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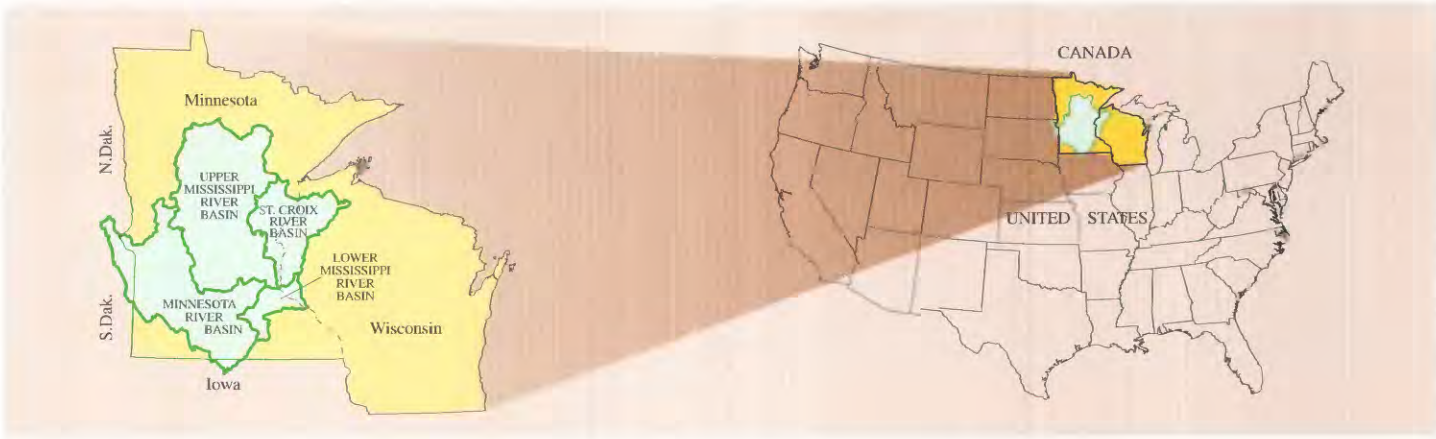

Nutrient Sources Within the Upper Mississippi River Basin, Minnesota and Wisconsin, 1991-93

The amount of nutrients contained in fertilizer, livestock manure, municipal wastewater, atmospheric deposition, and legume residues were quantified in each of the major drainage basins within the Upper Mississippi River Basin study unit (fig. 1) as part of the U.S. Geological Survey's National Water-Quality Assessment Program. These sources of nutrients may potentially affect surface- and ground-water quality, so knowledge about the relative importance of each source may assist in the management of surface and ground waters within the study unit. The relative importance of each nutrient source was expected to vary among each of the four drainage basins due to differences in land use across the study unit.

Fertilizer and livestock manure were potentially large sources of nitrogen and phosphorus in each of the four drainage basins. However, nitrogen in legume residues was a more important source in the Upper Mississippi, St. Croix, and Lower Mississippi River Basins because hay comprised a larger part of the total acreage of crops grown in these basins. Atmospheric deposition comprised a larger percentage of the nitrogen sources in the St. Croix River Basin compared to the other three drainage basins probably because amounts of the other sources are relatively low. Nitrogen and phosphorus yields in streams were greatest in the Lower Mississippi River Basin and the Minnesota River Basin, where amounts of nonpoint sources of these constituents also were the greatest per square mile.

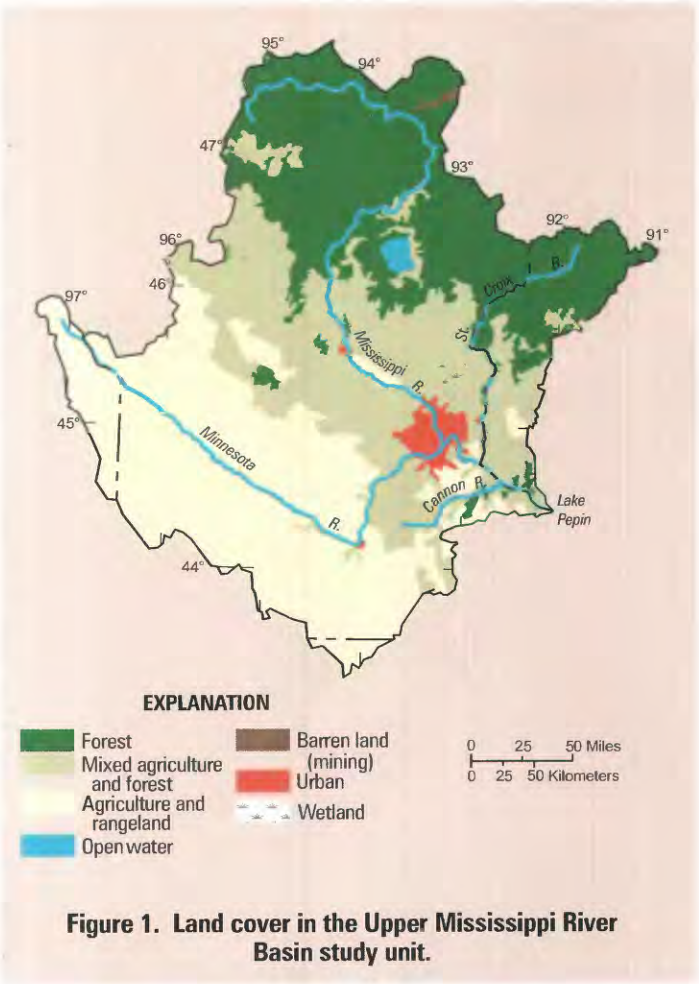

Figure 1. Land cover in the Upper Mississippi River Basin study unit.

Introduction

In 1994, the U.S. Geological Survey began studies in the Upper Mississippi River Basin as part of the National Water-Quality Assessment Program. The purpose of the program is to

assess the quality of a large, representative part of the Nation's water resources.

The Upper Mississippi River Basin study unit (fig. 1) encompasses an area of about 47,000 square miles and includes the drainage area of the Mississippi River from the source to the outlet of Lake Pepin, a natural lake on the river, and its two principal tributaries--the Minnesota and St. Croix Rivers. The seven-county Twin Cities (Minneapolis and St. Paul) metropolitan area (TCMA) is located in the southeastern part of the study unit.

There are four major drainage basins in the study unit--Upper Mississippi, Lower Mississippi, St. Croix, and Minnesota River Basins. In this paper, the Upper Mississippi River Basin (UMRB) is defined as the entire drainage of the Mississippi River upstream of Anoka, Minnesota, and the Lower Mississippi River Basin (LMRB) is defined as the drainage of the Mississippi River from Anoka, Minnesota to the outlet of Lake Pepin (excluding the drainage areas of the Minnesota and St. Croix Rivers).

Land use varies among these four drainage basins. The Minnesota River Basin (MRB) consists primarily of agricultural land. Soybeans and corn are the principal crops grown, and pigs are the dominant type of livestock raised in this basin. Data obtained from the state agricultural censuses (Iowa State University, 1994; Minnesota Agricultural Statistics Service, 1995; North Dakota Agricultural Statistics Service, 1994; South Dakota Agricultural Statistics Service, 1994) showed the MRB produced approximately 75 percent of the soybeans and 65 percent of the corn and pigs raised in the study unit in 1993.

Land use in the UMRB is primarily a mixture of agriculture and forest. The major crops grown in this drainage basin are hay and corn. The predominant livestock raised in the UMRB are dairy cows, beef cows, and pigs. Data obtained from the state agricultural censuses (Minnesota Agricultural Statistics Service, 1995; Wisconsin Agricultural Statistics Service, 1994) showed over half of the hay grown in the study unit in 1993 was from the UMRB. About half of the milk cows, 45 percent of the beef cows, and about 20 percent of the pigs raised in the study unit in 1993 also were from the UMRB.

The LMRB consists primarily of agricultural land and also includes the TCMA. The major crops grown in this drainage basin are corn, soybeans, and hay. The major livestock raised are pigs and cattle. Data obtained from the state agricultural censuses (Minnesota Agricultural Statistics Service, 1995; Wisconsin Agricultural Statistics Service, 1994) showed that about 10 percent of the corn, soybeans, hay, pigs, beef cows, and milk cows raised in the study unit in 1993 were from the LMRB.

The St. Croix River Basin (SCRB) consists predominantly of forested and agricultural land. The major crops produced in this drainage basin are hay and corn. The major livestock raised in the SCRB are cattle. Data obtained from the state agricultural censuses (Minnesota Agricultural Statistics Service, 1995; Wisconsin Agricultural Statistics Service, 1994) showed about 20 percent of the hay and less than 5 percent of the corn produced in the study unit in 1993 was from the SCRB. In 1993, about 15 percent of the milk cows and beef cows in the study unit also were raised in the SCRB.

Concerns About Nutrients

Nutrients are essential for plant and animal growth. However, elevated concentrations of nutrients in slower-moving reaches of streams and in lakes can result in eutrophication. Eutrophication is the excessive growth of aquatic plants and algae. This excessive growth can result in the water smelling and tasting foul, which may ultimately increase water treatment costs if the water is used for drinking. In addition, when these plants and algae die dissolved oxygen may be depleted in the water, which can ultimately result in fish kills. Excessive applications of nutrients to the land surface also could result in the leaching of more soluble forms, such as nitrate and ammonium, to ground water. Nitrate concentrations greater than 10 milligrams per liter (mg/L) in drinking water can cause a potentially-fatal condition called methemoglobinemia (blue-baby syndrome) in humans. Un-ionized ammonia in water can be toxic to fish and other aquatic life.

An assessment of streams by the Minnesota Pollution Control Agency (1992) indicated nutrient compounds were a frequent cause of river reaches in the study unit not supporting their designated uses, which includes swimming, boating, and the protection and fish and wildlife. Total phosphorus concentrations in the Mississippi River and some of its tributaries in the study unit have exceeded the recommended criterion of 0.1 mg/L as phosphorus set by the U.S. Environmental Protection Agency (1986) to control eutrophication (Kroening and Andrews, 1997).

Nitrate concentrations in streams draining the southern and southeastern part of the study unit have, at times (primarily during the spring and summer), exceeded the Maximum Contaminant Level (MCL) of 10 mg/L for drinking water set by the U.S. Environmental Protection Agency (1986) for the protection of human health (Payne, 1994; Kroening and Andrews, 1997). Nitrate is listed by the Minnesota Pollution Control Agency (1992) as a frequent contaminant in ground water. Within the study unit, concentrations in ground water have at times exceeded the MCL of 10 mg/L as nitrogen (Kroening and Andrews, 1997).

Nutrient Sources Within the Upper Mississippi River Basin

Fertilizer, livestock manure, municipal wastewater, atmospheric deposition, and legume residues are sources of nitrogen and/or phosphorus which may affect surface- and ground-water quality. Nutrients may reach surface waters from these sources by direct discharge, runoff, or atmospheric deposition. Nutrients may reach ground water from these sources by leaching through the soil. It is recognized that some of the nutrients contained in livestock manure may have orginated as fertilizer, atmospheric deposition, or as part of legumes. However, the amount of nutrients contained in livestock manure was quantified in this analysis because manure may affect surface- and ground-water quality. Legume residues are not traditionally regarded as a potential source of nitrogen to surface or ground water, but part of the nitrogen contained in legumes is fixed from the atmosphere and can become available to crops in subsequent years as a result of mineralization to more plant-available forms (University of Wisconsin-Extension, 1994). The amounts of nitrogen and phosphorus contained in each of the above mentioned sources were calculated using data from 1991, 1992, or 1993 for the MRB, SCRB, UMRB, and the study unit as described by Kroening and

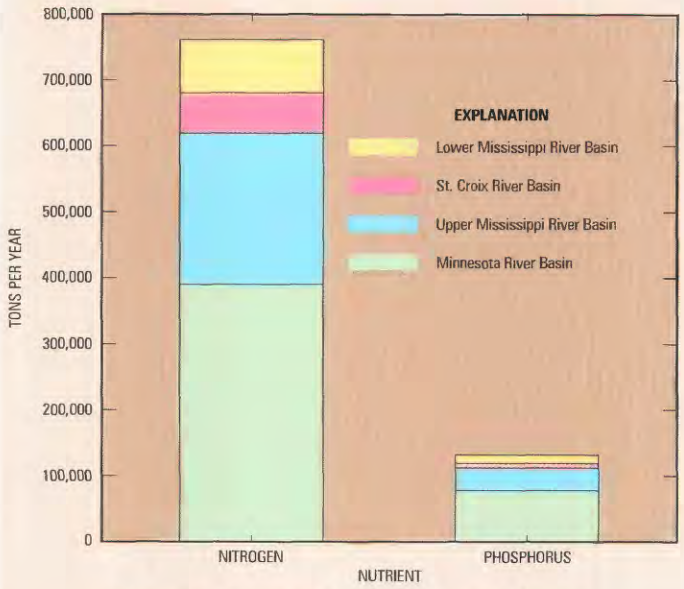

Figure 2. Sources of nutrients to the Upper Mississippi River Basin study unit, by drainage basin.

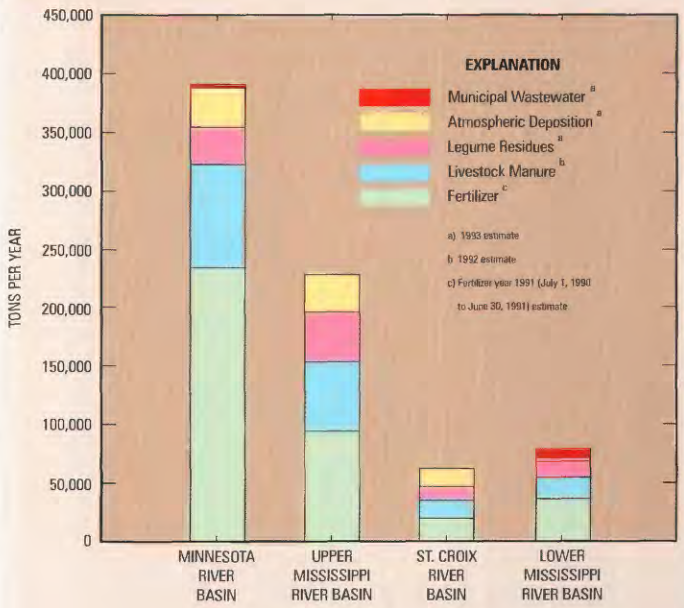

Figure 3. Nitrogen sources to the Upper Mississippi River Basin study unit, by drainage basin.

Andrews (1997). For the LMRB, the amount of nitrogen and phosphorus contained in each source was obtained by difference.

Approximately 760,000 tons of nitrogen and 132,000 tons of phosphorus from fertilizer, livestock manure, municipal wastewater, atmospheric deposition, and legume residues have the potential to affect water quality in the study unit each year (fig. 2). Most of the nitrogen and phosphorus from these sources in the study unit are from the MRB and the UMRB (fig. 2). However, these are the largest of the four drainage basins. Greater amounts of nutrients per unit area may increase the likelihood of transport to surface or ground water. On a per-square-mile basis, most of the nitrogen and phosphorus from the five sources quantified in this analysis (table 1) was to the MRB and LMRB.

Table 1. Amounts of nitrogen and phosphorus in the Upper Mississippi River Basin study unit that may potentially affect water quality, 1991-93, by drainage basin

[Units are tons per year per square mile]

Drainage basin	Nitrogen	Phosphorus
Minnesota River	23	4.6
Upper Mississippi River	12	1.8
St. Croix River	8	0.9
Lower Mississippi River	24	4.1

Fertilizer and livestock manure were the predominant sources of nitrogen and phosphorus to each of the drainage basins (figs. 3 and 4). These sources comprised from 57 to 83 percent of the nitrogen sources and from 91 to 99 percent of the phosphorus sources in each of the four drainage basins. The relative importance of the other sources of nitrogen in the study unit varied among each of the drainage basins. Nitrogen in legume residues was a more important source in the UMRB, SCRB, and LMRB relative to the MRB because hay comprises a larger part of the total acreage of crops grown these drainage basins. Atmospheric deposition is a more important source of nitrogen in the SCRB

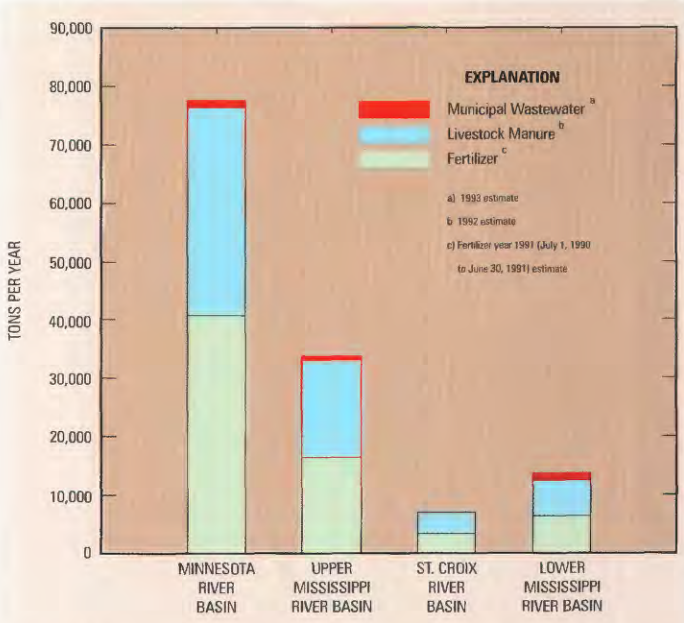

Figure 4. Phosphorus sources to the Upper Mississippi River Basin study unit, by drainage basin.

compared to most of the other sources probably because inputs from fertilizer, manure, and legume residues in this basin are relatively low. Municipal wastewater discharges comprise a larger nitrogen and phosphorus source in the LMRB relative to the other drainage basins because of direct discharges to the Mississippi River from the TCMA.

There were greater amounts of fertilizer and livestock manure applications per square mile in the MRB and LMRB relative to the UMRB and SCRB (table 2). However, the amounts of fertilizer and livestock manure applied in each drainage basin is not uniform. For example, in the UMRB more fertilizer and manure is probably applied in the southern and western parts where agri-

Table 2. Amounts of nitrogen and phosphorus in fertilizer, livestock manure, legume residues, atmospheric deposition, municipal wastewater, and streams in the Upper Mississippi River Basin study unit, 1991-93, by drainage basin

[Phosphorus values are in parenthesis. Units are tons per year per square mile]

Drainage basin	Fertilizer[a]	Livestock manure (1992 estimate)	Legume residues (1993 estimate)	Atmospheric deposition (1993 estimate)	Municipal wastewater (1993 estimate)	Yield in stream at basin outlet (1991-93 average)
Minnesota River	14 (2.40)	5.18 (2.11)	1.88	1.96	0.16 (0.07)	6.1 (0.22)
Upper Mississippi River	4.8 (0.85)	3.13 (0.88)	2.17	1.65	0.05 (0.02)	3.87 (0.07)
St. Croix River	2.5 (0.45)	2.09 (0.45)	1.50	1.99	0.02 (0.007)	0.78 (0.03)
Lower Mississippi River	11 (1.93)	5.42 (1.80)	4.14	1.08	2.20 (0.37)	8.08 (0.33)[b]

[a]Fertilizer year 1991 (July 1, 1990 to June 30, 1991) estimate

[b]Average of yields in Vermillion and Straight Rivers, major tributaries

cultural land use is more concentrated (fig. 1). More nitrogen is available per square mile from legume residues in the LMRB (table 2) because almost half of the crops grown in this basin in 1993 were hay and soybeans.

Implications to Water Quality

This analysis illustrates the importance of nonpoint sources of nitrogen and phosphorus, especially fertilizer and livestock manure, to the major drainage basins of the study unit. Nitrogen and phosphorus yields in streams were greatest in the MRB and LMRB, where amounts of nonpoint sources of these constituents also were the greatest per square mile (table 2). Nitrogen and phosphorus from nonpoint sources generally are transported to streams by runoff. However, point sources, which generally discharge directly to streams in the study unit (Kroening and Andrews, 1997), may be important local sources of nutrients in the study unit.

Sharon E. Kroening

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