Birch Island Lake Management Plan

Phase II: Hydrologic and Phosphorus Budgets

Prepared for
Birch Island Lake Association

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Birch Island Lake Management Plan-Phase II: Hydrologic and Phosphorus Budgets

Executive Summary

Hydrologic and phosphorus budgets were completed for Birch Island Lake (Townships of Scott and Jackson, Burnett County, Wisconsin) with the purpose of establishing a baseline hydrologic and phosphorus budget, which can be used to evaluate the potential effect of future development on lake water quality. Major conclusions of the study include:

- The 2003 average summer phosphorus concentration for Birch Island Lake was 13.5 $\mu g/L$. The average summer Secchi disc depth for the same year was 9.8 ft. Based on these parameters the general water quality of Birch Island is classified as Mesotrophic (intermediate range). This classification indicates that Birch Island Lake is moderately clear.
- Approximately 52 percent of the water budget (water inflows) to Birch Island Lake comes from direct precipitation onto Birch Island Lake; the remaining comes from surface and subsurface runoff.
- Because the water table is near the ground surface, the water quality of Birch Island Lake is expected to be strongly influenced by groundwater movement. Based upon elevation contours of the watershed surrounding Birch Island Lake and surface elevation data of lakes adjacent to Birch Island Lake, it can be generalized that groundwater moves from a South-East to North-West direction. The average net groundwater outflow from the lake is approximately 2,814 acre-ft.
- The hydraulic residence time for Birch Island Lake in an average rainfall year is 1.71 years, meaning, this lake is frequently flushed.
- Approximately 42 percent of the phosphorus loading to Birch Island Lake is estimated to come from septic systems. This does not imply that the septic systems are working improperly but rather that of the phosphorus sources contributing loading to the lake, loading from the septic systems is significant.

- Approximately 6 and 8 percent of the phosphorus loading to Birch Island Lake is estimated to come from residential lawns and the portion of a local golf course that lies within the Birch Island Lake watershed, respectively. A survey of residents and the golf course regarding fertilizer application practices as part of the Phase III study may be worthwhile to accurately characterize their respective contributions to Birch Island Lake phosphorus loading.
- Total phosphorus loading to Birch Island Lake on an annual basis ranges from approximately 240 kilograms (529 pounds) in a dry year to 358 kilograms (788 pounds) in a wet year. For an average precipitation year (2003), the total phosphorus loading to Birch Island Lake was approximately 287 kilograms (632 pounds).
- A water quality model for Birch Island Lake has been calibrated. This model can be used to estimate the effect of future development in the Birch Island Lake watershed on water quality.
- The extent of shoreline development for Birch Island Lake is slightly less than that of other lakes in the area. Further evaluation of the potential for development within the Birch Island Lake watershed and the potential effect of this development on the water quality of the Birch Island Lake is recommended for the Phase III study.

Table of Contents

Executive Summary i

Introduction 1

Hydrologic Budget 1

- Hydrologic Budget Development 1
- Hydrologic Budget Results 4

Phosphorus Budget 4

- Watershed and Atmosphere 5
- Septic Systems 6
- Phosphorus Loading Results 7
- Lake Modeling 8
- Lake Modeling Results 9
- Modeling Future Scenarios: Potential Effect of Increased Development in the Birch Island Lake Watershed 9

Effect of Phosphorus on Lake Clarity 11

Conclusions and Discussion 12

Tables ..... *Appendix A*

Figures ..... *Appendix B*

List of Tables

Table 1	Birch Island Lake Watershed Characteristics
Table 2	NCDC Wisconsin Rainfall Data
Table 3	Water Balance Results
Table 4	Phosphorus Export Coefficients
Table 5	Phosphorus Inputs for Lake Modeling
Table 6	Calculation of Phosphorus Loading to Birch Island Lake by Septic Systems
Table 7	Birch Island Lake Phosphorus Sources and Land Use Comparison

List of Figures

Figure 1	Elevation Contour and Hillshade of the Birch Island Lake Watershed
Figure 2	Birch Island Lake Watershed and Depth Contours
Figure 3a	2003 precipitation distribution for USGS stream gage 05332500 watershed
Figure 3b	2002 precipitation distribution for USGS stream gage 05332500 watershed
Figure 3c	1998 precipitation distribution for USGS stream gage 05332500 watershed
Figure 4	Birch Island Lake Monthly Water Balance for Average (2003), Wet (2002), and Dry (1998) Years Assuming a Constant Lake Surface Elevation
Figure 5	Birch Island Lake Average Precipitation Year (2003) Monthly Water Balance Incorporating Lake Level Data
Figure 6	Change in Birch Island Lake Water Surface Height in 2003
Figure 7	Annual Phosphorus Loading Budget for Birch Island Lake
Figure 8	Comparison of the Calibrated Retention Coefficients for Birch Island Lake during Average, Wet, and Dry Years to the Retention Coefficient Published by Kirchner and Dillon (1975).
Figure 9	Expected Change in Phosphorus Loading to Birch Island Lake Corresponding With a Change in the Number of Residences Adjacent to This Lake
Figure 10	Expected Change in Phosphorus Concentration in Birch Island Lake Corresponding With a Change in the Number of Residences Adjacent to the Lake
Figure 11	Approximate Number of Structures (residences on Several Lakes in Burnett County in Relation to the Total Shoreline Miles for Each Lake
Figure 12	Comparison of Birch Island Lake Clarity, Measured Secchi Disc Depth, to Other Lakes in North East Burnett County
Figure 13	Correlation Between Secchi Disc Depth and Phosphorus Concentrations Using the Tropic State Index (TSI)
Figure 14	Relationship Between Total Phosphorus in a Lake's Water Column and Lake Clarity
Figure 15	Concentration of Phosphorus in Birch Island Lake during an Average, Wet, and Dry Year and the Corresponding Cumulative Precipitation

Introduction

A hydrologic and phosphorus budget (Phase II) was prepared as part of a three phase study to characterize the biological, hydrologic, and chemical characteristics (Phase I) of Birch Island Lake (Burnett County, Wisconsin), and to develop a lake management plan (Phase III). The purpose of this Phase II study was to establish a baseline hydrologic and phosphorus budget for Birch Island Lake which could also be used to evaluate how potential future development or other activities within the Birch Island Lake watershed may affect the water quality of the Lake. The baseline hydrologic and phosphorus budget can also be used for the future development of a lake management plan.

Hydrologic Budget

Hydrologic Budget Development

A hydrologic budget is developed for a lake by evaluating the potential sources of water to the lake (i.e. direct precipitation to the lake, runoff from the surrounding watershed, and ground water inflows) and the potential losses from a lake, (i.e. evaporation, evapotranspiration, and groundwater outflows). Also, over short periods of time, it must be known how water storage (surface elevation) in the lake changes over time. In the long run storage can be assumed to be zero. The hydrologic budget can be expressed as the following equation:

$$\Delta Vol = I + (P_L - E_L) - GW_{out}$$

where:

ΔVol = change in the lake's storage volume

I = surface and subsurface water inflow from the watershed

P_L = direct precipitation on the lake surface

E_L = evaporation from the lake surface

GW_{out} = ground water outflow

To accurately determine the water balance a delineation of the area surrounding Birch Island Lake that contributes runoff to the Lake was performed. This delineation was based upon the change in elevation of the land surrounding the lake. A USGS map, showing elevation contours, was initially used to delineate the watershed. A site visit was conducted on February 11, 2005 to verify that the watershed was delineated properly. Warranted changes were made to the watershed delineation and the revised watershed is shown in Figures 1 and 2. Land use within the Birch Island Lake watershed was estimated from an aerial photograph and the site visit. Table 1 summarizes the area of each land use type and characteristics of Birch Island Lake itself. Since the water quality of Birch Island Lake is dependant upon cyclical changes in weather, water balances were performed for average (2003), wet (2002), and dry (1998) years.

To determine the contributions of surface and subsurface inflows to Birch Island Lake from the watershed (excluding wetlands and Birch Island Lake itself) the watershed yield was estimated. The watershed yield is the percentage of rainfall that falls within the watershed and is transported to Birch Island Lake. On account of similar soil characteristics (highly sandy) and availability of data, yield for Birch Island Lake was based upon the yield of the adjacent Namekagon River watershed. Yield was calculated using flow data collected at the USGS stream gage (USGS 05332500) located near Trego, Wisconsin. Using National Climatic Data Center (NCDC) annual rainfall data obtained from eleven weather stations located in Washburn and Burnett counties, average annual precipitation plots for the portion of the Namekagon watershed contributing to the stream gage near Trego, Wisconsin were created. Figures 3a, 3b, and 3c show these precipitation distributions for an average (2003), wet (2002), and dry (1998) year respectively. Table 2 shows the annual precipitation for each of the weather stations during the years of interest. The yields were calculated by dividing the USGS 05332500 annual stream flow by the average annual precipitation within the gages' contributing watershed. The estimated yields for 2002, 2003, and 1998 were 0.42, 0.43, and 0.40 respectively. The remaining water not transported to Birch Island Lake that falls within its' watershed is lost by other water sinks such as plant uptake (evapotranspiration) and evaporation.

Inflows from wetlands to Birch Island Lake were assessed separately since they represent a significant portion of the watershed (18%) and larger levels of evapotranspiration occur in these regions. Wetland evapotranspiration was estimated using the Blaney and Criddle equation (Wanielista et al. 1997) adjusted for the time of year, mean monthly temperatures, growing season, and latitude of interest.

Combining the established areas from the watershed delineation with the estimated yields, precipitation, and evapotranspiration computations, the net surface and subsurface water inflow can be expressed as the following equation:

$$I = (P_{WS} Y) + (P_{WL} - ET)$$

where:

P_{WS} = direct precipitation to the watershed excluding the wetlands and Birch Island Lake

Y = yield

P_{WL} = direct precipitation to the wetlands

ET = evapotranspiration from the wetlands

Precipitation not lost to evapotranspiration in the wetlands was assumed to be an inflow to Birch Island Lake since most of the wetlands are directly connected to the lake. From the net inflow calculations it is estimated that 14.2 of the 36.4 inches of rain in 2003, 19.2 of the 47.4 inches of rain in 2002, and 11.4 of the 28.7 inches of rain in 1998 within the Birch Island Lake watershed is delivered to Birch Island Lake respectively.

Precipitation data used in the water balance includes data collected by the Birch Island Lake Association when available (May through July 2003) and monthly National Climatic Data Center precipitation data obtained from the nearest weather station (Webster 9 SE, COOP ID 479012). Annual precipitation to a region within the watershed was weighted as the product of the average annual precipitation to the watershed and the area of the region of interest.

The Meyer Model (Meyer 1947) was used to estimate evaporation from the lake surface for the years of interest. This model uses inputs of precipitation, temperature, wind speed, and relative humidity to predict monthly evaporation. The movement of groundwater out of the lake was calculated as the difference from all the hydrologic budget components with the assumption that there was zero storage when lake level data was unavailable.

Hydrologic Budget Results

Monthly hydrologic budgets for an average (2003), wet (2002), and dry (1998) year are shown in Figure 4. The water budgets are presented monthly to demonstrate the relative sources and losses (outflows) of water for Birch Island Lake. However, for water quality evaluation purposes, annual water budgets were used. It can be seen in each of these figures that a significant fraction of the water budget to Birch Island Lake comes from direct precipitation to the lake. However, since the precipitation data does not distinguish between snowfall and rainfall, it is expected that inflows are actually slightly lower in the winter months (frozen storage) and are slightly higher in the spring (spring melt). Assuming that the water surface elevation remains unchanged on an annual basis there was a net groundwater outflow from Birch Island Lake in each of the study years. The net groundwater outflow for an average year was 2,814 acre-feet, for a wet year outflow was 3,990 acre-feet, and for a dry year outflow was 1,672 acre-feet. Assuming a constant lake volume, the hydraulic residence time (i.e. flushing rate) for an average, wet, and dry year are 1.7, 1.2, and 2.9 years respectively. The small hydraulic residence times indicate high flushing rates characteristic of the sandy soils in Northwestern Wisconsin.

Figure 5 incorporates lake level data obtained by the Birch Island Lake Association in 2003 to the hydrologic balance. The daily lake level gage records are shown in Figure 6. Incorporating the lake level data improves the accuracy of water balance and provides an improved depiction of the ground water movement during the months of available data. It can be seen that there is a significant amount of movement of groundwater out of the lake in the spring and influx of groundwater in August. This trend is consistent with what is expected for high inflows during the spring melt and increased evaporation in the late summer months. Annual water balance results are provided in Table 3. These results are expected to be used in future modeling efforts.

Phosphorus Budget

The eight potential sources of phosphorus to Birch Island Lake that can be readily estimated are: 1) forested areas, 2) cultivated agriculture, 3) open grassland/hay fields, 4) wetlands, 5) the local golf course, 6) lawns of residences, 7) septic systems all within the Birch Island Lake watershed and, 8) direct precipitation/atmospheric deposition. Because phosphorus loading associated with many of these sources is transmitted to the lake by subsurface runoff to the lake, it is difficult to separate them. However, their relative contribution can be determined using literature values and established methods. Surface (i.e. atmospheric deposition) and or combined surface and subsurface (i.e. lawns and golf courses) contribution can also be determined using literature values and established methods. Because the concentration of phosphorus in the water column of Birch Island Lake is a function of phosphorus loading from the surrounding watershed, the accuracy of these loading estimates can be checked through lake modeling (see *Lake Modeling* section below).

The data used to calibrate the in-lake phosphorus models were obtained from the Birch Island Lake Association for 2003 and from the Wisconsin DNR website for 2002 and 1998 (self-help monitoring data). The in-lake phosphorus data collected in 2003 (average precipitation year) by the Birch Island Lake Association is representative of the entire summer, while the 2002 and 1998 self-help in-lake phosphorus data is limited in comparison. As a result there is a higher level of confidence with the phosphorus balance results for 2003. Despite the lower levels of confidence in the 1998 and 2002 self-help in-lake phosphorus data, the results of the phosphorus balance for those years are useful when considering potential ranges of in-lake phosphorus concentrations and loadings at present and in the future. Also, only data collected in the main basin of Birch Island Lake by the Birch Island Lake Association in 2003 was used for modeling since it is likely the most well mixed region and therefore the most representative of the entire lake. The average summer in-lake phosphorus concentrations used to calibrate the models were 13.5 μg/L, 16.0 μg/L, and 12.0 μg/L for 2003, 2002, and 1998 respectively.

Watershed and Atmosphere

A summary of the phosphorus export coefficients (kg/ha or lb/acre) and loading estimates (kg/year) are provided in Tables 4 and 5 respectively. Forested area phosphorus loading estimates are from a Wisconsin Department of Natural Resources publication (Panuska and Lillie 1995). The values used are from the Popple River watershed in Northern Wisconsin, which exhibits similar land use characteristics and has a loading of 0.09 kg per ha for an average year. This estimate seems reasonable because of the sandy soil found in the Birch Island Lake watershed and the understanding that forested systems with sandy soil do not produce high phosphorus loads (US EPA 1980). Phosphorus loading estimates for cultivated agriculture (0.38 kg/ha average year) and atmospheric deposition (0.14 kg/ha average year) were derived from an assessment of phosphorus loadings to Minnesota watersheds prepared for the Minnesota Pollution Control Agency by Barr Engineering (Barr 2004). The values were determined by extrapolating phosphorus export coefficients in the St. Croix Watershed for the amount of precipitation in the Birch Island Lake watershed during the years of interest. Phosphorus loading estimates for grasslands/hay fields (0.30 kg/ha average year) and wetlands (0.10 kg/ha average year) were derived from the Wisconsin In-Lake Modeling Suite model (Wisconsin DNR 1995).

A study of four golf courses in the Twin Cities Metropolitan Area (Barten 1995) was used to estimate phosphorus loading from the golf course adjacent to Birch Island Lake. Findings from the study indicated a mean runoff phosphorus concentration of 0.5 mg/L from the golf courses. The export coefficient in kg/ha for the local golf course was estimated by taking the product of the mean phosphorus concentration in the runoff from Barten's report, the direct precipitation to the golf course in the Birch Island Watershed in the year of interest, and the yield for the year of interest. The phosphorus loading rate from the local golf course for an average year using this method was 1.85 kg/ha.

Phosphorus loading estimates from resident lawns adjacent to Birch Island Lake were derived from research performed at the University Of Wisconsin Department Of Soil Science by Wayne Kussow. The average phosphorus loading (0.38 kg/ha) in the results of work by Kussow was used as the phosphorus loading estimate in average, wet, and dry years since fertilizer application practices by Birch Island Lake residences is unknown.

Septic Systems

Phosphorus loading that originates from septic systems is based upon published literature on the phosphorus loading that is generated per resident of each household (US EPA 1980). This loading is expressed as kg phosphorus/capita/year. If a household is not occupied for a full year, then the loading from that household is adjusted to account for the number of days in a given year that it is occupied. It was assumed that each household on Birch Island Lake was occupied by four people, and that the loading was 0.8 kg phosphorus/capita/year. Published phosphorus loading estimates have been shown to be generally in the range from 0.74 to 1.59 kg/capita/year (results summarized in US EPA 1980). In a case study presented in a US EPA lake modeling document (US EPA 1980), high, average, and low phosphorus loading estimates were given as

1.0 kg/capita/year, 0.6 kg/capita/year, and 0.3 kg/capita/year. According to this case study, the phosphorus loading estimate used for Birch Island Lake is in the average to high range. For seasonal residences it was assumed that the residences were occupied for 100 days each year. It was also assumed that only 10 percent of the residences were permanently occupied. The septic loading calculation methodology and a summary of the input parameters for Birch Island Lake are shown in Table 6. The number of residences in the Birch Island Lake watershed was estimated from Burnett County Land Information System on the Burnett County website, counting each fire number as a residence.

After the potential phosphorus loading from septic systems has been estimated, it must be estimated how much of that phosphorus actually reaches Birch Island Lake. The mass of phosphorus from septic systems that travels through the soil and reaches Birch Island Lake is dependant upon the capacity of the soil in the drain field to retain phosphorus. This is expressed as a soil retention coefficient. The type of soil that surrounds a lake can have a significant effect on the capture or retention of phosphorus by soil. Because sandy soils have a lower capacity to immobilize phosphorus (Tofflemire and Chen 1977, USEPA 1980) and the soils surrounding Birch Island Lake are primarily sandy, a lower soil retention coefficient of 0.5 was used in this study.

Phosphorus Loading Results

The results of the phosphorus loading calculations are given for Birch Island Lake in Table 5 and the results are also shown graphically in Figure 7. Phosphorus loading to Birch Island Lake can be considered low, even for non-urban Lake. For example, phosphorus loading to several Western Wisconsin Lake ranges from 1.0 kg per ha of lake surface area (Bone Lake in Polk County, Barr Engineering 1999) to 5.0 kg per ha of lake surface area (Long Lake in Polk County, Barr Engineering 2001). North Twin Lake (Washburn County) has a loading rate of 1.15 kg per ha of lake surface area (Barr Engineering 2004) and Lac Courte Oreilles (Sawyer County) has a phosphorus loading rate of 1.1 kg per ha of lake surface area (Barr Engineering 1998). The phosphorus loading to Birch Island Lake is 0.76 kg per ha of lake surface in an average year.

It can be seen in Figure 7 that septic system loading is approximately 40% of the phosphorus loading in an average year. This does not imply that the septic systems are working improperly but rather that of the phosphorus sources contributing loading to the lake, loading from the septic systems is significant. Even though there is always some uncertainty in any phosphorus loading estimates, loading from other sources is low to moderate because the land use is predominately forest, the soil is sandy, and there are only small amounts of impervious area. The finding that septic systems are 40% of the total phosphorus loads to the lake is reasonable because of the low capacity of the sandy soil to retain phosphorus. Below in the *Lake Modeling* section is a discussion of how confidence in the overall phosphorus loading estimates is supported by the lake modeling findings.

Lake Modeling

The average annual concentration of phosphorus that exists in a lake is primarily dependant upon the movement of water into and out of a lake or flushing of the lake, phosphorus loading, and the settling or removal of phosphorus from the lake water column to the lake bottom sediments. Phosphorus is removed from a lake water column by settling of phosphorus attached to particles or the settling of phosphorus incorporated in bacteria, algae, or other biota. Hence, there is some consistency between phosphorus loading to a lake, hydrologic loading to a lake, and the resultant equilibrium phosphorus concentration. A lake model developed by Dillon and Rigler (1974) was used in this current study (formula provided below). Dillon and Rigler (1974) developed a coefficient (Rp) that defines the fraction of phosphorus loading to a lake that is settled or "retained" by the lake. In a follow-up study, Kirchner and Dillon (1975) calculated the retention coefficient, Rp, for several lakes. They showed that there was a consistent relationship between the loading to a lake and the concentration of phosphorus in a lake and that this relationship could also be defined by the flushing of the lake and the Rp for a lake.

Dillon and Rigler Model:

$$P = \frac{L(1-R)}{Zp}$$

where:

P=Phosphorus concentration in the lake (μg/L)

L=Phosphorus loading (kg/m^2)

R=Retention coefficient (no units)

Z=Average lake depth (m)

p=fraction of the lake volume that flows out of the lake annually (no units)

Lake Modeling Results

In this current study, Rp was calculated for an average (2003), wet (2002), and dry year (1998) to calibrate the Dillon and Rigler model. The Rp calculated for Birch Island Lake was compared to the Rp for the Lake analyzed by Kirchner and Dillon (Figure 8). Figure 8 shows that the retention coefficient, Rp, calculated for Birch Island Lake using phosphorus and hydrologic data from an average, wet, and dry year is similar to the Rp that was expected according to the Kirchner and Dillon study. Because the Rp calculated for Birch Island Lake is similar to the Kirchner and Dillon study where phosphorus loading and water inflows were measured in detail, there is a greater level of confidence in the results of the Birch Island Lake water and phosphorus balance. Also, this provides a greater level of confidence when trying to estimate the effect of changes in phosphorus loading to a lake on expected equilibrium in-lake phosphorus levels.

Modeling Future Scenarios: Potential Effect of Increased Development in the Birch Island Lake Watershed

Using the established water balance for 2003 (average year), the effect of an increase in the number of residences in the Birch Island Lake watershed on phosphorus loading to the Lake and in-lake phosphorus levels was estimated. Changes in phosphorus loading were estimated as a change in the number of septic systems, a change in the number of lawns in the watershed, and a change in the watershed area that is forested. From the Burnett County Land Information System map on the Burnett County, WI website, 217 residences were estimated to be within the Birch Island Lake watershed. The effect of up to a 100 percent increase in the number of these residences on phosphorus loading to Birch Island Lake, and the resultant phosphorus concentration in each lake's water column was calculated (see Figures 9 and 10). It should be noted that the increase in the number of residences used in this scenario is somewhat arbitrary and it may be that more residences could be developed in the Birch Island Lake watershed. In future evaluations it will be necessary to identify the maximum potential development in the Birch Island Lake watershed and its expected effect on the lake's water quality.

Although the above modeling scenario does not depict the actual change in water quality that may occur in Birch Island Lake, there is a real potential for change. According to the Northwest Regional Planning Commission's Comprehensive Plan for the town of Swiss in Burnett County (December 2004) and the town of Chicog in Washburn County (February 2003), there were significant increases in permanent and seasonal residences in the past two decades and continued growth is expected. Comprehensive planning has not been completed for the towns of Scott or Jackson, but similar trends can be expected on account of similarities between current land uses in these towns. In the town of Swiss, the number of residences increased 22 percent from 1980 to 2000 and is expected to increase an additional 27 percent between 2000 and 2020. Also, in the town of Chicog, there was a 138 percent increase in the residential acreage from 1981 to 2001. It is expected that there will be a 50 percent increase in the number of housing units in Washburn County in the next 20 years, and the number of seasonal homes is expected to increase by 62 percent. General trends sighted in the Comprehensive Plan for Washburn County include: 1) an increase in the number of seasonal residents, 2) increased demand for rural housing and larger sized parcels of land, 3) high demand for waterfront property and increased pressure to develop smaller lakes, and 4) increased road traffic.

It appears that the extent of development on Birch Island Lake is slightly less than that of other lakes in the area. The Burnett County Land Information System was used to count the shoreline residences on several Burnett County lakes. Based on this count there are an estimated 16 residences per mile of shoreline on Birch Island Lake. This is slightly below the number of estimated residences per mile of shoreline for the other Burnett Country lakes considered, as shown in Figure 11.

Effect of Phosphorus on Lake Clarity

In a lake environment, algae have primarily everything in abundance that they need to grow except for phosphorus. It is the lack of phosphorus in the water column of lakes that restricts the growth of algae. Because phosphorus historically has been low in lakes, algae are very efficient at utilizing low levels of phosphorus and any increase in phosphorus levels quickly results in increased algal growth. The growth of algae then reduces the clarity of lake water (typically measured as Secchi disc depth). Because phosphorus loading to Birch Island Lake is low, the clarity is good. Compared to other lakes near Birch Island Lake (Figure 12), the clarity of Birch Island Lake is comparable to many lakes in the area. It should be noted when comparing Secchi disc measurements, that approximately 45% of the recorded Secchi disc measurements used to compute a summer average for Birch Island Lake in 2003 reached the bottom of the lake. For comparison purposes, the Secchi disc depth was estimated using Trophic State Index (TSI). The TSI was calculated from Birch Island Lake total phosphorus concentrations (Figure 13). Using the TSI, the summer average Secchi disc depth for 2003 would be 11.6 ft (if the lake were that deep).

There is a direct relationship between the clarity of a lake (measured as Secchi disc depth) and the concentration of phosphorus in a lake. Figure 14 shows this relationship developed from several Minnesota lakes (Heiskary and Wilson 1990). Using this relationship, a Secchi disc depth of 13.7 ft was expected for the corresponding in-lake phosphorus concentration of 13.5 μg/L. As a result, the likely summer average Secchi disc depth for Birch Island Lake in 2003 would have been between 11.6 and 13.7 ft had the disc been allowed to extend pass the lake bottom during measurements. Also from Figure 14, it can be seen that at low phosphorus levels a small increase in phosphorus results in a large decrease in lake clarity (Secchi disc depth). There is not necessarily a phosphorus trigger level upon which rapid deterioration in lake clarity would occur; rather, because the water quality of Birch Island Lake is good now, any incremental increase in total phosphorus from current levels will result in the greatest incremental decline in water quality/clarity. Once Birch Island Lake has reached higher phosphorus levels (i.e. 20 μg/L and higher), the decline in water quality is less in terms of loss of clarity, but the loss of clarity will be accompanied with more frequent algal blooms.

As an example of the effect of lake shore development on lake clarity, the total phosphorus to Secchi disc depth relationship developed in Minnesota was used to estimate the effect of a doubling of residences on South Birch Island Lake on lake clarity (see above, *Modeling Future Scenarios: Potential Effect of Increased Development in the Birch Island Lake Watershed*). It was estimated that a doubling of the residences on Birch Island Lake would cause the phosphorus levels in the lake to increase from 13.5 μg/L (current levels) to 19.7 μg/L. According to Figures 13 and 14 this corresponds to a Secchi disc depth between 8.0 and 9.8 ft. Consequently, despite a decline in water quality/clarity, an increase in the number of residences may not result in lower Secchi disc measurements than are currently being recorded. This is important to keep in mind when analyzing Secchi disc trends over the course of several years.

Conclusions and Discussion

Birch Island Lake is defined as a seepage Lake, meaning that there are no above-ground inflows or outflows from the lake (i.e. streams), and because the soil is predominantly sand, rainfall in the Birch Island Lake watershed is the primary contributor of water to the lake after the rainfall has infiltrated into the soil. Based upon the topography of the land surrounding Birch Island Lake and water surface elevations of adjacent lakes, it can be surmised that groundwater and subsurface inflows enter the Lake predominantly from the South East and ground water outflows occur North Westwardly in the direction of Loon and Hanscom Lakes. Regardless of the actual direction of ground water inflows and outflows, the results of the water balance indicate that groundwater is moving in and out of Birch Island Lake. Since precipitation in the long run is greater than evaporation from the lake's surface in this region, there is a net outflow of groundwater from Birch Island Lake. This means that much of the phosphorus loading to and losses from Birch Island Lake occur though subsurface and groundwater flows.

The concentration of phosphorus that exists in Birch Island Lake is the result of a balance between phosphorus loading to the lake, flushing of water through the lake, and the settling of phosphorus particles to the lakes' bottom. It can be seen in Figure 15 that higher phosphorus concentrations are to some extent correlated with precipitation events and season. However, the source correlated to the precipitation events is difficult to distinguish. Although phosphorus is continually settling out of the water column throughout the year, Figure 15 provides some graphical evidence that phosphorus appears to settle out of the water column of Birch Island Lake near mid July. This is indicated by the decline in phosphorus concentrations. In this study, this phosphorus settling phenomenon was defined as the retention coefficient (Rp). The retention coefficient was calculated as 0.84, 0.78, and 0.90 for an average (2003), wet (2002), and dry year (1998) respectively.

Annual phosphorus loading was estimated to be 632 pounds (287 kg) for Birch Island Lake in 2003 (average year) and may range from 529 pounds (240 kg) in a dry year to 788 pounds (358 kg) in a wet year for current and recent land use conditions. It is estimated that the largest contributor to phosphorus loading is residential septic systems, followed by atmospheric deposition/precipitation, the surrounding forested watershed, the local golf course, the surrounding wetlands, and then residential lawns.

Table 7 summarizes the contributions of each potential loading source by a percentage of the total contribution and includes the relative percentage of the watershed area the source occupies. The largest contributing source relative to land area is the local golf course, contributing an estimated 8% of the total phosphorus load while occupying less than 2% of the total watershed area. Residential lawns are estimated to contribute 6% of the total phosphorus load while occupying less than 4% of the total watershed area. However, of the potential contributing sources to the Birch Island phosphorus load, there is the least amount of confidence in the estimates of the golf course and residential lawns. The lack of confidence is associated with unknown practices regarding fertilizer application for both of these sources. As a result, it may be worthwhile to include a survey of residents and the golf course regarding fertilizer application practices as part of the Phase III study to accurately characterize their respective contributions to Birch Island Lake phosphorus loading.

The effect of an increase in the number of residences in the Birch Island Lake watershed on the phosphorus loading to the Lake (Figure 15) was estimated with a hypothetical corresponding increase in the number of septic systems and lawns. It was shown that as phosphorus loading goes up, so too does the concentration of phosphorus in the water column. Hence, from a previously established relationship (Heiskary and Wilson 1990) between total phosphorus in the lake water column and Secchi disc depth, it was demonstrated that a small increase in total phosphorus in the water column of Birch Island Lake can result in a relatively large loss of lake clarity. Methods to manage water quality in Birch Island Lake given potential future development in the Birch Island Lake watershed will be addressed in a future lake management plan.

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Appendix A
Tables

Table 1. Birch Island Lake Watershed Characteristics

Characteristic	Value
Birch Island Lake Watershed (acres)	2,805
Birch Island Lake (acres)	838
Birch Island Lake Maximum Depth (ft)	13
Birch Island Lake Average Depth (ft)	5.7
Birch Island Lake Volume (acre-ft)	4,802
Birch Island Lake Shoreline (miles)	10.6
Forested Area in Watershed (acres)	1,257
Cultivated Agriculture Area in Watershed (acres)	44
Open Grassland/Hay Field Area in Watershed (acres)	35
Wetland Area in Watershed (acres)	493
Golf Course in Watershed (acres)	29
Resident Lawn Area in Watershed (acres)	109

Table 2. NCDC Wisconsin Rainfall Data

Station - COOP ID	Precipitation (in) 1998	2002	2003
471618	n/a	57.2	37.4
471847	29.6	59.2	39.4
471978	30.2	44.7	31.2
472240	35.4	45.5	35.0
473186	33.9	40.8	32.6
473511	30.4	45.9	30.5
475525	23.3	31.4	28.5
477892	33.0	38.3	36.1
478027	30.4	46.2	29.8
479012	n/a	46.0	32.6
479304	33.3	54.5	36.0
Mean	31.0	46.3	33.5
Average across watershed contributing to Namekagon USGS stream gage	**30.6**	**45.9**	**32.4**

Table 3. Water Balance Results

Description	Average Year 2003	Wet Year 2002	Dry Year 1998
Precipitation (in)	36.4	47.4	28.7
Watershed Runoff (in)	14.2	19.2	11.3
Total Watershed Runoff Volume (acre-ft)	2321	3147	1850
Direct Precipitation Volume to Lake (acre-ft)	2541	3309	2001
Evaporation (in)	29.3	35.3	31.2
Total Evaporation (acre-ft)	2049	2466	2179
*Net Groundwater Outflow (acre-ft)	2814	3990	1672

*The calculation of net groundwater outflow assumes that the water level remains unchanged from the beginning to the end of the year. A change in water level effectively changes the calculation of net groundwater outflow.

Table 4. Phosphorus Export Coefficients

Land Use	Export Coefficient (kg/ha or lb/acre) Average Year 2003	Wet Year 2002	Dry Year 1998
Forest	0.09	0.18	0.05
Cultivated Agriculture	0.38	0.69	0.18
Open Grassland	0.30	0.50	0.10
Wetlands	0.10	0.10	0.10
Golf Course	1.85	2.41	1.45
Lawns	0.38	0.38	0.38
Wet and Dry Atmospheric Deposition	0.14	0.19	0.11

Table 5. Phosphorus Inputs for Lake Modeling

Source	Average Phosphorus Loading (kg/year)		
	Average Year 2003	Wet Year 2002	Dry Year 1998
Forest	47.8	89.0	22.9
Cultivated Agriculture	6.8	12.3	3.2
Open Grassland	4.2	7.1	1.4
Wetlands	20.0	20.0	20.0
Golf Course	21.8	28.4	17.2
Lawns	16.7	16.7	16.7
Septic System	120.3	120.3	120.3
Wet and Dry Atmospheric Deposition	48.8	63.8	38.3
Total Loading (kg/year)	286.5	357.6	240.0

Table 6. Calculation of Phosphorus Loading to Birch Island Lake by Septic Systems.

Calculating Phosphorus Loading From Septic Systems

Basic Equation

Phosphorus Load (kg/year)=Export Coefficient (kg/capita-year) **x** Number of Capita Years **x** (1-SR)

where:

Number of Capita Years = (Number of Full Time Residences **x** Occupants Per Residence) **+** (Number of Seasonal Residences **x** [Number of Days Residence is Occupied/365 days in a year] **x** Occupants Per Residence)

SR = Soil Retention Coefficient (fraction of phosphorus that passes through soil and to lake)

Birch Island Lake

Export Coefficient (kg/year-capita)	0.8
Number of Residences	217
Full Time (10%)	21.7
Seasonal (90%)	195.3
Days Residence	100
Number of Residents per Residence	4
Capita Years	301
Soil Retention Coefficient	0.5
Phosphorus Loading (kg/year)	120.3

Table 7. Birch Island Lake Phosphorus Sources and Land Use Comparison

Phosphorus Loading by Percentages	Average 2003	Wet 2002	Dry 1998	Watershed Land Use
Watershed, Forest	17%	25%	10%	45%
Watershed, Cultivated Agriculture	2%	3%	1%	2%
Watershed, Open Grassland	1%	2%	1%	1%
Watershed, Wetlands	7%	6%	8%	18%
Golf Course	8%	8%	7%	1%
Lawns	6%	5%	7%	4%
Septic System	42%	34%	50%	n/a
Wet and Dry Atmospheric Deposition	17%	18%	16%	30%

Appendix B
Figures

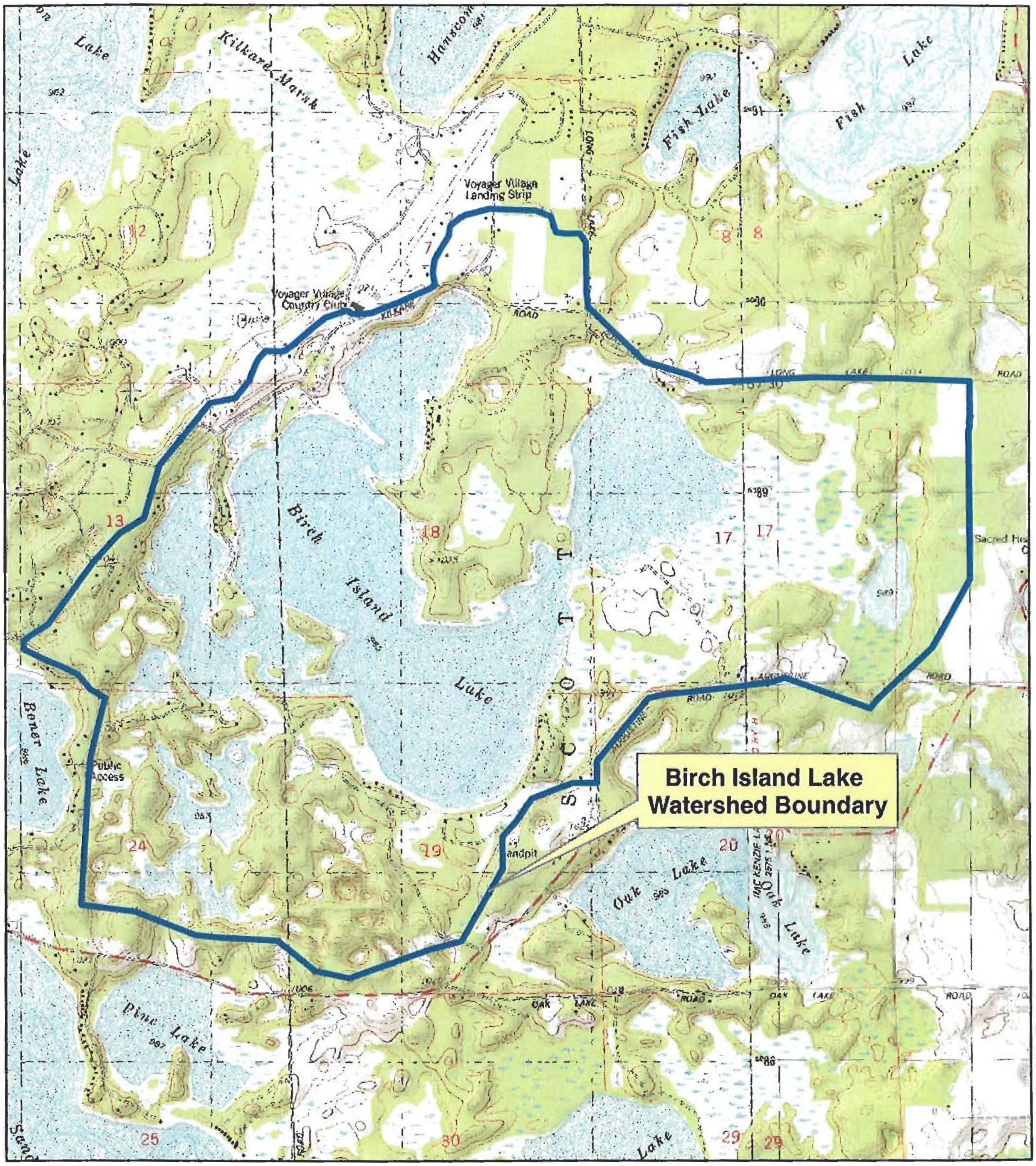
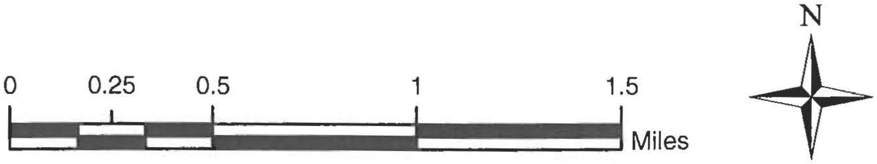


Figure 1. Elevation Contour and Hillshade of the Birch Island Lake Watershed



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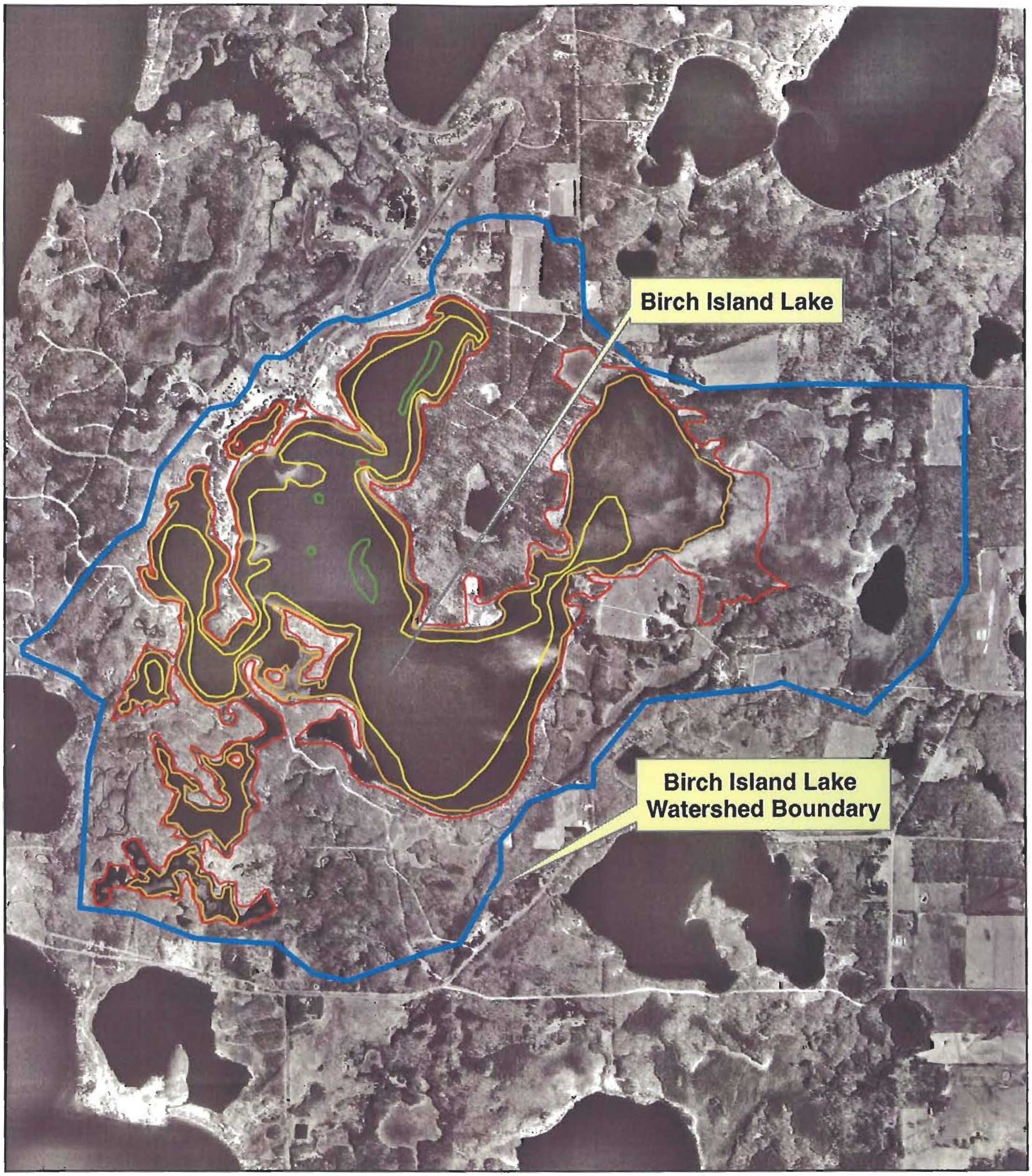
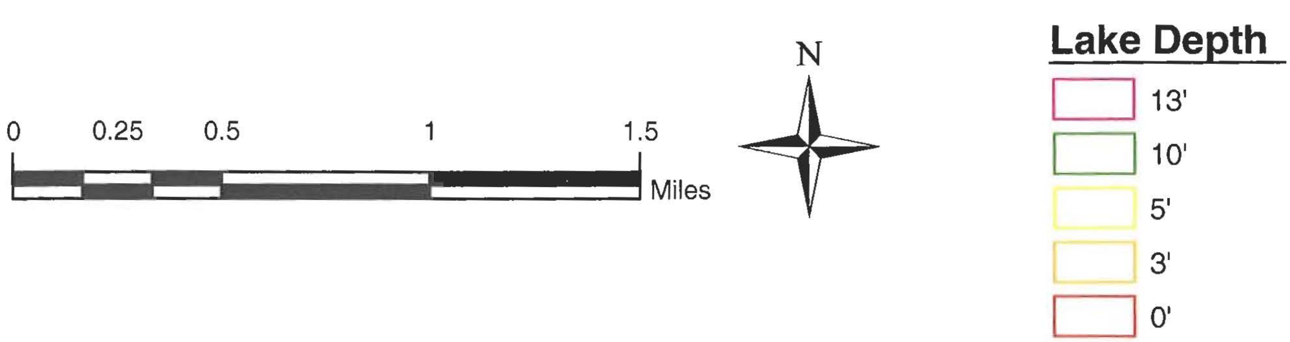


Figure 2. Birch Island Lake Watershed and Depth Contours



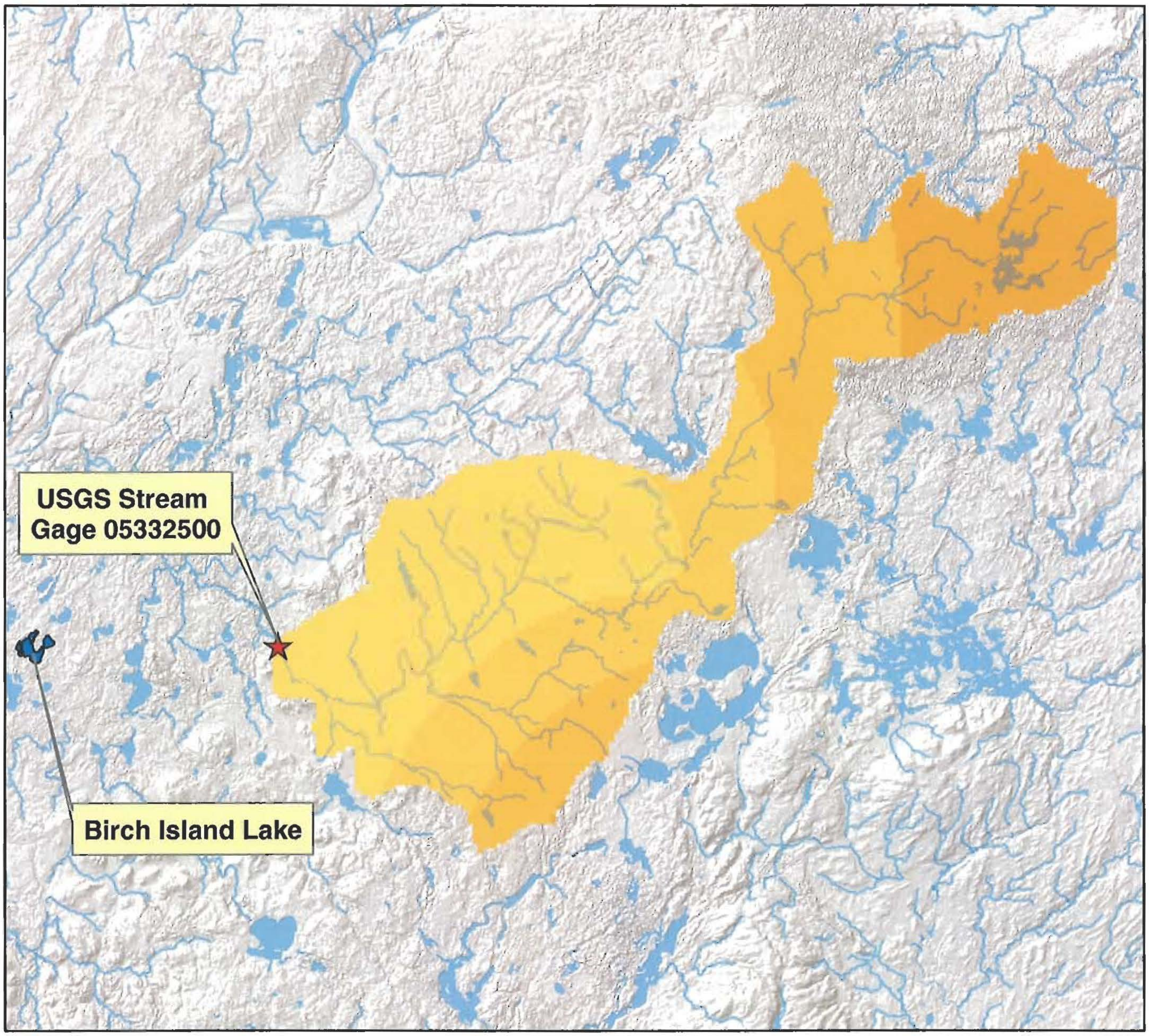


Figure 3a. 2003 precipitation distribution for USGS stream gage 05332500 watershed

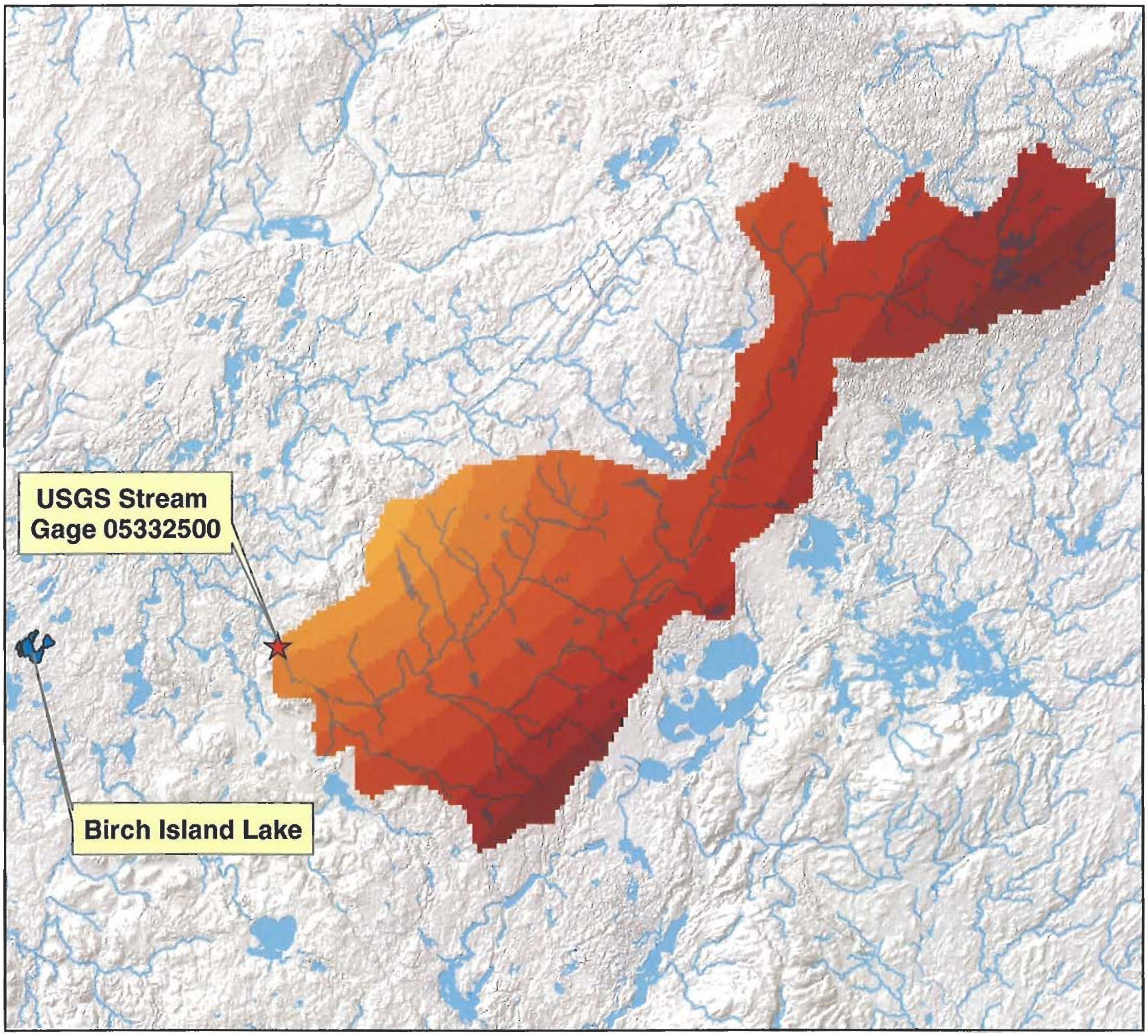
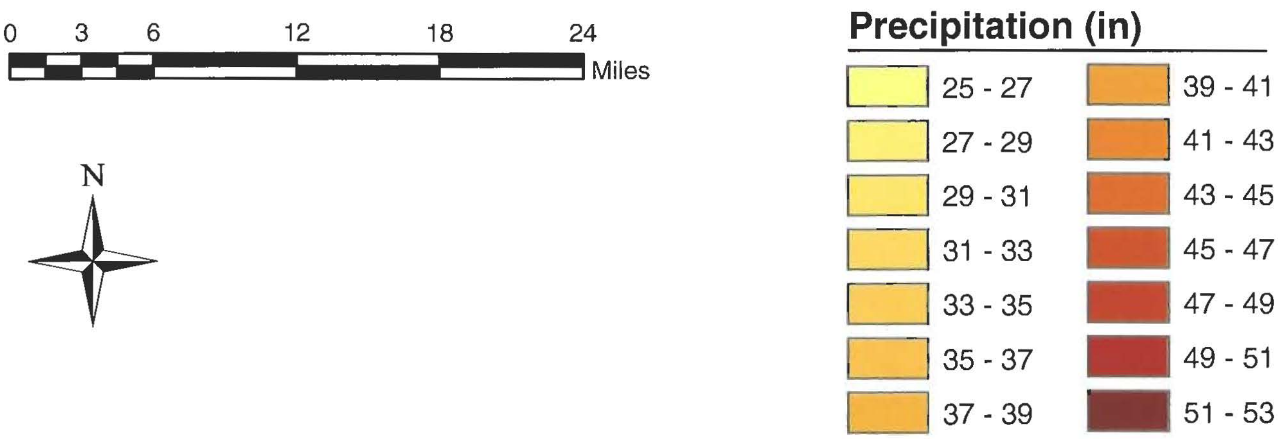


Figure 3b. 2002 precipitation distribution for USGS stream gage 05332500 watershed



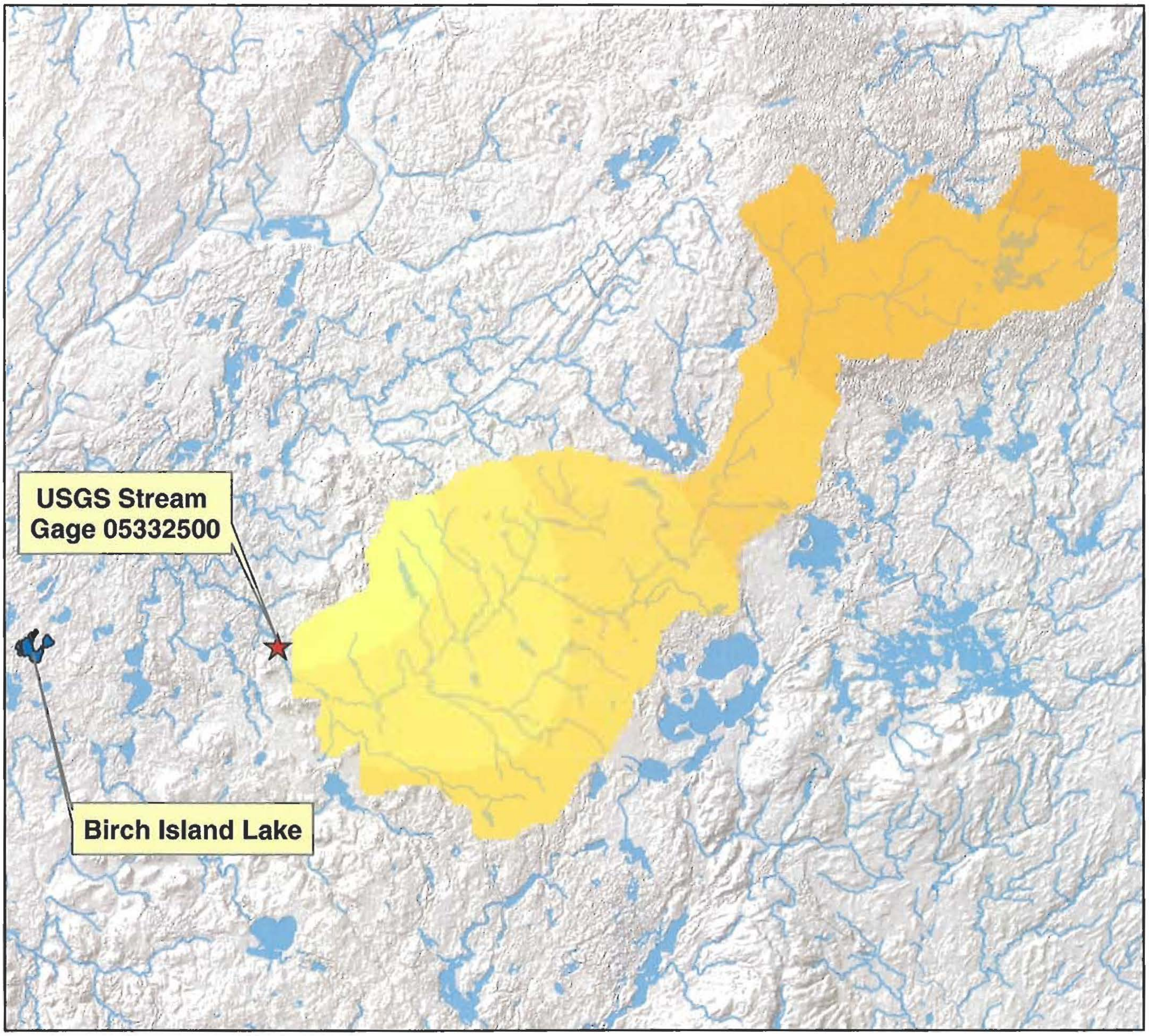
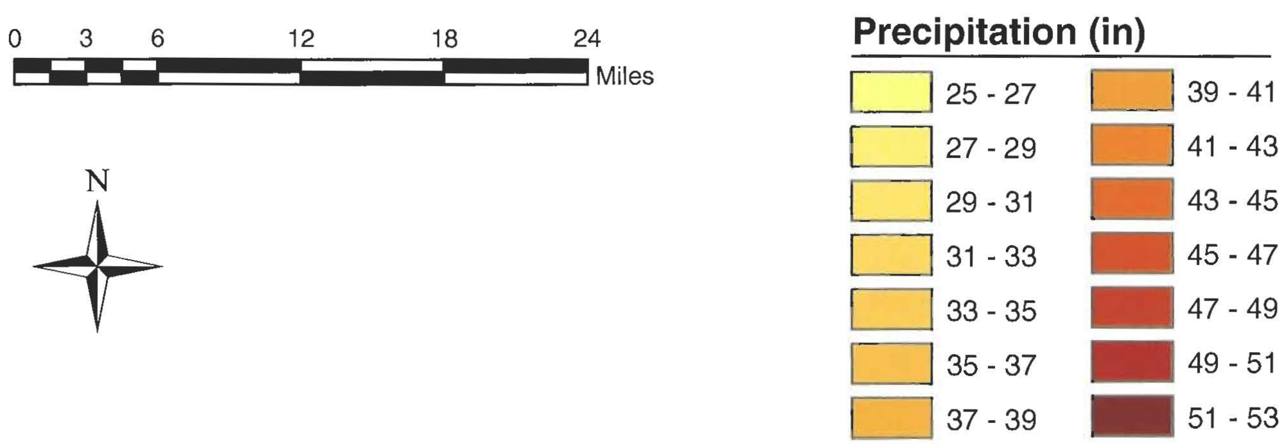
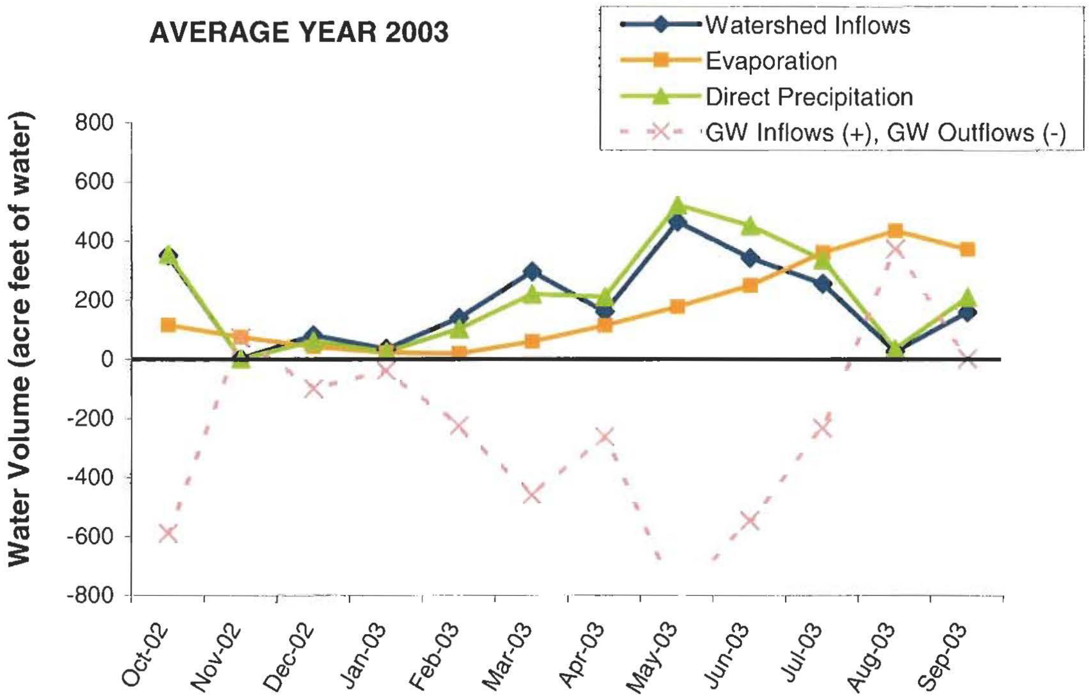


Figure 3c. 1998 precipitation distribution for USGS stream gage 05332500 watershed





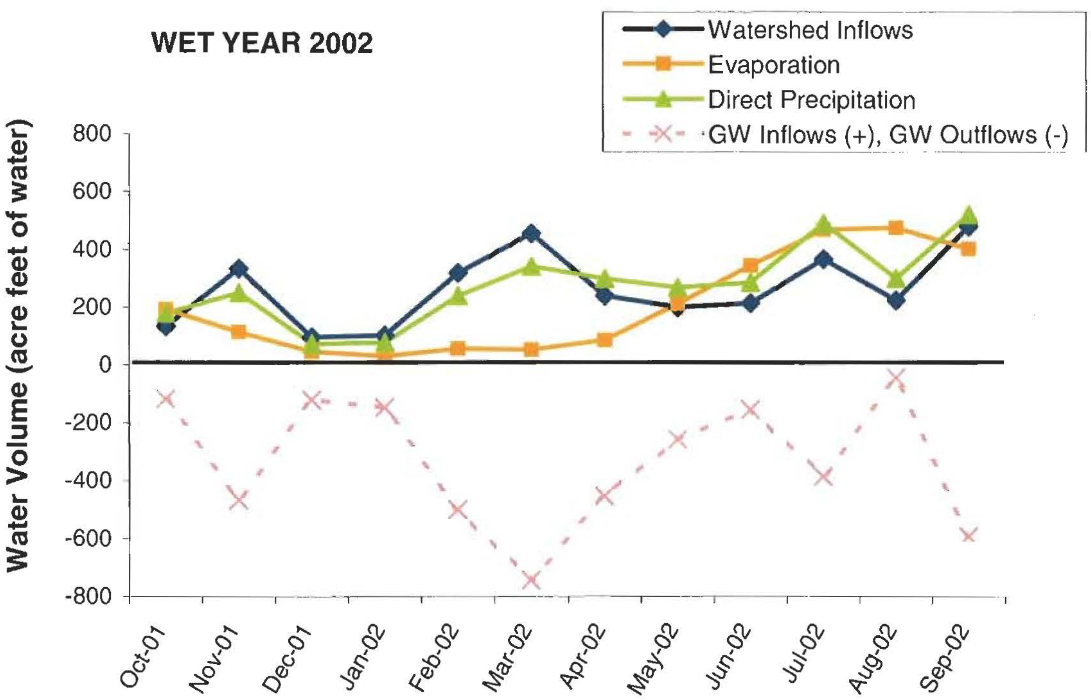


Figure 4. Birch Island Lake Monthly Water Balance for Average (2003), Wet (2002), and Dry (1998) Years Assuming a Constant Lake Surface Elevation

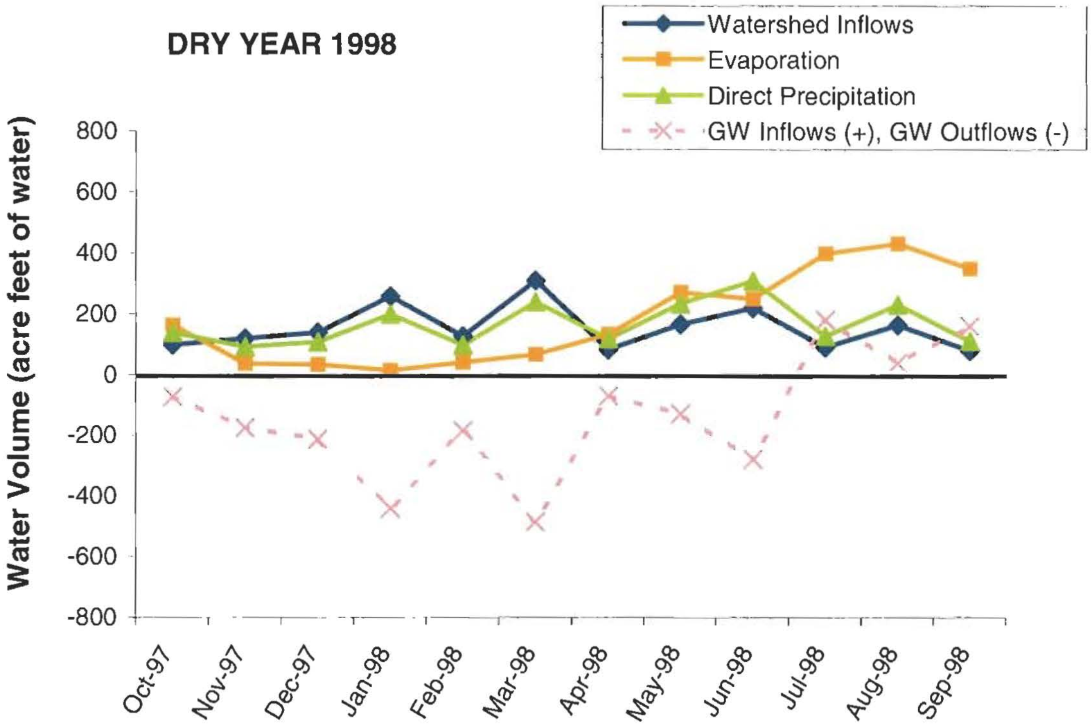


Figure 4 Continued….

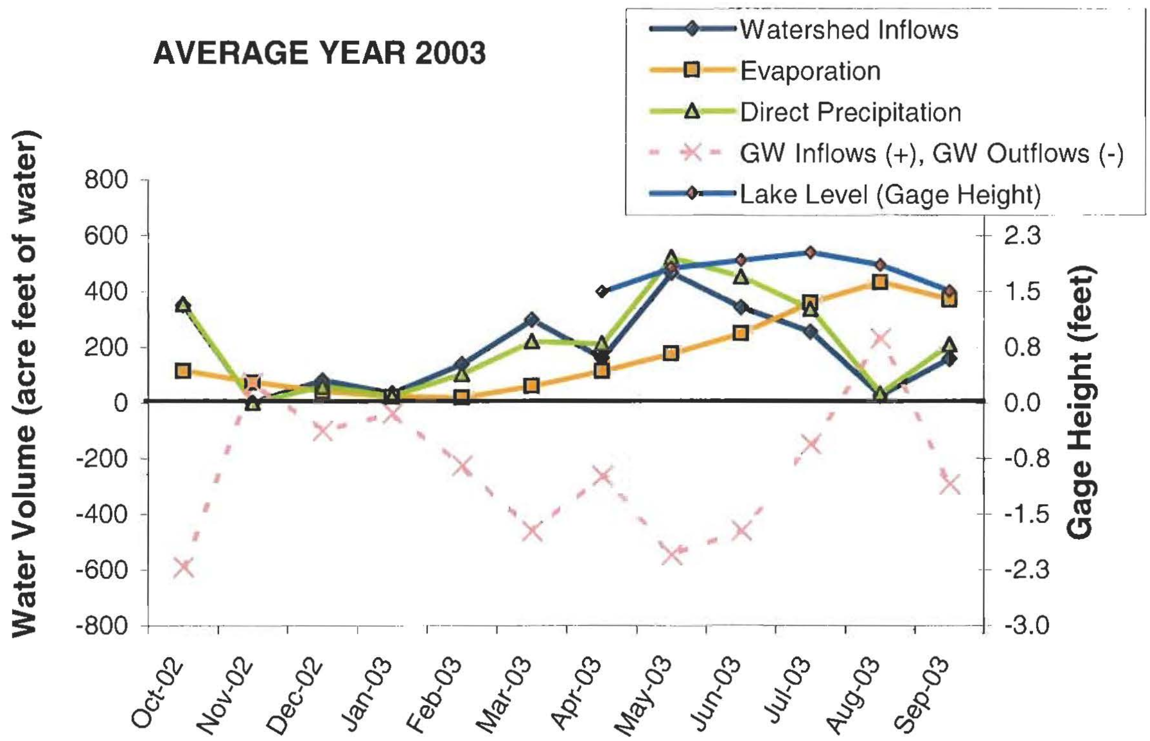


Figure 5. Birch Island Lake Average Precipitation Year (2003) Monthly Water Balance Incorporating Lake Level Data

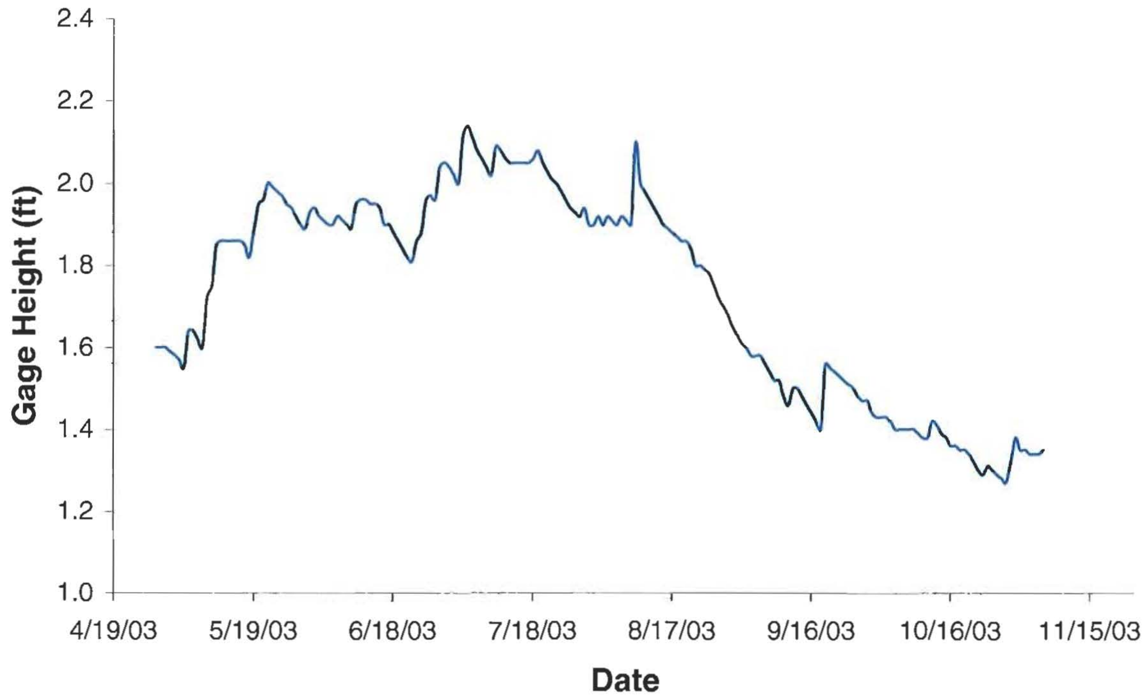
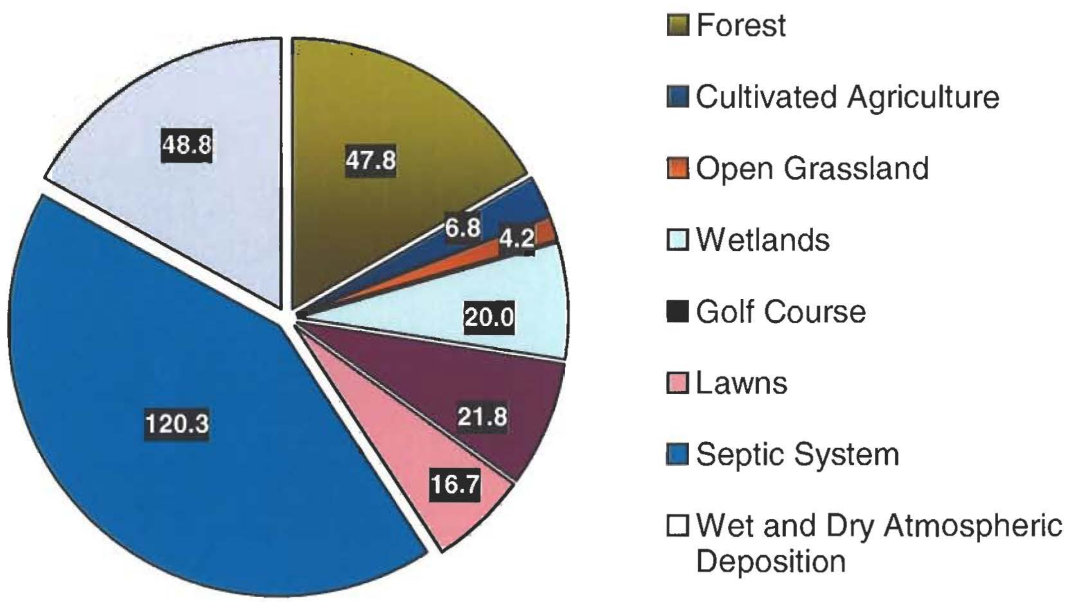


Figure 6. Change of Birch Island Lake Water Surface Height in 2003

Birch Island Lake Average Year (2003)



Birch Island Lake Wet Year (2002)

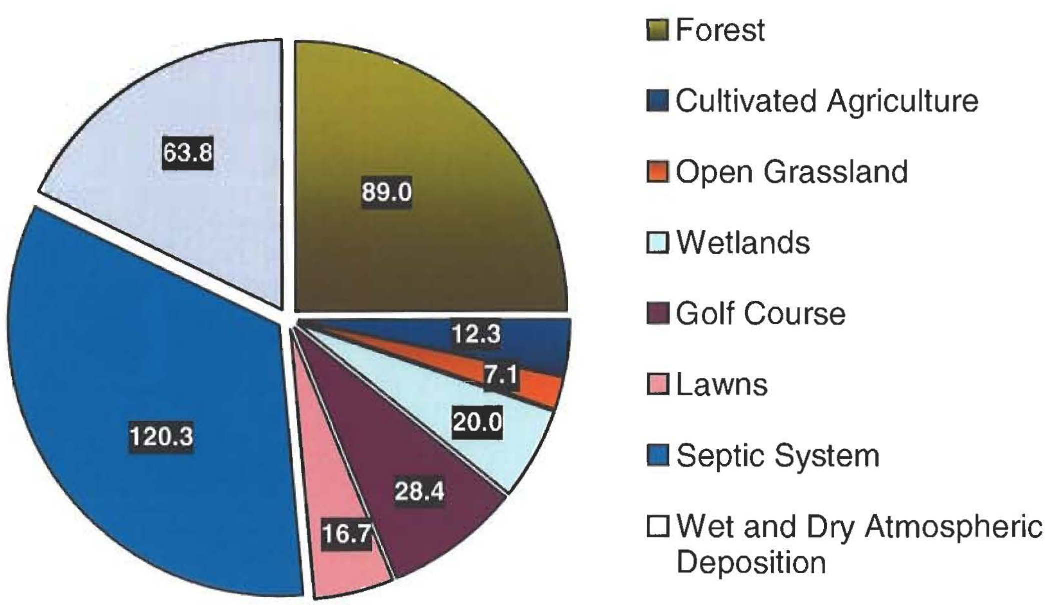


Figure 7. Annual Phosphorus Loading Budget for Birch Island Lake (kg/yr)

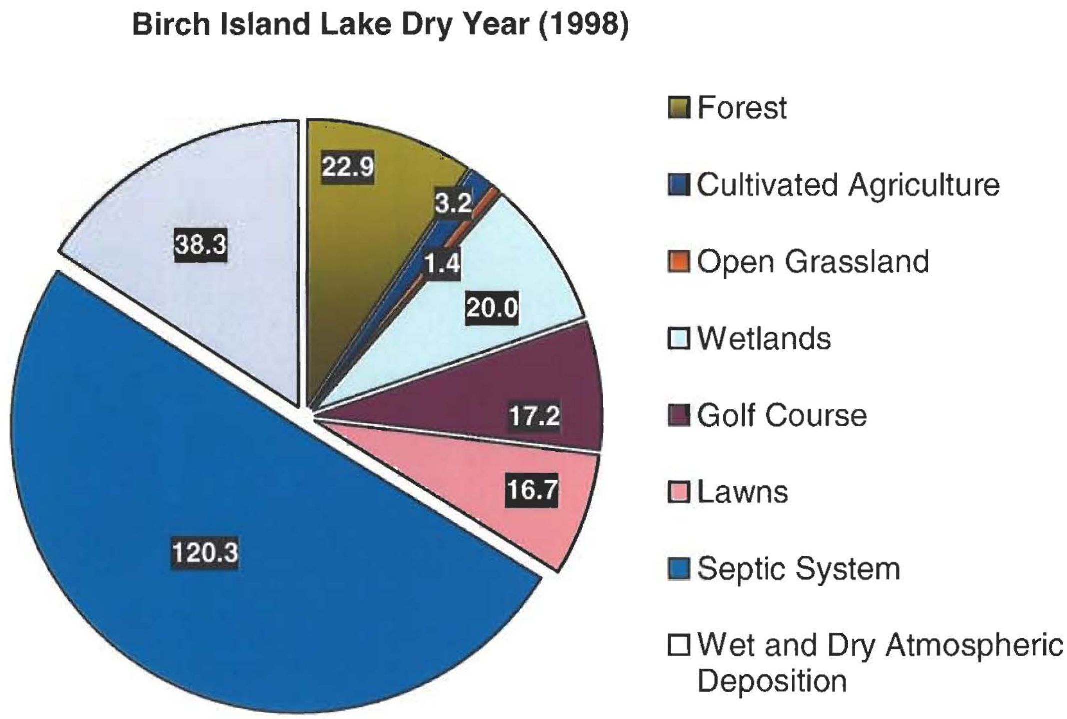


Figure 7. Annual Phosphorus Loading Budget for Birch Island Lake (kg/yr) Continued

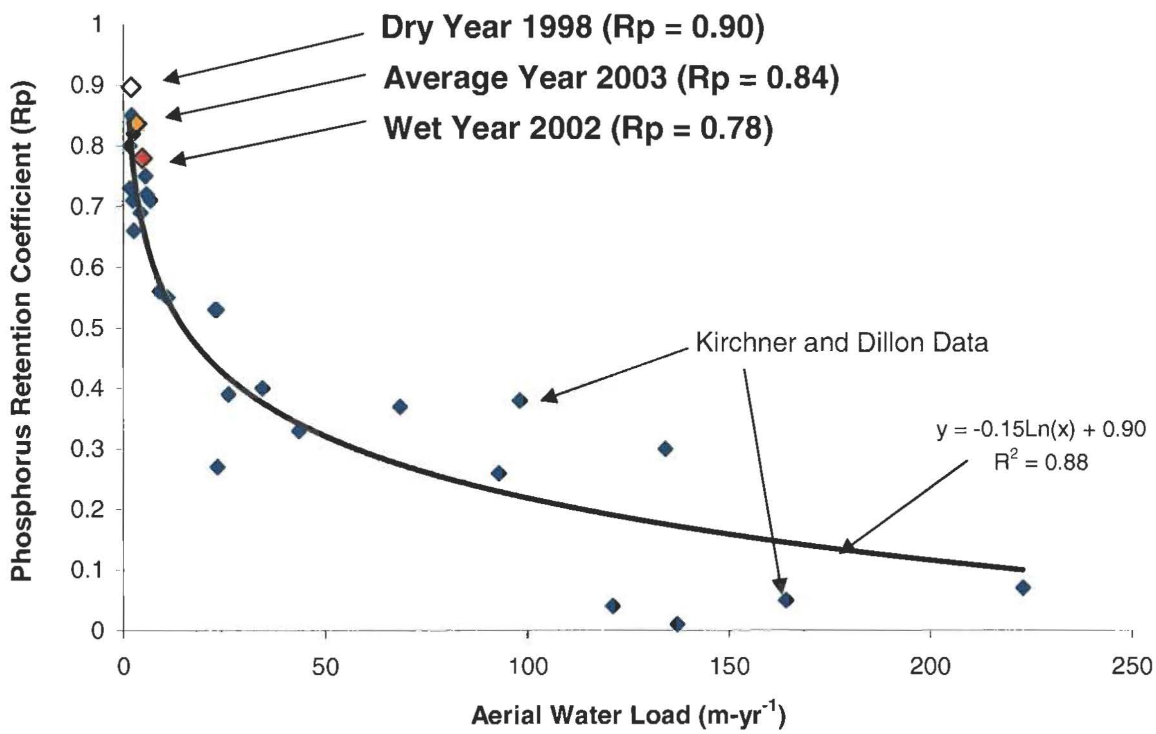


Figure 8. Comparison of the Calibrated Retention Coefficients for Birch Island Lake during Average, Wet, and Dry Years to the Retention Coefficients Published by Kirchner and Dillon (1975).

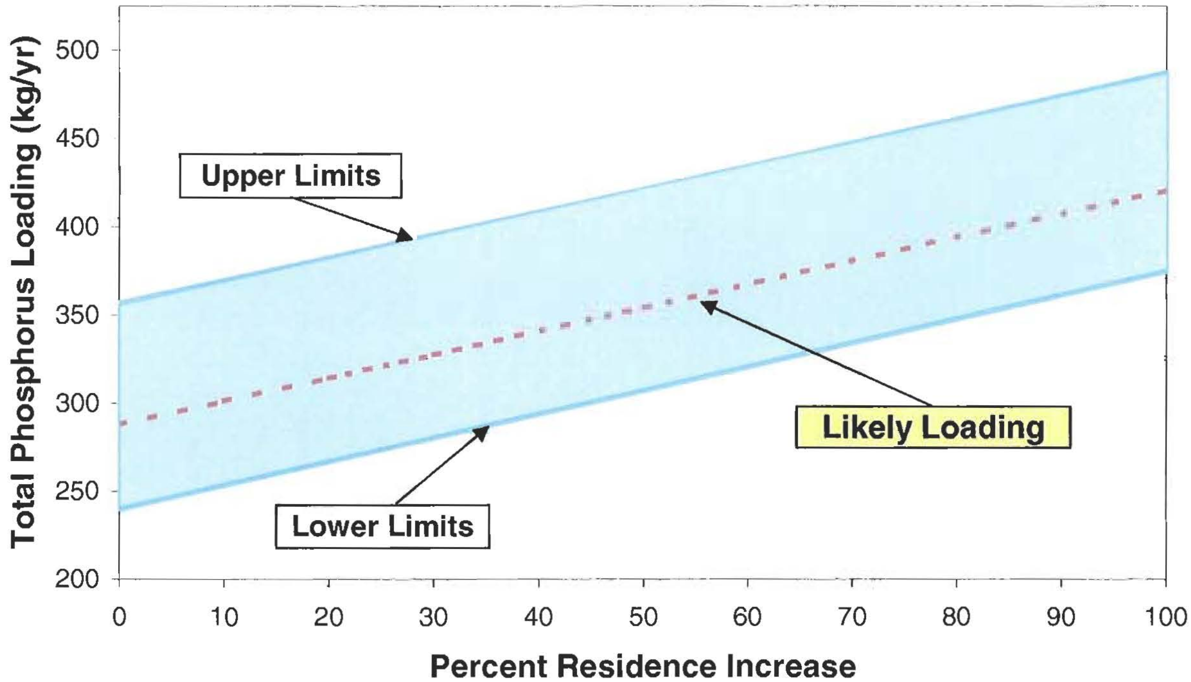


Figure 9. Expected Change in Phosphorus Loading to Birch Island Lake Corresponding With a Change in the Number of Residences Adjacent to This Lake.

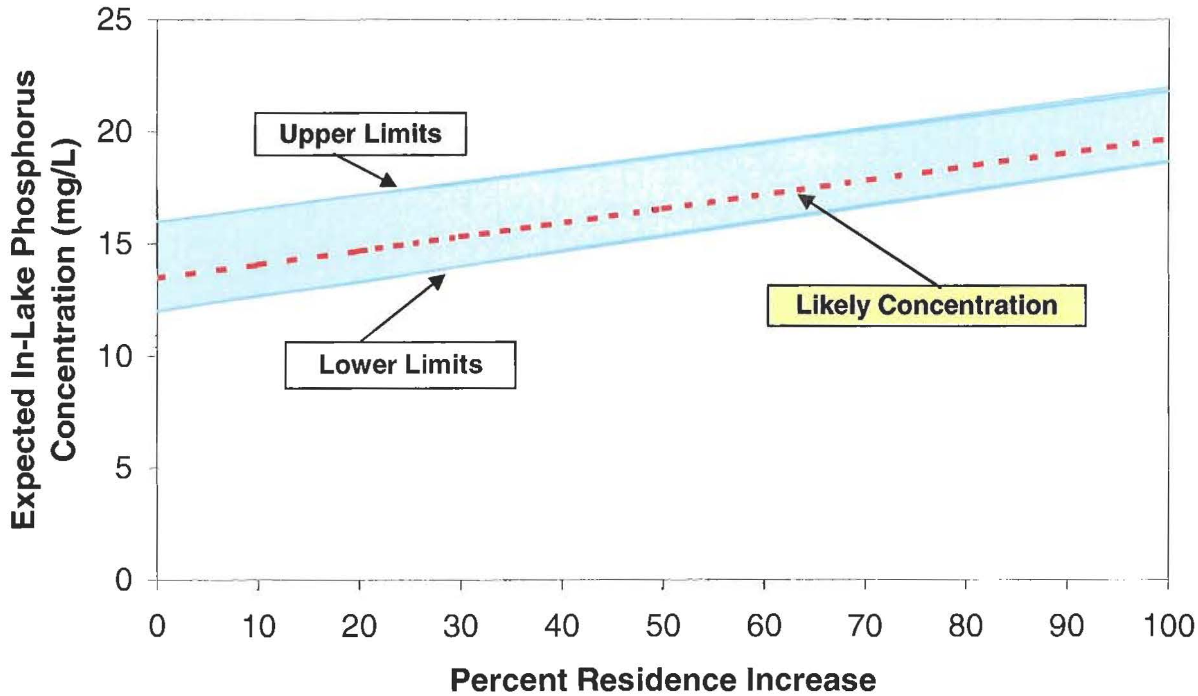


Figure 10. Expected Change in Phosphorus Concentration in Birch Island Lake Corresponding With a Change in the Number of Residences Adjacent to the Lake.

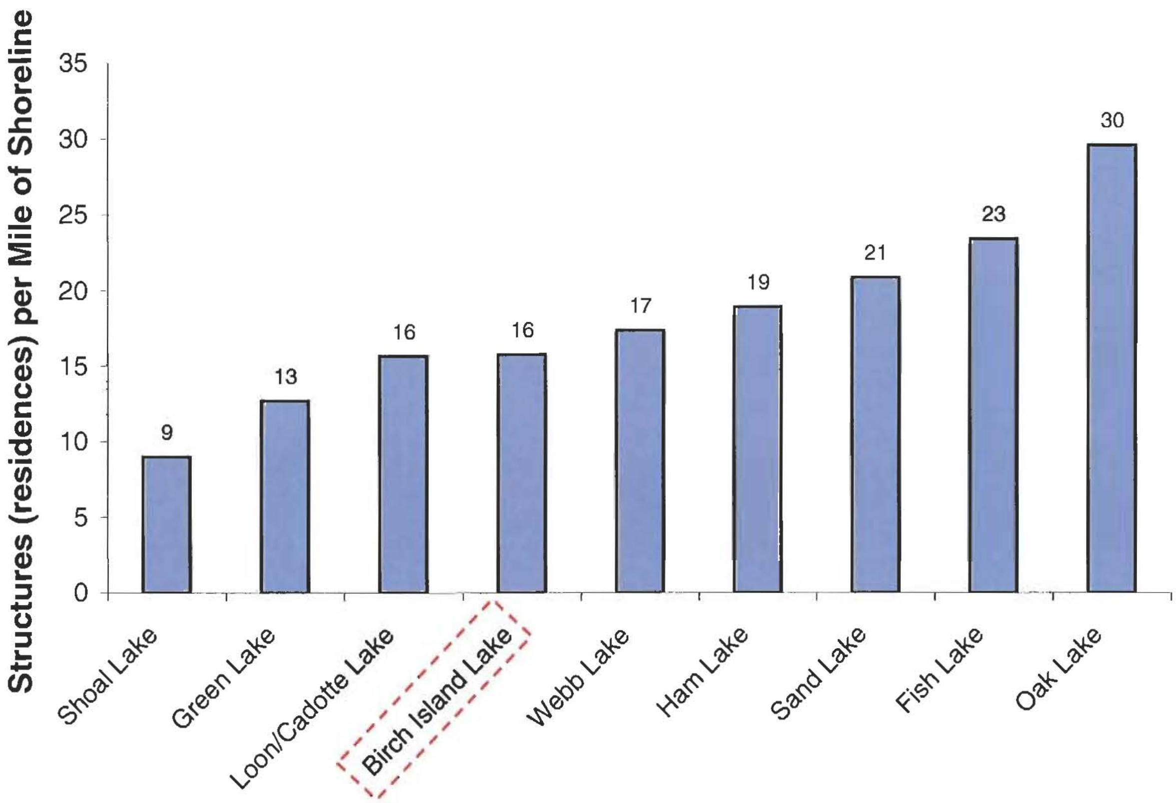


Figure 11. Approximate Number of Structures (residences on Several Lakes in Burnett County in Relation to the Total Shoreline Miles for Each Lake.

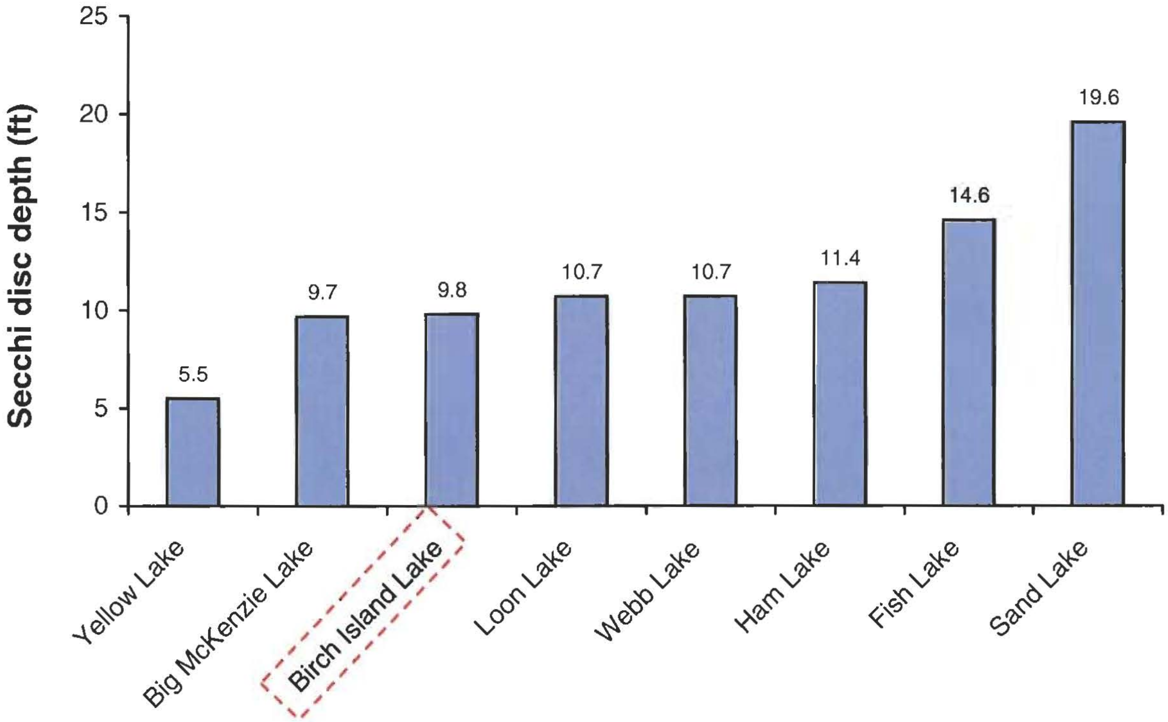


Figure 12. Comparison of Birch Island Lake Clarity, Measured as Secchi Disc Depth, to Other Lakes in North East Burnett County.

**Approximately 45% of Secchi disc depth measurements for Birch Island Lake reached lake bottom.*

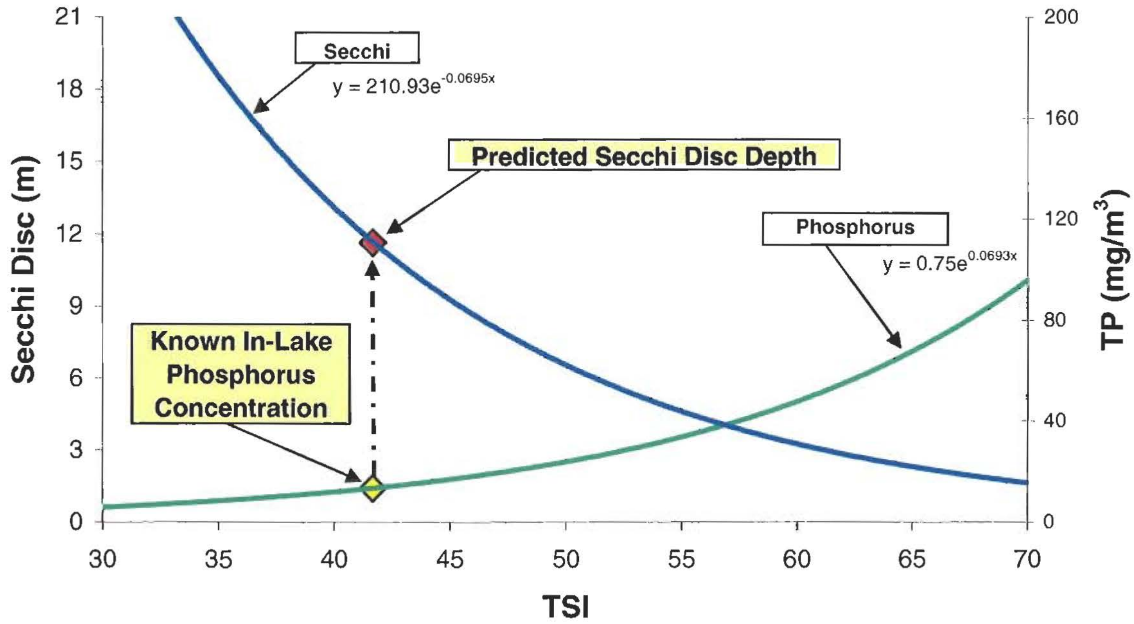


Figure 13. Correlation Between Secchi Disc Depth and Phosphorus Concentrations Using the Trophic State Index (TSI)

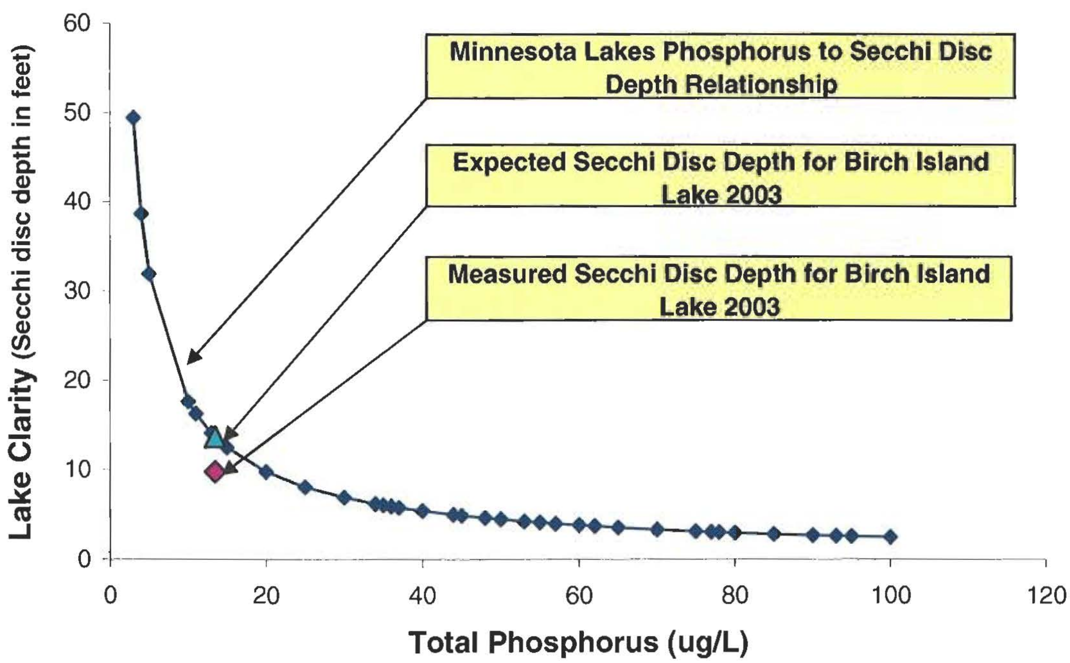
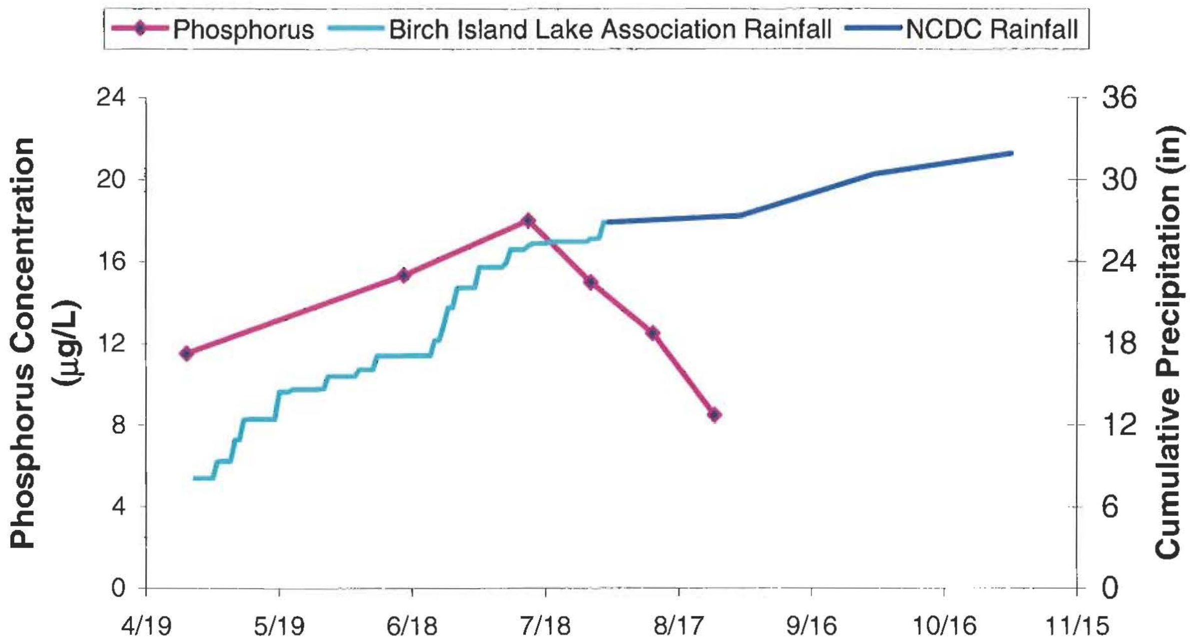


Figure 14. Relationship Between Total Phosphorus in a Lake's Water Column and Lake Clarity. **(Included in the Graph is the Average Summer Total Phosphorus and Secchi disc depth for Birch Island Lake for 2003)**

Average Year - 2003



Wet Year - 2002

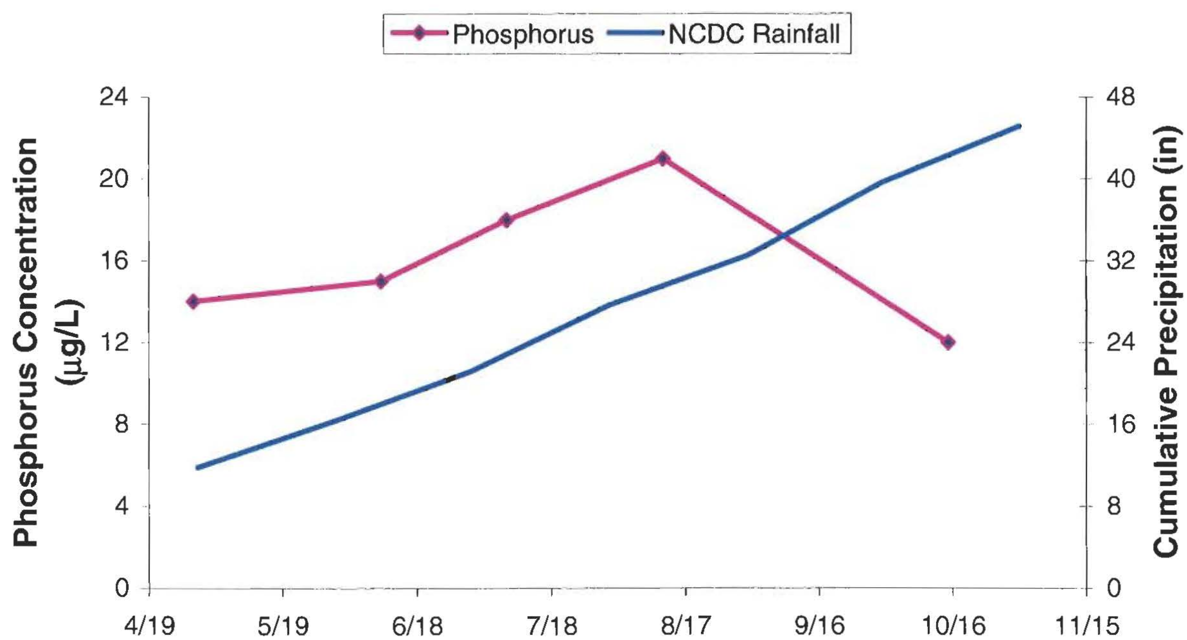


Figure 15. Concentration of Phosphorus in Birch Island Lake during an Average, Wet, and Dry Year and the Corresponding Cumulative Precipitation.

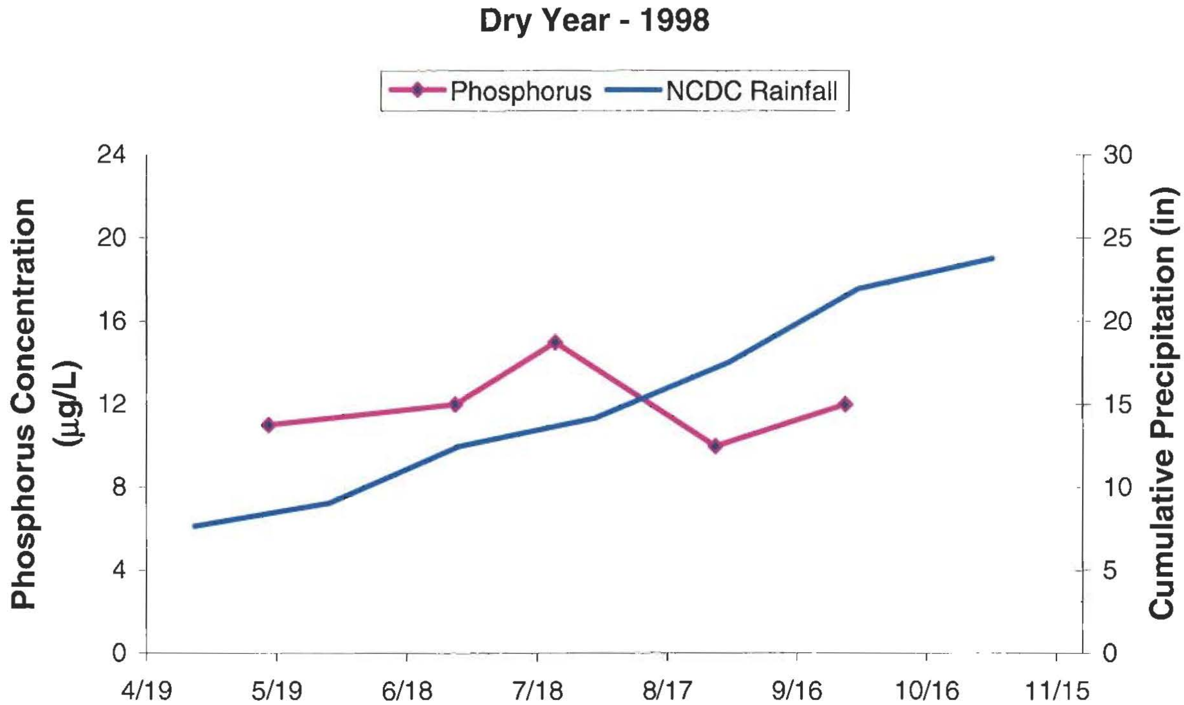


Figure 15 Continued....