THE RECOVERY OF RICE LAKE

A WATER QUALITY SUCCESS STORY

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ABSTRACT

Rice Lake is a shallow, 128 acre lake in Polk County. Sewage from the Village of Milltown, which received primary treatment only, was discharged for many years to a wetland that drains to the lake. Prior to severe degradation, the lake contained a largemouth bass and bluegill fishery and extensive wild rice beds. Eventually, the lake became algae dominated, with extremely poor water clarity. Summer Secchi depths averaged less than 1 foot for many years. The wild rice beds nearly disappeared. Other aquatic macrophytes were extremely reduced, with scattered patches of Sago pondweed and water lilies being the dominant remaining species. The fishery became dominated by bullheads, yellow perch and white suckers, with no bass or bluegills present. Conditions in the lake remained poor, even long after the sewage treatment plant was upgraded. In 1996, the lake began making dramatic improvements. Summer Secchi depths increased to 3 feet and eventually 5 feet. The aquatic plant community expanded greatly in response to the improved water clarity. Preliminary indications suggest the fishery is also recovering. Changes in the lake are largely attributable to changes in the operation of the Milltown wastewater treatment plant. Long lag periods were required for the lake to respond to changes in the treatment plant operation. The wetland receiving wastewater discharges apparently captured and stored phosphorus for many years, and later, continued to release phosphorus long after discharges ceased. Agricultural changes and improvements occurring in the watershed have also contributed to lake improvements.

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INTRODUCTION

Rice Lake developed severe water quality problems in the 1970's. Poorly treated wastewater from the Village of Milltown was the primary cause of the problems. Upgrades of the wastewater treatment plant were made in 1978 and 1998. The improvements in wastewater handling eventually resulted in dramatically improved lake water quality.

The recent history of Rice Lake demonstrates the negative impacts excessive nutrient loading can have on a lake. It also shows that lake restoration can be achieved, if nutrient loading is controlled.

LAKE AND WATERSHED DESCRIPTION

Rice lake is a shallow, 128 acre lake located in Polk County, Wisconsin (figure 1). The lake has a maximum depth of 6 feet.

The lake has an 8.6 mi^2 watershed, based on surfacial topography (figure 2). Only 1.8 mi^2 of the watershed provides direct drainage to the lake. The remaining 6.8 mi^2 is internally drained due to numerous closed depressions. This area can only provide groundwater inputs to the lake. This protects the lake from the runoff produced by a large agricultural area and the Village of Milltown.

Land use in the directly drained watershed is primarily agricultural, except for the wetland areas fringing the lake and its inlet stream, Rice Creek. Rice Creek originates in a wetland area northwest of the lake, enters the lake at its northwest end, exits the lake at its southeast end, and eventually flows into Balsam Lake about 1 ½ miles downstream.

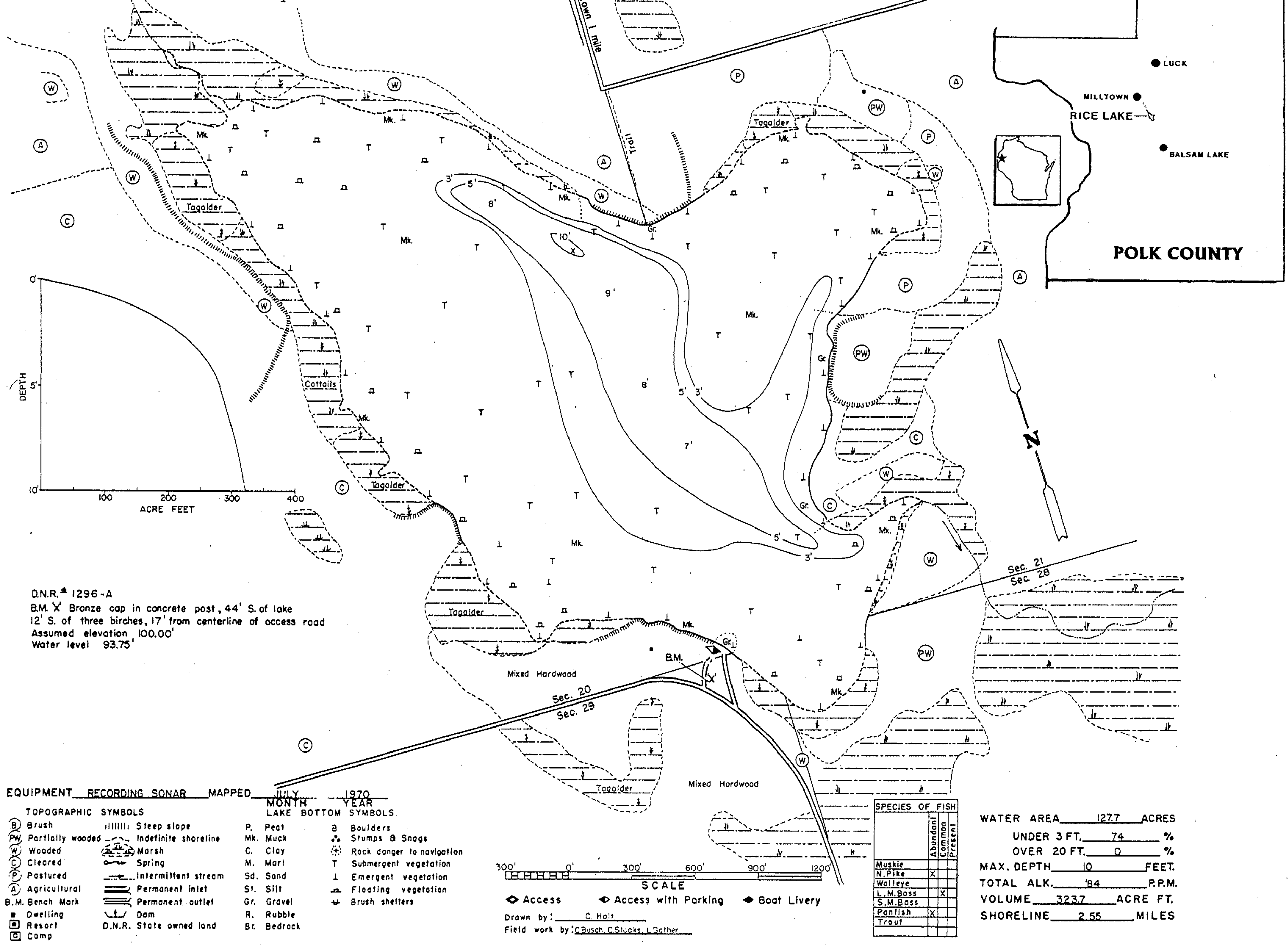
PAST IMPACTS TO THE LAKE

Agricultural activity in the Rice Lake watershed began in the mid-1800's. Runoff from land in agricultural use carries much higher sediment and nutrient loads than runoff from land with natural vegetative cover. Cropland erosion, barnyard runoff, nutrient enrichment of soils, and runoff from winter-spread manure can all be contributing factors.

A primary wastewater treatment plant for the Village of Milltown began operating in 1939. A creamery, which closed in 1954, and a cannery, which closed in 1962, also contributed wastewater to the plant. The plant discharged to the wetland at the headwaters of Rice Creek. Primary treatment is designed to mainly remove solids and only provides low levels of nutrient removal. The Milltown plant had a poor operating record. Frequent overloading in the 1970's resulted in discharges of raw sewage (Engel and Nichols 1994).

FIGURE 1. RICE LAKE LOCATION AND DEPTH MAP

This 1970 map shows a maximum depth of 10 feet. The lake currently has a maximum depth of 6 feet. Redistribution of sediment may account for much of the change. Many shallow areas, less than 3 feet deep in 1970, are now deeper.



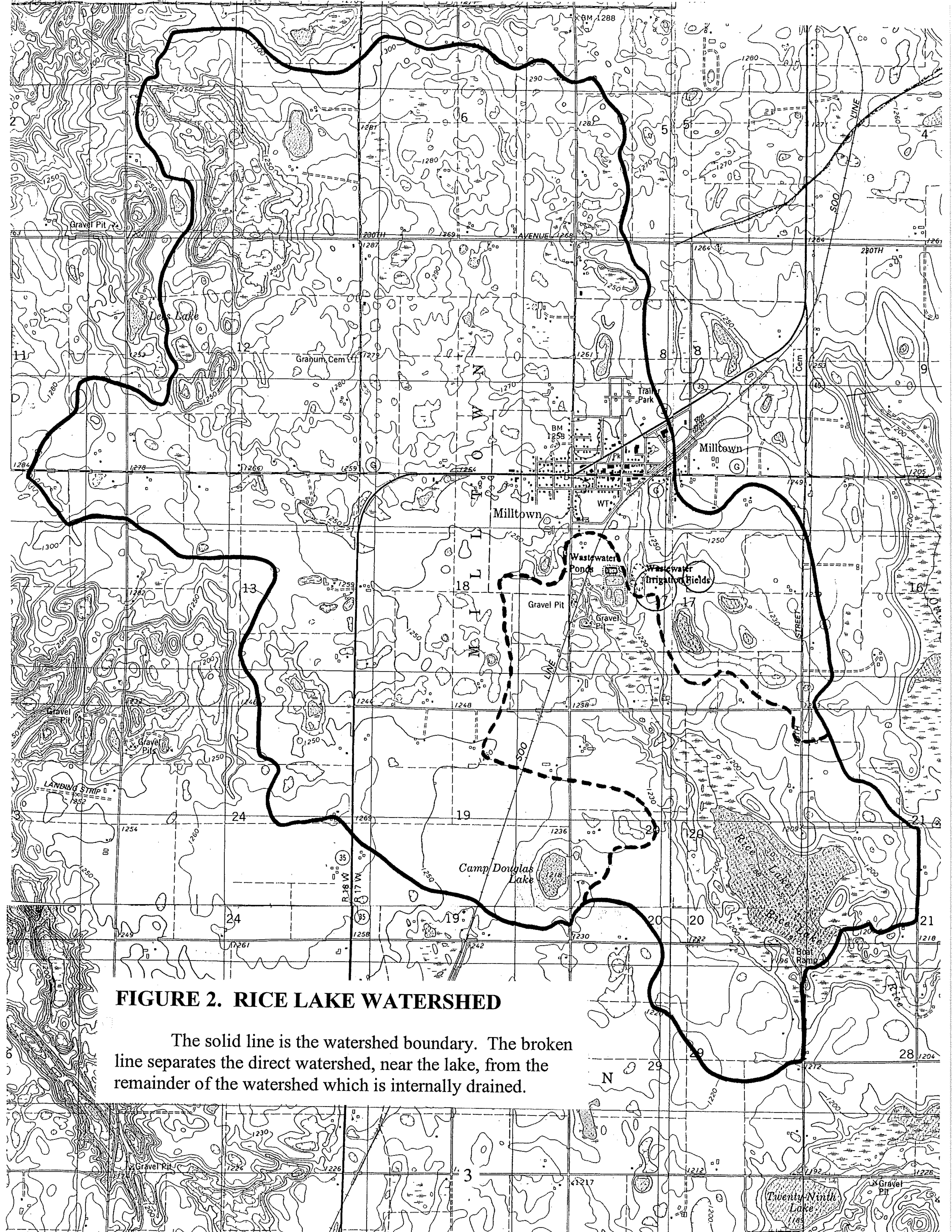


FIGURE 2. RICE LAKE WATERSHED

The solid line is the watershed boundary. The broken line separates the direct watershed, near the lake, from the remainder of the watershed which is internally drained.

A secondary wastewater treatment plant was constructed in 1978 on the same site. This plant had two aerated treatment ponds and a third seepage pond. No surface discharge of wastewater occurred.

The wastewater treatment plant was upgraded to tertiary treatment in 1998. An additional treatment pond was constructed and existing treatment ponds were sealed. The seepage pond was abandoned, but was still partially full in 1999. Treated wastewater is now spray irrigated on adjacent fields (see figure 2). Some spray irrigation began in the summer of 1997 during construction.

While agricultural runoff and sewage discharges undoubtedly influenced Rice Lake, it remained in relatively good condition for many years. During the 1950's and 1960's the lake was popular for swimming, bass and bluegill fishing, waterfowl hunting, and trapping. Large beds of wild rice were present. Water clarity was good.

It was not until the early 1970's that the lake reportedly experienced a major decline in water quality, based on interviews with local residents (Engel and Nichols 1994). Water clarity declined. Wild rice nearly disappeared. Waterfowl use declined. People no longer swam or fished the lake.

The reason for the dramatic change at that time is somewhat uncertain. Nutrient capture by the wetland area receiving wastewater discharge may have prevented the potential impacts from wastewater for many years. Wetlands receiving wastewater elsewhere have been observed to become saturated with phosphorus, at which point no further phosphorus retention occurs. Phosphorus is the nutrient which regulates the growth of algae in lakes. Increased phosphorus inputs to a lake fuel planktonic algae blooms which turn water green and reduce clarity. The problems with the operation of the wastewater treatment plant in the 1970's may also have been a factor.

Periods of above average lake levels could also have contributed. Water levels in Rice Lake appeared to be above average in the 1970's due to beaver dams at the lake outlet and above average precipitation (Engel and Nichols 1994). Increased water levels coupled with declining water clarity can further reduce light availability to aquatic macrophytes and prevent their survival. The collapse of the wild rice population and the probable decline of other aquatic macrophytes would expose lake sediment to wind-driven wave energy and result in sediment resuspension. Resuspended lake sediment would further reduce water clarity and increase stress on remaining aquatic macrophytes.

POOR LAKE QUALITY CONTINUES

Lake Water Quality

Direct measurement of water quality conditions in Rice Lake did not begin until the 1980's. Several samples were collected from Rice Creek at the town road crossing below Rice Lake during 1982 and 1983. Sampling during 1988-89 and more recently, has shown samples from this site are similar to lake samples. The summer samples collected during 1982-3 had total phosphorus concentrations ranging from 360 to 560 micrograms/liter (ug/l), with a mean of 430 ug/l. This is an extremely high level for lake water.

An extensive study of Rice Lake was conducted by Engel and Nichols in 1988 and 1989. Total phosphorus concentrations in the lake during those summers ranged from 98 to 244 ug/l, with a mean value of 152 ug/l. These levels are still very high, but it does appear substantial improvement had occurred since the early 1980's.

Summer water clarity, as measured by a Secchi disk, during 1988-89, was extremely poor and averaged only 0.8 feet. Poor water clarity was due primarily to algae, and secondarily to resuspended lake sediment. Summer chlorophyll a concentrations, which are a measure of algae, ranged from 70 to 146 ug/l, with a mean value of 92 ug/l.

For 1990 through 1994, only Secchi depths are available to document water quality conditions. However, Secchi depths are generally very good indicators of water quality and correlate closely with total phosphorus concentrations and chlorophyll a concentrations. Summer Secchi depths during these years were very similar to those found in 1988-89 and averaged 0.9 feet.

Rice Creek Water Quality

Samples collected from Rice Creek at the road crossing above Rice Lake in 1988-89 showed extremely high total phosphorus concentrations were present in the water entering the lake. Total phosphorus concentrations ranged from 159 to 3,790 ug/l, with a median value of 515 ug/l. This was 10 - 11 years after the wastewater treatment plant was upgraded from primary to secondary treatment. It is likely that wastewater phosphorus previously captured by the wetland was continuing to be released.

Aquatic Macrophytes

Aquatic macrophytes in Rice Lake were limited for many years by poor water clarity. Aquatic macrophyte surveys in 1987 and 1989 (Engel and Nichols 1994) showed a depressed plant community. The dominant emergent zone species were softstem bulrush (*Scirpus validus*), spikerush (*Eleocharis sp.*), and northern wild rice (*Zizania palustris*). Wild rice which was historically abundant, had become scarce. Softstem bulrush and spikerush were restricted to small scattered patches.

A floating-leaf zone dominated by water lilies (*Nuphar variegata* and *Nymphaea odorata*) was present in shallower areas of the lake. This zone covered 18% of the lake's area. Floating-leaf plants are less affected by water clarity since their leaves are at the surface.

Aquatic macrophytes in the submergent zone of the lake were very reduced. Submergent macrophytes were present at only 20-33% of the sites sampled. The submergent zone was dominated by Sago pondweed (*Potamogeton pectinatus*). Sago pondweed comprised 84-92% of the total standing crop of submergent species. Beds of this pondweed were growing in ring or loop formations, believed to result from turbidity stress.

Plantings of wild rice and various other aquatic macrophytes were made in 1988 and 1989 (Engels and Nichols 1994). It was hoped these plantings would help reduce sediment resuspension and would tie up nutrients. However, the plantings were generally unsuccessful. Rice plantings were heavily damaged by muskrats.

Fishery

Fish surveys conducted in 1988 and 1990 found that black bullheads, yellow perch, and white sucker were the most abundant species present. No largemouth bass and only one bluegill was found, although these species were reportedly a major component of the sport fishery in the 1950's and 60's. A fishery survey conducted in 1996 found a similar species composition. No largemouth bass or bluegills were found.

A winter dissolved oxygen survey in February 1989 found that the majority of the lake froze to the bottom or became anoxic. An area of higher oxygen concentrations was maintained near the lake's inlet. Winter fish kills have not been observed in the lake, but oxygen stress is likely to favor species tolerant of low dissolved oxygen levels.

Winter oxygen stress and very poor water clarity are both conditions which undoubtedly contributed to the decline of the largemouth bass and bluegill fishery. Both conditions are exacerbated by high algae concentrations.

LAKE QUALITY IMPROVEMENTS OCCUR

Lake Water Quality

A hint of additional water quality improvement appeared in 1995. A spring total phosphorus concentration of only 34 ug/l was found, along with a Secchi depth of 3.7 feet. Both these values were spring records for the period beginning in 1988. June and July saw a return to more normal values, but a record August Secchi depth of 1.7 feet was also measured.

In 1996, a dramatic change in lake water quality was evident. The summer mean Secchi depth was 3.2 feet, a 400% increase over the 1988-89 value (figure 3). The summer mean total phosphorus concentrations was 44 ug/l, a 71% decrease over the 1988-89 value (figure 4). The summer mean chlorophyll a concentration was 26 ug/l, a 72% decrease over the 1988-89 value (figure 5).

This improvement was sustained and strengthened in the following years. Water quality in 1997 was similar to that found in 1996. Further improvement was seen in 1998 and

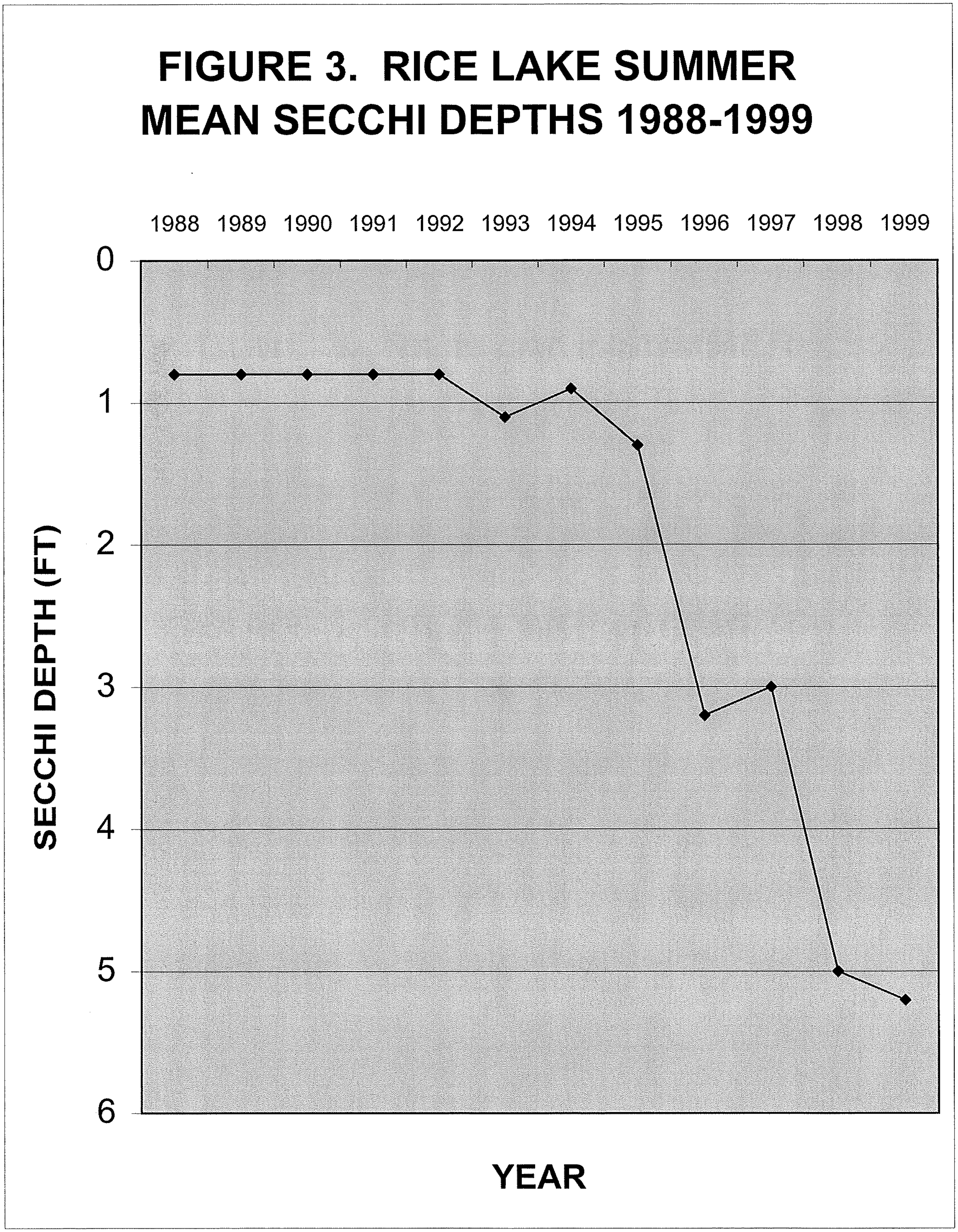


FIGURE 3. RICE LAKE SUMMER MEAN SECCHI DEPTHS 1988-1999
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
0
1
2
3
4
5
6
SECCHI DEPTH (FT)
YEAR

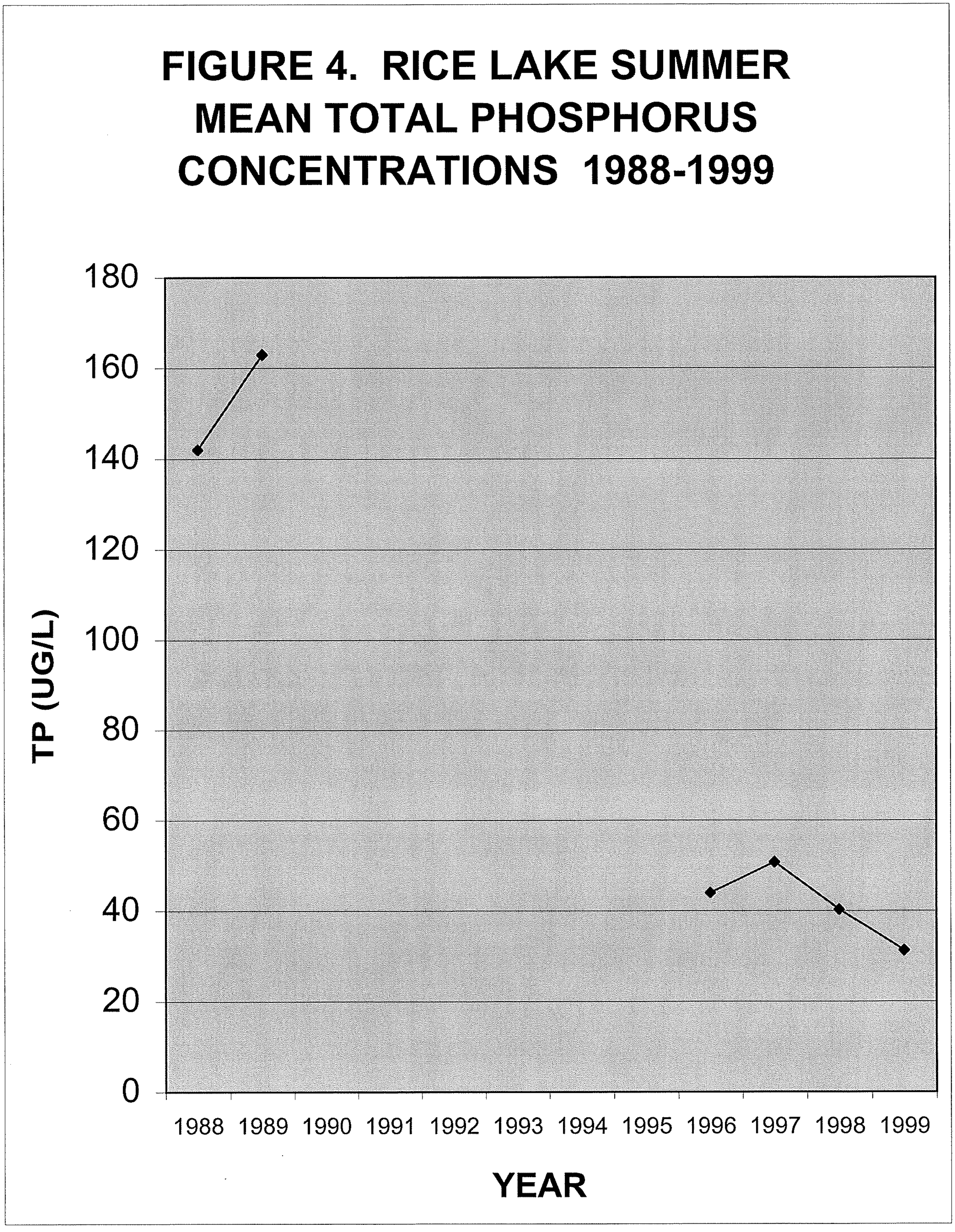
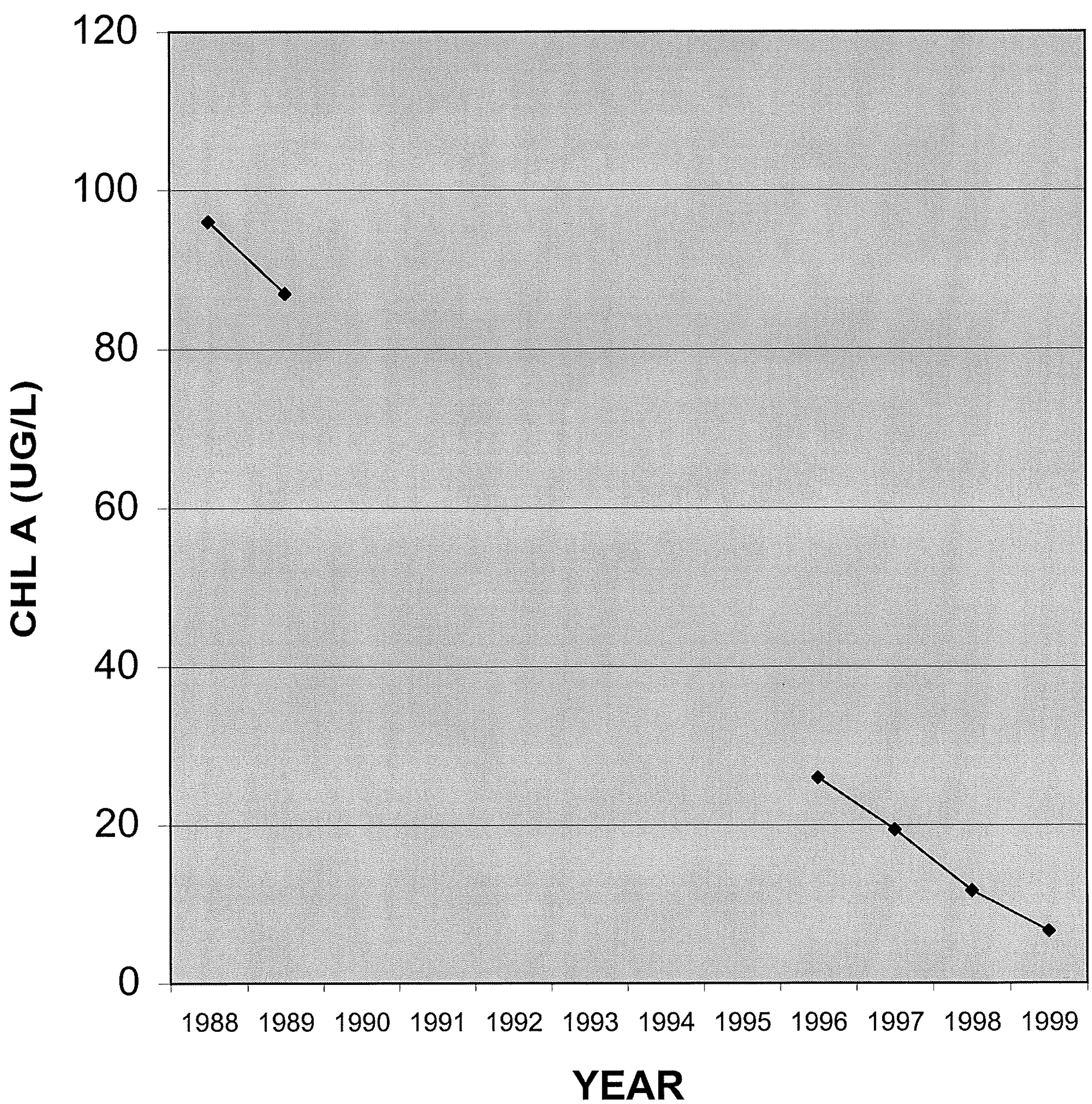


FIGURE 4. RICE LAKE SUMMER MEAN TOTAL PHOSPHORUS CONCENTRATIONS 1988-1999
TP (UG/L)
180
160
140
120
100
80
60
40
20
0
1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999
YEAR

FIGURE 5. RICE LAKE SUMMER MEAN CHLOROPHYLL A CONCENTRATIONS 1988-1999



1999 (figure 3, 4 and 5). The 1999 mean summer Secchi depth was 5.2 feet, a 650% increase over the 1988-89 value. In August of 1999, the Secchi disk was visible on the bottom at the lake's deepest spot (6 feet). The summer mean total phosphorus concentration was 31 ug/l, an 80% decrease over the 1988-89 value. The mean summer chlorophyll a concentration was 6.6 ug/l, a 93% decrease over the 1988-89 value.

Rice Creek Water Quality

Samples collected from Rice Creek at the road crossing above Rice Lake in 1996-98 showed substantially reduced total phosphorus concentrations entering the lake since 1988-89 sampling. Total phosphorus concentrations ranged from 24 to 950 ug/l, with a median value of 143 ug/l, a 72% reduction from the 1988-89 median value. Release of wastewater phosphorus stored in the wetland since the period of primary treatment may have still been the major source of the creek's elevated phosphorus concentrations. Highest concentrations occurred in summer months when daytime dissolved oxygen concentrations in the stream were regularly below 1 milligram/liter (mg/l). Release of iron-bound phosphorus is likely to occur under these conditions. The high clarity of creek samples indicated most phosphorus present was in the dissolved form.

The extent of phosphorus contributions from wastewater seepage to the creek during the period of secondary wastewater treatment is uncertain. Creek chloride concentrations in 1996-98 averaged 66 mg/l which indicates treated wastewater seepage was entering the creek via groundwater. Similar creek chloride concentrations were found in 1988-89. It is difficult to separate phosphorus derived from recent wastewater seepage from phosphorus derived from release of historically deposited wetland phosphorus. The seasonally low phosphorus concentrations (< 100 ug/l) found in the creek in spring and fall when chloride concentrations showed little change, suggests the secondary treatment system was not delivering large amounts of phosphorus to the creek. However, it is also possible that wastewater phosphorus from the secondary treatment system was being seasonally retained and released in the creek/wetland system.

Aquatic Macrophytes

Once water clarity began improving in 1996, the submergent macrophyte community expanded on its own. A steady increase in submergent macrophyte coverage and density was observed each year from 1996 to 1999. An aquatic macrophyte survey conducted in 1999 found submergent macrophytes present at 100% of the sites sampled (figure 6 and table 1 and 2), including the deepest area of the lake (6 feet).

Air photos show Sago pondweed beds increasing in area and density. The ring or loop formations of these beds seen in 1987-89 is no longer present. Beds are now relatively uniform with healthy centers.

Two other submergent macrophyte species, elodea (*Elodea canadensis*) and flat-stem pondweed (*Potamogeton zosteriformis*), have become more abundant than Sago pondweed. Elodea was described as scarce in the 1987 and 1989 surveys (Engel and

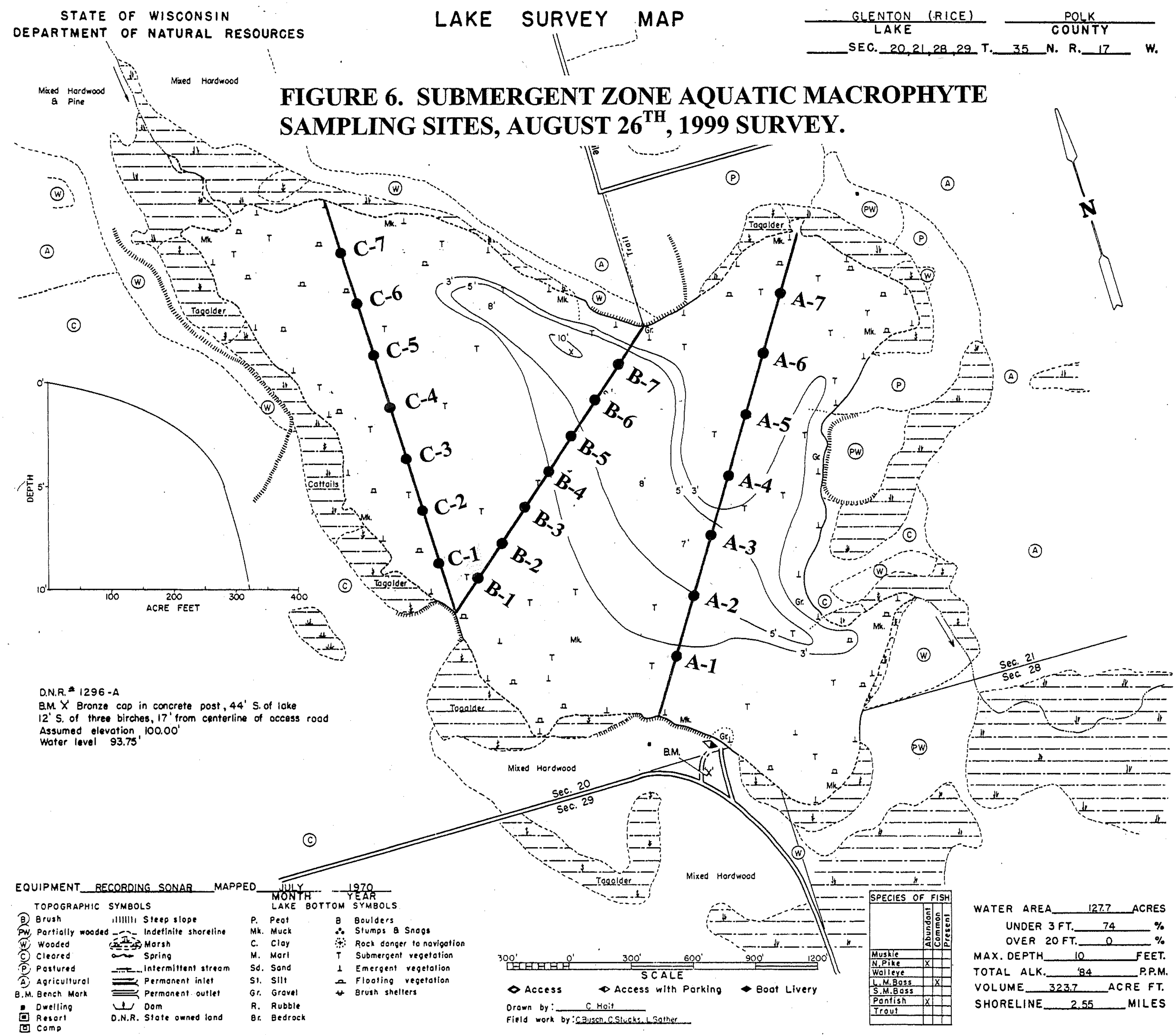


FIGURE 6. SUBMERGENT ZONE AQUATIC MACROPHYTE SAMPLING SITES, AUGUST 26TH, 1999 SURVEY.

TABLE 1. RICE LAKE SUBMERGENT MACROPHYTE SURVEY DATA, AUGUST 26TH, 1999

Sampling sites are shown in figure 6. Four rake drags, four feet in length, were made at each site. Lake elevation was 94.66' relative to the benchmark at the boat landing with an assumed elevation of 100.00'.

SAMPLING SITE	DEPTH (FT)	SUBSTRATE	SPECIES[1] – DENSITY[2]
A-1	4.0	MUCK	POTZO-3 ELOCA-3
A-2	4.0	MUCK	POTPE-4 POTZO-4 ELOCA-1
A-3	4.3	MUCK	POTZO-3 ELOCA-1
A-4	4.4	MUCK	POTZO-4 POTPE-2 ELOCA-1
A-5	4.2	MUCK	ELOCA-3 POTPE-3 POTZO-2
A-6	4.0	MUCK	ELOCA-5 POTZO-1
A-7	3.2	MUCK	ELOCA-5 POTZO-4 POTPE-1 RANLO-1
B-1	4.1	MUCK	ELOCA-4 POTZO-4
B-2	4.2	MUCK	POTZO-3 ELOCA-3 POTPE-1
B-3	4.1	MUCK	POTPE-4 POTZO-2 ELOCA-1
B-4	4.4	MUCK	POTPE-4 POTZO-1
B-5	4.5	MUCK	POTPE-4
B-6	4.5	MUCK	POTZO-4 ELOCA-3
B-7	6.0	MUCK	ELOCA-3 POTZO-1
C-1	3.9	MUCK	ELOCA-4 POTZO-2 POTPE-1
C-2	4.1	MUCK	ELOCA-4 POTZO-2
C-3	4.1	MUCK	ELOCA-4 POTZO-2
C-4	3.8	MUCK	ELOCA-3 POTZO-2 POTPE-1
C-5	4.3	MUCK	POTPE-4 ELOCA-3 POTZO-2
C-6	3.5	MUCK	ELOCA-4 POTZO-2 POTPE-2 CHASP-1
C-7	3.3	MUCK	ELOCA-4 POTPE-1

[1]Species I.D. codes are listed. The codes contain the first three letters of the genus name followed by the first two letters of the species name. Only 5 species were collected by rake drags at these sites. They are listed below:

Scientific Name	I.D. Code	Common Name	Relative Abundance[3]	Frequency[4]
Elodea canadensis	(ELOCA)	Elodea	59	90.5%
Potamogeton zosteriformis	(POTZO)	Flat-stem pondweed	48	90.5%
Potamogeton pectinatus	(POTPE)	Sago pondweed	32	61.9%
Ranunculus longirostris	(RANLO)	Stiff water crowfoot	1	0.5%
Chara sp.	(CHASP)	Muskgrass	1	0.5%

[2]Density ratings were determined as follows:
1 = species collected on 1 of 4 rake drags
2 = species collected on 2 of 4 rake drags
3 = species collected on 3 of 4 rake drags
4 = species collected on 4 of 4 rake drags; rake teeth partly full
5 = species collected on 4 of 4 rake drags; rake teeth full

[3]Relative Abundunce = Sum of density values from all sites.

[4]Frequency = % of sites sampled where species was present.

TABLE 2. RICE LAKE AQUATIC MACROPHYTE SPECIES LIST, AUGUST 26TH, 1999 SURVEY

Scientific Name	Common Name	Abundance
Brasenia schreberi	watershield	Sparse
Ceratophyllum demersum	coontail	Common
Chara sp.	muskgrass	Sparse
Eleocharis sp.	spikerush, tall	Sparse
Elodea canadensis	elodea	Abundant
Najas flexilis	slender naiad	Common
Nuphar variegata	spatterdock	Abundant
Nymphaea odorata	white water lily	Abundant
Potamogeton natans	floating-leaf pondweed	Common
Potamogeton pectinatus	sago pondweed	Abundant
Potamogeton zosteriformis	flat-stem pondweed	Abundant
Ranunculus longirostris	stiff water crowfoot	Sparse
Scirpus validus	softstem bulrush	Common
Sparganium eurycarpum	common bur-reed	Sparse
Vallisneria americana	wild celery	Sparse
Zizania palustris	northern wild rice	Sparse

Only open water species are listed. Species present in adjoining wetlands are not listed.

Nichols 1994). Flat-stem pondweed was not even found at that time. The 1999 survey shows elodea is now the dominant macrophyte in the lake, being present at over 90% of the sites sampled (table 1). Flat-stem pondweed was also present at over 90% of the sites, but at slightly lower densities. These two species may also be beginning to out-compete established Sago pondweed beds, especially in shallower areas.

Three additional submergent species found in 1999, but not found in the 1987-89 surveys are slender naiad (*Najas flexilis*), wild celery (*Vallisneria americana*), and chara (*Chara sp.*). Slender naiad is now common and found primarily in the floating-leaf zone. Wild celery is sparse, but present at scattered locations, some of which have small, but dense beds. Chara was found at only one site.

Air photos show areas of floating-leaf macrophytes have declined slightly since 1987, especially at the northwestern end of the lake near the inlet.

Populations of emergent macrophytes are similar to those found in 1987. Wild rice is still sparse despite several years of additional seedings at the northwest end of the lake. The last seeding of rice occurred in spring of 1997. Growth that year was only fair, and heavy losses due to muskrats continued to be a problem. Rice was still present in 1999 at the northwest end at densities similar to 1997. A small dense patch of rice has been present at the boat landing for several years. It is apparently self-sustaining, but has not expanded during that time.

Fishery

The fishery has not been assessed since lake quality has improved. However, general observations suggest the fishery is beginning to respond. Anglers were almost never seen at the lake until the last 2 to 3 years, when angler sightings became more frequent. Good catches of yellow perch and northern pike have been seen. One angler reported catching several bluegills. Stocking of largemouth bass is planned for 2000 (Cornelius 2000).

SUMMARY OF THE PATTERN OF CHANGES AND THE PROBABLE CAUSES

Rice Lake provides a relatively well documented case of lake restoration through the control of excessive nutrient loading. Operation of the Milltown wastewater treatment plant was undoubtedly the primary factor regulating the degradation and eventual improvement of Rice Lake.

Long lag periods occurred between treatment plant start-up and upgrades, and lake responses. Wetland influence on phosphorus transport from the treatment plant to the lake appears to be most likely explanation for the delayed responses.

The wastewater treatment plant, with primary treatment, began operating in 1939 with a discharge to the wetland at the headwaters of Rice Creek. The wetland appears to have effectively captured wastewater phosphorus for many years. A major decline in the water quality of Rice Lake occurred in the 1970's when the wetland's ability to capture phosphorus may have been exhausted. The effects of declining water clarity from phosphorus-fueled algae blooms could have been intensified by above normal water levels and resulted in major losses of aquatic macrophytes. This would have further contributed to poor water quality by exposing lake sediment to wave-induced resuspension.

The wastewater treatment plant was upgraded to secondary treatment in 1978. Little data exists to document lake conditions from 1978 to 1988. However, samples collected from Rice Creek below the lake suggest lake water quality improved considerably between 1982 and 1988.

Despite improvements, lake water quality in 1988-89 was still very poor. Samples at that time from Rice Creek above the lake showed extremely high phosphorus concentrations were still present 10-11 years after primary treated wastewater discharge had ceased. Release of phosphorus previously captured by the wetland was the likely source of this phosphorus.

The very poor lake water quality present in 1988-89 continued through 1995. In 1996, dramatic improvements in water quality occurred. The improvement was sustained and then strengthened during 1997-99. No specific cause is apparent to explain the sudden change in 1996. However, sampling of Rice Creek above the lake in 1996-98 showed phosphorus concentrations had declined greatly since 1988-89. Phosphorus release from the wetland was declining, although it is assumed this decline would have occurred gradually. Perhaps some threshold conditions were reached in the wetland or in the lake which produced the sudden change seen in the lake.

Aquatic macrophyte coverage began expanding in the lake in 1996 in response to the improved water clarity. This expansion may have contributed to additional water quality improvements by stabilizing lake sediment. Aquatic macrophytes can also help suppress planktonic algae by releasing allelopathic substances that are toxic to algae.

It is unclear what contributions the upgrade of the wastewater treatment plant to tertiary treatment made to the recent improvements in the lake. Lake improvements began in 1996, while construction for the upgrade did not begin until 1997. Some spray irrigation was done during construction, but the old seepage cell was not emptied and continued to seep during 1998 and 1999. Chloride concentrations found in Rice Creek above Rice Lake during 1996-98 indicated wastewater seepage was entering the creek via groundwater. However, the wide seasonal fluctuations in creek phosphorus concentrations and the potential for seasonal capture and release make it difficult to determine how much phosphorus from wastewater seepage was entering the creek.

The upgrade to tertiary treatment will undoubtedly contribute to the future long-term health of Rice Lake. Land application of wastewater is a highly effective way to prevent wastewater phosphorus from reaching surface waters. Soils have a high capacity for absorbing phosphorus and cropping practices on irrigated fields can allow additional phosphorus control.

Changes and improvements in agricultural practices in the direct watershed area for Rice Lake have probably also contributed to improvements in lake quality. In the past 10-15 years, the number of cattle present has declined 75% or more. Significant areas of erosive cropland have been enrolled in the Conservation Reserve Program. Most remaining cropland which had been conventionally tilled, now has conservation tillage in use (Timmons 2000).

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