Cross Lake and Turtle Lake Water Quality Study Report

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Table of Contents

List of Figures

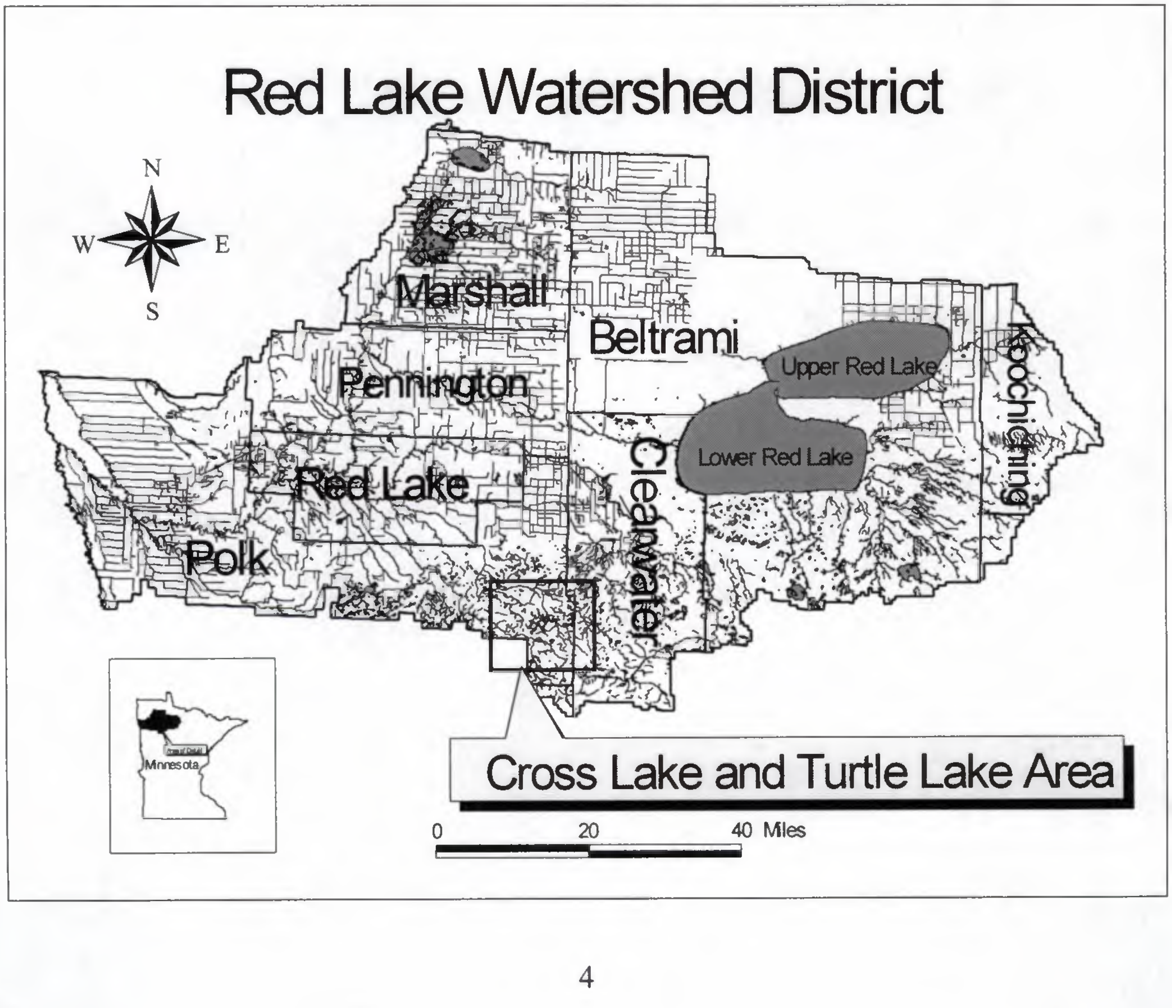
List of Appendices

Background

A long history of public concern exists over the water quality and hydrologic characteristics of the Cross Lake and Turtle Lake system. During the early 1930's, in an effort to control lake levels, the Works Progress Administration (WPA) constructed dams on South Connection Lake, Turtle Lake, and Cross Lake. Local residents often raise concern about the effects of these dams on the hydrology of the lake system. Residents believe some lakes within the system were held artificially high, thereby affecting the flow of water and the water quality of the system. Excessive algae and nutrients are the greatest concerns for Cross Lake and Turtle Lake water quality. There is also an on-going discussion about whether to manage Turtle Lake as a fishery or waterfowl lake. (Preliminary Study Design 1996)

The Cross Lake and Turtle Lake system is located in eastern Polk County, approximately 3 miles north-east of Fosston, Minnesota in the northwest part of the state. The system is near the origin of the Hill River, which is one of the main tributaries to the Clearwater River (Figure 1).

FIGURE 1. AREA OF STUDY



In 1997 the Red Lake Watershed District (RLWD) initiated a study of the hydrologic and water quality characteristics of the lakes. The purpose is to obtain basic information about the hydrologic characteristics of the lakes and to provide baseline water quality data. This first phase of the study will determine if future water quality monitoring is needed. The second phase (if needed) would provide a detailed nutrient balance for each lake.

History

Cross Lake and Turtle Lake have extended histories of water quality problems along with determining and maintaining water levels. Orrin Torgerson, a long time resident near Turtle Lake, and Paul Stolen, who currently resides in the area, apprised historical accounts and information (Appendix B).

Land Use

Agricultural production is a large part of the land use around the Cross Lake and Turtle Lake system. Agricultural practices in the contributing watershed include dairy farms, beef production, livestock pasture land, and some crop production such as corn, small grains, soybeans, hay and forage crops, sunflowers and other oilseed crops. There is also land in the Conservation Reserve Program along with lowland and forested areas, some of which are National Wildlife Management Areas. Area residents also reported a mink farm, which is no longer in operation, was located on the southeast side of Cross Lake or in the south central part of Section 21, Queen Township. According to residents much of the animal waste generated from the mink farm left in the area may have been buried in adjacent Cross Lake.

Project Overview

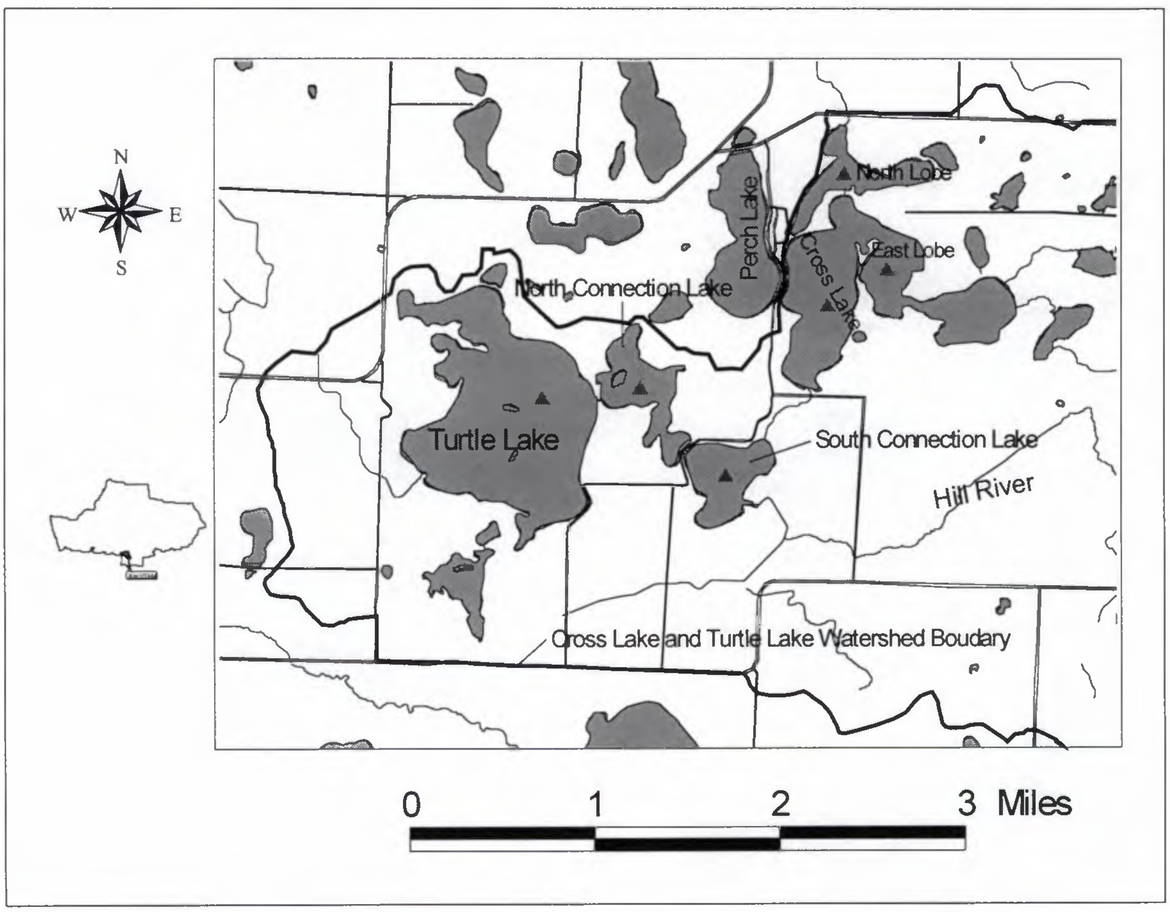
RLWD staff responsibilities included the installation of flow monitoring equipment, stream gaging, surveying, collection and analysis of water quality samples, some reduction of hydrologic data and summarization of the water quality information. Consulting services from Houston Engineering, Inc. used the information collected by RLWD staff to develop rating curves. The firm developed the hydrologic budgets for the study. Houston Engineering, Inc. provided the methods used to develop the hydrologic data, present hydrology data including the hydrologic budgets, some perspective relative to the accuracy of the hydrologic budgets and recommendations relative to the need for additional hydrologic monitoring.

Methods

Water Quality Methods

Water quality samples were collected from six in-lake monitoring locations (Figure 2). The samples were taken from the deepest part of South Connection Lake, North Connection Lake, Turtle Lake and three basin areas on Cross Lake. Water quality parameters included chlorophyll-a and total phosphorus. Secchi disk readings were also taken. More measurements of total phosphorus and chlorophyll-a were taken than secchi disk readings. Dissolved oxygen and water temperature profiles were also taken at the monitoring sites. Each of these parameters is important in determining trophic status. Originally, the preliminary study design specified one year of water quality and flow monitoring. Due to problems in flow monitoring, the study continued and water quality information was collected for two years, 1997 and 1998.

FIGURE 2. TURTLE LAKE AND CROSS LAKE IN-LAKE MONITORING LOCATIONS



The methods used for collection and analysis of the water quality samples are mainly described in the "Standard Operating Procedures for Field Samplers" manual from the RLWD. The study period did occur before this manual was created, so there are variations in the collection and analysis from this manual. Also, there were variations in methods between 1997 and 1998. The differences include:

1) Lab analysis, in 1997 the analysis of total phosphorus and chlorophyll-a took place at the water lab at the University of Minnesota Crookston (UMC). RLWD staff performed the analysis. In 1998 the samples were sent to a private lab, RMB Environmental Laboratories, Inc. in Detroit Lakes. The staff at RMB performed the analysis. Both labs were certified by the Minnesota Department of Health.
2) In 1997, all water quality samples were collected using a kemmerer bottle. In 1998, all water quality samples were collected using 2 meter long water column sampler with a diameter of 2 inches. The column sampler was used on all sampling points in 1998. The north lobe of Cross Lake, South Connection Lake and North Connection Lake have a maximum depth around 2 meters or less, a kemmerer bottle should have been used at these sites. Although, all of the sites were deep enough, in 1997 and 1998, for using a kemmerer bottle instead of taking a grab sample by hand.
3) In 1997, the chlorophyll-a samples were collected and filtered in the field, the filters were then wrapped in aluminum foil and kept on ice. The filters were transferred to the UMC lab for analysis. In 1998, the samples were collected in two liter opaque bottles with teflon caps. The samples were then put in a cooler with ice and shipped to RMB Environmental Labs, Inc. When the samples arrived, the staff at RMB filtered the samples in the lab. Both of these techniques are be acceptable, when comparing data from the same site, although this may be a cause for error.

Both of the labs utilized in this study had laboratory quality assurance/quality control (QA/QC) procedures outlined in their separate QA/QC manuals.

Another problem with collection of water quality data occurred with establishment of permanent markers or buoys at the maximum depth point at each monitoring point. Permanent markers of the maximum depths were never established leading to varying depths on the dissolved oxygen and water temperature profiles.

The water quality data collected at each site is provided (Appendix A). These tables show measurements were taken at each site in 1997 at two-week periods in July and August and once in October; in 1998, from the last part of May through October twice a month or two-week periods.

Hydrological Methods

A determination of the hydrologic budgets for Cross Lake and Turtle Lake includes surface water inflow and system discharge, evaporation, precipitation, groundwater inflow/outflow and the change in lake storage (Deutschman and Erickson 1999). In order to gage the surface water inflow and discharge, the RLWD purchased several Steven's model depth transmitters and data recorders. The instruments were installed at seven sites (Figure 3):

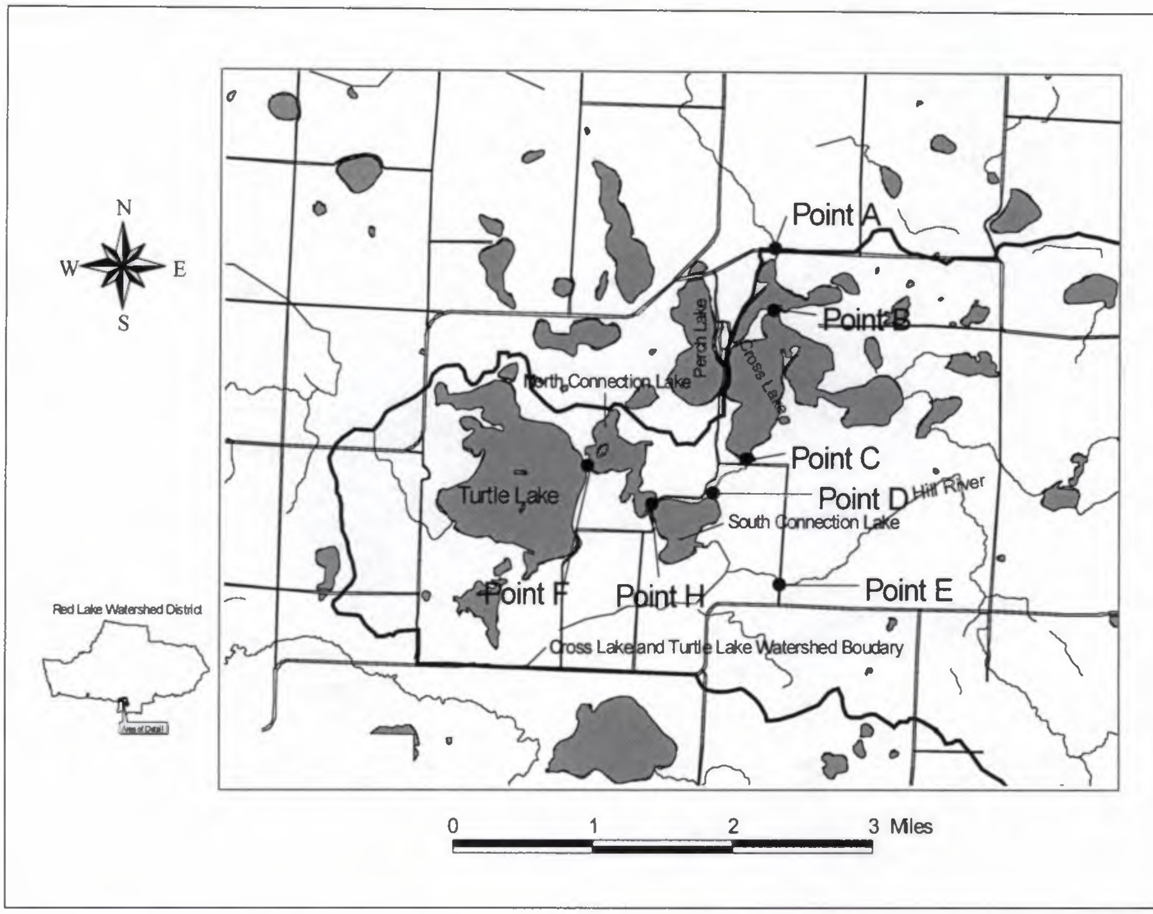
1) upstream of the box culvert on the Hill River on Polk County Road # 29 (designated point A)
2) near the dam or weir on the north side of Cross Lake (designated point B)
3) upstream of the culvert on the gravel road on the South side of Cross Lake (designated point C)
4) near the dam or weir on the northeast side of South Connection Lake (designated point D)
5) near the box culvert on the Hill River on the gravel road in the south central part of Section 28, Queen Township (designated point E)
6) near the dam or weir in the channel between North Connection Lake and Turtle Lake in the northwest corner of Section 29, Queen Township (designated point F)
7) near the culvert on the gravel road between South Connection Lake and North Connection Lake in the center of Section 29, Queen Township (designated point H)

The primary surface inflows and system discharges of Cross Lake and Turtle Lake were estimated using rating curves. Weirs serve as the primary flow control structure in Turtle Lake and Cross Lake systems. A specific weir equation was determined by varying a weir coefficient, values from 1.0 to 3.3. HEC-RAS models were utilized for the development of rating curves using the geometry and average slope of channeled stream sections. The rating curves were calibrated with measured stages and streamflows. For the ungaged sections of each watershed, as well as periods without recorded water levels stages within the primary inflow channels, runoff coefficients used in conjunction with assumed rainfall data were utilized to determine surface runoff.

Evaporation was estimated using the mean annual lake evaporation rate provided by the Soil Conservation Service Hydrology Manual. Neither of the watersheds (Cross Lake and Turtle Lake) had rain gages within; therefore, rainfall data provided by the Minnesota State Office of Climatology Volunteer Network was utilized. Because no independent measurements of lake stage were obtained, the net change in lake storage was assumed to be negligible. Groundwater inflow/outflow was assumed to be the difference between the assumed inflows and outflows of each lake. Because groundwater inflow/outflow was not actually measured, the calculated groundwater inflow/outflow also incorporates an error term. (Deutschman and Erickson 1999)

The determination of flow direction provides an understanding of how and when water moves through the Turtle Lake and Cross Lake systems. Flow direction is important for understanding mechanisms in water quality over the course of a year. Of special interest in this report is the flow direction from the Hill River into and out of the Turtle Lake system. A percentage of flow from the Hill River over time into and out of Turtle Lake needs to be determined. The stage at certain locations in the Turtle Lake system, sites E, F and H, could not be used to determine discharge (Figure 3). Problems with measurements will be discussed later in this report. The difference in height between continuous stage recordings was used to determine flow direction.

FIGURE 3. CROSS LAKE AND TURTLE LAKE FLOW MONITORING SITES



Using available survey information, a common datum was established for each of the continuous stage recorders locations. The stage recordings were adjusted to the common datum and the water surface elevations were found at each location. Flow direction, during certain periods of the year, into and out of the Turtle Lake system was found by comparing the water surface elevation at point H, F and D. The procedures for the flow direction determination are outlined in the "Documentation of Flow Direction" (Appendix D).

Trophic Status

The Carlson Trophic State Index (TSI) was used to compare measurements of chlorophyll-a, Secchi transparency and total phosphorus concentration for the determination of lake trophic status (Heiskary 1998 and Olem and Flock 1990).

Ecoregion Concept

To define the natural amount of algal biomass or trophic status, the Environmental Protection Agency (EPA) mapped ecoregions for the United States from information on soils, landform, potential natural vegetation, and land use. The EPA defined seven ecoregions within Minnesota. Cross Lake and Turtle Lake lie within the boundaries of the North Central Hardwood Forests Ecoregion. The Minnesota Pollution Control Agency (MPCA) chose several reference lakes, lakes deemed to be representative of the ecoregion and minimally impacted by human influences, to sample from and gain an understanding of the natural trophic status and water quality (Heiskary, 1998). Since the Cross Lake and Turtle Lake systems have a history of human influences, they are compared to the reference lakes to understand changes in trophic status and water quality.

Results

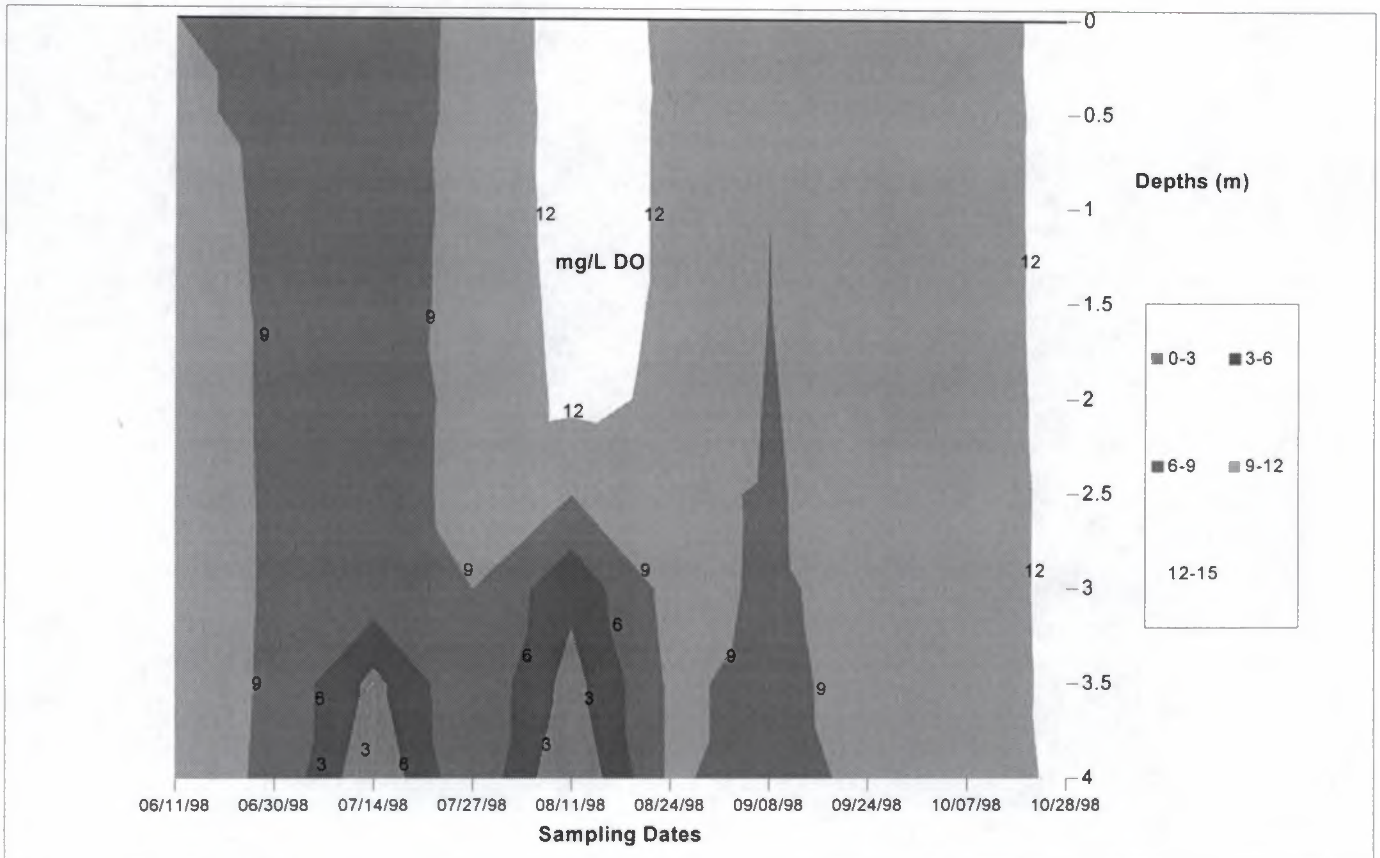
Water Quality Results

Dissolved Oxygen/Water Temperature Profiles

The dissolved oxygen and temperature profiles of Cross Lake are appropriate for lakes with depths greater than 2 meters. South Connection Lake, North Connection Lake and the north lobe of Cross Lake had depths during the sampling period of 2 meters or less. Dissolved oxygen and temperature in shallow lakes are usually evenly distributed throughout the water column. For these sites, a dissolved oxygen and water temperature at mid-level are reported on a table (Appendix A).

At the Cross Lake site, dissolved oxygen levels below 2.5 meters were less than 3 mg/L twice during the sampling period (Figure 4). Cross Lake is shallow with a maximum depth of 19 feet. Possible reasons for the periodic drop in dissolved oxygen levels include periods of mixing and non-mixing through wind and flowing water or temperature changes. The dissolved oxygen/water temperature profiles for Turtle Lake and the east lobe of Cross Lake only cover a depth of 2 meters and 2.5 meters respectively. This depth is not sufficient for identification of stratification or changes in the dissolved oxygen profile at these sites.

FIGURE 4. TEMPERATURE AND DISSOLVED OXYGEN PROFILE

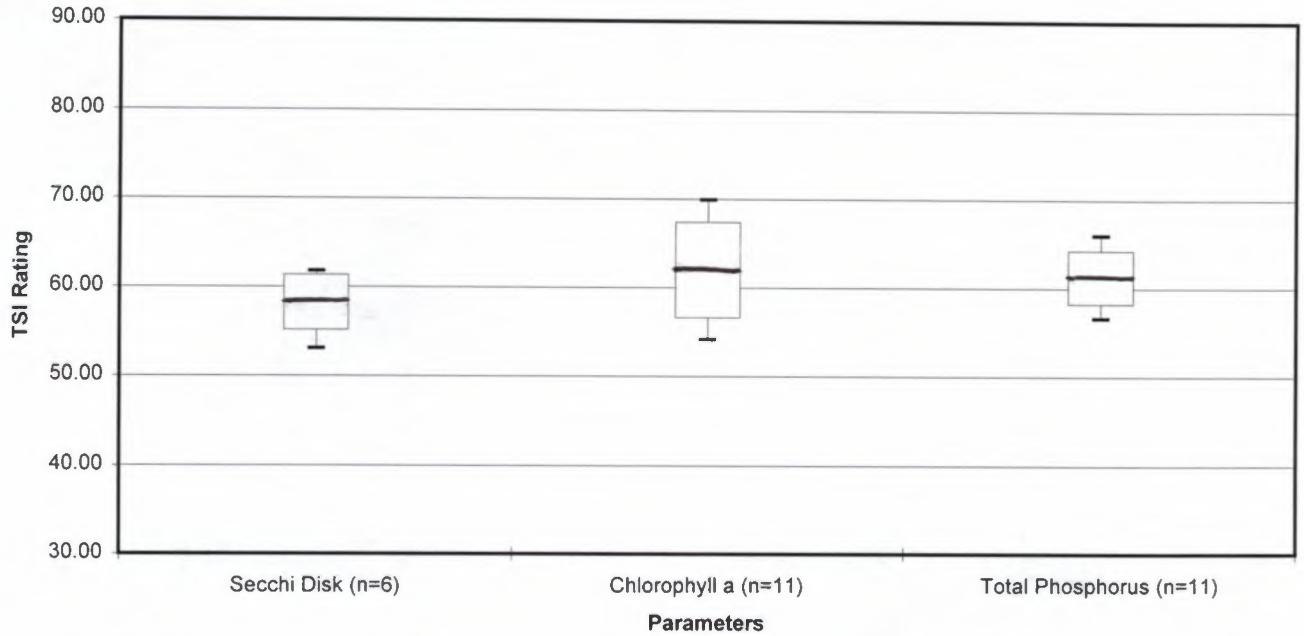


Trophic Status

For total phosphorus, chlorophyll-a and secchi disk measurments, a mean TSI value was found along with the standard deviation among the sets of measurements (Figures 5, 6 and 7). Whisker box plots were created for each site using the 1998 data.

As noted earlier in this report, the 1997 and 1998 measurements were collected utilizing different labs and the sampling methods were different.

FIGURE 5. CROSS LAKE TROPHIC STATUS INDEX



The 1997 water quality data was not considered for this report due to the following reasons.

1) For the east lobe of Cross Lake, the largest difference was in the total phosphorus measurements. 1997 phosphorus TSI values had a high of 74.88 and a low of 45.00, whereas the 1998 data had a high of 63.43 and low of 48.72.
2) For Cross Lake the TSI values for both chlorophyll-a and total phosphorus .
3) The range of the Turtle Lake measurements was less with 1998 data.
4) There were very few measurements (4) actually taken in 1997.

FIGURE 6. EAST LOBE OF CROSS LAKE TROPHIC STATUS INDEX

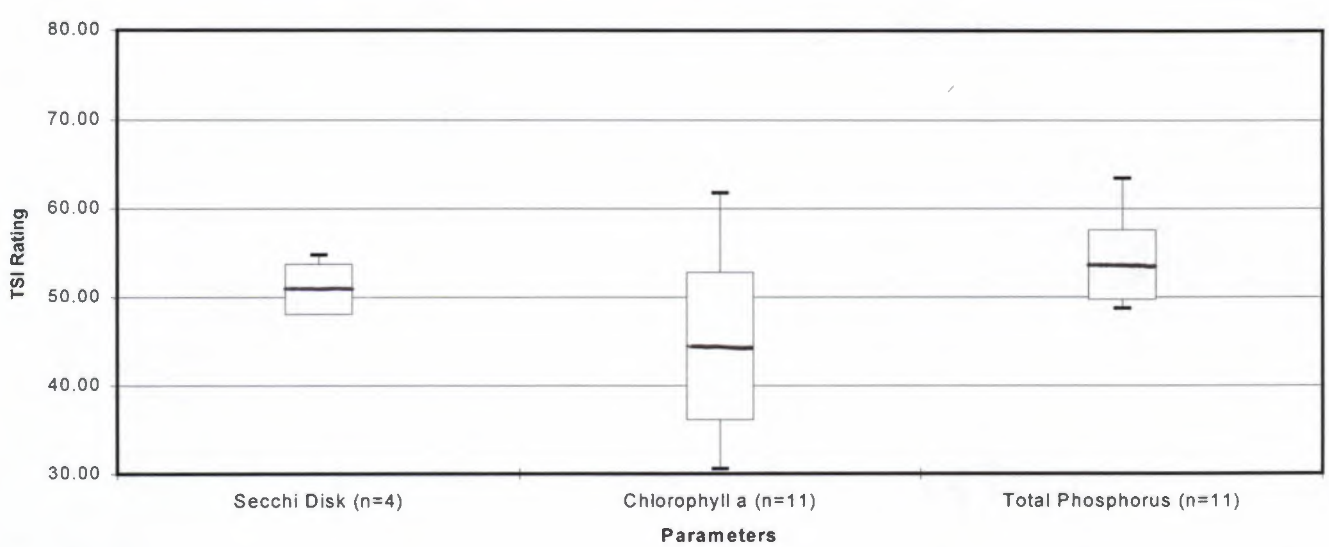
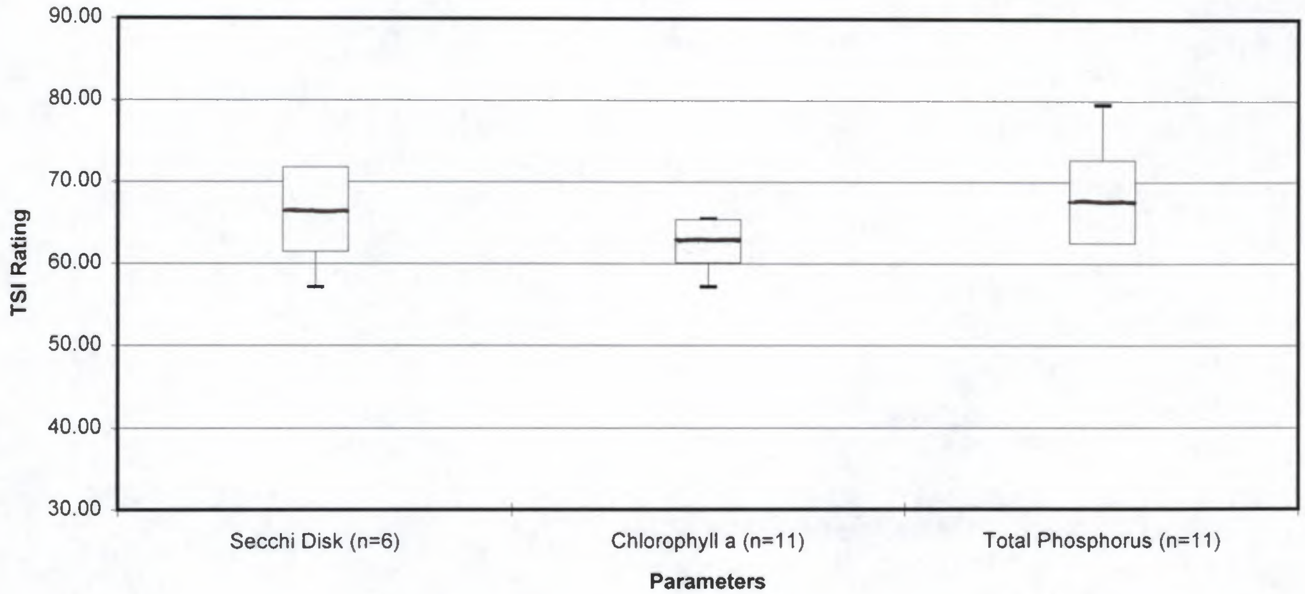


FIGURE 7. TURTLE LAKE TROPHIC STATUS INDEX

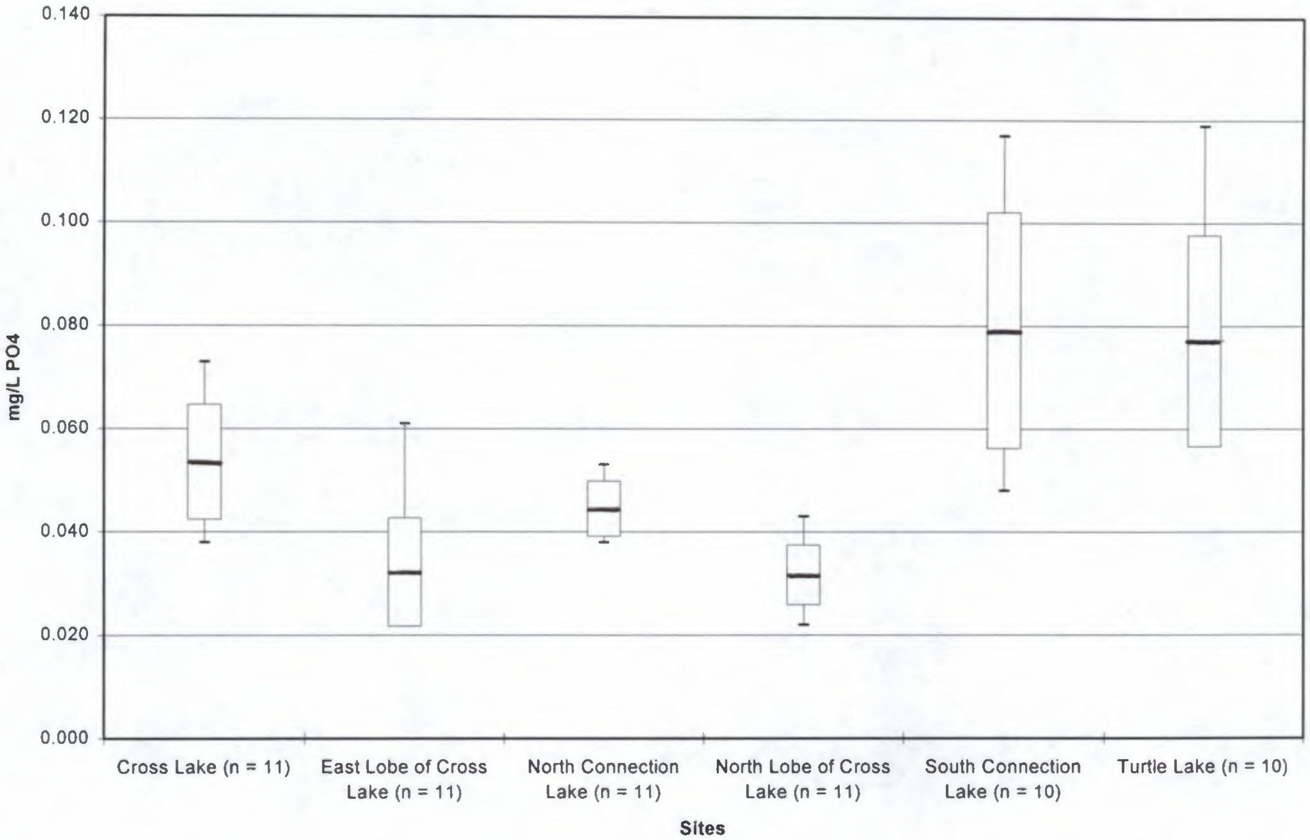


The east lobe of Cross Lake had an average chlorophyll-a TSI of 44.5. The average secchi disk TSI was 51 and the average total phosphorus TSI was 53.66. Much of the east lobe of Cross lake had dense emergent and submergent vegetation. Macrophyte growth competes with algae for nutrients and may give inaccurate chlorophyll-a and secchi disk measurements. In this case the total phosphorus is considered the more accurate TSI value. The average TSI values of Cross Lake and Turtle Lake were close (within 5 TSI). Although, there were fewer secchi disk readings (6) taken so the mean TSI for Cross Lake and Turtle Lake were found by averaging the mean chlorophyll-a TSI and the mean total phosphorus TSI.

Reference data from the North Central Hardwood Forests Ecoregion were used for comparison of TSI values found on the Cross Lake and Turtle Lake systems (Appendix E). The TSI values for Cross Lake exceeded this range by about 1 to 1.5 for both chlorophyll-a and total phosphorus. Turtle Lake exceeded this range by 2 for chlorophyll-a and 7 for total phosphorus. The TSI values for the east lobe of Cross Lake fell within this range.

South Connection Lake, the north lobe of Cross Lake and North Connection lake are all shallow in nature (2 meters max depth or less). Total phosphorus, chlorophyll-a and secchi disk measurements were taken in the same manner as the other three sites. All three sites had heavy submerged plant growth. Secchi disk and chlorophyll-a measurements are affected by this plant growth. This is evident by the "clear to the bottom" secchi disk readings at each of these sites. In this report only total phosphorus measuements are displayed (Figure 7). If points in the data set appeared to be outliers they were not considered for this report. The mean total phosphorus value for South Connection Lake and Turtle Lake

FIGURE 8. TOTAL PHOSPHORUS IN THE CROSS LAKE AND TURTLE LAKE SYSTEMS



are considerably higher than the mean levels of total phosphorus for any of the Cross Lake sites. It is not known how much phosphorus and other nutrients contained in water from the Turtle Lake system is actually adding to the Cross Lake system. Future monitoring at these sites may address this situation.

Hydrological Results

The estimated magnitude of each hydrologic budget parameter is discussed in the following with regard to each lake system. Graphical representations of the hydrologic budgets in absolute terms as well as percentages of the total volume of water passing through each hydrologic system are shown (Appendix C). Also included are plots of the surface inflow and system discharge hydrographs, as well as the daily rainfall hyetographs representating each lake system (Deutschman and Erickson 1999). An illustration of the flow direction over the year is provided (Appendix D).

Turtle Lake (Deutschman and Erickson 1999)

The 1998 hydrologic budget determined for Turtle Lake revealed a total inflow volume of 3,230 acre-feet. The principle sources of water to the lakes are precipitation and surface runoff. Total groundwater contribution was considered negligible. Precipitation accounted for a direct input of 1,634 acre-feet (approximately 51%) of the total inflow volume over the 729 acre combined surface area of Turtle Lake and North and South Connection Lakes. Surface runoff to the three lakes accounted for 1,591 acre-feet (approximately 49%) of the total inflow volume from the contributing drainage area (17.2 square miles).

Assuming there was no change in the storage of the system throughout 1998, the total outflow volume was considered equal to the total inflow volume (3,225 acre-feet). The predominant losses of water from Turtle Lake and North and South Connection Lakes resulted from surface outflow and evaporation. The system discharge from the primary outlet of the three lakes accounted for a volume loss of 1,666 acre-feet (approximately 52%) of the total outflow volume. Evaporation accounted for a direct volume loss of 1,564 acre-feet (approximately 48%) of the total outflow volume.

Cross Lake (Deutschman and Erickson 1999)

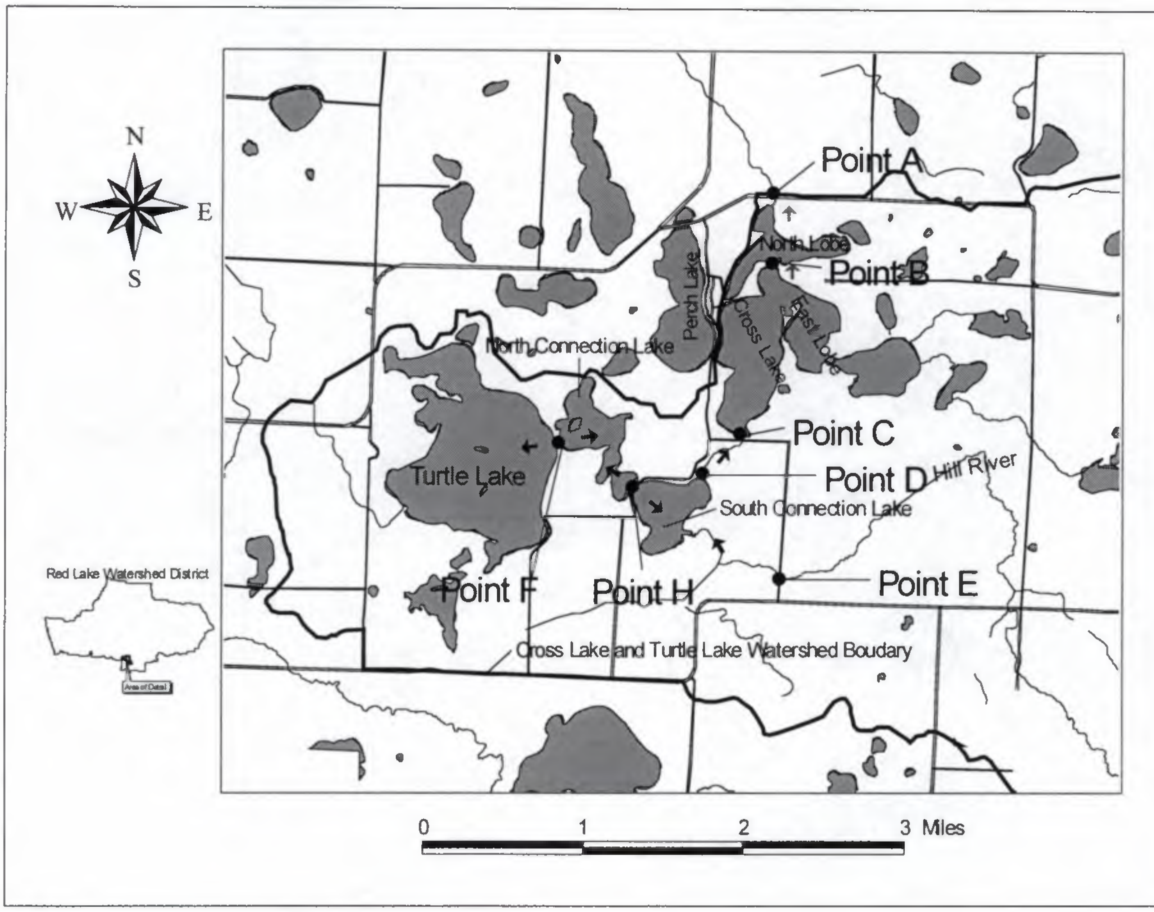
The 1998 hydrologic budget evaluated for Cross Lake revealed a total inflow volume of 5,808 acre-feet. Sources of water to Cross Lake include precipitation, groundwater inflows and inflow from Turtle Lake, as well as surface runoff from the watershed directly adjacent to Cross Lake. Precipitation accounted for a direct input volume of 735 acre-feet (approximately 13%) of the total inflow volume over the 328 acre surface area of Cross Lake. Surface inflow to Cross Lake accounted for an input volume of 2,144 acre-feet (approximately 37%) of the total inflow volume from the contributing drainage area of 25.9 square miles. Inflow from Turtle Lake accounted for 87% of the total surface inflow volume or 32% of the total inflow volume. Groundwater inflows accounted for 2,929 acre-feet or approximately 50% of the total inflow volume.

Assuming there was no change in the storage of Cross Lake throughout 1998, the total outflow volume of the system was therefore equal to the total inflow volume (5,808 acre-feet). The predominant losses of water from Cross Lake resulted from surface outflow and evaporation. System discharge from the primary outlet of Cross Lake accounted for a volume loss of 5,104 acre-feet (approximately 88%) of the total outflow volume. Evaporation accounted for a direct volume loss of 704 acre-feet (approximately 12%) of the total outflow volume.

Flow Direction

The flow direction throughout 1998 remained constant, moving from point D, South Connection Lake outlet, to point C, Cross Lake inlet, to point B, Cross Lake outlet, to point A, Cross Lake system outlet (Figure 9). The flow direction, from point E (Hill River) into and out of the Turtle Lake system point D, H and F, varied throughout the year. During the first part of 1998, water was either flowing toward Turtle Lake or there was no detectable flow between South Connection Lake and Turtle Lake. The second half of the actual recorded measurements, from 8/07/98 to 8/24/98, the height difference is much greater between Turtle Lake and South Connection Lake. Water was flowing out of Turtle Lake into South Connection Lake. Each step in flow direction determination is documented (RLWD 2000).

FIGURE 9. CROSS LAKE AND TURTLE LAKE SYSTEMS FLOW DIRECTION



Quality/Limitations of Data

The quality and limitations of the data used will be discussed with respect to each lake system. Independent lake stage data, as well as groundwater inflow/outflow data was not collected and, therefore, will not be discussed.

The precipitation data used for the Turtle Lake and Cross Lake systems was obtained from Fosston, Minnesota (Polk County, Township 147, Range 40, Section 4). Fosston is located approximately 3 miles southwest of the Turtle Lake and Cross Lake, watersheds.

Because of the distance between the rain gage and corresponding watersheds, as well as the probable spatial variation in rainfall, it is possible that the recorded rainfall is not representative of that within the watersheds (Deutschman and Erickson 1999). However, since the data is collected on an annual basis, the total precipitation at Fosston was assumed to be similar to the totals around each lake system.

The estimated evaporation rate for the individual lake systems was 25.75 inches per year. Because meteorological conditions were considered average for 1998, it is likely that the assumed annual evaporation rate is representative of the actual annual evaporation rate (Deutschman and Erickson, 1999).

In general, three factors affected the estimation of surface inflow and system discharge for each lake system. The first factor was the period of recorded stage data. In the absence of this data, other less accurate methods such as the use of runoff coefficients and watershed precipitation data was utilized. For the Cross Lake system, surface inflow and outflow stage data was recorded from May 28, 1998 to November 6, 1998. Because spring runoff occurs from late March through mid April in northern Minnesota, it is possible that a significant portion of the annual water budget was left unaccounted for. Surface outflow stage data was recorded for the Turtle Lake system. However, no useful surface inflow data was recorded. Unfortunately, all recorded stage data had segments of missing data resulting from equipment malfunction, vandalism, etc (Deutschman and Erickson 1999).

The second factor affecting the determination of surface inflows and system discharge was the ungaged sections of each system's watershed. The Cross Lake system had gaged primary inflows; however, significant portions of the total contributing drainage area were ungaged. The Turtle Lake system had no gaged surface inflows over the entire 17.2 square mile watershed. Cross Lake had an 8.7 square mile section of its total contributing watershed that was ungaged. This ungaged section represented approximately 34% of the total contributing watershed for Cross Lake. The ungaged section of the watershed contributes a significant uncertainty to the determination of the hydrologic budget. Therefore, surface runoff was determined for the ungaged section of the watershed using runoff coefficients and the assumed watershed precipitation data (Deutschman and Erickson 1999).

The third factor affecting the determination of surface inflows and system discharge was the placement of the transducers used to determine stage, as well as the collection of data necessary for the determination and adjustment of rating curves. The transducers at the outlet on South Connection Lake, point D, and at the outlet of Cross Lake, point B, were placed on the downstream sides of the weir structures during the first part of 1998. At the outlet of the Cross Lake system (point A) transducer elevations were changed without accurate detail of the elevation changes. Because of the previously mentioned issues, as well as a limited collection of observed streamflows, accurate rating curves could not be established. Therefore, the inflows and discharges determined for the three lake systems are of unknown accuracy (Deutschman and Erickson 1999). Similar problems were encountered in making the flow direction determinations (RLWD 2000).

Another problem with these measurements is the actual difference in water surface elevations between each location in the Turtle Lake system. Each of these locations has a minimal difference in water surface elevation, often less than .1 ft. Human and environmental factors may change the actual height of the transducers over time, and they may not be reflected in the survey data. Due to the flat nature of the Turtle Lake system these problems may be unavoidable.

The third problem is the lack of data from each location. Many stations were missing most of the recorded period (RLWD 2000). Due to these factors the flow direction is also of unknown accuracy.

Recommendations

Hydrologic

The Preliminary Study Design for the Turtle Lake and Cross Lake System study identified specific technical goals. Those goals are:

1) Determine the hydrology of the Cross Lake and Turtle Lake system;

2) Develop a hydrologic budget of the Cross Lake and Turtle Lake system;

3) Prepare a computerized hydrologic model of the Cross Lake and Turtle Lake system and use the model to evaluate water management options;

4) Develop a chronological history of lakeshore development within the watershed of the Cross Lake – Turtle Lake system;

5) Determine the present trophic status and identify the fisheries resources within the Cross Lake – Turtle Lake system;

6) Obtain qualitative information about the composition of the lake bottom through sediment coring and photography;

7) Inventory and map current land use within specific lake drainage areas and identify potential non-point pollution sources; and

8) Make future lake management and/or water quality monitoring recommendations based on results obtained from the preliminary (Phase I) water quality and hydrologic study.

A rudimentary understanding of the hydrology of the Cross Lake and Turtle Lake system is possible using the data collected to date. The information collected during 1998 allows for an estimate of how much water enters and leaves the lake. Vandalism of the continuous stage recorders, damage by animals and equipment failure prevented the collection of the daily discharge data needed to obtain a thorough understanding of flow direction and the development of a hydrologic model (Deutschman and Erickson 1999).

The following recommendations are presented, based on meeting the original technical hydrologic goals for the project (Deutschman and Erickson 1999):

1) Continuous recording rain gages should be installed within the contributing drainage area. The gages should be strategically placed to allow for the development of drainage area specific rainfall-runoff relationships. The number of gages needed is approximately one gage per 5 square miles of watershed (i.e., ~ 5 gages).

2) A velocity transducer capable of determining direction and magnitude of discharge should be installed within the channel between Turtle Lake and North Connection Lake and potentially within the culvert between North and South Connection Lakes.

3) Stream gaging should be performed at each location 5-6 times during the ice-free period. These data can be used to adjust the rating curves developed using engineering equations.

4) Improved record keeping (in the field) would enhance the ability to reduce and interpret the hydrologic data.

5) Daily flow data with sufficient continuous record are needed to successfully obtain the technical goals. Should vandalism, animal damage and other human related factors continue to prevent the development of sufficient high quality data, the study should be terminated.

Water Quality

The study has accomplished the goal of determining the present trophic status. Recommendations for future monitoring include the following:

1) Inventory and map of current land use within specific lake drainage areas and identify potential non-point pollution sources. This information would aid in making current land use improvements.

2) Future water quality monitoring should include monitoring of nutrients and other parameters at inlet and outlet water sources to the Cross Lake and Turtle Lake systems. The monitoring should correspond with the flow monitoring sites listed above. This would determine the nutrient loading into the lake systems.

3) Permanent buoys or GPS coordinates need to be established at the maximum depths of Cross Lake, Turtle Lake and the east lobe of Cross Lake for more accurate monitoring of depth profiles and other water chemistry.

4) The monitoring should follow the "Standard Operating Procedures for Field Samplers" manual from the RLWD.

5) Identify fisheries resources (using DNR collected information or as an actual fisheries study).

References:

HDR Engineering Inc. (1996). *Turtle – Cross Lake System Final Study Design.* Final Draft prepared for the Red Lake Watershed District.

Deutschman, M. and Erickson, T. (1999), *Memorandum: Good Lake and Turtle-Cross Lake Hydrologic Analysis.* Houston Engineering, Inc., Minneapolis, Minnesota.

Heiskary, S. (1998), *Minnesota Lake Water Quality Assessment Data: 1998.* Update to data presented in the Minnesota Lake Water Quality Assessment Report: 1990, Appendix 1. Minnesota Pollution Control Agency, Environmental Outcomes Division, Environmental Monitoring and Analysis Section, St. Paul, Minnesota.

Olem, H. and G. Flock, eds. (1990), *Lake and Reservoir Restoration Guidance Manual.* 2nd edition. EPA 440/4-90-006. Prepared by the North American Lake Management Society for the U. S. Environmental Protection Agency, Washington, DC.

Red Lake Watershed District, (2000), *Documentation on Flow Direction.* Red Lake Watershed District Staff.

Appendix A: Water Quality Data Tables

Site	Date	Time	H2O Temp. °C	Air Temp. °C	Conductivity µS\cm	Chlorophyll-a µg/L	Secchi Disk feet	Total Phosphorus mg/L PO_4^{3-}
Cross Lake	07/01/97		24.8	23	453	37.38	4.5	0.058
	07/22/97	10:25	23.4	21	426	13.98	6.5	0.05
	08/05/97	13:15		21.5	416	25.63	5	0.063
	08/11/97					44.856		
	08/20/97	13:20	14.5	21		98.256	4	0.079
	10/22/97	12:38	8.2	3.8	376	48.06		0.017
	05/20/98	13:00	19.6	24		11		0.038
	06/11/98	12:15	19.4	23	452	15		0.04
	06/30/98	14:40	23.2	26.7	419	16		0.048
	07/14/98	13:20	25.3		499	12		0.043
	07/27/98	16:20	24.2	29.5	430	28	3.3	0.063
	08/11/98	11:25	25.3	26.7	389	55		0.066
	08/24/98	15:50	24.2	26.7	433	54	2.9	0.073
	09/08/98	16:25	21.5	26.7	391	27	3.2	0.051
	09/24/98	13:45	17.4	21	406	35	4	0.058
	10/07/98	12:45	11.8	9.5	407	29	4	0.058
	10/28/98	11:45	10.5	12	412	27	5.3	0.051
East Lobe of Cross Lake	07/01/97	11:45	25		329	2.67	10	0.018
	07/22/97	10:40	23.2		403	3.35	8.5	0.056
	08/05/97	1:35			350	4.27	8.5	0.135
	08/11/97					6.408		
	08/20/97	1:40	14			0	9.1	0.017
	05/20/98	14:00	20.6	24		2		0.027
	06/11/98	13:00	19.6	24	320	2		0.022
	06/30/98	14:20	24.1	26.7	308	6		0.035
	07/14/98	12:55	25.1		369	3		0.03
	07/27/98	15:30	24.5	26.7	330	24	7	0.022
	08/11/98	11:05	26	26.7	342	8		0.028
	08/24/98	11:20	24.3	24	383	5	4.7	0.033
	09/08/98	15:55	22.2	26.7	347	3	6	0.033
	09/24/98	13:15	16.3	21	378	4	clear	0.033
	10/07/98	12:15	10.4	9	373	7	7.3	0.061
	10/28/98	11:15	10.6	11.5	379	1	clear	0.03
Turtle Lake	07/01/97		24.1		385	11.27	7	0.051
	07/22/97	1:05	22		403	18.45	4.5	0.025
	08/11/97					23.496		
	08/20/97	3:20				23.496	4	0.064
	10/22/97	12:02	7.7		367	12.46		0.018
	05/20/98	16:00	20.9	26.7		15		0.073
	06/12/98	11:15	19.2	15.5	329	26		0.066
	06/30/98	16:05	22.9	25	315	32		0.073
	07/14/98	15:40	26.3		370	23		0.058

Appendix A: Water Quality Data Tables

Site	Date	Time	H2O Temp. °C	Air Temp. °C	COND. µS\cm	Chlorophyll-a µg/L	Secchi Disk feet	Total Phosphorus mg/L PO_4^{3-}
	07/27/98	11:00	22.7	21	324	21	2	0.066
	08/11/98	13:45	25.7	29.5	321	21		0.058
	08/24/98	13:35	24	24	353	35	4	0.186
	09/08/98	17:30	21.5	26.7	316	29	1.5	0.076
	09/24/98	16:30	16.8	21	330	35	1.5	0.109
	10/07/98	14:30	11.6	11	338	35	2	0.119
	10/28/98	14:00	10.4	14.5	335	28	2.2	0.073
North Connection Lake	07/01/97		23.8	18	357	3.93		0.019
	07/22/97	13:50	27.5		376	3.35		0.027
	08/05/97	14:55				0	4	0.063
	08/11/97					10.68		
	08/20/97	14:50	16	21		0		0.023
	10/22/97	12:15	4.1	3.8		0		0.17
	05/20/98	16:30	22	26.7		4		0.051
	06/12/98	9:30	18.8		288	3		0.04
	06/30/98	16:45	24.5	23	272	6		0.04
	07/14/98	15:15	27.8		304	30		0.053
	07/27/98	11:15	23.3	21	269	28	4.9	0.045
	08/11/98	13:25	26.7	29.5	283	15		0.045
	08/24/98	13:15	23.8	24	335	10	4	0.045
	09/08/98	18:00	21.3	26.7	303	5	clear	0.051
	09/24/98	16:47	16	21	331	5	clear	0.043
	10/07/98	15:00	10.9	11.5	334	6	clear	0.038
	10/28/98	14:45	10.8	14.5	340	20		0.038
North Lobe of Cross Lake	07/01/97		25.5		423	18.69	4.3	0.036
	07/22/97	11:20	24.8		420	18.45	2.5	0.028
	08/05/97	2:00	24.1		395	8.54	3.52	0.081
	08/11/97					8.544		
	08/20/97	2:10	15.5			0	3.5	0.017
	10/22/97	12:50	6		369	2.289		0.022
	05/20/98	12:00	20.6	24		3		0.033
	06/11/98	14:00	20.4	24	345	6		0.038
	06/30/98	13:45	24.4	26.7	372	7		0.035
	07/14/98	12:30	24.8		458	12		0.043
	07/27/98	15:10	25.3	21	337	4	clear	0.028
	08/11/98	10:40	25.7	26.7	327	4		0.028
	08/24/98	10:45	22.2	25	369	14	clear	0.035
	09/08/98	15:00	21.7	26.7	321	4	clear	0.03
	09/24/98	12:40	15.5	21	358	3	clear	0.028
	10/07/98	11:45	9.9	8	371	1	clear	0.028
	10/28/98	10:30	10.6	11	366	1	clear	0.022

Appendix A: Water Quality Data Tables

Site	Date	Time	H2O Temp. °C	Air Temp. °C	COND. µS\cm	Chlorophyll-a µg/L	Secchi Disk feet	Total Phosphorus mg/L PO_4^{3-}
South	07/01/97		23.8	18	363	5.34		0.025
Connection	07/22/97	13:25	26.2		381	6.15	5	0.055
Lake	08/05/97	14:45		21	337	8.54	4	0.072
	08/11/97					6.408		
	08/20/97	14:40	15	21		0		0.023
	10/22/97	12:15	3.5	3.8	394	3.204		0.016
	05/20/98	17:00	21.8	26.7		13		0.099
	06/12/98	11:40	19.3	15.5	342	3		0.071
	06/30/98	15:30	25.6	26.7	446	29		0.094
	07/14/98	14:15	26.6		432	55		0.209
	07/27/98	12:15	23.6	24	321	28	3	0.094
	08/11/98	12:30	26.5	28	336	22		0.117
	08/24/98	14:30	25.1		346	17	clear	0.091
	09/08/98	13:15	20.3		274	2	clear	0.053
	09/24/98	15:30	16.3		330	4	clear	0.066
	10/07/98	16:15				9	clear	0.048
	10/28/98	13:00	11.2	14	388	4	clear	0.058

Cross Lake Dissolved Oxygen/Water Temperature Data

Date	Diss. Ox. Surface mg/L O_2	Wat. Temp Surface °C	Diss. Ox. 0.5 meter mg/L O_2	Wat. Temp 0.5 meter °C	Diss. Ox. 1 meter mg/L O_2	Wat. Temp 1 meter °C	Diss. Ox. 1.5 meter mg/L O_2	Wat. Temp 1.5 meter °C	Diss. Ox. 2 meter mg/L O_2
03/03/97					1.3				1
07/01/97					11.3	21			11.4
07/22/97									
08/05/97					7.8	20			7.7
08/11/97									
08/20/97	10.6	15			9.9	14.5			9.6
10/22/97	9.4	8.2							
05/20/98	6.6	19.6	6.6	19.6	6.65	19.5	6.65	19.5	6.6
06/11/98	9	18	9.35	17	9.9	16.5	10.05	16.5	10.2
06/30/98	8.5	21.5	8.5	21.3	8.6	21.1	8.65	21	8.65
07/14/98	6.75	24.5	6.9	24.3	7.4	24.2	7.6	24.4	7.8
07/27/98	10.15	23.5	10.15	23.5	10	23.3	10	23.2	9.7
08/11/98	13.2	24.1	13.05	24	13.1	23.9	12.9	23.8	12.7
08/24/98	11.6	23.1	11.7	23	11.7	22.9	11.7	22.9	11.55
09/08/98	9.1	20.2	9.1	20.2	9	20.1	8.95	20.1	8.8
09/24/98	10.8	16.1	10.7	16.1	10.65	15.9	10.6	15.8	10.6
10/07/98	9.95	10.1	9.65	10.2	9.7	10.2	9.65	10.4	9.6
10/28/98	13.65	8.3	13.7	8.3	13.7	8.2	13.65	8.1	13.5

Date	Wat. Temp 2 meter °C	Diss. Ox. 2.5 meter mg/L O_2	Wat. Temp 2.5 meter °C	Diss..Ox. 3 meter mg/L O_2	Wat, Temp 3 meter °C	Diss. Ox. 3.5 meter mg/L O_2	Water Temp 3.5 meter °C	Diss. Ox. 4 meter mg/L O_2	Wat, Temp 4 meter °C
03/03/97	1			0.8	1			0.2	3
07/01/97	21			10.2	20			3.2	19
07/22/97									
08/05/97	20			7.2	19			0.8	17
08/11/97									
08/20/97	14			9.6	14			9	14
10/22/97									

Appendix A: Water Quality Data Tables

Date	Wat. Temp. 2 meter °C	Diss. Ox. 2.5 meter mg/L O_2	Wat. Temp 2.5 meter °C	Diss. Ox. 3 meter mg/L O_2	Wat. Temp 3 meter °C	Diss. Ox. 3.5 meter mg/L O_2	Wat. Temp 3.5 meter °C	Diss. Ox. 4 meter mg/L O_2	Wat. Temp 4 meter °C
05/20/98	19.5			6.7	19.5			6.4	18.5
06/11/98	16.5	10.25	16.5	10.3	16.5	10.25	16	10.2	16
06/30/98	20.8	8.7	20.8	8.7	20.8	8.65	20.5	8.55	20
07/14/98	24.5	7.9	24.5	7.8	24.5	2.1	22.5	0.4	21.5
07/27/98	23	9.7	23	9	22.7	8.75	22.5	8.55	22.3
08/11/98	23.5	9.05	23	3.8	22	1.8	21.5	0	21.1
08/24/98	22.9	9.9	22.5	10	22	9.4	21.8	9.4	21.5
09/08/98	20	8.65	20	8.6	20	8.4	19.8	7.8	19.7
09/24/98	15.7	10.45	15.5	9.8	15.2	9.7	15.1	9.65	15.1
10/07/98	10.4	9.55	10.3	9.6	10.3	9.45	10.3	9.6	10.4
10/28/98	8.1	13.3	7.8	13.3	7.8	13.2	7.7	12.9	7.5

East Lobe of Cross Lake Dissolved Oxygen/Water Temperature Data

Date	Diss. Oxygen Surface mg/L O_2	Water Temp. Surface °C	Diss. Oxygen 0.5 meter mg/L O_2	Water Temp. 0.5 meter °C	Diss. Oxygen 1 meter mg/L O_2	Water Temp. 1 meter °C
07/01/97					8.3	21
07/22/97						
08/05/97					9.8	20
08/11/97						
08/20/97	9.2	14.5			8.6	14
05/20/98	5.8	21.3	5.9	21.3	6.1	21
06/11/98	10.4	18	10.8	18	10.9	17.5
06/30/98	8.2	23.1	7.8	22.2	7.8	22
07/14/98	7.75	25.1	7.8	25.1	7.8	25.1
07/27/98	10.1	23.9	10	23.9	9.5	23.9
08/11/98	9.2	24.9	9.15	24.8	9.15	24.8
08/24/98	8.5	22.8	8.4	22.7	8.5	22.5
09/08/98	9	20.5	9.05	20.3	9.2	20.4
09/24/98	9.9	14.8	9.9	14.8	9.9	14.4
10/07/98	10.45	8.8	10.4	8.8	10.5	8.8
10/28/98	12.9	8.5	12.85	8.5	12.85	8.5

Date	Diss. Oxygen 1.5 meter mg/L O_2	Water Temp. 1.5 meter °C	Diss. Oxygen 2 meter mg/L O_2	Water Temp. 2 meter °C	Diss. Oxygen 2.5 meter mg/L O_2	Water Temp. 2.5 meter °C
07/01/97			8.3	21		
07/22/97						
08/05/97			9.6	20	9.4	20
08/11/97						
08/20/97			8.5	13.5		
05/20/98	6.1	21	6.15	21	6	20.3
06/11/98	10.95	17.5	10.9	17.5	10.9	17.2
06/30/98	8.9	21.8	7.4	20.8	7.8	20.7
07/14/98	7.75	25.1				
07/27/98	9.8	22.9	9.25	22.3	9	22.1
08/11/98	9.05	24.8	8.9	24.8		
08/24/98	8.4	22.4	8.3	22.3	8.3	22.1

Appendix A: Water Quality Data Tables

Date	Diss. Oxygen 1.5 meter mg/L O_2	Water Temp. 1.5 meter °C	Diss. Oxygen 2 meter mg/L O_2	Water Temp. 2 meter °C	Diss. Oxygen 2.5 meter mg/L O_2	Water Temp. 2.5 meter °C
09/08/98	9.1	20.4	9	20.3	8.9	19.5
09/24/98	10.3	14.2				
10/07/98	10.55	8.8	10.6	8.7	10.6	8.5
10/28/98	12.95	8.5	12.95	8.5	13	8.4

Turtle Lake Dissolved Oxygen/Water Temperature Data

Date	Diss. Oxygen Surface mg/L O_2	Water Temp. Surface °C	Diss. Oxygen 0.5 meter mg/L O_2	Water Temp. 0.5 meter °C	Diss. Oxygen 1 meter mg/L O_2
07/01/97					8
07/22/97					
08/11/97					
08/20/97					
10/22/97	10.6	7.7			
05/20/98	6	20.9	6.05	20.5	6.1
06/12/98	11.5	18	12.9	17.9	11.1
06/30/98	9.5	22	9.6	21.5	9.5
07/14/98	7.2	25	7.2	25	7.2
07/27/98	8.8	22.4	8.9	22.1	8.9
08/11/98	9.75	24	9.8	24.7	9.9
08/24/98	9.8	22.4	9.9	22.4	9.9
09/08/98	9.2	19.9	9.1	19.9	9
09/24/98	11.4	15.1	11.45	14.9	11.6
10/07/98	11	9.1	11	9	10.95
10/28/98	13.9	8.1	13.95	8	13.95

Date	Water Temp. 1 meter °C	Diss. Oxygen 1.5 meter mg/L O_2	Water Temp. 1.5 meter °C	Diss. Oxygen 2 meter mg/L O_2	Water Temp. 2 meter °C
07/01/97	20			7.4	20
07/22/97					
08/11/97					
08/20/97					
10/22/97					
05/20/98	20.3	6.15	20	6.15	20
06/12/98	17.1	11.1	17		
06/30/98	21.5	9.45	21.2	9.3	21
07/14/98	25	7.2	24.9	7.2	24.8
07/27/98	22.1	8.65	21.9	8.55	21.8
08/11/98	24	9.95	23.9	9.6	23.6
08/24/98	22.2	9.9	22.1	9.75	22.1
09/08/98	19.9	8.9	19.9	8.9	19.9
09/24/98	14.9	11.6	14.9	11.65	14.9
10/07/98	9	10.95	9	11	9
10/28/98	8	13.95	8		

Other Dissolved Oxygen/Water Temperature Data

North Lobe of Cross Lake			North Connection Lake			South Connection Lake		
Date	Dis. Ox. 0.5 meter mg/L O_2	Wat. Temp 0.5 meter °C	Date	Dis. Ox. 0.5 meter mg/L O_2	Wat. Temp 0.5 meter °C	Date	Dis. Ox. 0.5 meter mg/L O_2	Wat. Temp 0.5 meter °C
07/01/97	10.8	21	07/01/97			07/01/97		
07/22/97			07/22/97			07/22/97		
08/05/97	8.3	20	08/05/97			08/05/97		
08/11/97			08/11/97			08/11/97		
08/20/97			08/20/97			08/20/97	10.2	15
10/22/97			10/22/97			10/22/97		
05/20/98	6	20.6	05/20/98	6.1	22	05/20/98	5.35	22.1
06/11/98	10.5	18.5	06/12/98	12.5	18.2	06/12/98	10.4	18.5
06/30/98		22.2	06/30/98	10.25	23.5	06/30/98		21.5
07/14/98	6.3	24.9	07/14/98	8.5	26.2	07/14/98	7.65	25.5
07/27/98	13.4	24.5	07/27/98	9.65	22.8	07/27/98	9.8	22.4
08/11/98	13.75	24.5	08/11/98	9.5	25.2	08/11/98	8.8	24.5
08/24/98	10.3	22.4	08/24/98	8.75	23	08/24/98	10.15	23.9
09/08/98	12.6	20.5	09/08/98	10.5	20.2	09/08/98	10	18.9
09/24/98	14	14	09/24/98	14.9	14.8	09/24/98	12.95	14.2
10/07/98	10.8	8.2	10/07/98	11.75	9	10/07/98	12.5	9.2
10/28/98	14	8.5	10/28/98	14.1	9	10/28/98	13.65	8.9

*0.5 meters is considered as the mid-depth at each of these sites.

Appendix B: Observed History of Cross Lake and Turtle Lake

I was born and raised on the north shore of Turtle Lake and I remember alot of what transpired of the past of Turtle Lake.

My first memory was when the fish died and I had walked down to the lakeshore and saw a row of fish, large and small, of all different kinds and it occurred to me I could walk on that line of fish without setting foot on any ground. This was about 1920. (I was about 10 years old.)

In 1883 the homesteaders who settled around the lakes, and who had becomes owners of their farms, some years later got the idea they could gain more land by lowering the Turtle and Connection Lakes. What they gained was mostly unproductive land. It was wonderful for sow thistle and Canadian thistle, however. So by a petition of the lakes landowners that passed, County Ditch #68 was cut to lower Turtle and Connection Lakes.

Then because of the main watershed coming into Connection Lake on the southeast side and the outlet of Connection Lake being on the northeast side, the flow had just a short way to go from inlet to outlet.

Turtle Lake did not get any water. So Turtle Lake became lower and lower until about 1920 when the fish died. Then in the drought of the 1930's the lake kept getting lower and lower until as I remember Turtle Lake. It then became Upper and Lower Turtle Lake and you could hardly find any depth of more than five feet.

My father, who was opposed to the ditching that took place, together with a neighbor, namely Roy Hoialmen, decided in the late 1920's to try to have the lakes restored.

Working with W.E. Row, Crookston Attorney, Erling Swanson, Director, Division of Game and Fish, Herman C. Wenzel, Conservation Commissioner of Minnesota, Walter S. Olson, Director, Division of Drainage and Waters of Minnesota and other interested parties, progress was made until a survey was taken from just north of Gully, Minnesota to the north shore of Turtle Lake.

A heavy iron stake was driven down. The top of the stake was then to establish the water level as it was before the ditch was dug to lower the lakes.

In the final Certificate of Condemnation, filed in the Fourteenth Judicial district of Polk County on July 18, 1932, the levels to which these lakes were to be stabilized are stated.as follows:

Cross Lake, 1303.50 Mean Sea Level Datum Fourth General Adjustment 1912
Turtle Lake, 1307.00 Mean Sea Level Datum Fourth General Adjustment 1912
Connection Lake, 1307.00 Mean Sea Level Datum Fourth General Adjustment 1912

Turtle and Connections Lakes are then 3 feet 6 inches higher than Cross Lake.

All water level easements were then paid for and the dams were constructed in 1933. Because of the drought of the 1930's there was no water for the lakes until 1941 when the rains came. By the fall of 1941 all three lakes were restored.

In 1942 heavy rains continued so that the water level would flood over the stabilized levels. Complaints then were made of the State Conservation Department.

The Department, being somewhat careful because of the controversy over the dams, decided to take out one stop log on each side of the Connection Lake dam. And that is the way it remains to this day as far as I know. (NOTE: Now Turtle and Connection Lakes have a water level of 1306.50, three feet higher than Cross Lake.)

cont.

Observations of Turtle Lake on Surrounding Bodies of Water

One half mile north of Turtle Lake is another lake by an old log barn next to the Gully Tar Road. Below the hill of this lake was a flowing well before Turtle Lake was lowered. It became low and then quit flowing until Turtle Lake was restored and then it started flowing again. It is flowing to this day. This lake was very low in the 30's.

Then just a short way to the east on the Gully Road is another lake on the south side called the Chapek Lake. That was very low in the 30's. A very short way more east on this road on the north side, you see a long lake in the north and south called the Saw Mill Lake. It is narrow across on the middle and you could walk across there from west to east in the 30's. It was also very low in the 30's.

All three of these lakes came back to the levels they are at as of today when Turtle and Connection Lakes were restored. All three of these lakes have only one half mile or less watershed to them so it would seem that Turtle and Connection Lakes maintain their levels.

Because Turtle and Connection Lakes are three feet higher than Cross Lake, perhaps it would also be of benefit to Cross Lake, especially during one or more dry years, with the interest in Cross Lake for fishing along with the Tilberg County Park. This could be worth considering.

Now if the stop logs that were taken out on the Connection Lake dam were to be put back, which then would restore Turtle and Connection Lakes back to the intended levels that were the stabilized levels of 1307.00 and that was paid for, it could also be of benefit to Cross Lake and the three other lakes north of Turtle Lake for perhaps better duck lakes -- especially Connection Lake.

I would hope that this could be seriously considered.

I believe that water is becoming a precious commodity to be conserved wherever possible.

Because Turtle Lake is the first lake on the Hill River Watershed, perhaps this would be of interest to the Water Conservation and/or the Flood Control groups.

I would like to see as much water as is possible in the beautiful body of water like Turtle Lake, just six miles northeast of Fosston, Minnesota.

Orrin Torgerson
Fosston, Minnesota
January 1989

TO: East Polk Soil and Water Conservation District
P.O. Box 57
McIntosh, Mn 56556

FROM: Paul Stolen
RR3, Box 116
Fosston, Mn 56542
Owner, SE 1/4, Sec 24 T148N, R44W

DATE: April 18, 1994

RE: Survey of Cross and Turtle Lakes

The comments that follow are not made as an employee of the Department of Natural Resources. Rather, they are made as a private citizen who grew up on the shores of these lakes, and who became a biologist because of the large amount of time I spent there. I support your planning efforts. This survey was a good idea. I may be able to assist both as a resident and in my job. Thanks for the opportunity to comment. Sorry it took so long.

My comments are influenced by my childhood and adult wanderings around the lakes, and by my present avocational interest in ecology, rather than my DNR employment or by any biological data obtained from studying the lakes objectively.

I will try to provide my best recollection of the time period from the early 1950's until about 1966 because that was when I was around the lakes year-around, every year. I probably better recall the more spectacular events from my childhood, such as fish kills, large waterfowl flights, very high or very low water, and what was happening at the lake inlets and outlets. However, I am attempting to recall the more mundane events also.

HISTORICAL INFORMATION ABOUT DRAINAGE OF TURTLE AND CONNECTION

I would first like to pass on some material from Orrin Torgerson, a neighbor who died last summer whom I have known since childhood, and from family stories about my grandfather, Roy Hoialmen, who died before I was old enough to know him. Orrin truly loved Turtle Lake. His father, Louis Torgerson, and my grandfather were involved in the 1930's in getting dams placed so that Turtle and Cross lake levels could be restored when rains returned. Orrin gave me his files before he died.

This material shows conclusively that it was not the drought of the 1930's that instigated the building of the two dams at the outlets of Connection Lake. Instead, it was the building of County Ditch #68 in about 1918 that resulted in lowering the levels of Connection and Turtle lakes. It is likely that the extremely low water levels suffered during the drought swung support to those who wanted Ditch #68 plugged. I have enclosed three items from Orrin Torgerson's files:

a) A statement Orrin put together about Turtle Lake in 1989. Comment: His description of the results of the restoration controversy reflect what I heard through my mother. It looks as if it was technically the Izaak Walton League that brought the petition to restore the lake levels. My grandfather was a member of the league. The petition was successful, and a 1932 court order resulted in the setting of lake levels, construction of structures, and payment of flowage easements. (I do not have a copy of the court order.)

b) A copy of an April 18, 1940 letter from attorney W.E. Rowe to Louis Torgerson discussing the 1932 Court Order. Comment: I believe this attorney was involved with the Izaak Walton League earlier, though I am not certain. This shows that there was still attention being paid to details eight years after the court order.

c) A copy of an April 29, 1940 letter from the State of Minnesota to Louis Torgerson. Comment. This letter discusses the court order. The water control structures placed between Turtle and Connection, and between Connection and Cross lakes (on the Naastad/Stewart place) were built at this time of restoration. This letter contains some interesting information about the apparent intent of the project to apportion flow between the lakes. The letter also points out the basic issue that when water levels are low in one lake, they are low in others. This is exactly what again occurred in the last few years. (NOTE: These records do not discuss the Cross Lake outlet structure in Tilberg Park. It was likely built at the same time, however.)

Interestingly, this letter refers to the 1932 Court Order establishing a "game refuge."

Orrin's files contain a number of other items of historical interest, including maps, letters, and a detailed engineering report for a WPA project to divert the Poplar River from just east of Whitefish Lake to Turtle Lake. The letters have to do with the 1934 controversy about the key structure at the Connection Lake outlet and the petition from the Izaak Walton League. I can provide copies if anyone wants them. One of the most interesting is a map that shows the flowage easements that were paid to restore Connection and Turtle lakes to the levels referred to in Orrin's statement.

The successful petition to restore lake levels resulted in a court order that set levels of all three lakes, apportioned flow, and ordered flowage easement payments from public money to some of the individuals who lost land they had gained from drainage some time before. Other affected individuals did not receive payment. According to family stories, these tended to be individuals in favor of the restorations.

OBSERVATIONS OF TURTLE, CONNECTION, AND CROSS LAKES.

A couple of points: Your survey should include Connection Lake--you cannot separate the three lakes hydrologically or ecologically. Secondly, my opinions about ecological relationships are not based on research done on the lakes.

Water levels of Turtle, Connection, and Cross. Perhaps the most interesting item regarding lake levels is that the 1950's and 1960's were a time of low water--lower than the drought that ended three years ago. During my wanderings around the lake, I always walked out to the big island on the west side (just north of Gene and Diane Hegge's farm.) It looks like a peninsula, but it is an island under normal water levels.

Until I graduated from high school in 1962, there was a mud flat between this island and the main lakeshore. Sometimes lake levels went up, and I had to use hip boots, or lay boards across the mud. Three years ago this area was dry as well. But not as dry as in 1959 or 1960. In one of those years, there was only a little puddle of water in the whole west arm of the lake (the arm that extends close to my place.) I remember this distinctly because my dog chased a raccoon out onto the mud flat, and I had heard the stories of raccoons being able to drown a dog if they got it out into deep water. At that time I could walk on the firm mud across the northwestern bay.

I monitored the lake level three years ago during the recent drought, and Turtle Lake reached its lowest point just before freeze-up in the fall of 1991. There was an edge of exposed mud flat around the northwest bay, but nothing like the low levels when my dog chased the raccoon.

I also watched the lakes during floods. When I started my walks in the early 1950's the water control structure between Turtle and Connection had not yet washed out. I think the wash-out occurred after the mid-1960's, and likely happened more than once. I think the big wash-out occurred when the road across Connection Lake washed out about 15-20 years ago. There never were any boards in the Turtle/Connection lake structure, even before it washed out. The channel between Turtle and Connection was often dry during the 1950's and early 1960's.

The enclosed letter from Walter Olson (State of Minnesota) to Louis Torgerson points out that there was still an ongoing drought in 1940. I know from my work on the recent Poplar River/Maple Lake diversion project that the rains returned in 1941, and a much wetter period ensued until the 1950's.

Waterfowl use. Turtle and Connection have been the main waterfowl lakes of the three, although Cross Lake had good numbers of scaup in the 1950's and 1960's. The comments that follow about waterfowl are about Turtle Lake.

I started walking around Turtle Lake when I was 8 or 9 years old, which would have been in about 1953. Every fall, I collected empty shotgun shells from the duck blinds. I did it to play with them in the beginning, and later to see how many I would get. By the middle and late 1950's, I was collecting eight or nine hundred each fall. I recall the most collected in one year was around 1200. And this was incidental to my main purpose, which was wandering around. Even then I knew that the numbers were not much of an accurate measure of the thousands of shells used every season because so many were lost. Before I was old enough to start duck hunting I would catch cripples along the shore.

There were hunters everywhere around the lake in the 1950's and early 60's. Duck numbers started dropping in the 1960's. Many of these hunters came from far away, and the Duluth hunters who used the sandbars were legendary. No one could remember when they had not been there. Since I started working in Bemidji, and when I've told people where I live, 5 or 6 have mentioned to me "Oh yeah, I used to go over to Turtle to duck hunt years ago."

Anyone who spent time on the lake was struck by the variety of species of waterfowl and water birds. Pretty much every species of duck using the Mississippi Flyway and then some. I saw Black Ducks there once in the early 1960's. There were large numbers of divers, such as scaup, canvasbacks and redheads. These were very abundant in the 1950's, and to some extent through the early 1960's. The first drake mallard I shot was banded, and the return letter to me showed that it had been banded in New York five years before.

The most memorable event with respect to waterfowl flights I ever saw anywhere occurred one October morning in the fall of 1960 or 1961 (either when I was a junior or senior in high school.) I had gone down to Turtle Lake for a quick look with the shotgun before the bus came. It was a still morning, and, it turned out, just before a sharp cold front came through. There were huge flocks of all kinds of waterfowl piling in from high up. Their wings could be heard before they were seen. Many were divers, but there were also flocks of widgeon calling. Later that day I ran into Carl Johnson (the Conservation Officer then) and he said he was on the lake with a federal biologist that morning, who estimated that 40,000 birds had come in overnight and in the morning.

The lake is important for many species of water birds that are not hunted. In the past I've seen hooded mergansers, several species of grebes, (including western grebes), black terns, and many other such birds. Eagles and loons use it now. When the lake was low and exposing mud flats, there were many species of shorebirds using it. American mergansers seem to really like it in the spring, and not as much in the fall.

Water quality. I have been around the lakes frequently enough since the mid-1960's to notice the general trends that have occurred. Water quality in the lakes is a puzzle. In the 1950's, Turtle Lake had tremendous algae blooms, and you could smell it for long distances both in the spring with the onset of warm weather, and when the blooms were on. Water clarity was very poor. Thick green mats formed on windblown shores. No point then in putting in a fish house in the winter--a person couldn't see enough to spear a fish.

This seems to have changed dramatically in recent years. Turtle Lake has generally had good clarity both in winter and summer. It has never smelled like it used to, and algal blooms have been present but not unusual. The water is not always clear in the winter, but usually has been good or at least minimally adequate for spearing.

On the other hand, Cross Lake's water quality seems to have declined in the last 15-20 years. Even though the 1950's and early 1960's were years of generally low water levels, there were never algal blooms similar to Turtle Lake during these times. Cross Lake seems to have more algae blooms, poor tasting fish, and poor swimming. Up until the 1970's and 1980's, Cross Lake was at times a popular swimming area. And we have family pictures of the Cross Lake swimming beach with a hundred people in and along the water in the 1920's.

Lake water quality is dependent on land practices on its watershed. There have been changes--two of the most obvious are a big decrease in intensive pasturing of cattle around the lakeshores of Cross, Turtle, and Connection, and an increase in the use of fertizilers on farm fields. The first would tend to decrease the amount of nutrients going into the lakes; the second would increase the amount of nutrients.

Fish in Cross, Turtle, and Connection.

Turtle Lake has always been a lake subject to explosions of fish and crashes from winterkill. My mother talks of Louis Hanson (or his father? He lived on the farm Gene and Diane Hegge live on now on the west side of Turtle) taking "wagonloads" of netted northern pike out about the time of World War I.

Few people fished Turtle in the 1950's and early 1960's, even though there were abundant fish at times. Each spring when there was a winter kill, I would measure northern pike, and I remember getting a 38 inch fish probably about in 1958 or so. That same year there was a lot of large crappies and suckers. Fishing didn't

5

really happen much in Turtle until the late 1960's.

Cross Lake on the other hand was a good and reliable fishing lake during the 1950's and 1960's. There never was a winterkill that I recall until after the middle-1960's (perhaps later--I was not around as much.) It was good for northern pike, walleyes, suckers (spring spearing) and sometimes crappies. It always had bullheads, but they never seemed to be super-abundant.

The dam on the outlet of Connection Lake has always had boards in it as far as I remember. I have also seen northern pike and walleyes run up to the dam, and have seen spring conditions both ways: too little water to allow them to get over it, and enough water so I have seen them run over it.

Other ecological issues.

The shoreline vegetation of these lakes has changed quite dramatically. Since the 1960's, cattails have increased enormously along the shorelines of Connection and Turtle lakes. The same increase has occurred on shorelines of other lakes. The result has been a decrease in diversity of wetland habitats.

Bulrush beds have become much more abundant in Turtle Lake than prior to 1970, and less common in Cross Lake.

CONCLUSIONS AND ANSWERS TO SURVEY QUESTIONS

Answers to most of the specific questions are given in the above sections. I will sum up the major issues here.

Water quality. It is hard to determine what is going on with respect to water quality. My guess, and it is only a guess, is that there have been long-term nutrient cycles. Turtle Lake in the 1950's exhibited symptoms of being extremely nutrient rich. This was only 15 years after the water returned after the long drought. Nutrients in drained lakes, previously bound up in lakebed soils, are chemically released to become available when water returns. It could well be that it has taken this long for nutrients to become bound up again in the lakebed.

There are no easy answers to questions about Cross Lake's water quality variations, in my opinion.

I feel that a watershed approach should be taken to focus on finding the sources, if any, of too much nutrient inflow into the lakes. In the long term, this should improve fishing in Cross Lake.

Best use of Turtle Lake. In the long term, Turtle Lake has been a very important lake for waterfowl. It is not just of local significance--in the past it was a major stopping point for migratory birds on their way down the Mississippi flyway and to Chesapeake Bay (canvasbacks.) Ducks and other migratory waterbirds don't use just any lake--this one has had significantly different habitats.

Northern pike quickly return after a winter die-off. The lake should be recognized by the county as an important waterfowl lake and managed as such. It should also be managed so as to not impede northern pike movement into it, and management recognition given that it is a local recreational resource for northern pike fishing.

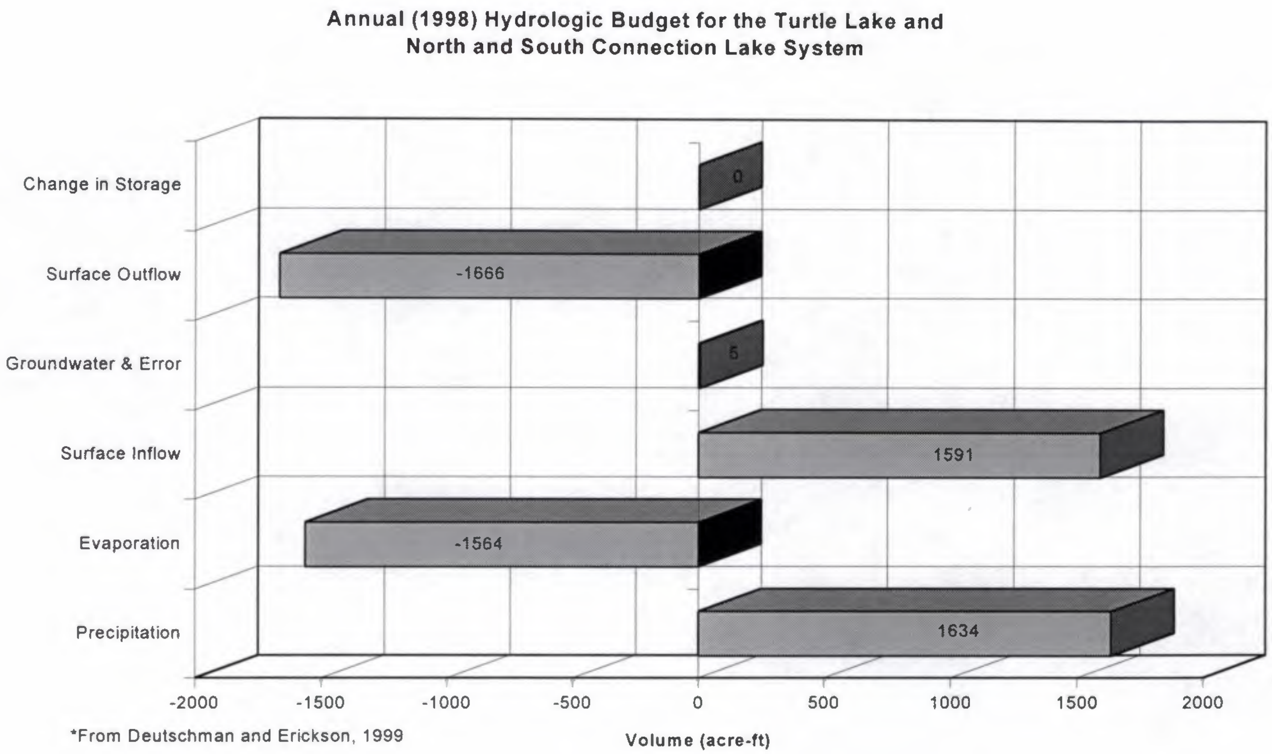
Water control structures. The water control structures in place now need to be dealt with. The structure at the outlet of Connection Lake has almost washed out previously, and will likely do so in a future flood event. This will likely result in substantial lowering of Connection and Turtle lake water levels, and likely large acreage loss of both wetlands and lake around the fringes of the current Turtle and Connection lakes. There were public funds expended in 1932 for taking these lands out of private use as farmland and putting them into public use as wetlands and lakes.

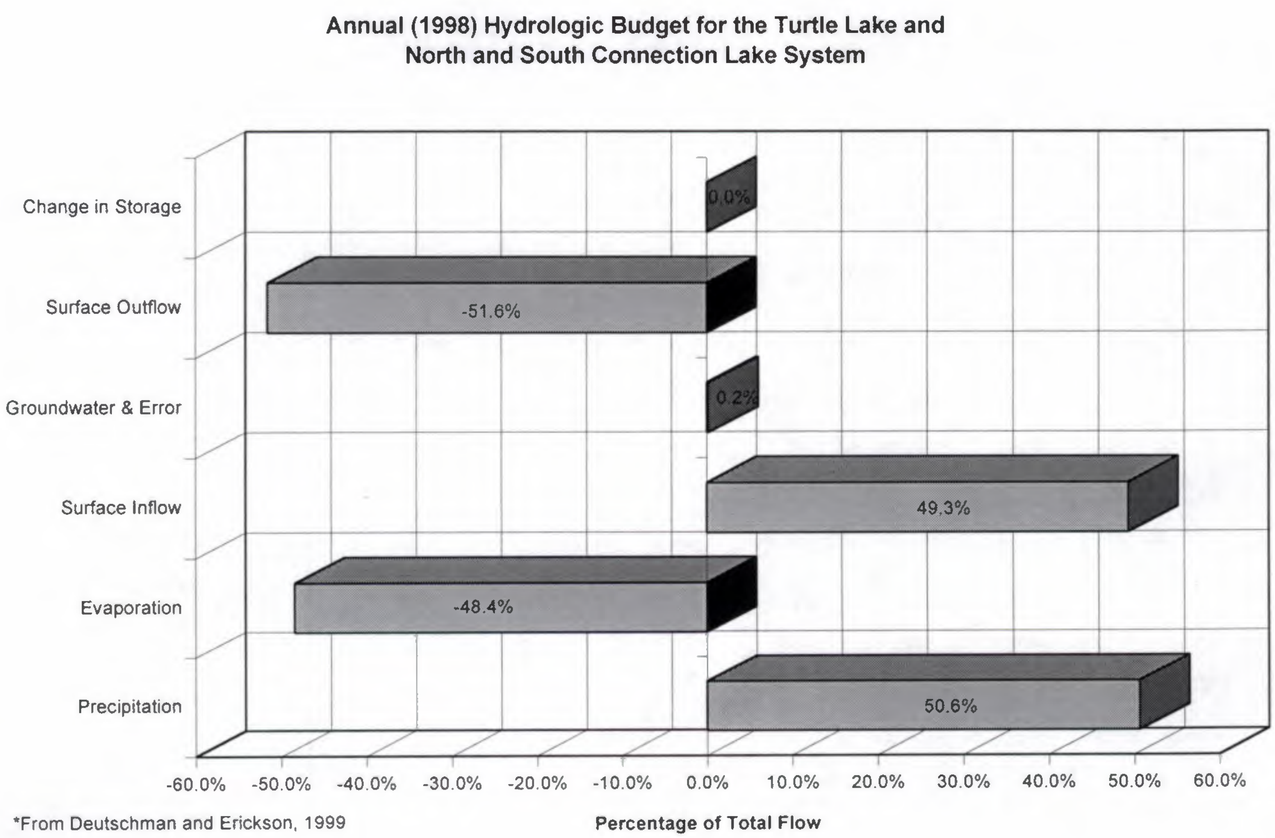
The county should look at the 1932 Court Order to find its legal status and relevance today. Because the key structure at the outlet of Connection Lake is subject to damage, consideration should be given to restoring the water control structures to their previous condition and following the Court Order. According to the Walter Olson letter, the structures were apportioned to give Cross Lake 60 percent of the Hill River flow because of Cross Lake's value for "resorts." (In modern terms that would likely read value for fishing.) Perhaps this is a reasonable apportionment, based on the historical record of kinds of uses for the lakes and on the biological attributes of all three lakes.

Other suggestions

Consideration should be given to establishing a hiking, biking, and cross-country ski trail from Fosston to Tilberg Park. Over the long-term, there are often grants available for such a project. Local initiative is needed. This could increase day use and camping use of the park, and add value and use for and by Fosston residents. I might be able to give some advice on how to proceed with such an idea.

Appendix C: Hydrologic Graphs





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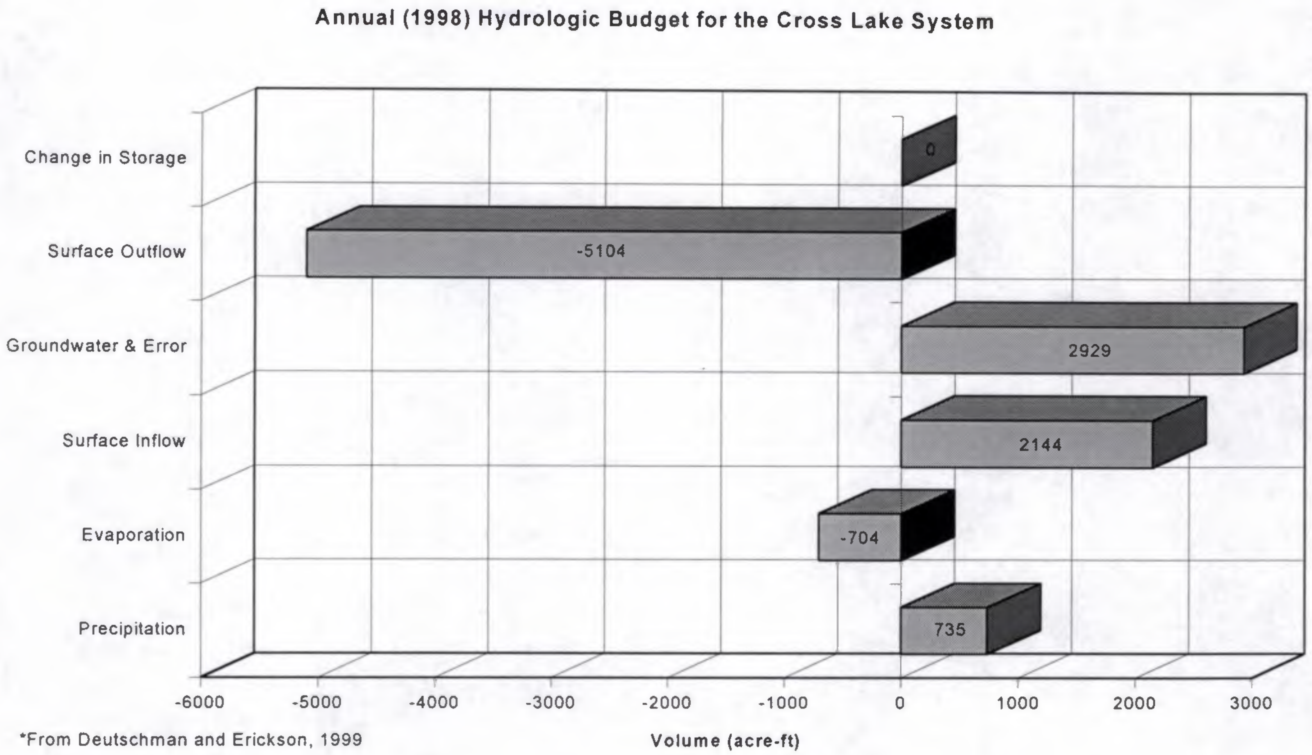

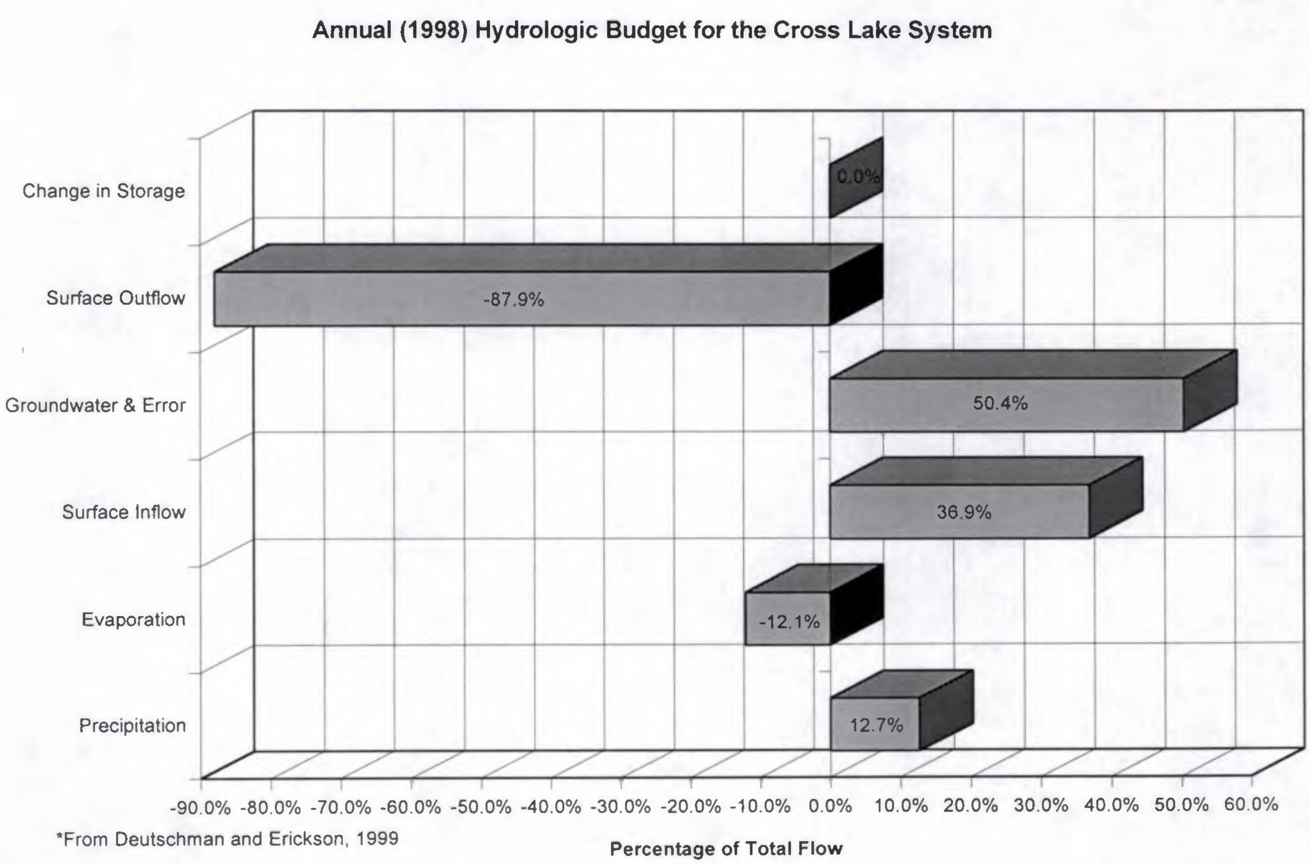

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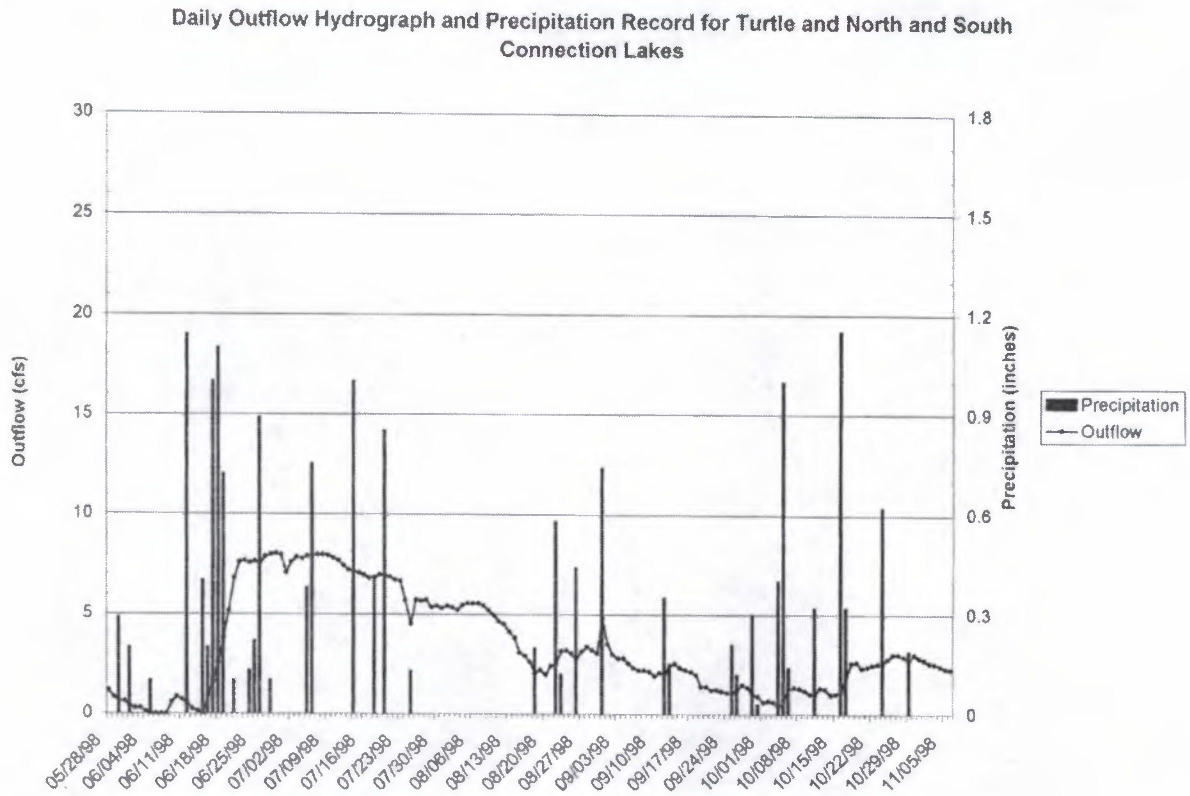
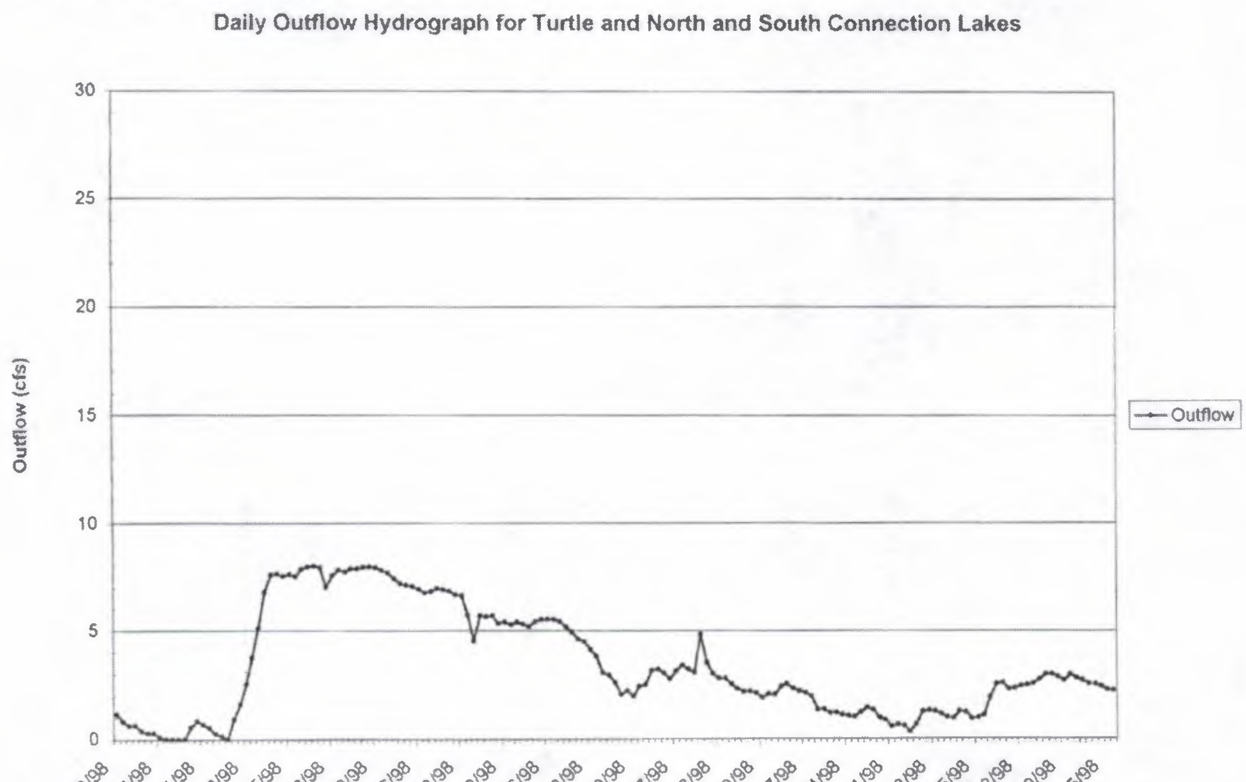


* From Deutschman and Erickson, 1999



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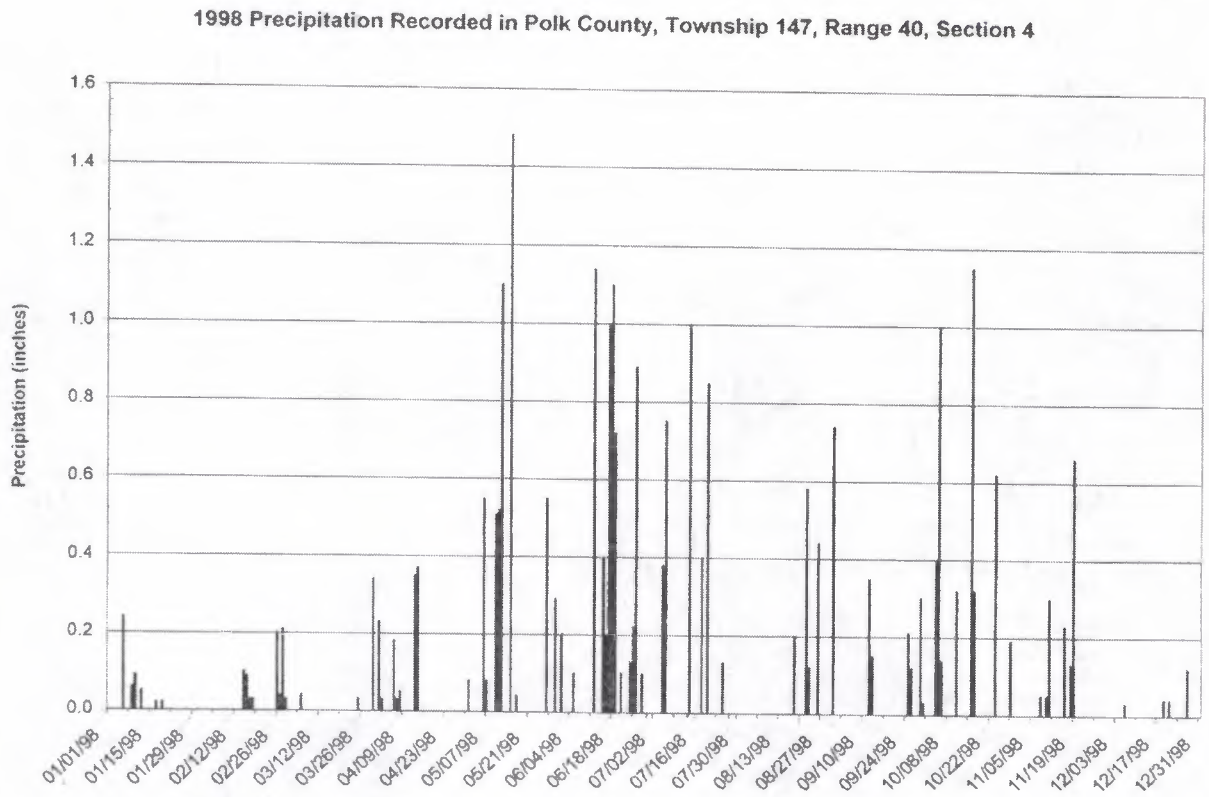

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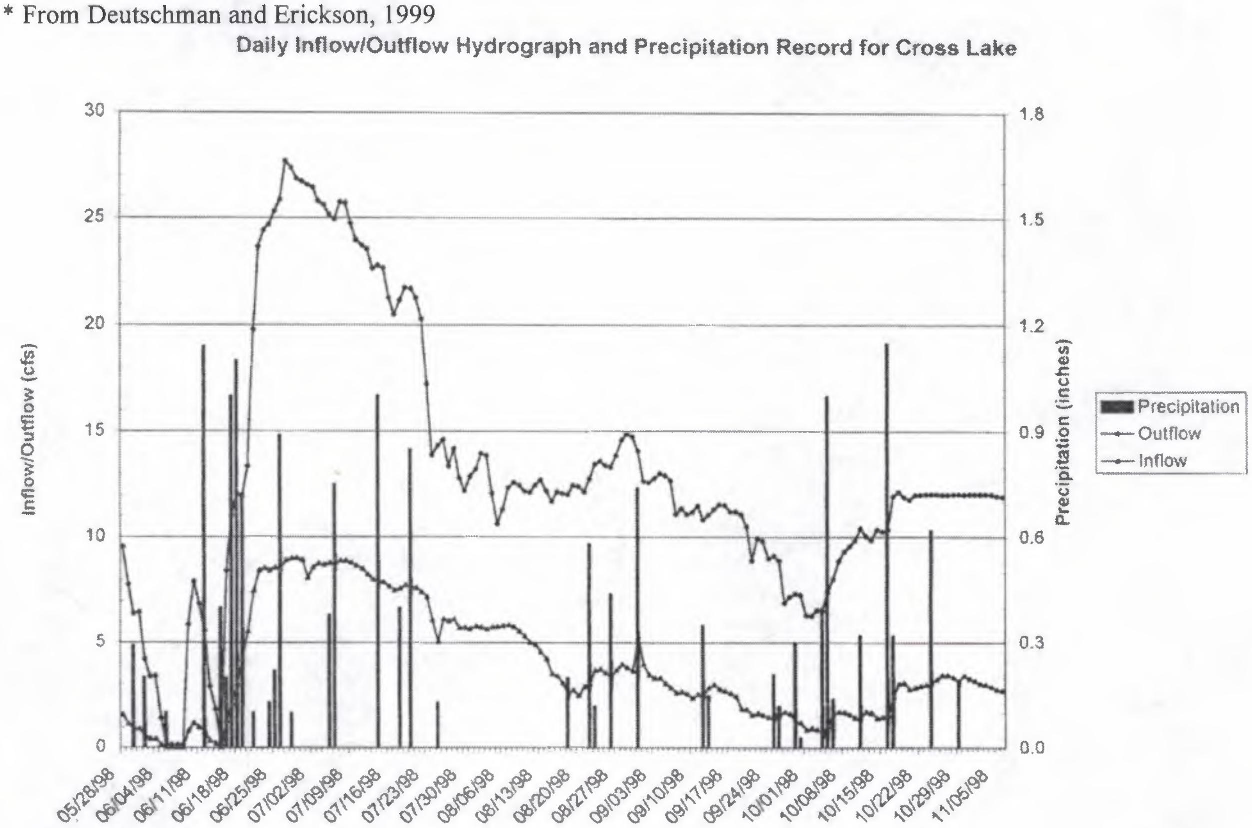

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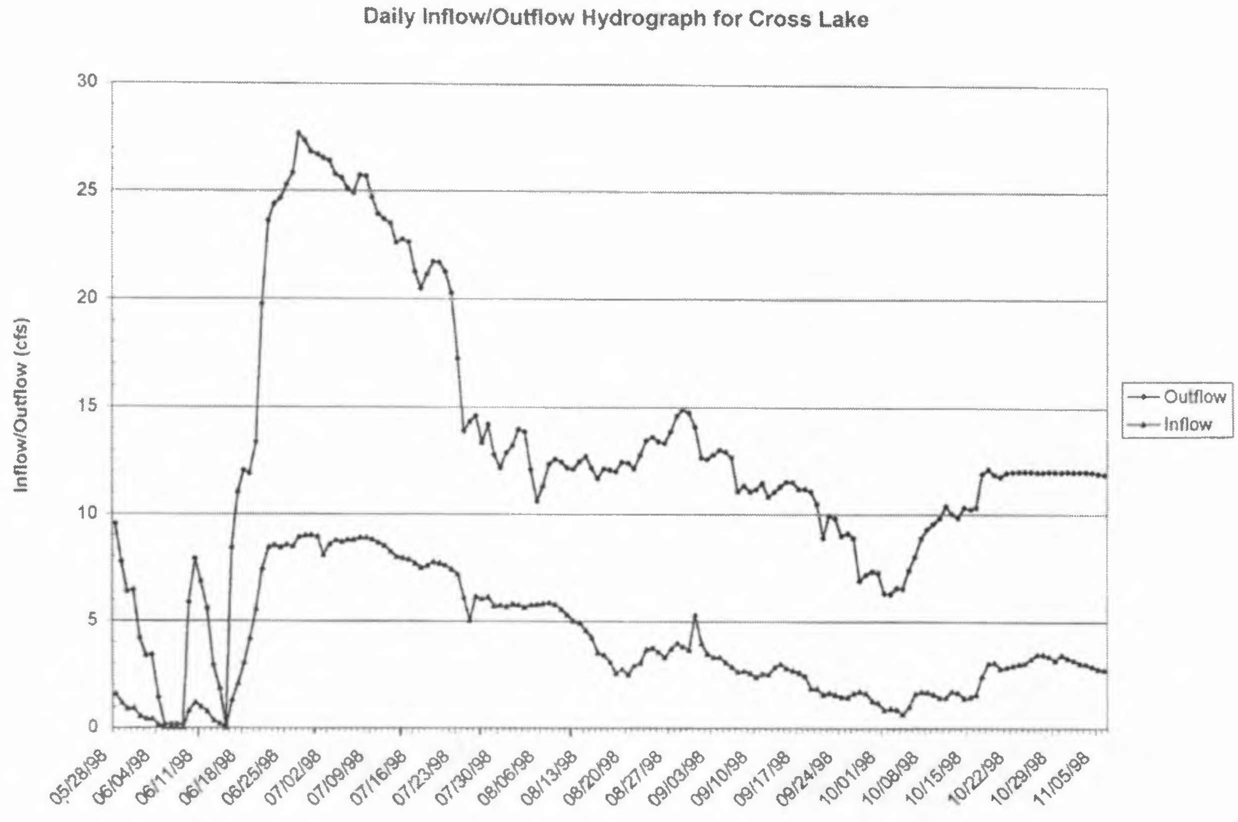

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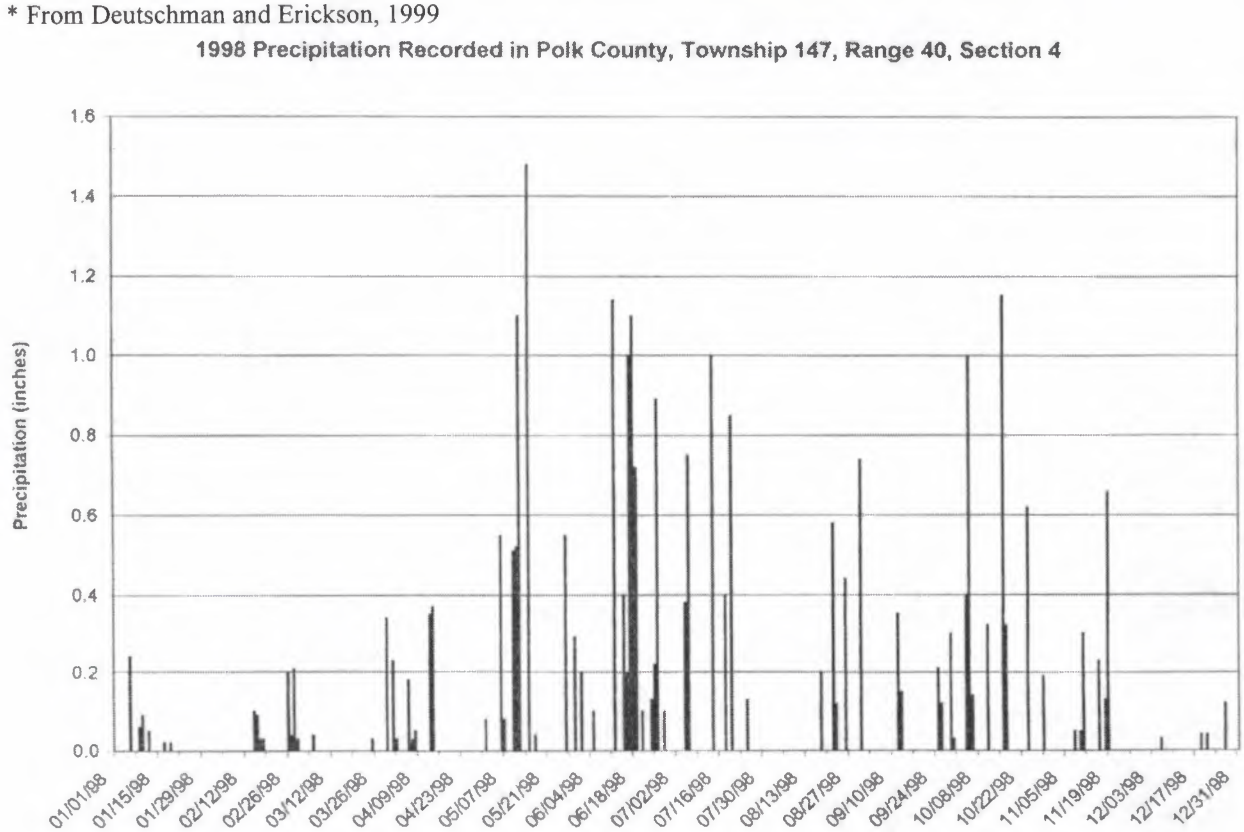
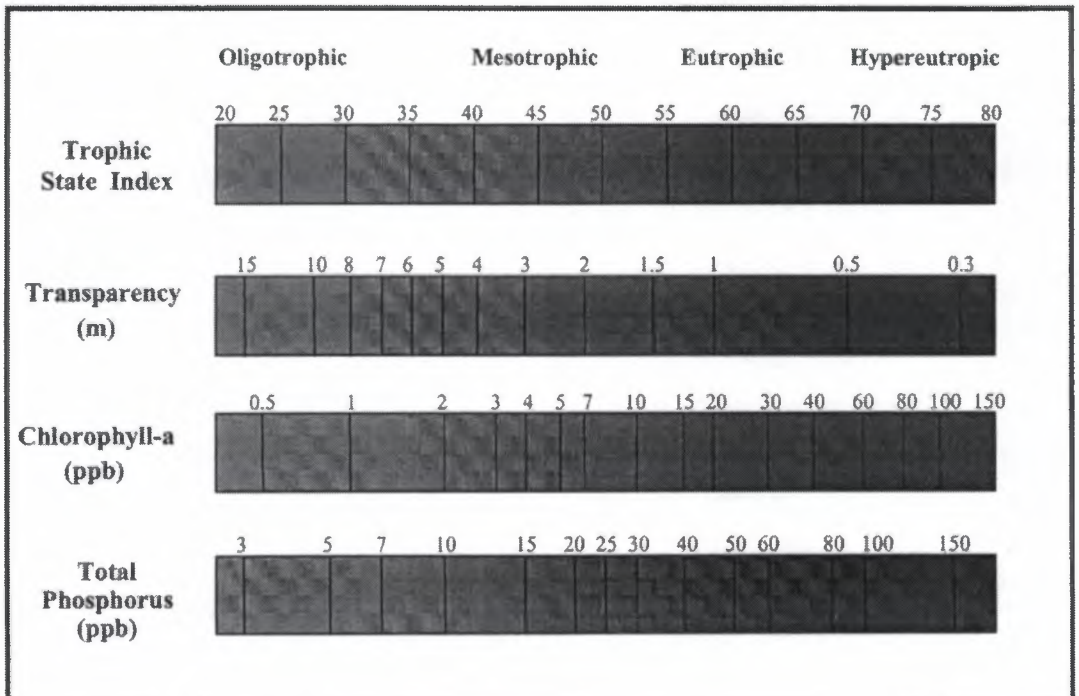


* From Deutschman and Erickson, 1999

Appendix D

Carlson's Trophic State Index
RE Carlson

TSI < 30	Classic Oligotrophy: Clear water, oxygen throughout the year in the hypolimnion, salmonid fisheries in deep lakes.
TSI 30 - 40	Deeper lakes still exhibit classical oligotrophy, but some shallower lakes will become anoxic in the hypolimnion during the summer.
TSI 40 - 50	Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.
TSI 50 - 60	Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimnia during the summer, macrophyte problems evident, warm-water fisheries only.
TSI 60 - 70	Dominance of blue-green algae, algal scums probable, extensive macrophyte problems.
TSI 70 - 80	Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypereutrophic.
TSI > 80	Algal scums, summer fish kills, few macrophytes, dominance of rough fish.



<u>After</u> Moore, 1. And K. Thornton, [Ed.]1988. Lake and Reservoir Restoration Guidance Manual. USEPA>EPA 440/5-88-002.

Ecoregion Lake Data Base Water Quality Summary

(Summer Average Water Quality Characteristics for Lakes by Ecoregion)*

Parameter	Northern Lakes and Forests	North Central Hardwood Forests	Western Corn Belt Plains	Northern Glaciated Plains
Total Phosphorus (ug/l)	14 - 27	23 - 50	65 - 150	130 - 250
Chlorophyll mean (ug/l)	4 - 10	5 - 22	30 - 80	30 - 55
Chlorophyll maximum (ug/l)	< 15	7 - 37	60 - 140	40 - 90
Secchi Disk (feet) (meters)	8 - 15 (2.4 - 4.6)	4.9 - 10.5 (1.5 - 3.2)	1.6 - 3.3 (0.5 - 1.0)	1.0 - 3.3 (0.3 - 1.0)
Total Kjeldahl Nitrogen (mg/l)	0.4 – 0.75	< 0.60 - 1.2	1.3 - 2.7	1.8 - 2.3
Nitrite + Nitrate-N (mg/l)	<0.01	<0.01	0.01 - 0.02	0.01 - 0.1
Alkalinity (mg/l)	40 – 140	75 - 150	125 - 165	160 - 260
Color (Pt-Co Units)	10 – 35	10 - 20	15 - 25	20 - 30
pH (SU)	7.2 - 8.3	8.6 - 8.8	8.2 - 9.0	8.3 - 8.6
Chloride (mg/l)	0.6 – 1.2	4 - 10	13 - 22	11 - 18
Total Suspended Solids (mg/l)	< 1 – 2	2 - 6	7 - 18	10 - 30
Total Suspended Inorganic Solids (mg/l)	< 1 – 2	1 - 2	3 - 9	5 - 15
Turbidity (NTU)	< 2	1 - 2	3 - 8	6 - 17
Conductivity (umhos/cm)	50 – 250	300 - 400	300 - 650	640 - 900
TN:TP ratio	25:1 - 35:1	25:1 - 35:1	17:1 - 27:1	7:1 - 18:1

*Based on Interquartile range (25th - 75th percentile) for ecoregion reference lakes.
Derived in part from Heiskary, S. A. and C. B. Wilson (1990).