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Scientific Investigations Report 2007–5065

U.S. Department of the Interior
U.S. Geological Survey

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U.S. Geological Survey, Reston, Virginia: 2007

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Suggested citation:
Christensen, V.G., 2007, Nutrients, suspended sediment, and pesticides in water of the Red River of the North River Basin, Minnesota and North Dakota, 1990–2004: U.S Geological Survey Scientific Investigations Report 2007–5065, 36 p.

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.4047	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram (kg)
	Hydraulic gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Application rate	
pounds per acre per year [(lb/acre)/yr]	1.121	kilograms per hectare per year [(kg/ha)/yr]

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:
°C=(°F-32)/1.8

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Nutrients, Suspended Sediment, and Pesticides in Water of the Red River of the North Basin, Minnesota and North Dakota, 1990–2004

By Victoria G. Christensen

Abstract

Nutrient, suspended sediment, and pesticide data from 1990 through 2004 in the Red River of the North Basin were compiled, summarized, and compared to historical data. Streamflow varied widely throughout the basin during the 1990–2004 study period. For 19 of 22 streamflow sites, median annual streamflow during the study period exceeded the long-term average streamflow. High streamflow can have a substantial effect on water quality. In water samples from selected surface-water sites, nitrite plus nitrate concentrations ranged from less than 0.005 to 7.7 milligrams per liter; total Kjeldahl nitrogen concentrations ranged from 0.1 to 7.5 milligrams per liter; total phosphorus concentrations ranged from less than 0.005 to 4.14 milligrams per liter; and dissolved phosphorus concentrations ranged from 0.003 to 4.13 milligrams per liter. Surface-water samples from the Pembina River Basin generally had higher nitrite plus nitrate, total phosphorus, and suspended sediment concentrations compared to samples from other Red River Basin sites. Historical data from 1970 through 1990 showed relatively high nitrite plus nitrate and suspended sediment concentrations in samples from some Pembina River sites; in contrast to the 1990–2004 period, total phosphorus concentrations from the 1970–90 period generally were highest at Red River of the North sites. Nitrate concentrations in ground-water samples for the 1990–2004 period were highest in Sheridan County, North Dakota and Marshall and Otter Tail Counties in Minnesota. Concentrations of nitrate in ground water in Marshall and Otter Tail Counties corresponded to relatively high reported fertilizer applications during 2002; however, Sheridan County did not have the high fertilizer applications in 2002 compared to other North Dakota and Minnesota counties. The most frequently detected pesticides or pesticide metabolites were 2,4-D, bentazon, deethylatrazine, metolachlor, picloram, and triallate in surface water and alachlor ethanesulfonic acid (ESA), atrazine, deethylatrazine, picloram, and triazine in ground water. None of the most frequently detected pesticides or metabolites sampled and analyzed by the U.S. Geological Survey or available in the U.S. Environmental Protection Agency Storage and Retrieval System (STORET) during 1990–2004 were detected frequently during 1970-90, with the exception of 2,4-D.

Introduction

The Red River of the North (herein referred to as the Red River) Basin covers parts of South Dakota, North Dakota, Minnesota (fig. 1), and flows north into Canada where it drains into Lake Winnipeg. The basin is rich in agriculture. Nutrients, such as nitrogen and phosphorus, are applied in the form of fertilizers to increase agricultural productivity. Pesticides also are used in abundance (Minnesota Department of Agriculture and Minnesota Agricultural Statistics Service, 2005; Zollinger and others, 2006). Nutrients, suspended sediment, and pesticides often are associated with sediment runoff from farm fields.

A comprehensive report, *Nutrients, Suspended Sediment, and Pesticides in Waters of the Red River of the North Basin, Minnesota, North Dakota, and South Dakota, 1970–1990* by Tornes and Brigham (1994), summarized water quality and related data collected by selected agencies in the Red River Basin from 1970–90. Because there is continued concern about agricultural chemicals in the Red River Basin and there has been considerable data collected since 1990, the U.S. Geological Survey (USGS) and the Minnesota Pollution Control Agency (MPCA) cooperated on a study to compile, review, and summarize available data collected from 1990 through 2004 by several agencies on sediment and agricultural chemicals in the Red River Basin in northwestern Minnesota and eastern North Dakota.

Purpose and Scope

The purpose of this report is to compile, review, and summarize available data on nutrients, suspended sediment, and pesticides in the Red River Basin in northwestern Minnesota and eastern North Dakota collected during 1990–2004. Data for this compilation includes surface- and ground-water data collected for a variety of sampling programs with different objectives and methods. The constituents described in this report are nitrite plus nitrate nitrogen, nitrate nitrogen, total Kjeldahl nitrogen, total phosphorus, dissolved phosphorus, suspended sediment, synthetic organic pesticides, and pesticide metabolites. The data compiled in this report also will be compared to a previous basin-wide analysis of water-quality data (Tornes and Brigham, 1994). Information from this report will provide a basis for future water-quality studies in the basin.

Environmental Setting

The Red River Valley was formed when glaciers deposited 150 to 300 feet (ft) of unconsolidated material over much of the basin (Tornes and Brigham, 1994). The land is mostly flat with gentle slopes, lakes, and wetlands at the margins. Land-surface altitudes in the basin range from about 2,350 ft in the extreme western part of the basin to about 750 ft where the Red River crosses the international boundary into Canada (Stoner and others, 1993).

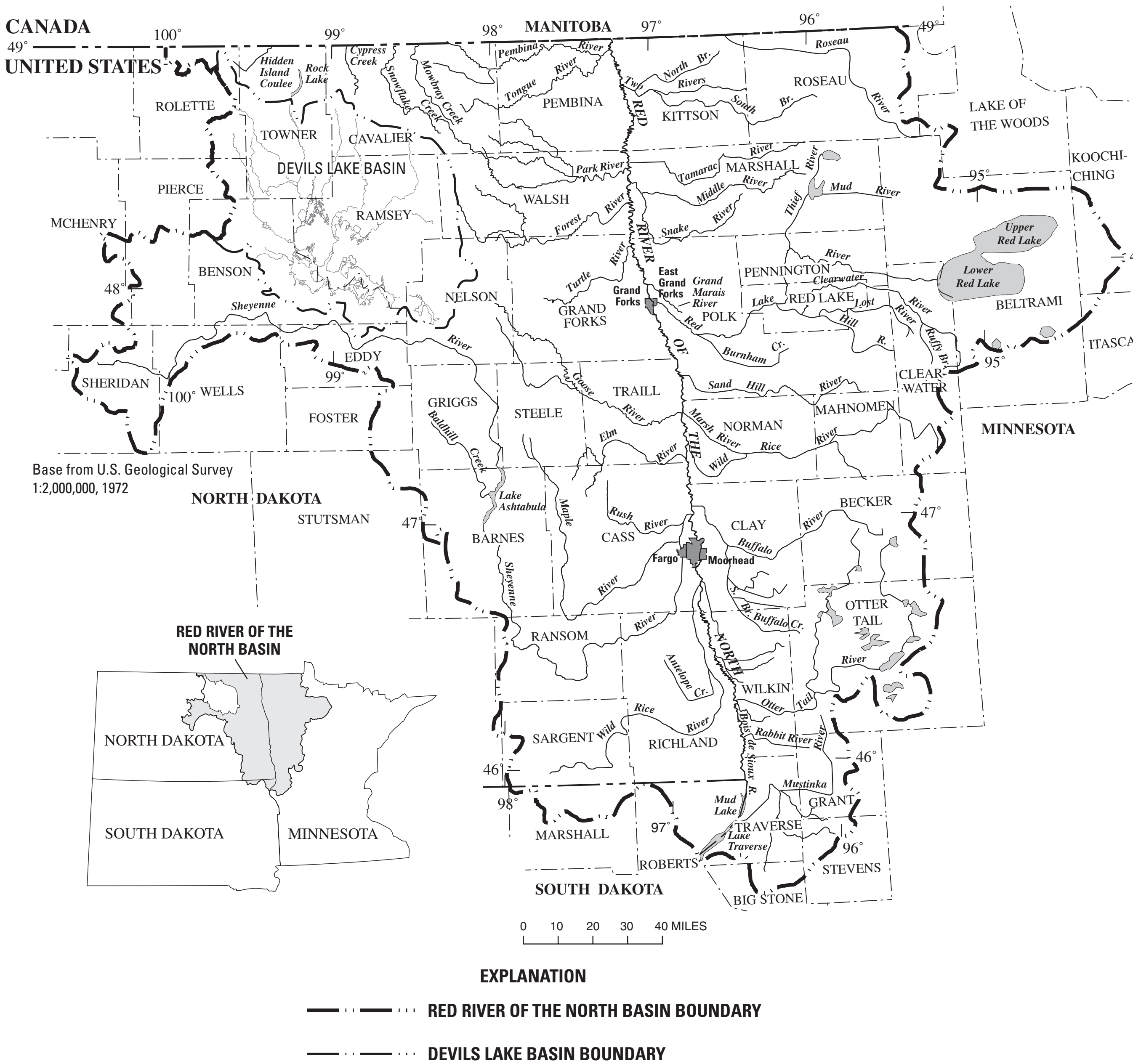

Figure 1. Location of the Red River of the North Basin in Minnesota and North Dakota.

Soils range from heavy, poorly drained clays and silts to light, well-drained sands (Stoner and others, 1993). Black, fine-grained soils are found throughout the basin. Because of the superior quality of soils, land use is primarily agricultural (74 percent, Stoner and others, 1993) of which 66 percent (Stoner and others, 1993) is cropland. Crops grown include barley, corn, dry beans, sugarbeets, soybeans, sunflower seeds, and wheat (U.S. Department of Agriculture, 2002). Livestock in the basin includes cattle, hogs, pigs, and sheep (U.S. Department of Agriculture, 2002).

The physiographic areas in the basin were first described by Anderson (1967) and include Drift Prairie, Red River Valley Lake Plain, Lake-Washed Till Plain, and Moraine (fig. 2). Tornes and others (1997) described the physiographic areas for the Red River Basin as follows: the Drift Prairies are an area of low rolling hills and prairie, with many prairie-pothole wetlands; the Red River Valley Lake Plain is an extensive area of flat land mostly comprised of clays and silts deposited by Glacial Lake Agassiz; the Lake-Washed Till Plain is a relatively flat upland area having extensive wetlands and peat deposits; and, the Moraine consists mostly of lakes and woodlands. The type of physiography can play heavily on the land uses that are established in an area. Land use, in turn, can be related to water quality.

From the confluence of the Bois de Sioux and Otter Tail Rivers, the Red River flows north, forming the border between North Dakota and Minnesota, into Canada, and ultimately into Lake Winnipeg in Manitoba, Canada. The study area includes 394 river miles to the United States-Canadian border (Tornes and Brigham, 1994). The slope of the main channel averages only about 0.5 feet per mile (ft/mi) (River Keepers, 2003). Seventy-five percent of the annual flow comes from the eastern tributaries (Tornes and Brigham, 1994) as a result of topography as well as regional patterns in precipitation, evaporation, and soils. Flooding in the spring can be a major problem (U.S. Geological Survey, 2001) and seasonal variability in streamflow is high (Vecchia, 2005). The drainage of the Red River Basin also includes the Devils Lake Basin, which is a closed basin except during extreme conditions. However, due to rising lake levels in Devils Lake and the construction of an emergency outlet to the Sheyenne River (Devils Lake Basin Joint Water Resources Board and North Dakota State Water Commission, 2006), it is important to consider the Devils Lake Basin as hydrologically connected to the Red River Basin and, thus, contributing to the water quality of the basin.

Sand and gravel aquifers occur in the glacial drift that underlies much of the Red River Basin. Regionally, the water moves toward the Red River. Many of the bedrock and glacial drift aquifers are hydraulically connected to streams in the region (Tornes and Brigham, 1994). Water levels in wells in glacial drift aquifers generally fluctuate less than 3 feet per year (Stoner and others, 1993, p. 601).

A recent study (River Keepers, 2003) has shown that nitrite and nitrate concentrations during 2001–2003 in water from the Red River generally were less than 1.0 milligrams per liter (mg/L). The MPCA uses the U.S. Environmental Protection Agency (USEPA) limit of 10 and 1.0 mg/L for nitrate and nitrite in public water supplies, respectively, whereas the North Dakota Department of Health (NDDH) has an interim guideline of 1.0 mg/L for nitrate. Nitrite plus nitrate concentrations increased significantly from the mid-1980s to the mid-1990s for several Red River locations (Vecchia, 2005). Increasing concentrations for main-stem Red River sites may have been caused by human activities. Phosphorus concentrations for the Red River from 2001 to 2003 were greater than the 0.1 mg/L North Dakota Department of Health standard (River Keepers, 2003). Only small amounts of pesticides have been detected in surface water—usually less than 2 percent of the amount applied (Tornes and Brigham, 1995). Surface-water quality in the Red River Basin varies seasonally (Red River Basin Board, 2001). Generally, concentrations of dissolved chemical constituents are low during spring runoff and after rain events (Tornes and Brigham, 1994). During low flow, the water quality reflects the chemistry of the glacial-drift aquifer system.

Ground water in surficial aquifers commonly is a calcium-bicarbonate type (Tornes and Brigham, 1994). Water deeper in the glacial drift is primarily a magnesium-sulfate type. Water in sedimentary bedrock aquifers is a sodium-chloride type and is characterized by dissolved solids concentrations of 1,000 mg/L or more (Tornes and Brigham, 1994). A previous study showed that ground water from the eastern part of the Red River Basin had significantly higher concentrations of nitrate and agricultural herbicides than did ground water from the western part of the basin (Cowdery, 1995). Agricultural land use and soil texture explain pesticide and nutrient distribution, respectively (Cowdery, 1995).

The Red River Basin has a subhumid to humid continental climate. North Dakota's climate is characterized by large temperature variations, irregular precipitation, and nearly continuous wind (Enz, 2003). The annual mean temperature in the area of Fargo, N.Dak. and Moorhead, Minn. is about 40 degrees Fahrenheit (ºF) (Owenby and others, 1992). However, the annual mean temperature can be misleading because of the large temperature variations. The January average temperature is about 0 ºF and the average temperature in July is about 65 ºF (Enz, 2003). The near continuous wind often results in large day to day temperature fluctuations in all seasons (Enz, 2003). Mean annual precipitation is about 21 inches (in.) (Owenby and others, 1992), most of which occurs during April through September. Precipitation in the basin generally increases from west to east. The greatest annual precipitation for the period of record for Fargo (34.75 in.) occurred in 2002 (Godon and Godon, 2002).

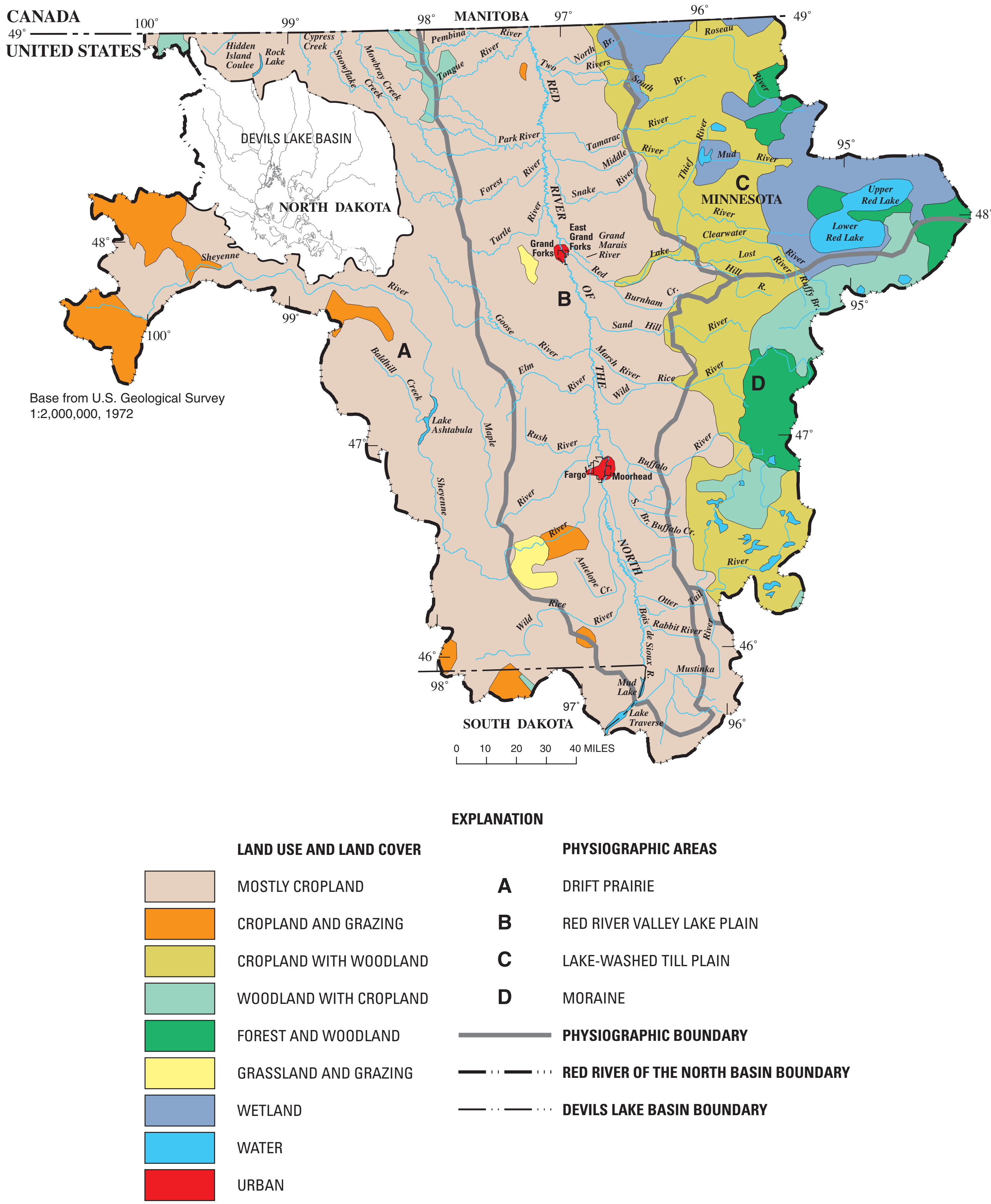

Figure 2. Land use and land cover and physiographic areas in the Red River of the North Basin.

Uses and Sources of Nutrients, Sediment, and Pesticides

Nutrients, such as nitrogen and phosphorus, are essential for the growth and reproduction of plants. Excess nutrients in water, however, can fertilize naturally occurring aquatic plants and cause excessive algal growth. This may produce taste and odor problems in drinking water, reduce the aesthetic and recreational value of the water, and stress aquatic organisms by the depletion of dissolved oxygen when algal blooms die (Christensen and Pope, 1997). Sources of nutrients in the Red River Basin include fertilizers, sewage treatment plants, septic systems, combined sewer overflows, sediment mobilization, runoff from animal feeding operations, atmospheric transport, and nutrient recycling from sediments to the water column (Red River Basin Board, 2001).

Application of nutrients to crops as manure and commercial fertilizer can result in increased nutrients in surface and ground water. Estimates of fertilizer applications are provided for the counties in the Red River Basin (table 1). The total nutrient input from fertilizer applications is calculated by adding input from commercial fertilizers to inputs from manure. Commercial fertilizer and total application is greatest in Polk County, Minn. and Cass County, N. Dak. Both of these counties border the main stem of the Red River (fig. 1). Previous research (Tornes and Brigham, 1994) also identified counties adjacent to the Red River as having the greatest fertilizer applications. Manure application is greatest in Otter Tail County, Minn.

Land use influences the movement of nutrients from land to surface water (Bourne and others, 2002). In the Red River Valley an estimated 1.56 pounds per acre per year [(lb/acre)/yr] of total nitrogen and 0.20 (lb/acre)/yr of total phosphorus are exported from pasture and 2.81 (lb/acre)/yr nitrogen and 0.58 (lb/acre)/yr total phosphorus are exported from cropland (Bourne and others, 2002). Commercial fertilizers and manure contain varying ratios of nitrogen to phosphorus (Tornes and Brigham, 1994). In several large rivers, nitrogen to phosphorus (N:P) ratios were significantly related to the N:P ratios in fertilizer applied to the basins (Caraco, 1995, p. 242). Due to the concern about phosphorus loading to the lakes in Minnesota, a phosphorus ban on lawn fertilizers was passed in 2005 (Minnesota, State of, 2005).

Land use and agricultural practices also can affect the amount of suspended sediment in surface water. Sediment is an important indicator of water quality because of solute-sediment interactions (between sediment and some organic compounds, for example). Excess sedimentation occurs in areas of larger municipal and industrial centers and in regions affected by agricultural and urban runoff (Red River Basin Board, 2001). Sediment erosion can be increased by cultivation practices and by livestock that trample stream banks (Stoner and others, 1993).

Pesticides applied to crops mainly include herbicides, fungicides, and insecticides. Other pesticides include fumigants, growth regulators, and defoliants. A 1997 survey (Gianessi and Marcelli, 2000) indicates that the pesticides used in the greatest abundance in Minnesota and North Dakota are 2,4-D, MCPA, and dicamba (acres treated, table 2). These three pesticides also were some of the most frequently applied pesticides in 1989 (Tornes and Brigham, 1994). Changes in pesticide use may be the result of a number of causes, including pest outbreaks, changes in pest populations, tillage practices, changes between nonchemical and chemical methods, changes in the acreage of major crops, or new developments in pest control technology (Zollinger and others, 2006).

Pesticide applications reported in table 2 are for the entire States of Minnesota and North Dakota and are not limited to the Red River Basin. Application rates specifically for the Red River Basin were not available. However, it is likely that the amounts and types of pesticides applied are different than the statewide applications due to the different crops grown in the region. For example, atrazine was one of the most widely applied pesticides (in acres treated) for the State of Minnesota. However, atrazine is applied mainly to corn crops and much of the corn is grown in the southern half of the State, south of the Red River Basin. It is important to consider this when comparing the pesticide applications in table 2 to pesticides detected in surface and ground water in the Red River Basin.

Erosion is a concern in many agricultural regions and it can be influenced by many factors. Tornes and Brigham (1994) noted that the Red River Valley was affected by many agricultural factors, including the frequency and timing of tillage, tillage of steep lands and gullies, direction of plowing with respect to the land slope, and overgrazing, which can damage plant cover. Many best management practices have been put into place to minimize erosion. These include reduced-tillage farming methods, contour farming, buffer strips along streams, cover crops, and conservation reserve programs.

Agricultural land is not the only source of pesticides that are transported to the waters of the basin. Many pesticides are applied to residential lawns, parks, and golf courses. Furthermore, land that is removed from agricultural production and planted in native grasses often is treated with pesticides to control the spread of weeds to nearby crops. These applications often are not well documented.

Table 1. Estimates of fertilizer application for counties in the Red River of the North Basin, 2002.

[Modified from U.S. Department of Agriculture (2002).]

County	Acres treated with commercial fertilizer	Acres treated with manure	Total	Percentage of county area (farms only) treated with fertilizer[1]
Minnesota				
Becker	143,300	23,000	166,300	20
Beltrami	29,000	7,300	36,300	2.3
Big Stone	154,100	5,000	159,100	50
Clay	367,700	10,000	377,700	57
Clearwater	52,600	4,700	57,300	9.0
Grant	197,600	3,600	201,200	58
Itasca	10,700	3,600	14,300	0.8
Kittson	338,900	6,600	345,500	49
Koochiching	8,100	1,700	9,800	0.5
Lake of the Woods	49,500	1,300	50,800	6.1
Mahnomen	107,900	7,300	115,200	32
Marshall	496,300	6,700	503,000	44
Norman	380,800	6,900	387,700	69
Otter Tail	313,200	71,600	384,800	30
Pennington	143,700	1,900	145,600	37
Polk	742,100	10,200	752,300	60
Red Lake	117,900	4,100	122,000	44
Roseau	320,900	12,100	333,000	31
Stevens	188,700	22,300	211,000	59
Traverse	212,000	6,600	218,600	60
Wilkin	281,300	8,800	290,100	60

Table 1. Estimates of fertilizer application for counties in the Red River of the North Basin, 2002.—Continued

[Modified from U.S. Department of Agriculture (2002).]

County	Acres treated with commercial fertilizer	Acres treated with manure	Total	Percentage of county area (farms only) treated with fertilizer[1]
North Dakota				
Barnes	540,100	4,400	544,500	57
Benson	387,900	4,900	392,800	44
Cass	748,500	4,300	752,800	67
Cavalier	649,900	600	650,400	68
Eddy	117,500	3,500	120,900	30
Foster	219,600	1,900	221,400	55
Grand Forks	548,600	2,100	550,700	60
Griggs	186,800	900	187,700	41
Nelson	286,800	1,900	288,700	46
Pembina	480,500	1,500	482,000	67
Pierce	239,100	5,000	244,100	38
Ransom	212,300	7,100	219,400	40
Richland	589,100	7,400	596,600	65
Rolette	189,900	2,900	192,900	33
Sargent	254,500	4,100	258,600	47
Sheridan	211,700	2,800	214,500	35
Steele	288,800	800	289,600	64
Towner	312,000	2,500	314,500	48
Traill	420,800	1,600	422,400	77

[1] Fertilizer application to land other than farms (for example golf courses and residences) was not included.

Table 2. Pesticide applications in Minnesota and North Dakota, 1997.

[Data from the National Center for Food and Agricultural Policy described in Gianessi and Marcelli (2004) and available at *http://www.ncfap.org*; all values in thousands; pesticides are in order of decreasing total (Minnesota plus North Dakota) acres treated; MCPA, methyl chlorophenoxy acetic acid; —, no data; EPTC, dipropyl thiocarbamic acid s-ethyl ester; <, less than]

Pesticide	Crops	Minnesota		North Dakota	
		Acres treated	Pounds applied	Acres treated	Pounds applied
	Herbicides				
2,4-D	Barley, corn, fallow land, flax, millet, oats, hay, pasture, rye, soybeans, wheat	2,463	711	7727	2,188
MCPA	Barley, flax, oats, rye, wheat	2,078	845	6,759	2,304
Dicamba	Barley, corn, fallow land, flax, millet, oats, wheat	3,093	1,137	5,209	525
Trifluralin	Alfalfa, barley, canola, dry beans, fallow land, flax, potatoes, soybeans, sugarbeets, sunflowers, wheat	2,509	2,073	3,586	1,928
Fenoxaprop	Barley, soybeans, wheat	1,744	134	4,121	251
Imazethapyr	Corn, dry beans, soybeans	4,583	184	533	26
Tribenuron	Barley, oats, wheat	598	2	4,138	25
Clopyralid	Barley, canola, corn, sugarbeets, wheat	1,379	176	2,470	267
Atrazine	Corn	3,199	1,982	186	186
Glyphosate	Alfalfa, barley, corn, fallow land, flax, oats, potatoes, rye, soybeans, sugarbeets, sunflowers, wheat	460	388	2,762	1,241
Bromoxynil	Barley, corn, flax, oats, rye, wheat	1,498	374	1,496	374
Thifensulfuron	Barley, corn, oats, soybeans, wheat	1,553	9	1,286	11
Nicosulfuron	Corn, sweet corn	2,145	43	334	8
Acetochlor	Corn	1,866	2,968	149	204
Metolachlor	Corn, potatoes, soybeans	1,730	3,550	30	69
Bentazon	Corn, dry beans, soybeans	887	654	675	506
Quizalofop	Canola, dry beans, soybean, sugarbeets	1,150	62	410	26
Sethoxydim	Alfalfa, canola, dry beans, flax, green beans, green peas, onion, potatoes, strawberries, soybeans, sunflowers	863	122	514	107
Pendimethalin	Corn, potatoes, soybeans, sunflowers	1,203	1,368	147	186
Ethalfluralin	Canola, dry beans, soybeans, sunflowers	69	58	1,248	972
Clethodim	Soybeans, sugarbeets	765	61	341	25
Flumetsulam	Corn, soybeans	847	30	79	4
Primisulfuron	Corn	867	17	—	—
Desmedipham	Sugarbeets	456	73	235	38
Phenmedipham	Soybeans	456	68	235	35
Triflusulfuron	Sugarbeets	456	9	235	5
Acifluorfen	Soybeans	494	123	128	38
Imazamethabenz	Barley, sunflowers, wheat	141	40	461	155
Lactofen	Soybeans	370	37	128	9
Fomesafen	Soybeans	432	82	53	10

Table 2. Pesticide applications in Minnesota and North Dakota, 1997.—Continued

[Data from the National Center for Food and Agricultural Policy described in Gianessi and Marcelli (2004) and available at *http://www.ncfap.org*; all values in thousands; pesticides are in order of decreasing total (Minnesota plus North Dakota) acres treated; MCPA, methyl chlorophenoxy acetic acid; —, no data; EPTC, dipropyl thiocarbamic acid s-ethyl ester; <, less than]

Pesticide	Crops	Minnesota		North Dakota	
		Acres treated	Pounds applied	Acres treated	Pounds applied
Herbicides—Continued					
EPTC	Alfalfa, corn, potatoes, sugarbeets, sunflowers	294	1090	178	642
Alachlor	Corn, soybeans	422	1179	39	92
Cyanazine	Corn	414	475	37	44
Dimenthenamid	Corn, soybeans	365	316	75	102
Diclofop	Barley, wheat	91	65	326	230
Fluazifop	Soybeans	373	34	32	6
Prosulfuron	Corn	400	8	—	—
Triallate	Barley, flax, wheat	113	113	283	283
Metsulfuron	Barley, wheat	1	<1	370	1
Picloram	Barley, flax, oats, hay, pasture	72	9	264	51
Chlorsulfuron	Barley, oats, wheat	—	—	282	3
Paraquat	Corn, dry beans, potatoes, soybeans, sugarbeets	128	52	133	29
Chlorimuron	Soybeans	247	2	—	—
Triasulfuron	Fallow land, wheat	—	—	238	2
Metribuzin	Potatoes, soybeans	157	29	79	27
Difenzoquat	Barley, wheat	89	59	131	99
Ethofumesate	Sugarbeets	137	34	75	19
Rimsulfuron	Corn	133	1	53	1
Cycloate	Sugarbeets	105	315	54	135
Clomazone	Green peas, pumpkin, soybeans	139	102	—	—
Halosulfuron	Corn	133	4	—	—
Diquat	Potatoes	59	18	37	17
Flumiclorac	Soybeans	62	2	—	—
2,4-DB	Alfalfa	22	16	13	14
Linuron	Potatoes	7	9	18	18
Endothall	Potatoes, sugarbeets	16	10	6	3
Hexazinone	Alfalfa	13	10	—	—
MCPB	Green peas	10	8	—	—
Propachlor	Corn, sweet corn	6	12	—	—
MCPP	Sod	4	1	—	—
Simazine	Apples	1	2	—	—
DCPA	Onions	<1	<1	—	—
Diuron	Apples	<1	1	—	—

Table 2. Pesticide applications in Minnesota and North Dakota, 1997.—Continued

[Data from the National Center for Food and Agricultural Policy described in Gianessi and Marcelli (2004) and available at *http://www.ncfap.org*; all values in thousands; pesticides are in order of decreasing total (Minnesota plus North Dakota) acres treated; MCPA, methyl chlorophenoxy acetic acid; —, no data; EPTC, dipropyl thiocarbamic acid s-ethyl ester; <, less than]

Pesticide	Crops	Minnesota		North Dakota	
		Acres treated	Pounds applied	Acres treated	Pounds applied
Herbicides—Continued					
Napropamide	Strawberries	<1	1	—	—
Oxyfluorfen	Onions	<1	<1	—	—
Terbacil	Strawberries	<1	<1	—	—
Fungicides					
Tebuconazole	Wheat	502	60	783	86
Mancozeb	Barley, potatoes, sugarbeets, wheat	331	990	316	636
Propiconazole	Barley, dry beans, sweet corn, wheat, wild rice	338	46	280	34
Triphenyltinhyd	Potatoes, sugarbeets	334	243	164	117
Thiophanate methyl	Dry beans, sugarbeets	118	70	139	9
Benomyl	Dry beans, sugarbeets, wheat	62	43	174	74
Chlorothalonil	Dry beans, potatoes	69	288	113	767
Maneb	Dry beans, potatoes, sugarbeets	73	156	54	91
Metalaxyl	Potatoes	7	2	45	9
Copper	Potatoes	21	32	7	7
Cymoxanil	Potatoes	13	3	14	2
Propamocarb	Potatoes	14	12	10	9
Metiram	Potatoes	8	31	10	47
Captan	Apples, pumpkin, strawberries	4	38	—	—
Dimethomorph	Potatoes	4	1	—	—
Myclobutanil	Apples	3	1	—	—
Iprodione	Onions	1	1	—	—
Vinclozolin	Green beans, onions, strawberries	1	1	—	—
Fenarimol	Apples	<1	<1	—	—
Streptomycin	Apples	<1	<1	—	—
Insecticides					
Chlorpyrifos	Barley, sugarbeets, wheat	400	424	473	250
Esfenvalerate	Dry beans, potatoes, soybeans, sunflowers	53	2	572	23
Terbufos	Corn, soybeans, sweet corn	451	457	162	187
Permethrin	Alfalfa, apples, corn, onions, potatoes, pumpkins, sweet corn	122	42	299	63
Lambdacyhalothrin	Canola, corn, sunflowers	45	2	236	7
Tefluthrin	Corn, sweet corn	272	22	7	1
Phorate	Corn, potatoes	141	143	60	103

Table 2. Pesticide applications in Minnesota and North Dakota, 1997.—Continued

[Data from the National Center for Food and Agricultural Policy described in Gianessi and Marcelli (2004) and available at *http://www.ncfap.org*; all values in thousands; pesticides are in order of decreasing total (Minnesota plus North Dakota) acres treated; MCPA, methyl chlorophenoxy acetic acid; —, no data; EPTC, dipropyl thiocarbamic acid s-ethyl ester; <, less than]

Pesticide	Crops	Minnesota		North Dakota	
		Acres treated	Pounds applied	Acres treated	Pounds applied
Insecticides—Continued					
Carbofuran	Alfalfa, canola, potatoes, sunflowers	44	27	112	52
Carbaryl	Canola, potatoes, sugarbeets, sunflowers,	27	28	51	64
Dimethoate	Alfalfa, potatoes	29	11	38	19
Azinphos-methyl	Potatoes	51	31	12	6
Endosulfan	Potatoes	48	22	14	13
Methyl Parathion	Potatoes, sunflowers	29	13	22	38
Methamidophos	Potatoes	14	10	11	23
Ethyl Parathion	Oats, sunflowers	—	—	18	16
Imidacloprid	Potatoes	14	2	1	<1
Malathion	Barley, strawberries, sugarbeets, wild rice	14	13	—	—
Tralomethrin	Soybeans, sunflowers	—	—	13	1
Ethoprop	Potatoes	—	—	11	45
Cyfluthrin	Sweet corn	9	1	—	—
Methomyl	Sweet corn	8	4	—	—
Acephate	Green beans	5	4	—	—
Oxamyl	Potatoes	5	2	—	—
Phosmet	Apples	3	12	—	—
Oil	Apples	2	37	—	—
Cypermethrin	Onions	<1	<1	—	—
Hexythiazox	Apples	<1	<1	—	—
Other pesticides[1]					
Sodium Chlorate	Dry beans	15	44	12	35
Sulfuric Acid	Potatoes	4	514	10	1403
Metam sodium	Potatoes	13	1581	—	—
Maleic Hydrazide	Potatoes	4	7	5	10
Chloropicrin	Strawberries	<1	6	—	—
Methyl Bromide	Strawberries	<1	31	—	—
NAA	Apples	<1	<1	—	—

[1]Other pesticides are fumigants, growth regulators, and defoliants.

Methods

Data for this report came from several different sources, primarily the USEPA's STORET (STOrage and RETrieval) data base (*http://www.epa.gov/storet/dbtop.html*) and the U.S. Geological Survey NWIS (National Water Information System) data base (http://waterdata.usgs.gov/nwis). Data in STORET are provided by many agencies and processed by the MPCA and NDDH. Additional ground-water data were obtained from Minnesota Department of Natural Resources (MDNR), the North Dakota State Water Commission (ND SWC), and the Minnesota Department of Agriculture (MDA).

The concentrations of constituents provided in this report are dependent on sampling and analytical methods. Sampling and analytical methods can vary among agencies and over time. These differences can confound direct comparison of water-quality data as methods change and improve. In addition, improvements in analytical methods can result in lower detection limits, and therefore lower reporting levels (Tornes and Brigham, 1994). Improved methods can yield data that, when combined with earlier data, show false downward temporal trends in chemical concentrations (Flegal and Coale, 1989).

In addition, different agencies may use different reporting levels in electronic data bases. For USGS data, reporting levels provided in the NWIS data base are the smallest concentration of a constituent that may be reported by using a given analytical method (Timme, 1995). The STORET data base reports detection limits. The USEPA defines a detection limit as the minimum concentration of a substance that can be measured and reported with 99-percent confidence that the analyte concentration is greater than zero (U.S. Environmental Protection Agency, 1997).

With the exception of the USGS data, no attempt was made to research the quality-assurance procedures used by the agencies that collected and analyzed the data presented in this report. For USGS data, in addition to the quality-control samples submitted from the field (Wershaw and others, 1987; Edwards and Glysson, 1988; Ward and Harr, 1990; and Horowitz and others, 1994), internal quality-assurance practices at the USGS National Water-Quality Laboratory (NWQL) included analysis of calibration standards, standard-reference samples, replicate samples, blanks, and spikes (Pritt and Raese, 1995).

In general, reporting levels, detection limits, and concentration values are reported uncensored as they are found in their respective data bases. The one exception is nitrate values. Nitrate was reported differently by different agencies. The values of nitrate reported for USGS and ND SWC well sites were nitrite plus nitrate. Both agencies have determined that the nitrite concentrations in ground water were negligible, and, therefore, concentrations of nitrite plus nitrate in ground water are reported here as nitrate. In addition, the ND SWC reports values of nitrate as nitrate (Bill Shuh, North Dakota State Water Commission, oral commun., October 15, 2006). Therefore, a conversion factor of 0.2258 was used to convert the nitrate as nitrate concentrations to nitrate as nitrogen for this report. The ND SWC laboratory changed nitrate methods in the early 1990s. No adjustment was made to the data to account for this method change.

To optimize comparability between sites and facilitate comparison to the earlier report (Tornes and Brigham, 1994), certain criteria were used to determine which surface-water sites were to be included in this analysis. These selection criteria were: (1) the site must have had at least 2 years of data collected over two sampling seasons, generally from about March through October, within the 1990–2004 time period, and (2) at least 8 samples from the site were analyzed for the constituent evaluated. The surface-water sites included in this report are listed in table 3 (USGS sites) and table 4 (STORET sites).

Many ground-water sites did not meet the same selection criteria as the surface-water sites of a minimum of 8 samples over 2 years. The study area has more ground-water wells than surface-water sampling sites. A large number of wells were sampled only a few times during 1990 through 2004; therefore, in order to evaluate nutrient concentrations, ground-water sites were grouped by county.

Several agencies throughout the Red River Basin have collected and analyzed ground-water samples. In North Dakota, most of the samples have been collected and analyzed by the ND SWC. Through cooperative studies, the USGS also has collected and analyzed some samples on the North Dakota side of the basin. Most of the ground-water samples from the Minnesota side of the basin were collected and analyzed by the USGS and the results are available from the NWIS data base. Some samples from Minnesota were collected and analyzed by the MDA, MDNR, or the MPCA's Ground Water Monitoring Assessment Program (GWMAP). Generally, very little Red River Basin ground-water nutrient and pesticide data were available from STORET.

The spatial distribution of ground-water wells sampled for nutrients was variable and no or very few wells were sampled in several counties (fig. 7). Samples were collected from more than 300 wells during 1990–2004 in Grand Forks, McHenry, Ransom, and Sargent Counties, N. Dak. In general, more wells in the basin were sampled in North Dakota than in Minnesota, and many of the wells in North Dakota had numerous nutrient samples because they were part of a long-term sampling program.

Data in this report generally are summarized as box plots truncated at the 10th and 90th percentiles (Helsel and Hirsch, 1992). Box plots are a good visual representation of range, central tendency, and skewness. By truncating the box plots, extreme values are not displayed. The exceptions are ground-water nitrate concentrations (because of the limited data available for Minnesota counties) and surface-water suspended-sediment concentrations, where all values for a site are shown. For a standard boxplot, the upper (or lower) adjacent value is defined as the largest (or smallest) observation within one step of the 75th percentile (Helsel and Hirsch, 1992). A step is 1.5 times the interquartile range. Upper (or lower) outside values are between 1 and 2 steps above (or below) the 75th percentile and upper (or lower) detached values are more than 2 steps above (or below) the 75th percentile.

Table 3. Selected U. S. Geological Survey surface-water sites sampled for streamflow or analysis of nutrients, suspended sediment, and pesticides.

[Sites are listed in downstream order; DD, degrees; MM, minutes; SS, seconds]

Map site identifier	USGS identifier (fig. 3)	Site name	Latitude DD MM SS	Longitude DD MM SS
1	05030150	Otter Tail River near Perham, Minn.	46 38 34	095 36 15
2	05030181	Otter Tail River at Little Pine Lake Outlet near Perham, Minn.	46 37 36	095 32 23
3	05030245	Toad River at Dead Lake Outlet near Perham, Minn	46 42 33	095 33 11
4	05030270	Toad River at Big Pine Lake Inlet near Perham, Minn.	46 28 39	095 30 37
5	05030290	Otter Tail River at Big Pine Lake Outlet near Perham, Minn.	46 35 31	095 30 13
6	05046000	Otter Tail River below Orwell Dam near Fergus Falls, Minn.	46 12 35	096 11 05
7	05051300	Bois de Sioux River near Doran, Minn.	46 09 08	096 34 44
8	05051510	Red River of the North below Wahpeton, N. Dak.	46 22 30	096 39 25
9	05051522	Red River of the North at Hickson, N. Dak.	46 39 35	096 47 44
10	05054000	Red River of the North at Fargo, N. Dak.	46 51 40	096 47 00
11	05054200	Red River of the North near Harwood, N. Dak.	46 58 37	096 49 14
12	05056000	Sheyenne River near Warwick, N. Dak.	47 48 20	098 42 57
13	05056100	Mauvais Coulee near Cando, N. Dak.	48 26 53	099 06 08
14	05056200	Edmore Coulee near Edmore, N. Dak.	48 20 12	098 39 36
15	05056220	Sweetwater Lake at Sweetwater, N. Dak.	48 12 39	098 52 15
16	05056239	Starkweather Coulee near Webster, N. Dak.	48 19 14	098 56 25
17	05056270	Big Coulee below Churchs Ferry, N. Dak.	48 15 33	099 12 00
18	05056400	Big Coulee near Churchs Ferry, N. Dak.	48 10 40	099 13 15
19	05056402	Big Coulee near Minnewaukan, N. Dak.	48 06 55	099 07 03
20	05056404	Big Coulee at Devils Lake Inlet near Minnewaukan, N. Dak.	48 03 55	099 09 21
21	05056410	Channel A near Penn, N. Dak.	48 10 00	098 58 47
22	05058700	Sheyenne River at Lisbon, N. Dak.	46 26 49	097 40 44
23	05059000	Sheyenne River near Kindred, N. Dak.	46 37 54	097 00 01
24	05060400	Sheyenne River at Harwood, N. Dak.	46 58 39	096 53 29

Table 3. Selected U. S. Geological Survey surface-water sites sampled for streamflow or analysis of nutrients, suspended sediment, and pesticides. —Continued

[Sites are listed in downstream order; DD, degrees; MM, minutes; SS, seconds]

Map site identifier	USGS identifier (fig. 3)	Site name	Latitude DD MM SS	Longitude DD MM SS
25	05062500	Wild Rice River at Twin Valley, Minn.	47 16 00	096 14 40
26	05064000	Wild Rice River at Hendrum, Minn.	47 16 05	096 47 50
27	05064500	Red River of the North at Halstad, Minn.	47 21 07	096 50 36
28	05064900	Beaver Creek near Finley, N. Dak.	47 35 41	097 42 33
29	05078470	Judicial Ditch 64 near Mentor, Minn. (SW4)	47 44 16	096 12 09
30	05078520	Cyr Creek near Marcoux Corners, Minn. (SW5)	47 48 13	096 16 36
31	05078730	County Ditch 140 near Benoit, Minn. (SW1)	47 41 15	096 22 22
32	05078770	Judicial Ditch 66 near Marcoux Corners, Minn. (SW6)	47 46 55	096 19 53
33	05079000	Red Lake River at Crookston, Minn.	47 46 32	096 36 33
34	05079200	County Ditch 72 (Burnham Creek) near Maple Bay, Minn. (SW3)	47 36 43	096 16 45
35	05079250	County Ditch 65 near Maple Bay, Minn. (SW2)	47 36 43	096 16 45
36	05082500	Red River of the North at Grand Forks, N. Dak.	47 55 37	097 01 44
37	05082625	Turtle River at Turtle River State Park near Arvilla, N. Dak.	47 55 55	097 30 51
38	05085900	Snake River above Alvarado, Minn.	48 10 27	096 59 55
39	05099400	Little South Pembina River near Walhalla, N. Dak.	48 51 55	098 00 20
40	05099600	Pembina River at Walhalla, N. Dak.	48 54 48	097 55 00
41	05099900	Pembina River above Neche, N. Dak.	48 57 49	097 41 14
42	05100100	Pembina River below Neche, N. Dak.	48 57 23	097 24 12
43	05100460	Tongue River near Olga, N. Dak.	48 45 40	098 06 11
44	05100480	Tongue River below Young Dam near Concrete, N. Dak.	48 45 18	098 00 50
45	05100800	Tongue River above Renwick Dam near Akra, N. Dak.	48 46 44	097 47 42
46	05101000	Tongue River at Akra, N. Dak.	48 46 42	097 44 47
47	05102490	Red River of the North at Pembina, N. Dak.	48 58 37	097 14 14
48	05112000	Roseau River below State Ditch 51 near Caribou, Minn.	48 58 54	096 27 46

Table 4. Selected U.S. Environmental Protection Agency STORage and RETrieval System surface-water sites sampled for analysis of nutrients, suspended sediment, or pesticides (listed in downstream order).

[Sites are listed in downstream order; STORET, U.S. Environmental Protection Agency Storage and Retrieval System ; DD, degrees; MM, minutes; SS, seconds]

Map site identifier	STORET identifier	Site name	Latitude DD MM SS	Longitude DD MM SS
S1	S002-001	Mustinka River at CSAH-9 Bridge, 1.3 mi NW of Norcross, Minn.	45 53 15	096 12 48
S2	S002-002	Rabbit River at CSAH-4 right bank of bridge, 0.1 mi southwest of Campbell, Minn.	46 05 43	096 24 38
S3	380001	Bois de Sioux River at Wahpeton, N. Dak.	46 15 50	096 35 56
S4	S002-170	Pelican River at Long Avenue in Detroit Lakes, Minn.	46 48 37	095 49 43
S5	S000-111	Otter Tail River Bridge on CSAH-15 west of Fergus Falls, Minn.	46 16 32	096 08 04
S6	380083	Red River of the North at Brushville, Minn.	46 22 10	096 39 24
S7	S002-114	Red River of the North on CR-8, 9 mi south of Moorhead, Minn.	46 43 52	096 47 02
S8	385234	Wild Rice River, N. Dak.	46 13 04	097 15 34
S9	380154	Red River of the North, south of Fargo, N. Dak.	46 50 52	096 46 50
S10	S000-183	Red River of the North Bridge on Main Avenue at 3rd Street, Moorhead, Minn.	46 52 26	096 46 35
S11	385040	Red River of the North near Harwood, N. Dak.	46 58 37	096 49 13
S12	380033	Bald Hill Creek at Dazey, N. Dak.	47 10 58	098 04 12
S13	380135	Sheyenne River southwest of Harvey, N. Dak.	47 42 09	099 56 56
S14	384155	Maple River at Mapleton, N. Dak.	46 54 19	097 03 09
S15	380156	Goose River at Hillsboro, N. Dak.	47 24 25	097 03 27
S16	384156	Red River of the North at Grand Forks, N. Dak.	47 55 37	097 01 42
S17	380037	Turtle River north of Manvel, N. Dak.	48 05 10	097 11 03
S18	380040	Forest River east of Minto, N. Dak.	48 18 30	097 11 21
S19	380046	Park River at Highway I-29, N. Dak.	48 27 36	097 11 00
S20	380004	Red River at Drayton, N. Dak.	48 34 22	097 08 53
S21	S002-370	Two Rivers, North Branch at US-75 at Northcote, Minn.	48 50 59	097 00 20
S22	380011	Pembina River at Walhalla, N. Dak.	48 54 49	097 55 00
S23	384157	Red River at Pembina, N. Dak.	48 58 39	097 14 18

Nutrients, Suspended Sediment, and Pesticides in Water of the Red River Basin

Numerous stream sites were sampled in the Red River Basin during 1990–2004 (fig. 3). The number of samples collected at each site, however, often was not sufficient to characterize water-quality during all streamflow conditions. Streamflow was greater than average during some years and was less than average during others. The distributions of mean annual streamflows for 1990–2004 are shown in figure 4 for 22 USGS stream sites with continuous streamflow record. Long-term average streamflows for the period of record at each site also are shown. Streamflows at the four Red River sites exceeded the long-term average during 1990–2004. This is particularly evident at the Red River at Fargo (site 10), where 75 percent of the flows were greater than the long-term average. For 19 of the 22 streamflow sites in the basin, average annual streamflow exceeded the long-term average for the period of record at that site (fig. 4). Streamflows generally were less than the long-term average at the Bois de Sioux (site 7), Turtle River (site 37), and Pembina River (site 40) sites.

The importance of streamflow variability to this report is that streamflow can have a substantial effect on water chemistry. The high streamflows of the early 1990s are particularly important because they occurred during the growing season after pesticides were applied. Tornes and others (1997) reported that streamflows at most sites in the Red River Basin exceeded the 90th percentile of historical mean annual streamflows during 1993–95. The effect of these high streamflows was more apparent for southern and western streams where runoff was especially large. Suspended sediment and constituents related to the solid phase rather than the dissolved phase (total phosphorus, for example) typically are higher during higher flows.

Flooding can affect water quality in the spring when agricultural chemicals have been applied and when there is no crop cover on fields to hold soils in place. There were large floods in the basin in 1997 and 2001. The 1997 floods were the result of record high snow packs across the region, whereas the 2001 floods were the result of above average soil moistures in some areas of the basin (Macek-Rowland, 2001). The flat terrain of the Red River Basin and the shallowness of the channel can aggravate flooding. Samples collected during floods usually indicate much different stream quality than samples collected during low flow. Whereas floods can cause increases for some constituents, such as fertilizers and sediment, they also can have a diluting effect on other constituents, such as dissolved solids.

Nutrients

Nutrients, particularly nitrogen and phosphorus, have been identified as a source of the degradation of much of the Nation’s surface water with respect to water quality (U.S. Environmental Agency, 2000). Although nutrients occur naturally in the environment, certain human activities can increase their transport to natural waters. Sources of nutrients include sewage effluent, lawn fertilizer, storm runoff, and certain agricultural practices such as livestock production and application of fertilizers.

Nitrogen occurs in several forms—ammonia, nitrite, nitrate, and as part of organic compounds. Ammonia plus organic nitrogen, also known as total Kjeldahl nitrogen (TKN), is a laboratory test for measuring the amount of organic nitrogen and ammonia in water. In most oxygenated surface water, nitrate is by far the most predominant ion because of the rapid oxidation of nitrite. Adverse human-health effects of large concentrations of nitrates (greater than 10 mg/L) in drinking water include methemoglobinemia, “blue-baby syndrome” in infants (U.S. Environmental Protection Agency, 1986).

Phosphorus is an essential nutrient for plant growth; however, if critical concentrations are exceeded, it may contribute to eutrophication. Eutrophication is characterized by an abundance of nutrients, decreases in dissolved oxygen, dense growth of algae, and an acceleration of the normal rate of ecological succession (Reid and Wood, 1976, p. 293).

Surface Water

Most of the sampling sites are primarily along the Red River (fig. 3) and in the Red River Valley Lake Plain (fig. 2). Another area of intense sampling is within the closed Devils Lake Basin (fig. 3). Few sites are in the Lake-Washed Till Plain or the Moraine. The limited distribution of sampling sites makes it difficult to generalize about the water quality for a certain physiographic area in the Red River Basin. Tornes and others (1997) found that nutrient concentrations generally were related to the physiographic area that a stream drains.

Because methods of collection and analysis are different, USGS data for nutrients in surface water and the nutrient data collected and analyzed by other agencies are discussed separately. All 23 USGS sites meeting selection criteria are included in figure 5. Nitrite plus nitrate concentrations ranged from 0.02 to 5.2 mg/L in samples from USGS stream sampling sites; concentrations between the 10th and 90th percentile are displayed in fig. 5A. Median nitrite plus nitrate concentrations ranged from 0.05 to 0.67 mg/L.

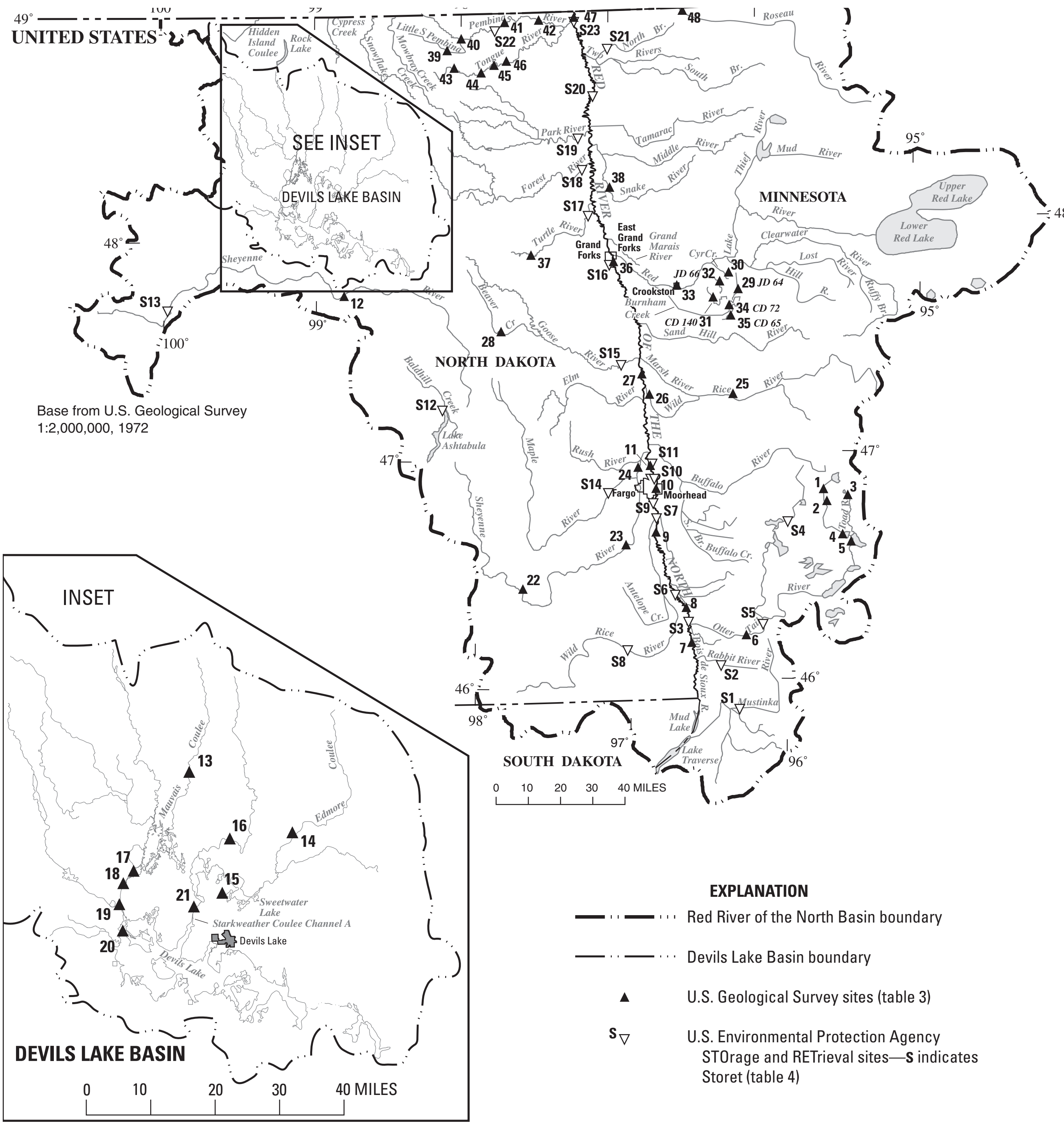

Figure 3. Surface-water sampling sites in the Red River of the North Basin, 1990–2004.

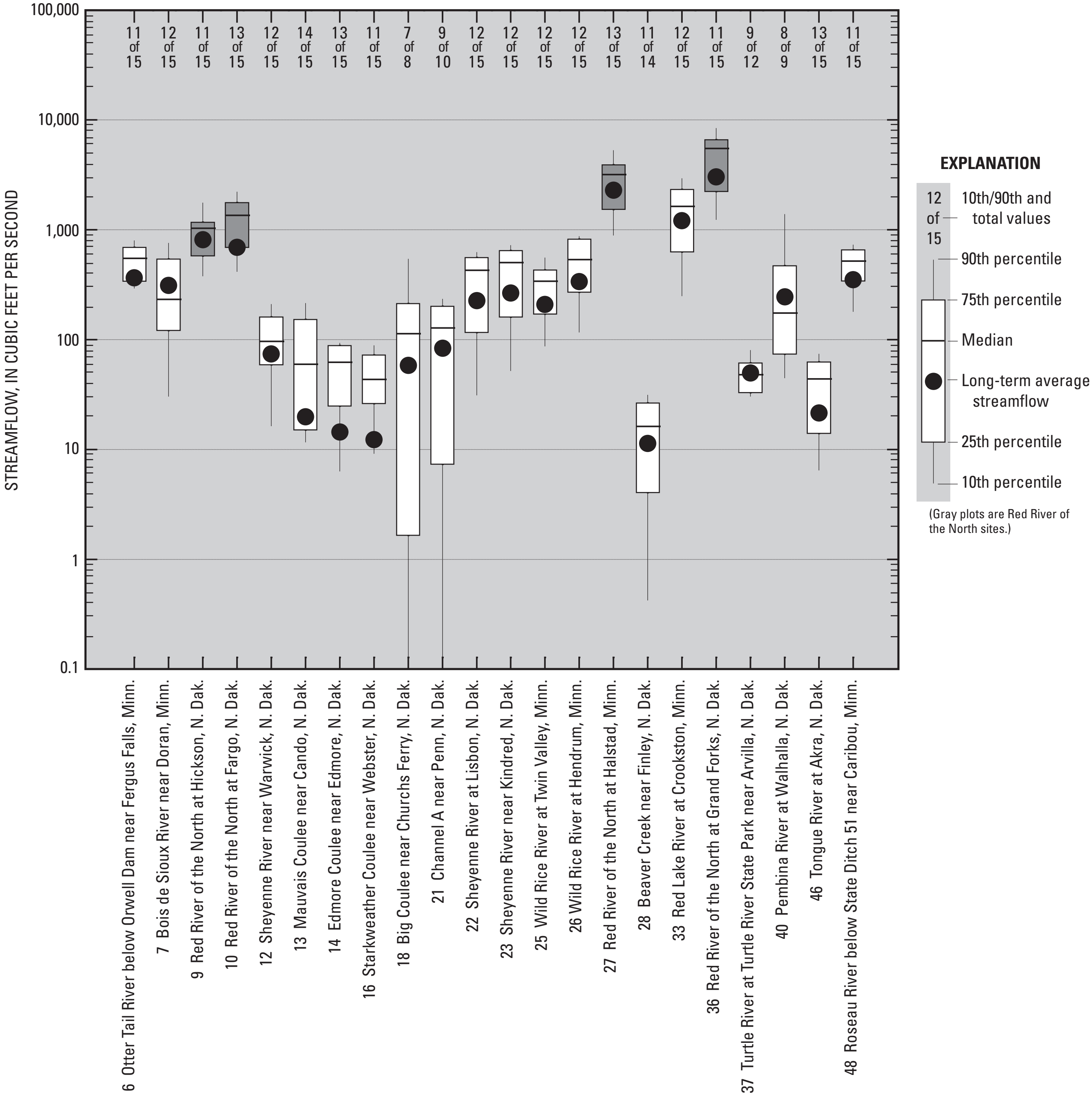

Figure 4. Distribution of mean annual streamflow for 22 U.S. Geological Survey sites with continuous streamflow record in the Red River of the North Basin, 1990–2004.

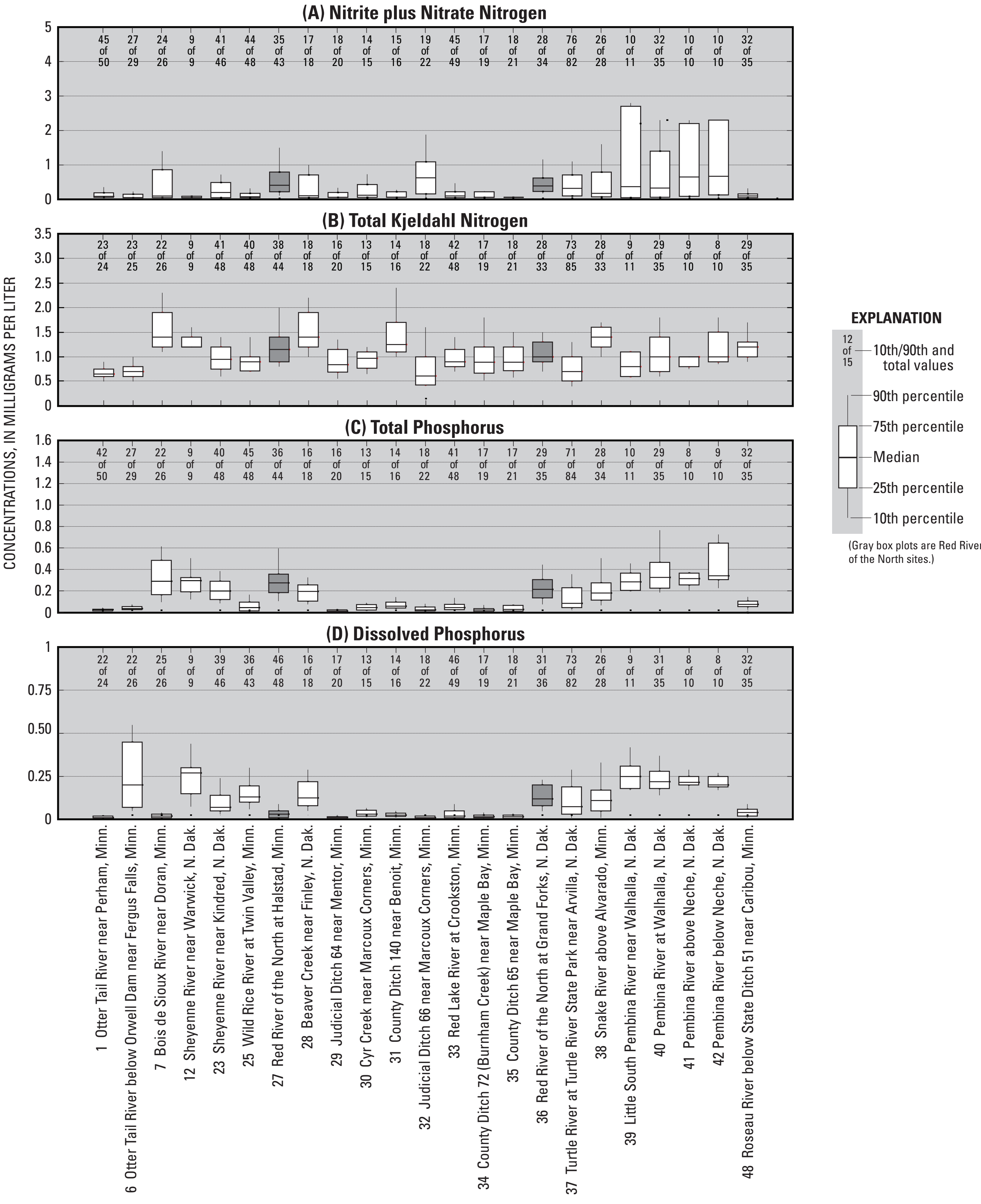

Figure 5. Distribution of (**A**) nitrite plus nitrate nitrogen, (**B**) total Kjeldahl nitrogen, (**C**) total phosphorus, and (**D**) dissolved phosphorus concentrations for 23 selected U.S. Geological Survey stream sites in the Red River of the North Basin, 1990–2004.

The most noticeable pattern in nitrite plus nitrate concentrations across the basin is the high concentrations in samples from the Little South Pembina and Pembina River (sites 39, 40, 41, and 42, fig. 3) compared to concentrations in samples from other Red River Basin sites (fig. 5A). Although these sites are located in the Drift Prairie and Red River Valley Lake Plain, they mainly drain the Drift Prairie physiographic area. Tornes and others (1997) found that streams draining the Drift Prairie had much higher concentrations of nitrate than other streams in the basin. The Drift Prairie physiographic area drains some of the steepest agricultural land in the basin, which probably contributed to more rapid runoff of nutrients (Tornes and Brigham, 1994). The Bois de Sioux River (site 7, fig. 3), the Red River at Halstad (site 27, fig. 3), and Judicial Ditch 66 near Marcoux Corners (site 32, fig. 3) had slightly higher concentrations than nearby sites. The main-stem site at Halstad probably is influenced by municipal and industrial wastes from the cities of Fargo and Moorhead (Tornes and Brigham, 1994). All nitrite plus nitrate concentrations in samples from USGS stream sites between 1990–2004 were less than the drinking water standard of 10 mg/L (U.S. Environmental Protection Agency, 1996). Nitrite plus nitrate concentrations less than 10 mg/L are not considered a threat to human health.

Ammonia concentrations typically were low at most sites where data were available; therefore the TKN results likely are mostly organic nitrogen. TKN concentrations in samples from USGS sites meeting selection criteria ranged from 0.1 to 7.5 mg/L; concentrations between the 10th and 90th percentile are shown in figure 5B. Median TKN concentrations in samples from USGS sites ranged from 0.61 to 1.4 mg/L; TKN concentrations were highest at Bois de Sioux (site 7), Beaver Creek near Finley (site 28), County Ditch 140 near Benoit (site 31), and Snake River at Alvarado (site 38). No regional pattern is apparent with these TKN concentrations, which were found in samples from different areas of the basin. Excessive organic nitrogen in water may indicate contamination from human and animal waste.

Total phosphorus concentrations in water samples from USGS stream sites ranged from less than 0.005 to 4.14 mg/L; concentrations between the 10th and 90th percentile are shown in figure 5C. Median total phosphorus concentrations ranged from 0.018 to 0.345 and were highest at the Bois de Sioux (site 7, fig. 3), Sheyenne River (site 12, fig. 3), Red River (sites 27 and 36, fig. 3), Little South Pembina River (site 39, fig. 3), and Pembina River (sites 40, 41, and 42, fig. 3) sites. Some Red River sites are near or downstream from wastewater effluent, which may explain high total phosphorus concentrations compared to those in samples from sites further upstream.

Samples from the Pembina River sites had higher total phosphorus concentrations than those from nearby sites. Soil characteristics or agricultural practices and steep topography most likely cause more phosphorus to be transported to the stream. In addition, Pembina River sites drain the Drift Prairie physiographic area, an area that had higher phosphorus concentrations than other Red River Basin sites in a previous study (Tornes and others, 1997).

Dissolved phosphorus concentrations at the USGS stream sites ranged from 0.003 to 4.13 mg/L; concentrations between the 10th and 90th percentile are shown in figure 5D. Median dissolved phosphorus concentrations ranged from 0.01 to 0.28 mg/L. Samples with high median dissolved phosphorus concentrations were from the Sheyenne River near Warwick, N. Dak. (site 12, fig. 3), Little South Pembina (site 39, fig. 3), and Pembina River sites (sites 40, 41, and 42, fig. 3). Because no large urban areas are located upstream from these sites, it is suspected that agricultural practices, such as livestock operations, are affecting water quality at some of the sites.

Data for nutrients in stream water from STORET were available for many sites. Results from 23 of these sites are shown in figure 6 and are discussed below. Nitrite plus nitrate concentrations for selected STORET sites ranged from less than 0.005 to 7.7 mg/L; concentrations between the 10th and 90th percentile are displayed in figure 6A. The highest median concentration occurred at the Red River of the North near Harwood, N. Dak. (site S11, fig. 3). This site is downstream from Fargo and Moorhead wastewater treatment plants, which may explain the higher nitrite plus nitrate concentrations.

For the STORET sites, TKN concentrations ranged from 0.234 to 2.38 mg/L; concentrations between the 10th and 90th percentile are shown in figure 6B. Median TKN concentrations ranged from 0.57 to 1.0 mg/L. TKN concentrations were highest at Mustinka River (site S1), Rabbit River (site S2), and Two Rivers (site S21). Relatively low TKN concentrations were found in samples from the Otter Tail River (site S5), Red River (sites S6, S11, S16, and S23), and Pembina River (site S22). Low concentrations of TKN occurred at all Red River sites except at the Bridge on Main Avenue at 3rd Street in Moorhead, Minn. (site S10). This pattern of low concentrations on the mainstem sites was not expected and was not observed from 1970–90 (Tornes and Brigham, 1994). The data for the Red River of the North Bridge on Main Avenue at 3rd Street was analyzed by a different lab during 1990–2004 than the other Red River sites in the graph (fig. 6B). This emphasizes the importance of documenting quality assurance procedures and considering these when evaluating data from numerous sources, such as those from STORET.

Total phosphorus concentrations in samples from selected STORET stream sites ranged from 0.018 to 1.44 mg/L; concentrations between the 10th and 90th percentile are shown in figure 6C. The range in median total phosphorus concentrations was 0.05 to 0.30 mg/L. The highest median concentrations were detected at the Pembina River site S22. Concentrations at Pelican River (site S4) were substantially lower than at other STORET sites (fig. 5C). A large number of samples (149) were analyzed at this site and, therefore, this is probably a valid difference and not an artifact of different sampling schemes.

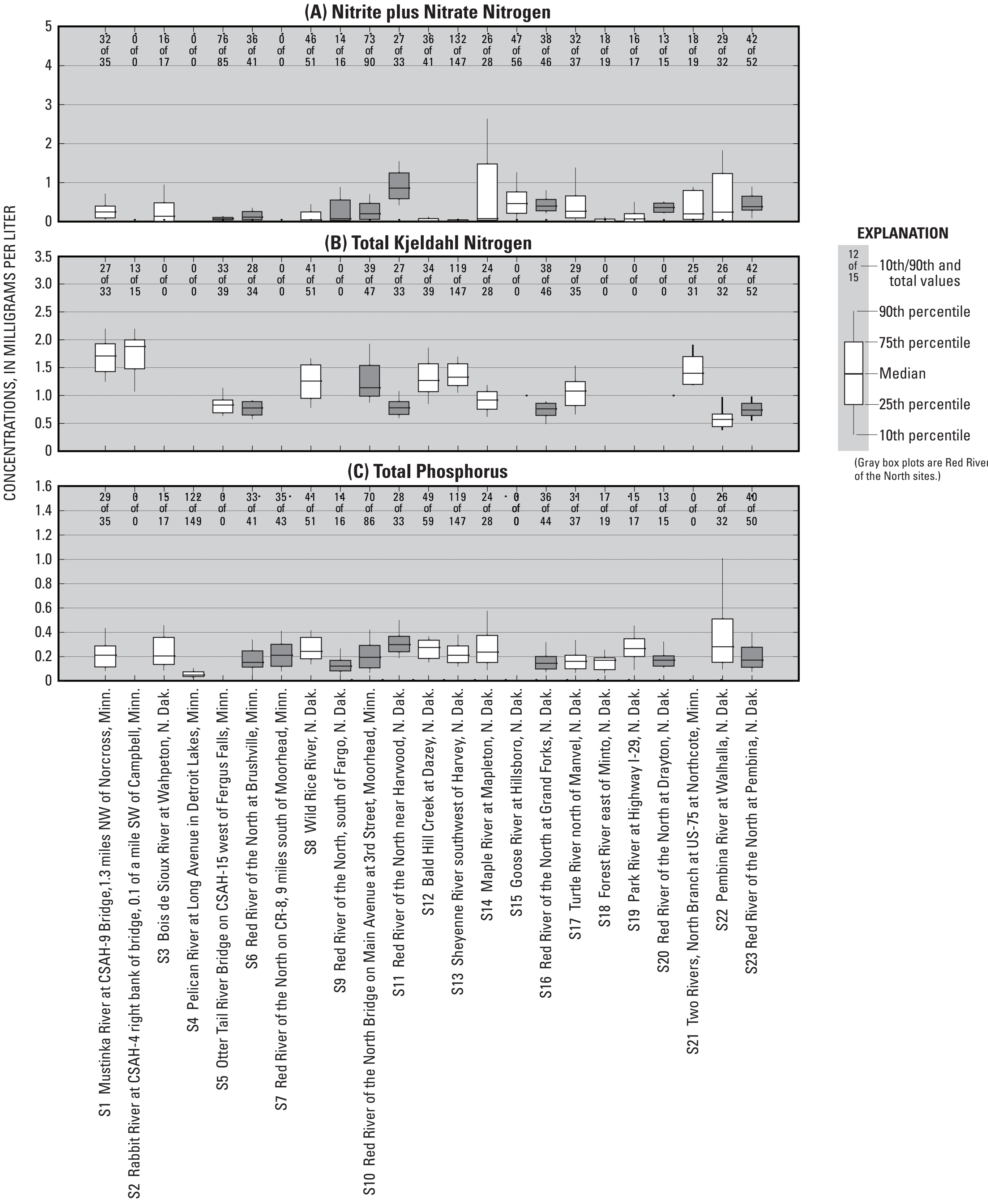

Figure 6. Distribution of (**A**) nitrite plus nitrate nitrogen, (**B**) total Kjeldahl nitrogen, and (**C**) total phosphorus concentrations for selected U.S. Environmental Protection Agency STOrage and RETrieval stream sites in the Red River of the North Basin, 1990–2004.

Ground Water

The form of nitrogen most frequently analyzed in ground water samples was nitrate; there were several reasons for this. Nitrate is a dissolved form, the analysis is reasonably easy, and there is the Maximum Contaminant Level of 10 mg/L, to which concentration values can be compared. Bacterially mediated reactions can reduce nitrate to other forms of nitrogen under anoxic conditions, but these forms are not typically analyzed. Therefore, nitrogen contamination in ground water may affect a wider area, but this would not be apparent when water samples are analyzed for only nitrate.

Reported nitrate concentrations (as nitrogen) in ground water from North Dakota counties ranged from less than 0.023 to 113 mg/L (fig. 8) from 1990 through 2004. About 15,000 samples from North Dakota counties from 1990 through 2004 were analyzed for nitrate. Samples from Sheridan County had the highest median nitrate concentrations, whereas samples from Rolette County had the lowest median concentrations. Sheridan County is located on the far western side of the basin in the Drift Prairie physiographic area and the land use is mainly cropland and grazing (fig. 2). Rolette County is in the far northwestern part of the basin and also is located in the Drift Prairie physiographic area, however, the land use is mixed with some woodland and cropland (fig. 2).

Nitrate concentrations in 613 samples from ground-water wells in Minnesota counties ranged from less than 0.005 to 133 mg/L (fig. 9). The highest concentrations were detected in Marshall and Otter Tail Counties. Very low median concentrations (most values were non-detectable) occurred in Itasca, Kittson, Norman, Stevens, and Wilkin counties. Ground-water nitrate data was not available for Big Stone, Clay, Lake of the Woods, and Roseau Counties. The samples with the highest median ground-water nitrate concentrations were collected from wells in Marshall, Otter Tail, and Polk Counties (fig. 9).

Fertilizer applications (table 1) were examined to determine if there was a correlation between these and nitrate concentrations in ground water (figs. 8 and 9). With the exception of Cavalier County, the North Dakota counties that had the highest fertilizer applications (Barnes, Cass, Richland) as shown by acres treated did not correspond to the North Dakota counties that had the highest ground-water nitrate concentrations (Ransom, Sheridan, and Traill). There appears to be little correlation between fertilizer applications (table 1) and nitrate concentrations in ground water in North Dakota Counties (fig. 8).

For Minnesota counties, Marshall, Norman, and Polk had the highest fertilizer applications as shown by acres treated with commercial fertilizers in table 1. Otter Tail County had considerably more acres treated with manure (table 1) than other Minnesota counties. Marshall, Otter Tail, and Polk counties also had the highest nitrate concentrations in ground-water wells when compared to other counties in the basin (fig. 9). Norman County did not have high ground-water nitrate concentrations, but only three wells were sampled in Norman County and it is possible that these wells were not representative of the general water quality of ground water in Norman County.

The lack of correlation for some counties between fertilizer applications and ground water nitrate concentrations in wells may be because the nitrate comes from another source. High nitrate concentrations in ground water also may be an indication of contamination by sewage or agricultural wastes (Drever, 1988, p. 70). Most investigators have attributed high nitrate concentrations in rural wells to drainage from nearby barnyards or septic systems (Hem, 1992).

The lack of correlation for some counties between fertilizer applications and ground water nitrate concentrations in wells also may be due to differences in surficial geology. Much of the ground water in Otter Tail and Becker Counties is in unconfined, shallow aquifers and susceptible to contamination (Tornes and Brigham, 1994). Shallow ground water is at risk for nitrate contamination because nitrate ions are highly soluble in water, susceptible to leaching, and move freely through soil along with water (Campbell and others, 2004, p. 152). Areas with the highest risk for nitrate contamination generally have high nitrogen inputs, well-drained soils, and a high ratio of cropland to woodland (U.S. Geological Survey, 1999). Contamination of shallow ground water may be a warning to alert populations of potential future risks from consumption of water from deeper wells in these aquifers (U.S. Geological Survey, 1999).

Three additional sources of ground-water quality data were reviewed for this report. These data were collected through the MDNR, MDA, and MPCA's GWMAP. The MDNR collected ground-water samples in the Red River Basin in Minnesota. These samples were collected during 1992 and 1993 and analyzed for phosphorus, phosphate, nitrite, and nitrate. Data were not available by county. Nitrate values for 178 samples collected ranged from less than 0.10 to 14.7 mg/L. The MDA also collected some ground-water samples in Minnesota in 2004. Electronic files for these data were provided to the MPCA from MDA (Catherine O'Dell, Minnesota Pollution Control Agency, written commun., 2006). Nitrite plus nitrate concentrations ranged from zero to 6.27 mg/L for samples collected from 18 wells. The MPCA collected large amounts of ground-water quality data through GWMAP. Baseline data were collected from 1992–1996 and included metals, major ions, field properties, nitrate, and total phosphorus. Of the 124 wells sampled in the Red River Basin, 7 had water with detectible concentrations of nitrate. The detected concentrations generally were from water collected from wells in the buried Quaternary aquifers and concentrations for these seven wells ranged from 0.5 mg/L to 2.6 mg/L. More information on the GWMAP data is available at *http://www.pca.state.mn.us/water/groundwater/gwmap/gwbaseline.html*.

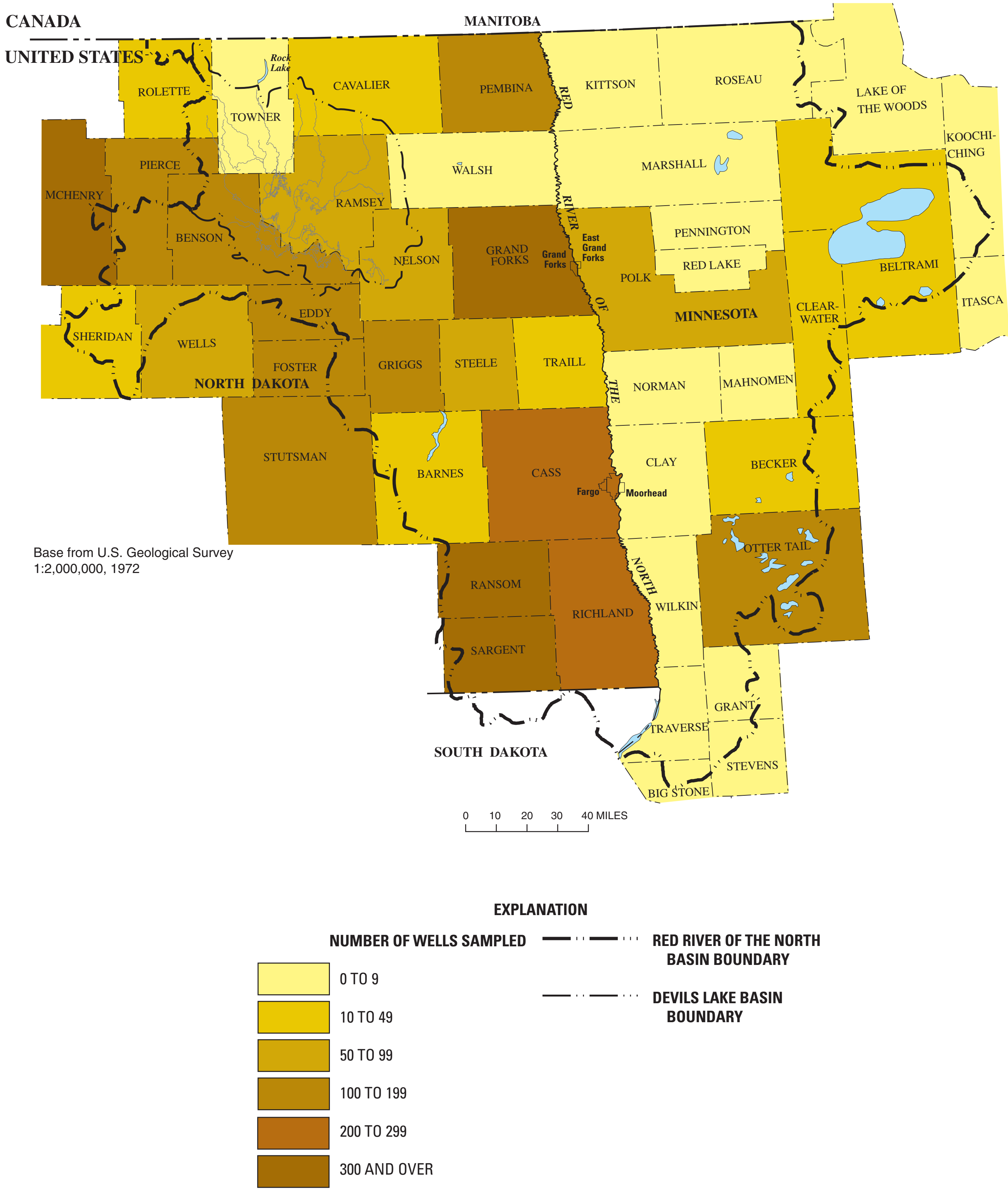

Figure 7. Numbers of wells sampled, by county, during 1990–2004 in the Red River of the North Basin.

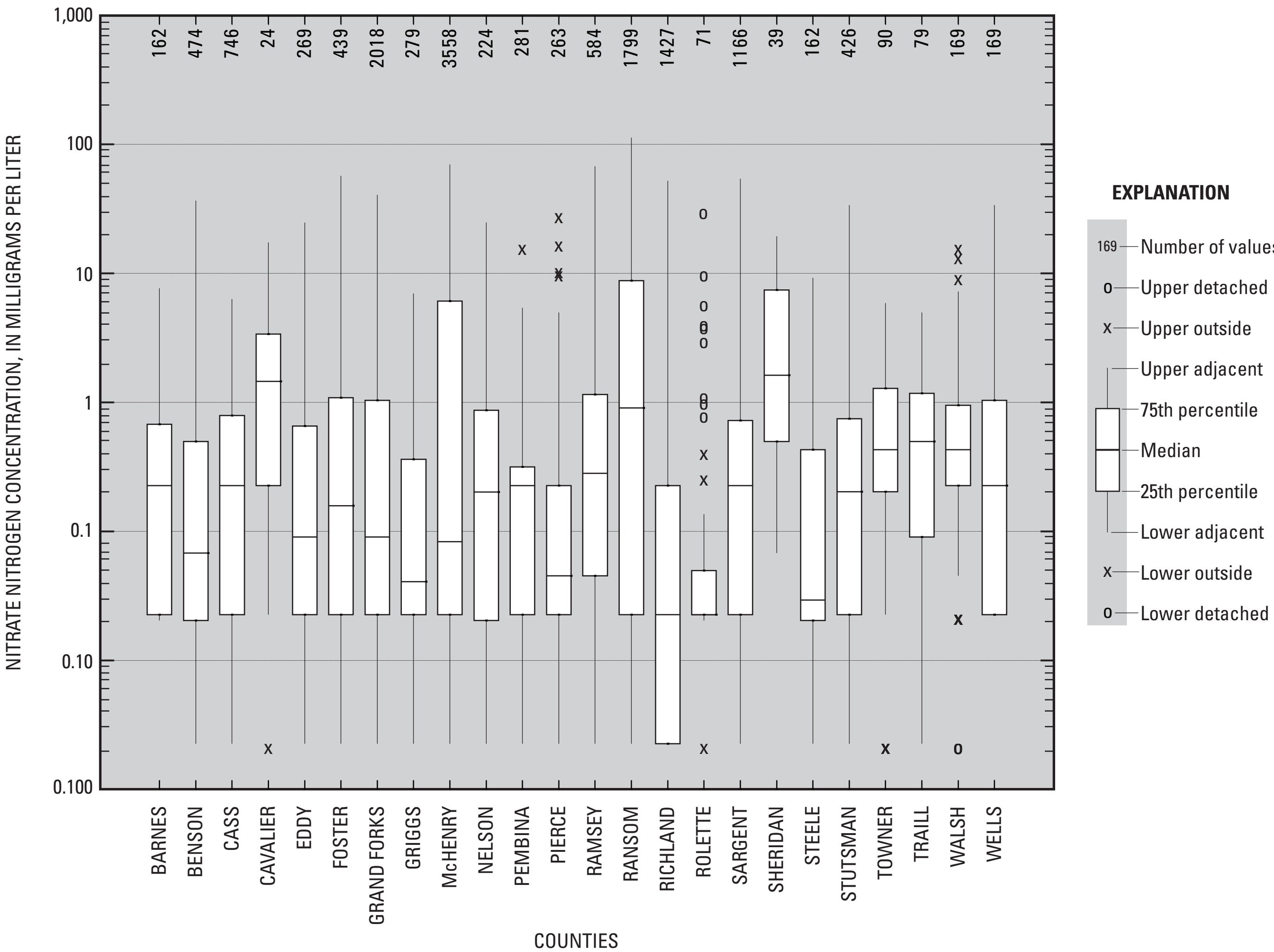

Figure 8. Distribution of nitrate nitrogen concentrations in water from wells in North Dakota counties in the Red River of the North Basin, 1990–2004.

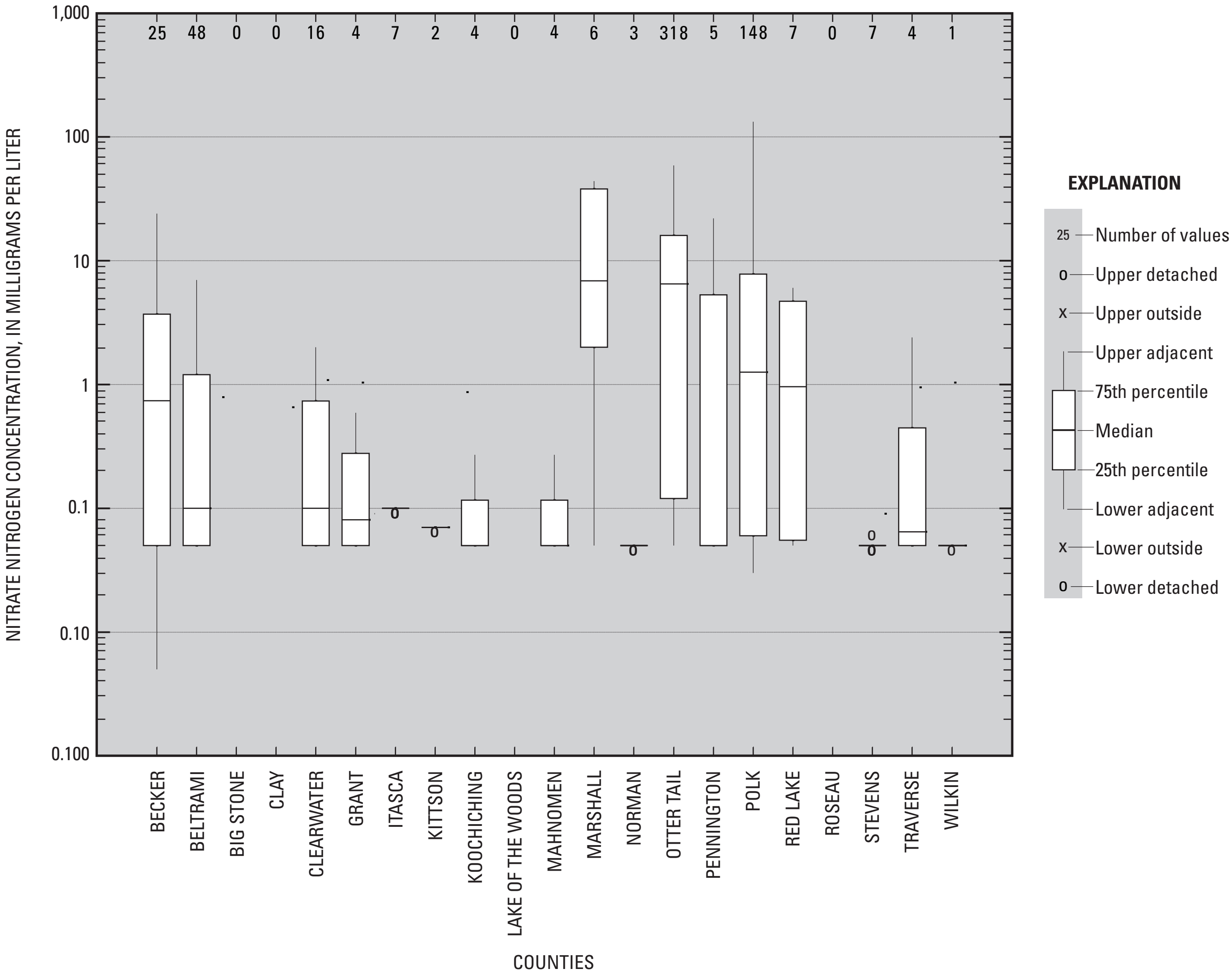

Figure 9. Distribution of nitrate nitrogen concentrations in water from wells in Minnesota counties in the Red River of the North Basin, 1990–2004.

Suspended Sediment

Sediment may be naturally transported to streams from soil erosion of stream banks and upland areas, especially during floods and other major hydrologic events. Sediment transport also can be increased by human activities such as construction, agriculture, and channel modifications. The increase in soil transport to streams from these human activities can have detrimental effects on water quality. For example, sediment in water can absorb, reflect, and scatter solar radiation and increase water temperatures, which may stress aquatic organisms and create conditions favorable to disease in fish populations (Christensen and others, 2006). The sediment smothers rooted vegetation and adversely affects benthic (bottom dwelling) organisms. In addition, the suspended sediment transported by streams can carry and deposit hydrophobic contaminants (those that do not dissolve in or combine with water) into reservoirs and lakes.

Certain solute-sediment interactions, such as those between sediment and organic compounds, for example, make suspended sediment an important water-quality factor. There are two different measures of solid material in a water sample, suspended-sediment concentration (SSC) and total suspended solids (TSS). SSC represents suspended solid-phase material in a water sample. SSC is determined by measuring the dry weight of all the sediment of a known volume of water-sediment mixture, unlike TSS in which the data are produced from a subsample of the original (Gray and others, 2001).

The differences between SSC and TSS are discussed in detail in Gray and others (2001) and a discussion of the difference between these two measures of suspended material in Minnesota and North Dakota are compared by Tornes and Brigham (1994). Tornes and Brigham demonstrated that TSS underestimates suspended-material content by more than a factor of two. The North Dakota Department of Health recently (about 2004) began analyzing the entire sample volume for TSS in order that TSS values from that laboratory would better correlate to SSC values from the USGS (Mike Ell, oral commun., January 22, 2007).

U.S. Geological Survey SSC data were available for the Red River Basin from 48 sites in Minnesota and 31 sites in North Dakota. In addition, data were available from 10 sites on the Red River, which forms the border between the two states.

Figures 10 and 11 show the distribution of SSC for all of the sites in the Red River Basin that meet the selection criteria of more than eight samples during at least two sampling seasons. Figure 10 shows the results of analysis of samples sites upstream from Grand Forks, N. Dak., and figure 11 shows the results of analysis of samples from Grand Forks and sites downstream. Median SSC ranged from about 4 mg/L at Otter Tail River at Pine Lake Outlet near Perham, Minn. (fig. 10, site 2), to 706 mg/L at Pembina River at Walhalla, N. Dak. (fig. 11, site 40). Median concentrations in the Red River ranged from 52 mg/L at the Red River of the North below Wahpeton, N. Dak. (fig. 10, site 8) to 206 mg/L at Red River at Pembina, N. Dak. (fig. 11, site 47). Median concentrations were lowest at the Otter Tail River sites (fig. 10, sites 2, 5, and 6) and Turtle River (fig. 11, site 37). The highest SSC generally were found in the Pembina River (fig. 11). SSC in the Pembina River at Walhalla, N. Dak. (fig. 11, site 40) ranged from 10 mg/L to 3,290 mg/L. Tornes and Brigham (1994) also noted that the highest concentrations in the Pembina River 1970–1990 ranged from 3 mg/L to nearly 7,000 mg/L. SSC in the Tongue River above Renwick Dam (site 45) also are relatively high, but some sediment settles out behind the dam so that downstream concentrations from site 46 are lower (fig. 11).

The fine clay and silt lake-plain sediments in the Red River Valley are easily suspended and tend to stay in suspension even during relatively low-flow conditions (Paakh and others, 2006). The higher concentrations of suspended sediment in the Pembina River may be due to the steeper topography in the Pembina watershed (Tornes and Brigham, 1994) and erodible stream channels (Stoner and others, 1998). However, topography in the upper reaches of the Otter Tail watershed also is steeper than that in the Red River Valley Lake Plain and, therefore, topography is not the only factor affecting sediment transport. The transport of suspended sediment to surface water is likely due to a number of factors. Land use (fig. 2) in the Pembina watershed is mostly cropland and some woodland, compared to a combination of cropland, forest, and woodland in watersheds, such as the Otter Tail River, in which lower SSC are found. The Otter Tail River and other sites with lower SSC flow through numerous lakes and reservoirs, resulting in lower SSC concentrations downstream (Stoner and others, 1998). In addition, SSC in the Otter Tail and Wild Rice Rivers have larger grain size (a higher percentage of sand-to-silt) than other sites in the basin (Tornes and others, 1997) and these larger grain sizes are not as easily suspended as smaller grain sizes and would tend to settle onto the streambed. Agricultural land use and stream modification for irrigation and drainage also can influence sediment transport to streams.

In addition to the differences stated above, SSC generally was higher in samples from main-stem Red River Basin sites upstream from Grand Forks than in samples from other tributary sites upstream from Grand Forks (fig. 10) because of the cumulative effect of streamflow at main-stem sites. However, the concentrations at the Red River at Grand Forks (site 36) and Pembina (site 47) generally are no higher than concentrations at surrounding tributary sites (fig. 11).

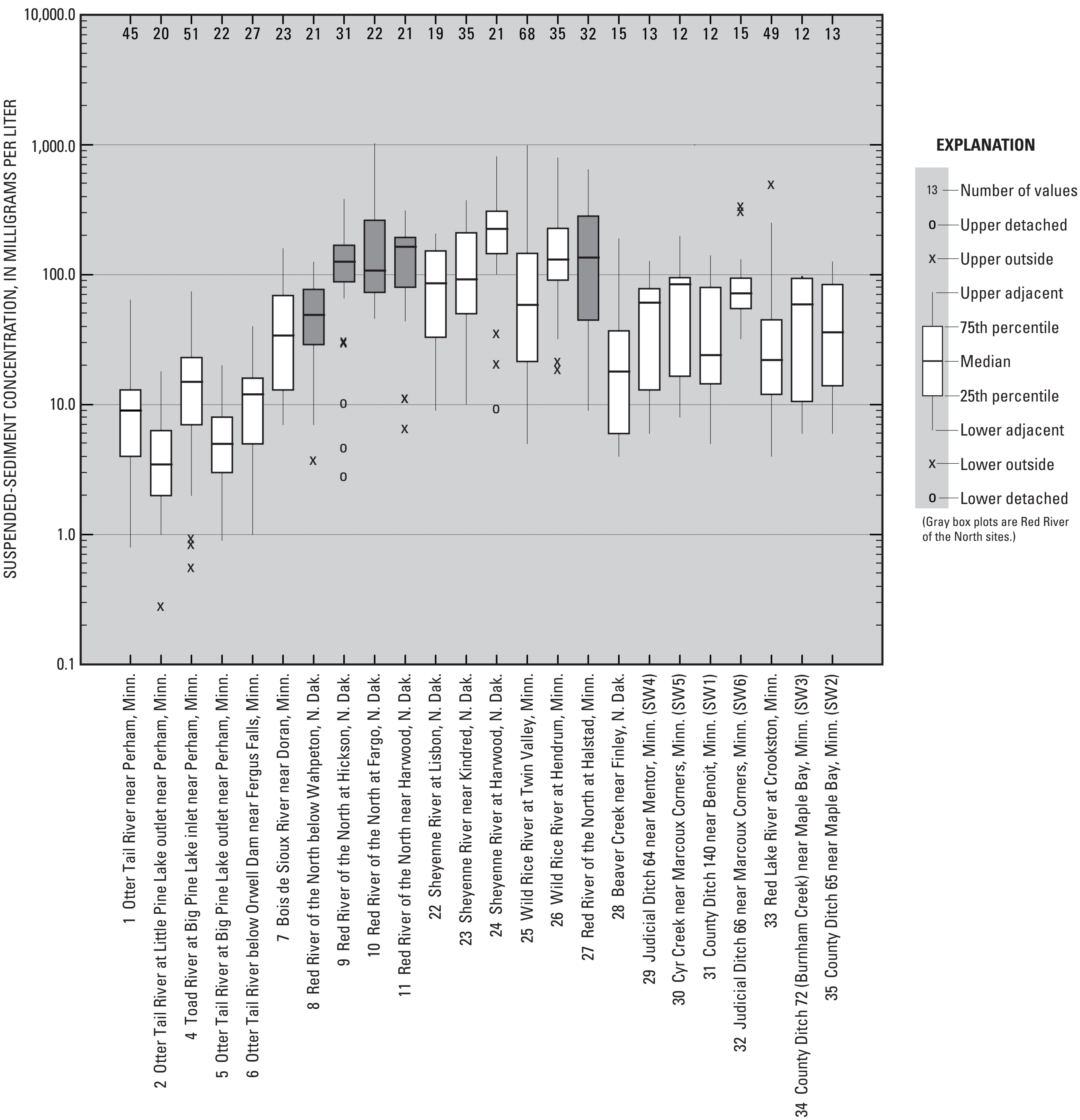

Figure 10. Distribution of suspended-sediment concentrations for stream sites in the Red River of the North Basin upstream from Grand Forks, North Dakota, 1990–2004.

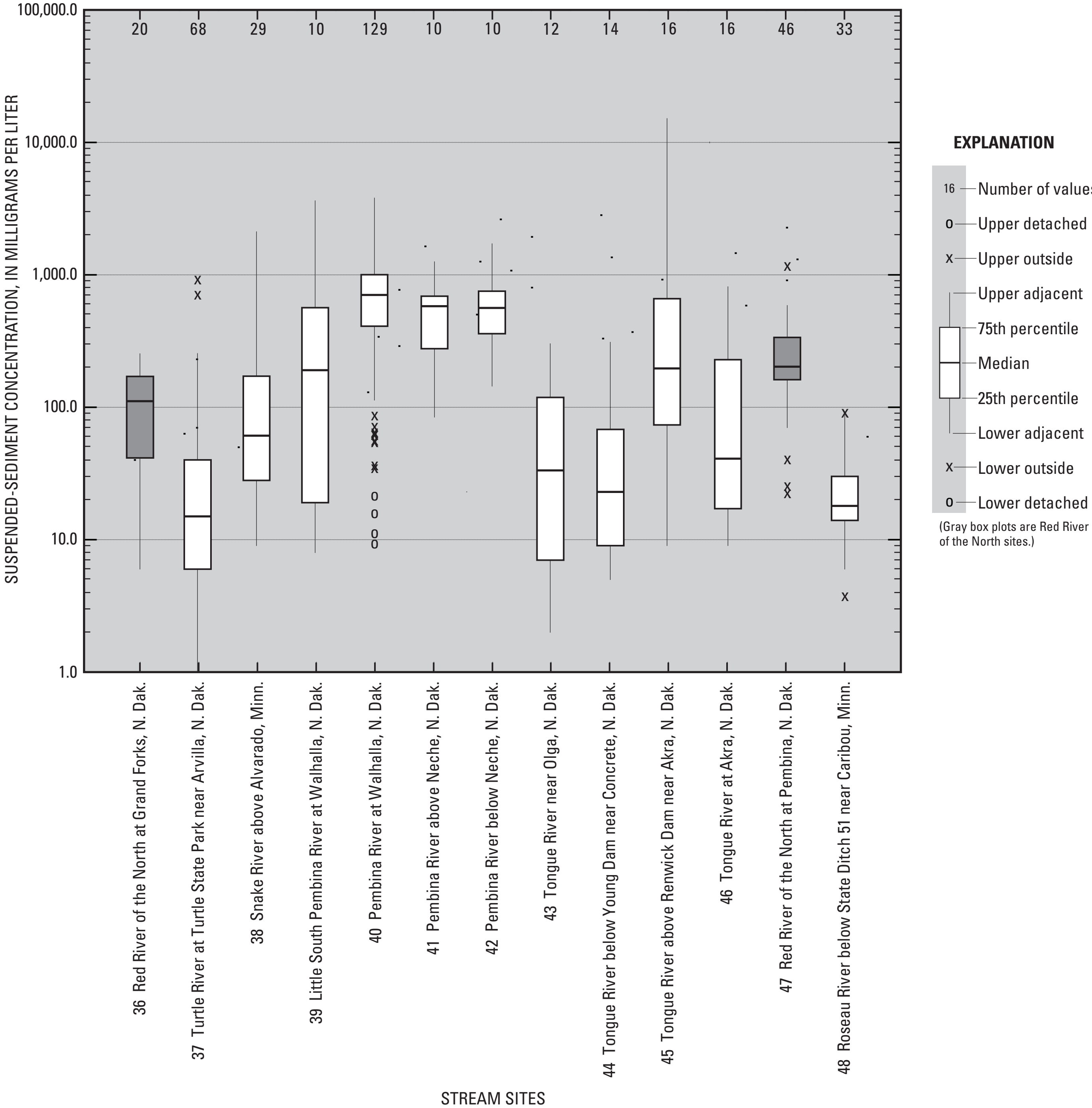

Figure 11. Distribution of suspended-sediment concentrations for stream sites in the Red River of the North Basin at Grand Forks, North Dakota and downstream, 1990–2004.

Pesticides

Pesticides include many chemicals that are commonly used to control weeds, insects, and other pests. The use of pesticides has many benefits, including increased food production, but also has adverse effects, including the adverse effect on water quality. Although pesticides seldom are detected in water at concentrations greater than human health guidelines, the likelihood of pesticide concentrations exceeding a human-health benchmark in streams is greatest for those streams draining urban or agricultural watersheds (Gilliom and others, 2006).

The occurrence of pesticides in aquatic systems may result from past or present uses in the watershed from agricultural land; golf courses; lawn and garden pest control in urban areas; forest management; maintenance of rights-of-way, for example, to control weeds on railroads; or atmospheric transport from other areas. The movement of pesticides through the aquatic system can be affected by aqueous solubility and adsorption to soils; vapor pressure; lipophilicity or the tendency of a chemical to dissolve in lipids; loss mechanisms, such as biological or chemical degradation and volatilization; and environmental factors, such as runoff events and topography (Tornes and Brigham, 1994). The transport of chemicals to surface water also is affected by some agricultural best management practices, such as vegetated buffers, and other conservation practices.

Pesticide data available for the Red River Basin is the result of several different studies and sampling programs. These studies and programs were designed for specific purposes and may be site specific; therefore, data for certain pesticides are available for only a few sites. This is not an indication that a particular pesticide was not used in other areas of the basin, but that there was no sampling program in those other areas. There is considerable difference in the sampling schemes between agencies in Minnesota and North Dakota. Pesticide data for surface water in the STORET data base are available for more sites in North Dakota than in Minnesota, but many of the North Dakota sites have fewer samples. The data in this report are limited to synthetic organic pesticides. Inorganic compounds used as pesticides, such as copper, are not included.

Surface-water and ground-water pesticide data are discussed separately. Red River Basin ground-water sites in NWIS or STORET from 1990 through 2004 do not have enough pesticide data to perform statistical analyses for trends and none of the sites met selection criteria. Most of the pesticide data available for the Red River Basin are from programs in which many sites over a large geographic area are sampled only once and this especially is true for ground-water surveys. Although these data cannot be used to detect trends at a particular site, they can be examined to determine which pesticides have been detected in surface and ground water and to assess potential contamination of water in the basin. Analyses in which pesticides are not detected because concentrations are below the reporting levels also are important in assessing contamination of water in the basin.

Surface Water

The NWIS data base was searched for all pesticide data collected from surface water during 1990–2004 in the Red River Basin. More than 120 different pesticides or metabolites were present in the data base. Pesticide data that met the selection criteria established in the Methods section of at least 8 samples over 2 years were found for 12 sites—2 sites on the Red River, 3 sites in Minnesota, and 7 sites in North Dakota. Among these 12 sites, 118 different pesticides met the selection criteria. Much of these data were collected between 1993 and 1995 as part of the Red River National Water Quality Assessment (NAWQA) study. Results from that study are presented in Tornes and others (1997). Of the 118 different pesticides, for the 12 sites that met the selection criteria, only 37 pesticides had concentrations that exceeded their respective reporting levels. Twenty-five of the 37 pesticides had more than 90 percent of their data censored at the highest reporting level. The 11 pesticides detected most often are listed in table 5.

Of the pesticides in table 5, de-ethylatrazine, metolachlor, and triallate were detected most frequently in surface water in the Red River Basin based on results in the USGS NWIS data base. The pesticide metabolite de-ethylatrazine was measured at concentrations greater than the reporting level 62 percent of the time (89 of 144 samples, table 5). Metolachlor and triallate were measured at concentrations greater than the reporting level 57 and 47 percent of the time, respectively.

Of the 12 sites that met selection criteria for any pesticide, 5 sites met the selection criteria for de-ethylatrazine, metolachlor, and triallate; 1 site was on the Red River, 2 sites were in Minnesota, and 2 sites were in North Dakota. All of the samples were collected between 1993 and 2000. The highest de-ethylatrazine and metolachlor concentrations were detected at Red River at Pembina (site 47, fig. 3). The highest triallate concentrations, however, were in samples from the Wild Rice River at Twin Valley (site 25, fig. 3). The Wild Rice River drains areas of woodland and cropland in the Moraine (fig. 2). Triallate is a pesticide that is typically used on barley, flax, and wheat (table 2) and it is applied more extensively in North Dakota than in Minnesota. Therefore, the high concentrations in the Wild Rice watershed were not expected.

The five USGS sites that met selection criteria were combined to determine if concentrations of de-ethylatrazine, atrazine, metolachlor, and triallate showed seasonal patterns. Atrazine was included for comparison to its metabolite, de-ethylatrazine. Most pesticides are detected during the spring, with the exception of atrazine, which had the highest concentrations during summer and early fall (fig. 12). Atrazine is typically applied in spring when crops are planted (Christensen and Ziegler, 1998). Because atrazine is applied mostly to corn, the timing and method of application is likely different than

Table 5. Summary of the most frequently detected pesticides from 12 surface-water sites in the Red River of the North Basin, 1990–2004.

[U.S. Geological Survey data from National Water Information System; µg/L, micrograms per liter; <, less than]

Pesticide	Concentration range (µg/L)	Median reported concentration (µg/L)	Number of observations greater than reporting level	Number of observations
Acetochlor	<0.002–0.585	<0.002	14	90
Alachlor	<0.002–0.284	<0.002	16	145
Atrazine	<0.001–0.54	0.016	19	145
Cyanazine	<0.004–0.25	<0.004	47	144
De-ethylatrazine	<0.002–0.056	0.004	89	144
EPTC	<0.002–0.488	<0.002	54	143
Metolachlor	<0.002–0.103	0.004	83	145
Simazine	<0.005–0.07	<0.005	18	144
Triallate	<0.001–0.21	<0.001	67	143
Triazine[1]	<0.1–0.7	<0.1	13	67
Trifluralin	<0.002–0.132	<0.002	54	143

[1]Triazines are a group of pesticides, which include atrazine, cyanazine, and simazine.

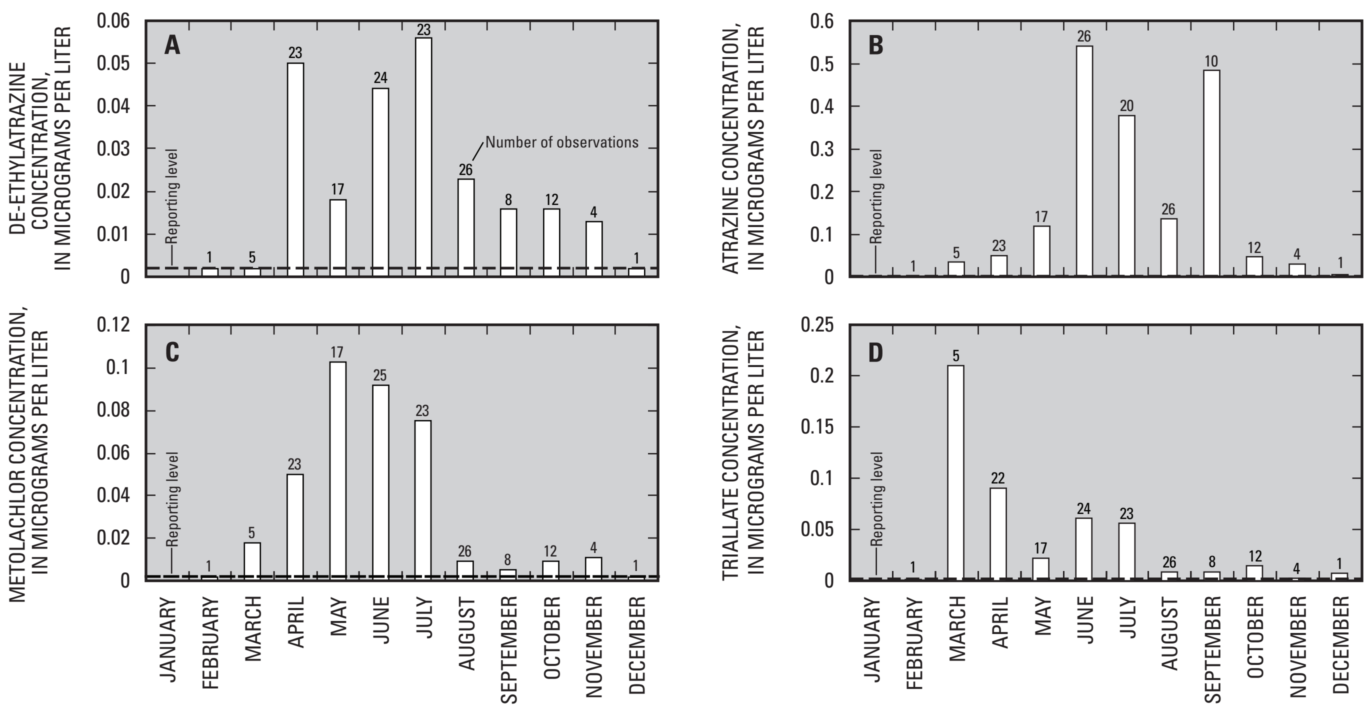

Figure 12. Monthly distribution of pesticide concentrations for five selected U.S. Geological Survey stream sites (1990–2004): (**A**) de-ethylatrazine, (**B**) atrazine, (**C**) metolachlor, and (**D**) triallate.

those for metolachlor and triallate, which are applied to other crops (table 2). In addition, physical factors, including the timing of the runoff and atrazine application, tillage type, amount of atrazine applied, and other land management techniques, may cause a difference in when high atrazine concentrations are detected (Christensen and Ziegler, 1998).

The STORET data base was searched for all 115 pesticides reported in table 2. In addition, STORET was searched for triazine compounds, which are a group of chemicals that include atrazine, cyanazine, and simazine. Analytical results for sites in the Red River Basin were available for 32 of the pesticides. Of these 32 pesticides, only censored values were reported for 20 of them. For the remaining 12 pesticides, very few concentrations were at or exceeded the detection limit. Only three pesticides, 2,4-D, bentazon, and picloram, were detected more than 10 percent of the time at concentrations that exceeded the detection limit. However, these three pesticides were not detected at any site that met the minimum selection criteria. Atrazine, cyanazine, and metolachlor were detected at three sites that met the selection criteria, but few of these detections were greater than the detection limit.

The pesticides 2,4-D, bentazon, and picloram were reported most frequently in samples in the STORET data base, but de-ethylatrazine, metolachlor, and triallate were reported most frequently in samples in the USGS NWIS data base. The North Dakota Department of Health collects many of the samples from North Dakota sites reported in STORET. Many of the sites and constituents sampled are based on routine monitoring for chemical constituents that are a concern. Most of the USGS NWIS pesticide data is the result of the 1993–95 Red River NAWQA study (Tornes and others, 1997) and included a broad range of chemical analyses. The differences in the most frequently detected pesticides between the two data bases may be because of the differences in sites sampled, dates sampled, laboratory methods, and the schedule of pesticide analyses that were determined. The differences also may be because of the difference in reporting levels and detection limits used by the different agencies.

Ground Water

Pesticide data for ground water in NWIS from 1990 through 2004 was widely distributed and denser than for 1970–1990. Ninety-nine wells were sampled in North Dakota and 157 wells were sampled in Minnesota for 1990–2004. Results for 156 pesticides were available for 1990–2004 in the NWIS data base. All concentrations were less than the reporting level for 127 pesticides. Of the remaining 29 pesticides, only 5 had more than 10 percent of values that exceeded their respective reporting level.

The chemicals that were detected most frequently were alachlor ethanesulfonic acid (ESA), atrazine, de-ethylatrazine, picloram, and triazine (table 6). Alachlor ESA is a metabolite of alachlor; de-ethylatrazine is a metabolite of atrazine; and triazine is a group of pesticides, which includes atrazine. Alachlor ESA concentrations ranged from less than 0.02 to 0.96 µg/L; atrazine concentrations ranged from less than 0.001 to 0.54 µg/L; de-ethylatrazine concentrations ranged from less than 0.002 to 1.9 µg/L; picloram concentrations ranged from less than 0.01 to 0.02 µg/L; and triazine concentrations ranged from less than 0.1 to 3 µg/L (table 6).

The chemicals that were detected most frequently in ground water showed consistent patterns of detection. Only alachlor ESA and picloram were detected in samples from Polk County, Minn., wells; the highest concentrations of atrazine, de-ethylatrazine, and triazine were in samples from Otter Tail County, Minn., wells. Aquifers in areas of high soil permeability may be susceptible to contamination because of the downward movement of pesticides.

Table 6. Summary of the most frequently detected pesticides in ground water from 263 sites in the Red River of the North Basin, 1990–2004.

[U.S. Geological Survey data from National Water Information System; µg/L, micrograms per liter; ESA, ethanesulfonic acid; <, less than]

Pesticide	Concentration range (µg/L)	Median reported concentration (µg/L)	Number of observations greater than reporting level	Number of observations
Alachlor ESA	<0.02–0.96	<0.02	10	61
Atrazine	<0.001–0.54	0.007	58	286
De-ethylatrazine	<0.002–1.9	0.006	13	285
Picloram	<0.01–0.02	<0.01	2	10
Triazine[1]	<0.1–3	<0.1	8	69

[1]Triazines are a group of pesticides, which include atrazine, cyanazine, and simazine.

Of the pesticides most frequently detected, only atrazine and picloram have MCLs established by the USEPA (U.S. Environmental Protection Agency, 1996). One of 285 samples exceeded the atrazine MCL of 3 µg/L. None of the 11 picloram samples exceeded the MCL of 0.5 µg/L.

There are few similarities between the most applied pesticides in Minnesota and North Dakota (table 2) and the most detected pesticides in the Red River Basin. This may be partially because table 2 includes all of the treated acreage, and thus, all of the basins in Minnesota and North Dakota, whereas tables 5 and 6 include only the Red River Basin. Crops grown and pesticides used in the Red River Basin are different than in the two States as a whole. Additionally, some pesticides, such as glyphosate, that were applied were not analyzed during 1990–2004 in the Red River Basin by the agencies that report data in NWIS or STORET.

Aside from the USGS NWIS data base, very little data existed for pesticides in ground water. STORET did not have ground-water data for most pesticides and the ND SWC also did not have ground-water pesticide data in their on-line data base. The MDA tested 18 ground water wells across Minnesota during 2004 for 21 pesticides or pesticide metabolites (electronic data from Catherine O'Dell, Minnesota Pollution Control Agency, August 30, 2006). Fourteen of the 21 pesticides were not detected in any well. Acetochlor oxanilic acid (OXA) and atrazine were each detected in one well. Acetochlor ESA, de-ethylatrazine, and metolachlor OXA each were detected in two wells. Alachlor ESA was detected in 5 of 18 wells with an average concentration of 0.14 µg/L, and metolachlor ESA was detected in 4 of 18 wells with an average concentration of 0.19 µg/L.

Comparison to Historical Data

Because this report is an update of the 1994 report by Tornes and Brigham, an attempt is made here to compare data from the 1970–1990 reporting period to that from the 1990–2004 reporting period. However, sampling schemes, methods, and sites sampled and median annual streamflow are different between the two reporting periods; therefore, a comparison of water-quality is difficult. Generally, however, a few consistencies and differences were evident.

For nitrogen compounds, samples from Pembina River surface-water sites had the highest nitrite plus nitrate concentrations during both reporting periods. However, TKN concentrations also were high at these sites when compared to other Red River Basin sites during 1970–90; whereas TKN concentrations at Pembina River sites during 1990–2004 were not substantially different than concentrations at other sites in the basin. During 1970–90 total phosphorus concentrations generally were highest at Red River sites, whereas during 1990–2004 total phosphorus concentrations generally were highest at Pembina River sites.

During 1970–90, three counties in North Dakota, Barnes, Griggs, and Steele, and only Otter Tail County in Minnesota had wells with nitrate concentrations greater than the 10 mg/L MCL. During 1990–2004, 18 counties in North Dakota and five counties in Minnesota had wells with nitrate concentrations greater than the MCL. However, considerably more samples were collected during 1990–2004 than during 1970–90, thus making the probability of detecting concentrations that exceeded the MCL greater during 1990–2004.

For SSC, only 13 sites had sufficient data during 1970–90 (Tornes and Brigham, 1994, fig. 20), whereas data were available for 43 sites during 1990–2004 (figs. 10 and 11). Pembina River sites had high SSC relative to other sites during both reporting periods.

The most notable differences between the two reporting periods were for pesticides. This is because samples were analyzed for different pesticides during the two reporting periods and because different pesticides were detected. Different pesticides were in the data bases for a number of reasons, including changes in the crops grown, the availability and use of newly developed pesticides, the banning of some pesticides, and the loss of favor of some pesticides among farmers. Of the pesticides that were analyzed during both reporting periods, different pesticides were detected, in part, because of changes in analytical methods and reporting levels.

When research supports the negative effects of certain pesticides on human health and wildlife, the USEPA acts to ban the pesticides. Since the Federal Environmental Pesticide Control Act was implemented in 1972, certain pesticides have continued to be added to the list beginning with the banning of DDT in 1972. The banning of certain pesticides affects what chemicals are detected in water and also affects the differences between the historical data (Tornes and Brigham, 1994) and the data presented in this report.

None of the most frequently detected pesticides for which water samples were collected and analyzed by the USGS during 1970–90 were detected frequently during 1990–2004. Only one pesticide, 2,4-D, was detected in more than 10 percent of surface-water samples that were analyzed during the 1970–90 reporting period, compared to 11 pesticides, shown in table 5, that were detected in more than 10 percent of the samples analyzed during 1990–2004.

Summary

Nutrient, suspended sediment, and pesticide data from 1990–2004 from the Red River of the North was compiled and summarized in this report, which serves as an update to the report, *Nutrients, suspended sediment, and pesticides in waters of the Red River of the North Basin, Minnesota, North Dakota, and South Dakota, 1970–90*. Water quality continues to be a concern for this mainly agricultural basin, and, therefore, the U.S. Geological Survey (USGS) and the Minnesota Pollution Control Agency (MPCA) cooperated to provide this update.

The Red River Basin is divided into the four physiographic areas, the Drift Prairie, Red River Valley Lake Plain, Lake-Washed Till Plain, and Moraine, based on topography and soils. These physiographic areas have some bearing on land use and, therefore, may be related to water quality. Sixty-six percent of the agricultural land in the basin is cropland. Nutrients and pesticides are applied to most of the crops in an effort to maximize production.

Fertilizer applications are greatest in Polk County, Minn. and Cass County, N. Dak., both of which border the main stem of the Red River. Manure application is greatest in Otter Tail County, Minn. Pesticides applied in the greatest abundance in Minnesota and North Dakota are 2,4-D, MCPA, and dicamba.

Streamflow varied widely throughout the basin during the 1990–2004 study period. For 19 of 22 streamflow sites, median annual streamflow during the study period exceeded the long-term average streamflow for the period of record at those sites. Streamflow at all four main-stem Red River sites exceeded long term average streamflows. High streamflows have substantial effect on water quality, especially in the spring when agricultural chemicals are applied and when there is no crop cover to hold the soil in place.

Although nutrients occur naturally in the environment, agricultural practices can increase their transport to natural waters, and transport may increase during storms. Nitrite plus nitrate concentrations ranged from 0.02 to 5.2 milligrams per liter at 23 USGS stream sampling sites and from less than 0.005 to 7.7 milligrams per liter at 23 USEPA STORET stream sites. Stream sites on the Pembina River, that drain a watershed mainly in the Drift Prairie physiographic area, had the highest nitrite plus nitrate concentrations compared to other Red River Basin sites. All nitrite plus nitrate concentrations at USGS stream sites included in this report during 1990 through 2004 were less than the USEPA drinking water standard of 10 milligrams per liter. Total Kjeldahl nitrogen concentrations at USGS stream sites ranged from 0.1 to 7.5 milligrams per liter, whereas STORET stream sites had total Kjeldahl nitrogen concentrations ranging from 0.234 to 2.38 milligrams per liter.

Total phosphorus concentrations ranged from less than 0.005 to 4.14 milligrams per liter for USGS stream sites and from less than 0.018 to 1.44 mg/L for STORET stream sites. Pembina River sites had higher total phosphorus concentrations than surrounding sites. Soil characteristics or agricultural practices may cause more phosphorus to be transported to the streams in the Drift Prairie physiographic area than to other streams. Dissolved phosphorus data were presented for USGS sites only, and concentrations ranged from 0.003 to 4.13 milligrams per liter; dissolved phosphorus concentrations were highest in samples from the Bois de Sioux and Pembina River sites.

Ground-water samples for nutrients also were collected and measured by a number of agencies in the basin and are compiled and summarized in this report. The number of wells sampled in each county varied greatly and ranged from zero to more than 300.

Reported nitrate concentrations in ground water from North Dakota counties ranged from less than 0.023 to 113 milligrams per liter during 1990–2004. Sheridan County, in the Drift Prairie physiographic area, had the highest ground-water nitrate concentrations when compared to other well sites on the North Dakota side of the basin. Nitrate concentrations in ground water from Minnesota counties ranged from less than 0.005 to 133 milligrams per liter. The highest concentrations were in samples from in the Lake-Washed Till Plain and Moraine physiographic areas. Marshall and Otter Tail Counties in Minnesota had high fertilizer applications relative to other Minnesota counties in 2002, which may explain high nitrate concentrations in ground water; however, Sheridan County in North Dakota did not have high fertilizer application rates in 2002 compared to other North Dakota and Minnesota counties. Although there appeared to be a correlation between fertilizer applications and ground water nitrate concentrations in Minnesota counties, there appeared to be little correlation between fertilizer applications and nitrate concentrations in ground water in North Dakota counties.

Suspended-sediment data were available for 48 surface-water sites in Minnesota, 31 sites in North Dakota, and 10 main-stem Red River sites. Median suspended-sediment concentrations ranged from about 4 to 706 milligrams per liter. The highest concentrations occurred in samples from the Pembina River, which is located in northern North Dakota in the Red River Valley Lake Plain and drains part of the Drift Prairie.

Pesticide data from 12 USGS stream sites in the Red River Basin were examined. Most of the 118 chemicals for which analyses were performed were either not detected in any sample or occurred below their respective reporting limits. De-ethylatrazine, which is a metabolite of atrazine, metolachlor, and triallate were detected most frequently at USGS stream sites. The highest de-ethylatrazine and metolachlor concentrations were detected at the Red River at Pembina. The highest triallate concentrations were detected at Wild Rice River at Twin Valley. The highest concentrations of these three pesticides were detected during the spring, in contrast to atrazine, for which the highest concentrations were detected during summer and early fall.

Some surface-water pesticide data were available in STORET. The most frequently detected pesticides for Red

River Basin sites in the STORET data base were 2,4-D, bentazon, and picloram.

The pesticide compounds detected most frequently in ground water were alachlor ESA, atrazine, de-ethylatrazine, picloram, and triazine at USGS-sampled well sites. Very little ground-water data were available from STORET. The USEPA has established MCLs for atrazine and picloram in drinking water of 0.003 and 0.5 milligrams per liter, respectively. None of the 11 picloram results exceeded this level, and one of the 285 ground-water atrazine samples exceeded the MCL.

When a comparison was made with the data presented in this report for 1990–2004 and the historical data during 1970–90, a few similarities as well as differences are evident. Pembina River surface-water sites continued to have the highest nitrite plus nitrate and suspended-sediment concentrations during the 1990–2004 time period. However, the Pembina River also had the highest total phosphorus concentrations for 1990–2004, in contrast to 1970–90, when Red River sites generally had the higher total phosphorus concentrations than Pembina River sites.

The most notable differences between the two reporting periods were seen in the pesticides, partly because different pesticides were analyzed during 1970–90 and 1990–2004. None of the most frequently detected pesticides or metabolites sampled and analyzed by the U.S. Geological Survey or available in STORET during 1990–2004 were detected frequently during 1970–90, with the exception of 2,4-D.

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