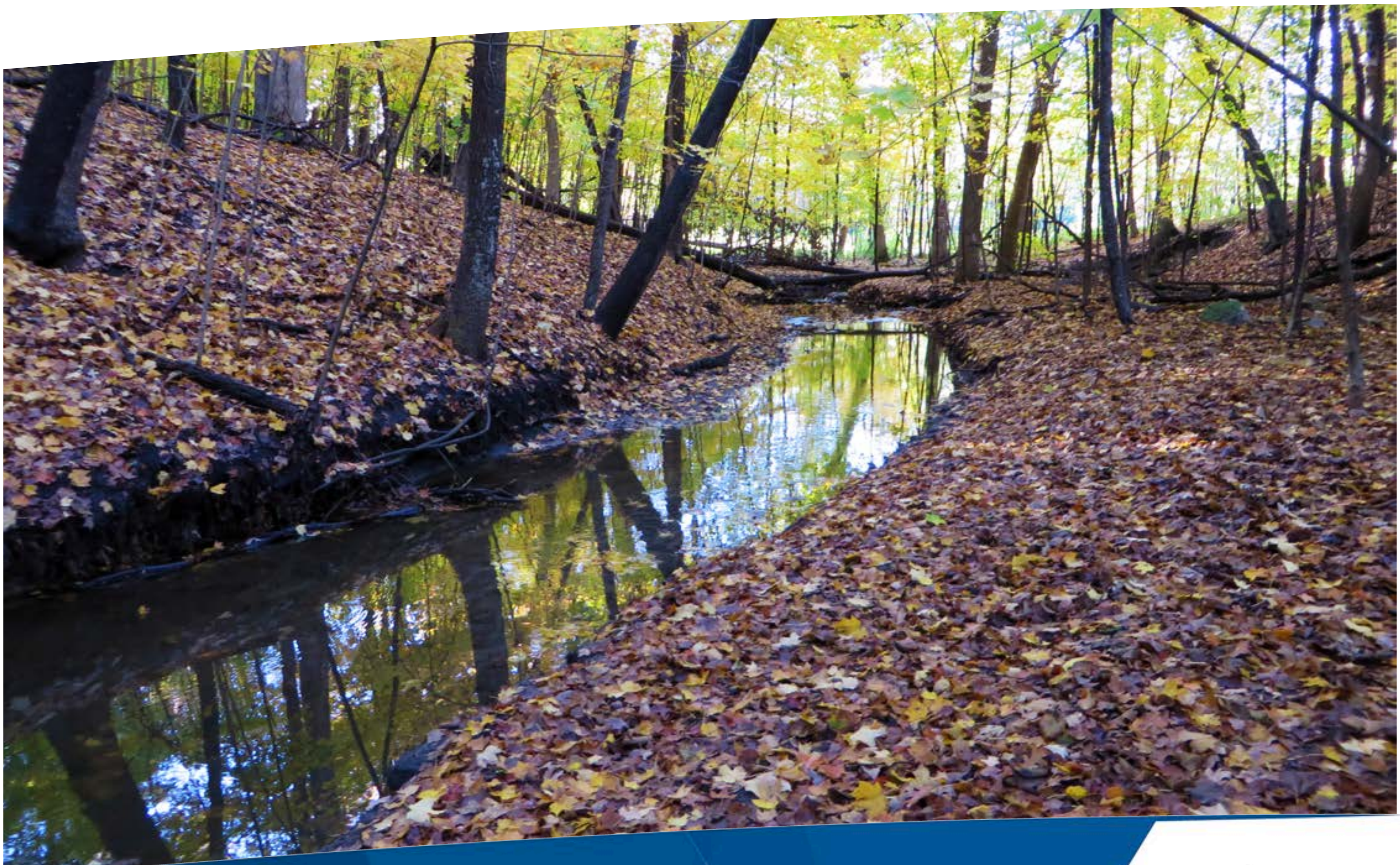
Comprehensive Water Quality Assessment of Select Metropolitan Area Streams

RILEY CREEK



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December 2014

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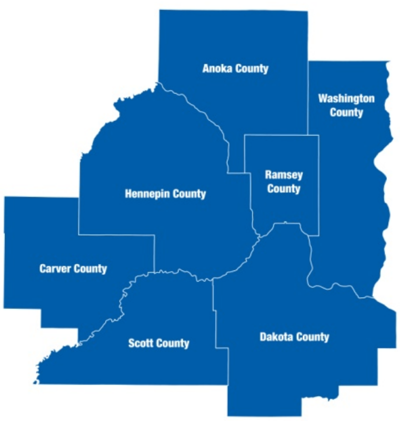

The Metropolitan Council is the regional planning organization for the seven-county Twin Cities area. The Council operates the regional bus and rail system, collects and treats wastewater, coordinates regional water resources, plans and helps fund regional parks, and administers federal funds that provide housing opportunities for low- and moderate-income individuals and families. The 17-member Council board is appointed by and serves at the pleasure of the governor.

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About the Study

The Twin Cities metropolitan area has a wealth of streams that traverse its landscape and ultimately flow into one of its three major rivers – the Mississippi, the Minnesota, and the St. Croix. These streams provide rich habitat for aquatic life and wildlife and enhance the recreational and aesthetic value of the metro area.

The Metropolitan Council is committed to the conscientious stewardship of the region's streams and works with its partners to maintain and improve their health and function. The foundation for these efforts is the collection and analysis of high-quality data about their condition over time.

The *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams* is a major study conducted by the Metropolitan Council that examines the water quality of 21 streams or stream segments that discharge into the metropolitan area's major rivers. The study provides a base of technical information that can support sound decisions about water resources in the metro area − decisions by the Council, state agencies, watershed districts, conservation districts, and county and city governments.

All background information, methodologies, and data sources are summarized in *Introduction and Methodologies*, and a glossary and a list of acronyms are included in *Glossary and Acronyms*. Both of these, as well as individual sections for each of the 21 streams, are available for separate download from the report website. The staff of Metropolitan Council Environmental Services (MCES) and local partners conducted the stream monitoring work, while MCES staff performed the data analyses, compiled the results and prepared the report.

About This Section

This section of the report, *Riley Creek*, is one in a series produced as part of the *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams.* Located in Carver and Hennepin counties, the Riley Creek is one of the nine Minnesota River tributaries examined. This section discusses a wide range of factors that have affected the condition and water quality of the Riley Creek.

CLEAN WATER LAND & LEGACY AMENDMENT

Cover Photo

The photo on the cover of this section depicts Riley Creek at the MCES monitoring site. It was taken by Metropolitan Council staff.

Recommended Citations

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Introduction

Riley Creek is located in the western metropolitan area and is a tributary to the Minnesota River. It drains approximately 13 square miles of mixed urban land, open space, and wetlands, located entirely within the cities of Chanhassen and Eden Prairie, in Carver and Hennepin counties (Metropolitan Council Districts 3 and 4). The creek flows through the Minnesota Valley National Wildlife Refuge before entering the Minnesota River. The Riley-Purgatory-Bluff Creek Watershed District (RPBCWD) is the local water management organization for the Riley Creek watershed.

Figure RI-1: Riley Creek

Photo credit: Riley-Purgatory-Bluff Creek Watershed District

This report:

- documents those characteristics of Riley Creek and its watershed most likely to influence stream flow and water quality.
- presents the results from assessments of flow and water quality data.
- presents statistical assessments of trends in stream chemistry concentrations.
- draws conclusions about possible effects of landscape features, climatological changes, and human activities on flow and water quality.
- compares Riley Creek flow and water quality with other streams within the metropolitan area monitored by Metropolitan Council Environmental Services (MCES).
- makes general recommendations for future monitoring and assessment activities, watershed management, and other potential actions to remediate any water quality or flow concerns.

MCES plans to update this report approximately every five to 10 years, in addition to issuing annual data summary reports.

Partnerships and Funding

MCES has supported water quality monitoring of Riley Creek since 1999. Funding for this site is partially provided by the Minnesota Legislature with Clean Water Legacy funds through a grant from the Minnesota Pollution Control Agency (MPCA). MCES partners with the city of Eden Prairie on the cost to operate and run the site. The city subcontracted the rating curve maintenance and station operation work to its consulting engineer.

Monitoring Station Description

The monitoring station is located on Riley Creek near Flying Cloud Drive in Eden Prairie, Minnesota, 1.3 miles upstream from the creek confluence with the Minnesota River. The monitoring station includes continuous flow monitoring, event-based composite sample collection, and on-site conductivity and temperature probes. The Riley Creek station also includes an in-stream turbidity sensor (Forest Technology Systems DTS-12). There is a rain gauge at this station; however it is rarely used due to infrequent site visits for calibration. Precipitation data are available from the Minnesota Climatology Working Group, Chanhassen Station Number 211448. Daily precipitation totals from this station was used to create the hydrograph in the ***Hydrology*** section of this report. For the analysis of precipitation-weighted loads, MCES used the Minnesota Climatological Working Group's monthly 10-kilometer gridded precipitation data to represent the variability of rainfall within the watershed (Minnesota Climatology Working Group, 2013). These data are generated from Minnesota's HIDEN (High Spatial Density Precipitation Network) dataset. The gridded data was aerially-weighted based on the watershed boundaries.

Riley Creek generally flows southeast from its headwaters in Lake Lucy and Lake Ann through Lake Susan, Rice Marsh Lake, and Riley Lake before it reaches the monitoring station. Below the station, Riley Creek flows into Grass Lake (a Minnesota River floodplain wetland) before reaching its confluence with the Minnesota River. The MCES monitoring station was out of commission from early 2005 through late 2006 due to equipment failure; therefore data are not presented for those years.

Reconstruction of Flying Cloud Drive/MN 101 will likely require the MCES Riley Creek monitoring station to be out of commission in 2015.

Stream and Watershed Description

The Riley Creek watershed is a total of 8,387 acres, with 6,642 acres (79.2%) of the watershed upstream of the monitoring station (Figure RI-2). The watershed land cover is primarily a mix of urban, forest, grasses/herbaceous, and wetlands. The watershed has 3,132 acres/37.3% (2,756 acres/41.5% within the monitored area) of developed urban land, including portions of the cities of Chanhassen and Eden Prairie. The most intense development in the watershed is along Highway 5 in downtown Chanhassen. The watershed also has 988 acres/11.8% (971 acres/14.6% within the monitored area) of forested land, 1,472 acres/17.6% (1,172 acres/17.6% within the monitored area) of grasses/herbaceous cover, 1,417 acres/16.9% (824 acres/12.4% within the monitored area) of wetlands, and 859 acres/10.2% (569 acres/8.6% within the monitored area) of open water. There are also 455 acres/5.4% (287 acres/4.3% within the monitored area) of agricultural land distributed throughout the watershed. Table RI-1 shows the watershed area by land cover.

Table RI-1: Riley Creek Land Cover Classes[1]

Land Cover Class	Monitored		Unmonitored		Total	
	Acres	Percent	Acres	Percent	Acres	Percent
5-10% Impervious	125	1.9%	223	12.8%	348	4.2%
11-25% Impervious	438	6.6%	4	0.2%	442	5.3%
26-50% Impervious	1,285	19.3%	21	1.2%	1,305	15.6%
51-75% Impervious	402	6.1%	15	0.8%	417	5.0%
76-100% Impervious	506	7.6%	113	6.5%	619	7.4%
Agricultural Land	287	4.3%	169	9.7%	455	5.4%
Forest (all types)	971	14.6%	17	1.0%	988	11.8%
Open Water	569	8.6%	291	16.6%	859	10.2%
Barren Land	0	0.0%	0	0.0%	0	0.0%
Shrubland	63	1.0%	0	0.0%	63	0.8%
Grasses/Herbaceous	1,172	17.6%	301	17.2%	1,472	17.6%
Wetlands (all types)	824	12.4%	593	34.0%	1,417	16.9%
Total	**6,642**	**100.0%**	**1,745**	**100.0%**	**8,387**	**100.0%**

[1] Land cover spatial data file provided by MnDNR. The data is a composite of the 2008 MLCCS (Minnesota Land Cover Classification System), which covered primarily the 7-county metro area; and the 2001 NLCD (National Land Cover Data), which covered the outstate areas not included in the 2008 MLCCS.

The watershed topography is moderate in the upstream areas, with the landscape punctuated by a series of lakes (Figure RI-3). As the creek nears the Minnesota River Valley the watershed becomes very steep and the creek enters the Minnesota River through a steep ravine. The maximum watershed elevation is 1083.8 MSL and the minimum elevation is 712.3 MSL within the monitored area. Within the monitored area, 8.6% of the slopes are considered steep, and an additional 3.6% are considered very steep.

Approximately 1/8 of a mile downstream of the MCES monitoring station, Riley Creek enters Grass Lake in the floodplain of the Minnesota River. Grass Lake has an area of about 467 acres with an average depth of 1.5 feet and a maximum depth of 3.5 feet (HDR Inc., 2011). The creek flows through the lake before entering the Minnesota River. Some attenuation and/or modification of the creek's load likely occurs in Grass Lake. As a flood plain lake, Grass Lake is totally inundated when the Minnesota River floods.

There are few point sources within the Riley Creek Watershed (Figure RI-4). The watershed contains three sites holding industrial stormwater permits, all in the unmonitored portion of the watershed. There are no cooling water, potable water, dewatering facilities, or industrial or domestic wastewater facilities in the watershed. There are no feedlots in the watershed.

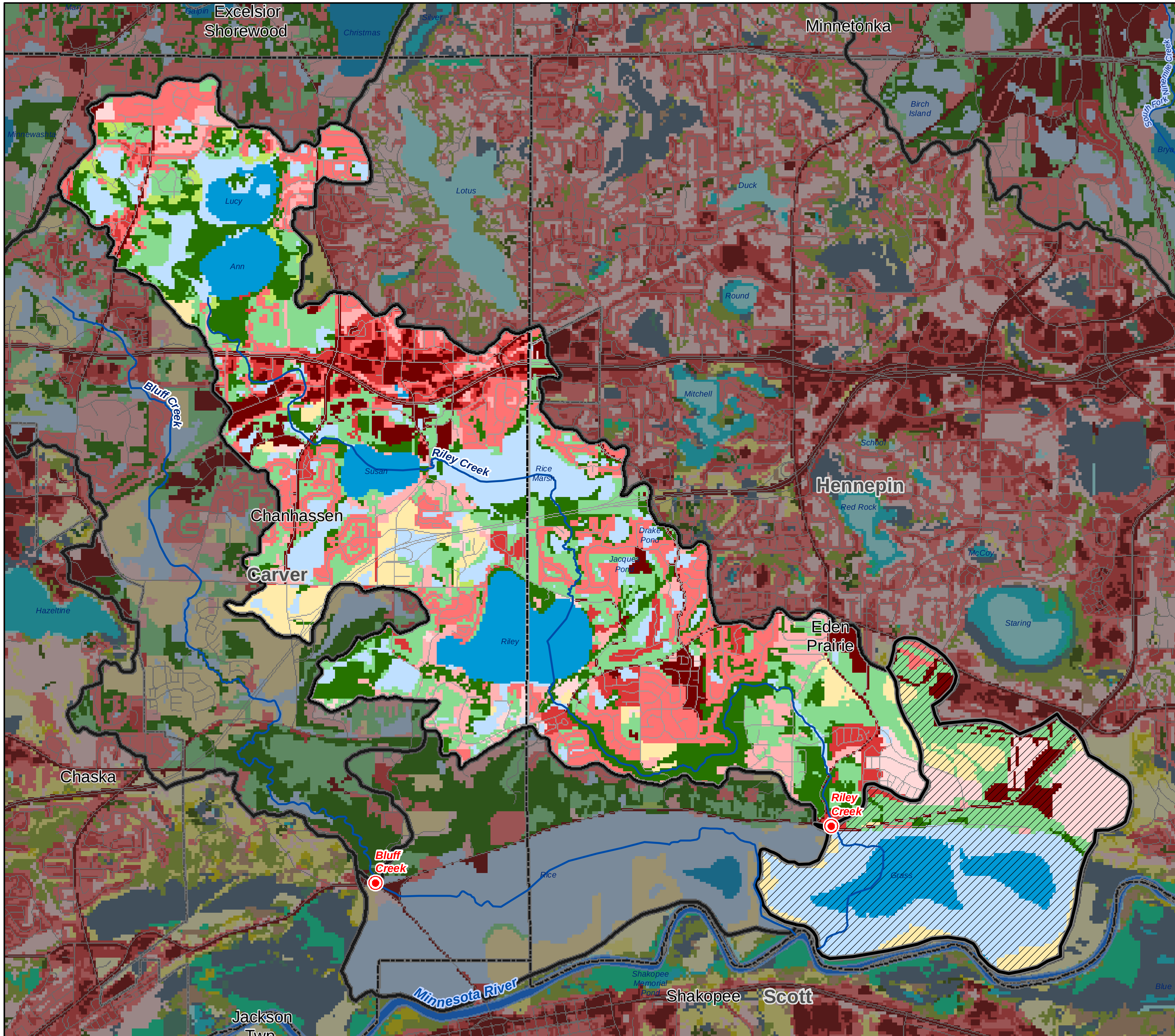

Figure RI-2

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MLCCS-NLCD Hybrid Land Cover

Riley Creek

- MCES Stream Monitoring Sites
- USGS Flow Stations
- Mainstems (Monitored and Unmonitored)
- Major Mainstem Tributaries
- Monitored Watershed Boundaries
- Unmonitored Portion of Watersheds
- Street Centerlines (NCompass, 2012)
- County Boundary
- City and Township Boundaries

MLCCS-NLCD Hybrid Land Cover

- 5-10% Impervious
- 11-25% Impervious
- 26-50% Impervious
- 51-75% Impervious
- 76-100% Impervious
- Agricultural Land
- Barren Land (rock, mud)
- Forest (all types)
- Grasses/Herbaceous
- Open Water
- Shrubland
- Unknown, or No Data
- Wetlands (open water, forest, shrub and emergent)

Data Source: MnDNR

MLSSC/NLCD Hybrid Land Cover
Riley Creek

Land Cover Class	Monitored Acres	Monitored Percent	Unmonitored Acres	Unmonitored Percent	Total Acres	Total Percent
5-10% Impervious	125	1.9%	223	12.8%	348	4.2%
11-25% Impervious	438	6.6%	4	0.2%	442	5.3%
26-50% Impervious	1,285	19.3%	21	1.2%	1,305	15.6%
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Open Water	569	8.6%	291	16.6%	859	10.2%
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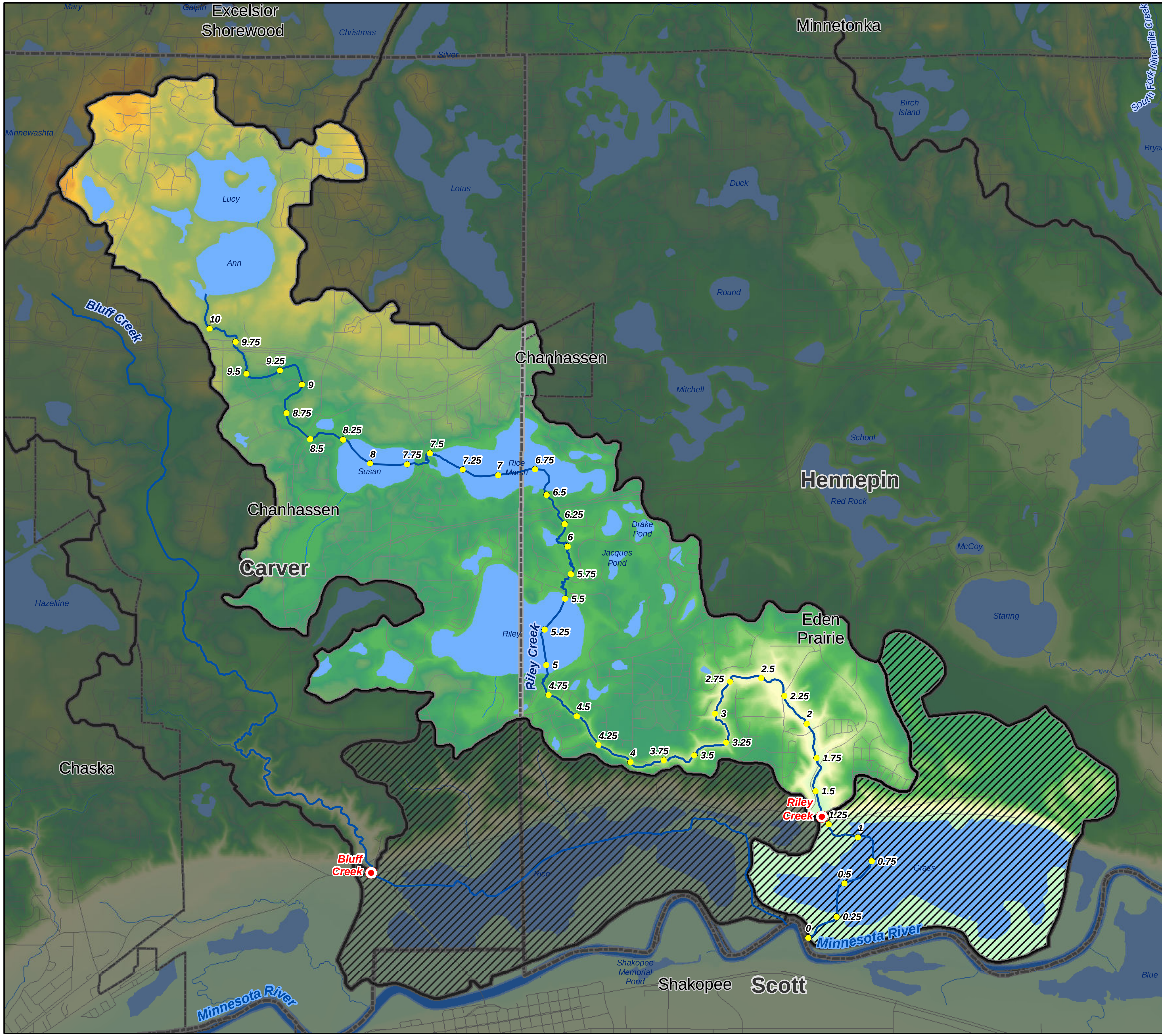
Shrubland	63	1.0%	0	0.0%	63	0.8%
Grasses/Herbaceous	1,172	17.6%	301	17.2%	1,472	17.6%
Wetlands (all types)	824	12.4%	593	34.0%	1,417	16.9%
Total	**6,642**	**100.0%**	**1,745**	**100.0%**	**8,387**	**100.0%**

0 0.5 1 1.5 2
Miles

Figure RI-3

Watershed Topography

Riley Creek



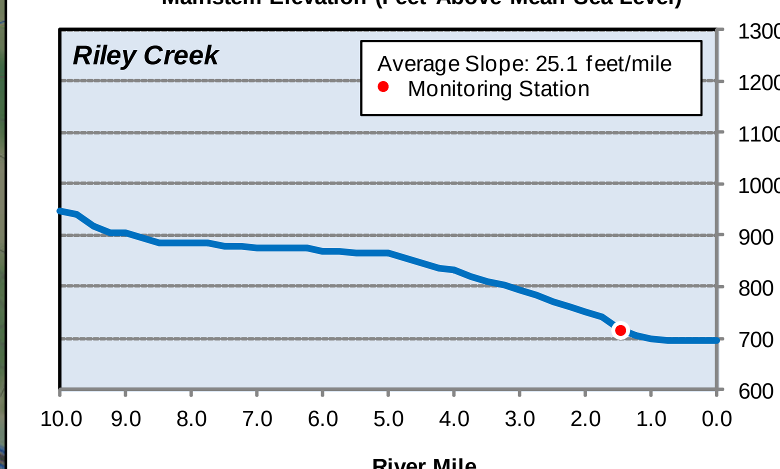
- MCES Stream Monitoring Sites
- USGS Flow Stations
- Stream Mile Markers
- Mainstems (Monitored and Unmonitored)
- Monitored Watershed Boundaries
- Unmonitored Watershed Areas
- Public Waters Inventory
- Other Rivers and Streams
- City and Township Boundaries
- County Boundary
- NCompass Street Centerlines, 2012

Elevation
Feet Above Mean Sea Level

High : 1594
1400
1200
1000
800
Low : 643

Source: USGS National Elevation Dataset, 1/3 arc-second, 10-meter resolution

Mainstem Elevation (Feet Above Mean Sea Level)



0 0.5 1 1.5
Miles

Water Quality Impairments

Waters within the Riley Creek watershed that have been designated as impaired by MPCA are listed in Tables RI2 and RI-3, and shown in Figure RI-4.

Table RI-2: Impaired Reaches of Riley Creek Watershed as Identified on the MPCA 2014 Impaired Waters List

Reach Name	Reach Description	Reach ID	Water Quality Impairment[1]	Approved	Needs Plan[2]
Riley Creek	Riley Lake to Minnesota River	07020012-511	AQL	---	T

[1] AQL = Aquatic Life; [2] T = Turbidity;

Table RI-3: Impaired in the Riley Creek Watershed as Identified on the MPCA 2014 Impaired Waters List

Lake Name	Lake ID	Water Quality Impairment `[1]	Approved Plan[2]	Needs Plan
Ann	10-0012-00	AQC	HgF	---
Lucy	10-0007-00	AQC	HgF	---
Riley	10-0002-00	AQC, AQR	---	Nutrients
Susan	10-0013-00	AQC, AQR	HgF	Nutrients

[1] AQC = Aquatic Consumption; AQR = Aquatic Recreation

[2] HgF = Mercury in Fish Tissue;

Figure RI-4

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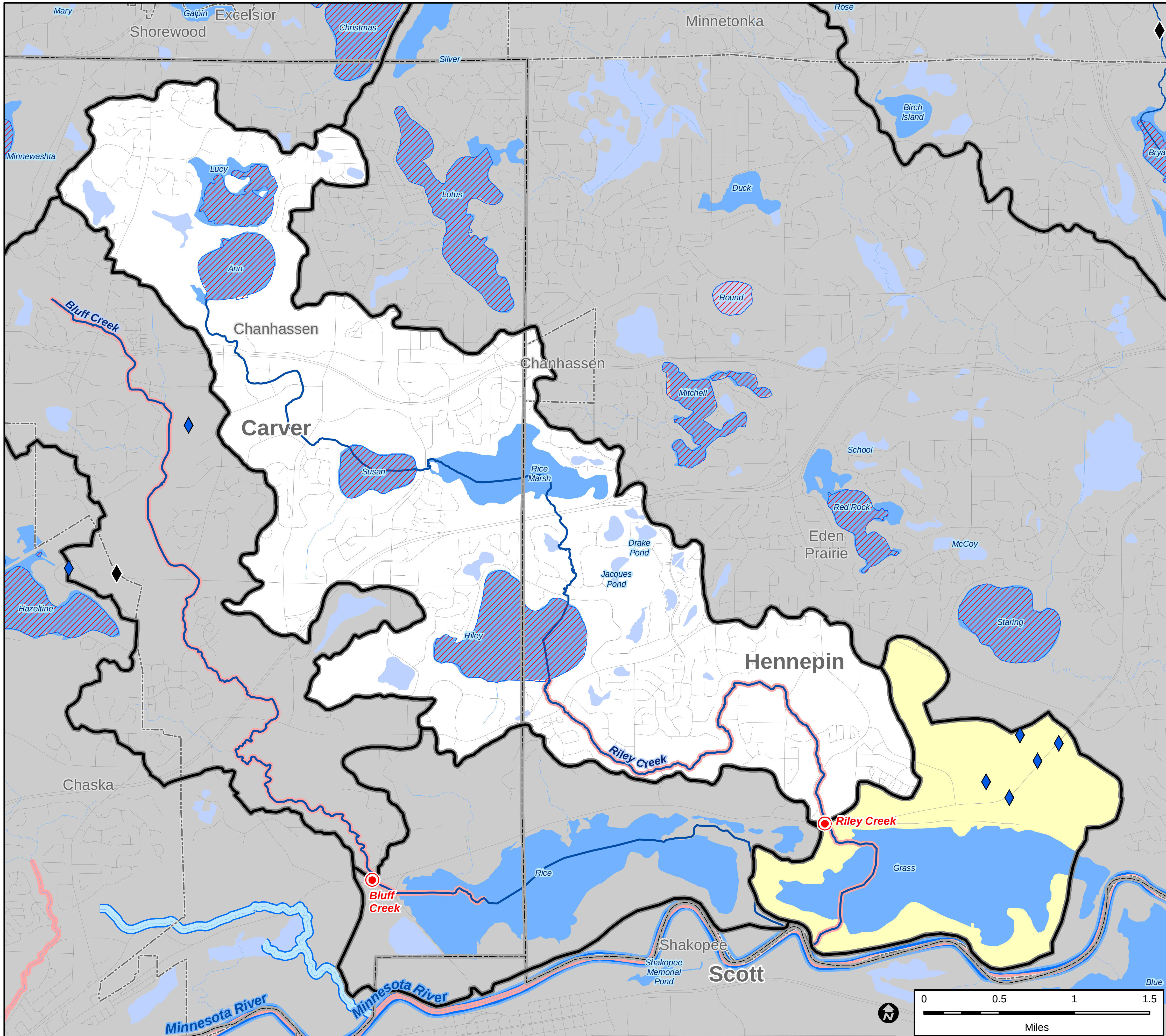
Public and Impaired Waters and Potential Pollution Sources

Riley Creek



- MCES Stream Monitoring Sites
- USGS Flow Stations
- Mainstems (Monitored and Unmonitored)
- Monitored Watershed Boundaries
- Unmonitored Portion of Watersheds

Industrial Discharges **

- Industrial Stormwater
- Industrial & Individual Wastewater
- Cooling, Potable Treatment & Dewatering

Domestic Wastewater Discharges **

- Class A
- Class B
- Class C
- Class D
- Class Unknown

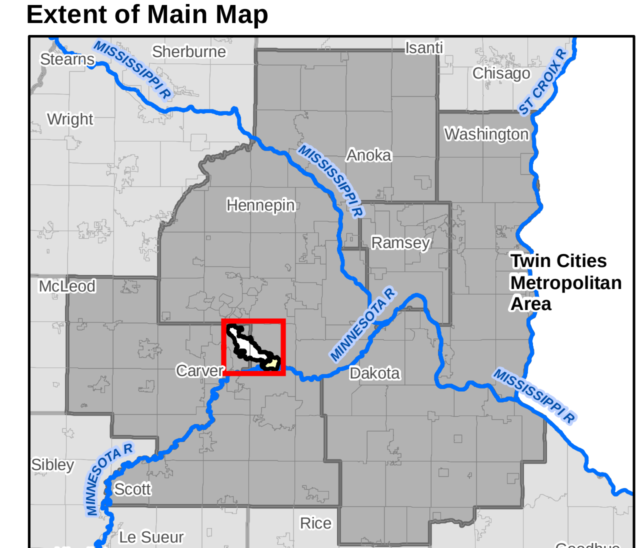
Feedlots with 100 or more animal units **

- 100 - 249
- 250 - 499
- 500 - 999
- 1000 or more

- Impaired Lakes (2014 Draft MPCA 303(d) List) **
- Impaired Streams (2014 Draft MPCA 303(d) List) **
- Other Rivers and Streams *
- Lakes and Other Open Water (PWI) *
- Wetlands (PWI) *
- Designated Trout Streams *
- NCompass Street Centerlines, 2013
- County Boundary
- City and Township Boundaries

*Data Sources: * MN DNR, ** MPCA, *** MN DOT*

Extent of Main Map



Hydrology

Riley Creek originates in Lake Lucy and flows a short distance into Lake Ann in the top of the watershed. The stream meanders through the middle of Chanhassen flowing into Lake Susan, then Rice Marsh Lake, and then through Lake Riley. From the outlet of Lake Riley, the stream descends steeply to the Minnesota River flood plain and flows through Grass Lake before entering the river.

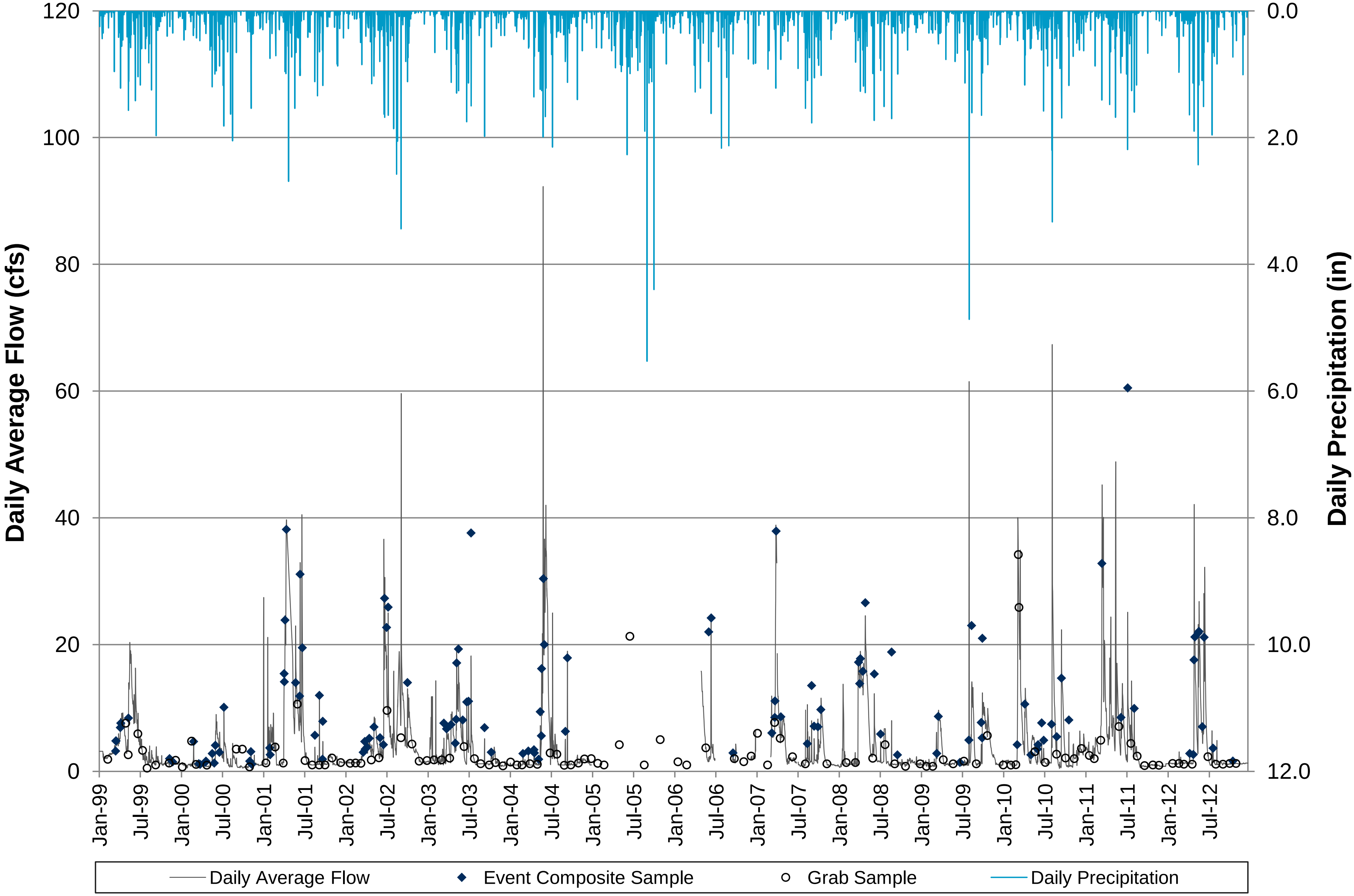
MCES has monitored flow on Riley Creek at mile 1.3 near Flying Cloud Drive since 1999. Flow measurements are collected at 15-minute intervals and converted to daily averages. The hydrograph of Riley Creek, which displays daily average flow, daily precipitation, and the flow associated with grab and composite samples, indicates the variations in flow rates from season to season and from year to year (Figure RI-5), and the effect of precipitation events on flow.

The MCES sampling program collects grab samples of base flows between events and composite samples of precipitation events. The hydrograph indicates samples were collected during most events and that baseflow was also adequately sampled.

Flow Analysis of the duration of daily average flows indicates that the upper 10th percentile flows for the period 1999-2012 ranged between approximately 9.5-92.3 cubic feet per second (cfs), while the lowest 10th percentile flows ranged from 0.5-1.0 cfs. (See Figure RI-12 in the ***Flow and Load Duration Curves*** section of this report.)

Additional annual flow/volume metrics are shown on Figures RI-6 – RI-9, along with the annual pollutant load parameters. The first graph on each sheet illustrates an annual flow metric: consisting of 1.) average annual flow (a measure of annual flow volume); 2.) areal-weighted flow; or 3.) the fraction of annual precipitation converted to flow. Figure RI-6 indicates the highest average annual flow (and thus the highest volume of flow) during 1999-2012 occurred during 2001 (approximately 6.1 cfs average annual flow); the lowest occurred in 2000 (approximately 1.5 cfs average annual flow).

Figure RI-5: Riley Creek Daily Average Flow, Sample Flow, and Precipitation, 1999-2012*



*Flow could not be determined during all of 2005 and parts of 2006, 2007; precipitation record was acquired from NWS COOP station 211448-Chanhassen WSFO

Vulnerability of Stream to Groundwater Withdrawals

Regional analysis (Metropolitan Council, 2010) of hydrogeologic conditions in the seven-county metropolitan area suggests that some surface water features are in direct connection with the underlying regional groundwater flow system and may be impacted by groundwater pumping. While regional in nature, this analysis serves as a screening tool to increase awareness about the risk that groundwater pumping may have for surface water protection and to direct local resources toward monitoring and managing the surface waters most likely to be impacted by groundwater pumping. Additional information, including assumptions and analytical methodologies, can be found in the 2010 report.

To assess the vulnerability of Riley Creek to groundwater withdrawals, MCES staff examined spatial datasets of vulnerable stream segments and basins created as part of the 2010 regional groundwater analysis. Within the Riley Creek watershed, five stream segments comprising the lower part of the creek starting in the city of Eden Prairie and extending to the confluence with Grass Lake and the Minnesota River were identified as potentially vulnerable. Several basins within the watershed, including Lake Susan, Rice Marsh Lake, Lake Riley, and Grass Lake were also identified as vulnerable to groundwater withdrawals.

MCES is continuing to evaluate the effects of groundwater withdrawal on surface waters, including updating analyses with the best available data and linking results to predictive groundwater modeling and the comprehensive planning process involving local communities.

Pollutant Loads

The U.S. Army Corps of Engineers program Flux32 (Walker, 1999) was used to convert daily average flow, coupled with grab and event-composite sample concentrations, into annual and monthly loads and flow-weighted mean concentrations. Loads were estimated for total suspended solids (TSS), total phosphorus (TP), total dissolved phosphorus (TDP), nitrate (NO_3), ammonia (NH_3), and chloride (Cl), for each year of monitored data in Riley Creek (1999-2012). Note that due to equipment failure, no flow data was collected at the Riley Creek monitoring station for all of 2005 and most of 2006; therefore results are not presented for those years.

Figures RI-6 to RI-9 illustrate annual loads expressed as mass, as flow-weighted mean (FWM) concentration, as mass –per-unit area (lb/ac), and as mass-per-unit area-per inch of precipitation (lb/ac/in), as well as two hydrological metrics (annual average flow rate and fraction of annual precipitation as flow). A later section in this report (***Comparison with Other Metro Area Streams***) offers graphical comparison of the Riley Creek loads and FWM concentrations with the other MCES-monitored metropolitan area tributaries.

The flow metrics indicate year-to-year variation in annual flow rate that is likely driven by variation in annual precipitation amount as well as by variation in frequency of intense storm events. The fraction of annual precipitation delivered as flow is relatively stable between years; year-to-year variation is likely influenced by drought periods, by low soil moisture caused by dry periods, by increased capacity in upland storage areas during drought periods, and other factors.

The annual mass loads for all parameters exhibit significant year-to-year variation, indicating the influence of precipitation and flow on the transport of pollutants within the watershed and the stream. The changes in annual mass load in Riley Creek essentially mirror the changes in annual flow.

The annual FWM concentrations for all parameters also fluctuate from year-to-year and are likely influenced by annual precipitation and flow. However, the dissolved constituents (TDP, NO_3, and Cl) do not match the annual flows as closely as the other constituents.

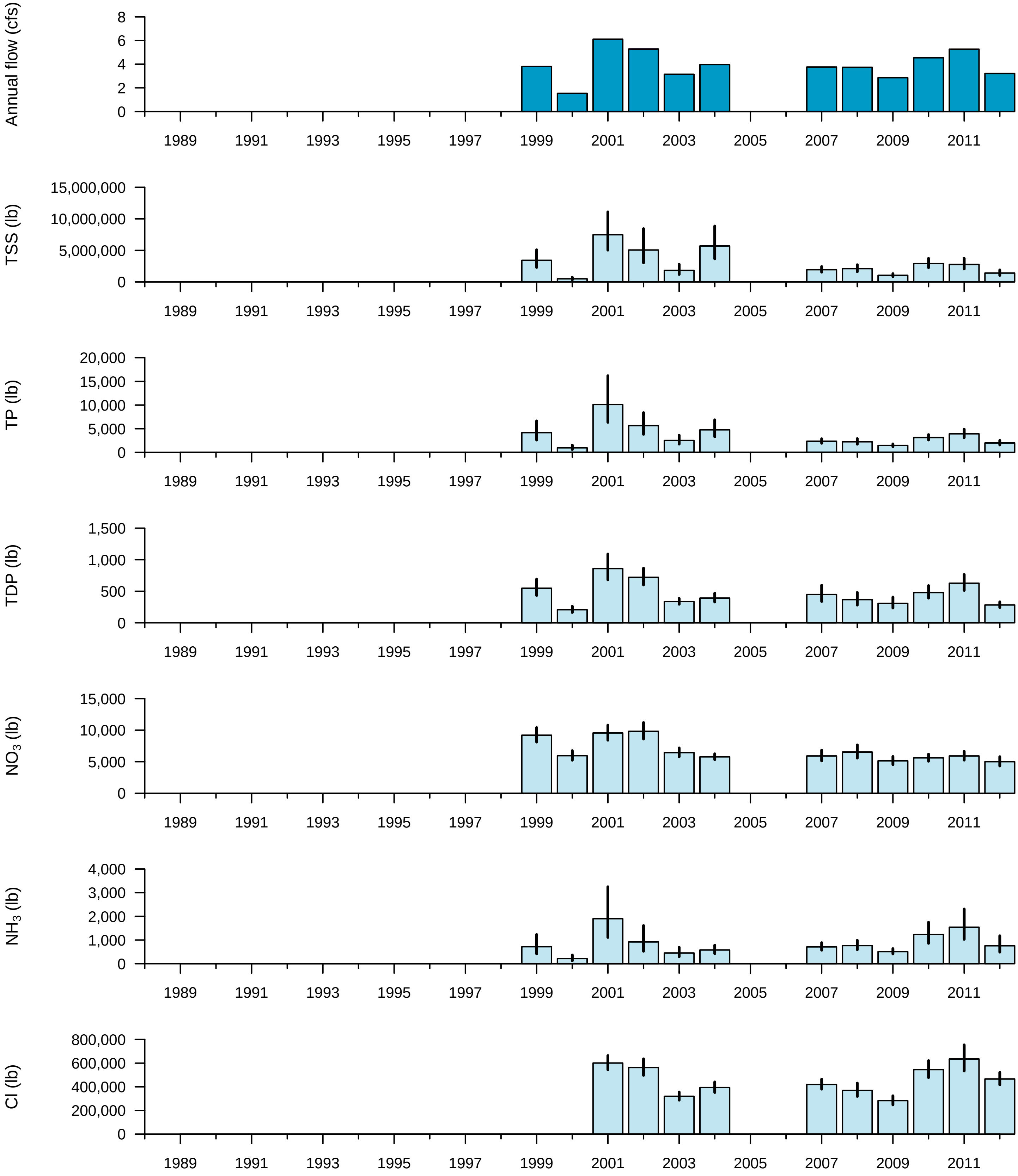
Figures RI-8 and RI-9 present the areal and precipitation-weighted loads, respectively. These graphics are presented to assist local partners and watershed managers, and will not be discussed here.

The Flux32 loads and FWM concentrations were also compiled by month to allow analysis of time based patterns in the loads in Riley Creek (Figures RI-10 and RI-11). The results for each month are expressed in two ways: the monthly results for the most recent year of data (2012 for Riley Creek) and the monthly average for 2003-2012 (with a bar indicating the maximum and minimum value for that month).

Over the 2003-2012 period highest average flows, and in turn mass loads, generally occur in the spring or early summer of each year, likely due to effects of snow melt and spring rains. Flows then generally decrease each subsequent month until late summer or fall, when a secondary flow/load pulse may occur.

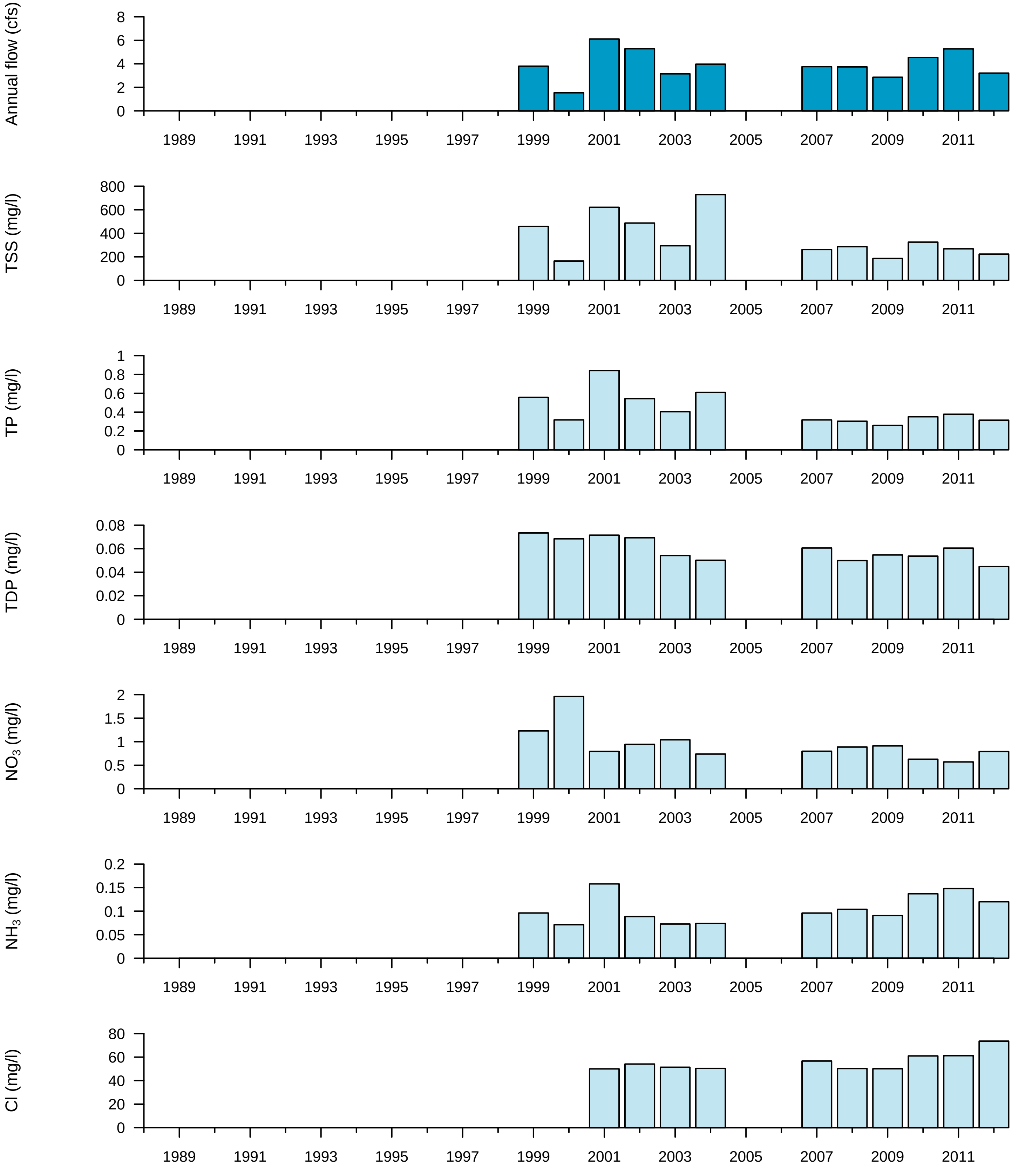
The FWM concentrations generally show month-to-month variability similar to the loads, with the exceptions of dissolved constituents NO_3, and Cl. NO_3 concentrations tend to be low when flows are high, and Cl concentrations show little variation throughout the year. The highest loads of these constituents tend to occur in March, April, and May when flows are highest due to snowmelt and spring rains. The likely source of chloride is thought to be salt applied to roads for de-icing during the winter months; however Cl concentrations tend to be fairly uniform from month to month throughout the year. The reasons for this are unknown.

Figure RI−6: Riley Creek*
Annual Mass Load



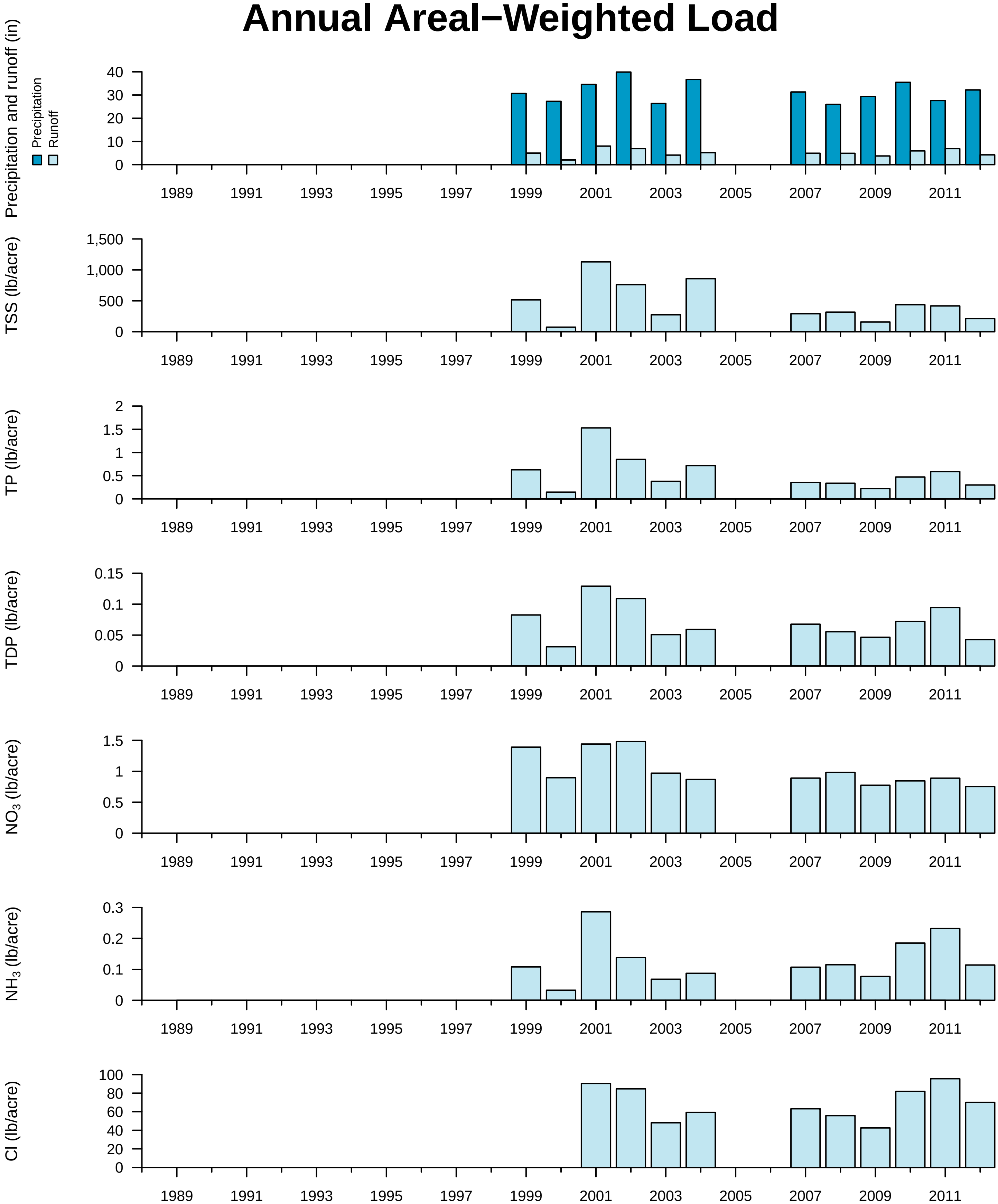
*TSS, TP, TDP, NO3, and NH3 sampling began in 1999, Cl began in 2001. The station was down in 2005 and 2006 so no loads could be calculated.
Bars represent 95% confidence intervals as calculated in Flux32.

Figure RI−7: Riley Creek*
Annual Flow−Weighted Mean Concentration



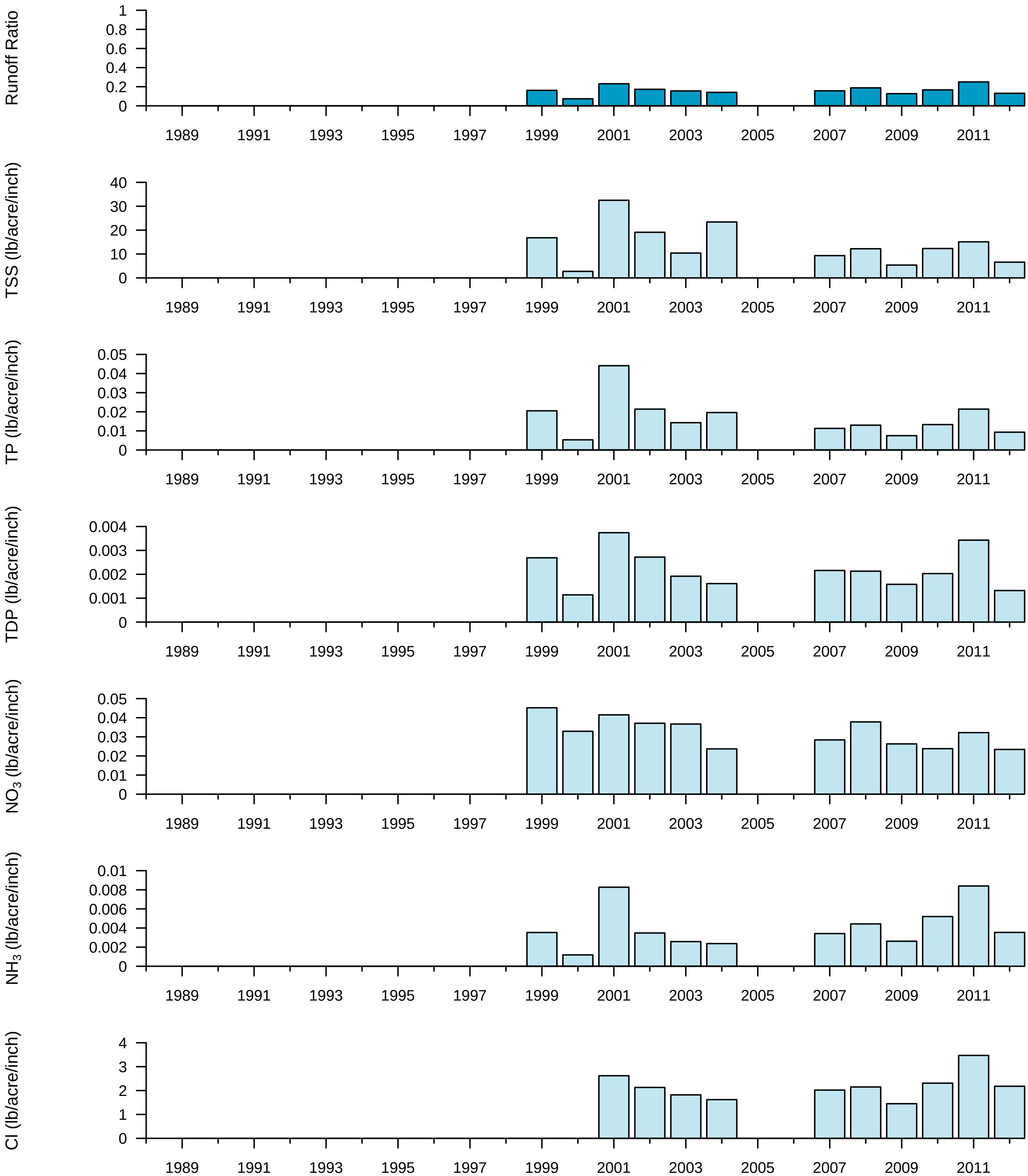
*TSS, TP, TDP, NO3, and NH3 sampling began in 1999, Cl began in 2001. The station was down in 2005 and 2006 so no loads could be calculated.

Figure RI−8: Riley Creek*
Annual Areal−Weighted Load



*TSS, TP, TDP, NO3, and NH3 sampling began in 1999, Cl began in 2001. The station was down in 2005 and 2006 so no loads could be calculated.

Figure RI−9: Riley Creek*
Annual Precipitation−Weighted Areal Load



*TSS, TP, TDP, NO3, and NH3 sampling began in 1999, Cl began in 2001. The station was down in 2005 and 2006 so no loads could be calculated.

Figure RI−10: Riley Creek Mass Load by Month

Most Recent Year (2012) of Data Compared to 2003−2012 Average

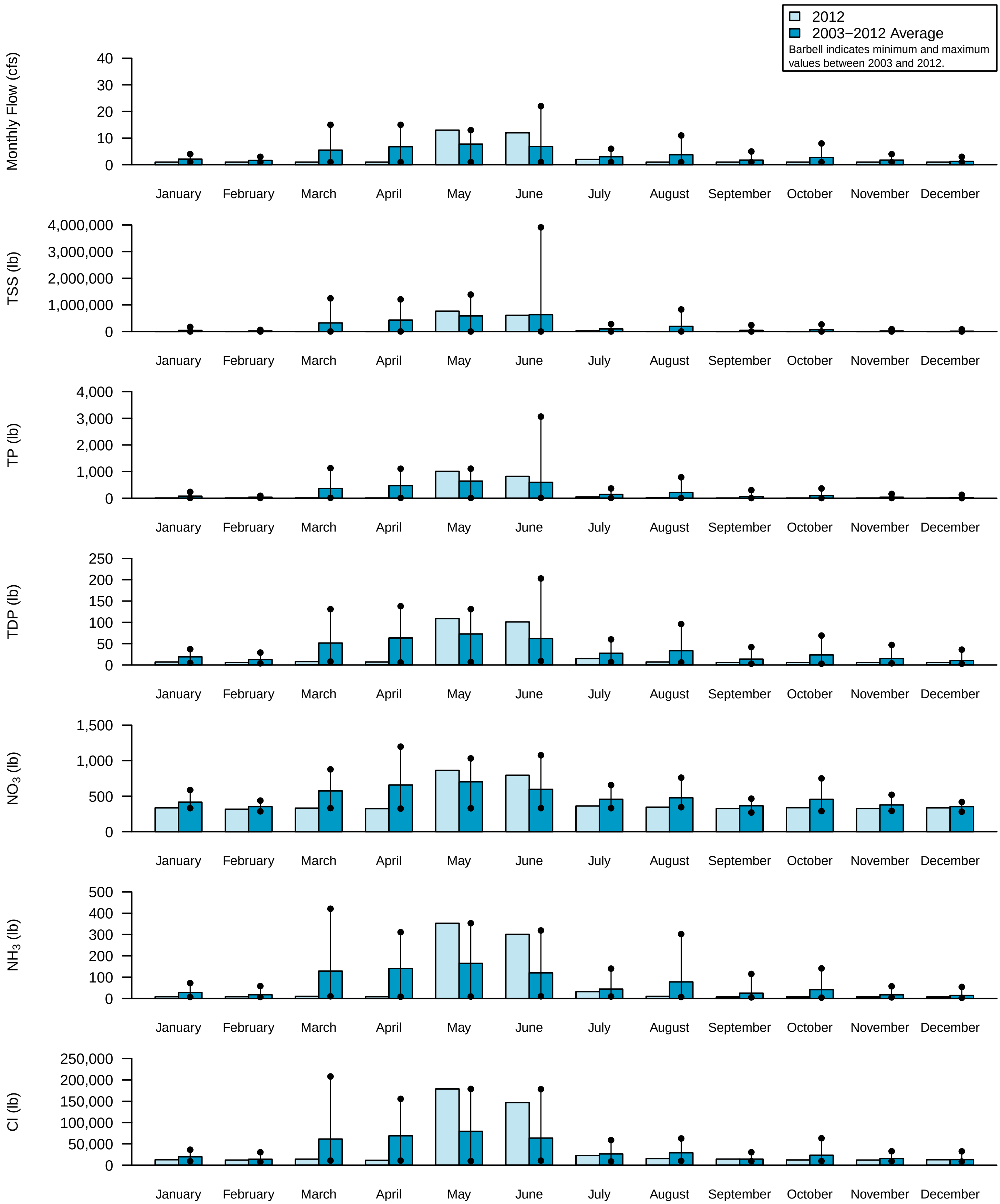
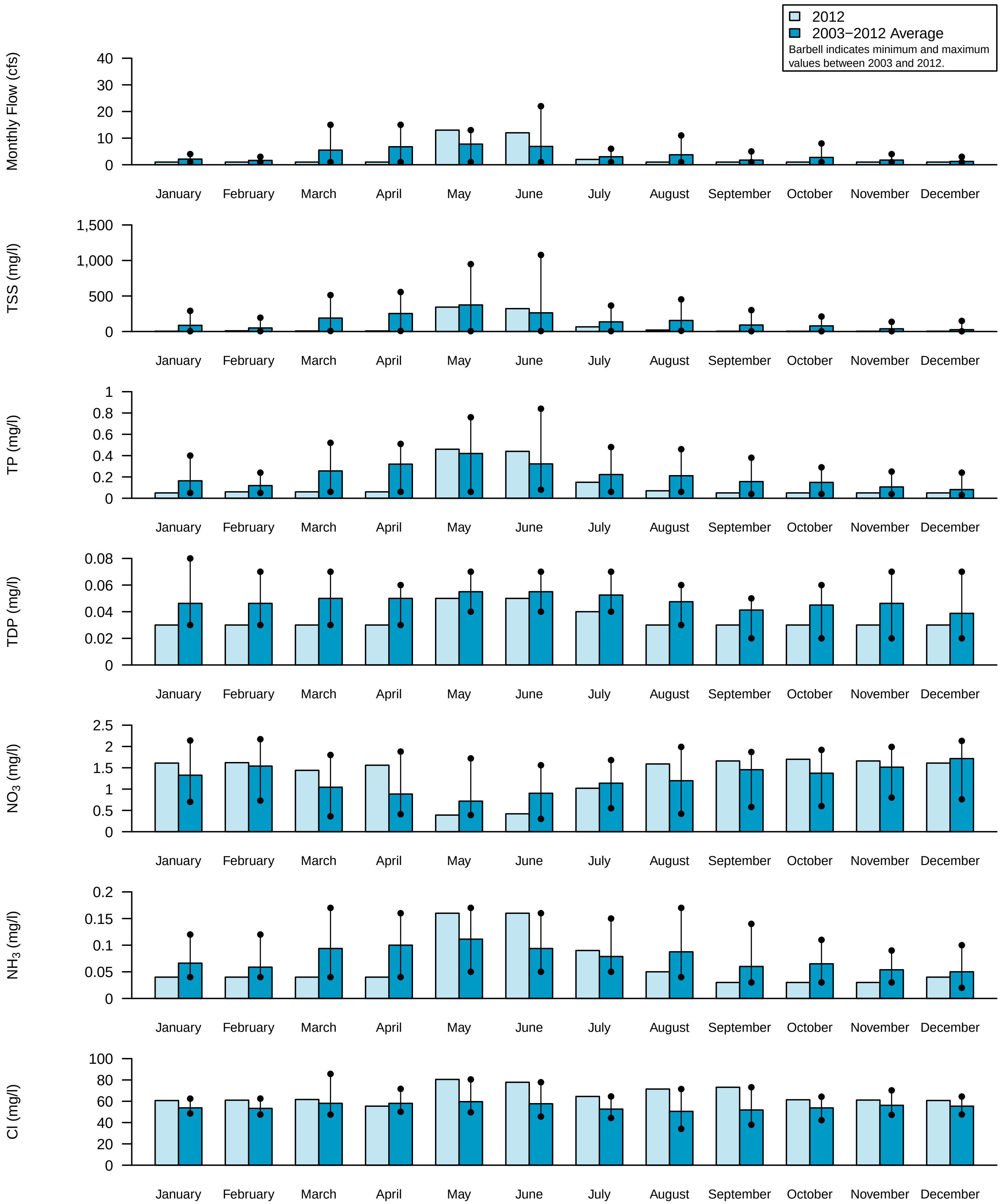


Figure RI−11: Riley Creek
Flow−Weighted Mean Concentation by Month

Most Recent Year (2012) of Data Compared to 2003−2012 Average



Flow and Load Duration Curves

Load duration curves are frequently used to assess water quality concentrations occurring at different flow regimes within a stream or river (high flow, moist conditions, mid-range, dry conditions, and low flow). The curves can also be used to provide a visual display of the frequency, magnitude, and flow regime of water quality standard exceedances if standard concentrations are added to the plots (USEPA, 2007).

MCES developed flow and load duration curves for each stream locations using recommendations of the U.S. Environmental Protection Agency, including:

- Develop flow duration curves using average daily flow values for the entire period of record plotted against percent of time that flow is exceeded during the period of record.
- Divide the flow data into five zones: high flows (0-10% exceedance frequency); moist conditions (10-40%); mid-range flows (40-60%); dry conditions (60-90%); and low flows (90-100%). Midpoints of each zone represent the 5^{th}, 25^{th}, 50^{th}, 75^{th}, and 95^{th} percentiles, respectively.
- Multiply concentration and flow for each sampling event for period of record, to result in approximate daily mass loads included on the curve as points.
- Multiply water quality standard concentration and monitored flow to form a line indicating allowable load. Sample load points falling below the line meet the standard; those falling above the line exceed the standard.

The final load duration curves provide a visual tool to assess if standard exceedances are occurring, and if so, at which flow regimes.

MCES selected four parameters to assess using load duration curves: TSS, TP, NO_3, and Cl. Each of the parameters was plotted using Riley Creek monitoring station daily average flows and sample data, along with the most appropriate MPCA draft numerical standard as listed in Table RI-4. No draft standard has been set for NO_3, so MCES used the drinking water standard of 10 mg/l.

Most of the draft standards proposed by MPCA have accompanying criteria that are difficult to show on the load duration curves. For example, for a water body to violate the draft TP river standard, the water body must exceed the causative variable (TP concentration), as well as one or more response variables: sestonic (suspended) chlorophyll, biochemical oxygen demand ($BOD_{5)}$, dissolved oxygen (DO) flux, and/or pH (MPCA, 2013a). Thus for this report, the load duration curves are used as a general guide to identify flow regimes at which water quality violations may occur. The MPCA is responsible for identifying and listing those waters not meeting water quality standards; the results of this report in no way supersede MPCA's authority or process.

The 1999–2012 flow duration curve and load duration curves for TSS, TP, NO_3, and Cl for the Riley Creek monitoring station (mile 1.3) are shown in Figure RI-12.

The TSS load duration curve shows that TSS concentrations have exceeded the proposed 30 mg/l TSS standard at four of the five flow regimes, with no violations occurring at the low flow regime. Most of the violations occur at higher flows (the high flow and moist conditions regimes).

It appears that essentially all of the monitored concentrations at the high flow regime exceed the proposed standard. This response is consistent with other streams in the Minnesota River watershed, where high flows lead to streambank, bluff, and ravine erosion.

TP concentrations have exceeded the draft nutrient criteria at all flow regimes, but the majority of the exceedances occur during the highest flows (the high flow and moist conditions regimes). Similar to TSS, it appears that almost all of the monitored TP concentrations at the high flow regime exceed the proposed standard.

All NO_3 concentrations at all flow regimes met the drinking water standard of 10 mg/l. The final river nutrient standard for NO_3 will likely be much less than that. From the load duration curve, NO_3 concentrations appear to be largely independent of flow.

Cl concentrations in Riley Creek are below the draft Cl criteria at all flow regimes. Cl concentrations do increase with increasing flow; possibly due to wash off of salt applied for road deicing.

Table RI-4: Riley Creek Beneficial Use and River Nutrient Region (RNR) Classifications and Pollutant Draft Standards

Monitoring Station	Use Classification[1] for Domestic Consumption (Class 1) and Aquatic Life and Recreation (Class 2)	River Nutrient Region (RNR)[2] of Monitoring Station	Chloride Draft Stnd[3] (mg/l)	TSS Draft Stnd[4] (mg/l)	TP Draft Criteria[5] (ug/l)	Nitrate DW Stnd[6] (mg/l)
Riley Creek Inlet to Grass Lake (RI1.3)	2B	Central	230	30	100	10

[1] Minn. Rules 7050.0470 and 7050.0430

[2] MPCA, 2010.

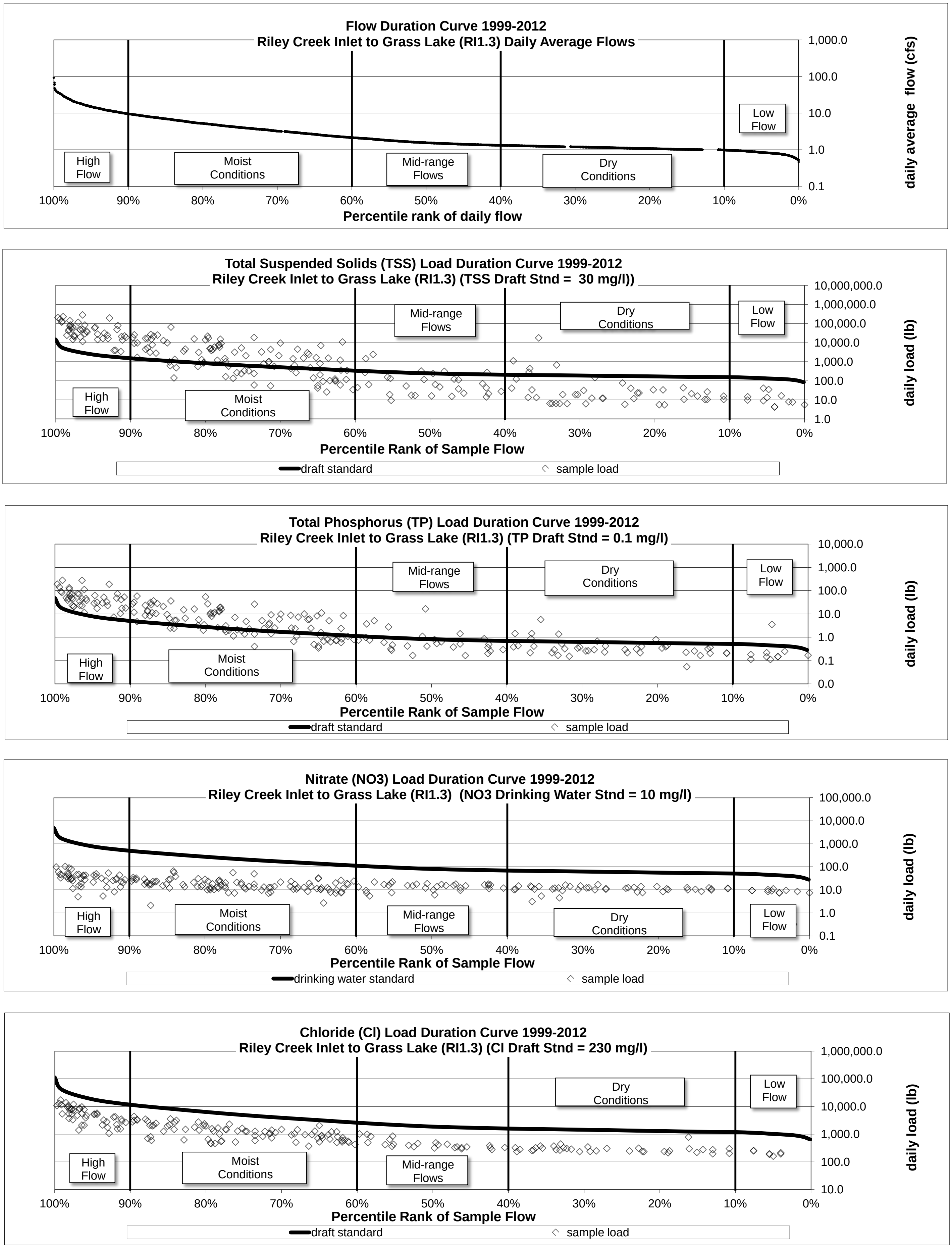
[3] Mark Tomasek, MPCA, personal communication, March 2013. MCES used 230 mg/l as the draft Cl standard pending results of EPA toxicity tests.

[4] MPCA, 2011. Draft standard states TSS standard concentration for Class 2A and 2B water must not be exceeded more than 10% of the time over a multiyear data window, with an assessment period of April through September.

[5] MPCA, 2013a. To violate standard, concentration of causative variable (TP) must be exceeded, as well as one or more response variables: sestonic chlorophyll, BOD_5, DO flux, and/or pH.

[6] MCES used the NO_3 drinking water standard of 10 mg/l pending results of EPA toxicity tests and establishment of a draft NO_3 standard for rivers and streams.

Figure RI-12: Riley Creek Flow and Load Duration Curves, 1999-2012



Aquatic Life Assessment Based on Macroinvertebrates

Macroinvertebrates, including aquatic insects, worms, snails, crustaceans, and bivalves, are important indicators of water quality. Different types of macroinvertebrates have differing sensitivities to changes in pollution levels, habitat, flows, energy, and biotic interactions. As these environmental attributes change over time, they shape the composition of the macroinvertebrate community. Metrics have been developed that relate these community shifts with human-caused stresses.

Each metric is independently important and clarifies one aspect of the ecosystem health: species richness, community diversity, water quality, and other factors. The results may have conflicting conclusions when comparing the single metric results. However, integrating the individual metrics into a multi-metric analysis provides a holistic assessment of the stream system.

MCES has not collected any macroinvertebrate data at the Riley Creek monitoring station.

Trend Analysis

Trend analysis was completed for the historical record of TP, NO_3, and TSS using the U.S. Geological Survey (USGS) program QWTREND (Vecchia, 2003). QWTREND removes the variability of annual flow from the statistical analysis, thus any trend identified should be independent of flow.

Due to relatively short flow record for the monitored streams, MCES did not attempt to assess increases or decreases in flow. However other researchers have performed regional assessments of alterations in flow rate; their results can be used to form general assumptions about changes in flows in the metropolitan area streams.

Novotny and Stefan (2007) assessed flows from 36 USGS monitoring stations across Minnesota over a period of 10 to 90 years, finding that peak flow due to snowmelt was the only streamflow statistic that has not changed at a significant rate. Peak flows due to rainfall events in summer were found to be increasing, along with the number of days exhibiting higher flows. Both summer and winter baseflows were found to be increasing, as well. Novotny and Stefan hypothesized that increases in annual precipitation, larger number of intense precipitation events, and more days with precipitation are driving the increased flows.

Alterations in land use and land management have also likely contributed to increasing flow rates. For example, Schottler et al. (2013) found that agricultural watersheds with large land use changes have exhibited increases in seasonal and annual water yields, with most of the increase in flow rate due to changes in artificial drainage and loss of natural storage. MCES staff plan to repeat the following trend analyses in five to 10 years. At that time, we anticipate sufficient data will have been collected for us to assess changes in flow rate, as well as to update the pollutant trends discussed below.

MCES staff assessed trends for the period of 1999-2012 on Riley Creek for TSS, TP, and NO_3. The results are presented below.

Total Suspended Solids (TSS)

Three trends were identified for TSS flow-adjusted concentration in Riley Creek from 1999 to 2012 (Figure RI-13, top panel). The assessment was performed using QWTREND without precedent 5-year flow setting. The trends identified were statistically significant (p=0.007).

- Trend 1: 1999 to 2004, TSS flow-adjusted concentration decreased from 26.8 mg/l to 11.5 mg/l (-57%) at a rate of -2.6 mg/l/yr.

- Trend 2: 2005 to 2008, TSS flow-adjusted concentration increased from 11.5 mg/l to 19.1 mg/l (66%) at a rate of 1.9 mg/l/yr.

- Trend 3: 2009 to 2012, TSS flow-adjusted concentration decreased from 19.1 mg/l to 9.3 mg/l (-51%) at a rate of -2.4 mg/l/yr.

The five-year trend in TSS flow-adjusted concentration in Riley Creek (2008-2012) was calculated to compare with other MCES-monitored streams, shown in the report section ***Comparison with Other Metro Area Streams***. TSS flow-adjusted concentration decreased from 17.5 mg/l to 9.3 mg/l (-47%) at a rate of -1.6 mg/l/yr. Based on these QWTREND results, the water quality in Riley Creek in terms of TSS improved during 2008-2012.

Total Phosphorus (TP)

Two trends were identified for TP flow-adjusted concentration in Riley Creek from 1999 to 2012 (Figure RI-13, middle panel). The assessment was performed using QWTREND without precedent 5-year flow. The trends identified for TP were statistically significant ($p=6.1x10^{-5}$).

- Trend 1: 1999-2001, TP flow-adjusted concentration decreased from 0.18 mg/l to 0.08 mg/l (-56%) at a rate of -0.033 mg/l/yr.

- Trend 2: 2001-2012, TP flow-adjusted concentration increased from 0.08 mg/l to 0.10 mg/l (34%) at a rate of 0.002 mg/l/yr.

The five-year trend in TP flow-adjusted concentration in Riley Creek (2008-2012) was calculated to compare with other MCES-monitored streams, shown in the report section ***Comparison with Other Metro Area Streams***. TP flow-adjusted concentration increased slightly from 0.09 mg/l to 0.10 mg/l (13%) at a rate of 0.0024 mg/l/yr. Based on these QWTREND results, the water quality in Riley Creek in terms of TP declined during 2008-2012.

Nitrate

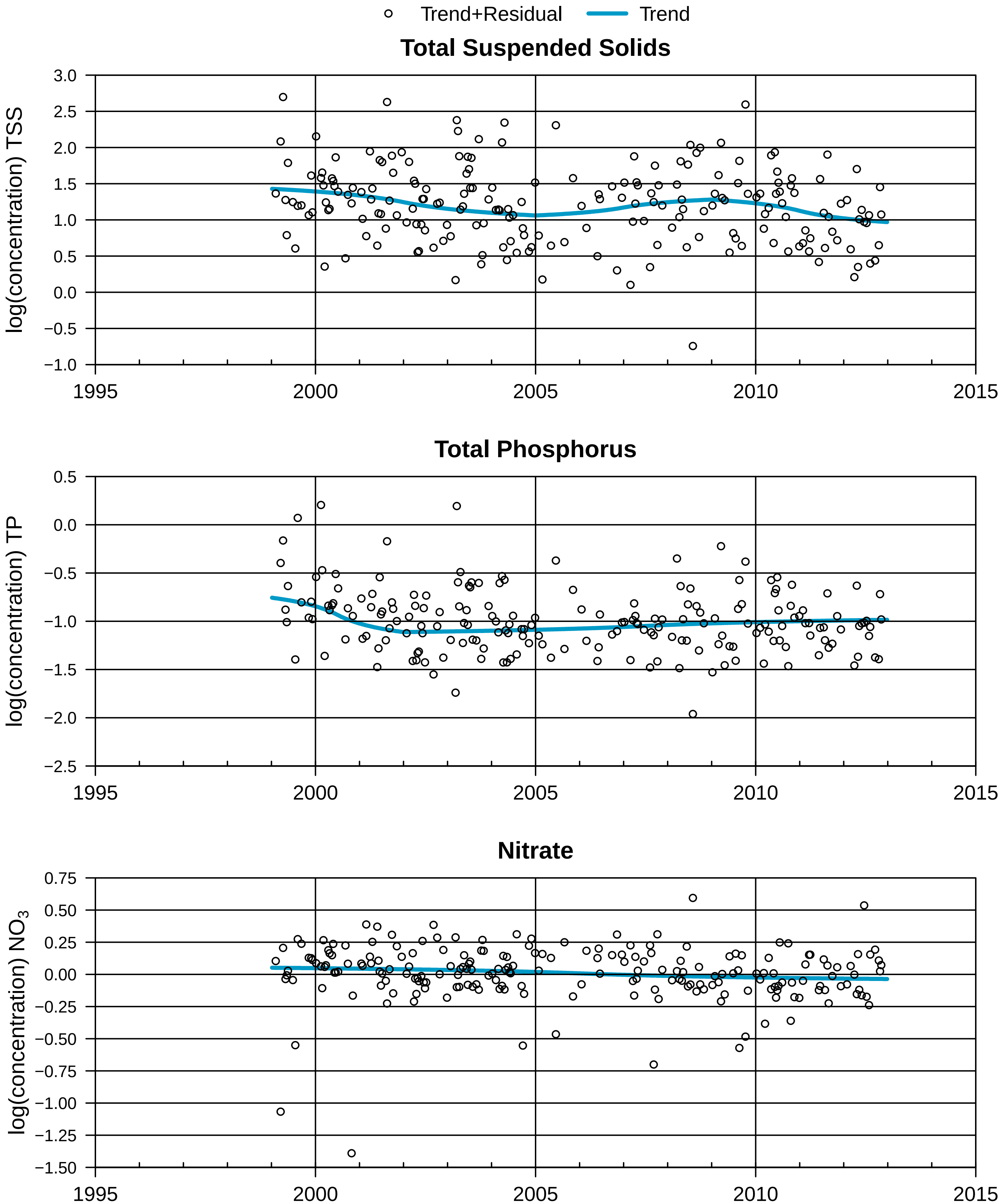
One downward trend was identified for NO_3 flow-adjusted concentration in Riley Creek from 1999 to 2012 (Figure RI-13, lower panel). The assessment was performed using QWTREND without precedent 5-year flow setting. The trend identified was statistically significant (p=0.00076).

Trend 1: 1999-2012, NO_3 flow-adjusted concentration decreased slightly from 1.1 mg/l to 0.9 mg/l (-18%) at a rate of -0.015 mg/l/yr.

The five-year trend in NO_3 flow-adjusted concentration in Riley Creek (2008-2012) was calculated to compare with other MCES-monitored streams, shown in the report section

Comparison with Other Metro Area Streams. NO_3 flow-adjusted concentration decreased slightly from 1.0 mg/l to 0.9 mg/l (-6%) at a rate of -0.011 mg/l/yr. Based on these QWTREND results, water quality in Riley Creek in terms of NO_3 improved during 2008-2012.

Figure RI–13: Riley Creek Trends for TSS, TP and NO_3



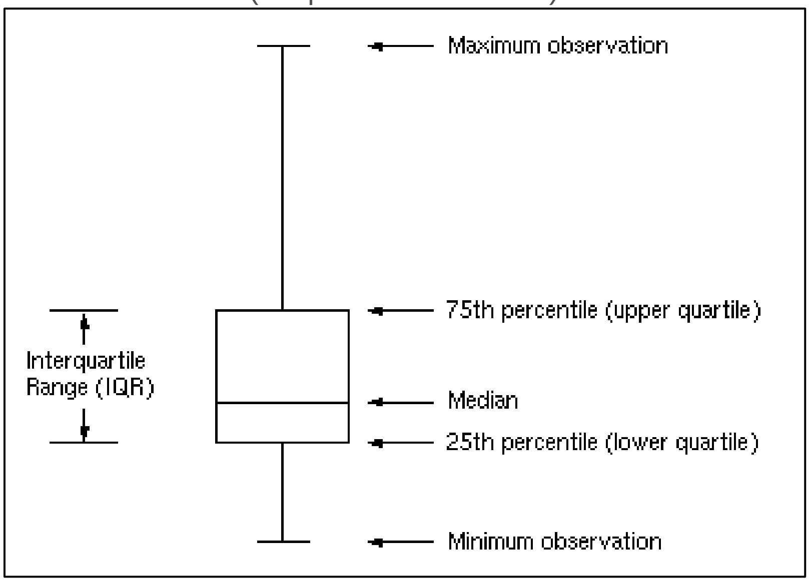
Comparison with Other Metro Area Streams

Chemistry

Box-and-whisker plots are used to summarize the comparison of the historical flow, TSS, TP, NO_3, and Cl data for Riley Creek with the other metropolitan area streams monitored by MCES and with the major receiving water (in this case the Minnesota River. The comparisons are show in Figure RI-15 to Figure RI-18.

Figure RI-14 shows the formatted legend of the of box-and-whisker plots used in this report. Note that 50% of data points fall within the box (also known as the interquartile range), with the centroid delineated by the median line. The outer extents of the whiskers designate the maximum and minimum values.

Figure RI-14: General Schematic of a Box-and-Whisker Plot
(adapted from *sas.com*)



Comparisons for each chemical parameter for period 2003-2012 are shown using box-and-whisker plots of four metrics (annual flow-weighted mean (FWM) concentration, annual runoff coefficient (volume/precipitation, which are identical on each of the four parameter pages), total annual load, and annual areal yield), grouped on one page, with streams grouped by major receiving river and listed in order of upstream-to-downstream. In addition, the plot of FWM concentration includes the 2003-2012 FWM concentration for the three receiving rivers (Mississippi, St. Croix, and Minnesota), shown as a dashed line.

Total Suspended Solids. The median annual FWM concentration for TSS in Riley Creek (277 mg/l) is similar to that of Sand Creek (344 mg/l), Bluff Creek (304 mg/l), and Lower Bevens Creek (252 mg/l). It is higher than that of Carver Creek (143 mg/l) and Credit River (107 mg/l), and much higher than the Minnesota River tributaries closer to the confluence of the Mississippi River, i.e. Nine Mile Creek, Willow Creek, and Eagle Creek (70, 54, and 11 mg/l respectively (Figure RI-15; Table RI-5). The FWM concentration in Riley Creek is also higher than that in the Minnesota River at Jordan, (277 mg/l vs. 142 mg/l), indicating that Riley Creek is serving to increase the TSS concentration in the Minnesota River. High TSS concentrations in Riley Creek are likely due to streambank and ravine erosion in the lower part of the watershed.

Although the median FWM TSS concentration ranks among the higher of the monitored Minnesota River tributaries, the median annual load ranks among the lowest of these creeks, at 2,025,000 pounds per year, greater than only Willow Creek (391,000 pounds per year) and Eagle Creek, (181,000 pounds per year). However, Riley Creek has the fourth highest median annual areal yield of TSS of the monitored Minnesota River tributaries (after Bevens Creek, Bluff Creek, and Sand Creek). The area upstream of the Riley 1.3 monitoring station is 10.38 square miles (6,642 acres), the fourth smallest monitored watershed in the metropolitan Minnesota River basin, which increases the areal yield value. Median annual runoff ratio for Riley Creek is also among the lowest of the monitored Minnesota River tributaries.

Total Phosphorus. The median annual FWM TP concentration in Riley Creek (0.335 mg/l) is higher than that of the Minnesota River (0.24 mg/l) and thus serves to increase the TP concentration in the river (Figure RI-16). The Riley Creek FWM concentration is lower than that of Bevens Creek, Sand Creek, and Bluff Creek, and higher than those of Credit River, Carver Creek, Nine Mile Creek, Willow Creek, and Eagle Creek. Riley Creek and the other upper Minnesota River metropolitan area tributaries also have higher FWM concentrations than most of the other MCES monitored metro area streams, with the exception of the south fork of the Crow River.

Riley Creek's median annual TP load is third lowest of the monitored Minnesota River tributaries; higher only than that of Willow, and Eagle Creeks. Despite the relatively small load, the median annual TP yield of Riley Creek ranks near the middle of the Minnesota River tributaries, probably due to the small monitored watershed area.

Nitrate. Riley Creek FWM NO_3 concentration in is much lower than in the Minnesota River, and thus serves to dilute the river concentration (0.79 mg/l vs. 7.1 mg/l, respectively). Median annual NO_3 load from Riley Creek is low, (5,840 pounds per year) higher only than Bluff, Willow and Eagle Creek among the monitored Minnesota River tributaries. The Riley Creek areal NO_3 yield, at 0.9 pounds/acre/year, is near the low end of the Minnesota River Tributaries, with only Nine Mile Creek and Willow Creek being lower (Figure RI-17).

Chloride. Cl FWM concentration in Riley Creek is higher than in the Minnesota River and is also higher than the concentration observed in the most rural and agricultural Minnesota River watersheds monitored by MCES (i.e. Sand, Bevens, Carver, and Credit). Total CL load is the second lowest of the Minnesota River tributaries (after Eagle Creek), while median annual yield is near the middle of the monitored Minnesota River tributaries (Figure RI-18). The likely explanation for the high concentration is Cl application to road surfaces as a de-icer; the low annual load and high areal yield relative to the other Minnesota River watersheds are probably due to the comparatively small size of the Riley Creek watershed above the monitoring station.

Figure RI−15: Total Suspended Solids for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

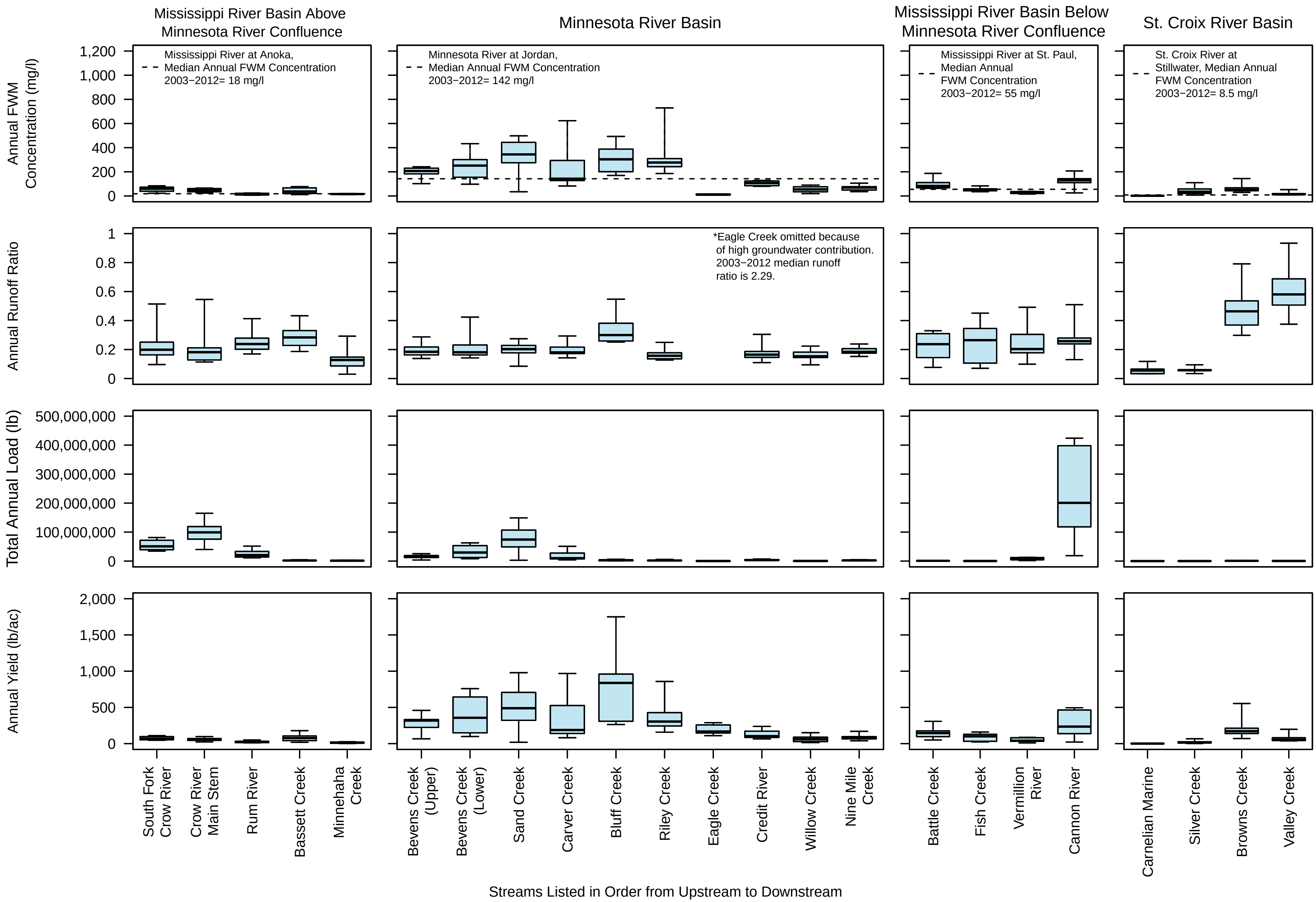


Figure RI−16: Total Phosphorus for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

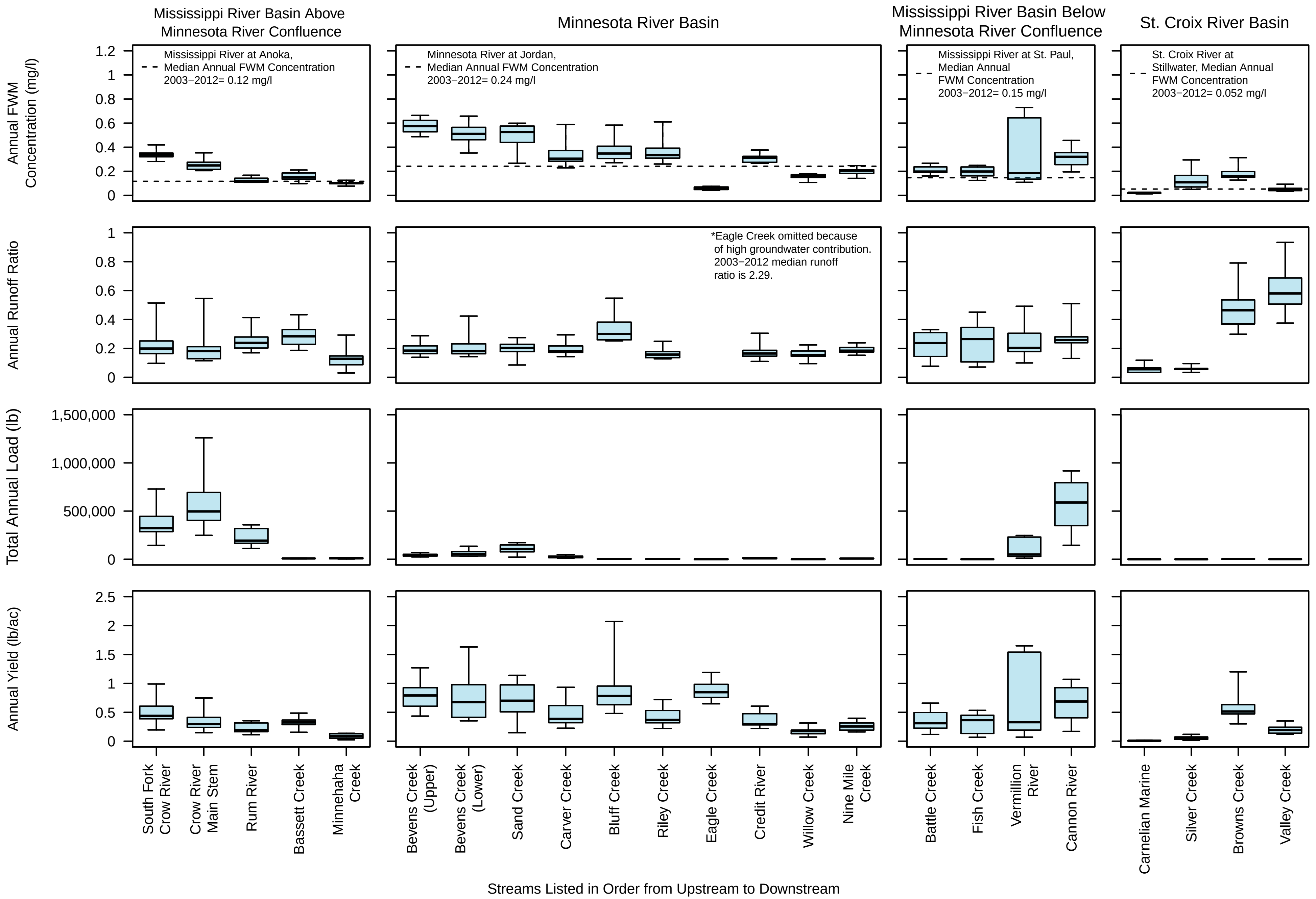


Figure RI−17: Nitrate for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

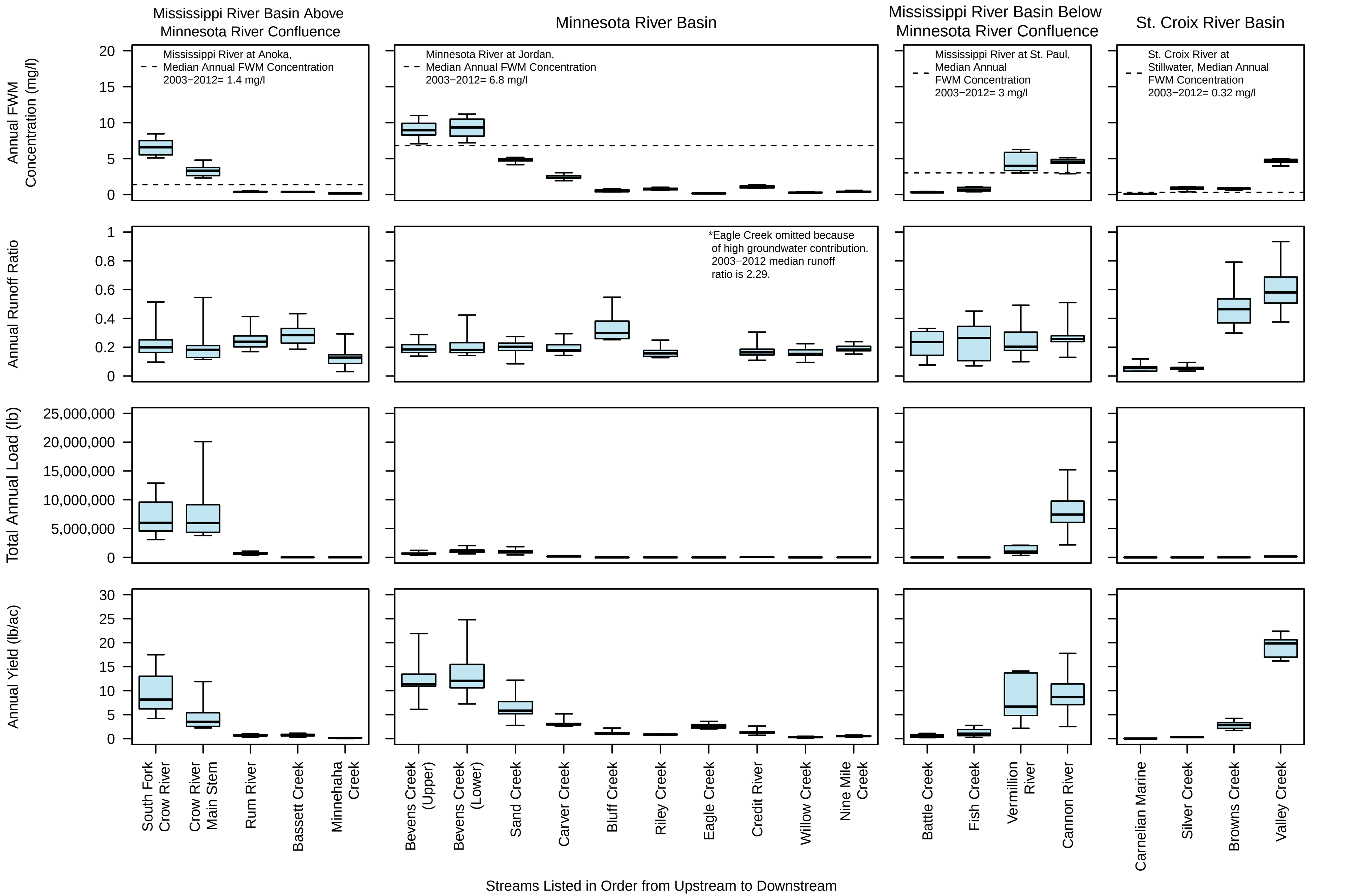


Figure RI−18: Chloride for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

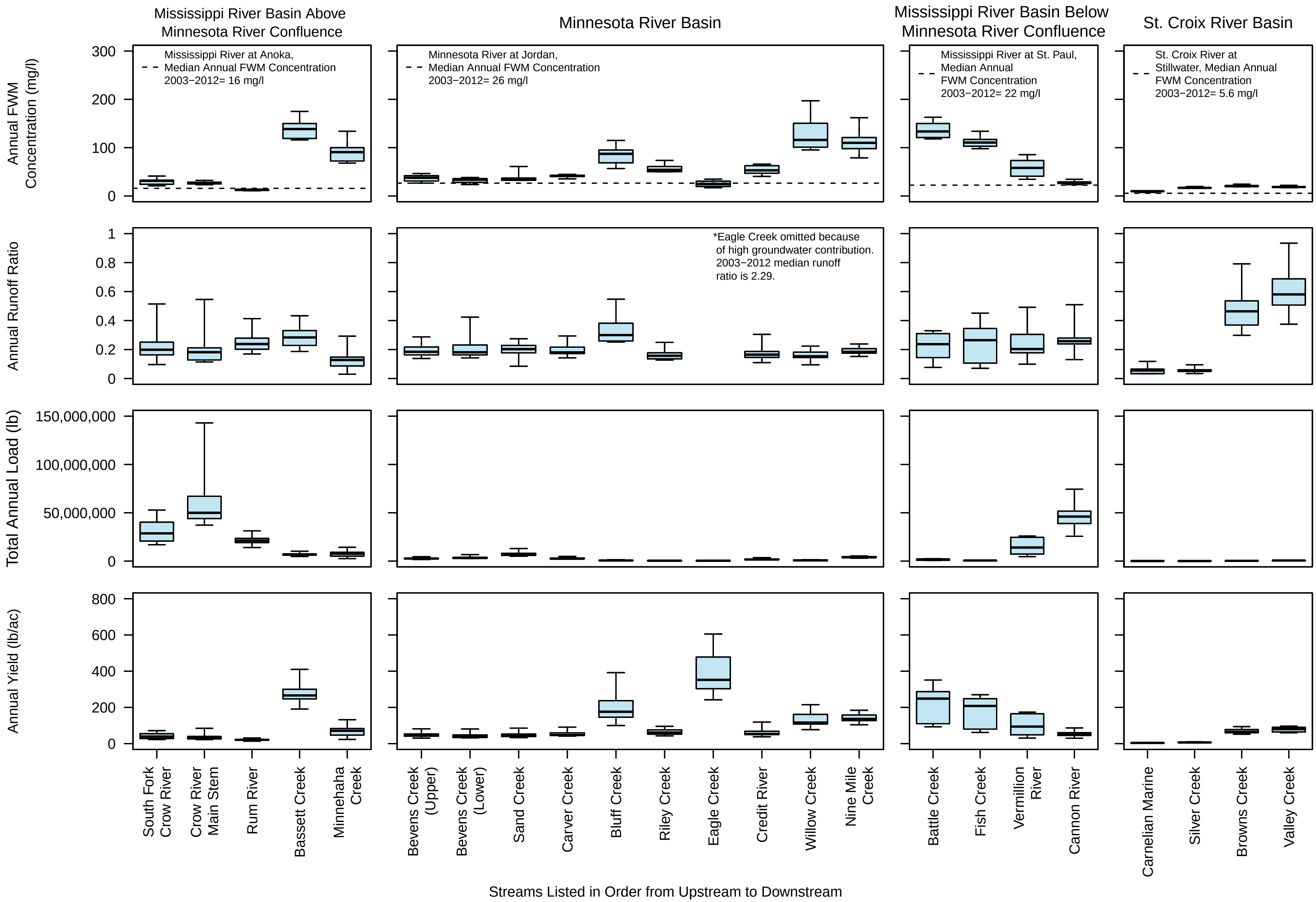


Table RI-5: Annual Median Concentrations, Loads, and Yields for MCES-Monitored Streams, 2003-2012

Station	Stream Name	Major Watershed	Median Runoff Ratio[1]	TSS Median Annual FWM Conc[2] (mg/l)	TSS Median Annual Load[3] (lb/yr)	TSS Median Annual Yield[4] (lb/ac/yr)	TP Median Annual FWM Conc[2] (mg/l)l	TP Median Annual Load[3] (lb/yr)	TP Median Annual Yield[4] (lb/ac/yr)	NO_3 Median Annual FWM Conc[2] (mg/l)	NO_3 Median Annual Load[3] (lb/yr)	NO_3 Median Annual Yield[4] (lb/ac/yr)	Cl Median Annual FWM Conc[2] (mg/l)	Cl Median Annual Load[3] (lb/yr)	Cl Median Annual Yield[4] (lb/ac/yr)
BE5.0	Bevens Creek (Upper)	Minnesota	0.18	207	17,600,000	319	0.575	43,650	0.791	8.95	628,000	11.4	38	2,600,000	47.2
BE2.0	Bevens Creek (Lower)	Minnesota	0.18	252	29,550,000	357	0.511	55,950	0.677	9.34	996,500	12.1	34	3,395,000	41.1
SA8.2	Sand Creek	Minnesota	0.20	344	74,200,000	489	0.526	106,000	0.700	4.85	886,000	5.8	36	6,980,000	46.0
CA1.7	Carver Creek	Minnesota	0.18	143	9,870,000	188	0.304	20,200	0.385	2.35	157,000	3.0	41	2,500,000	47.5
BL3.5	Bluff Creek	Minnesota	0.30	304	3,025,000	838	0.348	2,820	0.782	0.61	4,405	1.2	87	635,500	176.0
RI1.3	Riley Creek	Minnesota	0.16	277	2,025,000	305	0.335	2,440	0.367	0.79	5,840	0.9	54	407,000	61.3
EA0.8	Eagle Creek	Minnesota	2.29	11	181,000	167	0.055	918	0.848	0.17	2,760	2.6	25	381,000	352.0
CR0.9	Credit River	Minnesota	0.16	107	3,090,000	103	0.312	8,800	0.293	1.15	37,400	1.3	53	1,590,000	53.1
WI1.0	Willow Creek	Minnesota	0.15	54	391,000	61	0.161	1,130	0.175	0.28	1,980	0.3	116	750,000	116.0
NM1.8	Nine Mile Creek	Minnesota	0.18	70	2,520,000	88	0.205	7,335	0.255	0.38	15,750	0.5	110	3,930,000	136.5
CWS20.3	Crow River (South)	Mississippi	0.20	60	50,800,000	69	0.339	322,500	0.438	6.58	5,995,000	8.2	31	28,650,000	39.0
CW23.1	Crow River (Main)	Mississippi	0.18	46	98,950,000	59	0.248	496,000	0.294	3.33	5,960,000	3.5	27	49,950,000	29.6
RUM0.7	Rum River	Mississippi	0.24	12	20,700,000	21	0.119	193,000	0.191	0.38	654,000	0.6	13	21,150,000	21.0
BS1.9	Bassett Creek	Mississippi	0.28	37	1,905,000	77	0.150	8,090	0.325	0.38	19,350	0.8	139	6,620,000	266.0
MH1.7	Minnehaha Creek	Mississippi	0.13	16	1,415,000	13	0.102	9,095	0.084	0.17	16,400	0.2	91	7,700,000	71.0
BA2.2	Battle Creek	Mississippi	0.24	83	1,043,000	146	0.197	2,220	0.311	0.32	3,945	0.6	134	1,775,000	248.5
FC0.2	Fish Creek	Mississippi	0.26	55	296,500	101	0.198	1,066	0.364	0.71	3,035	1.0	111	610,000	208.0
VR2.0	Vermillion River	Mississippi	0.20	29	6,025,000	40	0.185	49,000	0.328	4.02	1,001,500	6.7	58	14,050,000	94.1
CN11.9	Cannon River	Mississippi	0.26	130	201,000,000	235	0.320	589,000	0.687	4.59	7,435,000	8.7	28	46,050,000	53.8
CM3.0	Carnelian-Marine Outlet	St. Croix	0.06	2	7,570	0.4	0.022	156	0.009	0.10	701	0.04	10	69,500	3.9
SI0.1	Silver Creek	St. Croix	0.06	35	80,700	15	0.108	235	0.042	0.83	1,765	0.3	17	37,100	6.7
BR0.3	Browns Creek	St. Croix	0.46	51	785,500	172	0.160	2,355	0.514	0.86	12,900	2.8	20	300,000	65.6
VA1.0	Valley Creek	St. Croix	0.58	14	392,500	54	0.047	1,415	0.193	4.74	145,500	19.9	19	589,500	80.4

[1] Runoff ratio = annual flow volume at monitoring station / annual area-weighted precipitation. Area-weighted precipitation for each watershed provided by Minnesota Climatological Working Group (2013)

[2] FWM conc = annual flow-weighted mean concentration estimated using Flux32 (Walker, 1999).

[3] Load = annual pollutant load mass estimated using Flux32 (Walker, 1999).

[4] Yield = watershed pollutant yield calculated from annual pollutant load mass estimated using Flux32 (Walker, 1999) divided by area of watershed upstream of MCES monitoring station

Metropolitan Area Trend Analysis

Statistical trend analysis for each MCES stream monitoring station was performed using QWTREND (Vecchia, 2003). Trend estimates were calculated for 2008-2012 (the last five years of available data) to allow comparison of changes in water quality between streams. A similar approach was used in the 2013 MPCA nitrogen study (MPCA, 2013b) to compare QWTREND assessments in statewide streams and rivers.

Estimated changes for TSS, TP, and NO_3 in MCES-monitored streams are presented below in two ways. First, tabulated results with directional arrows indicating improving (blue upward arrow) and declining (red downward arrow) water quality, paired with percent change in flow-adjusted concentration estimated for 2008-2012 (Figure RI-19). Second, changes are shown by three seven-county metropolitan area maps (one each for TSS, TP, and NO_3 trends) with stream watersheds colored to represent improving and declining water quality (Figure RI-20). In both figures no trend was reported for those QWTREND analyses with poor quality of statistical metrics ($p>0.05$).

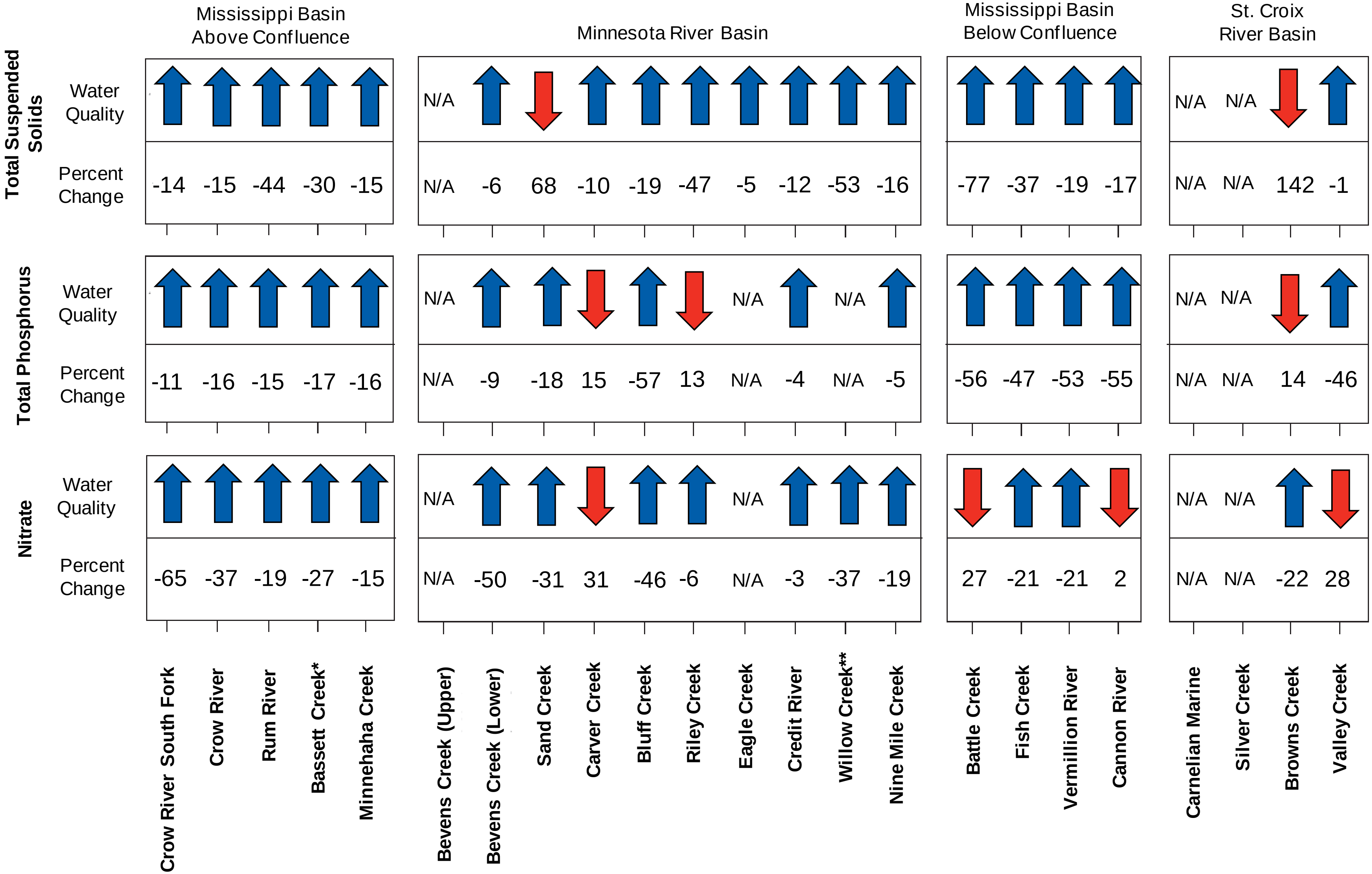
In general, of the 20 monitoring stations assessed, most exhibited increasing water quality (and thus decreasing flow-adjusted concentration) for TSS, TP, and NO_3. There does not appear to be a spatial pattern for those few stations with declining water quality. There is no station with declining water quality for all three parameters, although both TP and NO_3 concentrations increased in Carver Creek (a Minnesota River tributary), and TSS and TP increased in Browns Creek (a St. Croix River tributary).

The Minnesota River and its tributaries typically have had higher TSS concentrations than the Mississippi or St. Croix Rivers and associated tributaries. The trend analysis results indicate decreasing TSS flow-adjusted concentrations in all Minnesota River tributaries with the exception of Sand Creek. Although the TSS concentration in Sand Creek increased during the last five years, both TP and NO_3 decreased.

In Riley Creek, both TSS and NO_3 flow-adjusted concentrations decreased over the five year period of 2008-2012, and thus exhibited improved water quality for those pollutants. TP flow-adjusted concentrations increased over the same time period, resulting in declined water quality for TP. MCES monitoring data by itself is not sufficient to determine the causes of these concentration changes.

Figure RI-19: Regional Estimated Trends in Flow-Adjusted Stream Concentrations of TSS, TP, and NO_3, 2008-2012

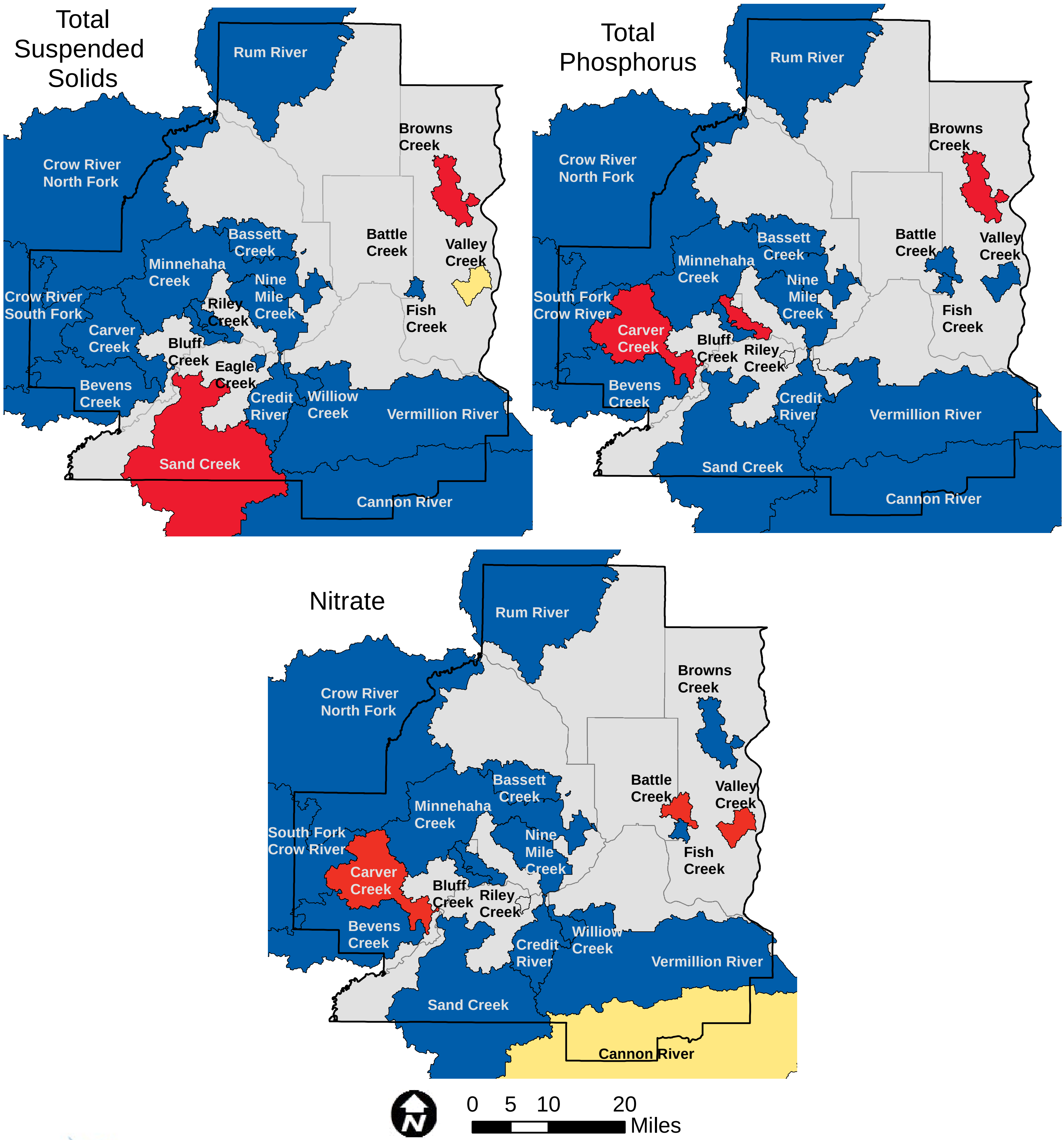
(Grouped by Major River Basin; As estimated by QWTrend)



Blue arrows indicate improved water quality; Red arrows indicate declining water quality.
“N/A” indicates analysis was not performed as data were not appropriate for analysis by QWTrend.
* Bassett Creek TSS Trends were assessed over 2009-2013. **Monitoring at Willow Creek was suspended in 2009.

Figure RI-20: Regional Maps of Estimated Trends in Flow-Adjusted Stream Concentrations of TSS, TP, and NO3, 2008-2012

(As estimated by QWTrend)



Less than -3% Change (Indicates Increasing Water Quality)

-3% to 3% Change

Greater than 3% Change (Indicates Decreasing Water Quality)

METROPOLITAN COUNCIL

Conclusions

Riley Creek is a tributary to the Minnesota River that drains approximately 13 square miles within the cities of Chanhassen and Eden Prairie, in Carver and Hennepin counties (Metropolitan Council Districts 3 and 4). MCES has been monitoring the water quality of Riley Creek near Flying Cloud Drive since 1999. Riley Creek generally flows southeast from its headwaters in Lake Lucy and Lake Ann through Lake Susan, Rice Marsh Lake, and Riley Lake before it reaches the monitoring station. Below the station, Riley Creek flows into Grass Lake (a Minnesota River floodplain wetland) and the Minnesota Valley National Wildlife Refuge before reaching its confluence with the Minnesota River.

Land use within the watershed is a mix of urban land, open space, and wetlands. Riley Creek is impaired for turbidity; Lake Ann and Lake Lucy are impaired for mercury in fish tissue, and Lake Riley and Lake Susan are impaired for mercury in fish tissue and excessive nutrients.

TSS concentration ranks among the highest of the monitored Minnesota River tributaries, and TP concentration is also above a majority of Minnesota River tributaries. These concentrations are likely due to bluff and ravine erosion. Cl concentration is also higher than a majority of Minnesota River tributaries, which is probably due to the developed nature of the watershed. NO_3 concentrations are among the lowest of the Minnesota River tributaries. Total loads for all four pollutants are among the lowest of the Minnesota River tributaries, which reflects the watershed's small size.

Trend analysis indicates both upward and downward trends in TSS flow-adjusted concentration since 1999; the most recent trend is of decreasing TSS flow-adjusted concentration and thus improving water quality. TP flow-adjusted concentrations decreased sharply from 1999 through 2001, but have gradually increased since, indicating a slight decline in water quality. NO_3 flow-adjusted concentrations have gradually decreased over the entire period of record, indicating improving water quality.

MCES has not conducted macroinvertebrate sampling or assessment for Riley Creek.

Recommendations

This section presents recommendations for monitoring and assessment of Riley Creek, as well as recommendations for partnerships to implement stream improvements. MCES recognizes that cities, counties, and local water management organizations, like RPBCWD, are ideally suited to target and implement volume reduction, pollutant removal, and stream restoration projects within the watershed. It is beyond the scope of this document to suggest locations for implementation projects. Instead, MCES encourages the local water management organizations to use the results of this report to leverage funding and partnerships to target, prioritize, and implement improvement projects. MCES will repeat its analysis of water quality trends in 5 years, to assess potential changes in water quality.

The following recommendations have been drafted from the results of this report and are intended to assist MCES and its partners in directing future assessment work:

- MCES should continue monitoring of Riley Creek and should partner with RPBCWD to investigate possible sources of pollutants in the creek.
- MCES should partner with the U.S. Fish and Wildlife Service to investigate the effect of Riley Creek on the Minnesota Valley National Wildlife Refuge.
- MCES should partner with the U.S. Fish and Wildlife Service to investigate the water quality of Grass Lake, and any attenuation effect it has on the actual Riley Creek loads entering the Minnesota River. In addition, the biologic and wildlife value of Grass Lake should also be evaluated.
- MCES and partners (especially RPBCWD) should create a timeline of past projects and management activities that may have improved or altered stream flow and/or water quality. This information would allow more accurate assessment and interpretation of trends.
- As resources allow, MCES should provide RPBCWD and other local water managers with information about the heightened potential for surface waters to be impacted by groundwater changes in the Riley Creek watershed. This information should be included in watershed and local surface water management plan updates.
- MCES should continue to evaluate the effects of groundwater withdrawal on surface waters, including updating analyses with the best available data and linking results to predictive groundwater modeling and the comprehensive planning process.
- As resources allow, MCES should consider initiating macroinvertebrate monitoring in Riley Creek.
- The trend analysis should be repeated in 5 years, expanding the list of assessed parameters to include NH_3, bacteria, and chlorophyll. Sufficient data should exist at that time to also assess trends in Cl and flow.

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