# Lake Pepin Phosphorus Study, 1994-1998:

## Effects of Phosphorus Loads on the Water Quality of the Upper Mississippi River, Lock and Dam No. 1 Through Lake Pepin

By

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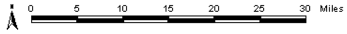
## ABSTRACT

In the summer of 1988, at the height of a prolonged drought in the Upper Midwest, low river flows and high nutrient levels led to severe nuisance algal blooms in Lake Pepin, a natural impoundment in Pool 4 of the Upper Mississippi River located between Red Wing and Wabasha, Minnesota. The algal blooms caused unsightly surface scum, obnoxious odors, low oxygen levels, and localized fish kills. The Metropolitan Wastewater Treatment Plant (Metro Plant), a 250-mgd advanced secondary facility, discharges to Pool 2 of the Mississippi River in St. Paul, Minnesota, and is the largest point source of phosphorus upstream of Lake Pepin. The Metro Plant is owned and operated by the Metropolitan Council, a regional planning agency that serves the seven-county metropolitan area of Minneapolis and St. Paul, Minnesota, and provides essential services to the region. In 1994–98 the Metropolitan Council and its partners conducted studies to determine the effects of phosphorus loads from the Metro Plant and other sources on the water quality of the Mississippi River, specifically algal blooms in Lake Pepin and Spring Lake, a backwater lake in lower Pool 2.

The Lake Pepin Phosphorus Study, 1994–98, had six major components. The Science Museum of Minnesota examined sediment cores from Lake Pepin to estimate historical changes in phosphorus and sediment loads, diatom communities, and phosphorus concentrations over the past




200 years. The University of Minnesota studied historical trends in agricultural practices and wastewater discharges since 1860 to relate human activities to changes in phosphorus and sediment loads. Metropolitan Council Environmental Services assessed a 21-year water-quality database to determine sources and patterns of phosphorus, chlorophyll, and sediment loads. The U.S. Army Engineer Waterways Experiment Station conducted limnological studies of Lake Pepin to analyze fluxes of nutrients and suspended solids and examine phytoplankton dynamics. The Minnesota-Wisconsin Boundary Area Commission coordinated a volunteer monitoring program of Lake Pepin and Spring Lake to evaluate water quality from the lake users' perspective. HydroQual, Inc., developed an advanced eutrophication model to study current water-quality conditions and project future conditions under various phosphorus management strategies.

The study yielded information on past, current, and future conditions in Lake Pepin and its watershed. Over the past 200 years, algal communities in Lake Pepin have changed from clear-water benthic and mesotrophic planktonic taxa to mostly planktonic assemblages characteristic of highly eutrophic conditions. The major factors contributing to this change are likely increased phosphorus concentrations and increased light attenuation. Phosphorus loads to Lake Pepin have increased by five- to seven-fold to 4000–5500 metric tons per year (mt/yr). Increased wastewater discharges and fertilizer applications are the likely causes. Phosphorus concentrations in the lake have increased approximately four-fold, from 50 to 200 micrograms per liter (µg/L). Sediment loads have increased ten-fold to nearly 900,000 mt/yr, most likely due to increases in the amount of watershed area planted in row crops. The greatest changes in phosphorus, algae, and sediment in Lake Pepin have occurred since 1940.

Currently, nutrients are abundant in the Mississippi River from Lock and Dam No. 1 through Lake Pepin and rarely decline to concentrations low enough to limit algal growth. When physical and hydrological conditions are favorable, severe nuisance algal blooms occur especially in lower Pool 2 and Lake Pepin. Blue-green algae dominate under these conditions, and maximum concentrations of viable chlorophyll *a* can exceed 200 µg/L. During periods of low river flows, point sources contribute the majority of phosphorus loads upstream of Lake Pepin (e.g., 89% in 1988). However, at high flows, nonpoint sources dominate phosphorus loads (e.g., 75% in 1993). At average flows, phosphorus loads are roughly split between point and nonpoint sources. The Metro Plant contributed approximately 20% of the total phosphorus and 40% of the soluble reactive phosphorus (SRP) loads during the past two decades. The Minnesota River Basin contributes the majority of phosphorus loads from nonpoint sources.

Only a small fraction of the phosphorus delivered to Pools 2–4 is retained; most is flushed through and transported downstream. During the period from 1985 to 1996, the overall phosphorus retention rate in Lake Pepin was approximately 10%. In all 12 years, Lake Pepin was a net sink of particulate phosphorus and a net source of SRP. Internal SRP loads represented approximately a tenth of the total SRP load to Lake Pepin during this 12-year period. This fraction climbed to a third in low flow years (1987–89) and two-thirds in low flow summers.

In a future low flow summer, water-quality conditions in Lake Pepin are projected to improve somewhat under various phosphorus reduction scenarios for point and nonpoint sources in the basin. In all scenarios, phosphorus concentrations in Lake Pepin would decrease dramatically but would remain high enough to support excessive algal growth. Even with phosphorus removal to 1.0 milligram per liter at all point sources in the basin and moderate phosphorus reductions from nonpoint sources, algal levels in Lake Pepin would remain excessive (i.e., viable chlorophyll *a* > 30 µg/L) over half of the summer. The main benefit of these phosphorus controls would be to reduce peak algal levels (i.e., viable chlorophyll *a* > 70 µg/L) during low flow periods. Biological phosphorus removal will be fully implemented at the Metro Plant by the end of 2003. However, long-term improvements in water quality will only be achieved through basin-wide reductions in phosphorus loads from both point and nonpoint sources.

**Aerial Photograph of Metro Plant**