Comprehensive Water Quality Assessment of Select Metropolitan Area Streams

CARVER CREEK

METROPOLITAN COUNCIL

December 2014

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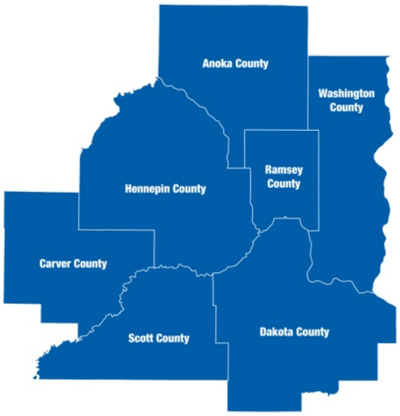

The Metropolitan Council is the regional planning organization for the seven-county Twin Cities area. The Council operates the regional bus and rail system, collects and treats wastewater, coordinates regional water resources, plans and helps fund regional parks, and administers federal funds that provide 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 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, *Caver Creek*, is one in a series produced as part of the *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams.* Located entirely in Carver County, Caver 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 Caver Creek.

Cover Photo

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

Recommended Citations

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Content

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Introduction

Carver Creek is located in the western metropolitan area and is a tributary to the Minnesota River. It drains approximately 83 square miles of mixed agricultural land, open space, bluff land, and urban areas (Figure CA-1), including all of the city of Waconia, and parts of the cities of Cologne and Carver in Carver County, Minnesota (Metropolitan Council District 4).

Figure CA-1: Carver Creek Near County Road 40

This report:

- documents those characteristics of Carver Creek and its watershed most likely to influence stream flow and water quality.
- presents the results from assessments of flow, water quality, and biological 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 Carver 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 5 years, in addition to issuing annual data summary reports.

Partnerships and Funding

MCES has supported water quality monitoring of Carver Creek since 1989. MCES staff maintain the rating curve and operate the monitoring station.

Monitoring Station Description

The monitoring station is located on Carver Creek in Carver, Minnesota, about 1.7 miles upstream from the creek's confluence with the Minnesota River. The creek starts in Benton Township and winds through the townships of Waconia, Laketown, Dahlgren, and Louisville before discharging to the Minnesota River.

The monitoring station includes continuous flow monitoring, event-based composite sample collection, and on-site conductivity and temperature probes. The Carver Creek station also includes an in-stream turbidity sensor (Forest Technology Systems DTS-12). There is no rain gauge at this station; however, precipitation data are available from the Minnesota Climatology Working Group, Chanhassen Station Number 211448, Chaska Stations Number 21465 and 211468, and Jordan Station Number 214176. Daily precipitation totals from these stations 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 aerially-weighted based on the watershed boundaries.

Maintaining the stage-discharge relationship on Carver Creek has been relatively challenging. Several large storms have shifted the profile of the stream bed near the monitoring station in recent years. Therefore, manual flow measurements are taken periodically each year to check validity of the rating curve.

Due to major roadwork and bridge replacement along County State Aid Highway (CSAH) 40 in Carver County, the monitoring station was shut down and removed on May 27, 2003. The station remained out of service for the duration of that year, and did not resume operation until October of 2004. Additionally, the stage/flow measurements were significantly impacted by large sand deposits in 2011. Therefore, data for the years 2003, 2004, and 2011 are not presented in this report.

Stream and Watershed Description

The Carver Creek watershed is a total of 53,061 acres, with 52,595 acres (99.1%) of the watershed upstream of the monitoring station. The watershed has 25,131 acres/47.4% (24,930 acres/47.4% within the monitored area) agricultural land, and 7,027 acres/13.2% (6,931 acres/13.2% within the monitored area) developed urban land, including the city of Waconia, the majority of the city of Cologne, and portions of Minnetrista and Carver. Of the agricultural land, 33.8% (34.0% within the monitored area) is planted in corn, 30.5% (30.5% within the monitored area) in soybeans, and 22.9% (22.8% within the monitored area) is pasture/hay. 16.8% (16.9% within the monitored area) of the agricultural land in the watershed is potentially drain tiled. The watershed has 4,431 acres/8.4% (4,431 acres/8.4% within the monitored area) of open water, with the majority of that area encompassed by Lake Waconia in the northern portion of the watershed. Other primary land covers in the watershed are forest, grasses/herbaceous, and wetlands. Table CA-1 and Figure CA-2 show the watershed area by land cover.

Table CA-1: Carver Creek Land Cover Classes[1]

Land Cover Class	Monitored		Unmonitored		Total	
	Acres	Percent	Acres	Percent	Acres	Percent
5-10% Impervious	1,147	2.2%	30	6.5%	1,177	2.2%
11-25% Impervious	1,745	3.3%	11	2.4%	1,756	3.3%
26-50% Impervious	1,291	2.5%	39	8.5%	1,330	2.5%
51-75% Impervious	1,536	2.9%	12	2.5%	1,547	2.9%
76-100% Impervious	1,213	2.3%	4	0.8%	1,217	2.3%
Agricultural Land	24,930	47.4%	201	43.1%	25,131	47.4%
Forest (all types)	4,843	9.2%	73	15.7%	4,916	9.3%
Open Water	4,431	8.4%	0	0.0%	4,431	8.4%
Barren Land	0	0.0%	0	0.0%	0	0.0%
Shrub land	44	0.1%	0	0.0%	44	0.1%
Grasses/Herbaceous	3,801	7.2%	52	11.1%	3,852	7.3%
Wetlands (all types)	7,616	14.5%	44	9.5%	7,660	14.4%
Total	**52,595**	**100.0%**	**466**	**100.0%**	**53,061**	**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 (Figure CA-3) is fairly flat at the upstream end, becoming steeper at the downstream end. The maximum watershed elevation is 1080.6 MSL and the minimum elevation is 729.0 MSL within the monitored area. Within the monitored area 3.3% of the slopes are considered steep, and an additional 1.1% are considered very steep.

The main stem of Carver Creek flows through several lakes and wetlands in the upstream area. Further downstream, the creek flows through Miller Lake, located about 12 miles upstream of the MCES monitoring station. Upon leaving Miller Lake, the slope of the stream increases sharply as it traverses the Minnesota River bluff.

Since 2000, the Carver Soil and Water Conservation District (SWCD) has assisted landowners in the Carver and Bevens Creeks watersheds with installing:

- 39.4 miles (339.2 acres) of CRP buffers
- 16.9 miles (102.8 acres) of permanent RIM buffers
- 12.7 miles (48 acres) of harvestable buffers

In addition, landowners have restored 91.8 acres of wetlands through CRP. The wetlands act like a sponge to help absorb excess runoff during large storm events (M. Wanous, Carver SWCD personal communication, 2014).

Figure CA-2

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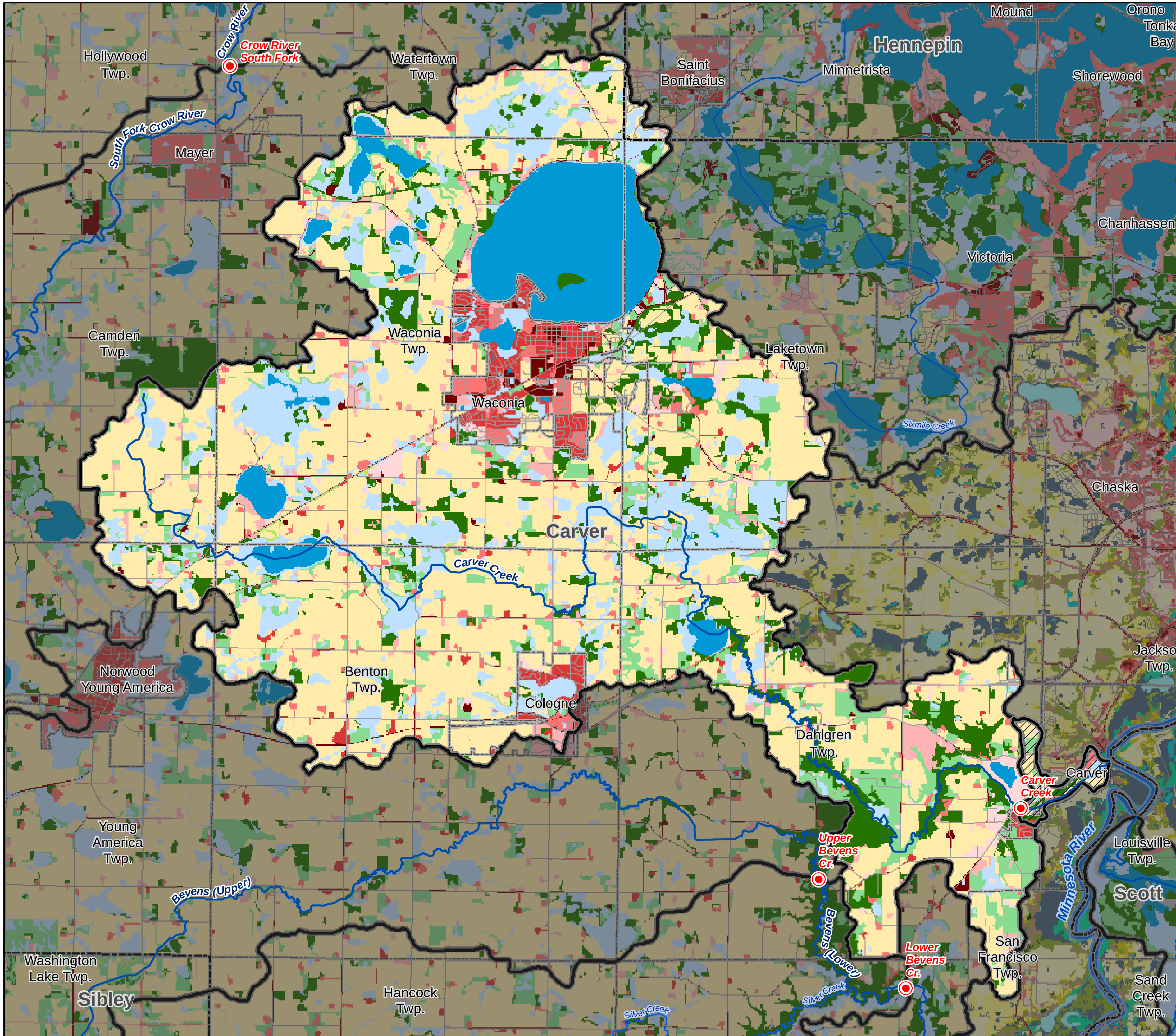
MLCCS-NLCD Hybrid Land Cover

Carver Creek



- MCES Stream Monitoring Sites
- USGS Flow Stations
- Mainstems (Monitored and Unmonitored)
- Major Mainstem Tributaries
- Monitored Watershed Boundaries
- Unmonitored Portion of Watersheds
- NCompass Street Centerlines, 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
Carver Creek

Land Cover Class	Monitored Acres	Monitored Percent	Unmonitored Acres	Unmonitored Percent	Total Acres	Total Percent
5-10% Impervious	1,147	2.2%	30	6.5%	1,177	2.2%
11-25% Impervious	1,745	3.3%	11	2.4%	1,756	3.3%
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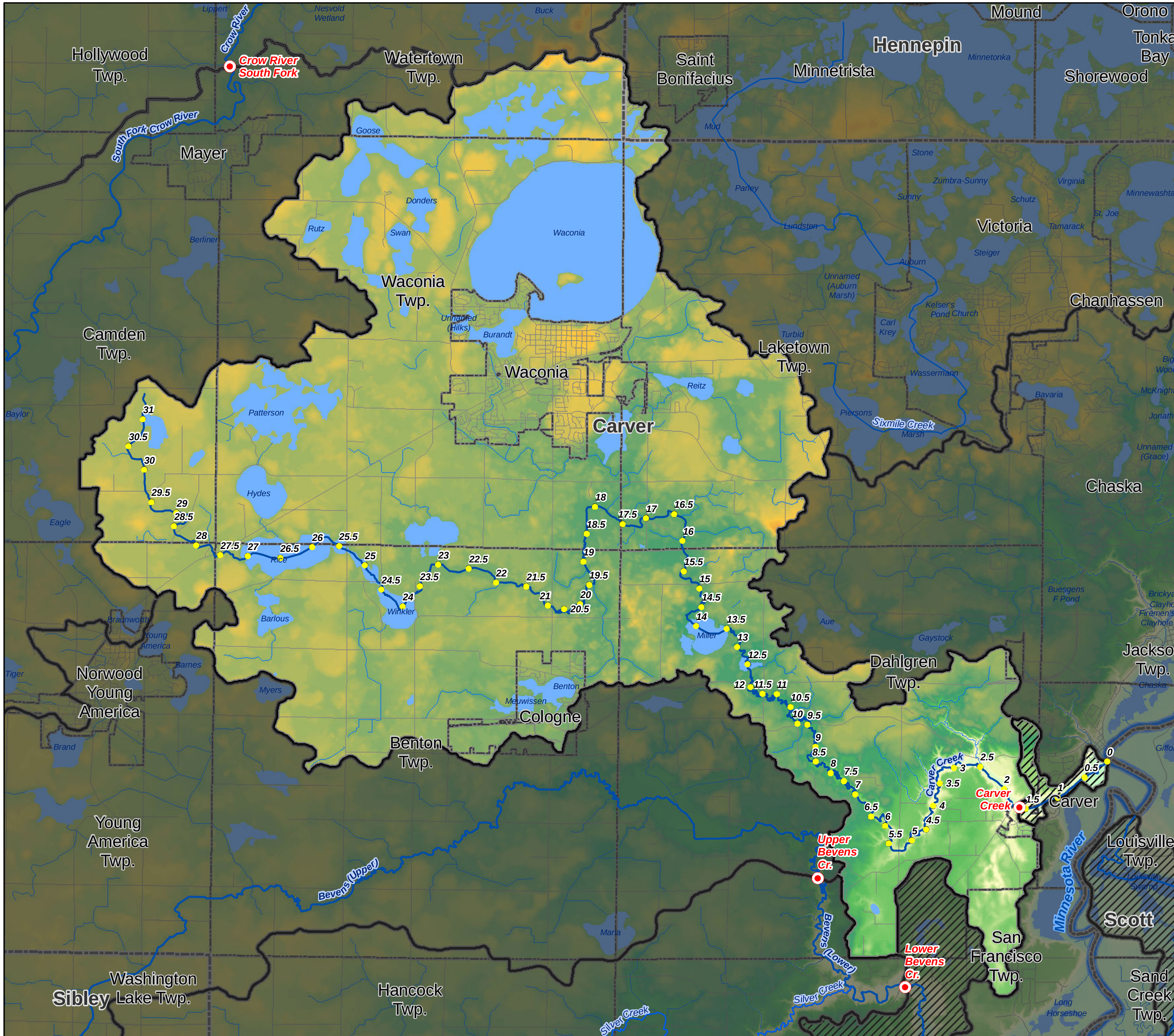
Figure CA-3

Watershed Topography

Carver Creek



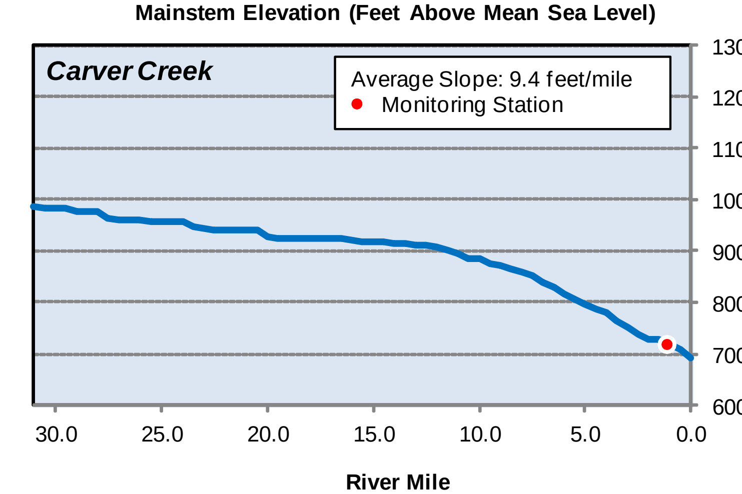
- MCES Stream Monitoring Sites
- USGS Flow Stations
- Stream Mile Markers
- Mainstems (Monitored and Unmonitored)
- Monitored Watershed Boundaries
- Unmonitored Watershed Areas
- County Boundary
- City and Township Boundaries
- NCompass Street Centerlines, 2010
- Public Waters Inventory
- Other Rivers and Streams

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 2 2.5 3 3.5 4
Miles

Water Quality Impairments

The Carver Creek watershed contains five stream reaches and nine lakes that are listed on the MPCA 's 2014 impaired waters list (Figure CA-4 and Tables CA-2 and CA-3). The main stem of Carver Creek is impaired for aquatic life due to turbidity and fecal coliform bacteria from its headwaters to its confluence with the Minnesota River. Several unnamed creeks that are tributary to Carver Creek are also impaired for aquatic recreation due to fecal coliform bacteria.

Table CA-2: Impaired Reaches of Carver Creek as Identified on the MPCA 2014 Impaired Waters List

Reach Name	Reach Description	Reach ID	Water Quality Impairments[1]	Approved Plan[2]	Needs Plan[2]
Carver Creek	Headwaters to Minnesota R	07020012-516	AQL, AQR	FC, T	---
Unnamed creek	Headwaters to Carver Creek	07020012-526	AQR	---	FC
Unnamed creek	Goose Lk (10-0089-00) to Unnamed wetland	07020012-618	AQR	---	FC
Unnamed creek (Lake Waconia Inlet)	Unnamed wetland to Lk Waconia	07020012-619	AQR	---	FC
Unnamed ditch	Burandt Lk to Unnamed creek	07020012-527	AQL, AQR	---	FC, DO

[1] AQR = aquatic recreation; AQL = aquatic life;

[2] FC = fecal coliform; T = turbidity; DO = dissolved oxygen

The lakes are mainly impaired for aquatic recreation due to excessive nutrients and mercury in fish tissue.

Table CA-3: Impaired Lakes in the Carver Creek watershed as identified on the MPCA 2014 Impaired Waters List

Lake Name	ID	Water Quality Impairment[1]	Approved Plan[2]	Needs Plan[2]
Benton	10-0069-00	AQR	---	Nutrients
Burandt	10-0084-00	AQR	Nutrients	---
Goose	10-0089-00	AQR	Nutrients	---
Hydes	10-0088-00	AQC, AQR	HgF, Nutrients	---
Miller	10-0029-00	AQC, AQR	Nutrients	---
Reitz	10-0052-00	AQC, AQR	HgF, Nutrients	---
Rutz	10-0080-00	AQR	---	Nutrients
Waconia	10-0059-00	AQC	HgF	---

Winkler	10-0066-00	AQR	Nutrients	---

[1] AQC = aquatic consumption; AQR = aquatic recreation

[2] HgF = mercury in fish tissue

The monitored Carver Creek watershed contains two domestic wastewater treatment plants (WWTPs) for the cities of Cologne and Carver (Table CA-4). Because of its rural makeup there are few industrial permits in the watershed; two industrial wastewater permit holders, and four industrial stormwater permit holders. There are also a number of permitted feedlots in the watershed with 100 or more animal units.

Table CA-4: Permitted wastewater treatment facilities discharging to Carver Creek at CSAH 40 (CA1.7)

Permit #[1]	Permit Holder	Design Flow (mgd)	Class[2]	Phosphorus removal[3]	General Notes[3]
MN0053457	Carver WWTP	0.361	B	---	P consistently = 4 mg/l. Permit expired 03/2013. Reissued permit will likely include P limit of 500 kg/yr
MN0023108	Cologne WWTP	0.325	B	1996	1 mg/l P permit limit

[1] Facilities with design flow > 1 mgd shaded in gray.

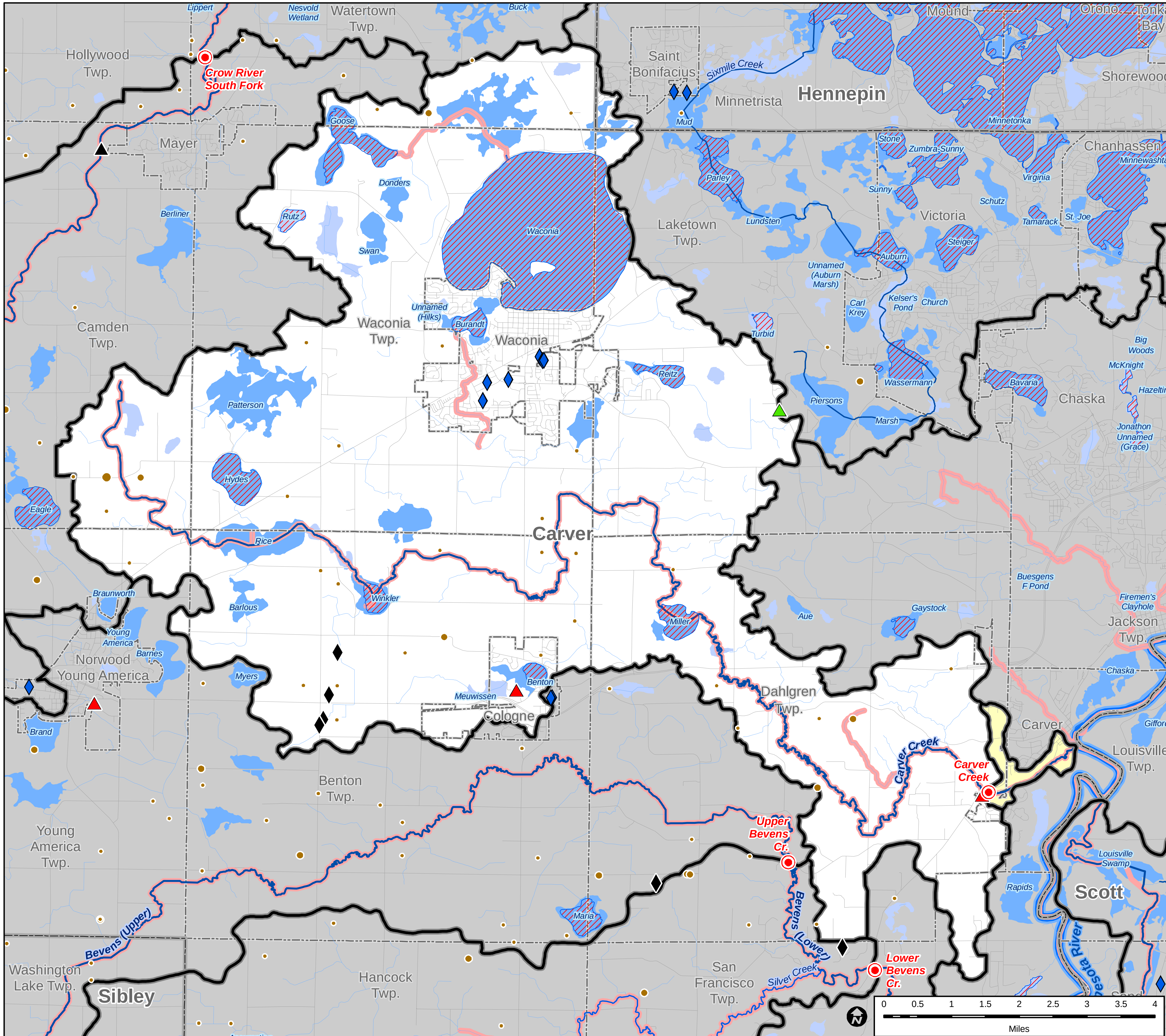
[2] In general, Class A and B WWTPs use mechanical systems with activated sludge that continuously discharge. Class D are stabilization ponds that are allowed to discharge March 1-June 15 (spring discharge) and September 15-December 31 (fall discharge). See Minn. Rule. 9400.0500, Classification of Facilities,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

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

Figure CA-4

Public and Impaired Waters and Potential Pollution Sources

Carver 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 *

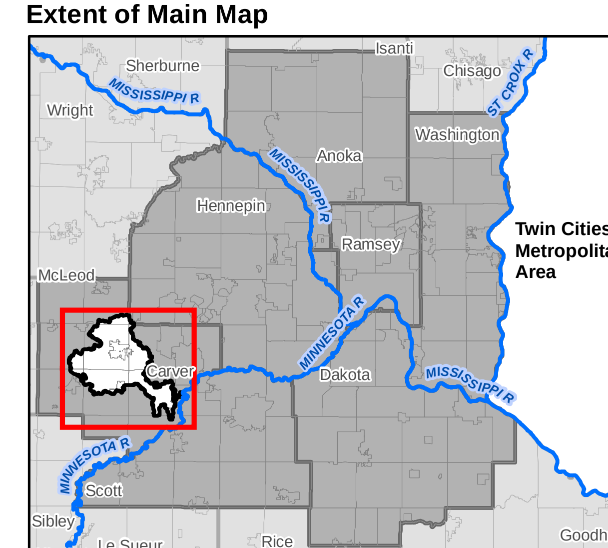
NCompass Street Centerlines, 2013

County Boundary

City and Township Boundaries

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

Extent of Main Map



Hydrology

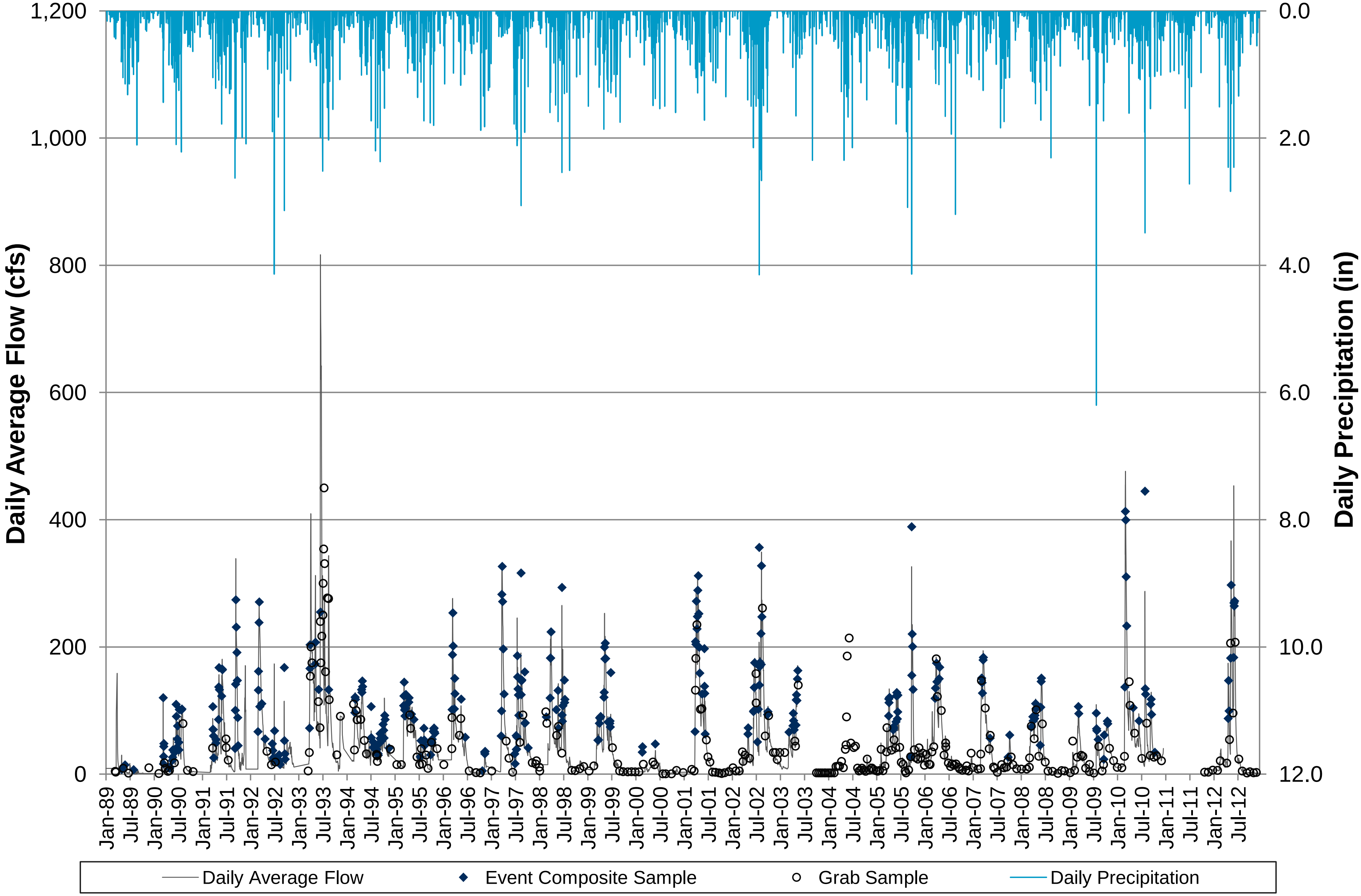
MCES has monitored flow on Carver Creek near CSAH 40 since 1989. Flow measurements are collected at 15-minute intervals and converted to daily averages. The hydrograph of Carver Creek, which displays daily average flow, daily precipitation, and the flow associated with grab and composite samples, indicates the variations in flow rates from season to season and from year to year (Figure CA-5), and the effect of precipitation events on flow.

The MCES sampling program collects grab samples of base flows between events and composite samples for precipitation events. 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 1989-2012 ranged between approximately 96-816 cubic feet per second (cfs), while the lowest 10th percentile flows ranged from 0.3-2.8 cfs. (See Figure CA-12 in the ***Flow and Load Duration Curves*** section of this report.)

Additional annual flow/volume metrics are shown on Figure CA-6 to CA-9, along with the annual pollutant load parameters. The first graph on each sheet illustrates an annual flow metric: average annual flow (a measure of annual flow volume); or the fraction of annual precipitation converted to flow. Figure CA-6 indicates that the highest average annual flow (and thus the highest volume of flow) during 1989-2012 occurred during 1993 (approximately 100 cfs average annual flow); the lowest occurred in 2000 (approximately 5.6 cfs average annual flow).

Figure CA-5: Carver Creek Daily Average Flow, Sample Flow, and Precipitation, 1989-2012*



*Station was not functional due to bridge replacement and road construction during parts of 2003 and 2004; 2011 flows are not accurate due to major changes to the stream bed; precipitation record was acquired from NWS COOP stations: 211465-Chaska, 214176-Jordan 1 S, 211448-Chanhassen WSFO, and 211468-Chaska 2NW

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 Carver 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 Carver Creek watershed, twelve stream segments comprising the lower part of the creek starting in Dahlgren Township and extending to the confluence with the Minnesota River were identified as potentially vulnerable. Two basins within the watershed, Lake Waconia and Reitz 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 Carver Creek (1989-2012). (The Carver monitoring station was out of commission from early 2003 through late 2004 due to road construction, and the stage/flow measurements were significantly impacted by large sand deposits in 2011; therefore results are not presented for those years.)

Figures CA-6 through CA-9 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 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 Carver 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 also varies 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 also 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 annual FWM concentrations for all parameters also fluctuate year-to-year and are likely influenced by annual precipitation and flow. Nitrate and chloride FWM concentrations seem less influenced by annual flow rates, probably due to the high solubility of these pollutants.

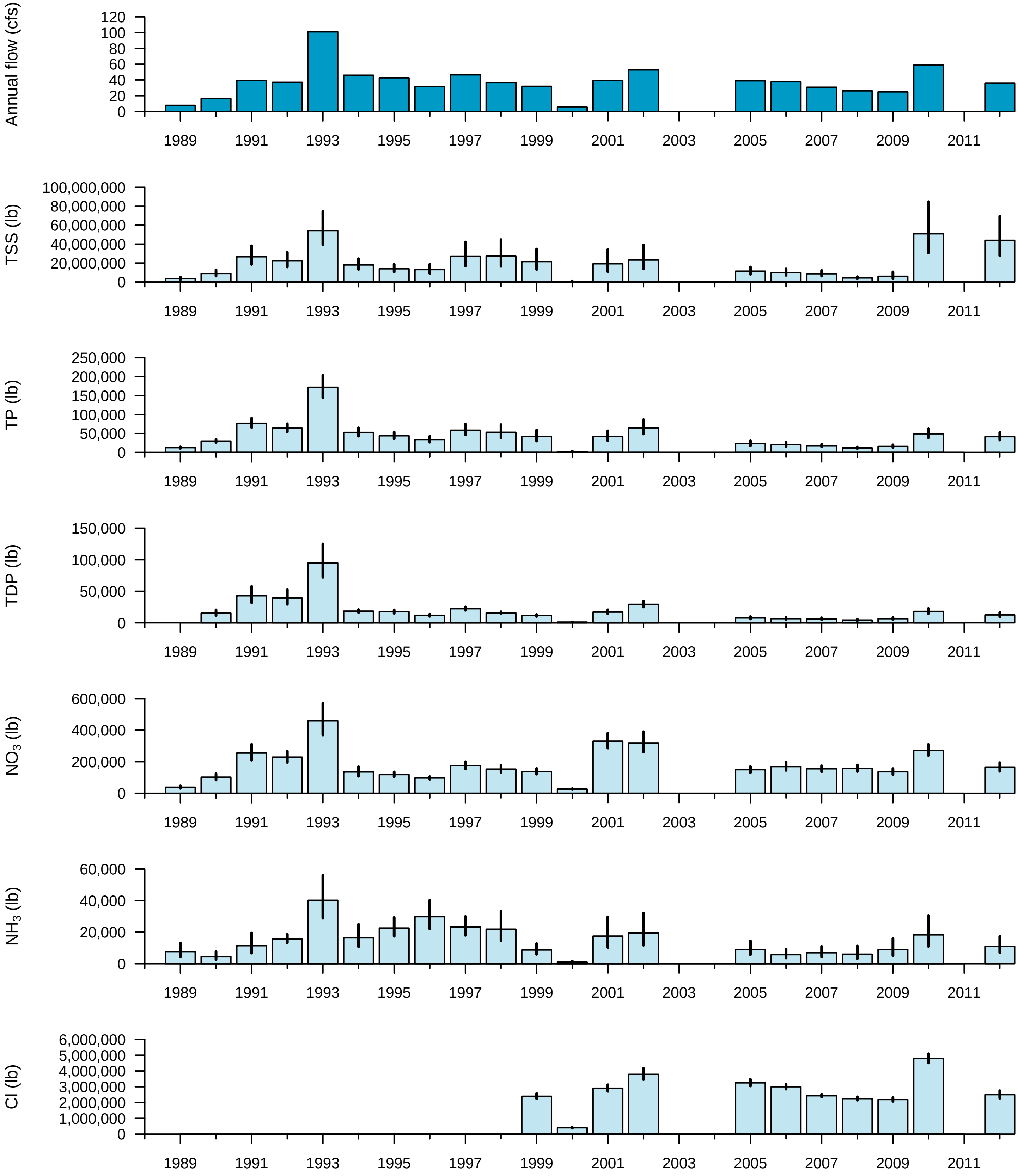
Figures CA-8 and CA-9 present the areal and precipitation-weighted loads, respectively. These graphics are presented to assist local partners and watershed managers, and will not be discussed here.

The Flux32 loads and FWM concentrations were also compiled by month to allow analysis of time based patterns in the loads in Carver Creek (Figures CA-10 and CA-11). The results for each month are expressed in two ways: the monthly results for the most recent year of data (2012 for Carver 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 March or June of each year, likely due to effects of snow melt and/or spring rains. Flows then generally decrease each subsequent month until August, September, or October, when a secondary flow/load pulse can occur.

The FWM concentrations generally show month-to-month variability similar to the loads, with the exceptions of dissolved constituents including TDP, NO_3, and Cl. The TP and TDP monthly concentration remain fairly stable and are likely influenced, even during low flow periods, by septic system and WWTP effluent discharge. Chloride concentrations show little variation throughout the year, with the highest loads in March and to a lesser extent, in April and May, likely reflecting the impact of snowmelt and spring rains on road de-icers applied during winter months.

Figure CA−6: Carver Creek*
Annual Mass Load

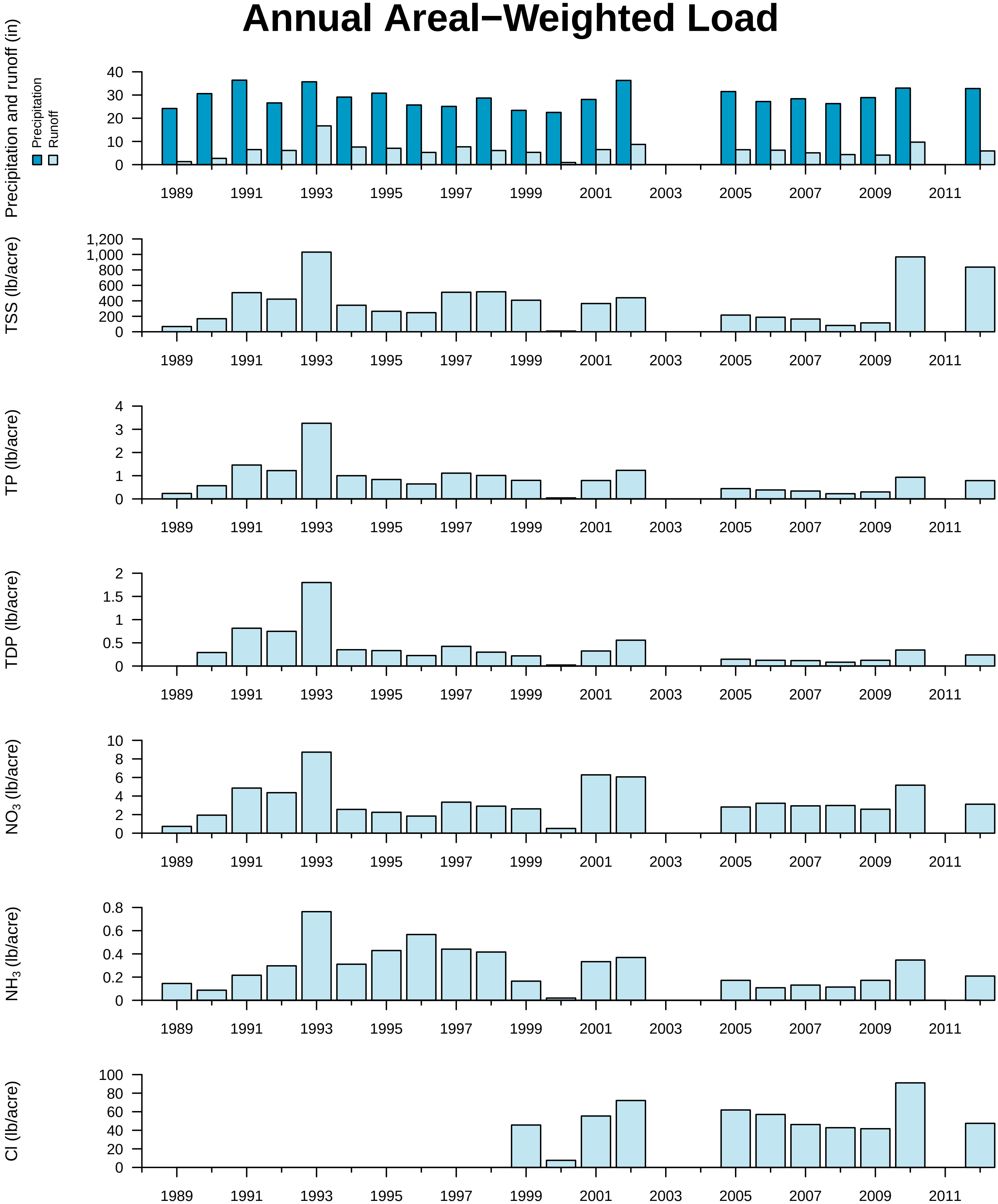


*TSS, TP, NO3, and NH3 sampling began in 1989, TDP began in 1990, and Cl began in 1999.
The station was down in 2003, 2004 and 2011 so no loads could be calculated.
Bars represent 95% confidence intervals as calculated in Flux32.

Figure CA−7: Carver Creek*
Annual Flow−Weighted Mean Concentration

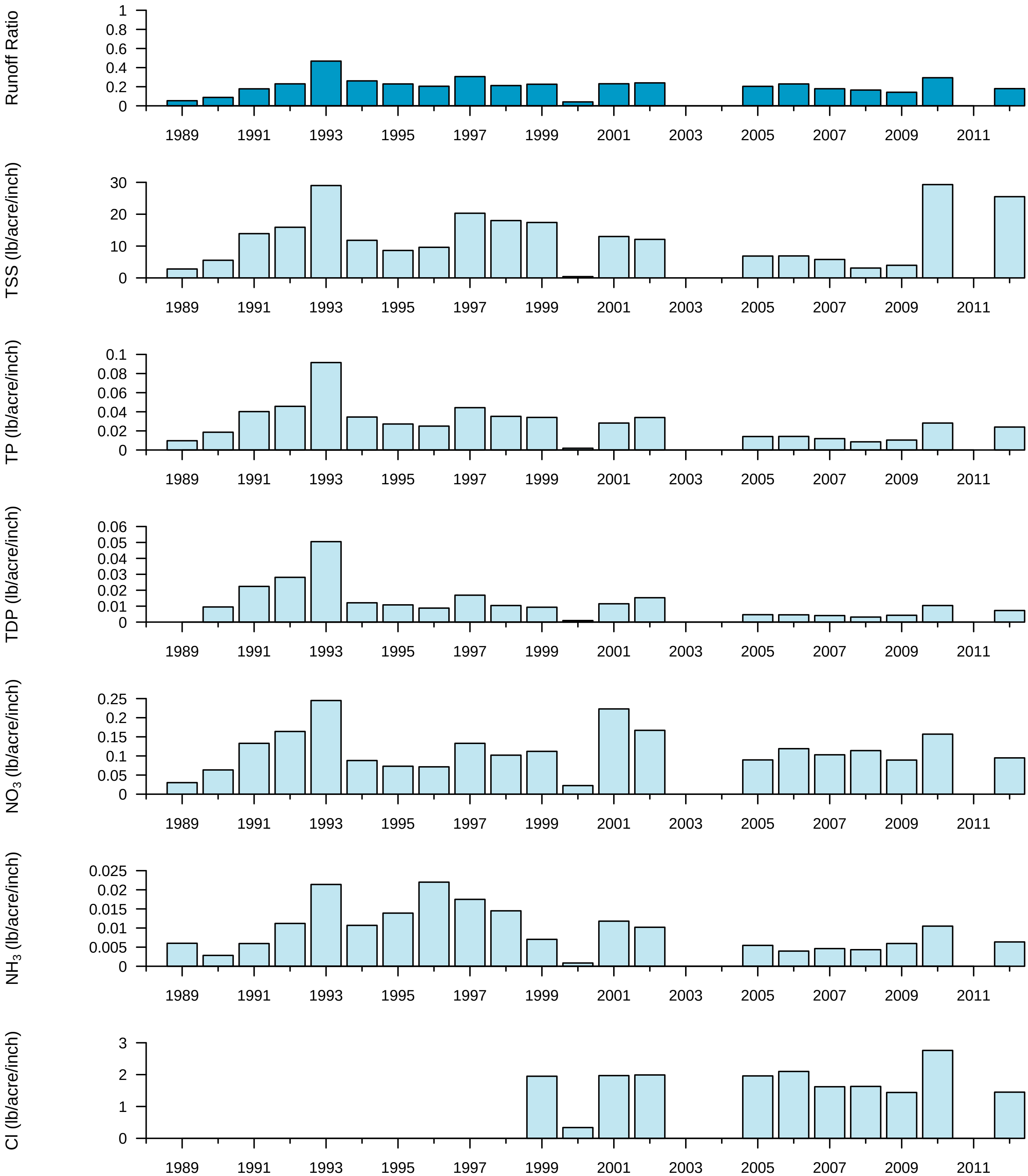
*TSS, TP, NO3, and NH3 sampling began in 1989, TDP began in 1990, and Cl began in 1999.
The station was down in 2003, 2004 and 2011 so no loads could be calculated.

Figure CA−8: Carver Creek*
Annual Areal−Weighted Load



*TSS, TP, NO3, and NH3 sampling began in 1989, TDP began in 1990, and Cl began in 1999.
The station was down in 2003, 2004 and 2011 so no loads could be calculated.

Figure CA−9: Carver Creek*
Annual Precipitation−Weighted Areal Load



*TSS, TP, NO3, and NH3 sampling began in 1989, TDP began in 1990, and Cl began in 1999.
The station was down in 2003, 2004 and 2011 so no loads could be calculated.

Figure CA−10: Carver Creek
Mass Load by Month

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

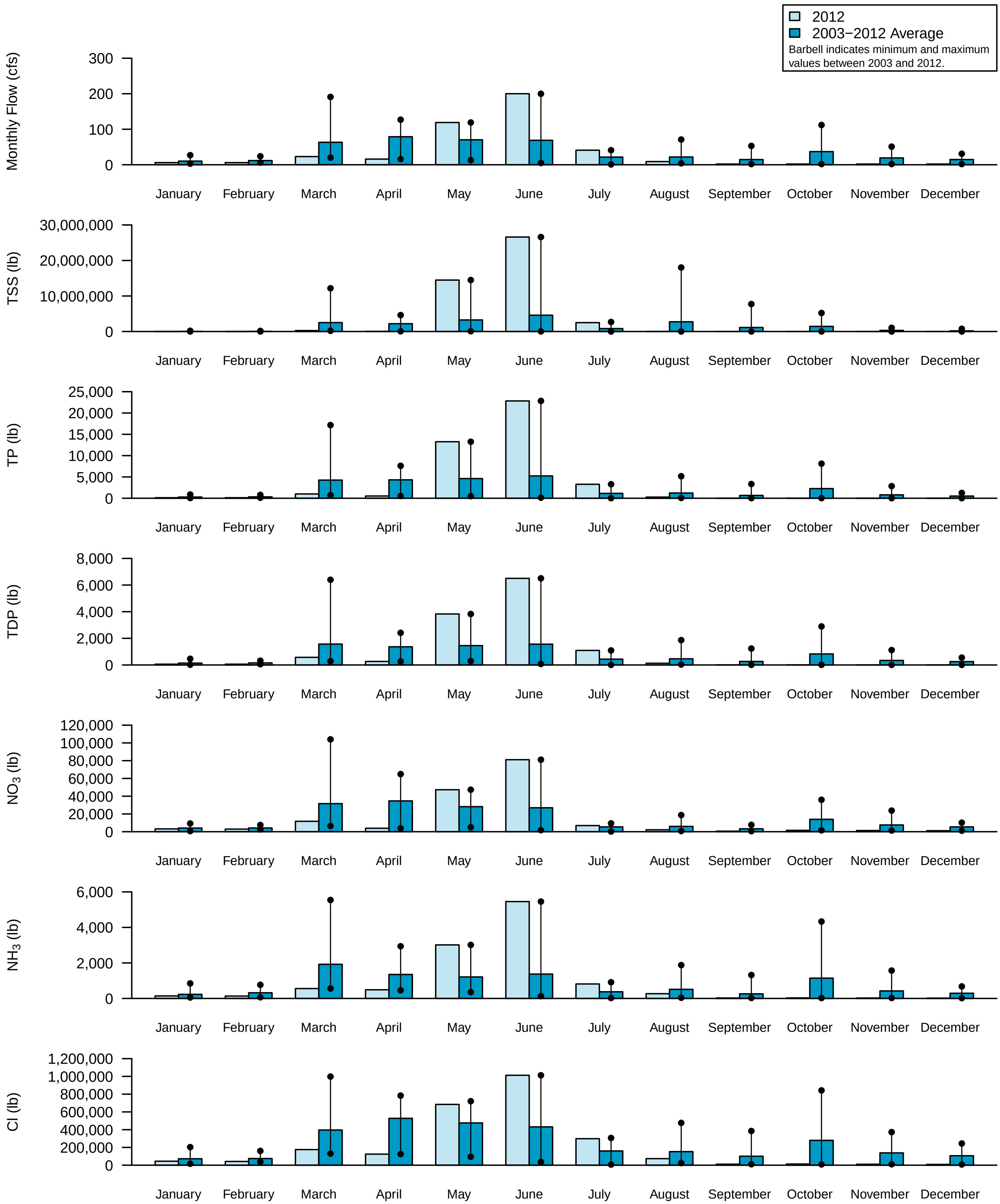
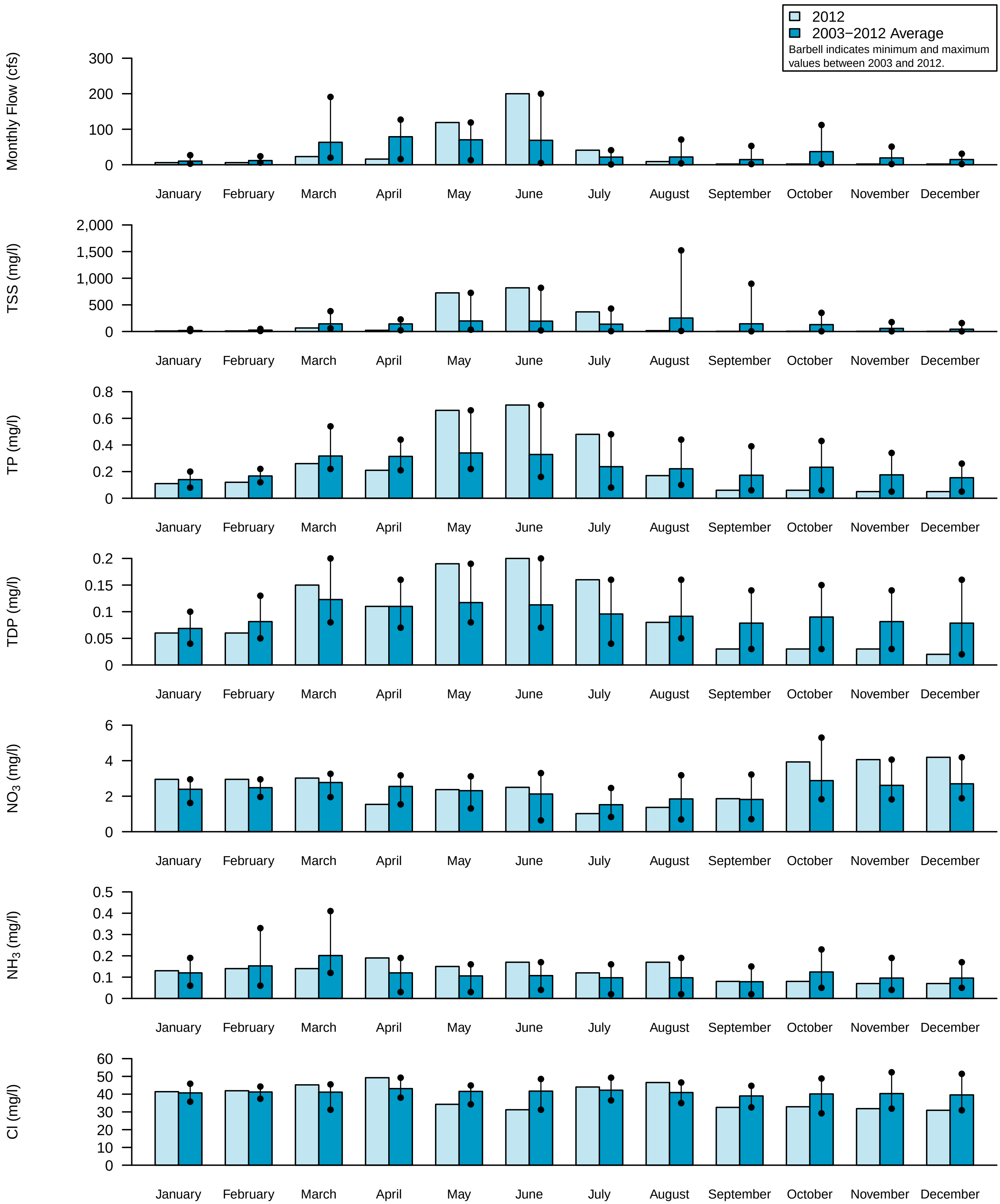


Figure CA−11: Carver Creek Flow−Weighted Mean Concentation by Month

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 location 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 Carver Creek monitoring station daily average flows and sample data, along with the most appropriate MPCA draft numerical standard as listed in Table CA-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 criteria, the water body must exceed the causative variable (TP concentration), as well as one or more response variables: sestonic (suspended) chlorophyll, five day 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 1998–2012 flow duration curve and load duration curves for TSS, TP, NO_3, and Cl for the Carver Creek monitoring station (mile 1.7, near CSAH 40) are shown in Figure CA-12. The majority of TSS concentrations are below the draft standard at low flow and dry conditions; at mid range flows, they are about evenly split above and below the draft standard, and during moist conditions and high flow most samples collected exceed the draft 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 exceed the draft nutrient concentration criteria at the high flow, moist conditions, and mid-range flow regimes. There are also some exceedances at the dry conditions and low flow regimes. Some of the low flow exceedances may reflect loading from wastewater treatment facilities, septic systems, or feedlots.

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 likely will be exceeded at the higher flow regimes.

Cl concentrations in Carver Creek are below the draft Cl criteria at all flow regimes. Concentrations are largely independent of flow, (Figure CA-7), indicating either groundwater contribution of Cl at baseflow conditions, or early spring snowmelt carrying dissolved road salt.

Table CA-5 : Carver 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)
Carver Creek at Co. Rd. 40 (CA1.7)	2B	Central	230	30	100	10

[1] Minn. Rules 7050.0470 and 7050.0430

[2] MPCA, 2010.

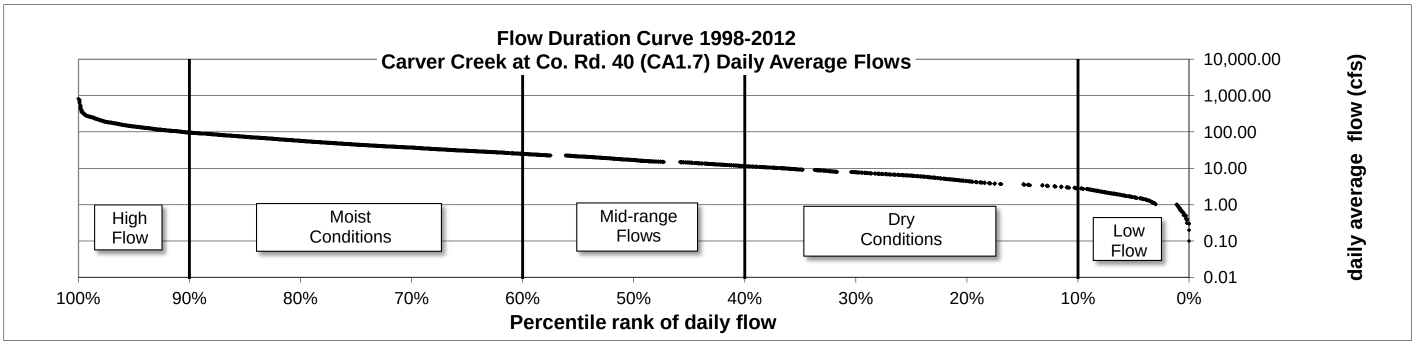
[3] Mark Tomasek, MPCA, personal communication, March 2013. MCES used 230 mg/l as the draft chloride standard pending results of EPA toxicity tests.

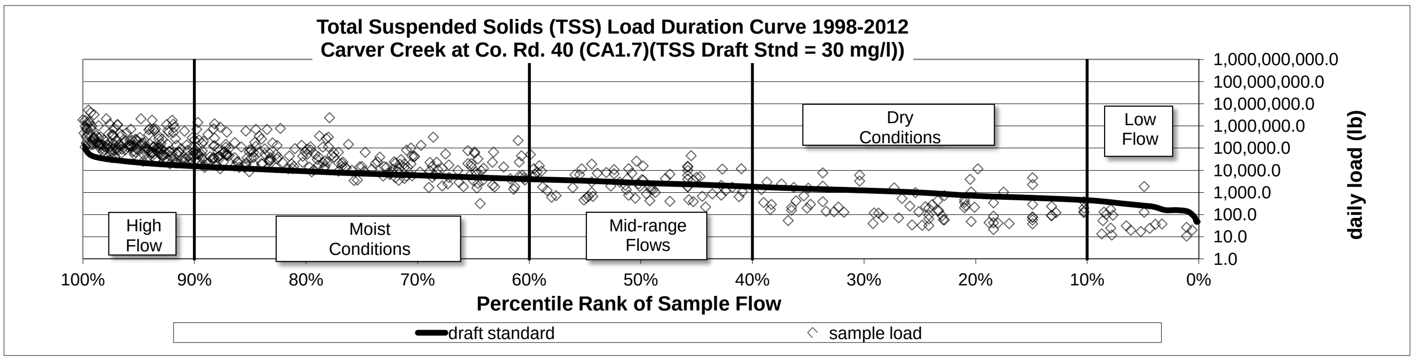
[4] MPCA, 2011. Draft standard states TSS standard concentration for Class 2A and 2B water must not be exceeded more than 10% of the time over a multiyear data window, with an assessment period of April through September.

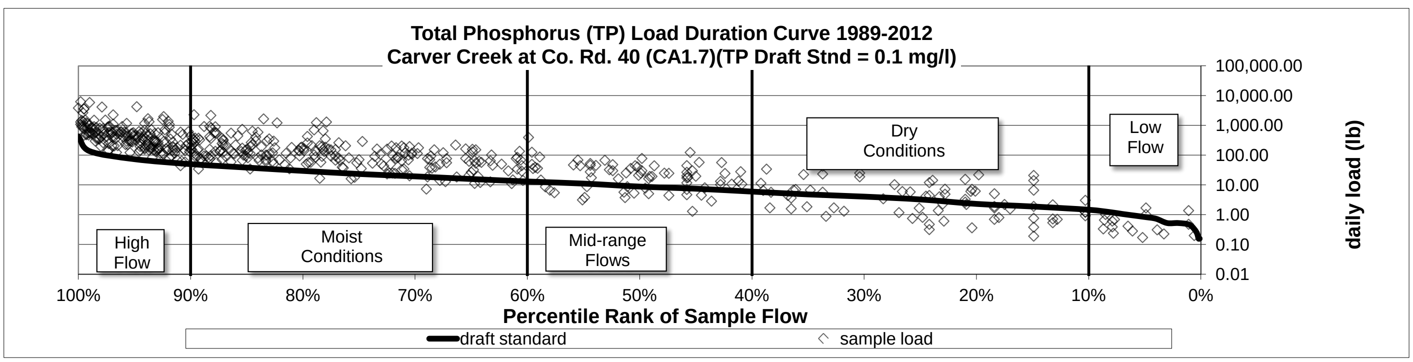
[5] MPCA, 2013a.

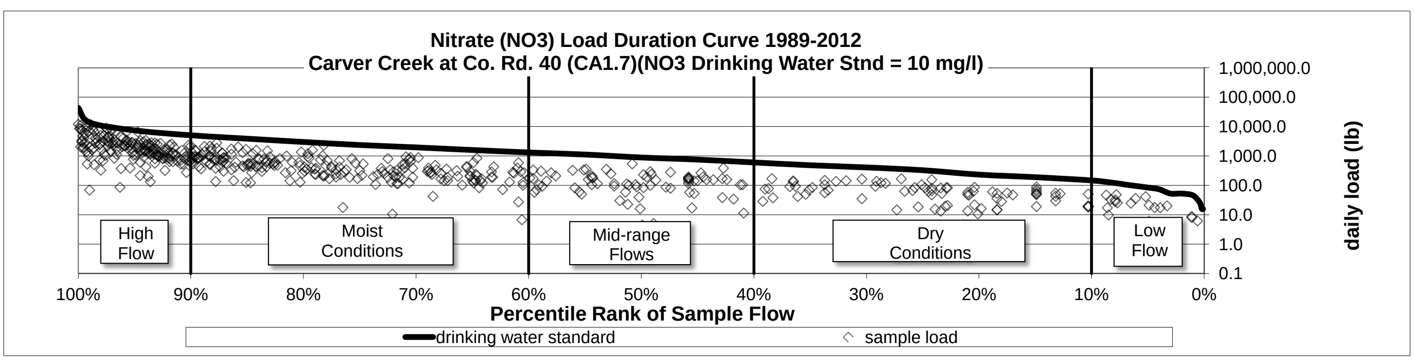
[6] MCES used the NO_3 drinking water standard of 10 mg/l pending results of EPA toxicity tests and establishment of a draft NO_3 standard for rivers and streams.

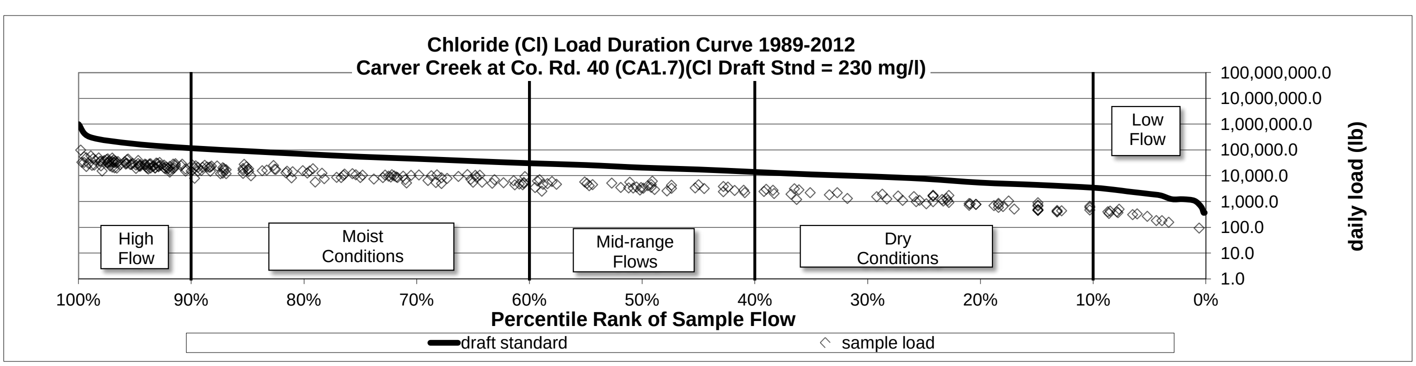
Figure CA-12: Carver Creek Flow and Load Duration Curves, 1998-2012











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.

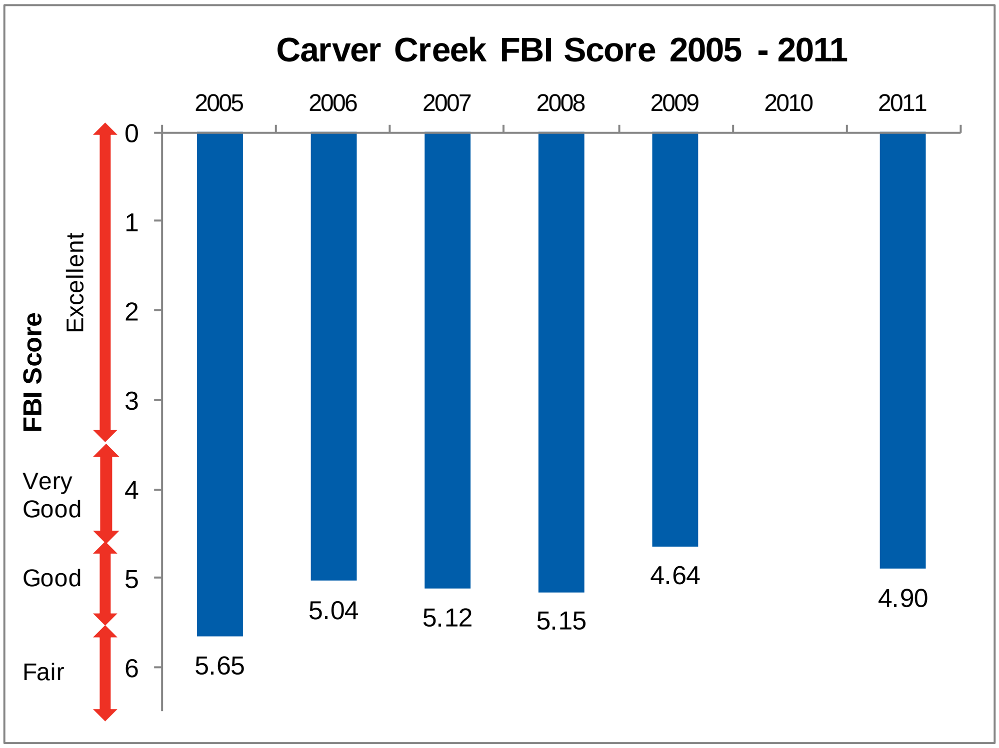
Each metric is independently important and clarifies one aspect of the ecosystem health: species richness, community diversity, water quality, and other factors. The results may have conflicting conclusions when comparing the single metric results. However, integrating the individual metrics into a multi-metric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

MCES has been sampling macroinvertebrates in Carver Creek since 2005. The entire dataset was analyzed with three metrics: Family Biotic Index (FBI), Percent Intolerant Taxa, and Percent POET Taxa. A subset of data, 2005-2009 and 2011, was analyzed using the multi-metric, Minnesota-specific, MPCA 2014 Macroinvertebrate Index of Biological Integrity (M-IBI).

Family Biotic Index (FBI)

The FBI is a commonly used water quality assessment. Each family is assigned a tolerance value that describes its ability to tolerate organic pollution. The values range from 0 to 10; zero is intolerant to pollution, 10 is quite tolerant of pollution. The tolerance values are used to calculate a weighted average tolerance value for the sample, allowing for comparisons from year to year. All the Carver Creek FBI scores show good water quality except 2005, which is in the fair water quality category. The good category indicates that there is likely some organic pollution in the stream and the fair category indicates that there is possibly fairly substantial organic pollution in the stream (Figure CA-13).

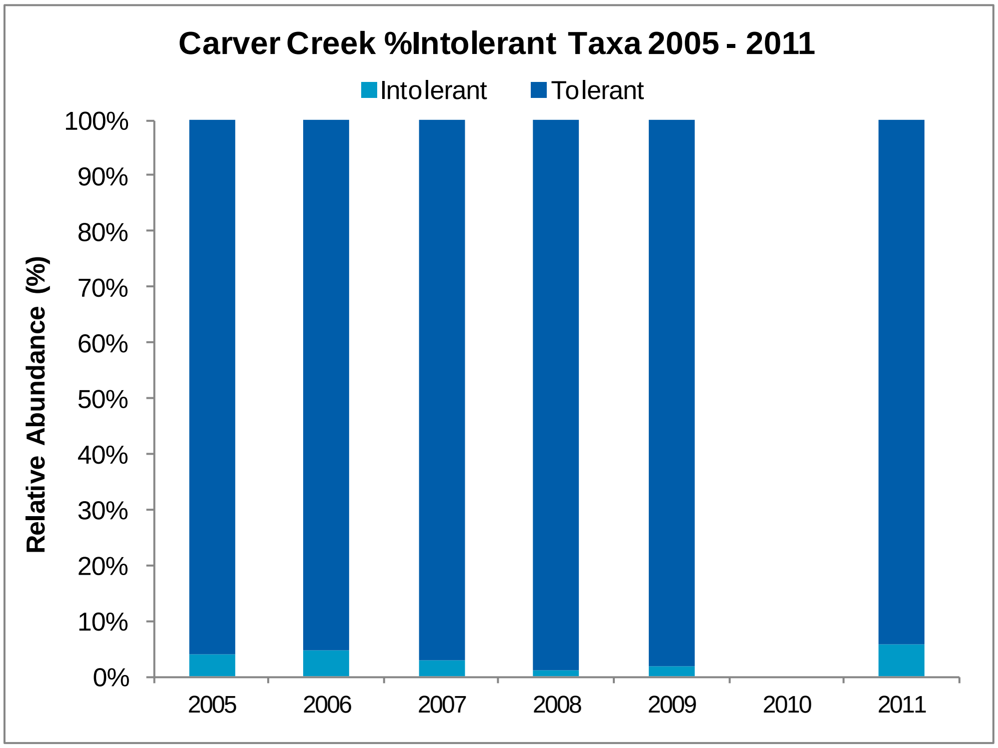
Figure CA-13: Carver Creek Annual Family Biotic Index (FBI) Scores, 2005-2011



Percent Intolerant Taxa

The Percent Intolerant Taxa is another assessment to evaluate the degree of pollution at the monitoring reach. This metric identifies the percent of taxa with a tolerance value of two or less (Figure CA-14). The presence of moderate numbers of intolerant taxa is an indicator of good aquatic health (Chirhart, 2003). Intolerant taxa were never greater than 10% of the Carver Creek samples. The highest percent intolerant taxa, 6%, occurred in 2011. Intolerant taxa were present in every sample.

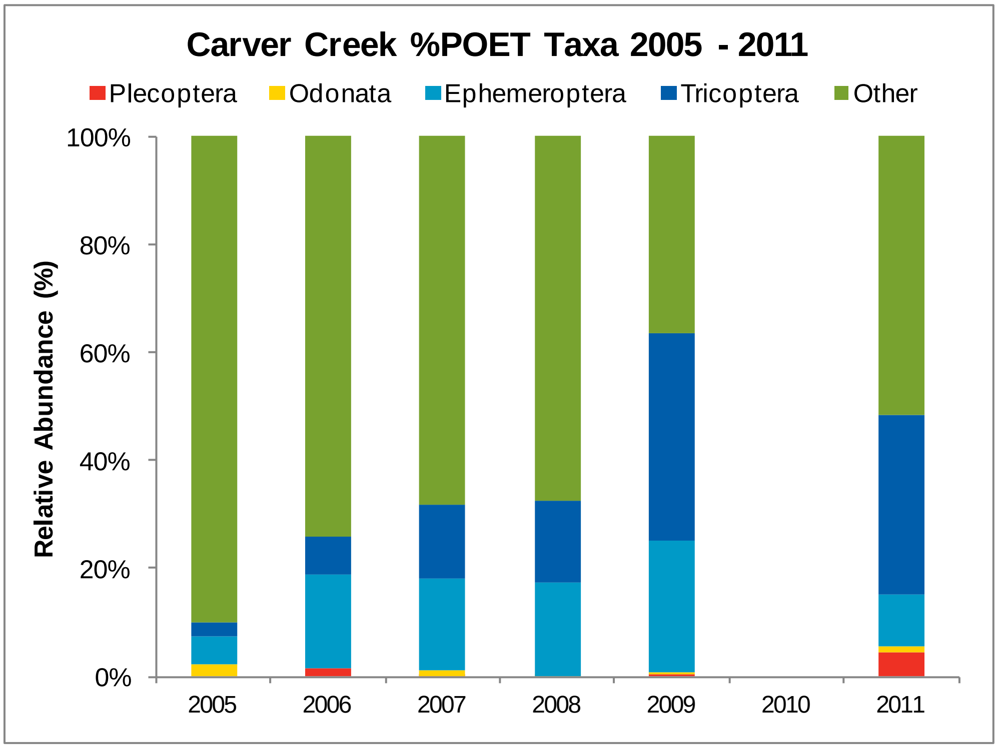
Figure CA-14: Carver Creek Percent Abundance of Pollution Intolerant Taxa, 2005-2011



Percent POET Taxa

The taxonomic richness metric, Percent POET Taxa (Figure CA-15), is the percent of individuals in the sample that belong to the orders **P**lecoptera (stoneflies), **O**donata (dragonflies and damselflies), **E**phemeroptera (mayflies), and **T**richoptera (caddisflies). Individuals in these orders vary in sensitivity to organic pollution and sedimentation. High percent POET values indicate high community diversity due to good water quality. The percent POET taxa value had was highest in 2009 at 64%, and lowest in 2005 at 10%.

Figure CA-15: Carver Creek Percent Abundance of POET Taxa, 2005-2011



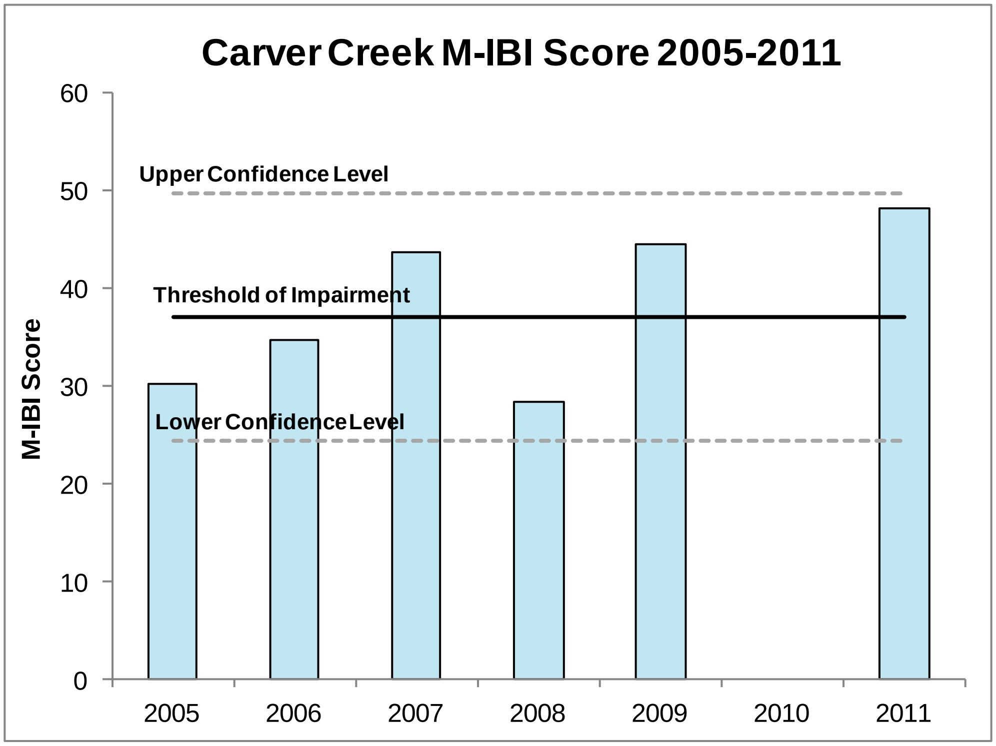
Macroinvertebrate Index of Biotic Integrity (M-IBI)

The M-IBI score integrates community richness and composition, pollution tolerance, life histories, trophic interactions, and physical and other parameters that all are components of the biological integrity of the stream. These composite scores are usually shown in context with a threshold value and confidence levels to aid in the assessment of the water quality. If the value for a given year is above the threshold of impairment and the upper confidence level, it can confidently be said the site is not impaired. Conversely, if the value is below the threshold of impairment and below the lower confidence level, it can be said the site is likely to be impaired.

All of the Carver Creek M-IBI data points fell above and below the impairment threshold, but inside the confidence levels (CA-16). When this situation occurs it is difficult to confidently assess the water quality by biological assessment alone, and it is necessary to incorporate other monitoring information, such as hydrology, water chemistry, land use change, etc. (MPCA 2014b).

The M-IBI scores are generally increasing, perhaps indicating an improving ability to support the needs of aquatic life. The exception to this trend was 2008; the data suggest the macroinvertebrate community was affected by a disturbance. The macroinvertebrate community appears to have recovered from the disturbance as the highest M-IBI score in 2011 approached the upper confidence level. MCES is planning additional future analysis to fully investigate our biological monitoring data.

Figure CA-16: Carver Creek Annual Macroinvertebrate Index of Biological Integrity (M-IBI) Scores, 2005-2011



Trend Analysis

Trend analysis was completed for the historical record of TSS, TP, and NO_3 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 variations 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 years. At that time, we anticipate sufficient data will have been collected to allow assessment of changes in flow rate and volume, as well as to update the pollutant trends discussed below.

MCES staff assessed trends for the period of 1989-2012 on Carver Creek for TSS, TP, and NO_3, (station was down in 2003, 2004, and 2011) using daily average flow, baseflow grab sample, and event composite sample data. The results are presented below. Readers should note that while QWTREND allows identification of changes of pollutant concentration with time, it does not identify causation. MCES staff have not attempted to identify changes in watershed management, climactic changes, or any other actions which may affected concentration in the stream. A recommendation of this report is for MCES staff to work with local partners to identify causative actions which will aid in interpretation when MCES repeats the trend analysis in five years.

Total Suspended Solids (TSS)

One downward trend was identified for TSS flow-adjusted concentration in Carver Creek from 1989 to 2012. The assessment was performed using QWTREND without precedent 5-year flow. The trend identified was statistically significant ($p=1.96x10^{-6}$). TSS flow-adjusted concentration decreased gradually from 36.4 mg/l to 16.0 mg/l (-56%) at a rate of -0.85 mg/l/yr from 1989 to 2012.

The five year trend In TSS flow-adjusted concentration in Carver 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 17.9 mg/l to 16.0 mg/l (10%) at an average rate of -0.37 mg/l/yr. Based on the QWTREND results, the water quality in Carver Creek in terms of TSS improved during 2008-2012.

Total Phosphorus (TP)

Two trends were identified for TP flow-adjusted concentration in Carver Creek during the 1989 to 2012 assessment period. The assessment was performed using QWTREND without precedent 5-year flow. The trends identified for TP in the stream were statistically significant ($p=1.9x10^{-11}$). Average TP flow-adjusted concentration decreased gradually from 0.32 mg/l to 0.11 mg/l (-65%) from 1989 to 2004 at a rate of -0.013 mg/l/yr, and then slightly increased from 0.11 mg/l to 0.14 mg/l (21%) at a rate of 0.0030 mg/l/yr from 2005 to 2012.

The five year trend In TP flow-adjusted concentration in Carver Creek (2008-2012) was calculated to compare with other MCES-monitored streams in the report section ***Comparison with Other Metro Area Streams***. TP flow-adjusted concentration increased slightly from 0.12 mg/l to 0.14 mg/l (15%) at a rate of 0.0035 mg/l/yr. Based on the QWTREND results, the water quality in Carver Creek in terms of TP declined during 2008-2012.

Nitrate (NO_3)

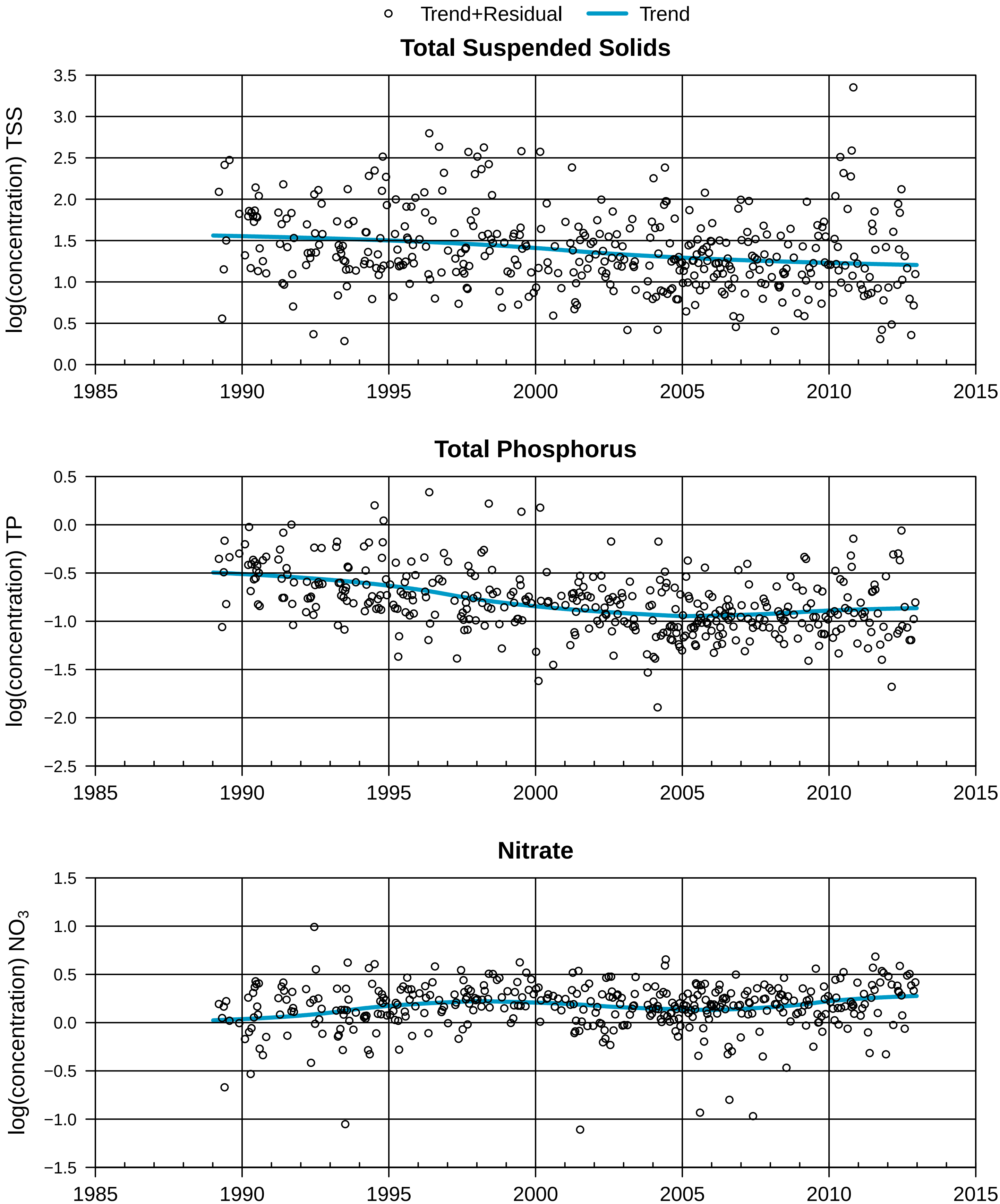
Three trends were identified for NO_3 flow-adjusted concentration in Carver Creek during the 1989 to 2012 assessment period. The assessment was performed using QWTREND without precedent 5-year flow. The trends identified for NO_3 in the stream were statistically significant ($p=0.01$).

- Trend 1: 1989-1997, NO_3 flow-adjusted concentration increased gradually from 1.06 mg/l to 1.67 mg/l (58%) at a rate of 0.068 mg/l/yr.

- Trend 2: 1997-2005, NO_3 flow-adjusted concentration decreased slightly from 1.67 mg/l to 1.35 mg/l (-19%) at a rate of -0.040 mg/l/yr.
- Trend 3: 2006-2012, NO_3 flow-adjusted concentration increased from 1.35 mg/l to 1.89 mg/l (40%) at a rate of 0.031 mg/l/yr.

The five year trend In NO_3 flow-adjusted concentration in Carver Creek (2008-2012) was calculated to compare with other MCES-monitored streams, shown in the report section ***Comparison with Other Metro Area Streams.*** The average NO_3 flow-adjusted concentration increased from 1.44 mg/l to 1.89 mg/l (31%) at a rate of 0.089 mg/l/yr. Based on these QWTREND results, the water quality in Carver Creek in terms of NO_3 declined during 2008-2012.

Figure CA−17: Carver Creek Trends for TSS, TP and NO_3



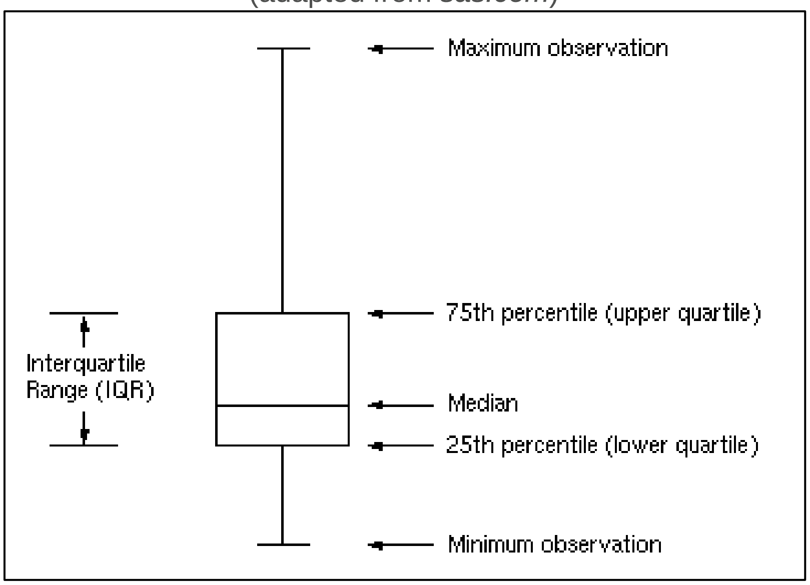
Comparison with Other Metro Area Streams

Chemistry

Box-and-whisker plots are used to summarize the comparison of the historical flow, TSS, TP, NO_3, and Cl data for Carver 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 Figures CA-19 to CA-22. The data were summarized on box-and-whisker plots. The historic biomonitoring data, summarized as M-IBI scores, were also exhibited as box-and-whisker plots. However, the streams were divided by stream type as the MPCA impairment thresholds are type-specific and this attribute does not correlate with major river basins.

Figure CA-18 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 CA-18: 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 ratio (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 Carver Creek (143 mg/l) is lower than other agricultural Minnesota River tributaries like Sand Creek, and nearby Bevens Creek. It is also lower than the developing Minnesota River streams Bluff Creek, and Riley Creek, but it is higher than that for tributaries closer to the convergence of the Minnesota River and the Mississippi River: Eagle, Credit, Willow, and Nine Mile (Figure CA-19; Table CA-6). The median annual FWM concentration in Carver Creek is also nearly identical to that of the Minnesota River (as measured at Jordan Minnesota; (143 mg/l vs. 142 mg/l, respectively), indicating that Carver Creek has little impact on the TSS concentration in the Minnesota River. It is apparent that those tributaries entering the Minnesota River nearest Jordan have significantly higher FWM TSS concentrations and annual yields (expressed in lb/acre) than the other tributaries to the Minnesota or any of the MCES monitored tributaries entering the Mississippi or St. Croix Rivers. This probably reflects the relatively unstable landform within the Minnesota River watershed, where the tributaries channels and associated gullies and ravines are still down-cutting towards geographic equilibrium (Jennings, 2010).

Median annual runoff ratio for Carver Creek is similar to the other monitored Minnesota River streams except Eagle Creek, which has a substantial ground water component. If Carver Creek flow was highly influenced by wetlands, lakes, or other impoundments on the stream channel, one would expect a relatively lower runoff ratio (e.g. Minnehaha Creek or Carnelian-Marine); if the flow was highly influenced by shallow groundwater inflow, one would expect a relatively higher runoff ratio (e.g. Eagle Creek or Valley Creek).

Total Phosphorus. The median FWM TP concentration in Carver Creek is higher than that of the Minnesota River (0.304 mg/l vs. 0.24 mg/l) and thus serves to increase the TP concentration in the river (Figure CA-20; Table CA-6). Carver Creek and the other upper Minnesota River metropolitan area tributaries also have higher FWM concentrations than most of the other MCES- monitored streams, with the exception of the Cannon River and Crow River South Fork. The Carver Creek annual TP yield ranks near the middle of the monitored Minnesota River tributaries (lower than Eagle, Bevens, Bluff, and Sand Creeks) and is higher than most of the Mississippi and St. Croix tributaries, with the exception of the Cannon River, and the south fork of the Crow River. These are much larger watersheds than Carver Creek. The TP concentration and load in Carver Creek is likely affected by a combination of land use management, especially in the highly agricultural sections of the watershed, and by the effluent from feedlots, domestic septic systems, and waste water from the cities of Carver and Cologne.

Nitrate. The Carver Creek median FWM NO_3 concentration in is lower than that of the Minnesota River, and thus serves to dilute the river concentration (Figure CA-21; Table CA-6). The median annual NO_3 load in Carver Creek is higher than all of the other MCES-monitored Minnesota River tributaries, except Bevens Creek and Sand Creek. Similarly, the median annual NO_3 yield in Carver Creek is also higher than all of the other monitored Minnesota River tributaries, except Bevens Creek and Sand Creek. The Carver yield is higher than most other MCES-monitored metro area streams, but lower than other primarily agricultural watersheds, including the Vermillion River, Crow River, the Cannon River, Sand Creek, Bevens Creek, and Valley Creek.

Chloride. Median Cl FWM concentration in Carver Creek is greater than that of the Minnesota River, but lower than the concentration observed in the most urbanized Minnesota River watersheds monitored by MCES (Willow Creek, Nine Mile Creek, Bluff Creek, Riley Creek, and Credit River). It is also lower than that of many other monitored watersheds in the metro area including Bassett, Minnehaha, Battle, and Fish Creeks. The two most prevalent sources of Cl to streams are road surfaces (from salt application as a de-icer) and WWTP effluent (from domestic water softeners).

Macroinvertebrates

The historic biomonitoring data, summarized as M-IBI scores, are also shown as box-and-whisker plots. However, the streams were organized by stream type because the MPCA impairment thresholds are type-specific and this attribute does not correlate with major river basins.

The M-IBI scores for Carver Creek intersect the MPCA impairment threshold (Figure CA-23). This shows the monitored reach scored values both above and below the threshold of impairment during the period of study. The median was above the threshold which suggests that this stream reach habitat and water quality generally were more likely to sustain the needs for aquatic life. These results are similar to other agricultural watersheds in both the Minnesota and Mississippi River basins, and higher than the urban stream reaches. This suggests the agricultural macroinvertebrate communities may be less stressed than the urban macroinvertebrate communities in the metropolitan area.

Figure CA−19: Total Suspended Solids for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

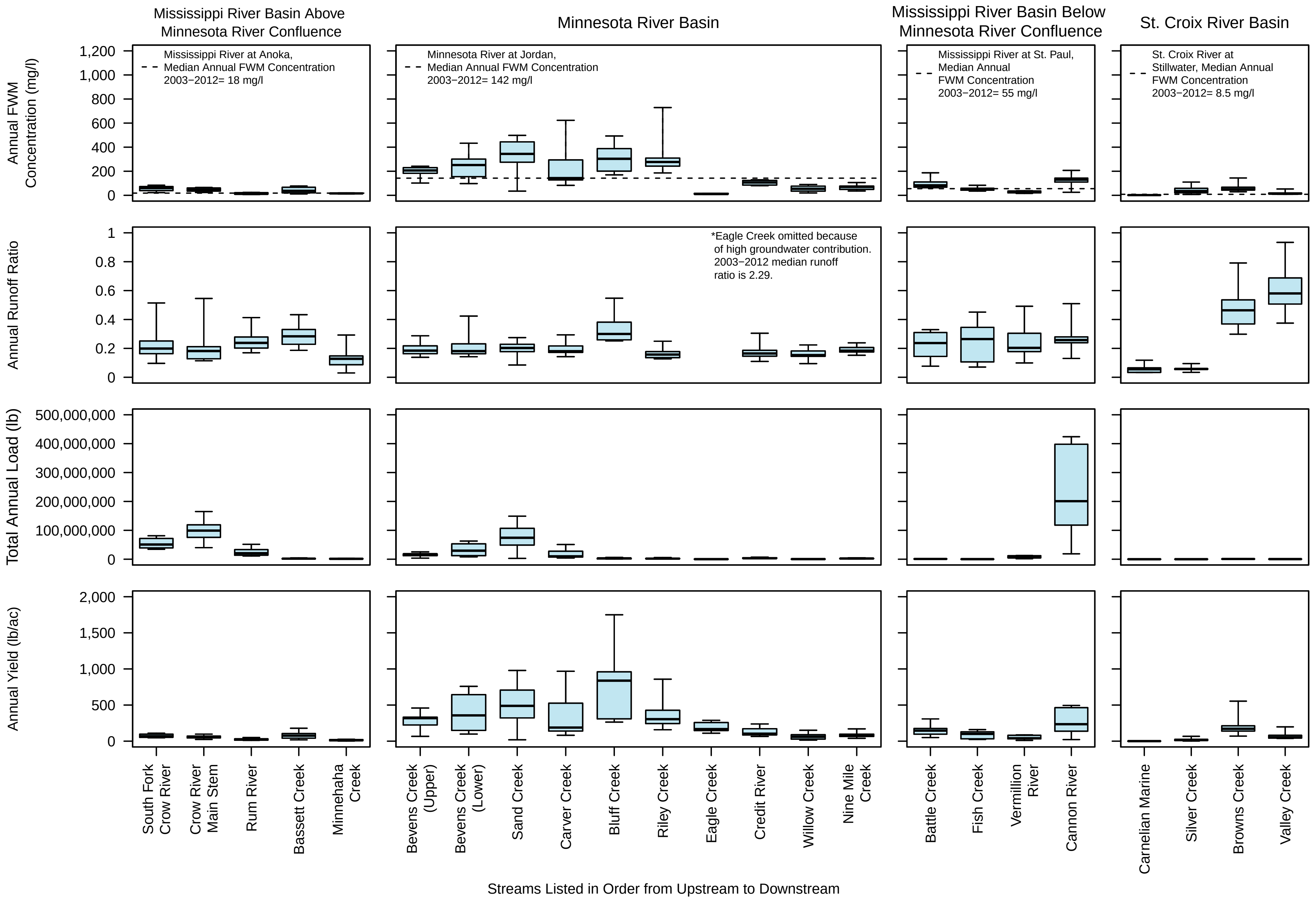


Figure CA−20: Total Phosphorus for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

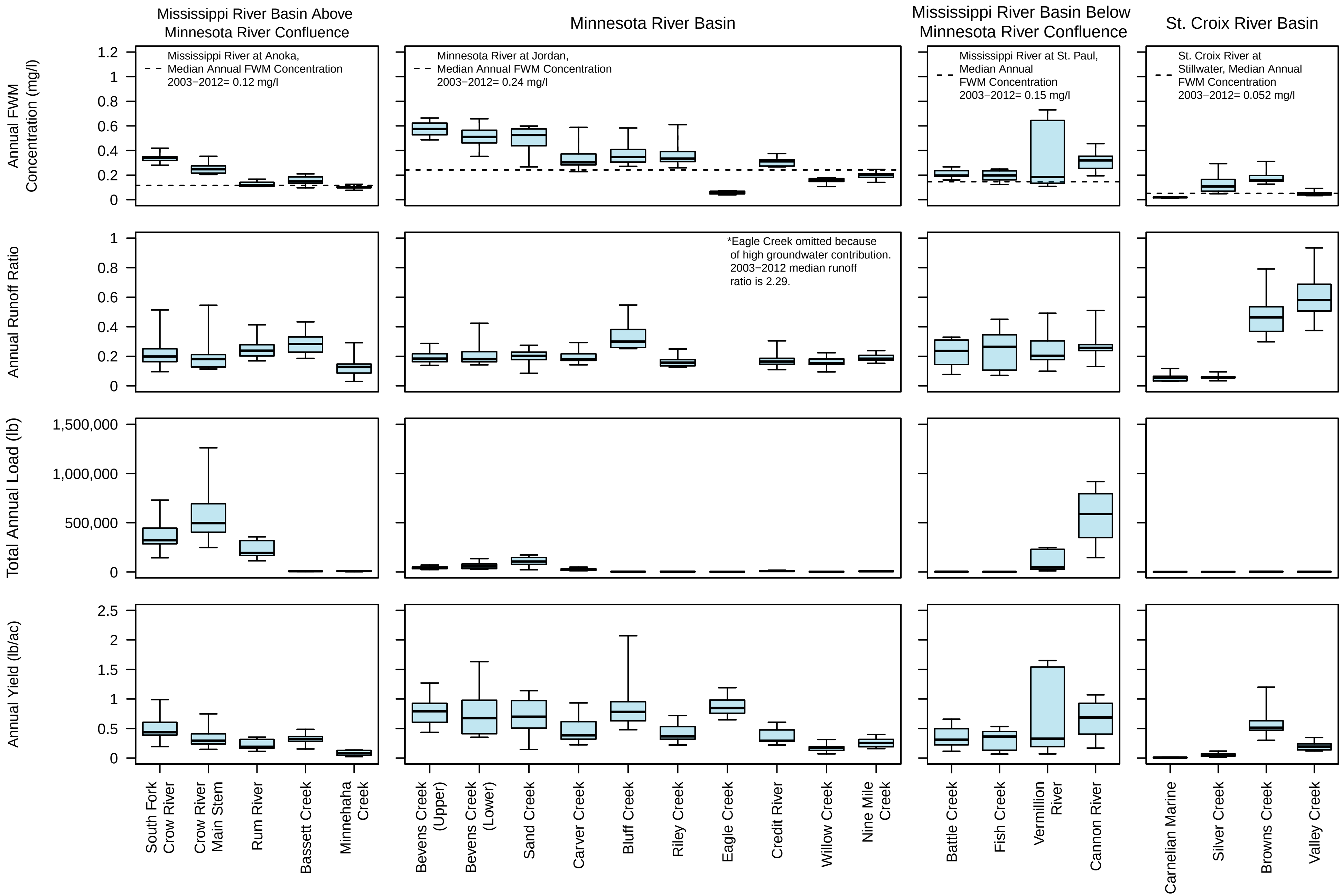


Figure CA−21: Nitrate for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

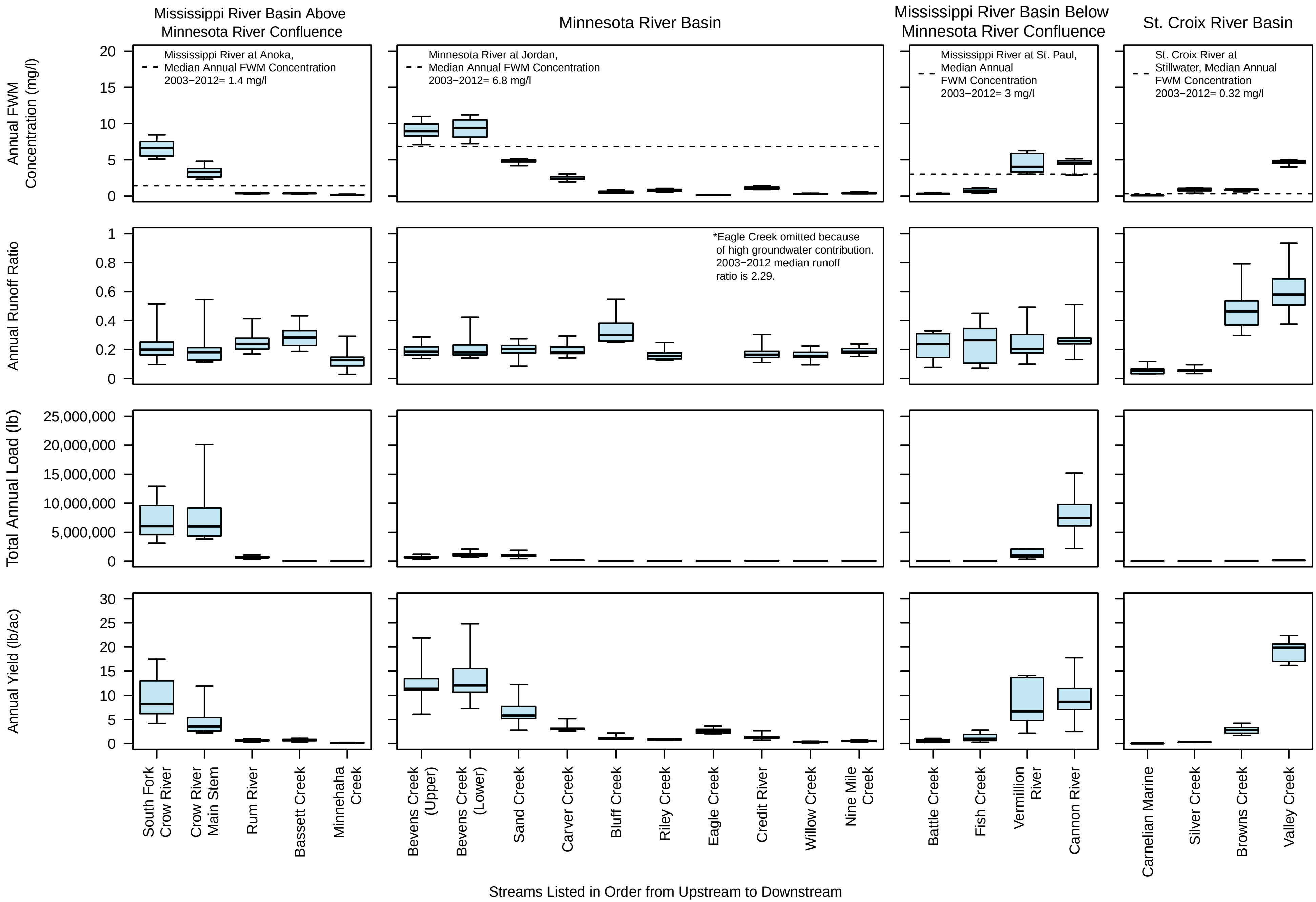


Figure CA−22: Chloride for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

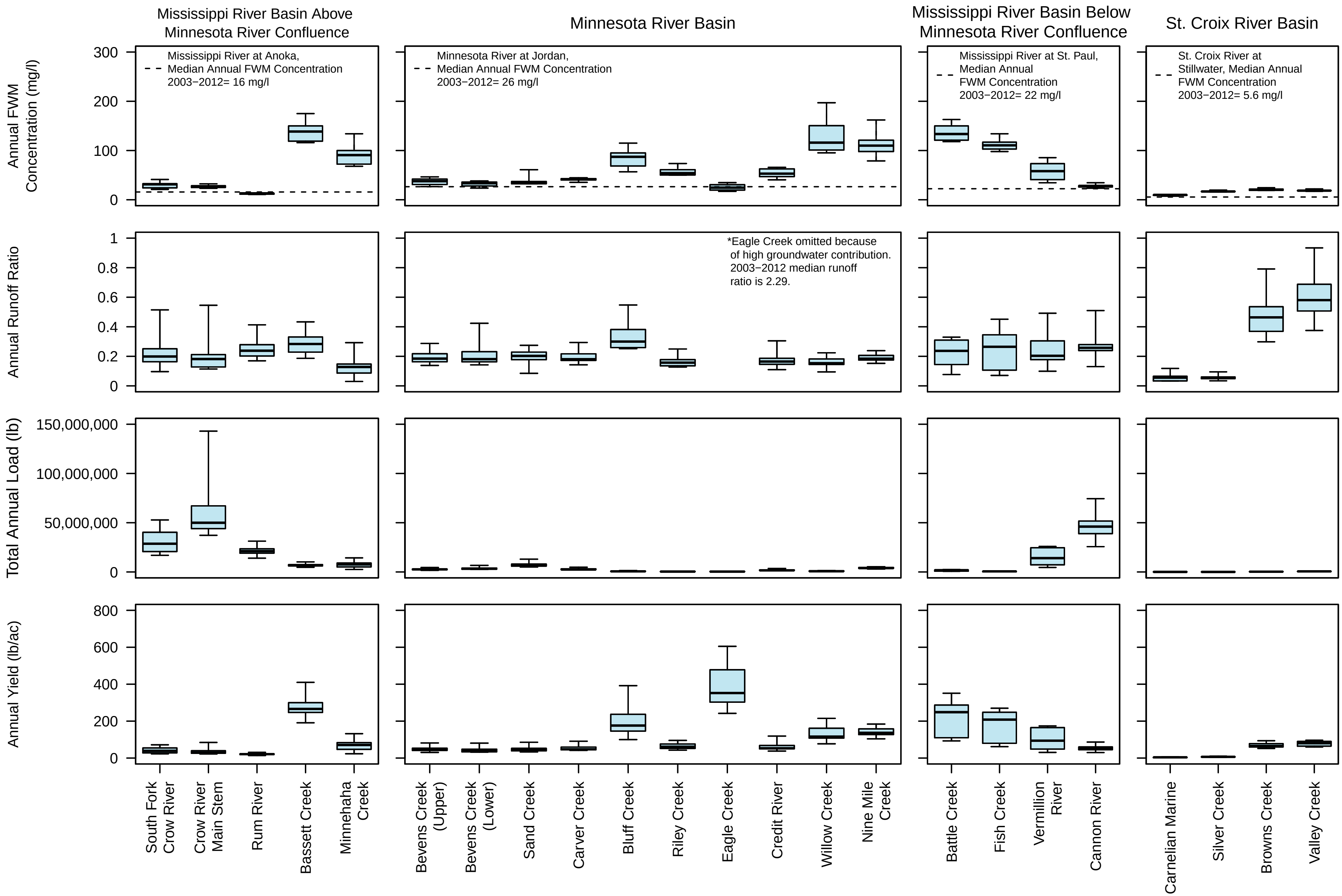


Table CA-6: Annual Median Concentrations, Loads, and Yields for MCES-Monitored Streams, 2003-2012

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)

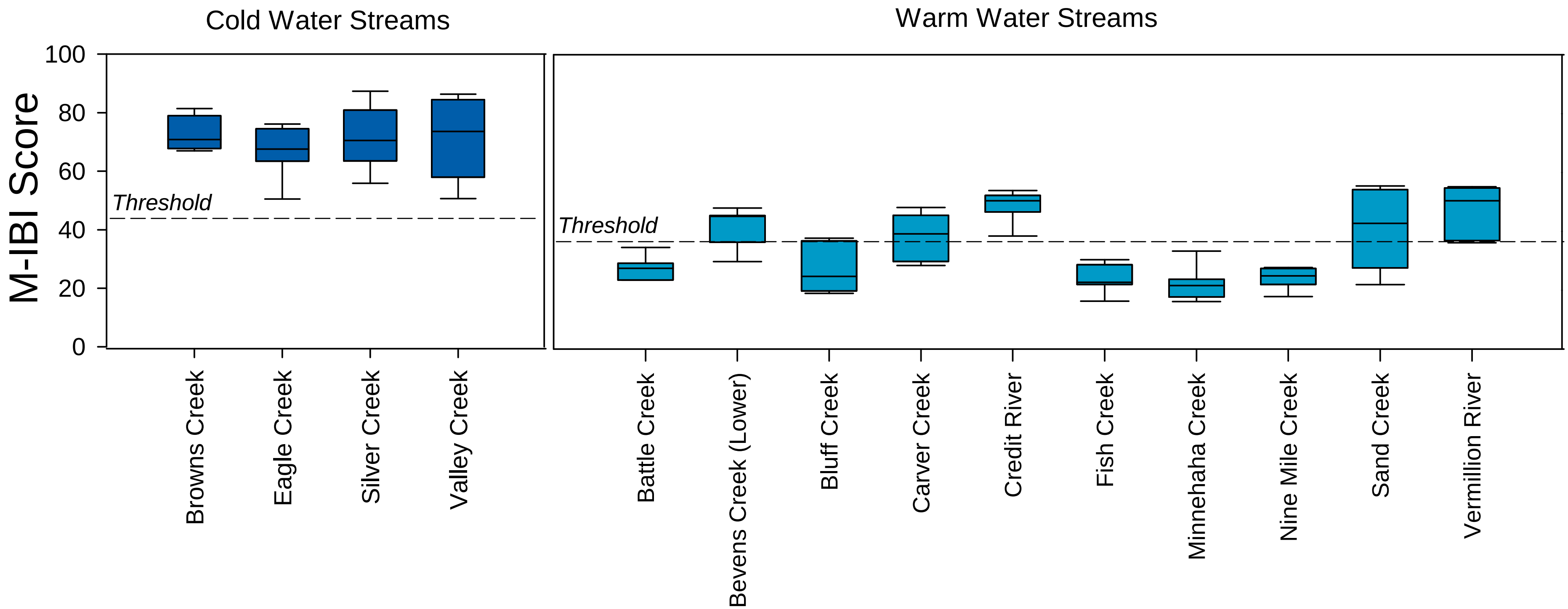
[2] FWM conc = annual flow-weighted mean concentration estimated using Flux32 (Walker, 1999).

[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

Figure CA-23: M-IBI Results for MCES-Monitored Streams, 2004-2011

Organized by Stream Type



Higher M-IBI scores are indicative of a better water quality.
Each stream type has system-specific impairment thresholds set by the MPCA (2014b).
If a portion of the box plot is below the threshold, the stream may not have supported the needs of aquatic life during the study period.

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.

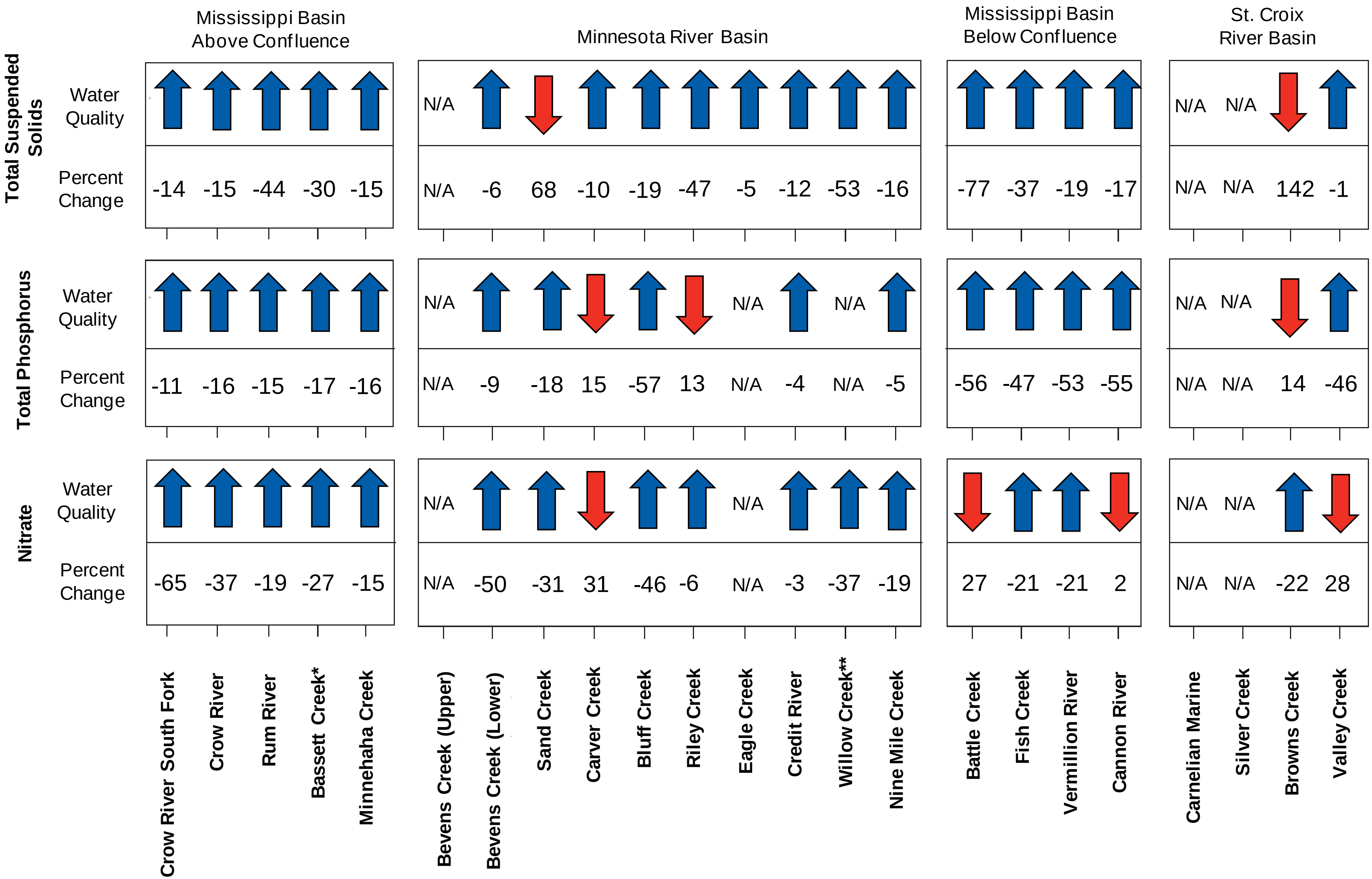
Estimated changes for TSS, TP, and NO_3 in MCES-monitored streams are presented below in two ways. First, tabulated results with directional arrows indicating improving (blue upward arrow) and declining (red downward arrow) water quality paired with percent change in flow-adjusted concentration estimated for 2008-2012 (Figure CA-24). 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 CA-25). In both figures no trend was reported for those QWTREND analyses with poor quality of statistical metrics (e.g. $p>0.05$).

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

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 except Sand Creek. Although the TSS concentration in Carver Creek decreased during the last five years, both TP and NO_3 concentrations increased, indicating declining water quality for these parameters.

Figure CA-24: Regional Estimated Trends in Flow-Adjusted Stream Concentrations of TSS, TP, and NO_3, 2008-2012

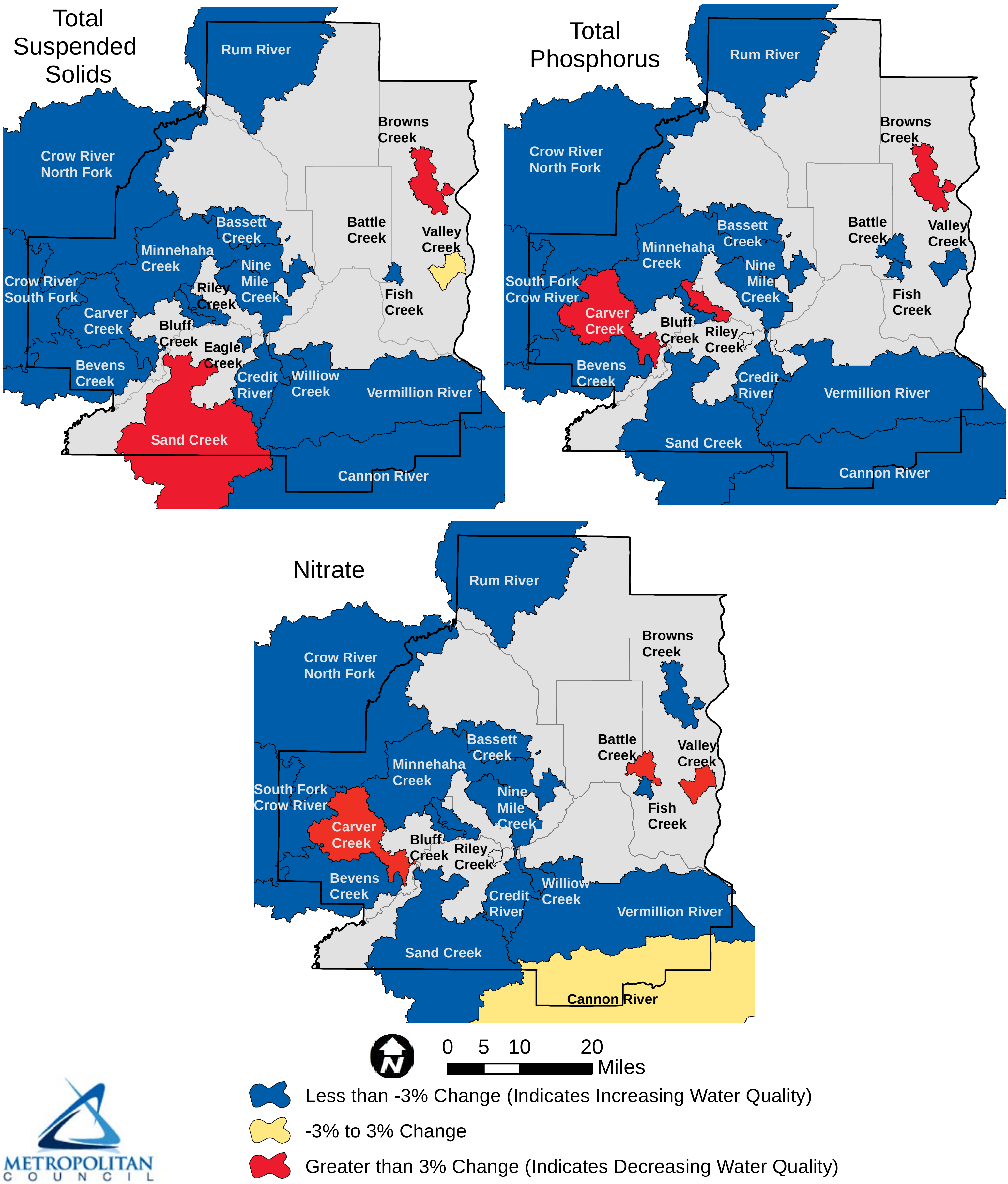
(Grouped by Major River Basin; As estimated by QWTrend)



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 CA-25: 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

Carver Creek is a tributary to the Minnesota River located in the western part of the metropolitan area. It has two headwater branches: one in Waconia Township and one in Camden Township. It drains approximately 83 square miles in Carver County, and receives runoff from all or parts of the cities of Waconia, Cologne, and Carver. The creek flows through lakes, including Lake Waconia and Miller Lake, wetlands, and the Minnesota Valley National Wildlife Refuge, before entering the Minnesota River. Land cover in the watershed is mostly agricultural, followed by forested, wetlands, open water, and developed areas. The east portion of the watershed is gradually converting to hobby farms and large lot residential. Two small WWTPs discharge to Carver Creek. The upper watershed is relatively flat, while the topography steepens at the transition from the Minnesota River bluff to the river floodplain. The MCES monitoring station is located near CSAH 40. About 0.9 percent of the watershed is located downstream of the monitoring station, and 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 Carver Creek is affected by several factors: agricultural activity; WWTP effluent; loss of wetlands and upland storage; sediment settlement and nutrient cycling in Miller Lake, and ravine and streambank erosion. TSS FWM concentration in the stream is similar to that of the Minnesota River but the average annual TSS load is lower than other MCES-monitored agricultural Minnesota River tributaries.

Trend analysis indicates a decrease in TSS flow-adjusted concentration since 1989 and thus an improvement in water quality in terms of TSS. The flow-adjusted concentration decrease may well reflect the level of management practices, including conservation tillage, agricultural buffer strips, field terracing, and other practices implemented by local farmers with support from Carver WMO and Carver SWCD. Settlement of TSS in Miller Lake over time may also have affected the trend results.

The NO_3 loads and concentrations are likely driven by agricultural activity in the watershed. The concentration in Carver Creek is lower than that in the Minnesota River (which carries runoff from the intensely farmed area of western Minnesota). The average annual NO_3 load and areal yields are lower than most of the other agricultural MCES-monitored metropolitan area tributaries, but higher than the more urban streams. Trend analysis for 2008-2012 indicates an increase in NO_3 flow-adjusted concentrations in Carver Creek and thus a decline in water quality in terms of NO_3.

Carver Creek TP loads and concentrations are likely affected by agricultural activity and effluent discharge from WWTPs, as well as nutrient cycling in Miller Lake. The concentration in Carver Creek is higher than that in Minnesota River, and is generally higher than most of the MCES-monitored tributaries in the Mississippi and St. Croix River basins. TP loading is lower than that of MCES-monitored agricultural streams in the Mississippi River basin, while areal loading is similar to other monitored agricultural streams. Trend analysis indicates a decrease in TP flow-adjusted concentrations from 1989 to 2004, followed by a very slight increase in flow-adjusted concentration from 2005 to 2012. Trend analysis for 2008-2012 indicates a slight increase in TP flow-adjusted concentrations in Carver Creek and thus a decline in water quality in terms of TP.

The Cl concentrations in Carver Creek were lower than the highly urbanized watersheds monitored by MCES, reflecting the low level of development and road density in the watershed and thus the relatively low input of Cl as road de-icer. Carver Creek Cl loads and areal yields are similar to other monitored rural Minnesota River tributaries.

Biological monitoring of macroinvertebrates in Carver Creek indicate fair to good water quality, a relative lack of pollutant intolerant species, and possible presence of organic (high oxygen demand) pollutants in the stream. Application of the Macroinvertebrate Index of Biotic Integrity indicates that Carver Creek may not fully support of the needs of aquatic life.

Recommendations

This section presents recommendations for monitoring and assessment of Carver Creek, as well as recommendations for partnerships to implement stream improvements. MCES recognizes that cities, counties, and local water management organizations, like Carver WMO, 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 organization 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 Carver Creek, and should partner with Carver WMO to investigate possible sources of pollutants in the creek.
- MCES should consider partnering with U.S. Fish and Wildlife Service (USFWS) to share data and assessment on the effects of Carver Creek on the Minnesota Valley National Wildlife Refuge.
- MCES should partner with Carver WMO to investigate potential loading of TP to the creek from nutrient cycling within Miller Lake.
- MCES and Carver WMO should consider sampling upstream of Miller Lake to help determine the effect of the lake on the creek.
- MCES should continue to evaluate the effects of groundwater withdrawal on surface waters in the Carver Creek watershed, including updating analyses with the best available data and linking results to predictive groundwater modeling and the comprehensive planning process.
- Macroinvertebrate monitoring for Carver Creek should be continued, and further investigation of the lack of intolerant species should be pursued. MCES should continue to analyze and evaluate the biomonitoring program. Potential additions should include a Stream Habitat Assessment similar to the habitat surveys performed by the MPCA or the addition of fish population and algal community data.
- In five years, when a reasonable amount of additional monitoring data has been collected, the trends analysis should be repeated. At that time, Cl, flow, NH_3, and bacteria should be included in the trend analysis.
- MCES and partners (especially Carver WMO) 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 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.

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