Comprehensive Water Quality Assessment of Select Metropolitan Area Streams

CANNON RIVER

METROPOLITAN COUNCIL

December 2014

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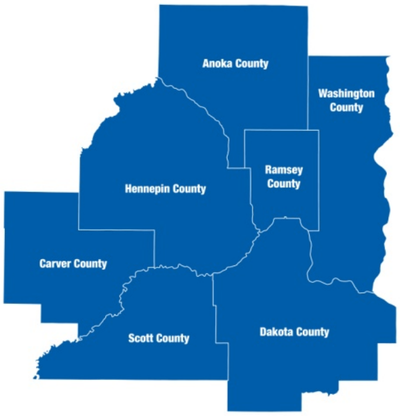

The Metropolitan Council is the regional planning organization for the seven-county Twin Cities area. The Council operates the regional bus and rail system, collects and treats wastewater, coordinates regional water resources, plans and helps fund regional parks, and administers federal funds that provide 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 22 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 22 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, *Cannon River*, is one in a series produced as part of the *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams.* Located in Freeborn, Steele, Waseca, Blue Earth, Le Sueur, Rice, Dakota, and Goodhue counties, the Cannon River is one of the eight Mississippi River tributaries examined. This section discusses a wide range of factors that have affected the condition and water quality of the Cannon River. Special funding for this project was provided through the Clean Water Fund.

CLEAN WATER LAND & LEGACY AMENDMENT

Cover Art

The photo on the cover of this section depicts the Cannon River near Welch, MN. It was provided courtesy of the MnDNR State Water Trail program.

Recommended Citations

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Content

Figures

Tables

Introduction

The Cannon River is located south of the metropolitan area and is a tributary to the Mississippi River, below the Mississippi's confluence with the Minnesota River. It drains approximately 1,470 square miles of agricultural land, grasses, forest, and urban areas (cities of Waseca, Owatonna, Faribault, Northfield, and Red Wing) through portions of Freeborn, Steele, Waseca, Blue Earth, Le Sueur, Rice, Dakota, and Goodhue Counties.

This report:

- documents the characteristics of the Cannon River 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 TSS (total suspended solids), TP (total phosphorus), and NO_3 (nitrate).
- draws conclusions about possible effects of landscape features, climatological changes, and human activities on flow and water quality.
- compares the Cannon River flow and water quality with other streams within the metropolitan area monitored by Metropolitan Council Environmental Services (MCES).
- makes watershed-specific recommendations for future monitoring and assessment activities, partnerships, 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 and load summary reports.

Partnerships

MCES has supported water quality monitoring of the Cannon River since 1999 through its Watershed Outlet Monitoring Program (WOMP). Partial funding for this site is provided by the Minnesota Legislature through a grant from the Minnesota Pollution Control Agency (MPCA) using Clean Water Land and Legacy Amendment funds. MCES partners with the Dakota County Soil and Water Conservation District to operate the station. The U.S. Geological Survey (USGS) has been monitoring river flow at this location - station number 05355200 - since 1909. The USGS also intermittently collected water quality samples at this station from 1961-1997.

Monitoring Station Description

The MCES monitoring station is located on the Cannon River near Welch, Minnesota, 11.9 miles upstream from the river confluence with the Mississippi River. MCES also operated a monitoring station on Cannon River at mile 4.0 from 1996 to 2007 as part of a special routine river monitoring study of phosphorus dynamics. The station was discontinued in 2008 due to the Minnesota Department of Natural Resources' (MnDNR) monitoring of the Cannon River at its confluence with the Mississippi River via the USGS Long Term Resource Monitoring Program. Only the data collected at the Welch station (Mile 11.9) will be discussed in this report.

The monitoring station includes continuous stage monitoring, baseflow grab sample collection, event-based composite sample collection, and *in situ* conductivity and temperature probes. The USGS and Metropolitan Council share a shelter but each has their own equipment. The USGS only monitors stage at the site and does not collect water quality samples. Stage is measured with a shaft encoder. The USGS calibrates stage on site visits with an electric tape in the stilling well. A continuous discharge record is obtained by relating stage to flow with a rating unique to the site. MCES relies on the current USGS rating which includes a flow value every 0.01 foot of stage, and fits an equation to those values. The USGS make 6-12 manual measurements a year at the site, and adjust or generate a new rating when measurements fall significantly off the existing rating, or a change in the station cross-section is observed. MCES adjusts its rating accordingly after the USGS rating is adjusted.

MCES maintains its own rating curve and stage sensor in order to trigger the autosampler for event-based composite sample collection, and in order to generate a continuous flow record for the calendar year. The USGS operates on an October-September water year, and October-December flows for a given calendar year are often not reviewed and approved by the USGS soon enough for MCES reporting purposes. During data review, the MCES and USGS flows are compared to ensure consistency.

A tipping bucket rain gauge is present at this location for measurement of precipitation. However, because there were some gaps in the precipitation record, daily precipitation totals from NWS (National Weather Service) COOP station 216822-Red Wing Dam 3 were 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 watersheds (Minnesota Climatology Working Group, 2013). These data are generated from Minnesota's HIDEN (High Spatial Density Precipitation Network) dataset. The gridded data was areally weighted based on the watershed boundaries.

The station at Welch has been in operation continuously since 1999. This report will use data from the period of record 1999-2012.

Stream and Watershed Description

The Cannon River flows from its headwaters at Shields Lake in Rice County west into Le Sueur County, then south and east back into Rice County, before draining northeast through Dakota and Goodhue Counties. The river has a total length of approximately 118 miles, and consists of several tributaries. The largest tributary, the Straight River, drains the southern third of the watershed, starting in Steele County and joining the Cannon River in Rice County near Faribault, Minnesota. Other major tributaries are Prairie Creek and the Little Cannon River, which both drain portions of the south-central watershed, and Chub Creek, which drains part of the northern watershed. Belle and Spring Creeks are both tributaries that join the Cannon River downstream of the MCES monitoring station.

In 1980, the State of Minnesota included the Cannon River from Faribault to the confluence with the Mississippi River in the Wild and Scenic Rivers Program. According to the MnDNR, in order to qualify for this program, a river "must possess outstanding scenic, recreations, natural, historical, scientific, or similar values" (MnDNR, 2014). The reach of the Cannon River from Faribault to the confluence with the Mississippi River was designated as both scenic and recreational. This designation increases the management activities to ensure the unique characteristics of the river are maintained.

The Cannon River watershed is a total of 940,540 acres, with 857,758 acres (91.2%) of the watershed upstream of the monitoring station (Figure CN-1; Table CN-1). The watershed has 553,255 acres/58.8% (511,605 acres/59.6% monitored) of agricultural land, and only 84,435 acres/9.0% (79,597 acres/9.3% monitored) of developed urban land, including the cities of Ellendale, Owatonna, Medford, Waterville, Kilkenny, Faribault, Dundas, Northfield, Nerstrand, Dennison, Randolph, New Trier, Miesville, and Cannon Falls, and portions of Geneva, Waseca, Elysian, Lonsdale, Elko New Market, and Red Wing. Only 2.2% (2.3% monitored) of the watershed is open water, while an additional 6.9% (7.0% monitored) is wetland. The majority of the open water and wetlands are in the northwestern part of the watershed. Other primary land covers in the watershed are forest and grasses/herbaceous.

Watershed management within the Cannon River watershed is covered by the Cannon River Watershed Partnership and by the North Cannon River Watershed Management Organization. The Cannon River Watershed Partnership is a nonprofit organization founded to protect and improve the water quality in the Cannon River watershed, and does not have any statutory authority. The North Cannon River Watershed Management Organization is a governmental joint powers organization between Dakota County communities contained in the watershed to manage the Cannon River watershed within Dakota County. Administrative and technical support for the North Cannon River Watershed Management Organization is provided by the Dakota County Soil and Water Conservation District. Parts of the Cannon River watershed are within the Metropolitan Council's jurisdiction (Council District 16).

Table CN-1: Cannon River Land Cover Classes[1]

Land Cover Class	Monitored		Unmonitored		Total	
	Acres	Percent	Acres	Percent	Acres	Percent
5-10% Impervious	34,327	4.0%	53	0.1%	34,380	3.7%
11-25% Impervious	9,170	1.1%	1,935	2.3%	11,105	1.2%
26-50% Impervious	15,196	1.8%	1,213	1.5%	16,409	1.7%
51-75% Impervious	3,576	0.4%	152	0.2%	3,728	0.4%
76-100% Impervious	17,328	2.0%	1,484	1.8%	18,813	2.0%
Agricultural Land	511,605	59.6%	41,650	50.3%	553,255	58.8%
Forest (all types)	66,955	7.8%	14,889	18.0%	81,845	8.7%
Open Water	20,027	2.3%	431	0.5%	20,458	2.2%
Barren Land	281	0.0%	54	0.1%	336	0.0%
Shrubland	5,041	0.6%	124	0.2%	5,165	0.5%
Grasses/Herbaceous	114,176	13.3%	15,790	19.1%	129,966	13.8%
Wetlands (all types)	60,075	7.0%	5,005	6.0%	65,080	6.9%
Total	**857,758**	**100.0%**	**82,782**	**100.0%**	**940,540**	**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 seven-county metro area; and the 2001 NLCD (National Land Cover Data), which covered the outstate areas not included in the 2008 MLCCS.

Figure CN-1

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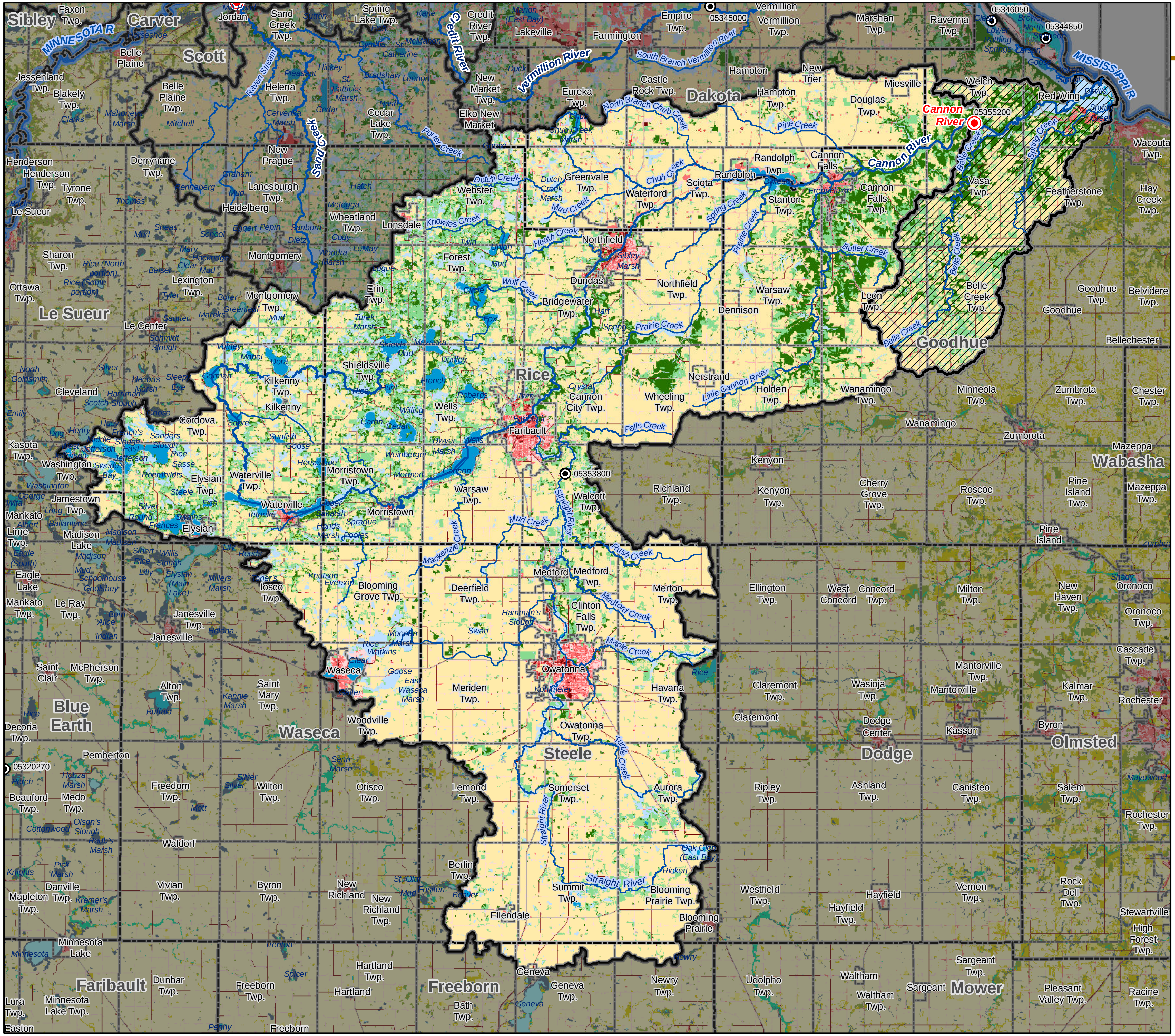
MLCCS-NLCD Hybrid Land Cover

Cannon River



MCES Stream Monitoring Sites
USGS Flow Stations
Mainstems (Monitored and Unmonitored)
Major Mainstem Tributaries
Monitored Watershed Boundaries
Unmonitored Portion of Watersheds
Highways and Other Major Roads (MnDOT)
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						
Cannon River						
	Monitored		**Unmonitored**		**Total**	
Land Cover Class	**Acres**	**Percent**	**Acres**	**Percent**	**Acres**	**Percent**
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Total	**857,758**	**100.0%**	**82,782**	**100.0%**	**940,540**	**100.0%**

0 5 10 15 20

Miles

Based on the United States Department of Agriculture (USDA), National Agricultural Statistics Service (NASS) 2009 Cropland Data Layer, 41% (41% monitored) of the agricultural land is planted in corn and 34% (34% monitored) in soybeans. According to a statewide estimate of potentially draintiled fields by University of Minnesota researchers, 24% (26% monitored) of the agricultural land in the watershed is potentially draintiled (D. Mulla, University of Minnesota, personal communication, 2012).

According to the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) STATSGO soils data, the majority (78.2%) of native soils in the monitored part of the Cannon River watershed are B soils, which have moderately low runoff potential (USDA, 2009). The monitored part of the watershed also has pockets of B/D soils (18.5%) which have high runoff potential if undrained, and moderately low runoff potential if drained; and C soils (2.7%) which have moderately high runoff potential. These soils are primarily distributed throughout the southern portion of the watershed.

The watershed topography is gently rolling ground moraine in the south with more hummocky till and outwash in the west (Lusardi et al., 2002) (Figure CN-2). The eastern, downstream part of the watershed was not glaciated during the Wisconsin ice age and is marked by a number of steep ravines carved into the underlying bedrock (Ojakangas, 1982). The ravines typically contain glacial outwash and post-glacial river sediments (Meyer, 2007). The deep ravines are caused by erosion from the mouth of the Cannon at the Mississippi River backwaters. (Schwartz and Thiel, 1954). The difference in surficial geology between the eastern and western parts of the watershed mean that the west is heavily dominated by lakes and wetlands, while the east is dominated by ravines.

The maximum watershed elevation is 1104.3 MSL (above mean sea level) and the minimum elevation is 699.1 MSL within the monitored area. 4% of the slopes in the entire watershed are considered steep, and an additional 2% are considered very steep. Steep slopes are those between 12-18%, and very steep slopes are those 18% or greater (MnDNR, 2011). The majority of steep slopes are at the downstream, northeastern part of the watershed, many in the unmonitored portion, where 9% of slopes are considered steep and 10% are considered very steep.

The Cannon River watershed contains 19 domestic wastewater treatment plants (WWTPs; Table CN-2), including three Class A facilities - the Northfield, Faribault, and Owatonna WWTPs - which together have a design flow of 17.2 MGD (26.6 cfs) (Figure CN-3, Table CN-2). All WWTPs are within the monitored part of the watershed. The six largest plants in the watershed have all begun phosphorus removal as of 2012. The watershed also has three cooling, potable, treatment and dewatering facilities, 16 industrial wastewater permit holders, and 49 industrial stormwater permit holders within the monitored part of the watershed. There is one additional industrial stormwater permit holder in the unmonitored portion. Some of these facilities have multiple discharge points shown on Figure CN-3.

The Cannon River watershed has 1,639 registered feedlots in its monitored area with a total of 190,221 animal units (AUs), and an additional 159 feedlots in the unmonitored area with 23,881 AUs. 455 of the feedlots in the monitored area have 100 AUs or more, and 63 feedlots in the unmonitored area have 100 AUs or more. The largest feedlot in the watershed is a pig farm with 2,880 AUs.

Table CN-2: Permitted Domestic Wastewater Treatment Facilities Discharging to Cannon River at Welch

Permit #[1]	Permit Holder	Design Flow (mgd)	Class[2]	Phosphorus Removal[3]	General Notes[2]
MN0030121	Faribault WWTP	7	A	Commenced 01/2012	--
MN0024368	Northfield WWTP	5.2	A	Commenced 07/2001	--
MN0051284	Owatonna WWTP	5	A	Commenced 10/2011	--
MN0022993	Cannon Falls WWTP	0.92	B	Commenced 03/2005	--
MN0031241	Lonsdale WWTP	0.687	B	Commenced 12/2004	--
MN0025208	Waterville WWTP	0.4	B	Commenced 12/2008	1 mg/l limit included in 2003 permit
MNG550017	Morristown WWTP	0.21	B	NA	--
MN0021776	Walnut Grove WWTP	0.203	B	NA	--
MN0024112	Medford WWTP	0.14	B	NA	--
MN0041114	Elysian WWTP	0.13	D	NA	--
MNG580014	Ellendale WWTP	0.1003	D	NA	--
MN0021008	Geneva WWTP	0.069	D	NA	--
MN0065668	Nerstrand WWTP	0.042	C	NA	--
MN0022195	Dennison WWTP	0.025042	D	NA	--
MNG580084	Kilkenny WWTP	0.0228	D	NA	--
MN0041106	Lazy U Community Mobile Home Park	0.0218	D	NA	--
MN0068713	Meriden Township WWTP	0.0161	D	NA	--
MN0049514	MNDOT Straight River Rest Area	0.012	D	NA	--
MN0068802	Hope - Somerset Township WWTP	0.0102	C	NA	--

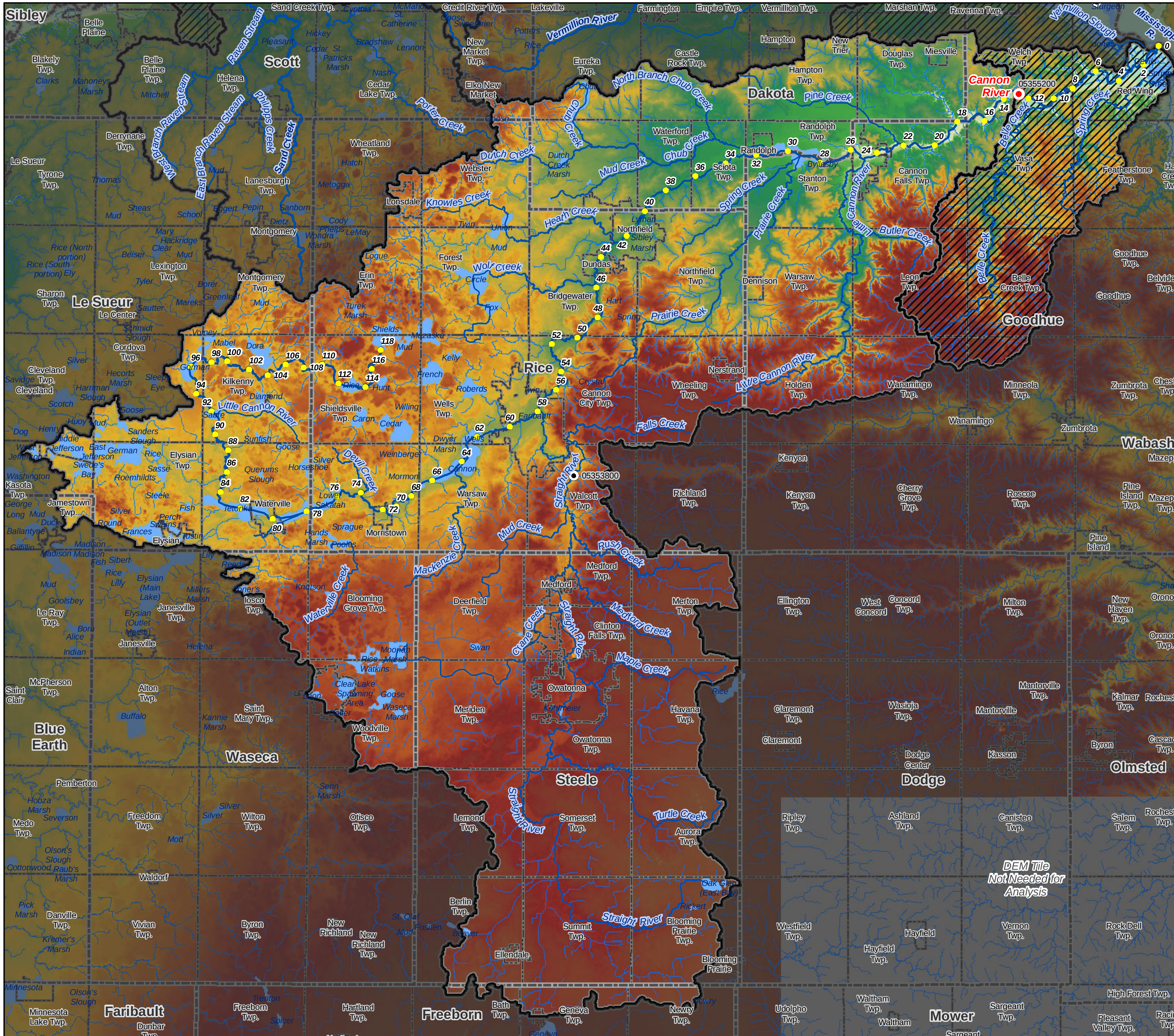
[1] Facilities with design flow > 1 mgd shown in gray

[2] In general, Class A and B WWTPs use mechanical systems with activated sludge that continuously discharge. Class D WWTPs are stabilization ponds that are allowed to discharge March 1-June 15 (spring discharge) and September 15- December 31 (fall discharge). See Minn.Rule 9400.0500 Classification of Facilities for more information.

[3] Information provided by MPCA, April 2013. Information was not tabulated for smallest facilities, thus labeled NA.

Figure CN-2

Watershed Topography
Cannon River



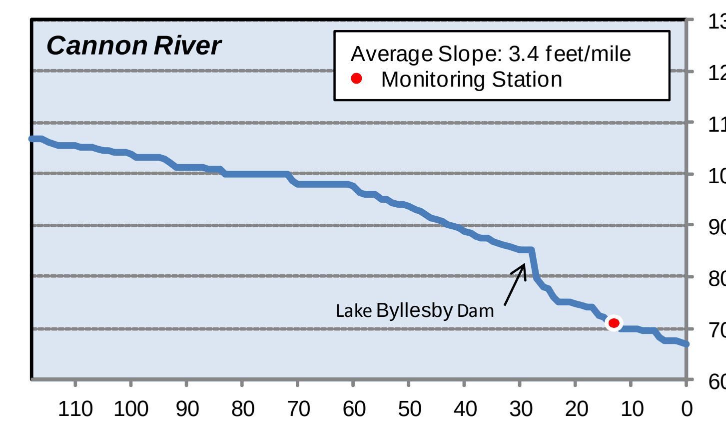
- MCES Stream Monitoring Sites
- USGS Flow Stations
- Stream Mile Markers
- Mainstems (Monitored and Unmonitored)
- Monitored Watershed Boundaries
- Unmonitored Watershed Areas
- Public Waters Inventory
- Other Rivers and Streams
- City and Township Boundaries
- County Boundary

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 2 4 6 8 10 12 16

Miles

Figure CN-3

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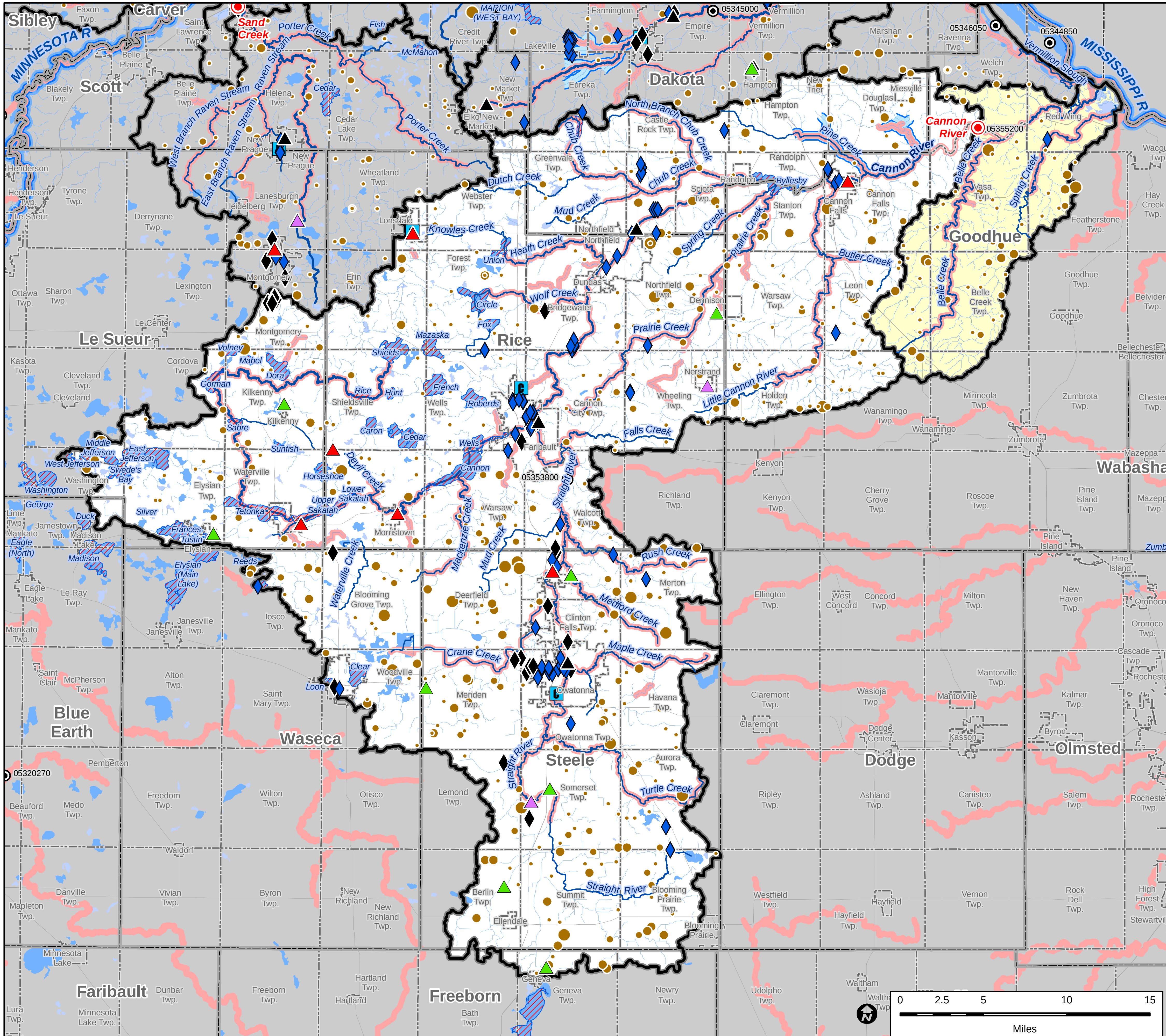
Public and Impaired Waters and Potential Pollution Sources

Cannon River



- 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

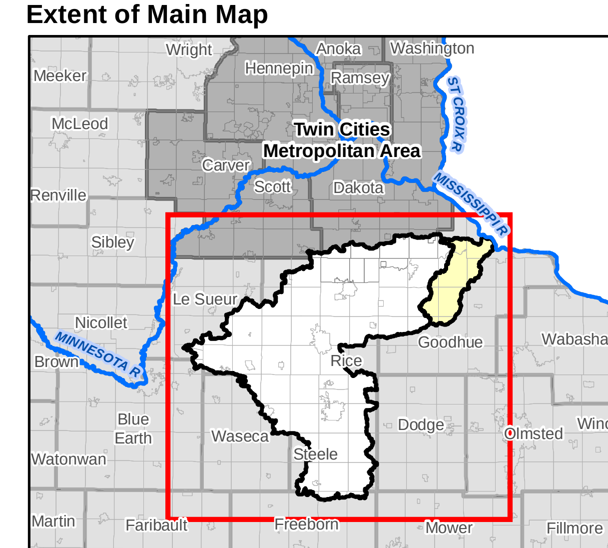
Feedlots with 100 or more animal units **

- 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 *
- Highways and Major Roads ***
- County Boundary
- City and Township Boundaries

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

Extent of Main Map



Water Quality Impairments

The Cannon River watershed contains 59 stream reaches (52 in the monitored part of the watershed) that are included on the MPCA 2014 303d list (Figure CN-3, Table CN-3). This includes 12 reaches of the Cannon River, from the headwaters at Shields Lake to the confluence with the Mississippi River, excluding the reaches through Cannon Lake and Lake Byllesby; 5 reaches of the Straight River, and a number of other tributaries to the Straight and Cannon Rivers. Common impairments for stream reaches in the watershed are aquatic recreation due to *E. coli* (*Escherichia coli*) or fecal coliform levels, and aquatic life due to turbidity or macroinvertebrate assessments. Five reaches of the Cannon River are impaired for aquatic consumption based on PCB in fish tissue, and five different reaches are impaired for aquatic consumption based on mercury in fish tissue. Four reaches - Unnamed creek (Spring Brook), Unnamed creek (Trout Brook), Little Cannon River from T110 R18W S10, west line to T111 R18W S13, east line, and Pine Creek - are impaired for drinking water based on nitrate levels. All the reaches impaired for aquatic consumption based on mercury in fish tissue have approved TMDL plans, as well as the majority of reaches impaired for aquatic recreation based on fecal coliform levels. Very few other TMDL plans have been completed in the watershed. Four reaches - Cannon River from T110 R20W S19, NE1/4 line to Wolf Cr, Cannon River from Cannon Lk to Straight R, Straight River from CD 25 to Turtle Cr, and Straight River from Turtle Cr to Owatonna Dam - were delisted for aquatic life based on turbidity in 2014 based on new data showing the reaches meet standards. The aquatic life impairment for Heath Creek based on turbidity was removed in 2013 because the original listing dataset included a lake outlet site which was not representative of the reach. New, more comprehensive data meets the standard.

The Cannon River watershed also has 36 lakes (all within the monitored part of the watershed) included on the MPCA 2014 303d list (Figure CN-4, Table CN-4). These lakes are mostly in the western part of the watershed. All of the lakes on the list are impaired for aquatic recreation due to nutrient levels, and no nutrient TMDL plans have been completed in the watershed. Almost half of the lakes are also impaired for aquatic consumption due to mercury in fish tissue. All but three of these lakes (Masaska, Sabre, and Volney) have approved TMDL plans for aquatic consumption due to mercury levels.

Table CN-3: Cannon River Impaired Stream Reaches as Identified on the MPCA 2014 Impaired Waters List

Reach Name	Reach Description	Reach ID	Affected Use(s)[1]	Approved Plan[2]	Needs Plan[2]
Belle Creek	Headwaters to Hwy 19	07040002-735	AQL, AQR	--	*E.coli*, T
Belle Creek	Hwy 19 to Cannon R	07040002-734	AQL, AQR	--	*E.coli*, T
Butler Creek	Unnamed cr to Little Cannon R	07040002-590	AQL, AQR	--	*E.coli*, M-IBI, T
Cannon River	Belle Cr to split near mouth	07040002-501	AQC, AQR	--	*E.coli*, PCBF
Cannon River	Byllesby Dam to Little Cannon R	07040002-539	AQC, AQL	--	M-IBI, PCBF

Cannon River	T110 R20W S19, NE1/4 line to Wolf Cr	07040002-582	AQC, AQL, AQR	HgF, T (delisted for T in 2014)	*E.coli*, M-IBI
Cannon River	Pine Cr to Belle Cr	07040002-502	AQC, AQL, AQR	FC, T	PCBF
Cannon River	Wolf Cr to Heath Cr	07040002-507	AQC, AQL, AQR	HgF	*E.coli*, M-IBI, T
Cannon River	Headwaters to Cannon Lk	07040002-542	AQL, AQR	--	DO, *E.coli*, M-IBI
Cannon River	Cannon Lk to Straight R	07040002-540	AQR	T (delisted for T in 2014)	*E.coli*
Cannon River	Heath Cr to Northfield Dam	07040002-508	AQC, AQL, AQR	HgF	*E.coli*, T
Cannon River	Northfield Dam to Lk Byllesby inlet	07040002-509	AQC, AQL, AQR	FC, HgF	F-IBI, M-IBI, T
Cannon River	Little Cannon R to Pine Cr	07040002-538	AQC	--	PCBF
Cannon River	Straight R to T110 R20W S19, SE1/4 line	07040002-581	AQC, AQR	HgF	*E.coli*
Cannon River	North branch of split to Vermillion R	07040002-646	AQC, AQL	T	PCBF
Chub Creek	Headwaters to Cannon R	07040002-528	AQL, AQR	FC	F-IBI, M-IBI
Chub Creek, North Branch	T113 R19W S19, west line to Chub Cr	07040002-566	AQR	--	FC
County Ditch 63	Unnamed cr to Lk Dora	07040002-621	AQR	--	*E.coli*
Crane Creek	Headwaters (Watkins Lk 81-0013-00) to Straight R	07040002-516	AQR	FC	--
Devils Creek	Unnamed cr to Cannon R	07040002-577	AQL, AQR	--	*E.coli*, M-IBI
Falls Creek	Unnamed cr to Straight R	07040002-704	AQR	--	*E.coli*
Heath Creek[3]	Headwaters (Union Lk 66-0032-00) to Cannon R	07040002-521	AQR	--	*E.coli*
Little Cannon River (Goodhue County)	T111 R17W S18, west line to Cannon R	07040002-526	AQL, AQR	--	*E.coli*, M-IBI, T

Little Cannon River (Goodhue County)	T110 R18W S10, west line to T111 R18W S13, east line	07040002-589	AQL, AQR, DW	--	*E.coli*, NO_3, T
MacKenzie Creek	T108 R21W S7, west line to Cannon Lk	07040002-576	AQL, AQR	--	*E.coli*, M-IBI
Maple Creek	Headwaters to Straight R	07040002-519	AQR	FC	--
Medford Creek	Headwaters to Straight R	07040002-547	AQL	--	F-IBI, M-IBI
Mud Creek	Unnamed cr to Chub Cr	07040002-558	AQR	--	FC
Pine Creek	T113 R18W S26, west line to Cannon R	07040002-520	DW	--	NO_3
Prairie Creek	Headwaters to Lk Byllesby	07040002-504	AQL, AQR	FC	M-IBI, T
Rush Creek	Headwaters to Straight R	07040002-505	AQL, AQR	FC	T
Spring Creek	T112 R15W S18, west line to T113 R15W S34, north line	07040002-569	AQL, AQR	--	*E.coli*, T
Spring Creek	T113 R15W S27, south line to Hay Cr	07040002-571	AQL	--	T
Spring Creek	Unnamed cr to Unnamed cr	07040002-591	AQL	--	M-IBI
Straight River	Rush Cr to Cannon R	07040002-515	AQL, AQR	FC	M-IBI, T
Straight River	Crane Cr to Rush Cr	07040002-536	AQL	--	M-IBI, T
Straight River	CD 25 to Turtle Cr	07040002-517	AQR	FC, T (delisted for T in 2014)	--
Straight River	Turtle Cr to Owatonna Dam	07040002-535	AQR	FC, T (delisted for T in 2014)	--
Straight River	Maple Cr to Crane Cr	07040002-503	AQL, AQR	FC	M-IBI, T
Turtle Creek	Headwaters to Straight R	07040002-518	AQR	FC	--
Unnamed creek	Unnamed cr to Cannon R	07040002-702	AQR	--	*E.coli*
Unnamed creek	Unnamed cr to Cannon R	07040002-703	AQR	--	*E.coli*
Unnamed creek	Unnamed cr to Cannon R	07040002-705	AQL, AQR	--	*E.coli*, F-IBI
Unnamed creek	Unnamed cr to Cannon R	07040002-638	AQL	--	M-IBI
Unnamed creek	Unnamed cr to Belle Cr	07040002-699	AQR	--	*E.coli*

Unnamed creek	Unnamed cr to Prairie Cr	07040002-723	AQL	--	M-IBI
Unnamed creek	Unnamed cr to Unnamed cr	07040002-731	AQL	--	M-IBI
Unnamed creek	Headwaters to Prairie Cr	07040002-512	AQL, AQR	FC	M-IBI, T
Unnamed creek	Unnamed cr to Unnamed cr	07040002-513	AQR	FC	--
Unnamed creek	Unnamed cr to Unnamed cr	07040002-587	AQL	--	M-IBI
Unnamed creek (Spring Brook)	Headwaters to T111 R20W S9, north line	07040002-562	AQR	--	*E.coli*
Unnamed creek (Spring Brook)	Unnamed cr to Cannon R	07040002-557	AQL, AQR, DW	--	*E.coli*, M-IBI, NO_3, T
Unnamed creek (Trout Brook)	Unnamed cr to Cannon R (trout stream portion)	07040002-567	AQL, DW	--	NO_3, T
Unnamed creek (Trout Brook)	T113 R17W S27, east line to Unnamed cr	07040002-573	AQL	--	M-IBI
Unnamed creek (Trout Brook)	Unnamed cr to Unnamed cr	07040002-580	AQL	--	M-IBI
Unnamed ditch	T111 R22W S1, north line to Unnamed cr	07040002-555	AQL	--	F-IBI, M-IBI
Waterville Creek	Hands Marsh to Upper Sakatah Lk	07040002-560	AQL, AQR	--	*E.coli*, F-IBI, M-IBI
Whitewater Creek	Unnamed cr to Waterville Cr	07040002-706	AQL, AQR	--	*E.coli*, M-IBI
Wolf Creek	Headwaters (Circle Lk 66-0027-00) to Cannon R	07040002-522	AQL, AQR	--	*E.coli*, T

[1] AQR = Aquatic Recreation; AQL = Aquatic Life; AQC = Aquatic Consumption; DW = Drinking Water;

[2] FC = Fecal Coliform; T = Turbidity; Cl- = Chloride; F-IBI = Fisheries Bioassessments; DO = Dissolved Oxygen; M-IBI = Aquatic Macroinvertebrates Bioassessments; HgF = Mercury in Fish Tissue;

[3] Aquatic life impairment for Heath Creek based on turbidity was removed in 2013. The listing dataset included a lake outlet site which was not representative of the reach. New, more comprehensive data meets the standard.

Table CN-4: Cannon River Watershed Impaired Lakes as Identified on the MPCA 2014 Impaired Waters List

Lake Name	Lake ID	Affected Use(s)[1]	Approved Plan[2]	Needs Plan[2]
Byllesby	19-0006-00	AQC, AQR	HgF	Nutrients
Cannon	66-0008-00	AQC, AQR	HgF	Nutrients
Caron	66-0050-00	AQR	--	Nutrients
Cedar	66-0052-00	AQC, AQR	HgF	Nutrients
Chub	19-0020-00	AQR	--	Nutrients
Circle	66-0027-00	AQC, AQR	HgF	Nutrients
Clear	81-0014-01	AQC, AQR	HgF	Nutrients
Dora	40-0010-00	AQR	--	Nutrients
East Jefferson	40-0092-01	AQR	--	Nutrients
Fox	66-0029-00	AQR	--	Nutrients
Frances	40-0057-00	AQC, AQR	HgF	Nutrients
French	66-0038-00	AQC, AQR	HgF	Nutrients
German	40-0063-00	AQR	--	Nutrients
Gorman	40-0032-00	AQC, AQR	HgF	Nutrients
Horseshoe	40-0001-00	AQR	--	Nutrients
Hunt	66-0047-00	AQC, AQR	HgF	Nutrients
Loon	81-0015-00	AQC, AQR	HgF	Nutrients
Lower Sakatah	66-0044-00	AQC, AQR	HgF	Nutrients
Mabel	40-0011-00	AQR	--	Nutrients
Mazaska	66-0039-00	AQC, AQR	--	HgF, Nutrients
Middle Jefferson	40-0092-04	AQR	--	Nutrients
Rice	66-0048-00	AQR	--	Nutrients
Roberds	66-0018-00	AQR	--	Nutrients
Sabre	40-0014-00	AQC, AQR	--	HgF, Nutrients
Shields	66-0055-00	AQC, AQR	HgF	Nutrients
Silver	40-0048-00	AQR	--	Nutrients
Sunfish	40-0009-00	AQR	--	Nutrients
Swede's Bay	40-0092-03	AQR	--	Nutrients
Tetonka	40-0031-00	AQC, AQR	HgF	Nutrients
Toner's	81-0058-00	AQR	--	Nutrients

Tustin	40-0061-00	AQR	--	Nutrients
Union	66-0032-00	AQR	--	Nutrients
Upper Sakatah	40-0002-00	AQC, AQR	HgF	Nutrients
Volney	40-0033-00	AQC, AQR	--	HgF, Nutrients
Wells	66-0010-00	AQC, AQR	HgF	Nutrients
West Jefferson	40-0092-02	AQR	--	Nutrients

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

[2] HgF = Mercury in Fish Tissue; Cl = Chloride;

Hydrology

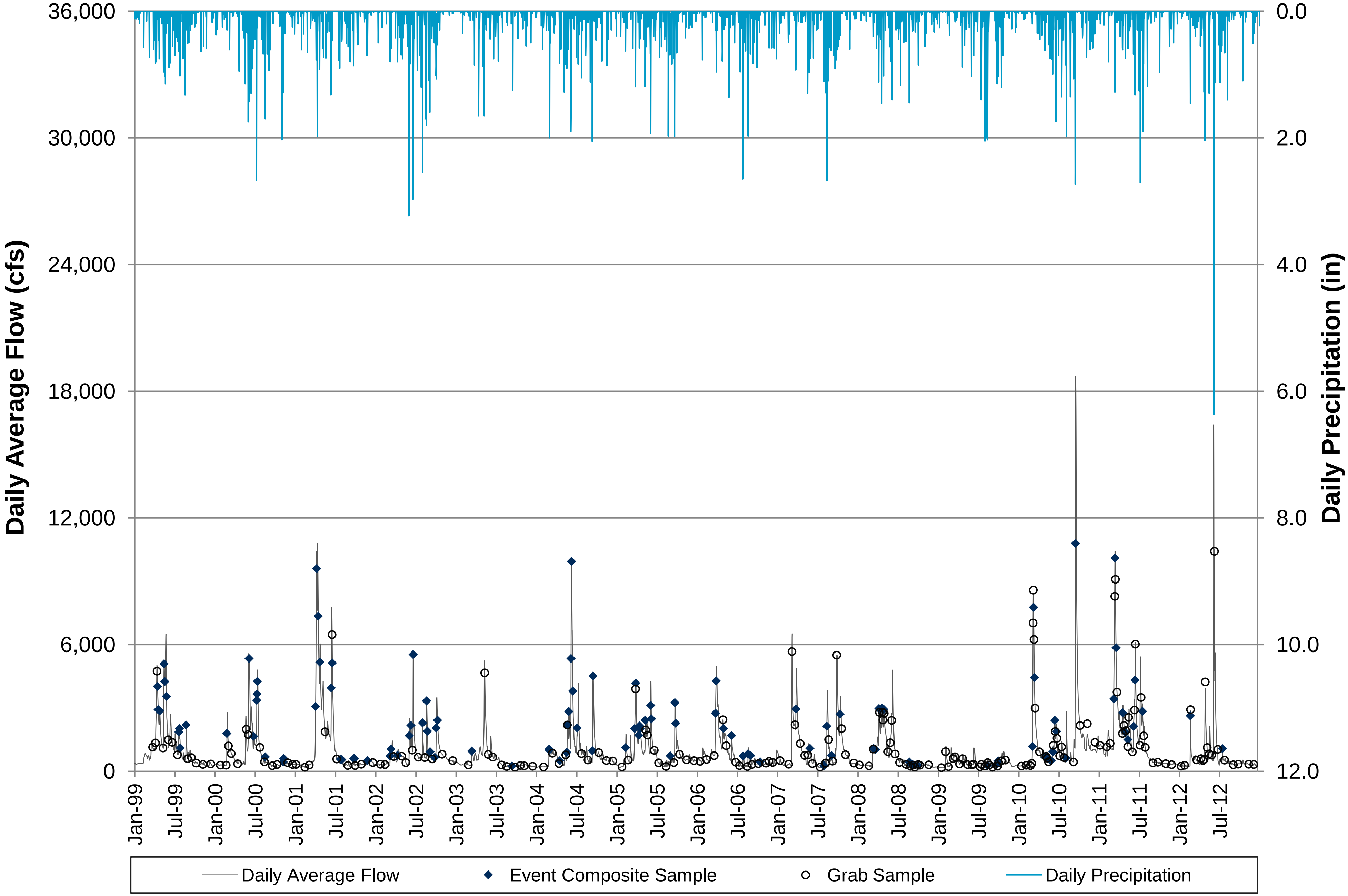
MCES has monitored flow on the Cannon River at Welch, Minnesota since 1999. Flow measurements are collected at 15-minute increments and converted to daily averages. The hydrograph of the Cannon River, which displays daily average flow, daily precipitation, and the flow associated with grab and composite samples, indicates the variations in flow rates from season to season and from year to year (Figure CN-4), and the effect of precipitation events on flow.

The MCES sampling program specifies collection of baseflow grab samples between events and event-based composites. The hydrograph indicates samples were collected during most events and that baseflow was also adequately sampled.

Analysis of the duration of daily average flows indicates that the upper 10th percentile flows for the period 1999-2012 ranged between approximately 2,100- 19,000 cubic feet per second (cfs), while the lowest 10th percentile flows ranged from 150-270 cfs. (See Figure CN-11 in the ***Flow and Load Duration Curves*** section of this report).

Additional annual flow and volume metrics are shown on Figures CN-5 to CN-8, 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; and 3) the fraction of annual precipitation ending up as flow. Figure CN-5 indicates the highest average annual flow (and thus the highest volume of flow) during 1999-2012 occurred during 2010 (approximately 1,510 cfs average annual flow); the lowest in 2009 (approximately 380 cfs average annual flow).

Figure CN-4: Cannon River Daily Average Flow, Sample Flow, and Precipitation, 1999-2012*



*Precipitation record was acquired from NWS COOP station 216822-Red Wing Dam 3

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 the Cannon River to groundwater withdrawals, MCES staff examined spatial datasets of vulnerable stream segments and basins created as part of the 2010 regional groundwater analysis. Results were available only for that portion of the Cannon River watershed located within the seven-county metropolitan area boundary, which is only a small northern part of the watershed included in Dakota County. Within Dakota County, a large number of waterbodies' bottom elevations were estimated as near or below the water table, indicating a groundwater connection. This includes Lake Byllesby, Chub Lake, and a significant number of wetlands. The length of Cannon River within Dakota County is identified as being susceptible to groundwater pumping, as well as Chub Creek and other minor tributaries to the Cannon River.

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 full year of monitored data in the Cannon River (1999-2012).

Figures CN-5 through CN-8 illustrate annual loads expressed as mass, as flow-weighted mean (FWM) concentration, as mass per unit of area (lb/ac), and as mass per unit of area per inch of precipitation (lb/ac/in), as well as three hydrological metrics (annual average flow rate, depth of flow (annual flow per unit area) coupled with precipitation depth, and runoff ratio). A later section in this report, ***Comparison with Other Metro Area Streams***, offers graphical comparison of the Cannon River loads and FWM concentrations with the other MCES-monitored metropolitan area tributaries.

The flow metrics indicate year-to-year variation in annual flow rate likely driven by variation in annual precipitation amount as well as by variation in frequency of intense storm events. The runoff ratio was relatively stable throughout much of the 2000s before dropping in 2009, increasing through 2010 and 2011, and dropping back to more typical levels in 2012. Year-to-year variation was likely influenced by drought periods, by low soil moisture caused by dry periods, and by increased capacity in upland storage areas during drought periods.

The annual mass loads for all parameters exhibited significant year-to-year variation, indicating the influence of precipitation and flow on the transport of pollutants within the watershed and the stream.

The annual FWM concentrations for all parameters also fluctuated from year-to-year and were likely influenced by annual precipitation and flow. TSS and TP concentrations peaked in 2004, decreased through 2009 (a drought year), and then increased sharply in 2010 before decreasing slightly. TDP, NO_3, NH_3, and Cl remained relatively stable over the monitoring period. Cl concentrations appeared to increase slightly over time.

Figures CN-7 and CN-8 present the areal- and precipitation-weighted loads, respectively. These graphics are presented to assist local partners and watershed managers, and will generally not be discussed here.

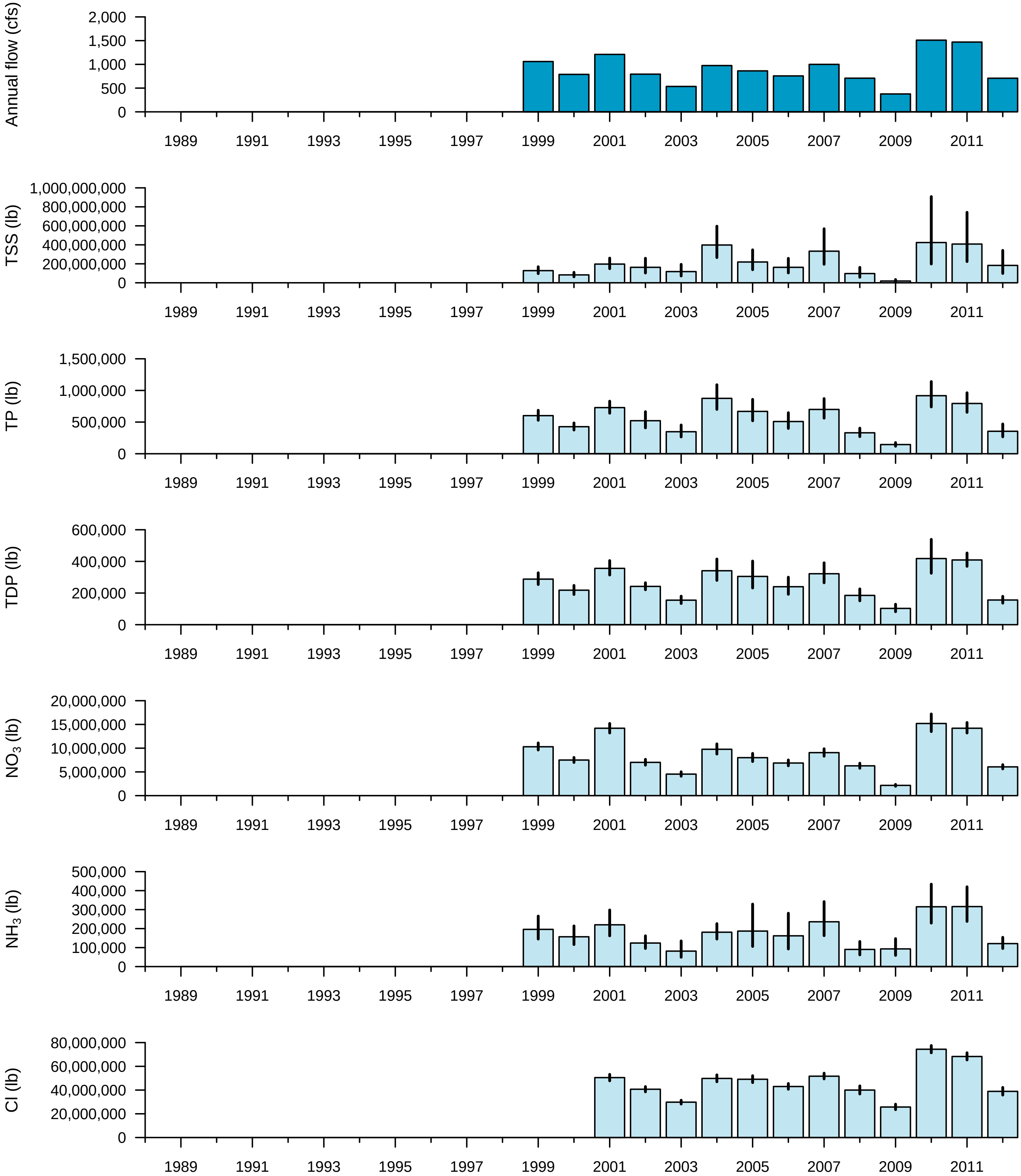
The Flux32 loads and FWM concentrations were also compiled by month to allow analysis of time-based patterns in the loads in the Cannon River (Figures CN-9 and CN-10). The results for each month are expressed in two ways: the monthly results for the most recent year of data (2012 for the Cannon River) and the monthly average for 2003-2012 (with a bar indicating the maximum and minimum value for that month).

For the constituents in the Cannon River, the mass load closely followed with monthly flow. The mass load was low in the months of January and February and then increased and peaked slightly in March, likely due to effects of snow melt and spring rains. Mass load usually peaked again in June before decreasing slightly through the summer months and then peaking again in September and October. This secondary load pulse is likely due to fall precipitation occurring after tree leaf fall and vegetation die-off. Loads fell off in November and December as lakes froze and snowpack began to build. The loads in June of 2012 were very high for all parameters, likely because of the high monthly flow.

The FWM concentration showed less month-to-month variability than the loads. TSS and TP still followed closely with flow, with the highest concentrations in the spring and fall. TDP and NO_3 concentrations were quite stable through the year. Cl concentrations were lowest in the spring and early summer, likely reflecting the impact of road de-icers during winter months. There is not a great difference in monthly Cl concentration, which may reflect the Cl in the Cannon River watershed is driven by the Cl used in water softeners which is later discharged from wastewater treatment plants rather than winter road de-icers.

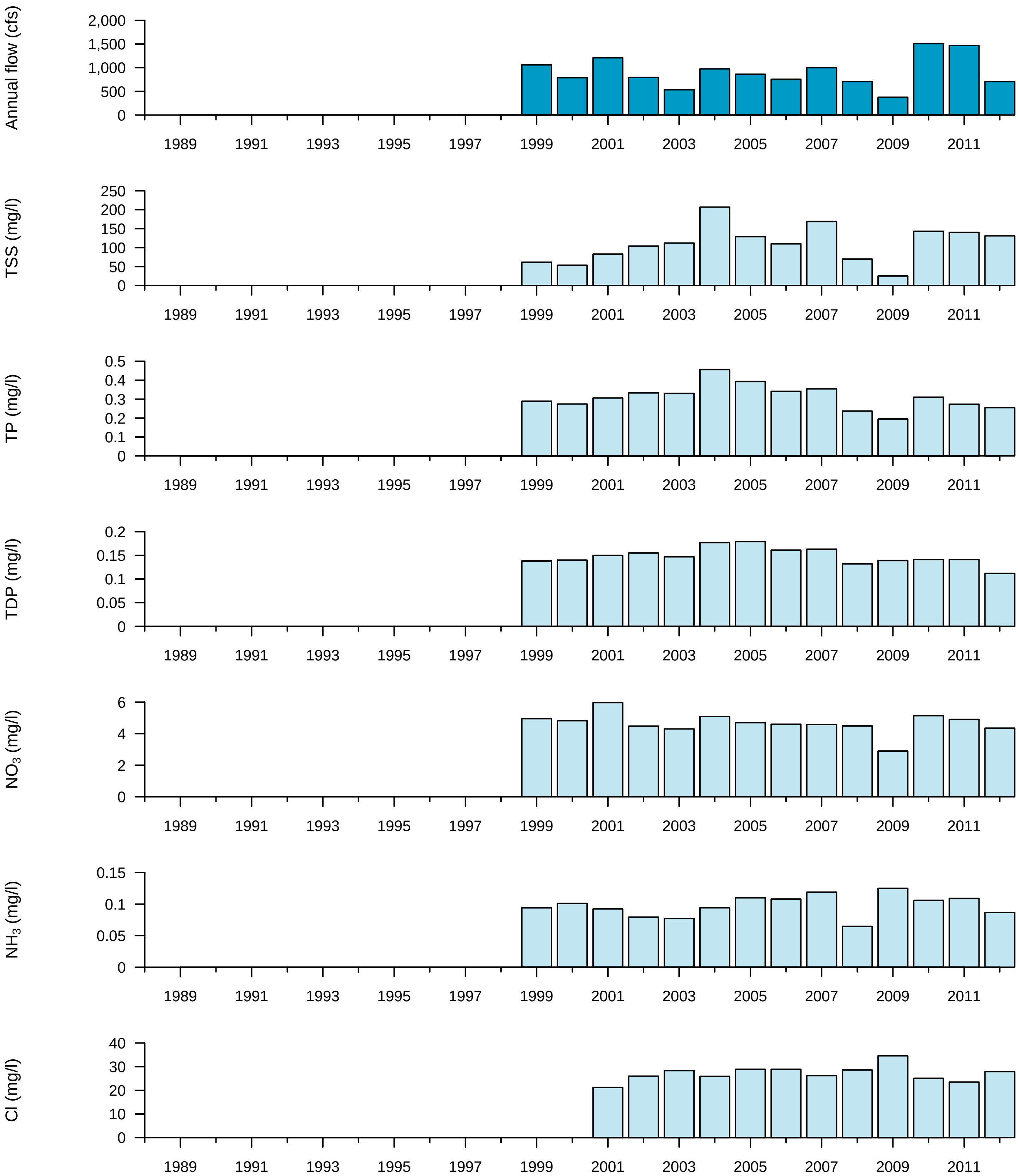
The NH_3 concentration patterns were significantly different from those of the other pollutants. NH_3 concentrations begin to increase in February and peak strongly in March, before dropping off sharply for the rest of the year. The high NH_3 concentrations may have been caused by lower rates of nitrification due to low temperatures, and limited algal assimilation because of low temperature and light limitation caused by snow cover (Lee *et al.*, 2012). There may also have been increased nitrogen mineralization of decaying organisms in the reducing environment of stream bottom sediments when the creek was frozen or partially frozen.

Figure CN−5: Cannon River*
Annual Mass Load



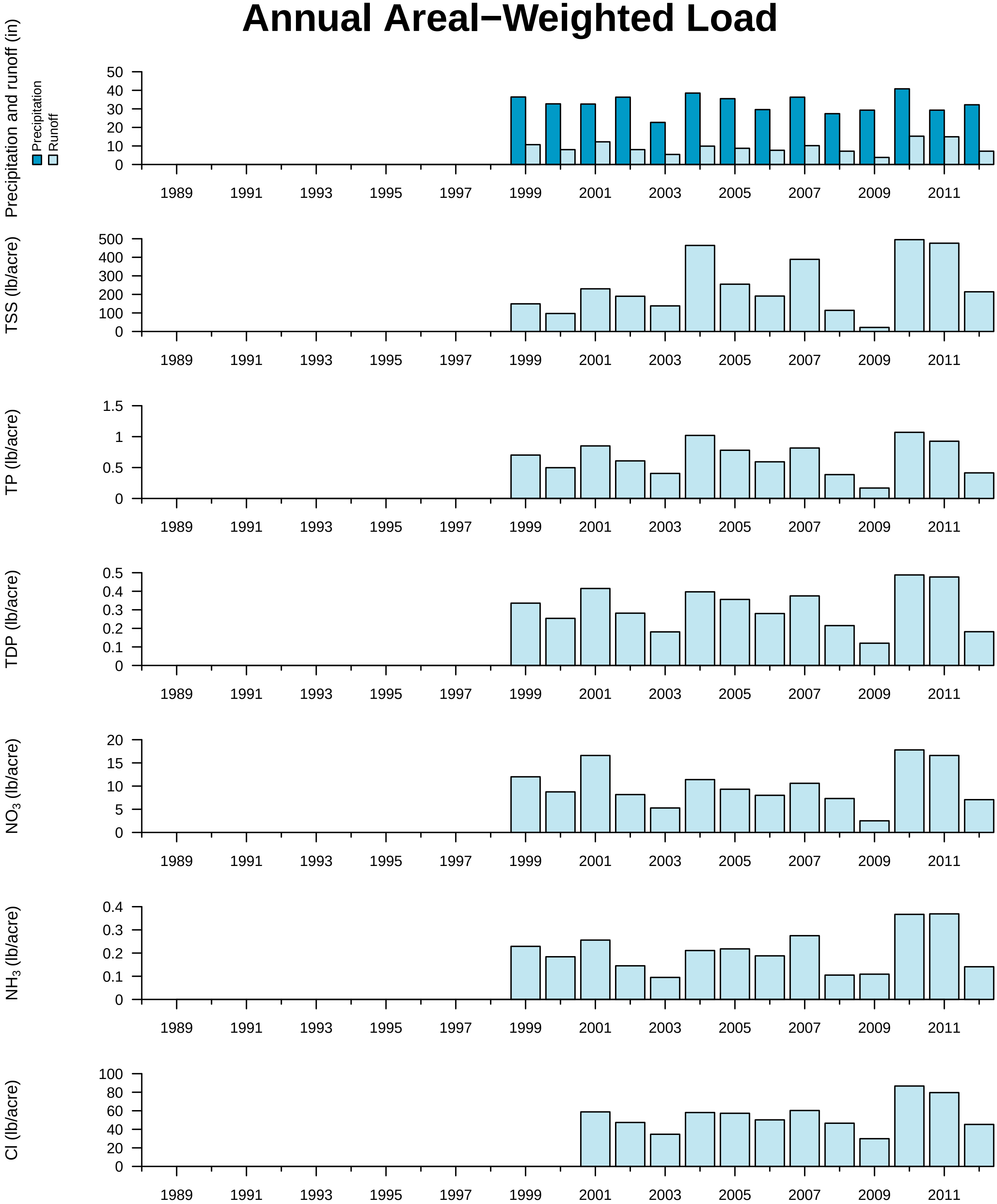
*TSS, TP, TDP, NO3, and NH3 sampling began in 1999, Cl began in 2001.
Bars represent 95% confidence intervals as calculated in Flux32.

Figure CN−6: Cannon River*
Annual Flow−Weighted Mean Concentration



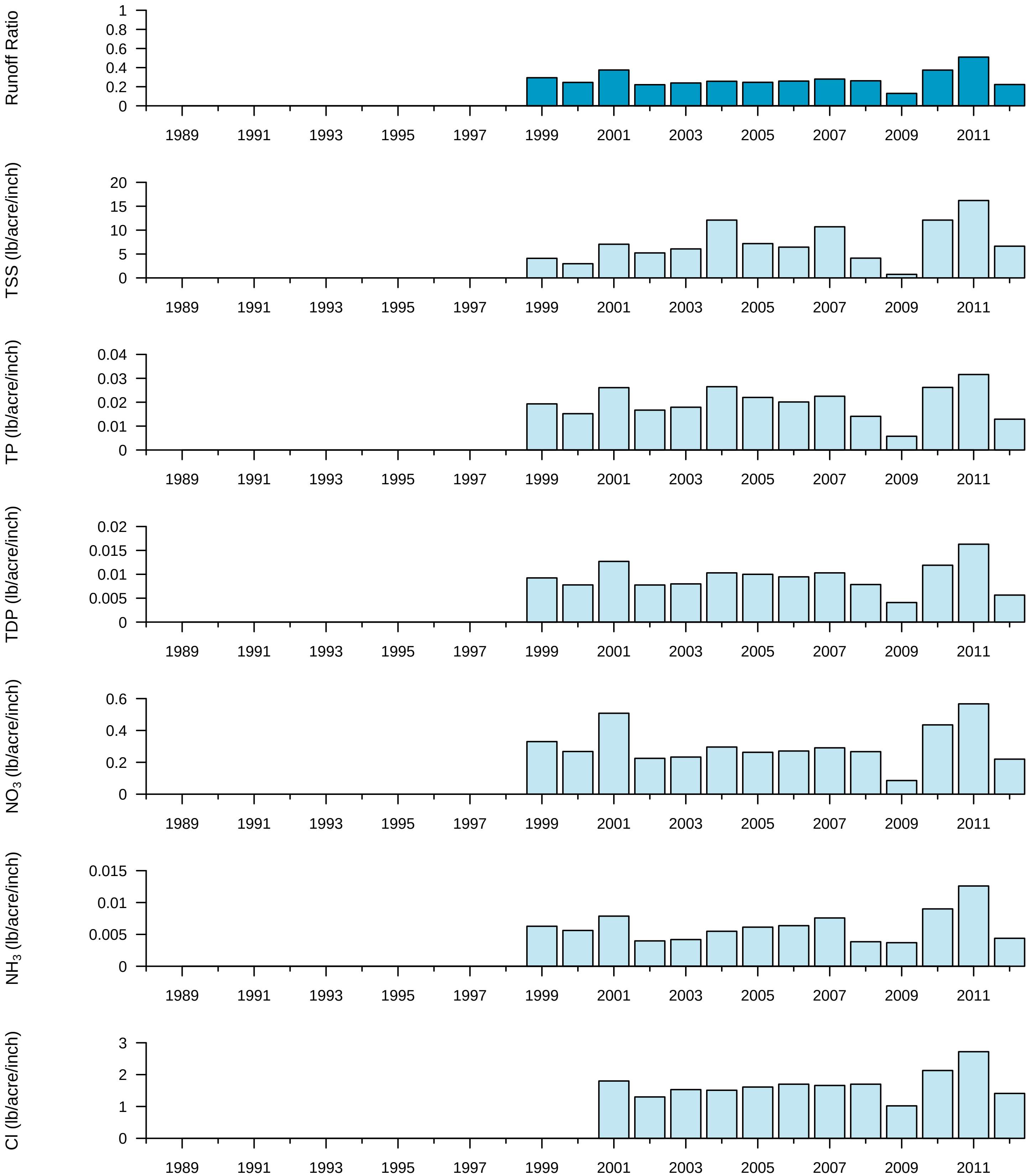
*TSS, TP, TDP, NO3, and NH3 sampling began in 1999, Cl began in 2001.

Figure CN−7: Cannon River*
Annual Areal−Weighted Load



*TSS, TP, TDP, NO3, and NH3 sampling began in 1999, Cl began in 2001.

Figure CN−8: Cannon River*
Annual Precipitation−Weighted Areal Load



*TSS, TP, TDP, NO3, and NH3 sampling began in 1999, Cl began in 2001.

Figure CN−9: Cannon River Mass Load by Month

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

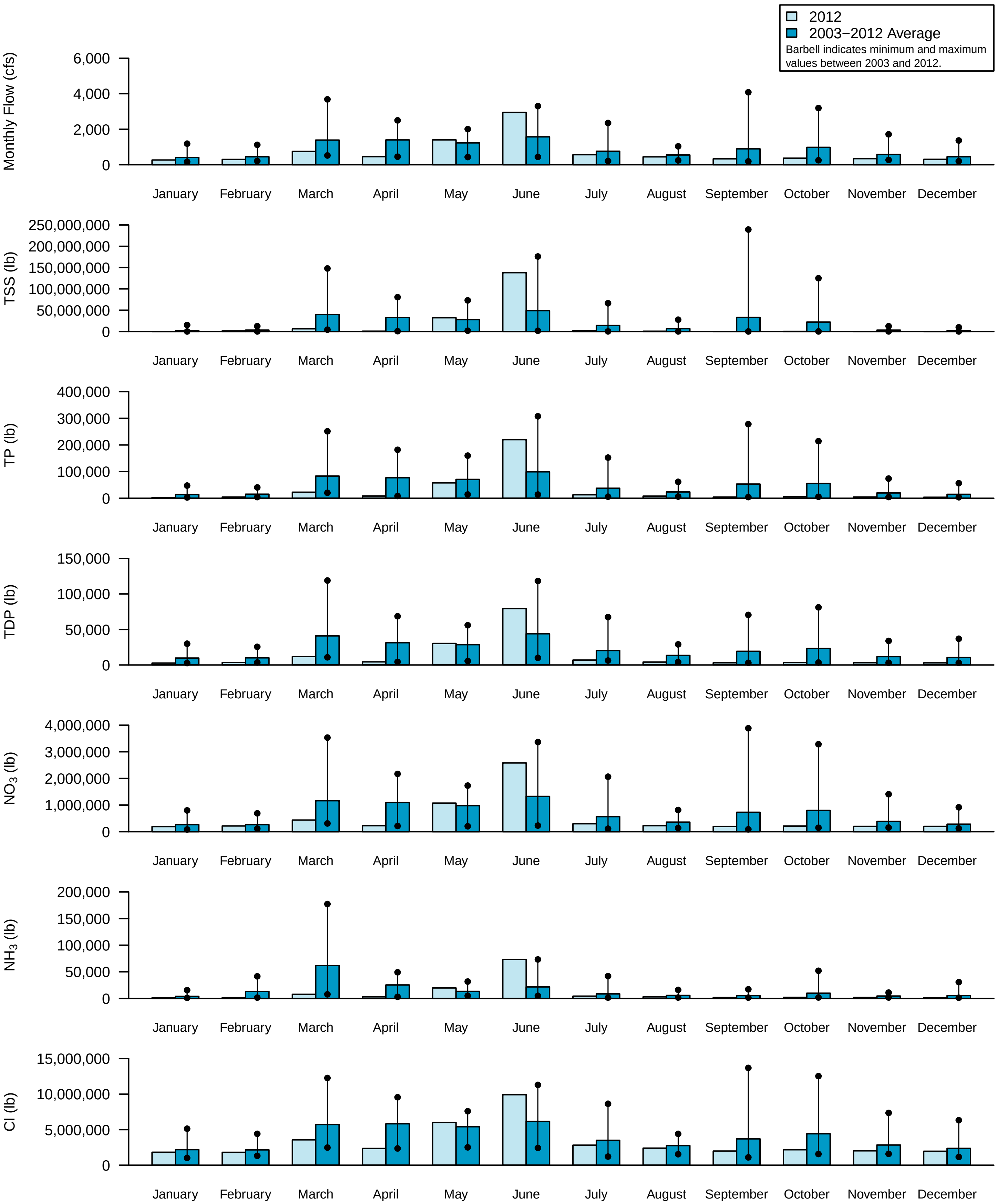
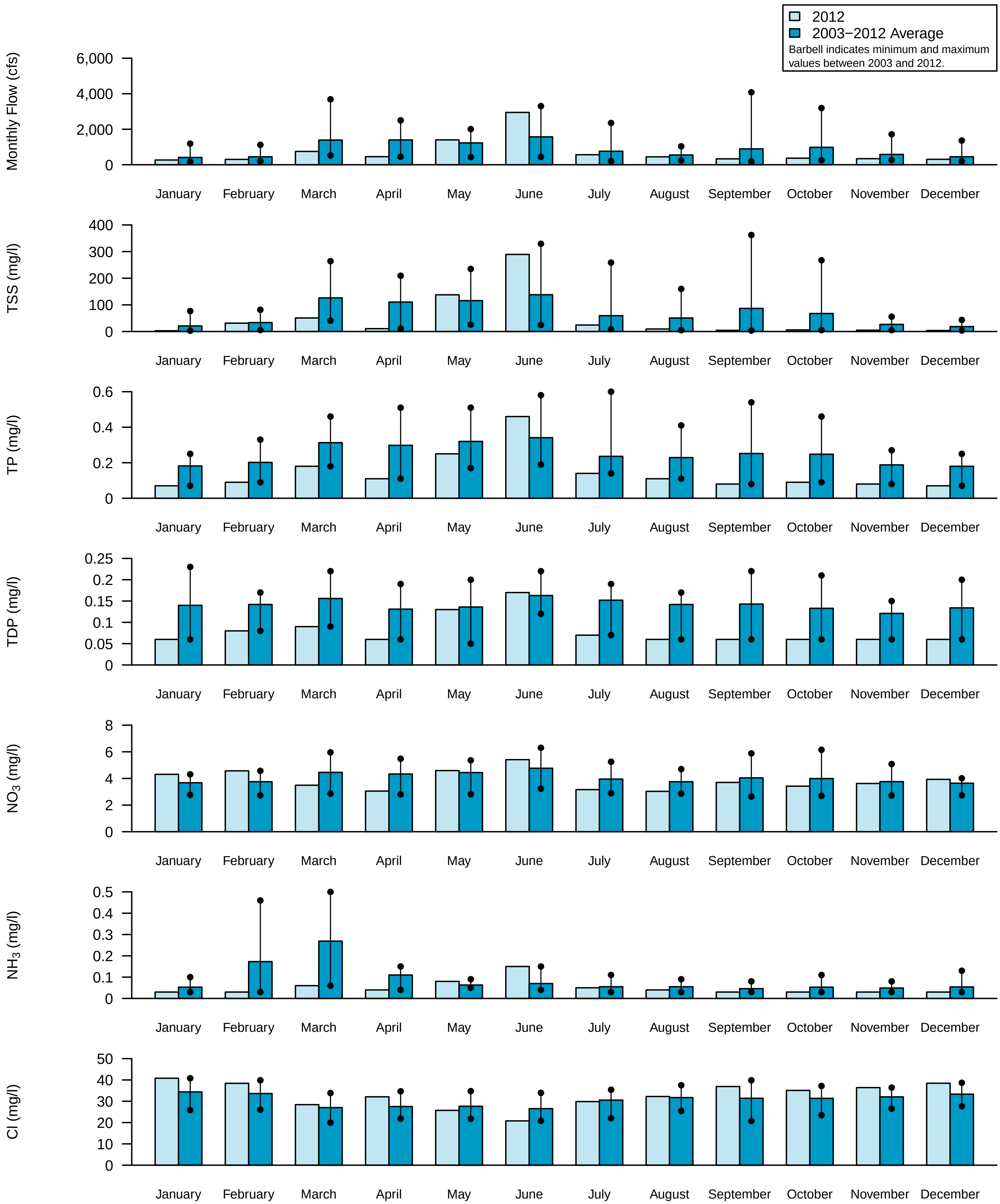


Figure CN−10: Cannon River
Flow−Weighted Mean Concentation by Month

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 location using recommendations of the U.S. Environmental Protection Agency (USEPA), 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 Cannon River monitoring station daily average flows and sample data, along with the most appropriate MPCA draft numerical standard as listed in Table CN-5. 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 Cannon River monitoring station are shown in Figure CN-11. TSS concentrations mostly remained below the draft standard at low flow and dry conditions; many samples exceed the draft standard during mid-range and moist conditions and most samples exceeded the draft standard during high flow conditions. This response is consistent with streambank and bluff erosion due to high flow runoff events.

TP concentrations consistently exceeded the draft nutrient standard concentration at all flows. The largest number of elevated concentrations was again in the mid-range to high flows. The six largest domestic WWTPs upstream of the monitoring station started effluent phosphorus reductions between 2001 and 2012. Since the stream sediments downstream of the WWTPs have likely been enriched by years of high phosphorus effluent discharge, it will take some time for the water-sediment phosphorus dynamics to equilibrate. Until then, the sediments may continue to release phosphorus to the stream flow.

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 and NO_3 concentrations in the Cannon River watershed will need to be reevaluated at that time.

Cl concentrations in the Cannon River were below the standard at all flow regimes. Concentrations were highest at the lowest flows, indicating a more consistent source of chloride such as groundwater contribution or wastewater treatment plant discharge, rather than seasonal road salt runoff.

Table CN-5: Cannon River 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[4] (mg/l)	TSS Draft Stnd[5] (mg/l)	TP Draft Stnd[6] (ug/l)	Nitrate DW Stnd[7] (mg/l)
Cannon River at Welch (CN11.9)	2B	Central[3]	230	30	100	10

[1] Minn. Rules 7050.0470 and 7050.0430.

[2] MPCA, 2010.

[3] Watershed includes more than one River Nutrient Region (RNR). Listed RNR is for watershed at monitoring station or as designated by MPCA, 2010.

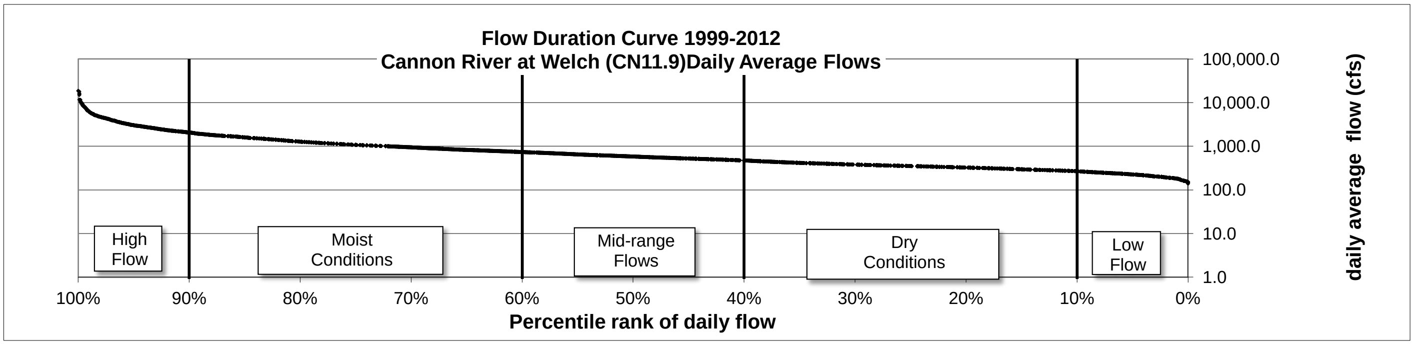
[4] Mark Tomasek, MPCA, personal communication, March 2013. MCES used 230 mg/l as the draft chloride standard pending results of EPA toxicity tests.

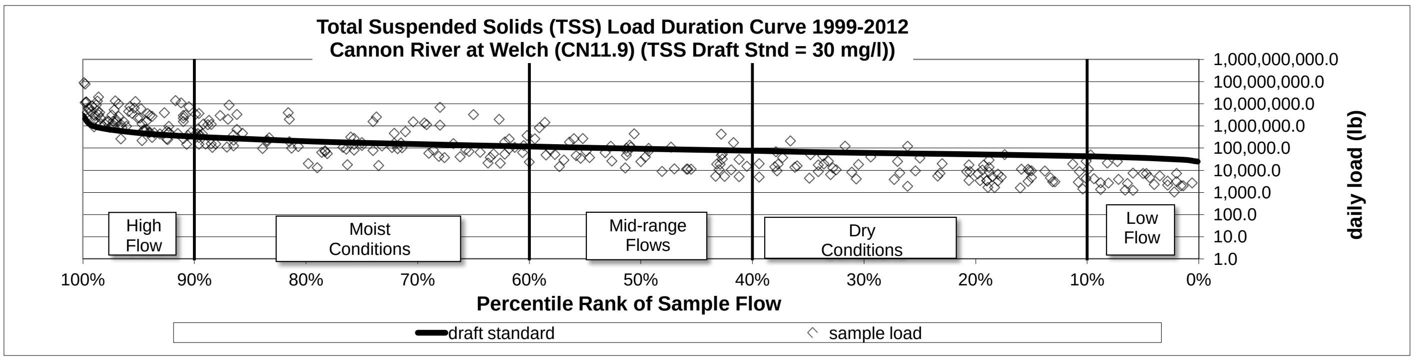
[5] MPCA, 2011. Draft standard states TSS standard concentration for Class 2A and 2B water must not be exceeded more than 10% of the time over a multiyear data window, with an assessment period of April through September.

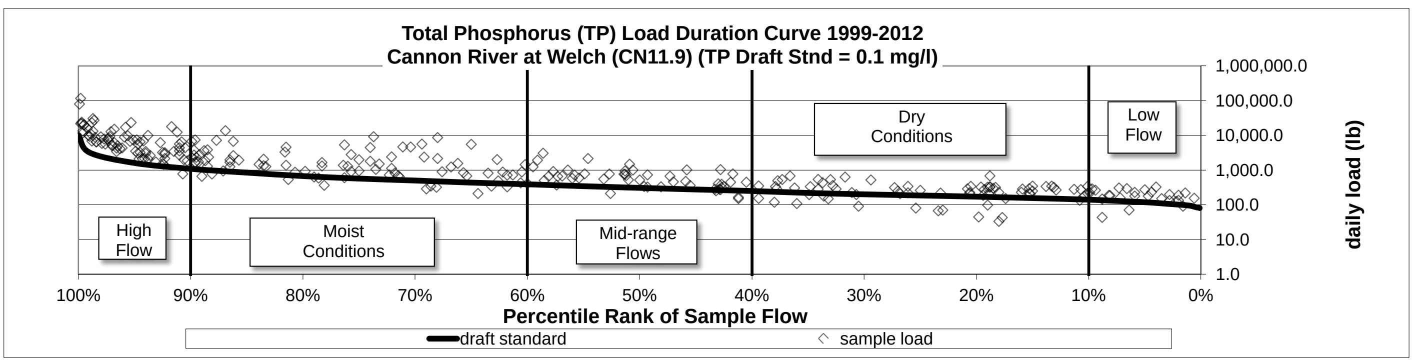
[6] MPCA, 2013a. To violate standard, concentration of causative variable (TP) must be exceeded, as well as one or more response variables: sestonic chlorophyll, BOD5, DO flux, and/or pH.

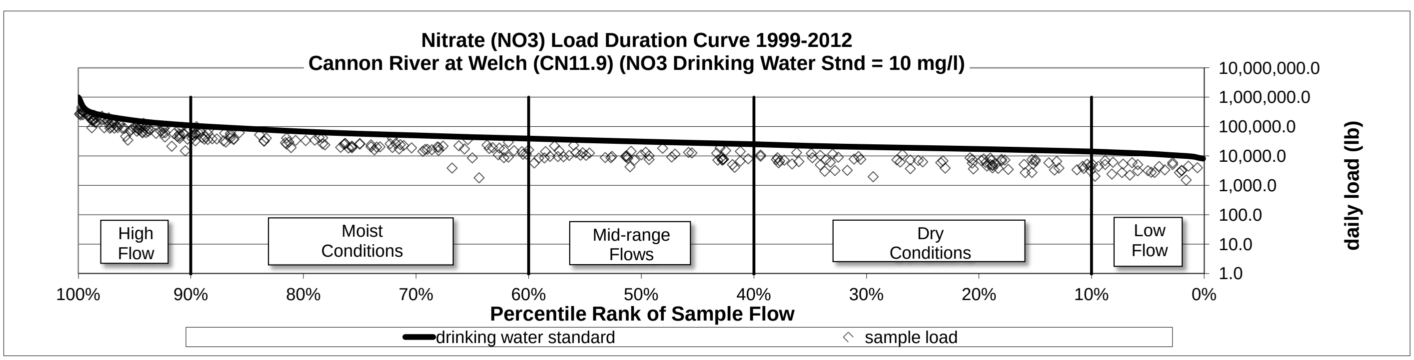
[7] MCES used the nitrate drinking water standard of 10 mg/l pending results of EPA toxicity tests and establishment of a draft nitrate standard for rivers and streams.

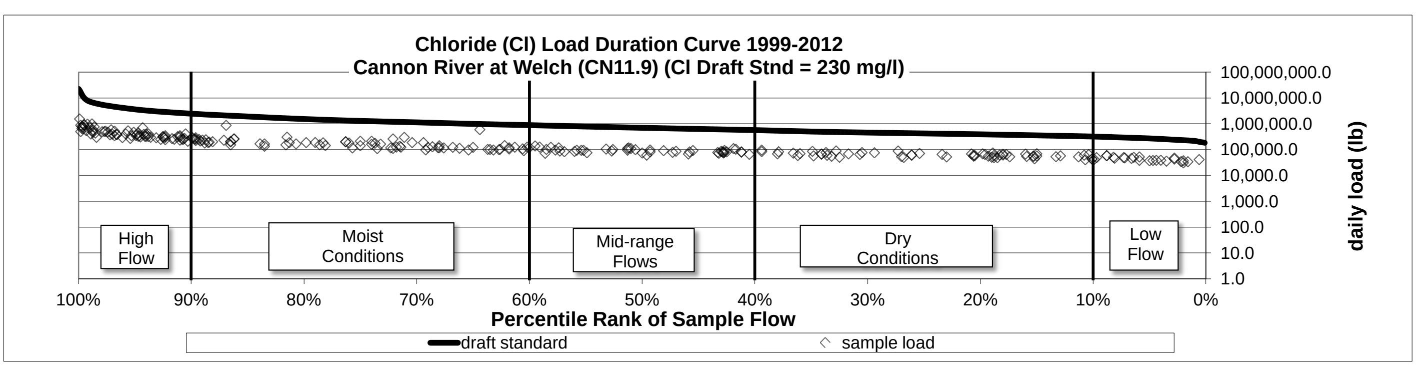
Figure CN-11: Cannon River Flow and Load Duration Curves, 1999-2012











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.

Cannon River has not been sampled for macroinvertebrates by MCES. Future adjustments to the MCES sampling program should consider adding macroinvertebrate sample collection and analysis on the Cannon River.

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 and seasonality from the statistical analysis, so any trend identified should be independent of flow or seasonal variation.

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 periods 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 likely have also 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 depressional storage. MCES staff plan to repeat the following trend analyses in five or ten 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 the Cannon River for TP, NO_3, TSS, and Chl-a, using daily average flow, baseflow grab sample, and event composite sample data. The results are presented below.

Total Suspended Solids (TSS)

One downward trend was identified for TSS flow-adjusted concentrations in the Cannon River during the assessment period from 1999 to 2012 (Figure CN-12; top graph). Based on the QWTREND model run without a five year flow precedent, the p value was 9.1×10^{-5}, indicating the trend identified was statistically significant. From 1999 to 2012, flow-adjusted TSS concentration decreased 50%, from 15.3 mg/l to 7.7 mg/l, at a rate of -0.51 mg/l/yr.

The five-year trend in TSS flow-adjusted concentration in the Cannon River (2008-2012) was calculated to compare with other MCES-monitored streams, shown in report section ***Comparison with Other Metro Area Streams***. From 2008 to 2012, TSS flow-adjusted concentration decreased 17%, 9.3 mg/l to 7.7 mg/l, at a rate of -0.32 mg/l/yr. Based on the QWTREND results, the water quality in the Cannon River improved during 2009-2012 in terms of TSS.

Total Phosphorus (TP)

Two downward trends were identified for TP flow-adjusted concentration in the Cannon River from 1999 to 2012 (Figure CN-12, second graph). Based on the QWTREND model run without a five year flow precedent, the p value was 1.35×10^{-7}, indicating the trends identified were statistically significant. From 1999 to 2007, TP flow-adjusted concentration decreased 14%, from 0.21 mg/l to 0.18 mg/l, at a rate of -0.0034 mg/l/yr. From 2008 to 2012, TP flow-adjusted concentration decreased 55%, from 0.18 mg/l to 0.08 mg/l, at a rate of -0.021 mg/l/yr.

The five-year trend in TP flow-adjusted concentration in the Cannon River (2008-2012) was calculated to compare with other MCES-monitored streams, as shown in report section ***Comparison with Other Metro Area Streams***. TP flow-adjusted concentration decreased 55%, from 0.18 mg/l to 0.08 mg/l, at a rate of -0.021 mg/l/yr. Based on the QWTREND results, the water quality in the Cannon River improved during 2009-2012 in terms of TP.

Chlorophyll a (Corrected)

Based on the QWTREND model run for chlorophyll-a (corrected) without a five year flow precedent, the p value was 0.38, indicating no statistically significant trend. Therefore, no trend was reported due to poor quality of statistical metrics (Figure CN-12, third graph).

Nitrate (NO_3)

Both upward and downward trends were identified for NO_3 flow-adjusted concentration in the Cannon River from 1999 to 2012 (Figure CN-12; bottom graph). Based on the QWTREND model run without a five year flow precedent, the p value was $p=1.4 \times 10^{-6}$, indicating the trends identified were statistically significant. From 1999 to 2006, NO_3 flow-adjusted concentration increased 8%, from 3.9 mg/l to 4.3 mg/l, at a rate of 0.04 mg/l/yr. From 2007 to 2009, NO_3 flow-adjusted concentration decreased 27%, from 4.3 mg/l to 3.1 mg/l, at a rate of -0.39 mg/l/yr. From 2010 to 2012, NO_3 flow-adjusted concentration increased 29%, from 3.1 mg/l to 4.0 mg/l, at a rate of 0.3 mg/l/yr.

The five-year trend (2008-20012) for NO_3 in the Cannon River was calculated to compare with other MCES-monitored streams, as shown in report section ***Comparison with Other Metro Area Streams***. From 2008 to 2012, NO_3 flow-adjusted concentration increased 2%, from 3.9

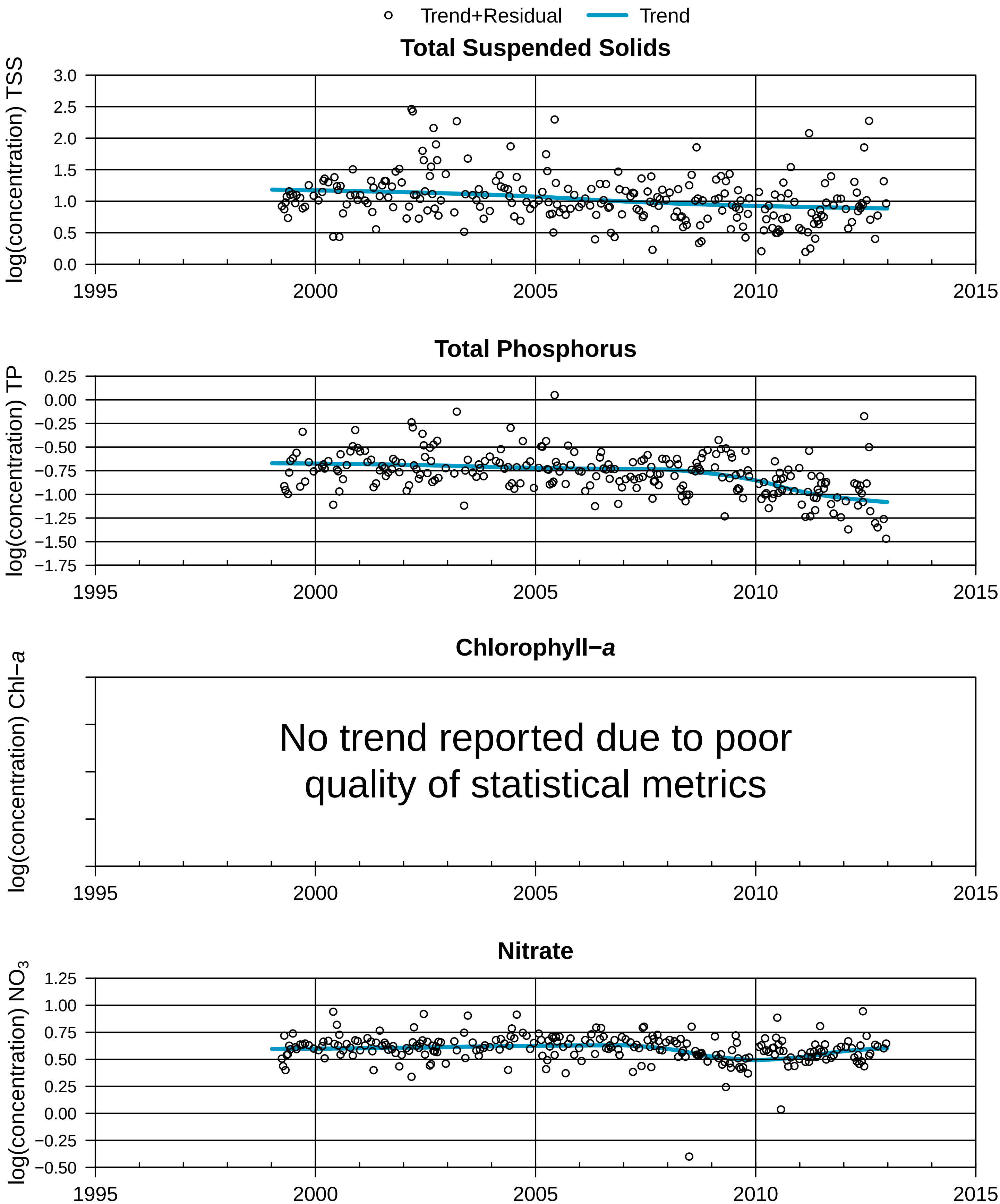
mg/l to 4.0 mg/l, at a rate of 0.013 mg/l/yr. Based on the QWTREND results, the water quality in the Cannon River declined during 2009-2012 in terms of NO_3.

While MCES staff have assessed monitoring data and trend analysis statistics, more work is needed to assign causative actions to the trend analysis results. TSS and TP chemistry, delivery, transport and remediation are complicated, although fairly well-understood. Identifying contributing events, implementation practices, and other causative actions is expected to be somewhat straightforward for these two parameters.

NO_3 chemistry and transport dynamics within the natural environmental are significantly more complicated. The NO_3 trends for most of 21 streams assessed in this study showed periods of both rising and falling flow-adjusted concentrations. NO_3 concentrations may be affected by periods of saturated and unsaturated soil conditions related to precipitation patterns, by agricultural crop rotations, by changing levels of fertilizer applications, or other unidentified causative variables, rather than true long-term improvement in concentrations based on intentional implementation of best management practices.

MCES staff will repeat the trend analysis in 5 or 10 years. In the meantime, MCES will continue to investigate the $NO_{3,}$ TSS, and TP dynamics in streams entering the metropolitan area with local partners and state agency staff.

Figure CN−12: Cannon River Trends for TSS, TP and NO_3



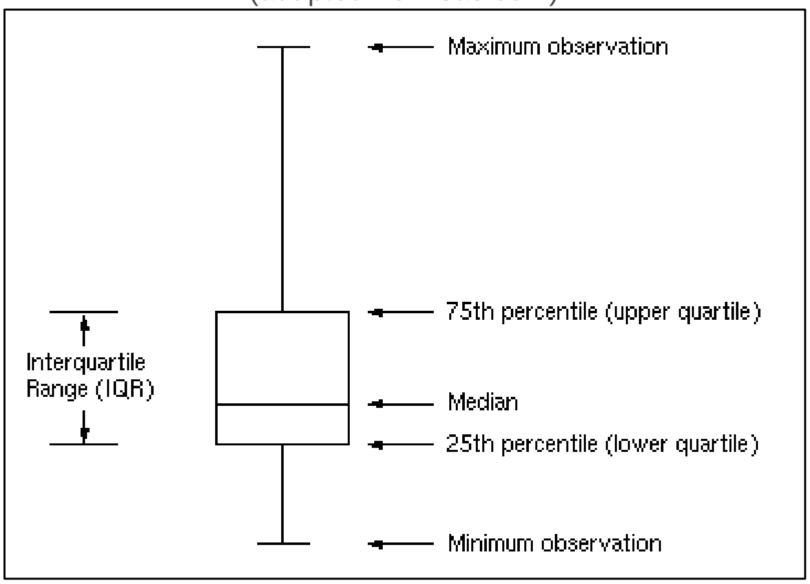
Comparison with Other Metro Area Streams

Chemistry

Box-and-whisker plots were used to summarize the comparison of the historical flow, TSS, TP, NO_3, and Cl data for the Cannon River with those of other metropolitan area streams monitored by MCES and with the major receiving water (in this case the Mississippi River above the confluence with the Minnesota River).

Figure CN-13 shows the formatted legend of the 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 CN-13: General Schematic of a Box-and-Whisker Plot
(adapted from *sas.com*)



Comparisons for each chemical parameter for the period 2003-2012 (Figure CN-14 to Figure CN-19) are shown using box-and-whisker plots of four metrics (annual flow-weighted mean (FWM) concentration, annual runoff ratio (volume/precipitation, which are identical on each of the four parameter pages), total annual load, and annual areal yield), grouped on each 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.

Flow. The median annual runoff ratio for the Cannon River is similar to but slightly higher than other highly agriculturally dominated watersheds, including the Crow and Vermillion Rivers. If the Cannon River flow was highly influenced by wetlands, lakes, or other impoundments on the stream channel, one would expect a relatively lower runoff ratio (i.e., Minnehaha Creek or Carnelian-Marine); if the flow was highly influenced by shallow groundwater inflow, one would expect a relatively higher runoff ratio (i.e. Eagle Creek or Valley Creek).

Total Suspended Solids. The FWM concentration in the Cannon River is significantly higher than that in the Mississippi River (as measured at St. Paul, Minnesota; 130 mg/l vs. 55 mg/l, respectively), indicating that the Cannon River flow serves to increase TSS concentration in the Mississippi River (Figure CN-14). The median annual FWM concentration for TSS in the Cannon River is higher than other agriculturally dominated Mississippi River tributaries (Crow River, Crow River South, Vermillion River), but is lower than agriculturally dominated Minnesota River tributaries of Bevens and Sand Creeks. All of the agricultural watersheds have significantly higher TSS concentrations than the urbanized watersheds.

Partially because of its large watershed, the Cannon River generates the largest TSS load of any MCES-monitored streams. Adjusting for area, the Cannon River's annual yield of TSS is highest of any Mississippi River tributaries, but is lower than a number of Minnesota River tributaries.

Total Phosphorus. As with TSS, the FWM TP concentration in the Cannon River is higher than that of the Mississippi River (0.32 mg/l vs. 0.15 mg/l, respectively), and thus the Cannon River flow increases the river's concentration (Figure CN-15). The Cannon River median annual FWM TP concentration is greater than the Vermillion and Crow River TP concentrations, but less than the Crow River South TP concentration. The Cannon River TP concentration is also significantly less than the median FWM concentrations of Bevens and Sand Creeks. All of the agricultural streams have a significantly higher FWM TP concentration than the more urbanized watersheds monitored by MCES.

Even though the concentrations of TP are lower than several Minnesota River tributaries, the load of TP from the Cannon River is higher than any other MCES-monitored stream, because of its large watershed. The TP concentration and load in the Cannon River is likely affected by a combination of land use management, especially in the highly agricultural sections of the watershed, and by the domestic effluent from the WWTPs in the watershed.

Nitrate. The NO_3 FWM concentration in the Cannon River is also higher than in the Mississippi River (4.6 mg/l vs. 3 mg/l, respectively), and thus the Cannon River flow increases the river concentration (Figure CN-16). The Cannon River NO_3 concentration is higher than the Vermillion and Crow Rivers, and lower than the Crow River South. It is also lower than Bevens and Sand Creeks. All of the agricultural streams have a significantly higher (often 10 times as high) FWM NO_3 concentrations than the more urbanized watersheds monitored by MCES.

The bulk of the nitrate load from MCES-monitored streams comes from the Cannon and Crow Rivers.

Chloride. The Cl FWM concentration in the Cannon River is higher than that in the Mississippi River (28 mg/l vs. 22 mg/l, respectively), and thus the Cannon River flow increases the Cl concentration in the river (Figure CN-17). The Cannon River Cl concentration is lower than other agricultural watersheds, including the Crow River South, Bevens Creek, and Sand Creek. The Crow River and Cannon River have very similar concentrations. All of the agricultural streams have a significantly lower FWM Cl concentrations than the more urbanized watersheds monitored by MCES, which have very dense road networks.

Because of the large watershed size, even with a fairly low FWM concentration the Cannon River is still one of the highest contributors of chloride load of MCES-monitored streams. The two most prevalent sources of chloride to streams are road surfaces (from chloride application as a de-icer) and WWTP effluent (from domestic water softeners).

Macroinvertebrates

In other chapters of this report, MCES created figures for area-wide comparisons of the macroinvertebrate M-IBI scores and the trends in water quality. However, since the Cannon River station was not included in the biomonitoring program, it cannot be compared to the other metropolitan area streams. Please see the other sections in the report for further information.

Figure CN−14: Total Suspended Solids for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

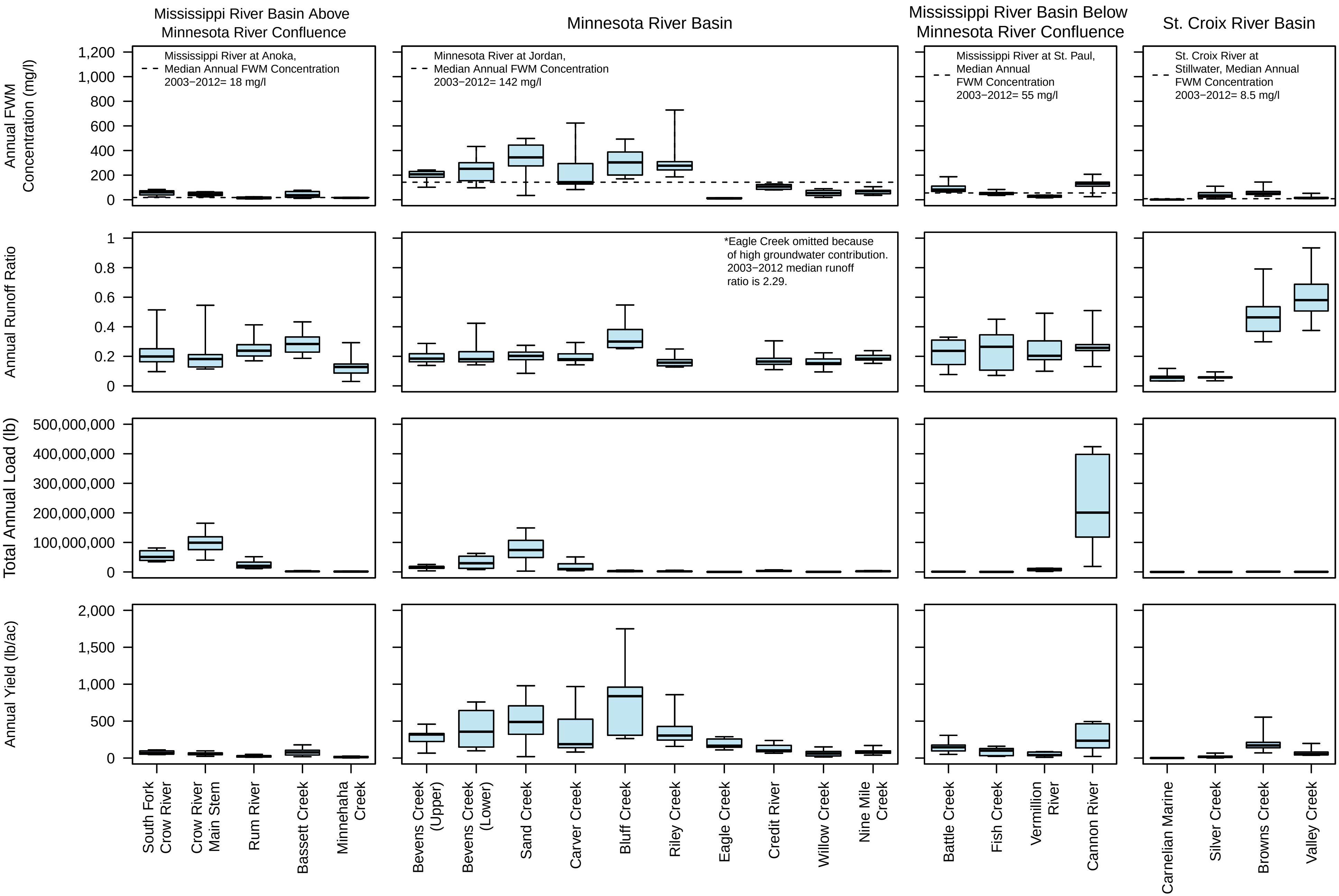


Figure CN−15: Total Phosphorus for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

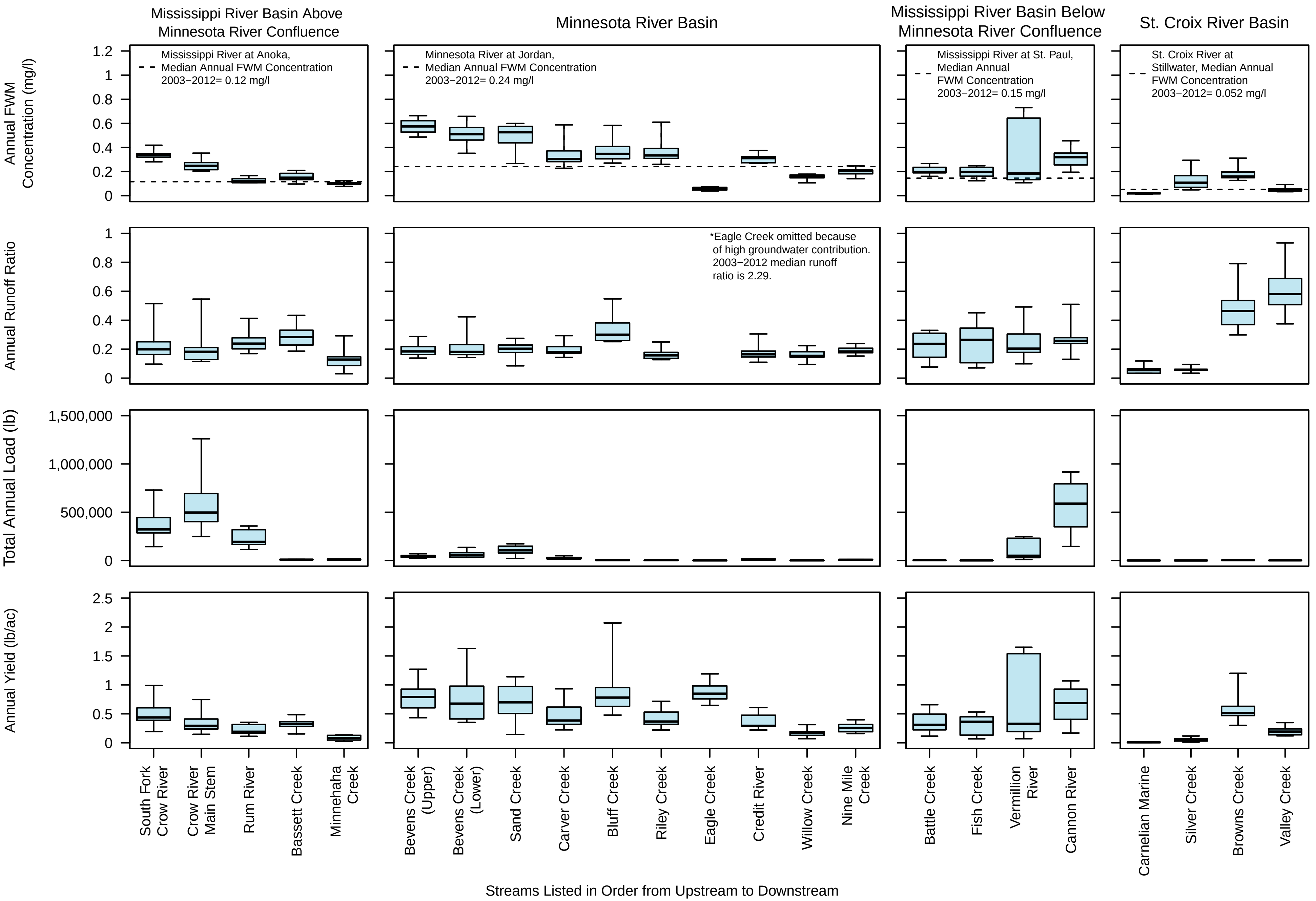


Figure CN−16: Nitrate for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

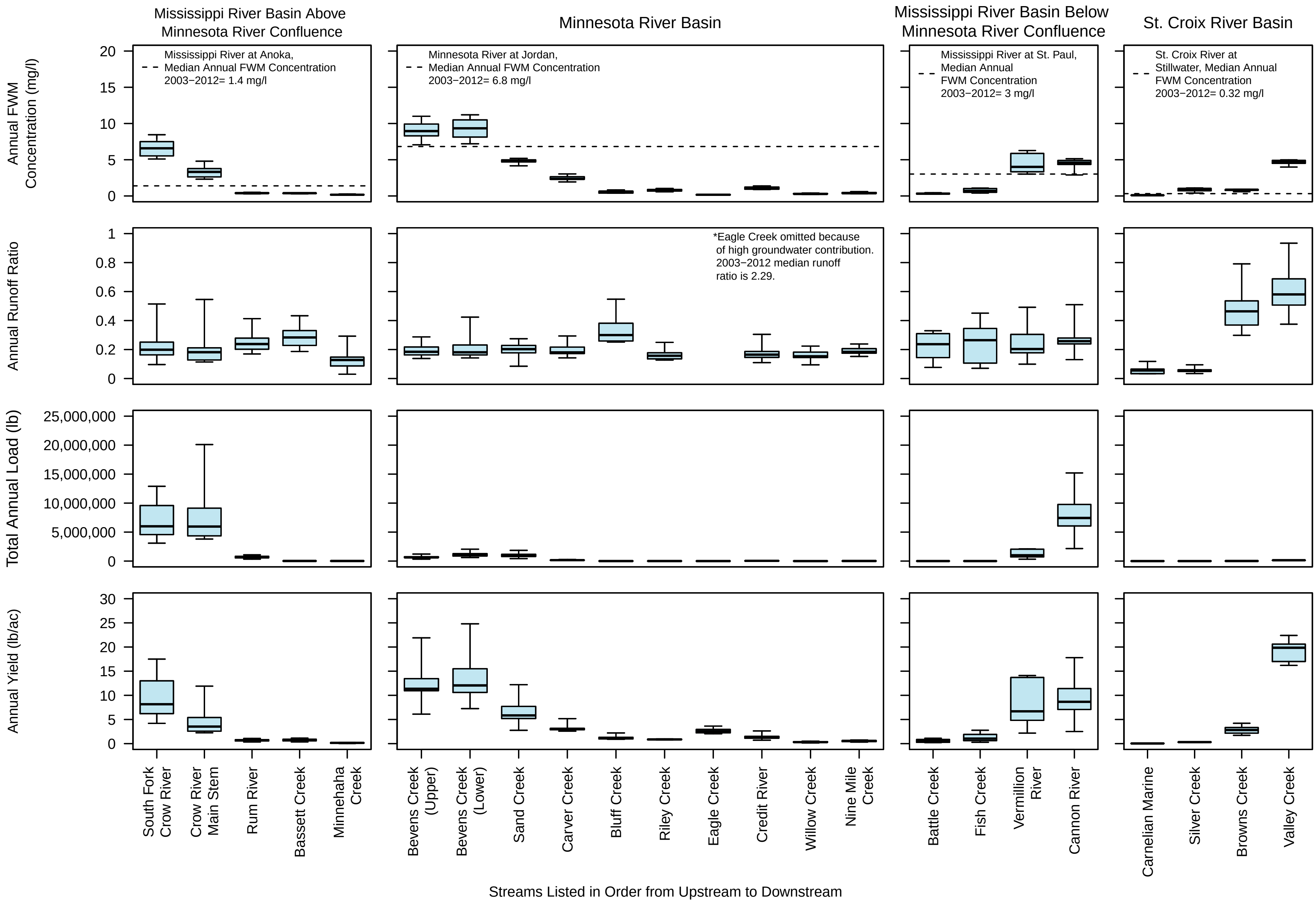


Figure CN−17: Chloride for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

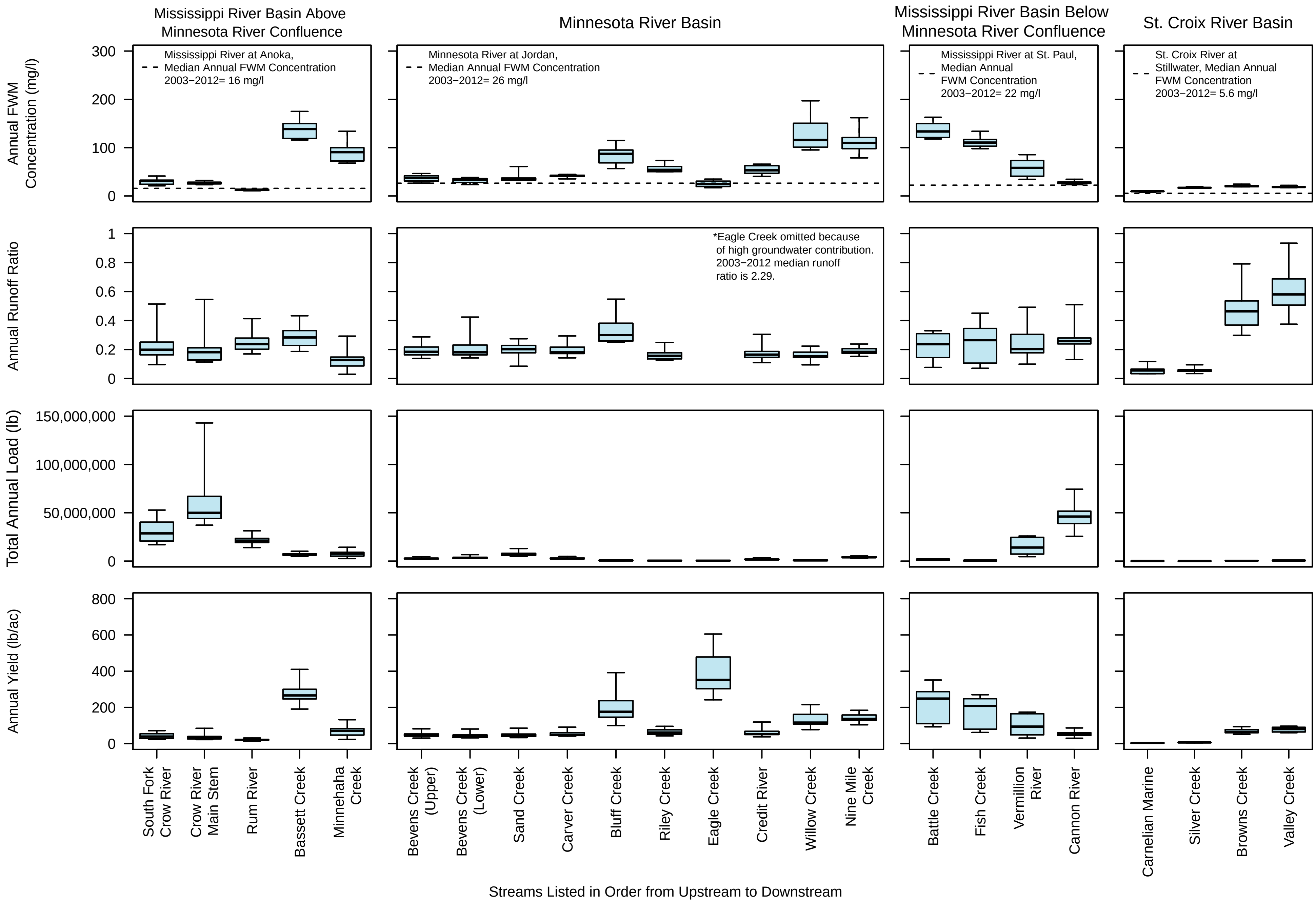


Table CN-6: Annual Median Concentrations, Loads, and Yields for MCES-Monitored Streams, 2003-2012

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 Trends 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 flow-corrected concentrations of 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 CN-18). Second, changes are shown by three seven-county metropolitan area maps (one each for TSS, TP, and NO_3 trends) with colored watersheds representing improving and declining water quality, placed at location of each monitoring station (Figure CN-19). In both figures no trend was reported for those QWTREND analyses with poor quality of statistical metrics (for example, $p>0.05$).

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 flow-adjusted concentrations increased in Carver Creek (a Minnesota River tributary) and TSS and TP increased in Browns Creek (a St. Croix River tributary).

The monitored tributaries to the Mississippi River below the confluence with the Minnesota River generally contribute waters higher in concentration in TSS and TP than the Mississippi River itself. The trend analysis results indicate decreasing flow-adjusted concentrations in TSS and TP for each of these sites, which could ultimately lead to cleaner water quality in the Mississippi River. Of the monitored tributaries to the Mississippi below the confluence with the Minnesota, both Battle Creek and the Cannon River had increasing NO_3 flow-adjusted concentrations, though the Cannon River's increase was very slight.

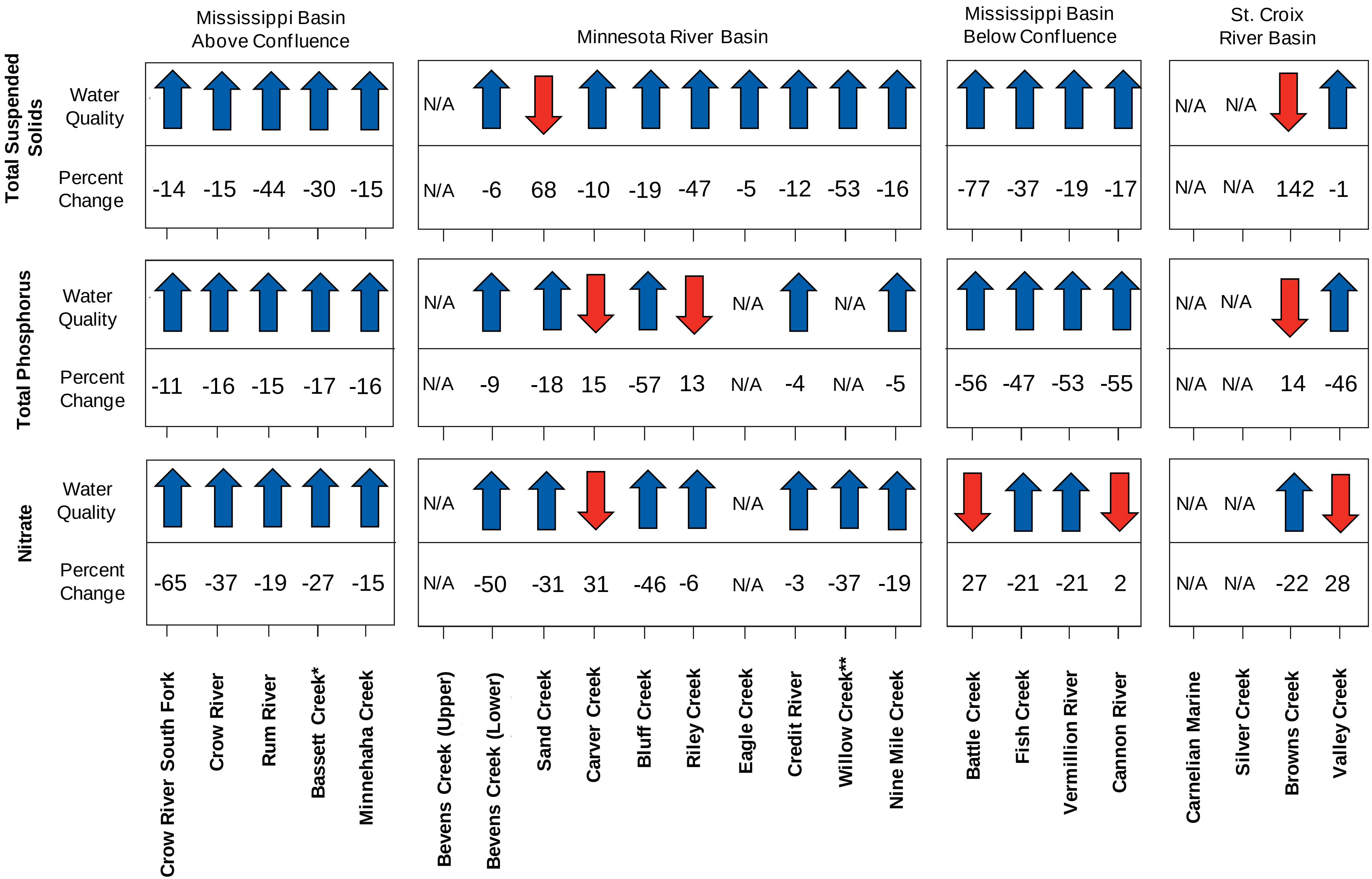
While MCES staff have assessed monitoring data and trend analysis statistics, more work is needed to assign causative actions to the trend analysis results. TSS and TP chemistry, delivery, transport and remediation are complicated, although fairly well-understood. Identifying contributing events, implementation practices, and other causative actions is expected to be somewhat straightforward for these two parameters.

NO_3 chemistry and transport dynamics within the natural environmental are significantly more complicated. The NO_3 trends for most of 21 streams assessed in this study showed periods of both rising and falling flow-adjusted concentrations. NO_3 concentrations may be affected by periods of saturated and unsaturated soil conditions related to precipitation patterns, by agricultural crop rotations, by changing levels of fertilizer applications, or other unidentified causative variables, rather than true long-term improvement in concentrations based on intentional implementation of best management practices.

MCES staff will repeat the trend analysis in 5 or 10 years. In the meantime, MCES will continue to investigate the $NO_{3,}$ TSS, and TP dynamics in streams entering the metropolitan area with local partners and state agency staff.

Figure CN-18: Regional Estimated Trends in Flow-Adjusted Stream Concentrations of TSS, TP, and NO_3, 2008-2012

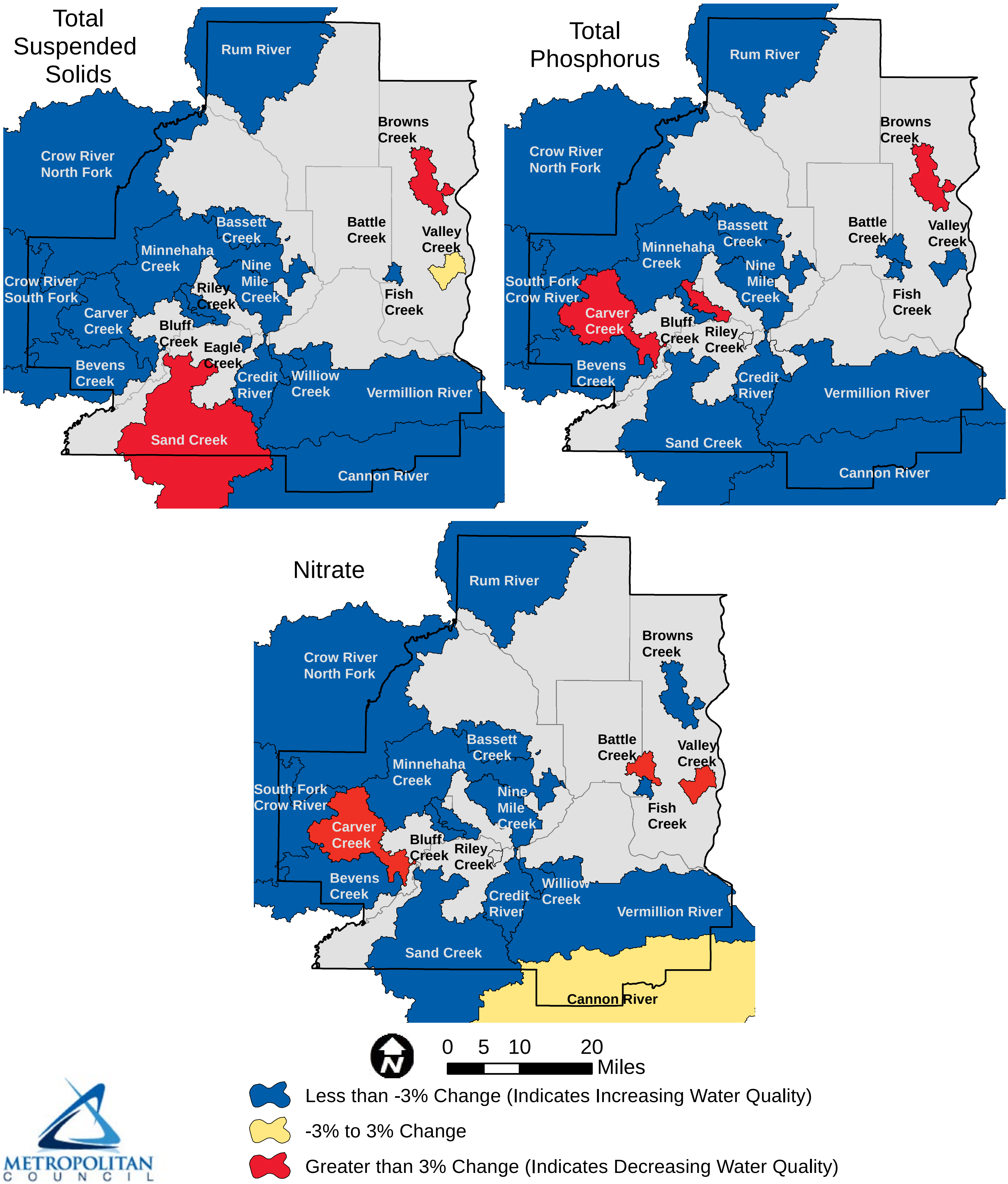
(Grouped by Major River Basin; As estimated by QWTrend)



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 CN-19: Regional Maps of Estimated Trends in Flow-Adjusted Stream Concentrations of TSS, TP, and NO3, 2008-2012

(As estimated by QWTrend)



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Conclusions

The Cannon River is a tributary to the Mississippi River and drains portions of Freeborn, Steele, Waseca, Blue Earth, Le Sueur, Rice, Scott, Dakota, and Goodhue Counties, including the cities of Waseca, Owatonna, Faribault, Northfield, and Red Wing. The watershed is primarily agricultural. 19 domestic wastewater treatment plants, including three major Class A facilities, discharge to the Cannon River. The upper watershed is relatively flat, while the topography steepens with deep ravines near the confluence with the Mississippi River.

The monitoring station is located 11.9 miles upstream of the river's confluence with the Mississippi River, at Welch, Minnesota. There are almost 83,000 acres downstream of the monitoring station, including 159 feedlots, thus the monitoring data presented in this report does not reflect the potential increases or decreases in water quality that may occur downstream of the monitoring station.

The water quality in the Cannon River is likely affected by several factors: agricultural activity; WWTP effluent; loss of wetlands and upland storage; and the instability of the area geology. TSS and TP concentrations in the river are high, both compared to the Mississippi River below the confluence with the Minnesota River, and many other MCES monitored watersheds, especially the urban watersheds. However, highly agriculturally dominated watersheds like Bevens and Sand Creeks have TSS and TP concentrations higher than the Cannon River. High TSS concentrations are likely due to erosion along streambanks. High TP concentrations may also be related to phosphorus bound up in sediments eroded from streambanks, but also may be tied to the large number of wastewater treatment facilities in the watershed, or agricultural land use practices. By 2012 all major WWTPs in the watershed had implemented phosphorus removal.

NO_3 concentrations in the Cannon River are higher than the Mississippi River below the confluence with the Minnesota River, and also higher than most other MCES-monitored metropolitan area tributaries other than Bevens, Sand and Valley Creeks and Crow River South. NO_3 concentrations are likely driven by agricultural activity in the watershed.

Cl concentrations in the Cannon River are lower than the urbanized streams which have high road densities. Chloride concentrations in the watershed are probably driven by a combination of road salt runoff and WWTP effluent.

Cannon River has the highest median pollutant load of all the MCES-monitored watersheds for TSS, TP, and NO_3, and the second highest for Cl (after the Crow River). The high loads are driven both by fairly high concentrations of pollutants, and also by the watershed area, which is the third largest of MCES monitoring streams (behind the Crow and Rum Rivers).

Trend analysis indicates downward trends in TSS and TP since 1999, indicating decreasing flow-adjusted concentrations and thus increasing water quality. There has been a sharper decline in TP flow-adjusted concentration since 2008, which may be a reflection of phosphorus removal practices introduced in WWTPs, or changing agricultural management practices. Trends analysis was completed for Chl-a, but no trend could be reported because of poor quality of statistical metrics. Trend analysis indicated both upward and downward trends in NO_3 flow-adjusted concentration since 1999, and the most recent trend is of increasing NO_3 concentration and thus declining water quality. This study did not identify causative actions affecting water quality trends. The trend analysis will be repeated in 5 -10 years; in the meantime, MCES staff will work with local and state agency partners to identify factors that may be affecting water quality dynamics and trends.

No biological monitoring has occurred at the Cannon River by MCES.

Recommendations

This section presents recommendations for monitoring and assessment of the Cannon River, as well as recommendations for partnerships to implement stream improvements. MCES recognizes that cities, counties, and local water management organizations, like the Cannon River Partnership, and the North Cannon River Water Management Organization, 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, cities, counties, and townships 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 five to 10 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 work with our partners to indentify all of the water quality and flow monitoring that is occurring on the Cannon River and its tributaries on a regular basis, to avoid duplicating efforts.

- MCES and partners (especially MnDNR, the counties, Cannon River Partnership, and North Cannon River Water Management Organization) 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. MCES plans to repeat the water quality trend analysis in 5 – 10 years.

- MCES staff should participate in future assessments and plan preparations for the Cannon River watershed led by the MPCA.

- Local surface water management plans should acknowledge the heightened potential for surface waters to be impacted by groundwater changes in this area.

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