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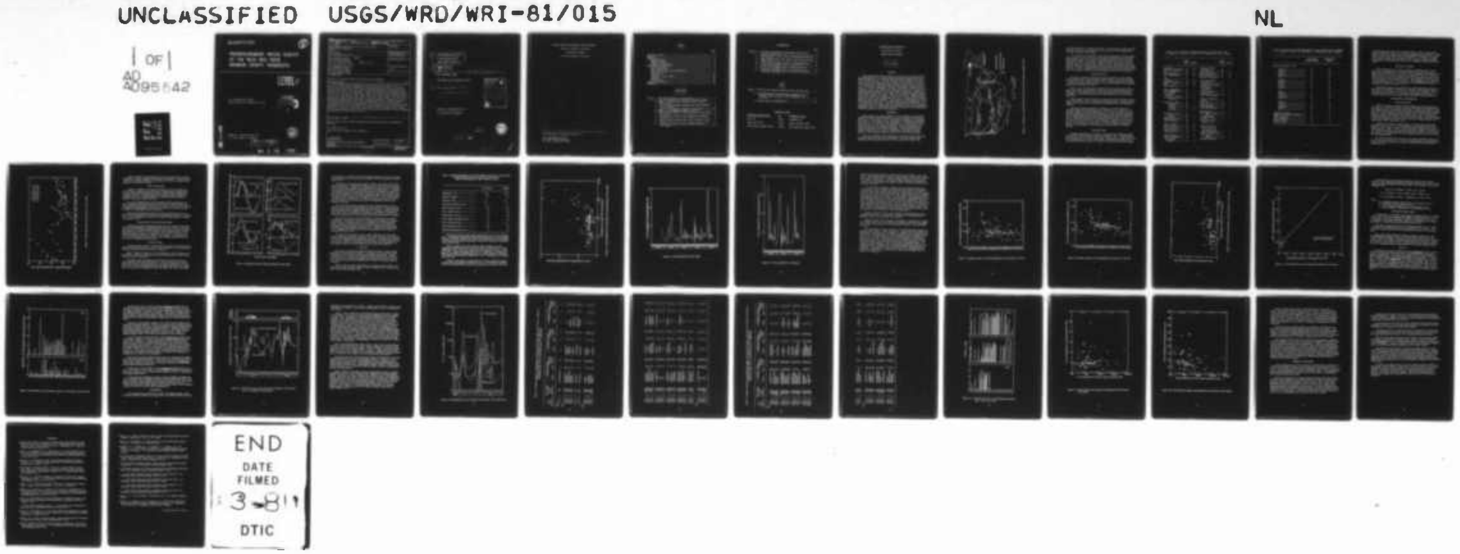

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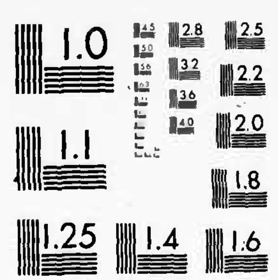

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PREIMPOUNDMENT WATER QUALITY OF THE WILD RICE RIVER, NORMAN COUNTY, MINNESOTA

LEVEL II

U. S. GEOLOGICAL SURVEY
Water—Resources Investigation 80—79

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Water samples have been collected at two sites on the Wild Rice River since September 1974 to establish baseline water-quality characteristics before construction of a reservoir near Twin Valley, Minnesota for recreation and flood control. A decline in water quality between the sites is shown by mean total-phosphorus concentrations that increase from 0.06 to 0.10 milligrams per liter downstream, and mean turbidity that increases from 12 to 24 units downstream. Phosphorus and ammonia concentrations as high as 0.31 and 2.7 milligrams per liter, respectively, could be the result of domestic waste input to the river upstream from Hendrum. Biochemical oxygen demand concentrations were significantly higher during spring runoff than during the rest of the year. Four out of 90 bacteria samples taken at Twin Valley indicate the presence of human fecal material, though bacteria densities do not exceed recommendations of the U.S. Environmental Protection Agency for public-water supplies. The dominance of organic-pollution tolerant phytoplankton in 49 out of 78 samples also indicates degradation of the river quality at Twin Valley. Nutrient concentrations at Twin Valley have no apparent effect on phytoplankton concentrations. None of the constituents sampled were found to exceed recommended concentrations for public-water supplies.

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702 Post Office Building
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ILLUSTRATIONS

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Multiply-inch pound units	By	To obtain SI units
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

PREIMPOUNDMENT WATER QUALITY
OF THE WILD RICE RIVER,
NORMAN COUNTY, MINNESOTA

By L. H. Tornes

ABSTRACT

Water samples have been collected at two sites on the Wild Rice River since September 1974 to establish baseline water-quality characteristics before construction of a reservoir near Twin Valley, Minnesota for recreation and flood control. A decline in water quality between the sites is shown by mean total phosphorus concentrations, which increase from 0.06 to 0.10 milligrams per liter downstream, and mean turbidity, which increases from 12 to 24 units downstream. Phosphorus and ammonia concentrations as high as 0.31 and 2.7 milligrams per liter, respectively, could be the result of domestic waste input to the river upstream from Hendrum. Biochemical oxygen demand concentrations were significantly higher during spring runoff than during the rest of the year. Four out of 90 bacteria samples taken at Twin Valley indicate the presence of human fecal material, though bacteria densities do not exceed recommendations of the U.S. Environmental Protection Agency for public-water supplies. The dominance of organic-pollution tolerant phytoplankton in 49 out of 78 samples might indicate degradation of the river quality at Twin Valley. Nutrient concentrations at Twin Valley have no apparent effect on phytoplankton concentrations. None of the constituents sampled were found to exceed concentrations recommended by the Environmental Protection Agency for public-water supplies.

INTRODUCTION

Water samples for selected chemical, bacteriological, and biological analyses have been collected regularly by the U.S. Geological Survey from two sites on the Wild Rice River in northwestern Minnesota since September 1974 (fig. 1). The purpose of this sampling is to establish water-quality characteristics of the river before impoundment for recreation and flood control by the U.S. Army Corps of Engineers. This report summarizes selected water-quality data through water year 1978 and supplements data analyses being made by the Corps of Engineers. Water-quality data for samples collected at the sites are contained in the annual water-data reports of the Geological Survey for 1974, 1975, 1976, 1977, and 1978.

Additional analyses of the water-quality data from the Wild Rice River have been prepared by the Corps of Engineers. The Corps (1979) report summarizes the water quality effects of the proposed Twin Valley Lake

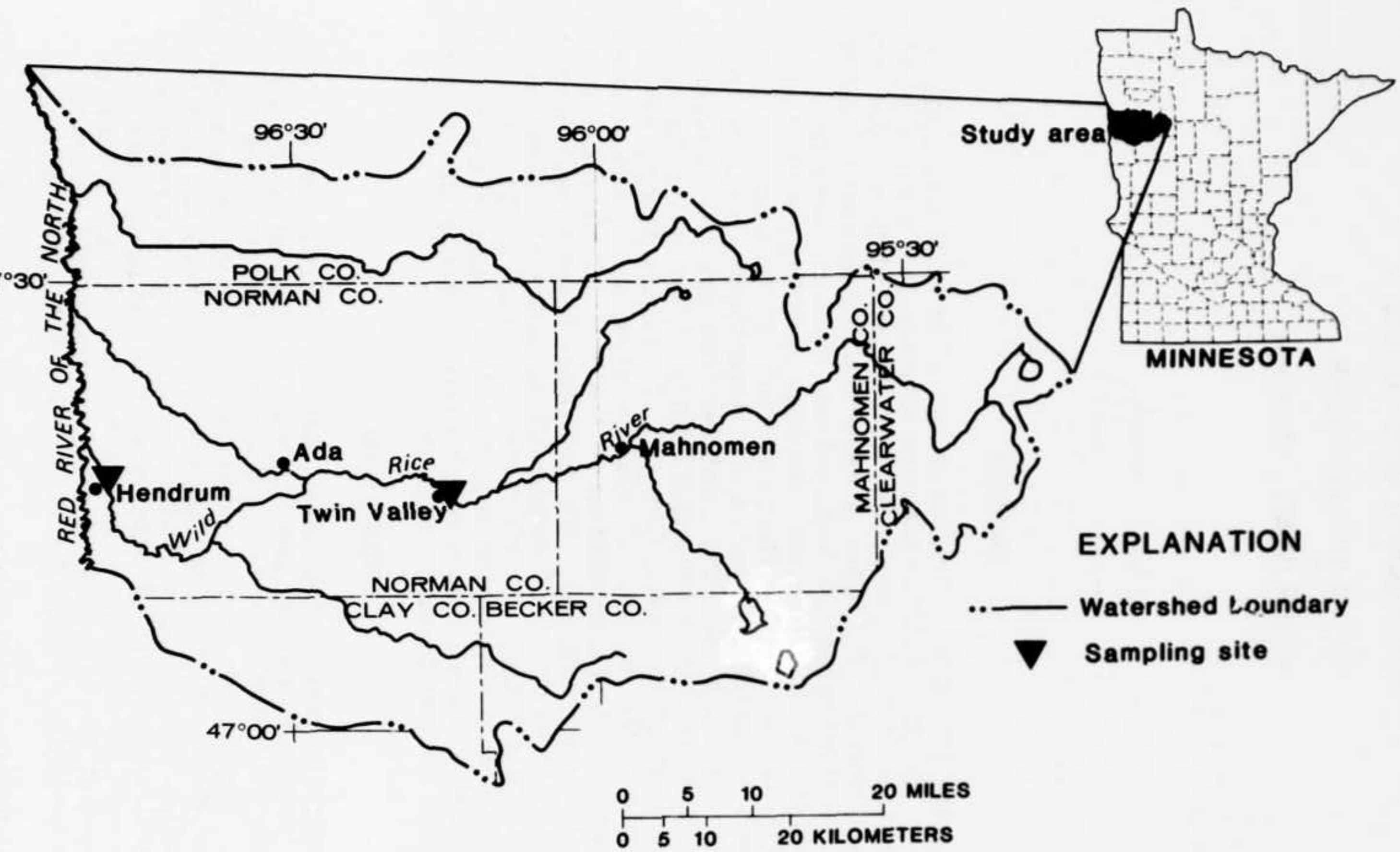

Figure 1.--Location of the Wild Rice River basin and water-quality sampling sites

and dam construction on the Wild Rice basin. Ford and others (1979) evaluate the water quality of the proposed lake with respect to its eutrophication potential, loading, and discharge.

The river has been sampled at Twin Valley and Hendrum, in Norman County, Minn. The sites are in the Glacial Lake Agassiz beach-ridge and lake-plain physiographic areas. The land surface slopes westward a few feet per mile toward the Red River of the North. The Twin Valley site, which is near the intended dam, has a drainage area of 888 mi^2 that consists mostly of agricultural lands, but includes some deciduous forest. The Hendrum site, drainage area 1,600 mi^2, is approximately 35 miles downstream from the Twin Valley site and is 6 miles upstream from the Wild Rice River confluence with the Red River of the North. Nearly all the area between the sites is cultivated.

Sampling Schedule

The Wild Rice River at Twin Valley has been sampled for this program since September 1974 on approximately a monthly basis. The Wild Rice River at Hendrum was first sampled in April 1976. In 1976, sampling was increased to weekly during April through October. Minor modifications of the sampling program have been made since then.

Table 1 lists the frequency of sample collection, constituents determined, and physical measurements at Twin Valley and Hendrum during the 1979 water year. Minor changes in the constituents determined have been made throughout the sampling program and will be mentioned in this report where applicable.

Weekly samples from Twin Valley are analyzed for more constituents than those from Hendrum. These include bacteria, phytoplankton, inorganic constituents, physical properties, nitrogen and phosphorus species, and suspended sediment.

Additional scheduled samples are obtained at the Twin Valley site. Suspended sediment is sampled daily by an observer at the centroid of the flow and checked weekly by hydrographers at the one-third discharge points. Quarterly samples at Twin Valley are analyzed for minor elements, dissolved and suspended organic carbon, and bottom sediment (for particle size analysis). Semiannual samples quantify common pesticides, PCB's, and PCN's in the water and bottom material. Bottom material is analyzed once a year for the presence of metals, oil and grease, kjeldahl nitrogen, and total phosphorus. A 24-hour diurnal profile for pH, dissolved oxygen, temperature, and specific conductance is done quarterly at Twin Valley as well as at Hendrum.

Sampling Methods

Discharge measurements and records of discharge are obtained by standard Geological Survey methods (Carter and Davidian, 1968). Measurements of discharge are generally obtained before the sampling, but a computed discharge may be obtained on the basis of gage height. Representative water quality and suspended-sediment samples are obtained with a depth-integrating sampler

Table 1.--Wild Rice River sampling schedule for the 1979 water year
[A = annually, D = daily, Q = quarterly, S = semiannually, and W = weekly]

	Twin Valley	Hendrum		Twin Valley	Hendrum
Discharge	W	W	Dissolved organic nitrogen	W	-
Specific conductance	W	W	Total nitrogen	W	W
pH	W	W	Dissolved nitrogen	W	-
Air temperature	W	W	Total phosphorus	W	W
Water temperature	W	W	Dissolved phosphorus	W	W
Color	W	-	Total hydrolizable phosphorus	W	-
Turbidity	W	W	Dissolved hydrolizable phosphorus	W	-
Dissolved oxygen	W	W	Total organic phosphorus	W	-
BOD	W	W	Dissolved organic phosphorus	W	-
Fecal coliform	W	-	Total orthophosphate	W	-
Fecal <u>Streptococci</u>	W	-	Dissolved orthophosphate	W	-
Total hardness	W	-	Total iron	W	-
Non-carbonate hardness	W	-	Dissolved iron	W	-
Dissolved, calcium	W	-	Total manganese	W	-
Magnesium	W	-	Dissolved manganese	W	-
Dissolved, sodium	W	-	Phytoplankton	W	-
Potassium	W	-	Total metals, water	Q	-
Sulfate	W	-	Sediment	A	-
Chloride	W	W	Suspended organic carbon	Q	-
Fluoride	W	-	Dissolved organic carbon	Q	-
Dissolved, silica	W	-	24-hour profile of DO, pH, specific conductance, and water temperature	Q	Q
Solids	W	-	Total pesticides, PCB, PCN, water	S	-
Bicarbonate	W	-	Sediment	S	-
Total alkalinity	W	-	Suspended sediment	D	-
Carbon dioxide	W	-			
Total fluoride	W	-			
Total nitrate	W	W			
Dissolved nitrate	W	-			
Total nitrite	W	W			
Dissolved nitrite	W	-			
Total ammonia	W	W			
Dissolved ammonia	W	-			
Total organic nitrogen	W	W			

Table 1.--Wild Rice River sampling schedule for the 1979 water year--Continued
[A = annually, D = daily, Q = quarterly, S = semiannually, and W = weekly)

	Twin Valley Bottom material	Twin Valley Water
Minor constituents, total		
Aluminum	A	Q
Arsenic	A	Q
Barium	A	Q
Beryllium	A	Q
Boron	A	Q
Cadmium	A	Q
Chromium	A	Q
Cobalt	A	Q
Copper	A	Q
Cyanide	A	Q
Lead	A	Q
Lithium	-	Q
Mercury	A	Q
Molybdenum	A	Q
Nickel	A	Q
Selenium	A	Q
Silver	A	Q
Strontium	A	Q
Vanadium	A	-
Zinc	A	Q
Dissolved vanadium	-	Q
Ammonia plus organic nitrogen	A	-
Total nitrogen	A	-
Total phosphorus	A	-
Organic carbon	A	-
Oil and grease	-	A

by the methods described by Guy and Norman (1970). Under ice and during low-flow conditions, samples are commonly hand-dipped and composited. Bottom material samples are composited from representative locations where the material may be scooped with a hand held container at low stages, or dredged with a bottom sampler (Guy and Norman, 1970). Bacteria and phytoplankton are sampled at a representative point in the streamflow (Greeson and others, 1977).

Analytical Procedures

Field determinations are made for specific conductance, pH, DO, and water and air temperature by the methods outlined by the American Public Health Association and others (1971) and Brown, Skougstad, and Fishman (1970) through the use of meters for specific conductance, DO, and pH. Five-day BOD's are done by the azide modification of the iodiometric titration method (American Public Health Association, 1971). This method has also been used for determining the river DO on occasion. Fecal Streptococci and fecal coliform bacteria samples are filtered through 0.7-μm filters and cultured, as specified by Greeson and others (1977).

Laboratory samples are filtered and (or) preserved before shipment to a Geological Survey central laboratory for analysis. The procedures used for preservation and analysis are specified in the listed references: biological—Greeson and others (1977), inorganic constituents and sediment—Skougstad and others (1978), organic substances—Goerlitz and Brown (1972).

WATER-QUALITY CHARACTERISTICS

Major Constituents

Results of chemical analyses of water samples collected from the Wild Rice River at Twin Valley indicate dissolved constituent concentrations that are consistent with the predominant soil types. The moraine deposits in the Twin Valley drainage area yield ground water and surface water with a predominance of calcium, magnesium, and bicarbonate ions. The concentrations of sodium, potassium, and chloride ions tend to be much lower. Contact with Cretaceous rocks, which underlie the Wild Rice River basin, may cause exchange of calcium and magnesium cations in river water with sodium cations in the ground water (Winter and others, 1970).

Variations of chemical concentrations in the Wild Rice River at Twin Valley are closely related to the proportions of ground-water inflow and surface runoff. Figure 2 shows the concentrations of dissolved solids for 3 consecutive water years. During the fall and winter, when surface runoff is at a minimum, the dissolved-solids concentrations are higher. In the spring and summer, the concentrations are lower probably owing to dilution by snowmelt and precipitation.

The effect of ground-water inflow to the river is apparent during late fall to early spring (fig. 2). The lack of precipitation in 1976 resulted in minimal dilution of ground water and high dissolved-solids concentrations through May 1977.

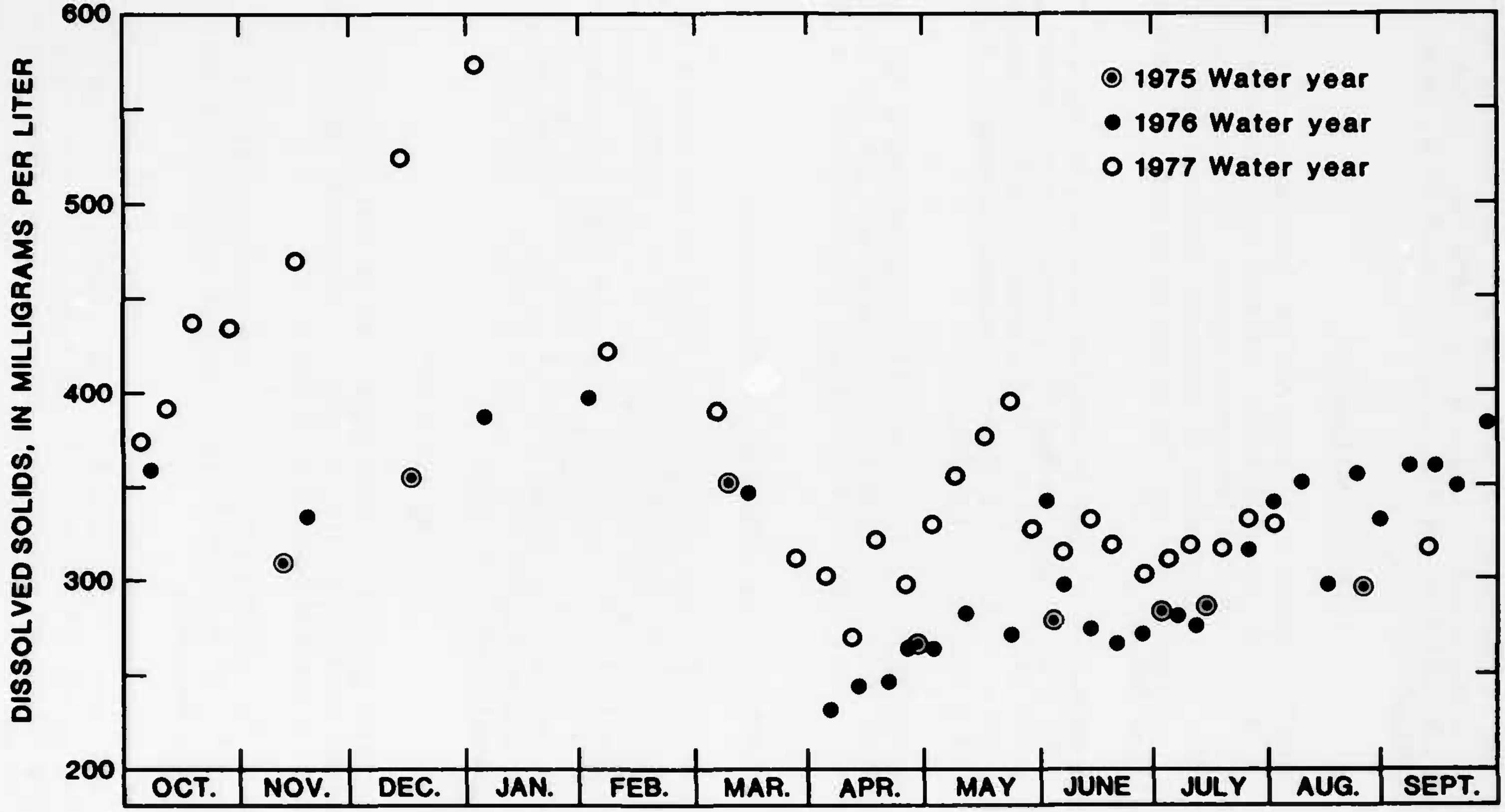

Figure 2.--Dissolved solids concentration at Twin Valley

Similar changes in concentration with time were observed for specific conductance, calcium, magnesium, alkalinity, and hardness. Inverse changes occurred for chloride, sulfate, and the amount of color in the water, suggesting a surface-runoff origin.

Minor Constituents

Analyses of samples collected at Twin Valley for minor constituents (heavy metals, cyanide, and oil and grease) indicate that concentrations are well within U.S. Environmental Protection Agency (EPA) drinking-water standards (EPA, 1976; National Academy of Sciences, National Academy of Engineering, 1972). In many samples, the constituents were either not present or were below detection levels.

The total concentration of lead in samples from Twin Valley was 200 μg/L in February 1977 and 100 μg/L in May 1977, both of which exceed the EPA drinking-water standard of 50 μg/L. The source of lead in these samples is probably contaminated nitric acid used to preserve the samples during shipment to the Geological Survey laboratory.

Strontium concentrations in the river water average nearly 400 μg/L. The lowest concentration of strontium in the samples was 130 μg/L in December 1974. No known standards exist for this element, which possibly is derived from granitic rocks.

Pesticides and Chlorinated Hydrocarbons

Pesticides and chlorinated hydrocarbons, which are man-made compounds, are virtually nonexistent in samples from Twin Valley. However, the concentration of PCB's (polychlorinated biphenyls) was 1 μg/kg of bottom material when sampled in July 1977. The herbicide 2,4-D was also detected in water samples collected in May 1977 (0.03 μg/L), and June 1977 (0.04 μg/L), and in bottom material collected in August 1977 (1 μg/kg). Concentrations of 2,4-D in the water are well below the 0.1 mg/L maximum levels specified by EPA (1976) for community water systems.

Diurnal Profiles

A 24-hour diurnal profile is taken quarterly at Twin Valley and Hendrum. Field determinations are made of pH, DO, water temperature, and specific conductance at each site every 2 hours for 24 hours.

Figure 3 shows the results of four representative profiles obtained at Twin Valley. Specific conductance is not included because it showed no discernible diurnal fluctuations.

The graph of water temperature shows diurnal fluctuations caused by solar radiation and contact with warm air. The river water warms from the lowest temperature at about 0900 hours to the highest temperature at about 1700 hours. After this temperature peak, the water loses heat to the atmosphere by radiation and evaporation until about 0900 hours, when the diurnal

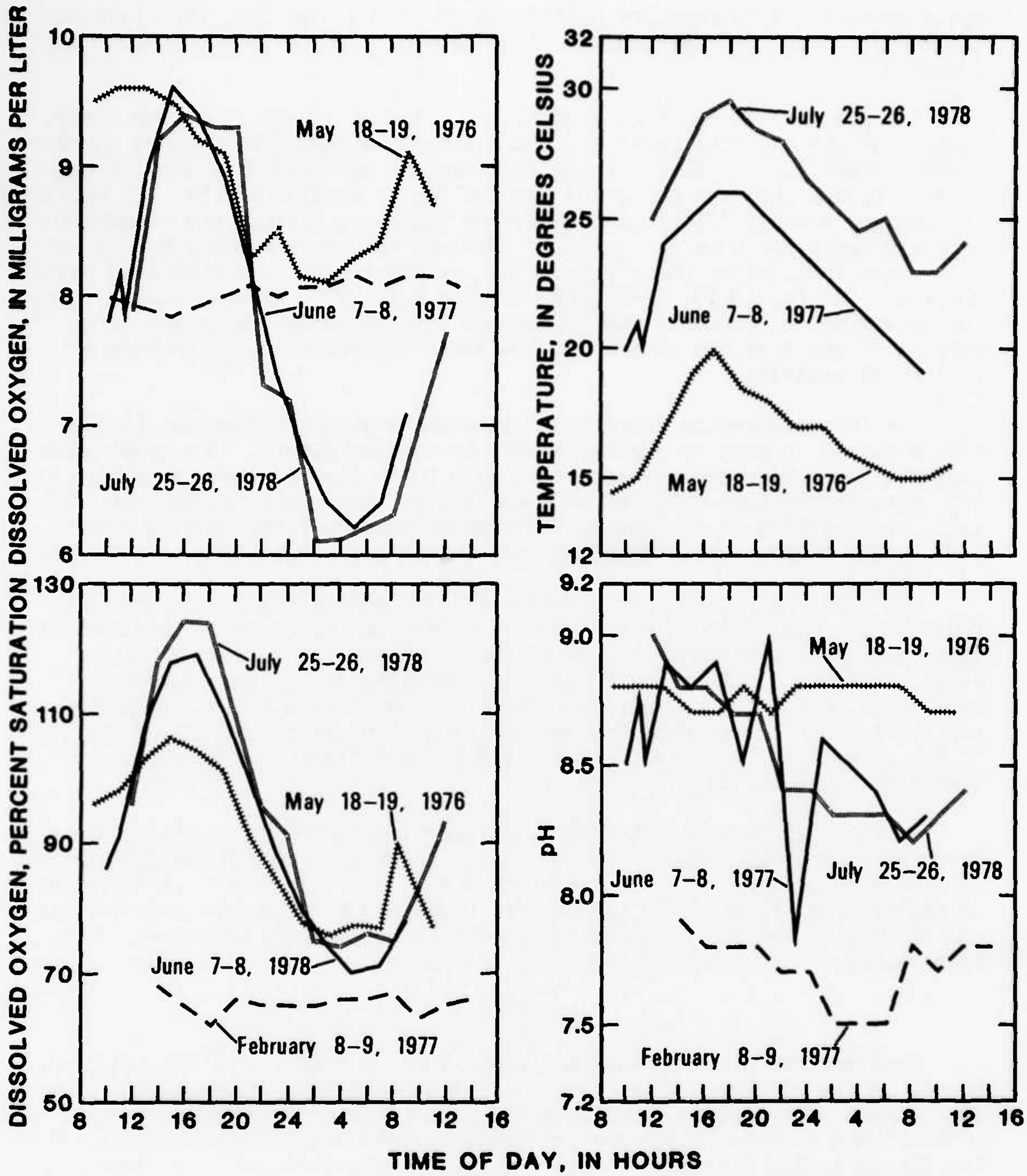

Figure 3.--Selected 24-hour diurnal profiles at Twin Valley

cycle repeats. A temperature profile obtained February 8-9, 1977 (not shown on graph), under ice cover, had no fluctuation, with the temperature remaining at 0.0°C.

The graph of DO concentration shows a diurnal fluctuation with a more sinusoidal rhythm. The peaks and troughs occur at about 1600 hours and 0400 hours, respectively. These strong fluctuations are caused by the influence of alternating photosynthesis and respiration by aquatic plants. DO reaches its maximum shortly after solar radiation reaches a maximum and oxygen from photosynthesis has been accumulated. Minimum DO occurs shortly before sunrise, when respiration has utilized the maximum amount of accumulated oxygen. DO graphs for May 18-19, 1976, and February 8-9, 1977, have a reduced range in concentration, probably due to reduced incident solar radiation (from partial overcast or ice cover) and low water temperatures, which reduce biological activity.

The DO percent-saturation graph also shows strong sinusoidal fluctuations caused in part by photosynthesis by aquatic plants. The graph shows that the water becomes supersaturated with DO in summer. Levels as high as 167 percent have been observed at Twin Valley. The graph for February 8-9, 1977, shows little or no diurnal fluctuation because little sunlight and 0.0°C water temperatures reduce photosynthesis and respiration to a minimum.

The graph of pH shows an erratic pattern, indicating little diurnal fluctuation. Variations in the pH of a stream may be caused by biological processes and the chemical nature of the substrate and inflowing ground water. Diurnal fluctuations of pH will generally follow the pattern of biological production and utilization of carbon dioxide with alternating respiration and photosynthesis, respectively. Incomplete mixing of waters at the sampling site can account for the pH variations seen in figure 3. (See Reid and Wood, 1976).

Profiles (not illustrated in this report) obtained at the Wild Rice River at Hendrum are similar to those at Twin Valley, though the fluctuations in dissolved oxygen and water temperature are less. The more stable nature of the river at Hendrum can probably be explained by increased sediment loads and turbidity (table 2), caused by runoff from crop lands downstream from Twin Valley, which block out sunlight and can reduce photosynthesis.

Nutrients

Analyses for nitrogen and phosphorus species indicate a high nutrient supply in the Wild Rice River system. The availability of nutrients after impoundment of the river can affect the lacustrine environment. Sources of nutrients at Twin Valley are primarily surface runoff from agricultural and forest areas. Periodic discharges from sewage-treatment facilities at various points along the river system can be a source of readily available nutrients.

Table 2 shows the mean concentrations of various nutrient species, DO, and chloride as well as mean values for water temperature and turbidity from April 1976 through September 1978.

Table 2.--Mean concentrations of various nutrient species, DO, and chloride and mean values for water temperature and turbidity
[Units in milligrams per liter except as noted]

	Twin Valley	Hendrum
Temperature (°C)....................	13.8	13.9
Dissolved oxygen....................	8.9	7.4
Turbidity (JTU).....................	12	24
Dissolved chloride (as Cl)...........	4.3	5.5
Total nitrate (as N).................	0.10	0.13
Total nitrite (as N).................	.00	.01
Total ammonia (as N).................	.05	.09
Total organic nitrogen (as N)........	.72	.76
Total nitrogen (as N)................	.90	1.0
Total phosphorus (as P)..............	.06	.10
Dissolved phosphorus (as P)..........	.02	.04

This table indicates that higher concentrations occur at the Hendrum site. Statistically significant differences beyond the 0.02 level through the use of Student's <u>t</u>-test were found for total phosphorus and turbidity. Differences for the other constituents listed were not found to be statistically significant.

Figure 4 shows the relation between stream discharge and total phosphorus concentrations in the Wild Rice River at Twin Valley. During discharges from 1 to 50 ft^3/s, base-level concentrations of 0.04 to 0.05 mg/L exist. During discharges above 50 ft^3/s, phosphorus concentrations generally increase with discharge because of surface runoff to the river. This apparent relationship is supported by an r^2 (coefficient of determination) of 0.54.

Figures 5 and 6 show the concentrations of total phosphorus sampled at Twin Valley and Hendrum, respectively. Minor fluctuations around the base-level concentrations can be seen through most of the year, with the

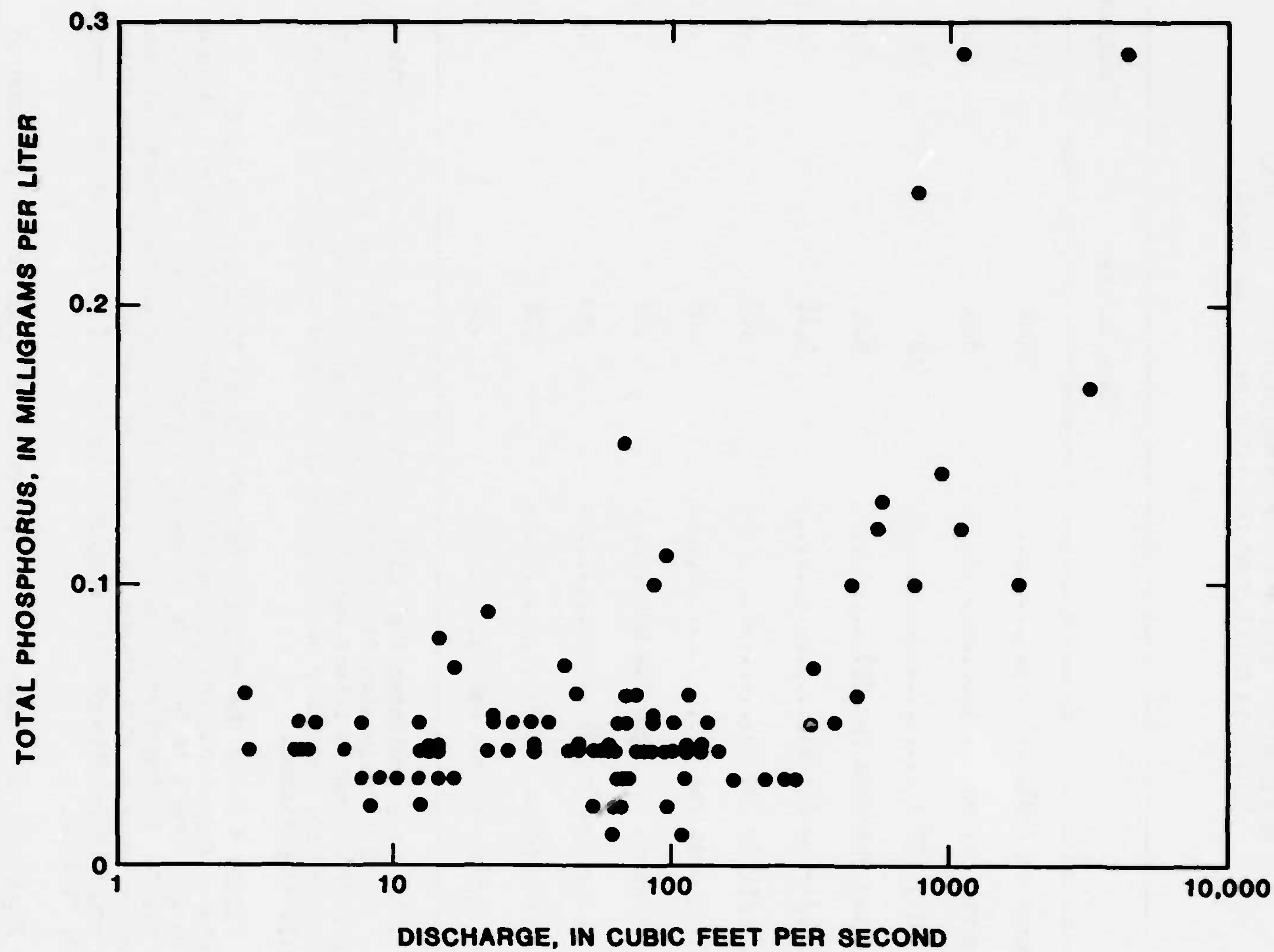

Figure 4.--Total phosphorus concentrations versus discharge at Twin Valley

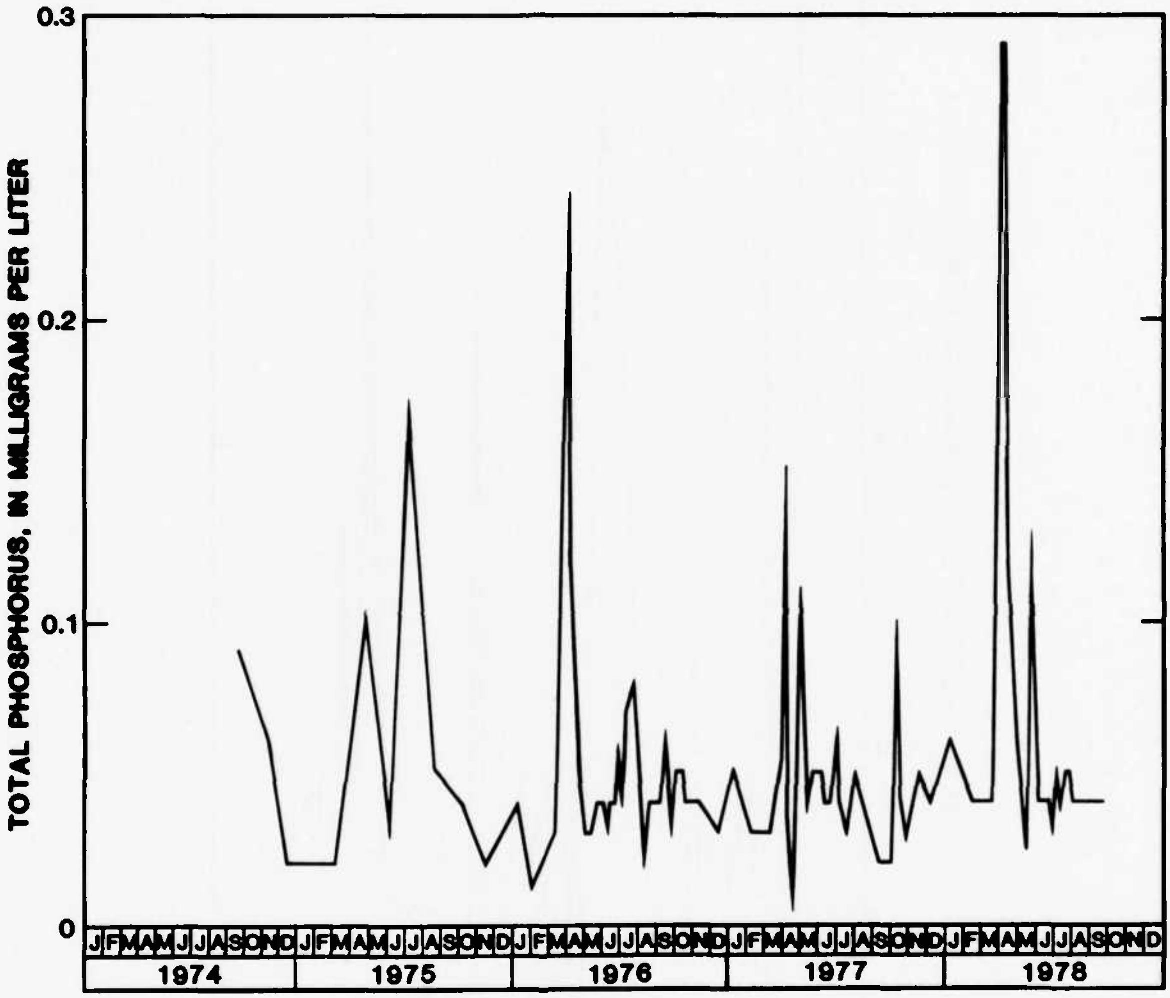

Figure 5.--Total phosphorus at Twin Valley

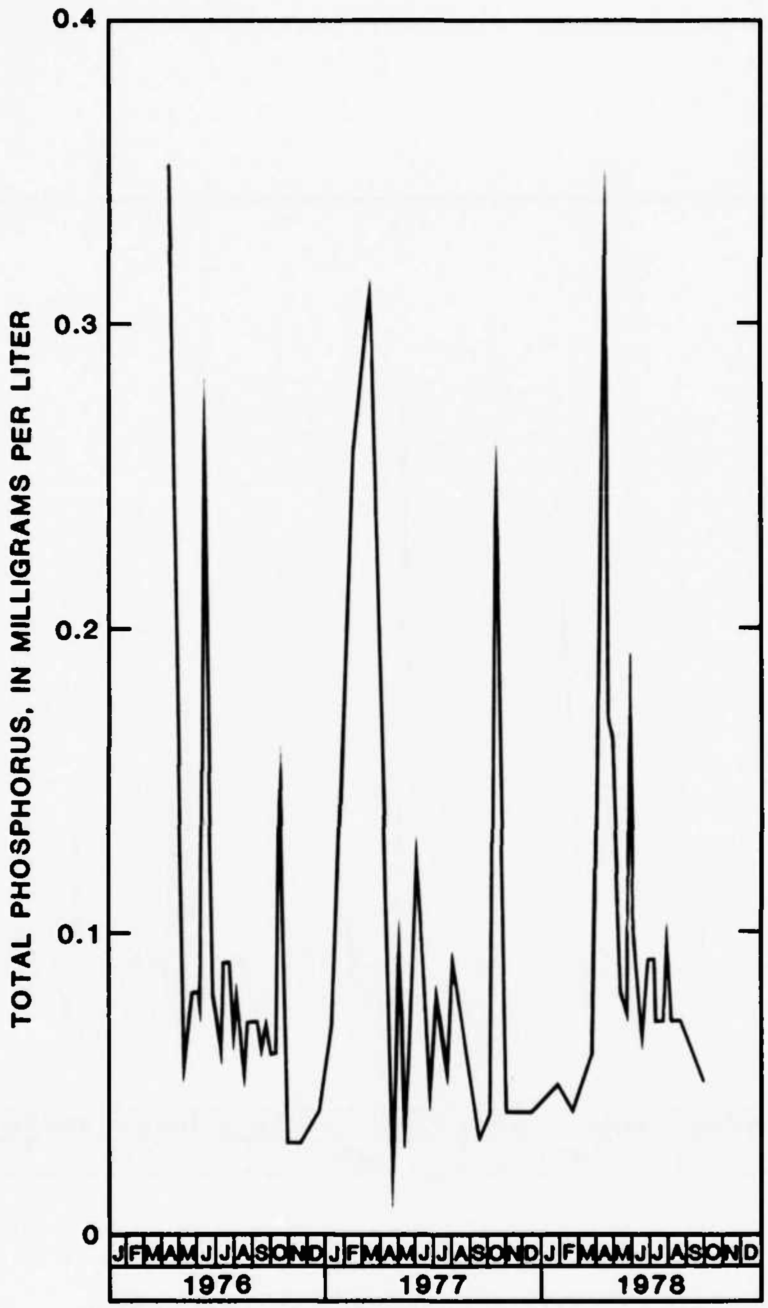

Figure 6.--Total phosphorus at Hendrum

highest concentrations generally during spring runoff (March, April, and May). High concentrations observed at other times of the year are probably the result of storm runoff. Sewage discharges might account for some of these high concentrations, but treatment-plant records are inadequate to determine when holding-pond discharges are made, providing only mean daily flow for each month.

As illustrated in figure 6, samples from the Hendrum site had additional peaks in total phosphorus concentrations not shown from samples at the Twin Valley site. These peaks may have been the result of runoff from areas to which fertilizer had been applied. Observations by field personnel, made during low flow in February 1977, describe the river water at Hendrum as having the odor of raw or poorly treated sewage. High phosphorus content associated with domestic effluents could explain the phosphorus concentrations as high as 0.31 mg/L in the river water in late winter and spring of 1977. The measured discharges were as low as 0.09 ft^3/s. The source of the high phosphorus could be biological decay of stream sediment or discharge from domestic waste-treatment systems during periods of reduced flow in the river. Ammonia concentrations, also associated with domestic wastes, were as high as 2.7 mg/L during late winter and spring 1977.

Figures 7 and 8 show that total phosphorus concentrations vary seasonally at both sites. As previously indicated, the concentrations are generally high in the spring and low in winter.

Figure 9 relates total nitrogen concentration to discharge for samples at the Twin Valley site. The relation is similar to that of total phosphorus in figure 4 and indicates that additional nitrogen is also introduced by runoff.

The relationship of total phosphorus to suspended-sediment samples collected at Twin Valley is shown in figure 10. Some of the scattering may be attributed to periodic input of sewage from treatment plants upstream from Twin Valley. The regression line shown on figure 10 has a regression coefficient of 0.57, which indicates that suspended-sediment concentrations may be used to predict concentrations of total phosphorus at Twin Valley. Adding discharge to the regression provides a better coefficient of 0.69. A similarly high regression coefficient between suspended-sediment, discharge, and total nitrogen, 0.66, indicates that approximate nutrient concentrations may be calculated from suspended-sediment concentrations and discharge. This predictive capability is helpful, as suspended-sediment samples are obtained daily at Twin Valley, and nutrient samples are collected less frequently.

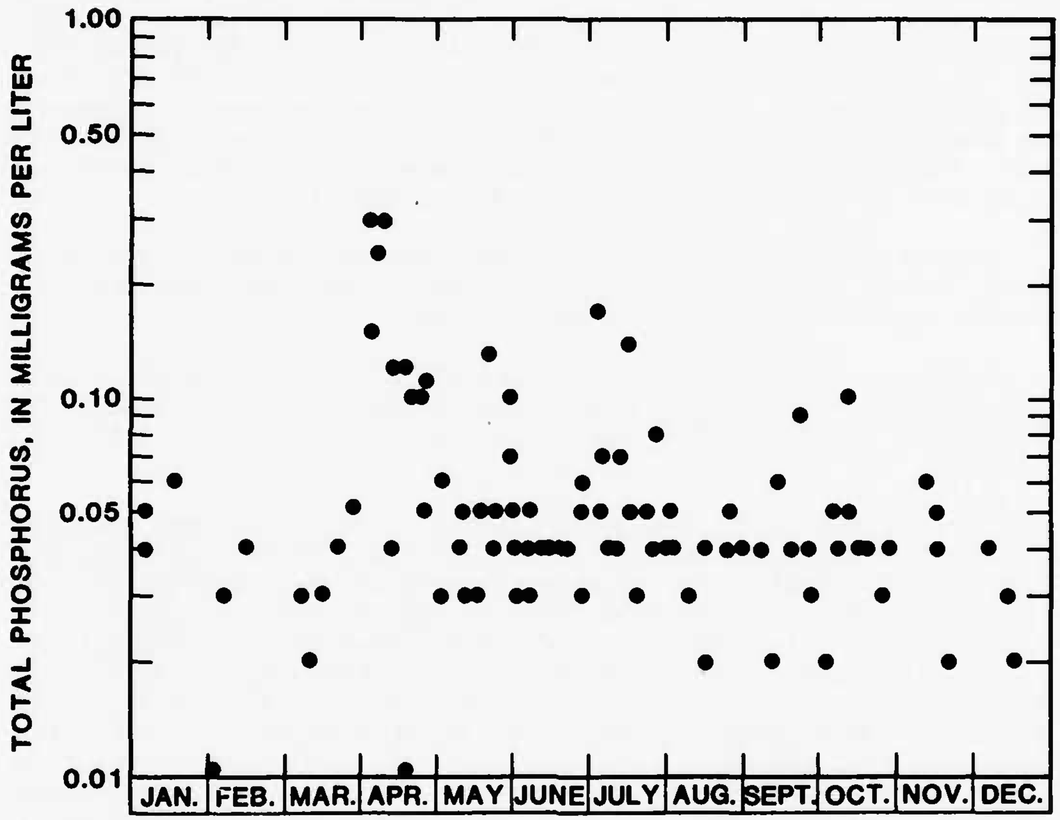

Figure 7.--Monthly values for total phosphorus at Twin Valley, 1975-78

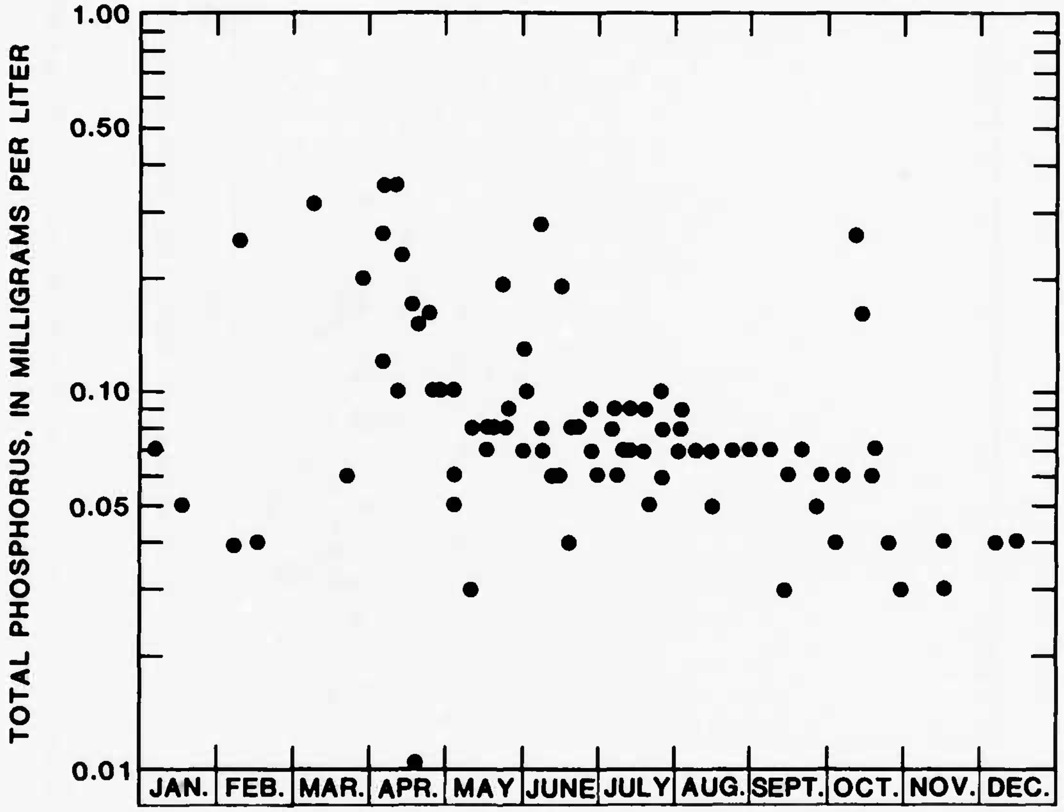

Figure 8.--Monthly values for total phosphorus at Hendrum, 1976-78

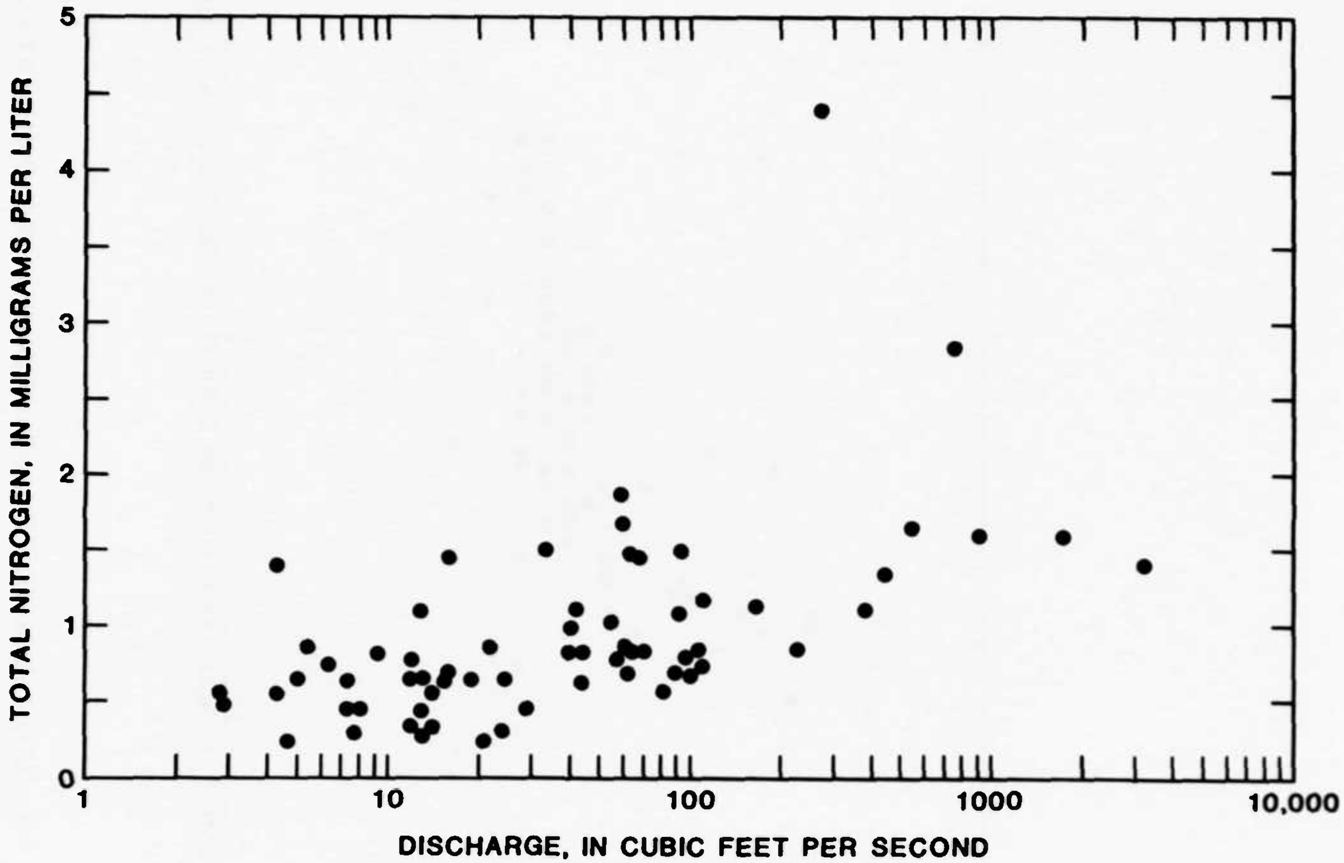

Figure 9.--Nitrogen concentrations versus discharge at Twin Valley

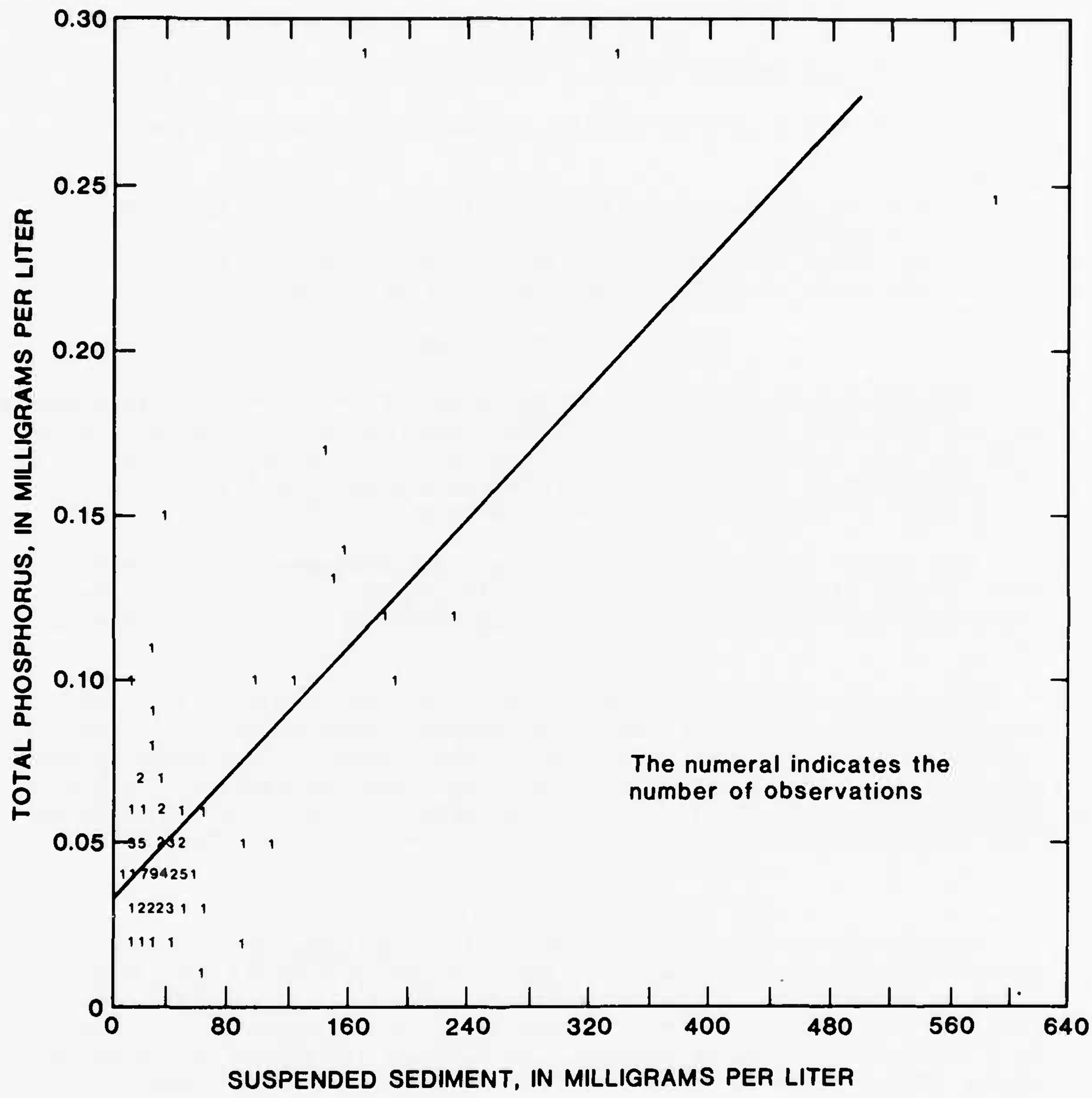

Figure 10.--Total phosphorus versus suspended sediment at Twin Valley

Given below are the regression equations for predicting suspended-sediment, total phosphorus, and total nitrogen concentrations at Twin Valley. These equations were derived from data obtained from September 1974 through September 1978.

$$\text{Log SS} \pm 16.7 \text{ percent} = 2.396 + 0.301 (\log Q)$$

$$N \pm 31.8 \text{ percent} = 0.320 + 0.00373 (SS) + 0.0994 (\log Q)$$

$$P \pm 46.9 \text{ percent} = 0.0348 + 0.0000362 (Q) + 0.000311 (SS)$$

where:

SS = Suspended-sediment concentration in milligrams per liter,
Q = Discharge in cubic feet per second,
N = Total nitrogen concentration in milligrams per liter,
P = Total phosphorus concentration in milligrams per liter.

Biochemical Oxygen Demand

Five-day BOD is an estimate of the amount of oxygen depleted in a sample of the river water as microorganisms decompose biodegradable matter over a 5-day period. Generally, BOD data are subject to considerable error and do not reflect actual stream conditions, making the applicability of the data questionable. (American Public Health Association, 1971).

Mean values of BOD from April 1976 through September 1978 are 6.4 mg/L in 60 samples at Hendrum and 4.8 mg/L in 62 samples at Twin Valley. This indicates a higher concentration of biodegradable materials at the Hendrum site.

BOD at Twin Valley varies with season, as shown in figure 11. More oxygen-demanding substances tend to be present during spring runoff than at other times of the year. Throwing out the extremely high values in March and July 1977, the difference in the seasonal means is statistically significant beyond the 0.02 level. There is no apparent relation of BOD to streamflow or to suspended-sediment, phytoplankton, and bacteria concentrations.

Bacteria

Concentrations of fecal coliform and fecal Streptococci bacteria can be used to indicate contamination by human or animal wastes and the possible presence of pathogens. In general, the probability of finding pathogens in water increases directly with indicator-bacteria concentrations. A ratio of fecal coliform to fecal Streptococci can indicate the origin of the contaminants. If the ratio is about 4 to 1, the source is probably human, if less than 0.7, the source is probably animal. This leaves a wide range of values where the source of contamination is difficult to determine. The ratios are dependable only if the samples are collected within 24 hours time of travel downstream and should not be applied if this time factor is unknown (Kittrell, 1969).

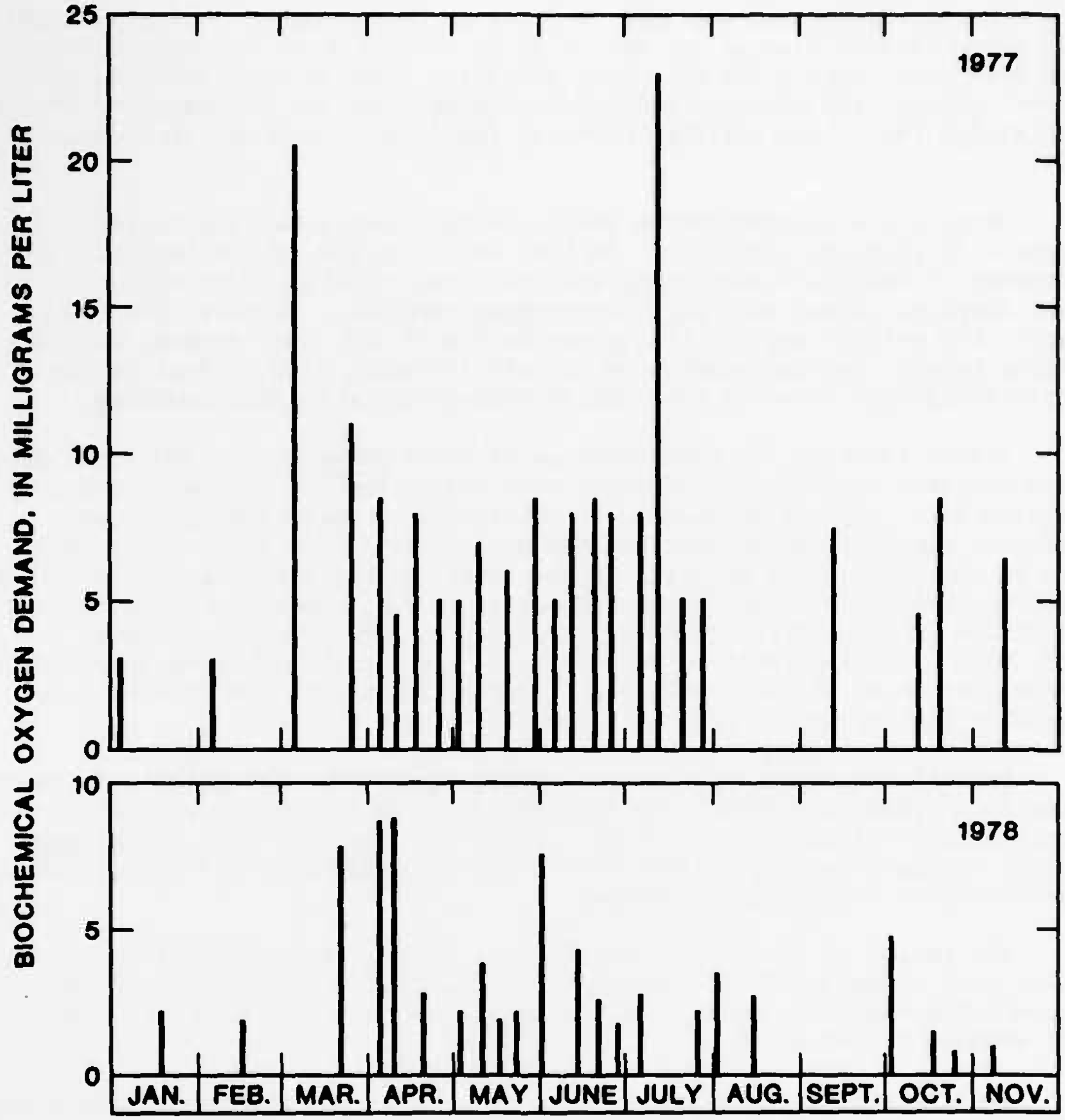

Figure 11.--Biochemical oxygen demand values at Twin Valley, 1977 and 1978

Reliability of fecal coliform and fecal Streptococci samples can be affected by delayed input of the waste into the stream, time of travel in the stream, exposure to sunlight, and stream temperatures (Kittrell, 1969). All these factors will affect the relative die-off rates of sampled bacteria and pathogens, making the data less reliable. Some studies indicate that under unusual circumstances pathogenic bacteria can be isolated from waters containing few if any coliform bacteria (American Public Health Association, 1971).

Obtaining a representative sample of the river water for bacteria cultures also presents a problem. As much as 99 percent of the bacteria may be attached to suspended particles, and most prescribed sampling methods promote grab sampling rather than depth-integrated sampling. Samples obtained by prescribed methods may not be representative of the river system, and variations between regular samples may result (Greeson, 1978). Most of the bacteria samples taken at Twin Valley were obtained by grab sampling.

Figure 12 shows the concentration of fecal Streptococci and fecal coliform bacteria sampled in 1977-78 at Twin Valley and the accumulated precipitation for 7 days prior to samples obtained from March through August. Rainfall runoff tends to increase sediment loads in the river (Guy, 1970) and to introduce fecal material in the runoff from pastures and in overflow from waste-treatment facilities. The variations in bacteria-colony counts in figure 12 show little or no relationship to precipitation recorded at Ada, Minn., 10 miles west of Twin Valley. Localized variations in rainfall, concentration of sediment and fecal material in runoff, and intensity of rainfall can all affect this relationship.

Bacteria-colony counts generally were highest in the spring and summer, when more viable microorganisms are introduced to the stream and the environment is more suitable for survival. Fecal coliform and fecal Streptococci colony counts generally follow similar patterns, indicating a strong association between these microorganisms.

The ratios of fecal coliform to fecal Streptococci ranged from 5.3 to 0.04, with a mean of 0.94. Only 4 of the 90 samples indicate the presence of human fecal material, while 41 imply animal sources; but this is inconclusive for reasons stated above.

The EPA (National Academy of Sciences, National Academy of Engineering, 1972) recommends that the geometric means of fecal coliform densities in raw waters for public water supplies do not exceed 2,000 per 100 mL. The highest density obtained at Twin Valley was 430 colonies per 100 mL, based on a colony count outside the ideal range of 20 to 60 colonies per filter, sampled on July 5, 1978, well below the EPA recommendations.

Phytoplankton

River systems such as the Wild Rice above Twin Valley contain a wide variety of habitats conducive to algal growth. The habitats range from lakes

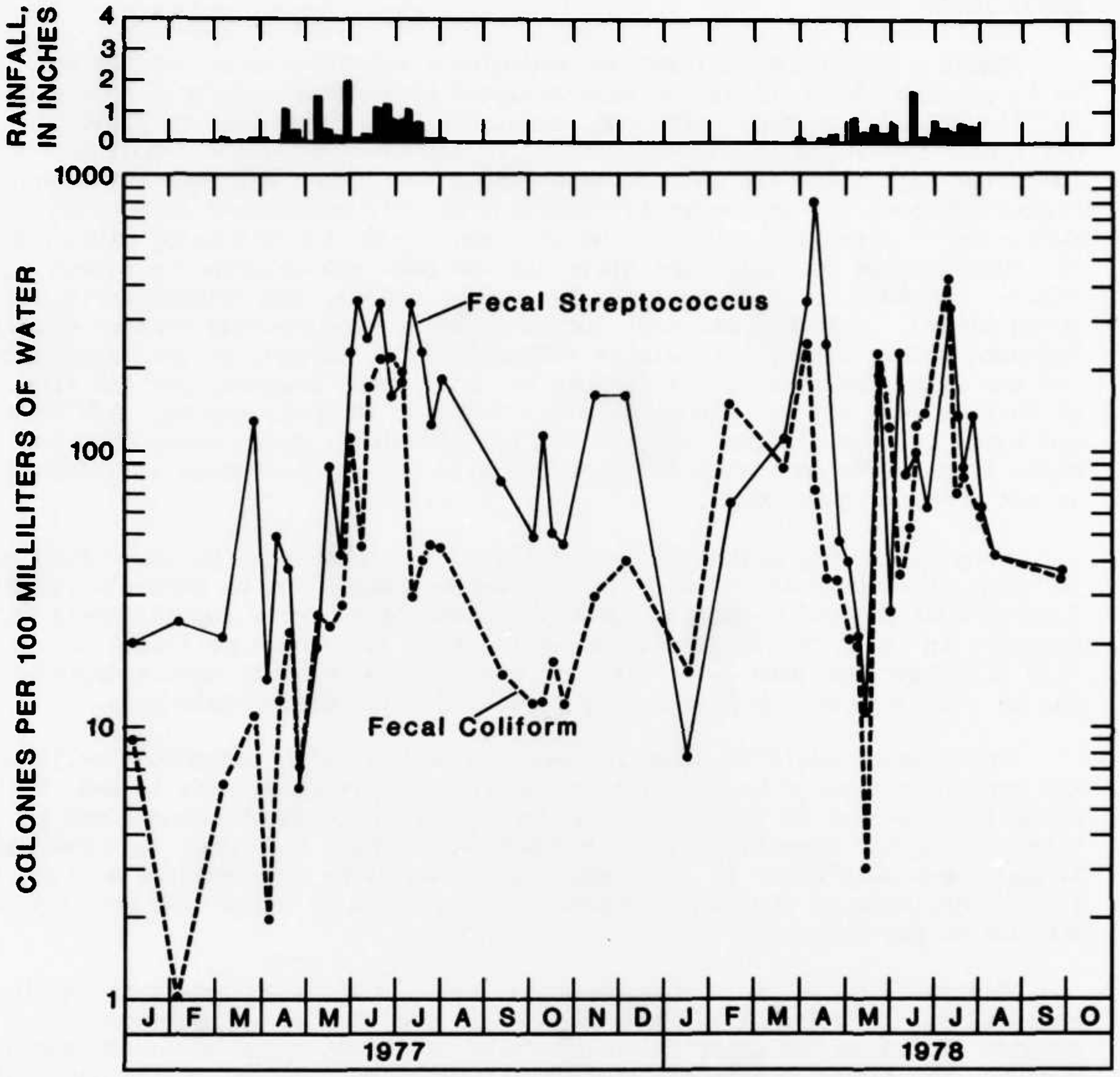

Figure 12.--Bacteria colony counts and total rainfall for seven days prior to sampling at Twin Valley

and ponds to the substrate in riffles. Changing flow patterns, currents, and scouring can introduce a wide variety of algal types to the river (Reid and Wood, 1976).

Table 3 lists the dominant and codominant genera greater than or equal to 15 percent of the total for each analyzed phytoplankton sample collected at Twin Valley. Phytoplankton concentrations ranged from 140 to 150,000 cells/mL. The inconsistency in genera present at consecutive samplings indicates that algae are introduced to the river from a variety of sources. Figure 13 shows the extensive fluctuations in cell counts and changes in dominance at Twin Valley during the 1977 water year for the major divisions of phytoplankton present. The divisions included are chlorophyta (green algae), chrysophyta (diatoms and yellow-brown algae), and cyanophyta (blue-green algae). Expected seasonal dominance is lacking because diatoms usually dominate waters during late winter (Wetzel, 1975), as seen in the table during the winter of 1975-76. This does not hold true, however, for the winters of 1976-77 and 1977-78. Apparent algal "blooms" in April and May 1977 were dominated by four different genera and two divisions, green algae and blue-green algae. The dominance of Scenedesmus in spring and summer 1976 (table 3) is not seen in other years.

Many of the phytoplankton genera listed in table 3 can be identified as tolerant of water polluted with organic wastes, according to Palmer's (1969) list of most pollution-tolerant genera. Seven of Palmer's top 10 genera were dominant in 49 of the 78 samples shown in table 3. Though pollution of the Wild Rice River at Twin Valley is not considered a problem, subtle degradation may be indicated by the presence of pollution-tolerant phytoplankton.

No relation could be found between the number of phytoplankton cells and the concentrations of the nutrient parameters sampled. Figures 14 and 15 exemplify the lack of relation of phytoplankton to total phosphorus and to total nitrogen, respectively. Relationships may have been more apparent had biomass been determined on the phytoplankton samples; however, the availability of nutrients at the sampling site does not seem to affect the presence or absence of phytoplankton.

Figure 16 shows the diversity index for phytoplankton genera in samples analyzed for 1976-78. This diversity index, computed by the Shannon-Weaver method, indicates the relative abundance of different types of phytoplankton genera. The higher the index, the more diverse and balanced is the population of phytoplankton. High diversity indicates a healthy environment, where conditions are suitable for many phytoplankton types. Low diversity indicates conditions where only more specialized phytoplankton types are able to survive or are dominant. On a seasonal basis, particularly in eutrophic temperate waters, diversity tends to increase in summer and decrease in winter (Wetzel, 1975).

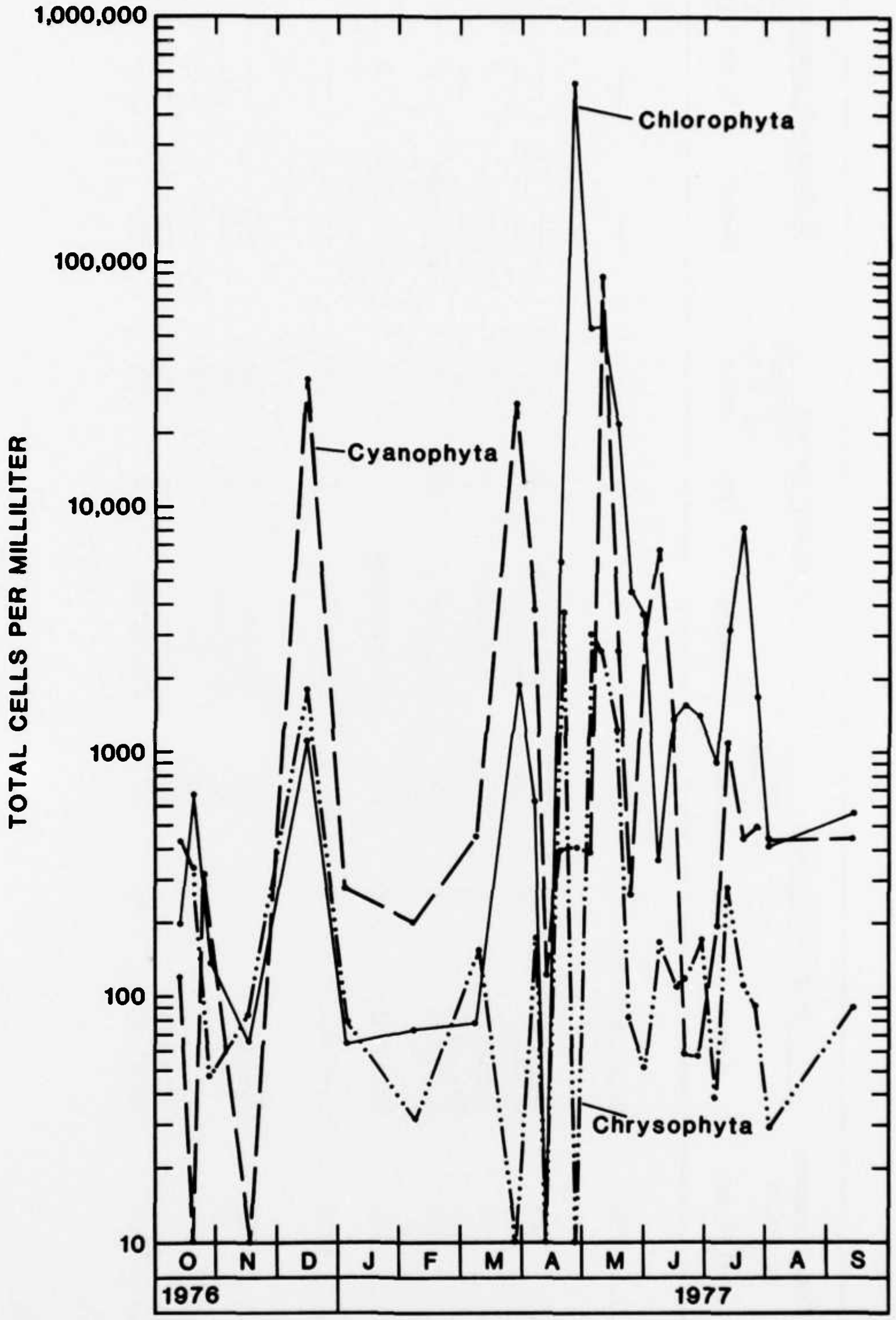

Figure 13.--Phytoplankton cell counts at Twin Valley, 1977 water year

Table 3.--Dominant genera of phytoplankton samples from Wild Rice River at Twin Valley, Minnesota
[Symbols used for types: D, diatoms; G, green algae; BG, blue-green algae; YB, yellow-brown algae; E, euglenoids]

Date of collection	Total number of cells per milliliter	Dominant genera			Codominant genera			Codominant genera		
		Genus	Type	Percent of total cells	Genus	Type	Percent of total cells	Genus	Type	Percent of total cells
1974										
12-16......	780	Coscinodiscus	D	33	—	—	—	—	—	—
1975										
1-28......	820	Phormidium	BG	39	Cyclotella	D	21	—	—	—
3-10......	400	Diatoma	D	34	Synedra	D	17	—	—	—
4-29......	750	Chlamydomonas	G	23	Nitzschia	D	23	Navicula	D	16
6-03......	570	Navicula	D	30	do	D	22	—	—	—
7-15......	670	Melosira	D	33	Navicula	D	25	Gomphonema	D	17
10-07......	540	Nitzschia	D	23	Scenedesmus	G	23	Cyclotella, Navicula	D D	19 19
11-18......	4000	Cyclotella	D	43	Nitzschia	D	24	—	—	—
1976										
1-05......	260	Synedra	D	48	Diatoma	D	31	—	—	—
2-02......	180	do	D	34	Navicula	D	22	—	—	—
3-15......	160	Nitzschia	D	20	do	D	18	—	—	—
4-06......	2000	Cocconeis	D	19	—	—	—	—	—	—
4-13......	3900	Lyngbya	BG	47	Nitzschia	D	25	—	—	—

4-21......	32000	Cyclotella	D	36	Nitzschia	D	20	Anacystis	BG	16
5-03......	3900	Anacystis	BG	24	—	—	—	—	—	—
5-12......	5300	Ankistrodesmus	G	20	Anacystis	BG	18	Scenedesmus	G	17
5-17......	14000	Anacystis	BG	48	Scenedesmus	G	24	Coelastrum	G	15
5-24......	1100	Scenedesmus	G	27	Chrysococcus	YB	17	Anacystis	BG	15
6-07......	2500	Scenedesmus	G	32	Cymbella	D	21	Micractinium	G	19
6-21......	1300	do	G	26	—	—	—	—	—	—
6-28......	990	do	G	37	Cocconeis	D	15	—	—	—
7-07......	1700	do	G	24	—	—	—	—	—	—
7-12......	1000	do	G	46	—	—	—	—	—	—
7-19......	1100	Scenedesmus	G	32	Nitzschia	D	17	Navicula	D	16
7-26......	1500	do	G	28	Oscillatoria	BG	24	—	—	—
8-02......	1400	Nitzschia	D	22	—	—	—	—	—	—
8-09......	410	Coelastrum	G	24	—	—	—	—	—	—
8-16......	1100	Scenedesmus	G	18	—	—	—	—	—	—
8-24......	2400	Scenedesmus	G	20	Navicula	D	16	—	—	—
8-30......	2000	Cyclotella	D	33	Anacystis	BG	19	Scenedesmus	G	15
9-20......	3600	Oscillatoria	BG	22	—	—	—	—	—	—
10-12......	830	Scenedesmus	G	23	—	—	—	—	—	—
10-19......	1000	do	G	39	Micractinium	G	17	—	—	—
10-28......	500	Oscillatoria	BG	63	—	—	—	—	—	—
11-15......	150	Nitzschia	D	28	Scenedesmus	G	21	—	—	—
12-13......	36000	Oscillatoria	BG	88	—	—	—	—	—	—
1977										
1-03......	430	Oscillatoria	BG	57	—	—	—	—	—	—
2-07......	310	do	BG	65	—	—	—	—	—	—
3-07......	690	do	BG	65	—	—	—	—	—	—
3-28......	29000	do	BG	92	—	—	—	—	—	—
4-05......	5400	do	BG	80	—	—	—	—	—	—

Table 3.--Dominant genera of phytoplankton samples from Wild Rice River at Twin Valley, Minnesota—Continued
[Symbols used for types: D, diatoms; G, green algae; BG, blue-green algae; YB, yellow-brown algae; E, euglenoids]

Date of collection	Total number of cells per milliliter	Dominant genera			Codominant genera			Codominant genera		
		Genus	Type	Percent of total cells	Genus	Type	Percent of total cells	Genus	Type	Percent of total cells
1977										
4-12......	140	Oscillatoria	BG	85	Trachelomonas	E	15	—	—	—
4-18......	16000	do	BG	25	Micractinium	G	16	—	—	—
4-26......	55000	Dictyosphaerium	G	90	—	—	—	—	—	—
5-03......	62000	Westella	G	55	—	—	—	—	—	—
5-09......	150000	Anacystis	BG	57	Actinastrum	G	15	—	—	—
5-17......	29000	Dictyosphaerium	G	38	—	—	—	—	—	—
5-24......	4800	Chlamydomonas	G	35	Crucigenia	G	28	Scenedesmus	G	22
5-31......	7500	Anacystis	BG	39	—	—	—	—	—	—
6-07......	7200	Anacystis	BG	92	—	—	—	—	—	—
6-14......	2900	Oscillatoria	BG	29	Scenedesmus	G	24	Anacystis	BG	16
6-20......	1700	Selenastrum	G	48	Scenedesmus	G	28	—	—	—
6-28......	1600	Ankistrodesmus	G	46	do	G	24	Cosmarium	G	17
7-05......	1300	Scenedesmus	G	40	Pediastrum	G	15	Lyngbya	BG	15
7-11......	4500	Anacystis	BG	25	Spermatozoopsis	G	19	Ankistrodesmus	G	15
7-19......	9300	Ankistrodesmus		33	—	—	—	—	—	—
7-26......	2500	Scenedesmus	G	30	Anacystis	BG	19	—	—	—
8-02......	970	Anacystis	BG	46	Dictyosphaerium	G	16	—	—	—
9-12......	1200	do	BG	37	Scenedesmus	G	36	—	—	—
10-03......	940	Scenedesmus	G	48	Anacystis	BG	21	—	—	—
10-11......	1900	do	G	46	Oscillatoria	BG	23	—	—	—

10-25......	2400	Scenedesmus	G	36	—	—	—	—	—	—
11-15......	3700	Dictyosphaerium	G	24	Crucigenia	G	19	Anacystis	BG	18
12-05......	1700	Nitzschia	D	17	—	—	—	—	—	—
1978										
1-17......	2100	Oscillatoria	BG	85	—	—	—	—	—	—
2-15......	540	do	BG	74	—	—	—	—	—	—
3-21......	230	Scenedesmus	G	30	Synedra	D	18	Navicula	D	15
4-04......	2000	Anabaena	BG	57	—	—	—	—	—	—
4-08......	590	Oscillatoria	BG	27	Ankistrodesmus	G	15	—	—	—
4-18......	2100	Hormogonales	BG	70	—	—	—	—	—	—
4-24......	570	Chlamydomonas	G	40	Nitzschia	D	21	—	—	—
5-02......	13000	Anacystis	BG	59	Kirchneriella	G	24	—	—	—
5-10......	11000	do	BG	38	Dictyosphaerium	G	27	—	—	—
5-16......	5000	Trachelomonas	E	49	Anacystis	BG	25	—	—	—
5-22......	790	Synedra	D	33	—	—	—	—	—	—
5-31......	270	Ankistrodesmus	G	23	Synedra	D	17	—	—	—
6-07......	1100	Anacystis	BG	24	Scenedesmus	G	20	Oscillatoria	BG	18
6-13......	690	Scenedesmus	G	39	Ochromonas	YB	23	—	—	—

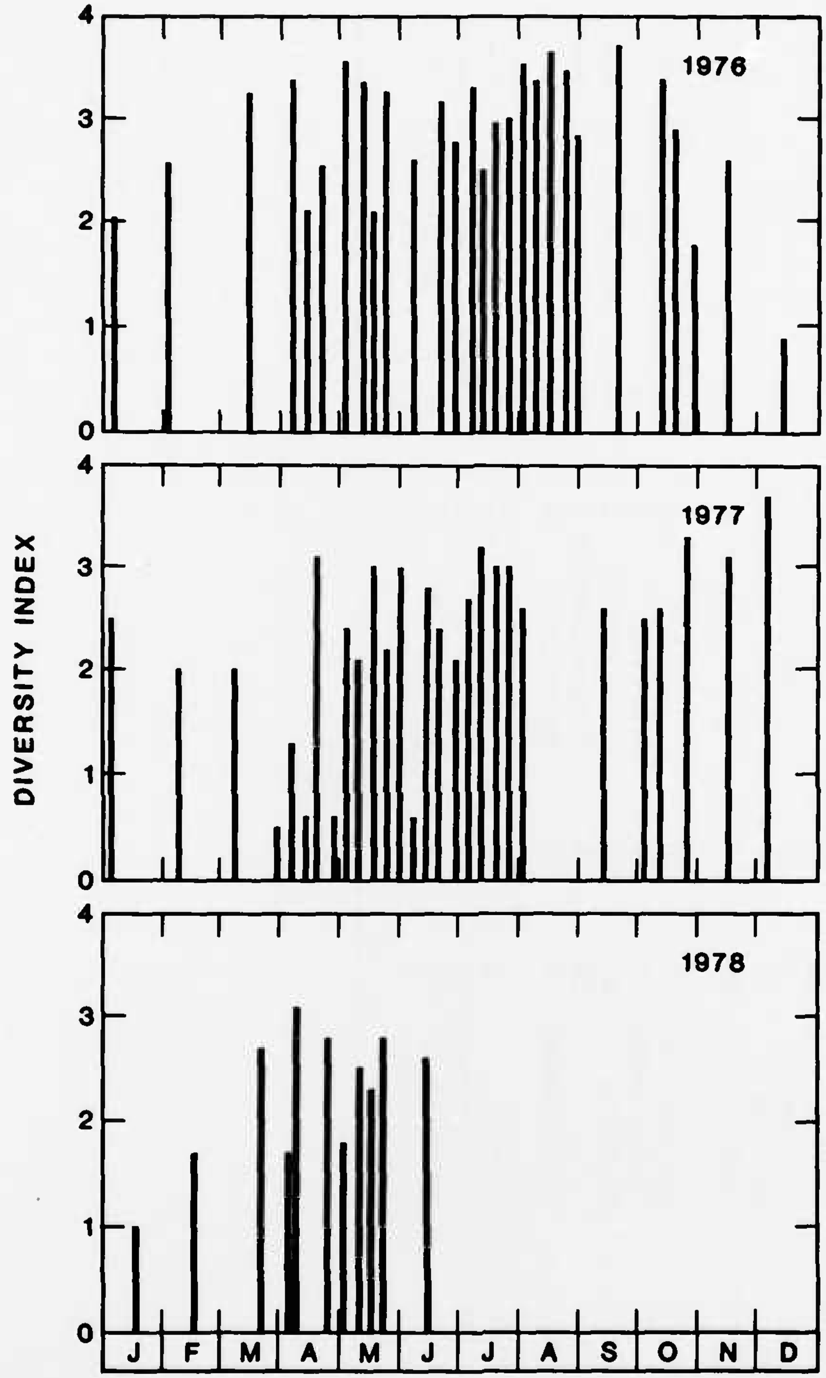

Figure 14.--Diversity indices of phytoplankton genera, 1976, 1977, and 1978

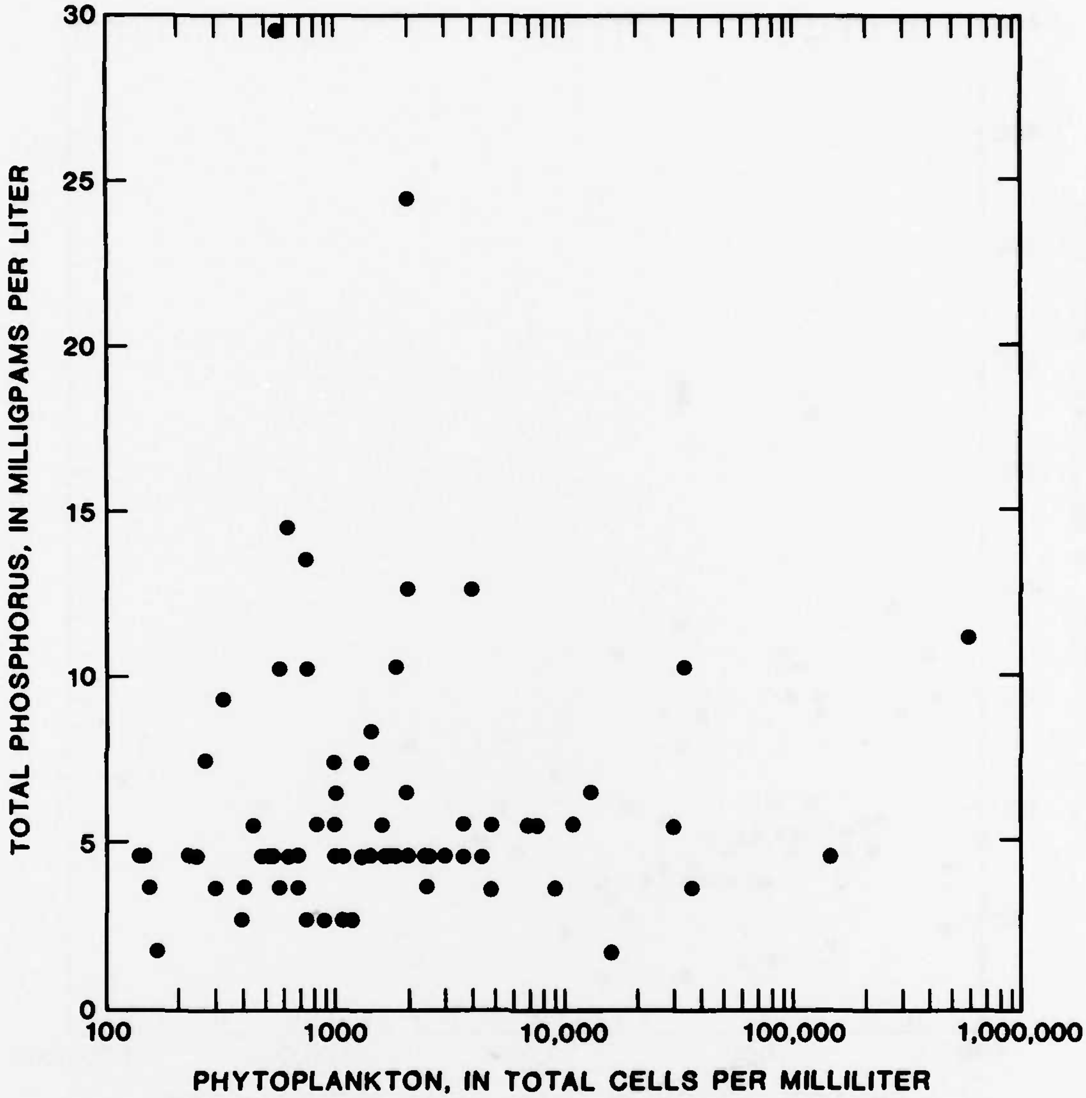

Figure 15.--Total phosphorus related to phytoplankton cell counts at Twin Valley

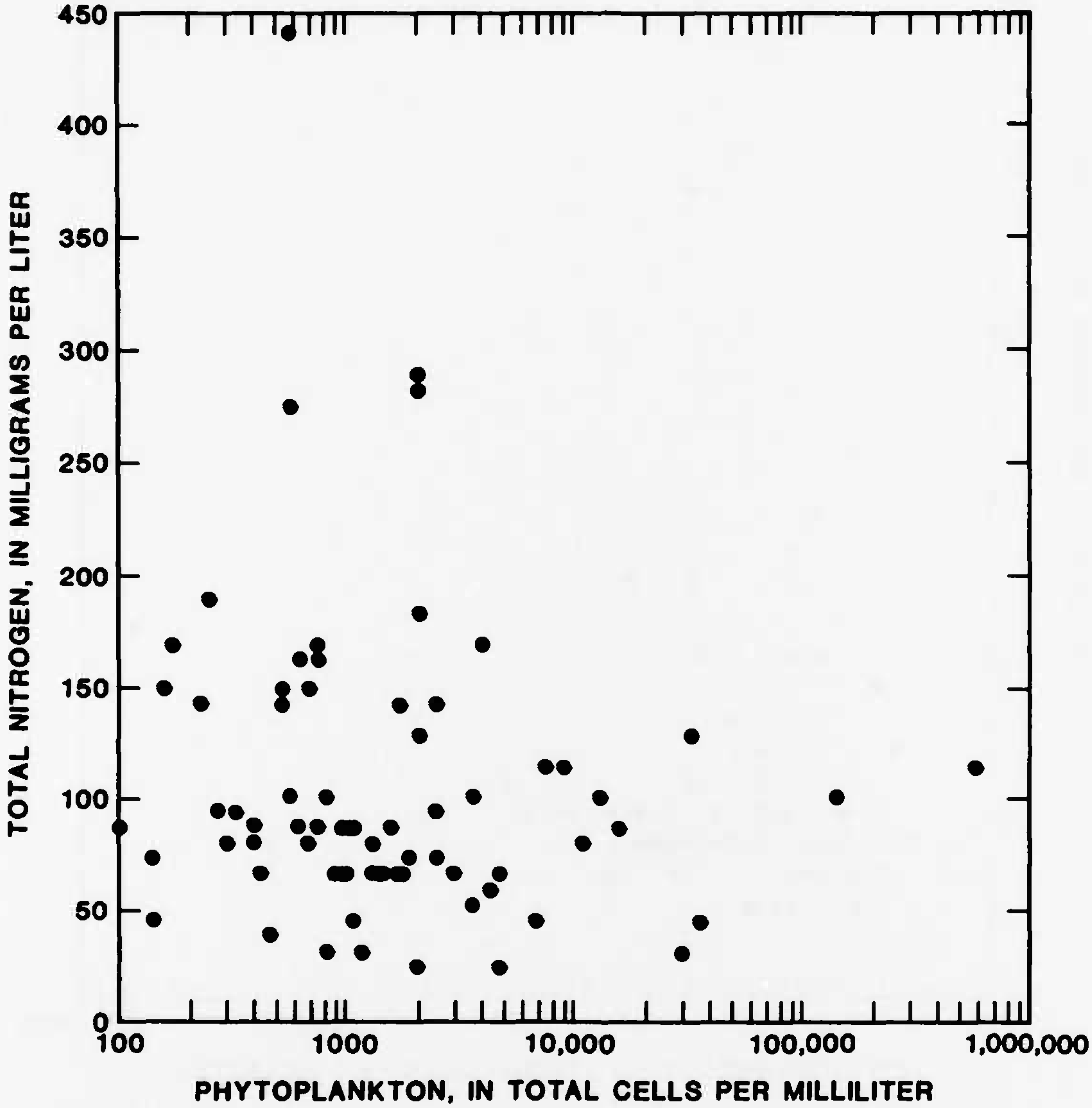

Figure 16.--Total nitrogen related to phytoplankton cell counts at Twin Valley

Figure 16 statistically shows a significantly lower diversity in winter, as expected, than during the rest of the year. A major exception to this observation is seen in December 1977. Diversity also seems to decrease over the time period graphed. Statistically, the diversity indices were significantly lower in 1978 than in 1977. This decrease may indicate changes in the river environment, where only more specialized phytoplankton genera are able to survive. Further monitoring of diversity may indicate a continuing degradation of the river or a recovery from temporarily adverse conditions.

The variety of phytoplankton species introduced to the sampling site from various habitats upstream make the data difficult to interpret. Evidence of relationships between phytoplankton and other constituents sampled might be observed if the phytoplankton originating in the stream could be isolated from those introduced to the stream. A better overview of the river quality and determination of sources of contamination could be realized.

Reid and Wood (1976) state that no distinctive phytoplankton community exists in streams, but that they are primarily introduced from upstream lakes or are dislodged periphyton called tychoplankton. Sampling of periphyton, through the use of an artificial substrate, would provide information about the presence of tychoplankton in Twin Valley samples. Sampling phytoplankton at several habitats upstream could help determine the sources of genera at Twin Valley. Periodic identification of phytoplankton at the species level could provide an indication of their origins. The information obtained might also be applied to adjacent phytoplankton samples, indicating specific phytoplankton types where only the genera were determined and providing more information from these analyses.

SUMMARY AND CONCLUSIONS

Intensive sampling of the Wild Rice River at Twin Valley and Hendrum has provided an abundance of data on the water-quality characteristics of the river. The data were collected before impoundment of the river at Twin Valley by the Corps of Engineers for recreation and flood control. This report summarizes selected water-quality data collected from 1975-78 and supplements data being analyzed by the Corps.

Results from analyses of the water samples show that the river had consistently high concentrations of essential plant nutrients and periodically had high concentrations of bacteria of fecal origin. Total nitrogen and phosphorus concentrations had mean values at the Twin Valley site of 0.90 and 0.06 mg/L and at the Hendrum site of 1.0 and 0.10 mg/L, respectively. Suspended-sediment concentrations and discharge can be used to predict total phosphorus and total nitrogen concentrations with regression coefficients of 0.69 and 0.66, respectively. The derived formulas have standard errors of 47 percent for total phosphorus and 32 percent for total nitrogen.

Inorganic constituents of the water were dominated by calcium and magnesium bicarbonate. Seasonal variations in dissolved-solids concentrations at Twin Valley were probably the result of varying proportions of ground-water discharge and surface runoff to the river.

Lead concentrations of 100 and 200 $\mu g/L$ exceeded the EPA drinking water standards of 50 $\mu g/L$. The high lead concentrations are probably the result of acidifying the samples with contaminated ampules.

PCB concentrations of 1 $\mu g/kg$ were found in one sample of bottom material. Concentrations of the herbicide 2,4-D were found as high as 0.04 $\mu g/L$, but these concentrations are well within EPA drinking-water standards.

Bacteria-colony counts generally were highest in the spring and summer, but showed no relationship to precipitation. Ratios of fecal coliform to fecal Streptococci bacteria indicated the presence of human fecal material in 4 out of 90 samples. Bacteria concentrations and other constituents sampled were not found to exceed EPA standards for public-water supplies.

Phytoplankton concentrations at Twin Valley showed extensive fluctuations in cell counts and dominance throughout the sampling period. Many of the 10 phytoplankton genera most tolerant of organic pollution were dominant in 49 out of 78 water samples, indicating possible degradation of the river. Diversity tended to be lower during the winter and decreased through the sampling period. Modifications of the phytoplankton sampling program might improve the interpretability of the data and improve correlation with nutrient constituents.

In general, the water quality of the river seems relatively stable at Twin Valley, though changes in land use may affect the quality in the future. At Hendrum, however, the river quality is not as good and may continue to decline. Agricultural practices and (or) municipal wastes may be major factors in the poorer quality at Hendrum. Additional sampling might be designed to determine the contribution of these sources to the quality of the river.

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