

# 1.0 Introduction

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## 1.1 Background

Eutrophication of surface waters is a condition in which excess nutrients cause excessive growth of algae and other aquatic plants. Phosphorus is the nutrient primarily responsible for the eutrophication of Minnesota's surface waters. Too much phosphorus causes excessive growths of nuisance algae (blooms) and reduced water transparency, making waters unsuitable for swimming or other recreational activities. When there are excessive amounts of algae in surface waters and those algae die, the decay of the algae may consume dissolved oxygen in the water and stress the biological community. This may cause fish kills. Additionally, severe algal blooms may directly poison animals that ingest the algae, or cause allergic reactions in people who swim in the polluted water.

Phosphorus in lakes and streams comes from both point and nonpoint sources. Point sources are typically industrial and publicly-owned wastewater treatment plants (POTWs). Point sources usually have distinct pipe discharges to surface water and are discharged from wastewater treatment plants. Nonpoint sources of phosphorus do not generally have distinct discharge points and are not typically regulated under State Water Pollution Permit programs.

The amounts of phosphorus contributed to Minnesota surface waters by point and nonpoint sources are known to vary, both geographically and temporally, in response to annual variations in weather and climate, primarily. Variations in rainfall and watershed runoff alter both the amounts of runoff-borne non-point source phosphorus reaching surface waters and the waters' dilution capacities. Generally speaking, nonpoint sources of phosphorus comprise a much larger fraction of the aggregate total phosphorus load to Minnesota surface waters during relatively wet periods, while point sources become more important during dry conditions, compared to wet conditions. Previous work by the MPCA, completed as part of their *Minnesota River Basin Plan*, estimated that nonpoint sources of phosphorus loading monitored in the basin at Jordan, MN (comprising approximately 19 percent of the area of the state), predominate under high and average river flow conditions. Point source phosphorus loads dominated the basin's phosphorus budget under low flow conditions (Table 1-1), the MPCA further estimated, based on analyses of data collected at Jordan, MN near the river mouth.

**Table 1-1 Minnesota River Point and Nonpoint Source Load Contributions at Various Flow Duration Intervals**

<b>Minnesota River Flow</b>	<b>Percentage of Duration Within Each Flow Interval</b>	<b>Nonpoint Source and Others Percent Contribution to Total Load</b>	<b>Point Source Percent Contribution to Total Load</b>
High (>7,100 cfs)	18.5	90	10
Average (2,750 cfs)	70.7 *	74	26
Low (<1,275 cfs)	10.8	28	72

\*Percent of time flow was between 7,100 and 1,275 cfs

Results of this study, using a variety of estimation techniques to calculate phosphorus loading to Minnesota surface waters, confirm these load distribution patterns for the Minnesota River basin and the nine other major river basins either wholly or partially within the state. The phosphorus load estimates reported here are aggregate totals contributed to all waters of the state, including lakes, ponds, rivers, streams and wetlands, and ditches.

The amount of phosphorus contributed to surface waters is not the only factor that determines adverse impact of the pollutant. The form of phosphorus and its ease of being utilized by algae and other plants are important. Excessive algal production is dependent on the availability of usable (bioavailable) phosphorus. Phosphorus from a point source may be more bioavailable and exert a larger impact on surface water quality than a similar amount of nonpoint source phosphorus that enters the same surface water. Phosphorus from point sources is largely in a chemical form readily useable by plants (ca. 97 percent bioavailable), while phosphorus from nonpoint sources may be only 30 to 60 percent bioavailable to plants. Other critical factors affecting the water quality impacts are the type of water body the phosphorus enters (lake, river, reservoir) and season of the year.

## **1.2 Legislative Mandate to Conduct this Study**

This watershed-based study of phosphorus contributions to Minnesota surface waters was conducted to inventory the following:

### **1. Sources and amounts of phosphorus entering three different sizes and categories of Publicly-Owned Treatment Works (POTWs; i.e., Wastewater Treatment Plants).**

#### **Sizes: (average daily flow rate)**

- Less than 0.2 million gallons per day (mgd)
- 0.2 to 1.0 mgd
- Greater than 1.0 mgd

**Categories: (flow contributors)**

- Primarily domestic
- Domestic with some commercial/industrial
- Predominately commercial/industrial

**Sources: (individual and/or categorical)**

- Automatic dishwasher detergents
- Other household cleaners or household non-ingested sources
- Commercial/industrial, including:
  - . Process wastewater
  - . Noncontact cooling water
  - . Other additives
- Water supply, including water treatment chemicals
- Human waste products
- Groundwater intrusion to sanitary sewers

Information developed in this portion of the phosphorus inventory is intended to assist the MPCA in complying with MN Laws 2003, Chap. 128 Art. 1, Sec. 122:

*The state goal for reducing phosphorus for non-ingested sources entering municipal wastewater treatment systems is at least 50 percent reduction based on the timeline for reduction developed by the commissioner under section 166, and a reasonable estimate of the amount of phosphorus from non-ingested sources entering municipal wastewater treatment system in calendar year 2003.*

**2. Sources and amounts of phosphorus entering Minnesota surface waters for each of the ten major basins and for the entire state of Minnesota from point- and nonpoint-sources during low (dry), average, and high (wet) flow conditions; and the effect of various phosphorus source reduction options on water quality.**

Information developed in this portion of the phosphorus inventory is intended to assist the MPCA in complying with MN Laws 2003, Chap. 128, Art. 1, Sec. 16:

*The commissioner of the pollution control agency must study the concept of lowering phosphorus in the wastewater stream and the effect on water quality in the receiving waters and how to best assist local units of government in removing phosphorus at public wastewater treatment plants, including the establishment of a timeline for meeting the goal in Minnesota Statutes, section 115.42 .*

### **1.3 Organization of this Report**

To facilitate the reading of this report, results have been organized around identification of the sources and amounts of phosphorus contributed both to POTWs and to surface waters of the state. Sources and amounts contributed to surface waters includes both point and nonpoint source contributions. Wastewater treatment plants (Publicly-Owned, Private and Industrial) are included as point source contributors, in this context. The report discusses phosphorus contributions to surface waters of the state, both in terms of source category and by major basin, for low, average and high flow conditions. The hydrology of each basin under low, average and high flow conditions is discussed in more detail in Appendix A. Detailed discussions about each source contribution category are included in Appendices B through J. The report further assesses the importance of each phosphorus source contributor in regards to the bioavailability of its contribution (described in detail in Appendix K). Finally, this report concludes with a brief assessment of effluent total phosphorus reduction efforts by wastewater treatment plants, recommendations for lowering nonpoint sources of phosphorus and reducing load calculation uncertainty as part of future efforts.

### **1.4 Frame of Reference for Quantifying Phosphorus Source Contributions to Surface Waters**

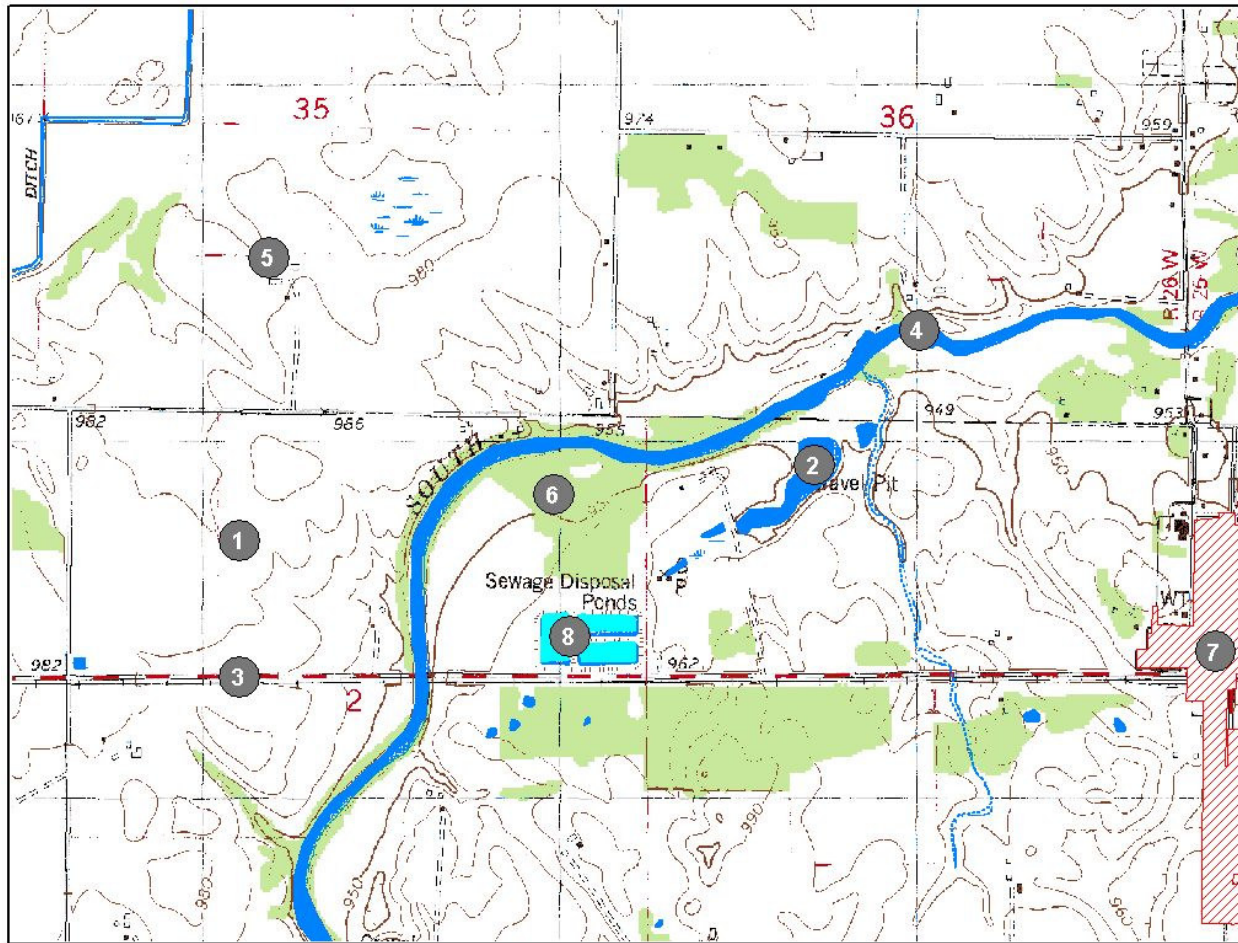
Estimating the phosphorus source contributions to Minnesota surface waters for each of the major basins requires the following information to establish a “frame of reference”, or a basis for comparison by source category and by basin:

- A clear definition of surface waters and information about the locations of surface waters throughout Minnesota
- Knowledge about the amount of phosphorus produced and mode of transport for each point and nonpoint source category

Figure 1-1 illustrates an example of where each of the following phosphorus source categories (numbered to coincide with the figure) are typically located in relation to the various types of surface waters considered in this analysis:

1. Cropland, pasture and feedlot runoff
2. Atmospheric deposition
3. Deicing agents
4. Streambank erosion
5. Individual sewage treatment systems (ISTS)/unsewered communities
6. Non-agricultural rural runoff
7. Urban runoff
8. Point sources

**Figure 1-1 Schematic for Phosphorus Source Contributions to Surface Waters**

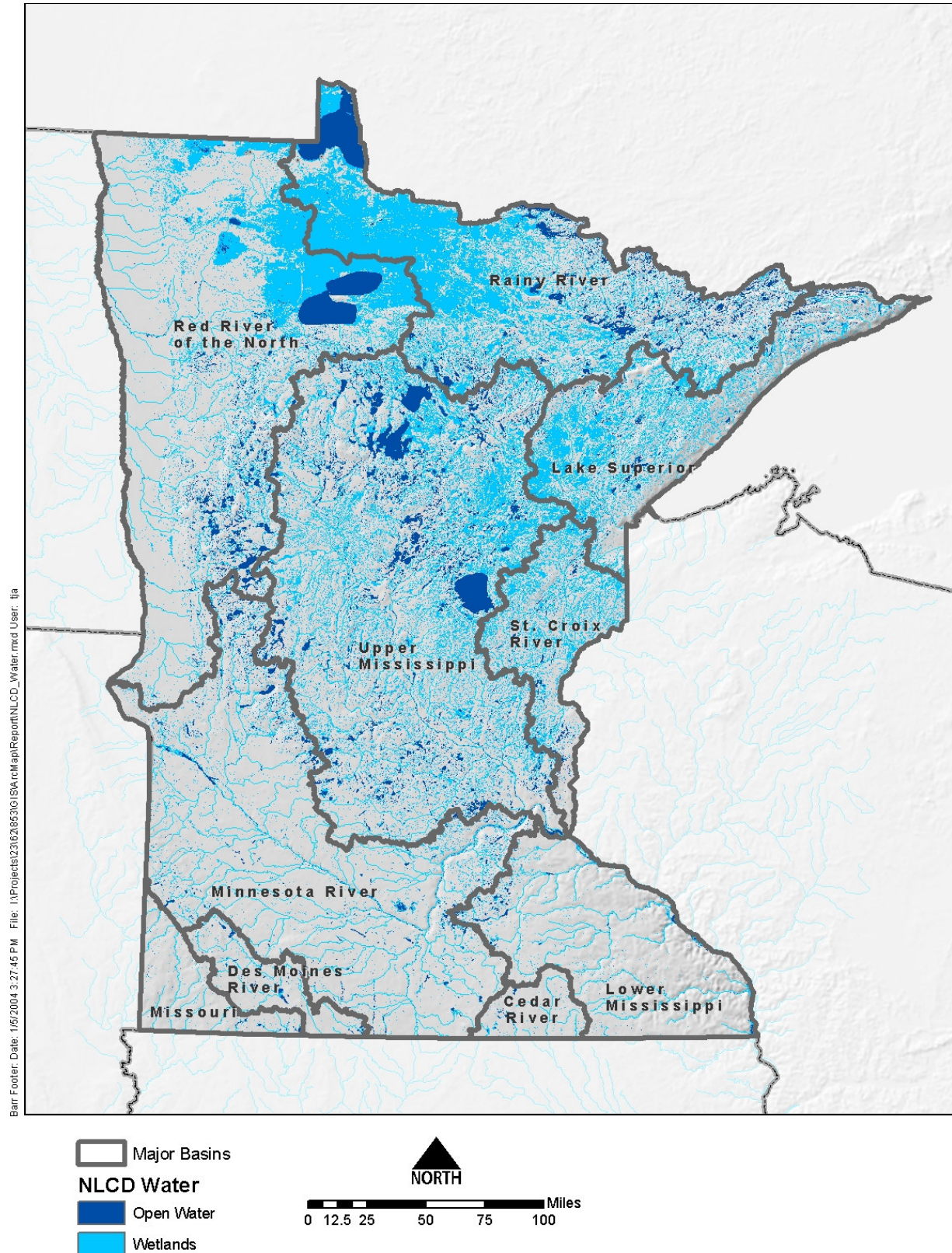


The analysis completed for this assessment consists of estimating the total amounts of phosphorus entering all of the various types of surface waters from each of the source categories within each major basin, as well as on a statewide basis.

### **1.4.1 Surface Waters Defined**

For purposes of this analysis, all of the surface waters in Minnesota were mapped using ESRI ArcGIS software and were defined by using all of the various types of water bodies contained in the Minnesota Department of Natural Resources 24K Stream Layer (all records, including ditches and intermittent streams) and the USGS National Land Cover Database [NLCD] (1992). All land cover types identified as wetlands or lakes in the NLCD database were used as surface waters. As a result, all of the water surface areas shown (in dark blue) on Figure 1-1, including ditches, wetlands, lakes, rivers and intermittent streams, would be considered surface waters for the analysis discussed in this report. Figure 1-2 shows the areas of all of Minnesota's surface waters, within each of the ten major basins.

Figure 1-2 Major basins with surface waters



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## 1.4.2 Context for Quantifying Phosphorus Source Contributions

As previously discussed, this assessment is intended to estimate the annual phosphorus loading (total and bioavailable), entering all of the various types of surface waters from each of the source categories under low, average and high flow conditions. The general nature and scale of this analysis allows for summarizing the estimated loadings for each major basin, and on a statewide basis. The characteristics of smaller watershed units (smaller than the major basin scale), or subwatersheds, were not utilized to estimate phosphorus loadings from the source categories. Since each of the various subwatersheds typically drain to wetlands, lakes, ditches or streams that each have their own unique processes for transformation or phosphorus uptake, no further breakdown of phosphorus inflow or outflow loadings by subwatershed or surface water type is possible with the scope of this analysis. As a result, the phosphorus loadings discussed in this report represent the total amount of phosphorus entering all of the combined surface water areas that are present within each major basin under each flow condition. For example, if urban runoff from the source area (#7) shown in Figure 1-1 is estimated to contribute 10 kg of phosphorus during average flow conditions, this analysis does not attempt to distinguish between how much of the 10 kg is going to the intermittent stream or to the river, nor does this analysis attempt to estimate how much this phosphorus load would be delivered to the mouth of the major basin. It should also be noted that the general nature of the results from this analysis means that minor sources of phosphorus, at the basin scale, may actually contribute the majority of phosphorus to specific surface water bodies, at a localized scale. For example, point sources typically represent contribute little or no phosphorus to Twin City Metropolitan and most outstate lakes, but can represent a significant portion of the total phosphorus load to rivers under low flow conditions. This explains the need to complete individual assessments of specific watersheds to evaluate specific loading conditions.

In addition, the phosphorus loadings estimated for this assessment are only intended to quantify the phosphorus source contributions originating in Minnesota for Minnesota surface waters. For example, no attempt has been made to estimate the phosphorus loadings to the St. Croix River basin, originating from Wisconsin, or the loadings to the Red River basin from North Dakota. While the context for this analysis does not allow for assessments to be made about the observed water quality at the mouth of each major river basin, it does allow for direct “apples to apples” comparison of the amounts of phosphorus originating from various source categories under various flow conditions. This analysis also facilitates comparison between basin, as well as statewide, so that the magnitude and proportional contribution of each source category can be compared throughout the state.