Phase VI Lake Management Protection Grant Report
English Lake
Manitowoc County, Wisconsin

Wisconsin Dept. of Natural Resources Project Number LPT-79
NES Ecological Services Job Number 13750001

Prepared for

English Lake Protection & Rehabilitation District

July 1, 2001

NES Ecological Services
A Division of Robert E. Lee & Associates, Inc.

Funding Sources

Funding for this project was provided by multiple sources.

- The wetland detention basin final designs and its construction were funded by the English Lake Protection & Rehabilitation District, the Wisconsin Department of Natural Resources Lake Management Grant Program, and the U.S. Fish and Wildlife Service
- The study reported on in this document was funded through the English Lake Protection & Rehabilitation District and the Wisconsin Department of Natural Resources Lake Management Grant Program
- The removal of the cattle from the English Lake watershed was funded through surplus funds of a Wisconsin Department of Natural Resources Lake Management Grant for improvements in the Silver Lake (Manitowoc County) watershed obtained by the Manitowoc County Land and Water Conservation Service.

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

English Lake is a 51-acre, eutrophic to mesotrophic, seepage lake, with a maximum depth of 85 feet. The lake is located six miles southwest of the City of Manitowoc in Manitowoc County. In an effort to protect and improve the lake, the English Lake Protection & Rehabilitation District has sponsored six projects, including the one being reported on here. Phases I-III concentrated on diagnostic testing of the lake and its watershed, while Phases IV and V aimed to prioritize the seven restoration alternatives presented in Phase III (Table 1) based on a cost-benefit system. Ultimately, each alternative was compared to the others using the estimated cost of the project and its potential benefit to English Lake in terms of reduced nutrient loading to the lake. The Phase IV and V study concluded that the most beneficial route would be Alternative 6A. The cattle were moved early in 1998, while construction of the wetland detention area was completed in the summer of that same year.

Table 1. English Lake Watershed Management Alternatives Analysis

Alternative	*Description*	*Rank by Cost/ Pound of Removed Phosphorus*
1	Natural Area Creation and Wetland Restoration South of English Lake	8
2	Rerouting two Agricultural Drain Tiles Located South of English Lake	5
3	Detention Basin to Treat Agricultural Drain Tiles Located South of English Lake	7
4	Relocating One Agricultural Drain Tile Discharge Located South of English Lake	4
5	Moving of Cattle Associated with Barnyard/Feedlot Located East of English Lake	1
6A	Wetland Detention Basin East of English Lake with Alternative 5	6
6B	Wetland Detention Basin East of English Lake without Alternative 5	3
7	Installation of Buffer Strip Northwest of English Lake	2

PROJECT OBJECTIVE

The primary objective of this study was to discover if the wetland detention basin is functioning as intended; that being the removal of sediments and nutrients (phosphorus and nitrogen) from the inflow water before it enters English Lake. A secondary objective was limnological monitoring of English Lake in hopes of finding trends in improved water quality as a result of the restoration activities.

METHODS

Flow Monitoring

The efficiency of the wetland detention basin was tested by measuring sediment and nutrient loads at the primary inlet as water entered the basin through a grassed-waterway, and at the basin's outlet where the water discharges and eventually makes its way to English Lake (Figure 1). Two factors are needed to determine the load of a material entering or leaving a basin: 1) the concentration of the material in the water and 2) the volume of water. Multiplying the concentration (mass per volume) by the volume for a specific time frame (e.g., duration of a storm event) will result in the load (milligrams) of materials entering or leaving the basin during that time frame. Ultimately, these parameters are collected remotely by automated machinery. The sampling unit records flow and when it reaches a specific level, such as those indicating a storm event, it collects water samples at specified volume intervals through the storm event. The resulting composite sample is retrieved and analyzed for the materials of concern. The composite sample concentration represents an average concentration for that storm event or time period. This method is the most accurate method for determining event-based loads, but is also very costly and time consuming. A less intense and inexpensive method is to record continuous flows remotely and collect multiple grab samples for lab analysis during storm events. Originally, this study was designed with the intension of collecting three grab samples during the course of a storm event; one during the rising leg of the hydrograph, one at the apparent peak, and one during the falling leg. Then the results of the three sample concentrations would be averaged to form an estimate of the storm volume. However, this design was abandoned due to the rapid rise and fall of the inlet hydrograph, which prevented three samples from being collected. Instead, a single grab sample was collected at the inlet and the outlet during each storm event.

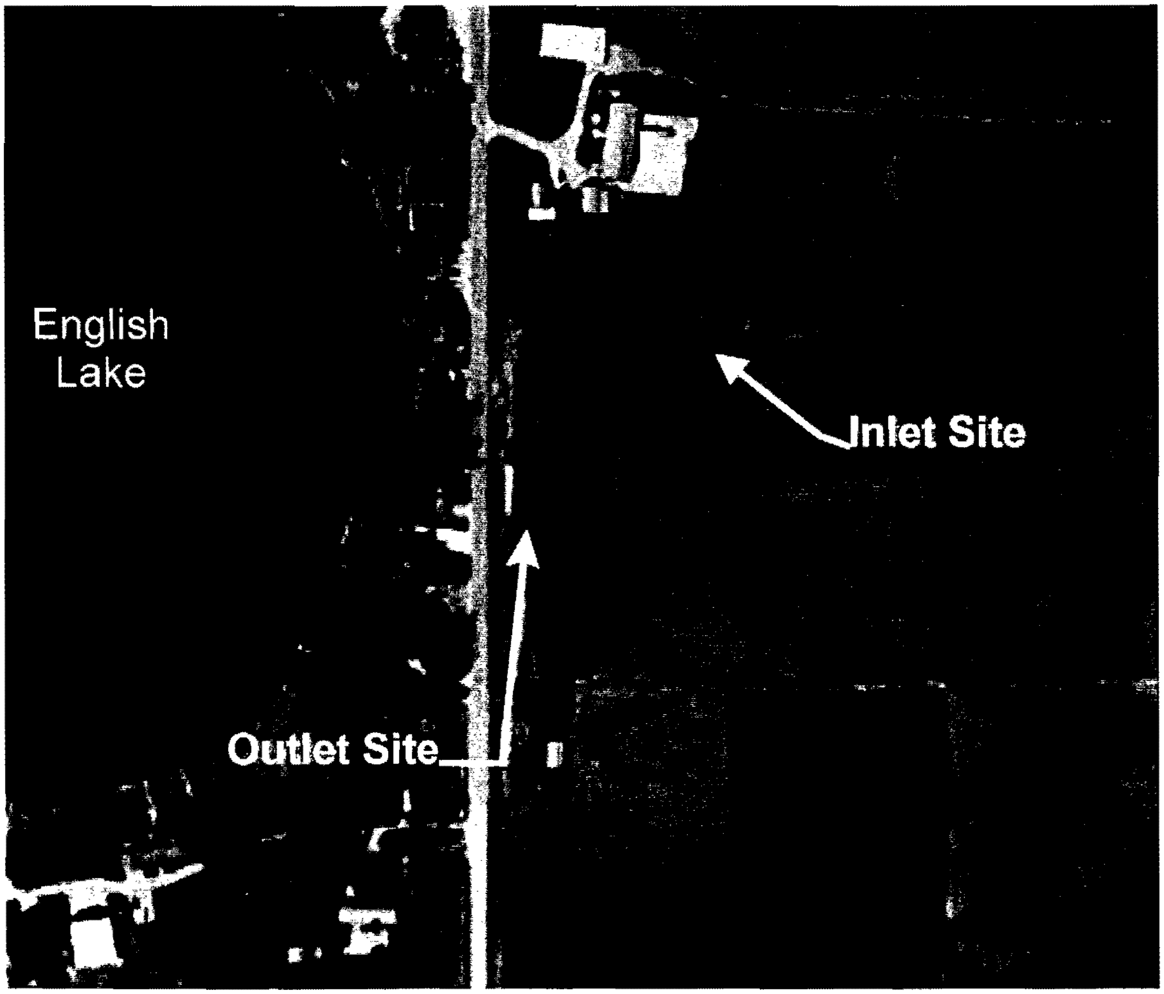


Figure 1. Monitoring sites at wetland detention basin east of English Lake.

Flows at both the inlet and outlet were monitored from April 4, 2000 to November 10, 2000 with Isco 4230 bubble-type flow meters. These meters measure water depth by passing an air bubble out of a tube placed in the lowest portion of the channel. The higher the water level, the more pressure it takes to pass the bubble. The required pressure is converted to water level and stored in the unit's memory. For this study, water level was measured at 10-minute intervals. WinXSPRO v.2.1B (United States Department of Agriculture-Forest Service) was used to estimate a rating-curve based on surveyed cross-sections of the inlet and outlet channel. The rating curve was entered into Flowlink v.4.01 (Isco), which was then used to calculate flow from the water level data.

Data from September 26 to October 6, 2000 were lost do to a malfunction in the equipment used to transfer the data from the Isco flow meters to a computer. However, no storms were sampled during this period. Storm volumes were calculated from instantaneous flow in Microsoft Excel 2000 utilizing standard integration formulas.

Grab Sample Collection and Analysis

Grab samples were collected during seven storm events during the spring, summer and fall of 2000. Weather radar was monitored on a daily basis from Green Bay to determine if sampling was needed at the detention basin. During each trip, two sample containers were filled at each channel by dipping a third container in the flow and transferring it to the analysis container supplied by the Wisconsin State Laboratory of Hygiene (SLH). One container was preserved for nutrient analysis by adding sulfuric acid (H_2SO_4) to the sample until it had a pH of 2 or less. The other container had no additions made to it and was analyzed for total suspended solids. Great care was taken during sample retrieval in order not to add sediments and debris that was resting on the bottom of the channel. At times this was difficult due to the low amount of flow that was occasionally encountered; especially at the inlet site. The samples were kept cool until they were shipped to the SLH in an ice-filled cooler. Collection time was noted at each site and recorded on the SLH lab slip.

Lake Water Quality

Water quality samples were collected at the deepest portion of the lake (Figure 2) during July and August 1999; April and November 2000; and February 2001. Samples were taken near the surface and near the bottom, when possible, using a Van Dorn type sampler. Samples were analyzed for total phosphorus (TP), total Kjeldahl nitrogen, nitrate-nitrite nitrogen, ammonia nitrogen, chlorophyll *a* and total suspended solids. In addition, a dissolved oxygen, temperature, pH and specific conductance profile was completed and Secchi disk transparency was determined. The container for nutrient analysis was preserved in the same manner as described above. Again, all samples were kept cool prior to shipping in an ice-filled cooler to the SLH for analysis.

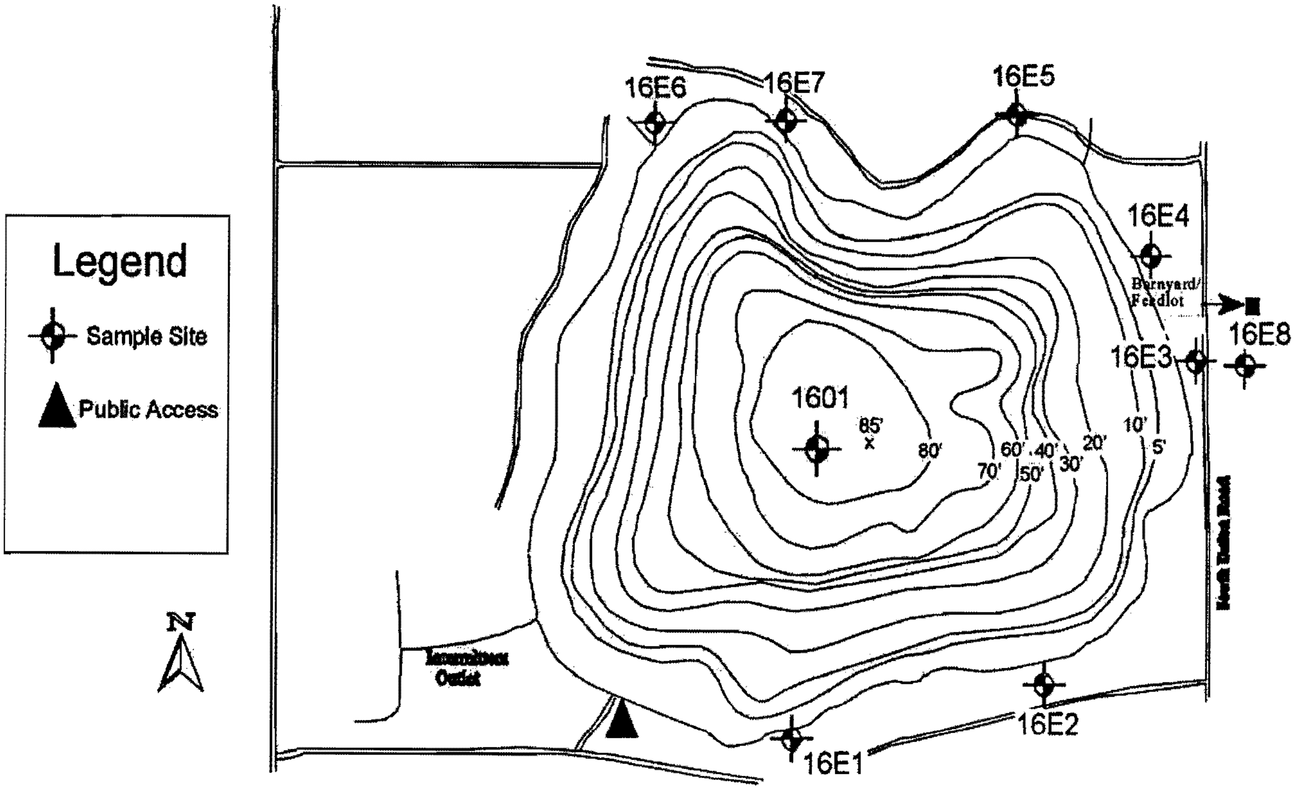


Figure 2. Sample site locations used during Phase I-III studies. Site 1601 indicates lake water quality sampling site used during this study.

RESULTS AND DISCUSSION

The results of both components of this study are presented below. Within each section the results are presented along with discussions about their pertinence. Where called for, discussion about the methods used to obtain the raw data and analysis of it are also discussed.

Detention Basin Monitoring

As outlined in the Methods section, the technique used to determine the nutrient and sediment loads flowing into and out of the detention basin is not the most accurate methodology. In fact, calculating a load from a single sample during a storm event could give drastically inaccurate results because of differences in material concentrations during parts of a storm flow. In most cases, the highest concentrations are found during the "first flush" or the beginning of the storm flow. Lower concentrations are usually found during the end of the storm flow because the loose particles of sediment and other pollutants are washed out when the flow first begins. To counteract this potential problem storm loads were not calculated using single event concentrations; instead, they were determined using an average concentration calculated from the seven sampled events. This provided concentration data from a variety of flows and minimized potential exaggeration in storm loads (either high or low).

Many of the storm events sampled were relatively small in nature and as a result, did not produce a large amount of *measurable* flow (August 17 & 22, 2000 Hydrographs, Appendix A). Measurable flow meaning flows with sufficient water levels that could be detected by the Isco flow meters. For both the inlet and outlet sites, the minimum flow was approximately 0.1 cubic feet per minute (cfm). Although flows lower than 0.1 cfm were not recorded, samples could still be taken in the slight depressions found in the channels. Please note that samples were only taken if there was visible water flow moving through the depression.

All grab sample concentrations (Table 2) were used to calculate the average inlet and outlet storm flow concentration; however, only four out of the seven storm events sampled had sufficient flow to allow for calculating storm volumes (Table 2). Storm values used in all calculations, including those for the outlet, represent the volume of water that entered the detention basin as a result of the storm. Outlet volumes were not determined because analysis showed that a much larger volume of water is discharged through the outlet than is received through the inlet. This trend is indicated in the Mean Daily Flow Hydrograph (Appendix A) by the fact that the daily mean outlet flow is greater than that of the inlet flow most of the project's duration. It is also shown during the May 12, 2000 (Appendix A) storm event by the extended period of time that the outlet flows after the inlet stops. The inlet during this storm received an estimated 27,618 ft^3 of water. That volume had exited through the outlet by 19:40 on May 12, 2000; however, the outlet continued to flow past May 16, 2000. The extra volume likely enters the basin through multiple points of overland flow and via ground water seeps.

Table 2. Grab sample, loading, and average removal efficiencies for English Lake Phase II study.

		Total Phosphorus				Total Nitrogen				Total Suspended Solids			
		Sample Conc. (mg/l)		Storm Load (lbs.)		Sample Conc. (mg/l)		Storm Load (lbs.)		Sample Conc. (mg/l)		Storm Load (lbs.)	
Sample Date	**Storm Vol. (ft^3)**	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**
04/20/00	NR[1]	0.471	0.171			16.17	3.08			<5[4]	16		
05/12/00	27,618	4.920	0.554	2.0	0.8	43.30	5.29	22.6	6.4	4350	61	1101.3	32.9
06/02/00	17,233	0.391	0.588	1.3	0.5	22.06	7.93	14.1	4.0	48	27	687.2	20.6
08/17/00	ND[2]	0.403	0.482			2.35	2.28			5	20		
08/22/00	ND[2]	0.721	0.471			3.15	2.28			9	5		
09/11/00	Comb[3]	0.798	0.374			2.26	2.45			22	<5[4]		
09/12/00	4,889[3]	0.477	0.402	0.4	0.1	2.63	2.55	4.0	1.1	44	<5[4]	195.0	5.8
Average		1.169	0.435			13.13	3.70			640	19		
Average Removal Efficiency		**63%**				**72%**				**97%**			

NR=Not Recorded, ND=Not Detected. [1]Grab samples were collected, but the flow meters were not recording. [2]Flows were below the detectable level of the flow meters. [3]The volumes of the 09/11/00 and 09/12/00 storms were combined into one storm event. [4]A value of 2.5 mg/l was used for samples that were below the 5 mg/l detection level achievable by the SLH when the average was calculated.

Using the average total phosphorus, nitrogen, and suspended sediment grab sample concentrations and the volume of water that entered the basin through the inlet during the four storm events, average removal efficiencies were calculated as listed in Table 2. These efficiencies should be taken for what they are – rough estimates. They are rough estimates for a number of reasons. First, the grab sample method used for determining storm event concentrations in this study can grossly over or under estimate the actual average concentration of materials in the storm volume. However, the fact that most samples were collected after the majority of the storm volume had passed the flow meter indicates that the concentrations used in the loading calculations were probably lower than that of the average storm concentrations for the reasons outlined in the beginning of this section. Second, the sample size of storm events used to calculate the efficiencies were minimal. A much larger sample size collected during a variety of flows would be needed to raise the accuracy of the efficiency estimates.

Comparisons with data from the Phase III study were also made to determine the effectiveness of the wetland detention basin. During the Phase III study, eight sites were sampled during storm events (Figure 2 and Table 3). The results from Sites 16E3 and 16E8 represent total phosphorus and nitrogen data prior to the construction of the detention pond and the relocation of the cattle outside the English Lake drainage basin. These results were compared to similar data collected at the inlet and outlet of the detention basin (Figures 3 and 4). Although these data actually represent improvements made by two restoration alternatives, the cattle relocation and construction of the detention, and as a result each alternative's portion of the improvement cannot be determined, it is apparent that there is a definite improvement in the amount of nutrients entering English Lake.

Table 3. Description of Sample Site Locations used during Phase I-III studies. Site 1601 indicates lake water quality sampling site used during this study.

REGULAR MONITORING

Site	Depth
1601	85.0 feet
1602	1.0 feet

EVENT MONITORING

Site	Description
16E1	Overland flow on property at 9304 S. Lake Drive
16E2	Drain tile outfall (multiple tiles) between 9112 and 9122 S. Lake Drive
16E3	Culvert outfall between 4350 and 4402 S. Union Road
16E4	Overland flow between English Lake and parking lot at 4420 S. Union Road
16E5	Drain tile outfall between 9031 and 9109 N. Lake Drive
16E6	Overland flow between Westland and Rexrode residences
16E7	Overland runoff near 9221 North Lake Drive (on north side of road) – goes into tile and enters lake subsurface
16E8	Overland flow about 150 feet upstream from Site 16E3

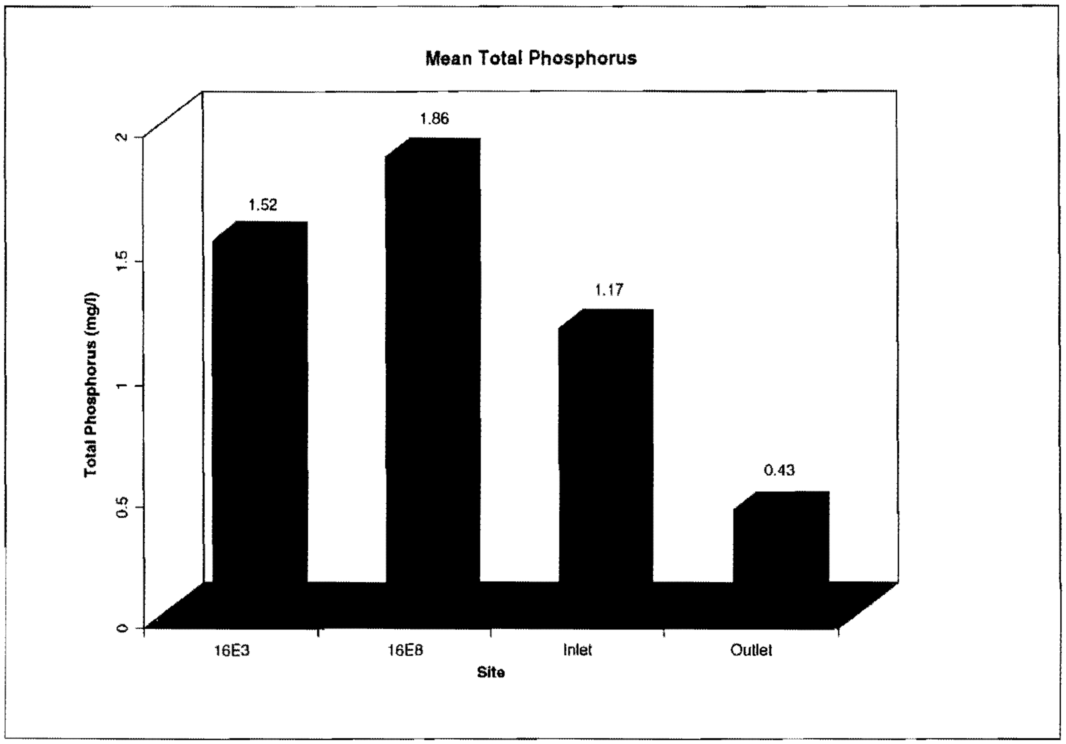


Figure 3. Mean Total Phosphorus levels from sample locations used in Phase I-III studies (16E3 & 16E8) and sample locations used in this study (Inlet & Outlet).

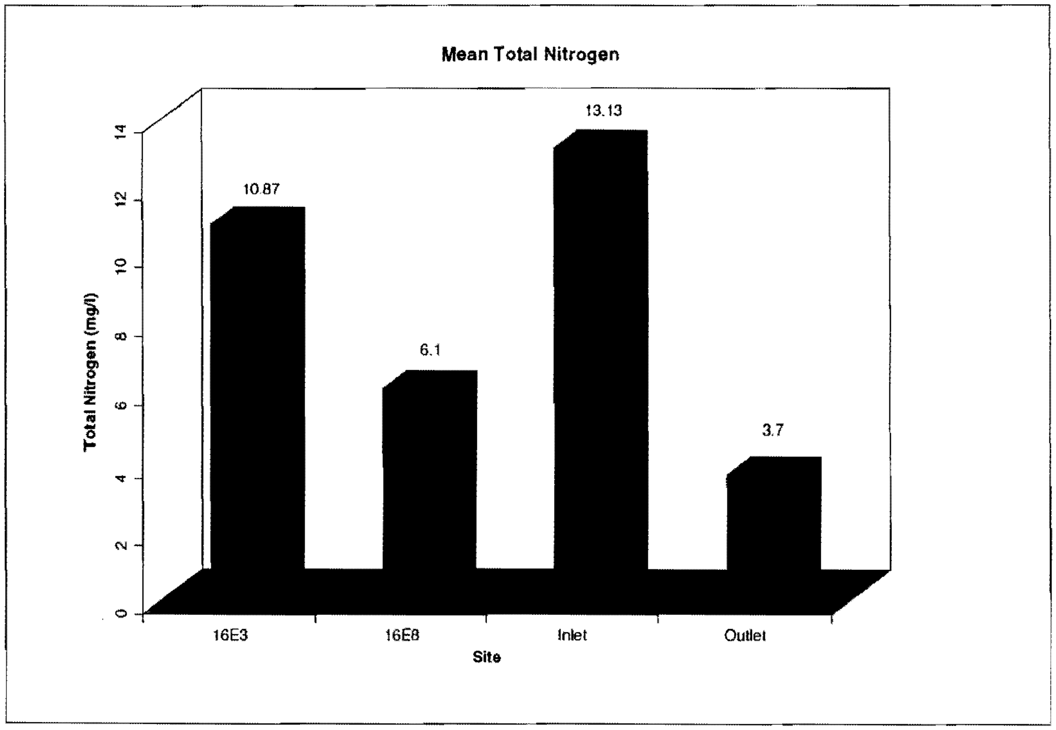


Figure 4. Mean Total Nitrogen levels from sample locations used in Phase I-III studies (16E3 & 16E8) and sample locations used in this study (Inlet & Outlet).

Lake Water Quality Monitoring

A great deal of water quality monitoring has been completed at English Lake including data collected through the Phase I-III studies and the Wisconsin Department of Natural Resources Self-Help Monitoring Program. Table 4 contains averages and sample sizes for near-surface data collected before and after the construction of the wetland detention basin. Interpretation of these data are difficult because there simply is not enough data for the time period after the construction of the wetland basin to make sound statistical conclusions about the differences between the averages. Apparent differences, whether positive or negative must be taken lightly because many factors affect nutrient, transparency, and chlorophyll levels in lakes. For example: changes in farming practices in the lake's watershed, precipitation levels, and even the seasonal timing of when the data were collected can all affect these parameters on a short-term basis. Continued monitoring would shed more light on long-term trends associated with decreased nutrient and sediment loads related to the construction of the wetland detention basin.

Table 4. Selected surface water quality averages from Pre and Post wetland basin construction.

Parameter	Pre-Basin (1976-97) Sample Size	Pre-Basin (1976-97) Average	Post-Basin (1999-2001) Sample Size	Post-Basin (1999-2001) Average
Secchi Transparency (ft)	79	8.9	5	10.4
Total Phosphorus (mg/l)	25	0.086	5	0.090
Total Nitrogen (mg/l)	22	1.24	4	1.39
Chlorophyll *a* (μg/l)	20	16.63	4	4.92

Overall, the limnological characteristics of English Lake have remained consistent when compared to results found in the Phase I-III studies. The average nitrogen to phosphorus ratios within the lake remain slightly over those found in most algal cells (15:1), indicating that the lake is phosphorus limited. Also, the dissolved oxygen and temperature profiles from this study indicate that the lake continues to display anoxic conditions in the deeper water layers (hypolimnion) during winter and summer stratification. Finally, the Trophic State Index (TSI) calculations based on project averages for total phosphorus, chlorophyll *a*, and Secchi disk transparency (63, 47, and 43, respectively) indicate that the English Lake is still in a mesotrophic/eutrophic state.

CONCLUSIONS AND RECOMMENDATIONS

The primary objective of this study was to discover if the wetland detention basin constructed east of English Lake is reducing nutrient and sediment loads to the lake. This study has shown that it is indeed functioning as it was intended. This claim is supported by two facts:

1. Examination of the hydrographs (Appendix A) indicates that the water that enters the basin very rapidly through its inlet is slowly released through its outlet. This process is what makes detention basins function as they do. The sediment carrying capacity of water is directly related to its flow rate – the faster the water is flowing, the more material it can carry. As the water enter the basin through the inlet, the flow velocity decreases. As the velocity decreases the sediment settles out and the water that passes through the outlet is of higher quality.

2. The data obtained through this study, despite its limitations, indicates that the water flowing out of the detention basin is of higher quality than the water flowing into it.

Completion of a more detailed (and expensive) study would give more accurate results pertaining to how efficiently the basin is removing sediments and nutrients, but would likely, as this study has, show that the basin is functioning as it was intended.

Although the results of the English Lake water quality monitoring were inconclusive in determining the impact of the wetland detention basin, the data collected is still important in the continued long-term monitoring of the lake's water quality. If an increase in water quality cannot be attributed to the construction of the wetland basin with continued lake water quality monitoring, this may be an indication that one or more processes are adding nutrients to the system and clouding the affects of the decreased nutrient and sediment loads attributable to the wetland detention basin. For example, agricultural processes may have changed in a portion of the watershed that now adds increased amounts of phosphorus to the lake through land-spreading of manure or degraded tile systems. Another likely cause may be internal loading of phosphorus from lake sediments during spring and fall turnover events. Inputs from the watershed could be reduced through implementation of Best Management Practices (BMPs) within the watershed. An excellent example is the construction of the wetland detention basin and removal of the cattle yard that has already been completed. Installation of buffer strips, diversion of drain tiles and surface flows through wetland restoration areas before the flows enter the lake, and grassed waterways are additional forms of BMPs. If these techniques are not feasible, diversion of the agricultural runoff from the lake may be a solution. Once all external sources of nutrients and sediment are minimized, internal nutrient loadings can be reduced with an alum treatment. The most important concept here is that the external sources of nutrients must be minimized before an alum treatment can be considered.

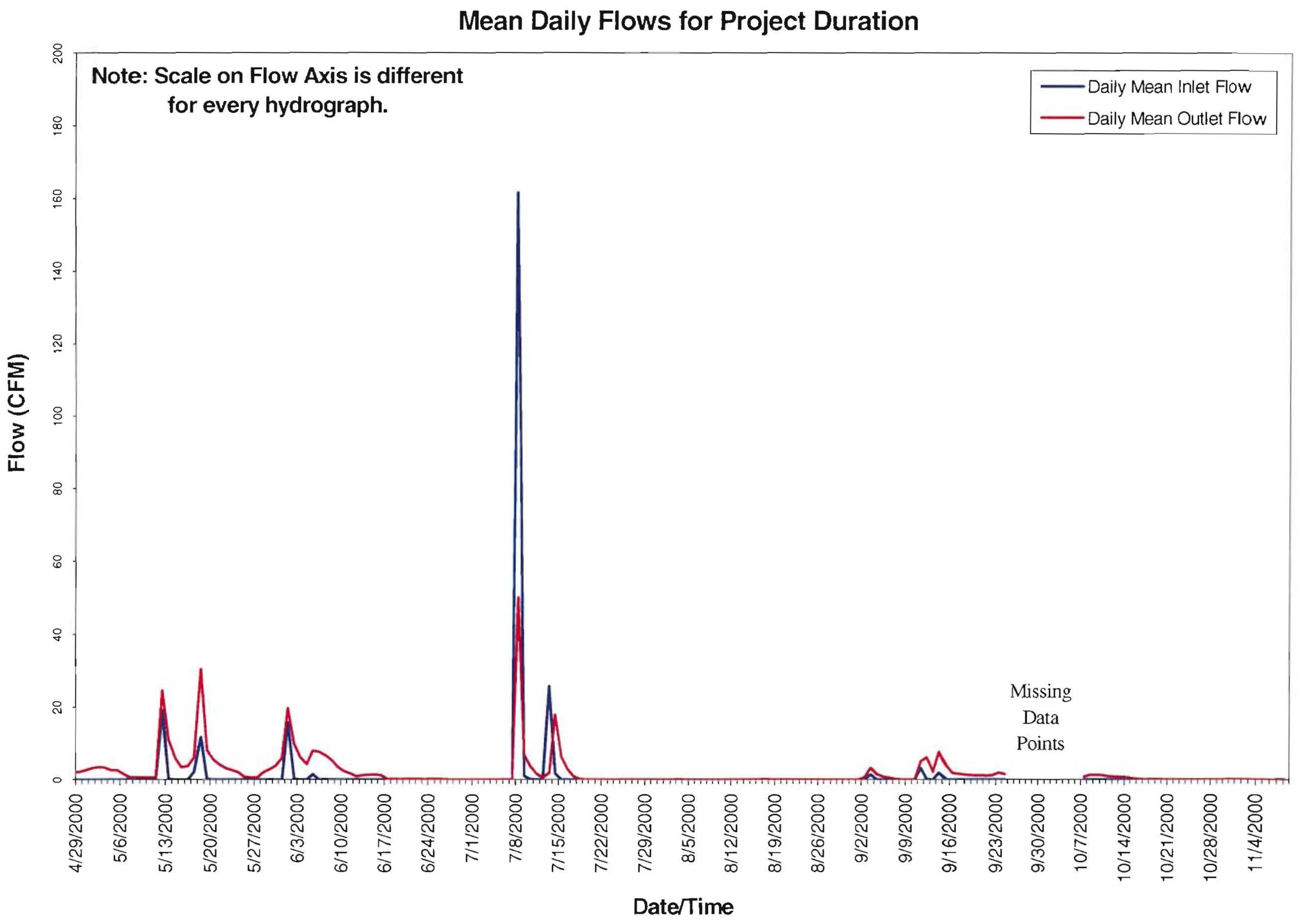
Water quality sampling should be continued to monitor transparency, phosphorus, nitrogen, suspended solids, and chlorophyll *a* levels in English Lake. Also, periodic (spring and fall) sampling should be completed at Site 16E3 (Figure 2) to monitor trends in nutrient and suspended solids concentrations entering the lake. Data collected at this site would give insight to the long-term functionality of the wetland detention basin and would help justify any future restoration plans such as an alum treatment.

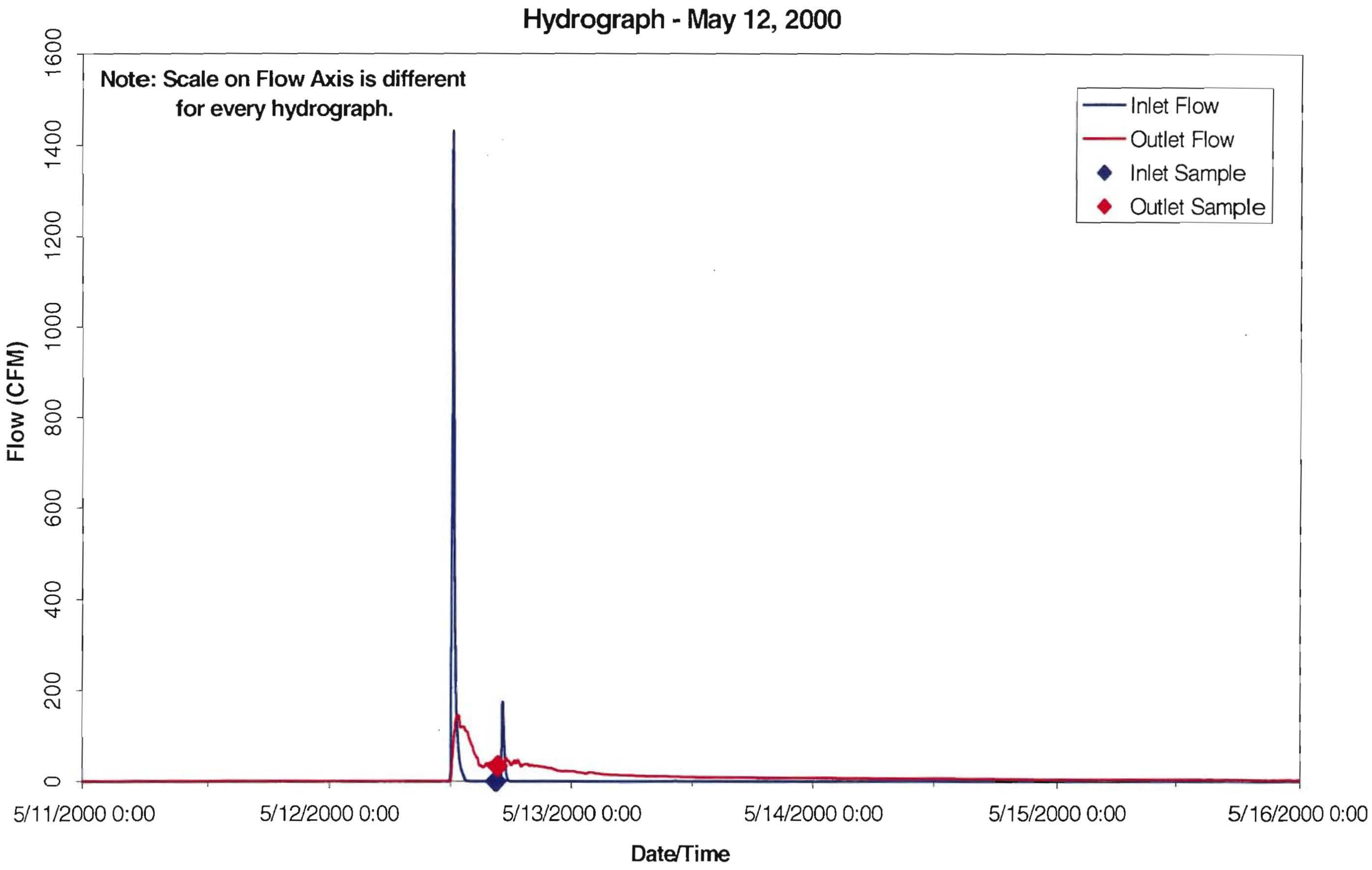
Finally, it is recommended that an area 30-50 feet from the edge of the basin, including the berm, be mowed no more than once a year and that native emergent, floating-leaved, and submergent aquatic vegetation be introduced to the basin. The implementation of both recommendations would enhance the sediment and nutrient filtering capabilities of the pond, plus limit impacts from waterfowl and muskrats.

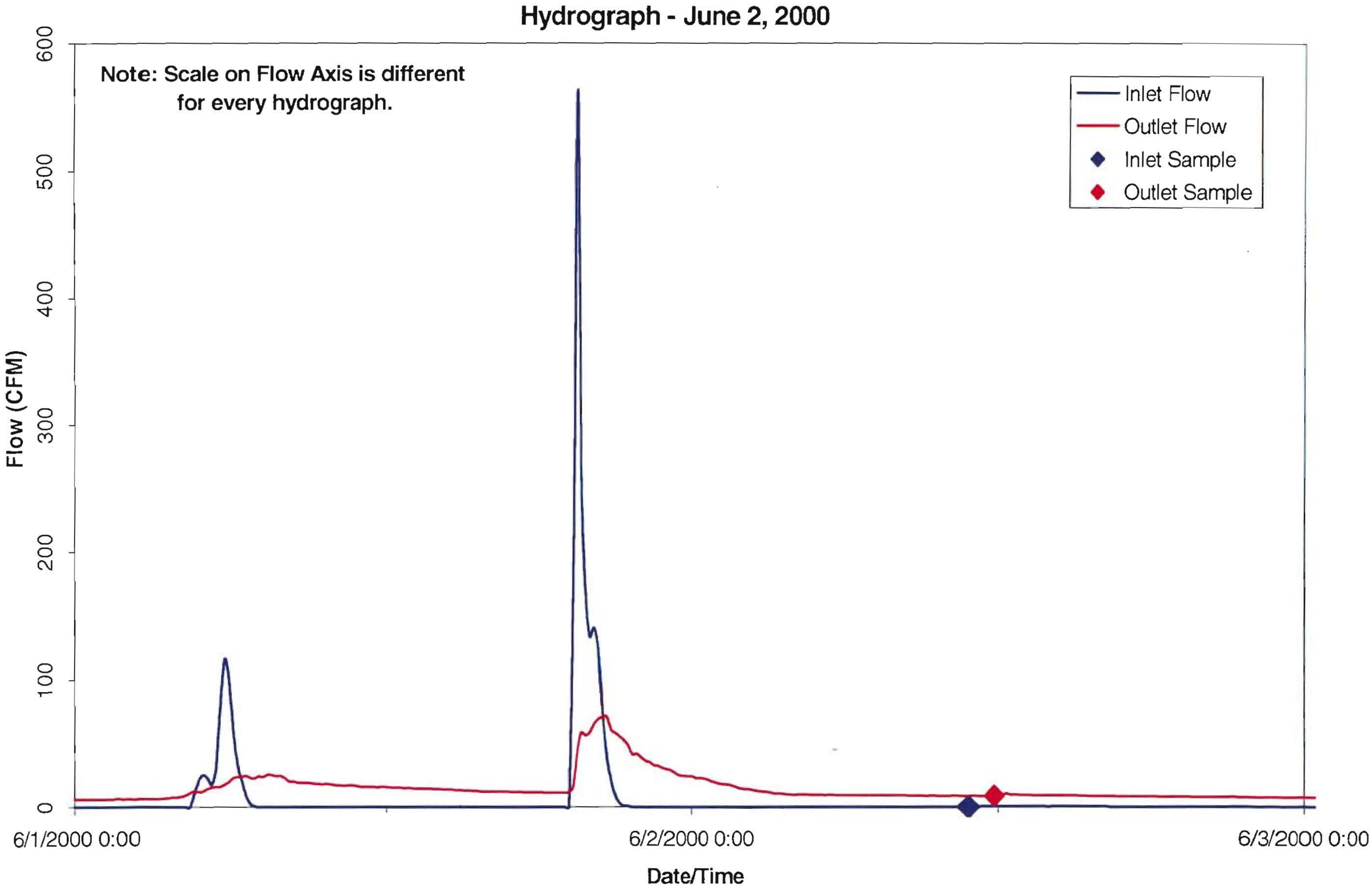
A

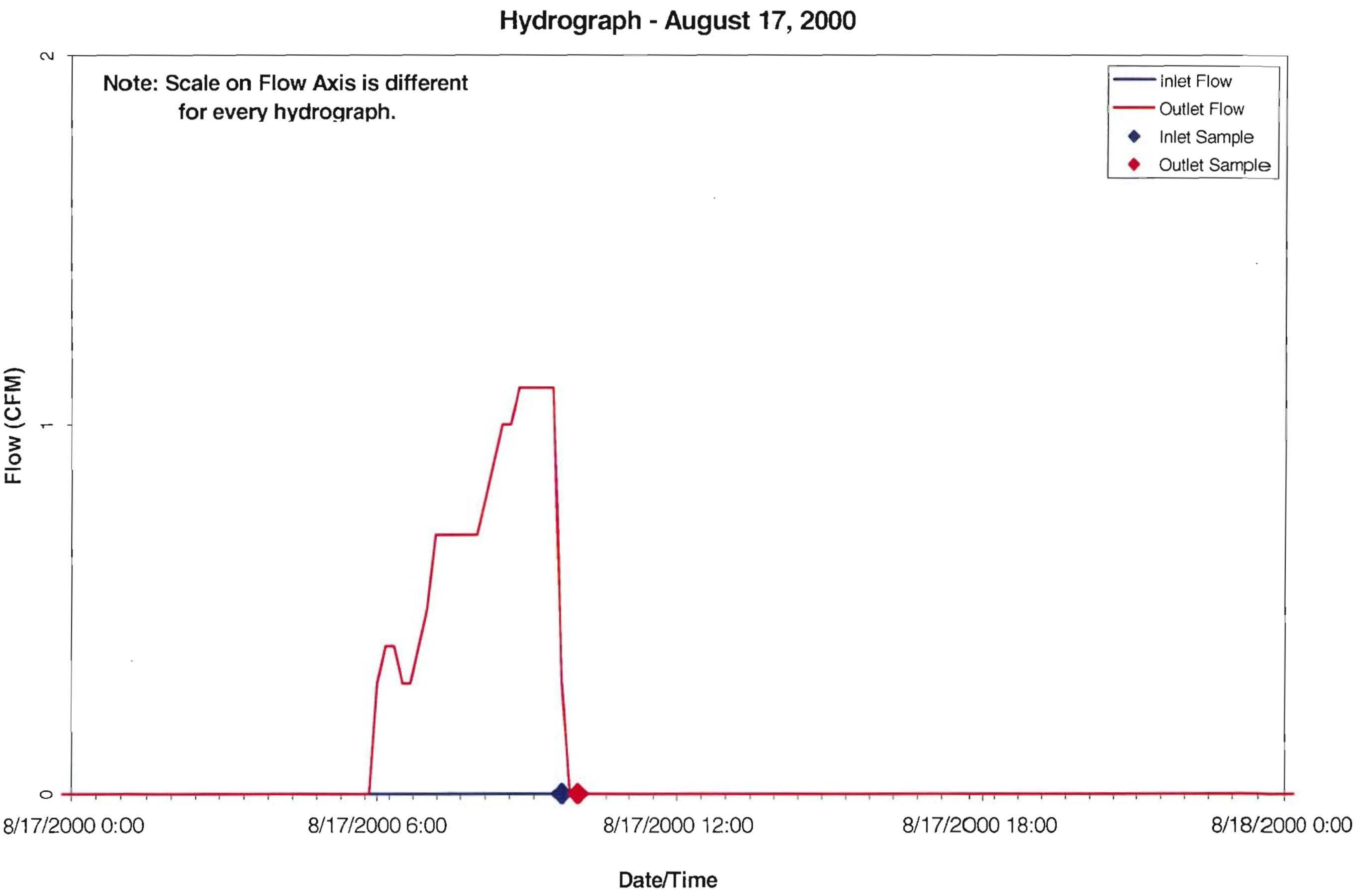
APPENDIX A

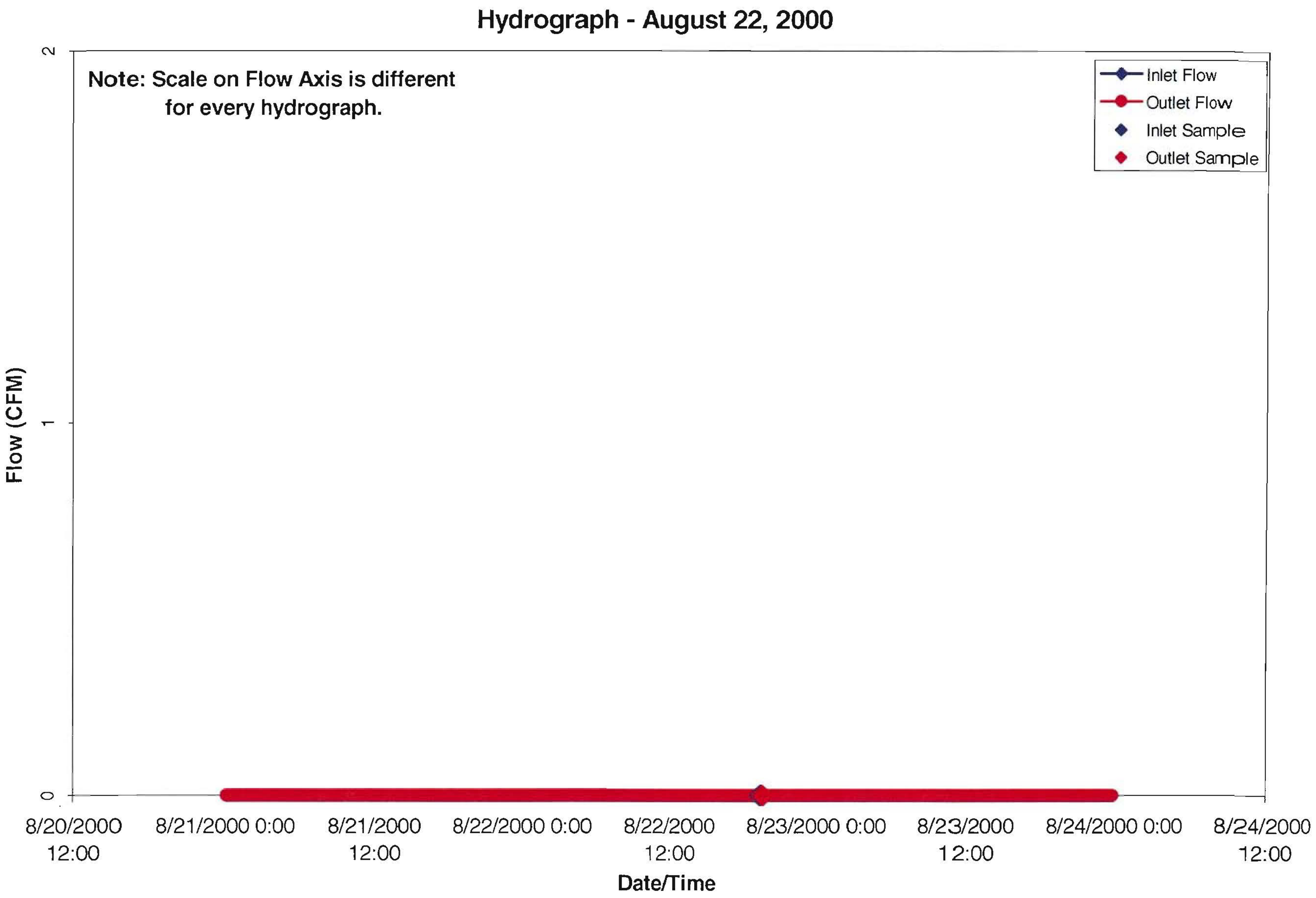
HYDROGRAPHS FOR STORM EVENTS SAMPLED


Mean Daily Flows for Project Duration
Note: Scale on Flow Axis is different for every hydrograph.
Daily Mean Inlet Flow
Daily Mean Outlet Flow
Flow (CFM)
0
20
40
60
80
100
120
140
160
180
200
Missing Data Points
4/29/2000
5/6/2000
5/13/2000
5/20/2000
5/27/2000
6/3/2000
6/10/2000
6/17/2000
6/24/2000
7/1/2000
7/8/2000
7/15/2000
7/22/2000
7/29/2000
8/5/2000
8/12/2000
8/19/2000
8/26/2000
9/2/2000
9/9/2000
9/16/2000
9/23/2000
9/30/2000
10/7/2000
10/14/2000
10/21/2000
10/28/2000
11/4/2000
Date/Time


Hydrograph - May 12, 2000
Note: Scale on Flow Axis is different for every hydrograph.
Inlet Flow
Outlet Flow
Inlet Sample
Outlet Sample
Flow (CFM)
1600
1400
1200
1000
800
600
400
200
0
5/11/2000 0:00
5/12/2000 0:00
5/13/2000 0:00
5/14/2000 0:00
5/15/2000 0:00
5/16/2000 0:00
Date/Time


Hydrograph - June 2, 2000
Note: Scale on Flow Axis is different for every hydrograph.
Inlet Flow
Outlet Flow
Inlet Sample
Outlet Sample
Flow (CFM)
0
100
200
300
400
500
600
6/1/2000 0:00
6/2/2000 0:00
6/3/2000 0:00
Date/Time


Hydrograph - August 17, 2000
Note: Scale on Flow Axis is different for every hydrograph.
Inlet Flow
Outlet Flow
◆ Inlet Sample
◆ Outlet Sample
Flow (CFM)
2
1
0
8/17/2000 0:00
8/17/2000 6:00
8/17/2000 12:00
8/17/2000 18:00
8/18/2000 0:00
Date/Time


Hydrograph - August 22, 2000
Note: Scale on Flow Axis is different
for every hydrograph.
Inlet Flow
Outlet Flow
Inlet Sample
Outlet Sample
Flow (CFM)
2
1
0
8/20/2000 12:00
8/21/2000 0:00
8/21/2000 12:00
8/22/2000 0:00
8/22/2000 12:00
8/23/2000 0:00
8/23/2000 12:00
8/24/2000 0:00
8/24/2000 12:00
Date/Time

Hydrograph - September 11-12, 2000