Vermillion River Monitoring Network

2020 Annual Report

Prepared for the Vermillion River Watershed Joint Powers Organization by the Dakota County Soil and Water Conservation District

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Contents

EXECUTIVE SUMMARY

The Vermillion River Monitoring Network (VRMN) was created to assess water quality and quantity in the Vermillion River Watershed. These data, which include a combination of chemical, physical, and biological parameters and assessments, enable local agencies to determine the health of the stream and implement appropriate management strategies (Table 1).

Table 1. Water quality parameters, acronyms, and descriptions.

Parameter	Description
Chloride	All natural waters contain some dissolved solids (salinity) from contact with soils, rocks, and other natural materials. Too much, though, and dissolved solids (of which chloride is a major component) can impair water quality and create toxic conditions for aquatic life.
Chlorophyll *a*	Chlorophyll *a* is a measure of the amount of algae growing in a waterbody. Although algae are a natural part of freshwater ecosystems, too much algae can cause aesthetic problems such as green scums and bad odors, and can result in decreased levels of dissolved oxygen.
Dissolved Oxygen (DO)	Characterizes the amount of oxygen available for aquatic life. At low concentrations, sensitive animals may move away, weaken, or die. Also influences decomposition rates and the composition and cycling of other water quality parameters. Low concentrations indicate either high demand for oxygen and/or limited reaeration from the atmosphere.
***Escherichia coli (E. coli)* bacteria**	An indicator of the prevalence of disease-causing pathogens.
Nitrate	An essential nutrient that stimulates growth of algae and other aquatic plants. Can affect reproductive success of aquatic organisms at high concentrations. Human consumption of water with elevated nitrate could cause serious health problems, particularly for infants (National Primary Drinking Water Regulations, United States Environmental Protection Agency).
Specific Conductance	Measures the ability of water to pass an electrical current. Affected by negatively charged ions (chloride, nitrate, sulfate, and phosphate) and positively charged ions (sodium, magnesium, calcium, iron, aluminum). Low conductivity water is considered “soft” while high conductivity water is considered “hard.”
Temperature	Rates at which biological and chemical processes progress depend on temperature. Aquatic organisms are dependent on certain temperature ranges for optimum health and become stressed when outside the optimal range for a prolonged period of time.
Total Phosphorus (TP)	A nutrient required by all living organisms. High levels, along with nitrate, can over-stimulate the growth of aquatic plants and algae, resulting in high dissolved oxygen consumption, causing death of fish and other aquatic organisms.
Total Suspended Solids (TSS)	Measurement of dissolved and suspended material in the water. Influences the transparency, color, and overall health of an aquatic ecosystem.

Annual data contributes to a robust data set in which long-term trends can be analyzed. A thorough discussion of the historical data is included in this report and evaluated against approved state water quality standards when possible.

Weather

Weather patterns are known to impact stream conditions, so flow is continuously monitored throughout the watershed to assist in interpreting stream health. The 2020 monitoring season began with snowmelt and late spring rain events increasing water levels from low levels in February. Waters remained elevated through early July thanks to multiple large rain events in May and June. Beginning in mid-summer, large rainfall events were few and far between resulting in most samples being collected during baseflow or low water level conditions.

The 2020 precipitation total for April through October was 23.82 inches, over 10 inches less than what was measured in 2019 and much more in line with the 30-year precipitation average for that period at the Minneapolis/St. Paul airport (25.46 inches).

Water Quality

Many of the water monitoring parameters are meeting standards and indicate a healthy condition in the Vermillion River and tributaries (Table 2). Nitrate (NO3; a form of nitrogen) levels were quite low, except at one station on the South Branch Vermillion River which has a significant nitrate load compared to others in the network. High levels of nitrate in drinking water pose a human health risk. The other primary nutrient monitored in the watershed is phosphorus, a limiting nutrient for plants, meaning that if it becomes available, plants (including algae) will use it to grow in size and/or number. Phosphorus levels throughout the watershed are at an acceptable level for most monitoring stations (below the state standard), except during runoff events when elevated concentrations are often recorded.

There are some parameters which are measured at undesirable levels. *Escherichia coli (E. coli)* bacteria levels are high in many streams of southeast Minnesota, and the Vermillion River and its tributaries are no exception. Monitoring results in 2020 show numerous low-level exceedances during the season at all of the sites in the network and the geometric mean at each site showed a much higher degree of variability than has been seen in previous years. *E. coli* levels at VR24 continue to be higher than samples collected at other monitoring sites within the watershed. The geometric mean for *E. coli* samples at VR24 was ten times more than the standard, a level more in line with historical levels. The geometric means for other sites were between two to four times higher than the standard and have decreased since the much higher levels seen in 2019.

While nitrate levels are meeting the surface water quality standard at all sites, high levels measured on the South Branch Vermillion River are of concern and are likely related to the soils, artificial drainage, and agricultural land use that dominates the South Branch Vermillion River subwatershed.

Low dissolved oxygen concentrations and high levels of total suspended solids (contributing to turbid, cloudy, water) following runoff events were also common at several sites. The median dissolved oxygen levels met the standard for both 2A and 2B stream sites during baseflow conditions. Median levels at the two sites on North Creek were below the standard during runoff sampling; individual event violations also occurred at several sites during runoff conditions. Regarding suspended solids, sample medians were at or below (meeting) the state standard at all stations during baseflow conditions. Standard exceedances occurred during runoff conditions at all monitoring water sites and none of the sites had exceedances during snowmelt efforts.

Load Duration Curves
A load duration curve provides a visual characterization of pollutant concentrations at different flow regimes, clearly presenting the frequency and magnitude of water quality standard exceedances (if any). Load duration curves were created for total phosphorus, nitrate, total suspended solids, and *E. coli* at all monitoring stations in the VRMN. Exceedances of the *E. coli,* total phosphorus, and total suspended solids state standards were identified during all flow regimes (unlike in previous years when exceedances were typically seen at very high and high flow regimes). Nitrate levels were highest at SB802, VR803, and VR0020 as expected. Concentrations exceeded the drinking water standard at mid-range and low regimes at VR803 and VR0020 (proposed aquatic life toxicity - chronic standard for 2B streams was used to analyze loading capacity for VR24, VR803, and VR0020).

Temperature
Since portions of the Vermillion River and its tributaries are home to a self-sustaining brown trout population, there is great interest in maintaining water temperatures suitable for a healthy brown trout fishery. During July in particular, stream temperatures continued to approach the chronic exposure limit of 20°C for brown trout (Bell, 2006). During periods when temperatures are approaching the chronic exposure limit, it is assumed that trout will seek refuge in nearby cool and deeper pools.

Biological Monitoring
The Minnesota Pollution Control Agency (MPCA) developed biological indices to evaluate the health of the macroinvertebrate community in the Vermillion River. In 2020, biomonitoring was conducted at nine sites in the watershed. Results were mixed, indicating a healthy macroinvertebrate community at some sites, while others indicate potential impairment due to low diversity and an abundance of pollution-tolerant species. Low water levels may have influenced the macroinvertebrate index of biological integrity (MIBI) score at several of the monitoring sites.

Habitat assessments were completed using the MPCA's Minnesota Stream Habitat Assessment protocol to further evaluate and understand the biological integrity of stream reaches. Of the sites monitored in 2020, eight sites had a 'fair' score and one site scored 'good'. The three sites with the highest scores (one 'good' (A03) and two 'fair' (A02 and A09)) showed positive changes in channel morphology (depth variability, water velocity, degree of meander). The two sites with the lowest scores (A06 and A07) had low land use scores as well as in the riparian area (vegetated area adjacent to the steam).

Conclusions
The Vermillion River has some areas with good water quality, but there is room for improvement, particularly with regard to sources of nitrogen, low dissolved oxygen, *E. coli* bacteria, temperature, and suspended solids. By measuring each of these parameters individually, along with the health of the biological community, we can better understand the impact of various pollutants, gauge successes in water resource management, and plan for future restoration and protection efforts within the watershed.

Table 2**. 2020 Vermillion River Scorecard.** M = meets criteria, V = violates criteria, N/A = determination could not be made as there is no standard to compare data to. Developed using monitoring data from 2020 only. See corresponding section of report for a detailed description of status and trends. Criteria include state standards and ecoregion means where standards do not exist.

	Station Location Description									
Parameter	Vermillion River at Cty 46 (VR24)	South Creek at Flagstaff Ave (SC806)	Vermillion River at 220th St (VR804)	Vermillion River at Denmark Ave (VR807)	Upstream North Creek at Highway 3 (NC808)	North Creek at Highway 3 (NC801)	South Branch Vermillion River at Cty Hwy 66 (SB802)	Vermillion River at Goodwin Ave (VR803)	Vermillion River in Vermillion Falls Park (VR0020)	**Criteria**
Chloride	M	M	M	M	M	M	M	M	M	Sample medians are below the standard during all conditions.
Chlorophyll *a*	*N/A*	M	M	M	M	M	M	M	M	Sample medians are below the standard during all conditions. Individual samples at all sites exceed the standard during runoff conditions
Dissolved Oxygen	M	M	M	M	V	V	M	M	M	Standard minimums violated at NC801 and NC808 during baseflow. Coldwater standard is violated by individual samples during runoff event sampling.
***E. coli* bacteria**	V	V	V	V	V	V	V	V	V	Violates criteria at all monitoring sites under all conditions.
Nitrate	*N/A*	M	M	M	M	M	M	*N/A*	*N/A*	All sites meet standard. SB802 is higher than other sites and has an increasing trend.
Temperature (Summer)	*N/A*	V	V	V	V	V	M	*N/A*	*N/A*	Maximums exceed the optimal range for all coldwater streams. Median temperature values are near or below optimal range in June, but in tolerance range for July and August for all sites excluding SB802.
Total Phosphorus	M	M	M	M	M	M	M	M	M	Sample medians are below the standard during all conditions. Individual samples at all sites exceed the standard during runoff conditions
Total Suspended Solids	M	M	V	V	V	V	M	M	M	Standard threshold was exceeded by individual samples during baseflow at VR804, VR807, NC808, and NC801, and during runoff at all stream sites

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Acknowledgements

This report would not be complete without contributions from the following:

Lindsey Albright - Dakota County Soil and Water Conservation District
Melissa Bokman - Scott County and Vermillion River Watershed Joint Powers Organization
Casandra Champion - Metropolitan Council Environmental Services
Joel Chirhart - Minnesota Pollution Control Agency
Nick Hayes - Minnesota Department of Natural Resources
Dave Holmen - Dakota County Soil and Water Conservation District
Travis Thiel - Dakota County and Vermillion River Watershed Joint Powers Organization
Jon Utecht - Scott Soil and Water Conservation District
Mark Zabel - Dakota County and Vermillion River Watershed Joint Powers Organization

Abbreviations and Acronyms

BMP	Best Management Practice
°C	Degrees Celsius
cf	Cubic feet
cfs	Cubic feet per second
DCSWCD	Dakota County Soil and Water Conservation District
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
eDNA	Environmental DNA
EPA	Environmental Protection Agency
°F	Degrees Fahrenheit
FIBI	Fish Index of Biological Integrity
FNU	Formazin Nephelometric Unit
ft	Foot
IBI	Index of Biological Integrity
in	Inch
IQR	Interquartile range
max	Maximum
MCES	Metropolitan Council Environmental Services
mg	Milligram
min	Minimum
mL	Milliliter
mMHO	micromhos or microseimens (µmhos/cm)
MNDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MPN	Most probable number
N/A	Not available
NO_3	Nitrate
SSWCD	Scott Soil and Water Conservation District
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TDP	Total Dissolved Phosphorus
TSS	Total Suspended Solids
USGS	United States Geological Survey
VRMN	Vermillion River Monitoring Network
VRWJPO	Vermillion River Watershed Joint Powers Organization
WWTP	Wastewater treatment plant

INTRODUCTION

With its close proximity to the Twin Cities Metropolitan Area and a self-sustaining brown trout population, the Vermillion River is a popular place for local anglers and nature enthusiasts. The Vermillion River Watershed includes about 50 miles of trout stream and is one of the last trophy trout fisheries in a metropolitan area, according to Trout Unlimited. It has been and is continuing to be threatened by rapid urban development and rural land uses. As the human population in the watershed grows with each passing year, so do concerns for maintaining the ecological integrity of the river and its tributaries. The Dakota County Soil and Water Conservation District (DCSWCD) and the Scott Soil and Water Conservation District (SSWCD) carry out annual monitoring (going back to 2000) on a network of sites sponsored by the Vermillion River Watershed Joint Powers Organization (VRWJPO). These strategically selected sites provide information about the status of the river, allowing for tracking of long-term trends and more effective management of the quality and quantity of the Vermillion River.

This report summarizes the surface water quality and quantity data, as well as biological data, for the monitoring season of 2020 (including historical context whenever possible).

Vermillion River Monitoring Network

The Vermillion River Monitoring Network (VRMN) was created in the late 1990's to obtain water quality and quantity data for the Vermillion River Watershed. The network consists of eight permanent monitoring stations and several biological monitoring stations (Figure 1).

Manual flow measurements and automated level measurements are used in combination with baseflow and runoff event-based water quality samples, which determine the concentration of pollutants in a stream across a variety of flow regimes. These data can then be used to determine if the Vermillion River and its tributaries are meeting water quality standards and can also be used to calculate pollutant loads, which helps staff understand what is happening in the watershed and set goals for a stream to meet or maintain its designated use criteria.

The Metropolitan Council's Watershed Outlet Monitoring Program (WOMP) site in Hastings (pictured at right) is also monitored by DCSWCD and the available data are included in this report. This site is particularly useful because it provides information regarding the water quality and quantity for the portion of the Vermillion River Watershed above the falls in Hastings. Comparing the quality at this location to various upstream monitoring stations can help to identify major sources of pollutants and prioritize areas for management. The VRMN is designed to be spatially extensive and representative of the wide range of flow regimes encountered by the Vermillion River Watershed and its subwatersheds. These data provide insight as to the chemical, physical, and biological integrity of the Vermillion River and its tributaries.

South Creek at Flagstaff Ave

South Branch Vermillion River
at 200th St E

Photo credit – L. Albright

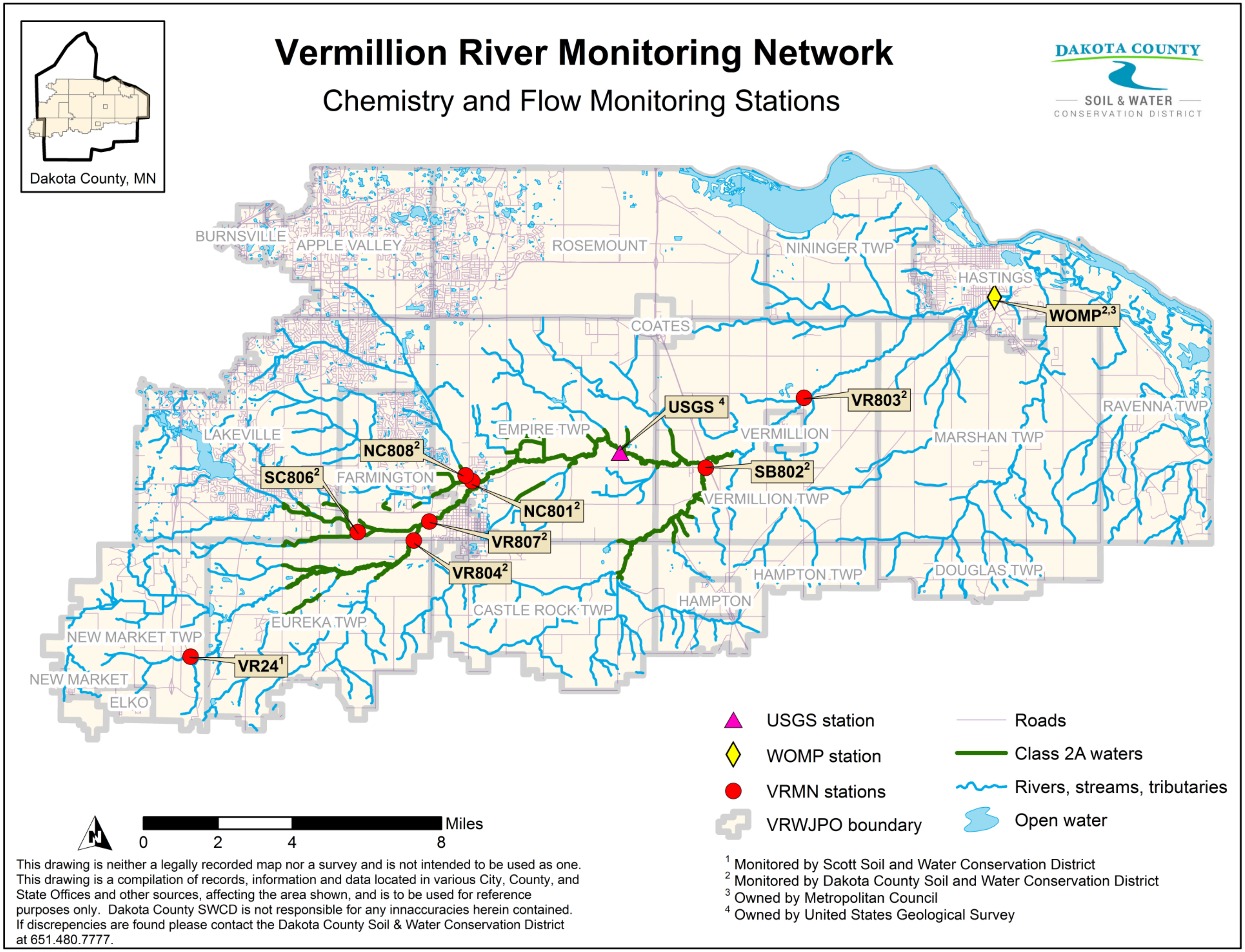


Figure 1. Vermillion River Monitoring Network (VRMN) chemistry and flow monitoring stations.

Designated Uses and State Standards

The Minnesota Pollution Control Agency (MPCA) is charged with designating beneficial uses for all waters and developing standards to help protect those designated uses. Standards must be legislatively approved to become part of the Minnesota Rules and enforceable under the Clean Water Act. Table 3 shows water quality parameters with standards for 2A and/or 2B waters applicable to this watershed's streams and rivers. In Minnesota, all class 2A streams are also protected as potential drinking water sources. In June 2014, the MPCA Board approved eutrophication standards for rivers and streams to include Chlorophyll *a*, Total Phosphorus, and Total Suspended Solids.

The monitoring network is composed of both cold (2A) and warm (2B) water designated reaches; however, some suggest that a site-specific designation would be more appropriate for the Vermillion River since it appears able to support both cold and warm water biota, but is challenged in being able to meet either the 2A or 2B standard.

Table 3. State standards for water quality parameters listed under the Water Quality Standards for Protection of Waters of the State, rule 7050.0222.

Parameter	State Standard
Chloride	≤ 230 mg/L (chronic standard)
Chlorophyll-a	≤ 35 mg/L *Assessment season is June to September*
Dissolved Oxygen	7 mg/L as a daily minimum (2A) 5 mg/L as a daily minimum (2B) *For class 2 waters, compliance required 50 percent of the days at which the flow of the receiving water is equal to the $7Q_{10}$ (Seven-day ten-year low flow means the lowest average seven-day flow with a once in ten-year recurrence interval)*
***E. coli* bacteria**	≤ 126 organisms/100mL *(as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms/100mL. Standard applies only between April 1 and October 31)*
Nitrate	≤ 10 mg/L (drinking water and 2A)
Total Phosphorus	≤ 0.15 mg/L (South Region)
Total Suspended Solids	≤ 10 mg/L (2A) (Southern River) ≤ 30 mg/L (2B) (Central River) * *Standard must not be exceeded more than 10% of the time over a multiyear window; the assessment season is April through September*
Temperature	"no material increase" (2A) No more than "5°F [~2.8°C] above natural in streams… based on monthly average of maximum daily temperature, except in no case shall it exceed the daily average temperature of 86°F [30°C]" (2B)

*Per conversation with MPCA staff in 2020, the VRWJPO reports TSS findings using the warm water (2B) stream standard for the Central River Nutrient Region, instead of the warm water standard for the Southern River Nutrient Region (≤ 65 mg/L) as has historically been used.

METHODS

Sample Collection

At all sites, routine samples were collected every two weeks and additional event grab samples were collected when river stage rose substantially due to storm event runoff. This sampling design ensures that significant events are captured while also collecting lower flow periods, resulting in a well-balanced dataset. Over the years, some changes have been made to the monitoring plan. Historical results presented in this report should be viewed with consideration as to the monitoring plan at the time of sample collection.

Sample collection variance:

- In 2019, added chloride and chlorophyll *a* to the analyte suite in response to growing concern for chloride levels in the metro area and the inclusion of chlorophyll *a* in the MPCA's water quality assessment process for rivers and streams
- In 2018, MNDNR began to collect flow measurements at NC801 and NC808.
- Beginning in 2015, continuous stage monitoring equipment was installed by the Minnesota Department of Natural Resources (MNDNR) at VRMN sites SC806, VR804, VR807, SB802, and VR803. MNDNR collected all flow measurements at these sites during the 2017 field season.
- In 2014, a new standard for total suspended solids (TSS) was established by the MPCA and is now used in place of the pre-existing turbidity standard. Due to the introduction of the new TSS standard, turbidity was not monitored at any of the VRMN sites in 2015 and will not be monitored in the future.
- In the beginning of 2011, monitoring station VR809 (at 235th St.) was abandoned due to the river frequently going dry at this location. The monitoring equipment was relocated to South Creek at Flagstaff Avenue (SC806) within the City of Farmington, where there was a clear need for additional monitoring data.
- In 2010 and 2011, event samples were not collected from VR24 or VR803.
- Prior to 2009, monthly base flow and event grab samples were collected from all sites.
- 'SC804' was renamed 'VR804' and 'MC801' was renamed 'NC801' to accurately reflect the river or tributary on which the station is found.

In addition to the Vermillion River Monitoring Network stations, DCSWCD staff collected baseflow and event (runoff) samples and chemical data from the Metropolitan Council's WOMP site (Figure 1) on the Vermillion River at Vermillion Falls Park in Hastings (VR0020).

Field Measurements

During each site visit, a YSI EXO1 multi-parameter probe was deployed in the stream to measure discrete field parameters (Temperature, Specific Conductance, pH, and Dissolved Oxygen). Prior to 2014, a Hydrolab Quanta Sonde (HACH) was used to measure these field parameters. Additionally, a secchi tube reading, as well as a tapedown or staff gage reading was recorded during each visit.

Flow (Discharge) Measurements

Flow measurements can be used to understand the volume of water moving through a stream during various flow conditions; and, in conjunction with pollutant concentration data, can be used to calculate pollutant loads in a stream.

Flow is typically measured manually five to seven times per season at each site over a variety of flow regimes to develop a mathematical relationship in which flow can be estimated at any river level (stage). In doing so, DCSWCD staff follows United States Geological Survey (USGS) established protocols for measuring flow (Buchanan, 1969). Additionally, each station is equipped with automated data loggers which record continuous stage at fifteen minute intervals. With these two approaches, it is possible to get an accurate discharge rate at any water level.

DCSWCD staff measuring flow at the NC808 monitoring site
Photo Credit – J. Van Der Werff Wilson

In 2015, the MNDNR began an investigation of groundwater losses from irrigation in the Vermillion River Watershed. As part of their investigation, they began monitoring continuous stage at many of the VRMN sentinel sites. Until the conclusion of their investigation, DCSWCD has suspended all flow and stage monitoring at seven of the eight sentinel sites. Flow monitoring is conducted by SSWCD at VR24. Water quantity data are available on the Minnesota Cooperative Stream Gaging Program website (http://www.dnr.state.mn.us/waters/csg/index.html).

Temperature monitoring equipment will continue to be installed by DCSWCD and SSWCD staff at all VRMN monitoring sites.

Biological Monitoring

Prior to macroinvertebrate sampling, a site visit was completed for each monitoring location. The primary purpose of each site visit was to ensure that sites were suitable for sampling and to identify sample reach lengths. Macroinvertebrate habitat was documented during reconnaissance trip so that all appropriate habitats were sampled when staff returned for macroinvertebrate sample collection, approximately one month later. Protocols for site reconnaissance were adopted from those specified by the MPCA (MPCA, 2009).

Macroinvertebrate samples were collected following the MPCA Qualitative Multi-Habitat Sample (QMH) protocol (MPCA, EMAP-SOP4) to ensure that macroinvertebrate data collected through this program could be used by the MPCA for future assessment purposes. All samples were collected during the macroinvertebrate index period (August 1st-September 30th) as specified by the MPCA.

Habitat Assessment

The habitat assessments were completed by following the MPCA Stream Habitat Assessment (MSHA) protocol (MPCA, 2007). DCSWCD staff has been trained by the MPCA in using the protocol that evaluates habitat based on surrounding land use, riparian and in-stream zones, and channel morphology (see the field data sheet in the Appendix).

Laboratory Analyses

Water quality samples were collected using standardized procedures established by the Metropolitan Council Environmental Services (Metropolitan Council, 2003). No less than 10% of the samples collected were submitted for quality assurance/quality control purposes.

Samples were delivered to the Metropolitan Council Environmental Services laboratory and analyzed according to Environmental Protection Agency (EPA) specified protocols for various standard bacterial and chemical parameters (Table 4).

Table 4. **Laboratory analysis method.**

Analyte	Method
Chlorophyll-a	D3731
Chloride	4500
Coliform/*E. coli* Enzyme substrate test; ONPG-MUG test	Colilert
Total Phosphorus after Block Digestion	365.4
Nitrate-Nitrite Nitrogen by Colorimetry	4500
Total Suspended Solids	2540-D

Field and laboratory data are submitted annually to the MPCA's Environmental Quality Information System (EQuIS) which can be viewed through the Environmental Data Access system on the MPCA's web site (https://cf.pca.state.mn.us/water/watershedweb/wdip/index.cfm).

Statistical graphing

JMP 11 software was used to plot field and laboratory data. An explanation of box plot figures is shown in Figure 2. In the event that outliers exist, lines are not drawn to the minimum and maximum but instead are drawn to 1.5 times the interquartile range (IQR) and outliers are shown as dots. The IQR effectively trims the highest and lowest 25% of values and represents the middle 50%. The median represents the value lying at the midpoint with an equal number of observed values above and below. N indicates sample size.

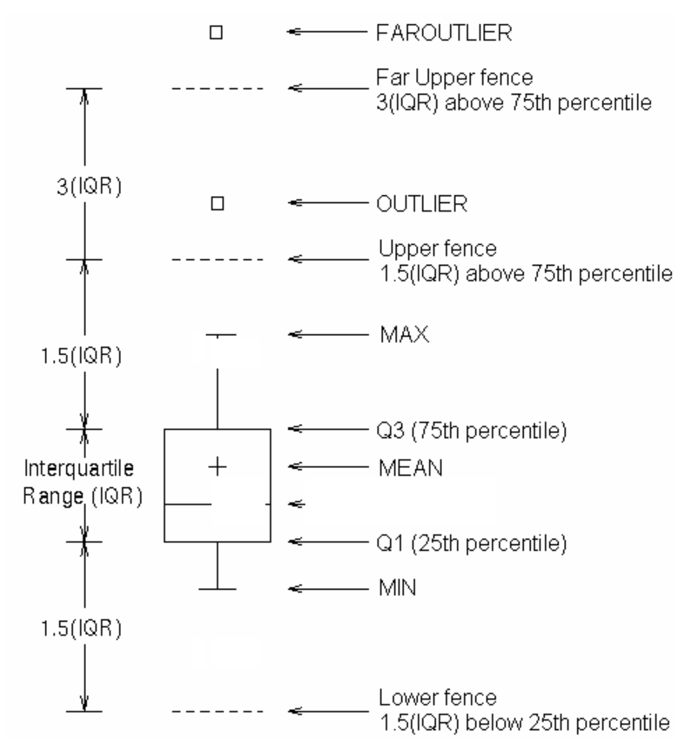


Figure 2. Vertical boxplot display key.

Load Duration Curves

A load duration curve provides a visual characterization of pollutant concentrations at different flow regimes, creating a clear representation of the frequency and magnitude of water quality standard violations, if any, for a given parameter (EPA 2007). The load duration curve is calculated by multiplying the average daily stream flow with water quality standard concentrations and the conversion factor for the pollutant of concern:

***E. coli*:** load (in billions of org/day) = flow (cfs) **X** standard concentration (cfu/100ml) **X** 0.03786

TP, TSS, NO_3: load (in pounds/day) = flow (cfs) **X** standard concentration (mg/L) **X** 5.3938

Instantaneous loads are calculated by multiplying the average daily stream flow with water quality concentrations and the conversion factor for the pollutant of concern:

***E. coli*:** load (in billions of org/day) = flow (cfs) **X** concentration (cfu/100ml) **X** 0.03786

TP, TSS, NO_3: load (in pounds/day) = flow (cfs) **X** concentration (mg/L) **X** 5.3938

Duration curve analysis of water quality data identifies different flow intervals, which can be used as a general indicator of the hydrologic condition at the specific monitoring location (i.e. lots of water versus little and to what relative degree). Flow intervals are demarcated as such: very high flows (0-10%), high flow conditions (10-40%), mid-range flows (40-60%), low flow conditions (60-90%), and dry conditions (90-100%). These intervals can provide additional information in regard to patterns and conditions associated with the impairment.

Loads that display on the graph above the curve (calculated using the state standard) indicate a violation of the water quality standard, while those plotting below the load duration curve indicate that the standard is being met for that monitoring event.

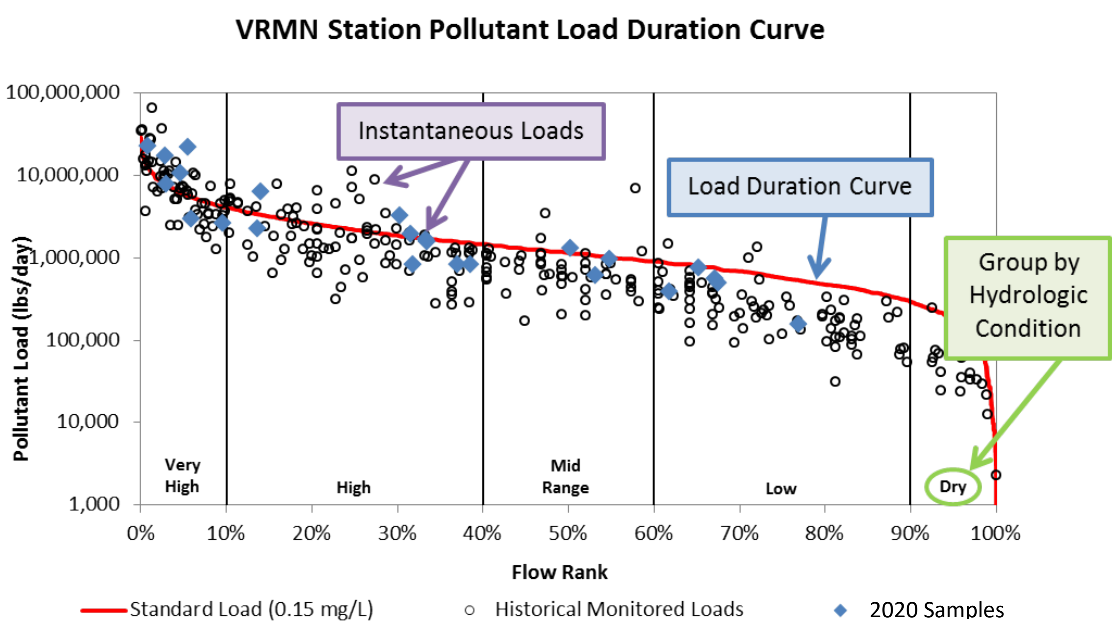


Figure 3. Example of a load duration curve

RESULTS AND DISCUSSION

Sampling summary

Staff collected 168 water quality grab samples. DCSWCD staff visited each site (SSWCD visited VR24) regularly from snowmelt (mid-March) through November 1 to collect samples, download continuous temperature and water level data, and ensure equipment was functioning properly.

Monitoring results from 2020 are graphically presented, reading left to right, with sites listed from west (upstream) to east (downstream) format. The western-most site is in Scott County, and the eastern-most site is the Metropolitan Council's WOMP site, located in Hastings. Laboratory results for nutrient concentrations, suspended sediment, and *E. coli* bacteria are shown. Streamflow and precipitation were included as both are essential in interpreting data. Pollutant load duration curves were created, providing a visual representation of the relationship between stream flow and loading capacity (frequency and magnitude of water quality standard exceedances) in the Vermillion River Watershed. Lastly, temperature, macroinvertebrate, and habitat monitoring data are included. All together, these data help us to understand the Vermillion River ecosystem in its entirety.

Water quality results are presented as an arithmetic mean (geometric mean for *E. coli* bacteria only) and are compared against State Water Quality Standards (Minnesota Statute 7050.0222) or proposed standards if approved standards do not exist. Stream temperature data are compared against optimal temperatures for adult brown trout (Bell, 2006).

Precipitation and flow

Precipitation records for the Minneapolis-St. Paul (MSP) airport were obtained from the Minnesota Climatology Working Group website (climate.umn.edu/) and serve as a benchmark to observe the deviation from normal precipitation for the current year. Monthly averages for the last 30 years were calculated and shown along with the precipitation data from the University of Minnesota weather station in Rosemount, Minnesota from April through October (Figure 4).

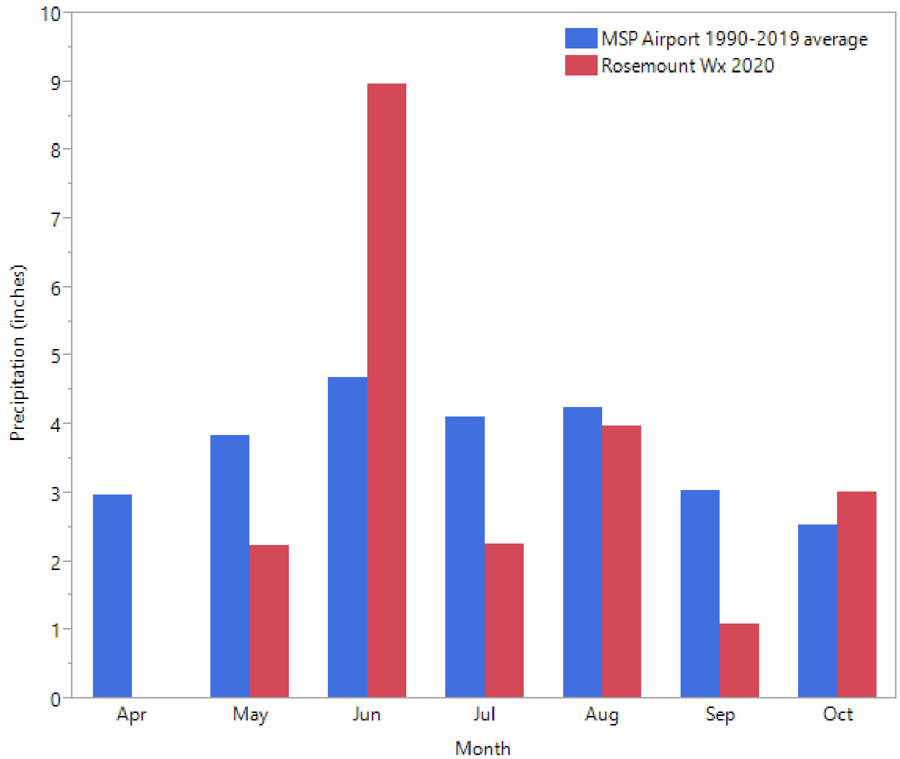


Figure 4. 30-year monthly average (1990-2019) precipitation at Minneapolis-St. Paul airport and 2020 monthly precipitation measured at the Rosemount weather station from April through October.

Large rainfall events were few and far between resulting in most samples being collected during baseflow or low water level conditions. The 30-year average (1990-2019) for the April-October period at the MSP Airport was 25.464 inches while the total April through October 2020 precipitation data was 23.82 inches.

Discharge is continuously monitored by the United States Geological Survey (USGS) at the monitoring station along Blaine Avenue in Empire Township, MN in cooperation with the Vermillion River Watershed Joint Powers Organization (Figure 5, courtesy of USGS). Due to its central location and length of record, it is considered a sentinel site to observe flow patterns in the Vermillion River.

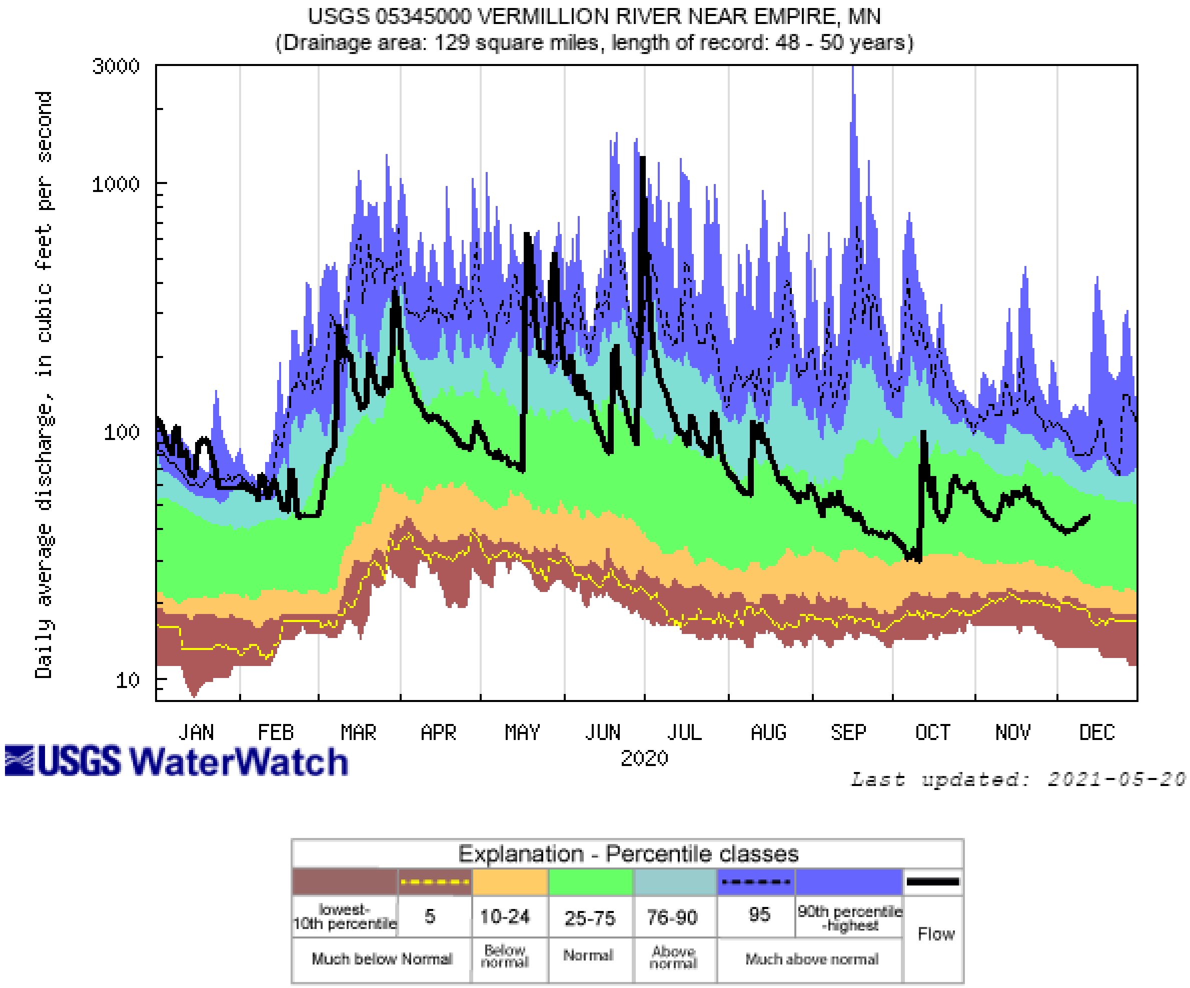


Figure 5. Daily average discharge (cfs) for the USGS station at Blaine Avenue in 2020.

Early spring rain events concurrent with snowmelt led to elevated water levels for much of the spring. Water levels were normal for April and half of May until a large rain event pushed levels back up. Levels stay elevated with the help of smaller rain events and a four inch soaker on June 30th. Minimal ran resulted in decreasing flow until a rain event in mid-October rose water levels and the river remained at a normal level for the remainder of the year.

The cumulative flow of the Vermillion River for 2020 stayed within the normal and above normal range for most of the monitoring season. Stream discharge remained in the normal range from August until the end of the calendar year.

Field Parameters

In 2020, the following parameters were monitored during each sampling event:

Field monitoring

- Conductivity
- Dissolved Oxygen
- pH
- Transparency
- Water Temperature

Lab analyses

- Chloride
- Chlorophyll *a*
- *E. coli* bacteria
- Nitrate and Nitrite nitrogen
- Total Kjeldahl Nitrogen
- Total Phosphorus
- Dissolved Phosphorus
- Total Suspended Solids

The results from each monitoring parameter (excluding pH, nitrite nitrogen, total kjeldahl nitrogen) will be discussed in the following section of this report.

Conductivity

Conductivity is a measure of water's ability to conduct an electrical current; it increases as the number of dissolved ions increases. There is no approved standard for conductivity and interpreting data can be complicated. Conductivity can vary widely in natural systems based on geology, temperature, climate, and groundwater influence. In dry years, less precipitation is available to dilute ions and more evaporation leaves dissolved ions behind. Additionally, biological processes such as nitrification and photosynthesis change the concentration of dissolved species of nitrogen and bicarbonate (Ort, 2008).

Anthropogenic effects such as road salt application can affect stream conductivity when these pollutants are washed into the stream during snowmelt. Furthermore, conductivity tends to be higher downstream of wastewater treatment plants (WWTPs).

In 2020, baseflow conductivity is higher than conductivity measurements collected during runoff events at all sites (Figure 6). Groundwater tends to have more dissolved ions from geologic sources and rainwater tends to have lower conductivity. Additionally, fields are often irrigated with groundwater during dry conditions. This high conductivity water then enters surface water through shallow groundwater discharge.

There do not appear to be major differences between stations with regards to specific conductance in 2020; median levels appear to be about the same throughout the watershed during baseflow and runoff conditions. Conductivity concentrations following snowmelt events show increased variability at SC806, NC801, and NC808 – the more urban tributaries in the watershed.

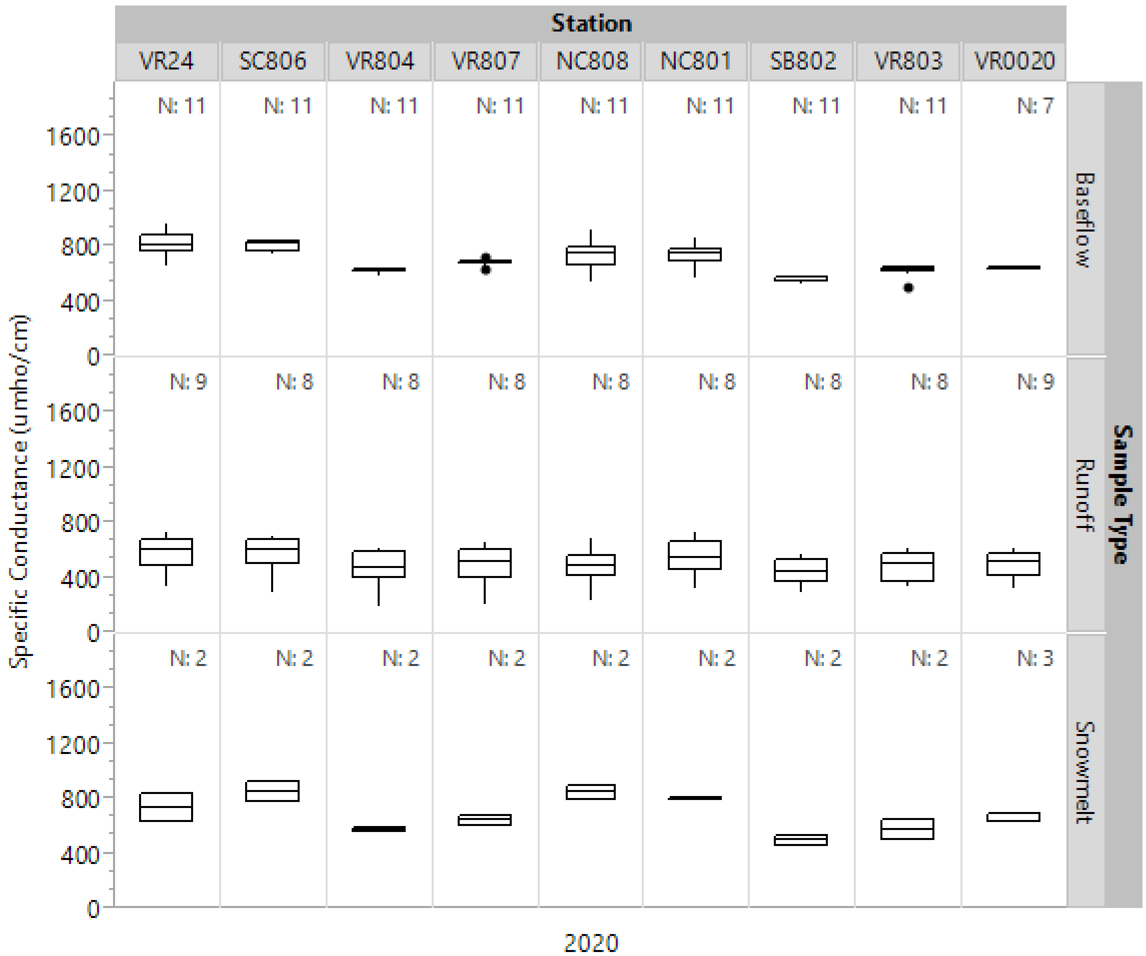


Figure 6. Specific conductance for each station, categorized by sample type, for 2020.

A few sites show baseflow conductivity increasing until about 2007, then leveling off or decreasing. MN DNR water use data shows that irrigation in the state increased through the 1990s and 2000s, peaking in 2007 (Figure 7). Since then, irrigation activities have decreased. Dakota County showed a similar pattern to the state water use data. Specific conductivity appears to be rising in the North Creek subwatershed, and may be related to residential irrigation, although further investigation is needed to determine the cause.

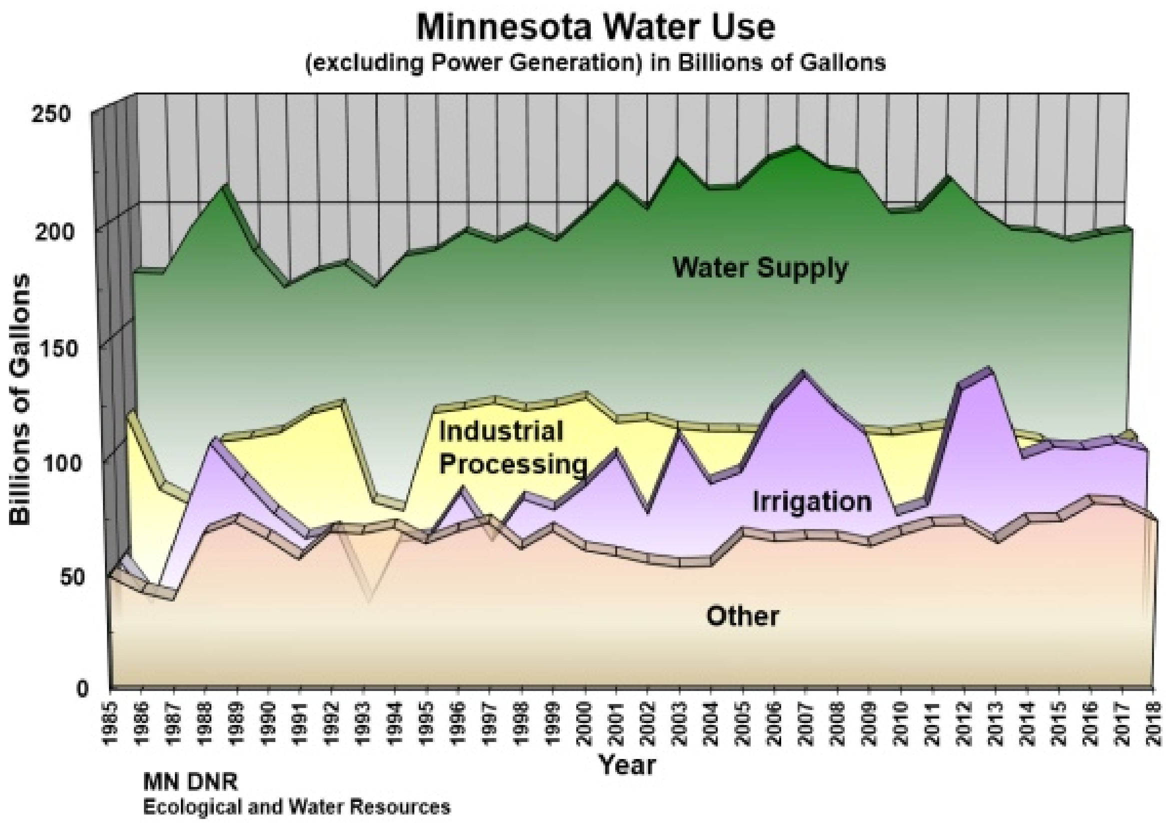


Figure 7. MNDNR Water Use - Water Appropriations Permit Program.
(http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html)

Historically, VR24 has much higher conductivity values compared to other stations in the network (take note of scale, Figures 9a-i). Conductivity tends to be higher downstream of WWTPs; a pattern that can be seen at VR24 and VR803 until the mid-2000s (Ort, 2008). Following the WWTP upstream of VR24 being redirected to the Empire WWTP in 2012, a decrease in conductivity has been observed and is expected to continue to decrease in the future. Additionally, a portion of the land use upstream of VR24 is sod farming, where the land is drained via tile and ditches as well as irrigated with groundwater, which may have contributed to elevated conductivity values. After the Empire WWTP was rerouted to the Mississippi River, the conductivity measured at VR803 showed a noticeable decrease in both the baseflow and runoff values.

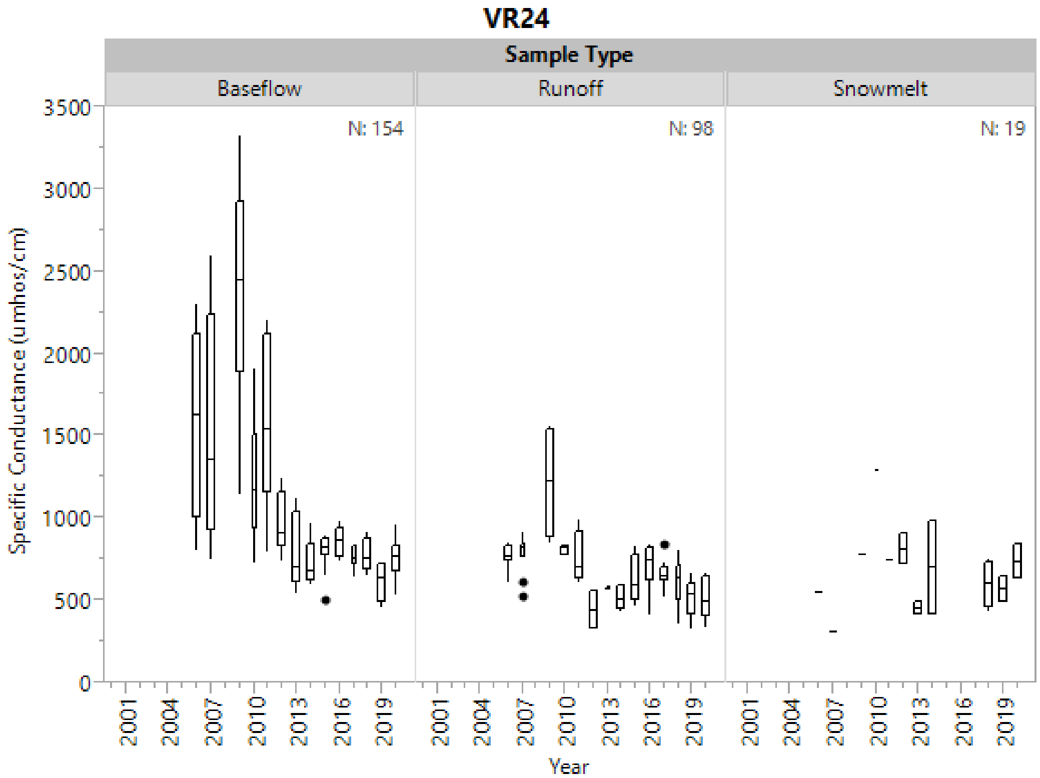


Figure 8a. Historical specific conductance by sample type at VR24.
**Note the scale difference between VR24 and other monitoring sites.

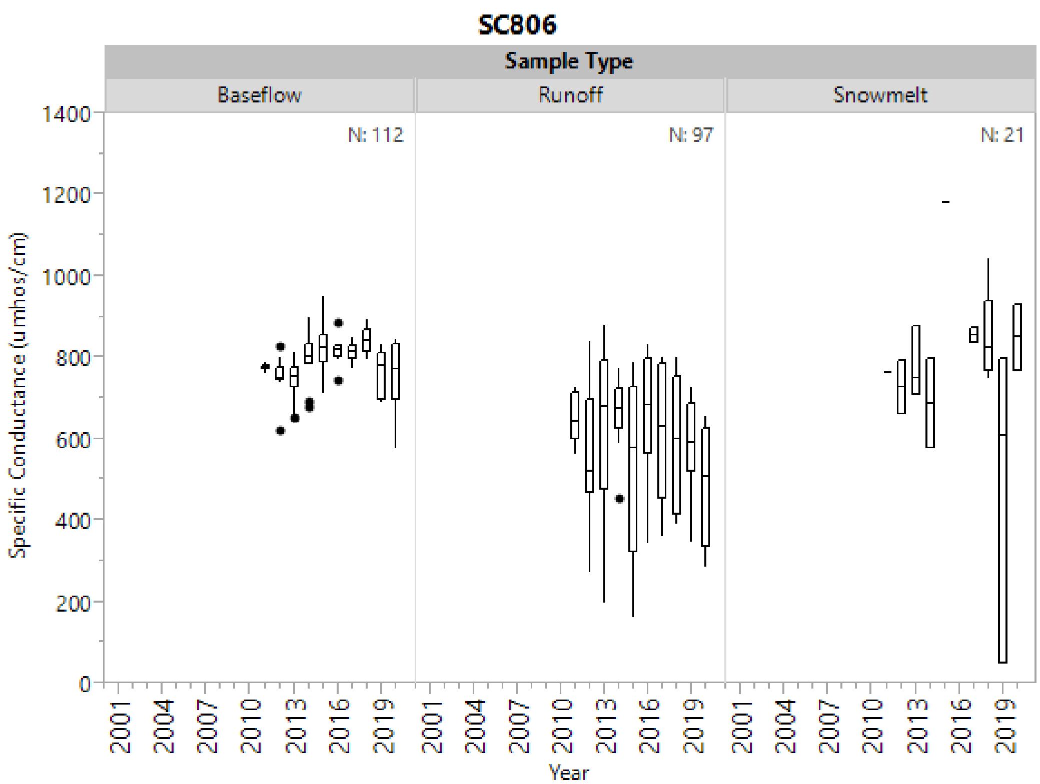


Figure 8b. Historical specific conductance by sample type at SC806.

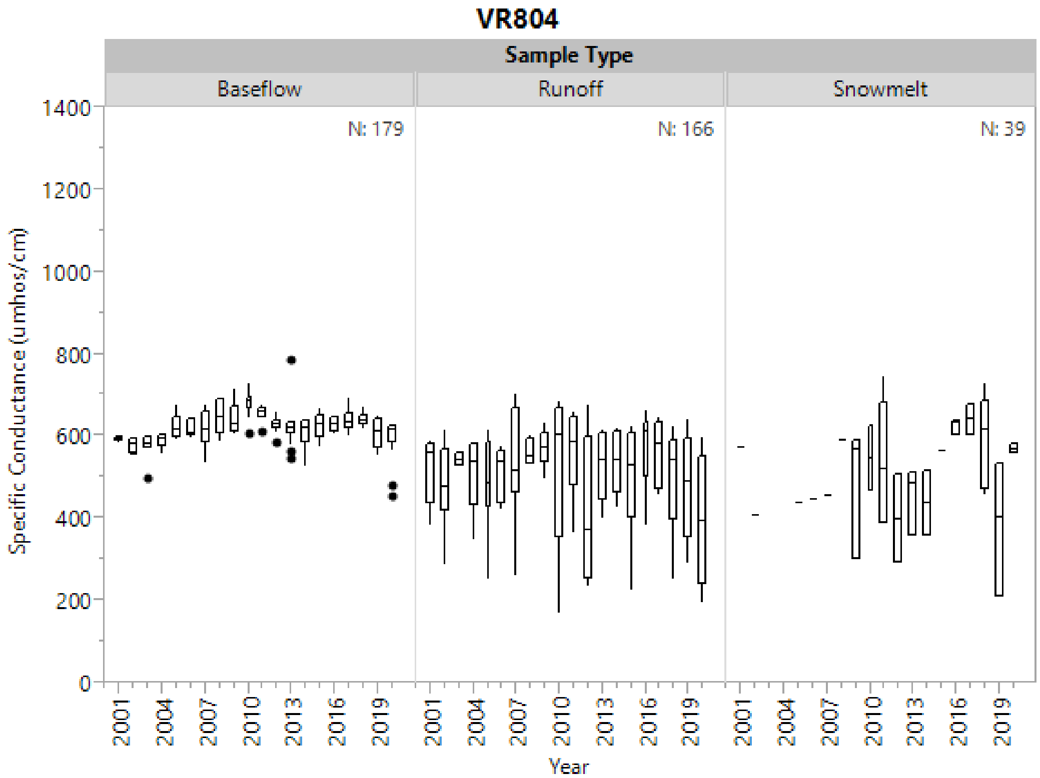


Figure 8c. Historical specific conductance by sample type at VR804.

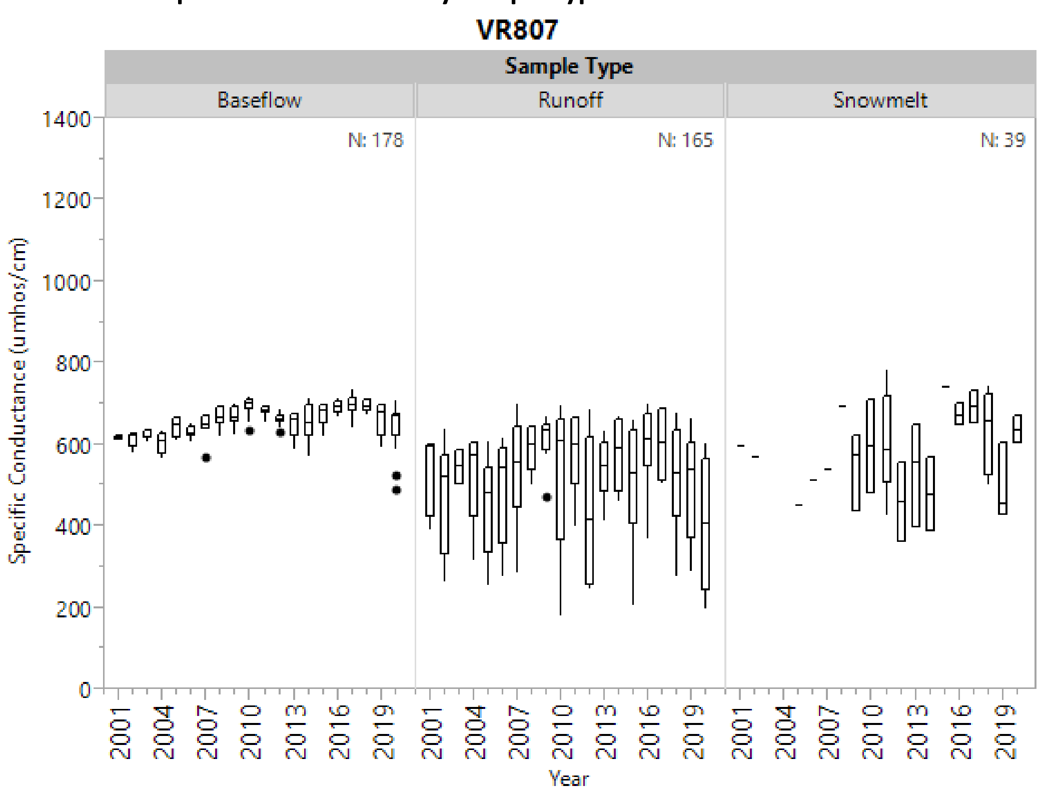


Figure 8d. Historical specific conductance by sample type at VR807.

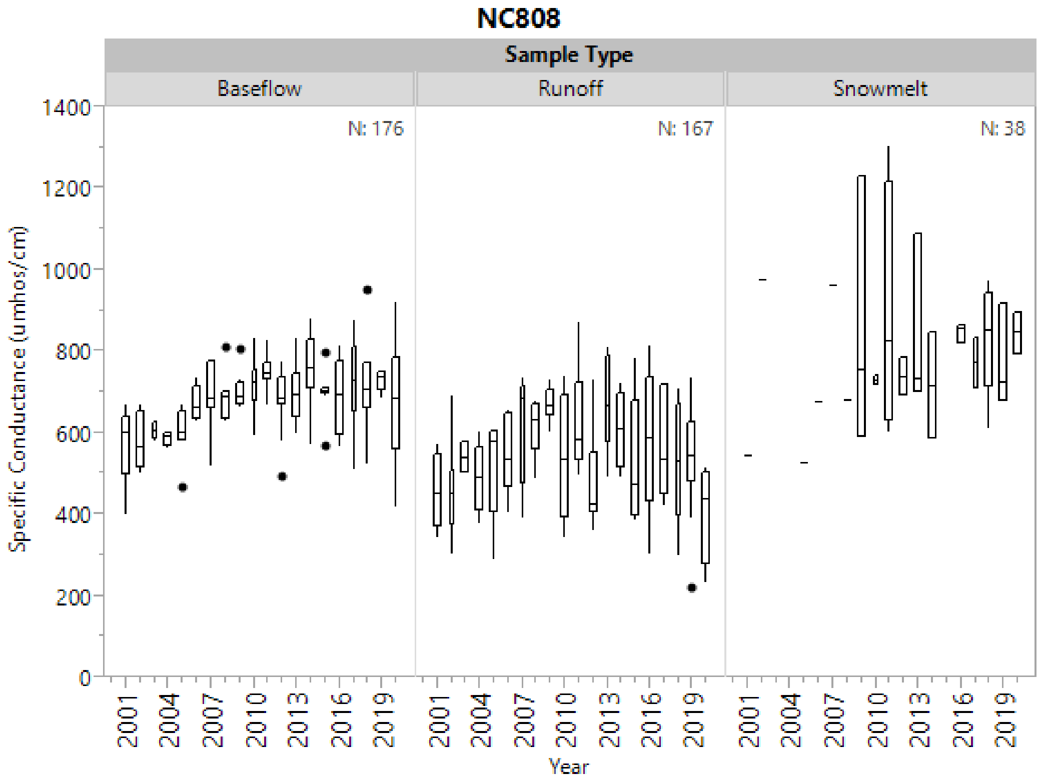


Figure 8e. Historical specific conductance by sample type at NC808.

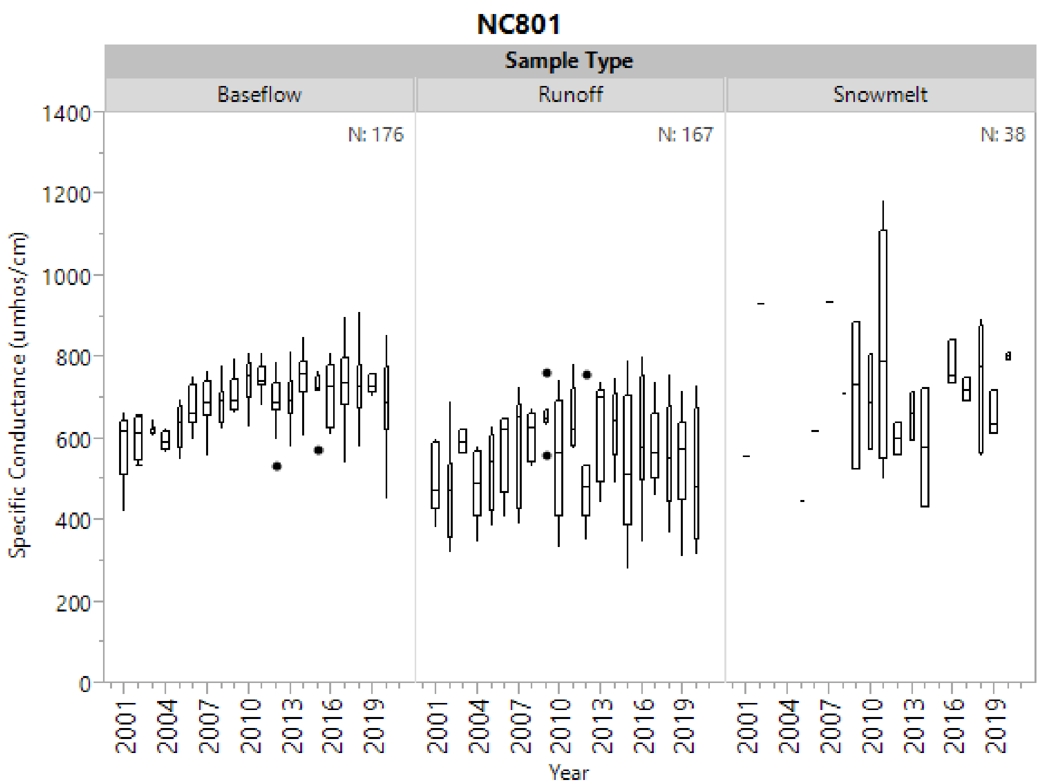


Figure 8f. Historical specific conductance by sample type at NC801.

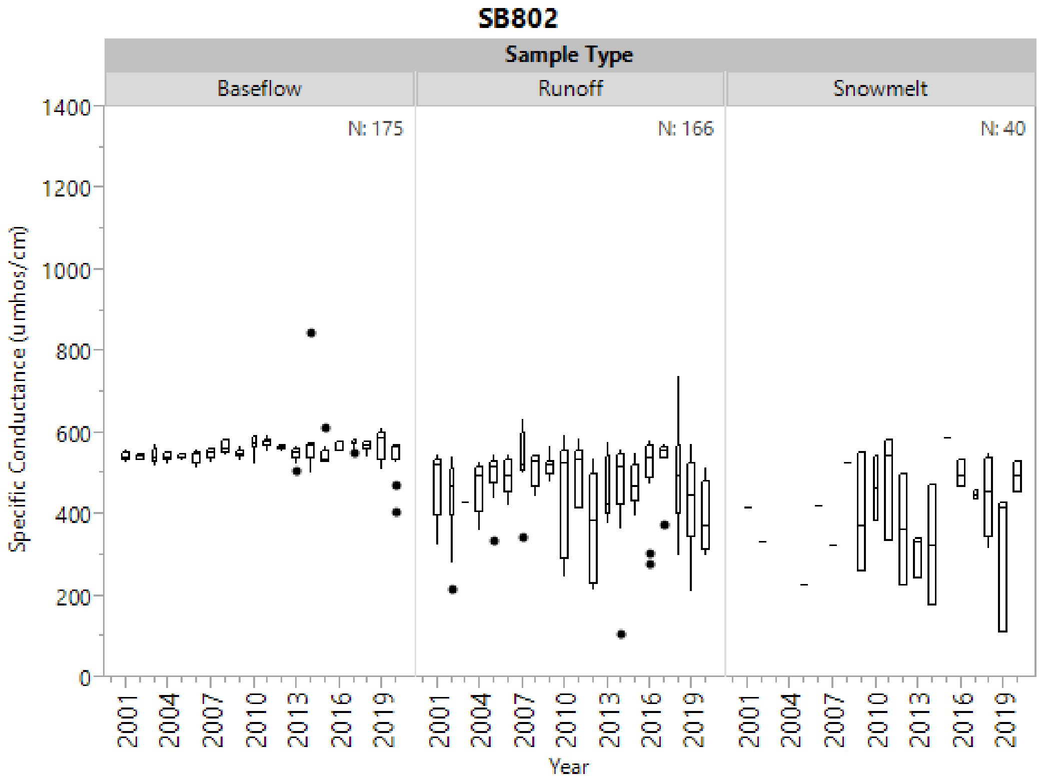


Figure 8g. Historical specific conductance by sample type at SB802.

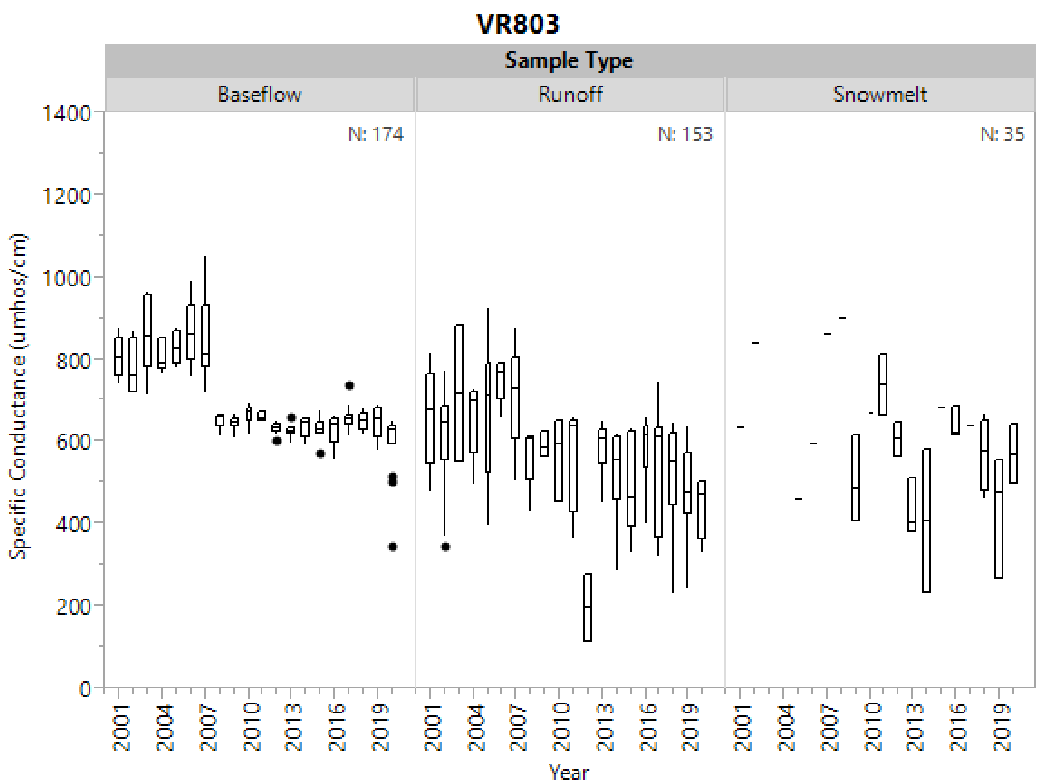


Figure 8h. Historical specific conductance by sample type at VR803.

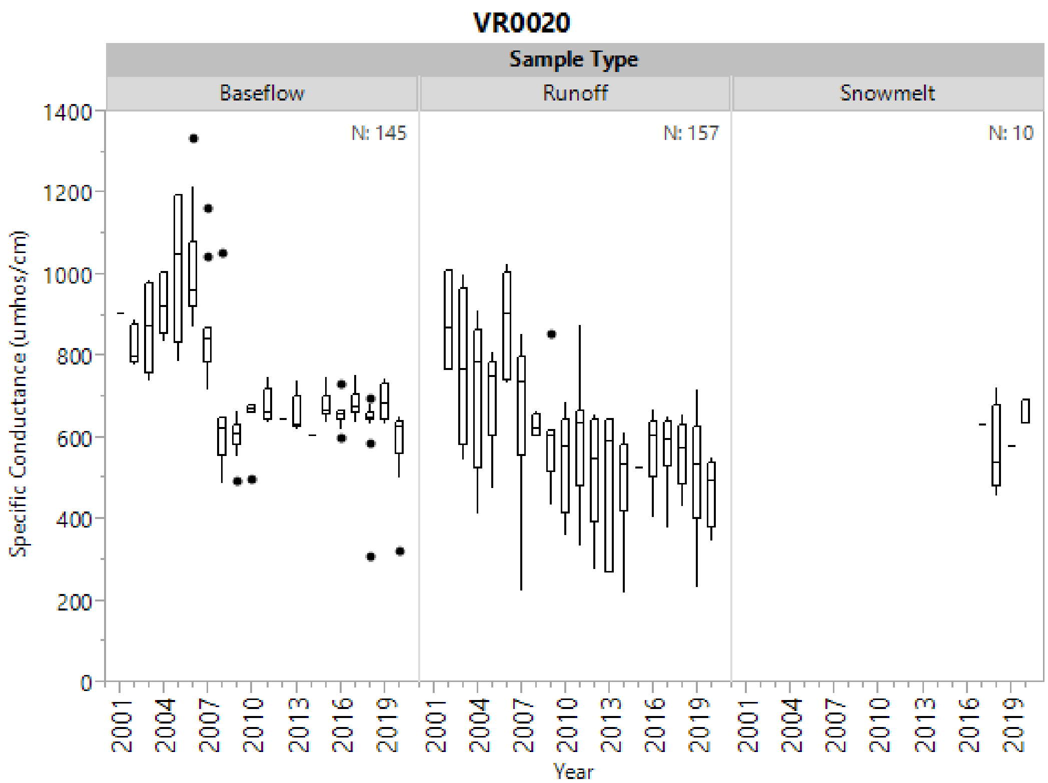


Figure 8i. Historical specific conductance by sample type at VR0020.

Dissolved Oxygen

Dissolved oxygen can fluctuate throughout the course of the day as a result of photosynthesis, respiration, biochemical and sediment oxygen demand, redox reactions, and re-aeration and degassing. In order to be listed as impaired by the MPCA for dissolved oxygen, there are several criteria that must be met; one of them being that the standard must be met prior to 9:00 a.m., after respiration has been occurring all night and photosynthetic organisms have not yet had a chance to replenish the dissolved oxygen concentration in the water column. The data presented here include all dissolved oxygen measurements without regard to time of day. Since many of these dissolved oxygen measurements occurred after 9:00 a.m., the results could be higher than if measurements had occurred prior to 9:00 a.m. on that same day.

A thorough analysis of dissolved oxygen in the Vermillion River Watershed was conducted during the MPCA's Watershed Restoration and Protection Strategies (WRAPS) project. Documents associated with the project, including the dissolved oxygen analysis found in the Stressor Identification Report can be found at https://www.pca.state.mn.us/water/tmdl/vermillion-river-watershed-restoration-and-protection-strategy-–-multiple-impairments.

In 2020, the median dissolved oxygen concentration was above the lower limit for warm water (2B) streams (5.0 mg/L as daily minimum) and cold water (2A) streams (7.0 mg/L as daily minimum) during baseflow conditions (dashed blue lines; Figure 9). Like in previous years, the North and South Creek sites were closer to the threshold than other monitoring sites. Median concentrations for runoff samples at seven of the nine reaches were above the threshold; median concentrations at NC808 and NC801 were below the standard threshold (SC806 was right at the threshold). Lower dissolved oxygen levels during or following runoff events could be the result of warmer water that is less capable of holding dissolved oxygen, flux of organic material which increases the biochemical oxygen demand, and/or flushing of warm ponded water or water draining directly from warm impervious surfaces from upstream. Snowmelt samples had relatively high dissolved oxygen medians at all stations. This is expected because the time of year is characterized by very cold water and minor biochemical oxygen demand.

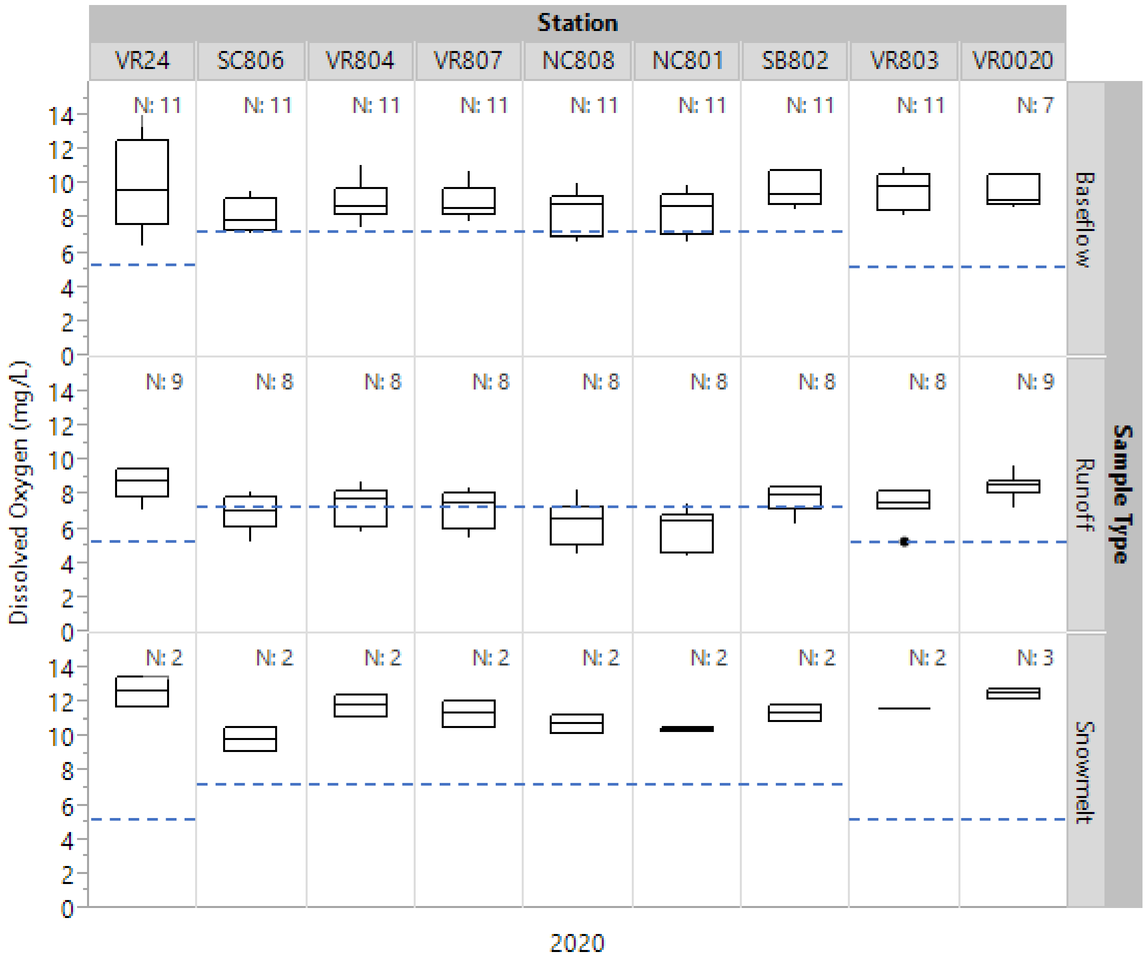


Figure 9. Dissolved oxygen for each station, categorized by sample type, for 2020.

Only a few sites (SC806, VR807, NC808, and NC801) had dissolved oxygen medians for baseflow samples that violated the standard during at least one year in the historical record (Figures 10a-i). Dashed blue lines indicate standards with 7.0 mg/L (2A streams; Figures 10b – g) and 5.0 mg/L (2B streams; Figures 10a, 10h, and 10i) as acceptable daily minimums.

Most of the samples collected in 2020 were performed under baseflow conditions with no medians below the standard. Some readings were below the standard and those are show as outliers stretching out from the box plot. Only VR24, VR803, and VR0020 have readings consistently above the warm water standard.

Samples collected in late May and early June and in late June/early July were collected during runoff events. Runoff events, usually bring warmer water and organic pollutants to the stream, resulting in some of the lowest dissolved oxygen annual medians monitored within the watershed. The three monitoring sites in warm water reaches, VR24, VR803, and VR0020, have a lower minimum dissolved oxygen threshold than the other sites. None of these three had a dissolved oxygen median that fell below the minimum acceptable value in any year with monitoring data. Snowmelt sample medians for dissolved oxygen were above (not violating) the standard at all stations in all years and 2020 samples are in line with historical sampling results.

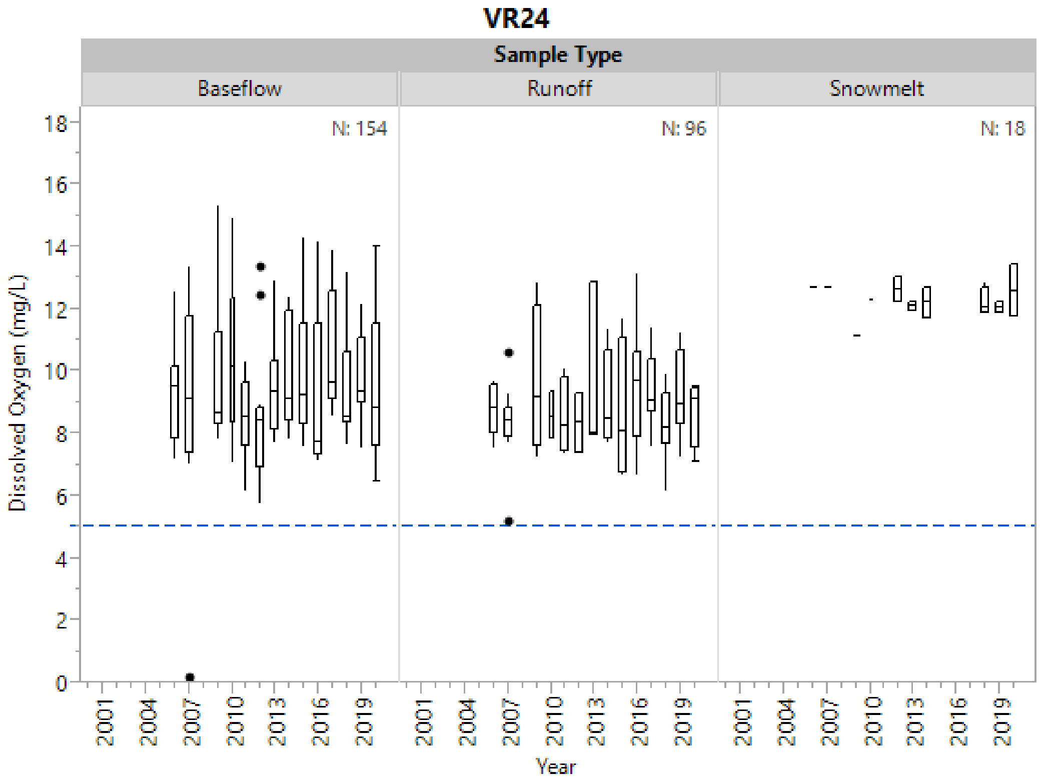


Figure 10a. Historical dissolved oxygen by sample type at VR24.

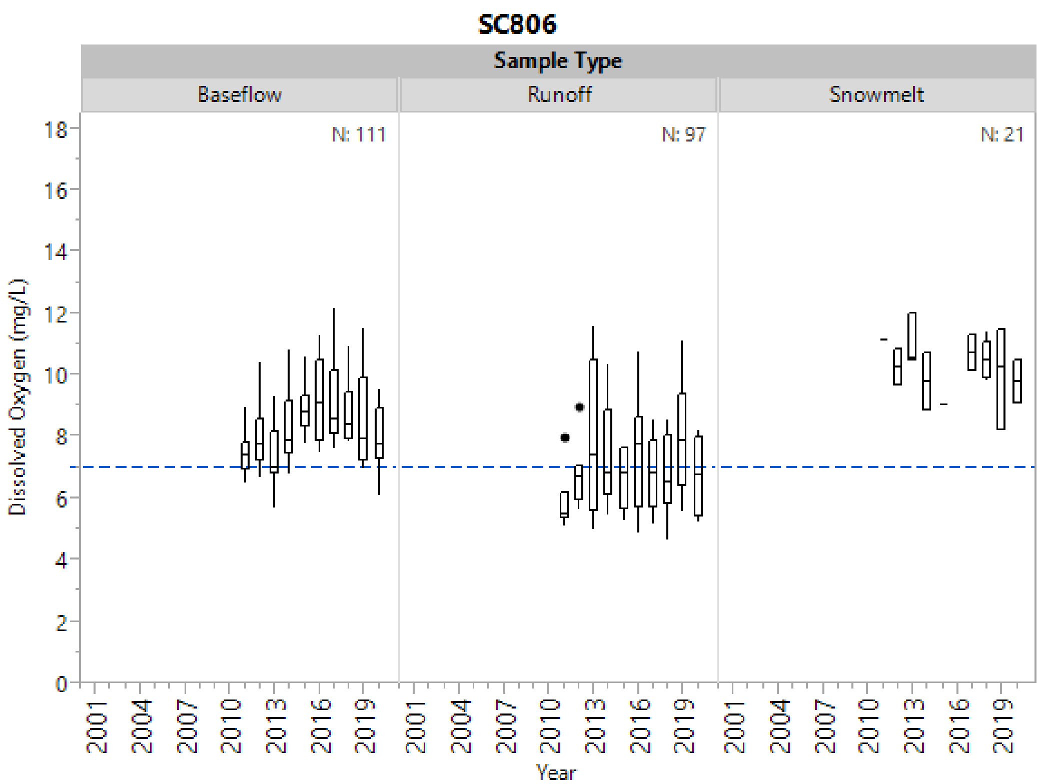


Figure 10b. Historical dissolved oxygen by sample type at SC806.

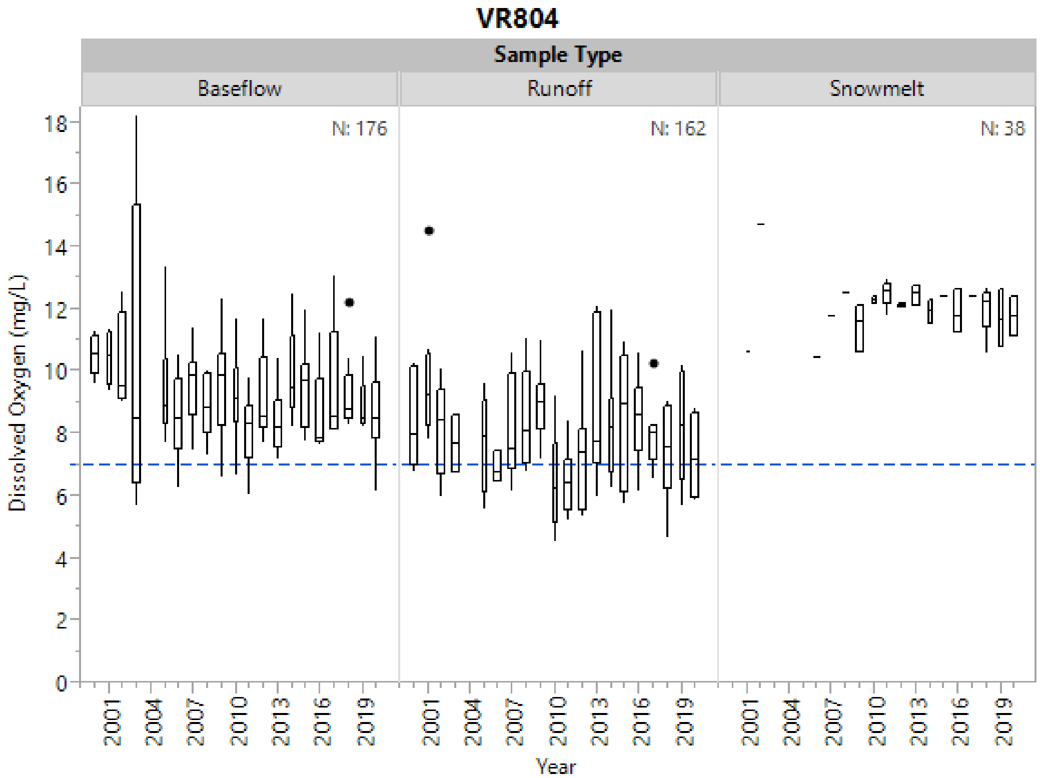


Figure 10c. Historical dissolved oxygen by sample type at VR804.

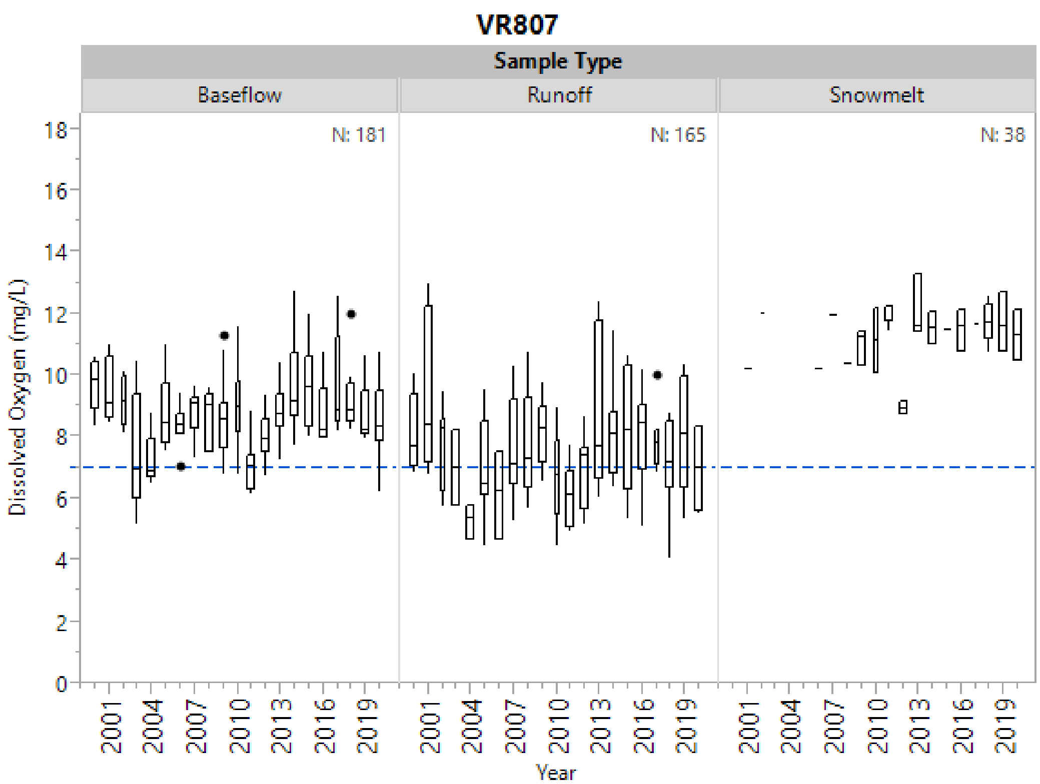


Figure 10d. Historical dissolved oxygen by sample type at VR807.

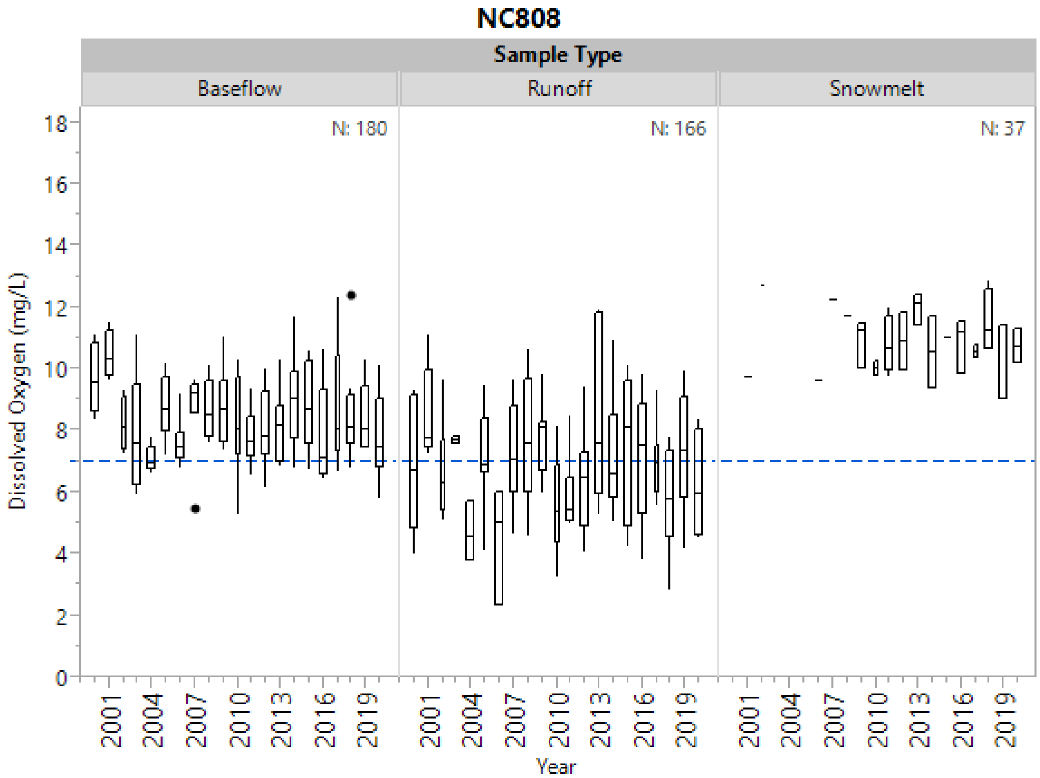


Figure 10e. Historical dissolved oxygen by sample type at NC808.

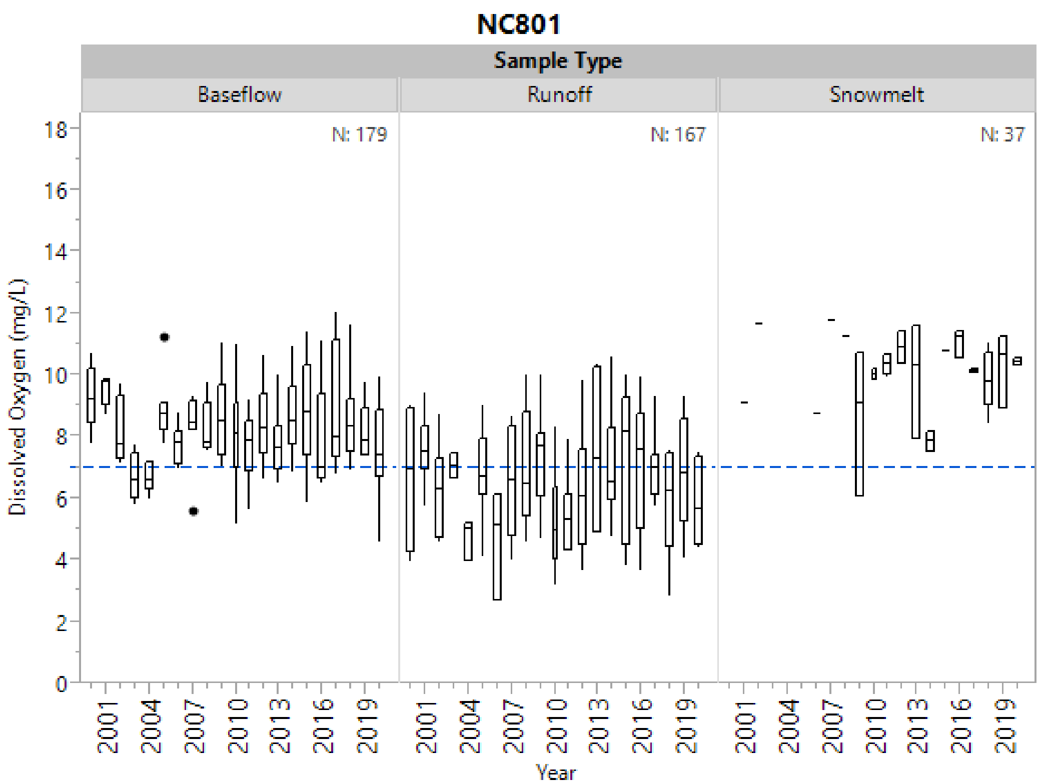


Figure 10f. Historical dissolved oxygen by sample type at NC801.

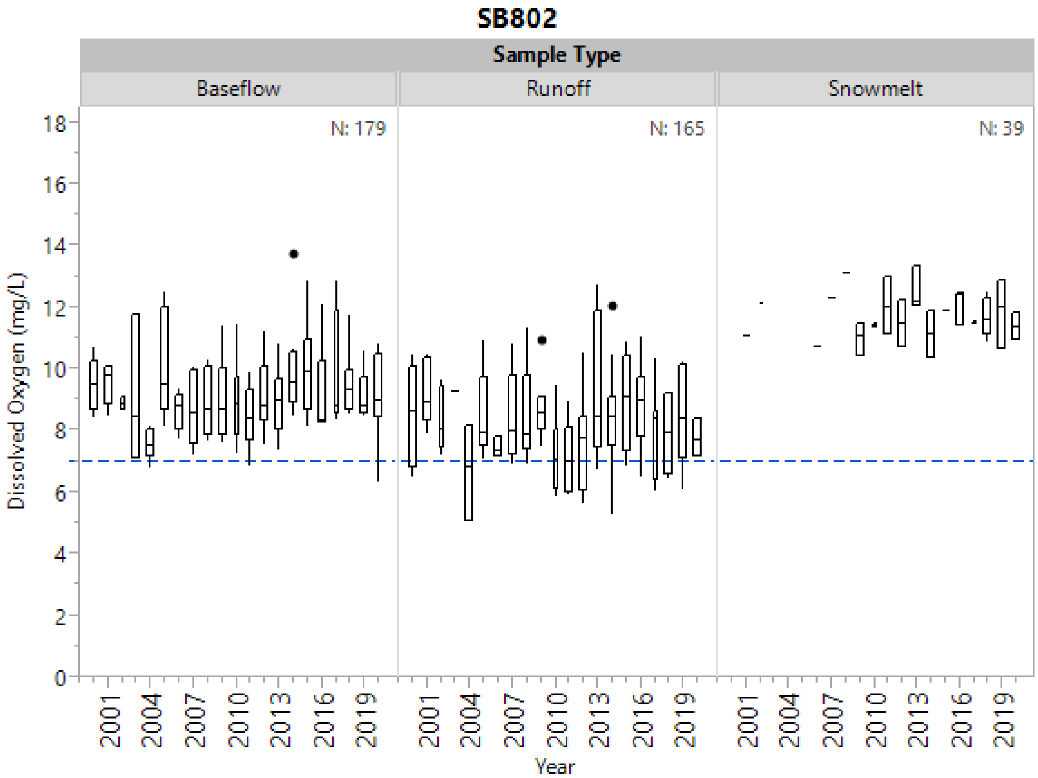


Figure 10g. Historical dissolved oxygen by sample type at SB802.

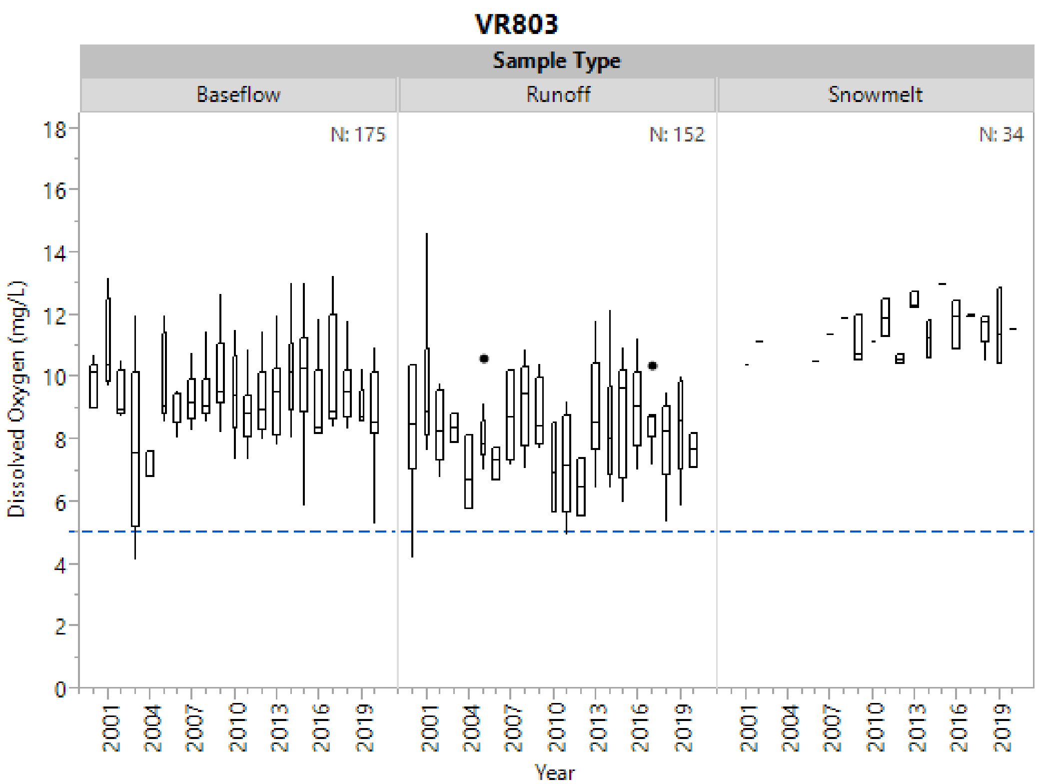


Figure 10h. Historical dissolved oxygen by sample type at VR803.

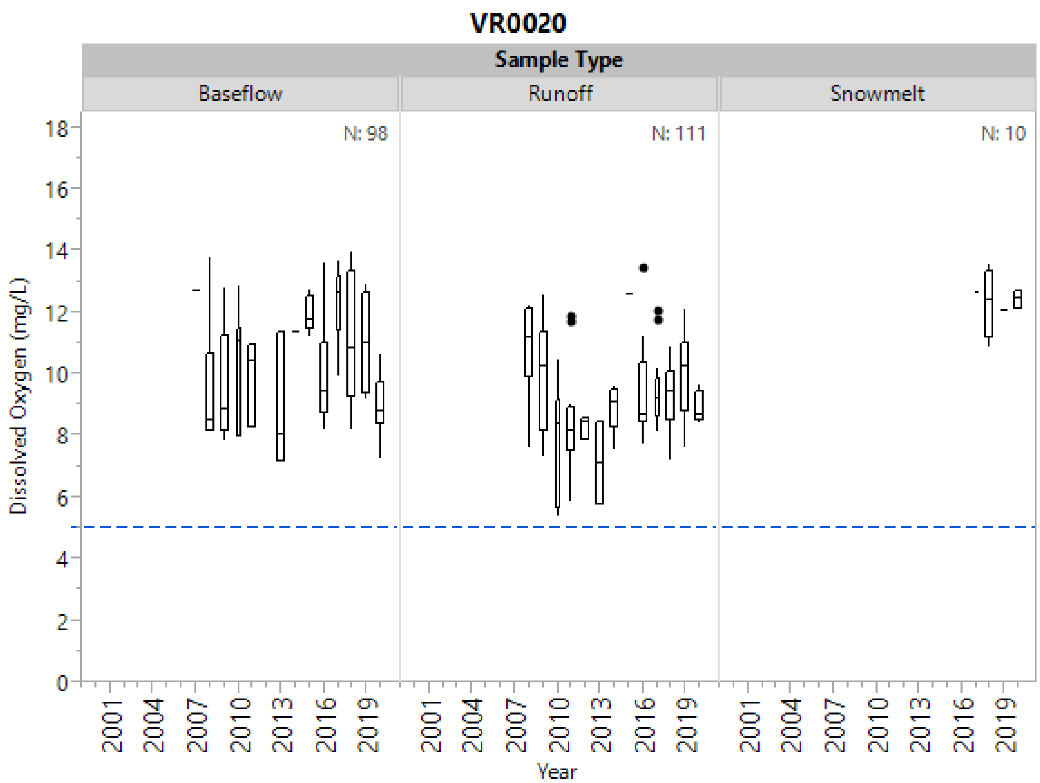


Figure 10i. Historical dissolved oxygen by sample type at VR0020.

Chloride

Chloride concentrations are increasing in Minnesota's surface waters and groundwater. Recent data has found that over fifty lakes or rivers currently exceed the 230 mg/L chronic aquatic life standard and are thus classified as impaired for aquatic life according to the MPCA's 2022 303(d) List of Impaired Waters (MPCA 2022). High chloride levels are toxic to fish, aquatic bugs, and vegetation, negatively impacting their overall health, community structure, and diversity. Common sources of chloride include de-icing salt, water softening, dust suppressant, fertilizer, and manure. Once in the water, there is no easy way to remove the chloride.

Urban lakes and rivers are at highest risk to elevated chloride levels because of the high percentages of impervious surface and abundant use of de-icing salt during the winter months. As urbanization increases in Dakota County, it is expected that chloride related water quality standards exceedances will also increase (Corsi et al. 2015). A study by the University of Minnesota found that about 78% of salt applied in the Twin Cities metro area for winter maintenance is either transported to groundwater or remains in the local lakes and wetlands (Stefan et al. 2008).

Increased salinization of groundwater is problematic for two-fold reasons: groundwater provides > 90% of Dakota County residents, and due to the surface water/groundwater interface, groundwater can easily contribute to increased chloride levels in surface waters.

The VRWJPO began monitoring chloride in 2020 at all monitoring locations (Figure 11). Sampling occurred most often during runoff conditions, but a few samples were collected during baseflow. According to the MPCA, a stream, lake, or wetland is impaired for chloride if two or more samples exceed 230 mg/L within a three-year period; or, one sample exceeds 860 mg/L. At this time, no samples exceeded the chronic standard.

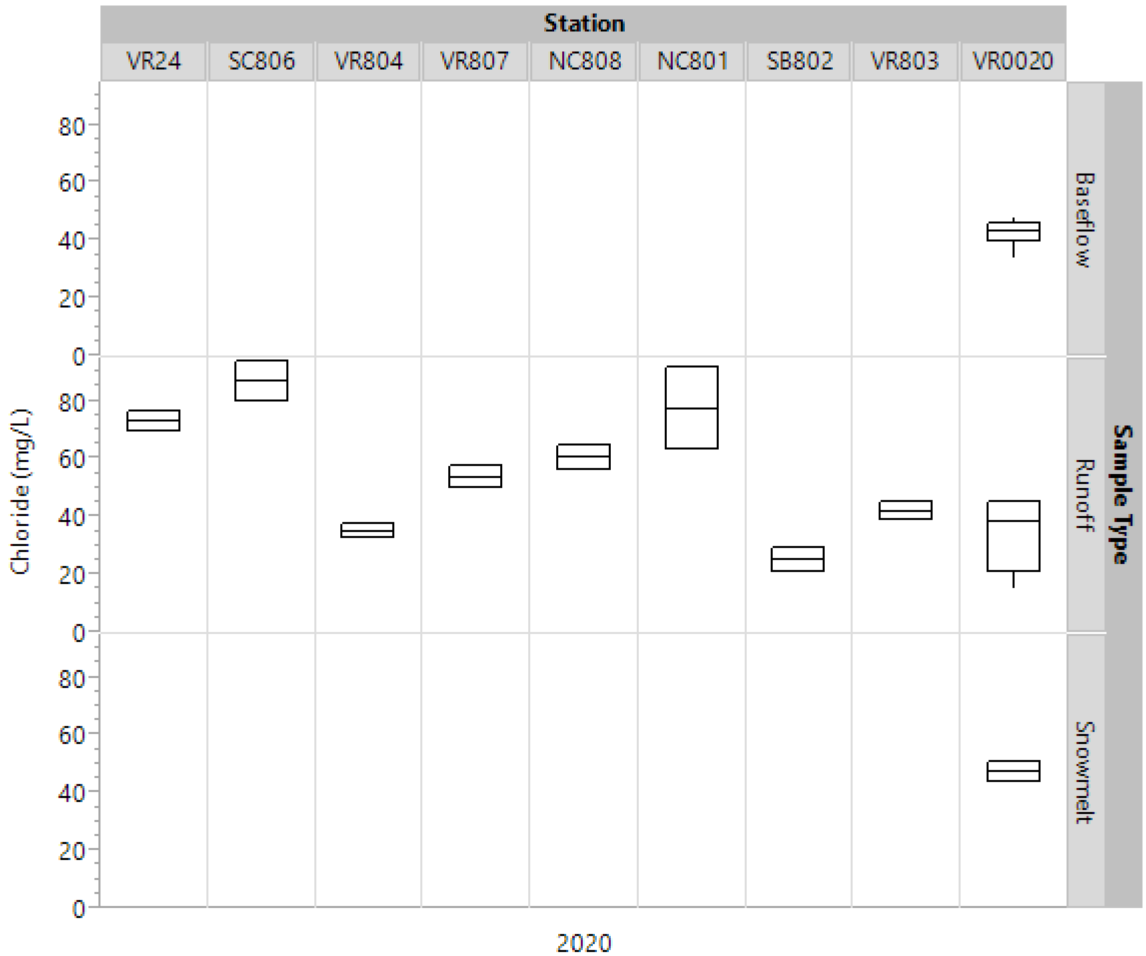


Figure 11. Chloride for each station for 2020.

Chlorophyll *a*

Chlorophyll allows plants, including algae, to photosynthesize (use sunlight to convert simple molecules into organic compounds). Chlorophyll *a* is the predominant type of chlorophyll found in green plants and algae and allows them to photosynthesize (use sunlight to convert simple molecules into organic compounds).

Waters with high levels of nutrients (nitrogen or phosphorus) from anthropogenic sources such as fertilizers, septic systems, sewage treatment plants and urban runoff, may have high concentrations of chlorophyll *a* and excess amounts of algae. One possible sign of degraded water quality is an increase of algae biomass, something that can easily be measured by monitoring for chlorophyll *a* as it serves as an indirect indicator of nutrient levels in a lake or river (high chlorophyll = high nutrients).

Chlorophyll *a* was added to the VRWJPO monitoring program in 2019 (added to VR24 in 2021) considering updated guidance from the MPCA in which chlorophyll *a* is now included as a response variable in the water quality impairment assessment strategy.

In 2019 and 2020, the sample median for all sites was below the state standard of ≤ 35 mg/L during all monitoring efforts (Figure 12). Some individual sampling events exceeded the standard during runoff conditions.

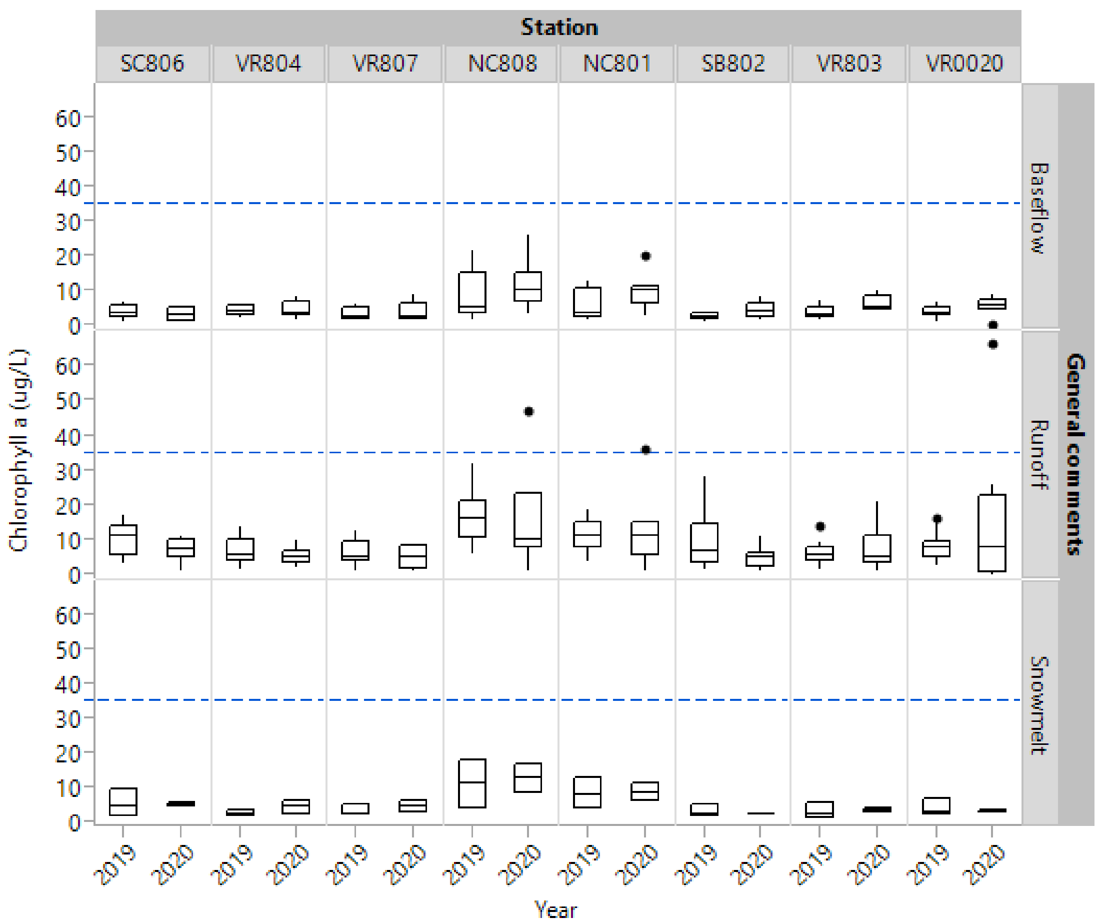


Figure 12. Chlorophyll *a* for each station during all sample types for 2019 and 2020.

Escherichia coli (E. coli) Bacteria

Although not necessarily pathogenic itself, *Escherichia coli* (*E. coli)* bacteria is a good indicator that disease-causing pathogens may be present in water. Elevated *E. coli* bacteria levels often occur following runoff events and are primarily indicative of septic system discharge, agricultural runoff, livestock wading and/or defecating in streams, urban runoff, and resuspension of bacteria in the sediment. Standards were developed to protect water sources for recreational use so humans and animals could wade with a diminished risk of becoming ill.

A standard of ≤126 MPN/100mL has been established (MPN stands for most probable number of organisms). This value is calculated as a geometric mean of not less than five samples representative of conditions within any calendar month. Additionally, no more than ten percent of all samples taken during any calendar month shall individually exceed 1,260 MPN/100mL. This standard applies only between April 1 and October 31, to coincide with the stream wading season.

In 2006, the Vermillion River was added to the 303(d) Impaired Waters List for bacteria – a pollution problem typical of the southeast region of the state. From 2001 to 2007, fecal coliform data were routinely collected to evaluate bacteria pollution. In anticipation of a rule change whereby *E. coli* bacteria would be the bacteria type for which a standard would be based, *E. coli* bacteria sample collection began in 2007. A conversion of 200 to 126 can be used to convert fecal coliform data to comparable *E. coli* values; however, a review by the MPCA revealed that there is a lot of variability when this conversion factor is used depending on stream location and lab analysis method. Additionally, sufficient *E. coli* data has been collected from the sites in the VRMN, so converting fecal coliform data would not be necessary for the purposes of evaluation through the Impaired Waters assessment process.

Data summarized in Figure 13 do not conform to the sampling protocol outlined in Minnesota Rule 7050.0222 because typically fewer than five samples were collected during a 30-day period; however, the annual geometric mean shown helps to quickly illustrate the status and trends of *E. coli* bacteria at each of the monitoring stations over time. Furthermore, Table 5 shows the frequency with which the individual sample standard of ≤1260 organisms/100mL was violated. Before making conclusions regarding year-to-year variability, weather patterns should be considered. The total annual precipitation for each year is also shown in Figure 13. A gray dotted line is drawn at 31.7 inches to indicate the 30 year (1990-2019) average total precipitation at the Minneapolis – St. Paul airport weather station.

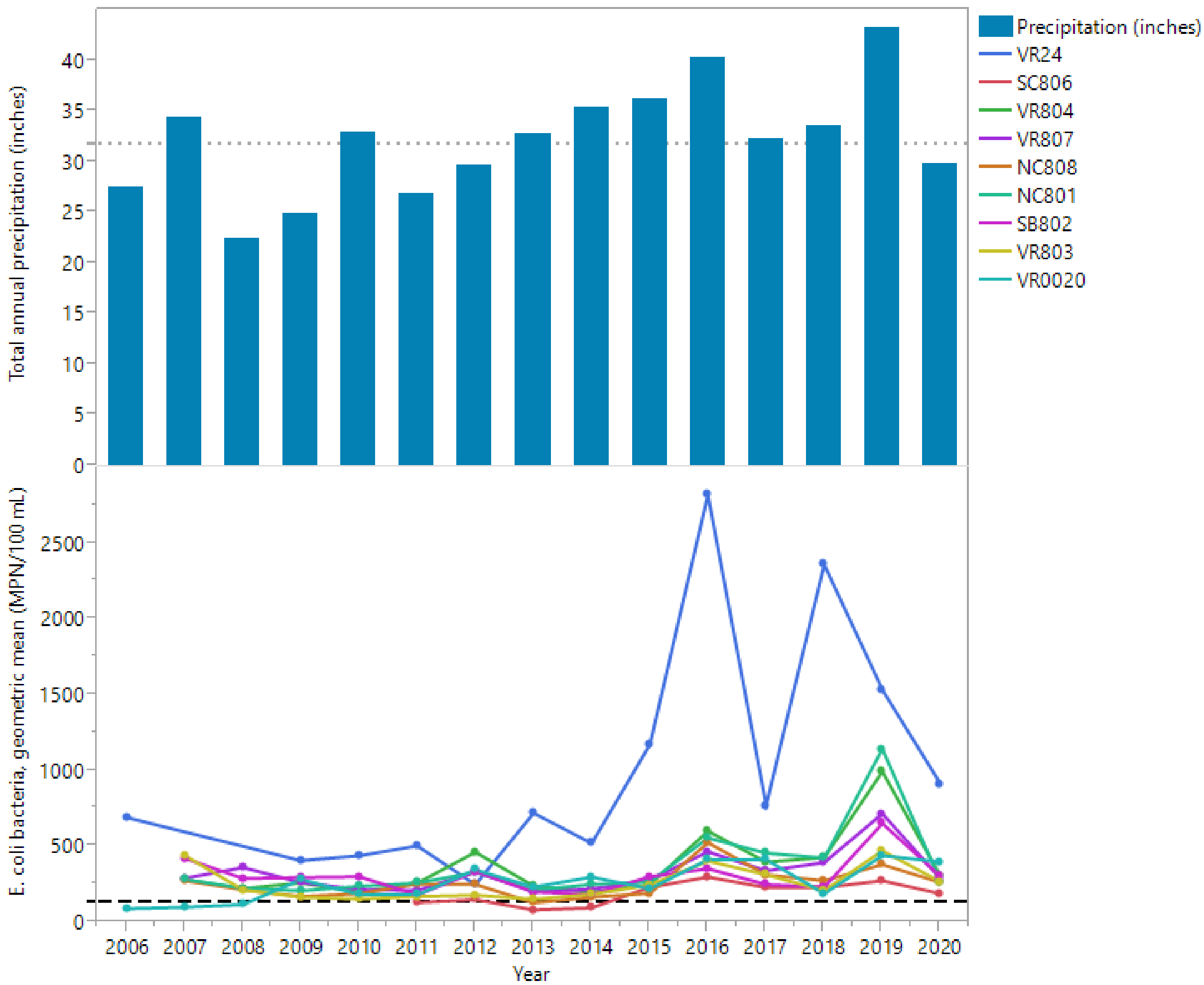


Figure 13. Annual geometric mean of Escherichia coli (E. coli) bacteria for all stations by year. MPN stands for most probable number of organisms. Black dashed line indicates the 30-day geometric mean standard (for data collected April through October) of ≤126 MPN/100 mL. Bars represent total annual precipitation for each year. Gray dotted line indicates the 30 year (1990-2019) total annual average precipitation at the Minneapolis – St. Paul airport weather station of 31.7 inches.

The annual *E. coli* geometric mean for each monitoring site violated the ≤126 organisms/100mL standard during most years at most monitoring stations with the exception of the following: SC806 (2011, 2013, 2014), VR803 (2010), and VR0020 (2006, 2007, 2008). During the aforementioned years, these three sites had annual geometric mean values below the standard. Since 2015, all sites have had geometric means that exceeded the state standard for *E. coli.*

Throughout the monitoring season, the individual sample standard was violated on several occasions at all sites within the watershed (Table 5). Exceedances ranged from one or two times the individual sample standard to 1,535 times the sample standard (193500 MPN/100mL) at VR24 in late October. All other monitoring sites had their highest *E. coli* levels in May and June.

Table 5. The number of samples which violate the E. coli standard of ≤1260 MPN/100 mL followed by the total sample size (shown in parentheses) for each station each year. -- indicates no data.

Year	Station								
	VR24	SC806	VR804	VR807	NC808	NC801	SB802	VR803	VR0020
2006	4 (11)	--	--	--	--	--	--	--	4 (6)
2007	--	--	3 (13)	2 (13)	2 (13)	3 (13)	4 (13)	5 (13)	0 (1)
2008	--	--	2 (11)	3 (11)	2 (11)	2 (11)	3 (11)	2 (11)	0 (12)
2009	6 (15)	--	1 (20)	1 (20)	0 (20)	1 (19)	2 (20)	1 (16)	2 (15)
2010	4 (15)	--	3 (19)	3 (20)	3 (20)	3 (20)	3 (20)	1 (15)	3 (14)
2011	3 (15)	2 (24)	1 (16)	1 (16)	2 (16)	2 (16)	2 (18)	2 (15)	1 (13)
2012	1 (15)	4 (20)	3 (20)	4 (20)	4 (20)	6 (20)	5 (20)	2 (15)	5 (14)
2013	6 (18)	2 (21)	3 (21)	3 (21)	2 (20)	3 (21)	3 (21)	2 (21)	1 (13)
2014	6 (16)	1 (20)	2 (21)	2 (21)	2 (20)	4 (21)	2 (21)	3 (21)	5 (13)
2015	9 (17)	2 (19)	3 (19)	2 (19)	3 (19)	2 (19)	3 (19)	3 (19)	1 (7)
2016	12 (18)	7 (23)	9 (23)	9 (23)	7 (23)	8 (23)	6 (23)	7 (23)	5 (21)
2017	7 (22)	5 (26)	6 (26)	6 (26)	4 (26)	7 (26)	3 (26)	4 (26)	7 (26)
2018	14 (22)	3 (23)	6 (23)	5 (23)	7 (23)	8 (23)	6 (23)	4 (23)	6 (24)
2019	24 (24)	18 (23)	21 (23)	19 (23)	16 (23)	19 (23)	19 (23)	18 (23)	19 (26)
2020	17 (22)	14 (21)	25 (21)	16 (21)	14 (20)	16 (21)	15 (21)	15 (21)	15 (19)

Station VR24 continues to have *E. coli* levels that are considerably higher than other stations in the network, violating the single sample standard in three-fourths of samples collected in 2020. Even after the WWTP effluent was diverted (in 2012), *E. coli* bacteria values continue to rise, indicating that the plant was likely a much smaller or non-contributing source of bacteria.

In 2016, under the directive of the VRWJPO, staff from SSWCD began an assessment of watercourses upstream of VR24 in order to determine the source of the elevated *E. coli* levels measured at VR24. Water samples were collected at three sites (in addition to VR24) and were tested for environmental DNA (eDNA), which indicates the presence of semi-specific or specific sources of DNA present in each sample. Multiple eDNA analyses exist, but each analysis come with significant costs, which required staff's best professional judgment and prioritization on which analyses to use.

Based on the surrounding land use and environmental conditions within the area of interest, human and cattle were assumed to be the most probable sources of eDNA. VRWJPO and SSWCD staff considered other potential sources of *E. coli* (e.g. birds, waterfowl, horses, deer) that could be assessed with the eDNA samples, and determined they were not likely to contribute the high concentrations of *E. coli* found in the samples to date, nor could they contribute an equivalent quantity of fecal matter as human or cattle sources could contribute. Monitoring results were mixed so it was concluded that continued investigation was required to further evaluate the bacteria source to VR24.

In 2017, standard bacteria sampling continued at two-week intervals at VR24 beginning in July. Sampling for eDNA also occurred on a more limited basis at VR24 and other locations higher in the watershed to identify possible bacteria sources. The results indicated that *E. coli* bacteria levels were highest at VR24, and eDNA results indicated that human bacteria was present at VR24 and at all sites upstream, except for the most upstream location, where no human bacteria were found to be present. No cow bacteria were detected at any of the sites.

Based on the bacteria information collected in 2017, staff didn't believe additional eDNA sampling was warranted following the initial effort. In 2018, the SSWCD collected *E. coli* samples at VR24 and at an additional site upstream at DuPont Avenue (~0.30mi upstream of VR24). If samples at DuPont Avenue were still consistently high compared to VR24, additional *E. coli* samples at locations upstream of DuPont Avenue were collected.

In addition to collecting *E.coli* samples at the VR24 station during bi-weekly and event based monitoring, samples were also collected just upstream of the Dupont Avenue crossing. A total of 6 samples were collected at Dupont in 2019 and five samples in 2020. This monitoring was conducted to see if there was significant *E.coli* increases between the two stations. *E. coli* levels were consistent, rising together throughout the summer and into the fall, with VR24 higher than Dupont where there were differences.

Nitrogen

Nitrogen can be found in many forms and is constantly changing forms as a result of nitrogen fixation, nitrification, denitrification, and ammonification with the help of bacteria, assimilation by plants, and even lightning. The nitrogen cycle is of interest because of its role in ecosystem processes including primary production and decomposition, and some forms of N are indicative of specific pollution sources. In 2020, only two forms of nitrogen (nitrate and nitrite) were included in the suite of parameters that were monitored as part of the Vermillion River Monitoring Network strategy. The results from the nitrite analyses were not included in this report as nitrite concentrations found in the Vermillion River are often below the reporting limit for the lab analysis method (0.03 mg/L) indicating that nitrite levels are not a concern in the watershed.

Nitrate concentrations vary throughout the watershed and those results are discussed in the following section.

Nitrate

Waters that are used for domestic consumption (drinking water) have an approved nitrate standard not to exceed 10 mg/L. In Minnesota, cold water streams (2A streams) are protected as potential drinking water sources and are subject to the 10 mg/L standard. Human consumption of water with elevated nitrate could cause serious health problems because it reduces the oxygen-carrying capacity of red blood cells. This is particularly dangerous for infants. High nitrate can also be toxic to aquatic animals, although plants do not seem to be harmed.

Nitrate pollution of shallow groundwater is common among agriculturally dominated watersheds with coarse textured soils. Upon application to a field, the nitrogen not utilized by plants can leach into the ground and either move into nearby lakes, streams, and wells or be carried by tile drainage and/or ditches directly into a stream. This groundwater loading of nitrate results in higher levels during baseflow or low flow conditions and lower concentrations during high flow conditions when it is diluted by surface water runoff. According to research by Watkins et al. (2011), nitrate concentrations measured in Minnesota streams have a direct positive relationship with row crop land use. In other words, as acres of row crop land use increases, so does nitrate concentrations in surface waters.

Station SB802 has the highest median nitrate concentration, but sample medians for all sites are below the approved domestic consumption standard. The subwatershed that drains to SB802 is predominately agricultural land use, has course-textured soils, and a high-water table. The high-water table in this subwatershed is often artificially lowered via tile and ditches to make agricultural production more viable. The nitrate loading at SB802 contributes to elevated nitrate levels at downstream sites VR803 and VR0020. The soils and underlying geology near VR803 allow for the water in the Vermillion River to recharge underlying groundwater aquifers. The soils east of State Highway 52 are course textured, and nitrogen leaching from agricultural production in this area has led to groundwater contamination in private drinking water wells and the city of Hastings drinking water supply. The South Branch Vermillion River, and the nitrate it contains, further exacerbates the drinking water contamination problem in the eastern portion of the watershed.

The baseflow nitrate values measured at SB802 appear to be increasing in recent years and a Kendall's tau (T) test was performed to determine if the apparent trend is statistically significant. Most generally, Kendall's tau (T) test is a test to determine whether measured nitrate concentrations tend to increase, decrease, or stay the same over time. For the entire period of record, baseflow nitrate at station SB802 seems to be increasing (T=0.3465, P<0.0001), as shown in Figure 14. The strong tau value suggests that this trend is statistically significant. By analyzing baseflow samples, changes attributed to weather patterns and background conditions can be ruled out with some confidence.

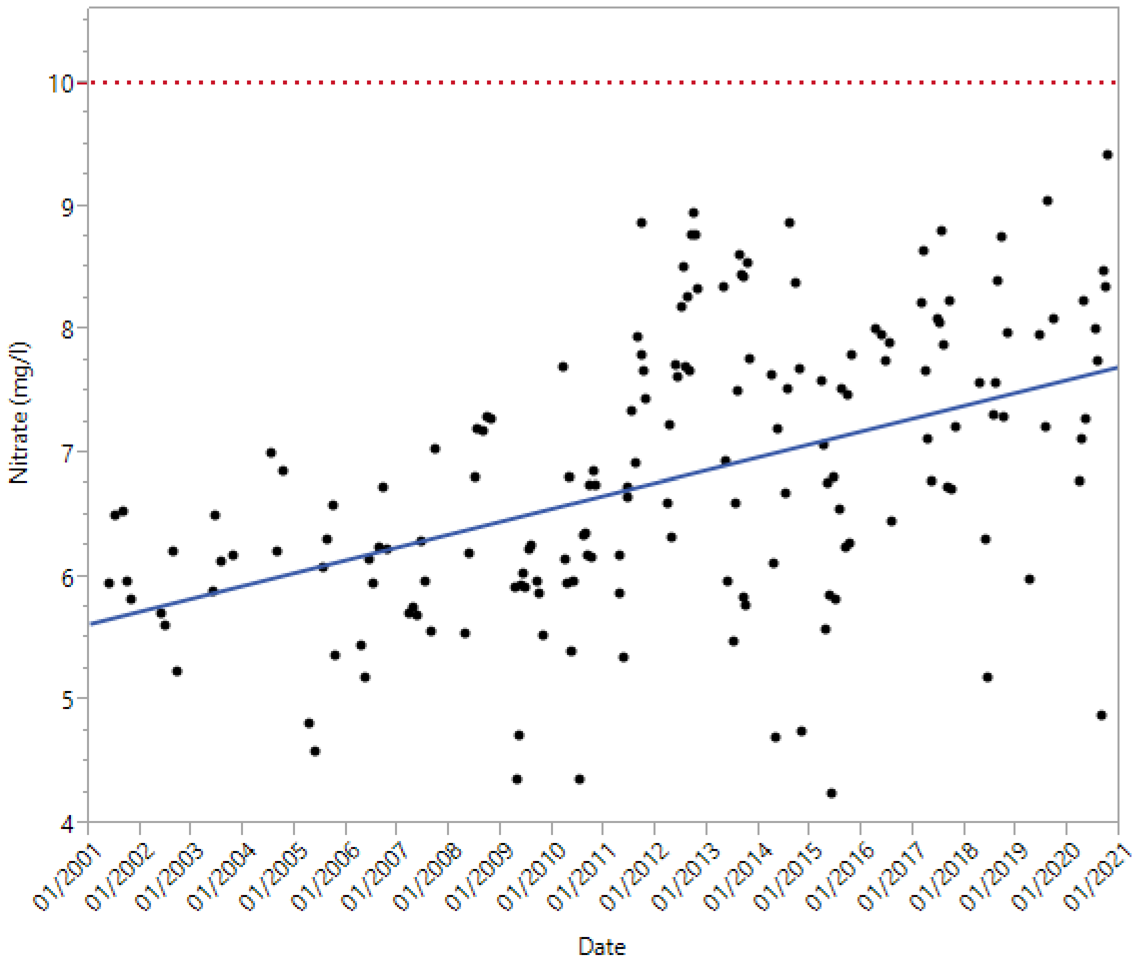


Figure 14. Baseflow nitrate concentration in South Branch Vermillion River, measured at 200th Street East near Highway 52, Dakota County. Samples reflect surface water baseflow conditions (March – October) from 2001 - 2020. Blue solid line represents linear regression. Red dotted line indicates upper limit of state standard, 10 mg/L.

The increasing nitrate in the watershed may be the result of one of the following factors - 1) an increase in the amount of drain tile installed, 2) the turnover of marginal land not in production (or lands in conservation programs) to lands in production with concurrent nitrogen application, 3) poor nutrient management resulting in the improper rate, source, time or placement of nitrogen fertilizers, or 4) an increase in the total acreage of agricultural land in the watershed, which in turn results in greater application of fertilizer to said land. All these factors can result in elevated nitrate levels in the soil, from which available nitrate can leach into shallow groundwater or be directly discharged to a nearby stream or ditch through drain tile.

Figure 15 shows the nitrate nitrogen levels for each station, classified by sample type for the year 2020. In Minnesota, there is an approved nitrate standard for waters that are used for domestic consumption (not to exceed 10 mg/L) which is applicable to all cold water streams (2A streams) in the Vermillion River Monitoring Network. The state standard is not applicable to warm water streams (2B streams) which include VR24, VR803, and VR0020.

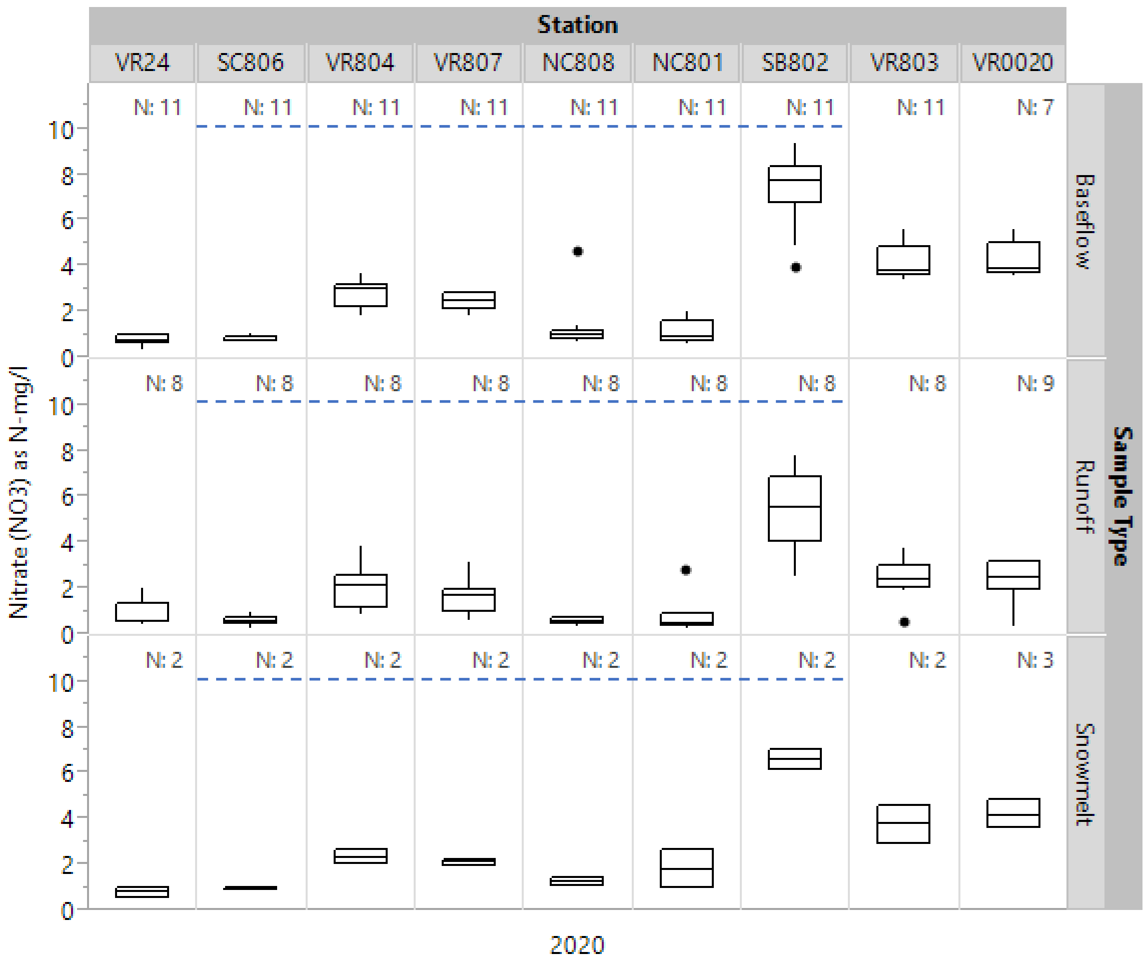


Figure 15. Nitrate nitrogen for each station, categorized by sample type, for 2020.

Historical nitrate nitrogen levels for each station are shown in Figures 16a - i. The blue dashed line on Figures 16b - g indicates the domestic consumption standard of ≤10 mg/L. The domestic consumption standard does not apply to Figures 16a, 16h, and 16i.

Nitrate concentrations at VR803 have dropped in 2007 which corresponds to the updates (2006) and eventual rerouting (2008) of the Empire WWTP. Since 2008, both baseflow and runoff sample concentrations have dropped. When looking at the historical record, VR24 shows higher nitrate concentrations in previous years. Rerouting the Elko New Market WWTP in 2012 may explain the apparent drop in median concentration in the same year.

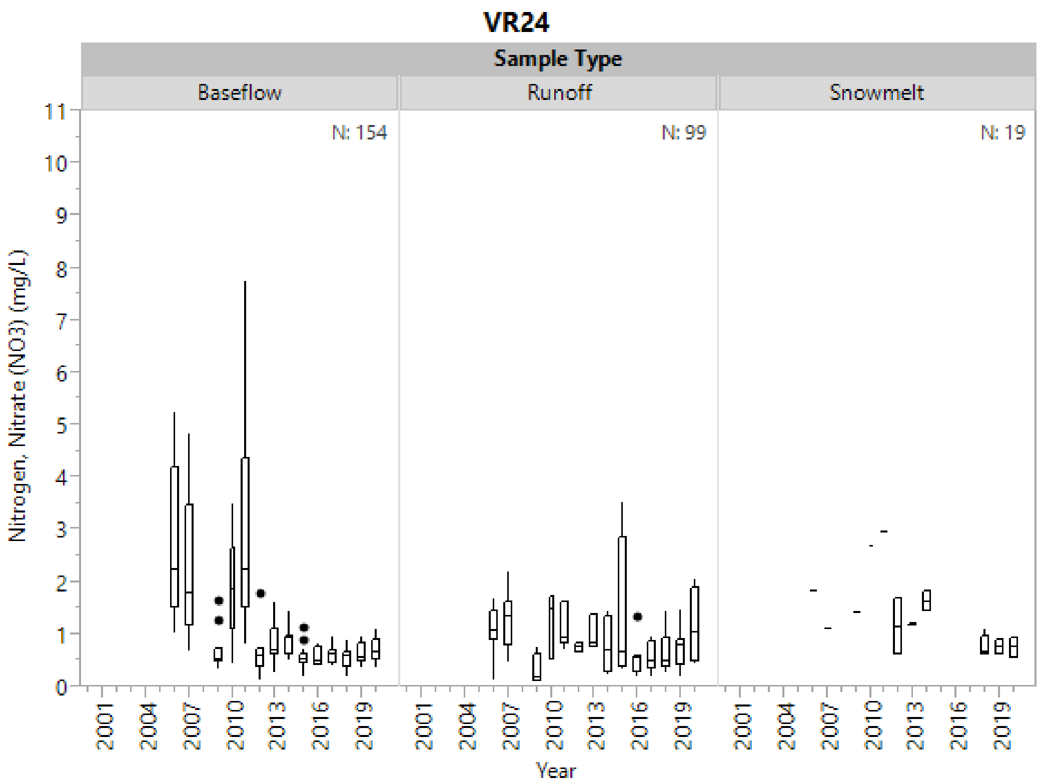


Figure 16a. Historical nitrate by sample type for VR24.

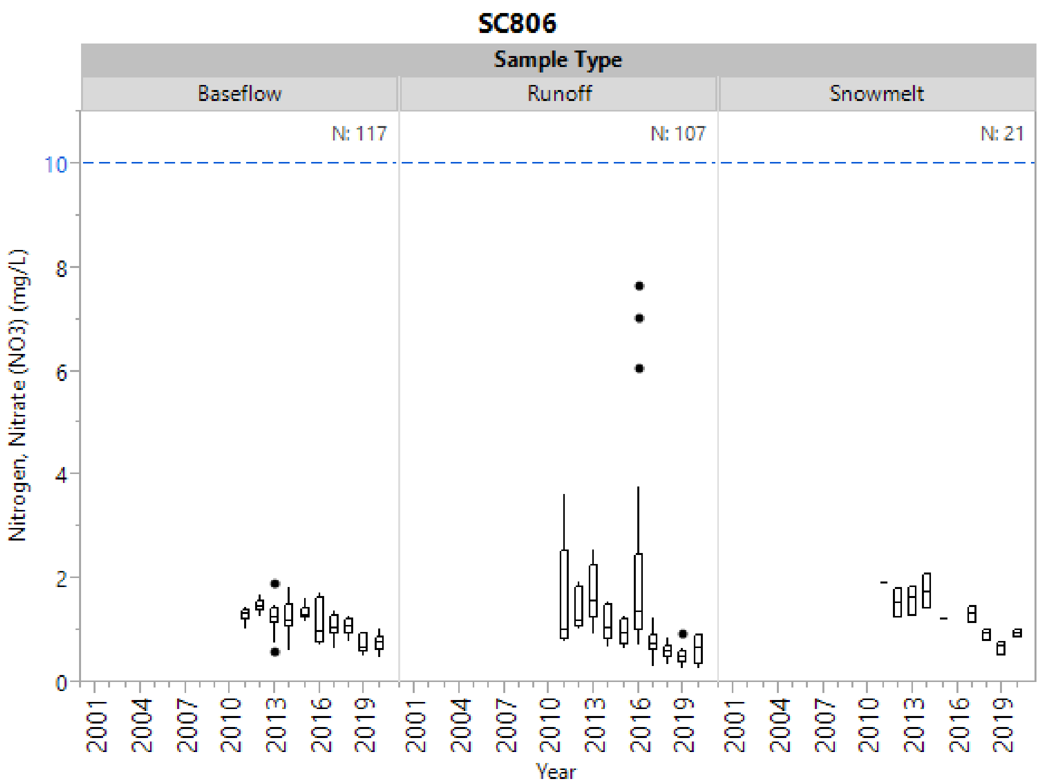


Figure 16b. Historical nitrate by sample type for SC806.

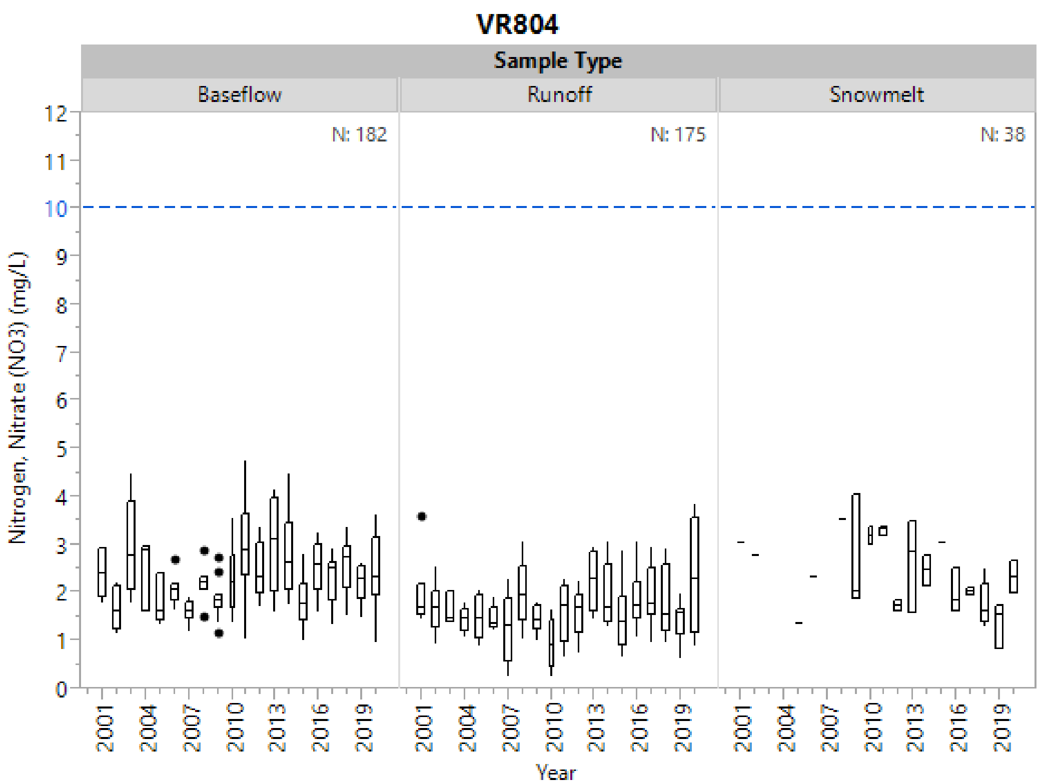


Figure 16c. Historical nitrate by sample type for VR804.

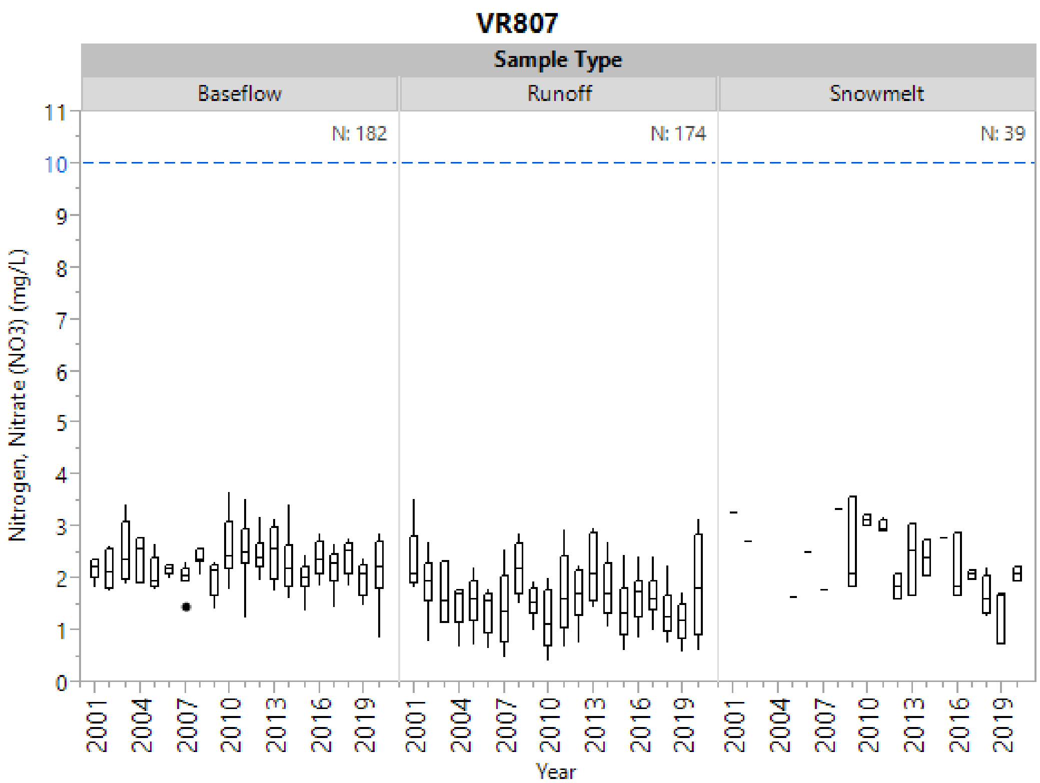


Figure 16d. Historical nitrate by sample type for VR807.

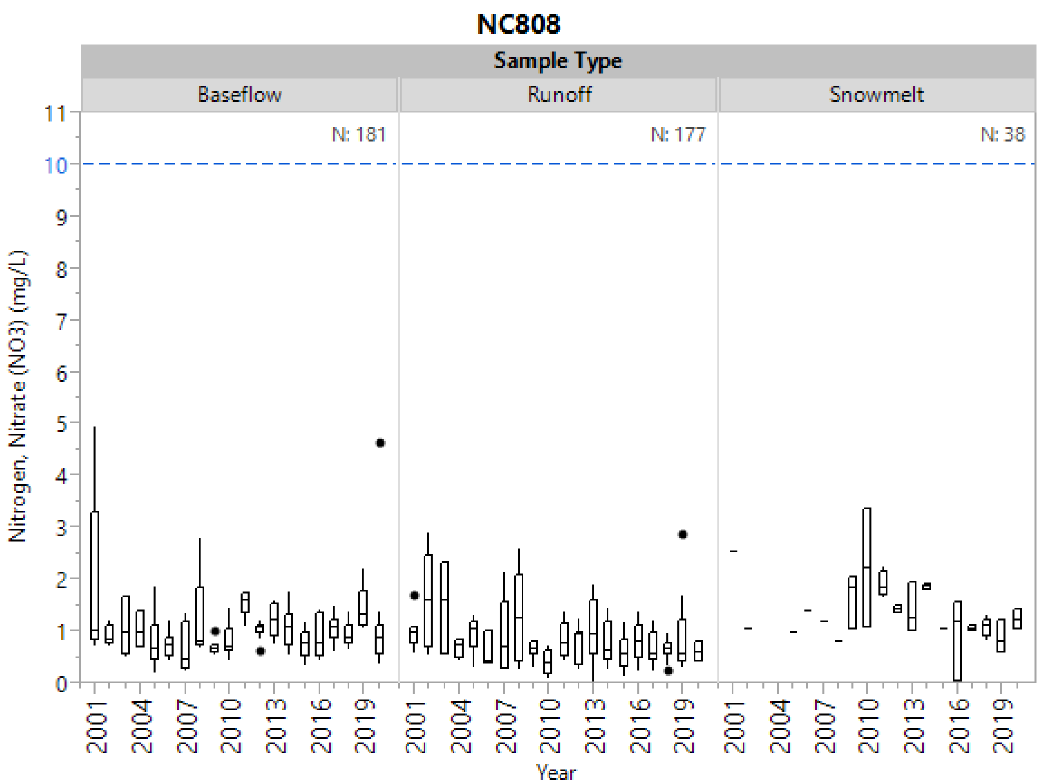


Figure 16e. Historical nitrate by sample type for NC808.

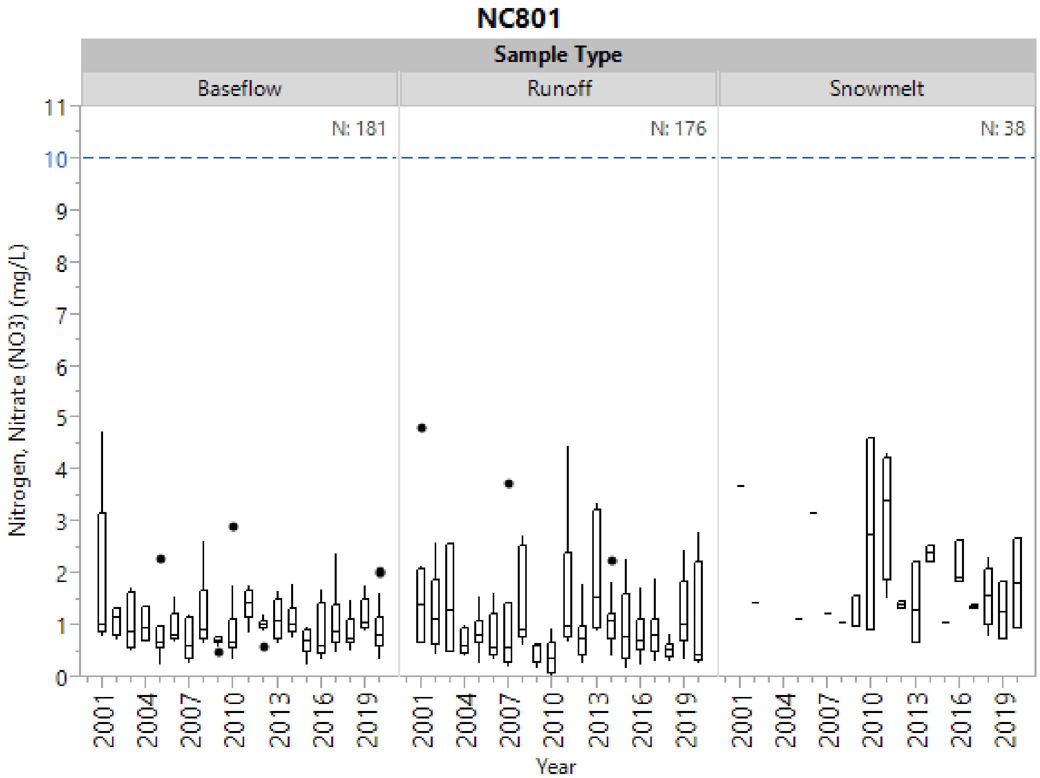


Figure 16f. Historical nitrate by sample type for NC801.

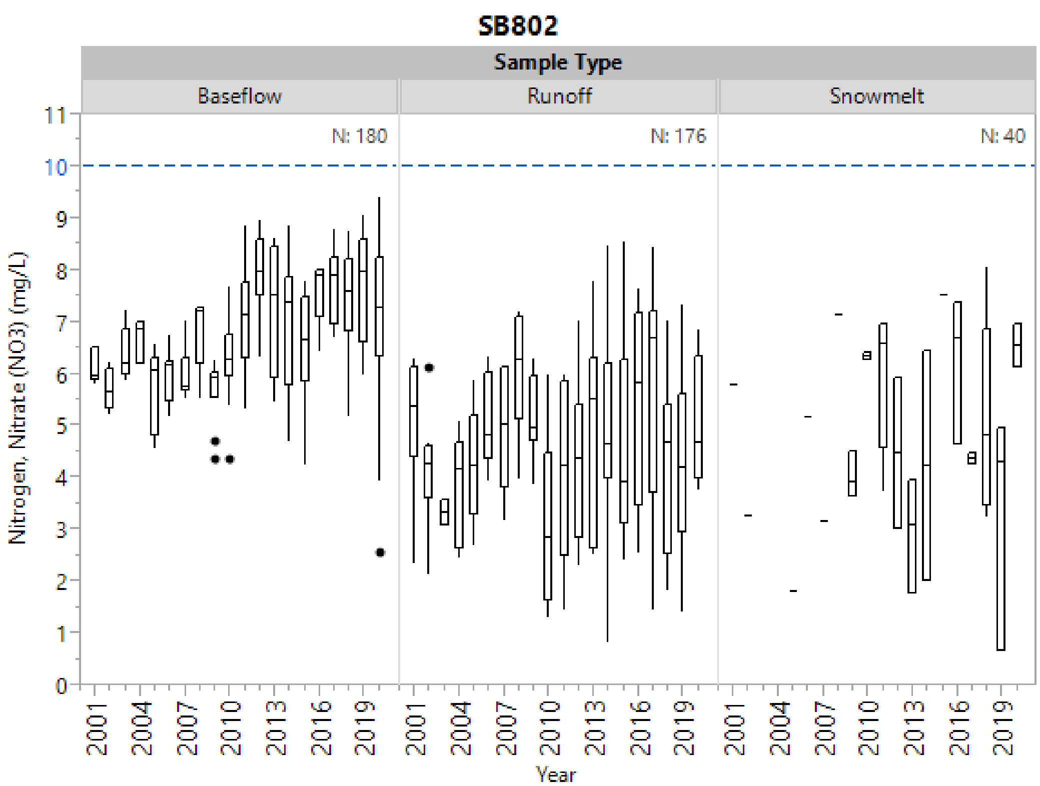


Figure 16g. Historical nitrate by sample type for SB802.

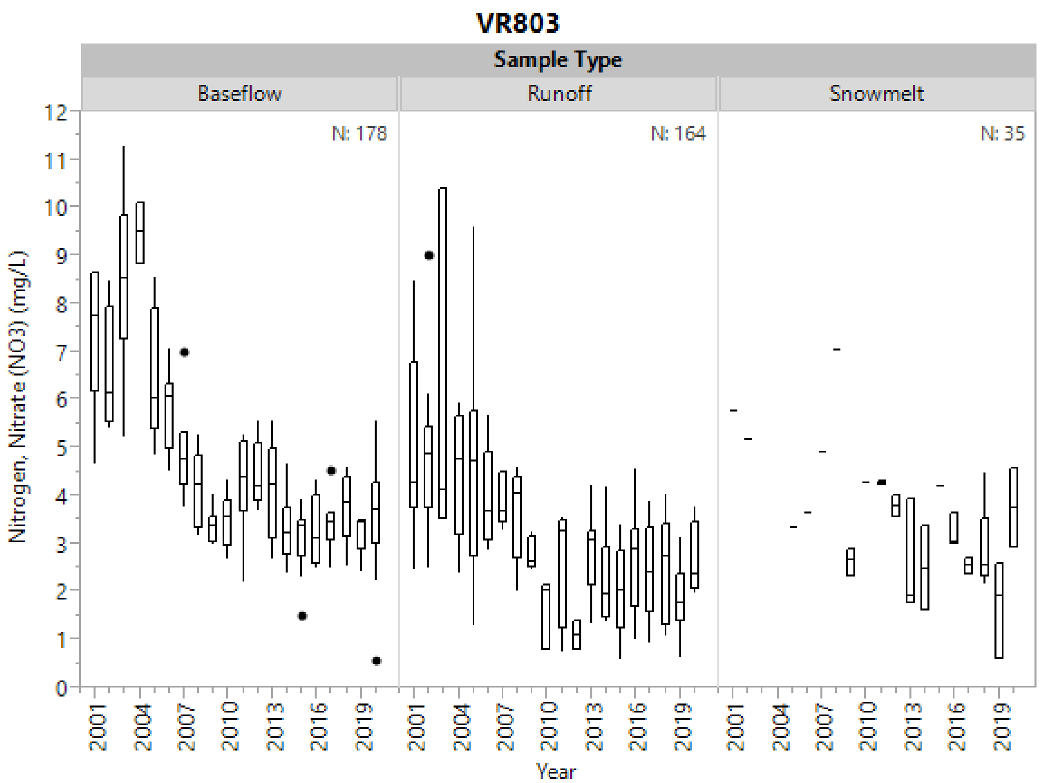


Figure 16h. Historical nitrate by sample type for VR803.

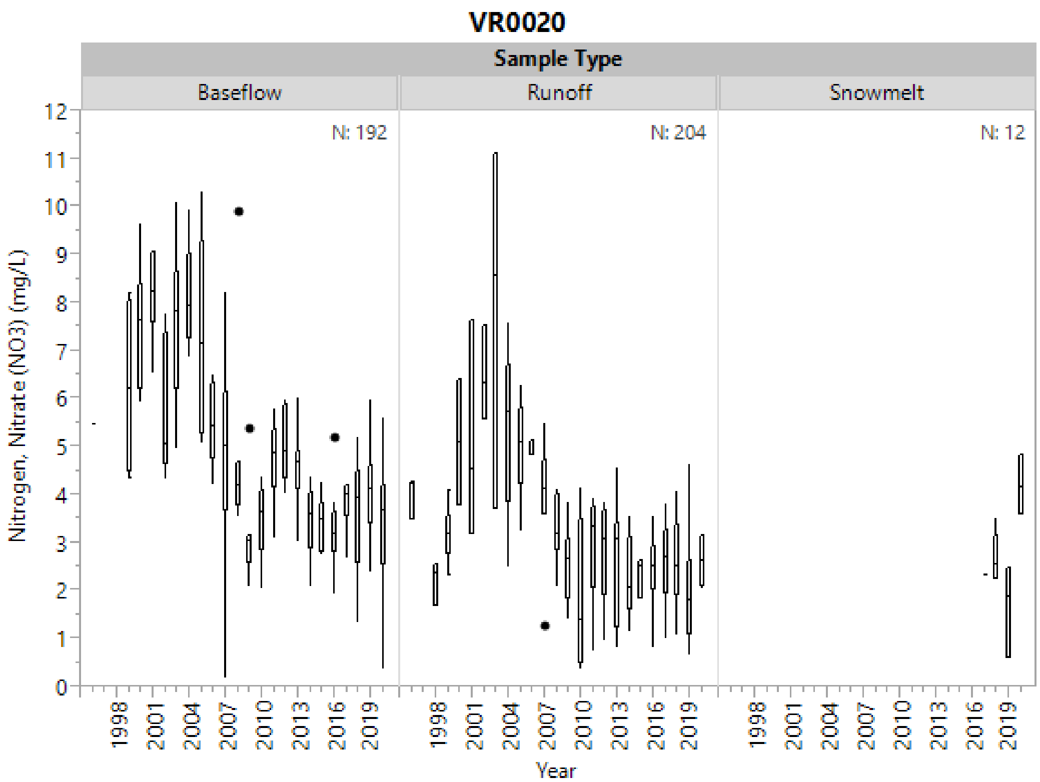


Figure 16i. Historical nitrate by sample type for VR0020.

Phosphorus

Phosphorus is an essential nutrient responsible for plants and animals that make up the aquatic food web. Small increases in phosphorus levels can bring about substantial increases in aquatic plant and algae growth, which can harm the natural ecosystem and water quality. It can also reduce recreational use and waterfront property values, as well as have a negative impact on human health. When the excess plants die and are decomposed, oxygen levels in the water drop dramatically which can lead to fish kills.

Phosphorus originates naturally from rocks, but major sources in streams and lakes are usually associated with human activities such as soil erosion, human and animal wastes, septic systems, and runoff from farmland or lawns. Non-point pollution occurs when heavy rain and melting snow wash over farm fields, feedlots, streets and parking lots. This carries with it fertilizers, manure, excess soil and contaminants from urban areas which eventually feed into lakes and streams. The impact that phosphorus can have in streams is less apparent than in lakes due to the overall movement of water, but in areas with slow velocity, where sediment can settle and deposit along the bottom substrate, algae blooms can result.

Phosphorus found in water exists in two main forms: dissolved (soluble) and particulate (attached to or a component of particulate matter). Because phosphorus changes form, total phosphorus is also measured to determine the amount of nutrient that can feed the growth of aquatic plants such as algae. Lab results for both total and dissolved phosphorus will be discussed in the following section of this report.

Phosphorus, Total

Figure 17 shows total phosphorus (TP) for each station categorized by sample type. All stations had a median baseflow TP concentration below the state standard of 0.15mg/L (blue dashed line). The median for runoff samples collected at the headwaters and middle of the watershed (VR24, SC806, VR804, VR807, NC808, and NC801) were below the standard, whereas sites in the lower watershed (SB802, VR803, VR0020) had medians that exceeded the standard. Individual samples exceeded the standard at all the monitoring sites during runoff conditions.

Phosphorus levels during snowmelt events varied, with the median phosphorus level below the standard at all monitoring sites in the watershed (individual samples at VR24 exceeded the standard, but the median remained below).

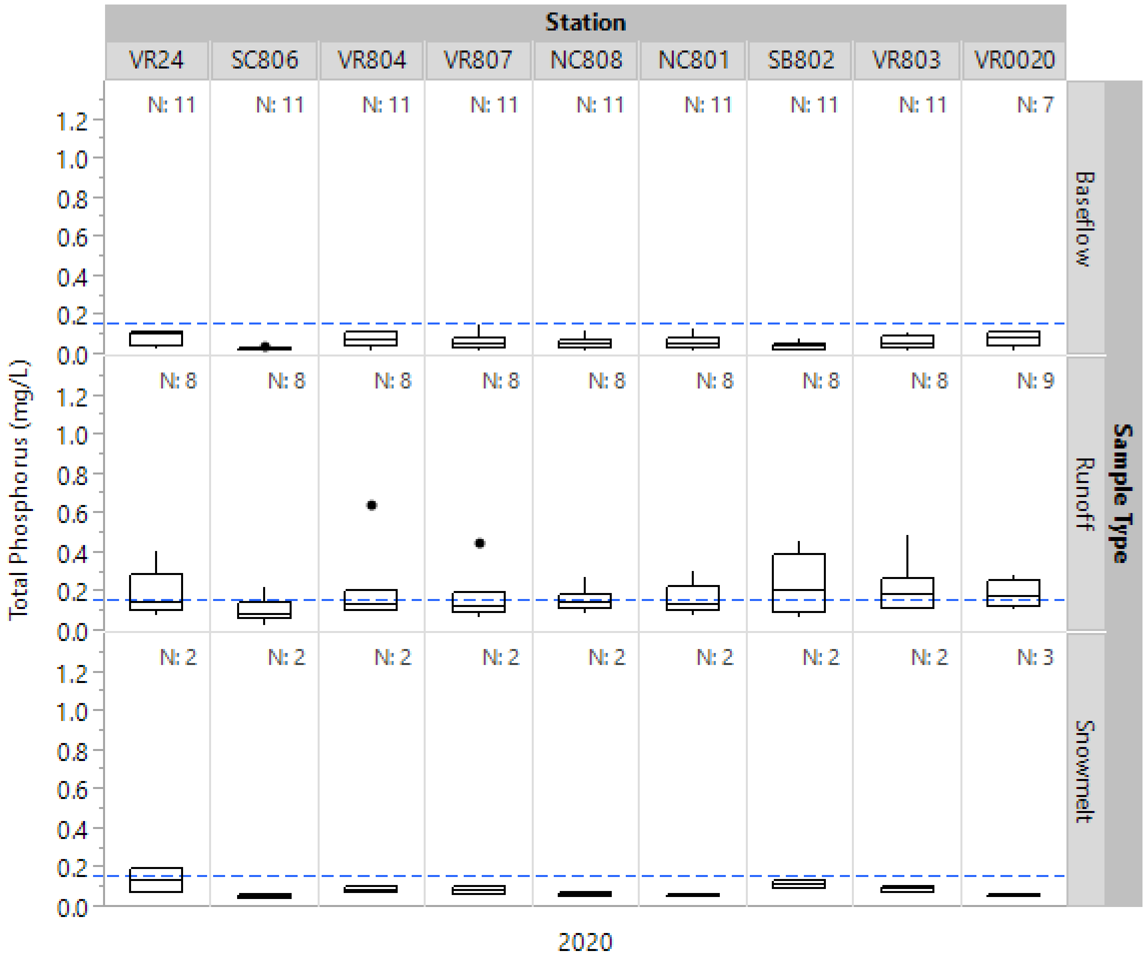


Figure 17. Total phosphorus (TP) for each station, categorized by sample type, for 2020.

Historical total phosphorus data for each station are shown in Figures 18a - i. At station VR24, data has been collected annually since 2006, except in 2008 when no samples were collected. For the seventh year in a row, the TP baseflow median was at or below the state standard at VR24. Unlike previous years, the TP median for runoff samples was near or above the state standard for most sites showing an increase in median concentrations from the last few years.

In August 2012, the wastewater treatment facility in the City of Elko New Market was decommissioned and the communities that it served were hooked up to the Empire Wastewater Treatment Plant in anticipation of future population growth in the area. Higher TP levels at VR24 during baseflow conditions compared to its downstream counterparts may be explained by a legacy effect, in which total phosphorus has adsorbed to sediment in the stream and continues to be a source of TP. A reduction in phosphorus loading may not reflect reduction in measured TP/TDP for several years due to potential influence from legacy phosphorus. The elevated phosphorus concentrations during runoff events in 2017 were most likely related to land use practices, not legacy effect, streamflow levels were elevated throughout the season due to frequent and substantial rainfalls.

Station SC806 has a relatively short historical record compared to other stations in the network. During baseflow conditions, TP is very low, but measured concentrations can be quite variable during runoff events and snowmelt. It appears TP was higher in runoff samples in 2012 compared to 2011 (which is true for all stations) and may be a result of the weather conditions in 2012 in which a massive June flood brought a lot of pollutants into the stream.

VR804, VR807, NC808, NC801 and SB802 all showed a similar pattern where baseflow sample medians for each year were below the state standard with a couple outliers extending beyond the threshold. Annual sample medians for runoff were mixed, staying below the state standard in some years and exceeding it in others. Snowmelt sample values were also quite variable for many stations.

In 2006, the Empire Wastewater Treatment Plant went through some upgrades which had a positive impact on water quality, reducing the total phosphorus downstream of the plant. TP at VR803 and VR0020 prior to 2006 was high during baseflow conditions, exceeding the proposed standard every year, and by a large margin. Since the upgrades, the baseflow TP median dropped below the proposed standard. TP measured during runoff conditions and snowmelt has also been noticeably reduced since 2006. Rerouting of the wastewater treatment plant in 2008 further benefitted water quality in the Vermillion River Watershed as effluent bypassed the Vermillion River and discharged directly into the Mississippi River.

In general, total phosphorus is at an acceptable level during baseflow conditions but can exceed the state standard during runoff conditions and snowmelt. Variability in these samples can be explained by studying the change in weather dynamics from one year to the next. Additionally, upgrades and rerouting of wastewater treatment plants seems to have made a noticeable improvement in water quality by reducing total phosphorus loading to the river.

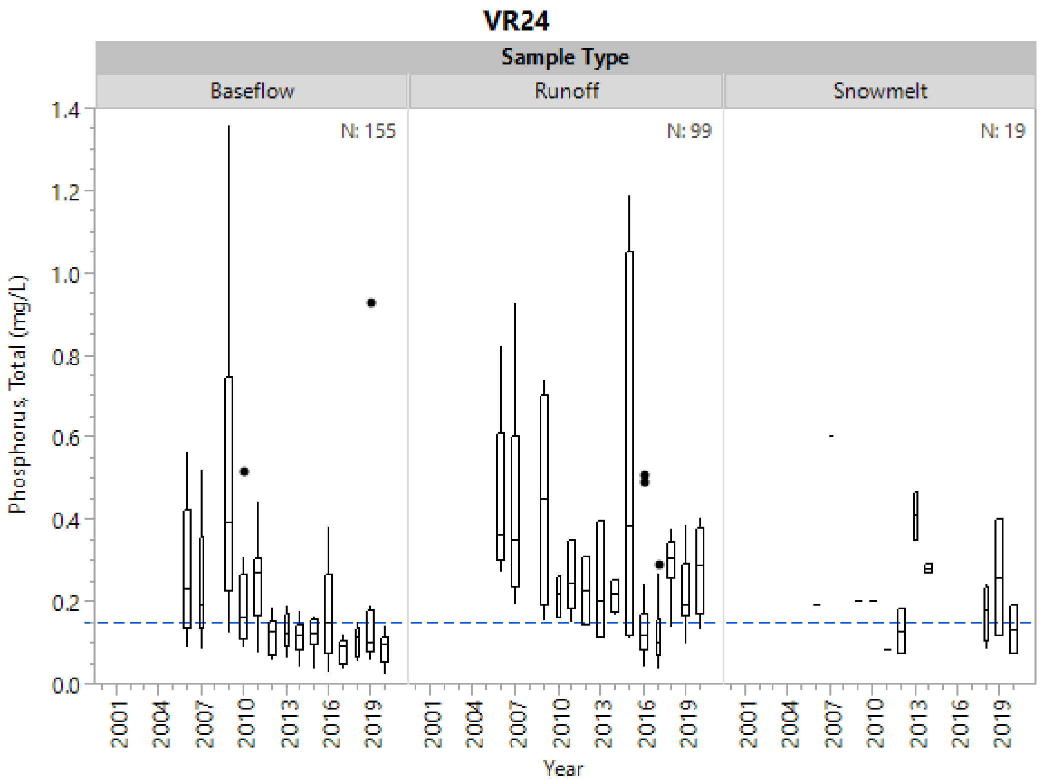


Figure 18a. Historical total phosphorus by sample type at VR24.

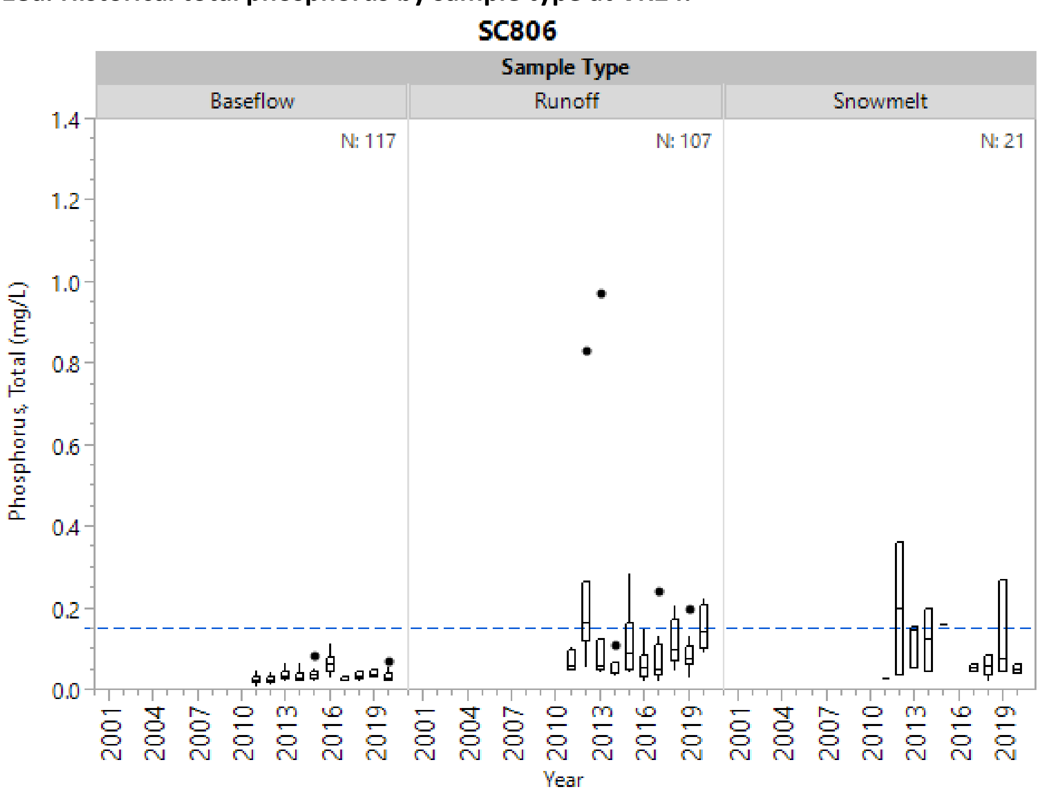


Figure 18b. Historical total phosphorus by sample type at SC806.

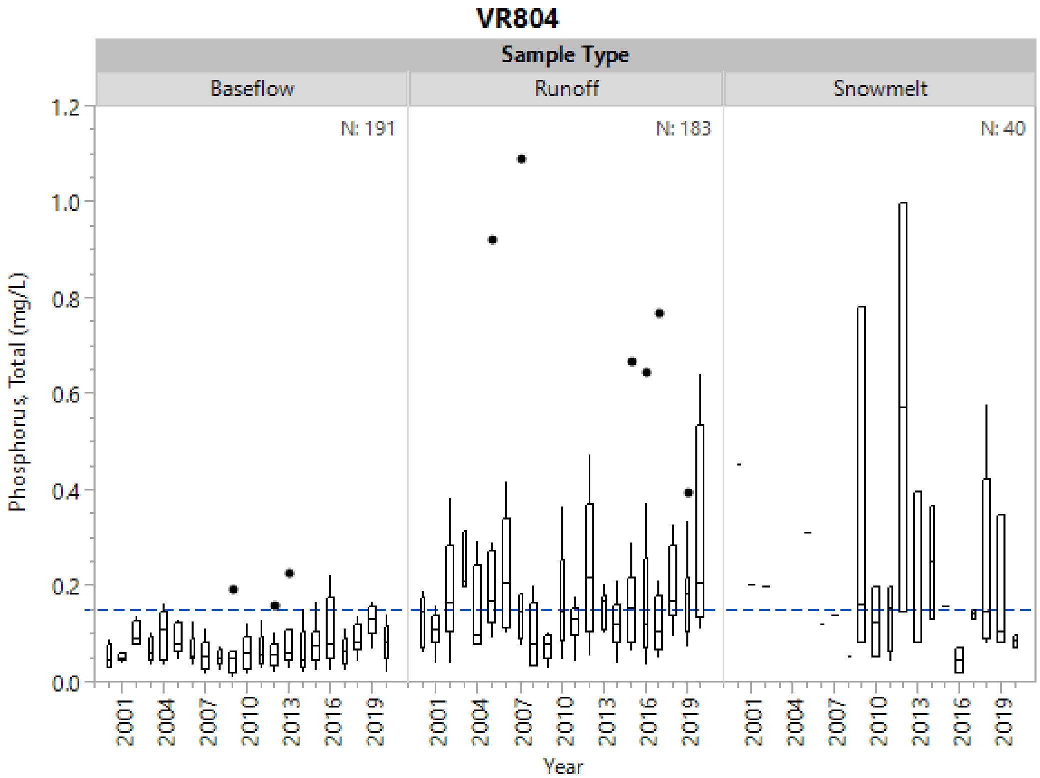


Figure 18c. Historical total phosphorus by sample type at VR804.

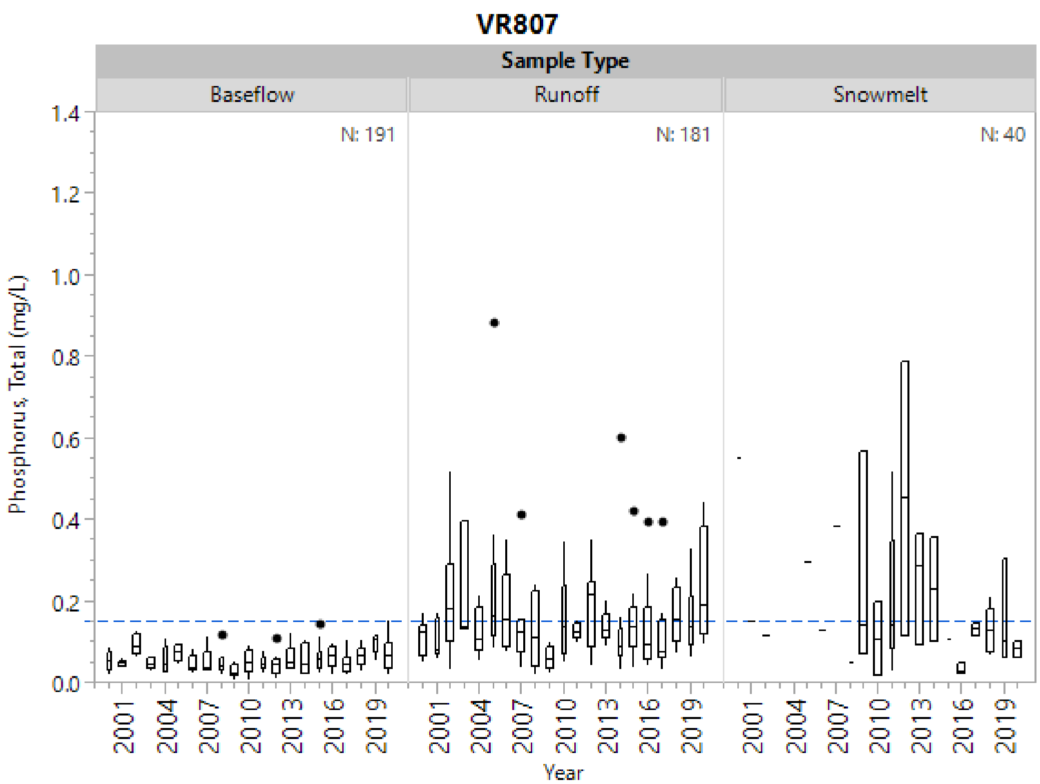


Figure 18d. Historical total phosphorus by sample type at VR807.

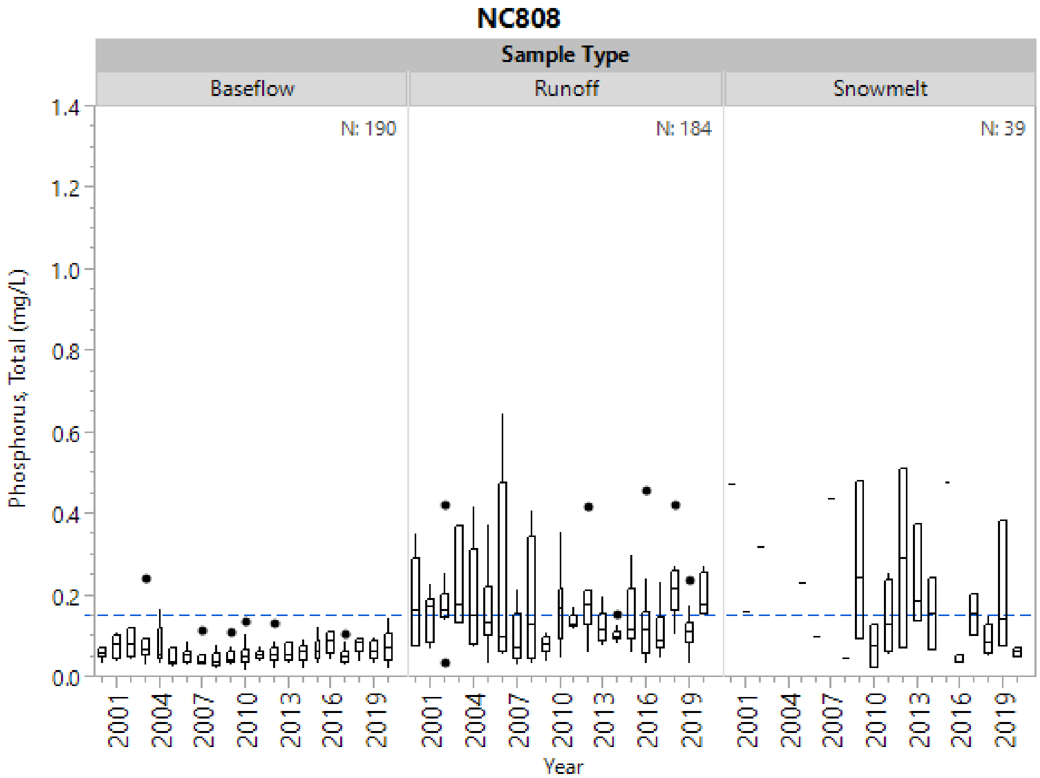


Figure 18e. Historical total phosphorus by sample type at NC808.

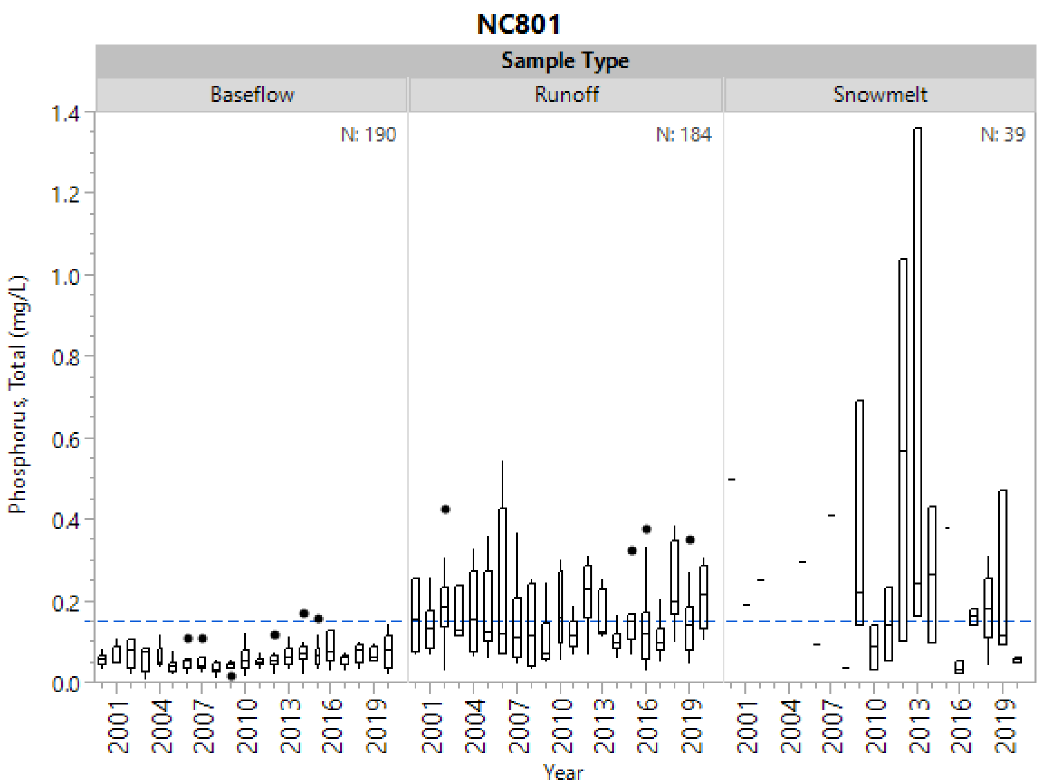


Figure 18f. Historical total phosphorus by sample type at NC801.

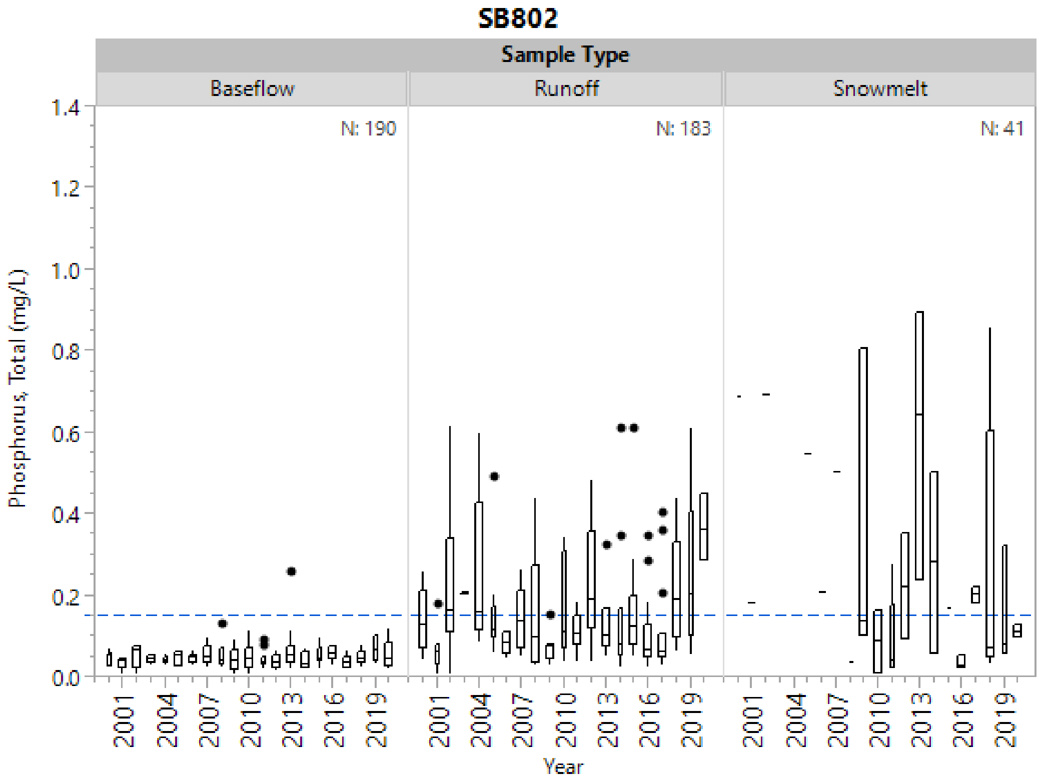


Figure 18g. Historical total phosphorus by sample type at SB802.

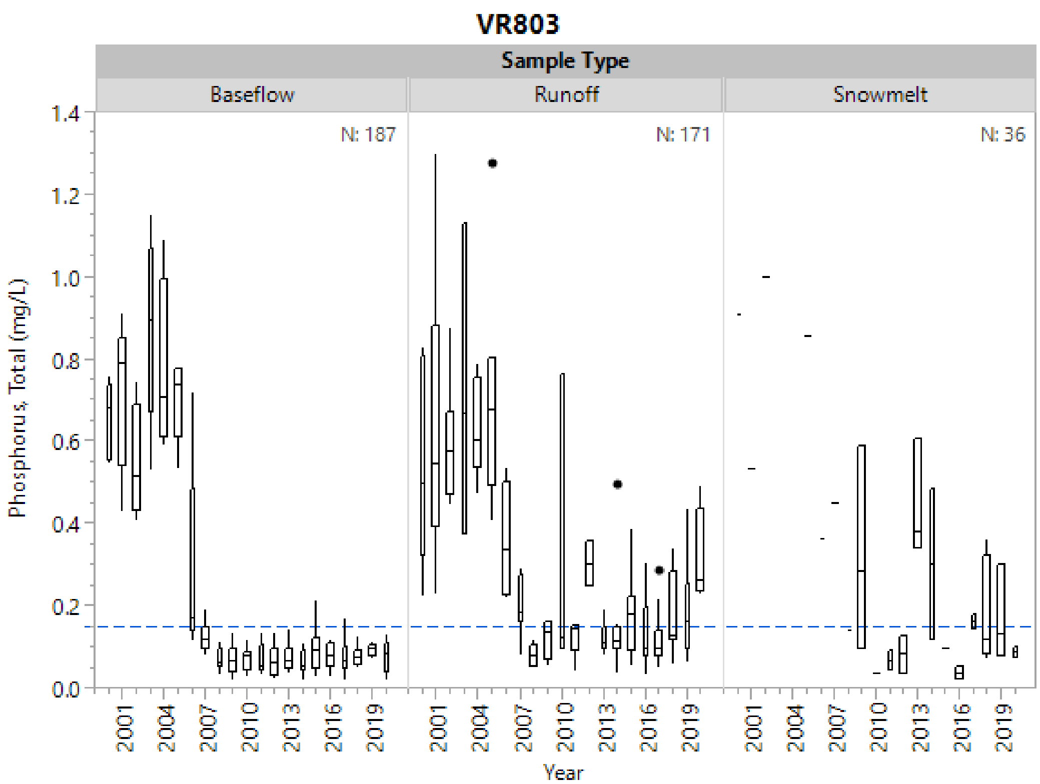


Figure 18h. Historical total phosphorus by sample type at VR803.

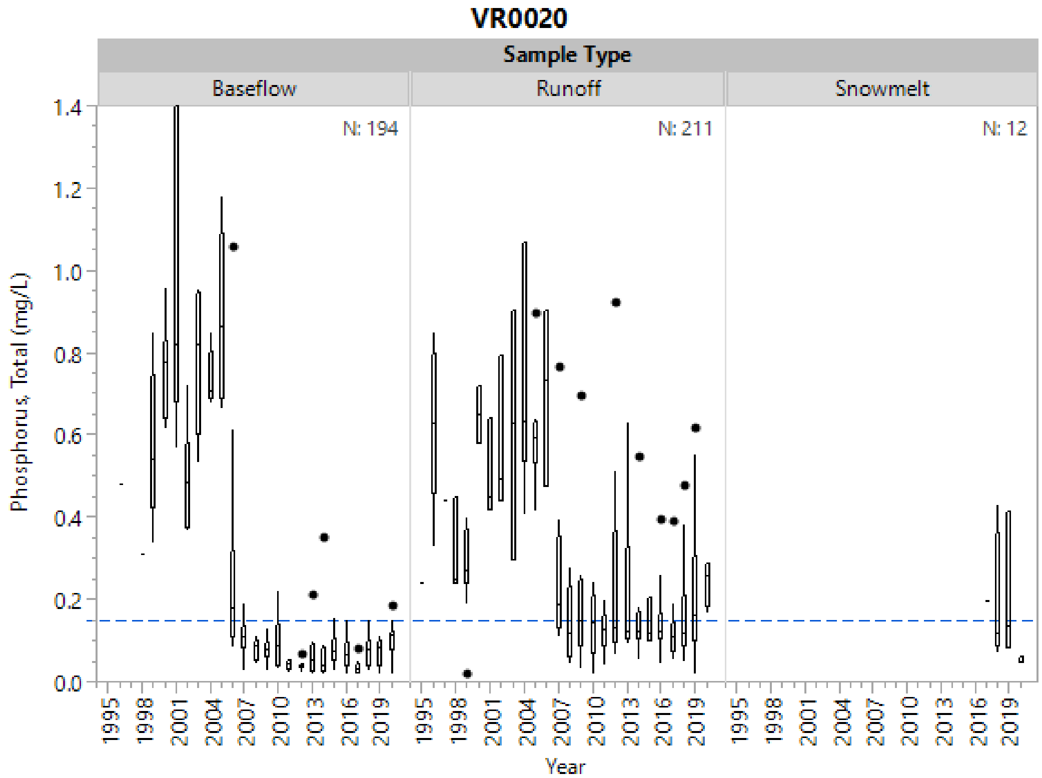


Figure 18i. Historical total phosphorus by sample type at VR0020. **VR0020 maximum for 2001 baseflow sample extends to 4 mg/L.

Phosphorus, Total Dissolved

Total dissolved phosphorus is the fraction of total phosphorus which can pass through a 0.45 µM filter. Since it is not adsorbed to minerals or sediment particles, it is potentially more bioavailable and may be utilized for algal growth and reproduction.

Sources of phosphorus include waste products from animals, including human waste coming from WWTPs, and agricultural and lawn fertilizer runoff. Other smaller sources include atmospheric deposition, direct input by wildlife, and natural decomposition of rocks and minerals. The ratio of TDP to TP changes often as phosphorus undergoes chemical and/or physical processes. This may change whether phosphorus is organic or inorganic, particulate or dissolved, and thus, more or less bioavailable.

By investigating the ratio of total dissolved phosphorus (TDP) to total phosphorus (TP), we can better understand how the sources of phosphorus change based on sample type as well as contrast the phosphorus sources for each stream reach.

Figure 19 shows the TDP to TP ratio boxplots for each station, classified by sample type for the year 2020. There is no state approved or proposed standard nor is there a published benchmark value for evaluating TDP levels in Minnesota.

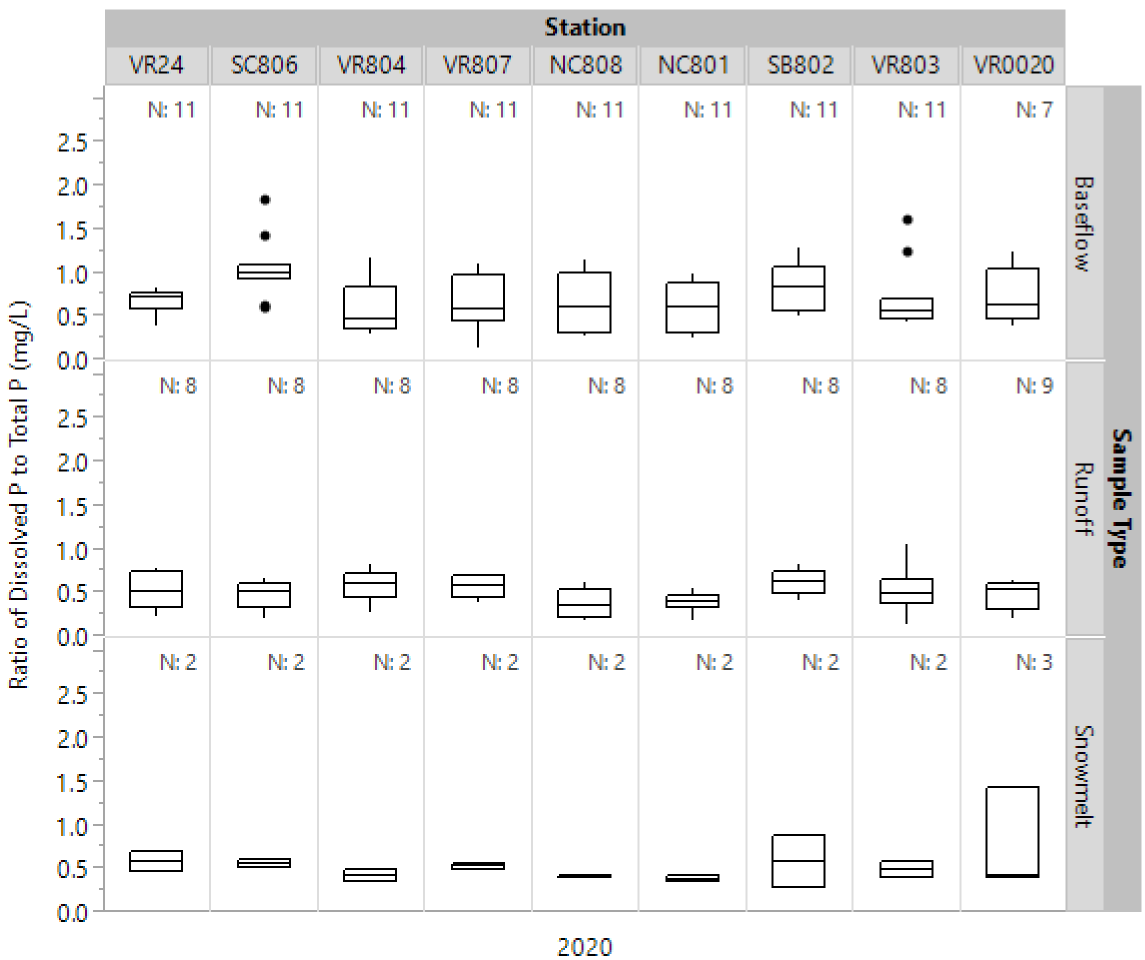


Figure 19. Ratio of dissolved phosphorus (TDP) to total phosphorus (TP) for each station, categorized by sample type, for 2020.

Historical TDP to TP ratio boxplots for each station are shown in Figures 20a - i. The TDP:TP ratios for runoff samples were generally lower than that of baseflow samples, which is in continuation of the trend for all sites when considering the historical data. Runoff event samples contain more suspended particulate material which has phosphorus adsorbed to it. This particulate phosphorus could be washed in from the land surface and/or resuspended from the stream bed resulting in a higher TDP to TP ratio.

During baseflow conditions, the TDP:TP ratio at VR803 had decreased about the time that wastewater treatment upgrades were implemented in 2006. Discharges from the wastewater treatment plant were likely the source of the TDP fraction; organic phosphorus excreted by organisms (including humans) would be dissolved, as opposed to particulate. WWTP upgrades in 2006 were important in reducing TDP levels at VR803 and significant reductions were apparent by 2007.

In some cases, the sample ratios exceeded 1.0 which indicates a field collection or laboratory analysis error. Since TDP is a fraction of TP, it was concluded that either the TP value was underestimated or the TDP value was overestimated as a result of field or lab error. Confounding factors such as an imperfect laboratory method for quantifying phosphate and plants taking up and releasing inorganic phosphorus over short periods of time contribute to some small error in the data. Nonetheless, the data provided here are useful and paint a good general picture of what is going on in the stream.

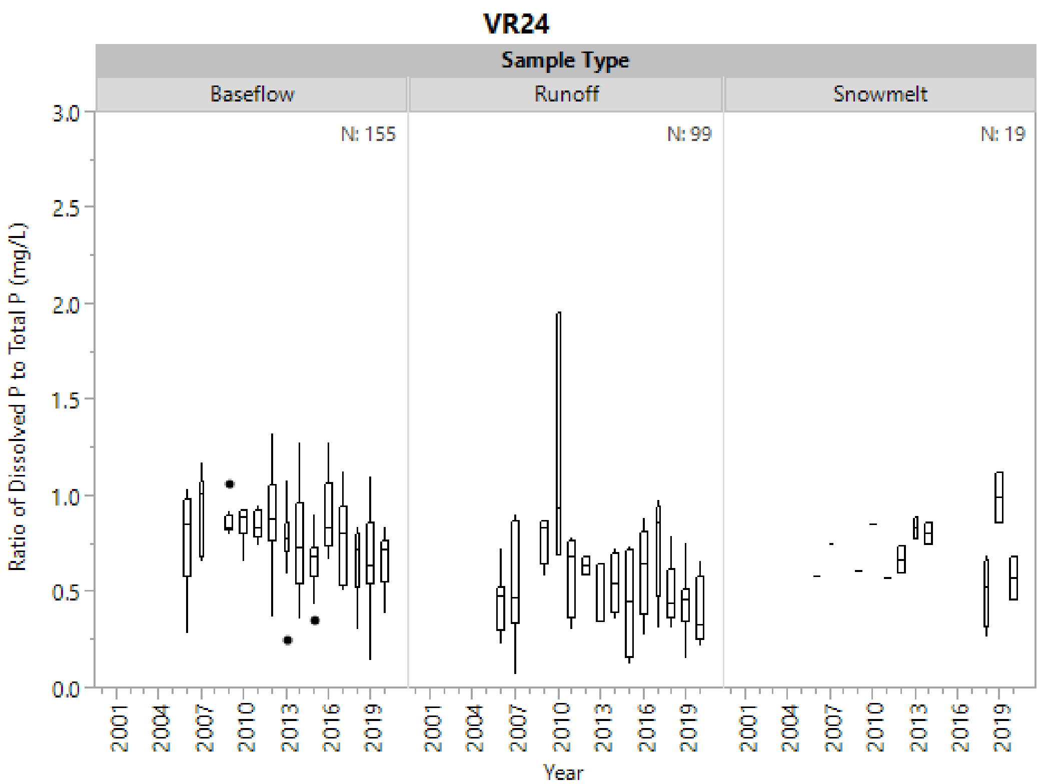


Figure 20a. Historical ratio of dissolved phosphorus to total phosphorus by sample type at VR24.

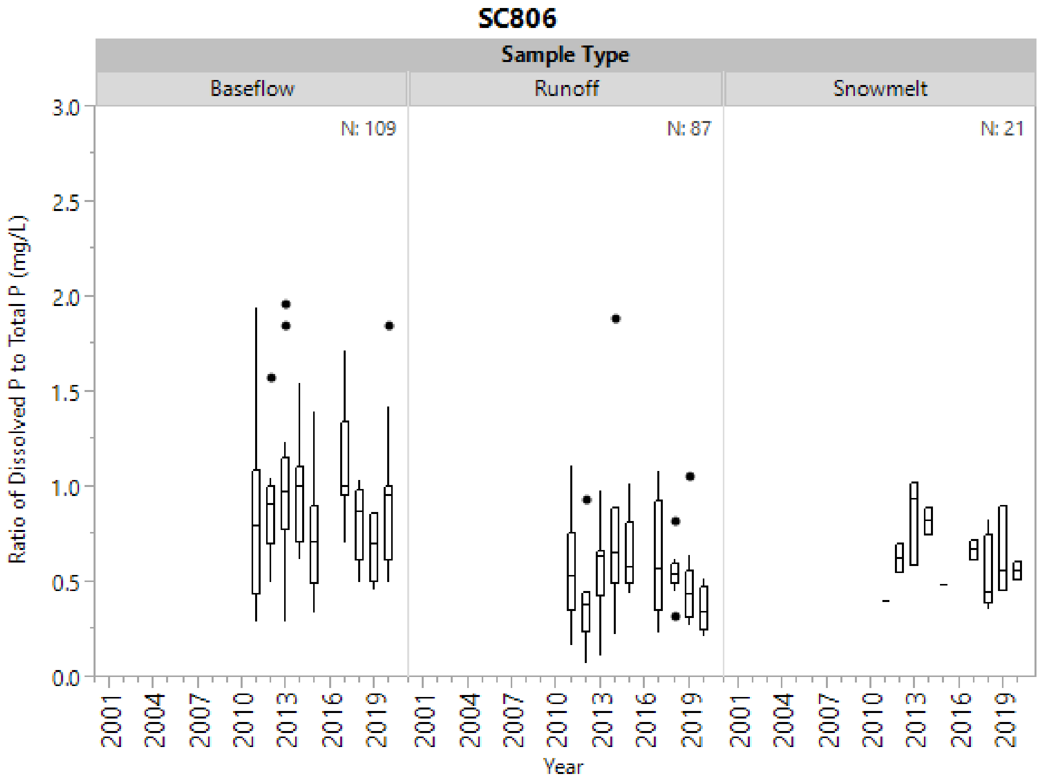


Figure 20b. Historical ratio of dissolved phosphorus to total phosphorus by sample type at SC806.

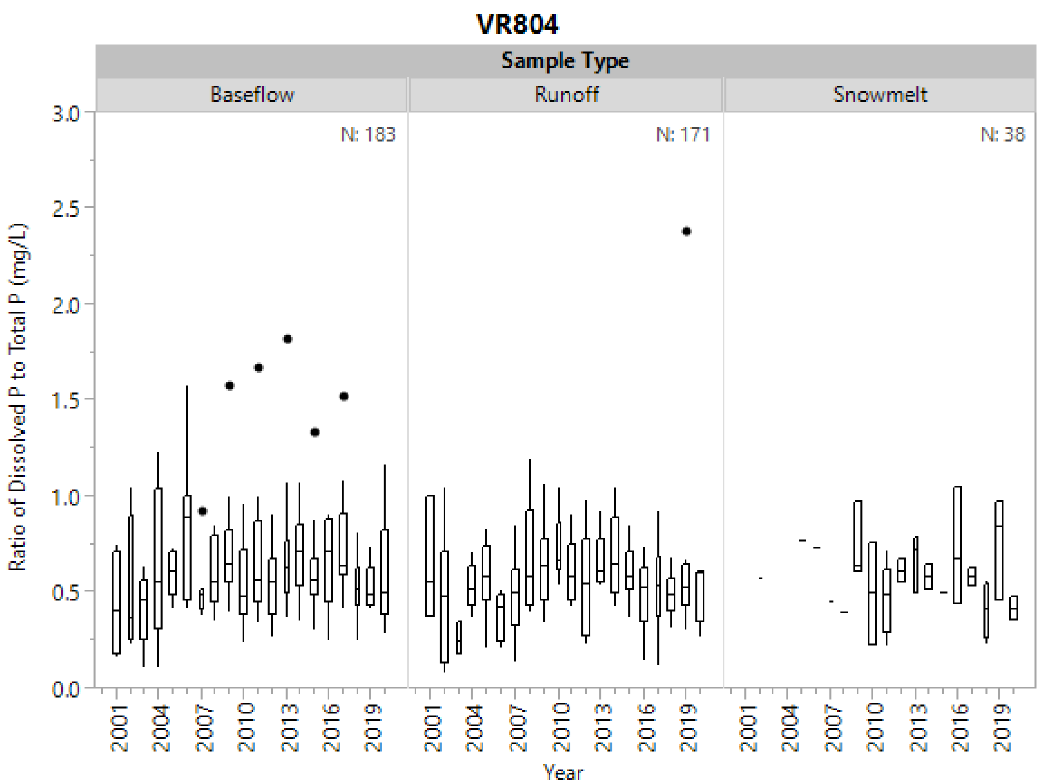


Figure 20c. Historical ratio of dissolved phosphorus to total phosphorus by sample type at VR804.

VR807

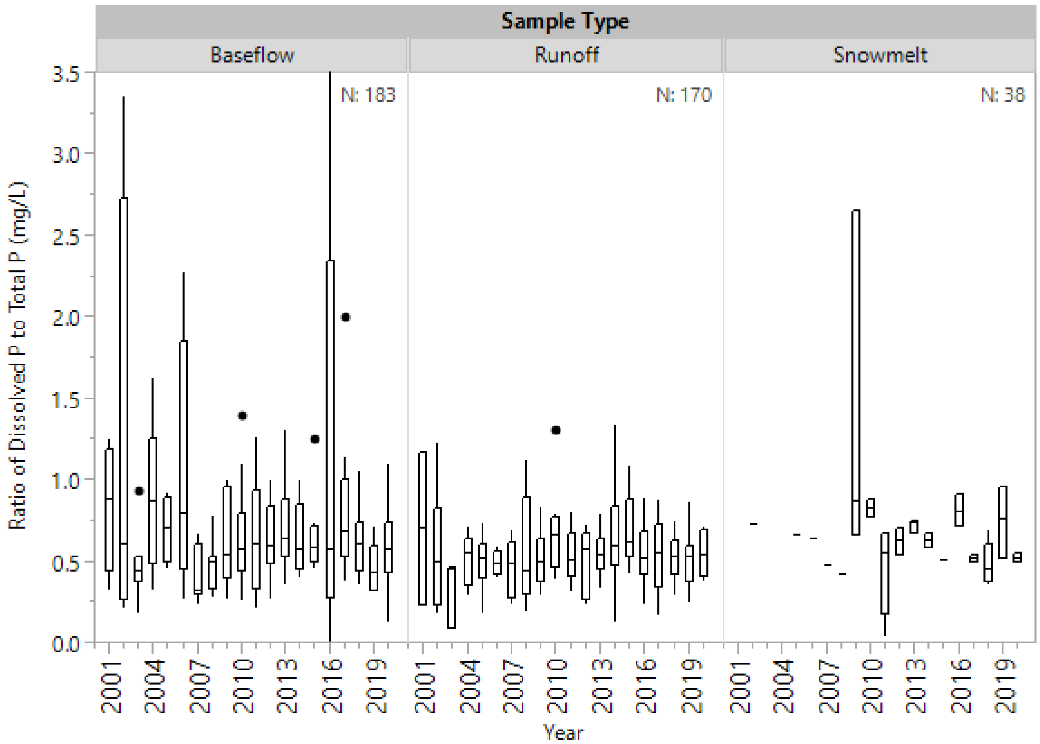


Figure 20d. Historical ratio of dissolved phosphorus to total phosphorus by sample type at VR807.
**VR807 maximum for 2016 baseflow sample extends to 3.77 mg/L.

NC808

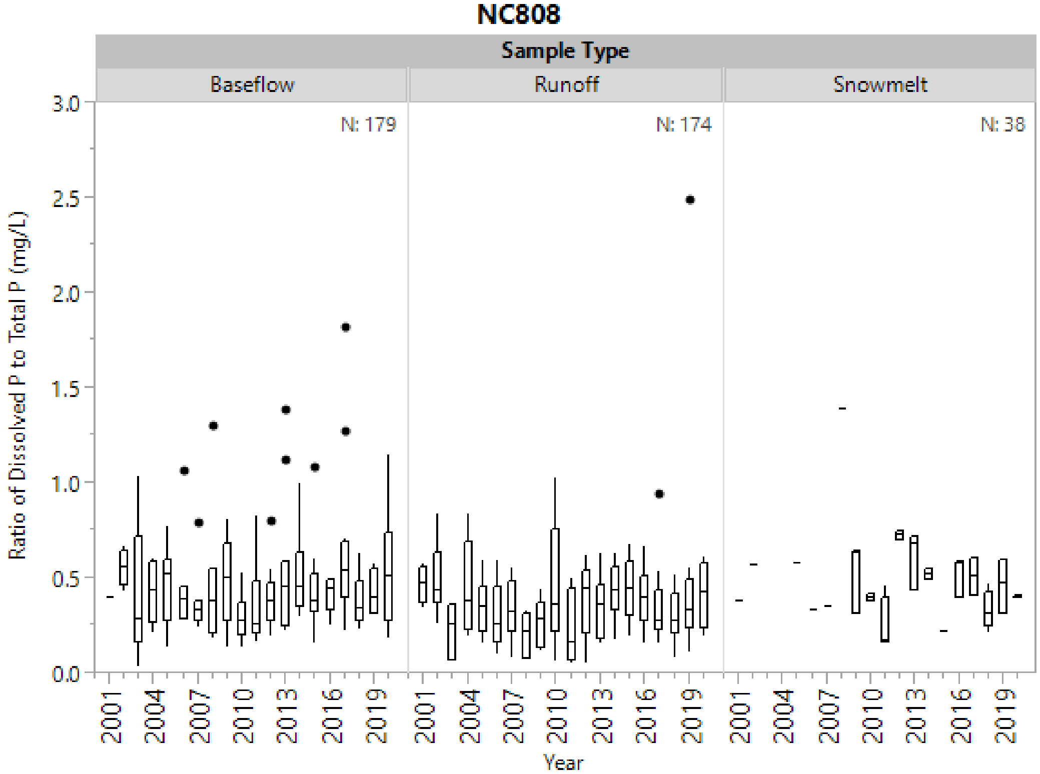


Figure 20e. Historical ratio of dissolved phosphorus to total phosphorus by sample type at NC808.

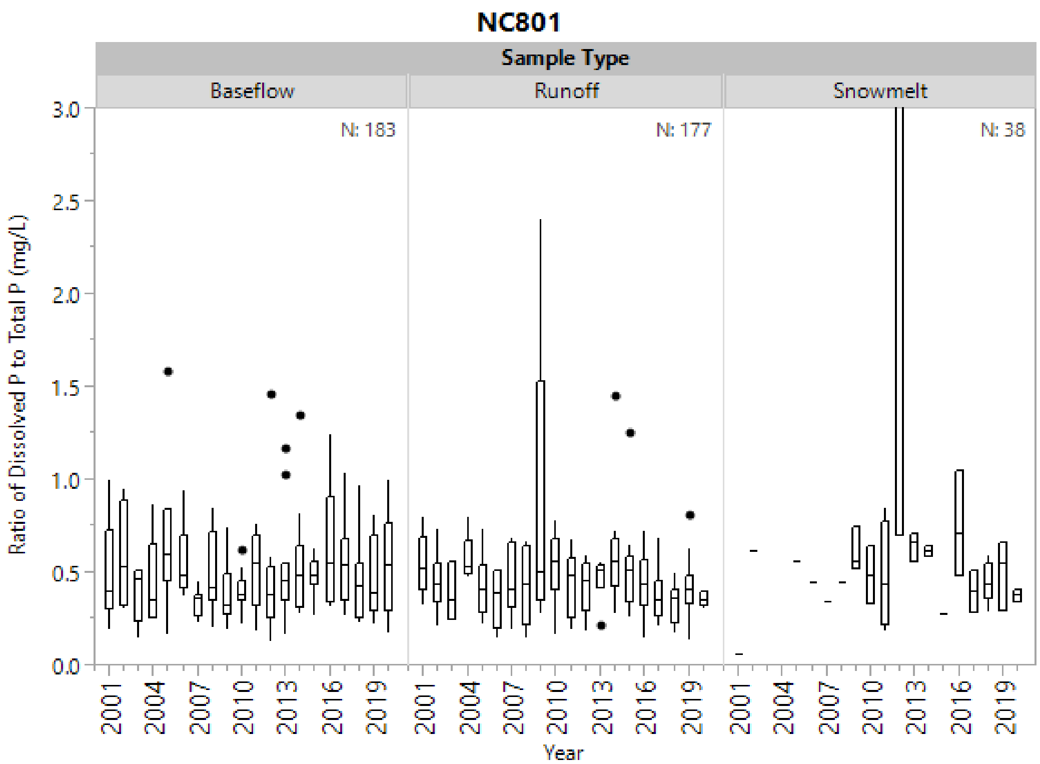


Figure 20f. Historical ratio of dissolved phosphorus to total phosphorus by sample type at NC801.
**NC801 has an outlier for 2003 baseflow at 3.7 mg/L and the maximum for 2012 snowmelt sample extends to 5.67 mg/L.

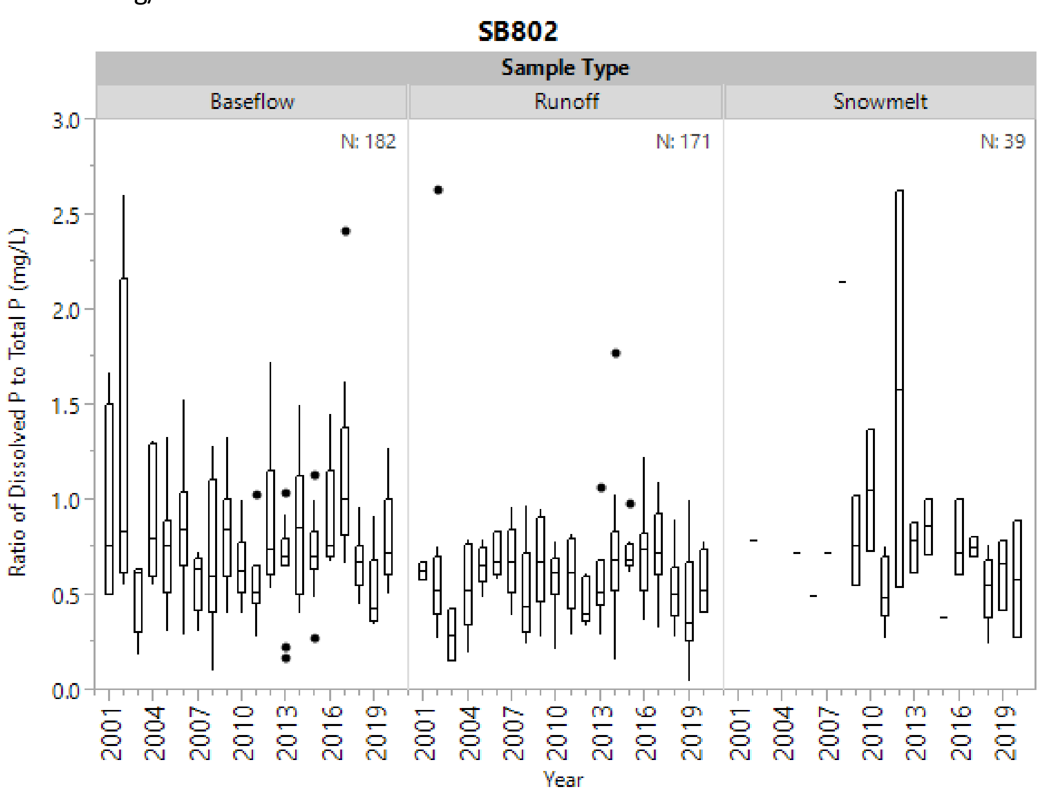


Figure 20g. Historical ratio of dissolved phosphorus to total phosphorus by sample type at SB802.

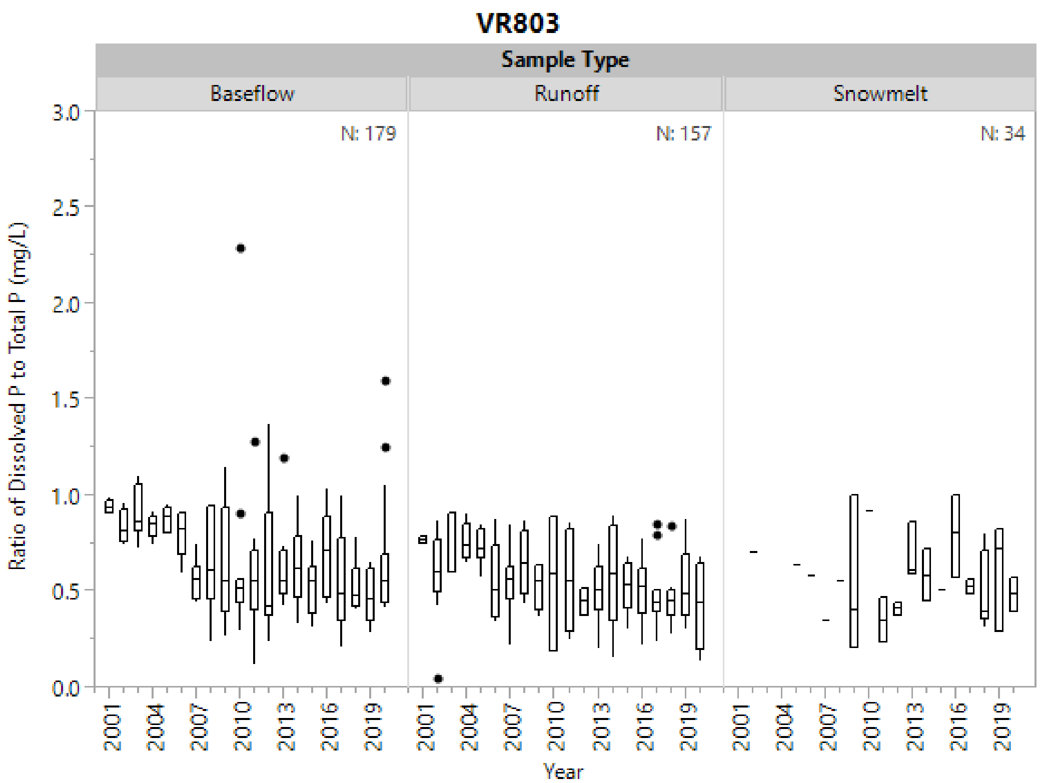


Figure 20h. Historical ratio of dissolved phosphorus to total phosphorus by sample type at VR803.

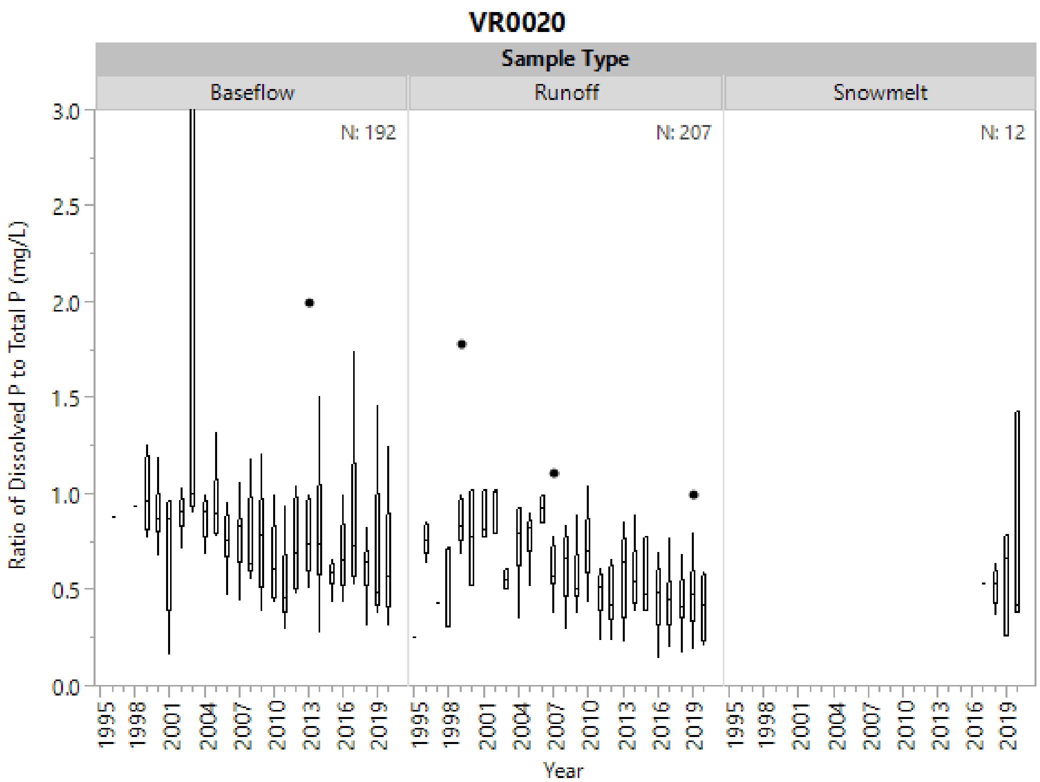


Figure 20i. Historical ratio of dissolved phosphorus to total phosphorus by sample type at VR0020.
**VR0020 has an outlier for 2003 baseflow at 37.9 mg/L.

Suspended Solids and Transparency

Water clarity is an obvious feature of surface waters in both lakes and rivers and is an important indicator of the health of a waterbody. The clarity, or transparency, of water is affected by a combination of the availability of sunlight and the amount of suspended particles and dissolved solids in the water column. Erosion and pollution can severely affect the clarity of water, as excessive suspended sediment can impair water quality for aquatic and human life and a reduction in light penetration can inhibit with the growth of aquatic plants. Reduced water clarity also interferes with the ability of fish to see and capture their prey. Too much sediment in water can negatively impact human life due to navigation difficulties and increased flooding risks.

In streams and rivers, soil particles (predominantly silts and clays) have a strong influence on transparency as water flows downstream, carrying and depositing sediment as it moves. Suspended particles can come from a variety of sources including soil erosion, runoff or point source discharges, stirred bottom sediments or algal blooms. While some streams do have naturally high levels of suspended solids, clear water is generally considered an indicator of a healthy waterbody. A sudden increase in turbidity (cloudy, murky water) in a previously clear body of water is a cause for concern.

VR803 at *baseflow* conditions.

Small amount of suspended particles being transported downstream.

Water transparency is high.

VR803 under *runoff* conditions.

Water is murky and there is a high level of suspended sediment in the water.

Water transparency is low.

There are two common methods by which to monitor water clarity in a stream. One is to collect water samples to be tested for total suspended solids (TSS) at a laboratory. TSS is one of the most visible indicators of water quality. The second process is to use a secchi tube (a modified transparency tube designed in a similar manner to the traditional secchi disk used in lakes monitoring) to assess water clarity in the field. Secchi tube measurements are a more subjective measurement than TSS, as they are determined by human observation of water collected.

Total Suspended Solids (TSS)

Total suspended solids (TSS) is a measure of all the organic and inorganic suspended particles in the water. TSS includes settleable solids and is the direct measurement of the total solids present in a water body. Most suspended solids are made up of inorganic materials, though bacteria and algae can also contribute to the total solids concentration. Potential sources include eroded soils from fields and stream banks, sediment from impervious surfaces such as parking lots and roads, decaying vegetation, and algae.

For cold water (2A) streams the standard is ≤10 mg/L and for warm water (2B) streams the standard is ≤30 mg/L* (blue dashed line). These standards apply from April through September; however, data shown here includes the entire monitoring season which goes from snowmelt (mid-March) through November 1st (Figure 21). Sample medians were below the state standard at all stations during baseflow conditions. At the six cold water monitoring sites, sample medians were at or above the standard during runoff monitoring. During snowmelt events in March and October, samples medians remained below the standard.

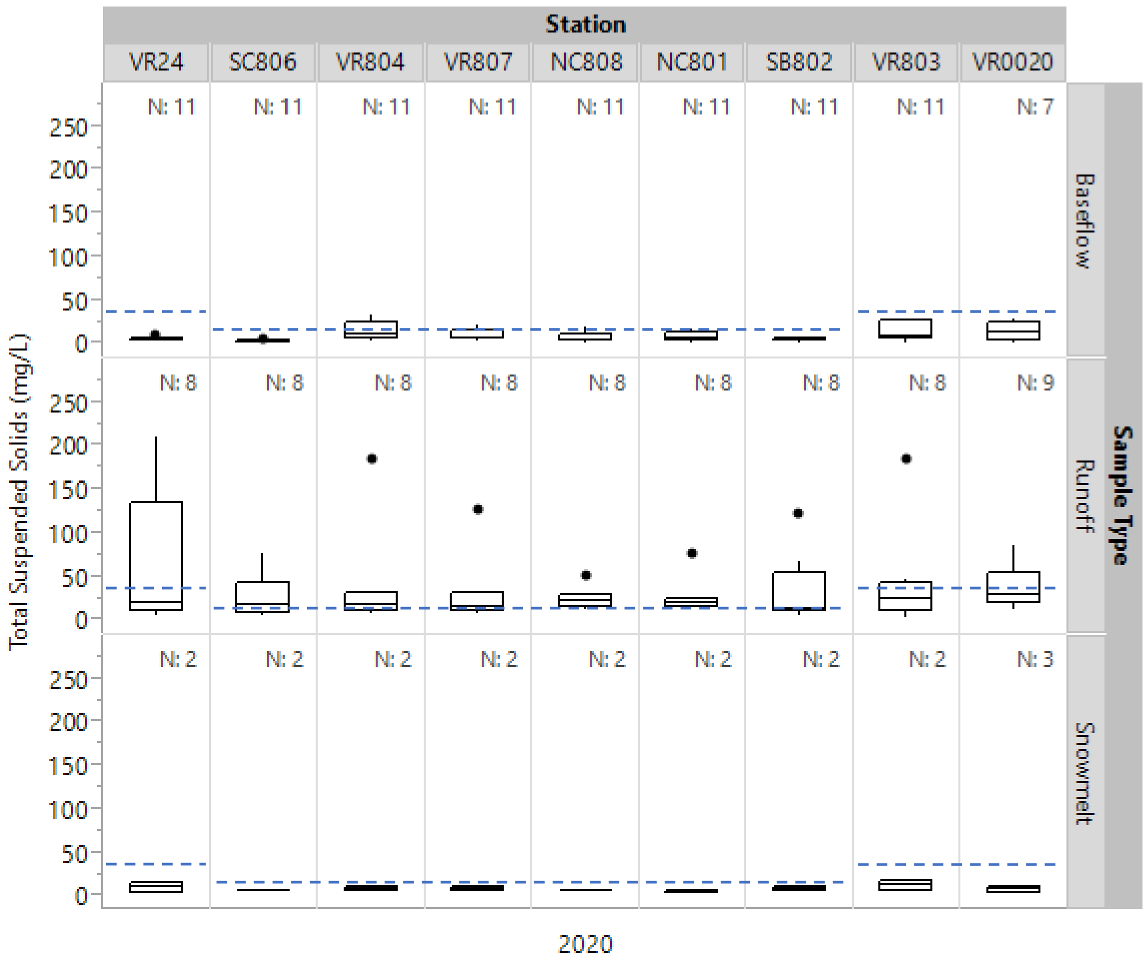


Figure 21. Total suspended solids categorized by sample type for 2020.

*Per conversation with MPCA staff in 2020, the VRWJPO reports TSS findings using the warm water (2B) stream standard for the Central River Nutrient Region, instead of the warm water standard for the Southern River Nutrient Region (≤65 mg/L) as has historically been used.

Storm duration and intensity play a role in contributing high suspended solids to a stream. The years with samples from larger storm events have higher TSS than years with samples from smaller storms that had lesser rainfall amounts and/or lower intensity.

The historical record shows that runoff sample medians violated the state standard for cold water streams in most years, but baseflow samples often met the standard (Figure 22a-i). Station VR24 has the highest variability of all monitoring sites during runoff conditions with individual samples up to 15x higher than the standard (2015 – 468 mg/L).

Stations VR803 and VR0020 had baseflow and runoff sample medians below the proposed standard under all regimes during all years up until 2020 when runoff medians jumped above the standard.

Blue dashed line indicates the upper limit of the state standard for 2A (10 mg/L) and 2B streams (30 mg/L) in Figures 22a-i.

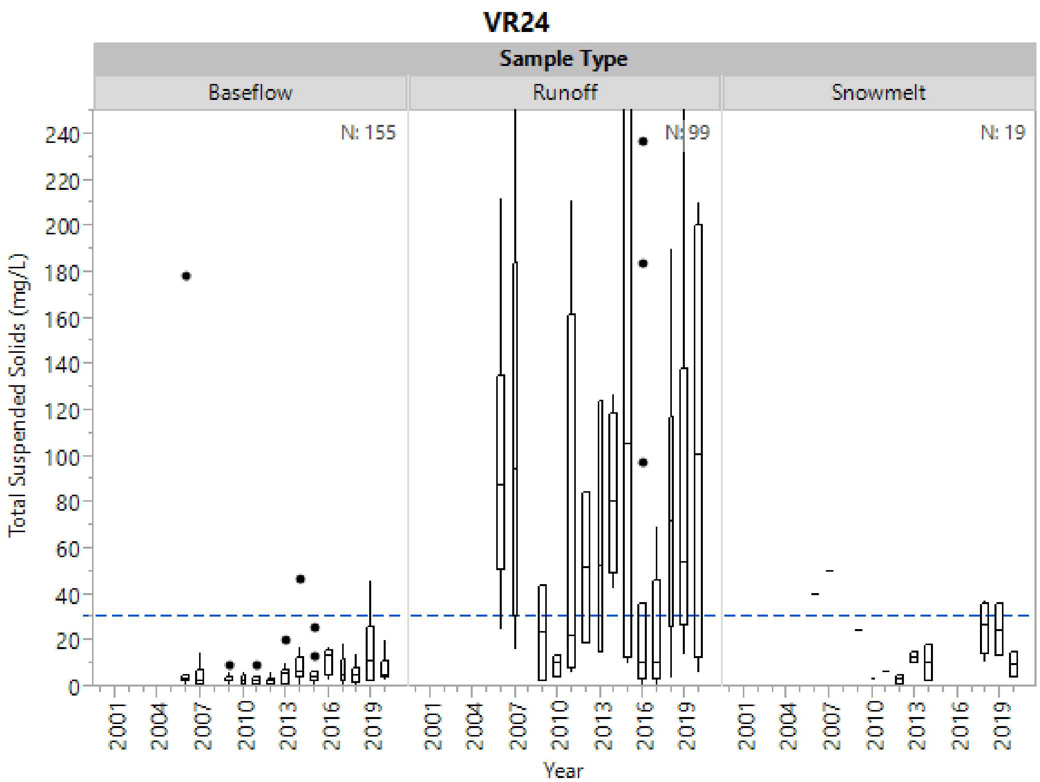


Figure 22a. Historical total suspended solids by sample type at VR24.

**VR24 maximum for 2007 runoff sample extends to 365 mg/L and has an outlier at 434 mg/L and the maximum for 2015 runoff sample extends to 468 mg/L.

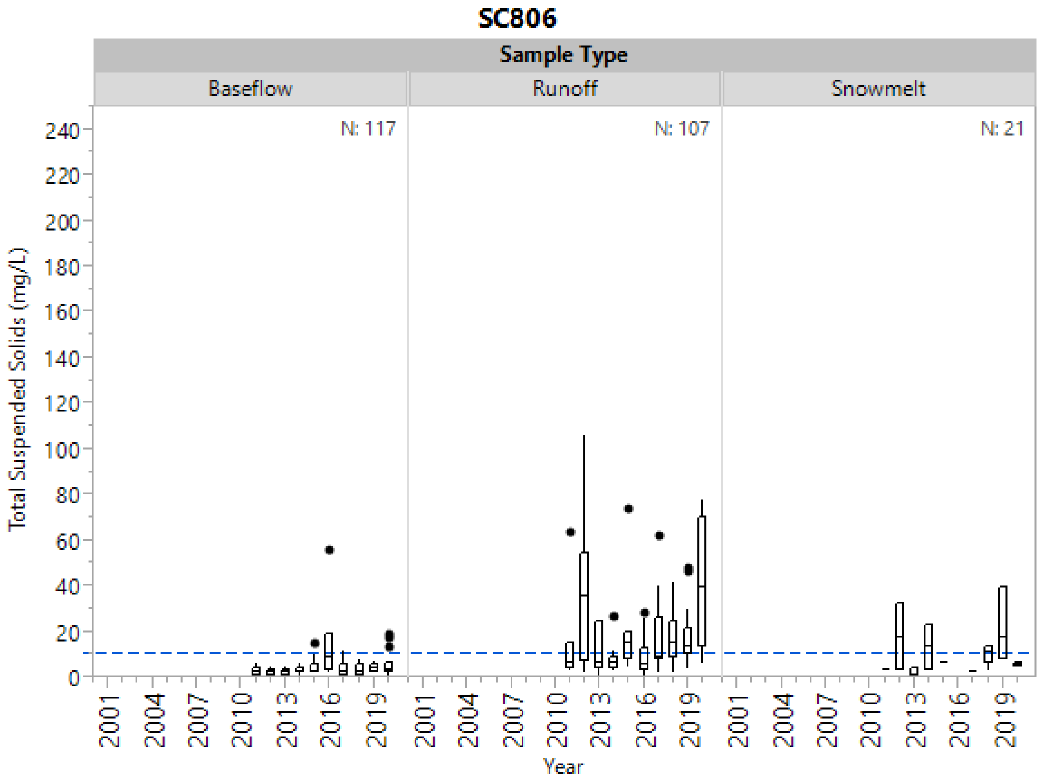


Figure 22b. Historical total suspended solids by sample type at SC806.

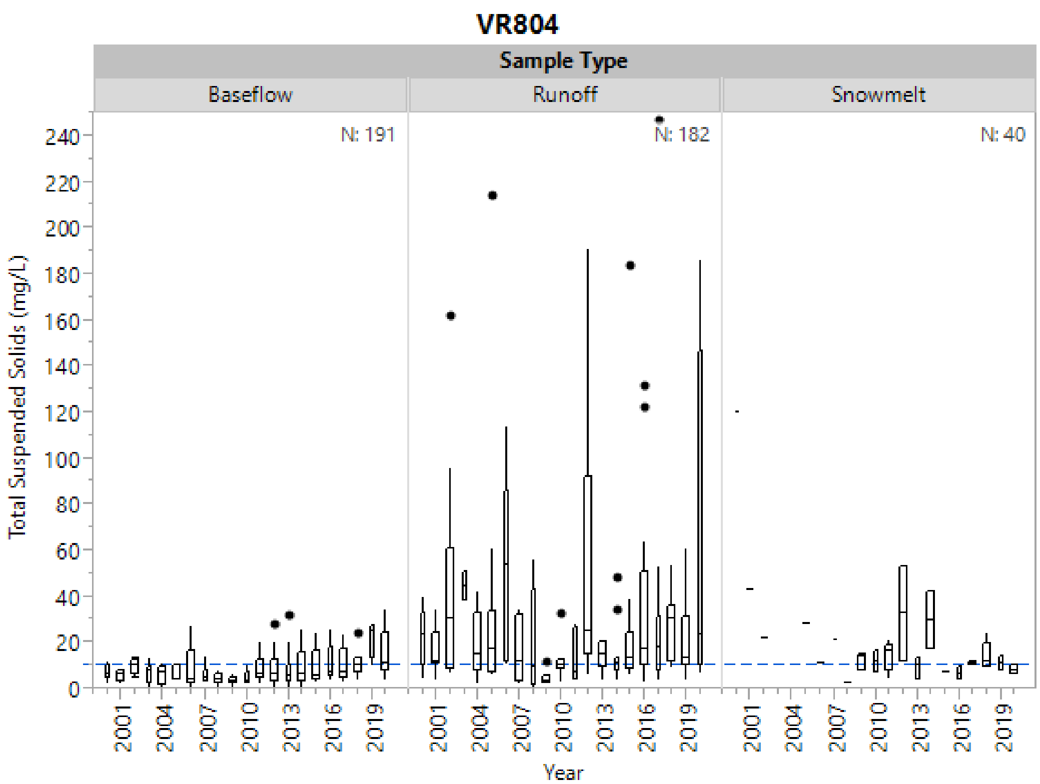


Figure 22c. Historical total suspended solids by sample type at VR804.

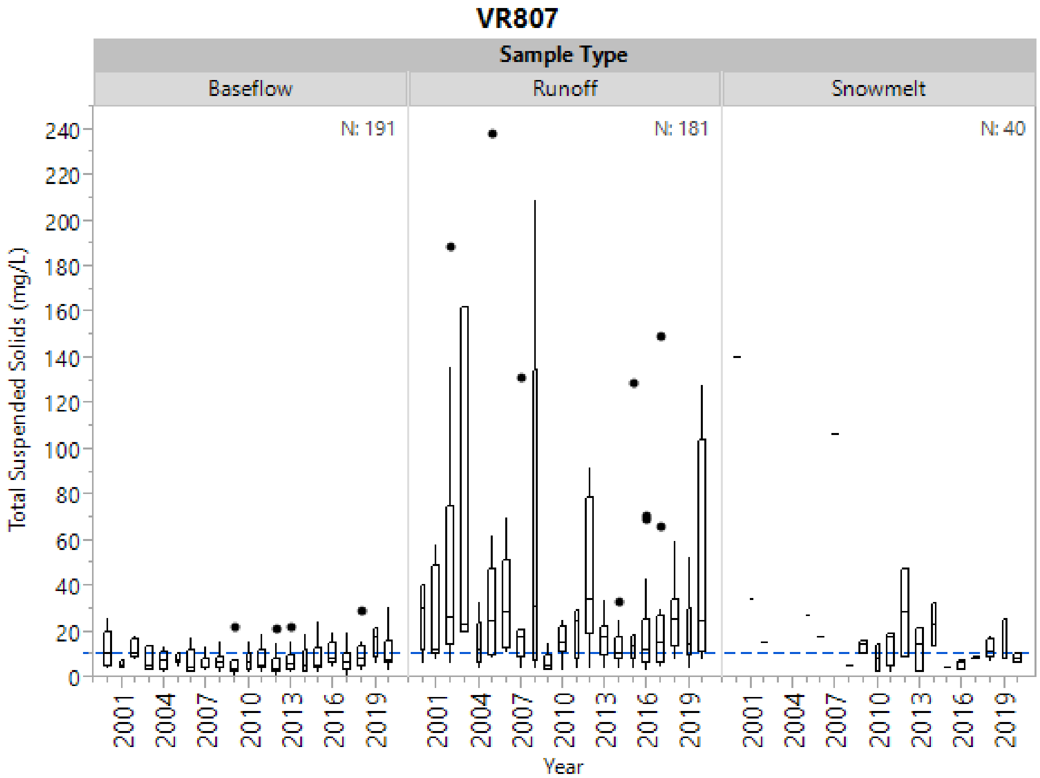


Figure 22d. Historical total suspended solids by sample type at VR807.

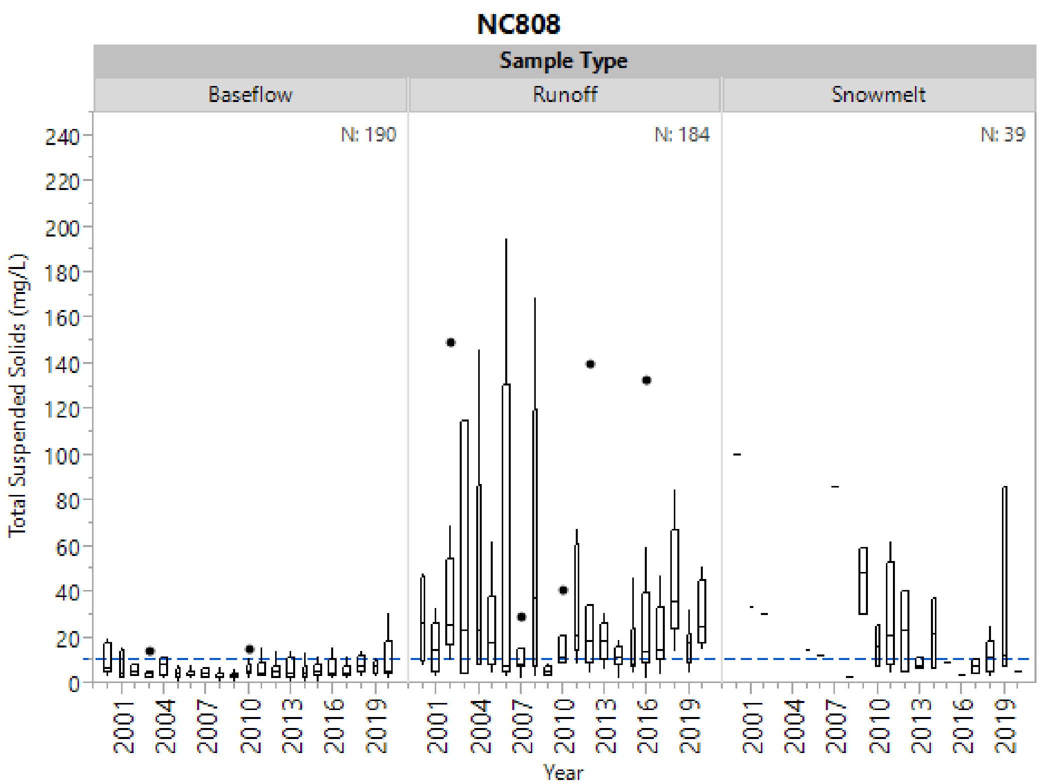


Figure 22e. Historical total suspended solids by sample type at NC808.

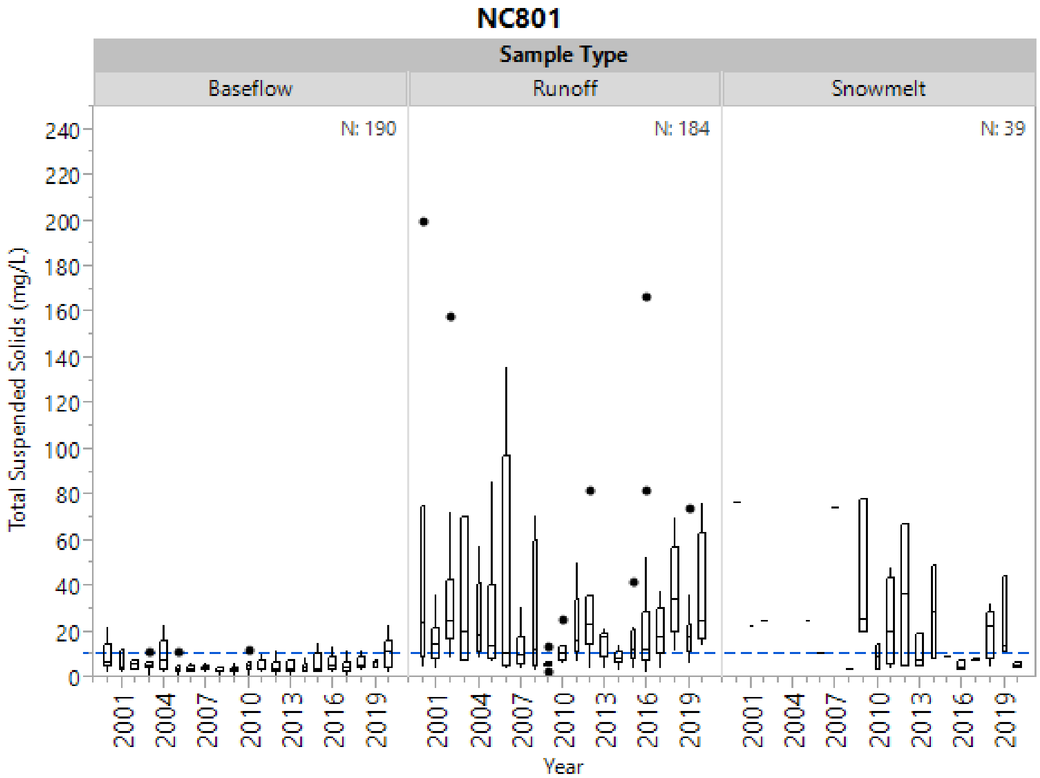


Figure 22f. Historical total suspended solids by sample type at NC801.

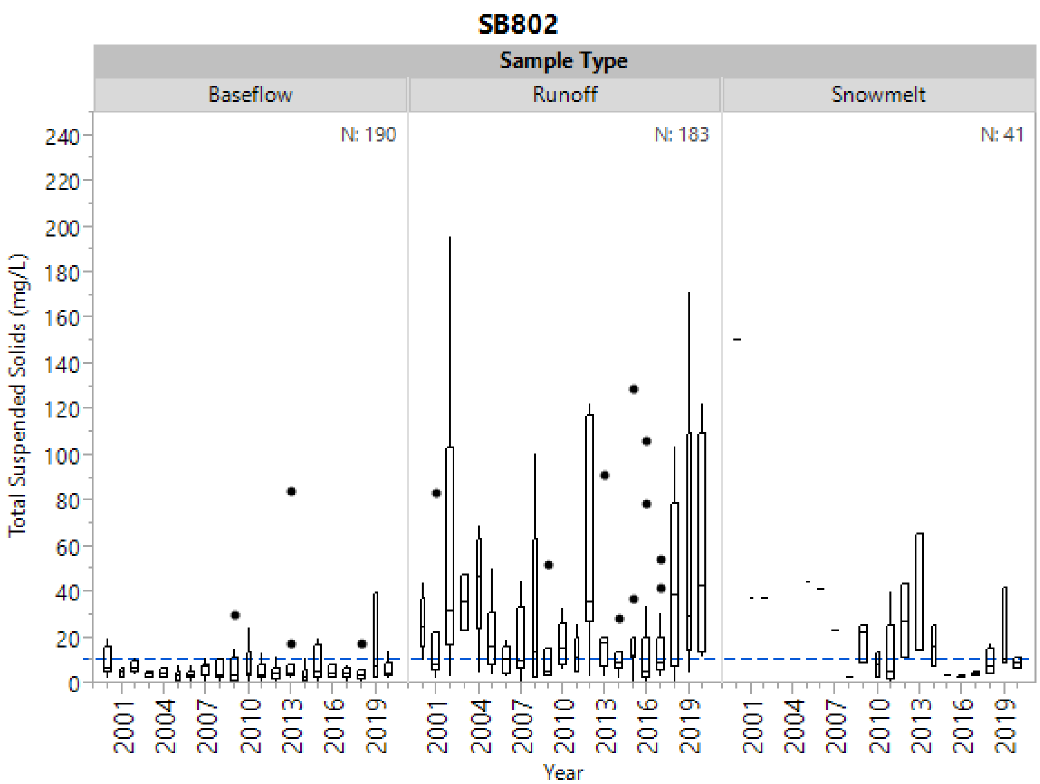


Figure 22g. Historical total suspended solids by sample type at SB802.

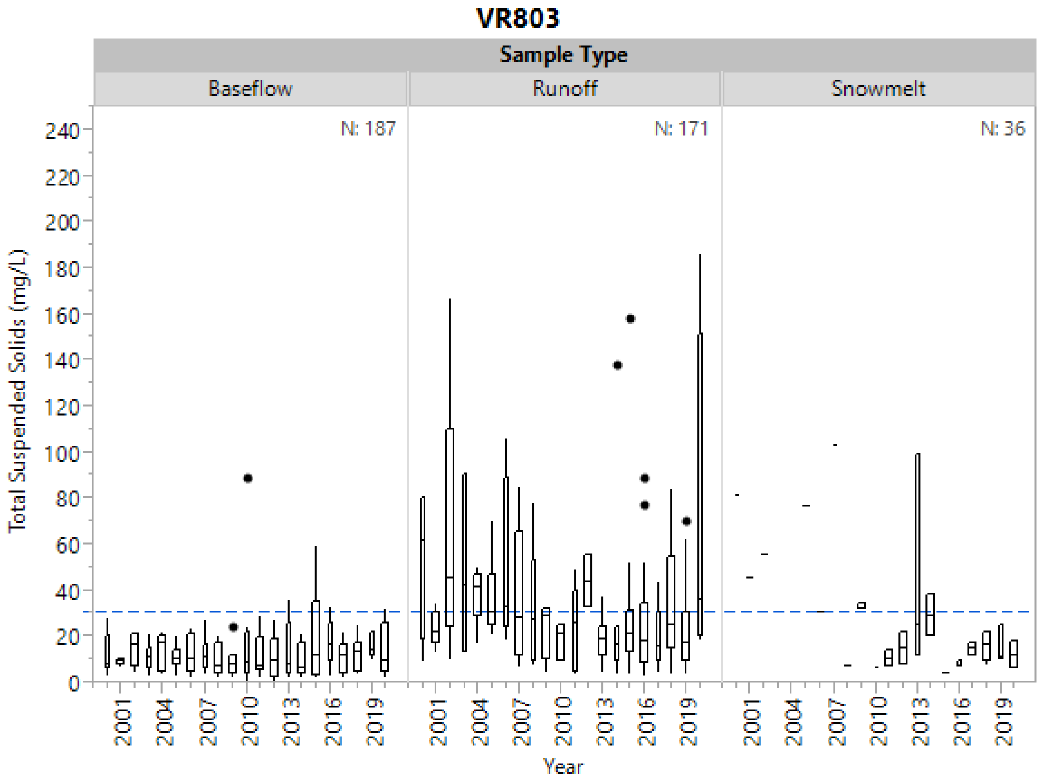


Figure 22h. Historical total suspended solids by sample type at VR803.

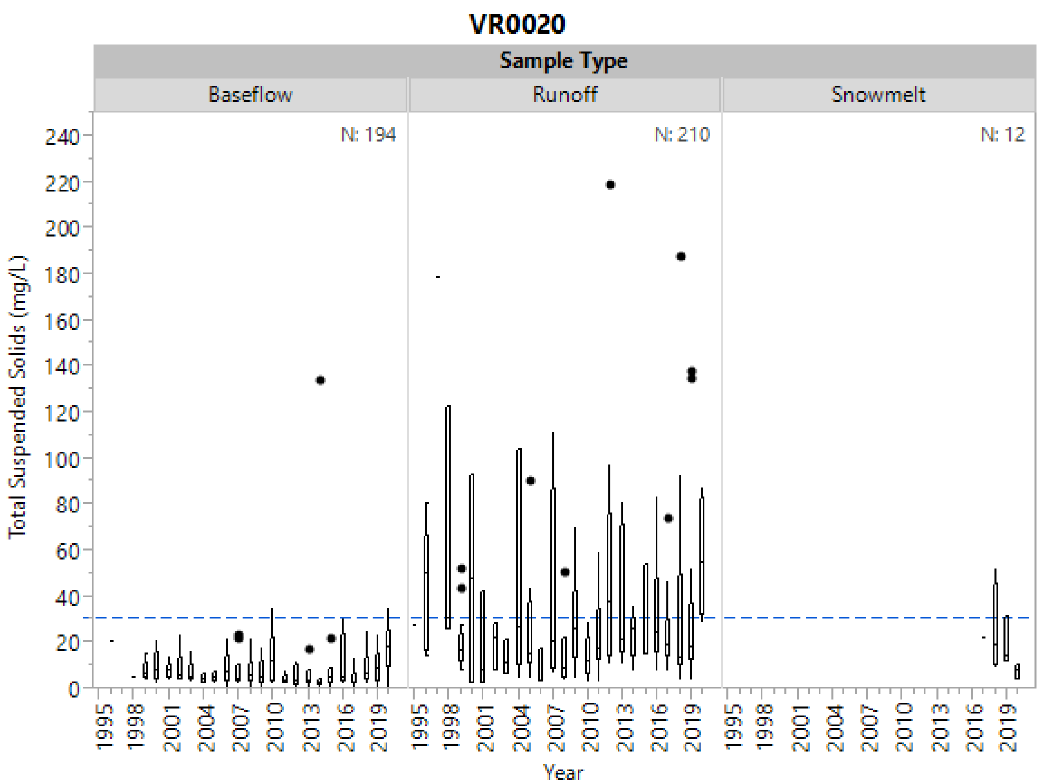


Figure 22i. Historical total suspended solids by sample type at VR0020.

Transparency

Transparency is a simple, fast, and inexpensive method for measuring the clarity of water. There is no state standard for transparency and the nature of the measurement introduces some subjectivity. Nonetheless, it is a useful tool. New equipment for measuring transparency, called a Secchi tube, was introduced in 2012, replacing the transparency tube. The new tubes are an improvement over their predecessors because the taller tubes (100 cm versus 60 cm) allow for more precise readings when water clarity is greater than 60 cm. Clearer water is indicated by a higher transparency reading and a reading of 80 cm means the black and white disk can be seen through a water column 80 cm tall.

When large volumes of water move through the stream at higher velocities, such as after a large rain event, the sediment is suspended in the water column. Transparency decreases for runoff samples as more material is suspended in the water. Snowmelt samples also have decreased transparency, though transparency readings can be quite variable depending on how quickly the snow melts.

Water is relatively clear during baseflow conditions at all stations, often exceeding the measurement limit of 100 cm (Figure 23). Station VR804 has the poorest baseflow sample medians relative to the other monitoring sites in the watershed. Sandy soils dominate the area and the stream bed contains a lot of sand. Sandy substrate is easily suspended in the water column, making the water cloudy.

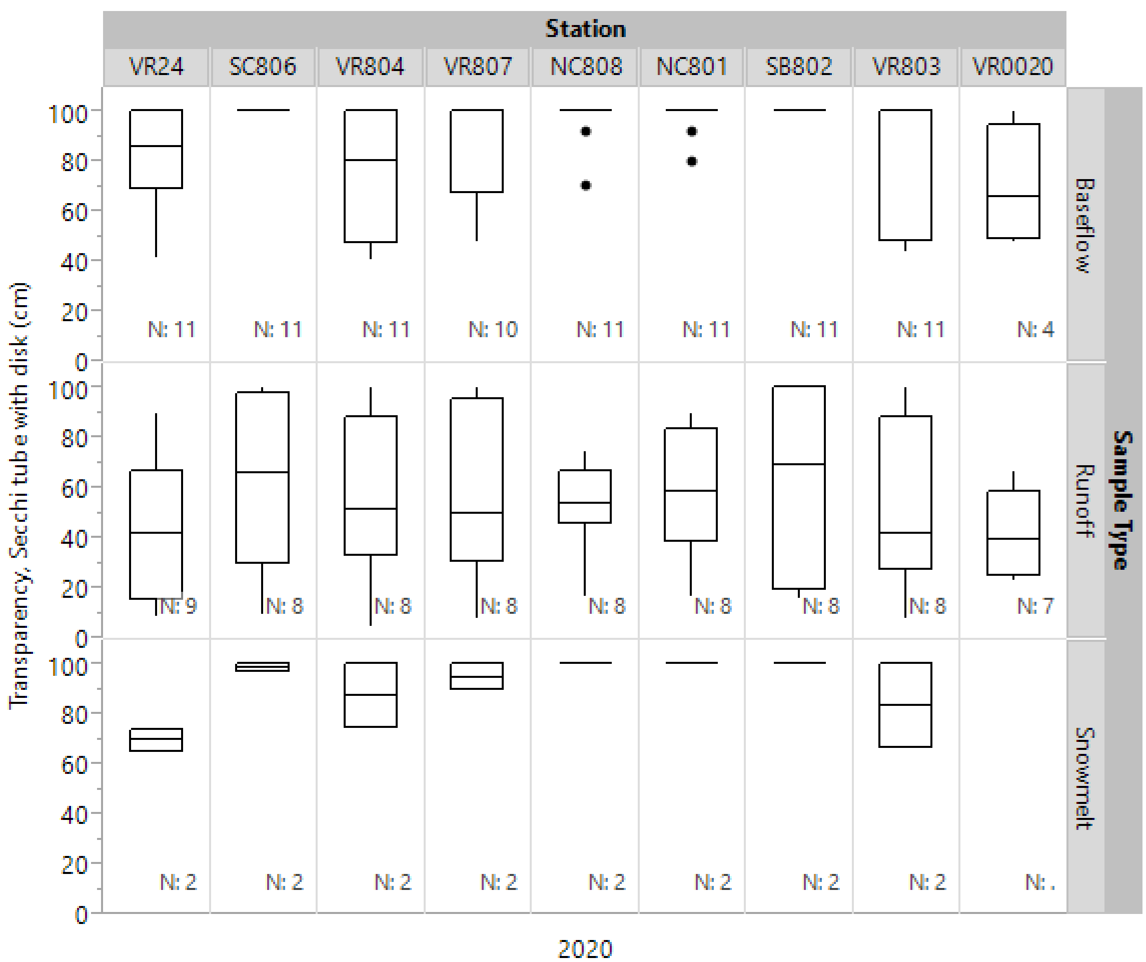


Figure 23. Transparency, categorized by sample type, for 2020.

The historical data in Figure 24a-i shows a lot of year-to-year variability, closely related to rainfall amount and intensity. Overall, baseflow condition measurements show greater clarity than runoff conditions and snowmelt measurements tend to be relatively clear, though not as clear as baseflow condition measurements. The vertical red line in each of the historical figures indicates when the 60 cm transparency tubes were phased out and the 100 cm Secchi tubes were introduced in 2012.

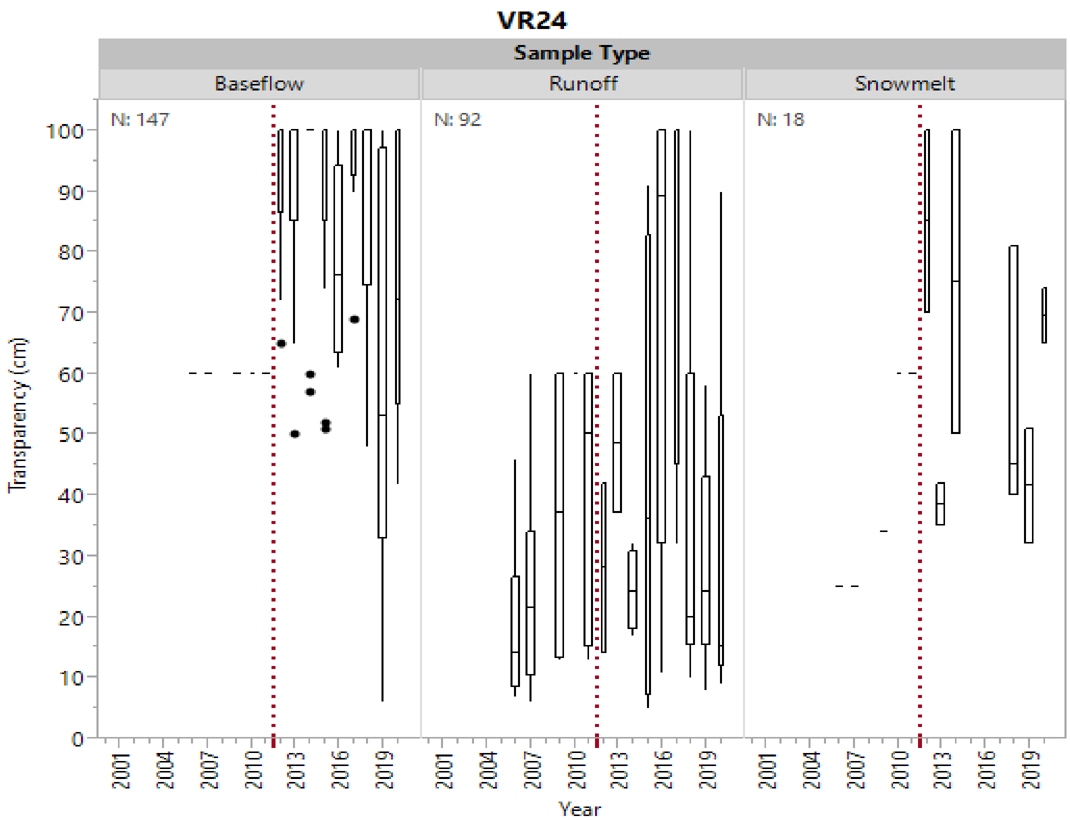


Figure 24a. Historical transparency by sample type for VR24.

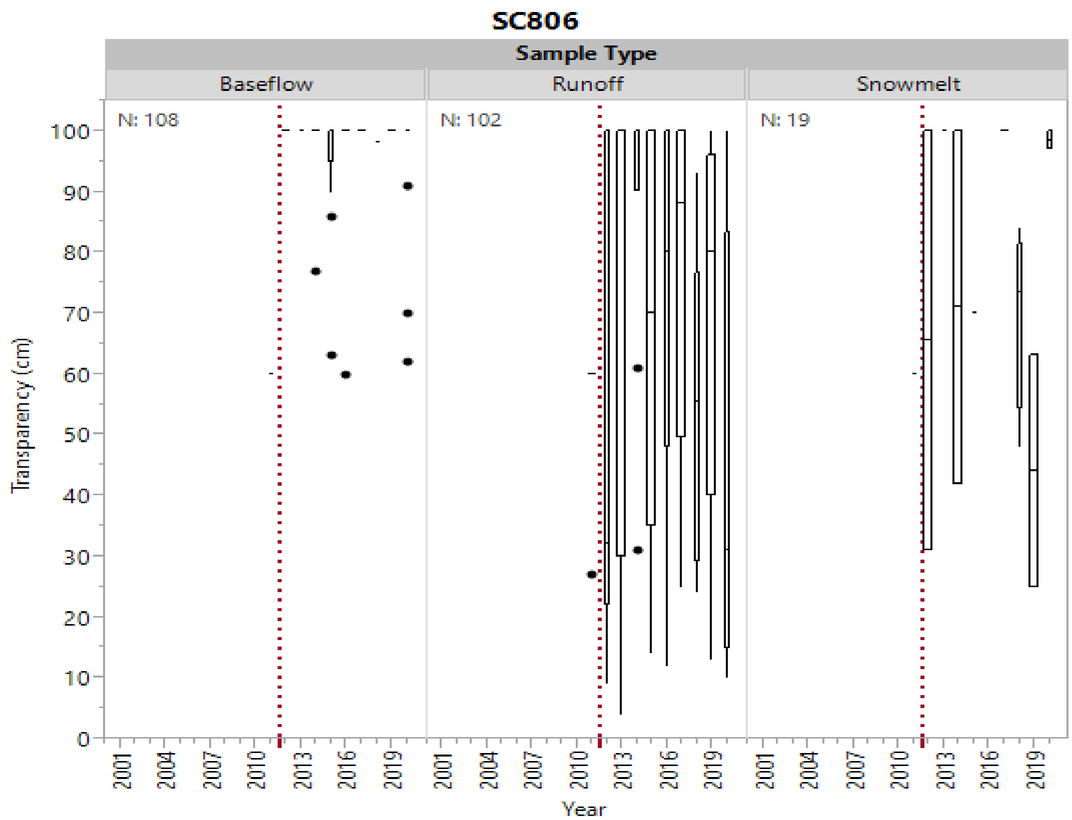


Figure 24b. Historical transparency by sample type for SC806.

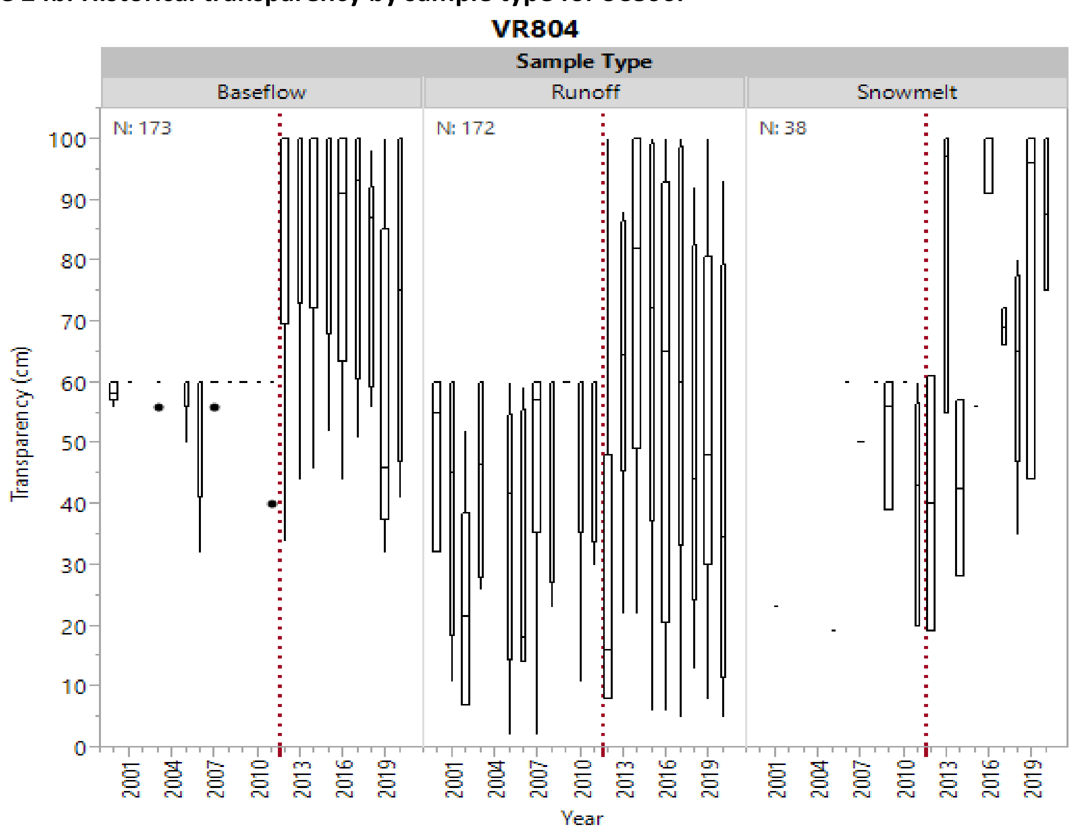


Figure 24c. Historical transparency by sample type for VR804.

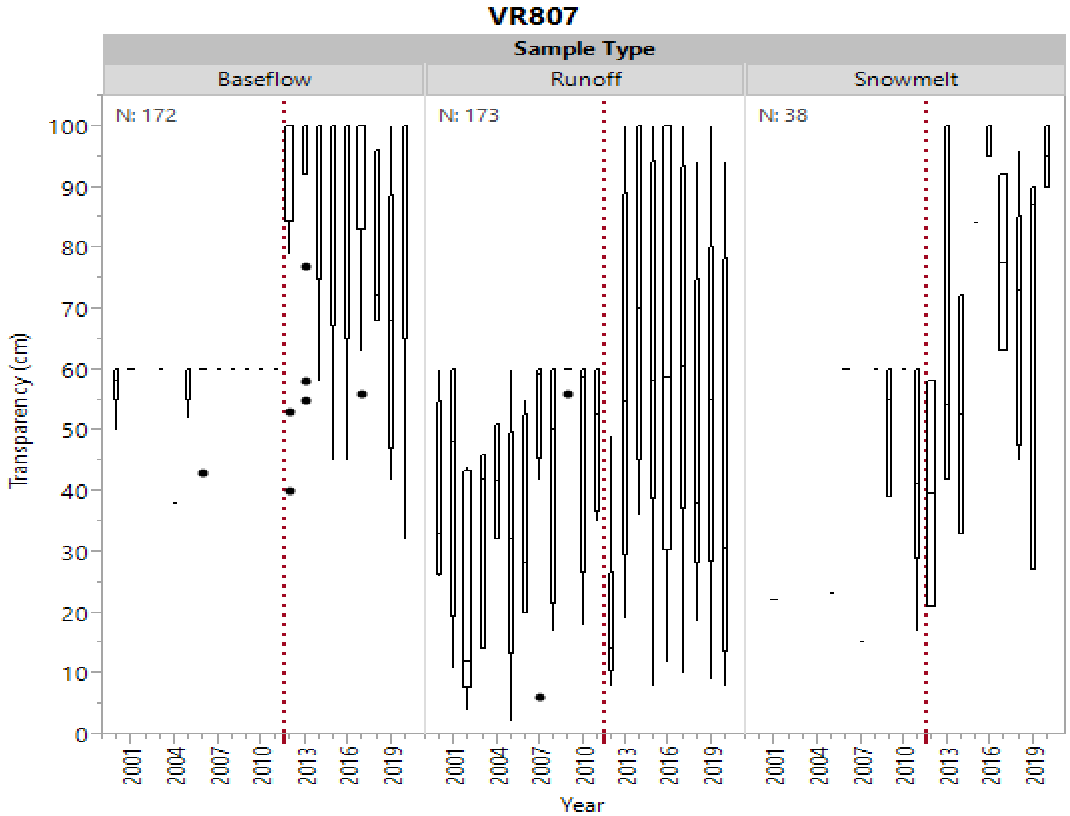


Figure 24d. Historical transparency by sample type for VR807.

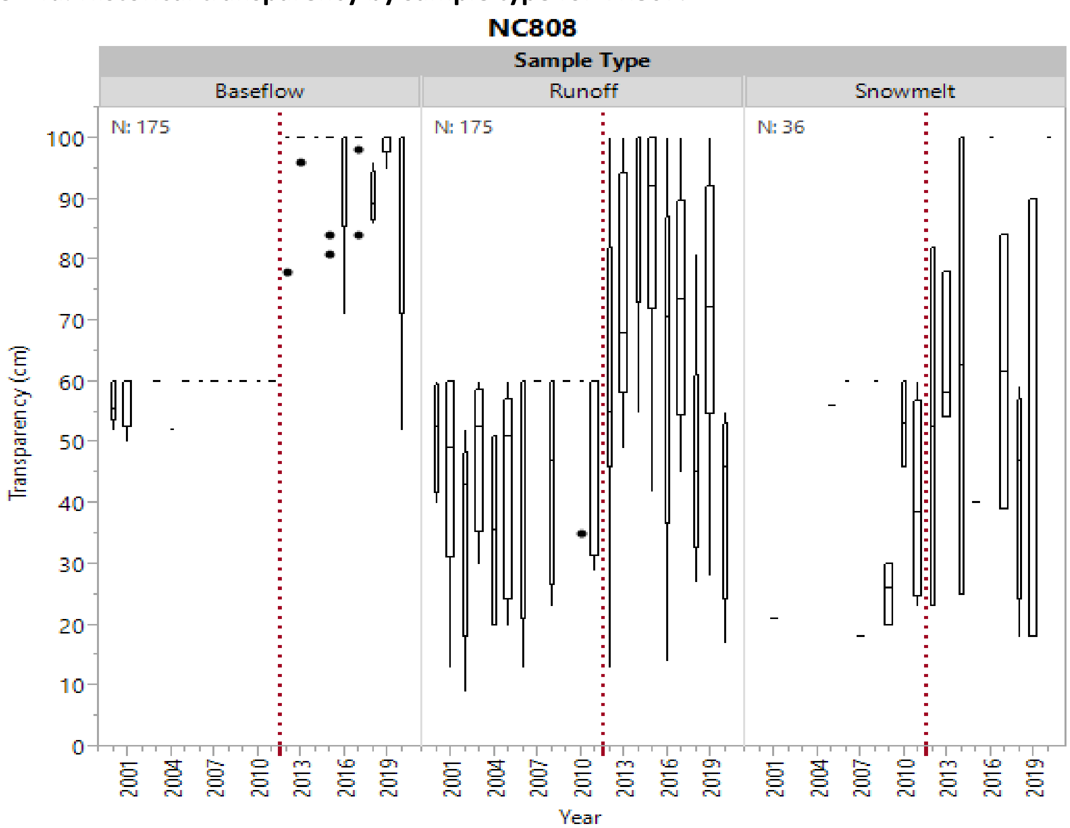


Figure 24e. Historical transparency by sample type for NC808.

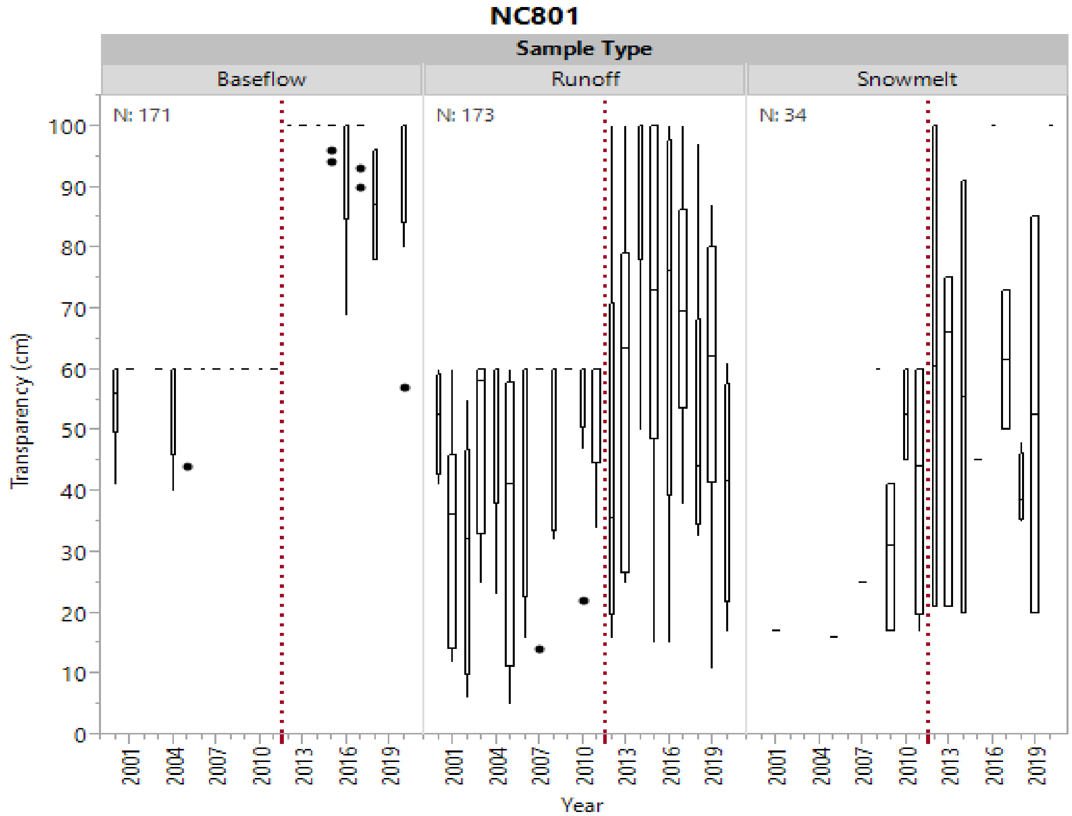


Figure 24f. Historical transparency by sample type for NC801.

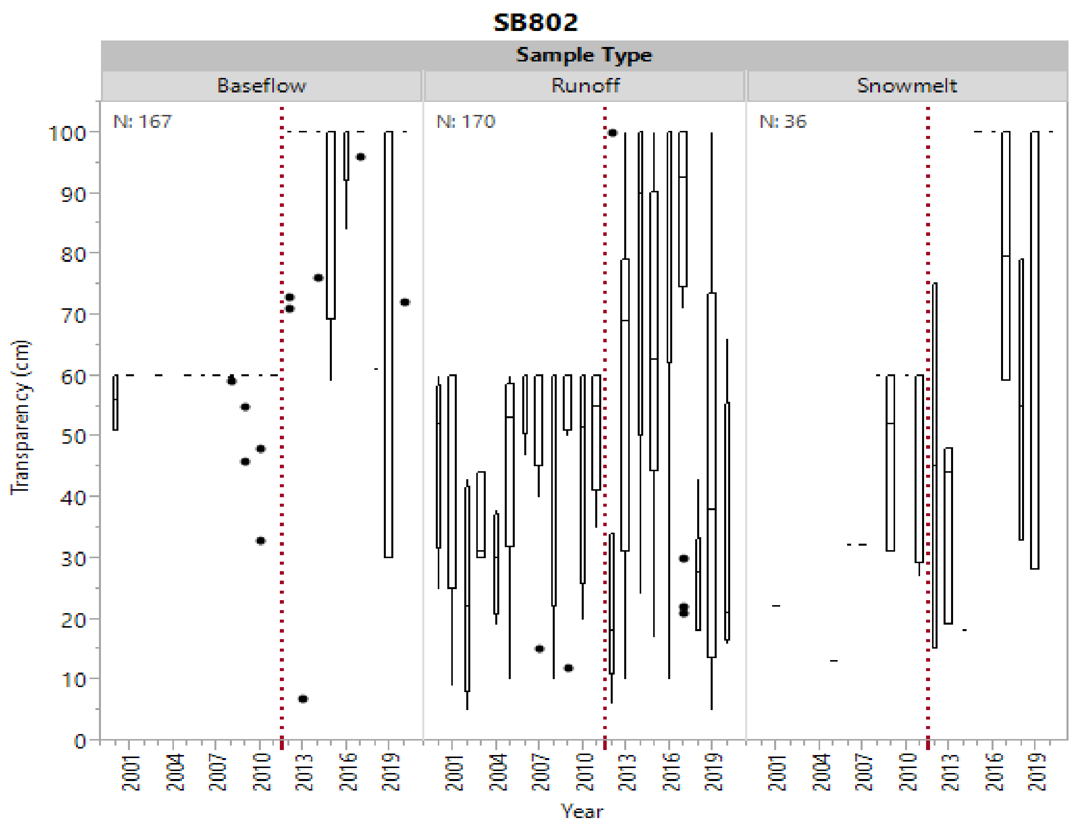


Figure 24g. Historical transparency by sample type for SB802.

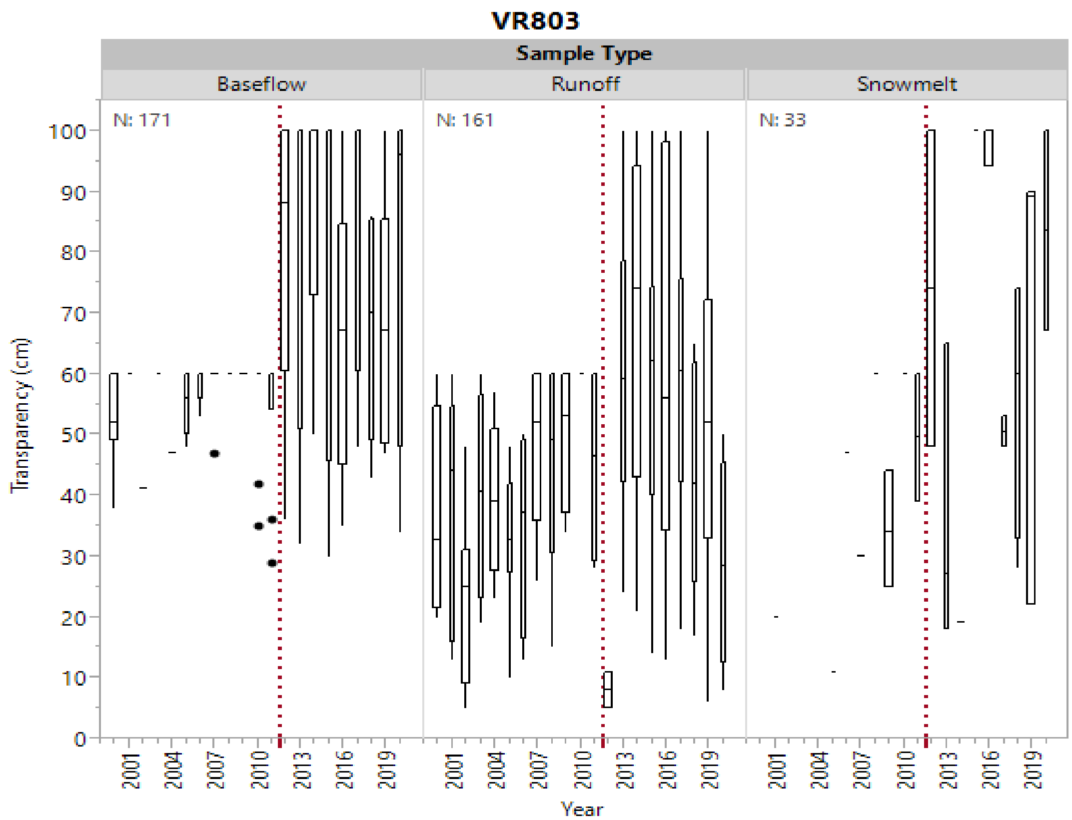


Figure 24h. Historical transparency by sample type for VR803.

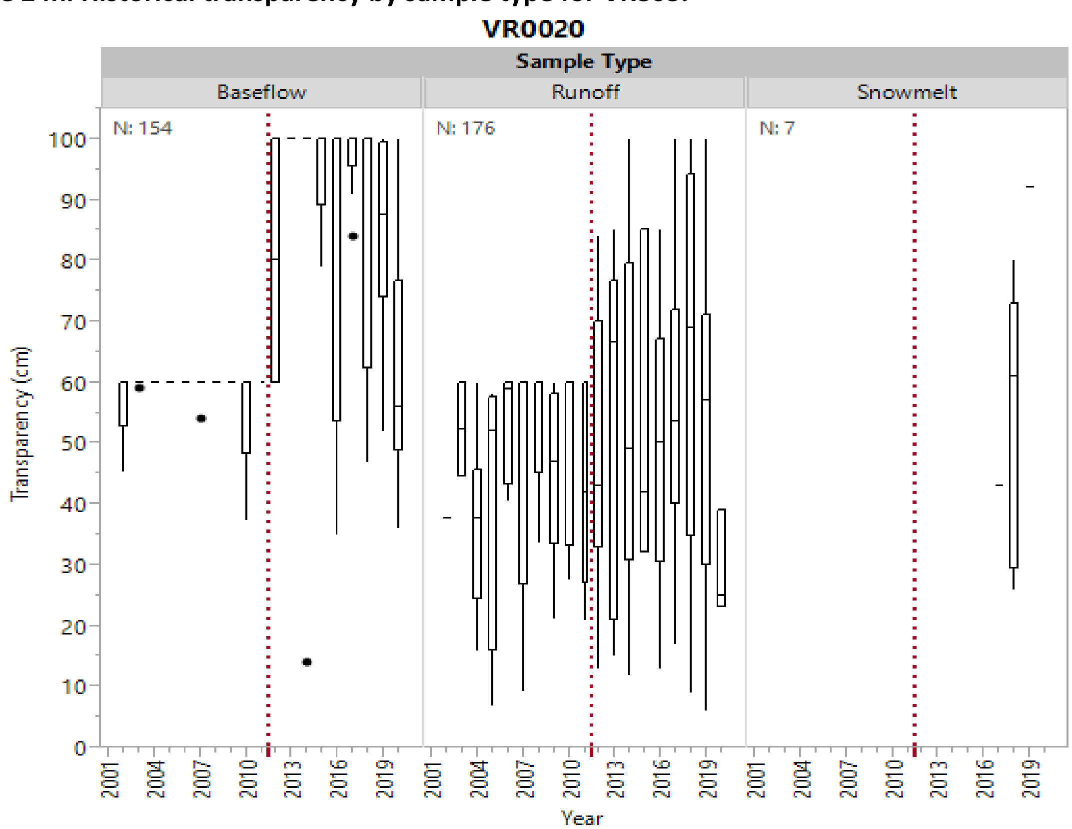


Figure 24i. Historical transparency by sample type for VR0020.

Load Duration Curve

A load duration curve provides a visual characterization of pollutant concentrations at different flow regimes, creating a clear representation of the frequency and magnitude of water quality standard violations, if any, for a given parameter (EPA 2007). By displaying instantaneous loads calculated from the discrete water quality data collected at a given monitoring location and the daily average flow on the sampling date, a pattern develops which illustrates the attributes of the water quality impairment for the parameter of interest.

Duration curve analysis of water quality data identifies different flow intervals, which can be used as a general indicator of the hydrologic condition at the specific monitoring location (i.e. lots of water versus little and to what relative degree). These intervals provide additional information regarding patterns and conditions that are associated with the impairment.

Loads that display on the graph above the curve (calculated using the state standard) indicate a violation of the water quality standard, while those plotting below the load duration curve indicate that the standard is being met. The impairment pattern on the graph can be examined to see if exceedances occur across all flow conditions, or if they occur only during high or low flow events. Standard exceedances observed in the low flow zones (60-100%) generally indicate influence by chronic sources (wastewater discharge), whereas exceedances in the high or very high zones (0-40%) reflect potential acute source contributions (streambank erosion, runoff, faulty septic systems) to the subwatershed.

Load duration curves were created for *E. coli*, nitrate, total phosphorus, and total suspended solids the all eight monitoring stations in the VRMN, plus the WOMP station in Hastings. Load duration curves are generated using both historical monitoring data and monitoring results from 2020.

E. coli

E. coli loads exceeded the state standard (≤126 MPN/100mL) across all flow regimes at all sites (Figures 25a-i). Consistently elevated levels of *E. coli* are indicative of a chronic source of *E. coli* in the watershed that is contributing across all flow regimes, not just during very high or high flows.

E. coli concentrations at all eight sites were elevated in 2020. The highest concentration was recorded in October at VR24 (193,500 MPN/100mL). The next highest value is 17,500 MPN/100mL, recorded at both NC801 and SB802 in May. High *E. coli* levels in the water could be caused by excess runoff from agricultural and urban land areas, failing septic systems, or resuspension of bacteria in the sediment.

VR24 *E. coli* Load Duration Curve

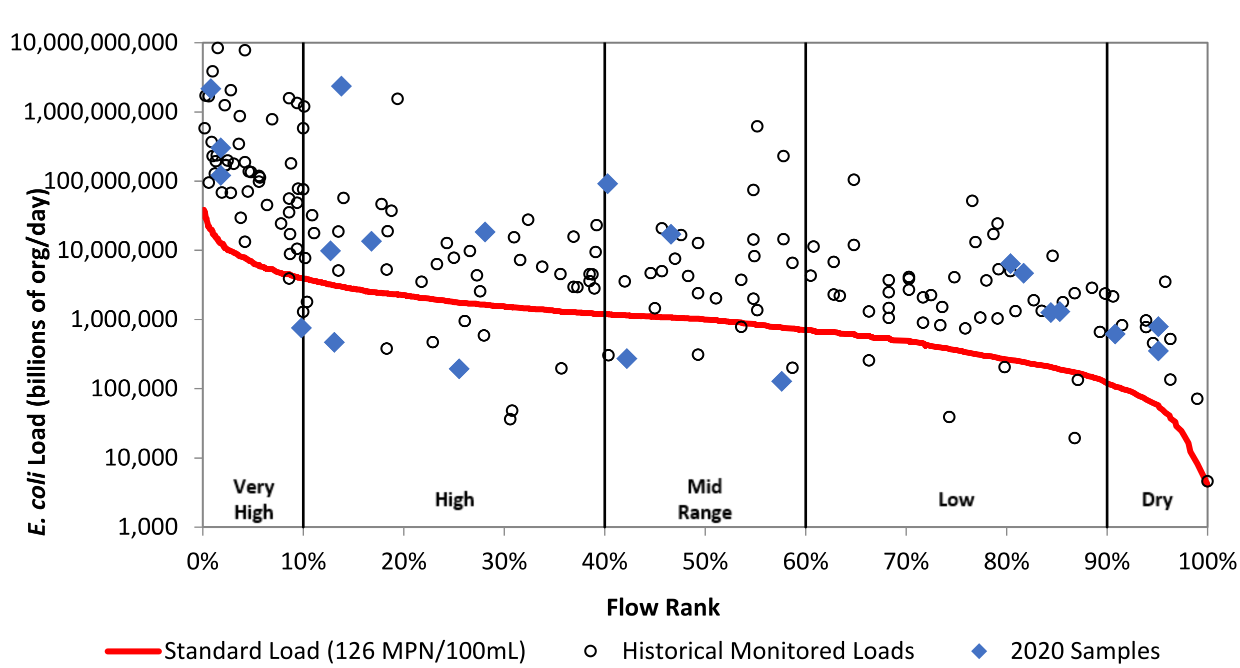


Figure 25a. Load duration curve for *E. coli* at VR24.

SC806 *E. coli* Load Duration Curve

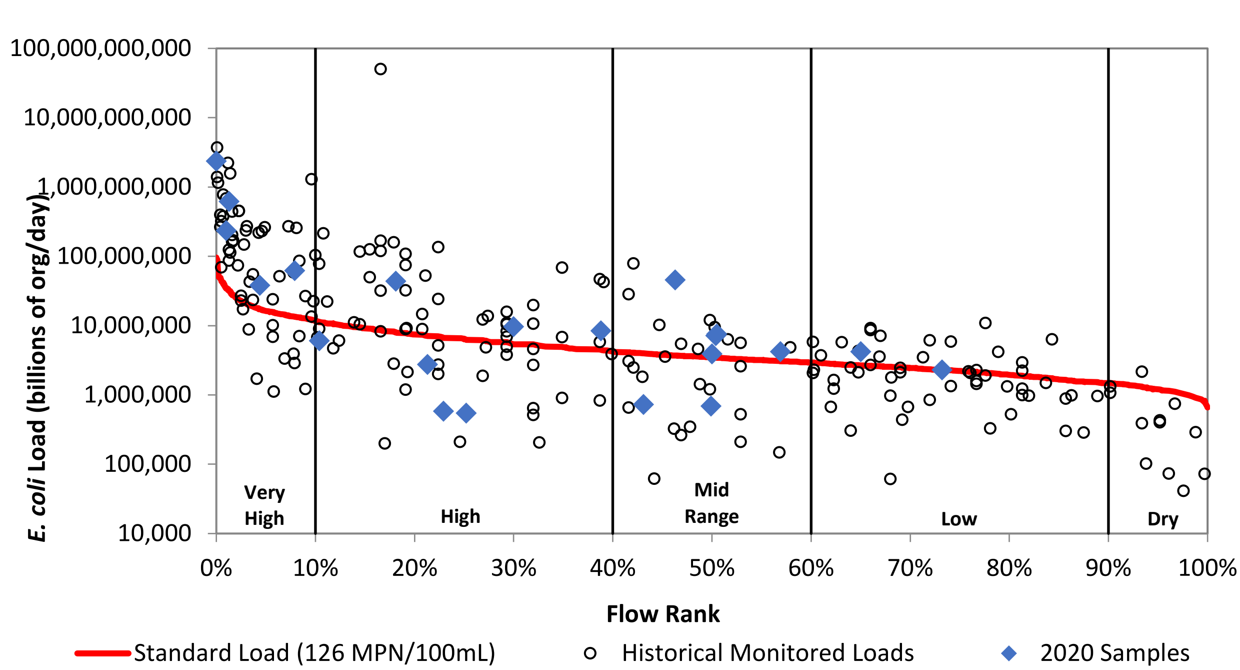


Figure 25b. Load duration curve for *E. coli* at SC806.

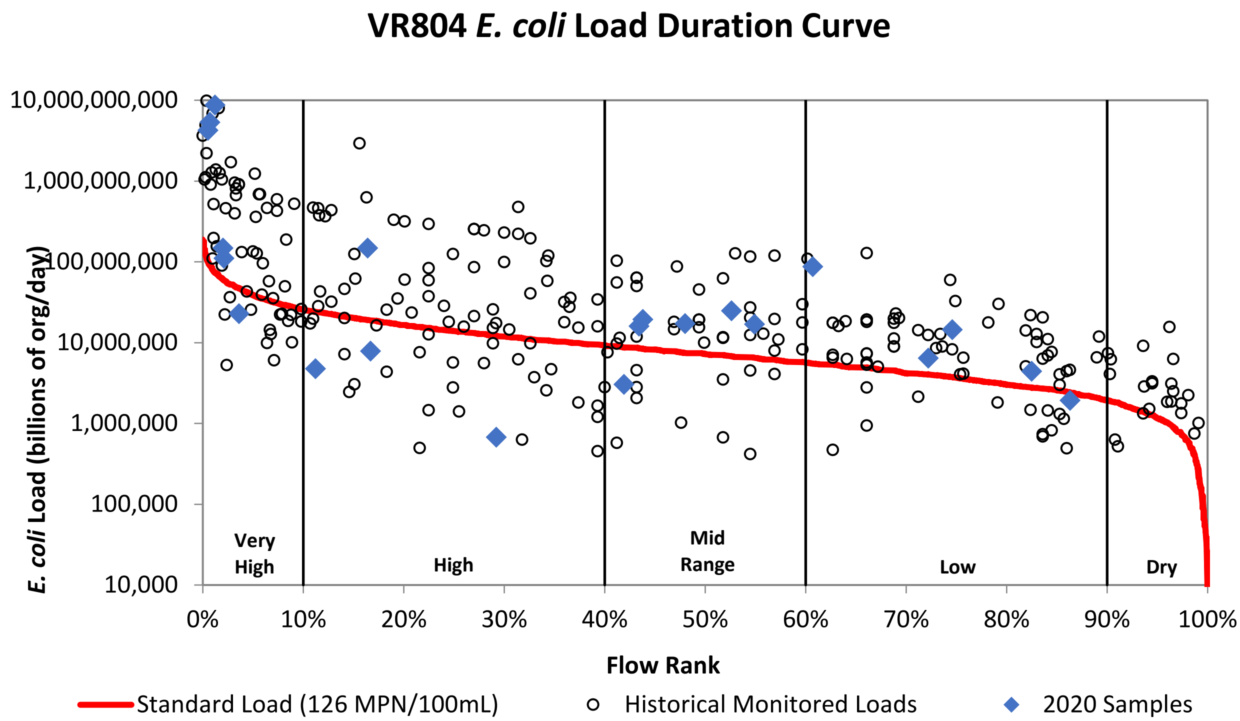


Figure 25c. Load duration curve for *E. coli* at VR804.

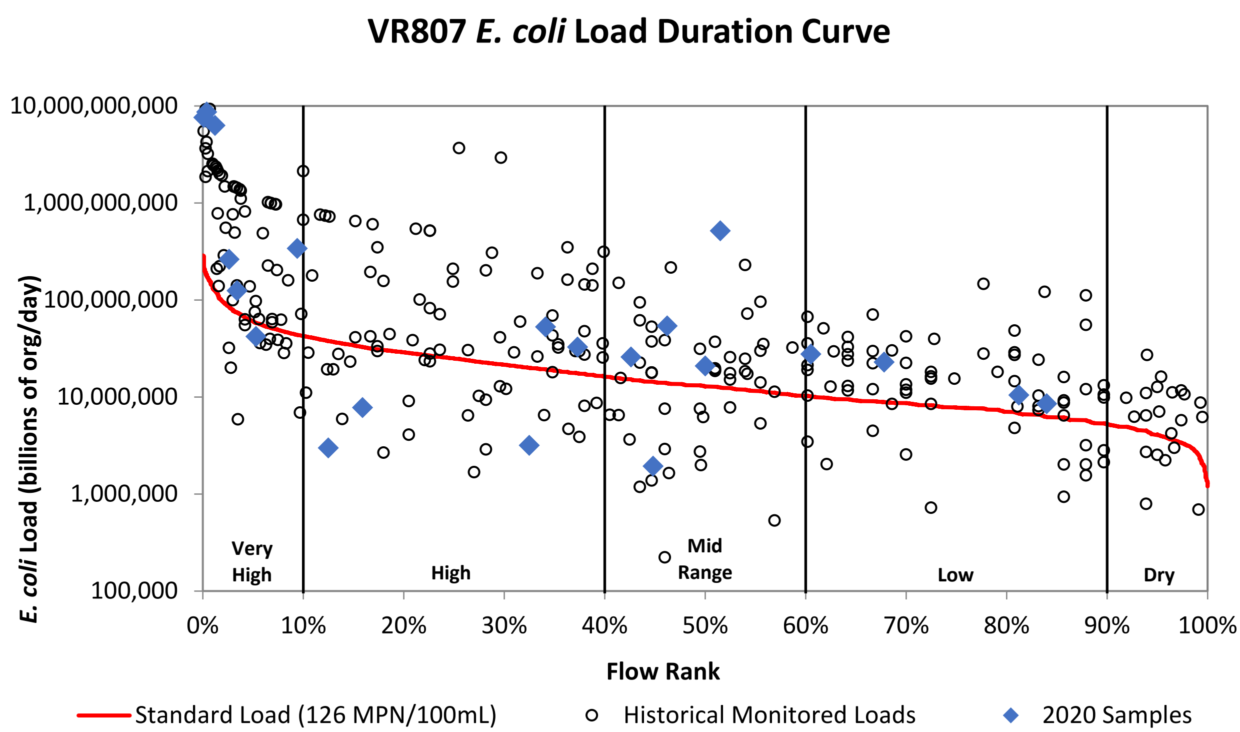


Figure 25d. Load duration curve for *E. coli* at VR807.

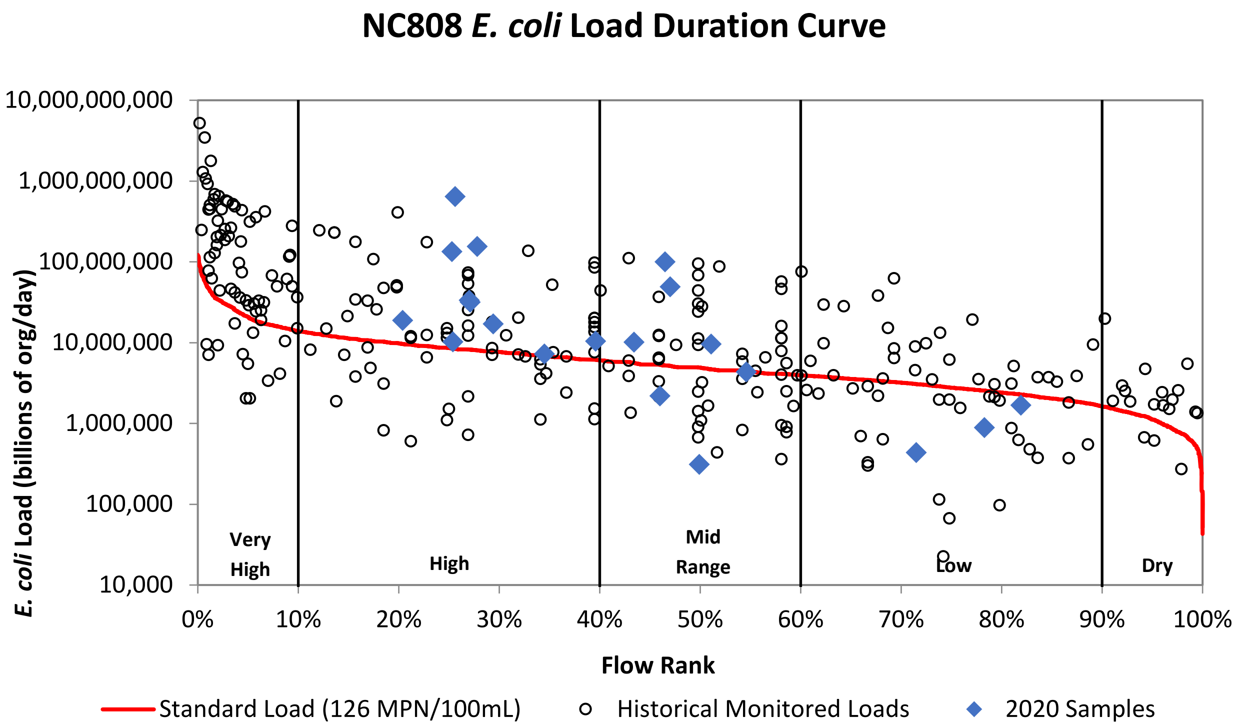


Figure 25e. Load duration curve for *E. coli* at NC808.

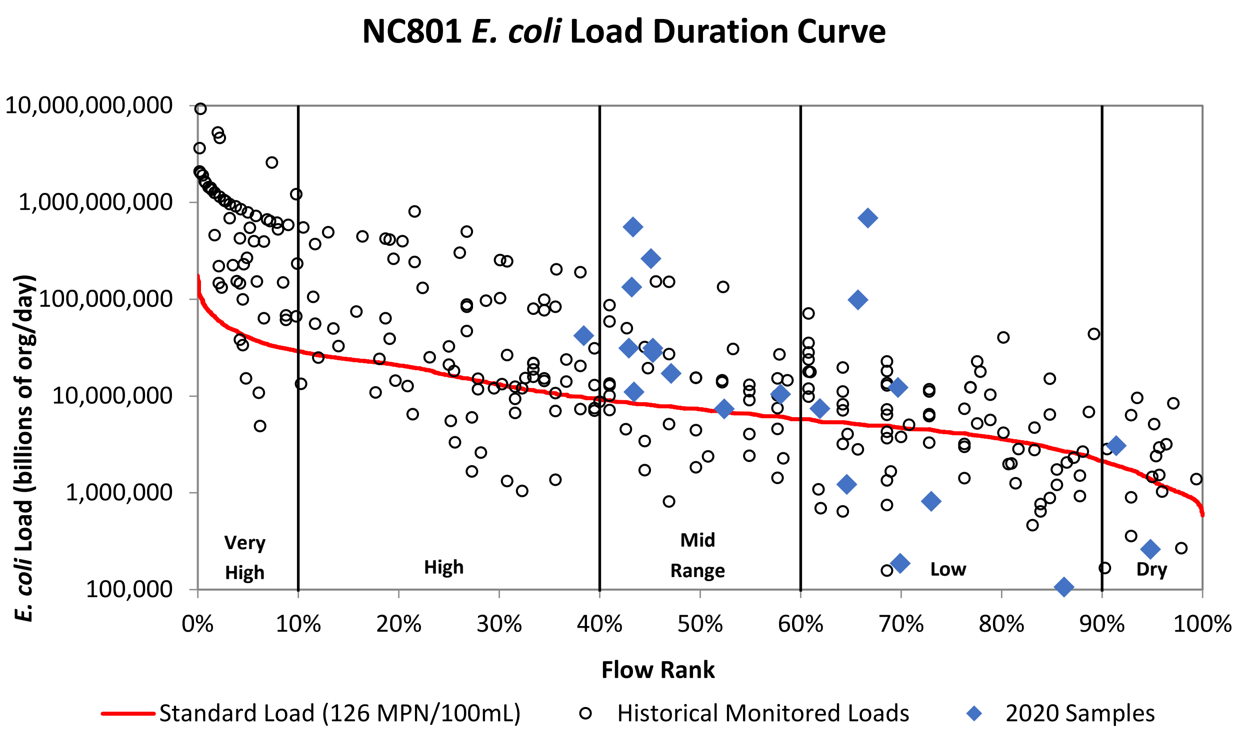


Figure 25f. Load duration curve for *E. coli* at NC801.

SB802 *E. coli* Load Duration Curve

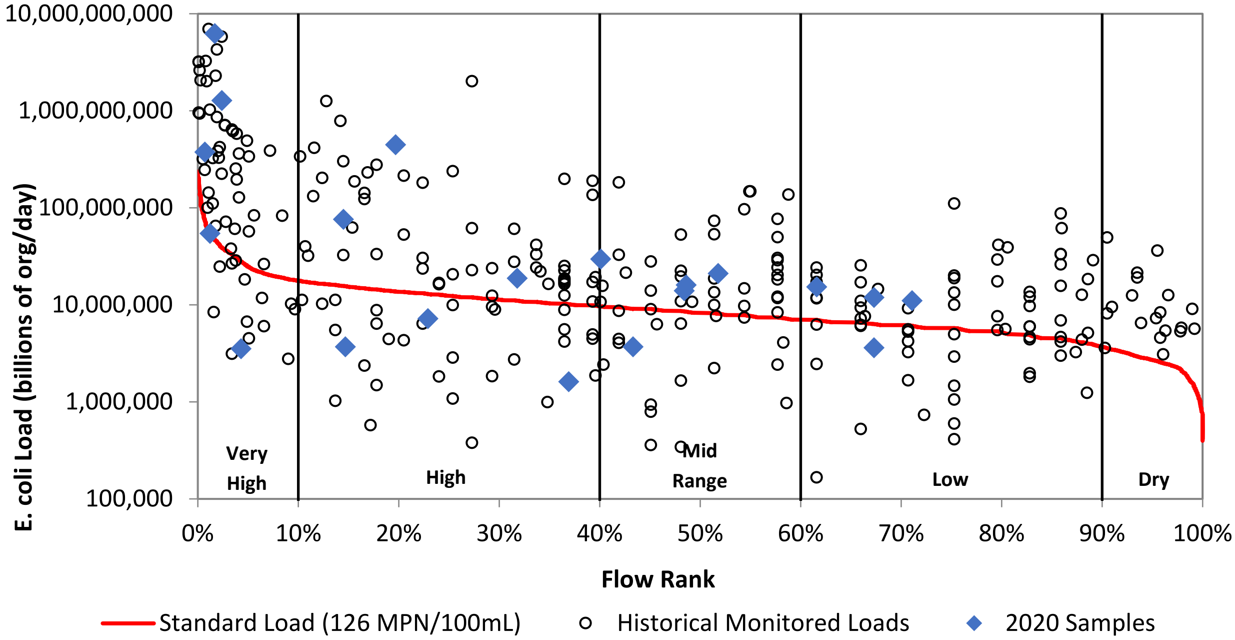


Figure 25g. Load duration curve for *E. coli* at SB802.

VR803 *E. coli* Load Duration Curve

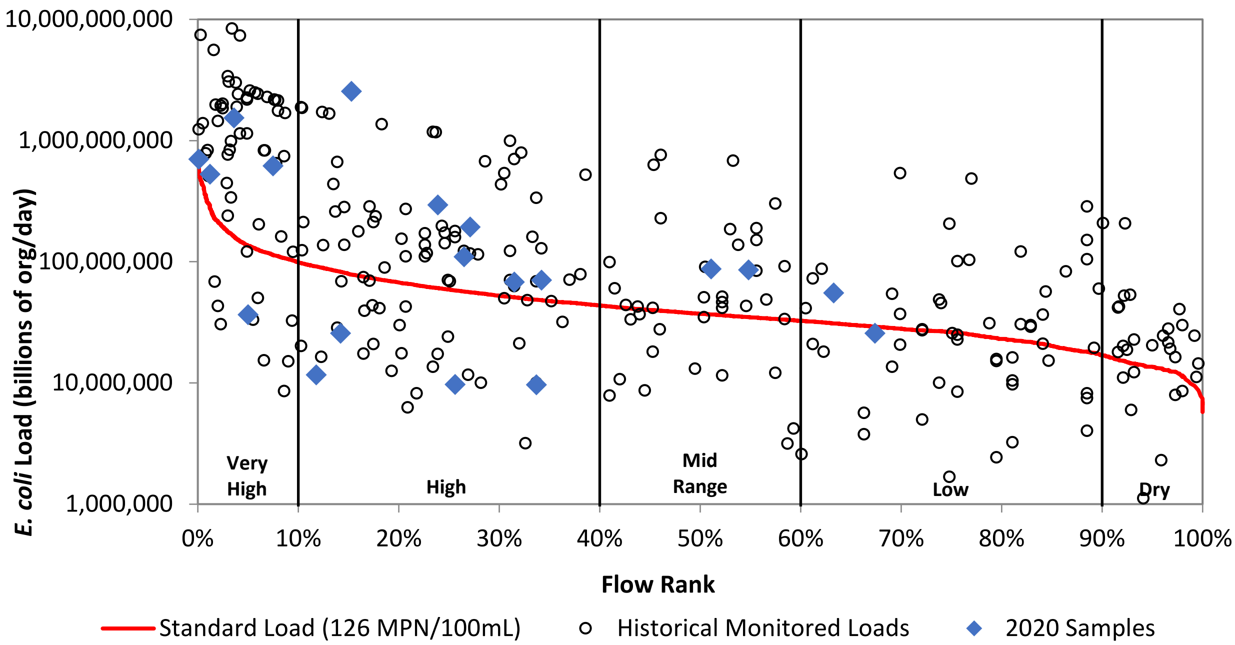


Figure 25h. Load duration curve for *E. coli* at VR803.

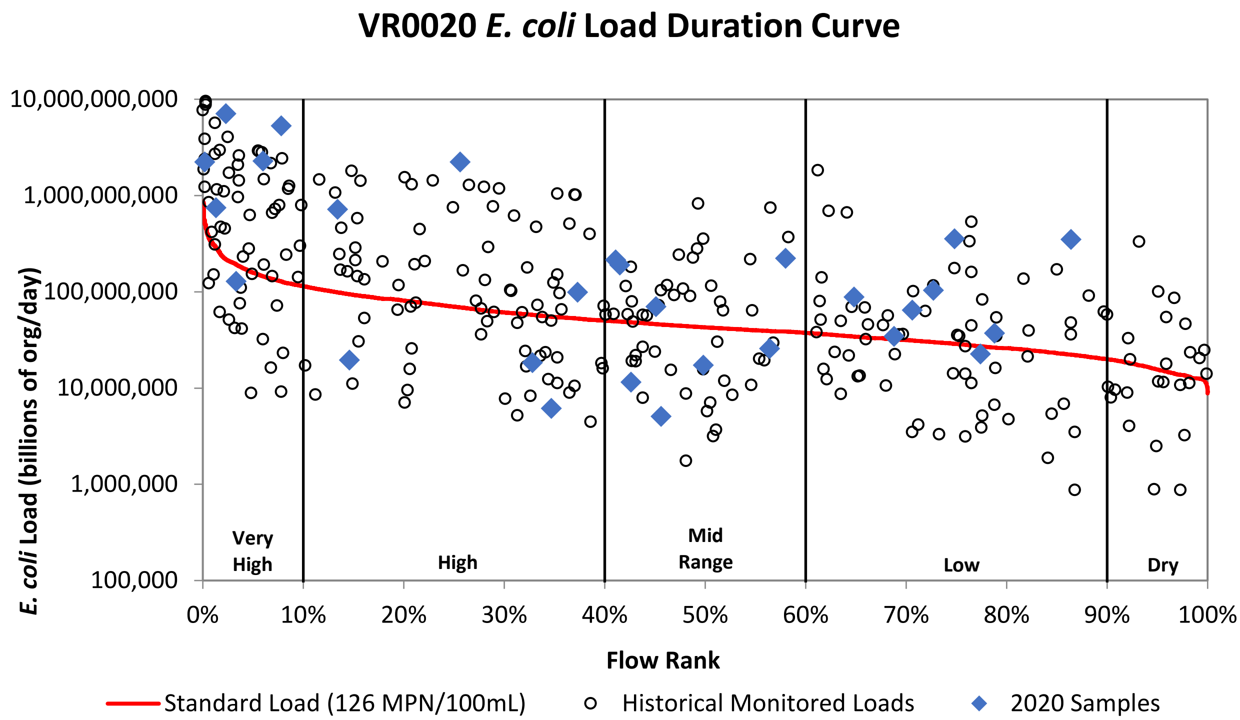


Figure 25i. Load duration curve for *E. coli* at VR0020.

Nitrate

As expected, nitrate loads were highest at SB802 (Figure 26g), though no monitoring site had exceedances of the drinking water standard at any flow regime in 2020 (≤10mg/L) (Figures 26a-i). Increased nitrate loads at SB802 could be attributed to the highly agricultural land use in the subwatershed, resulting from extensive use of drain tiles and/or increased fertilizer application resulting in nitrate leaching into shallow groundwater or directly discharged to the river through drain tiles.

The proposed chronic standard for acute life toxicity (four day average concentration of 4.9 mg/L) for 2B streams (warm water) was used to analyze loading capacity for VR24, VR803, and VR0020 (MPCA 2010). Single day loads at VR24 fell below the chronic standard (Figure 26a), but levels at VR803 and VR0020 were consistently at or near the standard load during very high, high, and mid-range regimes (Figure 26h and 26i). Nitrate loads exceeded the standard load during low flow regime at both sites for the first time ever. The nitrate loading at SB802 (Figure 26g) is a major contributor to elevated nitrate levels at downstream site VR803 and VR0020.

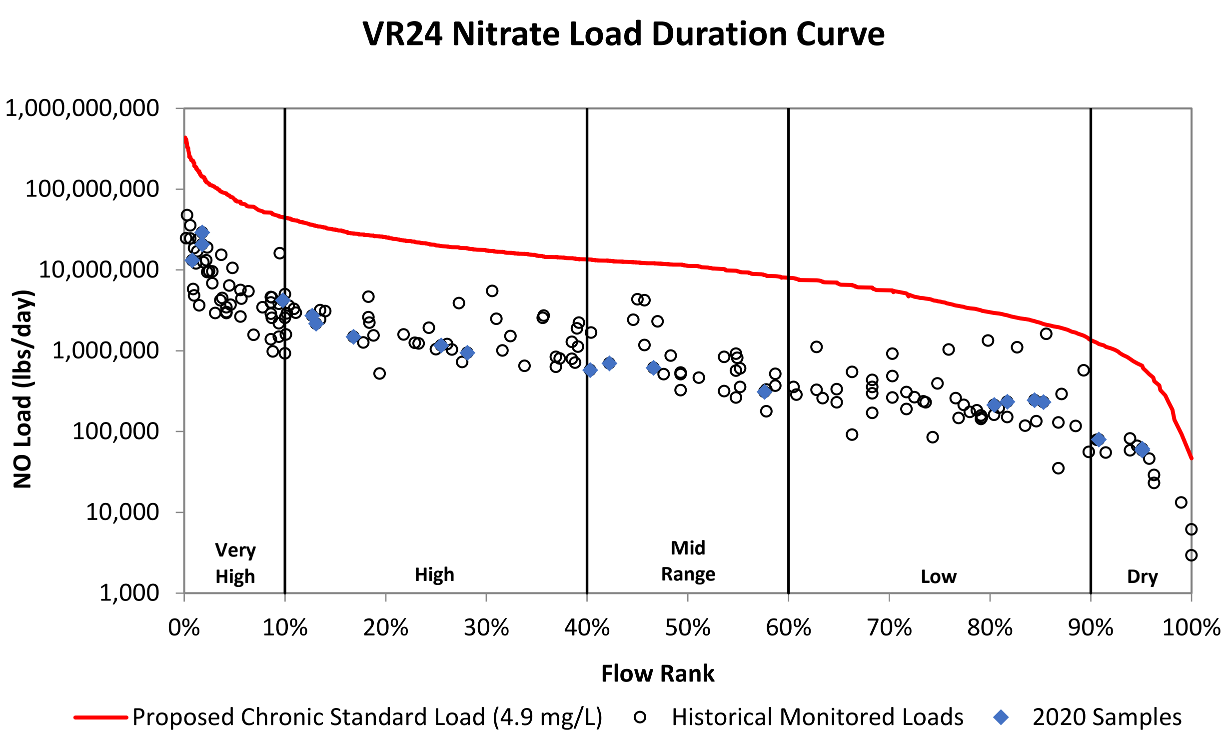


Figure 26a. Load duration curve for nitrate at VR24.

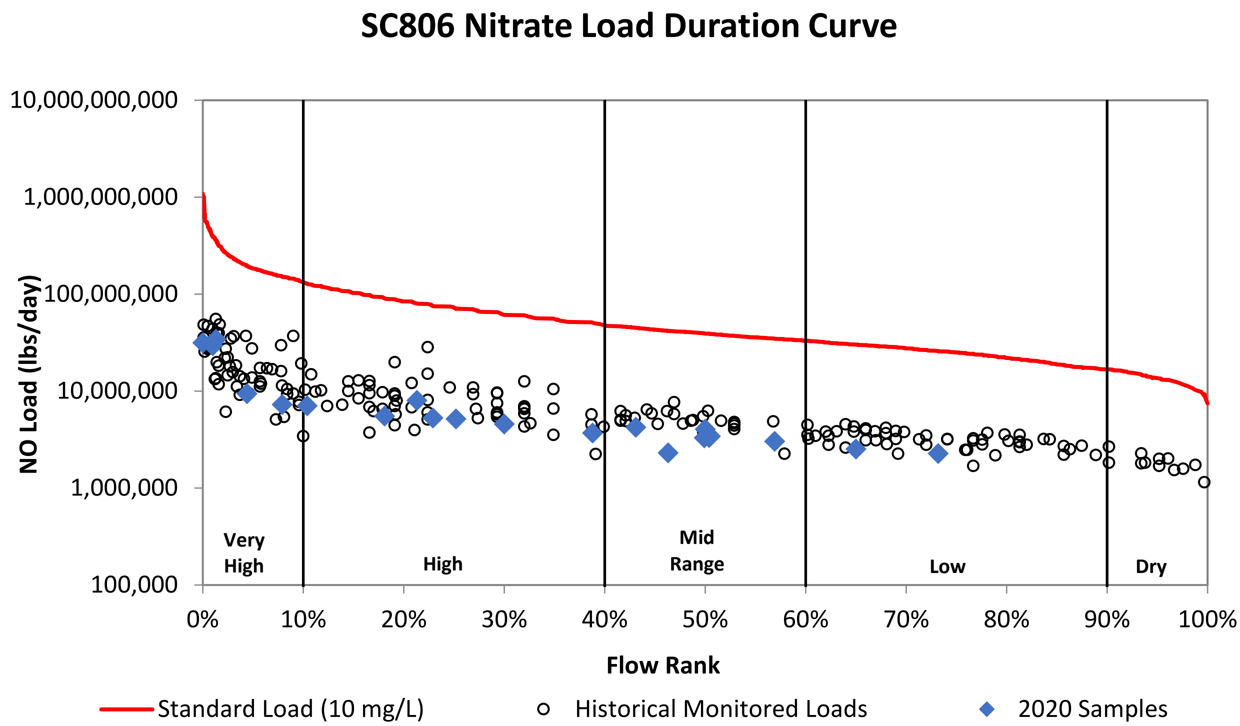


Figure 26b. Load duration curve for nitrate at SC806.

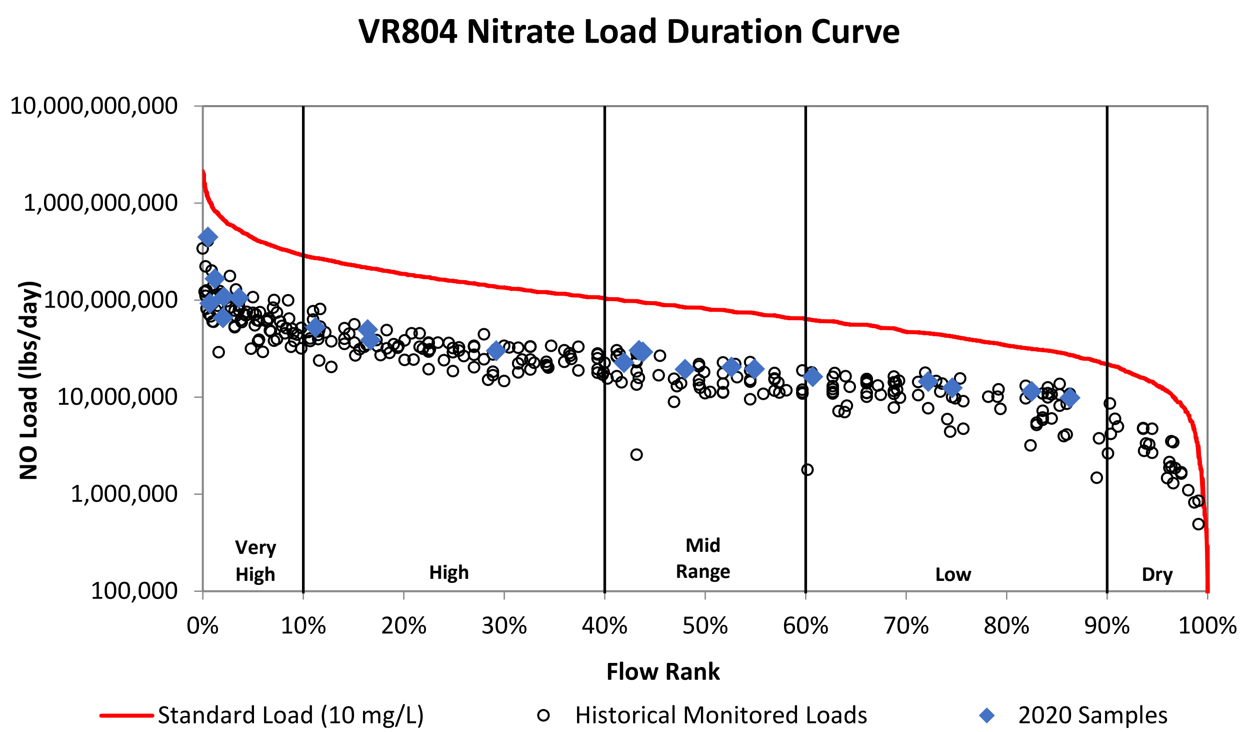


Figure 26c. Load duration curve for nitrate at VR804.

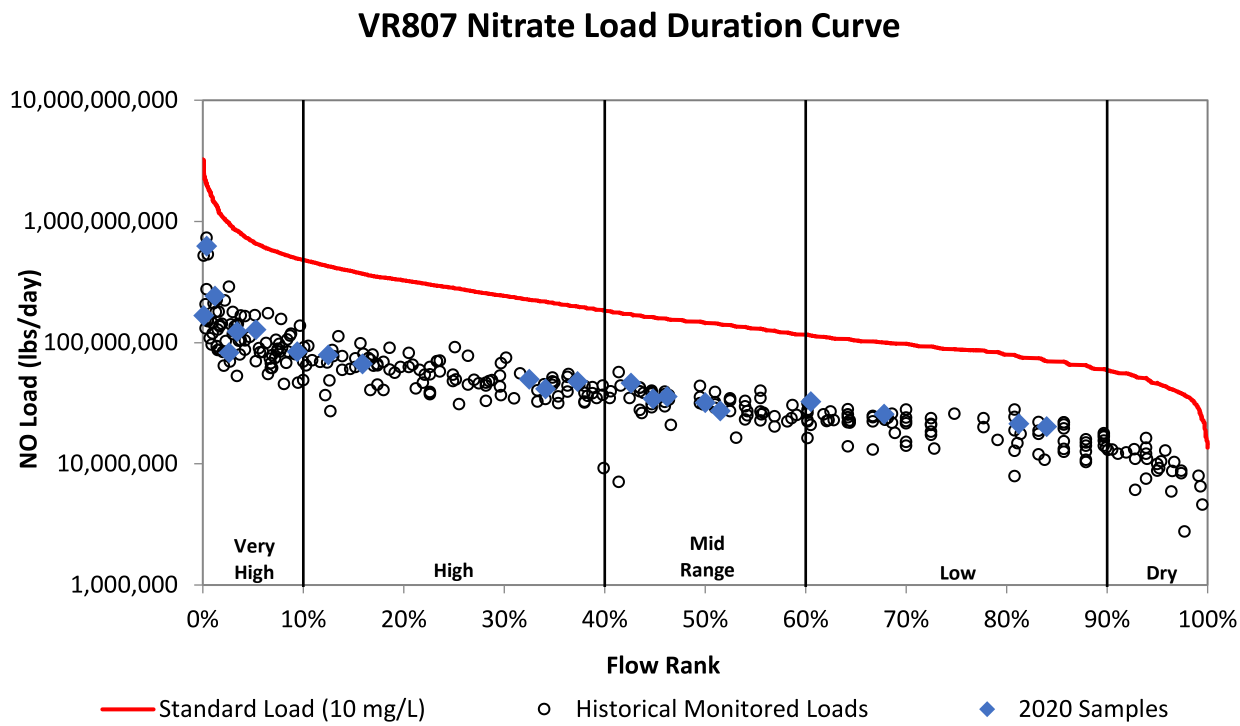


Figure 26d. Load duration curve for nitrate at VR807.

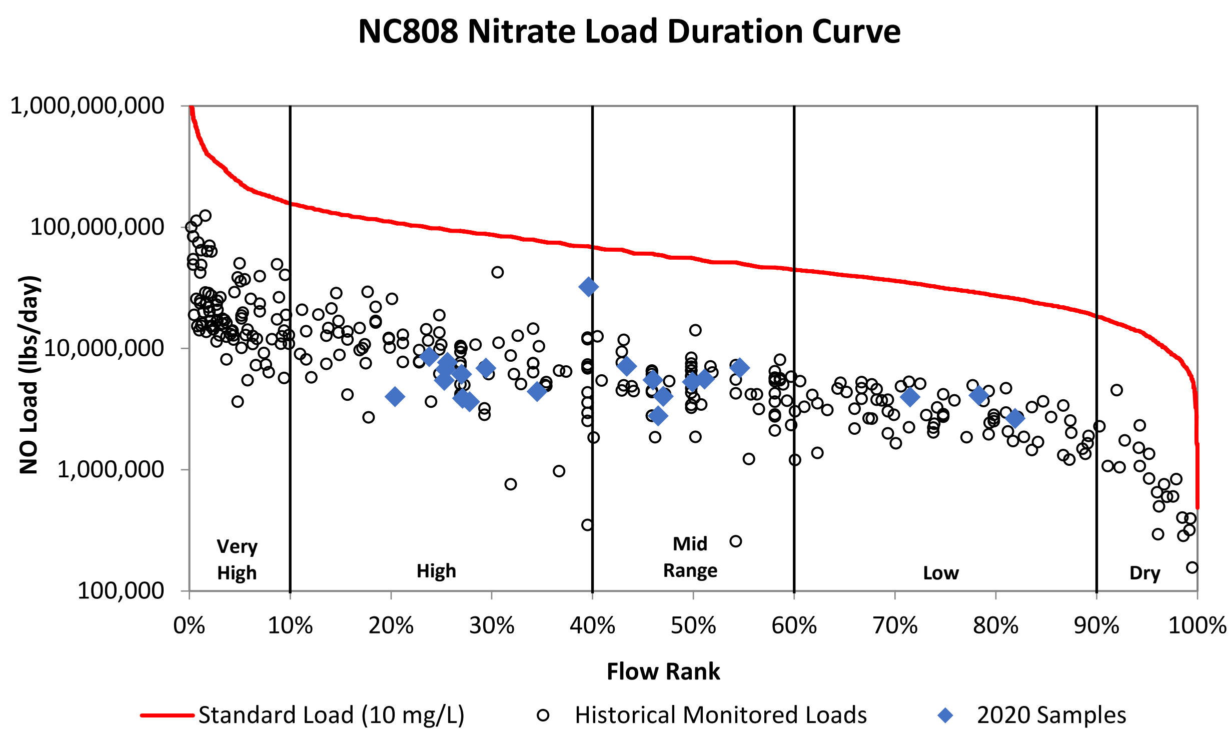


Figure 26e. Load duration curve for nitrate at NC808.

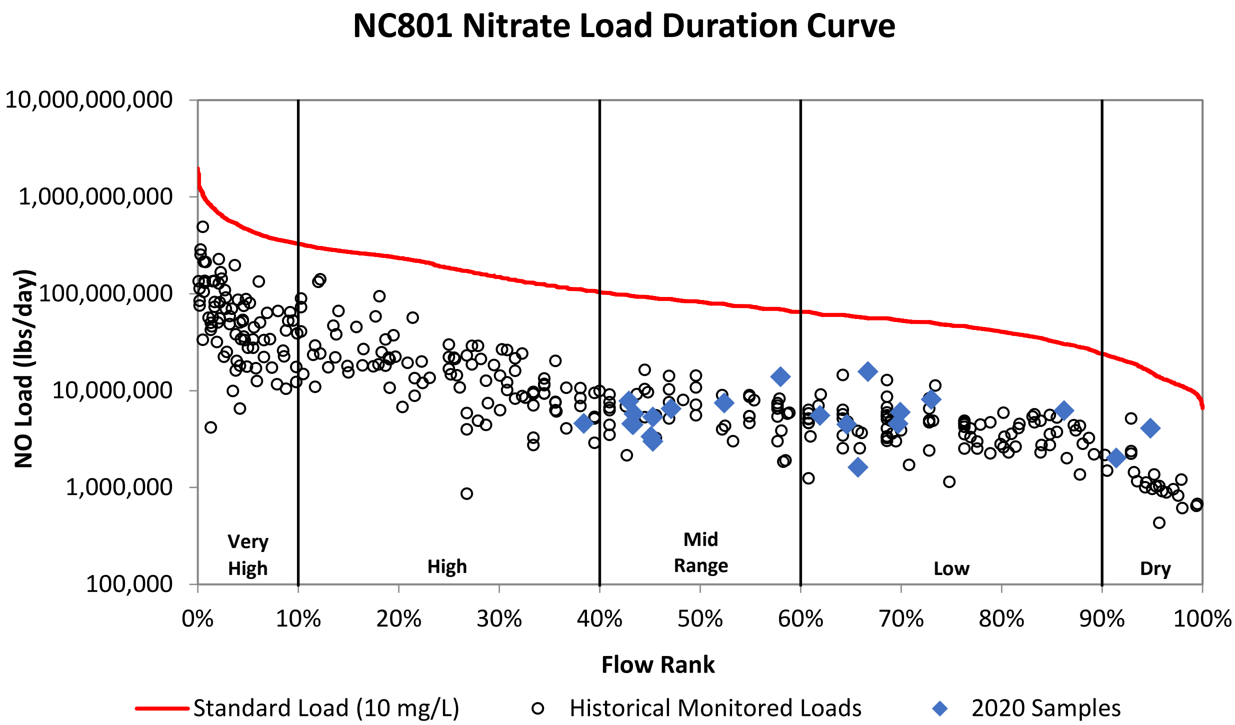


Figure 26f. Load duration curve for nitrate at NC801.

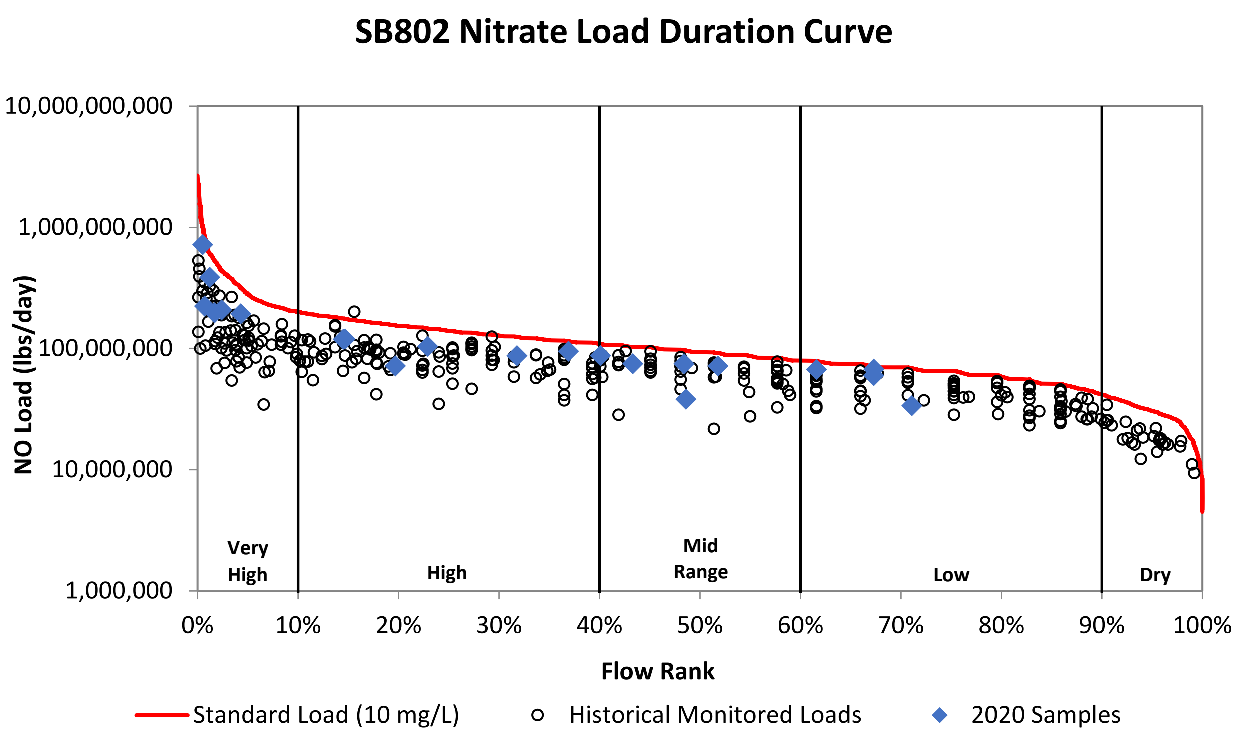


Figure 26g. Load duration curve for nitrate at SB802.

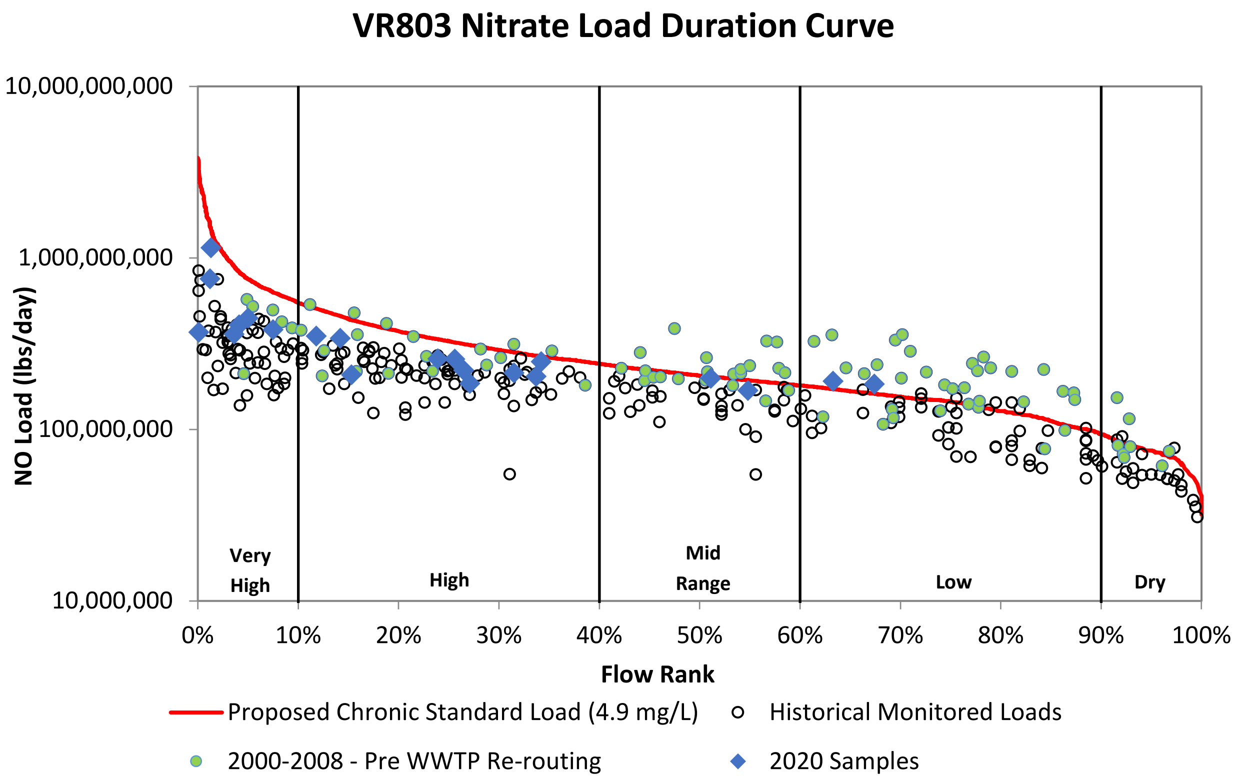


Figure 26h. Load duration curve for nitrate at VR803.

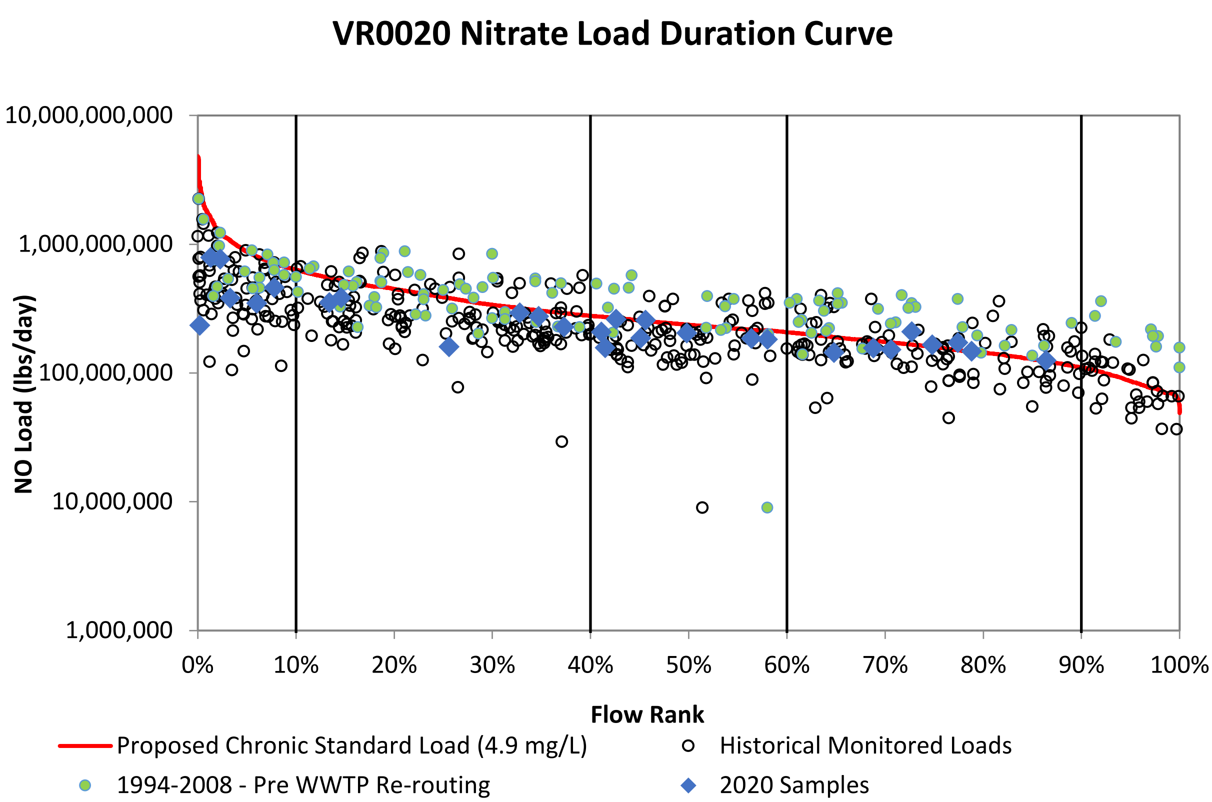


Figure 26i. Load duration curve for nitrate at VR0020.

Total Phosphorus

Excluding the two North Creek sites, all sites had exceedances for the total phosphorus standard load (0.15 mg/L) during high and very high flows (Figures 27a-i). A small percentage of samples were at or near the standard at mid-range, low flows, and dry conditions (VR24, VR804, NC808, NC801, VR0020).

In the last ten years, discharge from two WWTP have either been rerouted from the Vermillion River to the Mississippi River (Empire, 2008) or decommissioned and re-routed to the Empire WWTP (Elko New Market, 2012). Following the 2006 upgrades to the Empire WWTP and then the subsequent rerouting of the discharge to the Mississippi River (2008), total phosphorus concentrations at VR803 and VR0020 have shown great improvement. As shown in Figures 27h and 27i, historical sample concentrations show much greater variability in frequency and magnitude of standard exceedances across flow regimes. In comparison, water quality data collected in 2018 were consistently at or below the standard line, though one or two exceedances occurred during higher flow conditions.

Though Elko New Market WWTP was decommissioned and re-routed in 2012, total phosphorus levels remain at or near the standard during all flow regimes at VR24 (Figure 27a). The elevated concentrations could be a result of legacy phosphorus still present in the river and may continue to impact phosphorus levels for years to come.

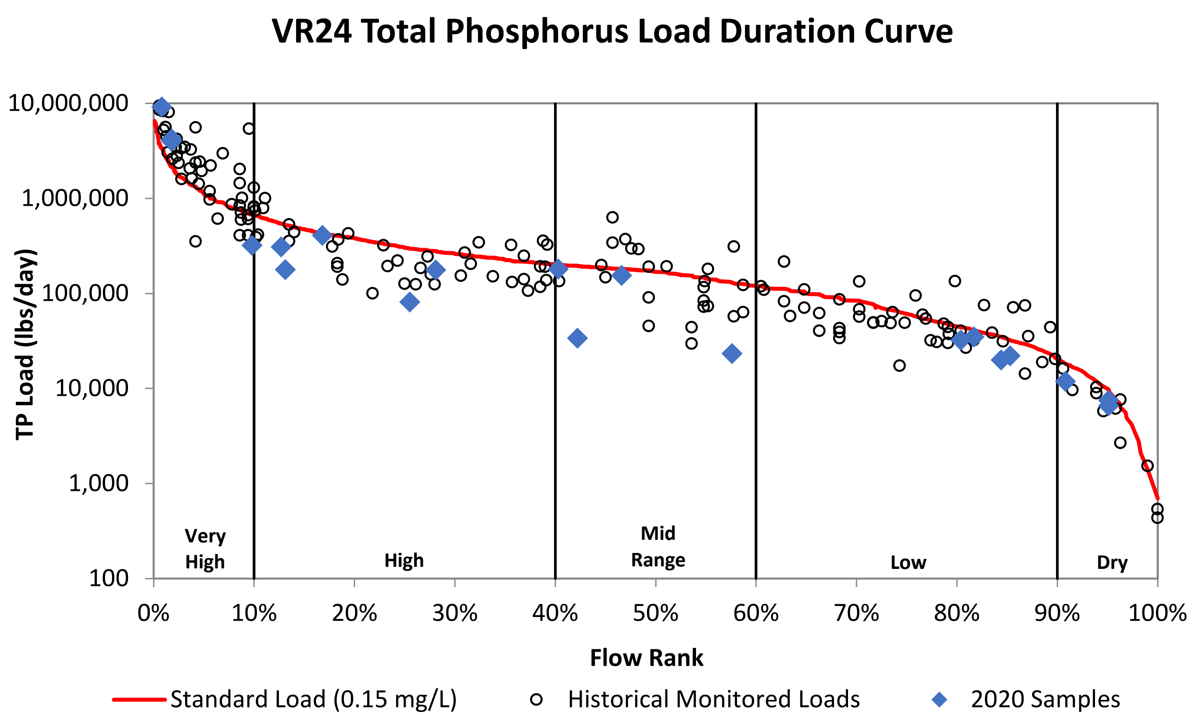


Figure 27a. Load duration curve for total phosphorus at VR24.

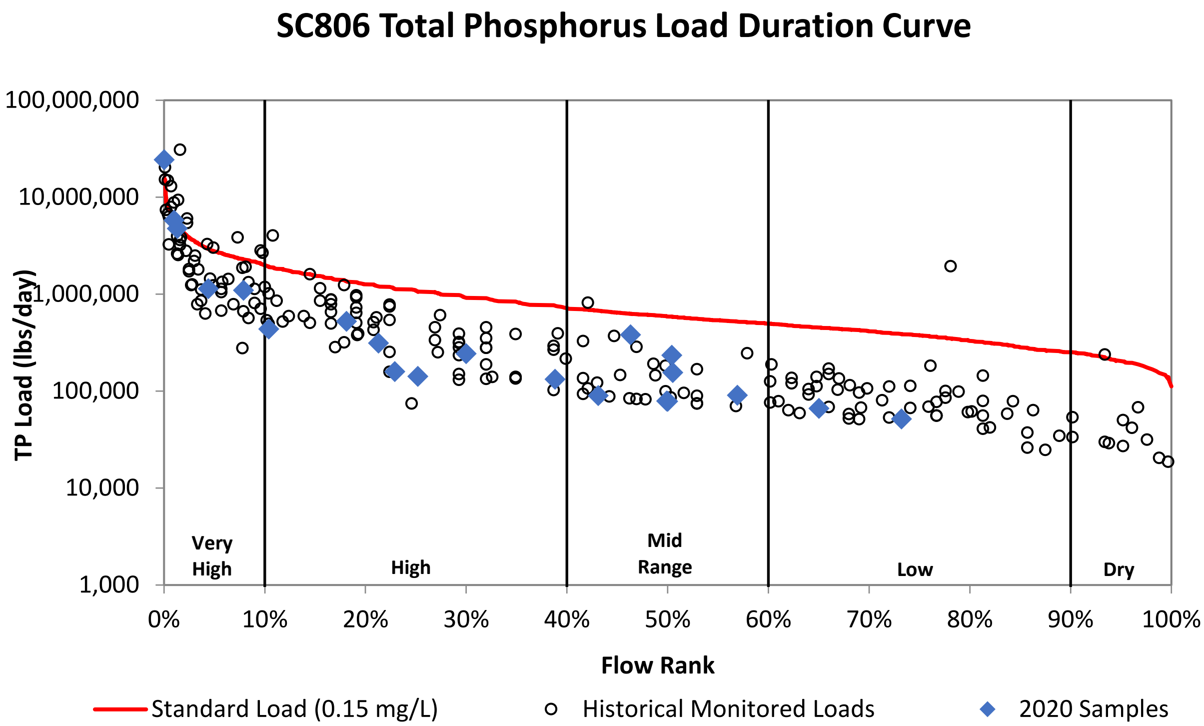


Figure 27b. Load duration curve for total phosphorus at SC806.

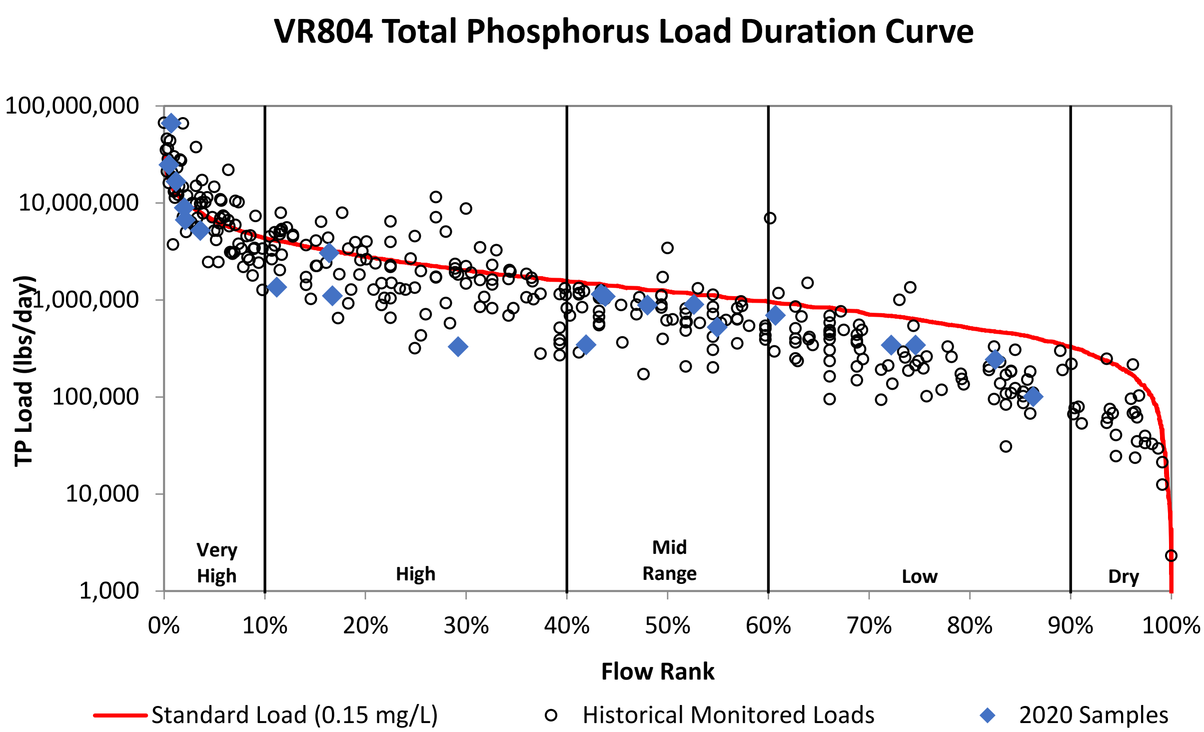


Figure 27c. Load duration curve for total phosphorus at VR804.

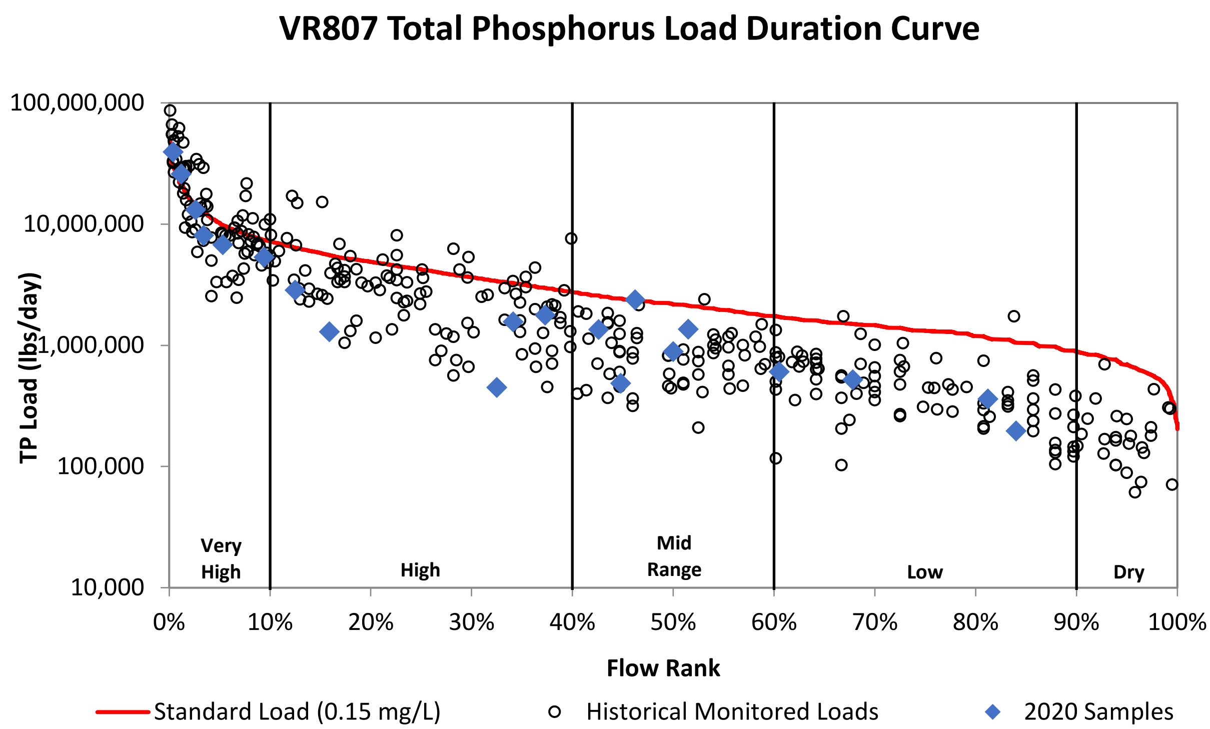


Figure 27d. Load duration curve for total phosphorus at VR807.

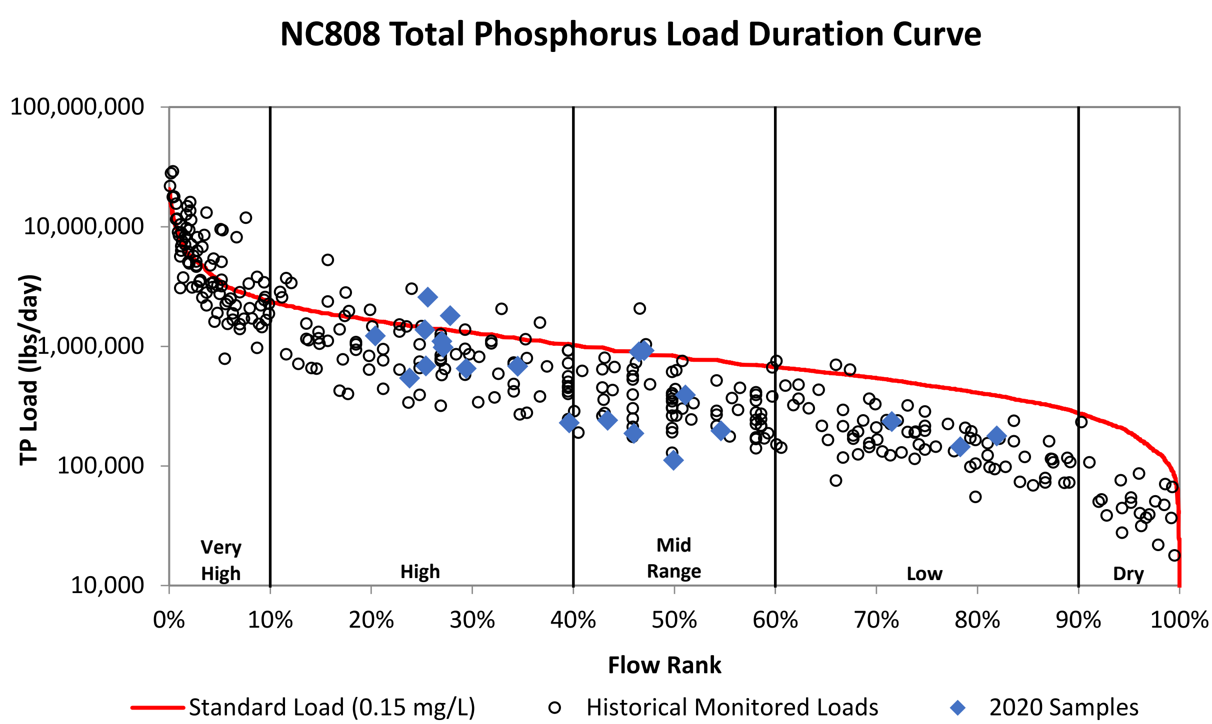


Figure 27e. Load duration curve for total phosphorus at NC808.

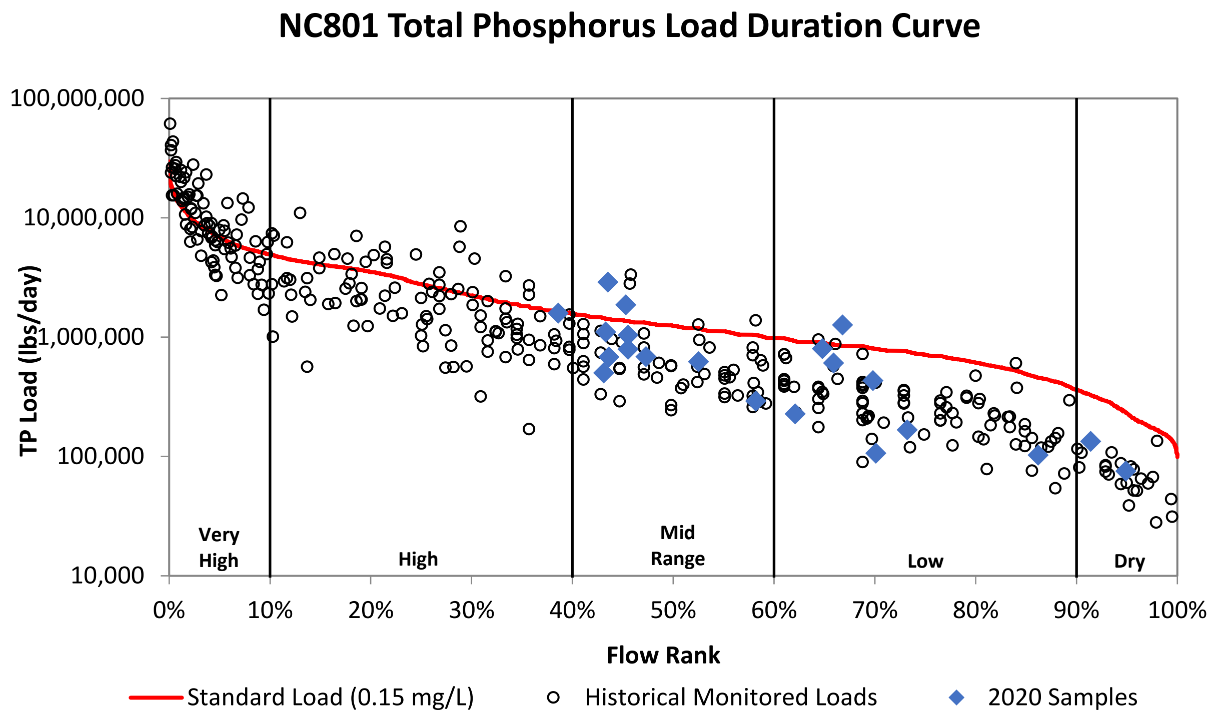


Figure 27f. Load duration curve for total phosphorus at NC801.

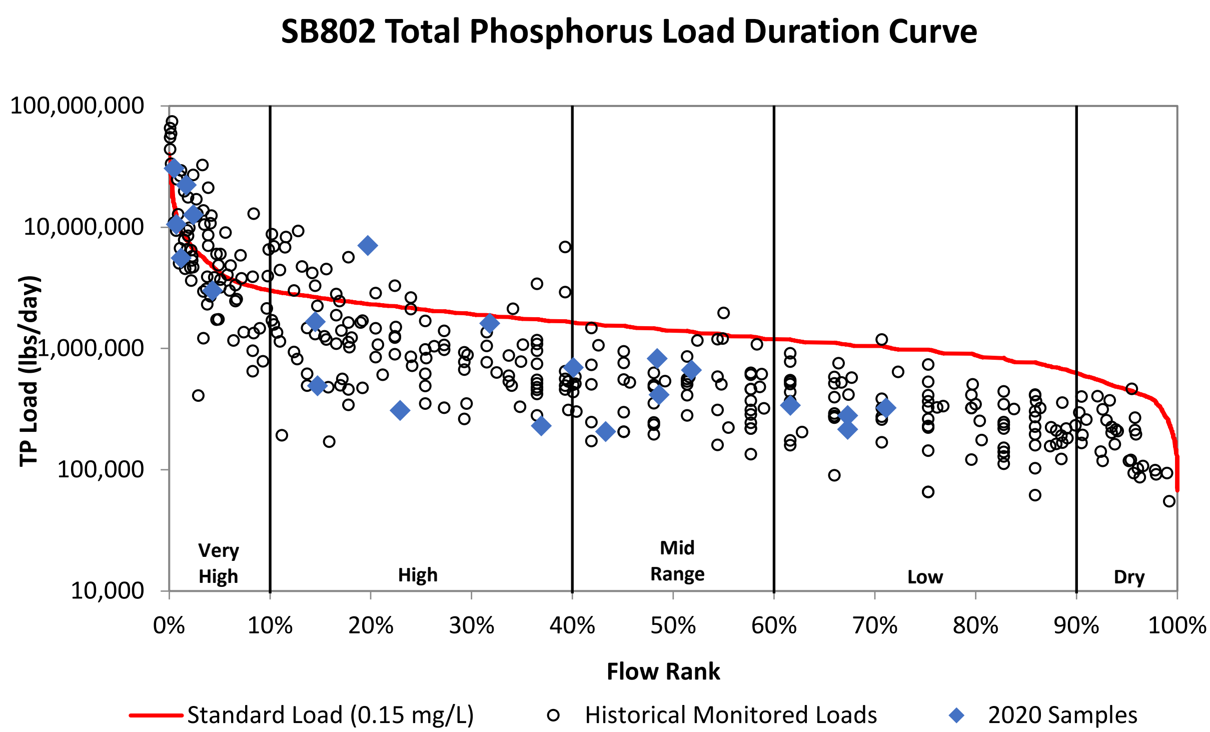


Figure 27g. Load duration curve for total phosphorus at SB802.

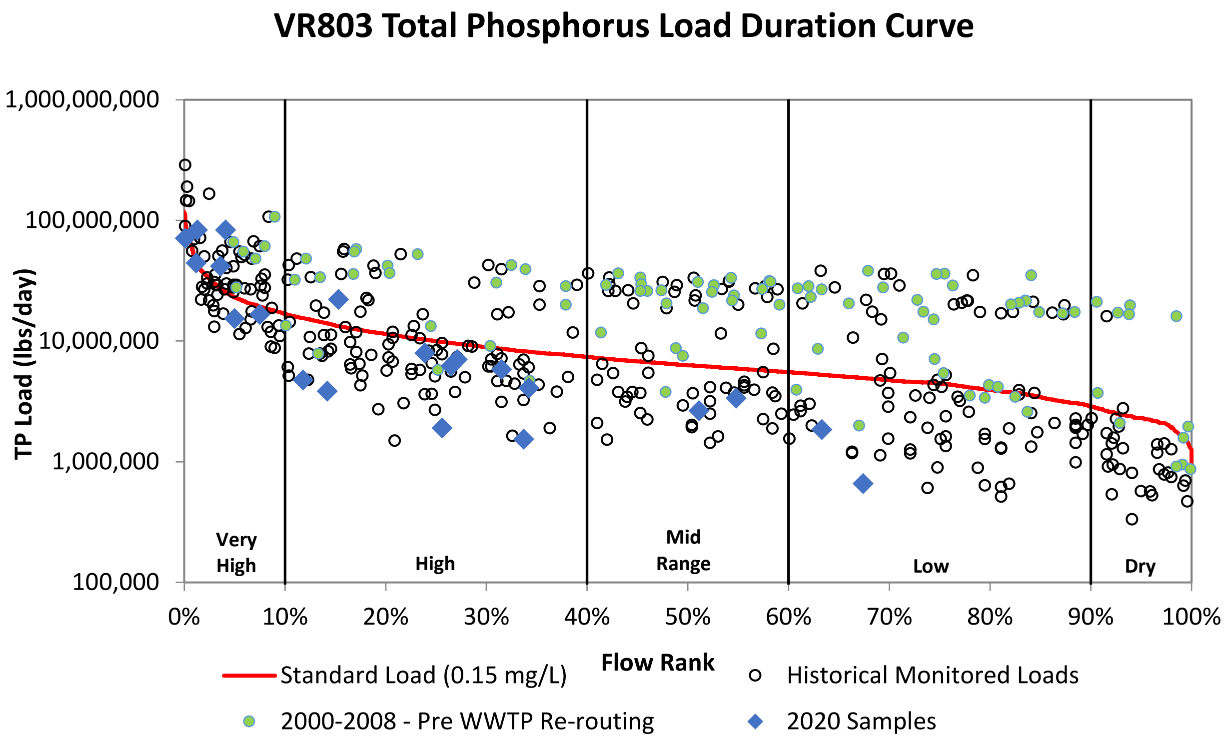


Figure 27h. Load duration curve for total phosphorus at VR803.

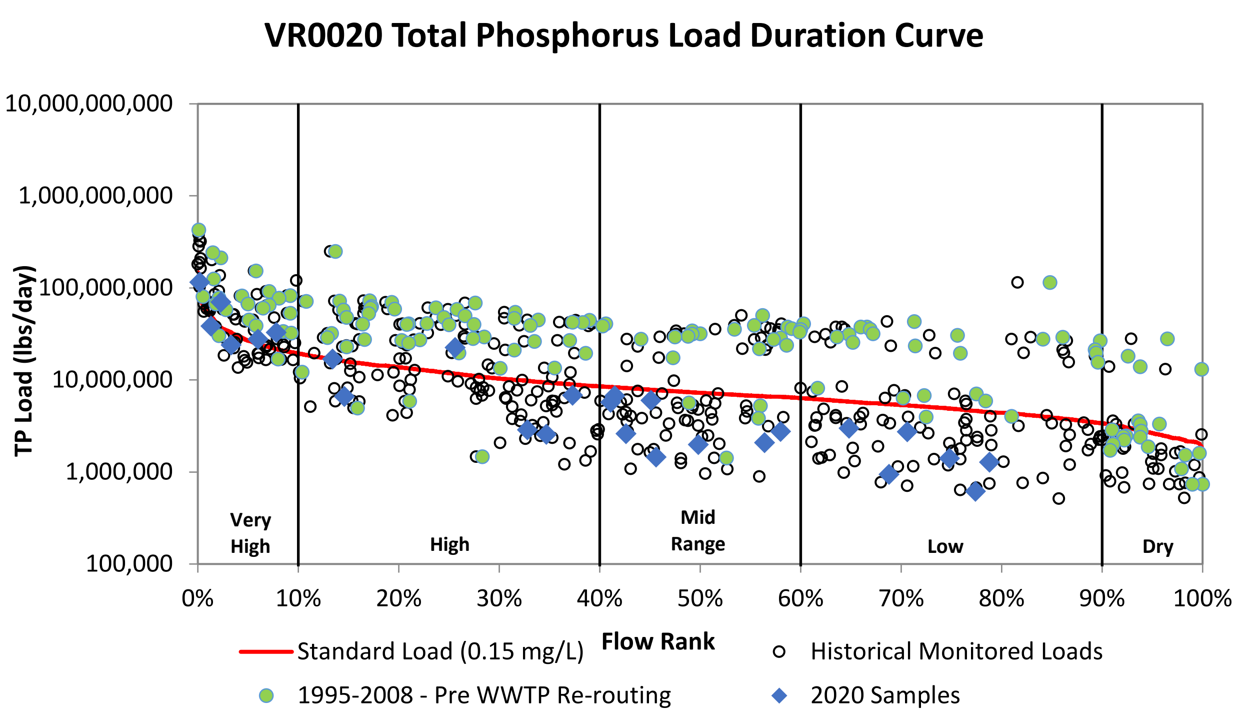


Figure 27i. Load duration curve for total phosphorus at VR0020.

Total Suspended Solids

The state standards for cold water (2A) streams (≤10 mg/L) and warm water (2B) streams (≤30 mg/L) were used to calculate the duration curve (Figures 28a-I). These standards apply from April through September; however, data shown here includes the entire monitoring season which goes from snowmelt (mid-March) through November 1st.

Most exceedances of the standard load for TSS in 2020 occurred during high and very high flows. VR804, VR807, NC808, and NC801 had exceedances during mid-range flows (NC801 also had exceedances during low flow). Higher levels of TSS are expected during those flow regimes due to increases in runoff from impervious surfaces and agricultural fields during rain events, as well as bank erosion when water levels and flow rates increase.

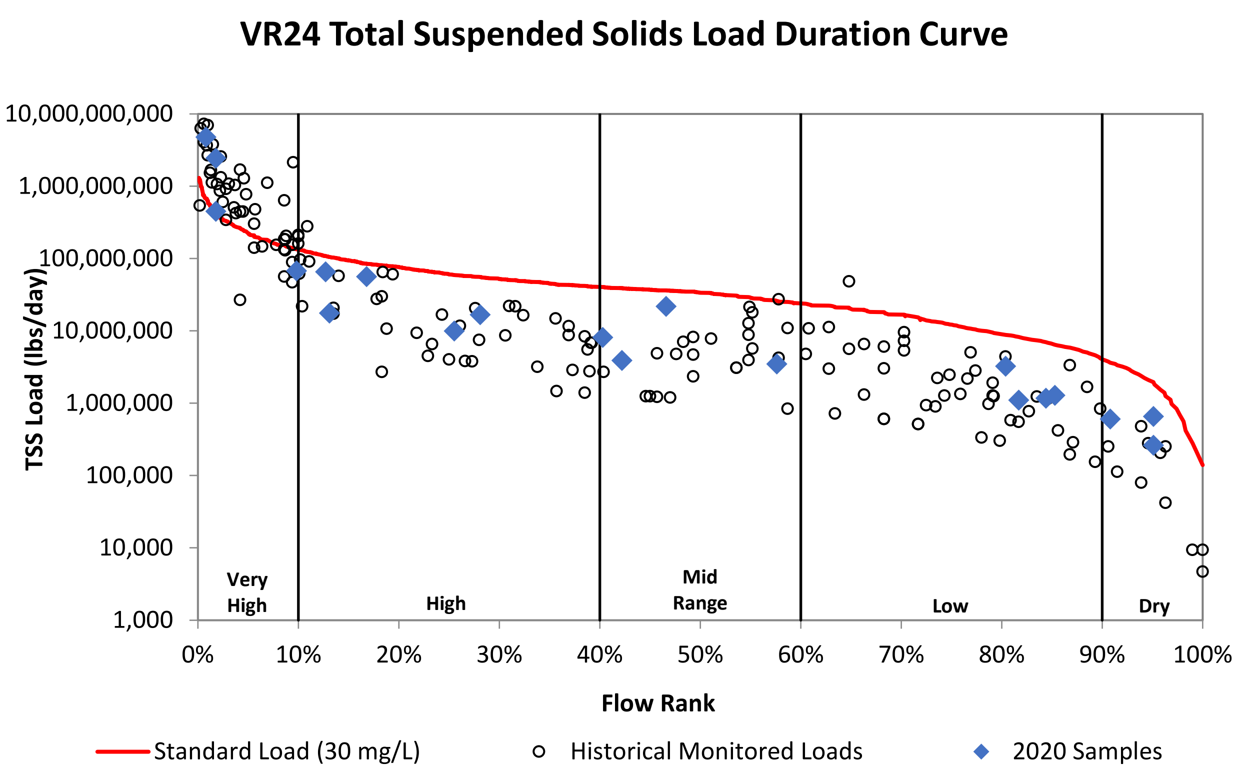


Figure 28a. Load duration curve for total suspended solids at VR24.

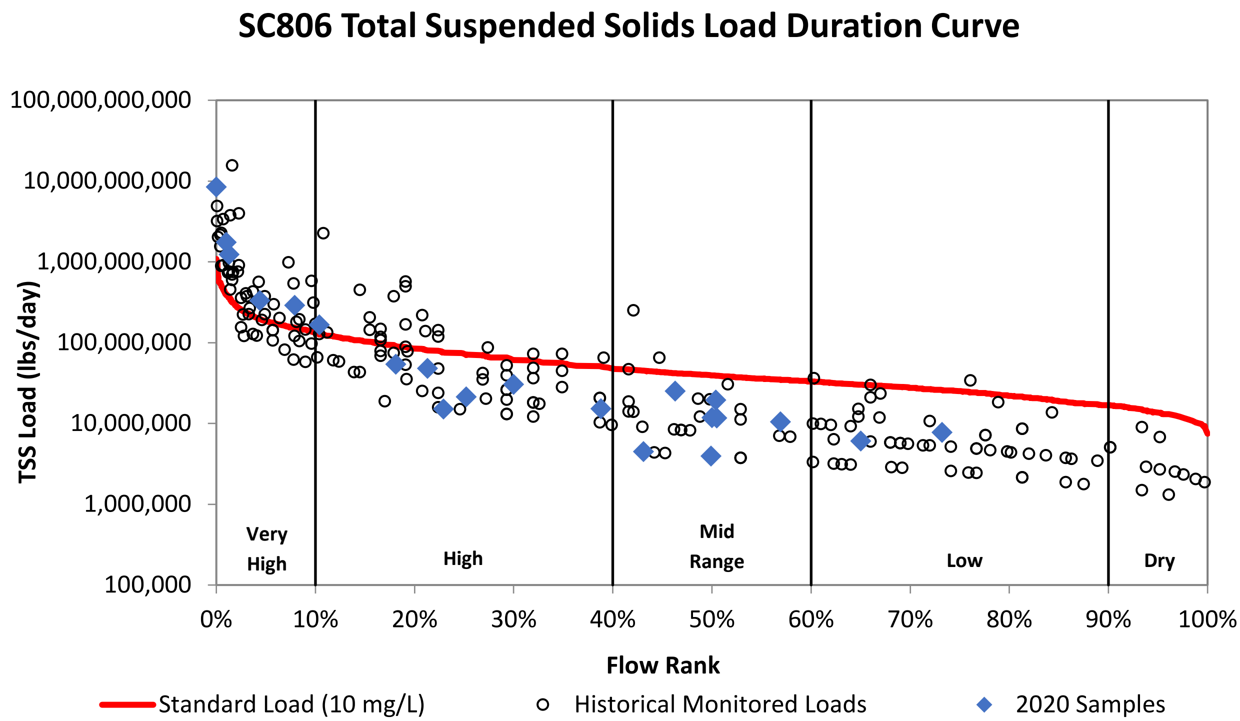


Figure 28b. Load duration curve for total suspended solids at SC806.

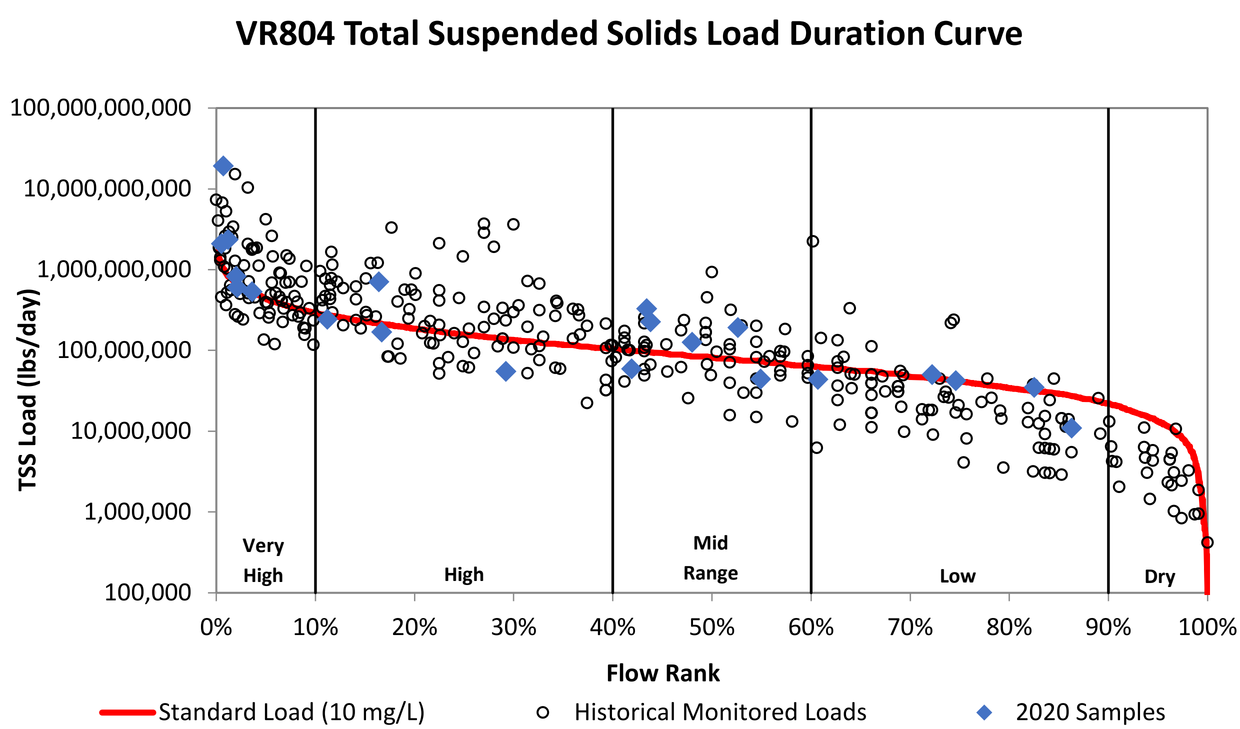


Figure 28c. Load duration curve for total suspended solids at VR804.

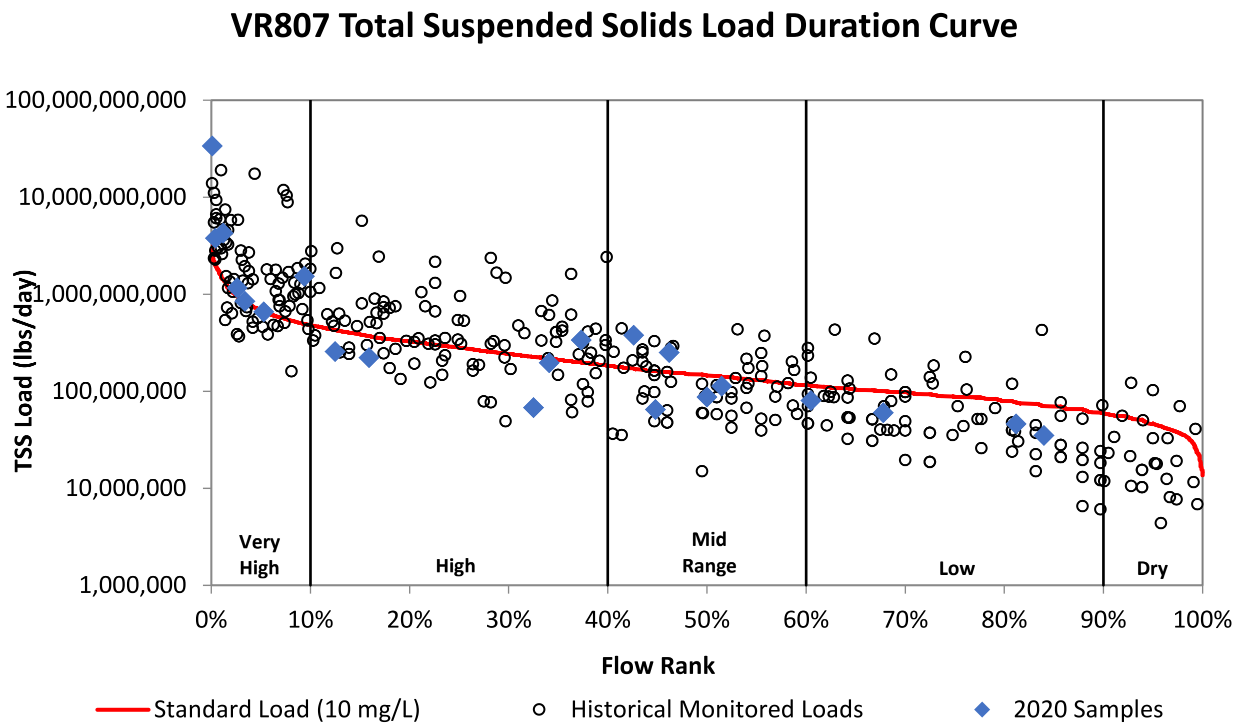


Figure 28d. Load duration curve for total suspended solids at VR807.

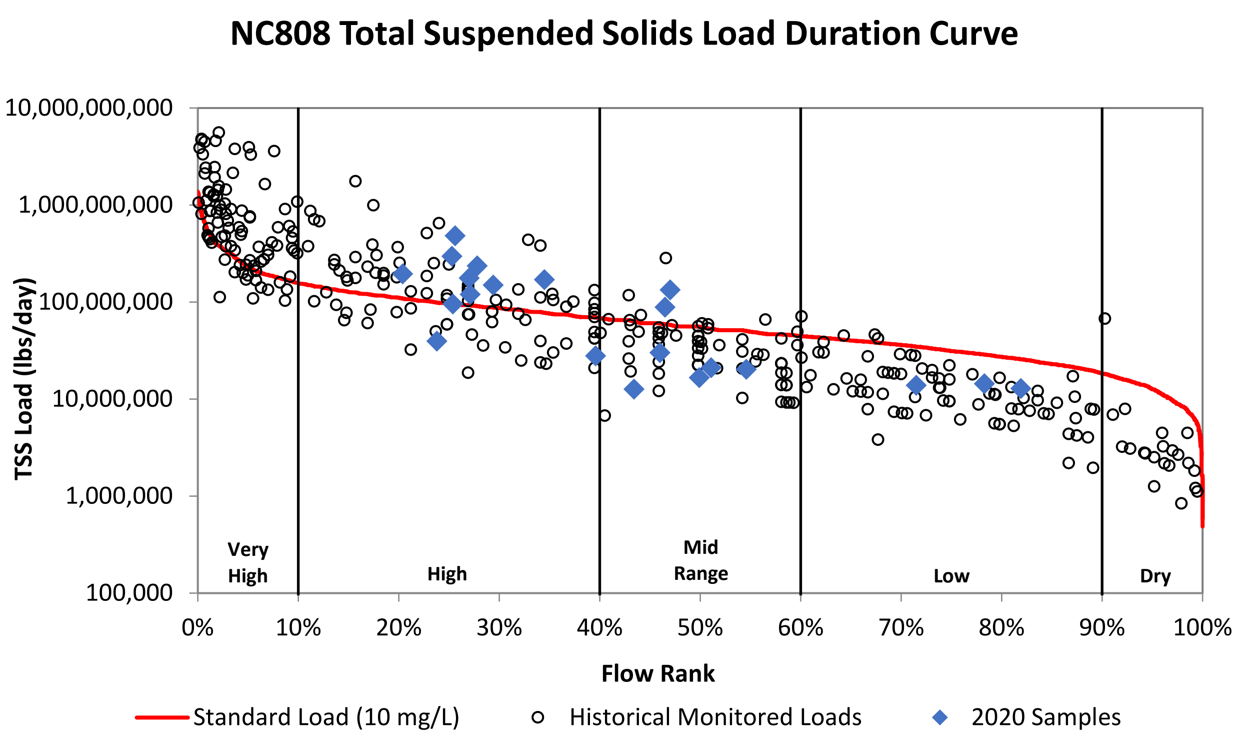


Figure 28e. Load duration curve for total suspended solids at NC808.

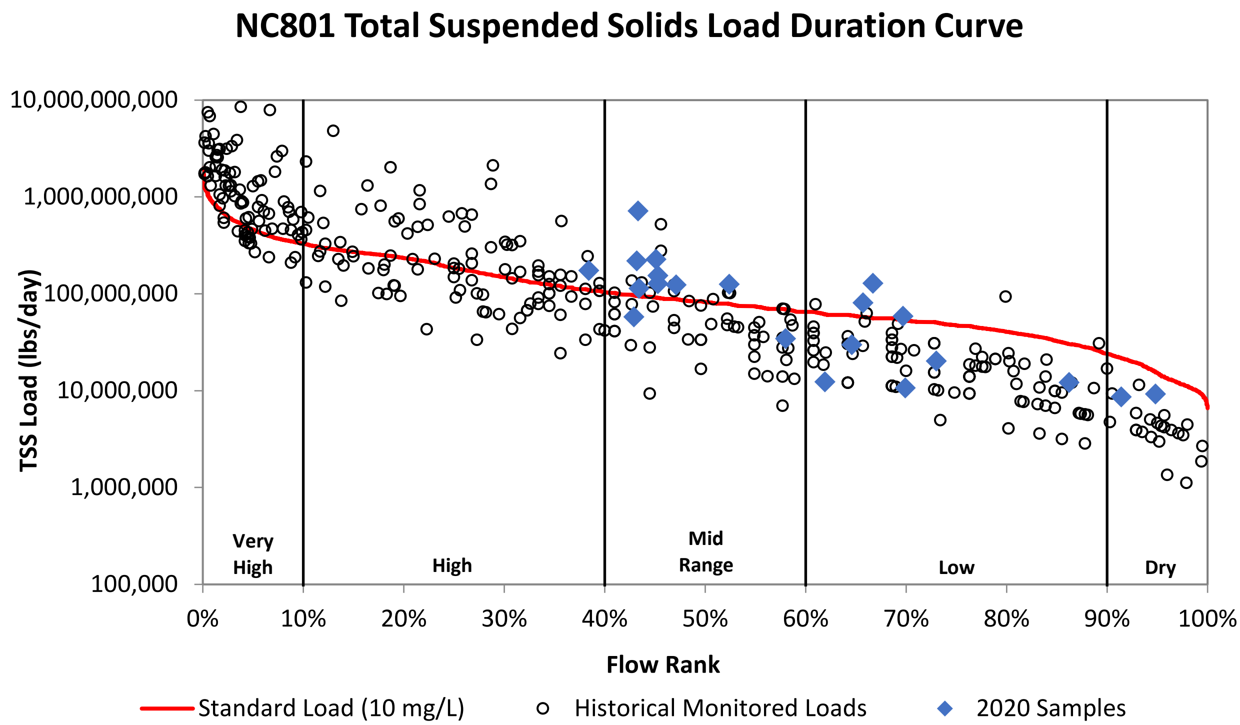


Figure 28f. Load duration curve for total suspended solids at NC801.

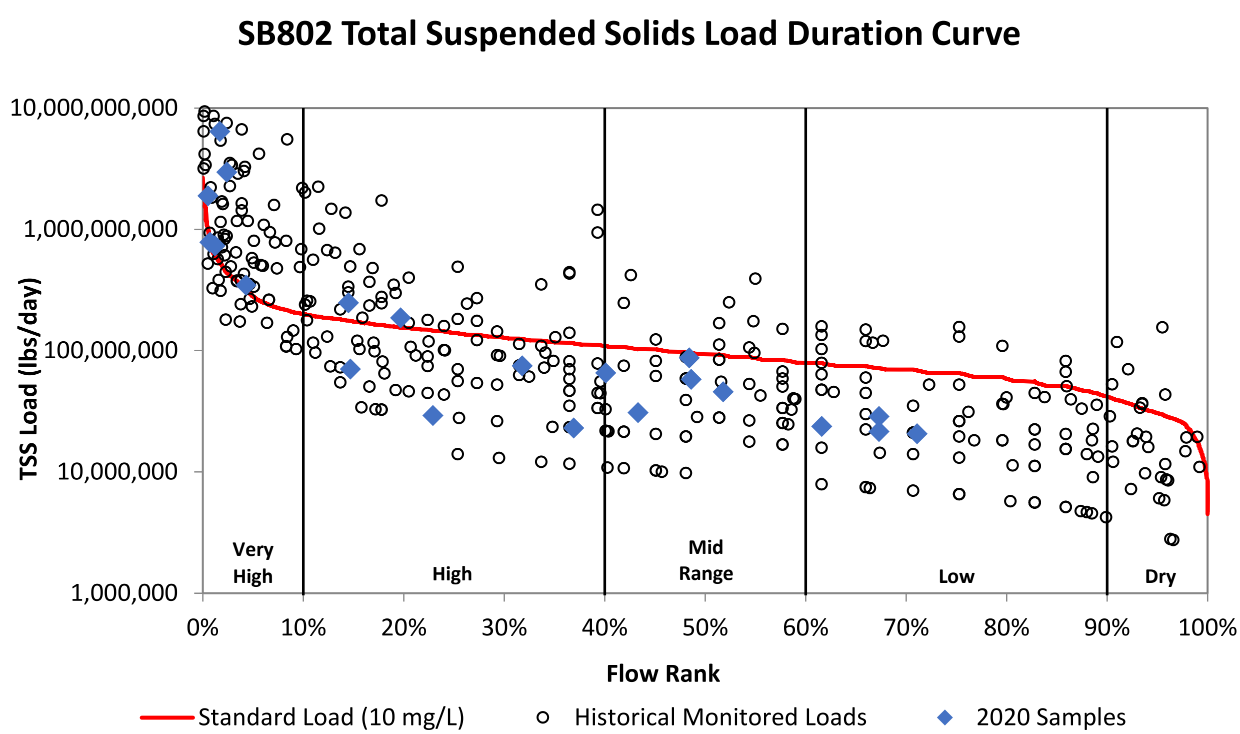


Figure 28g. Load duration curve for total suspended solids at SB802.

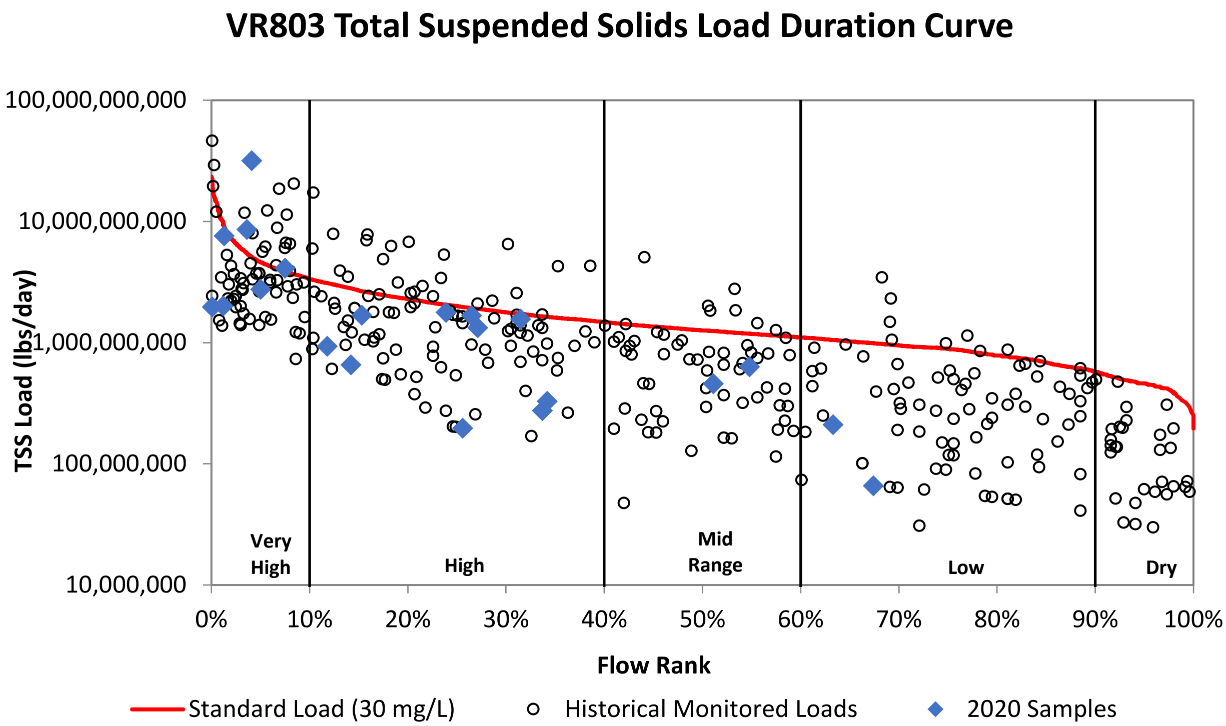


Figure 28h. Load duration curve for total suspended solids at VR803.

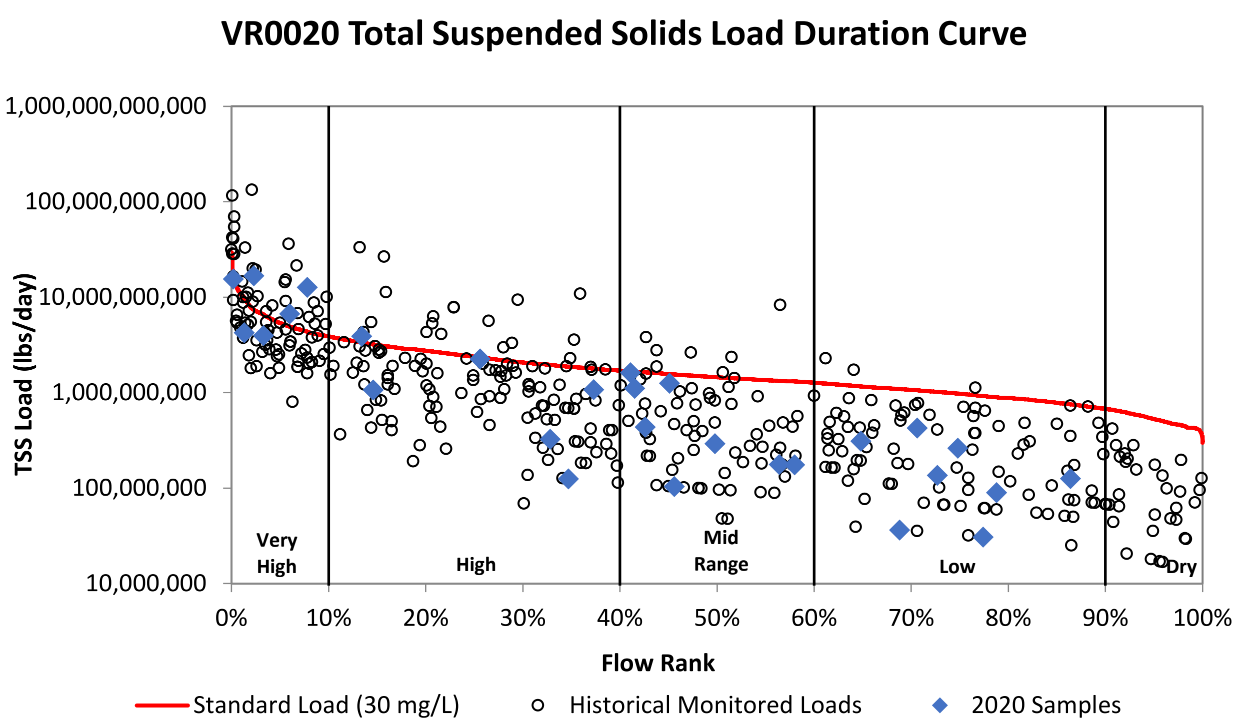


Figure 28i. Load duration curve for total suspended solids at VR0020.

Water Temperature

Temperature is an important factor in growth and reproduction rates of macroinvertebrates and fish. Although we know far less about temperature tolerance and stress levels in macroinvertebrates, it likely plays an important role in maintaining a healthy community. Fish biologists who study the physiological response to varying temperatures use the terms *optimum*, *tolerance*, and *resistance* to describe ranges of temperature preference specific to each fish species. Although the literature shows some slight variation in threshold values, the following temperature ranges for brown trout are based on a literature review by Bell (2006).

Brown Trout

Optimum: The 'optimum' temperature is that in which growth is optimized; fish will often preferentially move to the optimum temperature. For adult brown trout, the optimal temperature is less than 18°C (shown green in Figure 29).

Tolerance: Beyond the optimum range is the tolerance range. The tolerance range for adult brown trout is 18-20°C (shown yellow in Figure 29) and can be more clearly defined as the upper limit of the temperature beyond which 50% of the population survives an indefinitely long exposure. The tolerance range is generally avoided, but can be endured, and often is, for short periods of time for various reasons such as foraging for food.

Resistance: The upper limit of the resistance range is bounded by the critical thermal maximum at 20-22°C (shown orange in Figure 29) (Coutant, 1975). Prolonged exposure to temperatures in the resistance range often leads to high mortality rate, which is consistent with observations by Gardner and Leetham (1914) in which high mortality above 20°C and complete mortality above 25°C (red) was described.

Brown trout have been observed in stream reaches of the Vermillion River with temperatures above 25°C (Nerbonne and Chapman, 2007). During hot summer weeks, trout often seek refuge in overhanging banks and other heavily shaded areas and in deep pools with groundwater influence where water may be cooler. Nerbonne and Chapman (2007) defined refuge areas for trout as those where the daily mean stream temperatures exceeded 20°C for fewer than 10 days per year and never exceeded 23°C.

Continuous temperature data, measured in 15-minute intervals, has been collected annually starting in 2005 for many of the sentinel monitoring stations in the Vermillion River monitoring network. Figure 29 shows the median, 25^{th} and 75^{th} percentiles, and outliers for each site during the summer months (June through August). Stations VR24, VR803, and VR0020 are in warm water (2B) reaches; figures for these stations do not contain trout temperature limits as they do not apply.

Temperature data was not collected at SC806 in 2018 due to logger malfunction. Data is shown for 2011-2017 and 2019-2020.

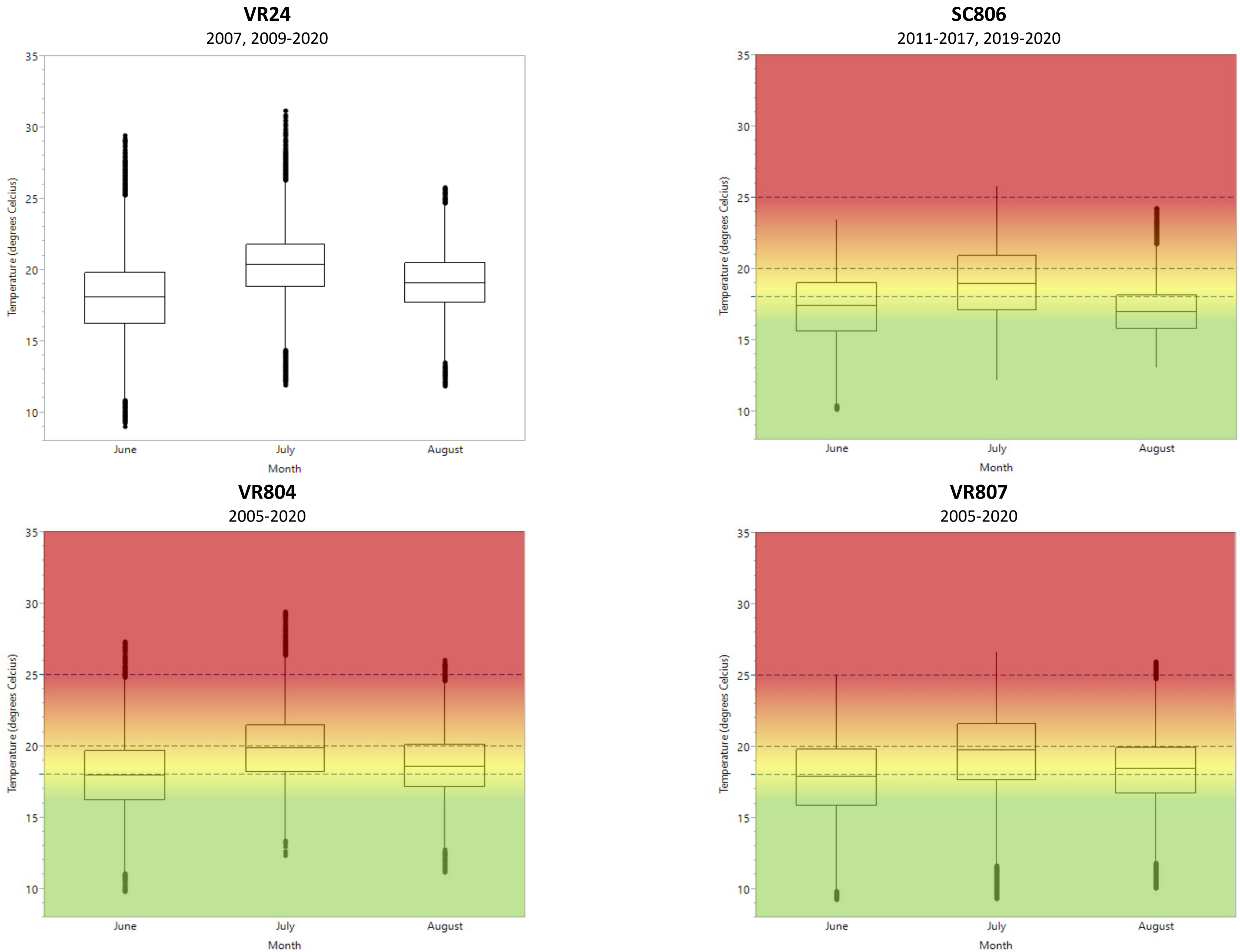
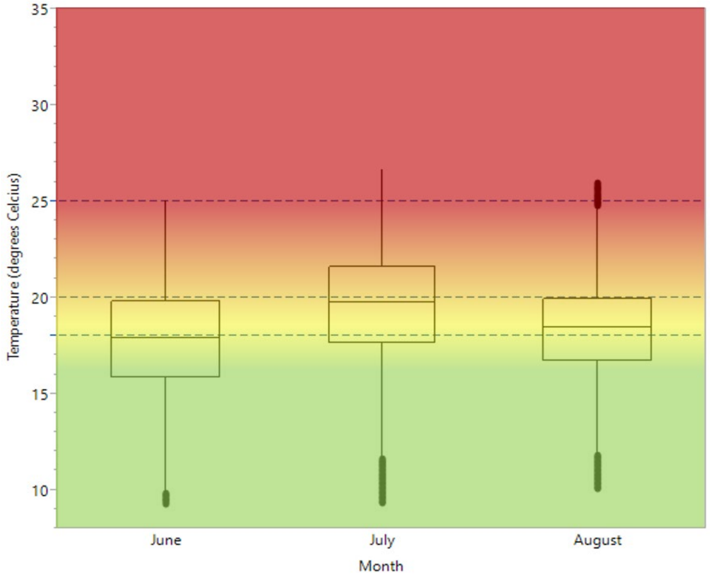
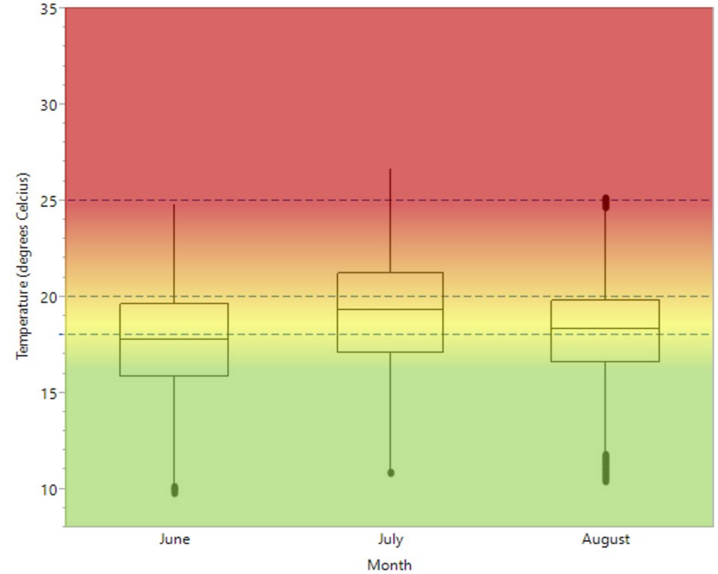


Figure 29. Continuous temperature data for each permanent monitoring station during the summer months from 2005-2020 (when available). Temperature ranges apply to adult Brown Trout. Optimal <18°C, tolerance 18-20°C, resistance 20-22°C, and complete mortality at 25°C (Coutant (1975), Gardner & Leetham (1914), Bell (2006))

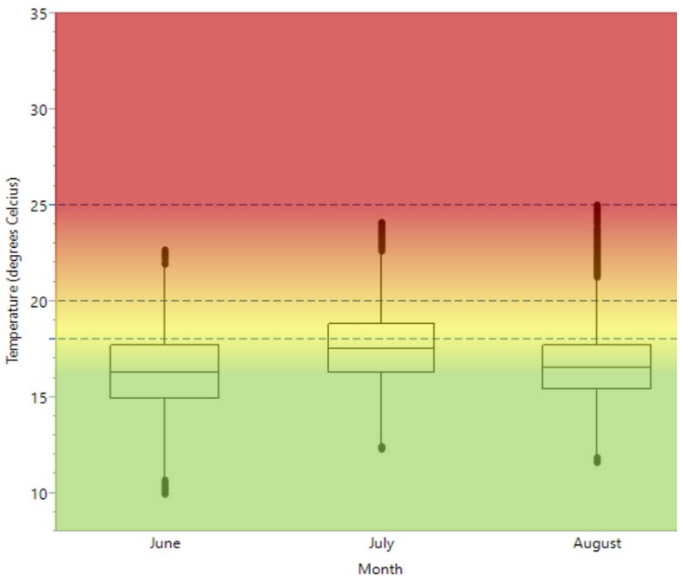
NC808
2005 - 2008, 2010 - 2011, 2013 - 2020



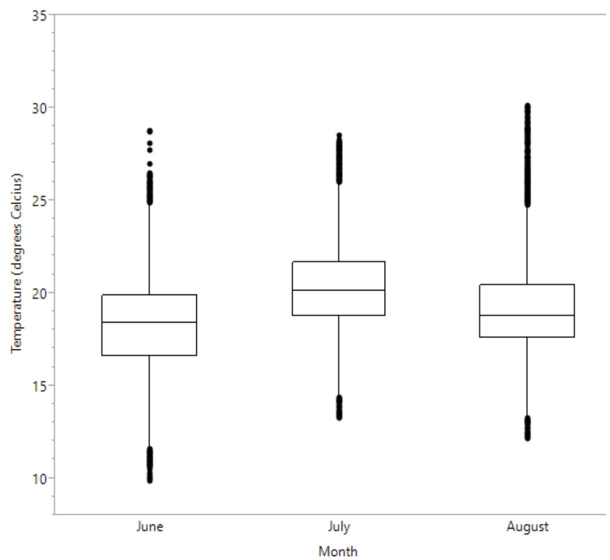
NC801
2005 - 2020



SB802
2005 - 2020



VR803
2005 – 2019* logger error, no data in 2020



VR0020
2000 – 2012, 2015 - 2020

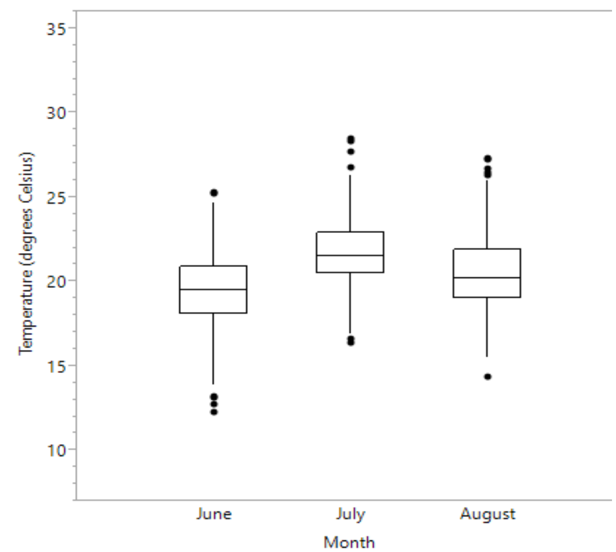


Figure 29. (continued)

Cold water (2A) stream temperature standards state that there must be ‘no material increase.’ Warm water stream temperature standards differ from cold water criteria, and state, ‘No more than 5°F [~2.8°C] above natural in streams and 3°F [~1.7°C] above natural in lakes, based on monthly average of maximum daily temperatures, except in no case shall it exceed the daily average temperature of 86°F [30°C].’ Stations VR24, VR803, and VR0020 are designated as warm water stream reaches and therefore are not evaluated based on the established cold water criteria. The following section refers to cold water streams.

According to Figure 29, temperature maximums were measured in the resistance range (orange; > 20°C) at all class 2A streams during all summer months with the highest median water temperatures observed in July. The June median was within the optimum (green; < 18°C) range for all 2A waters, though the June median temperature for station VR804 was just below the optimum/tolerant threshold.

In July, all stations had maximum temperatures that extended into the resistance range. All stations, except SB802, maintained a July median within the tolerance range (VR804 had a July median just below 19°C). The July median temperature at SB802 was within the optimum range (< 18°C). By August, median temperatures had decreased in the network and SC806 and SB802 were within the optimum temperature range, with the median temperature at NC808, NC801, and VR807 at the bottom edge of the optimum range. Station VR804 had a median August temperature in the tolerance range around 19°C, like the warm water reaches, VR24, VR803, and VR0020.

Water temperature and the concentration of dissolved oxygen have an inverse relationship. As water warms, oxygen gas becomes less soluble and the dissolved oxygen concentration is reduced. Although NC801 is listed as impaired for dissolved oxygen, it has summer median temperatures near or within the optimum range. It is hypothesized that the delivery of warm, low oxygen water, to this stream section following a storm event could cause a spike in temperature and subsequent low dissolved oxygen concentration measurements, but more information is needed to confirm this suspicion.

The August median temperature at SC806 and SB802 was lower than at other stream reaches. These lower temperatures may be attributed to cool groundwater feeding the stream during low flow conditions, either naturally from springs and seeps or artificially from tile drainage. Station SC806 has high conductivity values under low-flow conditions, consistent with the ion signature which is indicative of groundwater discharge to the reach, and there is little contribution from other tributaries. Station SB802 is representative of a subwatershed which has a lot of acres in agricultural production and presumably many acres of tile drained land. The nitrate concentrations near station SB802 further suggest a high degree of tile drainage (Watkins, et al., 2011). The tile, while a contributing factor towards some pollutant issues, appears to be an additional source of cold water to the South Branch Vermillion River, besides the groundwater inputs to the river.

The Stressor Identification Report completed as part of the WRAPS process (MPCA 2013) thoroughly evaluated the dissolved oxygen concentrations and the sources that affect them, such as temperature, on the main stem of the Vermillion River from Highview Avenue in Eureka Township to within the City of Farmington (including VR804 and VR807). One major finding specific to this reach is that the Vermillion River does not receive much groundwater discharge until approximately 225th St. in Eureka Township. This corroborates why station VR804, approximately 3,000 ft. downstream of 225th St., has warmer median summer temperatures compared to other cold water stream reaches that receive significant amounts of groundwater discharge. Station VR807 (downstream of VR804) has lower median temperatures than upstream sites because of the cool water from South Creek.

Based on these data, temperature maximums in the resistance range are measured during all summer months. During these short-term, high-temperature spikes, fish may be able to retreat to cooler areas such as deep pools, groundwater seeps, and shaded areas; however, prolonged exposure to these temperatures could result in death. The greatest temperature-induced stress on fish likely occurs in July at most stations where the mean temperature is typically higher. The reach at VR804 likely has the least desirable temperature structure for cold water fish, which is supported by few, if any, cold water fish caught in annual fish sampling surveys.

In 2005, the Vermillion River Watershed Joint Powers Organization received an EPA Targeted Watershed Grant that stimulated a great deal of thermal research which can be found on the Vermillion River Watershed website (www.vermillionriverwatershed.org) under "Thermal Trading Project."

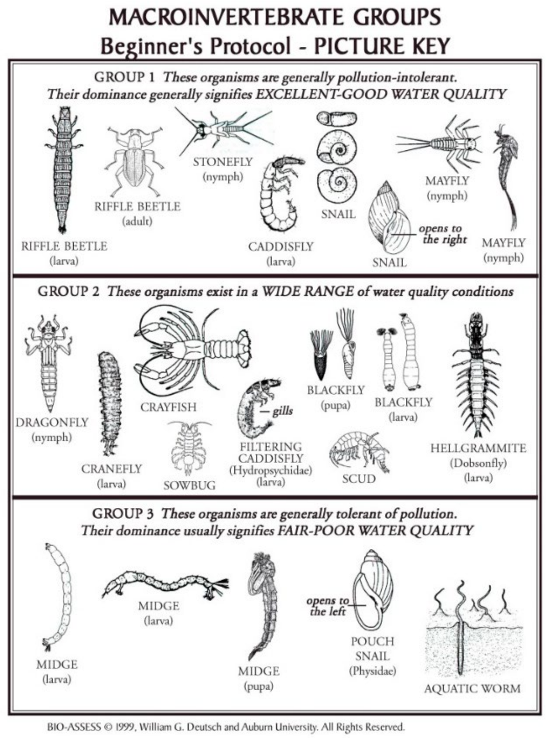
In one study, more than 2,000,000 temperature measurements, collected from a variety of agencies and organizations, over a variety of time periods, were analyzed in order to obtain a spatially and temporally extensive dataset. Although maximum temperatures were high where measured and exceeded temperature thresholds during some parts of the year, the 75th percentiles generally fell within the tolerance range (based on a seasonally adjusted temperature threshold, unlike the one described by Bell (2006)) and average temperatures were generally acceptable (LimnoTech, 2007). Up until 2013, the VRWJPO maintained a network of 35 temperature monitoring stations throughout the watershed to continue to build a long-term dataset (map shown in Appendix). Currently, continuous temperature is measured only at the 8 sentinel chemical monitoring stations.

The MPCA analyzed temperature data from one long-term temperature monitoring station and concluded that the stream temperature increased significantly while the air temperature did not, suggesting an anthropogenic cause for the temperature increase (MPCA, 2007b). LimnoTech (2007) reviewed the same data and determined that a temperature increase was occurring for winter (November through February), but not summer (May through August). This report further states that average annual flow had risen from 1974 to 2006. Increased development, wastewater treatment plant (WWTP) management, and/or changes in agricultural practices likely contributed to the increased discharge, and thus, increased stream temperature. During the review period, the Empire WWTP had increased their capacity for treatment and therefore, their discharge. With the diversion of the Empire WWTP in 2008, discharge to the stream decreased by approximately 12 million gallons per day (Mark Zabel, personal communication, July 2014). The report goes on to say that climate change may also be a factor as annual air temperatures recorded in Farmington have climbed from 1908 to 2005.

Many factors influence water temperature in the Vermillion River. Continued temperature monitoring and management will be important in maintaining the brown trout population in the Vermillion River.

Biomonitoring

Monitoring biological communities is becoming a widely accepted method for assessing the health of an aquatic environment. Using this strategy, a direct measurement of the quality of the biological community can be described, rather than attempting to infer the health of the community through the assessment of chemical and physical parameters alone. Biological monitoring may also be more sensitive in identifying the cumulative effects of numerous, simultaneous stressors on the biological community as opposed to chemical and physical parameters which only provide a snapshot of the abiotic factors throughout the monitoring season.



In 2009, the VRWJPO began implementing the Vermillion River Biomonitoring Plan to assist in assessing the health of waters within the Vermillion River (Vermillion River Watershed Joint Powers Organization, 2008). This program includes fish community monitoring, macroinvertebrate monitoring, geomorphic assessments, and habitat assessments. This monitoring strategy supplements pre-existing monitoring efforts by increasing the number of sites, frequency, and parameters of biological communities monitored within the watershed. This program has been carefully designed to seamlessly integrate with other biomonitoring efforts to ensure that adequate biological monitoring data is being obtained while minimizing monitoring expenses.

Macroinvertebrate sampling and habitat assessments were completed by DCSWCD staff. Fish community monitoring and geomorphic assessment work was completed by the MNDNR and private consultants hired by the VRWJPO; reports can be accessed from the VRWJPO website (www.vermillionriverwatershed.org) under “Monitoring Reports” in the “Plans/Reports” dropdown.

Biomonitoring in North Creek

Photo credit – L. Albright

Figure 30 shows the biological monitoring network stations with a color ramp to easily visualize the quality of the macroinvertebrate community and habitat based on indices that are described later in this section. Only the five sites that were actively monitored in 2020 are shown on the map. For more detailed information, including data and a map for biomonitoring sites which have been discontinued, refer to the following narrative sections and the Appendix.

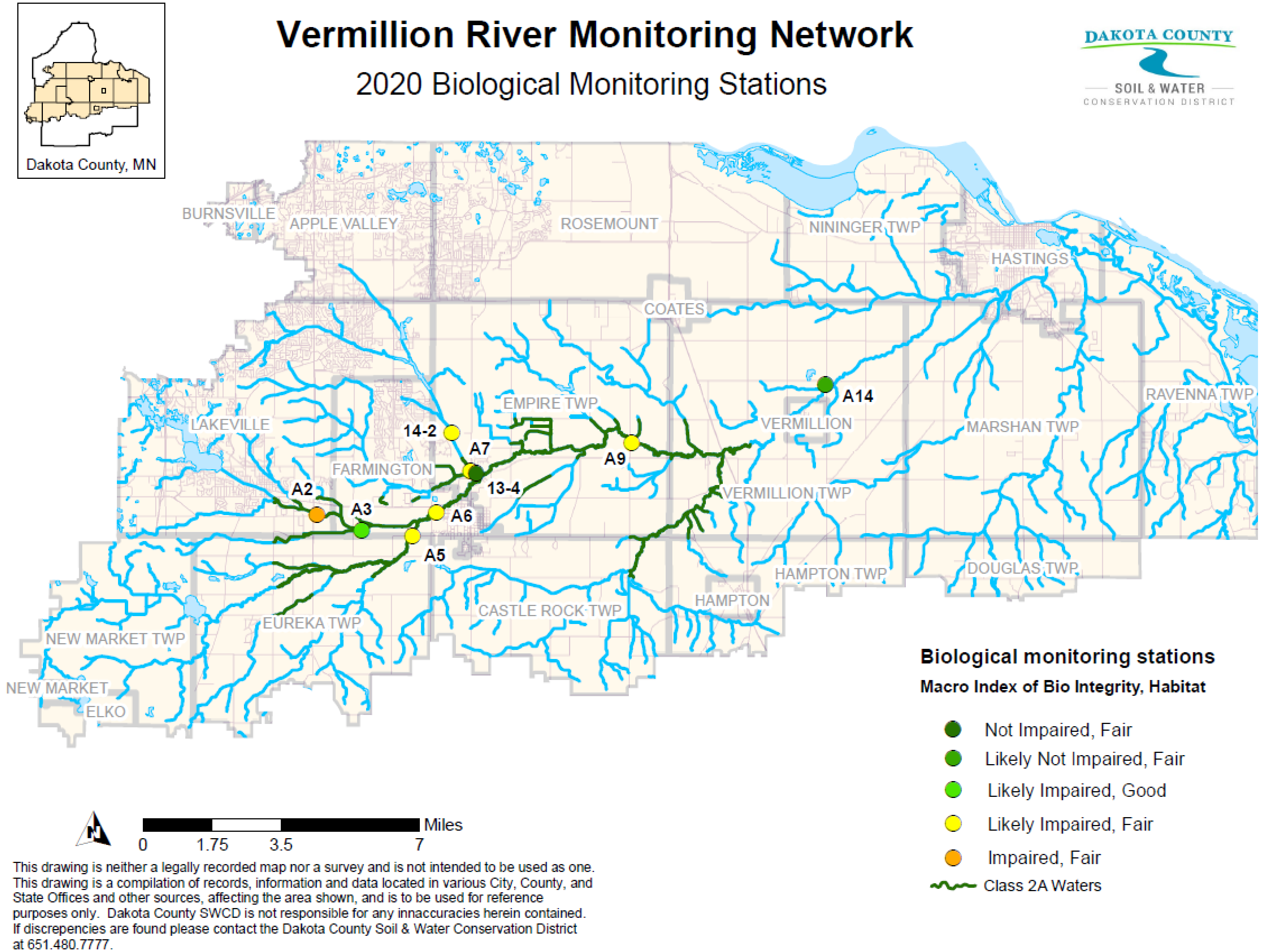


Figure 30. Vermillion River Monitoring Network biological monitoring stations for habitat and macroinvertebrates in 2020.

Macroinvertebrate sampling

Although biological stream monitoring is becoming a widely accepted method for assessing stream health, analysis of these results can be challenging. Biological results are described using a well-established and validated summary of monitoring results called an index of biological integrity (IBI), where individual components of the biological community, or metrics, are evaluated to provide an index score. Using indices specific to certain types of water resources located in similar geographical areas allows for direct comparisons of biological communities from different water resources. Biomonitoring stations in the Vermillion River Watershed are classified as Southern Coldwater Streams, Southern Forest Streams GP, or Southern Streams.

Figure 31 shows the cumulative MIBI scores for all current monitoring stations, along with sites that were historically monitored. The results show a mix of sites that indicate potential impairment and those that do not (see Appendix for annual scores). Sites with medians below the sample threshold, indicating a potential impairment, had low diversity and an abundance of pollution tolerant species. Multiple sites have medians above the impairment threshold, including the stretch of the Vermillion River that runs through Rambling River Park in Farmington (A06) and the part that cuts through the DNR Wildlife Management Area (13-5). Scores above the threshold indicate that a diverse population of macroinvertebrates were identified at the site and several of them are pollutant-sensitive species.

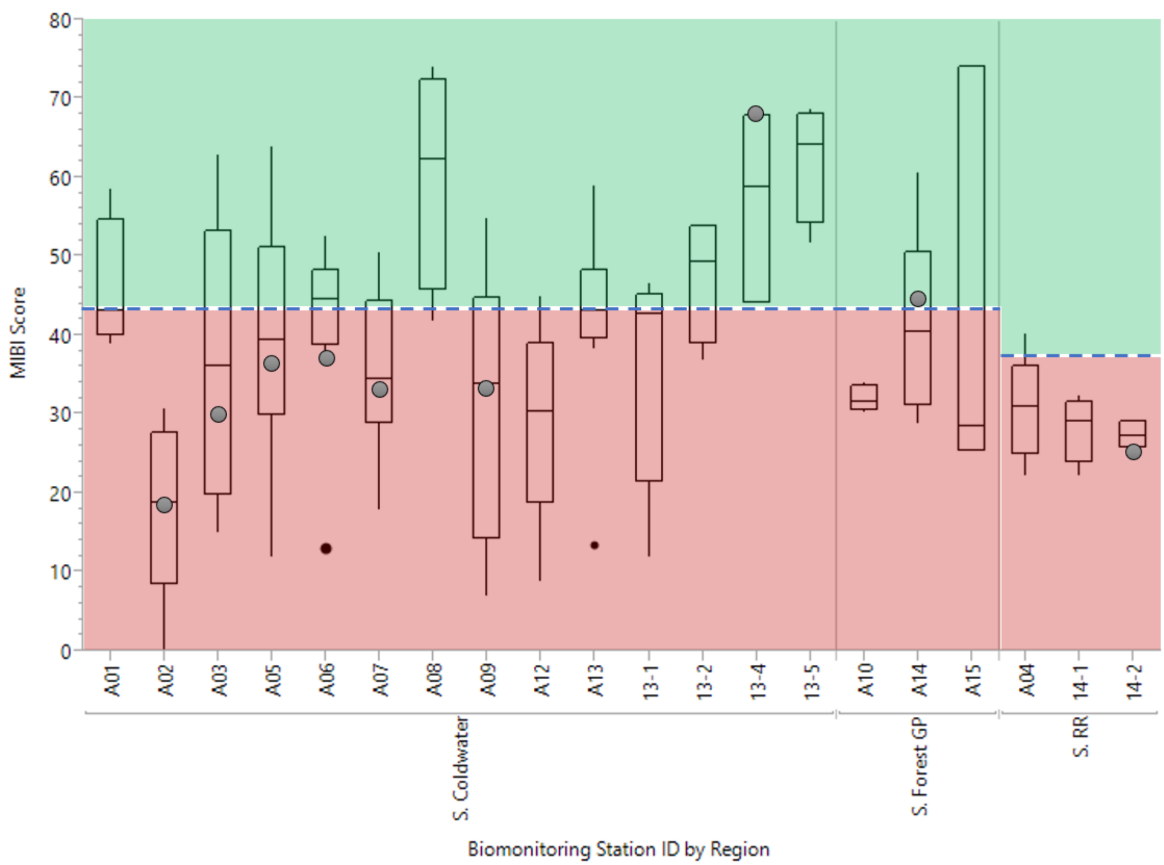


Figure 31. Macroinvertebrate Index of Biological Integrity (MIBI) score by region. Number of samples collected from 2009-2020 is shown in parenthesis (see Appendix for more details). The impairment threshold is indicated by a dashed blue line. Sites with scores above the threshold value (green area), are likely not to be considered 'impaired'. Sites with scores below the threshold value (red area), are likely to be considered 'impaired'. Sites monitored in 2020 have a grey circle indicating the MIBI score.

Habitat Assessments

Habitat assessments were completed at the biological monitoring stations to better understand possible stressors to the biotic community. Stations on the main stem and tributaries of the Vermillion were evaluated to get a representative sample of the watershed. A map of all stations (active and historical sites) and the field scoring sheet and a map, are included in the Appendix and the scoring protocol is described in the Stream Habitat Assessment Protocol for Stream Monitoring Sites (MPCA, 2007).

Total scores for the Minnesota Stream Habitat Assessment (MSHA) are shown in Figure 32. In general, sites that receive a 'good' score had little to no embeddedness (a measure of the degree to which rocks are covered or sunken into the silt, sand or mud of the stream bottom), moderately high to high channel stability, and good sinuosity and channel development. The lowest scoring stations were severely embedded with silt and muck, had no riffles, and poor depth variability and channel development.

One of the nine sites monitored in 2020 received a score of 'good' and eight sites received a 'fair' scoring. None of the sites received a score below 45 which would have rated as a 'poor' score.

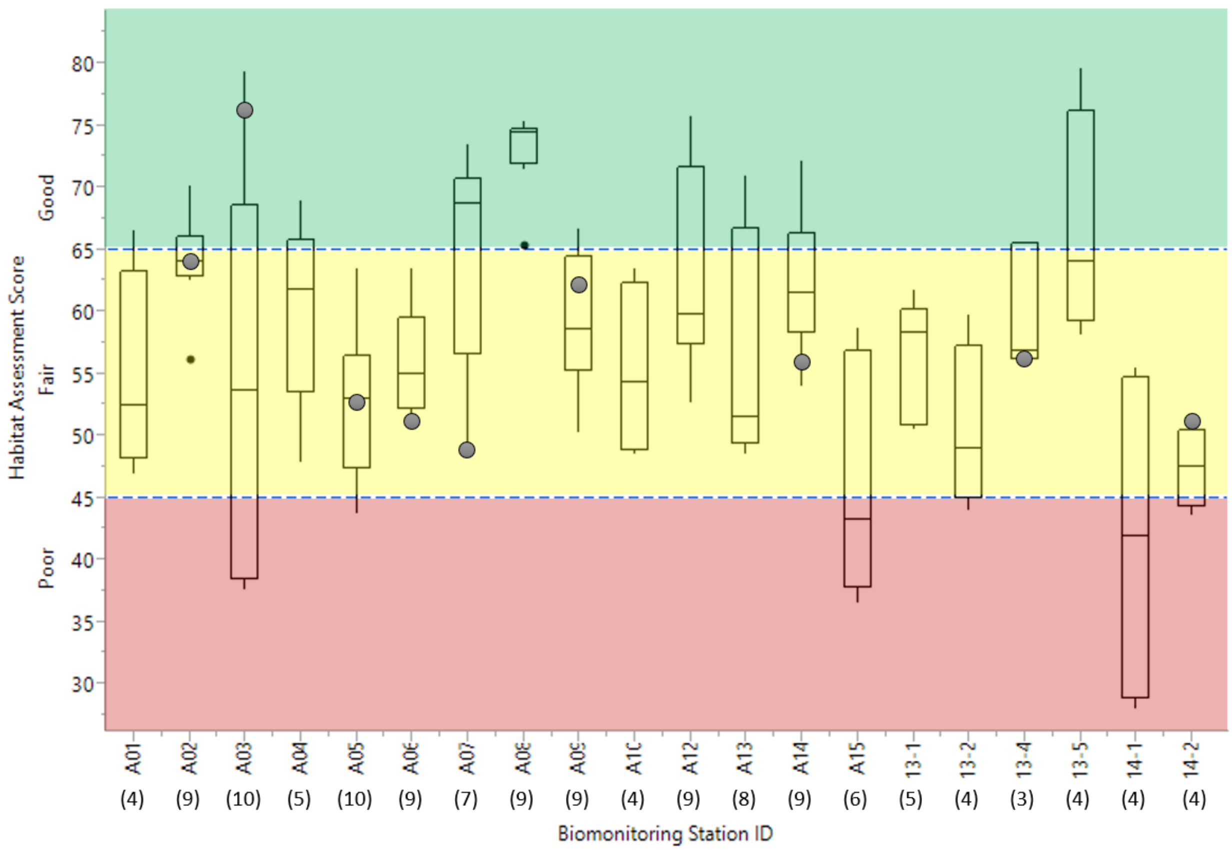


Figure 32. Habitat assessment scores for biomonitoring stations. Habitat scores for 2020 are indicated by grey circle. Dashed blue lines indicate limits for Good (≥66), Fair (45-65), and Poor (≤44) categories. Number of samples collected from 2009-2020 is shown in parenthesis (see Appendix for more details).

Variability in the data can be explained by the wide range of weather patterns, as some years are very wet at some points of the year and much drier during others. Very high and very low water levels can have negative impacts on the stream habitat score.

Figure 33 shows the breakdown of the habitat assessment score for each site in 2020. Sites were evaluated on five major categories per the MSHA program. The assessment categories include land use, riparian zone, substrate, fish cover, and channel morphology.

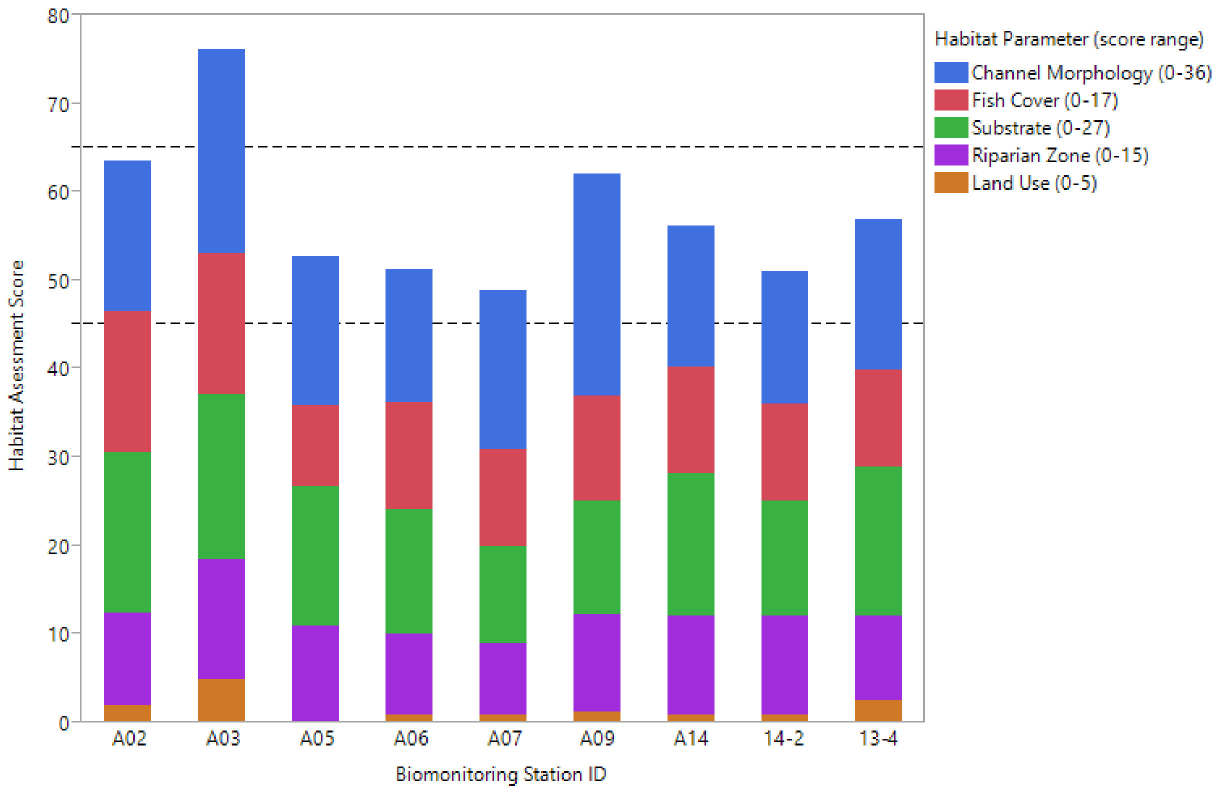


Figure 33. Habitat assessment score by habitat parameter for each biomonitoring station in 2020. Dashed black lines indicate limits for Good (≥66), Fair (45-65), and Poor (≤44) categories based on the total habitat assessment score (total score of 100).

Most sites scored low for the *Land Use* category due to a combination of the proximity of agricultural and urban influences on the stream and narrow buffers widths along the stream edge. Limited riparian width and light to moderate shade contributed to lower *Riparian Zone* scores for many of the sites including A06, A07, and 13-4.

The Vermillion River and most of its tributaries have dominantly sandy substrate. Although the lack of coarse substrate is expected in low-gradient streams, the protocol awards no points for this condition. This, along with reduced number of substrate types identified, explains the lower *Substrate* scores seen in Figure 33, particularly at sites A06, A07, and A09. Undercut banks, overhanging vegetation, and logs or woody debris are important refuges for fish and were the most commonly seen, with deep pools occurring occasionally, and boulders and root wads rarely observed (more often seen at sites that have been restored). The extent of these cover types was also evaluated, and most sites scored either moderate or extensive for cover amount. Lastly, the sites which scored poorly for *Channel Morphology* (A06, A14, 14-2) lacked riffles and pools and had poor sinuosity, exhibiting a poorly developed channel in which the pool/riffle/run pattern was absent.

CONCLUSION

The Vermillion River Monitoring Network is valuable in that it allows us to assess the watershed based on its physical, chemical, and biological characteristics, and use that information to make informed management decisions. A stream which supports a healthy and sustainable biotic community is a primary goal of the VRWJPO, and the various parameters that are monitored as part of this network help to determine which factors are influencing the biotic community.

The macroinvertebrate community and the habitat assessment scores were ‘fair’ for most sites, which is lower than desirable. Improvements to overall stream habitat, particularly in the areas that strongly influence the diversity and abundance of macroinvertebrates (such as cover and substrate) will likely have a positive impact on the macroinvertebrate population, and therefore, the fish population.

Other parameters such as total suspended solids, temperature, dissolved oxygen, nitrate, and *E. coli* bacteria are also of concern. Suspended materials in the water that increase measured levels of total suspended solids can make it difficult for fish to filter water through their gills and forage for food. This movement of material down the stream, particularly during high flows, also contributes to embeddedness and poor channel depth variability as large volumes of fast-moving water transport sediment from fields and streambanks. Additionally, runoff from impervious surfaces and flushing of stormwater ponds following storm events elevates water temperature above ideal levels for trout and other species that thrive in cold water. As a result, dissolved oxygen levels are reduced, which can be detrimental to the trout and macroinvertebrate populations. During low flow conditions, the concentration of nitrate increases, and data suggests that nitrate pollution is getting worse in the South Branch Vermillion River subwatershed. *E. coli* levels are consistently high throughout the watershed as bacteria on land are washed into the river, and bacteria settled into the stream bed are resuspended.

The Vermillion River Watershed faces some challenges; however, improvement is possible. Restoring in stream and riparian habitat, reducing nutrients and suspended materials in the stream, and minimizing temperature peaks, among other possible conservation strategies, will have a cascading positive effect on the overall health of the river.

Oftentimes, when we think of stressors to aquatic biota, water quality parameters, such as the concentration of a given chemical, is the main focus. It is also important to consider physical parameters such as temperature, which plays an essential role particularly in cold water streams. Water quantity and flow patterns have a significant impact on aquatic communities, with too much or too little causing stress. An effective management strategy would be one which integrates both the quality and quantity aspects of the Vermillion River.

Recommendations

- Investigate conductivity and dissolved oxygen issues in North Creek subwatershed
- Work with partners to install strategically placed water storage and retention features to minimize fluctuations in flow and temperature
- Continue *E. coli* assessment monitoring in the area upstream of VR24
- Implement projects to help address increasing nitrate levels in the South Branch subwatershed
- Undertake habitat improvement projects to improve fish cover, sinuosity, and channel substrate
- Network with local landowners to initiate dialogue of restoration opportunities
- Continue monitoring to assess progress toward reaching water quality goals

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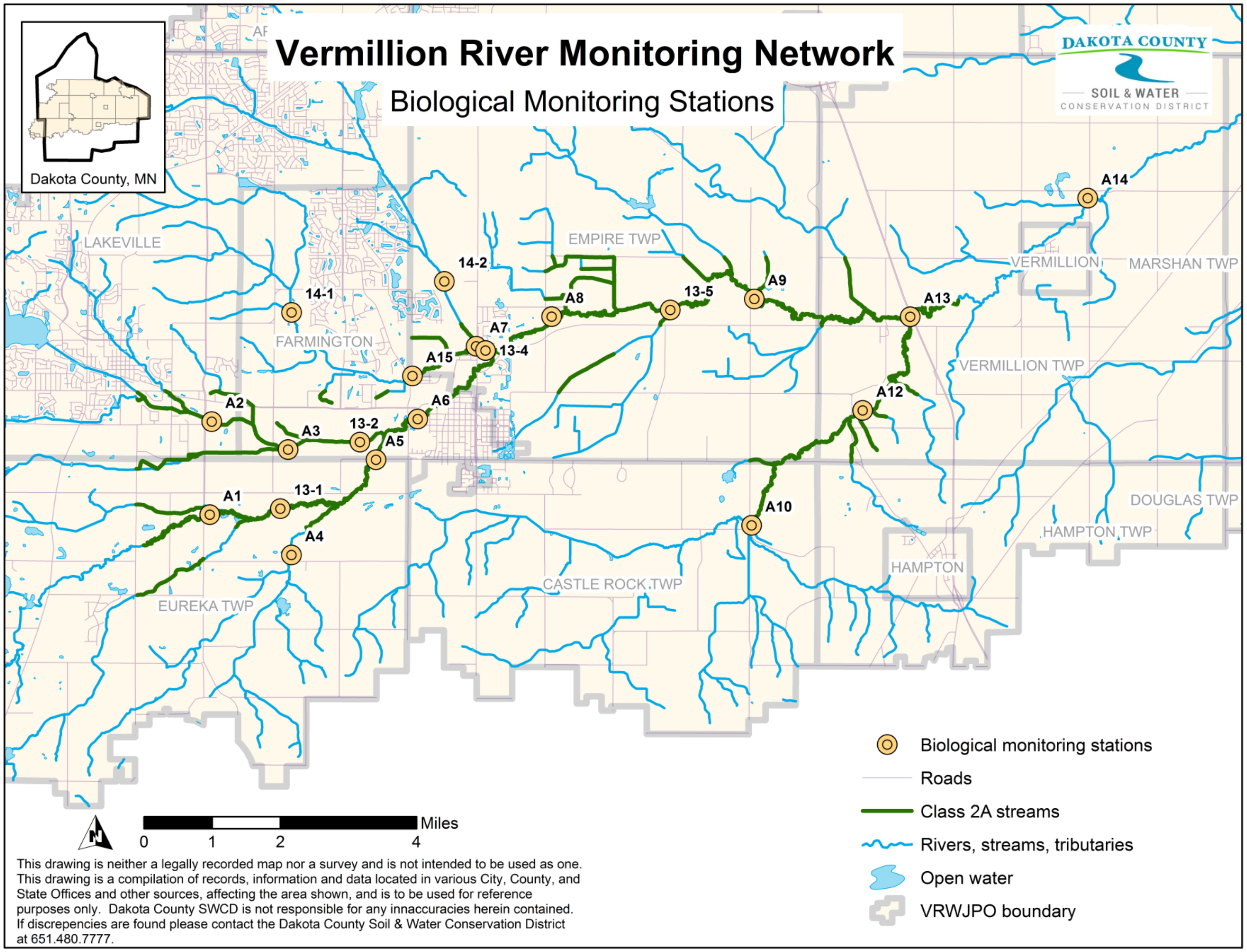
APPENDIX

Biological Monitoring Stations Comprehensive Map



Biological Monitoring Metadata

Bio Station ID	Year	Habitat Score	MIBI Score	MIBI Impairment Threshold	MIBI Stream Classification
A01	2009	53.3	58.520	43	Southern Coldwater Streams
A01	2010	66.6	43.100	43	Southern Coldwater Streams
A01	2011	51.5	43.030	43	Southern Coldwater Streams
A01	2012	47	39.000	43	Southern Coldwater Streams
A02	2009	62.5	0.300	43	Southern Coldwater Streams
A02	2010	65.45	14.600	43	Southern Coldwater Streams
A02	2011	66	19.470	43	Southern Coldwater Streams
A02	2012	70.2	6.000	43	Southern Coldwater Streams
A02	2013	66	11.040	43	Southern Coldwater Streams
A02	2014	64	25.110	43	Southern Coldwater Streams
A02	2015	63.1	30.034	43	Southern Coldwater Streams
A02	2017	52.2	30.680	43	Southern Coldwater Streams
A02	2020	63.5	18.838	43	Southern Coldwater Streams
A03	2009	57	16.200	43	Southern Coldwater Streams
A03	2010	54	42.010	43	Southern Coldwater Streams
A03	2011	66	15.120	43	Southern Coldwater Streams
A03	2012	52	21.000	43	Southern Coldwater Streams
A03	2013	37.6	62.800	43	Southern Coldwater Streams
A03	2014	53.2	57.620	43	Southern Coldwater Streams
A03	2015	38.3	28.987	43	Southern Coldwater Streams
A03	2016	38.4	51.600	43	Southern Coldwater Streams
A03	2018	79.3	42.470	43	Southern Coldwater Streams
A03	2020	76.11	30.075	43	Southern Coldwater Streams
A04	2009	47.85	22.170	37	Southern Streams RR
A04	2010	62.5	30.990	37	Southern Streams RR
A04	2011	61.7	40.280	37	Southern Streams RR
A04	2012	59	32.000	37	Southern Streams RR
A04	2018	69	27.880	37	Southern Streams RR
A05	2009	63.5	15.970	43	Southern Coldwater Streams
A05	2010	60.5	42.150	43	Southern Coldwater Streams
A05	2011	54	35.810	43	Southern Coldwater Streams
A05	2012	52	12.000	43	Southern Coldwater Streams
A05	2013	43.8	34.600	43	Southern Coldwater Streams
A05	2014	45.15	58.490	43	Southern Coldwater Streams
A05	2015	48.1	48.251	43	Southern Coldwater Streams
A05	2016	53.1	63.900	43	Southern Coldwater Streams
A05	2018	55	48.700	43	Southern Coldwater Streams
A05	2020	52.8	36.530	43	Southern Coldwater Streams

Bio Station ID	Year	Habitat Score	MIBI Score	MIBI Impairment Threshold	MIBI Stream Classification
A06	2009	63.5	50.090	43	Southern Coldwater Streams
A06	2010	59.5	44.610	43	Southern Coldwater Streams
A06	2011	59.5	43.790	43	Southern Coldwater Streams
A06	2012	56.9	13.000	43	Southern Coldwater Streams
A06	2013	54	46.340	43	Southern Coldwater Streams
A06	2014	55	44.870	43	Southern Coldwater Streams
A06	2015	53	40.448	43	Southern Coldwater Streams
A06	2017	46	52.600	43	Southern Coldwater Streams
A06	2020	51.2	37.060	43	Southern Coldwater Streams
A07	2009	73.5	28.770	43	Southern Coldwater Streams
A07	2010	70.7	50.590	43	Southern Coldwater Streams
A07	2011	68.8	44.390	43	Southern Coldwater Streams
A07	2012	68.7	39.000	43	Southern Coldwater Streams
A07	2016	64.8	17.900	43	Southern Coldwater Streams
A07	2018	56.55	34.530	43	Southern Coldwater Streams
A07	2020	48.9	33.306	43	Southern Coldwater Streams
A08	2009	73.2		43	Southern Coldwater Streams
A08	2010	71.5		43	Southern Coldwater Streams
A08	2011	74.45	73.950	43	Southern Coldwater Streams
A08	2012	74.5		43	Southern Coldwater Streams
A08	2013	74.75		43	Southern Coldwater Streams
A08	2014	74.75		43	Southern Coldwater Streams
A08	2015	72.4	41.897	43	Southern Coldwater Streams
A08	2017	75.3	67.350	43	Southern Coldwater Streams
A08	2019	65.35	57.120	43	Southern Coldwater Streams
A09	2009	62	21.420	43	Southern Coldwater Streams
A09	2010	50.3		43	Southern Coldwater Streams
A09	2011	57.5	54.920	43	Southern Coldwater Streams
A09	2012	58.4		43	Southern Coldwater Streams
A09	2013	66.7		43	Southern Coldwater Streams
A09	2014	66.7		43	Southern Coldwater Streams
A09	2015	58.6	7.056	43	Southern Coldwater Streams
A09	2016	53	34.600	43	Southern Coldwater Streams
A09	2020	62.03	33.847	43	Southern Coldwater Streams
A10	2009	58.45	31.290	43	Southern Forest Streams GP
A10	2010	48.5	30.380	43	Southern Forest Streams GP
A10	2011	50	34.100	43	Southern Forest Streams GP
A10	2012	63.5	32.000	43	Southern Forest Streams GP

Bio Station ID	Year	Habitat Score	MIBI Score	MIBI Impairment Threshold	MIBI Stream Classification
A12	2009	57.85	11.560	43	Southern Coldwater Streams
A12	2010	56.9	25.980	43	Southern Coldwater Streams
A12	2011	73.2	30.370	43	Southern Coldwater Streams
A12	2012	75.7	37.000	43	Southern Coldwater Streams
A12	2013	69.95	35.510	43	Southern Coldwater Streams
A12	2014	59.7	29.810	43	Southern Coldwater Streams
A12	2015	61.8	8.950	43	Southern Coldwater Streams
A12	2017	58.55	40.930	43	Southern Coldwater Streams
A12	2019	52.65	45.050	43	Southern Coldwater Streams
A13	2009	49.35	43.200	43	Southern Coldwater Streams
A13	2010	63.4	45.110	43	Southern Coldwater Streams
A13	2011	70.9	38.450	43	Southern Coldwater Streams
A13	2012	53.5	43.000	43	Southern Coldwater Streams
A13	2013	48.6	49.240	43	Southern Coldwater Streams
A13	2014	49.6	59.020	43	Southern Coldwater Streams
A13	2015	49.5	42.645	43	Southern Coldwater Streams
A13	2018	67.7	13.370	43	Southern Coldwater Streams
A14	2009	61.1	60.570	43	Southern Forest Streams GP
A14	2010	54	28.810	43	Southern Forest Streams GP
A14	2011	61.5	33.820	43	Southern Forest Streams GP
A14	2012	60.5	32.000	43	Southern Forest Streams GP
A14	2013	72.2	56.290	43	Southern Forest Streams GP
A14	2014	69.15	40.480	43	Southern Forest Streams GP
A14	2015	63.5	30.215	43	Southern Forest Streams GP
A14	2016	63	41.700	43	Southern Forest Streams GP
A14	2020	56.2	44.913	43	Southern Forest Streams GP
A15	2010	58.75		43	Southern Forest Streams GP
A15	2011	36.5		43	Southern Forest Streams GP
A15	2012	43.2	74.000	43	Southern Forest Streams GP
A15	2016	39	25.300	43	Southern Forest Streams GP
A15	2019	55	28.370	43	Southern Forest Streams GP
13-1	2013	58.3	12.030	43	Southern Coldwater Streams
13-1	2014	50.5	42.730	43	Southern Coldwater Streams
13-1	2015	51.1	31.061	43	Southern Coldwater Streams
13-1	2017	58.5	46.660	43	Southern Coldwater Streams
13-1	2019	61.8	43.700	43	Southern Coldwater Streams
13-2	2013	48	45.120	43	Southern Coldwater Streams
13-2	2014	50	53.280	43	Southern Coldwater Streams
13-2	2015	44	36.971	43	Southern Coldwater Streams
13-2	2018	59.7	53.970	43	Southern Coldwater Streams

Bio Station ID	Year	Habitat Score	MIBI Score	MIBI Impairment Threshold	MIBI Stream Classification
13-4	2013	56.1	44.030	43	Southern Coldwater Streams
13-4	2017	65.5	58.660	43	Southern Coldwater Streams
13-4	2020	56.85	67.780	43	Southern Coldwater Streams
13-5	2013	79.6	51.790	43	Southern Coldwater Streams
13-5	2014	65.7	68.590	43	Southern Coldwater Streams
13-5	2015	62.4	66.582	43	Southern Coldwater Streams
13-5	2018	58.1	61.730	43	Southern Coldwater Streams
14-1	2014	28	32.400	37	Southern Streams RR
14-1	2015	31.5	28.706	37	Southern Streams RR
14-1	2017	52.4	22.210	37	Southern Streams RR
14-1	2019	55.46	29.240	37	Southern Streams RR
14-2	2014	48.5	28.560	37	Southern Streams RR
14-2	2015	46.5	29.340	37	Southern Streams RR
14-2	2016	43.6	26.000	37	Southern Streams RR
14-2	2020	51	25.580	37	Southern Streams RR

MPCA Stream Habitat Assessment Field Sheet

MPCA STREAM HABITAT ASSESSMENT

(revised 6-2011)

1. Stream Documentation

Field Number: ________________ Stream Name: ______________________________

Date: ____________________ Person Scoring: ______________________________

MSHA SCORE ☐ **Max = 100**

2. Surrounding Land Use (check the most predominant or check two and average scores) [L=left bank/R =right bank, facing downstream]

L	R			L	R		
☐	☐	Forest, Wetland, Prairie, Shrub	[5]	☐	☐	Residential/Park	[2]
☐	☐	Old Field/Hay Field	[3]	☐	☐	Urban/Industrial	[0]
☐	☐	Fenced Pasture	[2]	☐	☐	Open Pasture	[0]
☐	☐	Conservation Tillage, No Till	[2]	☐	☐	Row Crop	[0]

Land Use ☐ **Max=5**

3. Riparian Zone (check the most predominant)

A. Riparian Width

L	R			
☐	☐	Extensive	> 300'	[5]
☐	☐	Wide	150'-300'	[4]
☐	☐	Moderate	30'-150'	[3]
☐	☐	Narrow	15'-30'	[2]
☐	☐	Very Narrow	3'-15'	[1]
☐	☐	None		[0]

B. Bank Erosion

L	R			
☐	☐	None		[5]
☐	☐	Little	5-25%	[4]
☐	☐	Moderate	25-50%	[3]
☐	☐	Heavy	50-75%	[1]
☐	☐	Severe	75-100%	[0]

C. Shade

L	R			
☐	☐	Heavy	>75%	[5]
☐	☐	Substantial	50-75%	[4]
☐	☐	Moderate	25-50%	[2]
☐	☐	Light	5-25%	[1]
☐	☐	None		[0]

Riparian ☐ **Max=15**

4. Instream Zone

A. Substrate (check two for each channel type)

	Boulder [10]	Cobble [9]	Gravel [8]	Sand [7]	Clay [5]	Bedrock [5]	Silt [2]	Muck [1]	Detritus [1]	Sludge [0]	Channel Type %
Pool	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	____
Riffle	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	____
Run	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	____
Glide	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	____

B. Embeddedness

- ☐ None [5]
- ☐ Light 25-50% [3]
- ☐ Moderate 50-75% [1]
- ☐ Severe 75-100% [-1]
- ☐ No coarse substrate [0]

C. Substrate Types

- ☐ >4 [2]
- ☐ <=4 [0]

D. Water Color

- ☐ Clear
- ☐ Stained

Turbid
- ☐ Brown
- ☐ Green
- ☐ Other

Substrate ☐ **Max=27**

E. Cover Type (check all that apply)

- ☐ Undercut Banks [1]
- ☐ Overhanging Vegetation [1]
- ☐ Deep Pools [1]
- ☐ Logs or Woody Debris [1]
- ☐ Boulders [1]
- ☐ Rootwads [1]
- ☐ Macrophytes: [1]
  - ☐ Emergent
  - ☐ Floating Leaf
  - ☐ Submergent
- ☐ No Macrophytes: [0]

F. Cover Amount (check one)

- ☐ Extensive >50% [10]
- ☐ Moderate 25-50% [7]
- ☐ Sparse 5-25% [3]
- ☐ Nearly Absent [0]
- ☐ Choking Vegetation only [-1]

Cover ☐ **Max=17**

5. Channel Morphology

A. Depth Variability

- ☐ Greatest Depth >4X Shallow Depth [6]
- ☐ Greatest Depth 2-4X Shallow Depth [3]
- ☐ Greatest Depth <2X Shallow Depth [0]

B. Channel Stability

- ☐ High [9]
- ☐ Moderate/High [6]
- ☐ Moderate [3]
- ☐ Low [0]

C. Velocity Types (check all that apply)

- ☐ Torrential [-1]
- ☐ Fast [1]
- ☐ Moderate [1]
- ☐ Slow [1]
- ☐ Eddies [1]
- ☐ Intermittent [-2]
- ☐ Interstitial [-1]

D. Sinuosity

- ☐ Excellent [6]
- ☐ Good [4]
- ☐ Fair [2]
- ☐ Poor [0]

E. Pool Width/Riffle Width

- ☐ Pool Width > Riffle Width [2]
- ☐ Pool Width = Riffle Width [1]
- ☐ Pool Width < Riffle Width [0]
- ☐ No Riffle [0]
- ☐ No Pool [0]

F. Channel Development

- ☐ Excellent [9]
- ☐ Good [6]
- ☐ Fair [3]
- ☐ Poor [0]

G. Present Water Level

- ☐ Flood
- ☐ High
- ☐ Normal
- ☐ Low
- ☐ Interstitial

Channel Morphology ☐ **Max=36**

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