FY2019 Water Quality Monitoring Report

Upland Stormwater Lakes and Pump Stations

September 30, 2020

Cardno

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1.0	9/13/2019	Update Graphs/Tables	Luke Westlake	Sheri Huelster
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4.0	9/30/2020	Finalize report document	Sheri Huelster/Ed Call	City of Naples

Table of Contents

Tables

Figures

Acronyms

%Sat	Percent Saturation
Ammonia as N	Ammonia as Nitrogen
°C	Degrees Celsius
CFU/100mL	Colony forming unit per 100 milliliters
DO	Dissolved Oxygen
DO Sat	Dissolved Oxygen Saturation
FDEP	Florida Department of Environmetal Protection
FY	Fiscal Year
GeoMean	Geometric Mean
MDL	Minimum Detection Limit
Mg/L	milligrams per liter
NNC	Numeric Nutrient Criteria
NOAA	National Oceanic and Atmospheric Adminstration
NO_x	Nitrate-Nitrite Nitrogen
NTU	Nephelometric Turbidity Unit
OrthoP	Orthophosphorus
QA/QC	Quality Assurance/Quality Control
SC	Specific Conductivity
SU	Standard Units
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TSS	Total Suspended Solids
U	Undetected
µg/L	micrograms per liter
µmhos/cm	micro ohms per centimeter

Executive Summary

Upland Stormwater Lakes

Monitoring results from data collected at stormwater lakes were reviewed to identify any outliers that exceed Class III Surface Water Quality Standards within the data collected over the Fiscal Year (FY) 2019 sampling events amongst the various stations. Class III Surface Water Standards are used as a reference for sampling data only. Nutrient parameters (total nitrogen, total phosphorus, chlorophyll-a) were variable by station and drainage basin during FY2019. Fecal coliform and enterococci values were variable throughout the FY2019 sampling period with isolated spikes in colony counts appearing to occur after stormwater inflows. Copper concentrations at lakes discharging to the same drainage basin appear to have a similar pattern, one exception being sampling location 1SE-B in Moorings Bay basin which had a large spike in concentration with a February measurement of 1160 µg/L. Gordon River and Gulf of Mexico basin remained constant.

Pump Stations

Quarterly pump station water quality monitoring was completed in November 2018, February 2019, May 2019, and August 2019 for FY2019 at pump locations 11-Pump, 14-Pump, and PW-Pump. Field measurements (temperature, dissolved oxygen, pH, conductivity, salinity, and turbidity) at all stations appeared to be consistent with expected temporal and seasonal variations. Nutrients remained fairly consistent during the sampling period; the exception is the rainfall-induced spikes in copper and mercury during August 2019 at 14-Pump. Fecal coliform measurements at all pump stations exceeded the Florida Class III Surface Water Quality Standards, which are used a reference value, during this 2019 monitoring year. The data indicates that rainfall is driving fecal coliform and enterococci spikes at the pump monitoring locations.

Management Recommendations

Overall water quality parameters were variable both spatially and temporally during the FY2019 sampling period. Challenges managing stormwater and the associated nutrients are complex and often require a multifaceted approach to adequately address the many sources of nutrient loading in to lakes, ponds and stormwater systems.

Management strategies for the reduction of total nitrogen (TN) and total phosphorous (TP) concentrations may include: additional littoral plantings, mechanical removal of organic muck and legacy nutrients by dredging, retrofitting stormwater conveyance systems with advanced filter treatment systems, changes in the duration and timing of street sweeping program, routine maintenance of catchment basins, use of binding agents for inactivation of TP, and consider the use of biological controls as a final strategy. Management of fecal coliform and enterococci levels within stormwater ponds may benefit from changes to the frequency and timing of street sweeper programs within these basins. Installing and maintaining pet waste stations coupled with targeted stormwater education/outreach may provide an effective management strategy for reducing bacterial loading from stormwater

The City of Naples should continue to monitor and collect water quality data to further identify trends in the data versus potential seasonal outliers caused by natural variability (rainfall, temperature, hurricanes, etc.). Continued data collection of marine resources (seagrass and fisheries data) is also recommended in order to compare against water quality data which will also aid in management decisions. Lastly, data from the upcoming FY 2020 sampling will help to identify potential long-term trends and to update previous studies that will aide in future management decisions for each waterbody described below.

1 Introduction

This summary report provides the results of the Fiscal Year (FY) 2019 water quality monitoring of the City of Naples Streets and Stormwater Department (City) stormwater lakes and pump stations (Table 1 and Figure 1). The stations sampled and frequency of sampling during FY2019 (October 2018 to September 2019) was based on the updated survey design that began in October 2017. Monthly sampling was completed at the following ten lakes – Devils Lake (1SE-B), Swan Lake (2B), Colonnade Lake (3B), Lake Suzanne (5B), North Lake (8B), South Lake (9B), 15th Avenue North Lake-WTP Lake (19B), Forest Lake (20B), Lake Manor (22B), and NCH Lake (26B); the remaining six stormwater lakes Mandarin Lake (6B), Sun Lake Terrace (15B), Alligator Lake (10B), East Lake (11B), Lantern Lake (14B), and Half Moon Lake (24B) were sampled quarterly. Pump station monitoring was also conducted on a quarterly basis for the entirety of FY2019. None of the lakes or pump stations sampled for this report qualify as Class III waterbodies, and the Class III Surface Water Quality Standards are used as a reference value only throughout this report. This summary report provides water quality results collected by Cardno staff from October 2018 to September 2019.

Table 1. City of Naples stormwater lakes and pump station names, station coordinates, drainage basin, and sampling frequency.

Monitoring Location	Lake Name	Drainage Basin	Latitude	Longitude	Sampling Frequency
1SE-B	Devils Lake	Moorings Bay	26.2054	-81.8081	Monthly
2B	Swan Lake		26.1980	-81.8067	
3B	Colonnade Lake		26.1935	-81.8067	
5B	Lake Suzanne		26.1831	-81.8018	
6B	Mandarin Lake	Gordon River	26.1646	-81.7989	Quarterly
15B	Sun Lake Terrace		26.1811	-81.7924	
19B	15th Ave N Lake (WTP Lake)		26.1660	-81.7950	Monthly
20B	Forest Lake		26.1621	-81.7944	
22B	Lake Manor		26.1565	-81.7921	
26B	NCH Lake		26.1495	-81.7975	
8B	North Lake	Gulf of Mexico	26.1549	-81.8027	
9B	South Lake		26.1534	-81.8034	
10B	Alligator Lake		26.1520	-81.8072	Quarterly
11B	East Lake	Naples Bay	26.1385	-81.7990	
14B	Lantern Lake		26.1163	-81.7998	
24B	Half Moon Lake		26.1151	-81.7995	
PW-Pump	Public Works Pump	Pump Stations	26.1509	-81.7902	Quarterly
11-Pump	Cove Pump		26.1341	-81.7939	
14-Pump	Port Royal Pump		26.1155	-81.7987	

Image:ESRI

Data Source: Cardno, Inc.

Figure 1. Stormwater Lakes and Pump Stations.

City of Naples
Collier County, Florida

0 | 0.75 | 1.5 Miles
0 | 1.2 | 2.4 Kilometers

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Date Created: 10/11/2017 Date Revised: 10/11/2017 File Path: Q:\UnitedStates\Florida\Tampa\City_Of_Naples\FY2016 Monitoring and Analysis\working\arcmap\Fig2_1City_of_Naples_Stormwater_Lakes_A_20171011.mxd
GIS Analyst: Lauren.Federsel

2 Upland Stormwater Lakes

2.1 Water Quality Summaries

The following table and time series plots summarize both field and lab water quality measurements collected by Cardno staff at designated stormwater lake monitoring locations (Figure 1) from October 2018 to September 2019.

Stormwater lake samples were collected at the control structures to represent water quality exiting the lake. Table 2 includes a summary of sampling days with observed flow over or into control structures, as well as minimums, maximums, and annual geometric means calculated for total nitrogen (TN), total phosphorus (TP), chlorophyll-a, and copper for each stormwater lake.

Results of all sampled water quality parameters are detailed in time series plots (Figures 2-19) in Sections 2.1.1 and 2.1.2. Monitoring locations are grouped on plots by the associated final drainage destinations (water bodies) and are as followed: Monitoring locations 1SE-B, 2B, 3B, and 5B correspond with lakes that discharge into Moorings Bay (represented with ■); 6B, 15B, 19B, 20B, 22B, and 26B correspond with lakes that ultimately discharge into the Gordon River (represented with a ●); and lakes 8B, 9B, 10B, 11B, 14B, and 24B correspond with lakes whose final discharge destination is either Naples Bay or the Gulf of Mexico (represented with a ▲, AMEC 2012).

Table 2. Minimums, maximums, and annual geometric means of total nitrogen, total phosphorus, chlorophyll-a, and copper for stormwater lakes in Naples, Florida from October 2018 to September 2019.

Lake Name	Monitoring Location	Associated Waterbody	Number of Samples	Sampling Days with Observed Flow	Total Nitrogen (mg/L)			Total Phosphorus (mg/L)			Chlorophyll-*a* (µg/L)			Copper (µg/L)		
					Min	Max	Annual Geometric Mean	Min	Max	Annual Geometric Mean	Min	Max	Annual Geometric Mean*	Min	Max	Annual Geometric Mean*
Devils Lake	1SE-B	Moorings Bay	12	11	0.782	1.57	1.06	0.017	0.09	0.036	U (0.25)	15.7	3.95	U (0.346)	1160	10.6
Swan Lake	2B		12	11	0.609	2.42	1.25	0.01	0.143	0.061	0.86	121	24.7	1.46	33.0	5.04
Colonnade Lake	3B		12	10	0.820	1.66	1.10	0.053	0.137	0.088	4.65	492	22.9	2.28	5.6	3.73
Lake Suzanne	5B		12	12	0.568	2.50	1.10	0.038	0.185	0.093	0.67	290	20.3	1.50	15.8	4.39
Mandarin Lake	6B	Gordon River	4	2	0.678	1.18	0.88	0.018	0.145	0.054	1.24	55.4	11.2	0.495	1.80	0.98
Sun Lake Terrace	15B		4	0	0.982	1.49	1.11	0.018	0.078	0.040	5.13	28.5	11.7	3.77	65.7	10.7
15th Ave N Lake (WTP Lake)	19B		12	12	0.985	1.57	1.28	0.027	0.116	0.059	2.45	46.7	27.1	0.521	2.68	0.97
Forest Lake	20B		12	8	1.16	2.23	1.67	0.015	0.111	0.057	14.2	198	48.8	0.590	3.32	1.18
Lake Manor	22B		12	10	0.362	2.84	0.76	0.035	0.096	0.051	3.46	32.6	10.6	0.728	25.6	2.00
NCH Lake	26B		12	12	0.681	3.17	1.19	0.029	0.177	0.076	13.0	779	25.8	7.24	81.5	33.4
North Lake	8B	Gulf of Mexico	12	9	1.13	10.5	3.33	0.022	1.07	0.174	28.5	249	87.5	2.44	41.0	7.39
South Lake	9B		12	9	1.22	2.94	1.76	0.014	0.231	0.088	5.74	114	48.2	1.21	46.0	6.37
Alligator Lake	10B		4	3	1.03	1.98	1.33	0.082	0.166	0.117	16.9	91.5	41.5	U (0.272)	22.30	3.11
East Lake	11B	Naples Bay	4	4	0.757	1.43	1.13	0.057	0.131	0.077	14.4	53.5	25.8	1.76	5.11	2.52
Lantern Lake	14B		4	3	1.34	2.39	1.86	0.059	0.665	0.177	49.8	165	83.0	1.84	19.3	6.46
Half Moon Lake	24B		4	0	0.719	3.84	2.32	0.980	2.64	1.424	80.1	253	131.6	1.69	11.30	3.32

Gray shaded rows indicate monitoring locations that typically have specific conductivities of 4580 µS/cm or higher; Class III Marine Standards are provided as reference only.
*Annual geometric mean calculated using one-half MDL value when result reported as non-detected.

2.1.1 Time Series Plots of Field Parameters

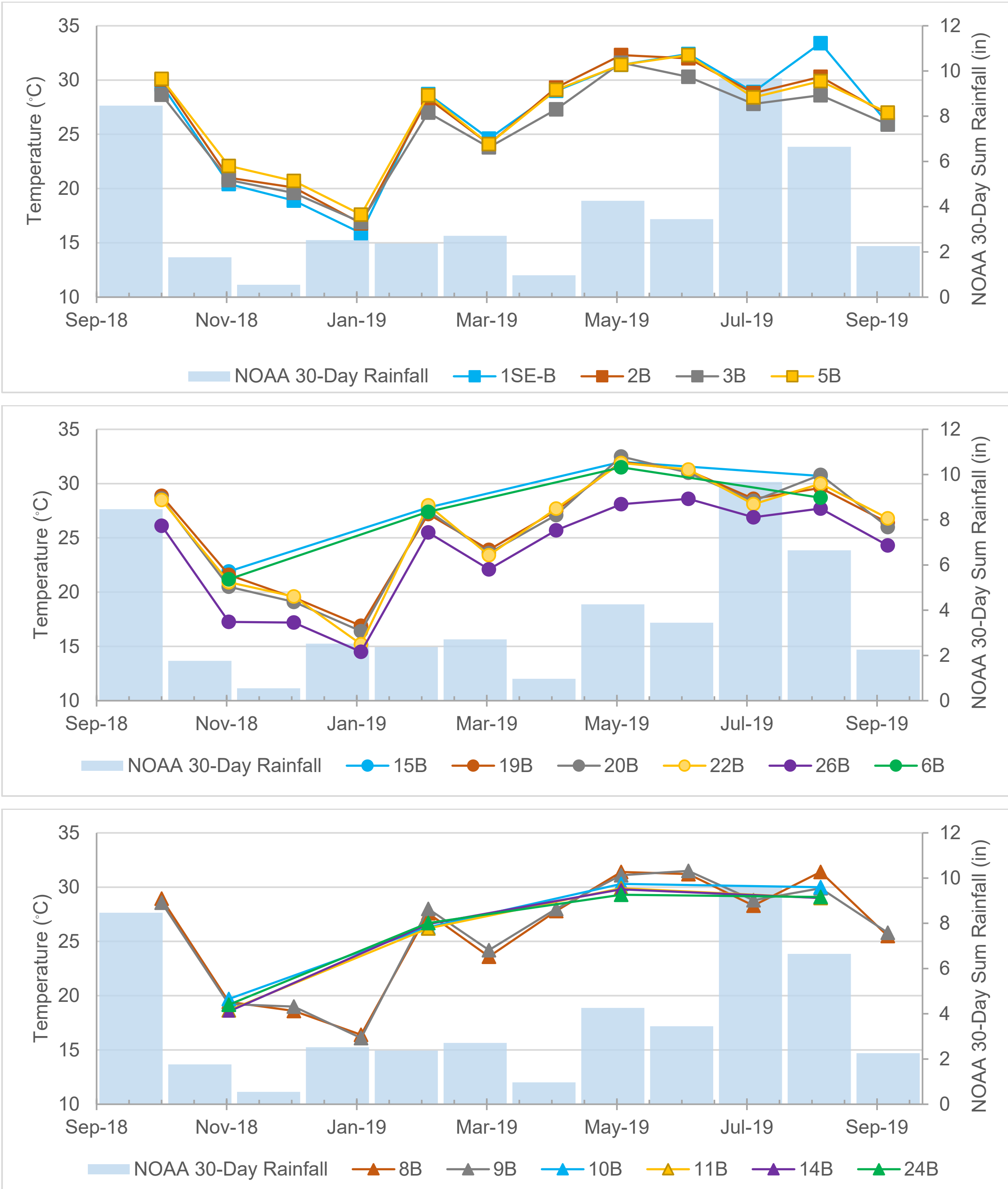


Figure 2. **Time series plots of water temperature and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).**

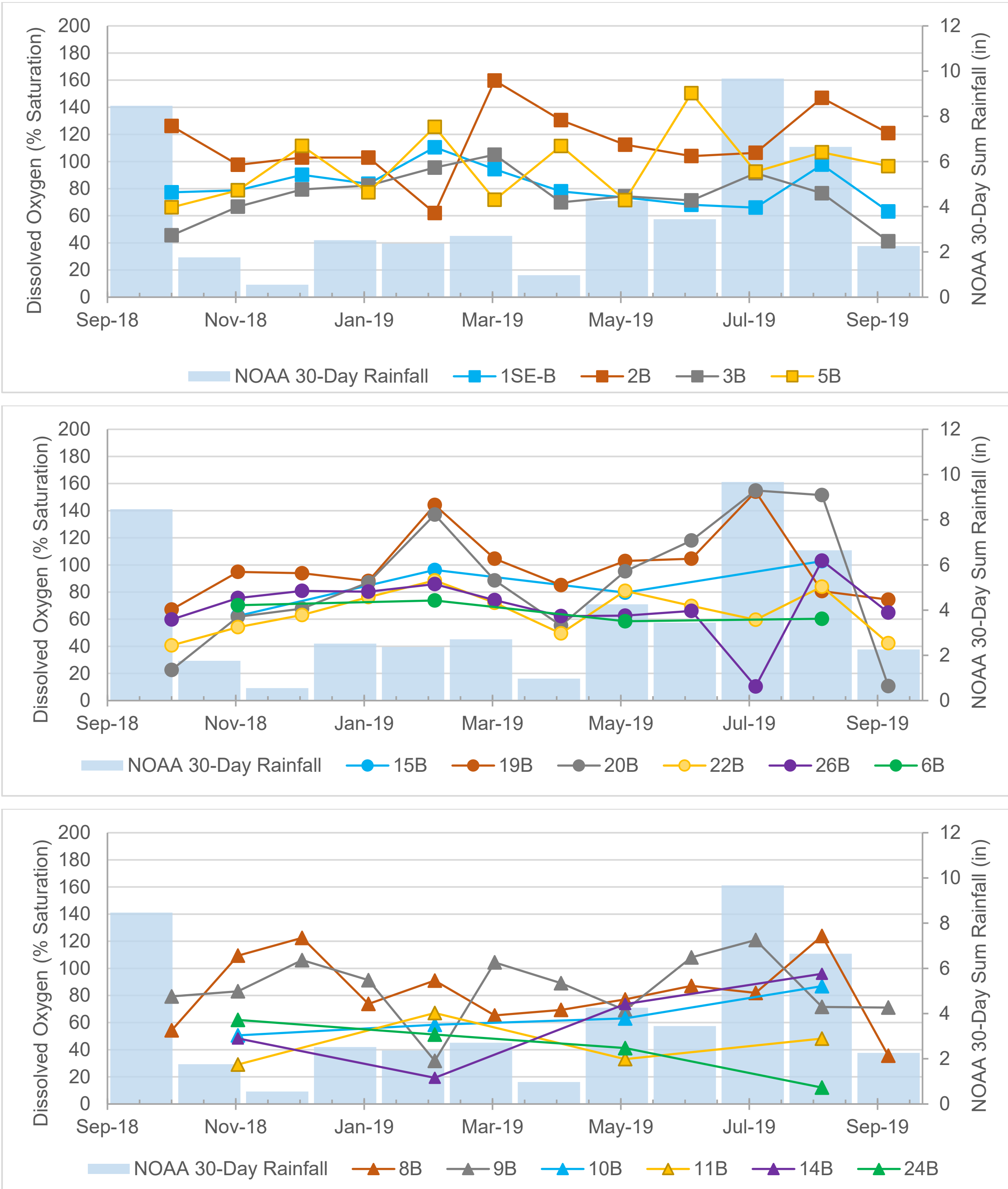


Figure 3. **Time series plots of dissolved oxygen saturation and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).**

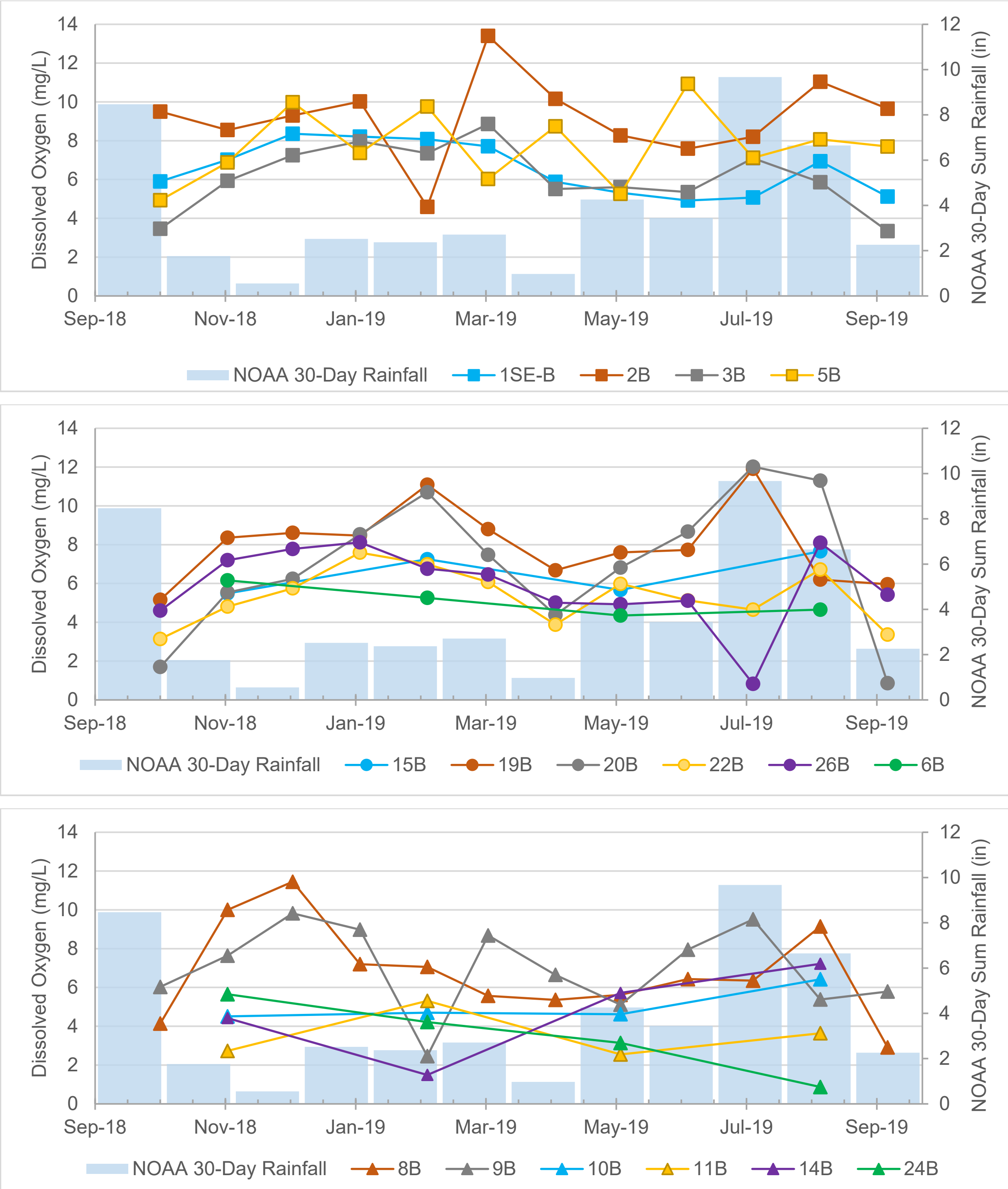
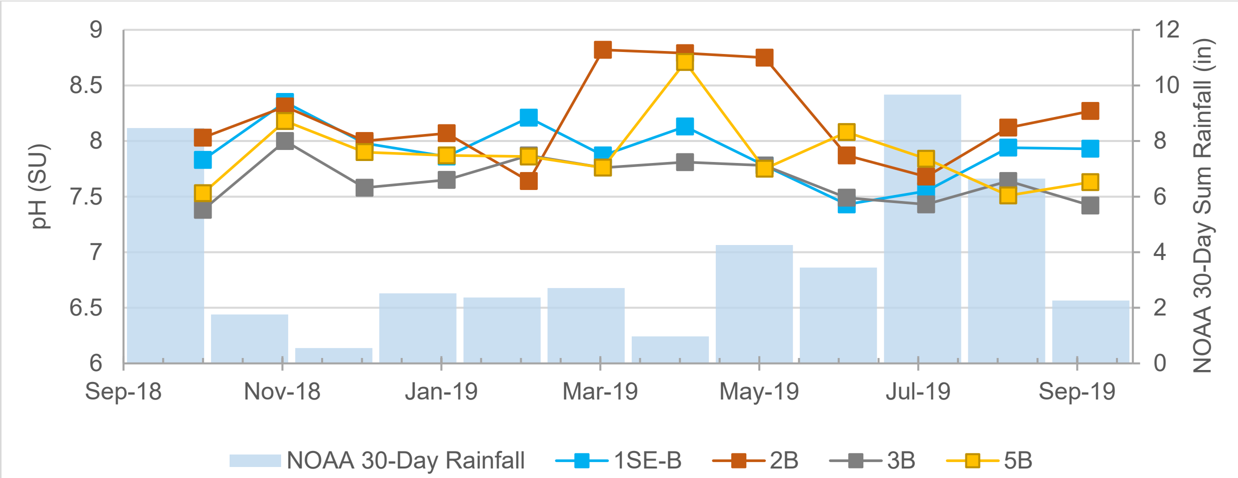
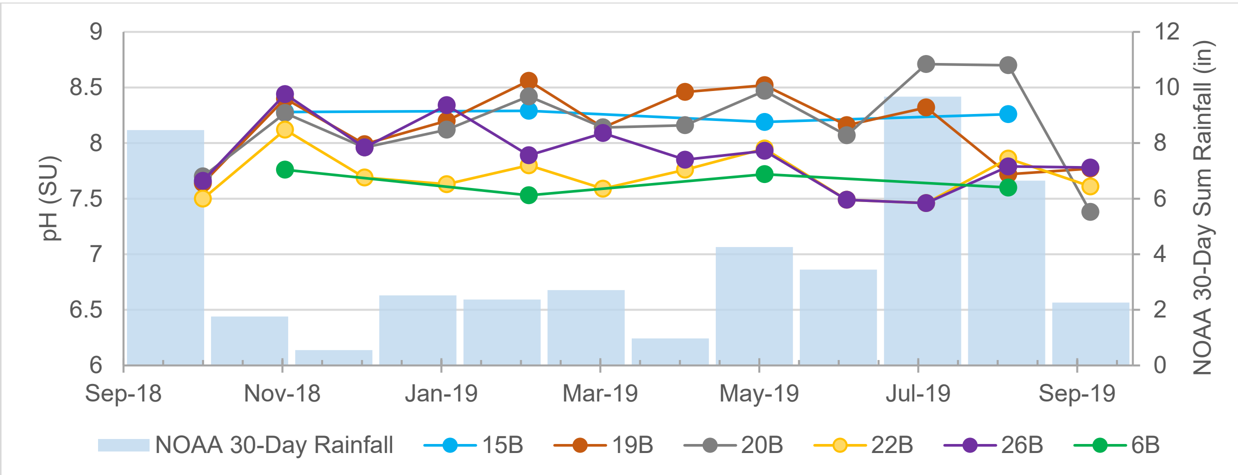


Figure 4. Time series plots of dissolved oxygen concentration (mg/L) and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).





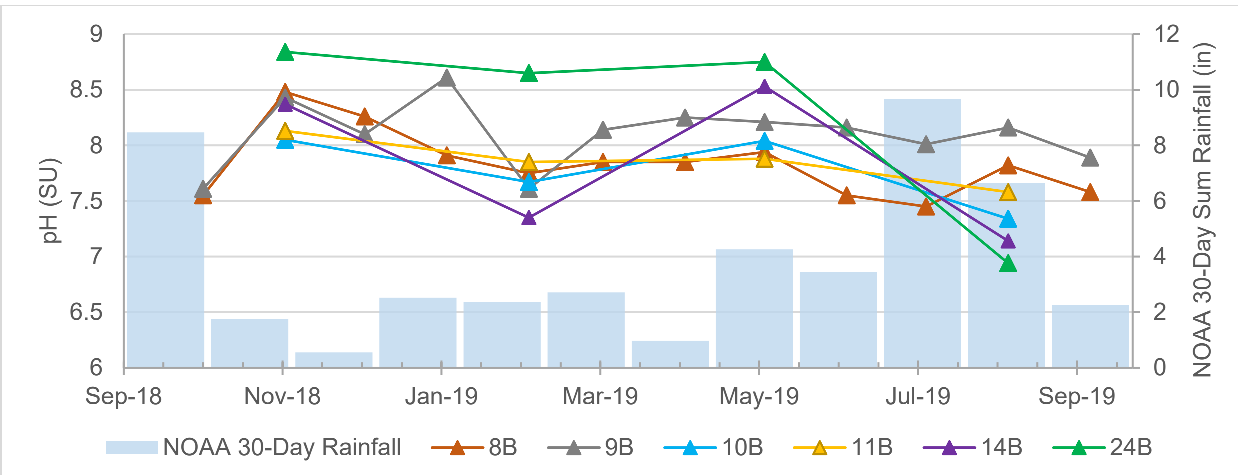


Figure 5. Time series plots of pH and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

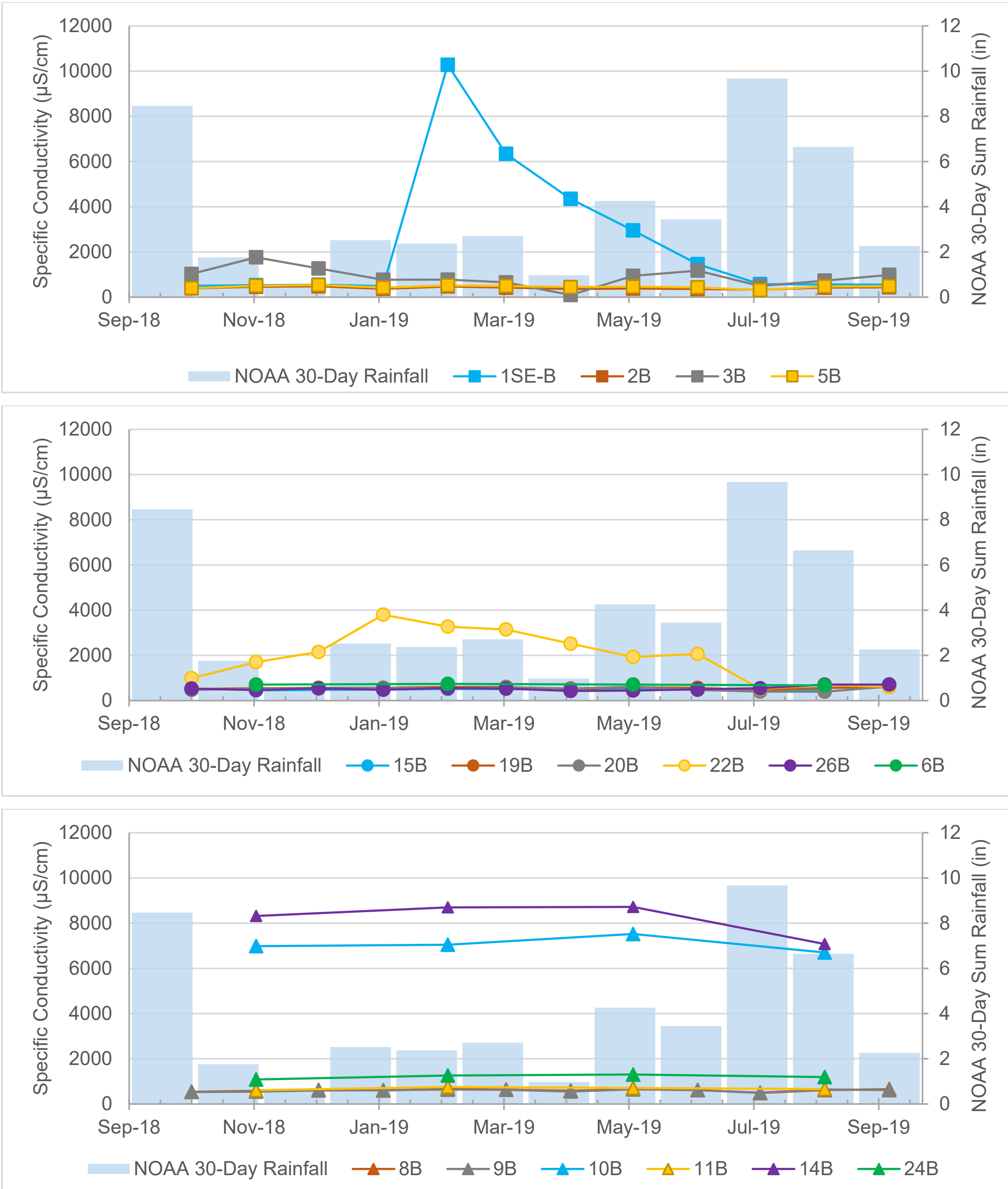


Figure 6. Time series plots of specific conductivity and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

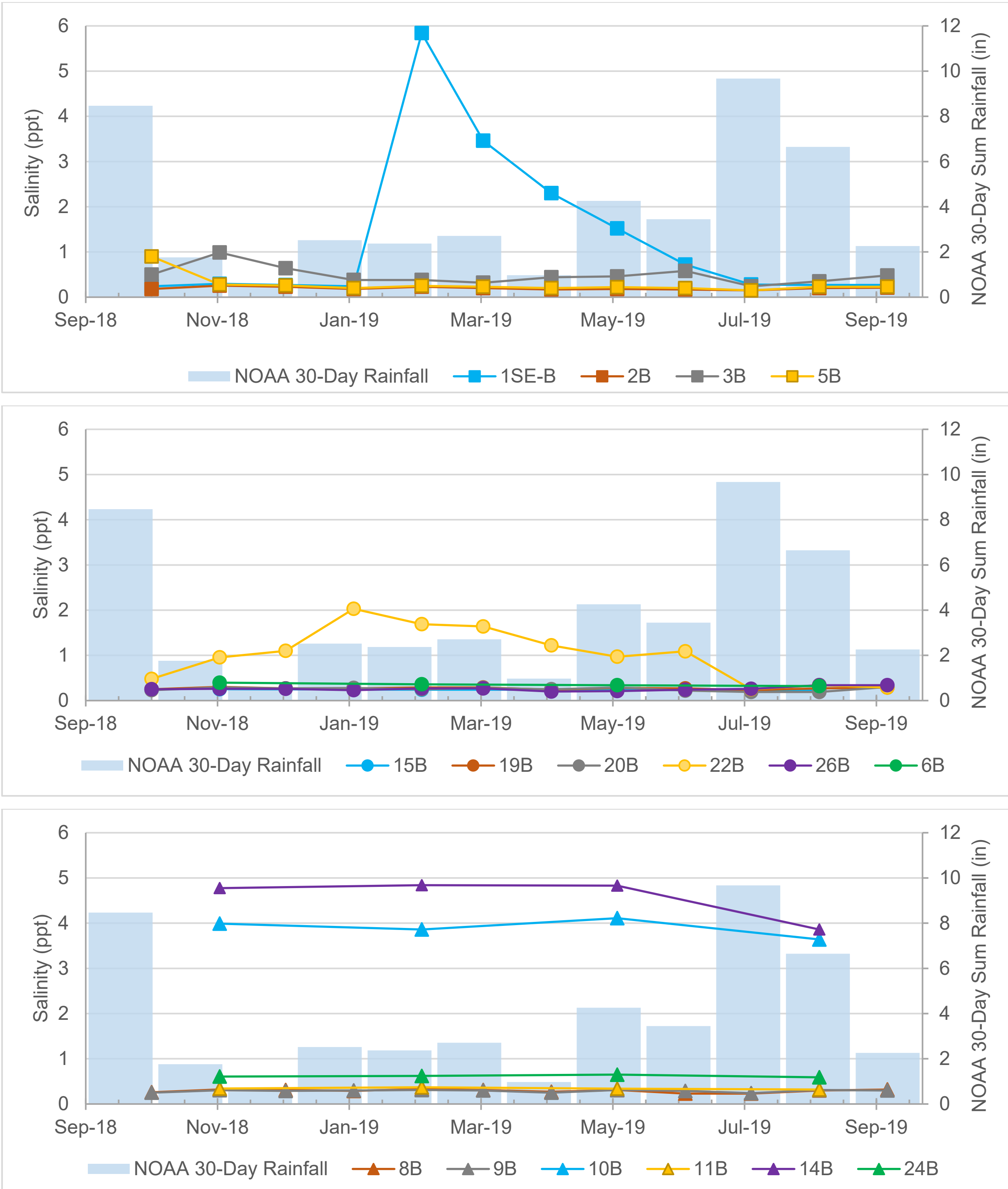


Figure 7. **Time series plots of salinity and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).**

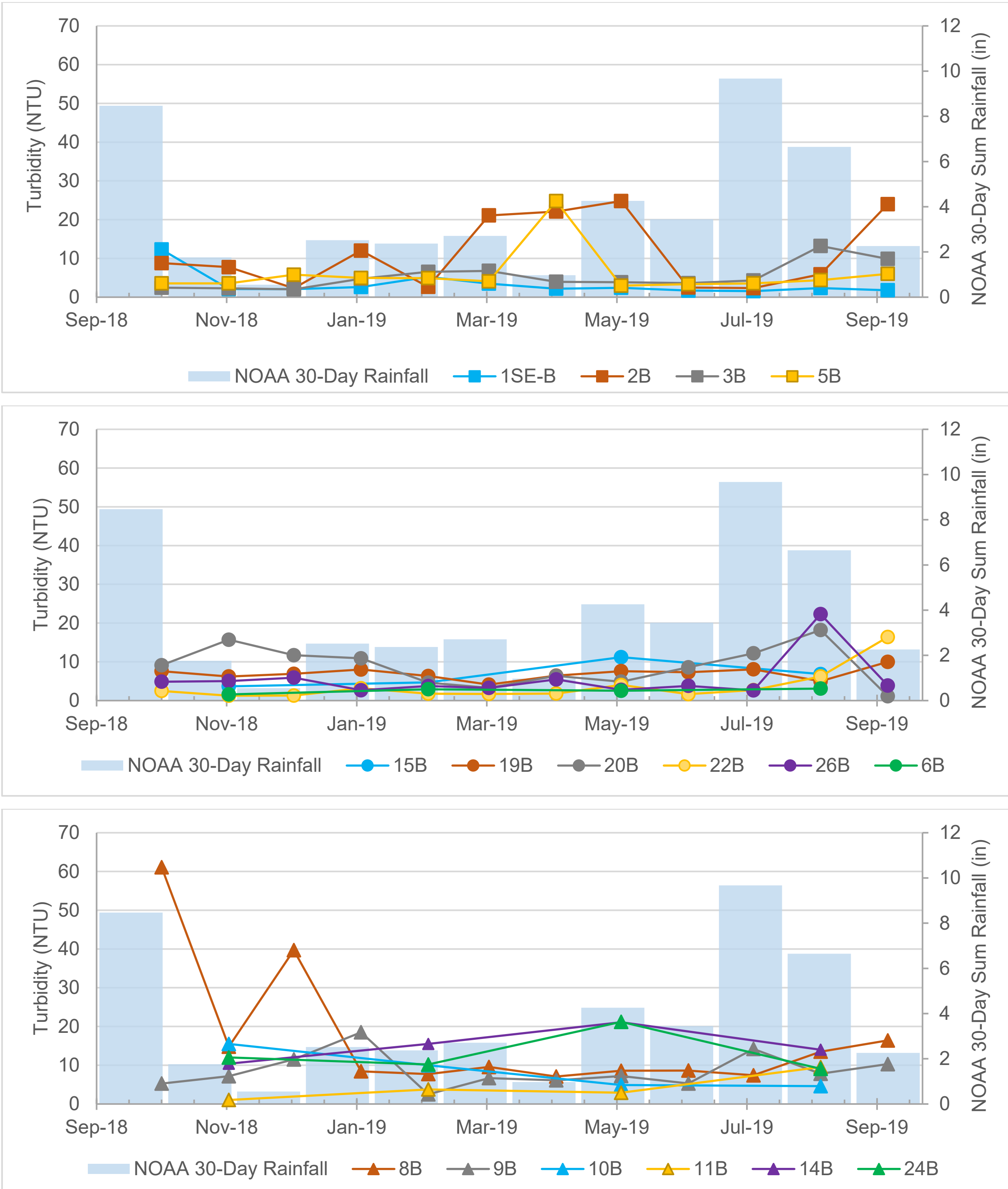


Figure 8. **Time series plots of turbidity and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).**

2.1.2 Time Series Plots of Lab Parameters

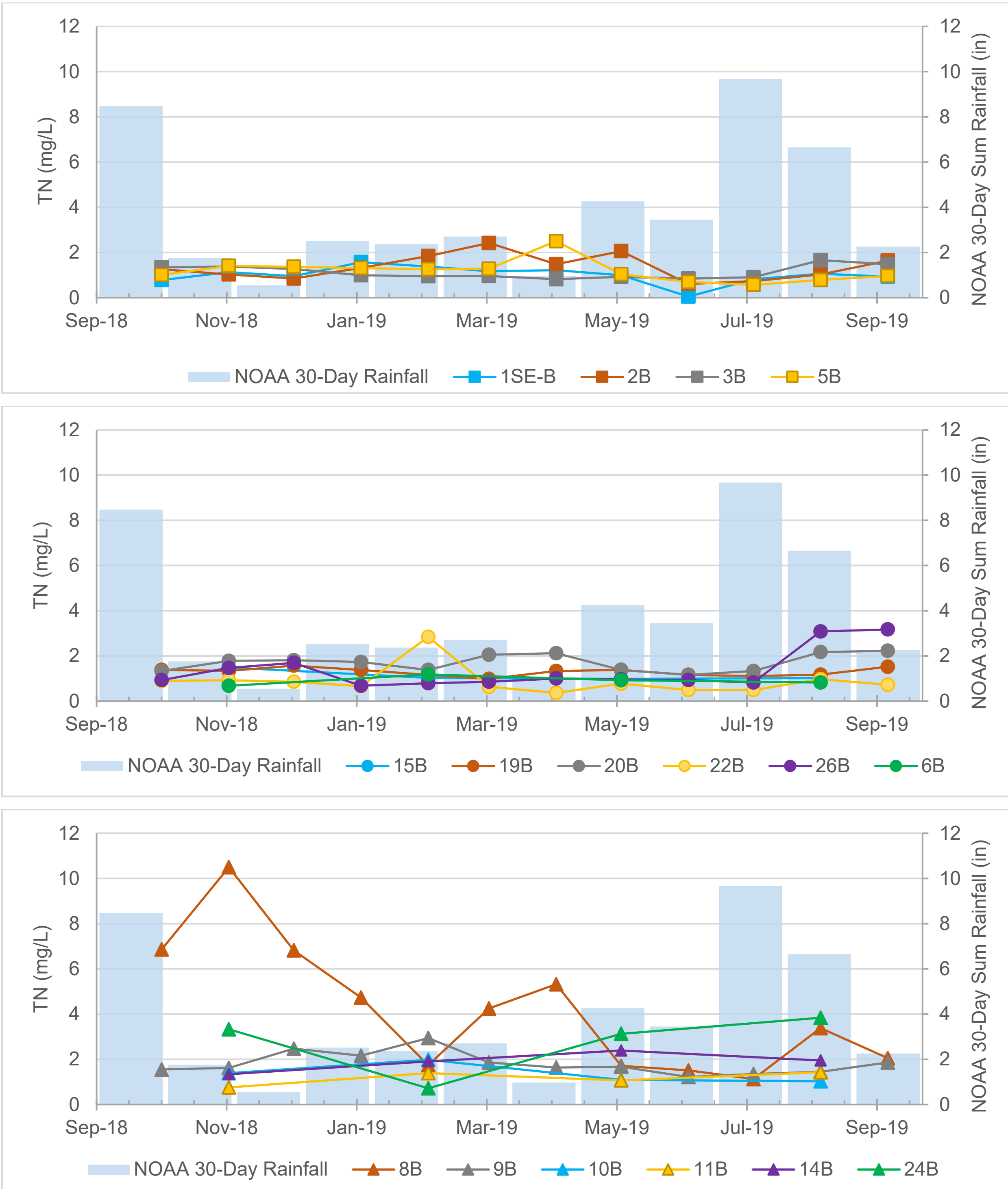


Figure 9. Time series plots of total nitrogen and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

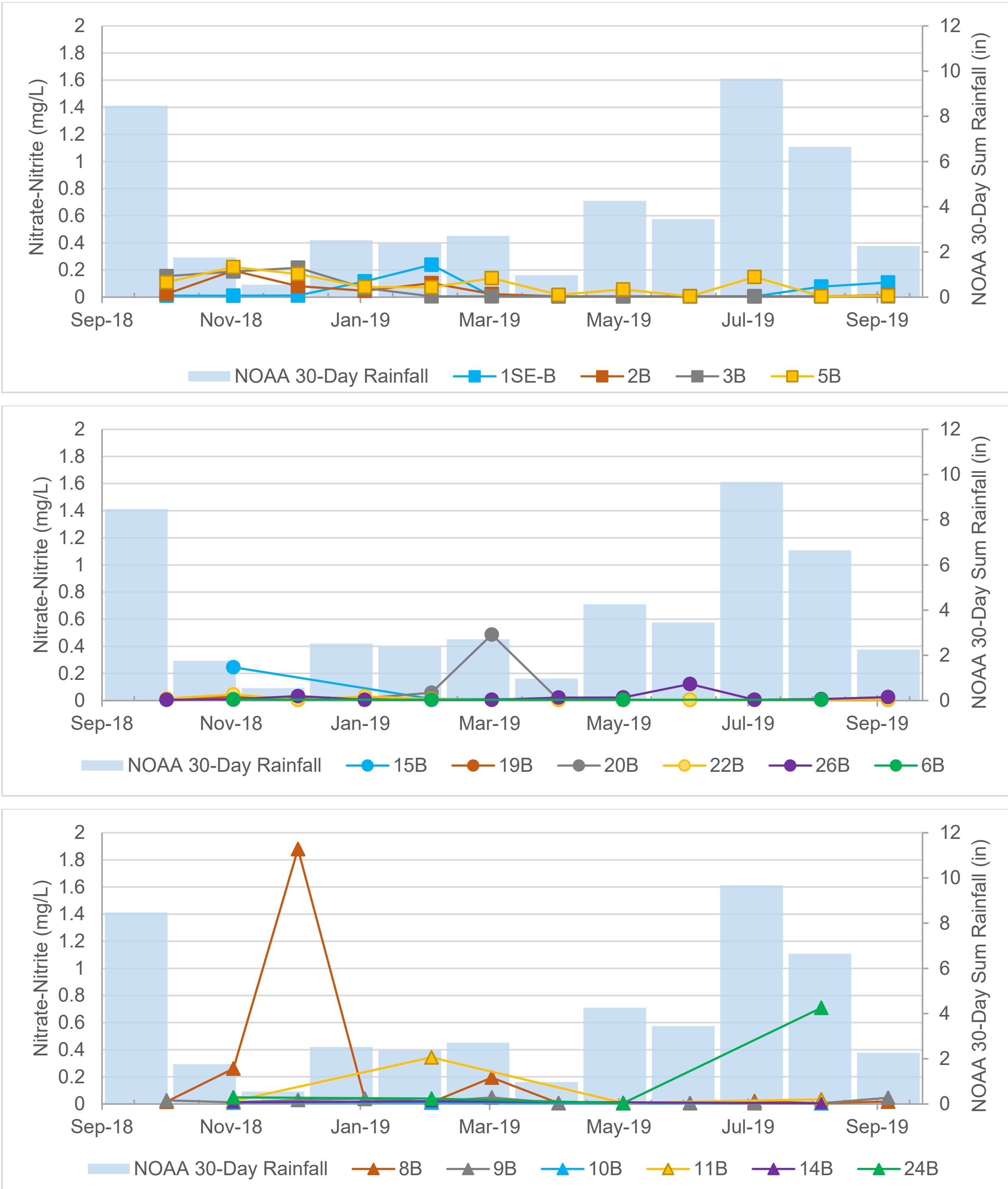


Figure 10. Time series plots of nitrate-nitrite and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

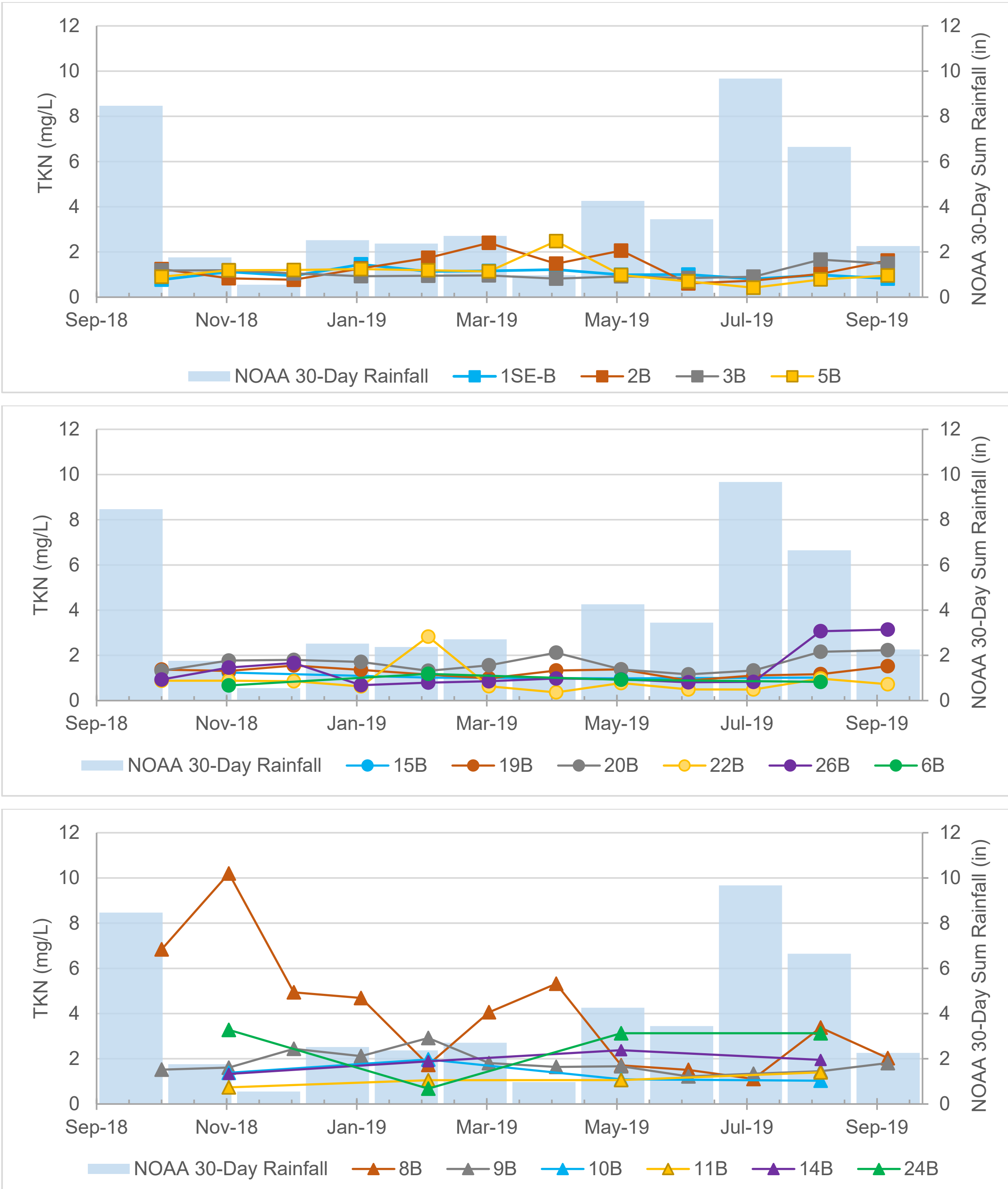


Figure 11. **Time series plots of Total Kjeldahl Nitrogen and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).**

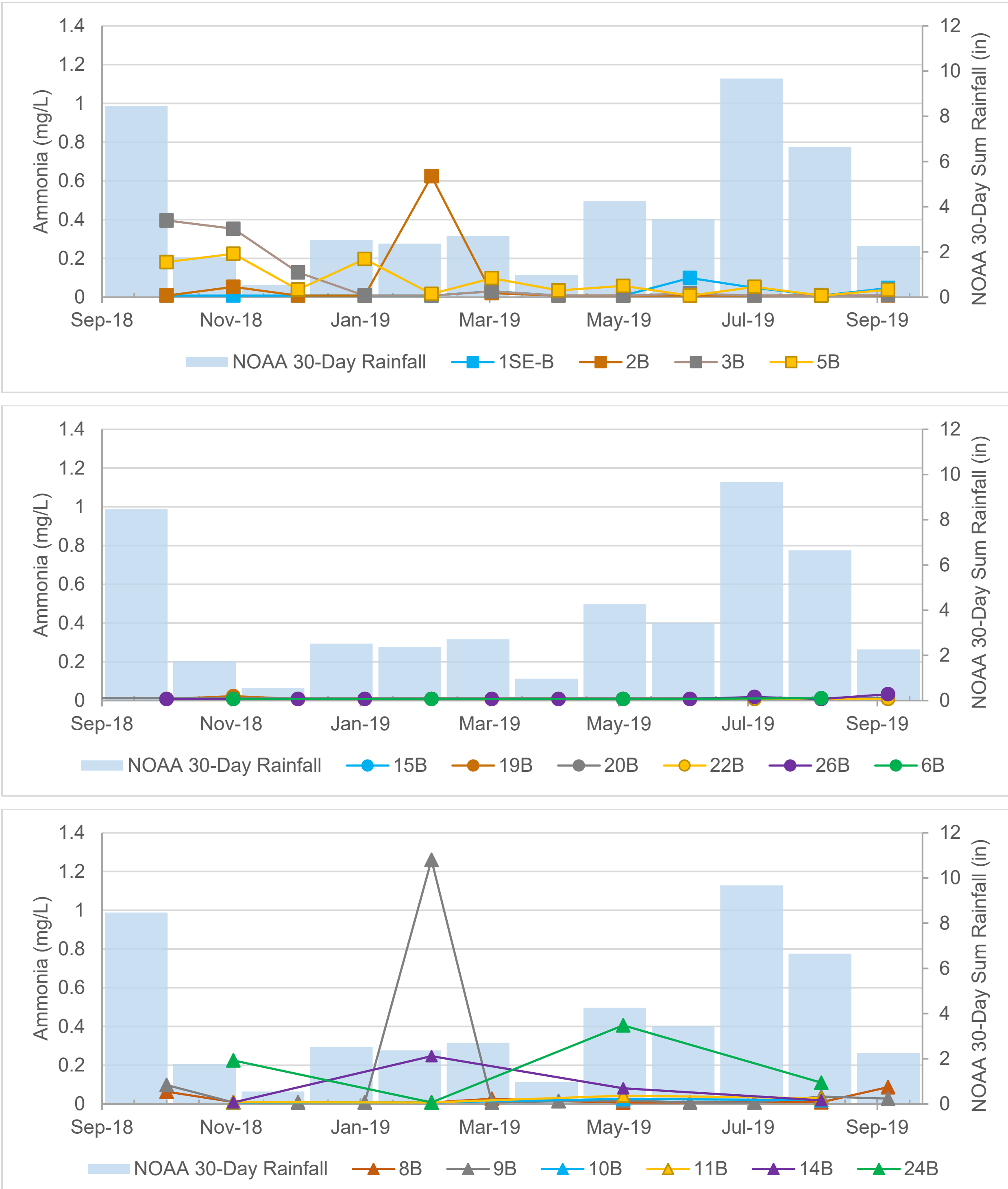


Figure 12. Time series plots of ammonia nitrogen and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

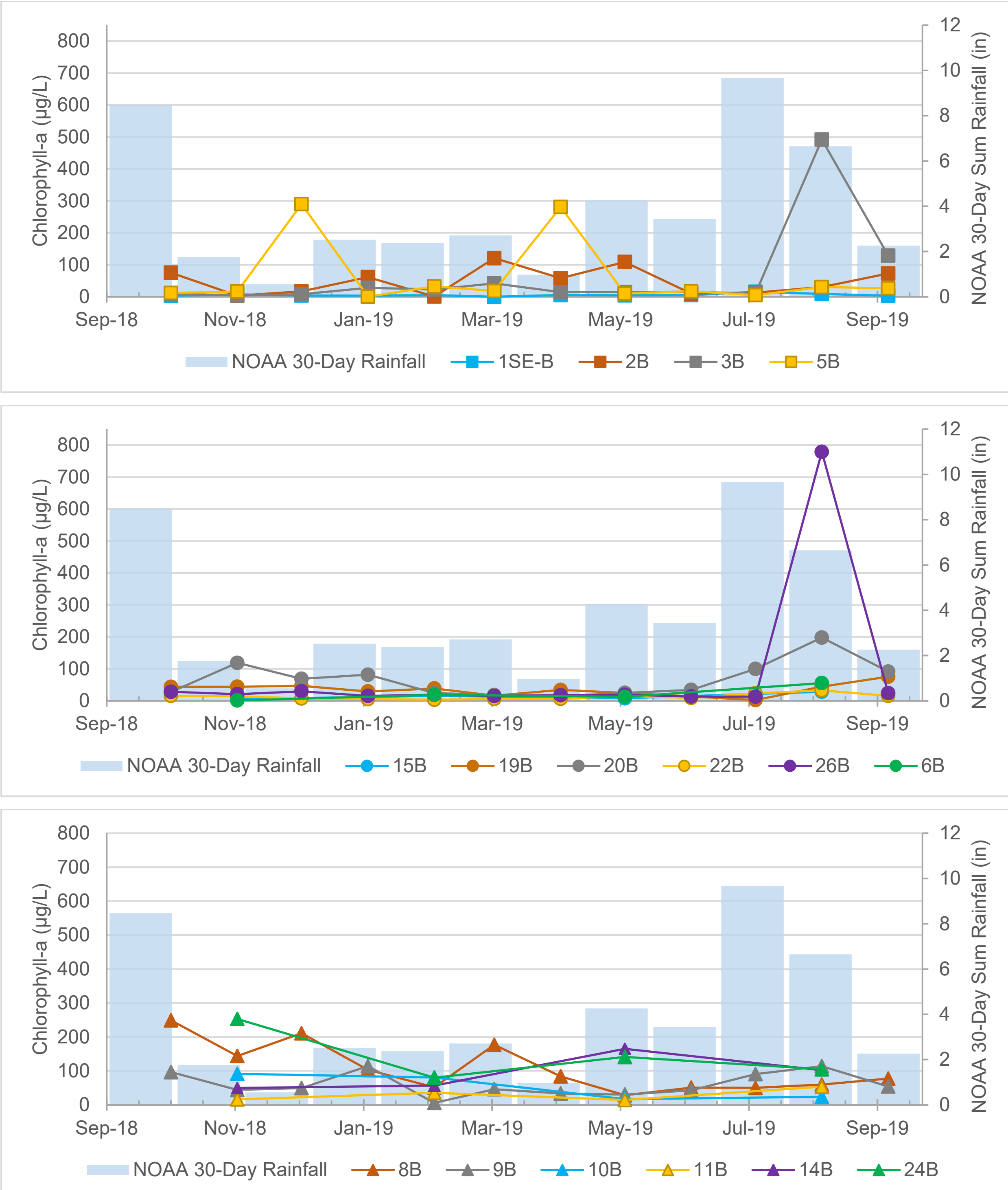


Figure 13. Time series plots of chlorophyll-a and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

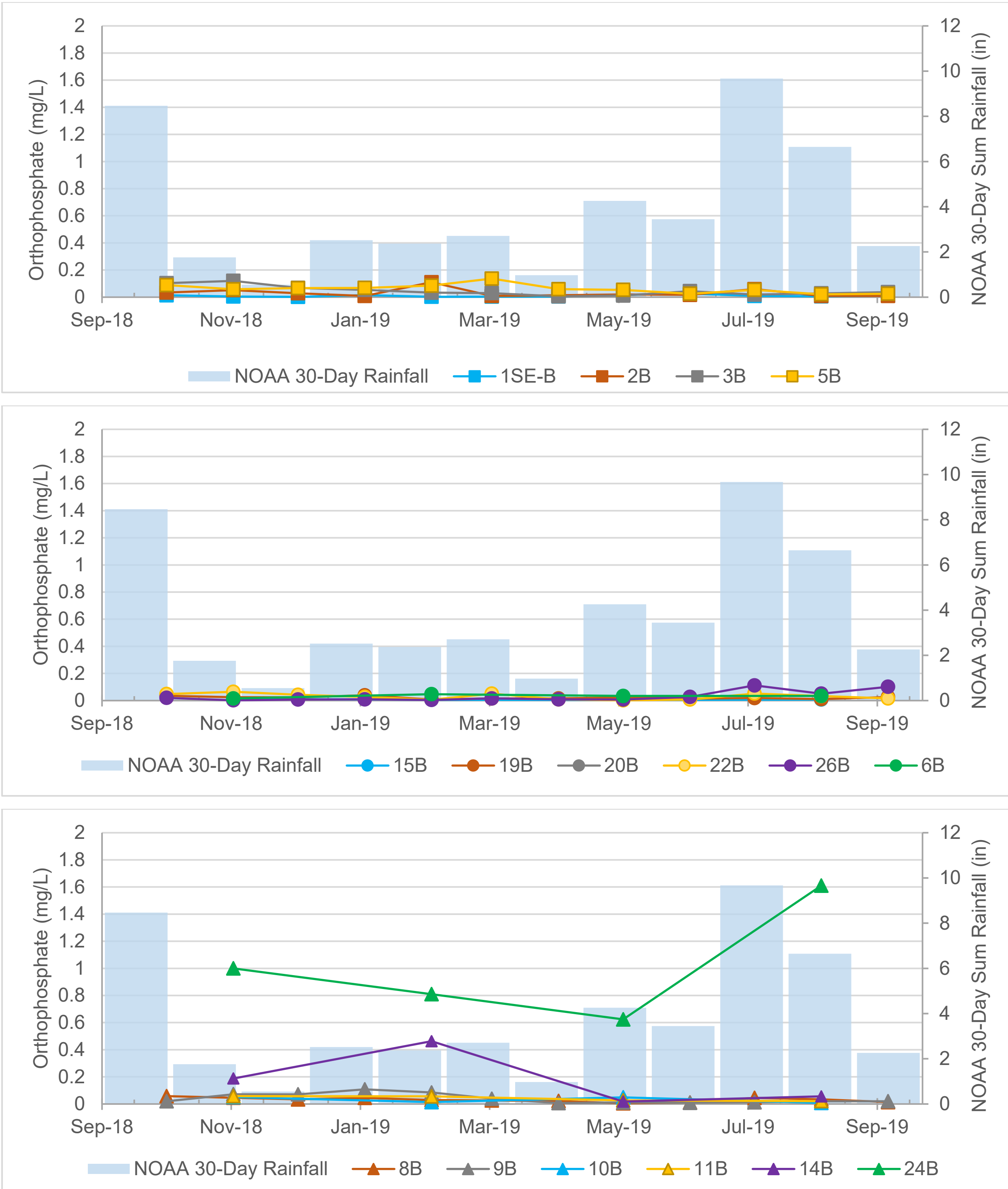


Figure 14. Time series plots of orthophosphate and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

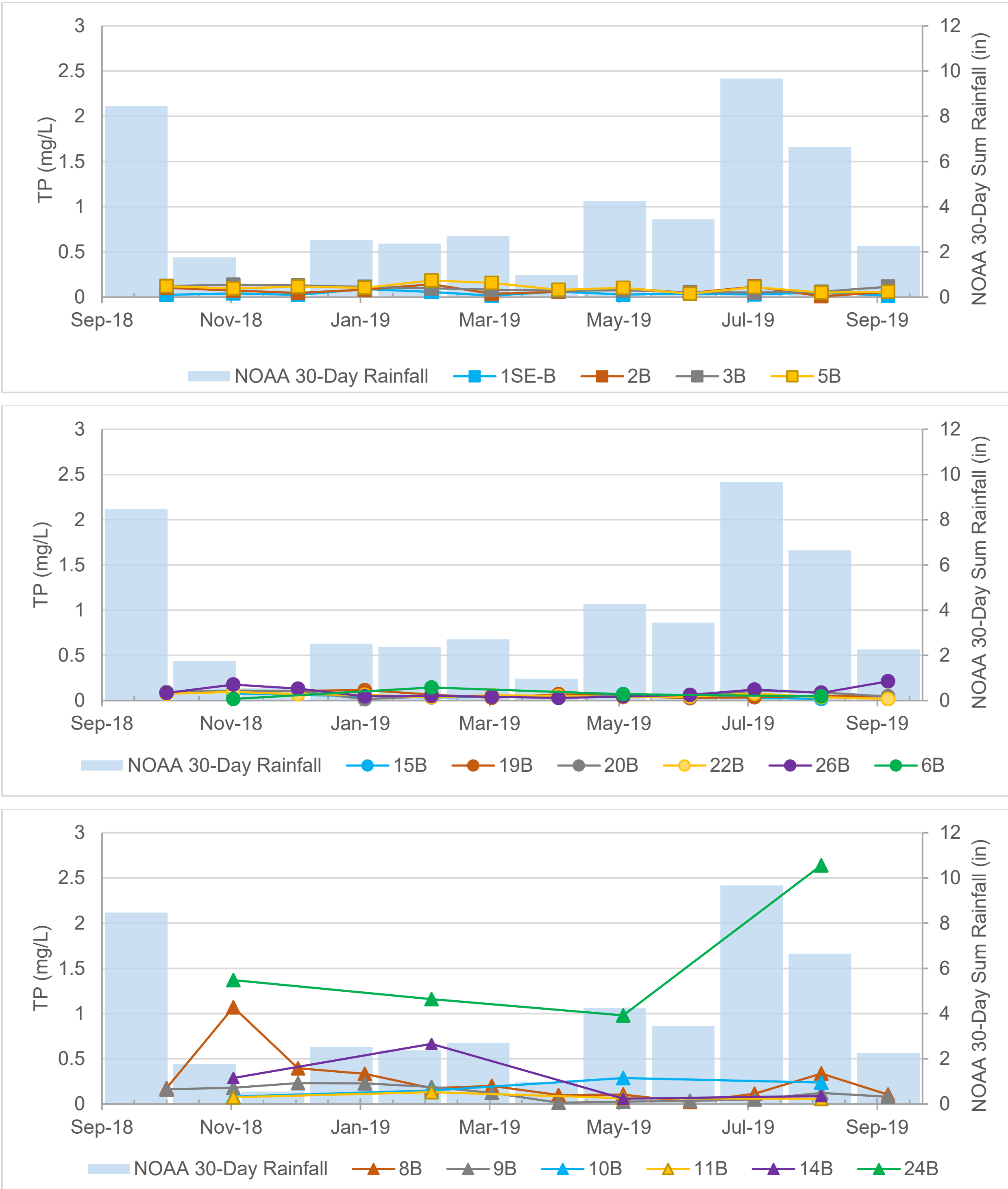


Figure 15. Time series plots of total phosphorus and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

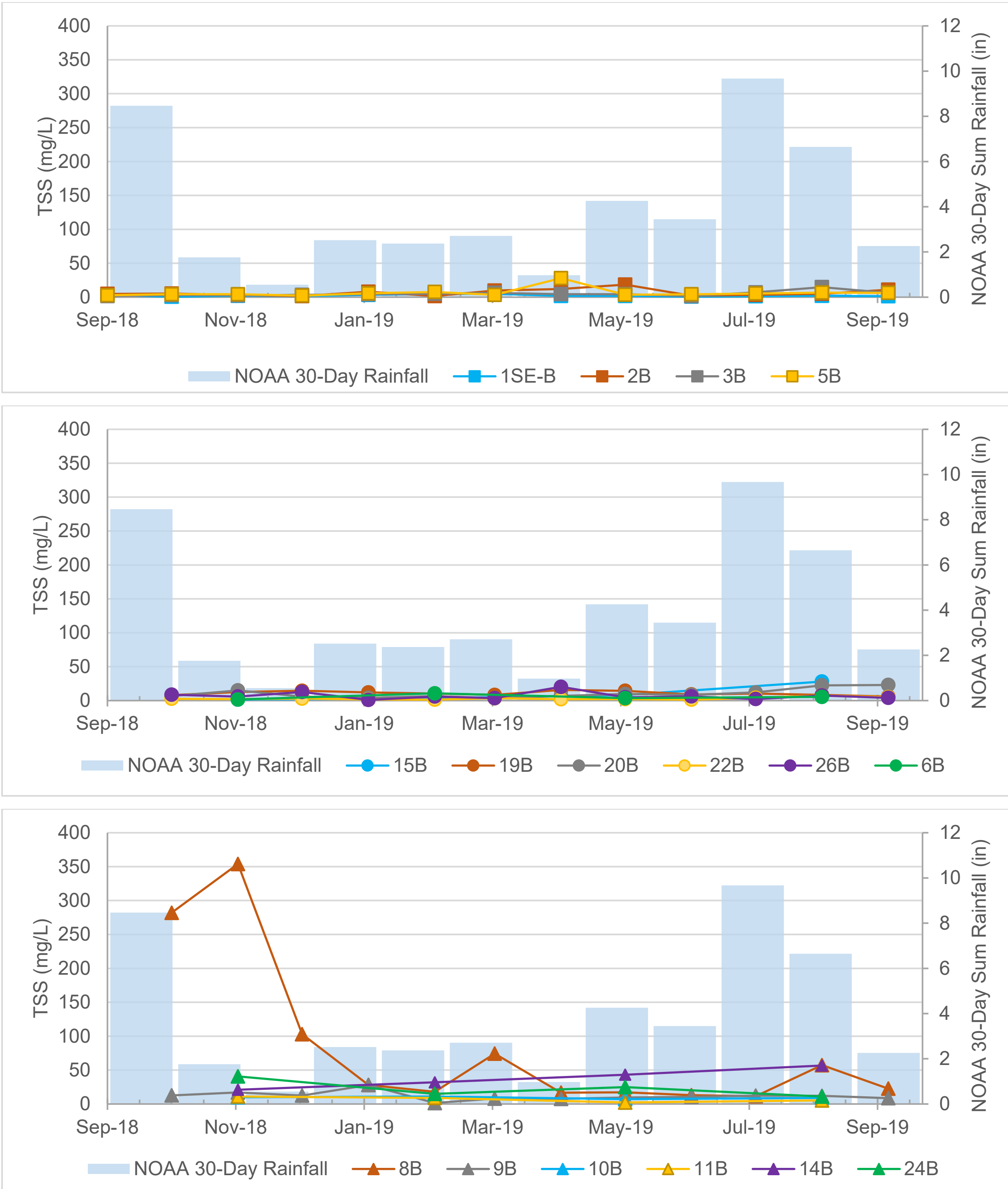


Figure 16. Time series plots of total suspended solids and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

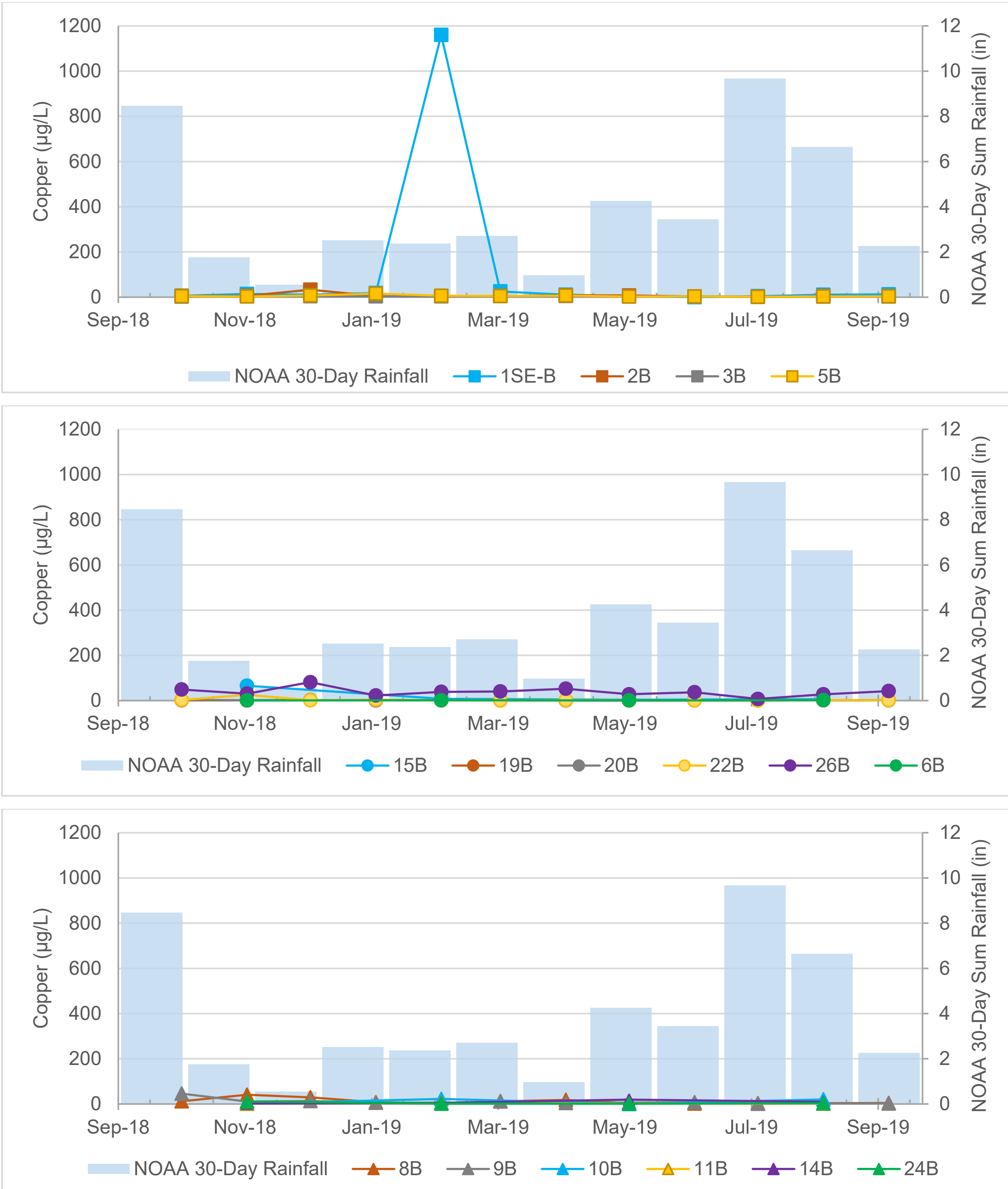


Figure 17. Time series plots of copper and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

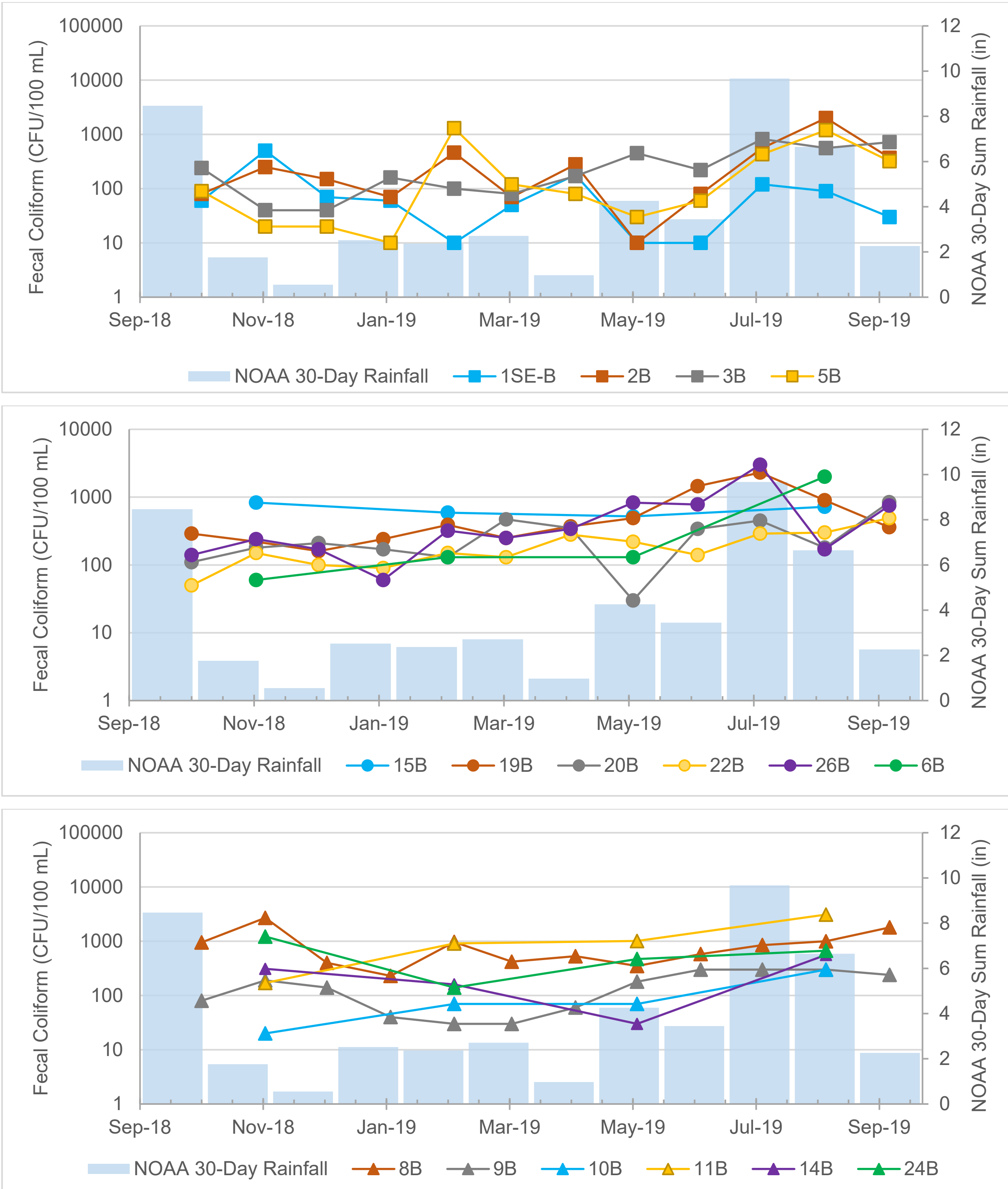


Figure 18. Time series semi-log scale plots of fecal coliform colony forming units (CFU) per100 mL and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

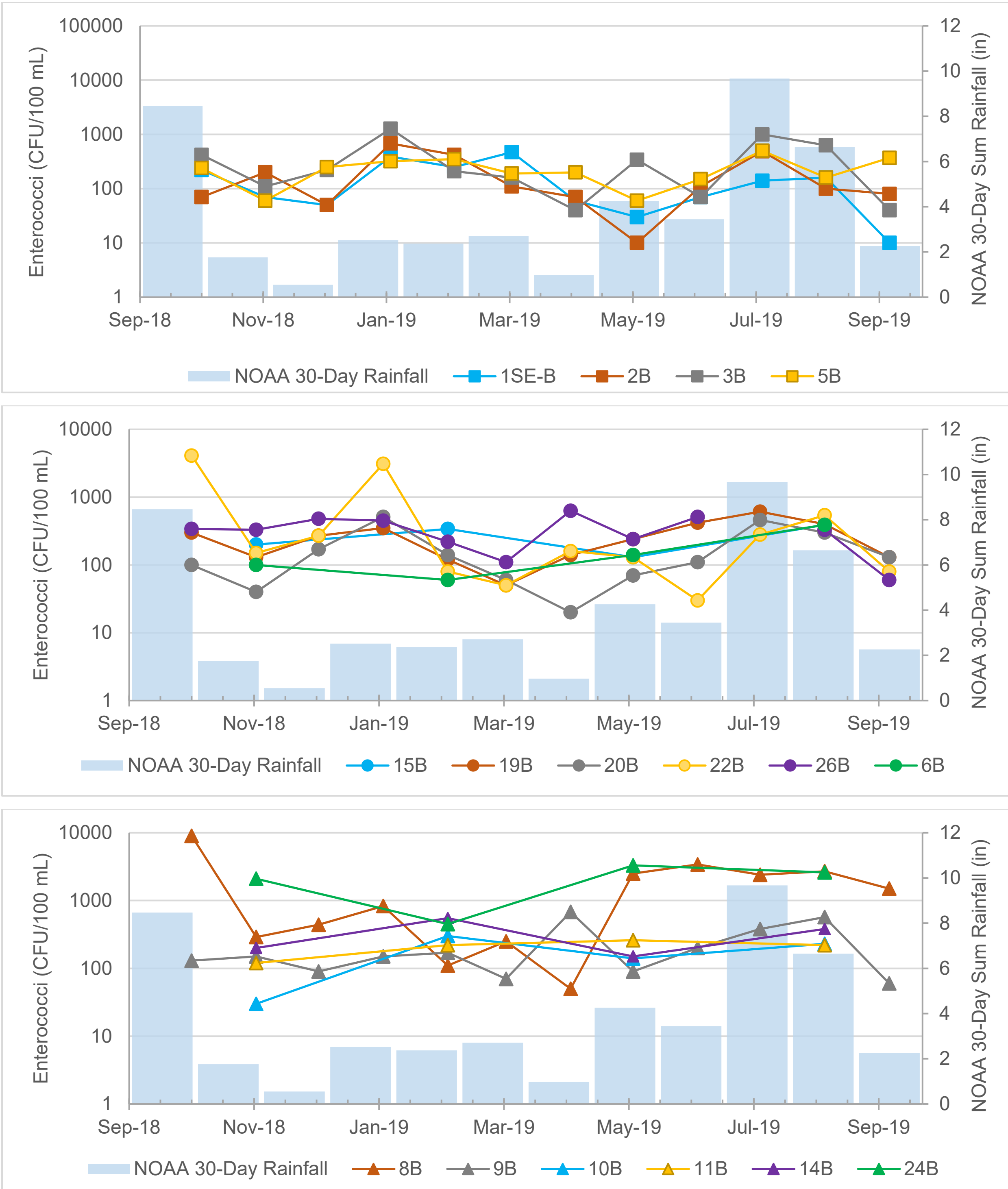


Figure 19. Time series semi-log scale plots of enterococci CFU per 100 mL and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at lakes that ultimately drain to Moorings Bay (top), Gordon River (middle), or Naples Bay/Gulf of Mexico (bottom).

2.2 Discussion

Monitoring results from data collected at stormwater lakes were reviewed to identify any outliers or visual trends within the data collected over the FY2019 sampling events amongst the various stations. Class III Surface Water Quality Standards are used to compare collected data against as reference only and the City of Naples is not required to achieve these values during this reporting period. Field parameter measurements (temperature, dissolved oxygen, pH, specific conductivity [SC], salinity, and turbidity) recorded at lakes within the same drainage basins were variable over the sampling period (Figures 2 to 8).

Temperatures appear to be slightly higher during the wet season within all drainage basins, as expected (Figure 2). Dissolved oxygen (concentration and percent saturation) was variable among the drainage basins with periods of both super saturation (well over 100 percent saturation at the surface) and hypoxia (concentrations below 2 mg/L) mainly prevalent within lakes draining either to Gordon River or Naples Bay/Gulf of Mexico (Figures 3 and 4). Two lake draining to the Gordon River (20B ad 26B), two lakes draining to the Gulf of Mexico (8B and 9B), and three lakes draining to Naples Bay (11B, 14B, and 24B) had dissolved oxygen saturations below the Class III time of day corrected daily average standards for fresh and marine waters (greater than 38 and 42 percent saturation, respectively). Low dissolved oxygen saturation generally occurred during warmer months with the exception of February 2019 at 9B and 14B (Figure 3).

Levels of pH remained consistent in stations draining to both Moorings Bay and Naples Bays/Gulf of Mexico, while the lakes draining to the Gordon River were more variable (Figure 5). Six lakes had measurements of pH above the Class III standard maximum of 8.5 during FY2019; lakes 9B and 5B had one measurement above 8.5, lakes 19B and 20B had two measurements above 8.5, and lakes 24B and 2B had three measurements above 8.5 (Figure 5).

Based on SC measurements, two of the sampling locations (10B and 14B) are typically identified as “predominately marine” (indicated by gray-shaded row headings in Table 2) according to the FDEP classification of specific conductivities greater than 4,580 µS/cm (62-302.200(30), F.A.C.); the remaining fourteen stormwater lakes have exhibited freshwater SC at the time of sampling (Figure 6). Four lakes, one draining to Napes Bay (24B), one draining to the Gordon River (22B), and two draining to Moorings Bay (1SE-B and 3B) had SC measures above the Class III Freshwater Standard of 1,275 µS/cm during various sampling events (Figure 6). A very high SC measurement in 1SE-B occurred during February 2019; this elevated value was most likely caused by treatment with copper sulfate (introduction of ions would also increase the SC) based on the very elevated copper concentration and blue color of the lake. Salinity followed the same patterns as conductivity at all locations (Figure 7).

Turbidity measured at all lakes and events was within the Class III Standards for fresh and marine waters, (less than or equal to 29 NTU above background or just less than or equal to 29 NTU if no established background for both fresh and marine waters) with the exception of lake 8B during October and December 2018 (Figure 8).

Nutrient parameters (TN, TP, and chlorophyll-a) were variable by station and drainage basin during FY2019 samples. TN at locations draining to Moorings Bay remained fairly consistent with concentrations ranging from 0.568 to 2.5 mg/L (Figure 9). TN concentrations at sites draining to the Gordon River were fairly consistent with an isolated spike in 22B in February 2019 and elevated concentrations in 26B during August and September 2019 (measurements ranging from 0.362 to 3.17 mg/L). Locations draining to Naples Bay and the Gulf of Mexico were variable by location (measurements ranging from 0.719 to 10.5 mg/L) with higher values at 8B and lower concentrations at 11B (Figure 9).

TP concentrations for sites draining to Moorings Bay and Gordon River were consistently below 0.2 mg/L for the duration of FY2019 (Figure 15). TP concentrations for both basins were fairly consistent over the sampling year. Three of the stormwater lakes draining to Naples Bay and the Gulf of Mexico (10B, 11B, and 9B) were consistent during FY2019, while 24B had higher overall values with a concentration increase between May and August 2019 sampling events. Initially, Lake 8B had a higher concentration in November 2018 (1.07 mg/L) but decreased during the other three events to below 0.40 mg/L (Figure 15).

Chlorophyll-a concentrations at stormwater lakes draining to Moorings Bay, were fairly consistent at lake 1SE-B, while the other three lakes had various spikes in chlorophyll-a (October 2018, January and March to May 2019 at 2B; August 2019 at 3B; and December 2018 and April 2019 at 5B) throughout the year (Figure 13). Stations that ultimately drain to the Gordon River were variable, with chlorophyll-*a* concentrations ranging from 1.25 to 779 µg/L; higher concentrations were consistently noted at 20B with a very high spike at 26B during August 2019 (Figure 13). Stations that ultimately drain to Naples Bay and the Gulf of Mexico had variable chlorophyll-a concentrations ranging from around 5.74 to 253 µg/L (Figure 13).

Copper concentrations at lakes discharging to the same location seem to generally keep a similar pattern, one exception being Gordon River basin monitoring location 26B, which had consistently higher concentrations overall including a December measurement of 81.5 µg/L. The lakes draining to the Gulf of Mexico had spikes in copper concentrations during October and November 2018 for lakes 8B and 9B. Lake 1SE-B, draining to Moorings Bay, had higher concentrations than the other three lakes with a maximum concentration of 1,160 µg/L recorded during the February 2019 event (Figure 17). Spikes of this nature would indicate recent dosing of copper sulfate.

Fecal coliform and enterococci colony counts were variable throughout the FY2019 sampling period with isolated spikes in colony counts appearing to occur after isolated stormwater inflows (Figures 18 and 19). Fecal coliform colony counts did have a slight upward visual trend for most of the stormwater lakes draining into Moorings Bay during the wet season (June to September). Enterococci colony counts showed small isolated spikes throughout the sampling period as a likely response to increased rainfall. Lake 8B had variable colony counts and exhibited the highest enterococci counts for the Gulf of Mexico basin lakes at 9000 CFU/100 mL in October 2018. Fecal Coliform values were erratic having a slight overall upward visual trend within the Gulf of Mexico drainage basin associated with summer rains. Enterococci values within the Gulf of Mexico basin lakes had a similar upward visual trend associated with the summer rainy season.

2.2.1 Nutrient and Bacterial Management

Stormwater management including nutrient and bacterial loading poses a significant challenge to resource managers across Florida. The following strategies are in no way an exhaustive list of management strategies but rather a high level approach the City may take to accomplish nutrient loading reductions in stormwater lakes.

Management strategies for TN reduction may include additional littoral plantings, mechanical dredging to remove organic muck and legacy nutrients, retrofitting stormwater conveyance systems with additional treatment systems such as Storm treat/ Aqua filter, street sweeper programs, routine weir and baffle box clean outs and public outreach and education programs.

Management actions for additional TP reduction with long term stormwater master planning and associated budgets for stormwater improvement projects. Simple and cost-effective strategies may also include: supplemental littoral plantings, changes in the duration and timing of street sweeping program, and routine maintenance of catchment basins. Binding agents may also effectively inactivate TP but treatments and costs vary greatly by the binding agent that is chosen.

Elevated chlorophyll-a concentrations often indicate water quality impairments from nutrients with stormwater runoff from urban landscapes containing readily metabolized nutrients that promote algal growth and reproduction. Management strategies that target reductions in TN and TP will also aid in reducing chlorophyll blooms within these stormwater catchments. Another area of concern is the residence time of nutrients within the lake or pond with longer periods of zero to no flow which may increase the duration and extent of a chlorophyll-a bloom. Algal proliferation within stormwater lakes and ponds is indicative of potential elevated nutrients. Continued monitoring and refinement of management strategies to include supplemental shoreline plantings, stormwater upgrades, aeration, and supplemental public education.

Management of fecal coliform and enterococci levels within stormwater ponds may benefit from changes to the frequency and timing of street sweeper programs within these basins. Installing and maintaining pet waste stations and having an education and outreach activities have been shown as effective management strategies in reducing bacterial loading from stormwater into lakes and ponds.

Overall water quality parameters were variable both spatially and temporally during the FY2019 sampling period. Challenges managing stormwater and the associated nutrients are complex and often require a multifaceted approach to adequately address the many sources of nutrient loading into lakes, ponds and stormwater systems. Additional data is needed to further identify trends in the data versus potential seasonal outliers caused by natural variability (rainfall, temperature, hurricanes, etc.) which will aid in future management decisions. Data from the upcoming FY 2020 sampling will help to identify potential trends that can be addressed with management decisions for each waterbody described above.

3 Pump Stations

3.1 Water Quality Summaries

The following table and time series plots summarize both field and lab water quality measurements collected quarterly by Cardno staff at the three City pump stations (Figure 1) from October 2018 to September 2019. The quarterly sampling events occurred in November 2018, February 2019, May 2019, and August 2019.

All FY2019 water quality monitoring samples were collected quarterly from the wet wells at each pump station. Table 3 includes a summary of sampling days with observed flow within wet wells, as well as minimums, maximums, and annual geometric means calculated from pump station water quality data for total nitrogen, total phosphorus and copper. Results of all sampled water quality parameters are displayed in time series plots in Sections 3.1.1 and 3.1.2 (Figures 20-45).

Table 3. Minimums, maximums, and annual geometric means of total nitrogen, total phosphorus, and copper for PW-Pump, 11-Pump, and 14-Pump in Naples, Florida measured quarterly from October 2018 to September 2019.

Lake Name	Monitoring Location	Number of Samples	Sampling Days with Observed Flow	Total Nitrogen (mg/L)			Total Phosphorus (mg/L)			Copper (µg/L)		
				Min	Max	Annual Geometric Mean	Min	Max	Annual Geometric Mean	Min	Max	Annual Geometric Mean*
Public Works Pump	PW-Pump	4	1	1.21	1.38	1.27	0.049	0.128	0.098	0.978	4.01	2.02
Cove Pump	11-Pump	4	1	0.99	1.57	1.21	0.151	0.444	0.239	0.136	9.48	0.817
Port Royal Pump	14-Pump	4	1	1.06	1.21	1.15	0.054	0.117	0.081	U (0.346)	3.23	1.19

Gray shaded rows indicate monitoring locations that typically have specific conductivities of 4580 µS/cm or higher; Class III Marine Standards are used as reference values only.
*Annual geometric mean calculated using one-half MDL value when result reported as non-detected.

3.1.1 Time Series Plots of Field Parameters

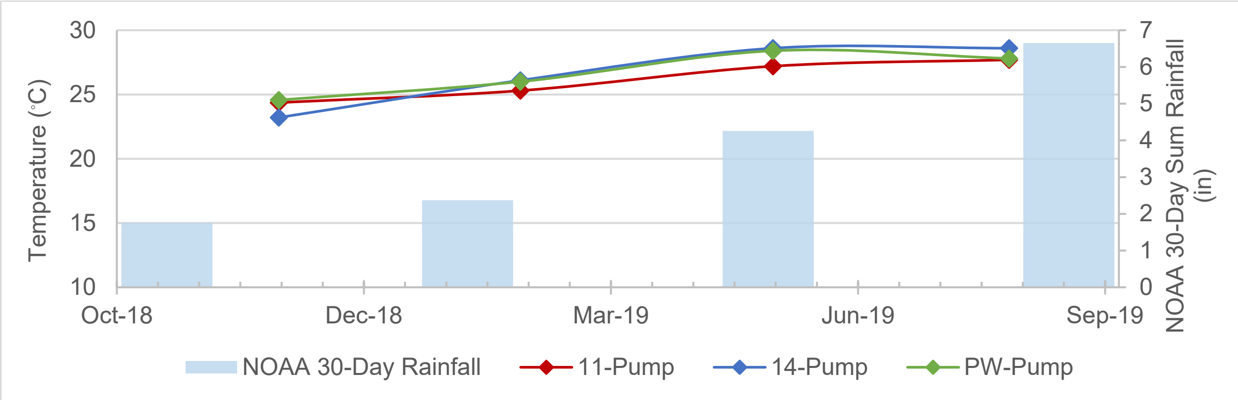


Figure 20. Time series plots of water temperature and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump, 11-Pump, and 14-Pump.

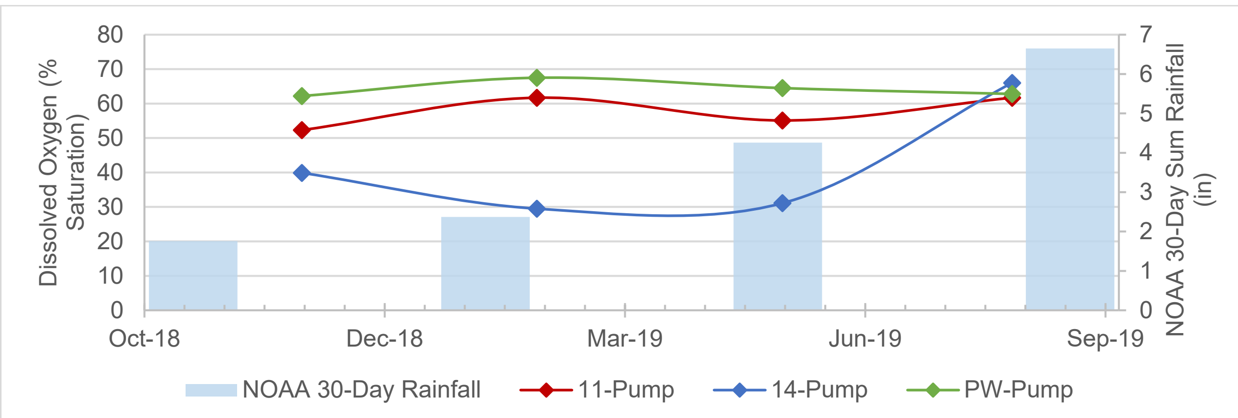


Figure 21. Time series plots of dissolved oxygen saturation and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump, 11-Pump, and 14-Pump.

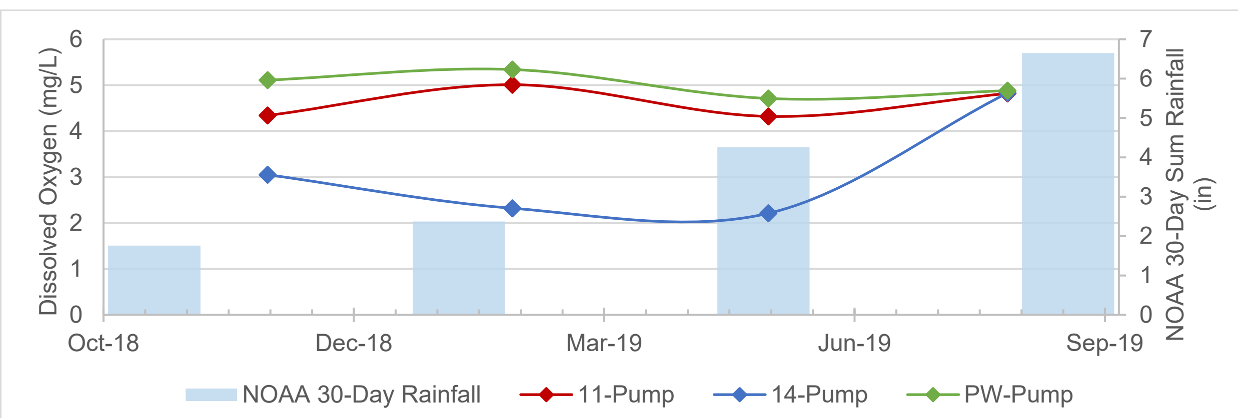


Figure 22. Time series plots of dissolved oxygen concentration (mg/L) and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump, 11-Pump, and 14-Pump.

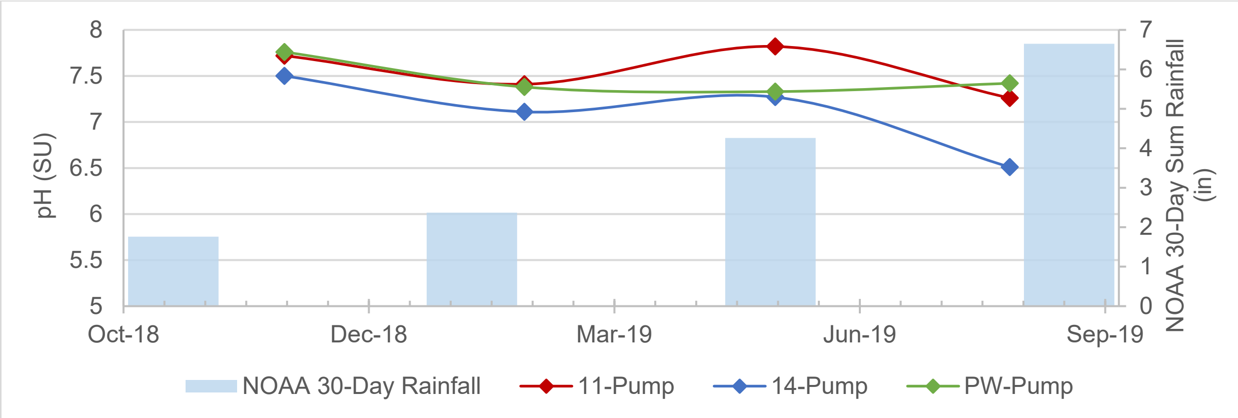


Figure 23. **Time series plots of pH and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump, 11-Pump, and 14-Pump.**

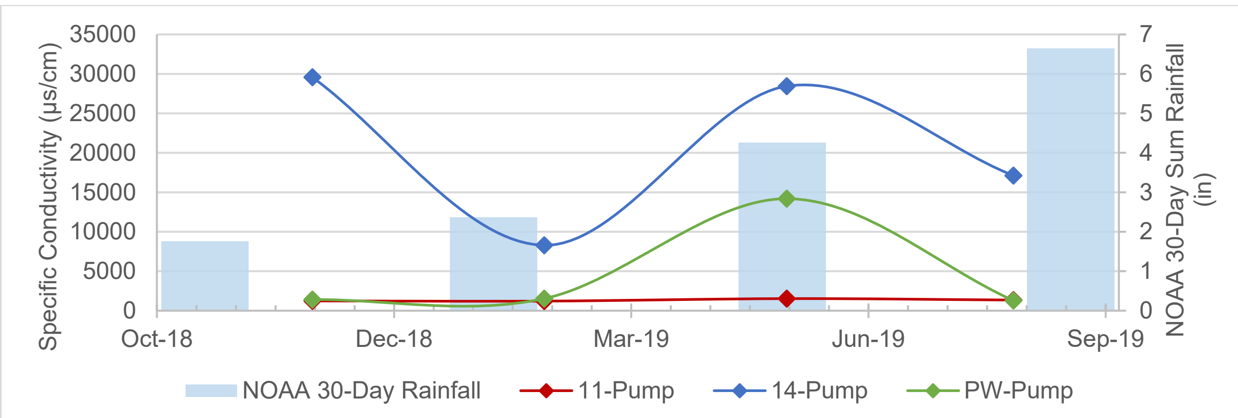


Figure 24. **Time series plots of specific conductivity and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump, 11-Pump, and 14-Pump.**

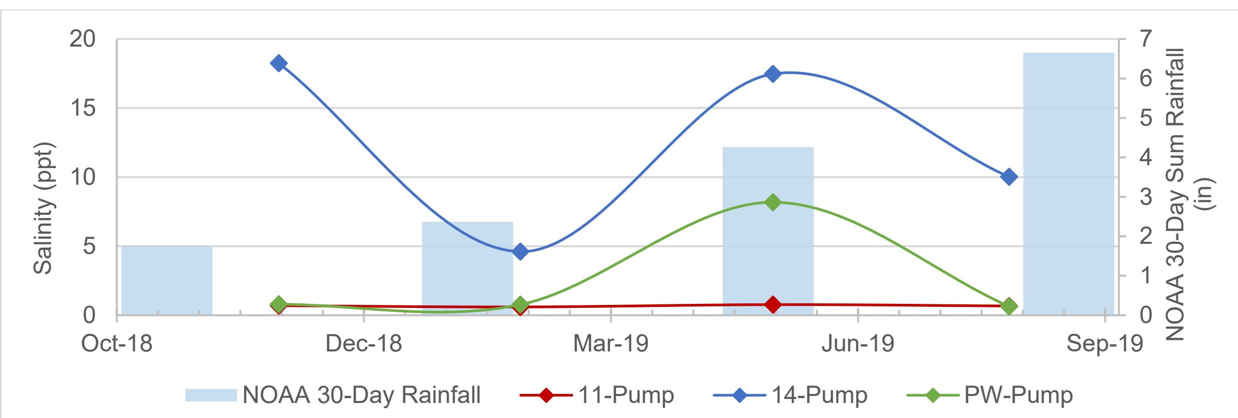


Figure 25. **Time series plots of salinity and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump, 11-Pump, and 14-Pump.**

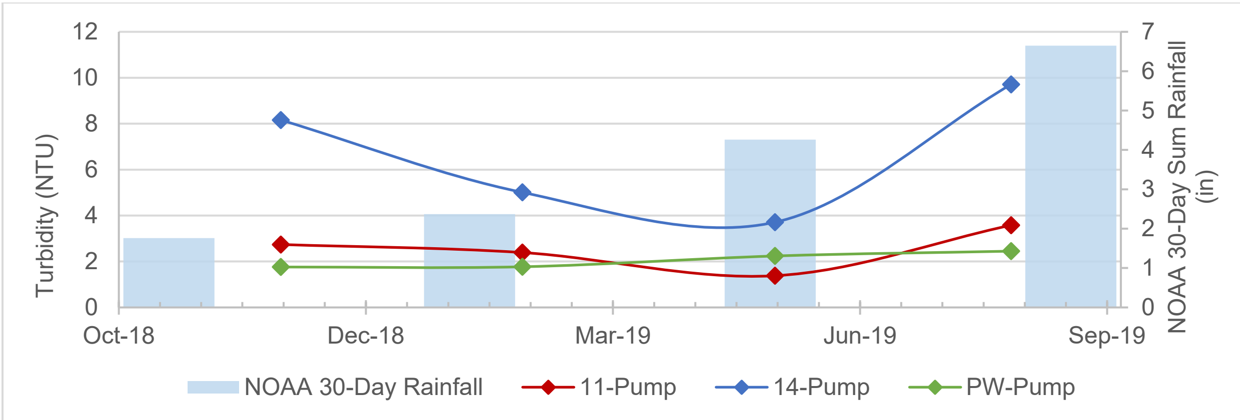


Figure 26. **Time series plots of turbidity and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump, 11-Pump, and 14-Pump.**

3.1.2 Time Series Plots of Lab Parameters

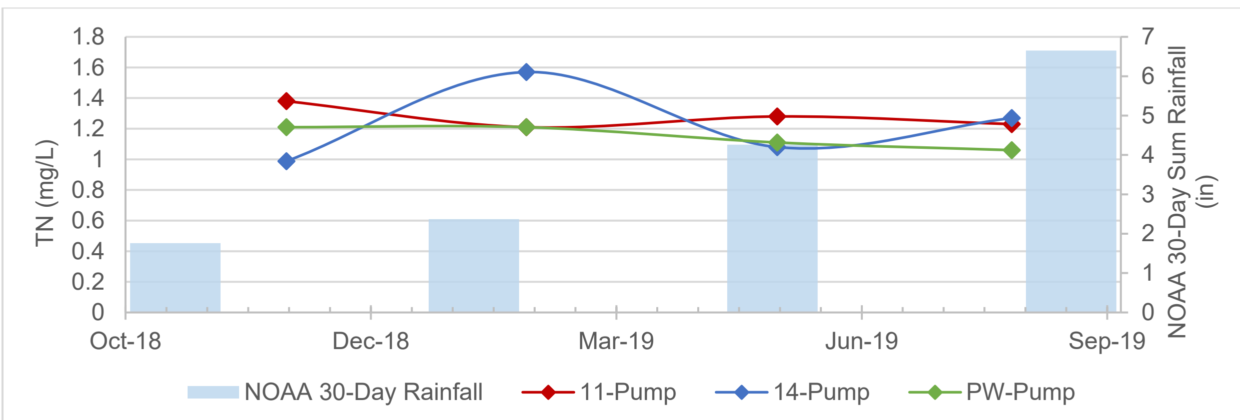


Figure 27. **Time series plots of total nitrogen and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump, 11-Pump, and 14-Pump.**

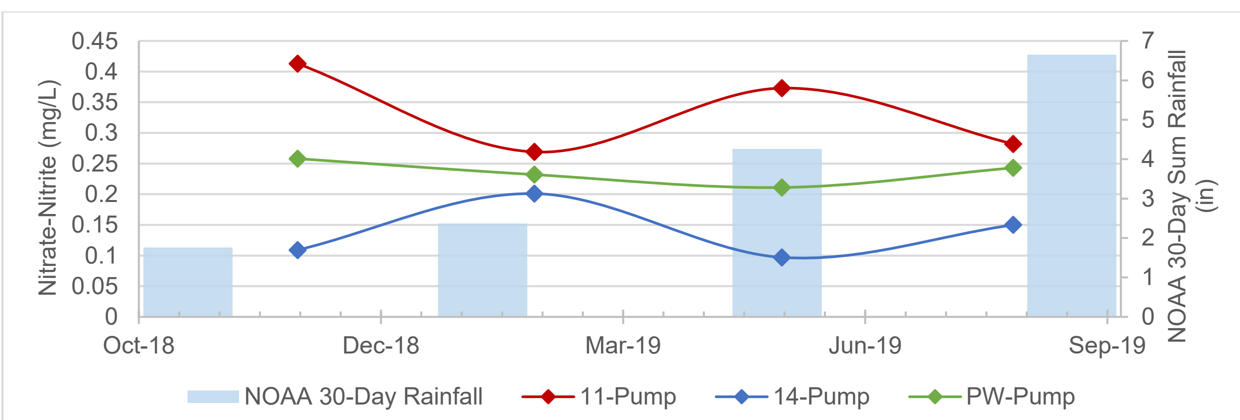


Figure 28. **Time series plots of nitrate-nitrite and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump, 11-Pump, and 14-Pump.**

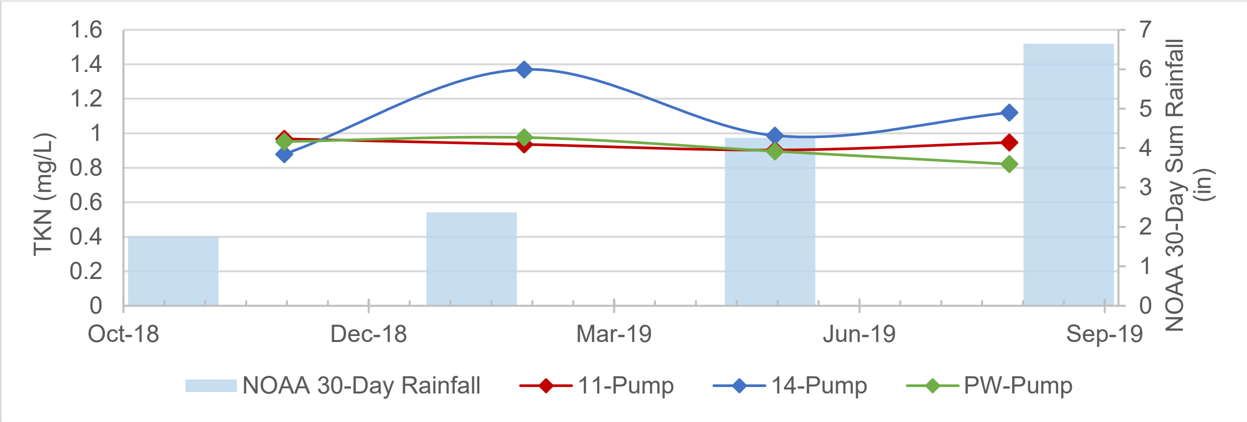


Figure 29. Time series plots of Total Kjeldahl Nitrogen and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump, 11-Pump, and 14-Pump.

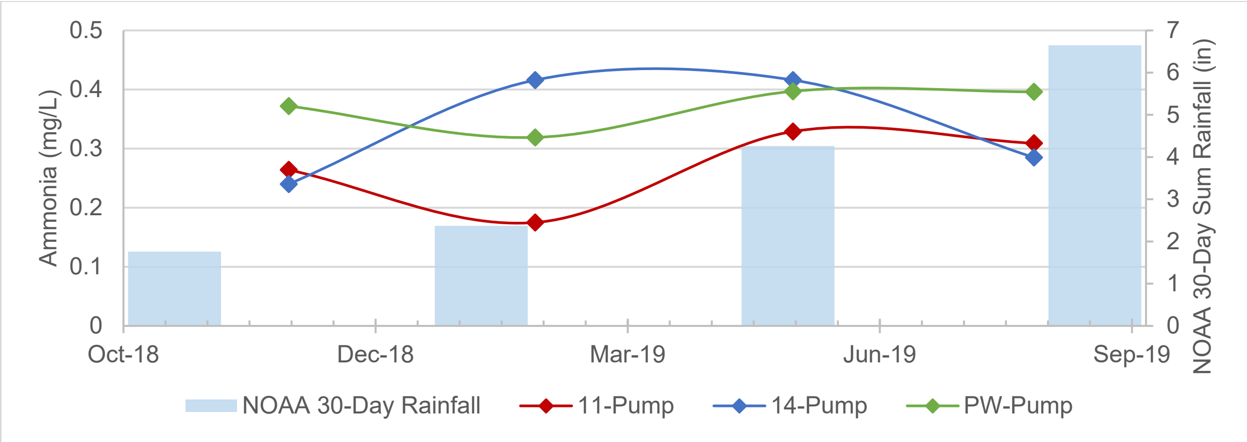


Figure 30. Time series plots of ammonia nitrogen and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump, 11-Pump, and 14-Pump.

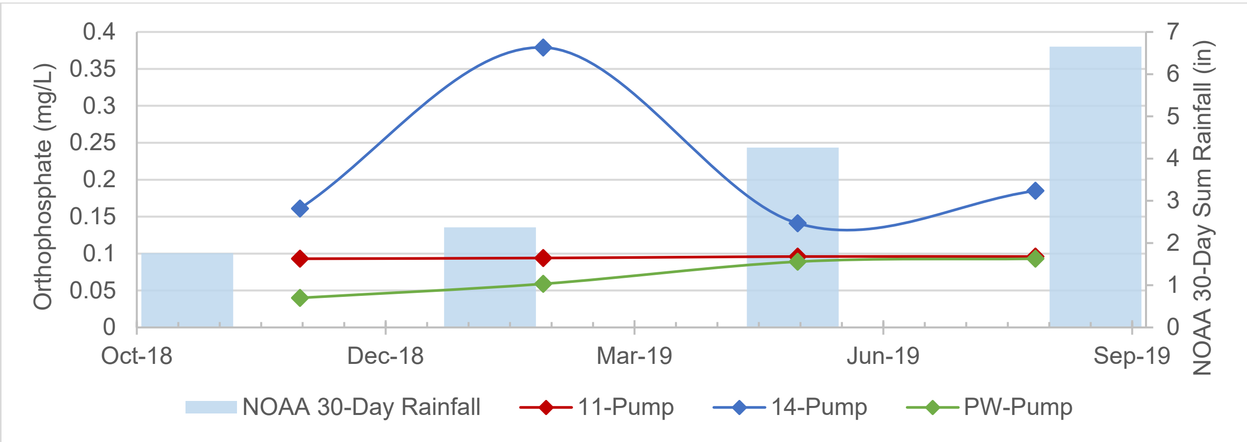


Figure 31. Time series plots of orthophosphate and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump, 11-Pump, and 14-Pump.

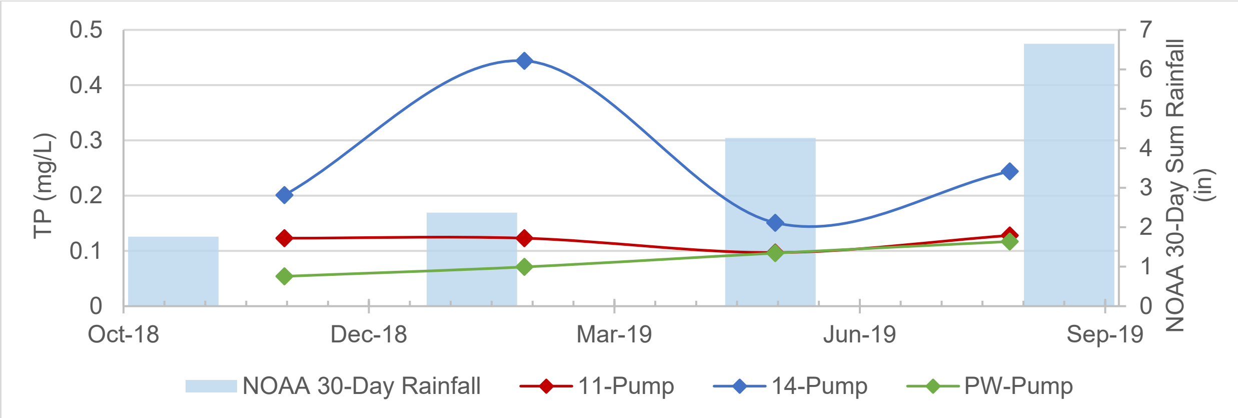


Figure 32. Time series plots of total phosphorus and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump, 11-Pump, and 14-Pump.

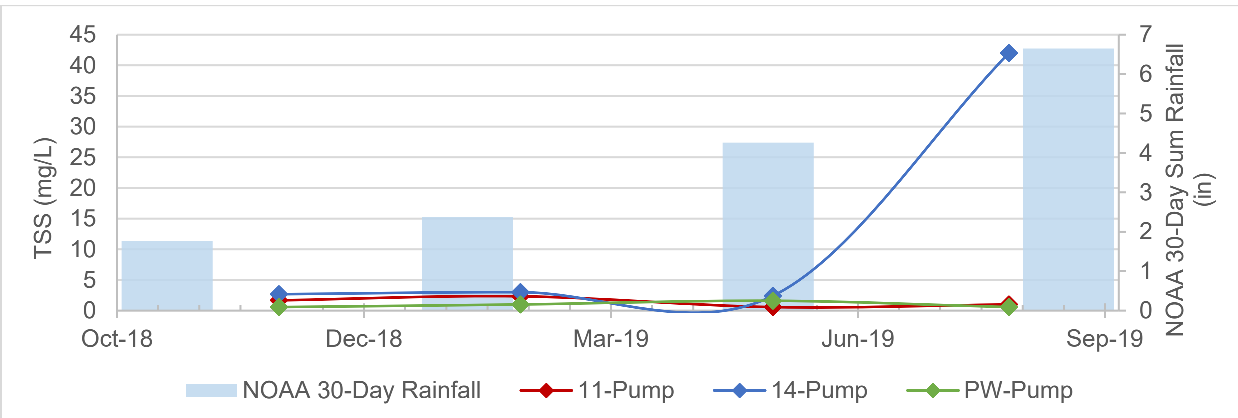


Figure 33. Time series plots of total suspended solids and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump, 11-Pump, and 14-Pump.

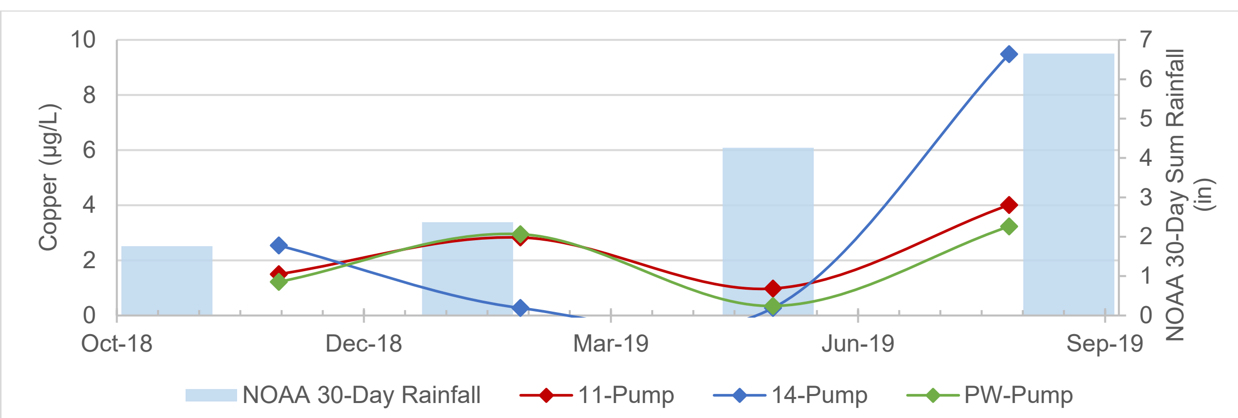


Figure 34. Time series plots of copper and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump, 11-Pump, and 14-Pump.

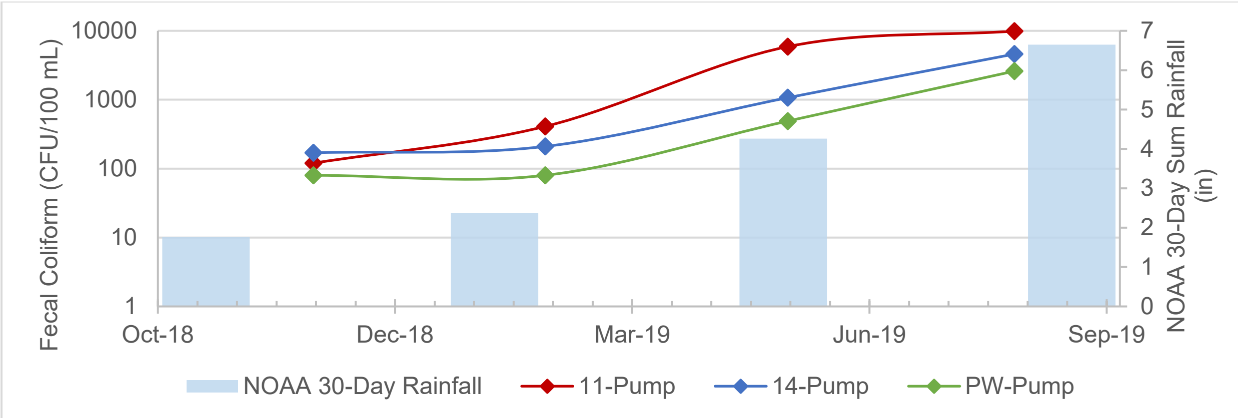


Figure 35. Time series semi-log scale plots of fecal coliform and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump, 11-Pump, and 14-Pump.

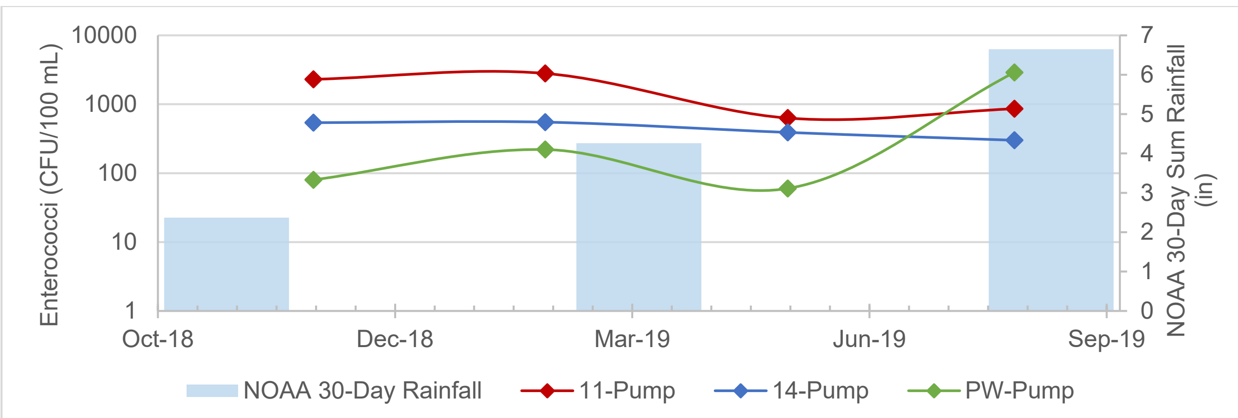


Figure 36. Time series semi-log scale plots of enterococci and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump, 11-Pump, and 14-Pump.

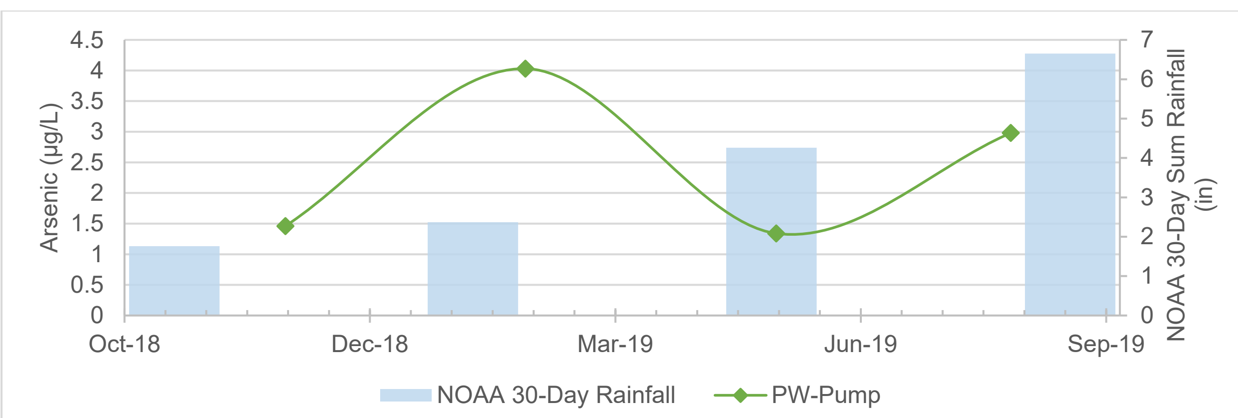


Figure 37. Time series plots of arsenic and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump.

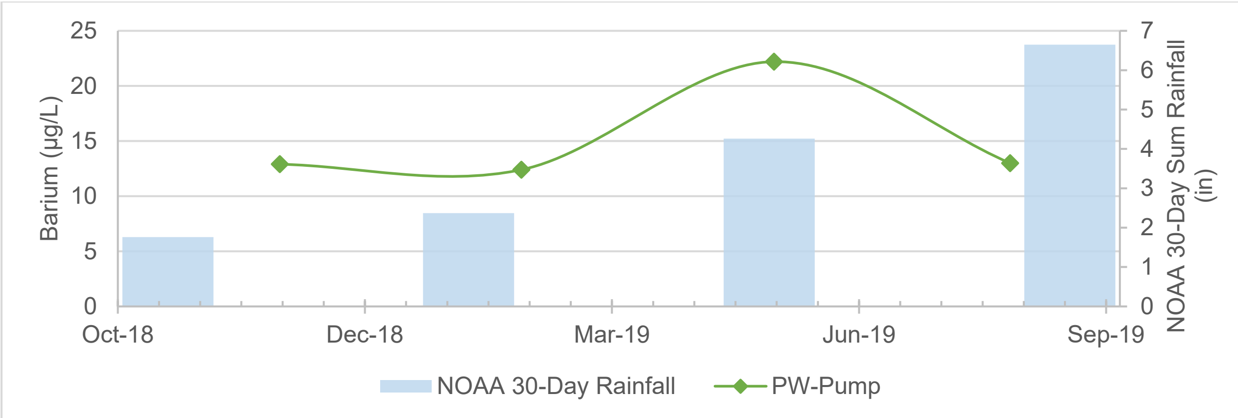


Figure 38. Time series plots of barium and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump.

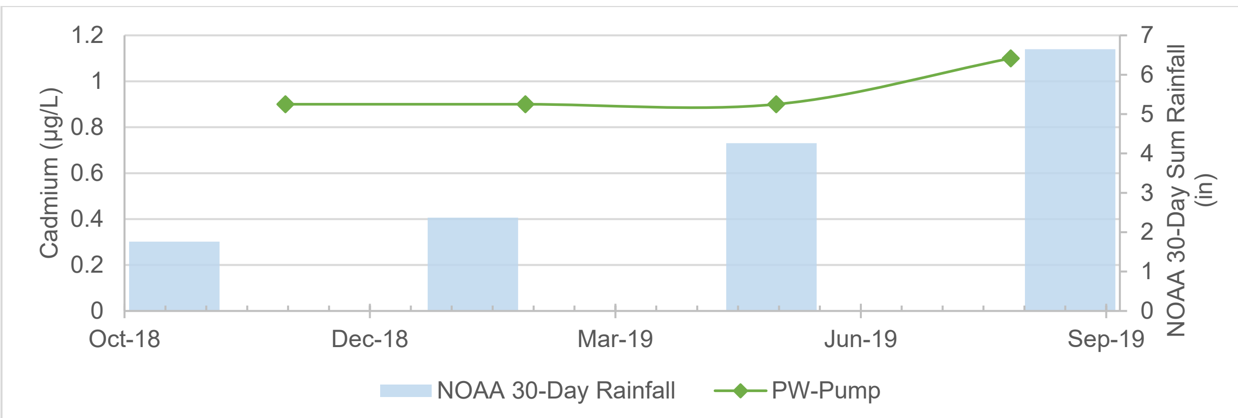


Figure 39. Time series plots of cadmium and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump.

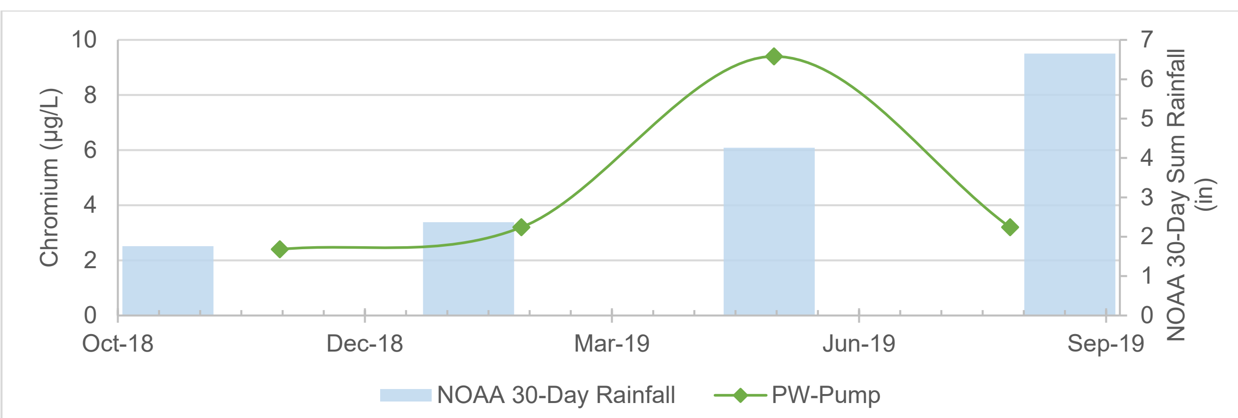


Figure 40. Time series plots of chromium and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump.

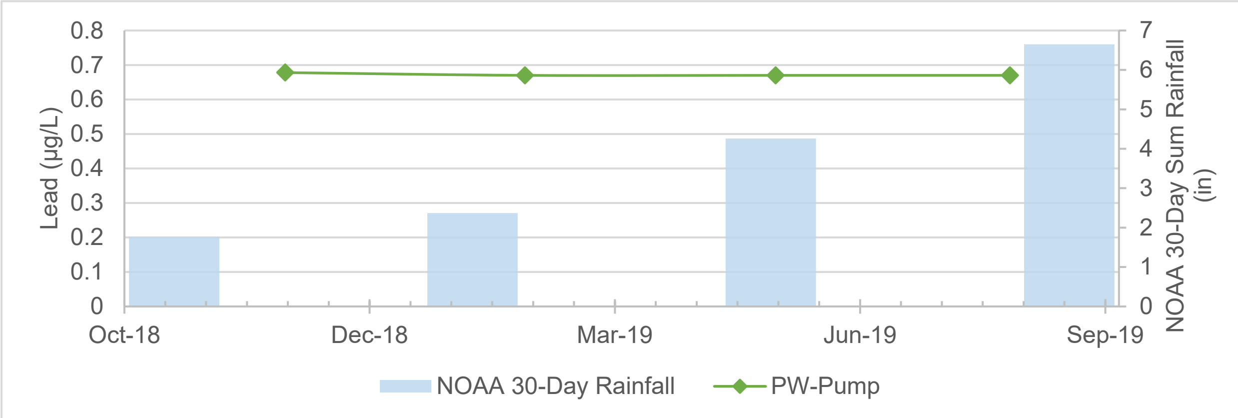


Figure 41. Time series plots of lead and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump.

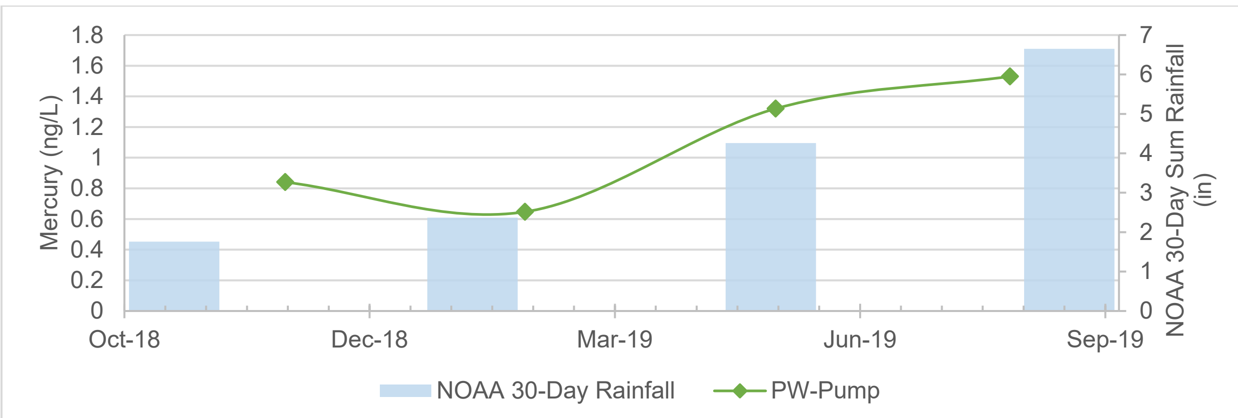


Figure 42. Time series plots of mercury and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump.

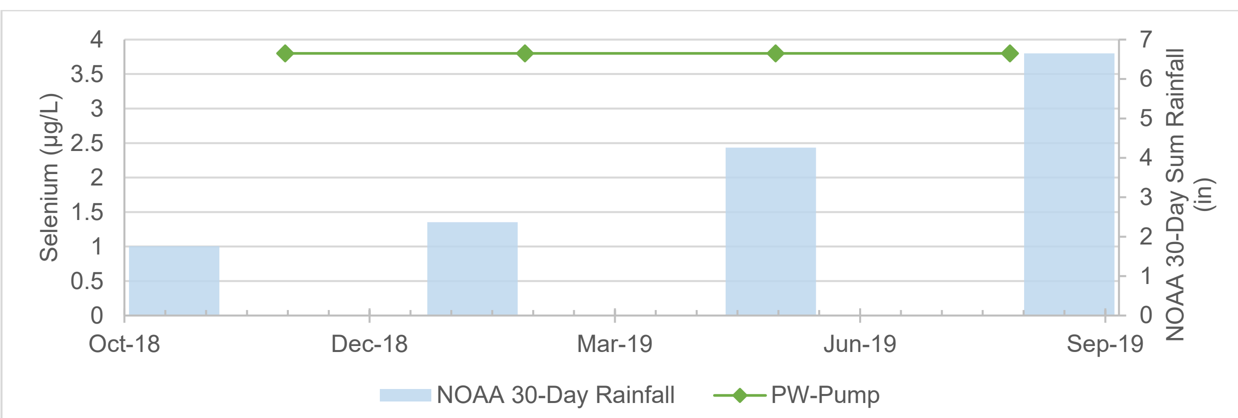


Figure 43. Time series plots of selenium and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump.

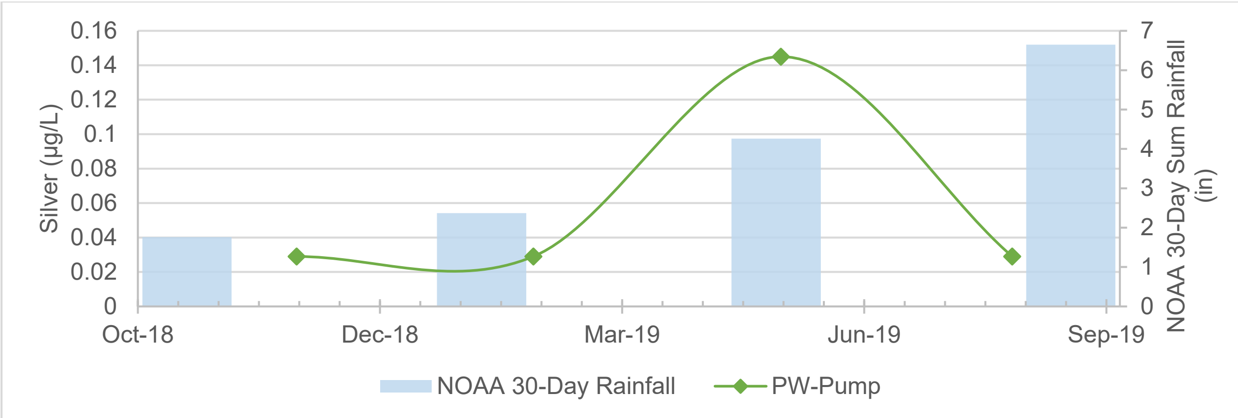


Figure 44. **Time series plots of silver and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump.**

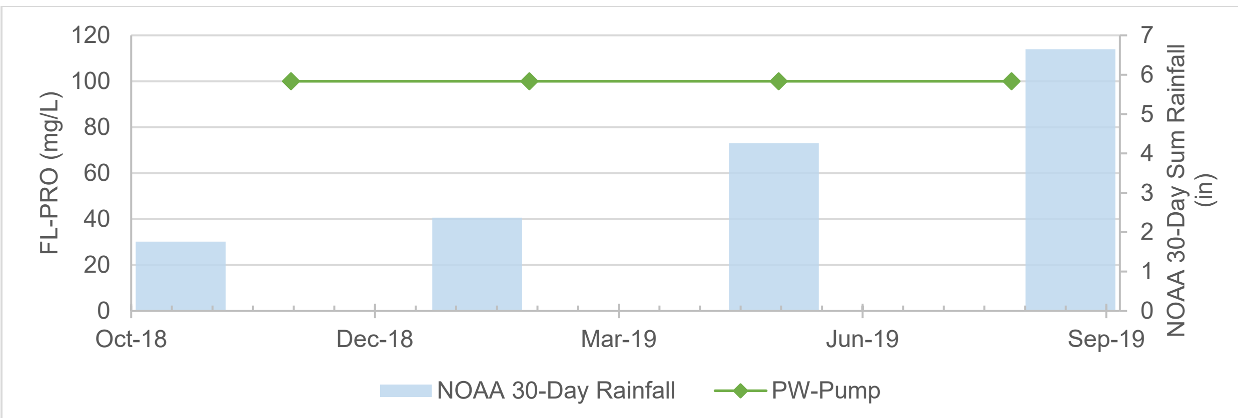


Figure 45. **Time series plots of petroleum range organics (FL-PRO) and prior 30-day sum NOAA rainfall from October 2018 through September 2019 at PW-Pump.**

3.2 Discussion

Monitoring data collected at pump stations were reviewed and summarized by parameter during FY2019. Pump station field measurements typically followed wet and dry seasonal trends. Temperature measurements at all pump stations increased in the wet season with the highest measurements in August 2019 with the exception of PW-Pump (highest temperature in May 2019). Dissolved oxygen at 14-Pump was elevated during the wet season with an increased surface water flow (months where flow was recorded during sampling events, Table 3 and Figures 21 and 22). Levels of pH were consistent during the FY2019 sampling period, with lower values recorded at 14-Pump and higher values at 11-Pump (Figure 23).

SC and salinity measurements at 14-Pump were higher than the other pump stations in FY2019 (Figures 24 and 25). A large spike in SC (29,570 µs/cm) was observed in November 2018 followed by an equally high spike (28,444 µs/cm) during May 2019 (Figures 24). Based on SC measurements, water quality measurements taken within 14-Pump were always characterized as being “predominately marine” according to the FDEP classification of specific conductivities greater than 4,580 µS/cm (62-302.200(30), F.A.C.). All turbidity measurements were well below the Class III reference value of 29 NTU during all sampling events in FY2019.

Nitrogen (TN, TKN, nitrate-nitrate, ammonia) and phosphorus (TP and orthophosphate) concentrations were low and showed little variability at 11-Pump and PW-Pump stations (Figures 27 to 32). At 14-Pump, concentrations of TN, TP, TKN, orthophosphate, and ammonia were slightly elevated during February 2019 (Figures 27 through 32). For comparison, the Naples Bay Numeric Nutrient Criteria for TN and TP are 0.57 mg/L and 0.045 mg/L, respectively (Rule 62-302.532; F.A.C.). TN for 14-Pump was 1.27 mg/L and TP was 0.444 mg/L in February 2019.

Copper concentrations typically stayed near or below 3.7 µg/L (the Class III marine standard) at pump stations 11-Pump and 14-Pump with the exception of a slight increase in concentration for 11-Pump in August 2019 having a value of 4.01 µg/L. At 14-Pump, copper concentrations were elevated and a maximum concentration of 9.48 µg/L was observed in August 2019 (Figure 34). The copper results reported were analyzed using the SM3113B method and methodology was altered depending on a monitoring location’s corresponding specific conductivity measurement.

Fecal coliform and enterococci colony counts were elevated at all three pump stations, with almost half (5/12) of the pump station samples collected for fecal coliform elevated above the Class III reference value of 800 cfu/100mL daily limit; 11-Pump and 14-Pump had two measurements above the referenced Class III values and PW-Pump only had one measurement above (Figure 35). The highest fecal coliform for each station was 2,600 cfu/100mL at PW-Pump, 4,600 cfu/100mL at 14-Pump, and 9,900 cfu/100mL at 11-Pump (Figure 35). Both fecal coliform and enterococci responded to increases in rainfall with generally increased values. Maximum enterococci values were 2,900 cfu/100mL at PW-Pump in August 2019 and 2,800 cfu/100mL at 11-Pump in February 2019. The seasonal variation in the bacteria data indicates that the primary driver of the increase in fecal coliform and enterococci concentrations appears to be rainfall.

Further sampling events are recommended to assess trends and variance of fecal coliform and enterococci. In addition, implementation of regular city street sweeping clean-ups, public education on proper handling of pet waste and lawn grass clippings, and routine inspections are possible effective management strategies to consider in reducing fecal bacteria concentrations in storm water systems.

Elevated values were detected at PW-Pump locations with arsenic being above 3 µg/L, barium above 10 µg/L, and mercury above 1 ng/L during various monitoring event (Figures 37, 38, and 42); none of these elevated values exceeded Class I or III Surface Water Quality Reference values (Rule 62-302.530, F.A.C.). All other heavy metal measurements were either non-detected or between the minimum detection limit (MDL) and practical quantitation limit (PQL) of the methodology.

3.3 Pump Station Loading Summary

Estimated monthly loadings for parameters of concern to the City (nutrients, copper, and solids) were calculated for each of the three pump stations. This analysis was based on monthly discharge volume calculations from the three City pump stations, which are estimates based on the pump run times and maximum pump rate for each system. Therefore, this analysis may not reflect actual volumes from each pump station, and the loadings calculated using these volume estimates should be considered estimates of the maximum loads. Because water quality monitoring is conducted quarterly for each pump station rather than monthly, we assumed the quarterly concentration to represent each month during that calendar quarter.

Table 4 shows the estimated monthly and annual total loads (in pounds) from each pump station from October 2018 through May 2019 (range of available monthly discharge totals) for copper, total nitrogen, total phosphorus, and total suspended solids.

Table 4. Monthly and annual total loadings (in pounds) from City of Naples Pump Stations from October 2018 to May 2019.

Pump Station	Month	Loads (lbs)			
		Copper	Total Nitrogen	Total Phosphorus	Total Suspended Solids
PW-Pump	October-18	0.72	712.8	31.8	335.8
	November-18	0.11	109.6	4.9	51.6
	December-18	0.58	576.0	25.7	271.3
	January-19	1.74	715.2	42.0	591.1
	February-19	0.41	169.0	9.9	139.6
	March-19	1.43	585.7	34.4	484.1
	April-19	0.20	650.7	56.3	938.0
	May-19	0.21	672.4	58.2	969.2
	June-19				
	July-19				
	August-19				
	September-19				
	Annual Total	**5.41**	**4191.50**	**263.09**	**3780.79**
11-Pump	October-18	2.22	2039.4	181.8	2468.0
	November-18	1.66	1529.5	136.3	1851.0
	December-18	2.21	2029.7	180.9	2456.3
	January-19	4.04	1727.0	175.6	3325.5
	February-19	3.63	1550.7	157.6	2986.1
	March-19	2.47	1056.4	107.4	2034.3
	April-19	1.86	2428.4	184.0	1081.4
	May-19	1.92	2509.3	190.2	1117.4
	June-19				
	July-19				
	August-19				
	September-19				
	Annual Total	**20.00**	**14870.53**	**1313.78**	**17319.92**
14-Pump	October-18	0.56	218.4	44.4	590.1
	November-18	0.41	160.3	32.6	433.1
	December-18	0.44	171.4	34.9	463.1
	January-19	0.05	260.5	73.7	497.9
	February-19	0.05	264.1	74.7	504.6
	March-19	0.04	222.8	63.0	425.8
	April-19	0.05	184.2	25.8	409.3
	May-19	0.05	190.3	26.6	422.9
	June-19				
	July-19				
	August-19				
	September-19				
	Annual Total	**1.64**	**1671.96**	**375.64**	**3746.82**

4 References

AMEC Environmental & Infrastructure, Inc. 2012. City of Naples Stormwater Quality Analysis, Pollutant Loading and Removal Efficiencies. Technical Publication Submitted to the City of Naples, Florida. 95pp.

Gordon E, Stein S. 2007. Stormwater BMPs Selection, Maintenance and Monitoring. Santa Barbara (CA): Forrester Press.

About Cardno

Cardno is an ASX-200 professional infrastructure and environmental services company, with expertise in the development and improvement of physical and social infrastructure for communities around the world. Cardno's team includes leading professionals who plan, design, manage, and deliver sustainable projects and community programs. Cardno is an international company listed on the Australian Securities Exchange [ASX:CDD].

Cardno Zero Harm

Cardno ZERO HARM EVERY JOB. EVERY DAY.

At Cardno, our primary concern is to develop and maintain safe and healthy conditions for anyone involved at our project worksites. We require full compliance with our Health and Safety Policy Manual and established work procedures and expect the same protocol from our subcontractors. We are committed to achieving our Zero Harm goal by continually improving our safety systems, education, and vigilance at the workplace and in the field. Safety is a Cardno core value and through strong leadership and active employee participation, we seek to implement and reinforce these leading actions on every job, every day.