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Mitchell Lake, Rice Marsh Lake, and Lake Riley Subwatershed Assessment

Prepared for:

Riley Purgatory Bluff Creek Watershed District

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Executive Summary

The goals of the Mitchell Lake and Lake Riley subwatershed assessment was to identify cost effective solutions to limit the export of bioavailable phosphorus from ponds that may be acting as net sources to nutrient impaired lakes. The purpose of the study was to assess each pond's capacity to re-release phosphorus through sediment release, evaluate enhancements that ensure ponds are not acting as sources of phosphorus, and provide cost effective alternatives for each pond. Four ponds in the Mitchell Lake watershed and five ponds in the Lake Riley watershed were monitored for water quality, dissolved oxygen dynamics, and sediment P release and chemistry. All of the ponds demonstrated significant anoxia throughout the summer growing season. In fact, some of the ponds were anoxic from surface to bottom for almost the entire season. Sediment P release ranged from 2 to 9 $mg/m^2/day$ resulting in an additional 1.2 to 7.7 pounds of P loading to surface waters. While all of the ponds monitored were net sinks of P when comparing sedimentation to P release, the additional sediment P loads educe the effectiveness of these ponds. Further, severe algal blooms occurred in all of the ponds with high phycocyanin concentrations suggesting that many of these blooms were potentially toxic cyanobacteria.

The potential impacts of P released from stormwater sediments were dramatic when applied across entire subwatershed. For the Mitchell Lake subwatershed, the impacts of sediment P release from stormwater ponds was likely minimal since the watershed is only minimally ponded. In contracts, the Lake Riley subwatershed has the potential to be a net source of P because it is highly ponded, offsetting any benefits of the stormwater ponds on P delivery to downstream waters.

Overall, controlling sediment P release in stormwater ponds offers numerous benefits, especially in watersheds that are highly ponded. Reducing sediment P release will improve the watershed's ability to retain P, protecting downstream receiving waters. Further, sediment P inactivation will reduce pond algal blooms that have the potential to be toxic and harmful to local residents. There are numerous options to prevent sediment P release in stormwater ponds including aeration or oxygenation to prevent anoxia or sediment P inactivation using metal hydroxides. Oxygenation and aeration require a power source and significant maintenance increasing the cost for this approach. Further, if the system is undersized or fails, P release will reoccur.

1.0 Introduction

1.1 BACKGROUND

There are several stormwater ponds located within impaired-lake watersheds in the Riley Purgatory Bluff Creek Watershed District (RPBCWD) that play a critical role in phosphorus removal. The prevailing wisdom is that phosphorus captured by stormwater ponds is permanently removed when deposited through sedimentation. However, recent monitoring efforts by the City of Eden Prairie and RPBCWD suggest that dissolved oxygen (DO) levels in several stormwater ponds periodically falls below 2 mg/L, which is considered anoxic. This anoxic threshold is typically associated with the re-release of trapped phosphorus that had previously been deposited in the stormwater pond through sedimentation.

Phosphorus re-released into the pond under anoxic conditions is highly bioavailable and has the potential to negate the initial benefits of phosphorus removal accomplished by sedimentation in the pond. Stormwater pond enhancements such as aluminum sulfate addition, iron addition, aeration, and iron enhanced sand filter installation may reduce the amount of bioavailable phosphorus that is exported from each pond. Each pond must be assessed individually to determine the most effective practice for the specific site conditions.

1.2 WATERSHED DESCRIPTIONS

The three watersheds addressed in this study are Eastern Lake Riley, Eastern Rice Marsh Lake, and Mitchell Lake watersheds.

The Eastern Lake Riley watershed is bound approximately by Highway 212 on the north, Dell Road and Belvedere Drive on the east and Pioneer Trail on the south (Figure 1-1). The watershed consists of residential area and a golf course. Lake Riley is a deep lake that serves as a regional recreational amenity, with public boat access, a public swimming beach, and fishing pier.

Eastern Rice Marsh Lake watershed includes the residential area bound approximately by Wynnfield Road on the north, Dell Road on the east and Highway 212 on the south (Figure 1-2). Rice Marsh is a shallow lake located upstream of Lake Riley.

The Mitchell Lake watershed is bound approximately by the railroad tracks to the north, and Eden Prairie Road to the east, excepting the area around Round Lake, Highway 212 to the south and Dell Road and Chanhassen Road to the west (Figure 1-2). Land use is primarily residential with some industrial area on the west side of the watershed.

1.3 PAST STUDIES

Several previously-completed stormwater basin studies are used as the basis for this study. The Basin Inventory and Use Attainability Analysis studies, outlined below, informed the selection criteria, pond characteristics and geometry, and the watershed loading used for this study's internal loading potential and cost estimation.

The *Mitchell Lake Watershed Basin Inventory and Maintenance Assessment – Phase V* project evaluated the effectiveness of key water treatment basins (constructed ponds, infiltration BMPs, creeks and wetlands which receive stormwater) within the Mitchell Lake Watershed Basin in the City of Eden Prairie. A total of 43 basins were assessed for functionality and sedimentation: 18 constructed ponds, 4 infiltration BMPs, 16 stormwater wetlands, 5 wetlands. The evaluation included a sedimentation survey of the basins. Sedimentation amounts, pollutant removal effectiveness, and sediment removal were estimated for each basin using the results of the sedimentation survey. A watershed-wide P8 model and a lake-response model were created for Mitchell Lake to evaluate how well the basins protect and support the water quality of Mitchell Lake. Four basins were identified for routine maintenance needs.

The goal of the *Lake Riley and Rice Marsh Lake Subwatersheds Basin Inventory and Maintenance Assessment* project was to enhance the understanding of the City's maintenance needs while assisting City staff with scheduling and budgeting of resources. The project evaluated basin effectiveness, identified basins requiring maintenance, identified basins that could provide additional treatment capacity, and prioritized and scheduled future inspections. The report also provides project and permitting recommendations.

The *Mitchell Lake Use Attainability Analysis* contains the results of a Use Attainability Analysis of Mitchell Lake. The analysis includes an evaluation of the causes and solutions to observed problems impacting the beneficial uses of Mitchell Lake. The evaluation indicated that Mitchell Lake's water quality has been poor since as far back as 1972. Issues impacting water quality in the lake were identified as excessive untreated stormwater inflow and internal load from decaying Curly-leaf pondweed. The report provided an implementation plan to address these sources of excess phosphorus.

The *Rice Marsh Lake and Lake Riley: Use Attainability Analysis Update* summarizes the results of an updated assessment of water quality in Rice Marsh Lake and Lake Riley after completion of water quality improvement projects by the Riley-Purgatory-Bluff Creek Watershed District since the original analysis in 1999 and 2002. The evaluation found that Rice Marsh Lake showed improvements in water quality and that Lake Riley water quality had remained stable. The report recommended several additional water quality improvement projects.

Figure 1-1: Mitchell Lake Watershed

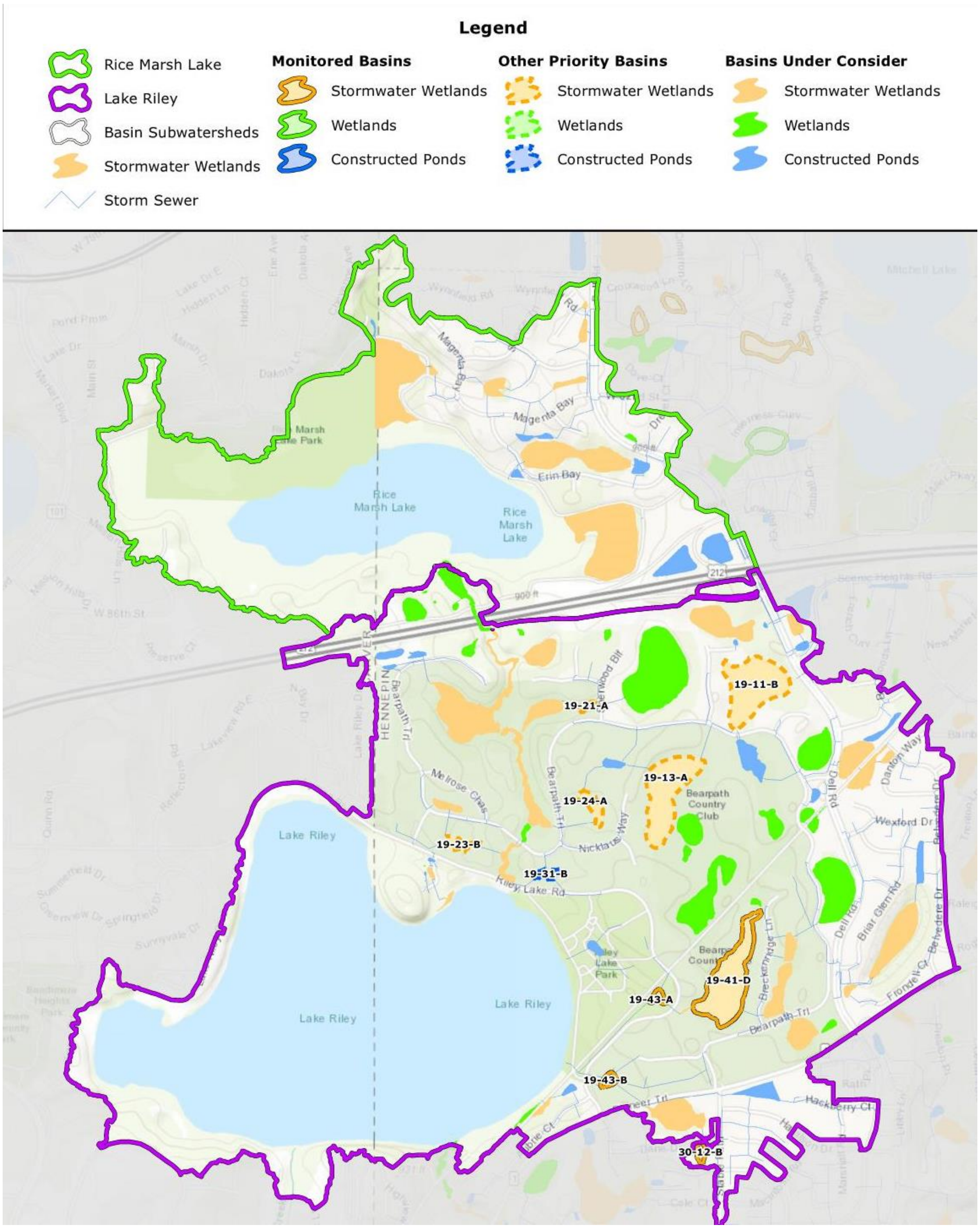


Figure 1-2: Riley and Rice Marsh Lake Watershed

1.4 GOALS AND OBJECTIVES

The goals of this study are to identify cost effective solutions to limit the export of phosphorus from ponds that may be acting as net sources of bioavailable phosphorus to nutrient impaired lakes. The study will:

- assess each pond's capacity to re-release phosphorus through sediment release.
- evaluate enhancements that ensure ponds are not acting as net exporters of phosphorus.
- provide cost benefit analysis of enhancement alternatives for each pond.

Specifically, this study updates the current watershed phosphorus loading estimates with internal phosphorus loading estimates based on the:

- Monitoring of 9 ponds for DO, temperature and phosphorus (P)
- Measurement of sediment chemistry and P release rate
- Modelling of DO and P release in ponds.
- Extending the model watershed wide as possible to determine P loading.
- Updating watershed BMPs targeting dissolved/ortho P fractions

2.0 Pond Selection and Monitoring

2.1 POND SELECTION

Four ponds in the Mitchell Lake watershed and five ponds in the Lake Riley watershed were selected based on the outlined criteria in Table 2-1. The selected ponds represent the basin characteristics and basin function diversity within both watersheds (Table 2-2; Figure 2-1 and 2-2).

The selection criteria are based on key physical and hydrologic conditions that have the potential to influence DO, phosphorus, and other biogeochemical cycling within the stormwater pond. The phosphorus cycle is driven by chemical and mechanical influences from both watershed inputs and basin characteristics. Phosphorus settling is the main function for these ponds however, internal loading caused by anoxic release of phosphorus from settled particulates can occur. Internal loading in ponds is facilitated by anoxia near the sediments, this anoxia is driven by mixing potential (or lack thereof). Thus, parameters like, surface area, residence time, depth, sheltering and open-water (duckweed or vegetation presence) are key to determining the potential of wind and temperature driven mixing and the corresponding ability to maintain anoxic conditions near the sediment.

Table 2-1: Pond study selection criteria

Selection Criteria	Rationale
Basin Type	Diversity for the study to capture basin functioning (i.e., constructed ponds (CP), stormwater wetlands (SW))
Drainage Area (ac)	Potential for phosphorus loading
NURP Water Quality Volume (acre-ft)	Sediment settling potential, TP removal efficiency, residence time
Surface Area	Mixing potential
As-built	Basin age and construction information
Max Depth	Mixing potential
Ave Depth	Mixing potential
Access	Ease of monitoring and maintenance (Easy, Moderate, Difficult)
P data	More monitoring data available
Open Water	Mixing potential
Sheltered	Mixing potential (houses, trees, low depressions)

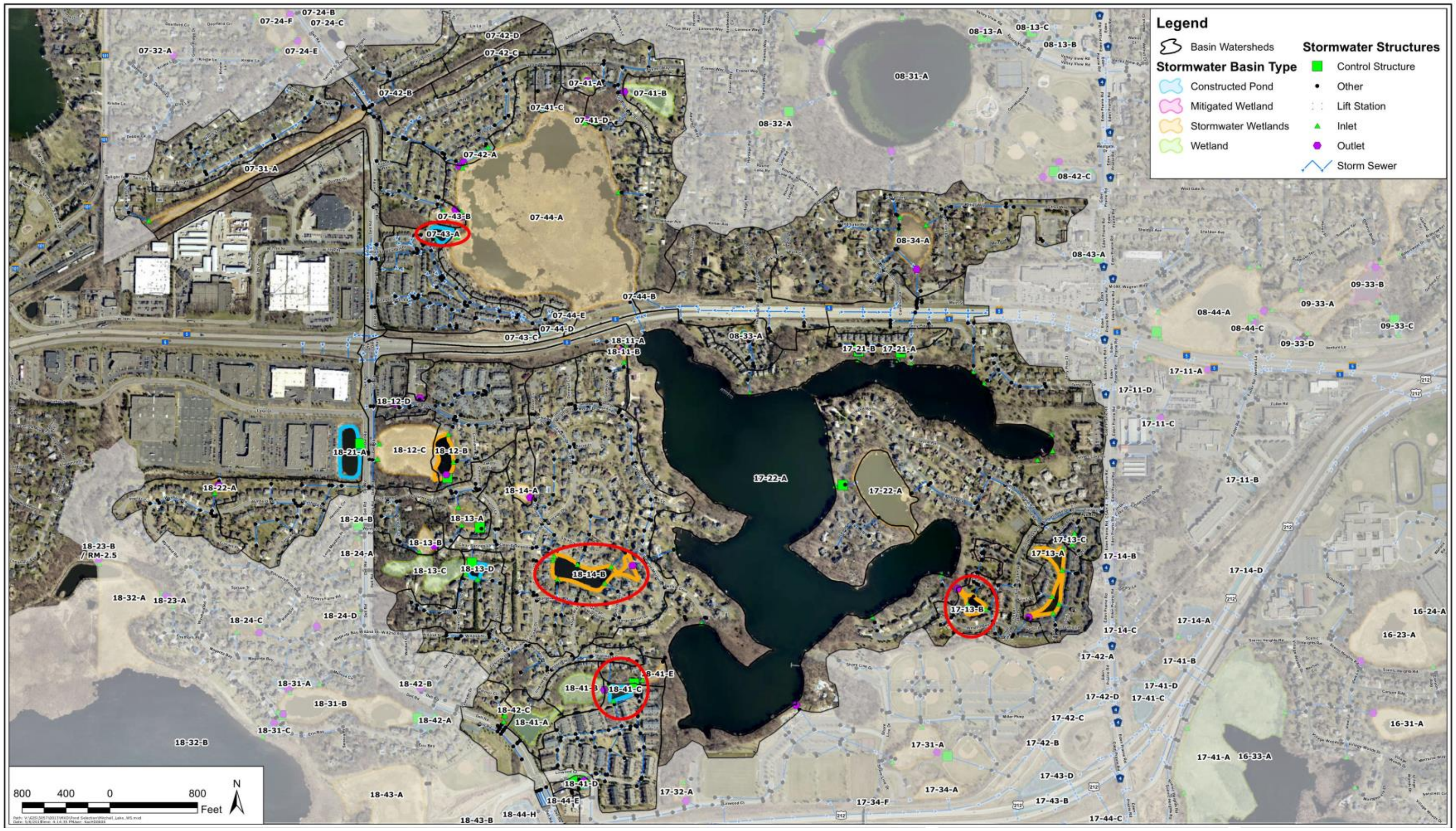


Figure 2-1: Ponds Selected for Mitchell Lake Watershed

Figure 2-2: Ponds Selected for Rice Marsh Watershed

Table 2-2: Characteristics of Study Ponds

Pond ID	Basin Type	Drainage Area (acres)	SA (acres)	As-built	Max Depth (feet)	Ave Depth (feet)	Open Water	Sheltered	Year Built	Age
Mitchell Lake										
18-14-B	SW	70.6	2.0	Yes	6.8	3.4	Yes	Somewhat	1992	27
07-43-A	CP	19.2	0.4	Yes	10.3	5.2	Yes	Yes	1995	24
18-41-C	CP	32.4	0.4	Yes	3.5	1.8	Yes	Yes	1994	25
17-13-B	SW	14.4	0.5	Yes	6.9	3.5	Yes	Somewhat	1986	33
Rice Marsh Lake										
18-24-C	SW	21.3	0.8	Yes	5.0	2.5	Yes	Somewhat	1992	27
Lake Riley										
30-11-A	CP	29.7	1.0	Yes	10.47	5.24	Yes	Somewhat	2000	19
19-11-B	SW	18.1	8.1	Yes	9.17	4.58	Yes	Somewhat	1993	26
19-24-A	SW	10.1	1.0	Yes	6.66	3.33	Yes	No	1994	25
19-31-B	CP	26.5	0.7	Yes	5.50	2.75	Yes	No	1994	25

3.0 Methods

3.1 WATER QUALITY MONITORING

Water quality monitoring included three components: depth profiles, continuous data logging, and grab samples. Every two weeks, RPBCWD staff collected depth profiles (0.5 meter intervals) for DO, temp, pH, conductivity, phycocyanin, and photosynthetically active radiation (PAR), to supplement continuous data (discussed below) and grab samples (Table 3-1). The depth profiles provide key information on the chemical and temperature stratification within the pond and help validate the continuous data.

Each pond housed two continuous monitoring stations: a DO station and a wind speed station to help model mixing. The DO stations collected DO and temperature data from two depths at the deepest part of the pond. The first DO/temperature probe was positioned one to two feet off of the bottom and the other probe was approximately two feet below the surface. This setup allowed us to capture the upper limit of the anoxic zone. The continuous data helped determine the DO dynamics and extent of anoxia at the sediment/water interface at high resolution. The water chemistry grab samples were used to validate the continuous data and to understand the macro-nutrients (nitrogen and phosphorus), carbon cycle and organic chemistry within the pond which contribute to dissolved oxygen functioning within the pond.

Table 3-1: Water Quality Parameters

Parameter	Depth	Frequency	Equipment
Full suite from sonde	profile	biweekly	Sonde
TP	surface and bottom	biweekly	Grab and van dorne sample
Secchi	profile	biweekly	Disk
Chlorophyll-a	surface only	monthly	Grab
BOD	surface only	monthly	Grab
alkalinity	surface only	monthly	Grab
TKN	surface only	monthly	Grab
Nitrate/Nitrite	surface only	monthly	Grab
Ammonia as N	surface only	monthly	Grab
OP as P dissolved	surface only	monthly	Grab
T Organic Carbon	surface only	monthly	Grab
BOD (5-day)	surface only	monthly	Grab

3.2 SEDIMENT CHEMISTRY

Sediment cores were collected from each selected pond and analyzed for sediment chemistry and phosphorus anoxic release rate (see Appendix A for methods). This data was used to determine internal loading potential within stormwater ponds. Sediment chemistry and phosphorus release rates were collected at different locations on Mitchell Lake for internal load analysis and sediment activation dosing (see Appendix C for results).

3.3 INTERNAL LOADING

One of the primary bonds for phosphorus is with iron. When oxygen is depleted near the sediment surface (water concentration less than 2.0 mg/L), phosphorus-iron ($FeOOH-PO_4$) bonds are one of the first bonds that are broken, thus releasing, releasing dissolved phosphorus that is transported into the water column. The phosphorus that is released from the sediment is in a soluble form (PO_4) that is readily available to algae and plants.

Historically, the sediment P release phenomena has been extensively studied in lakes and is important to lake P budgets. Less is known about sediment P release in SW ponds and that is the goal of this project.

4.0 Pond Dissolved Oxygen Dynamics

4.1 DISSOLVED OXYGEN IN STORMWATER PONDS

Since the extent of anoxia is the primary driver of phosphorus release from the sediments, understanding DO dynamics in stormwater ponds is critical. Anoxia in lakes is well understood, but conditions in stormwater ponds can be quite different from those seen in lakes. Our hypothesis was that anoxia in stormwater ponds is due to:

1. Higher sediment oxygen demand, (SOD).
2. Higher biological oxygen demand (BOD).
3. Lack of mixing and the cover/shading caused by duckweed.

Oxygen demand in ponds commonly occurs via loading of organic material from the watershed to the pond, and subsequent breakdown of the organic matter within the system. Loading of biological oxygen demanding (BOD) substances can be traced to both natural (plant and leaf debris) and human sources (grass clippings, fertilizer, pet feces). As these organics settle to the bottom of the basin they are measured as sediment oxygen demand (SOD). SOD and BOD are different in stormwater ponds than in lakes because of the high organics in stormwater effluent from city streets and lawns and accumulate in stormwater ponds. The volume in a SW pond is considerably less than most lakes, so BOD is more concentrated in a pond after it is delivered and therefore exerts more oxygen demand than lakes (i.e. less dilution)

The presence of duckweed plays a large role in DO dynamics in stormwater ponds. The presence of duckweed shields gas exchange with the atmosphere, blocks light from aquatic plants and dampens mixing from wind. The impact of duckweed is a new area of study in MN and our hypothesis is that the key mechanisms which drive pond anoxia are dependent on gas exchange, mixing, and light attenuation, all of which are altered by the presence of duckweed on the ponds. Ponds with duckweed cover tend to represent the extremes on the spectrum of these mechanisms.

One of the goals of this project was to determine how susceptible stormwater ponds are to anoxia and how the oxygen dynamics in ponds differ from those in lakes. Dissolved oxygen modeling was conducted to try to understand the distinct drivers of the DO dynamics of stormwater ponds compared to lakes.

4.2 MODEL METHODS

All nine basins were analyzed for data quality, dissolved oxygen dynamics (note: most ponds were anoxic throughout the entire water column throughout the entire observation period), and representative driving mixing conditions. Two ponds were suitable for full season modelling of DO dynamics: one with duckweed (07-43-A) and one without (19-11-B). The modeled ponds also represent the highest and near the lowest anoxic factor. Thus, our first investigation compares the extremes of gas exchange, mixing, and light attenuation.

To determine the factors in driving anoxia in stormwater ponds, we compared two model scenarios to identify the specific drivers of anoxia in these ponds. The first using the measured pond bathymetry and default mixing, light, water and sediment chemistry conditions representative of MN lakes. The second scenario we made the following modifications to better match the stormwater ponds:

1. Changing the SOD and BOD to represent values from literature and observed conditions.
2. The wind was turned off and the light attenuation was turned up to simulate duckweed cover. At this time, there is no way to turn off gas exchange all together, but without the wind it certainly decreases the gas exchange significantly.

4.3 MODEL RESULTS

The results from the default settings show what we would suspect for a shallow freshwater system such as a pond: a non-stratified (well mixed) system with high DO (Figure 4-1 and 4-2). However, the field observations show the opposite: stratification observed throughout the season and low DO concentrations. The second modeled dissolved oxygen is much closer to that observed in the ponds.

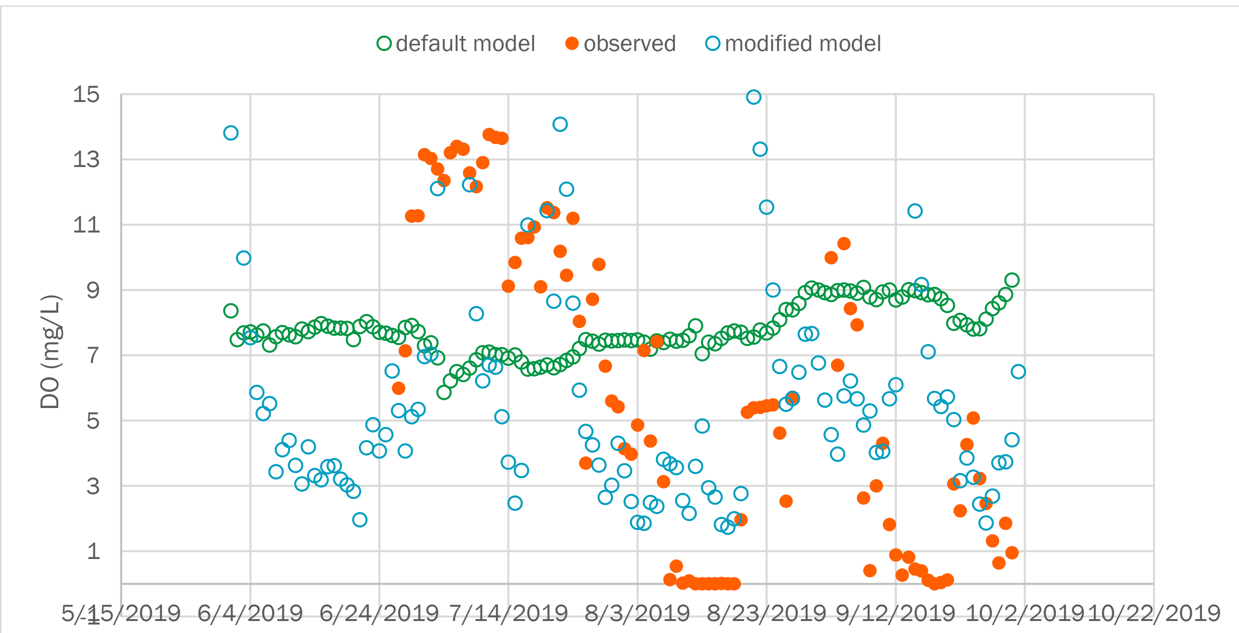


Figure 4-1: DO time series at the surface at the sample collection site for the non-duckweed pond 19-11-B

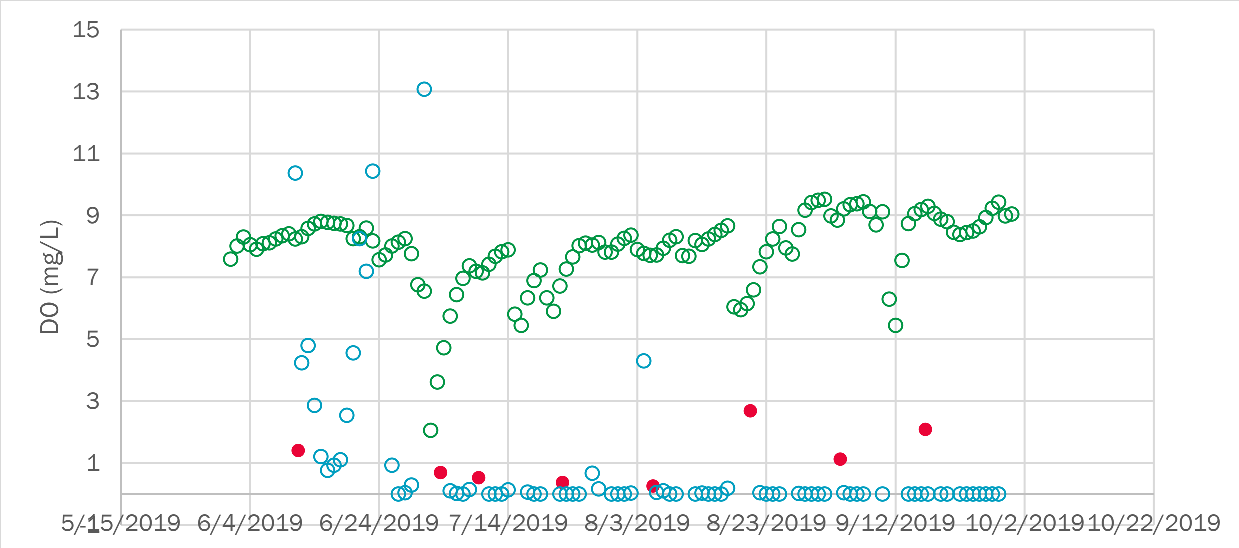


Figure 4-2: DO time series at the surface at the sample collection site for the duckweed pond 07-43-A

4.4 MODEL CONCLUSION

BOD and SOD

Adjusting the BOD and SOD to observed (BOD) and literature (Taguchi et al 2020) has decreased the DO such that it matches the observed low DO conditions fairly well (the model is not able to resolve all of the temporal variations).

Mixing

For both the duckweed covered and non-duckweed covered ponds, wind sheltering was the only parameter that would allow the model to match the stratification in DO and temperature.

Overall, the model results show that stormwater ponds are susceptible to anoxia because of high biological oxygen demand (BOD) and the lack of mixing. Lack of mixing allows the low DO created from the high BOD and SOD to persist near the sediments. In some cases, the entire water column is depleted of DO, especially in the case of ponds with duckweed cover. The presence of duckweed is a symptom of high nutrients and lack of mixing, but the duckweed also acts as a positive feedback for low DO because of the lack of gas exchange with the atmosphere and the suppression of light which blocks primary production (DO pumps) within the pond.

5.0 Pond Phosphorus Cycling

5.1 POND WATER QUALITY

Phosphorus

Total phosphorus (TP) concentrations in the ponds were highly variable throughout the monitoring season. Average surface TP was moderate in all of the ponds, however maximum concentrations were often above 0.4 mg/L. Bottom TP concentrations were high in all of the ponds with maximum concentrations exceeding 500 ug/L in most ponds and 1 mg/L in two of the ponds. The differences in bottom and surface TP demonstrates that active sediment P release is often occurring. See Appendix C for sediment chemistry data.

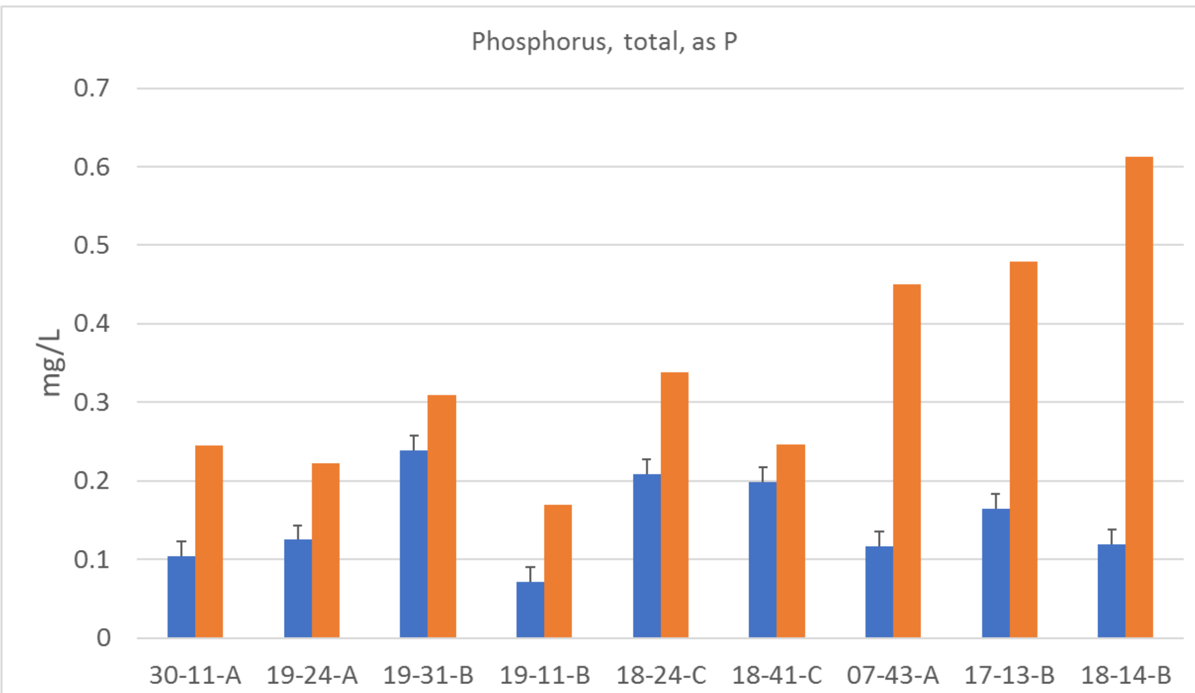


Figure 5-1: Total phosphorus at the surface (blue bar) and bottom (orange bar) for each of the monitored ponds in 2019.

Algal Production

As a result of the high TP concentrations, all the ponds were highly productive for algae with most ponds' average chlorophyll-a concentrations exceeding 50 ug/L. The least productive ponds often demonstrated high phosphorus concentrations but were covered in duckweed preventing algal production. For water quality sedimentation purposes, algal production can enhance the uptake and settling of available phosphorus. However, phosphorus that is included in the sediments as dead algal cells is often highly susceptible to recycling due and increases sediment oxygen demand.

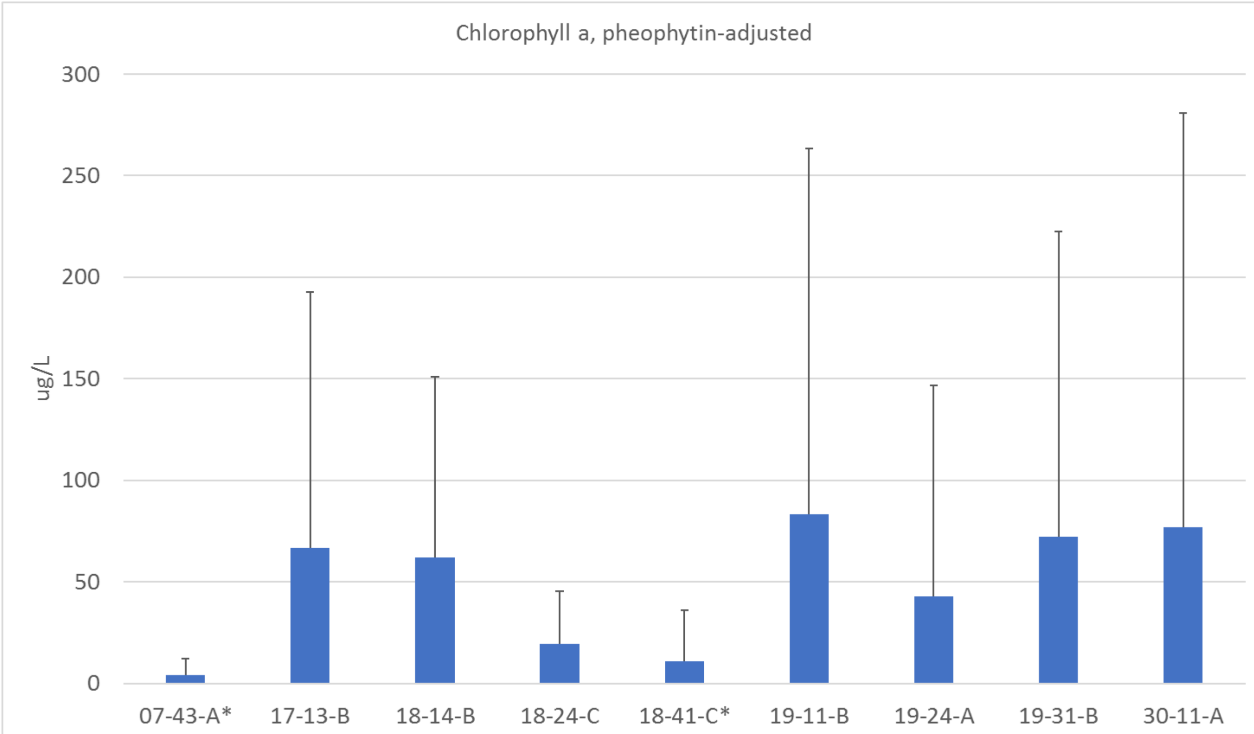


Figure 5-2: Chlorophyll-a concentrations in the monitored ponds.

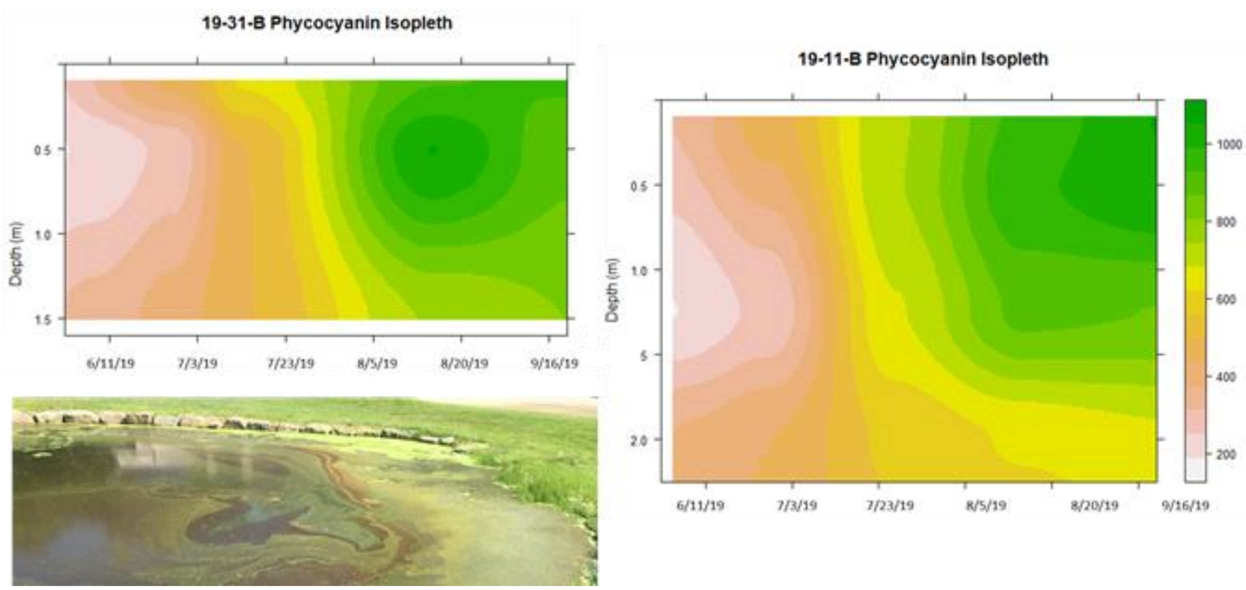


Figure 5-3: Phycocyanin time series contour plots for two ponds throughout the summer of 2019.

In addition to the DO profiles, phycocyanin profiles were also measured every two weeks. Phycocyanin is the photosynthetic pigment specific to cyanobacteria. Several of the stormwater ponds studied in the summer of 2019 experienced cyanobacteria blooms throughout the summer. Cyanobacteria take advantage of calm warm stratified nutrient rich water. This evidence supports the assertion that stormwater ponds present the perfect conditions for cyanobacteria blooms. More studies must be conducted to determine the extent of harmful algal blooms in stormwater ponds and the risk they pose to public health and lake water quality.

5.2 DISSOLVED OXYGEN

Continuous DO profiles were not available for calculating the anoxic factor for each of the ponds due to inconsistencies in the data collected from the continuous monitoring probes. Therefore, the bi-weekly DO profiles were used to calculate the AF for each of the ponds.

Regardless of the level of sheltering or pond size (Table 5-1), all of the ponds demonstrated significant anoxia through the summer monitoring period (Figure 5-4). The two highly sheltered ponds with heavy duck weed coverage were anoxic throughout the water column for the entire monitoring period (Figure 5-4). The remaining ponds varied, with most ponds demonstrating anoxia for more than 50% of the potential AF. The two ponds with the lowest amount of anoxia were the two smallest ponds that were only partially sheltered.

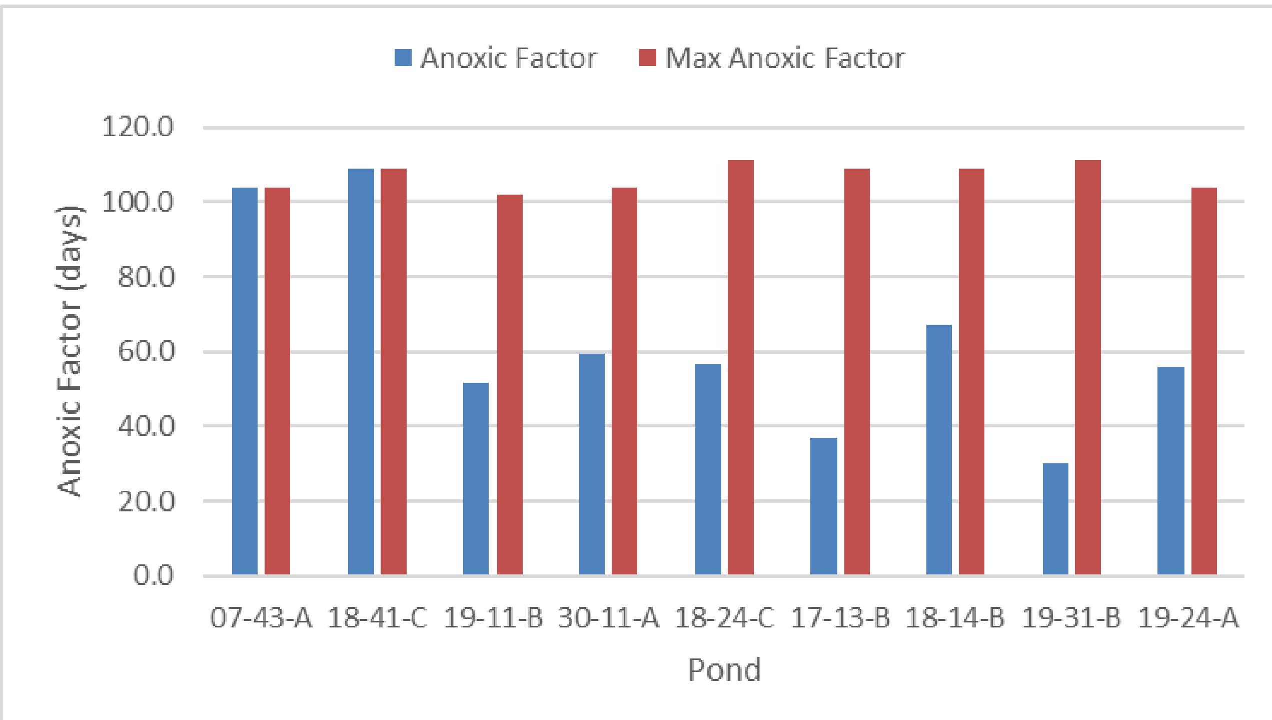


Figure 5-4: Anoxic factors using routine bi-weekly DO profiles for the ponds. Ponds are ordered from most sheltered to least sheltered.

Table 5-1: Pond characteristics related to dissolved oxygen and mixing dynamics.

Pond ID	Basin Type	SA (acres)	Ave Depth (feet)	Sheltered
07-43-A	CP	0.4	5.2	Yes
18-41-C	CP	0.4	1.8	Yes
19-11-B	SW	8.1	4.6	Somewhat
30-11-A	CP	1.0	5.2	Somewhat
18-24-C	SW	0.8	2.5	Somewhat
17-13-B	SW	0.5	3.5	Somewhat
18-14-B	SW	2.0	3.4	Somewhat
19-31-B	CP	0.7	2.8	No
19-24-A	SW	1.0	3.3	No

5.3 SEDIMENT PHOSPHORUS RELEASE

Internal loading is typically the result of accumulated organic sediment releasing phosphorus to the water column. This often occurs when anoxic conditions are present, meaning that the water in and above the sediment is devoid of oxygen. Over time, basins tend to accumulate phosphorus in their bottom sediments. One of the primary bonds for phosphorus is with iron. Phosphorus bound to iron in the sediments is of limited availability for use by algae and plants. When oxygen is depleted near the sediment surface (water concentration less than 2.0 mg/L), the phosphorus-iron (FeOOH-PO4) bonds are broken, releasing dissolved phosphorus into the water column. The phosphorus released through this process is in a dissolved form that is readily available to algae and plants. Thus, anoxic conditions near the sediment tend to result in a release of phosphorus that can fuel the growth of algae and aquatic vegetation.

5.4 POND PHOSPHORUS CYCLING

P8 models were available from the City of Eden Prairie for the three focal watersheds in this study. Using a mass balance approach, each of the ponds were assessed for net phosphorus retention when including sediment P release. All the ponds were net sinks of P even when including sediment phosphorus release (Figure 5-5). However, the overall efficiency of the ponds was reduced (Figure 5-6). Further, released phosphorus is often in a highly reactive dissolved form which can bypass downstream ponds or more readily cause eutrophication in downstream receiving waters. Only one pond was close to being a net phosphorus exporter (19-11-B)..

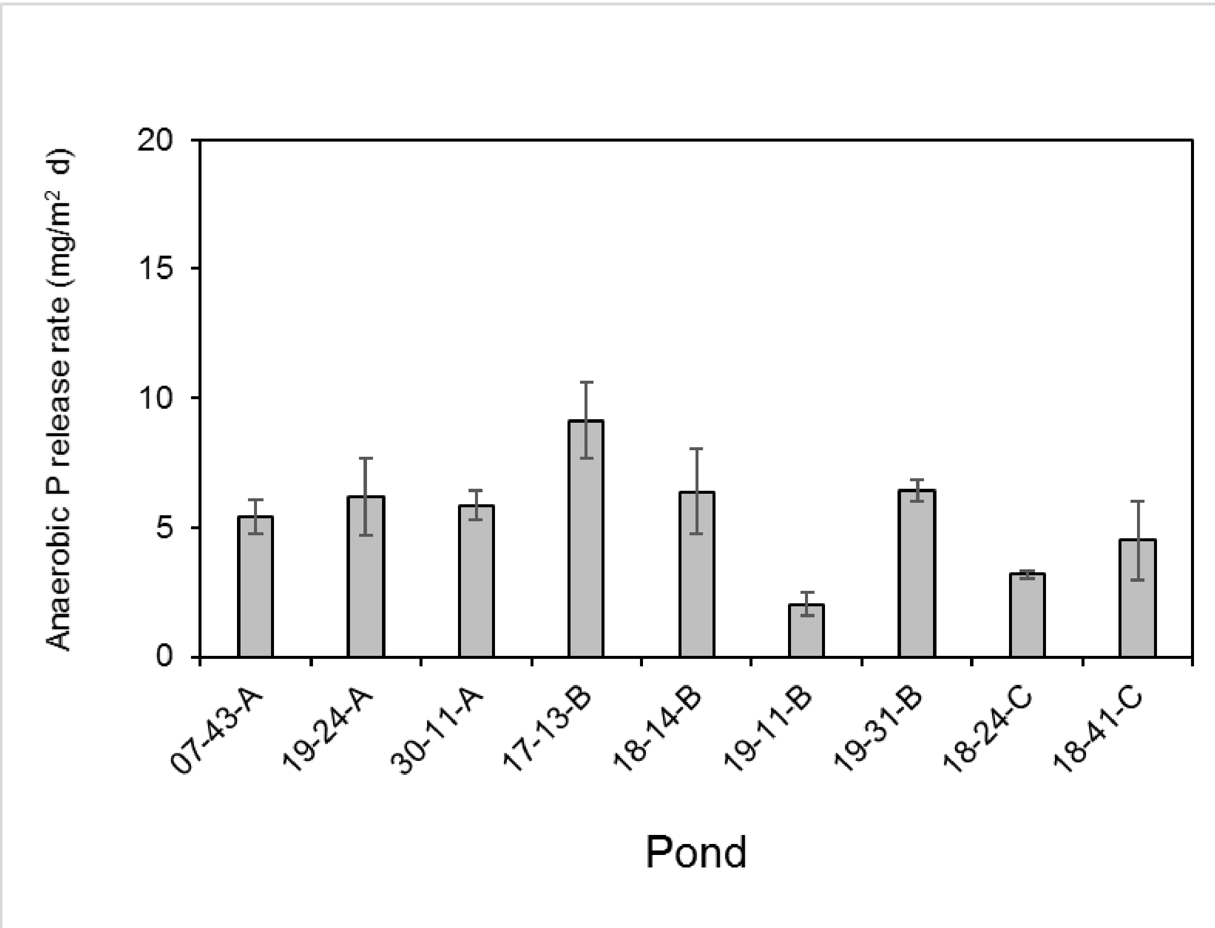


Figure 5-5: Sediment P release in the monitored ponds.

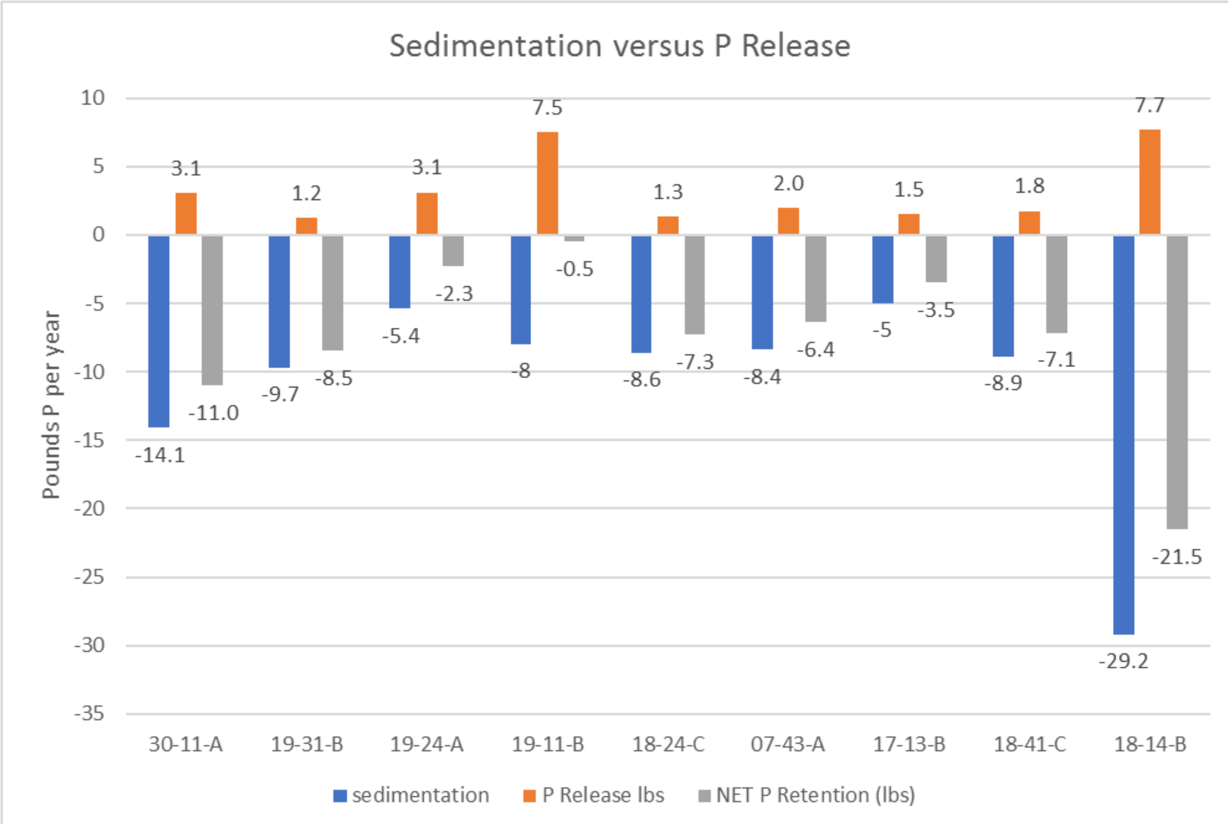


Figure 5-6: Mass P flux through the monitored stormwater ponds using P8 and measured sediment P release.

While the ponds remained effective BMPs for retaining watershed phosphorus, sediment phosphorus release reduced the efficiency of these ponds (Figure 5-6). In two cases, the phosphorus retention efficiency was reduced by more than 50%. These ponds were acting as transformers of phosphorus, releasing particulate phosphorus as dissolved P which is more difficult to capture with traditional watershed BMPs.

5.5 WATERSHED P CYCLING

To assess the overall watershed efficiency of these ponds, average anoxic factors and release rates were applied to all of the ponds in each of the three focal watersheds. It should be noted that not all of the ponds are open water where sediment phosphorus release as measured in this study are expected to occur. However, wetlands have been demonstrated to be effective sources of phosphorus in watersheds and were therefore included in the watershed analysis. Further study is needed on the extent and magnitude of phosphorus release from wetlands that receive stormwater.

Using the previously described methods, all three watersheds demonstrated the potential for significant reduction in phosphorus retention as a result of sediment phosphorus release (Figure 5-7). For the Mitchell Lake watershed, sediment phosphorus release was small enough to have only a minor impact on overall phosphorus retention. In contrast, the eastern Lake Riley watershed has the potential to be net exporter of phosphorus to Lake Riley. This is likely a result of the high proportion of the watershed that is either ponded or wetland. These saturated areas have a high potential for anoxia and release of P bound in their sediments. The Rice Marsh Lake watershed impacts were more muted than the Lake Riley watershed but still reduced watershed P retention potential by more than 50%.

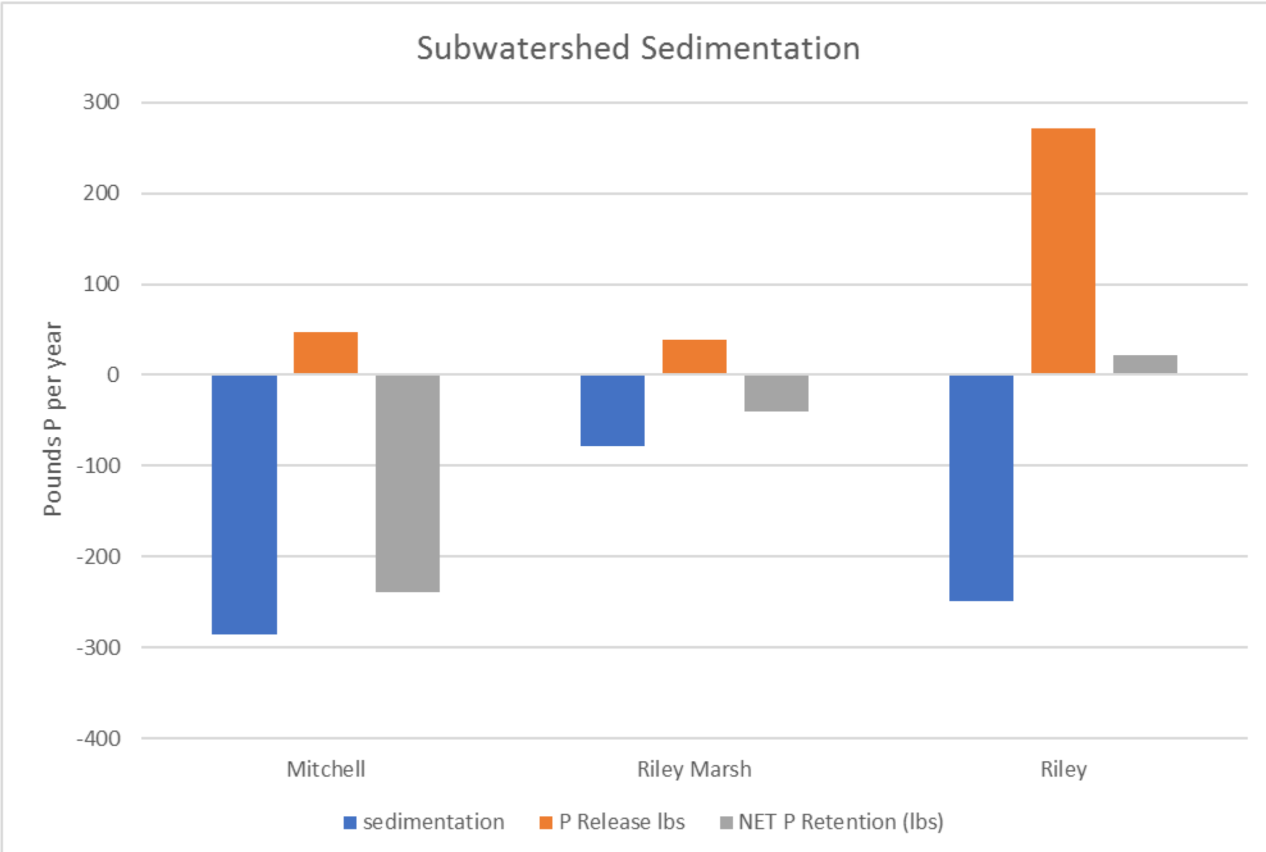


Figure 5-7: Watershed P retention potential based on P8 model results and average sediment P release.

6.0 Conclusions and Recommendations

6.1 SUMMARY

Using measured sediment P release and P8 estimated settling, all of the ponds in the study demonstrated net retention of P, albeit at a reduced rate when factoring in sediment sources of P. When these factors were applied at a watershed scale, watershed P retention was reduced by as much as 50% and the Lake Riley watershed actually has the potential to be a net source of P even when accounting for all of the P sedimentation in the watershed. Based on these results, addressing sediment P release in the watershed will improve the efficiently of the stormwater

6.2 PRIORITY PONDS

Priority ponds were developed for each of the watersheds to improve the P retention efficiency of the stormwater system. Ponds that had the largest potential mass P release when average anoxic factors and P release rates were applied were selected for potential improvements. Ponds that did not have significant open water were screened out for potential BMPs. While these ponds/wetlands still have a large capacity to release P, there are few BMPs currently available for addressing these sources. As expected, the largest water bodies have the highest potential for releasing a large mass of P due to the large sediment surface area. In most cases, more than 75% of the released P load could be addressed by restoring P retention in ponds greater than 2 acres in size.

It should be noted that the assumed mass discharge is based on averages and actual sediment release and anoxia should be verified.

Rice Marsh Lake

There are 3 priority ponds in the Rice Marsh Lake watershed that have a potential mass P load of approximately 23 pounds of P from the sediments (Figure 6-1) (Table 6-1).

Table 6-1: Priority Ponds from Rice Marsh Lake.

Basin ID	Area (Ac)	P8 TP Removal (%)	Sediment P load (pounds)
18-31-B	3.1	30	9.7
18-44-H	2.3	67	7.2
18-43-B	1.8	69	5.6

Lake Riley

The Lake Riley watershed has the greatest need for sediment P release reductions because the high number of open water ponds and wetlands. While the duration of anoxia should be verified, four of the pounds have the potential for very high mass P loads because of their size (Figure 6-1) (Table 6-2).

Table 6-2: Priority Ponds from Lake Riley.

Basin ID	Area (Ac)	P8 TP Removal (%)	Sediment P load (pounds)
19-41-D	8.2	22	25.8
19-11-B	8.1	30	25.3
19-13-A	7.4	24	23.3
20-32-A	3.6	43	11.4
19-44-B	2.1	96	6.7
30-12-A	2.1	49	6.5
19-22-A	1.7	28	5.4
19-44-C	1.7	16	5.3
19-14-B	1.4	34	4.3
30-11-A	1.0	56	3.2
18-44-B	3.8	96	11.8
19-24-A	1.0	14	3.2

Mitchell Lake

The Mitchell Lake watershed had the lowest potential for sediment P release and only 4 ponds were candidates for controlling sediment P release (Figure 6-2) (Table 6-3).

Table 6-3: Priority Ponds from Mitchell Lake.

Basin ID	Area (Ac)	P8 TP Removal (%)	Basin Type[2]	Sediment P load (pounds)
18-14-B	2.0	26	SW	6.2
18-41-A	1.5	45	SW	4.7
17-13-A	1.4	63	SW	4.4
18-12-B	1.4	32	SW	4.3

Figure 6-1: Riley and Rice Marsh Lake Watershed recommended ponds

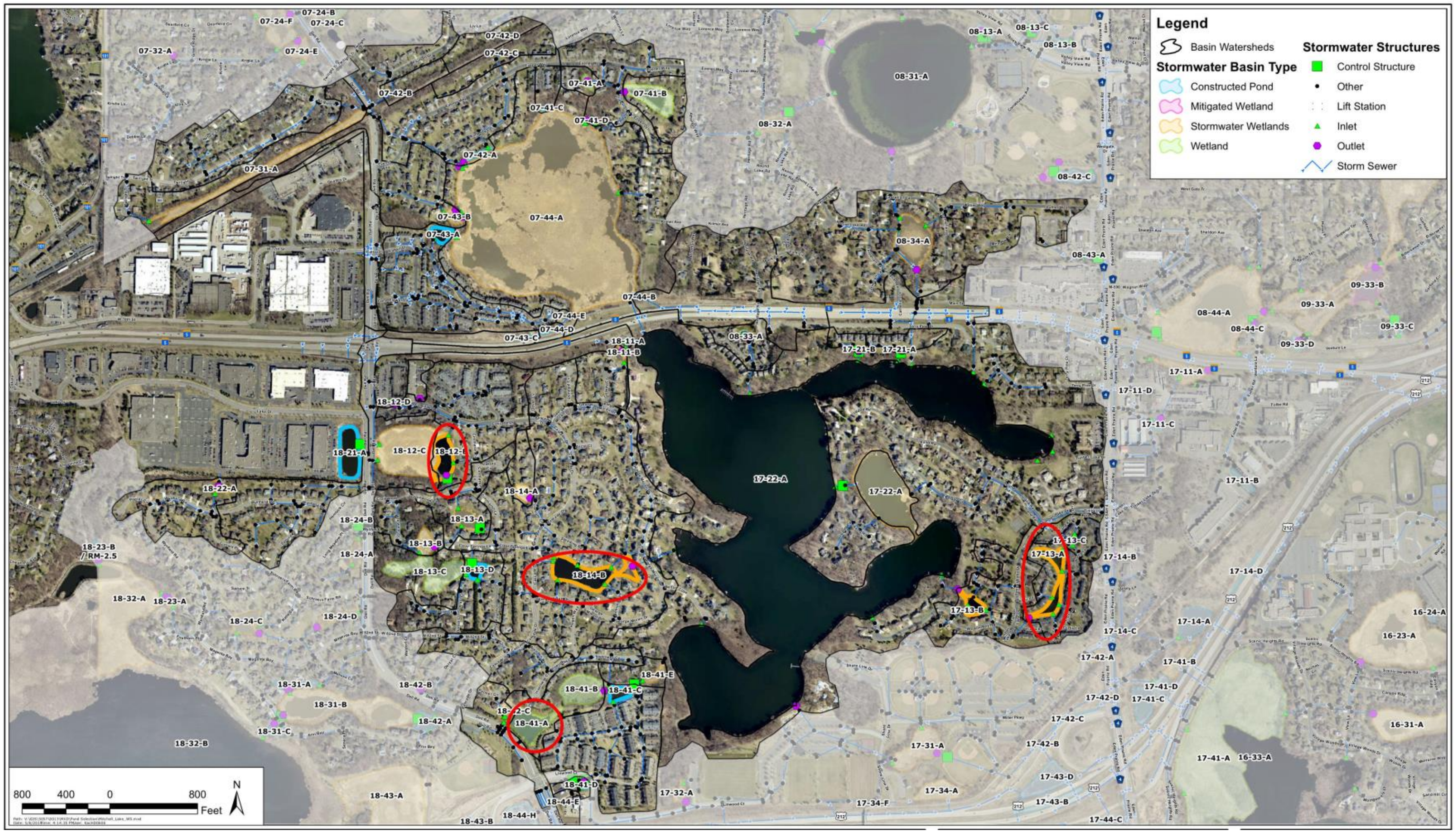


Figure 6-2: Mitchell watershed recommended ponds

6.3 MANAGEMENT OPTIONS AND RECOMMENDATIONS

There are numerous management options to address sediment P release in ponds. Following is a brief description of each of the methods. Some of these techniques can be combined. For example, a light alum or iron dose along with aeration may be effective at minimizing sediment P release. In our experience, the most cost-effective approach is the use of alum to inactivate sediment P.

Pond Aeration

For ponds that are near homes, seen as amenities or have bad odor issues, aeration is a potential solution. However, there are many failed attempts at aeration in ponds due to undersized systems or erratic system behavior. Aeration requires a power source and maintenance, so only ponds with easy access are potential candidates. Due to these restrictions, Wenck does not recommend pursuing this approach unless there is a willing homeowner or association willing to maintain the system.

Excavation

Basin expansion attempts to remove sediments that are high in P concentrations, However, this can be a difficult task in that P is often high quite deep into the sediment profile. In those cases, redox sensitive P will remain at the surface and internal P loading will continue to occur. If a pond is particularly undersized, it could be expanded and then line with an engineered soil that is low in redox-P. This approach is experimental and can be quite expensive.

Pond Filtration

Water leaving a pond can be filtered with BMPs such as iron enhanced sand filters to strip P out of the water column. Past basin inventory studies identified basins 19-41-D,19-13-A,19-44-C,19-14-B (also recommended in the UAA), and 19-24-A as having low TP efficiency. The basin inventory studies recommended the addition of an iron enhanced sand filter to help improve the TP efficiency for their treatment trains. This technique is effective if there are a number of upstream ponds with high internal loads that are difficult to address. However, iron enhanced sand filters are often expensive and using it for a high internal P load pond just transfers the P from the sediments to the filter, significant reduction the life of the filter. In these cases, Wenck often recommends using alum on the pond thus allowing the filter to address soluble P from upstream sources.

Sediment P Inactivation

This study combined the efforts of modeling and monitoring to identify stormwater ponds with the potential for internal loading within three watersheds. The other management strategies outlined above can be effective for improving sedimentation efficiency however the most effective tool for reducing sediment P release is sediment P inactivation. While there are a number of chemicals that can inactivate sediment P, the most commonly used is aluminum sulfate, often called “alum”. The cost of a stormwater pond alum treatment is estimated to be about $4,000/acre based on past alum applications. Cost estimates were developed for high priority ponds (Table 6-4).

Table 6-4: Alum applications area and probable cost estimate.

Basin ID	Area (Acres)	Sediment P load (pounds)	Applied Alum costs
18-31-B	2.48	9.7	$9,920
18-44-H	1.84	7.2	$7,360
18-43-B	1.44	5.6	$5,760
19-41-D	6.56	25.8	$26,240
19-11-B	6.48	25.3	$25,920
19-13-A	5.92	23.3	$23,680
20-32-A	2.88	11.4	$11,520
19-44-B	1.68	6.7	$6,720
30-12-A	1.68	6.5	$6,720
19-22-A	1.36	5.4	$5,440
19-44-C	1.36	5.3	$5,440
19-14-B	1.12	4.3	$4,480
30-11-A	0.80	3.2	$3,200
18-44-B	3.04	11.8	$12,160
19-24-A	0.80	3.2	$3,200
18-14-B	1.60	6.2	$6,400
18-41-A	1.20	4.7	$4,800
17-13-A	1.12	4.4	$4,480
18-12-B	1.12	4.3	$4,480

Stormwater Pond Alum Treatment Consideration

Overall, alum applications to stormwater ponds are a relatively new application of this technology. The application to stormwater ponds presents unique challenges including:

1. Due to the restricted access to these sites, equipment mobilization costs are higher because of the need for additional equipment for deployment and remove of application equipment (i.e., tow trucks, specialty trailers, etc.).
2. Restricted access increases the manual labor cost to carry equipment safely to the site.
3. Restricted access also will require more site restoration which will increase the cost.
4. The freight cost is higher than for larger dose sites because the small doses for these sites require only partial truckloads. The supplier charges higher freight cost to compensate for selling less material.
5. The multiple locations require multiple drops of material each with an additional fee.
6. Multiple drops mean the material will be sitting onsite unattended so security measures must be put in place to protect the material after it is delivered onsite
7. The multiple locations also require more labor for setup, deployment, and take down at the different locations.
8. Due to the small surface area and basin depth unique equipment is required (including smaller boom, pumps, motors, and other items).
9. This equipment applies at a much slower rate than in a larger basin and thus the application time is substantially longer.

7.0 Mitchell Lake Sediment Assessment

Another part of this study is to determine the feasibility of an alum treatment for Mitchell Lake.

7.1 MITCHELL LAKE HISTORIC DATA

Mitchell Lake Watershed Basin Inventory and Maintenance Assessment – Phase V report included a BATHTUB model to determine the P budget for Mitchell lake. In 2016, Mitchell lake was not on the 303-D list but was considered a protection lake for phosphorus. Although annual TP concentrations appear to be meeting water quality standards (60 µg/L), internal loading appears to be causing elevated surface TP concentrations during the late summer and early fall. Typically, lakes with high internal loads demonstrate a steady increase in total phosphorus throughout the summer with phosphorus concentrations peaking in the late summer or early fall as the water column breaks down and P-rich bottom water mixes with surface waters. This trend was observed nearly every year from 2008 to 2014 (Figure 7-1) even though there have been improvements in water quality. These data suggest that internal phosphorus loading is likely causing unsightly algal blooms during late summer months in Mitchell Lake.

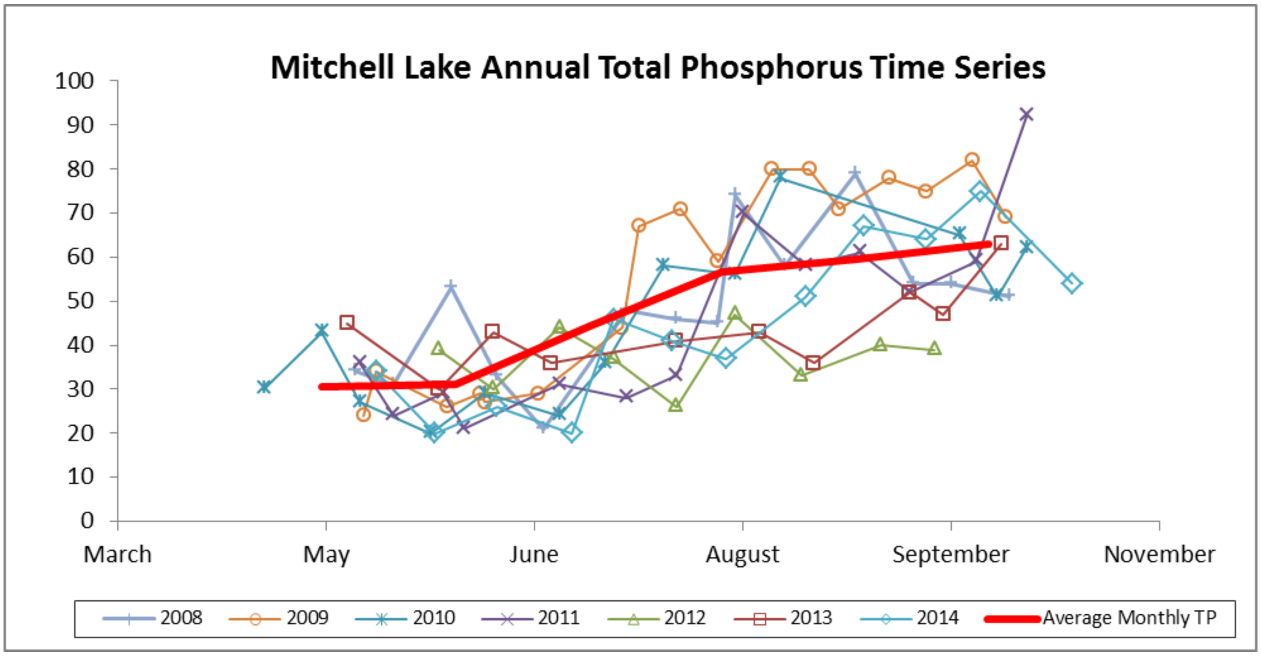


Figure 7-1: Mitchell Lake Total Phosphorus Growing Season Time Series for Recent Years (2008-2014). The red line represents the monthly average total phosphorus concentration from 2008-2014 in Mitchell Lake.

7.2 ESTIMATING INTERNAL PHOSPHORUS LOAD

As described earlier, P release from the sediment is controlled by two factors: anoxic conditions near the sediment/water interface and the sediment phosphorus release rate. In order to determine the extent of anoxia in Mitchell Lake, DO profiles were analyzed from 2000, 2003, 2009, 2010, and 2016. Using these profiles, AFs were calculated to estimate the number of days that Mitchell Lake's surface area is overlain by anoxic water. Based on this analysis, the average anoxic factor for Mitchell Lake is 12.1 days (Table 7-1).

Table 7-1: Historic Dissolved Oxygen Profile Data Summary

Year	Summer growing season profiles (count)	Profiles Demonstrating DO < 2.0 mg/L (count)	Average depth DO < 2.0 mg/L (ft)	AF (days)
2000	12	7	4.18	3.7
2003	11	4	4.86	4.0
2009	21	20	4.25	24.9
2010	7	7	4.76	21.1
2016	6	5	4	6.9

Sediment phosphorus release rates were measured in the laboratory by collecting intact sediment cores (see Appendix A for methods). A preliminary sediment core was taken to inform the P budget. Sediment cores from one location (Station 1) were sampled in 2014 as part of the original study (Figure 7-2). These cores showed an average anaerobic release rate of 2.9 mg/m^2/day. Subsequently, in 2019, sediment cores were collected from 4 additional stations as part of this study. Results of these analysis indicate sediment P release ranges from 3.1 – 5.9 mg/m^2/day (Figure 7-3).

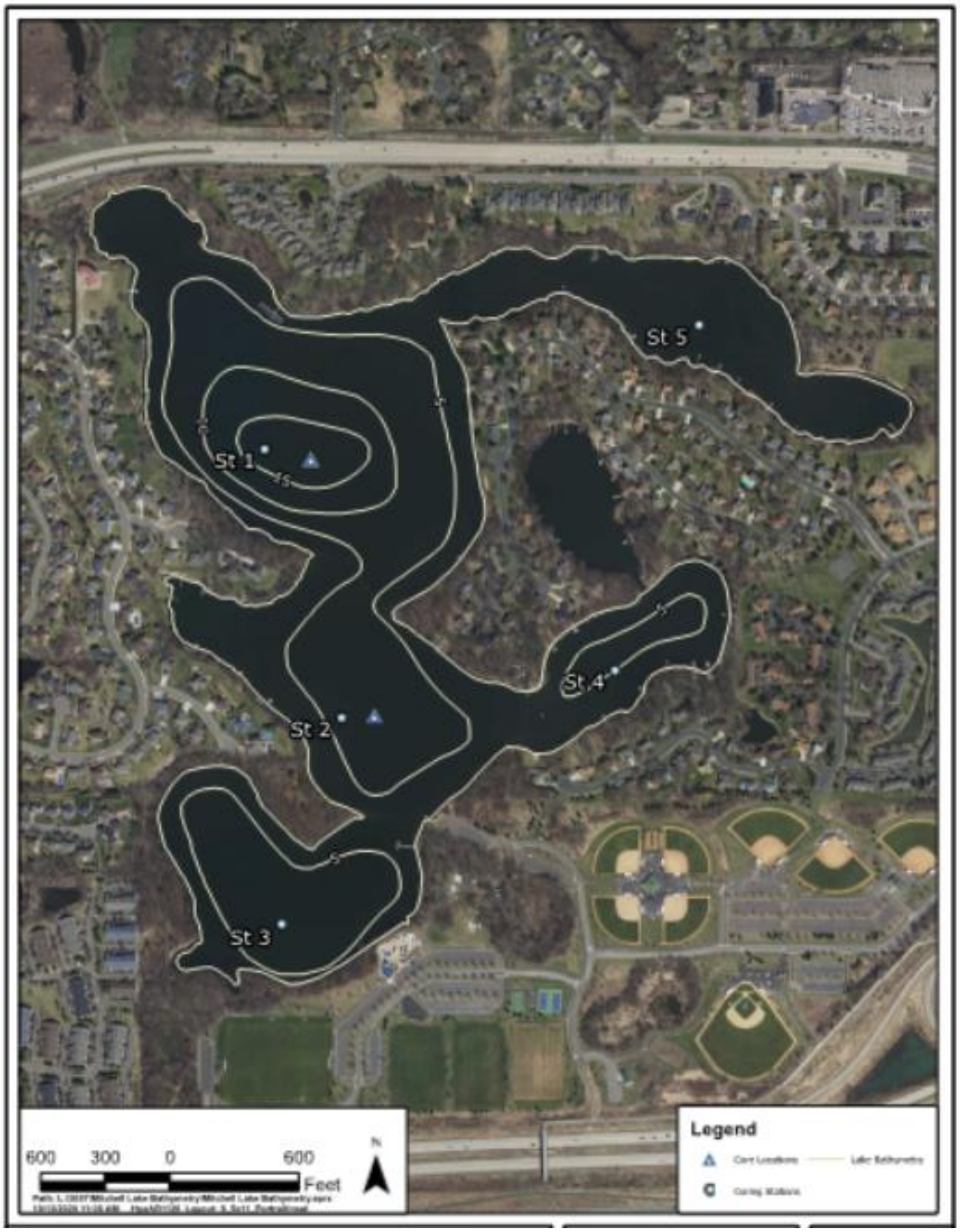


Figure 7-2: Mitchell Lake sediment coring locations.

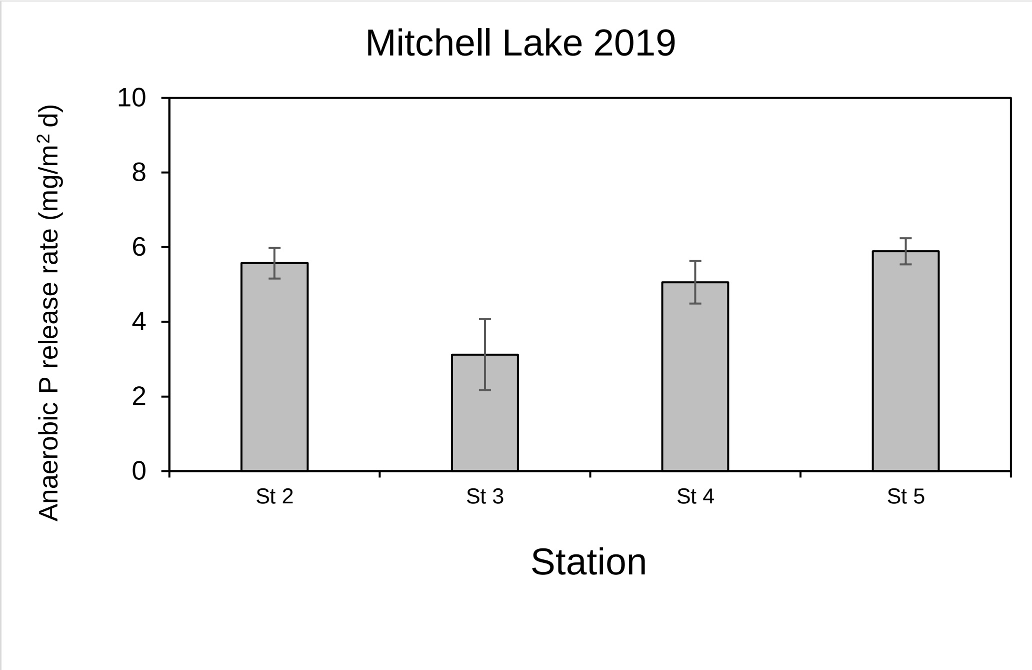


Figure 7-3: Sediment phosphorus release rates for Mitchell Lake

7.3 MITCHELL LAKE PHOSPHORUS BUDGET

Mitchell Lake Watershed Basin Inventory and Maintenance Assessment – Phase V report included a BATHTUB model to determine the P budget for Mitchell lake. An average of the ten modeled years was used to develop an average total phosphorus budget for Mitchell Lake (Figure 7-4). Internal loading represents 21% of the total phosphorus inputs to Mitchell Lake with stormwater comprising 63% of the total phosphorus load. Although stormwater comprises nearly two-thirds of the total phosphorus budget, internal loading is still a significant portion of the total phosphorus budget. This is especially important during late summer (when watershed sources slow down) as shown in the data (Figure 7-1).

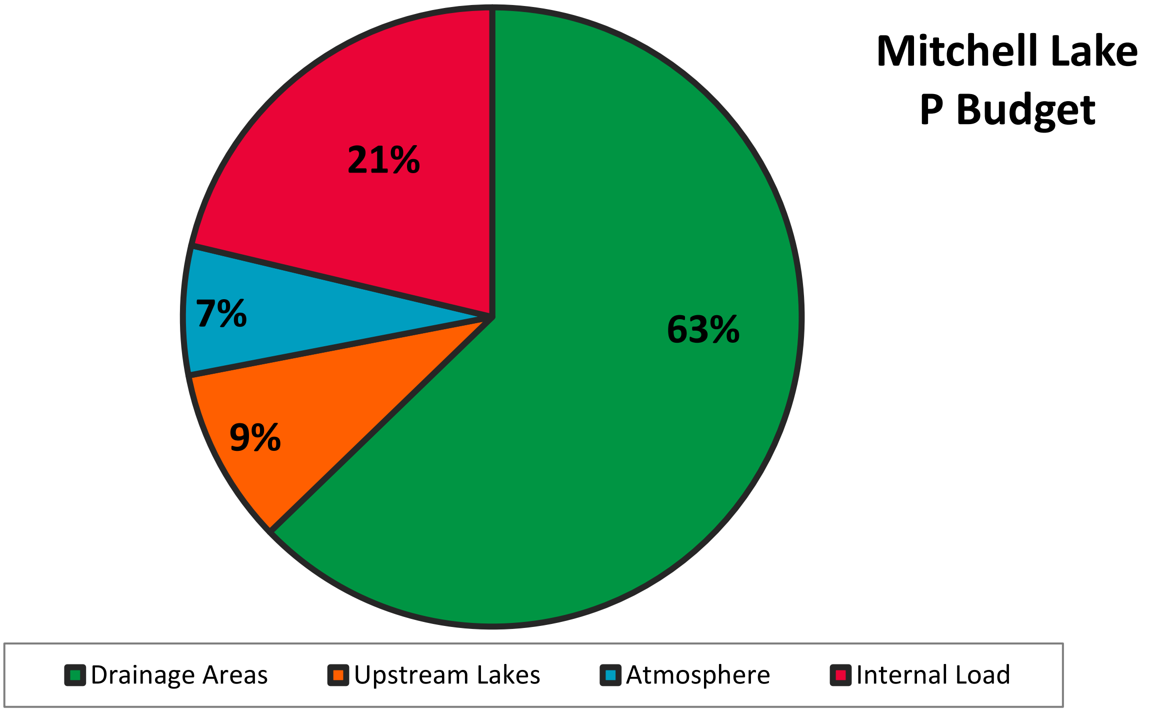


Figure 7-4: Mitchell Lake phosphorus budget (2016).

7.4 ALUM DOSING COSTS & RECOMMENDATIONS

Above we have presented multiple lines of evidence that internal loading is concern in Mitchell Lake:

1) Surface TP concentrations increase throughout the summer growing season and peak during late summer/fall turnover.
2) Sediment cores collecting from the deep site and several shallow sites indicate anaerobic sediment P release rates that exceed 1.0 $mg/m^2/day$.
3) DO profiles collected at the deep site suggest anoxic conditions at the sediment/water interface for prolonged periods of time during the summer.

Internal loading can be managed through sediment phosphorus inactivation. While there are a number of P inactivation agents available, alum treatments have proven to be cost-effective and very successful for managing sediment phosphorus release Thus, it is recommended that an alum treatment be pursued for Mitchell Lake.

There are three primary factors to consider when developing an alum dose to inactivate sediment phosphorus release:

1) The amount of aluminum to apply must be determined based on the mass of mobile sediment P.
2) The depth into the sediment profile to attempt to inactivate must be determined and is influenced by sediment density.
3) And finally, the area of the lake to be treated must be determined.

Based on the profiles collected at station 1, anoxia in Mitchell Lake occurs as shallow as 6 feet during peak summer stratification. It should be pointed out, however, that this expanse of anoxia is relatively short lived. The upper limit of anoxia is typically in the 10 to 15-foot range, based on the profiles collected at station 2. Therefore, at this time we recommend treating the area of Mitchell Lake greater than 10 feet in depth, 10.6 acres.

The sediment chemistry profiles from station 2 were used for the preliminary dosing because it is most representative of the application area and has the highest release rate. The mobile phosphorous is highest at station 2 in the top 6 cm of the sediment profile, this is also where the sediment is least dense. The alum dose calculations target the highest mobile phosphorus concentration to trap the greatest internal load potential with the alum treatment.

The amount of aluminum needed to inactivate sediment phosphorus was determined using a regression relationship between redox P and the required aluminum to phosphorus ratio needed to inactivate 90% of the surficial redox P (James and Bischoff 2015). The overall required dose for Mitchell Lake is presented in Table 7-2.

7.5 APPLICATION APPROACH

To provide the best outcomes for sediment activation, taking into account loss of aluminum binding efficiency over time and migration of alum floc, we recommend applying the whole alum treatment over two applications to achieve sediment targets (Table 7-2). The first half-dose application will be followed by sediment collection to determine progress toward sediment chemistry targets. Results of the sediment monitoring will allow adjustments as needed prior to the second application. Each application will take 2 to 4 days to complete.

Table 7-2: Alum quantities and costs for a dose treatment on Mitchell Lake

Item	Unit	Quantity	Unit Cost	Total Cost
Total alum application (10.4 acres; top 6 cm; 10-feet and deeper)				
Aluminum sulfate	Gal $Al_2(SO_4)_3$	18,131	$2.10	$38,075
Mobilization	Lump sum	2	$15,000	$30,000
Total application cost estimate				**$68,075**

8.0 References

Mitchell Lake Watershed Basin Inventory and Maintenance Assessment – Phase V (2016) Wenck Associates on behalf of the City of Eden Prairie, MN

Mitchell Lake Use Attainability Analysis http://www.rpbcwd.org/files/4414/9339/4880/LotusSilverDuckRoundMitchellRedRock-UAAUpdate_LakeIdlewildSt.pdf

Lake Riley and Rice Marsh Lake Subwatersheds Basin Inventory and Maintenance Assessment (2020) Wenck Associates on behalf of the City of Eden Prairie, MN

Rice Marsh Lake and Lake Riley: Use Attainability Analysis Update http://www.rpbcwd.org/files/4114/5332/1752/Riley_RiceMarsh_UAAUpdate_FINAL-012016_v1_combined_r.pdf

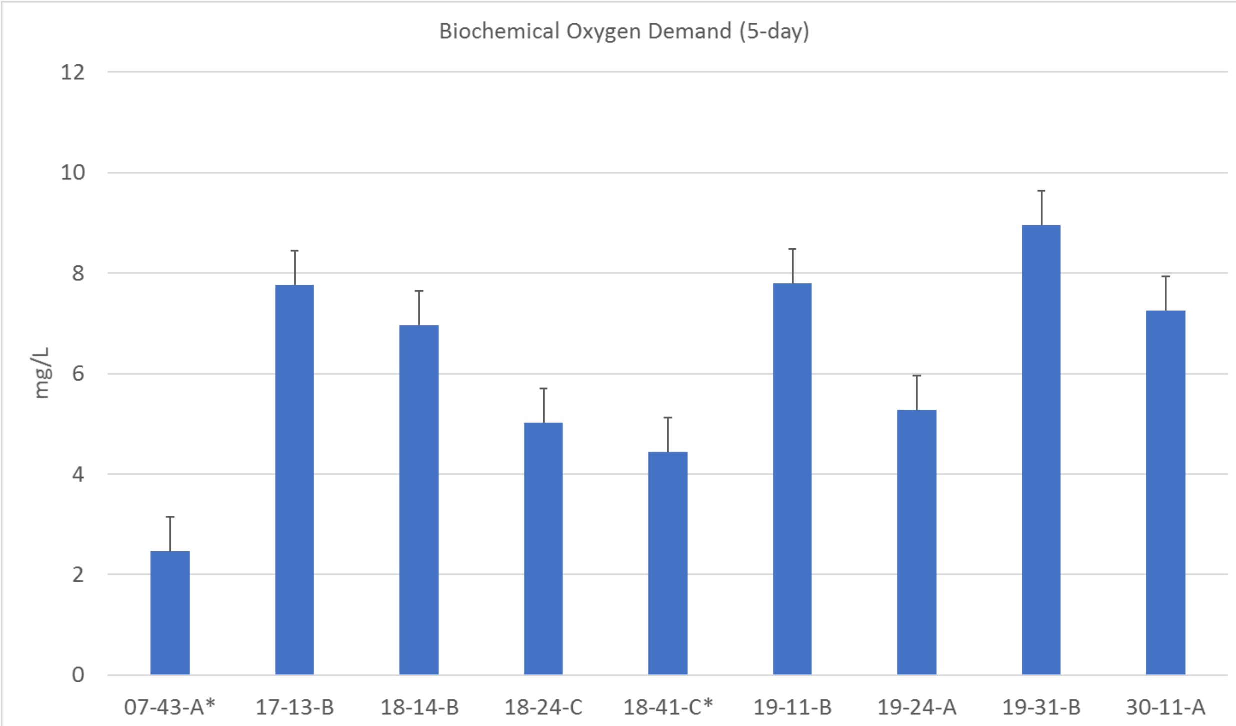
Taguchi, V. J., Olsen, T. A., Natarajan, P., Janke, B. D., Gulliver, J. S., Finlay, J. C., & Stefan, H. G. (2020). Internal loading in stormwater ponds as a phosphorus source to downstream waters. *Limnology and Oceanography Letters*, *5*(4), 322–330. https://doi.org/10.1002/lol2.10155

Appendix A: Sediment Coring Methods

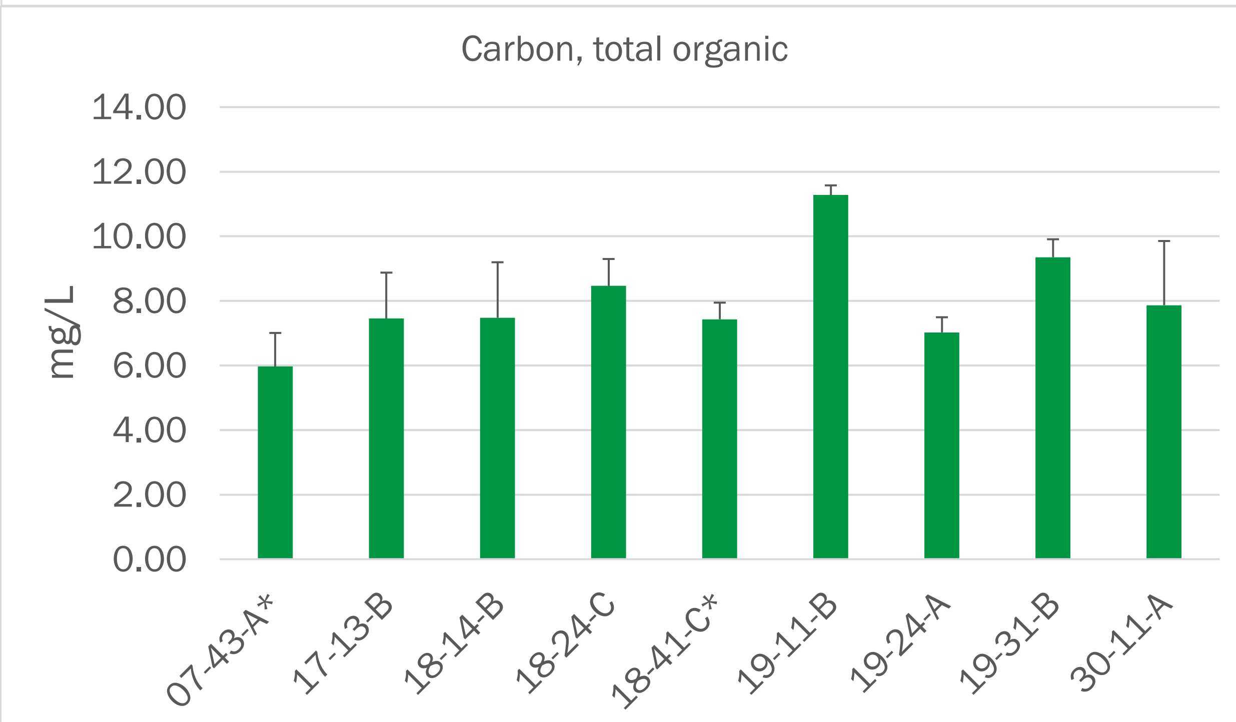
Field and Laboratory Methods

A gravity sediment coring device (Aquatic Research Instruments, Hope ID) equipped with an acrylic core liner was used to collect sediment cores. To evaluate physical, textural and chemical characteristics of sediment, one core from each location was sectioned vertically into the following six sections: 0 to 2 cm, 2 to 4 cm, 4 to 6 cm, 6 to 8 cm, 8 to 10 cm, 10 to 15 cm, and 15 to 20 cm. Three cores were also taken from each location to measure phosphorus release rates from sediment. These cores were incubated for 7 days at 20 to 25 degrees Celsius while phosphorus release was measured.

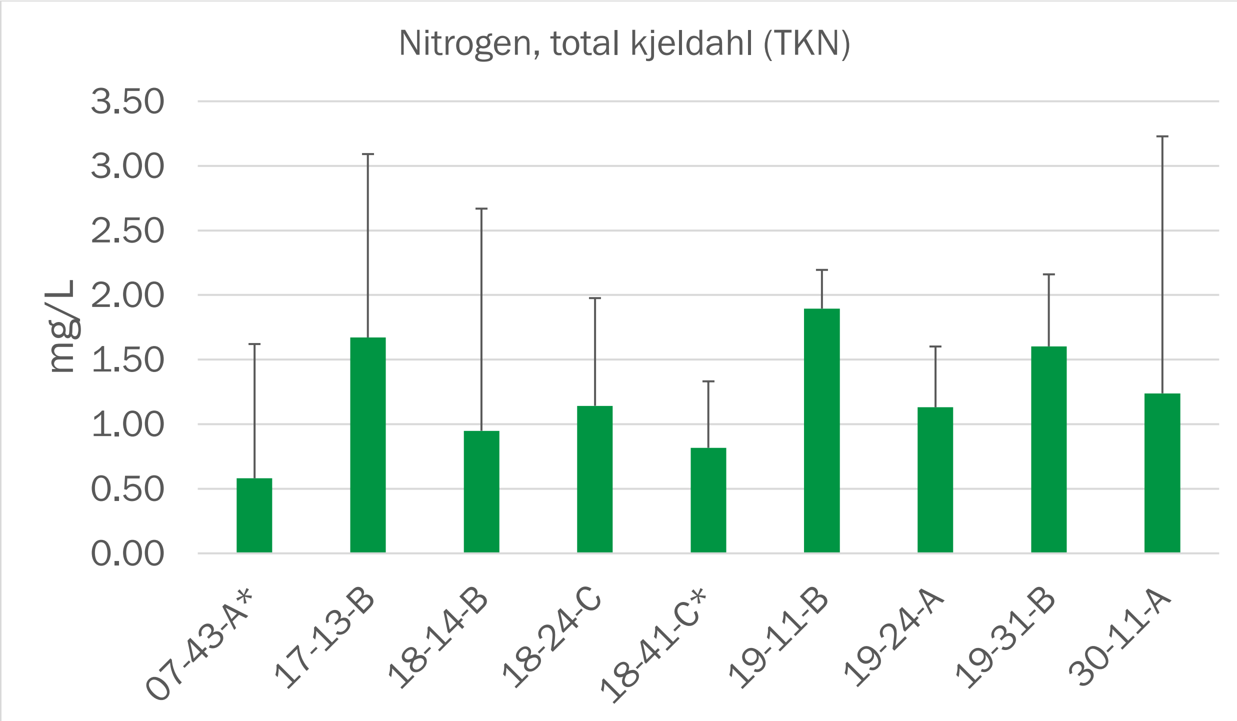
Appendix B: Pond Monitoring Data

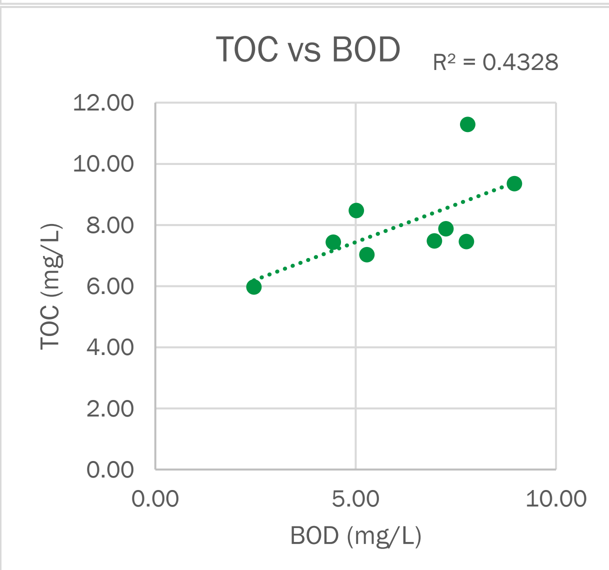


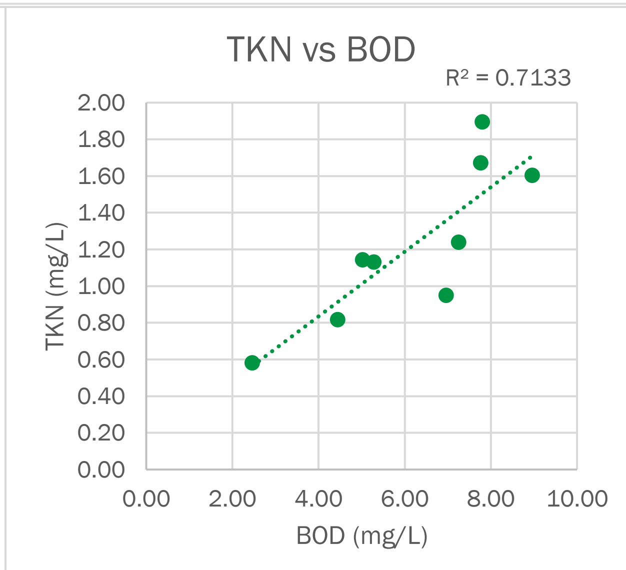
Biochemical Oxygen Demand (5-day)
mg/L
0
2
4
6
8
10
12
07-43-A*
17-13-B
18-14-B
18-24-C
18-41-C*
19-11-B
19-24-A
19-31-B
30-11-A

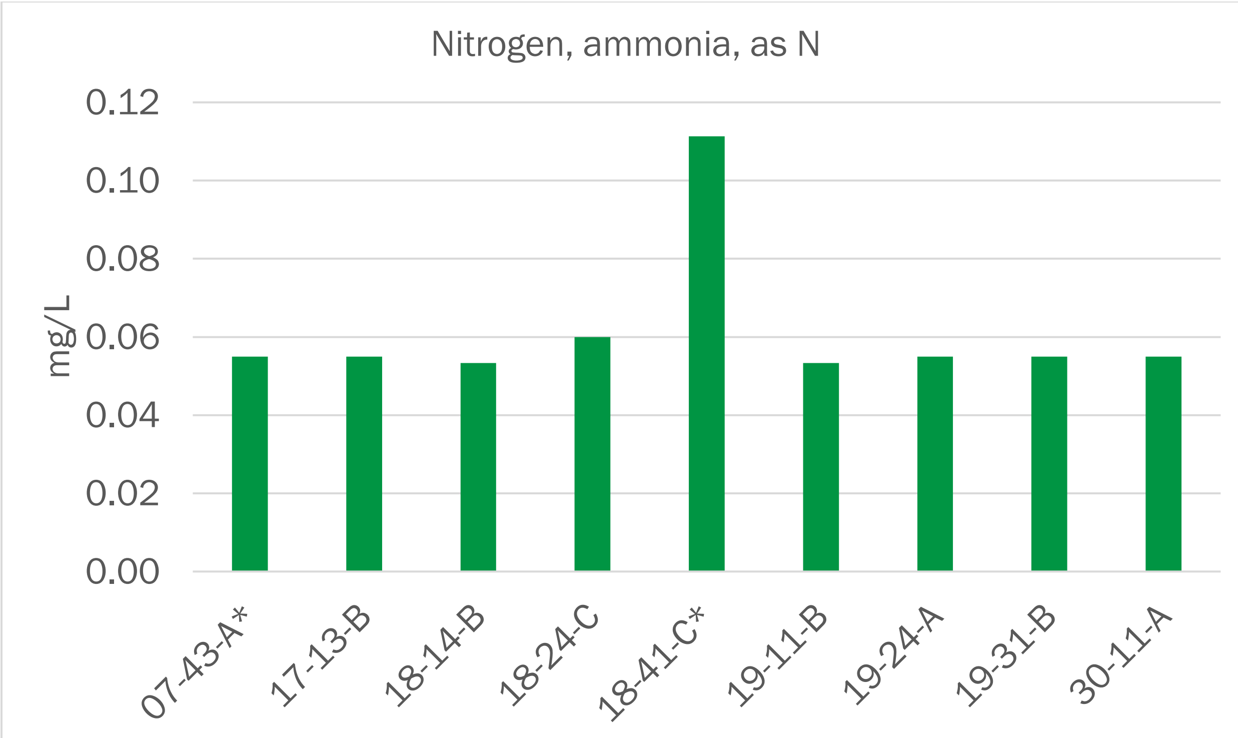


Carbon, total organic
mg/L
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
07-43-A*
17-13-B
18-14-B
18-24-C
18-41-C*
19-11-B
19-24-A
19-31-B
30-11-A

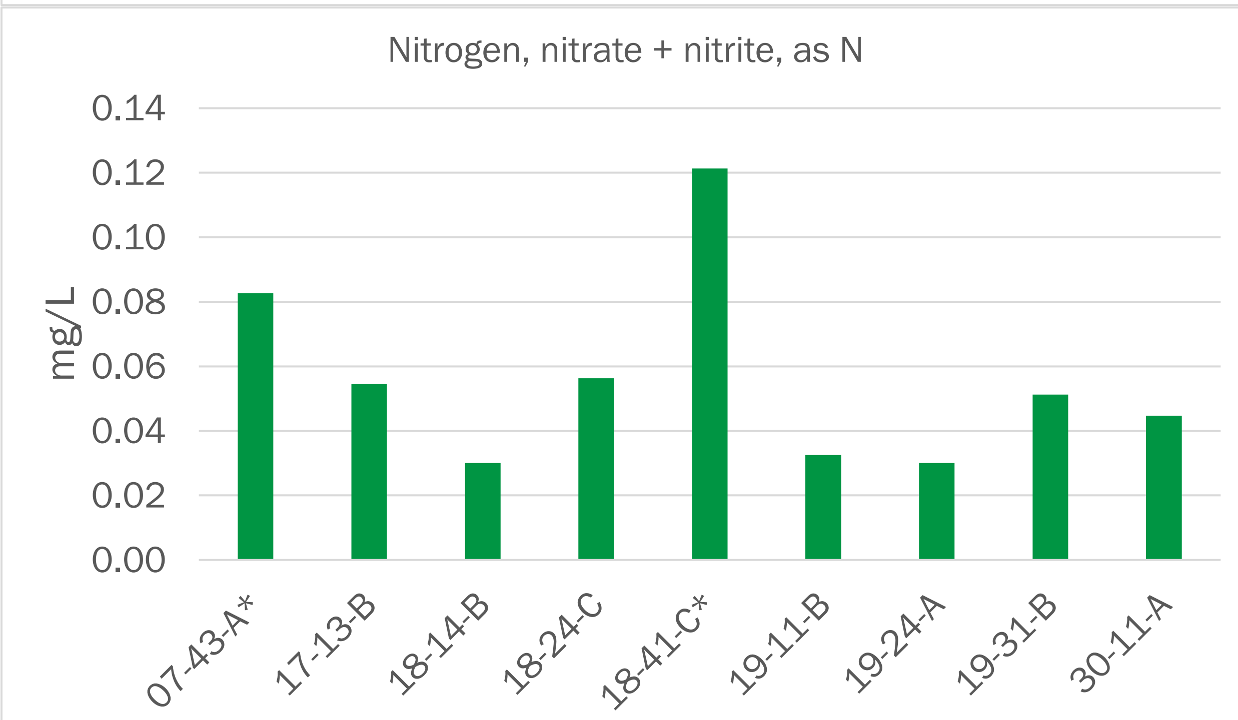

Nitrogen, total kjeldahl (TKN)
mg/L
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
07-43-A*
17-13-B
18-14-B
18-24-C
18-41-C*
19-11-B
19-24-A
19-31-B
30-11-A


TOC vs BOD
R² = 0.4328
TOC (mg/L)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.00
5.00
10.00
BOD (mg/L)

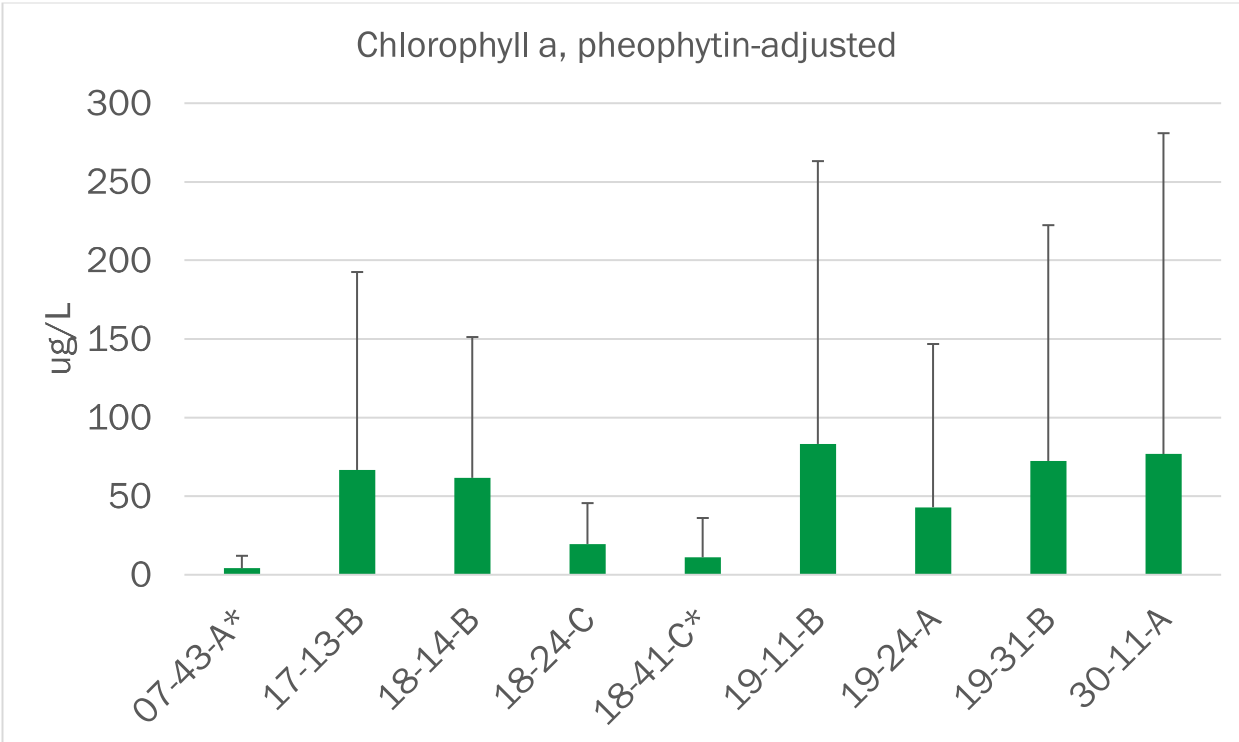

TKN vs BOD
R² = 0.7133
TKN (mg/L)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.00
2.00
4.00
6.00
8.00
10.00
BOD (mg/L)

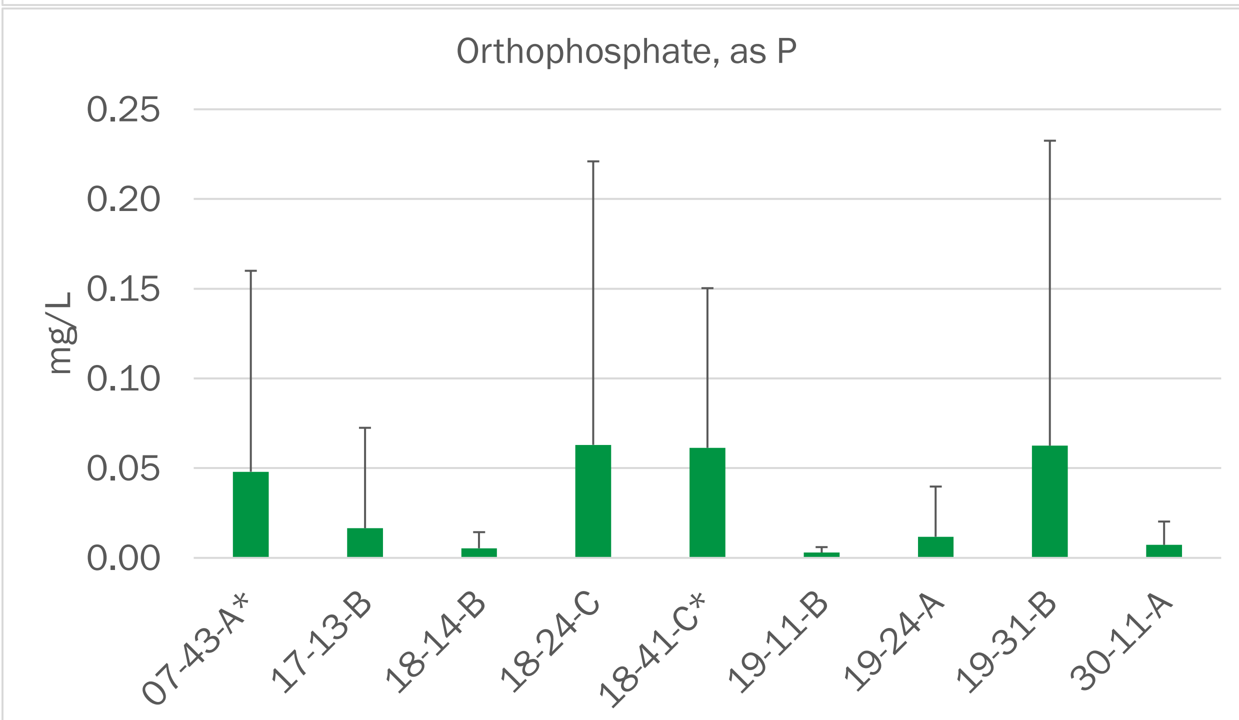


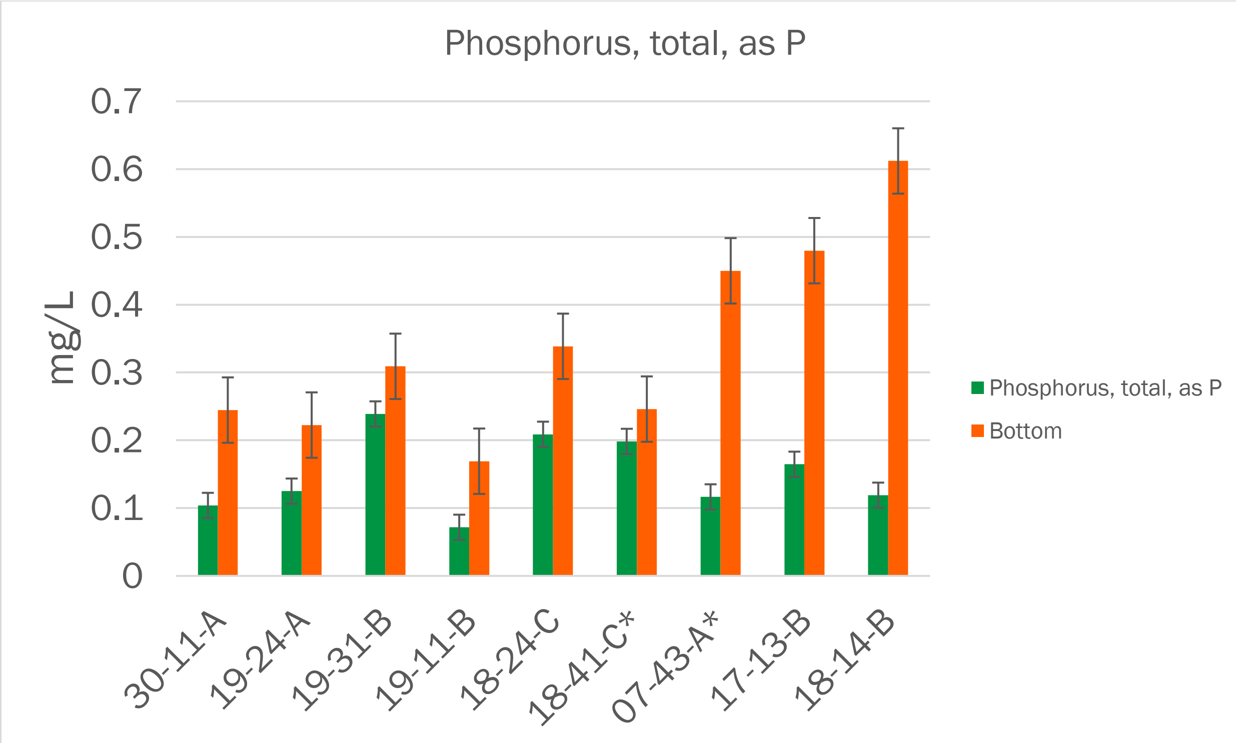
Nitrogen, ammonia, as N
mg/L
0.12
0.10
0.08
0.06
0.04
0.02
0.00
07-43-A*
17-13-B
18-14-B
18-24-C
18-41-C*
19-11-B
19-24-A
19-31-B
30-11-A

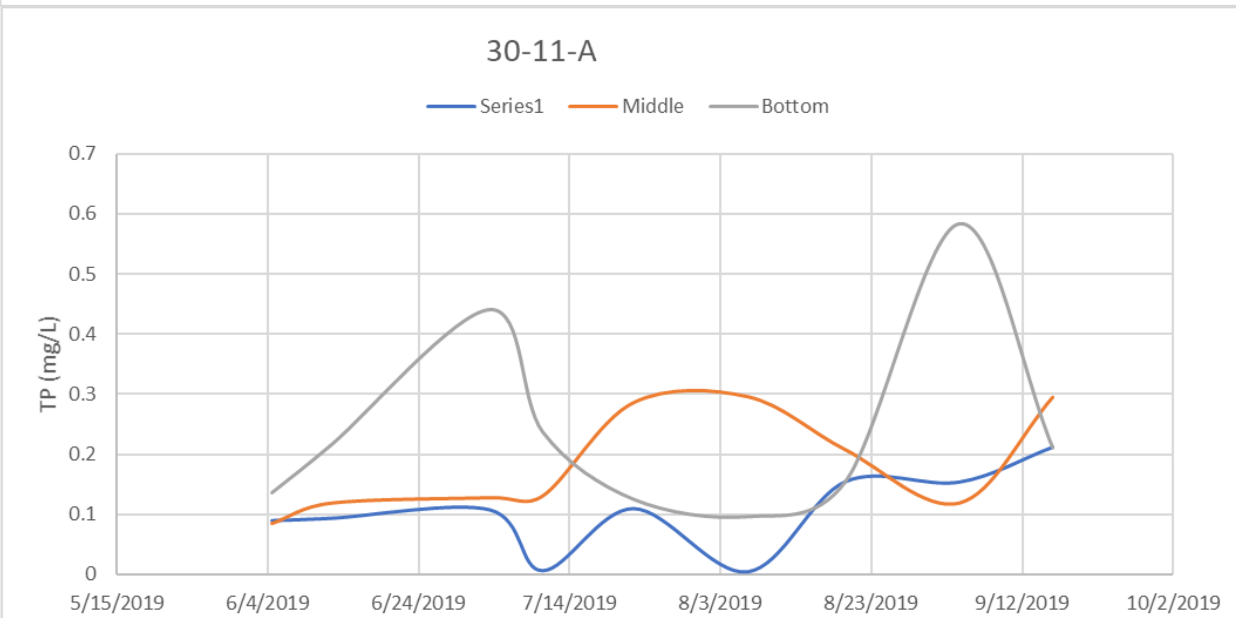


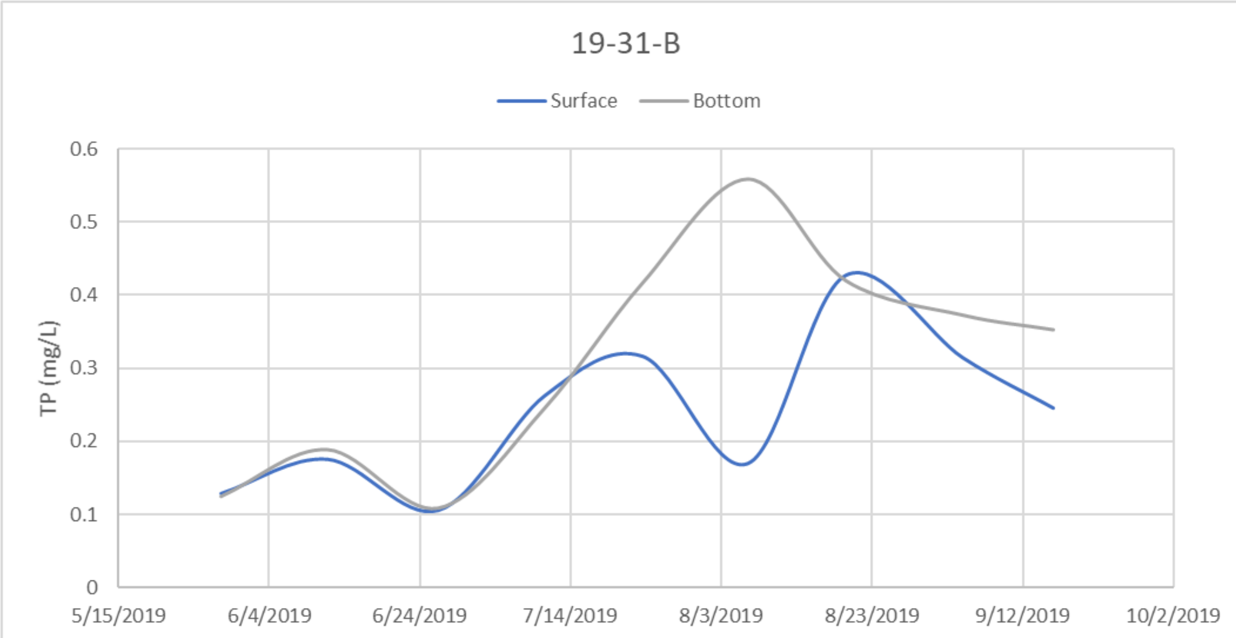
Nitrogen, nitrate + nitrite, as N
mg/L
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
07-43-A*
17-13-B
18-14-B
18-24-C
18-41-C*
19-11-B
19-24-A
19-31-B
30-11-A

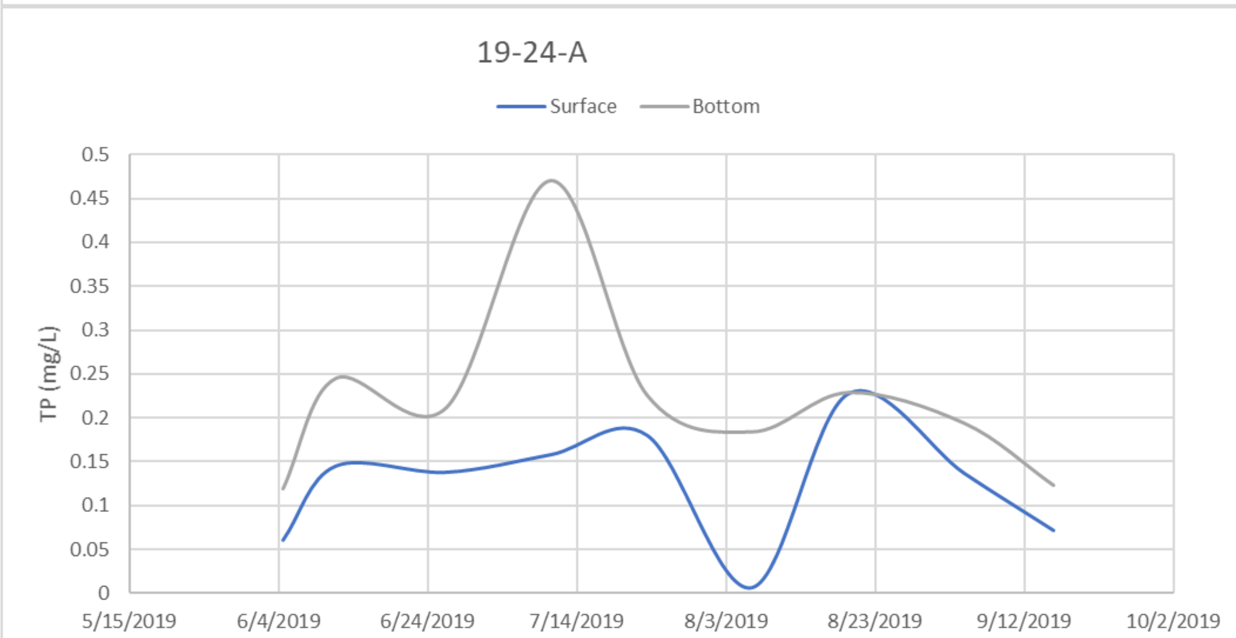

Chlorophyll a, pheophytin-adjusted
ug/L
300
250
200
150
100
50
0
07-43-A*
17-13-B
18-14-B
18-24-C
18-41-C*
19-11-B
19-24-A
19-31-B
30-11-A

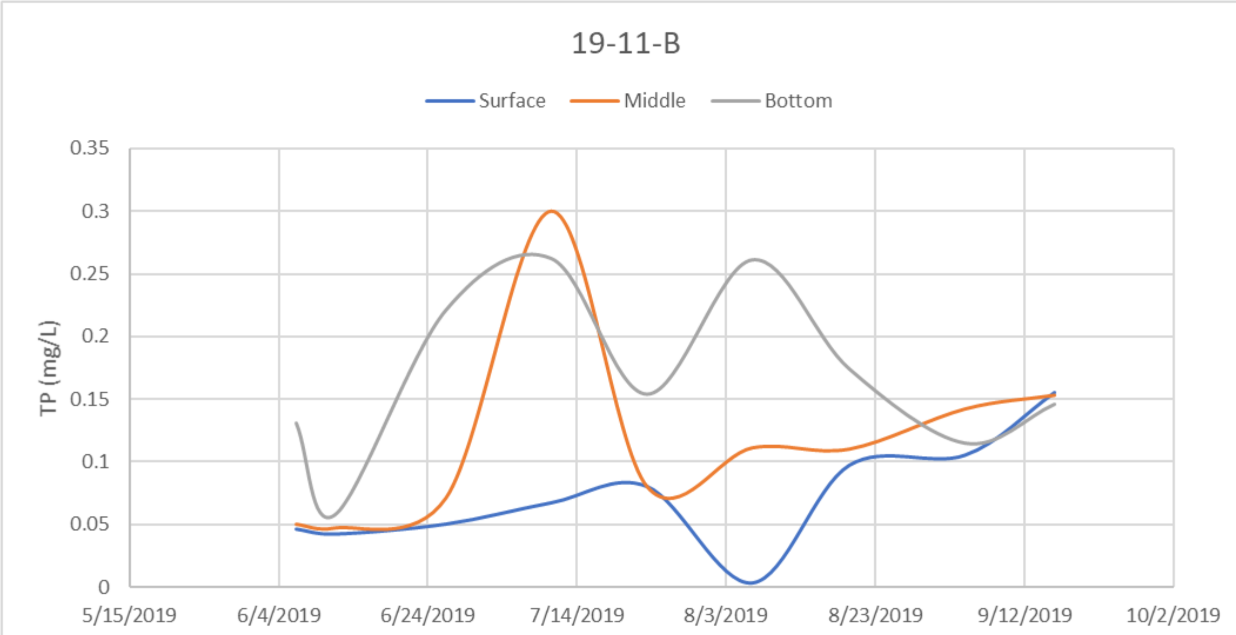

Orthophosphate, as P
mg/L
0.25
0.20
0.15
0.10
0.05
0.00
07-43-A*
17-13-B
18-14-B
18-24-C
18-41-C*
19-11-B
19-24-A
19-31-B
30-11-A

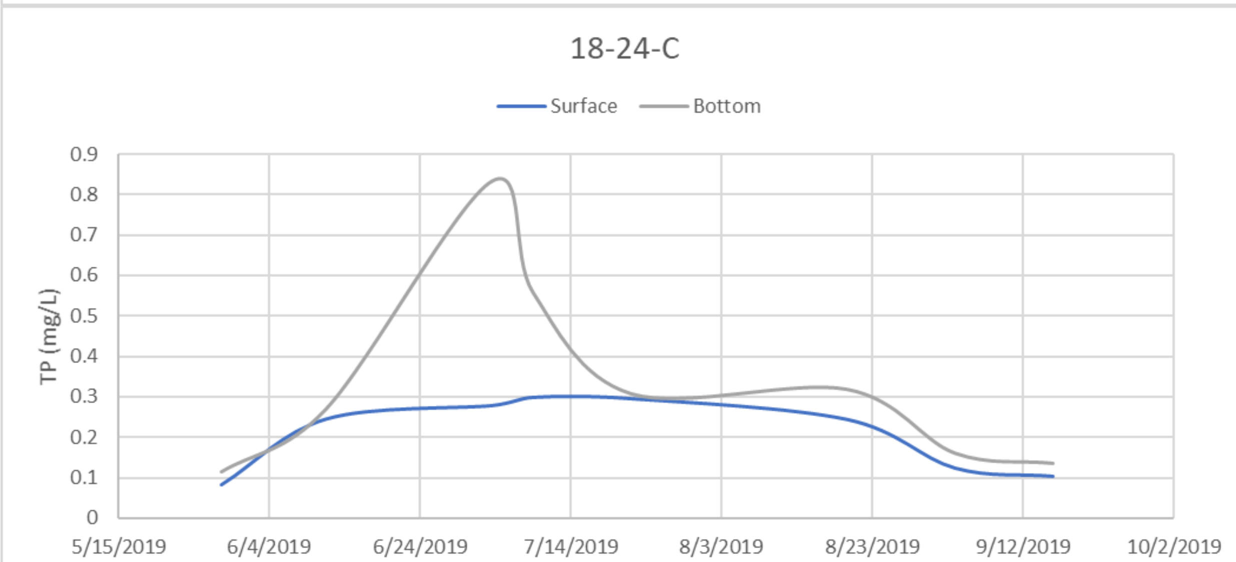

Phosphorus, total, as P
mg/L
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
30-11-A
19-24-A
19-31-B
19-11-B
18-24-C
18-41-C*
07-43-A*
17-13-B
18-14-B
Phosphorus, total, as P
Bottom

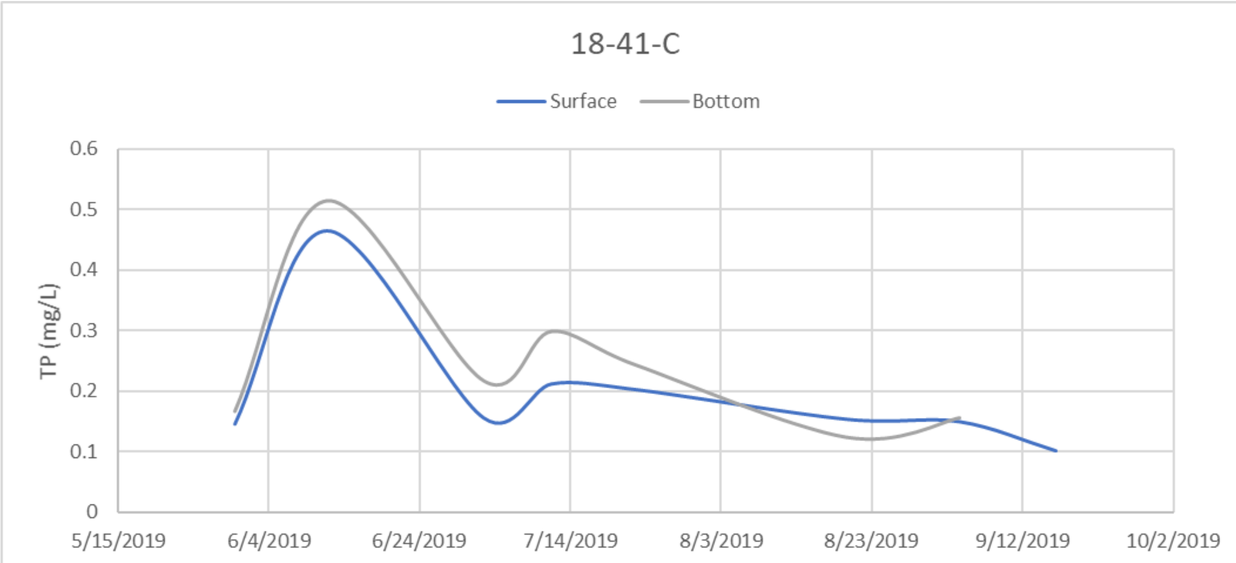

30-11-A
Series1
Middle
Bottom
TP (mg/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5/15/2019
6/4/2019
6/24/2019
7/14/2019
8/3/2019
8/23/2019
9/12/2019
10/2/2019


19-31-B
Surface
Bottom
TP (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
5/15/2019
6/4/2019
6/24/2019
7/14/2019
8/3/2019
8/23/2019
9/12/2019
10/2/2019


19-24-A
Surface
Bottom
TP (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
5/15/2019
6/4/2019
6/24/2019
7/14/2019
8/3/2019
8/23/2019
9/12/2019
10/2/2019


19-11-B
Surface
Middle
Bottom
TP (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
5/15/2019
6/4/2019
6/24/2019
7/14/2019
8/3/2019
8/23/2019
9/12/2019
10/2/2019


18-24-C
Surface
Bottom
TP (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5/15/2019
6/4/2019
6/24/2019
7/14/2019
8/3/2019
8/23/2019
9/12/2019
10/2/2019


18-41-C
Surface
Bottom
TP (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
5/15/2019
6/4/2019
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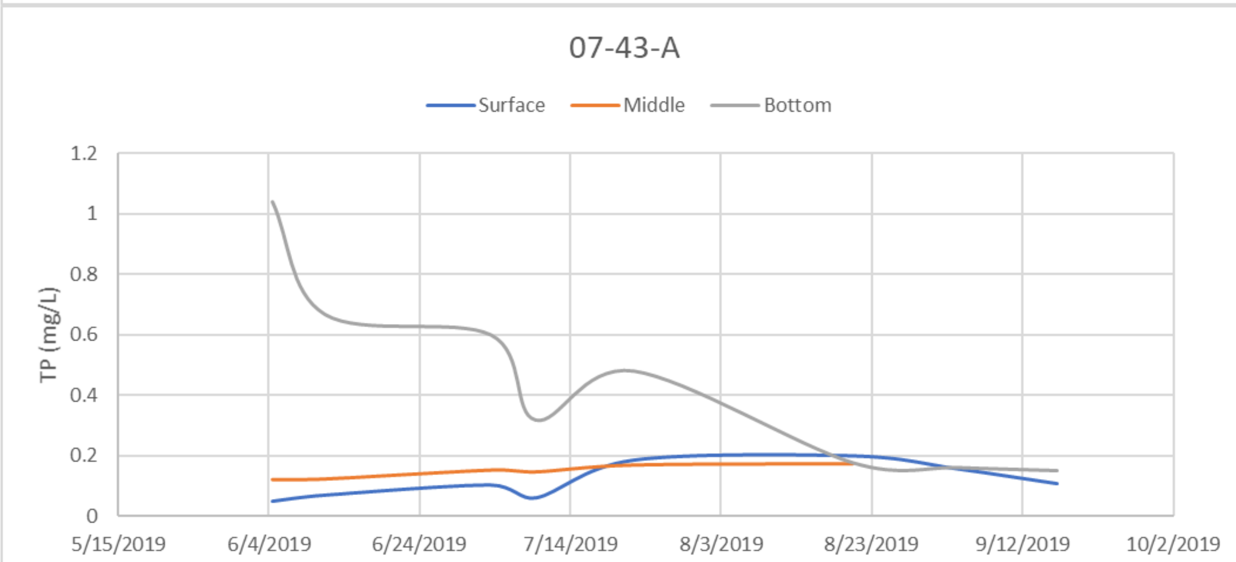
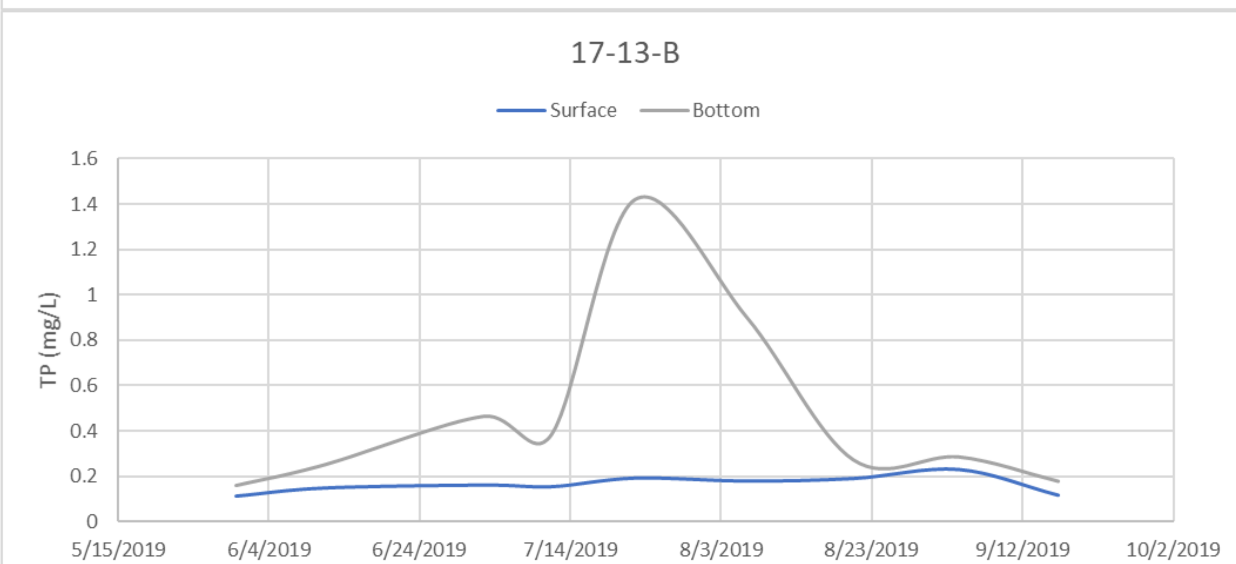
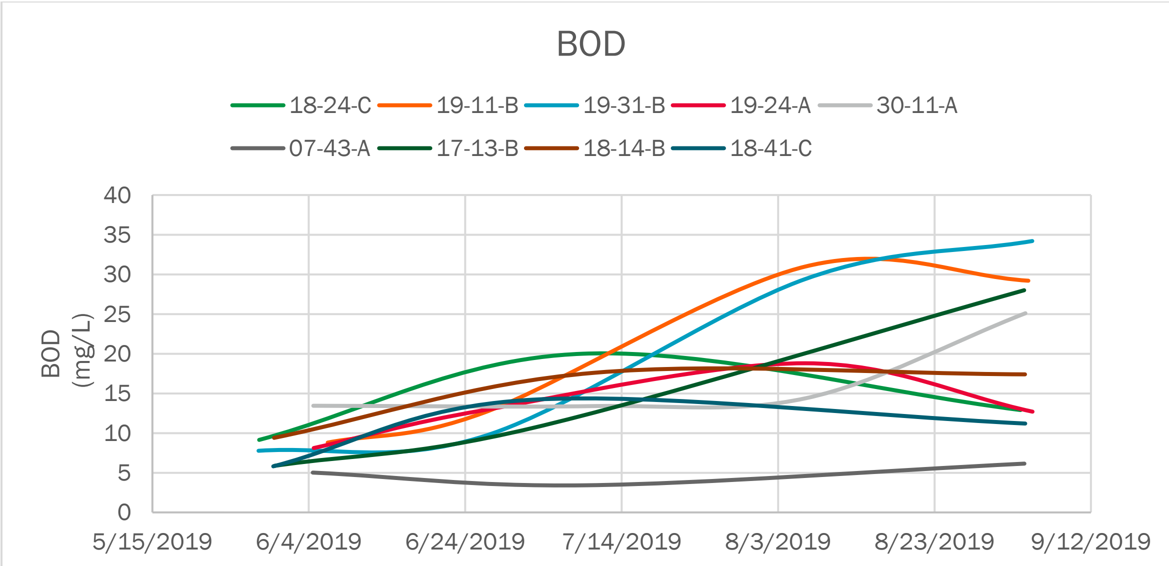
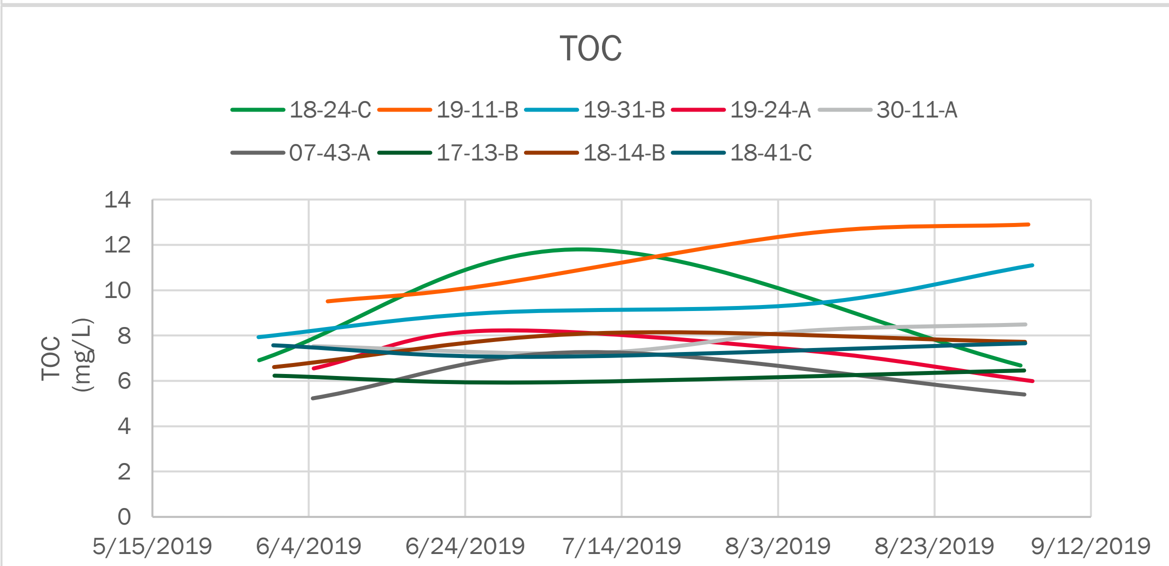
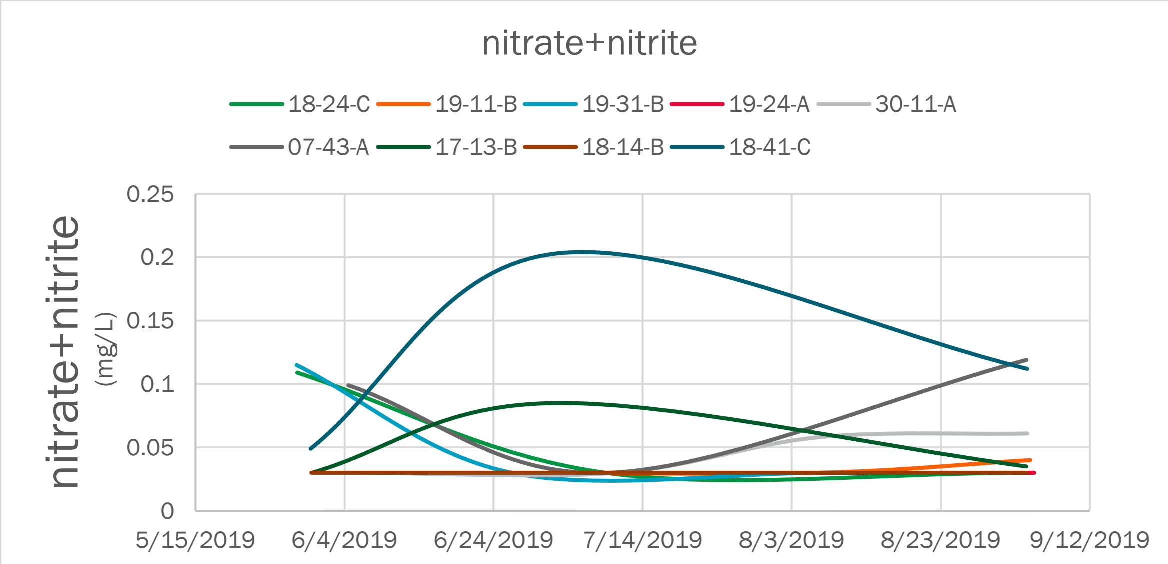
8/23/2019
9/12/2019
10/2/2019

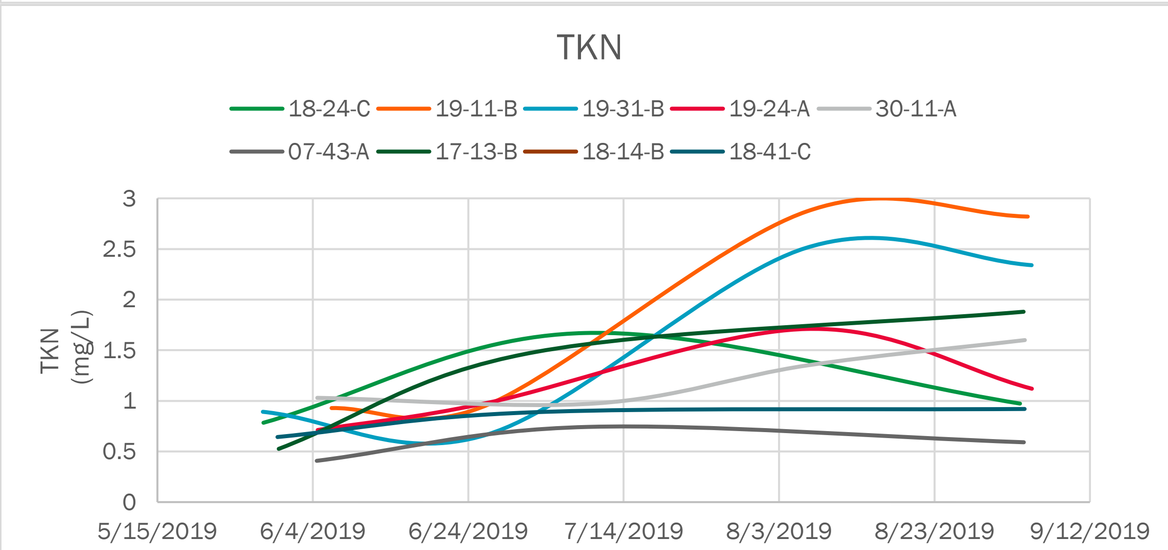

07-43-A
Surface
Middle
Bottom
TP (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
5/15/2019
6/4/2019
6/24/2019
7/14/2019
8/3/2019
8/23/2019
9/12/2019
10/2/2019

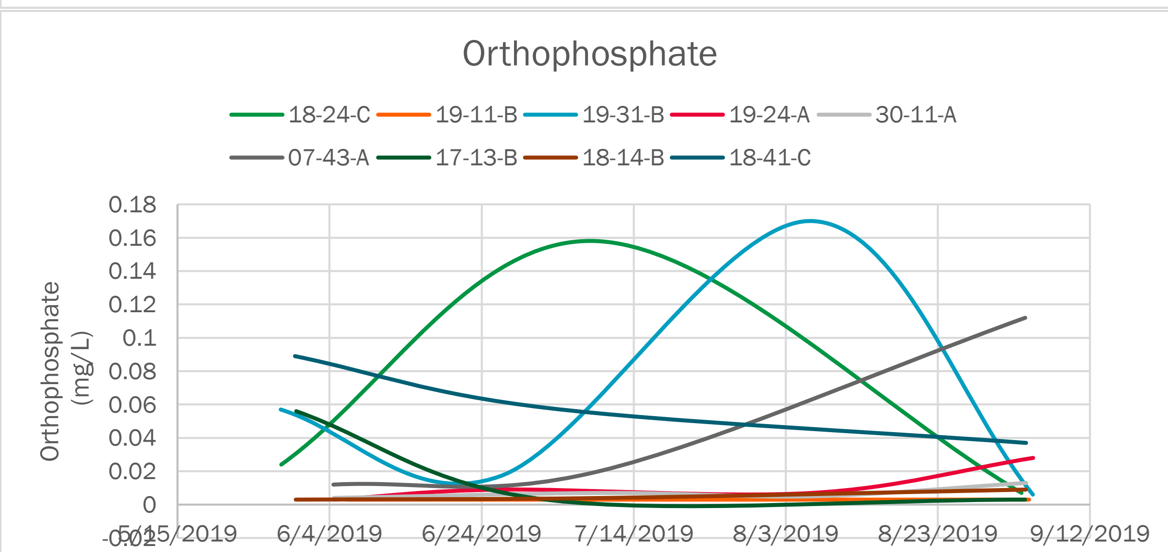

17-13-B
Surface
Bottom
TP (mg/L)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
5/15/2019
6/4/2019
6/24/2019
7/14/2019
8/3/2019
8/23/2019
9/12/2019
10/2/2019

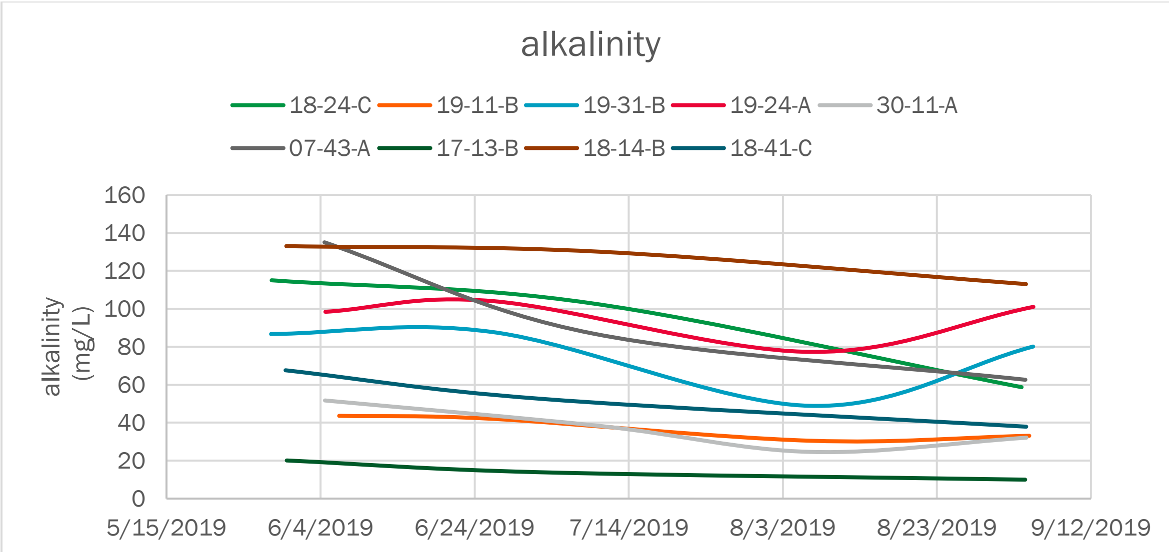

BOD
18-24-C
19-11-B
19-31-B
19-24-A
30-11-A
07-43-A
17-13-B
18-14-B
18-41-C
BOD (mg/L)
40
35
30
25
20
15
10
5
0
5/15/2019
6/4/2019
6/24/2019
7/14/2019
8/3/2019
8/23/2019
9/12/2019

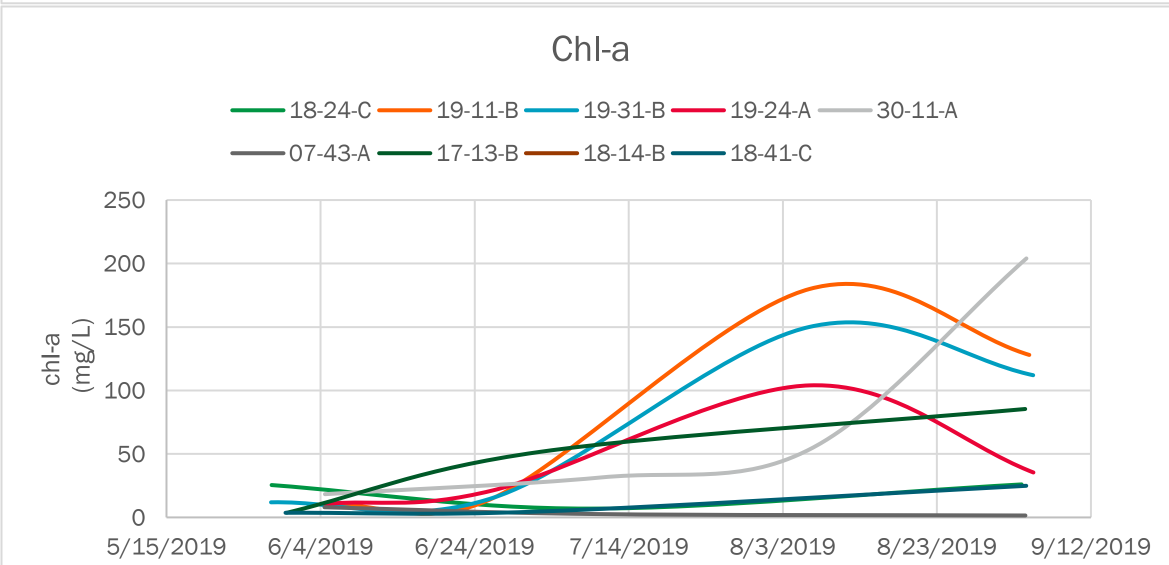

TOC
18-24-C
19-11-B
19-31-B
19-24-A
30-11-A
07-43-A
17-13-B
18-14-B
18-41-C
TOC (mg/L)
14
12
10
8
6
4
2
0
5/15/2019
6/4/2019
6/24/2019
7/14/2019
8/3/2019
8/23/2019
9/12/2019

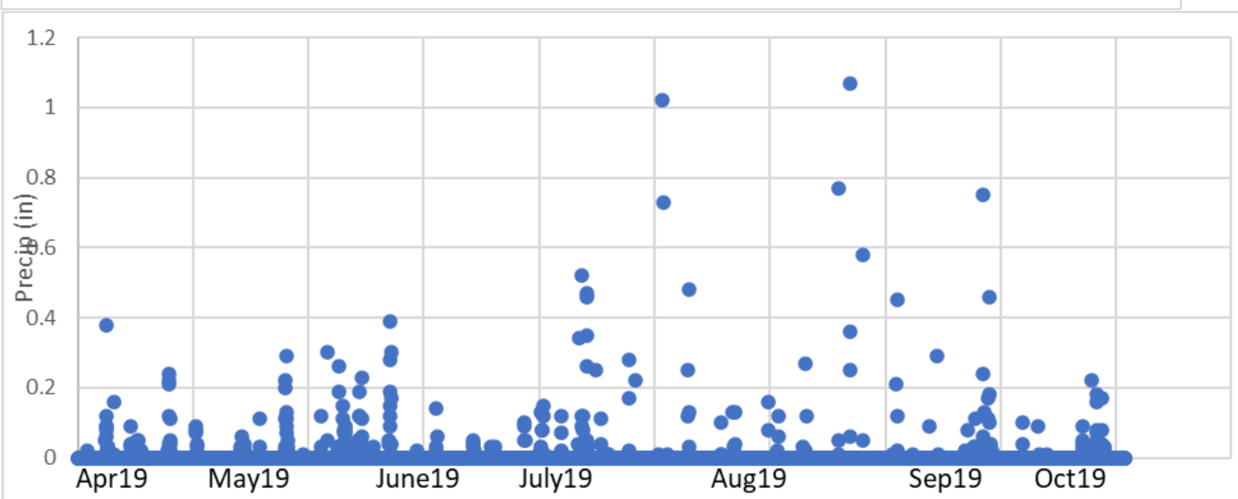

nitrate+nitrite
18-24-C
19-11-B
19-31-B
19-24-A
30-11-A
07-43-A
17-13-B
18-14-B
18-41-C
nitrate+nitrite (mg/L)
0.25
0.2
0.15
0.1
0.05
0
5/15/2019
6/4/2019
6/24/2019
7/14/2019
8/3/2019
8/23/2019
9/12/2019


TKN
18-24-C
19-11-B
19-31-B
19-24-A
30-11-A
07-43-A
17-13-B
18-14-B
18-41-C
TKN (mg/L)
3
2.5
2
1.5
1
0.5
0
5/15/2019
6/4/2019
6/24/2019
7/14/2019
8/3/2019
8/23/2019
9/12/2019

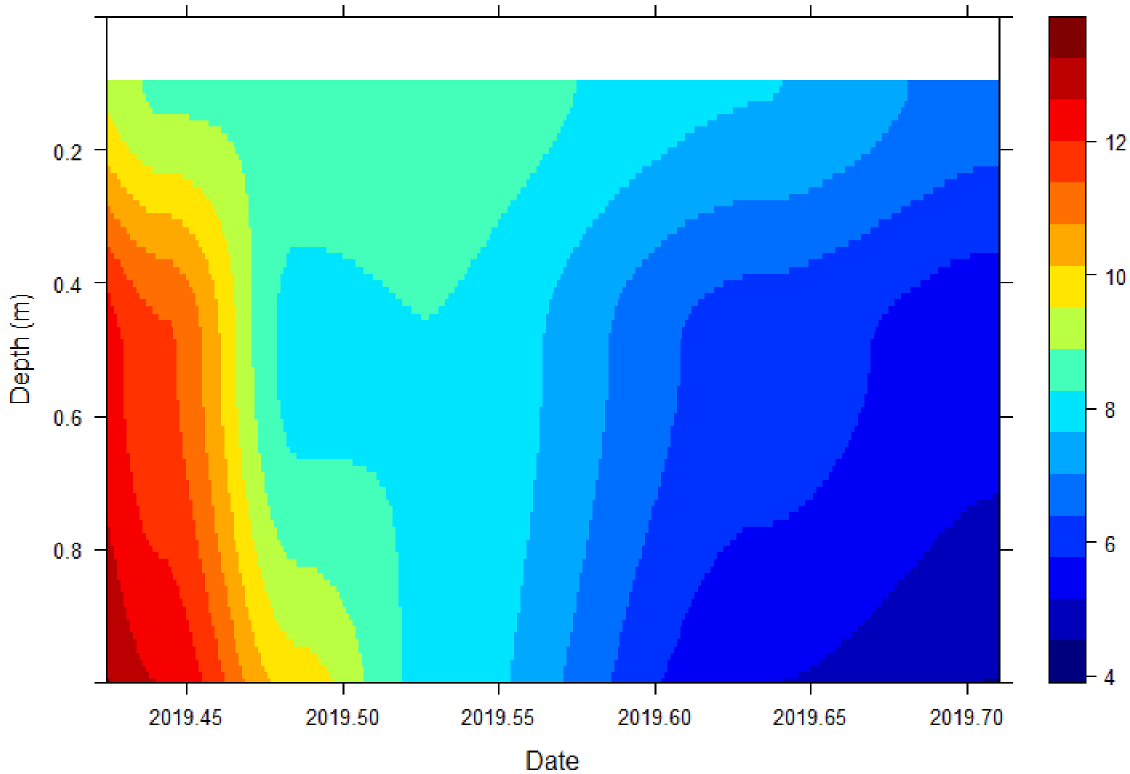

Orthophosphate
18-24-C
19-11-B
19-31-B
19-24-A
30-11-A
07-43-A
17-13-B
18-14-B
18-41-C
Orthophosphate (mg/L)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
5/15/2019
6/4/2019
6/24/2019
7/14/2019
8/3/2019
8/23/2019
9/12/2019


alkalinity
18-24-C
19-11-B
19-31-B
19-24-A
30-11-A
07-43-A
17-13-B
18-14-B
18-41-C
alkalinity (mg/L)
160
140
120
100
80
60
40
20
0
5/15/2019
6/4/2019
6/24/2019
7/14/2019
8/3/2019
8/23/2019
9/12/2019

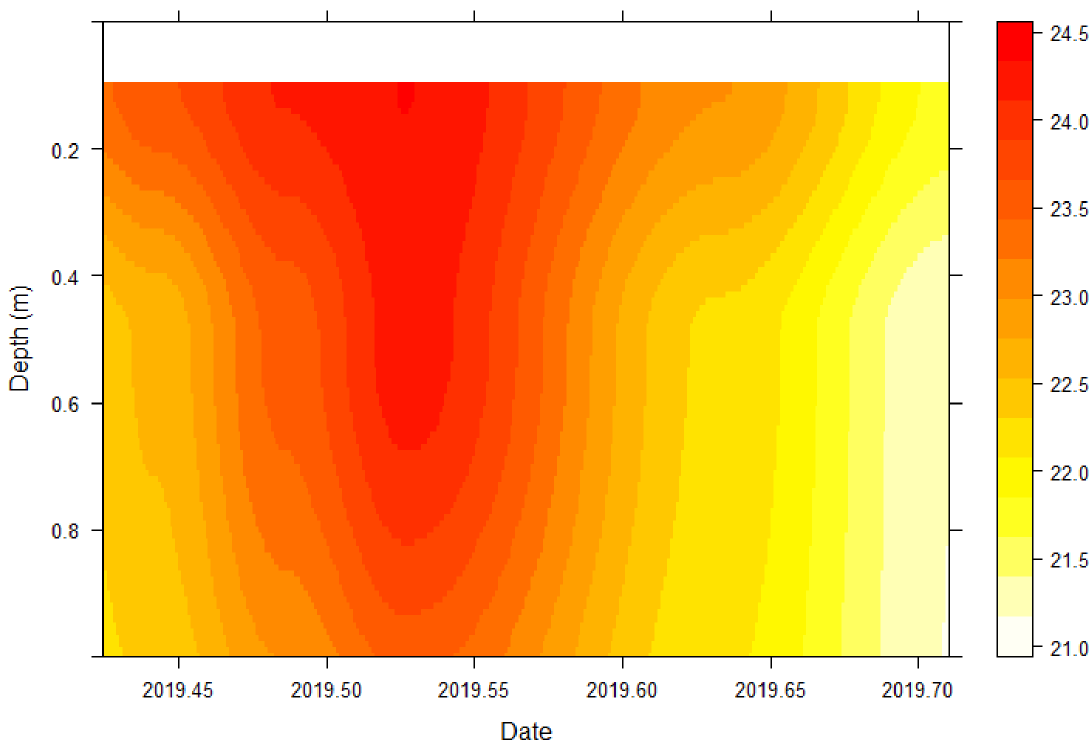

Chl-a
18-24-C
19-11-B
19-31-B
19-24-A
30-11-A
07-43-A
17-13-B
18-14-B
18-41-C
chl-a (mg/L)
250
200
150
100
50
0
5/15/2019
6/4/2019
6/24/2019
7/14/2019
8/3/2019
8/23/2019
9/12/2019

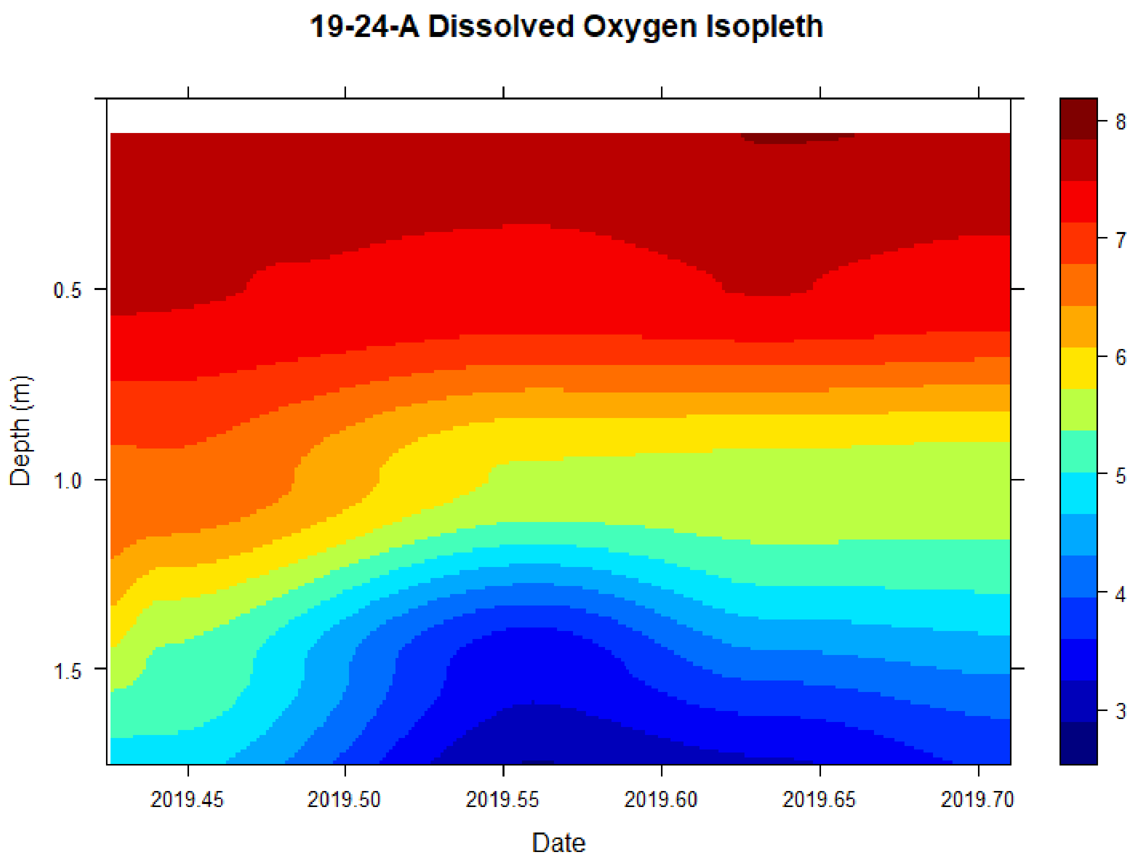

Precip (in)
1.2
1
0.8
0.6
0.4
0.2
0
Apr19
May19
June19
July19
Aug19
Sep19
Oct19

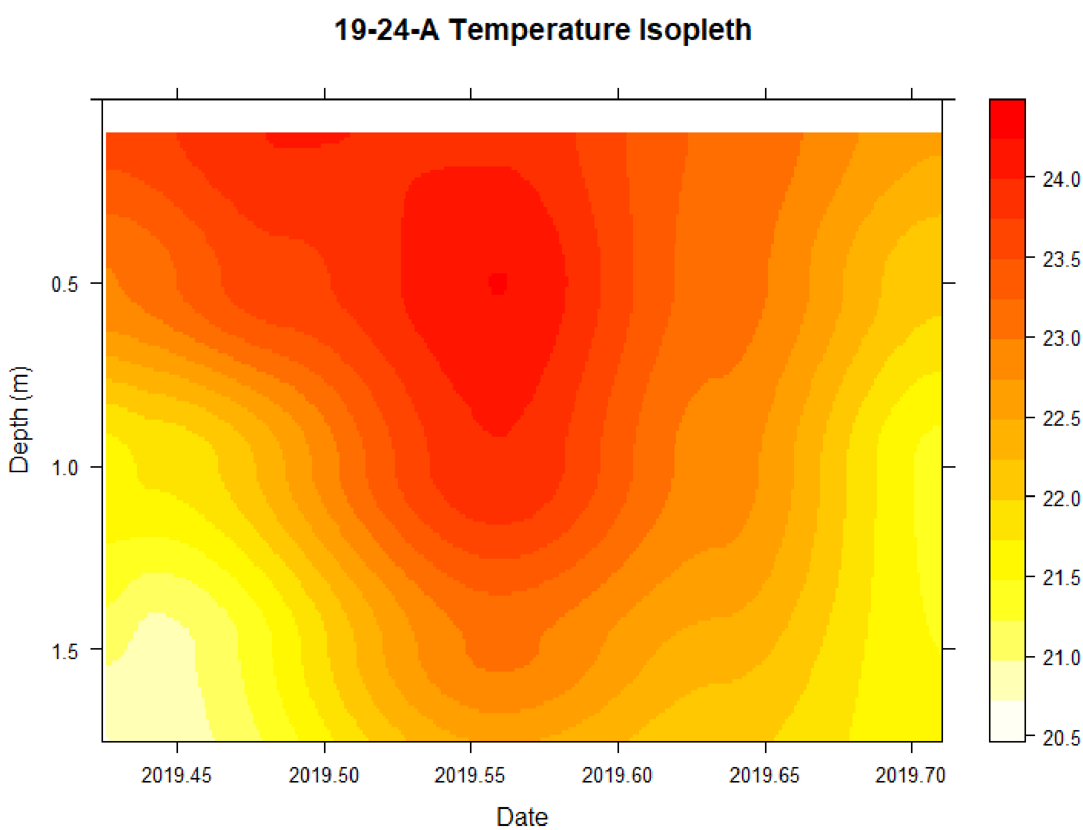
19-31-B Dissolved Oxygen Isopleth



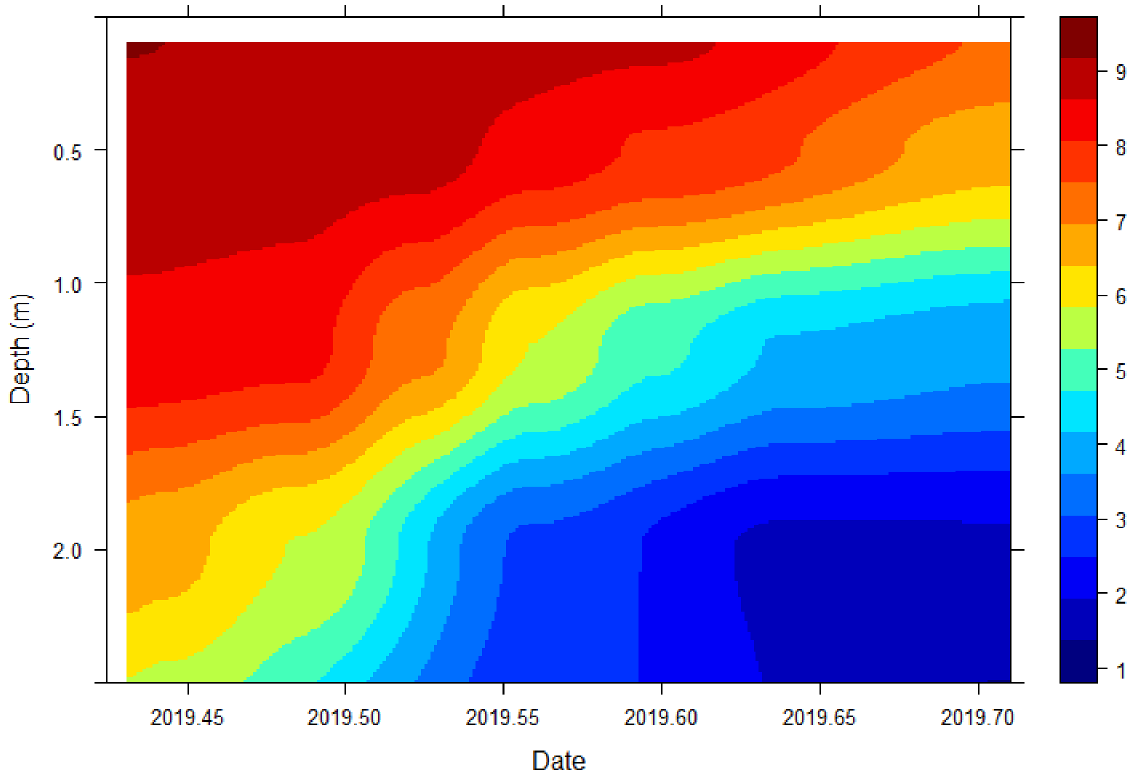
19-31-B Temperature Isopleth



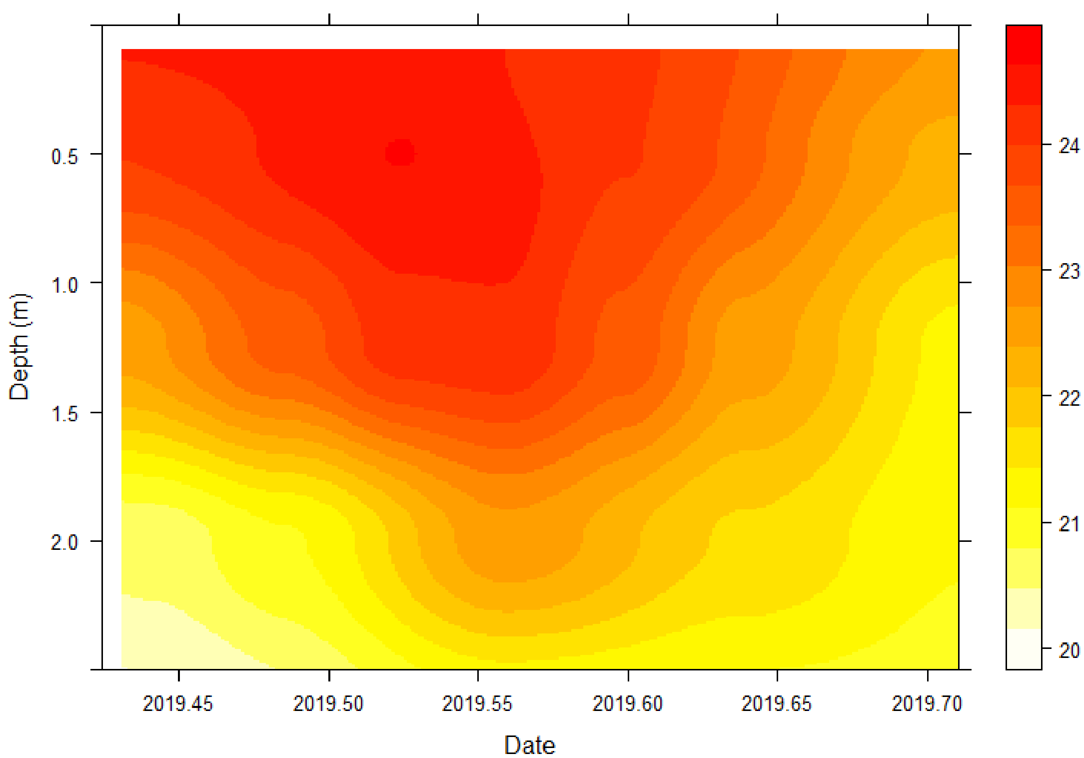

19-24-A Dissolved Oxygen Isopleth
Depth (m)
0.5
1.0
1.5
2019.45
2019.50
2019.55
2019.60
2019.65
2019.70
Date
8
7
6
5
4
3


19-24-A Temperature Isopleth
Depth (m)
0.5
1.0
1.5
2019.45
2019.50
2019.55
2019.60
2019.65
2019.70
Date
24.0
23.5
23.0
22.5
22.0
21.5
21.0
20.5

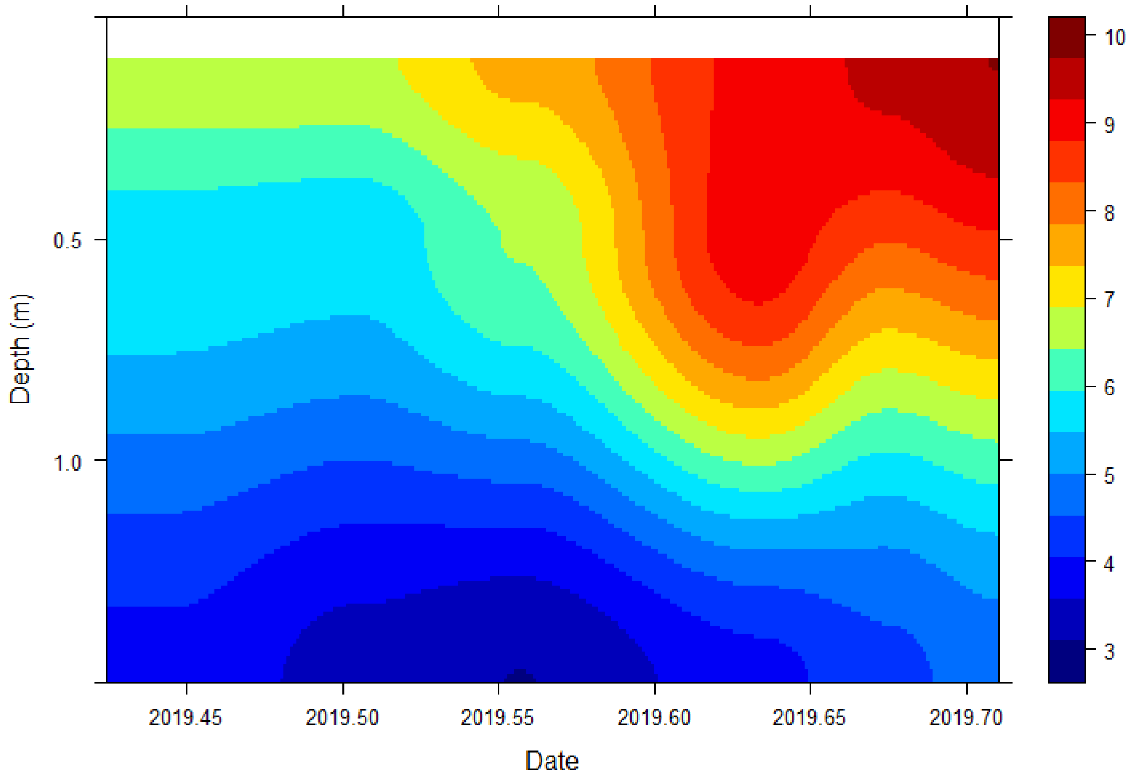
19-11-B Dissolved Oxygen Isopleth



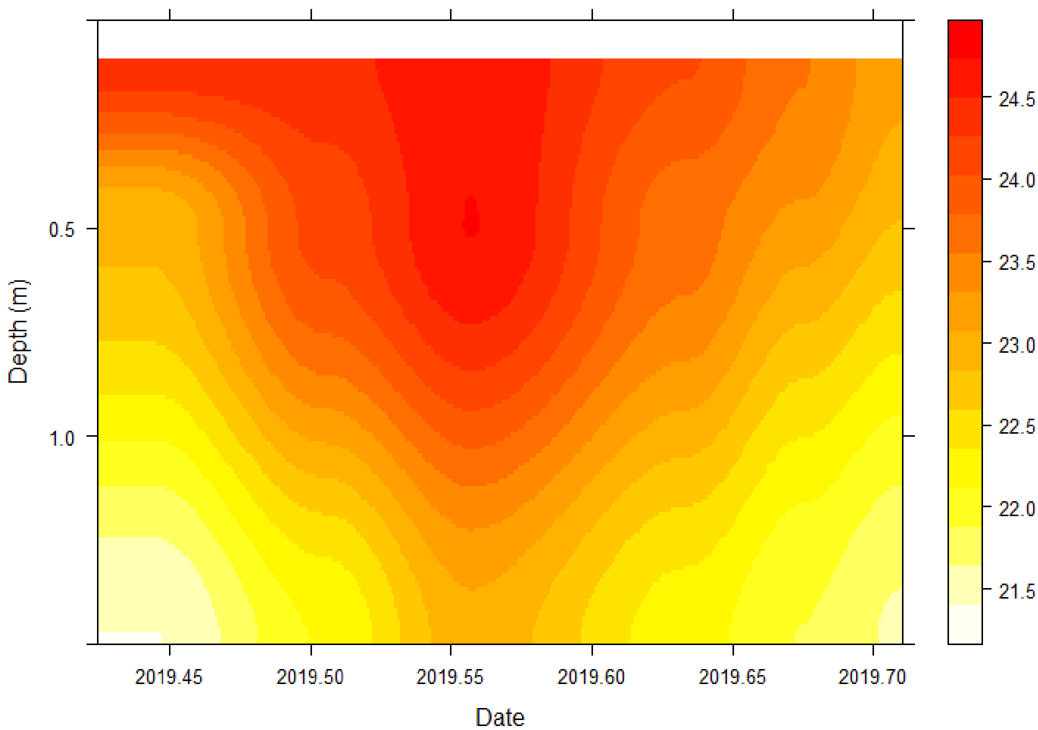
19-11-B Temperature Isopleth



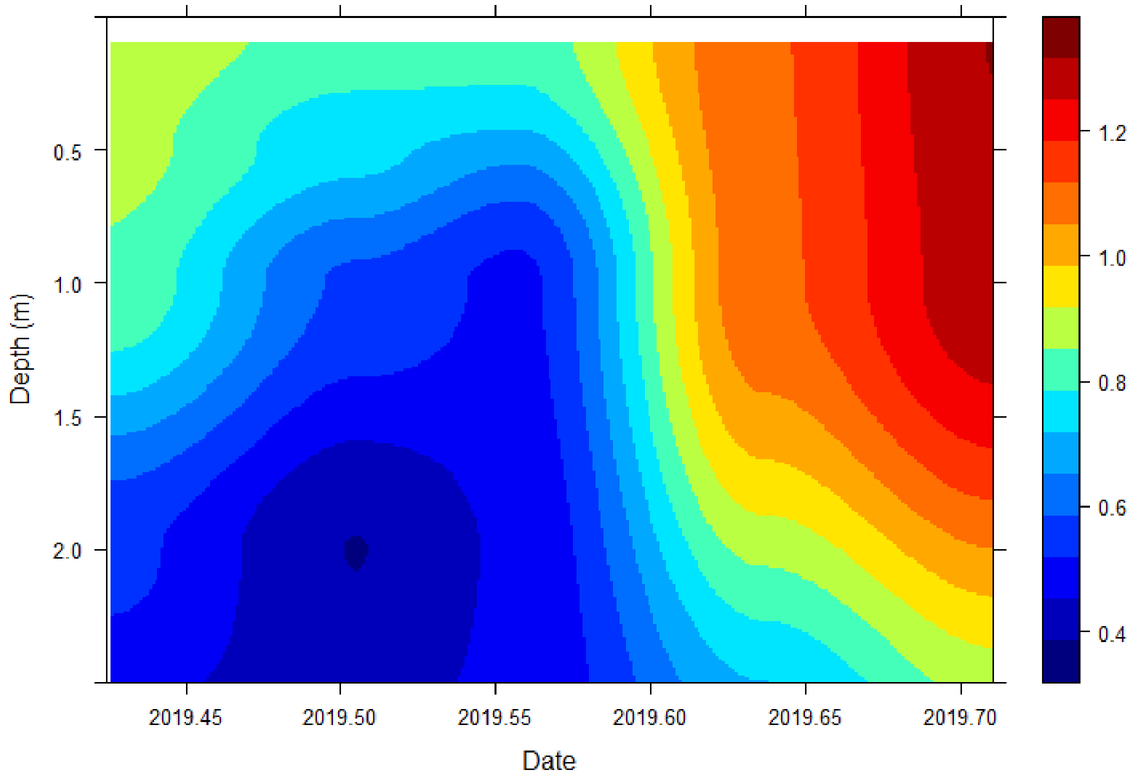
18-24-C Dissolved Oxygen Isopleth



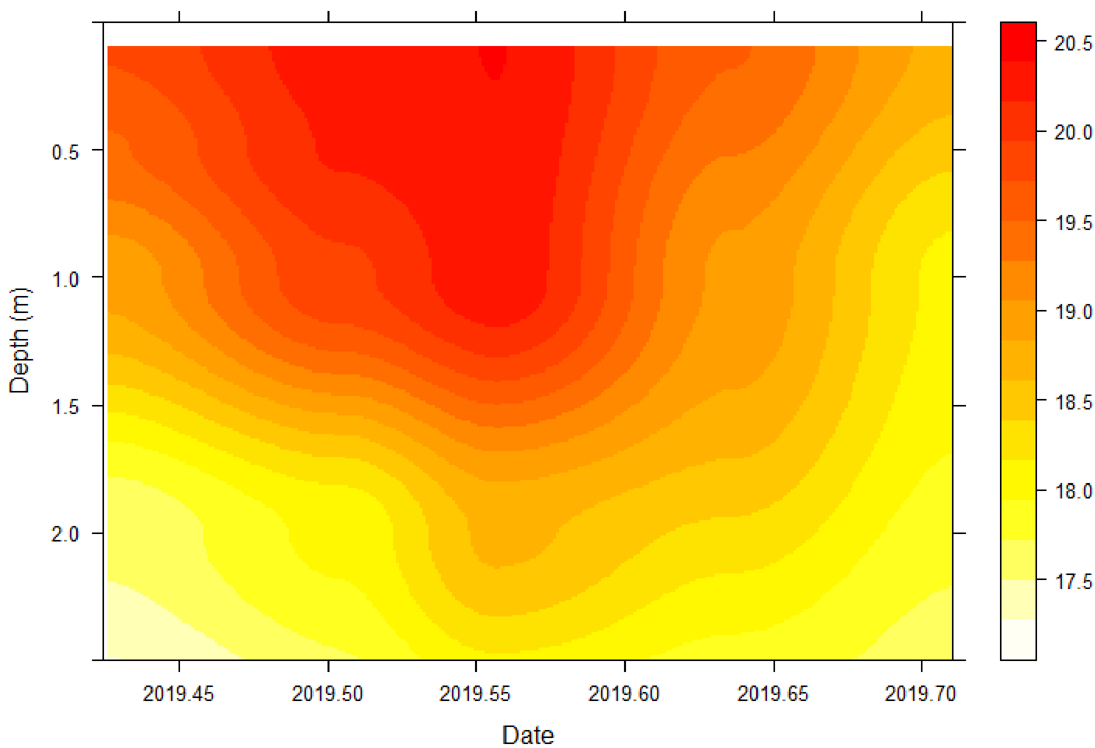
18-24-C Temperature Isopleth



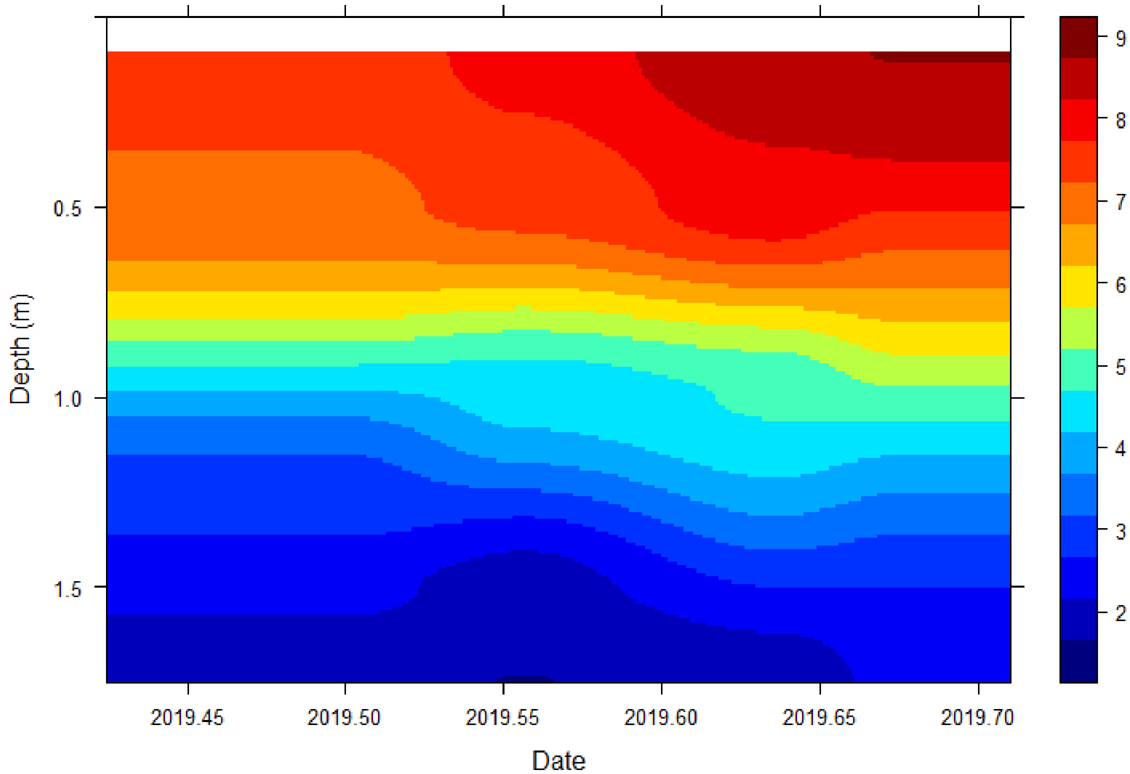
07-43-A Dissolved Oxygen Isopleth



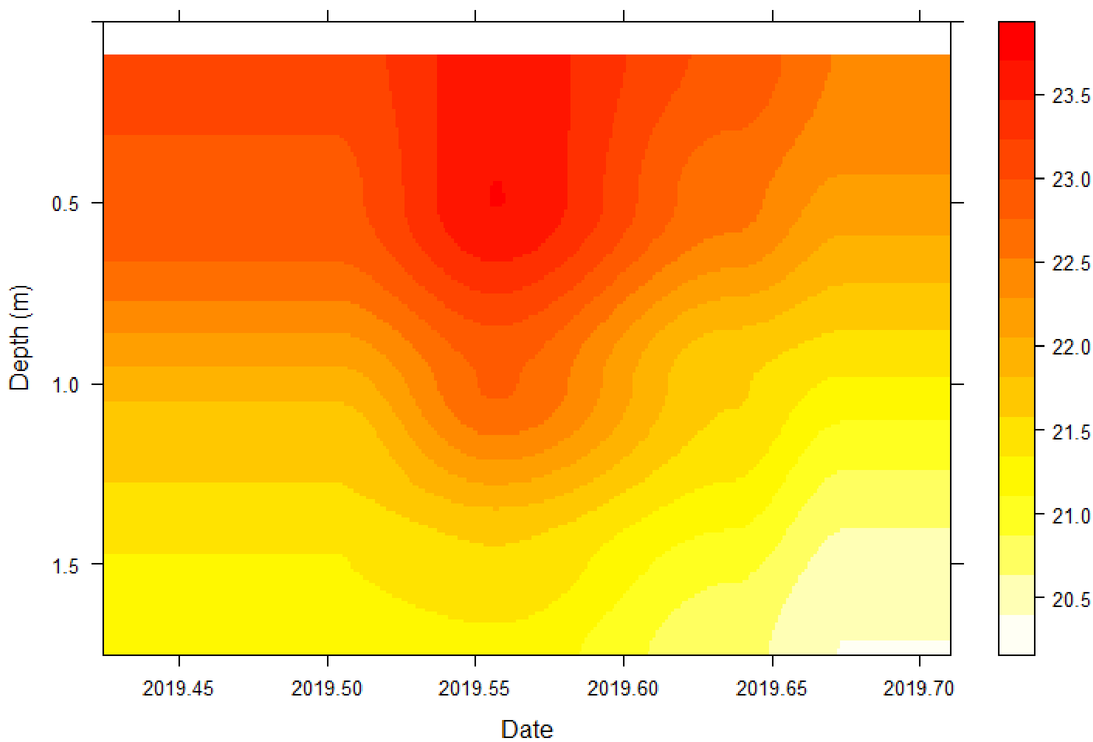
07-43-A Temperature Isopleth



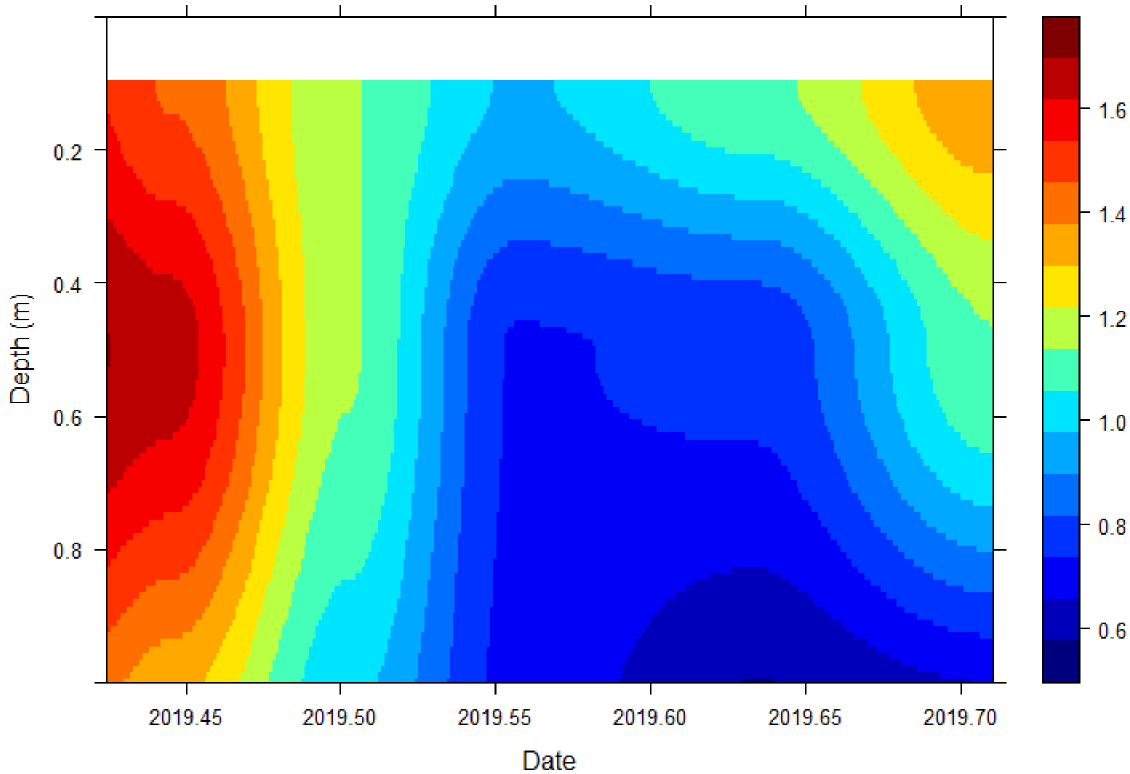
17-13-B Dissolved Oxygen Isopleth



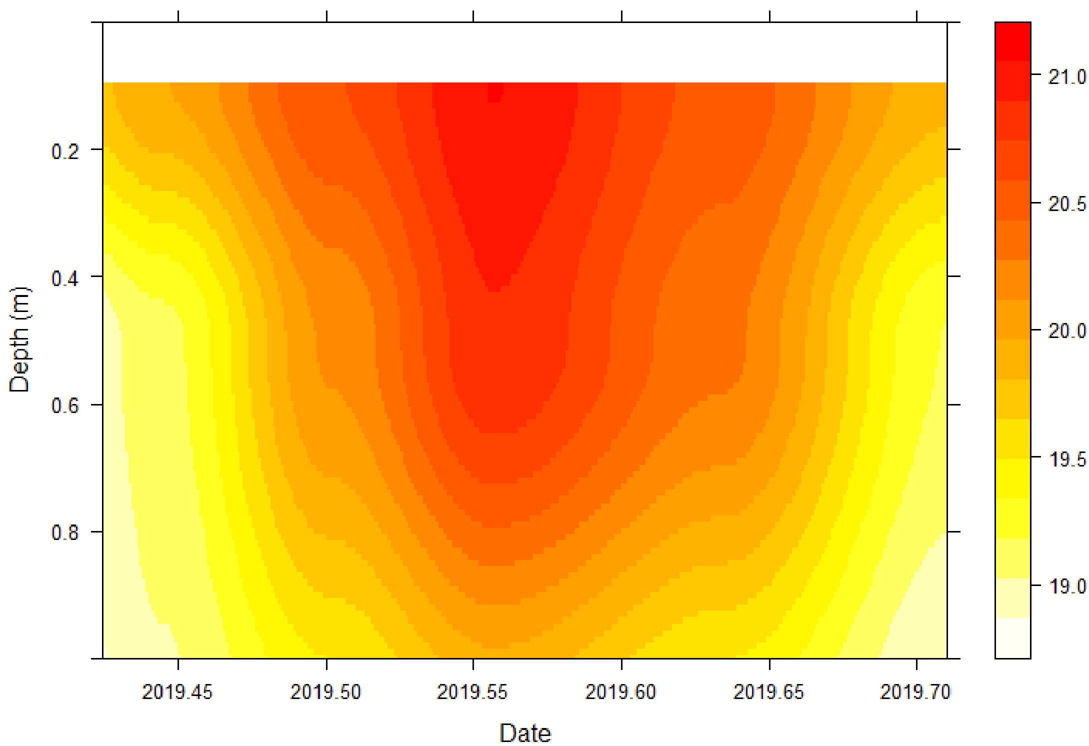
17-13-B Temperature Isopleth

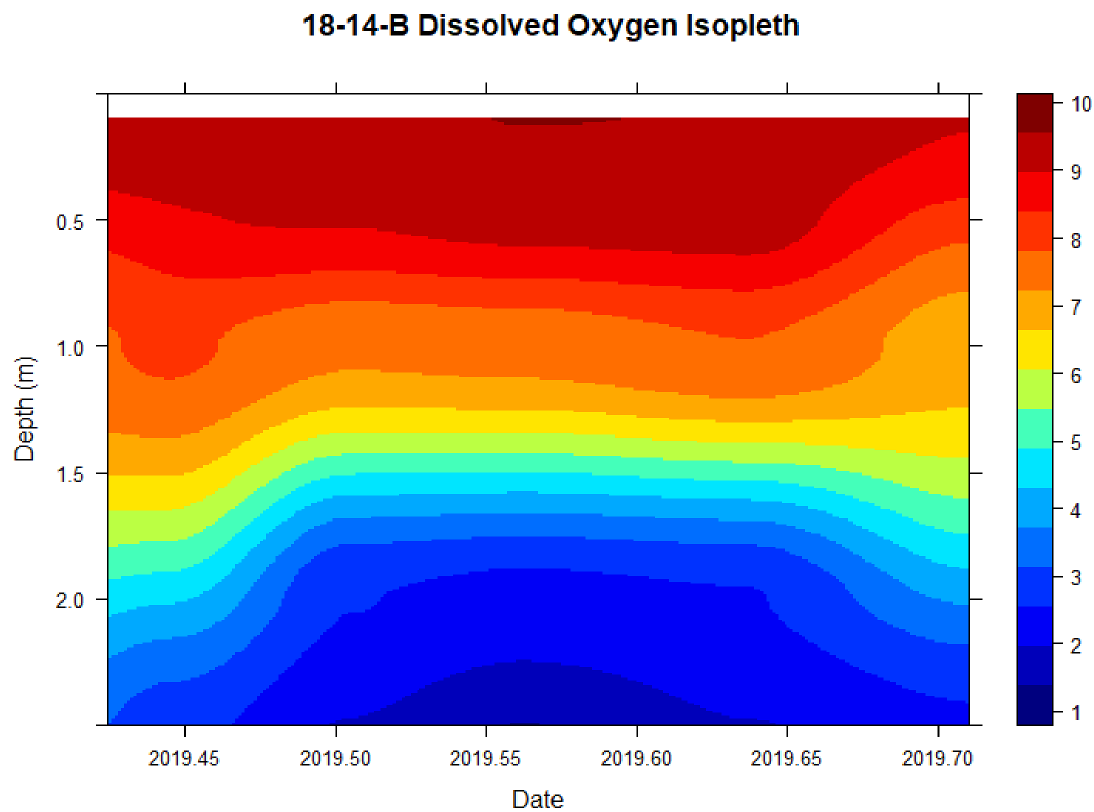


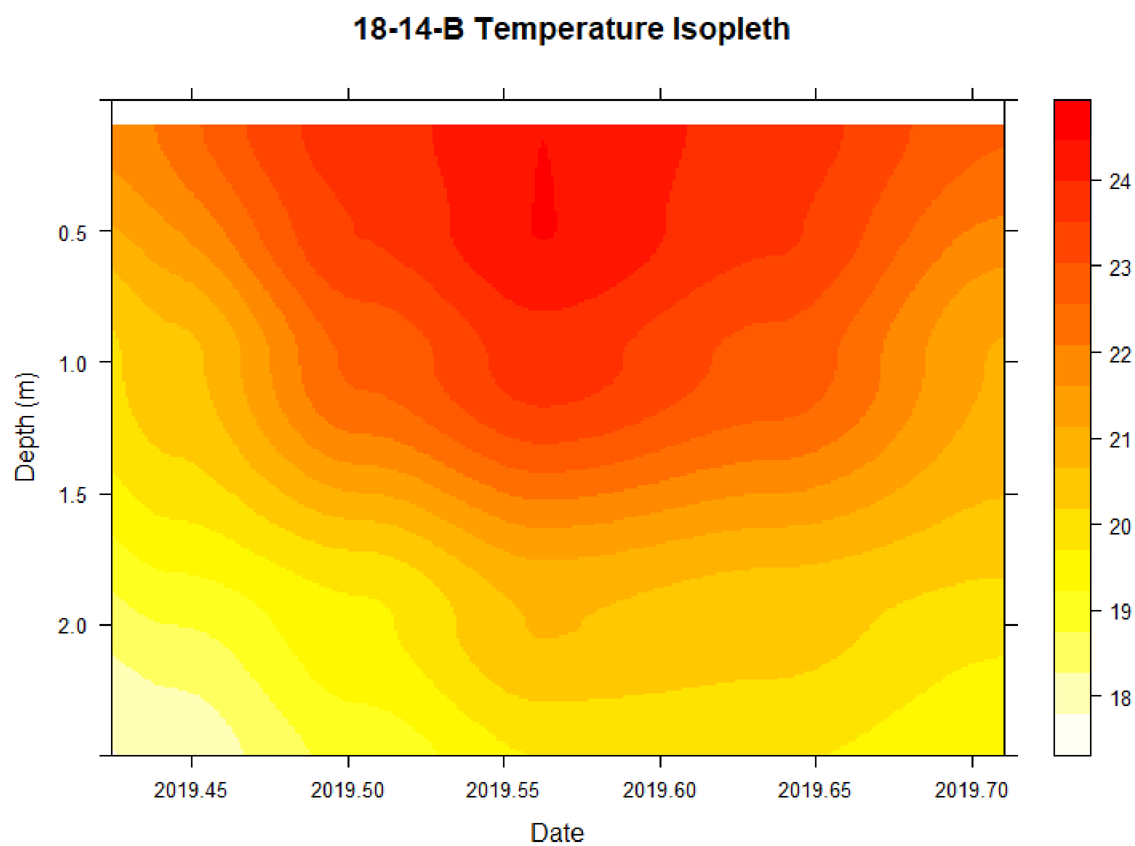
18-41-C Dissolved Oxygen Isopleth



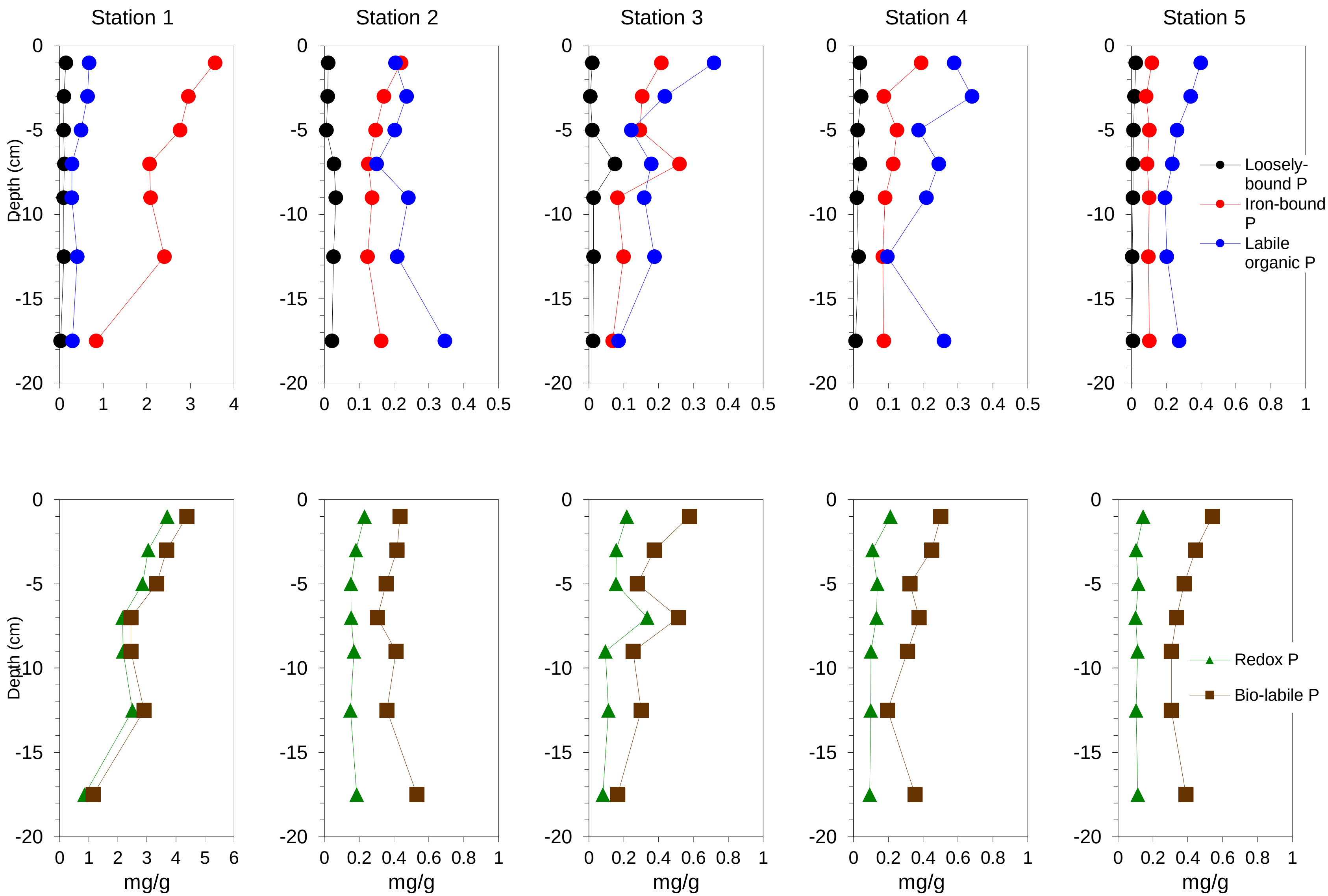
18-41-C Temperature Isopleth



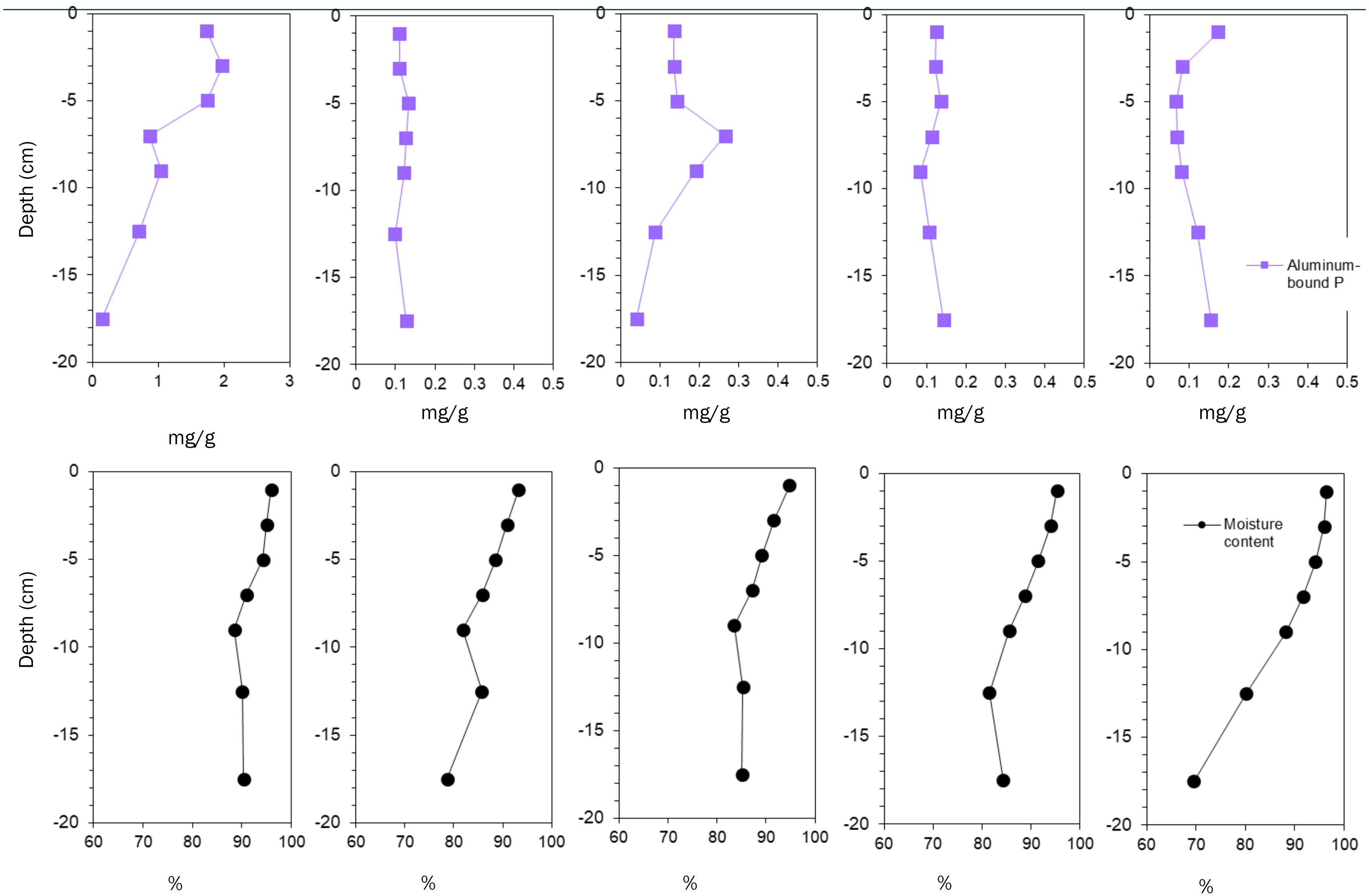

18-14-B Dissolved Oxygen Isopleth
Depth (m)
0.5
1.0
1.5
2.0
2019.45
2019.50
2019.55
2019.60
2019.65
2019.70
Date
10
9
8
7
6
5
4
3
2
1

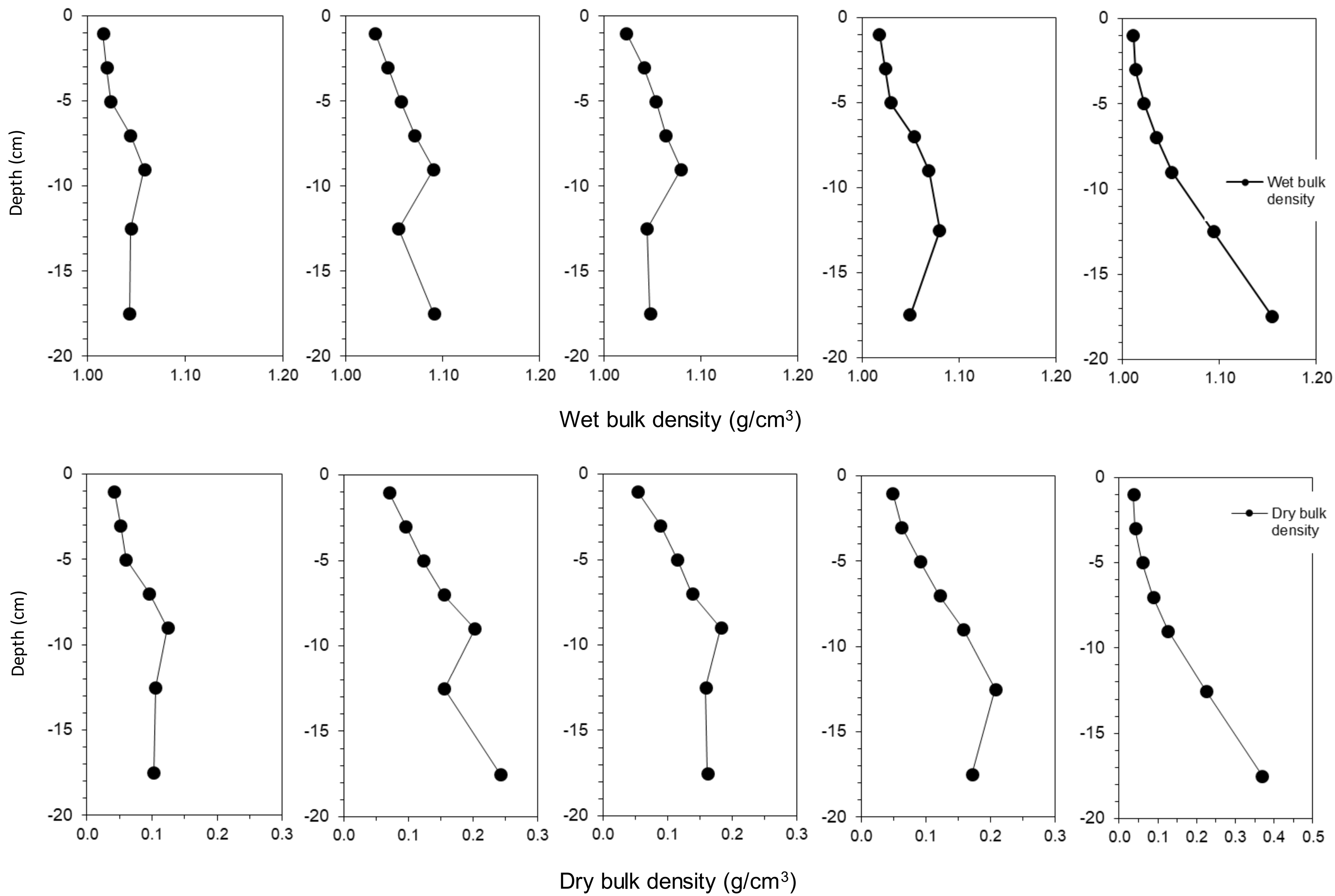

18-14-B Temperature Isopleth
Depth (m)
0.5
1.0
1.5
2.0
2019.45
2019.50
2019.55
2019.60
2019.65
2019.70
Date
24
23
22
21
20
19
18

Appendix C: Mitchell Lake Sediment Coring



Station 1
Station 2
Station 3
Station 4
Station 5
Depth (cm)
Loosely-bound P
Iron-bound P
Labile organic P
Redox P
Bio-labile P
mg/g


Depth (cm)
mg/g
Aluminum-bound P
%
Moisture content



Depth (cm)
Wet bulk density
Wet bulk density (g/cm3)
Depth (cm)
Dry bulk density
Dry bulk density (g/cm3)

Appendix D: Water Quality Data Summaries

Table 1
Pond 30-11-A
2019-2020 Analytical Results Summary
Riley Purgatory Bluff Creek Watershed District

Parameter	Unit	Pond Depth	2019					2020				
			Min	Max	Mean	Median	Standard Error	Min	Max	Mean	Median	Standard Error
Alkalinity, total, as CaCO3	mg/l	Surface	25	52	39	38	5.2	29	38	35	37	2.1
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Biochemical Oxygen Demand (5-day)	mg/l	Surface	5.5	12	6.9	5.8	1.2	4.9	29	12	7.1	5.7
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Biochemical Oxygen Demand (Ultimate; lab calculation)	mg/l	Surface	13	25	16	14	2.2	11	58	24	14	11
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Carbon, total organic	mg/l	Surface	6.1	8.5	7.5	7.5	0.42	5.8	8.3	7	6.8	0.66
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Chlorophyll a, pheophytin-adjusted	ug/l	Surface	18	200	76	54	33	18	480	140	36	110
	ug/l	Middle	--	--	--	--	--	--	--	--	--	--
	ug/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, ammonia, as N	mg/l	Surface	0.04	0.42	0.13	0.1	0.072	0.06	0.06	0.06	0.06	0
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, nitrate + nitrite, as N	mg/l	Surface	0.03	0.061	0.048	0.1	0.007	0.03	0.1	0.048	0.03	0.018
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, total kjeldahl (TKN)	mg/l	Surface	0.98	1.6	1.3	1.4	0.13	0.66	3.3	1.4	0.82	0.64
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Phosphorus, total, as P	mg/l	Surface	0.084	0.34	0.16	0.14	0.023	0.056	0.38	0.13	0.09	0.03
	mg/l	Middle	0.084	0.44	0.16	0.13	0.033	0.067	0.26	0.13	0.12	0.021
	mg/l	Bottom	0.13	2	0.49	0.3	0.17	0.1	1.1	0.42	0.39	0.092
Orthophosphate, as P (Dissolved)	mg/l	Surface	0.004	0.11	0.027	0.007	0.02	0.004	0.037	0.014	0.008	0.0077
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
C-Phycocyanin	cells/ml	Surface	0.0067	1100	210	110	68	26	1100	200	96	57
	cells/ml	Middle	0.004	2800	380	130	110	38	410	160	130	15
	cells/ml	Bottom	0.0042	1300	380	360	84	37	1400	270	180	60
Redox (oxidation potential)	mV	Bottom	-61	340	110	120	28	-120	230	3.1	-11	19
Secchi disc	m	Pond	0.45	1.6	1	1	0.098	0.42	2	1.2	1.2	0.13
Vegetation Coverage	%	Pond	0	25	23	25	2.3	1	30	9.2	5	2.5

Notes

--: Not analyzed/not available
Surface: Samples collected at a depth of 0.5 m or less
Middle: Samples collected between 0.6-2.25m
Bottom: Samples collected at a depth greater than 2.25 m

Non-detected results were set to the reporting limit for all calculations

Standard error = Standard deviation / square root of total number of samples

Table 2
Pond 17-13-B
2019-2020 Analytical Results Summary
Riley Purgatory Bluff Creek Watershed District

Parameter	Unit	Pond Depth	2019					2020				
			Min	Max	Mean	Median	Standard Error	Min	Max	Mean	Median	Standard Error
Alkalinity, total, as CaCO3	mg/l	Surface	10	20	15	14	2.3	15	18	17	17	0.82
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Biochemical Oxygen Demand (5-day)	mg/l	Surface	2.3	13	7.7	7.2	2.4	5	20	10	7.8	3.4
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Biochemical Oxygen Demand (Ultimate; lab calculation)	mg/l	Surface	5.9	33	19	17	5.1	11	20	16	17	2
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Carbon, total organic	mg/l	Surface	5.5	11	7.1	6.2	1	4.3	10	6.7	6.2	1.3
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Chlorophyll a, pheophytin-adjusted	ug/l	Surface	3.7	130	74	85	22	45	140	86	80	22
	ug/l	Middle	--	--	--	--	--	--	--	--	--	--
	ug/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, ammonia, as N	mg/l	Surface	0.04	0.06	0.056	0.06	0.004	0.06	0.11	0.073	0.06	0.013
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, nitrate + nitrite, as N	mg/l	Surface	0.03	0.085	0.05	0.035	0.011	0.03	0.11	0.05	0.03	0.02
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, total kjeldahl (TKN)	mg/l	Surface	0.53	2.8	1.6	1.5	0.37	0.73	2.3	1.3	1.2	0.33
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Phosphorus, total, as P	mg/l	Surface	0.11	0.23	0.17	0.16	0.013	0.082	0.23	0.13	0.13	0.012
	mg/l	Middle	0.13	0.33	0.23	0.23	0.1	0.1	0.16	0.13	0.13	0.015
	mg/l	Bottom	0.1	1.4	0.42	0.27	0.12	0.11	0.53	0.27	0.19	0.036
Orthophosphate, as P (Dissolved)	mg/l	Surface	0.003	0.056	0.014	0.003	0.011	0.003	0.004	0.0035	0.0035	0.00029
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
C-Phycocyanin	cells/ml	Surface	0.013	1800	370	250	110	62	850	210	150	39
	cells/ml	Middle	0.012	1300	300	220	110	61	360	140	110	24
	cells/ml	Bottom	0	2100	470	330	140	57	2100	650	370	120
Redox (oxidation potential)	mV	Bottom	-14	390	200	210	28	-67	240	50	65	27
Secchi disc	m	Pond	0.3	1.8	0.7	0.5	0.15	0.34	0.9	0.69	0.65	0.06
Vegetation Coverage	%	Pond	0	25	23	25	2.3	0	60	9.2	3	5.8

Notes

--: Not analyzed/not available

Surface: Samples collected at a depth of 0.5 m or less

Middle: Samples collected between 0.6-1.4 m

Bottom: Samples collected at a depth greater than 1.5 m

Non-detected results were set to the reporting limit for all calculations

Standard error = Standard deviation / square root of total number of samples

Table 3
Pond 07-43-A
2019-2020 Analytical Results Summary
Riley Purgatory Bluff Creek Watershed District

Parameter	Unit	Pond Depth	2019					2020				
			Min	Max	Mean	Median	Standard Error	Min	Max	Mean	Median	Standard Error
Alkalinity, total, as CaCO3	mg/l	Surface	63	160	110	94	17	39	150	92	91	24
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Biochemical Oxygen Demand (5-day)	mg/l	Surface	2.1	4.7	3	2.8	0.46	2	7.7	4.1	3.3	1.2
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Biochemical Oxygen Demand (Ultimate; lab calculation)	mg/l	Surface	3.4	10	6.3	6.2	1.1	4.2	15	9	8.2	2.4
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Carbon, total organic	mg/l	Surface	5.2	7.4	6.2	5.6	0.48	4.2	7.6	6.5	7	0.76
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Chlorophyll a, pheophytin-adjusted	ug/l	Surface	1.5	8.4	5	4.6	1.4	2	91	27	7.1	21
	ug/l	Middle	--	--	--	--	--	--	--	--	--	--
	ug/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, ammonia, as N	mg/l	Surface	0.044	0.29	0.1	0.06	0.046	0.16	0.31	0.26	0.3	0.035
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, nitrate + nitrite, as N	mg/l	Surface	0.03	0.2	0.064	0.037	0.019	0.03	0.19	0.12	0.13	0.034
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, total kjeldahl (TKN)	mg/l	Surface	0.41	0.74	0.6	0.63	0.055	0.57	0.93	0.81	0.87	0.08
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Phosphorus, total, as P	mg/l	Surface	0.05	0.2	0.13	0.11	0.017	0.046	0.27	0.14	0.12	0.019
	mg/l	Middle	0.12	1	0.3	0.17	0.094	0.071	0.24	0.18	0.18	0.02
	mg/l	Bottom	0.15	0.67	0.33	0.26	0.069	0.22	0.74	0.42	0.4	0.058
Orthophosphate, as P (Dissolved)	mg/l	Surface	0.012	0.11	0.056	0.025	0.023	0.059	0.1	0.074	0.069	0.0095
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
C-Phycocyanin	cells/ml	Surface	0.0038	69	20	15	4.1	21	36	25	24	0.87
	cells/ml	Middle	0.0037	80	21	14	3.4	18	34	25	24	0.7
	cells/ml	Bottom	8	97	41	32	10	12	150	52	39	9.1
Redox (oxidation potential)	mV	Bottom	-76	230	62	55	38	-150	160	-59	-110	26
Secchi disc	m	Pond	0.8	2	1.5	1.6	0.13	0.45	2.5	1.3	1.3	0.21
Vegetation Coverage	%	Pond	25	100	77	75	7.1	20	100	78	100	10

Notes

--: Not analyzed/not available
Surface: Samples collected at a depth of 0.5 m or less
Middle: Samples collected between 0.6-2.25 m
Bottom: Samples collected at a depth greater than 2.25 m

Non-detected results were set to the reporting limit for all calculations

Standard error = Standard deviation / square root of total number of samples

Table 4
Pond 18-14-B
2019-2020 Analytical Results Summary
Riley Purgatory Bluff Creek Watershed District

Parameter	Unit	Pond Depth	2019					2020				
			Min	Max	Mean	Median	Standard Error	Min	Max	Mean	Median	Standard Error
Alkalinity, total, as CaCO3	mg/l	Surface	110	140	130	130	4.5	99	170	130	130	14
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Biochemical Oxygen Demand (5-day)	mg/l	Surface	4.1	9.6	7	7.6	1.2	5	8.1	6.9	7.3	0.74
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Biochemical Oxygen Demand (Ultimate; lab calculation)	mg/l	Surface	9.4	23	15	17	2.5	11	17	15	15	1.4
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Carbon, total organic	mg/l	Surface	6.6	8.1	7.5	7.6	0.25	7.0	10	8.6	8.6	0.76
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Chlorophyll a, pheophytin-adjusted	ug/l	Surface	19	89	53	59	14	29	46	37	36	3.6
	ug/l	Middle	--	--	--	--	--	--	--	--	--	--
	ug/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, ammonia, as N	mg/l	Surface	0.04	0.12	0.067	0.06	0.013	0.06	0.06	0.06	0.06	0.0
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, nitrate + nitrite, as N	mg/l	Surface	0.03	0.13	0.05	0.03	0.019	0.03	0.03	0.03	0.03	0.0
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, total kjeldahl (TKN)	mg/l	Surface	0.71	1.9	1.1	0.8	0.22	0.8	1.1	0.96	0.96	0.066
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Phosphorus, total, as P	mg/l	Surface	0.081	0.16	0.12	0.12	0.0076	0.075	0.49	0.15	0.13	0.032
	mg/l	Middle	0.11	0.19	0.14	0.14	0.0089	0.099	0.51	0.22	0.18	0.05
	mg/l	Bottom	0.14	3.4	0.84	0.37	0.32	0.13	0.51	0.31	0.3	0.043
Orthophosphate, as P (Dissolved)	mg/l	Surface	0.003	0.045	0.014	0.008	0.0079	0.003	0.021	0.0095	0.007	0.004
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
C-Phycocyanin	cells/ml	Surface	39	960	280	190	59	28	890	180	150	37
	cells/ml	Middle	44	4100	750	240	170	27	2600	340	220	67
	cells/ml	Bottom	73	2000	820	470	200	5	360	200	240	31
Redox (oxidation potential)	mV	Bottom	-56	340	130	140	36	-160	160	-45	-74	28
Secchi disc	m	Pond	0.5	1.4	0.83	0.8	0.077	0.65	2.1	0.95	0.78	0.14
Vegetation Coverage	%	Pond	25	25	25	25	0	5	30	14	10	3.2

Notes

--: Not analyzed/not available
Surface: Samples collected at a depth of 0.5 m or less
Middle: Samples collected between 0.6-2.25 m
Bottom: Samples collected at a depth greater than 2.25 m

Non-detected results were set to the reporting limit for all calculations

Standard error = Standard deviation / square root of total number of samples

Table 5
Pond 18-24-C
2019-2020 Analytical Results Summary
Riley Purgatory Bluff Creek Watershed District

Parameter	Unit	Pond Depth	2019					2020				
			Min	Max	Mean	Median	Standard Error	Min	Max	Mean	Median	Standard Error
Alkalinity, total, as CaCO3	mg/l	Surface	59	120	86	81	10	52	91	69	67	9.2
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Biochemical Oxygen Demand (5-day)	mg/l	Surface	3.8	6.2	4.8	4.4	0.41	3.7	7.9	4.9	3.9	1
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Biochemical Oxygen Demand (Ultimate; lab calculation)	mg/l	Surface	9.1	17	13	13	1.3	8.5	16	11	9.3	1.9
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Carbon, total organic	mg/l	Surface	6.7	12	8.2	7.2	0.95	5.9	9.7	7.6	7.4	0.9
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Chlorophyll a, pheophytin-adjusted	ug/l	Surface	6.9	33	25	26	4.7	12	25	19	19	2.8
	ug/l	Middle	--	--	--	--	--	--	--	--	--	--
	ug/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, ammonia, as N	mg/l	Surface	0.04	0.13	0.069	0.06	0.015	0.06	0.06	0.06	0.06	0
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, nitrate + nitrite, as N	mg/l	Surface	0.03	0.11	0.046	0.03	0.016	0.03	0.03	0.03	0.03	0
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, total kjeldahl (TKN)	mg/l	Surface	0.78	1.7	1.2	1	0.16	0.56	0.99	0.8	0.81	0.092
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Phosphorus, total, as P	mg/l	Surface	0.083	0.3	0.21	0.25	0.027	0.087	0.27	0.17	0.18	0.018
	mg/l	Middle	0.12	0.12	0.12	0.12	0	--	--	--	--	--
	mg/l	Bottom	0.13	0.83	0.34	0.31	0.076	0.087	0.45	0.24	0.25	0.033
Orthophosphate, as P (Dissolved)	mg/l	Surface	0.007	0.16	0.067	0.025	0.03	0.022	0.15	0.088	0.089	0.028
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
C-Phycocyanin	cells/ml	Surface	28	280	150	140	14	0	140	64	65	7.2
	cells/ml	Middle	31	330	150	140	29	45	140	92	100	16
	cells/ml	Bottom	24	3400	440	100	300	37	350	130	100	16
Redox (oxidation potential)	mV	Bottom	-54	360	150	110	41	-63	320	88	88	16
Secchi disc	m	Pond	0.45	1.5	0.86	0.8	0.1	0.7	1.6	1.1	1.1	0.077
Vegetation Coverage	%	Pond	0	25	22	25	2.8	0	40	11	6.5	4.2

Notes

--: Not analyzed/not available
Surface: Samples collected at a depth of 0.5 m or less
Middle: Samples collected between 0.5-1 m
Bottom: Samples collected at a depth greater than 1 m

Non-detected results were set to the reporting limit for all calculations

Standard error = Standard deviation / square root of total number of samples

Table 6
Pond 18-41-C
2019-2020 Analytical Results Summary
Riley Purgatory Bluff Creek Watershed District

Parameter	Unit	Pond Depth	2019					2020				
			Min	Max	Mean	Median	Standard Error	Min	Max	Mean	Median	Standard Error
Alkalinity, total, as CaCO3	mg/l	Surface	38	75	54	53	7.6	40	56	47	47	4
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Biochemical Oxygen Demand (5-day)	mg/l	Surface	1.9	22	7.9	4.7	3.6	2	7.2	4.2	3.9	1.1
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Biochemical Oxygen Demand (Ultimate; lab calculation)	mg/l	Surface	5.8	40	16	11	6.2	3.2	16	10	11	2.7
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Carbon, total organic	mg/l	Surface	7.1	17	9.9	7.7	1.8	7.1	9.2	8.3	8.4	0.44
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Chlorophyll a, pheophytin-adjusted	ug/l	Surface	3.7	25	13	9.8	4.6	8.2	22	15	16	2.8
	ug/l	Middle	--	--	--	--	--	--	--	--	--	--
	ug/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, ammonia, as N	mg/l	Surface	0.06	0.16	0.091	0.06	0.02	0.06	0.33	0.13	0.066	0.066
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, nitrate + nitrite, as N	mg/l	Surface	0.049	0.21	0.12	0.11	0.035	0.03	0.054	0.036	0.03	0.006
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, total kjeldahl (TKN)	mg/l	Surface	0.64	1.6	0.96	0.89	0.17	0.71	1.3	1.1	1.1	0.12
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Phosphorus, total, as P	mg/l	Surface	0.1	0.46	0.22	0.19	0.033	0.13	0.34	0.22	0.2	0.019
	mg/l	Middle	0.36	0.36	0.36	0.36	0	0.19	0.19	0.19	0.19	0
	mg/l	Bottom	0.12	0.52	0.26	0.24	0.039	0.13	0.55	0.35	0.34	0.048
Orthophosphate, as P (Dissolved)	mg/l	Surface	0.037	0.24	0.093	0.058	0.039	0.029	0.15	0.069	0.049	0.027
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
C-Phycocyanin	cells/ml	Surface	0.0039	280	50	32	15	24	260	88	65	12
	cells/ml	Middle	0.0038	0.0038	0.0038	0.0038	0	--	--	--	--	--
	cells/ml	Bottom	1	670	100	38	64	24	620	120	57	33
Redox (oxidation potential)	mV	Bottom	-24	350	160	130	33	-79	370	110	110	20
Secchi disc	m	Pond	0.3	1.2	0.8	0.7	0.087	0.5	1.3	0.87	0.8	0.073
Vegetation Coverage	%	Pond	38	100	79	75	5.9	10	100	79	95	7.5

Notes

--: Not analyzed/not available

Surface: Samples collected at a depth of 0.5 m or less

Middle: Samples collected between 0.5-0.9 m

Bottom: Samples collected at a depth greater than 0.9m

Non-detected results were set to the reporting limit for all calculations

Standard error = Standard deviation / square root of total number of samples

Table 7
Pond 19-11-B
2019-2020 Analytical Results Summary
Riley Purgatory Bluff Creek Watershed District

Parameter	Units	Pond Depth	2019					2020				
			Min	Max	Mean	Median	Standard Error	Min	Max	Mean	Median	Standard Error
Alkalinity, total, as CaCO3	mg/l	Surface	31	44	37	36	2.5	36	41	38	38	1.4
	mg/l	Middle	--	--	--	--	--	46	46	46	46	0
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Biochemical Oxygen Demand (5-day)	mg/l	Surface	3	12	8.1	9.2	1.7	5.5	6.5	6	6	0.28
	mg/l	Middle	--	--	--	--	--	5.8	5.8	5.8	5.8	0
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Biochemical Oxygen Demand (Ultimate; lab calculation)	mg/l	Surface	8.8	31	22	28	4.6	16	18	17	16	0.64
	mg/l	Middle	--	--	--	--	--	21	21	21	21	0
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Carbon, total organic	mg/l	Surface	9.5	13	11	12	0.65	9.6	11	10	10	0.29
	mg/l	Middle	--	--	--	--	--	10	10	10	10	0
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Chlorophyll a, pheophytin-adjusted	ug/l	Surface	9.3	180	87	100	33	24	40	34	37	5
	ug/l	Middle	--	--	--	--	--	110	110	110	110	0
	ug/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, ammonia, as N	mg/l	Surface	0.06	0.7	0.19	0.06	0.13	0.06	0.07	0.06	0.06	0.0035
	mg/l	Middle	--	--	--	--	--	0.17	0.17	0.17	0.17	0
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, nitrate + nitrite, as N	mg/l	Surface	0.03	0.04	0.033	0.03	0.002	0.03	0.03	0.03	0.03	0
	mg/l	Middle	--	--	--	--	--	0.03	0.03	0.03	0.03	0
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, total kjeldahl (TKN)	mg/l	Surface	0.93	3.1	2.1	2.8	0.49	1.5	1.8	1.7	1.8	0.094
	mg/l	Middle	--	--	--	--	--	2.7	2.7	2.7	2.7	0
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Phosphorus, total, as P	mg/l	Surface	0.042	0.16	0.09	0.89	0.013	0.041	0.19	0.089	0.064	0.016
	mg/l	Middle	0.047	0.3	0.14	0.13	0.018	0.049	0.25	0.11	0.1	0.016
	mg/l	Bottom	0.058	0.26	0.18	0.2	0.044	0.12	0.2	0.15	0.14	0.013
Orthophosphate, as P (Dissolved)	mg/l	Surface	0.003	0.003	0	0	0	0.003	0.003	0.003	0.003	0
	mg/l	Middle	--	--	--	--	--	0.003	0.003	0.003	0.003	0
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
C-Phycocyanin	cells/ml	Surface	33	2500	850	800	190	0	920	350	250	52
	cells/ml	Middle	41	2400	700	590	89	110	1600	650	570	53
	cells/ml	Bottom	220	770	520	530	77	12	1600	730	740	85
Redox (oxidation potential)	mV	Bottom	-5	360	200	240	59	-99	270	-7.7	-53	24
Secchi disc	m	Pond	0.25	1.9	0.72	0.45	0.18	0.2	0.75	0.53	0.53	0.049
Vegetation Coverage	%	Pond	25	25	25	25	0	0	25	6	5	2

Notes

--: Not analyzed/not available
Surface: Samples collected at a depth of 0.5 m or less
Middle: Samples collected between 0.5-2.3 m
Bottom: Samples collected at a depth greater than 2.3m

Non-detected results were set to the reporting limit for all calculations

Standard error = Standard deviation / square root of total number of samples

Table 8
Pond 19-24-A
2019-2020 Analytical Results Summary
Riley Purgatory Bluff Creek Watershed District

Parameter	Units	Pond Depth	2019					2020				
			Min	Max	Mean	Median	Standard Error	Min	Max	Mean	Median	Standard Error
Alkalinity, total, as CaCO3	mg/l	Surface	77	120	100	100	7.3	69	90	82	86	6.4
	mg/l	Middle	--	--	--	--	--	100	100	100	100	0
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Biochemical Oxygen Demand (5-day)	mg/l	Surface	3.2	7.3	5.3	5.4	0.65	5.1	7.8	6.5	6.5	0.76
	mg/l	Middle	--	--	--	--	--	7.6	7.6	7.6	7.6	0
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Biochemical Oxygen Demand (Ultimate; lab calculation)	mg/l	Surface	8.1	19	13	13	1.7	13	21	16	15	2.5
	mg/l	Middle	--	--	--	--	--	20	20	20	20	0
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Carbon, total organic	mg/l	Surface	6	8.2	7.2	7.3	0.42	6.7	8.9	7.7	7.5	0.62
	mg/l	Middle	--	--	--	--	--	6	6	6	6	0
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Chlorophyll a, pheophytin-adjusted	ug/l	Surface	11	100	41	33	16	11	85	57	76	23
	ug/l	Middle	--	--	--	--	--	100	100	100	100	0
	ug/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, ammonia, as N	mg/l	Surface	0.04	0.06	0.056	0.06	0.004	0.06	0.44	0.19	0.06	0.13
	mg/l	Middle	--	--	--	--	--	0.06	0.06	0.06	0.06	0
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, nitrate + nitrite, as N	mg/l	Surface	0.03	0.091	0.042	0.03	0.012	0.03	0.19	0.082	0.03	0.052
	mg/l	Middle	--	--	--	--	--	0.03	0.03	0.03	0.03	0
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, total kjeldahl (TKN)	mg/l	Surface	0.71	1.7	1.1	1.1	0.16	1.1	2.2	1.5	1.2	0.33
	mg/l	Middle	--	--	--	--	--	1.9	1.9	1.9	1.9	0
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Phosphorus, total, as P	mg/l	Surface	0.061	0.23	0.13	0.14	0.015	0.09	0.45	0.22	0.19	0.034
	mg/l	Middle	0.1	0.1	0.1	0.1	0	0.16	0.4	0.25	0.24	0.028
	mg/l	Bottom	0.11	0.47	0.2	0.19	0.031	0.15	0.97	0.36	0.29	0.083
Orthophosphate, as P (Dissolved)	mg/l	Surface	0.003	0.028	0.012	0.009	0.0043	0.003	0.14	0.066	0.056	0.04
	mg/l	Middle	--	--	--	--	--	0.005	0.005	0.005	0.005	0
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
C-Phycocyanin	cells/ml	Surface	33	1200	290	210	68	81	2500	580	340	140
	cells/ml	Middle	46	2400	480	240	120	130	530	330	340	27
	cells/ml	Bottom	150	3900	820	290	390	240	750	450	440	36
Redox (oxidation potential)	mV	Bottom	-44	370	180	170	40	-160	270	-8.9	-71	39
Secchi disc	m	Pond	0.4	1	0.63	0.6	0.063	0.3	1.3	0.57	0.5	0.082
Vegetation Coverage	%	Pond	25	25	25	25	0	0	25	7	2.5	3.2

Notes

--: Not analyzed/not available
Surface: Samples collected at a depth of 0.5 m or less
Middle: Samples collected between 0.5-1.5 m
Bottom: Samples collected at a depth of 1.5 m or greater

Non-detected results were set to the reporting limit for all calculations

Standard error = Standard deviation / square root of total number of samples

Table 9
Pond 19-31-B
2019-2020 Analytical Results Summary
Riley Purgatory Bluff Creek Watershed District

Parameter	Units	Pond Depth	2019					2020				
			Min	Max	Mean	Median	Standard Error	Min	Max	Mean	Median	Standard Error
Alkalinity, total, as CaCO3	mg/l	Surface	25	52	39	38	7.9	--	--	--	--	--
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Biochemical Oxygen Demand (5-day)	mg/l	Surface	5.5	12	6.9	5.8	2.3	--	--	--	--	--
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Biochemical Oxygen Demand (Ultimate; lab calculation)	mg/l	Surface	13	25	16	14	5.4	--	--	--	--	--
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Carbon, total organic	mg/l	Surface	6.1	8.5	7.5	7.5	0.52	--	--	--	--	--
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Chlorophyll a, pheophytin-adjusted	ug/l	Surface	18	200	76	54	28	--	--	--	--	--
	ug/l	Middle	--	--	--	--	--	--	--	--	--	--
	ug/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, ammonia, as N	mg/l	Surface	0.04	0.42	0.13	0.06	0.0087	--	--	--	--	--
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, nitrate + nitrite, as N	mg/l	Surface	0.03	0.061	0.048	0.058	0.016	--	--	--	--	--
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Nitrogen, total kjeldahl (TKN)	mg/l	Surface	0.98	1.6	1.3	1.4	0.4	--	--	--	--	--
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
Phosphorus, total, as P	mg/l	Surface	0.084	0.34	0.16	0.14	0.037	--	--	--	--	--
	mg/l	Middle	0.084	0.44	0.16	0.13	0.044	--	--	--	--	--
	mg/l	Bottom	0.13	2	0.49	0.3	0.061	--	--	--	--	--
Orthophosphate, as P (Dissolved)	mg/l	Surface	0.004	0.11	0.027	0.007	0.031	--	--	--	--	--
	mg/l	Middle	--	--	--	--	--	--	--	--	--	--
	mg/l	Bottom	--	--	--	--	--	--	--	--	--	--
C-Phycocyanin	cells/ml	Surface	0.0067	1100	210	110	92	140	150	150	150	6.5
	cells/ml	Middle	0.004	2800	380	130	110	160	160	160	160	0
	cells/ml	Bottom	0.0042	1300	380	360	320	140	360	220	160	70
Redox (oxidation potential)	mV	Bottom	-61	340	110	120	87	-10	190	120	170	64
Secchi disc	m	Pond	0.45	1.6	1	1	0.095	1.2	1.2	1.2	1.2	0
Vegetation Coverage	%	Pond	0	25	23	25	1	--	--	--	--	--

Notes

--: Not analyzed/not available
Surface: Samples collected at a depth of 0.5 m or less
Middle: Samples collected between 0.5-2.3 m
Bottom: Samples collected at a depth greter than 2.3 m
Non-detected results were set to the reporting limit for all calculations
Standard error = Standard deviation / square root of total number of samples

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