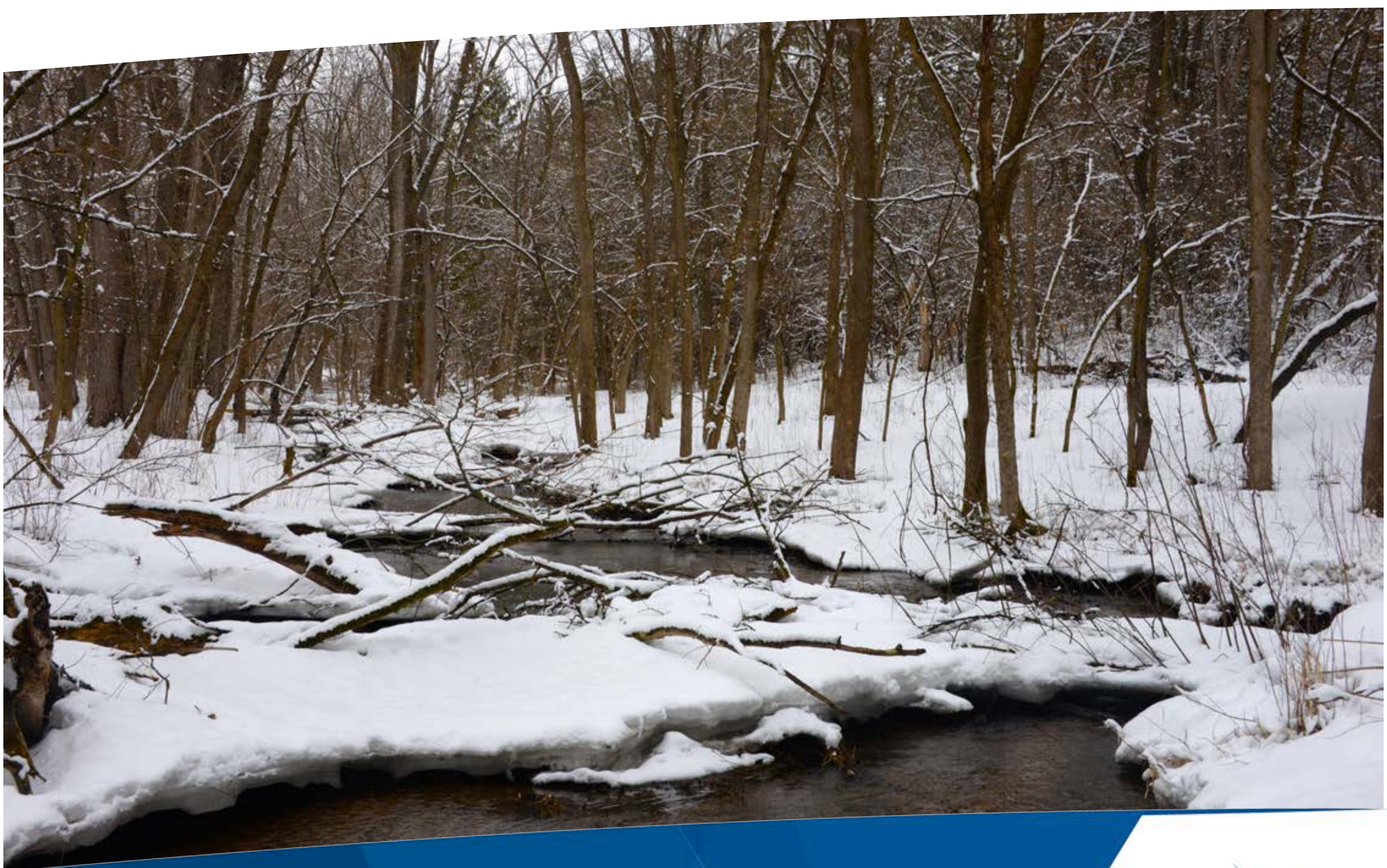
Comprehensive Water Quality Assessment of Select Metropolitan Area Streams

VALLEY CREEK



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December 2014

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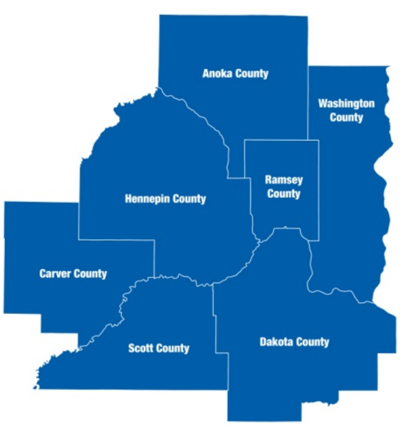

The Metropolitan Council is the regional planning organization for the seven-county Twin Cities area. The Council operates the regional bus and rail system, collects and treats wastewater, coordinates regional water resources, plans and helps fund regional parks, and administers federal funds that provide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

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About the Study

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

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

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

All background information, methodologies, and data sources are summarized in *Introduction and Methodologies*, and a glossary and a list of acronyms are included in *Glossary and Acronyms*. Both of these, as well as individual sections for each of the 21 streams, are available for separate download from the report website. The staff of Metropolitan Council Environmental Services (MCES) and local cooperators 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, *Valley Creek*, is one in a series produced as part of the *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams.* Located entirely in Washington County, Valley Creek is one of the four St. Croix River tributaries examined. This section discusses a wide range of factors that have affected the condition and water quality of Valley Creek.

Cover Photo

The photo on the cover of this section depicts Valley Creek at the MCES monitoring site near Afton, Minnesota.

Recommended Citations

Please use the following to cite this section of the report:

Metropolitan Council. 2014. *Valley Creek*. In *Comprehensive water quality assessment of select metropolitan area streams*. St. Paul: Metropolitan Council.

Please use the following to cite the entire report:

Metropolitan Council. 2014. *Comprehensive water quality assessment of select metropolitan area streams*. St. Paul: Metropolitan Council.

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Introduction

Valley Creek is located in the eastern metropolitan area and is a tributary to the St. Croix River. It drains approximately 12.5 square miles of mixed agricultural land, forest land, grass lands, and urban areas (cities of Woodbury and Afton) through Washington County (Figure VA-1).

Figure VA-1: Valley Creek at Putnam Boulevard

This report:

- documents those characteristics of Valley 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 Valley Creek flow and water quality with other streams within the metropolitan area monitored by Metropolitan Council Environmental Services (MCES).
- makes general recommendations for future assessment activities, watershed management, partnerships, and other potential actions to remediate water quality or flow concerns.

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

Partnerships and Funding

MCES has supported water quality monitoring of Valley Creek, also referred to as Valley Branch, since 1999 as part of its Watershed Outlet Monitoring Program (WOMP). Funding for this site was provided by the Minnesota Legislature, most recently through a Clean Water Fund grant from the MPCA.

MCES partners with the Valley Branch Watershed District (VBWD) and the Science Museum of Minnesota's St. Croix Watershed Research Station (SCWRS) to conduct monitoring at this station. From 1998 until 2010, the SCWRS was subcontracted by VBWD to conduct continuous monitoring, maintain the rating curve, and collect all water quality samples. After 2010 the station maintenance, monitoring, and water collection responsibilities were transferred to the Washington Conservation District (WCD). The VBWD has also been responsible for conducting continuous monitoring and collecting water quality samples at other Valley Creek locations, the North and South Branches of Valley Creek since 1998.

Monitoring Station Description

The MCES monitoring station is located on Valley Creek near Putnam Boulevard in Afton, Minnesota, one mile upstream from the creek's confluence with the St. Croix River. Situated in a groundwater discharge (or upwelling) zone, Valley Creek is a gaining stream along much of the channel length, and has a disproportionately high water yield relative to its drainage area. The groundwater-fed stream flows perennially and does not freeze during the winter.

The monitoring station includes continuous flow monitoring (Design Analysis H350/H355 Bubbler), baseflow grab sample collection, event-based composite sample collection (Hach Sigma Sampler), and on-site conductivity and temperature probes (Campbell Scientific Inc.). Additionally, a Side-Looking Doppler Current Meter (SonTek/YSI Argonaut-SL) is deployed at this site to quantify stream velocity. A dense canopy cover precludes the collection of precipitation data at the MCES station. However, precipitation data are continuously collected and recorded at the two SCWRS stations upstream of the MCES station.

Daily precipitation totals from this station 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.

During November 2007 through March 2008, the monitoring station experienced local channel instability, which created significant errors in the flow values derived from the rating curve. The recorded values were corrected to match measured values. Flow values between measurements were calculated with provisional rating curves that filtered out small flow variations (J. Almendinger, SCWRS, personal communication, 2013).

Stream and Watershed Description

The Valley Creek watershed lies entirely within Washington County. Originally, the watershed had a larger drainage area of 65 square miles (35,413 acres), which drained to the St. Croix River through Valley Creek. The watershed spanned from the cities of Mahtomedi and Grant south to the city of Afton. In order to solve localized flooding problems, the Valley Branch

Watershed District completed Project 1007 in 1987 (Barr Engineering Company, 2005). This project prevented flooding by diverting the flows from the northern two-thirds of the watershed through an outlet pipe along Interstate-94 and hydrologically separated the watershed.

The current Valley Creek watershed has a drainage area of approximately 12.5 square miles. It contains two headwater branches, the North and South Branches of Valley Creek. The North Branch originates at the outlet of Lake Edith, and generally flows south with a channel length of 1.5 miles. The South Branch originates near the city of Woodbury and flows east and southeasterly through Afton, where it converges with the North Branch 0.6 miles upstream of the monitoring station. The main stem of Valley Creek continues to flow southeasterly for one mile, and discharges into the St. Croix River. Portions of the Valley Creek watershed fall within the Metropolitan Council's jurisdiction (Council Districts 11 and 12).

All three branches of Valley Creek are designated as trout streams by the Minnesota Department of Natural Resources (MnDNR) and fall within the Minnesota Pollution Control Agency's (MPCA) Class 2A Water Regulations for Aquatic Life and Recreation. In addition to Valley Creek, there are two other open water bodies within the northeast portion of the watershed: Metcalf Marsh, a large, spring-fed wetland that drains into Lake Edith (77 acres).

The watershed encompasses a total of 7,506 acres of which 7,327 acres (97.6%) is upstream of the monitoring station (Figure VA-2; Table VA-1). There is a total of 1,181 acres of landlocked areas; these are not included in the areal calculations as they do not contribute to the stream flow or load. The watershed is 36.2% agricultural land, which falls entirely in the monitored areas, and 17.6% developed urban land (17.5% within the monitored area), based on Minnesota Land Cover Classification System (MLCCS) 2008 data. The urbanized land includes portions of the cities of Woodbury and Afton, with very small portions of Lakeland, Lake St. Croix Beach, and St. Mary's Point in the unmonitored portion.

Impervious coverage is distributed fairly evenly throughout the watershed in large-lot residential properties and roads. Based on the U. S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS) 2009 Cropland Data Layer, 33% (33% within the monitored area) of the agricultural area is planted in corn and 20% (20% monitored) in soybeans. According to a statewide estimate of potentially draintiled fields by University of Minnesota researchers (D. Mulla, University of Minnesota, personal communication, 2012), less than 0.1% of the agricultural land in the watershed is potentially draintiled. Other primary land covers in the watershed are forest, grasses/herbaceous, and wetlands (See Table VA-1).

Table VA-1: Valley Creek Land Cover Classes[1]

Land Cover Class	Monitored		Unmonitored		Total		Landlocked	
	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent
5-10% Impervious	337	4.6%	7	4.0%	344	4.0%	128	10.8%
11-25% Impervious	537	7.3%	21	11.6%	558	11.6%	22	1.9%
26-50% Impervious	160	2.2%	8	4.4%	168	4.4%	16	1.4%
51-75% Impervious	81	1.1%	<0.1	<0.1%	81	<0.1%	4	0.3%
76-100% Impervious	168	2.3%	4	2.2%	172	2.2%	11	0.9%
Agricultural Land	2,720	37.1%	<0.1	<0.1%	2,720	<0.1%	163	13.8%
Forest (all types)	2,017	27.5%	49	27.3%	2,066	27.3%	558	47.2%
Open Water	108	1.5%	<0.1	<0.1%	108	<0.1%	<0.1%	<0.1%
Barren Land	<0.1	<0.1%	<0.1	<0.1%	<0.1	<0.1%	<0.1%	<0.1%
Shrubland	22	0.3%	4	2.4%	26	2.4%	<0.1%	<0.1%
Grasses/Herbaceous	985	13.4%	27	15.0%	1,011	15.0%	242	20.5%
Wetlands (all types)	194	2.6%	59	33.2%	253	33.2%	36	3.0%
Total	**7,327**	**100.0%**	**179**	**100.0%**	**7,506**	**100.0%**	**1,181**	**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.

The geologic history of a watershed dictates many hydrologic properties and surface topography. The area south of the Valley Creek watershed was last glaciated during the Illinoian Glaciation (~300,000–130,000 years ago), which resulted in an older landscape of mainly Keewatin till. The Valley Creek watershed was subjected to a secondary glacial episode, the Wisconsin Glaciation (approximately 20,000 years ago). As the glaciers retreated they exposed the limestone, dolomite, sandstone, and shale bedrock. Additionally, they deposited till that created a younger landscape with the St. Croix moraine at the southwestern boundary of the watershed and covered the remainder of the catchment with glacier outwash (Pitt et al., 2003).

According to the U. S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) STATSGO soils data, nearly all of the soils in the Valley Creek watershed are characterized as Type B soils, which have a moderate infiltration capacity. There are few, localized regions of soils with low infiltration capacities, or Type D soils, corresponding with the St. Croix moraine in the southwestern portion of the watershed (Barr Engineering Company, 2005). The STATSGO soil survey may not be representative of actual conditions. For installation of infiltration practices, soil borings should be taken from the exact location of the proposed site location to assess level of soil filling or disturbance.

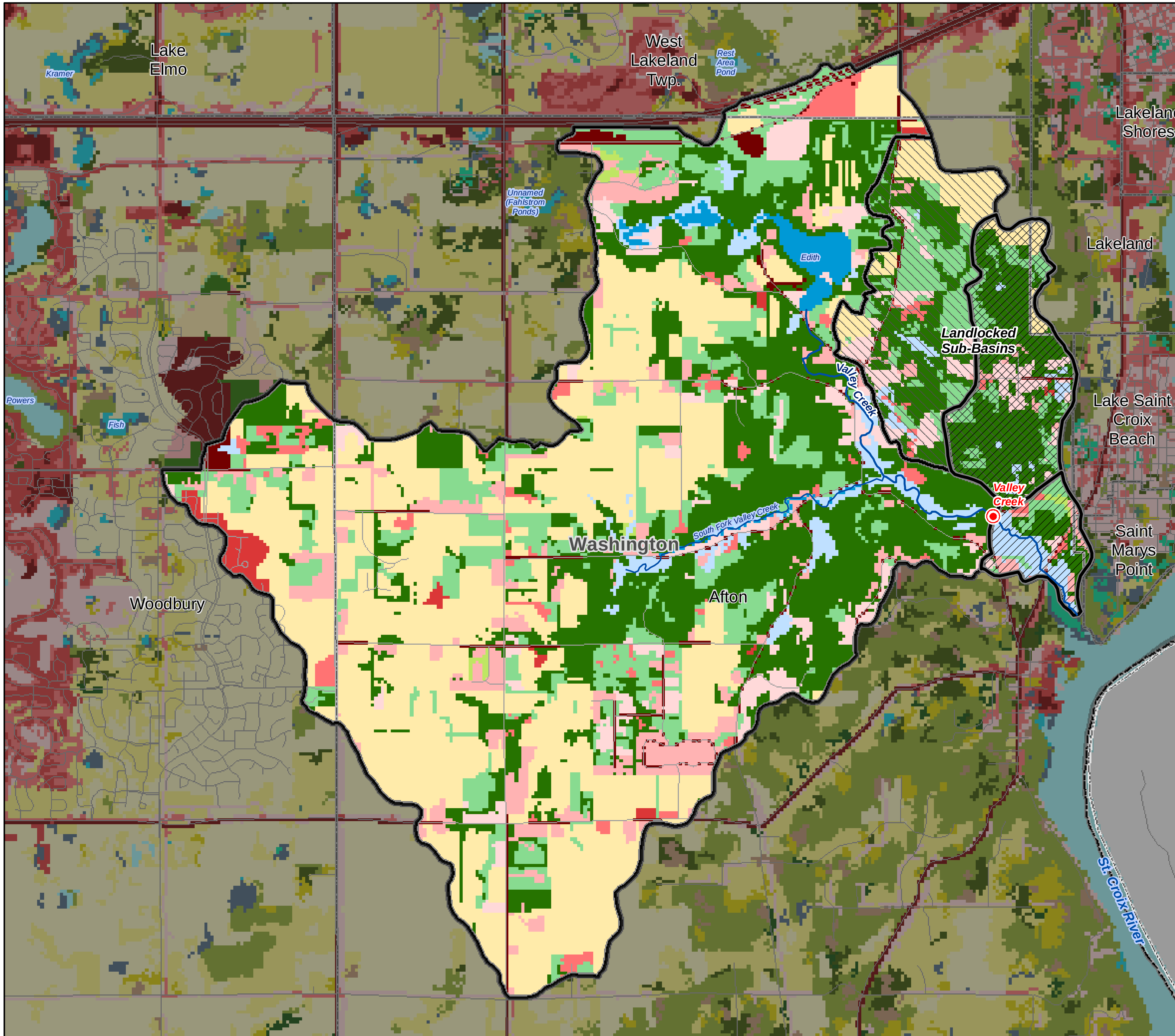

Figure VA-2

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MLCCS-NLCD Hybrid Land Cover

Valley Creek

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

MLCCS-NLCD Hybrid Land Cover

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

Data Source: MnDNR

MLSSC/NLCD Hybrid Land Cover
Valley Creek

Land Cover Class	Value	Monitored Contributing Acres	Percent	Monitored Land-Locked Acres	Percent	Monitored Total Acres	Percent
5-10% Impervious	1	337	4.6%	81	12.1%	418	5.2%
11-25% Impervious	2	537	7.3%	12	1.9%	549	6.9%
26-50% Impervious	3	160	2.2%	15	2.2%	175	2.2%
51-75% Impervious	4	81	1.1%	2	0.3%	83	1.0%
76-100% Impervious	5	168	2.3%	7	1.1%	175	2.2%
Agricultural Land	6	2,720	37.1%	126	18.8%	2,846	35.6%
Forest (all types)	8	2,017	27.5%	243	36.4%	2,260	28.3%
Open Water	11	108	1.5%	0	0.0%	108	1.3%
Barren Land	12	0	0.0%	0	0.0%	0	0.0%
Shrubland	14	22	0.3%	0	0.0%	22	0.3%
Grasses/Herbaceous	15	985	13.4%	163	24.3%	1,147	14.3%
Wetlands (all types)	17	194	2.6%	20	3.0%	213	2.7%
Total		**7,327**	**100.0%**	**669**	**100.0%**	**7,997**	**100.0%**

Land Cover Class		Unmonitored Contributing Acres	Percent	Unmonitored Land-Locked Acres	Percent	Un-Monitored Total Acres	Percent
5-10% Impervious	1	7	4.0%	47	9.2%	54	7.8%
11-25% Impervious	2	21	11.6%	10	1.9%	30	4.4%
26-50% Impervious	3	8	4.4%	2	0.3%	9	1.4%
51-75% Impervious	4	0	0.0%	2	0.3%	2	0.2%
76-100% Impervious	5	4	2.2%	4	0.7%	8	1.1%
Agricultural Land	6	0	0.0%	38	7.4%	38	5.5%
Forest (all types)	8	49	27.3%	314	61.5%	363	52.6%
Open Water	11	0	0.0%	0	0.0%	0	0.0%
Barren Land	12	0	0.0%	0	0.0%	0	0.0%
Shrubland	14	4	2.4%	0	0.0%	4	0.6%
Grasses/Herbaceous	15	27	15.0%	80	15.6%	107	15.5%
Wetlands (all types)	17	59	33.2%	16	3.1%	75	10.9%
Total		**179**	**100.0%**	**511**	**100.0%**	**690**	**100.0%**

0 0.5 1 1.5
Miles

The watershed topography is gradual at the western, upstream end, and gets steeper in the east, culminating with a very steep drop into the St. Croix River (Figure VA-4). The maximum watershed elevation is 1055.4 above mean sea level and the minimum elevation is 691.8 within the monitored area. Within the monitored area, 10% of the slopes are considered steep and an additional 7% are considered very steep. Steep slopes are those between 12-18%, and very steep slopes are those 18% or greater (MnDNR, 2011). The creek average gradient is 39.1 feet/mile with a maximum gradient of 125.9 feet/mile.

The Valley Creek watershed is relatively undeveloped compared to other watersheds in the metropolitan area. There are no MPCA-permitted point source discharges within the Valley Creek watershed. As of 2010, the watershed had four registered feedlots with a total of 440 animal units (AU), all within the monitored portion of the watershed. Only one feedlot has over 100 AUs, with 230 AUs (Figure VA-5).

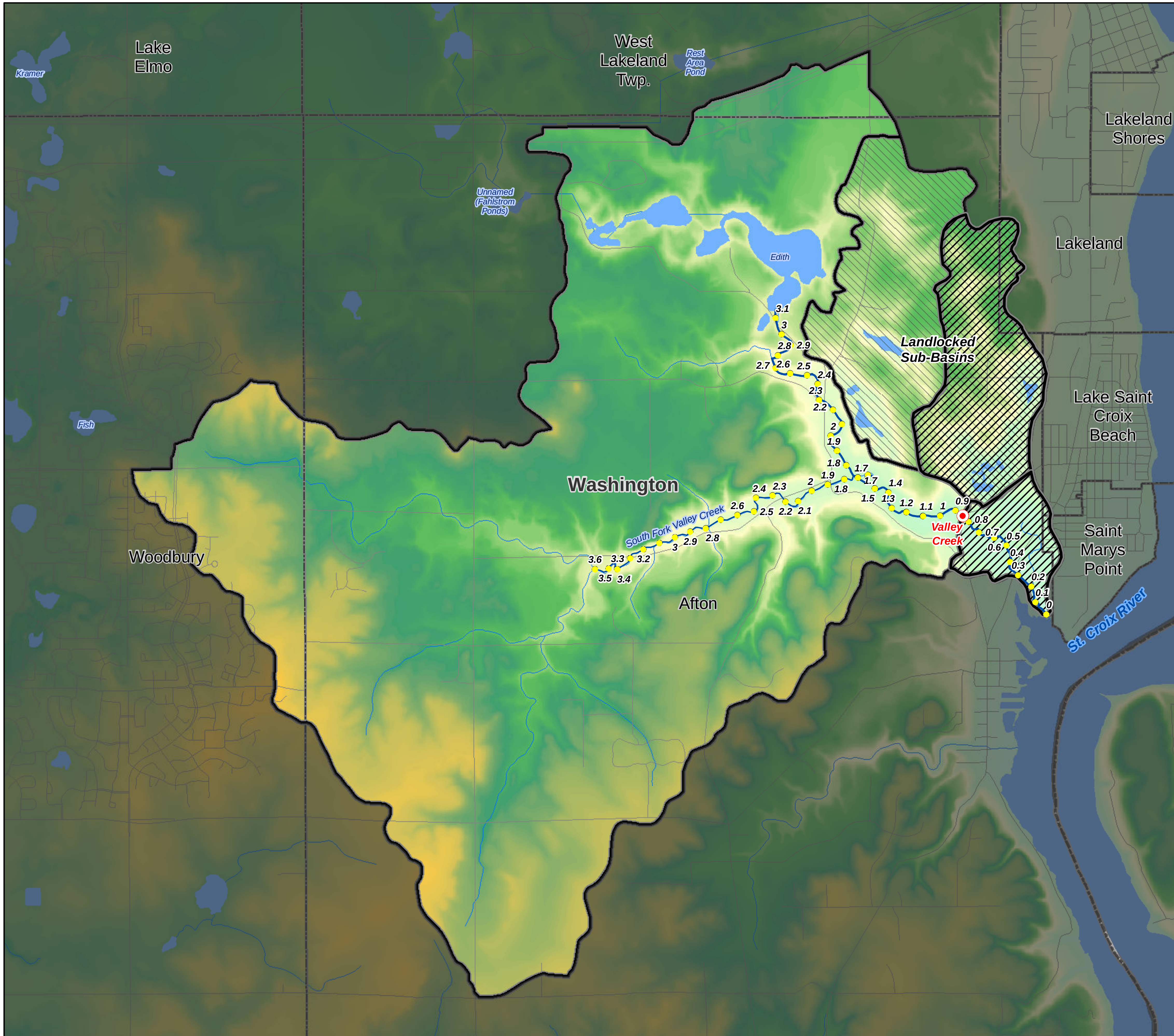
The rural nature of the Valley Creek watershed and a lack of a centralized sewer system necessitates the use of on-site septic systems to manage wastewater. A well maintained septic system percolates wastewater through the soils, where microorganisms treat and purify the effluent before it enters the shallow groundwater. However, failing septic systems can negatively influence the water quality by leaching pollutants (nutrients, pharmaceuticals, and other toxic chemicals) into the subsurface. The Washington County Department of Public Health and Environment is the regulatory authority for these systems, and they permit, inspect, and track the maintenance of all septic systems in the county (Washington County, 2014).

Figure VA-3: Valley Creek
Photo credit: Belwin Conservancy

Nongovernmental organizations actively participate in Valley Creek stream habitat protection. One example, the Belwin Conservancy, has a long history with the region. Established in 1970, it has acquired property to prevent overdevelopment in the stream corridor and the watershed (Belwin Conservancy, 2013). The conservation efforts have been focused on land protection, restoration, and education projects. In 2008, the Belwin Conservancy partnered with the Minnesota Land Trust, Trout Unlimited, the Valley Branch Watershed District, and the Washington County Land and Water Legacy Program to form the Valley Creek Protection Partnership. The group has restored or protected 125 acres of land. Additionally, funding from the Clean Water, Land, and Legacy Amendment has been set aside to protect 80 acres of land through conservation easements, secure public fishing access, and restore and enhance in-stream habitat (Legislative Coordinating Commission, 2013). These efforts have preserved undeveloped forested areas that help to keep the waters clean and clear (Figure VA-3), and have fostered a conservation approach that benefits both the stream and watershed well into the future.

Figure VA-4

Watershed Topography
Valley Creek



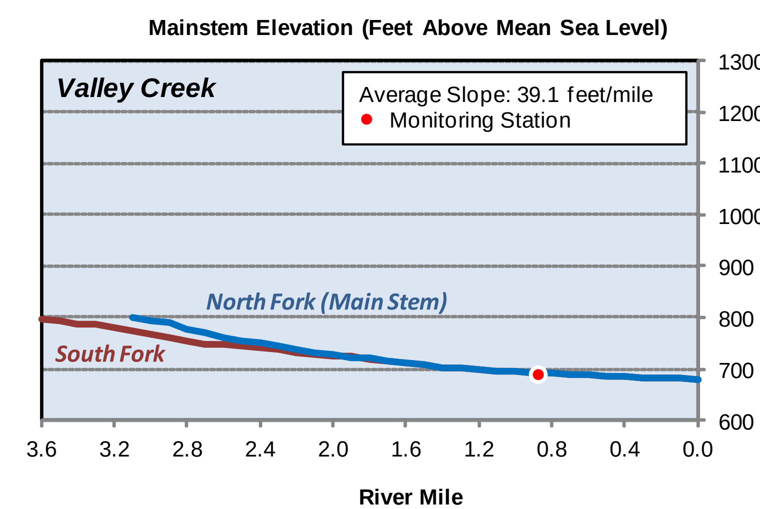


Figure VA-5

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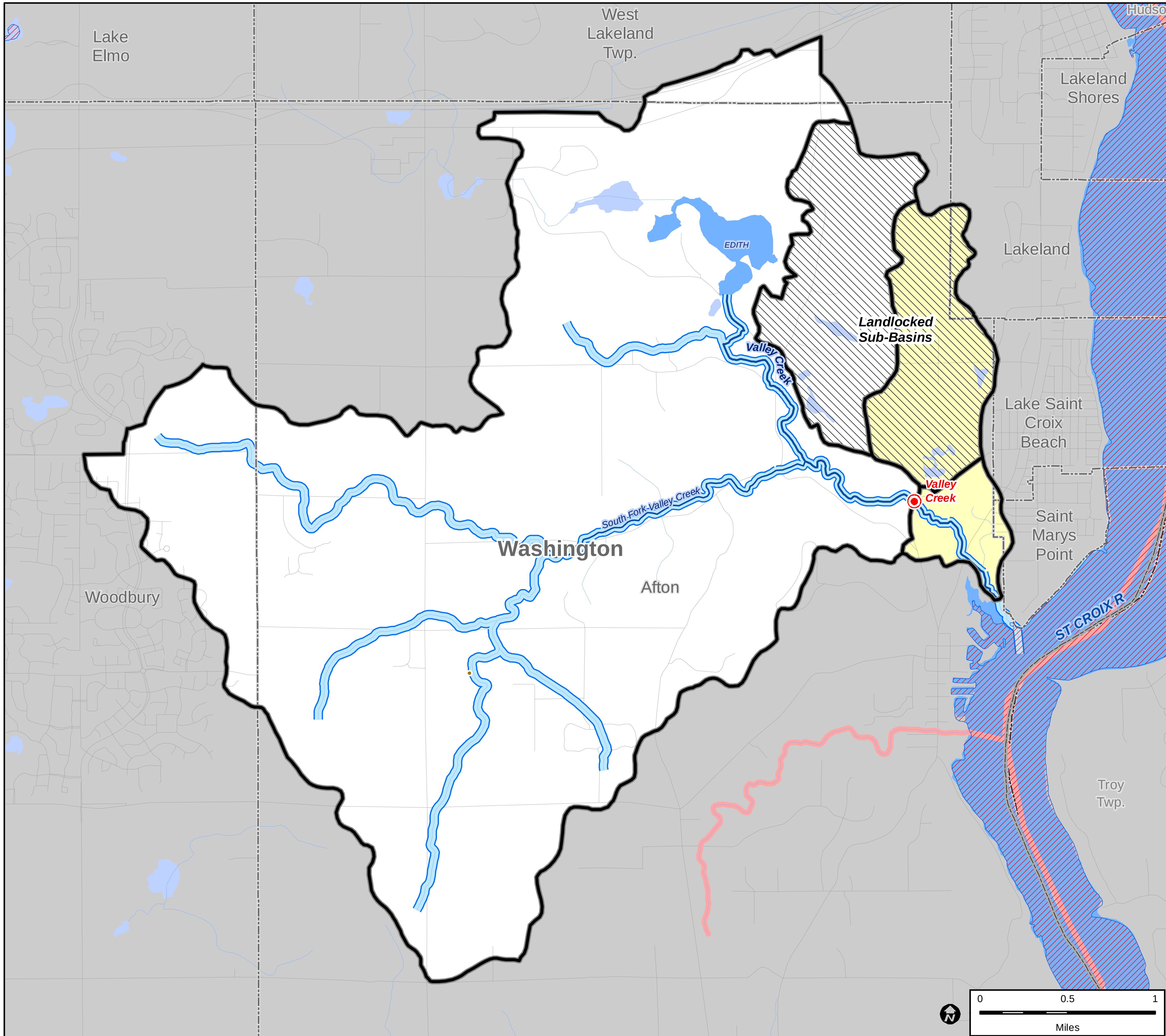
Public and Impaired Waters and Potential Pollution Sources

Valley 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

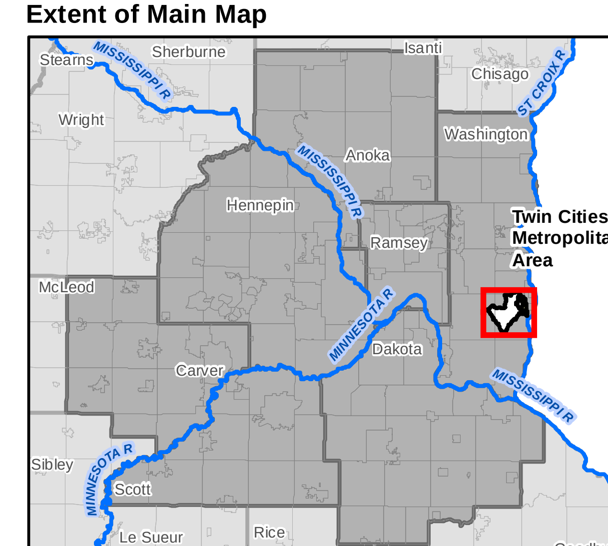
Feedlots with 100 or more animal units **

- 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



Water Quality Impairments

The Valley Creek watershed does not contain any impaired streams or lakes on the MPCA 2014 303d (Impaired Waters) list (MCPA, 2014a).

Hydrology

MCES has monitored flow on Valley Creek at Putnam Boulevard since 1999. Flow measurements are collected at 15-minute intervals and converted to daily averages. The hydrograph of Valley Creek, which displays daily average flow, daily precipitation, and the flow associated with grab and composite samples, indicates the variation in flow rates from season to season and from year to year (Figure VA-6), 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.

The Valley Creek hydrograph is characteristic of a small, responsive groundwater-fed stream system. Generally, the storm event daily average flows were less than 60 cubic feet per second (cfs); three spring rains or snowmelt-driven events exceeded this level in 2003, 2005, and 2007. Of those events, the highest recorded daily average flow in Valley Creek, 139.2 cfs, occurred in 2007. The mean average daily flow is much lower, 16.3 cfs, which is close to the median average daily flow of 15.6 cfs. Due to the upwelling groundwater, Valley Creek maintains a baseflow and does not freeze during the winter months or run dry during prolonged periods with little precipitation.

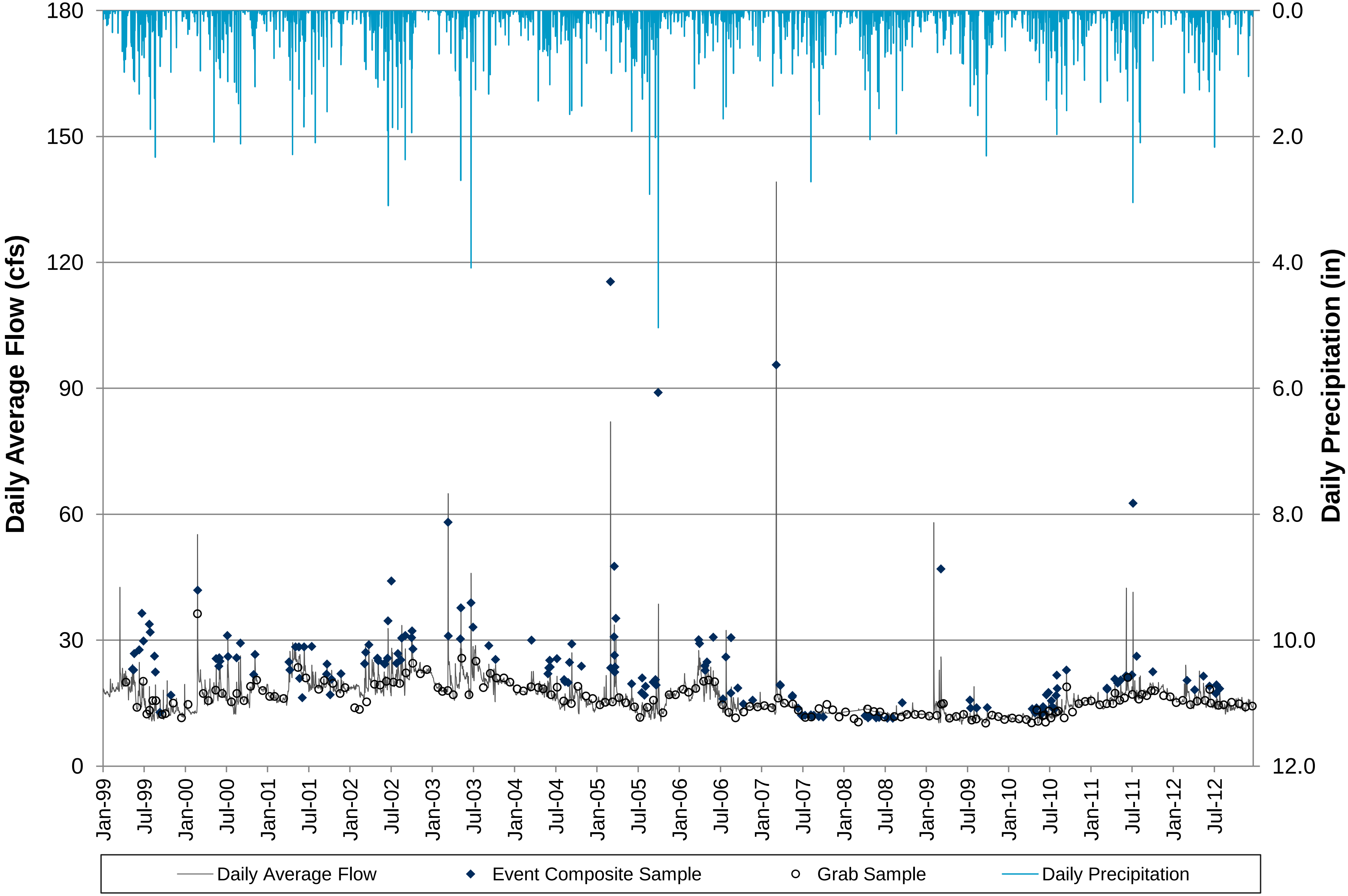
Analysis of the duration of daily average flows indicates the upper 10^{th} percentile flows for period 1999-2012 ranged between approximately 21.0-139.2 cfs, while the lowest 10^{th} percentile flows ranged from 10-12 cfs (See Figure VA-13 in the ***Flow and Load Duration Curves*** section of this report).

The variations in flow are somewhat driven by annual precipitation amounts as well as by variation in frequency of intense storm events. However, nearly half of the precipitation most likely does not affect the stream as surface runoff or overland flows. During the years 1999-2012, the median runoff ratio was 0.62, indicating an average of 38% of the precipitation either infiltrated the soils, evaporated off of the surface, was evapotranspirated by vegetation, or was stored in watershed wetlands, lakes, and ponds.

As mentioned in the stream and watershed description, the Valley Creek soil types (Types A and B) facilitate high or moderately high infiltration which may extract much of the overland flow. Over time the infiltrated precipitation recharges the groundwater, which in turn feeds into the stream. This potential flow regime may account for the slight lag between the precipitation and rise in the flows and the nonlinear response between in the magnitude of flows and the amount of precipitation (Figure VA-6).

In the years 1998-1999, the SCWRS performed an extensive hydrological study to determine the sources of Valley Creek stream flow and identify the degree and importance of the surface- and groundwater interaction. The isotopic analysis confirmed the flows in the South Branch and main stem primarily originated from the Prairie du Chien and Jordan aquifers (Almendinger, 2003). This groundwater source moderates the water temperatures in both branches of the stream to maintain suitability for trout habitat. Both the stream and groundwater tend to be young, about 50 years old, which indicates a short residence time in the aquifer that can be measured in decades, not centuries. The North Branch flows primarily originate from Lake Edith. A piezometric survey revealed this section of the stream was a ‘losing’ reach, in which a portion of streamflow seeps into the groundwater. Additional sampling throughout the watershed verified a high level of interaction and water exchange between the groundwater in the Prairie du Chien and Jordan aquifers and the water bodies in the Valley Creek catchment.

Figure VA-6: Valley Creek Daily Average Flow, Sample Flow, and Precipitation, 1999-2012*



*Precipitation record was acquired from NWS COOP stations: 218037-Stillwater 1 SE, 213567-Hastings Dam 2, and 218039-Stillwater 2SW

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 Valley 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 city of Afton, almost the entire extent of Valley Creek and the St. Croix River proper was identified as potentially vulnerable. The only exception was a short segment in the far western end of the city, near Woodbury. All of the basins within the watershed were identified as vulnerable to groundwater withdrawals, including Metcalf Marsh and Lake Edith, plus a number of surrounding smaller unnamed wetlands.

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 Valley Creek (1999-2012).

Figures VA-7 to VA-10 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), and precipitation depth coupled with runoff ratio). A later section in this report (***Comparison with Other Metro Area Streams***) offers graphical comparison of the Valley Creek loads and FWM concentrations with the other MCES-monitored metropolitan area tributaries.

The first charts in Figures VA-7 and VA-8 plot the annual flows from 1999-2012. The flow metrics indicate small year-to-year variations in annual flow rate, as expected from a groundwater fed stream. The highest average annual flow, and thus the highest volume of flow, occurred during 2002 (approximately 21.1 cfs average annual flow); the lowest average annual flow and lowest volume of flow occurred in 2009 (approximately 12.1 cfs average annual flow). The mean average annual flow was 16.3 cfs, which is equivalent to the median average annual flow of 16.3 cfs, suggesting the annual flows were evenly distributed around the mean annual flow.

The annual mass loads for NO_3 and Cl demonstrate a comparatively steady signal throughout the 1999-2012 time period (Figure VA-7). This lack of variation suggests the groundwater NO_3 and Cl concentrations overwhelm any additional pollutant contribution by runoff. In contrast, the annual mass loads for TSS, TP, TDP, and NH_3 do exhibit significant year-to-year variation, indicating the influence of precipitation and surficial flowpaths transporting pollutants within the watershed to the stream.

The annual FWM concentrations reinforce and emphasize the observations from the annual mass loads (Figure VA-8) The NO_3 and Cl FWM concentrations exhibited steady values, again suggesting a steady, contaminated groundwater source. The TSS, TP, TDP, and NH_3 FWM concentrations fluctuate year to year, and are likely influenced by the frequency, magnitude, timing, and the routing of precipitation.

All four pollutants have the highest FWM concentration in the year 2007. This corresponds with the highest recorded Valley Creek flow. Due to the infiltration capacity of the upland soils, this suggests a near-stream pollutant source was flushed and transported by precipitation. The NH_3 FWM concentrations showed the four highest concentrations in 2003, 2005, 2007, and 2011, corresponding with large snowmelt or spring rain events. It is widely accepted that soil microbes are highly active under insulating snows, accumulating large stores of NH_3 in the soils (Brooks et al., 2011). The large snowmelt events produce a large volume of water to flow over the thawed soils that flush and transport the NH_3 into the stream.

Figures VA-9 and VA-10 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 Valley Creek (Figure VA-11 and VA-12). The results for each month are expressed in two ways: the monthly results for the most recent year of data (2012 for Valley Creek) and the monthly average for 2003-2012 (with a bar indicating the maximum and minimum value for that month).

It is apparent that the highest mass loads of TSS, TP, TDP, and NH_3 in Valley Creek occur in March and/or April each year, likely due to effects of snow melt and spring rains. The NO_3 and Cl mass loads appear to be independent of the spring influences and do not show any monthly differences throughout the remainder of the year. The FWM concentrations show similar patterns as the loads. Although NO_3 FWM concentrations do exhibit a very slight reduction during June through August, most likely attributable to biological uptake, comparatively both Cl and NO_3 show little monthly variation.

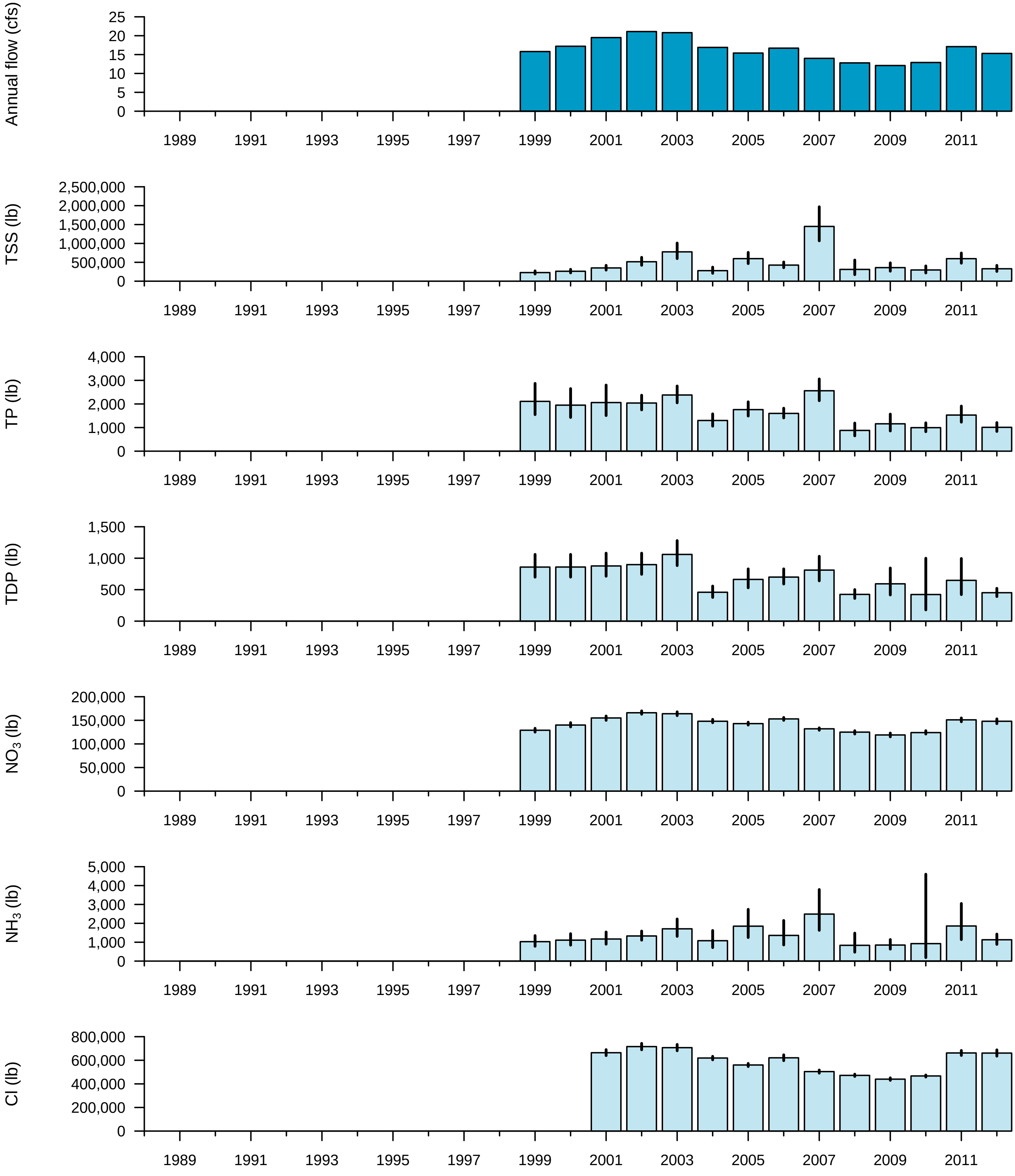
The consistency in NO_3 and Cl monthly average FWM concentrations points to a contaminated groundwater source. Usually, Cl concentrations in streams tend to increase during spring snowmelt due to the flushing of road de-icers. However, Valley Creek's Cl concentration does not exhibit this trend. Given the undeveloped nature of the watershed, this signal should not be as large as in urban watersheds, but should still be present. This suggests that the groundwater source is more contaminated with Cl than the spring runoff, and drowns out any potential road salt signal. Similarly, an increase in NO_3 would be expected during the spring months as fields are prepared for crop production, but there is no monthly variation in NO_3.

Given these data, it is impossible to attribute the contamination to any specific source in the watershed. However, there are plausible mechanisms that could cause the elevated levels of NO_3 and Cl in the groundwater. For example, the application of nitrogen and potash (KCl; potassium chloride) fertilizers on agricultural lands could raise groundwater concentrations. While NH_3 is the most common form of nitrogen applied to fields, it readily converts to NO_3, the most mobile form of nitrogen (Böhlke, 2002). Potassium is a macronutrient for plants, and the most common potassium source in Minnesota is KCl fertilizer (Rehm and Schmitt, 1997). The combination of high to moderately high infiltration capacity of the soils and the need for fertilizer application may result in a direct application of NO_3 and Cl into the groundwater aquifer when soil waters drain downwards.

Another potential source of Cl could be related to sewage and water treatment. The lack of a centralized sewer system necessitates the use of on-site septic systems to manage wastewater, which provides another plausible avenue for Cl contamination. Untreated domestic wastewater typically contains 30-90 mg/l of Cl (Metcalf and Eddy, 2003). Further, water softening can increase this Cl load, as the softening chemicals used to remove minerals from water are primarily salt resins (Sander et al., 2008). During the recharging process these resins are rinsed, creating a brine backwash. If released into a drain field, both the wastewater and the brine would infiltrate the soils and contaminate the groundwater.

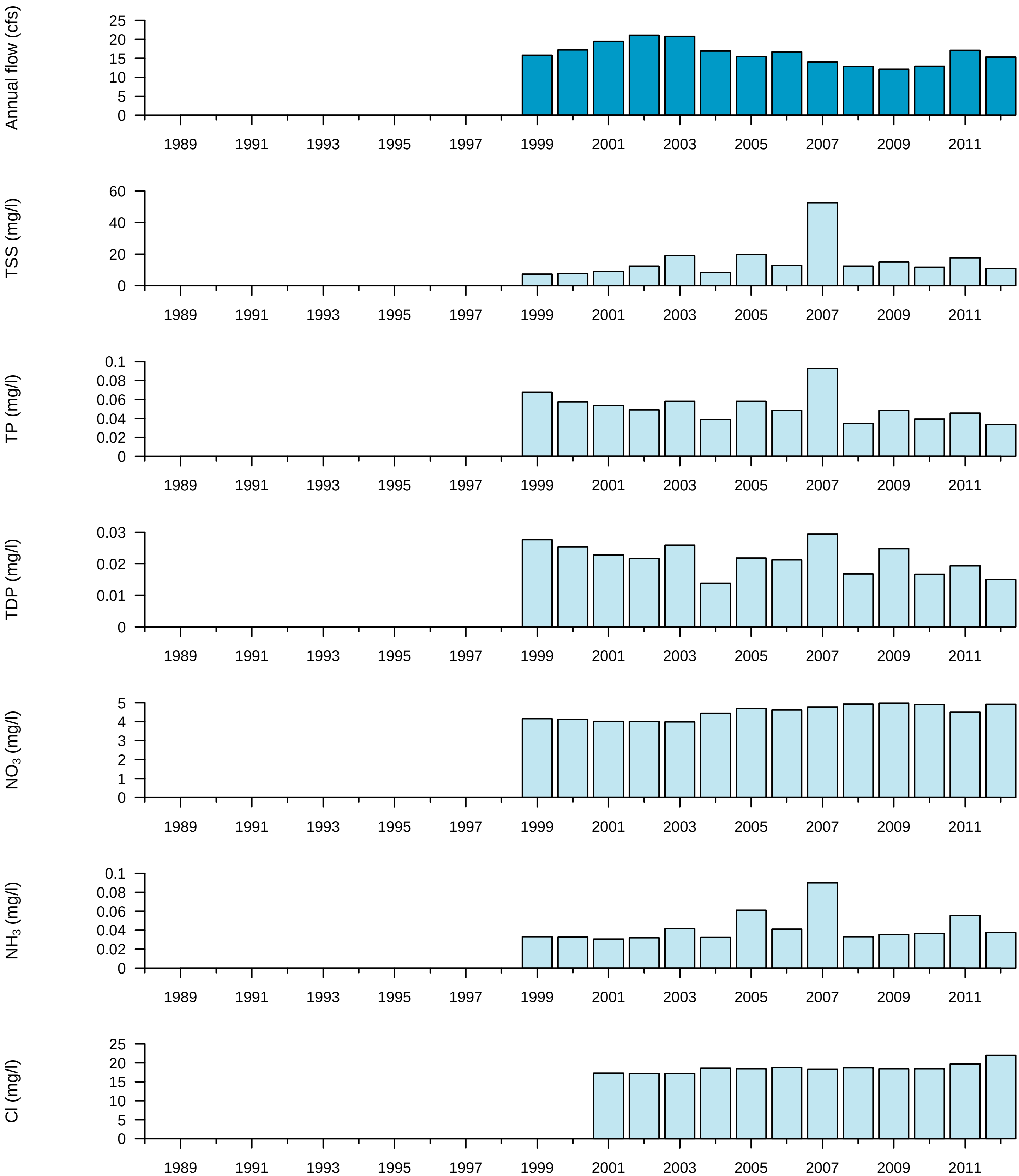
To complicate the issue further, there is time-related component to the contamination problem. The isotopic work completed by Almendinger (2003) estimated a residence time of fifty years in the aquifer. If this estimation still holds, the contamination presently found in the Valley Creek could be from actions that occurred in the watershed during the 1960s. While this may mean there is no direct action to reverse the contamination, it does highlight the need to act conservatively now so that the effects of our current actions will not be detrimental to the future chemical composition and flows in Valley Creek.

Figure VA−7: Valley Creek*
Annual Mass Load



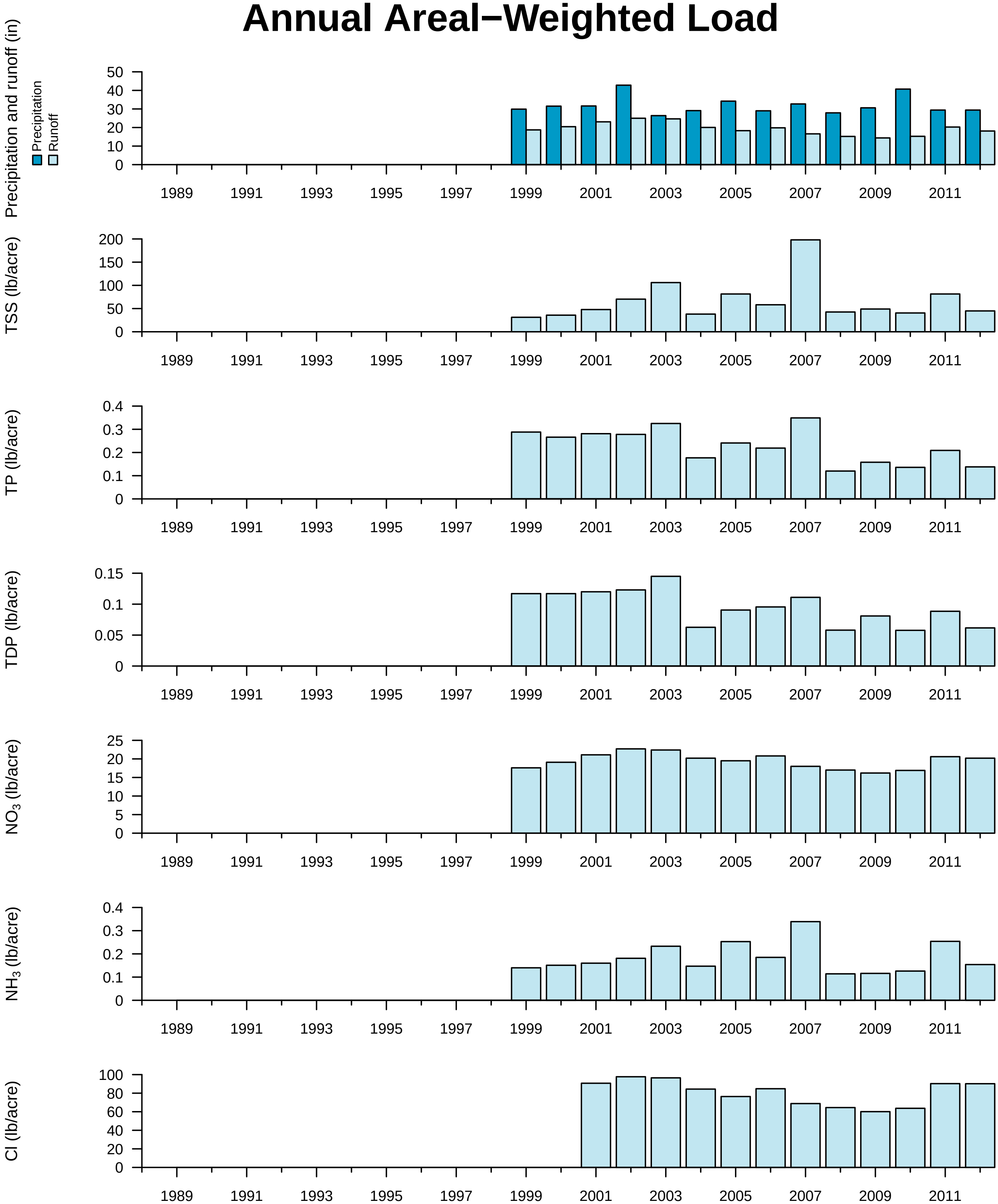
*TSS, TP, TDP, NO3, and NH3 sampling began in 1999, Cl began in 2001.
Bars represent 95% confidence intervals as calculated in Flux32.

Figure VA−8: Valley Creek*
Annual Flow−Weighted Mean Concentration



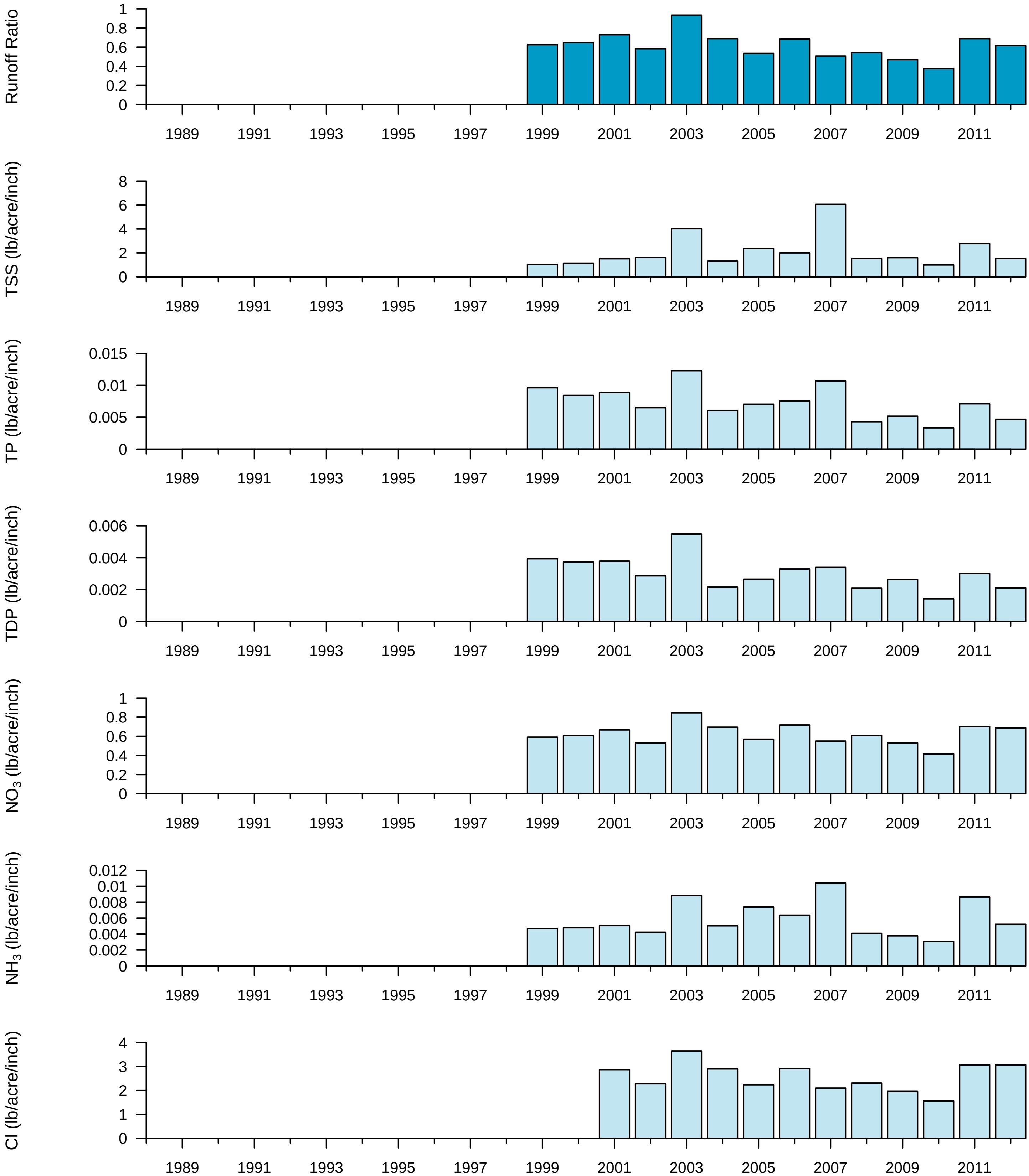
*TSS, TP, TDP, NO3, and NH3 sampling began in 1999, Cl began in 2001.

Figure VA−9: Valley Creek*
Annual Areal−Weighted Load



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

Figure VA−10: Valley Creek*
Annual Precipitation−Weighted Areal Load



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

Figure VA−11: Valley Creek Mass Load by Month

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

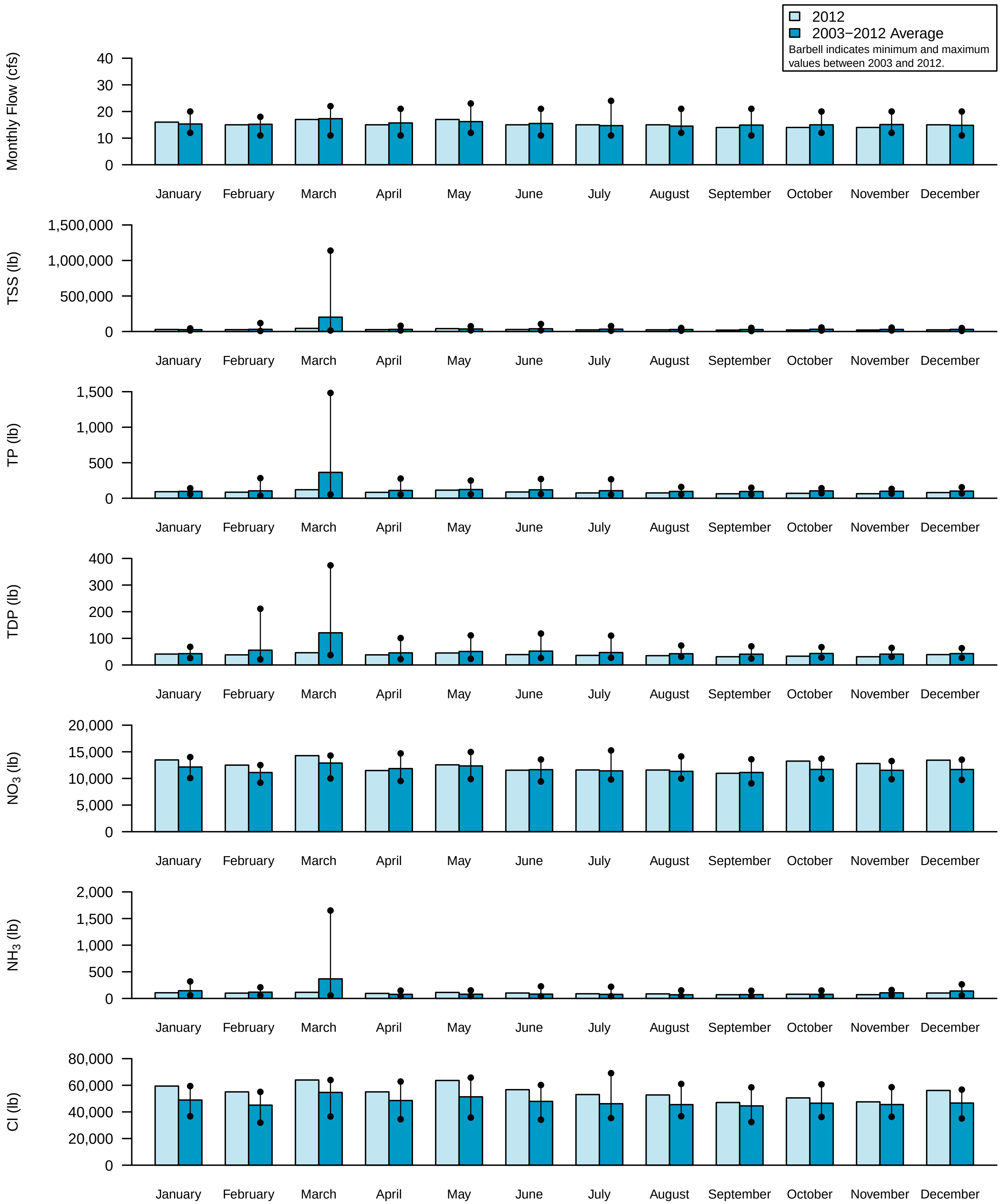
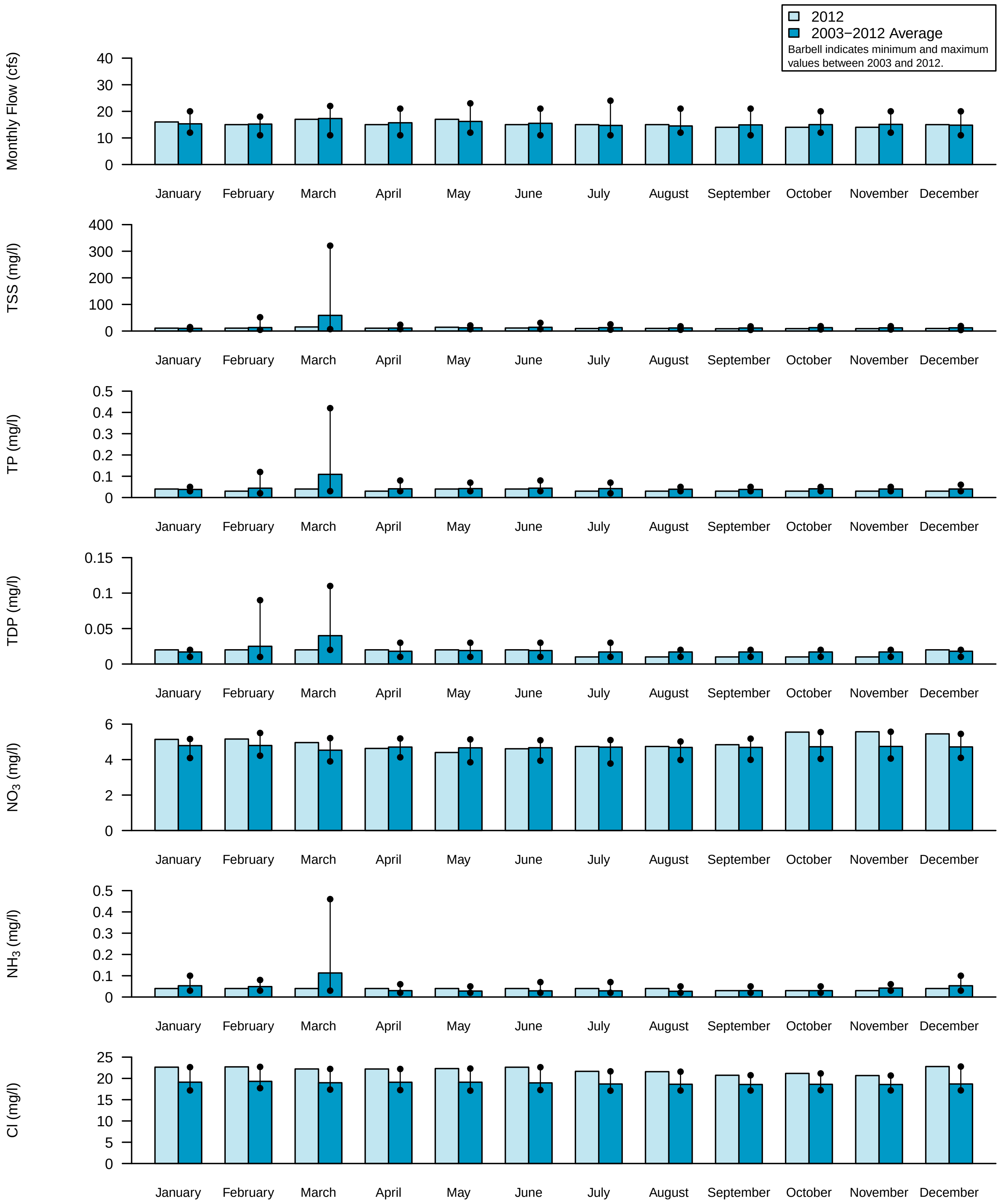


Figure VA−12: Valley Creek
Flow−Weighted Mean Concentation by Month

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 (USEPA) recommendations, 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 Valley Creek monitoring station daily average flows and sample data, along with the most appropriate MPCA draft numerical standard as listed in Table VA-2. 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 standards 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 Valley Creek monitoring station (mile 1.0, near Putnam Blvd.) is shown in Figure VA-13. The range of flows and the flow duration curve shape describe the flow regime of the stream system. Flow duration analysis of daily average flows indicates the upper 10^{th} percentile flows ranged between approximately 21.0 -139.2 cfs, while the lowest 10^{th} percentile flows ranged from 10 -

12.1 cfs). The steep curve in the High Flow category indicates that high flows last for short periods of time, usually attributed to rain-induced floods. The flat line in the Low Flow category indicates that Valley Creek maintains flows throughout the year, which can be attributed to the groundwater source of stream flow.

The load duration curves provide insight into the influence of flow conditions on stream load compliance with state standards. At low flows, the Valley Creek loads were below the loads dictated by the draft standards for TSS, TP, Cl, and the drinking water standard for NO_3. As the flows increase, the TSS and TP daily loads fell both above and below the dark lines designating the standard. Under high flows, a large portion of the TSS and TP samples exceeded the standards. Regardless of flow conditions, both NO_3 and Cl loads are consistently below the drinking water and Cl draft standards, respectively. This lack of variation in the daily loads of NO_3 and Cl add an additional line of evidence pointing to groundwater contamination.

Table VA-2: Valley 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[2] (Class 2)	River Nutrient Region (RNR)[3] of Monitoring Station	Cl Draft Stnd[4] (mg/l)	TSS Draft Stnd[5] (mg/l)	TP Draft Stnd[6] (ug/l)	NO_3 DW Stnd[7] (mg/l)
Valley Creek at Putnam Boulevard (VA1.0)	2A	Central	230	10	100	10

[1] Minn. Rules 7050.0470 and 7050.0430.

[2] Trout stream identified in Minn. Rule 7050.0470.

[3] MPCA, 2010.

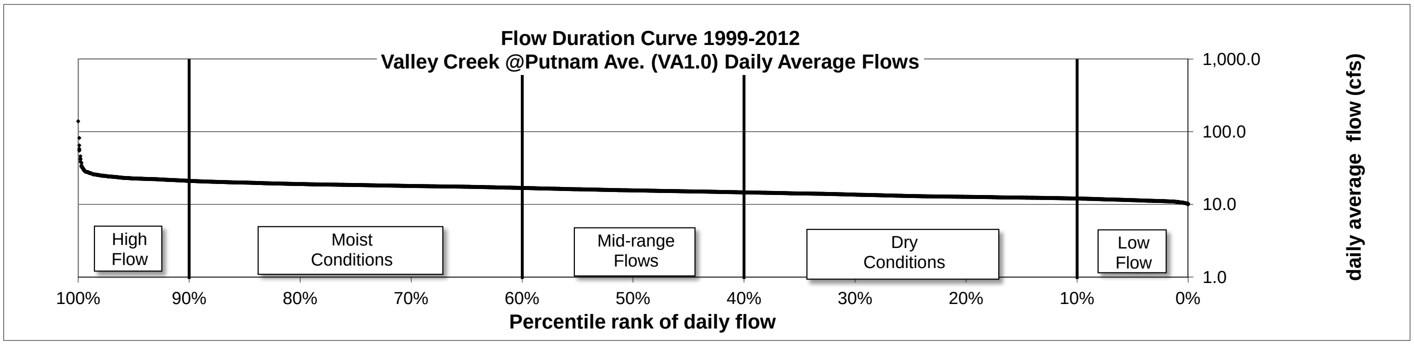
[4] Mark Tomasek, MPCA, personal communication, March 2013. MCES used 230 mg/l as the draft Cl standard pending results of USEPA toxicity tests.

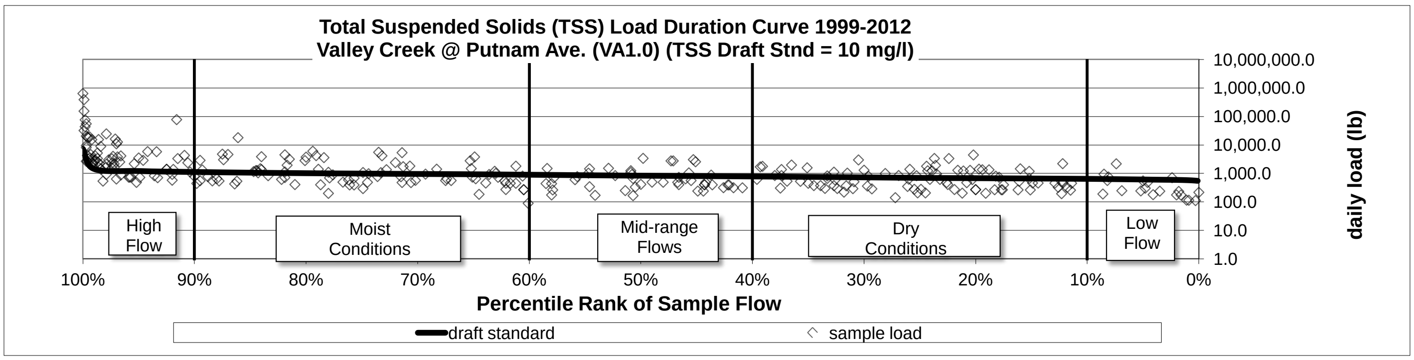
[5] MPCA, 2011. Draft standard states TSS standard concentration for Class 2A and 2B water must not be exceeded more than 10% of the time over a multiyear data window, with an assessment period of April through September.

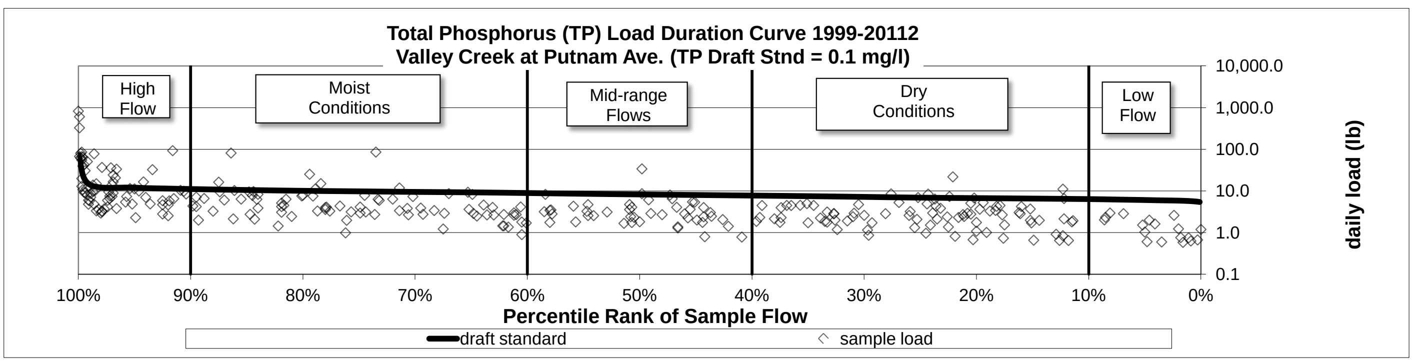
[6] MPCA, 2013a. To violate standard, concentration of causative variable (TP) must be exceeded, as well as one or more response variables: sestonic chlorophyll, BOD_5, DO flux, and/or pH.

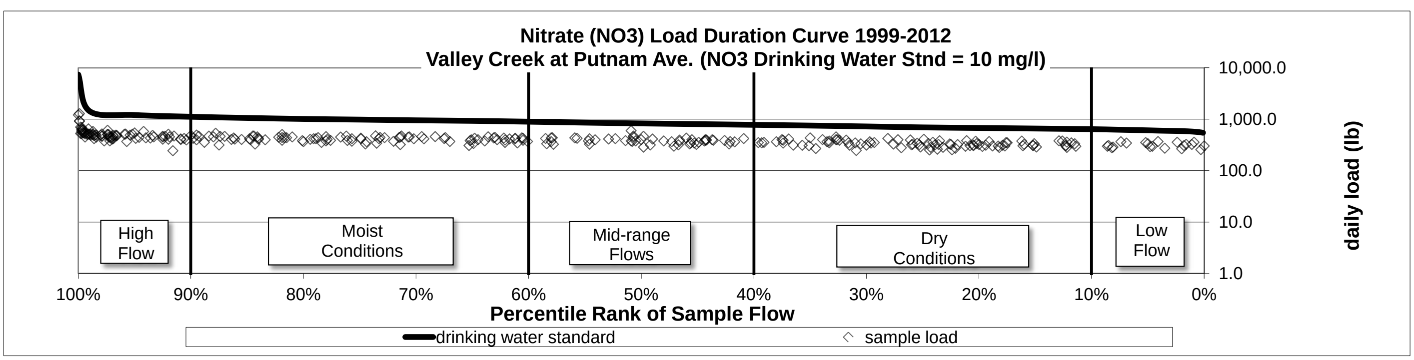
[7] MCES used the NO_3 drinking water standard of 10 mg/l pending results of USEPA toxicity tests and establishment of a draft NO_3 standard for rivers and streams.

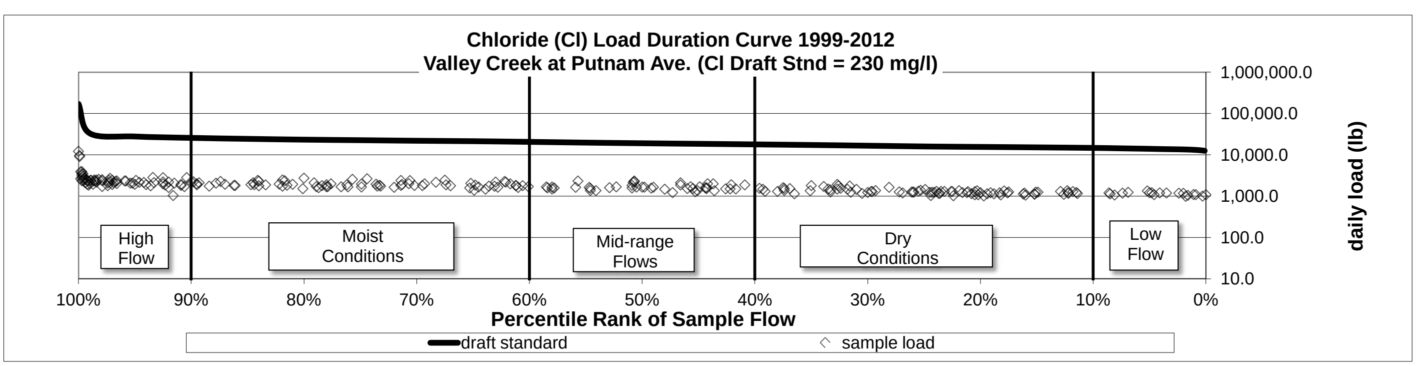
Figure VA-13: Valley Creek Flow and Load Duration Curves, 1999-2012











Aquatic Life Assessment Based on Macroinvertebrates

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

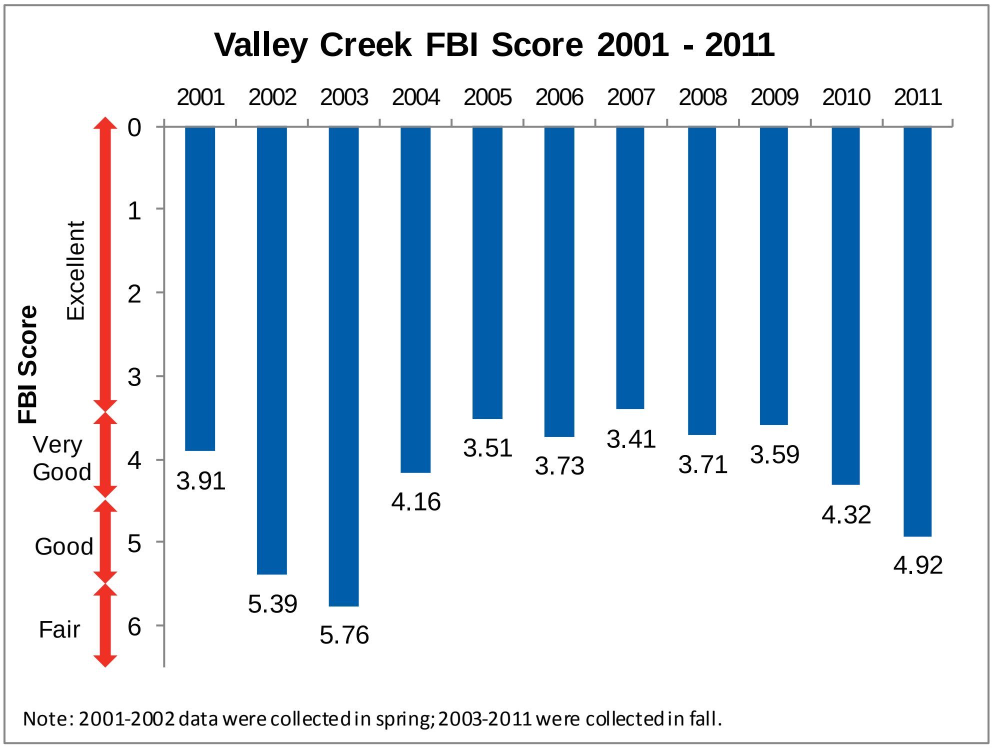
Each metric is independently important and clarifies one aspect of the ecosystem health: species richness, community diversity, water quality, and other factors. The results may have conflicting conclusions when comparing the single metric results. However, integrating the individual metrics into a multi-metric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

MCES has been sampling for macroinvertebrates in Valley Creek since 2001. The 2001-2002 macroinvertebrates were sampled in late spring; the remaining years (2003-2011) were collected in the fall (September or October). The entire dataset was analyzed with three metrics: Family Biotic Index (FBI), Percent Intolerant Taxa, and Percent POET Taxa. A subset of data, 2004-2009 and 2011, was analyzed using the multi-metric, Minnesota-specific, MPCA 2014 Macroinvertebrate Index of Biological Integrity (M-IBI).

Family Biotic Index (FBI)

FBI is a commonly used water quality assessment. Each family is assigned a tolerance value that describes its ability to tolerate organic pollution, such as insecticides or herbicides. 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. The Valley Creek FBI scores ranged from excellent water quality (2007) to fair water quality (2003), indicating the presence of some organic pollution during most years (Figure VA-14).

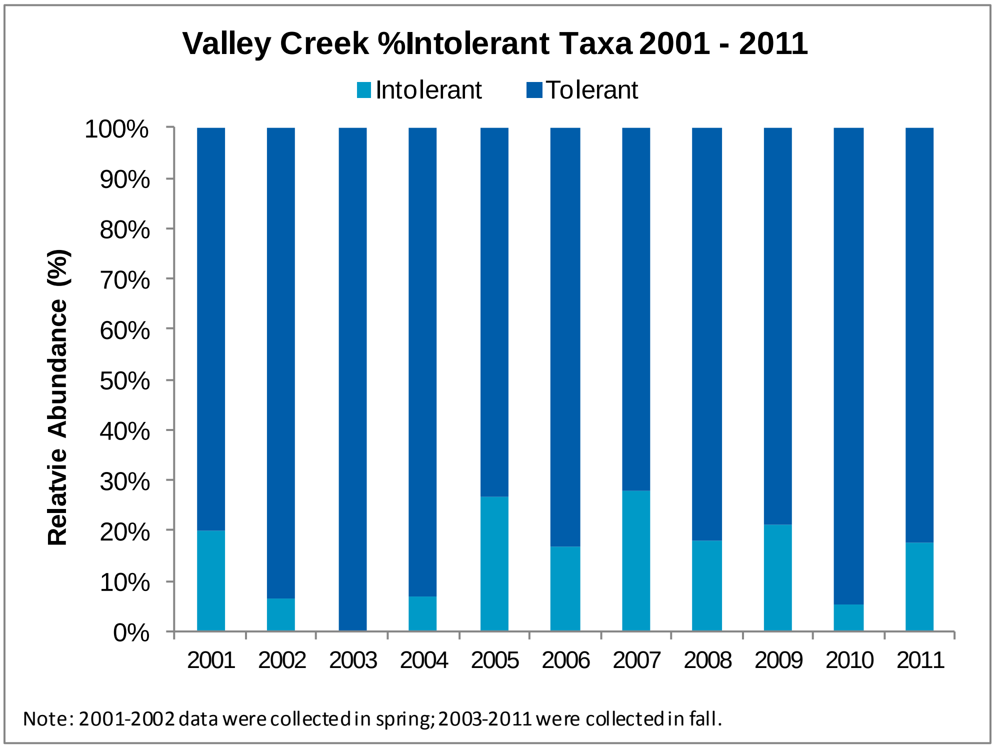
Figure VA-14: Valley Creek Annual Family Biotic Index (FBI) Scores, 2001-2011



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 VA-15). The presence of moderate numbers of intolerant taxa is an indicator of good aquatic health (Chirhart, 2003). The Valley Creek intolerant taxa were greater than 10% of the sample in 2001, 2005-2009, and 2011. The highest Percent Intolerant Taxa, 28%, occurred in 2007. Intolerant taxa were present in every sample except 2003.

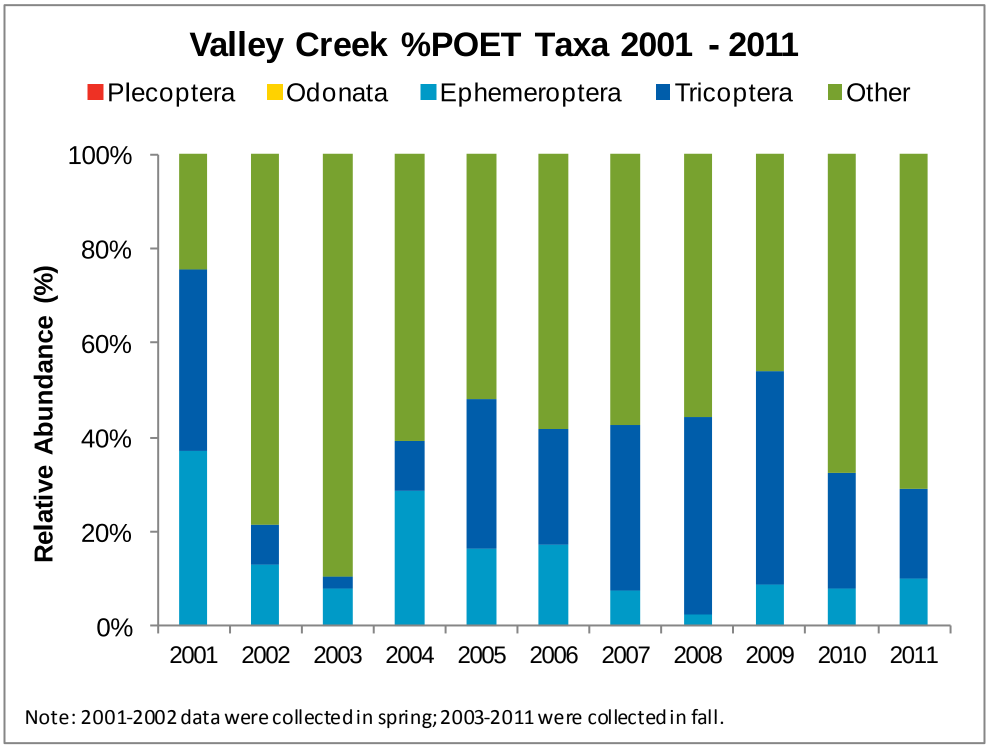
Figure VA-15: Valley Creek Percent Abundance of Pollution Intolerant Taxa, 2001-2011



Percent POET Taxa

The taxonomic richness metric, Percent POET Taxa (Figure VA-16), 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 was highest in 2001 at 76%, and lowest in 2003 at 11%.

Figure VA-16: Valley Creek Percent Abundance of POET Taxa, 2001-2011



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.

Six of the eight years of monitoring resulted in M-IBI scores above the impairment threshold and the upper confidence level (Figure VA-17). This suggests the stream was able to sustain the needs of aquatic life.

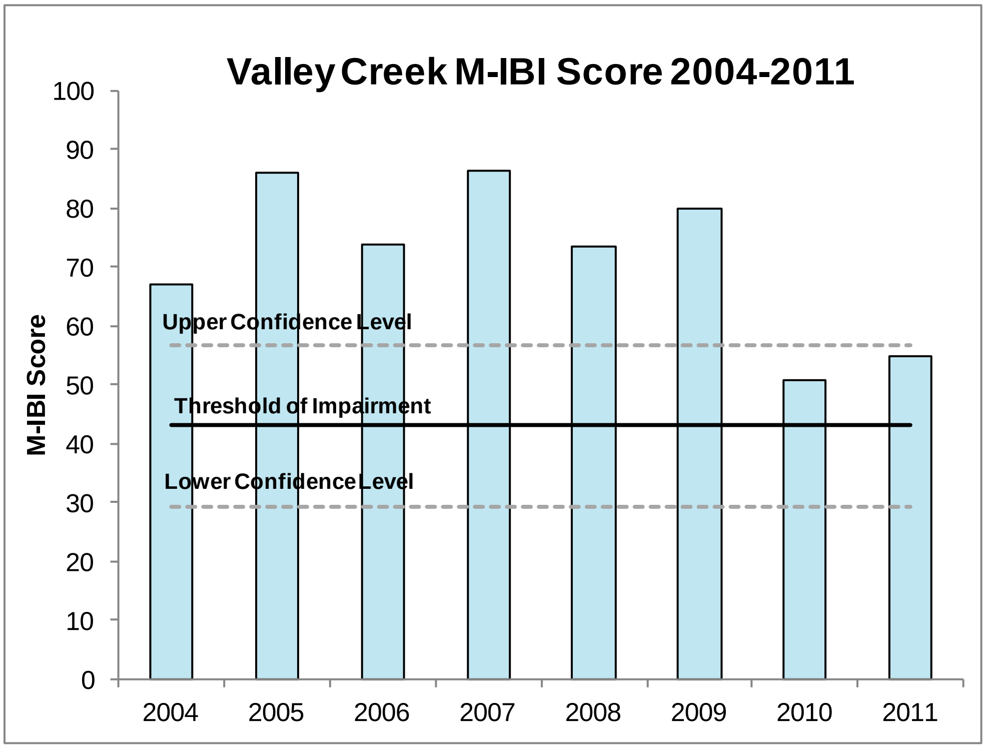
In 2010 and 2011, the Valley Creek M-IBI scores were between the threshold of impairment and the upper confidence level. When the scores fall between the confidence levels, it is difficult to confidently assess the water quality by biological assessment alone. It is necessary to incorporate other monitoring information, such as hydrology, water chemistry and land use change (MPCA, 2014b).

Understanding physical and chemical influences on M-IBI scores leads to a more complete assessment of water quality. When plausible physical or chemical explanations exist for M-IBI scores between the confidence levels, these scores may be assigned more or less weight in the final evaluation.

In 2010, the sample was collected almost three weeks after a large storm (23 September 2010, 22.6 cfs peak flow). This storm affected the rating of the stream and flushed the macroinvertebrates. In 2011, the M-IBI score shows the stream was recovering from the disturbance.

The most recent M-IBI scores, 2010 and 2011, are between the threshold of impairment and the upper confidence level. This suggests the storm disturbance and other stressors are not negatively affecting the macroinvertebrate community. Future M-IBI scores will show whether the stream will recover and return to the previous pattern of M-IBI scores above the upper confidence level. MCES is planning additional future analysis to fully investigate our biological monitoring data and the sample collection program.

Figure VA-17: Valley Creek Annual Macroinvertebrate Index of Biological Integrity (M-IBI) Scores, 2004-2011



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; thus any trend identified should be independent of flow or seasonal variation.

Due to a 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 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 Valley Creek for TP, NO_3, and TSS, 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)

Two trends were identified for TSS flow-adjusted concentrations in Valley Creek during the assessment period from 1999 to 2012 (Figure VA-18, top panel). The assessment was performed using QWTREND without precedent five-year flow setting. The trends were statistically significant ($p=0.0027$):

- Trend 1: 1999 to 2004, TSS flow-adjusted concentration increased from 5.5 mg/l to 10.2 mg/l (84%) at a rate of 0.8 mg/l/yr.
- Trend 2: 2005 to 2012, TSS flow-adjusted concentration decreased from 10.2 mg/l to 10.1 mg/l (0.7%) at a rate of -0.009 mg/l/yr.

The five-year trend in TSS flow-adjusted concentration in Valley 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 10.2 mg/l to 10.1 mg/l (0.5%), at a rate of -0.009 mg/l/yr. Based on the QWTREND results, the water quality in Valley Creek in terms of TSS improved during 2008-2012.

Total Phosphorus (TP)

Three trends were identified for TP flow-adjusted concentration in Valley Creek from 1999 to 2012 (Figure VA-18, middle panel). The assessment was performed using QWTREND without precedent five-year flow setting. The trends were statistically significant ($p=2.7 \times 10^{-10}$):

- Trend 1: 1999 to 2001, TP flow-adjusted concentration decreased from 0.14 mg/l to 0.02 mg/l (-86%) at a rate of -0.04 mg/l/yr.
- Trend 2: 2001 to 2010, TP flow-adjusted concentration increased from 0.02 mg/l to 0.06 mg/l (212%) at a rate of -0.005 mg/l/yr.
- Trend 3: 2010 to 2012, TP flow-adjusted concentrations decreased from 0.06 mg/l to 0.02 mg/l (-59%) at a rate of -0.02 mg/l/yr.

The five-year trend in TP flow-adjusted concentration in Valley Creek (2008-2012) was calculated to compare with other MCES-monitored streams, shown in the report section ***Comparison with Other Metro Area Streams***. TP flow-adjusted concentration decreased from 0.05 mg/l to 0.02 mg/l (-46%) at a rate of -0.004 mg/l/yr. Based on the QWTREND results, the water quality in Valley Creek in terms of TP improved during 2008-2012.

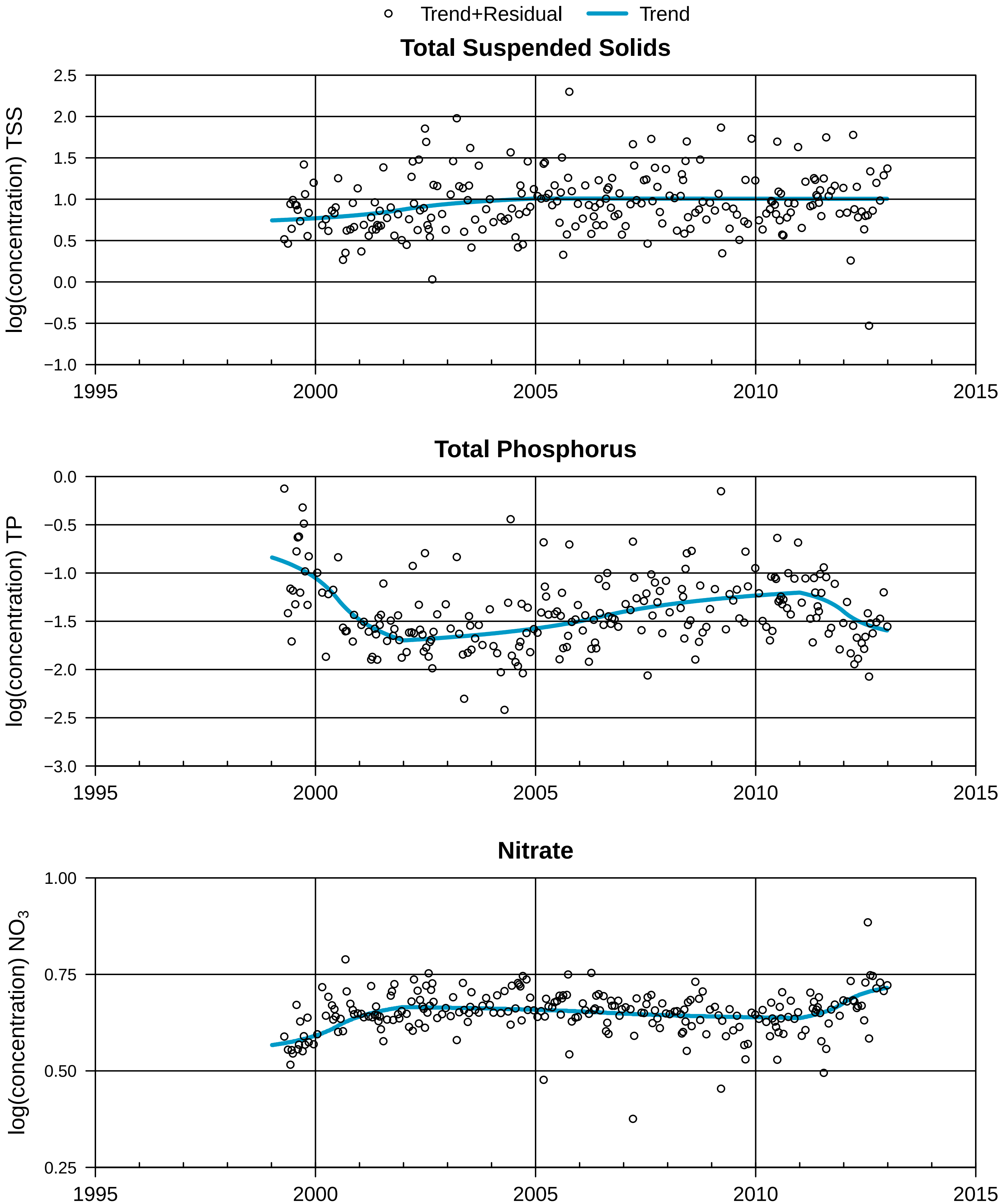
Nitrate (NO_3)

Three trends were identified for NO_3 flow-adjusted concentration in Valley Creek from 1999 to 2012 (Figure VA-18, lower panel). The assessment was performed using QWTREND without precedent five-year flow setting. The trends were statistically significant ($p=1.05x10^{-10}$):

- Trend 1: 1999 to 2001, NO_3 flow-adjusted concentration increased from 3.7 mg/l to 4.6 mg/l (25%) at a rate of 0.3 mg/l/yr.
- Trend 2: 2001 to 2010, NO_3 flow-adjusted concentrations decreased slightly from 4.6 mg/l to 4.3 mg/l (-6%) at a rate of -0.03 mg/l/yr.
- Trend 3: 2010 to 2012, NO_3 flow-adjusted concentrations increased quickly from 4.3 mg/l to 5.6 mg/l (30%) at a rate of 0.7 mg/l/yr.

The five-year trend in NO_3 flow-adjusted concentration in Valley Creek (2008-2012) was calculated to compare with other MCES-monitored streams, shown in the report section ***Comparison with Other Metro Area Streams***. NO_3 flow-adjusted concentration increased from 4.4 mg/l to 5.6 mg/l (28%) at a rate of 0.2 mg/l/yr. Based on the QWTREND results, the water quality in Valley Creek in terms of NO_3 declined during 2008-2012.

Figure VA−18: Valley Creek Trends for TSS, TP and NO_3



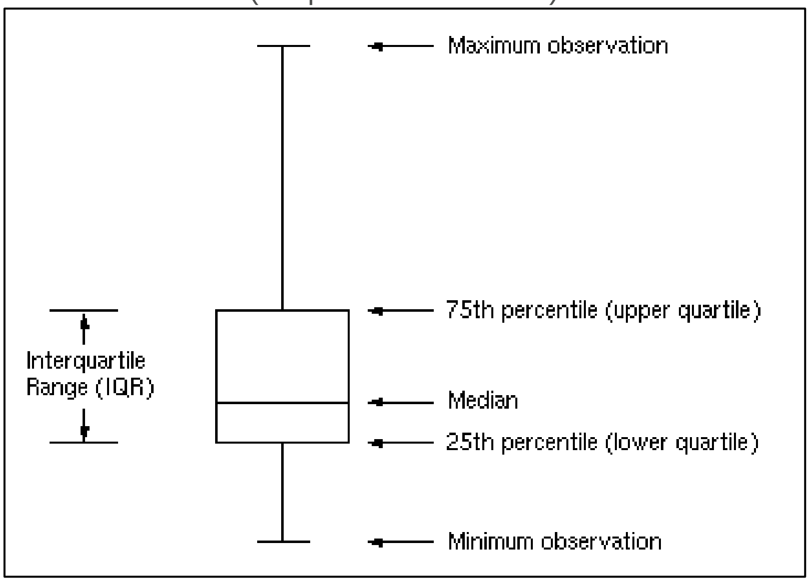
Comparison with Other Metro Area Streams

Chemistry

Box-and-whisker plots are used to summarize the comparison of the historical flow, TSS, TP, and NO_3, and Cl data for Valley Creek with those of the other metropolitan area streams monitored by MCES and with the major receiving water (in this case the St. Croix River). The comparisons are show in Figure VA-20 to Figure VA-24.

Figure VA-19 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 VA-19: General Schematic of a Box-and-Whisker Plot
(adapted from *sas.com*)



Comparisons for each chemical parameter for the 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 Valley Creek is greater than for another St. Croix River tributary, Carnelian Marine, but lower than both Silver and Browns Creeks (Figure VA-20; Table VA-3). The FWM concentration in Valley Creek is also higher than that in the St. Croix River (as measured at Stillwater, Minnesota, ~14 mg/l vs. 8.3 mg/l, respectively), indicating that Valley Creek is serving to increase the TSS concentration in the St. Croix. It is apparent that those tributaries entering the St. Croix River have significantly lower FWM TSS concentrations and annual yields (expressed in lb/acre) than the other tributaries entering the Mississippi or Minnesota Rivers monitored by MCES. This reflects the pristine waters and virtually undisturbed areas along the St. Croix River watershed (Gunard, 1985).

Median annual runoff ratio for Valley Creek is greater than for all metropolitan area streams, with the exception of Eagle Creek. Both Eagle Creek and Valley Creek are groundwater-fed, which increases the runoff ratios for both watersheds. If Valley Creek flow was influenced by wetlands, lakes, or other impoundments on the stream channel, one would expect a relatively lower runoff ratio (that is, similar to Minnehaha Creek or Carnelian-Marine).

*Total Phosphorus***.** Unlike TSS, the FWM TP concentration in Valley Creek is lower than the St. Croix River and thus served to dilute the TP concentration in the river (Figure VA-21; Table VA-3). Valley Creek and the other St. Croix River metropolitan area tributaries also have lower FWM concentrations than most of the other MCES-monitored streams, with the exception of Eagle Creek, the Rum River, and Minnehaha Creek. The Valley Creek median annual yield is higher than five other metropolitan area tributaries (Minnehaha Creek, the Rum River, Willow Creek, Carnelian Marine, and Silver Creek), but lower than the other Mississippi and Minnesota River tributaries.

Nitrate. The Valley Creek median annual FWM NO_3 concentration of 4.7 mg/l is lower than the drinking water standard (Table VA-2). However, when compared to the other St. Croix tributaries, this concentration is an order of magnitude higher. This concentration of NO_3 is much greater than that in the St. Croix River, and thus serves as a contaminant to the river (Figure VA-22; Table VA-3). The median annual yield in Valley Creek is the highest of all MCES-monitored tributaries, surpassing the other streams with primarily agricultural watersheds, including the Crow River, the Cannon River, and Bevens Creek.

Chloride. The Cl annual median FWM concentration was similar to other streams in the St. Croix watershed, but Valley Creek had the greatest total annual load and annual yield in the catchment (Figure VA-23; Table VA-3). This is notable, as Valley Creek is not as urbanized as Browns Creek, but still has a greater Cl load. The Valley Creek median Cl FWM concentration was higher than the St. Croix River and is considered a source of contamination. When compared to the other MCES-monitored tributaries in the metropolitan area, Valley Creek Cl was most similar to other agricultural catchments, including Riley Creek, the Credit River, and the Vermillion River.

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 Valley Creek were above the MPCA impairment threshold (Figure VA-24). This includes the median, which suggests that this stream reach habitat and water quality typically were able to sustain the needs for aquatic life. These results were similar to the other cold water streams, Browns, Eagle, and Silver Creeks. The cold water, spring-fed streams appear to have less negative stressors on their macroinvertebrate communities than the warm water, surface-fed streams in the metropolitan area.

Figure VA−20: Total Suspended Solids for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

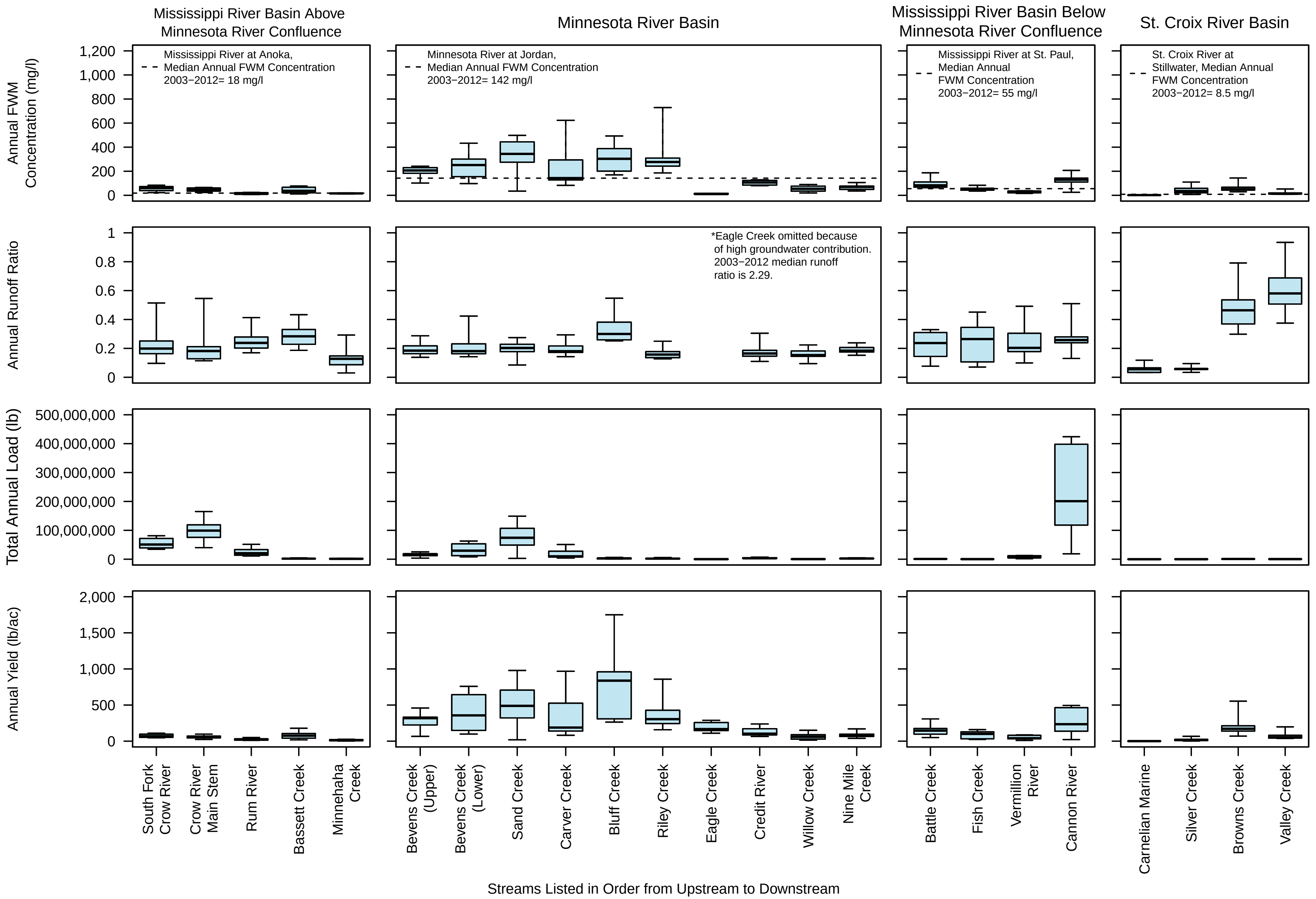


Figure VA−21: Total Phosphorus for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

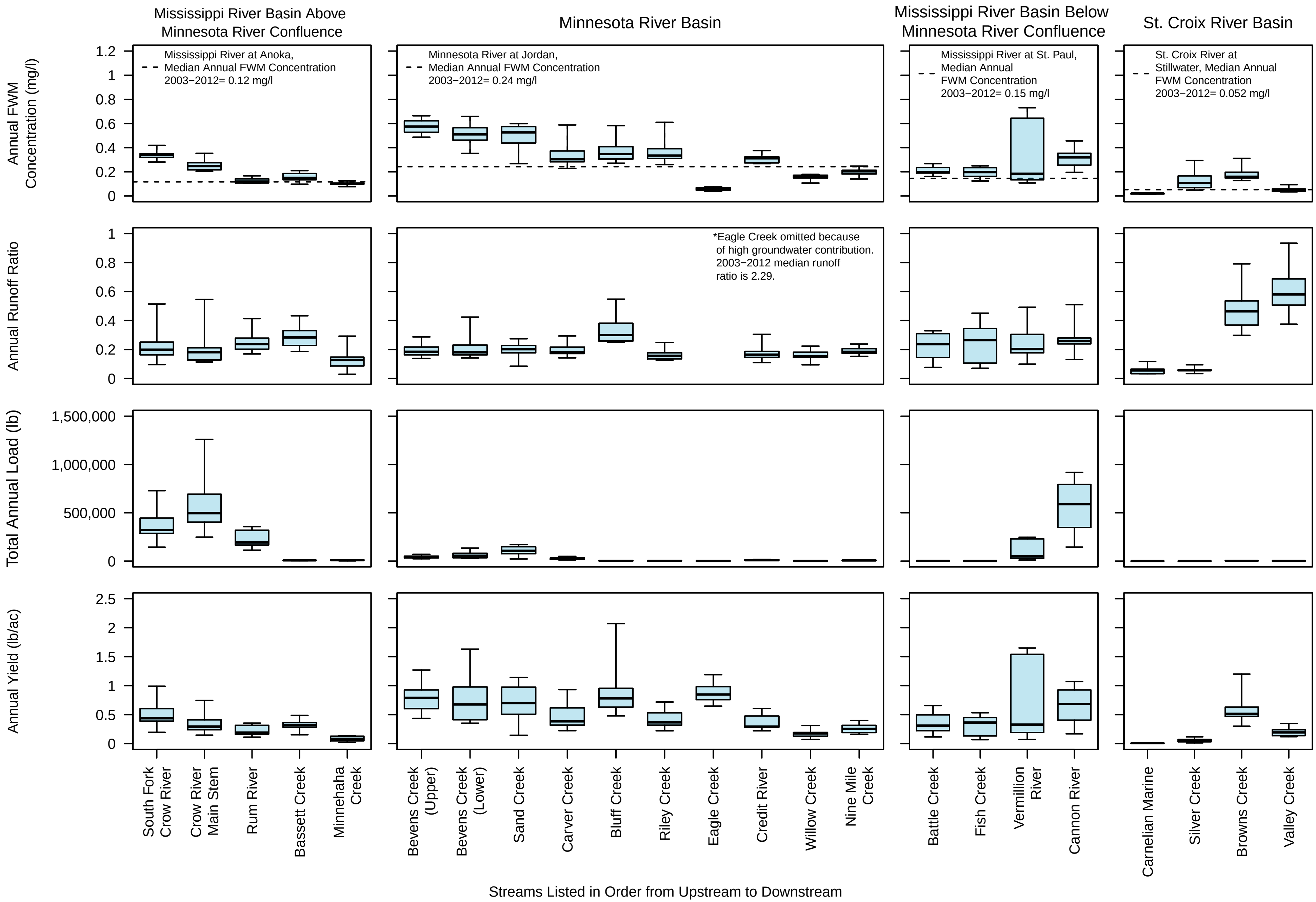


Figure VA−22: Nitrate for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

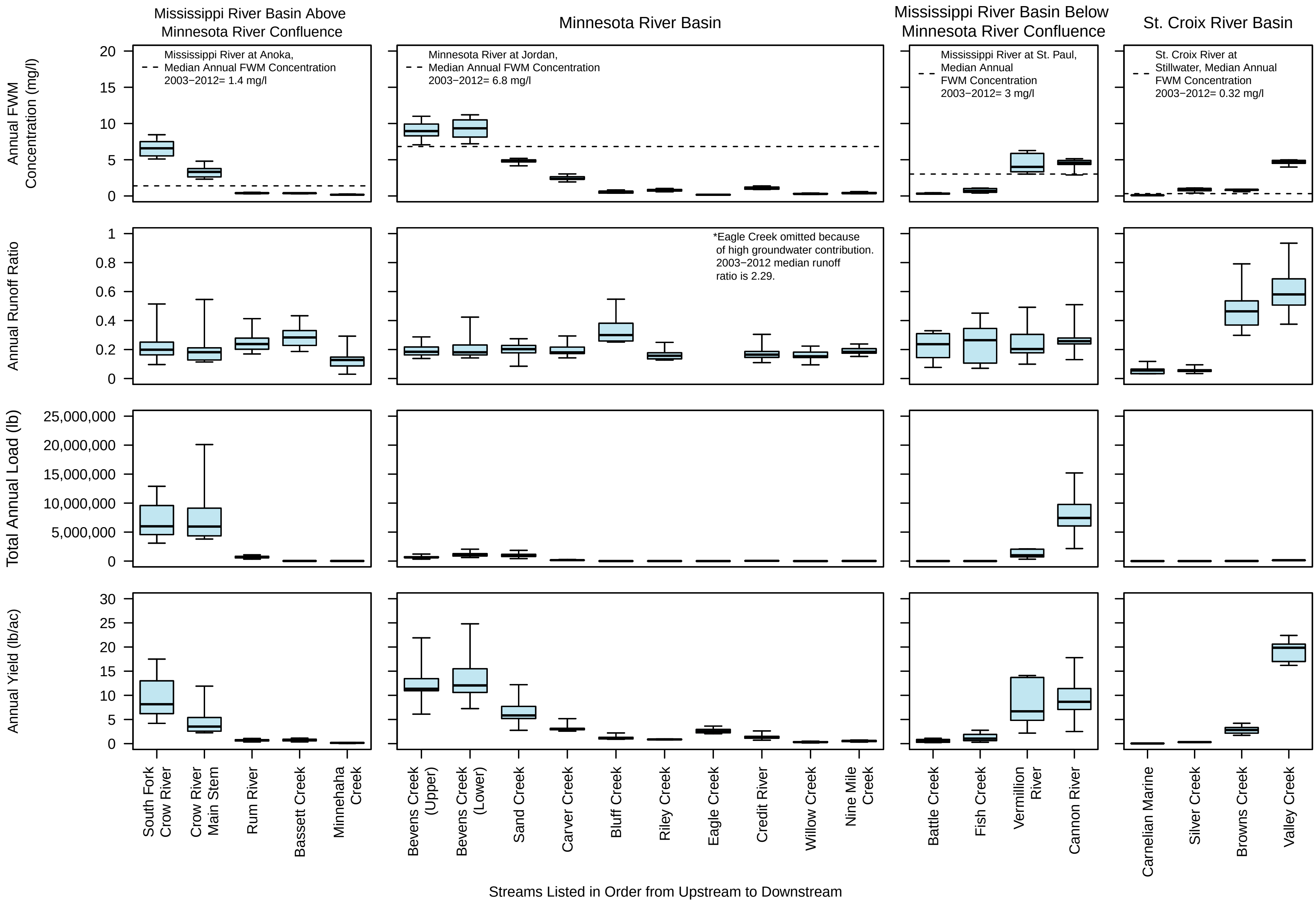


Figure VA−23: Chloride for MCES−Monitored Streams, 2003−2012

Organized by Major River Basin

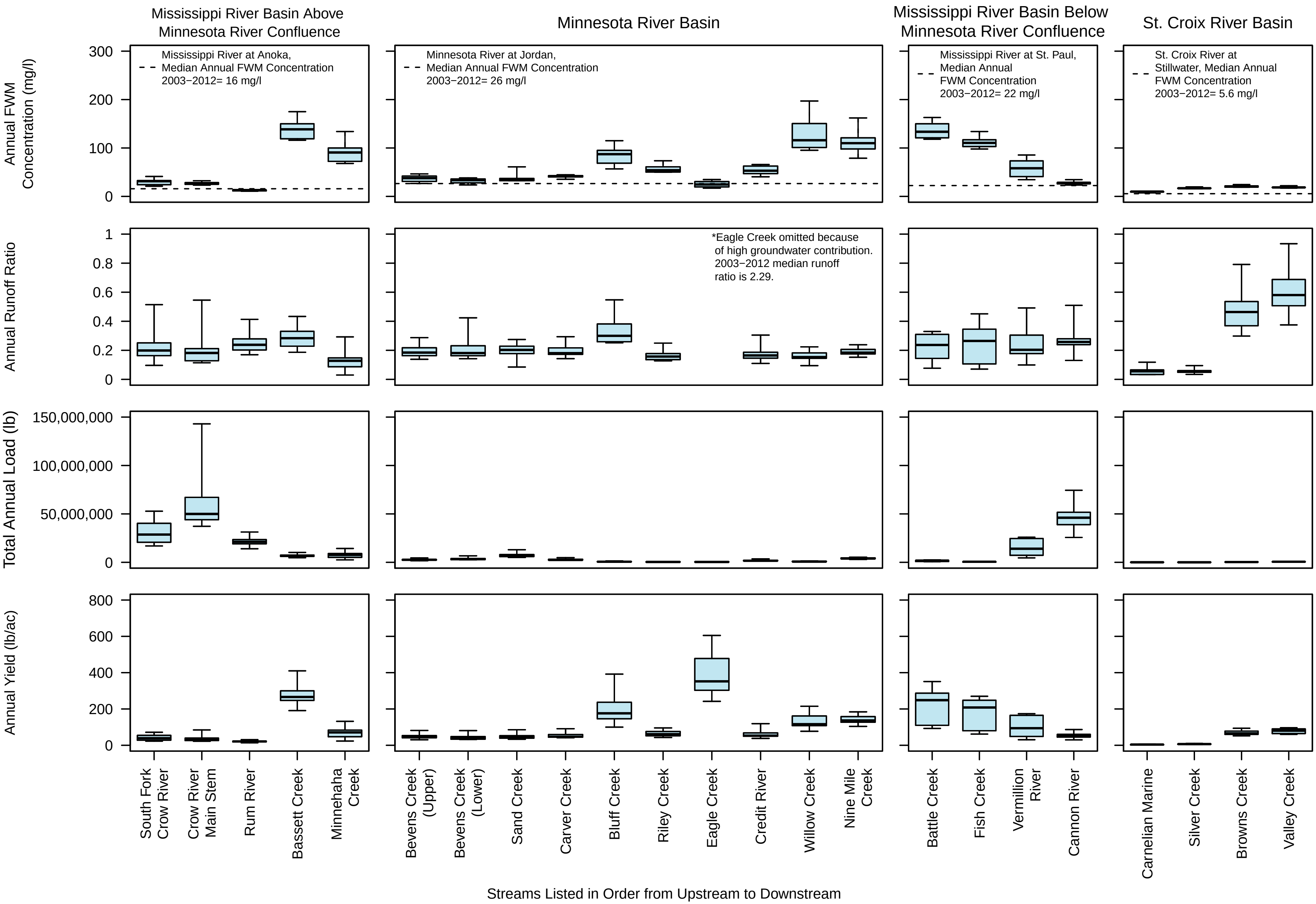


Table VA-3: Annual Median Concentrations, Loads, and Yields for MCES-Monitored Streams, 2003-2012

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)

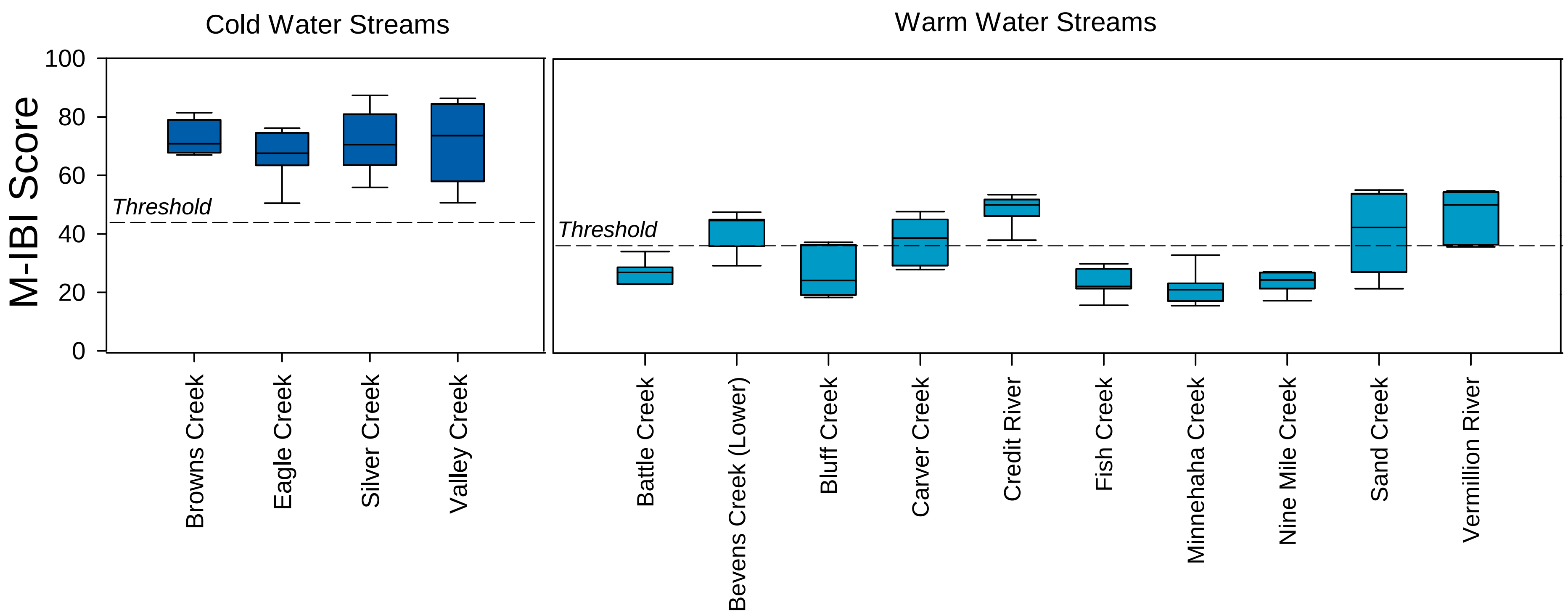
[2] FWM conc = annual flow-weighted mean concentration estimated using Flux32 (Walker, 1999).

[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 VA-24: 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.

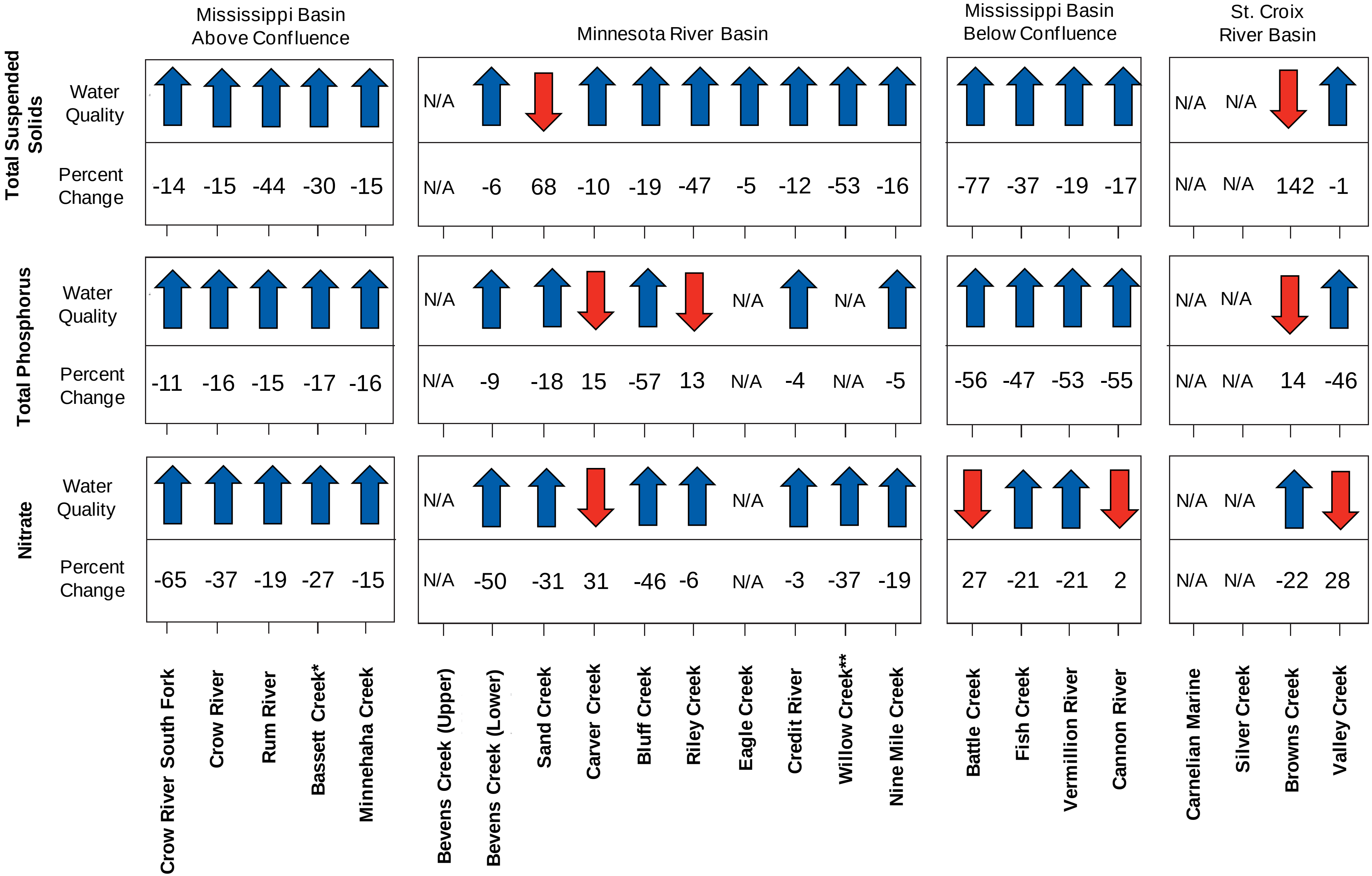
Estimated changes for TSS, TP, and NO_3 in MCES-monitored streams are presented below in two ways. First, tabulated results with directional arrows indicate improving (blue upward arrow) and declining (red downward arrow) water quality, paired with percent change in flow-adjusted concentration estimated for 2008-2012 (Figure VA-25). 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 VA-26).

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 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).

Valley Creek is one of 17 streams to have decreasing TSS and TP flow-adjusted concentrations since 2008, suggesting an improvement in water quality. However, it is also one of four metro area streams to have an increasing trend in NO_3 flow-adjusted concentrations over the same time period. This may suggest a variation in the proportion of stream water source (surface water vs. groundwater), or a decline in groundwater quality over time.

Figure VA-25: Regional Estimated Trends in Flow-Adjusted Stream Concentrations of TSS, TP, and NO_3, 2008-2012

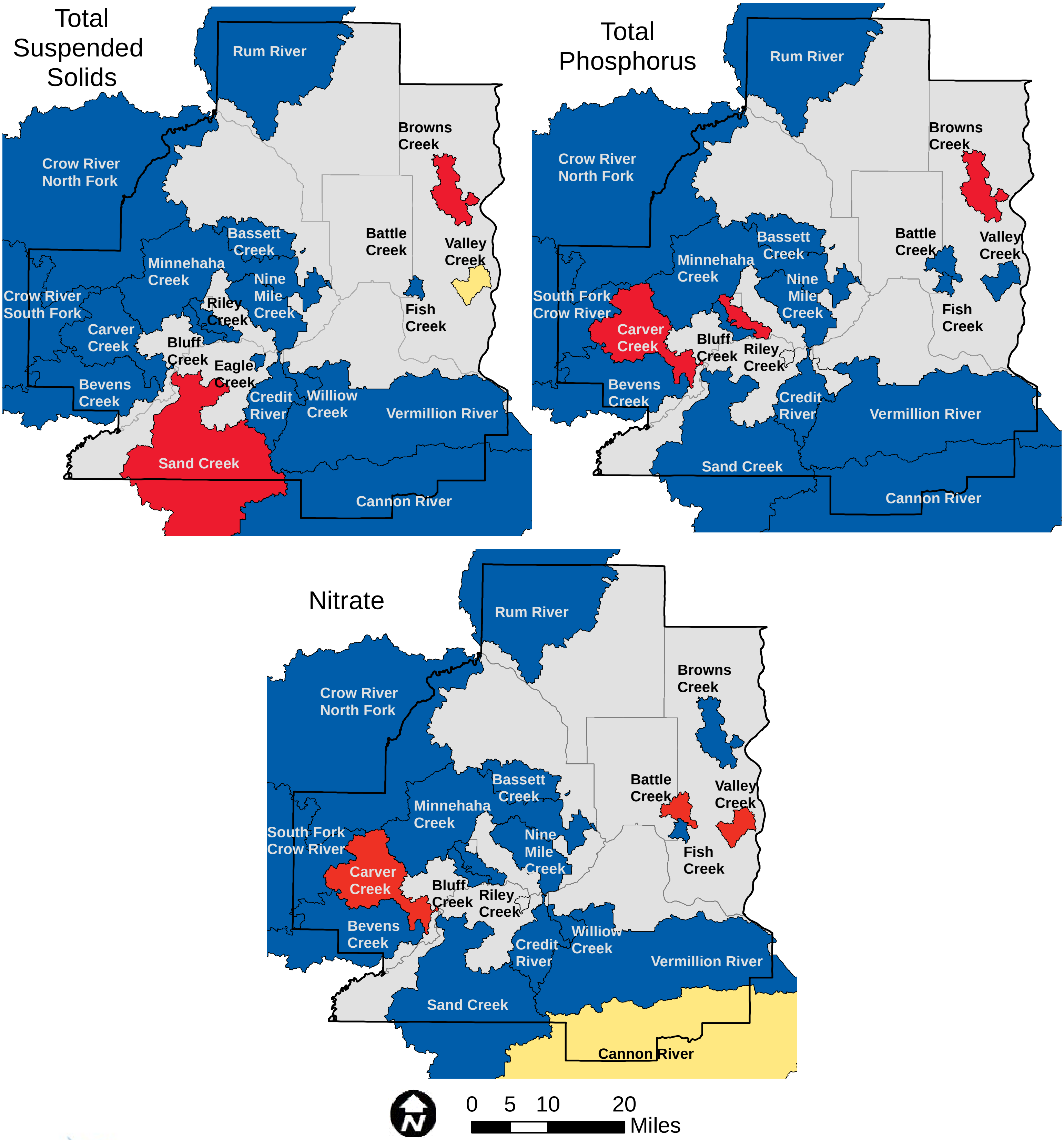
(Grouped by Major River Basin; As estimated by QWTrend)



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 VA-26: Regional Maps of Estimated Trends in Flow-Adjusted Stream Concentrations of TSS, TP, and NO3, 2008-2012

(As estimated by QWTrend)



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

-3% to 3% Change

Greater than 3% Change (Indicates Decreasing Water Quality)

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Conclusions

Valley Creek is a MnDNR-designated Class 2A Trout Stream and a groundwater-fed tributary to the St. Croix River. The watershed lies entirely in Washington County, and contains portions of the cities of Woodbury and Afton. It is primarily agricultural and forested, with small pockets of low-density residential areas. The west portion of the watershed is gradually converting from agriculture to residential as suburban Woodbury continues to grow. There are no major point source contributions to Valley Creek. The upper watershed has rolling hills and the topography steepens towards the channelized creek valley. There are two headwater branches of Valley Creek that eventually converge to form the main branch. The North Branch of Valley Creek begins at the outlet of Lake Edith, whereas the South Branch of Valley Creek is spring fed. The monitoring station is located 0.6 miles downstream of the convergence of the two branches, near the city of Afton, Minnesota. Downstream of the monitoring station, the creek flows a mile before discharging into the St. Croix River; 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 Valley Creek is affected by several factors including the frequency and intensity of precipitation events, land use activities, the soil infiltration capacity, and the ground water quality.

The TSS, TP, and TDP in Valley Creek (both FWM concentration and annual yield) are low, both in comparison to the St. Croix River and the other MCES-monitored metropolitan area tributaries. The data show that TSS, TP, and TDP concentrations and loads are greatly influenced by the intensity and duration of storm events. Large storm events flush TSS and phosphorus constituents from the riparian and near stream areas. Almendiger (2003) indicated that the North Branch of Valley Creek had significantly higher TSS concentrations than the other reaches, and attributed it to channel scour or bank erosion. However, during snowmelt the South Branch had the highest TSS values, presumably from overland flow in agricultural fields, but the solids fell out of suspension before the main stem emptied into the St. Croix. Trend analysis indicates both TSS and TP flow-adjusted concentrations are currently decreasing, resulting in improved water quality for those parameters. These flow-adjusted concentration decreases may well reflect the level of management practices, including land conservation and stream buffering implemented by residents and local organizations like the Belwin Foundation and the Valley Branch Watershed District.

The NO_3 and Cl loads and concentrations are likely driven by past agricultural and water treatment activities contaminating the groundwater in the watershed. All crops benefit from amending soils with fertilizers. Unfortunately, these applications combined with the high infiltration rates of the catchment soils may have resulted in a contaminated aquifer, and by extension, the creek as well. This process of cropland leaching into groundwater accounts for 30% of nitrogen contributions to surface water in the state of Minnesota (MPCA, 2013b). The Valley Creek NO_3 and Cl concentrations and loads are higher than those in the St. Croix River (which carries runoff from the forested lands in northern Minnesota and Wisconsin), and are more similar to other agricultural MCES-monitored metropolitan area tributaries. Trend analysis revealed the five-year trend in NO_3 had a 28% increase in flow-adjusted concentration from 2008-2012, resulting in declined water quality for that parameter. In addition to an agricultural source, elevated Cl in the groundwater could be attributed to road salts, leaking septic systems, or the use of water softeners.

The results from the biological monitoring suggest that Valley Creek has a diverse, healthy macroinvertebrate community and good water quality. While the FBI scores indicated the presence of some organic pollution during most years of monitoring, there were pollution-intolerant taxa were present in every sample except 2003. The most recent M-IBI scores were lower due to a storm disturbance. Continuing monitoring is necessary to determine if the stream will recover and return to the typical higher M-IBI scores. Overall, the monitoring stream reach habitat and water quality typically were able to sustain the needs for aquatic life.

As one of 15 designated trout streams in the metropolitan area, a great effort has been to mitigate negative impacts on the stream and improve the habitat. The combination of consistently cool temperatures from groundwater, a stable macroinvertebrate food source, low in-stream siltation, and shady, forested riparian areas provide a good habitat for the naturally occurring brook, rainbow, and brown trout communities. While our data do indicate a NO_3 and Cl contamination, the levels do not appear to affect the trout population in Valley Creek. As the groundwater cycles through the aquifers and into Valley Creek, the effects of improved agricultural practices and concerted water quality improvement efforts may reduce the in-stream concentrations of NO_3 and Cl pollution.

Recommendations

This section presents recommendations for monitoring and assessment of Valley Creek, as well as recommendations for partnerships to implement stream improvements. MCES recognizes that cities, counties, and local water management organizations, like VBWD, 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 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 analyze the load data from the monitoring stations upstream from our MCES station. This will help identify the origins of potential sources of the chemical loads in the main branch of Valley Creek. VBWD currently has monitoring stations on the north and south branches, upstream of the MCES station.

- MCES should validate spatial data for the Valley Creek watershed to ensure the proper watershed boundaries are identified and determine if there are any special circumstances (that is, internal drainages, rerouted flows, or other factors) that alter previously reported boundaries. Some corrections to the MCES spatial data for Valley Creek were made during the preparation of this report.

- 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 involving local communities.

- MCES should continue to analyze and evaluate the biomonitoring program. Potential additions could include adding a Stream Habitat Assessment similar to the habitat surveys performed by the MPCA or the addition of fish population and algal community data.

- As resources allow, MCES should partner with VBWD to provide educational outreach to watershed residents on the dynamic interactions between surface water and groundwater in the Valley Creek watershed, the potential for groundwater pollution, and recommended protective and restorative measures.

- MCES and partners (especially Valley Branch Watershed District, the Belwin Foundation, and the Science Museum of Minnesota St. Croix Research Station) 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 and partners (especially Valley Branch Watershed District, the Belwin Foundation, and the Science Museum of Minnesota St. Croix Research Station) should convene a work group to investigate sources of NO_3 and Cl in the shallow groundwater.

- MCES staff should continue to serve on technical advisory committees and other work groups to aid in management of Valley Creek.

- As resources allow, MCES should provide VBWD and other local water managers with information about the heightened potential for surface waters to be impacted by groundwater changes in the Valley Creek watershed. This information should be included in watershed and local surface water management plan updates.

- The Valley Creek watershed is relatively undisturbed, and many of the native soils are maintained. However, published soil surveys may not be representative of actual conditions at specific locations. For installation of infiltration-based stormwater practices (like bioinfiltration basins, raingardens, and pervious pavers), soil borings should be taken from the exact location of the proposed location to assess level of soil filling or disturbance. Based on the boring results, best management practices designs should be customized and appropriate soil amendments added.

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