2003 Stream Monitoring and Assessment for 11 Metropolitan Area Streams

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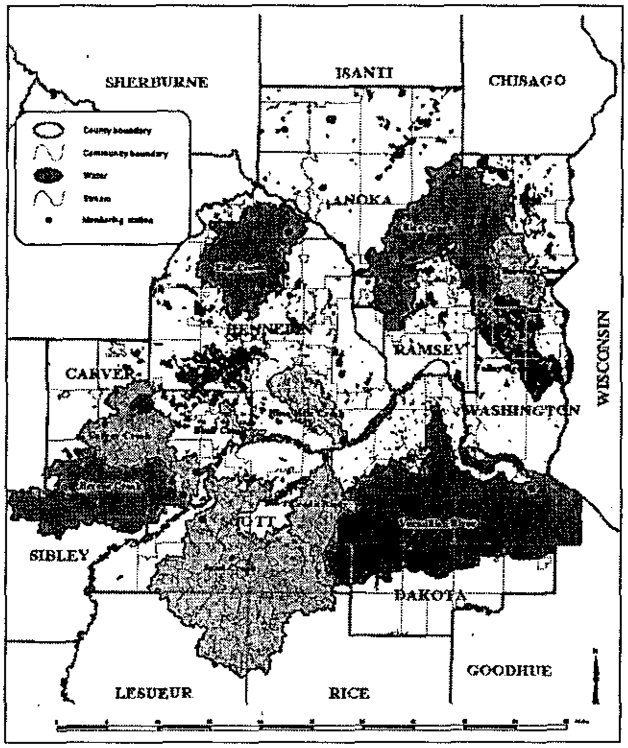

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EXECUTIVE SUMMARY

The Metropolitan Council has conducted environmental monitoring of stream water quality since 1989. The Council and its partners currently operate monitoring stations on 25 streams in the seven-county metropolitan area.

This report presents the assessment of 2003 and historical water quality and water quantity dynamics in 11 of the Metropolitan Area streams. The Metropolitan Council and monitoring partners collected the data used in this report with the exception of Elm and Rice Creeks, which were monitored by the United States Geological Survey and the Rice Creek Watershed District, respectively. The streams assessed in this report and the respective main stem river into which they discharge are listed below:

Mississippi River: Vermillion River, Rice Creek, and Elm Creek

Minnesota River: Bevens Creek, Bluff Creek, Carver Creek, Credit River, Nine Mile Creek, and Sand Creek

St. Croix River: Browns Creek and Valley Creek

Water quality and quantity variables assessed in this report were stream flow rate and volume, total phosphorus, total suspended solids, total dissolved phosphorus, and nitrate.

2003 and historical pollutant loads and streamflow:

For most of the Metropolitan Area, 2003 was a year of below-normal precipitation. Therefore the flow in the streams was less than would be expected during a typical year, and annual pollutant loads were less than typical, as well.

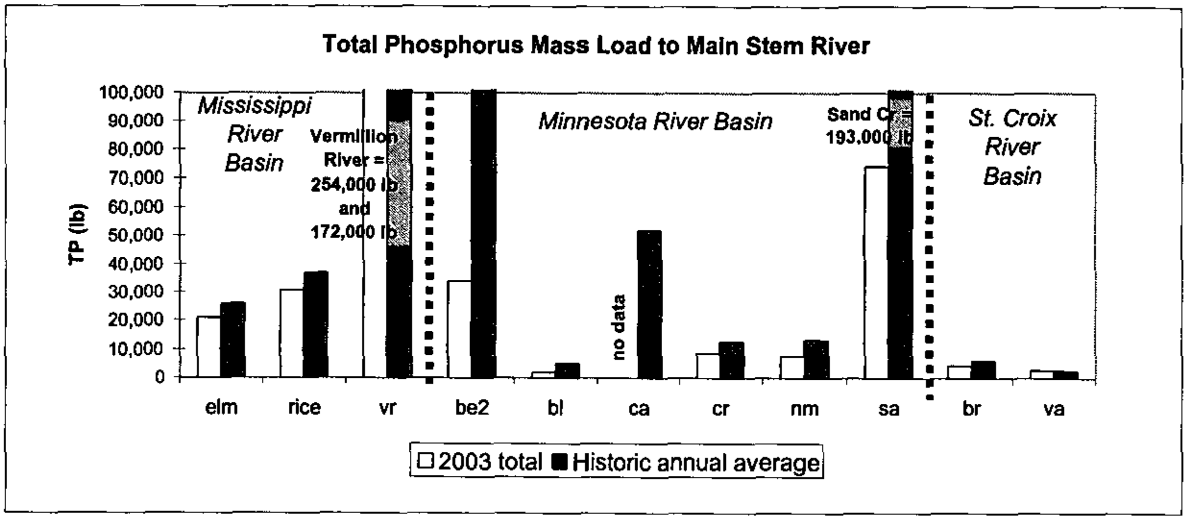
Figure E1 presents the 2003 total and the historical average annual loads for total phosphorus (TP), total suspended solids (TSS), and nitrate for the 11 streams, organized according to recipient main stem river.

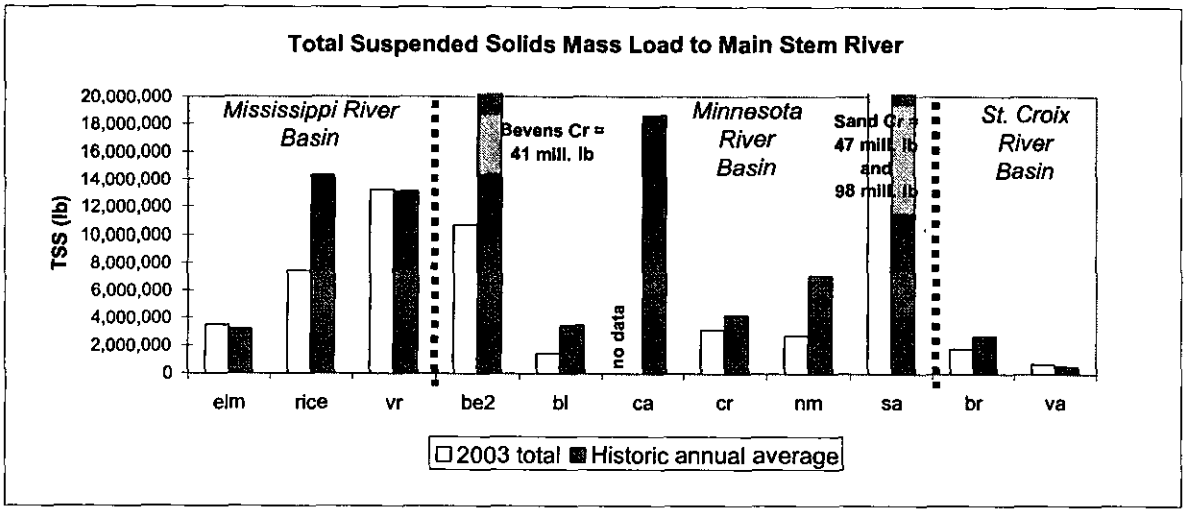
The Mississippi River tributaries discharged moderate loads of TP, TSS, and nitrate with the exception of TP and nitrate loads discharged by the Vermillion River. It had comparatively high nutrient (TP and nitrate) loads for both 2003 and for the historical annual average. The effluent discharged into the Vermillion from the Empire Wastewater Treatment Plant in Empire Township is a significant source of the river's nutrient load.

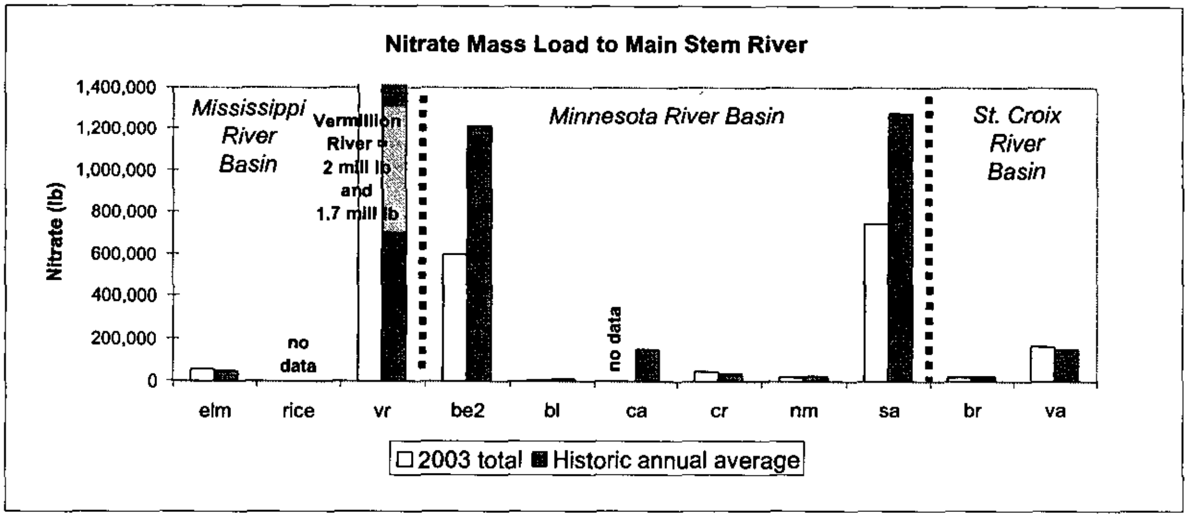
The Minnesota River tributaries varied in nutrient and TSS loads. Sand and Bevens Creeks had comparatively high loads for TP, TSS, and nitrate. Carver Creek discharged comparatively moderate loads, and Bluff Creek, Nine-Mile Creek, and Credit River discharged comparatively low loads to the Minnesota.

The St. Croix River tributaries discharged comparatively low loads of all three constituents. Of note is the nitrate load of Valley Creek, which is five times greater

Figure E1. Stream Comparison – 2003 and Historical Pollutant Loads Discharged to Main Stem Rivers


Total Phosphorus Mass Load to Main Stem River


Total Suspended Solids Mass Load to Main Stem River


Nitrate Mass Load to Main Stem River

Elm = Elm Creek Rice = Rice Creek vr = Vermillion River be2 = Bevens Creek ca = Carver Creek
cr = Credit River nm = Nine Mile Creek sa = Sand Creek bl = Bluff Creek br = Browns Creek va = Valley Creek

than that of Browns Creek, also a tributary of the St. Croix. Studies conducted by researchers at the Science Museum of Minnesota's St. Croix Field Station have shown that discharge of nitrate-contaminated groundwater is the primary source of nitrate to Valley Creek.

Trend Analysis:

Trend analysis (examination of stream data for changes over time) was performed on annual loads and flow-weighted mean concentrations of the 11 streams. The analysis did identify some changes in water quality and quantity over time, but additional analysis of changes in watershed land use and management policies is necessary to substantiate those trends.

Of note, however, is Nine Mile Creek, a tributary of the Minnesota River. Trend analysis indicated improvement in water quality and decrease in pollutant loads since 1993, when the Nine Mile Creek Watershed District completed the Lower Valley Project. This project stabilized scarps and restored streambed stability in the Nine Mile Creek segment just south of Old Shakopee Road to just upstream of the stream outlet to the Minnesota River.

Stream Assessment Rankings

Three assessment methods were used to rank the streams discussed in this report.

- Percent deviation from the recipient river concentration was used to assess whether tributary streams were causing degradation of the main stem rivers.
- Exceedance of the Minnesota Pollution Control Agency's 25 NTU turbidity standard was used to assess whether the streams were meeting state water quality goals.
- Deviation from ecoregion benchmarks was used to assess how stream water quality differed from predicted pre-settlement concentrations.

The ranks from the three methods were averaged, and the resulting ranking of streams, from lowest rank (and therefore relatively high water quality) to highest rank (relatively low water quality) is:

Valley Creek (1)
Credit River and Elm Creek (2)
Vermillion River (4)
Nine Mile and Rice Creeks (5)
Browns Creek (7)
Bevens Creek (8)
Carver Creek (9)
Sand Creek (10)
Bluff Creek (11)

ACKNOWLEDGEMENTS

This report was prepared by Judy Sventek (Environmental Planning Analyst; phone: 651-602-1156) and Karen Jensen (Environmental Planner, phone 651-602-1401), both of the Environmental Quality Assurance Department of the Metropolitan Council Environmental Services Division (MCES). Questions about the content of this report can be referred directly to them.

Data was collected and verified by staff in the Environmental Quality Assurance Department of the Metropolitan Council's Environmental Services Division. Special thanks go to Tim Pattock, Mike Ahlf, Cassandra Champion, Leigh Harrod, Heather Offerman, Hong Wang, Steve Kloiber, Kent Johnson and Marcel Jouseau.

Council staff wishes to thank our local partners who have been working with MCES staff to operate and maintain stream monitoring stations throughout the Metropolitan Area. Special thanks go to Browns Creek Watershed District, Dakota County and Dakota County Soil and Water Conservation District, Carver County and Carver County Soil and Water Conservation District, Scott County and Scott County Soil and Water Conservation District, Nine-Mile Creek Watershed District, St. Croix Watershed Research Station, Rice Creek Watershed District, Riley-Purgatory-Bluff Creek Watershed District, United States Geological Survey, Valley Branch Watershed District, and Washington County Soil and Waters Conservation District.

Finally staff wish to thank the Minnesota Legislature and the Minnesota Pollution Control Agency for providing funding for several of the stations discussed in this report.

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Overview

Growth in the Twin Cities Metropolitan Area during the 1990s has placed strains upon our natural resources. This growth has brought prosperity – new jobs, rising incomes, new tax revenue, and the highest rate of home ownership in the nation. However, growth has brought challenges as well. Urbanization is consuming our remaining natural areas. Stormwater runoff (rainfall, snowmelt, or irrigation water that has not evaporated or infiltrated into the soil) has polluted our rivers, lakes and streams in the metro area.

Stormwater runoff from both urban and rural landscapes transports nonpoint source pollution into metro area lakes, rivers and streams. Nonpoint pollution is generated by the many diverse land uses in the metro area and the everyday activities of its population. Human activities that create nonpoint source pollution include, among others: applying excessive fertilizer to lawns; plowing fields or operating construction sites in a manner that results in soil erosion; discarding grass clippings into streets or directly into storm drains; or driving cars that leak oil or exhaust hydrocarbon particulates into the air.

Nonpoint source pollution begins when agricultural production or urban development causes alteration of the natural landscape. Undisturbed vegetation and natural drainage systems filter out pollutants generated by stormwater runoff, and thus minimize impact to the receiving waters. The efficiency of these natural drainage systems is reduced or negated by an increase in impervious surfaces, often created by new structures, wider roads and compacted soils. Both the volume and rate of runoff increase in a landscape altered by impervious surfaces and some agricultural practices, and more pollution is transported by the runoff into receiving water bodies.

Metropolitan Council Monitoring Programs

Collectively the nonpoint and point source programs at the Metropolitan Council (Council) form the policy basis for achieving the Council's no adverse impact goal, "*water quality leaving the metro area is as good as the water quality entering the metro area, and in compliance with federal and state regulations*". No adverse impact means that as a region, we must live within the capacity of the water resource systems to assimilate the activities of our population without furthering harm to our water resources.

The Council has several programs in place that can be used to measure our attempts at meeting the no adverse impact goal: our target pollution load effort and our monitoring programs for watershed outlets, lakes, and rivers. The Nonpoint Source Program (NPS) started in 1989, and involves only Minnesota River tributaries. The Watershed Outlet Monitoring Program 1 (WOMP1) started in 1995. The Watershed Outlet Monitoring Program 2 (WOMP2) started in 1998. The stream stations in both WOMP programs are operated by cooperating agencies. The Council's stream monitoring programs currently collect data from 25 streams at 26 monitoring stations as summarized in the following:

Stream	Monitoring Program	Monitoring Start/End Date	Participating Cooperator
Lower Rum River	WOMP1	1996	Anoka SWCD
Carnelian-Marine Outlet	WOMP1	1995	Carnelian-Marine WD
Silver Creek	WOMP1	1998	Carnelian-Marine WD
Coon Creek	WOMP1	1995/1999	Coon Creek WD
Vermillion River	WOMP1	1995	Dakota SWCD
Elm Creek	WOMP1	1995/1998	Elm Creek WMO
Pioneer Creek	WOMP1	1995/1998	Pioneer-Sarah WMO
Sarah Creek	WOMP1	1995/1998	Pioneer-Sarah WMO
Fish Creek	WOMP1	1995	Ramsey-Washington Metro WD
Battle Creek	WOMP1	1995	Ramsey-Washington Metro WD
Beltline Interceptor	WOMP1	1995	Ramsey-Washington Metro WD
Rice Creek	WOMP1	1995	Rice Creek WD
Shingle Creek	WOMP1	1995	Shingle Creek WMO
Springbrook	WOMP1	1995/1998	Six Cities WMO
Browns Creek	WOMP1	1997	Washington SWCD
Crow River-South	WOMP1	2001	Carver County
Bassett Creek	WOMP2	2000	Bassett Creek WMO
Cannon River	WOMP2	1999	Dakota SWCD
Crow River	WOMP2	1998	Wright SWCD
Eagle Creek	WOMP2	1999	Lower Minnesota WD
Minnehaha Creek	WOMP2	1998	Minneapolis Park & Recreation Board
Riley Creek	WOMP2	1999	Riley-Purgatory-Bluff Creeks WD
Valley Creek	WOMP2	1998	Valley Branch WD
Willow Creek	WOMP2	1999	Black Dog WMO
Bluff Creek	NPS	1991	Metropolitan Council
Carver Creek	NPS	1989	Metropolitan Council
Credit River	NPS	1988	Metropolitan Council
Bevens Creek – Lower	NPS	1989	Metropolitan Council
Bevens Creek – Upper	NPS	1992	Metropolitan Council
Nine-Mile Creek	NPS	1988	Metropolitan Council
Sand Creek	NPS	1988	Metropolitan Council

In 2001 and 2002, MCES staff prepared stream monitoring reports that included annual monitoring data from the 28 MCES stream monitoring stations. This report includes assessments of 11 streams: 9 of the 25 streams in the Council's monitoring program and two streams (Elm and Rice Creeks) monitored by other agencies (U.S.G.S. and Rice Creek Watershed District, respectively). Assessments in this report include analysis of 2003 monitoring data, a historical pollutant loading assessment for the 11 streams completed with the FLUX computer model, and ranking of the streams according to three water quality criteria. The streams discussed in this report are Nine-Mile Creek, Carver Creek, Credit River, Bluff Creek, Bevens Creek (lower station), Sand Creek, Valley Creek, Browns Creek, Vermillion River, Elm Creek and Rice Creek.

Target Pollutant Load Project

In 1990, the Minnesota Legislature charged the Metropolitan Council with the preparation of target pollution loads for watersheds situated within the seven-county metropolitan area. The total mass of a pollutant leaving a watershed is the stream's load, which is typically measured in pounds per year. A stream's load is the product of the amount of water flowing in the stream and the concentration of a chemical substance, such as phosphorus, nitrate or sediment. The target pollution loads are supposed to account for both the stream's loading characteristics, as well as any additional pollution that may be generated by anthropogenic land use activity.

Target pollution loads are being developed at the Council. The first step in developing the target pollution loads is to determine the existing water quality in streams that are tributary to the Mississippi, Minnesota and St. Croix Rivers. MCES and local partners have established a network of stream monitoring stations at 28 sites on 26 streams in the metro area and in the vicinity of Mankato. All streams are continuously monitored and sampled under both normal, baseflow conditions, as well as during significant runoff events, such as snowmelt or heavy rainfall. These monitoring stations provide the information necessary to determine the level, type and extent of nonpoint pollution coming from the watershed.

The next step is to set goals (targets) for future water quality in these watersheds. These water quality target loads would be aimed at having no adverse impact on the rivers as water passes through the metropolitan area. This process is compatible with the State's efforts to determine total maximum daily loads. The State is required by federal mandate to determine the allowable load that can be discharged into waters which have been determined to be already "impaired" by either point on nonpoint source inputs.

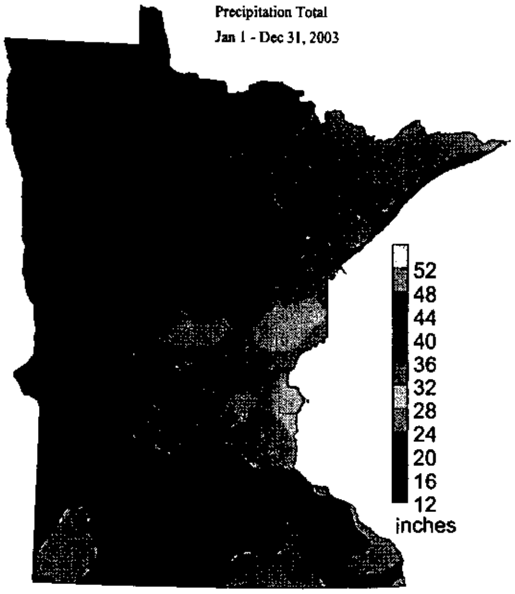
Climate

Annual statewide total precipitation data for the year 2003 and departure from normal precipitation data as obtained from the Minnesota State Climatology Office are presented in Figures 1 and 2. The figures indicate that statewide, Minnesota was drier than normal. Statewide the annual precipitation departure from normal ranged from + 2 to –10 inches.

Figure 1 indicates that overall the metro area was drier than normal in 2003. Precipitation totals ranged from 22 inches at the airport weather station in the central part of the region, to 28 inches in the northeastern part of the region. The annual precipitation departure from normal ranged from –2 to –8 inches below normal (Figure 2).

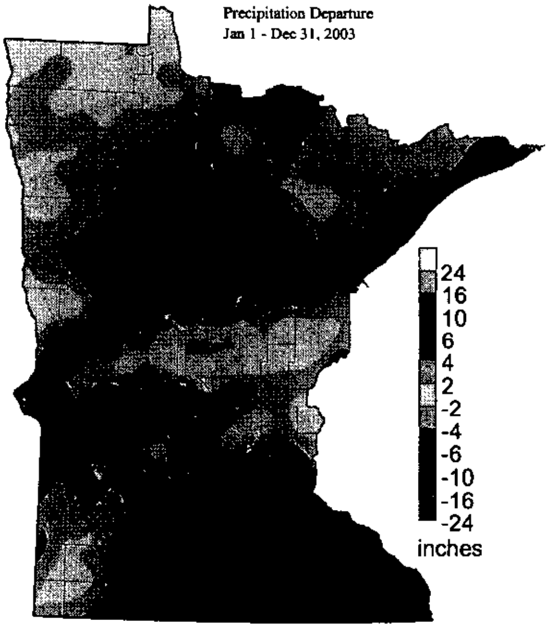
Figure 3 shows the actual precipitation and departure from normal precipitation for 2003 at the airport weather station. The year started off close to normal in regards to amount of precipitation, had more than normal precipitation in May and June and then quickly fell below normal for the rest of the year. The average monthly temperature for 2003 ranged from 15.3 F to 75.3 F in August. Overall the average monthly temperatures were very close to the normal average monthly temperatures. The 30-year (1971-2000) average temperature and precipitation data for the Minneapolis-St. Paul weather station at the airport is summarized in Figure 4.

Figure 1. Minnesota 2003 Total Precipitation



State Climatology Office - DNR Waters, March 12, 2004

Figure 2. Minnesota 2003 Precipitation Departure From Normal



State Climatology Office - DNR Waters, March 12, 2004

Figure 3. Actual and Normal Minneapolis-St. Paul Airport Precipitation

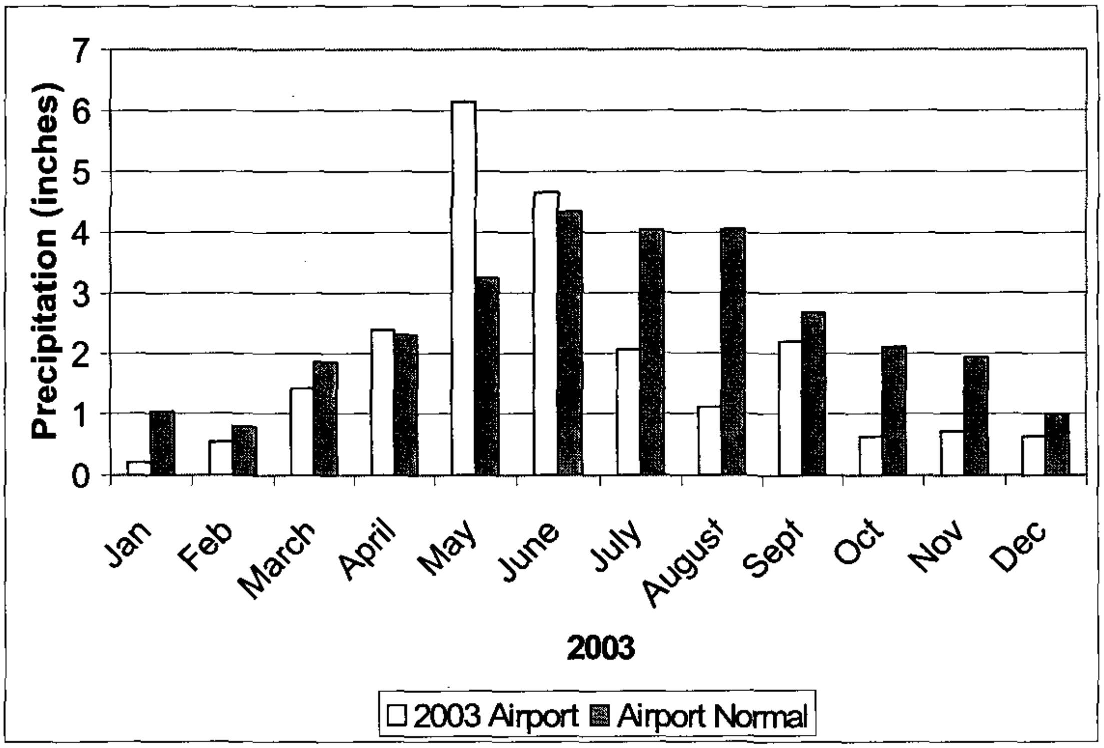
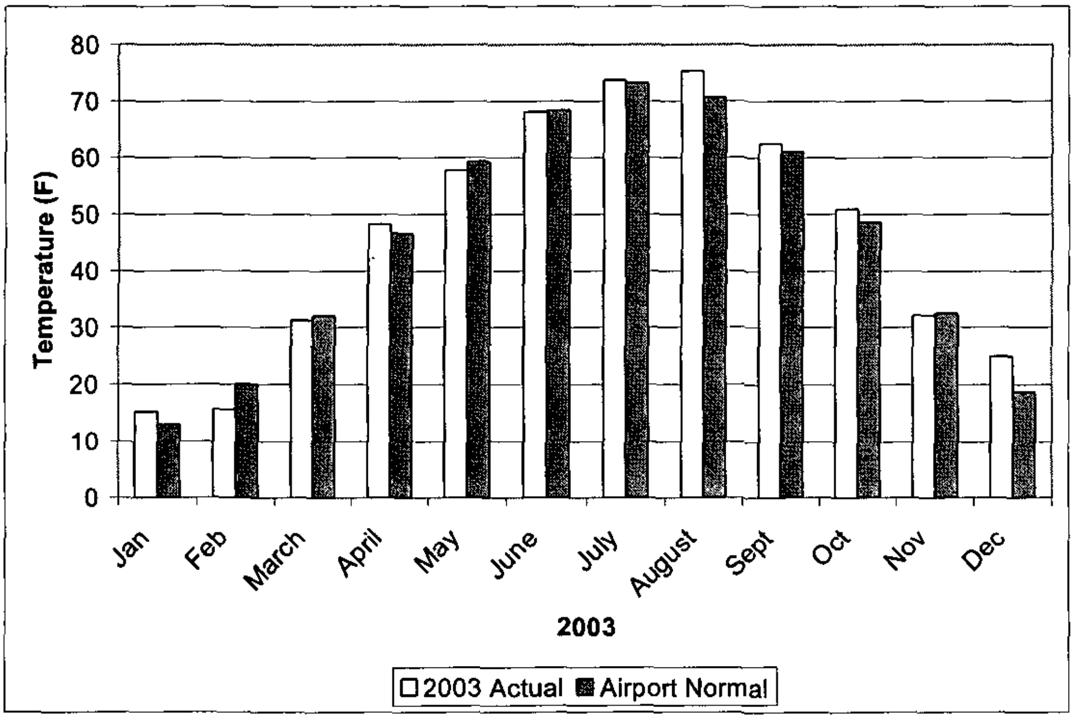


Figure 4. Actual and Normal Minneapolis-St. Paul Airport Temperature



Because annual precipitation amounts vary across the metro area, each stream was analyzed using data from the meteorological station or stations closest to that stream (Table 1). While the 2003 precipitation was below historical averages, the actual deficit varied by watershed. The 2003 deficit was greatest for the Minnesota River tributaries. The 2003 precipitation in the Bevens and Sand Creek watersheds was 44% below average precipitation for period 1989 – 2003. The deficit was 29% in Bluff Creek and Credit River.

Table 1. Meteorological Stations and Data for Each Stream

Stream	Recipient River	Proximate Meteorological Stations	2003 Precip (inches)	1989 -2003 Average Annual Precip, (inches)	2003 Precip. Deficit (%)
Elm	Mississippi	New Hope / Delano (Sta. #215838 + #212088)	26.9	30.2	-11%
Rice	Mississippi	St. Paul / Lake Vadnais (Sta. #217377 +#218477)	27.7	34.5	-20%
Vermillion	Mississippi	Hastings Dam (Sta. #213567)	26.2	32.1	-18%
Bevens	Minnesota	Jordan (Sta. # 214176)	17.7	31.9	-44%
Bluff	Minnesota	Chaska/Chanhassen (Sta. # 211448 + #21465)	19.9	27.9	-29%
Carver	Minnesota	Chaska/Chanhassen (Sta. # 211448 + #21465)	19.9	27.9	-29%
Credit	Minnesota	Savage / Bloomington (Sta. # 217538)	29.4	34.5	-15%
Nine-Mile	Minnesota	Savage / Bloomington (Sta. # 217538)	29.4	34.5	-15%
Sand	Minnesota	Jordan (Sta. # 214176)	17.7	31.9	-44%
Browns	St Croix	Stillwater / Browns Creek Watershed District (Sta. #218037)	24.2	33.8	-28%
Valley	St Croix	Stillwater (Sta. #218037)	28.6	33.0	-13%

Geology and Geomorphology

Most of the glacial sediment in Minnesota was deposited during the Wisconsin Age, which began about 75,000 years ago. Several glacial advances and retreats left sediments across the state. The most recent advances were the Rainy, Superior and Des Moines lobes during the late Wisconsin Age.

Much of the metro area is underlain by sediments, boulders, gravel, sand, silt and clay, laid down by glaciers between 20,000 and 14,000 years ago from two distinct glacial lobes, the Superior Lobe and the Grantsburg Sub-Lobe of the Des Moines Lobe. While sediments deposited in glacial events prior to this are present in some areas, weathering and erosion have obscured them.

The Superior Lobe deposited the St. Croix Moraine in the metro area composed of distinctly red sandy sediments derived from the red sandstone, shale and agates of the Lake Superior Region. The eastern edge of the hilly St. Croix Moraine extends from the northern Dakota County and St. Paul area through Stillwater into Wisconsin.

In the metro area the St. Croix Moraine was overridden by the Des Moines Lobe and its Grantsburg sub-lobe except for an area of Washington and Dakota Counties. The sediments deposited by this lobe are primarily gray to brown clayey moraine sediments derived from shales and limestones of North Dakota and Canada. In the northern part of this area, part of the Big Woods, the terrain is rugged and forested. Southward the relief decreases and is dominated by prairie.

In the Anoka County area, meltwaters from the retreating glaciers trapped behind the St. Croix Moraine left the sandy soils known as the Anoka Sand Plain. The terrain in the Anoka Sand Plain is a generally undulating plain. Beyond the margin of the most recent glacial advances in Southern Washington County and Southeastern Dakota County lies a nearly featureless area with sediments from previous glacial episodes as well as outwash from the retreat of the more recent glacial events. These deposits are thin to absent in areas leaving only thin soils over bedrock.

In more recent times, rivers and streams have carved the glacial landscape. Most notably are the valleys associated with the Minnesota, St. Croix, and Mississippi Rivers. The higher volumes of water carried by these rivers during the glacial retreat created wide valleys and deep gorges along with terrace deposits. Below the glacial deposits lies a sequence of sedimentary rocks in a structural basin known as the Twin City Basin.

Population and Household Growth Trends

During the last three decades, the population of the seven-county metro area increased by nearly 800,000 people. The 2000 Census Bureau figures revealed that the 7-county area experienced its largest population growth in any decade in its history in the 1990s. By the year 2030, the metro area is projected to add another 966,000 people and 471,000 households (Table 2). Council forecasts for population and households for the metro area cities and townships are compiled in Appendix A.

Table 2. Twin Cities Metropolitan Growth, 1970-2030

	1970	2000	2030	1970-2000 Increase	2000-2030 Projected Increase
Population	1,874,612	2,642,056	3,608,000	767,000	966,000
Households	573,634	1,021,454	1,492,000	448,000	471,000

Regional Development Framework 2030

The importance of discussing household and population growth is two-fold. Studies have shown a direct correlation between increased impervious cover in a watershed, which accompanies growth and stream water quality. Watersheds with less than 10% impervious cover have the potential to have high water quality in their streams. Watersheds with 10-25% impervious cover generally have impacted water quality. Once watersheds have greater than 25% impervious cover their stream water quality is generally classified as impaired and non-supporting. As the impervious cover increases, you have a similar effect on channel enlargement. At 8-10% imperviousness, a stream typically can become mildly unstable. Channels are often two times as big as natural conditions when imperviousness reaches greater than 15%. When the watershed has more than 40% impervious cover, a stream can be four times as large as natural conditions and by the time imperviousness is greater than 65%, the stream is no longer considered a stream.

As the population and number of households in the metro area continues to grow, more impervious surfaces will be created, reinforcing the need for educated decisions intended to protect the quality of the region's water resources.

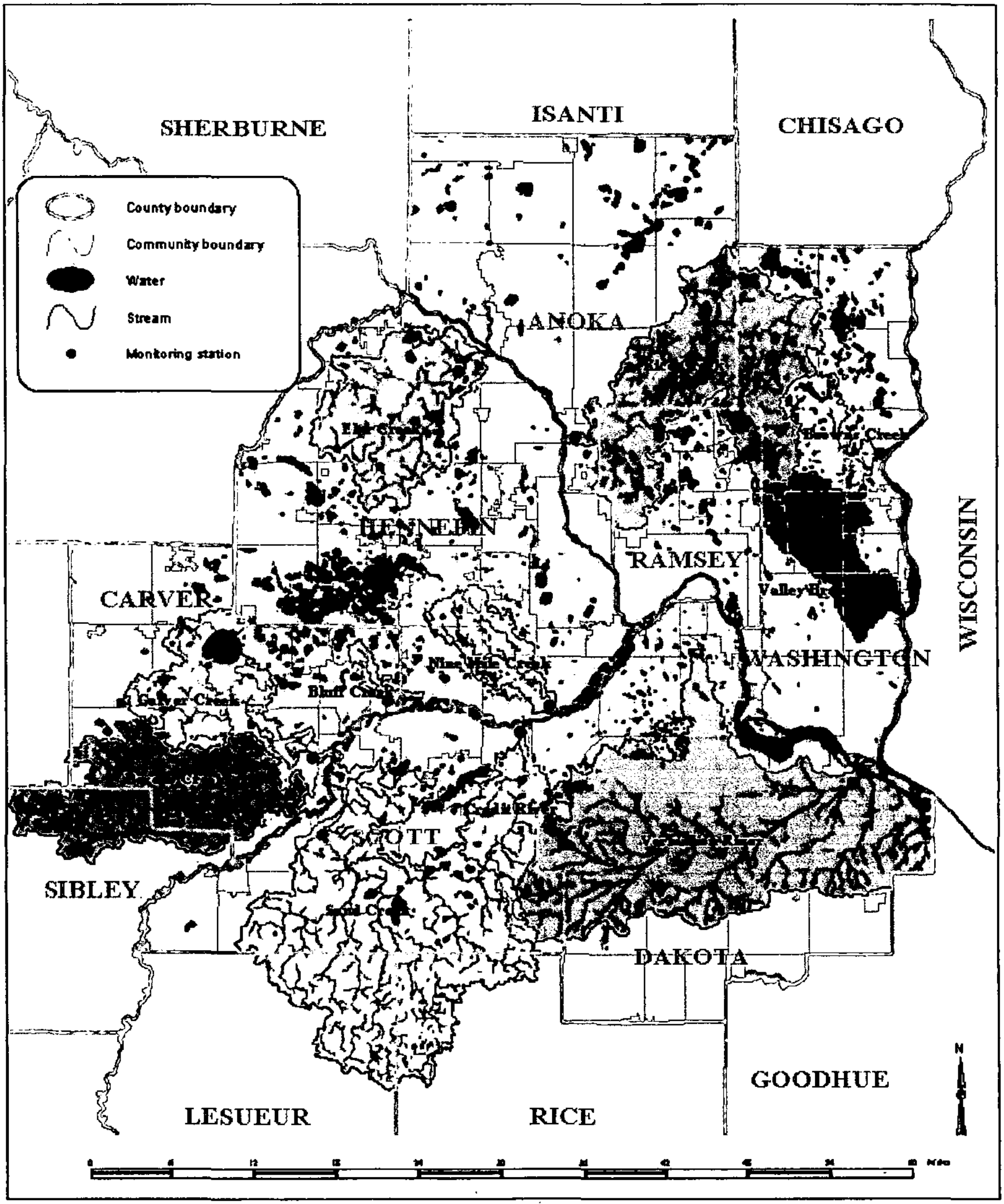
WATERSHED DESCRIPTIONS

This report includes information on the quality and quantity of water for 11 streams in the metro area (Figure 5). The streams are tributary to either the Minnesota, Mississippi or St. Croix Rivers. Monitoring sites are generally located near the mouths of the stream tributary to the three major rivers. Sites were identified and placed far enough upstream to avoid tailwater conditions from the major rivers, when these rivers are at flood stage. The tributary watersheds in this report range from 9 to 327 square miles. The watersheds of the streams also span a range of land cover, from predominantly agricultural to predominantly urban (Table 3).

Table 3. Stream Monitoring Sites

Monitoring Site	Major Basin	Dominant Land Use	Year Initiated	Watershed Size (miles^2)
Bevens Creek - Lower	Minnesota – Lower	Agricultural	1989	131
Bluff Creek	Minnesota – Lower	Rural/Transitional	1990	9
Browns Creek	St. Croix	Rural/Transitional	1998	34
Carver Creek	Minnesota – Lower	Agricultural	1989	83
Credit River	Minnesota – Lower	Rural/Transitional	1989	51
Elm Creek	Mississippi – Upper	Urban/Transitional	Discontinued	106
Nine Mile Creek	Minnesota – Lower	Urban	1989	38
Rice Creek	Mississippi – Upper	Urban/Transitional	Discontinued	184
Sand Creek	Minnesota – Lower	Agricultural	1989	255
Valley Creek	St. Croix	Mixed/Transitional	1999	62
Vermillion River	Mississippi – Lower	Agricultural	1995	327

Figure 5. Long Term Stream Monitoring Stations Locations



Bevens Creek

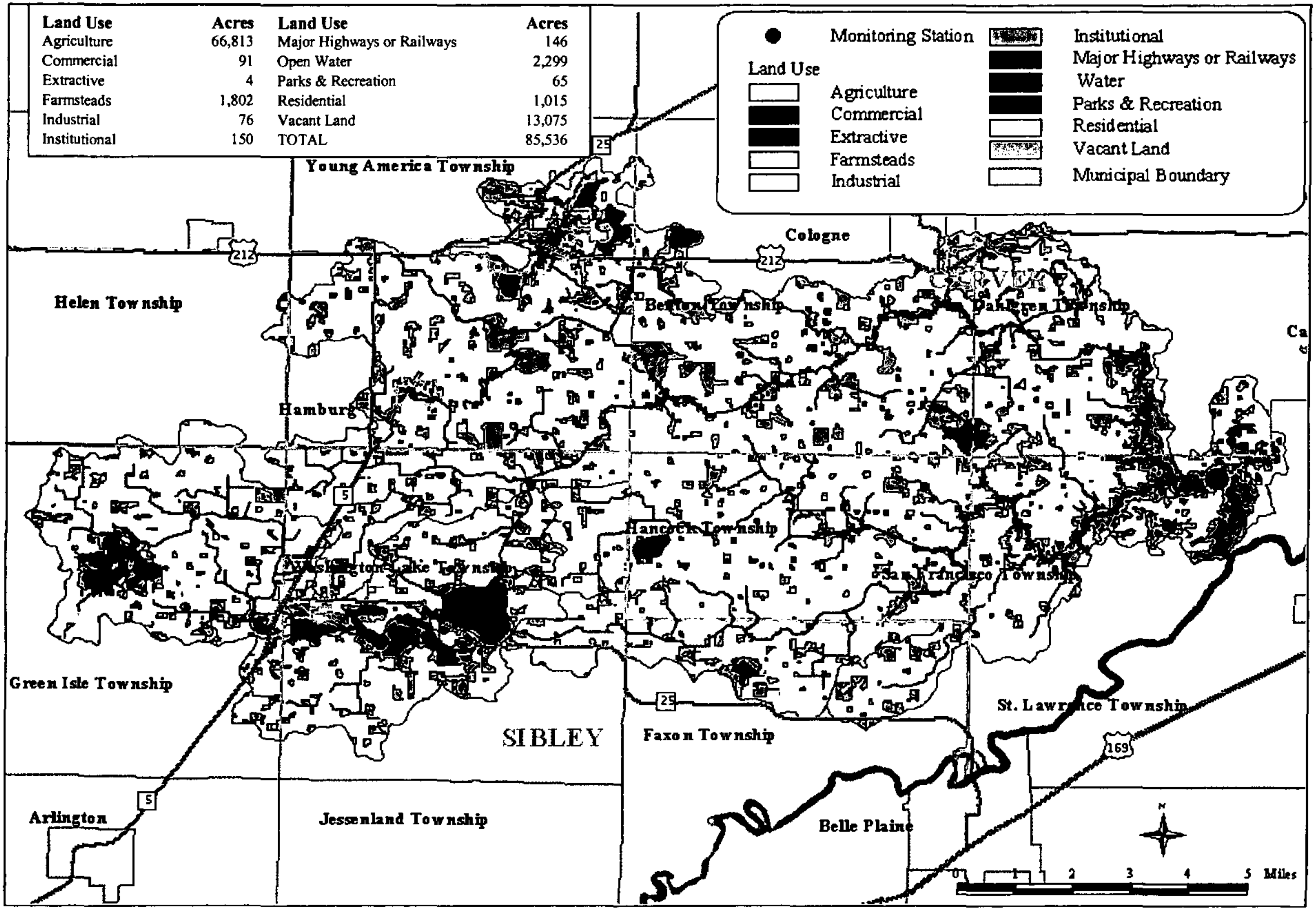
The Bevens Creek watershed covers parts of Sibley and Carver Counties, Minnesota. The mouth of the creek is in Sibley County. Once the creek enters the metro area, it winds easterly through Hancock and San Francisco Township before ultimately discharging into the Minnesota River. Bevens Creek is located in the Carver County Watershed Management Organization. Bevens Creek has a drainage area of approximately 134 square miles (85,536 acres).

As shown in Table 4, Bevens Creek is generally surrounded by agriculture (78%) and undeveloped land (15%). Three percent of the watershed is single family residential and farmsteads and 3% of the land use is open water covers (Figure 7).

MCES has conducted water quality monitoring of Bevens Creek since 1989 (Figure 6). The monitoring station is located near Carver, Minnesota, 2.0 miles upstream from the creek confluence with the Minnesota River.

Figure 6. Bevens Creek

Figure 7. Bevens Creek Monitoring Station Location and Watershed Characteristics



Land Use	Acres	Land Use	Acres
Agriculture	66,813	Major Highways or Railways	146
Commercial	91	Open Water	2,299
Extractive	4	Parks & Recreation	65
Farmsteads	1,802	Residential	1,015
Industrial	76	Vacant Land	13,075
Institutional	150	TOTAL	85,536

Bluff Creek

Bluff Creek is located in Chanhassen, Minnesota, in the Riley-Purgatory-Bluff Creek Watershed District. The main branch of Bluff Creek flows southeasterly through the city of Chanhassen until it ultimately discharges to the Minnesota River. Bluff Creek drains approximately 9 square miles (5,724 acres).

Watershed land use consists of single family residential, undeveloped land, agriculture and parks and open space (Table 4). Thirty-three percent of the watershed is undeveloped, 19% is agricultural, 22% is parks and open space, and 15% is single family residential. The remaining 11% is multifamily residential, industrial, commercial, public semi-public, roads or water (Figure 9).

The monitoring station (Figure 8) is located in Chanhassen, Minnesota, 3.5 miles upstream from the creek confluence with the Minnesota River. MCES staff maintains the monitoring station. During the 1989-1990 period, MCES also operated a second monitoring station on Bluff Creek near the creek confluence with the Minnesota River (Mile 0.2). MCES has conducted water quality monitoring of Bluff Creek since 1990.

Figure 8. Bluff Creek Monitoring Station

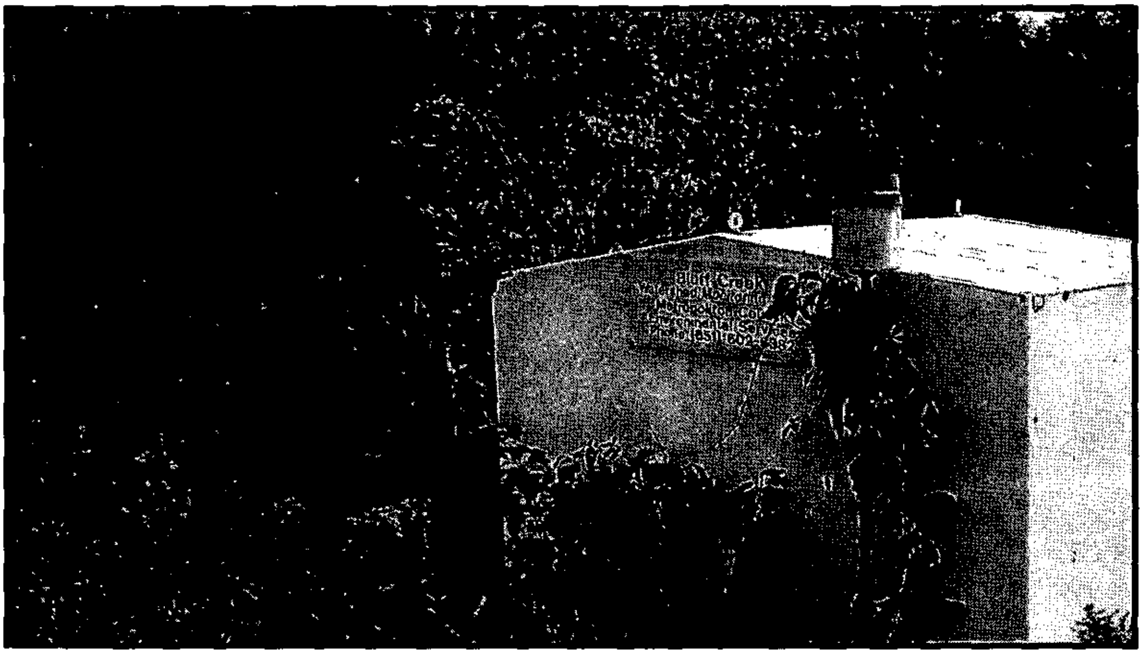
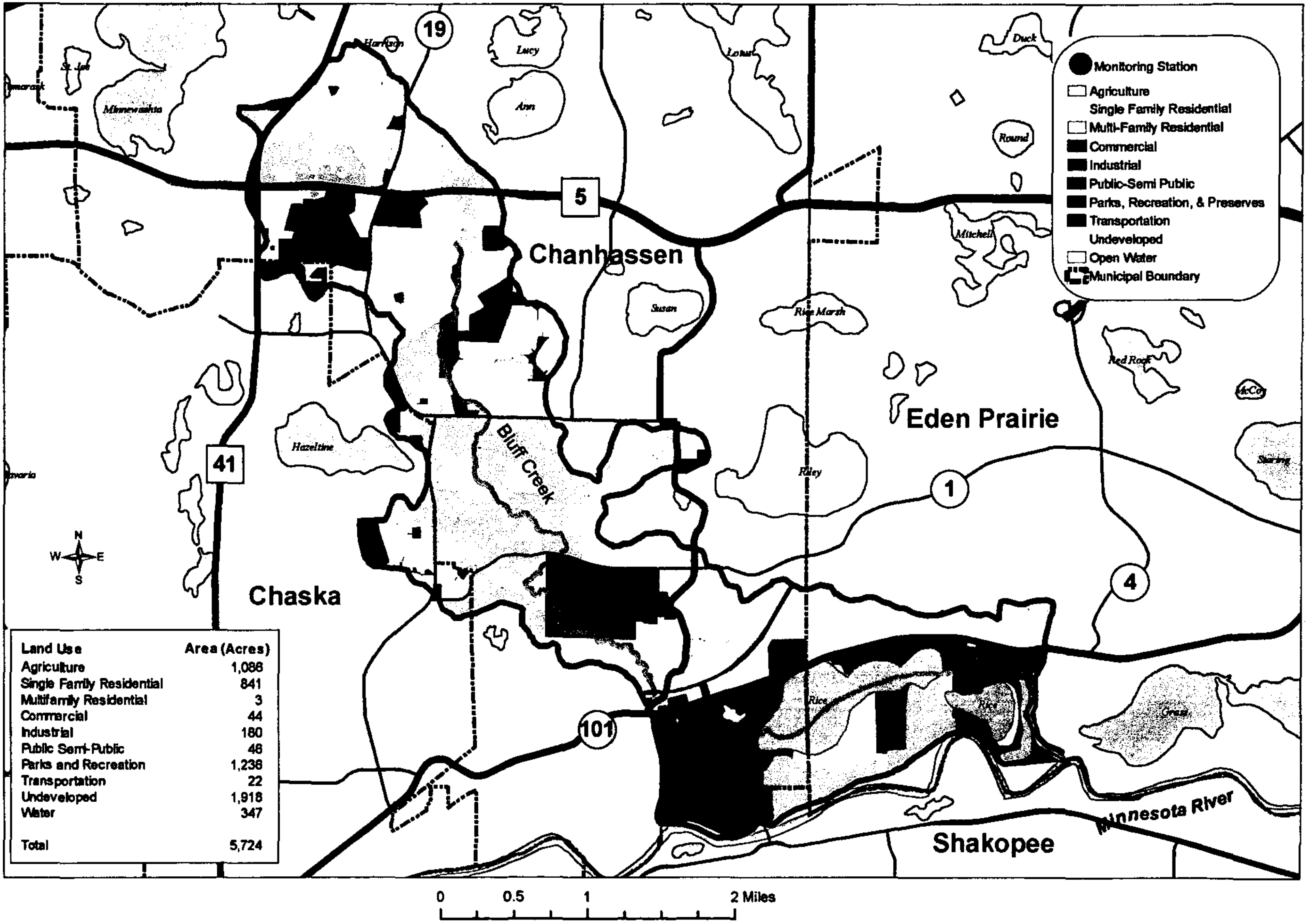


Figure 9. Bluff Creek Monitoring Station Location and Watershed Characteristics



Land Use	Area (Acres)
Agriculture	1,086
Single Family Residential	841
Multifamily Residential	3
Commercial	44
Industrial	180
Public Semi-Public	46
Parks and Recreation	1,238
Transportation	22
Undeveloped	1,918
Water	347
Total	5,724

Browns Creek

Browns Creek is in Washington County, Minnesota. Browns Creek starts in May Township and runs southeasterly through the city of Grant, Stillwater Township, and the city of Stillwater before ultimately discharging to the St. Croix River. Browns Creek is located in the Browns Creek Watershed District, and has a drainage area of approximately 34 square miles (21,826 acres).

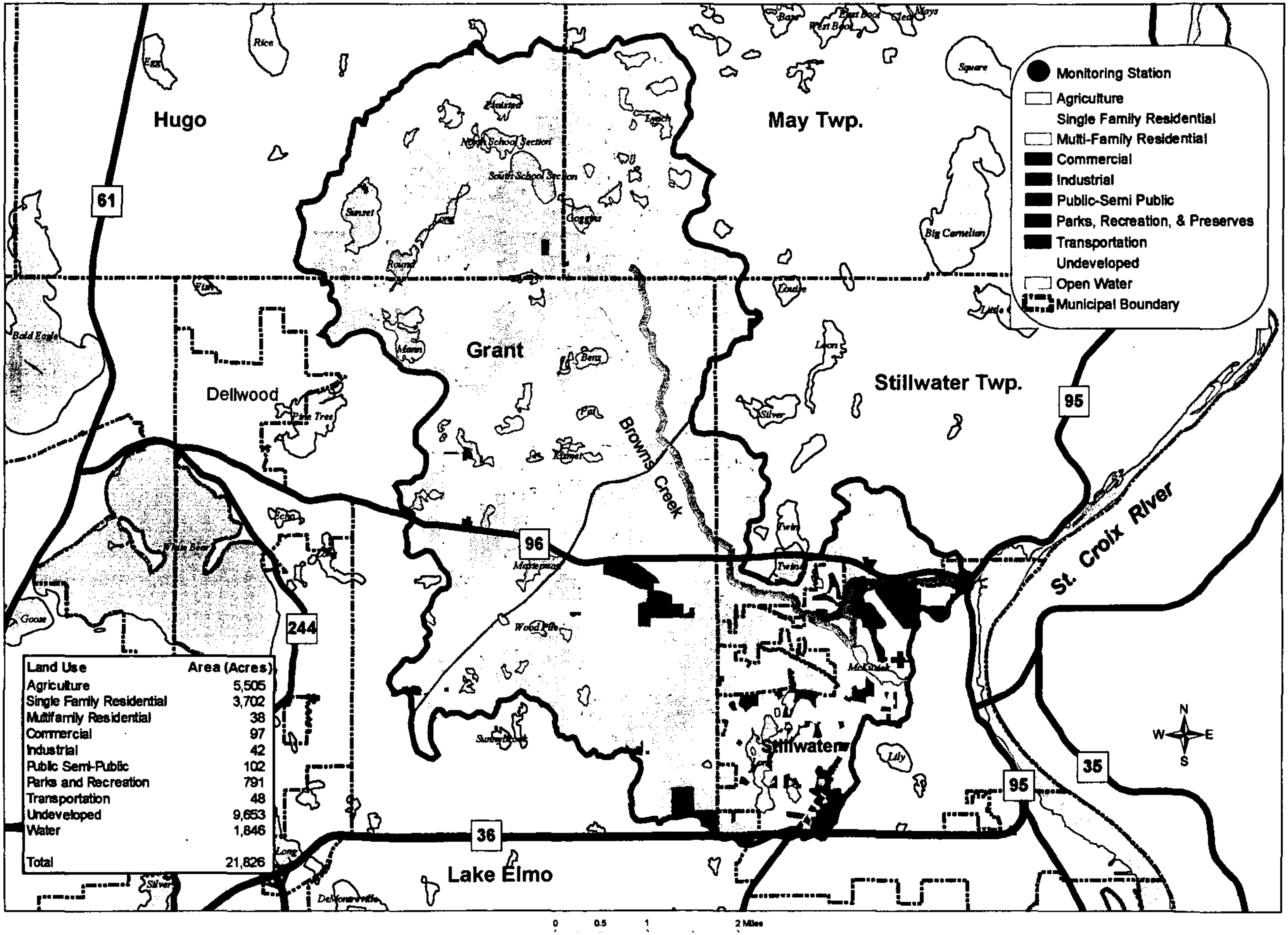
Nearly forty-four percent of the land in the Browns Creek watershed is undeveloped, 25% is agricultural, 17% is single family residential and 8% is water (Table 4). The remaining 5% is classified as multifamily residential, industrial, commercial, public semi-public, and roads (Figure 11).

MCES has supported water quality monitoring of Browns Creek since 1998. The monitoring station is located in Stillwater, Minnesota, 0.3 mile upstream from the creek confluence with the St. Croix River. New monitoring equipment was installed at this station in 2000. Browns Creek, like portions of the Vermillion River, is a Minnesota Department of Natural Resources designated trout stream.

Washington County Soil and Water Conservation District staff currently maintains the monitoring station and collects samples at this site (Figure 10).

Figure 10. Browns Creek Monitoring Station

Figure 11. Browns Creek Monitoring Station Location and Watershed Characteristics



Land Use	Area (Acres)
Agriculture	5,505
Single Family Residential	3,702
Multifamily Residential	38
Commercial	97
Industrial	42
Public Semi-Public	102
Parks and Recreation	791
Transportation	48
Undeveloped	9,653
Water	1,846
Total	21,826

Carver Creek

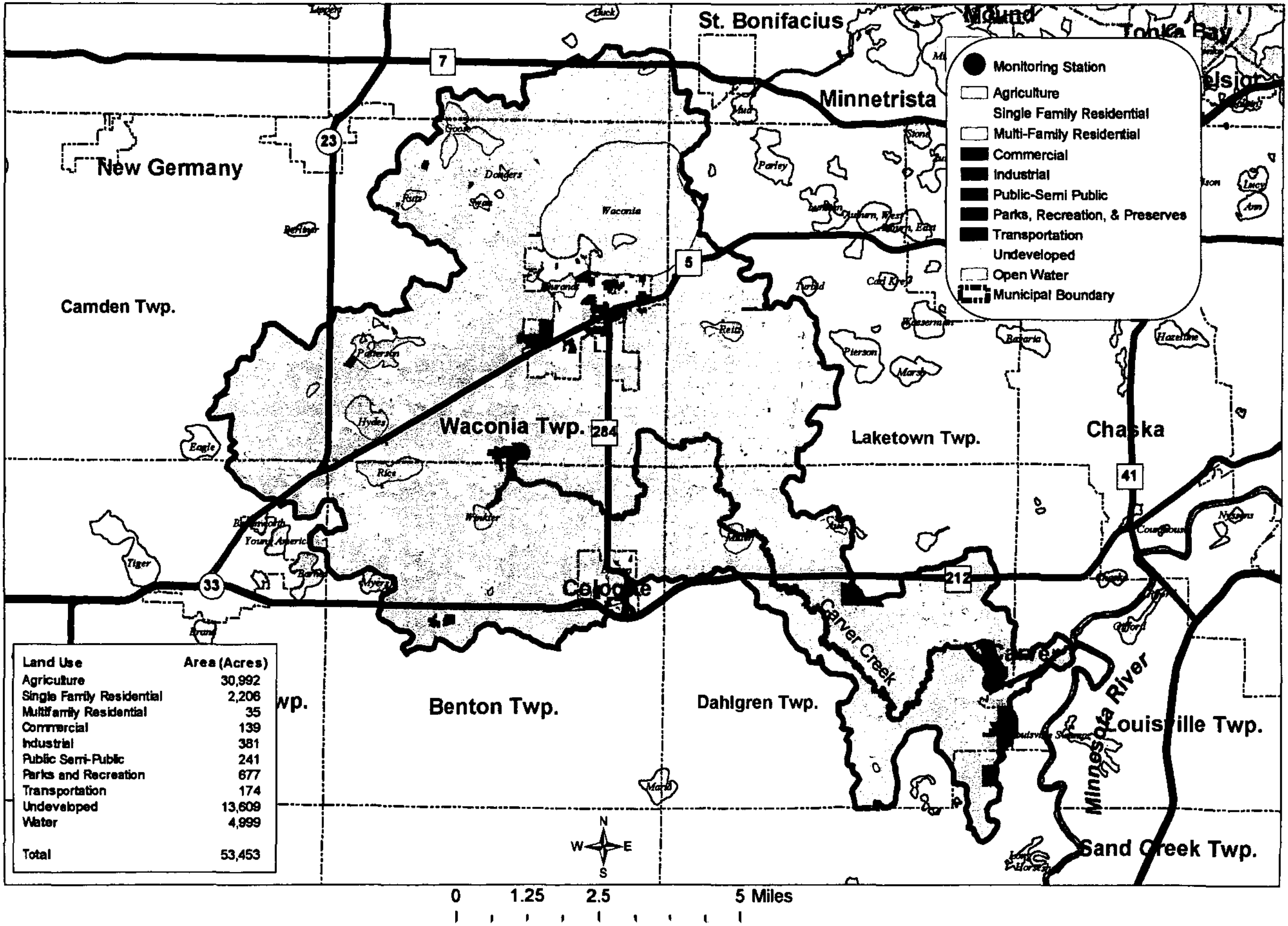
Carver Creek is located in Carver County, Minnesota. The creek starts in Benton Township and winds through the Townships of Waconia, Laketown, Dahlgren and Louisville before discharging into the Minnesota River. Carver Creek is located in the Carver County Watershed Management Organization. Carver Creek has a drainage area of approximately 83 square miles (53,453 acres).

Fifty-eight percent of the Carver Creek watershed is in some form of agriculture, while 25% is undeveloped and 9% is water (Table 4). Just over 4% of the land in the watershed is classified as single family residential while the remaining 3% is used for multifamily residential, industrial, commercial, public semi-public, roads, and parks and open space (Figure 13).

MCES has conducted water quality monitoring of Carver Creek since 1989 (Figure 12). The monitoring station is located 1.7 miles upstream from the creek confluence with the Minnesota River in Carver. There is no rain gage at this station.

Figure 12. Carver Creek

Figure 13. Carver Creek Monitoring Station Location and Watershed Characteristics



Land Use	Area (Acres)
Agriculture	30,992
Single Family Residential	2,206
Multifamily Residential	35
Commercial	139
Industrial	381
Public Semi-Public	241
Parks and Recreation	677
Transportation	174
Undeveloped	13,609
Water	4,999
Total	53,453

Credit River

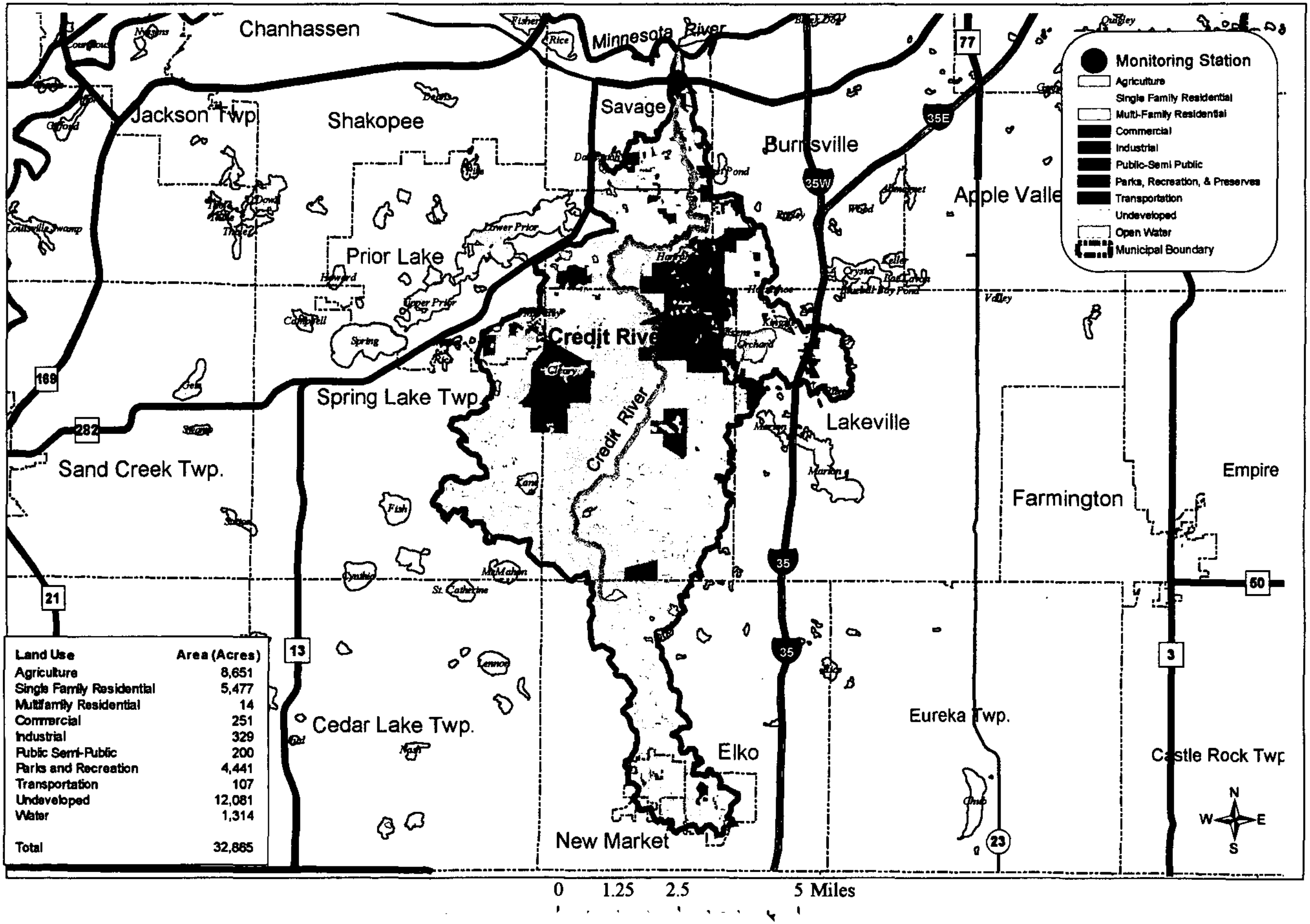
Credit River is located in Scott County, Minnesota. Credit River starts in New Market Township and flows generally north through Credit River Township before it ultimately discharges to the Minnesota River in the city of Savage. Credit River is located in the Scott County Watershed Management Organization. Credit River drains approximately 51 square miles (32,865 acres).

The major land uses in Credit River watershed are undeveloped (37%), agricultural (26%), single family residential (17%) and parks and open space (14%) (Table 4). The remaining 6% of the land in the watershed is classified as multifamily residential, industrial, commercial, public semi-public, roads or water (Figure 15).

MCES has conducted water quality monitoring of Credit River since 1989 (Figure 14). The monitoring station is located in Savage, Minnesota, 0.9 mile upstream from the river confluence with the Minnesota River. Due to site logistical problems, the monitoring station was moved in 2000, from the former site at Credit River Mile 0.6 to the current location at Mile 0.9. There is no rain gage at this station.

Figure 14. Credit River

Figure 15. Credit River Monitoring Station Location and Watershed Characteristics



Land Use	Area (Acres)
Agriculture	8,651
Single Family Residential	5,477
Multifamily Residential	14
Commercial	251
Industrial	329
Public Semi-Public	200
Parks and Recreation	4,441
Transportation	107
Undeveloped	12,081
Water	1,314
Total	32,865

Elm Creek

Elm Creek is located in Hennepin County, Minnesota. The creek starts in the city of Medina and runs generally north northeasterly through the cities of Plymouth, Maple Grove, and Dayton before it ultimately discharges to the Mississippi River in the city of Champlin. Elm Creek lies within the Elm Creek Watershed Management Commission watershed area.

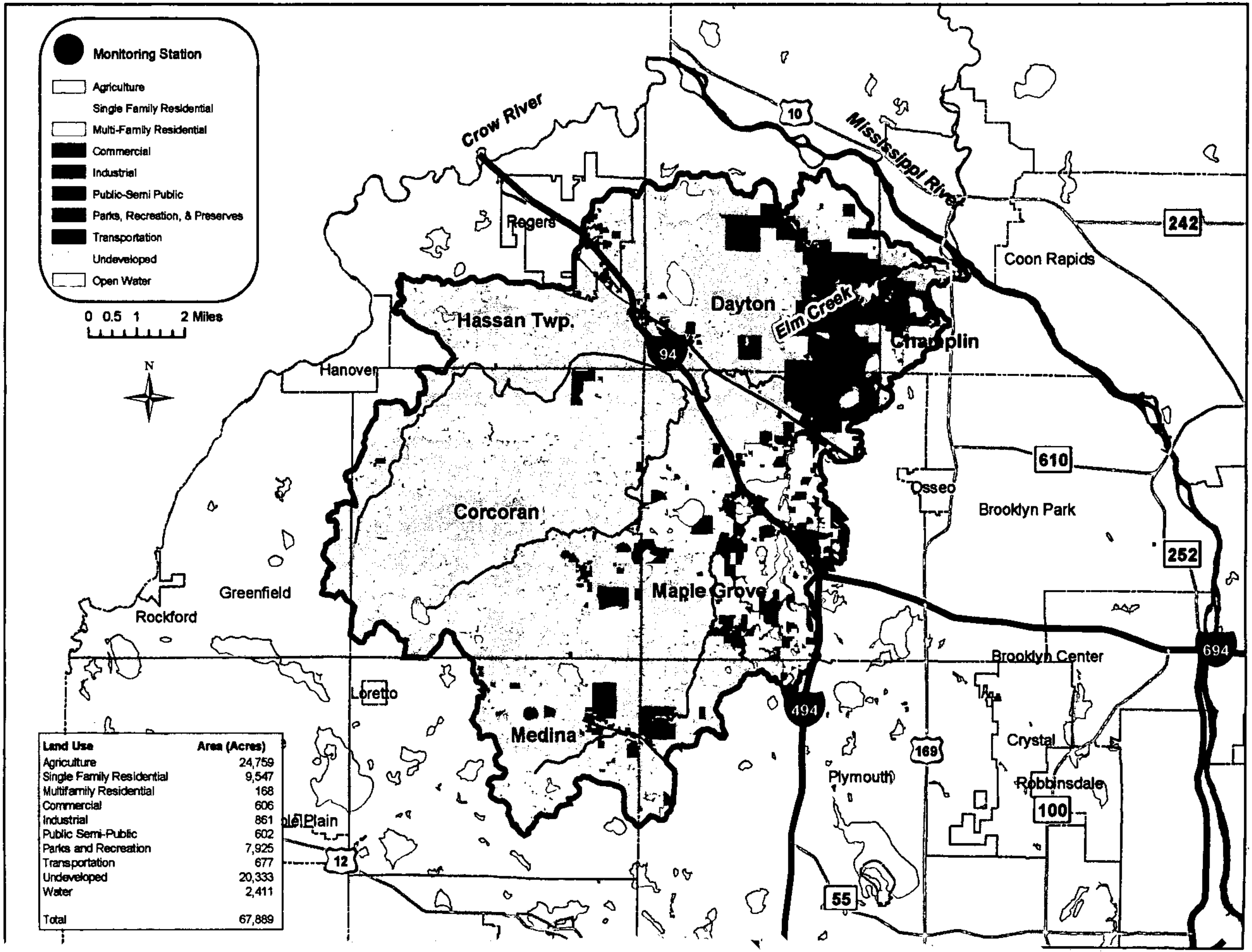
Elm Creek has three major subwatersheds: Rush Creek, North Fork Rush Creek, and Diamond Creek. North Fork Rush Creek drains a small portion of Greenfield and Dayton and drains through Corcoran and Hassan Township to join Rush Creek in Maple Grove. Rush Creek drains through Medina, Corcoran, and Maple Grove and joins Elm Creek in Dayton. Diamond Creek drains parts of Rogers, Hassan Township and Dayton and joins Elm Creek just upstream of Hayden Lake. Diamond Creek subwatershed is not monitored by the United States Geological Survey gauging station. The entire watershed is approximately 106 square miles (67,889 acres) with approximately 86 square miles (55,040 acres) monitored at the United States Geological Survey gauging station.

Land uses within the watershed include 36 percent agricultural production, 30% undeveloped, 14% single family residential, 12% parks and open space, and 4% water (Table 4). The remaining 4% of the land in the watershed is forest, multifamily residential, commercial, industrial, public semi-public and roads (Figure 16).

The United States Geological Survey has conducted monitoring at the Elm Creek site since October 1978. The monitoring station is located 2.5 miles southwest of downtown Champlin on Elm Creek Road. The United States Geological Survey computes a continuous record of streamflow throughout the year. This is accomplished by continuously recording stage and maintaining a stage-discharge relation through direct measurements of stream stage and streamflow at approximately six-week intervals and extreme hydrologic conditions. Water-quality samples are collected by the United States Geological Survey using depth-and width-integrating techniques to obtain samples representative of the entire cross-section of the stream, and with automated samplers to composite large runoff events. Real-time streamflow and historical water quality and streamflow data for station number 05287890 are available from the United States Geological Survey at http://waterdata.usgs.gov/mn/nwis/nwis.

Streamflow statistics for the period of record indicate a median daily-mean discharge of 109 cubic feet per second, or an annual runoff of 6.16 inches. The maximum streamflow recorded was 875 cubic feet per second, April 25, 2001. The minimum streamflow of 0.29 cubic feet was recorded July 9, 1989.

Figure 16. Elm Creek Monitoring Station Location and Watershed Characteristics



Land Use	Area (Acres)
Agriculture	24,759
Single Family Residential	9,547
Multifamily Residential	168
Commercial	606
Industrial	861
Public Semi-Public	602
Parks and Recreation	7,925
Transportation	677
Undeveloped	20,333
Water	2,411
Total	67,889

Nine Mile Creek

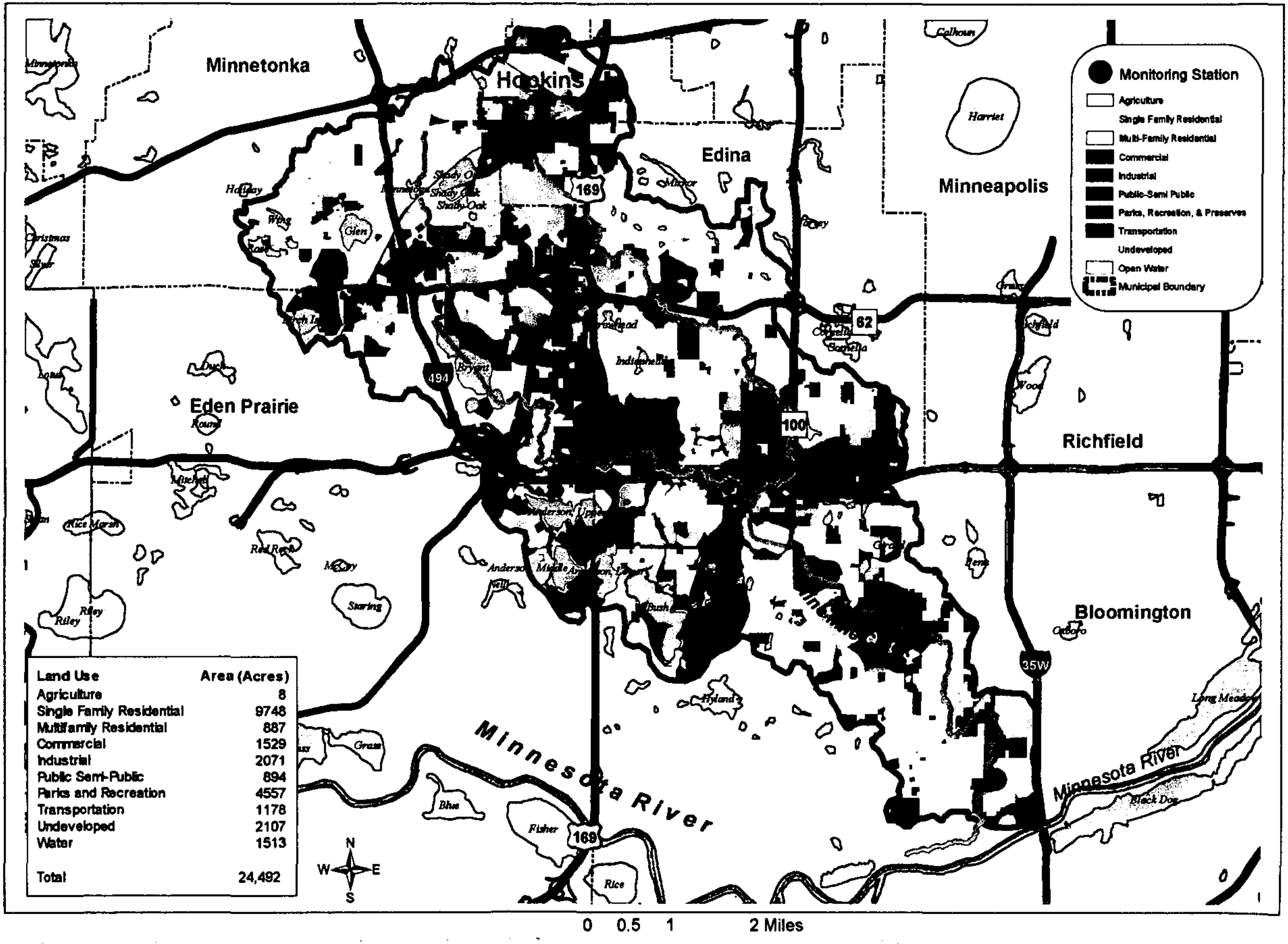
Nine Mile Creek is located in Hennepin County, Minnesota. The two main branches of Nine Mile Creek start in the cities of Minnetonka and Hopkins and run southeasterly through the cities of Edina, Eden Prairie, and Bloomington before ultimately discharging to the Minnesota River. Nine Mile Creek is located in the Nine Mile Creek Watershed District. Nine Mile Creek drains approximately 38 square miles (24,492 acres).

Forty percent of the land in the watershed is classified as single family residential, while 19% is parks and open space, 9% is undeveloped and 8% is industrial (Table 4). The remaining 24% of the land in the watershed is classified as multifamily residential, agriculture, commercial, public semi-public, roads or water (Figure 18).

MCES has conducted water quality monitoring of Nine Mile Creek since 1989 (Figure 17). The monitoring station is located in Bloomington, Minnesota, 1.8 miles upstream from the creek confluence with the Minnesota River. There is no rain gage at this station.

Figure 17. Nine Mile Creek

Figure 18. Nine Mile Creek Monitoring Station Location and Watershed Characteristics



Land Use	Area (Acres)
Agriculture	8
Single Family Residential	9748
Multifamily Residential	887
Commercial	1529
Industrial	2071
Public Semi-Public	894
Parks and Recreation	4557
Transportation	1178
Undeveloped	2107
Water	1513
Total	24,492

Rice Creek

Rice Creek is located in northern Ramsey and Eastern Anoka Counties. It flows southwesterly from Forest Lake to Fridley until it discharges into the Mississippi River. Rice Creek drains approximately 184 square miles (115,308 acres).

Thirty four percent of the Rice Creek watershed is undeveloped, 22% is residential, 13% is agricultural, 10% of the watershed is classified as water, and 10 % is parks and open space (Table 4). The remaining 11% is multifamily, public semi-public, roads, railways and airports, and commercial and industrial. (Figure 20)

The monitoring station is located in Fridley, Minnesota, 0.25 miles downstream of Highway 65 (Figure 19). Rice Creek Watershed District staff maintains the monitoring station. A minimum of five stage-flow readings are taken annually and compared against historical rating curve data to assess any changes in channel morphology. The Rice Creek Watershed District has been collecting flow data at this site since 1994 and collecting flow-weighted composite water quality samples since 1995.

Figure 19. Rice Creek

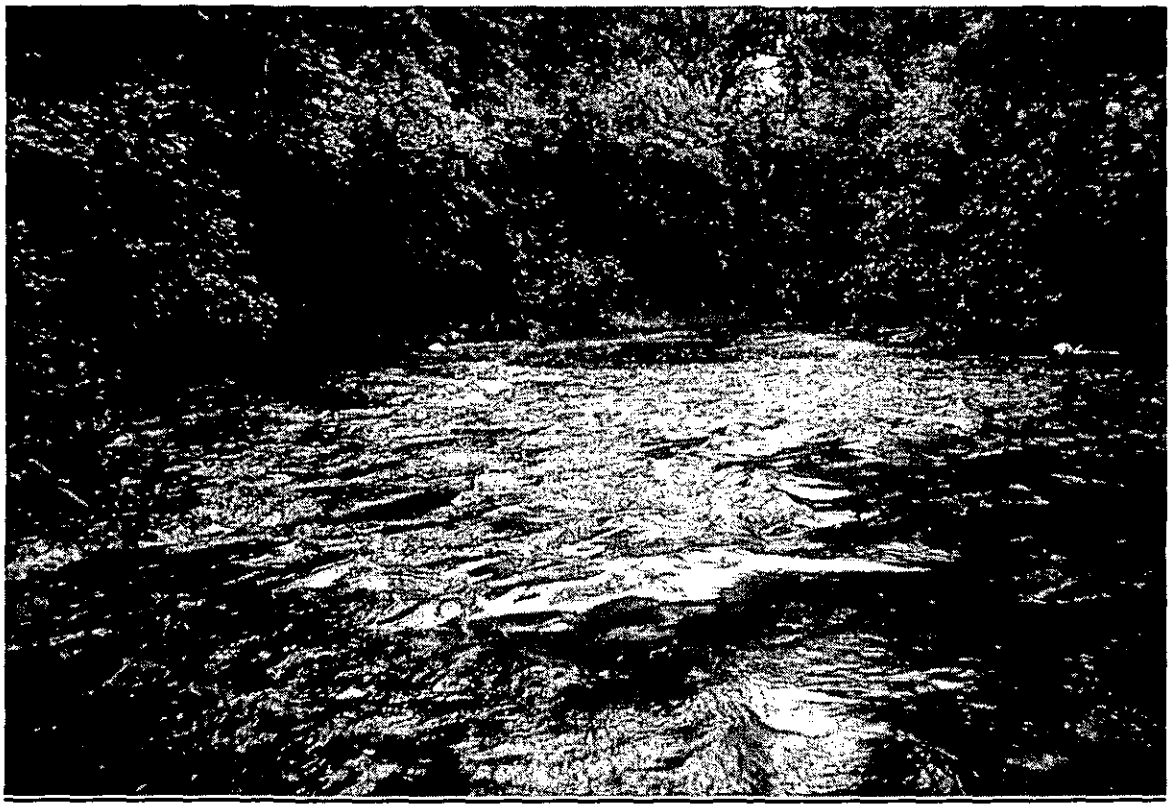
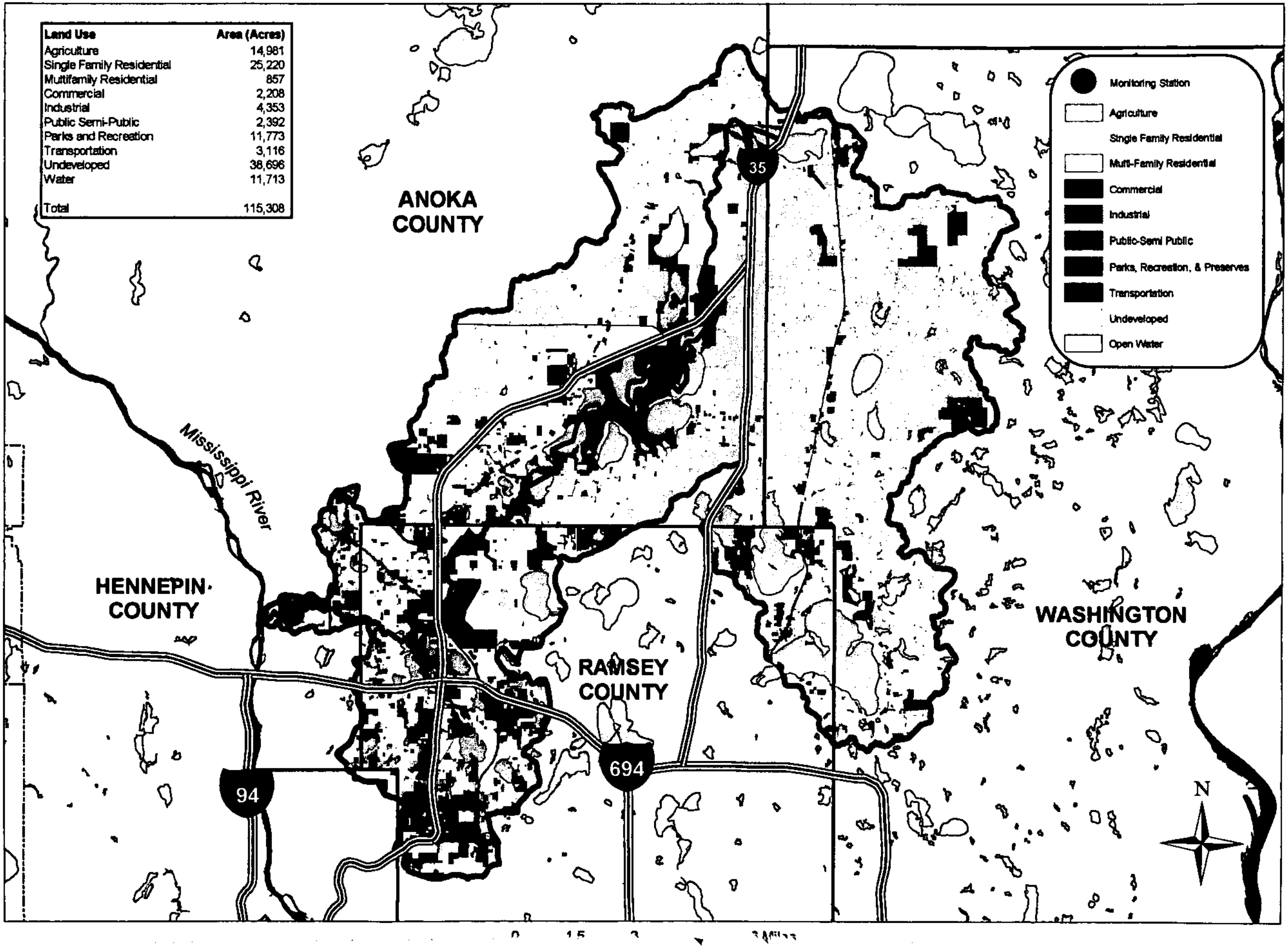


Figure 20. Rice Creek Monitoring Station Location and Watershed Characteristics



Land Use	Area (Acres)
Agriculture	14,981
Single Family Residential	25,220
Multifamily Residential	857
Commercial	2,208
Industrial	4,353
Public Semi-Public	2,392
Parks and Recreation	11,773
Transportation	3,116
Undeveloped	38,696
Water	11,713
Total	115,308

Sand Creek

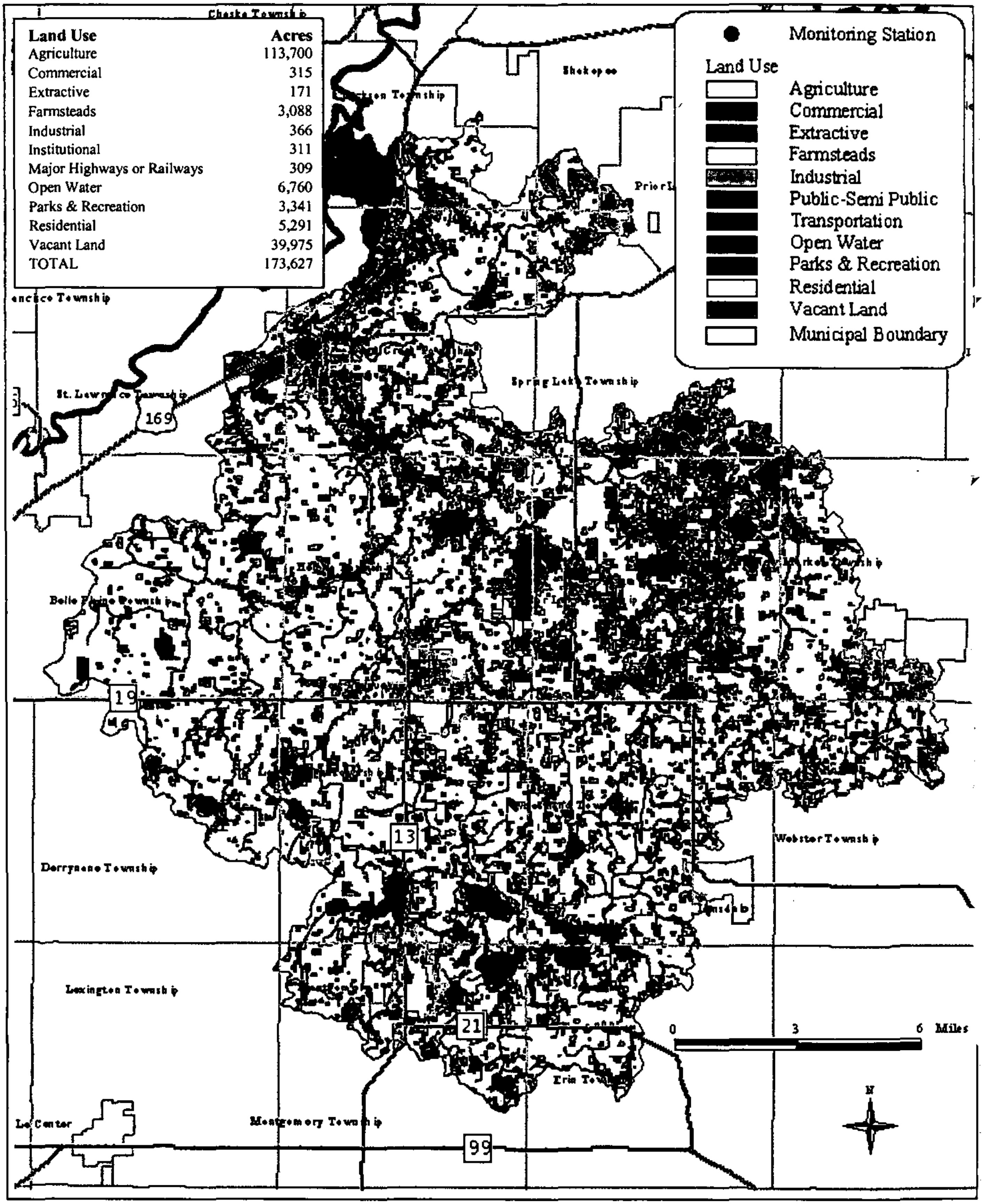
The drainage area for Sand Creek covers approximately 271 square miles (173,627 acres) and includes portions of Scott, LeSueur and Rice Counties. The portion of Sand Creek in the Metropolitan Area is in the Scott County Watershed Management Organization. The main branch of Sand Creek flows northerly through LeSueur County into Helena Township, Sand Creek Township, the city of Jordan and Louisville Township before ultimately discharging to the Minnesota River.

Sixty-five percent of the watershed is in agricultural production, 23% is vacant, nearly 4% of the watershed is water and 5% is residential and farmsteads (Table 4). The remaining 3% is commercial, industrial, roads, public, and parks and open space (Figure 22).

MCES has conducted water quality monitoring of Sand Creek since 1989 (Figure 21). The monitoring station is located in Jordan, Minnesota, 8.2 miles upstream from the creek confluence with the Minnesota River. There is no rain gage at this station. During the 1989-1990 period, MCES also operated a second monitoring station on Sand Creek in Louisville Swamp, near the creek confluence with the Minnesota River (Mile 1.6).

Figure 21. Sand Creek

Figure 22. Sand Creek Monitoring Station Location and Watershed Characteristics



Land Use	Acres
Agriculture	113,700
Commercial	315
Extractive	171
Farmsteads	3,088
Industrial	366
Institutional	311
Major Highways or Railways	309
Open Water	6,760
Parks & Recreation	3,341
Residential	5,291
Vacant Land	39,975
TOTAL	173,627

Valley Creek

Valley Creek is in Washington County, Minnesota. Valley Creek lies within the cities of Woodbury and Afton in the Valley Branch Watershed District. The creek starts in Woodbury and flows east and southeasterly through Afton before discharging into the St. Croix River. Valley Creek has a drainage area of approximately 62 square miles (39,175 acres).

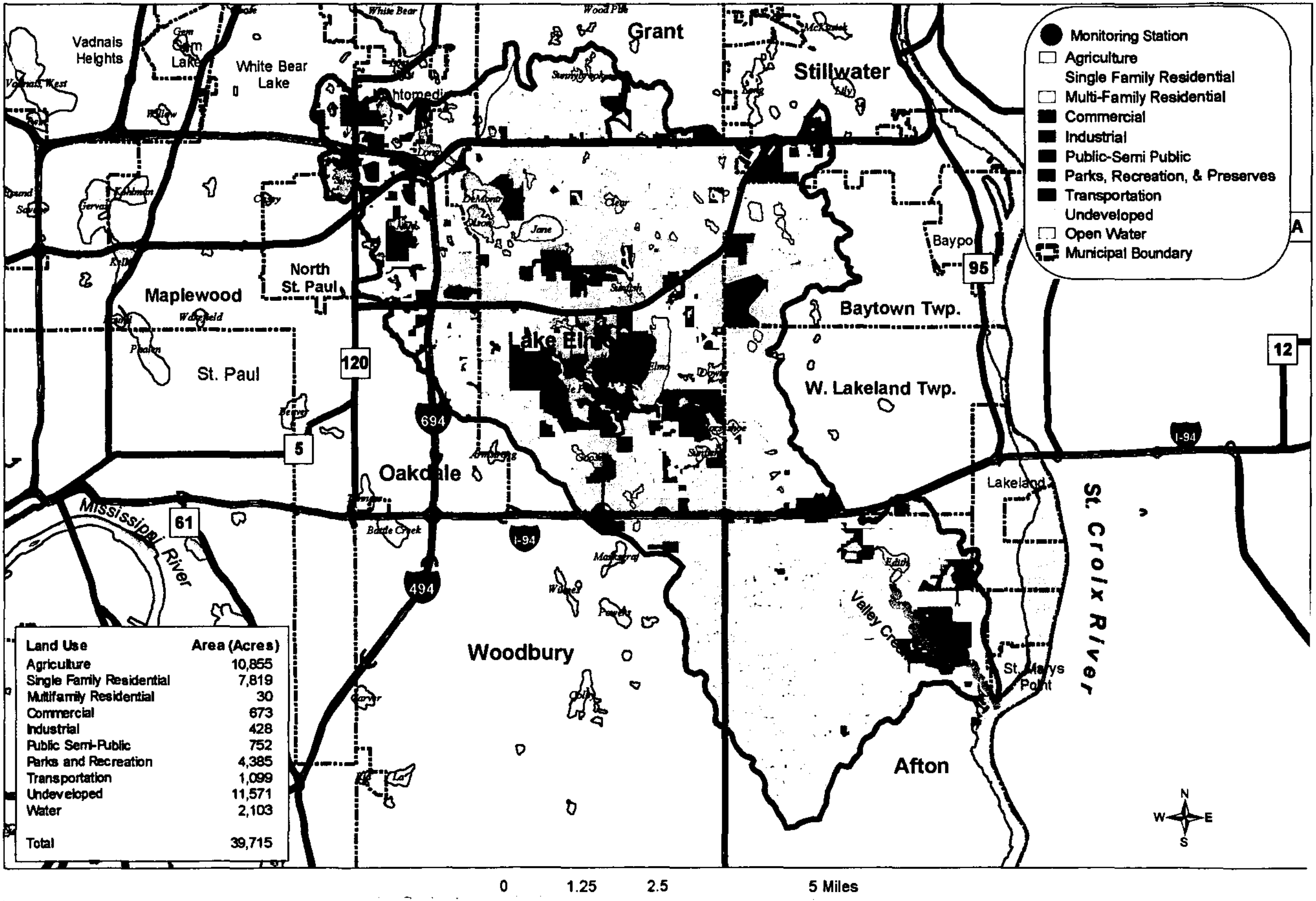
Twenty-nine percent of the Valley Creek watershed is undeveloped, 27% is in agricultural production, 20% is single family residential, 11% is parks and open space and 5% is water (Table 4). The remaining 8% is classified as multifamily residential, industrial, commercial, public semi-public, and roads (Figure 24).

MCES has supported water quality monitoring of Valley Creek since 1999. The monitoring station is located in Afton, Minnesota, 1.0 mile upstream from the creek confluence with the St. Croix River. Situated in a groundwater discharge zone, Valley Creek has a disproportionately high water volume in relation to its relatively small drainage area of 62 square miles. The stream flows perennially and does not freeze during the winter. Valley Creek, like parts of the Vermillion River and Browns Creek, is a Minnesota Department of Natural Resources designated trout stream.

MCES partners with the St. Croix Watershed Research Station of the Science Museum of Minnesota to maintain this monitoring station (Figure 23). The St. Croix Watershed Research Station has been collecting water quality samples and conducting continuous monitoring at two upstream Valley Creek locations since 1998. While there is no rain gage at the MCES station, precipitation data are continuously collected and recorded at the upstream stations.

Figure 23. Valley Creek

Figure 24. Valley Creek Monitoring Station Location and Watershed Characteristics



Land Use	Area (Acres)
Agriculture	10,855
Single Family Residential	7,819
Multifamily Residential	30
Commercial	673
Industrial	428
Public Semi-Public	752
Parks and Recreation	4,385
Transportation	1,099
Undeveloped	11,571
Water	2,103
Total	39,715

Vermillion River

The Vermillion River is in Scott and Dakota Counties, Minnesota. The watershed has a drainage area of approximately 327 square miles (209,263 acres). The river runs easterly from New Market Township in Scott County to the city of Hastings in Dakota County where it ultimately discharges to the Mississippi River. The river watershed drainage area covers 6 cities, 5 rural towns and 10 townships. The river and watershed is governed by the Vermillion River Watershed Joint Powers Board.

Fifty-nine percent of the Vermillion River watershed is classified as agriculture, 20% is undeveloped, 10% is single family residential, and 4% is in parks and open space (Table 4). The remaining 7% is classified as multifamily residential, commercial, industrial, public semi-public, roads or water (Figure 26).

In 1988 and 2002 part of the Vermillion River and a few of its tributaries were designated as a trout stream by the Minnesota Department of Natural Resources.

The Metropolitan Council's Empire Wastewater Treatment Plant is located along the Vermillion River. The Council is permitted to discharge 12 million gallons per day of treated wastewater to the river. Actual daily discharge is approximately 8 million gallons per day. Recognizing that the discharge volume increase associated with future plant expansions could have detrimental impacts on the Vermillion River; the Council began a project in 2003 to take the wastewater effluent out of the river. The wastewater will still be treated at the plant, but the treated effluent will be discharged to the Mississippi River through the Council's outfall pipe in Rosemount.

MCES has supported water quality monitoring of the Vermillion River since 1995 (Figure 25). The monitoring station is located inside the ConAgra Mill near Highway 61 in Hastings, Minnesota, about two miles upstream from the Mississippi River floodplain. There is no rain gage at this station. The Vermillion River flows from western Scott County and drains approximately 55% of Dakota County.

Figure 25. Vermillion River

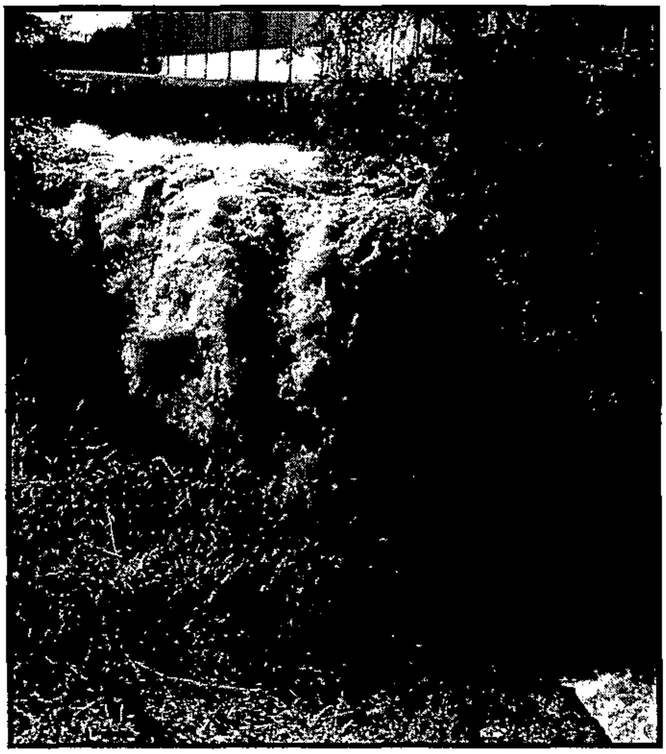
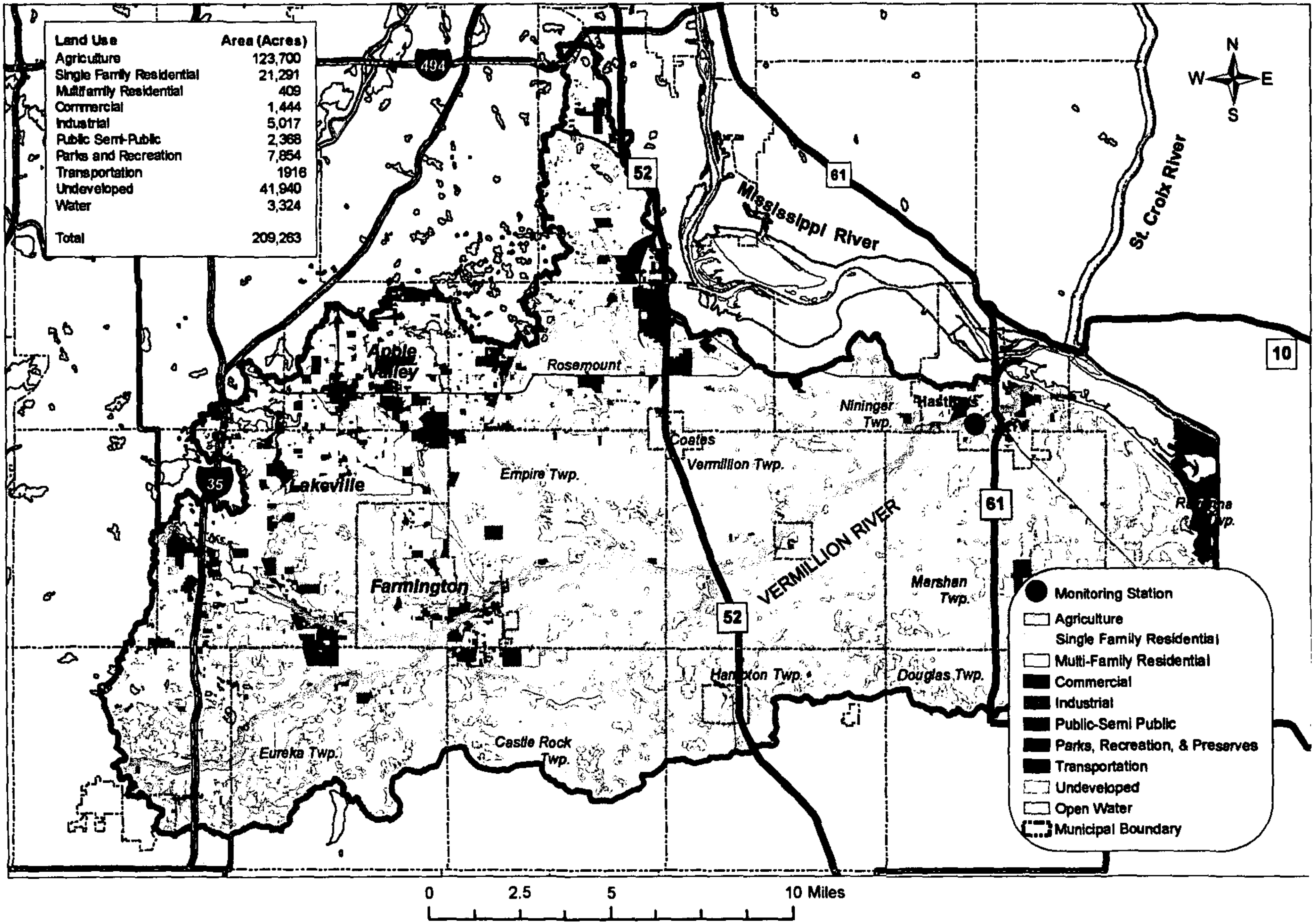


Figure 26. Vermillion River Monitoring Station Location and Watershed Characteristics



Land Use	Area (Acres)
Agriculture	123,700
Single Family Residential	21,291
Multifamily Residential	409
Commercial	1,444
Industrial	5,017
Public Semi-Public	2,368
Parks and Recreation	7,854
Transportation	1916
Undeveloped	41,940
Water	3,324
Total	209,263

- ● Monitoring Station
- ☐ Agriculture
- Single Family Residential
- ☐ Multi-Family Residential
- ■ Commercial
- ■ Industrial
- ■ Public-Semi Public
- ■ Parks, Recreation, & Preserves
- ■ Transportation
- ☐ Undeveloped
- ☐ Open Water
- ☐ Municipal Boundary

Table 4. Watershed Information for Streams Studied

Watershed	Land Use Percentage										Watershed Area (mi2)
	Ag	Single Family	Multi Family	Comm.	Ind	Public	Parks	Roads	Vacant	Water	
Bevens Creek	78	3	Unk.	<1	<1	<1	15	<1	<1	3	134
Bluff Creek	19	15	<1	1	3	1	22	<1	34	6	9
Browns Creek	25	17	<1	<1	<1	<1	4	<1	44	8	34
Carver Creek	58	4	<1	<1	1	<1	1	<1	25	9	83
Credit River	26	17	<1	1	1	<1	14	<1	37	4	51
Elm Creek	36	14	<1	1	1	1	12	1	30	4	106
Nine Mile Creek	<1	40	4	6	8	4	19	5	9	6	38
Rice Creek	13	22	<1	2	4	2	10	3	34	10	184
Sand Creek	65	5	Unk.	<1	<1	<1	2	<1	23	4	271
Valley Creek	27	20	<1	2	1	2	11	3	29	5	62
Vermillion River	59	10	<1	1	2	1	4	1	20	2	327

(Data obtained from Metro Council GIS)

METHODS

Streamflow Measurement

AUTOMATIC MONITORING EQUIPMENT

Each monitoring station is equipped with a datalogger that continuously records water stage and flow, conductivity, and temperature at 15-minute intervals during the open-water season. Precipitation (rainfall) is measured in 0.01-inch increments via a tipping-bucket rain gauge. The open-water season varies from site-to-site and year-to-year, but a typical operational period for the automated equipment is from mid-March through the end of November. Typical minimum sampling frequency is summarized in Table 5.

Table 5. Stream Monitoring Frequency

Sample Type	Typical Minimum Frequency
Grab	12 samples / year
Composite	10 - 15 samples / year
Continuous[1]	24,960 records for each variable

[1] 260 days of operation times 96 records per day.

The standard equipment layout for each monitoring station is:

- A walk-in shelter equipped with AC power, a phone line, and modem for data transmission.
- A stage reference guide, usually a staff gauge or a wire weight gauge.
- A stage measurement device, usually a bubbler/pressure transducer system. Stations without this system are equipped with an ultrasonic sensor or a shaft encoder.
- A Sigma® or ISCO® automatic sampler, with either 24 1000-ml sample bottles or 1 5-gallon composite sample bottle. At monitoring stations where extended hydrographs and sampling times are possible after storm events, a refrigerated automatic sampler is used to maintain sample integrity.
- A conduit which runs from the shelter to the stream. The conduit contains autosampler tubing, heat tape, a temperature/conductivity probe, and a bubbler line. The end of the conduit is securely anchored to a solid surface (typically a fence post) in the stream, at a representative monitoring location. The remainder of the conduit, between the shelter and the stream, is typically buried or covered with rip-rap.
- A Campbell CR10X datalogger, which activates/deactivates the automatic sampler and writes a data record every fifteen minutes for stage, flow, temperature, conductivity, and rainfall.

STAGE

Measurements of water stage (level) are averaged over a 15-minute interval by the Campbell CR10X datalogger. Water stage measurements are typically made using a bubbler/pressure transducer system, but an ultrasonic sensor or a shaft encoder is used at some stations.

The bubbler/pressure transducer system detects water stage by using a pressure transducer to measure the pressure needed to force a gas (air or nitrogen) bubble from the end of the submerged bubbler line. The higher the water stage, the greater the pressure necessary to force a gas bubble out of the bubbler line. The gas source (either a compressed nitrogen gas cylinder or an air pump) is located in the monitoring shelter, along with the pressure transducer. The bubbler line extends from the shelter to the stream (or stilling well), through a conduit. The end of the bubbler line is securely mounted in a fixed position under the water surface. The bubbling rate, controlled by a needle valve in the shelter, is typically set at one to three bubbles per second.

The ultrasonic sensor detects water stage by emitting an acoustic pulse and measuring the travel time to the water surface and back. The ultrasonic sensor is installed in a fixed position above the water surface, typically on the underside of a bridge or culvert. The shaft encoder, typically located in a stilling well, employs a float and counter-weight system supported above the water surface by a chain draped over a wheel mounted on a movable shaft. The encoder outputs a digital pulse per unit angle of rotation of the wheel on its shaft, thereby sensing whether the water level under the float is rising or falling, and by how much.

The instrument stage measurement is also manually calibrated by comparing it against the stage reference guide (usually a fixed staff gauge or wire weight gauge). If the instrument stage measurement and the reference stage measurement differ by more than 0.05 foot, then the instrument stage measurement is re-calibrated to equal the reference stage measurement. An exception to this procedure occurs if there is reason to believe that the reference stage has been altered (i.e. the staff gauge has been moved).

FLOW

Stream flow is recorded at 15-minute intervals by the Campbell CR10X datalogger, based upon the 15-minute stage measurements and a stage-discharge rating curve that is programmed into the datalogger. The rating curve is developed by fitting a curve to paired in-stream measurements of stage and flow, under a variety of flow conditions.

TEMPERATURE

Measurements of water temperature are recorded at 15-minute intervals by the Campbell CR10X datalogger. A temperature probe, connected to the datalogger, extends from the shelter to the stream (or stilling well), through a conduit. A thermistor at the end of the temperature probe is encapsulated in a protective housing. Thermistors are thermally sensitive resistors that exhibit a large change in electrical resistance with a small change in temperature. Temperature measurements are manually calibrated by comparing the instrument measurement to a manual field temperature measurement obtained with an independently calibrated portable meter or thermometer.

CONDUCTIVITY

Conductivity is the inverse of electrical resistance. In water, conductivity is related to ionic strength, or the amount of ions in solution, including calcium, magnesium, sodium, potassium, chloride, sulfate and others. Measurements of water conductivity are recorded at 15-minute intervals by the Campbell CR10X datalogger. A conductivity probe, connected to the datalogger, extends from the shelter to the stream (or stilling well), through a conduit. The end of the conductivity probe consists of two or more metal plates separated by a gap through which water can flow. An electrical voltage is then applied across the plates and the resulting electrical resistance is measured. Conductivity measurements are manually calibrated by comparing the instrument measurement to a manual field conductivity measurement obtained with an independently calibrated conductivity meter. If an adjustment is needed, the conductivity probe is assigned an appropriate offset (via the datalogger keypad) to match the conductivity meter measurement.

PORTABLE MONITORING EQUIPMENT

Portable monitoring equipment is routinely used to collect additional stream monitoring data, including dissolved oxygen concentration, pH, temperature, conductivity, and stream flow. The portable equipment is also used to calibrate the permanent in-situ equipment in the monitoring stations. The portable field monitoring equipment used in this program is listed in Table 6.

Table 6. Portable Stream Monitoring Equipment

Variable	Equipment Used
Dissolved Oxygen	YSI 650/6820 Multiparameter Meter
Dissolved Oxygen	YSI 85 Multiparameter Meter
PH	YSI 650/6820 Multiparameter Meter
PH	Hanna pHep Meter
Temperature	YSI 650/6820 Multiparameter Meter
Temperature	YSI 85 Multiparameter Meter
Temperature	Fisher Scientific Digital Thermometer
Conductivity	Oakton C 100, 300, 440 Meter
Conductivity	YSI 650/6820 Multiparameter Meter
Conductivity	YSI 85 Multiparameter Meter
Flow	Dye Drip Pump and Fluorometer
Flow / Velocity	Marsh-McBirney Velocity Meter
Flow / Velocity	SonTek Acoustic Doppler Velocity meter
Flow / Velocity	Acoustic Doppler Current Profiler (ADCP)
Flow/ Velocity	USGS Price Meter and Aqua Calc 5000
Flow/ Velocity	Gurley Velocity Meter
Transparency	Transparency Tube

The stream monitoring program uses portable monitoring equipment in additional to automatic monitoring equipment for several reasons. First, portable-monitoring equipment can be used to obtain stream information that is not ordinarily obtained via permanent in-situ monitoring equipment or laboratory analysis. Examples include dissolved oxygen and transparency tube measurements. Second, measurements of flow (or discharge) are paired with stage measurements to develop a rating curve for each monitoring site, which is used to calculate continuous flow from the continuous stage measurements. Third, portable equipment measurements can be compared to corresponding measurements from the permanent in-situ equipment. Because the portable equipment can be independently calibrated, these comparisons can provide the basis for identifying instrument drift and other possible malfunctions in the permanently installed equipment. Finally, field measurements made via portable equipment can be compared to corresponding laboratory measurements to identify possible problems with the use of the field equipment or possible changes in water chemistry resulting from sample storage or handling.

DISSOLVED OXYGEN

Field dissolved oxygen measurements are made using a portable dissolved oxygen meter. Field staff typically wade into the stream, place the dissolved oxygen probe directly into a well-mixed area of the stream, read the result from the meter, and record the result on the field data sheet. If it is not possible to wade into the stream due to safety considerations, a grab sample may be collected using one of the alternative methods described on page 46, and the dissolved oxygen measurement is made on the grab sample. Dissolved oxygen measurements are often obtained at select stream monitoring stations in conjunction with the collection of grab and composite samples. Dissolved oxygen is measured with a membrane-covered sensor, which detects the electrical current associated with the reduction of oxygen as it diffuses through a Teflon® membrane. The electrical current associated with this process is proportional to the amount of oxygen present in the solution outside the membrane (YSI 6820 operations manual).

Before each field trip, the portable dissolved oxygen meter is air-calibrated in the laboratory, using local barometric pressure and air temperature, according to the procedure recommended by the instrument manufacturer. At the conclusion of each field trip, upon returning to the lab building, an end-of-day dissolved oxygen measurement is made in laboratory water and recorded. The dissolved oxygen meter is then re-calibrated, and a new dissolved oxygen measurement is made in the same water and recorded, to document any meter drift that may have occurred during the course of the monitoring day.

Maintenance of the dissolved oxygen probe requires changing the potassium chloride electrolyte solution and Teflon membrane as recommended by the instrument manufacturer. The potassium chloride solution and membrane should be changed when bubbles are present under the membrane, when dried electrolyte is visible on the membrane/O-ring, or if the meter exhibits unstable measurements. The silver electrodes beneath the probe membrane should be resurfaced if they become black in color, as directed by the instrument manufacturer (YSI 6820 operations manual).

PH

Field pH measurements are made using a portable pH meter. Field staff typically wade into the stream, place the pH probe directly into a well-mixed area of the stream, read the result from the meter, and record the result on the field data sheet. If it is not possible to wade into the stream due to safety considerations, a grab sample may be collected using one of the alternative methods described on page 46, and the pH measurement is made on the grab sample.

Before each field trip, the portable pH meter is calibrated in the laboratory, using the two-point calibration procedure recommended by the instrument manufacturer. At the conclusion of each field trip, upon returning to the laboratory, the pH meter calibration should be verified by measuring the pH of a known reference sample.

Cleaning of the pH probe is required whenever deposits or contaminants are apparent, or when the response of the probe becomes slow (YSI 6820 operations manual).

TEMPERATURE

Field temperature measurements are made using the temperature function of the dissolved oxygen meter, pH meter, or conductivity meter. Field staff typically wade into the stream, place the temperature probe directly into a well-mixed area of the stream, read the result from the meter, and record the result on the field data sheet. If it is not possible to wade into the stream due to safety considerations, a grab sample may be collected using one of the alternative methods described on page 46, and the temperature measurement is made on the grab sample. The temperature sensors in the dissolved oxygen, pH, and conductivity meters are factory-calibrated, but should be checked for accuracy on an annual basis, using a certified NBS thermometer.

CONDUCTIVITY

Field conductivity measurements are made using a portable conductivity meter. Field staff typically wade into the stream, place the conductivity probe directly into a well-mixed area of the stream, read the result from the meter, and record the result on the field data sheet. If it is not possible to wade into the stream due to safety considerations, a grab sample may be collected using one of the alternative methods described on page 46, and the conductivity measurement is made on the grab sample.

Before each field trip, the portable conductivity meter is calibrated in the laboratory, using the one-point calibration procedure recommended by the instrument manufacturer. At the conclusion of each field trip, upon returning to the laboratory, the conductivity meter calibration should be verified by measuring the conductivity of a known reference sample.

The openings in the conductivity probe that allow water access to the conductivity electrodes must be cleaned regularly using a small brush (YSI 6820 operations manual).

STREAM FLOW

Stream flow (discharge) measurements paired with stream stage measurements are critical for establishing a reliable and accurate stage-discharge rating curve at each stream monitoring station. The rating curve is programmed into the Campbell CR10X datalogger to produce a continuous time-series of flow data from the record of continuous stage measurements at each station, obtained via the permanent in-situ monitoring equipment (bubbler/pressure transducer, ultrasonic sensor, or shaft encoder).

Velocity (or current) meters, such as the Marsh-McBirney Meter, Son Tek Meter, USGS Price Meter, and Gurley Meter, are used to measure water velocity at a specific point in the stream channel. Stream flow (discharge) can be calculated by making regularly spaced velocity measurements across a stream or river transect, coupled with measurements of the cross-sectional stream channel geometry at the same transect locations. The current meters are factory-calibrated.

An estimate of stream flow is obtained in the following manner. Velocity meters are only used when conditions allow wading across the entire stream channel. A measuring tapeline is extended perpendicularly across the stream channel from bank to bank, at a suitable location. The width of the stream channel is divided up into ten equal intervals (typically 1-3 feet). Each of these intervals represents an idealized trapezoidal panel. A graduated wading rod is used to measure the stream depth at the mid-point of each panel. For panels with a water depth greater than 30 inches, the velocity is measured at 20% and 80% of the water depth, along a vertical line at the mid-point of the panel. These two velocity measurements are averaged to determine an average velocity for the panel. If the water depth is less than 30 inches, the velocity is measured at 60% of the water depth, along a vertical line at the mid-point of the panel. This single velocity measurement is used as the average velocity for the panel. The flow for each panel is derived by multiplying the average velocity for that panel by the area of the panel (determined from the depth and width of the panel). The flows for all the panels are then summed to arrive at the total stream flow.

Instantaneous stream flow measurements over a wide range of flow conditions are paired with concurrent measurements of stream stage and plotted on a chart for each stream monitoring station. The flow and stage data are reviewed and a rating curve is fit to the data. Rating curve measurements should be regularly obtained at each monitoring station throughout the year, to ensure that the rating curve has not changed, or to establish a new rating curve if stream channel morphology changes.

TRANSPARENCY

Transparency, a measure of water quality, is an indicator of water clarity or the ability to transmit light. Transparency can be measured with a transparency tube, a graduated, clear plastic, 60 or 100 cm-long tube with a black and white Secchi-type disk on the bottom. Transparency tube data provides information on the clarity of stream water, indicating how much sediment, algae, and other particulate materials are suspended in the water. To obtain a transparency tube measurement, a grab sample is collected from a well-mixed stream location, using one of the alternative methods described on page 46. The transparency tube is filled with water from the grab sample. While viewing the transparency tube from the top, water is slowly released from a valve and spigot near the bottom, until the black and white Secchi disk on the bottom of the tube first becomes visible. Water depth in the tube is recorded to the nearest 0.1 cm. A bit more water is then released from the tube until the Secchi disk is clearly visible. Water depth in the tube is again recorded to the nearest 0.1 cm. The two water depth measurements are averaged to provide the final transparency tube measurement. While making transparency tube measurements, avoid direct sunlight and do not wear sunglasses. Keep the transparency tube clean and free from scratches.

Water Quality Sampling

The streams in this report are monitored for a variety of water quality variables (Table 7). These variables are not always analyzed at all sites on every sampling occasion. The variables and frequency of analysis depend upon the sample condition (such as holding time requirements and available sample volume) and water quality concerns for a given stream.

Stream samples are collected on a regular basis during baseflow conditions. In the winter, monthly grab samples are obtained if ice conditions allow. In the spring, summer, and fall, baseflow grab sampling frequency may increase to twice per month. Depending on specific site conditions, additional grab samples might be obtained to help further characterize water quality.
In addition to the baseflow grab samples, flow-weighted composite samples are collected by the automatic samplers during all storm runoff events in the open-water (ice-free) season. About 10-15 storm events per year are characterized via composite sampling, although this number can vary depending upon rainfall frequency and distribution.

Table 7. Stream Monitoring Variables

Aluminum, Filtered
Aluminum, Unfiltered
Ammonia Nitrogen, Unfiltered
Bicarbonate Alkalinity, Unfiltered
BOD 5-day, Unfiltered
BOD Ultimate, Unfiltered
Cadmium, Filtered
Cadmium, Unfiltered
Calcium, Unfiltered
Carbonate Alkalinity, Unfiltered
CBOD 5-day, Unfiltered
CBOD Ultimate, Unfiltered
Chloride, Unfiltered
Chlorophyll-a, Pheo-Corrected
Chlorophyll-a Trichromatic Uncorr.
Chlorophyll-b
Chlorophyll-c
Chromium, Filtered
Chromium, Unfiltered
COD, Filtered
COD, Unfiltered
Conductivity[1]
Copper, Filtered
Copper, Unfiltered
Dissolved Oxygen
Fecal Coliform Bacteria
Flow[1]
Hardness, Unfiltered
Iron, Unfiltered
Lead, Filtered
Lead, Unfiltered
Magnesium, Unfiltered
Manganese, Filtered
Manganese, Unfiltered
Mercury, Methyl
Mercury, Unfiltered
Nickel, Filtered
Nickel, Unfiltered
Nitrate N, Unfiltered
Nitrite N, Unfiltered
Ortho Phosphate, Filtered
Ortho Phosphate, Unfiltered
pH[2]
Pheophytin-a
Potassium, Unfiltered
Precipitation[1]
Sodium, Unfiltered
Stage[1]
Sulfate, Unfiltered
Temperature[1]
Total Alkalinity, Unfiltered
Total Dissolved Solids
Total Kjeldahl Nitrogen, Unfiltered
Total Kjeldahl Nitrogen, Filtered
Total Organic Carbon, Unfiltered
Total Phosphorus, Filtered
Total Phosphorus, Unfiltered
Total Suspended Solids
Turbidity[2]
Volatile Suspended Solids
Zinc, Filtered
Zinc, Unfiltered

[1] Continuous and routine in-situ measurements
[2] Laboratory and in-situ measurements

GRAB SAMPLING PROCEDURES

To ensure representativeness, grab samples are generally collected from the stream thalweg, where water is well mixed. The grab sample is stored and transported in a clean, labeled one-gallon container. Half-gallon and 2-gallon containers may also be acceptable, depending on the type and number of water quality variables to be analyzed. The container is rinsed twice with sample water before the sample is collected. When sampling, enough volume should be collected to fill the one-gallon container, with the exception of a 1-inch headspace. The sample bottle is capped, stored in a cooler with ice packs, and transported to the laboratory within 48 hours.

The following equipment is used for collecting grab samples. The exact equipment will vary slightly, depending upon the protocol for the grab sampling methods used.

- Chest or Hip Waders
- Personal Flotation Device
- Clean, Labeled One-Gallon Sample Bottle (Half-Gallon or Two-Gallon may be used at times)
- Telescoping Reach Pole

- Labline Polypro® Sampler with 50-Foot Nylon Rope
- Automatic Sampler (either Sigma® or ISCO®)
- Polypropylene Sample Tubing
- Cooler and Ice

Four different methods are used for grab sample collection. The method used for any particular sample depends on several factors, including flow rate, stream depth, stream width, and accessibility. However, the overriding factor is safety of the sampling crew.

WADING AND HAND COLLECTION

If the stream is safe to wade, the person collecting the sample wades to the center of the stream with a sample bottle. The sample collector should face upstream, taking care to ensure that any stream bottom debris disturbed by wading does not contaminate the sample. After the sample container is rinsed twice with site water, the bottle cap is removed and the sample bottle is inverted and dipped below the surface, then turned upright to collect the sample while holding the bottle about 1 foot below the water surface.

REACH POLE COLLECTION

When wading conditions are not safe in smaller streams, a grab sample may be collected using a reach pole. In this case, the sample bottle is fitted into a wire cage attached to the end of a long, telescoping reach pole. After the sample container is rinsed twice with site water, the bottle cap is removed and the sample bottle is inverted and dipped below the surface, then turned upright to collect the sample while holding the bottle about 1 foot below the water surface.

BRIDGE AND ROPE COLLECTION

For larger rivers where the sampling station is adjacent to a bridge, a grab sample may be collected using a Labline Polypro® (or equivalent) sampler lowered from the bridge deck near the river thalweg. The Labline sampler is lowered to the river surface and plunged into the water to an approximate depth of 1 meter below the water surface. The sampler is then raised to the bridge deck, and the grab sample is poured into the sample container. In this variation, both the Labline sampler and the sample bottle should be rinsed twice with site water before collection of the final sample, as described above.

AUTOSAMPLER PUMP COLLECTION

If it is not possible to use one of the other three grab sampling methods, the pump from the automatic sampler can be used to collect a grab sample. The autosampler should be programmed to rinse and purge the intake line before the sample is collected. Once this has been done, the sample container is rinsed twice and the final sample is collected via the autosampler pump.

FLOW-WEIGHTED COMPOSITE SAMPLING PROCEDURE

Flow-weighted composite samples are collected by the automatic samplers during storm runoff events. The automatic sampler collects samples on an equal-flow increment basis. With equal-flow increment basis sampling, the datalogger is programmed to trigger the autosampler to collect discrete sub-samples representing equal volumes of stream flow. For example, an autosampler may be programmed to collect a sub-sample for every 100,000 cubic feet of stream discharge. If a storm runoff event had a total of 1,000,000 cubic feet of discharge, the autosampler would collect 10 discrete sub-samples. The discrete sub-samples can be collected in separate 1000-ml plastic containers in the automatic sampler during the runoff event, then mixed thoroughly and combined into a 5-gallon plastic container, to create a composite sample. As an alternative, a composite sample can be directly created by placing a 5-gallon glass container in the automatic sampler to receive all of the discrete flow-weighted sub-samples collected during the runoff event. The composite sample is placed in a cooler with ice and transported to the laboratory, for analysis within 48 hours.

The following equipment is used for collecting flow-weighted composite samples.

- 24 Clean, 1000-ml Plastic Sample Bottles
- Clean, Labeled Five-Gallon Composite Sample Bottle
- Automatic Sampler (either Sigma® or ISCO®)
- Polypropylene Sample Tubing
- Campbell CR10X Datalogger
- Cooler and Ice

Laboratory Analytical Procedures

All laboratory analyses for the stream monitoring program are performed by the MCES laboratory. The MCES laboratory is certified under the State of Minnesota laboratory certification program. The Minnesota Department of Health, which is the certifying agency for Minnesota, has assigned the laboratory a certification number of 027-123-172. The analytical methods are listed in Table 8.

Table 8. Laboratory Analytical Methods for Stream Monitoring Variables

Lab Parameters	Method	Certified Ref.	Lab Parameters	Method	Certified Ref.
Aluminum, Unfiltered	MCES 550.1.2	EPA 200.8	Magnesium, Unfiltered	MCES 550.1.2	EPA 200.8
Ammonia Nitrogen, Unfiltered	MCES 501.0.2	EPA 350.1	Manganese, Unfiltered	MCES 550.1.2	EPA 200.8
Bicarbonate Alkalinity, Unfiltered	NA	NA (Titration)	Mercury, Filtered	MCES 548.5.1	EPA 245.1
BOD 5-day, Unfiltered	MCES 300.0.1	SMEWW 507	Mercury, Unfiltered	MCES 548.5.1	EPA 245.1
BOD Ultimate, Unfiltered	MCES 324.0.0	SMEWW 507	Nickel, Unfiltered	MCES 550.1.2	EPA 200.8
Cadmium, Filtered	MCES 550.1.2	EPA 200.8	Nitrate N, Unfiltered	MCES 529.0.3	EPA 353.1
Cadmium, Unfiltered	MCES 550.1.2	EPA 200.8	Nitrite N, Unfiltered	MCES 529.0.3	EPA 353.1
Calcium, Unfiltered	MCES 550.1.2	EPA 200.8	Ortho Phosphate, Filtered	MCES 502.1.2	EPA 351.2 EPA 365.4
Carbonate Alkalinity, Unfiltered	NA	NA (Titration)	Ortho Phosphate, Unfiltered	MCES 502.1.2	EPA 351.2 EPA 365.4
CBOD 5-day, Unfiltered	MCES 300.0.1	SMEWW 507	pH	NA	NA (Probe)
CBOD Ultimate, Unfiltered	MCES 324.0.0	SMEWW 507	Pheophytin-a	MCES 802.0.3	ASTM D3731-87
Chloride, Unfiltered	MCES 608.1.1	EPA 325.2	Potassium, Unfiltered	MCES 550.1.2	EPA 200.8
Chlorophyll-a Trichromatic Uncorr.	MCES 802.0.3	ASTM D3731-87	Sodium, Unfiltered	MCES 550.1.2	EPA 200.8
Chlorophyll-a, Pheo-Corrected	MCES 802.0.3	ASTM D3731-87	Sulfate (SO4), Unfiltered	NA	NA (Turbidimetric)
Chlorophyll-b	MCES 802.0.3	ASTM D3731-87	Suspended Solids	MCES 700.0.1	SMEWW 2540D
Chlorophyll-c	MCES 802.0.3	ASTM D3731-87	Total Alkalinity, Unfiltered	NA	NA (Titration)
Chromium, Filtered	MCES 550.1.2	EPA 200.8	Total Dissolved Solids	MCES 716.0.0	SMEWW 2540C
Chromium, Unfiltered	MCES 550.1.2	EPA 200.8	Total Kjeldahl Nitrogen, Filtered	MCES 502.1.2	EPA 351.2 EPA 365.4
COD, Filtered	MCES 609.0.2	EPA 410.4	Total Kjeldahl Nitrogen, Unfiltered	MCES 502.1.2	EPA 351.2 EPA 365.4
COD, Unfiltered	MCES 609.0.2	EPA 410.4	Total Organic Carbon, Unfiltered	NA	NA
Copper, Unfiltered	MCES 550.1.2	EPA 200.8	Total Phosphorus, Filtered	MCES 502.1.2	EPA 351.2 EPA 365.4
Dissolved Oxygen	MCES 301.0.0	ASTM D888-92A	Total Phosphorus, Unfiltered	MCES 502.1.2	EPA 351.2 EPA 365.4
Fecal Coliform Bacteria	MCES 302.0.0	NA (Membrane Filt.)	Turbidity	MCES 320.0.0	SMEWW 2130 B
Hardness, Unfiltered	NA	NA (EDTA Titration)	Volatile Suspended Solids	MCES 714.0.1	USGS 1-3767-78
Iron, Unfiltered	MCES 550.1.2	EPA 200.8	Zinc, Filtered	MCES 550.1.2	EPA 200.8
Lead, Filtered	MCES 550.1.2	EPA 200.8	Zinc, Unfiltered	MCES 550.1.2	EPA 200.8
Lead, Unfiltered	MCES 550.1.2	EPA 200.8			

Loading Calculations

The term load refers to the total amount or mass of a water quality pollutant delivered by a stream to its receiving water during a given time period, often seasonally or annually. Loading calculations were completed using the computer model FLUX, a standard assessment technique developed by the United States Army Corps of Engineers (Walker, 1999). The FLUX model is a DOS-based calculation tool that allows the user to estimate loads and flow weighted mean concentrations for water quality variables, using grab sample concentration data and continuous stream flow records. Flux incorporates six calculation techniques to map the streamflow and concentration relationship developed from the sample record onto the entire record to calculate total mass discharge and associated error statistics.

The results and discussion section of this report includes information on the estimates of loads and flow weighted mean concentrations for total phosphorus, total dissolved phosphorus, nitrate, and total suspended solids.

It is important to note that there are several alternative methods to FLUX available to calculate annual constituent loads. Future analysis may show that FLUX is not the most accurate method for some stations, and the loads reported in this report will be revised.

Trend Analysis

The stream monitoring program administered by the Metropolitan Council has been designed to collect data necessary to determine pollutant loads within each stream and the pollutant load delivered by each stream to the recipient main stem river. Samples are collected during each precipitation event, as well as during inter-event periods. To identify changes in water quality over time (trend analysis) is difficult due to the myriad of complicated factors that determine runoff volume and concentration. Variable precipitation, snow depth, spring melt rate, intensity of temporary construction or agricultural activity, variable application of road chemicals, and more influence stream quality each year. For lakes and large rivers, trend analysis is relatively uncomplicated compared to that of streams, which often change dramatically in flow and concentration from day-to-day.

Trend analysis was performed on annual pollutant loads and annual mean flow-weighted concentrations calculated using FLUX for each stream, using the seasonal Kendall Tau test ($p \leq 0.05$) (SPSS version 10.0). Using annual values makes the trend analysis rather simplistic, but this is the best approach at this time. The longer the monitoring program is implemented, the more sophisticated the trend analysis techniques that can be used. The Kendall Tau test did identify some trends, however some positive results were deemed insignificant after further analysis.

RESULTS AND DISCUSSION

The following sections present and discuss the results of monitoring data analysis, both for 2003 and for the historical data record. Water quality parameters to be discussed include flow volume, total phosphorus, total dissolved phosphorus, total suspended solids, total nitrates, and other minor miscellaneous monitoring data. Discussion is divided into three general sections:

- analysis of each individual stream for 2003 water quality and flow volume, and discussion of historical flow volumes and nutrient and suspended solids loads as calculated by FLUX.
- comparison of streams based on 2003 and historical pollutant loads and concentrations as calculated by FLUX.
- identification of potential trends in stream volume or water quality

Several points should be considered while reading the data analyses. First, for much of the metro area 2003 was abnormal in precipitation amount and monthly distribution. The total annual precipitation measured at the Minneapolis/St. Paul International Airport was 22.7 inches, as compared to the average annual precipitation for period 1989 – 2003 of 30.7 inches, and most precipitation fell in the first half of the year. Analysis of data from meteorological stations throughout the metro area indicates precipitation is also spatially variable. Therefore each stream was analyzed using data from the nearest meteorological station.

The Metropolitan Council's Target Pollutant Load project is focussed on total phosphorus, total dissolved phosphorus, nitrate, total suspended solids, and turbidity, so greatest emphasis will be placed on these parameters. For each stream graphs were prepared of annual chemical loads (lbs/year), annual flow-weighted mean concentrations, annual flow volume (ft3/year), and the precipitation record from the nearest meteorological station. An error bar indicating the 95% confidence interval has been shown for each annual estimate; this indicates the range of values within which the estimated value has a 95% chance of occurring. The top of each box indicates the mean value estimated by FLUX.

For each stream a hydrograph of the historical flow record was prepared, showing the average daily flow (solid black line), the flow at which samples were collected (solid dots), and daily precipitation. Each hydrograph illustrates the seasonal variations in flow rate and peak flows characteristic of that stream. Flow variations are due to annual snow depth, rate of spring snowmelt, the magnitude of spring, summer and fall rainfall, the relationship of time between storms and resulting soil dryness (also referred to as "antecedent conditions"), the amount of impervious surface in the watershed and the buffering influence of ponds, lakes, and wetlands on flow rate. The hydrograph may also be used to assess the monitoring program used to sample a stream. To best determine water quality conditions in a stream, samples should be taken during a variety of flow regimes, such as at maximum flow for storm events, during intermediate flows, and during baseflow conditions. Most samples should be collected at high flows as most chemical constituents are transported in the stream at that time.

2003 Water Quality and Flow and Historical Load Analysis

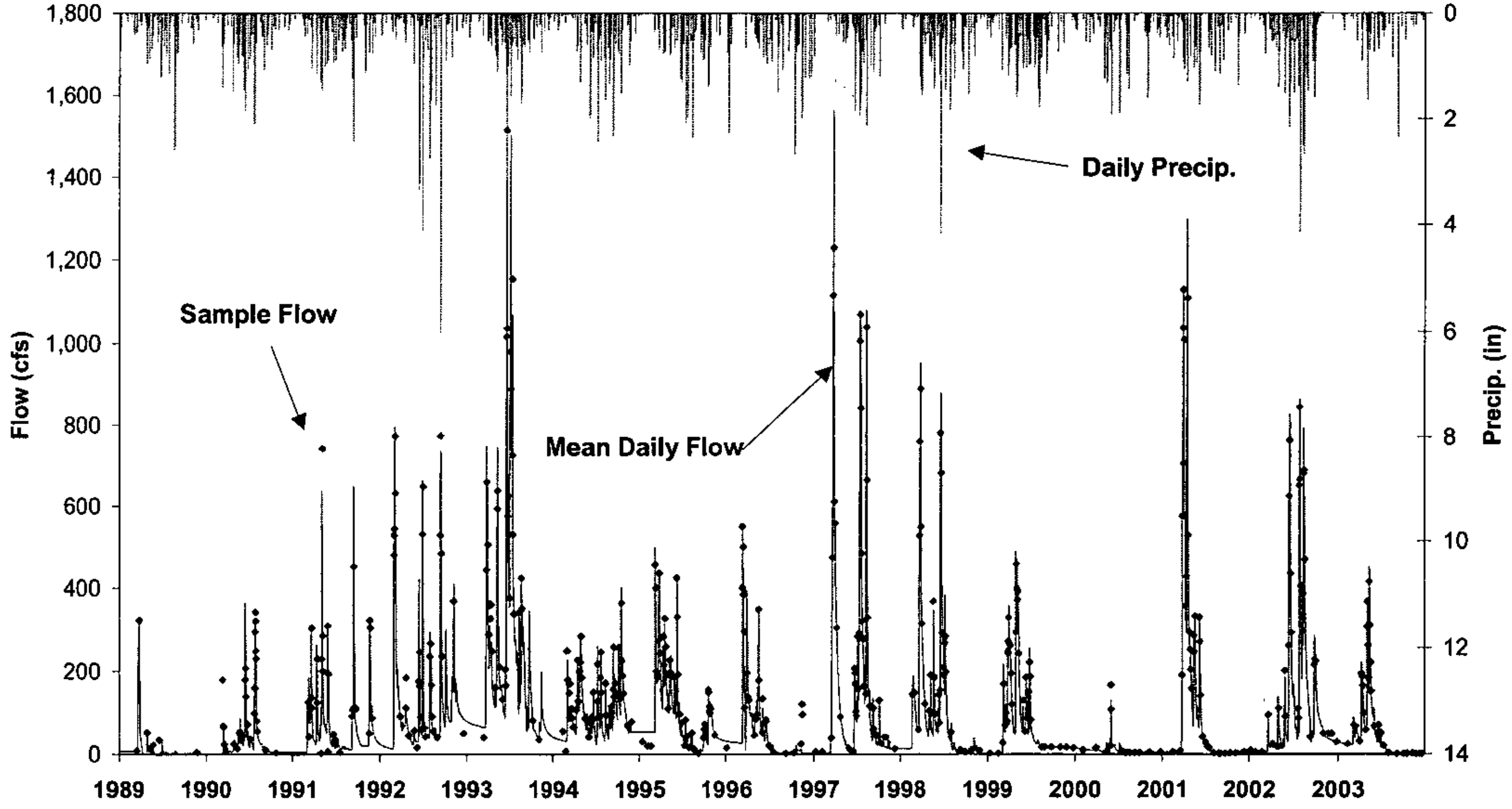
BEVENS CREEK

Stream Flow

Bevens Creek has a watershed of 134 square miles, and is tributary to the Minnesota River. Land use is primarily agricultural and open, with small amounts of single family residential. The watershed has nine lakes, but only Lake Maria is located in the lower portion of the watershed. The watershed has few existing wetlands.

For 2003, the stream flow was greatest in the first half of the year with a peak flow of 451 cubic feet per second (cfs) on May 20 (Figure 27). Flow had fallen off to 70 cfs by the end of June, and to 3 cfs by end of August. The flow rate remained less than 3 cfs for the remainder of 2003. This pattern reflects the precipitation events of 2003 as discussed previously. The total runoff volume was 1.18 billion cubic feet (ft3), with a watershed yield (annual volume divided by watershed area) of 3.9 inches.

Figure 27. Bevens Creek Mean Daily and Sample Flows and Daily Precipitation (Jordan Sta. #214176)



Highest recorded peak flows in past years include 1,560 cfs during March 1997, 1,520 cfs during June 1993, and 1,500 cfs during July 1993. The stream flow tends to rise and fall quickly in response to rainfall.

Examination of the Bevens Creek hydrograph shows that a good effort has been made to collect samples near peak storm flows. Samples have also been collected routinely at intermediate flows. Prior to 1996, few baseflow samples were collected, but the sampling program has been modified and baseflow is now routinely monitored. Overall, sample collection in Bevens Creek appears adequate for analysis of current conditions.

2003 Water Quality

Appendix B summarizes the chemical and physical data collected during 2003. Of particular note is the mean total phosphorus sample concentration of 330 parts per billion (ppb), mean total suspended solids sample concentration of 150 parts per million (ppm), and mean chloride sample concentration of 35 ppm. Nutrients and solids are typically high in Bevens Creek, which may be due to intense agricultural activity, streambank erosion, failing septage systems, and careless use of household fertilizers. The chloride concentration at the monitoring station is lower than in other more urbanized streams such as Nine Mile Creek.

Table 9 lists the Bevens Creek stream reaches that have been listed on the Minnesota State 303d Impaired Waters Inventory. For each affected reach and associated pollutant or stressor, a total maximum daily load (TMDL) study and management plan must be completed by the Minnesota Pollution Control Agency. Those stream sections affected by fecal coliform may have atypical discharges of farm animal wastes or discharges from malfunctioning septage systems. Those reaches impaired by turbidity likely have high concentrations of suspended solids from field or bank erosion. The chloride impairment of the upper reach seems unusual due to lack of development in the watershed. Further study may find the chloride impairment was caused by an abnormality in chloride concentrations.

Table 9. Bevens Creek MPCA Impaired Waters Inventory

Stream Reach	Yr	Affected use	Pollutant or stressor	TMDL start/ completion
Bevens Creek; Silver Cr to Minnesota R	02	Swimming	Fecal coliform	2005//2008
Bevens Creek; Silver Cr to Minnesota R	02	Aquatic life	Turbidity	2005//2009
Bevens Creek; Headwaters (Washington Lk) to Silver Cr	02	Aquatic life	Chloride	2005//2007
Bevens Creek; Headwaters (Washington Lk) to Silver Cr	02	Swimming	Fecal coliform	2005//2008
Bevens Creek; Headwaters (Washington Lk) to Silver Cr	02	Aquatic life	Turbidity	2005//2009

Bevens Creek Historical Chemical Loads and Concentrations Calculated by FLUX

As stated previously, the annual flow volume and pollutant loads are below the long term (1990-2003) average due to the paucity of precipitation in 2003 (Figures 28 and 29). Annual total phosphorus loads have ranged from 324,000 pounds (lbs) (1993) to 4,900 lbs (2000). Similarly, suspended solids loads have ranged from 132 million lbs (1993) to 366,000 lbs (2000). Annual pollutant loads in the creek were likely more strongly influenced by the timing of storm events and antecedent conditions and watershed activities than by simply the total annual precipitation.

Pollutant concentrations followed a similar pattern. The 1990-2003 average total phosphorus and total suspended solids flow-weighted mean concentration were 660 ppb and 230 ppm, respectively.

Figure 28. Bevens Creek
Mass Loads to Minnesota River

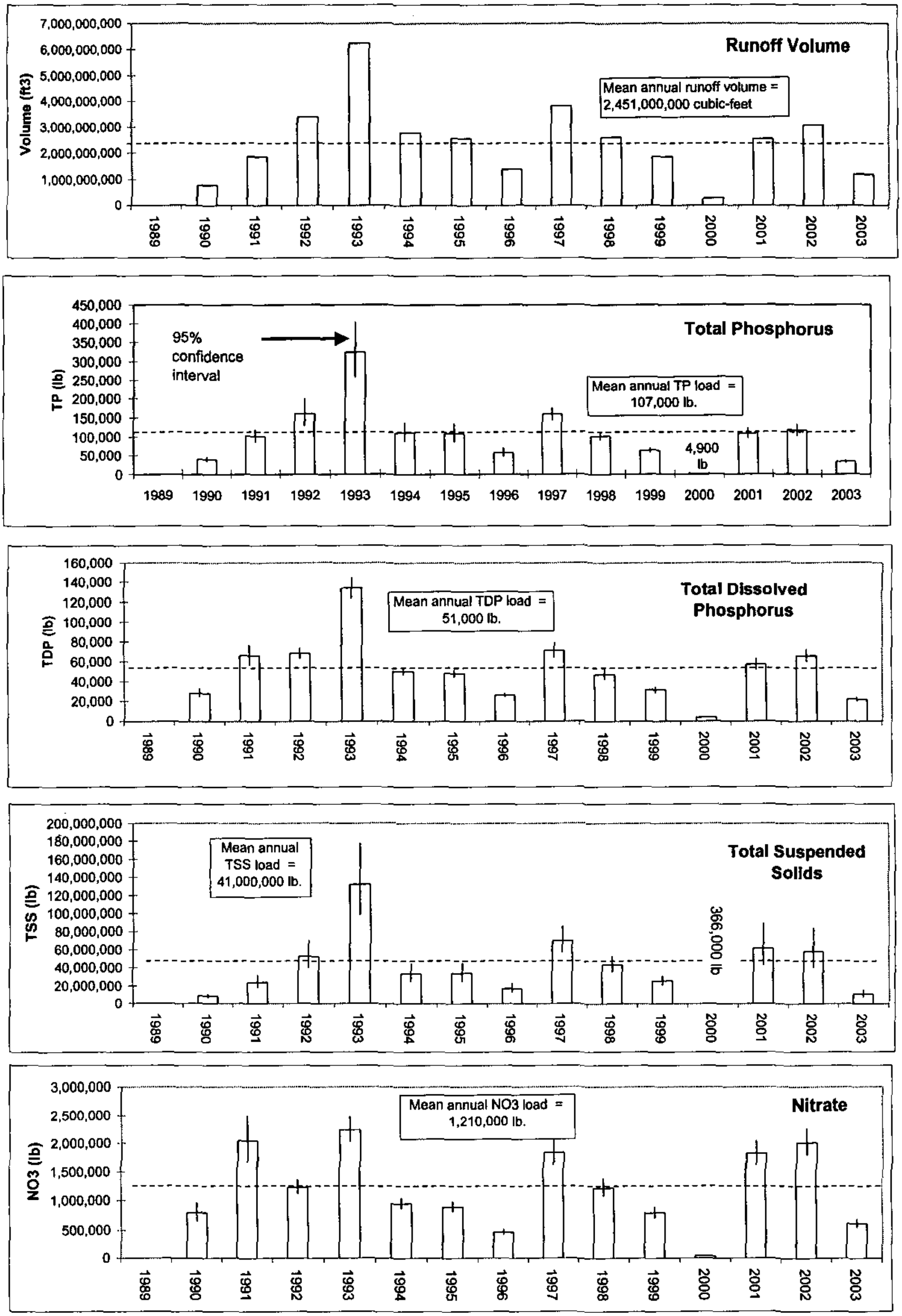
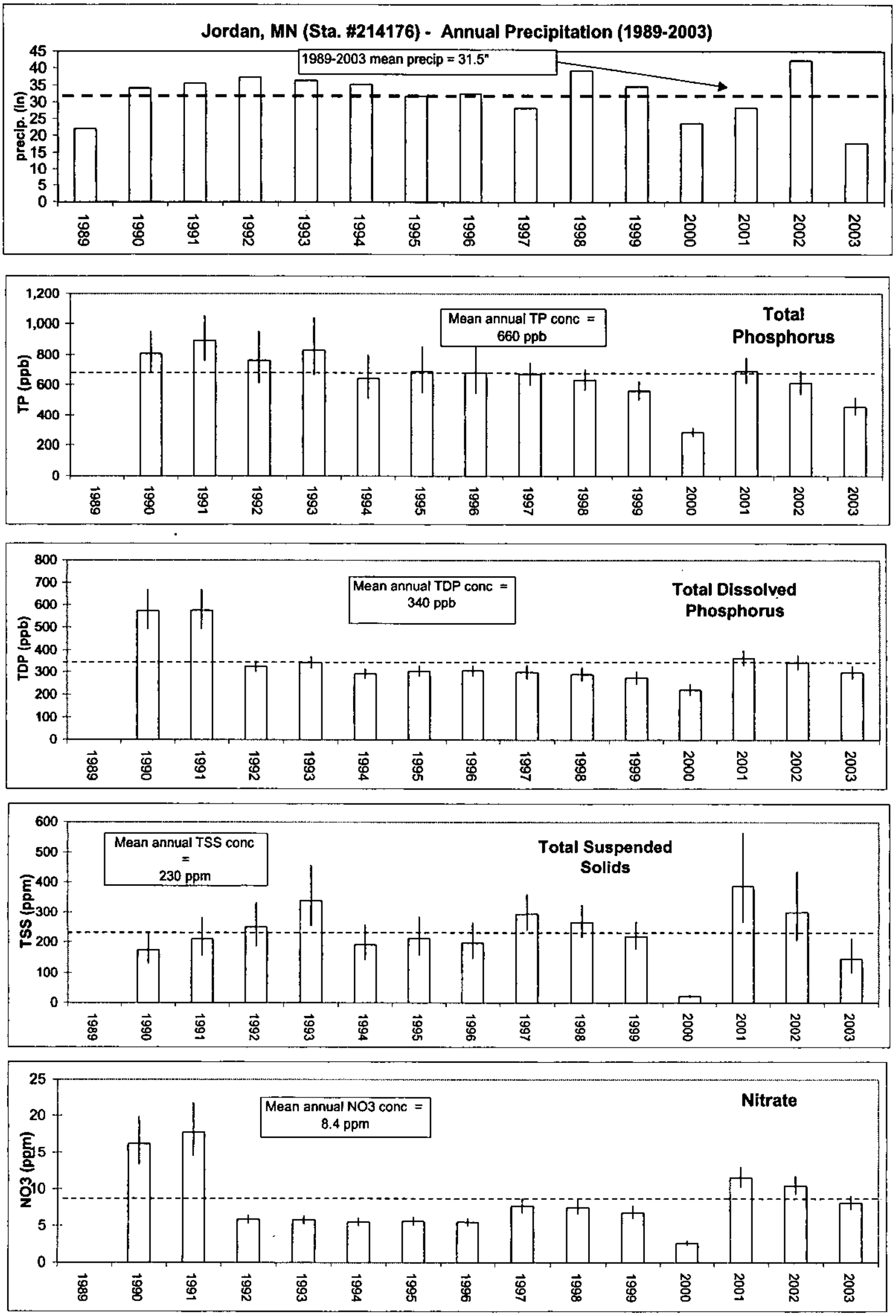


Figure 29. Bevens Creek
Annual Flow-weighted Mean Concentrations



BLUFF CREEK

Streamflow

Bluff Creek has a watershed of 9 square miles, and is a tributary of the Minnesota River. The creek has been straightened and ditched through much of the agricultural portion of the watershed. Land use is primarily agricultural with some rural residential. Increased urbanization is expected in the near future. There are no lakes in the watershed, and few significant wetlands through which the creek flows.

Monitoring was started in 1989, but the complete station was not online until 1991 (Figure 30). From superficial examination of the hydrograph it appears average daily flow rate and peak flows may have decreased since 1991. During 2003, the daily flows follow the precipitation pattern for the year. Most flow occurred in the first half of the year, with peak daily flow occurring on May 11 (36 cfs). A sample was collected on the same day at an instantaneous flow of 60 cfs. By the end of July the daily flow rate had fallen below 1 cfs, and remained at same level through the rest of 2003. The total volume of water carried by Bluff Creek in 2003 was 90 million ft3, while the watershed yield (annual volume divided by watershed area) was 4.3 inches.

Highest recorded daily peak flows in past years of record include 176 cfs in September 1991 and 114 cfs in July 1992. Samples were collected at instantaneous flows of 215 cfs and 319 cfs in April and August 1998, respectively.

Examination of the Bluff Creek hydrograph shows that the first few years of monitoring did not include many intermediate or baseflow samples, however since then a good effort has been made to collect samples near peak storm flows, at intermediate flows and at baseflow. Overall, sample collection in Bluff Creek appears adequate for analysis of current conditions.

2003 Water Quality

Appendix B summarizes the chemical and physical data collected in Bluff Creek during 2003. The mean total phosphorus sample concentration was 170 ppb, with a range between 10 ppb and 870 ppb. Average total suspended solids sample concentration was 197 ppm, with a range between 1 ppm and 2,430 ppm. Average turbidity was 15 ntu, with a range between 1 ntu and 140 ntu. Mean chloride concentration in 2003 was 69 ppm (with minimum and maximum values of 51 ppm and 130 ppm).

Figure 30. Bluff Creek Mean Daily and Sample Flows and Daily Precip. (Chaska/Chanhassen Sta. # 211448 + #21465)

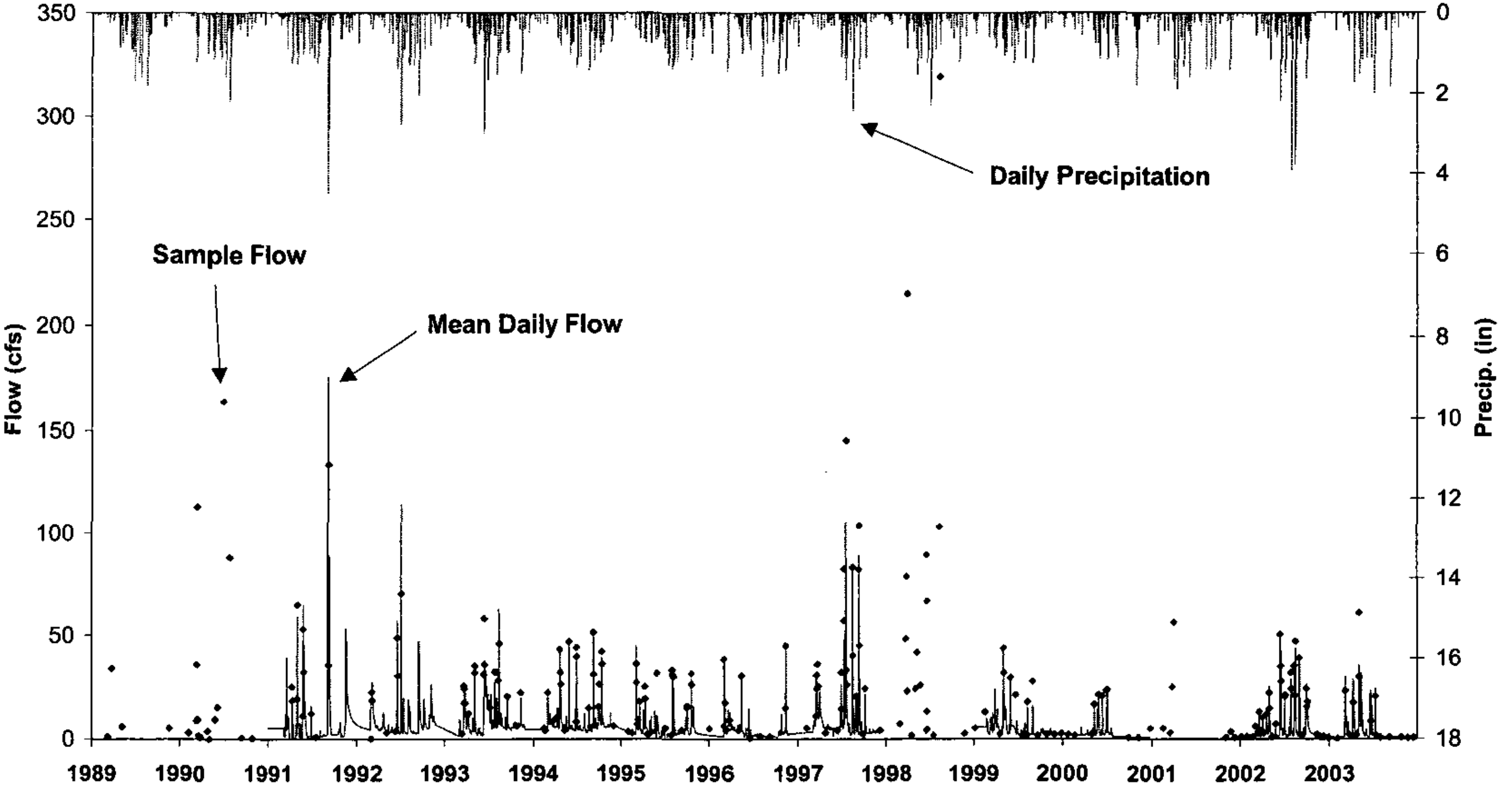


Table 10. Bluff Creek MPCA Impaired Waters Inventory

Reach	Yr	New[9]	Assessment Unit ID	Prev Seg	Affected use	Pollutant or stressor	Target start// completion
Bluff Creek; Headwaters to Minnesota R	02	New	07020012-510	NA	Aquatic life	Turbidity	2005//2009

One Bluff Creek stream reach has been listed on the Minnesota State 303d Impaired Waters Inventory (Table 10) for turbidity. Agricultural runoff, streambank erosion, or resuspension of particles from the creek bottom may have caused the high turbidity levels resulting in the Impaired Waters listing.

Bluff Creek Historical Chemical Loads and Concentrations Calculated by FLUX

The annual flow volume and pollutant loads are below the long term (1991-2003) average due to the paucity of precipitation in 2003 (Figure 31). Total phosphorus loads have ranged from 10,500 lbs (1991) to 1,250 lbs (2000). Similarly, suspended solids loads have ranged from 7.4 million lbs (1991) to 730,000 lbs (2000).

The 1990-2003 average total phosphorus and total suspended solids flow-weighted mean concentrations were 490 ppb and 320 ppm, respectively (Figure 32). In 2003, total dissolved phosphorus, total suspended solids, and nitrate concentrations exceeded or were near long term average concentrations. Reduced pollutant loads in 2003 were due to reduced flows, not reductions in watershed sources.

Figure 31. Bluff Creek
Annual Mass Loads to Minnesota River

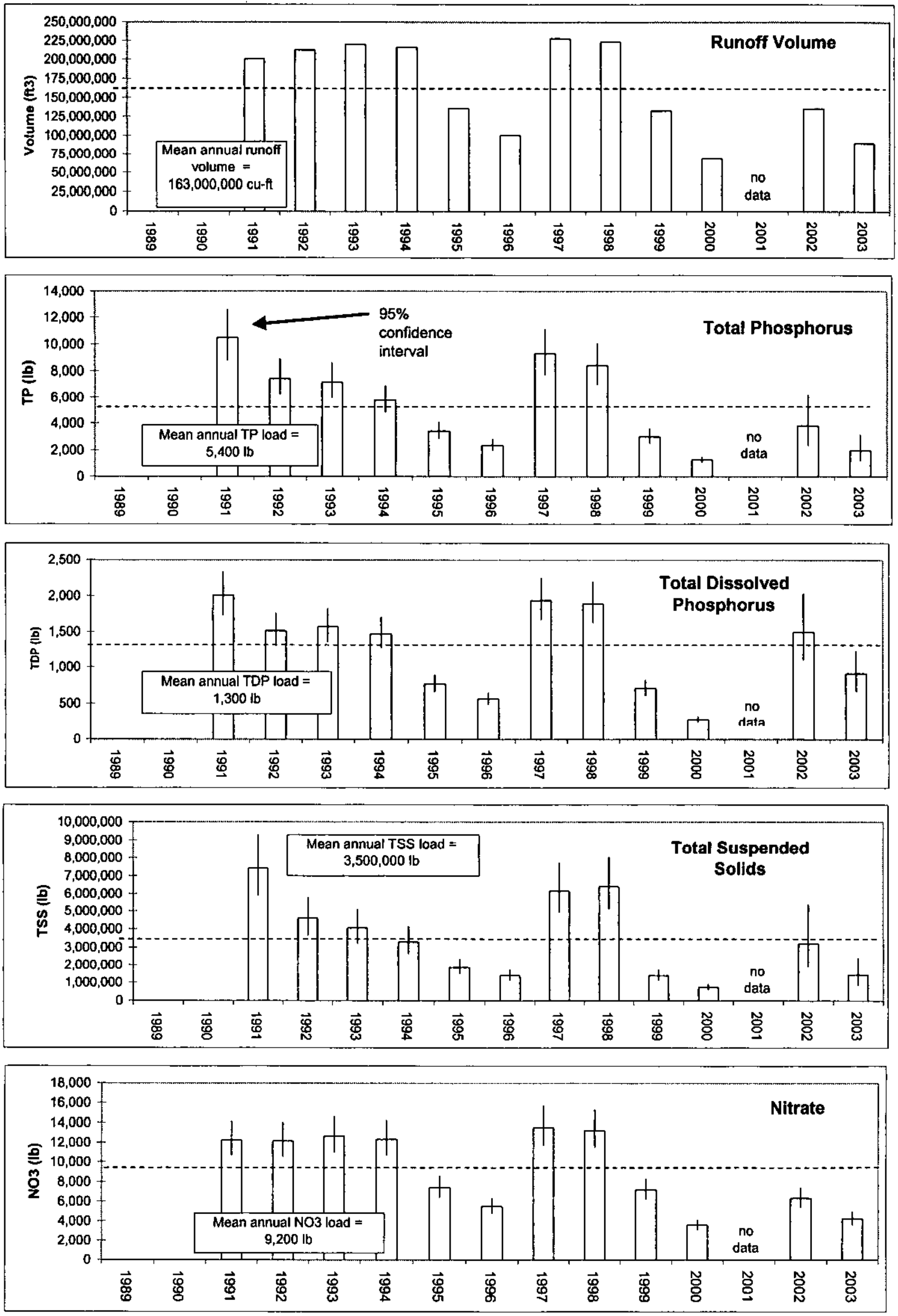
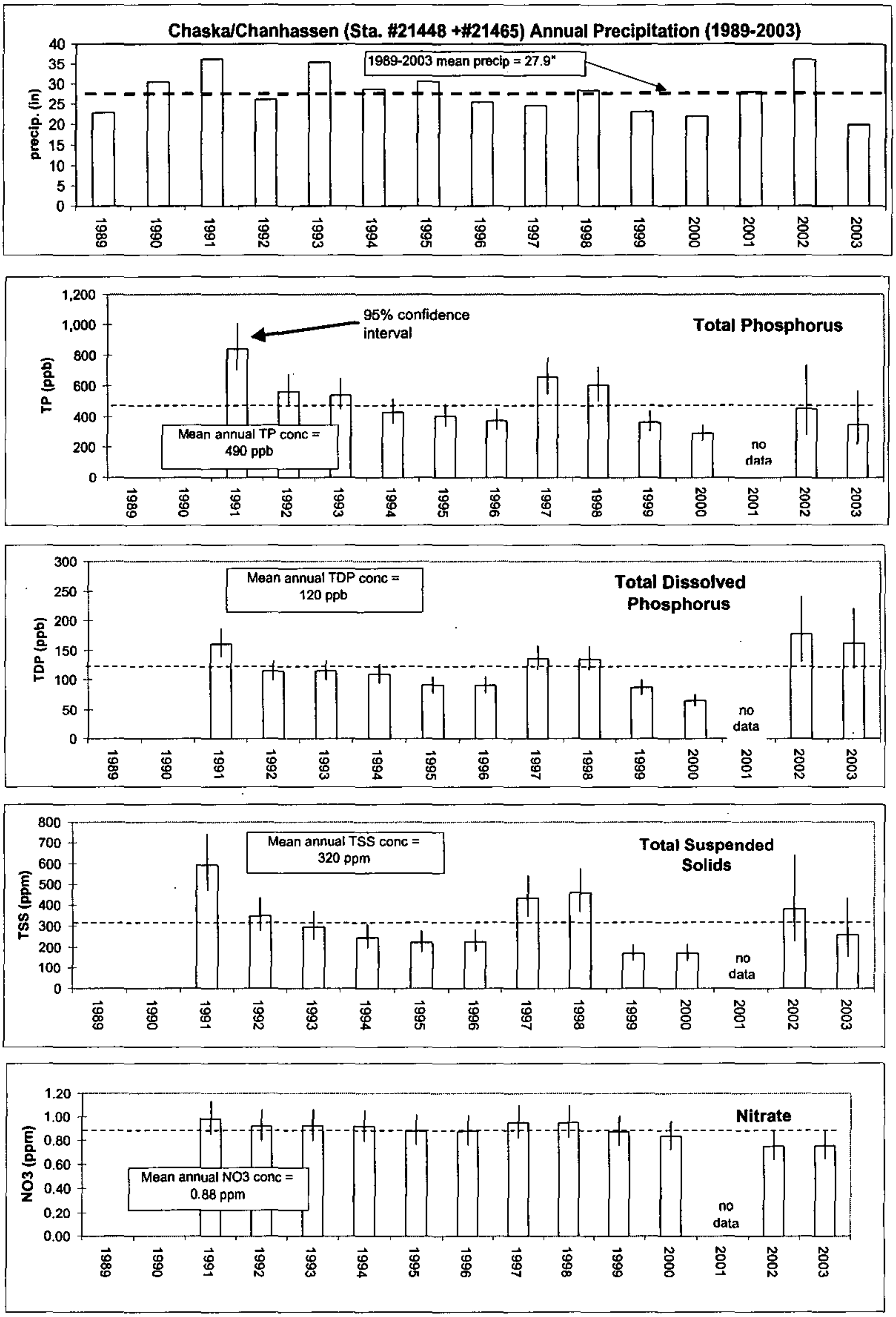


Figure 32. Bluff Creek
Annual Flow-weighted Mean Concentrations



BROWNS CREEK

Streamflow

Browns Creek has a watershed of 34 square miles. Land use is primarily agricultural, forest, open space, and urban residential. In recent years substantial urban development in the City of Stillwater has occurred in the watershed. Browns Creek has two branches, the North and South, which join to form the main stem. The North Branch is the larger of the two, and has its headwaters in a shrub-scrub wetland. The South Branch headwater is the outflow from Long Lake. The upper reaches of the watershed have numerous small lakes and wetlands, however the connection of these waterbodies and the main stem of Browns Creek is ephemeral. The main stem does pass through several large wetlands prior to discharging to the St. Croix River. Once runoff from the urbanized portion of the watershed discharges to the creek, there are no wetlands or impoundments to enhance pollutant removal within the creek.

A major restoration and diversion project on Browns Creek was begun in 2001 and completed in June 2003. Low-to-midflow runoff from 5.4 square miles (3,431 acres) of developed watershed was diverted from Browns Creek to McKusick Lake. Outflow from McKusick Lake drains through the McKusick Ravine stormwater system to the St. Croix River. This represents diversion of over one-third the Browns Creek watershed runoff for small to mid-size storm events. Additional activities included restoration of the historic Browns Creek channel at the Oak Glen Golf Course and restoration of trout habitat.

The Browns Creek monitoring station was installed in 1997; only six years of data have been collected thus far (Figure 33). The creek responds quickly to precipitation events, as evidenced by the sharp peaks in flow throughout each year. During 2003, the flow pattern follows that of the annual precipitation. Highest streamflow occurred in the first half of the year (74 cfs on May 12), while baseflow dominated the second half. The total volume carried by the creek in 2003 was 363 million ft3, with a watershed yield (annual volume divided by watershed area) of 4.6 inches.

Highest recorded daily peak flows in the past years of record include 109 cfs during April 2001 and 107 cfs during March 2000. A sample was collected at 186 cfs on April 11, 2001.

Starting in 2004, watershed areas used in calculations will be adjusted to reflect the McKusick Lake Diversion.

Examination of the Browns Creek hydrograph shows that a good effort has been made to collect samples near peak storm flows, at intermediate flows and at baseflow. Overall, sample collection in Browns Creek appears adequate for analysis of current conditions.

2003 Water Quality

Appendix B summarizes the chemical and physical data collected during 2003. The average total phosphorus concentration was 170 ppb, with a range between 30 ppb and 900 ppb. The average total suspended solids concentration was 37 ppm, with a range between 4 ppm and 207 ppm. Turbidity measurements resulted in mean, minimum, and maximum values of 7 ntu, 3 ntu, and 20 ntu, respectively. Since Browns Creek is a designated trout stream, the suspended solids and turbidity measurements should be low to avoid impacting the fishery habitat. For comparison, the mean total suspended solids and turbidity in Sand Creek in 2003 were 479 ppm and 38 ntu, respectively. Mean chloride concentration in Browns Creek for 2003 was 18 ppm (with minimum and maximum values of

10 ppm and 28 ppm), low in comparison to other urbanized streams such as Nine-Mile Creek (156 ppm) or the Vermillion River (74 ppm).

Figure 33. Browns Creek Mean Daily and Sample Flows and Daily Precipitation (Stillwater Sta. #218037/Browns Creek WD)

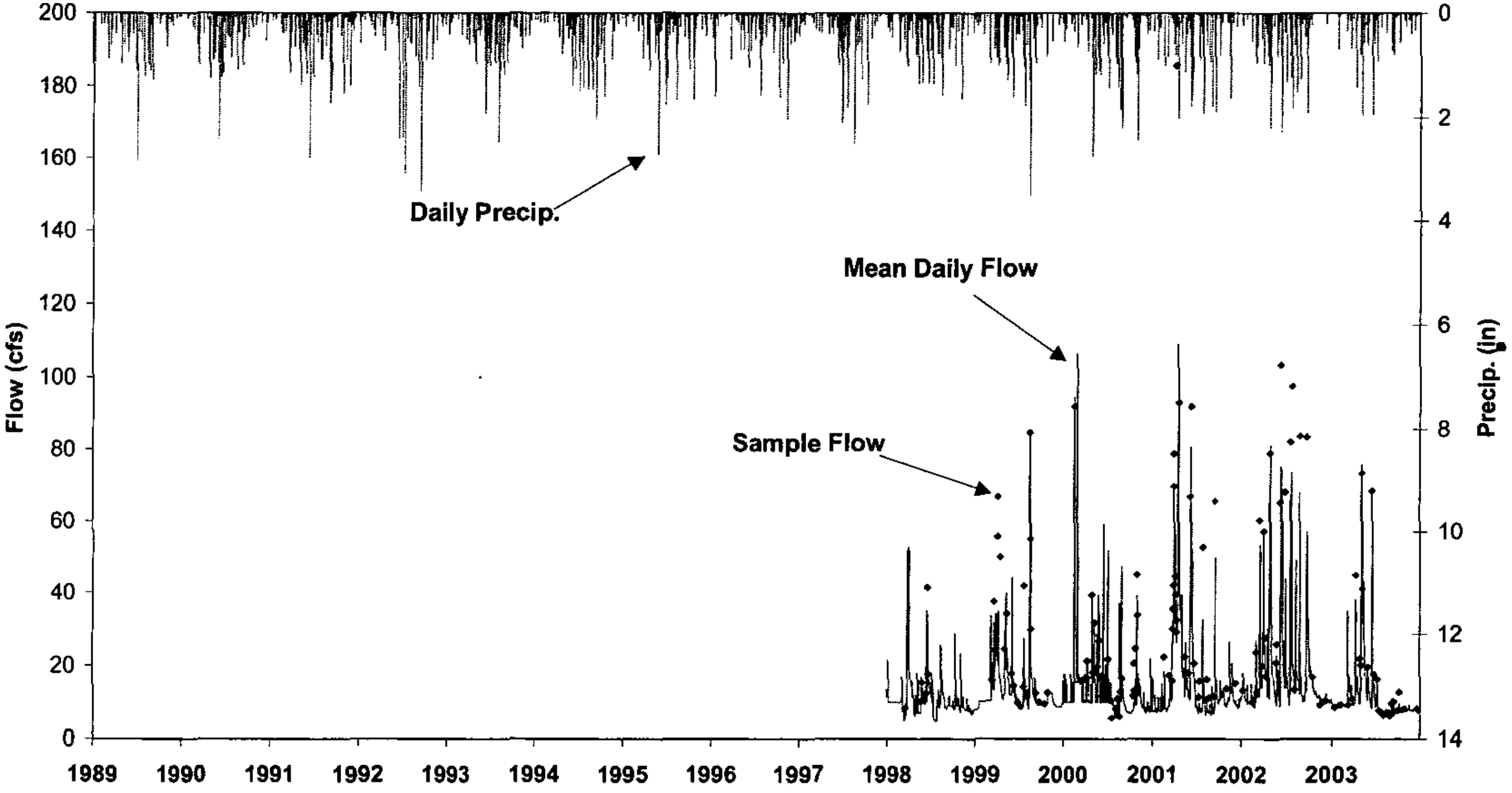


Table 11. Browns Creek Impaired Waters Inventory

Reach	Yr	New	Assessment Unit ID	Prev Seg	Affected use	Pollutant or stressor	Target start// completion
Browns Creek; Headwaters to trout stream portion	02	New	07030005-512	107	Aquatic life	Impaired biota	2004//2008

Browns Creek has one impaired stream segment (Table 11).

Browns Creek historical chemical loads and concentrations calculated by FLUX
The annual flow volume and pollutant loads are below the long term (1998-2003) average due to the scarcity of precipitation in 2003 (Figure 34). Total phosphorus loads have ranged from 9,050lbs (2002) to 4,200 lbs (1998). Similarly, suspended solids loads have ranged from 4.9 million lbs (2002) to 1.1 million lbs (1998). Reduced pollutant loads in 2003 were due to reduced flows, not a reduction in watershed sources.

The 1998-2003 average total phosphorus and total suspended solids flow-weighted mean concentrations were 220 ppb and 93 ppm, respectively (Figure 35). In 2003, total dissolved phosphorus, total suspended solids, and nitrate concentrations exceeded or were near long term average concentrations.

Starting in 2004, analysis will be made to determine the effects of the McKusick Lake diversion on the water quantity and quality in Browns Creek.

Figure 34. Browns Creek
Annual Mass Loads to St. Croix River

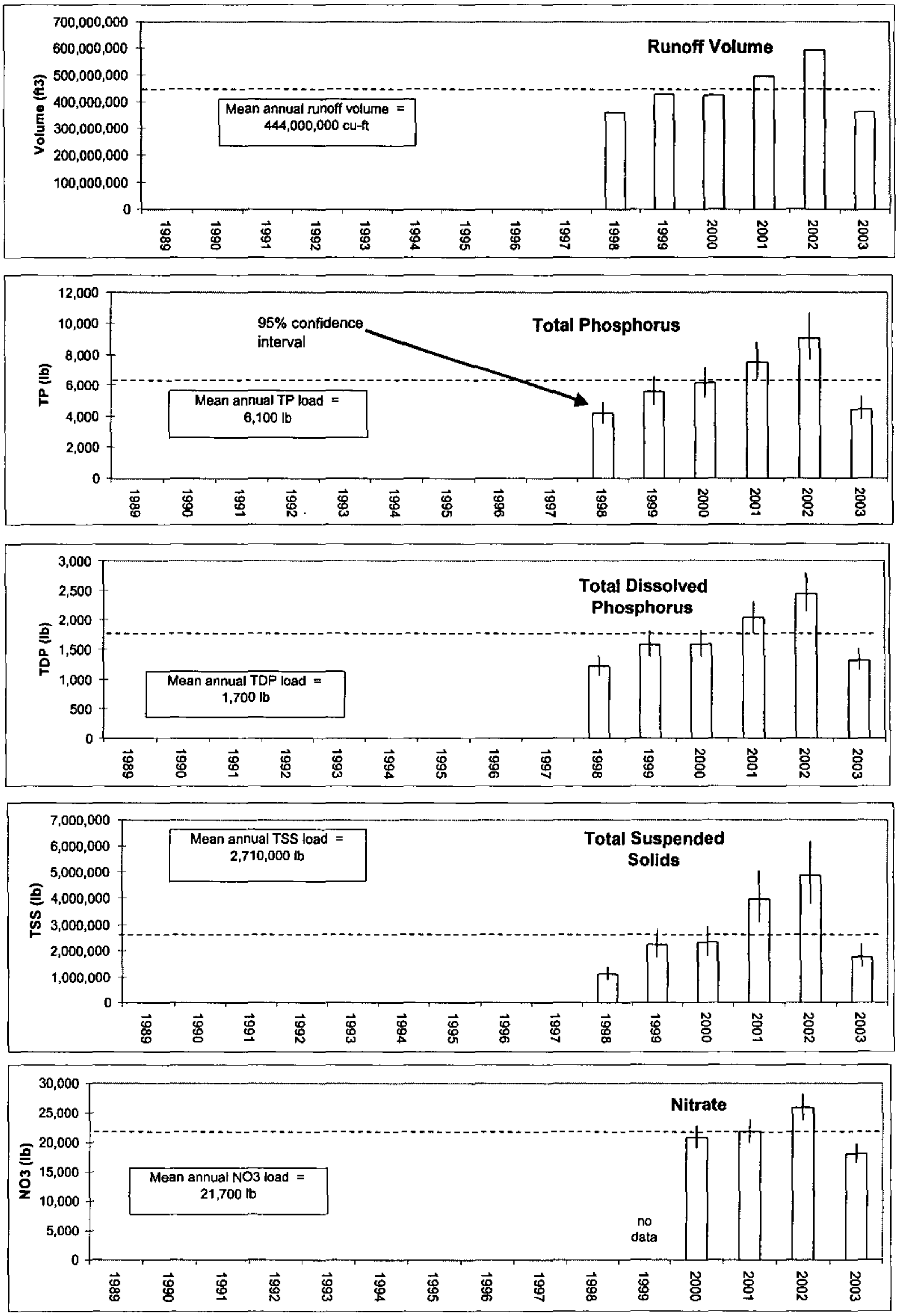
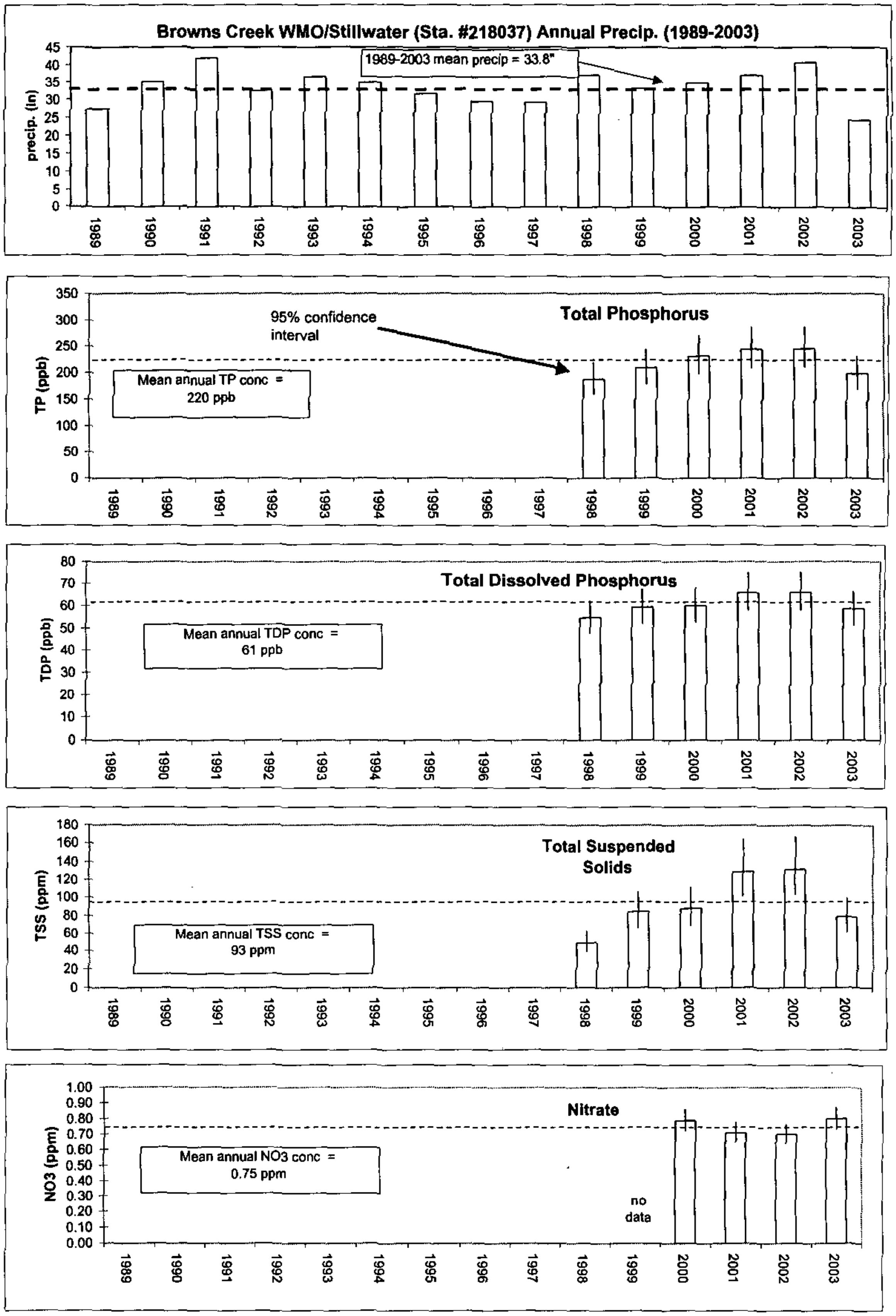


Figure 35. Browns Creek
Annual Flow-weighted Mean Concentrations



CARVER CREEK

Streamflow

Carver Creek has a watershed of 83 square miles. Land use is primarily agricultural, with some urban (City of Waconia) and rural residential. Carver Creek flows through numerous lakes and wetlands prior to discharge into the Minnesota River.

Carver Creek has been monitored since 1989 (Figure 36). Because the creek flows through a number of waterbodies upstream of the monitoring station, one would expect the stream to respond slowly to precipitation events, with periods of prolonged discharge but tempered peak flows. The monitoring station was not operational during 2003 due to a highway bridge installation, but data will be collected in 2004.

Highest recorded daily peak flows in the past 14 years of record include 819 cfs (June 1993), 410 cfs (April 1993), 349 cfs (August 2002), and 339 cfs (September 1991).

The Carver Creek hydrograph shows that while the first few years of monitoring did not include many intermediate or baseflow samples, a good effort has been made to collect samples near peak storm flows, at intermediate flows and at baseflow during the past 10 years. Overall, sample collection in Bluff Creek appears adequate for accurate analysis of current conditions.

2003 Water Quality

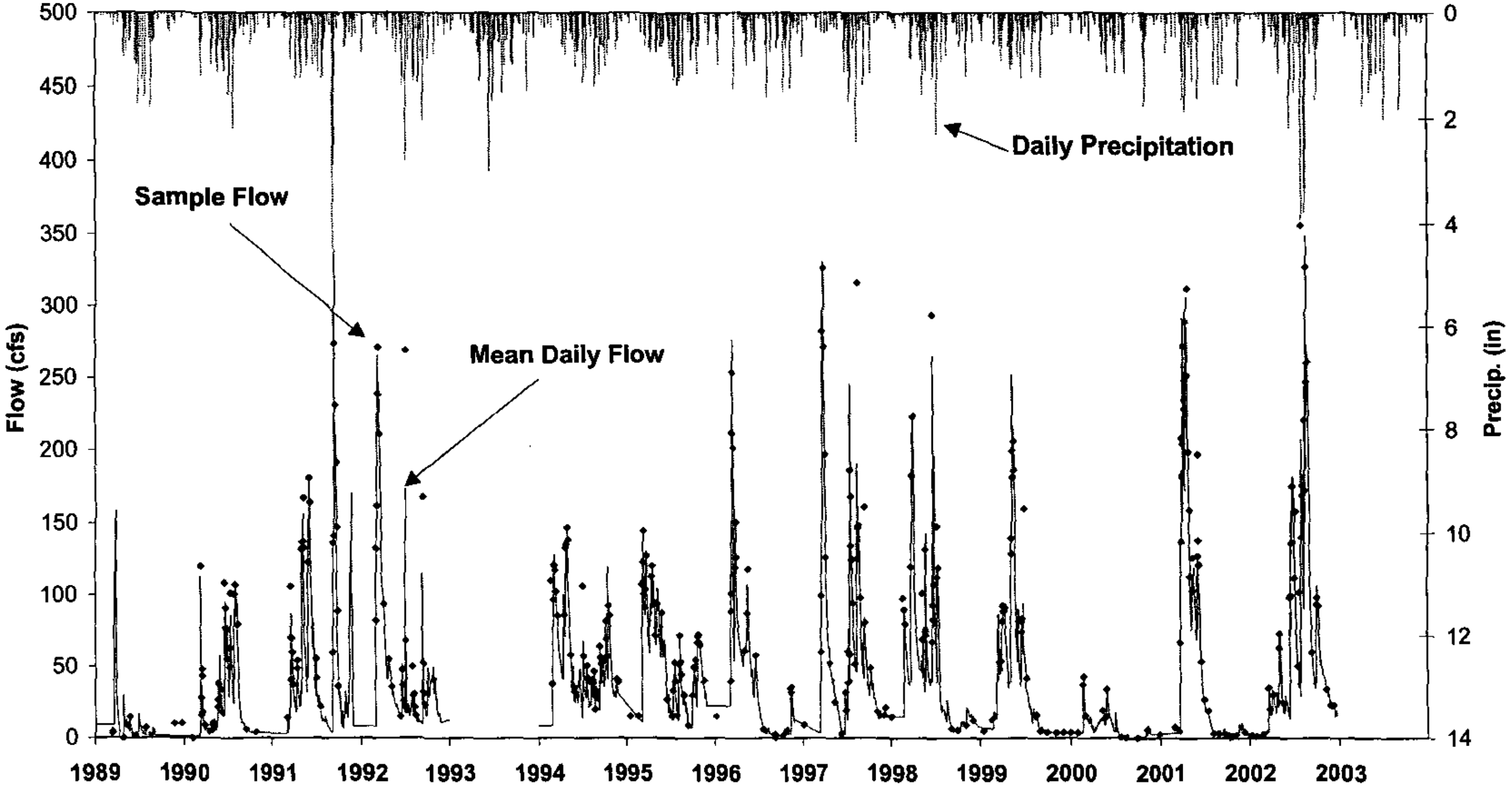
The Carver Creek station was inoperable during 2003.

Table 12. Carver Creek MPCA Impaired Waters Inventory

Reach	Yr	New	Assessment Unit ID	Prev Seg	Affected use	Pollutant or stressor	Target start// completion
Carver Creek; Headwaters to Minnesota R	02	New	07020012-516	002	Swimming	Fecal coliform	2005//2009
Carver Creek; Headwaters to Minnesota R	02	New	07020012-516	002	Aquatic life	Turbidity	2005//2009

Table 12 lists the Carver Creek stream reaches listed on the Minnesota State 303d Impaired Waters Inventory. During 2004, in preparation for development of the TMDL assessment, Carver County personnel are carrying a comprehensive monitoring program of the entire watershed, including numerous locations on Carver Creek. Council staff are assisting in this effort by sharing results of the Target Pollutant Load project modeling effort, which should be completed in 2005.

Figure 36. Carver Creek Mean Daily and Sample Flows and Daily Precipitation (Chaska/Chanhassen Sta. # 211448 + #21465)



Carver Creek Historical Chemical Loads and Concentrations Calculated by FLUX

Total phosphorus loads have ranged from 86,000 lbs (1994) to 3,700 lbs (2000) (Figure 37). Similarly, suspended solids loads have ranged from 25 million lbs (1991) to 535,000 lbs (2000).

The 1989-2002 average total phosphorus and total suspended solids flow-weighted mean concentrations were 770 ppb and 260 ppm, respectively (Figure 38).

All annual loads for Carver Creek have been calculated using FLUX. Due to damping effects of Miller Lake on flow and water quality in the lower portion of the watershed, FLUX may not be the best method for load calculation in this stream. Future assessments of this stream will include analysis of more appropriate load calculation methods, and the historical annual loads listed in this report may be replaced with adjusted loads.

Figure 37. Carver Creek
Mass Loads to Minnesota River

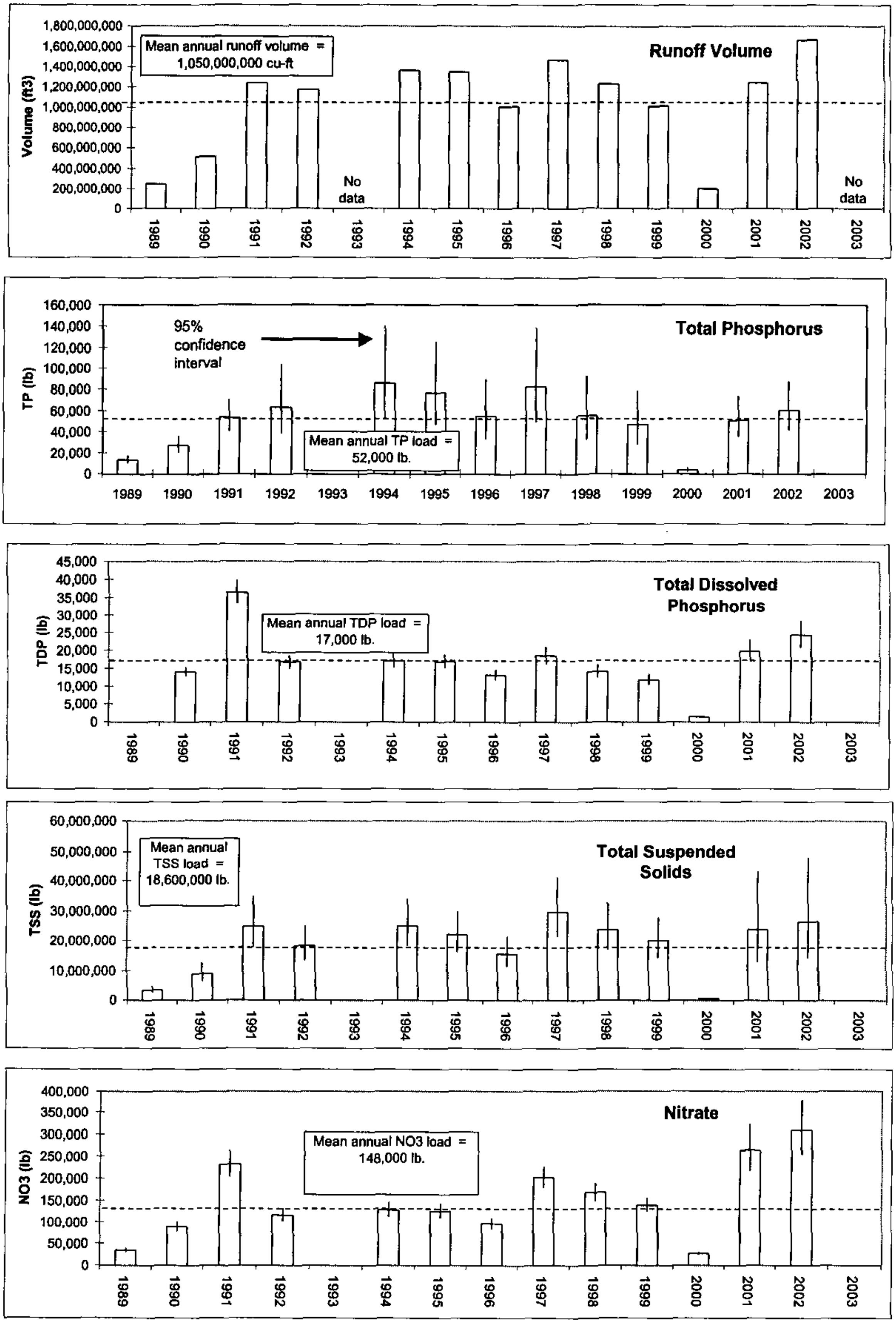
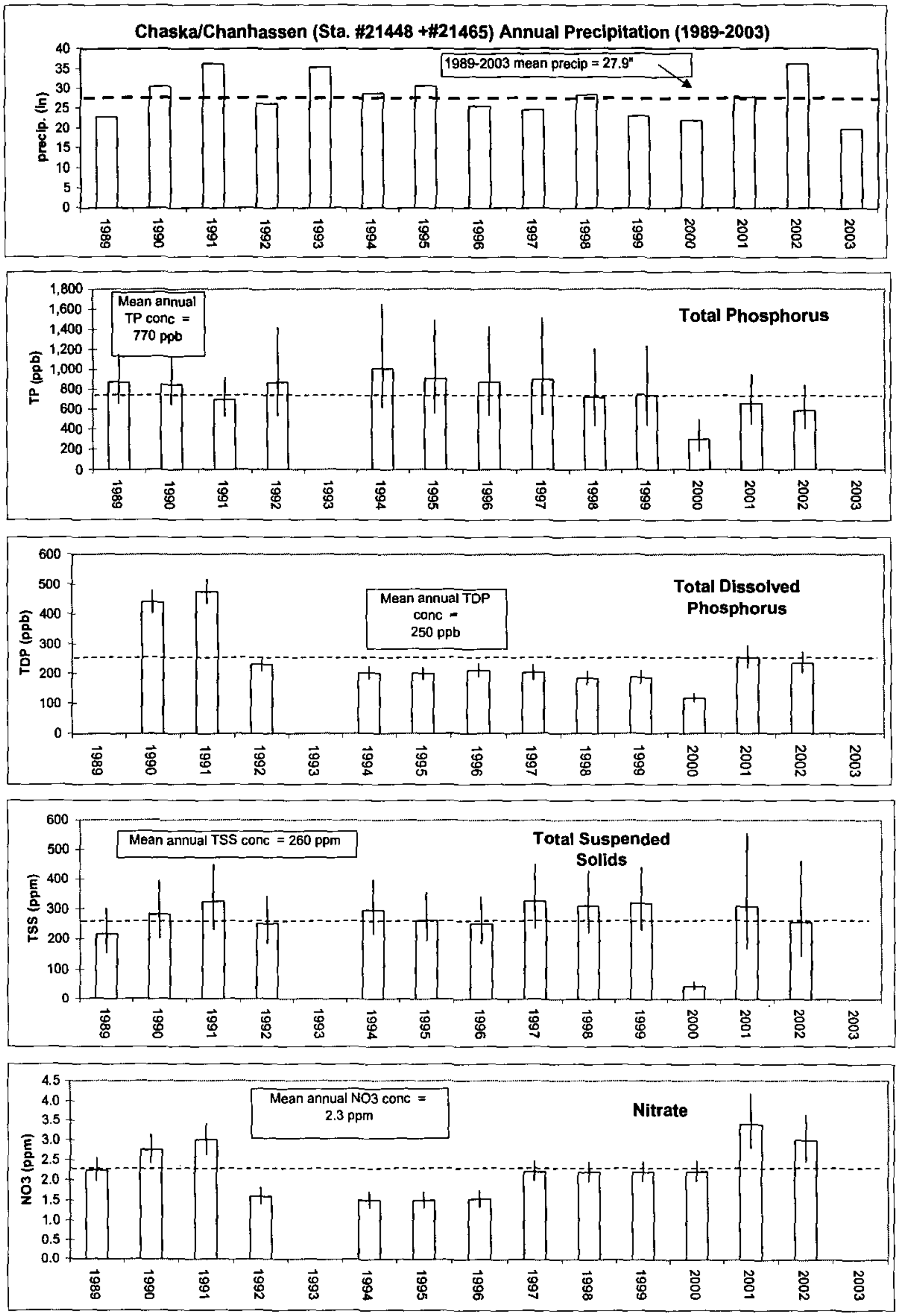


Figure 38. Carver Creek
Annual Flow-weighted Mean Concentrations



CREDIT RIVER

Streamflow

Credit River has a watershed area of 51 square miles, and is a tributary of the Minnesota River. Land use is primarily agricultural with some rural residential and open space. Although there are a few lakes in the watershed (Hanrehan, Murphy), the creek does not flow directly through them.

Monitoring of Credit River commenced during 1989 (Figure 39). The station was out of commission during 2000 and 2002. The sharp peaks of the hydrograph indicate the stream responds relatively quickly to precipitation events. During 2003, the daily flow rates generally follow the precipitation pattern for the year, with most flow occurring in the first half of the year. Peak flows in 2003 include 169 cfs (May 11), 160 cfs (May 20), and 110 cfs (March 15). By the beginning of August the flow had dropped below 3 cfs. The total volume of water carried by Credit River in 2003 was 588 million ft3, while the watershed yield (annual volume divided by watershed area) was 5.0 inches.

Highest recorded daily peak flows in past years include 234 cfs (May 1999), 232 cfs (June 1993), and 231 cfs (June 1998).

The Credit River hydrograph shows that while the first few years of monitoring did not include many intermediate or baseflow samples, a good effort has been made to collect samples near peak storm flows, at intermediate flows and at baseflow during the past10 years. Overall, sample collection in Credit River appears adequate for accurate analysis of current conditions.

2003 Water Quality

Appendix B summarizes the chemical and physical data collected in Credit River during 2003. The mean total phosphorus concentration was 170 ppb, with minimum and maximum measured concentrations of 20 ppb and 750 ppb, respectively. Total suspended solids concentrations measured were 52 ppm (mean), 1 ppm (minimum) and 634 (maximum). Turbidity measurements resulted in mean, minimum, and maximum values of 8 ntu, 1 ntu, and 60 ntu, respectively. Mean chloride concentration in 2003 was 45 ppm (with minimum and maximum values of 29 ppm and 67 ppm).

Table 13. Credit River MPCA Impaired Waters Inventory

Reach[14]	Yr[12]	New[9]	Assessment Unit ID[10]	Prev Seg[13]	Affected use	Pollutant or stressor[3]	Target start// completion[7]
Credit River; Headwaters to Minnesota R	02	New	07020012-517	C01	Aquatic life	Turbidity	2006//2010

One Credit River stream reach has been listed for excess turbidity on the Minnesota State 303d Impaired Waters Inventory (Table 13). Agricultural runoff, streambank erosion, or resuspension of particles from the creek bottom may have caused the high turbidity levels resulting in the Impaired Waters listing.

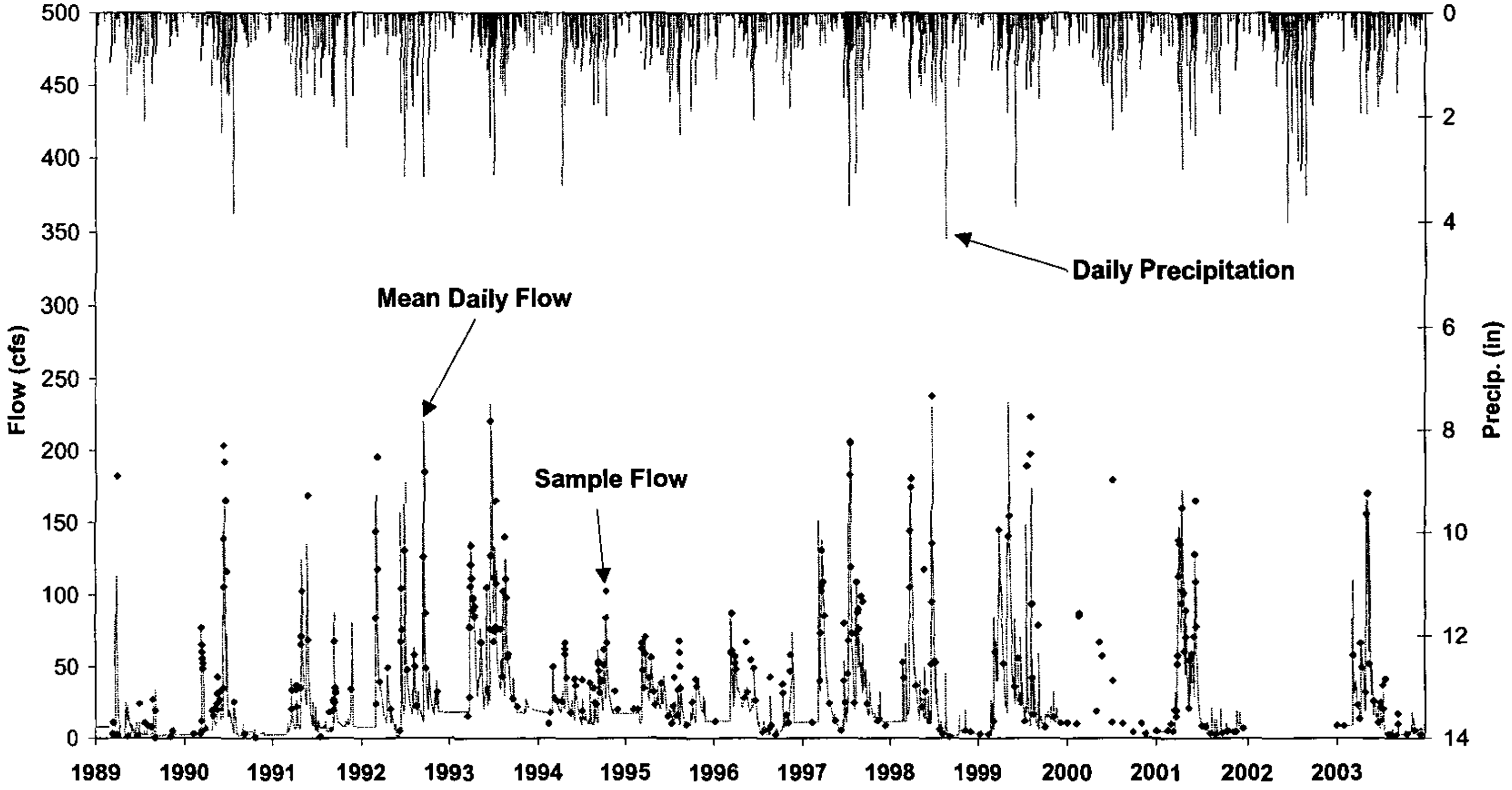


Figure 39. Credit River Mean Daily and Sample Flows and Daily Precipitation (Bloomington/Savage Sta. # 217538)

Credit River Historical Chemical Loads and Concentrations Calculated by FLUX

Credit River 2003 annual loads were lower than the historical average except for nitrate (44,000 lbs for 2003 compared to 35,000 lbs historical annual average) (Figure 40). The 2003 annual flow-weighted mean concentrations were also below the historical average, except again for nitrate (Figure 41). Historical total phosphorus loads have ranged from 23,000 lbs (1993) to 3,800 lbs (1989). Similarly, suspended solids loads have ranged from 7.3 million lbs (1993) to 1.7 million lbs (1996). Annual pollutant loads in the creek have likely been strongly influenced by the timing of storm events and antecedent conditions as well as watershed activities than by simply total annual precipitation amounts.

The 1989-2003 average total phosphorus and total suspended solids flow-weighted mean concentrations were 320 ppb and 100 ppm, respectively.

Figure 40. Credit River
Mass Loads to Minnesota River

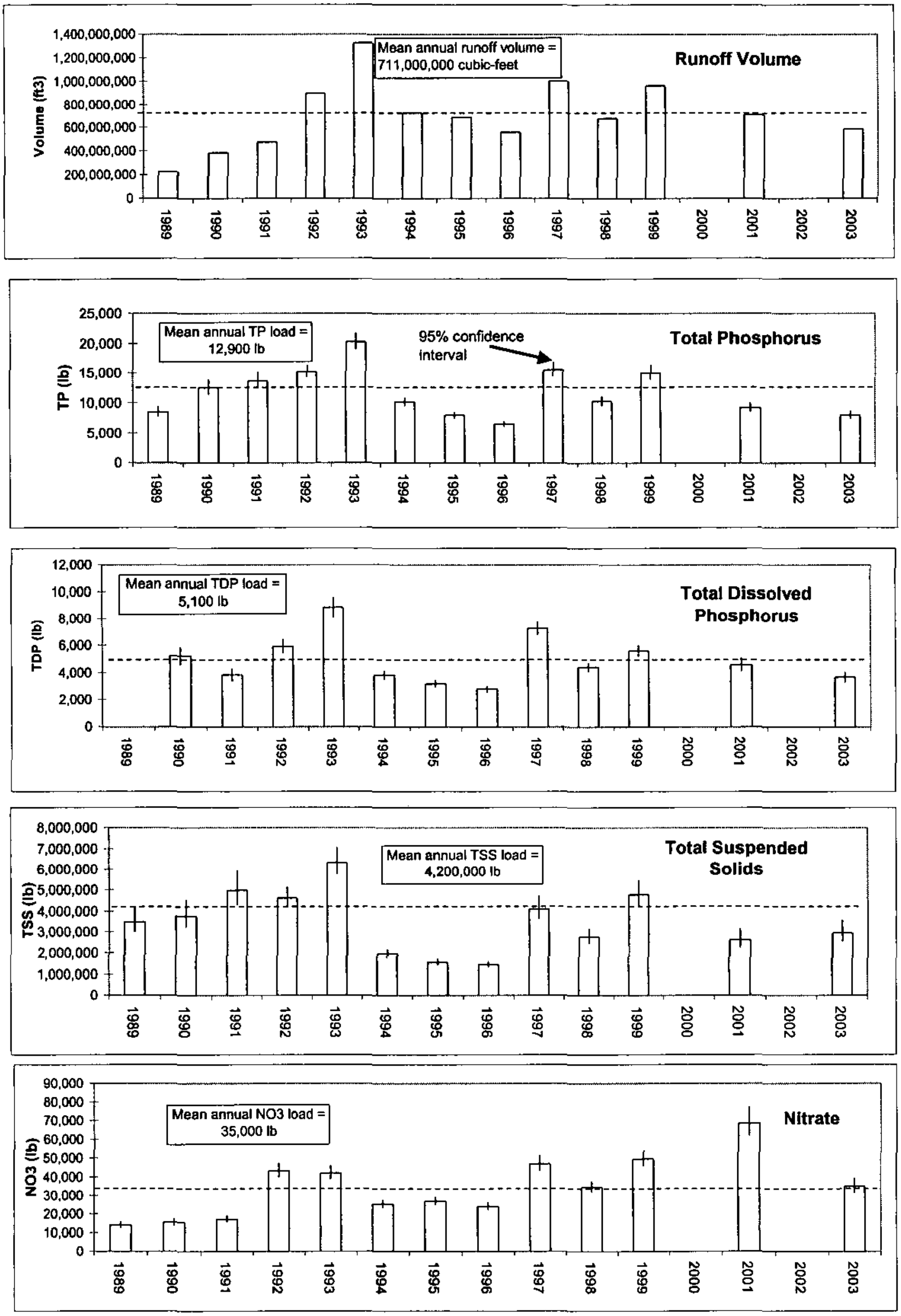
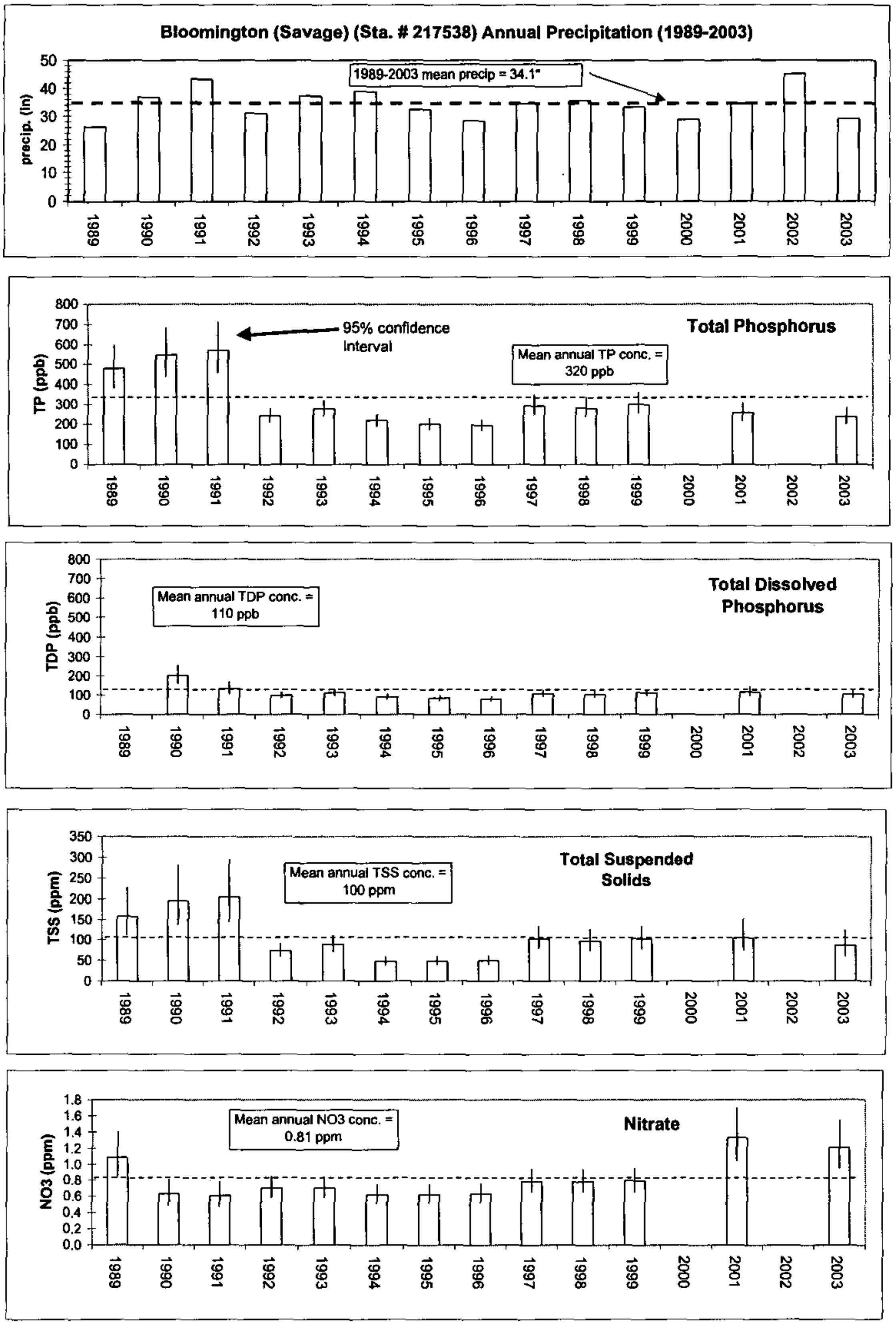


Figure 41. Credit River
Annual Flow-weighted Mean Concentrations



ELM CREEK

Streamflow

Elm Creek has a watershed area of 106 square miles, and is tributary to the Mississippi River. Land use in the watershed includes urban, open space, and rural transitional. Four drainage areas (Diamond Creek, North Fork Rush Creek, Rush Creek, and Elm Creek) join at Hayden Lake within the Elm Creek Regional Park Reserve to form Elm Creek. Numerous lakes (for example Diamond Lake, French Lake, Weaver Lake, Powers Lake) and wetlands lie within the watershed area. Each of the tributary creeks flows through both lakes and wetlands prior to joining and discharging to the Mississippi.

The Elm Creek monitoring station is currently run by the U.S. Geological Survey, and data has been collected since before 1970.

The hydrograph for the period 1989 – 2003 (Figure 42) shows the average daily flow (solid black line) and the flow at which samples were collected (solid dots). The hydrograph illustrates the annual variations in general flow rate and peak flows. The width of the individual storm hydrographs indicates that the lakes and wetlands buffer the creek from high flows and discharge runoff at regulated rate; in other words, the creek flow is not "flashy".

During 2003, the daily flow rates generally follow the precipitation pattern for the year, with most flow occurring in the first half of the year. Peak flows in 2003 include 651 cfs (June 29) and 212 cfs (May 15). By early September flow had dropped below 8 cfs and remained at this level through the rest of 2003. The total volume carried by Elm Creek in 2003 was 1.4 billion ft3, while the watershed yield (annual volume divided by watershed area) was 5.8 inches.

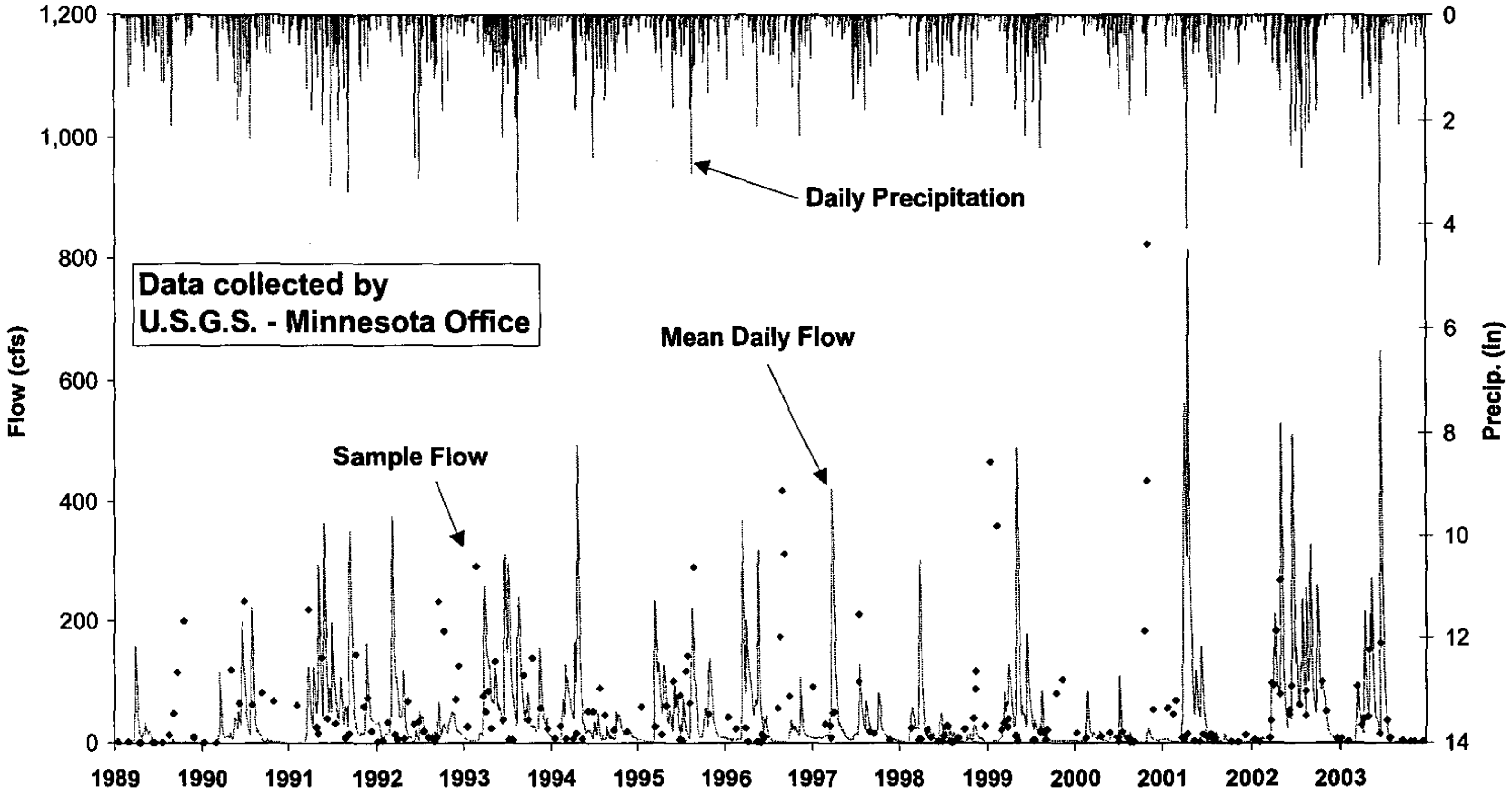
Highest recorded daily peak flows in past years include 815 cfs (April 2001), 492 cfs (May 1999) and 494 cfs (April 1994).

The Elm Creek hydrograph shows that many samples have been taken at baseflow and intermediate flow conditions, but very few samples have been collected to encompass the peak flow of storm events. Since most pollutant transport occurs during storm events, calculations to estimate pollutant loads in Elm Creek are likely too low. Also, sample and daily mean flows show poor correlation, with sample flows far exceeding daily mean flows on many occasions. It appears either equipment problems or changes in the flow rating curve have occurred occasionally since 1989. Correlation between sample and mean daily flows is more reasonable during 2002 and 2003.

2003 Water Quality

Appendix B summarizes the chemical and physical data collected in Elm Creek during 2003. The mean total phosphorus sample concentration was 190 ppb, with values ranging from 40 ppb to 510 ppb. Total suspended solids sample concentrations measured were 18 ppm (mean), 5 ppm (minimum) and 128 (maximum). Neither turbidity nor chloride has been measured in Elm Creek. The numerous lakes and wetlands in the watershed likely serve to remove suspended solids and some nutrients. If the waterbodies are eutrophic, more nutrients may be exported to the creek.

Figure 42. Elm Creek Mean Daily and Sample Flows and Daily Precipitation (New Hope/Delano Sta. #215838 + #212088)



Data collected by U.S.G.S. - Minnesota Office

Elm Creek has not been listed on the Minnesota State 303d Impaired Waters Inventory, and therefore there are no plans for preparation of a TMDL (total maximum daily load) study and management plan

Elm Creek Historical Chemical Loads and Concentrations Calculated by FLUX

Elm Creek 2003 annual loads and flow volume were close to the historical average (Figure 43). The 2003 annual flow-weighted mean concentrations were at or slightly above the historical average (Figure 43). Historical total phosphorus loads have ranged from 122,000 lbs (2001) to 4,400 lbs (1989). Similarly, suspended solids loads have ranged from 7.5 million lbs (2001) to 680,000 lbs (2000). Annual pollutant loads in the creek have likely been strongly influenced by the timing of storm events and antecedent conditions as well as watershed activities than by simply the total annual precipitation amounts. The creek flows through Hayden Lake prior to discharge to the Mississippi River, and it is likely large suspended solids in the creek are removed due to settlement into the lake.

The 1989-2003 average total phosphorus and total suspended solids flow-weighted mean concentrations were 290 ppb and 36 ppm, respectively (Figure 44). There is little variation from the historical mean of suspended solids concentrations, additional evidence that Hayden Lake is removing sediment from the Creek. Future analysis of volatile suspended solids compared with total suspended solids may show that the suspended solids flowing from Hayden Lake are organic based (algae, plant fragments, etc.) rather than mineral based (soil erosion).

Figure 43. Elm Creek
Annual Mass Loads to Missippi River

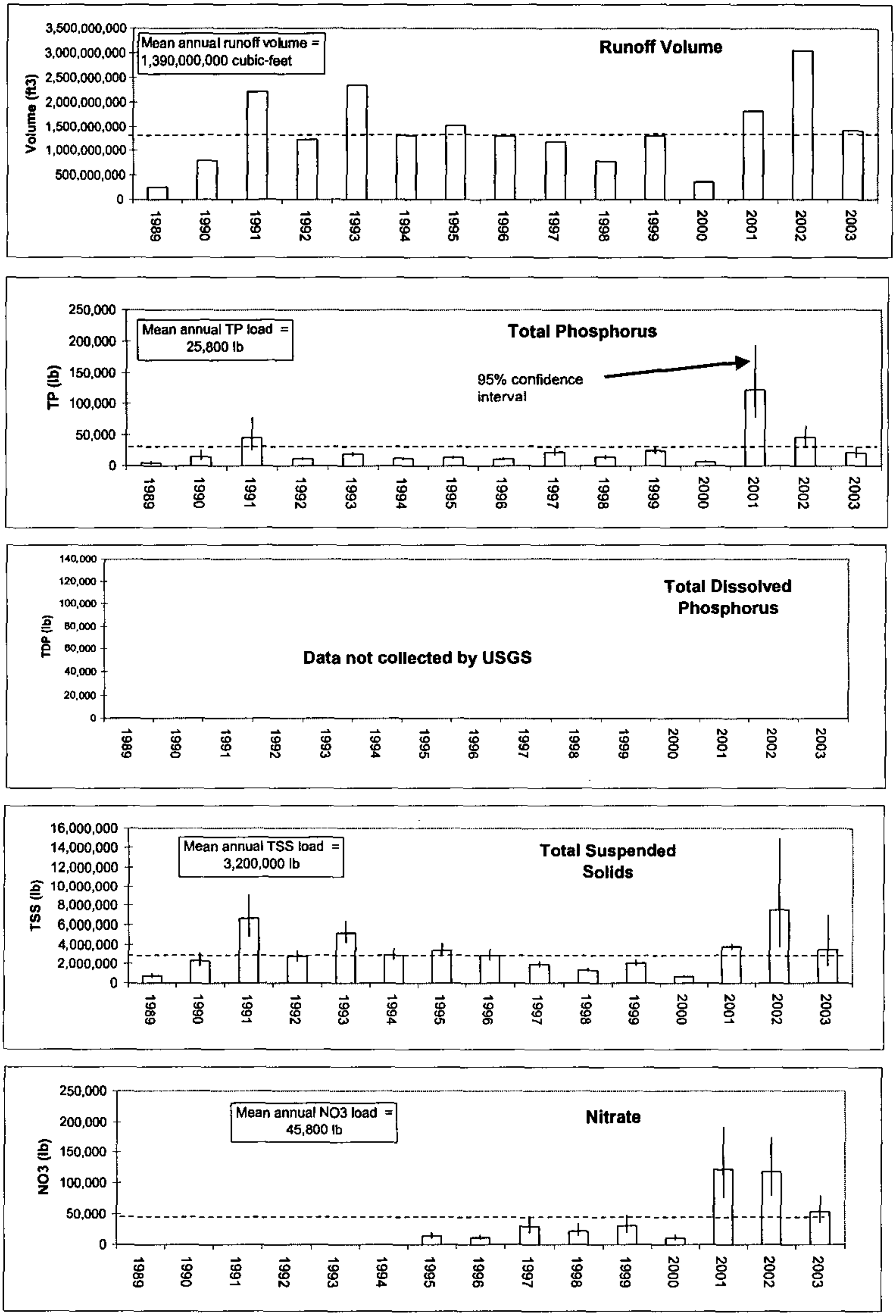
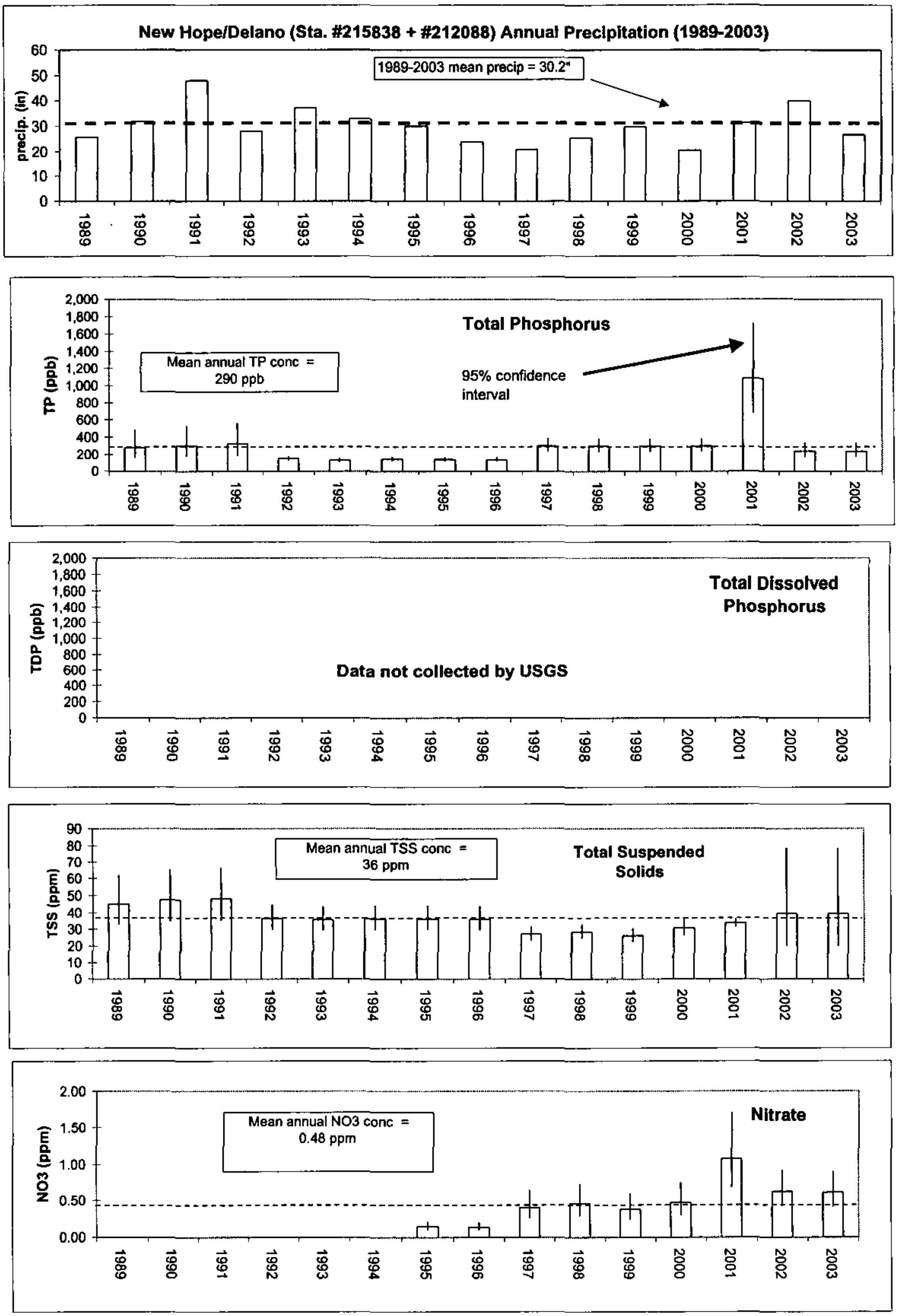


Figure 44. Elm Creek
Annual Flow-weighted Mean Concentrations



NINE MILE CREEK

Streamflow

Nine Mile Creek has a watershed of 38 square miles, and is tributary to the Minnesota River. Two branches, the North Fork and South Fork, join immediately upstream of Normandale Lake. Discharge from Normandale Lake flows through Marsh Lake, and then to the Minnesota River. The South Fork flows through wetlands and lakes in its upper reaches, for example Minnetoga, Bryant, and Smetana Lakes. The North Fork flows through no lakes prior to joining the South Fork. The watershed land use is primarily urban.

Monitoring of Nine Mile Creek commenced during 1989 (Figure 45). Even though the creek flows through several lakes, the peaks of the hydrograph are relatively sharp, indicating the stream responds relatively quickly to precipitation events, likely due to the large amount of impervious surface in the watershed which facilitates more rapid transport of stormwater to the creek. During 2003, the daily flow rates generally follow the precipitation pattern for the year, with most flow occurring in the first half of the year, with some minor storm events in the later half. Peak daily flows in 2003 include 171 cfs (June 28), 165 cfs (May 11), and 107 cfs (May 22). Many sample flows were higher than daily flows due the damping of the daily flow value by averaging over 24 hours. Samples were collected at the highest flows during the day, but due to the rapid rise and fall of flowrate, the daily average flow is lower. Peak sample flows in 2003 were 236 cfs (May) and 225 cfs (June). The daily average flow had dropped to 2 cfs by November 2003.

The total volume of water carried by Nine Mile Creek in 2003 was 576 million ft3, while the watershed yield (annual volume divided by watershed area) was 6.5 inches.

Highest recorded daily peak flows in past years include 518 cfs (July 1997), 383 cfs (August 1998), 255 (March 1990). Due to the "flashy" nature of the watershed, many sample flows exceed the mean daily flows.

The Nine Mile Creek hydrograph shows a good effort has been made to collect samples throughout the flow regime. Overall, sample collection in Nine Mile Creek appears adequate for accurate analysis of current conditions.

2003 Water Quality

Appendix B summarizes the chemical and physical data collected in Nine Mile Creek during 2003. The mean total phosphorus concentration was 120 ppb, with values ranging from 10 ppb to 830 ppb. Total suspended solids concentrations measured were 25 ppm (mean), 1 ppm (minimum) and 304 (maximum). Turbidity measurements resulted in mean, minimum, and maximum values of 10 ntu, 1 ntu, and 100 ntu, respectively. Mean chloride concentration in 2003 was 156 ppm (with minimum and maximum values of 71 ppm and 556 ppm). Elevated concentrations of chloride are likely caused by road deicing on impervious surfaces.

Figure 45. Nine Mile Creek Mean Daily and Sample Flows and Daily Precipitation (Bloomington/Savage Sta. # 217538)

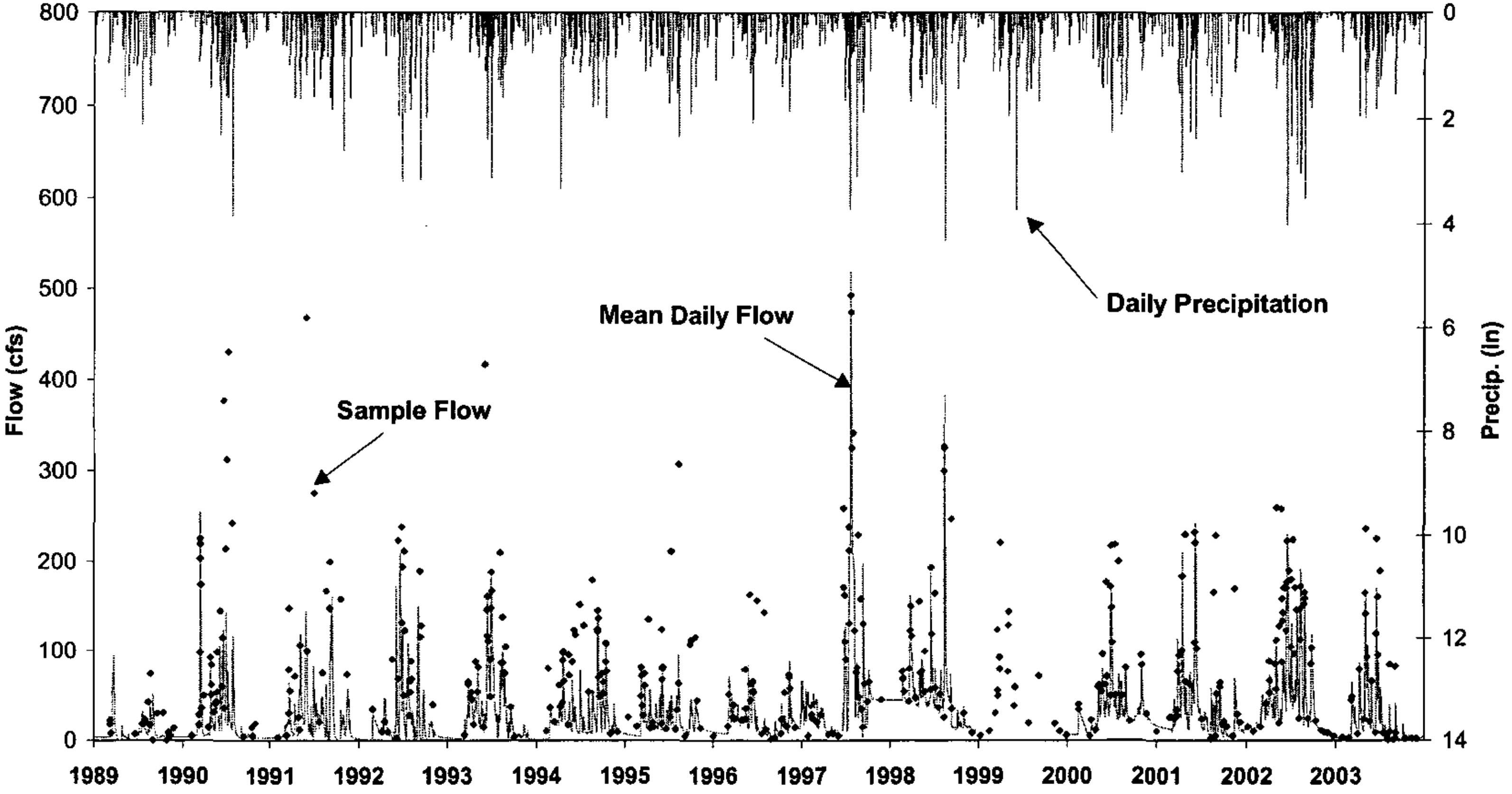


Table 14. Nine Mile Creek MPCA Impaired Waters Inventory

Reach	Yr	New	Assessment Unit ID	Prev Seg	Affected use	Pollutant or stressor	Target start// completion
Nine Mile Creek; Headwaters to Minnesota R	02	New	07020012-518	701	Aquatic life	Turbidity	2005//2009

One Nine Mile Creek stream reach has been listed for excessive turbidity on the Minnesota State 303d Impaired Waters Inventory (Table 14). General and construction site erosion, streambank erosion, or resuspension of particles from the creek bottom may have caused the high turbidity levels resulting in the Impaired Waters listing.

Nine Mile Creek Historical Chemical Loads and Concentrations Calculated by FLUX

Nine Mile Creek 2003 annual loads and flow volume were below the historical average (Figure 46). The 2003 annual flow-weighted mean concentrations were also below the historical average with the exception of nitrate (2003 concentration of 0.5 ppm compared to historical average of 0.42 ppm) (Figure 47). Historical total phosphorus loads have ranged from 22,600 lbs (1997) to 7,900 lbs (2003). Similarly, suspended solids loads have ranged from 11.9 million lbs (1997) to 2.7 million lbs (2003). Annual pollutant loads in the creek have likely been strongly influenced by the timing of storm events and antecedent conditions as well as watershed activities than by simply the total annual precipitation amounts. The creek flows through Normandale and Marsh Lakes prior to discharge to the Minnesota River; it is likely large suspended solids in the creek are removed in the lakes due to settlement. However the Creek passes through an urbanized reach downstream of the lakes, so additional pollutants are likely added between the lakes and the Minnesota. The Nine Mile Creek Watershed District completed the Lower Valley Project, a substantial stream bank stabilization and channel restoration, around 1993. Trend analysis has shown concentrations of total phosphorus and total suspended solids have decreased since the project completion.

The 1989-2003 average total phosphorus and total suspended solids flow-weighted mean concentrations were 250 ppb and 140 ppm, respectively (Figure 47). One would expect little variation among historical mean suspended solids concentrations due to sediment removal in the lakes, but concentrations show significant deviation from the average. It appears that total suspended solid concentrations have decreased over time, like due to the Lower Valley Project.

Figure 46. Nine Mile Creek
Annual Mass Loads to Minnesota River

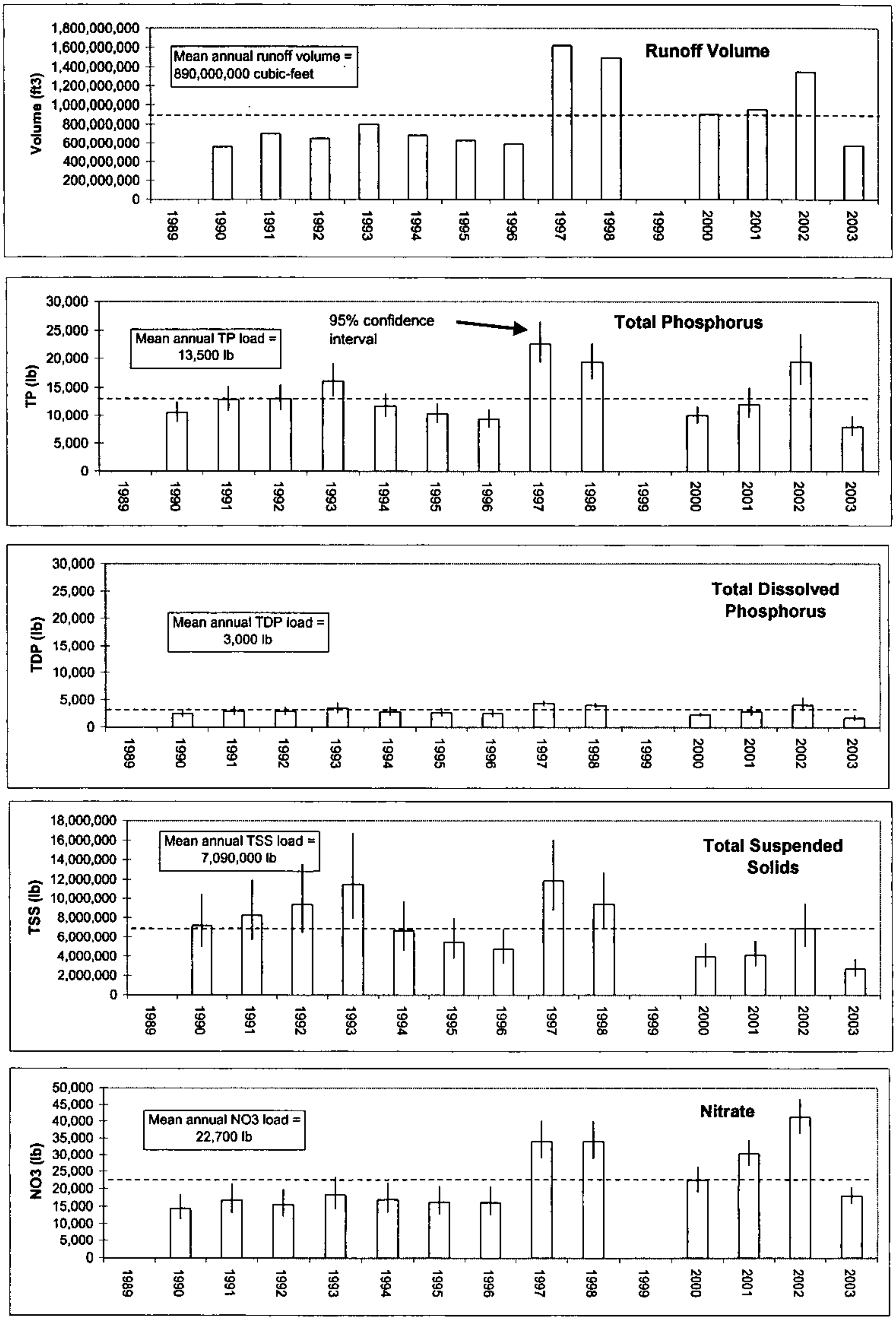
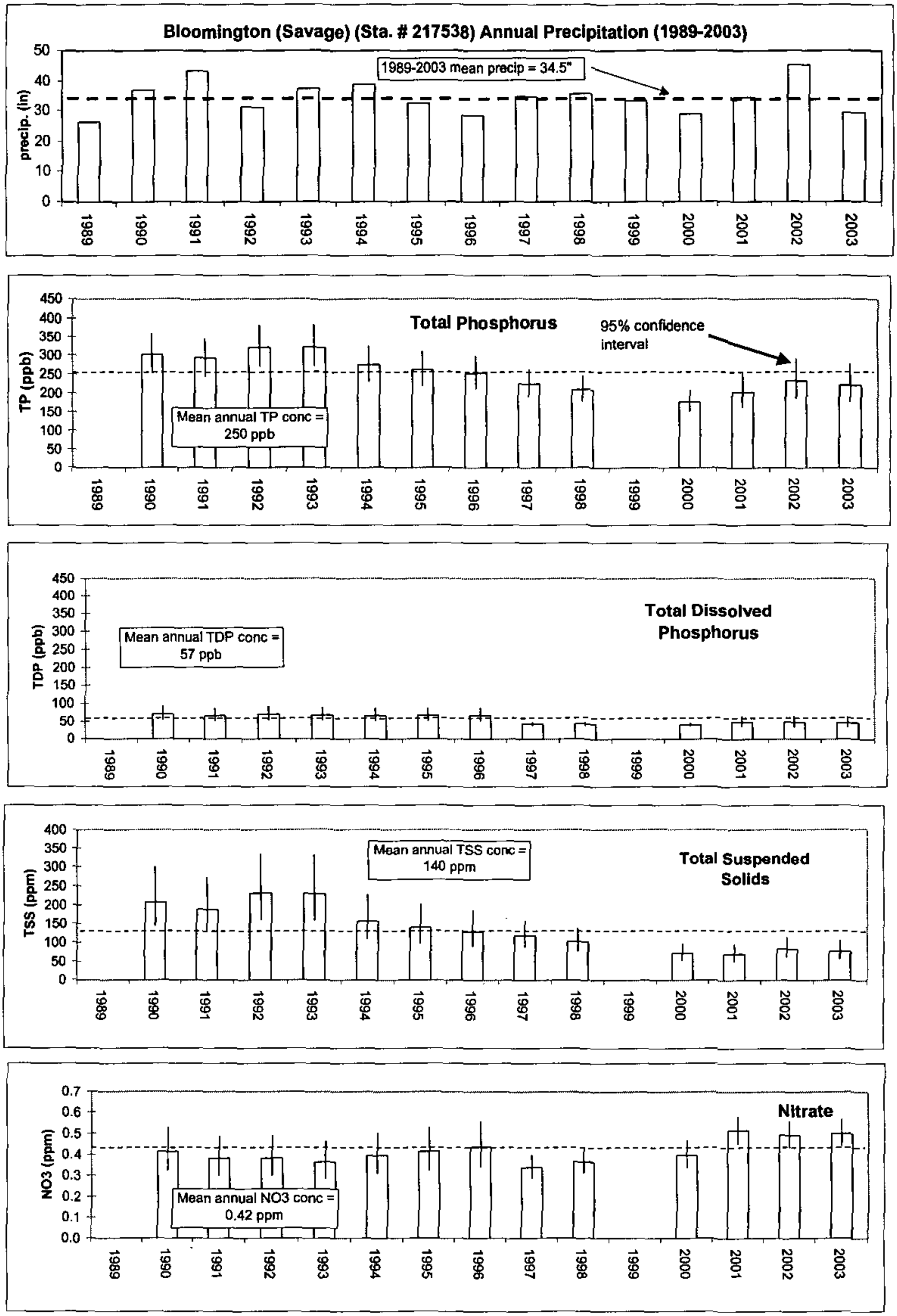


Figure 47. Nine Mile Creek
Annual Flow-weighted Mean Concentrations



RICE CREEK

Streamflow

Rice Creek has a watershed of 184 square miles, and is tributary to the Mississippi River. Watershed land use is primarily urban (southern portion) and transitional rural (northern portion). The Rice Creek headwater is Clear Lake (near Forest Lake), and the creek has two tributaries (Hardwood Creek and Clearwater Creek). Hardwood Creek enters Rice Creek immediately upstream of Peltier Lake, while Clearwater Creek discharges into Peltier Lake. The Rice Creek watershed has numerous lakes and wetlands. Clearwater Creek receives flow from White Bear, Eagle Point, and Otter Lakes. Hardwood Creek flows through Rice Lake. Rice Creek flows through the Rice Creek Chain of Lakes (Peltier, George Watch, Marshan, Rice and Baldwin) and receives flow from Lake Josephine, Lake Johanna, Round lake, Valentine Lake, and others. Water stored in the Rice Creek lake complex had been used as a source of drinking water for the City of St. Paul until the 1970s.

Monitoring of Rice Creek is conducted by the Rice Creek Watershed District.

Monitoring of Rice Creek commenced during 1993 (Figure 48). The shape of the hydrograph peaks is broad, indicating the stream responds slowly to precipitation events. This is due to the dampening effect of flow rate provided by the numerous lakes. Flows in the creek generally rise and fall slowly. During 2003, the daily flow rates generally follow the precipitation pattern for the year, with most flow occurring in the first half of the year. Peak daily flows in 2003 include 602 cfs (June 26), 477 cfs (May 21), and 307 cfs (May 19). The total volume of water carried by Rice Creek in 2003 was 2.69 billion ft3, while the watershed yield (annual volume divided by watershed area) was 6.3 inches.

Highest recorded daily peak flows in past years include 735 cfs (July 1993) and 740 cfs (April 2001).

The hydrograph may also be used to assess the monitoring program used to sample the stream. To best determine water quality conditions in the stream, samples should be taken during a variety of flow regimes. Samples should be taken at maximum flow for storm events, during intermediate flows, and during baseflow conditions. Most samples should be collected at high flows as most chemical constituents are transported in the stream at that time. Examination of the Rice Creek hydrograph shows sample collection has occurred primarily at intermediate flows, although a fair number of samples were collected during large storms. Few baseflow samples have been collected, and the total number of samples collected each year is low (for example 7 samples were analyzed for total phosphorus in 2003). Collection of more samples each year and more samples at baseflow conditions is recommended.

2003 Water Quality

Appendix B summarizes the chemical and physical data collected in Rice Creek during 2003. This report analyzed total phosphorus and total suspended solids data only. The mean total phosphorus concentration was 240 ppb, with values ranging from 120 ppb and 580 ppb. Total suspended solids concentrations measured were 182 ppm (mean), 19 ppm (minimum) and 970 ppm (maximum).

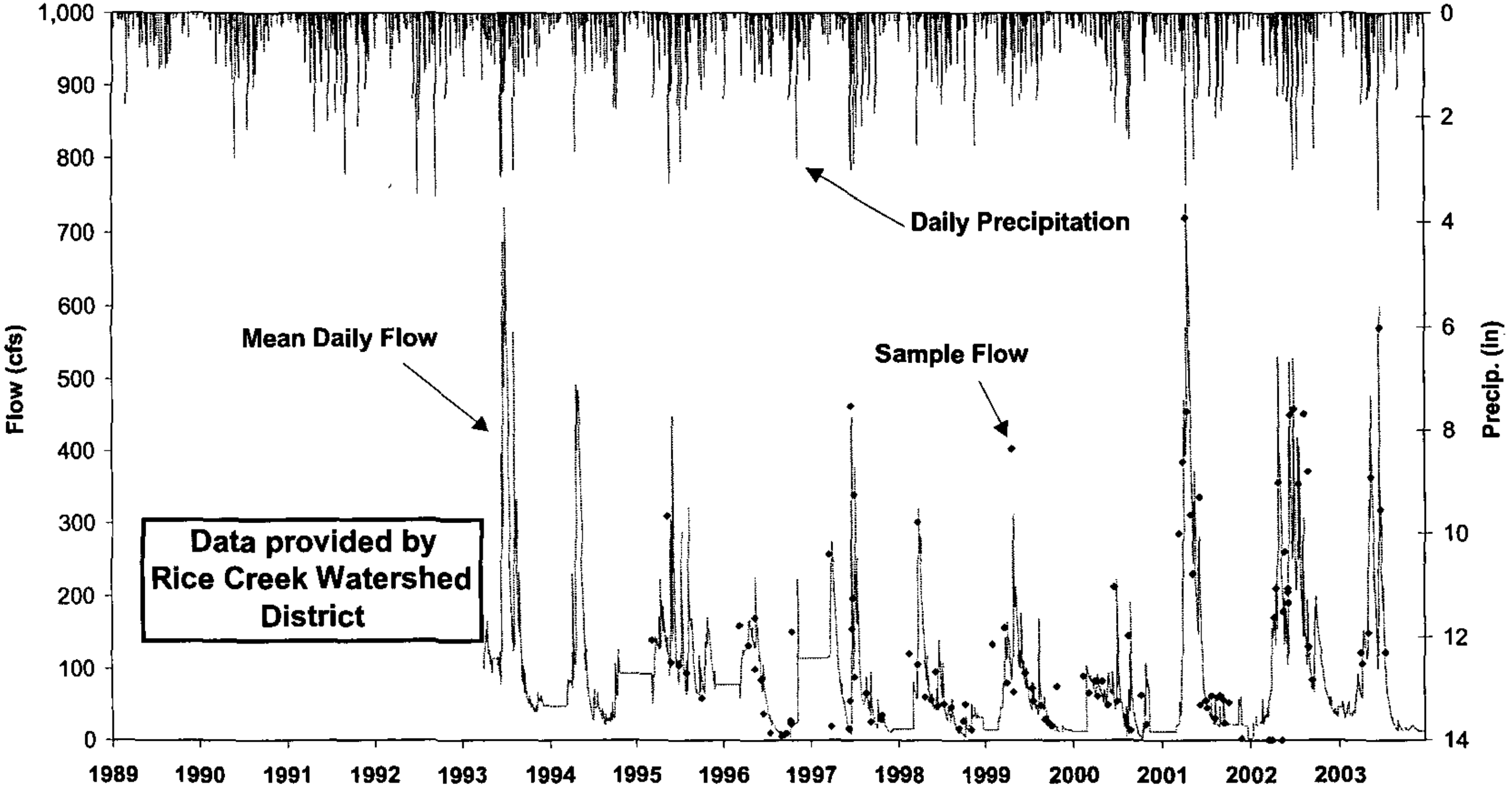


Figure 48. Rice Creek Mean Daily and Sample Flows and Daily Precipitation (St. Paul/Lake Vadnais Sta. #217377 +#218477)

Table 15. Rice Creek MPCA Impaired Waters Inventory

Reach	Yr	New	Assessment Unit ID	Prev Seg	Affected use	Pollutant or stressor	Target start// completion
Rice River; Headwaters to Section 5 Cr	02	New	07010104-505	021	Aquatic life	Impaired biota	2006//2013

One segment of Rice Creek has been listed on the Minnesota State 303d Impaired Waters Inventory (Table 15). For each affected reach and associated pollutant or stressor, a TMDL study and management plan must be completed by the Minnesota Pollution Control Agency.

Rice Creek historical chemical loads and concentrations calculated by FLUX

Rice Creek 2003 annual total phosphorus and suspended solids loads were slightly below the historical average, while the flow volume was at the historical average (Figure 49). The 2003 annual flow-weighted mean concentrations were slightly below the historical average (Figure 50). Significant variation has occurred between both annual loads and flow-weighted mean concentrations for the period of record (1995 – 2003). Historical total phosphorus loads have ranged from 71,000 lbs (1997) to 10,200 lbs (2000). Similarly, suspended solids loads have ranged from 43.7 million lbs (1997) to 2.4 million lbs (2000). Annual pollutant loads in the creek have likely been strongly influenced by the timing of storm events and antecedent conditions as well as watershed activities rather than by simply the total annual precipitation amounts. Since the creek flows through numerous lakes prior to discharge to the Mississippi River it is likely large suspended solids in the creek are removed due to settlement. The section of watershed downstream of the lakes may influence both total phosphorus and suspended solid loads, or the lakes may act as a source of both phosphorus and organic suspended solids through release of sediment bound phosphorus, algae, or plant fragments.

The 1995-2003 average total phosphorus and total suspended solids flow-weighted mean concentrations were 230 ppb and 93 ppm, respectively (Figure 50). The annual average total phosphorus and suspended solids concentrations are fairly similar with the exception of 1997 and 1998, which were quite high.

Figure 49. Rice Creek
Mass Loads to Mississippi River

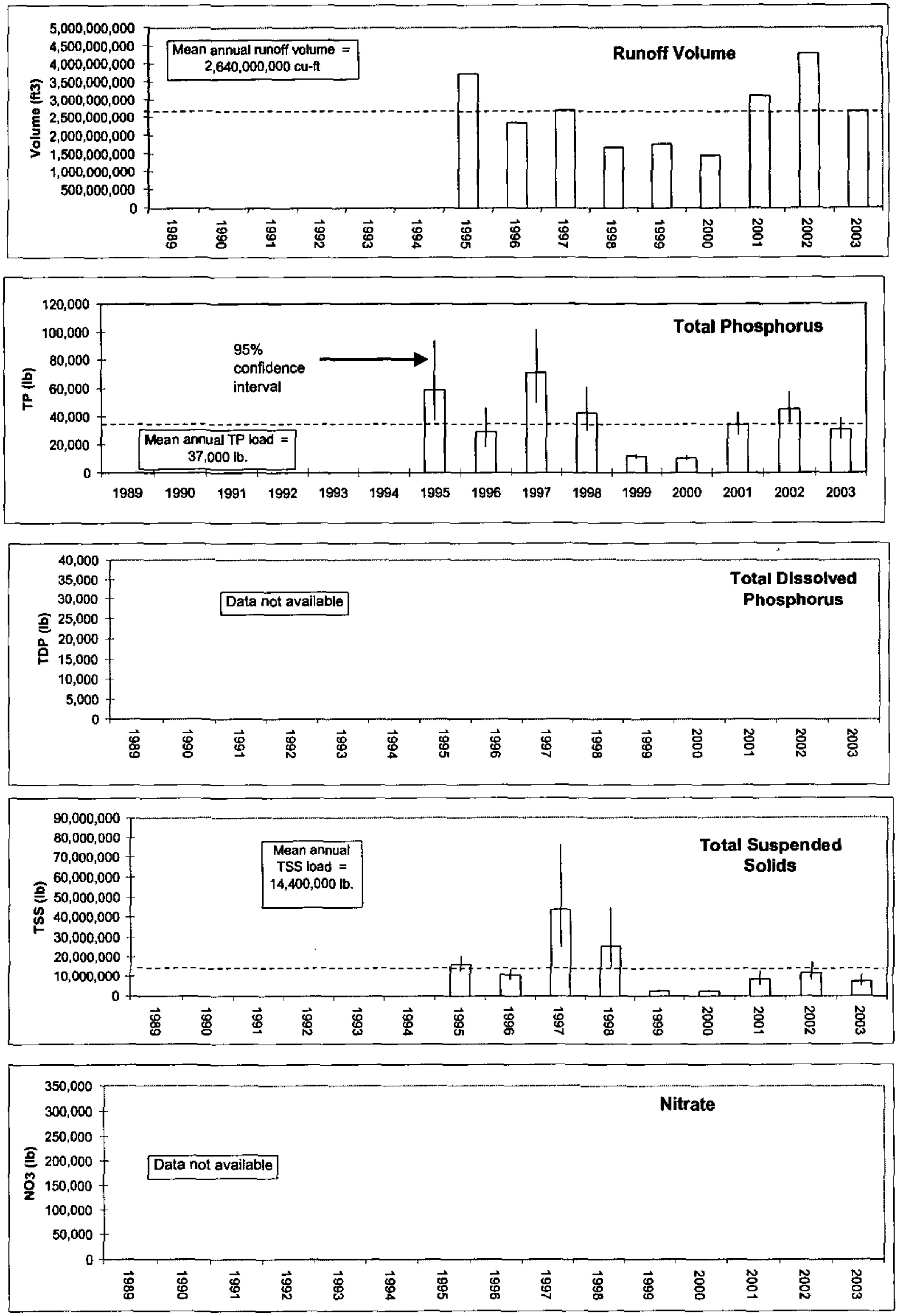
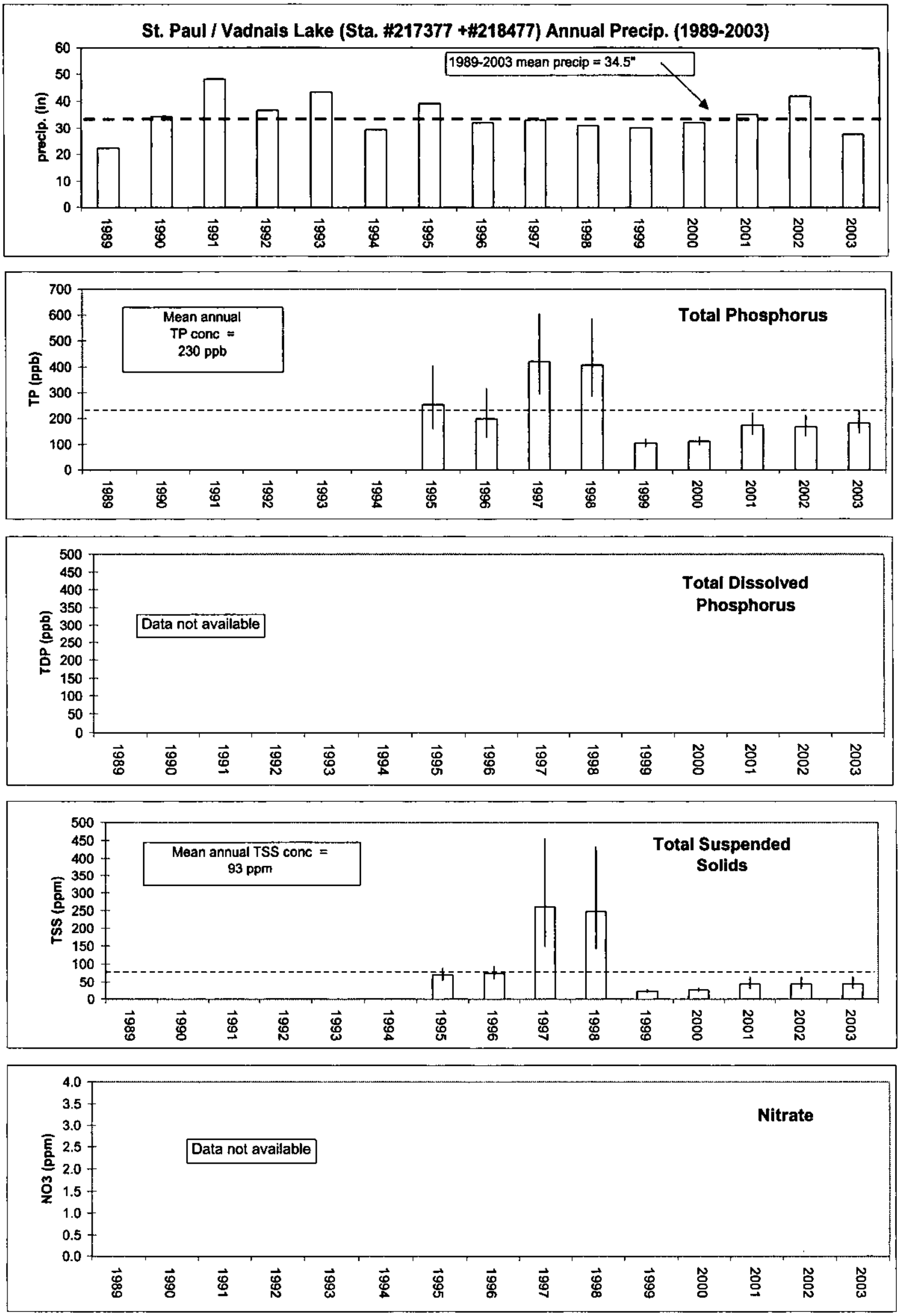


Figure 50. Rice Creek
Annual Flow-weighted Mean Concentrations



SAND CREEK

Streamflow

Sand Creek has a watershed of 271 square miles, and is tributary to the Minnesota River. The watershed is primarily agricultural.

Monitoring of Sand Creek commenced during 1989, but 1990 was the first complete year of monitoring (Figure 51). The hydrograph peaks are narrow and flow between storm events is very low, indicating lack of lakes and wetlands to hold water and moderate flow. During 2003, the daily flow rates generally follow the precipitation pattern for the year. The peak daily flow in 2003 is 980 cfs (May 12). The daily average flow had dropped below 2 cfs by August 2003.

The total volume of water carried by Sand Creek in 2003 was 2.45 billion ft3, while the watershed yield (annual volume divided by watershed area) was 4.1 inches.

Highest recorded daily peak flows in past years include 4,380 cfs (June 1998), 2,440 cfs (June 1993), and 2,370 (September 1992).

Examination of the Sand Creek hydrograph shows a good effort has been made to collect samples throughout the flow regime. Overall, sample collection in the Creek appears adequate for accurate analysis of current conditions.

2003 Water Quality

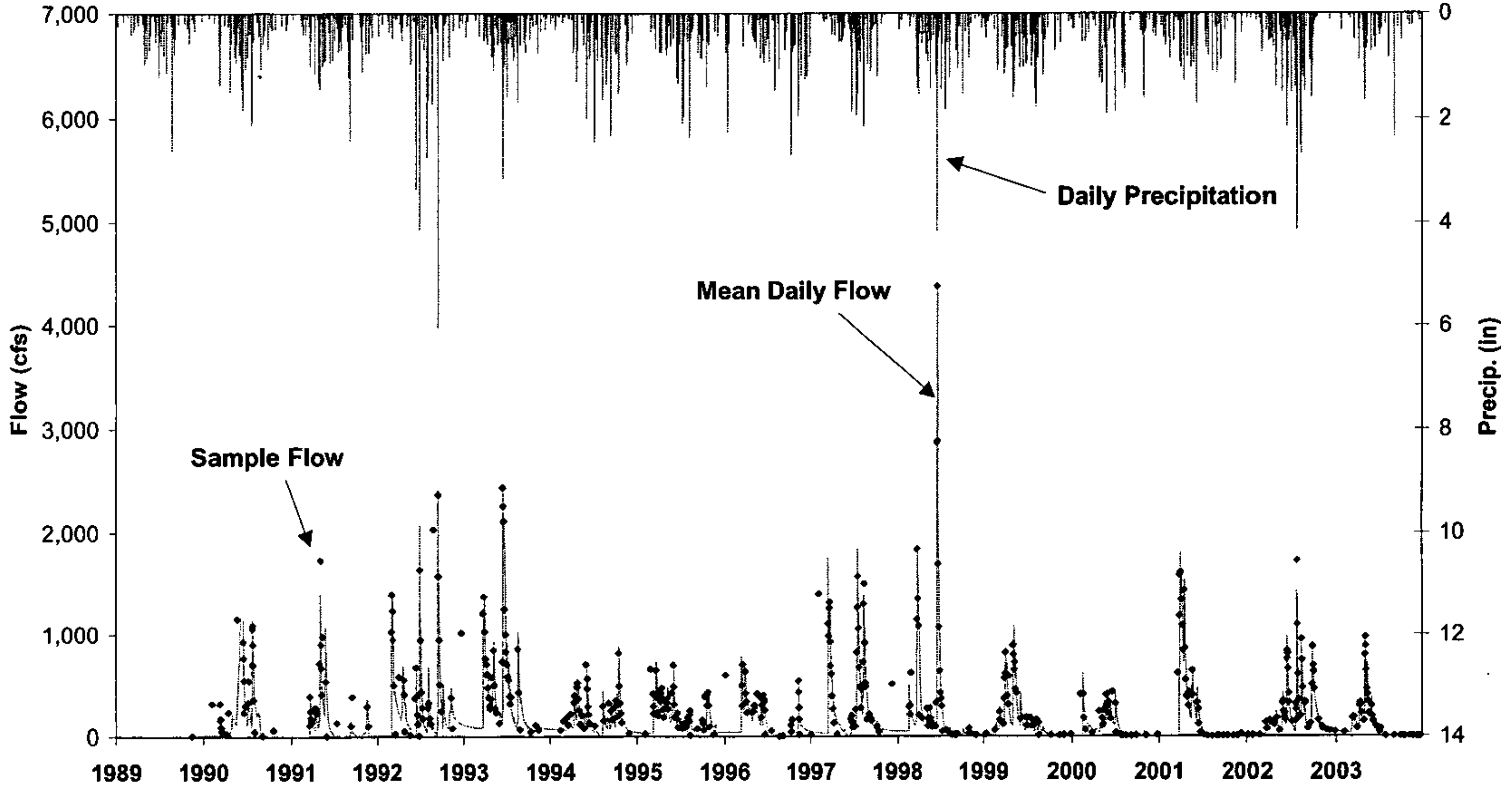
Appendix B summarizes the chemical and physical data collected in Sand Creek during 2003. The mean total phosphorus concentration was 510 ppb, with values ranging from 80 ppb to 1,100 ppb. The mean total suspended solids concentration was 480 ppm, with values ranging between 1 ppm and 4,400 ppm. Turbidity measurements resulted in mean, minimum, and maximum values of 38 ntu, 2 ntu, and 170 ntu, respectively. Mean chloride concentration in 2003 was 64 ppm (with minimum and maximum values of 22 ppm and 243 ppm).

Table 16. Sand Creek MPCA Impaired Waters Inventory

Reach	Yr	New	Assessment Unit ID	Prev Seg	Affected use	Pollutant or stressor	Target start// completion
Sand Creek; Porter Cr to Minnesota R	02	New	07020012-513	022	Aquatic life	Turbidity	2006//2010

One segment of Sand Creek has been listed for excessive turbidity on the Minnesota State 303d Impaired Waters Inventory (Table 16). For each affected reach and associated pollutant or stressor, a TMDL study and management plan must be completed by the Minnesota Pollution Control Agency. Agricultural and streambank erosion, or resuspension of particles from the creek bottom may have caused the high turbidity levels resulting in the Impaired Waters listing.

Figure 51. Sand Creek Mean Daily and Sample Flows and Daily Precipitation (Jordan Sta. #214176)



Sand Creek Historical Chemical Loads and Concentrations Calculated by FLUX

Sand Creek 2003 annual loads and flow volume were below the historical average (Figure 52). The 2003 annual flow-weighted mean concentrations were close to the historical average (Figure 53). Historical total phosphorus loads have ranged from 375,000 lbs (1993) to 74,300 lbs (2000). Similarly, suspended solids loads have ranged from 223 million lbs (1993) to 24.5 million lbs (2000). Annual pollutant loads in the creek have likely been strongly influenced by the timing of storm events and antecedent conditions as well as watershed activities than by simply the total annual precipitation amounts.

The 1989-2003 average total phosphorus and total suspended solids flow-weighted mean concentrations were 620 ppb and 310 ppm, respectively.

Figure 52. Sand Creek Annual Mass Loads to Minnesota River

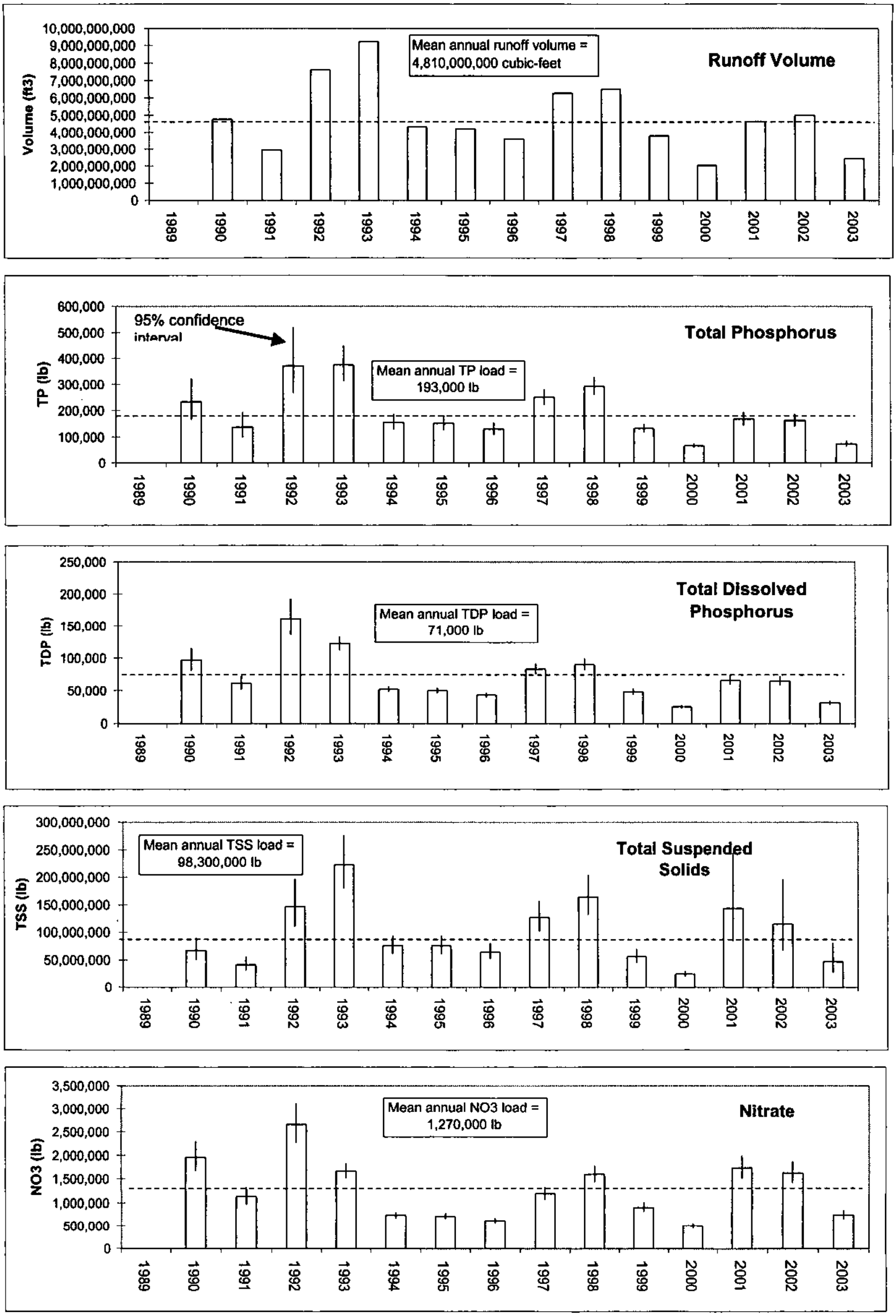
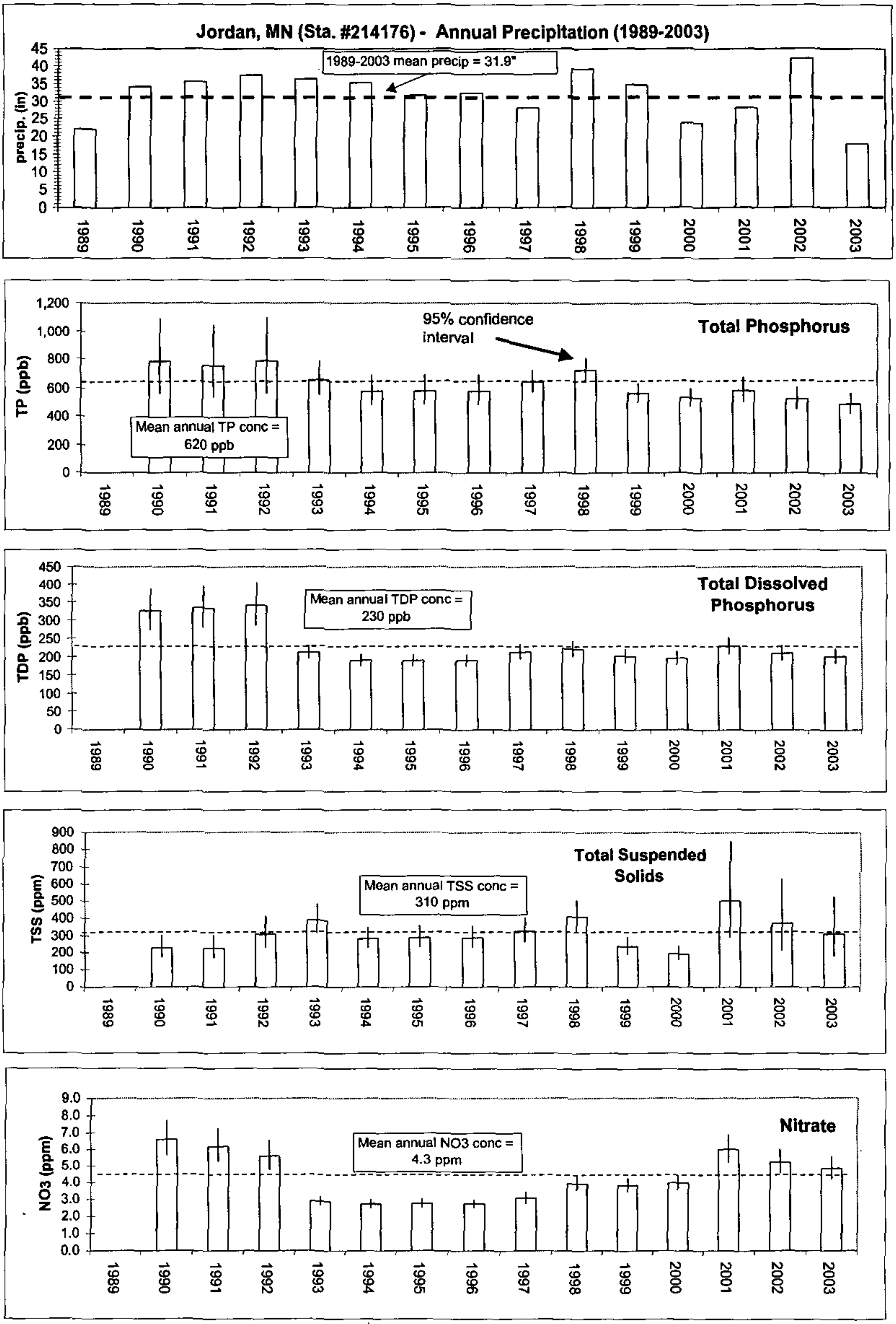


Figure 53. Sand Creek
Annual Flow-weighted Mean Concentrations



VALLEY CREEK

Streamflow

Valley Creek has a watershed of 62 square miles, and is tributary to the St. Croix River. Land use is primarily agriculture, forest, and rural residential. Valley Creek has two main branches, the North and South Branch, which combine 1.5 miles upstream from the St. Croix River. The creek enters the St. Croix just north of Afton. The creek receives significant groundwater, the South Branch exclusively from bedrock springs, while the headwater of the North Branch, Lake Edith, is primarily groundwater fed. The creek has a viable, reproducing population of trout. Numerous lakes and wetlands are present in the upper portion of the watershed, but outflow from these systems is ephemeral.

1999 was the first complete year of monitoring (Figure 54). The hydrograph is "perched", with no flows less than approximately 10 cfs, indicating the effect of perennial groundwater flows. Storm event peaks are fairly sharp, indicating the creek flow rises and falls rapidly in response to precipitation events. During 2003, the daily flow rates generally follow the precipitation pattern for the year. The peak daily flows in 2003 were 65 cfs (March 15), 58 cfs (May 11), and 46 cfs (June 26). The daily average flow was approximately 20 cfs during November, indicating the influence of groundwater on the streamflow.

The total volume of water carried by Valley Creek in 2003 was 655 million ft3, while the watershed yield (annual volume divided by watershed area) was 4.5 inches. This value is not reflective of the effects of stormwater runoff as in the other creeks due to the high inflows of groundwater to this system.

Highest recorded daily peak flows in past years include 55 cfs (February 2000) and 43 cfs (March 1999).

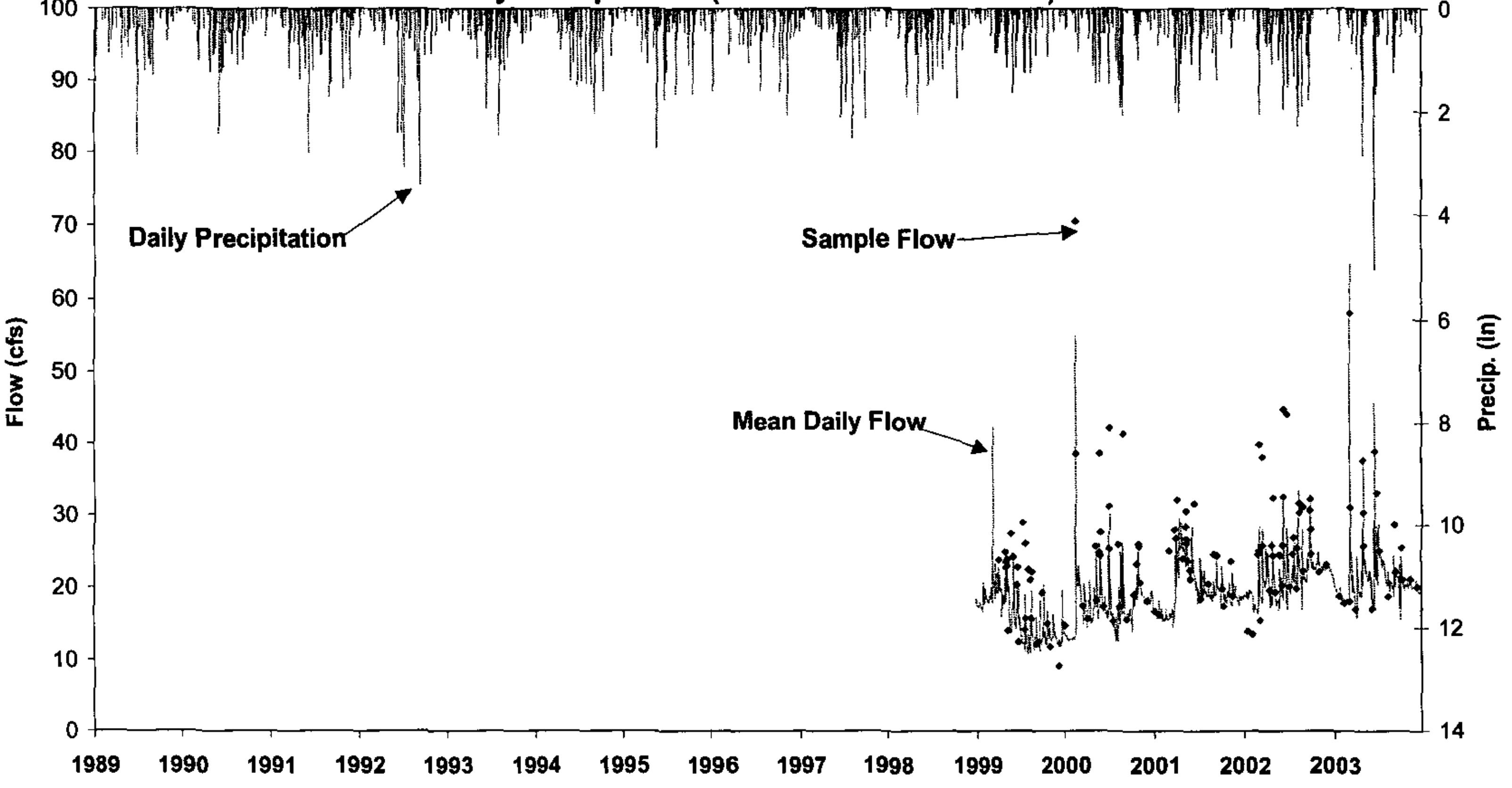
Examination of the Valley Creek hydrograph shows a good effort has been made to collect samples throughout the flow regime. Overall, sample collection in the Creek appears adequate for accurate analysis of current conditions.

2003 Water Quality

Appendix B summarizes the chemical and physical data collected in Valley Creek during 2003. The mean total phosphorus concentration was 130 ppb, with values ranging from 20 ppb to 950 ppb. The mean total suspended solids concentration was 50 ppm, with a concentration range between 4 ppm and 450 ppm. Turbidity measurements resulted in mean, minimum, and maximum values of 7 ntu, 1 ntu, and 38 ntu, respectively. Mean chloride concentration in 2003 was 19 ppm (with minimum and maximum values of 16 ppm and 28 ppm), indicating minimal impact of deicing chemicals. Suspended solids and turbidity levels indicate fairly clear water, but phosphorus values appear high, particularly the 2003 maximum value of 950 ppb.

Of special note are the nitrate concentrations, which the Science Museum of Minnesota's St. Croix Watershed Research Station researchers have found are affected by high-nitrate groundwater discharges to the creek (Almendinger et. al., 1999, Zapp and Almendinger, 2001). The groundwater nitrate concentration at the headwater springs is approximately 7 mg/L. The 2003 average sample nitrate concentration at the Valley Creek monitoring station is 3.8 mg/L.

Figure 54. Valley Creek Mean Daily and Sample Flows and Daily Precipitation (Stillwater Sta. #218037)



Valley Creek has not been listed on the Minnesota State 303d Impaired Waters Inventory, and therefore there are no plans for preparation of a TMDL study and management plan.

Valley Creek Historical Chemical Loads and Concentrations Calculated by FLUX

Valley Creek 2003 annual loads, flow volume, and annual flow-weighted mean concentrations were close to or slightly above the historical average (Figures 55-56). Little year-to-year variation occurs in load, flow volumes, or pollutant concentrations. Historical total phosphorus loads have ranged from 2,800 lbs (1999) to 2,400 lbs (2000, 2001). Similarly, suspended solids loads have ranged from 689,000 lbs (2003) to 375,000 lbs (1999).

The 1999-2003 average total phosphorus and total suspended solids flow-weighted mean concentrations were 71 ppb and 14 ppm, respectively (Figure 56). Valley Creek is a designated trout stream, and the creek's low turbidity and suspended solids concentrations are appropriate for the fishery.

Figure 55. Valley Creek
Annual Mass Loads to St. Croix River

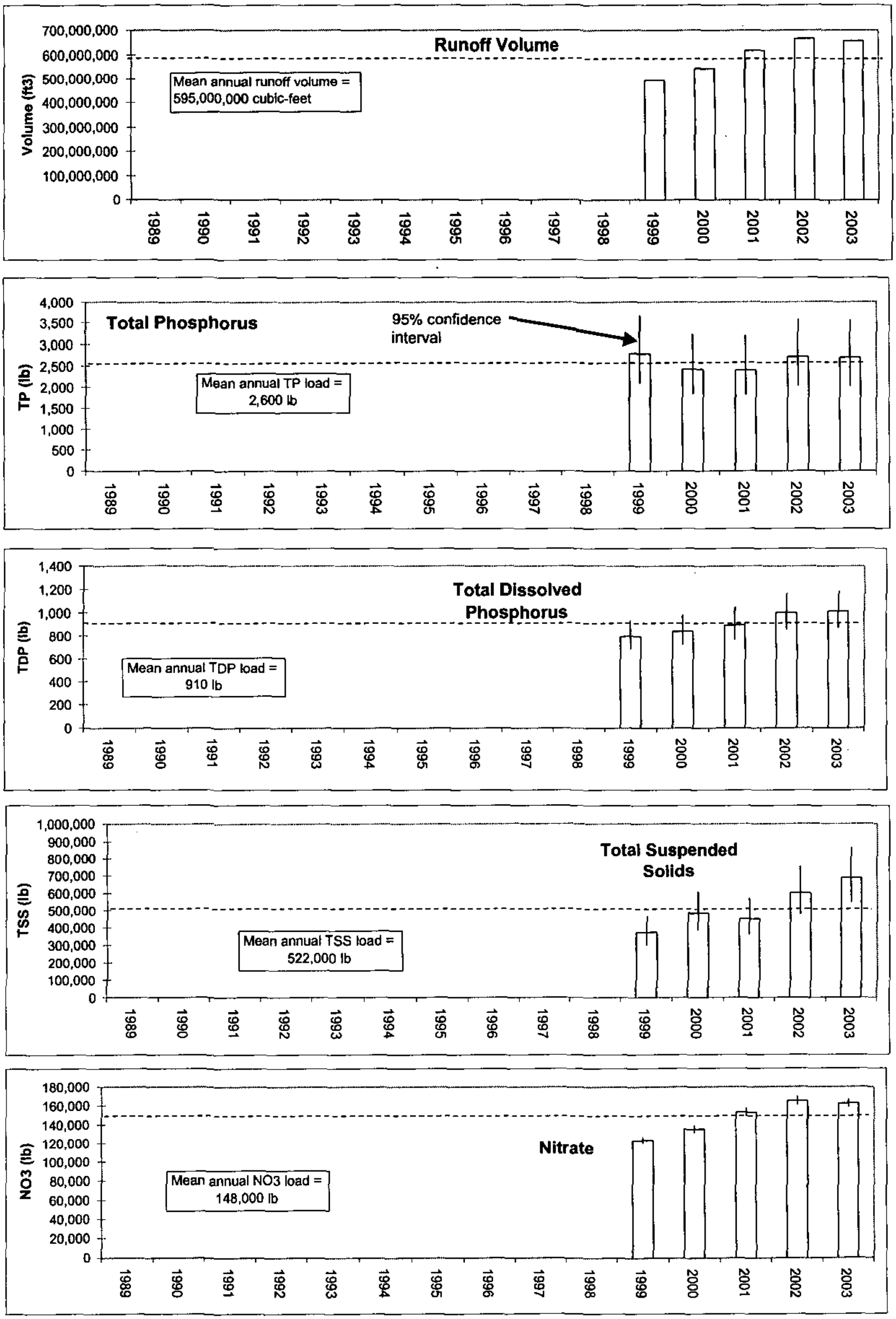
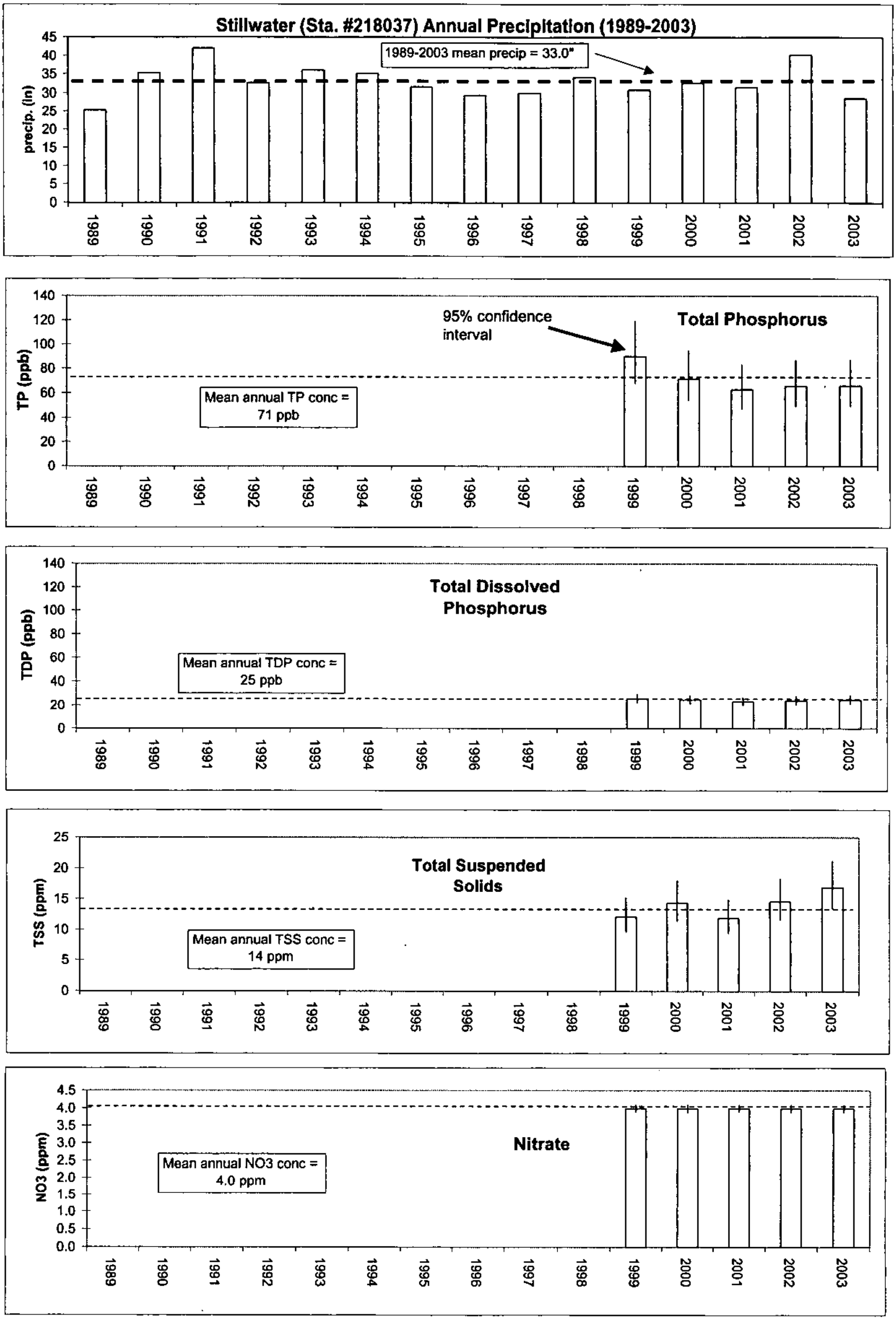


Figure 56. Valley Creek
Annual Flow-weighted Mean Concentrations



VERMILLION RIVER

Streamflow

The Vermillion River has a watershed of 327 square miles and is tributary to the Mississippi River. Major land use includes agriculture, urban residential, and rural residential. Portions of the watershed are rapidly developing into urban residential and commercial uses. Several branches converge to form the River. The headwaters of the main branch of the Vermillion is in the New Market / Elko area. South Creek joins the main branch in Farmington. Middle Creek and North Creek enter the main branch in Empire Township. The South Fork of the Vermillion joins in Vermillion Township. The upper portion of the watershed contains numerous wetlands. Portions of the Main Branch and South Creek are designated trout streams. The Metropolitan Council's Empire Wastewater Treatment Plant (WWTP) discharged on average 8.6 million gallons (1.1 million cubic feet) per day of treated effluent water into the river at Empire Township.

The Vermillion River Volume Study prepared by Dakota County indicates that the section of river between the cities of Vermillion and Hastings oscillates between recharge from groundwater and outflow to groundwater.

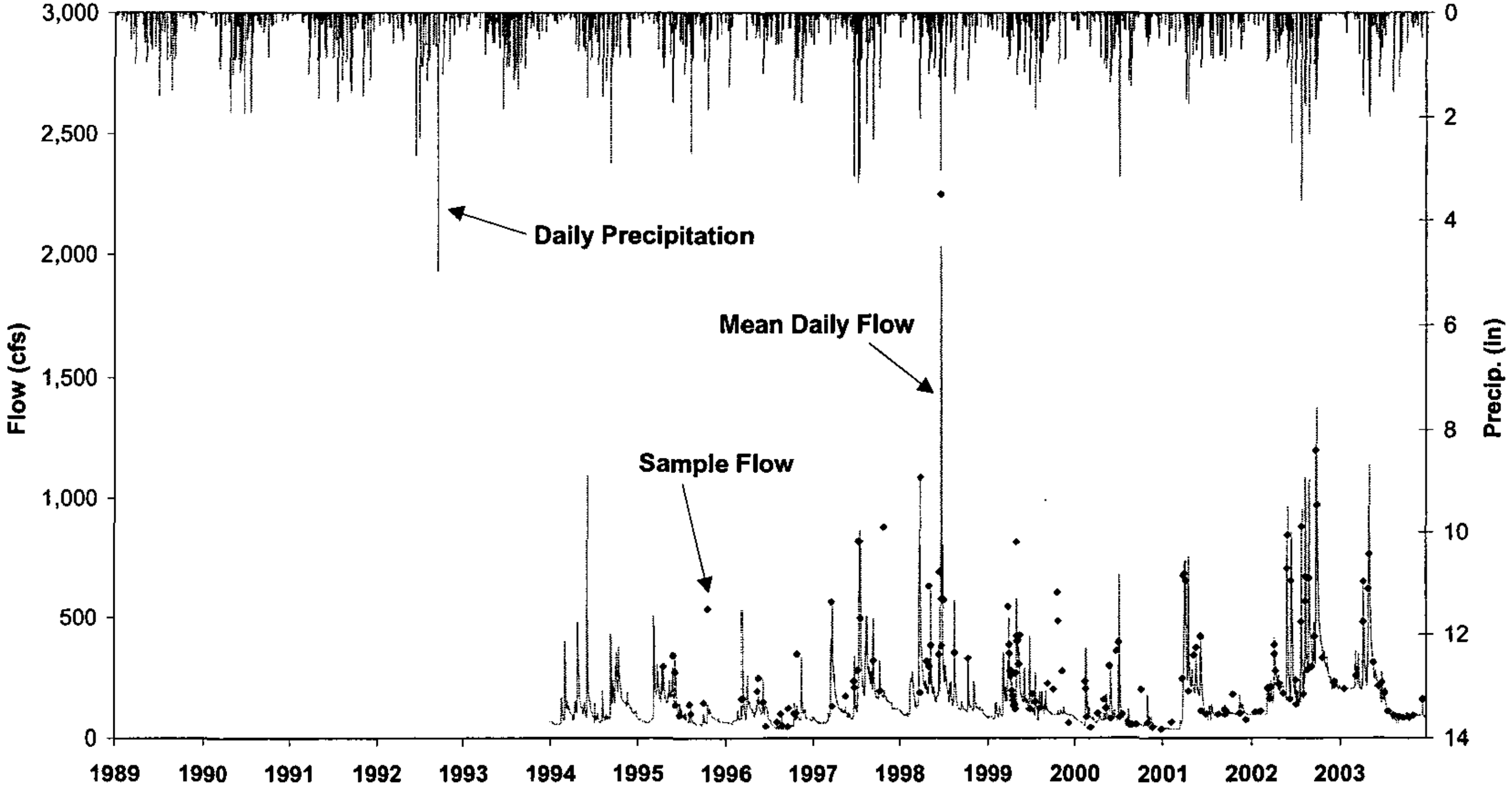
This report uses the results of the monitoring station at the Con-Agra building in Hastings, and therefore the results discussed here pertain only to the portion of the river upstream of this point. Other pollutant sources (primarily suspended solids) enter the river below Hastings. The river reach from Hastings to the Mississippi is currently the subject of a TMDL study.

Flow monitoring at Hastings commenced during 1994, sample collection in 1995 (Figure 57). The shapes of individual storm event peaks indicate the river responds rapidly to precipitation events. Evidence of perennial baseflow (from either groundwater or wastewater treatment plant discharge) is indicated by flow rates between precipitation events. During 2003, the daily flow rates generally follow the precipitation pattern for the year, with most flow occurring in the first half of the year, with some minor storm events in the later half. Peak daily flows in 2003 include 1,140 cfs (May 12), 650 cfs (April 18), and 670 cfs (May 18). The total volume of water carried by the Vermillion River in 2003 past the monitoring station in Hastings was 6.01 billion ft3. The watershed yield (annual volume divided by watershed area) and runoff coefficient (annual volume divided by annual precipitation) were 7.9 and 30.2%, but these values are skewed due to effluent discharge from the Empire WWTP (418,516,528 ft3 in 2003). Ignoring any effects of groundwater recharge or outflow, subtraction of 2003 Empire discharge results in a total runoff volume of 5.59 billion ft3, a watershed yield of 7.4 in., and a runoff coefficient of 28.1%.

Highest recorded daily peak flows in past years include 2,040 cfs (June 1998), 1,100 cfs (June 1994), 1,400 (October 2002).

Examination of the Vermillion River hydrograph shows that while initially more samples (particularly baseflow) should have been collected, in the past five year good effort has been made to collect samples throughout the flow regime. Overall, sample collection in Vermillion River appears adequate for accurate analysis of current conditions.

Figure 57. Vermillion River Mean Daily and Sample Flows and Daily Precipitation (Hastings Lock and Dam Sta. #213567)



2003 Water Quality

Appendix B summarizes the chemical and physical data collected in the Vermillion River during 2003. The mean total phosphorus concentration was 680 ppb, with values ranging from 270 ppb to 960 ppb. Phosphorus concentrations in the river are influenced by the WWTP discharge, which had a 2003 mean phosphorus concentration of 4,800 ppb. Total suspended solids concentrations measured were 25 ppm (mean), 2 ppm (minimum) and 94 (maximum). The WWTP discharge had a 2003 mean suspended solids concentration of 7.3 mg/L. Turbidity measurements resulted in mean, minimum, and maximum values of 6 ntu, 1 ntu, and 17 ntu, respectively. Mean chloride concentration in 2003 was 74 ppm (with minimum and maximum values of 36 ppm and 114 ppm). 2003 Vermillion total dissolved phosphorus data was excluded from this study due to possible contamination from suspended sediments.

Table 17. Vermillion River MPCA Impaired Waters Inventory

Reach	Yr	New	Assessment Unit ID	Prev Seg	Affected use	Pollutant or stressor	Target start// completion
Vermillion River/Vermillion Slough; Hastings Dam to Mississippi R	98	1A	07040001-504	112	Aquatic life	PCB FCA	2002//2015
Vermillion River/Vermillion Slough; Hastings Dam to Mississippi R	94		07040001-504	112	Aquatic life	Turbidity	2001//2005
Vermillion River; S Br Vermillion R to the Hastings Dam	96		07040001-506	212	Swimming	Fecal coliform	1999//2002
Vermillion River; Below trout stream portion to South Br Vermillion R	94		07040001-507	312	Aquatic life	Fecal coliform	1999//2002

Table 17 lists the Vermillion River stream reaches that have been listed on the Minnesota State 303d Impaired Waters Inventory. For each affected reach and associated pollutant or stressor, a TMDL study and management plan must be completed by the Minnesota Pollution Control Agency. This report does not cover the river reach from Hastings through the Vermillion River Slough to the Mississippi River.

Vermillion River Historical Chemical Loads and Concentrations Calculated by FLUX

Vermillion River 2003 annual total phosphorus and suspended solids loads and flow volume were all slightly above the historical average (Figure 58). The 2003 annual flow-weighted mean concentrations were above the historical average with the exception of total suspended solids, which was below the average (Figure 59). Some variation has occurred between both annual loads and flow-weighted mean concentrations for the period of record (1995 – 2003). Historical total phosphorus loads have ranged from 343,000 lbs (2002) to 103,000 lbs (1999). Similarly, suspended solids loads have ranged from 18.7 million lbs (1995) to 5.6 million lbs (2000). Annual pollutant loads in the creek have likely been strongly influenced by the timing of storm events and antecedent conditions as well as watershed activities than by simply the total annual precipitation amounts. The routine effluent discharge of the

Figure 58. Vermillion River
Annual Mass Loads to Mississippi River at Hastings Station *

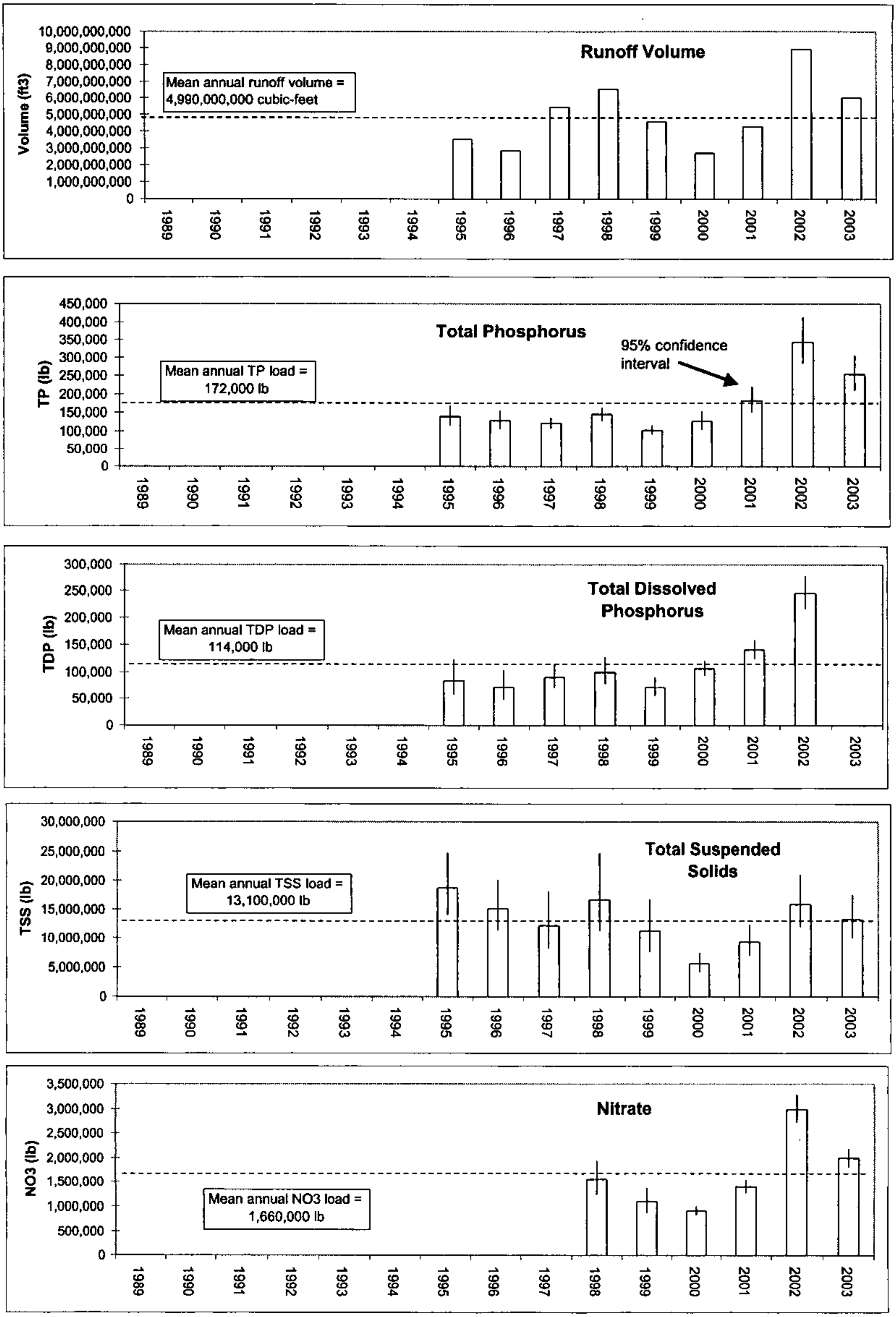
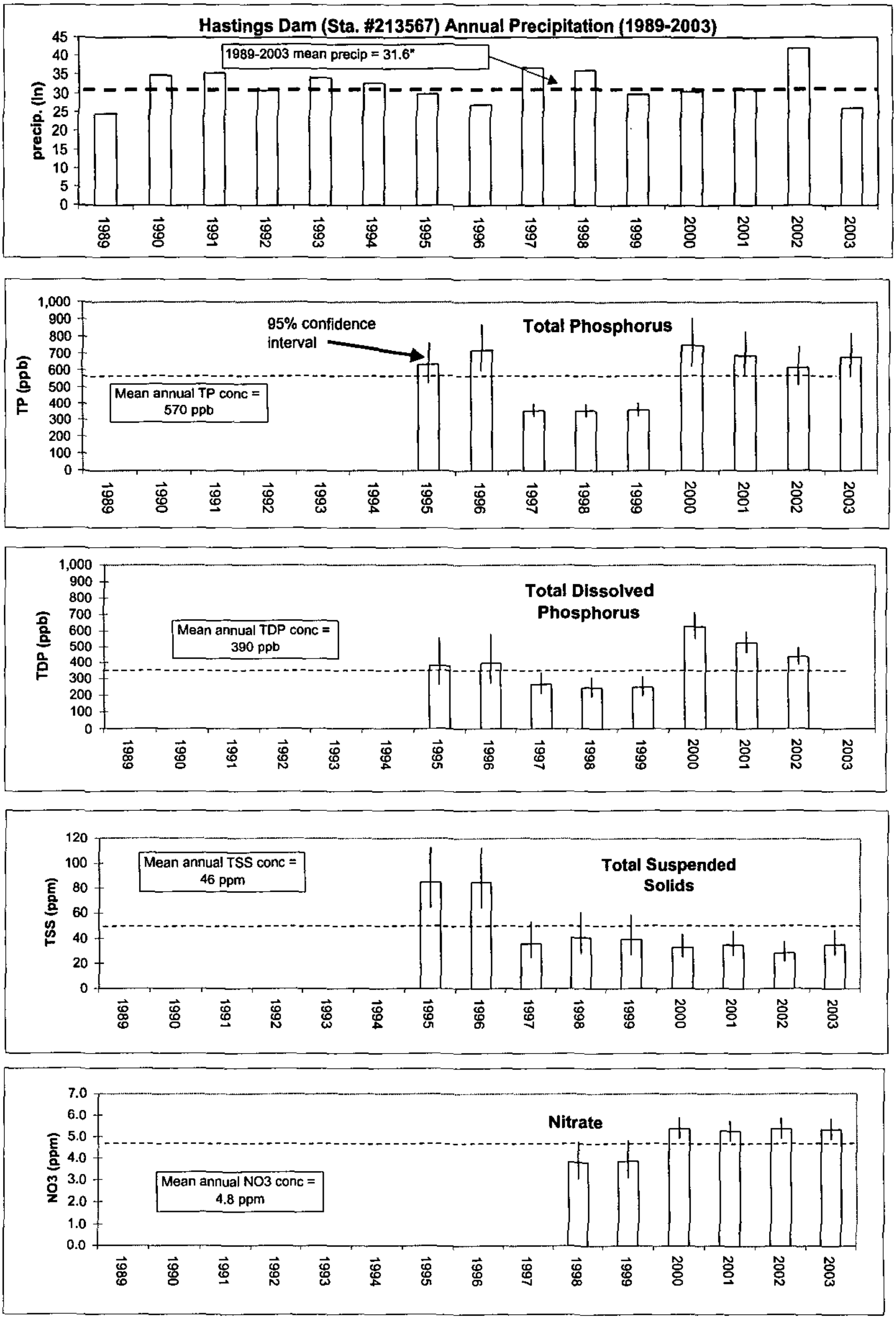


Figure 59. Vermillion River Annual Flow-weighted Mean Concentrations at Hastings Monitoring Station*



2003 and Historical Average Stream Data Comparisons

The average 2003 and average historical data for total phosphorus, total suspended solids, total dissolved phosphorus, and nitrates were plotted for comparison of the streams. Loads to main stem rivers (Figure 60), flow-weighted mean concentrations (Figure 61), and runoff and pollutant areal yield (total flow volume or total mass load divided by watershed area) (Figure 62) will be discussed below.

During 2003 the Vermillion River had greatest total annual flow volume (6.01 billion ft3), followed by Rice Creek (2.69 billion ft3), Sand Creek (2.45 billion ft3), and Elm Creek (1.42 billion ft3). Watershed areas and rank among the 11 creeks in this report are 327 square miles (Vermillion River; largest watershed), 184 square miles (Rice Creek, 3rd largest watershed), 255 square miles (Sand Creek; 2nd largest watershed), and 106 square miles (Elm Creek, 4th largest watershed). Total runoff volume quite clearly is strongly influenced by watershed area in these streams.

The historical annual average flow volume generally mirrors the 2003 volumes. The 2003 volumes in Sand and Bevens Creeks were significantly lower than the historical average, likely due to a precipitation deficit of 44% in that region of the metro area.

The runoff coefficient (Figure 61) is the total annual runoff volume divided by the total annual precipitation, and is typically expressed as a percentage. This parameter indicates the portion of annual precipitation over the watershed that reaches the stream as stormwater runoff. A high runoff coefficient indicates a watershed with much impervious area or a large network of agricultural drainage tiles and ditches – characteristics that prevent infiltration of precipitation. Runoff coefficient will be incongruously high for streams with a large inflow of groundwater.

Watershed yield (total annual flow volume divided by watershed area, (Figure 62) standardizes flow volumes so watershed area is excluded from analysis of the annual volumes in each stream. Thus stream watershed yields can be directly compared to one another, and give a general indication of watershed characteristics, precipitation variability, and groundwater effects. Watershed yield is expressed in inches of runoff.

During 2003 the Vermillion River had greatest watershed yield (7.9 inches), followed by Nine Mile Creek (6.5 inches), Rice Creek (6.3 inches), Credit River (5.0 inches), Browns Creek (4.6 inches), Valley Creek (4.5 inches) and Sand Creek (4.1 inches). The flow in the Vermillion River is augmented by approximately 8.6 million gallons (1.15 million ft3) per day from the Empire Wastewater Treatment Plant. Both Elm and Rice Creeks have numerous wetlands and lakes in their watersheds, which one would expect to store water, thus lowering the annual watershed yield. The watershed yield in Nine Mile Creek is likely affected by the high degree of urbanization, and thus impervious area, within the watershed. Flow in both Browns and Valley Creeks are augmented by groundwater flow, thus influencing the runoff yield. Sand, Bluff and Bevens Creeks had relatively low watershed yields in 2003 due to precipitation deficits, but historically these streams have high watershed yields, likely due to lack of lakes and wetlands and presence of ditching and tiling.

2003 and historical annual pollutant mass loads and flow-weighted mean concentrations (as calculated using FLUX) are shown in Figures 60 and 61. For both 2003 and historical average annual total phosphorus, Vermillion River had the greatest total load. The Vermillion River had the highest total phosphorus flow-weighted mean concentration in 2003, but historically the concentrations in Bevens, Carver, and Sand Creeks exceed that of the Vermillion. The mean annual total phosphorus concentration of Empire Wastewater Treatment Plant effluent discharge to the Vermillion is 4,800 ppb, and thus is likely the primary source of phosphorus to the river. The Wastewater Treatment Plant effluent will be diverted from the Vermillion and discharged directly to the Mississippi within the next few years.

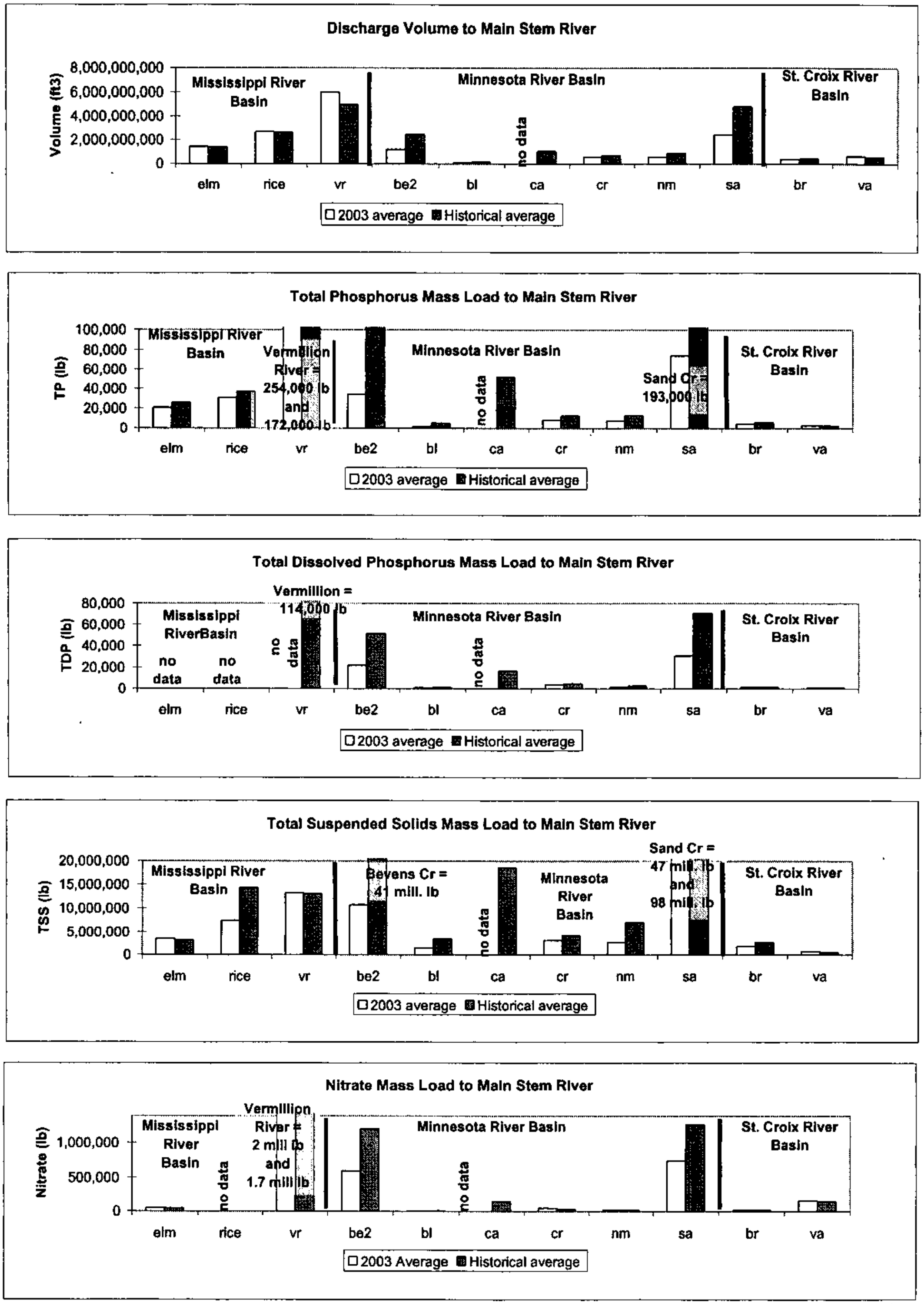
For total dissolved phosphorus, again the Vermillion River had the greatest historical average annual load (114,000 lbs) and flow-weighted mean concentration (2003 data total dissolved phosphorus data had to be excluded from this study due to possible contamination from suspended sediments). The Empire Wastewater Treatment Plant is the greatest influence on the load and concentration. Sand Creek and Bevens Creek also each have relatively high loads of total dissolved phosphorus, likely due to the agricultural nature and size of the watersheds. Nine Mile Creek has relatively low total and total dissolved phosphorus concentration and loads. From the degree of urbanization in the watershed, one would expect higher loads, however intensive installation of best management practices by the watershed district have likely reduced phosphorus in the creek. Due to the small watershed size, the St. Croix River tributaries (Browns and Valley Creek) had low 2003 and historical average annual phosphorus loads and concentrations. The 2003 and historical average annual phosphorus concentrations in Browns Creek are higher than in Valley Creek due to the greater degree of urbanization in the Browns Creek watershed.

Bevens and Sand Creeks had the largest annual suspended solids loads for 2003 (41 million lbs and 47 million lbs, respectively, and Bevens, Sand, and Carver Creeks had the highest loads for the historical average (2003 data was not available for Carver). The highest annual total suspended solids concentrations for 2003 and for the historical average were observed in Bevens, Bluff, Carver, and Sand Creeks.

The Vermillion River had the largest 2003 and historical average mass load of nitrate. The Empire WWTP effluent discharge is likely the primary source rather than watershed influences. Bevens and Sand Creeks had relatively high nitrate loads and concentrations for both 2003 and historically. Valley Creek nitrate concentration is high in relation to its other chemical constituents, but the source is likely groundwater rather than watershed influences.

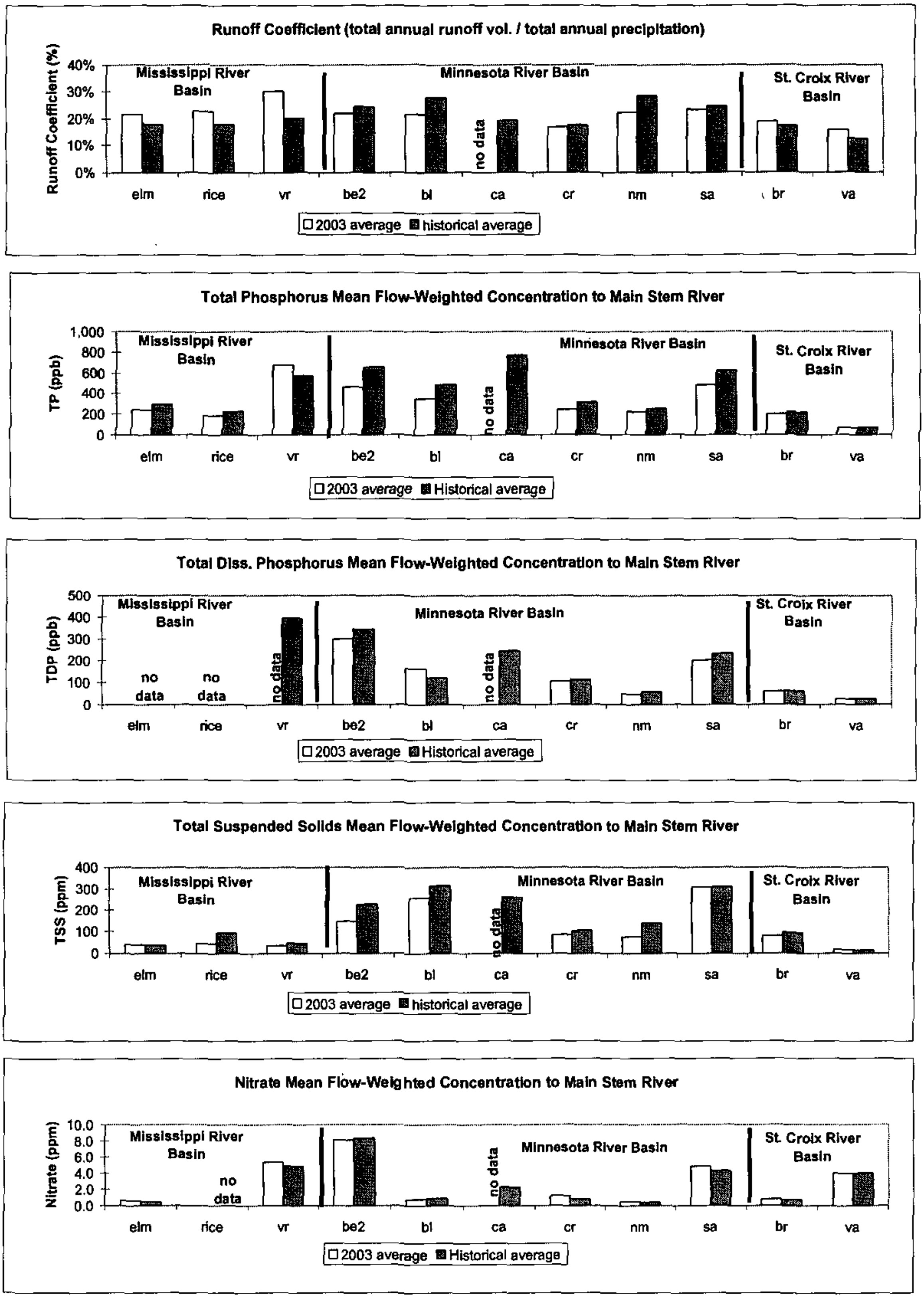
Figure 62 illustrates the pollutant yield of each watershed, which is calculated by dividing the total annual load by the watershed area of the stream, and is express in lbs/acre. This analysis standardizes annual loads by removing the effect of watershed size. A small stream may have a relatively low annual total phosphorus load by mass, but may have a high yield of total phosphorus per acre, indicating poor management of nutrients within the watershed. The Minnesota River tributaries (Bevens, Bluff, Carver, Sand, and Nine Mile Creeks and Credit River) have the largest per-acre nutrient and suspended solids yields.

Figure 60. Stream Comparison: 2003 and Historical Mass Loads Discharged to Main Stem River Receiving Waters



Elm = Elm Creek   Rice = Rice Creek   vr = Vermillion River   be2 = Bevens Creek   ca = Carver Creek
cr = Credit River   nm = Nine Mile Creek   sa = Sand Creek   bl = Bluff Creek   br = Browns Creek   va = Valley Creek

Figure 61. Stream Comparison: 2003 and Historical Mean Flow-Weighted Concentrations



Runoff Coefficient (total annual runoff vol. / total annual precipitation)

Total Phosphorus Mean Flow-Weighted Concentration to Main Stem River

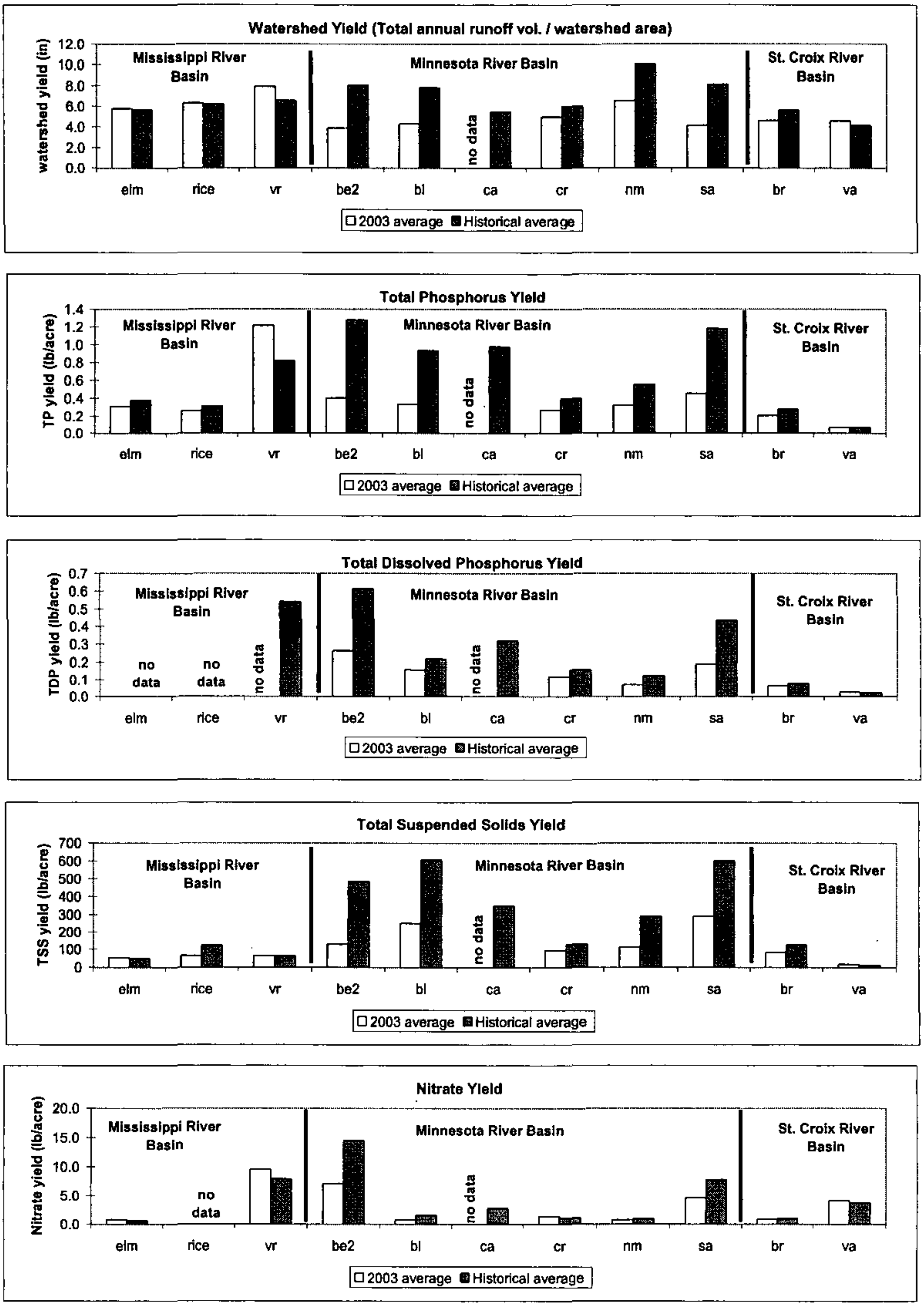
Total Diss. Phosphorus Mean Flow-Weighted Concentration to Main Stem River

Total Suspended Solids Mean Flow-Weighted Concentration to Main Stem River

Nitrate Mean Flow-Weighted Concentration to Main Stem River

Elm = Elm Creek Rice = Rice Creek vr = Vermillion River be2 = Bevens Creek ca = Carver Creek
cr = Credit River nm = Nine Mile Creek sa = Sand Creek bl = Bluff Creek br = Browns Creek va = Valley Creek

Figure 62. Stream Comparison: 2003 and Historical Mean Watershed Yields



Elm = Elm Creek Rice = Rice Creek vr = Vermillion River be2 = Bevens Creek ca = Carver Creek
cr = Credit River nm = Nine Mile Creek sa = Sand Creek bl = Bluff Creek br = Browns Creek va = Valley Creek

Trend Analysis

Trend analysis was performed on annual pollutant loads and annual mean flow-weighted concentrations calculated using FLUX for each stream, using the seasonal Kendall Tau test ($p \leq 0.05$) (SPSS version 10.0). The Kendall Tau test was appropriate for this analysis as it does not require normal distribution of data. Correlation coefficients (tau-b) for the Kendall Tau test range in value from -1 (a perfect negative relationship) and +1 (a perfect positive relationship). A value of 0 indicates no linear relationship. Correlation coefficients significant at the 0.05 (95% certainty) level are identified with a single asterisk, and those significant at the 0.01 (99% certainty) level are identified with two asterisks. Therefore the closer the coefficient are to 1 or –1, the stronger the indication of possible trend.

Using annual values makes the trend analysis rather simplistic, but this is the best analysis choice for the stream monitoring data given the variability in number of samples and timing between sample collection. As the monitoring data set expands over time, more sophisticated trend analysis techniques can be used for future analysis.

The Kendall Tau test did identify some potential trends (Table 18). However, identification of a potential trend may not mean an actual trend exists. Presence of supplemental evidence to explain changes in water quality or quantity strengthens the likelihood of a valid trend. For future versions of this report, local governmental units will be surveyed regarding changes in watershed land use or installation of BMP or restoration projects.

Trends in annual load without comparable change in concentration or runoff volume may not be accurate. Thus trends identified for TSS load in Bluff Creek and TDP loads in Sand and Valley Creeks and Vermillion River may not be genuine.

Determination of changes in watershed land use practices or policies and annual reassessment of monitoring data will be necessary to identify the genuine trends.

Evidence exists to explain trends in the following:
The Nine Mile Creek Watershed District completed the Lower Valley Project around 1993. This project stabilized scarps and restored streambed stability in the Nine Mile Creek segment just south of Old Shakopee Road to just upstream of the stream outlet to the Minnesota River. It is likely that concentrations of TSS, TP, and TDP have decreased as a result of the stabilization project.

A major restoration and diversion project on Browns Creek was begun in 2001 and completed in June 2003. Low-to-midflow runoff from 5.4 square miles (3,431 acres) of developed watershed was diverted from Browns Creek to McKusick Lake. Outflow from McKusick Lake drains through the McKusick Ravine stormwater system to the St. Croix River. This represents diversion of over one-third the Browns Creek watershed runoff for small to mid-size storm events. Additional activities included restoration of the historic Browns Creek channel at the Oak Glen Golf Course and restoration of trout habitat. Trend analysis shows the runoff yield in Browns Creek has a significant upward trend, indicating more runoff per unit area. It is anticipated that the diversion project will cause a downward trend in runoff yield. Results of future monitoring will aid in re-analyzing this trend.

Table 18. Results of Kendall Tau Trend Analysis

Parameter	Bevens Creek	Bluff Creek	Browns Creek	Carver Creek	Credit River	Elm Creek	Nine Mile Creek	Rice Creek	Sand Creek	Valley Creek	Vermillion River
Annual Precip.											
Annual Runoff Volume											
Annual Watershed Yield											
Annual Runoff Coefficient			↑ (1.000*)								
Annual Nitrate Mass Load					↑ (.487*)		↑ (.487*)				
Annual Nitrate Concentration		↓ (-0.636**)			↑ (.462*)	↑ (.667*)					
Annual TDP Mass Load									↓ (-.407*)	↑ **(1.00**)**	↑ (.643*)
Annual TDP Concentration	↓ (-.486*)						↓ (-.590**)				
Annual TP Load		↓ (-.515*)									
Annual TP Concentration	↓ (-.695**)	↓ (-.515*)					↓ (-.692**)		↓ (-.604**)		
Annual TSS Load		↓ **(-.455*)**									
Annual TSS Concentration							↓ (-.795**)				↓ (-.611*)

Stream Water Quality Assessments

This report has thus far focussed on water quality measured in 11 streams over a number of years. Results of chemical and physical measurements of each stream have been discussed, and the characteristics for each stream have been compared for year 2003 and for the historical data record.

What has not been discussed are any quantitative or qualitative rankings of water quality; for example which streams have "good" water quality and which have "poor". Lake water quality can be readily characterized using the Carlson Trophic Index, a statistical tool which uses measurements of total phosphorus and chlorophyll a concentrations and water transparency to assign trophic states to lakes. Lakes are typically assessed as "oligotrophic" (minimal biological activity with few algae and clear water), "mesotrophic", "eutrophic", or 'hypereutrophic" (high biological activity with dense algal mats, low dissolved oxygen, and murky water). The trophic state of a lake provides an easy way to classify water quality in lakes, as well as rank lakes according to their water quality characteristics. Unfortunately, stream systems are more complicated and variable than lakes, and a convenient system for classifying stream water quality is not yet available.

In the following sections, several different assessments of stream water quality and a general statement regarding the relative quality of each stream will be made. The methods selected for assessment include: comparison of stream concentrations with receiving river concentrations; comparison of stream water turbidity with the MPCA's turbidity standard for Class 2 and Class 2b waters; comparison of stream water quality with that predicted by the MPCA for associated ecoregion streams.

The results of these assessments are discussed below. These assessment methods will likely be expanded and stream quality critiqued further as Target Pollutant Loads are developed for each stream.

ASSESSMENT METHOD 1: COMPARISON OF STREAM AND MAIN STEM RIVER CONCENTRATIONS

The Metropolitan Council has a general policy of no degradation of water quality of the main stem rivers (the Mississippi, the Minnesota, and the St. Croix) within the boundaries of the metropolitan area. In other words, the quality of river water leaving the metro area should be as clean as that entering it. To comply with the non-degradation goal, concentration of stream discharge entering the main stem rivers within the metro area should not exceed that of the recipient river.

Since river and stream samples are rarely collected on the same day, and since streams have greater short-term variability in water quality than rivers, the comparison was made using annual flow-weighted mean concentrations calculated using FLUX. The FLUX calculation methods for the streams are discussed on page 52 of this report. Corresponding calculations for the main stem rivers are discussed in *Regional Progress in Water Quality: Analysis of Water Quality Data from 1976 to 2002 for the Major Rivers in the Twin Cities*, Metropolitan Council, 2004.

For each year of record for each stream, the recipient river annual concentration for total phosphorus and total suspended solids was subtracted from the annual stream concentration. Thus, a negative value resulted when the river concentration exceeded that of the stream; a positive value resulted when the stream exceeded the river. To summarize the results, one box plot representing all years of data collection was prepared for each stream (Figures 63 and 64). In each box plot, the lower edge of the shaded portion represents the 25th percentile value, the upper edge of the shaded portion represents the 75th percentile value, and dark line across the shaded portion represents the median value. The "whiskers" extending from top and bottom of the shaded box, as well as the * and o symbols represent statistical outliers. The longer the shaded box, the greater variation within values for that stream. Portions of the box plots extending above the "0" line represent stream concentration that is greater than the river concentration, and therefore degrades the river. Portions extending below the "0" line represent stream concentration less than river concentration and therefore non-degrading.

Total phosphorus concentrations for Credit River and Nine Mile and Valley Creeks are similar to or lower than the respective recipient river (Minnesota River for Credit and Nine Mile and St. Croix River for Valley Creek). Phosphorus concentrations greatly exceed river concentrations in Bevens, Carver, and Sand Creeks and the Vermillion River.

Total suspended solids concentrations for Elm and Valley Creeks and the Vermillion River are fairly similar to that of the respective recipient river (Mississippi for Elm and Vermillion, and St. Croix for Valley Creek). Total suspended solids concentrations of Credit River and Nine Mile Creek frequently are less than the Minnesota River. Inspection of results for Nine Mile Creek indicates that total suspended solids concentrations have declined since the early 1990's, and current concentrations are typically less than those of the Minnesota River. Total suspended solids concentrations for Bevens, Bluff, Browns, Carver, Sand, and Rice exceed that of the recipient river during most years.

Streams were ranked by average deviation from river concentration for both total phosphorus and total suspended solids (Table 19); an average rank was then calculated. Nine Mile and Valley Creeks and Credit River were ranked lowest with least deviation from river quality. Sand, Carver, and Bluff Creeks ranked highest with greatest deviation from river quality.

Table 19. Ranking of Stream Quality by Deviation from Recipient River Concentration

Stream	Recipient River	Total Phosphorus Average Deviation from River Conc. (ppb)	Rank (1)	Total Suspended Solids Average Deviation from River Conc. (ppm)	Rank (1)	Ave. Rank (1)
Bevens Creek	Minnesota	370	9	54	6	7.5
Bluff Creek	Minnesota	199	7	145	11	9
Browns Creek	St. Croix	157	5	85	8	6.5
Carver Creek	Minnesota	485	11	93	9	10
Credit River	Minnesota	30	3	-63	1	2
Elm Creek	Mississippi	163	6	16	4	5
Nine Mile Creek	Minnesota	-36	1	-34	2	1.5
Rice Creek	Mississippi	109	4	73	7	5.5
Sand Creek	Minnesota	335	8	137	10	9
Valley Creek	St. Croix	8	2	5	3	2.5
Vermillion River	Mississippi	457	10	27	5	7.5

Notes: (1) Streams were ranked 1-11 with 1 assigned to the stream with lowest percentage of exceedances

Figure 63. Box Plots Summarizing Variation between Stream Concentration and Recipient River Concentrations: Total Phosphorus

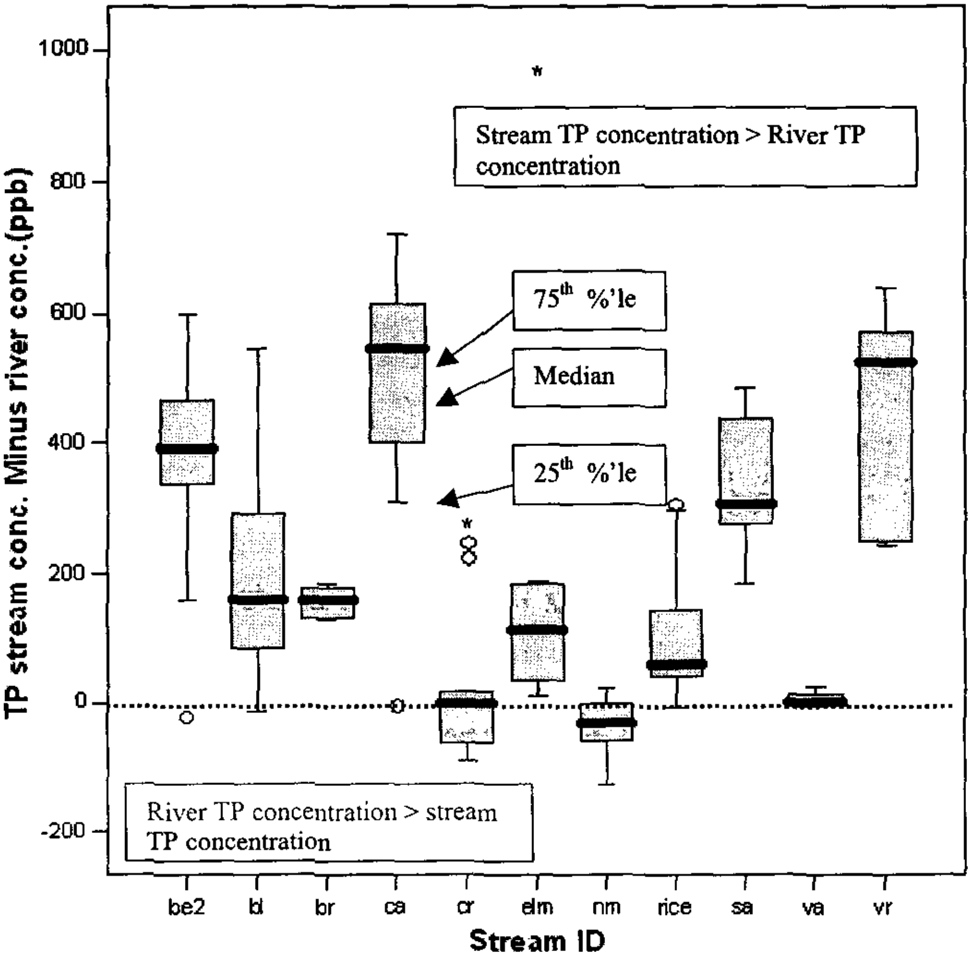
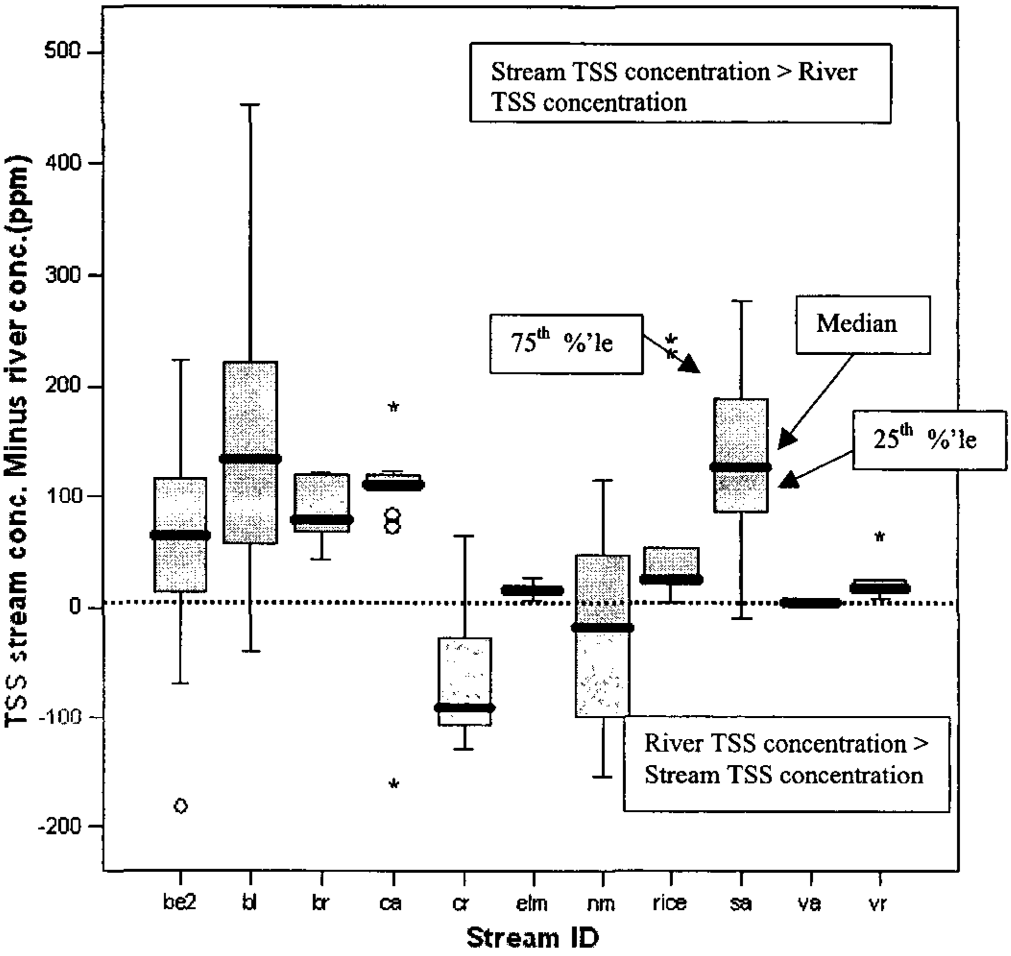


Figure 64. Box Plots Summarizing Variation between Stream Concentration and Recipient River Concentrations: Total Suspended Solids



ASSESSMENT METHOD 2: COMPARISON OF STREAM QUALITY WITH MPCA TURBIDITY STANDARD

Turbidity is a measure of the amount of light-refracting materials, such as suspended particles and algae, in a waterbody. High turbidity makes water appear cloudy, and therefore can negatively effect waterbody use through diminished aesthetics for human users. Aquatic biota are also negatively affected by high turbidity: smothering of invertebrates, clogging of fish gills, destruction of spawning beds. Due to the potential for negative impacts, the MPCA has established turbidity standards based on waterbody use class. For Class 2Bd, B, C, and D streams, the turbidity standard is 25 NTU. (nephelometric turbidity units). This standard applies to all streams in this assessment report (MPCA, 2004).

Stream quality was assessed by comparison of turbidity measurements with the 25 NTU standard. The fraction of samples exceeding the standard was identified using histograms (Figure 65) and summarized in Table 20. Each stream was ranked from 1 to 11, with 1 assigned to the stream with the lowest fraction of samples exceeding the standard. Bluff Creek had the largest fraction of samples exceeding the standard (59%), followed by Sand, Bevens, and Carver Creeks. The high level of turbidity in these streams is likely caused by sediments in runoff from agricultural areas, stream bank erosion, or construction activity erosion. Vermillion River had the smallest fraction of exceedances (7%) followed closely by Valley Creek (8%).

For this assessment, all turbidity measurements for each stream were included. As part of the Target Pollutant Load project, analysis of turbidity value versus stream flow will be done to identify the conditions during which exceedances are occurring. Countless researchers have established the relationship between turbidity level and suspended solid concentration. As part of the Target Pollutant Load project, this relationship will be determined for each stream, and will be used to predict future turbidity levels based on simulated suspended solids concentrations predicted for full-development conditions. Remedial measures to decrease stream turbidity can then be identified.

Table 20. Ranking of Stream Quality by Exceedance of Turbidity Standard

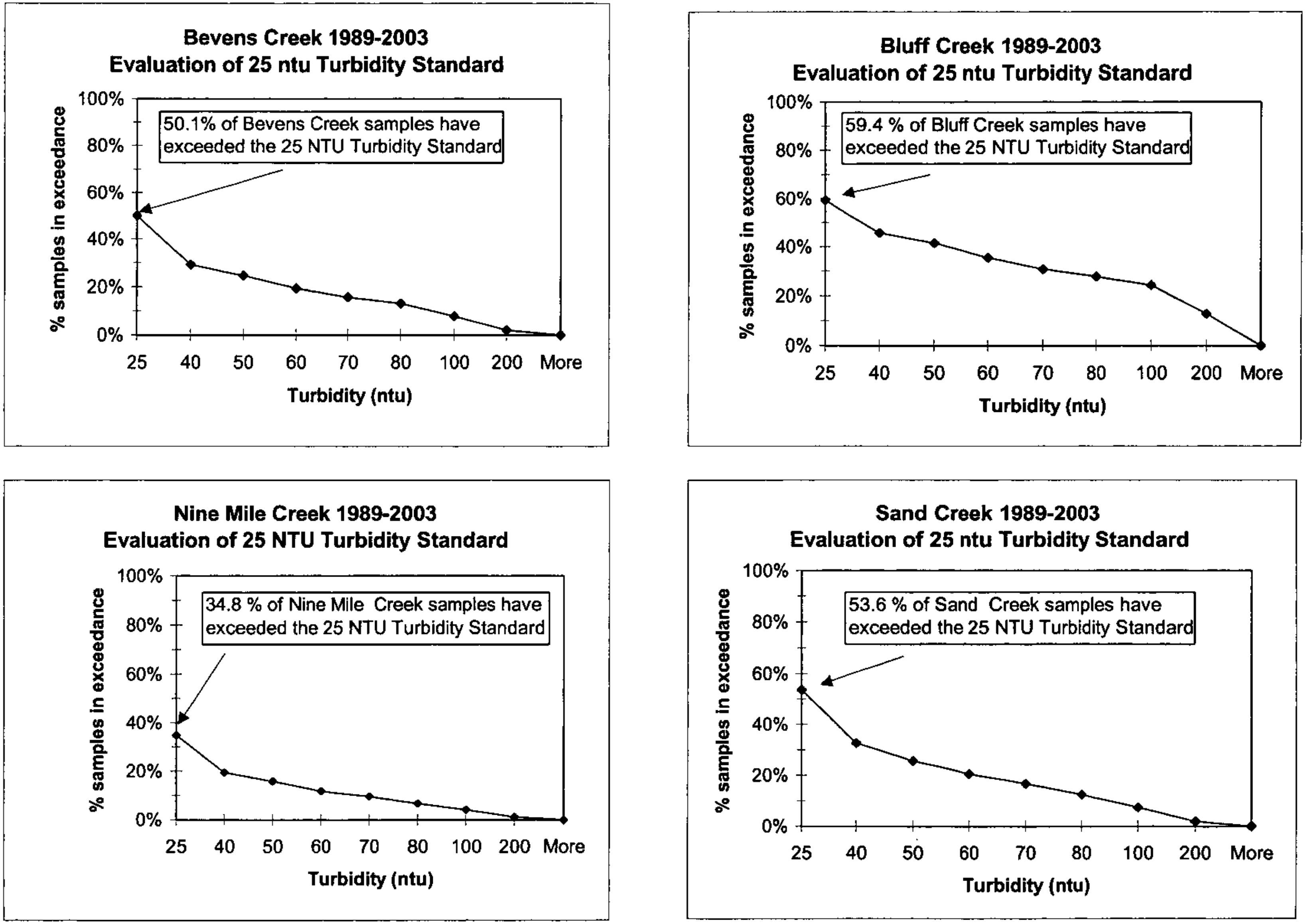
Stream	**Number of Samples**	**Exceedance of Turbidity Standard (1)**	**Rank (2)**
Bevens Creek	463	50 %	7
Bluff Creek	234	59%	9
Browns Creek	98	17%	3
Carver Creek	396	49%	6
Credit River	348	27%	4
Elm Creek	N/A	N/A	
Nine Mile Creek	417	35%	5
Rice Creek	N/A	N/A	
Sand Creek	483	54%	8
Valley Creek	86	8%	2
Vermillion River	106	7%	1

Notes:

(1) Percent exceedance was calculated by dividing number of samples exceeding the 25 NTU standard by total number of samples

(2) Streams were ranked 1-11 with 1 assigned to the stream with lowest percentage of exceedances

Figure 65. Percent of Samples Exceeding the MPCA's 25 NTU Turbidity Standard



Bevens Creek 1989-2003
Evaluation of 25 ntu Turbidity Standard

50.1% of Bevens Creek samples have exceeded the 25 NTU Turbidity Standard

Bluff Creek 1989-2003
Evaluation of 25 ntu Turbidity Standard

59.4 % of Bluff Creek samples have exceeded the 25 NTU Turbidity Standard

Nine Mile Creek 1989-2003
Evaluation of 25 NTU Turbidity Standard

34.8 % of Nine Mile Creek samples have exceeded the 25 NTU Turbidity Standard

Sand Creek 1989-2003
Evaluation of 25 ntu Turbidity Standard

53.6 % of Sand Creek samples have exceeded the 25 NTU Turbidity Standard

Figure 65. Percent of Samples Exceeding the MPCA's 25 NTU Turbidity Standard (continued)

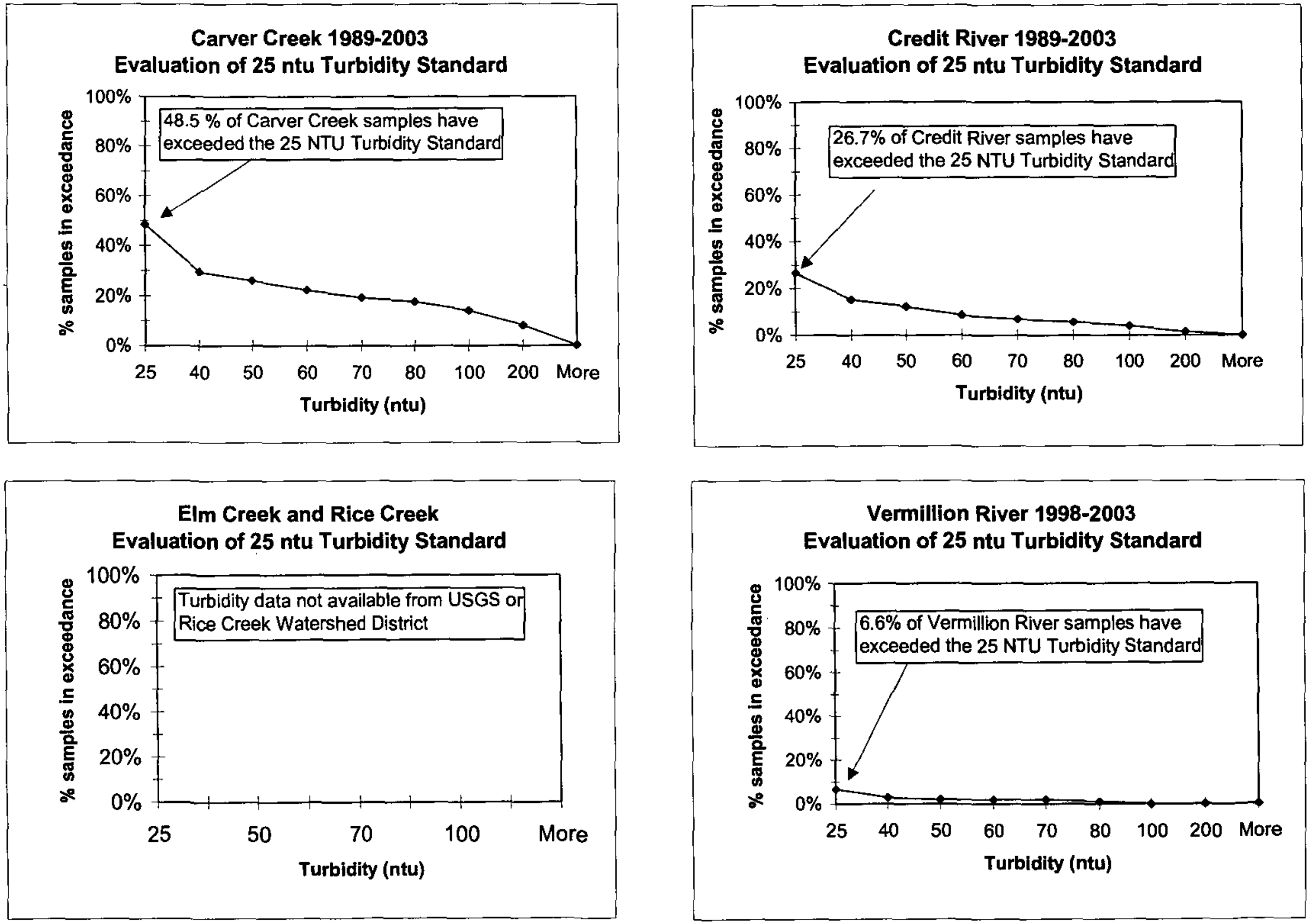
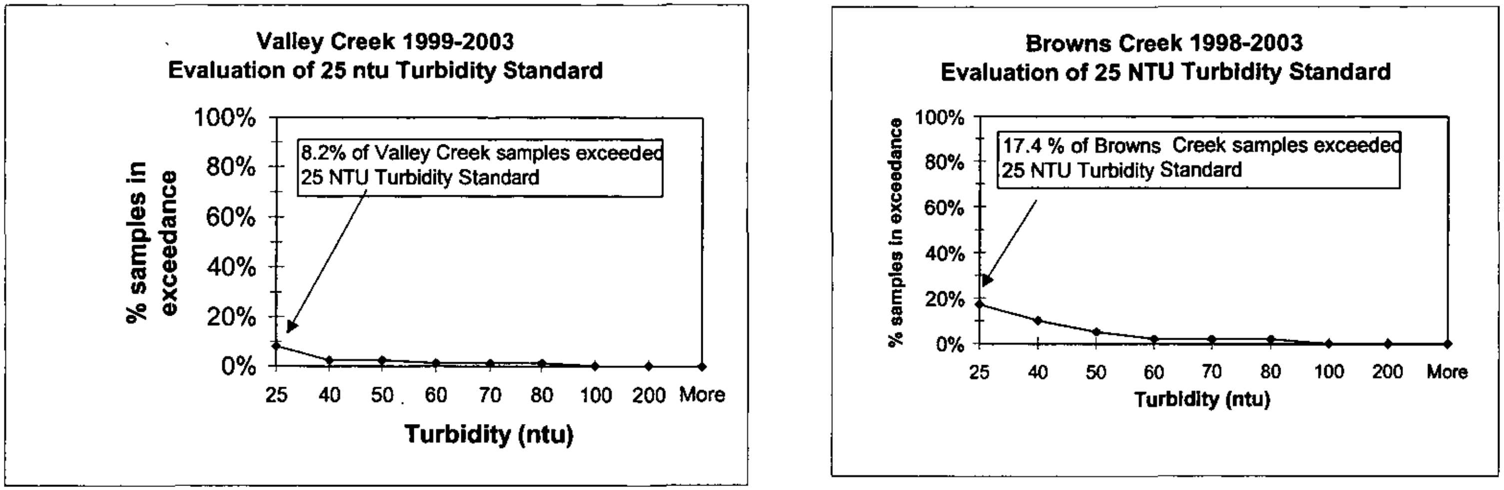


Figure 65. Percent of Samples Exceeding the MPCA's 25 NTU Turbidity Standard (continued)



ASSESSMENT METHOD 3: COMPARISON WITH ECOREGION WATER QUALITY CHARACTERISTICS

Water quality of the 11 streams was compared with reference ecoregion stream characteristics. Ecoregions are land areas relatively homogenous in distinctive regional ecological factors, including land use, soils, topography and natural vegetation. Studies have shown that prior to human development, streams and lakes within each ecoregion tended to have similar water quality characteristics. Therefore, remaining minimally impacted streams in an ecoregion can be used to estimate predevelopment water quality conditions in other streams within that ecoregion.

There are seven ecoregions in the state of Minnesota (Figure 66); two are within the metropolitan area: northern hardwood forests (NCHF) and western cornbelt plains (WCBP). The Minnesota Pollution Control Agency has estimated the predevelopment water quality of streams in each ecoregion from data (1970-1992) for minimally impacted streams (McCullor and Heiskary, 1993). The ecoregion water quality characteristics can be used as benchmarks to determine the extent of water quality changes in impacted streams

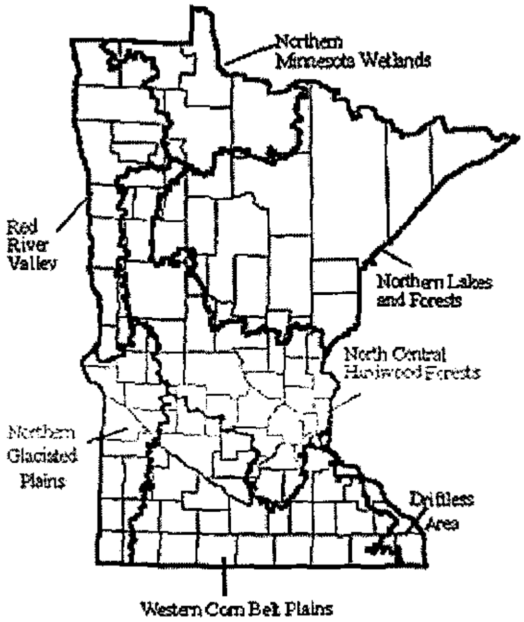


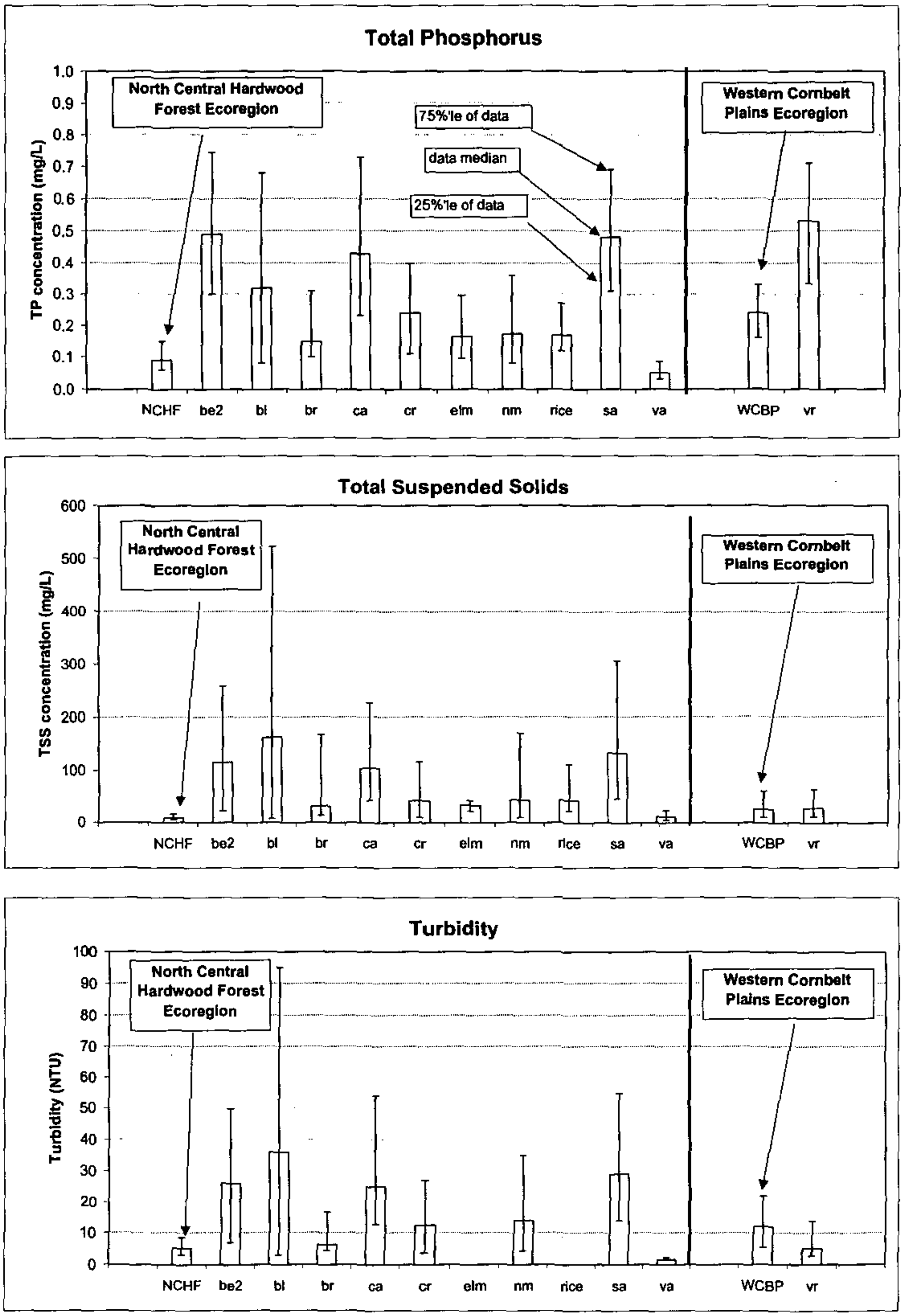
Figure 66. Map of Minnesota Ecoregions

Of the 11 streams discussed in this report only the Vermillion River is in WCBP. The other streams are in the NCHF. The NCHF is an area of transition between the forested areas to the north and east, and the agricultural areas to the south and west. This ecoregion is characterized by terrain varying from rolling hills to smaller plains, by hardwood and conifer forests in upland areas, and agriculture in the plains. The densely populated metropolitan area dominates the eastern portion of this region. Row crops have replaced the vast majority of natural vegetation in WCBP. Surface water quality problems are typically caused by runoff of sediment and fertilizers from agricultural land.

To make accurate comparisons with the MPCA's ecoregion stream water quality estimates, quartile, median and 75th percentile values were determined from total phosphorus, total suspended solids, and turbidity data for the 11 streams (Figure 67). The MPCA generally advises use of the 75th percentile value of ecoregion data as the comparison benchmark. To quantify the difference between stream quality and the ecoregion benchmarks, the 75th percentile value of each stream parameter was divided by the 75th percentile value for the appropriate ecoregion (Table 21). The resulting value is the multiplier between stream and ecoregion parameters. For example, a value of 4 means the stream value is four times the ecoregion value. This value has been called the "exceedance" for simplicity. For the three parameters of interest (total phosphorus, total suspended solids, and turbidity), the streams were ranked 1 to 10 depending on the exceedance value, with 1 representing the lowest value. The values of the three exceedances for each stream were averaged to give an overall rank.

For the NCHF, Bevens, Carver, Bluff, and Sand Creeks have highest average rankings (and thus greatest exceedances of ecoregion benchmarks). Valley Creek has the lowest ranking and has water quality quite similar to the ecoregion benchmarks. For the WCBP, the Vermillion River has water quality similar to the ecoregion benchmarks, with exception of total phosphorus. However, phosphorus concentrations in the Vermillion are strongly impacted by the Empire Wastewater Treatment Plant discharges and are not reflective of watershed runoff.

Figure 67. Comparison of Stream Quality to Ecoregion Reference Values for Minimally Impacted Streams



NCHF = North Central Hardwood Forest be2 = Bevens Creek bl = Bluff Creek br = Browns Creek ca = Carver Creek elm = Elm Creek nm = Nine Mile Creek rice = Rice Creek sa = Sand Creek va = Valley Creek WCBP = Western Cornbelt Plains vr = Vermillion River

Table 21. Ranking of Stream Quality Characteristics by Comparison with MPCA Ecoregion Benchmarks

		Total Phosphorus		Total Suspended Solids		Turbidity		
Stream	**Ecoregion (1)**	**Exceedance (2)**	**Rank (3)**	**Exceedance (2)**	**Rank (3)**	**Exceedance (2)**	**Rank (3)**	**Average Rank (3)**
Bevens Creek	NCHF	5.0	11	16.1	9	5.9	6	8.7
Bluff Creek	NCHF	4.5	8	32.7	11	11.2	9	9.3
Browns Creek	NCHF	2.1	4	10.5	6	2.0	3	4.3
Carver Creek	NCHF	4.9	10	14.1	8	6.4	7	8.3
Credit River	NCHF	2.7	7	7.3	5	3.2	4	5.3
Elm Creek	NCHF	2.0	3	2.7	3	N/A		3.0
Nine Mile Creek	NCHF	2.4	6	10.7	7	4.1	5	6.0
Rice Creek	NCHF	1.8	2	7.0	4	N/A		3.0
Sand Creek	NCHF	4.6	9	19.2	10	6.5	8	9.0
Valley Creek	NCHF	0.6	1	1.5	2	0.2	1	1.3
Vermillion River	WCBP	2.1	5	1.1	1	0.6	2	2.7

Notes:

(1) NCHF = North Central Hardwood Forest; WCBP = Western Corn Belt Plains

(2) Exeedance = 75th percentile stream value / 75th percentile ecoregion value

(3) Streams were ranked 1-11 with 1 assigned to the stream with lowest exceedance and therefore water quality most similar to the ecoregion benchmark

AVERAGE STREAM RANKS

A rank of 1 to 11 was assigned to each stream as part of the three assessment methods. Table 22 summarizes those rankings and provides the overall average rank per stream. Valley and Elm Creeks and Vermillion and Credit Rivers received the lowest rank, representative of better water quality than the other streams according to the three assessment methods. Sand, Carver, Bevens, and Bluff Creeks received the highest ranks.

Table 22. Overall Ranking of Stream Quality

Stream	Recipient River	Average Rank: Deviation from river quality	Average Rank: Exceedance of 25 NTU turbidity standard	Average Rank: Deviation from ecoregion benchmarks	Average Rank	Overall Rank
Valley Creek	St. Croix	2.5	2	1.3	1.7	1
Credit River	Minnesota	2	4	5.3	4.0	2
Elm Creek	Mississippi	5	N/A	3.0	4.0	2
Vermillion River	Mississippi	7.5	1	2.7	4.2	4
Nine Mile Creek	Minnesota	1.5	5	6.0	4.3	5
Rice Creek	Mississippi	5.5	N/A	3.0	4.3	5
Browns Creek	St. Croix	6.5	3	4.3	4.8	7
Bevens Creek	Minnesota	7.5	7	8.7	7.8	8
Carver Creek	Minnesota	10	6	8.3	8.7	9
Sand Creek	Minnesota	9	8	9.0	8.8	10
Bluff Creek	Minnesota	9	9	9.3	9.2	11

CONCLUSIONS

This report has presented descriptive water quality and assessments on 11 streams: Bevens, Browns, Bluff, Carver, Elm, Nine Mile, Rice, Sand, and Valley Creeks, and Credit and Vermillion Rivers. The results of several analyses have been presented:

- pollutant (total suspended solids, total and dissolved phosphorus, and nitrate) annual loads and annual flow-weighted mean concentrations for the period of record (starting as early as 1989) as calculated using FLUX. Discussion was made of conditions in each stream as well as inter-stream comparisons.
- annual flow volumes as calculated by FLUX
- 2003 water quality data. Discussion was made of conditions in each stream as well as inter-stream comparisons.
- Stream assessment. Three methods were used to assign ranks to the 11 streams, giving a measure of relative water quality.

2003 was a year of below-normal precipitation (22.7 inches as compared to the 1989 – 2003 precipitation average of 30.7 inches for Minneapolis-St. Paul International Airport), and most precipitation occurred in the first six months of the year, leaving a year-end precipitation deficit. Thus, it is likely water quality and flow measurements made during 2003 do not represent typical conditions in each stream.

Hydrographs of the period-of-record indicate the Council's monitoring program collects samples at a variety of flows, with most samples collected during storm events. Daily average flows are also determined. The monitoring program provides adequate data for stream assessments.

Comparisons of the 11 streams assessed for 2003 conditions indicate that the Vermillion River discharged the largest annual loads of total phosphorus and nitrates to its receiving water (Mississippi River). Sand Creek discharged the largest load of total suspended solids, in this case to the Minnesota River. The Vermillion River flow and pollutant load is affected by effluent discharge from the Empire Wastewater Treatment Plant.

Comparisons of 2003 watershed yields for both flow and pollutant load indicate that the Mississippi tributaries (Elm and Rice Creeks and Vermillion River) had the greatest flow volume yield (i.e. carried more flow per area) than the other streams. The Vermillion River had the greatest pollutant yields (lbs per area) for total phosphorus and nitrate. As stated previously, this is likely due to effluent discharge from the Empire WWTP. In general, the streams tributary to the Minnesota River had the greatest suspended solids yield (lbs per area) of the 11 assessed streams. In the St. Croix River tributaries, suspended solids yield from Browns Creek was approximately that of the Mississippi River tributaries. Since portions of the Creek are designated as a trout stream, the suspended solids yield is higher than optimal for trout habitat. Valley Creek shows low pollutant yields except for nitrate, which is likely influenced by high groundwater discharge to the creek.

Three assessment methods were used to rank the 11 streams in this report.

- Method 1: Deviation from Recipient River Concentration: For total phosphorus concentration, Valley and Nine Mile Creeks and Credit River had the lowest deviation from river concentrations. Bevens, Carver, and Sand Creeks and Vermillion River had the highest deviation from river concentrations.

- Method 2: Exceedance of 25 NTU turbidity standard: Vermillion River and Valley Creek had the lowest percentages of samples exceeding the standard (7% and 8%, respectively). Bevens, Sand, and Bluff Creeks had the highest percentages of samples exceeding the turbidity standard (50%, 54%, and 59%, respectively). Rice and Elm Creeks were not assessed, as turbidity data was not available.
- Method 3: Deviation from ecoregion benchmarks: Valley Creek and Vermillion River had the lowest deviation from ecoregion benchmarks for total phosphorus, turbidity, and total suspended solids (turbidity data was not available for Vermillion River). Bevens, Bluff, Carver, and Sand Creeks had the highest deviations from ecoregion benchmarks.
- The ranks from the three methods were averaged, and the overall ranking of streams, from lowest rank (and therefore relatively high water quality) to highest rank (relatively low water quality) are:
  - Valley Creek (1)
  - Credit River and Elm Creek (2)
  - Vermillion River (4)
  - Nine Mile and Rice Creeks (5)
  - Browns Creek (7)
  - Bevens Creek (8)
  - Carver Creek (9)
  - Sand Creek (10)
  - Bluff Creek (11)

RECOMMENDATIONS

The Metropolitan Council's stream monitoring program collects not only daily flow rate but also a wide range of data on chemical, physical and biological parameters. This report shows that data collected since1989 provides a detailed picture of water quality in the metropolitan area streams. Few such intensive long-term monitoring efforts exist, and the data collected will support management decisions made to improve water quality in all of the metro area streams.

The following recommendations are made to strengthen the Council's stream monitoring program and to provide beneficial data for both the Council's Target Pollutant Load project and the MPCA's Total Maximum Daily Load Program.

1. The Council's stream monitoring program currently focuses on collection and assessment of chemical and physical data. To further assess ecological stream health, additional biological samples need to be collected. In particular, macroinvertebrate samples should be collected at least twice annually for comparison with standard biotic indices such as the Hilsenhoff Biotic Index or the Shannon-Wiener Diversity Index for Macroinvertebrates. Sporadic fecal coliform samples are currently collected. Consideration should be given to expanding collection of fecal coliform samples to assess possible public health issues.

2. Council staff should conduct a survey of watershed districts, soil and water conservation districts, counties and cities to identify changes in land use, construction of major projects, or stream bank erosion within watersheds that may affect, either positively or negatively, the quality of the stream. The completion date of specific projects should be noted to aid in trend analysis interpretation.

3. Council staff are currently designing a set of protocols to ensure continued quality assurance of sample collection and handling, prompt reviewing and proofing of data, and prompt availability of final data for stream assessments for use by other agencies and the public. It is recommended that these protocols be instituted as soon as completed during 2005.

4. For future stream assessment reports prepared by the Met Council, the following assessments should be included:
    - Analysis and quantification of relationship between total suspended solids and turbidity, and between total suspended solids and total phosphorus.
    - Besides total phosphorus, total dissolved phosphorus, total suspended solids, and nitrates, annual loads should be calculated for volatile suspended solids and total Kjeldahl nitrogen.
    - Analysis and quantification of the relationship between TSS and VSS (volatile suspended solids) in each stream. This analysis will aid identification of the sources of suspended solids as organic-based (for example algae or plant detritus) or inorganic-based (for example, eroded sediment from watershed activities or streambank erosion).
    - Analysis of biological data (for example, macro-invertebrate surveys) to assess the ecological health of each stream.

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APPENDIX A: 2030 REGIONAL DEVELOPMENT FRAMEWORK POPULATION AND HOUSEHOLD FORECASTS

Appendix A-1 2030 Regional Development Framework Population Forecasts: Anoka County

ANOKA COUNTY

Metropolitan Council Population Forecasts

City or Township	1970	1980	1990	2000	2010	2020	2030
Andover	3,904	9,387	15,216	26,588	33,000	39,000	40,500
Anoka	13,591	15,634	17,192	18,076	19,000	19,800	20,800
Bethel	311	272	394	443	450	460	510
Blaine (pt.)	20,568	28,558	38,975	45,014	65,000	72,000	76,000
Burns Twp.	1,129	1,976	2,401	3,557	4,400	5,200	6,300
Centerville	534	734	1,633	3,202	3,700	4,100	4,700
Circle Pines	3,902	3,321	4,704	4,663	5,400	5,300	5,400
Columbia Hgts.	23,997	20,029	18,910	18,520	20,000	21,400	21,700
Columbus Twp.	1,999	3,232	3,690	3,957	4,000	4,100	4,500
Coon Rapids	30,505	35,826	52,978	61,607	65,000	66,000	65,000
East Bethel	2,586	6,626	8,050	10,941	12,300	13,200	14,300
Fridley	29,233	30,228	28,335	27,449	27,000	26,900	27,500
Ham Lake	3,327	7,832	8,924	12,710	16,100	18,100	19,000
Hilltop	1,015	817	749	766	770	770	770
Lexington	2,165	2,150	2,279	2,142	2,250	2,250	2,300
Lino Lakes	3,692	4,966	8,807	16,791	22,500	25,900	29,700
Linwood Twp.	1,004	2,839	3,588	4,668	5,000	5,400	5,900
Oak Grove	1,674	3,926	5,488	6,903	7,400	7,600	8,100
Ramsey	2,360	10,093	12,408	18,510	30,000	43,000	45,000
St. Francis	897	1,184	2,538	4,910	7,700	10,400	12,800
Spring Lake Park (pt.)	6,319	6,368	6,429	6,667	6,700	6,700	6,800
ANOKA COUNTY TOTAL	154,712	195,998	243,688	298,084	357,670	397,580	417,580

Appendix A-1 2030 Regional Development Framework Population Forecasts: Carver County

CARVER COUNTY
Metropolitan Council Population Forecasts

City or Township	1970	1980	1990	2000	2010	2020	2030
Benton Twp.	947	939	895	939	940	940	940
Camden Twp.	895	898	910	955	960	980	1,030
Carver	669	642	744	1,266	2,900	4,000	5,600
Chanhassen (pt.)	4,839	6,351	11,732	20,321	27,500	34,500	38,000
Chaska	4,352	8,346	11,339	17,449	23,800	24,200	24,500
Chaska Twp.	119	205	174	154	2,700	7,800	10,000
Cologne	558	545	563	1,012	1,800	2,500	3,200
Dahlgren Twp.	1,147	1,225	1,296	1,453	2,000	5,700	9,400
Hamburg	405	475	492	538	600	750	1,000
Hancock Twp.	402	391	364	367	390	420	440
Hollywood Twp.	1,064	1,100	1,060	1,102	1,100	1,150	1,300
Laketown Twp.	1,558	2,424	2,232	2,331	5,000	9,700	15,000
Mayer	325	388	471	554	1,600	2,550	3,500
New Germany	303	347	353	346	420	570	830
Norwood Young America	1,784	2,456	2,705	3,108	4,500	6,700	8,800
San Francisco Twp.	509	650	773	888	980	1,100	1,200
Victoria	1,042	1,425	2,354	4,025	6,500	7,700	8,300
Waconia	2,465	2,638	3,498	6,814	7,500	8,000	8,200
Waconia Twp.	1,369	1,402	1,287	1,284	1,380	2,100	2,800
Watertown	1,456	1,818	2,408	3,029	4,700	5,800	6,200
Watertown Twp.	1,282	1,429	1,349	1,432	1,500	2,100	3,100
Young America Twp.	841	952	916	838	870	950	1,200
CARVER COUNTY TOTAL	28,331	37,046	47,915	70,205	99,640	130,210	154,540

Appendix A-1 2030 Regional Development Framework Population Forecasts: Dakota County

DAKOTA COUNTY
Metropolitan Council Population Forecasts

City or Township	1970	1980	1990	2000	2010	2020	2030
Apple Valley	8,502	21,818	34,598	45,527	54,000	63,000	66,000
Burnsville	19,940	35,674	51,288	60,220	61,500	63,000	64,000
Castle Rock Twp.	1,235	1,340	1,480	1,495	1,500	1,550	1,650
Coates	212	207	186	163	170	190	200
Douglas Twp.	552	614	670	760	820	850	880
Eagan	10,398	20,700	47,409	63,557	67,000	68,000	69,000
Empire Twp.	1,136	1,224	1,340	1,638	2,050	4,400	4,900
Eureka Twp.	860	1,268	1,405	1,490	1,500	1,650	1,800
Farmington	3,464	4,370	5,940	12,365	20,500	27,100	32,000
Greenvale Twp.	624	641	685	684	730	790	880
Hampton	369	299	363	434	690	730	740
Hampton Twp.	595	848	866	986	1,000	1,050	1,200
Hastings (pt.)	12,179	12,811	15,473	18,201	23,000	27,500	30,000
Inver Grove Hgts.	12,148	17,171	22,477	29,751	35,300	40,900	41,900
Lakeville	7,196	14,790	24,854	43,128	58,000	77,000	86,000
Lilydale	322	417	553	552	860	860	860
Marshan Twp.	1,186	1,655	1,215	1,263	1,300	1,350	1,400
Mendota	266	219	164	197	210	230	270
Mendota Hgts.	6,565	7,288	9,381	11,434	12,000	12,000	12,100
Miesville	192	179	135	135	150	150	150
New Trier	153	115	96	116	120	120	120
Nininger Twp.	554	774	805	865	940	990	1,050
Northfield (pt.)	0	13	170	557	740	940	1,150
Randolph	350	351	331	318	420	530	630
Randolph Twp.	267	385	448	536	620	630	670
Ravenna Twp.	550	1,683	1,926	2,355	2,500	2,600	2,800
Rosemount	4,034	5,083	8,622	14,619	22,700	30,100	35,700
Sciota Twp.	213	242	252	285	370	430	500
South St. Paul	25,016	21,235	20,197	20,167	19,900	20,000	20,700
Sunfish Lake	269	344	413	504	510	520	530
Vermillion	359	438	510	437	520	600	720
Vermillion Twp.	779	1,070	1,201	1,243	1,250	1,350	1,500
Waterford Twp.	521	486	485	517	540	560	570
West St. Paul	18,802	18,527	19,248	19,405	20,100	21,100	21,700
DAKOTA COUNTY TOTAL	139,808	194,279	275,186	355,904	413,510	472,770	504,270

Appendix A-1 2030 Regional Development Framework Population Forecasts: Hennepin County

HENNEPIN COUNTY
Metropolitan Council Population Forecasts

City or Township	1970	1980	1990	2000	2010	2020	2030
Bloomington	81,970	81,831	86,335	85,172	87,500	90,500	93,000
Brooklyn Center	35,173	31,230	28,887	29,172	29,500	29,500	29,500
Brooklyn Park	26,230	43,332	56,381	67,388	74,500	80,500	85,000
Champlin	4,704	9,006	16,849	22,193	23,700	24,500	25,800
Chanhassen (pt.)	40	8	-	-	0	0	0
Corcoran	1,656	4,252	5,199	5,630	11,600	19,300	23,000
Crystal	30,925	25,543	23,788	22,698	22,700	22,800	23,500
Dayton (pt.)	2,631	4,000	4,392	4,693	5,600	17,000	28,700
Deephaven	3,853	3,716	3,653	3,853	3,900	3,900	3,900
Eden Prairie	6,938	16,263	39,311	54,901	60,000	62,500	63,000
Edina	44,046	46,073	46,070	47,425	49,000	50,000	51,500
Excelsior	2,563	2,523	2,367	2,393	2,500	2,700	2,800
Fort Snelling	624	223	97	442	0	0	0
Golden Valley	24,246	22,775	20,971	20,281	20,500	20,600	21,300
Greenfield	973	1,391	1,450	2,544	2,900	3,500	4,300
Greenwood	587	653	614	729	760	770	780
Hanover (pt.)	96	248	269	332	410	510	630
Hassan Twp.	917	1,766	1,951	2,463	2,900	11,000	19,100
Hopkins	13,428	15,336	16,534	17,367	17,800	18,500	18,900
Independence	1,993	2,640	2,822	3,236	4,000	4,400	4,800
Long Lake	1,506	1,747	1,984	1,842	2,100	2,250	2,450
Loretto	340	297	404	570	690	700	700
Maple Grove	6,275	20,525	38,736	50,365	64,500	75,000	84,000
Maple Plain	1,169	1,421	2,005	2,088	2,250	2,350	2,400
Medicine Lake	446	419	385	368	390	440	470
Medina	2,396	2,623	3,096	4,005	5,800	7,200	10,500
Minneapolis	434,400	370,951	368,383	382,747	402,000	423,000	435,000
Minnetonka	35,776	38,683	48,370	51,102	51,500	51,500	53,500
Minnetonka Beach	586	575	573	614	640	640	630
Minnetrista	2,878	3,236	3,439	4,358	5,600	7,500	10,000
Mound	7,572	9,280	9,634	9,435	10,400	11,000	11,400
New Hope	23,180	23,087	21,853	20,873	21,500	22,000	22,500
Orono	6,787	6,845	7,285	7,538	8,300	9,200	9,800
Osseo	2,908	2,974	2,704	2,434	2,600	2,750	3,300
Plymouth	18,077	31,615	50,889	65,894	73,000	76,000	78,500
Richfield	47,231	37,851	35,710	34,310	37,700	41,300	45,000
Robbinsdale	16,845	14,422	14,396	14,123	15,000	16,000	16,500
Rockford (pt.)	166	380	440	144	240	470	700
Rogers	544	652	698	3,588	6,400	7,000	7,800
St. Anthony (pt.)	6,886	5,619	5,278	5,664	6,200	6,700	7,100
St. Bonifacius	685	857	1,180	1,873	2,850	2,750	2,900
St. Louis Park	48,883	42,931	43,787	44,102	47,000	49,300	51,500
Shorewood	4,223	4,646	5,917	7,400	7,500	7,600	8,100
Spring Park	1,087	1,465	1,571	1,717	1,850	2,000	2,100
Tonka Bay	1,397	1,354	1,472	1,547	1,700	1,800	1,800
Wayzata	3,700	3,621	3,806	4,113	4,200	4,400	4,700
Woodland	544	526	496	480	480	510	490
HENNEPIN COUNTY TOTAL	960,080	941,411	1,032,431	1,116,206	1,202,160	1,293,840	1,373,350

Appendix A-1 2030 Regional Development Framework Population Forecasts: Ramsey County

RAMSEY COUNTY
Metropolitan Council Population Forecasts

City or Township	1970	1980	1990	2000	2010	2020	2030
Arden Hills	5,149	8,012	9,199	9,652	10,800	13,000	22,500
Blaine (pt.)	5	0	-	-	0	0	0
Falcon Hgts.	5,530	5,291	5,380	5,572	6,100	6,100	6,100
Gem Lake	216	394	439	419	440	450	490
Lauderdale	2,530	1,985	2,700	2,364	2,400	2,450	2,500
Little Canada	3,481	7,102	8,971	9,771	10,900	11,900	12,800
Maplewood	25,186	26,990	30,954	35,258	37,500	38,100	39,300
Mounds View	10,599	12,593	12,541	12,738	12,900	13,000	13,400
New Brighton	19,507	23,269	22,207	22,206	22,700	22,500	22,800
North Oaks	2,002	2,846	3,386	3,883	4,400	5,500	5,900
North St. Paul	11,950	11,921	12,376	11,929	11,900	12,500	13,400
Roseville	34,438	35,820	33,485	33,690	36,000	37,000	38,300
St. Anthony (pt.)	2,353	2,362	2,449	2,348	2,450	2,700	2,900
St. Paul	309,866	270,230	272,235	286,840	305,000	320,000	331,000
Shoreview	10,978	17,300	24,587	25,924	26,000	25,200	25,300
Spring Lake Park (pt.)	98	109	103	105	110	110	110
Vadnais Hgts.	3,411	5,111	11,041	13,069	13,800	14,300	16,800
White Bear Twp.	5,666	5,921	9,424	11,293	12,200	11,700	12,100
White Bear Lake (pt.)	23,290	22,528	24,306	23,974	25,000	26,000	27,000
RAMSEY COUNTY TOTAL	476,255	459,784	485,783	511,035	540,600	562,510	592,700

Appendix A-1 2030 Regional Development Framework Population Forecasts: Scott County

SCOTT COUNTY
Metropolitan Council Population Forecasts

City or Township	1970	1980	1990	2000	2010	2020	2030
Belle Plaine	2,328	2,754	3,149	3,789	6,450	8,300	10,800
Belle Plaine Twp.	805	765	691	806	950	1,050	1,300
Blakeley Twp.	565	515	456	496	520	570	640
Cedar Lake Twp.	1,051	1,507	1,688	2,197	2,800	3,200	3,700
Credit River Twp.	1,165	2,360	2,854	3,895	4,900	6,800	8,600
Elko	115	274	223	472	2,100	4,200	5,700
Helena Twp.	1,016	1,215	1,107	1,440	1,600	1,800	2,200
Jackson Twp.	1,526	1,483	1,359	1,361	1,400	3,900	10,300
Jordan	1,836	2,663	2,909	3,833	5,800	7,600	10,700
Louisville Twp.	571	813	910	1,359	1,450	1,500	1,700
New Market	215	286	227	332	2,600	5,200	7,200
New Market Twp.	1,236	1,636	2,008	3,057	4,100	5,300	7,200
New Prague (pt.)	1,871	1,898	2,356	3,157	4,700	6,200	7,200
Prior Lake	4,127	7,284	11,482	15,917	27,500	30,000	30,500
St. Lawrence Twp.	388	350	418	472	600	800	1,400
Sand Creek Twp.	1,250	1,516	1,511	1,551	1,800	2,130	2,500
Savage	3,115	3,954	9,906	21,115	31,400	39,000	42,700
Shakopee	7,716	9,941	11,739	20,568	39,500	48,500	52,000
Spring Lake Twp.	1,527	2,570	2,853	3,681	5,600	9,300	14,600
SCOTT COUNTY TOTAL	32,423	43,784	57,846	89,498	145,770	185,350	220,940

Appendix A-1 2030 Regional Development Framework Population Forecasts: Washington County

WASHINGTON COUNTY
Metropolitan Council Population Forecasts

City or Township	1970	1980	1990	2000	2010	2020	2030
Afton	1,993	2,550	2,645	2,839	2,900	3,000	3,100
Bayport	2,987	2,932	3,200	3,162	3,400	4,100	6,000
Baytown Twp.	723	851	939	1,533	1,900	2,300	3,400
Birchwood	926	1,059	1,042	968	930	900	880
Cottage Grove	13,419	18,994	22,935	30,582	37,000	43,900	53,000
Dellwood	524	751	887	1,033	1,050	1,000	1,000
Denmark Twp.	923	1,140	1,172	1,348	1,750	2,150	2,550
Forest Lake	6,197	9,927	12,523	14,440	17,700	21,800	28,000
Grant	1,797	3,083	3,778	4,026	4,500	4,800	5,000
Grey Cloud Twp.	389	351	414	307	4,900	6,800	6,800
Hastings (pt.)	16	16	5	3	0	0	0
Hugo	2,669	3,771	4,417	6,363	11,800	18,200	25,800
Lake Elmo	3,542	5,296	5,903	6,863	9,400	15,200	24,000
Lakeland	962	1,812	2,000	1,917	1,930	1,850	1,800
Lakeland Shores	72	171	291	355	350	320	320
Lake St. Croix Beach	1,111	1,176	1,078	1,140	1,150	1,150	1,150
Landfall	671	679	685	700	700	700	700
Mahtomedi	3,828	3,851	5,633	7,563	8,300	8,900	9,200
Marine on St. Croix	513	543	602	602	760	880	1,000
May Twp.	1,298	2,076	2,535	2,928	3,200	3,600	4,000
Newport	2,922	3,323	3,720	3,715	3,850	4,350	5,050
New Scandia Twp.	1,513	2,858	3,197	3,692	3,900	4,200	4,700
Oakdale	7,818	12,123	18,374	26,653	28,000	28,400	30,000
Oak Park Hgts.	1,256	2,591	3,486	3,777	4,900	5,400	5,700
Pine Springs	165	267	436	421	400	380	360
St. Mary's Point	319	348	339	344	370	380	390
St. Paul Park	5,587	4,864	4,965	5,070	5,800	6,400	7,100
Stillwater	10,208	12,290	13,882	15,323	17,200	18,300	19,200
Stillwater Twp.	979	1,599	2,066	2,553	2,800	3,700	4,500
West Lakeland Twp.	772	1,318	1,736	3,547	3,900	4,100	4,300
White Bear Lake (pt.)	23	10	336	351	630	690	710
Willernie	697	654	584	549	550	550	570
Woodbury	6,184	10,297	20,075	46,463	60,000	73,500	84,000
WASHINGTON COUNTY TOTAL	83,003	113,571	145,880	201,130	245,920	291,900	344,280

Appendix A-2 2030 Regional Development Framework Household Forecasts: Anoka County

ANOKA COUNTY
Metropolitan Council Household Forecasts

City or Township	1970	1980	1990	2000	2010	2020	2030
Andover	888	2,469	4,430	8,107	12,100	14,600	15,500
Anoka	3,894	5,382	6,394	7,262	7,900	8,500	9,000
Bethel	88	93	130	149	160	180	200
Blaine (pt.)	5,010	8,474	12,825	15,926	24,800	29,300	31,200
Burns Twp.	281	536	754	1,123	1,500	1,900	2,300
Centerville	147	214	519	1,077	1,340	1,600	1,850
Circle Pines	819	922	1,562	1,697	2,050	2,100	2,200
Columbia Hgts.	6,861	7,343	7,766	8,033	8,600	9,200	9,300
Columbus Twp.	487	870	1,129	1,328	1,450	1,600	1,750
Coon Rapids	6,777	10,336	17,449	22,578	25,000	26,500	27,000
East Bethel	706	1,955	2,542	3,607	4,400	5,000	5,500
Fridley	7,855	10,416	10,909	11,328	11,600	11,900	12,300
Ham Lake	865	2,226	2,720	4,139	5,700	6,800	7,200
Hilltop	465	453	410	400	400	400	400
Lexington	633	746	829	820	900	950	1,000
Lino Lakes	812	1,388	2,603	4,857	7,100	8,600	10,100
Linwood Twp.	299	833	1,146	1,578	1,850	2,100	2,300
Oak Grove	393	1,093	1,638	2,200	2,600	2,800	3,000
Ramsey	647	2,660	3,620	5,906	10,300	15,500	16,500
St. Francis	240	355	760	1,638	2,800	4,000	5,000
Spring Lake Park (pt.)	1,521	1,952	2,302	2,676	2,750	2,800	3,000
ANOKA COUNTY TOTAL	39,688	60,716	82,437	106,429	135,300	156,330	166,600

Appendix A-2 2030 Regional Development Framework Household Forecasts: Carver County

CARVER COUNTY
Metropolitan Council Household Forecasts

City or Township	1970	1980	1990	2000	2010	2020	2030
Benton Twp.	234	260	276	307	320	330	340
Camden Twp.	232	257	287	316	340	370	400
Carver	182	218	262	458	1,100	1,600	2,300
Chanhassen (pt.)	1,343	2,073	4,016	6,914	9,900	13,000	15,000
Chaska	1,299	3,006	4,212	6,104	9,000	9,500	10,000
Chaska Twp.	29	59	60	65	1,000	3,000	4,000
Cologne	174	202	216	385	700	1,000	1,300
Dahlgren Twp.	265	331	394	479	700	2,100	3,600
Hamburg	132	173	184	206	240	300	400
Hancock Twp.	100	108	110	121	140	160	170
Hollywood Twp.	266	314	327	371	410	450	500
Laketown Twp.	403	521	601	637	1,700	3,500	5,500
Mayer	106	142	166	199	600	1,000	1,400
New Germany	106	130	138	143	180	250	370
Norwood Young America	570	856	972	1,171	1,800	2,800	3,800
San Francisco Twp.	126	194	244	293	350	410	460
Victoria	215	427	756	1,367	2,400	3,000	3,300
Waconia	810	988	1,401	2,568	3,000	3,300	3,500
Waconia Twp.	345	408	407	429	500	800	1,100
Watertown	462	658	848	1,078	1,800	2,300	2,500
Watertown Twp.	326	412	439	478	550	800	1,200
Young America Twp.	212	274	285	267	300	350	450
CARVER COUNTY TOTAL	7,937	12,011	16,601	24,356	37,030	50,320	61,590

Appendix A-2 2030 Regional Development Framework Household Forecasts: Dakota County

DAKOTA COUNTY
Metropolitan Council Household Forecasts

City or Township	1970	1980	1990	2000	2010	2020	2030
Apple Valley	2,031	6,376	11,145	16,344	21,000	26,000	27,500
Burnsville	4,879	12,080	19,127	23,687	25,300	27,100	28,500
Castle Rock Twp.	290	395	460	514	550	600	650
Coates	61	65	66	64	70	80	90
Douglas Twp.	122	164	192	235	270	300	320
Eagan	2,607	6,824	17,427	23,773	26,500	28,000	29,000
Empire Twp.	271	360	426	515	700	1,600	1,800
Eureka Twp.	216	373	447	496	550	630	700
Farmington	1,054	1,511	2,064	4,169	7,500	10,500	12,500
Greenvale Twp.	151	187	228	227	260	300	340
Hampton	103	101	118	156	260	290	300
Hampton Twp.	126	223	260	320	360	400	450
Hastings (pt.)	3,108	4,197	5,401	6,640	8,800	11,000	12,500
Inver Grove Hgts.	2,845	5,551	7,803	11,257	14,000	17,000	18,000
Lakeville	1,883	4,337	7,851	13,609	20,200	28,000	33,500
Lilydale	124	222	297	338	480	490	490
Marshan Twp.	253	431	373	404	450	490	520
Mendota	87	80	69	80	90	100	120
Mendota Hgts.	1,641	2,210	3,302	4,178	4,600	4,800	5,000
Miesville	43	49	47	52	60	60	60
New Trier	32	31	29	31	30	30	30
Nininger Twp.	121	201	241	280	330	370	400
Northfield (pt.)	0	3	54	216	300	400	500
Randolph	96	110	111	117	160	210	260
Randolph Twp.	69	118	158	192	240	260	280
Ravenna Twp.	120	433	546	734	840	920	1,000
Rosemount	1,025	1,456	2,779	4,742	8,000	11,200	13,500
Sciota Twp.	56	75	86	92	130	160	190
South St. Paul	7,518	7,748	7,914	8,123	8,300	8,600	9,000
Sunfish Lake	76	107	138	173	190	200	210
Vermillion	81	123	157	160	200	240	300
Vermillion Twp.	171	281	354	395	430	500	550
Waterford Twp.	152	164	182	193	210	230	240
West St. Paul	6,148	7,501	8,441	8,645	8,900	9,300	9,600
DAKOTA COUNTY TOTAL	37,560	64,087	98,293	131,151	160,260	190,360	208,400

Appendix A-2 2030 Regional Development Framework Household Forecasts: Hennepin County

HENNEPIN COUNTY
Metropolitan Council Household Forecasts

City or Township	1970	1980	1990	2000	2010	2020	2030
Bloomington	21,824	28,660	34,488	36,400	37,700	39,200	40,000
Brooklyn Center	9,151	10,751	11,226	11,430	11,800	12,000	12,100
Brooklyn Park	7,343	15,268	20,386	24,432	28,400	32,000	35,000
Champlin	1,291	2,733	5,423	7,425	8,500	9,200	10,000
Chanhassen (pt.)	6	2	0	0	0	0	0
Corcoran	407	1,243	1,545	1,784	4,000	7,000	8,500
Crystal	8,296	8,977	9,272	9,389	9,700	10,100	10,500
Dayton (pt.)	691	1,161	1,359	1,546	2,000	6,500	11,000
Deephaven	1,062	1,223	1,324	1,373	1,450	1,450	1,450
Eden Prairie	1,653	5,383	14,447	20,457	23,500	25,500	26,500
Edina	13,005	17,961	19,860	20,996	21,600	22,000	22,500
Excelsior	900	1,149	1,160	1,199	1,250	1,330	1,400
Fort Snelling	105	17	7	0	0	0	0
Golden Valley	6,534	7,597	8,273	8,449	8,900	9,200	9,600
Greenfield	252	402	457	817	1,000	1,300	1,600
Greenwood	194	234	250	285	320	330	330
Hanover (pt.)	28	64	82	113	150	200	250
Hassan Twp.	215	452	585	778	1,000	4,000	7,000
Hopkins	4,667	7,061	7,973	8,358	8,500	8,800	9,000
Independence	533	789	925	1,088	1,380	1,600	1,800
Long Lake	422	586	747	756	900	1,000	1,100
Loretto	88	109	167	225	280	290	300
Maple Grove	1,503	6,239	12,531	17,532	24,500	30,000	34,000
Maple Plain	324	465	696	770	870	950	1,000
Medicine Lake	157	162	169	159	170	190	200
Medina	582	765	1,007	1,309	2,070	2,700	4,000
Minneapolis	161,141	161,858	160,682	162,352	172,000	181,000	187,000
Minnetonka	9,088	12,667	18,687	21,270	22,300	23,000	24,000
Minnetonka Beach	181	187	204	215	230	230	230
Minnetrista	731	974	1,195	1,505	2,100	3,000	4,000
Mound	2,355	3,384	3,710	3,982	4,350	4,600	4,800
New Hope	6,019	7,627	8,507	8,665	9,100	9,600	9,800
Orono	1,976	2,291	2,613	2,766	3,200	3,700	4,100
Osseo	807	1,015	995	1,035	1,090	1,160	1,400
Plymouth	4,645	10,491	18,361	24,820	29,000	31,500	33,500
Richfield	14,801	15,258	15,551	15,073	16,500	18,000	19,500
Robbinsdale	5,290	5,705	6,008	6,097	6,400	6,800	7,000
Rockford (pt.)	47	125	163	57	100	200	300
Rogers	134	210	259	1,195	2,300	2,700	3,000
St. Anthony (pt.)	1,887	1,935	2,208	2,402	2,600	2,800	3,000
St. Bonifacius	188	281	398	681	1,100	1,100	1,200
St. Louis Park	15,781	17,669	19,925	20,773	22,000	23,000	24,000
Shorewood	1,112	1,484	2,026	2,529	2,770	3,000	3,200
Spring Park	458	684	741	930	1,000	1,080	1,130
Tonka Bay	428	495	577	614	700	760	780
Wayzata	1,260	1,560	1,715	1,929	2,000	2,130	2,200
Woodland	157	183	176	173	180	200	200
HENNEPIN COUNTY TOTAL	309,719	365,536	419,060	456,133	500,960	546,400	583,470

Appendix A-2 2030 Regional Development Framework Household Forecasts: Ramsey County

RAMSEY COUNTY
Metropolitan Council Household Forecasts

City or Township	1970	1980	1990	2000	2010	2020	2030
Arden Hills	1,343	2,284	2,904	2,959	3,600	4,600	8,000
Blaine (pt.)	1	0	0	0	0	0	0
Falcon Hgts.	1,766	1,894	2,016	2,103	2,350	2,400	2,500
Gem Lake	92	118	140	139	160	170	190
Lauderdale	856	809	1,166	1,150	1,160	1,200	1,200
Little Canada	995	2,936	3,902	4,375	4,870	5,300	5,700
Maplewood	6,495	8,806	11,496	13,758	15,600	16,500	17,500
Mounds View	2,777	4,248	4,702	5,018	5,350	5,600	6,000
New Brighton	5,467	7,739	8,523	9,013	9,400	9,800	10,000
North Oaks	472	810	1,085	1,300	1,600	2,100	2,300
North St. Paul	3,189	3,980	4,447	4,703	4,900	5,400	6,000
Roseville	9,584	12,876	13,562	14,598	15,500	16,000	16,500
St. Anthony (pt.)	867	1,110	1,245	1,295	1,350	1,500	1,600
St. Paul	104,126	106,223	110,249	112,109	120,000	127,000	133,000
Shoreview	2,775	5,954	8,991	10,125	10,500	10,700	11,200
Spring Lake Park (pt.)	28	40	41	48	50	50	50
Vadnais Hgts.	868	1,760	3,924	5,064	5,600	6,100	7,400
White Bear Twp.	1,378	1,797	3,205	4,010	4,700	4,800	5,000
White Bear Lake (pt.)	5,851	7,121	8,902	9,469	10,200	11,000	11,500
RAMSEY COUNTY TOTAL	148,930	170,505	190,500	201,236	216,890	230,220	245,640

Appendix A-2 2030 Regional Development Framework Household Forecasts: Scott County

SCOTT COUNTY

Metropolitan Council Household Forecasts

City or Township	1970	1980	1990	2000	2010	2020	2030
Belle Plaine	714	942	1,092	1,396	2,500	3,300	4,400
Belle Plaine Twp.	189	202	211	266	340	400	500
Blakeley Twp.	140	149	140	166	190	220	250
Cedar Lake Twp.	223	396	523	719	1,000	1,200	1,400
Credit River Twp.	243	637	864	1,242	1,700	2,500	3,200
Elko	33	80	75	155	800	1,600	2,200
Helena Twp.	221	321	352	450	550	650	800
Jackson Twp.	448	466	459	461	520	1,500	4,000
Jordan	530	893	1,042	1,349	2,250	3,100	4,400
Louisville Twp.	115	232	278	410	470	520	600
New Market	70	99	82	131	1,000	2,000	2,800
New Market Twp.	282	441	627	956	1,400	1,900	2,600
New Prague (pt.)	558	677	870	1,160	1,800	2,500	3,000
Prior Lake	1,070	2,313	3,901	5,645	10,500	12,000	12,500
St. Lawrence Twp.	92	101	122	144	200	280	500
Sand Creek Twp.	242	371	412	478	600	750	900
Savage	828	1,234	3,255	6,807	11,000	14,500	16,000
Shakopee	2,109	3,226	4,163	7,540	15,000	19,500	21,500
Spring Lake Twp.	379	721	899	1,217	2,000	3,500	5,700
SCOTT COUNTY TOTAL	8,486	13,501	19,367	30,692	53,820	71,920	87,250

Appendix A-2 2030 Regional Development Framework Household Forecasts: Washington County

WASHINGTON COUNTY
Metropolitan Council Household Forecasts

City or Township	1970	1980	1990	2000	2010	2020	2030
Afton	521	776	890	996	1,100	1,200	1,250
Bayport	655	677	743	763	840	1,000	1,500
Baytown Twp.	184	237	302	492	630	800	1,200
Birchwood	235	326	364	357	360	360	360
Cottage Grove	2,853	5,127	6,856	9,932	13,000	16,500	20,000
Dellwood	147	223	301	353	380	390	400
Denmark Twp.	231	318	367	481	650	820	990
Forest Lake	1,770	3,311	4,424	5,433	7,000	9,000	12,000
Grant	438	831	1,173	1,374	1,580	1,740	1,830
Grey Cloud Twp.	98	112	165	117	1,800	2,500	2,500
Hastings (pt.)	2	4	2	2	0	0	0
Hugo	654	1,082	1,416	2,125	4,300	7,000	10,000
Lake Elmo	918	1,687	1,973	2,347	3,500	6,000	9,500
Lakeland	273	550	645	691	720	730	730
Lakeland Shores	27	65	101	116	120	120	120
Lake St. Croix Beach	325	397	415	462	480	500	510
Landfall	261	310	300	292	300	300	300
Mahtomedi	1,016	1,239	1,874	2,503	3,000	3,400	3,550
Marine on St. Croix	170	201	234	254	320	370	430
May Twp.	348	611	820	1,007	1,200	1,400	1,600
Newport	830	1,153	1,323	1,418	1,550	1,800	2,200
New Scandia Twp.	408	851	1,060	1,294	1,500	1,700	1,900
Oakdale	1,982	4,004	6,699	10,243	11,300	12,000	13,000
Oak Park Hgts.	372	868	1,322	1,528	2,000	2,300	2,500
Pine Springs	41	77	135	140	140	140	140
St. Mary's Point	88	114	126	132	150	160	170
St. Paul Park	1,390	1,511	1,749	1,829	2,200	2,500	2,900
Stillwater	3,035	4,065	4,982	5,797	6,900	7,700	8,300
Stillwater Twp.	245	448	639	833	1,000	1,400	1,700
West Lakeland Twp.	180	355	524	1,101	1,300	1,450	1,550
White Bear Lake (pt.)	8	3	168	149	270	300	300
Willernie	181	236	227	225	230	240	250
Woodbury	1,428	3,232	6,927	16,676	23,500	30,500	35,000
WASHINGTON COUNTY TOTAL	21,314	35,001	49,246	71,462	93,320	116,320	138,680

APPENDIX B: SUMMARY OF 2003 MONITORING DATA

Alkalinity (mg/l as CaCo3)

Site	N	Mean	Min	Max
Bevens Creek	31	290	138	369
Bluff Creek	15	272	118	324
Browns Creek	26	156	68	203
Carver Creek	insuff. data	insuff. data	insuff. data	Insuff. data
Credit River	22	238	117	338
Elm Creek	n/a	n/a	n/a	n/a
Nine Mile Creek	17	200	119	310
Rice Creek	n/a	n/a	n/a	n/a
Sand Creek	33	249	141	363
Valley Creek	20	196	118	225
Vermillion River	17	212	157	241

Total COD (mg/l)

Site	N	Mean	Min	Max
Bevens Creek	31	42	6	101
Bluff Creek	15	27	5	84
Browns Creek	26	64	6	227
Carver Creek	insuff. data	insuff. data	insuff. data	Insuff. data
Credit River	22	27	6	79
Elm Creek	n/a	n/a	n/a	n/a
Nine Mile Creek	17	34	10	203
Rice Creek	n/a	n/a	n/a	n/a
Sand Creek	33	62	9	131
Valley Creek	20	21	3	138
Vermillion River	17	24	5	65

Chloride (mg/l)

Site	N	Mean	Min	Max
Bevens Creek	31	35	22	61
Bluff Creek	15	69	51	133
Browns Creek	26	18	10	28
Carver Creek	insuff. data	insuff. data	insuff. data	insuff. data
Credit River	22	45	29	67
Elm Creek	n/a	n/a	n/a	n/a
Nine Mile Creek	17	156	71	554
Rice Creek	n/a	n/a	n/a	n/a
Sand Creek	32	64	22	243
Valley Creek	19	19	16	28
Vermillion River	17	74	36	114

Chlorophyll-a (ug/l)

Site	N	Mean	Min	Max
Bevens Creek	8	3.9	1.0	10.0
Bluff Creek	3	8.8	1.5	22.0
Browns Creek	insuff. data	insuff. data	insuff. data	insuff. data
Carver Creek	insuff. data	insuff. data	insuff. data	insuff. data
Credit River	7	82.4	73.0	90.0
Elm Creek	n/a	n/a	n/a	n/a
Nine Mile Creek	4	79.3	5.2	170.0
Rice Creek	n/a	n/a	n/a	n/a
Sand Creek	8	20.0	3.3	120.0
Valley Creek	2	3.4	1.0	5.7
Vermillion River	insuff. data	insuff. data	insuff. data	insuff. data

Total ammonium (mg/l as N)

Site	N	Mean	Min	Max
Bevens Creek	30	0.09	0.02	0.83
Bluff Creek	15	0.11	0.02	0.96
Browns Creek	26	0.08	0.02	0.75
Carver Creek	insuff. data	insuff. data	insuff. data	insuff. data
Credit River	22	0.11	0.02	1.53
Elm Creek	n/a	n/a	n/a	n/a
Nine Mile Creek	17	0.15	0.02	0.98
Rice Creek	n/a	n/a	n/a	n/a
Sand Creek	33	0.11	0.02	1.19
Valley Creek	20	0.08	0.02	0.83
Vermillion River	16	0.05	0.02	0.20

Total Kjeldahl nitrogen (mg/l as N)

Site	N	Mean	Min	Max
Bevens Creek	31	1.5	0.1	3.5
Bluff Creek	15	0.8	0.1	3.7
Browns Creek	26	1.7	0.1	6.6
Carver Creek	insuff. data	insuff. data	insuff. data	insuff. data
Credit River	22	0.9	0.1	4.4
Elm Creek	n/a	n/a	n/a	n/a
Nine Mile Creek	17	1.0	0.2	4.7
Rice Creek	n/a	n/a	n/a	n/a
Sand Creek	33	2.3	0.4	6.0
Valley Creek	19	0.7	0.0	5.4
Vermillion River	17	1.0	0.5	2.5

Total nitrate (mg/l as N)

Site	N	Mean	Min	Max
Bevens Creek	30	6.2	0.3	15.9
Bluff Creek	15	0.7	0.2	1.6
Browns Creek	26	0.8	0.1	1.5
Carver Creek	insuff. data	insuff. data	insuff. data	insuff. data
Credit River	22	0.9	0.4	1.6
Elm Creek	15	0.4	0.0	1.5
Nine Mile Creek	17	0.6	0.2	1.1
Rice Creek	n/a	n/a	n/a	n/a
Sand Creek	33	3.0	0.1	8.5
Valley Creek	20	3.8	2.7	4.9
Vermillion River	17	6.5	2.6	11.1

Total nitrite (mg/l as N)

Site	N	Mean	Min	Max
Bevens Creek	30	0.05	0.03	0.23
Bluff Creek	15	0.03	0.03	0.07
Browns Creek	26	0.03	0.03	0.07
Carver Creek	insuff. data	insuff. data	insuff. data	insuff. data
Credit River	22	0.03	0.03	0.08
Elm Creek	n/a	n/a	n/a	n/a
Nine Mile Creek	17	0.04	0.03	0.09
Rice Creek	n/a	n/a	n/a	n/a
Sand Creek	33	0.05	0.03	0.25
Valley Creek	20	0.04	0.03	0.12
Vermillion River	17	0.05	0.03	0.08

Dissolved orthophosphorus (ug/l as P)

Site	N	Mean	Min	Max
Bevens Creek	28	0.17	0.01	0.71
Bluff Creek	14	0.07	0.01	0.44
Browns Creek	13	0.04	0.02	0.09
Carver Creek	insuff. data	insuff. data	insuff. data	insuff. data
Credit River	22	0.06	0.01	0.43
Elm Creek	n/a	n/a	n/a	n/a
Nine Mile Creek	16	0.02	0.01	0.14
Rice Creek	7	0.03	0.01	0.05
Sand Creek	32	0.18	0.01	0.66
Valley Creek	12	0.01	0.01	0.01
Vermillion River	10	0.61	0.18	0.98

Total phosphorus (ug/l as P)

Site	N	Mean	Min	Max
Bevens Creek	31	0.33	0.01	1.00
Bluff Creek	15	0.17	0.01	0.87
Browns Creek	17	0.17	0.03	0.90
Carver Creek	insuff. data	insuff. data	insuff. data	insuff. data
Credit River	22	0.17	0.02	0.75
Elm Creek	15	0.19	0.04	0.51
Nine Mile Creek	17	0.12	0.01	0.83
Rice Creek	7	0.24	0.12	0.58
Sand Creek	33	0.51	0.08	1.14
Valley Creek	18	0.13	0.02	0.95
Vermillion River	17	0.68	0.27	0.96

Total dissolved phosphorus (ug/l as P)

Site	N	Mean	Min	Max
Bevens Creek	31	0.20	0.01	0.82
Bluff Creek	15	0.09	0.01	0.53
Browns Creek	26	0.06	0.01	0.12
Carver Creek	insuff. data	Insuff. data	insuff. data	insuff. data
Credit River	23	0.08	0.01	0.53
Elm Creek	n/a	n/a	n/a	n/a
Nine Mile Creek	18	0.12	0.01	1.25
Rice Creek	n/a	n/a	n/a	n/a
Sand Creek	32	0.20	0.03	0.60
Valley Creek	20	0.06	0.01	0.58
Vermillion River	15	0.70	0.17	1.49

Total suspended solids (mg/l)

Site	N	Mean	Min	Max
Bevens Creek	30	150	1	820
Bluff Creek	15	197	1	2430
Browns Creek	18	37	4	207
Carver Creek	insuff. data	Insuff. data	insuff. data	insuff. data
Credit River	23	52	1	634
Elm Creek	15	18	5	128
Nine Mile Creek	18	25	1	304
Rice Creek	7	182	19	972
Sand Creek	30	479	1	4380
Valley Creek	20	50	4	448
Vermillion River	17	25	2	94

Total volatile suspended solids (mg/l)

Site	N	Mean	Min	Max
Bevens Creek	30	15	1	76
Bluff Creek	15	9	1	82
Browns Creek	19	11	2	53
Carver Creek	insuff. data	insuff. data	insuff. data	insuff. data
Credit River	23	7	1	46
Elm Creek	13	5	5	5
Nine Mile Creek	18	10	1	96
Rice Creek	7	37	12	131
Sand Creek	30	41	1	180
Valley Creek	20	10	1	74
Vermillion River	17	8	1	25

Sulfate (mg/l)

Site	N	Mean	Min	Max
Bevens Creek	29	55	27	97
Bluff Creek	15	25	16	36
Browns Creek	26	8	2	14
Carver Creek	insuff. data	insuff. data	insuff. data	insuff. data
Credit River	23	17	6	27
Elm Creek	n/a	n/a	n/a	n/a
Nine Mile Creek	18	18	6	28
Rice Creek	n/a	n/a	n/a	n/a
Sand Creek	31	43	14	90
Valley Creek	20	16	11	25
Vermillion River	16	30	20	37

Total organic carbon (mg/l)

Site	N	Mean	Min	Max
Bevens Creek	31	9	3	20
Bluff Creek	15	7	2	19
Browns Creek	25	5	1	12
Carver Creek	insuff. data	insuff. data	insuff. data	insuff. data
Credit River	22	7	2	22
Elm Creek	n/a	n/a	n/a	n/a
Nine Mile Creek	16	7	2	21
Rice Creek	n/a	n/a	n/a	n/a
Sand Creek	33	11	4	17
Valley Creek	20	3	1	17
Vermillion River	16	4	2	12

Turbidity (ntu)

Site	N	Mean	Min	Max
Bevens Creek	31	28	1	160
Bluff Creek	15	15	1	140
Browns Creek	19	7	3	20
Carver Creek	insuff. data	insuff. data	insuff. data	insuff. data
Credit River	22	8	1	60
Elm Creek	n/a	n/a	n/a	n/a
Nine Mile Creek	16	10	1	100
Rice Creek	n/a	n/a	n/a	n/a
Sand Creek	33	38	2	170
Valley Creek	20	7	1	38
Vermillion River	17	6	1	17

APPENDIX C: SUMMARY OF FLUX CALCULATIONS AND RESULTS

Bevens Creek

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
be2	Nitrate	1989						21.93		
be2	Nitrate	1990	29	792,949	9.46	16.24	783,776,070	34.13	2.58	7.5%
be2	Nitrate	1991	25	2,047,601	24.42	17.80	1,846,607,070	35.53	6.07	17.1%
be2	Nitrate	1992	31	1,232,045	14.70	5.85	3,382,980,480	37.33	11.12	29.8%
be2	Nitrate	1993	34	2,245,239	26.78	5.77	6,247,468,920	36.3	20.53	56.6%
be2	Nitrate	1994	51	946,056	11.28	5.47	2,777,661,150	35.3	9.13	25.9%
be2	Nitrate	1995	43	888,865	10.60	5.59	2,553,725,130	31.8	8.39	26.4%
be2	Nitrate	1996	27	466,497	5.56	5.46	1,371,334,470	32.47	4.51	13.9%
be2	Nitrate	1997	30	1,836,479	21.90	7.73	3,815,210,190	28.25	12.54	44.4%
be2	Nitrate	1998	21	1,219,438	14.54	7.51	2,607,431,640	39.31	8.57	21.8%
be2	Nitrate	1999	33	783,893	9.35	6.80	1,849,396,560	34.64	6.08	17.5%
be2	Nitrate	2000	14	45,373	0.54	2.62	277,713,150	23.77	0.91	3.8%
be2	Nitrate	2001	34	1,821,936	21.73	11.53	2,536,635,090	28.37	8.33	29.4%
be2	Nitrate	2002	32	2,017,349	24.06	10.48	3,089,695,620	42.29	10.15	24.0%
be2	Nitrate	2003	31	599,707	7.15	8.14	1,182,178,800	17.74	3.88	21.9%
be2	TDP	1989						21.93		
be2	TDP	1990	27	27,998	0.33	0.57	783,776,070	34.13	2.58	7.5%
be2	TDP	1991	22	66,087	0.79	0.57	1,846,607,070	35.53	6.07	17.1%
be2	TDP	1992	32	68,379	0.82	0.32	3,382,980,480	37.33	11.12	29.8%
be2	TDP	1993	31	133,761	1.60	0.34	6,247,468,920	36.3	20.53	56.6%
be2	TDP	1994	46	50,440	0.60	0.29	2,777,661,150	35.3	9.13	25.9%
be2	TDP	1995	40	48,410	0.58	0.30	2,553,725,130	31.8	8.39	26.4%
be2	TDP	1996	21	26,099	0.31	0.31	1,371,334,470	32.47	4.51	13.9%
be2	TDP	1997	28	71,194	0.85	0.30	3,815,210,190	28.25	12.54	44.4%
be2	TDP	1998	22	47,038	0.56	0.29	2,607,431,640	39.31	8.57	21.8%
be2	TDP	1999	32	31,555	0.38	0.27	1,849,396,560	34.64	6.08	17.5%
be2	TDP	2000	12	3,822	0.05	0.22	277,713,150	23.77	0.91	3.8%
be2	TDP	2001	28	57,399	0.68	0.36	2,536,635,090	28.37	8.33	29.4%
be2	TDP	2002	31	66,072	0.79	0.34	3,089,695,620	42.29	10.15	24.0%
be2	TDP	2003	30	21,993	0.26	0.30	1,182,178,800	17.74	3.88	21.9%

Bevens Creek (continued)

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
be2	TP	1989						21.93		
be2	TP	1990	29	39,438	0.47	0.81	783,776,070	34.13	2.58	7.5%
be2	TP	1991	26	102,745	1.23	0.89	1,846,607,070	35.53	6.07	17.1%
be2	TP	1992	32	160,625	1.92	0.76	3,382,980,480	37.33	11.12	29.8%
be2	TP	1993	34	323,795	3.86	0.83	6,247,468,920	36.3	20.53	56.6%
be2	TP	1994	51	111,052	1.32	0.64	2,777,661,150	35.3	9.13	25.9%
be2	TP	1995	45	109,223	1.30	0.69	2,553,725,130	31.8	8.39	26.4%
be2	TP	1996	29	58,153	0.69	0.68	1,371,334,470	32.47	4.51	13.9%
be2	TP	1997	37	159,440	1.90	0.67	3,815,210,190	28.25	12.54	44.4%
be2	TP	1998	31	102,680	1.22	0.63	2,607,431,640	39.31	8.57	21.8%
be2	TP	1999	35	64,799	0.77	0.56	1,849,396,560	34.64	6.08	17.5%
be2	TP	2000	14	4,892	0.06	0.28	277,713,150	23.77	0.91	3.8%
be2	TP	2001	35	109,343	1.30	0.69	2,536,635,090	28.37	8.33	29.4%
be2	TP	2002	34	118,034	1.41	0.61	3,089,695,620	42.29	10.15	24.0%
be2	TP	2003	32	33,935	0.40	0.46	1,182,178,800	17.74	3.88	21.9%
be2	TSS	1989						21.93		
be2	TSS	1990	27	8,480,795	101.15	173.67	783,776,070	34.13	2.58	7.5%
be2	TSS	1991	24	24,109,734	287.57	209.55	1,846,607,070	35.53	6.07	17.1%
be2	TSS	1992	31	52,331,444	624.18	248.28	3,382,980,480	37.33	11.12	29.8%
be2	TSS	1993	32	132,009,328	1574.54	339.14	6,247,468,920	36.3	20.53	56.6%
be2	TSS	1994	51	33,029,414	393.96	190.85	2,777,661,150	35.3	9.13	25.9%
be2	TSS	1995	45	33,629,596	401.12	211.36	2,553,725,130	31.8	8.39	26.4%
be2	TSS	1996	28	16,789,791	200.26	196.50	1,371,334,470	32.47	4.51	13.9%
be2	TSS	1997	37	69,757,974	832.04	293.46	3,815,210,190	28.25	12.54	44.4%
be2	TSS	1998	32	42,990,662	512.77	264.63	2,607,431,640	39.31	8.57	21.8%
be2	TSS	1999	35	25,152,644	300.01	218.29	1,849,396,560	34.64	6.08	17.5%
be2	TSS	2000	14	365,720	4.36	21.14	277,713,150	23.77	0.91	3.8%
be2	TSS	2001	35	61,207,718	730.05	387.28	2,536,635,090	28.37	8.33	29.4%
be2	TSS	2002	34	57,675,266	687.92	299.60	3,089,695,620	42.29	10.15	24.0%
be2	TSS	2003	32	10,713,054	127.78	145.45	1,182,178,800	17.74	3.88	21.9%

Bluff Creek

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
bl	Nitrate	1989						22.87		
bl	Nitrate	1990						30.53		
bl	Nitrate	1991	9	12,261	2.13	0.98	200,172,390	36.26	9.57	26.4%
bl	Nitrate	1992	8	12,160	2.11	0.92	212,389,650	26.16	10.16	38.8%
bl	Nitrate	1993	19	12,649	2.20	0.92	220,051,920	35.47	10.52	29.7%
bl	Nitrate	1994	21	12,335	2.14	0.92	216,026,580	28.73	10.33	36.0%
bl	Nitrate	1995	21	7,427	1.29	0.88	135,413,850	30.65	6.48	21.1%
bl	Nitrate	1996	13	5,491	0.95	0.88	100,386,330	25.55	4.80	18.8%
bl	Nitrate	1997	21	13,524	2.35	0.95	228,067,290	24.62	10.91	44.3%
bl	Nitrate	1998	13	13,251	2.30	0.95	223,688,850	28.47	10.70	37.6%
bl	Nitrate	1999	13	7,184	1.25	0.87	132,059,400	23.09	6.32	27.4%
bl	Nitrate	2000	9	3,575	0.62	0.84	68,713,260	21.91	3.29	15.0%
bl	Nitrate	2001						27.99		
bl	Nitrate	2002	31	6,322	1.10	0.75	135,201,990	36.18	6.47	17.9%
bl	Nitrate	2003	16	4,214	0.73	0.75	89,652,090	19.87	4.29	21.6%
bl	TDP	1989						22.87		
bl	TDP	1990						30.53		
bl	TDP	1991	9	2,006	0.35	0.16	200,172,390	36.26	9.57	26.4%
bl	TDP	1992	7	1,514	0.26	0.11	212,389,650	26.16	10.16	38.8%
bl	TDP	1993	19	1,570	0.27	0.11	220,051,920	35.47	10.52	29.7%
bl	TDP	1994	18	1,469	0.25	0.11	216,026,580	28.73	10.33	36.0%
bl	TDP	1995	21	768	0.13	0.09	135,413,850	30.65	6.48	21.1%
bl	TDP	1996	10	567	0.10	0.09	100,386,330	25.55	4.80	18.8%
bl	TDP	1997	21	1,937	0.34	0.14	228,067,290	24.62	10.91	44.3%
bl	TDP	1998	13	1,889	0.33	0.14	223,688,850	28.47	10.70	37.6%
bl	TDP	1999	10	711	0.12	0.09	132,059,400	23.09	6.32	27.4%
bl	TDP	2000	7	280	0.05	0.07	68,713,260	21.91	3.29	15.0%
bl	TDP	2001						27.99		
bl	TDP	2002	29	1,496	0.26	0.18	135,201,990	36.18	6.47	17.9%
bl	TDP	2003	16	908	0.16	0.16	89,652,090	19.87	4.29	21.6%

Bluff Creek (continued)

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
bl	TP	1989						22.87		
bl	TP	1990						30.53		
bl	TP	1991	9	10,492	1.82	0.84	200,172,390	36.26	9.57	26.4%
bl	TP	1992	7	7,440	1.29	0.56	212,389,650	26.16	10.16	38.8%
bl	TP	1993	19	7,174	1.25	0.54	220,051,920	35.47	10.52	29.7%
bl	TP	1994	21	5,786	1.00	0.43	216,026,580	28.73	10.33	36.0%
bl	TP	1995	22	3,414	0.59	0.40	135,413,850	30.65	6.48	21.1%
bl	TP	1996	13	2,352	0.41	0.38	100,386,330	25.55	4.80	18.8%
bl	TP	1997	24	9,294	1.61	0.65	228,067,290	24.62	10.91	44.3%
bl	TP	1998	18	8,418	1.46	0.60	223,688,850	28.47	10.70	37.6%
bl	TP	1999	14	3,001	0.52	0.36	132,059,400	23.09	6.32	27.4%
bl	TP	2000	11	1,245	0.22	0.29	68,713,260	21.91	3.29	15.0%
bl	TP	2001						27.99		
bl	TP	2002	32	3,810	0.66	0.45	135,201,990	36.18	6.47	17.9%
bl	TP	2003	16	1,947	0.34	0.35	89,652,090	19.87	4.29	21.6%
bl	TSS	1989						22.87		
bl	TSS	1990						30.53		
bl	TSS	1991	11	7,407,578	1286.04	593.90	200,172,390	36.26	9.57	26.4%
bl	TSS	1992	7	4,601,225	798.82	347.73	212,389,650	26.16	10.16	38.8%
bl	TSS	1993	18	4,058,380	704.58	295.99	220,051,920	35.47	10.52	29.7%
bl	TSS	1994	21	3,314,868	575.50	246.29	216,026,580	28.73	10.33	36.0%
bl	TSS	1995	21	1,869,681	324.60	221.61	135,413,850	30.65	6.48	21.1%
bl	TSS	1996	13	1,409,874	244.77	225.38	100,386,330	25.55	4.80	18.8%
bl	TSS	1997	22	6,166,233	1070.53	433.95	228,067,290	24.62	10.91	44.3%
bl	TSS	1998	18	6,406,569	1112.25	459.66	223,688,850	28.47	10.70	37.6%
bl	TSS	1999	13	1,391,625	241.60	169.14	132,059,400	23.09	6.32	27.4%
bl	TSS	2000	11	730,197	126.77	170.58	68,713,260	21.91	3.29	15.0%
bl	TSS	2001						27.99		
bl	TSS	2002	29	3,209,826	557.26	381.04	135,201,990	36.18	6.47	17.9%
bl	TSS	2003	16	1,444,797	250.83	258.70	89,652,090	19.87	4.29	21.6%

Browns Creek

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
br	Nitrate	1989						27.33		
br	Nitrate	1990						35.27		
br	Nitrate	1991						42.03		
br	Nitrate	1992						32.62		
br	Nitrate	1993						36.74		
br	Nitrate	1994						35.1		
br	Nitrate	1995						31.66		
br	Nitrate	1996						29.44		
br	Nitrate	1997						29.19		
br	Nitrate	1998						37.15		
br	Nitrate	1999						33.37		
br	Nitrate	2000	12	20,863	0.96	0.79	424,920,540	34.99	5.38	15.4%
br	Nitrate	2001	28	21,836	1.00	0.71	493,775,040	37.01	6.25	16.9%
br	Nitrate	2002	20	25,880	1.19	0.70	592,042,770	40.58	7.50	18.5%
br	Nitrate	2003	26	18,110	0.83	0.80	363,269,280	24.17	4.60	19.0%
br	TDP	1989						27.33		
br	TDP	1990						35.27		
br	TDP	1991						42.03		
br	TDP	1992						32.62		
br	TDP	1993						36.74		
br	TDP	1994						35.1		
br	TDP	1995						31.66		
br	TDP	1996						29.44		
br	TDP	1997						29.19		
br	TDP	1998	7	1,226	0.06	0.05	360,409,170	37.15	4.56	
br	TDP	1999	22	1,579	0.07	0.06	427,992,510	33.37	5.42	
br	TDP	2000	22	1,588	0.07	0.06	424,920,540	34.99	5.38	15.4%
br	TDP	2001	18	2,027	0.09	0.07	493,775,040	37.01	6.25	16.9%
br	TDP	2002	20	2,442	0.11	0.07	592,042,770	40.58	7.50	18.5%
br	TDP	2003	26	1,327	0.06	0.06	363,269,280	24.17	4.60	19.0%

Browns Creek (continued)

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
br	TP	1989						27.33		
br	TP	1990						35.27		
br	TP	1991						42.03		
br	TP	1992						32.62		
br	TP	1993						36.74		
br	TP	1994						35.1		
br	TP	1995						31.66		
br	TP	1996						29.44		
br	TP	1997						29.19		
br	TP	1998	7	4,188	0.19	0.19	360,409,170	37.15	4.56	
br	TP	1999	17	5,551	0.26	0.21	427,992,510	33.37	5.42	
br	TP	2000	24	6,114	0.28	0.23	424,920,540	34.99	5.38	15.4%
br	TP	2001	28	7,508	0.35	0.24	493,775,040	37.01	6.25	16.9%
br	TP	2002	20	9,049	0.42	0.25	592,042,770	40.58	7.50	18.5%
br	TP	2003	25	4,470	0.21	0.20	363,269,280	24.17	4.60	19.0%
Br	TSS	1989						27.33		
Br	TSS	1990						35.27		
Br	TSS	1991						42.03		
Br	TSS	1992						32.62		
Br	TSS	1993						36.74		
Br	TSS	1994						35.1		
Br	TSS	1995						31.66		
Br	TSS	1996						29.44		
Br	TSS	1997						29.19		
Br	TSS	1998	7	1,120,650	51.50	49.91	360,409,170	37.15	4.56	
Br	TSS	1999	19	2,241,912	103.03	84.07	427,992,510	33.37	5.42	
Br	TSS	2000	25	2,327,417	106.96	87.91	424,920,540	34.99	5.38	15.4%
Br	TSS	2001	27	3,962,757	182.11	128.81	493,775,040	37.01	6.25	16.9%
Br	TSS	2002	20	4,850,976	222.93	131.51	592,042,770	40.58	7.50	18.5%
Br	TSS	2003	25	1,776,295	81.63	78.48	363,269,280	24.17	4.60	19.0%

Carver Creek

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
Ca	Nitrate	1989	7	34,670	0.65	2.24	248,158,680	22.87	1.29	5.6%
Ca	Nitrate	1990	28	88,655	1.67	2.76	515,526,000	30.53	2.67	8.8%
ca	Nitrate	1991	23	231,285	4.35	3.01	1,235,179,110	36.26	6.41	17.7%
ca	Nitrate	1992	24	115,707	2.18	1.59	1,168,796,310	26.16	6.06	23.2%
ca	Nitrate	1993						35.47		
ca	Nitrate	1994	39	127,431	2.40	1.50	1,361,977,320	28.73	7.06	24.6%
ca	Nitrate	1995	35	124,955	2.35	1.49	1,348,100,490	30.65	6.99	22.8%
ca	Nitrate	1996	19	95,311	1.79	1.52	1,005,522,870	25.55	5.21	20.4%
ca	Nitrate	1997	29	201,367	3.79	2.20	1,466,883,330	24.62	7.61	30.9%
ca	Nitrate	1998	18	167,987	3.16	2.20	1,226,775,330	28.47	6.36	22.3%
ca	Nitrate	1999	24	138,341	2.60	2.20	1,010,360,340	23.09	5.24	22.7%
ca	Nitrate	2000	12	27,377	0.52	2.21	199,254,330	21.91	1.03	4.7%
ca	Nitrate	2001	33	263,998	4.97	3.42	1,239,592,860	27.99	6.43	23.0%
ca	Nitrate	2002	31	310,283	5.84	3.00	1,662,359,490	36.18	8.62	23.8%
ca	Nitrate	2003						19.87		
ca	TDP	1989						22.87		5.6%
ca	TDP	1990	24	14,091	0.27	0.44	515,526,000	30.53	2.67	8.8%
ca	TDP	1991	20	36,471	0.69	0.47	1,235,179,110	36.26	6.41	17.7%
ca	TDP	1992	23	16,748	0.32	0.23	1,168,796,310	26.16	6.06	23.2%
ca	TDP	1993						35.47		
ca	TDP	1994	35	17,087	0.32	0.20	1,361,977,320	28.73	7.06	24.6%
ca	TDP	1995	33	16,808	0.32	0.20	1,348,100,490	30.65	6.99	22.8%
ca	TDP	1996	16	13,201	0.25	0.21	1,005,522,870	25.55	5.21	20.4%
ca	TDP	1997	27	18,546	0.35	0.20	1,466,883,330	24.62	7.61	30.9%
ca	TDP	1998	22	14,093	0.27	0.18	1,226,775,330	28.47	6.36	22.3%
ca	TDP	1999	21	11,822	0.22	0.19	1,010,360,340	23.09	5.24	22.7%
ca	TDP	2000	10	1,474	0.03	0.12	199,254,330	21.91	1.03	4.7%
ca	TDP	2001	32	19,736	0.37	0.26	1,239,592,860	27.99	6.43	23.0%
ca	TDP	2002	32	24,383	0.46	0.24	1,662,359,490	36.18	8.62	23.8%
ca	TDP	2003						19.87		

Carver Creek (continued)

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
ca	TP	1989	9	13,458	0.25	0.87	248,158,680	22.87	1.29	5.6%
ca	TP	1990	28	27,216	0.51	0.85	515,526,000	30.53	2.67	8.8%
ca	TP	1991	26	53,476	1.01	0.69	1,235,179,110	36.26	6.41	17.7%
ca	TP	1992	25	63,350	1.19	0.87	1,168,796,310	26.16	6.06	23.2%
ca	TP	1993						35.47		
ca	TP	1994	39	85,705	1.61	1.01	1,361,977,320	28.73	7.06	24.6%
ca	TP	1995	38	76,818	1.45	0.91	1,348,100,490	30.65	6.99	22.8%
ca	TP	1996	22	54,908	1.03	0.88	1,005,522,870	25.55	5.21	20.4%
ca	TP	1997	31	82,674	1.56	0.90	1,466,883,330	24.62	7.61	30.9%
ca	TP	1998	26	55,211	1.04	0.72	1,226,775,330	28.47	6.36	22.3%
ca	TP	1999	26	46,932	0.88	0.75	1,010,360,340	23.09	5.24	22.7%
ca	TP	2000	12	3,715	0.07	0.30	199,254,330	21.91	1.03	4.7%
ca	TP	2001	32	50,917	0.96	0.66	1,239,592,860	27.99	6.43	23.0%
ca	TP	2002	32	60,529	1.14	0.58	1,662,359,490	36.18	8.62	23.8%
ca	TP	2003						19.87		
Ca	TSS	1989	8	3,348,774	63.04	216.57	248,158,680	22.87	1.29	5.6%
Ca	TSS	1990	28	9,082,515	170.98	282.77	515,526,000	30.53	2.67	8.8%
Ca	TSS	1991	27	24,858,130	467.96	323.01	1,235,179,110	36.26	6.41	17.7%
Ca	TSS	1992	26	18,261,580	343.78	250.77	1,168,796,310	26.16	6.06	23.2%
Ca	TSS	1993						35.47		
Ca	TSS	1994	39	24,953,940	469.77	294.06	1,361,977,320	28.73	7.06	24.6%
Ca	TSS	1995	39	21,940,653	413.04	261.22	1,348,100,490	30.65	6.99	22.8%
Ca	TSS	1996	22	15,655,200	294.71	249.89	1,005,522,870	25.55	5.21	20.4%
Ca	TSS	1997	31	29,610,394	557.42	323.98	1,466,883,330	24.62	7.61	30.9%
Ca	TSS	1998	26	23,580,744	443.91	308.51	1,226,775,330	28.47	6.36	22.3%
Ca	TSS	1999	26	19,985,368	376.23	317.47	1,010,360,340	23.09	5.24	22.7%
Ca	TSS	2000	12	535,124	10.07	43.11	199,254,330	21.91	1.03	4.7%
Ca	TSS	2001	32	23,672,066	445.63	306.50	1,239,592,860	27.99	6.43	23.0%
Ca	TSS	2002	30	26,334,902	495.76	254.26	1,662,359,490	36.18	8.62	23.8%
Ca	TSS	2003						19.87		

Credit River

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
Cr	Nitrate	1989	14	15,396	0.47	1.09	227,184,540	26.22	1.92	7.3%
Cr	Nitrate	1990	27	14,994	0.46	0.62	385,479,270	37	3.25	8.8%
cr	Nitrate	1991	19	18,026	0.55	0.61	476,049,420	43.4	4.02	9.3%
cr	Nitrate	1992	21	39,178	1.20	0.70	900,405,000	31.04	7.60	24.5%
cr	Nitrate	1993	32	58,063	1.78	0.70	1,327,973,790	37.45	11.21	29.9%
cr	Nitrate	1994	33	27,842	0.85	0.62	725,373,330	39.05	6.12	15.7%
cr	Nitrate	1995	26	26,571	0.81	0.62	689,463,060	32.52	5.82	17.9%
cr	Nitrate	1996	22	21,907	0.67	0.63	558,533,580	28.37	4.71	16.6%
cr	Nitrate	1997	28	49,359	1.51	0.79	1,004,993,220	34.73	8.48	24.4%
cr	Nitrate	1998	18	33,290	1.02	0.79	680,494,320	35.75	5.74	16.1%
cr	Nitrate	1999	20	47,887	1.47	0.80	966,081,600	33.42	8.15	24.4%
cr	Nitrate	2000						28.82		
cr	Nitrate	2001	36	59,087	1.81	1.33	712,520,490	34.69	6.01	17.3%
cr	Nitrate	2002						45.29		
cr	Nitrate	2003	25	44,352	1.36	1.21	588,264,600	29.35	4.96	16.9%
cr	TDP	1989						26.22		7.3%
cr	TDP	1990	24	4,819	0.15	0.20	385,479,270	37	3.25	8.8%
cr	TDP	1991	17	3,959	0.12	0.13	476,049,420	43.4	4.02	9.3%
cr	TDP	1992	21	5,566	0.17	0.10	900,405,000	31.04	7.60	24.5%
cr	TDP	1993	29	9,286	0.28	0.11	1,327,973,790	37.45	11.21	29.9%
cr	TDP	1994	31	4,095	0.13	0.09	725,373,330	39.05	6.12	15.7%
cr	TDP	1995	23	3,604	0.11	0.08	689,463,060	32.52	5.82	17.9%
cr	TDP	1996	16	2,775	0.09	0.08	558,533,580	28.37	4.71	16.6%
cr	TDP	1997	26	6,803	0.21	0.11	1,004,993,220	34.73	8.48	24.4%
cr	TDP	1998	18	4,437	0.14	0.10	680,494,320	35.75	5.74	16.1%
cr	TDP	1999	18	6,764	0.21	0.11	966,081,600	33.42	8.15	24.4%
cr	TDP	2000						28.82		
cr	TDP	2001	31	5,096	0.16	0.11	712,520,490	34.69	6.01	17.3%
cr	TDP	2002						45.29		
cr	TDP	2003	25	3,827	0.12	0.10	588,264,600	29.35	4.96	16.9%

Credit River (continued)

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
cr	TP	1989	15	6,769	0.21	0.48	227,184,540	26.22	1.92	7.3%
cr	TP	1990	27	13,153	0.40	0.55	385,479,270	37	3.25	8.8%
cr	TP	1991	20	16,918	0.52	0.57	476,049,420	43.4	4.02	9.3%
cr	TP	1992	22	13,595	0.42	0.24	900,405,000	31.04	7.60	24.5%
cr	TP	1993	33	23,077	0.71	0.28	1,327,973,790	37.45	11.21	29.9%
cr	TP	1994	32	9,859	0.30	0.22	725,373,330	39.05	6.12	15.7%
cr	TP	1995	25	8,573	0.26	0.20	689,463,060	32.52	5.82	17.9%
cr	TP	1996	23	6,754	0.21	0.19	558,533,580	28.37	4.71	16.6%
cr	TP	1997	32	18,515	0.57	0.30	1,004,993,220	34.73	8.48	24.4%
cr	TP	1998	21	11,953	0.37	0.28	680,494,320	35.75	5.74	16.1%
cr	TP	1999	21	18,188	0.56	0.30	966,081,600	33.42	8.15	24.4%
cr	TP	2000						28.82		
cr	TP	2001	35	11,480	0.35	0.26	712,520,490	34.69	6.01	17.3%
cr	TP	2002						45.29		
cr	TP	2003	24	8,789	0.27	0.24	588,264,600	29.35	4.96	16.9%
cr	TSS	1989	14	2,246,763	68.83	158.72	227,184,540	26.22	1.92	7.3%
cr	TSS	1990	28	4,700,421	144.01	195.71	385,479,270	37	3.25	8.8%
cr	TSS	1991	20	6,089,939	186.58	205.32	476,049,420	43.4	4.02	9.3%
cr	TSS	1992	22	4,075,632	124.87	72.65	900,405,000	31.04	7.60	24.5%
cr	TSS	1993	33	7,273,781	222.85	87.91	1,327,973,790	37.45	11.21	29.9%
cr	TSS	1994	33	2,118,066	64.89	46.87	725,373,330	39.05	6.12	15.7%
cr	TSS	1995	27	2,049,534	62.79	47.71	689,463,060	32.52	5.82	17.9%
cr	TSS	1996	23	1,693,320	51.88	48.66	558,533,580	28.37	4.71	16.6%
cr	TSS	1997	33	6,418,876	196.66	102.51	1,004,993,220	34.73	8.48	24.4%
cr	TSS	1998	21	4,103,266	125.71	96.78	680,494,320	35.75	5.74	16.1%
cr	TSS	1999	19	6,133,224	187.91	101.89	966,081,600	33.42	8.15	24.4%
cr	TSS	2000						28.82		
cr	TSS	2001	37	4,609,955	141.24	103.84	712,520,490	34.69	6.01	17.3%
cr	TSS	2002						45.29		
cr	TSS	2003	23	3,127,648	95.82	85.34	588,264,600	29.35	4.96	16.9%

Elm Creek

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
elm	Nitrate	1989						25.85		4.0%
elm	Nitrate	1990						31.79		10.0%
elm	Nitrate	1991						48		18.7%
elm	Nitrate	1992						28.1		17.7%
elm	Nitrate	1993						37.02		25.7%
elm	Nitrate	1994						32.73		16.3%
elm	Nitrate	1995	13	14,051	0.21	0.15	1,530,406,020	30.02	6.21	20.7%
elm	Nitrate	1996	15	11,108	0.16	0.14	1,307,246,820	24	5.31	22.1%
elm	Nitrate	1997	11	29,651	0.44	0.40	1,182,390,660	20.89	4.80	23.0%
elm	Nitrate	1998	19	21,813	0.32	0.46	761,989,800	25.5	3.09	12.1%
elm	Nitrate	1999	17	30,706	0.45	0.38	1,300,996,950	29.72	5.28	17.8%
elm	Nitrate	2000	15	10,511	0.15	0.47	356,772,240	20.57	1.45	7.0%
elm	Nitrate	2001	17	121,939	1.80	1.08	1,813,592,220	31.36	7.36	23.5%
elm	Nitrate	2002	19	118,343	1.74	0.62	3,043,298,280	40.15	12.36	30.8%
elm	Nitrate	2003	15	54,131	0.80	0.61	1,422,428,040	26.85	5.78	21.5%
Elm	TP	1989	12	4,441	0.07	0.28	256,562,460	25.85	1.04	4.0%
Elm	TP	1990	8	14,823	0.22	0.30	783,458,280	31.79	3.18	10.0%
Elm	TP	1991	13	44,819	0.66	0.33	2,206,310,040	48	8.96	18.7%
Elm	TP	1992	17	11,559	0.17	0.15	1,225,610,100	28.1	4.98	17.7%
Elm	TP	1993	15	19,054	0.28	0.13	2,343,489,390	37.02	9.52	25.7%
Elm	TP	1994	12	11,868	0.17	0.15	1,310,212,860	32.73	5.32	16.3%
Elm	TP	1995	13	13,667	0.20	0.14	1,530,406,020	30.02	6.21	20.7%
Elm	TP	1996	15	11,212	0.17	0.14	1,307,246,820	24	5.31	22.1%
Elm	TP	1997	11	21,937	0.32	0.30	1,182,390,660	20.89	4.80	23.0%
Elm	TP	1998	19	14,137	0.21	0.30	761,989,800	25.5	3.09	12.1%
Elm	TP	1999	17	24,138	0.36	0.30	1,300,996,950	29.72	5.28	17.8%
Elm	TP	2000	15	6,619	0.10	0.30	356,772,240	20.57	1.45	7.0%
Elm	TP	2001	17	122,258	1.80	1.08	1,813,592,220	31.36	7.36	23.5%
Elm	TP	2002	19	45,708	0.67	0.24	3,043,298,280	40.15	12.36	30.8%
Elm	TP	2003	15	21,003	0.31	0.24	1,422,428,040	26.85	5.78	21.5%

Elm Creek (continued)

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
Elm	TSS	1989	12	719,950	10.61	45.04	256,562,460	25.85	1.04	4.0%
Elm	TSS	1990	7	2,315,280	34.13	47.43	783,458,280	31.79	3.18	10.0%
elm	TSS	1991	13	6,645,716	97.96	48.34	2,206,310,040	48	8.96	18.7%
elm	TSS	1992	17	2,785,812	41.06	36.48	1,225,610,100	28.1	4.98	17.7%
elm	TSS	1993	14	5,198,325	76.63	35.60	2,343,489,390	37.02	9.52	25.7%
elm	TSS	1994	12	2,954,695	43.55	36.20	1,310,212,860	32.73	5.32	16.3%
elm	TSS	1995	13	3,449,393	50.85	36.18	1,530,406,020	30.02	6.21	20.7%
elm	TSS	1996	14	2,921,879	43.07	35.87	1,307,246,820	24	5.31	22.1%
elm	TSS	1997	10	1,983,257	29.23	26.92	1,182,390,660	20.89	4.80	23.0%
elm	TSS	1998	19	1,341,934	19.78	28.26	761,989,800	25.5	3.09	12.1%
elm	TSS	1999	17	2,110,637	31.11	26.04	1,300,996,950	29.72	5.28	17.8%
elm	TSS	2000	14	680,638	10.03	30.62	356,772,240	20.57	1.45	7.0%
elm	TSS	2001	15	3,813,311	56.21	33.75	1,813,592,220	31.36	7.36	23.5%
elm	TSS	2002	19	7,496,227	110.50	39.53	3,043,298,280	40.15	12.36	30.8%
elm	TSS	2003	15	3,503,936	51.65	39.54	1,422,428,040	26.85	5.78	21.5%

Nine Mile Creek

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
nm	Nitrate	1989						26.22		
nm	Nitrate	1990	30	14,447	0.59	0.42	558,109,860	37	6.32	17.1%
nm	Nitrate	1991	16	16,794	0.69	0.38	704,434,500	43.4	7.98	18.4%
nm	Nitrate	1992	22	15,536	0.64	0.38	650,975,160	31.04	7.37	23.8%
nm	Nitrate	1993	30	18,257	0.75	0.36	804,785,520	37.45	9.12	24.3%
nm	Nitrate	1994	34	16,936	0.70	0.40	686,285,160	39.05	7.77	19.9%
nm	Nitrate	1995	31	16,270	0.67	0.41	630,565,980	32.52	7.14	22.0%
nm	Nitrate	1996	25	16,101	0.66	0.44	592,678,350	28.37	6.71	23.7%
nm	Nitrate	1997	28	34,132	1.40	0.34	1,620,764,310	34.73	18.36	52.9%
nm	Nitrate	1998	25	34,083	1.40	0.37	1,495,413,810	35.75	16.94	47.4%
nm	Nitrate	1999						33.42		
nm	Nitrate	2000	27	22,332	0.92	0.40	903,794,760	28.82	10.24	35.5%
nm	Nitrate	2001	31	30,384	1.25	0.51	950,686,440	34.69	10.77	31.0%
nm	Nitrate	2002	43	41,276	1.70	0.49	1,348,912,620	45.29	15.28	33.7%
nm	Nitrate	2003	28	17,911	0.74	0.50	575,588,310	29.35	6.52	22.2%
nm	TDP	1989						26.22		
nm	TDP	1990	31	2,464	0.10	0.07	558,109,860	37	6.32	17.1%
nm	TDP	1991	11	2,909	0.12	0.07	704,434,500	43.4	7.98	18.4%
nm	TDP	1992	21	2,855	0.12	0.07	650,975,160	31.04	7.37	23.8%
nm	TDP	1993	30	3,405	0.14	0.07	804,785,520	37.45	9.12	24.3%
nm	TDP	1994	29	2,825	0.12	0.07	686,285,160	39.05	7.77	19.9%
nm	TDP	1995	27	2,621	0.11	0.07	630,565,980	32.52	7.14	22.0%
nm	TDP	1996	22	2,496	0.10	0.07	592,678,350	28.37	6.71	23.7%
nm	TDP	1997	20	4,372	0.18	0.04	1,620,764,310	34.73	18.36	52.9%
nm	TDP	1998	23	3,982	0.16	0.04	1,495,413,810	35.75	16.94	47.4%
nm	TDP	1999						33.42		
nm	TDP	2000	25	2,291	0.09	0.04	903,794,760	28.82	10.24	35.5%
nm	TDP	2001	30	2,868	0.12	0.05	950,686,440	34.69	10.77	31.0%
nm	TDP	2002	35	4,033	0.17	0.05	1,348,912,620	45.29	15.28	33.7%
nm	TDP	2003	26	1,653	0.07	0.05	575,588,310	29.35	6.52	22.2%

Nine Mile Creek (continued)

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
nm	TP	1989						26.22		
nm	TP	1990	33	10,473	0.43	0.30	558,109,860	37	6.32	17.1%
nm	TP	1991	19	12,802	0.53	0.29	704,434,500	43.4	7.98	18.4%
nm	TP	1992	23	13,036	0.54	0.32	650,975,160	31.04	7.37	23.8%
nm	TP	1993	30	16,098	0.66	0.32	804,785,520	37.45	9.12	24.3%
nm	TP	1994	36	11,689	0.48	0.27	686,285,160	39.05	7.77	19.9%
nm	TP	1995	30	10,232	0.42	0.26	630,565,980	32.52	7.14	22.0%
nm	TP	1996	30	9,297	0.38	0.25	592,678,350	28.37	6.71	23.7%
nm	TP	1997	31	22,630	0.93	0.22	1,620,764,310	34.73	18.36	52.9%
nm	TP	1998	30	19,398	0.80	0.21	1,495,413,810	35.75	16.94	47.4%
nm	TP	1999						33.42		
nm	TP	2000	27	9,937	0.41	0.18	903,794,760	28.82	10.24	35.5%
nm	TP	2001	31	11,977	0.49	0.20	950,686,440	34.69	10.77	31.0%
nm	TP	2002	43	19,452	0.80	0.23	1,348,912,620	45.29	15.28	33.7%
nm	TP	2003	29	7,892	0.32	0.22	575,588,310	29.35	6.52	22.2%
nm	TSS	1989						26.22		
nm	TSS	1990	32	7,212,106	296.55	207.40	558,109,860	37	6.32	17.1%
nm	TSS	1991	18	8,240,008	338.82	187.74	704,434,500	43.4	7.98	18.4%
nm	TSS	1992	23	9,359,788	384.86	230.77	650,975,160	31.04	7.37	23.8%
nm	TSS	1993	29	11,518,877	473.64	229.73	804,785,520	37.45	9.12	24.3%
nm	TSS	1994	36	6,700,056	275.50	156.69	686,285,160	39.05	7.77	19.9%
nm	TSS	1995	29	5,485,216	225.54	139.62	630,565,980	32.52	7.14	22.0%
nm	TSS	1996	30	4,742,769	195.02	128.44	592,678,350	28.37	6.71	23.7%
nm	TSS	1997	32	11,871,292	488.13	117.56	1,620,764,310	34.73	18.36	52.9%
nm	TSS	1998	30	9,413,650	387.07	101.04	1,495,413,810	35.75	16.94	47.4%
nm	TSS	1999						33.42		
nm	TSS	2000	27	3,960,755	162.86	70.34	903,794,760	28.82	10.24	35.5%
nm	TSS	2001	29	4,102,787	168.70	69.26	950,686,440	34.69	10.77	31.0%
nm	TSS	2002	33	6,884,029	283.06	81.91	1,348,912,620	45.29	15.28	33.7%
nm	TSS	2003	27	2,711,533	111.49	75.61	575,588,310	29.35	6.52	22.2%

Rice Creek

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
rice	TP	1989						22.31		
Rice	TP	1990						34.55		
rice	TP	1991						48.17		
rice	TP	1992						36.73		
rice	TP	1993						43.23		
rice	TP	1994						29.44		
rice	TP	1995	5	58,962	0.50	0.25	3,720,296,910	39.12	8.70	22.2%
rice	TP	1996	13	28,967	0.25	0.20	2,332,366,740	32.07	5.46	17.0%
rice	TP	1997	13	70,988	0.60	0.42	2,695,812,570	33.12	6.31	19.0%
rice	TP	1998	12	42,479	0.36	0.41	1,667,726,610	31.06	3.90	12.6%
rice	TP	1999	12	11,572	0.10	0.11	1,764,334,770	30.19	4.13	13.7%
rice	TP	2000	12	10,153	0.09	0.11	1,451,241,000	32.17	3.39	10.6%
rice	TP	2001	18	33,904	0.29	0.17	3,119,497,260	35.36	7.30	20.6%
rice	TP	2002	15	45,054	0.38	0.17	4,292,742,630	41.77	10.04	24.0%
rice	TP	2003	7	30,590	0.26	0.18	2,689,633,320	27.7	6.29	22.7%
rice	TSS	1989						22.31		
rice	TSS	1990						34.55		
rice	TSS	1991						48.17		
rice	TSS	1992						36.73		
rice	TSS	1993						43.23		
rice	TSS	1994						29.44		
rice	TSS	1995	6	16,226,635	137.79	70.00	3,720,296,910	39.12	8.70	22.2%
rice	TSS	1996	13	10,758,843	91.36	74.04	2,332,366,740	32.07	5.46	17.0%
rice	TSS	1997	13	43,721,612	371.28	260.30	2,695,812,570	33.12	6.31	19.0%
rice	TSS	1998	11	25,672,218	218.00	247.07	1,667,726,610	31.06	3.90	12.6%
rice	TSS	1999	13	2,568,337	21.81	23.36	1,764,334,770	30.19	4.13	13.7%
rice	TSS	2000	12	2,406,221	20.43	26.61	1,451,241,000	32.17	3.39	10.6%
rice	TSS	2001	17	8,603,654	73.06	44.27	3,119,497,260	35.36	7.30	20.6%
rice	TSS	2002	15	11,834,328	100.50	44.25	4,292,742,630	41.77	10.04	24.0%
rice	TSS	2003	6	7,418,264	62.99	44.27	2,689,633,320	27.7	6.29	22.7%

Sand Creek

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
sa	Nitrate	1989						21.93		
sa	Nitrate	1990	27	1,958,220	12.00	6.60	4,764,272,370	34.13	8.04	23.6%
sa	Nitrate	1991	19	1,136,576	6.96	6.19	2,947,961,280	35.53	4.98	14.0%
sa	Nitrate	1992	32	2,660,658	16.30	5.60	7,631,373,750	37.33	12.88	34.6%
sa	Nitrate	1993	38	1,669,810	10.23	2.91	9,220,464,990	36.3	15.56	42.9%
sa	Nitrate	1994	37	735,737	4.51	2.72	4,336,915,440	35.3	7.32	20.7%
sa	Nitrate	1995	47	719,194	4.41	2.74	4,205,209,140	31.8	7.10	22.3%
sa	Nitrate	1996	26	616,238	3.78	2.74	3,612,318,930	32.47	6.10	18.8%
sa	Nitrate	1997	30	1,197,662	7.34	3.07	6,261,522,300	28.25	10.57	37.4%
sa	Nitrate	1998	29	1,599,095	9.80	3.95	6,505,726,260	39.31	10.98	27.9%
sa	Nitrate	1999	31	909,689	5.57	3.84	3,805,040,910	34.64	6.42	18.5%
sa	Nitrate	2000	25	505,058	3.09	3.98	2,034,385,650	23.77	3.43	14.4%
sa	Nitrate	2001	32	1,735,449	10.63	6.02	4,624,232,910	28.37	7.81	27.5%
sa	Nitrate	2002	44	1,628,046	9.98	5.25	4,975,955,820	42.29	8.40	19.9%
sa	Nitrate	2003	33	744,121	4.56	4.87	2,450,196,210	17.74	4.14	23.3%
sa	TDP	1989						21.93		
sa	TDP	1990	27	96,852	0.59	0.33	4,764,272,370	34.13	8.04	23.6%
sa	TDP	1991	17	61,348	0.38	0.33	2,947,961,280	35.53	4.98	14.0%
sa	TDP	1992	32	161,975	0.99	0.34	7,631,373,750	37.33	12.88	34.6%
sa	TDP	1993	35	122,043	0.75	0.21	9,220,464,990	36.3	15.56	42.9%
sa	TDP	1994	34	51,685	0.32	0.19	4,336,915,440	35.3	7.32	20.7%
sa	TDP	1995	43	49,965	0.31	0.19	4,205,209,140	31.8	7.10	22.3%
sa	TDP	1996	22	43,044	0.26	0.19	3,612,318,930	32.47	6.10	18.8%
sa	TDP	1997	28	83,694	0.51	0.21	6,265,582,950	28.25	10.58	37.4%
sa	TDP	1998	28	90,340	0.55	0.22	6,506,962,110	39.31	10.98	27.9%
sa	TDP	1999	30	48,041	0.29	0.20	3,805,076,220	34.64	6.42	18.5%
sa	TDP	2000	25	24,917	0.15	0.20	2,034,385,650	23.77	3.43	14.4%
sa	TDP	2001	30	66,365	0.41	0.23	4,624,232,910	28.37	7.81	27.5%
sa	TDP	2002	46	65,318	0.40	0.21	4,975,955,820	42.29	8.40	19.9%
sa	TDP	2003	32	30,881	0.19	0.20	2,450,160,900	17.74	4.14	23.3%

Sand Creek (continued)

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
sa	TP	1989						21.93		
sa	TP	1990	83	231,738	1.42	0.78	4,764,272,370	34.13	8.04	23.6%
sa	TP	1991	83	137,867	0.84	0.75	2,947,961,280	35.53	4.98	14.0%
sa	TP	1992	83	371,936	2.28	0.78	7,641,119,310	37.33	12.90	34.6%
sa	TP	1993	38	374,812	2.30	0.65	9,220,464,990	36.3	15.56	42.9%
sa	TP	1994	37	155,232	0.95	0.57	4,336,915,440	35.3	7.32	20.7%
sa	TP	1995	52	151,027	0.93	0.58	4,205,209,140	31.8	7.10	22.3%
sa	TP	1996	29	129,784	0.80	0.58	3,612,318,930	32.47	6.10	18.8%
sa	TP	1997	38	250,115	1.53	0.64	6,265,582,950	28.25	10.58	37.4%
sa	TP	1998	38	292,053	1.79	0.72	6,506,962,110	39.31	10.98	27.9%
sa	TP	1999	35	133,025	0.82	0.56	3,805,076,220	34.64	6.42	18.5%
sa	TP	2000	25	67,315	0.41	0.53	2,034,385,650	23.77	3.43	14.4%
sa	TP	2001	31	167,370	1.03	0.58	4,624,232,910	28.37	7.81	27.5%
sa	TP	2002	49	161,699	0.99	0.52	4,975,955,820	42.29	8.40	19.9%
sa	TP	2003	33	74,272	0.46	0.49	2,450,196,210	17.74	4.14	23.3%
sa	TSS	1989						21.93		
sa	TSS	1990	28	67,433,828	413.20	227.17	4,764,272,370	34.13	8.04	23.6%
sa	TSS	1991	22	41,764,404	255.91	227.38	2,947,961,280	35.53	4.98	14.0%
sa	TSS	1992	34	147,355,648	902.91	309.91	7,631,373,750	37.33	12.88	34.6%
sa	TSS	1993	36	222,970,440	1366.24	388.12	9,220,464,990	36.3	15.56	42.9%
sa	TSS	1994	36	76,290,038	467.46	282.33	4,336,915,440	35.3	7.32	20.7%
sa	TSS	1995	51	75,772,796	464.29	289.20	4,205,209,140	31.8	7.10	22.3%
sa	TSS	1996	30	65,079,828	398.77	289.16	3,612,318,930	32.47	6.10	18.8%
sa	TSS	1997	38	127,056,116	778.53	325.47	6,265,582,950	28.25	10.58	37.4%
sa	TSS	1998	41	164,931,646	1010.61	406.82	6,506,962,110	39.31	10.98	27.9%
sa	TSS	1999	35	56,636,954	347.04	238.90	3,805,076,220	34.64	6.42	18.5%
sa	TSS	2000	24	24,514,908	150.21	193.41	2,034,385,650	23.77	3.43	14.4%
sa	TSS	2001	32	143,851,708	881.44	499.29	4,624,232,910	28.37	7.81	27.5%
sa	TSS	2002	47	115,071,682	705.10	371.16	4,975,955,820	42.29	8.40	19.9%
sa	TSS	2003	31	47,461,370	290.82	310.90	2,450,196,210	17.74	4.14	23.3%

Valley Creek

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
va	Nitrate	1989						27.33		
va	Nitrate	1990						35.27		
va	Nitrate	1991						42.03		
va	Nitrate	1992						32.62		
va	Nitrate	1993						36.74		
va	Nitrate	1994						35.1		
va	Nitrate	1995						31.66		
va	Nitrate	1996						29.44		
va	Nitrate	1997						30.02		
va	Nitrate	1998						34.1		
va	Nitrate	1999	25	123,716	3.12	3.99	497,588,520	30.82	3.45	11.2%
va	Nitrate	2000	26	135,202	3.41	3.99	544,268,340	32.64	3.78	11.6%
va	Nitrate	2001	28	153,022	3.86	3.99	615,170,820	33.22	4.27	12.9%
va	Nitrate	2002	34	165,096	4.16	3.99	664,604,820	40.16	4.61	11.5%
va	Nitrate	2003	20	162,590	4.10	3.98	655,318,290	28.59	4.55	15.9%
va	TDP	1989						27.33		
va	TDP	1990						35.27		
va	TDP	1991						42.03		
va	TDP	1992						32.62		
va	TDP	1993						36.74		
va	TDP	1994						35.1		
va	TDP	1995						31.66		
va	TDP	1996						29.44		
va	TDP	1997						30.02		
va	TDP	1998						34.1		
va	TDP	1999	19	797	0.02	0.03	497,588,520	30.82	3.45	11.2%
va	TDP	2000	21	841	0.02	0.02	544,268,340	32.64	3.78	11.6%
va	TDP	2001	25	895	0.02	0.02	615,170,820	33.22	4.27	12.9%
va	TDP	2002	32	999	0.03	0.02	664,604,820	40.16	4.61	11.5%
va	TDP	2003	20	1,012	0.03	0.02	655,318,290	28.59	4.55	15.9%

Valley Creek (continued)

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
va	TP	1989						27.33		
va	TP	1990						35.27		
va	TP	1991						42.03		
va	TP	1992						32.62		
va	TP	1993						36.74		
va	TP	1994						35.1		
va	TP	1995						31.66		
va	TP	1996						29.44		
va	TP	1997						30.02		
va	TP	1998						34.1		
va	TP	1999	26	2,784	0.07	0.09	497,588,520	30.82	3.45	11.2%
va	TP	2000	22	2,424	0.06	0.07	544,268,340	32.64	3.78	11.6%
va	TP	2001	27	2,405	0.06	0.06	615,170,820	33.22	4.27	12.9%
va	TP	2002	35	2,706	0.07	0.07	664,604,820	40.16	4.61	11.5%
va	TP	2003	18	2,687	0.07	0.07	655,318,290	28.59	4.55	15.9%
va	TSS	1989						27.33		
va	TSS	1990						35.27		
va	TSS	1991						42.03		
va	TSS	1992						32.62		
va	TSS	1993						36.74		
va	TSS	1994						35.1		
va	TSS	1995						31.66		
va	TSS	1996						29.44		
va	TSS	1997						30.02		
va	TSS	1998						34.1		
va	TSS	1999	24	374,893	9.45	12.09	497,588,520	30.82	3.45	11.2%
va	TSS	2000	21	486,983	12.27	14.36	544,268,340	32.64	3.78	11.6%
va	TSS	2001	22	455,149	11.47	11.88	615,170,820	33.22	4.27	12.9%
va	TSS	2002	31	603,476	15.21	14.57	664,604,820	40.16	4.61	11.5%
va	TSS	2003	20	689,254	17.37	16.88	655,318,290	28.59	4.55	15.9%

Vermillion River

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
vr	Nitrate	1989						24.65		
vr	Nitrate	1990						34.66		
vr	Nitrate	1991						35.34		
vr	Nitrate	1992						30.84		
vr	Nitrate	1993						34.11		
vr	Nitrate	1994						32.63		
vr	Nitrate	1995						29.98		15.5%
vr	Nitrate	1996						27.11		13.9%
vr	Nitrate	1997						36.69		19.5%
vr	Nitrate	1998	8	1,551,623	7.41	3.81	6,541,777,770	35.98	8.61	23.9%
vr	Nitrate	1999	25	1,100,482	5.26	3.86	4,580,342,580	29.83	6.03	20.2%
vr	Nitrate	2000	19	913,815	4.37	5.38	2,727,415,020	30.55	3.59	11.8%
vr	Nitrate	2001	20	1,400,797	6.69	5.26	4,270,603,260	31.28	5.62	18.0%
vr	Nitrate	2002	29	2,993,393	14.30	5.38	8,935,477,980	42.09	11.76	27.9%
vr	Nitrate	2003	17	1,997,072	9.54	5.33	6,010,609,440	26.23	7.91	30.2%
vr	TDP	1989						24.65		
vr	TDP	1990						34.66		
vr	TDP	1991						35.34		
vr	TDP	1992						30.84		
vr	TDP	1993						34.11		
vr	TDP	1994						32.63		
vr	TDP	1995	9	84,209	0.40	0.38	3,535,449,060	29.98	4.65	15.5%
vr	TDP	1996	12	71,155	0.34	0.40	2,863,040,730	27.11	3.77	13.9%
vr	TDP	1997	12	90,401	0.43	0.27	5,445,861,300	36.69	7.17	19.5%
vr	TDP	1998	12	99,692	0.48	0.24	6,541,777,770	35.98	8.61	23.9%
vr	TDP	1999	24	70,754	0.34	0.25	4,580,342,580	29.83	6.03	20.2%
vr	TDP	2000	15	106,552	0.51	0.63	2,727,415,020	30.55	3.59	11.8%
vr	TDP	2001	15	140,426	0.67	0.53	4,270,603,260	31.28	5.62	18.0%
vr	TDP	2002	29	245,580	1.17	0.44	8,935,477,980	42.09	11.76	27.9%
vr	TDP	2003						26.23		30.2%

Vermillion River (continued)

Site	Parameter	Year	Samples Used	Annual Stream Load (lbs)	Load/watershed area (lbs/acre)	Annual FWM Conc (ppm)	Annual Stream Volume (ft3)	Annual precip (in)	Watershed Yield (stream vol./ watershed area) (in)	Runoff Coeff. (stream vol./ annual precip) (%)
vr	TP	1989						24.65		
vr	TP	1990						34.66		
vr	TP	1991						35.34		
vr	TP	1992						30.84		
vr	TP	1993						34.11		
vr	TP	1994						32.63		
vr	TP	1995	9	139,732	0.67	0.63	3,535,449,060	29.98	4.65	15.5%
vr	TP	1996	12	128,628	0.61	0.72	2,863,040,730	27.11	3.77	13.9%
vr	TP	1997	12	121,510	0.58	0.36	5,445,861,300	36.69	7.17	19.5%
vr	TP	1998	14	145,212	0.69	0.36	6,541,777,770	35.98	8.61	23.9%
vr	TP	1999	28	103,411	0.49	0.36	4,580,342,580	29.83	6.03	20.2%
vr	TP	2000	18	127,209	0.61	0.75	2,727,415,020	30.55	3.59	11.8%
vr	TP	2001	20	182,576	0.87	0.69	4,270,603,260	31.28	5.62	18.0%
vr	TP	2002	29	342,751	1.64	0.62	8,935,477,980	42.09	11.76	27.9%
vr	TP	2003	17	254,089	1.21	0.68	6,010,609,440	26.23	7.91	30.2%
vr	TSS	1989						24.65		
vr	TSS	1990						34.66		
vr	TSS	1991						35.34		
vr	TSS	1992						30.84		
vr	TSS	1993						34.11		
vr	TSS	1994						32.63		
vr	TSS	1995	9	18,707,601	89.39	84.93	3,535,449,060	29.98	4.65	15.5%
vr	TSS	1996	12	15,149,585	72.39	84.93	2,863,040,730	27.11	3.77	13.9%
vr	TSS	1997	12	12,196,037	58.28	35.94	5,445,861,300	36.69	7.17	19.5%
vr	TSS	1998	12	16,723,502	79.91	41.03	6,541,777,770	35.98	8.61	23.9%
vr	TSS	1999	28	11,302,546	54.01	39.61	4,580,342,580	29.83	6.03	20.2%
vr	TSS	2000	19	5,617,229	26.84	33.06	2,727,415,020	30.55	3.59	11.8%
vr	TSS	2001	20	9,303,114	44.45	34.96	4,270,603,260	31.28	5.62	18.0%
vr	TSS	2002	29	15,890,321	75.93	28.54	8,935,477,980	42.09	11.76	27.9%
vr	TSS	2003	17	13,263,023	63.37	35.42	6,010,609,440	26.23	7.91	30.2%