Special Publication SJ2000-SP5

An Evaluation of the Periphyton Filtration System at Lake Wade, Orlando, Florida

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Prepared by

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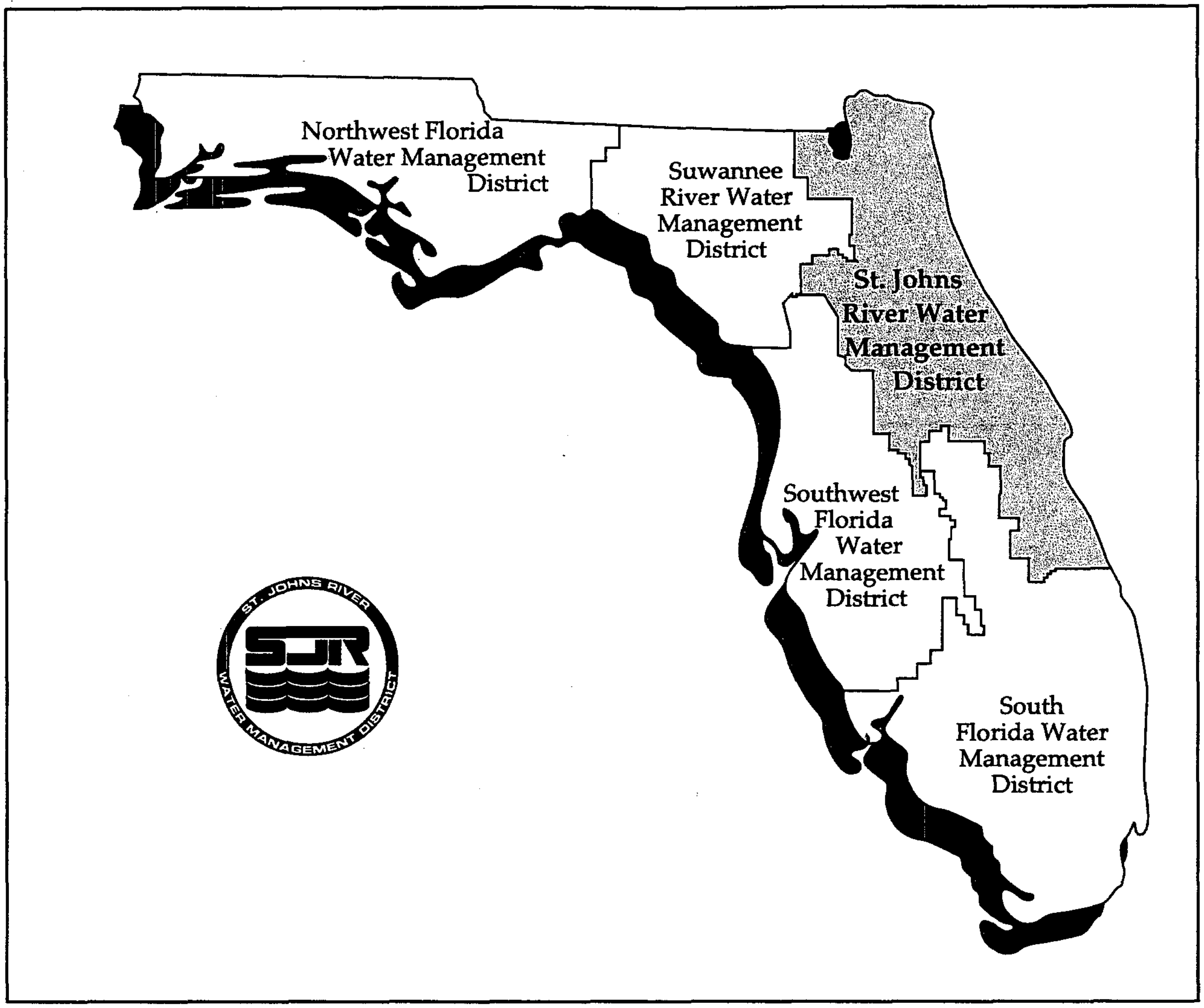
2000



The St. Johns River Water Management District (SJRWMD) was created by the Florida Legislature in 1972 to be one of five water management districts in Florida. It includes all or part of 19 counties in northeast Florida. The mission of SJRWMD is to manage water resources to ensure their continued availability while maximizing environmental and economic benefits. It accomplishes its mission through regulation; applied research; assistance to federal, state, and local governments; operation and maintenance of water control works; and land acquisition and management.

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EXECUTIVE SUMMARY

A periphyton filter consists of a series of flat surfaces, inoculated with algae, over which water flows. The algae and captured pollutants are periodically scraped off and harvested with a vacuum. To determine the applicability of this technology for renovation of urban lakes, the St. Johns River Water Management District (SJRWMD) and its contractors constructed, operated, and monitored a periphyton filter at Lake Wade in Orlando, Florida.

SJRWMD collected both weekly water quality samples and three diurnal sample sets from January through December 1998. The city of Orlando collected monthly samples at the center of Lake Wade. A subcontractor, Azurea, measured the periphyton standing crop every 2 weeks during 1998.

For the first 5 months, periphyton biomass was curtailed due to predation by chironomids. In late May 1998, a biological insecticide, *Bacillus thuringiensis israelensis* (BTI), was applied, which allowed accumulation of greater algal biomass and associated pollutant removal during the last 7 months of the project.

Weekly treatment efficiencies were calculated, based on concentration at the intake and discharge points. For total phosphorus, treatment efficiencies were generally slightly higher in the afternoon than in the morning, with a mean of 17.2% and 12.5%, respectively, for the duration of the project. During the first 5 months, the periphyton filter often exported phosphorus and only averaged 1.4% removal (afternoon sampling). Following the application of BTI, treatment efficiencies for total phosphorus averaged 28.6% (afternoon sampling) for the last 7 months.

Overall treatment efficiencies for ammonia nitrogen almost doubled, from an average of 42.2% before application of BTI to an average of 82.7% after application. A similar trend was observed for nitrate ammonia, which averaged 27.4% removal before BTI application and 42.5% after application. The periphyton filter consistently reduced cadmium, copper, and lead levels following application of BTI.

For the sampling period (50 weeks), the periphyton filter removed a total of 5.8 kg of total phosphorus, based on concentration differences and flow. Following application of BTI, 98% of the total was removed. For the last 7 months of 1998, the periphyton filter removed an average of 62.2 $mg/m^2/day$, based on concentration differences and flow. In comparison, phosphorus removal rates averaged 71 $mg/m^2/day$ for the last 7 months, based on biomass data collected by Azurea.

No significant change in trophic status or nutrient levels was found in Lake Wade.

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ACKNOWLEDGMENTS

The city of Orlando provided substantial assistance for this project through funding and in-kind services. Rick Howard, city engineer, shepherded the project through the city's contract process. Kevin McCann, with the Stormwater Utility Bureau, provided water quality monitoring and technical review. Other members of the Stormwater Utility Bureau provided assistance in operating the automatic samplers. The city also provided staff for the weekly vacuum harvest of algal material. The city Department of Parks and Recreation provided staff to maintain landscaping.

Special credit should be given to the staff of the St. Johns River Water Management District's Orlando office, who conducted the weekly water quality monitoring. The project could not have been completed without the dedicated effort of Cammie Dewey, who supervised the construction and the data collection and resolved day-to-day issues related to filter operation. Additional assistance was provided by Lorne Malo, Victor McDaniel, Liz Johnson, Scott Bray, Tom Ward, David Eunice, Ansonia Cobb, and Rosemary Guffanti (intern).

Both the contractor, Science Applications International Corporation (SAIC), and the subcontractor, Azurea, were enthusiastic participants in this study. Kyle Jensen and Glenn Brosch of SAIC spent long hours to ensure that the filter operated continually and was well received by the public.

INTRODUCTION

Urban lakes often have poor water quality due to stormwater runoff from lawns, streets, and other paved areas. However, the ability to retroactively provide treatment of this stormwater runoff is limited when land is already developed. As an alternative to treating stormwater before it enters the lake, the St. Johns River Water Management District (SJRWMD) studied a periphyton filter, which has the potential to remove pollutants from the lake while using minimal land area.

A periphyton filter consists of a series of flat surfaces over which water flows. The surfaces are inoculated with algae, which is periodically scraped off and harvested with a vacuum. The algae remove pollutants from lake water as it is pumped over the filter surfaces. In 1998, a periphyton filter was installed adjacent to Lake Wade in the city of Orlando (Figure 1). The filter was constructed and operated by a District contractor, Science Applications International Corporation (SAIC). SAIC's subcontractor, Azurea, monitored algal biomass. SJRWMD monitored water quality at the filter, while the city of Orlando monitored water quality in Lake Wade. The project was funded jointly by SJRWMD and the city of Orlando.

Since the use of periphyton filters is an experimental technology, this report summarizes both the construction and operation aspects and the monitoring results.

PERIPHYTON FILTER CONCEPT

Plants are often used as a mechanism to remove pollutants. A periphyton filter, similar to an algal scrubber, is a specialized version of a plant treatment system (Figure 2). Large flat surfaces promote shallow sheetflow of water and the growth of attached algae (periphyton). The periphyton are "harvested" regularly by dewatering, scraping, and then vacuuming the algal material into a tank. Harvesting removes nutrients and other pollutants that have been incorporated into the algal biomass. Algae rapidly grow back from "holdfasts" where they were attached to the surface, and the cycle of pollutant removal begins again. One constraint of the periphyton filter design is that the algal surface cannot be allowed to dry out for more than a few hours.

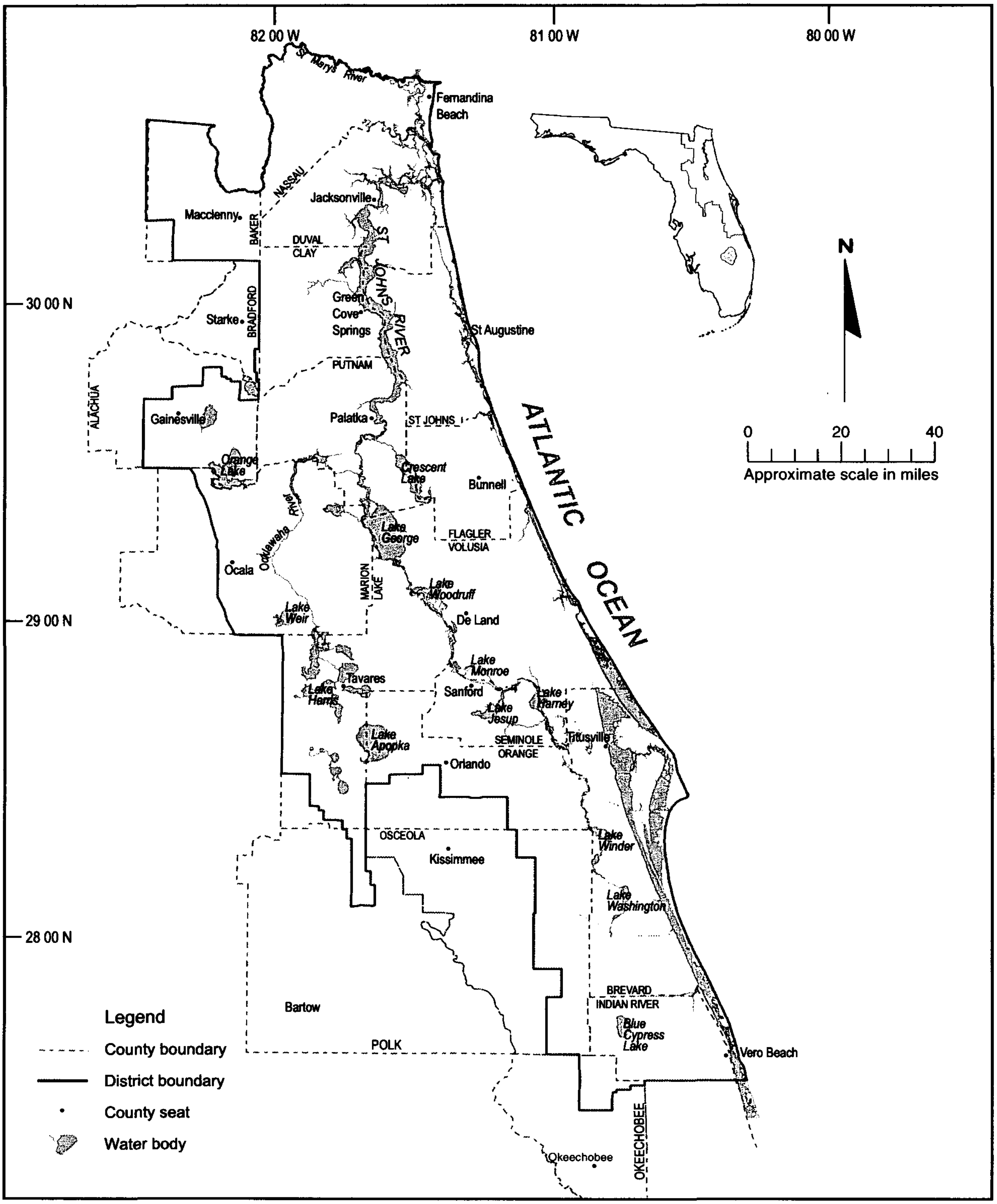

Figure 1. The St. Johns River Water Management District

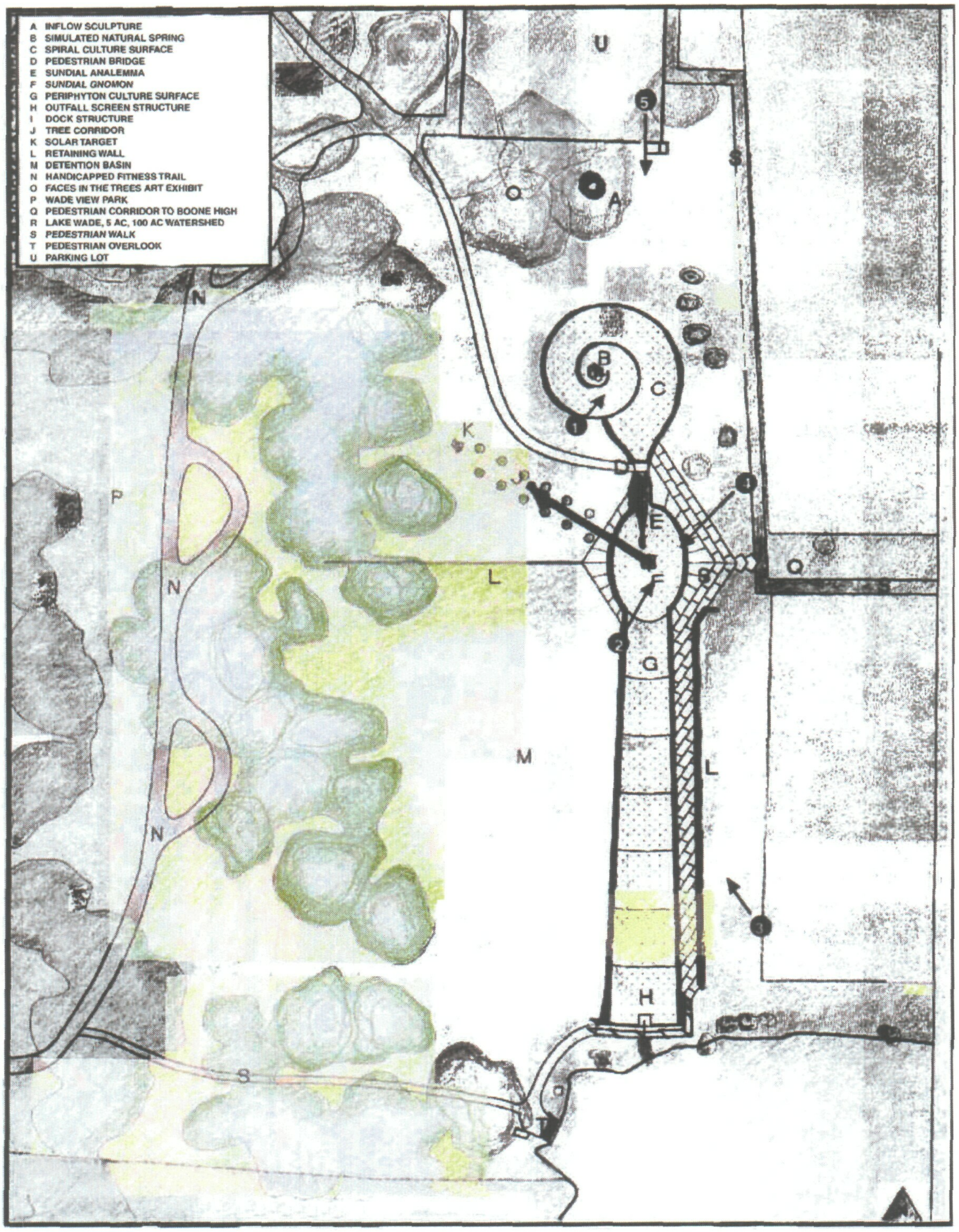

Figure 2. Periphyton filter design

The purpose of this project was to test the treatment efficiency and real-world operational constraints of a periphyton filter. During actual operation, SAIC and the city of Orlando varied harvesting techniques in response to equipment failures, development of improved scraping implements, and other lessons learned. A new filter surface made from recycled tires was tested. Although the harvested algal material may be used as a soil amendment or to manufacture products such as packing materials, these potential uses were not evaluated as part of this study, due, in part, to harvesting equipment failure.

LAKE WADE

Lake Wade is a 4.2-acre lake located in downtown Orlando (McCann et al. 1998). The bathymetry is characteristic of a sinkhole lake, with a maximum depth of about 8 ft (Figure 3). With a mean depth of 4.0 ft, the lake has a volume of approximately 720,000 ft^3. A drainage well is used to reduce flooding impact and discharges during high water levels.

The lake is sampled regularly by the city of Orlando. Water quality is generally poor. From 1988 through 1996, total phosphorus and total nitrogen concentrations averaged 0.117 mg/L and 1.31 mg/L, respectively. Chlorophyll *a* levels averaged 50 mg/m^3, with a trophic state index of 65.5. The lake is stocked with grass carp (*Ctenopharyngodon idella*) for aquatic weed control.

The 188-acre drainage basin is highly urbanized, with a mix of residential (77%) and commercial (23%) land uses (McCannet al. 1998). Based on typical phosphorus loading rates for similar land uses in Florida (Harper 1994), the drainage basin would contribute approximately 245 lbs of phosphorus per year.

The periphyton filter was theoretically sized at 5,100 ft^2 (465 m^2) to remove 50–100 lbs (23–45 kg) of TP (20%–40% of the incoming load) and 500–1,000 lbs (227–454 kg) of N per year (SAIC 1997). The pumps were sized to move a volume equivalent to the lake volume through the filter each month.

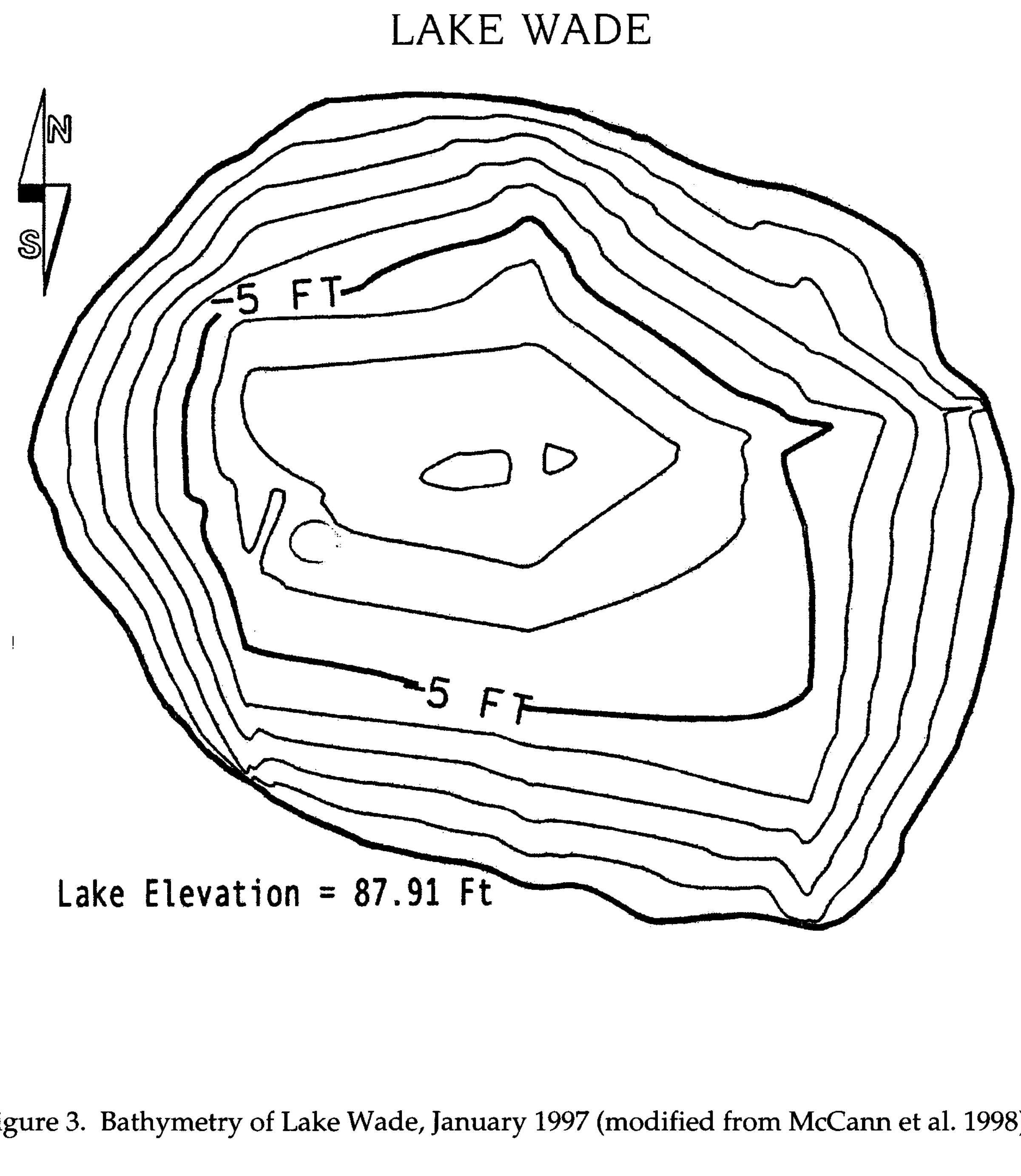

Figure 3. Bathymetry of Lake Wade, January 1997 (modified from McCann et al. 1998)

LITERATURE REVIEW

Periphyton filters have been evaluated as a potential treatment mechanism in the past, although not for urban lakes (Table 1). A prototype was used to remove phosphorus from agricultural drainage canals in the Everglades Agricultural Area in South Florida (Adey et al. 1993). The small raceway system, 15.2 m long and 0.79 m wide, incorporated a surge device to maximize contact between the water column and algae. Phosphorus removal rates ranged from 104 to 139 mgTP/m^2/day during the November through May sampling period. In a single pass, phosphorus concentrations were reduced by 20 ppb for 130 ppb of influent total phosphorus (Brown and Caldwell 1993).

Table 1. Comparison of periphyton filter projects

Project	Type	Average Influent TP (mg/L)	Areal Hydraulic Loading (gal/min/m^2)	Length (ft)	Mean P Removal (biomass)* (mg/m^2/day)	P Treatment Efficiency† (% by conc.)
Patterson, California	Wastewater treatment plant	3.1	0.23	500	730	45
Everglades	Agricultural runoff	0.047	2.3	50	104–139	17
Lake Wade	Urban	0.117	0.31	350	71‡	17§

*From Adey et al. 1993
†From Brown and Caldwell 1993
‡Optimum operational period (BTI added), 7 months
§Study period, 12 months

Periphyton filters have also been tested to remove phosphorus from wastewater treatment plant effluent. Craggs et al. (1996) described a periphyton filter that was constructed in Patterson, California. This large-scale filter (152.4 m long and 6.5 m wide) also incorporated a surge device. Hydraulic loading rates ranged from 436 to 899 m^3/day. An inverse relationship between the hydraulic loading and phosphorus removal was observed. The yearly mean removal of phosphorus was 0.73 g/m^2/day, with a significant portion of this removal attributed to precipitation.

The Southwest Florida Water Management District is currently conducting a study on a periphyton filter constructed at Lake Conine near Winter Haven, Florida. The filter consists of two 500-ft-long filters which can be operated in series or parallel. Monitoring began in January1999 and a final report is expected this year.

METHODS

CONSTRUCTION AND OPERATION

The periphyton filter was constructed at Wade View Park in downtown Orlando, Florida. The park is adjacent to Lake Wade and a school complex, which consists of Blankner Elementary School and Boone High School (Figure 4). The park is subject to heavy use by students and the general public.

The high level of pedestrian traffic and the potential for vandalism were considered in the periphyton filter design. The filter was required to be both functional in water movement and aesthetically integrated with the surroundings. Since this filter was occupying lakefront open space, the visual features of the project were given a high priority.

The periphyton filter consisted of 4-inch concrete slabs with side copings to retain water at a 2- to 3-inch depth. The slabs are terraced and carefully sloped to maximize contact between the water and algae (Figure 5). The filter surface was approximately 5,100 ft^2 (465 m^2) and 350 linear feet (106.7 m). To prevent degradation of the filter surface by algae, the concrete was covered by an asphaltic rubber membrane (80% asphalt, 20% recycled crumb rubber). The membrane was reheated at a later date with heat guns so that sand could be applied to facilitate adhesion of the periphyton. Water was pumped from the center of the lake using two submersible pumps (100-gpm design flow) and allowed to flow over the membrane. Based on the head and the actual operating conditions, the pumps discharged 140–150 gpm. Water discharged over a metal weir and through a triangular wire sieve, designed to catch sloughed algal material. A rock-lined channel then conveyed the water back to the lake (Figure 6).

Several features were added to improve the visual aspects of the periphyton filter, including an initial spiral and an interior sundial (Figure 7). The spiral, while adding visual interest, also increased the flow length and the potential treatment provided. Several sculptures and vegetative landscaping were incorporated into the filter design. Instead of pumping water directly from the lake to the filter, the water first flowed through an overflowing well (Figure 8), which also aided sample collection.

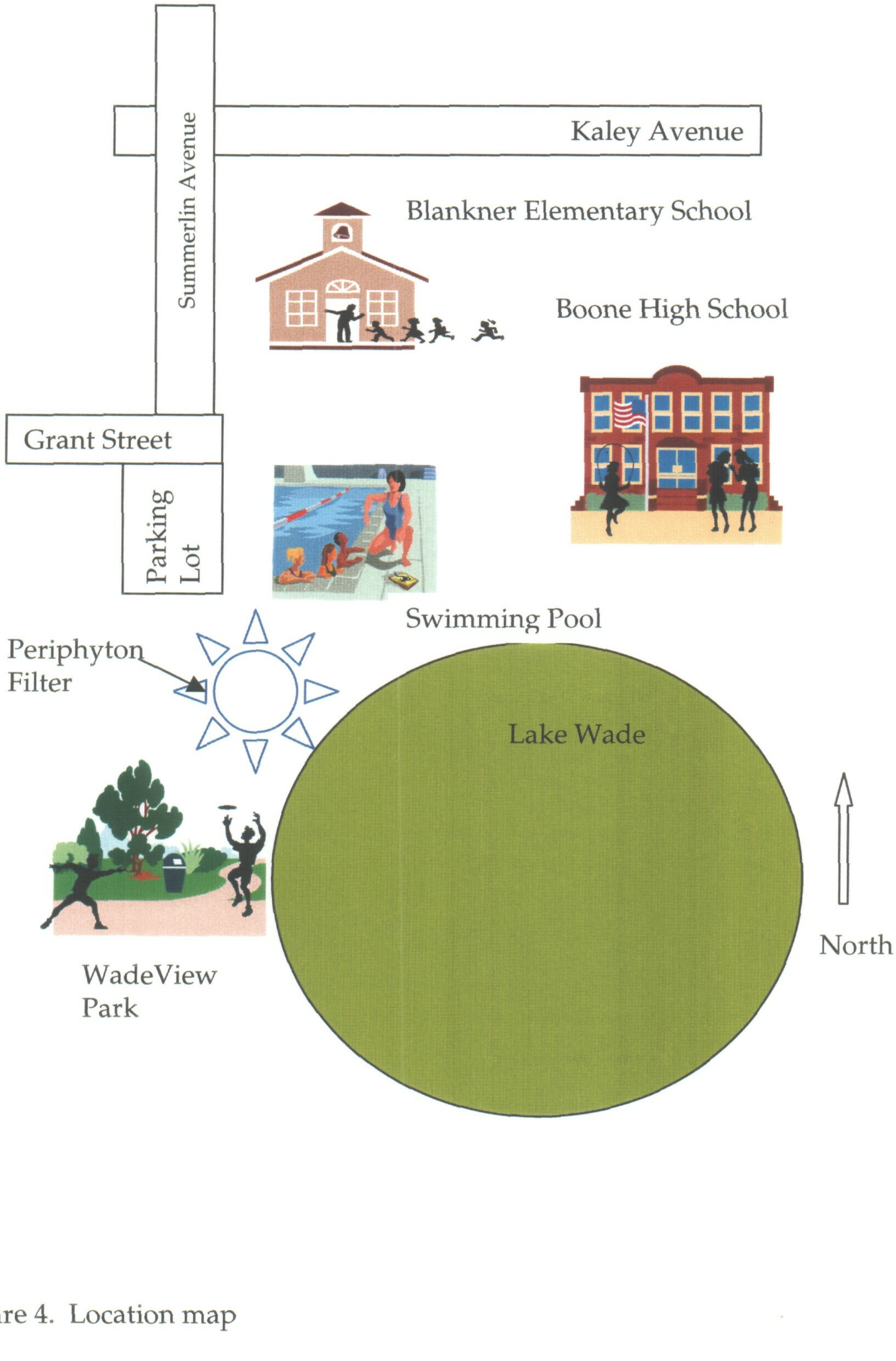

Figure 4. Location map

Figure 5. Periphyton filter terraces

Figure 6. Periphyton filter rock channel

Figure 7. Periphyton filter overflow well, spiral, and sundial

Figure 8. Periphyton filter overflow well (detail)

Pedestrian crossings, walkways, and a lake overlook were constructed to integrate the periphyton filter with earlier foot-traffic patterns. Informational signs were installed to explain the purpose of the filter.

Harvesting

The periphyton on the filter surface were harvested weekly (Figure 9). The procedure for harvesting is as follows:

1. Turn off the pumps and wait 20–30 minutes for the water to drain off the upper portion of the filter.
2. Begin scraping the upper portion of the filter with squeegees, pushing the algal material toward one of two sumps located on the filter.
3. Vacuum the algal material from the sumps into a tank truck.
4. Continue scraping and vacuuming until the periphyton has been removed.
5. Turn the water back on.

The actual harvesting process required about 3 person-hours (two persons scraping algae and one vacuuming). Additional staff time is required for the initial draindown, travel time to the project, and disposal of the collected biomass.

Initially, a special vacuum truck was planned to perform the harvesting. Due to delays in purchase and in licensing and mechanical problems, this special truck was used very little. Most of the harvesting was performed by the city of Orlando's Vactor truck.

Periphyton Inoculation

From December 1997 through April 1998, Azurea personnel collected periphyton from central and south Florida locations and placed this biomass onto the periphyton filter surface. Genera used to inoculate the filter surface included *Pithophora*, *Spirogyra*, *Hydrodictyon*, and *Oscillatoria*. During the 1-year study, Azurea periodically examined the culture surface to determine species composition of the periphyton.

Beginning on May 28, 1998, regular applications of Bacillus thuringiensis israelensis, or BTI, were made to control juvenile midge larvae, which graze on periphyton. BTI is a naturally occurring bacteria commonly used to control pests. The system was dosed twice per week initially, then once

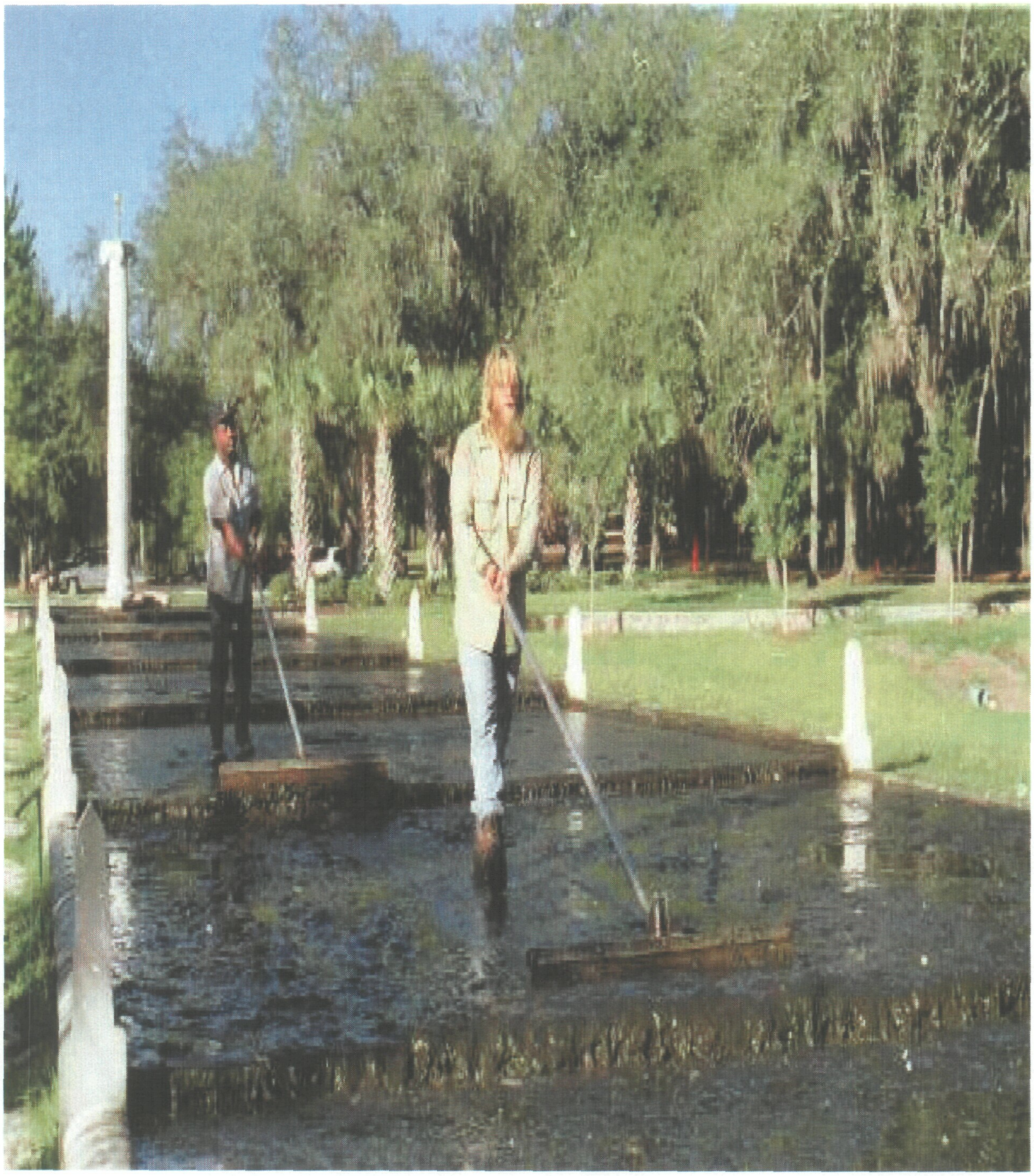

Figure 9. Periphyton filter harvesting

per week for the remainder of the project. A dose consisted of 250 mL of VECTOBAC AS 12 at the overflow well.

MONITORING

St. Johns River Water Management District

SJRWMD collected both routine weekly samples and three diurnal sample sets. Discrete weekly samples were collected twice daily at approximately 9 a.m. and 3 p.m. Samples were collected manually at the overflow well (inlet) and the vacuum sump (outfall). The inlet sample was collected 10 minutes before the outfall sample, based on calculated travel times. The first five sets of intake samples were collected in the pump sump area. However, access to the pump sump was difficult, requiring that a heavy metal door be lifted. To determine an alternate intake sampling site, SJRWMD collected a series of samples at the center of the lake, pump sump, overflow well, and autosampler in February. No significant differences were observed between the four sites, so intake sampling shifted to the overflow well for manual sampling. The autosampler tubing was set to collect samples at the pump sump (inlet) and the vacuum sump (outfall).

Field data (temperature, pH, dissolved oxygen, and specific conductivity) were collected using a Hydrolab Surveyor II. Water samples were analyzed by the SJRWMD laboratory in Palatka. Weekly samples were analyzed for total phosphorus, orthophosphorus, total Kjeldahl nitrogen, nitrate-nitrite nitrogen, ammonia nitrogen, total suspended solids, hardness, and total alkalinity. Analysis for chlorophyll at the outfall began in May 1998. Additional twice-daily samples were collected monthly at the inlet and outlet and analyzed for metals, including cadmium, copper, iron, lead, nickel, silver, and zinc.

SJRWMD conducted 24-hour sample events on August 10–11, September 9–10, and December 3–4, 1998. Samples were collected manually for the first 12 hours and by automatic sampler for the remaining 12 hours. Samples were analyzed for total phosphorus, orthophosphorus, total Kjeldahl nitrogen, nitrate-nitrite nitrogen, ammonia nitrogen, and total alkalinity. Field data were collected during the manual portion of the sample event.

Water samples were collected and analyzed in accordance with SJRWMD's Comprehensive Quality Assurance Plan No. 870413G, as approved by the Florida Department of Environmental Protection (FDEP) on October 28, 1997.

To monitor flow, a totalizing flow meter was installed at the inlet. Flow volumes were recorded weekly, beginning in May. Flow volumes for January through April were assumed to be 144 gpm, equivalent to the overall average flow from May through December.

To calculate mass removal, the concentration change observed in the morning was multiplied by a 12-hour time period, the average flow for the sampling period, and the number of days between sampling periods. The same calculation was performed for afternoon samples and the results summed to obtain milligrams removed per sample period.

City of Orlando

The city of Orlando increased the frequency of their regular lake monitoring to accommodate this project. The city collected monthly samples at the center of Lake Wade at approximately a 0.5-meter depth. Field data (temperature, pH, dissolved oxygen, specific conductivity, and oxidation-reduction potential) were collected using a Hydrolab Surveyor II. Water samples were analyzed by a certified laboratory for pH (EPA 150.1), total alkalinity (EPA 310.1), total phosphorus (EPA 365.2), orthophosphorus (EPA 365.2), total nitrogen, ammonia nitrogen (EPA 350.1), nitrate nitrogen (EPA 353.1), nitrite nitrogen (EPA 354.1), total Kjeldahl nitrogen (EPA 351.2), total suspended solids (EPA 160.2), volatile suspended solids (EPA 160.4), total dissolved solids (EPA 160.1), chlorophyll *a* (SM 10200H), and fecal coliform (SM 9222D).

Additional samples were collected quarterly and analyzed for metals, including beryllium (EPA 210.2), cadmium (EPA 213.2), chromium (EPA 218.2), copper (EPA 7211), iron (EPA 210.7), lead (EPA 7420), mercury (EPA 245.1), nickel (EPA 200.7), selenium (EPA 270.2), silver (EPA 212.2), and zinc (EPA 200.7).

Azurea, Inc.

Azurea personnel measured the periphyton standing crop every 2 weeks during 1998. The influent pump was turned off for at least one-half hour prior to the initiation of standing crop measurements. After collection of quadrat samples, the entire culture surface was harvested. The periphyton standing crop was measured using a small quadrat (0.0625 m^2) placed on the culture surface, typically at four locations, from influent to effluent region of the periphyton filter-based water garden. The algae within the quadrats were harvested, placed in plastic containers, and transported to the laboratory for analyses (Azurea 1999).

Samples collected from each quadrat were analyzed for dry matter content, ash (EPA/COE method 3-59), total phosphorus (COE 2-227 digestion followed by EPA 365.2 analysis), total nitrogen, and carbon (Carlo-Erba elemental analyzer, method validation package approved by FDEP). Standing crop data for dry matter were converted to productivity values by dividing by the quadrat area and the number of days since the previous harvest. Mass nutrient removal by the periphyton standing crop was calculated by multiplying the dry matter productivity by the nitrogen or phosphorus content (Azurea 1999).

As a comparison to the quadrat sampling, monthly biomass samples were scheduled to be collected from the algal slurry vacuumed into the tanker. However, this was not possible due to substitution of a vacuum truck that collected material from a variety of sources in addition to the periphyton filter.

RESULTS

CONSTRUCTION AND OPERATION

The cost of construction of the functional periphyton filter was $65,958. The cost of the landscaping and aesthetic features was $110,413. These costs do not include in-kind services provided by the city of Orlando, which included relocation and replumbing of an existing stormwater treatment system.

Construction of the periphyton filter system took approximately 4 months. It was difficult to find skilled craftsmen, particularly masons, to handle high-quality concrete work. Mid-way through the project the concrete slab and side copings developed a small leak, which was repaired.

The rubberized asphaltic membrane was difficult to apply correctly and consistently using a hot application and squeegee process. During operation, the membrane peeled away from the concrete in some patches and wrinkled up in others. The sand did not stick; by the end of the project, most of the sand had been removed through the harvesting process.

Actual operational costs were difficult to quantify. As part of a contract, SJRWMD paid SAIC $7,279 for periodic inspections, repairs, and part of the harvesting (scraping). City of Orlando personnel performed the balance of the harvesting (vacuuming) as in-kind services and provided the power for the pump.

SAIC (1999) estimated the operational cost at $4,755 per year (man-hours plus power). This estimate was calculated using the approximate man-hours per week for harvesting, repair, and inspection, with an associated cost per hour, depending on the level of expertise required, for a total personnel cost of $3,555. Pump operating costs were estimated at $1,200.

Periphyton Growth

Periphyton were established in December through January, then began to decline. Biomass and coverage began to increase and stabilize in late May

1998, following regular treatments of the filter surface with BTI. From June through December, the culture surface was dominated by *Rhizoclonium* or *Oscillatoria*. The results of the biomass monitoring by Azurea are in Appendix A. Mean algal productivity for the last 7 months averaged 11.5 g dry wt/m^2-day. Ash (nonorganic material) comprised 34.1% of the biomass. Nitrogen and phosphorus contents averaged 3.55% and 0.61%, respectively.

WATER QUALITY

Weekly total phosphorus concentrations, measured in the morning at the intake to the periphyton filter, ranged from 0.077 mg/L to 0.185 mg/L, averaging 0.127 mg/L (Table 2 and Appendix B). Ammonia nitrogen levels averaged 0.08 mg/L, ranging from 0.005 mg/L to 0.165 mg/L. Nitrate-nitrite nitrogen levels declined substantially over the study period (Figure 10), with concentrations in excess of 0.3 mg/L for the first 2 months. This decline in nitrate-nitrite nitrogen levels was confirmed by the city of Orlando's monitoring in Lake Wade (Figure 11). Discharge concentrations are in Appendix C.

Weekly treatment efficiencies were calculated, based on concentration at the intake and discharge points, for the morning and afternoon samples (Appendix D). For total phosphorus, treatment efficiencies were generally slightly higher in the afternoon than in the morning, with a mean of 17.2% and 12.5%, respectively, for the duration of the project. However, treatment efficiency varied widely during the study period (Figure 12). During the first 5 months, the periphyton filter often exported phosphorus and only averaged 1.4% removal (afternoon sampling). Following the application of BTI and the expansion of the periphyton biomass, treatment efficiencies for total phosphorus averaged 28.6% (afternoon sampling) for the last 7 months.

Overall treatment efficiencies for ammonia nitrogen almost doubled, from an average of 42.2% (afternoon sampling) before application of BTI to an average of 82.7% (afternoon sampling) after application (Figure 13). A similar trend was observed in the afternoon for nitrate-nitrite nitrogen, which averaged 27.4% removal before BTI and 42.5% after application of the insecticide (Figure 14). No significant differences were observed between morning and afternoon treatment efficiencies for ammonia nitrogen.

Table 2. Statistical summary of intake data

	AM					PM				
	Mean	Median	Max	Min	Obs	Mean	Median	Max	Min	Obs
Alk	55.486	55.749	62.772	43.042	47	55.593	55.873	63.217	44.129	47
Hardness	71.9	72.0	95.0	48.0	43	72.1	72.0	95.0	51.0	44
TSS	10	9	19	5	48	10	9	20	4	49
TP	0.127	0.121	0.185	0.077	50	0.122	0.123	0.246	0.055	50
PO4	0.026	0.021	0.065	0.007	50	0.025	0.021	0.056	0.009	50
TKN	1.102	1.060	1.590	0.668	49	1.087	1.050	2.300	0.470	49
NH4	0.080	0.072	0.165	0.005	50	0.075	0.072	0.172	0.005	50
NOx	0.097	0.028	0.528	0.003	50	0.099	0.024	0.526	0.002	50
Ag*	0.145	0.001	0.820	0.001	9	0.083	0.002	0.499	0.001	10
Ca	23.772	24.200	30.340	16.370	44	23.893	24.165	31.540	17.400	44
Cd*	0.048	0.007	0.424	0.00	11	0.029	0.008	0.227	0.000	11
Cu*	1.319	1.140	2.220	.860	11	1.273	1.200	1.880	0.930	11
Fe*	60.509	61.500	83.400	36.250	11	59.988	57.200	85.500	38.260	11
Mg	3.064	2.855	4.691	1.699	44	3.003	2.818	4.568	1.080	44
Ni*	1.065	0.760	3.130	0.240	11	0.509	0.380	1.440	0.000	11
Pb*	1.966	1.970	3.070	0.850	11	1.949	2.120	2.910	0.720	2.823
Zn*	9.316	9.870	20.730	1.091	11	7.090	6.920	15.860	2.823	11
W temp	25.0	24.7	31.7	15.1	49	25.1	25.0	32.0	15.6	50
pH	6.65	6.62	7.10	6.19	49	6.79	6.68	7.83	6.33	50
DO	3.43	2.47	10.45	0.15	49	3.68	2.54	12.45	0.18	50
Cond	216	223	286	138	49	216	221	228	140	50

Note: All units are in mg/L except for selected metals (*) which are reported as µg/L and water temperature (°C), pH (s.u.), and conductance (umhos/cm)

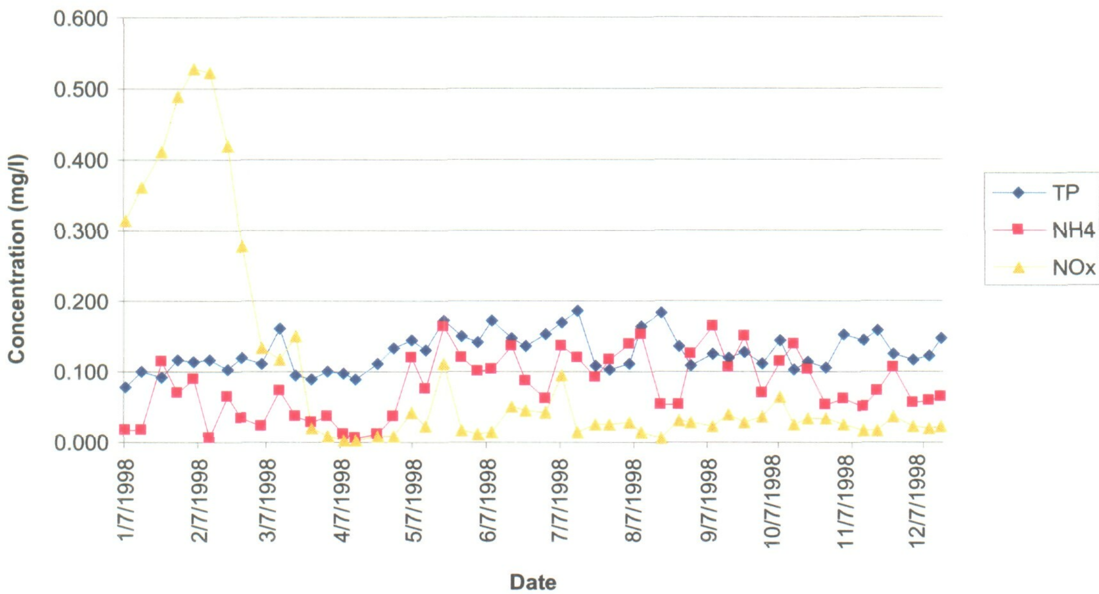

Figure 10. Nutrient concentrations at intake

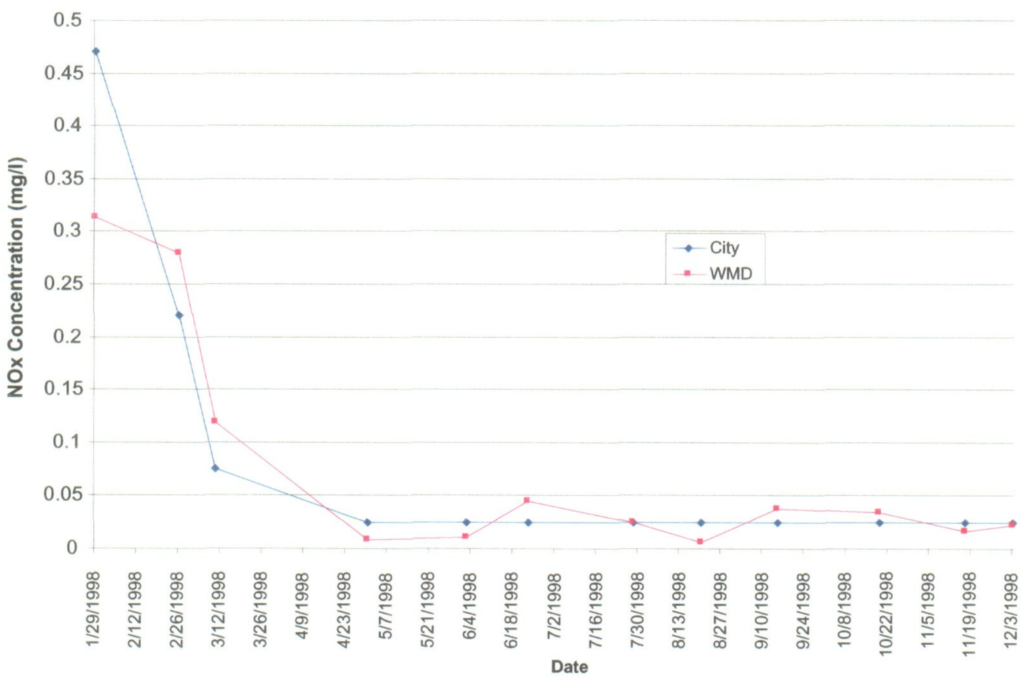

Figure 11. Comparison of nitrate-nitrite nitrogen (NOx) measured by the city of Orlando and by the St. Johns River Water Management District

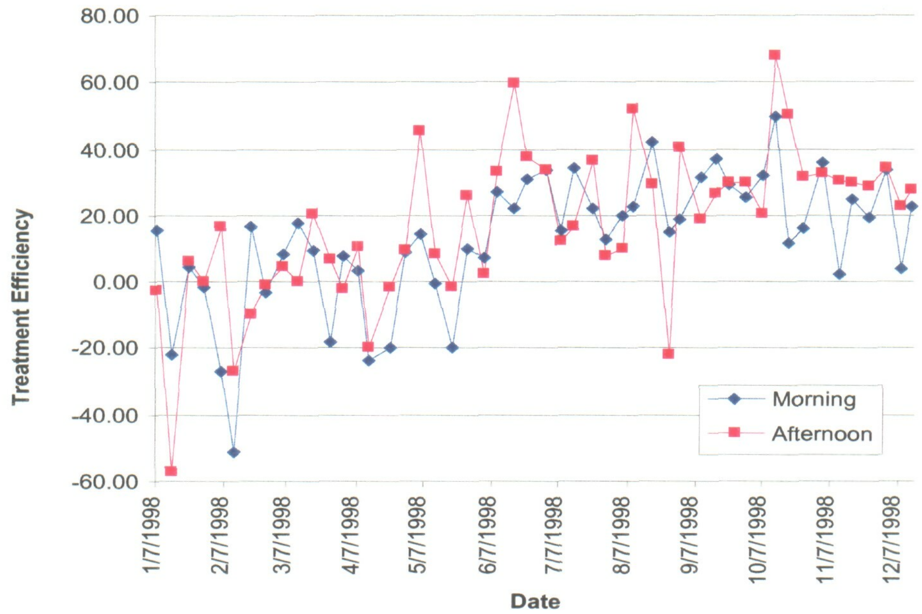

Figure 12. Total phosphorus treatment efficiency

Figure 13. Ammonia nitrogen treatment efficiency

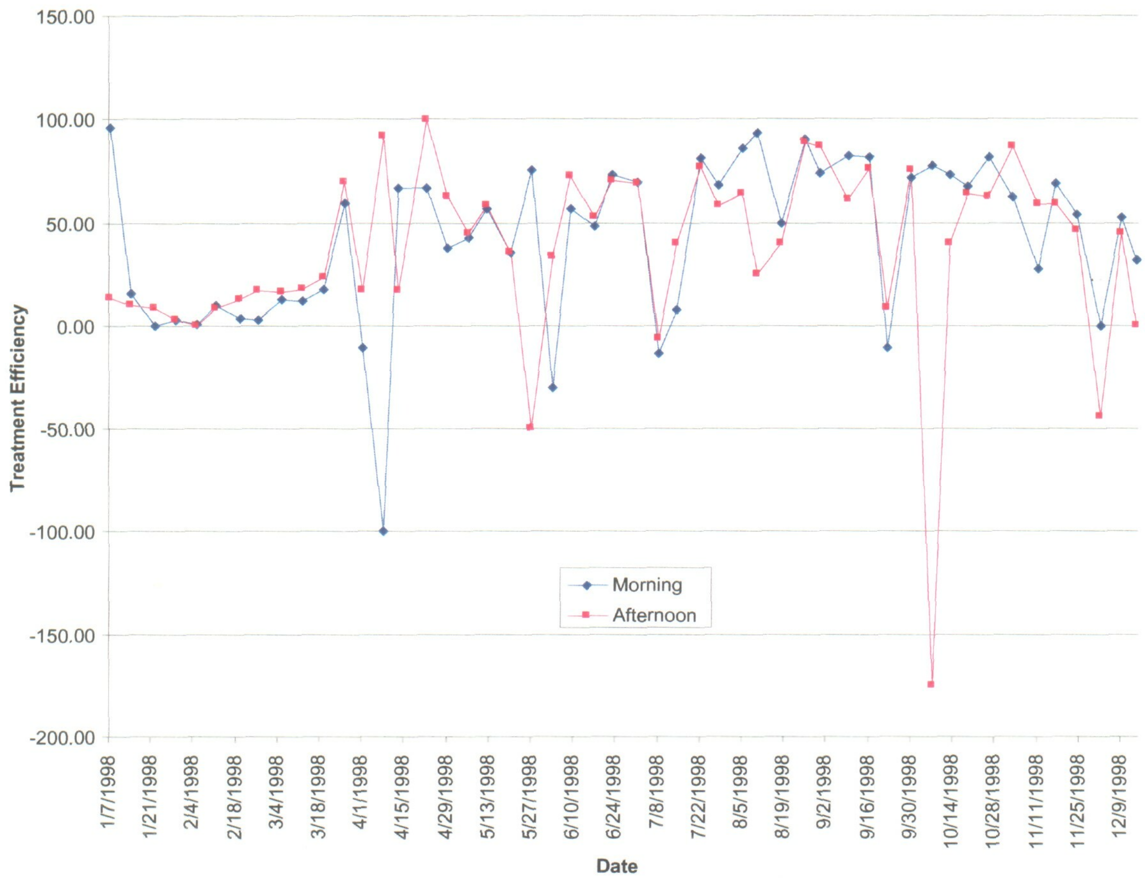

Figure 14. Nitrate-nitrite nitrogen treatment efficiency

In comparison to the nutrient levels, conductance was essentially unchanged, varying by less than 1% on average, with a maximum change of 9.3% (Figure 15). However, the periphyton filter was very effective at adding oxygen. Dissolved oxygen concentrations increased eight-fold on average.

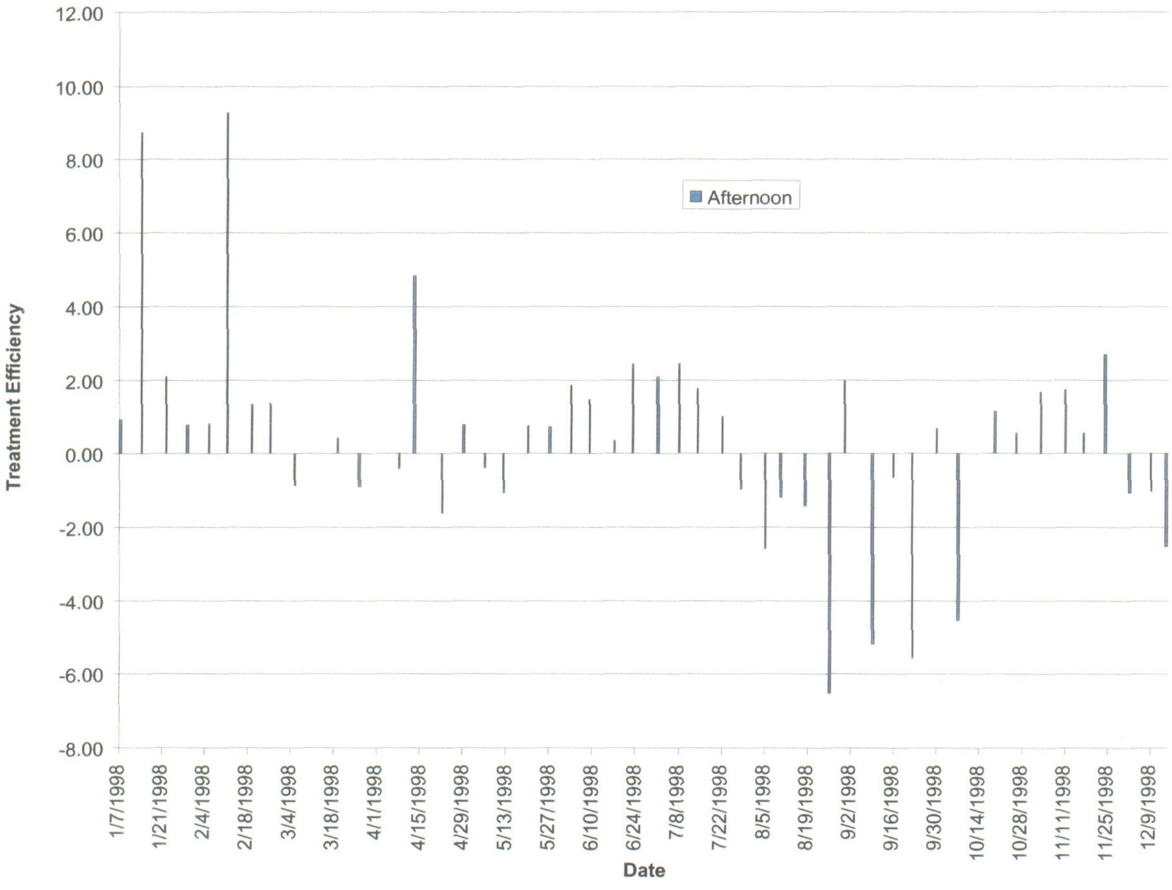

Figure 15. Changes in conductance

Metals (cadmium, copper, iron, lead, nickel, silver, and zinc) were sampled to evaluate pollutant removal and potential release from the recycled crumb rubber. The periphyton filter consistently reduced cadmium, copper, and lead levels (Figure 16) following application of BTI.

Figure 16. Treatment efficiency for metals

Diurnal samples were collected on three occasions to further examine variations in treatment efficiency. For total phosphorus, treatment efficiency did not seem to vary with the amount of insolation throughout the 24-hour period on each sampling occasion. The lowest treatment efficiencies were observed at mid-day, compared to the hours between midnight and dawn (Figure 17). During the August diurnal sample, treatment efficiency ranged from -31.8% to 86% (median 49%). In September, the median treatment efficiency dropped to 34%. The median treatment efficiency for December was 32%.

Figure 17. Diurnal total phosphorus removal efficiency

Inorganic nitrogen levels exhibited wider variations during the diurnal sampling on occasion. In August, treatment efficiencies for ammonia nitrogen were consistently high, ranging from 91% to 98% (Figure 18). Treatment efficiencies in September ranged from 87% to 99%, and were consistently 99% once the sampling shifted from manual to automatic. By contrast, treatment efficiencies in December slowly declined from 70% to 10% during manual sampling, then abruptly shifted to negative values when automatic sampling commenced.

Figure 18. Diurnal ammonia nitrogen (NH_4) removal efficiency

Nitrate-nitrite nitrogen exhibited a similar drastic shift in treatment efficiency when sampling shifted from automatic to manual in August (Figure 19). Values that ranged from 25% to 94% during manual sampling in August shifted to negative levels during automatic sampling. In September, treatment efficiencies ranged from 20% to 94%, with two-thirds of the values ranging from 55% to 80%. During the December diurnal sampling, the periphyton filter was exporting nitrate-nitrite nitrogen. Treatment efficiencies peaked at 18% at 11 a.m. and slowly decreased to the point that outgoing concentrations exceeded incoming concentrations by 220% at 1 a.m.

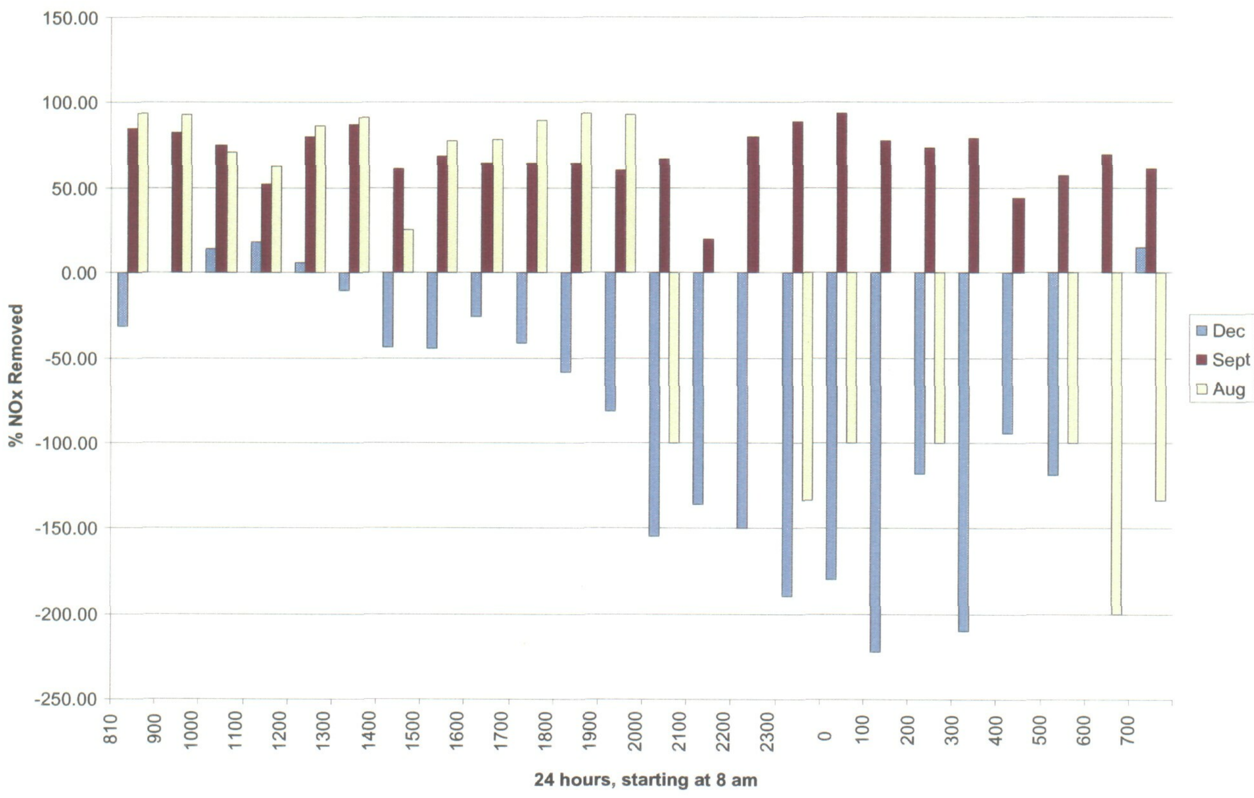

Figure 19. Diurnal nitrate-nitrite nitrogen (NOx) removal efficiency

The transition between manual and automatic sampling during diurnals produced erratic results. In August, nitrate-nitrite nitrogen concentrations at the intake dropped to less than 0.003 mg/L upon initiation of automatic sampling at 8 p.m. (Figure 20). These low intake concentrations yielded negative treatment efficiencies. Ammonia nitrogen and total phosphorus did not exhibit a similar shift in concentration or removal efficiency.

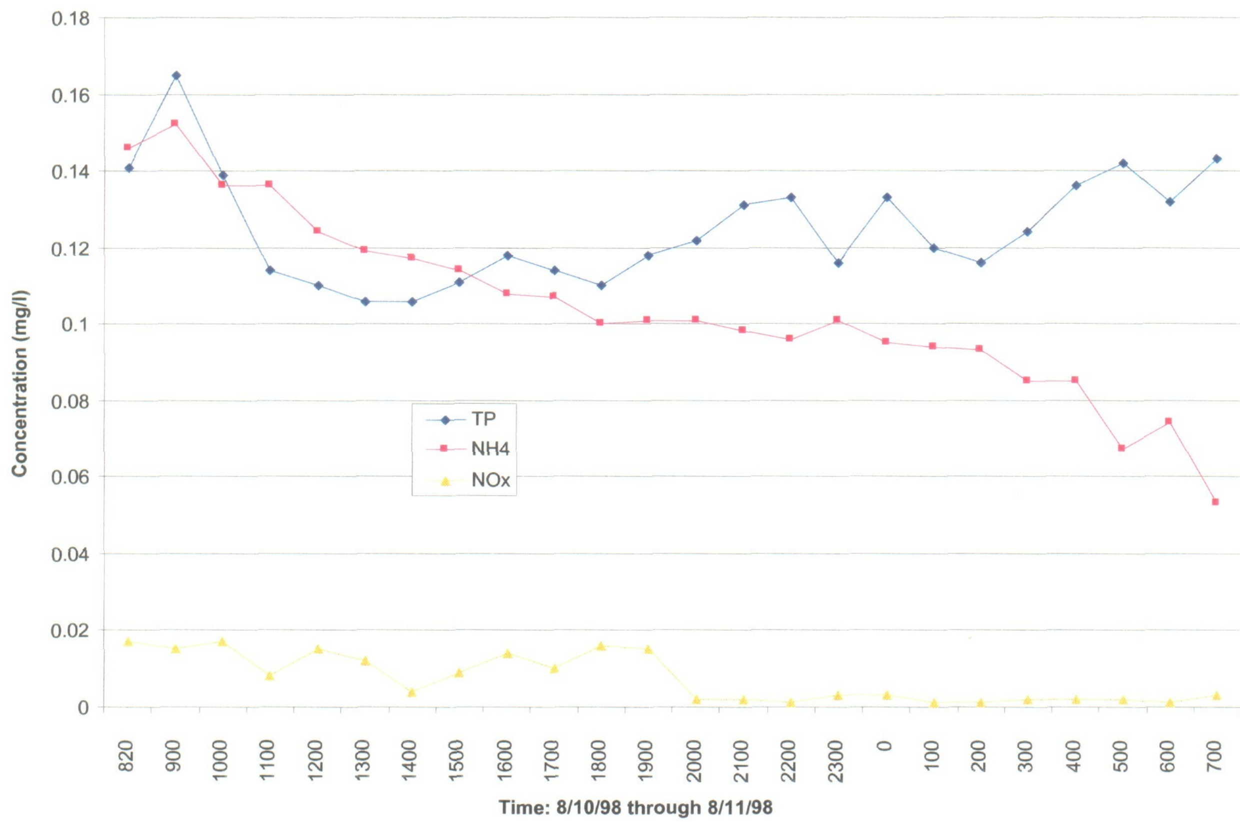

Figure 20. Diurnal nutrient concentrations at intake (8/10/98)

In September, no distinct concentration changes at the intake were noted following the shift from manual to automatic sampling at 8 p.m. (Figure 21). However, the removal efficiency for ammonia nitrogen shifted to 99% and remained at that level (Figure 18).

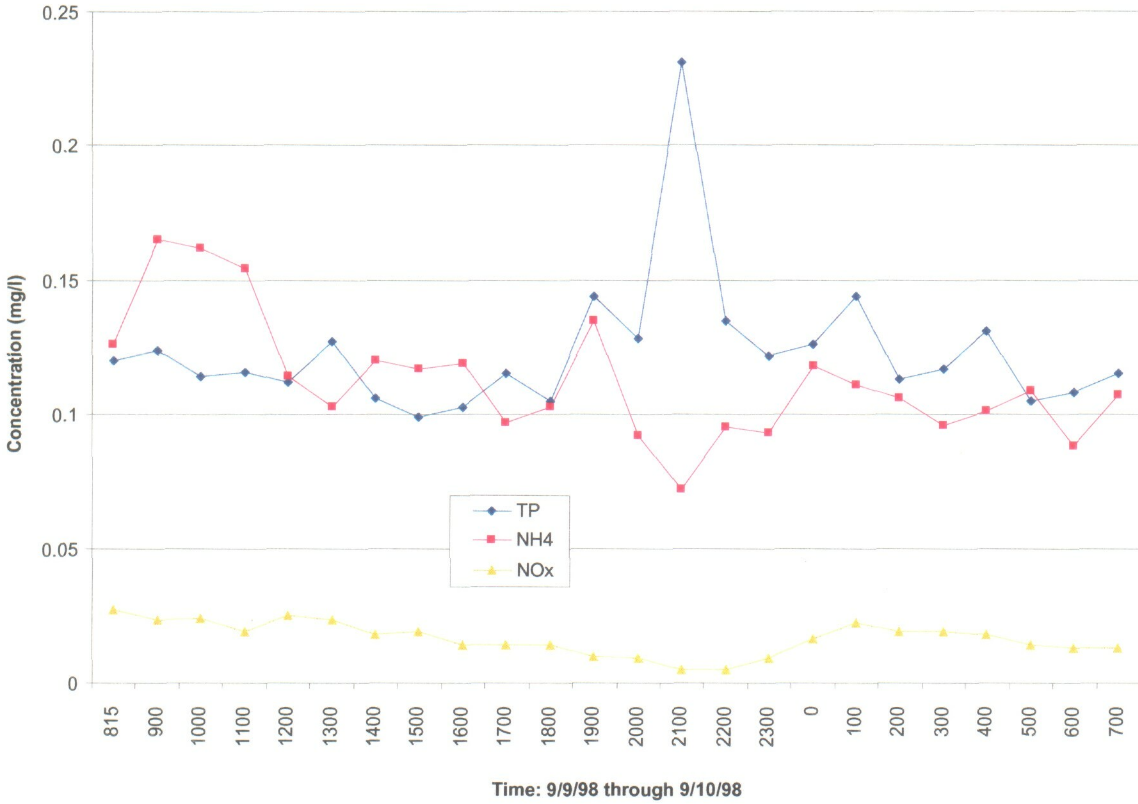

Figure 21. Diurnal nutrient concentrations at intake (9/9/98)

In contrast, the removal efficiency for ammonia nitrogen dropped from positive to negative values when sampling shifted from manual to automatic in December. Removal efficiency averaged 48% in the 12 hours before the 8 p.m. shift and -17% thereafter. No significant changes were observed in the intake concentrations (Figure 22), although a substantial increase in ammonia nitrogen levels at the discharge point was noted (Figure 23).

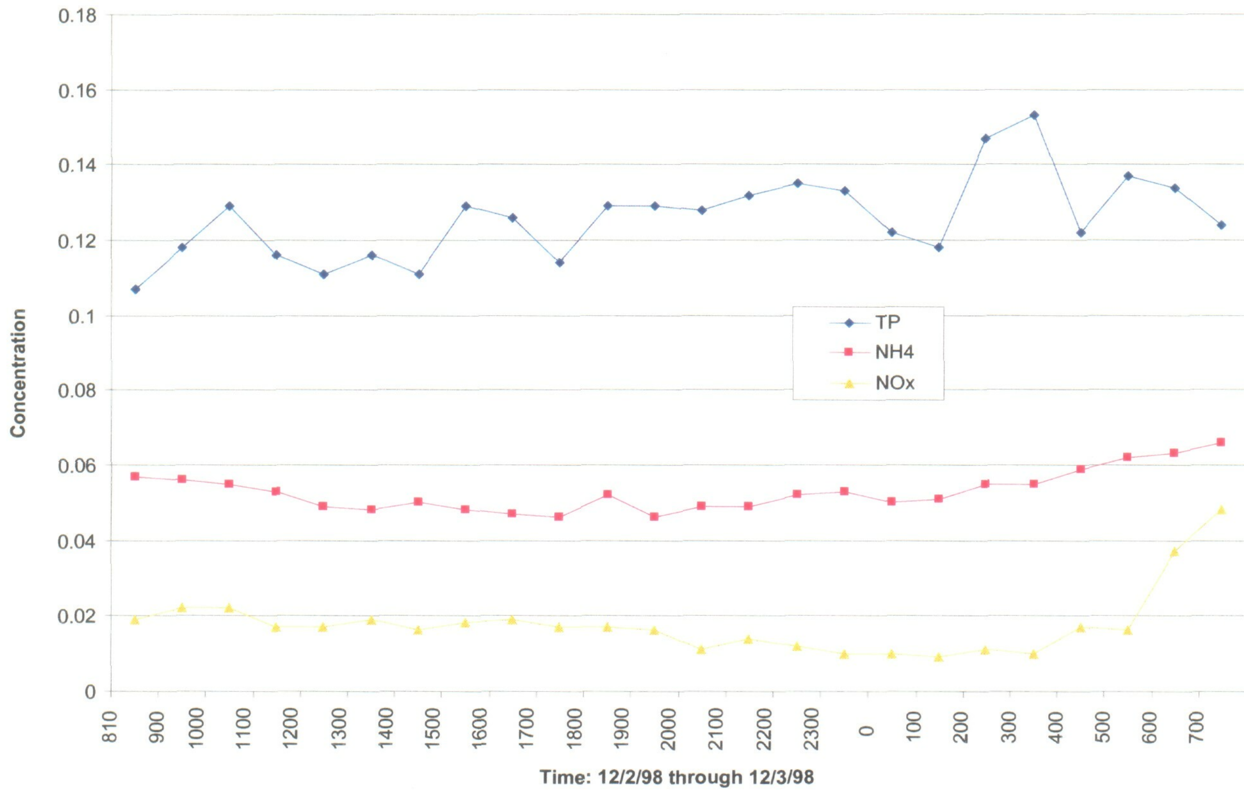

Figure 22. Diurnal nutrient concentrations at intake (12/2/98)

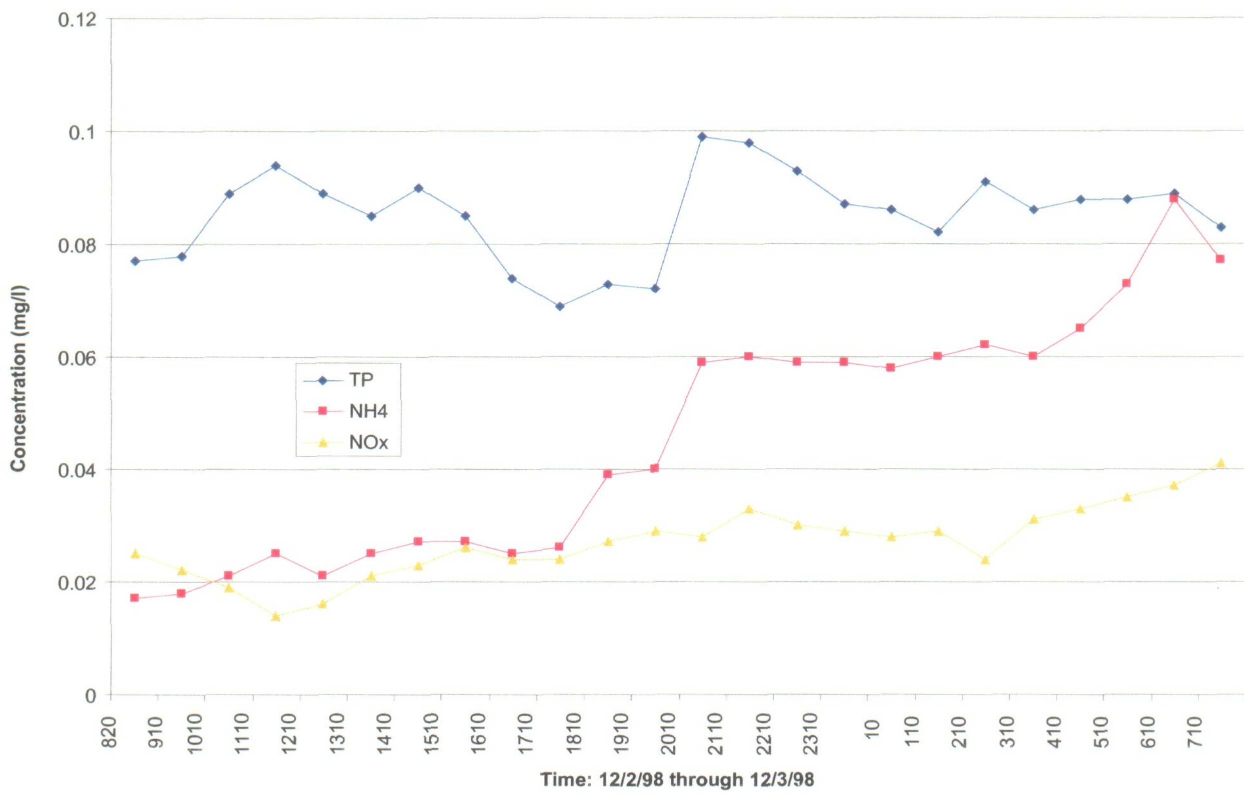

Figure 23. Diurnal nutrient concentrations at outfall (12/2/98)

For the sampling period (50 weeks), the periphyton filter removed a total of 5.8 kg of total phosphorus, based on concentration differences and flow. Following application of BTI, 98% of the total phosphorus was removed (Figure 24). For the last 7 months of 1998, the periphyton filter removed an average of 62.2 mg/m^2/day of phosphorus, based on concentration differences and flow.

In comparison, phosphorus removal rates averaged 71 mg/m^2/day for the last 7 months, based on biomass data collected by Azurea (1999).

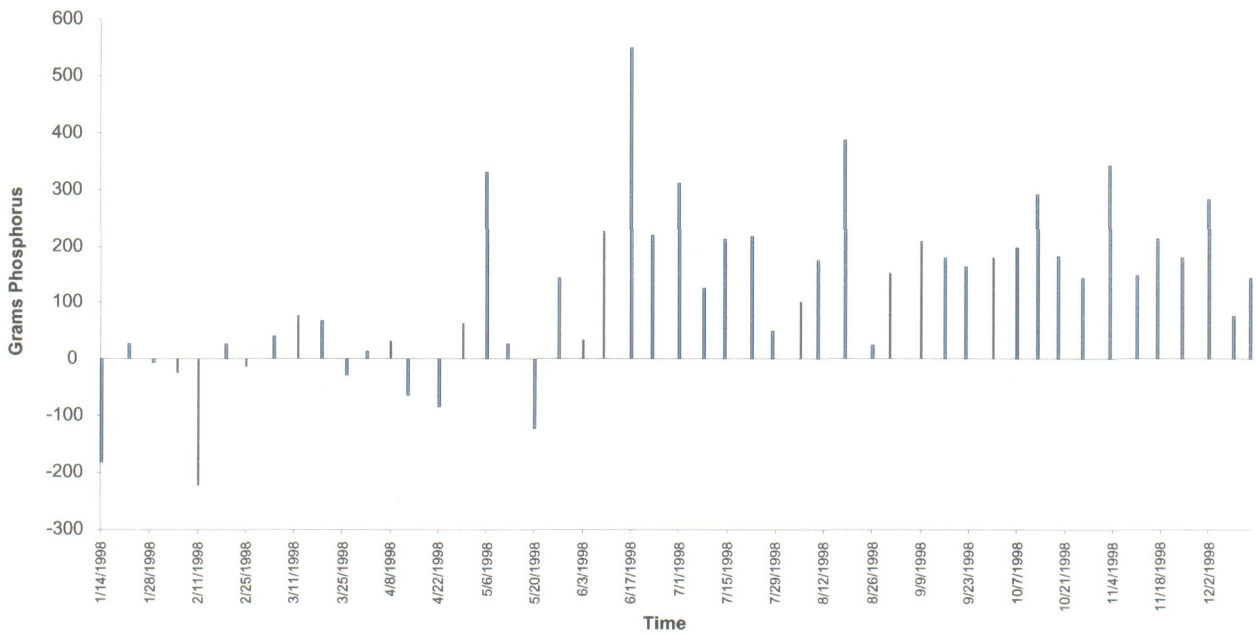

Figure 24. Phosphorus removed per week

Monitoring results for Lake Wade are in Appendix C. Nitrate nitrogen and ammonia nitrogen concentrations were typically at the level of detection (0.02 and 0.005 mg/L, respectively). Total phosphorus levels appeared to decline during the sampling period in 1998 (Figure 25). However, the decline was within the range of variation observed in previous years.

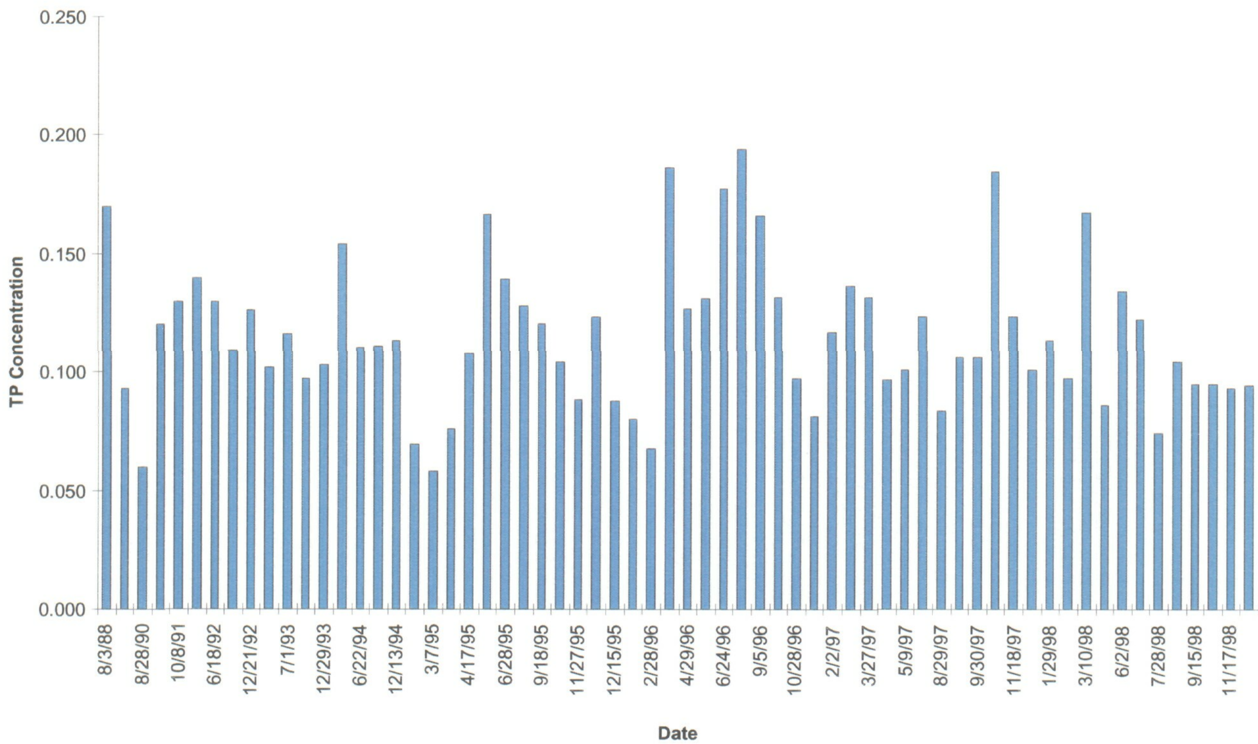

Figure 25. Lake Wade total phosphorus (TP) over time

DISCUSSION

CONSTRUCTION AND OPERATION

The periphyton filter was well received by the general public. It provided an opportunity to educate students and the general public about water pollution and treatment provided by plants. SJRWMD staff and subcontractors answered numerous questions about the purpose and treatment mechanisms of the periphyton filter.

The site was subject to periodic vandalism, including removal of detachable parts. Although the vandalism was not extensive, it caused minor malfunctions, such as loss of power to the sump pump. In the future, readily detachable parts should be eliminated.

SAIC (1999) has evaluated the failure of the rubberized membrane to adhere to the concrete. The investigation revealed that the membrane has a lower than desired softening point, which allowed vandals to peel the material away from the concrete. By reheating the membrane with heat guns to apply the sand, pinhole leaks were created that allowed water to seep under the membrane, further separating the material from the concrete. This procedure is not recommended in future. SAIC has located an alternate membrane with a higher softening point and greater resistance to pinhole leaks. This material is being tested at another periphyton filter site and will be installed at Lake Wade.

The lightweight plastic duct used to convey water from the center of Lake Wade to the pumps was periodically snagged by fishermen or work crews. In one case, this caused shutdown of the pumps. Additional ballast was added to the duct to reduce flotation. This conveyance method would not be suitable for a lake that has significant boat traffic.

Harvesting techniques evolved during the first year of operation. Better squeegees were developed to scrape the algae, which reduced man-hours. City crews preferred to use the Vactor truck, which they routinely use for other types of cleanup, rather than the specially built vacuum truck. While use of the Vactor truck may reduce the overall time needed, since the crews can travel from one vacuum job to the next, it limits the options for reuse of the material collected. The current sump sizes (less than 1-ft^2

capacity) hinder collection, since the material must be pushed into the sump at a rate matching the vacuum pump. Larger sumps or a pipeline hookup would alleviate this bottleneck.

WATER QUALITY

Treatment efficiency and mass of pollutants removed were drastically lower during the first 5 months of operation, presumably due to predation by juvenile midge larvae. The low levels of algal growth were due to numerous causes, including toxic materials in the recycled rubber substrate, light intensity, nutrient balance, intolerance of the inoculated algal species to flowing water, and predation. Since algal biomass increased substantially following application of the insecticide BTI, macroinvertebrate grazing was apparently the major limiting factor.

The ratio of available nutrients (N:P) also remains a concern. Azurea (1999) noted that inorganic nutrient levels (orthophosphorus and ammonia nitrogen) were low in the feedwater. This, in combination with high densities of macroinvertebrate grazers, caused erratic algal growth. The lack of available nitrogen is a typical condition in hypereutrophic lakes and would be a consistent constraint when using periphyton filters to renovate urban lakes or other hypereutrophic lakes, such as Lake Apopka.

The erratic water quality data collected by manual versus automatic samplers is puzzling. A change in intake concentration, such as that observed for nitrate in August, may have been due to the shift in sampling location from the overflow well to the pump sump. However, no decline in nitrate nitrogen was noted for September or December, when the same shift in sampling location occurred. The jump in ammonia nitrogen levels at the outfall in December would not have been due to a change in sample location, since both manual and automatic samples were collected from the vacuum sump.

The phosphorus removal rates generated using the water quality data (62 $mg/m^2/day$) and biomass results (71 $mg/m^2/day$) are comparable, contrary to statements in the Azurea final report (1999). The differences between Azurea's estimate of nutrient removal using SJRWMD's water quality data (23 $mg/m^2/day$) and SJRWMD's estimate (62 $mg/m^2/day$) are apparently due to averaging the upstream and downstream data over the sampling period versus calculating and summing nutrient removal for each sampling period. However, it was not possible to compare these sampling methods with the third estimate of nutrient removal using the vacuum slurry data because of the switch to a nondedicated vacuum truck.

No significant change in trophic status or nutrient levels was found in Lake Wade. The lack of improvement may have been due to the short operational timeframe (only 7 months of effective nutrient removal) or because not enough phosphorus was removed relative to loading. The periphyton filter only removed about 25% of the phosphorus that was expected when it was designed (5.8 kg removed vs 23 kg anticipated removal). The filter removed 5% of the expected annual total phosphorus load to Lake Wade.

The nutrient removal efficiencies observed for the periphyton filter were lower than those observed for wet detention basins. The periphyton filter removed an average of 28.6% of the total phosphorus, 82% of the ammonia nitrogen, and 42% of the nitrate-nitrite nitrogen when at optimum operation for the final 7 months. In comparison, wet detention basins removed an average of 52% of the total phosphorus and 80% of the nitrate-nitrite nitrogen (Whalen and Cullum 1988).

CONCLUSION

A periphyton filter was successfully constructed and operated for one year in Orlando, Florida. Periphyton were difficult to grow in sufficient mass to remove nutrients until a biological pesticide was added to control macroinvertebrate grazers. During the final 7 months of the project, the periphyton filter successfully removed nutrients, but not in sufficient quantities to improve the quality of Lake Wade. The periphyton filter, in the form of a water garden, was well received by the public as a means of improving lake water quality.

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APPENDIX A—AZUREA, INC., FINAL REPORT ON THE PERIPHYTON FILTER

A Performance Assessment of the Lake Wade Periphyton Water Garden

Prepared By
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Rockledge, FL

Prepared For
Science Applications International Corporation
Orlando, FL

January 12, 1999

Executive Summary

This report is a performance assessment of the Lake Wade Periphyton Filter Water Garden (PFWG), a 465 m^2 water treatment system in which attached algae (periphyton) are used to assimilate nutrients from pumped lake water. During the first four months of 1998, algal growth on the PFWG culture surface was erratic and generally poor. Inorganic nutrient availability (orthophosphorus and ammonium) in the feed water at this time was low, and macroinvertebrate grazer densities were high. Productivity and performance improved markedly in June 1998, likely due to the use of a microbial-based herbivore control agent.

Periphyton productivity during the period May–mid-December 1998 averaged 11.5 g dry wt./m^2-day. Nitrogen (N) and phosphorus (P) removal based on algal standing crop harvest averaged 406 and 71 mg/m^2-day, respectively. Over a years time, the PFWG therefore can produce 1,950 dry kg of algal solids (ca. 65,000 wet kg), containing 68.9 kg N and 12.1 kg P.

Water quality analyses revealed little change in plant nutrients as lake water was fed across the PFWG culture surface, probably due to the high flow (1.75 m/day) applied to the system. An exception was ammonium-N: average influent levels of this constituent were reduced from 0.109 to 0.015 mg/L. System N removal performance estimated from influent-effluent N data was 2.1-fold lower than that calculated by N standing crop uptake. Relative to standing crop P assimilation, the influent-effluent P data underestimated PFWG performance by a factor of 3.1.

Our monitoring data demonstrate that, on a mass per unit area basis, the Lake Wade PFWG is capable of moderate to high P removal performance. Control of macroinvertebrate grazers is required to achieve these performance levels.

Introduction

During 1997, Science Applications International Corporation (SAIC) constructed a Periphyton Filter-Based Water Garden (PFWG) on the shore of Lake Wade, Orlando, FL. This water garden is an amenity to the landscape, and is also intended to serve as a water treatment system for reducing nutrient levels in Lake Wade. The PFWG has a 465 m^2 (5,100 ft^2) culture surface that receives an average of 816 m^3/day (150 gallons/minute) of water pumped from a submerged intake in the lake. Attached algae which grow on the culture surface are harvested weekly and removed from the site, thereby exporting the nutrients contained in the algal biomass from the Lake Wade watershed. Operation of the PFWG was initiated early in December 1997. Azurea, Inc. was contracted by SAIC to conduct biomass monitoring (dry matter standing crop and elemental composition), and to assess overall system nutrient removal performance.

Methods

During the first several months of operation, Azurea personnel collected periphyton from central and south Florida locations and inoculated this biomass onto the PFWG culture surface. During the one year study, we also periodically examined the culture surface to determine species composition of the periphyton.

Azurea personnel measured periphyton standing crop every two weeks during 1998. The influent pump was turned off for at least 0.5 hour prior to the initiation of standing crop measurements. After collection of quadrat samples, the entire culture surface was harvested. Periphyton standing crop was measured using a small quadrat (0.0625 m^2) placed on the culture surface, typically at four locations from influent to effluent region of the PFWG. The algae within the quadrats was harvested, placed in plastic containers, and transported to the laboratory for analyses.

Samples collected from each quadrat were analyzed for dry matter content, ash (EPA/COE method 3-59), total phosphorus (COE 2-227 digestion followed by EPA 365.2 analysis), total nitrogen and carbon (Carlo-Erba elemental analyzer, method validation package approved by FDEP).

Dry matter standing crop data were converted to productivity values by dividing by the quadrat area and the number of days since the previous harveSt. Mass nutrient removal by the periphyton standing crop was calculated by multiplying the dry matter productivity by the nitrogen (N) or phosphorus (P) content. We compared mass removal performance of the periphyton with PFWG performance based on influent and effluent water quality data provided by the St. Johns Water Management District (SJWMD). A mean flow rate of 816 m^3/day (150 gpm) was used for these calculations.

Results and Discussion

Periphyton Productivity and Composition

Complications to PFWG Biomass Monitoring

Biomass monitoring at the PFWG was complicated by several factors. First, algae growth on the culture surface was extremely heterogeneous, so random placement of quadrats resulted in enormous variability in standing crop measurements. Early in the study we therefore changed to subjective placement, where the biomass standing crop on the culture surface was first inspected, and then the quadrat was placed in a region of "average" algal density. An assessment of this subjective placement technique suggests that it provided comparable productivity estimates to random placement of numerous quadrats (Table 1).

A second complication was the continuous loss of algal biomass from the culture surface due to sloughing. SAIC personnel attempted to minimize this by frequent (weekly) harvesting, but nevertheless, a moderate amount of algae was lost from the system, particularly during rain events. While this loss of algae by sloughing would result in our standing crop values underestimating system productivity, this may have been compensated for by the remnants of periphyton left on the culture surface after each harveSt. We never quantified these remnants (essentially the algal standing crop at "day zero"), but this biomass varied widely in distribution, and clearly could have resulted in us slightly overestimating system productivity.

Third, harvested biomass samples collected during the period December 1997–April 1998 were contaminated with sand, which had been applied to the asphaltic rubber surface coating during PFWG construction. Because the sand particles could not readily be separated from the algae biomass, this resulted in an overestimate of productivity (and ash content), and an underestimate in the carbon, phosphorus and nitrogen contents. Data from this period are included in the appendix tables, but are not included in graphs or system performance calculations.

Finally, we were unable to directly measure the dry weight biomass of the algae harvested from the entire culture surface. At the beginning of the study we intended to measure the volume of harvested algal slurry, and to subsample this material to obtain a volume to dry matter conversion. The container on the vacuum truck used for harvest, however, could not be sampled in this fashion.

Despite the above complications, we are confident that the data collected from the period June through December 1998 provide a good estimate of PFWG biomass production and nutrient removal performance.

Periphyton Growth Characteristics

Algae stocking was performed intermittently during the period December 1997 through April 1998. Our goal was to establish a diverse standing crop of periphyton that could thrive in a range of environmental conditions. Genera stocked during this period included *Pithophora, Spirogyra, Hydrodictyon,* and *Oscillatoria.*

Pithophora remained the dominant genus on the PFWG during the first four months of operation. Growth was generally poor, however, and high numbers of macroinvertebrate grazers were observed on the culture surface. In late May, SAIC personnel initiated weekly applications of a microbial-based pesticide. Coincident with these applications, macroinvertebrate densities decreased and algal productivity (principally *Rhizoclonium*) began to increase.

Productivity remained fairly high through December, with the culture surface dominated by either *Rhizoclonium* or *Oscillatoria.*

Biomass Production and Composition

Mean PFWG algal productivity for the period June–mid-December averaged 11.5 g dry wt/m^2-day. Ash (non-organic material) comprised 34.1% of the biomass, and N and P contents averaged 3.55 and 0.61%, respectively. As noted above, initial algal productivity measurements were confounded by the presence of sand on the culture surface, but most of this material was removed by May 1998. Growth at this time was poor, but biomass production increased sharply in June (Figures 1 and 2). We observed a slight decreasing trend in productivity with distance from the influent (Figures 1 and 2): this could be due to feedwater solids settling in the influent region, or to a limitation of some nutrient near the effluent region of the culture surface.

Phosphorus content of the algae was comparable with distance along the culture surface, whereas N content exhibited a slight increase towards the effluent region (Fig. 3). During the study, algae in the effluent region exhibited a slight increase in P content, and a slight decrease in N content over time (Figures 4 and 5). Carbon content was consistent among all sampling locations, whereas ash content for algae in the influent region was slightly higher than for other culture surface locations (Fig. 6). Both carbon and ash varied over time, possibly due to the intermittent settling of inorganic particles on the culture surface (Figures 7 and 8).

Nitrogen and P removal rates over the period June–mid-December averaged 406 and 71 mg/m^2-day, respectively. Uptake rates of these constituents was slightly greater near the influent region of the PFWG (Fig. 9). These removal rates also varied over time, due to their close relationship with dry matter production (Figures 10 and 11).

Influent and Effluent Water Quality

Influent water quality data for the period January–October 1998 reveal that the Lake Wade feedwater is fairly dynamic in composition (Figures 12–25). Some of the variability is likely due to the intermittent runoff loading to the lake and some to seasonal variablity in phytoplankton growth rates. In addition, feedwater concentrations of a few constituents, such as NH_4-N and NO_3-N, may have been influenced by the depth of the pump intake (the intake was moved closer to the sediment in late Spring) (Figures 16–19).

In general, the PFWG had little effect on the feedwater constituent concentrations. The pH was most markedly affected, with effluent levels rising to above 8 during morning hours and above 9 in the afternoon (Figures 20 and 21). Some constituents, such as total P, exhibited export in the morning and removal in the afternoon (Figures 12 and 13).

When the PFWG standing crop biomass became more robust after June, the effluent ammonium-N levels dropped markedly (Figures 16 and 17). Ammonium is the favored N form for most algae, and these data suggest that N potentially could have limited growth during this period. By contrast, we did not observe a decline in algal tissue N levels down the culture surface, which indicates that N probably was not in short supply (Fig. 3).

The Lake Wade feedwater is moderately "soft", and we observed little change in calcium and alkalinity levels as water passed through the PFWG (Figures 22–25). This suggests that $CaCO_3$ precipitation was not occurring on the culture surface. Other studies with periphyton filters have suggested co-precipitation of P with $CaCO_3$ as a prominent P removal mechanism. The consistent P content of algae with distance down the culture surface further suggests that P co-precipitation was not occurring in this system (Fig. 3).

PFWG Nutrient Removal Performance: Biomass Harvest vs. Water Quality

We averaged morning and afternoon water quality data from June–October 1998 to assess N and P removal performance of the PFWG (Table 2). We multiplied the average N (ammonium + nitrate) or P (total P) concentration change by an average daily flow rate of 816 m^3/day. The mean N and P removal rates for this period, based on water data, are 191 mgN and 23 mgP/m^2-day. These rates are between 2 and 3 times lower than the mean N and P removal rates (406 mgN and 71 mgP/m^2-day) calculated from biomass production and composition data. This discrepancy probably is related to the difficulty in obtaining a representative water sample from the fast-flowing, particle-laden PWG effluent. Clearly, the harvest and recovery of biomass provides a more reliable measurement of mass nutrient removal performance.

Table 1. Comparison of random and subjective standing crop quadrat measurements. At each location, one quadrat was placed subjectively on the culture surface (at a site of "typical" algal coverage), and four quadrats were placed randomly.

location	random		subjective
	---------- g. dry wt./quadrat --------		
influent region	5.79		*5.33*
	4.05		
	6.12		
	9.07	x = *6.26*	
middle (a)	6.63		*7.53*
	6.42		
	5.61		
	8.63	x = *6.53*	
middle (b)	3.61		*4.43*
	3.53		
	2.50		
	3.66	x = *3.33*	
effluent	5.22		*6.16*
	3.52		
	14.1		
	1.41	x = *6.07*	

Table 2. Average PFWG influent and effluent water quality data for the period June 3–October 7, 1998.

	morning		afternoon	
	influent	effluent	influent	effluent
	mg/L			
total phosphorus	0.094	0.103	0.130	0.094
orthophosphorus	0.037	0.032	0.035	0.037
ammonium-N	0.109	0.015	0.108	0.016
nitrate-N	0.032	0.015	0.025	0.013
pH	6.5	8.6	6.6	9.2
alkalinity	52.6	51.3	52.8	52.5
calcium	23.5	22.8	24.1	23.6

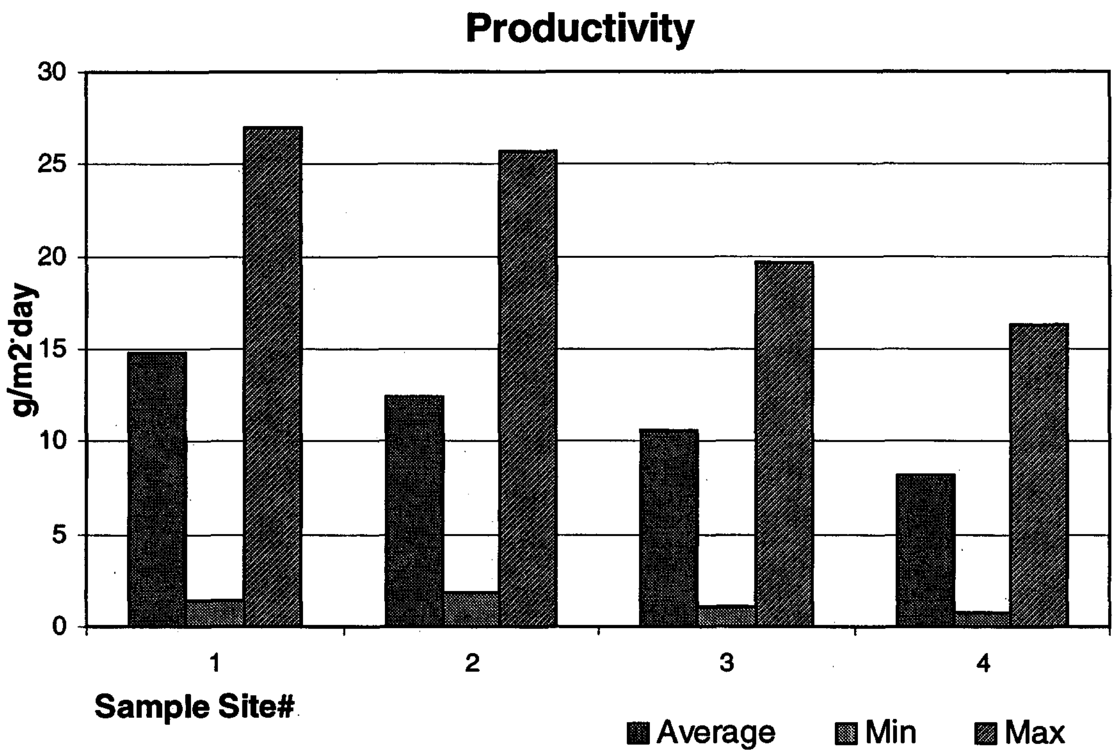


Figure 1. Mean and range of productivities for algae on the PFWG from May – December 1998. Sample sites represent locations from influent (1) to effluent (4) regions of the culture surface.

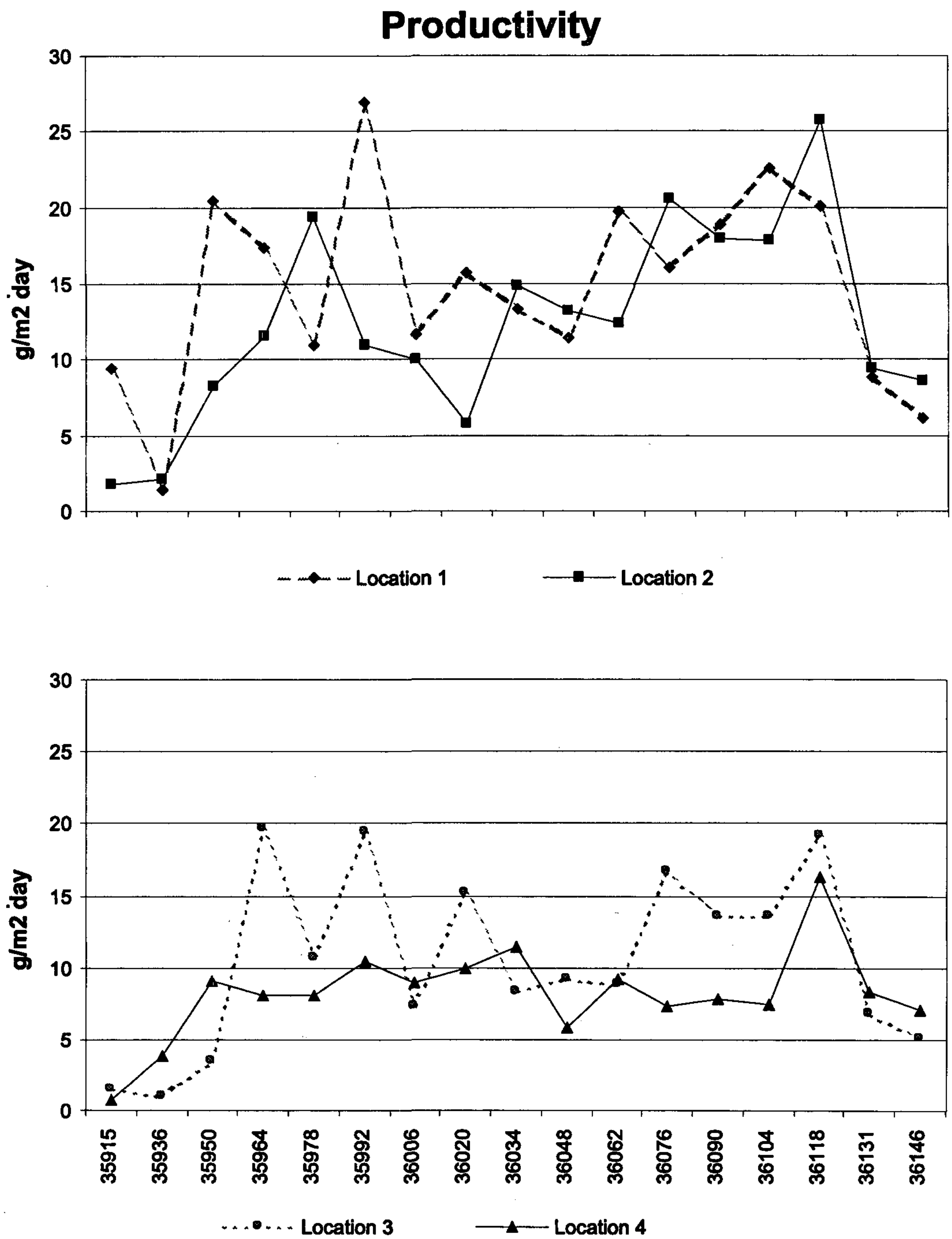


Figure 2. Productivity of PFWG algae at four locations (ranging from influent [1] to effluent [4]) on the culture surface.

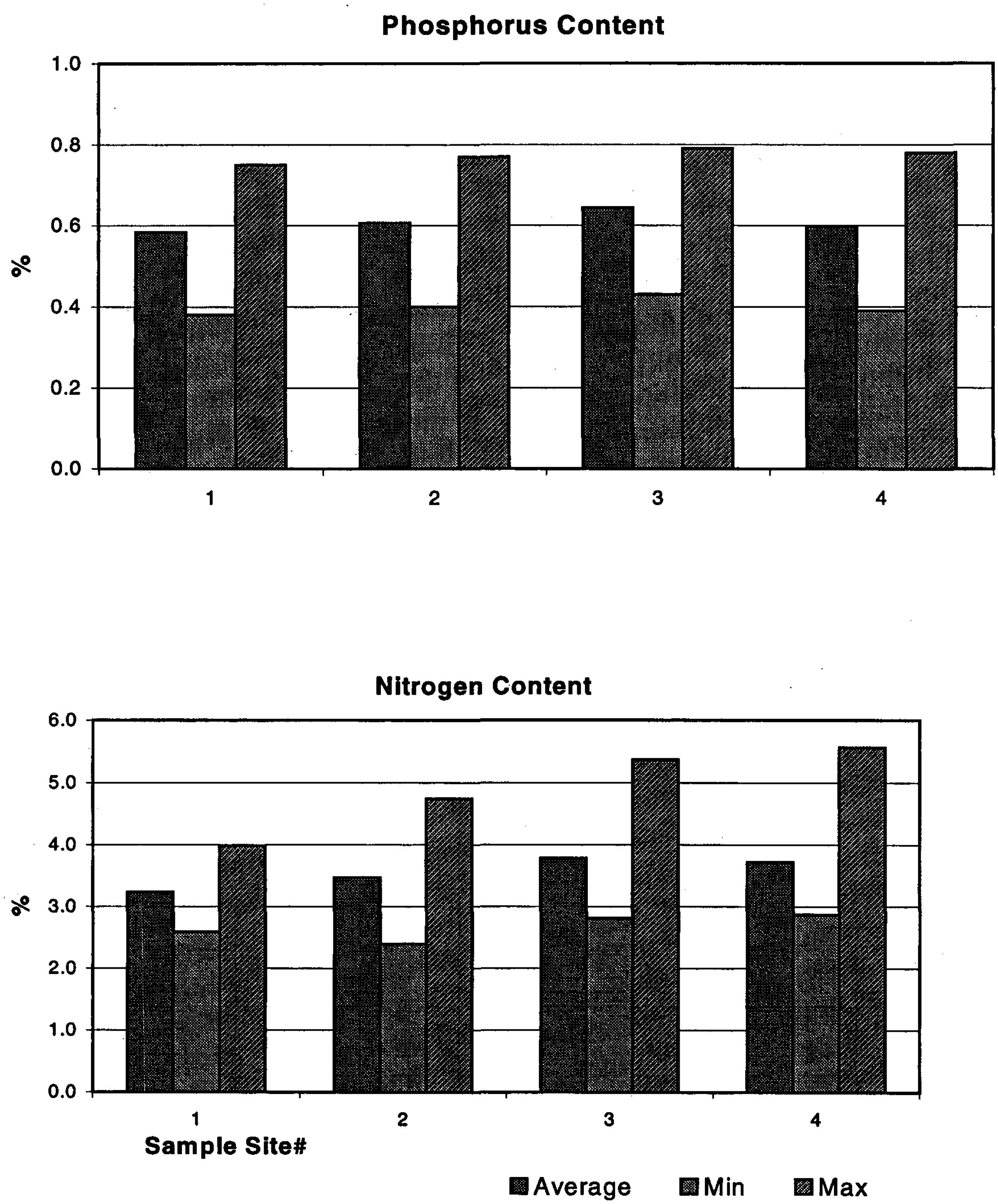


Figure 3. Mean and ranges of phosphorus and nitrogen contents for algae on the PFWG from May – December 1998. Sample sites represent locations from influent (1) to effluent (4) regions of the culture surface.

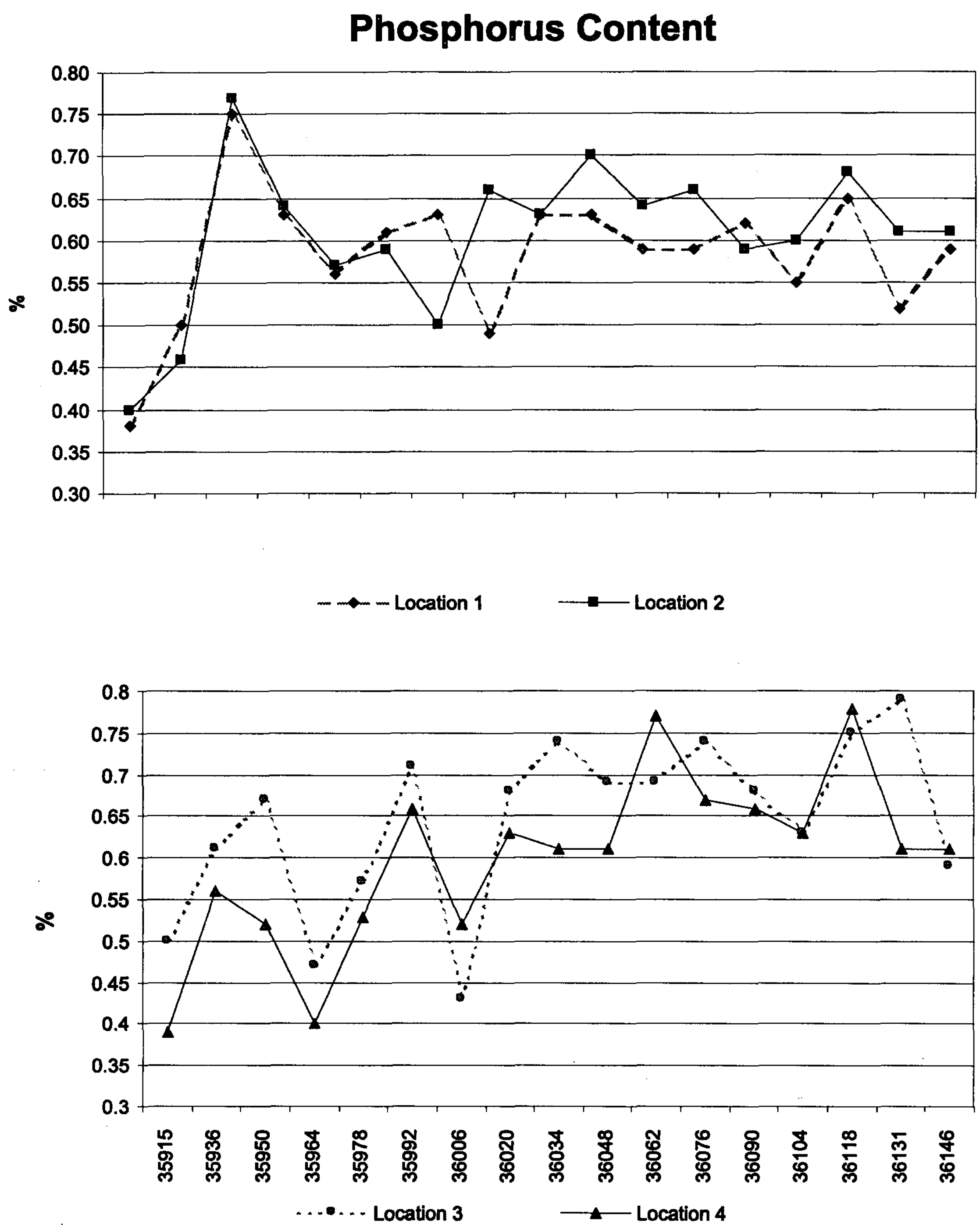


Figure 4. Phosphorus content of PFWG algae at four locations (ranging from influent [1] to effluent [4]) on the culture surface.

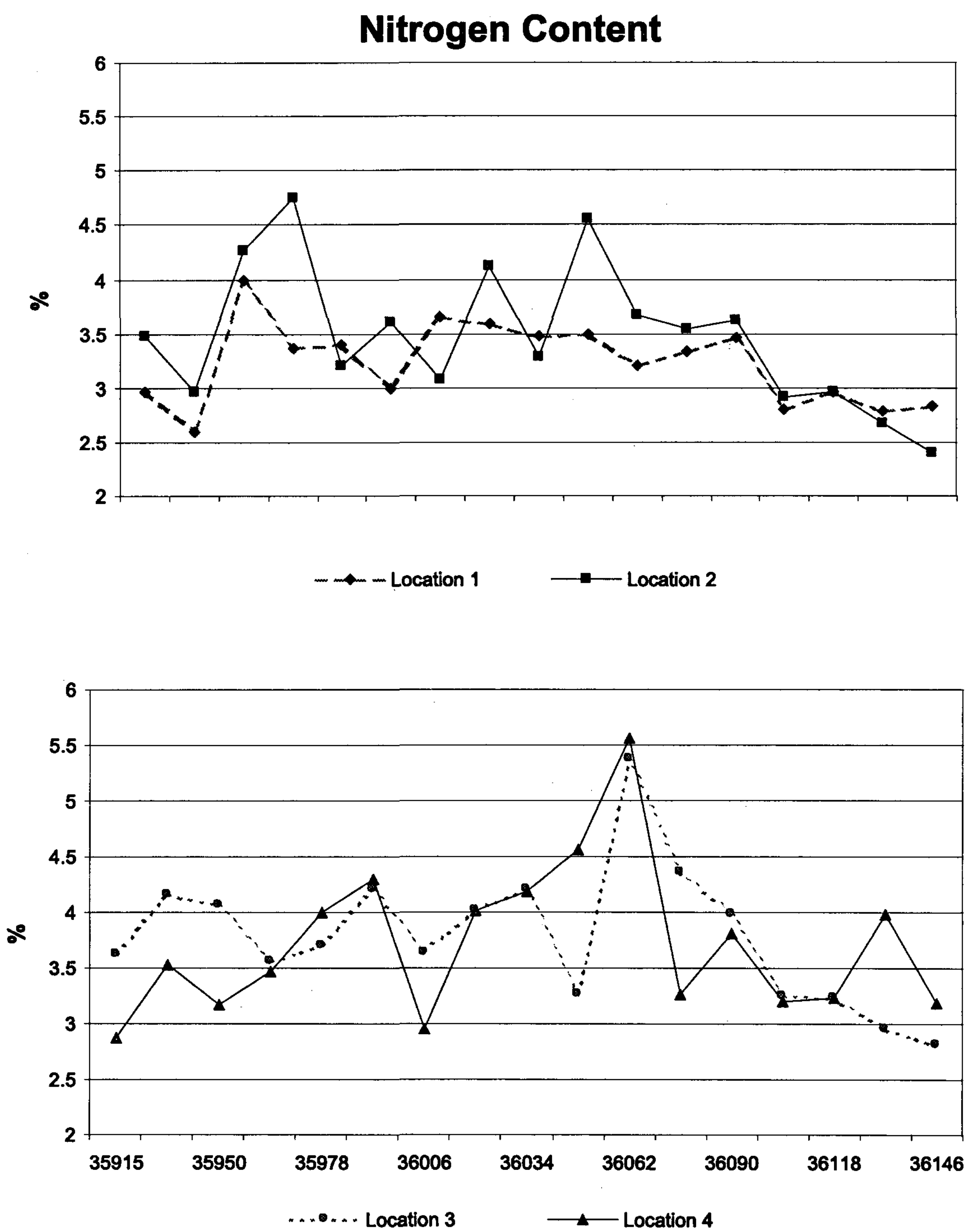
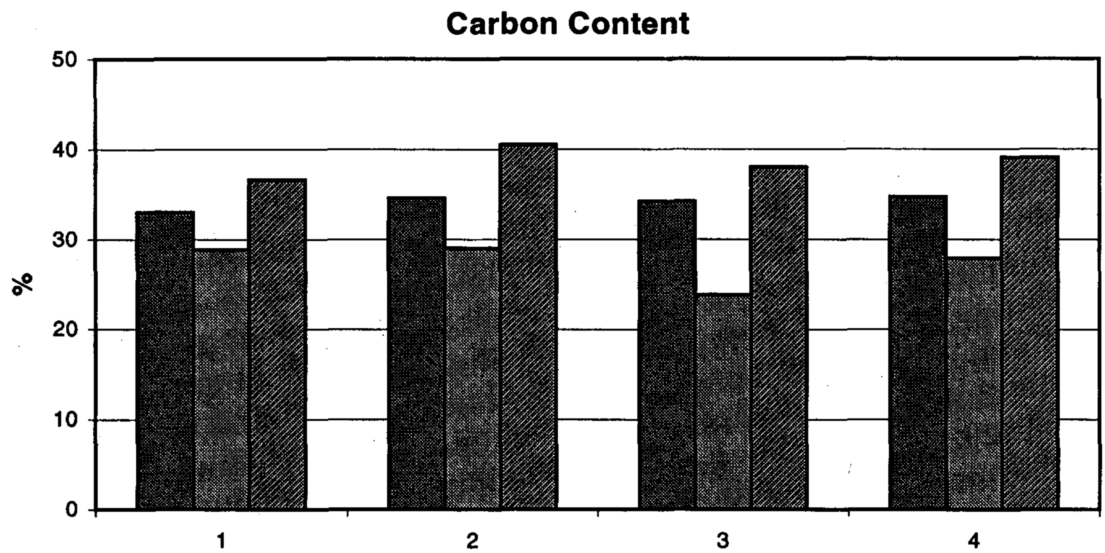


Figure 5. Nitrogent content of PFWG algae at four locations (ranging from influent [1] to effluent [4]) on the culture surface.



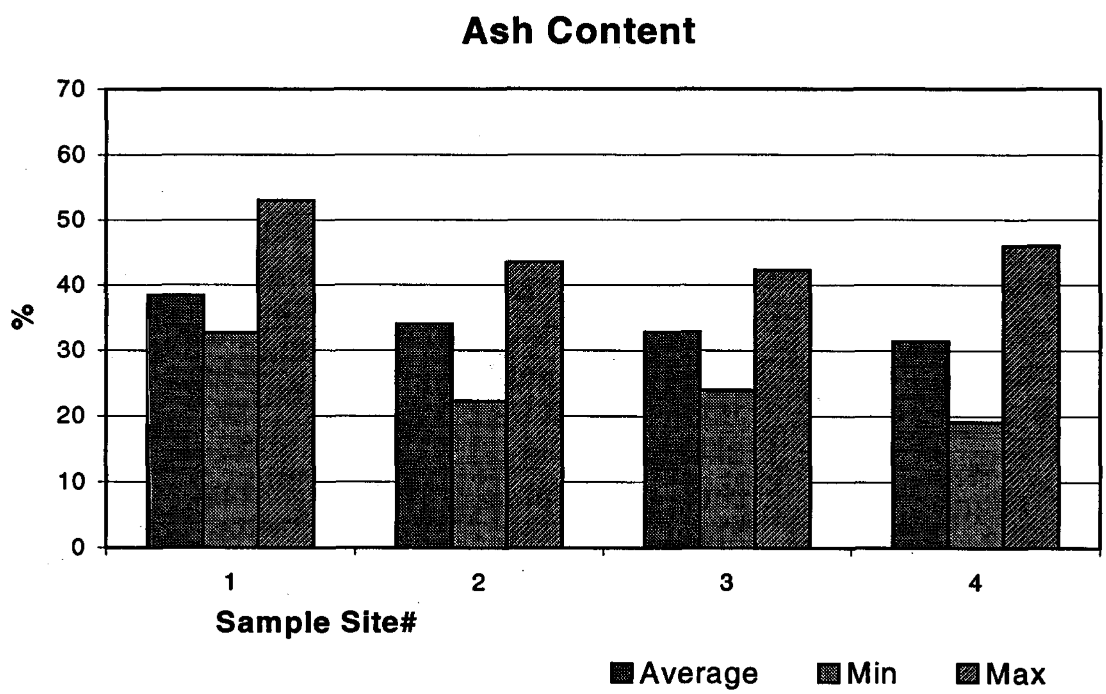
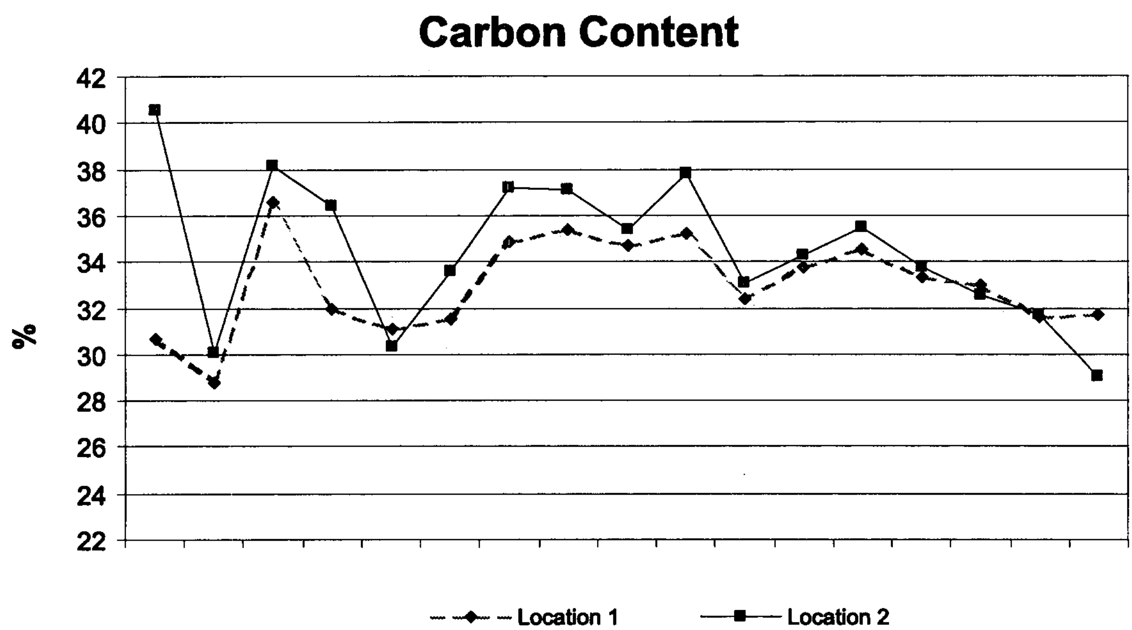


Figure 6. Mean and ranges of carbon and ash contents for algae on the PFWG from May – December 1998. Sample sites represent locations from influent (1) to effluent (4) regions of the culture surface.



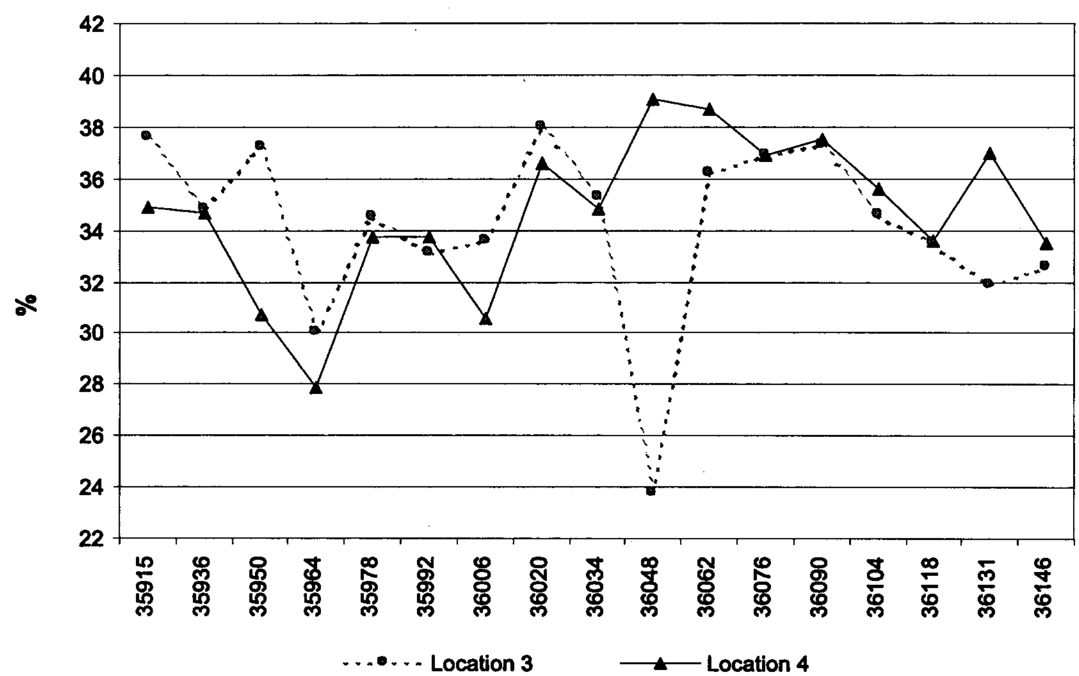


Figure 7. Carbon content of PFWG algae at four locations (ranging from influent [1] to effluent [4]) on the culture surface.

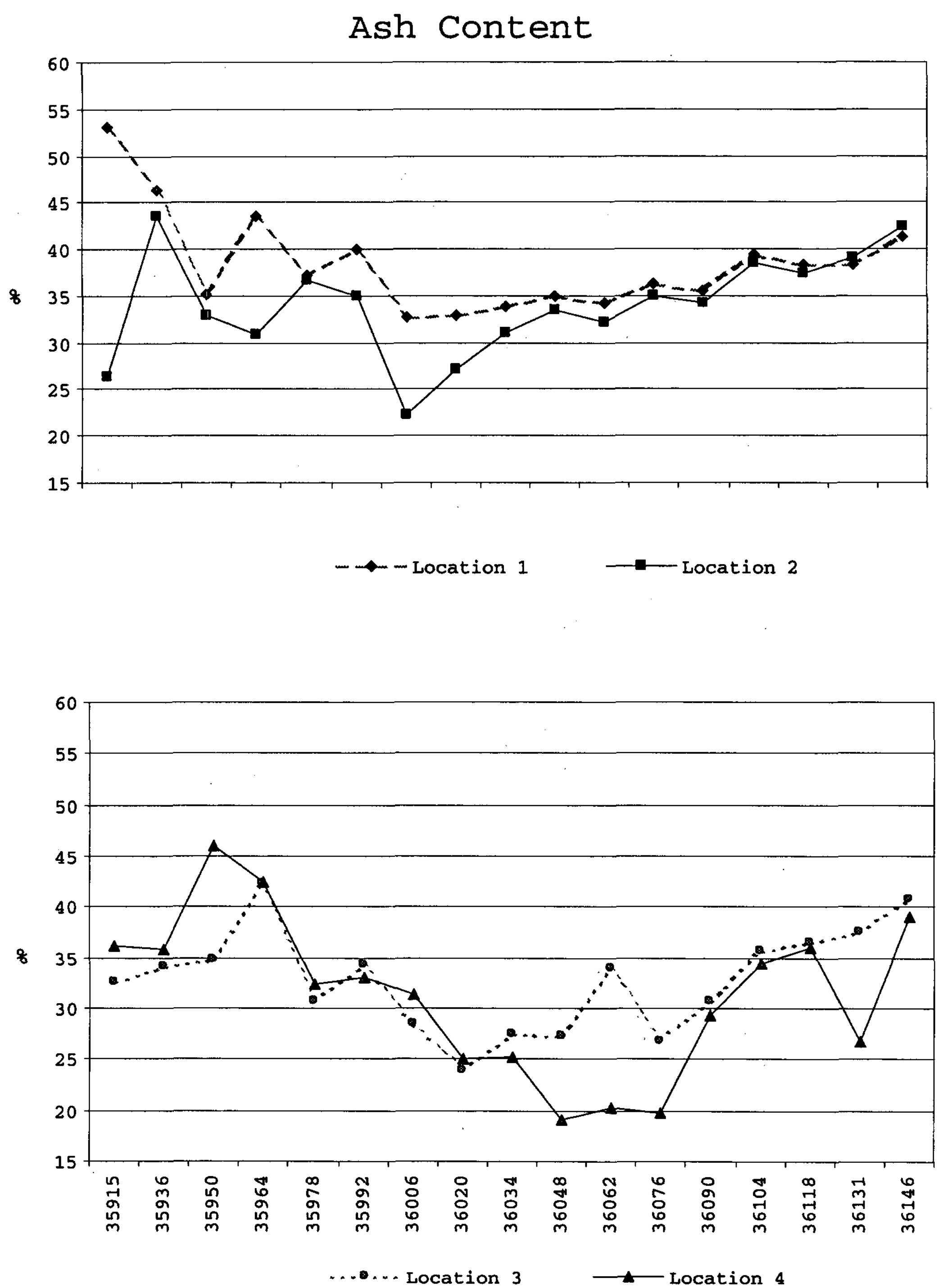


Figure 8. Ash content of PFWG algae at four locations (ranging from influent [1] to effluent [4]) on the culture surface.

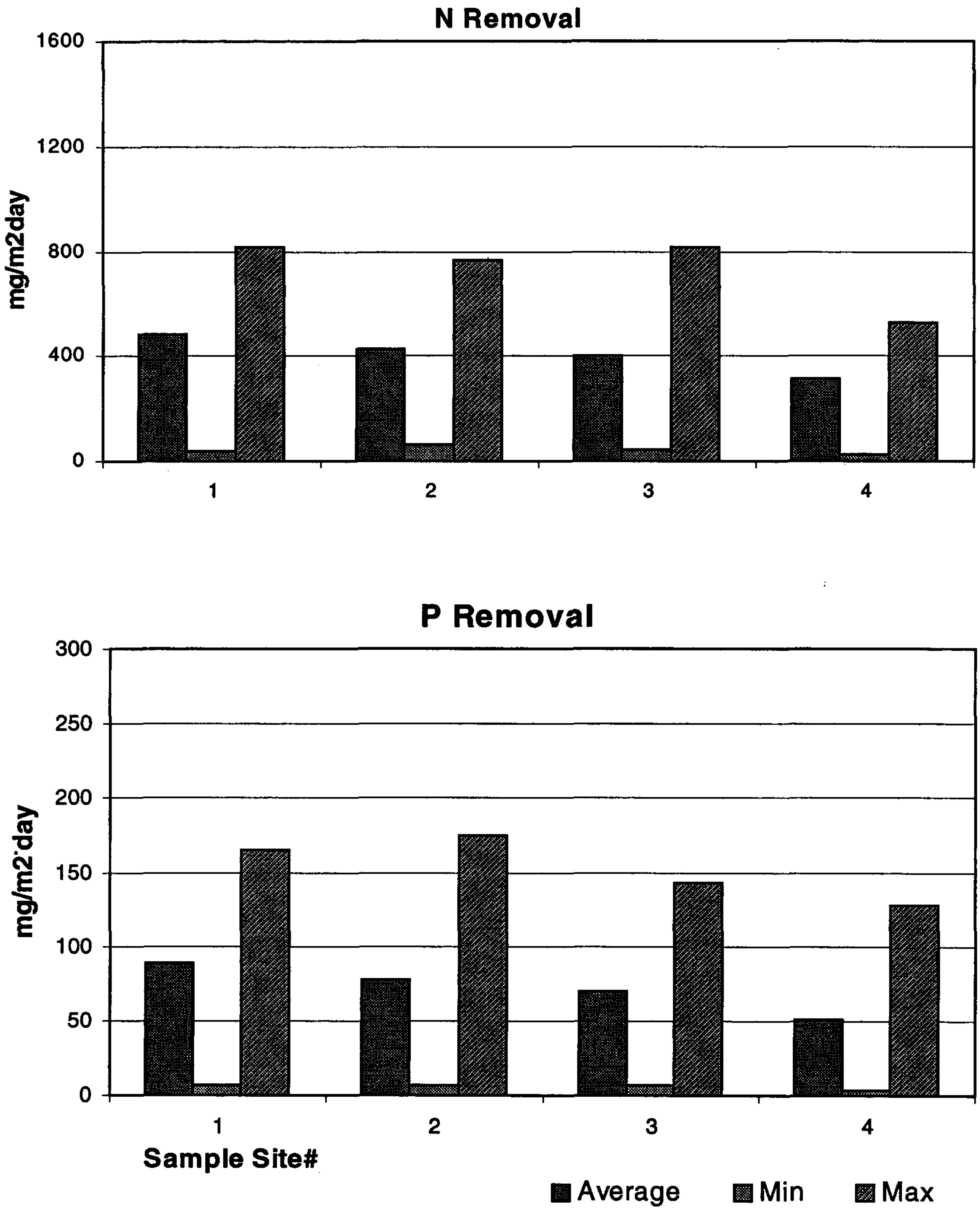


Figure 9. Mean and rangesof nitrogen and phosphorus removal rates for algae on the PFWG from May – December 1998. Sample sites represent locations from influent (1) to effluent (4) regions of the culture surface.

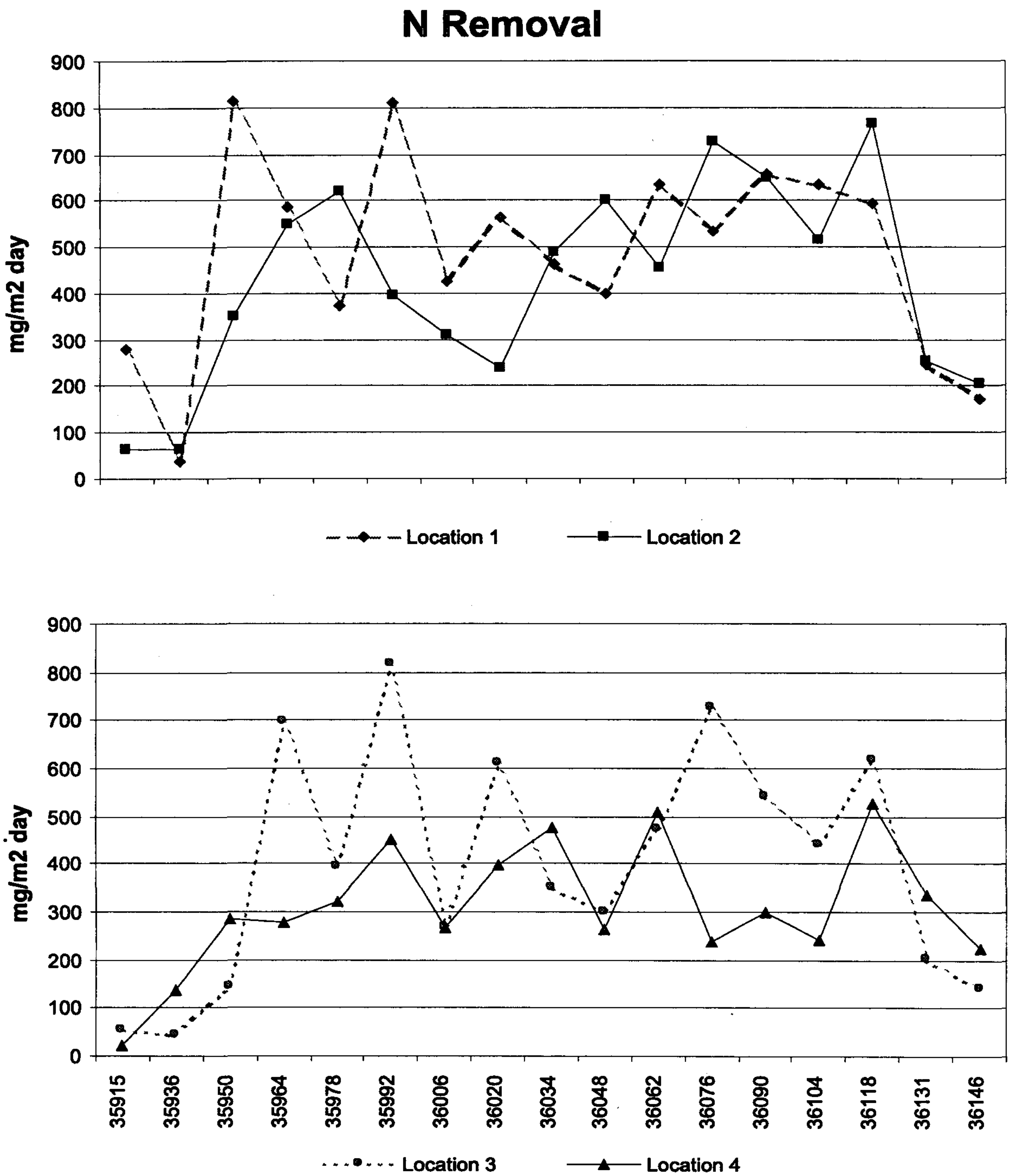


Figure 10. Nitrogen removal rate of PFWG algae at four locations (ranging from influent [1] to effluent [4]) on the culture surface.

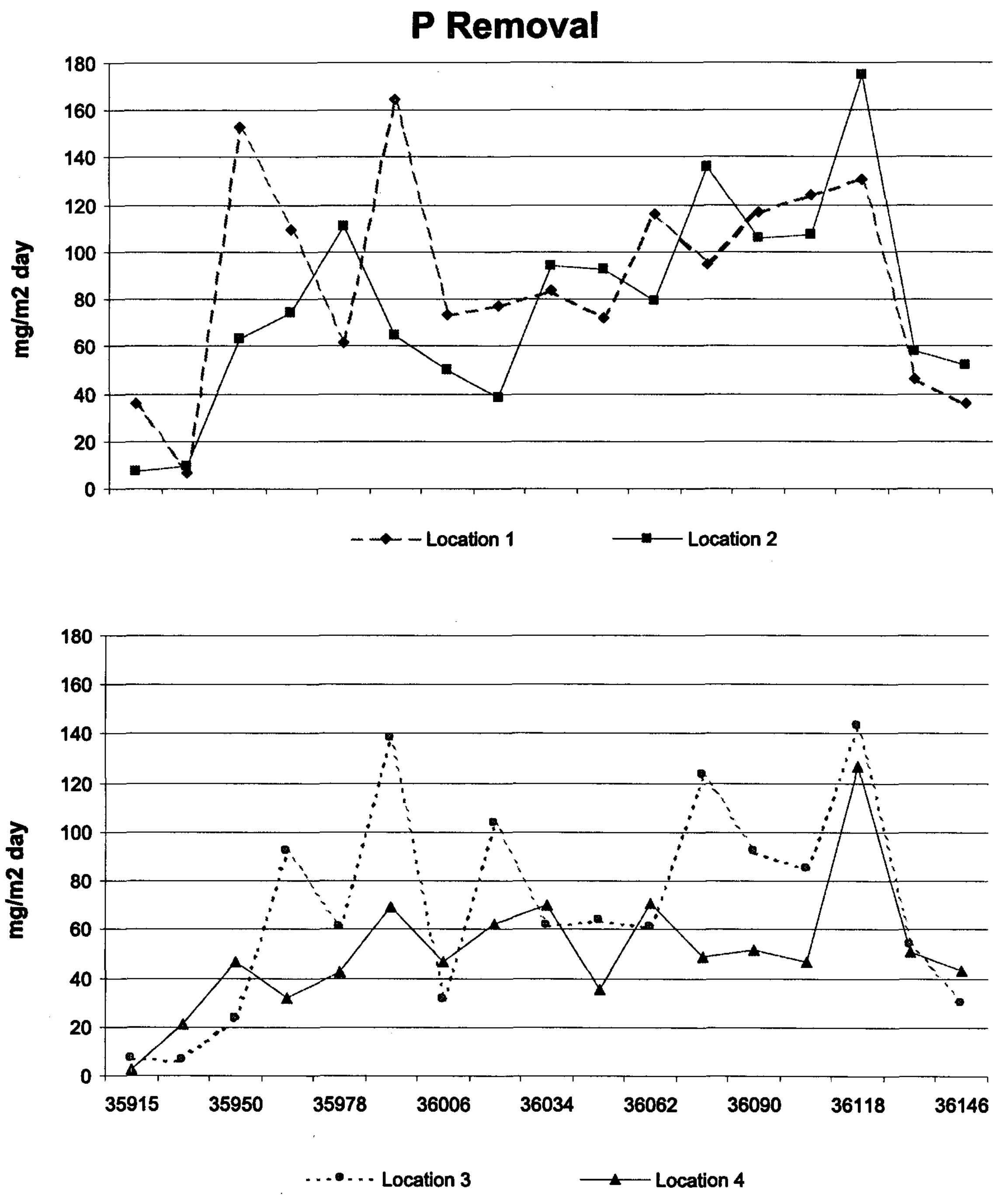


Figure 11. Phosphorus removal rate of PFWG algae at four locations (ranging from influent [1] to effluent [4]) on the culture surface.

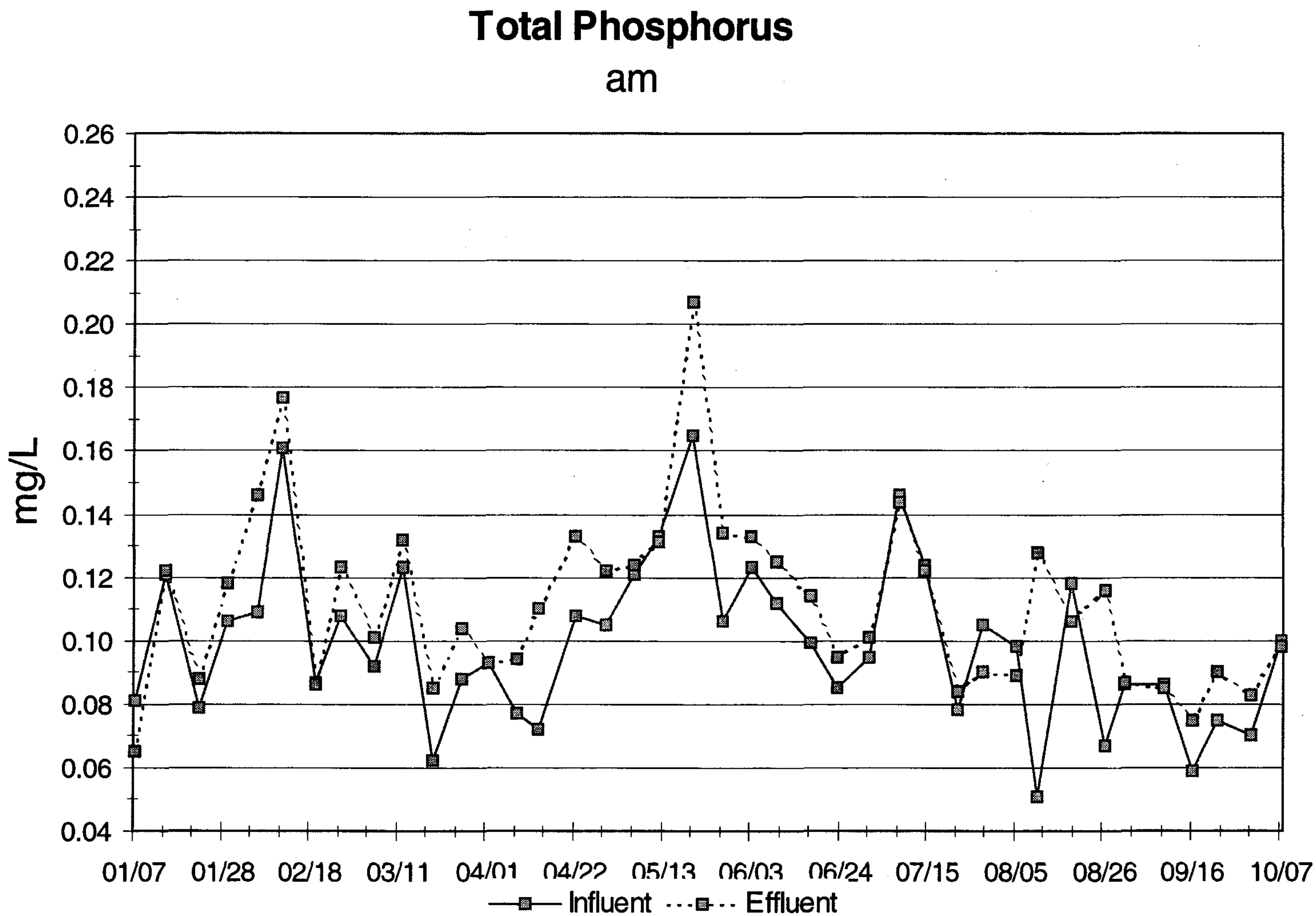


Figure 12. Morning influent and effluent total phosphorus concentrations for the PFWG

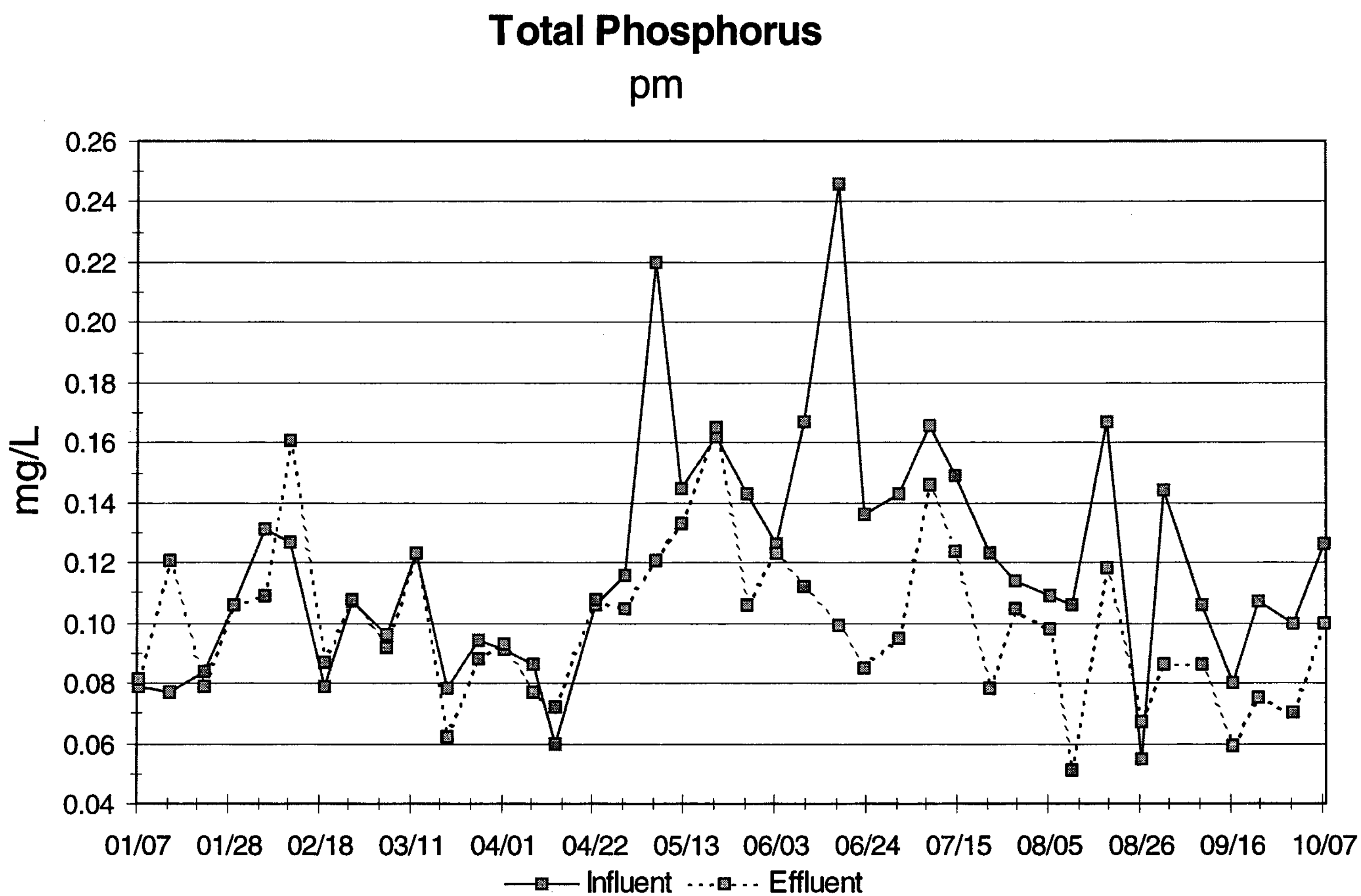


Figure 13. Afternoon influent and effluent total phosphorus concentrations for the PFWG

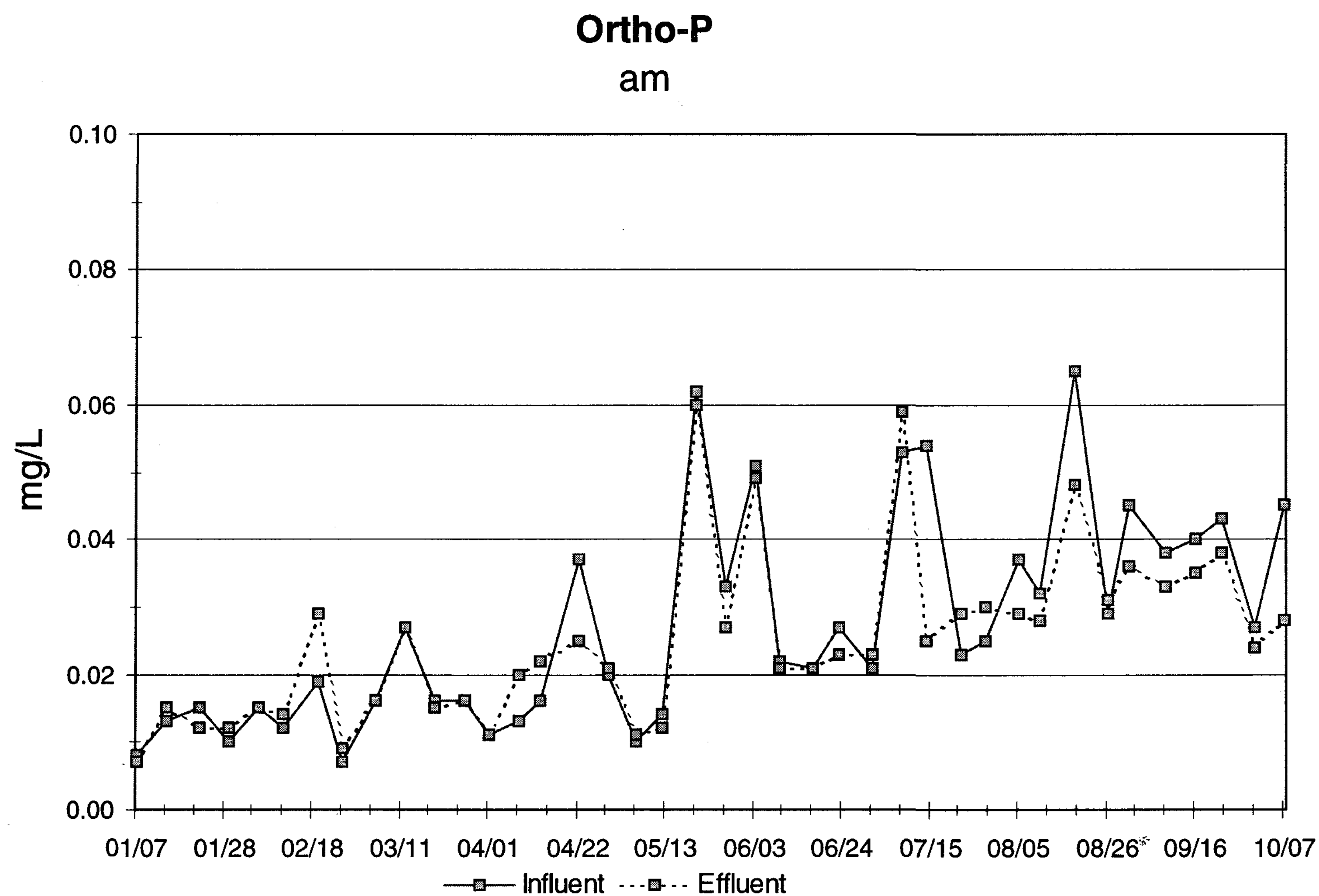


Figure 14. Morning influent and effluent orthophosphorus concentrations for the PFWG

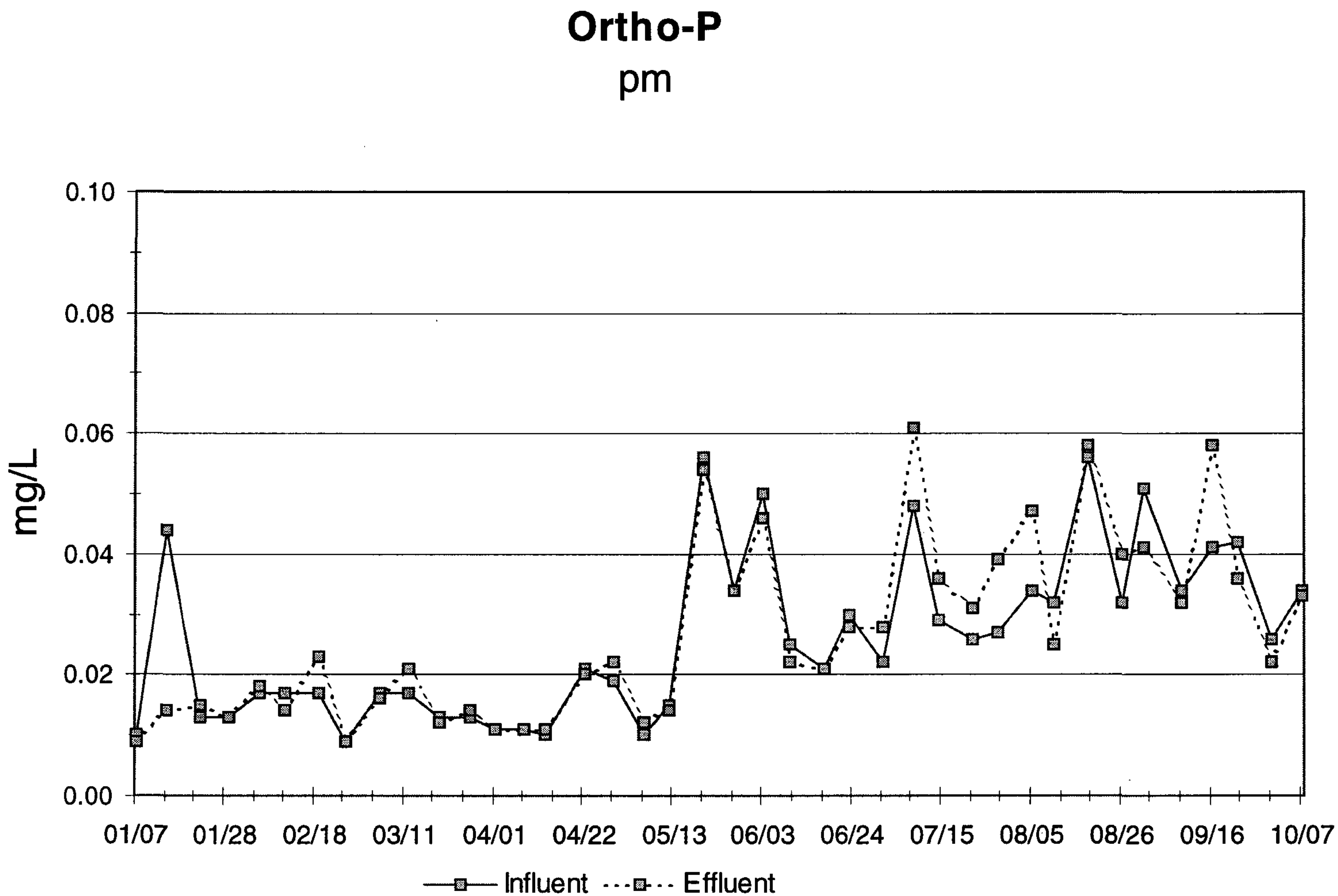


Figure 15. Afternoon influent and effluent orthophosphorus concentrations for the PFWG

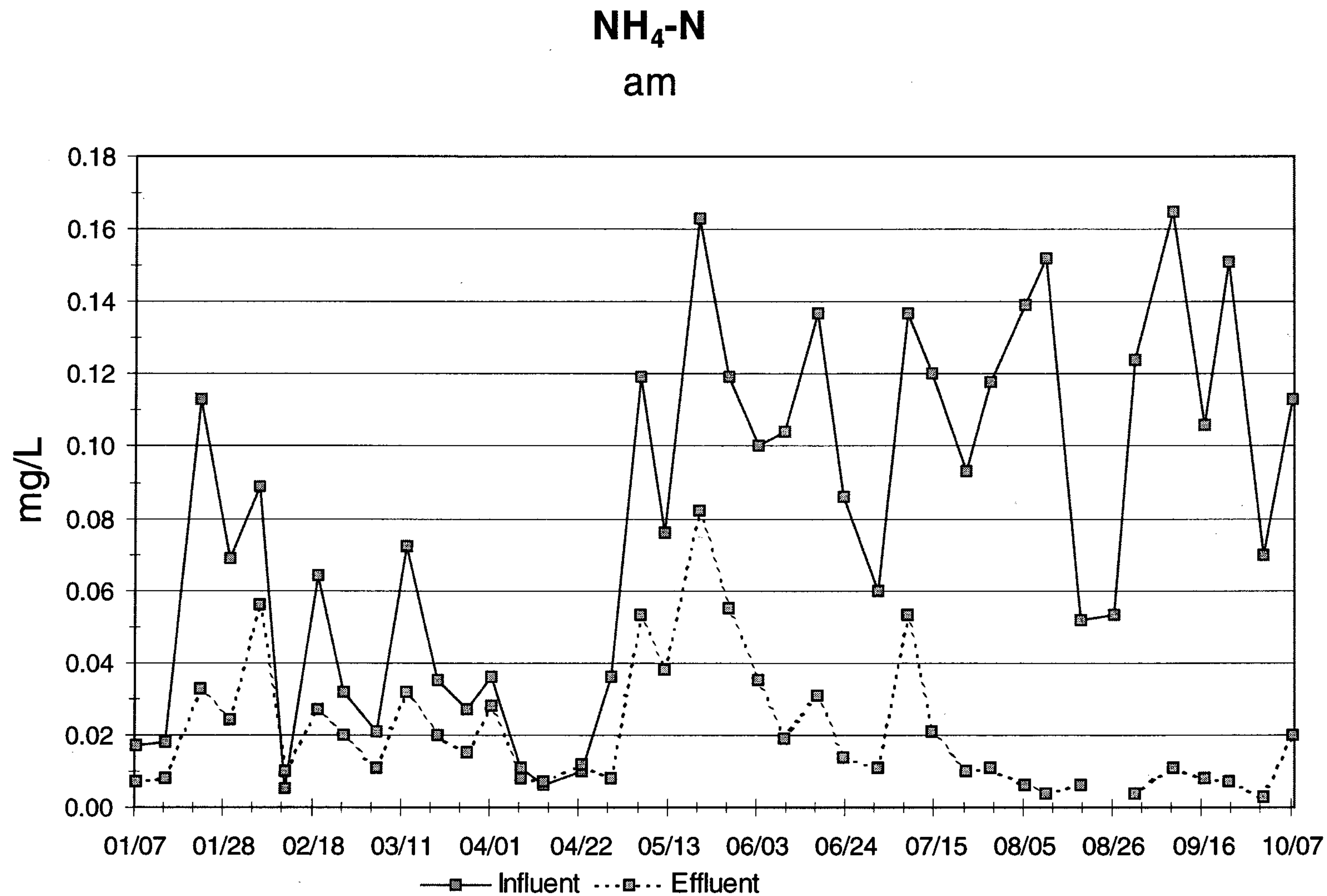


Figure 16. Morning influent and effluent ammonium concentrations for the PFWG

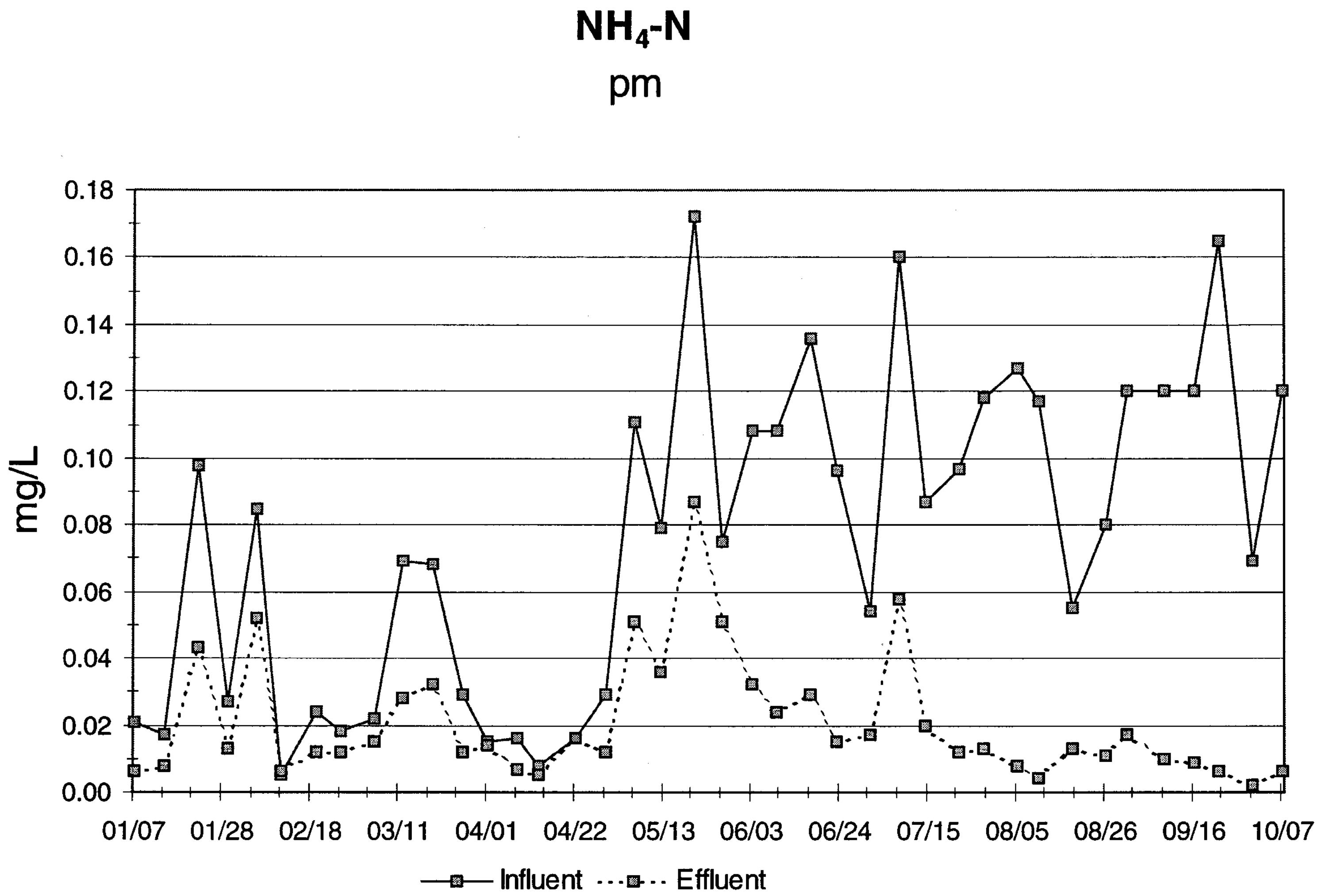


Figure 17. Afternoon influent and effluent ammonium concentrations for the PFWG

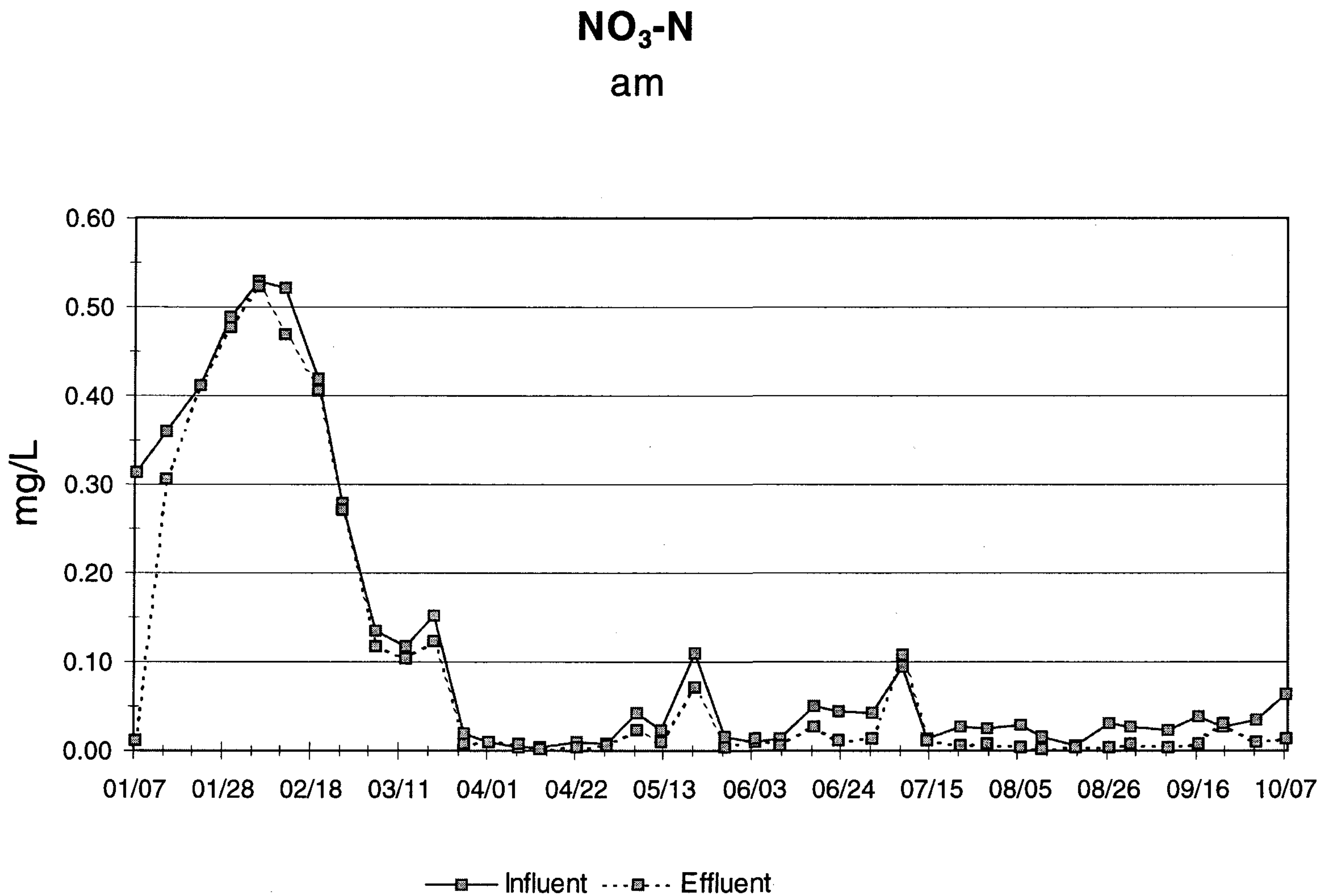


Figure 18. Morning influent and effluent nitrate concentrations for the PFWG

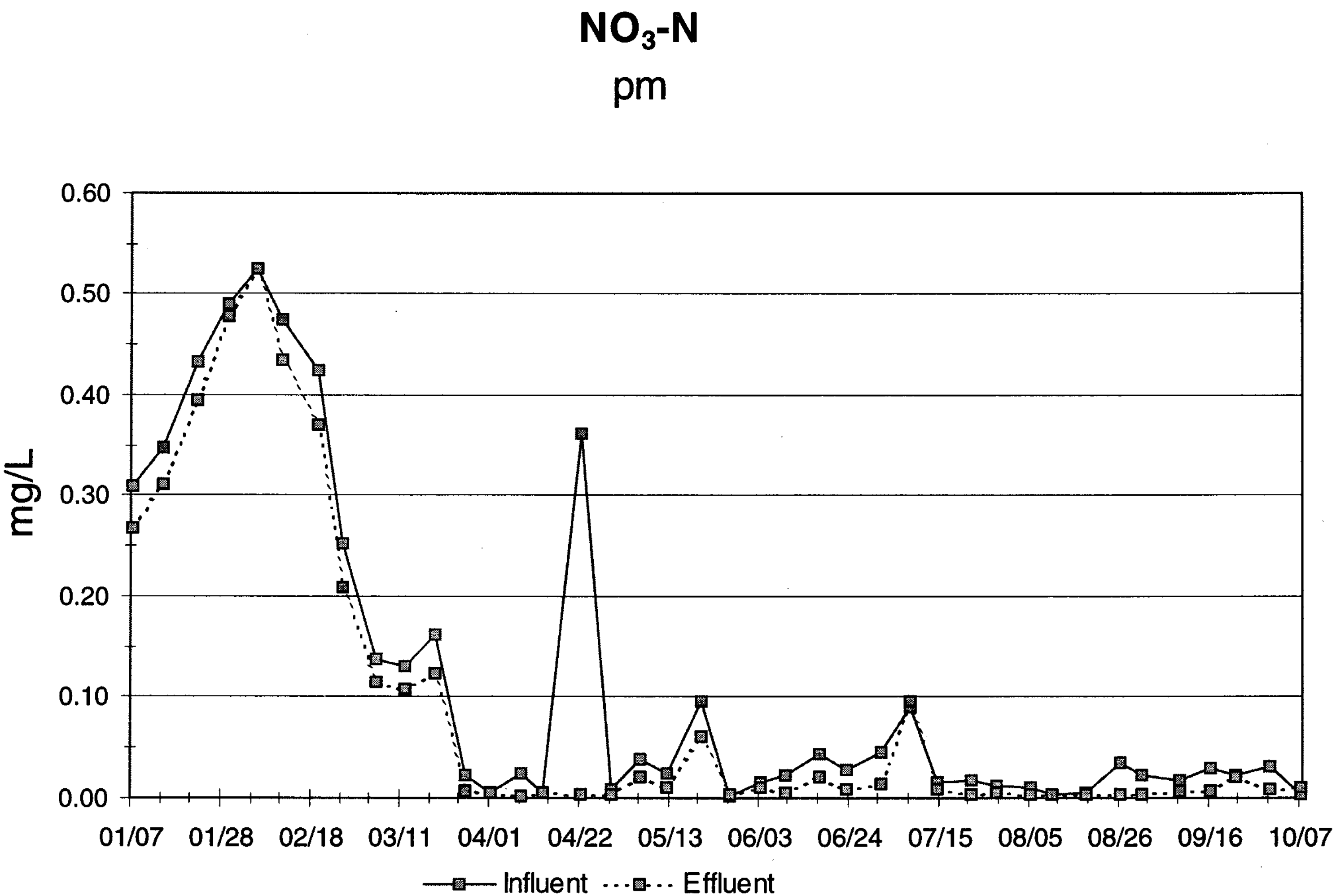


Figure 19. Afternoon influent and effluent nitrate concentrations for the PFWG

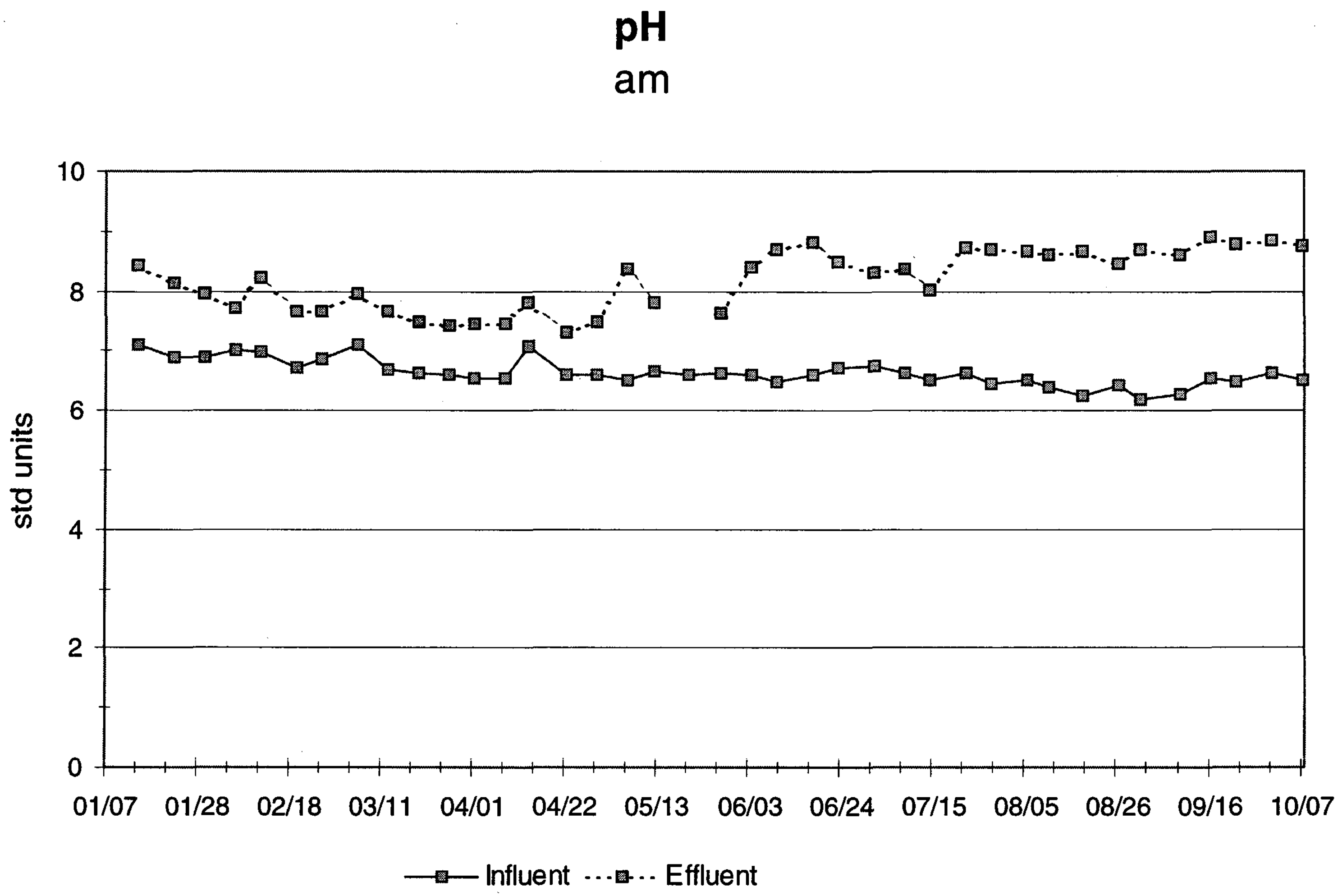


Figure 20. Morning influent and effluent pH levels for the PFWG

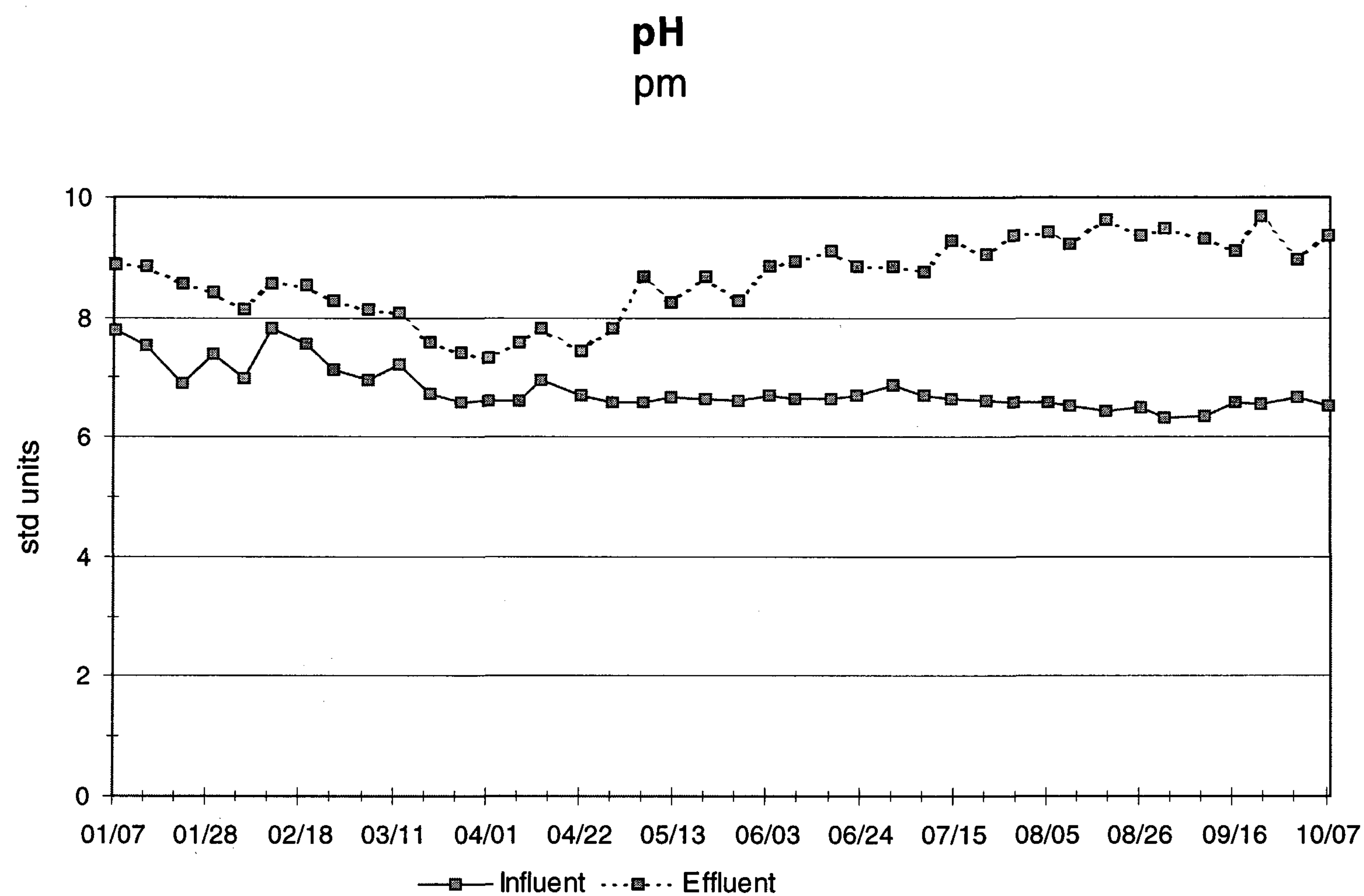


Figure 21. Afternoon influent and effluent pH levels for the PFWG

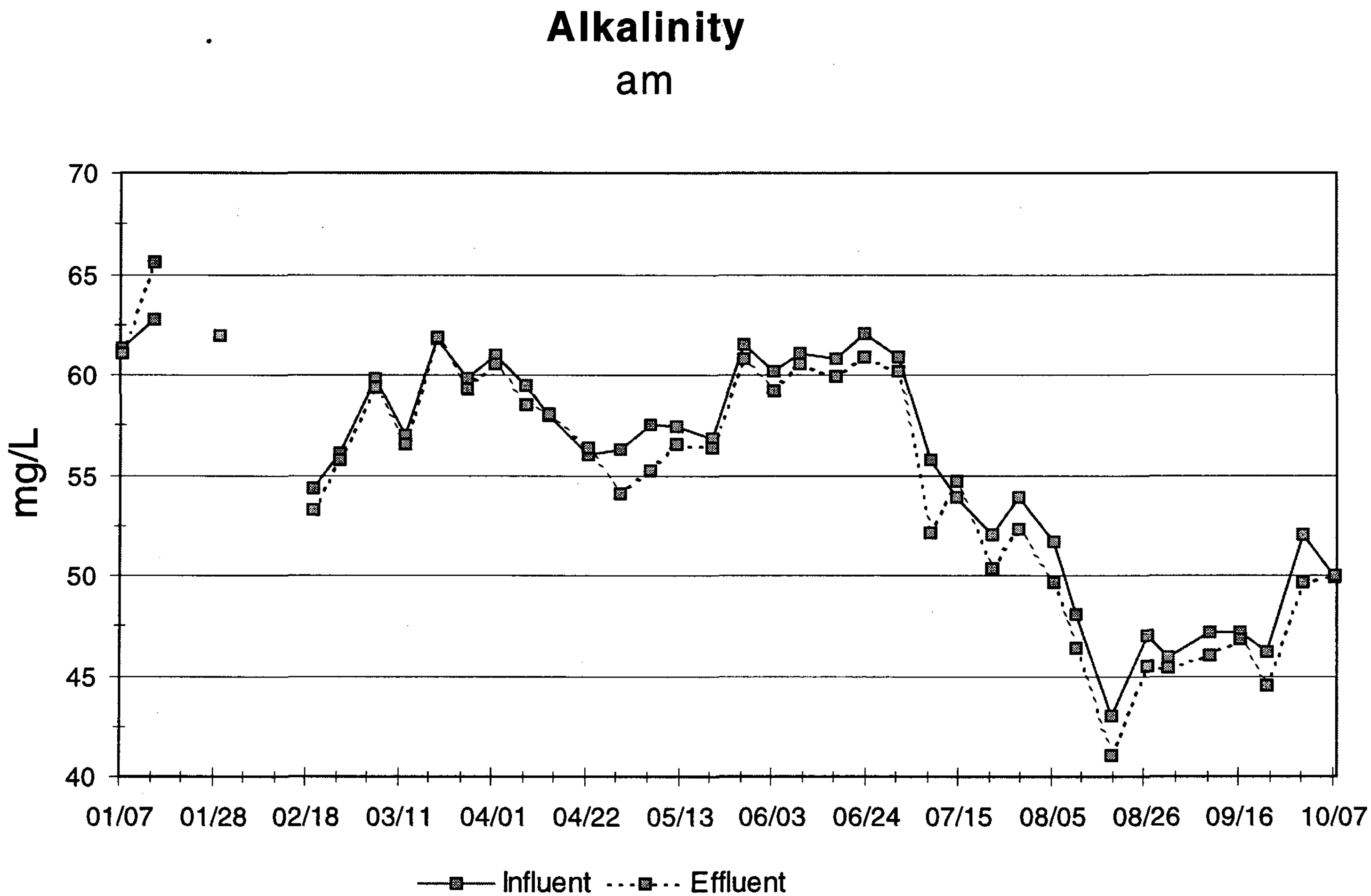


Figure 22. Morning influent and effluent alkalinity concentrations for the PFWG

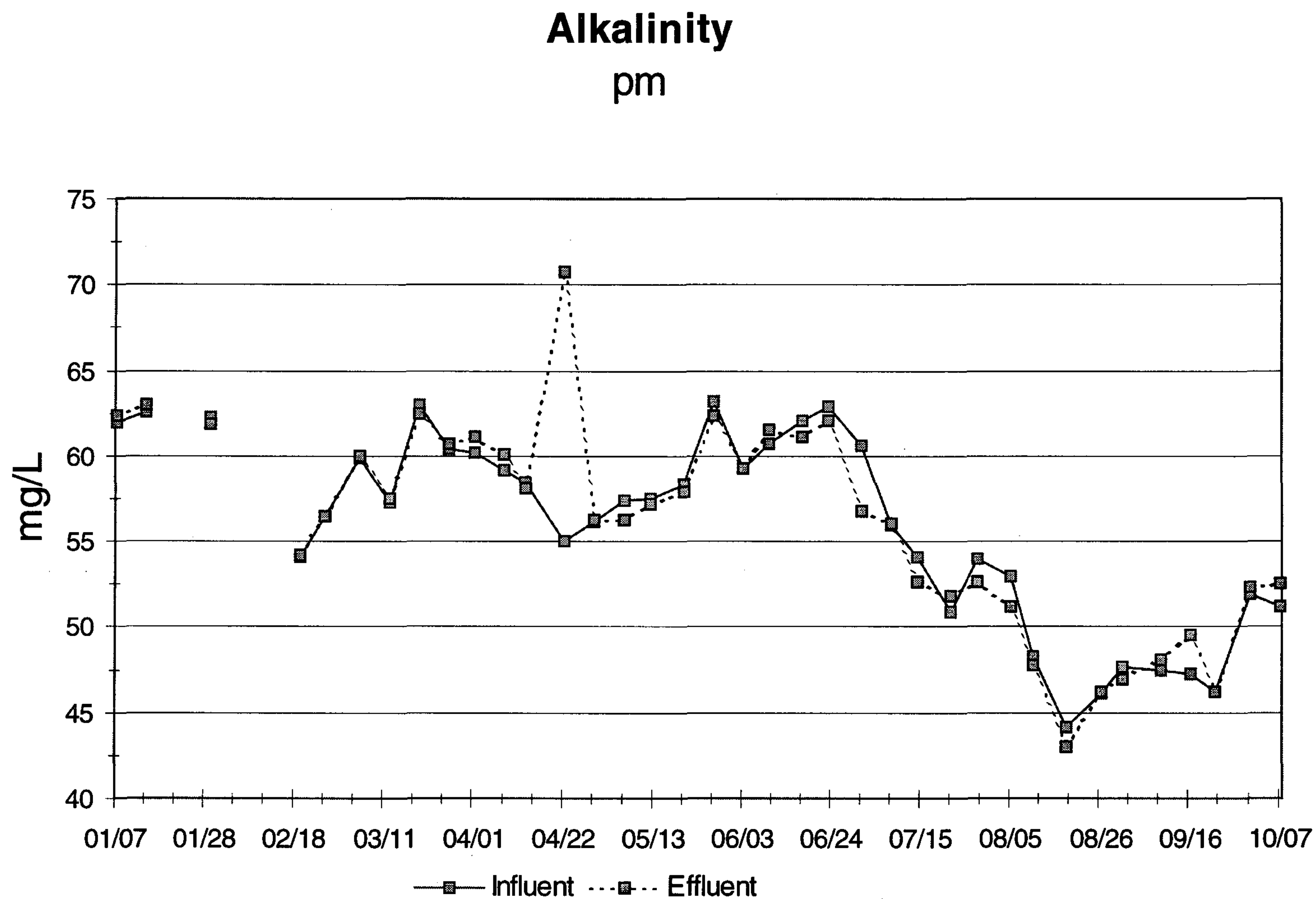


Figure 23. Afternoon influent and effluent alkalinity concentrations for the PFWG

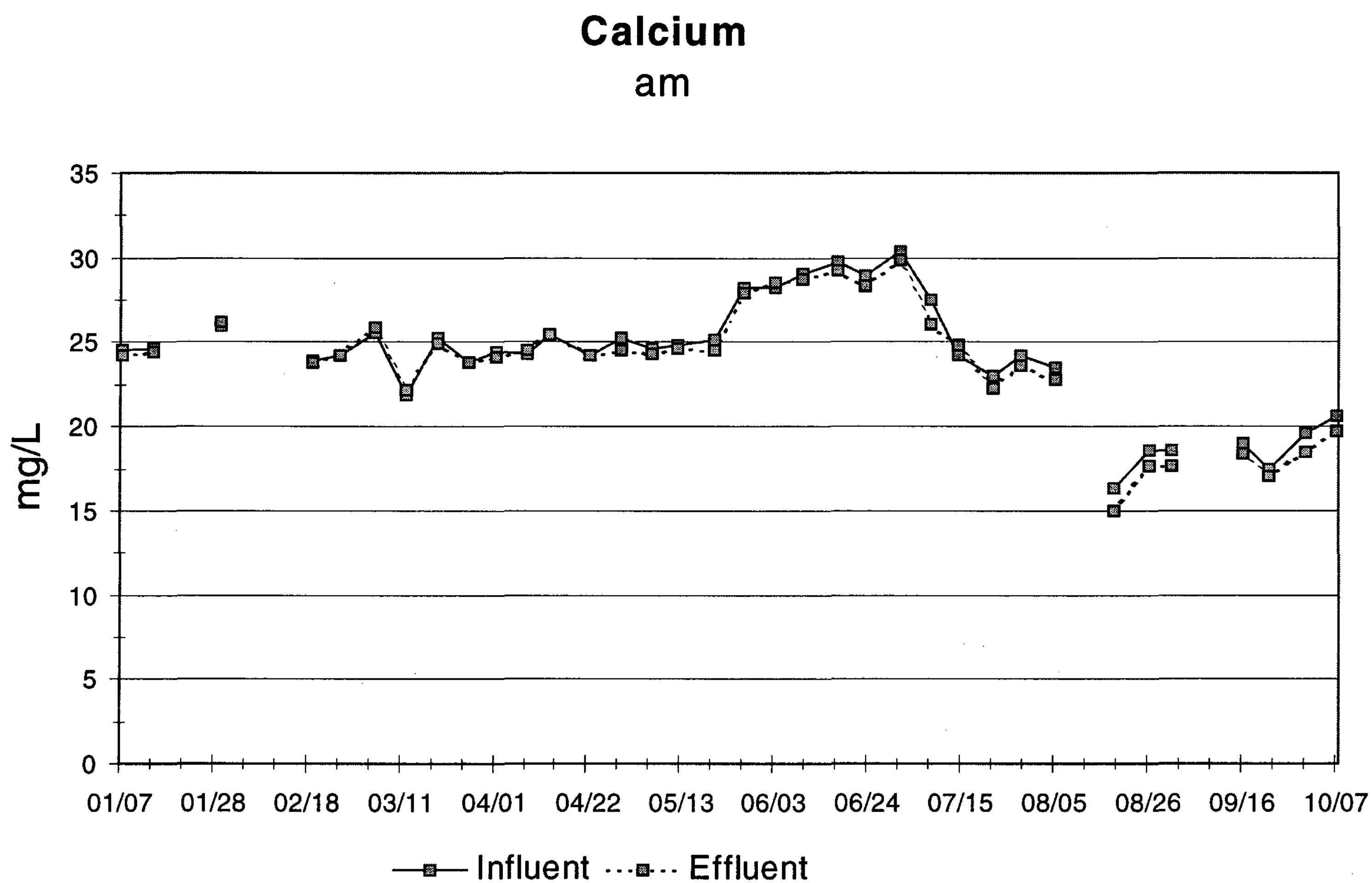


Figure 24. Morning influent and effluent calcium concentrations for the PFWG

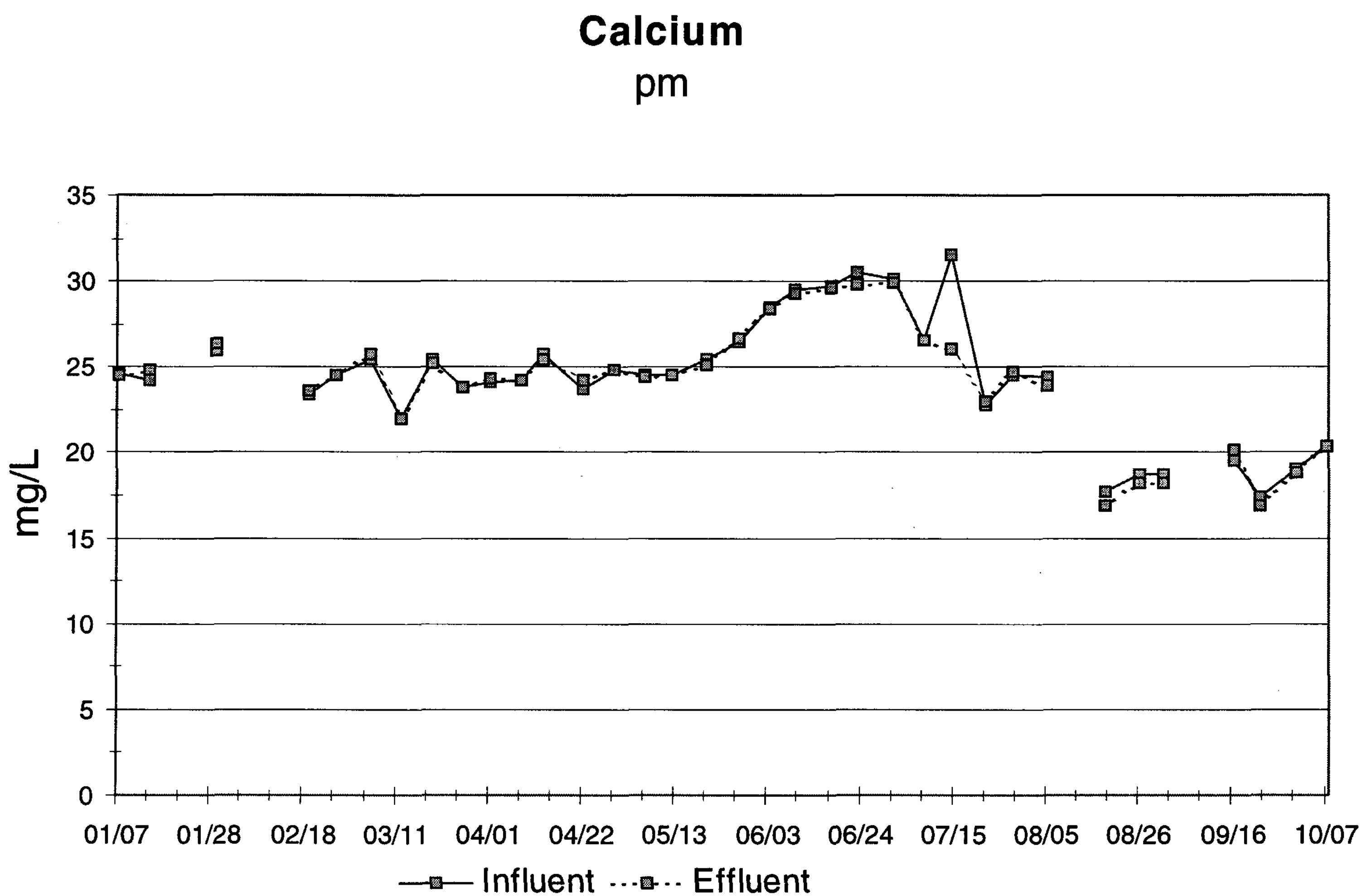


Figure 25. Afternoon influent and effluent calcium concentrations for the PFWG

Appendix

Raw Productivity and Composition Data

(shaded values not used in graphs or mass removal calculations)

Date Sam.	Sample I.D.	dry wt (g)	Productivity g/m²·day	TP %	TN %	TC %	ASH %	N Removal mg/m²·day	P Removal mg/m²·day
1/23/1998	#1			0.33	1.94	18	33.3		
1/23/1998	#2			0.55	2.73	24.9	49.6		
1/23/1998	#3			0.36	2.68	23.3	51.2		
1/23/1998	#4			0.30	1.94	17.2	65.2		
1/23/1998	#5			0.50	3.13	26	49.9		
1/23/1998	#6			0.61	3.4	27.8	42.2		
1/30/1998	#1	2.93	6.70	0.35	1.6	17.7	63.8	107	23
1/30/1998	#2	40.35	92.23	0.091	0.386	3.32	92.5	356	84
1/30/1998	#3	6.51	14.88	0.44	1.88	21.1	55.6	280	65
1/30/1998	#4	5.01	11.45	0.32	1.47	16.3	69.7	168	37
1/30/1998	#5	6.8	15.54	0.085	0.481	4.32	91.3	75	13
1/30/1998	#6	0.74	1.69	0.48	2.41	25.4	48.8	41	8
		AVG.	8.68				AVG.	149	33
3/17/1998	#1	6.81	15.57	0.55	2.67	25.3	52.9	416	86
3/17/1998	#2	20.02	45.76	0.62	3.46	29.3	42.9	1583	284
3/17/1998	#3	1.72	3.93	0.49	2.53	25.7	48.2	99	19
3/17/1998	#4	3.99	9.12	0.44	2.85	25.9	48.7	260	40
		AVG.	18.59				AVG.	590	107
3/24/1998	#1	22.6	51.66	0.38	1.98	18.9	66.1	1023	196
3/24/1998	#2	3.14	7.18	0.53	3.34	28	45	240	38
3/24/1998	#3	1.46	3.34	0.37	2.37	22.6	53.9	79	12
3/24/1998	#4	19.88	45.44	0.35	2.21	23.7	55.4	1004	159
		AVG.	18.65				AVG.	441	70
3/31/1998	#1	12.17	27.82	0.56	2.75	26.5	52.9	765	156
3/31/1998	#3	2.43	5.55	0.42	2.28	23	55.8	127	23

Date Sam.	Sample I.D.	dry wt (g)	Productivity g/m²day	TP %	TN %	TC %	ASH %	N Removal mg/m²day	P Removal mg/m²day
3/31/1998	#4	4.1	9.37	0.49	2.45	24.3	51.6	230	46
		AVG.	14.25				AVG.	374	75
4/7/1998	#1	3.39	7.75	0.52	2.68	28.7	48.4	208	40
4/7/1998	#3	2.25	5.14	0.47	2.68	29.3	46.1	138	24
4/7/1998	#4	2.54	5.81	0.32	2.21	26	52.6	128	19
		AVG.	6.23				AVG.	158	28
4/16/1998	#1	5.05	11.54	0.45	2.73	29.4	46.1	315	52
4/16/1998	#3	6.66	15.22	0.41	1.28	12.8	53.2	195	62
4/16/1998	#4	1.56	3.57	0.36	2.3	26.6	47.4	82	13
		AVG.	10.11				AVG.	197	42
4/30/1998	#1	4.13	9.44	0.38	2.97	30.7	53	280	36
4/30/1998	#2	0.78	1.78	0.40	3.48	40.5	26.4	62	7
4/30/1998	#3	0.65	1.49	0.50	3.62	37.6	32.6	54	7
4/30/1998	#4	0.34	0.78	0.39	2.87	34.9	36.1	22	3
		AVG.	3.37				AVG.	105	13
5/21/1998	#1	0.61	1.39	0.5	2.59	28.8	46.4	36	7
5/21/1998	#2	0.92	2.10	0.46	2.97	30.1	43.5	62	10
5/21/1998	#3	0.46	1.05	0.61	4.15	34.8	34.1	44	6
5/21/1998	#4	1.68	3.84	0.56	3.53	34.7	35.8	136	22
		AVG.	2.10				AVG.	69	11
6/4/1998	#1	8.92	20.39	0.75	3.99	36.6	35.2	814	153
6/4/1998	#2	3.6	8.23	0.77	4.26	38.14	33	351	63
6/4/1998	#3	1.54	3.52	0.67	4.06	37.2	34.8	143	24
6/4/1998	#4	3.96	9.05	0.52	3.17	30.7	46	287	47
		AVG.	10.30				AVG.	398	72
6/18/1998	#1	7.6	17.37	0.63	3.37	32	43.5	585	109
6/18/1998	#2	5.08	11.61	0.64	4.74	36.4	30.9	550	74

Date Sam.	Sample I.D.	dry wt (g)	Productivity g/m²·day	TP %	TN %	TC %	ASH %	N Removal mg/m²·day	P Removal mg/m²·day
6/18/1998	#3	8.58	19.61	0.47	3.56	30	42.3	698	92
6/18/1998	#4	3.52	8.05	0.40	3.47	27.9	42.5	279	32
		AVG.	14.16				AVG.	528	77
7/2/1998	#1	4.82	11.02	0.56	3.4	31.1	37.2	375	62
7/2/1998	#2	8.49	19.41	0.57	3.2	30.3	36.7	621	111
7/2/1998	#3	4.66	10.65	0.57	3.7	34.5	30.7	394	61
7/2/1998	#4	3.52	8.05	0.53	4	33.7	32.4	322	43
		AVG.	12.28				AVG.	428	69
7/16/1998	#1	11.8	26.97	0.61	3	31.5	40	809	165
7/16/1998	#2	4.8	10.97	0.59	3.6	33.6	34.9	395	65
7/16/1998	#3	8.5	19.43	0.71	4.2	33.1	34.3	816	138
7/16/1998	#4	4.6	10.51	0.66	4.3	33.7	33	452	69
		AVG.	16.97				AVG.	618	109
7/30/1998	#1	5.12	11.70	0.63	3.65	34.9	32.7	427	74
7/30/1998	#2	4.4	10.06	0.5	3.07	37.2	22.3	309	50
7/30/1998	#3	3.2	7.31	0.43	3.64	33.6	28.5	266	31
7/30/1998	#4	3.94	9.01	0.52	2.95	30.6	31.4	266	47
		AVG.	9.52				AVG.	317	51
8/13/1998	#1	6.87	15.70	0.49	3.59	35.4	33	564	77
8/13/1998	#2	2.52	5.76	0.66	4.12	37.1	27.1	237	38
8/13/1998	#3	6.66	15.22	0.68	4.02	38	23.9	612	104
8/13/1998	#4	4.33	9.90	0.63	4.01	36.6	25.1	397	62
		AVG.	11.65				AVG.	452	70
8/27/1998	#1	5.83	13.33	0.63	3.47	34.7	33.8	462	84
8/27/1998	#2	6.51	14.88	0.63	3.28	35.4	31.1	488	94
8/27/1998	#3	3.63	8.30	0.74	4.21	35.3	27.4	349	61
8/27/1998	#4	5.01	11.45	0.61	4.18	34.8	25.3	479	70

Date Sam.	Sample I.D.	dry wt (g)	Productivity g/m²·day	TP %	TN %	TC %	ASH %	N Removal mg/m²·day	P Removal mg/m²·day
		AVG.	11.99				AVG.	445	77
9/10/1998	#1	5.02	11.47	0.63	3.49	35.2	35	400	72
9/10/1998	#2	5.77	13.19	0.7	4.56	37.8	33.5	601	92
9/10/1998	#3	4.03	9.21	0.69	3.27	23.8	27.3	301	64
9/10/1998	#4	2.54	5.81	0.61	4.57	39.1	19.1	265	35
		AVG.	9.92				AVG.	392	66
9/24/1998	#1	8.63	19.73	0.59	3.21	32.4	34.3	633	116
9/24/1998	#2	5.43	12.41	0.64	3.67	33.1	32.1	455	79
9/24/1998	#3	3.86	8.82	0.69	5.37	36.2	33.9	474	61
9/24/1998	#4	4.01	9.17	0.77	5.57	38.7	20.2	511	71
		AVG.	12.53				AVG.	518	82
10/8/1998	#1	7.03	16.07	0.59	3.33	33.8	36.2	535	95
10/8/1998	#2	8.99	20.55	0.66	3.55	34.3	34.9	729	136
10/8/1998	#3	7.29	16.66	0.74	4.36	36.9	26.7	727	123
10/8/1998	#4	3.21	7.34	0.67	3.27	36.9	19.7	240	49
		AVG.	15.15				AVG.	558	101
10/22/1998	#1	8.29	18.95	0.62	3.46	34.5	35.6	656	117
10/22/1998	#2	7.85	17.94	0.59	3.62	35.5	34.3	650	106
10/22/1998	#3	5.95	13.60	0.68	3.98	37.3	30.7	541	92
10/22/1998	#4	3.45	7.89	0.66	3.81	37.5	29.3	300	52
		AVG.	14.59				AVG.	537	92
11/5/1998	#1	9.88	22.58	0.55	2.81	33.3	39.4	635	124
11/5/1998	#2	7.78	17.78	0.6	2.91	33.8	38.5	517	107
11/5/1998	#3	5.93	13.55	0.63	3.25	34.6	35.7	441	85
11/5/1998	#4	3.29	7.52	0.63	3.2	35.6	34.4	241	47
		AVG.	15.36				AVG.	458	91
11/19/1998	#1	8.79	20.09	0.65	2.96	33	38.4	595	131

Date Sam.	Sample I.D.	dry wt (g)	Productivity $g/m^2 \cdot day$	TP %	TN %	TC %	ASH %	N Removal $mg/m^2 \cdot day$	P Removal $mg/m^2 \cdot day$
11/19/1998	#2	11.26	25.74	0.68	2.97	32.6	37.5	764	175
11/19/1998	#3	8.36	19.11	0.75	3.24	33.5	36.5	619	143
11/19/1998	#4	7.13	16.30	0.78	3.24	33.6	36	528	127
		AVG.	20.31				AVG.	627	144
12/2/1998	#1	7.78	8.89	0.52	2.79	31.6	38.4	248	46
12/2/1998	#2	8.29	9.47	0.61	2.67	31.7	39.1	253	58
12/2/1998	#3	6.03	6.89	0.79	2.95	31.9	37.5	203	54
12/2/1998	#4	7.35	8.40	0.61	3.99	37	26.7	335	51
		AVG.	8.41				AVG.	260	52
12/17/1998	#1	5.33	6.09	0.59	2.84	31.7	41.4	173	36
12/17/1998	#2	7.53	8.61	0.61	2.4	29	42.4	207	52
12/17/1998	#3	4.43	5.06	0.59	2.81	32.6	40.7	142	30
12/17/1998	#4	6.16	7.04	0.61	3.18	33.5	39	224	43
		AVG.	6.70				AVG.	186	40

Comparison between quadrat and tank sampling techniques

	% TP		% TN		% TC		% ASH		Productivity (g/m^2day)		N removal (mg/m^2day)		P removal (mg/m^2day)	
Date	Quad.	Tank	Quad.	Tank	Quad.	Tank	Quad.	Tank	Quad.	Tank	Quad	Tank	Quad	Tank
3/17/1998	0.53	0.49	2.88	2.75	26.5	24.4	48.2	52.3	18.59	6	590	165	107	29
3/24/1998	0.41	0.49	2.47	2.82	23.3	26.5	55.1	49.3	18.65	3.98	441	112	70	19
3/31/1998	0.49	0.58	2.49	2.84	24.6	28.8	53.4	48.0	14.25	3.29	374	94	75	19
4/7/1998	0.44	0.60	2.52	3.27	28.0	33.0	49.0	39.8	6.23	2.65	158	87	28	16
4/16/1998	0.41	0.50	2.10	3.04	22.9	32.3	48.9	41.8	10.11	12.32	197	375	42	62
4/30/1998	0.42	0.50	3.23	3.62	35.9	35.3	37.0	36.8	3.37	4.56	105	165	13	23
6/4/1998	0.68	0.72	3.87	3.95	35.7	35.4	37.3	37.5	10.3	13.8	398	545	72	99
6/18/1998	0.53	0.59	3.78	4.01	31.6	31.3	39.8	28.9	14.16	NA	528	NA	77	NA

APPENDIX B—ST. JOHNS RIVER WATER MANAGEMENT DISTRICT, MONITORING DATA FOR THE PERIPHYTON FILTER

Periphyton Filter Upstream (am)

Variable	Time	Alkalinity	Hardness	TSS	TP-T	PO_4-T	TKN-T	NH_4-T	NO_x-T	Ag-T	Ca-T	Cd-T	Cu-T	Fe-T
Storet		410	46570	530	665	70507	625	610	630	1077	916	1027	1042	1045
Units		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1/7/1998	855	61.328	72.0	6	0.077	0.008	0.900	0.017	0.313		24.530			
1/14/1998	1005	62.772	73.0	7	0.100	0.013	0.940	0.018	0.360		24.590			
1/22/1998	925			8	0.092	0.015	0.960	0.113	0.412					
1/29/1998	930	61.959	77.0	9	0.116	0.010	1.090	0.069	0.489	0.410	25.970	0.017	1.140	64.800
2/5/1998	925			10	0.115	0.015	1.040	0.089	0.528					
2/11/1998	945			7	0.117	0.012	1.060	0.005	0.522					
2/19/1998	910	54.305	71.0	5	0.103	0.019	0.668	0.064	0.420		23.920			
2/25/1998	935	56.081	72.0	9	0.119	0.007	0.940	0.032	0.279		24.220	-0.001	2.220	49.490
3/5/1998	945	59.815	77.0		0.110	0.016	0.960	0.021	0.134		25.570			
3/12/1998	930	56.948	66.0	8	0.160	0.027	1.240	0.072	0.118		21.890			
3/19/1998	900	61.764	76.0	12	0.094	0.016	0.881	0.035	0.151		25.260			
3/26/1998	945	59.839	72.0	8	0.088	0.016	1.030	0.027	0.020	0.001	23.780	0.424	1.100	56.700
4/1/1998	1050	61.009	74.0	10	0.101	0.011	1.060	0.036	0.009		24.420			
4/8/1998		59.467	75.0	8	0.097	0.013		0.011	0.004		24.290			
4/13/1998		57.953	80.0	8	0.089	0.016	1.330	0.006	0.003		25.440			
4/22/1998	930	55.996	77.0	10	0.111	0.037	1.240	0.010	0.009		24.240			
4/29/1998	830	56.239	82.0	6	0.134	0.020	1.230	0.036	0.008		25.270			
5/6/1998	940	57.491	79.0	9	0.145	0.010	1.510	0.119	0.042	0.001	24.600	0.014	1.120	64.100
5/12/1998	950	57.430	80.0	9	0.130	0.014	1.320	0.076	0.023		24.840			
5/20/1998	900	56.781	79.0	8	0.173	0.062	1.370	0.163	0.110		25.140			
5/27/1998	910	61.480	88.0	7	0.149	0.033	1.260	0.119	0.016	0.001	28.180	0.007	2.030	36.250
6/3/1998	915	60.154	87.0	8	0.143	0.051	1.230	0.100	0.010		28.240			
6/9/1998	930	61.100	91.0	10	0.171	0.022	0.950	0.104	0.014		29.040			
6/17/1998	945	60.823	93.0	11	0.146	0.021	1.430	0.137	0.050		29.740			
6/23/1998	935	61.998	91.0	18	0.137	0.027	1.530	0.086	0.045		28.980			
7/1/1998	935	60.862	95.0	16	0.152	0.021	1.430	0.060	0.043	0.020	30.340	-0.007	1.190	82.200
7/8/1998	935	55.749	86.0	15	0.170	0.053	1.590	0.137	0.095		27.530			
7/14/1998	915	53.930		15	0.185	0.054	1.590	0.120	0.013		24.200			
7/22/1998	945	52.009	69.0	8	0.108	0.023	1.060	0.093	0.026		23.010			
7/28/1998	935	53.889	73.0	19	0.103	0.025	0.980	0.118	0.025	0.001	24.200	0.004	0.990	46.460
8/5/1998	925	51.681	70.0	6	0.111	0.037	1.040	0.139	0.029		23.520			

Variable	Time	Alkalinity	Hardness	TSS	TP-T	PO_4-T	TKN-T	NH_4-T	NO_X-T	Ag-T	Ca-T	Cd-T	Cu-T	Fe-T
Storet		410	46570	530	665	70507	625	610	630	1077	916	1027	1042	1045
Units		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
8/10/1998	900	48.021		6	0.165	0.032	0.850	0.152	0.015					
8/18/1998	855	43.042	48.0	15	0.183	0.065	1.030	0.052	0.006		16.370			
8/26/1998	925	46.950	55.0		0.136	0.029	0.670	0.053	0.030		18.590	0.025	0.860	55.000
8/31/1998	915	45.898	54.0	8	0.107	0.045	0.810	0.124	0.027		18.560			
9/9/1998	900	47.212		9	0.124	0.038	0.899	0.165	0.023					
9/16/1998	935	47.209	56.0	6	0.119	0.040	0.980	0.106	0.038		18.980			
9/22/1998	920	46.205	51.0	6	0.127	0.043	1.030	0.151	0.027		17.500			
9/30/1998	950	52.057	56.0	10	0.111	0.027	1.010	0.070	0.035	0.820	19.570	0.037	1.130	65.700
10/7/1998	915	49.938	59.0	6	0.144	0.045	0.920	0.113	0.063		20.670			
10/13/1998	925	55.057	62.0	9	0.103	0.033	1.040	0.138	0.026		21.390			
10/19/1998	850	53.411	62.0	7	0.114	0.033	0.82	0.103	0.034		21.2			
10/26/1998	940	54.07	63.0	11	0.105	0.016	1.02	0.053	0.033	0.001	21.44	0.007	1.42	61.5
11/3/1998	900	55.55	64.0	16	0.154	0.023	1.15	0.062	0.024		21.95			
11/11/1998	920	55.686	66.0	14	0.144	0.02	1.25	0.049	0.018		23.07			
11/17/1998	910	57.455	70.0	16	0.158	0.018	1.17	0.072	0.016		24.08			
11/24/1998	1010	55.41	66.0	11	0.126	0.02	1.06	0.106	0.035	0.05	22.37	0.006	1.31	83.4
12/2/1998	900	55.585		12	0.118	0.016	1.08	0.056	0.022					
12/9/1998	940	53.727	66.0	8	0.122	0.01	1.11	0.058	0.019		22.28			
12/14/1998	930	54.5	68.0	14	0.146	0.012	1.22	0.064	0.022		22.99			
Mean	925	55.486	71.9	10	0.127	0.026	1.102	0.080	0.097	0.145	23.772	0.048	1.319	60.509
Median		55.749	72.0	9	0.121	0.021	1.060	0.072	0.028	0.001	24.200	0.007	1.140	61.500
Maximum	1050	62.772	95.0	19	0.185	0.065	1.590	0.165	0.528	0.820	30.340	0.424	2.220	83.400
Minimum	830	43.042	48.0	5	0.077	0.007	0.668	0.005	0.003	0.001	16.370	-0.007	0.860	36.250
# of Obs.	48	47	43	48	50	50	49	50	50	9	44	11	11	11

Periphyton Filter Upstream (am)

Variable	Time	Mg-T	Ni-T	Pb-T	Zn-T	Water Temp	pH-Field	DO	Cond	Depth Coll	Depth Str	Weather	Air Temp
Storet		927	1067	1051	1092	10	400	299	94	98	82903	41	20
Units		mg/L	µg/L	µg/L	µg/L	C°	std units	mg/L	µmhos/cm	m	m	code no.	C°
1/7/1998	855	2.697								0.1	0.4	20	24.0
1/14/1998	1005	2.814				18.4	7.10	8.65	227	0.1	0.4	20	21.5
1/22/1998	925					17.3	6.89	6.49	240	0.1	1.0	20	
1/29/1998	930	3.040	0.240	3.000	7.230	15.8	6.89	7.53	254	0.2	1.0	20	
2/5/1998	925					15.3	7.00	7.47	243	0.2	1.0	20	15.5
2/11/1998	945					15.1	6.99	10.45	247	0.2	1.0	20	21.5
2/19/1998	910	2.607				19.0	6.73	6.44	223	0.3	1.0	20	17.5
2/25/1998	935	2.755	0.760	2.250	20.730	18.3	6.86	6.58	218	0.3	1.0	20	21.0
3/5/1998	945	3.277				17.7	7.10	9.21	237	0.3	1.0	20	19.5
3/12/1998	930	2.691				17.0	6.70	6.16	216	0.3	1.0	20	9.5
3/19/1998	900	3.225				19.2	6.63	4.05	234	0.3	1.0	20	20.5
3/26/1998	945	3.056	1.540	1.180	15.580	19.5	6.61	5.14	223	0.2	1.0	20	22.0
4/1/1998	1050	3.235				23.2	6.53	0.87	234	0.3	2.0	20	
4/8/1998		3.407				23.4	6.55	2.15	244	0.3	1.0	20	24.0
4/13/1998		3.972				21.5	7.06	7.67	247	0.3	1.0	20	22.5
4/22/1998	930	4.032				24.6	6.59	3.15	251	0.3	1.0	20	26.0
4/29/1998	830	4.611				24.5	6.59	3.24	258	0.3	1.0	20	25.0
5/6/1998	940	4.331	0.590	1.270	6.760	24.7	6.52	3.20	274	0.3	1.0	20	27.0
5/12/1998	950	4.358				27.4	6.66	3.76	279	0.3	1.0	20	29.0
5/20/1998	900	4.023				27.0	6.60	1.10	266	0.3	1.0	20	28.0
5/27/1998	910	4.166	3.130	0.850	1.091	29.7	6.64	2.22	274	0.3	1.0	20	28.0
6/3/1998	915	4.078				29.9	6.61	1.29	272	0.3	1.0	20	30.0
6/9/1998	930	4.357				29.4	6.48	1.97	276	0.3	1.0	20	28.5
6/17/1998	945	4.500				31.3	6.61	2.17	283	0.3	1.0	20	32.0
6/23/1998	935	4.596				31.5	6.71	2.40	284	0.3	1.0	20	31.5
7/1/1998	935	4.691	0.490	3.070	10.810	31.2	6.75	3.60	286	0.3	1.0	20	32.5
7/8/1998	935	4.123				29.6	6.64	1.46	245	0.3	1.0	20	28.0
7/14/1998	915	3.476				29.9	6.52	0.48	227	0.3	1.0	20	28.5
7/22/1998	945	2.895				30.1	6.64	1.47	199	0.3	1.0	20	30.0
7/28/1998	935	3.019	0.770	1.770	2.402	31.7	6.46	2.10	204	0.3	1.0	20	31.5

Variable	Time	Mg-T	Ni-T	Pb-T	Zn-T	Water Temp	pH-Field	DO	Cond	Depth Coll	Depth Str	Weather	Air Temp
Storet		927	1067	1051	1092	10	400	299	94	98	82903	41	20
Units		mg/L	µg/L	µg/L	µg/L	C°	std units	mg/L	µmhos/cm	m	m	code no.	C°
8/5/1998	925	2.772				29.9	6.50	0.76	191	0.3	1.0	20	28.0
8/10/1998	900					29.5	6.39	0.68	170	0.3	1.0	20	30.0
8/18/1998	855	1.775				30.3	6.24	0.15	138	0.3	1.0	20	29.6
8/26/1998	925	1.973	0.660	1.010	6.660	29.7	6.42	1.53	153	0.3	1.0	20	28.5
8/31/1998	915	1.879				30.6	6.19	0.74	153	0.3	1.0	20	29.2
9/9/1998	900					29.5	6.27	0.62	154	0.3	1.0	20	27.7
9/16/1998	935	2.029				27.9	6.54	1.35	154	0.3	1.0	20	26.3
9/22/1998	920	1.699				27.5	6.47	0.66	144	0.3	1.0	20	26.2
9/30/1998	950	1.791	1.960	1.970	10.080	28.3	6.62	2.26	149	0.3	1.0	20	27.0
10/7/1998	915	1.855				28.8	6.52	2.63	156	0.3	1.0	20	27.4
10/13/1998	925	2.043				28.6	6.69	0.96	174	0.3	1.0	20	26.5
10/19/1998	850	2.126				26.8	6.65	2.10	187	0.3	1.0	20	22.8
10/26/1998	940	2.269	1.06	2.74	9.87	23.1	6.67	5.80	177	0.3	1.0	20	25.2
11/3/1998	900	2.293				24.1	6.62	2.95	180	0.3	1.0	20	23.0
11/11/1998	920	2.147				21.3	6.58	2.47	177	0.3	1.0	20	23.7
11/17/1998	910	2.363				23.3	6.60	1.60	180	0.3	1.0	20	23.8
11/24/1998	1010	2.485	0.51	2.52	11.26	24.1	6.76	2.90	186	0.3	1.0	20	24.9
12/2/1998	900					22.2	6.86	4.60	189	0.3	1.0	20	23.7
12/9/1998	940	2.617				22.7	6.90	5.73	194	0.3	1.0	20	23.3
12/14/1998	930	2.65				21.7	6.80	5.22	198	0.3	1.0	20	15.6
Mean	925	3.064	1.065	1.966	9.316	25.0	6.65	3.43	216	0.3	1.0	20	25.253
Median		2.855	0.760	1.970	9.870	24.7	6.62	2.47	223	0.3	1.0	20	26.200
Maximum	1050	4.691	3.130	3.070	20.730	31.7	7.10	10.45	286	0.3	2.0	20	32.500
Minimum	830	1.699	0.240	0.850	1.091	15.1	6.19	0.15	138	0.1	0.4	20	9.500
# of Obs.	48	44	11	11	11	49	49	49	49	50	50	50	47

Periphyton Filter Downstream (am)

Variable	Time	Alkalinity	Hardness	TSS	TP-T	PO_4-T	TKN-T	NH_4-T	NO_X-T	Ag-T	Ca-T	Cd-T	Cu-T	Fe-T
Storet Code		410	46570	530	665	70507	625	610	630	1077	916	1027	1042	1045
Units		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1/7/1998	850	61.057	72.0	4	0.065	0.007	0.870	0.007	0.012		24.270			
1/14/1998	1000	65.550	73.0	15	0.122	0.015	1.100	0.008	0.305		24.410			
1/22/1998	915			7	0.088	0.012	0.880	0.033	0.412					
1/29/1998	915	61.945	78.0	9	0.118	0.012	1.100	0.024	0.477	0.110	26.210	0.000	3.670	59.500
2/5/1998	915			10	0.146	0.015	1.240	0.056	0.524					
2/11/1998	905			11	0.177	0.014	1.170	0.010	0.469					
2/19/1998	855	53.272	70.0	6	0.086	0.029	0.677	0.027	0.405		23.810			
2/25/1998	925	55.778	72.0	8	0.123	0.009	1.000	0.020	0.271		24.240	0.002	1.380	31.970
3/5/1998	935	59.398	78.0		0.101	0.016	1.020	0.011	0.117		25.840			
3/12/1998	920	56.541	67.0	5	0.132	0.027	1.120	0.032	0.104		22.140			
3/19/1998	910	61.889	76.0	10	0.085	0.015	0.774	0.020	0.124		24.980			
3/26/1998	955	59.296	72.0	10	0.104	0.016	1.190	0.015	0.008	0.001	23.810	0.632	1.070	39.850
4/1/1998	1100	60.493	74.0	9	0.093	0.011	1.010	0.028	0.010		24.160			
4/8/1998		58.461	75.0	7	0.094	0.020		0.008	0.008		24.480			
4/13/1998		58.021	80.0	9	0.110	0.022	1.510	0.007	0.001		25.490			
4/22/1998	940	56.405	77.0	8	0.133	0.025	1.360	0.012	0.003		24.250			
4/29/1998	840	54.039	79.0	6	0.122	0.021	1.250	0.008	0.005		24.480			
5/6/1998	950	55.264	78.0	5	0.124	0.011	1.280	0.053	0.024	0.001	24.330	0.014	1.160	26.610
5/12/1998	1000	56.578	80.0	8	0.131	0.012	1.390	0.038	0.010		24.680			
5/20/1998	910	56.378	77.0	9	0.207	0.060	1.440	0.082	0.071		24.490			
5/27/1998	920	60.826	87.0	6	0.134	0.027	1.200	0.055	0.004	0.001	27.950	-0.005	1.500	9.230
6/3/1998	925	59.175	88.0	5	0.133	0.049	1.190	0.035	0.013		28.540			
6/9/1998	940	60.564	89.0	5	0.125	0.021	0.970	0.019	0.006		28.690			
6/17/1998	955	59.936	91.0	6	0.114	0.021	1.280	0.031	0.026		29.220			
6/23/1998	945	60.847	89.0	9	0.095	0.023	1.220	0.014	0.012		28.330			
7/1/1998	945	60.196	94.0	8	0.101	0.023	1.120	0.011	0.013	0.001	29.890	-0.012	0.820	26.170
7/8/1998	945	52.118	81.0	10	0.144	0.059	1.310	0.053	0.108		26.100			
7/14/1998	925	54.666		8	0.122	0.025	1.250	0.021	0.012		24.800			
7/22/1998	955	50.381	67.0	5	0.084	0.029	0.840	0.010	0.005		22.260			
7/28/1998	945	52.295	71.0	4	0.090	0.030	0.890	0.011	0.008	0.001	23.630	0.003	0.670	16.130
8/5/1998	935	49.670	68.0	6	0.089	0.029	0.840	0.006	0.004		22.770			

Variable	Time	Alkalinity	Hardness	TSS	TP-T	PO_4-T	TKN-T	NH_4-T	NO_X-T	Ag-T	Ca-T	Cd-T	Cu-T	Fe-T
Storet Code		410	46570	530	665	70507	625	610	630	1077	916	1027	1042	1045
Units		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
8/10/1998	910	46.354		2	0.128	0.028	0.700	0.004	0.001					
8/18/1998	905	41.025	44.0	9	0.106	0.048	0.540	0.006	0.003		15.010			
8/26/1998	935	45.522	52.0		0.116	0.031	0.400		0.003		17.690	-0.012	0.740	19.640
8/31/1998	925	45.424	51.0	2	0.087	0.036	0.790	0.004	0.007		17.660			
9/9/1998	910	46.025		3	0.085	0.033	0.739	0.011	0.004					
9/16/1998	945	46.800	54.0	2	0.075	0.035	0.740	0.008	0.007		18.400			
9/22/1998	930	44.511	49.0	2	0.090	0.038	0.740	0.007	0.030		17.030			
9/30/1998	1000	49.674	53.0	4	0.083	0.024	0.660	0.003	0.010	0.910	18.480	-0.001	1.420	28.990
10/7/1998	925	49.981	57.0	2	0.098	0.028	0.710	0.020	0.014		19.740			
10/13/1998	935	53.986	60.0	4	0.052	0.027	0.7	0.008	0.007		20.63			
10/19/1998	905	53.091	59.0	3	0.101	0.018	0.5	0.008	0.011		20.32			
10/26/1998	950	52.678	60.0	6	0.088	0.014	1.04	0.008	0.006	0.001	20.39	0.003	0.59	47.41
11/3/1998	910	54.078	63.0	6	0.099	0.017	0.91	0.003	0.009		21.66			
11/11/1998	930	55.361	65.0	3	0.141	0.017	0.92	0.009	0.013		22.54			
11/17/1998	920	55.56	68.0	8	0.119	0.014	0.96	0.01	0.005		23.43			
11/24/1998	1020	55.483	64.0	7	0.102	0.017	0.8	0.009	0.016	0.001	21.81	0.005	0.88	30.22
12/2/1998	910	54.266		3	0.078	0.017	0.8	0.018	0.022					
12/9/1998	950	52.275	65.0	4	0.117	0.013	0.94	0.015	0.009		22			
12/14/1998	940	53.364	67.0	8	0.113	0.011	0.98	0.021	0.015		22.48			
Mean	934	54.606	70.6	6	0.109	0.023	0.981	0.019	0.075	0.114	23.353	0.057	1.264	30.520
Median	930	55.264	72.0	6	0.105	0.021	0.970	0.011	0.012	0.001	23.985	0.002	1.070	28.990
Maximum	1100	65.550	94.0	15	0.207	0.060	1.510	0.082	0.524	0.910	29.890	0.632	3.670	59.500
Minimum	840	41.025	44.0	2	0.052	0.007	0.400	0.003	0.001	0.001	15.010	-0.012	0.590	9.230
# of Obs.	48	47	43	48	50	50	49	49	50	9	44	11	11	11

Periphyton Filter Downstream (am)

Variable	Time	Mg-T	Ni-T	Pb-T	Zn-T	Water Temp.	pH-Field	DO	Cond	Depth Coll	Depth Str	Weather	Air Temp
Storet Code		927	1067	1051	1092	10	400	299	94	98	82903	41	20
Units		mg/L	µg/L	µg/L	µg/L	C°	std units	mg/L	µmhos/cm	m	m	code no.	C°
1/7/1998	850	2.680								0.1	0.2	20	24.0
1/14/1998	1000	2.856				19.0	8.43	11.48	223	0.1	0.2	20	21.5
1/22/1998	915					18.8	8.14	11.36	235	0.1	0.2	20	
1/29/1998	915	3.055	-0.150	1.940	4.577	16.7	7.97	11.42	252	0.1	0.2	20	
2/5/1998	915					16.3	7.72	9.84	240	0.1	0.2	20	15.5
2/11/1998	905					17.9	8.23	11.30	243	0.1	0.2	20	21.5
2/19/1998	855	2.647				19.4	7.66	9.76	223	0.1	0.2	20	17.5
2/25/1998	925	2.717	0.230	2.800	5.890	20.5	7.65	9.18	217	0.1	0.2	20	21.0
3/5/1998	935	3.270				20.0	7.96	10.50	237	0.1	0.2	20	19.5
3/12/1998	920	2.740				15.8	7.66	10.37	213	0.1	0.2	20	9.5
3/19/1998	910	3.208				20.2	7.50	9.61	233	0.1	0.2	20	20.5
3/26/1998	955	2.987	1.280	0.930	11.550	21.9	7.44	9.38	222	0.1	0.2	20	22.0
4/1/1998	1100	3.249				27.6	7.45	8.30	229	0.1	0.2	20	
4/8/1998		3.440				24.4	7.46	8.27	243	0.1	0.2	20	24.0
4/13/1998		3.968				23.7	7.81	9.01	247	0.1	0.2	20	22.5
4/22/1998	940	4.058				26.5	7.30	7.45	251	0.1	0.2	20	26.0
4/29/1998	840	4.368				25.2	7.48	8.79	255	0.1	0.2	20	25.0
5/6/1998	950	4.215	0.660	0.510	16.700	27.6	8.37	11.31	270	0.1	0.2	20	27.0
5/12/1998	1000	4.339				29.7	7.82	9.47	278	0.1	0.2	20	29.0
5/20/1998	910	3.922				28.4		9.95	260	0.1	0.2	20	28.0
5/27/1998	920	4.177	0.980	0.400	-0.221	28.6	7.62	7.91	274	0.1	0.2	20	28.0
6/3/1998	925	4.097				31.4	8.39	9.51	267	0.1	0.2	20	30.0
6/9/1998	940	4.231				31.0	8.69	11.16	272	0.1	0.2	20	28.5
6/17/1998	955	4.370				33.5	8.81	10.83	277	0.1	0.2	20	32.0
6/23/1998	945	4.484				32.3	8.48	10.17	280	0.1	0.2	20	31.5
7/1/1998	945	4.599	0.810	0.800	6.390	31.8	8.32	9.70	279	0.1	0.2	20	32.5
7/8/1998	945	3.947				31.8	8.38	9.04	235	0.1	0.2	20	28.0
7/14/1998	925	3.480				30.2	8.02	8.34	225	0.1	0.2	20	28.5
7/22/1998	955	2.772				32.5	8.73	10.07	193	0.1	0.2	20	30.0
7/28/1998	945	2.996	0.860	0.340	2.133	33.2	8.70	10.08	198	0.1	0.2	20	31.5

Variable	Time	Mg-T	Ni-T	Pb-T	Zn-T	Water Temp.	pH-Field	DO	Cond	Depth Coll	Depth Str	Weather	Air Temp
Storet Code		927	1067	1051	1092	10	400	299	94	98	82903	41	20
Units		mg/L	µg/L	µg/L	µg/L	C°	std units	mg/L	µmhos/cm	m	m	code no.	C°
8/5/1998	935	2.698				31.6	8.68	10.60	183	0.1	0.2	20	28.0
8/10/1998	910					30.9	8.62	9.52	162	0.1	0.2	20	30.0
8/18/1998	905	1.585				31.3	8.67	9.50	132	0.1	0.2	20	29.6
8/26/1998	935	1.775	0.310	0.030	4.423	30.2	8.45	10.48	150	0.1	0.2	20	28.5
8/31/1998	925	1.769				31.5	8.69	11.44	148	0.1	0.2	20	29.2
9/9/1998	910					30.1	8.61	11.22	149	0.1	0.3	20	27.7
9/16/1998	945	1.938				28.3	8.91	11.72	149	0.1	0.2	20	26.3
9/22/1998	930	1.614				28.1	8.80	11.97	137	0.1	0.2	20	26.2
9/30/1998	1000	1.728	1.820	0.400	6.680	29.6	8.86	10.51	144	0.1	0.2	20	27.0
10/7/1998	925	1.751				29.4	8.77	12.06	147	0.1	0.2	20	27.4
10/13/1998	935	1.947				29.2	8.98	11.57	168	0.1	0.2	20	26.5
10/19/1998	905	2.047				26.6	8.37	10.30	143	0.1	0.2	20	22.8
10/26/1998	950	2.119	0.84	0.52	4.43	27.0	9.05	11.52	171	0.1	0.2	20	25.2
11/3/1998	910	2.249				24.8	8.23	10.32	174	0.1	0.2	20	23.0
11/11/1998	930	2.077				23.8	8.34	10.70	172	0.1	0.2	20	23.7
11/17/1998	920	2.318				25.4	8.39	10.30	175	0.1	0.2	20	23.8
11/24/1998	1020	2.395	0.38	0.8	8.8	26.4	8.87	11.08	179	0.1	0.2	20	24.9
12/2/1998	910					23.3	7.51	8.50	187	0.1	0.2	20	23.7
12/9/1998	950	2.539				25.2	8.70	10.56	188	0.1	0.2	20	23.3
12/14/1998	940	2.617				21.2	7.90	9.47	195	0.1	0.2	20	15.6
Mean	934	3.001	0.729	0.861	6.487	26.3	8.24	10.14	211	0.1	0.2	20	25.3
Median	930	2.814	0.810	0.520	5.890	27.6	8.37	10.30	222	0.1	0.2	20	26.2
Maximum	1100	4.599	1.820	2.800	16.700	33.5	9.05	12.06	280	0.1	0.3	20	32.5
Minimum	840	1.585	-0.150	0.030	-0.221	15.8	7.30	7.45	132	0.1	0.2	20	9.5
# of Obs.	48	44	11	11	11	49	48	49	49	50	50	50	47

Periphyton Filter Upstream (pm)

Variable	Time	Alkalinity	Hardness	TSS	Chl-a	Chl-b	Chl-c	Chl-a_Corr	Pheo_Corr	Chl-a/Pheo
Storet		410	46570	530	32210	32212	32214	32211	32218	32219
Units		mg/L	mg/L	mg/l	mg/m	mg/m	mg/m	mg/m	mg/m	ratio
1/7/1998	1440	61.969	73.0	4						
1/14/1998	1440	62.558	72.0	8						
1/22/1998	1425			7						
1/29/1998	1445	62.212	77.0	9						
2/5/1998	1415			11						
2/11/1998	1420			9						
2/19/1998	1440	54.117	69.0	4						
2/25/1998	1450	56.461	72.0	10						
3/5/1998	1455	59.931	77.0							
3/12/1998	1410	57.328	66.0	6						
3/19/1998	1400	63.015	77.0	9						
3/26/1998	1400	60.377	72.0	8						
4/1/1998	1435	60.237	73.0	10						
4/8/1998		59.141	75.0	7						
4/13/1998		58.439	81.0	6						
4/22/1998	1500	55.062	76.0	8						
4/29/1998	1405	56.112	80.0	8						
5/6/1998	1440	57.425	79.0	8						
5/12/1998	1420	57.482	80.0	11	45.421	5.184	3.927	34.844	15.900	1.481
5/20/1998	1457	58.354	80.0	9	38.305	4.841	2.478	28.202	15.463	1.452
5/27/1998	1415	63.217	84.0	8	31.945	1.876	0.554	16.314	24.842	1.277
6/3/1998	1440	59.249	88.0	7	45.692	2.920	1.842	27.835	27.932	1.349
6/9/1998	1400	60.689	92.0	14	39.817	1.016	2.425	24.644	23.501	1.358
6/17/1998	1410	62.081	93.0	12	57.397	1.734	2.761	40.184	25.979	1.425
6/23/1998	1435	62.898	95.0	14	64.514	5.880	2.548	46.280	27.795	1.437
7/1/1998	1435	60.561	94.0	17	52.211	1.891	1.256	37.580	21.901	1.442
7/8/1998	1410	55.900	83.0	14	56.456	1.518	1.695	35.734	31.955	1.370
7/14/1998	1420	54.106	83.0	13	50.183	3.441	3.415	35.645	22.108	1.432
7/22/1998	1425	50.894	69.0	5	30.061	1.985	1.837	20.426	14.805	1.406
7/28/1998	1410	53.938	74.0	9	30.807	3.645	2.734	20.025	16.934	1.379
8/5/1998	1410	52.931	72.0	5	26.599	2.332	1.909	16.073	16.578	1.345

Variable	Time	Alkalinity	Hardness	TSS	Chl-a	Chl-b	Chl-c	Chl-a_Corr	Pheo_Corr	Chl-a/Pheo
Storet		410	46570	530	32210	32212	32214	32211	32218	32219
Units		mg/L	mg/L	mg/l	mg/m	mg/m	mg/m	mg/m	mg/m	ratio
8/10/1998	1400	48.278		6						
8/18/1998	1435	44.129	52.0	15	37.339	4.190	4.947	27.341	15.310	1.449
8/26/1998	1415	46.135	55.0	9	22.274	1.465	1.878	14.498	12.060	1.382
8/31/1998	1425	47.641	54.0	6	20.379	1.192	1.494	11.634	13.785	1.320
9/9/1998	1400	47.468		7						
9/16/1998	1455	47.282	57.0	7	24.458	2.010	2.736	15.192	14.543	1.358
9/22/1998	1415	46.243	51.0	4	20.019	1.102	1.285	12.905	11.018	1.378
9/30/1998	1405	51.873	55.0	12	33.949	1.227	2.869	21.775	18.803	1.376
10/7/1998	1450	51.173	59.0	8	26.568	0.848	1.956	14.554	18.927	1.304
10/13/1998	1405	53.520	63.0	9	24.205	0.179	1.361	12.442	18.546	1.281
10/19/1998	1435	55.343	61.0	10	26.284	1.337	1.544	15.733	16.474	1.342
10/26/1998	1510	54.233	62.0	12	27.727	2.664	1.823	16.768	17.286	1.345
11/3/1998	1415	55.551	64.0	20	33.834	1.360	2.946	18.557	24.103	1.304
11/11/1998	1425	53.540	67.0	12	29.251	1.779	2.244	16.821	19.587	1.323
11/17/1998	1500	56.870	70.0	13	33.316	2.224	2.990	21.680	18.055	1.382
11/24/1998	1415	55.873	64.0	12	26.261	1.093	2.595	15.175	17.408	1.326
12/2/1998	1500	52.990		12						
12/9/1998	1500	54.246	64.0	12	21.881	1.671	1.876	13.697	12.805	1.362
12/14/1998	1505	53.805	67.0	15	31.104	2.791	1.697	19.536	18.125	1.363
Mean	1434	55.593	72.1	10	34.767	2.255	2.263	22.486	19.053	1.371
Median	1425	55.873	72.0	9	31.104	1.876	1.956	19.536	18.055	1.363
Maximum	1510	63.217	95.0	20	64.514	5.880	4.947	46.280	31.955	1.481
Minimum	1400	44.129	51.0	4	20.019	0.179	0.554	11.634	11.018	1.277
# of Obs.	48	47	44	49	29	29	29	29	29	29

Periphyton Filter Upstream (pm)

Variable	Time	TP-T	PO_4-T	TKN-T	NH_4-T	NO_X-T	Ag-T	Ca-T	Cd-T	Cu-T	Fe-T	Mg-T	Ni-T	Pb-T
Storet		665	70507	625	610	630	1077	916	1027	1042	1045	927	1067	1051
Units		mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L
1/7/1998	1440	0.079	0.010	0.890	0.021	0.310		24.630				2.668		
1/14/1998	1440	0.077	0.044	0.820	0.017	0.347		24.250				2.875		
1/22/1998	1425	0.084	0.013	1.050	0.098	0.433								
1/29/1998	1445	0.106	0.013	1.110	0.027	0.490	0.002	25.910	0.008	1.200	54.900	3.022	0.220	2.830
2/5/1998	1415	0.131	0.017	1.040	0.085	0.526								
2/11/1998	1420	0.127	0.017	1.220	0.005	0.475								
2/19/1998	1440	0.079	0.017	0.622	0.024	0.424		23.420				2.524		
2/25/1998	1450	0.107	0.009	0.950	0.018	0.252		24.550	0.001	1.510	52.900	2.676	0.250	1.220
3/5/1998	1455	0.096	0.017	0.990	0.022	0.137		25.470				3.278		
3/12/1998	1410	0.123	0.017	1.060	0.069	0.131		21.980				2.754		
3/19/1998	1400	0.078	0.013	0.683	0.068	0.161		25.400				3.213		
3/26/1998	1400	0.094	0.013	1.130	0.029	0.023	0.001	23.800	0.227	1.060	47.310	3.047	0.850	1.390
4/1/1998	1435	0.091	0.011	1.100	0.015	0.006		24.100				3.207		
4/8/1998		0.086	0.011		0.016	0.024		24.230				3.426		
4/13/1998		0.060	0.010	1.010	0.008	0.006		25.720				3.986		
4/22/1998	1500	0.106	0.021	1.220	0.016	0.362		23.750				4.009		
4/29/1998	1405	0.116	0.019	1.320	0.029	0.008		24.800				4.492		
5/6/1998	1440	0.220	0.010	2.300	0.111	0.038	0.001	24.540	0.010	1.660	57.200	4.317	0.670	1.000
5/12/1998	1420	0.145	0.015	1.310	0.079	0.024		24.550				4.446		
5/20/1998	1457	0.162	0.056	1.320	0.172	0.095		25.440				4.068		
5/27/1998	1415	0.143	0.034	1.160	0.075	0.002	0.001	26.430	0.008	1.230	38.260	4.340	0.080	0.720
6/3/1998	1440	0.126	0.050	1.280	0.108	0.015		28.510				4.170		
6/9/1998	1400	0.167	0.025	1.150	0.108	0.022		29.500				4.427		
6/17/1998	1410	0.246	0.021	1.020	0.136	0.044		29.730				4.446		
6/23/1998	1435	0.136	0.030	1.530	0.096	0.027		30.550				4.568		
7/1/1998	1435	0.143	0.022	1.660	0.054	0.045	0.180	30.090	0.008	1.880	68.400	4.538	0.490	2.710
7/8/1998	1410	0.166	0.048	1.590	0.160	0.090		26.530				4.119		
7/14/1998	1420	0.149	0.029	1.450	0.087	0.015		31.540				1.080		
7/22/1998	1425	0.123	0.026	1.120	0.097	0.017		22.800				2.917		
7/28/1998	1410	0.114	0.027	1.100	0.118	0.012	0.001	24.500	0.018	0.930	85.500	3.048	1.050	2.120
8/5/1998	1410	0.109	0.034	1.020	0.127	0.011		24.370				2.760		

Variable	Time	TP-T	PO_4-T	TKN-T	NH_4-T	NO_X-T	Ag-T	Ca-T	Cd-T	Cu-T	Fe-T	Mg-T	Ni-T	Pb-T
Storet		665	70507	625	610	630	1077	916	1027	1042	1045	927	1067	1051
Units		mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L
8/10/1998	1400	0.106	0.032	0.970	0.117	0.004								
8/18/1998	1435	0.167	0.056	1.080	0.055	0.005		17.690				1.896		
8/26/1998	1415	0.055	0.032	0.470	0.080	0.035	0.090	18.770	0.022	1.170	55.600	1.904	0.170	1.270
8/31/1998	1425	0.144	0.051	0.910	0.120	0.022		18.700				1.739		
9/9/1998	1400	0.106	0.034	0.775	0.120	0.018								
9/16/1998	1455	0.080	0.041	0.710	0.120	0.029		19.530				2.049		
9/22/1998	1415	0.107	0.042	0.980	0.165	0.023		17.400				1.752		
9/30/1998	1405	0.100	0.026	0.840	0.069	0.032	0.499	19.000	0.022	1.000	66.600	1.771	0.380	2.910
10/7/1998	1450	0.126	0.034	0.900	0.120	0.004		20.360				1.878		
10/13/1998	1405	0.112	0.033	0.960	0.116	0.010		21.880				2.005		
10/19/1998	1435	0.127	0.022	0.710	0.089	0.033		20.950				2.099		
10/26/1998	1510	0.112	0.016	0.940	0.051	0.024	0.001	21.000	0.000	1.130	59.900	2.213	0.000	2.680
11/3/1998	1415	0.154	0.020	1.150	0.057	0.023		21.780				2.327		
11/11/1998	1425	0.131	0.020	1.230	0.048	0.022		23.300				2.233		
11/17/1998	1500	0.147	0.015	1.170	0.054	0.017		23.970				2.341		
11/24/1998	1415	0.132	0.018	1.020	0.099	0.028	0.050	21.570	0.000	1.230	73.300	2.385	1.440	2.590
12/2/1998	1500	0.129	0.009	1.020	0.048	0.018								
12/9/1998	1500	0.142	0.013	1.150	0.065	0.018		21.560				2.540		
12/14/1998	1505	0.144	0.014	1.050	0.059	0.020		22.740				2.585		
Mean	1434	0.122	0.025	1.087	0.075	0.099	0.083	23.893	0.029	1.273	59.988	3.003	0.509	1.949
Median	1425	0.123	0.021	1.050	0.072	0.024	0.002	24.165	0.008	1.200	57.200	2.818	0.380	2.120
Maximum	1510	0.246	0.056	2.300	0.172	0.526	0.499	31.540	0.227	1.880	85.500	4.568	1.440	2.910
Minimum	1400	0.055	0.009	0.470	0.005	0.002	0.001	17.400	0.000	0.930	38.260	1.080	0.000	0.720
# of Obs.	48	50	50	49	50	50	10	44	11	11	11	44	11	11

Periphyton Filter Upstream (pm)

Variable	Time	Zn-T	Water Temp.	pH-Field	DO	Cond	Depth Coll	Depth Str	Weather	Air Temp
Storet		1092	10	400	299	94	98	82903	41	20
Units		µg/L	C°	std units	mg/L	µmhos/cm	m	m	code no.	C°
1/7/1998	1440		19.8	7.78	12.45	220	0.1	0.4	20	27.0
1/14/1998	1440		18.7	7.53	9.91	228	0.1	0.4	20	24.0
1/22/1998	1425		17.7	6.90	7.52	241	0.1	1.0	20	
1/29/1998	1445	3.452	16.3	7.38	9.96	253	0.2	1.0	20	
2/5/1998	1415		15.7	6.98	7.60	242	0.2	1.0	20	18.5
2/11/1998	1420		15.6	7.83	11.73	248	0.2	1.0	20	24.5
2/19/1998	1440		19.7	7.56	9.34	222	0.3	1.0	20	26.0
2/25/1998	1450	6.920	19.2	7.13	9.52	219	0.3	1.0	20	24.0
3/5/1998	1455		18.1	6.95	10.22	234	0.3	1.0	20	24.5
3/12/1998	1410		17.3	7.21	6.70	216	0.3	1.0	20	11.0
3/19/1998	1400		19.3	6.71	3.25	234	0.2	1.0	20	21.0
3/26/1998	1400	7.430	19.7	6.59	4.19	222	0.2	1.0	20	24.5
4/1/1998	1435		23.5	6.61	1.22	234	0.3	1.0	20	32.0
4/8/1998			23.8	6.61	2.92	242	0.3	1.0	20	28.5
4/13/1998			21.8	6.95	6.63	248	0.3	1.0	20	23.5
4/22/1998	1500		25.0	6.69	3.88	249	0.3	1.0	20	27.0
4/29/1998	1405		24.8	6.59	2.45	260	0.3	1.0	20	29.0
5/6/1998	1440	6.010	24.9	6.59	2.78	273	0.3	1.0	20	31.0
5/12/1998	1420		27.7	6.67	3.13	279	0.3	1.0	20	31.5
5/20/1998	1457		27.3	6.63	0.75	267	0.3	1.0	20	32.0
5/27/1998	1415	7.550	29.7	6.60	0.64	275	0.3	1.0	20	31.0
6/3/1998	1440		30.3	6.69	1.78	271	0.3	1.0	20	35.5
6/9/1998	1400		29.7	6.63	1.91	276	0.3	1.0	20	34.0
6/17/1998	1410		31.6	6.64	2.17	280	0.3	1.0	20	36.0
6/23/1998	1435		32.0	6.70	1.01	287	0.3	1.0	20	37.0
7/1/1998	1435	4.607	31.6	6.87	3.71	288	0.3	1.0	20	39.0
7/8/1998	1410		29.8	6.69	0.97	246	0.3	1.0	20	36.0
7/14/1998	1420		30.0	6.64	0.38	227	0.3	1.0	20	34.0
7/22/1998	1425		30.2	6.62	0.86	200	0.3	1.0	20	37.0
7/28/1998	1410	2.823	31.8	6.57	0.64	204	0.3	1.0	20	35.5

Variable	Time	Zn-T	Water Temp.	pH-Field	DO	Cond	Depth Coll	Depth Str	Weather	Air Temp
Storet		1092	10	400	299	94	98	82903	41	20
Units		µg/L	C°	std units	mg/L	µmhos/cm	m	m	code no.	C°
8/5/1998	1410		30.1	6.58	1.88	194	0.3	1.0	20	35.0
8/10/1998	1400		29.7	6.51	0.44	169	0.3	1.0	20	34.0
8/18/1998	1435		30.5	6.43	0.18	140	0.3	1.0	20	34.5
8/26/1998	1415	15.860	29.9	6.49	1.39	154	0.3	1.0	20	35.0
8/31/1998	1425		30.8	6.33	0.47	151	0.3	1.0	20	34.3
9/9/1998	1400		29.6	6.36	0.41	154	0.3	1.0	20	31.0
9/16/1998	1455		28.0	6.58	0.88	154	0.3	1.0	20	29.0
9/22/1998	1415		27.5	6.54	0.58	144	0.3	1.0	20	
9/30/1998	1405	7.820	28.5	6.66	2.10	148	0.3	1.0	20	29.9
10/7/1998	1450		28.9	6.52	0.74	155	0.3	1.0	20	30.5
10/13/1998	1405		28.8	6.72	0.58	178	0.3	1.0	20	29.6
10/19/1998	1435		27.0	6.69	1.67	174	0.3	1.0	20	29.8
10/26/1998	1510	9.350	23.3	6.75	5.33	177	0.3	1.0	20	26.2
11/3/1998	1415		24.3	6.64	2.51	181	0.3	1.0	20	25.5
11/11/1998	1425		21.4	6.66	2.57	175	0.3	1.0	20	27.9
11/17/1998	1500		23.6	6.69	3.45	180	0.3	1.0	20	28.0
11/24/1998	1415	6.170	24.1	6.79	2.88	185	0.3	1.0	20	25.5
12/2/1998	1500		22.3	6.89	4.71	188	0.3	1.0	20	26.2
12/9/1998	1500		23.8	6.94	5.27	194	0.3	1.0	20	25.4
12/14/1998	1505		21.6	7.06	5.95	198	0.3	1.0	20	15.2
Mean	1434	7.090	25.1	6.79	3.68	216	0.3	1.0	20	29.1
Median	1425	6.920	25.0	6.68	2.54	221	0.3	1.0	20	29.6
Maximum	1510	15.860	32.0	7.83	12.45	288	0.3	1.0	20	39.0
Minimum	1400	2.823	15.6	6.33	0.18	140	0.1	0.4	20	11.0
# of Obs.	48	11	50	50	50	50	50	50	50	47

Periphyton Filter Downstream (pm)

Variable	Time	Alkalinity	Hardness	TSS	Chl-a	Chl-b	Chl-c	Chl-a_Corr	Pheo_Corr	Chl-a/Pheo	TP-T
Storet Code		410	46570	530	32210	32212	32214	32211	32218	32219	665
Units		mg/L	mg/L	mg/L	mg/m	mg/m	mg/m	mg/m	mg/m	ratio	mg/L
1/7/1998	1435	62.385	72.0	4							0.081
1/14/1998	1435	63.004	74.0	8							0.121
1/22/1998	1415			7							0.079
1/29/1998	1435	61.838	78.0	7							0.106
2/5/1998	1405			10							0.109
2/11/1998	1350			10							0.161
2/19/1998	1430	54.190	69.0	6							0.087
2/25/1998	1435	56.487	72.0	10							0.108
3/5/1998	1440	59.977	78.0								0.092
3/12/1998	1405	57.482	66.0	5							0.123
3/19/1998	1410	62.519	76.0	8							0.062
3/26/1998	1410	60.728	72.0	7							0.088
4/1/1998	1445	61.158	74.0	9							0.093
4/8/1998		60.047	75.0	7							0.077
4/13/1998		58.149	80.0	5							0.072
4/22/1998	1510	70.719	77.0	7							0.108
4/29/1998	1415	56.242	80.0	4							0.105
5/6/1998	1450	56.300	78.0	6							0.121
5/12/1998	1430	57.209	80.0	10	40.393	5.763	3.679	31.826	12.861	1.499	0.133
5/20/1998	1507	57.957	79.0	9	40.645	5.175	2.634	31.573	13.610	1.489	0.165
5/27/1998	1425	62.395	85.0	6	25.800	1.541	0.331	15.726	15.729	1.350	0.106
6/3/1998	1450	59.291	88.0	5	31.951	3.953	1.636	22.061	15.366	1.413	0.123
6/9/1998	1410	61.572	91.0	8	41.898	2.008	2.322	29.504	18.773	1.428	0.112
6/17/1998	1420	61.131	92.0	6	43.422	2.123	1.607	34.221	13.252	1.505	0.099
6/23/1998	1445	62.022	93.0	8	48.579	4.091	1.327	40.495	11.276	1.548	0.085
7/1/1998	1445	56.800	93.0	10	40.432	1.890	1.119	31.773	12.476	1.503	0.095
7/8/1998	1420	56.015	83.0	9	50.259	4.383	2.051	36.001	21.720	1.437	0.146
7/14/1998	1430	52.586	95.0	6	42.876	3.145	0.859	30.104	19.471	1.425	0.124
7/22/1998	1435	51.788	70.0	5	15.315	1.905	0.770	8.998	10.047	1.331	0.078
7/28/1998	1420	52.640	75.0	5	26.064	5.386	1.573	20.159	9.138	1.482	0.105
8/5/1998	1420	51.217	71.0	5	16.765	2.179	0.886	10.493	9.916	1.360	0.098

Variable	Time	Alkalinity	Hardness	TSS	Chl-a	Chl-b	Chl-c	Chl-a_Corr	Pheo_Corr	Chl-a/Pheo	TP-T
Storet Code		410	46570	530	32210	32212	32214	32211	32218	32219	665
Units		mg/L	mg/L	mg/L	mg/m	mg/m	mg/m	mg/m	mg/m	ratio	mg/L
8/10/1998	1410	47.777		1							0.051
8/18/1998	1445	42.985	49.0	12	21.138	2.741	0.832	11.855	14.835	1.311	0.118
8/26/1998	1425	46.203	53.0	5	16.326	1.992	0.581	10.413	9.305	1.370	0.067
8/31/1998	1435	46.948	52.0	6	13.398	0.267	1.046	8.849	6.957	1.392	0.086
9/9/1998	1410	48.044		4							0.086
9/16/1998	1505	49.488	59.0	3	2.093	0.333	-0.722	2.430	-0.673	1.968	0.059
9/22/1998	1425	46.201	49.0	2	13.166	0.100	0.433	8.891	6.472	1.405	0.075
9/30/1998	1415	52.312	54.0	3	17.016	0.140	1.708	11.615	8.178	1.411	0.070
10/7/1998	1500	52.557	58.0	3	13.859	0.946	0.897	8.170	8.950	1.334	0.100
10/13/1998	1415	56.003	61.0	2	12.533	0.000	0.464	6.461	9.537	1.283	0.036
10/19/1998	1455	57.383	61.0	2	13.882	0.238	0.693	0.000	23.192	0.993	0.063
10/26/1998	1520	54.683	62.0	5	17.855	1.506	0.893	12.362	8.440	1.146	0.077
11/3/1998	1425	55.929	64.0	6	30.335	3.220	1.991	22.895	11.214	1.470	0.104
11/11/1998	1435	53.710	67.0	5	18.092	0.936	0.990	10.894	11.254	1.344	0.091
11/17/1998	1510	57.038	71.0	6	24.874	1.265	1.341	18.156	10.066	1.450	0.103
11/24/1998	1425	56.592	63.0	4	19.764	0.399	1.793	12.505	11.201	1.369	0.094
12/2/1998	1510	56.556		8							0.085
12/9/1998	1510	55.963	68.0	4	16.028	0.417	0.436	10.093	9.158	1.367	0.110
12/14/1998	1515	54.815	70.0	8	28.094	1.146	1.498	19.447	13.168	1.417	0.104
Mean	1441	56.065	72.2	6	25.616	2.041	1.230	17.861	11.893	1.407	
Median		56.487	72.0	6	21.138	1.890	1.046	12.505	11.214	1.411	0.097
Maximum	1520	70.719	95.0	12	50.259	5.763	3.679	40.495	23.192	1.968	0.097
Minimum	1350	42.985	49.0	1	2.093	0.000	-0.722	0.000	-0.673	0.993	0.165
# of Obs.	48	47	44	49	29	29	29	29	29	29	0.036
											50

Periphyton Filter Downstream (pm)

Variable	Time	PO_4-T	TKN-T	NH_4-T	NO_X-T	Ag-T	Ca-T	Cd-T	Cu-T	Fe-T	Mg-T	Ni-T	Pb-T	Zn-T
Storet Code		70507	625	610	630	1077	916	1027	1042	1045	927	1067	1051	1092
Units		mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L
1/7/1998	1435	0.009	0.990	0.006	0.268		24.520				2.718			
1/14/1998	1435	0.014	1.090	0.008	0.312		24.780				2.828			
1/22/1998	1415	0.015	1.080	0.043	0.395									
1/29/1998	1435	0.013	1.060	0.013	0.478	0.001	26.320	-0.013	1.120	50.300	3.008	-0.220	2.300	1.257
2/5/1998	1405	0.018	1.050	0.052	0.525									
2/11/1998	1350	0.014	1.080	0.006	0.435									
2/19/1998	1430	0.023	0.681	0.012	0.371		23.650				2.515			
2/25/1998	1435	0.009	0.940	0.012	0.209		24.540	-0.002	1.640	47.900	2.717	0.870	1.290	33.630
3/5/1998	1440	0.016	1.040	0.015	0.115		25.700				3.301			
3/12/1998	1405	0.021	1.060	0.028	0.108		22.010				2.706			
3/19/1998	1410	0.012	0.673	0.032	0.123		25.190				3.151			
3/26/1998	1410	0.014	0.980	0.012	0.007	0.001	23.760	0.261	1.160	40.880	2.981	1.010	0.980	5.020
4/1/1998	1445	0.011	1.060	0.014	0.005		24.300				3.285			
4/8/1998		0.011		0.007	0.002		24.250				3.465			
4/13/1998		0.011	0.880	0.005	0.005		25.440				3.955			
4/22/1998	1510	0.020	1.120	0.016	0.003		24.190				4.041			
4/29/1998	1415	0.022	1.270	0.012	0.003		24.790				4.443			
5/6/1998	1450	0.012	1.220	0.051	0.021	0.001	24.380	0.004	1.220	46.320	4.184	0.600	1.030	9.170
5/12/1998	1430	0.014	1.290	0.036	0.010		24.560				4.420			
5/20/1998	1507	0.054	1.370	0.087	0.061		25.170				4.014			
5/27/1998	1425	0.034	1.080	0.051	0.003	0.001	26.700	0.004	1.060	29.930	4.319	0.200	0.400	3.757
6/3/1998	1450	0.046	1.130	0.032	0.010		28.360				4.156			
6/9/1998	1410	0.022	1.160	0.024	0.006		29.310				4.335			
6/17/1998	1420	0.021	1.160	0.029	0.021		29.600				4.389			
6/23/1998	1445	0.028	1.260	0.015	0.008		29.820				4.467			
7/1/1998	1445	0.028	1.230	0.017	0.014	0.110	29.900	0.007	1.190	26.740	4.560	1.070	1.400	4.350
7/8/1998	1420	0.061	1.410	0.058	0.096		26.530				4.160			
7/14/1998	1430	0.036	1.320	0.020	0.009		26.090				7.160			
7/22/1998	1435	0.031	0.820	0.012	0.004		23.030				2.936			
7/28/1998	1420	0.039	0.930	0.013	0.005	0.001	24.750	-0.006	0.670	56.500	3.093	0.580	0.580	1.859

Variable	Time	PO_4-T	TKN-T	NH_4-T	NO_X-T	Ag-T	Ca-T	Cd-T	Cu-T	Fe-T	Mg-T	Ni-T	Pb-T	Zn-T
Storet Code		70507	625	610	630	1077	916	1027	1042	1045	927	1067	1051	1092
Units		mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L
8/5/1998	1420	0.047	0.870	0.008	0.004		23.940				2.661			
8/10/1998	1410	0.025	0.730	0.004	0.003									
8/18/1998	1445	0.058	0.940	0.013	0.003		16.930				1.706			
8/26/1998	1425	0.040	0.610	0.011	0.004	0.130	18.230	0.006	0.860	19.430	1.786	0.560	0.230	4.827
8/31/1998	1435	0.041	0.710	0.017	0.003		18.260				1.642			
9/9/1998	1410	0.032	0.584	0.010	0.007									
9/16/1998	1505	0.058	0.600	0.009	0.007		20.100				2.078			
9/22/1998	1425	0.036	0.700	0.006	0.021		16.860				1.658			
9/30/1998	1415	0.022	0.600	0.002	0.008	1.390	18.840	-0.013	0.690	26.740	1.719	0.660	0.150	5.660
10/7/1998	1500	0.033	0.670	0.006	0.011		20.390				1.774			
10/13/1998	1415	0.026	0.660	0.000	0.006		21.160				1.900			
10/19/1998	1455	0.018	0.610	0.009	0.012		20.990				2.098			
10/26/1998	1520	0.013	0.830	0.008	0.009	0.001	21.020	0.000	0.770	26.640	2.278	0.090	0.970	3.588
11/3/1998	1425	0.018	0.800	0.005	0.003		21.970				2.316			
11/11/1998	1435	0.019	0.820	0.010	0.009		23.270				2.156			
11/17/1998	1510	0.012	0.950	0.008	0.007		24.270				2.396			
11/24/1998	1425	0.014	0.750	0.012	0.015	0.120	21.470	0.000	0.750	24.670	2.389	0.700	0.500	7.390
12/2/1998	1510	0.019	0.860	0.027	0.026									
12/9/1998	1510	0.011	0.930	0.019	0.010		22.950				2.695			
12/14/1998	1515	0.013	1.050	0.025	0.020		23.450				2.656			
Mean	1441		0.953	0.019	0.076	0.176	23.767	0.023	1.012	36.005	3.119	0.556	0.894	7.319
Median		0.025	0.950	0.013	0.010	0.001	24.260	0.000	1.060	29.930	2.882	0.600	0.970	4.827
Maximum	1520	0.021	1.410	0.087	0.525	1.390	29.900	0.261	1.640	56.500	7.160	1.070	2.300	33.630
Minimum	1350	0.061	0.584	0.000	0.002	0.001	16.860	-0.013	0.670	19.430	1.642	-0.220	0.150	1.257
# of Obs.	48	0.009	49	50	50	10	44	11	11	11	44	11	11	11

Periphyton Filter Downstream (pm)

Variable	Time	Water Temp.	pH-Field	DO	Cond	Depth Coll	Depth Str	Weather	Air Temp	Meter	Gallons	Days	Average
Storet Code		10	400	299	94	98	82903	41	20	Reading	per sample	between	GPM
Units		C°	std units	mg/L	µmhos/cm	m	m	code no.	C°	gallons	period	samples	
1/7/1998	1435	22.5	8.87	11.84	218	0.1	0.2	20	27.0				144
1/14/1998	1435	19.8	8.85	11.66	208	0.1	0.2	20	24.0		1451520	7	144
1/22/1998	1415	20.4	8.56	11.15	236	0.1	0.2	20			1658880	8	144
1/29/1998	1435	18.3	8.43	11.61	251	0.1	0.2	20			1451520	7	144
2/5/1998	1405	20.2	8.13	10.10	240	0.1	0.2	20	18.5		1451520	7	144
2/11/1998	1350	20.0	8.56	11.24	225	0.1	0.2	20	24.5		1244160	6	144
2/19/1998	1430	22.6	8.53	10.46	219	0.1	0.2	20	26.0		1658880	8	144
2/25/1998	1435	24.3	8.27	10.03	216	0.1	0.2	20	24.0		1244160	6	144
3/5/1998	1440	22.3	8.13	10.65	236	0.1	0.2	20	24.5		1658880	8	144
3/12/1998	1405	20.4	8.08	10.27	216	0.1	0.2	20	11.0		1451520	7	144
3/19/1998	1410	20.4	7.59	9.50	233	0.1	0.2	20	21.0		1451520	7	144
3/26/1998	1410	23.1	7.41	8.86	224	0.1	0.2	20	24.5		1451520	7	144
4/1/1998	1445	25.0	7.32	7.65	234	0.1	0.2	20	32.0		1244160	6	144
4/8/1998		27.0	7.58	8.30	243	0.1	0.2	20	28.5		1451520	7	144
4/13/1998		25.4	7.83	6.68	236	0.1	0.2	20	23.5		1036800	5	144
4/22/1998	1510	29.8	7.43	7.38	253	0.1	0.2	20	27.0		1866240	9	144
4/29/1998	1415	28.0	7.82	9.06	258	0.1	0.2	20	29.0		1451520	7	144
5/6/1998	1450	31.5	8.68	11.51	274	0.1	0.2	20	31.0	30015300	1451520	7	144
5/12/1998	1430	32.0	8.26	10.25	282	0.1	0.2	20	31.5	31324700	1309400	6	152
5/20/1998	1507	32.9	8.67	10.50	265	0.1	0.2	20	32.0	33066500	1741800	8	151
5/27/1998	1425	29.9	8.27	9.28	273	0.1	0.2	20	31.0	34523700	1457200	7	145
6/3/1998	1450	36.7	8.86	10.36	266	0.1	0.2	20	35.5	35924800	1401100	7	139
6/9/1998	1410	33.3	8.93	10.81	272	0.1	0.2	20	34.0	37109800	1185000	6	137
6/17/1998	1420	37.3	9.12	11.08	279	0.1	0.2	20	36.0	38732800	1623000	8	141
6/23/1998	1445	37.3	8.85	10.34	280	0.1	0.2	20	37.0	39980600	1247800	6	144
7/1/1998	1445	35.9	8.86	10.75	282	0.1	0.2	20	39.0	41642900	1662300	8	144
7/8/1998	1420	33.4	8.76	9.18	240	0.1	0.2	20	36.0	43087600	1444700	7	143

Variable	Time	Water Temp.	pH-Field	DO	Cond	Depth Coll	Depth Str	Weather	Air Temp	Meter	Gallons	Days	Average
Storet Code		10	400	299	94	98	82903	41	20	Reading	per sample	between	GPM
Units		C°	std units	mg/L	µmhos/cm	m	m	code no.	C°	gallons	period	samples	
7/14/1998	1430	34.6	9.27	12.83	223	0.1	0.2	20	34.0	44357500	1269900	6	147
7/22/1998	1435	33.7	9.06	10.30	198	0.1	0.2	20	37.0	46022000	1664500	8	144
7/28/1998	1420	37.9	9.36	11.06	206	0.1	0.2	20	35.5	47223100	1201100	6	139
8/5/1998	1420	36.3	9.43	11.57	199	0.1	0.2	20	35.0	48828200	1605100	8	139
8/10/1998	1410	34.2	9.22	11.19	171	0.1	0.2	20	34.0	49834300	1006100	5	140
8/18/1998	1445	37.1	9.63	12.73	142	0.1	0.2	20	34.5	51457600	1623300	8	141
8/26/1998	1425	34.9	9.36	13.00	164	0.1	0.2	20	35.0	53115600	1658000	8	144
8/31/1998	1435	36.6	9.49	20.00	148	0.1	0.2	20	34.3	54139800	1024200	5	142
9/9/1998	1410	31.9	9.31	13.21	162	0.1	0.3	20	31.0	55998200	1858400	9	143
9/16/1998	1505	30.7	9.11	10.84	155	0.1	0.2	20	29.0	57456000	1457800	7	145
9/22/1998	1425	30.8	9.67	14.33	152	0.1	0.2	20		58710900	1254900	6	145
9/30/1998	1415	30.4	8.97	10.48	147	0.1	0.2	20	29.9	60331500	1620600	8	141
10/7/1998	1500	32.8	9.36	12.92	162	0.1	0.2	20	30.5	61782300	1450800	7	144
10/13/1998	1415	32.4	9.46	12.88	178	0.1	0.2	20	29.6	62987300	1205000	6	139
10/19/1998	1455	28.8	8.18	10.65	172	0.1	0.2	20	29.8		*1244160*	6	*144*
10/26/1998	1520	25.0	8.71	9.70	176	0.1	0.2	20	26.2	65688100	2700800	7	144
11/3/1998	1425	25.4	8.80	10.82	178	0.1	0.2	20	25.5	67404600	1716500	8	149
11/11/1998	1435	25.0	8.54	10.20	172	0.1	0.2	20	27.9	69207500	1802900	8	157
11/17/1998	1510	25.8	8.40	9.12	179	0.1	0.2	20	28.0	70555800	1348300	6	156
11/24/1998	1425	25.7	8.69	10.55	180	0.1	0.2	20	25.5	72086500	1530700	7	152
12/2/1998	1510	23.6	7.61	8.08	190	0.1	0.2	20	26.2	73850100	1763600	8	153
12/9/1998	1510	24.6	8.37	8.34	196	0.1	0.2	20	25.4	74932200	1082100	7	107
12/14/1998	1515	20.2	8.06	8.71	203	0.1	0.2	20	15.2			5	*144*
Mean	1441	28.6	8.61	10.68	214	0.1	0.2	20	29.1		1475769	7	143.8
Median		29.3	8.69	10.53	217	0.1	0.2	20	29.6			7	144.0
Maximum	1520	37.9	9.67	20.00	282	0.1	0.3	20	39.0			9	156.5
Minimum	1350	18.3	7.32	6.68	142	0.1	0.2	20	11.0			5	107.4
# of Obs.	48	50	50	50	50	50	50	50	47			49	50

August Diurnal
8/10/98–8/11/98
Upstream

Time	Alkalinity	TSS	TP-T	PO_4-T	TKN-T	NH_4-T	NO_x-T	Water Temp	pH-Field	DO	Cond	Depth Coll	Depth Str	Weather	Air Temp
Storet Code	410	530	665	70507	625	610	630	10	400	299	94	98	82903	41	20
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	C°	std units	mg/L	mmhos/cm	m	m	code no.	C°
820	48.3	6	0.141	0.03	0.85	0.146	0.017	29.5	6.33	0.74	170	0.3	1	20	28.5
900	48.021	6	0.165	0.032	0.85	0.152	0.015	29.5	6.39	0.68	170	0.3	1	20	30
1000	48.479	9	0.139	0.032	0.42	0.136	0.017	29.6	6.47	0.73	169	0.3	1	20	33.5
1100	48.743	7	0.114	0.031	0.93	0.136	0.008	29.6	6.48	0.51	170	0.3	1	20	33
1200	48.751	6	0.11	0.033	1.02	0.124	0.015	29.6	6.5	0.5	169	0.3	1	20	33
1300	47.733	6	0.106	0.033	1.01	0.119	0.012	29.7	6.51	0.58	168	0.3	1	20	33
1400	48.278	6	0.106	0.032	0.97	0.117	0.004	29.7	6.51	0.44	169	0.3	1	20	34
1500	48.219	6	0.111	0.032	1.11	0.114	0.009	29.7	6.51	0.46	170	0.3	1	20	35
1600	47.967	6	0.118	0.032	1.04	0.108	0.014	29.8	6.52	0.63	170	0.3	1	20	35
1700	48.146	8	0.114	0.03	1.01	0.107	0.01	29.8	6.51	0.44	168	0.3	1	20	32
1800	47.537	6	0.11	0.03	1.03	0.1	0.016	29.8	6.53	0.73	169	0.3	1	54	
1900	48.142	2	0.118	0.034	0.95	0.101	0.015	29.8	6.52	0.65	168	0.3	1	54	
2000	48.2	8	0.122	0.026	1.1	0.101	0.002					0.3	1	20	
2100	48.458	8	0.131	0.025	1.13	0.098	0.002					0.3	1	20	
2200	47.902	8	0.133	0.024	1.11	0.096	0.001					0.3	1	20	
2300	47.657	8	0.116	0.024	1.09	0.101	0.003					0.3	1	20	
0	47.767	7	0.133	0.024	1.19	0.095	0.003					0.3	1	20	
100	48.234	6	0.12	0.025	1.02	0.094	0.001					0.3	1	20	
200	48.397	7	0.116	0.027	1.11	0.093	0.001					0.3	1	20	
300	48.609	7	0.124	0.025	1.11	0.085	0.002					0.3	1	20	
400	48.548	8	0.136	0.025	1.13	0.085	0.002					0.3	1	20	
500	48.536	8	0.142	0.027	1.2	0.067	0.002					0.3	1	20	
600	48.563	6	0.132	0.026	1.1	0.074	0.001					0.3	1	20	
700	48.647	7	0.143	0.029	1.11	0.053	0.003					0.3	1	20	

August Diurnal
8/10/98–8/11/98
Downstream

Time	Alkalinity	TSS	TP-T	PO_4-T	TKN-T	NH_4-T	NO_x-T	Water Temp	pH-Field	DO	Cond	Depth Coll	Depth Str	Weather	Air Temp	Meter	Gal/hr
Storet Code	410	530	665	70507	625	610	630	10	400	299	94	98	82903	41	20		Approx.
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	C°	std units	mg/L	mmhos/cm	m	m	code no.	C°	Gal	
830	46.533	2	0.103	0.029	0.63	0.004	0.001	29.7	8	9.01	162	0.1	0.2	20	28.5	49785900	
910	46.354	2	0.128	0.028	0.7	0.004	0.001	30.9	8.62	9.52	162	0.1	0.2	20	30	49791600	5700
1010	46.399	3	0.134	0.035	0.65	0.008	0.005	32.5	9.07	10.88	165	0.1	0.2	20	33.5	49800100	8500
1110	46.533	2	0.076	0.032	0.82	0.005	0.003	34.3	9.27	11.65	170	0.1	0.2	20	33	49808700	8600
1210	46.968	2	0.145	0.034	0.88	0.01	0.002	36	9.42	11.05	175	0.1	0.2	20	33	49817200	8500
1310	45.783	1	0.064	0.039	0.78	0.006	0.001	37.1	9.48	12.5	179	0.1	0.2	20	33	49825800	8600
1410	47.777	1	0.051	0.025	0.73	0.004	0.003	34.2	9.22	11.19	171	0.1	0.2	20	34	49834300	8500
1510	47.82	2	0.104	0.031	1.09	0.005	0.002	35.6	9.37	11.75	175	0.1	0.2	20	35	49842900	8600
1610	47.303	4	0.065	0.027	0.79	0.006	0.003	35.8	9.4	11.65	179	0.1	0.2	20	35	49851900	9000
1710	50.926	2	0.016	0.016	0.46	0.004	0.001	31	8.61	9.3	166	0.1	0.2	20	32	49860500	8600
1810	49.789	8	0.045	0.012	0.7	0.003	0.001	29.6	7.38	7.02	170	0.1	0.2	54		49868500	8000
1910	49.054	2	0.049	0.012	0.71	0.002	0.001	28.8	7.09	6.17	170	0.1	0.2	54		49875600	7100
2010	47.831	2	0.062	0.019	0.71	0.006	0.004					0.1	0.2	20			
2110	48.25	2	0.046	0.015	0.69	0.006	0.002					0.1	0.2	20			
2210	48.562	5	0.067	0.016	0.71	0.005	0.001					0.1	0.2	20			
2310	48.741	4	0.076	0.016	0.74	0.006	0.007					0.1	0.2	20			
10	48.622	2	0.07	0.015	0.92	0.004	0.006					0.1	0.2	20			
110	48.641	3	0.062	0.043	0.79	0.006	0.009					0.1	0.2	20			
210	49.102	2	0.042	0.012	0.73	0.007	0.002					0.1	0.2	20			
310	48.815	2	0.056	0.013	0.75	0.006	0.002					0.1	0.2	20			
410	48.594	1	0.052	0.014	0.64	0.006	0.002					0.1	0.2	20			
510	48.442	2	0.069	0.012	0.56	0.006	0.004					0.1	0.2	20			
610	48.413	2	0.047	0.014	0.71	0.005	0.003					0.1	0.2	20			
710	48.353	2	0.055	0.022	0.65	0.004	0.007					0.1	0.2	20			

September Diurnal
9/9/98–9/10/98
Upstream

Time	Alkalinity	TSS	TP-T	PO_4-T	TKN-T	NH_4-T	NO_X-T	Water Temp	pH-Field	DO	Cond	Depth Coll	Depth Str	Weather	Air Temp
Storet Code	410	530	665	70507	625	610	630	10	400	299	94	98	82903	41	20
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	C°	std units	mg/L	mmhos/cm	m	m	code no.	C°
805	46.629	8	0.12	0.037	0.857	0.126	0.027	29.5	6.22	0.73	154	0.3	1	20	25.6
900	47.212	9	0.124	0.038	0.899	0.165	0.023	29.5	6.27	0.62	154	0.3	1	20	27.7
1000	47.432	7	0.114	0.038	0.823	0.162	0.024	29.5	6.32	0.62	154	0.3	1	20	29.6
1100	47.418	8	0.116	0.036	0.883	0.154	0.019	29.5	6.33	0.51	154	0.3	1	20	30.2
1200	47.331	7	0.112	0.032	0.798	0.114	0.025	29.6	6.37	0.66	154	0.3	1	20	31.3
1300	47.295	10	0.127	0.032	0.867	0.103	0.023	29.6	6.37	0.55	154	0.3	1	20	30.6
1400	47.468	7	0.106	0.034	0.775	0.12	0.018	29.6	6.36	0.41	154	0.3	1	20	31
1500	47.551	6	0.099	0.033	0.773	0.117	0.019	29.6	6.36	0.39	155	0.3	1	20	31.5
1600	47.459	8	0.103	0.03	0.76	0.119	0.014	29.6	6.33	0.38	154	0.3	1	20	31
1700	47.553	6	0.115	0.031	0.844	0.097	0.014	29.6	6.36	0.35	154	0.3	1	54	28.7
1800	47.522	8	0.105	0.031	0.801	0.103	0.014	29.6	6.37	0.32	154	0.3	1	20	28.6
1900	47.915	10	0.144	0.043	1.03	0.135	0.01	29.6	6.36	0.25	155	0.3	1	20	27.1
2000	46.861	9	0.128	0.026	1.2	0.092	0.009					0.3	1	20	
2100	47.341	8	0.231	0.027	5.27	0.072	0.005					0.3	1	20	
2200	47.483	8	0.135	0.027	0.922	0.095	0.005					0.3	1	20	
2300	47.142	8	0.122	0.027	0.83	0.093	0.009					0.3	1	20	
0	47.148	8	0.126	0.028	0.871	0.118	0.016					0.3	1	20	
100	47.469	10	0.144	0.026	0.9	0.111	0.022					0.3	1	20	
200	47.621	7	0.113	0.026	0.927	0.106	0.019					0.3	1	20	
300	47.324	10	0.117	0.024	0.888	0.096	0.019					0.3	1	20	
400	47.14	8	0.131	0.023	1.87	0.101	0.018					0.3	1	20	
500	47.486	7	0.105	0.026	0.84	0.109	0.014					0.3	1	20	
600	47.934	6	0.108	0.025	0.873	0.088	0.013					0.3	1	20	
700	47.607	12	0.115	0.028	0.911	0.107	0.013	29.2	6.33	1.04	154	0.3	1	20	

September Diurnal
9/9/98–9/10/98
Downstream

Time	Alkalinity	TSS	TP-T	PO_4-T	TKN-T	NH_4-T	NO_x-T	Water Temp	pH-Field	DO	Cond	Depth Coll	Depth Str	Weather	Air Temp	Meter	Gal/hr
Storet Code	410	530	665	70507	625	610	630	10	400	299	94	98	82903	41	20		approx.
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	C°	std units	mg/L	mmhos/cm	m	m	code no.	C°	Gal	
815	44.97	3	0.078	0.023	0.625	0.012	0.004	29.2	7.87	9.52	149	0.1	0.3	20	25.6	55948500	
910	46.025	3	0.085	0.033	0.739	0.011	0.004	30.1	8.61	11.22	149	0.1	0.3	20	27.7	55954800	6300
1010	46.222	2	0.094	0.036	0.758	0.01	0.006	30.9	9.01	12.38	154	0.1	0.3	20	29.6	55963800	9000
1110	46.723	4	0.092	0.042	0.681	0.017	0.009	31.6	9.1	12.39	157	0.1	0.3	20	30.2	55972300	8500
1210	45.89	3	0.098	0.038	0.632	0.015	0.005	32.4	9.32	13.5	162	0.1	0.3	20	31.3	55981100	8800
1310	47.451	4	0.094	0.036	0.63	0.008	0.003	31.8	9.27	12.97	159	0.1	0.3	20	30.6	55989600	8500
1410	48.044	4	0.086	0.032	0.584	0.01	0.007	31.9	9.31	13.21	162	0.1	0.3	20	31	55998200	8600
1510	48.545	2	0.071	0.028	0.55	0.008	0.006	30.7	8.99	11.58	155	0.1	0.3	20	31.5	56007000	8800
1610	49.005	5	0.063	0.023	0.548	0.003	0.005	29.8	8.24	8.72	154	0.1	0.3	20	31	56017000	10000
1710	47.284	3	0.08	0.022	0.547	0.007	0.005	30	8.53	9.89	151	0.1	0.3	54	28.7	56024400	7400
1810	48.121	2	0.069	0.019	0.57	0.008	0.005	29	7.74	8.14	153	0.1	0.3	20	28.6	56033300	8900
1910	49.107	6	0.066	0.014	0.629	0.006	0.004	28.4	6.83	5.7	156	0.1	0.3	20	27.1	56041600	8300
2010	48.43	3	0.106	0.02	0.977	0.001	0.003					0.1	0.3	20			
2110	48.199	4	0.082	0.015	0.74	0.001	0.004					0.1	0.3	20			
2210	47.774	2	0.074	0.015	0.633	0.001	0.001					0.1	0.3	20			
2310	47.492	3	0.068	0.016	0.55	0.001	0.001					0.1	0.3	20			
10	47.973	3	0.074	0.016	0.61	0.001	0.001					0.1	0.3	20			
110	47.426	2	0.069	0.016	0.57	0.001	0.005					0.1	0.3	20			
210	47.731	3	0.076	0.018	0.619	0.001	0.005					0.1	0.3	20			
310	47.371	4	0.06	0.016	0.576	0.001	0.004					0.1	0.3	20			
410	47.273	3	0.062	0.016	0.56	0.001	0.01					0.1	0.3	20			
510	47.466	2	0.07	0.017	0.606	0.001	0.006					0.1	0.3	20			
610	47.423	2	0.061	0.018	0.596	0.001	0.004					0.1	0.3	20			
710	47.567	5	0.09	0.023	0.638	0.001	0.005	27.6	6.56	3.73	155	0.1	0.3	20			

December Diurnal
12/2/98–12/3/98
Upstream

Time	Alkalinity	TSS	TP-T	PO_4-T	TKN-T	NH_4-T	NO_x-T	Water Temp	pH-Field	DO	Cond	Depth Coll	Depth Str	Weather	Air Temp
Storet Code	410	530	665	70507	625	610	630	10	400	299	94	98	82903	41	20
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	C°	std units	mg/L	mmhos/cm	m	m	code no.	C°
810	55.205	10	0.107	0.02	1.12	0.057	0.019	22.2	6.79	4.74	189	0.3	1	20	20.7
900	55.585	12	0.118	0.016	1.08	0.056	0.022	22.2	6.86	4.6	189	0.3	1	20	23.7
1000	55.396	12	0.129	0.016	1.18	0.055	0.022	22.2	6.87	4.65	189	0.3	1	20	23.9
1100	55.376	10	0.116	0.01	1.12	0.053	0.017	22.2	6.89	4.69	189	0.3	1	20	26.4
1200	55.635	10	0.111	0.01	1.12	0.049	0.017	22.2	6.9	4.99	188	0.3	1	20	26.2
1300	56.145	12	0.116	0.009	1.12	0.048	0.019	22.3	6.9	5.15	188	0.3	1	20	27.9
1400	55.834	10	0.111	0.009	1.17	0.05	0.016	22.3	6.9	4.88	188	0.3	1	20	26.9
1500	52.99	12	0.129	0.009	1.02	0.048	0.018	22.3	6.89	4.71	188	0.3	1	20	26.2
1600	53.365	14	0.126	0.012	1.29	0.047	0.019	22.4	6.92	4.91	188	0.3	1	20	25.4
1700	53.147	5	0.114	0.014	1.13	0.046	0.017	22.3	6.86	4.55	189	0.3	1	20	24
1800	53.395	11	0.129	0.013	1.28	0.052	0.017	22.3	6.91	4.46	189	0.3	1	20	23.4
1900	53.184	11	0.129	0.014	1.25	0.046	0.016	22.3	6.9	4.41	189	0.3	1	20	22.9
2000	53.285	12	0.128	0.011	1.28	0.049	0.011					0.3	1	20	
2100	53.441	12	0.132	0.009	1.27	0.049	0.014					0.3	1	20	
2200	53.38	13	0.135	0.011	1.28	0.052	0.012					0.3	1	20	
2300	53.204	13	0.133	0.01	1.4	0.053	0.01					0.3	1	20	
0	52.39	10	0.122	0.012	1.25	0.05	0.01					0.3	1	20	
100	53.228	12	0.118	0.013	1.3	0.051	0.009					0.3	1	20	
200	53.477	17	0.147	0.012	1.28	0.055	0.011					0.3	1	20	
300	53.569	15	0.153	0.012	1.23	0.055	0.01					0.3	1	20	
400	53.886	9	0.122	0.013	1.19	0.059	0.017					0.3	1	20	
500	52.579	14	0.137	0.015	1.37	0.062	0.016					0.3	1	20	
600	53.453	15	0.134	0.016	1.36	0.063	0.037					0.3	1	20	
700	53.425	10	0.124	0.013	1.33	0.066	0.048					0.3	1	20	

December Diurnal
12/2/98–12/3/98
Downstream

Time	Alkalinity	TSS	TP-T	PO_4-T	TKN-T	NH_4-T	NO_x-T	Water Temp	pH-Field	DO	Cond	Depth Coll	Depth Str	Weather	Air Temp	Meter	Gal/Hr
Storet Code	410	530	665	70507	625	610	630	10	400	299	94	98	82903	41	20		Approx
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	C°	std units	mg/L	mmhos/cm	m	m	code no.	C°	Gal	
820	54.421	3	0.077	0.011	0.83	0.017	0.025	22	7.3	8.06	187	0.1	0.2	20	20.7	73796300	
910	54.266	3	0.078	0.017	0.8	0.018	0.022	23.3	7.51	8.5	187	0.1	0.2	20	23.7	73804200	7900
1010	54.216	2	0.089	0.024	0.94	0.021	0.019	24.7	7.96	9.22	187	0.1	0.2	20	23.9	73813500	9300
1110	55.591	3	0.094	0.033	0.99	0.025	0.014	25.6	8.23	9.58	185	0.1	0.2	20	26.4	73822700	9200
1210	54.613	4	0.089	0.027	0.89	0.021	0.016	26	8.23	10.15	186	0.1	0.2	20	26.2	73831700	9000
1310	57.152	2	0.085	0.027	0.93	0.025	0.021	24.6	7.87	8.69	189	0.1	0.2	20	27.9	73840900	9200
1410	56.902	4	0.09	0.024	0.93	0.027	0.023	24.7	8.05	8.58	189	0.1	0.2	20	26.9	73850100	9200
1510	56.556	8	0.085	0.019	0.86	0.027	0.026	23.6	7.61	8.08	190	0.1	0.2	20	26.2	73859400	9300
1610	55.392	3	0.074	0.015	0.94	0.025	0.024	22.3	7.35	7.26	189	0.1	0.2	20	25.4	*73867500*	8100
1710	55.695	3	0.069	0.013	0.84	0.026	0.024	22.2	7.17	6.27	190	0.1	0.2	20	24	73877500	10000
1810	54.423	2	0.073	0.016	0.88	0.039	0.027	21.8	7.07	5.8	190	0.1	0.2	20	23.4	73886300	8800
1910	54.165	3	0.072	0.015	0.99	0.04	0.029	22	7.07	5.8	189	0.1	0.2	20	22.9	73895800	9500
2010	50.78	4	0.099	0.014	1.16	0.059	0.028					0.1	0.2	20			
2110	52.26	5	0.098	0.014	1.06	0.06	0.033					0.1	0.2	20			
2210	52.824	4	0.093	0.014	1.13	0.059	0.03					0.1	0.2	20			
2310	51.661	5	0.087	0.015	1.05	0.059	0.029					0.1	0.2	20			
10	53.176	4	0.086	0.015	1.06	0.058	0.028					0.1	0.2	20			
110	53.031	5	0.082	0.016	1.01	0.06	0.029					0.1	0.2	20			
210	51.948	5	0.091	0.016	0.91	0.062	0.024					0.1	0.2	20			
310	51.692	5	0.086	0.015	0.96	0.06	0.031					0.1	0.2	20			
410	49.426	4	0.088	0.016	1.1	0.065	0.033					0.1	0.2	20			
510	50.796	6	0.088	0.017	1.09	0.073	0.035					0.1	0.2	20			
610	53.319	5	0.089	0.016	1.09	0.088	0.037					0.1	0.2	20			
710	51.357	4	0.083	0.015	1.14	0.077	0.041					0.1	0.2	20			

Appendix C—City of Orlando, Monitoring Data for Lake Wade

Appendix C

Wade	ALK. mg/l	pH	Cond uS/cm	DO(S) mg/l	DO(B) mg/l	% Sat S	% Sat B	Temp C	Temp Bottom	T.P. mg/l	O.P mg/l	T.N. mg/l	NH3 mg/l	NO3 mg/l	NO2 mg/l	TKN mg/l	TSS mg/l	VSS mg/l	TDS mg/l	F.C. 100ml	S.D. m	Chl-a mg/m3	TN/TP	TSI (Chl a)	TSI (S.D.)	TSI (T.P.)	TSI (T.N.)	TSI (FL.)	Trophic State	Limiting Nutrient
8/3/1988	46	7.70								0.170	0.008	1.34	0.155	0.05	0.005	1.34	23.0	21.0	96	590	0.71	58.2	8	75	70	0	66	70	Eutrophic	Nitrogen
4/17/1990	31	7.90								0.093	0.014	1.13	0.02	0.02	0.02	1.13	3.0	0.5	79	185	0.71	25	12	63	70	66	58	65	Eutrophic	Balanced
8/28/1990	41	7.09								0.060	0.005	1.14	0.02	0.02	0.02	1.14	8.0	8.0	96	1200	0.75	40	19	70	69	58	59	66	Eutrophic	Balanced
3/21/1991	33	7.50								0.120	0.026	1.11	0.03	0.04	0.02	1.07	6.0	5.0	80	180	0.70	7.7	9	46	71	0	62	60	Mesoeutrophic	Nitrogen
10/8/1991	40	7.45								0.130	0.007	1.05	0.03	0.02	0.02	1.03	7.0	7.0	73	118	1.05	39.0	8	70	59	0	61	63	Eutrophic	Nitrogen
2/18/1992	22	7.23								0.140	0.005	1.51	0.03	0.02	0.02	1.49	2.0	2.0	99	5	0.71	19.0	11	59	70	74	64	66	Eutrophic	Balanced
6/18/1992	31	6.94								0.130	0.005	1.10	0.03	0.02	0.02	1.10	13.0	13.0	87	40	0.85	15.0	8	56	65	0	62	61	Mesoeutrophic	Nitrogen
9/22/1992	47	6.60								0.109	0.012	1.11	0.09	0.11	0.02	1.00	13.0	10.0	93	94	0.72	43.0	10	71	70	69	58	68	Eutrophic	Balanced
12/21/1992	47	7.45								0.126	0.005	1.71	0.07	0.41	0.02	1.30	5.0	2.0	133	20	1.20	28.0	14	65	55	72	67	63	Eutrophic	Balanced
3/3/1993	48	7.20								0.102	0.016	0.94	0.03	0.02	0.02	0.94	6.0	6.0	120	94	1.25	10.0	9	50	53	0	58	54	Mesoeutrophic	Nitrogen
7/1/1993	32	6.80	157.0	2.93	2.14			28.40		0.116	0.016	1.00	0.03	0.02	0.02	1.00	5.0	4.0	100	773	1.05	38.0	9	69	59	0	60	62	Eutrophic	Nitrogen
9/28/1993	35	6.87	142.0	4.3	3.62			29.0		0.097	0.007	0.93	0.03	0.02	0.02	0.93	6.0	6.0	96	580	1.15	35.0	10	68	56	0	58	61	Mesoeutrophic	Nitrogen
12/29/1993	35	6.83	166.0	10.0				18.6		0.103	0.005	1.31	0.03	0.14	0.011	1.16	4.0	2.5	92	210	0.70	20.0	13	60	71	68	61	65	Eutrophic	Balanced
3/22/1994	39	7.31	203.0	8.09	0.08			23.89		0.154	0.009	1.16	0.03	0.02	0.005	1.16	4.0	4.0	92	74	1.13	35.0	8	68	56	0	63	62	Eutrophic	Nitrogen
6/22/1994	21	7.13	96.0	5.53	0.07			29.76		0.110	0.012	0.82	0.03	0.02	0.005	0.82	9.0	9.0	60	76	1.07	27.0	7	64	58	0	55	59	Mesoeutrophic	Nitrogen
10/5/1994	49	6.69	173.0	4.75	0.07			26.29		0.111	0.007	1.15	0.08	0.10	0.006	1.04	7.0	7.0	62		1.00	45.0	10	72	60	69	59	65	Eutrophic	Balanced
12/13/1994	50	7.22	201.0	6.35	5.70			20.54		0.113	0.005	1.54	0.03	0.17	0.009	1.36	15.0	12.0	118	300	0.87	49.0	14	73	64	70	65	68	Eutrophic	Balanced
2/20/1995										0.069		1.43									1.12	23	21	62	57	60	63	60	Mesoeutrophic	Balanced
3/7/1995										0.058		1.29									1.47	55	22	74	48	57	61	61	Mesoeutrophic	Balanced
3/14/1995	48	7.64	243.0	7.18	6.34			19.84		0.076	0.005	1.33	0.03	0.4	0.018	0.91	4	4	144	4	1.14	16	18	57	56	62	62	58	Mesoeutrophic	Balanced
4/17/1995										0.108		1.13									1.12	110	10	84	57	69	58	68	Eutrophic	Balanced
5/19/1995										0.166		1.97									0.76	71	12	78	68	77	69	73	Hypereutrophic	Balanced
6/28/1995	34	8.03	125	8.38	0.25			28.15		0.139	0.022	1.03	0.14	0.02	0.005	1.03	8	8	85	300	0.95	76	7	79	62	0	60	67	Eutrophic	Nitrogen
9/14/1995	50	6.74	205	7.27	0.31			29.45		0.128	0.013	1.61	0.07	0.13	0.009	1.47	9	5	122	145	0.88	85	13	81	64	72	65	71	Hypereutrophic	Balanced
9/18/1995										0.120		1.38									1.02	98	11	83	60	71	62	70	Eutrophic	Balanced
10/30/1995										0.104		1.13									0.86	70	11	78	64	68	58	69	Eutrophic	Balanced
11/27/1995										0.088		1.22									0.86	45	14	72	64	65	60	66	Eutrophic	Balanced
12/13/1995	52	7.53	224	5.71	5.11			16.86		0.123	0.005	1.84	0.31	0.22	0.013	1.61	9.5	6.5	127	70	0.77	16	15	57	68	71	68	65	Eutrophic	Balanced
12/15/1995										0.088		1.39									1.22	48	16	73	54	65	62	63	Eutrophic	Balanced
1/24/1996										0.080		1.57									1.52	67.5	20	77	47	63	65	63	Eutrophic	Balanced
2/28/1996										0.067		1.20									1.32	22.7	18	62	52	60	60	58	Mesoeutrophic	Balanced
3/28/1996	47	7.26	187	10.14	0.49			22.3		0.186	0.008	1.57	0.03	0.13	0.011	1.43	12	9	118	2	0.79	52	8	74	67	0	69	70	Eutrophic	Nitrogen
4/29/1996										0.127		1.23									1.25	67.3	10	77	53	0	64	65	Eutrophic	Nitrogen
5/17/1996										0.131		1.32									0.73	77.7	10	79	69	72	62	72	Hypereutrophic	Balanced
6/24/1996	40	7.73	188	5.4				29.57		0.177	0.01	1.6	0.3	0.04	0.006	1.55	66	42	94	1400		32	9	67	####	0	70	69	Eutrophic	Nitrogen
8/30/1996										0.194		1.87									0.69	142.0	10	88	71	0	73	77	Hypereutrophic	Nitrogen
9/5/1996	46	7.71	192	5.35	5.46			29.65		0.166	0.005	1.8	0.06	0.02	0.005	1.8	14	12	121	700	0.79	80	11	80	67	77	68	73	Hypereutrophic	Balanced
9/27/1996										0.131		1.42									0.51	125.0	11	86	80	72	63	78	Hypereutrophic	Balanced
10/28/1996										0.097		1.01									0.76	59.7	10	76	68	67	56	68	Eutrophic	Balanced
12/18/1996	44	8.13	173	10.86				20.16		0.081	0.005	1.01	0.03	0.17	0.005	0.84	7	2	128	84		16	12	57	####	63	56	58	Mesoeutrophic	Balanced
2/2/1997										0.117		0.98									0.64	41.00	8	70	73	0	59	68	Eutrophic	Nitrogen
3/26/1997	51	7.76	237	2.95				26.44		0.136	0.011	1.24	0.03	0.02	0.005	1.24	20	17	138	330		7.7	9	46	####	0	64	55	Mesoeutrophic	Nitrogen
3/27/1997										0.132		1.02									0.91	37.00	8	69	63	0	60	64	Eutrophic	Nitrogen
4/21/1997										0.096		1.06									1.12	16.00	11	57	57	67	57	58	Mesoeutrophic	Balanced
5/9/1997										0.101		1.05									0.71	46.33	10	72	70	67	57	68	Eutrophic	Balanced
6/12/1997	53	7.59	136.9	5.39	0.1			27.3		0.123	0.005	1.44	0.09	0.02	0.005	1.44	23	1	104	114	0.79	31.2	12	66	67	71	63	67	Eutrophic	Balanced
8/29/1997										0.084		1.02									0.89		12	####	63	64	56	62	Eutrophic	Balanced
9/25/1997	63	6.94	165	4.5				29.01		0.106	0.005	0.81	0.03	0.02	0.005	0.81	10	9	120	1000		12.8	8	54	####	0	55	55	Mesoeutrophic	Nitrogen
9/30/1997										0.106		1.06									0.82	68.00	10	78	66	68	57	69	Eutrophic	Balanced
10/28/1997	55	7.36	180	4.71	4.68			23.54		0.184	0.025	1.24	0.03	0.03	0.005	1.2	14	8	120	1200		27.6	7	65	####	0	64	65	Eutrophic	Nitrogen
11/18/1997	54.3	7.51	156	5.45				18.96		0.123	0.008	1.22	0.02	0.01	0.005	1.22	17	11	104	568	0.69	29.4	10	65	71	0	64	67	Eutrophic	Nitrogen

Wade	ALK. mg/l	pH	Cond uS/cm	DO(S) mg/l	DO(B) mg/l	% Sat S	% Sat B	Temp C	Temp Bottom	T.P. mg/l	O.P mg/l	T.N. mg/l	NH3 mg/l	NO3 mg/l	NO2 mg/l	TKN mg/l	TSS mg/l	VSS mg/l	TDS mg/l	F.C. 100ml	S.D. m	Chl-a mg/m3	TN/TP	TSI (Chl a)	TSI (S.D.)	TSI (T.P.)	TSI (T.N.)	TSI (FL.)	Trophic State	Limiting Nutrient
12/22/1997	55.8	7.08	183	9.1	5.19			18.17		0.101	0.025	1.85	0.09	0.36	0.02	1.47	4	4	76	54	1.13	12	18	53	56	67	68	59	Mesoeutrophic	Balanced
1/29/1998	67	6.78	249	7.89	7.28	79.6	73	15.72	15.49	0.113	0.005	1.48	0.06	0.44	0.031	1.01	7.6	6.6	142	66	0.81	42.2	13	71	66	70	64	68	Eutrophic	Balanced
2/26/1998	61	7.22	194	9.32	0.16	101.7	1.7	19.6	18.46	0.097	0.005	0.53	0.03	0.2	0.021	0.31	7.2	7.2	130	50	0.89	20.2	5	60	63	0	46	57	Mesoeutrophic	Nitrogen
3/10/1998	60	6.78	190	5.19	0.25	57	2.7	19.94	19.46	0.167	0.005	0.64	0.28	0.07	0.005	0.71	9.6	9.6	88	370	0.63	34.4	4	68	74	0	50	64	Eutrophic	Nitrogen
4/30/1998	58	6.82	236	6.05	1.52	73.3	18.3	25.07	24.64	0.086	0.005	1.29	0.03	0.02	0.005	1.29	7	7	156	42	0.97	29.9	15	66	61	64	61	63	Eutrophic	Balanced
6/2/1998	62	6.76	237	5.67	0.09	74.4	1.2	29.53	28.83	0.134	0.005	1.37	0.03	0.02	0.005	1.37	8	8	126	120	0.77	28	10	65	68	73	62	67	Eutrophic	Balanced
6/23/1998	65	7.25	247	6.55	4.88	89.3	66.1	31.66	31.4	0.122	0.006	1.5	0.03	0.02	0.005	1.5	12	12	162	290	0.7	36.5	12	69	71	71	64	69	Eutrophic	Balanced
7/28/1998	56	7.37		0.8		11.6		33.5		0.074	0.008	0.64	0.05	0.02	0.005	0.64	4	4	102	2300		19.1	9	59	####	0	50	55	Mesoeutrophic	Nitrogen
8/20/1998	24	6.82		5.35		70.7		32		0.104	0.014	0.44	0.03	0.02	0.005	0.44	3	3	102	900	1.05	29.5	4	66	59	0	42	55	Mesoeutrophic	Nitrogen
9/15/1998	47	6.85	137.1	5.32	3.05	68.7	38.9	28.55	27.8	0.095	0.005	0.47	0.03	0.02	0.005	0.47	3	3	102	2300	0.89		5	####	63	0	43	53	Mesoeutrophic	Nitrogen
10/19/1998	56	7.35	155	6.51	3.69	82.3	46.3	27.37	26.91	0.095	0.005	0.79	0.03	0.02	0.005	0.79	4	4	88	400	0.84	37.3	8	69	65	0	55	63	Eutrophic	Nitrogen
11/17/1998	55	7.25	161	7.64	3.26	91.7	38.3	24.53	23.4	0.093	0.005	0.71	0.03	0.02	0.005	0.71	4	4	114	21	0.72	11.9	8	52	70	0	52	58	Mesoeutrophic	Nitrogen
12/3/1998	55	7.59	174	7.71	5.48	89.4	63	22.67	22.29	0.094	0.005	0.97	0.03	0.02	0.005	0.97	4	4	100	94	0.8	26.2	10	64	67	66	55	64	Eutrophic	Balanced

APPENDIX D—CALCULATED TREATMENT EFFICIENCIES FOR THE PERIPHYTON FILTER

Appendix D

Variable	Alkalinity	Hardness	TSS	Chl-a	Chl-b	Chl-c	Chl-a_Corr	Pheo_Corr	Chl-a/Pheo	TP-T	PO4-T	TKN-T	NH4-T	NOX-T	Ag-T	Ca-T	Cd-T	Cu-T	Fe-T	Mg-T	Ni-T	Pb-T	Zn-T	Water Temp	pH-Field	DO	Cond
Storet Code	410	46570	530	32210	32212	32214	32211	32218	32219	665	70507	625	610	630	1077	916	1027	1042	1045	927	1067	1051	1092	10	400	299	94
1/7/1998	-0.67	1.37	0.00							-2.53	10.00	-11.24	71.43	13.55		0.45				-1.87				-13.64	-14.01	4.90	0.91
1/14/1998	-0.71	-2.78	0.00							-57.14	68.18	-32.93	52.94	10.09		-2.19				1.63				-5.88	-17.53	-17.66	8.77
1/22/1998			0.00							5.95	-15.38	-2.86	56.12	8.78										-15.25	-24.06	-48.27	2.07
1/29/1998	0.60	-1.30	22.22							0.00	0.00	4.50	51.85	2.45	50.00	-1.58	262.50	6.67	8.38	0.46	200.00	18.73	63.59	-12.27	-14.23	-16.57	0.79
2/5/1998			9.09							16.79	-5.88	-0.96	38.82	0.19										-28.66	-16.48	-32.89	0.83
2/11/1998			-11.11							-26.77	17.65	11.48	-20.00	8.42										-28.21	-9.32	4.18	9.27
2/19/1998	-0.13	0.00	-50.00							-10.13	-35.29	-9.49	50.00	12.50		-0.98				0.36				-14.72	-12.83	-11.99	1.35
2/25/1998	-0.05	0.00	0.00							-0.93	0.00	1.05	33.33	17.06		0.04	300.00	-8.61	9.45	-1.53	-248.00	-5.74	-385.98	-26.56	-15.99	-5.36	1.37
3/5/1998	-0.08	-1.30								4.17	5.88	-5.05	31.82	16.06		-0.90				-0.70				-23.20	-16.98	-4.21	-0.85
3/12/1998	-0.27	0.00	16.67							0.00	-23.53	0.00	59.42	17.56		-0.14				1.74				-17.92	-12.07	-53.28	0.00
3/19/1998	0.79	1.30	11.11							20.51	7.69	1.46	52.94	23.60		0.83				1.93				-5.70	-13.11	-192.31	0.43
3/26/1998	-0.58	0.00	12.50							6.38	-7.69	13.27	58.62	69.57	0.00	0.17	-14.98	-9.43	13.59	2.17	-18.82	29.50	32.44	-17.26	-12.44	-111.46	-0.90
4/1/1998	-1.53	-1.37	10.00							-2.20	0.00	3.64	6.67	16.67		-0.83				-2.43				-6.38	-10.74	-527.05	0.00
4/8/1998	-1.53	0.00	0.00							10.47	0.00		56.25	91.67		-0.08				-1.14				-13.45	-14.67	-184.25	-0.41
4/13/1998	0.50	1.23	16.67							-20.00	-10.00	12.87	37.50	16.67		1.09				0.78				-16.51	-12.66	-0.75	4.84
4/22/1998	-28.44	-1.32	12.50							-1.89	4.76	8.20	0.00	99.17		-1.85				-0.80				-19.20	-11.06	-90.21	-1.61
4/29/1998	-0.23	0.00	50.00							9.48	-15.79	3.79	58.62	62.50		0.04				1.09				-12.90	-18.66	-269.80	0.77
5/6/1998	1.96	1.27	25.00							45.00	-20.00	46.96	54.05	44.74	0.00	0.65	60.00	26.51	19.02	3.08	10.45	-3.00	-52.58	-26.51	-31.71	-314.03	-0.37
5/12/1998	0.47	0.00	9.09	11.07	-11.17	6.32	8.66	19.11	-1.22	8.28	6.67	1.53	54.43	58.33		-0.04				0.58				-15.52	-23.84	-227.48	-1.08
5/20/1998	0.68	1.25	0.00	-6.11	-6.90	-6.30	-11.95	11.98	-2.55	-1.85	3.57	-3.79	49.42	35.79		1.06				1.33				-20.51	-30.77	-1300.00	0.75
5/27/1998	1.30	-1.19	25.00	19.24	17.86	40.25	3.60	36.68	-5.72	25.87	0.00	6.90	32.00	-50.00	0.00	-1.02	50.00	13.82	21.77	0.48	-150.00	44.44	50.24	-0.67	-25.30	-1350.00	0.73
6/3/1998	-0.07	0.00	28.57	30.07	-35.38	11.18	20.74	44.99	-4.74	2.38	8.00	11.72	70.37	33.33		0.53				0.34				-21.12	-32.44	-482.02	1.85
6/9/1998	-1.45	1.09	42.86	-5.23	-97.64	4.25	-19.72	20.12	-5.15	32.93	12.00	-0.87	77.78	72.73		0.64				2.08				-12.12	-34.69	-465.97	1.45
6/17/1998	1.53	1.08	50.00	24.35	-22.43	41.80	14.84	48.99	-5.61	59.76	0.00	-13.73	78.68	52.27										-18.04	-37.35	-410.60	0.36
6/23/1998	1.39	2.11	42.86	24.70	30.43	47.92	12.50	59.43	-7.72	37.50	6.67	17.65	84.38	70.37		2.39				2.21				-16.56	-32.09	-923.76	2.44
7/1/1998	6.21	1.06	41.18	22.56	0.05	10.91	15.45	43.03	-4.23	33.57	-27.27	25.90	68.52	68.89	38.89	0.63	12.50	36.70	60.91	-0.48	-118.37	48.34	5.58	-13.61	-28.97	-189.76	2.08
7/8/1998	-0.21	0.00	35.71	10.98	-188.74	-21.00	-0.75	32.03	-4.89	12.05	-27.08	11.32	63.75	-6.67		0.00				-1.00				-12.08	-30.94	-846.39	2.44
7/14/1998	2.81	-14.46	53.85	14.56	8.60	74.85	15.54	11.93	0.49	16.78	-24.14	8.97	77.01	40.00		17.28				-562.96				-15.33	-39.61	-3276.32	1.76
7/22/1998	-1.76	-1.45	0.00	49.05	4.03	58.08	55.95	32.14	5.33	36.59	-19.23	26.79	87.63	76.47		-1.01				-0.65				-11.59	-36.86	-1097.67	1.00
7/28/1998	2.41	-1.35	44.44	15.40	-47.76	42.47	-0.67	46.04	-7.47	7.89	-44.44	15.45	88.98	58.33	0.00	-1.02	133.33	27.96	33.92	-1.48	44.76	72.64	34.15	-19.18	-42.47	-1628.13	-0.98
8/5/1998	3.24	1.39	0.00	36.97	6.56	53.59	34.72	40.19	-1.12	10.09	-38.24	14.71	93.70	63.64		1.76				3.59				-20.60	-43.31	-515.43	-2.58
8/10/1998	1.04		83.33							51.89	21.88	24.74	96.58	25.00										-15.15	-41.63	-2443.18	-1.18
8/18/1998	2.59	5.77	20.00	43.39	34.58	83.18	56.64	3.10	9.52	29.34	-3.57	12.96	76.36	40.00		4.30				10.02				-21.64	-49.77	-6972.22	-1.43
8/26/1998	-0.15	3.64	44.44	26.70	-35.97	69.06	28.18	22.84	0.87	-21.82	-25.00	-29.79	86.25	88.57	-44.44	2.88	72.73	26.50	65.05	6.20	-229.41	81.89	69.56	-16.72	-44.22	-835.25	-6.49
8/31/1998	1.45	3.70	0.00	34.26	77.60	29.99	23.94	49.53	-5.45	40.28	19.61	21.98	85.83	86.36		2.35				5.58				-18.83	-49.92	-4155.32	1.99
9/9/1998	-1.21		42.86							18.87	5.88	24.65	91.67	61.11										-7.77	-46.38	-3121.95	-5.19
9/16/1998	-4.67	-3.51	57.14	91.44	83.43	126.39	84.00	104.63	-44.92	26.25	-41.46	15.49	92.50	75.86		-2.92				-1.42				-9.64	-38.45	-1131.82	-0.65
9/22/1998	0.09	3.92	50.00	34.23	90.93	66.30	31.10	41.26	-1.96	29.91	14.29	28.57	96.36	8.70		3.10				5.37				-12.00	-47.86	-2370.69	-5.56
9/30/1998	-0.85	1.82	75.00	49.88	88.59	40.47	46.66	56.51	-2.54	30.00	15.38	28.57	97.10	75.00	-178.56	0.84	159.09	31.00	59.85	2.94	-73.68	94.85	27.62	-6.67	-34.68	-399.05	0.68
10/7/1998	-2.70	1.69	62.50	47.84	-11.56	54.14	43.86	52.71	-2.30	20.63	2.94	25.56	95.00	-175.00		-0.15				5.54				-13.49	-43.56	-1645.95	-4.52
10/13/1998	-4.64	3.17	77.78	48.22	100.00	65.91	48.07	48.58	-0.16	67.86	21.21	31.25	100.00	40.00		3.29				5.24				-12.50	-40.77	-2120.69	0.00
10/19/1998	-3.69	0.00	80.00	47.18	82.20	55.12	100.00	-40.78	26.01	50.39	18.18	14.08	89.89	63.64		-0.19				0.05				-6.67	-22.27	-537.72	1.15
10/26/1998	-0.83	0.00	58.33	35.60	43.47	51.01	26.28	51.17	14.80	31.25	18.75	11.70	84.31	62.50	0.00	-0.10		31.86	55.53	-2.94		63.81	61.63	-7.30	-29.04	-81.99	0.56
11/3/1998	-0.68	0.00	70.00	10.34	-136.76	32.42	-23.38	53.47	-12.73	32.47	10.00	30.43	91.23	86.96		-0.87				0.47				-4.53	-32.53	-331.08	1.66
11/11/1998	-0.32	0.00	58.33	38.15	47.39	55.88	35.24	42.54	-1.59	30.53	5.00	33.33	79.17	59.09		0.13				3.45				-16.82	-28.23	-296.89	1.71
11/17/1998	-0.30	-1.43	53.85	25.34	43.12	55.15	16.25	44.25	-4.92	29.93	20.00	18.80	85.19	58.82		-1.25				-2.35				-9.32	-25.56	-164.35	0.56
11/24/1998	-1.29	1.56	66.67	24.74	63.49	30.91	17.59	35.66	-3.24	28.79	22.22	26.47	87.88	46.43	-140.00	0.46		39.02	66.34	-0.17	51.39	80.69	-19.77	-6.64	-27.98	-266.32	2.70
12/2/1998	-6.73		33.33							34.11	-111.11	15.69	43.75	-44.44										-5.83	-10.45	-71.55	-1.06
12/9/1998	-3.17	-6.25	66.67	26.75	75.04	76.76	26.31	28.48	-0.37	22.54	15.38	19.13	70.77	44.44		-6.45				-6.10				-3.36	-20.61	-58.25	-1.03
12/14/1998	-1.88	-4.48	46.67	9.68	58.94	11.73	0.46	27.35	-3.96	27.78	7.14	0.00	57.63	0.00		-3.12				-2.75				6.48	-14.16	-46.39	-2.53

Variable	Alkalinity	Hardness	TSS	Chl-a	Chl-b	Chl-c	Chl-a_Corr	Pheo_Corr	Chl-a/Pheo	TP-T	PO4-T	TKN-T	NH4-T	NOX-T	Ag-T	Ca-T	Cd-T	Cu-T	Fe-T	Mg-T	Ni-T	Pb-T	Zn-T	Water Temp	pH-Field	DO	Cond
Storet Code	410	46570	530	32210	32212	32214	32211	32218	32219	665	70507	625	610	630	1077	916	1027	1042	1045	927	1067	1051	1092	10	400	299	94
Mean Eff.	-0.89	-0.09	31.53	29.01	12.48	43.75	24.49	36.83	-2.67	17.20	-2.52	10.63	65.69	36.16	-27.41	0.42	115.02	20.18	37.62	-12.14	-53.17	47.83	-10.32	-13.79	-27.31	-832.70	0.38
Eff(Jan-May)	-1.55	-0.16	7.94	8.07	-0.07	13.42	0.10	22.59	-3.16	1.40	-0.44	2.47	42.20	27.40	12.50	-0.29	131.50	5.79	14.44	0.40	-41.28	16.79	-58.46	-16.24	-17.07	-226.12	1.32
Eff(Jun-Dec)	-0.48	-0.04	47.81	31.43	13.93	47.25	27.30	38.47	-2.62	28.64	-4.03	16.26	82.70	42.50	-54.02	0.94	94.41	32.17	56.93	-21.17	-65.06	73.70	29.79	-12.02	-34.72	-1271.95	-0.30