Deer Lake Planning Grant II Report
Polk County, Wisconsin

Prepared for
Deer Lake Improvement Association

In Cooperation with
Polk County Land Conservation Department
Wisconsin Department of Natural Resources

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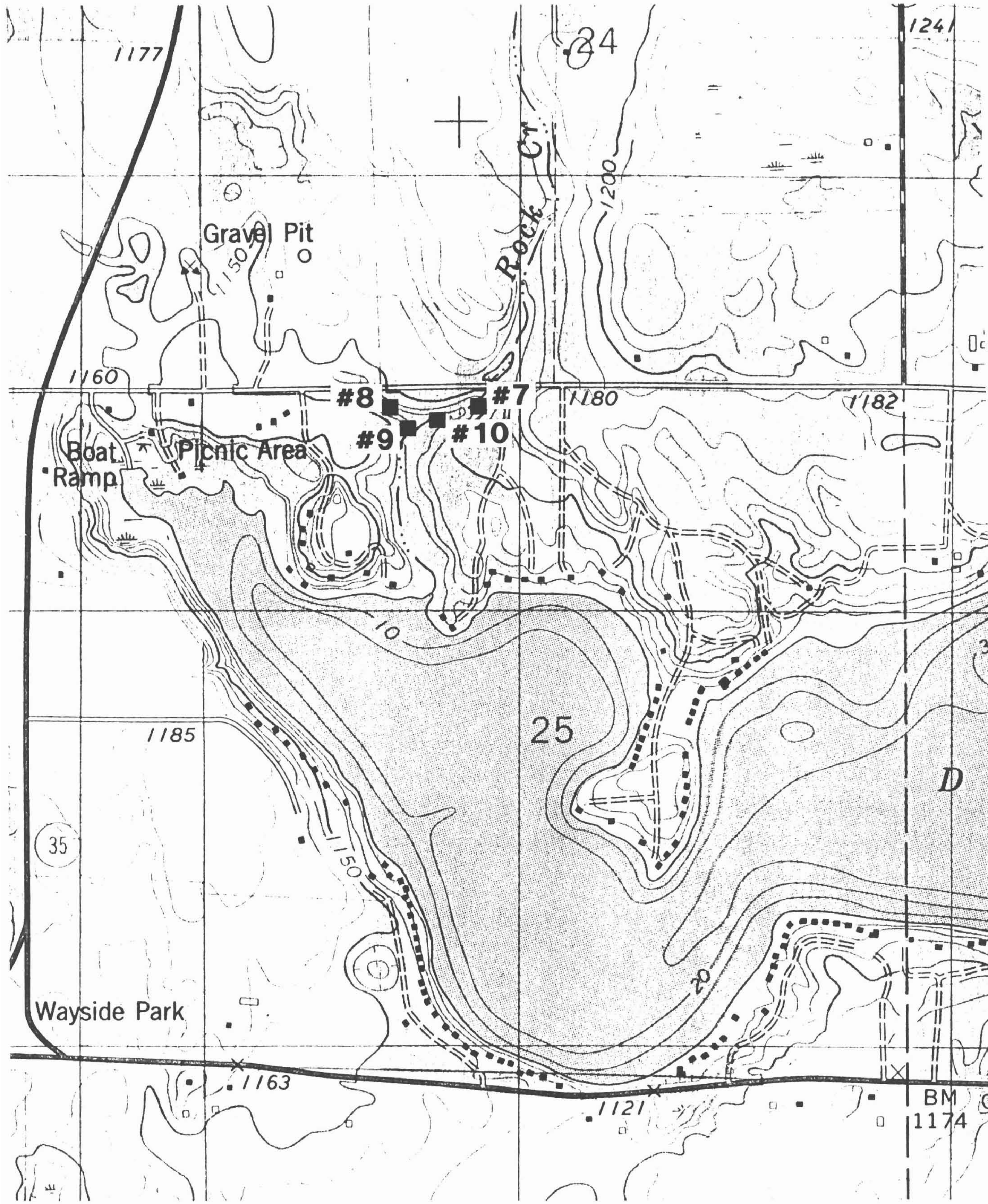

Source: Centuria and Balsam Lake, Wisconsin Quadrangle, 7.5 Minute Series, 1978.

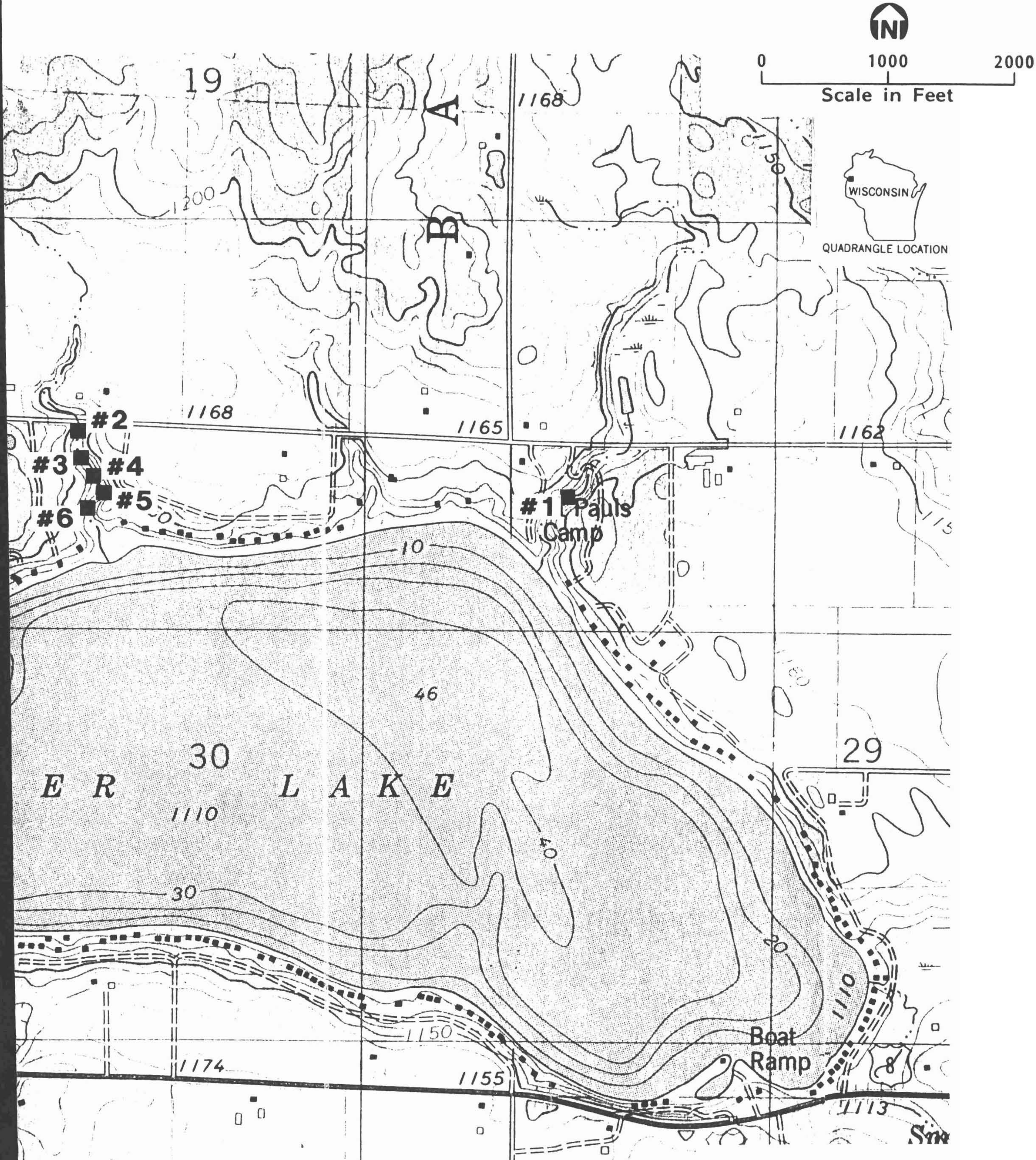

Figure 12

AREAS REQUIRING EROSION PROTECTION/STABILIZATION

1.0 Executive Summary

The study described by this report was initiated by the Deer Lake Improvement Association for the purpose of providing information to water resource managers and citizens regarding the management of Deer Lake. The study resulted in determining that Deer lake is a mesotrophic to slightly eutrophic lake, which experiences degraded water quality in the fall due to internal loads of phosphorus.

Hydrologic budgets constructed from study data indicate that the lake is strongly influenced by groundwater inflows during dry periods and by watershed inflows during wet periods (such as in 1994). The lake is at a trophic level where it is very sensitive to even slight increases in nutrient loads. The sources of nutrients which represent the greatest potential for degrading Deer Lake's water quality are the Lake's urban and agricultural watersheds. Water quality monitoring conducted on the stormwater and snowmelt runoff indicates that some tributaries are experiencing degraded water quality, likely due to agricultural sources.

Management recommendations include participation in the Priority Watershed Project and additional lake planning grant studies to assist the Priority Watershed Management Team. These efforts should focus on better quantifying and subsequently reducing the nutrient loadings from Watershed 1 as well as providing erosion protection and/or stabilization of Deer Lake's tributary streambanks.

2.0 Introduction

Deer Lake is located in Polk County, in western Wisconsin. The lake is located in the Balsam Branch of the Apple River Watershed system. The watershed is ultimately tributary to the St. Croix River.

Deer Lake is an important local recreational resource, popular for fishing and boating. The likely reason for the lake's popularity is its relatively good water quality. Water quality data from the Wisconsin Self Help Lake Monitoring Program, which is collected by volunteers of the Deer Lake Improvement Association, has shown that the lake is mesotrophic to slightly eutrophic in nature. Lakes within this classification typically exhibit relatively good water quality, however, they can be very susceptible to even minor increases in pollutant loads.

The Deer Lake Improvement Association recognized the importance of the maintaining Deer Lake's water quality and preventing its degradation. Therefore, the Association has initiated an application to the Wisconsin Lake Planning Grant Program to receive a $10,000 grant. The grant money was to be used to conduct a study of the lake and its watershed.

2.1 Summary of First Lake Planning Grant

The objectives of the first Deer Lake Planning Grant study (Barr, 1993) were as follows:

1. Provide a means to educate the public about lake water quality management.

2. Provide a guide to resource managers in their continuing efforts to protect the quality of Deer Lake.

3. Collect detailed information about Deer Lake and its tributary watershed.

4. Use the information to develop management strategies for future protection/restoration actions.

Results of the study indicated that Deer Lake is a mesotrophic to slightly eutrophic lake, which experiences degraded water quality in the fall, presumably, due to internal loads of phosphorus. Hydrologic budgets constructed from study data indicated that the lake is strongly influenced by groundwater inflows, especially during dry periods. The lake is at a trophic level where it is very sensitive to even slight increases in nutrient loads. The sources of nutrients which represent the greatest potential for degrading Deer Lake's water quality are the Lake's urban and agricultural watersheds. Water quality monitoring conducted on the stormwater and snowmelt runoff indicates that some tributaries are experiencing degraded water quality, likely due to agricultural sources.

Management recommendations included increased education of lake shore property owners, participation in the Priority Watershed Project and additional lake planning grant studies to assist the Priority Watershed Management Team. The recommendation included identifying means to retain/detain stormwater on Deer Lake's watershed and minimizing increases in nutrient loads associated with the projected increase of permanent residents on Deer Lake.

2.2 Goals of the Second Lake Planning Grant Study

The second Deer Lake Planning Grant Study has two main goals, these are to further define the significance of the internal phosphorus loads on spring and early summer water quality, and with more precision, quantify the loading of nutrients and water from Deer Lake's tributary watersheds.

The second study focused on collecting the following information:

- Winter and spring lake water quality data
- Collect additional snowmelt runoff data from the lakes five main tributary watersheds.
- Continued collection of the rainfall and staff gage data.
- Intensive storm event monitoring and continuous flow gaging on two of Deer Lake's five tributary watersheds. (Sample six storms during 1994, two spring, two summer and two fall.)

2.3 Lake and Watershed Description

The physical morphometry of Deer Lake is outlined in Table 1 and is shown on Figure 1. The lake consists of two basins; the larger East basin has a maximum depth of 45 feet, the West basin has a maximum depth of approximately 26 feet.

Deer Lake has five main watersheds in addition to its direct watershed; the areas are presented in Table 2. Watersheds 4 and 5 drain into the West basin, while Watersheds 1, 2 and 3 drain into the East basin. Watershed land use was not specifically addressed during this project; however, the watershed is generally agricultural in origin with a ring of seasonal and permanent homes immediately adjacent to the lake. A watershed map is also presented on Figure 1.

3.0 Results and Discussion

3.1 Watershed Runoff Water Quality

The results of the laboratory analyses of the storm runoff and snowmelt samples are presented in the sections below. The concentrations of several common contaminants found in runoff were monitored as part of the watershed study. It is important to understand the potential sources of each contaminant in order to interpret the results of the laboratory analyses. The sources are described below.

Phosphorus is the nutrient which limits algal growth in Deer lake and is present naturally in the environment. However, excess phosphorus added to a lake from the watershed may cause excessive, unpleasant algal growth. Potential sources of phosphorus include livestock feed lots, fertilizers, decaying plant matter (such as grasses and leaves), eroded soils, and malfunctioning septic systems. Total phosphorus, which provides an estimate of all the phosphorus forms present in a sample was measured during this study.

Nitrogen is also a naturally occurring nutrient important for aquatic plant growth. While phosphorus typically stimulates excess algal growth, in some cases nitrogen may play a part as well. Also, several forms of nitrogen will be present in runoff. These include: ammonia nitrogen, nitrate + nitrite nitrogen, and total Kjeldahl nitrogen. These nutrients were all measured as a part of this watershed study. A complex biological nitrogen cycle determines the form of nitrogen present in natural waters. For example, microbial decomposition of organic nitrogen waste will produce ammonia; however, over time another type of microbe may convert the ammonia to nitrate and nitrite. The relative concentrations of ammonia and nitrate + nitrite may give an indication of the nitrogen source and its proximity to the sampling site. Runoff from a nitrogen source in close proximity to the site may have high concentrations of ammonia relative to nitrate + nitrite; runoff from a more remote source may have higher concentrations of nitrate + nitrite relative to the concentration of ammonia (Minnesota Pollution Control Agency, 1989). Possible sources of nitrogen include fertilizers, malfunctioning septic systems, and animal wastes.

Total suspended solids was also measured as part of this study. Total suspended solids is a direct measurement of the concentration of suspended particulates, inorganic and organic, in water.

Particulate matter directly affects aquatic environments by decreasing light availability, interfering with the filter feeding mechanisms of aquatic animals, and covering bottom habitats (including spawning beds). Other pollutants are often adsorbed to the particulate matter. These pollutants include nutrients, pesticides, other organics, bacteria, and metals. Possible sources of total suspended solids include decaying plant matter (such as grasses and leaves), eroded soils, and animal waste.

It is important to note that the concentration of contaminants in runoff will often vary throughout the runoff event. In some cases the runoff produced early in a storm or snowmelt event will flush debris and other accumulated materials out of stream beds and culverts. This runoff may have much higher concentrations of contaminants than the runoff produced later in the storm event. In other cases, the runoff may have higher concentrations of contaminants later in the storm event, when water from non-point sources upstream reach the sampling site. Since the samples were composited from individual samples taken at specific flow intervals throughout each runoff event, the samples will generally approximate the average flow-weighted concentration of the runoff. The only case in which this will not hold true is when the runoff event continues beyond the time that the automatic sampler has filled the last sample bottle.

3.1.1 Snowmelt Event Sampling

Grab samples were collected during three snowmelt events on March 7, March 14, and March 21, 1994 from all five watersheds. Table 3 summarizes the water quality results of the snowmelt monitoring. Watershed 1 showed consistently high concentrations of nutrients, while Watershed 4 showed consistently low concentrations of nutrients and total suspended solids. Watersheds 2 and 5 also exhibited slightly elevated concentrations of nutrients. Watershed 5 consistently showed the highest total suspended solids concentrations. Watershed 3 also exhibited slightly elevated concentrations of nutrients from the third sampling. These data point out the variability in collection of grab sample data. A significant number of data points needs to be collected to ascertain the exact loading of nutrients from each of these watersheds.

Comparison of the snowmelt sampling results with that of 1993 (Barr, 1993) show no significant differences between the two study years. As in 1993, Watersheds 1 and 5 contribute larger nutrient and total suspended solids concentrations. Watershed 2 appeared to exhibit larger snowmelt runoff nutrient concentrations during this study period than during the 1993 study.

Since the watersheds of Deer Lake are primarily agricultural in origin, it is likely that the elevated concentrations observed in Watersheds 1, 2 and 5 have a agricultural source. The elevated concentrations observed in these watersheds could occur from several sources. These include: runoff from bare agricultural fields, application of manure to frozen fields, and runoff from feedlots and pasture areas. Comparison of the ratio between the total suspended solids and nutrient concentrations indicate that bare agricultural fields are likely the main source in Watershed 5, while animal waste is a more likely source of the pollutants observed in Watershed 1.

3.1.2 Storm Event Sampling

Flow-weighted composite samples were collected during summer storm runoff events between April 25 and October 17, 1994 from monitoring sites for Watersheds 1 and 4. The results of the laboratory analyses performed on the samples are presented in Table 3.

Examination of the data reveals that the concentrations of the various nutrients in the runoff from Watershed 1 were consistently higher than Watershed 4. With the exception of the July 19 storm event, total suspended solids concentrations from Watershed 1 were also significantly higher than Watershed 4. The relatively high concentrations of ammonia nitrogen in the runoff from Watershed 1 indicates that the sampling station is in close proximity to a pollution source.

Examination of the results from the July 19 storm event indicates that the relatively low constituent concentrations from Watershed 1 may have been diluted by the large volume of runoff on that date, while the relatively high constituent concentrations from Watershed 4 may have been due to a flush of debris and other accumulated materials out of the stream beds or other upstream nonpoint sources.

Comparison of the stormwater runoff sample results from this study with the data collected in 1992 (Barr, 1993) shows that no significant differences exist for either Watershed 1 or Watershed 4 over the two study years. The total phosphorus concentration observed in the July 7, 1992 sample was slightly higher than all of the 1994 samples. However, the other nutrient and total suspended solids concentrations closely resembled those in the 1992 sample.

With the exception of the April 25 storm event, the elevated concentrations of nutrients in the stormwater runoff samples are likely caused by the runoff from feedlots and pasture areas since most fields have been planted and have a cover crop prior to the sampled storm event. However, the study is not extensive enough to specify any particular location within the watershed which could be causing the pollution.

3.2 Rainfall and Lake Outlet Data

Rain gages accurate to within 1/100th of an inch were installed throughout Deer Lake's watershed and read daily by volunteers during the ice free period, to determine daily precipitation amounts. Table 4 shows the daily precipitation amounts recorded by each of the volunteers during 1994. Total average precipitation during the 1994 ice free period was 26.88 inches. This rainfall was considerably higher than the 14 inches measured during the 1992 study. During one very large storm on July 19, 1994, four out of the five volunteers measured rainfall amounts between 3.35 and 4.25 inches. The National Weather Service data from the Minneapolis/St. Paul airport was used during the winter months to determine total precipitation amounts for the unmonitored periods. According to the airport data, approximately seven inches (water equivalent) of snowfall occurred during the winter of 1993-94.

A staff gage was installed at the lake outlet and a rating curve developed for the outlet structure to determine the quantity of water leaving the lake. Deer Lake's outlet structure consists of a concrete structure with a sheet pile crest. A survey of the crest had previously been performed to determine its configuration in relation to the water surface profile. Discharge at the structure was measured on four occasions in 1994 and twice in 1992 to assist in calibrating a standard weir equation for discharge. The appropriate headlosses were included in the equation following methods recommended by Henderson (1966) for weirs with small water depths. The staff gage was accurate to within 0.02 feet and read on a daily basis during the open water period. Table 4 shows the staff gage readings recorded by the volunteers during 1994. The staff gage data show two very large peaks following the spring snowmelt period and the very large storm on July 19 along with several smaller peaks corresponding to the more modest rainfalls.

3.3 Water Quality Survey of Deer Lake

As mentioned previously, phosphorus may enter lakes and ponds from both external and internal sources. A relative review of the water quality from external nutrient sources, the five tributary watersheds, was described previously. Lakes can also receive phosphorus from an internal source, the lake's sediments. The lake sediments are an important source of phosphorus in many lakes because dead algae and weeds settle to the lake bottom and decompose. As they decompose nutrients are added to the lake sediments.

In many lakes, such as Deer Lake, the bottom waters of the lake become void of oxygen during the summer stratified period. The lack of oxygen results in a chemical/physical change to the bottom sediments which results in a release of phosphorus from the sediments. This process was observed to occur in Deer Lake and will be discussed in detail in the following paragraphs.

3.3.1 Deer Lake Water Quality

Deer Lake's mixing status is classified as dimictic, which means the water column is stratified during the summer months and circulates during the spring and fall overturn periods. However, from the temperature profiles for the East and West basins presented in Tables 5a and 5b, it is apparent that only the East basin is deep enough to stratify throughout the summer. The West basin appears to circulate freely from top to bottom throughout most portions of the summer and fall months. The fall circulation period in the East basin occurred in early September. Examination of the dissolved oxygen profiles, presented in Tables 5a and 5b, reveals the implications of the thermal structure in each basin. Circulation in the West basin ensures that the water column remains well-oxygenated throughout the summer. The dissolved oxygen concentration near the lake bottom was below 6 mg/L briefly during August; however, oxygen levels for the remainder of the summer were in excess of 6 mg/L. Stratification in the East basin implies that oxygen is not replenished into the lake hypolimnion (near-bottom layer) through wind mixing or photosynthesis. Therefore, oxygen is depleted by microbial decomposition and respiration. During July, August, and September the dissolved oxygen near the bottom of the basin was less than 1 mg/L. This level is unsuitable for fish and other aerobic (oxygen breathing) organisms. As stated previously, at low dissolved oxygen concentrations, the chemical environment of the lake sediments will favor release of dissolved phosphorus into the water column.

An attempt was made to quantify the amount of phosphorus being released from the sediments of the East basin during 1994. Examination of the near-sediment samples collected during July, August, and September from the East basin shows that the total phosphorus concentration is high - .374 mg/L, 0.547 mg/L, and 0.580 mg/L, respectively, at the 40 feet depth. These high concentrations indicate that phosphorus release from the sediment is occurring in the East basin during the latter part of the summer. While the sediment-released phosphorus remains sequestered in the hypolimnion during the summer, some is transported to the lake surface during late September and early October as the lake mixes (see Table 5a). This is discussed further in the following paragraphs.

The near-surface total phosphorus concentrations, chlorophyll *a* concentrations, and Secchi disc transparency during 1990 - 1994 for the East and West basins of Deer Lake were compared to Carlson's Trophic State Index; the results are plotted on Figures 2 through 7. The Trophic State Index can be used to estimate the trophic state of a lake (i.e., whether a lake is eutrophic, mesotrophic, or oligotrophic) based on its total phosphorus, chlorophyll *a* concentration and transparency.

The trophic state analysis of the East basin of Deer Lake is illustrated on Figure 2 through 4. The total phosphorus concentrations during June, July, and August were in the oligotrophic to mesotrophic range. The total phosphorus concentrations during September and October increased dramatically all five years. This increase was probably due to the transport of sediment-released phosphorus to the lake surface during the fall mixing period for dryer years, and from a combination of sediment-released phosphorus and the watershed phosphorus load during wetter than normal years. The addition of phosphorus to the lake's surface water stimulates algal growth, which causes a decrease in water transparency and an increase in the chlorophyll *a* concentration (which indicates algal abundance). The chlorophyll and transparency data indicate degraded water quality during the late summer and early fall of both 1993 and 1994 compared to previous years. Total annual precipitation during 1993 and 1994 was considerably higher than that of 1992. In general, the East basin of Deer Lake appears to be mesotrophic during the majority of the summer period and becomes characteristic of a eutrophic lake during September and October. The data collected as part of this study and the self help monitoring indicate that the cause of the annual degradation of late season water quality is the result of a internal load of phosphorus during dryer than normal years and from a combination of internal load and watershed phosphorus load during wet years.

The trophic status of the West basin of Deer Lake is illustrated on Figures 5 through 7. Based on the total phosphorus data, the West basin (like the East basin) also appears to be mesotrophic to slightly eutrophic. All three water quality parameters indicate degraded water quality during the late summer and early fall of both 1993 and 1994 compared to previous years. The total phosphorus concentrations gradually increased throughout the summer and fall each year. This increase was probably due to the transport of the watershed phosphorus load to the lake surface during these wetter than normal years.

3.3.2 Hydrologic and Nutrient Budgets

To determine the volume of surface runoff into Deer Lake from the lake's five watersheds, automated flowloggers were installed by Barr near culverts under Tipperary Road. Manning's equation was utilized to estimate the rates and volumes of water flow through each culvert. Each flowlogger was housed in an enclosure and placed on platforms constructed by the Deer Lake Association. Polk County Land Conservation Department personnel were trained by Barr in the operation of the flowloggers, and were responsible for bi-weekly downloading of flow data. Flow data was compiled from April 18 through October 26, 1994.

In order to estimate an annual yield of water from Deer Lake's watersheds, the measured watershed runoff volumes were divided by the watershed area of the respective watershed to compute a yield value expressed in inches of water. The runoff yield was divided by the total precipitation for the monitored period. The resultant number represents the runoff coefficient for the particular watershed. Watershed runoff volumes for areas which were not monitored were estimated by multiplying the ratio of the 1994:1992-93 runoff coefficients for Watershed 1 from both studies by the average coefficient from the earlier study. The runoff coefficients from Watershed 1 were used (instead of Watershed 4) for the rest of the watersheds because the 1994 coefficient experienced a mild (45%) increase over that of the previous study. Whereas, Watershed 4 contributed 20 times more runoff during 1994 than in the previous study period.

A hydrologic (water) budget for Deer Lake was determined by measuring or estimating the important components of the budget. The important components of the budget include:

- Precipitation
- Surface Runoff
- Lake Outflow
- Evaporation
- Groundwater Flow

Evaporation from the lake surface was estimated using the 1994 monthly evaporation rates observed by the Soil Science Department at the University of Minnesota, St. Paul campus. A pan coefficient was applied to the rates to account for the additional evaporation which typically occurs from the pan. The evaporation rates were applied on a monthly basis to the surface area of Deer Lake to estimate the amount of evaporation from the lake's surface.

Groundwater appears to be a large component to the hydrologic budget of Deer Lake. The groundwater inflow to Deer Lake was determined by solving the water balance equation for Deer Lake as presented below.

$$+/- GW = P + RO - OF - EVAP$$

Where:

GW = groundwater inflow or outflow

P = Direct Precipitation on the lake's surface

RO = Watershed Runoff

OF = Lake Outflow

EVAP = Evaporation from the Lakes Surface

The collection of data for the hydrologic budget of Deer Lake was a valuable exercise. The hydrologic budget for Deer Lake is presented on Figure 8. As the budget indicates, groundwater inflows and direct precipitation play an important role in providing water to Deer Lake, especially during dry years as occurred in 1992. The large inflow of groundwater into the lake indicates that effluent from leaking septic tanks and drain fields will likely reach Deer Lake. It underscores the importance of emphasizing the continued upgrade and maintenance of these systems.

Compared to the study in 1992, the larger amount of watershed runoff which reached the lake during 1994 indicates that watershed runoff had a much larger impact on the water quality of Deer Lake. The majority of the storm event runoff which reached the lake came from the direct watershed and Watersheds 2, 4 and 5. Watershed 2 is relatively steep and has very little depression storage, whereas, Watersheds 4 and 5 are the largest watersheds and experienced enough rainfall during 1994 to overcome the storage provided by the natural wetlands and other depressions. The influence of watershed runoff on the overall 1994 water budget of Deer Lake and the relatively poor water quality of the lake (compared to previous years) are interrelated. Typically, lakes which receive a majority of this water from watershed runoff, experience significantly poorer water quality than groundwater controlled lakes.

The hydrologic budget is an important factor in determining the breakdown of nutrient loads into Deer Lake. Because phosphorus is the parameter of most concern, the discussion of nutrient budgets will be limited to phosphorus only.

Numerous researchers have demonstrated the relationship between phosphorus loads, water loads and lake basin characteristics to the observed in-lake total phosphorus concentration. The relationship was used to predict the annual phosphorus load into Deer Lake based on mean summer surface phosphorus concentrations, the lake's hydrologic budget, and lake basin characteristics. The relationship has many forms, the equation used for Deer lake was adapted from one developed by Dillon and Rigler (1974), modified by Nurnberg (1984) and has the form of:

$$[P] = [L_A*(1-R)]/Q_s + L_{IL}/V$$

Where:

P =	is the mean phosphorus concentration
L_A =	amount of phosphorus added per unit surface area of lake from all sources except from the internal load of the lake
R =	the coefficient which describes the total amount of phosphorus retained by the sediments each year
Q_s =	the outflow of the lake divided by its surface area
L_{IL} =	mass of phosphorus added to the lake from internal loading
V =	total lake volume

In the case of Deer Lake, all variables of the equation were measured or could be computed based on data collected during the study except for L_A, the loading term. Therefore, it was possible to determine the annual load of phosphorus into Deer Lake by solving for L_A. The computation reveals that the annual phosphorus load into Deer Lake is approximately 2,528 pounds per year, based on 1994 data.

Phosphorus export rates, published by the U.S. EPA for septic systems, were used to estimate an annual load of 88 pounds per year from drain fields. An atmospheric wet and dry deposition rate published by Uttormark and Wall (1976) of 0.56 kg/ha/yr applied to the surface area of Deer Lake. The computation indicates that the atmospheric component of the load is approximately 405 pounds per year. The watershed snowmelt runoff component was estimated by computing the numeric average phosphorus concentration of each watersheds snowmelt runoff grab samples. Each value was applied to the estimate of snowmelt runoff water loading from the respective watershed. The result is an estimate of 900 pounds per year from the watershed snowmelt runoff. The watershed rainfall runoff component was estimated using the FLUX model (Walker, 1987) for both monitored watersheds and multiplying the average increase in the flow-weighted concentrations from 1994 to 1992 by the 1992 flow-weighted concentrations of the unmonitored watersheds. The result is an estimate of 488 pounds per year from the watershed rainfall runoff. Groundwater and internal loading comprise the remaining 647 pounds of phosphorus into the lake. Due to inconsistencies in the lab data and the limited scope of the project, there is insufficient information to differentiate between groundwater and internal loading of phosphorus. The results of the phosphorus loading budgets are presented on Figure 9 and in Table 6. The total watershed loading component of the phosphorus budget was further broken down and Figure 10 shows the contributions from each of the watersheds for both snowmelt and rainfall runoff. Based on the estimates, approximately 65 percent of the total watershed phosphorus load comes from snowmelt runoff with Watershed 5 being the largest contributor. On an annual basis, the individual rainfall and snowmelt runoff contributions to the total watershed load show that Watershed 5 and the direct watershed comprise 33 percent (27 percent from snowmelt runoff) and 31 percent, respectively. The percentage of the 1994 total watershed load coming from Watershed 1 was 9.4 percent despite the fact that the watershed represents less than 3.9 percent of the lake's watershed area. During dry years (like 1992), the total watershed load percentage coming from Watershed 1 would be approximately 15 percent.

As the budgets indicate, phosphorus inputs into Deer Lake primarily result from the watersheds, groundwater, internal and atmospheric sources. The data suggest that with increased watershed development the greatest potential for increased nutrient loads into Deer Lake will be from the lake's tributary watershed and drain fields.

4.0 Recommendations and Management Actions

The recommendations and management actions presented in this report are based on the evaluation of the Self Help Lake Monitoring Data, the Deer Lake Planning Grant Studies and designation of the Deer Lake Watershed as a priority watershed. The Priority Watershed Program is a multi-year effort to categorize the watershed's of lakes in the Balsam Branch watershed. The priority watershed project is being managed through the Polk County Land Conservation Department. Representatives from the Deer Lake Improvement Association are members of a advisory committee which is overseeing the priority watershed project.

The management recommendations are broken down into three main categories. These include:

1. Watershed 1 Recommendations
2. Erosion Protection/Stabilization Recommendations for Tributary Streambanks
3. Additional Work Tasks

4.1 Watershed 1 Recommendations

Results of the 1994 monitoring, as well as monitoring done in 1992 and 1993, showed that runoff from Watershed 1 had significantly higher total phosphorus concentrations than the remaining watersheds. A feedlot and an associated downstream wetland located south of the Tipperary Road are suspected of causing the elevated phosphorus concentrations in the surface water runoff from this watershed (see Figure 11). The following elements are recommended for significantly reducing the elevated nutrient concentrations in runoff from Watershed 1.

1. Some type of best management practice should be instituted to eliminate the feedlot, east of the wetland, as a source of phosphorus in runoff from Watershed 1. Available options for the feedlot include:

    - Construction of a runoff management system and/or waste storage structure to minimize pollution potential in runoff from the feedlot.

- Regrading the feedlot area to minimize runoff or divert runoff to another area that is not intimately connected to the outlet to Watershed 1 should be continued in 1995. In addition, Polk County LCD officials recommend two more monitoring sites be installed to quantify the nutrient loads coming into the adjacent wetland from the feedlot area and from the wetland north of Tipperary Road. Figure 11 shows the recommended monitoring locations.

3. Collect three sediment core samples (one near the south wetland outlet, one near the south wetland inflow point from the feedlot, and one in the north wetland) from the top few feet of the surficial sediments. The north wetland drains into the wetland south of the road via a 12-inch corrugated metal pipe and presumably does not have a significant source of phosphorus draining to it. Individual layers of soil from all three soil borings should be analyzed for total phosphorus to determine whether or not the surficial sediments of the wetland(s) are going to continue to be a source of phosphorus in surface water runoff even after runoff from the feedlot has been eliminated.

4. If analyses of the wetland soil borings indicate that the wetland(s) will continue to be a source of phosphorus in runoff from Watershed 1, even if feed lots best management practices are implemented, then a project should be initiated to excavate or seal off the wetland sediments that are high in phosphorus.

5. Following excavation of the wetland sediments (if necessary) or even if the wetland is not excavated, construction of an extended wet detention basin within the wetland boundary should be considered as a structural BMP option to provide treatment of stormwater runoff from Watershed 1. Extended wet detention would be provided by installing a slotted riser pipe on the upstream end of the culvert that drains the wetland. The elevation and slot design for the riser pipe would be designed to ensure that the county road north of the wetland would not be inundated by the design storm (presumably the 100-year event).

If, based on sediment core analyses from the wetland(s), it is determined that surficial sediments will need to be excavated from the wetland, then a Section 404 Permit would be required. According to the Federal Rules, the Section 404 Permit will be granted only if it can be shown that the wetland is contributing a significant portion of the total phosphorus and that there are no other feasible or practicable alternatives to excavating the wetland.

A Section 404 Permit would not required for the installation of the slotted riser pipe at the upstream end of the culvert draining the wetland as long as the construction activities do not involve the excavation or filling of the watershed's outlet to the lake.

4.2 Erosion Protection/Stabilization Recommendations for Tributary Streambanks

A field inspection of the tributary streambanks leading from the county road north of the lake to their respective outlets was conducted on December 2, 1994. The purpose of the visit was to identify areas which may require streambank protection or stabilization and to identify other areas where flow velocities in the channels could be reduced. Figure 12 shows the tributary areas which require some method of erosion protection/stabilization. Significant erosion was also occurring at some of the stormwater culvert outfalls. Area 1 is located within the Watershed 1 tributary streambank. Areas 2 through 6 are located within the Watershed 3 tributary streambank which also has several old tires beneath the culvert outlet at Tipperary Road and spread throughout the streambank reach. Areas 7 through 10 on Figure 12 are located just upstream from the confluence of the tributaries of Watersheds 4 and 5. Some of these areas could also be protected by reducing channel flow velocities with the installation of nearby check dams or by providing upstream detention systems and improved outlet protection. The Association should also continue to assist the Priority Watershed project in identifying further upstream tributary areas in need of restoration and protection.

No known permits would be required for the installation of erosion control practices along the tributary streambanks. However, approval from the present landowner or purchase of an easement within the tributary streambank would be required to complete the installation of erosion control practices.

4.3 Additional Work Tasks

It is recommended that the Deer Lake Association follow three parallel tracks in the process of implementing the recommendations of this report these include:

1. Actively participate in the Priority Watershed Project.

2. Actively implement and pursue the educational activities and programs.

3. Collect additional data on Deer Lake and its tributary watershed.

In conjunction with the Priority Watershed Project, the Polk County LCD encourages the Deer Lake Improvement Association to continue baseline data collection. This baseline data includes:

- Continued participation in the Self Help Monitoring Program
- Continued daily reading of the lake outlet gage
- Redistribute rain gages and continue collecting data
- Apply for a third Lake Planning Grant

The third study should focus on collecting the following information:

Data Collection

- Collect additional snowmelt runoff water quality data (including flows) from Deer Lake's five main tributary watersheds.

- Continued collection of the rainfall and staff gage data

- Intensive storm event monitoring and continuous flow gaging on Watershed 1 of Deer Lake. (Sample six storms during 1995, two spring, two summer and two fall from the outlet and inlets to the south wetland.)

- Collect early spring through late fall lake water quality data.

Implementation

- Collect three sediment core samples from the wetland areas near the Watershed 1 outlet to further define the sources of elevated phosphorus concentrations in the surface runoff.

- Prepare engineering feasibility report of corrective action for Watershed 1 water quality problems.

The third lake planning grant has two main goals, these are to further define the significance of the snowmelt runoff phosphorus loads on spring and early summer water quality, and to develop an engineering feasibility study to implement solutions for the obvious water quality problems of

Watershed 1. The study will be completed by the end of 1995 and the results can be incorporated by the Priority Watershed Committee in recommending and prioritizing corrective actions in Deer Lake's tributary watershed. The third grant application should be submitted early in 1995, or shortly thereafter.

The estimated costs for completing future work are as follows:

Estimated Future Costs Suitable for Lake Planning and Other Grants

Item	Cost
Data Collection	
Analysis of Snowmelt Runoff Samples	$1,300
Analysis of Watershed 1 Runoff Samples	$1,500
Installation, Maintenance and Rental of Watershed 1 Sampling Equipment	$9,300
Analyzing Sampler Data and Project Management	$4,700
Implementation	
Sediment Core Sampling and Analysis	$1,900
Engineering Feasibility Report and Wetland Permitting	$11,700
Total Cost	$30,400

The estimated timetable for the aforementioned work tasks and implementation of the recommended corrective actions is as follows:

Data Collection				Implementation				
Snowmelt Runoff Sampling	Watershed 1 Runoff Sampling	Installation, Maint. & Rental of Sampling Equipment	Analyzing Sampler Data; Project Mgmt.	Feasibility Report; Preliminary Recommendations; Const. Cost Estimate	Wetland Permitting	Final Design; Plans & Spec.	Bid Letting	Construction
1 month	9 months	9 months	10 months	1-2 months	1 month	1-2 months	1 month	1-3 months

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Nurnberg, G.K., 1984. The prediction of internal phosphorus load in lakes with anoxic hypolimnia. Limnol. Oceanogr. **29:** 111-124.

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Table 1

Deer Lake Physical Morphometry

Normal Elevation		1,109 feet (MSL)
Surface Area @ Normal		812 acres
Maximum Depth	- East Basin	45 feet
	- West Basin	26 feet
Volume @ Normal		20,762 acre-feet
Mean Depth (Volume/Surface Area)		25.6 feet
Watershed Area to Lake Area Ratio		7.1 : 1

Table 2

Deer Lake Watershed Areas

Direct (excluding lake)	1,157 acres
Watershed 1	222 acres
Watershed 2	145 acres
Watershed 3	350 acres
Watershed 4	2,241 acres
Watershed 5	1,649 acres
Total Watershed Area	5,764 acres

Table 3

Deer Lake Tributary Runoff
Water Quality Data

Date	Sampling Location	Field #	Total Phosphorus (mg/L)	Ammonia-N (mg/L)	Nitrate-Nitrite-N (mg/L)	Total Kjeldahl Nitrogen-N (mg/L)	Total Suspended Solids (mg/L)
07-Mar-94	Unnamed Trib. to Deer L.-Sec.29	W-1	0.91	2	0.377	4.6	6
	Unnamed Trib. to Deer L.-NE 1/4 Sec.30	W-2	0.66	1.03	0.413	4.5	16
	Unnamed Trib. to Deer L.-NW 1/4 Sec.30	W-3	0.43	0.065	0.265	1.9	5
	Rock Cr. East Fk. Trib. to Deer L.	W-4	0.24	<0.005	0.285	0.9	5
	Rock Cr. West Fk. Trib. to Deer L.	W-5	0.32	0.714	0.324	2.2	30
14-Mar-94	Unnamed Trib. to Deer L.-Sec.29	W-1	0.86	1.7	0.131	4	4
	Unnamed Trib. to Deer L.-NE 1/4 Sec.30	W-2	0.58	0.357	0.491	2.3	18
	Unnamed Trib. to Deer L.-NW 1/4 Sec.30	W-3	0.21	0.02	0.098	0.9	3
	Rock Cr. East Fk. Trib. to Deer L.	W-4	0.122	0.018	0.055	0.4	3
	Rock Cr. West Fk. Trib. to Deer L.	W-5	0.78	0.774	0.196	3.3	226
21-Mar-94	Unnamed Trib. to Deer L.-Sec.29	W-1	0.8	1.19	0.258	3.7	82
	Unnamed Trib. to Deer L.-NE 1/4 Sec.30	W-2	0.46	0.409	1.45	2.1	12
	Unnamed Trib. to Deer L.-NW 1/4 Sec.30	W-3	0.93	0.423	0.606	2.1	10
	Rock Cr. East Fk. Trib. to Deer L.	W-4	0.095	0.024	0.218	0.5	3
	Rock Cr. West Fk. Trib. to Deer L.	W-5	0.61	1.05	1.67	3.4	82
25-Apr-94	Unnamed Trib. to Deer L.-Sec.29	W-1	6.81	3.29	1.72	21	650
	Rock Cr. East Fk. Trib. to Deer L.	W-4	0.076	0.045	0.046	0.5	7
05-Jul-94	Rock Cr. East Fk. Trib. to Deer L.	W-4	0.39	0.163	0.486	1.6	76
19-Jul-94	Unnamed Trib. to Deer L.-Sec.29	W-1	4.42	1.39	1.92	11	280
	Rock Cr. East Fk. Trib. to Deer L.	W-4	2.44	0.271	0.225	9.8	1100
02-Sep-94	Unnamed Trib. to Deer L.-Sec.29	W-1	3.1	2.57	2.02	10.95	46
14-Sep-94	Unnamed Trib. to Deer L.-Sec.29	W-1	6.58	1.5	2.91	12.7	404
	Rock Cr. East Fk. Trib. to Deer L.	W-4	0.625	0.177	0.268	3	172
22-Sep-94	Unnamed Trib. to Deer L.-Sec.29	W-1	7.18	2.45	4.69	15.1	260
	Rock Cr. East Fk. Trib. to Deer L.	W-4	0.454	<0.027	0.256	1.64	78
07-Oct-94	Unnamed Trib. to Deer L.-Sec.29	W-1	9.48	5.58	2.59	27.15	128
17-Oct-94	Rock Cr. East Fk. Trib. to Deer L.	W-4	0.55	<0.027	0.072	1.4	88

Table 4

Deer Lake
1994 Staff Gage and Rainfall Summary

Date	Dam Gage Reading (ft)	Daily Precipitation (inches)					
		Gage #1 Swanson	Gage #2 Adamson	Gage #3 McKenzie	Gage #4 Lumsden	Gage #5 Peterson	Average
15-Apr-94		1.25	1.25			1.80	1.43
16-Apr-94							
17-Apr-94							
18-Apr-94							
19-Apr-94							
20-Apr-94							
21-Apr-94							
22-Apr-94							
23-Apr-94							
24-Apr-94							
25-Apr-94	0.60	2.00	1.94			1.20	1.71
26-Apr-94	0.62	0.40	0.50		2.50	1.97	1.34
27-Apr-94	0.70						
28-Apr-94	0.68	0.64	0.62			0.89	0.72
29-Apr-94	0.70						
30-Apr-94	0.70						
01-May-94	0.68						
02-May-94	0.66						
03-May-94	0.66						
04-May-94	0.65						
05-May-94	0.62						
06-May-94	0.61						
07-May-94	0.60						
08-May-94	0.59						
09-May-94	0.59						
10-May-94	0.58						
11-May-94	0.58						
12-May-94	0.54						
13-May-94	0.54						
14-May-94		0.76	0.78		0.80	0.80	0.79
15-May-94	0.57						
16-May-94	0.56						
17-May-94	0.54						
18-May-94	0.54						
19-May-94	0.52						
20-May-94	0.50						

Table 4 (Continued)

Deer Lake
1994 Staff Gage and Rainfall Summary

Date	Dam Gage Reading (ft)	Daily Precipitation (inches)					
		Gage #1 Swanson	Gage #2 Adamson	Gage #3 McKenzie	Gage #4 Lumsden	Gage #5 Peterson	Average
21-May-94	0.50						
22-May-94	0.50	0.10	0.10			0.12	0.11
23-May-94	0.50						
24-May-94	0.50						
25-May-94	0.50						
26-May-94	0.49						
27-May-94	0.48						
28-May-94	0.47						
29-May-94	0.50	0.36	0.40		0.60	0.43	0.45
30-May-94	0.50	0.12	0.40		0.60	0.36	0.37
31-May-94	0.49						
01-Jun-94	0.49						
02-Jun-94	0.49						
03-Jun-94	0.48						
04-Jun-94	0.48						
05-Jun-94	0.48	0.64	0.58	0.56	0.52	0.54	0.57
06-Jun-94	0.48						
07-Jun-94	0.48						
08-Jun-94	0.46						
09-Jun-94	0.44						
10-Jun-94	0.44						
11-Jun-94	0.44	0.08	0.20	0.24	0.10	0.12	0.15
12-Jun-94	0.45						
13-Jun-94	0.48	0.64	0.66	0.50	0.60	0.50	0.58
14-Jun-94	0.48						
15-Jun-94	0.47						
16-Jun-94	0.47						
17-Jun-94	0.48	0.30	0.30	0.28	0.30	0.25	0.29
18-Jun-94	0.48						
19-Jun-94	0.49						
20-Jun-94	0.50	0.30	0.32	0.24	0.26	0.56	0.34
21-Jun-94	0.50						
22-Jun-94	0.50						
23-Jun-94	0.49						
24-Jun-94	0.49						
25-Jun-94	0.48	1.00	1.15	1.20	0.80	0.48	0.93

Table 4 (Continued)

Deer Lake
1994 Staff Gage and Rainfall Summary

Date	Dam Gage Reading (ft)	Daily Precipitation (inches)					
		Gage #1 Swanson	Gage #2 Adamson	Gage #3 McKenzie	Gage #4 Lumsden	Gage #5 Peterson	Average
26-Jun-94	0.48						
27-Jun-94	0.48						
28-Jun-94	0.48						
29-Jun-94	0.46						
30-Jun-94	0.46						
01-Jul-94	0.46						
02-Jul-94	0.45						
03-Jul-94	0.44						
04-Jul-94	0.44	0.50	0.35	0.35	0.30	0.48	0.40
05-Jul-94	0.50	1.10	1.28	0.90	1.20	1.20	1.14
06-Jul-94	0.50						
07-Jul-94	0.50	0.20	0.24	0.35	0.40	0.29	0.30
08-Jul-94	0.50						
09-Jul-94	0.48						
10-Jul-94	0.47						
11-Jul-94	0.46						
12-Jul-94	0.46						
13-Jul-94	0.46						
14-Jul-94	0.46						
15-Jul-94	0.46						
16-Jul-94	0.45	0.66	0.82	0.80	0.80	0.22	0.66
17-Jul-94	0.46	0.72	0.70	0.75	0.70	0.51	0.68
18-Jul-94	0.46						
19-Jul-94	0.46	3.35	3.65	4.40	4.25	0.62	3.25
20-Jul-94	0.65						
21-Jul-94	0.65						
22-Jul-94	0.64						
23-Jul-94	0.63						
24-Jul-94	0.60						
25-Jul-94	0.59						
26-Jul-94	0.58						
27-Jul-94	0.57						
28-Jul-94	0.54						
29-Jul-94	0.52						
30-Jul-94	0.50						
31-Jul-94	0.50						

Table 4 (Continued)

Deer Lake
1994 Staff Gage and Rainfall Summary

Date	Dam Gage Reading (ft)	Daily Precipitation (inches)					
		Gage #1 Swanson	Gage #2 Adamson	Gage #3 McKenzie	Gage #4 Lumsden	Gage #5 Peterson	Average
01-Aug-94	0.50						
02-Aug-94	0.50						
03-Aug-94	0.50	0.44	0.40		0.36	0.28	0.37
04-Aug-94	0.52	0.68	0.62	0.40	0.42	0.46	0.52
05-Aug-94	0.50						
06-Aug-94	0.50						
07-Aug-94	0.48						
08-Aug-94	0.47						
09-Aug-94	0.46						
10-Aug-94	0.48	0.86	0.74	0.72	0.70	0.74	0.75
11-Aug-94	0.47						
12-Aug-94	0.47						
13-Aug-94	0.48						
14-Aug-94	0.48						
15-Aug-94	0.46						
16-Aug-94	0.44						
17-Aug-94	0.44						
18-Aug-94	0.44						
19-Aug-94	0.44	0.46	0.36	0.35	0.40	0.39	0.39
20-Aug-94	0.46						
21-Aug-94	0.46						
22-Aug-94	0.44						
23-Aug-94	0.44						
24-Aug-94	0.46						
25-Aug-94	0.44						
26-Aug-94	0.48	0.76	0.80	0.82	0.80	0.83	0.80
27-Aug-94	0.46						
28-Aug-94	0.46						
29-Aug-94	0.44						
30-Aug-94	0.46	0.70	0.66	0.60	0.50	0.54	0.60
31-Aug-94	0.46						
01-Sep-94	0.46						
02-Sep-94	0.46						
03-Sep-94	0.44	0.30	0.42	0.22	0.20	0.29	0.29
04-Sep-94							
05-Sep-94	0.44	0.10		0.20	0.30	0.14	0.19

Table 4 (Continued)

Deer Lake
1994 Staff Gage and Rainfall Summary

Date	Dam Gage Reading (ft)	Daily Precipitation (inches)					
		Gage #1 Swanson	Gage #2 Adamson	Gage #3 McKenzie	Gage #4 Lumsden	Gage #5 Peterson	Average
06-Sep-94	0.42						
07-Sep-94	0.42						
08-Sep-94	0.42						
09-Sep-94	0.42						
10-Sep-94	0.42						
11-Sep-94	0.42						
12-Sep-94	0.42	0.22	0.84	0.66	0.60	0.25	0.51
13-Sep-94	0.44			0.56	0.30	0.53	0.46
14-Sep-94	0.47	0.96	1.38	1.27	1.25	1.23	1.22
15-Sep-94	0.48			0.20	0.15	0.13	0.16
16-Sep-94	0.50						
17-Sep-94	0.48						
18-Sep-94	0.48						
19-Sep-94	0.48						
20-Sep-94	0.47						
21-Sep-94	0.46						
22-Sep-94	0.50						
23-Sep-94	0.50	1.55	1.56		1.15	1.56	1.46
24-Sep-94	0.48						
25-Sep-94	0.48						
26-Sep-94	0.48						
27-Sep-94	0.48						
28-Sep-94	0.48						
29-Sep-94	0.47						
30-Sep-94	0.46						
01-Oct-94	0.46						
02-Oct-94	0.45						
03-Oct-94	0.45	0.42		0.69	0.50	0.44	0.51
04-Oct-94	0.44						
05-Oct-94	0.46						
06-Oct-94	0.46						
07-Oct-94	0.47						
08-Oct-94	0.47						
09-Oct-94	0.47						
10-Oct-94	0.49						
11-Oct-94	0.47						

Table 4 (Continued)

Deer Lake
1994 Staff Gage and Rainfall Summary

Date	Dam Gage Reading (ft)	Daily Precipitation (inches)					
		Gage #1 Swanson	Gage #2 Adamson	Gage #3 McKenzie	Gage #4 Lumsden	Gage #5 Peterson	Average
12-Oct-94	0.44						
13-Oct-94	0.44						
14-Oct-94	0.42						
15-Oct-94	0.40						
16-Oct-94	0.42						
17-Oct-94	0.44	1.75					1.75
18-Oct-94	0.48						
19-Oct-94	0.49						
20-Oct-94	0.50						
21-Oct-94	0.50						
22-Oct-94	0.50						
23-Oct-94	0.52						
24-Oct-94	0.52						
25-Oct-94		0.73					0.73

Table 5a

Deer Lake—East Basin
1994 Lake Water Quality

Date	Depth (ft)	Total Phosphorus (mg/L)	Chl-a (μg/L)	Temp (Degrees F)	D.O. (mg/L)	Secchi Disc (ft)
03-Jan-94	3	0.033		35	15.2	
	5			35	14.2	
	10			36	12.0	
	15			36	11.8	
	20			36	10.6	
	25			36	10.0	
	30			38	8.8	
	35			38	4.8	
	40	0.026		38	4.3	
	43			39		
03-Feb-94	3			33	12.5	
	5			33	12.1	
	10			35	11.0	
	15			35	10.8	
	20			36	9.1	
	25			36	8.5	
	30			37	6.1	
	35			38	3.7	
	40			39	1.5	
	43					
07-Mar-94	3	0.023		35	10.9	
	5			35	11.0	
	10			36	9.9	
	15			37	9.7	
	20			37	7.7	
	25			37	7.0	
	30			37	6.6	
	35			39	2.3	
	40	0.019		39	1.0	

Table 5a (Continued)

Deer Lake—East Basin
1994 Lake Water Quality

Date	Depth (ft)	Total Phosphorus (mg/L)	Chl-a (μg/L)	Temp (Degrees F)	D.O. (mg/L)	Secchi Disc (ft)
21-Mar-94	3	0.008		38	13.2	
	5			39	14.3	
	10			40	14.6	
	15			40	13.3	
	20			40	13.2	
	25			39	9.9	
	30			39	9.6	
	35			40	3.0	
	40	0.017		40	2.2	
25-Apr-94	3	0.069		45	10.0	
	5			46	10.0	
	10			46	10.0	
	15			46	10.0	
	20			46	9.8	
	25			46	9.3	
	30			46	9.4	
	35			46	9.7	
	40	0.028		46	9.8	
25-May-94	3	0.011	**6.1**	68	9.7	**20.0**
	5			67	9.4	
	10			67	9.6	
	15			65	9.8	
	20			63	9.6	
	25			60	9.7	
	30			55	8.4	
	35			52	4.0	
	40	0.035		52	2.2	

Table 5a (Continued)

Deer Lake—East Basin
1994 Lake Water Quality

Date	Depth (ft)	Total Phosphorus (mg/L)	Chl-a (µg/L)	Temp (Degrees F)	D.O. (mg/L)	Secchi Disc (ft)
20-Jun-94	3	0.007		69	9.5	12.0
	5			69	9.5	
	10			68	8.9	
	15			68	8.9	
	20			68	8.8	
	25			66	8.4	
	30			64	6.2	
	35			64	3.5	
	40	0.011		58	2.0	
28-Jul-94	3	0.010	9	73	8.4	**8.7**
	5			73	10.0	
	10			73	8.9	
	15			73	8.7	
	20			73	8.8	
	25			71	5.4	
	30			64	1.6	
	35			62	1.8	
	40	0.374		57	0.5	
29-Aug-94	3	0.019	15.5	76	13.0	4.8
	5			76	11.8	
	10			75	10.0	
	15			73	8.0	
	20			72	7.6	
	25			72	6.6	
	30			69	3.1	
	35			62	0	
	40	0.547		60	0	

Table 5a (Continued)

Deer Lake—East Basin
1994 Lake Water Quality

Date	Depth (ft)	Total Phosphorus (mg/L)	Chl-a (µg/L)	Temp (Degrees F)	D.O. (mg/L)	Secchi Disc (ft)
20-Sep-94	3	0.028	29.9	67	7.0	5.5
	5			68	7.2	
	10			68	7.0	
	15			68	7.1	
	20			68	6.9	
	25			68	6.6	
	30			68	3.7	
	35			65	1.2	
	40	0.580		61	0	
27-Oct-94	3	0.039	39	52	11.4	
	5			52	11.3	
	10			52	11.3	
	15			52	11.2	
	20			52	11.3	
	25			52	11.0	
	30			52	11.0	
	35			52	11.6	
	40	0.043		52	11.8	

Numbers in BOLD from Tim Asplund, Wisconsin DNR Bureau of Research, personal communication.

Table 5b

Deer Lake—West Basin
1994 Lake Water Quality

Date	Depth (ft)	Total Phosphorus (mg/L)	Chl-a (µg/L)	Temp (Degrees F)	D.O. (mg/L)	Secchi Disc (ft)
28-Jul-94	3	0.021	11.1	73	9.6	**6.7**
	9			73	8.8	
	12			73	9.1	
	15			73	8.3	
	20			73	8.2	
	25	0.029		71	6.7	
29-Aug-94	3	0.024	16.6	76	12.1	4
	9			75	11.8	
	12			75	11.0	
	15			74	9.8	
	20			73	9.2	
	25	0.050		71	5.2	
20-Sep-94	3	0.034	31.2	67	7.3	5.5
	9			67	8.1	
	12			67	8.2	
	15			67	8.0	
	20			67	7.7	
	25	0.033		67	7.2	
27-Oct-94	3	0.037	39.4	52	11.6	
	9			51	11.6	
	12			51	11.6	
	15			51	11.6	
	20			50	11.8	
	25	0.043		50	11.2	

Numbers in BOLD from Tim Asplund, Wisconsin DNR Bureau of Research, personal communication.

Table 6

1994 Deer Lake Phosphorus Budgets

Phosphorus Sources	Load (lbs)
Drain Fields/Septic Systems	88
Atmospheric Deposition	405
Watershed Loading	1,388
Groundwater and Internal	647
Total Load	2,528

Deer Lake-East Basin 1990-1994
Near-Surface Total Phosphorus

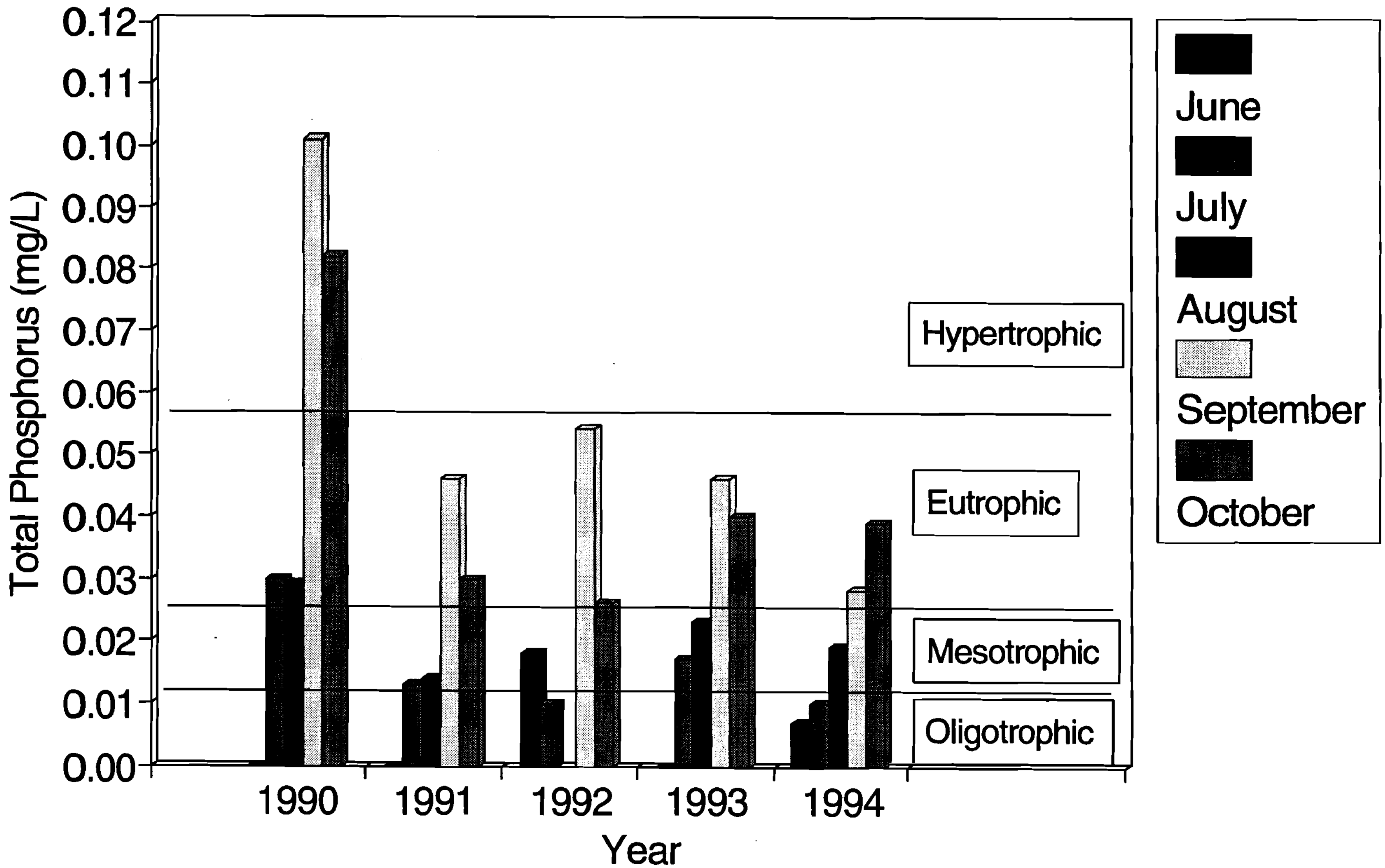


Figure 2

Deer Lake-East Basin 1990-1994
Near-Surface Chlorophyll

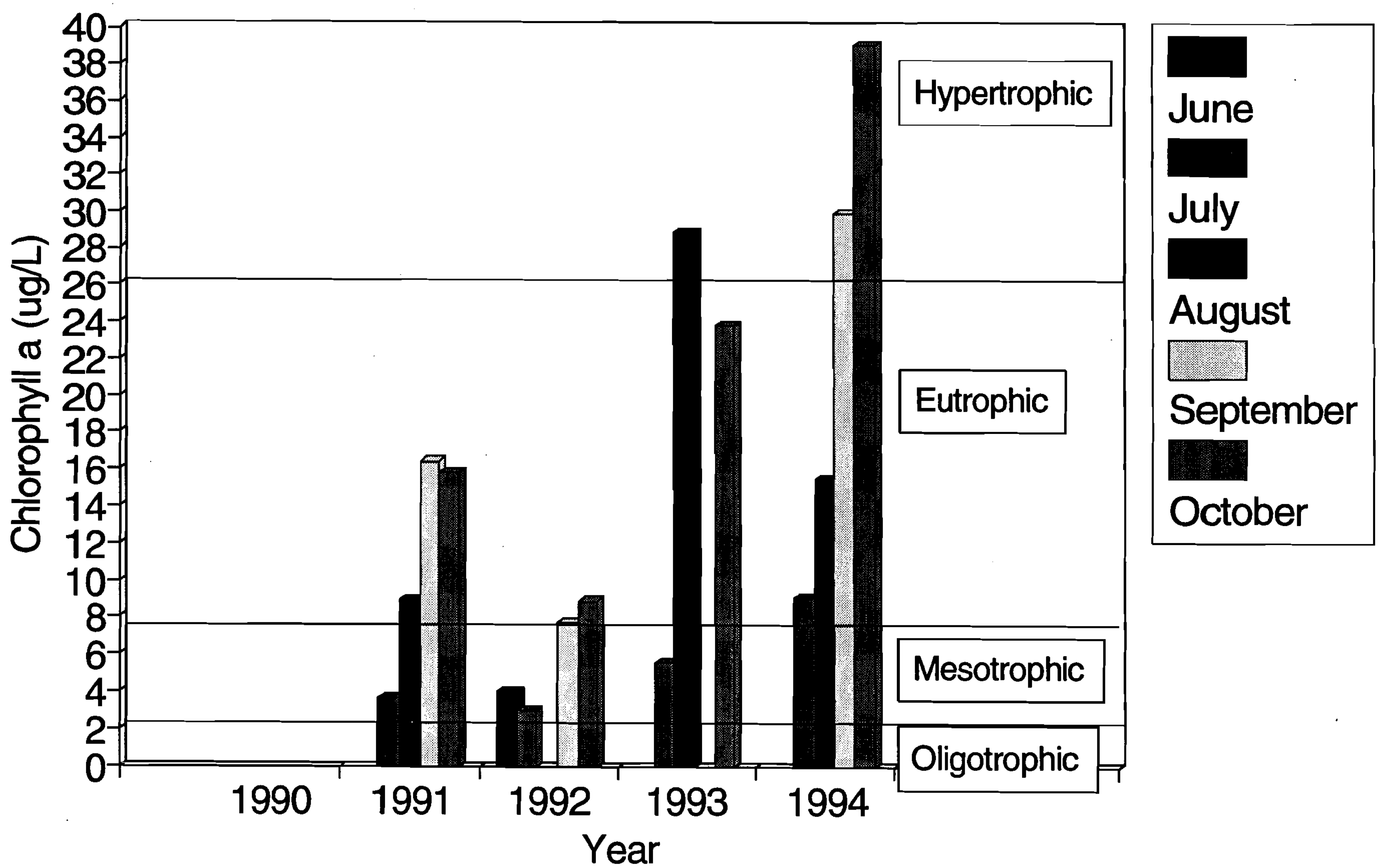


Figure 3

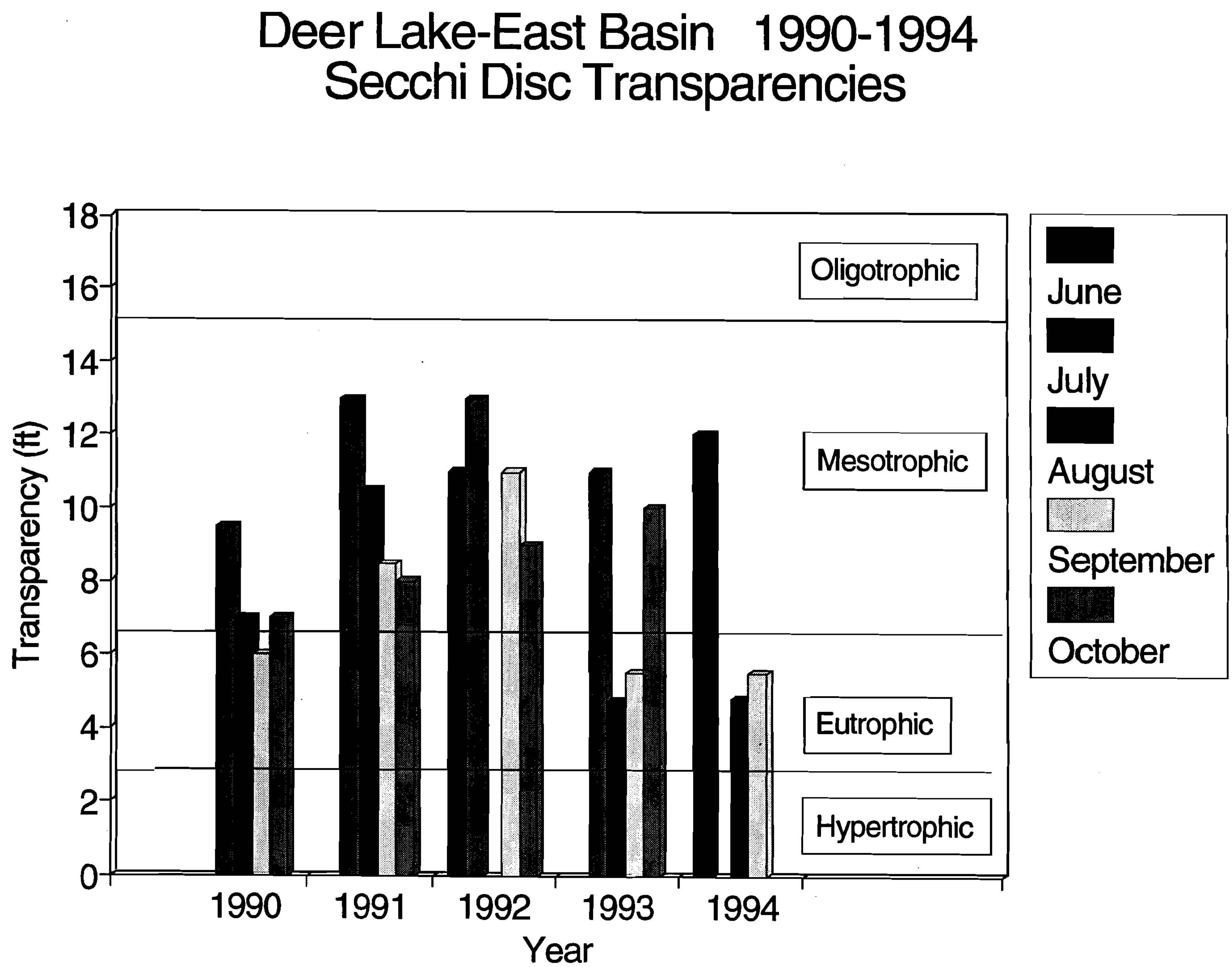

Deer Lake-East Basin 1990-1994
Secchi Disc Transparencies
Transparency (ft)
18
16
14
12
10
8
6
4
2
0
Oligotrophic
Mesotrophic
Eutrophic
Hypertrophic
1990
1991
1992
1993
1994
Year
June
July
August
September
October

Figure 4

Deer Lake-West Basin 1990-1994
Near-Surface Total Phosphorus

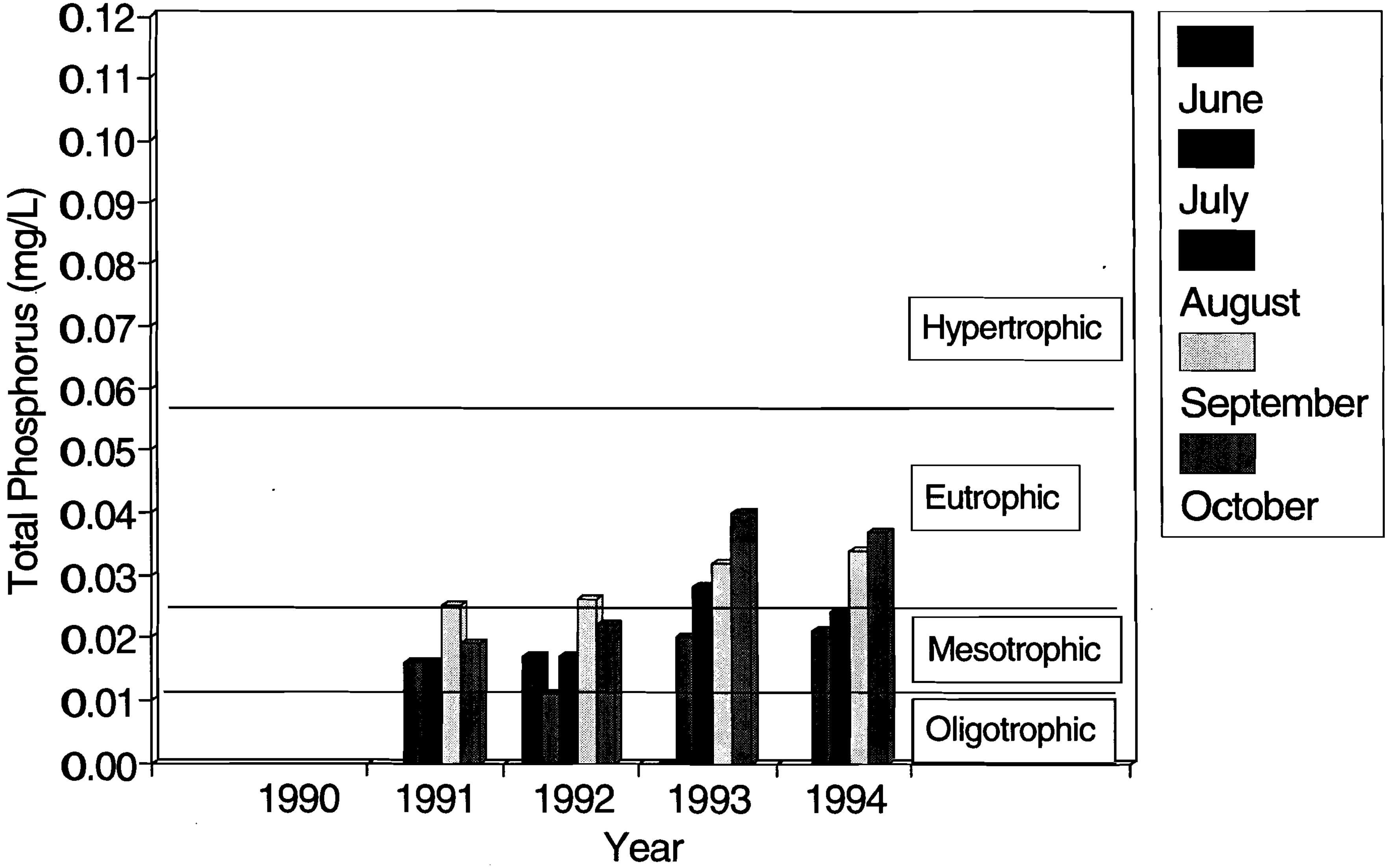


Figure 5

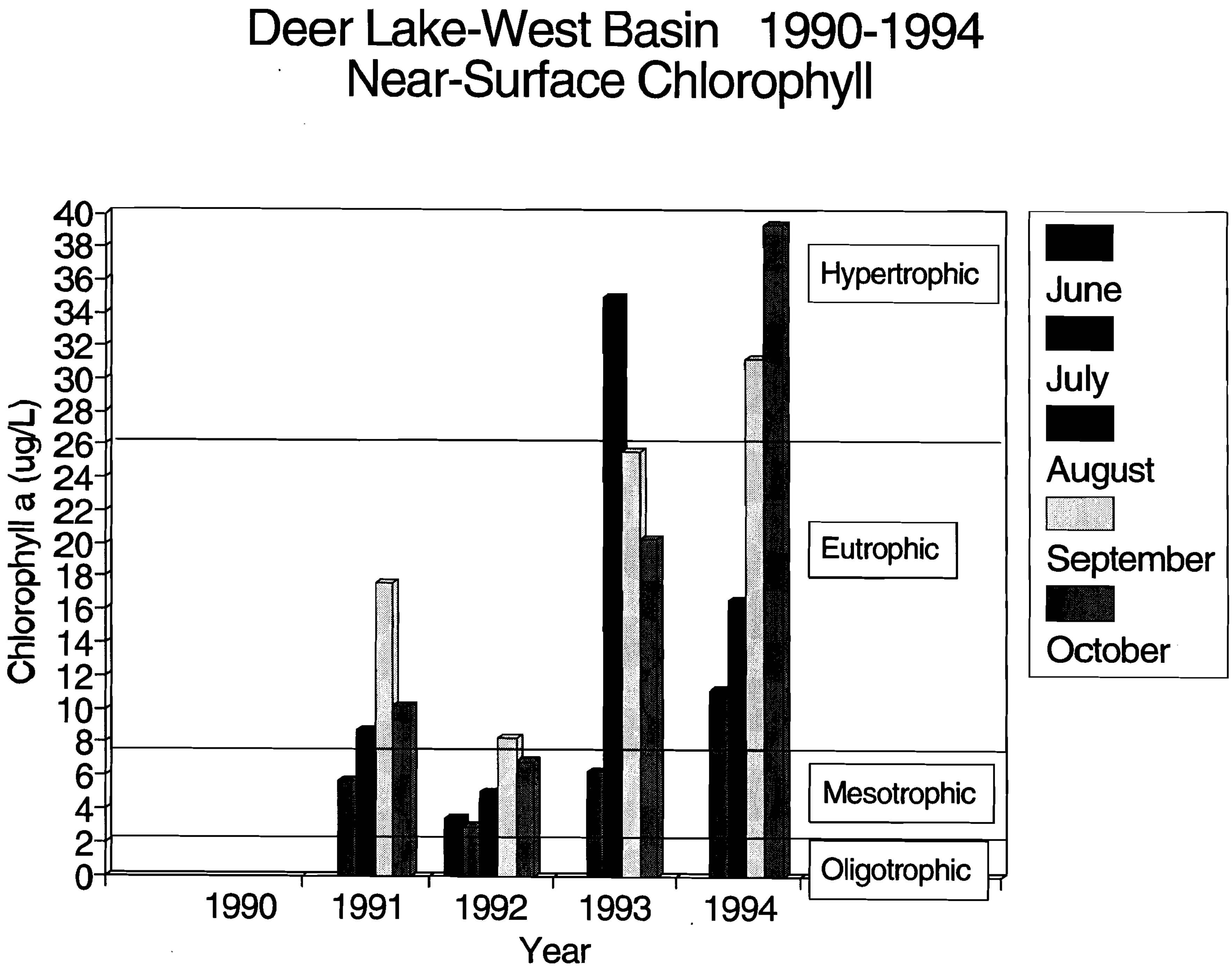

Deer Lake-West Basin 1990-1994
Near-Surface Chlorophyll
Chlorophyll a (ug/L)
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Hypertrophic
Eutrophic
Mesotrophic
Oligotrophic
1990
1991
1992
1993
1994
Year
June
July
August
September
October

Figure 6

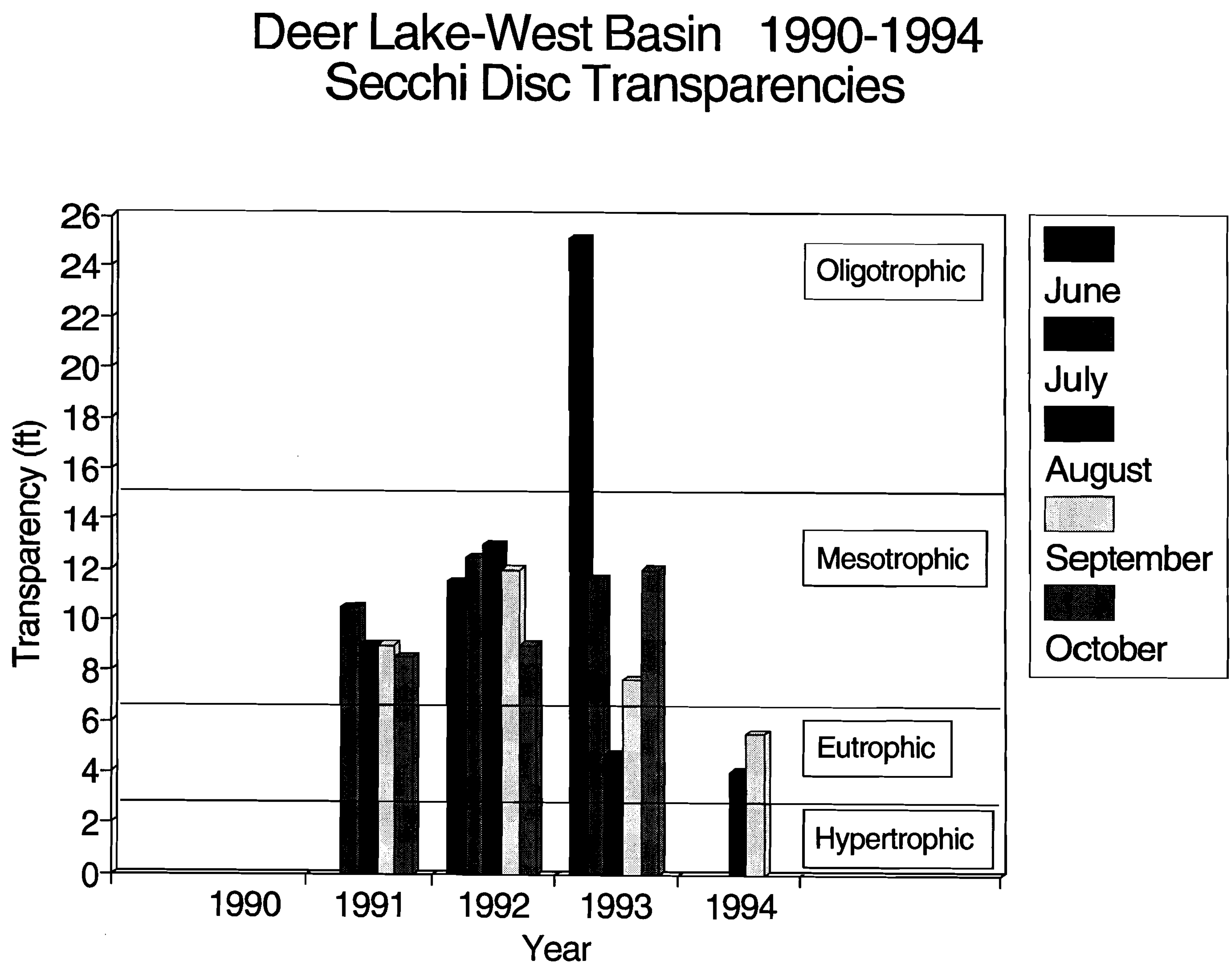
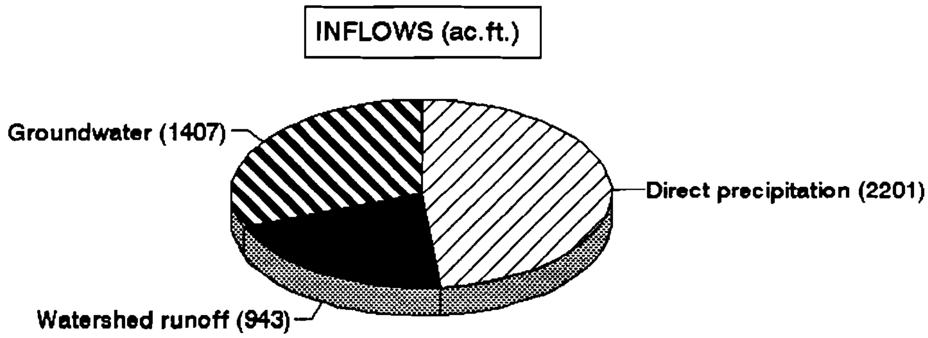

Deer Lake-West Basin 1990-1994
Secchi Disc Transparencies
Transparency (ft)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Oligotrophic
Mesotrophic
Eutrophic
Hypertrophic
1990
1991
1992
1993
1994
Year
June
July
August
September
October

Figure 7

Deer Lake Hydrologic Budget
November 1, 1993 - October 30, 1994



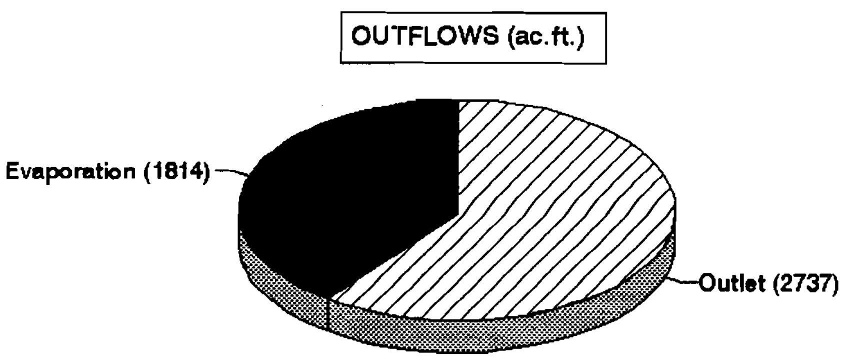


Figure 8

Deer Lake Phosphorus Loading Budget
November 1, 1993 - October 30, 1994

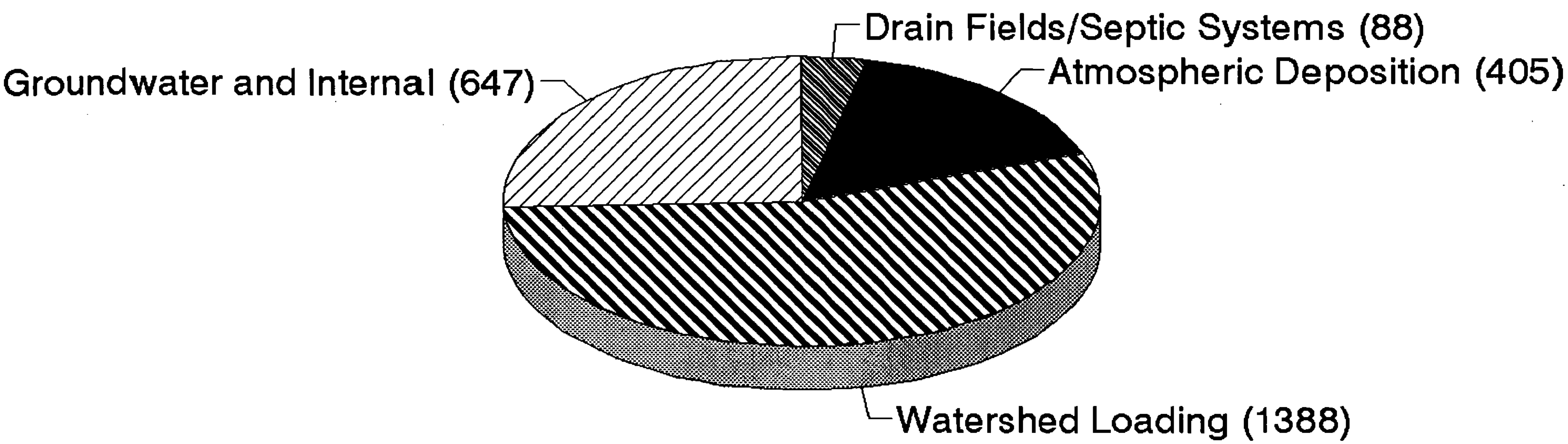


Figure 9

Deer Lake Watershed Phosphorus Loadings
November 1, 1993 - October 30, 1994

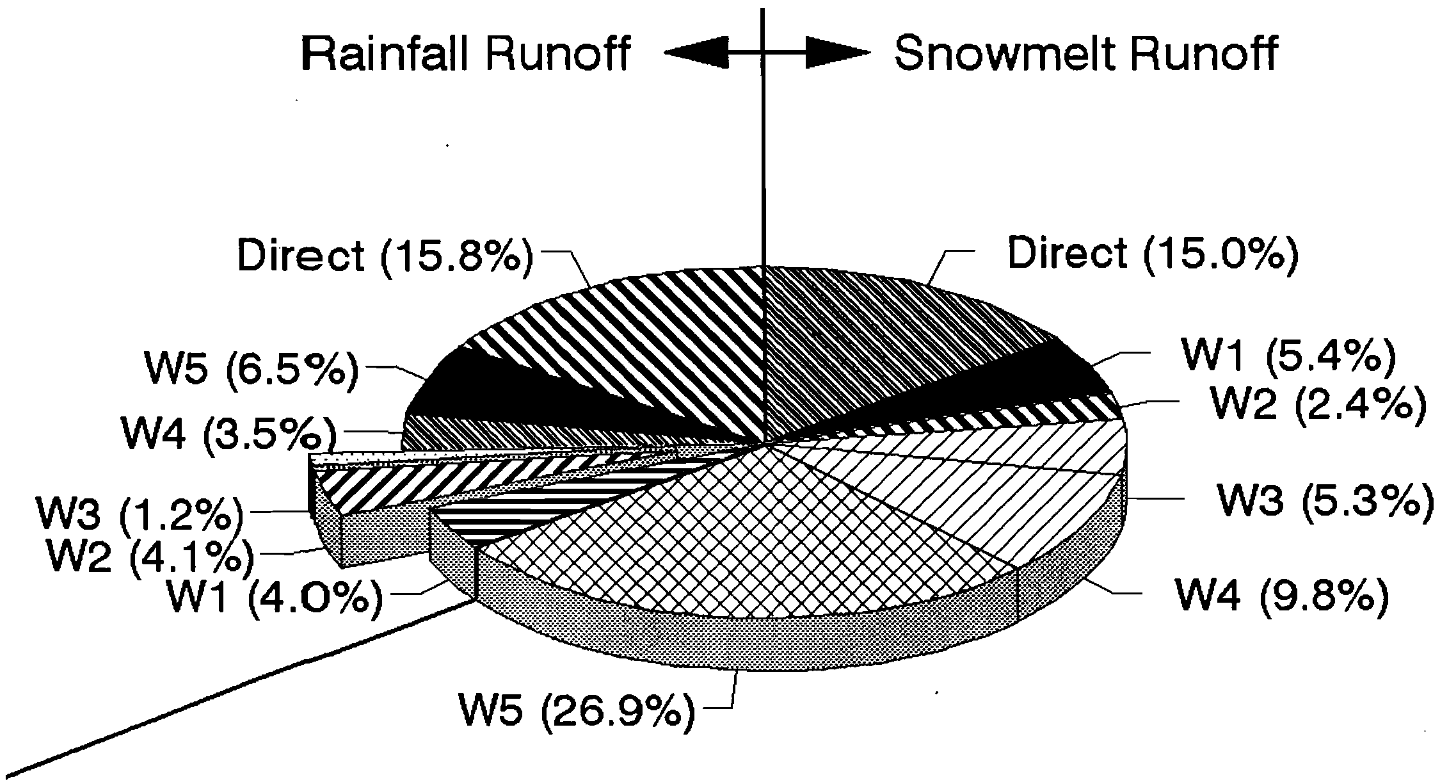
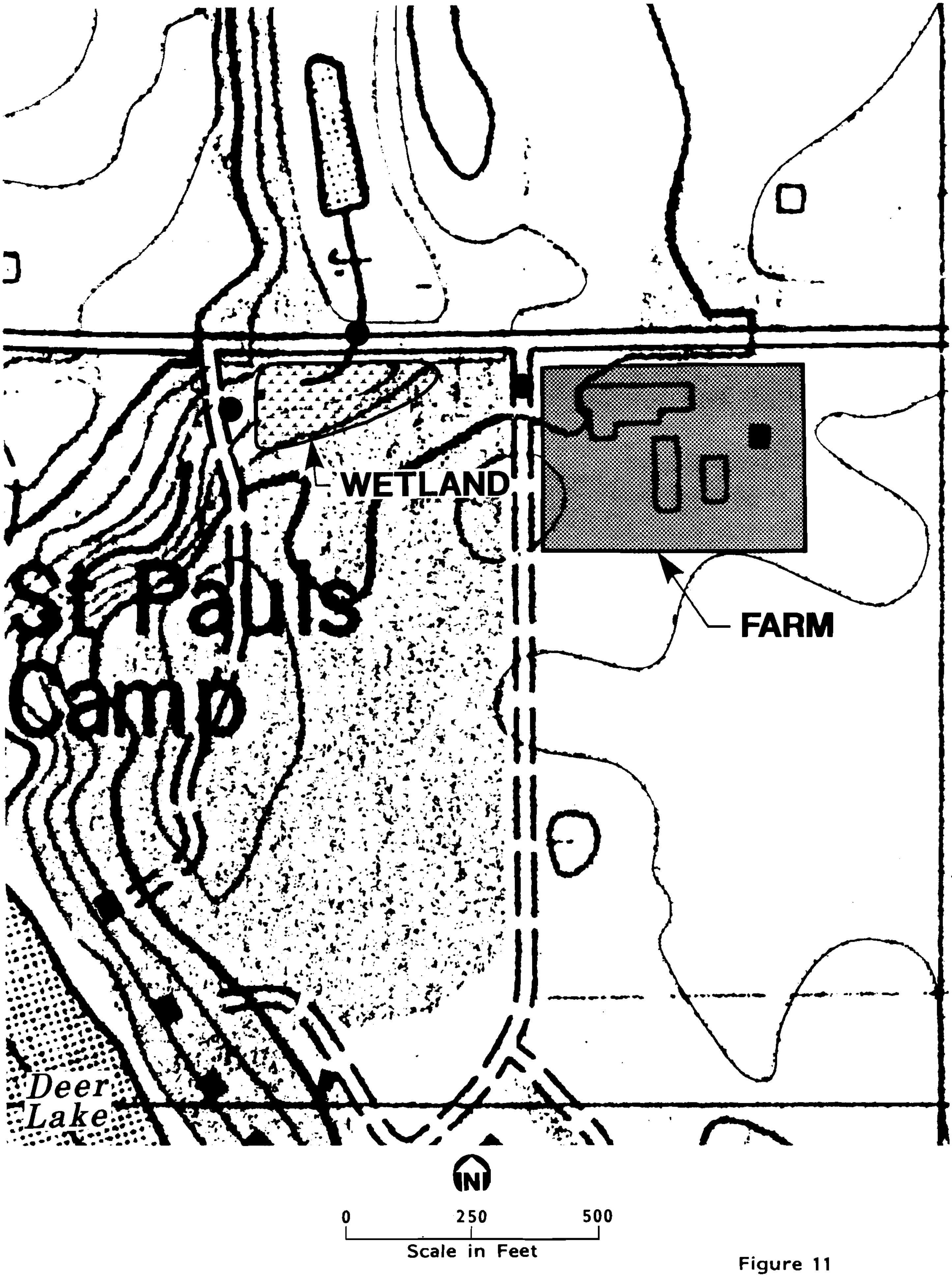


Figure 10



Proposed Monitoring Location

Figure 11

RECOMMENDED 1995
MONITORING LOCATIONS