Vermillion River Monitoring Network 2011 Report

Prepared for:
Vermillion River Watershed Joint Powers Organization

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Prepared by:
Dakota County Soil and Water Conservation District

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Acknowledgments:

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Executive Summary:

Overview
The Vermillion River Monitoring Network (VRMN) was created to collect water quality and quantity information from throughout the Vermillion River Watershed. Water quality samples are analyzed for a variety of parameters including nutrients, bacteria, and sediment. Continuous temperature and turbidity (cloudiness) monitoring is conducted to ensure stream conditions remain conducive to supporting a healthy fishery, including a robust brown trout fishery. Macroinvertebrate populations and habitat are also assessed to provide insights into the health of biological communities living in the waters of the Vermillion River.

All results are used to establish long-term water quality and quantity data, provide trend analysis, and determine pollutant loading values. Results are compared against current state water quality standards, or minimally impacted stream eco-region means developed by the Minnesota Pollution Control Agency (MPCA) (Table 1). Results in red text exceed state water quality standards or eco-region means.

Chemistry Results
In general, water quality monitoring results for 2011 were below or near state standards or minimally impacted stream eco-region means, although several endpoints appear problematic (Table 1). Wastewater treatment plant discharge and urban runoff may have contributed to elevated conductivity results for some VRMN sites located near urbanized areas of the watershed (VR24, SC806). Since numerous reaches of the Vermillion River have been listed as impaired for bacteria, it is not surprising that 2011 *E. coli* bacteria results continue to exceed the state standard at all monitoring stations. A region-wide Total Maximum Daily Load (TMDL) study has been completed to help address elevated bacteria concentrations (MPCA 2006). Nitrate concentrations on the South Branch Vermillion River, continue to remain elevated. Although nitrate concentrations are currently below existing state water quality standards, proposed changes to the nitrate standard will likely lead to a future nitrate impairment in this area. Mean turbidity results at all sites were near the state standard, but individual measurements exceed state water quality standards. It should be noted that the state standard is measured in NTUs while 2011 results are reported in NTRUs.

Pollutant Loading Results
Nitrate and total suspended solids (TSS) pollutant yields (pollutant load per acre) were calculated for all monitoring stations and associated tributaries within the Vermillion River Watershed. Nitrate pollutant yields continue to be high in the South Branch of the Vermillion River. Agricultural production, combined with sandy soils and large groundwater inputs, are the likely cause of high nitrate yields in this watershed. Total suspended solids pollutant yields were surprisingly high in the South Creek sub-watershed. This may be due to urban and agricultural runoff, as well as a highly mobile bed load in this subwatershed. However, South Creek TSS yields should be carefully considered since supporting statistical analysis reveals that pollutant loads for TSS may be inaccurate.

Temperature Results
Temperature monitoring results from 2011 were near or slightly above the brown trout chronic exposure limit of 64°F for the warmer summer months (June-August). This was slightly more problematic than usual in 2011, since late summer and fall were extremely dry in the Vermillion River Watershed. Since Vermillion River base flow consists largely of surficial groundwater aquifer discharge, less precipitation likely led to a reduction in groundwater entering the river. During periods where temperatures are approaching the chronic exposure limit, it is assumed that trout seek refuge in nearby cool and deeper pools. Temperatures appear to be supportive of maintaining a healthy trout fishery.

Biological Monitoring Results
The MPCA recently developed biological indices appropriate for the analysis of macroinvertebrates originating from the Vermillion River. When applied to these indices, 2011 results suggest that macroinvertebrate populations are not able to meet minimum index thresholds and are impaired. Habitat assessments were completed using the MPCA's Multi-Stream Habitat Assessment Protocol. These assessments revealed that most sites have "good" or "fair" habitat. Site A15 had the least desirable aquatic habitat, primarily due to poor channel development and stagnant conditions.

Table 1. 2011 Water Quality Data Summary

Parameter (state standard or eco-region mean)	Monitoring Sites: Vermillion River and Cty. 46 (Scott Co.) (VR24)	South Creek at Flagstaff Ave. (SC806)	Vermillion River and 220th St. (SC804)	Vermillion River and Denmark Ave. (VR807)	North Creek and Hwy. 3 (NC808)	Middle Creek and Hwy. 3 (MC801)	South Branch Vermillion River and Cty. 66 (SB802)	Vermillion River and Goodwin Ave. (VR803)	2011 Notes
Mean Conductivity (698 mMHOs)	1208 mMHOs	735 mMHOs	598 mMHOs	634 mMHOs	740 mMHOs	732 mMHOs	535 mMHOs	639 mMHOs	Above eco-region at several locations
Mean Dissolved Oxygen (*7.0 mg/L)(**5.0 mg/L)	8.36 mg/L	7.37 mg/L	8.66 mg/L	7.96 mg/L	7.82 mg/L	7.52 mg/L	8.96 mg/L	8.74 mg/L	Adequate for trout fishery
Geometric Mean E. coli (126 MPN/100ml)	402 MPN/100ml	155 MPN/100ml	206 MPN/100ml	158 MPN/100ml	213 MPN/100ml	228 MPN/100ml	129 MPN/100ml	168 MPN/100ml	Exceeding state standard at all sites
Mean Nitrate (10 mg/L)	2.43 mg/L	1.41 mg/L	2.62 mg/L	2.43 mg/L	1.39 mg/L	1.81 mg/L	6.03 mg/L	3.72 mg/L	In compliance with state standard
Un-ionized Nitrogen Ammonia (*16 µg/L)(**40 µg/L)	0.63 µg/L	0.41 µg/L	0.81 µg/L	0.70 µg/L	1.01 µg/L	1.03 µg/L	0.77 µg/L	0.87 µg/L	In compliance with state standard
Mean Total Phosphorus (0.28 mg/L)	0.24 mg/L	0.07 mg/L	0.10 mg/L	0.11 mg/L	0.10 mg/L	0.09 mg/L	0.07 mg/L	0.09 mg/L	Below ecoregion mean
Mean pH (*8.5)(**9.0)	8.15	7.79	7.96	7.96	7.78	7.83	7.96	8.11	In compliance with state standard
Mean Total Suspended Solids (45.3 mg/L)	24.84 mg/L	11.78 mg/L	10.86 mg/L	12.05 mg/L	18.00 mg/L	13.30 mg/L	8.75 mg/L	14.59 mg/L	Below ecoregion mean
Mean Summer Temperature (64 °F)	66.1 °F	64.1 °F	67.2 °F	64.9 °F	67.1 °F	67.2 °F	61.8 °F	67.3 °F	Slightly elevated for trout fishery
Mean Turbidity (*10 NTU)(**25NTU)	8.72 NTRU	6.41 NTRU	10.48 NTRU	9.30 NTRU	9.90 NTRU	8.95 NTRU	7.33 NTRU	8.35 NTRU	Exceeds state standard (10% exceedence)

mg/L = milligrams per liter or parts per million (ppm)
mMHO = micromhos or microseimens
MPN = most probable number
°F = degrees Fahrenheit

NTU= nephelometric turbidity unit
NTRU = nephelometric turbidity ratio unit
*applies only to monitoring locations located within 2A waters (SC804, VR807, MC801, NC808, SB802)
**applies only to monitoring locations located within 2B waters (VR24, VR809, VR803)

Results in red text are exceeding state water quality standards or eco-region means.

Introduction:

The Vermillion River Watershed is one of the largest watersheds located within the Minneapolis/St. Paul metropolitan area. More importantly, the watershed is home to a robust and thriving brown trout population located within two rapidly growing counties in Minnesota. As a result, numerous water quality monitoring programs are actively assessing the health of this watershed. The purpose of this report is to concisely summarize the results of the surface water quality monitoring activities completed by the Dakota County Soil and Water Conservation District (DCSWCD) and the Scott Soil and Water Conservation District (SSWCD) and sponsored by the Vermillion River Watershed Joint Powers Organization (VRWJPO).

In addition to describing results from 2011, this report includes historical water quality monitoring results from as early as 2000. The historical results presented here are intended to provide perspective with regards to long-term water quality trends in the watershed.

Vermillion River Monitoring Network:

The Vermillion River Monitoring Network (VRMN) was created in the late 1990's to obtain water quality and quantity data from the Vermillion River Watershed and initially consisted of six monitoring stations located in Dakota County. Since then, the network has grown to include a total of eight permanent monitoring stations (Figure 1) and includes an automated weather station designed to assist with water quality/quantity analysis in the Vermillion River Watershed. In 2011, monitoring station VR809 was abandoned due to the river frequently going dry at this location. However, the monitoring equipment was relocated to South Creek and Flagstaff Avenue, within the City of Farmington, where there is a clear need for additional monitoring information. Data from the Metropolitan Council's Watershed Outlet Monitoring Program (WOMP) site in Hastings is also included for comparison purposes. All stations are equipped with a continuous water level logger and temperature logging equipment. Water quality grab samples are collected during large rain events and on a scheduled, bi-weekly basis. Flow is typically measured five to seven times per season, at every site. Staff attempt to measure flow during a variety of flow regimes, to ensure that the mathematical relationship between stage and volume is well understood under most climatic conditions.

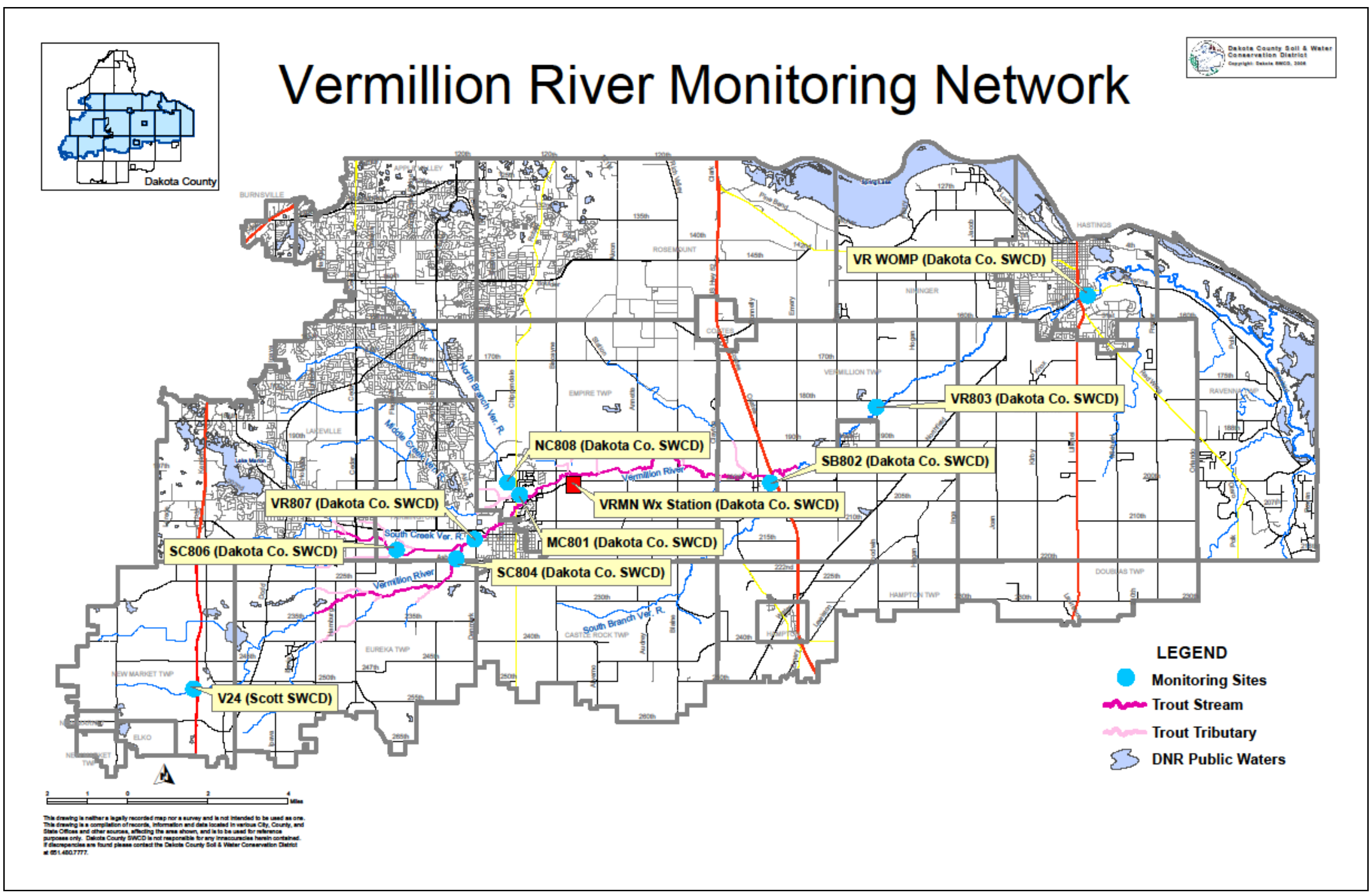


Figure 1. Vermillion River Monitoring Network and WOMP Station Locations

Temperature Monitoring

Since the Vermillion River is home to a thriving brown trout population, there is great interest in maintaining cold water temperatures, suitable for a healthy trout fishery. In addition to water quality and quantity monitoring stations, the VRMN also includes 35 temperature monitoring sites, designed to help identify areas where the fishery could be stressed due to high water temperatures (Figure 2). Results presented in this report only include temperature data collected from the eight permanent water quality and quantity monitoring stations (Figure 1).

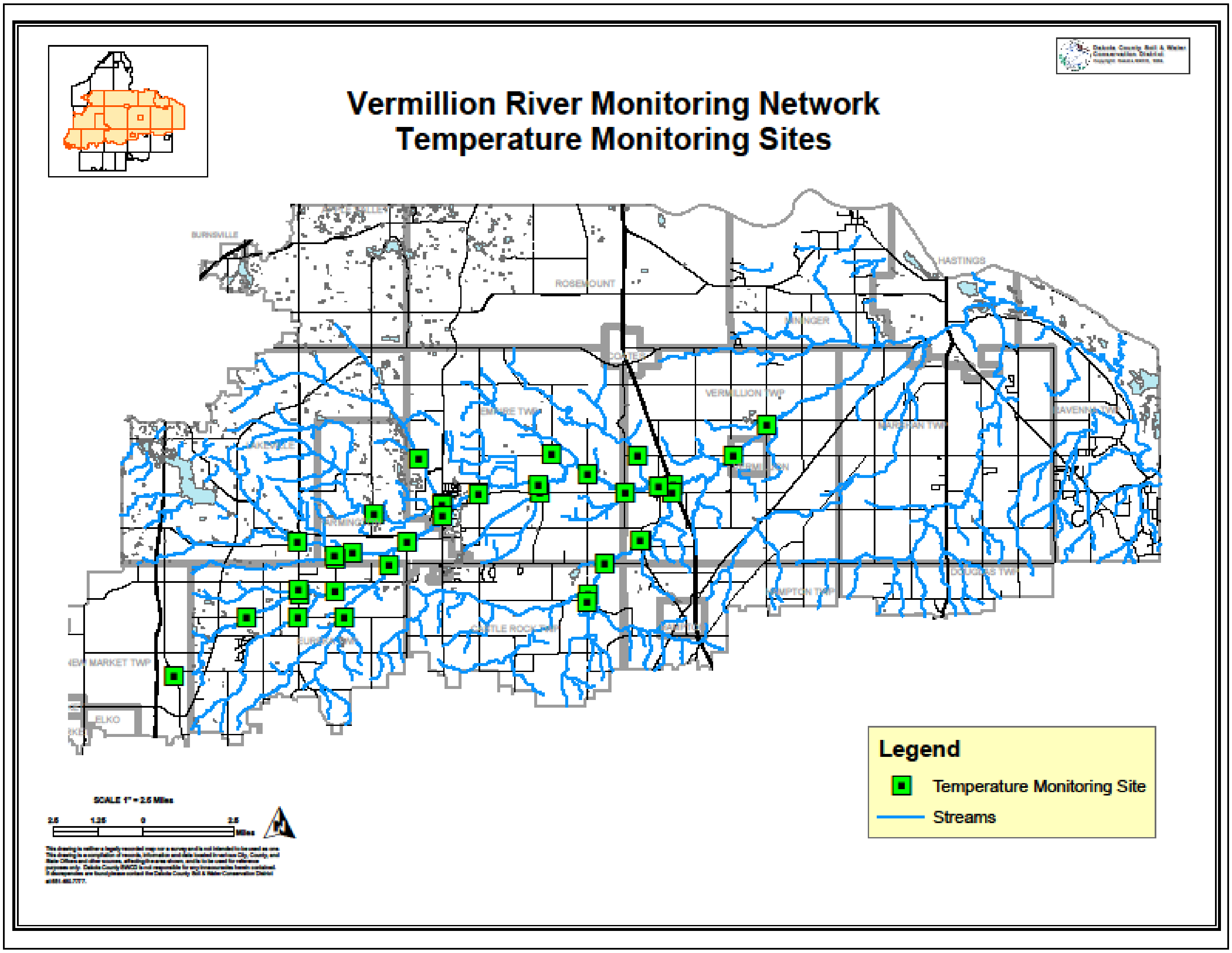


Figure 2. 2011 VRMN Temperature Monitoring Sites

Turbidity Monitoring

In 2008, the Minnesota Pollution Control Agency (MPCA) listed the Vermillion River as impaired for turbidity. In anticipation of the forthcoming turbidity Watershed Restoration and Protection Plan (WRAPP), the VRWJPO added two automated turbidity probes to the VRMN in an attempt to supplement existing turbidity data for the impaired reach (Figure 3). This new equipment allows for an improved understanding of conditions contributing to turbidity exceedances of state water quality standards and will aid in future TMDL load calculations.

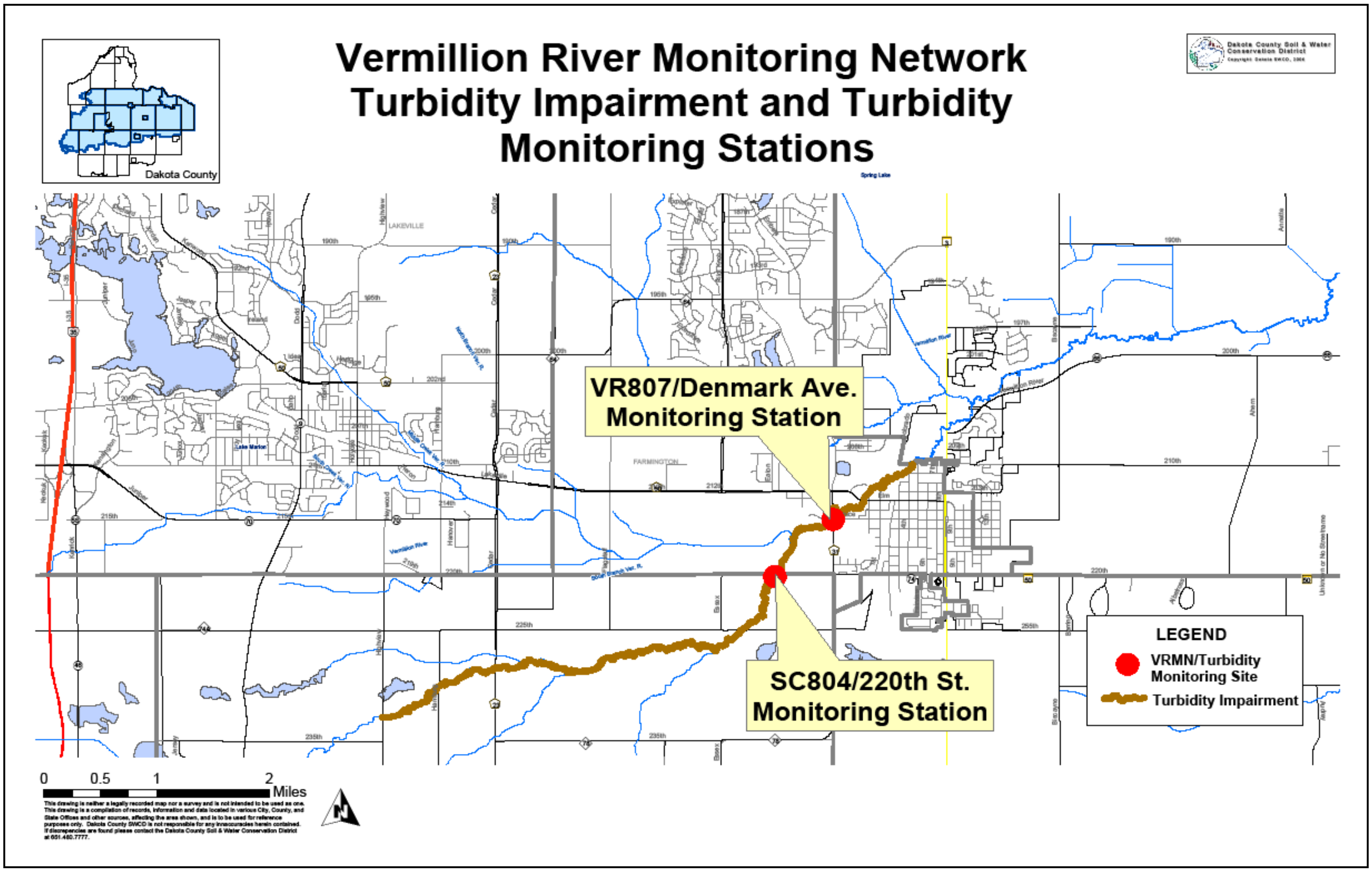


Figure 3. Vermillion River (upper) Turbidity Impairments and Turbidity Monitoring Stations.

Supplemental Flow Monitoring and Data Analysis

The Vermillion River Joint Powers Board continues to contract with the Minnesota Department of Natural Resources (MNDNR) to assist in refining flow measurements and the data analysis necessary to convert VRMN 15-minute stage data into 15-min flow data, which is used by various water resource management organizations. By using some of the most modern technology and techniques available, this process ensures that the VRMN produces the highest quality flow data possible for the watershed. These water quantity data are available on the Minnesota Cooperative Stream Gaging Program website (http://www.dnr.state.mn.us/waters/csg/index.html).

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 parameters. Biological monitoring may also be more sensitive at identifying the cumulative effects of numerous, simultaneous stressors on the biological community.

Figure 4. DCSWCD Staff Collecting Macroinvertebrate Samples

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 whole fish community monitoring, geomorphic assessments, macroinvertebrate monitoring, 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 (Figure 5). This program has also been carefully designed to seamlessly integrate with other biomonitoring efforts to ensure that adequate biological monitoring data is being obtained, while minimizing monitoring expenses.

Whole fish community monitoring and geomorphic assessment work was completed by the MNDNR and private consultants hired by the VRWJPO, while macroinvertebrate sampling and habitat assessments were completed by the DCSWCD.

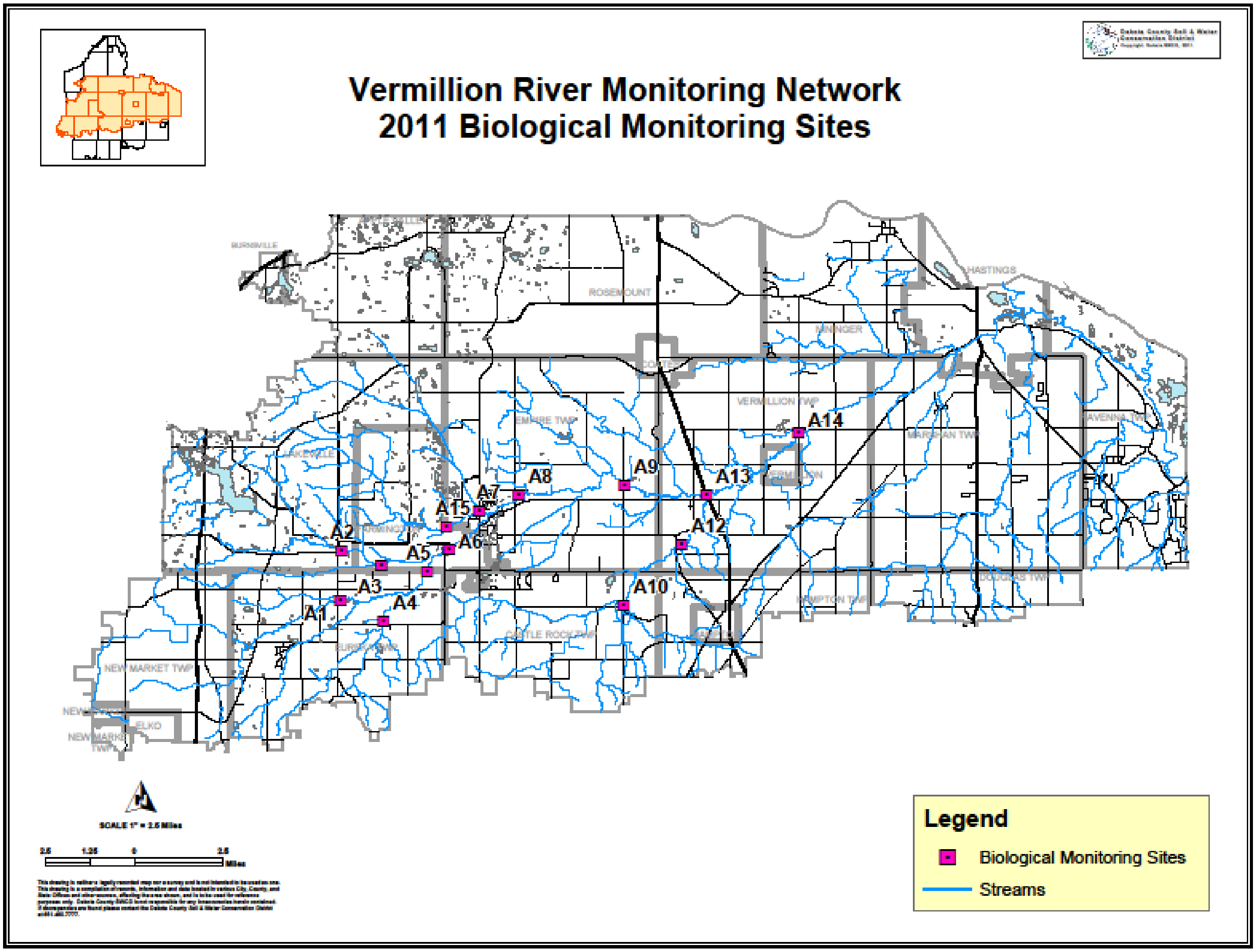


Figure 5. Vermillion River Monitoring Network Biological Monitoring Sites

Methods:

Vermillion River Monitoring Network

Scheduled samples were collected every two weeks from all VRMN sites. Event flow grab samples were collected from sites SC806, SC804, VR807, NC808, MC801, and SB802 whenever river stage responded strongly to precipitation events. These samples were collected to ensure that pollutant loads could be calculated for the major tributaries in the watershed. Event flow samples were not collected from VR24 or VR803 since load calculations for these locations has been deemed unnecessary. However, it should be mentioned that prior to 2009, monthly base flow and event flow grab samples were collected from all sites. Historical results presented below include data from both of these separate monitoring strategies.

Water quality samples were collected from the Vermillion River Monitoring Network utilizing standardized procedures established by the Metropolitan Council Environmental Services (Metropolitan Council, 2003). At each station, automated equipment records stage every fifteen minutes, which is then converted to flow values through the use of MNDNR developed rating tables. A temperature logger is also located at each station to continuously record temperature throughout the warm summer months.

All samples are transported to the Metropolitan Council Environmental Services laboratory and are analyzed according to Environmental Protection Agency (EPA) specified protocols for various endpoints. These endpoints include standard bacterial and chemical parameters. Quality assurance and quality control samples are reviewed annually using MPCA established data quality objectives. At the end of every sampling season, all chemistry data are entered into the MPCA's Environmental Data Access system (http://www.pca.state.mn.us/index.php/data/surface-water.html).

Recognizing that accurate flow data is an essential, but often overlooked, component of load calculations and future TMDL modeling efforts, great care is taken to ensure that VRMN flow measurements are producing the highest quality data possible. Staff carefully follow United States Geological Survey (USGS) established protocols for measuring flow (Buchanan, 1969). Additionally, staff have received field training from both USGS and MNDNR hydrologists to improve flow measurement techniques.

Macroinvertebrate and Habitat Monitoring

Prior to macroinvertebrate sampling or habitat assessments, 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 also documented during site reconnaissance 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).

Dakota County Soil and Water Conservation District staff have been trained by the MPCA to ensure that procedures are being followed correctly and to make certain that macroinvertebrate data collected from this program can be used by the MPCA for future assessment purposes. Macroinvertebrate samples were collected following the MPCA Qualitative Multi-Habitat Sample (QMH) protocol (MPCA, EMAP-SOP4). All samples were collected during the MPCA specified macroinvertebrate index period (August 1st-September 30th).

The habitat assessments were completed by following the MPCA's Stream Habitat Assessment (MSHA) protocol (MPCA, 2007). Dakota County Soil and Water Conservation District staff have been trained by the MPCA to ensure that protocols are being used by DCSWCD staff appropriately.

Results and Discussion:

In addition to results from the Vermillion River Monitoring Network, data from the Metropolitan Council's WOMP site, located on the Vermillion River in Hastings, are included to provide water quality data from the extreme eastern portion of the watershed. This site is labeled as VR WOMP in Figure 1. Dakota County Soil and Water Conservation District staff collected monthly low flow samples and event flow samples from this location, for the Metropolitan Council's monitoring program.

Results presented in the following graphs follow similar formats in that the graphs are generally constructed, reading left to right, in a west (upstream) to east (downstream) format. The western most site is located in Scott County, and the eastern most site is the Metropolitan Council's WOMP site, located in Hastings. Results include flow, precipitation, nutrient concentrations, pollutant yields, turbidity, *E. coli* (bacteria) concentrations, temperature, macroinvertebrate, and habitat monitoring data.

Water quality results are presented as an arithmetic or geometric mean and are compared against mean values for minimally impacted streams of the Western Corn Belt Plains ecoregion, published by the Minnesota Pollution Control Agency (MPCA) (McCollor and Heiskary, 1993). The Western Corn Belt Plains ecoregion was selected since the majority of the Vermillion River Watershed is located within this ecoregion. Results are also compared against State Water Quality Standards (Minnesota Statute 7050) where appropriate. Stream temperature data are compared against optimal temperatures for adult brown trout (Bell, 2006).

Comparisons with ecoregion means and state standards are simple and are only intended to be used as a coarse method to identify water quality values exceeding normal regional ranges or water quality standards. These analyses are not intended to be the definitive determination of water quality impairments. Water quality assessments are completed routinely by the MPCA using more comprehensive processes and methods.

Sampling Summary

Staff made 45 flow measurements to maintain MNDNR established rating tables and collected 167 water quality grab samples. Staff made 238 individual site visits to ensure equipment was functioning properly or to download continuous data. Continuous monitoring equipment generated well over a million lines of data regarding water quality/quantity in the Vermillion River.

In general, VRMN automated equipment functioned well in 2011, with few exceptions. The flow monitoring equipment located at VR803 appeared to malfunction in early summer, rendering much of the stage data suspect for the remainder of the year. The flow data from this site described below has been estimated using MNDNR hydrological modeling software. The only other data loss came in the form of a lost temperature logger on the main channel at Donnelly Avenue. Although wired to sturdy adjacent equipment, sustained high flows in the spring and early summer may have ripped the logger off its mounting.

Flow and Precipitation:

Mean daily flow and precipitation data for the 2011 monitoring season are presented in Figure 6. According to National Weather Service data, the 50 year average (1960-2010) for the same April-October period is 22.80 inches. Total April through October 2011 precipitation data from the VRMN weather station was 19.96 inches. However, more than half (52%) of the April through October precipitation fell within the months of June and July alone, while only 6% of total rainfall fell within the months of September and October. As a result, flow values in the early summer months began high but then dropped dramatically in the fall (Figure 6). The 2011 mean monitoring season 15-minute flow volume for all monitoring stations was near or below historical averages (Appendix A).

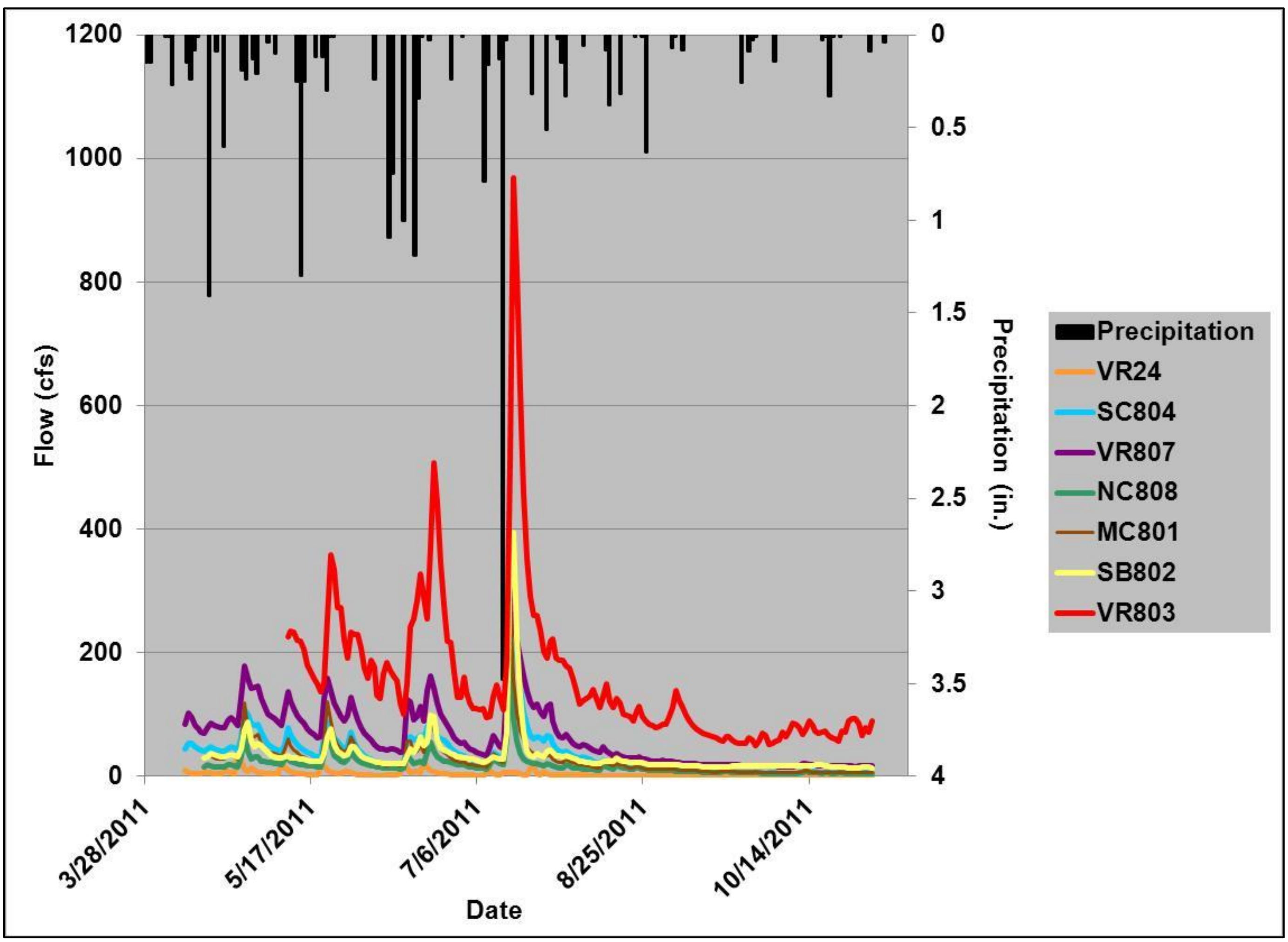


Figure 6. 2011 Vermillion River Monitoring Network Flow and Precipitation Results

Total Phosphorus

Total phosphorus is a commonly used indicator of overall water quality for surface waters and is included in this report for a similar purpose. Total phosphorus concentrations in 2011 (Figure 7) were generally low, but occasional event samples exceeded the Western Corn Belt Plains eco-region mean. Site VR24, located immediately downstream from the Elko/New Market waste water treatment plant, frequently had higher total phosphorus results than other monitoring locations. Storm event mean total phosphorus concentrations generally exceeded scheduled sample mean concentrations. This is to be expected since total phosphorus is highly mobile in the aquatic environment and strongly influenced by precipitation events. All 2011 total phosphorus results can be found in Appendix B.

Historical total phosphorus results are presented in Figure 8. Empire wastewater treatment plant (located upstream from site VR803) upgrades and effluent re-routes to the Mississippi River appear to have dramatically reduced total phosphorus concentrations at the VR803 site. Higher concentrations at site VR24 may be due to its proximity to the Elko-New Market wastewater treatment plant. Discharge from this plant was re-routed to the Mississippi in August of 2011, which may have had an impact on downstream water quality later in the monitoring year. In general, 2011 total phosphorus concentrations are similar to what has been observed in more recent years.

Nitrates

Mean nitrate concentrations in 2011 were well below the current cold water nitrate standard of 10 mg/L (Figure 9). However, scheduled sample or low flow concentrations at site SB802 frequently exceeded the eco-region mean. Higher concentrations at the SB802 site may be the result of a combination of nitrate sources including agricultural production and various groundwater inputs. All 2011 nitrate results can be found in Appendix B.

When 2011 nitrate concentrations are plotted against historical annual mean concentrations, a few general trends begin to emerge. Since 2006, mean nitrate concentrations have consistently been highest at the SB802 monitoring site (Figure 10). This is likely the result of a chronic source of nitrates and sandy soils allowing the leaching of nitrates into surficial groundwater aquifers in the South Branch sub-watershed. Since 2011 grew unusually dry in the late summer and fall, it is not surprising that mean nitrate concentrations at most sites appear higher than more recent and wetter monitoring seasons. Concentrations at the VR803 site continue to remain low, since a peak in 2003. Wastewater treatment plant improvements and the eventual re-routing of the Empire wastewater treatment plant discharge are most likely responsible for the observed reduction in nitrate concentrations here.

Turbidity

Turbidity results in 2011 were relatively consistent throughout the watershed (Figure 11). Event flow mean turbidity results were substantially higher than scheduled sample results at all monitoring stations. Mean event flow conditions at stations located within the trout stream designated portion of the river often exceeded the state turbidity standard. Also, individual sample results for site NC808 exceed the state standard and may constitute an expansion of the current turbidity impairment into this Vermillion River tributary. However, it should be noted that 2011 sample results are reported in Nephelometric Turbidity Ratio Units (NTRU), while the state standard is evaluated in Nephelometric Turbidity Units (NTU). For this report NTRU results are compared against the state NTU standard even though they are not equivalent units of measure. All 2011 turbidity results can be found in Appendix B.

Mean turbidity results are generally near the state water quality standard over the period of record (Figure 12). The 2011 results were similar to what has been observed in recent years, with average turbidity values near or below state water quality standards. However, individual results from all years frequently exceed state water quality standards at the SC804 and VR807 sites, which has led to subsequent turbidity impairments on the main channel of the Vermillion River. It should also be noted that laboratory methodology changed in 2006 such that turbidity was no longer measured in NTUs but switched to NTRUs. Therefore, the reported units in Figure 12 are not consistent across the period of record.

Escherichia coli

The 2011 geometric mean *Escherichia coli (E. coli)* results for the VRMN continue to exceed the state standard (Figure 13). Precipitation event samples continue to produce the highest results. This is expected, since heavy precipitation tends to carry bacteria off of the landscape and into the river. The highest concentrations were observed at the VR24 site located in Scott County. Possible explanations for elevated *E. coli* results include septic system discharge, agricultural runoff, livestock in streams, urban runoff, and re-suspension of bacteria in the sediment. All 2011 *E. coli* results can be found in Appendix B.

The historical geometric mean *E. coli* results are typically exceeding the state standard at most monitoring locations and under most monitoring conditions (Figure 14). The 2011 *E. coli* results follow a similar trend as the historical results. This is not unexpected since the Vermillion River has been listed as impaired for bacteria since 2008. The highest geometric mean *E.* coli results were observed at the VR24 site. This also appears consistent with historical VRMN results. Although the source of bacteria in this location is not clear, it is possible that upstream land uses may be partially responsible for consistently higher bacteria concentrations at the VR24 monitoring site. In addition, flow is typically very low at this site and high bacteria concentrations may be more of a reflection of low volume, rather than prominent source of bacteria in this area.

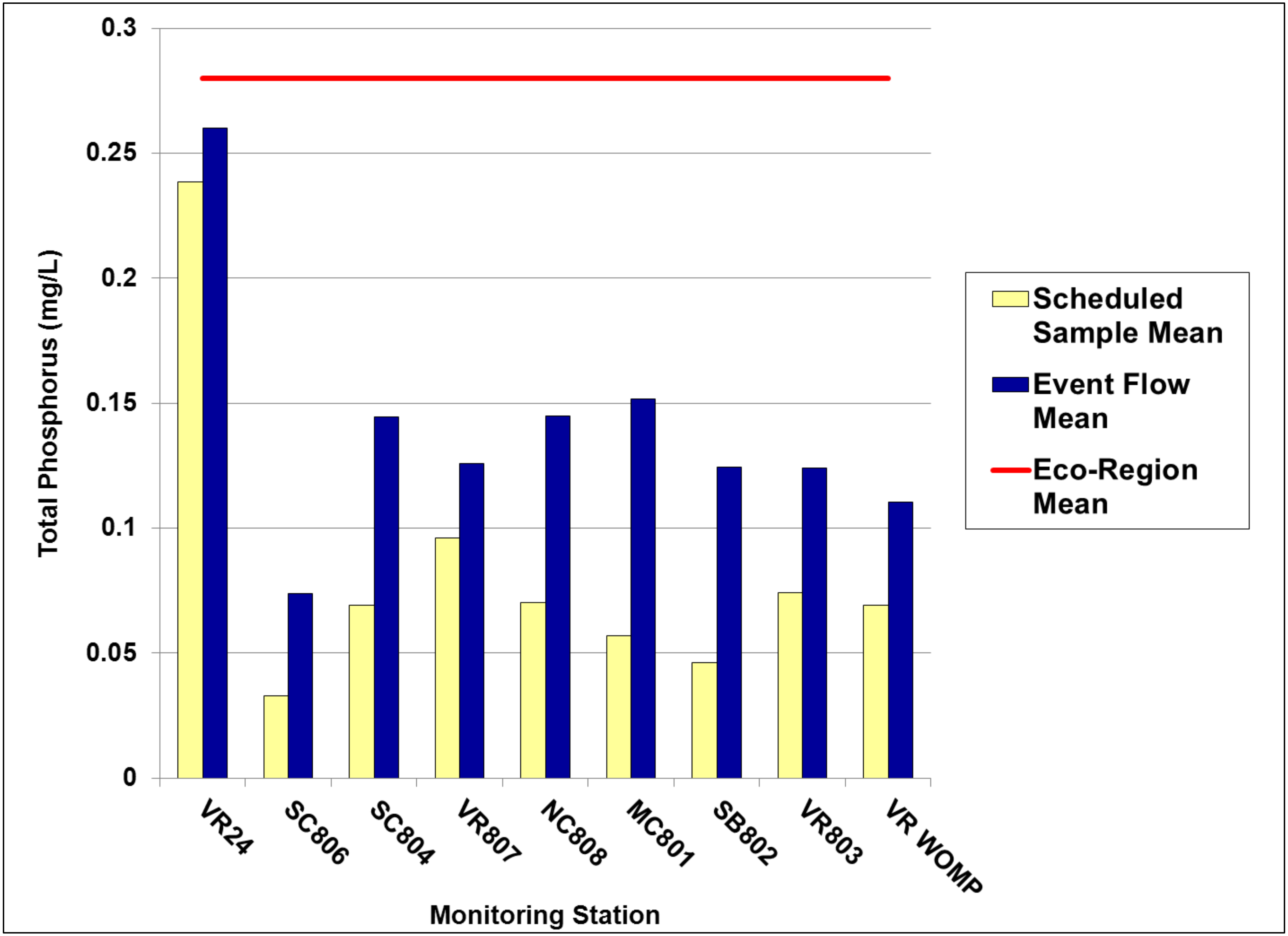


Figure 7. 2011 Mean Total Phosphorus Results

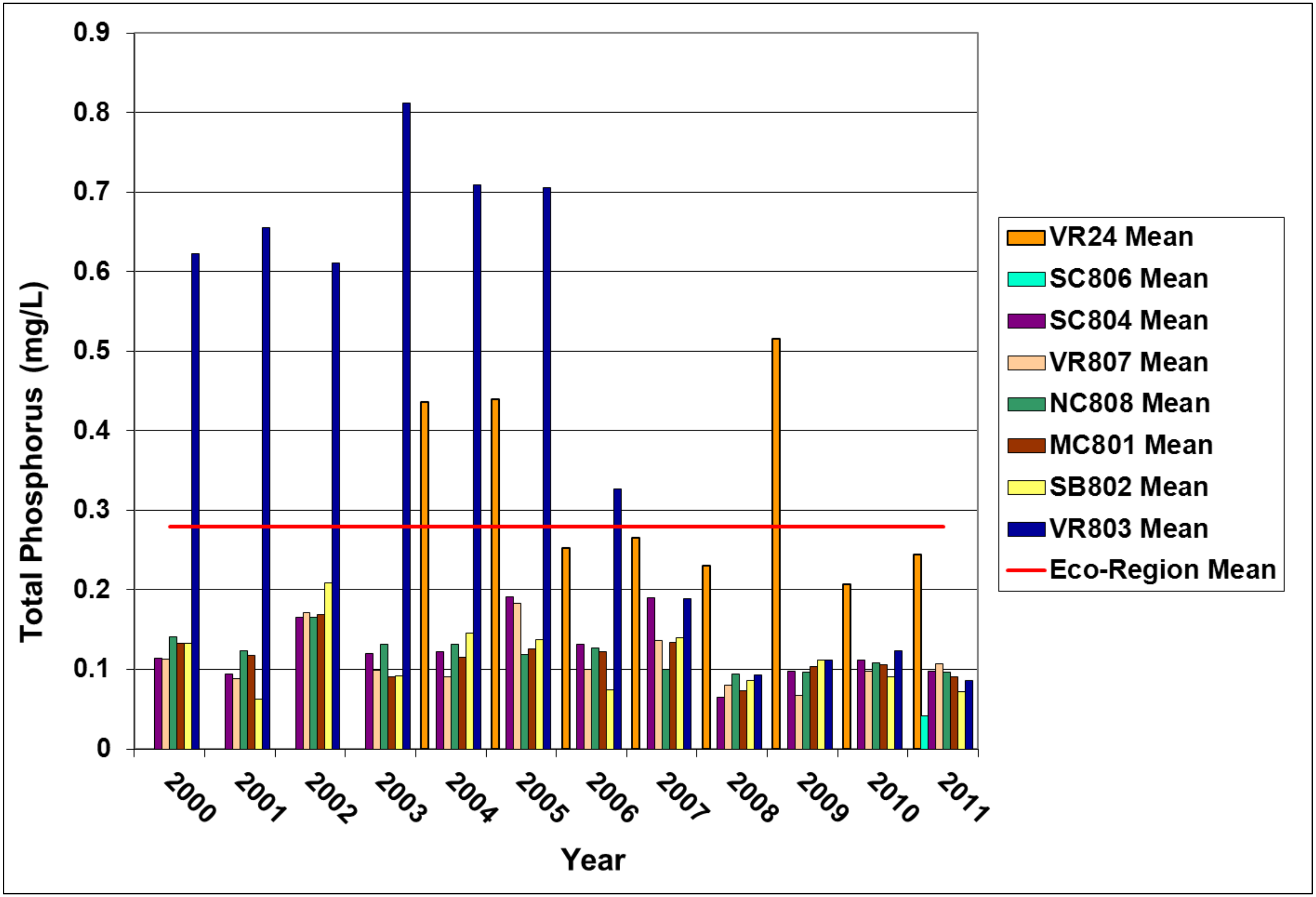


Figure 8. Historical VRMN Total Phosphorus Results

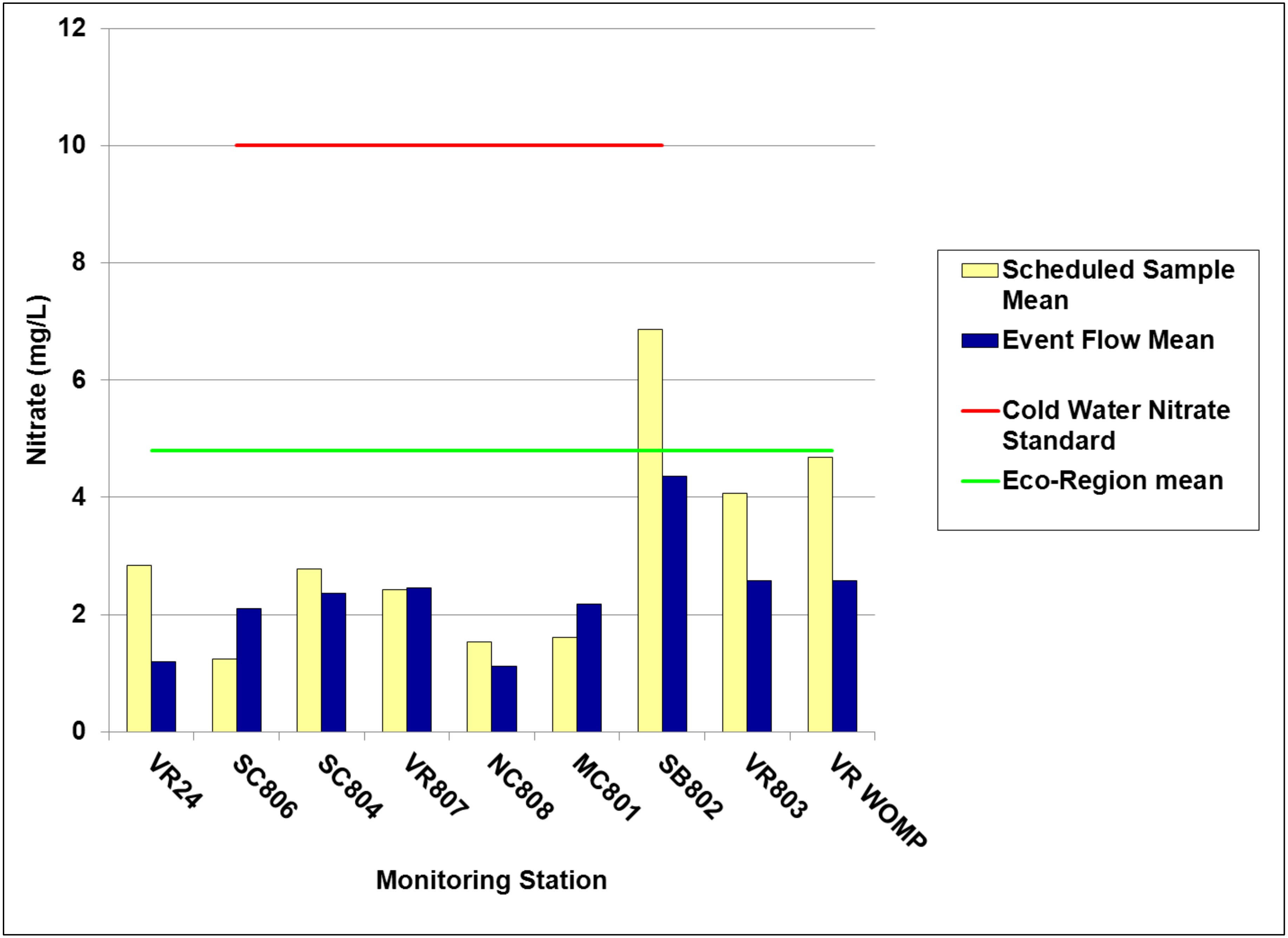


Figure 9. 2011 Mean Nitrate Results

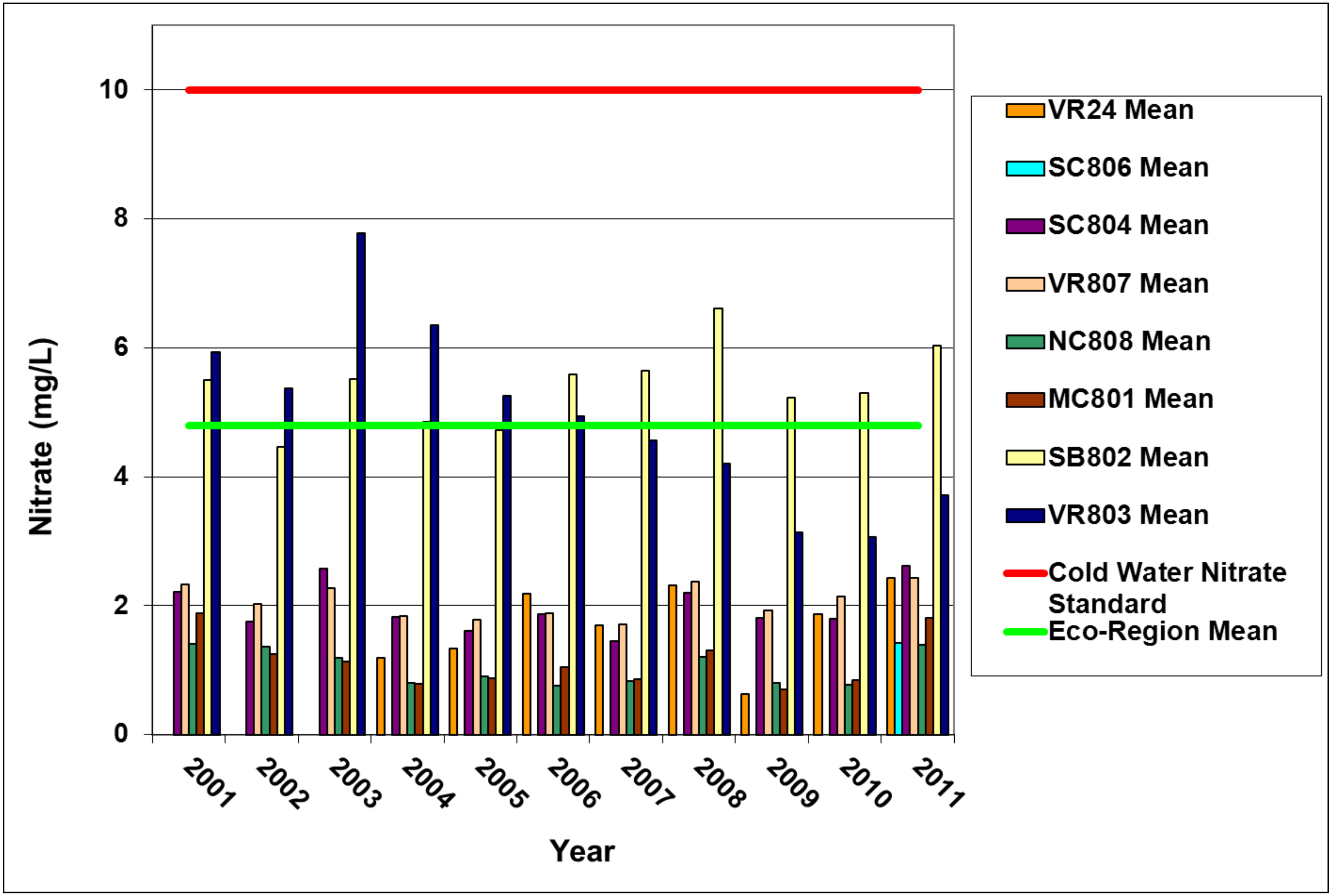


Figure 10. Historical VRMN Nitrate Results

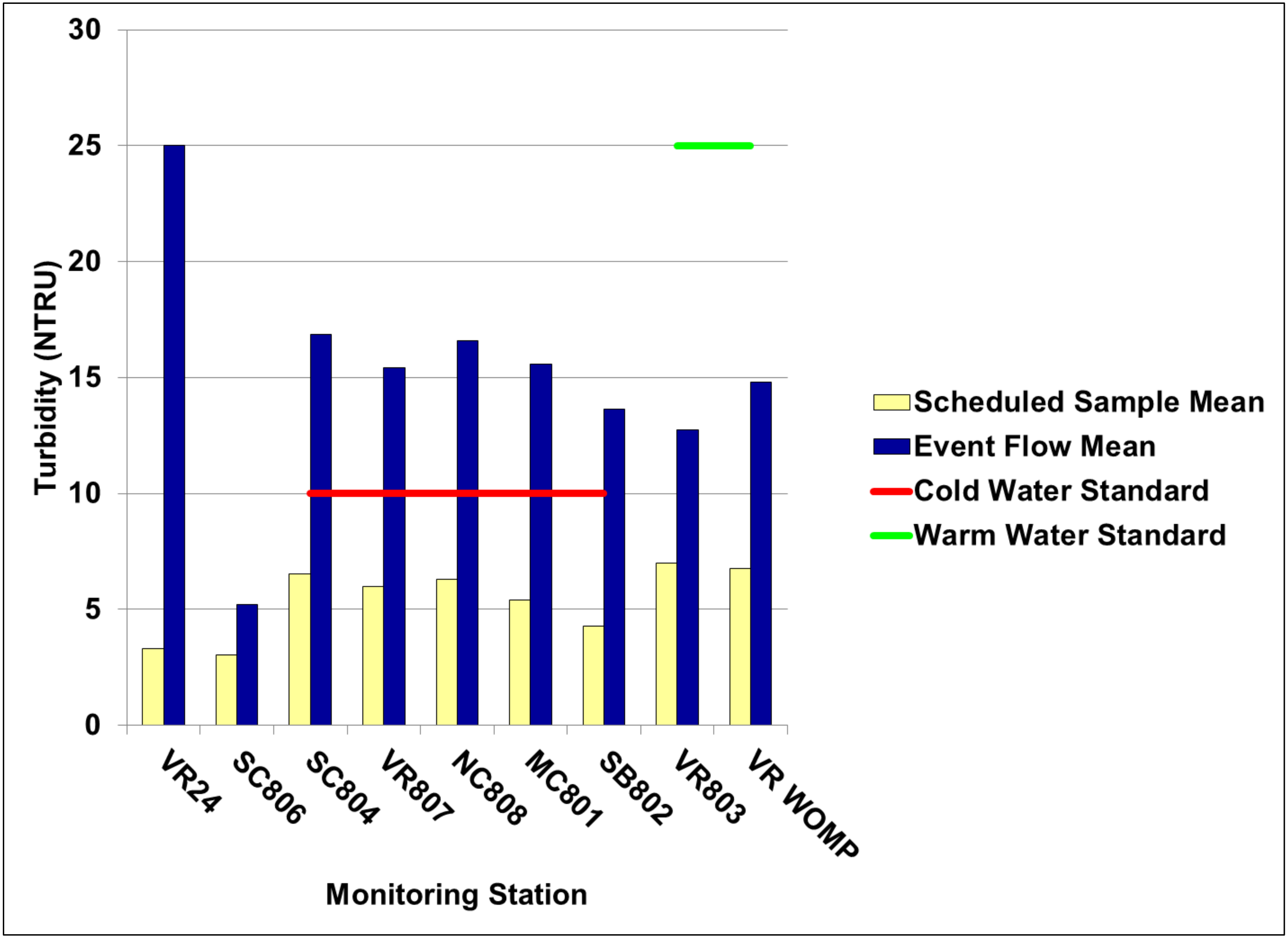


Figure 11. 2011 Mean Turbidity Results

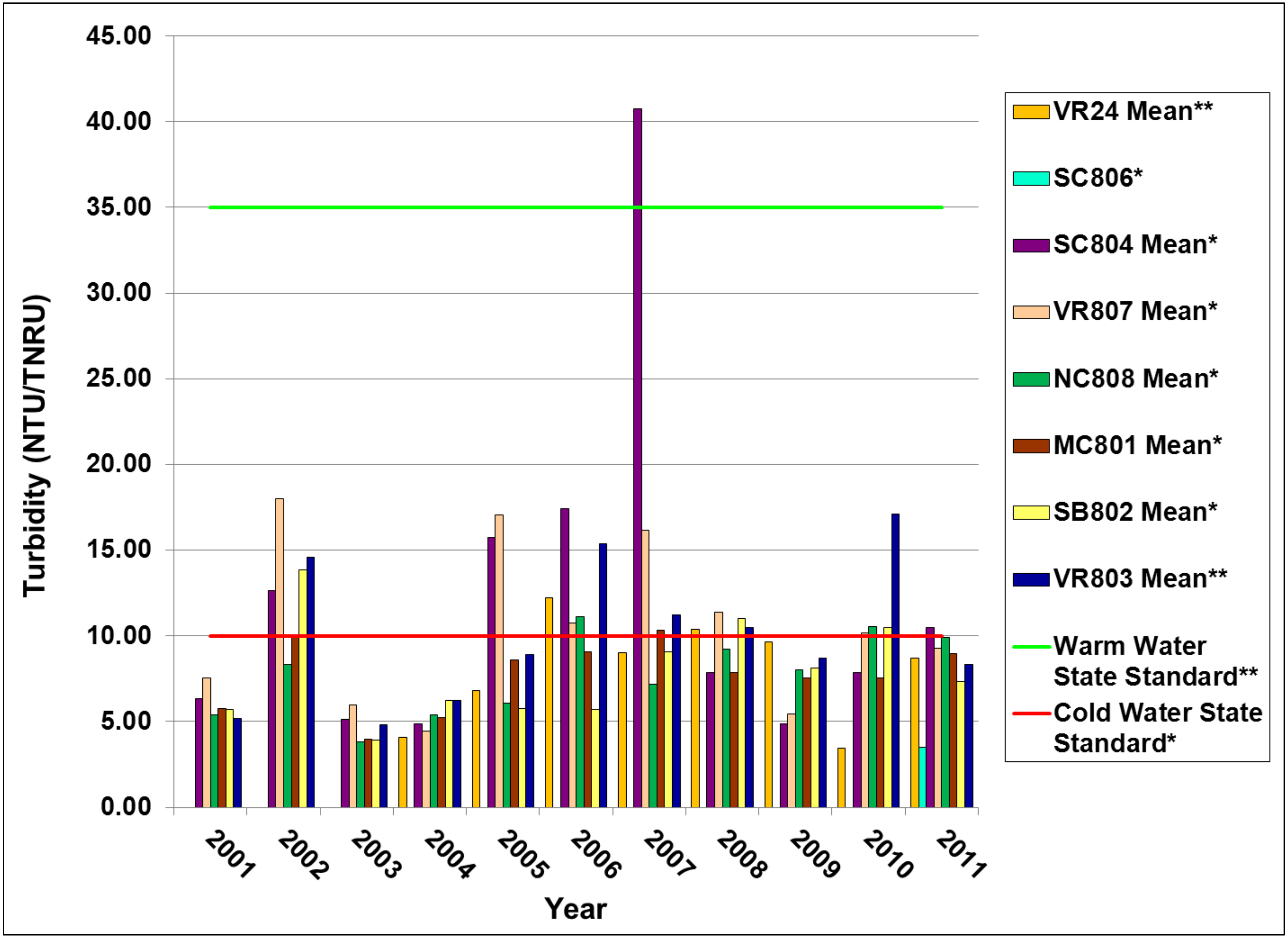


Figure 12. Historical VRMN Turbidity Results

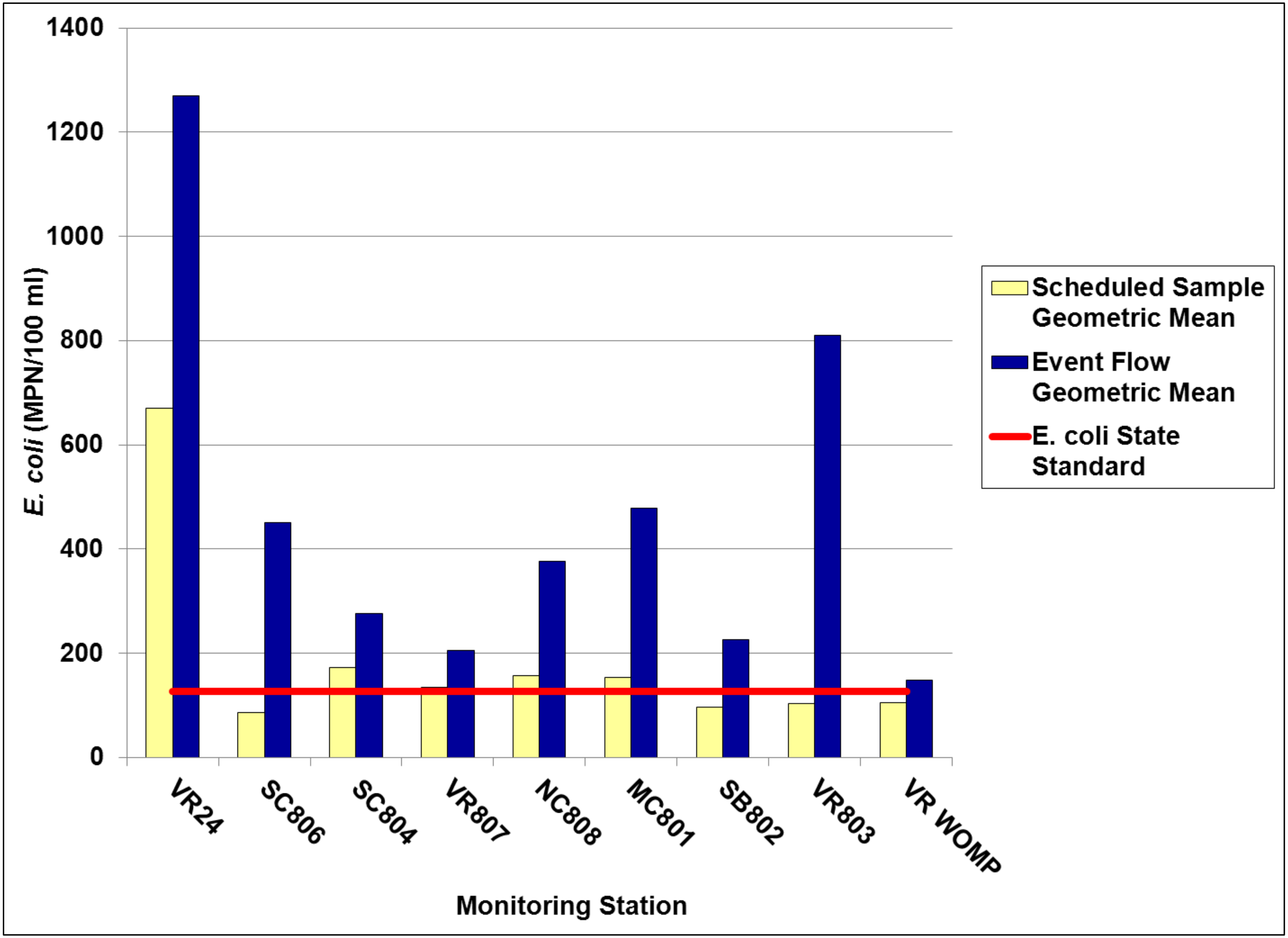


Figure 13. 2011 Geometric Mean *E. coli* Results

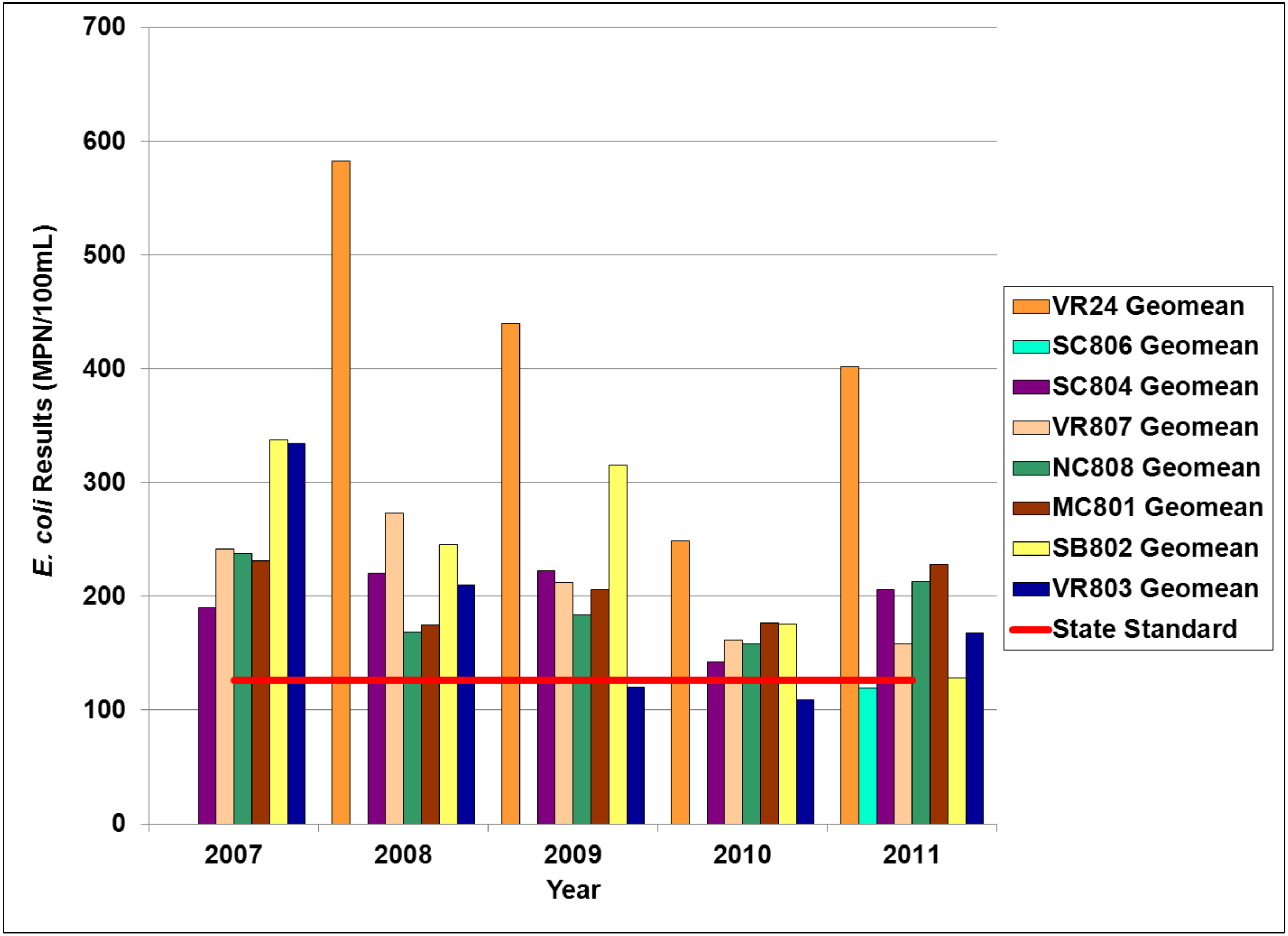


Figure 14. Historical VRMN *E. coli* Results

Pollutant Yields

Nitrate and total suspended solids (TSS) pollutant loads were calculated using the FLUX stream load computation tool (Walker, 1999) for the 2011 monitoring season (March-November), for each monitoring station and/or associated tributary (Figure 15). A pollutant load is the total mass of a particular pollutant that flows through a monitoring station over a given period of time. Calculated loads are then divided by the area of the associated subwatershed for each monitoring station/tributary to provide a pollutant load per acre or a pollutant yield. This type of analysis allows for a comparison of pollutants produced per unit area, regardless of total watershed size, among various subwatersheds.

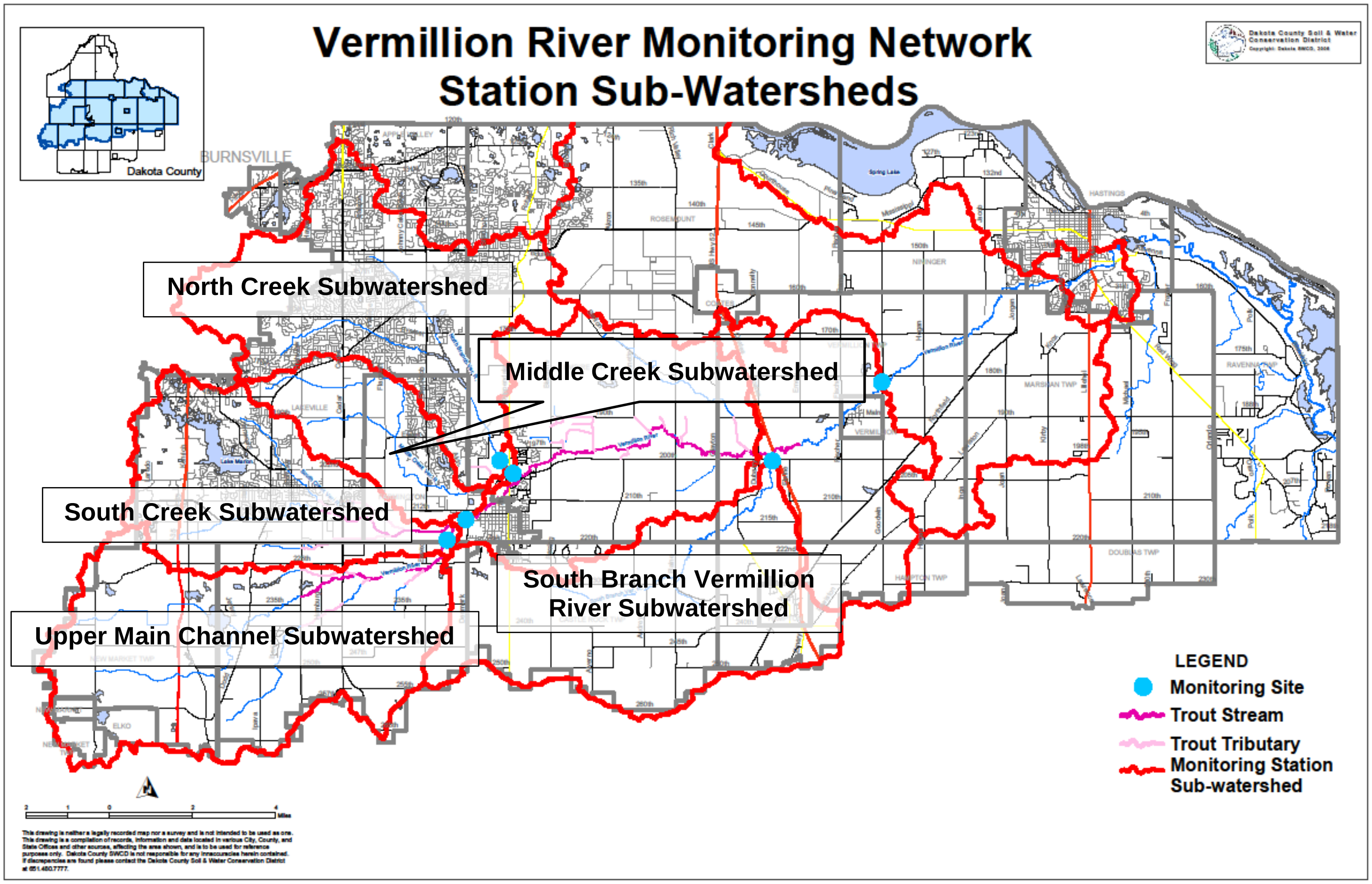


Figure 15. Pollutant Yield Monitoring Sub-Watersheds

Nitrate yields for 2011 were highest for the South Branch Vermillion River subwatershed (Figure 16). The South Branch subwatershed, which is of similar size and similar land use as the Upper Main Channel Subwatershed (SC804), produced pollutant yields roughly three times larger than the upper main channel subwatershed. These results suggest that the South Branch Vermillion River Subwatershed continues to generate disproportionately large amounts of nitrates to the Vermillion River.

Surprisingly, the South Creek subwatershed appears to continues to contribute the second highest nitrate yields within the watershed. An additional monitoring station was established on South Creek and Flagstaff Avenue in 2011 to help identify nitrate sources in this subwatershed and confirm nitrate yields at this site (Figure 16). Flow monitoring results from this station are still preliminary and will be finalized in the next (2012) monitoring report. Nitrate yields will be made available at that time.

Total suspended solids (TSS) yields for 2011 were highest in the South Creek sub-watershed (Figure 17). The results from South Creek are somewhat surprising, since much of this watershed is developed and is generally considered stable. As mentioned above, flow monitoring results from this subwatershed are still preliminary and will be finalized in the next (2012) monitoring report. Pollutant loads from this station will be calculated in subsequent reports and will help identify where the high TSS load is originating from. Potential TSS sources include urban development, agricultural runoff, and in-stream bed load.

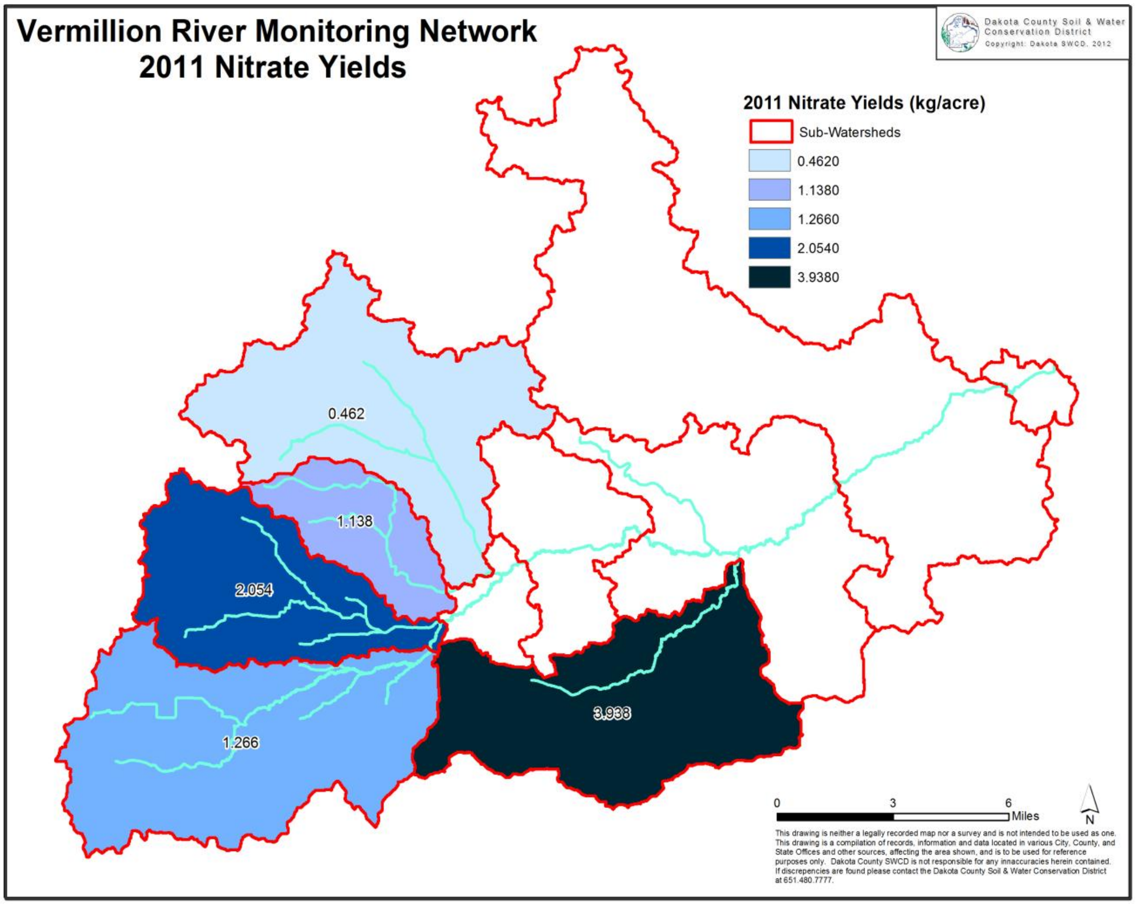


Figure 16. 2011 Nitrate Yields

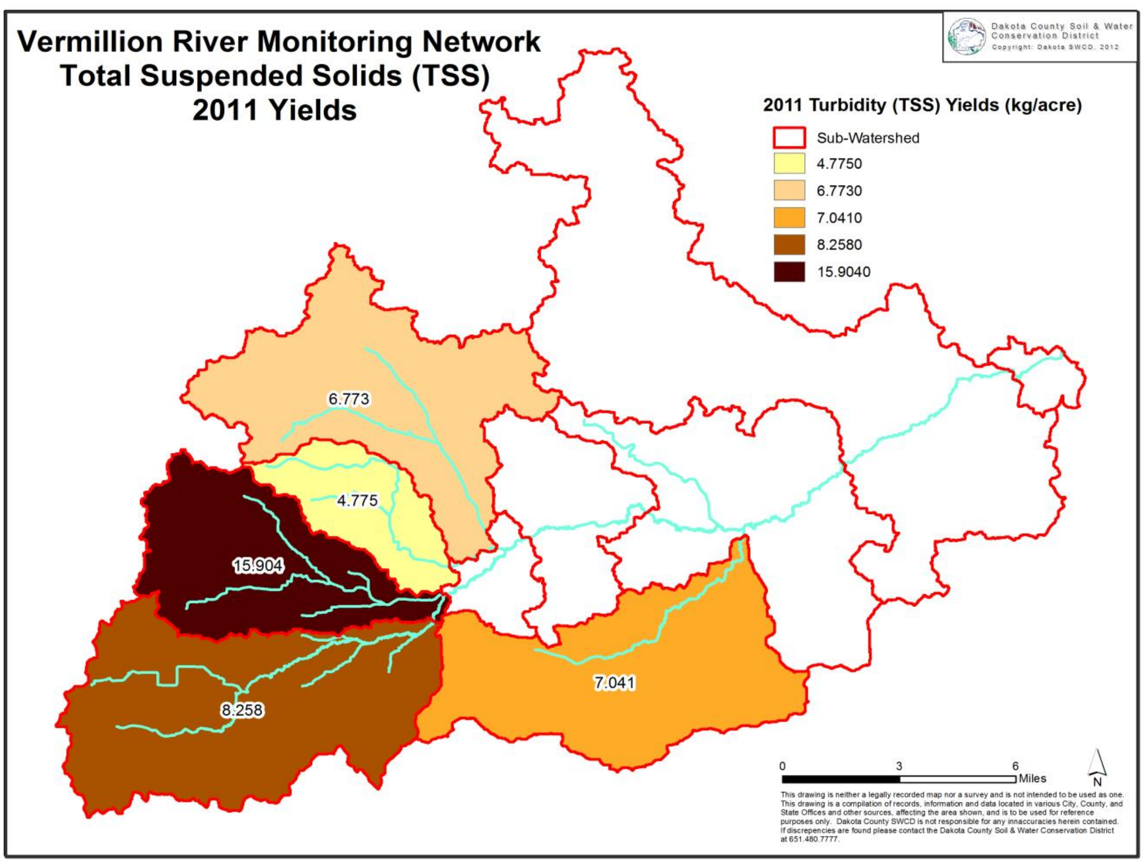


Figure 17. 2011 Total Suspended Solids Yields

Pollutant Load Trend Analysis

The VRWJPO has sponsored monitoring within the Vermillion River Watershed for the last eleven years. In addition, the watershed has intentionally developed a monitoring program that produces data conducive to load computation (see Pollutant Yields). Pollutant loads can be "normalized" through division by annual flow volumes recorded at each site. This allows for an annual comparison of pollutant loads across multiple years of monitoring data regardless of flow conditions. In this case, flow values are calculated by adding mean daily flows for each monitoring site, for each monitoring year, during a uniform index period. Based on the consistency of the VRWJPO flow data, the index period was selected to include flow values from May 1st to October 15th.

Select parameters and sites were chosen for trend analysis. These parameters were selected because they are either general indicators of water quality at key locations throughout the watershed or because a particular parameter is of concern in certain locations within the watershed. Sites were selected based on their ability to describe overall water quality for a portion of a specific subwatershed or as a representative example of water quality within the larger watershed.

Total Phosphorus

Total phosphorus loads were divided by index period flows for the VR807 (Denmark Avenue) site located in Farmington and for the Metropolitan Council WOMP site in Hastings. The VR807 site was selected to describe conditions more representative of the upper reaches of Vermillion River Watershed. The WOMP site was selected to provide information on conditions on the lower reaches of the watershed.

As can be observed in Figure 18, total phosphorus loads/flow are decreasing in both the upper and lower portion of the watershed. Installation of best management practices, like raingardens and buffer/filter strips, may account for the trends observed here. However, the total phosphorus load/flow trend appears to be decreasing much faster in the lower portion of the watershed. This is likely a consequence of the Empire WWTP re-route, which occurred in 2008.

Nitrates

Nitrate concentrations and pollutant loads continue to be a concern in the South Branch of the Vermillion River. When nitrate pollutant loads on the South Branch are divided by flow volumes and are plotted over time, a weak decreasing trend becomes apparent (Figure 19). This suggests that although nitrate concentrations remain a serious concern, the total amount of nitrate leaving the South Branch system may be decreasing over time.

Nitrate load/flows within the lower portion of the Vermillion River Watershed also suggest a decreasing trend. As seen in Figure 19, nitrate load/flow trends at the Metropolitan Council WOMP station in Hastings have been decreasing over the last five years. This too suggests that nitrate conditions may be improving within the watershed.

Turbidity

The upper portion of the Vermillion River Watershed has been listed as impaired for turbidity by the MPCA. For this reason, there is considerable interest in reducing turbidity in this region of the Vermillion River. Since turbidity is a measure of light clarity and is not a measure of a pollutant mass or volume loads cannot be calculated for turbidity. However, total suspended solids (TSS) can be used as a surrogate for turbidity and can be used for pollutant load calculations. Total suspended solid loads/flow for an upper watershed (VR807) site and for a lower watershed location (VR WOMP) are presented in Figure 20. It should be noted that the additional sampling required for TSS load analysis was not initiated until 2009 for the Vermillion River Monitoring Network sites and is the reason TSS loads prior to 2009 are not available.

Similar to total phosphorus and nitrate loads/flow for the VR WOMP station, total suspended solids loads/flow in Hastings also appear to be following a decreasing trend. However, it appears that TSS loads/flow in the upper reach (VR807) are increasing. This site is located within the impaired turbidity reach and may suggest a worsening of turbidity conditions. Improvements resulting from the ongoing Watershed Restoration and Protection Plan for the Vermillion River should help address this issue.

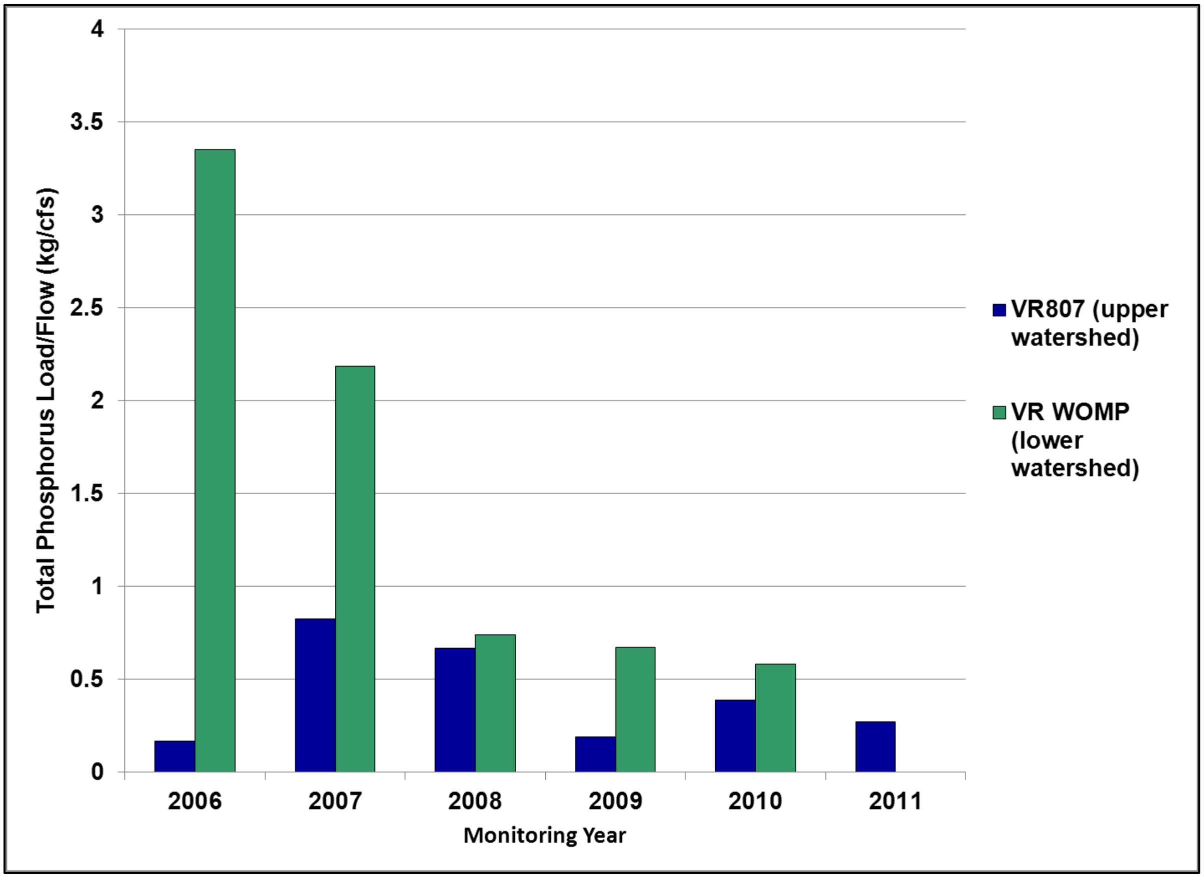


Figure 18. Historical Total Phosphorus Load/Flow for VR807 and VR WOMP Monitoring Sites

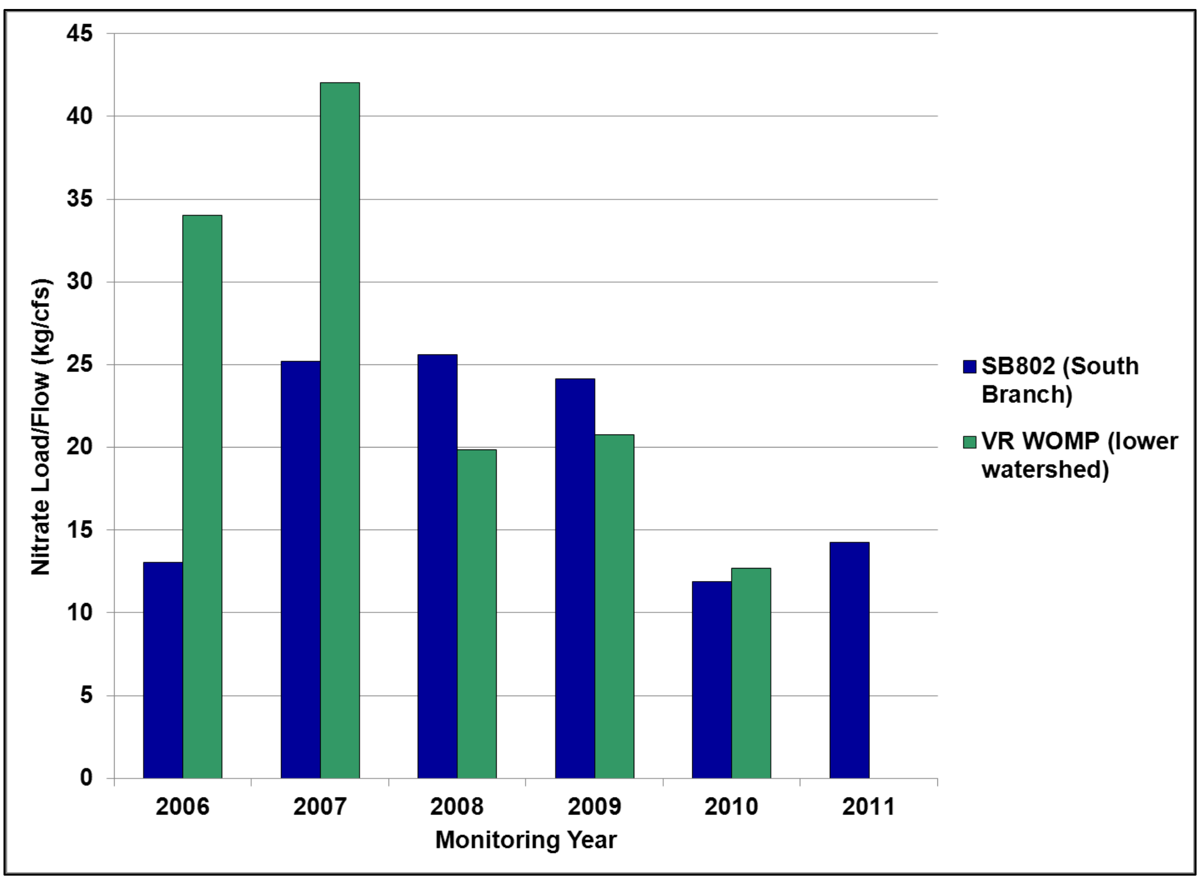


Figure 19. Historical Nitrate Load/Flow for SB802 and VR WOMP Monitoring Sites

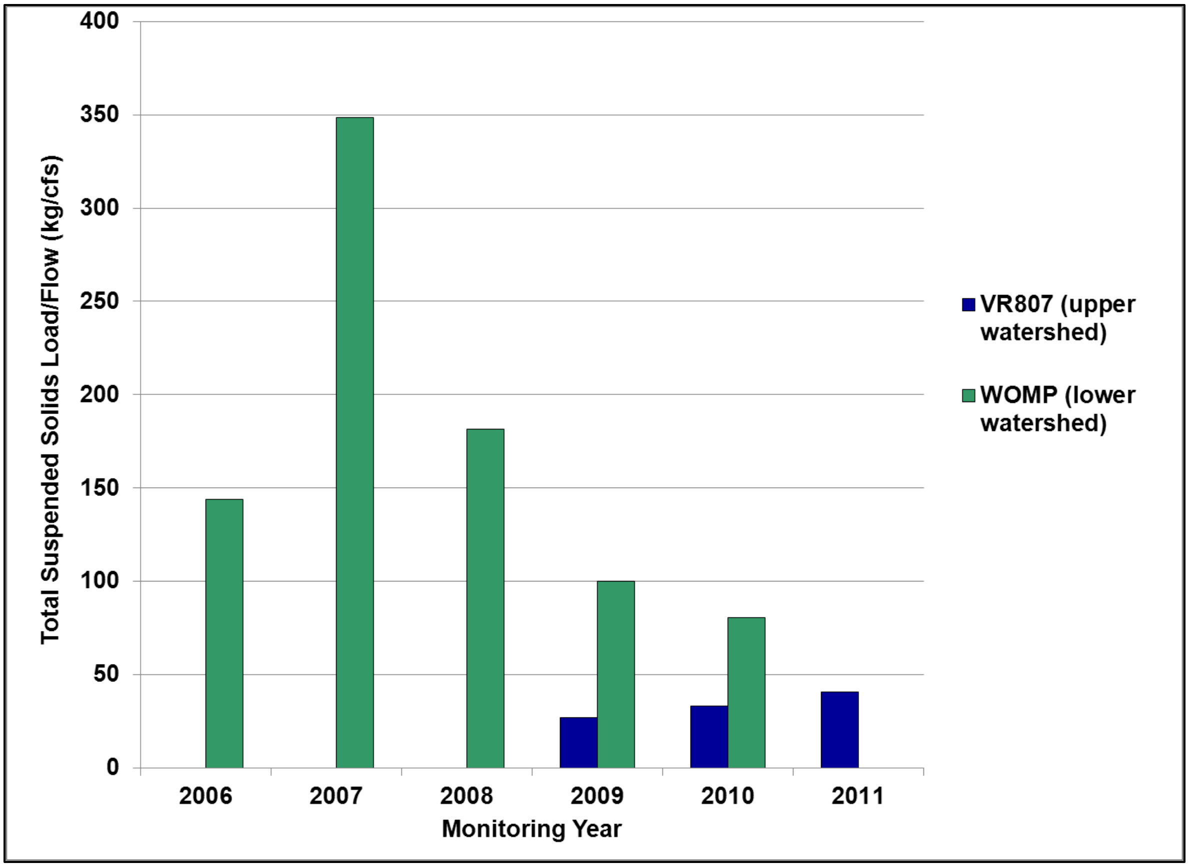


Figure 20. Historical Total Suspended Solids Load/Flow for VR807 and VR WOMP Monitoring Sites

Temperature

The Minnesota Department of Natural Resources (MNDNR) has been very active in monitoring stream temperatures in the Vermillion River Watershed. Since 2005, the DCSWCD has been assisting the MNDNR with temperature monitoring to help delineate the trout stream designation on the Vermillion River. In addition, the VRWJPO was awarded an EPA Targeted Watershed Grant in 2005 to identify and describe the way in which groundwater and anthropogenic inputs are influencing the temperatures of the Vermillion River. The current stream temperature monitoring network has been developed and expanded from these initial temperature monitoring studies to comprehensively monitor temperature throughout the watershed. The limited results presented here are only from temperature monitoring sites immediately adjacent to VRMN permanent water quality/quantity monitoring stations.

Automated temperature loggers were placed at each of the VRMN stations, and water temperature was recorded at 15-minute intervals. Mean temperatures for the period of June 2nd through September 2nd were plotted and are shown in Figure 21. According to a recent literature review, the adult brown trout chronic (long-term) exposure temperature limit is approximately 64° F (Bell, 2006). Mean temperatures at most monitoring stations in 2011 were above or slightly above this threshold. This is likely a reflection of reduced precipitation in 2011, especially during the critical late summer and fall months. As precipitation amounts decreased, groundwater discharge to the Vermillion River likely decreased as well, effectively driving up stream water temperatures. The 2011 results far exceed mean historical temperature results in the central portion of the watershed. Site SC806 was a new station installed in 2011 and therefore has no historical data to compare against. The mean 2011 temperature at site SB802 was well below the historical average which likely demonstrates the disproportionately large amount of groundwater entering the South Branch during periods of reduced precipitation.

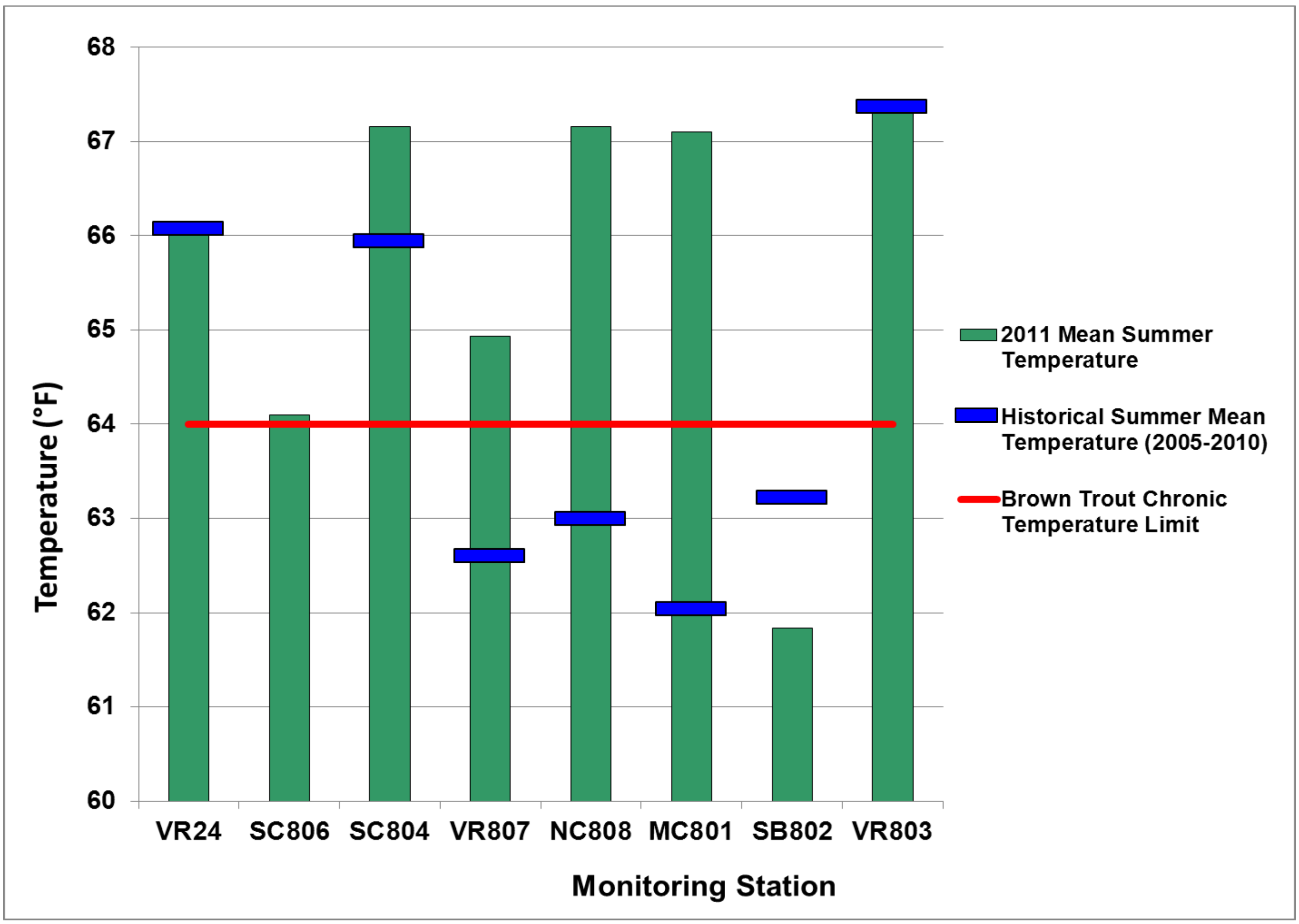


Figure 21. Historical Temperature Monitoring Results

Macroinvertebrate/Habitat Monitoring

Although biological stream monitoring is becoming a widely accepted method for assessing stream health, analysis of these results can be challenging. Typically, 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.

The MPCA recently developed macroinvertebrate indices specific to various portions of the state, including the southern coldwater/warmwater areas of the Vermillion River Watershed. These indices were applied to the Vermillion River Watershed Joint Powers Organization 2009-2011 macroinvertebrate monitoring data (Figure 22). These results were presented against the approximate impairment threshold determined by the MPCA for IBI scores originating from river like the Vermillion River. As can be observed in Figure 22, the majority of sites do not meet the minimum threshold and likely constitute a biological impairment. Although annual results are presented on one graph, it should be noted that sites A4, A10, and A14 fall outside of the cold water designation and that a slightly different index was used to evaluate these sites. As such, a different threshold is applied to these locations. However, results still fail to meet their appropriate thresholds and could be considered impaired.

Habitat Assessments

Habitat assessments were completed for each biological monitoring location using the MPCA's Stream Habitat Assessment (MSHA). Total scores for the MSHA assessments are shown in Figure 23, which can be interpreted using the MPCA's MSHA scoring table shown in Table 4.

Sites with the highest MSHA habitat scores, or the best habitat conditions, were A08 and A12. Sites with the lowest MSHA scores were sites A15 and A10. According to the MSHA scoring table, most sites received a "good" habitat quality score, with only site A15 receiving "fair" scores.

The general pattern of MSHA results appears to be relatively consistent among the three monitoring years. However, there is a fair amount of year to year variability within these results. Some of this variability can be explained by the unusual weather patterns of the last three years. Site A15 appears to be the only site that has demonstrated a substantial change in habitat quality. The stream quality and channel morphology components of the MSHA dropped at site A15 in 2011. The creek channel widens at this location, and the site appears to receive a large amount of sediment from the upstream watershed. The high amounts of precipitation in the early months of 2011 may have deposited excess sediment within site A15, resulting in lower habitat scores.

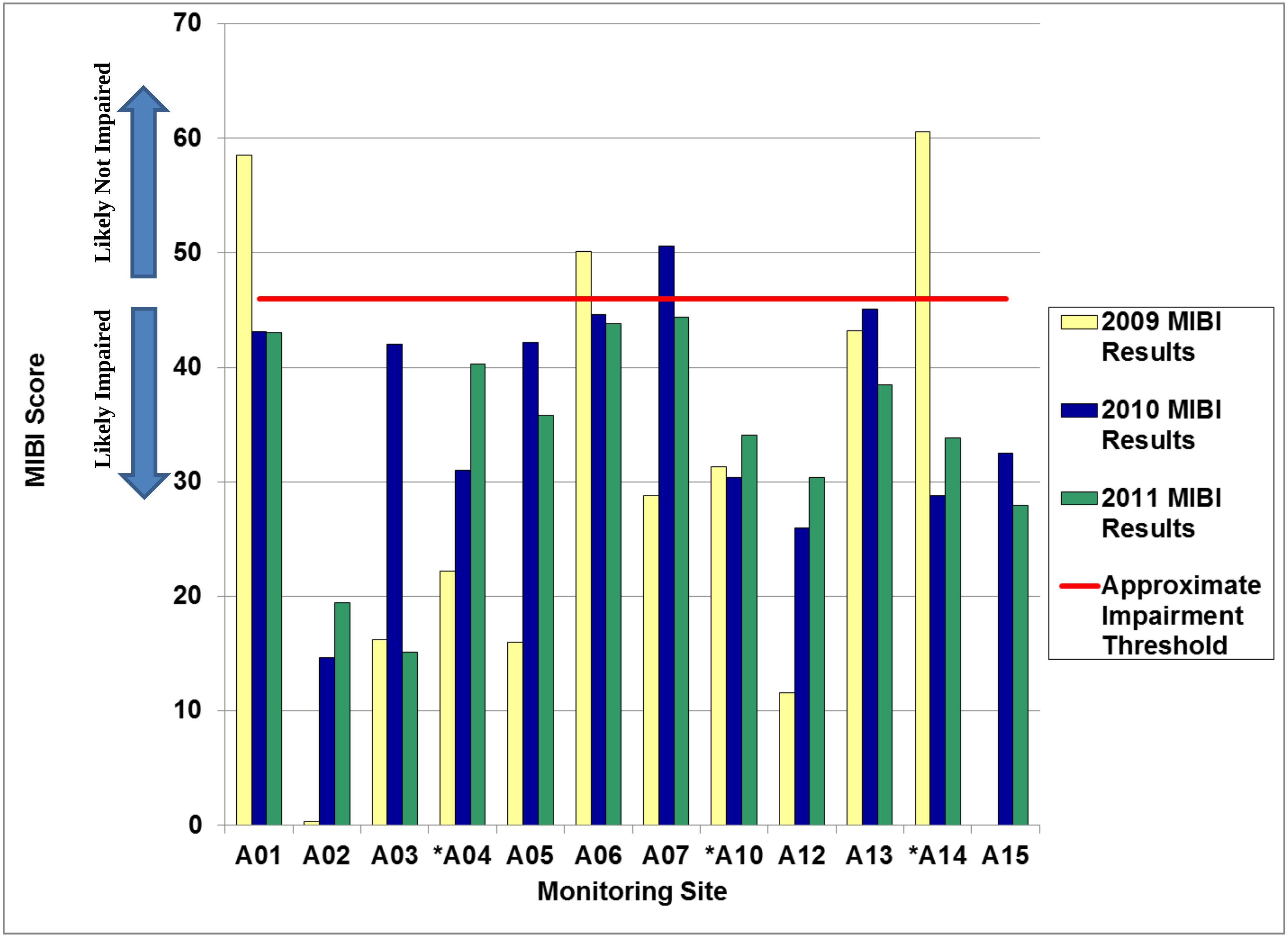


Figure 22. 2009-11 VRMN Macroinvertebrate Monitoring Results

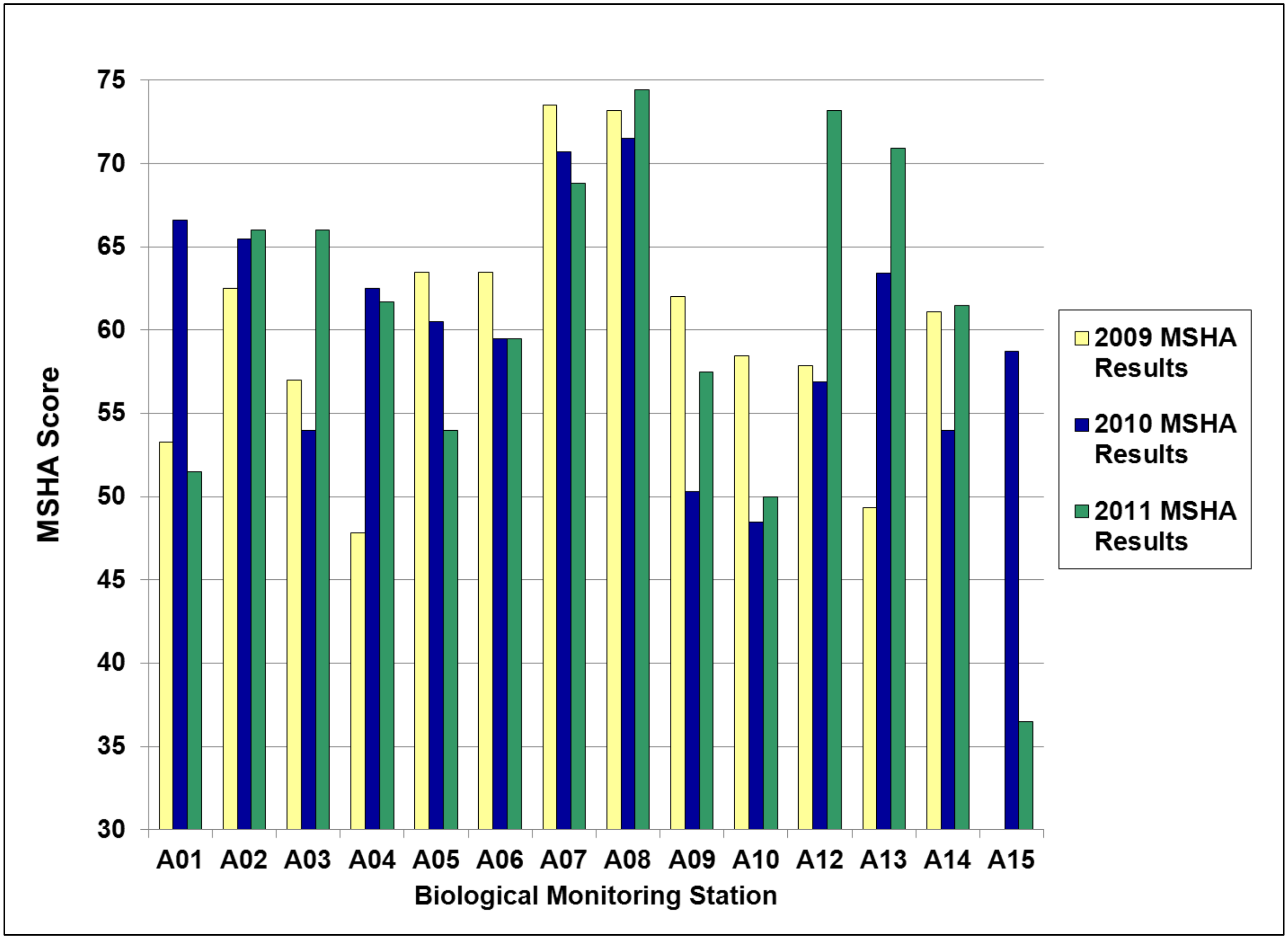


Figure 23. 2009-11 VRMN MPCA Stream Habitat Assessment Results

Table 4. MPCA MSHA Scoring Table

MPCA MSHA Habitat Score	Habitat Quality
75-100	Excellent
50-74	Good
25-49	Fair
0-24	Poor

Conclusions:

Chemistry

The 2009 monitoring strategy included a new emphasis on regularly scheduled grab samples, in addition to event grab samples, in an attempt to collect water quality data that most accurately reflects actual conditions in the Vermillion River Watershed. The 2009-10 results appeared to have captured this change in strategy, which also is evident in the 2011 results. Many individual samples still exceeded state standards or eco-region means, but mean 2011 values were generally near historical averages.

The 2011 field conductivity levels were often observed above the eco-region mean, especially in upper portions of the watershed. This trend is also observed in historical monitoring results. On the main channel of the Vermillion River (site VR24), the close proximity of the Elko-New Market Wastewater Treatment plant was a potential source of elevated conductivity measurements at this site until its discharge was re-routed to the Mississippi River in August. Elevated conductivity levels on Middle Creek, North Creek, and South Creek may be due to the relative abundance of mineral rich clay soils in these sub-watersheds (USDA, 2010).

The geometric mean *Escherichia coli* results from 2011indicate that bacteria concentrations remain a problem in the watershed. Source identification of bacteria continues to be a challenge in surface water management. Although a TMDL has been completed to address bacteria problems in this and other SE Minnesota watersheds, until the bacteria source identification methodology improves it appears unlikely that bacteria concentrations will be reduced in the Vermillion River Watershed in the near future.

Nitrate concentrations within the South Branch of the Vermillion River continue to be problematic. Nitrate concentrations at site SB802 remain substantially higher than anywhere else in the watershed. In addition, VRWJPO staff further investigated potential nitrate sources in the South Branch sub-watershed by sampling at numerous road crossings. Surprisingly, high nitrate concentrations were recorded throughout the South Branch sub-watershed. The source of these elevated levels still remains largely unknown. The VRWJPO may want to consider developing strategies to minimize nitrate concentrations in this region of the watershed

Pollutant Yields

Pollutant yields continue to reveal valuable information regarding the health of the watershed. The 2011 nitrate yields were highest in the South Branch of the Vermillion River. In fact, nitrate yields for the South Branch Subwatershed are roughly three times larger than nitrate yields for a subwatershed of similar size and land use (Upper Main Channel Subwatershed) in the area. Further study to identify nitrate sources in South Branch of the Vermillion River subwatershed may be warranted. Nitrate yields were surprisingly high in the South Creek Subwatershed as well. This may help explain poorer macroinvertebrate scores observed here (Figure 22). Additional chemistry data from this subwatershed will be helpful in identifying nitrate sources.

Total suspended solids pollutant yields were also unexpectedly high in the South Creek Subwatershed when compared against subwatersheds of similar size and land use (Upper Main Channel Subwatershed and North Creek Subwatershed). Staff have observed that sediment substrates in subwatersheds with higher TSS yields are predominately sand, while sediments in similar subwatersheds, with lower TSS yields, appear to consist of more cobble and gravel materials. Although extensive sediment surveys have not been completed for the entire Vermillion River Watershed, it is possible that higher TSS yields are a consequence of sediment substrates dominated by sandy materials which may be re-suspended under higher flow conditions and captured in event samples. However, evidence for this explanation is anecdotal at best. Additional chemistry monitoring on South Creek may help identify TSS sources in this region.

Pollutant Load Trends

Although the level of analysis presented here is relatively simplistic, recent pollutant load/flow analysis does provide some context by which water quality trends can be identified. It appears that total phosphorus loads are decreasing in both the upper and lower portions of the watershed. The same appears to be true for nitrate loads. Although TSS loads are decreasing in the lower portion of the Vermillion River, recent TSS loads are increasing in the upstream and turbidity impaired portions of the river.

Temperature

Temperature results from 2011 were slightly higher than historical averages. Although this may suggest a modest increase in temperature at monitoring sites on the Vermillion River, it is more likely that this is simply a reflection of dramatically reduced flow in the summer months of 2011. Beginning in late July, the watershed received surprisingly little precipitation throughout the remainder of the summer and fall months. As a result, it is possible that flow was reduced significantly such that water temperatures were more easily warmed by atmospheric influences and streams received less cold groundwater. This is only one possible explanation and additional low flow temperature monitoring data will be needed to confirm these results in future years.

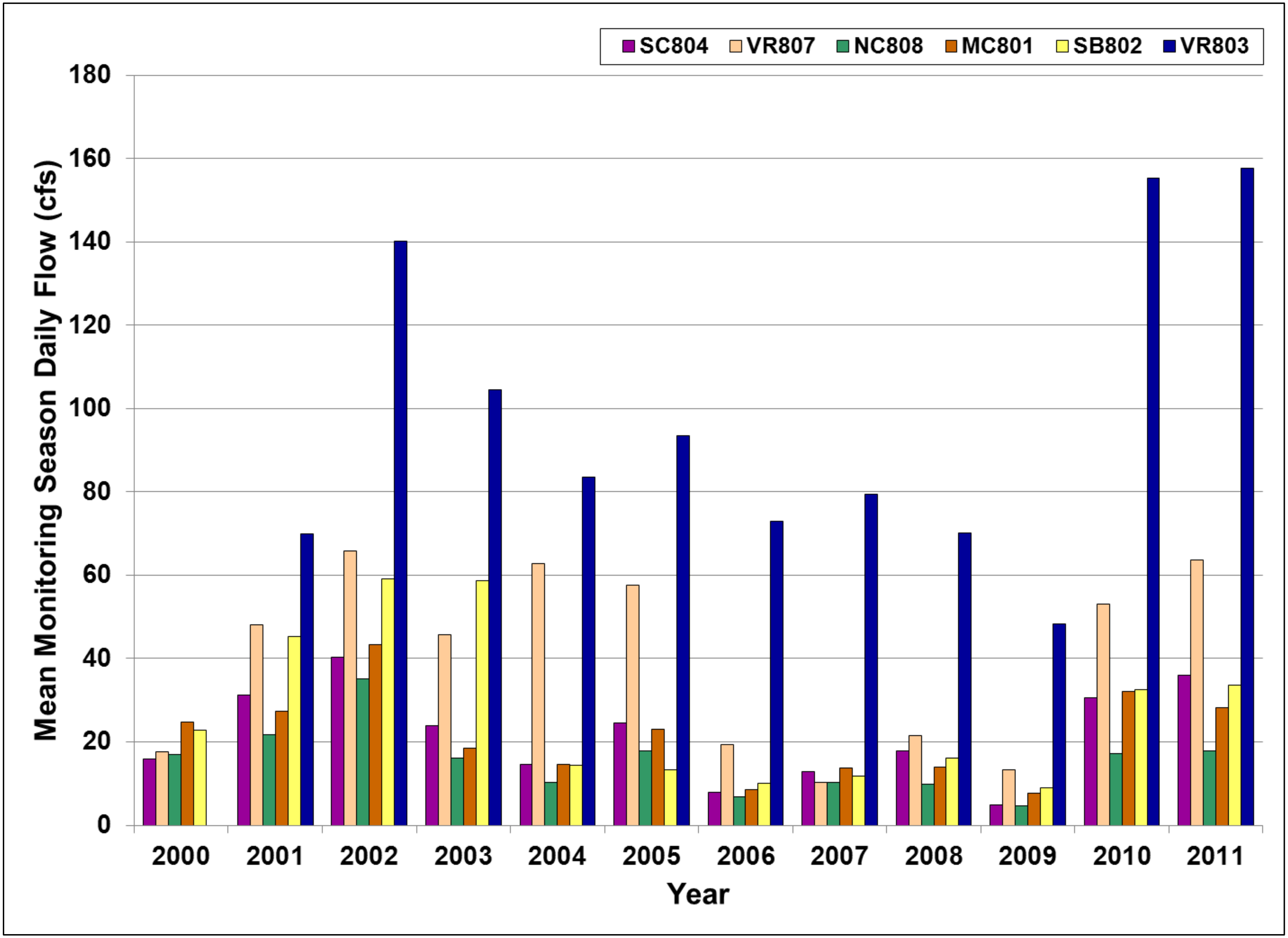
Macroinvertebrate and Habitat Monitoring

Since the VRWJPO biological monitoring program has only been operating for three field seasons, it is very difficult to draw conclusions from the 2011 data. However, initial results appear promising. Despite the high degree of variability in weather conditions among macroinvertebrate monitoring years, the monitoring results are surprisingly consistent. Although the exact results vary among years, the general pattern of these results seems to be approximately the same during the period of record. At a minimum, this suggests that conditions are not dramatically changing from year to year, despite large fluctuations in water level. This consistency may also prove beneficial in identifying long-term trends as additional years of macroinvertebrate data are collected, since sudden changes in these patterns will appear more obvious.

Although results appear consistent among years, the macroinvertebrate IBI values for all sites fail to meet the minimum thresholds established for their respective IBIs. As a result, proposed macroinvertebrate impairments for the Vermillion River appear justified for the majority of the watershed. The watershed is actively involved in an ongoing project with various consulting agencies, the Scott and Dakota County SWCDs, and the MPCA to identify stressors contributing to poor macroinvertebrate results in the Vermillion River.

In general, habitat monitoring results follow similar patterns among all monitoring years. This suggests that evaluation techniques are consistent from year to year and that habitat is not changing substantially in this timeframe. Most sites scored within the “good” range, and only site A15 scored within the “fair” range. Based on these results, habitat within the Vermillion River Watershed should be considered good with only minor changes occurring among monitoring years.

Appendix A: Historical Monitoring Season Mean Daily Flow Results



Appendix B: Abbreviated Water Quality Sample Results

Station	Date	Time	Event	Temperature (C)	DO (mg/L)	Conductivity (mhos/cm)	pH	Ammonia (mg/L)	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	Turbidity (NTRU)	E. Coli (MPN/100ml)
MC801	2/16/2011	11:05	Event	-3.18	10.69	1186	7.93	0.27	1.51	0.053	4	9	114
MC801	3/18/2011	10:30	Event	0.51	10.18	701	7.75	0.48	2.91	0.239	48	26	138
MC801	3/23/2011	10:45	Event	0.12	10.58	501	7.82	0.3	3.9	0.219	29	40	1414
MC801	3/29/2011	11:10	Non-Event	3.54	9.92	878	7.84	0.09	4.33	0.061	10	6	17
MC801	4/13/2011	10:15	Non-Event	11.5	8.91	811	7.89	<0.02	1.77	~0.038	3	4	96
MC801	4/26/2011	10:10	Non-Event	9.75	7.9	784	7.8	<0.02	1.71	0.071	28	12	397
MC801	5/11/2011	9:40	Non-Event	16.67	5.67	786	7.75	~0.03	0.85	0.076	10	4	79
MC801	5/24/2011	10:50	Event	16.7	5.5	700	7.65	~0.03	4.46	0.101	18	8	119
MC801	6/7/2011	11:00	Non-Event	20.2	6.27	774	7.8	0.08	1.28	0.068	9	6	261
MC801	6/15/2011	10:40	Event	15.98	5.36	593	7.75	~0.05	0.7	0.189	50	16	>2420
MC801	6/22/2011	10:25	Event	18.95	4.3	583	7.59	~0.05	1.04	0.126	13	6	1300
MC801	7/6/2011	10:15	Non-Event	17.99	7.05	771	7.92	<0.02	1.13	0.053	6	4	249
MC801	7/18/2011	11:15	Event	24.27	4.32	578	7.55	0.1	0.76	0.136	7	4	687
MC801	8/2/2011	9:45	Non-Event	20.49	5.19	647	7.71	0.1	0.93	0.093	12	8	866
MC801	8/16/2011	9:35	Non-Event	17.63	7.65	681	7.81	~0.02	1.16	~0.045	5	4	172
MC801	8/30/2011	10:25	Non-Event	15.85	7.23	731	7.84	~0.05	1.62	0.054	3	4	172
MC801	9/14/2011	11:15	Non-Event	12.31	8.35	742	7.99	~0.02	1.69	~0.037	3	4	276
MC801	9/26/2011	11:20	Non-Event	11.93	8	741	7.88	~0.05	1.66	~0.045	3	4	78
MC801	10/12/2011	11:20	Non-Event	13.32	8.16	728	8.03	~0.04	1.31	~0.049	3	5	187
MC801	10/25/2011	10:10	Non-Event	8.47	9.2	733	8.23	~0.05	1.52	0.05	~2	5	75
NC808	2/16/2011	11:15	Event	4.31	10.41	1303	7.85	0.27	1.67	0.056	5	10	70
NC808	3/18/2011	10:55	Event	1.14	12	707	7.88	0.18	1.86	0.255	62	34	770
NC808	3/23/2011	11:00	Event	0.32	10.87	604	7.72	0.22	1.82	0.183	26	22	179
NC808	3/29/2011	11:20	Non-Event	4.97	9.8	943	7.77	0.14	2.24	0.075	15	8	15
NC808	4/13/2011	10:30	Non-Event	11.57	9.36	828	7.88	<0.02	1.64	~0.045	4	5	78
NC808	4/26/2011	10:25	Non-Event	10.02	8.47	871	7.79	~0.05	1.39	0.172	58	19	613
NC808	5/11/2011	9:50	Non-Event	16.13	7.18	797	7.71	~0.04	1.09	0.074	16	7	135
NC808	5/24/2011	11:00	Event	16.67	5.76	673	7.58	~0.06	0.81	0.143	20	11	155
NC808	6/7/2011	11:10	Non-Event	20.14	6.59	763	7.77	0.09	1.7	0.064	11	6	326
NC808	6/15/2011	10:55	Event	16.19	5.75	562	7.71	~0.06	0.69	0.118	68	24	>2420
NC808	6/22/2011	10:40	Event	19.06	5.08	542	7.55	~0.04	0.46	0.133	21	10	2420
NC808	7/6/2011	10:30	Non-Event	17.69	7.88	753	7.68	~0.02	1.44	~0.040	4	4	194
NC808	7/18/2011	11:30	Event	24.39	4.98	497	7.53	0.06	0.52	0.126	9	5	121
NC808	8/2/2011	10:00	Non-Event	20.52	5.09	596	7.63	0.12	1.04	0.126	16	8	1120
NC808	8/16/2011	9:45	Non-Event	17.8	7.37	669	7.75	~0.04	1.34	0.055	8	4	172
NC808	8/30/2011	10:40	Non-Event	15.93	7.25	723	7.8	~0.04	1.75	0.059	3	3	171
NC808	9/14/2011	11:25	Non-Event	12.7	8.15	743	7.94	~0.03	1.69	~0.045	3	4	166
NC808	9/26/2011	11:30	Non-Event	12.03	7.02	742	7.87	0.06	1.76	~0.046	3	4	88
NC808	10/12/2011	11:30	Non-Event	13.39	8.13	733	7.91	~0.04	1.32	0.062	5	5	228
NC808	10/25/2011	10:25	Non-Event	8.63	9.29	741	8.24	0.06	1.57	0.051	3	5	53
SB802	2/16/2011	12:40	Event	4.23	12.97	583	8.18	~0.03	6.52	~0.021	~2	4	12

Station	Date	Time	Event	Temperature (C)	DO (mg/L)	Conductivity (mhos/cm)	pH	Ammonia (mg/L)	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	Turbidity (NTRU)	E. Coli (MPN/100ml)
SB802	2/16/2011	12:40	Event	4.23	12.97	583	8.18	~0.03	6.6	~0.024	~1	6	7
SB802	3/18/2011	11:15	Event	0.65	12.03	336	8.14	0.28	3.72	0.277	40	29	649
SB802	3/23/2011	11:25	Event	0.04	11.89	334	7.91	0.12	4.85	0.142	20	29	727
SB802	3/29/2011	11:45	Non-Event	3.4	11.13	540	7.94	<0.02	6.94	~0.041	6	4	13
SB802	3/29/2011	11:45	Non-Event	3.4	11.13	540	7.94	<0.02	6.96	~0.036	4	5	19
SB802	4/13/2011	10:55	Non-Event	10.88	9.37	556	7.96	<0.02	5.86	~0.020	3	3	47
SB802	4/13/2011	10:55	Non-Event	10.88	9.37	556	7.96	<0.02	6.17	~0.032	3	3	57
SB802	4/26/2011	11:00	Non-Event	9.55	8.98	540	7.93	<0.02	5.5	~0.038	5	3	71
SB802	5/11/2011	10:10	Non-Event	15.02	7.63	565	7.88	~0.02	5.34	~0.035	5	3	29
SB802	5/24/2011	11:20	Event	15.12	6.94	526	7.81	~0.05	1.45	0.103	11	5	158
SB802	6/7/2011	11:25	Non-Event	17.3	6.88	577	7.95	~0.03	6.73	0.092	12	7	194
SB802	6/7/2011	11:25	Non-Event	17.3	6.88	577	7.95	~0.03	6.65	0.081	13	8	172
SB802	6/15/2011	11:25	Event	13.37	7.79	546	7.95	0.17	5.97	0.185	26	14	1986
SB802	6/22/2011	11:05	Event	18.43	6.02	416	7.65	~0.04	2.95	0.14	18	17	1300
SB802	7/6/2011	10:45	Non-Event	15.34	7.74	596	7.97	<0.02	7.34	~0.049	9	6	488
SB802	7/18/2011	11:50	Event	22.56	5.96	415	7.69	~0.03	2.85	0.104	5	5	435
SB802	8/2/2011	10:20	Non-Event	17.05	6.99	586	7.86	~0.03	5.82	0.095	11	9	488
SB802	8/16/2011	10:00	Non-Event	15.5	8.74	578	7.94	<0.02	6.92	~0.044	5	4	219
SB802	8/30/2011	11:25	Non-Event	13.88	8.28	580	7.93	<0.02	7.94	~0.035	~2	2	119
SB802	9/14/2011	11:45	Non-Event	11.43	9.01	586	8.03	<0.02	8.86	~0.024	~2	2	114
SB802	9/26/2011	11:55	Non-Event	11.51	8.53	577	7.99	<0.02	7.8	~0.037	3	3	179
SB802	10/12/2011	11:45	Non-Event	12.97	8.02	574	7.92	<0.02	7.66	~0.036	~1	2	118
SB802	10/25/2011	11:10	Non-Event	8.62	9.88	574	8.39	~0.02	7.43	~0.046	3	3	86
SC804	2/16/2011	9:50	Event	2.02	12.95	747	8.25	~0.03	3.41	~0.045	5	8	35
SC804	3/18/2011	9:40	Event	0.11	12.57	521	8.06	0.12	3.18	0.155	17	18	144
SC804	3/23/2011	10:00	Event	-0.08	12.59	387	8.09	0.19	3.32	0.201	16	39	365
SC804	3/23/2011	10:00	Event	-0.08	12.59	387	8.09	0.18	3.31	0.193	21	38	411
SC804	3/29/2011	10:10	Non-Event	1.2	11.79	614	8	<0.02	3.18	0.079	10	7	13
SC804	4/13/2011	9:40	Non-Event	11.23	8.91	644	7.99	<0.02	1.85	~0.031	4	4	111
SC804	4/26/2011	9:25	Non-Event	9.45	8.42	631	7.89	<0.02	1.76	~0.043	4	4	126
SC804	5/11/2011	8:50	Non-Event	16.83	6.08	612	7.78	<0.02	1.04	0.056	6	4	99
SC804	5/24/2011	9:55	Event	16.46	6.72	642	7.75	~0.04	1.08	0.115	8	4	88
SC804	6/7/2011	10:20	Non-Event	19.39	6.97	664	7.98	~0.04	2.54	0.129	14	9	135
SC804	6/15/2011	9:45	Event	14.61	6.21	517	7.84	~0.04	2.29	0.181	28	19	>2420
SC804	6/22/2011	9:35	Event	18.62	5.6	542	7.77	~0.03	1.68	0.122	6	5	1203
SC804	7/6/2011	9:20	Non-Event	17.77	7.3	661	8.02	<0.02	2.61	0.091	12	8	219
SC804	7/18/2011	10:35	Event	24.71	5.22	366	7.65	~0.02	0.66	0.144	4	4	172
SC804	8/2/2011	9:15	Non-Event	20.35	6.55	658	7.9	0.06	2.06	0.141	26	14	461
SC804	8/16/2011	8:50	Non-Event	17.16	8.46	671	7.95	<0.02	2.6	0.099	20	11	326
SC804	8/30/2011	9:35	Non-Event	15.89	8.1	674	8.01	~0.03	3.14	0.058	7	6	291
SC804	9/14/2011	10:35	Non-Event	12.21	8.84	660	8.14	<0.02	3.63	~0.036	8	6	517
SC804	9/26/2011	10:50	Non-Event	12.08	8.63	648	8.03	~0.04	3.67	~0.039	5	4	199
SC804	10/12/2011	10:10	Non-Event	14.21	7.61	651	7.79	<0.02	3.27	0.061	~2	3	326
SC804	10/25/2011	9:30	Non-Event	8.39	9.79	658	8.2	~0.03	4.74	~0.035	5	5	147

Station	Date	Time	Event	Temperature (C)	DO (mg/L)	Conductivity (mhos/cm)	pH	Ammonia (mg/L)	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	Turbidity (NTRU)	E. Coli (MPN/100ml)
SC806	3/29/2011	9:55	Non-Event	2.98	11.13	762	8	<0.02	1.9	~0.025	3	5	16
SC806	4/13/2011	9:20	Non-Event	9.78	8.95	789	7.9	<0.02	1.46	<0.010	~2	2	4
SC806	5/11/2011	8:40	Non-Event	14.08	6.82	761	7.76	<0.02	1.04	~0.018	4	2	36
SC806	5/24/2011	9:35	Event	15.15	6.15	725	7.67	~0.02	1.01	0.058	6	3	29
SC806	5/24/2011	9:35	Non-Event	15.15	6.15	725	7.67	~0.02	1.03	~0.048	5	3	30
SC806	6/7/2011	10:05	Non-Event	16.34	7.16	773	7.87	0.07	1.33	~0.048	6	2	38
SC806	6/15/2011	9:25	Event	16.05	5.45	563	7.66	~0.02	3.58	0.094	15	8	>2420
SC806	6/15/2011	9:25	Event	16.05	5.45	563	7.66	~0.03	3.63	0.098	15	8	>2420
SC806	6/22/2011	9:00	Event	18.01	5.12	643	7.68	<0.02	1.44	0.052	5	4	866
SC806	7/6/2011	9:00	Non-Event	15.03	6.91	773	7.71	<0.02	1.22	~0.023	3	2	76
SC806	7/6/2011	9:00	Non-Event	15.03	6.91	773	7.71	<0.02	1.2	~0.024	3	1	86
SC806	7/18/2011	10:15	Event	23.4	5.32	641	7.67	<0.02	0.87	0.067	6	3	127
SC806	8/2/2011	8:50	Non-Event	20.23	5.35	702	7.67	<0.02	0.81	0.051	3	2	248
SC806	8/2/2011	8:50	Non-Event	20.23	5.35	702	7.67	<0.02	0.8	~0.048	3	2	236
SC806	8/16/2011	8:35	Non-Event	15.17	7.52	763	7.83	<0.02	1.07	~0.034	~1	<1	118
SC806	8/30/2011	9:10	Non-Event	14.03	6.49	771	8.16	<0.02	1.23	~0.019	~1	<1	261
SC806	8/30/2011	9:10	Non-Event	14.03	6.49	771	8.16	<0.02	1.23	~0.029	~1	<1	185
SC806	9/14/2011	10:15	Non-Event	11.97	8.13	779	8.02	<0.02	1.33	~0.031	4	<1	105
SC806	9/14/2011	10:15	Non-Event	11.97	8.13	779	8.02	<0.02	1.36	~0.018	~2	<1	105
SC806	9/26/2011	10:20	Non-Event	12.86	7.77	775	7.84	0.06	1.38	~0.037	4	2	148
SC806	10/12/2011	9:50	Non-Event	12.85	7.38	781	7.52	<0.02	1.38	~0.023	~2	2	129
SC806	10/12/2011	9:50	Non-Event	12.85	7.38	781	7.52	~0.02	1.34	~0.030	3	2	114
SC806	10/25/2011	9:10	Non-Event	10.23	7.78	781	7.89	~0.02	1.42	~0.019	~2	2	81
SC806	10/25/2011	9:10	Non-Event	10.23	7.78	781	7.89	~0.02	1.41	~0.019	~1	2	80
VR803	2/16/2011	13:05	Event	4.38	12.49	811	8.19	~0.05	4.31	~0.043	7	8	308
VR803	3/29/2011	12:10	Non-Event	3.76	11.27	663	8.04	~0.03	4.21	0.09	14	11	76
VR803	4/13/2011	11:20	Non-Event	11.75	9.74	672	8.11	<0.02	3.17	0.051	6	5	24
VR803	4/26/2011	11:20	Non-Event	10.13	9.24	657	9.08	<0.02	3.24	~0.044	6	4	36
VR803	5/11/2011	10:25	Non-Event	16.92	7.9	651	7.95	~0.02	2.21	~0.047	10	5	161
VR803	6/7/2011	11:50	Non-Event	20.23	7.35	674	8.03	~0.02	3.84	0.134	29	12	172
VR803	6/15/2011	11:50	Event	14.73	8.29	635	8.11	<0.02	3.56	0.152	49	20	>2420
VR803	6/22/2011	11:20	Event	18.67	6.34	484	7.79	~0.03	1.7	0.155	26	19	1986
VR803	7/6/2011	11:10	Non-Event	18.36	8.12	673	8.12	<0.02	3.91	0.098	24	13	219
VR803	7/18/2011	12:10	Event	25.84	4.94	367	7.59	<0.02	0.76	0.146	4	4	291
VR803	8/2/2011	10:35	Non-Event	19.05	7.14	646	7.96	~0.03	3.38	0.142	30	15	488
VR803	8/16/2011	10:20	Non-Event	17.83	8.95	649	8.08	~0.02	4.17	0.073	18	8	194
VR803	8/30/2011	11:40	Unknown	16.17	8.66	659	8.11	<0.02	4.66	0.05	6	4	127
VR803	9/14/2011	12:05	Non-Event	13.22	9.28	665	8.14	<0.02	5.26	~0.038	6	4	128
VR803	9/26/2011	12:10	Non-Event	12.82	8.73	653	8.09	<0.02	5.19	~0.046	8	4	110
VR803	10/12/2011	12:05	Non-Event	14.64	9.19	649	8.07	<0.02	4.57	0.117	~2	3	93
VR803	10/25/2011	11:30	Non-Event	9.18	10.87	650	8.47	<0.02	5.08	~0.036	3	3	24
VR807	2/16/2011	10:40	Event	3.47	12.09	785	8.14	~0.02	3.18	~0.033	~2	6	17
VR807	3/18/2011	10:00	Event	0.31	12.23	586	7.94	0.13	2.91	0.141	19	19	109
VR807	3/18/2011	10:00	Event	0.31	12.23	586	7.94	0.12	2.9	0.136	19	19	105

Station	Date	Time	Event	Temperature (C)	DO (mg/L)	Conductivity (mhos/cm)	pH	Ammonia (mg/L)	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	Turbidity (NTRU)	E. Coli (MPN/100ml)
VR807	3/23/2011	10:25	Event	-0.02	12.26	429	7.96	0.17	2.93	0.179	17	38	387
VR807	3/29/2011	10:40	Non-Event	1.99	11.45	648	8	~0.02	3.06	0.519	8	7	15
VR807	4/13/2011	9:50	Non-Event	10.8	8.86	673	7.98	<0.02	2.01	~0.038	5	4	11
VR807	4/26/2011	9:50	Non-Event	9.11	7.72	635	7.88	~0.04	1.4	0.125	28	12	140
VR807	5/11/2011	9:10	Non-Event	15.81	6.2	654	7.83	<0.02	1.25	~0.042	8	4	96
VR807	5/24/2011	10:25	Event	15.18	6.17	669	7.87	~0.04	1.6	0.103	12	6	99
VR807	6/7/2011	10:30	Non-Event	17.95	6.65	695	7.95	~0.04	2.4	0.06	19	8	119
VR807	6/15/2011	10:20	Event	14.9	6.57	534	7.82	~0.04	2.93	0.156	30	16	>2420
VR807	6/22/2011	10:05	Event	18.34	5.14	565	7.77						816
VR807	7/6/2011	9:40	Non-Event	16.4	7.25	690	8.08	<0.02	2.37	0.07	16	8	194
VR807	7/18/2011	10:55	Event	24.4	4.92	402	7.64	<0.02	0.69	0.132	4	4	219
VR807	8/2/2011	9:25	Non-Event	19.92	6.04	663	8	~0.04	1.9	0.12	24	12	461
VR807	8/16/2011	9:10	Non-Event	16.32	7.32	686	8.01	<0.02	2.36	0.055	10	6	345
VR807	8/30/2011	10:00	Non-Event	15.01	6.34	692	7.99	~0.03	2.72	~0.037	4	4	435
VR807	9/14/2011	10:55	Non-Event	12.42	7.51	692	8.12	<0.02	2.92	~0.035	4	3	248
VR807	9/26/2011	11:05	Non-Event	12.59	6.89	682	8	~0.03	3.07	~0.042	5	3	260
VR807	10/12/2011	10:20	Non-Event	13.98	6.17	677	7.89	<0.02	2.55	0.081	~2	3	236
VR807	10/25/2011	9:55	Non-Event	9.32	7.22	681	8.27	~0.02	3.54	~0.026	5	4	86
VR24	3/29/11	11:53	Non-Event	1.45	na	742	7.91	~0.06	2.94	0.083	6	4	14
VR24	4/12/11	10:00	Non-Event	7.76	na	894	8.15	~0.04	1.73	0.077	~1	2	20
VR24	4/26/11	12:32	Event	8	10.1	695	na	~0.04	1.57	0.349	211	55	1986
VR24	5/11/11	11:25	Event	16.05	9.64	795	na	<0.02	0.83	0.096	5	2	59
VR24	5/24/11	11:00	Unknown	15.49	8.87	838	na	~0.03	0.92	0.154	6	3	770
VR24	6/7/11	9:23	Non-Event	19.66	7.49	1248	na	0.08	1.5	0.291	4	4	435
VR24	6/21/11	11:32	Event	17.9	7.6	655	na	~0.04	1.65	0.35	111	34	13200
VR24	7/5/11	8:35	Non-Event	18.89	7.77	1389	na	~0.025	1.64	0.24	9.5	7	1050
VR24	7/18/11	10:05	Event	22.96	na	614	na	~0.03	0.72	0.245	22	9	613
VR24	8/2/11	9:10	Unknown	21.68	7.39	991	8.17	~0.06	0.93	0.212	10	8	>2420
VR24	8/16/11	10:00	Non-Event	18.3	8.53	1669	8.25	<0.02	2.715	0.25	3.5	2.5	276
VR24	8/30/11	8:50	Non-Event	16.7	7.89	2199	8.31	<0.02	4.31	0.295	3	3	1046
VR24	9/14/11	9:45	Non-Event	12.2	8.67	1920	8.27	<0.02	3.73	0.287	1	2	613
VR24	9/27/11	11:56	Unknown	13.05	9.6	2087	8.53	<0.02	7.74	0.341	~2	1	1210
VR24	10/11/11	9:15	Non-Event	13.29	6.19	2206	7.85	<0.02	4.43	0.445	~1	1	96
VR24	10/25/11	11:40	Non-Event	8.57	10.31	1409	7.93	~0.03	1.52	0.1865	~1.5	2	100
VRWOMP	3/1/2011	12:50	Non-Event	2.9	na	687	na	~0.03	4.52	0.05	8	8	162
VRWOMP	3/18/2011	12:55	Event	3.9	11.84	877	8.37	0.12	2.98	0.191	59	31	111
VRWOMP	3/22/2011	11:45	Event	1.8	11.68	437	8.58	0.11	3.34	0.202	42	25	62
VRWOMP	3/25/2011	12:20	Event	3.8	na	519	na	0.07	3.52	0.135	16	22	43
VRWOMP	4/13/2011	11:45	Event	11.99	10.92	659	8.32	<0.02	3.1	~0.042	~3	5	10
VRWOMP	4/26/2011	11:50	Event	10.08	8.69	613	8.24	<0.02	2.75	~0.044	3	5	99
VRWOMP	5/11/2011	12:20	Event	17.38	8.38	646	8.2	<0.02	2.27	0.053	11	5	219
VRWOMP	5/20/2011	12:55	Non-Event	14.7	9.01	671	8.21	<0.02	3.63	0.085	12	7	70
VRWOMP	5/24/2011	12:45	Event	17.23	7.5	621	8.16	~0.02	1.54	0.096	15	8	214
VRWOMP	6/7/2011	12:20	Non-Event	21.97	7.51	664	8.23	<0.02	3.94	0.15	27	12	384

Station	Date	Time	Event	Temperature (C)	DO (mg/L)	Conductivity (mhos/cm)	pH	Ammonia (mg/L)	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	Turbidity (NTRU)	E. Coli (MPN/100ml)
VRWOMP	6/15/2011	12:20	Event	15.5	7.93	633	8.25	~0.02	3.81	0.125	30	15	980
VRWOMP	6/22/2011	11:55	Event	19	7.2	493	7.99	~0.03	1.81	0.164	38	23	1300
VRWOMP	7/6/2011	11:30	Non-Event	20.05	8.35	664	8.31	<0.02	3.65	0.092	17	10	214
VRWOMP	7/18/2011	12:30	Event	26	5.85	340	7.7	<0.02	0.74	0.161	13	9	293
VRWOMP	8/8/2011	10:50	Non-Event	20.8	na	652	na	<0.02	3.94	0.094	21	11	98
VRWOMP	9/12/2011	11:20	Non-Event	17.75	8.29	650	8.36	~0.03	4.85	~0.032	5	4	145
VRWOMP	10/4/2011	12:15	Non-Event	12.79	10.43	637	8.42	<0.02	5.19	0.052	~2	2	156
VRWOMP	11/9/2011	11:00	Non-Event	na	na	na	na	<0.02	4.84	~0.025	~2	2	32
VRWOMP	12/6/2011	11:30	Non-Event	1.8	na	749	na	~0.04	5.81	~0.044	4	5	23

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