Reviewed by UBub Date 2/2004

Region WCR **County** St Croix **Report Date** 11/1995 **Classification** LAL

Water Body: Twin Lakes

Discharger: Roberts WWTP

If stream is classified as Limited Forage Fish (LFF) or Limited Aquatic Life (LAL), check any of the following Use Attainability Analysis factors that are identified in the classification report:

__________ Naturally occurring pollutant concentrations prevent the attainment of use

__________ Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating State water conservation requirements to enable uses to be met

__________ Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place

__________ Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or operate such modification in a way that would result in the attainment of the use

__________ Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses

__________ Controls more stringent than those required by sections 301(b) and 306 of the Act would result in substantial and widespread economic and social impact

Supporting Evidence in the report (include comments on how complete/thorough data is)

__________ Biological Data (fish/invert)

✓ Chemical Data (temp, D.O., etc.)

__________ Physical Data (flow, depth, etc.)

__________ Habitat Description

✓ Site Description/Map

__________ Other:

Historical Reports in file:

11/6/95 - Paul LaLiberte
11/95 - Ken Schreiber
9/29/88 - Paul LaLiberte
9/22/76 - Terry Moe

Additional Comments/How to improve report:

- LAL b/c considered a wetland -- is this still appropriate?
- recommend East T.L. to LFF — should West Twin L also change?
- Check w/ Region on these classifications.

TWIN LAKES WATER QUALITY STANDARDS REVIEW

November 6, 1995
Paul La Liberte

Treated domestic wastewater from the Roberts WWTP discharges to Twin Lakes in St. Croix County. The original water quality standards review for this waterbody was done in 1976, following promulgation of NR104, Wisconsin Administrative Code. It was reviewed in 1988. This classification review includes an initial application of NR103, Water Quality Standards for Wetlands (promulgated in 1991) as well as NR104. The results of a Department basin assessment study recently finalized (Schreiber, 1995) forms the basis for this review.

HYDROLOGY & VEGETATION

Historical aerial photos and personal observations of long-time observers of the waterbodies were used to determine that, depending on local water levels, West Twin Lake has changed from a deep water marsh at past water levels (estimated 5-8' feet deep) to open water lake (>10' deep) at current water levels. East Twin Lake has changed from a shallow marsh with little open water at low water to a deep, open water marsh at current levels. The lakes have apparently not experienced the low water conditions for about 30 years. Prior to this time they may have fluctuated between hydrologic types in wet vs dry years. While the timing of the last low water condition roughly coincides with the building of the WWTP, many similar lakes in the region are experiencing the highest water levels in several decades. The recent death of very large, and presumably old, shoreline trees, as well as the need to raise the road grade that separates the lakes suggests that recent water elevations have progressed beyond those experienced in the past. It is not possible to predict when, or if , the waterbodies will ever revert back to their former hydrologic condition. The role of the WWTP discharge in this hydrologic change is unclear, since the annual hydrologic budget of the waterbodies is not known.

FISHERY USE

Both East and West Twin Lakes experience winterkill virtually every year. They also experience periods of summer oxygen stress as well. These water quality problems limit the fishery potential of both waterbodies. Fish are present in limited numbers despite the oxygen problems (primarily bullheads and fathead minnows), but are not expected to develop into a diverse forage fishery or a significant sport fishery as long as winterkill conditions persist. Knowledge of the fishery is based on anecdotal reports including observations made during fish kills, since a fishery survey has not been conducted recently. Comparison with other physically similar waterbodies in the area suggest that deeper, clearer (less eutrophic) conditions would reduce the likelihood of winterkill. Two options exist for reducing the frequency of winterkill and significantly improving the fishery use of the waterbodies:

1. A combination of continued high water levels and an aeration system(currently being discussed by local organizations).

2. A combination of continued high water levels and a reduction in algal production in the lake.

Both of these actions require significant commitment of local resources. Without further investigation, it is difficult to assess the chances for success of either approach. Additional investigation should include a fishery survey and the techniques outlined in the Schreiber report.

RECOMMENDED AQUATIC USE CLASSIFICATION - Change the classification of East Twin Lake from Limited Aquatic Life (Marginal) to Limited Forage Fish, year-round. Absent artificial aeration or other remedial measures, this classification should also apply to West Twin Lake. A seasonal classification of warmwater fish & aquatic life is not recommended due to the expectation that the incidental, annual introduction of fish by birds (via eggs) and people would be unlikely to maintain a significant population of intolerant fish.

WILDLIFE USE

The lakes are used by ducks, songbirds, reptiles and amphibians. Past use by sight-feeding shore birds was apparently greater than it is now due to recent declines in water clarity. It appears that local land use changes in recent years, including teh WWTP, have played a role in this change.

RECREATION, AESTHETICS & OTHER USES

Anecdotal evidence and paleolimnological evaluation indicates that water clarity was once better than it is now. The objectional odors from decaying algae impair the aesthetic value and limit recreational uses of the lakes such as nature watching, boating and hiking. The presence of toxic algae further raises questions over wildlife, pet and livestock safety. The WWTP is likely a contributor to these problems. While only a small number of residences exist around the lakes at the present time, the rapid development occurring in Wisconsin in the Twin Cities area could bring in more residents over time. Local residents suggest that use was higher in the past when water quality was better and then dropped off. However, recent increases in residential density appear to be once again increasing the amount of use the waterbodies receive.

GROUNDWATER

The lakes serve as a groundwater recharge area. There is no evidence to indicate whether the practice of discharging wastewater effluent into the lakes has effected groundwater quality. It is likely that the WWTP discharge has contributed to elevated local groundwater levels. However, the significance of this contribution is unknown. The earliest aerial photos suggest that groundwater elevations were once 5-7 feet lower than the current condition. Recent information suggests year to year elevation changes of 2-3 feet while still supporting the concept of an overall, historic increase in water levels.

ALTERNATIVES ANALYSIS

Due to winterkill conditions, the most important functional values of Twin Lakes are wildlife and recreation/aesthetics. These uses are adversely impacted by nutrient loading from the WWTP and nonpoint sources in the watershed. WWTP hydrologic loading is also a controlling factor. If the preventable, cultural watershed impacts to the waterbodies were controlled, the following classification alternatives could exist:

1. With watershed nonpoint control and a highly treated effluent, both waterbodies have potential to support a classification of an open water wetland / lake with a significant aquatic macrophyte component and much reduced algae densities. While the lakes would likely still winterkill, the frequency of this problem could decline, depending on water levels.

2. With watershed nonpoint source control and redirection of the WWTP elsewhere, past conditions might return, namely, a heavily vegetated shallow marsh on East Twin and a open water wetland / lake with a significant submerged macrophyte community on West Twin. The waterbodies would likely still winterkill. This alternative would require the return of historic low water levels.

With either option, the aquatic use classification would likely remain Limited Forage Fish, due to the presence of winterkill conditions. Both options require improvements in nonpoint sources, as well as the Roberts WWTP, and therefore cannot be implemented solely by the WWTP. The contribution of accumulated nutrients from the sediments under both alternatives is a significant unknown, complicating any prediction (Schreiber).

CRITERIA COMPLIANCE AND EFFLUENT LIMIT RECOMMENDATIONS

NR104 associates effluent limits with use designations. These limits were developed primarily with streams in mind, and professional judgement must be exercised when applying them to wetlands lacking stream channels. The primary goal is compliance with the appropriate criteria.

OXYGEN/BOD_5 - Although winterkill conditions are well documented on Twin Lakes, the continued presence of stress tolerant fish species demonstrates that some refuge locations must exist. It also appears that the oxygen problems experienced by the waterbodies are more likely the result of primary production, not WWTP BOD_5 load. Given this information, it is concluded that the current BOD_5 effluent limits for the Roberts WWTP are adequate.

AMMONIA - In recognition of the lack of toxic ammonia concentrations in the mixing zone during the 1993 sampling, the existing WWTP appears to provide adequate treatment for this parameter.

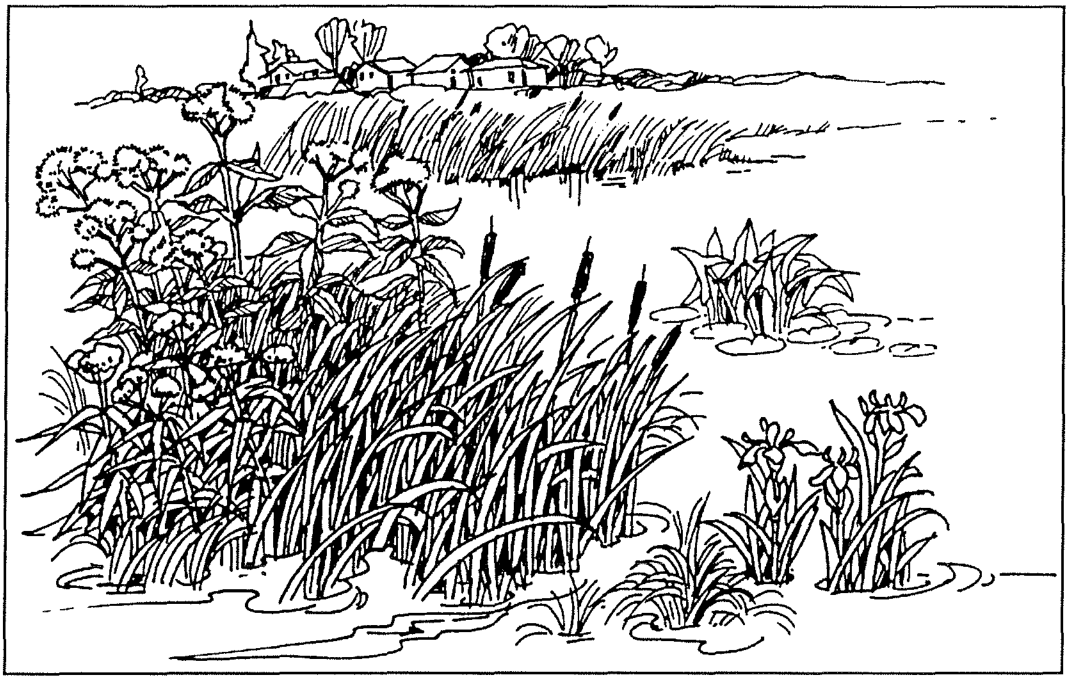
PHOSPHORUS - The phosphorus load from the Roberts WWTP is below the cutoff where the effluent phosphorus standard of 1 mg/L is mandated by NR217. However, the WWTP is contributing to the use impairments of Twin Lakes. Different approaches to dealing with the problem have been identified (Schreiber). The alternatives most likely to succeed involve combined reductions in all controllable phosphorus sources. For this reason, it is recommended that phosphorus reduction at the Roberts WWTP be part of a watershed-wide phosphorus control effort.

Schreiber, K. Twin Lakes / Roberts Water Quality Assessment, WI DNR Western District, November, 1995.

twinlk.rpt

Twin Lakes/Roberts WWTP Water Quality Assessment

November 1995



Prepared by

Ken Schreiber
Wisconsin Department of Natural Resources
Western District

Introduction

Twin Lakes are a pair of shallow, seepage waterbodies (about 168 acres in size) located approximately one mile southwest of the Village of Roberts in St. Croix County, Wisconsin (Fig. 1). In 1976, Twin Lakes were classified as wetlands by the Department, for purposes of establishing wastewater treatment effluent limits. Twin Lakes are not listed in the surface water resources inventory of St. Croix County (WDNR, 1961), but are identified as lakes in the Wisconsin Lakes publication (WDNR, 1991).

The Village of Roberts began discharging wastewater effluent to two wastewater stabilization ponds located in the northeastern portion of Twin Lakes in December 1962. In 1984, the ponds were abandoned and a rotating biological contactor plant went on-line. The Roberts wastewater treatment plant (WWTP) is currently required to meet WPDES permit limits of 16 mg/l $CBOD_5$ (carbonaceous 5-day biochemical demand) and 20 mg/l suspended solids. The discharge permit does not currently require phosphorus or nitrogen removal.

Water depth in Twin Lakes fluctuates considerably, depending on prevailing climatic conditions. Maximum depth of the larger western portion (referred to as West Twin in this report) reportedly ranges from about 9-12 feet. The smaller eastern portion (East Twin), which is hydraulically connected to West Twin by a culvert, has a maximum depth ranging from about 3-6 feet. Historically, Twin Lakes and other comparable waterbodies in the region have fluctuated from a wetland condition with little open water during dry periods, to open-water lakes capable of supporting a limited forage fishery during wet periods.

Both waterbodies suffer from severe summer algae blooms and winterkill due to dissolved oxygen (D.O.) depletion. During July 1991, the Department received reports of an intense algae bloom in Twin Lakes and water samples confirmed the presence of blue-green algal toxins. An ice-cover survey conducted in February 1993 found dissolved oxygen levels throughout the water column below 1.0 mg/l in both portions of Twin Lakes, indicating probable winterkill conditions.

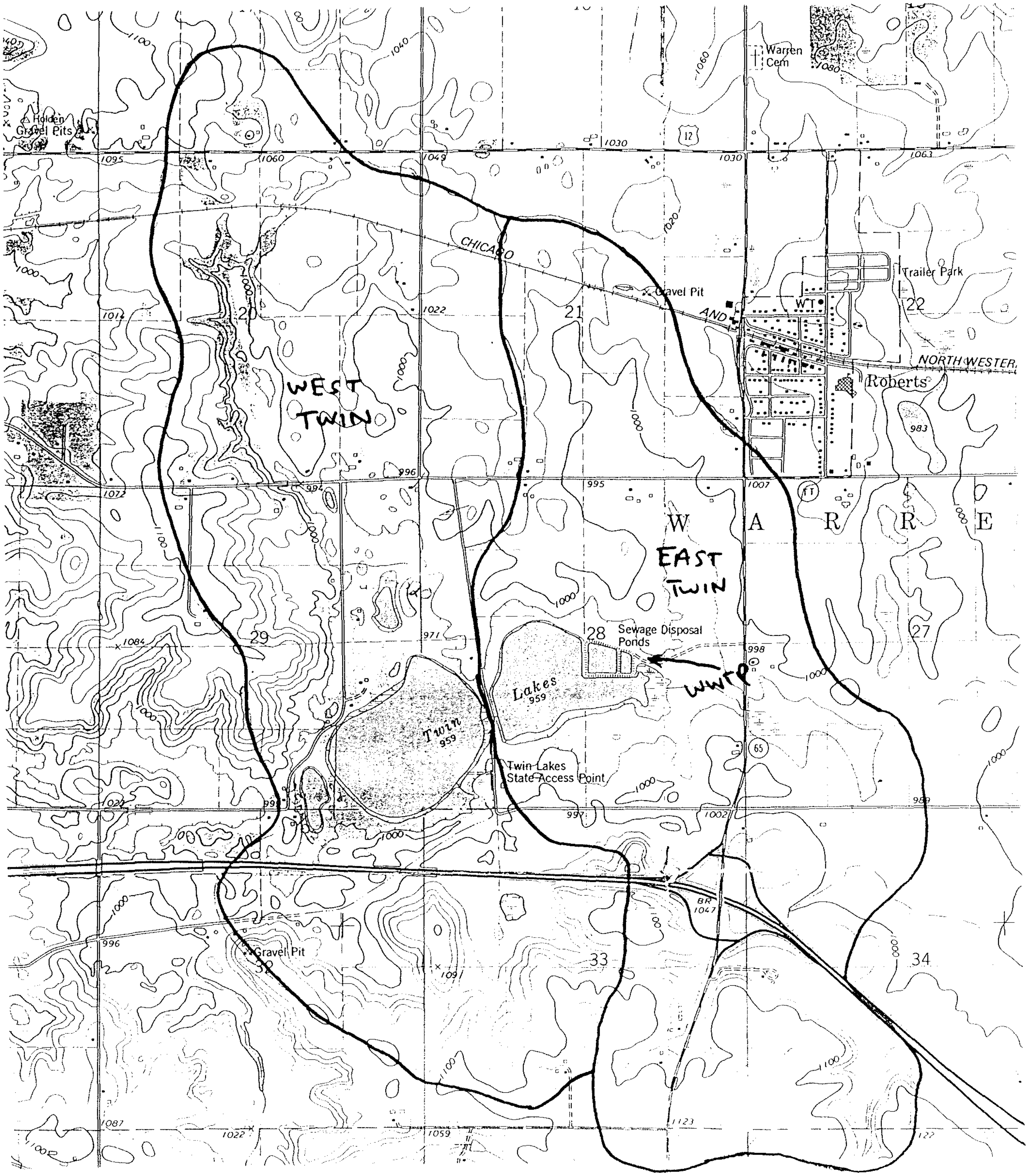


Figure 1. Twin Lakes study area showing drainage area to each waterbody and location of Roberts WWTP outfall.

Anecdotal evidence suggests water quality may have deteriorated in Twin Lakes since the 1960s. The red-necked grebe, a sight-feeding shore bird and Wisconsin threatened species, nested along Twin Lakes from 1967-77 (Evrard 1988). Reductions in water clarity due to frequent algae blooms, and consequent elimination of rooted aquatic plants, may explain the disappearance of these birds from these waterbodies.

Study Objective

The purpose of this study was to evaluate past and present water quality conditions in Twin Lakes, and estimate nutrient loading from point and nonpoint sources in the watershed.

Methods

The study examined historic and existing water quality conditions in Twin Lakes using land use inventories, water quality monitoring and sediment coring. Lake sampling was initiated in February 1993 and completed in September 1993. Additional sediment core and dissolved oxygen data was collected during summer 1995.

Lake Sampling

Water quality monitoring in Twin Lakes was conducted at one site in each lake, generally following the ambient lake monitoring protocol identified in Appendix 1. Water samples were collected in the middle of each lake from two depths (surface and bottom), except when the lakes were clearly well-mixed, when only one sample was taken. Water samples were cooled and sent on ice to the State Laboratory of Hygiene (SLOH) for analysis.

Additional water samples were collected during summer 1993 from ponds located west and northwest of West Twin, and Oakridge Lake in north central St. Croix County for comparison purposes.

Historic water quality of East Twin Lake was examined using paleolimnology, an analytical method using radioactive Cesium ($_{137}Cs$) dating, chemical analysis and algal identification of a lake sediment core. DNR Bureau of Research staff collected the sediment core from East Twin during August 1993. The core was collected with a 4-inch piston-type corer from the deepest location on the lake, sliced into 1cm. segments and placed in one gallon plastic bags in a cooler with ice. Water content was determined by weight loss after drying at 90° C for at least 24 hours. The core segments were analyzed for total phosphorus (P), Fe, Kjeldahl N, Cl, K, Al and $_{137}Cs$ concentrations. Algal identification and enumeration of the core was conducted by the DNR Bureau of Research. Cesium dating and other chemical analysis of the core was conducted by the SLOH.

An additional sediment core was collected from the center of East Twin Lake in 1995 for use in estimating sediment phosphorus release. Sediment P release rates were measured at the U.S. Corps of Engineers Eau Galle Aquatic Ecology Laboratory in Spring Green, Wisconsin according to methods outlined in James and Barko (1991). Phosphorus release rate measurements were conducted under both aerobic and anaerobic conditions.

Point Source Monitoring

The Roberts WWTP operator collected bi-weekly effluent samples from January to December 1993. The samples were sent on ice to the State Lab of Hygiene (SLOH) for analysis of ammonia-N, nitrite+nitrate-N, total Kjeldahl-N and total P. Temperature and pH were measured in the field by the operator.

A study of the WWTP discharge was conducted in East Twin on August 31, 1993 to evaluate the concentrations and distribution of un-ionized ammonia in the mixing zone. Rhodamine WP dye was pumped into the WWTP final contact tank and traced in the mixing zone using a fluorometer. Water samples were collected throughout the mixing zone, sent on ice to the SLOH and analyzed for ammonia-nitrogen. Temperature and pH were measured in the field at all sample sites.

Loading Estimates

The annual phosphorus (P) load from the Roberts WWTP was determined from flow data reported on the WWTP monthly discharge report and P concentrations from bi-weekly sampling. Land use in the watershed was determined from aerial photos and field verification. Drainage area P loading was estimated by applying nutrient export coefficients from Uttormark, et al. (1974), Reckhow et al. (1980) and Panuska and Lillie (1995) to land uses in the watershed.

Internal P loading estimates were based on sediment P release measurements conducted on the sediment core collected from East Twin in 1995. Sediment P release rates for aerobic and anaerobic conditions were applied to 50% the respective area of each waterbody (assuming only the deepest 50% is anaerobic) to estimate the P load. Anaerobic sediment/ water interface conditions were assumed to occur approximately 50% of the time, based on D.O. profiles and limited continuous D.O and temperature recordings.

Phosphorus loading from East to West Twin was estimated as the product of East Twin mid-lake surface concentrations and the WWTP flow. However, actual flow between the two waterbodies was not measured.

Results and Discussion

Land Use

The drainage area of Twin Lakes is approximately 3,500 acres and is primarily gently rolling, agricultural land. The East Twin watershed is predominantly cropland (corn and hay), with a small portion draining the Village of Roberts (Fig. 2). A relatively smaller proportion of the West Twin watershed is in corn production, with greater than 40% of the watershed in fallow agricultural land use. Wetlands comprise less than one percent of the combined Twin Lakes watershed.

Hydrology

Twin Lakes are primarily groundwater seepage lakes with no surface water outlet. Water flowing into the waterbodies is either lost through evaporation or as groundwater discharge. Regional groundwater movement is generally from east to west in the Twin lakes area, draining to the St. Croix River basin. Surface water appears to flow from East to West Twin through a connecting culvert. A plume of turbid, algae-laden water was frequently seen moving into West Twin through the culvert from East Twin during the 1993 sampling season.

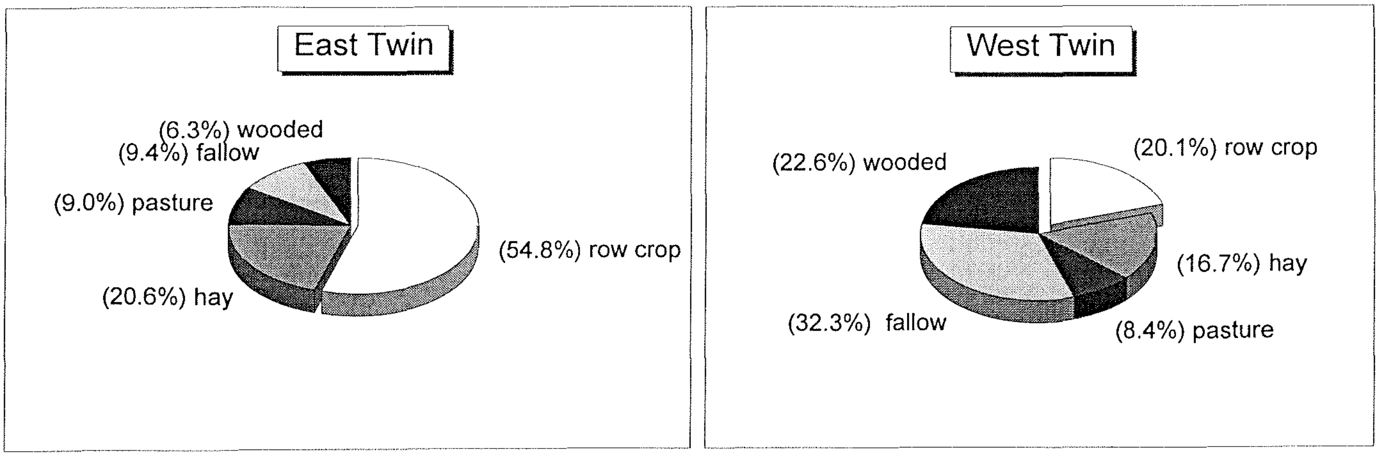


Figure 2. Land use in the Twin Lakes watershed.

Historically, Twin Lakes has undergone extreme water level fluctuations. Based on an examination of aerial photos, East Twin lacked open water areas in 1939, and both waterbodies appeared to be shallow water marshes as recently as 1965. Local residents report that in 1965 the East Twin wetland burned, suggesting low water levels were present at the time. However, review of annual aerial photos suggest the two waterbodies have been filled with water since 1965.

Recently, water levels in Twin Lakes have been unusually high, as have several other waterbodies in St. Croix County. During the course of summer 1993, water levels in West Twin increased 1.25 feet (Fig. 3). Water levels in East Twin eventually overtopped the road between the two lakes, requiring placement of fill to increase the road elevation. Precipitation during June-September 1993 was 8 inches, or 50%, above the long-term average. During May 1995, the water level in West Twin was nearly two feet above the April 1993 level.

Surface water sources were estimated for the Twin Lakes watershed using a regional gain of runoff per unit area value of 0.45 cfs/square mile from Young and Hindall (1973). The Roberts WWTP is estimated to contribute about 4% of the total annual surface flow (or about 0.4 feet in lake level) to Twin Lakes during an average year (Fig. 4). However, the continuous flow contributed by the WWTP may help prevent East Twin from reverting to a shallow marsh condition during dry years.

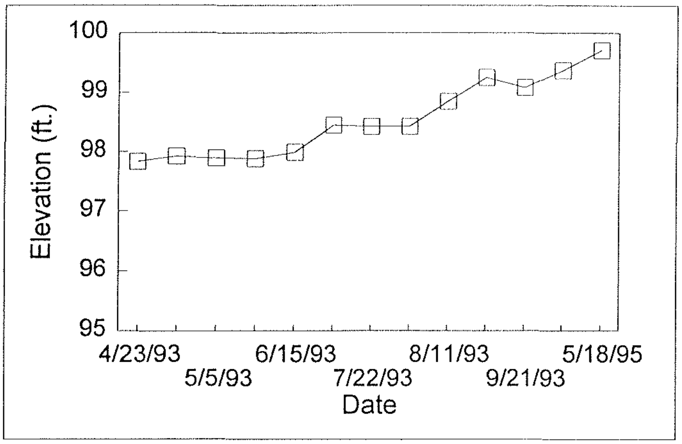


Figure 3. Water levels in Twin Lakes (relative to assumed elevation of 100 ft.)

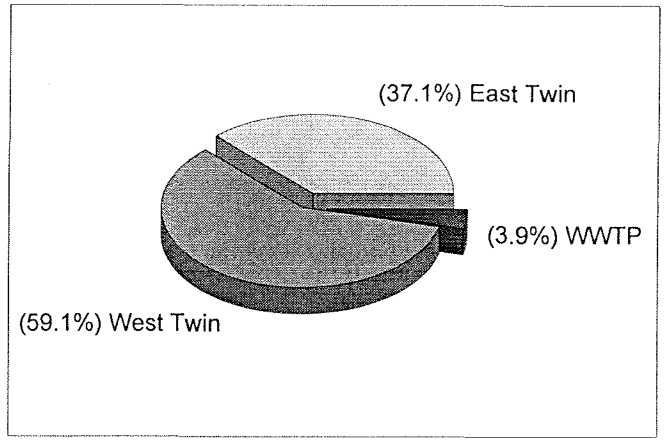


Figure 4. Relative proportion of water sources to Twin Lakes.

Roberts WWTP Discharge

Total P concentrations in the Roberts WWTP final effluent ranged from 1.86 - 8.53 mg/l, with an annual mean of 4.33 mg/l. The mean monthly load of 65 pounds P from the treatment plant is well below the NR 217 (Wisconsin Administrative Rule) threshold which requires P control for discharges exceeding 150 pounds P per month.

A study of the WWTP discharge was conducted on August 31, 1993 to determine the distribution of un-ionized ammonia nitrogen in the East Twin mixing zone. The toxicity of ammonia is a function of the concentration of total ammonia, pH and water temperature. As temperature and pH increase, the portion of ammonia that is un-ionized (NH_3) increases. Un-ionized ammonia is particularly toxic to fish and other aquatic life. During the mixing zone study, the Roberts WWTP effluent un-ionized ammonia concentration was 0.27 mg/l (11.6 mg/l total ammonia), well above the Wisconsin warmwater chronic criterion of 0.04 mg/l.. However, un-ionized ammonia concentrations in the mixing zone ranged from 0.001 to 0.013 mg/l, well below the chronic criterion (Appendix 2).

Water Quality

Water quality in Twin Lakes is very poor, with frequent, severe algae blooms in the summer and oxygen depletion during winter (Fig. 5). The waterbodies frequently winterkill and have a limited fishery. Both lakes have a distinct lack of rooted aquatic plants, probably due to poor water clarity.

Phosphorus is generally the plant nutrient that limits algal production in lakes (Wetzel, 1983). However, nitrogen often becomes limiting to primary production when phosphorus concentrations are very high. Nitrogen limitation favors the growth of blue-green algae which can fix atmospheric nitrogen. When P is not limiting to algal growth, increases in P loading will not appreciably affect water quality. A summary of water quality characteristics of Twin Lakes is presented in Appendix 3.

The ratio of total nitrogen : total phosphorus (N:P) can be used to determine whether P is limiting, with a ratio greater than 10:1 generally indicating that a lake is phosphorus-limited. East Twin N:P ratios were considerably less than 10:1 during the growing season, and West Twin ratios were greater than 10:1 during the same period (Fig. 6). These ratios suggest that East Twin is nitrogen-limited and West Twin is phosphorus-limited. The mean annual N:P ratio of 4.68 in East Twin is nearly identical to the Roberts WWTP mean effluent N:P ratio of 4.93. This similarity of N:P ratios suggests the WWTP has a noticeable impact on nutrient balances in East Twin. Water quality in East Twin would not significantly improve with reductions in P loading until N:P ratios are above 10:1.

Most of the phosphorus discharged by the WWTP is in a dissolved form that is readily available for algae to assimilate. This continuous source of dissolved phosphorus from the treatment plant during dry summer months, likely has a more direct impact on algae growth than particulate-bound phosphorus from nonpoint sources.

Lake trophic conditions can also be evaluated using the Trophic State Index (TSI) (Carlson, 1977). The TSI is calculated using total P and chlorophyll-a concentrations and Secchi disc depth measurements. Figure 7 shows both East and West Twin lakes are in the eutrophic (nutrient-rich) classification for all parameters.

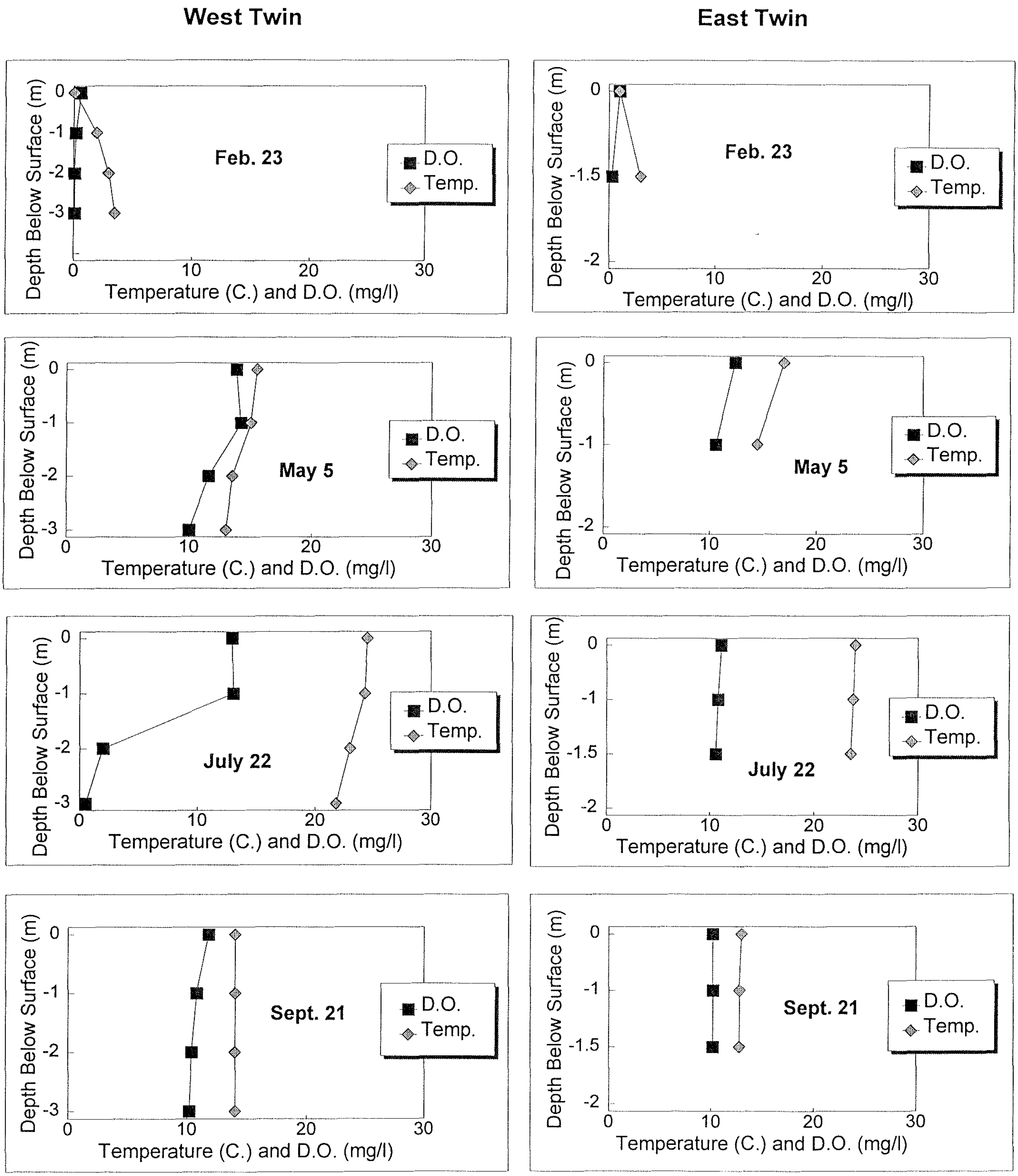


Figure 5. Dissolved oxygen and temperature profiles in Twin Lakes during 1993.

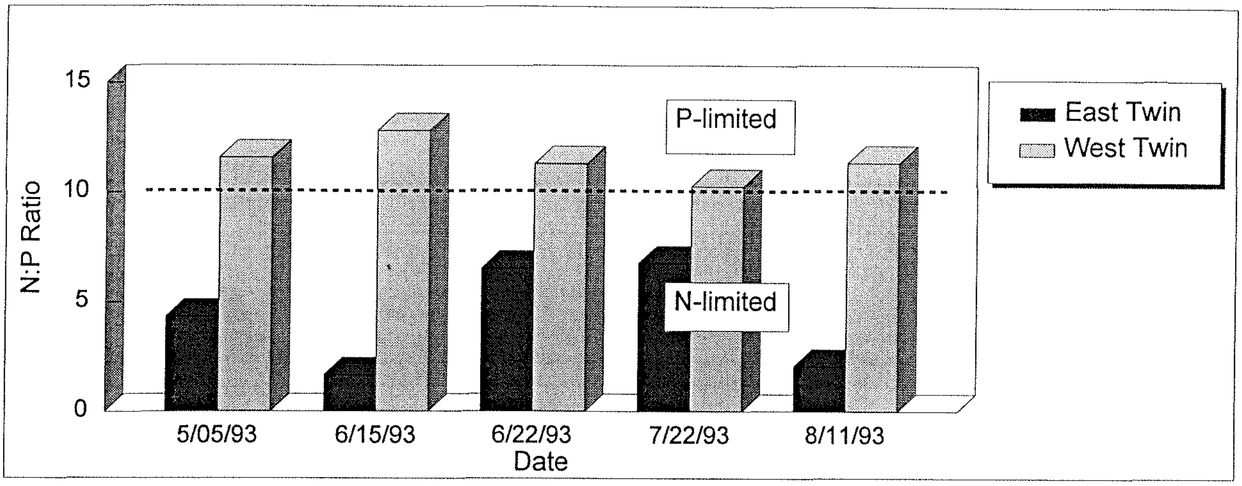
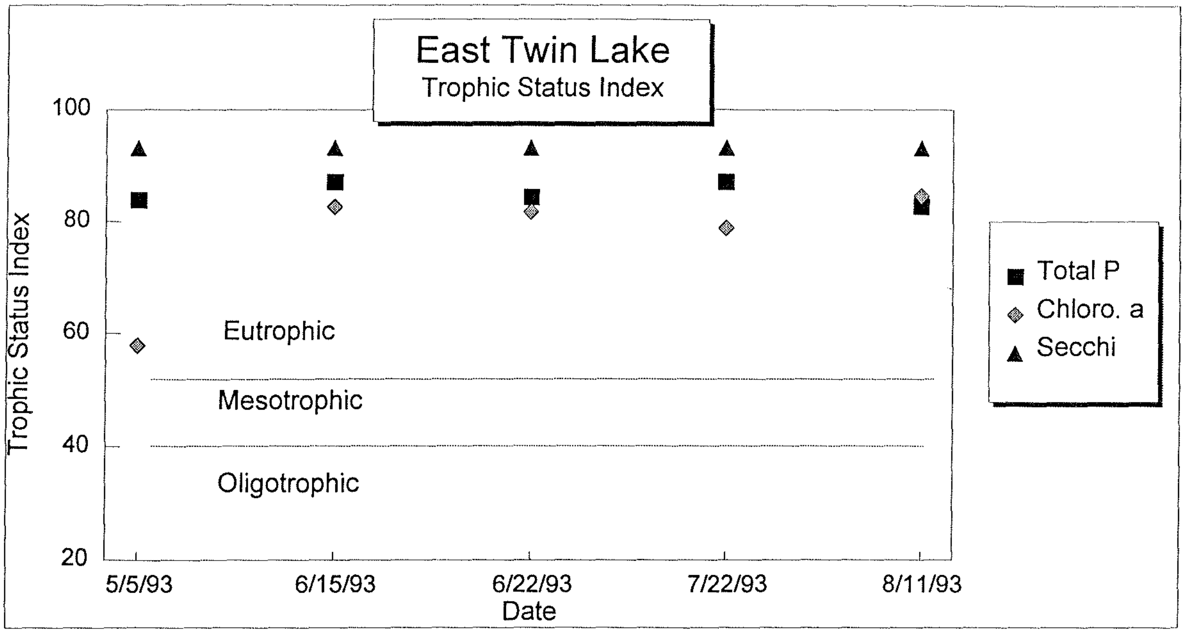


Figure 6. Nitrogen:Phosphorus (N:P) ratios in Twin Lakes during 1993.

Light penetration is a critical factor limiting rooted aquatic plants (macrophytes) in lakes and streams. Generally, plants will not grow where light levels are less than about 10% of surface illumination, which is approximated by the Secchi depth (Wetzel, 1983). The mean summer Secchi depth was 0.3 and 0.7 feet in East and West Twin lakes, respectively, suggesting very limited light available for macrophyte growth. Macrophytes were nearly absent from both waterbodies except for a narrow band of emergent aquatic plants around the perimeter of each lake.

The study design for this project proposed the use of lake eutrophication models to characterize and predict water quality responses to changes in P loading to Twin Lakes. However, the models are based on the assumption of P-limitation, which was not true for East Twin. Consequently, the available models are not appropriate for use with East Twin data. West Twin could not be modelled because an accurate measure of P-loading from East to West Twin was not available. As indicated earlier, surface flow generally occurs from east to west through a culvert in the road separating the two waterbodies. During summer 1993, considerable water also flowed over the road to West Twin. Lake response predictions would not be meaningful without an accurate measure of the phosphorus load from East Twin to West Twin. At this time, the proportion of the annual P load from the Roberts WWTP that reaches West Twin is not known and simulations of various load reductions through modelling is not possible. Accurate measurement of loading from one waterbody to the other would



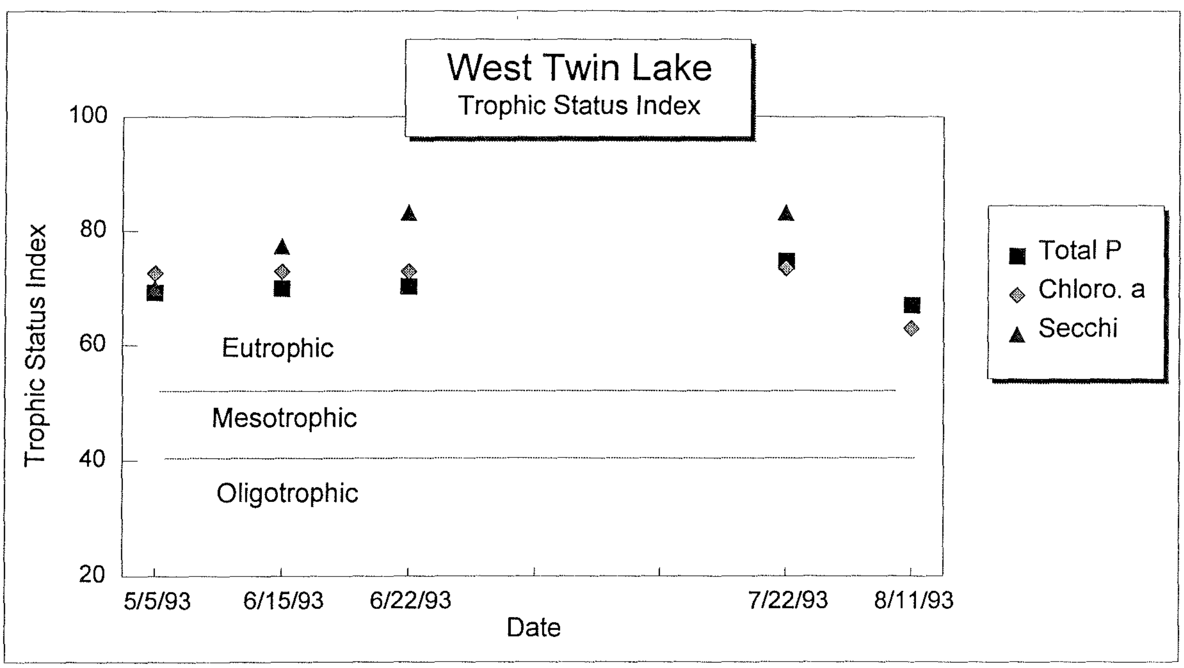


Figure 7. Trophic status index of Twin Lakes

require continuous water level measurement on each side and frequent sampling of the discharge (culvert), which was beyond the scope of this study.

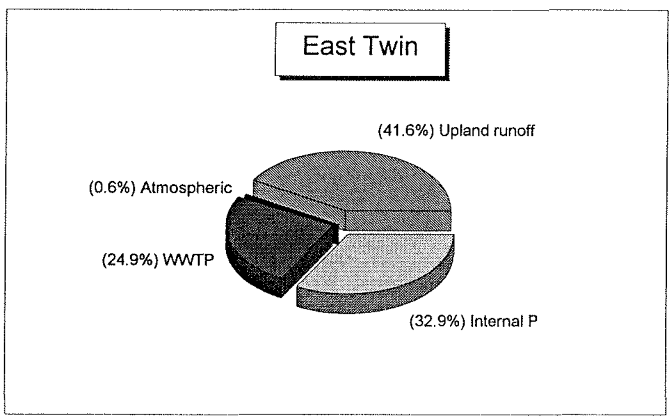
Annual P Loading

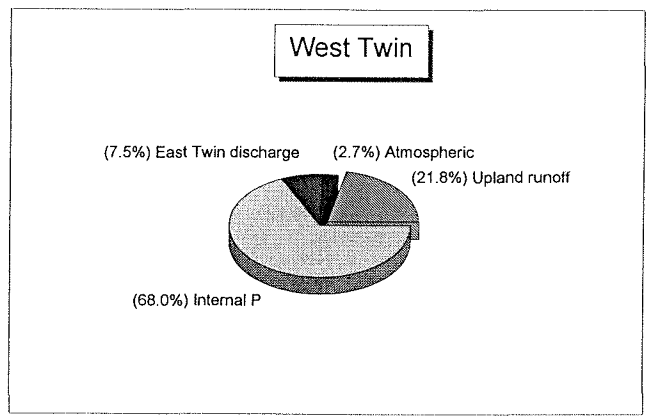
The estimated annual phosphorus load to Twin Lakes is summarized in Table 1 and Figure 8. These P load estimates are considered a "best guess" approximation since the WWTP discharge was the only actual measured load. Sediment P release was the major source of phosphorus to Twin Lakes, accounting for about 49% of the total annual load (Table 1). This internal loading is the result of aerobic and anaerobic breakdown and release of particulate (algae and soil particles) and chemically-bound phosphorus from water and sediments. Most of the sediment P originates from sources external to the waterbody, including nonpoint sources and the WWTP, but the exact proportions from these sources are not known. The anaerobic (anoxic) sediment P release rate was considerably higher (18.7 $mg/m^2/day$) than the aerobic rate (0.3 $mg/m^2/day$). Anoxic sediment conditions were assumed to exist approximately 50% of the time in Twin Lakes (about 180 days per year) based on dissolved oxygen profiles and limited continuous dissolved oxygen monitoring in East Twin (Appendix 4). Anoxic conditions were also assumed to occur in the deepest 50% of the bottom surface area. The actual duration and extent of sediment/ water interface anoxia is necessary to accurately estimate the internal load, but was not measured during the study.

Land use P loading estimates calculated from export coefficients based on Uttormark, et al. (1974) and Reckhow, et al. (1980), generally ranged between what Panuska and Lillie (1995) termed "most likely" and "high" loading rates. Upland runoff was estimated as a significant source of phosphorus to Twin Lakes, accounting for about 34% of the total annual load. During 1993, the Roberts WWTP contributed about 783 pounds (or, about 25% of the total load) to East Twin Lake. However, since the two waterbodies are hydraulically connected, combining loading from both watersheds may be more appropriate. When combined, the WWTP accounts for about 15% of the total annual P load to both waterbodies.

Table 1. Estimated annual phosphorus load to Twin Lakes.

	Total P (pounds/year)		
Source	**East Twin**	**West Twin**	**Combined**
Upland runoff	1,307	488	1,795
Atmospheric	18	60	78
Roberts WWTP	783	---	783
East Twin discharge	---	167	---
Internal P	1,035	1,523	2,558
Totals:	3,143	2,238	5,214





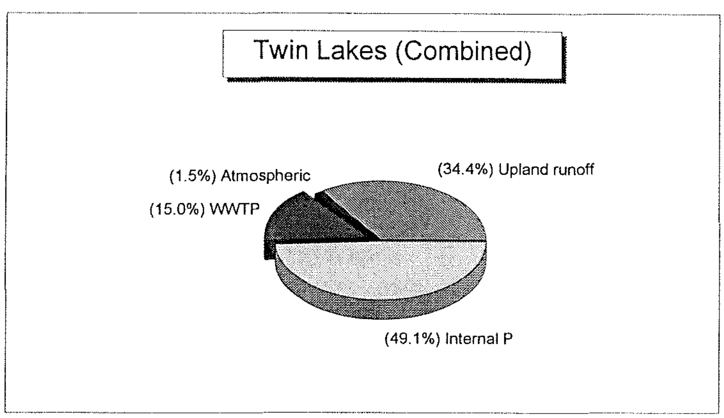


Figure 8. Relative proportions of estimated annual P load to Twin Lakes.

Paleolimnology

Paleolimnological results of the East Twin sediment core are presented in Garrison (1995) and are summarized as follows;

Lake sediment paleolimnology relies on use of radioactive ^{137}Cs to determine the time of sediment deposition. Nuclear weapons testing from 1954 through the mid-1960s resulted in atmospheric deposition of ^{137}Cs. Peak deposition occurred in 1963 when the Soviet Union was conducting many of their tests (Pennington et al., 1973). The peak ^{137}Cs value in the East Twin sediment core was found in the 9-10 cm section, which was assumed to represent the year 1963. The mean sedimentation rate for the period 1963-1993 was about 1/3 the rate for the decade prior to the beginning of the WWTP discharge. This decrease may be the result of a reduction in macrophyte growth, since macrophytes would not be expected to degrade as readily as algae, thus enhancing the sedimentation rate (Garrison, 1995). The reduced sedimentation rate may also reflect changes in land use in the watershed.

Geochemistry of the sediment core appears to reflect changes resulting from the WWTP discharge and land use in the watershed. Indicators of soil erosion (Al, K) suggest that land disturbance increased in the 1950s contributing sediments and nutrients to the lake. Nitrogen concentrations dramatically increased in the mid-1960s when the WWTP began discharging to Twin Lakes, then declined in the 1980s and increased again in the past few years. Based on sediment N:P versus P:K ratios, the primary source of P to East Twin appears to have changed over time. Prior to the mid-1960s, agricultural activity was the source of P, but during the following two decades the WWTP was the major contributor. During the 1980s, nonpoint sources were again the primary source of P, but in recent years the WWTP was the major source. The variability in the relative proportion of P loading from nonpoint sources may be primarily a function of climatic conditions, rather than land use changes.

Diatom frustules in the sediments can be used to reconstruct the trophic history of a lake. The diatom composition of the East Twin core suggests the lake was dominated by benthic diatoms which grow attached to plants and sediments prior to the 1950s. A decline in these species since the 1950s indicates light reaching the lake bottom decreased from increased water levels and/or turbidity

(Garrison, 1995). The sediment core diatom assemblage did not indicate further degradation in water quality as a result of the WWTP discharge.

Comparison with Oakridge Lake

Oakridge Lake was selected as a reference site for purposes of this study because it is a seepage waterbody located in St. Croix County, and has physical features comparable to Twin Lakes (Table 2). East Twin Lake is similar in depth, but considerably smaller than Oakridge, whereas West Twin is deeper, but more comparable in surface area to Oakridge Lake. However, water quality is considerably poorer in Twin Lakes than Oakridge Lake (Figure 9). Total phosphorus, chlorophyll *a* and Secchi depth TSI values all indicate Oakridge Lake is within, or slightly above the mesotrophic category. The relatively good water quality of Oakridge Lake likely reflects land use in the immediate drainage area, which is primarily wetland and woodlands, providing an effective buffer from agricultural runoff. A significant portion of the lake watershed is within a federal Waterfowl Production Area.

Table 2. Comparison of physical characteristics of Oakridge Lake and Twin Lakes.

	Oakridge	**East Twin**	**West Twin**	**Twin Lakes (Combined)**
Surface Area (acres)	149	68	100	168
Maximum Depth (ft.)	6	7	12	--
Drainage Area (acres)	2944	1095	1748	2843

Water clarity is generally good in Oakridge Lake, with Secchi depths typically reaching the lake bottom. Light penetration to the bottom allows luxuriant macrophyte growth throughout Oakridge Lake. The abundant plant growth provides habitat for aquatic insects, a primary food source for waterfowl.

The two aquatic systems provide a dramatic contrast when comparing water quality and biological parameters. Oakridge Lake has generally good water quality and is macrophyte-dominated, whereas

Twin Lakes are algae-dominated and have very poor water quality. Phosphorus concentrations in Twin Lakes are sufficient to cause nearly continuous algal blooms during the growing season, resulting in reduced light penetration and an almost complete lack of macrophyte growth. The lack of macrophytes and resulting instability of the lake bottom likely contributes to re-suspension of phosphorus-laden sediments, fueling the algal growth cycle.

Conclusions

1. Twin Lakes are highly eutrophic as a result of phosphorus loading from the Roberts WWTP, internal recycling of phosphorus and nonpoint source loading from the watershed. Sediment P release was estimated to contribute about 49% of the annual P load to Twin Lakes, however, most of this P likely originates from the watershed . During 1993, the Roberts WWTP contributed about 15% of the annual phosphorus load. The predominance of dissolved P from this source, which is readily available for algal uptake, may be a significant factor during the summer growing season.

2. East Twin Lake is nitrogen-limited during most of the growing season, suggesting extremely high phosphorus levels. Nitrogen:phosphorus ratios in East Twin closely reflect ratios in the WWTP final effluent suggesting the discharge has a significant influence on water chemistry. Sediment N:P ratios also suggest the WWTP discharge as a major P source during recent years. Nitrogen-limiting conditions generally favor growth of nitrogen-fixing blue-green algae. Consequently, East Twin supports nuisance growths of blue-green algae throughout most of the summer.

3. Twin Lakes are experiencing unusually high water levels primarily due to recent climatic conditions. The Roberts WWTP annually contributes about 72 acre-feet, or 0.4 feet in water level to Twin Lakes. The overall hydraulic impact of this continuous source of water is unknown, however, several other waterbodies in St. Croix County were also at historic high water levels during recent years.

Management Alternatives

A significant reduction in phosphorus loading would be beneficial to the water quality of Twin Lakes and could be accomplished by several methods. However, reducing the net input of phosphorus from external sources would only control a portion of the annual load. Sediment P release due to historical enrichment of the lake sediments would likely continue to contribute substantially to the overall phosphorus balance. Consequently, control of only external P sources may not immediately improve lake water quality, but may require many years to bury previously enriched sediments and reduce the internal P load.

Reduce External P Load to Twin Lakes

Phosphorus control in the Twin Lakes watershed could be accomplished in several ways, including the following:

1. Reduce P loading from the Roberts WWTP:

Reducing the effluent P concentration from the 1993 mean concentration of 4.37 mg/l to 1.0 mg/l (NR 217 standard) would result in a 77% reduction in the annual load from the WWTP to Twin Lakes. A 1.0 mg/l P discharge would then contribute only about 3% of the annual P load to Twin Lakes. However, the Roberts WWTP monthly P load is currently well under 150 pounds, which is the threshold level required to meet a 1.0 mg/l P effluent limit (NR 217). The Village of Roberts would not be required to reduce P in its WWTP effluent unless statewide lake water quality standards are promulgated or a site-specific standard (which requires modelling) is developed for Twin Lakes.

Land spreading of wastewater would provide another method to reduce P loading from the WWTP, provided groundwater nitrate standards could be maintained. Land spreading of wastewater in an adjacent watershed would have the additional benefit of reducing hydraulic loading to Twin Lakes. Feasibility of this alternative should consider protection of groundwater quality.

Reducing phosphorus loading from the WWTP could include discharging to the abandoned stabilization ponds prior to East Twin. Phosphorus removal efficiency of the ponds may be enhanced by alum treatment or conversion of the second pond to a wetland. Wetland conversion would likely require reducing water depth in the second pond to allow emergent macrophytes to become established. Effluent from the second pond should have significantly lower P concentrations than the current WWTP discharge. The feasibility of this approach would require further investigation prior to implementation.

2. Reduce nonpoint source P load by implementing Best Management Practices (BMPs) in the watershed:

The Kinnickinnic River watershed (which includes Twin Lakes) has been selected as a nonpoint source Priority Watershed Project and and is eligible for funding from the Wisconsin Nonpoint Source Pollution Abatement Program. This designation provides landowners with 50-70% cost-sharing for installation of BMPs in the watershed. However, St. Croix and Pierce counties have not officially accepted to participate in the project, and funding will not be provided until the counties indicate thier interest. A Priority Watershed Project could possibly achieve a 50% reduction in the annual nonpoint source P load to Twin Lakes.

3. Reduce P load from East Twin to West Twin by installing control gate in road grade:

Installation of a control gate between East and West Twin would force more water through the roadway dike, providing some removal of particulate P. A slide gate could be opened or lowered during storm events to protect the road from over-topping. This alternative could reduce the insoluble portion (approximately 80% of total P) of the P load from East to West Twin . However, this alternative would only provide a 5% reduction in the annual P load to West Twin.

3. Conversion of East Twin to a shallow marsh:

Shallow marshes have been found to provide effective phosphorus control for wastewater discharges. Two factors are likely responsible for the alteration of wetland conditions in East Twin Lake; 1) the lack of water clarity, eliminating macrophyte growth, and 2) increased water depth. A significant reduction in P concentrations would reduce algal growth and increase water clarity. Reducing water depth would allow light penetration to the bottom over a larger portion of the waterbody, stimulating increased macrophyte growth.

Wetland conditions could possibly be restored in East Twin in several ways, including:

1. Reduce hydraulic and P loading from the Roberts WWTP - this action would reduce water depth and algae growth during summer months, allowing for increased water clarity and macrophyte growth.

2. Dredge West Twin and place spoils in East Twin - this action would be very expensive and is unlikely to occur, however, it would provide several benefits, including:

- Increased water depth in West Twin which would improve fish habitat.
- Reduced water depth in East Twin to provide for increased macrophyte growth.
- Increased P-uptake by macrophtyes in East Twin would help reduce P load to West Twin.
- Waterfowl would benefit by improved wetland conditions in East Twin

Reduce Internal P Load in East Twin

The internal P load in East Twin could be reduced by several means including dredging, alum treatment or aeration. Based on sediment core analysis, phosphorus concentrations decrease significantly with depth in the sediments suggesting that dredging of the upper layer of sediments would likely reduce sediment P release. However, this alternative would be very expensive and only effective if combined with control of external inputs of phosphorus. Alum treatment can provide an effective barrier to sediment P release in some lakes, however, treatment of East Twin would likely provide only temporary control due to continued deposition of enriched sediments on the alum layer. Also, the combination of wind and shallow depth of East Twin would probably result in re-suspension, mixing and burial of the alum layer, rendering it ineffective in P control. Alum treatment may be more effective in West Twin, but further analysis should be conducted before this alternative is pursued.

Aeration has been used in lakes to prevent excessive sediment P release under anaerobic conditions. This alternative would probably significantly reduce internal loading rates, but may not be effective in measurably improving water quality unless external P sources are also controlled.

Biomanipulation

Some shallow, eutrophic lakes have benefitted from manipulation of the food chain to increase production of algae-consuming zooplankton, and reduce predation of these zooplankton by fish. Total fish removal (by use of a fish toxicant) has been shown to improve water clarity and increase macrophyte growth in response to increased zooplankton grazing on algae (Hanson and Butler, 1994). Biomanipulation may be applicable to Twin Lakes, provided the algae present can be readily consumed by zooplankton. Some forms of blue-green algae are not effectively consumed because of their large size or gelatinous sheath.

Additional monitoring should be conducted in Twin Lakes prior to implementing biomanipulation, including surveys to determine the abundance and species of fish present, and algae identification to determine suitability for plankton grazing.

Additional Study

Further monitoring of several parameters of Twin Lakes would enhance our understanding of this complex system, and possibly allow use or development of a suitable eutrophication model. Modelling would provide a means to simulate the water quality response to various P load reduction scenarios. Following are recommended additional monitoring activities for Twin Lakes:

1. Measure water levels in both East and West Twin Lakes using continuous recording equipment. This information would provide an accurate estimate of flow between the two waterbodies.

2. Collect summer bi-weekly P samples from water flowing through the culvert between East and West Twin Lakes. This information, in conjunction with flow data, could be used to calculate P loading from one waterbody to the other.

3. Conduct additional laboratory P release studies on cores collected from East and West Twin Lakes. Sediment P release data could be used in determining the internal P load for each waterbody.

4. Conduct continuous pH, dissolved oxygen and temperature monitoring of bottom waters in the center of each waterbody for several 48-hour periods during the open water season. Also, measure D.O./Temperature profiles throughout the lake during the continuous monitoring surveys. This information would be useful in determining duration and extent of anaerobic conditions and estimating annual internal P loading.

Recommendations

Significant reduction of the external P load would likely improve water quality of Twin Lakes and should be pursued through control of point and nonpoint sources. Nonpoint source control could be achieved by implementation of BMPs throughout the watershed. St. Croix County should be encouraged to participate in the Kinnickinnic River Priority Watershed, which would provide cost-sharing to local landowners.

Reduction of P loading from the Roberts WWTP should be pursued concurrent with implementation of the Priority Watershed project. Since the Village of Roberts is not legally required to reduce P in its treatment plant effluent until statewide or site-specific standards are developed, a voluntary effort would be necessary.

Finally, additional monitoring should be conducted to further understand the sources and impacts of nutrient loading to Twin Lakes.

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Appendix 1. Monitoring Protocol for Lake Water Quality Trend Monitoring

Parameter	Approximate date of sample collection: Spring Turnover	Mid June	Mid July	Mid August	Late Winter	Remarks
Complete Water Chemistry	X					Two depths: .5 meter from the water surface and 1 meter above the lake bottom. Constituents: Cl, Diss.P, Ca, Mg, Na, K, pH, SO4, total alkalinity, Fe,Mn,color,turbidity,volatile solids, and suspended solids.
Total Phosphorus Nitrogen series, (KJN-N,NH_3N, NO_2-N + NO_3-N), pH	X**	X***	X***	X***	X**	** = 2 depths: 1 foot below water surface and 2 feet above the lake bottom. *** = third additional depth at the top of the hypolimnion, if lake is stratified.
Water Temperature, Dissolved Oxygen	X	X	X	X	X	Profile - 1 foot below water surface and proceed to lake bottom using 1 meter intervals.
Chlorophyll a	X	X	X	X	X	One depth - composite sample from 0-2 meters.
Secchi disk depth	X	X	X	X		Minimum frequency -weekly local observer is preferred.
Lake water level	X	X	X	X		Minimum frequency - weekly by local observer is preferred.

Appendix 2. Roberts WWTP/East Twin Lake - Ammonia Mixing Zone Study

SURVEY CONDUCTED: 8/31/93

FIELD NO.	LOCATION	Temp. (C.)	pH	NH3N (MG/L)	Unionized NH3-N (MG/L)
	East Twin Lake				
	ROBERTS WWTP OUTFALL	19	7.82	11.6	0.2762
1	40 FT. FROM WWTP OUTFALL - SURFACE	21	8.21	0.045	0.0029
2	40 FT. FROM WWTP OUTFALL - BOTTOM	20	7.89	0.342	0.0102
3	75 FT. WEST OF OUTFALL (SITE 11) - SURFACE	21	8.45	0.082	0.0088
4	75 FT. WEST OF OUTFALL (SITE 11) - BOTTOM	20.5	7.86	0.066	0.0019
5	100 FT. SW OF OUTFALL (SITE 12) - SURFACE	21	8.52	0.029	0.0036
6	100 FT. SW OF OUTFALL (SITE 12) - BOTTOM	20.5	7.89	0.047	0.0015
7	50 FT. WEST OF OUTFALL (SITE 13) - SURFACE	21	8.64	0.03	0.0047
8	50 FT. WEST OF OUTFALL (SITE 13) - BOTTOM	20.5	7.95	0.034	0.0012
9	50 FT. SW OF OUTFALL (SITE 14) - SURFACE	21	8.68	0.076	0.0129
10	50 FT. SW OF OUTFALL (SITE 14) - BOTTOM	21	7.85	0.456	0.0134
11	10 FT. FROM WWTP OUTFALL	21	8.92	0.067	0.0176

Appendix 3. Summary of water quality characteristics of Twin Lakes during 1993.

All values in mg/l unless otherwise indicated

		TEMP.	pH		Unionized				TOTAL	CHLOR. a	SECCHI
STATION	DATE	(C.)	(su)	NH3N	NH3N	TOT P	KJEL-N	NO3-N	N	(UG/L)	(M)
EAST TWIN											
SURFACE	2/23/93	1	7.18	2.87	0.0039	0.56	5	0.314	5.31	21.2	
	5/05/93	17	9.00	0.042	0.0101	1.35	4.7	1.12	5.82	561	0.1
	6/15/93	19.2	9.35	0.032	0.0146	2.04	3.4	<.007	3.4	501	0.1
	6/22/93	25	10.10	0.028	0.0246	1.44	9.4	0.012	9.412	342	0.1
	7/22/93	24	10.35	0.035	0.0323	2.04		0.03	13.83	729	0.1
	8/11/93	32	10.50	0.033	0.0319	1.17	2.4	0.014	2.414	49.4*	
	9/21/93	13	8.14	0.015	0.0005	0.91	1.7	0.016	1.716	133	0.1
BOTTOM	2/23/93	3	NA	3.82		0.76	6.1	0.352	6.452		
	6/15/93	18.9	9.45	0.026	0.0132	1.86	8.4	0.018	8.418		
	8/11/93	21.5	9.94			1.8					
WEST TWIN											
SURFACE	2/23/93	0	6.91	0.604	0.0004	0.101	2.6	<.01	2.6		
	5/5/93	15.5	9.54	0.027	0.0134	0.2	2.3	0.016	2.316	148	0.5
	6/15/93	20.5	9.85	0.088	0.0655	0.22	2.8	0.018	2.818	153	0.3
	6/22/93	26.5	10.55	0.039	0.0373	0.23	2.6	<.01	2.6	153	0.2
	7/22/93	24.5	10.61	0.033	0.0316	0.41	4.2	0.011	4.211	166	0.2
	8/11/93	26.5	10.30	0.027	0.0198	0.15	1.7	<.007	1.7	41	
	9/21/93	14	9.30	0.019		0.18	2.1	0.008	2.108	166	0.3
BOTTOM	2/23/93	3.5		0.665		0.102	2.6	0.031	2.631		
	5/5/93	13	NO SAMPLE								
	6/15/93	19	9.80	0.094	0.0658	0.19	2.6	0.009	2.609		
	6/22/93	18	9.25	0.517	0.1958	0.18	2.5	<.01	2.5		
	7/22/93	23	9.75	0.023	0.0169	0.26	2.5	0.008	2.508		
	8/11/93	21.5	9.72	0.041	0.0287	0.28	2.3	0.02	2.32		
	9/21/93	14	9.30								

* Lab error, results are approximate only.

CORRESPONDENCE/MEMORANDUM

STATE OF WISCONSIN

Date: September 29, 1988

File Ref: WD - WQSR

To: Roberts Facility File

From: Paul LaLiberte P.L.

Subject: Water Quality Standards Review

The Roberts POTW discharges to the eastern portion of Twin Lakes. Twin Lakes are a pair of water bodies about one mile southwest of Roberts in St. Croix County. For purposes of setting treatment plant effluent limitations, the water bodies were classified as wetlands by Water Resources Management in 1976. The Wisconsin wetlands inventory classified the western portion of Twin Lakes as an open, standing water lake (sub class unknown). The eastern portion (where the discharge is located) was classified similarly in part, with the remainder being described as a standing water lake with an aquatic bed and the floating-leaved vegetation. Twin Lakes were not mentioned when the surface water resources of St. Croix County were inventoried in 1961.

Background information on Twin Lakes was gathered by contacting DNR resource managers and wardens, county and local officials, and UW-River Falls staff.

The water depth fluctuates from year to year depending upon precipitation. The maximum depth of the larger western lake reportedly ranges between 6-12 feet. Twin Lakes and other comparable water bodies in the area fluctuate between wetlands and open-water lakes capable of supporting a sport fishery. For example, rising water levels in Twin Lakes over the last several years have reportedly promoted the development of a panfish fishery. However, water levels dropped considerably this year and summer or winter dissolved oxygen problems may set back the fishery and start the cycle again, as apparently happened in the past. Many of the wetlands/lakes in the region are being managed for wildlife under the federal waterfowl production area program.

The vegetation in the two halves of Twin Lakes was reportedly more similar prior to construction of the original lagoon POTW in the 1960's. The plant was upgraded to a rotating biological contactor plant in 1984.

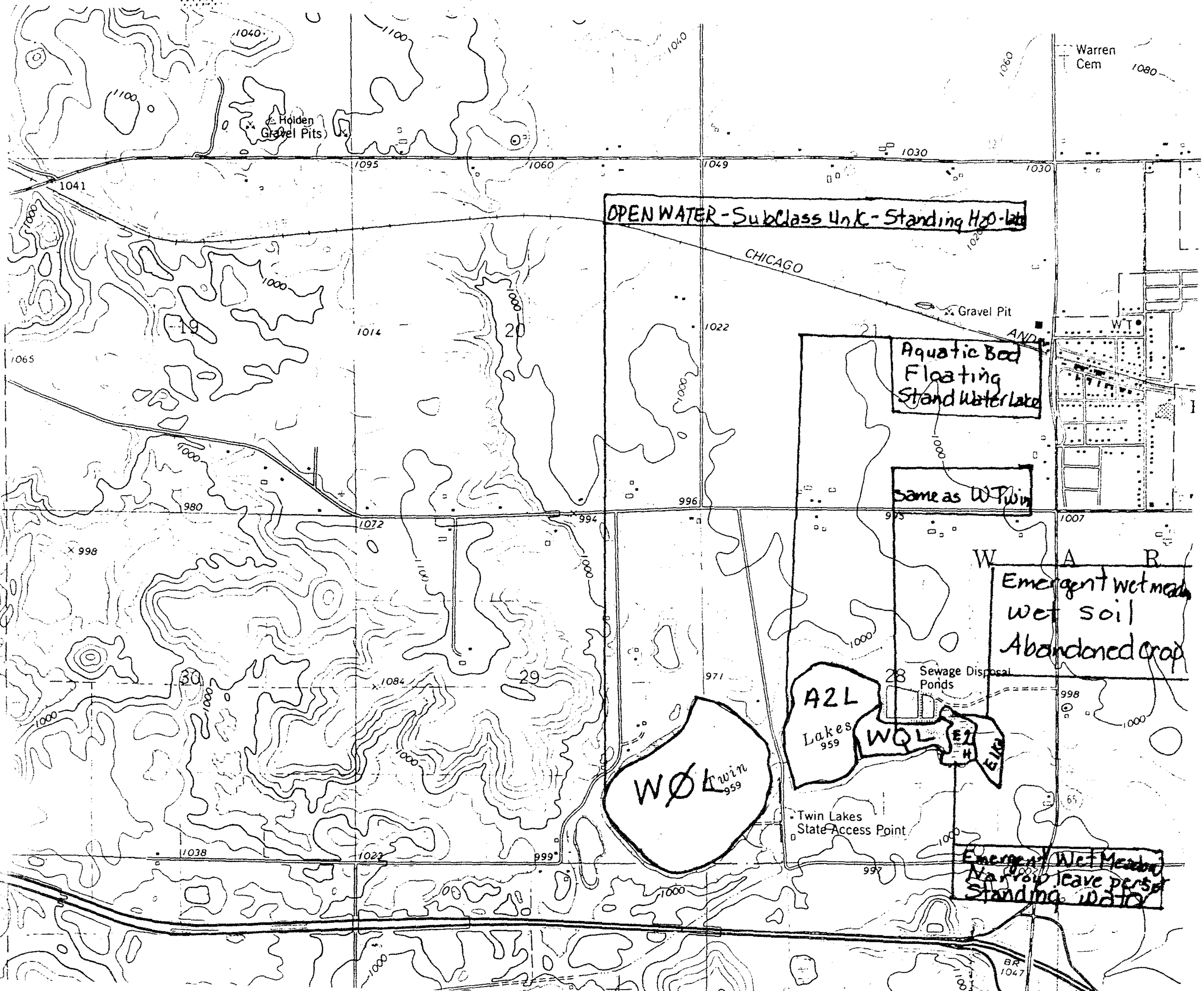
A dissolved oxygen survey at two locations in the eastern portion of Twin Lakes in March 1988 found a maximum depth of 1.5 meters and no oxygen. The western portion could not be sampled due to weak ice.

In recognition of the hydrologic and biological history as well as current use trends and management activities, it is recommended that Twin Lakes continue to be classified as a class E surface water wetland, supporting marginal fish and aquatic life. Effluent limitations for the Roberts POTW should be based on NR 104.02(3)(b).

Enc.
c: John Paddock
Duane Schuettpelz - WR/2

WR\PL004.plm

3 1988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1100
Holden
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OPEN WATER - SubClass Unk - Standing H2O-Lake
CHICAGO
Gravel Pit
AND
19
20
21
1014
1022
1065
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Aquatic Bed
Floating
Stand Water Lake
same as W Twin
980
1072
994
996
1007
W A R
Emergent wet meadow
wet soil
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998
30
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28
1084
971
Sewage Disposal
Ponds
A2L
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959
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Twin
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Twin Lakes
State Access Point
1038
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999
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Emergent Wet Meadow
Standing water
BR
1047

ROBERTS, ST. CROIX COUNTY

WASTEWATER RECEIVING STREAM CLASSIFICATION

Receiving stream - Twin Lakes (east lake).

Effluent from Roberts WWSP treatment system is discharged from the second cell. Aquatic plants in the ponds include submerged Potamogeton and Ceratophyllum and marginal representatives are Sagittaria and grasses. Twin Lakes (east lake) receives the discharge. Submergent and emergent vegetation are common in the lake. The lake is very eutrophic and is considered a wetland area. The waters are used heavily by water-fowl and has no fishery value due to winterkill. Land use around the ponds and lakes is agricultural.

Roberts WWSP - second cell with discharge pipe, looking WNW

Twin Lakes (east lake) - center post marks point of discharge, looking WSW

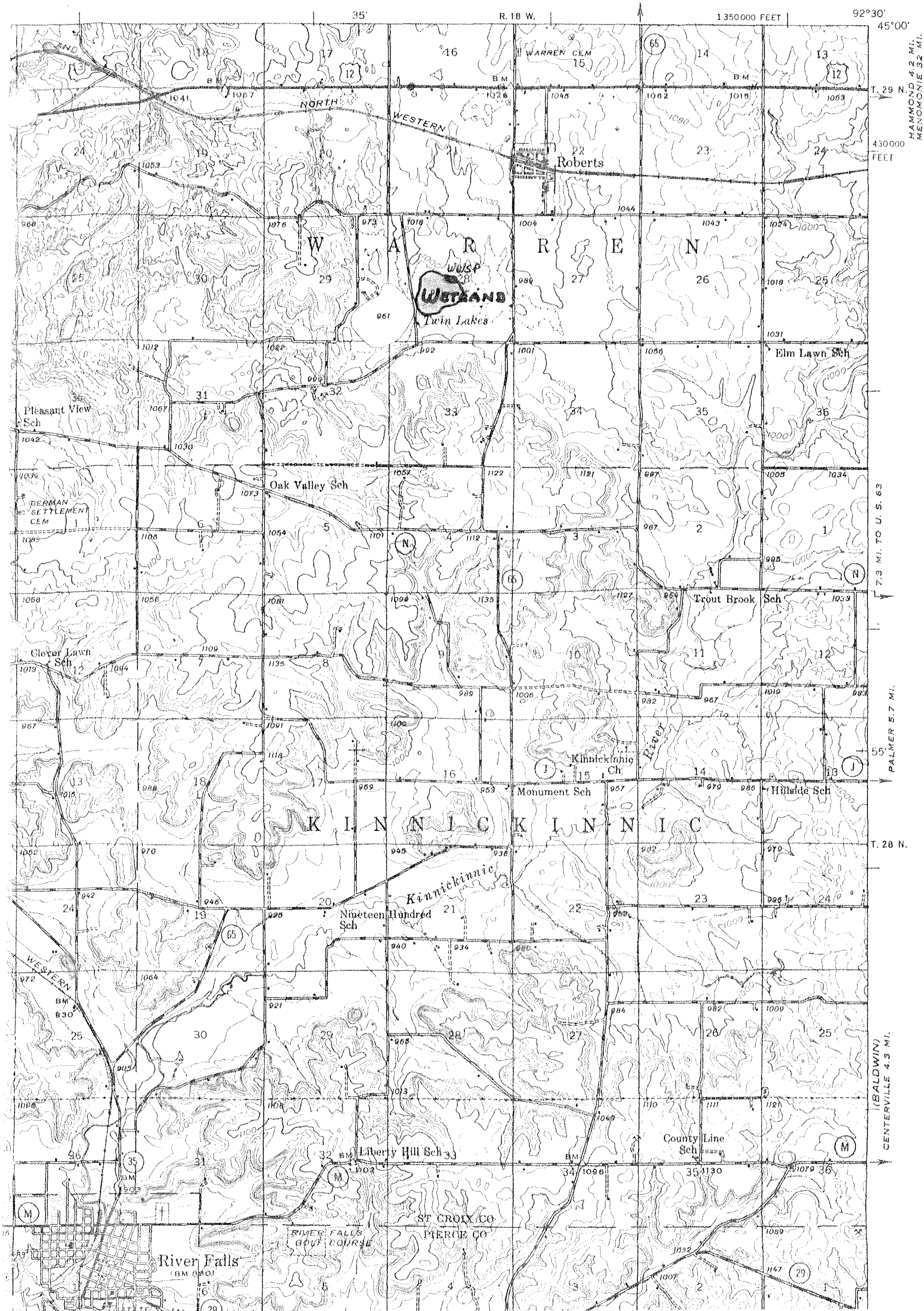
RECOMMENDATIONS:

East lake of Twin Lakes receiving Roberts WWSP shall be classified a wetland.

EVALUATION DATE: September 22, 1976

PERSONNEL:

Terry A. Moe - Water Pollution Biologist - WCD


35'
R.18 W.
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HAMMOND 4.2 MI.
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T. 29 N.
430000 FEET
WARREN CEM
NORTH WESTERN
Roberts
W A R R E N
WDSP
WETLAND
Twin Lakes
Elm Lawn Sch
Pleasant View Sch
Oak Valley Sch
GERMAN SETTLEMENT CEM
7.3 MI. TO U. S. 63
Trout Brook Sch
Clover Lawn Sch
PALMER 5.7 MI.
River
Kinnickinnic Ch
Monument Sch
Hillside Sch
K I N N I C K I N N I C
T. 28 N.
Kinnickinnic
Nineteen Hundred Sch
WESTERN
Liberty Hill Sch
County Line Sch
(BALDWIN)
CENTERVILLE 4.3 MI.
ST CROIX CO
PIERCE CO
RIVER FALLS GOLF COURSE
River Falls
(BM 880)