Fish, Weaver and Diamond Lakes were sampled by the Commission in 1994 (Figures 2 - 4). Fish and Weaver lakes are located in Maple Grove. Diamond Lake is located in Dayton. Fish and Weaver lakes are defined as category I critical lake drainage basins. Diamond Lake is a category III lake. The critical lake drainage basins as defined in the Elm Creek Watershed Management Plan are shown in Figure 4. Lake morphometry, watershed area and land use data are summarized for each lake in Table 2. Land uses with potentially adverse effects on water quality include, row crops, commercial, industrial and medium and high density residential uses. These land uses are classified as deleterious uses in the Elm Creek watershed plan. Land uses with potentially positive effects on water quality include grasslands, wetlands, woods and parks. These uses are classified as sustaining uses. The percentages of deleterious and sustaining use were determined from 1980 aerial photos.

The 1994 monitoring of Fish and Weaver Lakes was conducted by Instrumental Research of Spring Lake Park, Minnesota under contract with the Commission. Surface water samples were collected as composites of the upper two meters of water. The samples were analyzed by Instrumental Research laboratory. Diamond Lake was sampled by a volunteer lake resident through the Metropolitan Council's Citizen-Assisted Lake Monitoring Program (CAMP). The Cityof Maple Grove sampled Fish, Weaver and Rice lakes three times in 1994. Samples were analyzed at Instrumental Research Laboratories. The monitoring dates from the Commission's and City's programs were coordinated to provide the best time coverage. These results are included in the analysis. Although the Commission does not monitor Rice Lake, analysis of the data collected by the City of Maple Grove is included in this report since Rice Lake is located in the Elm Creek Watershed.

Water quality parameters monitored in 1994 are summarized in Table 3. Under the Commission's program, Fish and Weaver Lakes were sampled monthly from May through September on the following dates, May 17, June 10, July 11, August 15 and September 14. Analyses of lake samples for chloride were conducted in May and August. All other parameters were monitored or analyzed monthly. Samples were collected and delivered to the laboratory that same day. Diamond Lake was sampled approximately biweekly from May to October. The volunteer monitor received training from Metropolitan Council staff on proper lake monitoring procedures and sample handling techniques. Samples were collected just below the surface using a clean plastic milk jug. Chlorophyll a samples were filtered and frozen. Total phosphorus and total Kjeldahl nitrogen samples were also frozen. Samples were picked up within 30 days and analyzed at the Metropolitan Council's Wastewater Services laboratory.

Phosphorus is a chemical element that is essential for plant growth. Concentrations of total phosphorus (TP) indicate the maximum growth potential for algae in a lake and may be used to classify a lake's trophic status. Maximum TP concentrations were observed in July and June for Fish and Weaver Lakes respectively (Figure 5). Diamond Lake exhibited two peaks in phosphorus concentration, one at the end of June and one at the end of August. Diamond Lake had the highest mean TP concentration (144 µg/l) of the three lakes sampled by the Commission. Weaver Lake had the lowest mean TP concentration (34 µg/1). Fish Lake had a mean TP concentration of 46 µg/1. Rice Lake had a mean TP of 373 µg/l based upon 3 samples.

Chlorophyll a is a photosynthetic pigment found in all green plants. The concentration of chlorophyll a is a measure of algal abundance. Weaver lake exhibited fairly low chlorophyll a concentrations throughout the summer (Figure 5). Fish Lake chlorophyll a concentrations in July - September indicate that some nuisance algal blooms occurred. Diamond Lake had the highest mean chlorophyll a concentration at 46 µ.g/l. Nuisance algal blooms occurred throughout the summer. An

extreme peak of 130 µg/l was measured on June 15th. Rice Lake had high chlorophyll a values for all three sampling dates.

Secchi disk transparency is a measure of water clarity. Higher Secchi disk transparency indicates greater water clarity. Weaver Lake had its highest reading of 12.0 feet in May. The maximum Secchi disk transparency of 10.0 feet for Fish Lake occurred in June (Figure 5c). Minimum transparency occurred in September in Fish lake and July and September in Weaver Lake. Diamond Lake had a minimum transparency of 1.0 foot in August. Weaver Lake had a mean transparency of 7.3 feet. This is a good average for the metropolitan area. Fish Lake had a mean transparency of 5.1 feet. Diamond Lake had the lowest mean transparency (1.7 feet) of the three lakes sampled by the Commission. Rice Lake had a mean transparency of 2.2 feet.

Temperature and dissolved oxygen measurements were taken from Fish and Weaver Lakes. Dissolved oxygen concentrations generally mirrored temperature profiles with a rapid decrease in dissolved oxygen below the thermocline during stratification. Dissolved oxygen conditions varied from lake to lake. Temperature profiles show that both lakes were stratified throughout the monitoring season (Figures 7 - 8). Weaver Lake was weakly stratified on the May 17 monitoring date. Weaver lake was fairly well oxygenated to the bottom in May and June. Fish Lake oxygen concentrations dropped to approximately 1 mg/1 below a depth of 6 meters in May and June. However, profiles for the remainder of the season showed anoxia below approximately 6 to 7 meters (20 to 23 feet) for both lakes. Rice Lake profiles were measured on all three sampling dates. Rice Lake is shallow and was oxygenated throughout the water column (Figure 9). Oxygen concentrations should remain above 5 mg/1 for long-term game fish survival.

Lakes may be classified as to their trophic state based on Carlson's Trophic State Index (Carlson 1977). This index indicates nutrient enrichment and is calculated based on measured values for total phosphorus, chlorophyll a and Secchi disk transparency. Trophic state index values for the lakes sampled in 1994 are shown in Figure 10. Fish Lake is considered eutrophic (nutrient rich). The index values for Weaver Lake placed it between mesotrophic to eutrophic (moderately nutrient rich to nutrient rich). The TSI for phosphorus indicates the potential trophic state for the lakes. High phosphorus concentrations suggests that either the lake may exhibit dense macrophyte beds or heavy algal blooms throughout the summer. Diamond and Rice lakes am hyper-eutrophic based on very high TSI's of 71.2 and 75.1 respectively.

It is difficult to determine trends when extensive data is not available for a lake. The accuracy of these evaluations increases with increasing number of samples. The following trend analysis is based on limited data and therefore may not be an accurate assessment of water quality trends for the lakes. The Elm Creek Watershed Management Commission, in its Management Plan, established water quality goals for lakes within the watershed. These numerical goals differ depending upon lake classification. In order to simplify the meaning of these goals, they are referred to as upper or lower limits in this report. Weaver and Fish Lakes are category I lakes and have the most stringent water quality goals. Diamond Lake is a category III lake which has the least stringent goals. In 1993, the Management Plan was amended to include revised goals for chlorophyll a. These goals were revised to 20 and 30 pg/l for category I & II lakes respectively.

At this time Rice Lake is not classified in the Elm Creek Plan. Rice Lake is actually an impoundment created by a dam in Elm Creek. It is fairly large (306 acres) but shallow. The maximum depth is 11 feet. Rice Lake has a history of nuisance algal blooms. The data collected in 1991 - 1994 indicate Rice Lake is eutrophic to hypereutrophic. Phosphorus concentrations in Rice

Lake are extremely high. Concentrations ranged from 277 to 514 µg/1 (152 µg/1 to 1057 µg/l in 1994). Algal blooms in the lake are limited by other factors such as turbidity, as evidenced by the lower chlorophyll a mean value than expected based upon total phosphorus concentrations. Rice lake also receives herbicide treatments to control algae. Based upon the phosphorus concentration measured for Rice Lake, it could exhibit potentially much poorer conditions than observed. A mean phosphorus concentration of 373 µg/1 could support severe algal blooms and very limited transparencies.

Fish Lake's mean phosphorus was above the upper limit of 35 14/1 but lower than it has been since 1989 (Figure 11). The 1994 mean phosphorus concentration for Weaver Lake is below the upper limit listed in the Plan and is lower than it has been since 1988 (Figure 12). Diamond Lake has been sampled 5 years since 1980. Mean concentrations of chlorophyll a and total phosphorus (Figure 13) have increased since 1989. Mean Secchi disk transparency for Fish Lake has remained fairly stable since 1987 but fell below the lower limit in 1992 (Figure 11). The mean transparency in 1994 was above the lower limit. The Minnesota Pollution Control Agency (MPCA) lists a mean transparency of 5.6 feet for Fish Lake. This value is based on 101 measurements from 1977-1992 and provides a means for comparison to a long term average.

Long-term averages for the lakes were determined as an average of the annual mean of the data collected by the Commission. Long-term averages for each of the lakes are listed below. Values for Fish and Weaver lakes are similar to that measured in 1994. Diamond Lake 1994 values were better than the values for the long-term average which is high due to extremely poor water quality observed in 1989. Rice Lake has been sampled since 1991 (Figure 14). Only three samples were collected in 1994. Based on the limited sampling, Rice Lake 1994 conditions were slightly worse than the long-term average.

	Fish (1980-1994)	Weaver (1980-1994)	Diamond 1986-1994)	Rice (1991-1994)
TP	48.2	35.3	443	373.5
SDT	6.1	7.4	1.4	3.4
CHL	20.1	15.6	195	34.6

Trend analysis was conducted on the data for Fish and Weaver lakes. Trend lines were predicted based upon annual means for 1985-1994 for phosphorus, chlorophyll a and transparency (Figures 15 and 16). Regression trend lines were determined based upon both a linear and an exponential equation. For Fish Lake, the analysis indicates an increasing and then leveling off of total phosphorus. Chlorophyll a shows a similar trend. The transparency trend is slightly downward. Weaver Lake trend analysis indicates a fairly stable phosphorus and chlorophyll a concentration. Transparency is predicted to improve slightly.

The water quality of Fish and Weaver Lakes, as measured by total phosphorus, appears to be declining slightly. However, as development in the watersheds of these two lakes reaches completion, the nutrient loading to the lakes should stabilize.

Diamond Lake's watershed is primarily agricultural land use. Feedlots drain into the lake and some property is farmed right down into the lake. Improved feedlot management and conservation fanning practices are needed to improve the water quality of Diamond Lake. There are several residents on the lake. Shoreline best management practices should be used by these residents.

The Commission has taken steps in the past to reduce nutrient loading through requiring erosion control plans and stormwater treatment for new development. Although these practices have reduced the impact of new development on water quality, it is apparent that additional management practices or improvement projects are needed to improve water quality of the lakes in the Elm Creek Watershed to meet the water quality goals of the plan. Beginning in 1994, the Commission began a revision of its Management Plan. The revised Plan will include updated administrative and structural methods to be implemented in order to protect and improve the water and soil resources of the Elm Creek Watershed.

The water quality of Elm Creek Watershed lakes may be compared to that of lakes that should be similar in water quality based on location, land use, soils, land form and potential natural vegetation. The MPCA in cooperation with the Environmental Protection Agency (EPA) has developed a means to group Minnesota Lakes based on the above characteristics. These areas are called aquatic ecoregions. There are seven of these ecoregions in the state (Figure 17) (Wilson and Walker 1989). The Twin Cities Metropolitan area is within the ecoregion known as the North Central Hardwood Forests (NCHF). Lakes within an ecoregion should be somewhat similar to each other. Elm Creek Watershed lakes may be compared with other NCHF lakes. The MPCA rankings for Fish, Weaver, Diamond and Rice lakes are 41, 64, 18 and 10 percentile respectively. These rankings are based on limited data and may change somewhat with additional data. The rankings are percentile values with a value of 0 indicating the poorest water quality and 100 indicating the best water quality in comparison with other lakes in the ecoregion.

Ecoregions also provide a means for gathering useful information for setting water quality goals. The potential water quality of a lake may be estimated based on data for the lakes having the best water quality for the ecoregion. The MPCA refers to these lakes as minimally impacted lakes. Mean values for monitored lakes may be compared to interquartile ranges for the NCHF lakes (Table 5). The 1994 total phosphorus concentration for Fish Lake was at the upper end of the interquartile range. This indicates the potential water quality of Fish Lake is much better than existing conditions. It has been impacted by pollutant loading from the watershed. The 1994 mean phosphorus concentration for Weaver Lake is on the lower end of the interquartile range. It has been less impacted by nutrient loading from the watershed. Both Diamond and Rice lake's total phosphorus is well beyond the upper end of the interquartile range. They have been greatly impacted by pollutant loading from the watershed. The remainder of the water quality parameters for Fish and Weaver as lakes listed in Table 5 are generally within the interquartile range for the ecoregion except for chlorides. The high chlorides may be due to high concentrations of chloride left behind from road salting and carried in snowmelt and rainfall runoff. Diamond and Rice lakes are not minimally impacted. Therefore, their water quality does not fit within the range of minimally impacted lakes.

The three main parameters, total phosphorus, chlorophyll a and Secchi disk transparency are all interrelated. For most lakes in this area, phosphorus is the nutrient that determines the amount of algae and macrophyte growth in a lake. High phosphorus concentrations will generally result in either dense macrophyte growth or algal blooms. The frequency and severity of these algal blooms is dependent upon phosphorus concentrations. Chlorophyll a is a measure of the amount of algae in a lake and Secchi disk transparency is dependent upon chlorophyll a concentrations. Transparency may also be limited by other dissolved or suspended materials in the lake.

The interrelationships described above are shown graphically on scatterplots in Figure 18. The 1994 mean data are plotted. Data from Fish and Weaver Lakes fit the general relationship

shown in the graphs. Diamond and Rice lake's chlorophyll a /transparency relationships are as expected. However, the TP/CHL and TP/SDT do not fit the relationship of the ecoregion data. The total phosphorus is not being expressed as chlorophyll a to the extent possible (i.e. the water quality exhibited in these lakes is much better than expected based upon the high phosphorus concentrations).

Probably the most important information that can be taken from Figure 13 is noting the critical points for TP and chlorophyll a as they affect transparency. On the middle graph, the "critical area" is at a concentration of about 5 to 10 .g/l. When concentrations exceed this range and up to a concentration of about 30 14/1, the result is a substantial reduction in transparency. Once concentrations exceed about 30 14/1, there is only a small decrease in transparency with increases in chlorophyll a. Similarly, at TP concentrations greater than 10 µg/l there is a rapid decrease in transparency with increases in TP up to a concentration of about 60 p.g/l. Fish Lake's TP concentration is at the end of the critical point. Any increases in TP will result in increases in the frequency and severity of algal blooms and reduced transparency or increases in macrophyte density and coverage, however they will likely not be dramatic changes Weaver Lake is in the middle to end of the critical range. Increases in phosphorus will result in noticeable reductions in transparency. Diamond and Fish lakes are beyond the critical points.

The computer model "MINLEAP" was used to compare the 1994 data to water quality values expected for minimally impacted lakes in the ecoregion (Wilson 1988). The modeling results also provided predictions of lake conditions in terms of algal blooms. The results are presented in Table 7. The predicted parameters for all four lakes indicated potentially improved water quality compared to observed values. MINLEAP predicted lower phosphorus than was observed in all four lakes. MINLEAP predicts phosphorus based upon parameters including watershed size, location, lake depth and existing conditions.

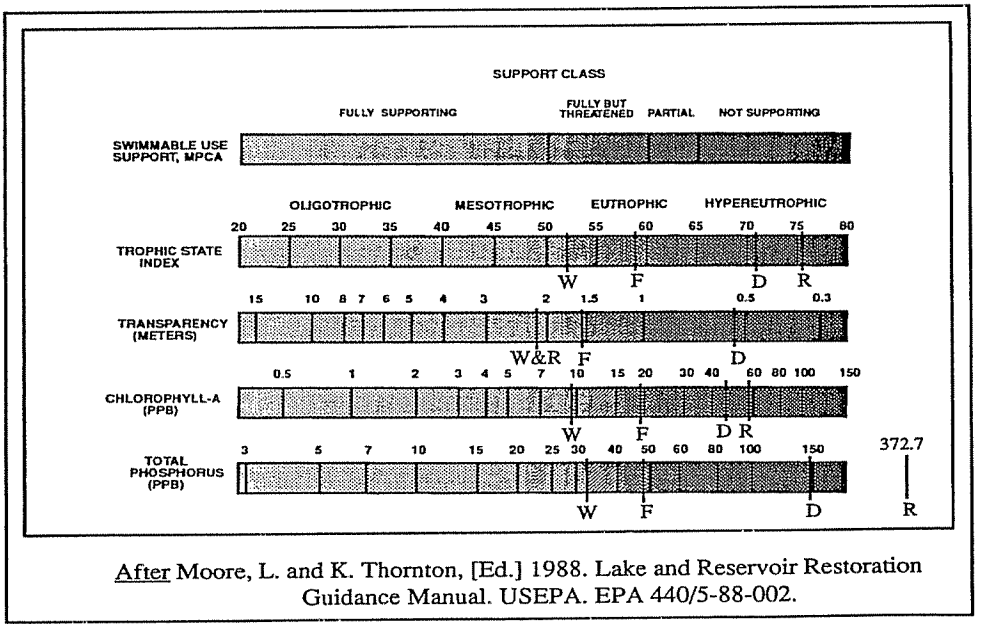
MINLEAP also provides rough estimates of phosphorus loading to the lakes from the watershed. For Fish and Weaver lakes the estimated phosphorus load for 1994 was 163 kg/yr and 46 kg/yr respectively. The estimated water residence time for the lakes is 5.7 years for Fish Lake and 20 years for Weaver Lake. The estimated phosphorus load for Diamond Lake was 202 kg/yr. The water residence time was estimated as 0.9 year. Rice Lake had an estimated phosphorus load of 1082 kg/yr and a residence time of 0.35 year.

Estimates of a lake's water quality prior to the influences of man can be made using a relationship developed to estimate the fraction of phosphorus due only to natural sources. Phosphorus concentrations due to natural, background loading can be predicted from the morphoedaphic index which is calculated from the alkalinity or conductivity of the water and mean depth using an equation developed by Vighi and Chiaudani (1985). The method provides a prediction of the potential attainable phosphorus concentration and can be used as one of several tools to help establish water quality goals. Monthly alkalinity measurements were collected from Fish and Weaver lakes. The calculations indicate that Fish Lake has a background total phosphorus concentration of 21 14/1 and Weaver Lake has a background phosphorus concentration of 19 µg/1.

FISH LAKE	SDT feet	TP µg/l	CHL µg/l	NO_2 + NO_3 mg/l	NH_3 mg/l	TKN mg/l	TN mg/l	Lab pH	COND µmhos/cm	ALK. $CaCO_3$	CL mg/l
May-18	4.5	35	12.1	0.101	0.29	0.94	1.23	8.02	342	142	36
Jun-11	10.0	46	7.3	0.03	0.52	0.72	1.23	7.63	377	112	
Jun-29*	4.0	51	21.4								
Jul-12	5.0	79	18.5	<0.03	0.30	1.24	1.54	8.29	380	133	
Aug-02*	4.0	38	18.7								
Aug-16	5.0	43	24.2	<0.03	0.32	1.06	1.38	8.09	409	131	
Sep-15	3.7	24	30.2	<0.03	0.17	1.06	1.23	8.05	408	134	
Sep-15*	4.5	52	25.1								
Mean	5.1	46	19.7	0.04	0.32	1.00	1.32	8.02	383	130	
Median	4.5	45	20.1	0.03	0.30	1.06	1.23	8.05	380	133	
Std. Deviation	2.0	16	7.3	0.03	0.13	0.19	0.14	0.24	28	11	
TSI (mean 57.6)	53.6	59.4	59.8								

	Ecoregion*	1994 Fish Lake	1994 Weaver Lake	1994 Diamond Lake
TP (µg/l	23 - 50	46	33.8	144
CHL a (µg/l)	5 - 22	19.7	9.8	46
SDT (ft)	4.9 - 10.5	5.1	7.3	1.7
Chloride (mg/l)	4 - 10	36	41	
Alkalinity (mg/l)	75 - 150	130	106	
TKN (mg/l)	<.6 - 1.2	1.0	0.79	2.32
NO_3 + NO_2 (mg/l)	<.01	.04	<.03	
pH	8.6 - 8.8	8.0	8.2	
Conductivity	300 - 400	383	349	
TN:TP	25:1 - 35:1	22:1	37:1	16:1

*Interquartile (25th to 75th percentile) values for minimally impacted lakes



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

D-Diamond Lake F-Fish Lake R-Rice Lake W-Weaver Lake

```
Minnesota Lake Eutrophication Analysis Procedure
ENTER INPUT VARIABLES
LAKE NAME ? FISH
ECOREGION NUMBER 1=NLF,2=CHF,3=WCP,4=NGP ? 2
WATERSHED AREA (HA)            ? 700
LAKE SURFACE AREA (HA)         ? 96
LAKE MEAN DEPTH (M)            ? 5.6
OBSERVED MEAN LAKE TP (UG/L)   ? 46
OBSERVED MEAN CHL-A (UG/L)     ? 19.7
OBSERVED MEAN SECCHI (M)       ? 1.55

INPUT DATA:
LAKE NAME =FISH                    ECOREGION=CHF
LAKE AREA = 96  HA
WATERSHED AREA (EXCLUDING LAKE) = 700  HA
MEAN DEPTH = 5.6  METERS
OBSERVED MEAN TP = 46  UG/L
OBSERVED MEAN CHL-A = 19.7  UG/L
OBSERVED MEAN SECCHI = 1.55  METERS

<press ENTER to view results>
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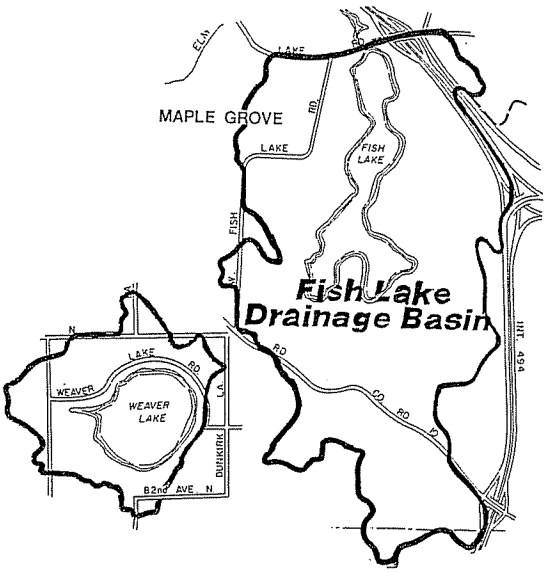



```
LAKE = FISH                                ECOREGION = CHF
AVERAGE INFLOW TP = 172.3745  UG/L         TOTAL P LOAD       = 163.48  KG/YR
LAKE OUTFLOW      = .9483999  HM3/YR      AREAL WATER LOAD   = .9879166 M/YR
RESIDENCE TIME    = 5.668494  YRS          P RETENTION COEF   = .8143789
```

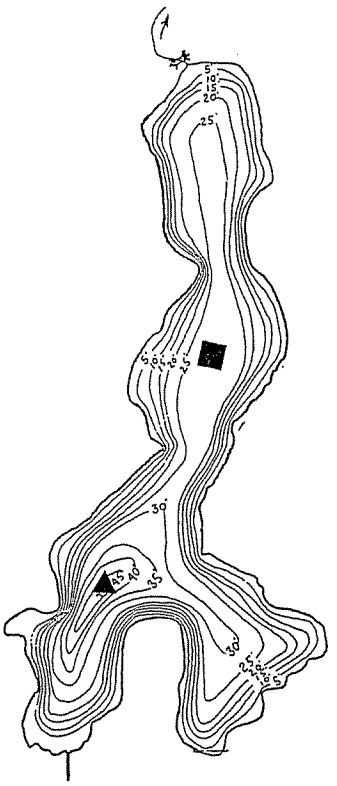
VARIABLE	UNITS	OBSERVED	PREDICTED	STD ERROR	RESIDUAL	T-TEST
TOTAL P	(UG/L)	46.00	32.00	12.43	0.16	0.86
CHL-A	(UG/L)	19.70	10.41	6.97	0.28	0.88
SECCHI	(METERS)	1.55	1.95	0.86	-0.10	-0.49

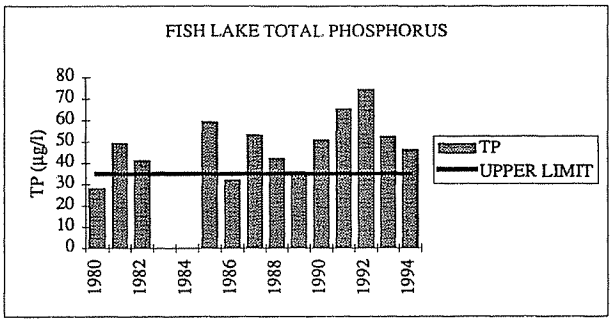
NOTE: RESIDUAL = LOG10(OBSERVED/PREDICTED)
T-TEST FOR SIGNIFICANT DIFFERENCE BETWEEN OBS. AND PREDICTED

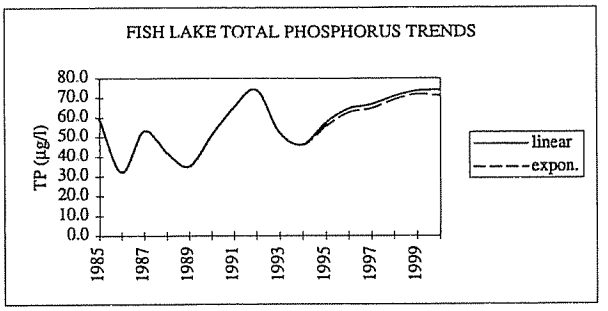
CHLOROPHYLL-A INTERVAL FREQUENCIES (%)

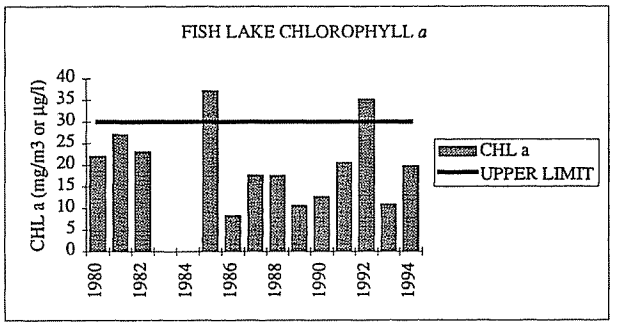
CHL-A		PREDICTED	PREDICTED	PREDICTED
PPB	OBSERVED	CASE A	CASE B	CASE C
10	87.97	43.77	44.24	46.43
20	39.25	5.48	6.98	18.22
30	13.20	0.73	1.20	8.30
60	0.52	0.01	0.02	1.38

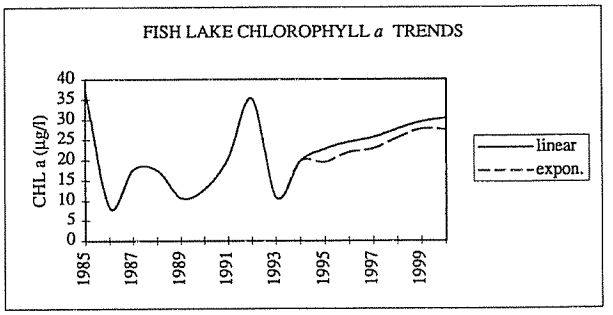
CASE A = WITHIN-YEAR VARIATION CONSIDERED
CASE B = WITHIN-YEAR + YEAR-TO-YEAR VARIATION CONSIDERED
CASE C = CASE B + MODEL ERROR CONSIDERED
0

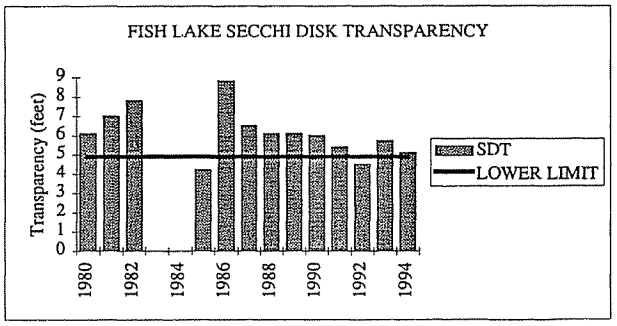


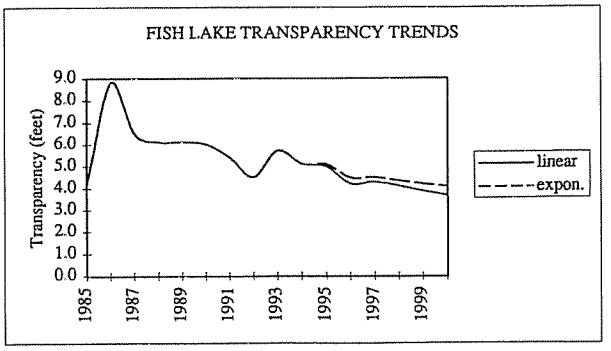

FISH LAKE TOTAL PHOSPHORUS
TP (µg/l)
TP
UPPER LIMIT

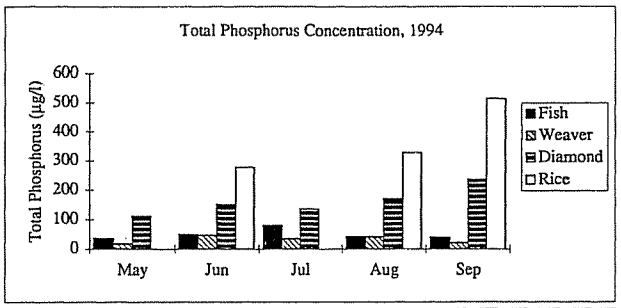

FISH LAKE TOTAL PHOSPHORUS TRENDS
TP (µg/l)
linear
expon.

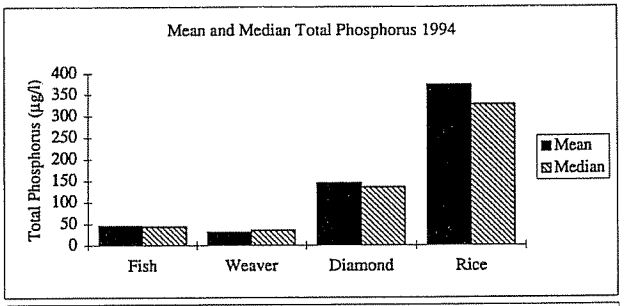

FISH LAKE CHLOROPHYLL a
CHL a (mg/m3 or µg/l)
CHL a
UPPER LIMIT

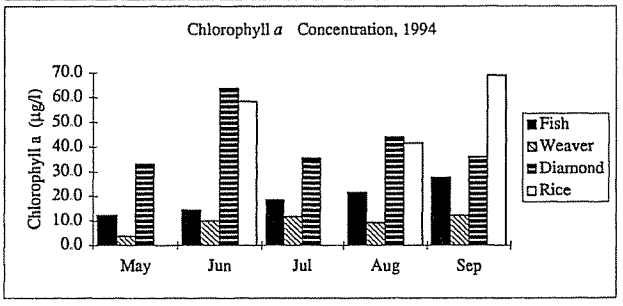

FISH LAKE CHLOROPHYLL a TRENDS
CHL a (µg/l)
linear
expon.

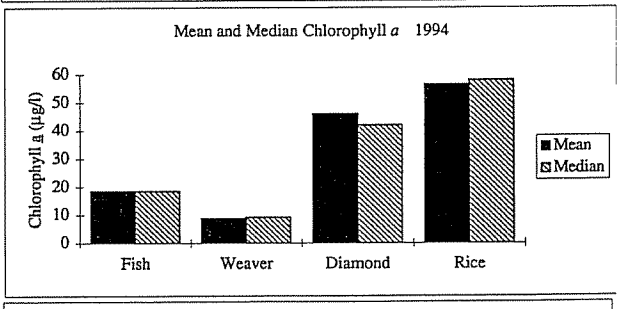

FISH LAKE SECCHI DISK TRANSPARENCY
Transparency (feet)
SDT
LOWER LIMIT

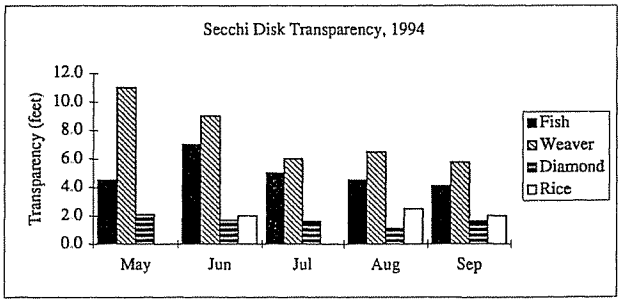

FISH LAKE TRANSPARENCY TRENDS
Transparency (feet)
linear
expon.

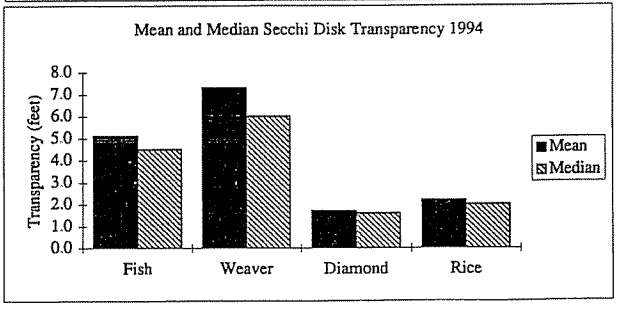

Total Phosphorus Concentration, 1994
Total Phosphorus (µg/l)
Fish
Weaver
Diamond
Rice
May
Jun
Jul
Aug
Sep

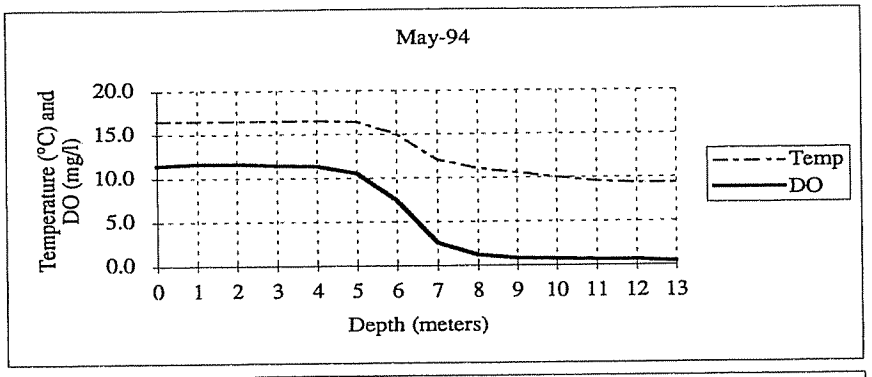

Mean and Median Total Phosphorus 1994
Total Phosphorus (µg/l)
Mean
Median
Fish
Weaver
Diamond
Rice

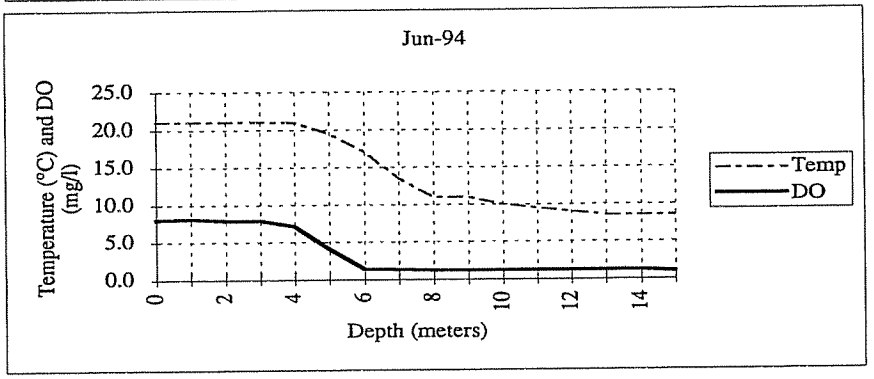

Chlorophyll a Concentration, 1994
Chlorophyll a (µg/l)
Fish
Weaver
Diamond
Rice
May
Jun
Jul
Aug
Sep

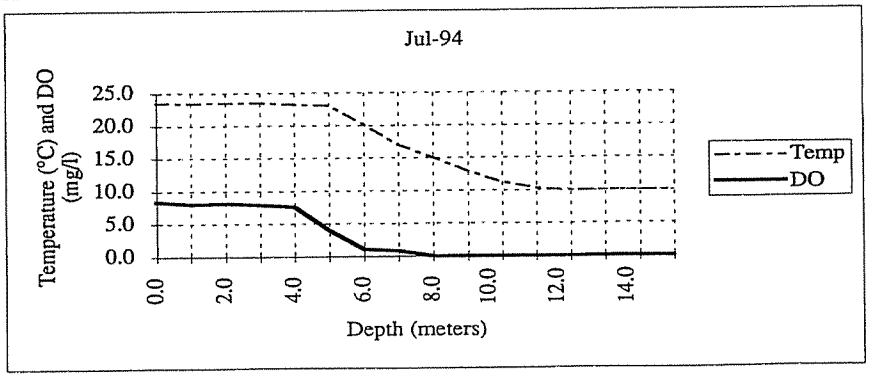

Mean and Median Chlorophyll a 1994
Chlorophyll a (µg/l)
Mean
Median
Fish
Weaver
Diamond
Rice

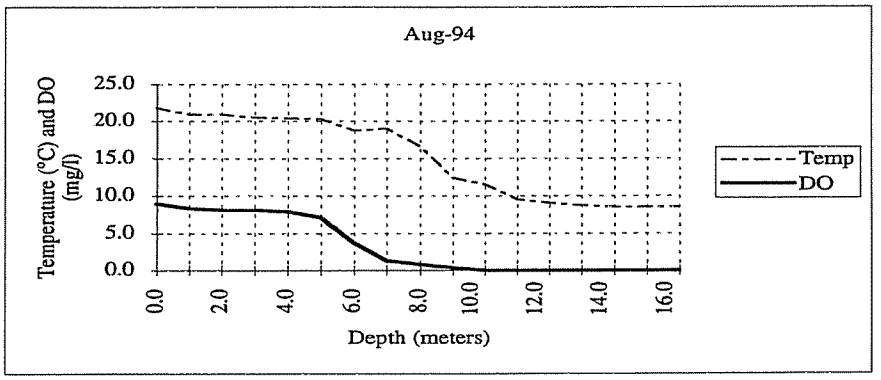

Secchi Disk Transparency, 1994
Transparency (feet)
Fish
Weaver
Diamond
Rice
May
Jun
Jul
Aug
Sep

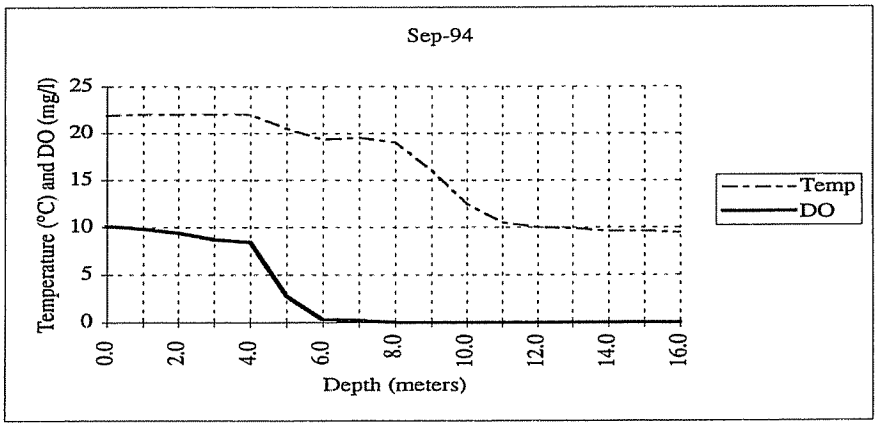

Mean and Median Secchi Disk Transparency 1994
Transparency (feet)
Mean
Median
Fish
Weaver
Diamond
Rice


May-94
Temperature (°C) and DO (mg/l)
20.0
15.0
10.0
5.0
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Depth (meters)
Temp
DO


Jun-94
Temperature (°C) and DO (mg/l)
25.0
20.0
15.0
10.0
5.0
0.0
0 2 4 6 8 10 12 14
Depth (meters)
Temp
DO


Jul-94
Temperature (°C) and DO (mg/l)
25.0
20.0
15.0
10.0
5.0
0.0
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0
Depth (meters)
Temp
DO


Aug-94
Temperature (°C) and DO (mg/l)
25.0
20.0
15.0
10.0
5.0
0.0
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0
Depth (meters)
Temp
DO


Sep-94
Temperature (°C) and DO (mg/l)
25
20
15
10
5
0
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0
Depth (meters)
Temp
DO