Water Quality Based Effluent Limitation for the Plant City Water Reclamation Facility

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FOREWORD

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VHB – Field logistics and sampling

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Hillsborough County Parks and Recreation – Site access

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Background

Description of Problem

The City of Plant City operates the Plant City Water Reclamation Facility (Plant City WRF) under permit number FL0026557 under Chapter 403, Florida Statutes covering a period from January 15, 2016 – January 14, 2021. At the time of issuance, the Florida Department of Environmental Protection issued an Administrative Order (AO-002SWD15) establishing a compliance schedule under Section 403.088(2)(f), Florida Statues. The order calls for the City to, among other things, develop a Level II Water Quality Based Effluent Limitation (WQBEL) to authorize an increase in the permitted discharge to East Canal that was requested by the City of Plant City. The WQBEL shall provide reasonable assurance that the receiving waters continue to meet the applicable numeric nutrient criteria for total nitrogen (TN) and total phosphorus (TP).

Description of the Plant City WRF

The Plant City WRF is a 10.0 MGD annual average daily flow Type 1 activated sludge domestic wastewater treatment plant with chlorine disinfection (Figure 1). Treated effluent is either disposed via an existing discharge to East Canal after dechlorination and reaeration. The plant also supplies reclaimed water to a public access reuse system serving the city and surrounding area and an industrial reuse system. The permitted capacity is set at 8.0 MGD until such time as the City develops the master reuse service area.

Figure 1. Aerial view of the City of Plant City Water Reclamation Facility.

Applicable Regulatory Criteria

Under the Plant City WRF Domestic Wastewater Permit, the facility must meet several different but related nutrient effluent limits. Effluent discharged by the plant must meet certain criteria, established by Florida Statute (403.086, F.S.), as an advance wastewater treatment facility with a surface water discharge as shown in Table 1.

Table 1. Effluent Limitations for TN and TP for the Plant City WRF.

Temporal Basis	TN (mg/L)	TP (mg/L)
Annual Average	3.0	1.0
Monthly Average	3.75	1.25
Weekly Average	4.5	1.5
Single Sample	6.0	2.0

The discharge must also be in accordance with the "Final Order Adopting Water Quality Based Effluent Limits (WQBEL) for Point Source Discharges to the Tampa Bay Watershed" adopted in 2010 by FDEP. The annual total load is calculated as a 12-month rolling total based on the current month plus the previous 11-month's load not to exceed 21.0 tons TN /year. The discharge is also limited to 10.5 tons TN/year on a 5-year rolling average calculated as the current month plus the previous 59 months divided by 5.

The Plant City WRF discharges through outfall D-002 to East Canal (WBID 1518) (Figure 2). East Canal is a Class III freshwater stream located in the West Central Nutrient Watershed Region. Nutrient criteria for these waterbodies are found in subparagraph 62-302.531(2)(c)(2) F.A.C, with TN and TP criteria of 1.64 mg/L annual geometric mean (AGM) and 0.49 mg/L AGM, respectively. Neither should be exceeded more than once in a three-year period. It should be noted that East Canal does not flow year round, so it is considered an intermittent stream and will be assessed with regard to the narrative nutrient criteria per Chapter 62-302.300(19) F.A.C..

East Canal was last assessed by the FDEP Assessment Section in 2016 using data collected from January 1, 2007 to June 30, 2014. The WBID was delisted for two previous impairments, one for dissolved oxygen and the other for nutrients (chlorophyll *a*).

Figure 2. Plant City WRF D-002 outfall to East Canal.

Any proposed changes to the permitted discharges from the Plant City WRF will also need to take into account any downstream impairments and TMDLs as the effluent passes through 11 waterbodies on its way to Hillsborough Bay (Figure 3). The figure is accompanied by a table (Table 2) of downstream impairments associated with nutrients, *i.e.*, nutrients, chlorophyll *a*, and dissolved oxygen. The Hillsborough Reservoir (1443H) is the only downstream WBID impaired for a nutrient impairment, TP.

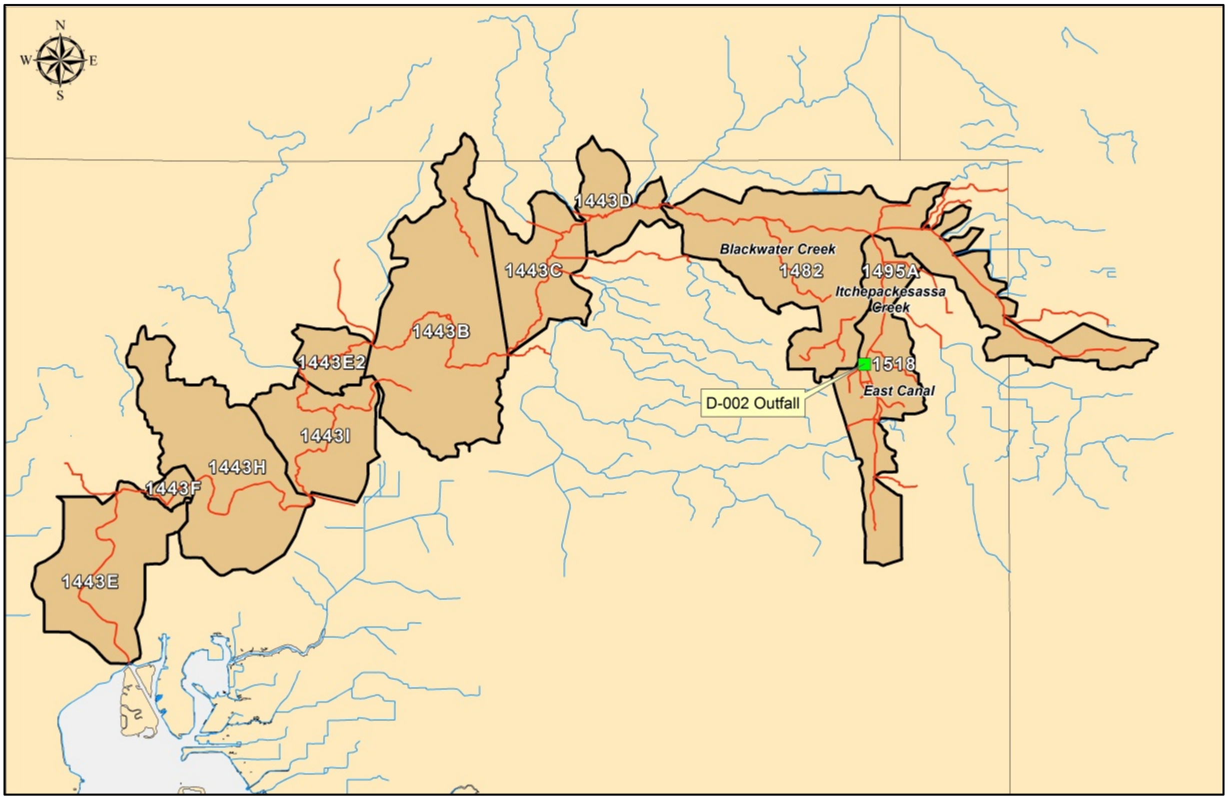


Figure 3. Map of WBIDs downstream of the outfall of the Plant City WRF.

Table 2. Nutrient Impaired WBIDs downstream of the Plant City WRF outfall (D-002).

WBID	Waterbody	Waterbody Type	Waterbody Class	Parameter
1443H	Hillsborough Reservoir	Lake	1	Nutrients (Total Phosphorus)

Water Quality Based Effluent Limitations

The Water Quality Based Effluent Limitation (WQBEL) process, pursuant to Chapter 62-650, F.A.C., is the mechanism for determining the levels of nutrients in a point source discharge (*i.e.*, effluent nutrient limits) that will comply with the narrative criterion in paragraph 62-302.530(47)(b), F.A.C. The derivation of a Level II nutrient WQBEL is a site-specific interpretation of the NNC and is based on the highest permitted flows and the associated nutrient loads from a discharge. To serve as the interpretation of the narrative nutrient criteria, the WQBEL must provide nutrient limits for the discharge, and calculate the total allowable load that would maintain the designated use of the waterbody. Further, if downstream waters are anticipated to be potentially affected by the discharge of nutrients from an upstream facility, the potential impact must also be assessed, regardless of distance.

The Plant City WRF permit was renewed on January 15, 2016, with an Administrative Order (AO) that required a Level II WQBEL study with interim discharge limitations for flow.

A WQBEL is recognized as the applicable interpretation of the narrative nutrient criteria if:

A. The documentation for the WQBEL includes a site-specific numeric interpretation of the narrative criterion at paragraph 62-302.530(47)(b), F.A.C., for the waterbody;
B. The WQBEL is established pursuant to the Level II Process contained at Rule 62-650.500, F.A.C.; and c) The public notice for the WQBEL specifically states that the Level II WQBEL includes a site-specific interpretation of the narrative for the receiving waterbody.

Because NPDES dischargers must demonstrate reasonable assurance that they comply with all applicable water quality standards, a Level II WQBEL is a scientifically and legally defensible method to establish appropriate nutrient targets and assure compliance. This WQBEL study assessed the feasibility of expanding the discharge volume while fully protecting designated uses. In addition, if higher flows or higher levels of TN and/or TP are demonstrated to be protective of East Canal and downstream waters, then the Plant City WRF would be able to discharge at the protective flows or nutrient levels as needed. This study examined a range of potential effluent characteristics (concentrations and flow, including flows higher than those currently observed) and those scenario outcomes are presented in the modeling chapter below. When the results of this WQBEL study is approved by FDEP, the AO and permit will be revised and the permit will incorporate the effluent limitations shown to be acceptable.

FDEP's Map Direct showed that there are no other NPDES surface water discharges upstream of the Plant City WRF or in Itchepackesassa Creek upstream of the confluence with East Canal. In summary, this Level II WQBEL Study assures compliance with any active TMDLs and provides reasonable assurance that the proposed Plant City WRF capacity increases will be associated with effluent limits that comply with water quality standards.

Description of Remaining Sections of this Report

The remaining sections of this report include:

- Characterization of East Canal-Itchepackesassa System
- Conceptual Model of Potential Effect of the Plant City WRF on East Canal/ Itchepackesassa System
- Analytical Approach
- Analytical Results
- Conclusions and Recommendations

Characterization of East Canal-Itchepackesassa System

Physical Setting

The location of the Plant City WRF, the D-002 outfall, East Canal, Itchepackesassa Creek and Blackwater Creek are shown on Figure 4. The Plant City WRF is located just south of I-4 in Plant City and the discharge is located north of I-4 at the intersection of Knights-Griffin Rd and East Canal. The East Canal combines with Itchepackesassa Creek before entering Blackwater Creek to the Hillsborough River and ultimately Hillsborough Bay.

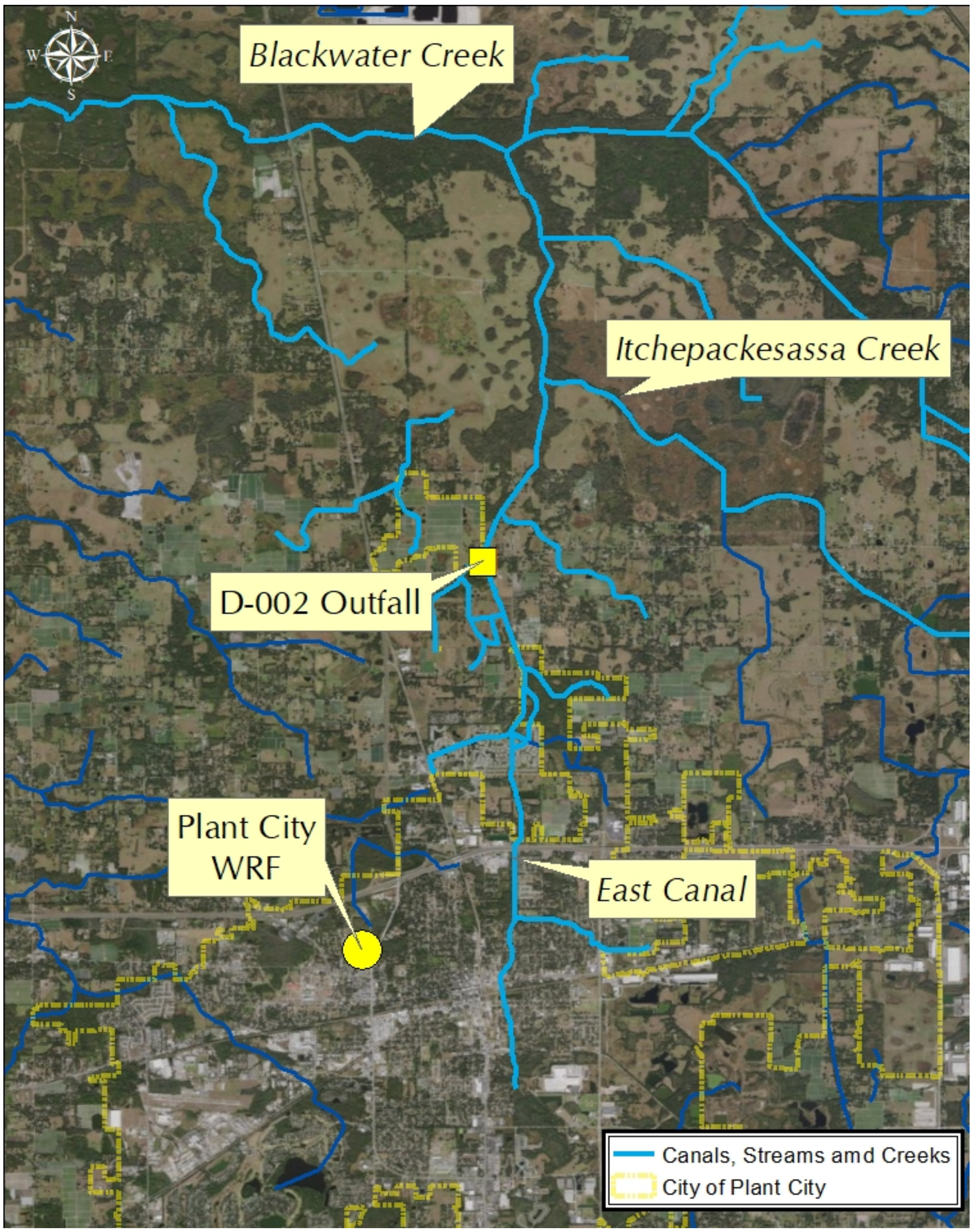


Figure 4. Location of the City of Plant City Water Reclamation Facility.

Hydrology

East Canal directs excess stormwater runoff away from Plant City. The stormwater is diverted from East Canal into the McIntosh Park Enhanced Stormwater Treatment Wetland Project by a diversion dam located approximately 1000m south of Knights Griffin Road. The treated stormwater is then discharged back into East Canal 600m downstream of the diversion dam. The diversion dam is set at an elevation to prevent upstream flooding by allowing excessive high flows to bypass the treatment system. The outfall of the Plant City WRF enters East Canal an additional 500m downstream of the discharge from the wetland treatment system. Approximately 3,500m further downstream is the confluence between East Canal and Itchepackesassa Creek. The Itchepackesassa Creek flow about another 4.5KM to Blackwater Creek. The location of the East Canal drainage basin is shown in Figure 5.

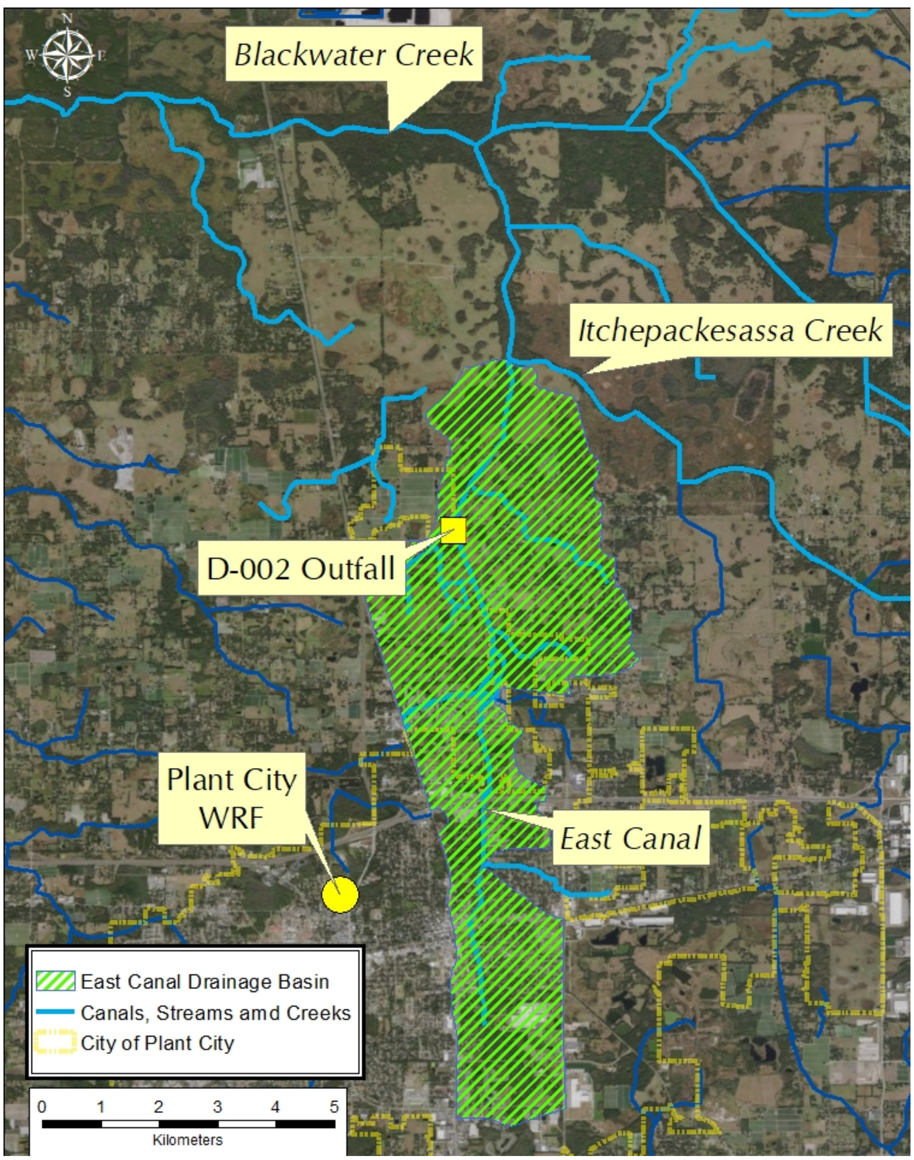


Figure 5. Location of the East Canal drainage Basin

Stream Flow

Stream flow measurements were made monthly during the monitoring year at the sites shown in Figure 6. Time-series plots of flow from all sites are shown in Figure 7 from upstream (WQ-1, top panel) to downstream (WQ-5, bottom panel). The daily data of the Plant City WRF discharge to East Canal was provided by City staff.

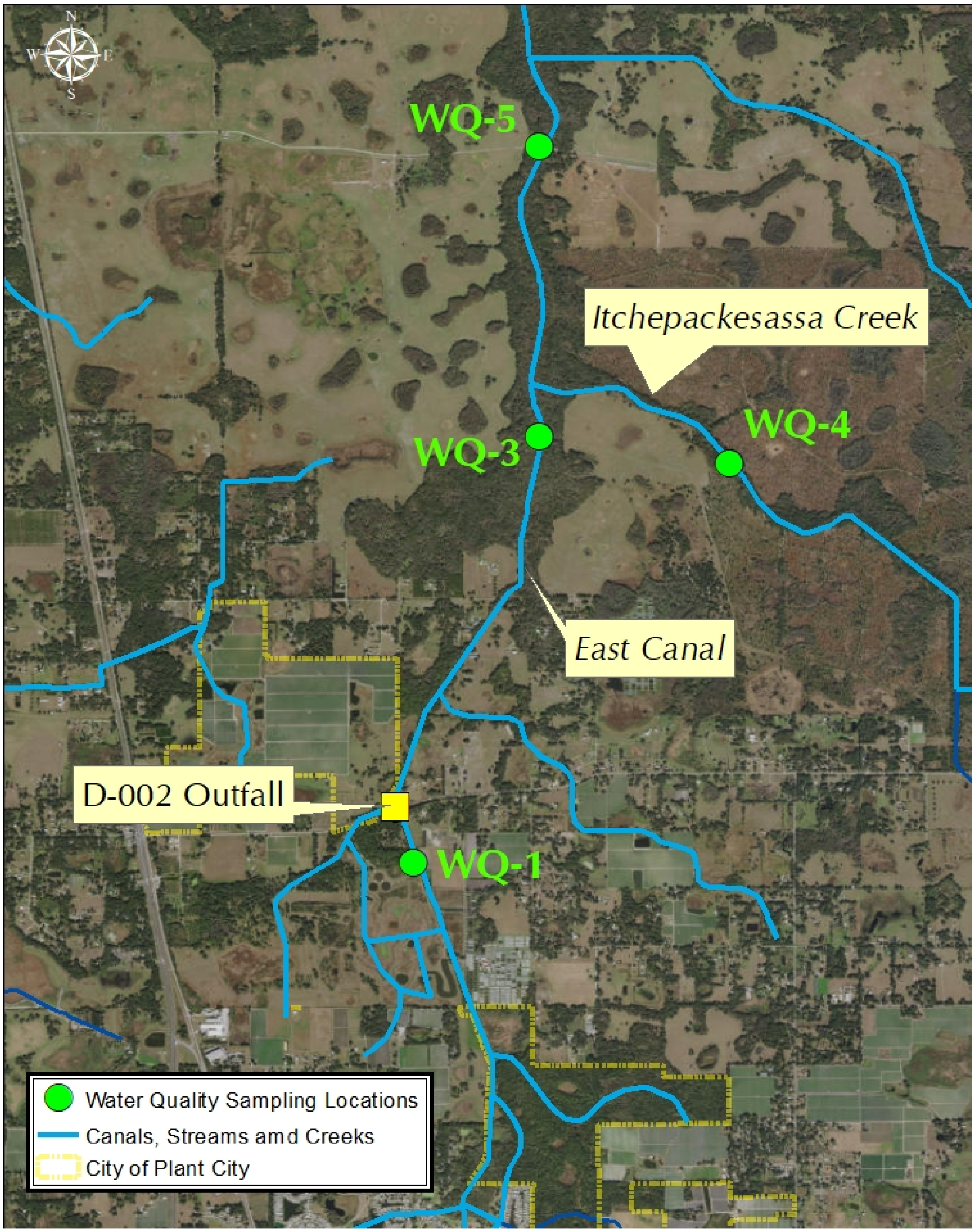


Figure 6. Location of flow monitoring sites.

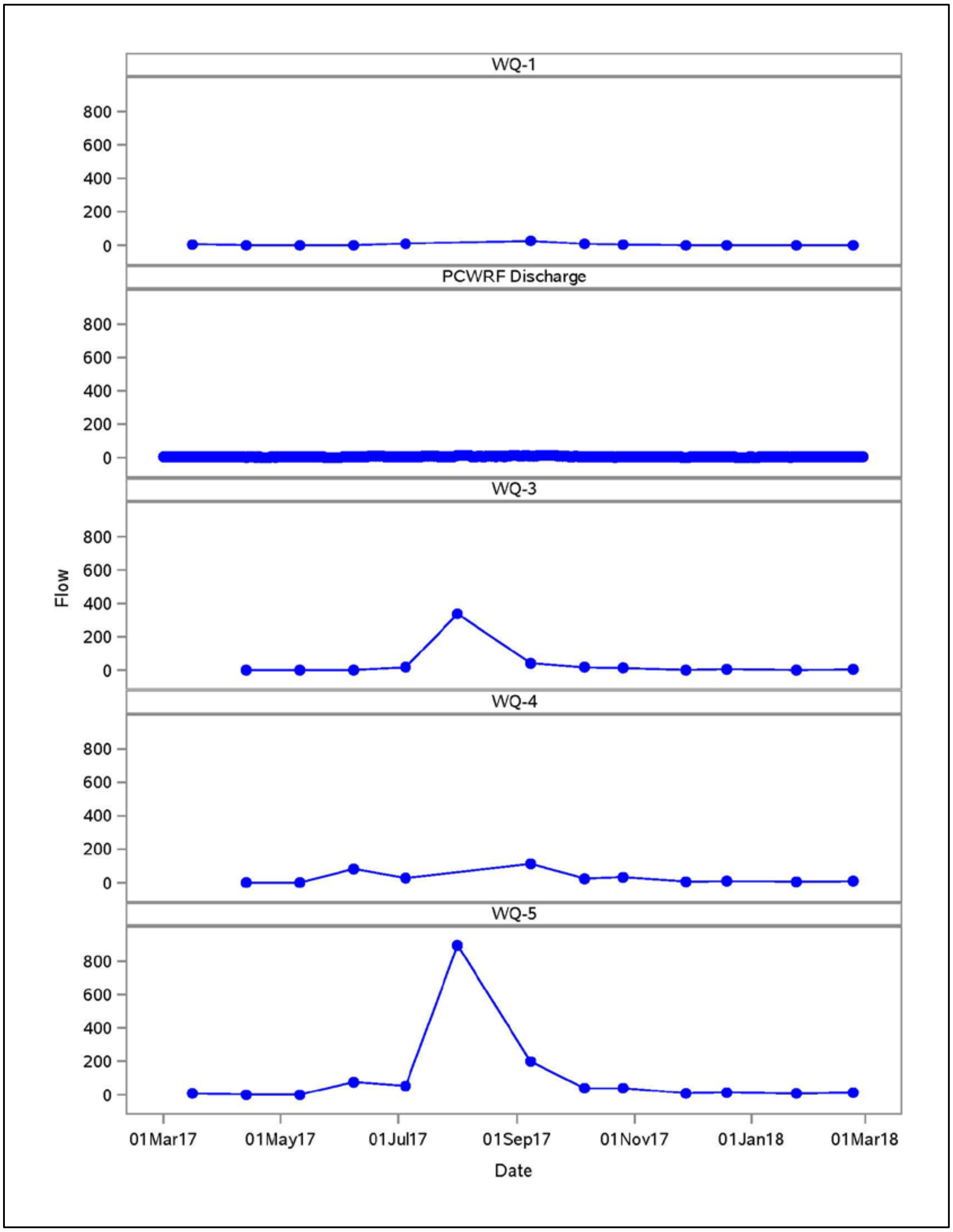


Figure 7. Time series plots of recent flow data collected during this project.

Rainfall

Rainfall information was downloaded from the National Weather Service for Plant City. Plots of the monthly rainfall data for the monitoring period (March 2017 – March 2018) are shown in Figure 8. For comparison, calendar month summaries for the period of record are also shown. Rainfall for the monitoring period exhibited the same temporal pattern as the historical record. Rainfall in June was the highest on record, and the area experienced two tropical systems, Emily in July and Irma in September. Regardless, rainfall in 2017 at 56.7 in. was only slightly higher than the mean annual rainfall over the last 20-year 54.7 in.

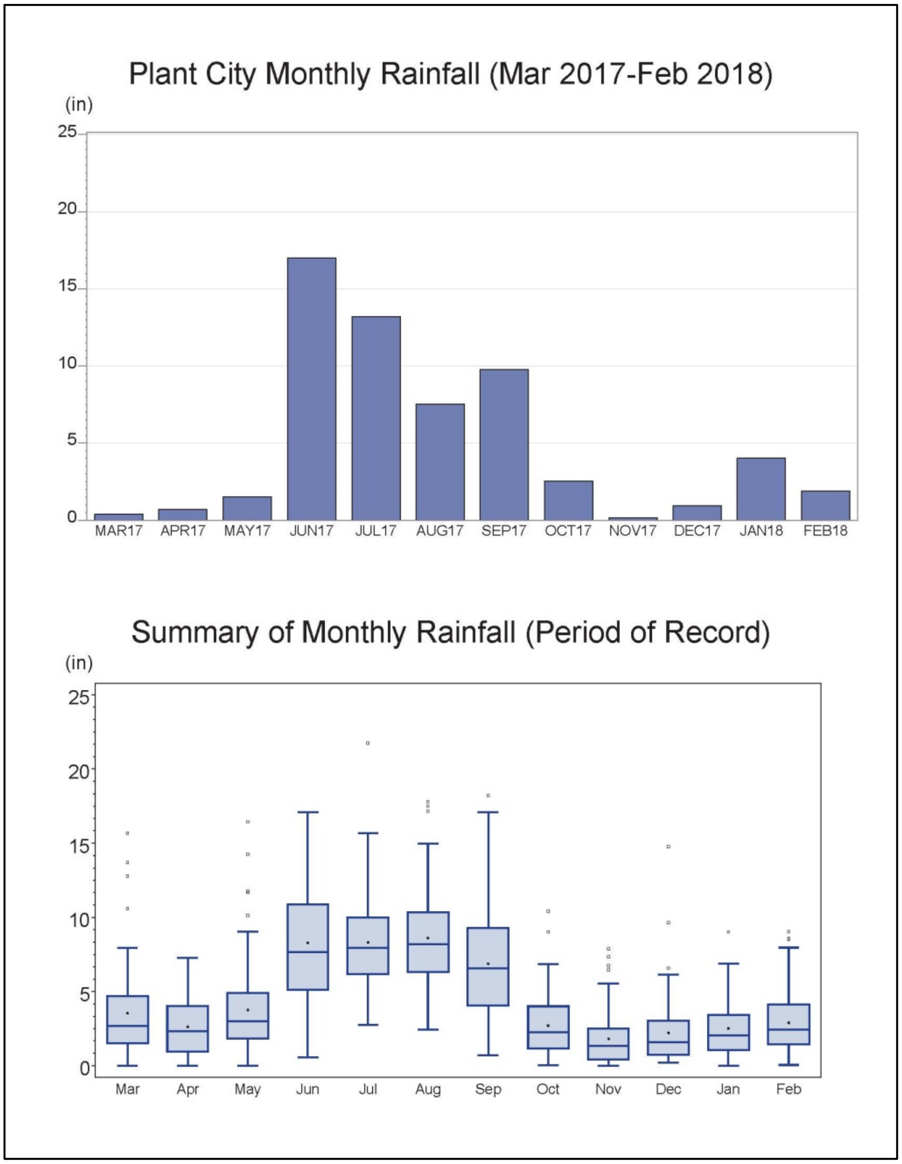


Figure 8. Plots of monthly rainfall during the monitoring period (top panel) and summarized by calendar month for the period of record (bottom panel).

Land Use

Land uses upstream of the discharge point range from rural/agriculture to urban. Stormwater runoff is treated through the McIntosh Park Enhanced Stormwater Treatment Wetland Project funded by a number of agencies completed in 2009 (Figure 9). Stormwater is diverted from East Canal and routed through series of wetlands and settling ponds, treated with alum, routed through another series of ponds and discharged to back to East Canal. During the monitoring period of this project, discharges from this wetland was limited to the rainy season, June to October, leaving the Plant City WRF as the only source of water in East Canal in the dry months.

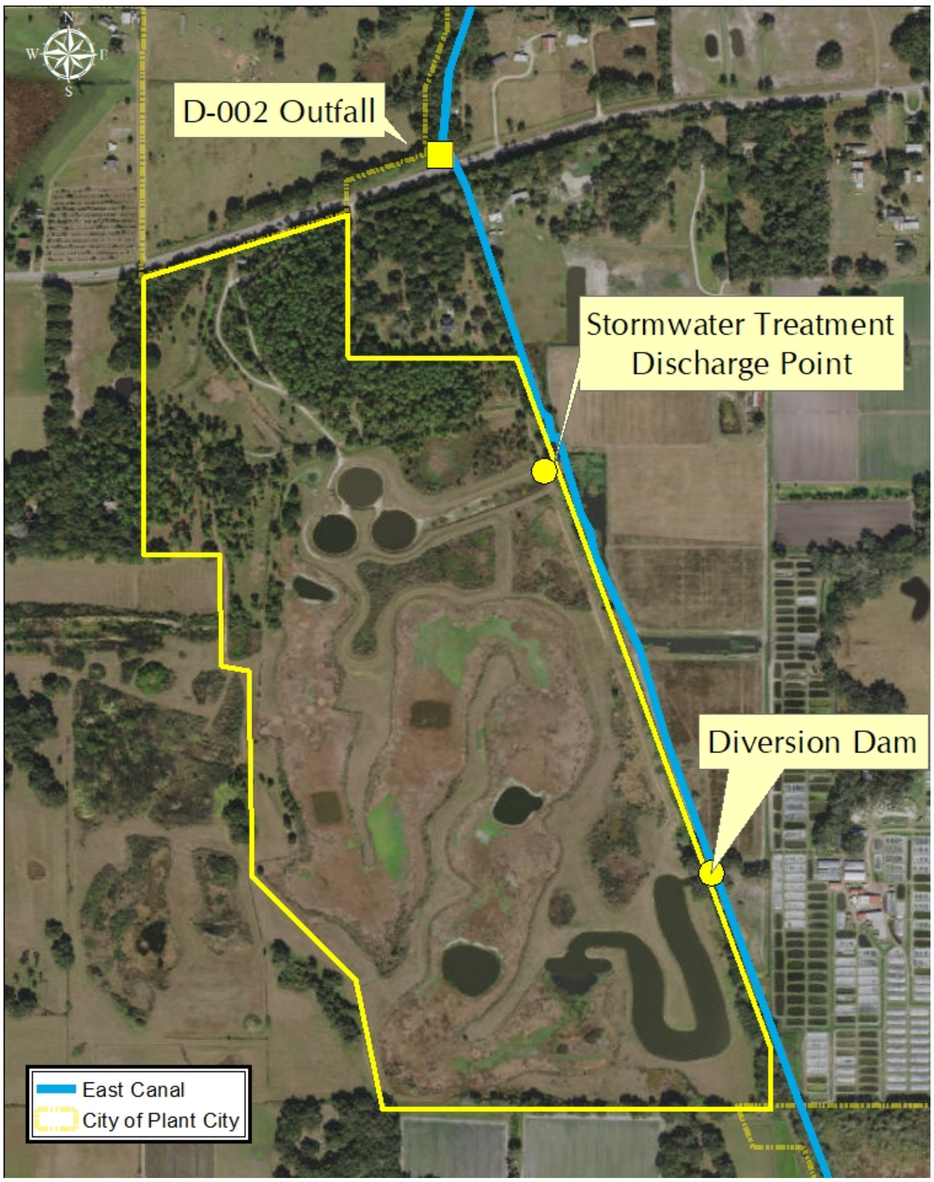


Figure 9. Map showing the approximate boundary of the McIntosh Park Enhanced Stormwater Treatment Wetland Project.

Biological Communities

]An assessment of the biological communities was conducted twice during the monitoring period at the three locations depicted in Figure 10.

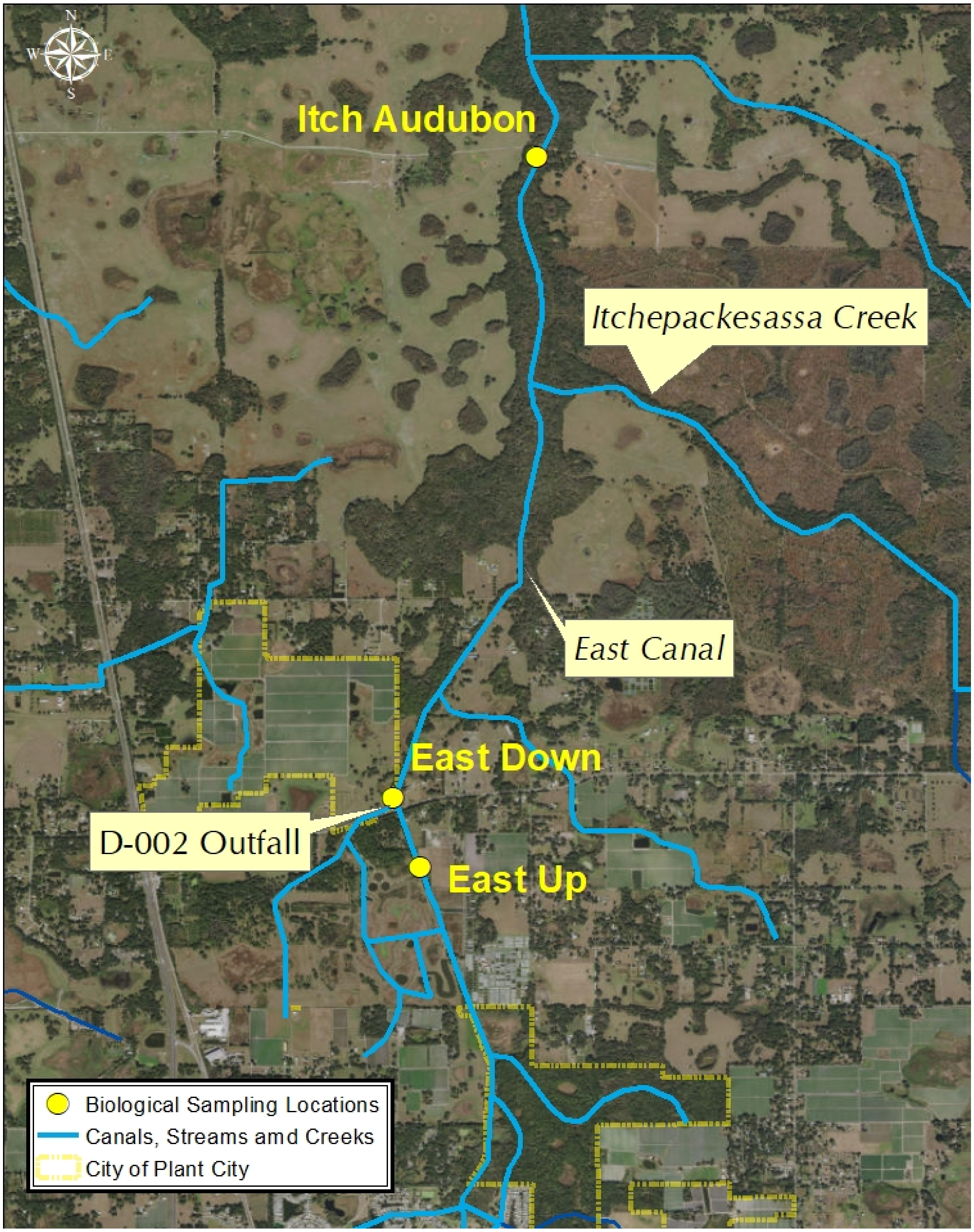


Figure 10. Location of Biological Sampling Locations.

Four sampling events (which comprised two temporally independent samplings) were conducted on 2/13/2017, 3/13/2017, 11/6/2017, and 12/4/2017. Sampling consisted of: Physical/chemical characterization (FDEP SOP FT 3001); Habitat Assessment (HA) (FDEP SOP FT 3010); Stream Condition Index (SCI) at Itchepackesassa Creek and BioRecon at the two East Canal sites (FDEP SOP SCI 1000 and BRN 1000); Rapid Periphyton Survey (RPS) (FDEP SOP FS 7230); Linear Vegetation Survey (LVS) (FDEP SOP FS 7320); and Periphyton rack deployment and retrieval for chlorophyll a and ash-free-dry-weight (FDEP SOP FS 2110). A summary of the parameters sampled follows:

- Physical/chemical characterization (FDEP SOP FT 3001);
- Habitat Assessment (HA) (FDEP SOP FT 3010);
- Stream Condition Index (SCI) at Itchepackesassa Creek and BioRecon at the two East Canal sites (FDEP SOP SCI 1000, BRN 1000);
- Rapid Periphyton Survey (RPS) (FDEP SOP FS 7230);
- Linear Vegetation Survey (LVS) (FDEP SOP FS 7320); and
- Periphyton rack deployment and retrieval for chlorophyll a (FDEP SOP FS 2110).

Biological sampling dates were established in accordance with the hydrologic requirements as specified in DEP SOP SCI 1000. One complete sampling event (consisting of a deployment and retrieval of periphyton racks, one faunal sampling, and two RPS, LVS, and Habitat Assessments) occurred during February/March 2017, and another was conducted during November/December 2017 (Table 3). The second set of sampling tasks was delayed until November to achieve proper antecedent hydrologic conditions necessary for biological sampling (FDEP, 2012). This was due to extreme flooding associated with Hurricane Irma (which was followed by usually high precipitation during the fall period).

Table 3. Summary of biological sampling efforts.

Parameters	February-March 2017		November-December 2017	
	East Canal Control and Test sites	Itchepackesassa Creek at Audubon Road	East Canal Control and Test sites	Itchepackesassa Creek at Audubon Road
RPS	Twice	Twice	Twice	Twice
LVS	Twice	Twice	Twice	Twice
HA	Twice	Twice	Twice	Twice
SCI	NA	Once	NA	Once
BioRecon	Once	NA	Once	NA
Physical/Chemical	Twice	Twice	Twice	Twice
Periphyton Rack (deployment and retrieval – 2 visits)	Once	Once	Once	Once

These data were interpreted according to the NNC Implementation Document (FDEP, 2013). This means that the ditch sites were compared qualitatively (control to test sites) and the downstream protection site was assessed according to the floral, faunal, and nutrient evidentiary thresholds. Biological sampling locations are shown in Figure 9.

Stream Habitat Assessment

The FDEP Stream Habitat Assessment consists of scoring eight parameters based on field measurements and observations, including substrate diversity, substrate availability, water velocity, habitat smothering, bank stability, degree of artificial channelization, riparian zone buffer width and riparian zone vegetation quality. Mean habitat scores 30.3 points (poor) upstream of the Plant City discharge, 47.3 points (poor) downstream of the discharge, and 102 points (sub-optimal) at the Itchepackesassa far-field site (Table 4).

Table 4. Average habitat assessment scores for the East Canal Control site, the East Canal test site, and Itchepackesassa Creek site at Audubon Road.

Location	Mean
East Canal Upstream	30.3
East Canal Downstream	47.3
Itchepackesassa Creek	102

Rapid Periphyton Survey

The Rapid Periphyton Survey (RPS) achieved the expected floral evidentiary threshold for streams (< 25% coverage of rank 4-6) at all sites during all 4 RPS samplings associated with the study, which included two (2) temporally independent samplings (conducted > 3 months apart) (Table 5). Therefore, the RPS evidentiary threshold requirement in Rule 62-302.531, F.A.C., was achieved both upstream and downstream of the Plant City WRF (an indication of no nutrient-induced imbalances). The RPS evidentiary threshold was also achieved at the far-field test site (Itchepackesassa Creek at Audubon Road), which is one floral indicator of downstream protection.

Table 5. Rapid Periphyton Survey results.

Station	Date	RPS (% 4-6)	Pass?
East Up	2/13/2017	11	Yes
East Down	2/13/2017	0	Yes
Itch Audubon	2/13/2017	0	Yes
East Up	3/13/2017	0	Yes
East Down	3/13/2017	0	Yes
Itch Audubon	3/13/2017	0	Yes
East Up	11/6/2017	0	Yes
East Down	11/6/2017	0	Yes
Itch Audubon	11/6/2017	0	Yes
East Up	12/4/2017	0	Yes
East Down	12/4/2017	0	Yes
Itch Audubon	12/4/2017	0	Yes

Periphyton rack artificial substrate (glass slides) results are found in Table 6 and Figure 11. All chlorophyll *a* results were lower than the range of periphyton chlorophyll *a* values collected by FDEP from glass slides at several minimally disturbed control or references sites in Florida (Table 6). This indicates that the existing responses to nutrient concentrations downstream of the Plant City discharge are acceptable, as the periphyton biomass was lower than many control sites in Florida. Note that the East Canal test site periphyton rack was stolen during the second sampling event.

Table 6. Periphyton chlorophyll a and Ash-Free-Dry-Weight results from artificial substrates.			
Station	**Date**	**Periphyton Chlorophyll (mg/m^2)**	**Periphyton AFDW (mg/m^2)**
East Up	3/13/2017	3.98	213
East Down	3/13/2017	12.2	506
Itch Audubon	3/13/2017	12.2	1000
East Up	12/4/2017	7.3	1660
East Down	12/4/2017	Stolen	Stolen
Itch Audubon	12/4/2017	2.85	327

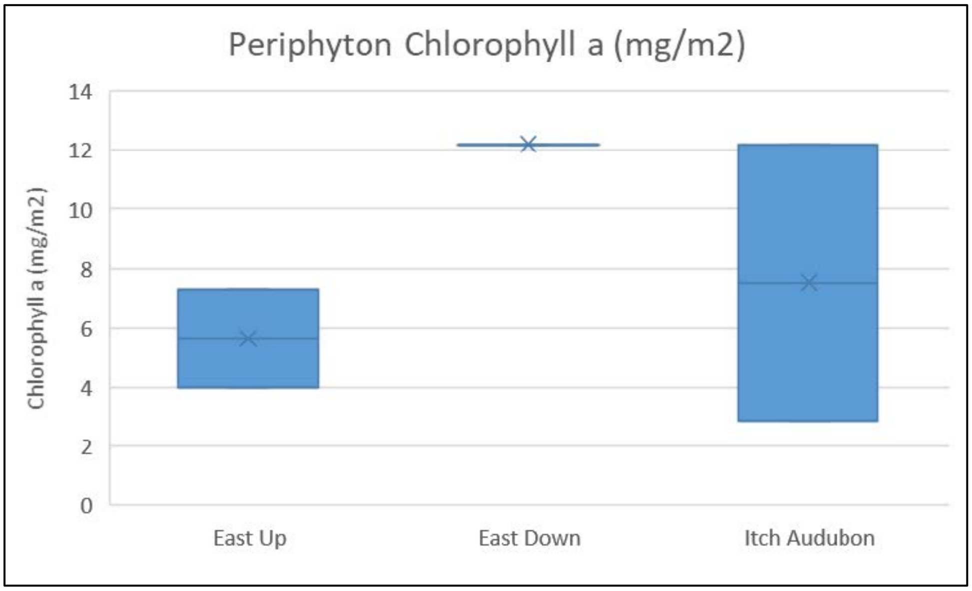


Figure 11. Box plots of periphyton chlorophyll a results (artificial substrates). The periphyton rack from the East Canal test site was stolen during the second sampling. Note that all values are lower than periphyton chlorophyll a from selected FDEP minimally disturbed control sites in Florida (see Table 7).

Table 7. FDEP periphyton chlorophyll a data (glass slides) from selected minimally disturbed control sites in Florida.		
Waterbody	**Periphyton Chlorophyll (mg/m^2)**	**Citation**
Upper Suwannee Control (above White Springs)	28.1	(FDEP, 1995)
Upper Suwannee Control (above Gold Kist)	43.8	(FDEP, 2001)
Camp Branch Control (above Bonifay)	25.2	(FDEP, 1993a)
Troublesome Creek Control (Polk County)	19.3	(FDEP, 1993b)
Withlacoochee River Control (Hamilton County)	32.5	(FDEP, 1997)
Econfina Creek Reference Site (Bay County)	20.4 (mean)	(FDEP, 1992)

Linear Vegetation Survey

The Linear Vegetation data are presented in Table 8 and Figures 12 and 13. Because there were no aquatic plants present, the Itchepackesassa Creek at Audubon Road passed the LVS all 4 times it was sampled, demonstrating compliance with Chapter 52-302.531, F.A.C. For graphical purposes, Itchepackesassa Creek was assigned a FLEPPC score of zero and a Coefficient of. Conservatism (C of C) score of 5. The East Canal control site failed the LVS all four times it was sampled. The East Canal test site failed the LVS twice and passed the LVS twice (for one temporally independent passing score and one temporally independent failing score). The passing LVS results occurred after ditch maintenance, which consisted of herbicide spraying of invasive exotic aquatic and riparian zone vegetation. Because the narrative nutrient criterion is in effect at East Canal, the test site LVS results were compared with the control site LVS results. There were slight improvements in both LVS components at the test site, indicating there were no imbalances in aquatic flora attributable to nutrients in the discharge.

Table 8. Linear Vegetation Survey (LVS) data. Itchepackesassa Creek at Audubon Road had no aquatic vegetation present (passing the LVS).

Station	Date	LVS (C of C)	LVS (% FLEPPC)	Pass LVS?
East Up	2/13/2017	1.2	65.5	No
East Down	2/13/2017	1.7	46.2	No
Itch Audubon	2/13/2017	NA	NA	Yes
East Up	3/13/2017	0.84	72.7	No
East Down	3/13/2017	1.3	53.1	No
Itch Audubon	3/13/2017	NA	NA	Yes
East Up	11/6/2017	2.5	28.6	No
East Down	11/6/2017	2.9	16.7	Yes
Itch Audubon	11/6/2017	NA	NA	Yes
East Up	12/4/2017	1.8	45	No
East Down	12/4/2017	2.7	23.1	Yes

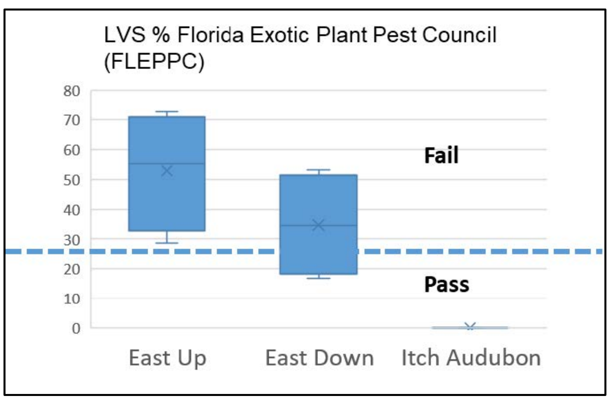


Figure 12. Box plots of LVS % Florida Exotic Plant Pest Council (FLEPPC) results at sites located upstream (control site) and downstream (test site) from the Plant City WRF discharge. N = 4. Passing score for streams (not ditches) is 25% and lower.

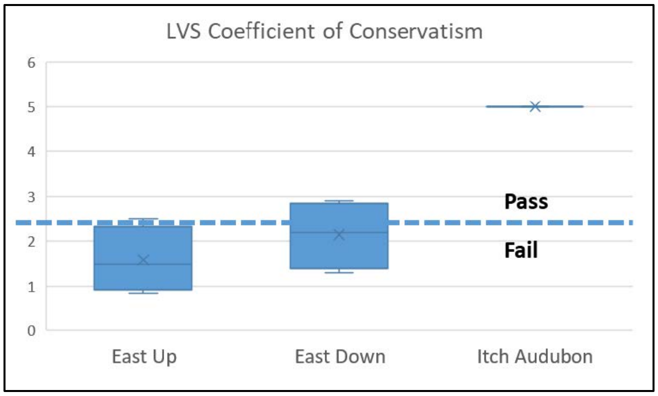


Figure 13. Box plots of LVS Coefficient of Conservatism results at sites located upstream (control site) and downstream (test site) from the Plant City WRF discharge. N = 4. Passing score for streams (not ditches) is 2.5 and higher.

BioRecon

BioRecon was conducted upstream and downstream from the Plant City discharge to evaluate potential differences in the invertebrate community that may be associated with the discharge (Table 9, Figure 14). Although the stream BioRecon thresholds are not applicable to ditches, the test site exceeded the threshold once (with a BioRecon score of 4.6) and was below the threshold once (with a BioRecon score of 3.3). The test site results were higher than the control site results, where the BioRecon scores were 0.53 and 0.69 during two temporally independent sampling events. The observation that the BioRecon scores were higher at the test site, when compared with the control site is likely due to the substantially higher water velocity at the test site (increasing from 0.0 m/sec to an average of 0.12 m/sec), which was attributable to the Plant City WRF discharge. The improvements in BioRecon scores at the test site also indicate that there were no imbalances in fauna from nutrients in the discharge.

Table 9. BioRecon results from two temporally independent samplings at sites located upstream (control site) and downstream (test site) from the Plant City WRF discharge. Passing score for streams (not ditches) is 4 or higher.

Station	Date	BioRecon Score	BioRecon Interpretation
East Up	3/13/2017	0.53	Fail
East Down	3/13/2017	4.6	Pass
East Up	12/4/2017	0.69	Fail
East Down	12/4/2017	3.3	Fail

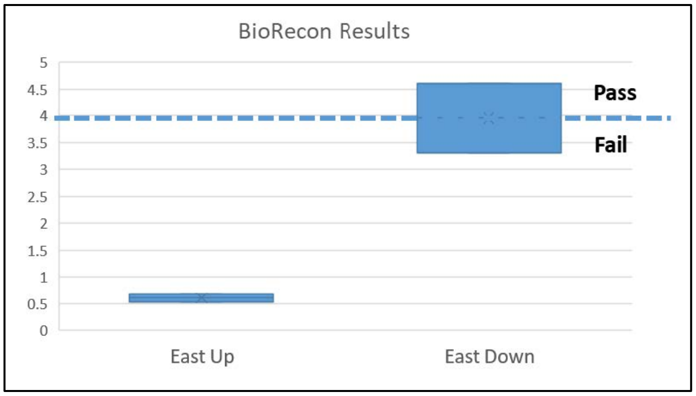


Figure14. Box plots of BioRecon results from two temporally independent samplings at sites located upstream and downstream from the Plant City WRF discharge. Passing score for streams (not ditches) is 4 or higher.

Stream Condition Index

During the 2017 WQBEL study, the Stream Condition Index averaged 59 (n = 2) at Itchepackesassa Creek, the far-field site established to assess downstream protection (Table 10). Neither of the most recent two scores was less than 35. Therefore, achievement of the streams faunal measurements required in Chapter 62-302.531, F.A.C., indicated that fauna was healthy at the far-field test site, demonstrating downstream protection.

Table 10. Stream Condition Index (SCI) scores for Itchepackesassa at Audubon Road, the far-field test site.

Station	Date	SCI Score	SCI Interpretation
Itchepackesassa at Audubon	3/13/2017	58	Pass
Itchepackesassa at Audubon	12/4/2017	60	Pass
Mean		59	Pass

Summary

Because East Canal meets the "ditch" exception to NNC, the flora and fauna inhabiting the test site (downstream of the Plant City WRF) were compared with flora and fauna at the control site (upstream of the discharge). The RPS indicated low algal abundance at both the East Canal control and test sites, which is one aspect of demonstrating no imbalances in flora. The LVS results indicated a somewhat better quality vascular plant community at the test site compared with the control, which is additional evidence demonstrating no floral imbalances associated with the discharge. Finally, water column chlorophyll *a* was much lower at the East Canal test site and at the Itchepackesassa far-field test site, compared to their respective upstream control sites. This is site-specific evidence that the Plant City WRF does not cause or contribute to phytoplanktonic floral imbalances, but instead, reduces the existing phytoplankton biomass. These three individual types of floral measures (RPS, LVS, and chlorophyll *a*) clearly demonstrated there were no floral imbalances attributable to nutrients in the Plant City WRF discharge.

Similarly, the improvements in the BioRecon scores between the control and test sites demonstrate no faunal imbalances attributable to the Plant City WRF discharge.

The Itchepackesassa Creek far-field site (which met the definition of a "stream") achieved the streams evidentiary thresholds for the RPS, LVS, chlorophyll *a*, and SCI during two temporally independent samplings, demonstrating healthy flora and fauna, in compliance with NNC (Chapter 62-302.531, F.A.C.). This demonstrates that downstream communities were protected.

Recent Water Quality Conditions

To aid the development of the WQBEL, water quality data were collected monthly from March 2017 through March 2018. Field data and sample collection was followed FDEP SOP-001/01 with samples analyzed by a NELAC certified laboratory. Field and laboratory parameters were collected at 4 sites listed below and shown in Figure 15:

- WQ-1 – East Canal downstream of the McIntosh Stormwater Treatment system and upstream WRF outfall
- WQ-3 – East Canal downstream of the WRF outfall and upstream of the confluence of East Canal and the Itchepackesassa Creek
- WQ-4 – Itchepackesassa Creek upstream of the confluence with East Canal
- WQ-5 – Itchepackesassa Creek downstream of the confluence with East Canal and upstream of Blackwater Creek

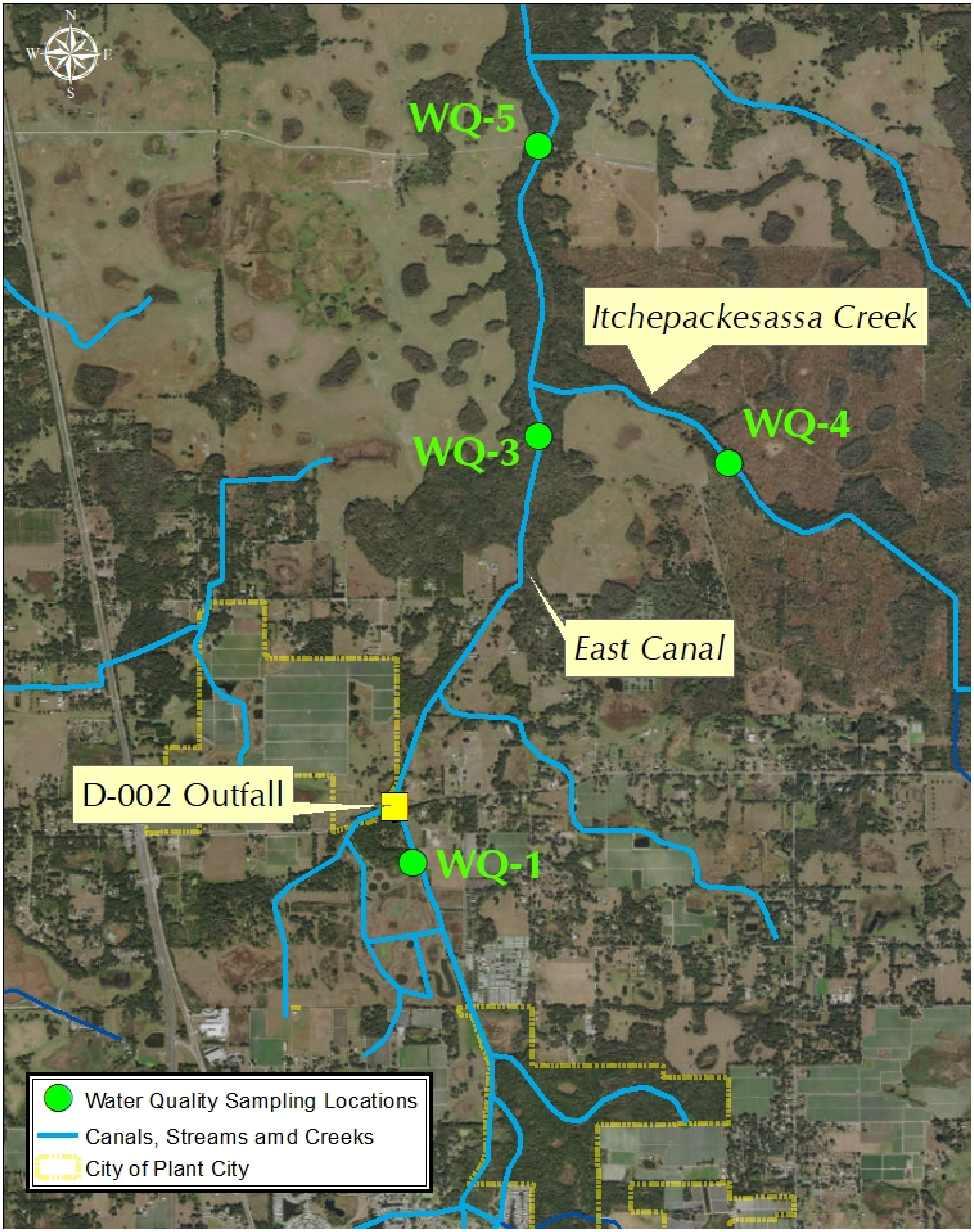


Figure 15. Location of Water Quality Sampling Locations.

The field and laboratory parameters collected are listed in Table 11. Time-series plots of key parameters, specific conductance, TP, TN, TKN, NOx, NH_3, chlorophyll *a*, and DO percent saturation are shown for each station from which data are available in Figures 17 to 25. It should be noted that little or no flow on several dates during the monitoring period precluded collection of water quality samples (Figure 16).

Table 11. Table of field and laboratory parameters.

Field Parameters	Laboratory Parameters
Temperature (°C) pH (SU) Specific Conductance (μmhos) Dissolved Oxygen (mg/L) Dissolved Oxygen (μg/L) Flow (cfs) Depth (feet)	Ammonia (mg/L) Total Kjeldahl Nitrogen (mg/L) Nitrate (mg/L) Nitrate-Nitrite as N (mg/L) Orthophosphate as P (mg/L) Total Phosphorus as P (mg/L) Chlorophyll a (μg/L) Ammonium as NH_4 (mg/L) Total Suspended Solids (mg/L) Volatile Suspended Solids (mg/L) Nitrite (mg/L) Carbonaceous BOD (mg/L) Total Organic Carbon (mg/L) Dissolved Organic Carbon (mg/L)

Figure 16. Photograph of Itchepackesassa Creek sampling site (WQ-4) on 11MAY17.

With respect to specific conductance (Figure 17), there is a rather distinct seasonal pattern in that values are depressed during the rainy season. Sites inline with East Canal, WQ-1, WQ-3, WQ-5, all have similar patterns where the Itchepackesassa site, WQ-4 has generally lower values.

Total phosphorus (TP) (Figure 18) exhibits the same seasonal pattern with higher concentrations during the rainy season. The project site is located in the West Central Nutrient region known for the presence of high concentrations of phosphorus in the soils just below the surface. This is expressed as higher than normal concentrations of phosphorus leached out during the rainy season. Orrthophosphate (Figure 19) follows a similar temporal pattern as TP.

Total nitrogen (TN) (Figure 20) is slightly higher in the wet season, though the increase isn't as obvious as for TP. The site in Itchepackesassa has generally higher values than those in East Canal possibly due to increase in the breakdown of detritus deposited after the rainy season. It should also be noted that the 5-year mean average daily mean of the PC WRF is 1.152 mg/L which marked lower then many of the samples collected as part of this project, particulary those collected in Itchepackesassa Creek (WQ-4) and downstream of the confluence between East Canal and Itchepackesassa (WQ-5).

Organic nitrogen, measured in the form of total kjeldahl nitorgen (TKN) (Figure 21), exhibits similar patterns as TN above. This is expected since most inorganic forms of nitrogen are used up by available plankton communities. It was the dominant fraction of nitrogen until November.

Inorganic nitrogen, includes nitrate-nitrite (Figure 22) and ammonia (Figure 23). Nitrate-nitrite becomes the dominant fraction of nitrogen in the latter part of the year in Itchepackesassa at WQ-4 and at WQ-5. Ammonia remains relatively low throughout the monitoring period.

Water column chlorophyll *a* (Figure 24) also exhibits a season pattern with higher values in the wet season. This is not unexpected as phytoplankton is known to proliferate with increase temperatures and available sunlight of the summer season. Of note are the relatively consistent lower chlorophyll a values at station WQ-3, downstream of the PC WRF outfall.

Dissolved oxygen (Figure 25) values expressed as percent saturation values are lowest downstream of the wetland system (WQ-1) as can be expected. In other sites, the percent saturation results are rarely $<$ 50% saturation. The criteria for freshwater streams in the Peninsular Region in 38% saturation.

The ambient water quality data generally show seasonal patterns related to rainfall variability. As a result the relative effect of the discharges from the Plant City WRF was most notable during the dry months. The spatial patterns in water quality also reflected the influence of flows from Itchepackesassa Creek particularly at WQ-5.

The limiting nutrient for each of the sites was also determined using the mean N:P ratio of the samples. Each of the sites had N:P ratios less than 4. The FDEP has determined that N:P ratios less than 10 were N limited. As such, all of these sites are nitrogen limited.

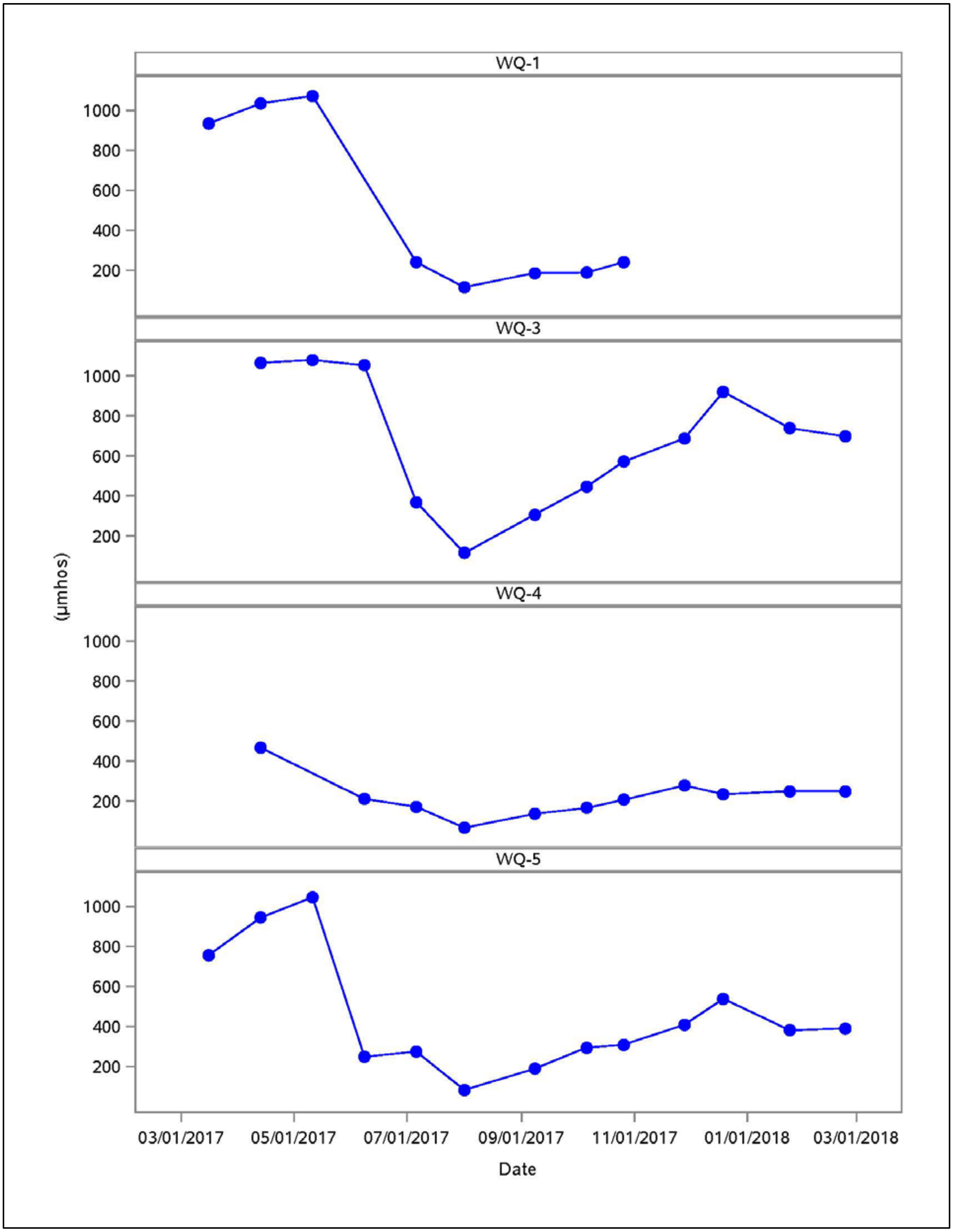


Figure 17. Time series plots the specific conductance data from the 4 project sampling sites – March 2017-March 2018.

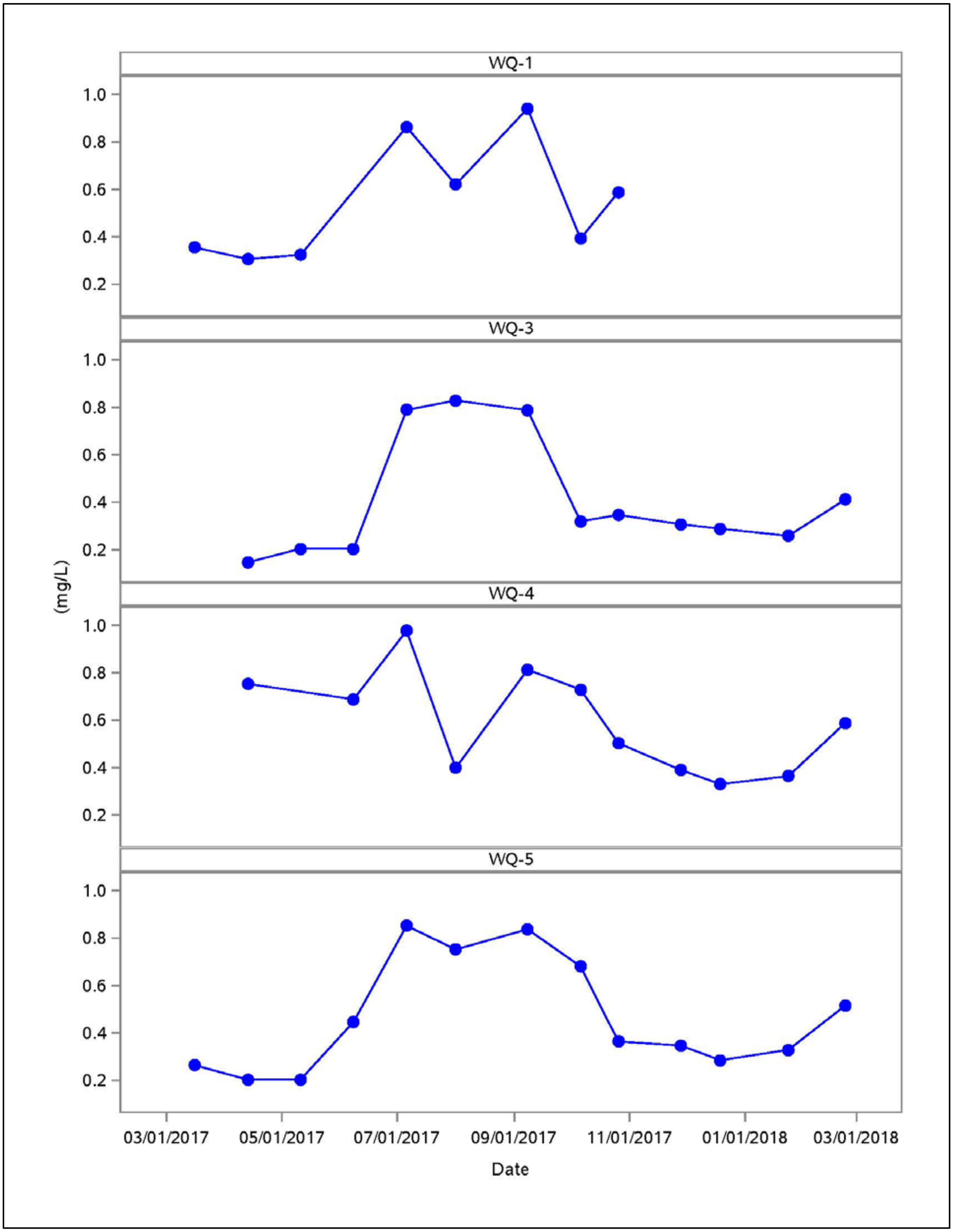


Figure 18. Time series plots the TP concentration data from the 4 project sampling sites – March 2017-March 2018.

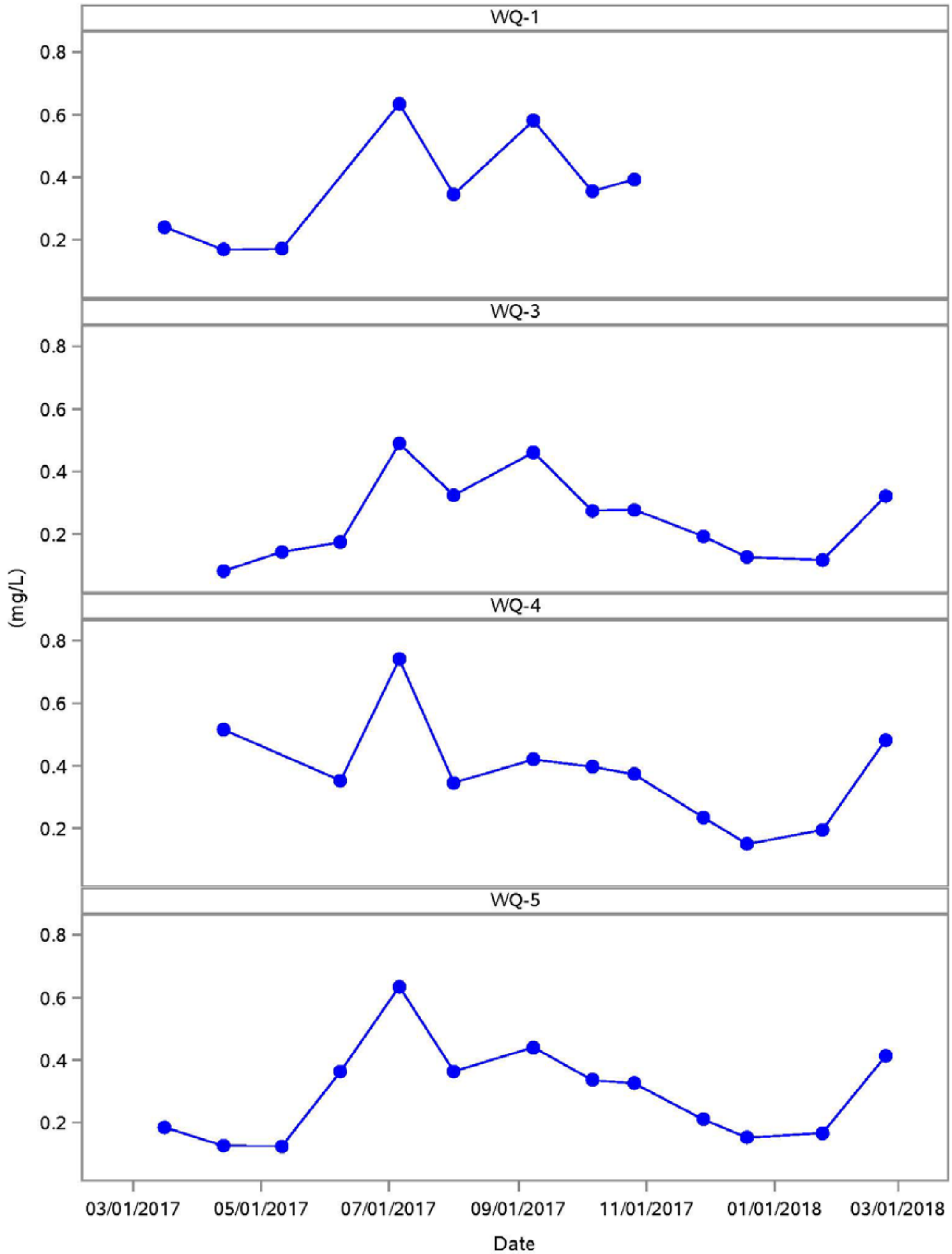


Figure 19. Time series plots the orthophosphate concentration data from the 4 project sampling sites – March 2017-March 2018.

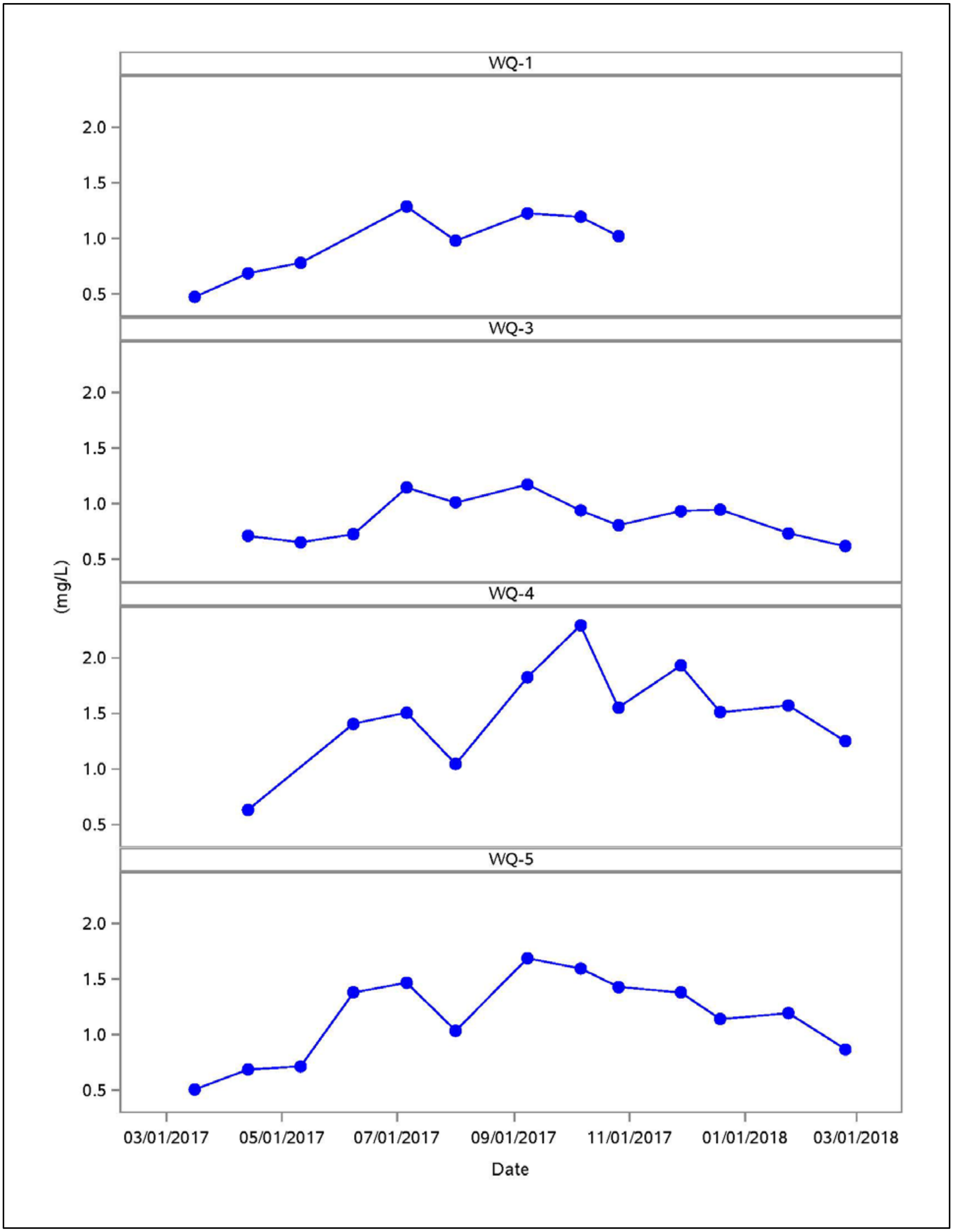


Figure 20. Time series plots the TN concentration data from the 4 project sampling sites – March 2017-March 2018.

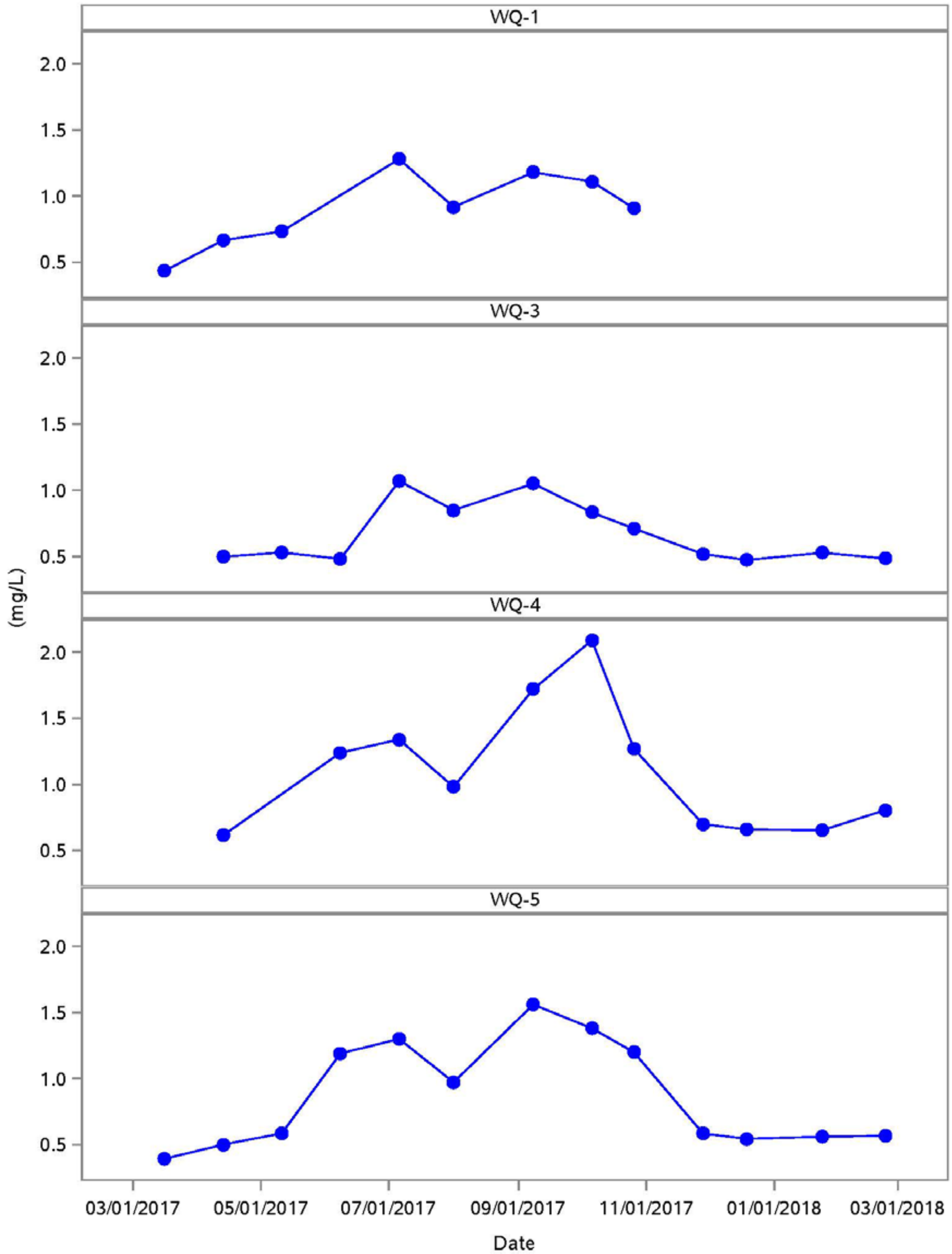


Figure 21. Time series plots the TKN concentration data from the 4 project sampling sites – March 2017-March 2018.

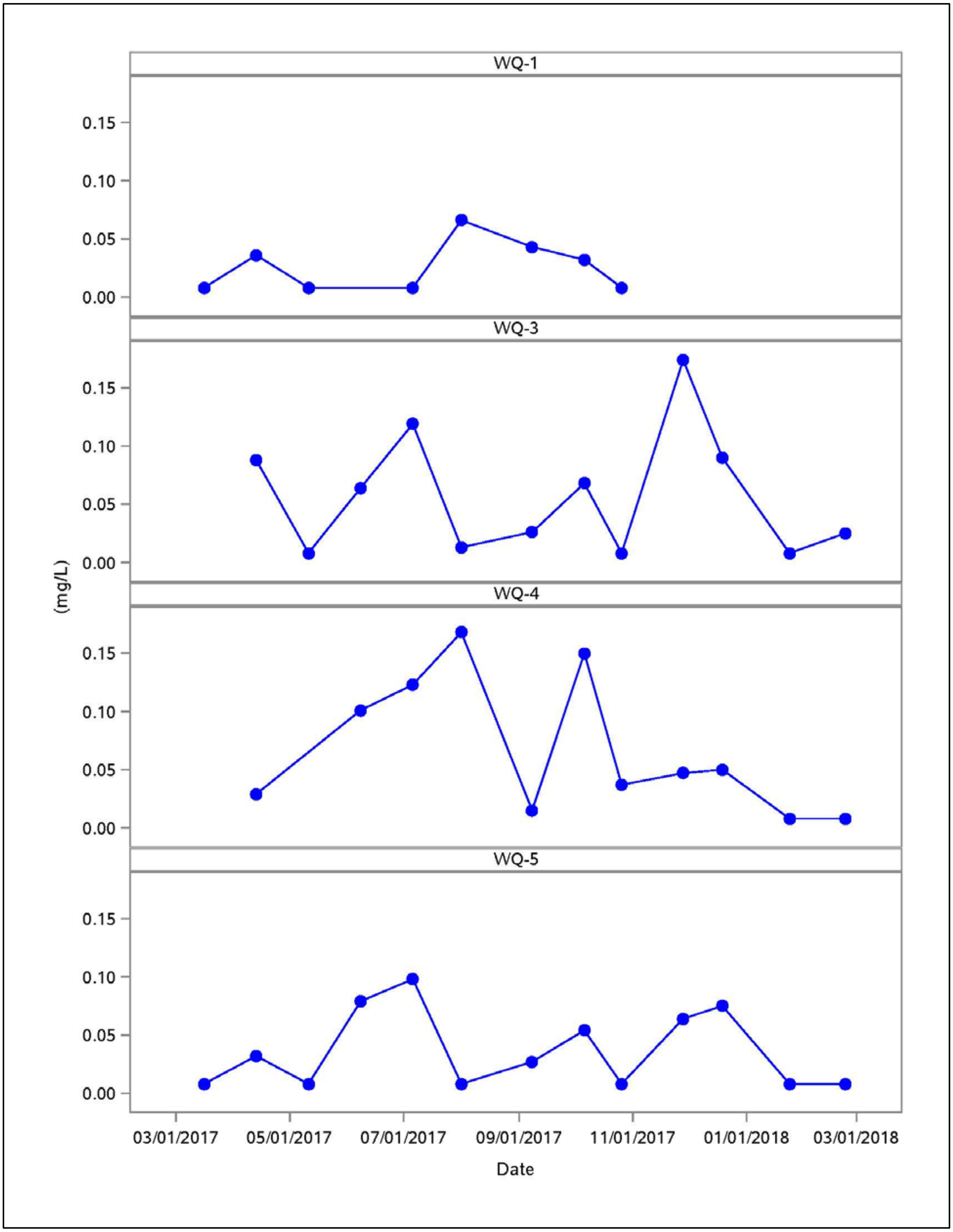


Figure 22. Time series plots the NO_3-NO_2 concentration data from the 4 project sampling sites – March 2017-March 2018.

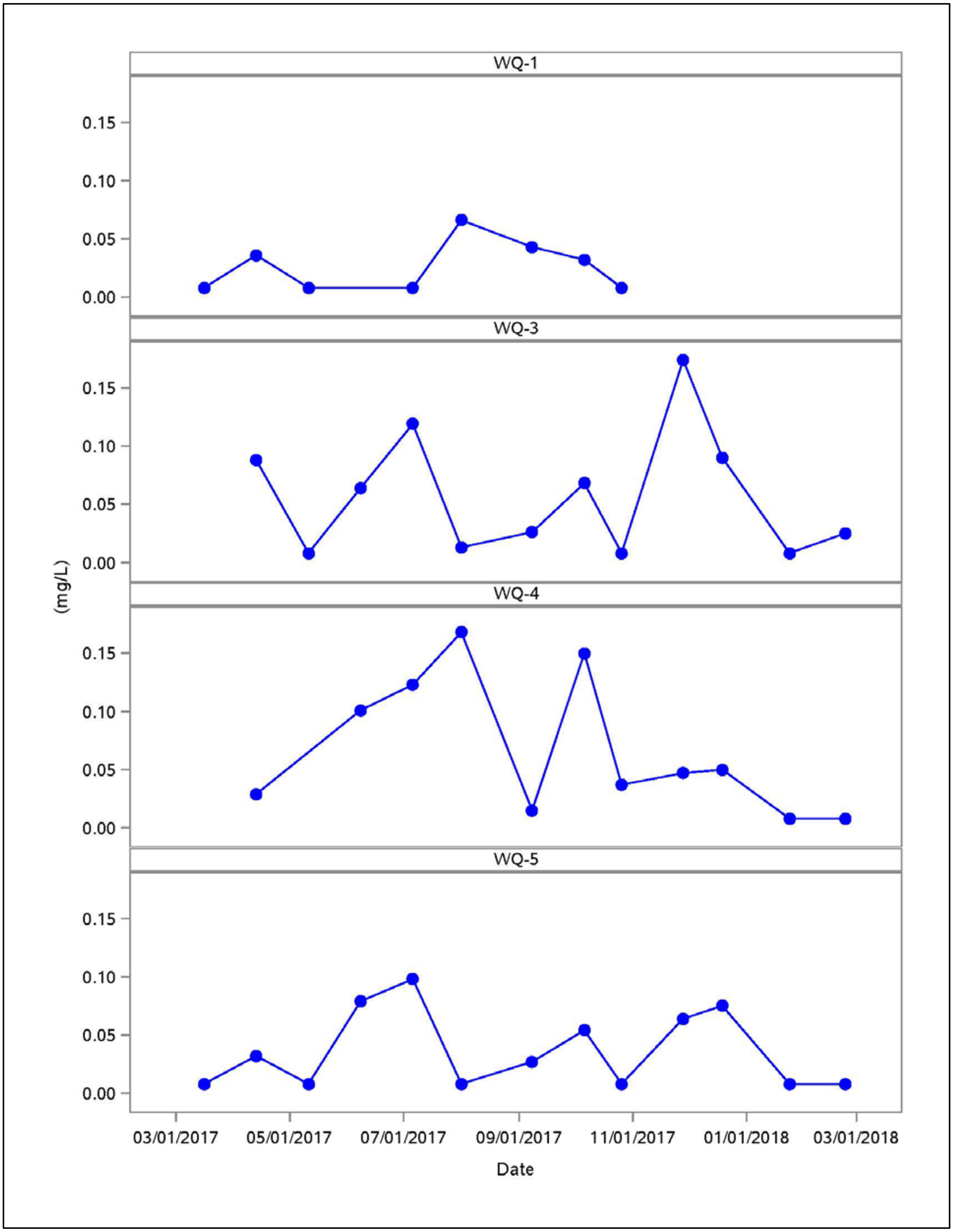


Figure 23. Time series plots the NH_3 concentration data from the 4 project sampling sites – March 2017-March 2018.

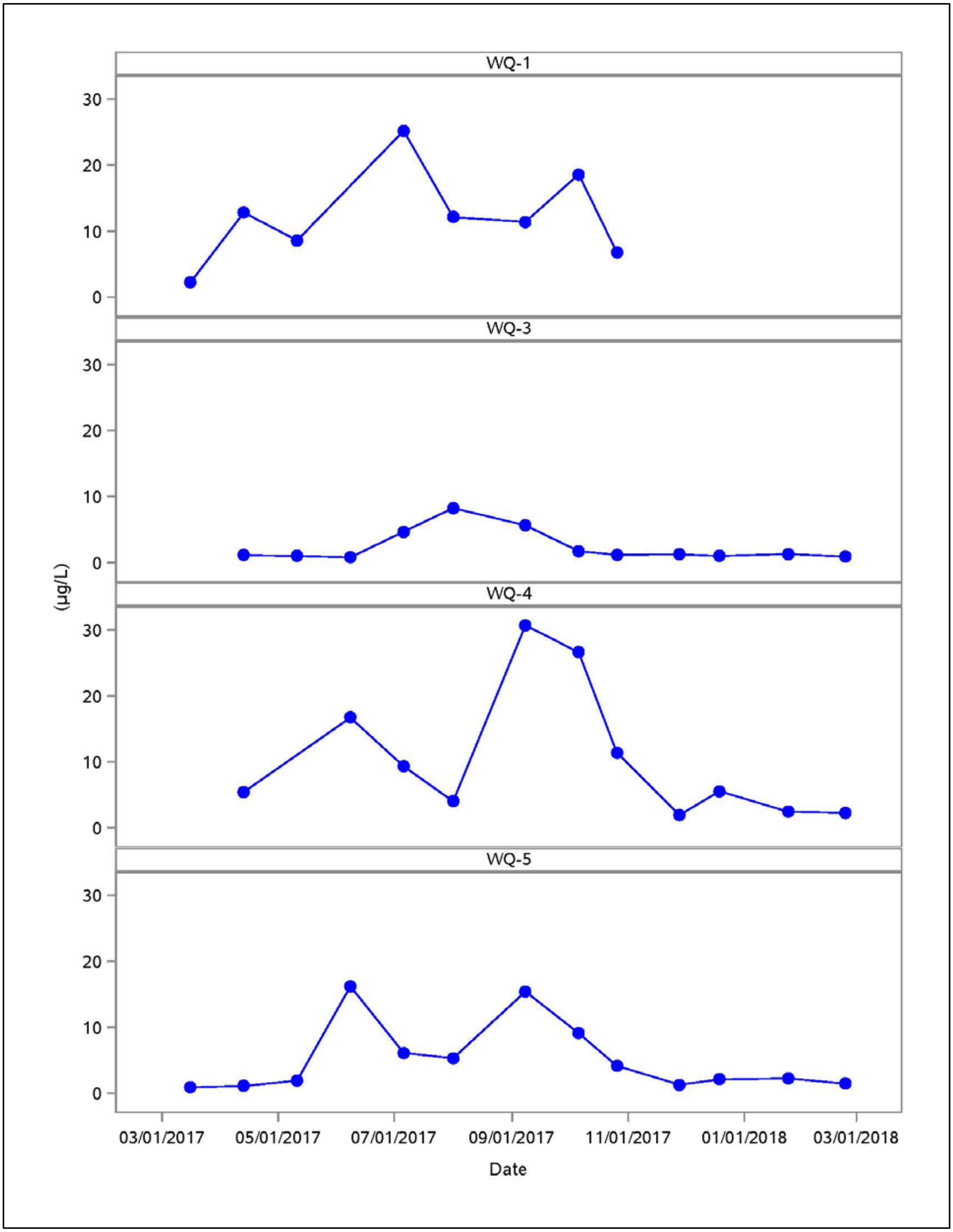


Figure 24. Time series plots the chlorophyll *a* concentration data from the 4 project sampling sites – March 2017-March 2018.

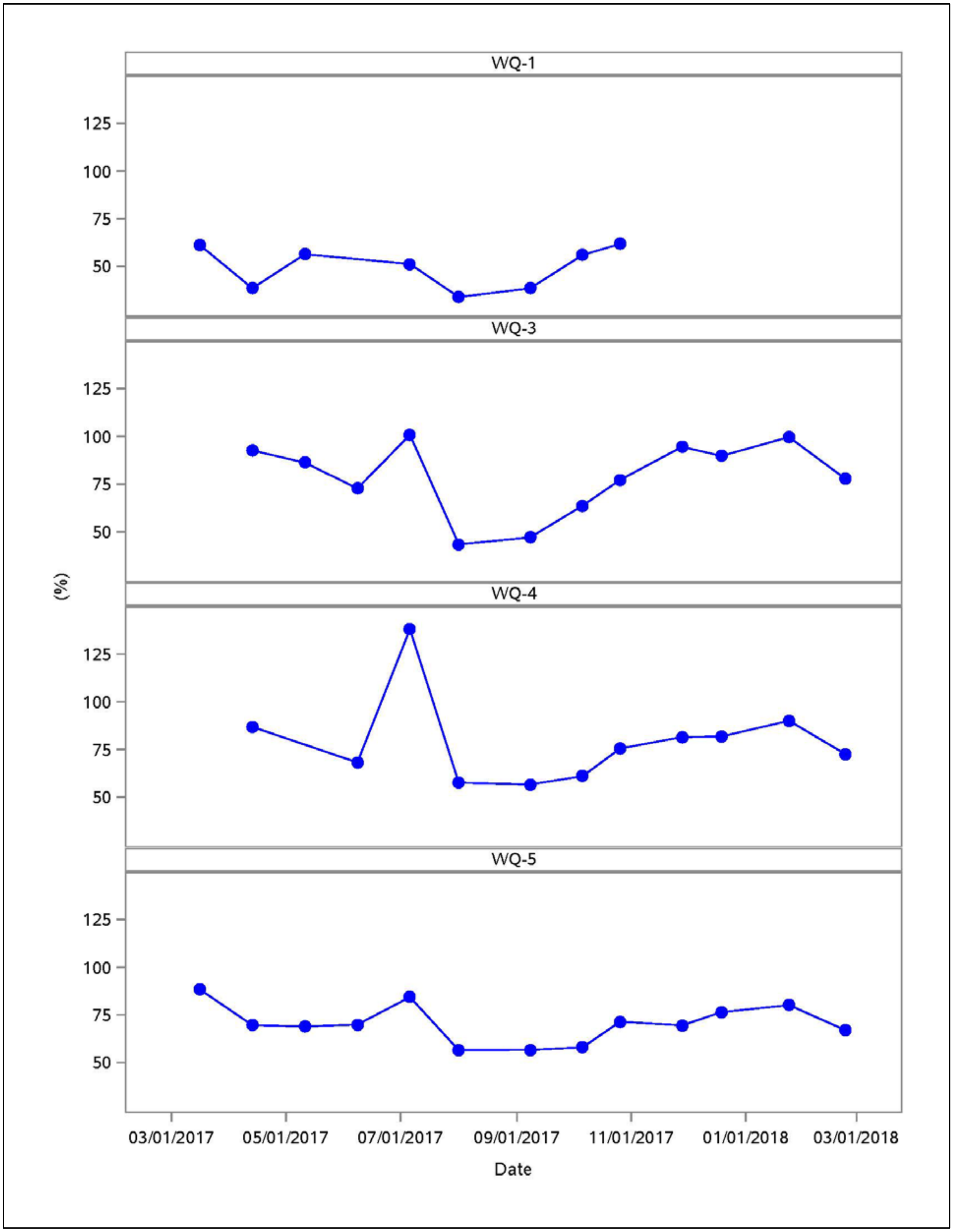


Figure 25. Time series plots the DO percent saturation data from the 4 project sampling sites – March 2017-March 2018.

Conceptual Model of Potential Effect of Plant City WRF on East Canal/ Itchepackesassa System

Understanding of the manner by which the discharge from the Plant City WRF can influence the East Canal system provides the context that can lead to meaningful and defensible conclusions and recommendations. The inter-relationships of the watershed and stream channel characteristics along with the hydrology and water quality of the East Canal/Itchepackesassa System have both direct and indirect effects on how the discharges from the Plant City WRF influence the downstream areas. Figure 26 presents a simple flow diagram that depicts these inter-relationships.

The information/data that have been provided by field collection of the physio-chemical and biological data along with the predictive modeling of the water quality responses to changes in WRF discharges are necessary to draw defensible conclusions regarding those responses. The following sections describe the analytical approach to the quantitative methods of data analysis and predictive modeling and the results obtained by the implementation of this approach.

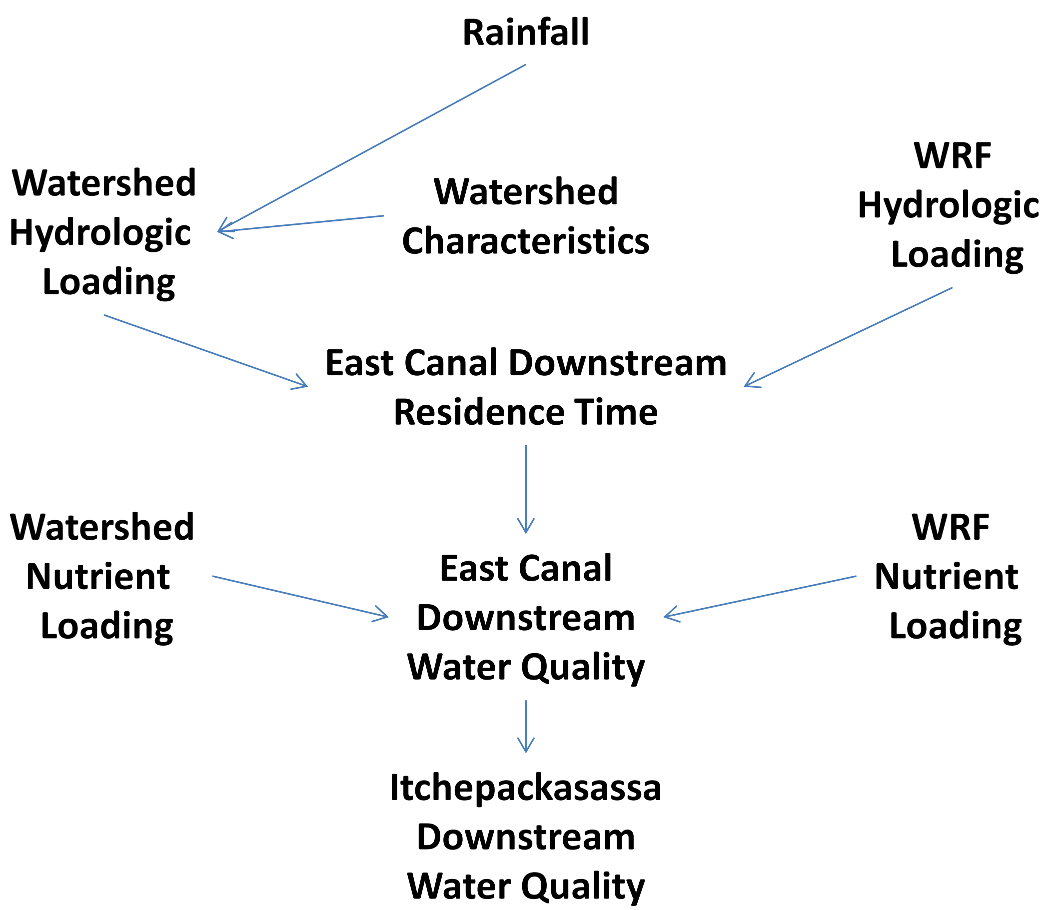


Figure 26. Conceptual model of critical inter-relationships that influence the effects of the Plant City WRF.

Analytical Approaches

The following provides a discussion of the approaches used to assess the relationships between the water quality responses to changes in loadings, particularly those from the WRF.

Objectives

Three analytical approaches were applied to assess the potential influence of variation in the loadings from the Plant City WRF on water quality within East Canal and Itchepackesassa Creek:

- Empirical stressor-response analysis,
- Simple box model, and
- Mechanistic modeling.

Specifically, the objective is to provide a predictive tool that quantifies the relationships between the water quality responses to changes in loadings, particularly those from the WRF.

Empirical Stressor-Response Approach

Linear regression is a parametric statistical technique that is used to explore the relationship between two or more variables. In univariate ordinary linear regression, the relationship between the dependent variable (y-axis) and independent variable (x-axis) is developed. This is done by fitting a straight line through the set of points such that the sum of squared residuals of the model is as small as possible. That is to say, the vertical distances between the individual points and the fitted line are minimized. Ordinary linear regression is a well-established method.

In linear regression, it is assumed that the data are independent samples from the population. For example, if the objective is to define the relationship between chlorophyll a concentrations and nutrient loading, the data should come from samples that are representative of the spatial and temporal variability of the system. Another important assumption of linear regression is that the error term of the model is normally distributed, with constant variance. Often times, one or more of the variables exhibits a non-linear relationship with the other variables. While there are non-linear regression techniques that can be employed, one approach often taken is to transform the data. Often times ordinary linear regressions can be developed using transformed data and these models will satisfy the assumptions of linear regression.

Diagnostic statistics and plots are commonly used to determine if the regression model meets the assumptions of linear regression. The most commonly used statistics are the statistical significance of the model coefficients and the coefficient of determination (r^2). The statistical significance of the model coefficients tests whether the slope and intercept of the model are significantly different from zero. The coefficient of determination is a measure of the variance in the dependent variable that is explained by the model. A plot of the residuals versus the independent variable can be used to judge if the assumption of constant variance is met. Additional plots of residuals versus other variables can also be instructive. For example, a time-series plot of the residuals can be used to assess whether or not the residuals vary seasonally. Additional diagnostics can be run to identify outliers and test for leverage or influential points. Data points that are identified by these additional diagnostics should be further investigated to determine if they are the result of a data entry error or other problem that merits removing them from the analysis.

Linear regression models that meet the above assumptions and satisfy the diagnostic tests should be validated using independent data or with other techniques like bootstrapping. In traditional regression caution should be used when applying a regression model to the range of data that is outside of the bounds of the data used to develop the model; however, recent advances in specifying random effects allow for the generalization of regression models outside of the domain.

An example of linear regression is presented below. The relationship of TN concentrations to chlorophyll *a* was investigated. Preliminary analyses between chlorophyll *a* and various water quality constituents revealed a correlation between chlorophyll *a* and TN concentration. Generally, chlorophyll *a* concentrations increase with increasing TN concentrations, though the relationship is non-linear at lower TN concentrations. Therefore, the variables were log transformed and the fit of the model was improved (Figure 27). Though the amount of variation explained by the model was less than 50%, the coefficients were highly significant. Obviously a large portion of the variation in chlorophyll is explained by other variables that are not included in the model, suggesting the model could be improved with the addition of relevant variables and possibly interaction terms.

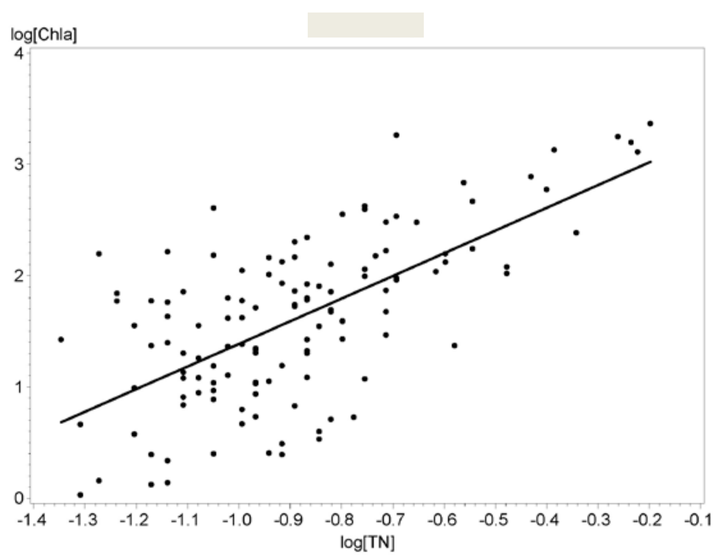


Figure 27. Relationship between chlorophyll and TN concentrations as defined by a linear regression.

For this project the quantitative relationships between chlorophyll *a* and nutrient (N and P) loadings were investigated and the results presented in the next section.

Box model/Mass Balance Approach

To understand the overall relative influence of the loadings from the Plant City WRF, a simple box model was developed. A mass balance model will provide information pertaining to the relative importance of the various inflows to the East Canal and Itchepackesassa Creek in terms of loadings of constituents of interest (nitrogen, phosphorus, organic carbon). A mass balance model considers the fluxes of water into the system from all sources, and associated masses of constituents. Initial estimates of constituent mass fluxes can be developed employing conservative tracers associated with different water sources, and evaluating the combined effects of all water sources in the downstream reaches of the system.

Mechanistic Modeling Approach

Model Selection

A number of water quality models within the public domain were considered for this project. These include models developed and supported by EPA and ACOE and include WASP, CE-QUAL, and QUAL2E. Given the relatively simple system to be modeled, the amount of data either readily available or easily obtained, and the potential importance of periphyton in the receiving waters QUAL2Kw was selected for this project.

Description of QUAL2Kw

QUAL2Kw is a public domain mechanistic modeling tool for simulating water quality in streams and rivers, and is a modernized version of the QUAL2E model (Brown and Barnwell, 1987). Modifications to QUAL2E in the early 2000s (Chapra and Pelletier, 2003; Pelletier and Chapra, 2005) were directed at improvements in numerical methods and addition of constituent interactions. Like QUAL2E, QUAL2Kw simulates a well-mixed one-dimensional channel, allows for branched tributaries, simulates diel heat/temperature and water quality kinetics, including nutrients and phytoplankton, and provides for pollutant loadings from point and nonpoint sources. The model initially only allowed for steady state hydraulics and repeating diel boundary conditions, but the version employed for this modeling effort, Version 6.0, allows for continuous simulation of temporally varying flows and other boundary conditions.

QUAL2Kw is implemented via an Excel user interface, with interface operations programmed in Microsoft Office Visual Basic for Applications (VBA) (Chapra et al., 2012). The model simulates responses in the water column to time-varying loadings and inflows and the subsequent physical interactions with the modeled system physiography (bathymetry). The model provides for sediment-water interactions, incorporates bottom algae (periphyton), and includes alkalinity/pH/inorganic carbon interactions. The model also incorporates a genetic algorithm to aid in model calibration, with direct user input as to which model parameters are to be included in the optimization and the formulation of the goodness-of-fit measure.

Data Needs

Application of the QUAL2Kw model to the system to be modeled requires several data types to execute and calibrate the model. The following discusses those data needs.

Flow

Flow data are a critical data need to calibrate and execute the QUAL2Kw model. To provide these data, field data collection of stream velocities and depths were obtained at each of the water quality sampling sites (Figure 14). Appendix 3 provides a description of the data collection methods.

As the model requires temporally variable flow data and since the data collection was limited to the monthly sampling schedule, a method to estimate daily flows was needed. To achieve this need, a regression of the measured flows at each of the sampling sites on the daily flow data available from Blackwater Creek (USGS Site 02302500), located below the confluence with Itchepackesassa Creek, was completed. The results of these regressions are presented in Appendix 5. The plant discharge records provided the daily flows from the plant.

Ambient Water Quality and Other Model Needs

The list of ambient water quality and other data either collected in the field or obtained in the laboratory are provided in Appendix 7. These data include physical parameters (temperature, flow, depth) as well as chemical and biological parameters (nutrients, oxygen, chlorophyll, and oxygen demanding constituents.

The set of constants and rates needed to execute the model is also provided in Appendix 7. Recommended values and ranges of values for surface water quality model constants and rates are provided in the QUAL2K documentation (Chapra et al. 2012) and in the EPA document "Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling" (Bowie et al. 1985), as well as within the model spreadsheets for ease of reference.

Drivers

The variables needed to execute the model (drivers), other than inflows as described above, were primarily obtained from the National Weather Service site at Plant City airport. These drivers include the following:

- Air temperature
- Dew point temperature
- Wind speed
- Cloud cover
- Solar radiation (obtained from UF IFAS FAWN site at Dover)
- Shade (estimated based on observations in the field and from aerial photography)

Time series at hourly frequency were developed from the initial data via interpolation for input to the model.

Model Set-up

There are two important aspects to the set-up of the QUAL2Kw model – both spatial and temporal extents of the model.

Model Set-up – Spatial Aspect

Bathymetry data were collected at seven cross section locations along the stream (Figure 28), with the downstream six transects (from Knights Griffin Rd. and downstream, transects B-G is Figure 28) of these used to define the stream bed and side elevations. The elevations for the transects are as provided in Appendix 4.

The East Canal/Itchepackesassa Creek system study area includes two distinct stream regions, with the upstream region defined as that between the plant discharge location just north of Knights Griffin Rd. and the confluence with Itchepackesassa Creek, and the downstream region defined as that from the confluence to Blackwater Creek. The system was divided into six reaches (Figure 29) so that each reach represented relatively similar conditions and dimensions (Table 12).

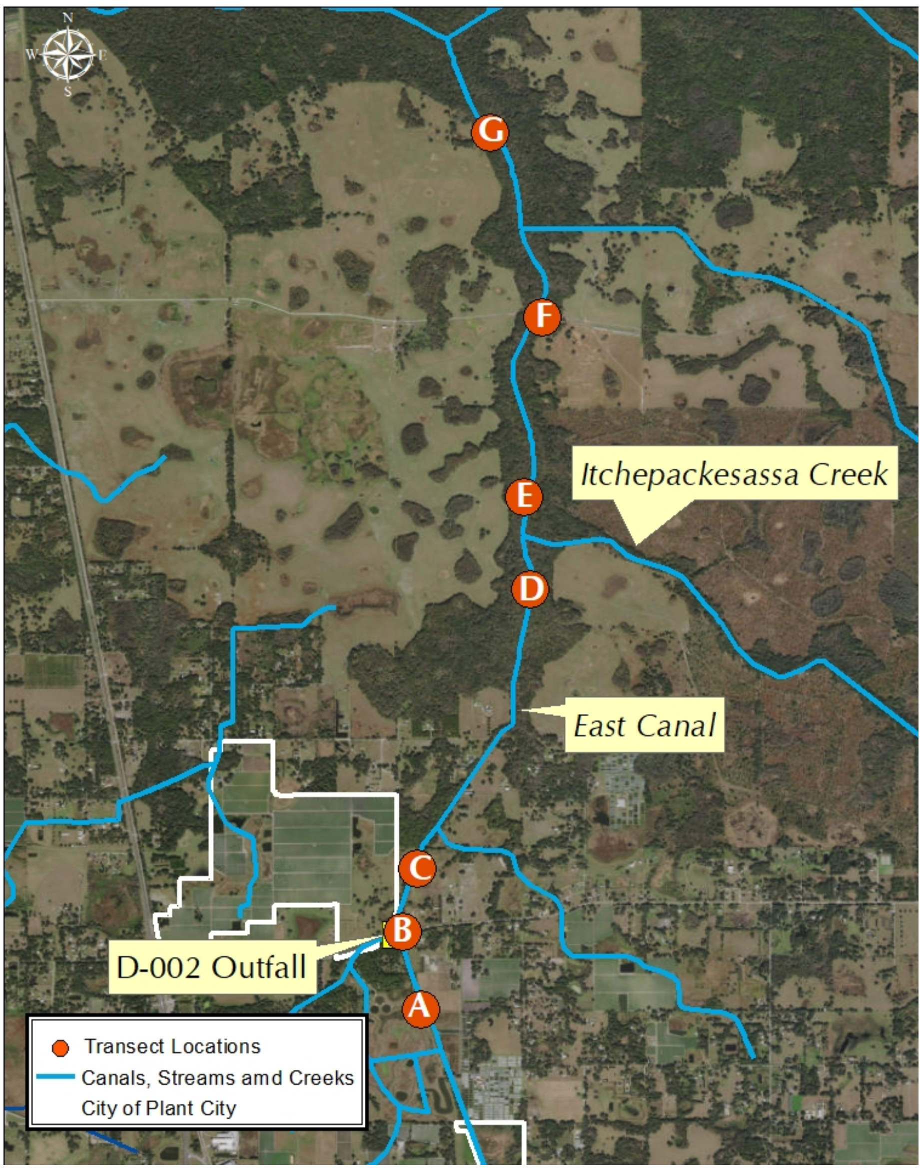


Figure 28. Locations of bathymetric transects used to develop model segment (reach) dimensions.

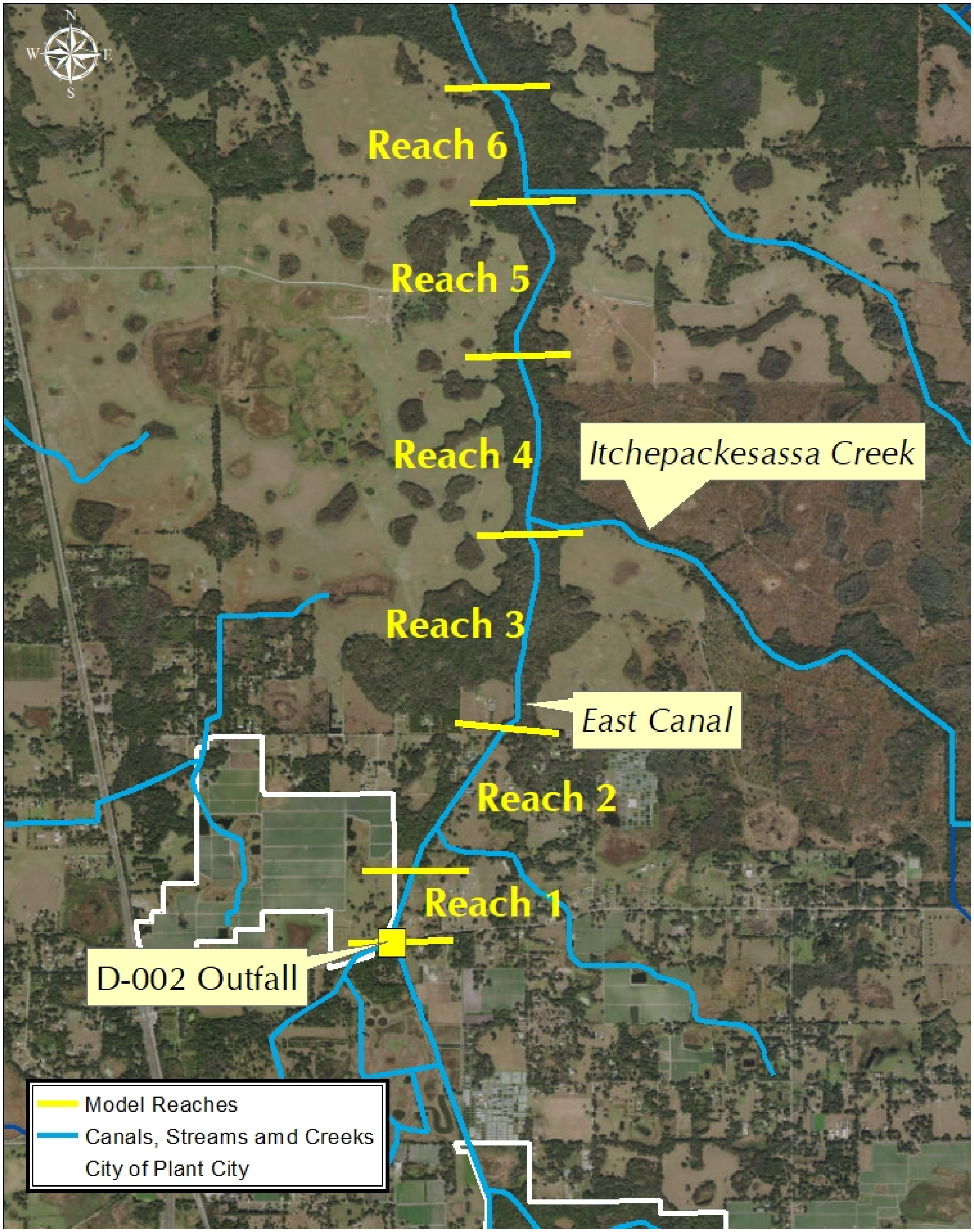


Figure 29. Location of model reaches extending from Knights Griffin Rd. upstream to just above Blackwater Creek downstream.

The stream is relatively narrow upstream (Reach 1 - 6.5 m wide) and widens as it extends downstream to Blackwater Creek, to 10.2 m in the downstream-most reach. Typical depths in the upstream three reaches are on the order of 0.25 m, and in the downstream three reaches are on the order of 0.4 m, with variation over time in response to inflows. During especially high inflows, the stream overtops its banks, so that the care should be taken in interpretation of model results during the out-of-bank period.

Table 12. Model reach dimensions. *Depths are based on observed values.

Reach	Length (m)	Width (m)	Depth* (m)	Volume (m^3)
1	503	6.5	0.25	818
2	1120	6.5	0.25	1821
3	1353	7.2	0.25	2420
4	1218	7.6	0.4	3725
5	1079	9.2	0.4	3969
6	812	10.2	0.4	3306

Boundary conditions are the inputs to the model system from inflowing water sources. Reach 1 (Figure 29) receives flow and water quality inputs from upstream (south of Knights Griffin Rd.), although flow is heavily dependent on rainfall and is often zero. Reach 1 also receives the wastewater treatment plant discharge, so that the upstream inflows and the plant inflows with associated water quality serve as boundary conditions for Reach 1.

Reach 5 includes the confluence of East Canal and Itchepackesassa Creek, and thus the flows and associated water quality from the creek above the confluence serve as boundary conditions for Reach 5. The downstream boundary of the model domain, at the northern limit of Reach 6, is an open boundary, with no external boundary conditions, so that water quality and flows within the model domain are not influenced by conditions downstream of Reach 6.

Model Set-up - Temporal Aspect

The temporal extent of the model, and the calibration period, is March 16, 2017 through March 15, 2018, or one year. The QUAL2Kw allows continuous simulation (providing for temporally varying inputs from boundaries) for a maximum of one year. The monitoring programs for data collection for both water quality and periphyton were completed within this one year period. The time step for the model is 2.8 minutes.

Initial conditions were developed based on observed data in March 2017, for the water quality conditions, depths, and periphyton status.

Model Calibration

The model was calibrated with respect to physical measurements and chemical and biological data collected as discussed previously. Tests of the goodness of fit were performed both by visual inspection and statistical comparisons between observed and simulated conditions. Initial calibration focused on accurate simulation of observed physical conditions, such as flow, temperature, and water depth. Following successful simulation of these conditions, as compared to the observed data, calibration with respect to water column water quality and periphyton biomass was completed. Comparisons of predicted and observed conditions were based on water quality data collected in Reach 3 and Reach 5, and comparisons of periphyton conditions were to the December 2017 data collected in Reach 5.

Calibration Results

Time series plots of simulated and observed physical conditions include those for depth (Figure 30), temperature (Figure 31), specific conductance (Figure 32), and flows (Figure 33). Simulated data are provided at a frequency of 45 minutes from the model, so that statistical comparison to observed data includes a mean of the simulated data over a three-hour period centered on the time associated with the observed data collection.

Visual inspection supports the model calibration with respect to these parameters. Statistical comparisons of predicted and observed data are provided in Appendix 8, and examination of these statistical tables also lends support to the strength of the calibration. The statistical evaluation of the physical data calibration results indicates very good relationships between simulated and observed data, with r^2 in excess of 0.9 for all except temperature, although the r^2 for temperature is still greater than 0.8. All other calibration statistics (RMSE, Mean Error, Absolute Mean Error, and Relative Error) employed for evaluation of the physical parameters support the conclusion that the model is very well calibrated with respect to these variables. It should be noted that for depth and flows, the greatest discrepancies between the simulated and observed data occurred when the system experienced out-of-bank flows in August 2017, so that the model cannot be expected to accurately simulate conditions during this brief period.

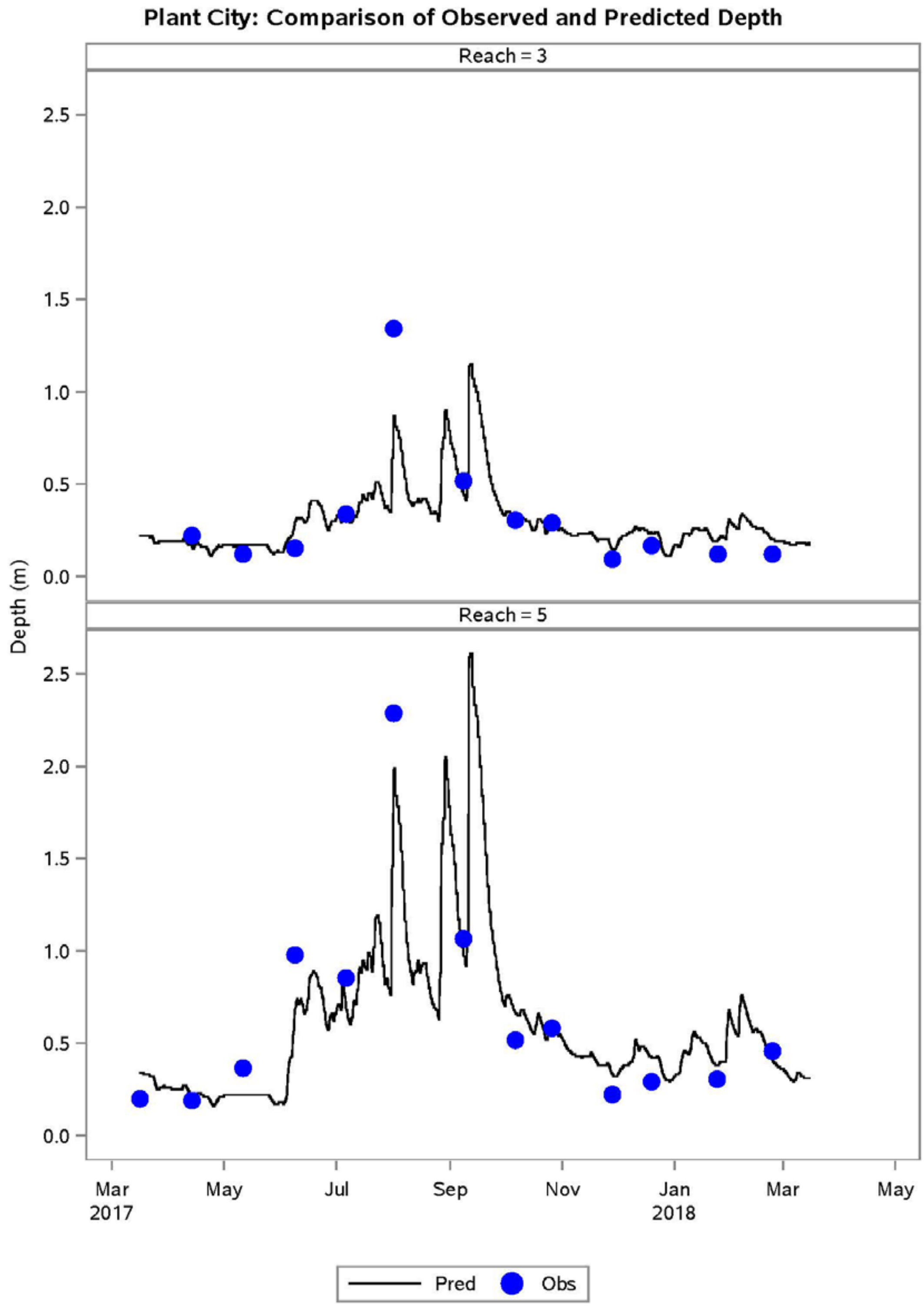


Figure 30. Comparison of predicted and observed depth in model reaches 3 and 5.

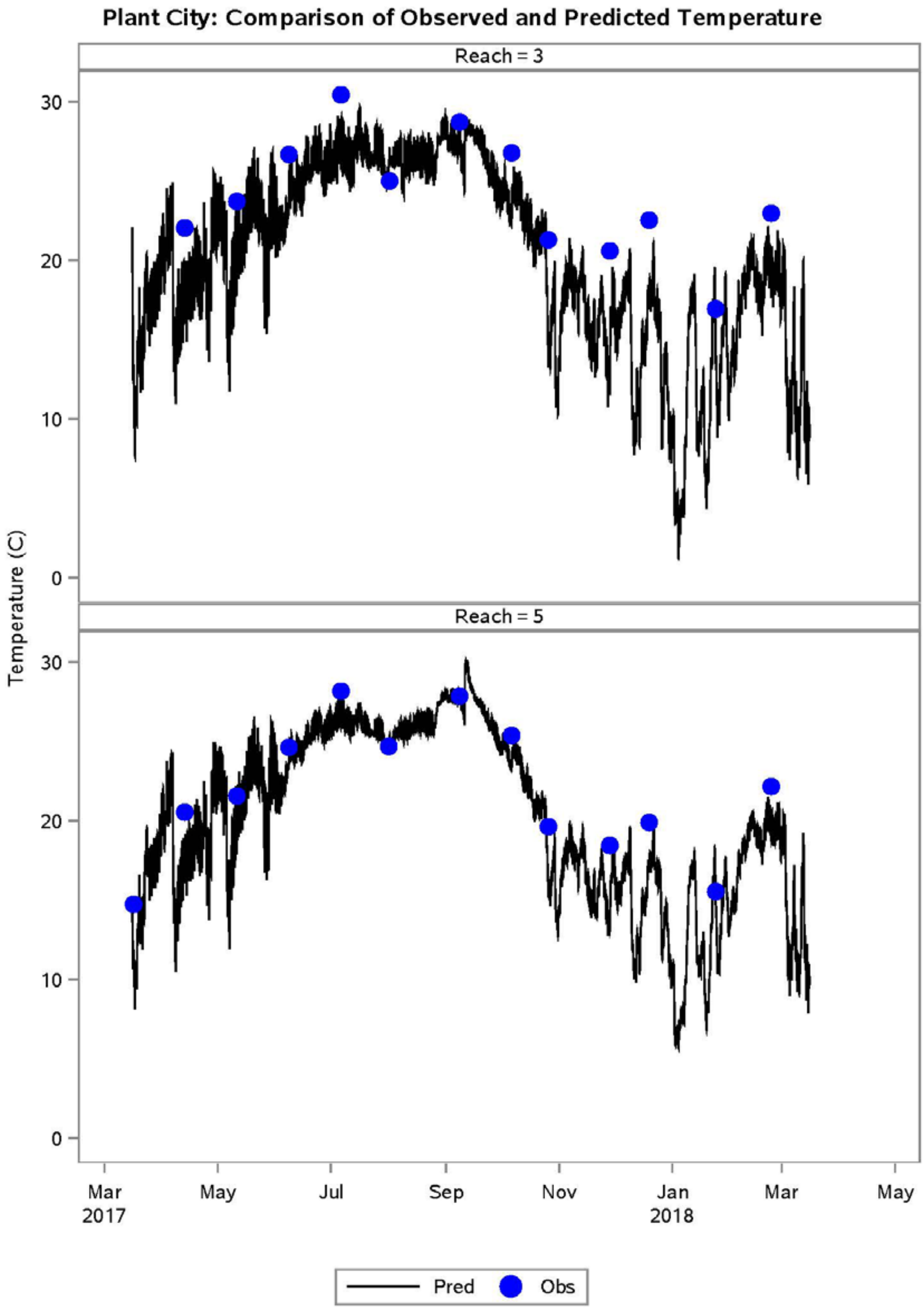


Figure 31. Comparison of predicted and observed temperature in model reaches 3 and 5.

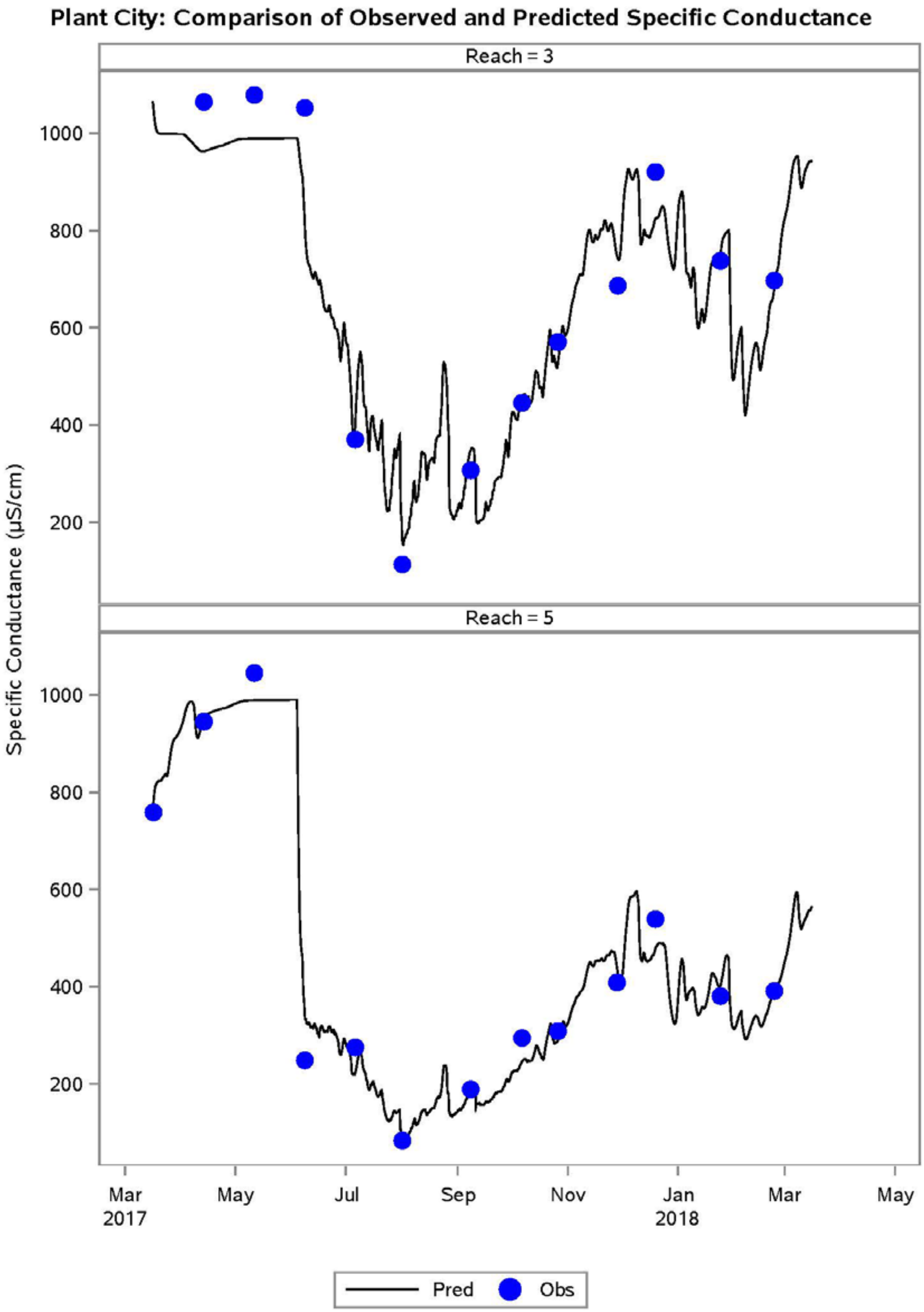


Figure 32. Comparison of predicted and observed specific conductance in model reaches 3 and 5.

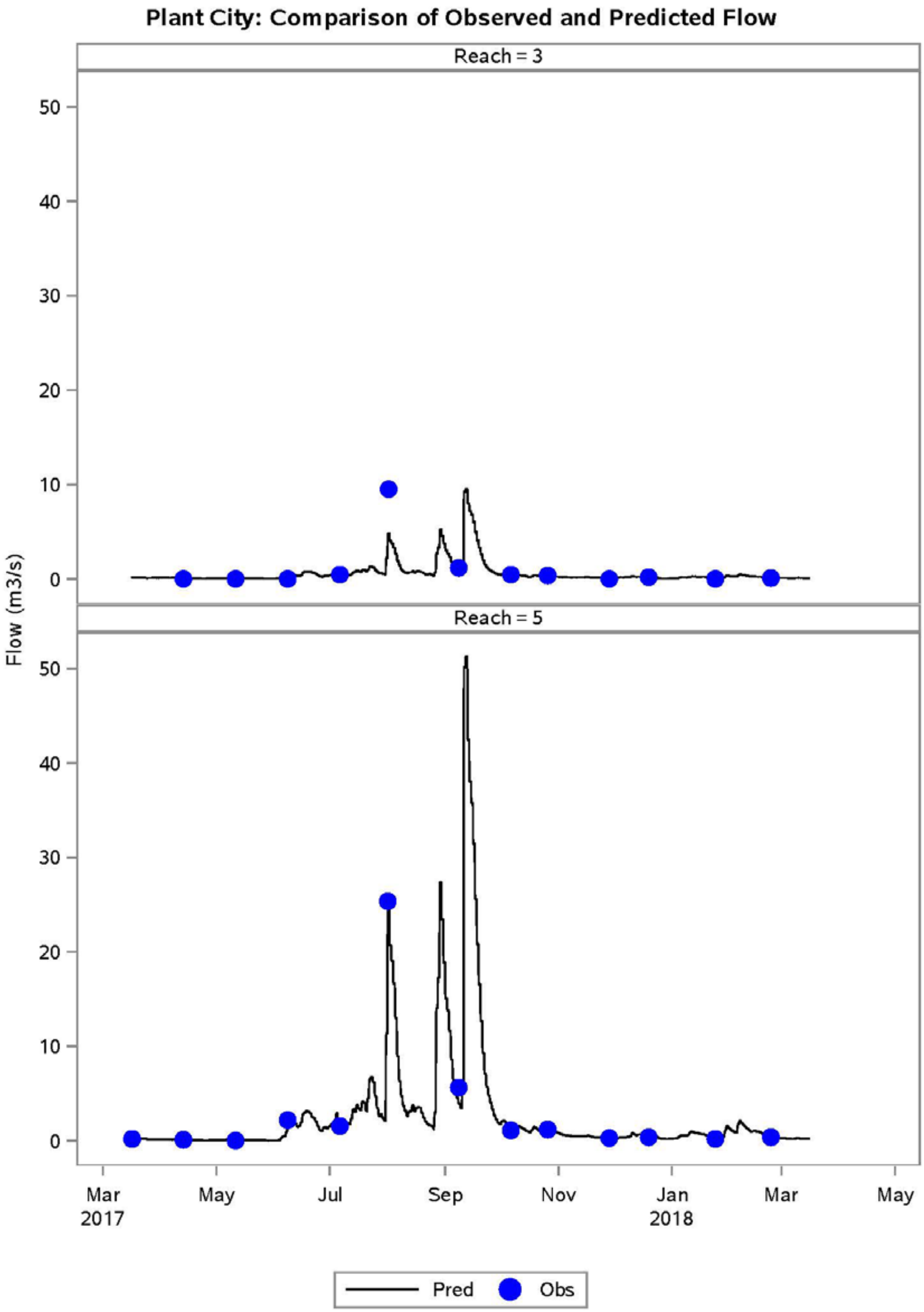


Figure 33. Comparison of predicted and observed stream flow in model reaches 3 and 5.

Time series plots of simulated and observed water quality data in Reach 3 and Reach 5 are provided for the following:

- pH (Figure 34),
- dissolved oxygen (DO) (Figure 35),
- total nitrogen (TN) (Figure 36),
- nitrate-nitrite (NO_3-NO_2 (Figure3 7),
- total Kjeldahl nitrogen (TKN) (Figure 38),
- total phosphorus (TP) (Figure 39),
- ortho-phosphorus (Figure 40),
- chlorophyll *a* (Figure 41),
- total organic carbon (TOC) (Figure 42), and
- dissolved organic carbon (DOC) (Figure 43).

Examination of these figures indicates the model calibration does a very good job in simulating observed conditions in both reaches. Statistical comparisons of simulated and observed values are also provided in Appendix 8. The goodness-of-fit as expressed by the r^2 is greater than 0.5 for all constituents, with most constituents having values greater than 0.7. The validity of the calibration for the water quality constituents is supported by the very high values for all other statistical measures (Appendix 8). The combination of the graphical time series comparison and the statistical comparison provides confidence that the model is well calibrated, and is appropriate for use in evaluation of proposed plant flow scenarios.

A final check of the model's ability to simulate observed conditions was comparison of the simulated periphyton biomass in Reach 5 to that observed on December 4, 2017. The observed periphyton chlorophyll *a* in Reach 5 was 2.85 mg/m^2. The predicted value for that day (2.25 mg/m^2) compares favorably with the observed data. This comparison further supports that the model is well calibrated for periphyton as well as for water quality and flows.

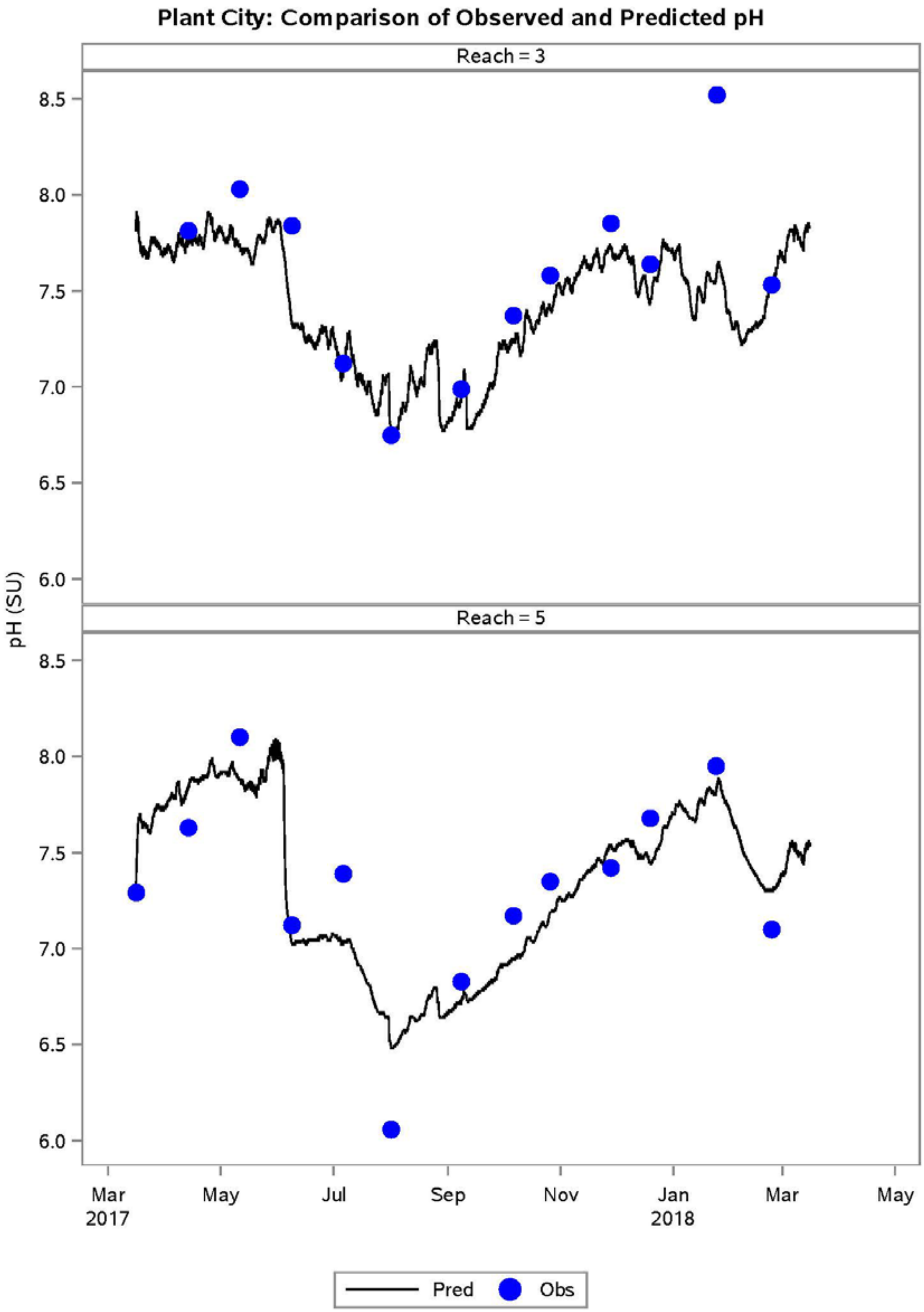


Figure 34. Comparison of predicted and observed pH in model reaches 3 and 5.

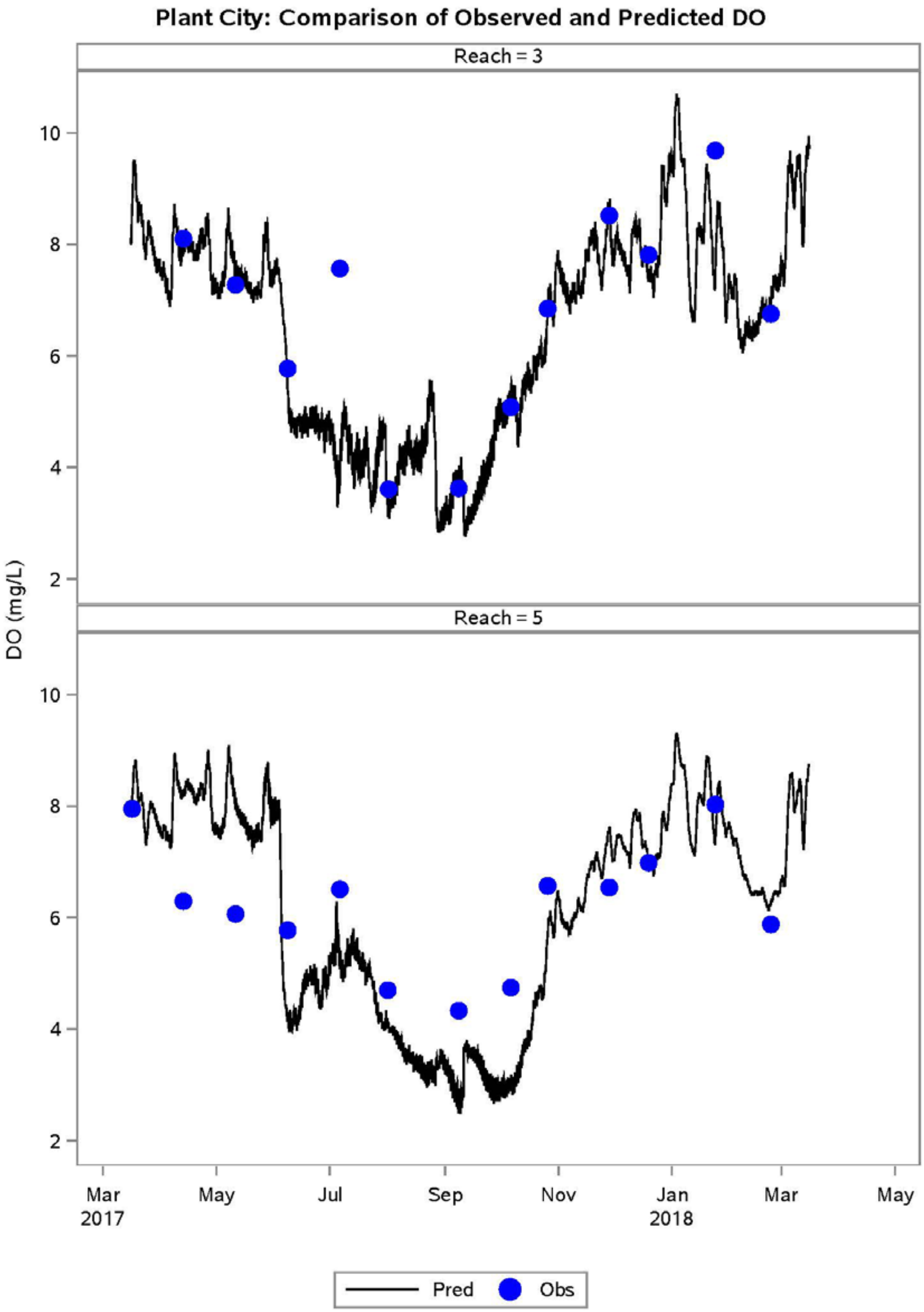


Figure 35. Comparison of predicted and observed DO in model reaches 3 and 5.

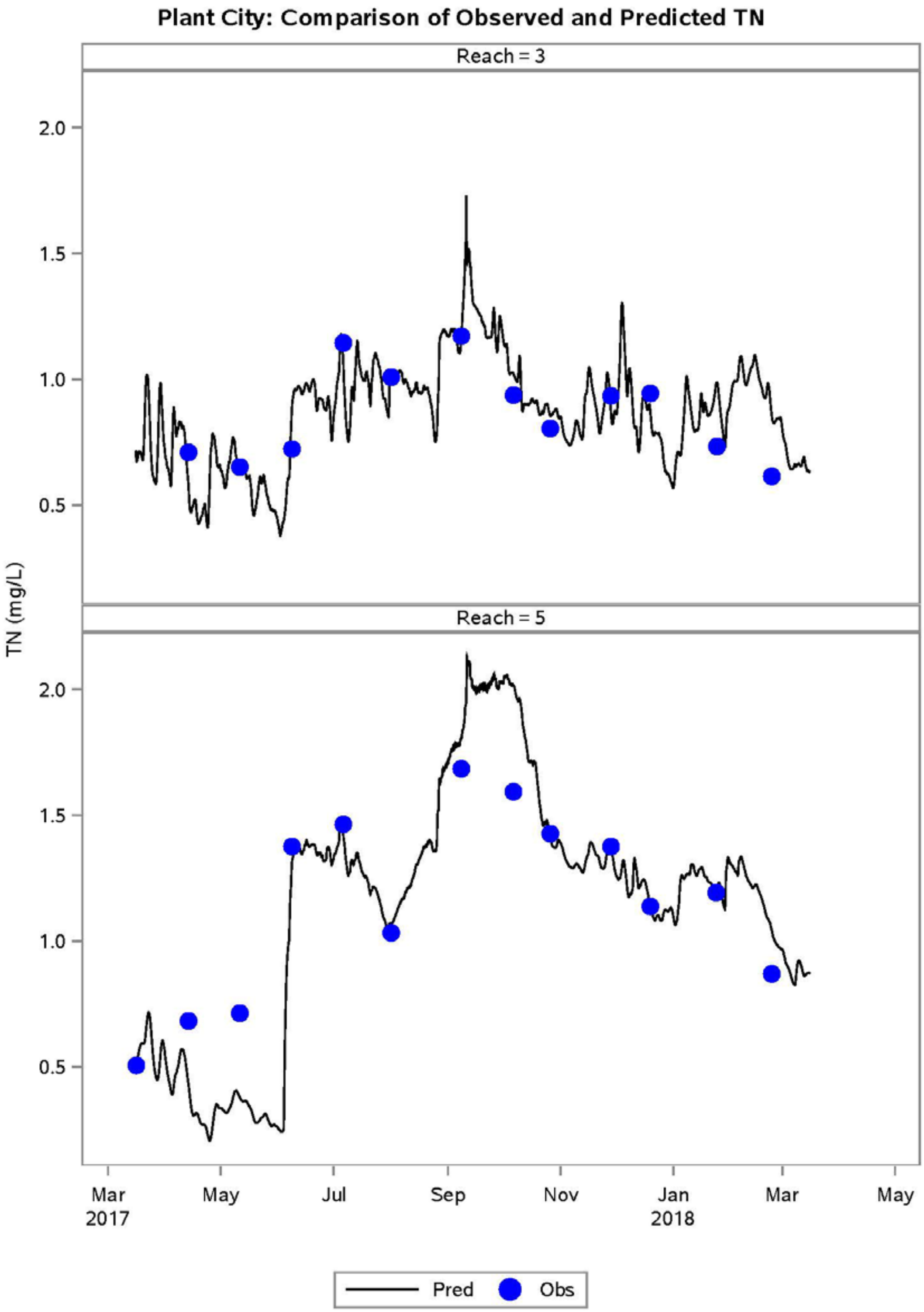


Figure 36. Comparison of predicted and observed TN in model reaches 3 and 5.

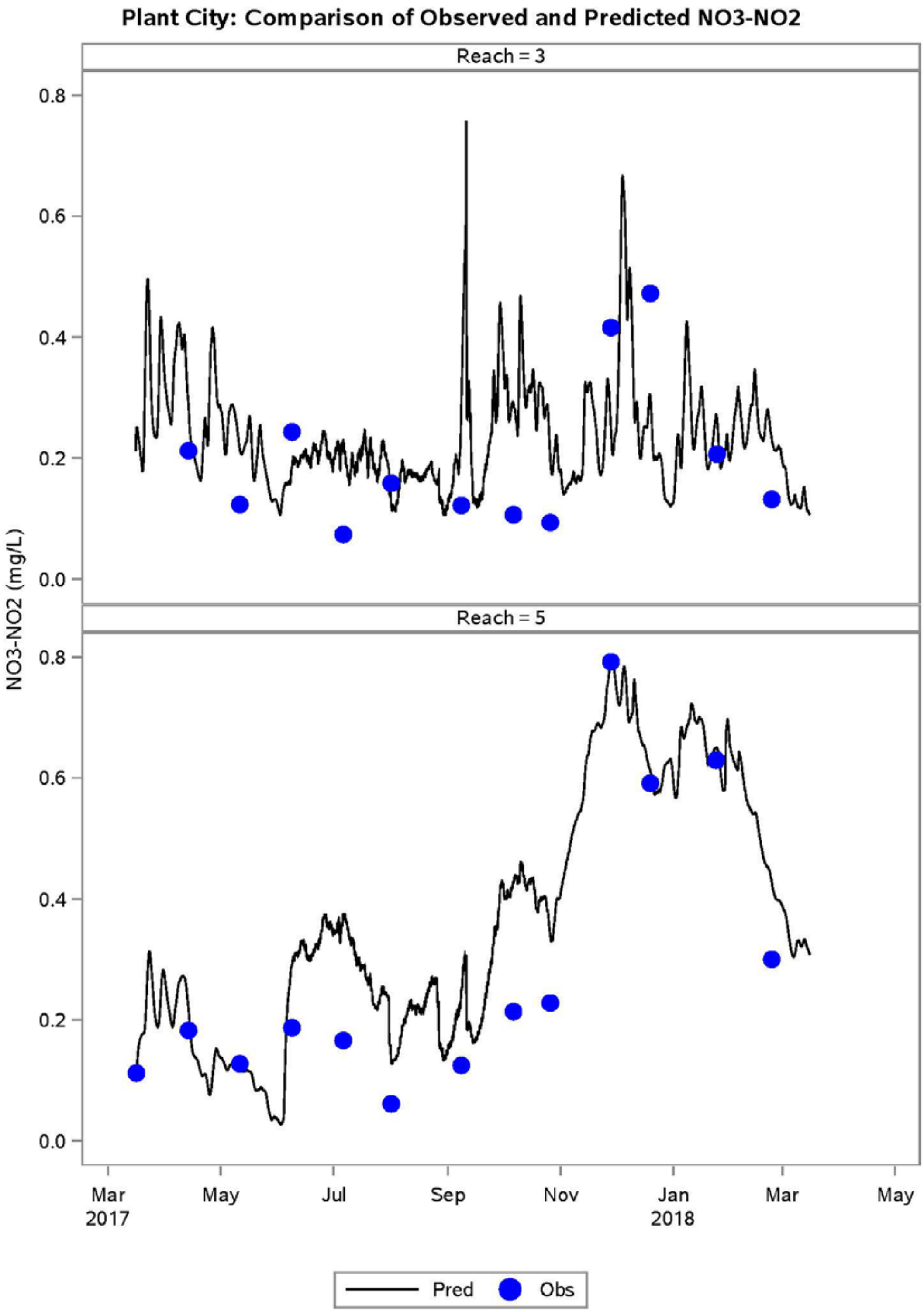


Figure 37. Comparison of predicted and observed NO_3-NO_2 in model reaches 3 and 5.

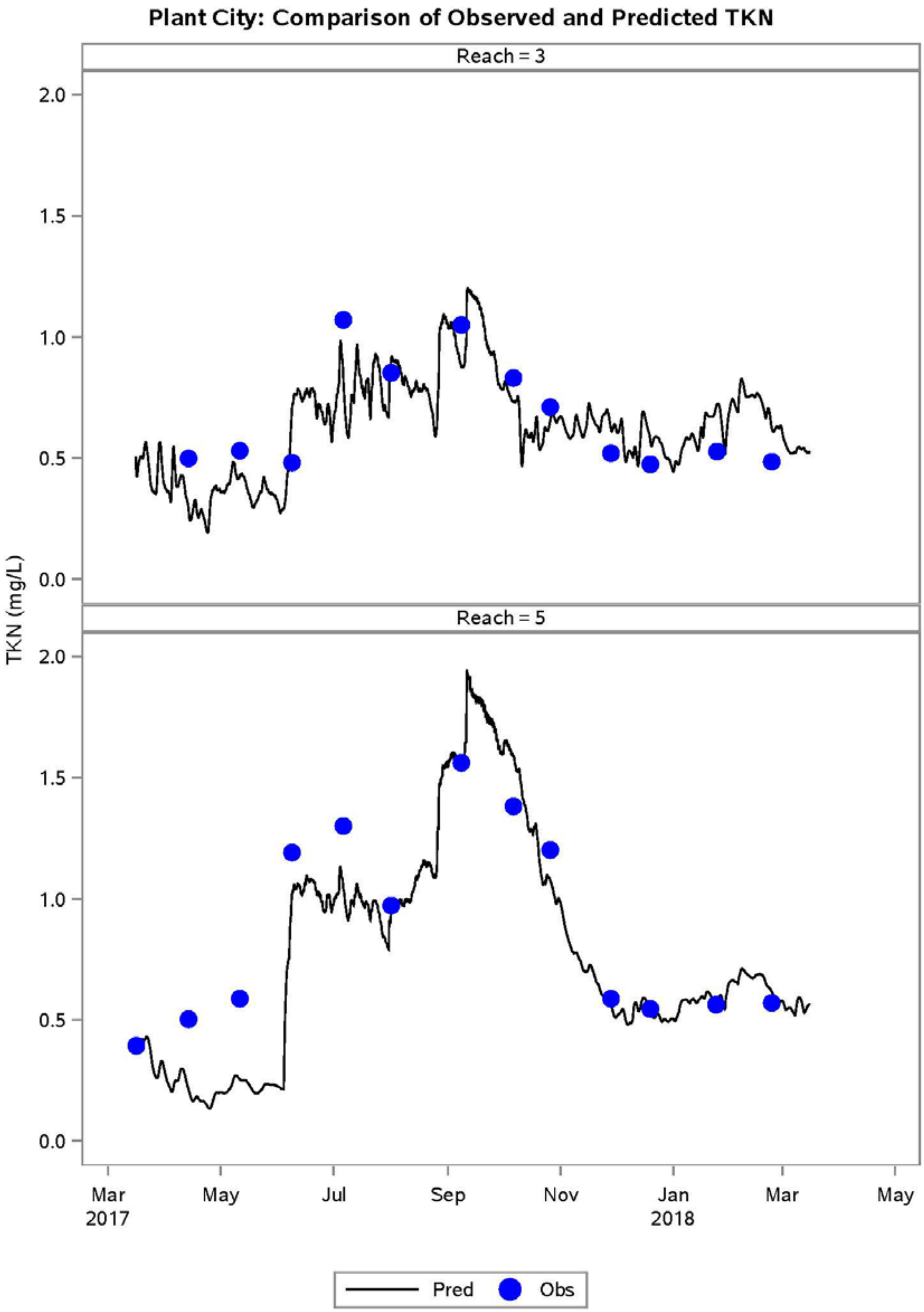


Figure 38. Comparison of predicted and observed TKN in model reaches 3 and 5.

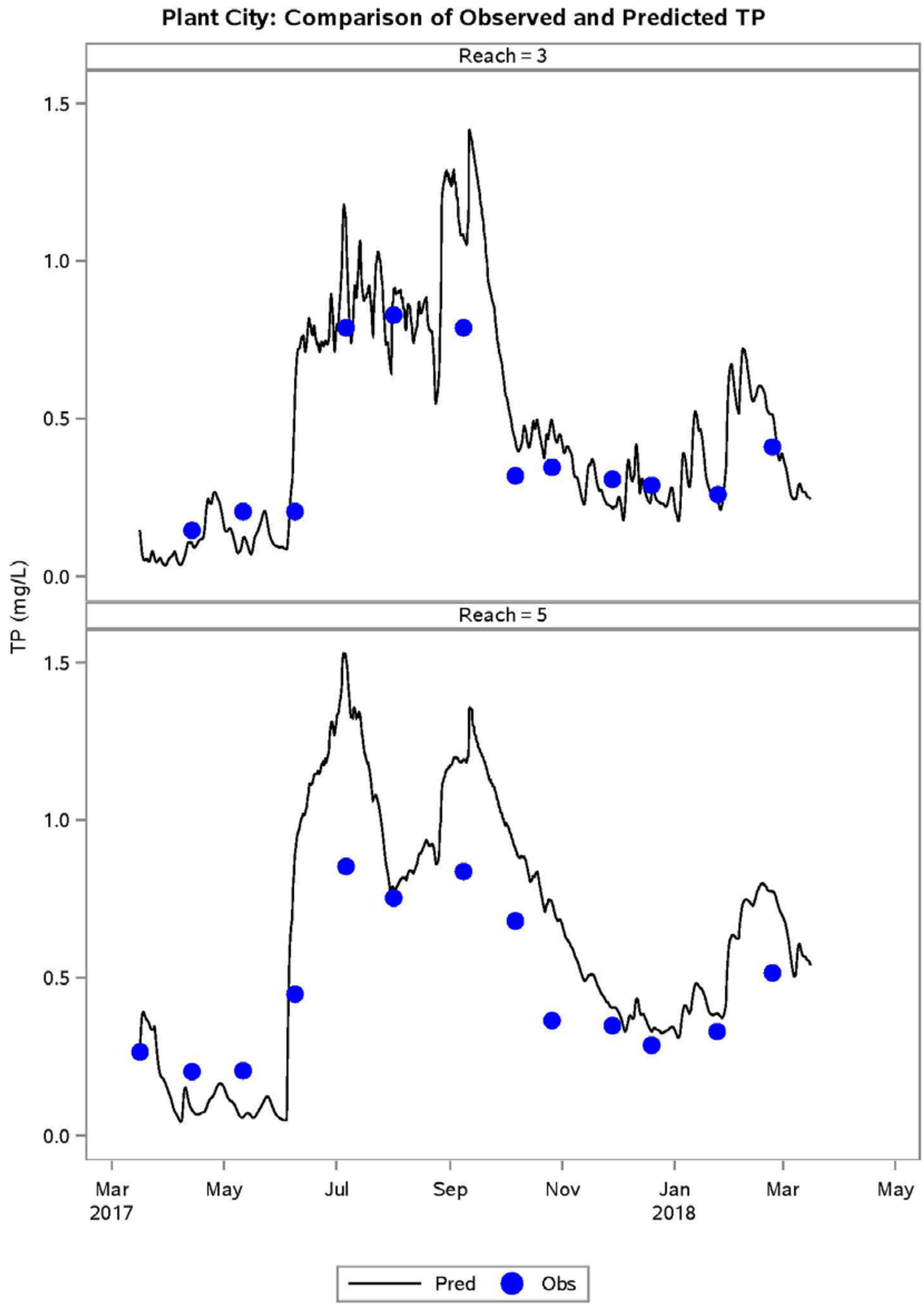


Figure 39. Comparison of predicted and observed TP in model reaches 3 and 5.

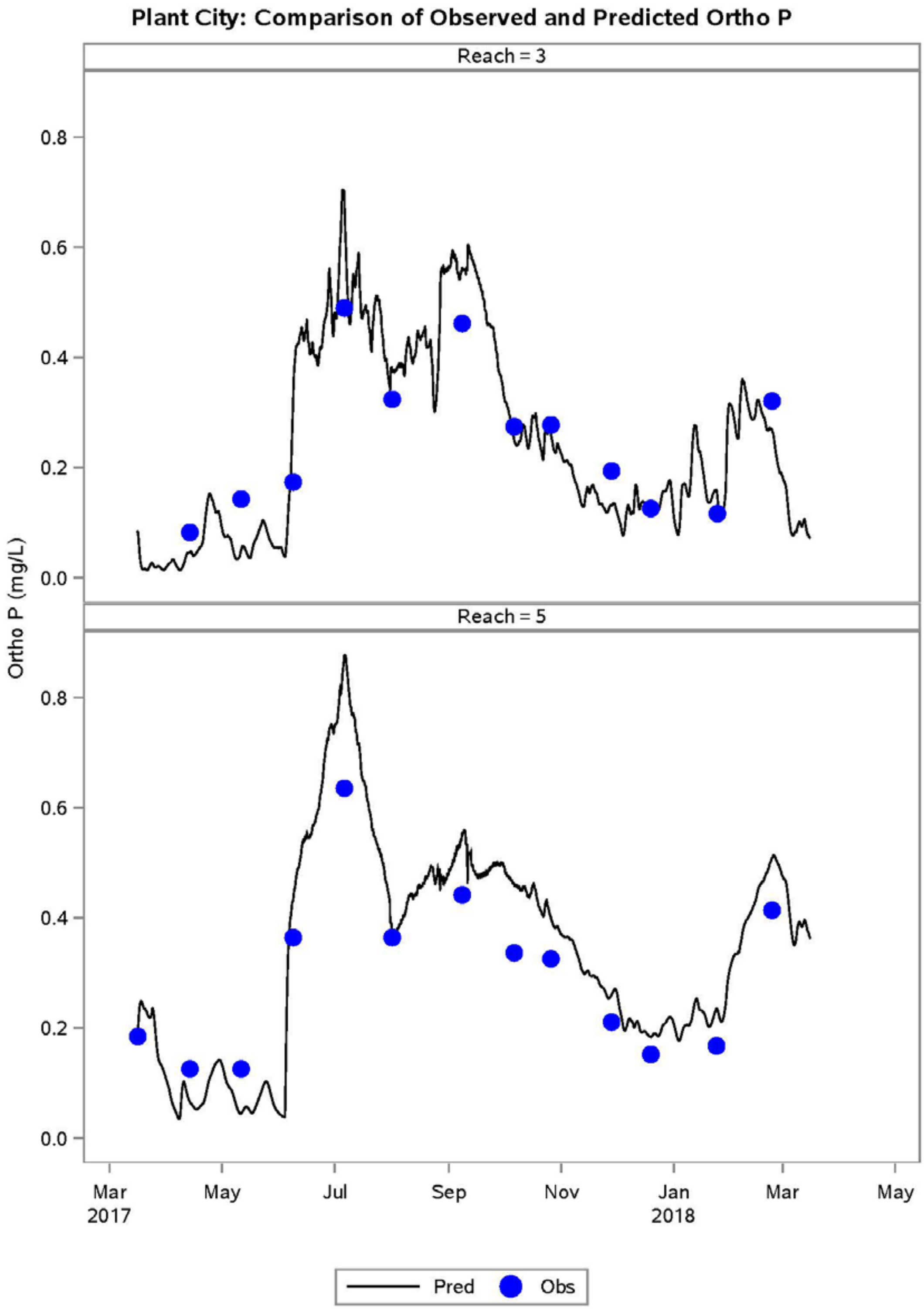


Figure 40. Comparison of predicted and observed ortho P in model reaches 3 and 5.

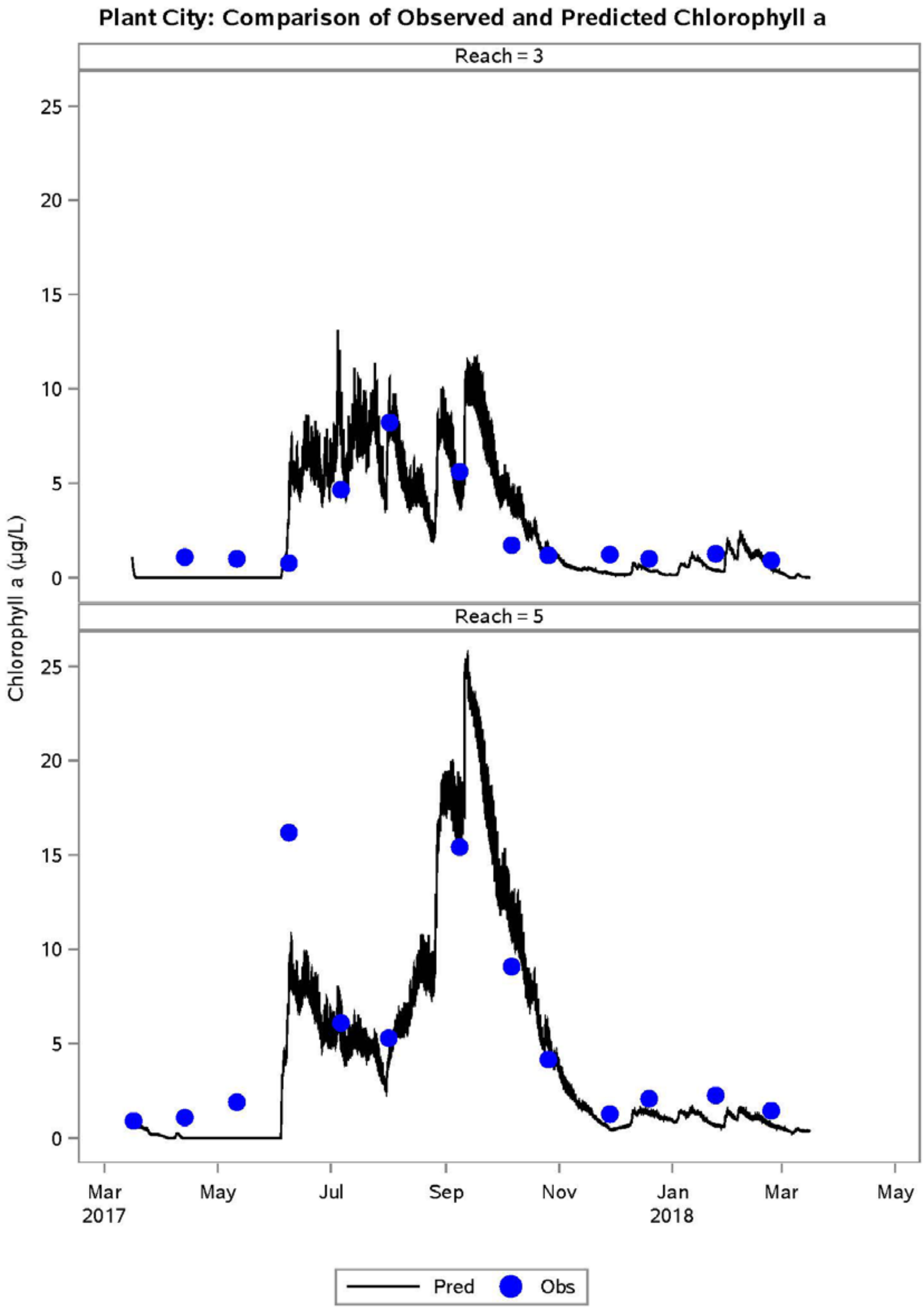


Figure 41. Comparison of predicted and observed chlorophyll *a* in model reaches 3 and 5.

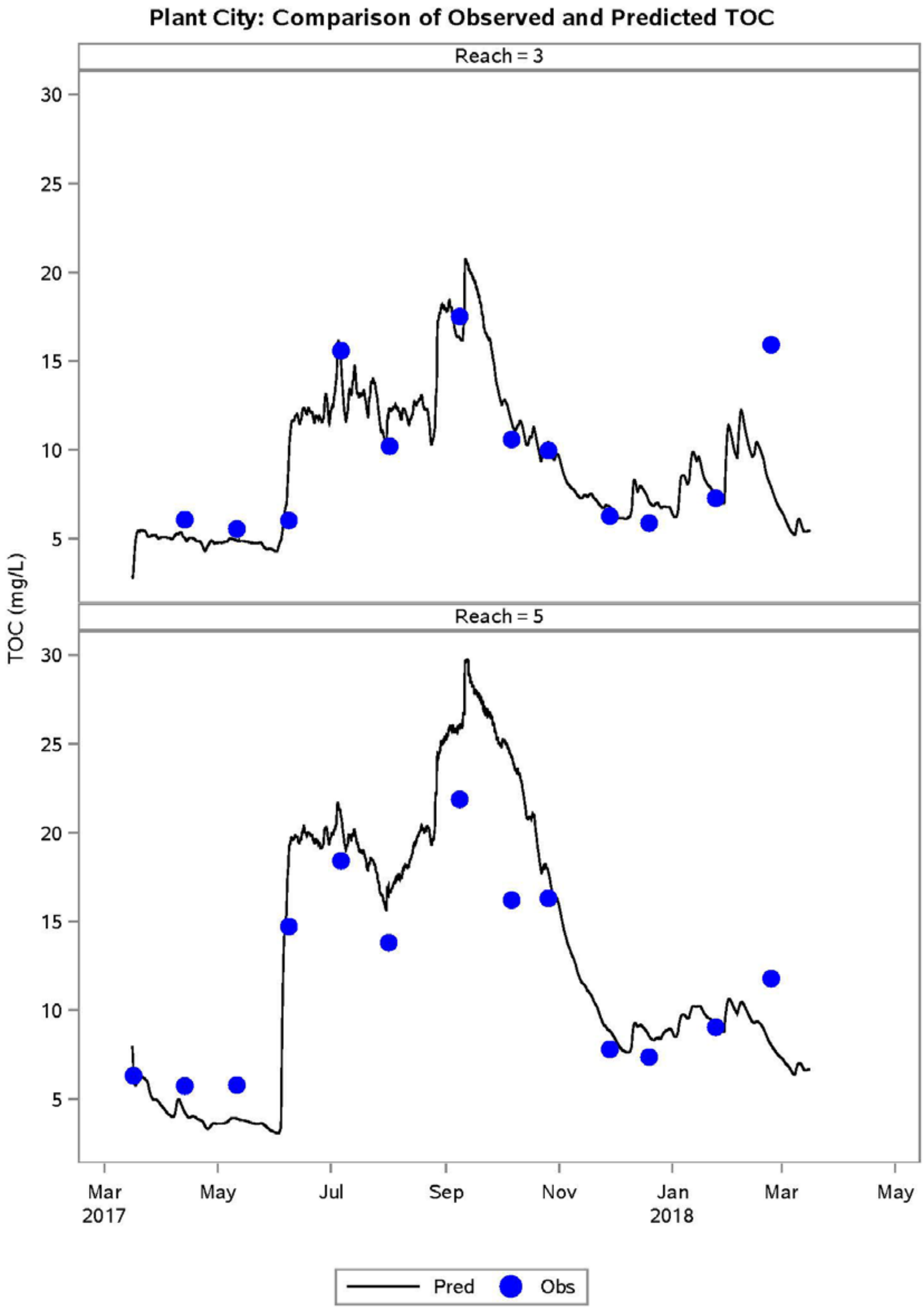


Figure 42. Comparison of predicted and observed TOC in model reaches 3 and 5.

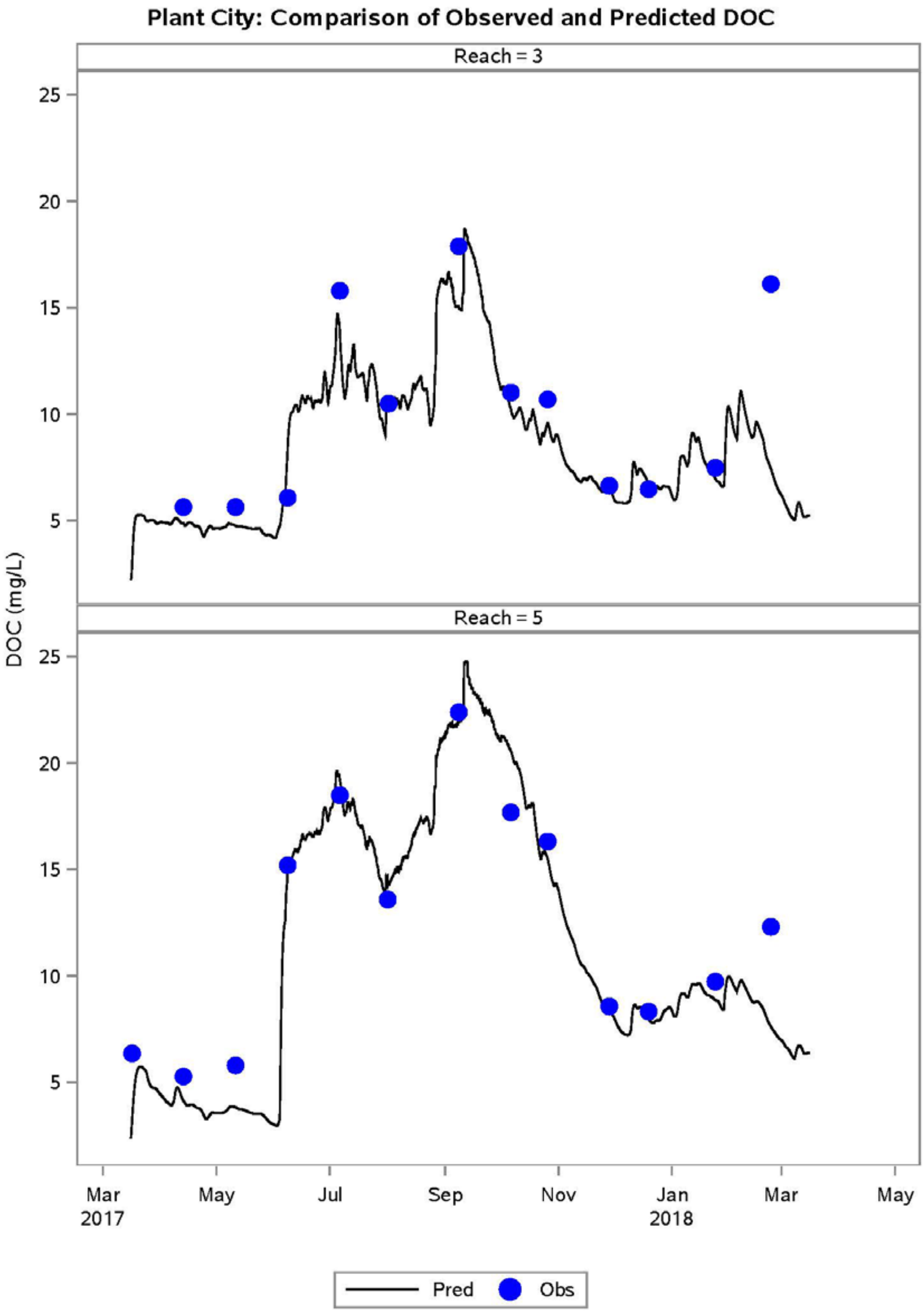


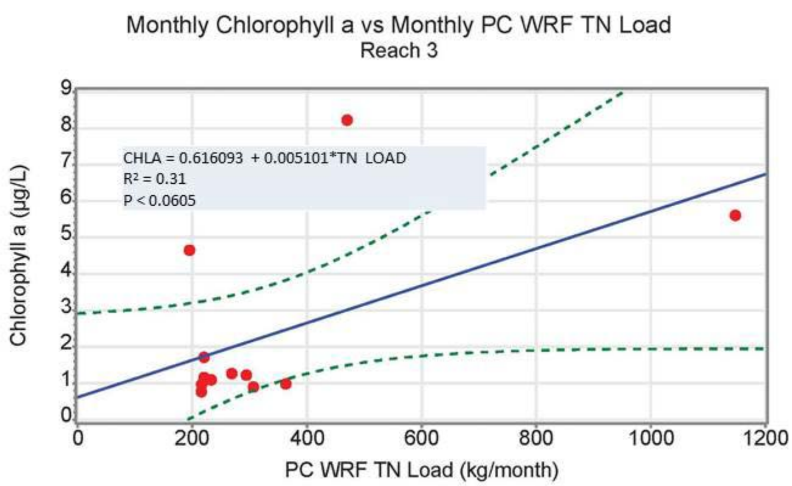
Figure 43. Comparison of predicted and observed DOC in model reaches 3 and 5.

Analytical Results

The following presents the results from the three analytical approaches defined above: empirical model, box model, and mechanistic model.

Empirical Model Approach

To examine the relationship between chlorophyll *a* concentrations and nutrient loading a series of regression analyses were completed (Figures 44 and 45). The results of these regressions suggest that the relationships between both TN or TP loads and chlorophyll *a* are not simple as none of the regression model fits are statistically significant. As a result using an empirical modeling approach to develop a predictive tool that allows assessment of the potential effects of changes in discharges from the Plant City WRF is not justified.



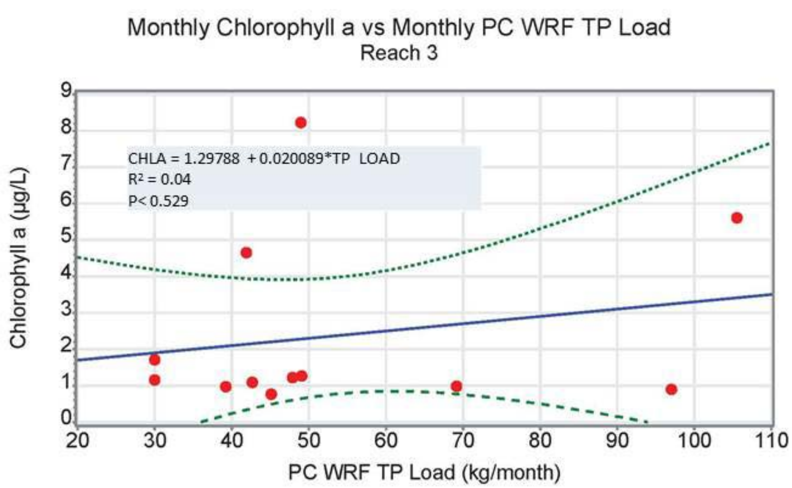
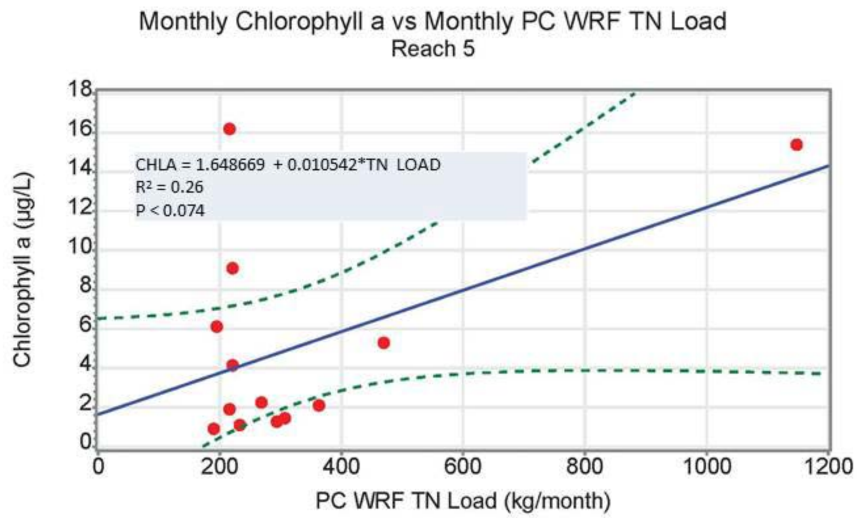


Figure 44. Relationships between chlorophyll *a* and TN (upper) and TP (lower) loads in Reach 3.



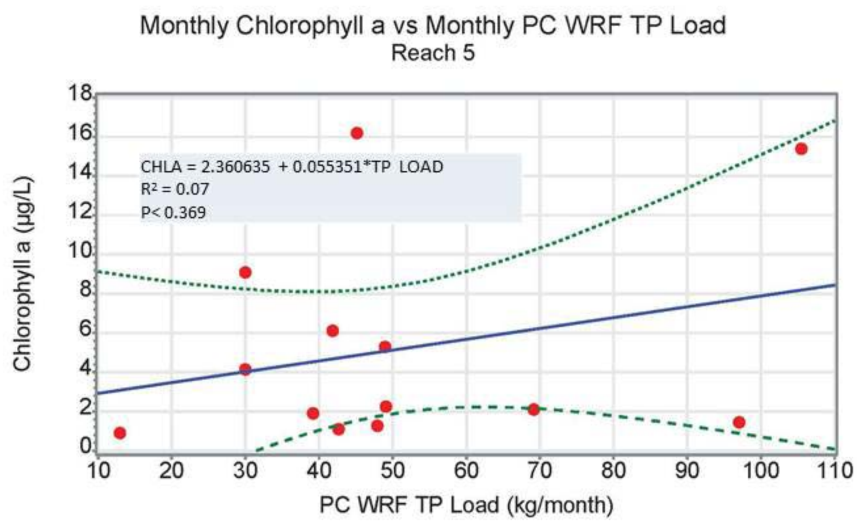


Figure 45. Relationships between chlorophyll a and TN (upper) and TP (lower) loads in Reach 5.

Box Model/Mass Balance Approach

Figure 46 presents the results of a box model/mass balance approach as defined above. The data presented have an annual basis – mean mass of TN and TP in two stream segments – East Canal Downstream of the Plant Discharge and the confluence of East Canal and the Itchepackesassa Creek. The fluxes – Upstream Inputs, Plant City WRF Inputs, Itchepackesassa Creek Inputs, and flux from Itchepackesassa Creek to Blackwater Creek – are expressed as kg/year. Similar box model diagrams for each month in the model period are provided in Appendix 6.

The data presented in Figure 45 clearly show the relatively smaller fluxes of both TN and TP from the Plant City WRF than the fluxes from either the Upstream area or Itchepackesassa Creek. The mass balances also indicate that the fluxes into the two regions of the East Canal/Itchepackesassa

Creek system are approximately equal to the fluxes out suggesting there is little accumulation of TN and TP with the stream channel.

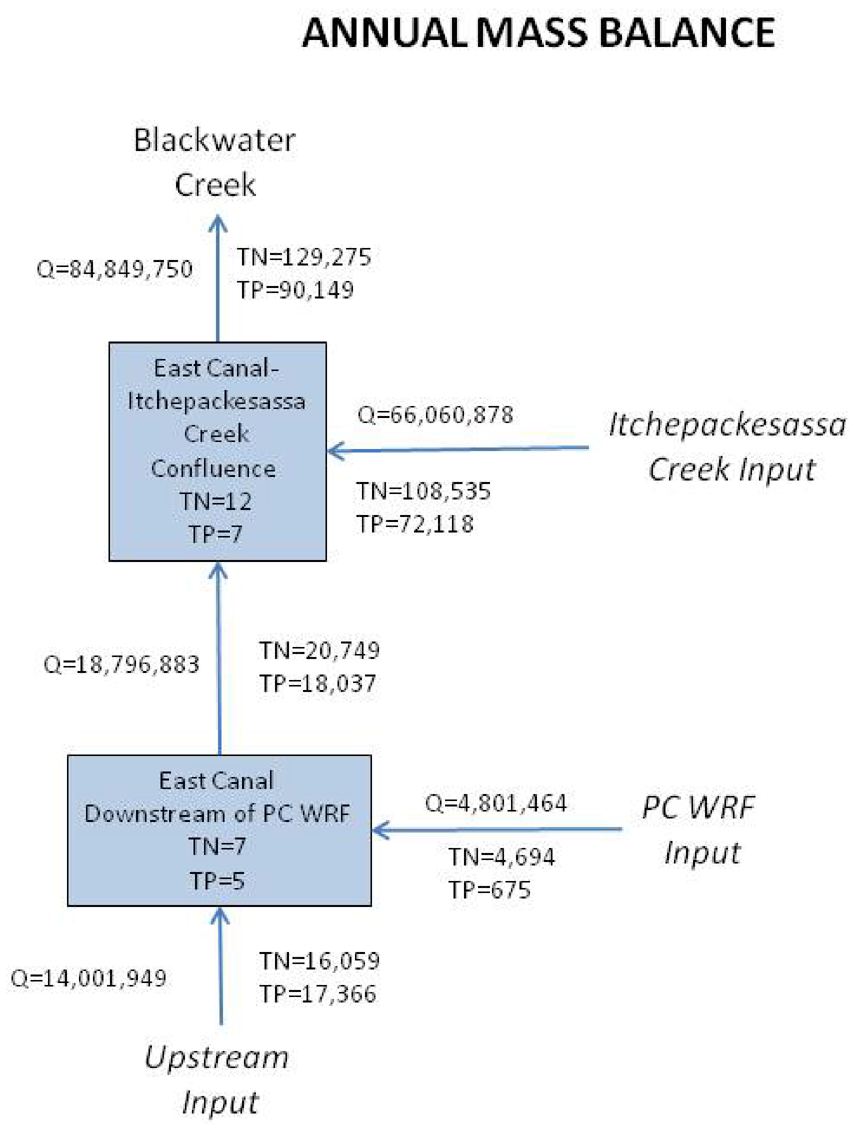


Figure 46. Annual mass balances of water (fluxes = m3/year), TN (mass = kg, fluxes = kg/year), and TP (mass = kg, fluxes = kg/year).

Mechanistic Model Approach

The following presents the results from two model scenario runs to assess the potential changes in the East Canal/Itchepackesassa system due to a proposed increase in discharges from the Plant City WRF. These model scenarios are:

- **Baseline** – a model scenario run for the same model period, the same drivers, i.e., meteorological conditions and external loads from upstream and Itchepackesassa Creek, the same initial conditions, the same set of constants and rate coefficients used in the model calibration. The daily plant discharge was held constant at 3.68 MGD, the current maximum permitted daily discharge. The nutrient concentrations were also held constant – TN = 1.152 mg/L and TP = 0.144 mg/L. These concentrations represent the mean measured discharge concentrations over the past 5 years.

- **Proposed Plant Discharge Limit** – a model scenario run with all model inputs, all drivers and external loads from upstream and Itchepackesassa Creek model period, all initial conditions, constants and rate coefficients, and plant discharge nutrient concentrations as in the Baseline scenario run. The daily plant discharge was held constant at 6.0 MGD in this model scenario run.

Hydrologic and Nutrient Loads

Figure 47 presents the daily hydrologic loads from the three major inputs – Upstream loads, Plant City WRF discharge, and Itchepackesassa Creek loads. The differences in the Y-axes in these plots should be noted. Several observations are clearly apparent. First, Itchepackesassa Creek contributes the greatest hydrologic loads (median = 35,320 m^3/day) and accounts for about 70% of the total hydrologic load. The Plant City WRF contributed the second greatest hydrologic load (median = 11,120 m^3/day) and accounts for 19% of the total hydrologic loads. The Upstream hydrologic loads were the smallest (median = 5,737 m^3/day) and accounts for 11% of the total hydrologic loads.

Figure 48 presents the daily TN loads from the three major inputs – Upstream loads, Plant City WRF discharge, and Itchepackesassa Creek loads. The differences in the Y-axes in these plots should be noted. Several observations are clearly apparent. First, Itchepackesassa Creek contributes the greatest TN loads (median = 56.9 kg/day) and accounts for about 79% of the total TN loads. The Plant City WRF contributed the second greatest TN loads (median = 10.1 kg/day) and accounts for 13% of the total TN loads. The smallest TN loads originated from Upstream (median = 5.9 kg/day) and accounts for 8% of the total TN loads.

Figure 49 presents the daily TP loads from the three major inputs – Upstream loads, Plant City WRF discharge, and Itchepackesassa Creek loads. The differences in the Y-axes in these plots should be noted. Several observations are clearly apparent. First, Itchepackesassa Creek contributes the greatest TP loads (median = 26.5 kg/day) and accounts for about 79% of the total TP loads. The Upstream area contributed the second greatest TP loads (median = 5.6 kg/day) and accounts for 15% of the total TP loads. The smallest TP loads originated from the Plant City WRF (median = 1.4 kg/day) and accounts for 5% of the total TP loads.

With respect to all three sources of hydrologic and nutrient loads, there is a clear seasonal signal in the loads from the Upstream area and Itchepackesassa Creek. Of particular note is the effect of Hurricane Irma on the hydrologic and nutrient loads from all three sources that occurred in September 2017. Also, there tended to be greater variation in the loads from the Plant City WRF during the dry season while the day-to-day variation from the Upstream area and Itchepackesassa Creek was much lower during the dry months.

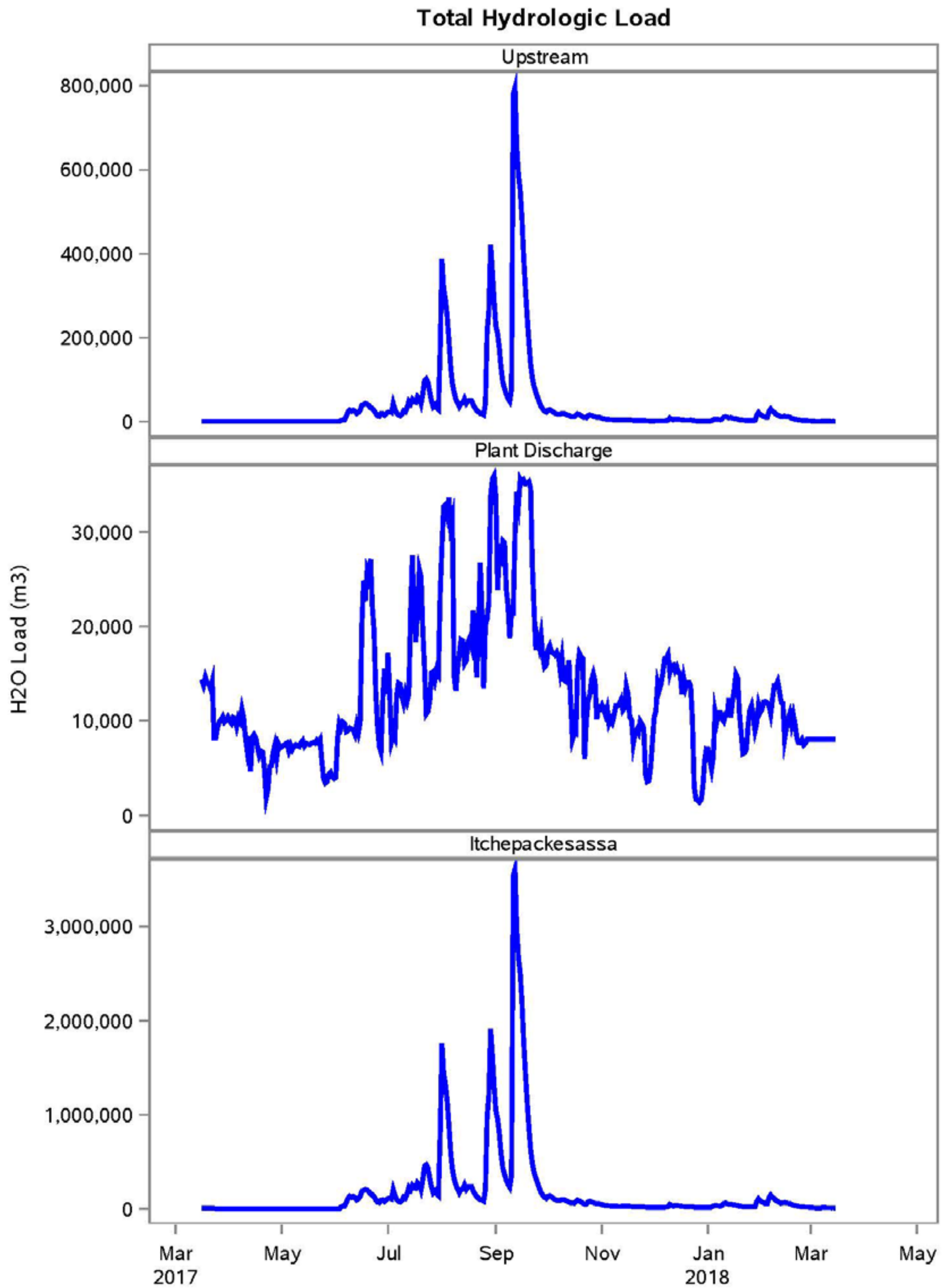


Figure 47. Daily hydrologic loads (m^3/day) from the three major sources

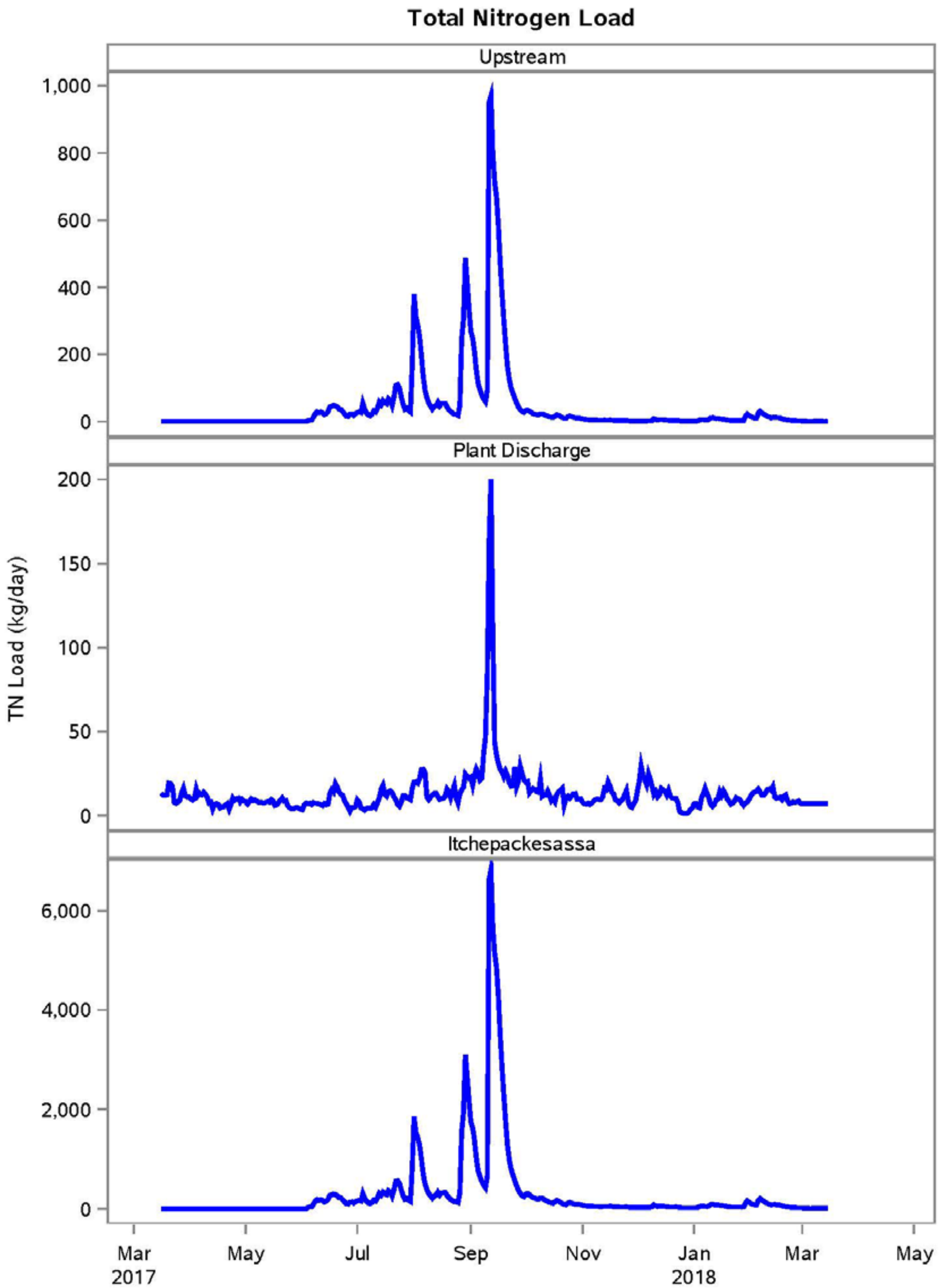


Figure 48. Daily TN loads from the three major sources.

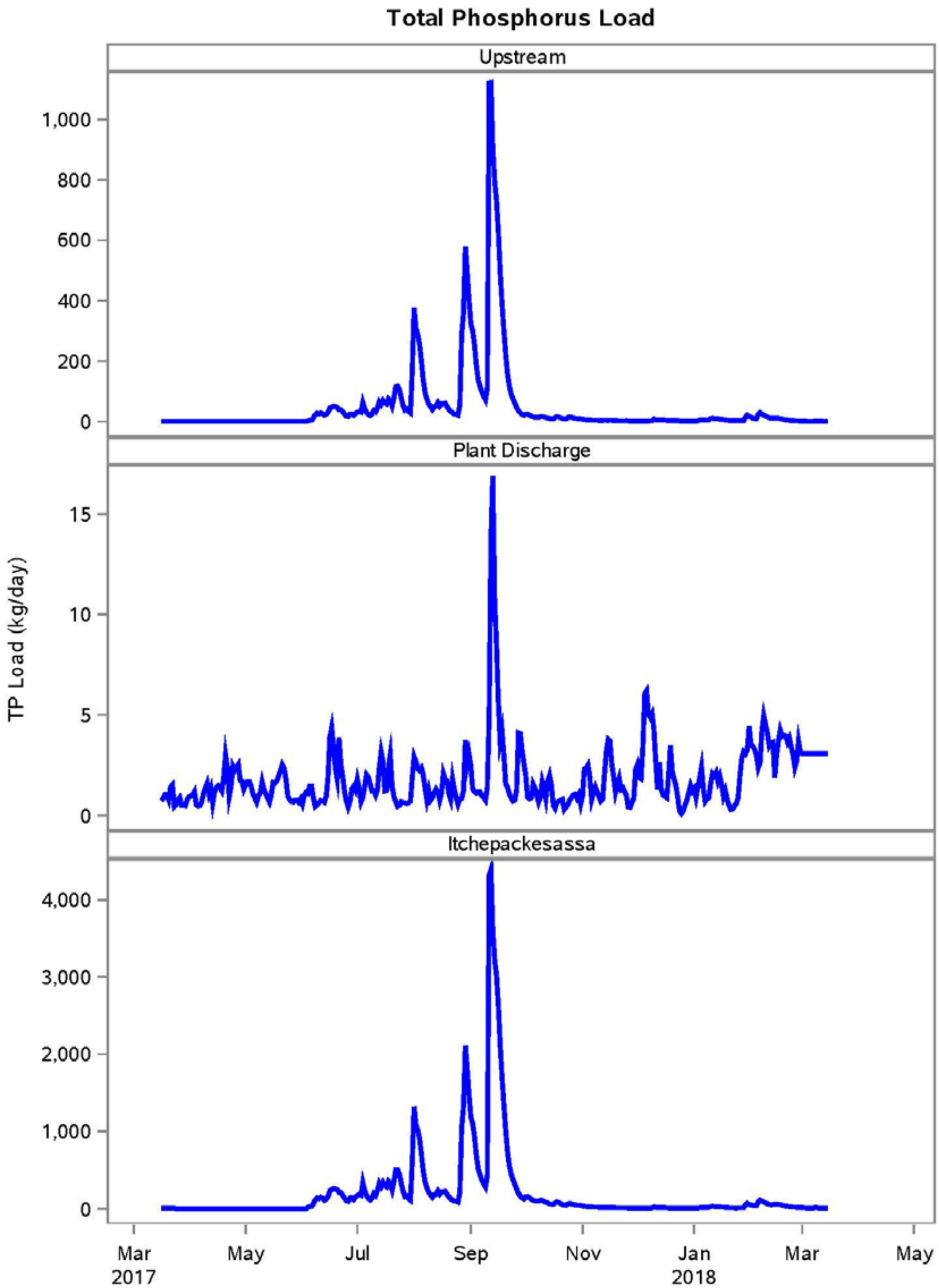


Figure 49. Daily TP loads from the three major sources.

Comparison of Model Outputs from the Two Model Scenarios – Baseline and Proposed Plant Discharge Limit

As described above, the QUAL2Kw model was executed for two model scenarios – Baseline and Proposed Plant Discharge Limit (Proposed). To assess the potential influences of the proposed scenario on the water quality within the receiving waters, the model outputs are presented in two ways:

- Time series plots that compare the water quality responses in each of the 6 model reaches (Figure 29). These plots allow examination of the potential effects both spatially and temporally of the two discharge scenarios.
- Tabular presentation of the summary statistics (mean, 10th, 25th, median, 75th, and 90th percentiles) of a series of critical water quality constituents from both model scenarios and the differences between the model predictions from the two model scenarios.

Chlorophyll *a*

The time series of mean monthly responses in chlorophyll *a* in each of the 6 model reaches from the Baseline and Proposed model scenarios are presented in Figure 50. The results from the two model runs are clearly very similar. In all East Canal reaches (1-3) above the confluence with the Itchepackesassa, the mean monthly chlorophyll *a* concentrations range from near 1 μg/L during the dry months to higher levels between 10 and 15 μg/L in July through September. This temporal pattern was found in both model scenario results. The somewhat lower values from the Proposed model run suggest that the higher hydrologic loads results in reduced residence times.

The difference in residence times for the two scenarios was further evaluated by calculating a mean replacement time, in days, for each reach given the inflows from the two difference discharge scenarios. This is similar to the approach taken to develop the mass balance analysis. This evaluation resulted in the mean estimated replacement times in each reach from the Baseline and Proposed model scenarios as provided in Table 13. These results support the assertion that the higher hydrologic loads from the Proposed scenario result in reduced residence time in the system.

Table 13. Mean replacement time (days) in each reach from the Baseline and Proposed model scenarios.

Scenario	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Baseline	0.04	0.08	0.11	0.10	0.10	0.09
Proposed	0.02	0.05	0.07	0.07	0.07	0.06

In the portion of the model region affected by inflows from the Itchepackesassa Creek (reaches 4-6) the model results from the two scenario runs again are very similar but at higher levels (peaks ranging from 10 to 15 μg/L) than those found upstream. Most notable is the clear effect of Hurricane Irma in September in those reaches.

Table 14 presents summary statistics for the responses in chlorophyll *a* in all reaches for both the Baseline and Proposed scenarios. The differences in the predicted chlorophyll *a* tended to be somewhat greater in the upstream reaches (1-3).

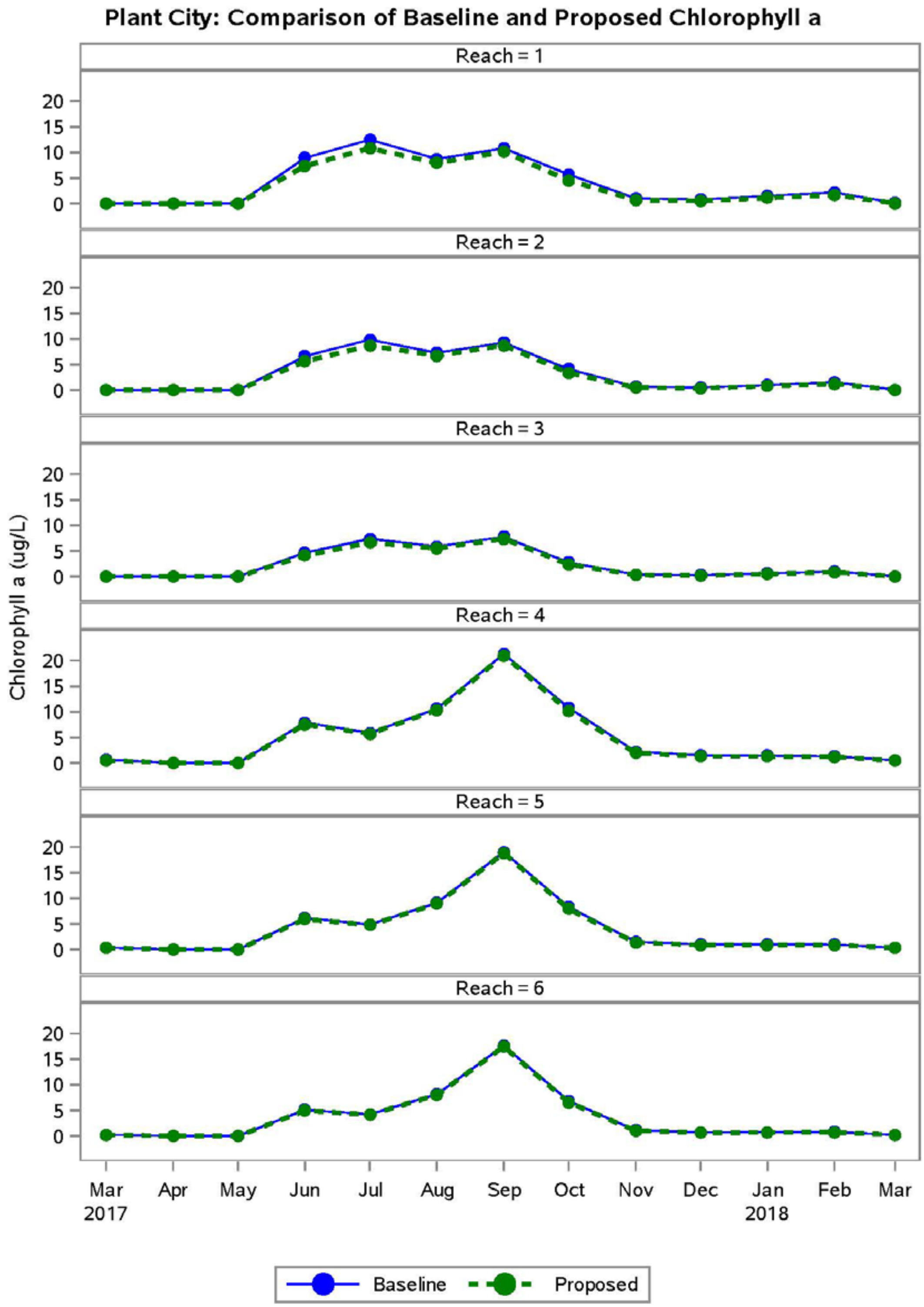


Figure 50. Comparison of the mean monthly chlorophyll *a* concentrations in each model reach from the Baseline and Proposed Plant Discharge Limit model scenarios.

Table 14. Summary statistics of the model outputs for the Baseline and Proposed Plant Discharge Limit for chlorophyll *a*. Differences are Baseline – Proposed.

Parameter	Reach	Scenario	10th Percentile	25th Percentile	Median	Mean	75th Percentile	90th Percentile
Chlorophyll *a* (μg/L)	1	Baseline	0.00	0.14	1.52	4.03	8.72	10.80
		Proposed	0.00	0.09	1.12	3.46	7.35	10.10
		Difference	0.00	0.05	0.40	0.57	0.77	1.56
	2	Baseline	0.00	0.09	1.00	3.15	6.62	9.25
		Proposed	0.00	0.07	0.79	2.78	5.63	8.65
		Difference	0.00	0.03	0.22	0.37	0.55	0.99
	3	Baseline	0.00	0.06	0.62	2.38	4.66	7.38
		Proposed	0.00	0.05	0.52	2.16	4.10	6.64
		Difference	0.00	0.01	0.10	0.22	0.36	0.56
	4	Baseline	0.04	0.66	1.55	4.95	7.90	10.79
		Proposed	0.03	0.51	1.34	4.74	7.54	10.36
		Difference	0.01	0.11	0.15	0.20	0.28	0.36
	5	Baseline	0.02	0.39	1.01	4.06	6.16	9.08
		Proposed	0.02	0.33	0.93	3.94	5.94	8.92
		Difference	0.00	0.05	0.10	0.12	0.16	0.22
	6	Baseline	0.01	0.27	0.78	3.52	5.11	8.12
		Proposed	0.01	0.24	0.75	3.44	4.96	8.00
		Difference	0.00	0.02	0.05	0.08	0.13	0.18

Total Phosphorus

The time series of mean monthly responses in TP in each of the 6 model reaches from the Baseline and Proposed model scenarios are presented in Figure 51. The results from the two model runs are clearly very similar. In all East Canal reaches (1-3) above the confluence with the Itchepackesassa, the mean monthly TP concentrations range from near 0.2 mg/L during the dry months to higher levels around 1 mg/L in July through September. This temporal pattern was found in both model scenario results. The somewhat lower values from the Proposed model run result from the increased volume of discharge with lower TP concentrations than found in the inflows from East Canal upstream of the plant, as the long-term plant TP concentration is 0.144 mg/L.

In the portion of the model region affected by inflows from the Itchepackesassa Creek (reaches 4-6) the model results from the two scenario runs again are very similar but with longer periods of relatively high (>1 mg/L) TP concentrations than those found upstream. Most notable is the clear effect of Hurricane Irma in September in those reaches, as well as those of Tropical Storm Emily in July.

Table 15 presents summary statistics for the responses in TP in all reaches for both the Baseline and Proposed scenarios. The differences in the predicted TP tended to be somewhat greater in the upstream reaches (1-3).

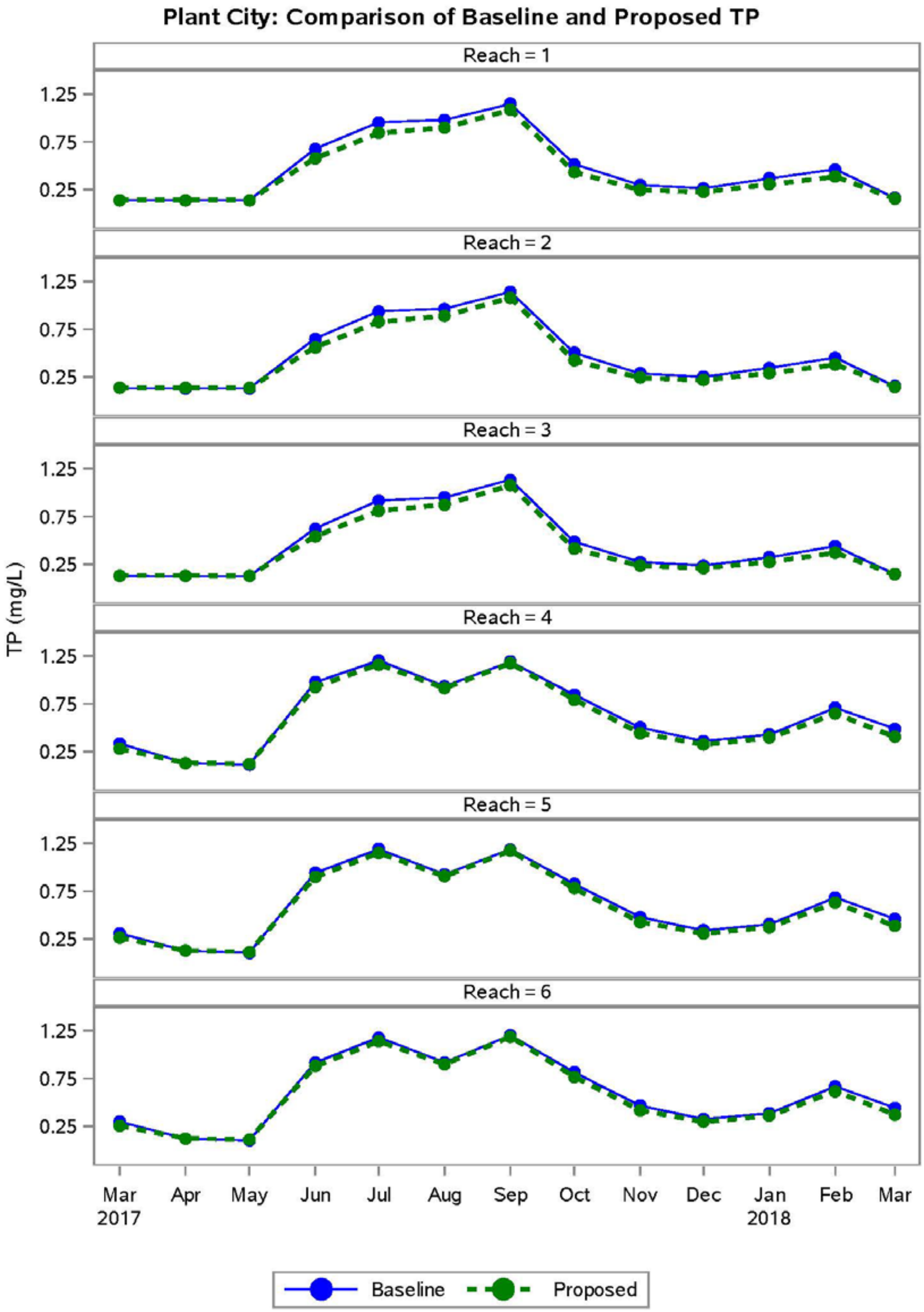


Figure 51. Comparison of the mean monthly TP concentrations in each model reach from the Baseline and Proposed Plant Discharge Limit model scenarios.

Table 15. Summary statistics of the model outputs for the Baseline and Proposed Plant Discharge Limit for TP. Differences are Baseline – Proposed.

Parameter	Reach	Scenario	10th Percentile	25th Percentile	Median	Mean	75th Percentile	90th Percentile
TP (mg/L)	1	Baseline	0.14	0.16	0.37	0.48	0.68	0.98
		Proposed	0.14	0.15	0.30	0.43	0.58	0.90
		Difference	0.00	0.01	0.06	0.05	0.08	0.10
	2	Baseline	0.13	0.15	0.35	0.47	0.65	0.97
		Proposed	0.14	0.15	0.29	0.42	0.56	0.89
		Difference	0.00	0.00	0.06	0.05	0.08	0.09
	3	Baseline	0.13	0.14	0.32	0.45	0.63	0.95
		Proposed	0.13	0.14	0.28	0.41	0.54	0.88
		Difference	-0.01	0.00	0.05	0.04	0.07	0.08
	4	Baseline	0.13	0.36	0.50	0.63	0.94	1.19
		Proposed	0.13	0.32	0.45	0.59	0.92	1.16
		Difference	0.00	0.02	0.04	0.04	0.06	0.06
	5	Baseline	0.12	0.34	0.48	0.61	0.93	1.19
		Proposed	0.13	0.31	0.43	0.58	0.90	1.15
		Difference	0.00	0.02	0.04	0.03	0.05	0.05
	6	Baseline	0.12	0.33	0.47	0.60	0.92	1.18
		Proposed	0.12	0.30	0.42	0.57	0.88	1.14
		Difference	0.00	0.02	0.04	0.03	0.05	0.05

Ortho-Phosphate

The time series of mean monthly responses in ortho-P in each of the 6 model reaches from the Baseline and Proposed model scenarios are presented in Figure 52. The results from the two model runs are clearly very similar. In all East Canal reaches (1-3) above the confluence with the Itchepackesassa, the mean monthly ortho-P concentrations range from near 0.1 mg/L during the dry months to higher levels around 0.5 mg/L in July through September. This temporal pattern was found in both model scenario results. The somewhat lower values from the Proposed model run result from the increased volume of discharge with lower ortho-P concentrations than found in the inflows from East Canal upstream of the plant, similar to what was seen with TP.

In the portion of the model region affected by inflows from the Itchepackesassa Creek (reaches 4-6) the model results from the two scenario runs again are very similar but with somewhat reduced periods of relatively high (>0.5 mg/L) ortho-P concentrations than those found upstream. The effect of Hurricane Irma in September is slightly less than that from Tropical Storm Emily in July, as the ortho-P concentrations from Itchepackesassa Creek upstream of the confluence with East Canal were somewhat lower in the fall than in summer.

Table 16 presents summary statistics for the responses in ortho-P in all reaches for both the Baseline and Proposed scenarios. The differences in the predicted ortho-P tended to be somewhat greater in the upstream reaches (1-3).

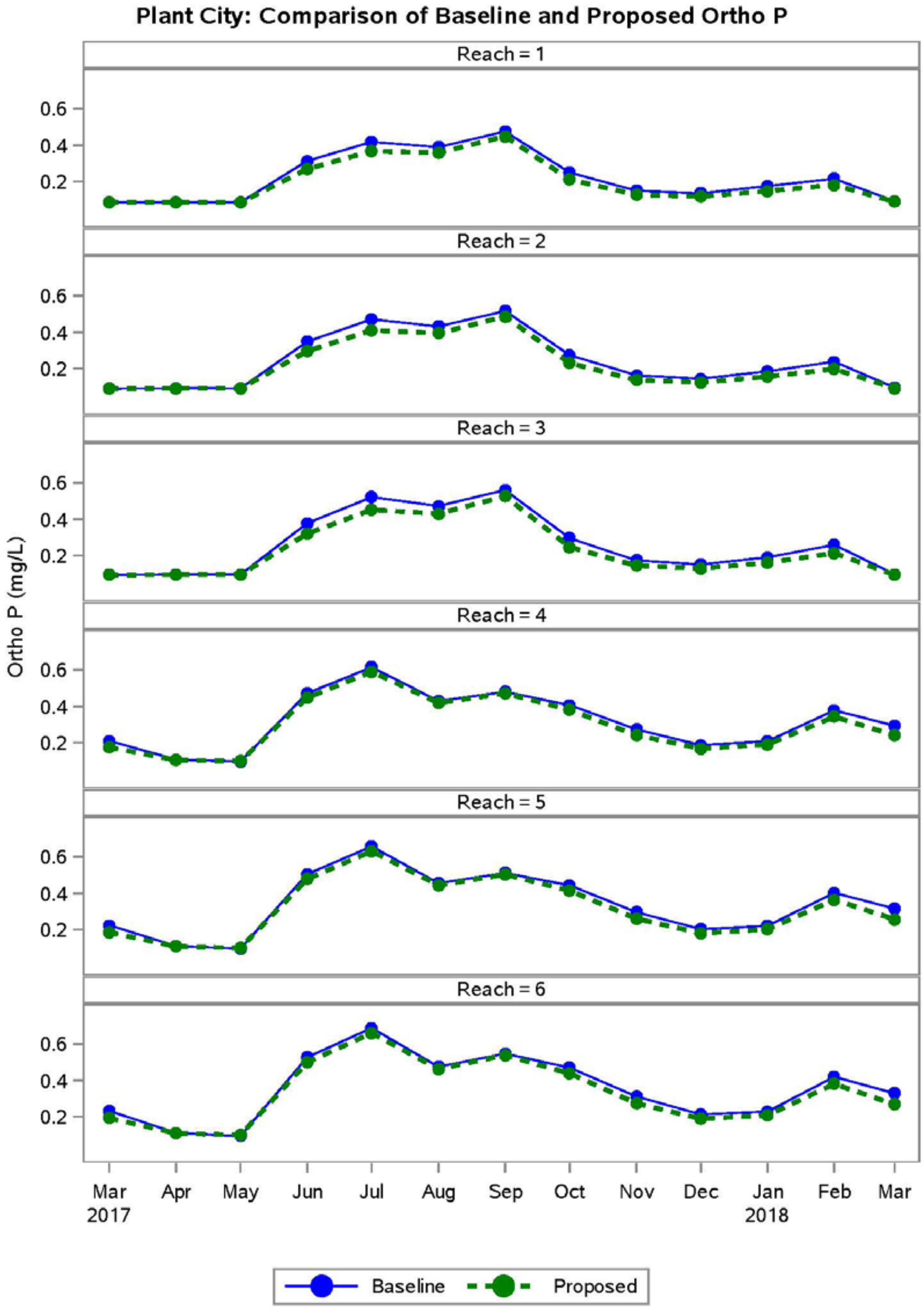


Figure 52. Comparison of the mean monthly Ortho-phosphate concentrations in each model reach from the Baseline and Proposed Plant Discharge Limit model scenarios.

Table 16. Summary statistics of the model outputs for the Baseline and Proposed Plant Discharge Limit for ortho P. Differences are Baseline – Proposed.

Parameter	Reach	Scenario	10th Percentile	25th Percentile	Median	Mean	75th Percentile	90th Percentile
Ortho P (mg/L)	1	Baseline	0.08	0.09	0.17	0.22	0.31	0.42
		Proposed	0.08	0.09	0.15	0.20	0.27	0.37
		Difference	0.00	0.00	0.03	0.02	0.03	0.04
	2	Baseline	0.09	0.09	0.18	0.24	0.35	0.47
		Proposed	0.09	0.09	0.15	0.21	0.30	0.41
		Difference	0.00	0.00	0.03	0.03	0.04	0.05
	3	Baseline	0.09	0.10	0.19	0.26	0.38	0.52
		Proposed	0.09	0.09	0.16	0.23	0.32	0.45
		Difference	0.00	0.00	0.03	0.03	0.05	0.06
	4	Baseline	0.11	0.21	0.29	0.32	0.43	0.48
		Proposed	0.10	0.17	0.24	0.30	0.42	0.47
		Difference	0.00	0.01	0.02	0.02	0.03	0.04
	5	Baseline	0.11	0.22	0.31	0.34	0.46	0.51
		Proposed	0.11	0.18	0.26	0.32	0.44	0.50
		Difference	0.00	0.01	0.03	0.02	0.04	0.04
	6	Baseline	0.11	0.23	0.33	0.36	0.47	0.55
		Proposed	0.11	0.19	0.27	0.33	0.46	0.54
		Difference	0.00	0.01	0.03	0.03	0.04	0.04

Total Nitrogen

The time series of mean monthly responses in TN in each of the 6 model reaches from the Baseline and Proposed model scenarios are presented in Figure 53. The results from the two model runs are clearly very similar. In all East Canal reaches (1-3) above the confluence with the Itchepackesassa, the mean monthly TN concentrations range from just less than to just greater than 1.0 mg/L during the entire year, with little seasonal variation. This temporal pattern was found in both model scenario results. The somewhat higher values from the Proposed model run during the dry period (March-May 2017) result from the increased volume of plant discharge with slightly higher TN concentrations (1.15 mg/L) than found in the inflows from East Canal upstream of the plant during this period. During the wetter periods, the TN concentrations in the upstream inputs were higher than those from the plant.

In the portion of the model region affected by inflows from the Itchepackesassa Creek (reaches 4-6) the model results from the two scenario runs again are very similar but with longer periods of relatively high (>1.2 mg/L) TN concentrations than those found upstream. Most notable is the clear effect of Hurricane Irma in September in those reaches.

Table 17 presents summary statistics for the responses in TN in all reaches for both the Baseline and Proposed scenarios. The differences in the predicted TN tended to be somewhat greater in the downstream reaches during the dry period, when concentrations were lower (4-6).

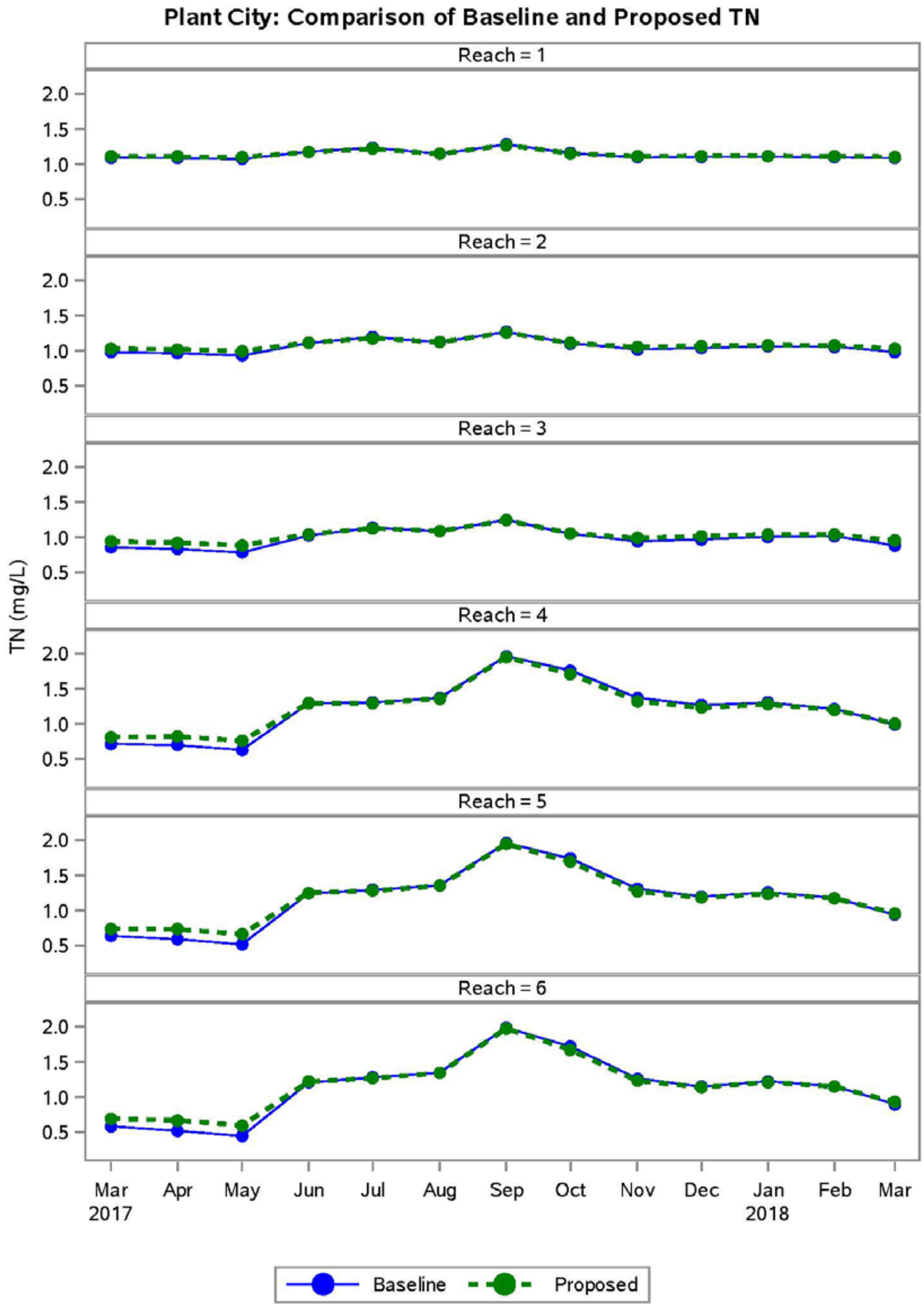


Figure 53. Comparison of the mean monthly TN concentrations in each model reach from the Baseline and Proposed Plant Discharge Limit model scenarios.

Table 17. Summary statistics of the model outputs for the Baseline and Proposed Plant Discharge Limit for TN. Differences are Baseline – Proposed.

Parameter	Reach	Scenario	10th Percentile	25th Percentile	Median	Mean	75th Percentile	90th Percentile
TN (mg/L)	1	Baseline	1.08	1.09	1.10	1.13	1.16	1.23
		Proposed	1.10	1.11	1.12	1.14	1.15	1.22
		Difference	-0.02	-0.02	-0.01	-0.01	0.00	0.01
	2	Baseline	0.96	0.98	1.06	1.06	1.11	1.19
		Proposed	1.02	1.03	1.07	1.09	1.11	1.18
		Difference	-0.06	-0.05	-0.02	-0.02	0.00	0.01
	3	Baseline	0.83	0.88	1.01	0.99	1.05	1.14
		Proposed	0.92	0.95	1.04	1.02	1.05	1.13
		Difference	-0.09	-0.07	-0.03	-0.04	-0.01	0.01
	4	Baseline	0.69	0.99	1.29	1.22	1.37	1.76
		Proposed	0.81	1.00	1.28	1.23	1.32	1.71
		Difference	-0.12	-0.01	0.01	-0.01	0.03	0.05
	5	Baseline	0.59	0.94	1.24	1.17	1.31	1.74
		Proposed	0.73	0.96	1.24	1.19	1.28	1.69
		Difference	-0.14	-0.02	0.01	-0.02	0.02	0.04
	6	Baseline	0.52	0.90	1.20	1.14	1.28	1.72
		Proposed	0.67	0.93	1.21	1.16	1.27	1.67
		Difference	-0.15	-0.03	0.01	-0.02	0.01	0.03

Nitrate-Nitrite

The time series of mean monthly responses in NO_3-NO_2 in each of the 6 model reaches from the Baseline and Proposed model scenarios are presented in Figure 54. The results from the two model runs are clearly very similar. In all East Canal reaches (1-3) above the confluence with the Itchepackesassa, the mean monthly in NO_3-NO_2 concentrations range from just greater than 0.1 mg/L during the wetter period to almost 0.4 mg/L during the dry period. This temporal pattern was found in both model scenario results. The somewhat higher values from the Proposed model run during the dry period (March-May 2017) result from the increased volume of plant discharge with slightly higher NO_3-NO_2 concentrations than found in the inflows from East Canal upstream of the plant during this period.

In the portion of the model region affected by inflows from the Itchepackesassa Creek (reaches 4-6) the model results from the two scenario runs again are very similar but with longer periods of relatively high (>0.5 mg/L) NO_3-NO_2 concentrations than those found upstream.

Table 18 presents summary statistics for the responses in NO_3-NO_2 in all reaches for both the Baseline and Proposed scenarios. The differences in the predicted NO_3-NO_2 tended to be somewhat greater in the downstream reaches during the early dry period, when concentrations were relatively low (4-6).

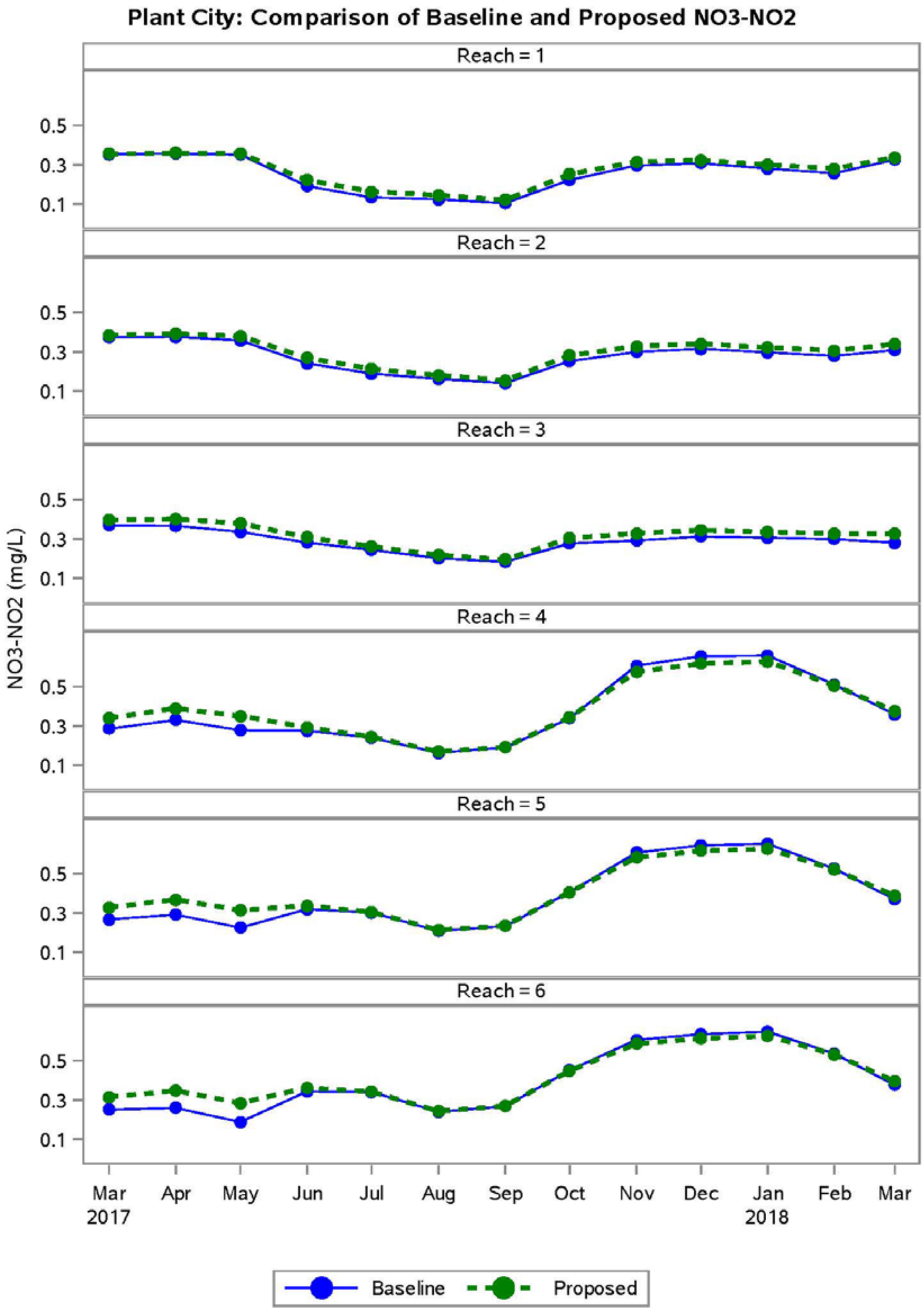


Figure 54. Comparison of the mean monthly NO_3-NO_2 concentrations in each model reach from the Baseline and Proposed Plant Discharge Limit model scenarios.

Table 18. Summary statistics of the model outputs for the Baseline and Proposed Plant Discharge Limit for NO_3-NO_2. Differences are Baseline – Proposed.

Parameter	Reach	Scenario	10th Percentile	25th Percentile	Median	Mean	75th Percentile	90th Percentile
NO_3-NO_2 (mg/L)	1	Baseline	0.12	0.19	0.28	0.25	0.33	0.35
		Proposed	0.15	0.22	0.30	0.27	0.34	0.36
		Difference	-0.03	-0.02	-0.02	-0.02	-0.01	0.00
	2	Baseline	0.16	0.24	0.30	0.28	0.32	0.37
		Proposed	0.18	0.27	0.32	0.30	0.34	0.38
		Difference	-0.03	-0.03	-0.02	-0.02	-0.02	-0.01
	3	Baseline	0.20	0.28	0.29	0.29	0.31	0.37
		Proposed	0.22	0.30	0.33	0.32	0.34	0.39
		Difference	-0.04	-0.03	-0.03	-0.03	-0.03	-0.02
	4	Baseline	0.19	0.28	0.33	0.38	0.51	0.65
		Proposed	0.19	0.29	0.35	0.39	0.51	0.62
		Difference	-0.06	-0.02	0.00	-0.01	0.00	0.03
	5	Baseline	0.23	0.27	0.32	0.39	0.52	0.64
		Proposed	0.24	0.31	0.37	0.40	0.52	0.62
		Difference	-0.08	-0.02	0.00	-0.01	0.00	0.03
	6	Baseline	0.24	0.26	0.34	0.40	0.53	0.64
		Proposed	0.27	0.32	0.36	0.41	0.53	0.61
		Difference	-0.09	-0.02	0.00	-0.02	0.00	0.02

Total Kjeldahl Nitrogen

The time series of mean monthly responses in TKN in each of the 6 model reaches from the Baseline and Proposed model scenarios are presented in Figure 55. The results from the two model runs are clearly very similar, and the time series of TKN concentrations are very similar to those for TN concentrations. In all East Canal reaches (1-3) above the confluence with the Itchepackesassa, the mean monthly TKN concentrations range over approximately 0.5-1.1 mg/L during the year, with small seasonal variation. This temporal pattern was found in both model scenario results. The somewhat higher values from the Proposed model run during the dry period (March-May 2017) result from the increased volume of plant discharge with slightly higher TKN concentrations than found in the inflows from East Canal upstream of the plant during this period. During the wetter periods, the TKN concentrations in the upstream inputs were higher than those from the plant.

In the portion of the model region affected by inflows from the Itchepackesassa Creek (reaches 4-6) the model results from the two scenario runs again are very similar but with longer periods of relatively high (>1.0 mg/L) TKN concentrations than those found upstream. Most notable is the clear effect of Hurricane Irma in September in those reaches.

Table 19 presents summary statistics for the responses in TKN in all reaches for both the Baseline and Proposed scenarios. The differences in the predicted TKN tended to be somewhat greater in the downstream reaches during the dry period, when concentrations were lower (4-6).

Dissolved Organic Carbon

The time series of mean monthly responses in DOC in each of the 6 model reaches from the Baseline and Proposed model scenarios are presented in Figure 56. The results from the two model runs are clearly very similar. In all East Canal reaches (1-3) above the confluence with the Itchepackesassa, the mean monthly DOC concentrations range from near 5 mg/L during the dry months to higher levels of 10-15 mg/L in July through September. This temporal pattern was found in both model scenario results. The somewhat lower values from the Proposed model run result from the increased volume of discharge with lower DOC concentrations than found in the inflows from East Canal upstream of the plant.

In the portion of the model region affected by inflows from the Itchepackesassa Creek (reaches 4-6) the model results from the two scenario runs again are very similar but with longer periods of relatively high (>15 mg/L) DOC concentrations than those found upstream. Most notable is the clear effect of Hurricane Irma in September in those reaches, as well as those of Tropical Storm Emily in July.

Table 20 presents summary statistics for the responses in DOC in all reaches for both the Baseline and Proposed scenarios. The differences in the predicted DOC tended to be somewhat greater in the downstream reaches at lower concentrations (<7 mg/L) and greater in the upstream reaches at higher concentrations.

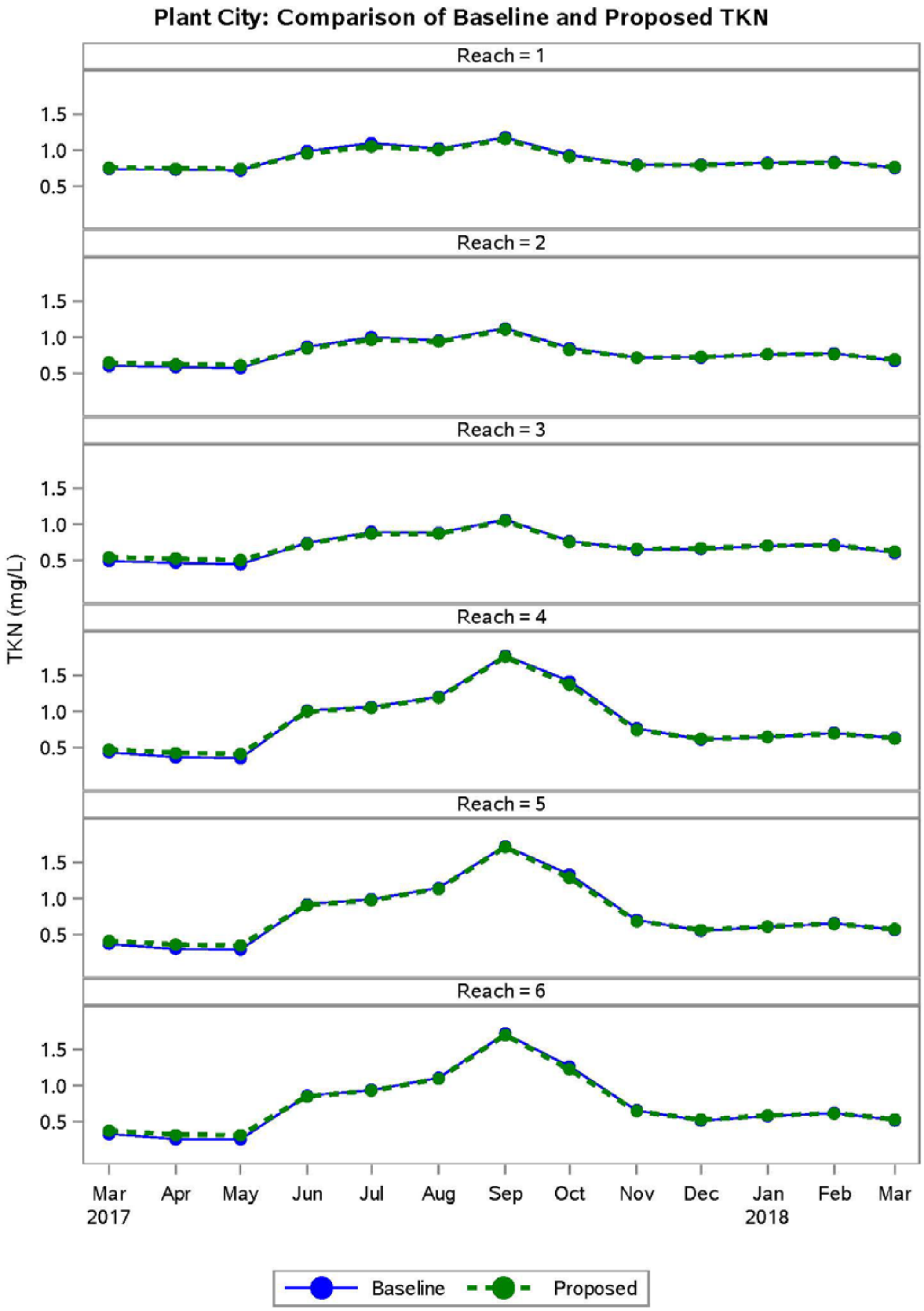


Figure 55. Comparison of the mean monthly TKN concentrations in each model reach from the Baseline and Proposed Plant Discharge Limit model scenarios.

Table 19. Summary statistics of the model outputs for the Baseline and Proposed Plant Discharge Limit for TKN. Differences are Baseline – Proposed.

Parameter	Reach	Scenario	10th Percentile	25th Percentile	Median	Mean	75th Percentile	90th Percentile
TKN (mg/L)	1	Baseline	0.73	0.76	0.83	0.88	0.99	1.10
		Proposed	0.75	0.77	0.82	0.87	0.95	1.05
		Difference	-0.02	-0.01	0.01	0.01	0.02	0.04
	2	Baseline	0.59	0.67	0.76	0.79	0.87	1.00
		Proposed	0.63	0.69	0.76	0.79	0.85	0.97
		Difference	-0.04	-0.02	0.00	0.00	0.02	0.03
	3	Baseline	0.47	0.60	0.70	0.70	0.77	0.89
		Proposed	0.52	0.63	0.70	0.71	0.75	0.87
		Difference	-0.06	-0.02	0.00	-0.01	0.01	0.02
	4	Baseline	0.36	0.61	0.70	0.84	1.06	1.42
		Proposed	0.43	0.62	0.70	0.85	1.05	1.37
		Difference	-0.06	-0.01	0.01	0.00	0.02	0.02
	5	Baseline	0.30	0.55	0.65	0.78	0.99	1.33
		Proposed	0.36	0.56	0.65	0.79	0.98	1.28
		Difference	-0.06	-0.01	0.00	0.00	0.01	0.02
	6	Baseline	0.26	0.51	0.62	0.74	0.94	1.27
		Proposed	0.32	0.53	0.62	0.75	0.93	1.22
		Difference	-0.06	-0.01	0.00	-0.01	0.01	0.01

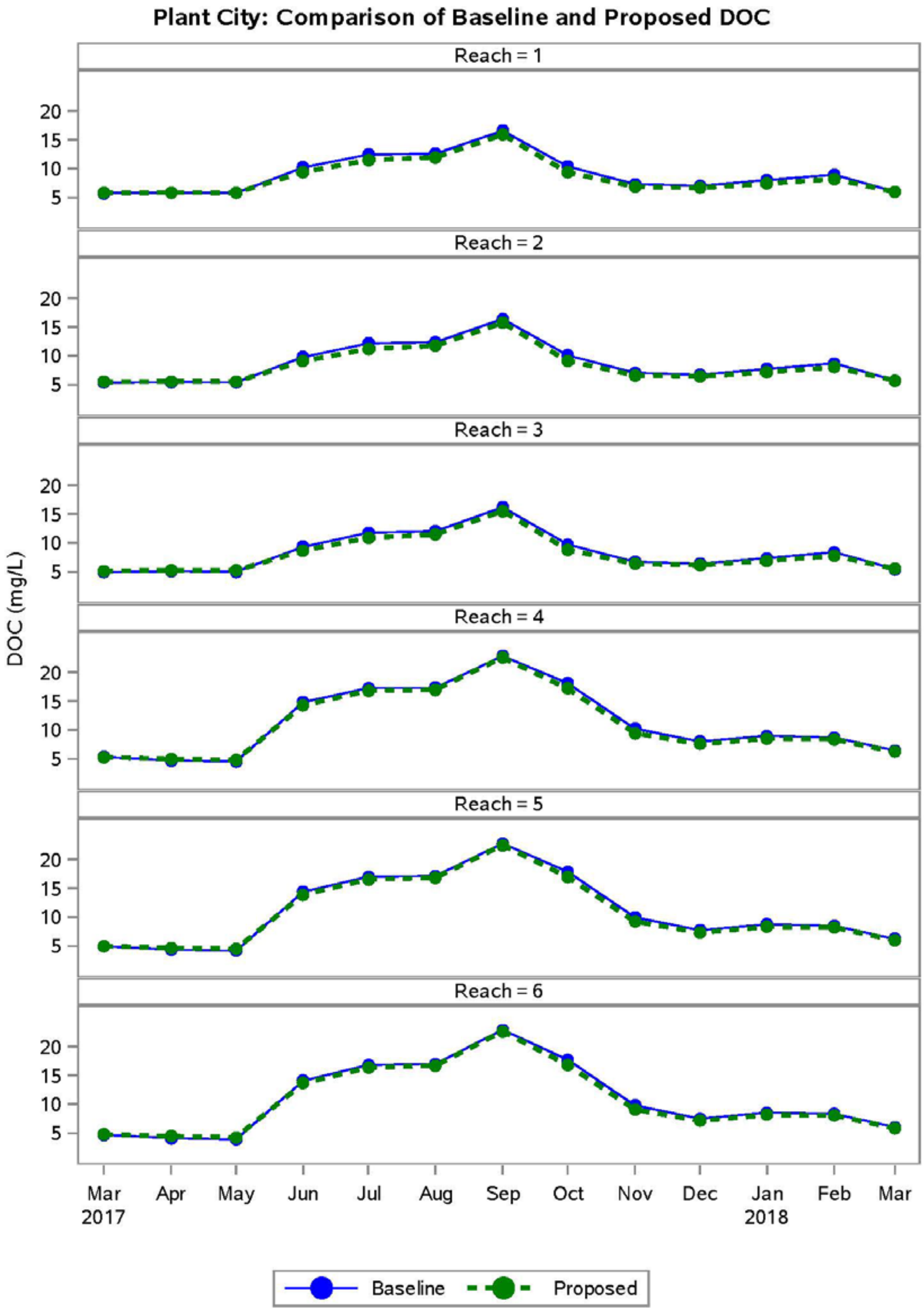


Figure 56. Comparison of the mean monthly DOC concentrations in each model reach from the Baseline and Proposed Plant Discharge Limit model scenarios.

Table 20. Summary statistics of the model outputs for the Baseline and Proposed Plant Discharge Limit for DOC. Differences are Baseline – Proposed.

Parameter	Reach	Scenario	10th Percentile	25th Percentile	Median	Mean	75th Percentile	90th Percentile
DOC (mg/L)	1	Baseline	5.80	6.04	8.05	9.00	10.38	12.59
		Proposed	5.85	6.00	7.45	8.53	9.41	11.95
		Difference	-0.05	0.04	0.60	0.47	0.75	0.94
	2	Baseline	5.41	5.75	7.73	8.69	10.09	12.33
		Proposed	5.55	5.76	7.20	8.27	9.13	11.71
		Difference	-0.13	-0.01	0.53	0.42	0.71	0.91
	3	Baseline	5.02	5.47	7.38	8.34	9.75	12.03
		Proposed	5.23	5.53	6.92	7.98	8.84	11.43
		Difference	-0.21	-0.06	0.46	0.36	0.65	0.87
	4	Baseline	4.72	6.48	9.01	11.33	17.26	18.08
		Proposed	4.96	6.23	8.54	11.00	16.80	17.16
		Difference	-0.24	0.26	0.31	0.33	0.47	0.77
	5	Baseline	4.38	6.22	8.75	11.05	16.98	17.85
		Proposed	4.68	6.00	8.31	10.76	16.53	16.95
		Difference	-0.30	0.22	0.30	0.29	0.45	0.74
	6	Baseline	4.14	6.04	8.56	10.87	16.77	17.70
		Proposed	4.47	5.85	8.14	10.60	16.33	16.80
		Difference	-0.33	0.19	0.30	0.27	0.44	0.71

Total Organic Carbon

The time series of mean monthly responses in TOC in each of the 6 model reaches from the Baseline and Proposed model scenarios are presented in Figure 57. The results from the two model runs are clearly very similar, and very similar to those for DOC. In all East Canal reaches (1-3) above the confluence with the Itchepackesassa, the mean monthly DOC concentrations range from near 5 mg/L during the dry months to higher levels of 10-15 mg/L in July through September. This temporal pattern was found in both model scenario results. The somewhat lower values from the Proposed model run result from the increased volume of discharge with lower TOC concentrations than found in the inflows from East Canal upstream of the plant.

In the portion of the model region affected by inflows from the Itchepackesassa Creek (reaches 4-6) the model results from the two scenario runs again are very similar but with longer periods of relatively high (>20 mg/L) TOC concentrations than those found upstream. Most notable is the clear effect of Hurricane Irma in September in those reaches, as well as those of Tropical Storm Emily in July.

Table 21 presents summary statistics for the responses in TOC in all reaches for both the Baseline and Proposed scenarios. The differences in the predicted TOC tended to be somewhat greater in the downstream reaches at lower concentrations (<7 mg/L) and greater in the upstream reaches at higher concentrations.

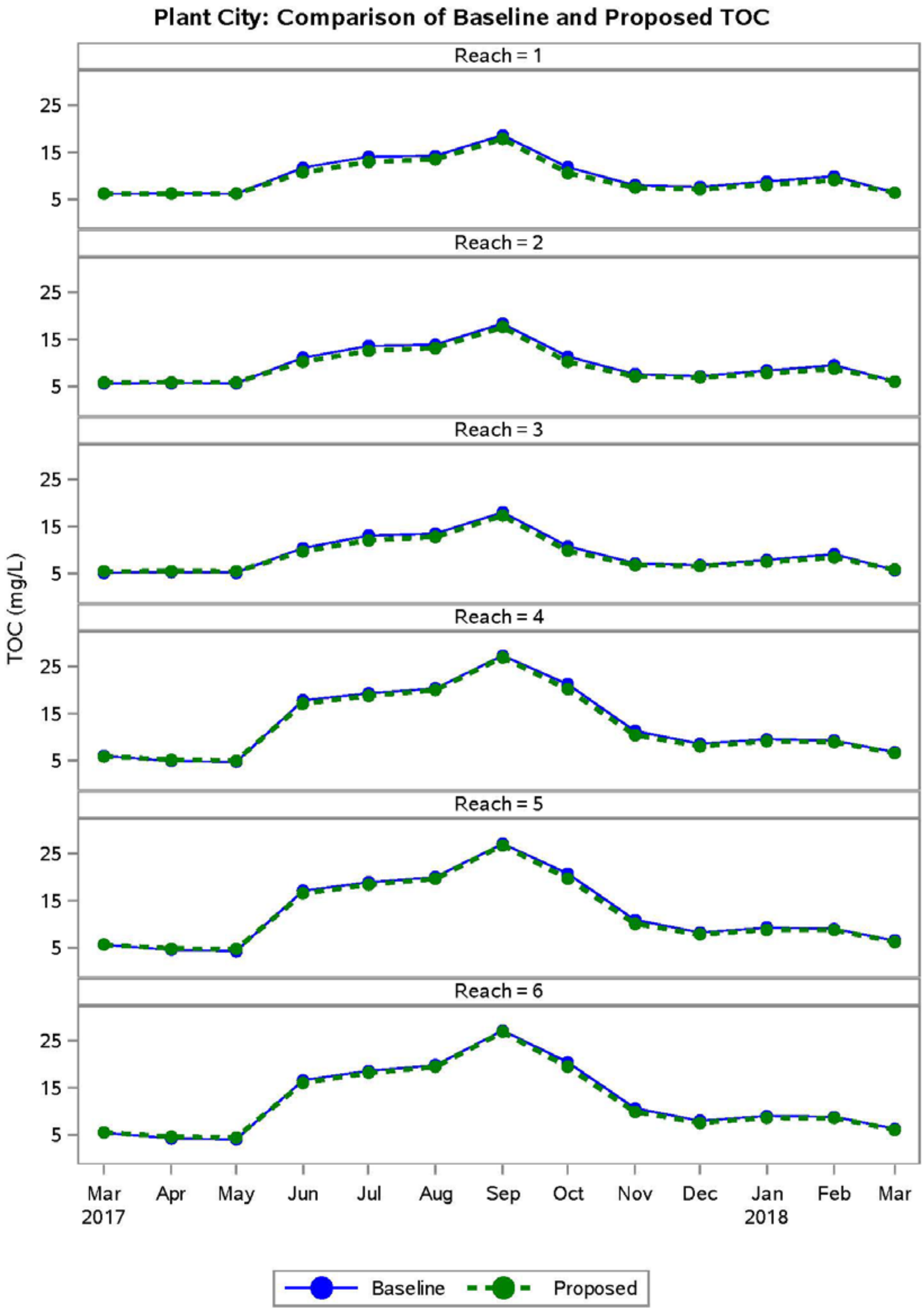


Figure 57. Comparison of the mean monthly TOC concentrations in each model reach from the Baseline and Proposed Plant Discharge Limit model scenarios.

Table 21. Summary statistics of the model outputs for the Baseline and Proposed Plant Discharge Limit for TOC. Differences are Baseline – Proposed.

Parameter	Reach	Scenario	10th Percentile	25th Percentile	Median	Mean	75th Percentile	90th Percentile
TOC (mg/L)	1	Baseline	6.15	6.44	8.82	9.99	11.85	14.28
		Proposed	6.22	6.39	8.11	9.43	10.74	13.52
		Difference	-0.06	0.04	0.70	0.56	0.88	1.11
	2	Baseline	5.69	6.09	8.37	9.55	11.36	13.91
		Proposed	5.85	6.11	7.77	9.08	10.25	13.19
		Difference	-0.17	-0.02	0.59	0.48	0.80	1.05
	3	Baseline	5.22	5.74	7.90	9.09	10.83	13.48
		Proposed	5.47	5.83	7.41	8.70	9.80	12.81
		Difference	-0.25	-0.08	0.48	0.39	0.73	0.98
	4	Baseline	4.89	6.83	9.58	12.86	19.29	21.26
		Proposed	5.18	6.57	9.08	12.49	18.77	20.16
		Difference	-0.29	0.26	0.37	0.38	0.51	0.87
	5	Baseline	4.51	6.50	9.25	12.49	18.89	20.79
		Proposed	4.85	6.29	8.80	12.15	18.40	19.72
		Difference	-0.34	0.21	0.36	0.33	0.50	0.81
	6	Baseline	4.25	6.28	9.01	12.23	18.61	20.46
		Proposed	4.62	6.10	8.59	11.93	18.12	19.45
		Difference	-0.37	0.18	0.35	0.30	0.49	0.77

Dissolved Oxygen

The time series of mean monthly responses in DO in each of the 6 model reaches from the Baseline and Proposed model scenarios are presented in Figure 58. The results from the two model runs are clearly very similar. In all East Canal reaches (1-3) above the confluence with the Itchepackesassa, the DO values are slightly higher under the Proposed scenario during the entire year, with minimum DO values just below 4 mg/L during the wettest period. During drier period, DO values from both scenarios were typically >7 mg/L.

In the portion of the model region affected by inflows from the Itchepackesassa Creek (reaches 4-6) the model results from the two scenario runs again are very similar but with longer periods of relatively low (<4 mg/L) DO concentrations than those found upstream. The differences in scenario DO are minimal during the wetter period when the lower DO values occur.

Table 22 presents summary statistics for the responses in DO in all reaches for both the Baseline and Proposed scenarios. The differences in the predicted DO tended to be somewhat greater in the upstream reaches over all concentrations.

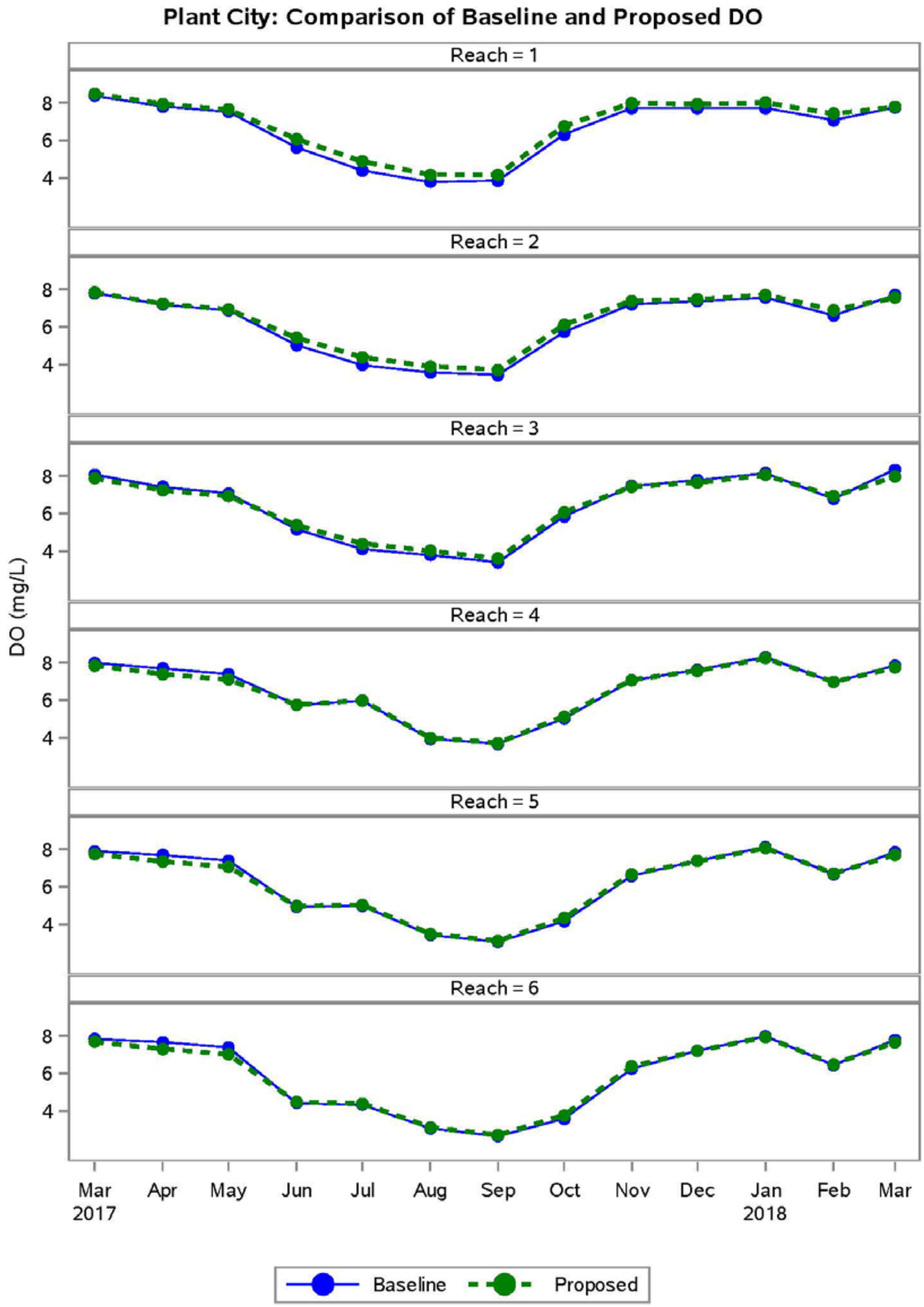


Figure 58. Comparison of the mean monthly DO concentrations in each model reach from the Baseline and Proposed Plant Discharge Limit model scenarios.

Table 22. Summary statistics of the model outputs for the Baseline and Proposed Plant Discharge Limit for DO. Differences are Baseline – Proposed.

Parameter	Reach	Scenario	10th Percentile	25th Percentile	Median	Mean	75th Percentile	90th Percentile
DO (mg/L)	1	Baseline	3.87	5.64	7.52	6.59	7.72	7.81
		Proposed	4.19	6.08	7.64	6.87	7.94	8.01
		Difference	-0.45	-0.40	-0.29	-0.28	-0.13	-0.12
	2	Baseline	3.59	5.05	6.89	6.17	7.37	7.70
		Proposed	3.91	5.43	6.94	6.36	7.47	7.72
		Difference	-0.39	-0.33	-0.19	-0.19	-0.05	-0.03
	3	Baseline	3.80	5.17	7.09	6.42	7.79	8.14
		Proposed	4.02	5.39	6.93	6.43	7.66	7.97
		Difference	-0.22	-0.22	0.02	-0.01	0.16	0.20
	4	Baseline	3.95	5.75	7.06	6.56	7.69	7.99
		Proposed	4.01	5.77	7.09	6.51	7.58	7.84
		Difference	-0.06	-0.03	-0.01	0.05	0.12	0.29
	5	Baseline	3.44	4.94	6.68	6.17	7.69	7.90
		Proposed	3.51	4.99	6.71	6.13	7.37	7.75
		Difference	-0.09	-0.05	-0.04	0.04	0.14	0.33
	6	Baseline	3.08	4.34	6.45	5.90	7.67	7.84
		Proposed	3.15	4.41	6.50	5.87	7.31	7.68
		Difference	-0.12	-0.07	-0.05	0.04	0.14	0.36

The assessment of the potential effects of the proposed plant discharges must also consider compliance with the TN loading allocation given to the City as part of its participation in the Tampa Bay Reasonable Assurance Plan. The TN loading allocation is 19.7 tons/year which includes allocations for its domestic wastewater facility of 10.5 tons/year and for its nonpoint sources of 9.2 tons/year. The proposed plant discharge of 6 MGD results in an annual TN load of 10.5 tons, thus in compliance with its current allocation.

Conclusions

- The City is seeking to expand its WRF's permitted discharge from 2.68 MGD to at least 6.0 MGD
- The WRF discharge is to East Canal, a tributary of Itchepackesassa Creek north of Plant City
- An Administrative Order (AO-002SWD15) requires a Level II WQBEL determination for this facility
- FDEP gave final approval to a Plan of Study to conduct a Level II WQBEL study on November, 2016.

- The Plan of Study was implemented including elevation transects of the stream, habitat assessment, and a 12-month water quality data collection effort
- A comparison of an upstream control site with a test site downstream of the Plant City WRF discharge indicated that there were no imbalances in flora or fauna caused by nutrients. In fact, chlorophyll a, Rapid Periphyton Survey (RPS), Linear Vegetation Survey (LVS) and BioRecon data indicated somewhat improved conditions at the test site, compared to the control site. Farther downstream in Itchepackesassa Creek (which met the stream definition), the floral measures (chlorophyll *a*, RPS, LVS) AND faunal measures (Stream Condition Index), were achieved, as specified in Chapter 62-302.531, F.A.C. This demonstrates that the biological health in waters downstream of the Plant City WRF was protected.
- FDEP District staff has observed that the East Canal system does dry out completely at times, with the only water source to the stream being the Plant City WRF discharge. East Canal is a man-made ditch created for flood control and stormwater management purposes, and thus is not classified as a stream and is not subject to numeric nutrient criteria and the narrative criteria apply.
- Both TN and TP concentrations in the discharge are typically lower than the ambient concentrations in East Canal and Itchepackesassa Creek.
- The water quality data were used to evaluate potential stressor-response models relating water quality to nutrient loading; the analytical results do not support the use of empirical relationships as a predictive tool for this purpose of this project.
- A box model/mass balance approach was developed to provide insight into the relative influence of loadings from the WRF, with findings indicating that there is little accumulation of TN and TP in the stream channel, and that the flows and associated loads from the WRF are a relatively small component of the totals to the entire system.
- A mechanistic water quality model was developed and calibrated using the observed water quality and flow data, for use in evaluation of WRF discharge scenarios.
- Two flow scenarios were examined, one of 3.68 MGD as per the current AO, denoted the Baseline, and another denoted Proposed which included 6 MGD discharge from the WRF.
- Model results indicated little difference in water quality within the stream resulting from increasing the WRF discharge from 3.68 MGD to 6 MGD, supported by the very low residence times within the system under both scenarios.
- The Proposed discharge TN loadings maintain the City's compliance with its Tampa Bay Nitrogen Management Consortium loading allocation of 10.5 tons/yr. The mean discharge TN concentration over the 2013-2017 period was 1.15 mg/L, which combined with the Proposed 6 MGD discharge does not exceed the facility allocation.

Recommendation

The proposed discharge limit of 6 MGD for the City of Plant City Water Reclamation Facility be approved assuming the current plant operations and resulting quality of the plant's effluent be maintained.

References

Ambrose, R.B., and T.A. Wool. 2017. WASP8 Stream Transport - Model Theory and User's Guide. Supplement to Water Quality Analysis Simulation Program (WASP) User Documentation. U.S. Environmental Protection Agency, Center for Exposure Assessment Modeling, Athens, GA.

Brown, L.C., and T.O. Barnwell. 1987. The Enhanced Stream Water Quality Models QUAL2E and QUAL2E-UNCAS, EPA/600/3-87-007. U.S. Environmental Protection Agency, Athens GA. 189 pp.

Chapra, S.C., and G.J. Pelletier. 2003. QUAL2 K: a modeling framework for simulating river and stream water quality (beta version): documentation and users manual. Civil and Environmental Engineering Dept., Tufts University, Medford, MA.

Chapra, S.C., G.J. Pelletier, and H. Tao. 2012. QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality, Verions 2.12: Documentation and Users Manual. Civil and Environmental Engineering Dept., Tufts University, Medford, MA.

Cole, T.M, and S.A. Wells. 2015. CE-QUAL-W2: A Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 3.72. User Manual. Department of Civil and Environmental Engineering, Portland State University, Portland, OR.

FDEP (1992). Biological water quality of the Deer Point Lake Drainage Basin.

FDEP (1993a). Bioassessment of Bonifay WWTP.

FDEP (1993b). Biological assessment of IMC-Agrico Payne Creek Mine.

FDEP (1995). Biological assessment of the City of White Springs Wastewater Treatment Plant.

FDEP (1997). Biological assessment of Tenneco Packaging Company.

FDEP (2001). Bioassessment of Gold Kist- Poultry Division.

FDEP (2012). Sampling and Use of the Stream Condition Index (SCI) for Assessing Flowing Waters: A Primer. DEP-SAS-001/11.

FDEP (2013). Implementation of Florida's Numeric Nutrient Standards: Document Submitted to EPA in Support of the Department of Environmental Protection's Adopted Nutrient Standards for Streams, Spring Vents, Lakes, and Selected Estuaries. Florida Dept. Environmental Protection.

Pelletier, G.J., and S.C. Chapra. 2005. QUAL2Kw theory and documentation (version 5.1), a modeling framework for simulating river and stream water quality. Washington: Department of Ecology.

UF (2015). Archive of historic aerial photos of Florida Counties.

Wool, T.A., R.B. Ambrose, J.L. Martin, and E.A. Comer. 2006. Water Quality Analysis Simulation Program (WASP), Version 6.0 DRAFT: User's Manual. US Environmental Protection Agency, Environmental Research Laboratory, Athens, GA

Appendix 1 Streams Exception Demonstration

The FDEP Implementation Document (FDEP, 2013) states that streams do not include nonperennial water segments where fluctuating hydrologic conditions include periods of desiccation. FDEP District staff have observed the East Canal system to dry out completely with the only water present from the Plant City WRF discharge (Jacquelyn Champion, FDEP, personal communication).

The Implementation Document also states that streams do not include ditches, canals and other conveyances, or segments of conveyances, that are man-made, or predominantly channelized or predominantly physically altered; and 1) are primarily used for water management purposes, such as flood protection, stormwater management, irrigation, or water supply; and 2) have marginal or poor stream habitat or habitat components, such as a lack of habitat or substrate that is biologically limited, because the conveyance has cross sections that are predominantly trapezoidal, has armored banks, or is maintained primarily for water conveyance.

In human channelized, hydrologically altered ditches, there are many other non-nutrient stressors that influence the biological communities. Therefore, biological impairments in altered ditch systems may potentially be attributable to stressors such as physical disturbance, poor aquatic habitat, and hydrologic alterations (FDEP, 2013).

Based on historical and current aerial photos and ongoing ditch maintenance activities by Hillsborough County, the use of East Canal is for flood control and stormwater management purposes (Figure 1-1, Figure 1-2, and Figure 1-3 (UF, 2015). Dating back as far as 1938, East Canal has been a human-created ditch (Figure 1-1, Figure 1-2). East Canal is also managed as a stormwater management conveyance. Hillsborough County routinely conducts herbicide treatment to manage invasive aquatic plants and to maintain sufficient flow in East Canal (generally in the vicinity of Macintosh Park Wetlands Restoration and south towards Plant City (northern red line on map, David Glicksberg, Hillsborough County, personal communication) (Figure 1-3). On an "as needed" basis, Hillsborough County conducts dredging in East Canal to remove sediment and improve flows for flood control. In approximately 2007, over a linear mile of East Canal was dredged near Sam Allen Road (southern red line on map, Mike Holcomb, Hillsborough County, personal communication). During the WQBEL Study, herbicide treatment for invasive riparian plants occurred upstream and downstream from the Plant City WRF discharge in late October, 2017. This was clearly evidenced by extensive dead riparian and aquatic vegetation observed at the control and test sites during the sampling trips of 11-6-17 and 12-4-17.

Artificial channelization, substrate diversity and substrate availability were 5 or lower during all four habitat assessments at the East Canal sites (**Table 1-1**). Additionally, total habitat assessment scores, both upstream and downstream of the discharge in East Canal, were less than 80 (in the poor or marginal range. (**Table 1-1**). These conditions are consistent with the exceptions to the streams definition found in Rule 62-302.200(36), F.A.C.

Figure 1-1. A 1938 aerial photograph of East Canal at Knights Griffin Road, clearly showing the artificial channelization.

Figure 1-2. 1968 aerial photo of East Canal at Knights Griffin Road, showing that maintaining the artificial channelization for flood control continues to routinely occur.

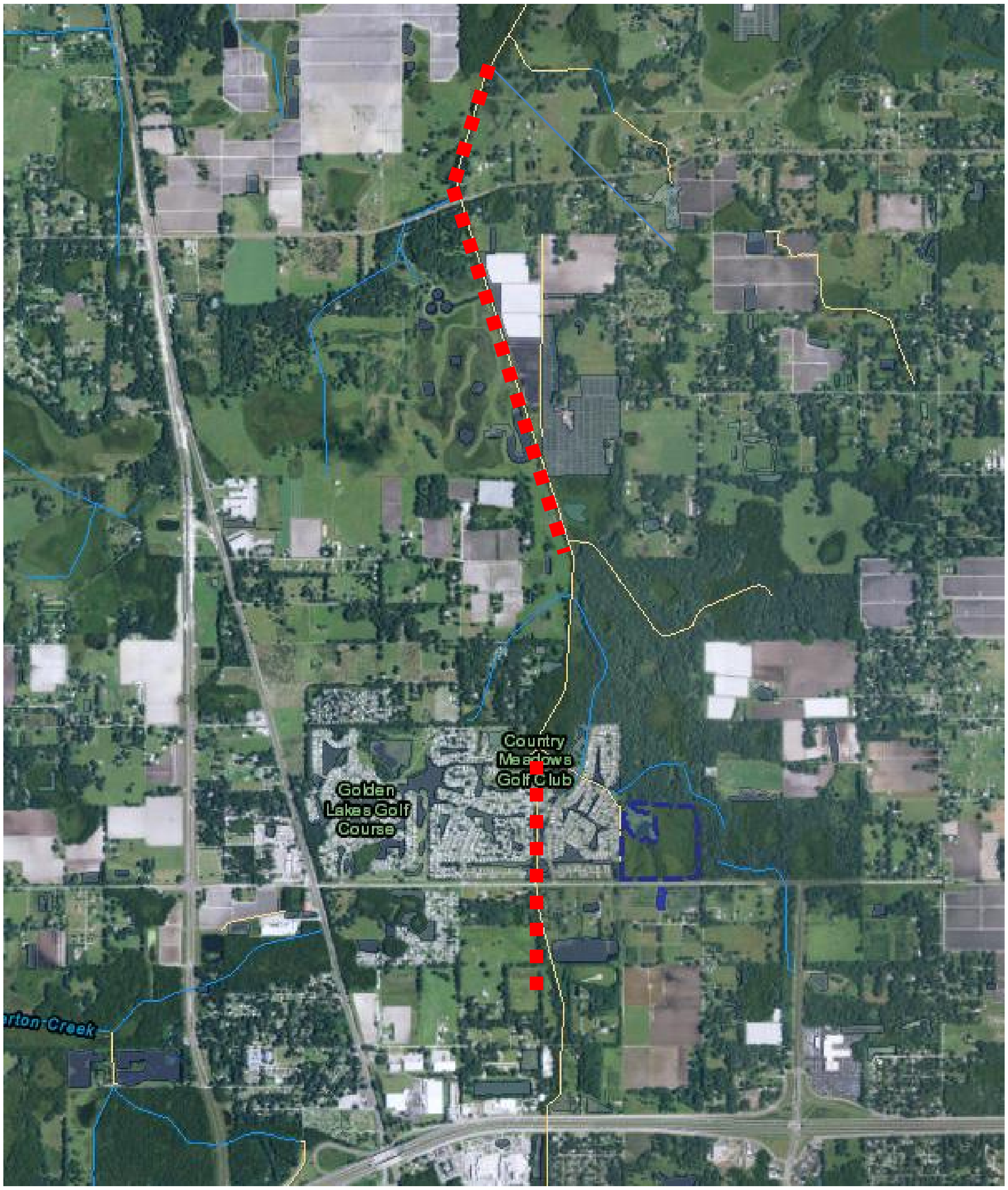


Figure 1-3. Current aerial photo of East Canal at Knights Griffin Road demonstrating the continued artificial channelization of the system. Red dashed lines indicate locations of maintenance activities conducted by Hillsborough County.

Table 1-2. Selected habitat measures for the study areas, including the control site (upstream of the discharge in East Canal), the test site (downstream of the discharge in East Canal), and the far-field test site (Itchepackesassa Creek at Audubon Road).

Station	Date	Latitude	Longitude	Substrate Diversity	Substrate Availability	Artificial Channelization	Habitat Assessment Total Score
East Up	2/13/2017	28.076111	82.121111	3	2	1	29
East Down	2/13/2017	28.079444	82.123889	5	3	1	45
Itch Audubon	2/13/2017	28.118889	82.112778	14	8	6	102
East Up	3/13/2017	28.076111	82.121111	3	4	1	29
East Down	3/13/2017	28.079444	82.123889	5	4	1	46
Itch Audubon	3/13/2017	28.118889	82.112778	14	9	6	103
East Up	11/6/2017	28.076111	82.121111	3	4	1	28
East Down	11/6/2017	28.079444	82.123889	5	4	1	47
Itch Audubon	11/6/2017	28.118889	82.112778	13	8	5	103
East Up	12/4/2017	28.076111	82.121111	3	4	1	35
East Down	12/4/2017	28.079444	82.123889	5	5	2	51
Itch Audubon	12/4/2017	28.118889	82.112778	14	9	6	100

All sites meeting the exception criteria are evaluated according to the narrative nutrient criterion (no imbalances in aquatic flora or fauna). To comply with the narrative nutrient criterion, no specific nutrient or biological thresholds are established. Instead, a test site for flora and fauna (e.g., a site downstream of the discharge) is compared qualitatively, or “narratively”, with a control site for flora and fauna. For this study, a control site located upstream of the discharge was used to determine if the test site biota were similar to, more healthy, or less healthy than the control site. Therefore, a habitat altered segment of East Canal located upstream of the discharge was qualitatively compared with a habitat altered ditch segment downstream from the discharge to assess biology.

Appendix 2 Biological Field Methods

To conform to NNC requirements, flora and fauna in the systems were sampled on two temporally independent occasions, following FDEP Standard Operating Procedures (SOPs, see http://www.dep.state.fl.us/water/sas/sop/sops.htm for details). Habitat and biological assessment sampling was conducted by Russell Frydenborg and Beck Frydenborg, Frydenborg EcoLogic, L.L.C., who are both certified by FDEP (http://www.dep.state.fl.us/water/sas/qa/index.htm). Sampling and analyses met FDEP quality assurance and quality control standards (see http://www.dep.state.fl.us/water/sas/qa/index.htm) and table below for current FDEP bioassessment registry status for Frydenborg EcoLogic staff).

The Stream and River Habitat Assessment (HA) was conducted per FDEP SOP FT 3100 . The Habitat Assessment is a rapid field method in which a sampler scores eight in-stream and riparian components to estimate the influence of habitat factors on the resident aquatic organisms. Habitat Assessment scores range from 11-160 and overall habitat quality is assigned to one of four categories: Optimal (120-160 points), Suboptimal (80-119 points), Marginal (40-79 points), and Poor (11-39 points).

The Rapid Periphyton Survey (RPS) was conducted according to DEP SOP FS 7230. The RPS is a tool to measure the coverage and thickness of attached algae. If greater than 25% of the RPS measurements are Rank 4-6 (reflective of attached algae thickness of 6 mm or greater), that is evidence that a site does not achieve the expectations of a reference stream.

The Linear Vegetation Survey (LVS) was conducted according to DEP SOP FS 7320. The LVS assesses the health of the vascular plant community. Coefficient of Conservation scores of 2.5 or greater and a 25% or less frequency of occurrences of Florida Exotic Pest Plant Council (FLEPPC) Category 1 and 2 invasive plants are indications that a site meets the expectations of a reference stream. If no (or less than 2 m2) plants are growing in the water, the LVS evidentiary threshold is achieved, meaning the stream is healthy, since the majority of minimally disturbed reference streams used to formulate the LVS expectations were also characterized by no (or less than 2 m2) plants present in the water. Channelized and maintained systems may have growth of invasive aquatic plants, despite moderate nutrients, due to the plant's ability to outcompete native taxa due to the physical disturbance.

The Stream Condition Index (SCI) was sampled per FDEP SOP FS SCI 1000 and calculated per FDEP SOP SCI 2000 in Itchepackesassa Creek, where habitat is not a limiting factor. The SCI consists of collecting macroinvertebrates via 20 D-frame dipnet sweeps (0.5 m in length) in the most productive habitats in a 100 m reach of stream. The organisms are sub-sampled, and identified to the lowest practical taxonomic level. The SCI is composed of ten metrics, eight of which decrease in response to human disturbance, with two metrics increasing in response to human disturbance. Biological health assessment criteria in Chapter 62-302, F.A.C., state that a site is considered to meet designated uses if the average of the two most recent SCI scores is 40 or higher and neither of those scores is less than 35. The BioRecon method was for East Canal, upstream and downstream from the discharge, as these sites are consistent with the "ditch" exception to NNC. For BioRecon, four sweeps of the best available habitats are sampled, field sorted, and identified to the lowest practical taxonomic level in the laboratory, and the results were interpreted by comparing the control site to the test site.

Appendix 3 Field WQ Data

Table 3-1. Field data collected at water quality sites from March 2017 - February 2018.

Site	Date	Time	Temperature (°C)	Specific Conductance (μmhos)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)	pH (SU)	Flow (CFS)	Total Depth (ft)
WQ-1	3/16/2017	929	22.25	931	9.43	109.6	6.89	6.651	1.72
WQ-3	3/16/2017	No Sample due to access issues							
WQ-4	3/16/2017	No Sample due to access issues							
WQ-5	3/16/2017	1050	14.72	758	7.95	88.3	7.29	7.591	0.65
WQ-1	4/13/2017	1342	21.02	1035	3.45	38.6	7.24	0.439	1.08
WQ-3	4/13/2017	1128	22.07	1065	8.11	92.6	7.81	1.63	0.73
WQ-4	4/13/2017	1244	21.89	467	7.66	86.8	7.45	0.04	0.45
WQ-5	4/13/2017	931	20.52	945	6.29	69.6	7.63	2.256	0.62
WQ-1	5/11/2017	1134	22.94	1072	4.8	56.39	7.6	0	0.7
WQ-3	5/11/2017	1039	23.74	1079	7.28	86.23	8.03	1.177	0.4
WQ-4	5/11/2017	1104	No Sample. Sample site completely dry!						
WQ-5	5/11/2017	0914	21.59	1046	6.07	68.9	8.1	1.729	1.2
WQ-1	6/8/2017	1213	No Sample due to maintenance activities.						
WQ-3	6/8/2017	1025	26.7	1052	5.77	72.7	7.84	1.439	0.5
WQ-4	6/8/2017	1102	24.71	210.94	5.62	68.21	7.01	81.69	2.5
WQ-5	6/8/2017	909	24.61	249	5.77	69.9	7.12	77.90	3.2
WQ-1	7/5/2017	1202	32.2	241	3.73	51.3	6.88	11.30	3.25
WQ-3	7/5/2017	1019	30.44	369	7.56	100.8	7.12	16.55	1.1
WQ-4	7/5/2017	1105	27.48	172	10.7	138	7.19	27.12	1.4
WQ-5	7/5/2017	0850	28.19	275	6.51	84.3	7.39	54.17	2.8
WQ-1	8/1/2017	1218	26.52	116	2.74	34	6.66		
WQ-3	8/1/2017	1025	24.98	113.65	3.61	43.51	6.75	336	4.4
WQ-4	8/1/2017	1100	24.83	67	4.78	57.6	6.42		5
WQ-5	8/1/2017	0900	24.71	83	4.7	56.5	6.06	896	7.5
WQ-1	9/8/2017	1230	29.17	187.16	2.95	38.52	6.74	27.15	2.35
WQ-3	9/8/2017	1036	28.71	306	3.63	47.05	6.99	41.64	1.7
WQ-4	9/8/2017	1130	28.75	136.96	4.41	56.68	6.71	111.3	2.11
WQ-5	9/8/2017	0910	27.88	189	4.33	56.7	6.83	198.5	3.5
WQ-1	10/6/2017	1230	26.89	189	4.47	56	6.94	8.742	2.5
WQ-3	10/6/2017	1055	26.78	445	5.09	63.7	7.37	16.25	1
WQ-4	10/6/2017	1140	25.61	165.9	4.98	61.02	6.94	24.57	1.5
WQ-5	10/6/2017	0935	25.39	295	4.75	58	7.17	39.17	1.69
WQ-1	10/26/2017	1230	20.32	241	5.59	61.8	7.1	4.019	1.8
WQ-3	10/26/2017	1030	21.32	570	6.84	77.2	7.58	12.13	0.95
WQ-4	10/26/2017	1132	19.18	206.41	6.99	75.5	7.12	33.04	1.6
WQ-5	10/26/2017	0855	19.61	309	6.57	71.4	7.35	40.46	1.9

Table 3-1. Field data collected at water quality sites from March 2017 - February 2018.

Site	Date	Time	Temperature (°C)	Specific Conductance (μmhos)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)	pH (SU)	Flow (CFS)	Total Depth (ft)
WQ-1	11/28/2017	No Sample zero flow							
WQ-3	11/28/2017	1055	20.61	687	8.51	94.5	7.85	1.560	0.31
WQ-4	11/28/2017	1149	18.31	278.6	7.7	81.5	7.35	6.455	0.62
WQ-5	11/28/2017	0915	18.46	409	6.54	69.49	7.42	9.775	0.72
WQ-1	12/19/2017	No Sample zero flow							
WQ-3	12/19/2017	1048	22.55	919.9	7.81	89.75	7.64	6.126	0.55
WQ-4	12/19/2017	1133	19.14	235	7.63	81.79	7.39	7.772	0.8
WQ-5	12/19/2017	0925	19.92	539	6.99	76.4	7.68	14.05	0.96
WQ-1	1/24/2018	No Sample zero flow							
WQ-3	1/24/2018	1109	16.95	737.39	9.68	99.6	8.52	1.171	0.4
WQ-4	1/24/2018	1200	16.18	250.35	8.9	90.01	7.98	6.860	1.2
WQ-5	1/24/2018	0920	15.53	381	8.02	80.1	7.95	7.444	1
WQ-1	2/23/2018	No Sample zero flow							
WQ-3	2/23/2018	1038	22.97	697	6.76	77.8	7.53	3.528	0.4
WQ-4	2/23/2018	1126	22.12	250.3	6.42	72.63	7.05	7.275	1
WQ-5	2/23/2018	0850	22.15	391	5.88	67	7.1	12.68	1.5

Appendix 4 Stream Cross-Sections

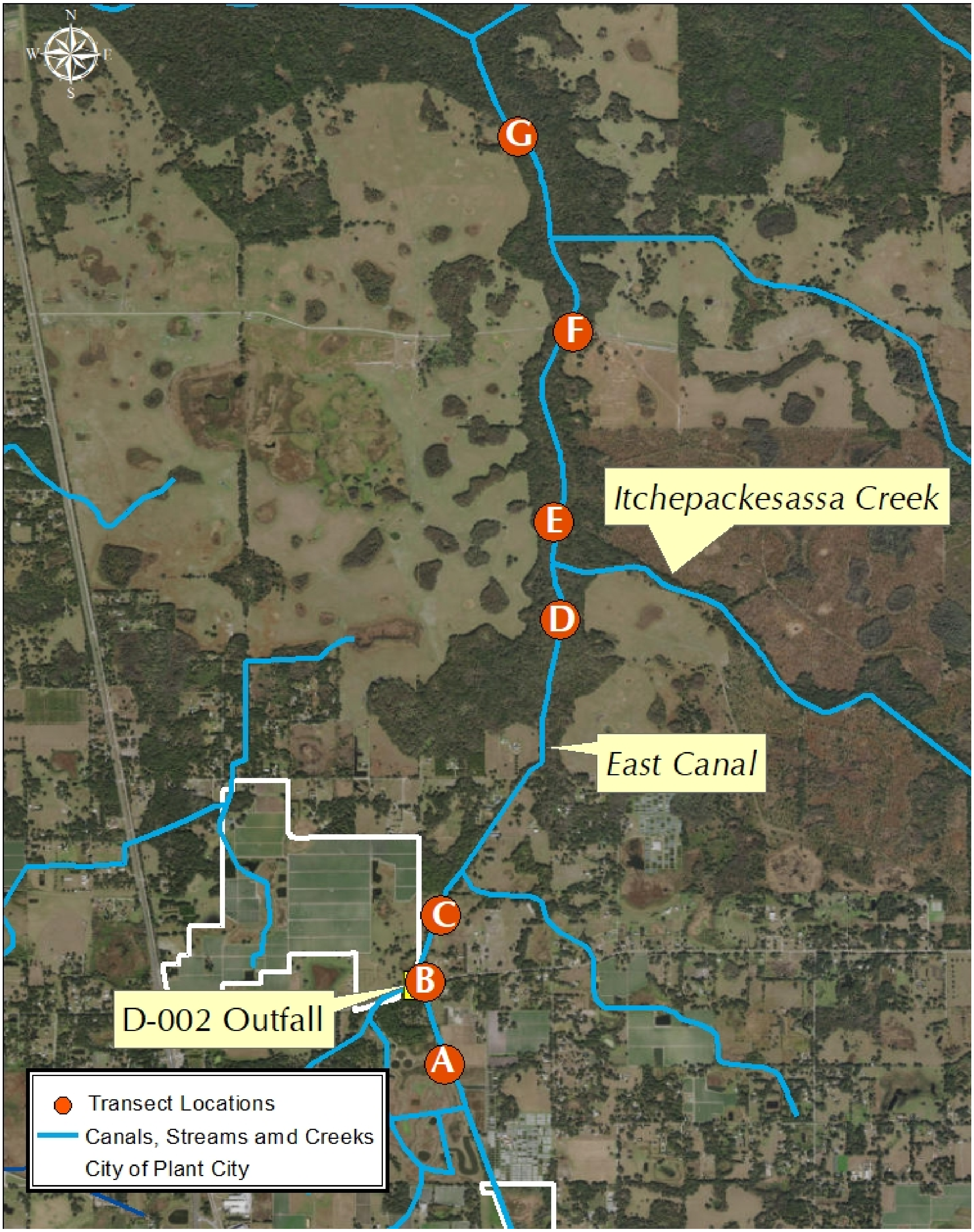


Figure 4-1. Locations of bathymetric transects used to develop model segment (reach) dimensions.

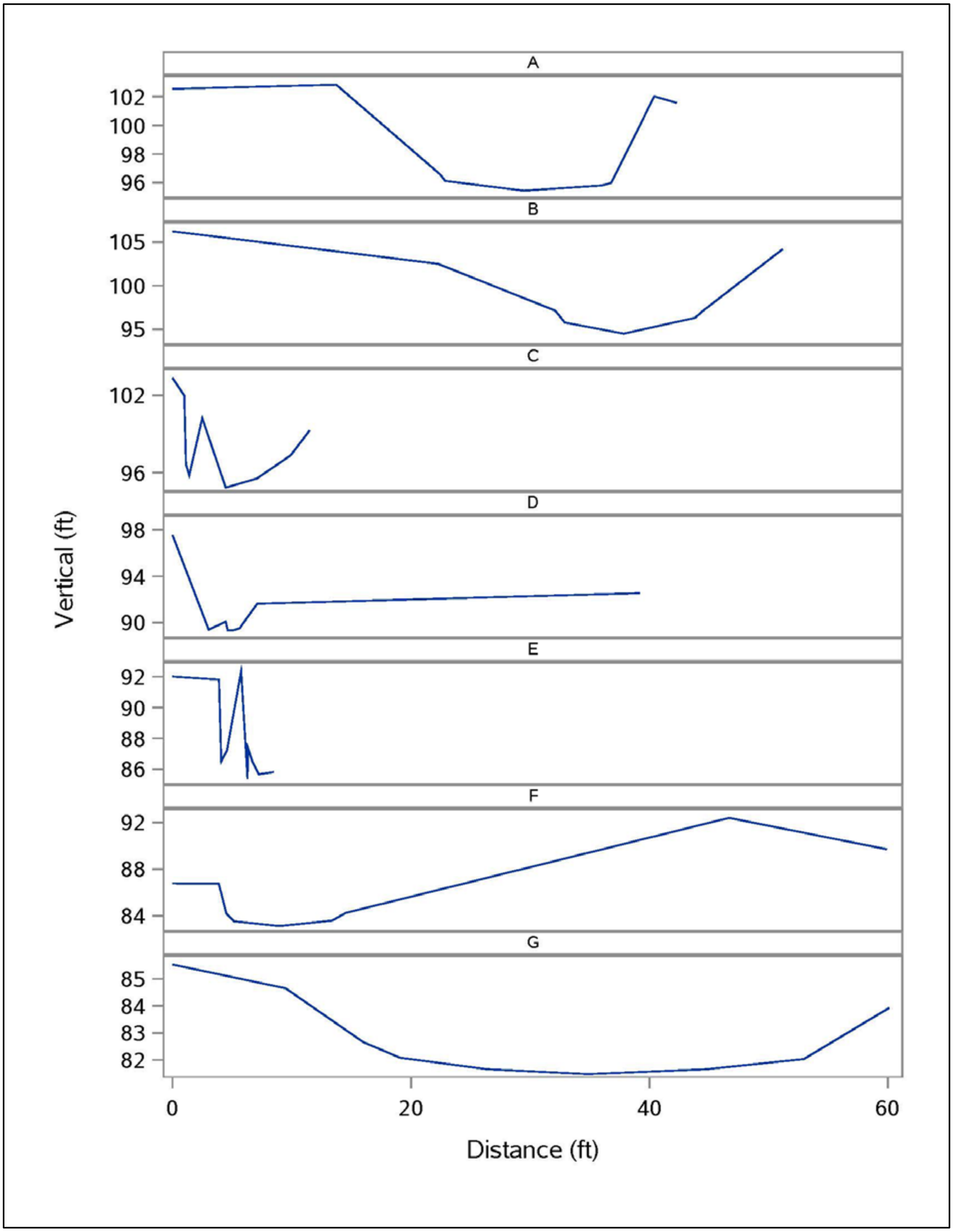
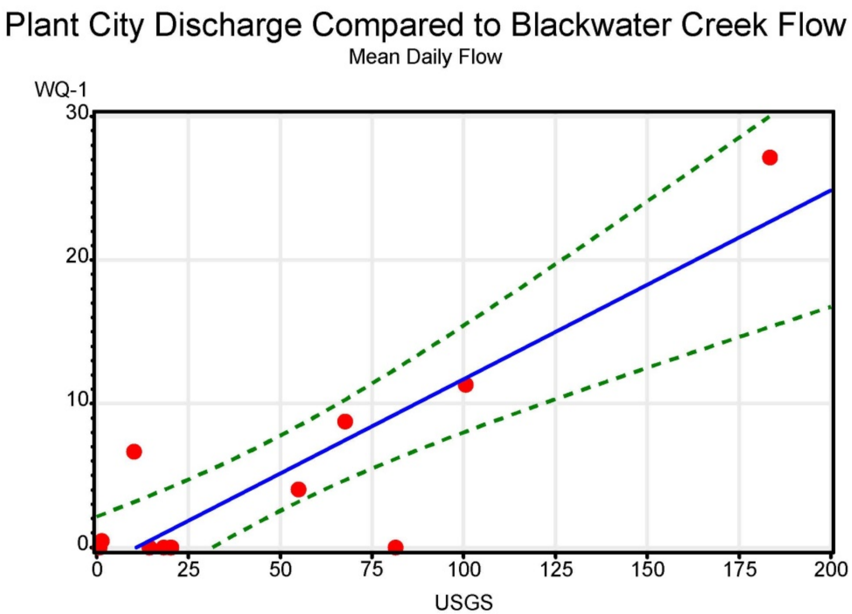


Figure 4-2. Bathymetric transects used to develop model segment (reach) dimensions.

Appendix 5 Flow Regressions

During the monthly sampling events, flow measurements were made using the USGS cross-sectional area methodology where twenty measurements are made evenly across the creek and integrated into a final flow value in cubic feet per second and a mean velocity value. Since the QUAL2KW model calls for input data at a higher frequency, hourly, a regression model was developed between sites WQ-1 and WQ-4 and the USGS gage located downstream on Blackwater Creek near Knights FL (02302500). The regression equations were then used to calculate an hourly flow value for input into the model. The regression plots and statistics are shown below.



Regression Equation:
WQ_1 = -1.414331 + 0.131407*USGS

Plant City Discharge Compared to Blackwater Creek Flow
Mean Daily Flow

The REG Procedure
Model: MODEL1
Dependent Variable: WQ_1 WQ-1

Number of Observations Read	391
Number of Observations Used	12
Number of Observations with Missing Values	379

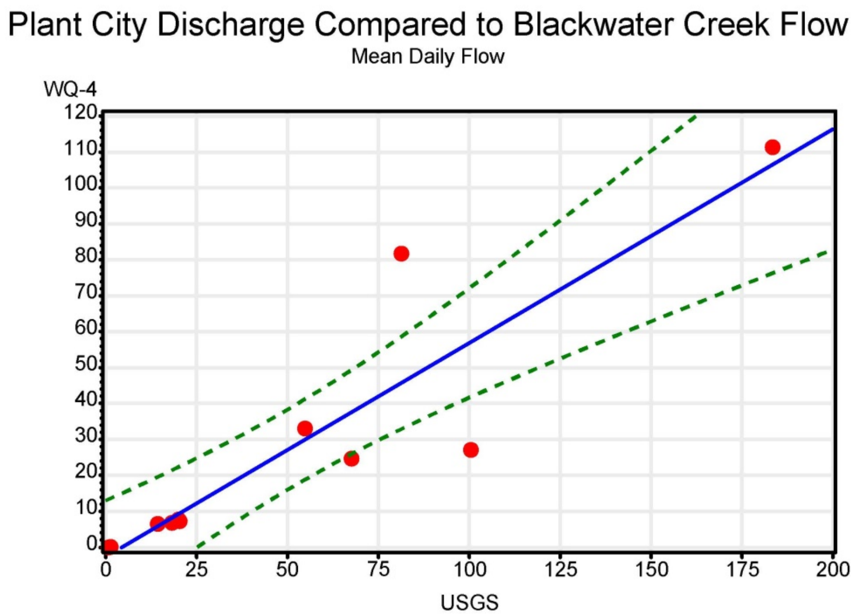
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	553.63720	553.63720	33.53	0.0002
Error	10	165.12049	16.51205		
Corrected Total	11	718.75769			

Root MSE	4.06350	R-Square	0.7703
Dependent Mean	4.85925	Adj R-Sq	0.7473
Coeff Var	83.62406		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	Intercept	1	-1.41433	1.59682	-0.89	0.3966
USGS		1	0.13141	0.02269	5.79	0.0002



Regression Equation:
WQ_4 = -2.556728 + 0.594207*USGS

Plant City Discharge Compared to Blackwater Creek Flow
Mean Daily Flow

The REG Procedure
Model: MODEL1
Dependent Variable: WQ_4 WQ-4

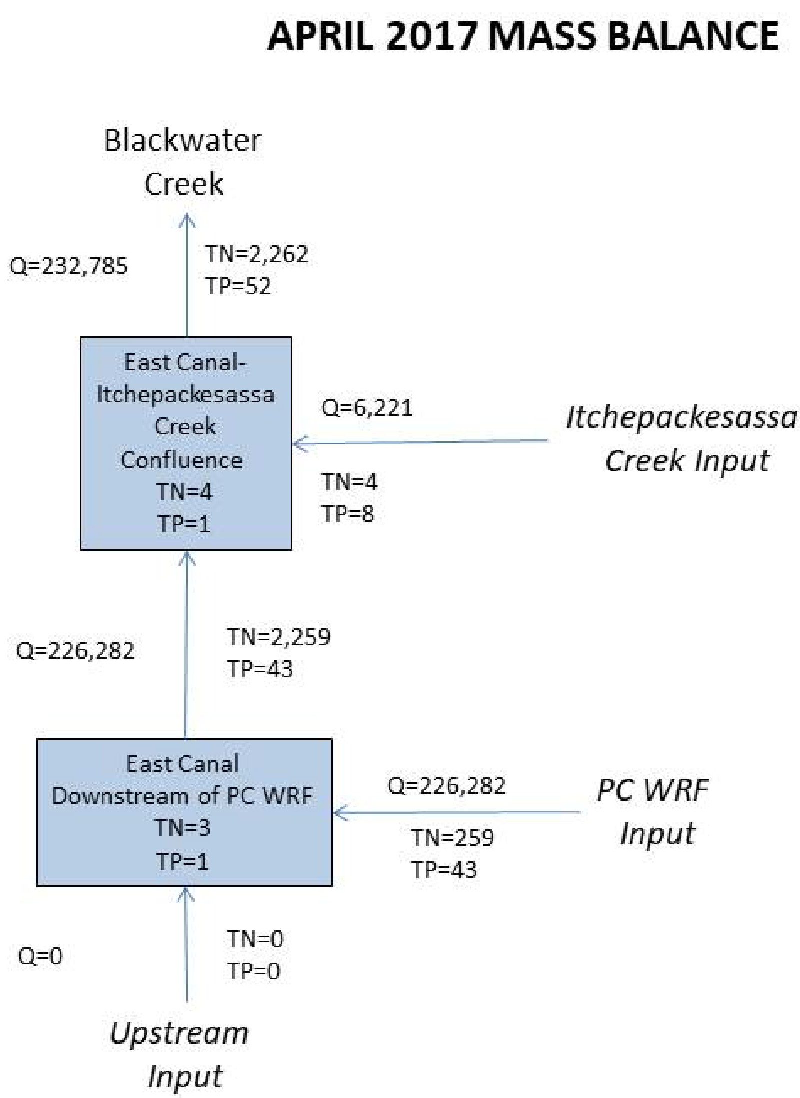
Number of Observations Read	391
Number of Observations Used	11
Number of Observations with Missing Values	380

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	10778	10778	40.20	0.0001
Error	9	2412.69602	268.07734		
Corrected Total	10	13190			

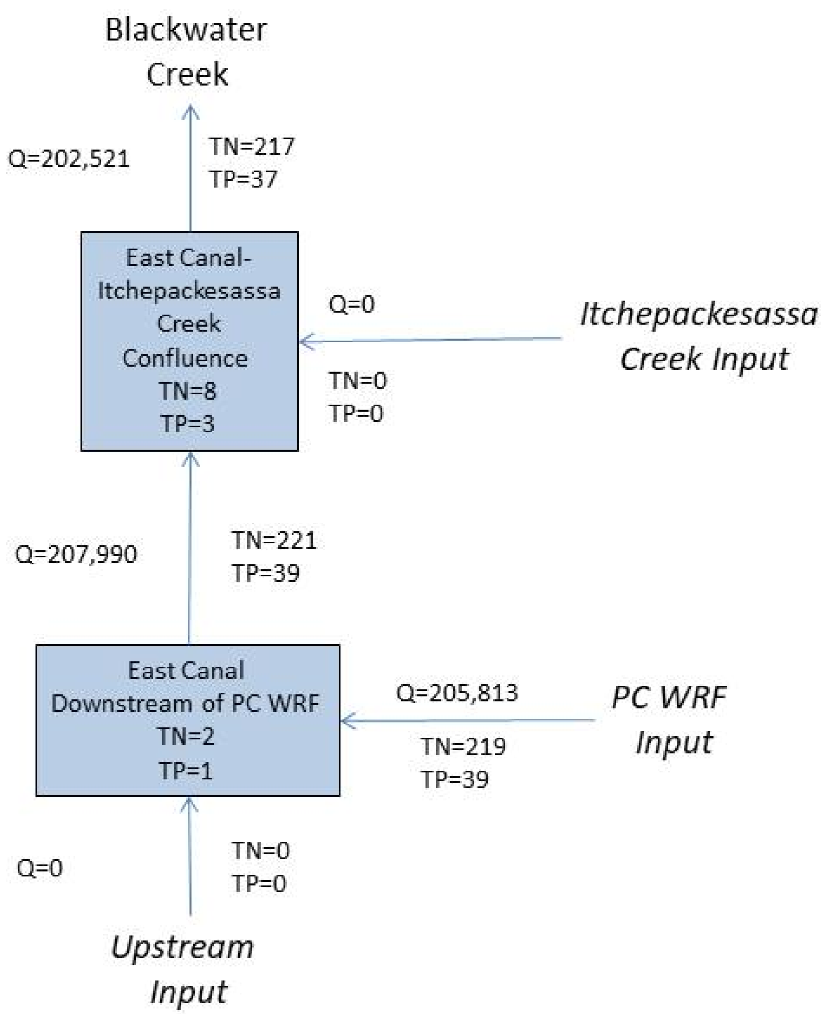
Root MSE	16.37307	R-Square	0.8171
Dependent Mean	27.83968	Adj R-Sq	0.7968
Coeff Var	58.81198		

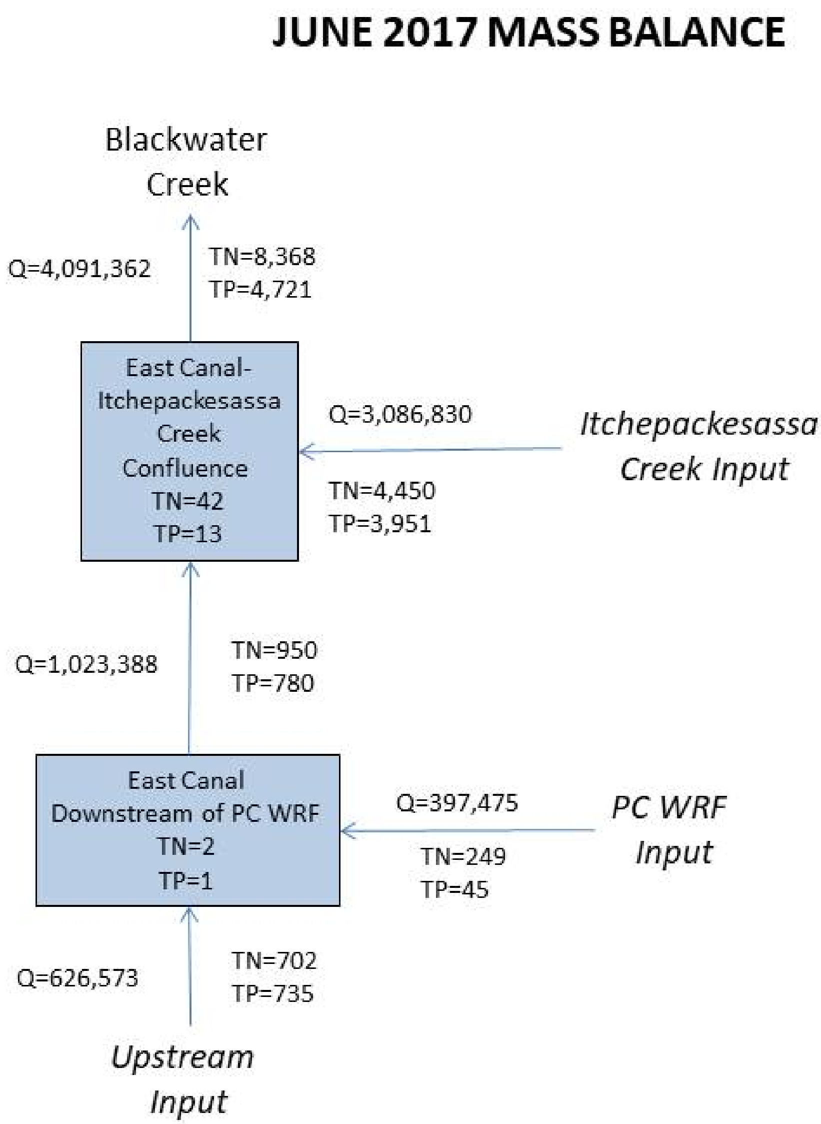
Parameter Estimates						
Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	Intercept	1	-2.55673	6.88130	-0.37	0.7188
USGS		1	0.59421	0.09371	6.34	0.0001

Appendix 6 Monthly Box Model

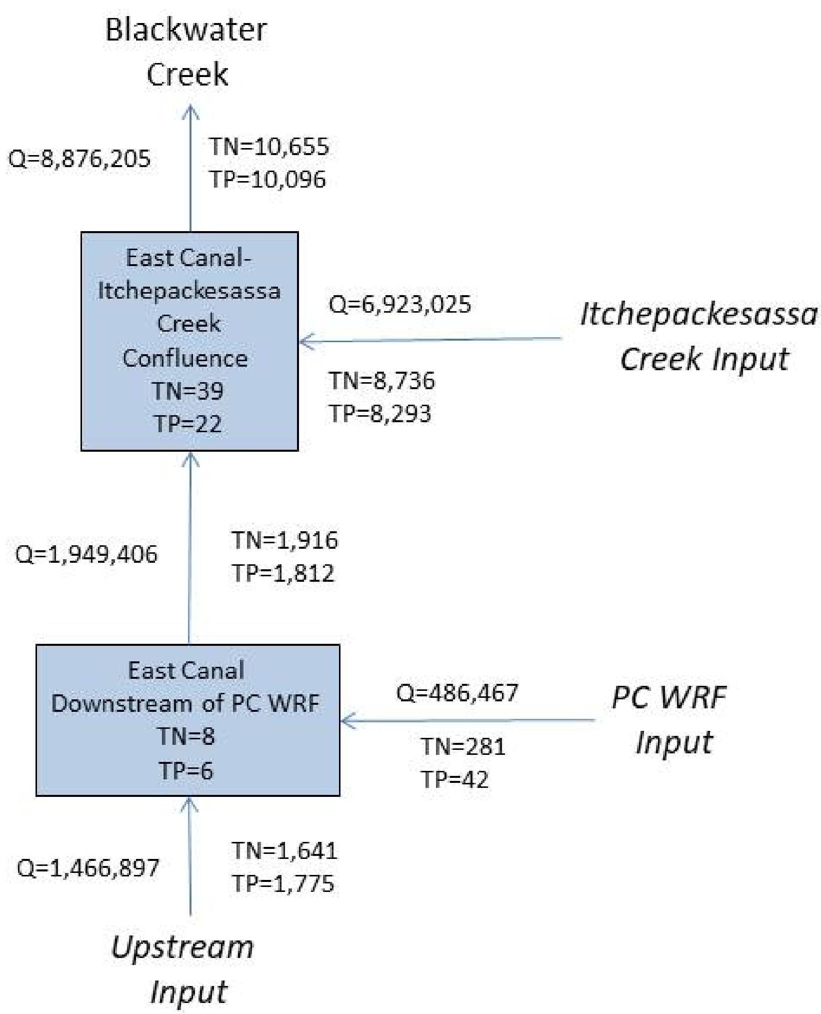


MAY 2017 MASS BALANCE

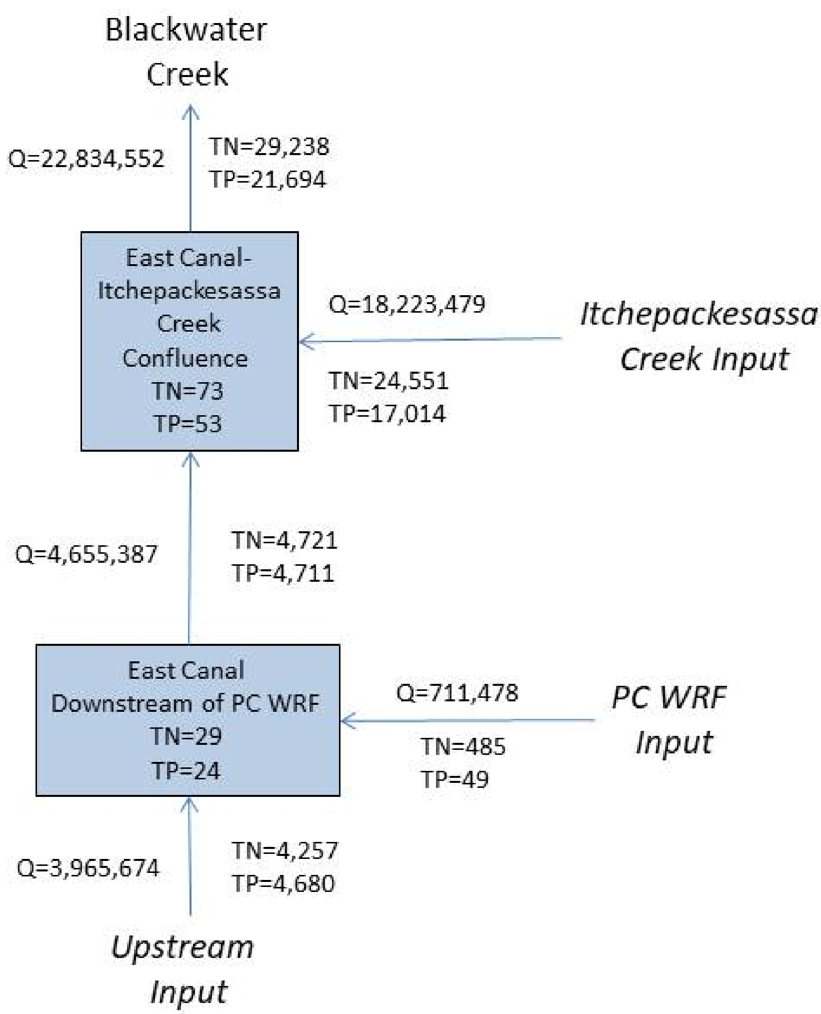



JUNE 2017 MASS BALANCE
Blackwater Creek
Q=4,091,362
TN=8,368
TP=4,721
East Canal-Itchepackesassa Creek Confluence
TN=42
TP=13
Q=3,086,830
Itchepackesassa Creek Input
TN=4,450
TP=3,951
Q=1,023,388
TN=950
TP=780
East Canal Downstream of PC WRF
TN=2
TP=1
Q=397,475
PC WRF Input
TN=249
TP=45
Q=626,573
TN=702
TP=735
Upstream Input

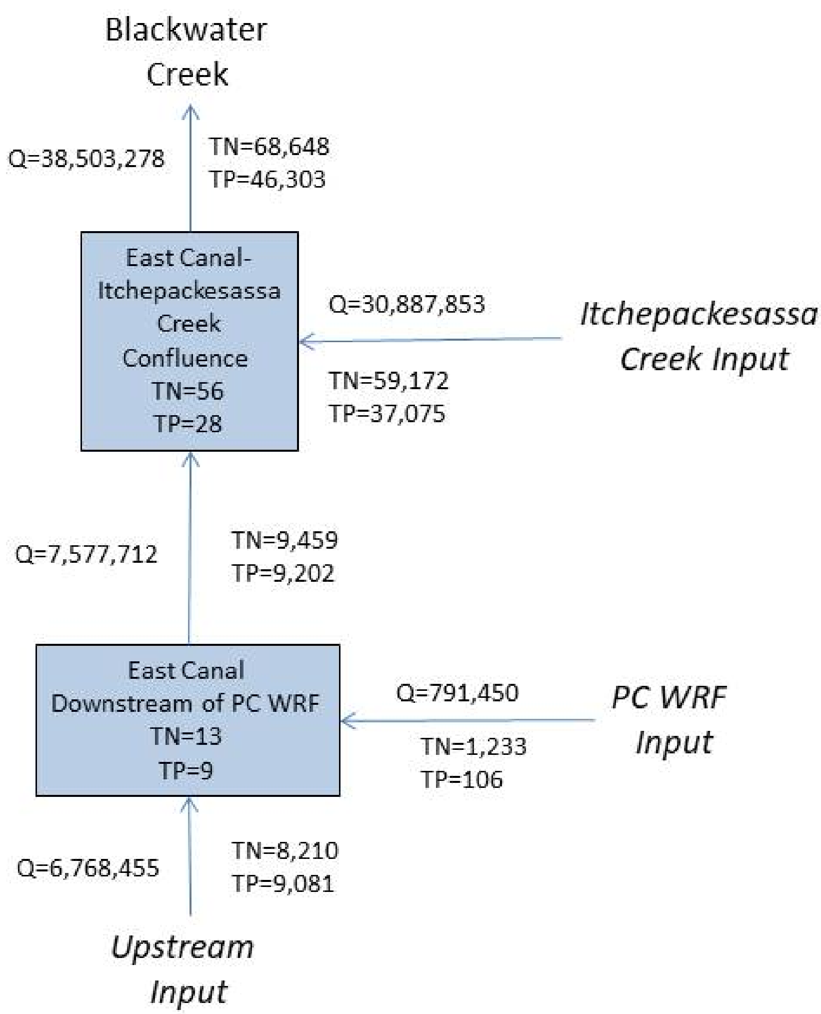
JULY 2017 MASS BALANCE

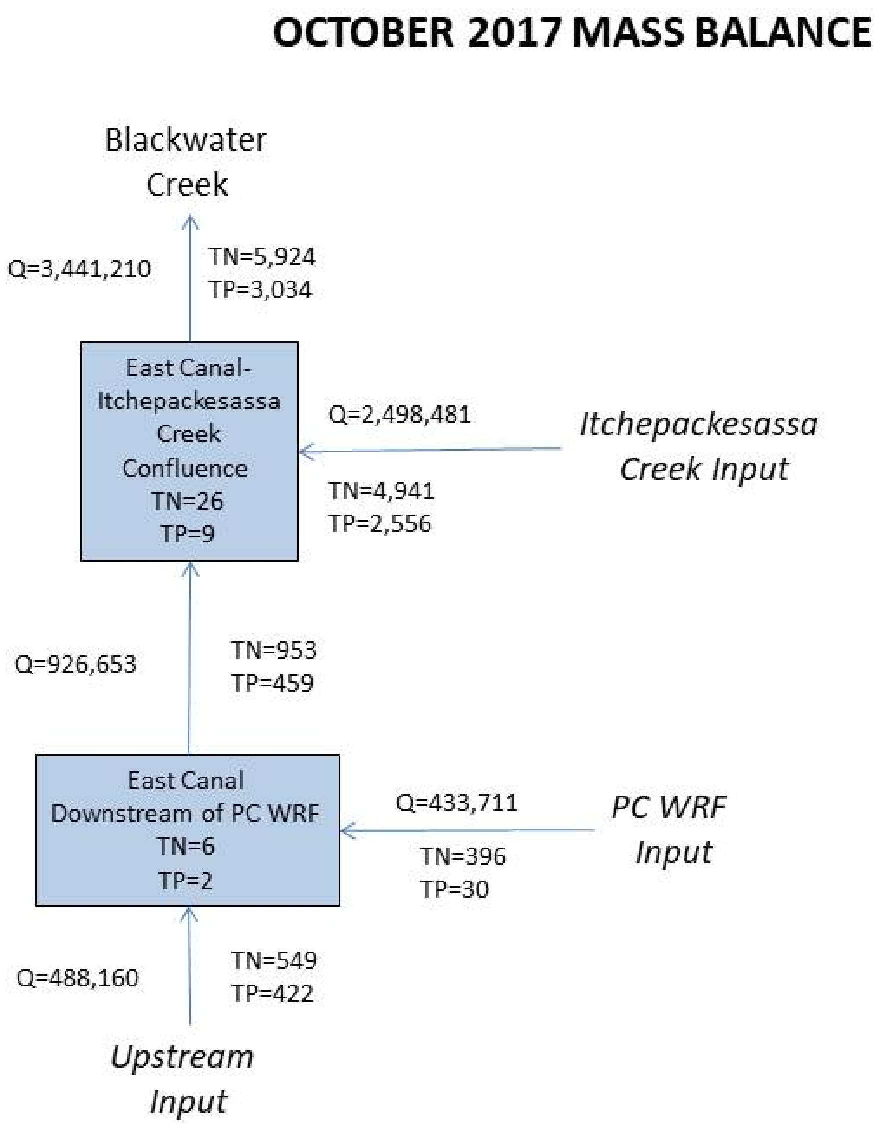


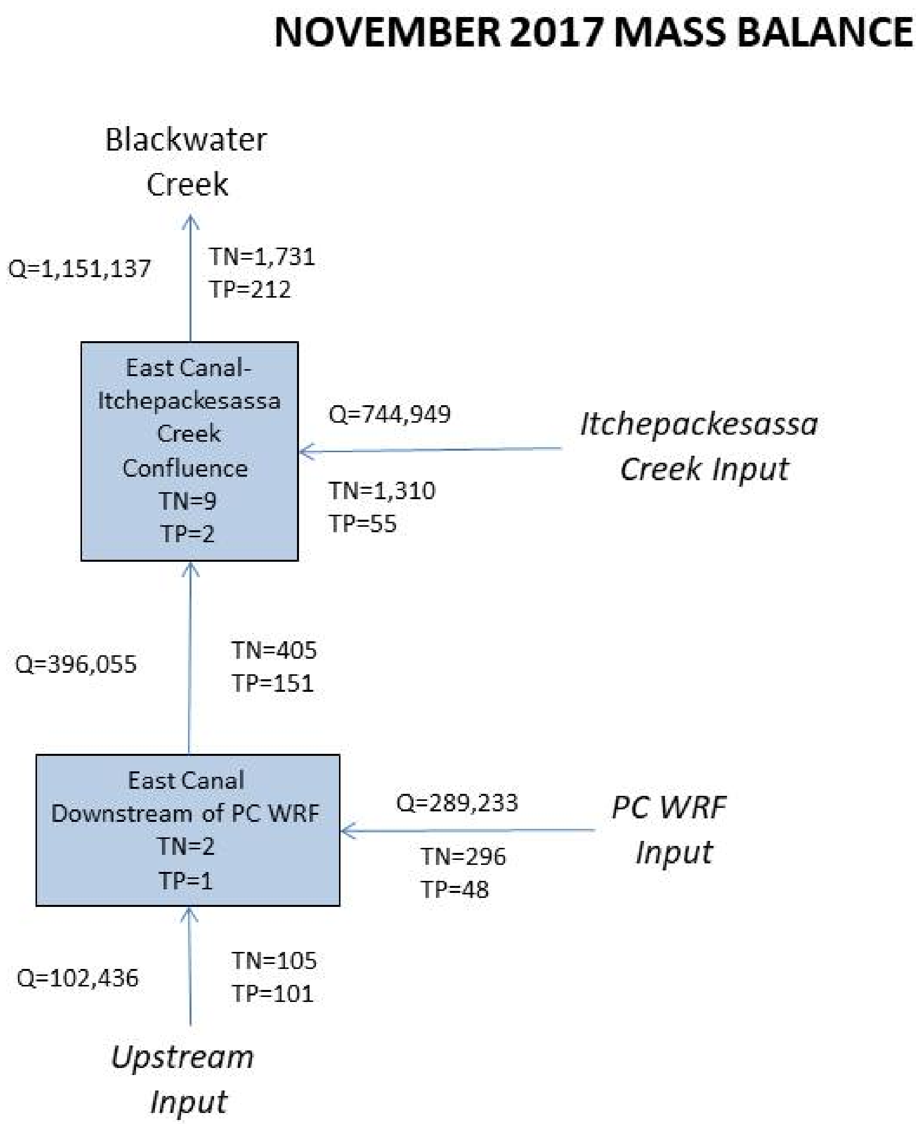
AUGUST 2017 MASS BALANCE



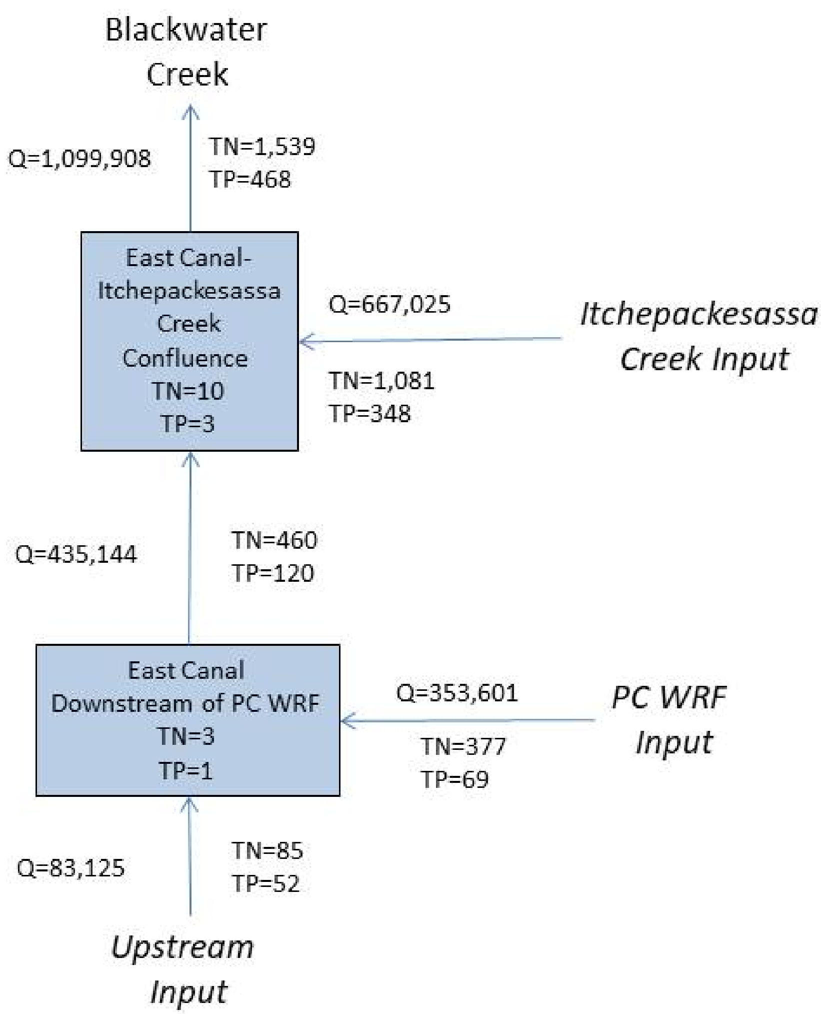
SEPTEMBER 2017 MASS BALANCE



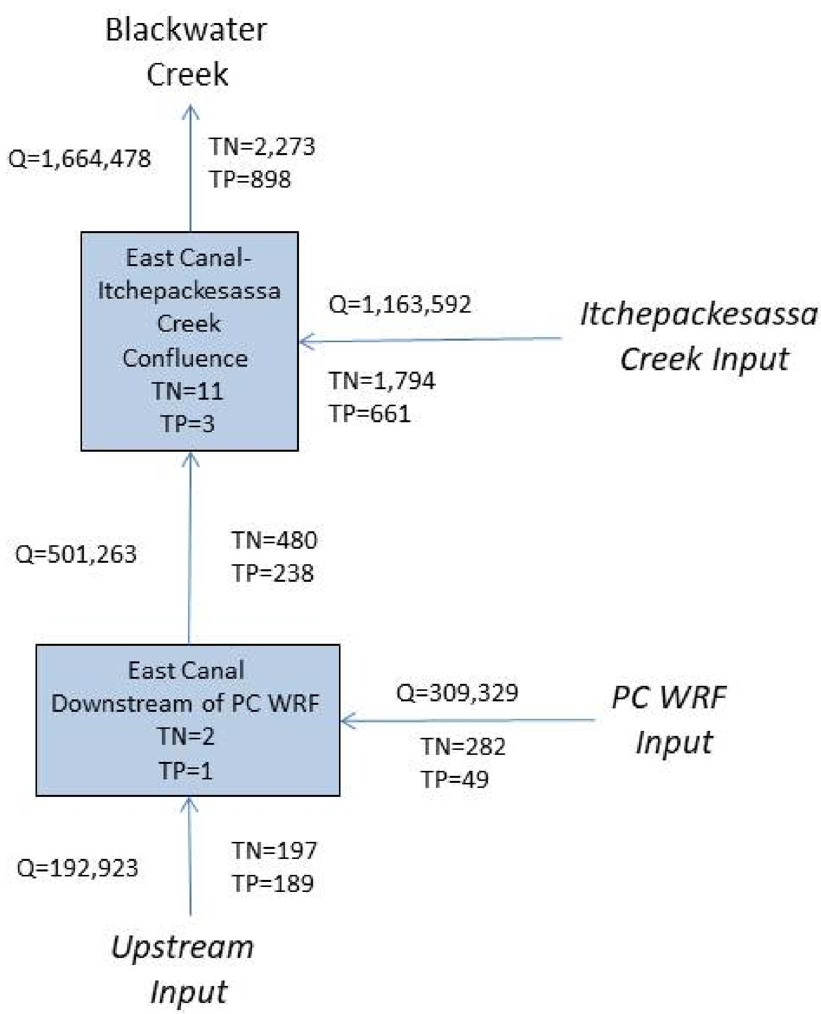

OCTOBER 2017 MASS BALANCE
Blackwater Creek
Q=3,441,210
TN=5,924
TP=3,034
East Canal-Itchepackesassa Creek Confluence
TN=26
TP=9
Q=2,498,481
Itchepackesassa Creek Input
TN=4,941
TP=2,556
Q=926,653
TN=953
TP=459
East Canal Downstream of PC WRF
TN=6
TP=2
Q=433,711
PC WRF Input
TN=396
TP=30
Q=488,160
TN=549
TP=422
Upstream Input

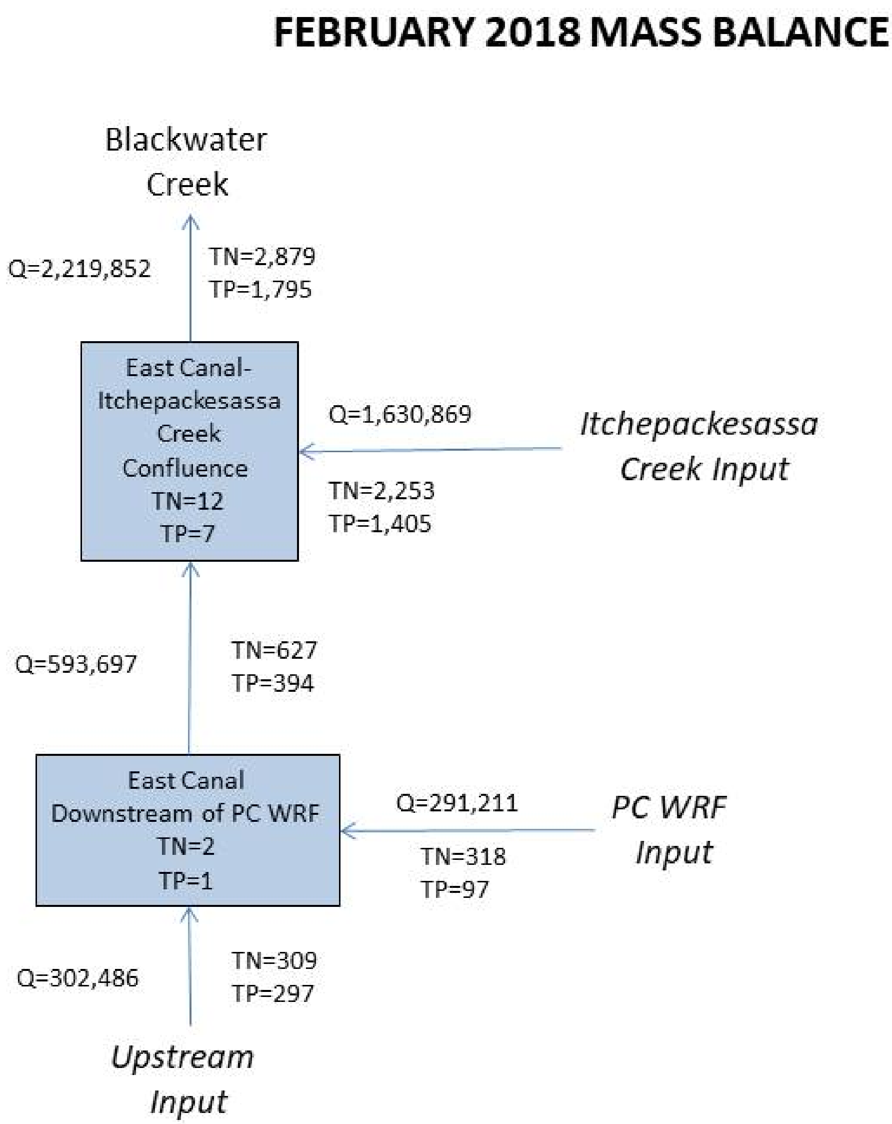

NOVEMBER 2017 MASS BALANCE
Blackwater Creek
Q=1,151,137
TN=1,731
TP=212
East Canal-Itchepackesassa Creek Confluence
TN=9
TP=2
Q=744,949
Itchepackesassa Creek Input
TN=1,310
TP=55
Q=396,055
TN=405
TP=151
East Canal Downstream of PC WRF
TN=2
TP=1
Q=289,233
PC WRF Input
TN=296
TP=48
Q=102,436
TN=105
TP=101
Upstream Input

DECEMBER 2017 MASS BALANCE

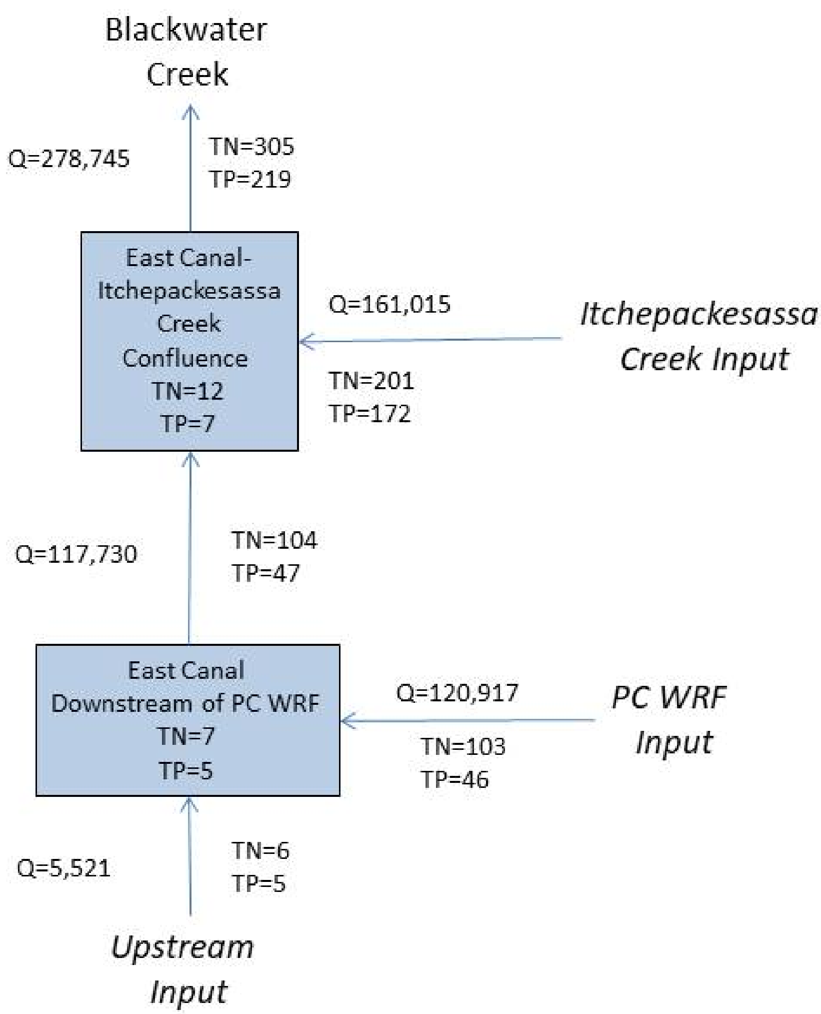


JANUARY 2018 MASS BALANCE




FEBRUARY 2018 MASS BALANCE
Blackwater Creek
Q=2,219,852
TN=2,879
TP=1,795
East Canal-Itchepackesassa Creek Confluence
TN=12
TP=7
Q=1,630,869
Itchepackesassa Creek Input
TN=2,253
TP=1,405
Q=593,697
TN=627
TP=394
East Canal Downstream of PC WRF
TN=2
TP=1
Q=291,211
PC WRF Input
TN=318
TP=97
Q=302,486
TN=309
TP=297
Upstream Input

MARCH 2018 MASS BALANCE



Appendix 7 QUAL2Kw Model Inputs

Table 7-1. Table of field and laboratory parameters.

Field Parameters	Laboratory Parameters
Temperature (°C) pH (SU) Specific Conductance (μmhos) Dissolved Oxygen (mg/L) Dissolved Oxygen (μg/L) Flow (cfs) Depth (feet)	Ammonia (mg/L) Total Kjeldahl Nitrogen (mg/L) Nitrate (mg/L) Nitrate-Nitrite as N (mg/L) Orthophosphate as P (mg/L) Total Phosphorus as P (mg/L) Chlorophyll a (μg/L) Ammonium as NH_4 (mg/L) Total Suspended Solids (mg/L) Volatile Suspended Solids (mg/L) Nitrite (mg/L) Carbonaceous BOD (mg/L) Total Organic Carbon (mg/L) Dissolved Organic Carbon (mg/L)

Table 7-2. Table of model rates and constants identifiers.

Rates & Constants	Source
Organic Matter Stoichiometry: Carbon:Nitrogen:Phosphorus:Dry weight:Chlorophyll	Chapra et al. 2012; Bowie et al. 1995
Inorganic suspended solids settling velocity	Recommended range in model file
O_2 for carbon oxidation	Chapra et al. 2012
O_2 for NH4 nitrification	Chapra et al. 2012
O_2 inhibition parameter for CBOD oxidation	Chapra et al. 2012
O_2 inhibition parameter for nitrification	Chapra et al. 2012
O_2 enhancement parameter for nitrification	Chapra et al. 2012
O_2 inhibition parameter for phytoplankton respiration	Chapra et al. 2012
O_2 enhancement parameter for bottom algae respiration	Chapra et al. 2012
Slow CBOD hydrolysis rate	Recommended range in model file; Bowie et al. 1995
Temperature correction for slow CBOD hydrolysis	Recommended range in model file; Bowie et al. 1995
Slow CBOD oxidation rate	Recommended range in model file; Bowie et al. 1995
Temperature correction for slow CBOD oxidation	Recommended range in model file; Bowie et al. 1995
Fast CBOD oxidation rate	Recommended range in model file; ; Bowie et al. 1995
Temperature correction for fast CBOD oxidation	Recommended range in model file; Bowie et al. 1995
Organic N hydrolysis rate	Recommended range in model file; Bowie et al. 1995

Table 7-2. Table of model rates and constants identifiers.

Rates & Constants	Source
Temperature correction for organic N hydrolysis	Recommended range in model file; Bowie et al. 1995
Organic N settling velocity	Recommended range in model file
Ammonium nitrification rate	Recommended range in model file; Bowie et al. 1995
Temperature correction for ammonium settling	Recommended range in model file; Bowie et al. 1995
Nitrate denitrification rate	Recommended range in model file; Bowie et al. 1995
Temperature correction for nitrate denitrification	Recommended range in model file; Bowie et al. 1995
Nitrate sediment denitrification transfer coefficient	Recommended range in model file
Temperature correction for nitrate sediment denitrification transfer	Recommended range in model file
Organic phosphorus hydrolysis rate	Recommended range in model file; Bowie et al. 1995
Temperature correction for organic phosphorus hydrolysis	Recommended range in model file; Bowie et al. 1995
Organic phosphorus settling rate	Recommended range in model file
Inorganic phosphorus settling rate	Recommended range in model file
Sediment phosphorus oxygen attenuation half saturation constant	Chapra et al. 2012; recommended range in model file
Phytoplankton maximum growth rate	Recommended range in model file; Bowie et al. 1995
Temperature correction for phytoplankton growth	Recommended range in model file; Bowie et al. 1995
Phytoplankton respiration rate	Recommended range in model file; Bowie et al. 1995
Temperature correction for phytoplankton respiration	Recommended range in model file; Bowie et al. 1995
Phytoplankton death rate	Recommended range in model file; Bowie et al. 1995
Temperature correction for phytoplankton death	Recommended range in model file
Nitrogen half saturation constant for phytoplankton uptake	Recommended range in model file; Bowie et al. 1995
Phosphorus half saturation constant for phytoplankton uptake	Recommended range in model file; Bowie et al. 1995
Inorganic carbon half saturation constant for phytoplankton uptake	Recommended range in model file
Light constant for phytoplankton growth	Recommended range in model file
Ammonia preference for phytoplankton uptake	Recommended range in model file
Phytoplankton setting rate	Recommended range in model file; Bowie et al. 1995
Phytoplankton fraction of nitrogen uptake from water column	Recommended range in model file
Phytoplankton fraction of phosphorus uptake from water column	Recommended range in model file

Table 7-2. Table of model rates and constants identifiers.

Rates & Constants	Source
Bottom algae maximum growth rate	Recommended range in model file; Bowie et al. 1995
Temperature correction for bottom algae growth	Recommended range in model file
Bottom algae first-order model carrying capacity	Recommended range in model file
Bottom algae basal respiration rate	Recommended range in model file; Bowie et al. 1995
Bottom algae photo-respiration rate parameter	Recommended range in model file
Temperature correction for bottom algae photo-respiration	Recommended range in model file
Bottom algae excretion rate	Recommended range in model file
Temperature correction for bottom algae excretion	Recommended range in model file
Coefficient of scour function	Recommended range in model file
Exponent of scour function	Recommended range in model file
Minimal bottom algae biomass after scour event	Recommended range in model file
Catastrophic scour rate during flood event	Recommended range in model file
Critical flow or velocity for catastrophic scour	
Bottom algae external nitrogen half saturation constant for uptake	Recommended range in model file
Bottom algae external phosphorus half saturation constant for uptake	Recommended range in model file
Bottom algae inorganic carbon half saturation constant for uptake	Recommended range in model file
Bottom algae light constant for light model	Recommended range in model file
Bottom algae ammonia preference	Recommended range in model file
Bottom algae nitrogen subsistence quota	Recommended range in model file
Bottom algae phosphorus subsistence quota	Recommended range in model file
Bottom algae maximum nitrogen uptake rate	Recommended range in model file
Bottom algae maximum phosphorus uptake rate	Recommended range in model file
Bottom algae internal nitrogen half saturation ratio	Recommended range in model file
Bottom algae internal phosphorus half saturation ratio	Recommended range in model file
Bottom algae nitrogen uptake water column fraction	Recommended range in model file
Bottom algae phosphorus uptake water column fraction	Recommended range in model file
Detritus dissolution rate	Recommended range in model file
Temperature correction for detritus dissolution	Recommended range in model file
Detritus settling rate	Recommended range in model file
Partial pressure of carbon dioxide	National Oceanic and Atmospheric Administration
Phytoplankton and bottom algae photosynthetic quotient for NO_3 vs NH_4 use	Recommended range in model file
Phytoplankton and bottom algae respiratory	Recommended range in model file

Table 7-2. Table of model rates and constants identifiers.	
Rates & Constants	**Source**
quotient	
Fraction of photosynthetically available radiation	Chapra et al. 2012
Background light extinction	Recommended range in model file
Linear chlorophyll light extinction	Chapra et al. 2012
Nonlinear chlorophyll light extinction	Chapra et al. 2012
Inorganic suspended solids light extinction	Recommended value in model file
Detritus light extinction	Recommended value in model file
Macrophyte light extinction	Recommended value in model file
Coefficient for attenuation of solar radiation by cloud cover	Recommended value in model file
Exponent for attenuation of solar radiation by cloud cover	Recommended value in model file
Coefficient for cloudy sky adjustment of longwave radiation	Recommended value in model file
Exponent for cloudy sky adjustment of longwave radiation	Recommended value in model file

Appendix 8 Calibration Statistics

Stats based on 3-hour average, 1.5 hours preceding and 1.5 hours following observed

pH			
	Reach 3	Reach 5	Combined
r2	0.72	0.82	0.76
RMSE	0.33	0.23	0.29
Mean Error	-0.21	-0.05	-0.13
Absolute Mean Error	0.21	0.21	0.21
Relative Error (%)	-2.78	-0.62	-1.72

NO3-NO2			
	Reach 3	Reach 5	Combined
r2	0.05	0.90	0.71
RMSE	0.13	0.11	0.12
Mean Error	0.04	0.09	0.06
Absolute Mean Error	0.12	0.09	0.10
Relative Error (%)	21.48	29.05	26.05

Temperature			
	Reach 3	Reach 5	Combined
r2	0.82	0.90	0.82
RMSE	4.69	2.95	3.92
Mean Error	-4.07	-2.42	-3.24
Absolute Mean Error	4.30	2.47	3.38
Relative Error (%)	-16.96	-10.82	-14.00

Orthophosphate			
	Reach 3	Reach 5	Combined
r2	0.86	0.96	0.92
RMSE	0.08	0.10	0.09
Mean Error	0.02	0.06	0.04
Absolute Mean Error	0.07	0.08	0.08
Relative Error (%)	7.17	19.99	14.24

Specific Conductance			
	Reach 3	Reach 5	Combined
r2	0.95	0.98	0.96
RMSE	90.44	43.06	70.83
Mean Error	-30.83	-8.57	-19.70
Absolute Mean Error	66.60	33.12	49.86
Relative Error (%)	-4.60	-2.01	-3.60

Chlorophyll *a*			
	Reach 3	Reach 5	Combined
r2	0.75	0.77	0.75
RMSE	1.60	2.73	2.24
Mean Error	0.30	-1.14	-0.42
Absolute Mean Error	1.32	1.78	1.55
Relative Error (%)	12.48	-20.63	-10.66

Dissolved Oxyen			
	Reach 3	Reach 5	Combined
r2	0.63	0.58	0.56
RMSE	1.24	1.32	1.28
Mean Error	-0.48	-0.26	-0.37
Absolute Mean Error	0.70	1.16	0.93

TKN			
	Reach 3	Reach 5	Combined
r2	0.50	0.88	0.79
RMSE	0.15	0.17	0.16
Mean Error	-0.01	-0.08	-0.05
Absolute Mean Error	0.14	0.13	0.13

Relative Error (%)	-7.12	-4.34	-5.80

Relative Error (%)	-1.09	-9.28	-5.81

Total Nitrogen			
	Reach 3	Reach 5	Combined
r2	0.57	0.89	0.83
RMSE	0.13	0.18	0.16
Mean Error	0.03	0.00	0.02
Absolute Mean Error	0.10	0.13	0.11
Relative Error (%)	4.04	0.21	1.81

Dissolved Organic Carbon			
	Reach 3	Reach 5	Combined
r2	0.64	0.93	0.82
RMSE	2.86	1.79	2.39
Mean Error	-1.26	-0.54	-0.90
Absolute Mean Error	1.72	1.26	1.49
Relative Error (%)	-12.64	-4.23	-7.92

Total Phosphorus			
	Reach 3	Reach 5	Combined
r2	0.86	0.83	0.83
RMSE	0.17	0.30	0.24
Mean Error	0.09	0.19	0.14
Absolute Mean Error	0.14	0.23	0.18
Relative Error (%)	22.81	38.33	31.24

Flow			
	Reach 3	Reach 5	Combined
r2	1.00	0.99	0.97
RMSE	1.36	0.54	1.04
Mean Error	-0.38	-0.15	-0.27
Absolute Mean Error	0.47	0.29	0.38
Relative Error (%)	-36.91	-4.64	-12.54

Total Suspended Solids			
	Reach 3	Reach 5	Combined
r2	0.25	0.85	0.64
RMSE	4.69	3.21	4.02
Mean Error	-1.57	-1.73	-1.65
Absolute Mean Error	2.82	2.26	2.54
Relative Error (%)	-34.58	-22.70	-27.13

Depth			
	Reach 3	Reach 5	Combined
r2	0.96	0.95	0.94
RMSE	0.15	0.16	0.16
Mean Error	-0.01	-0.04	-0.03
Absolute Mean Error	0.09	0.13	0.11
Relative Error (%)	-4.40	-6.41	-5.77

Total Organic Carbon			
	Reach 3	Reach 5	Combined
r2	0.58	0.90	0.77
RMSE	2.74	3.39	3.08
Mean Error	-0.21	1.52	0.66
Absolute Mean Error	1.72	2.72	2.22
Relative Error	-2.13	12.29	5.95

(%)			