MINNESOTA

Phosphorus in Surface Waters: The Minnesota River Case Study

By David J. Mulla

Phosphorus is often a limiting factor for growth of algae in surface waters. Enrichment of surface waters with P can stimulate excessive growth of algae. When large populations of algae die, they sink through the water and decay, thereby consuming large amounts of dissolved oxygen. When flow in the river is at low levels, there is not enough oxygen in the flowing water to replenish that lost by the biological oxygen demand. The result is eutrophication, which is often associated with the death of fish and other aquatic organisms.

> A closer look at phosphorus (P) concerns in the Minnesota River basin indicates recent gains in management of agricultural land, reducing losses from both point and non-point sources. Municipal sources of P are also significant. Wetter than average climate in recent years is also a factor.

The rivers in many states of the Corn Belt have summertime occurrences of eutrophication brought on by P enrichment. As a result, state and federal regulatory agencies are developing plans, programs, and policies to control P deposition into affected surface waters. One of the policy solutions being discussed involves placing a concentration limit of 1 part per million (ppm) on P levels in municipal wastewater effluent discharging to surface waters. Other policy solutions involve education to accelerate the adoption of P best management practices on agricultural lands, including soil testing, fertilizer placement and banding, and the use of conservation tillage to control erosion.

Much of the confusion about P and its role in surface water eutrophication arises from two issues. The first is that the amounts of P needed to stimulate algal growth are quite small compared to typical concentrations in the soil and those from point or non-point sources of P. In lakes, it may only take a concentration of 0.025 ppm to produce eutrophication, whereas levels for soil test P typically run about 1,000 times higher. The second is that it is often not clear whether the predominant source of P in surface waters is from point or non-point sources. Point sources include the effluent from wastewater treatment plants and industries. Non-point sources include sediment and/or runoff waters from farms, feedlots, and septic tanks.

The Minnesota River basin illustrates many of the issues that are typical in a discussion of P management for improved surface water quality. The Minnesota River is currently one of the 20 most endangered rivers in America due to pollution by sediment, P, and pathogens. This basin is located in the southern part of Minnesota (**Figure 1**), covers an area of about 10 million acres, consists of 12 major watersheds, and has land use patterns dominated by corn-soybean row-cropping. The Twin Cities metropolitan area, with its nearly 2 million residents,

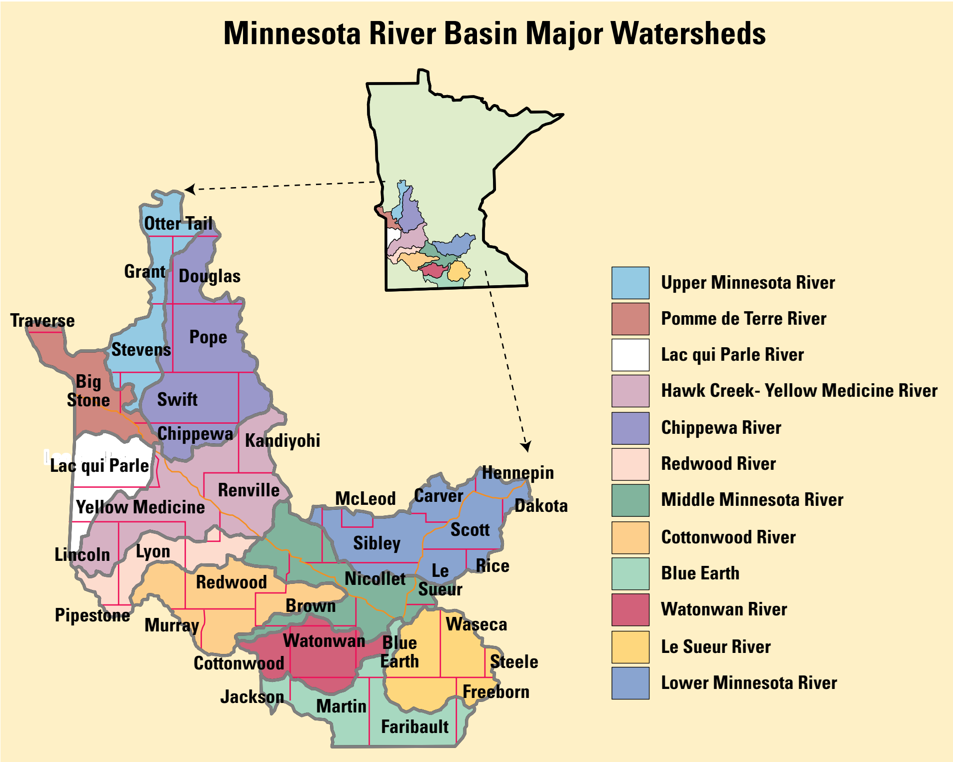

Figure 1. This map shows the 12 major watersheds and 37 counties located in the Minnesota River basin.

and the Mississippi River are at the mouth of the Minnesota River basin. Eutrophication and low levels of dissolved oxygen are common during summer low flows near the mouth of the Minnesota River. Downstream of the Twin Cities, the Mississippi River widens to form Lake Pepin, a prime recreational area for residents of Minnesota and Wisconsin and which also experiences severe eutrophication during summer low flows. A large proportion of the P which causes eutrophication in Lake Pepin originates in the Minnesota River basin.

Monitoring data collected during the period from 1968-1994 by the Minnesota Pollution Control Agency (MPCA), the U.S. Geological Survey (USGS), and the Metropolitan Council Environmental Services (MCES) show that near the mouth of the Minnesota River, dissolved oxygen concentrations violate federal water quality standards about 4 percent of the time, mostly during summer low flows. Eutrophication problems are even more serious farther downstream in Lake Pepin. The low levels of oxygen are indirectly caused by elevated levels of P, which are higher near the mouth of the Minnesota River than the basin-wide mean river concentration of 0.25 ppm about 75 percent of the time.

An analysis of P monitoring data by our group at the University of Minnesota shows that from 1968-1994, three of the 12 major watersheds generated two-thirds of all the P that flows to the mouth of the river. The major source of P is the Lower Minnesota watershed, one of the 12 major watersheds in the basin, which accounted

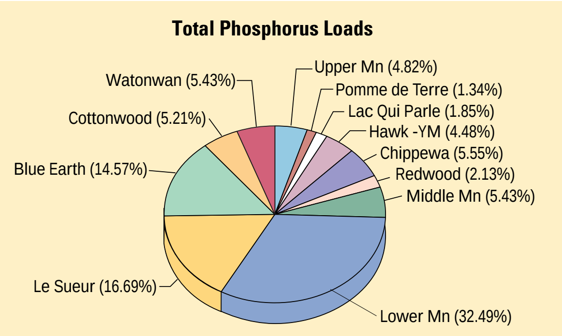

Figure 2. Comparison of P loadings generated within each of the 12 major watersheds in the Minnesota River basin.

for 33 percent of all the P discharged into the Minnesota River (**Figure 2**). Two wastewater treatment plants (at Blue Lake and Seneca) discharge treated sewage from hundreds of thousands of households directly into the Lower Minnesota watershed. During average river flow years, these treatment plants generated about one-third of all the P discharged into the Minnesota River from the Lower Minnesota watershed. In addition, the Lower Minnesota watershed contains a region of very steep cultivated slopes with high rates of erosion due to a relatively high mean annual precipitation. These two factors, namely; discharge of large quantities of P in wastewater effluent and erosion or runoff generated from steep agricultural fields account for the large amounts of P discharged into the Minnesota River from the Lower Minnesota watershed.

Two other watersheds account for nearly 32 percent of the P discharged into the Minnesota River; the Blue Earth and Le Sueur watersheds (**Figure 2**). They are dominated by agricultural land use and do not have significant P discharges from point sources. Much of the land in each of these two watersheds is prone to runoff and erosion due to steep slopes and heavy precipitation.

Other significant sources of P to the Minnesota River include discharges from septic tank systems and runoff from manure in fields and feedlots. It is estimated that there are about 60,000 septic systems in the Minnesota River basin and that about 400 million tons of manure are annually applied to agricultural lands.

When all sources of P are taken into account, it is estimated that for the period from 1968-1994, approximately 60 percent of the P entering the Minnesota River originated from non-point sources, including agricultural lands receiving P fertilizer and manure. The remaining 40 percent of the P was generated from point sources, primarily municipal wastewater treatment plants. These figures assume an average flow in the river.

Since eutrophication near the mouth of the Minnesota River generally does not occur during medium to high flow conditions, it makes sense to evaluate the relative contributions to P in the river from point versus non-point sources during low flow conditions. During low flow conditions, greater than 90 percent of the P near the mouth of the river originated from point sources. Thus, during low flow conditions that lead to eutrophication, it is very important to control P emissions from point sources, especially wastewater treatment plants. This is exactly what has happened recently at the two largest wastewater treatment plants on the river. The Blue Lake and Seneca wastewater treatment facilities near the mouth of the river have adopted a biological treatment method for removing P from the wastewater effluent stream. This new approach has been a great success, and P concentrations in wastewater effluent have been reduced from about 3 ppm to slightly less than 1 ppm.

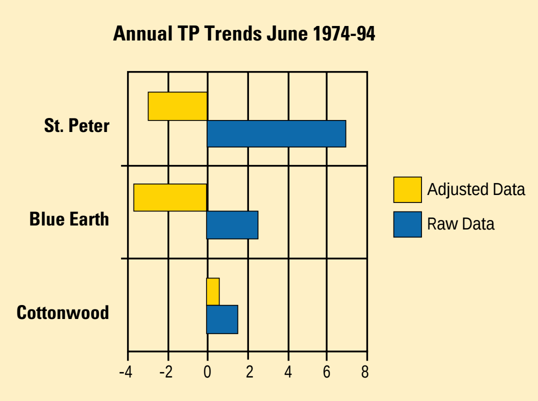

Figure 3. Trends in total phosphorus (TP) loadings (tons/year) for selected locations in the Minnesota River basin for the month of June from 1974-1994. The gold bars represent annual trends after adjusting for climatic changes.The blue bars represent annual trends when climatic effects are included in the analysis.

Occasionally, there are significant discharges from wastewater treatment plants during storm and flood events. For instance, high flows in the Lower Minnesota watershed during the flood of 1997 caused a pipe to break which delivers raw sewage from the city of St. Peter to its wastewater treatment plant. About one million gallons of raw sewage was directly discharged into the Minnesota River each day for several weeks until the pipe was repaired. As a result of this disaster, the city has decided to relocate its wastewater treatment plant to a less vulnerable area.

It is also important to control P losses from agricultural lands during medium and high flows because sediment bound P transported downstream during medium and high flows can be deposited in sensitive areas, to be released during low flow conditions. Farmers in the Minnesota River basin have employed a wide range of activities for improved P management. These include the adoption of conservation tillage, which reduces erosion and losses of adsorbed P, soil testing, and P credits for manured lands. As a result of these improved management practices, there has been a significant reduction in the P loads generated from agricultural lands in the Minnesota River basin during the month of June over the last 20 years. After compensating for the effects of wetter precipitation patterns, there has been an annual reduction of almost 4 percent in P loads from agricultural lands in the Blue Earth watershed (**Figure 3**). Over a period of 20 years, this translates to a reduction of about 53 percent in P loads from agricultural lands during June.

The analysis of P issues for the Minnesota River basin is typical of those in many regions of the north central Corn Belt. There are significant municipal sources of P, and these sources dominate water quality impacts during low flow periods in the river. There are also significant agricultural sources of P, which dominate water quality impacts during medium and high flow periods. In the Minnesota River basin, significant progress has occurred in managing P emissions to surface water from both point and non-point sources. Some of the gains in P management on agricultural lands have been offset, however, by an increasingly wetter climate in recent years. This has caused greater than average rates of erosion, runoff, and delivery of P to surface waters from agricultural lands. The full extent of benefits from improved farm management of P will only be realized if and when climate returns to a more benign pattern. BC

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