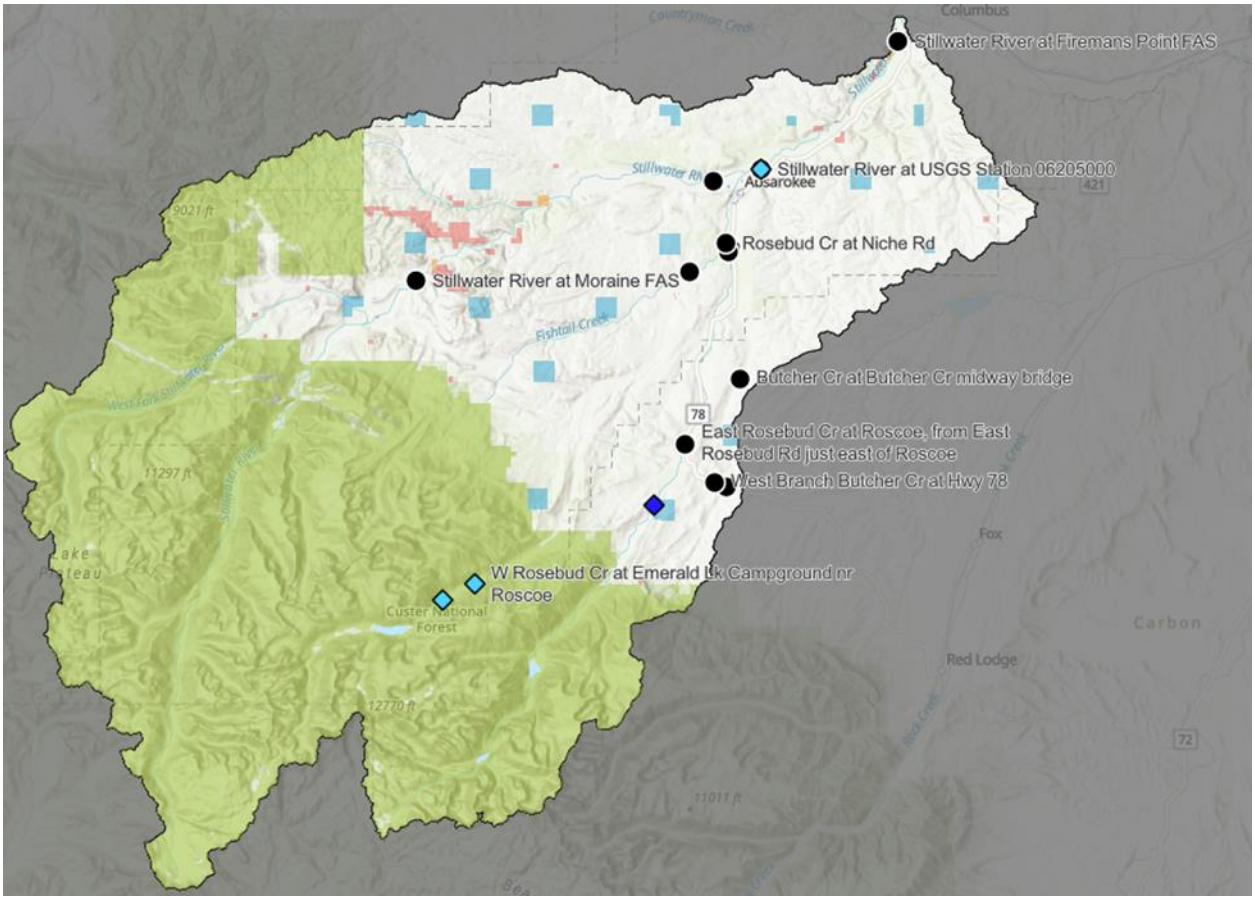
# Stillwater Valley Watershed Council 2021-23 Water Quality Data Analysis - MSU Student Project

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# Forward and Acknowledgements

This work was conducted as part of a one semester Montana State University undergraduate research course, led by Dr. Adam Sigler with support from Bridget Warrenfeltz. Paula Diaz was the undergraduate student assigned to the Stillwater program for the course.

This work was conducted in consultation with the Stillwater Valley Watershed Council representatives Karen Marts, Lindsey Clark, and Tom Osborne.

Fall 2024 was the initial pilot of this course, with the intention to produce useful data summaries for volunteer monitoring programs while simultaneously providing hands on student learning opportunities.

This work is supported by funding from Montana Department of Environmental Quality (MDEQ).

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# Introduction

## Watershed Description

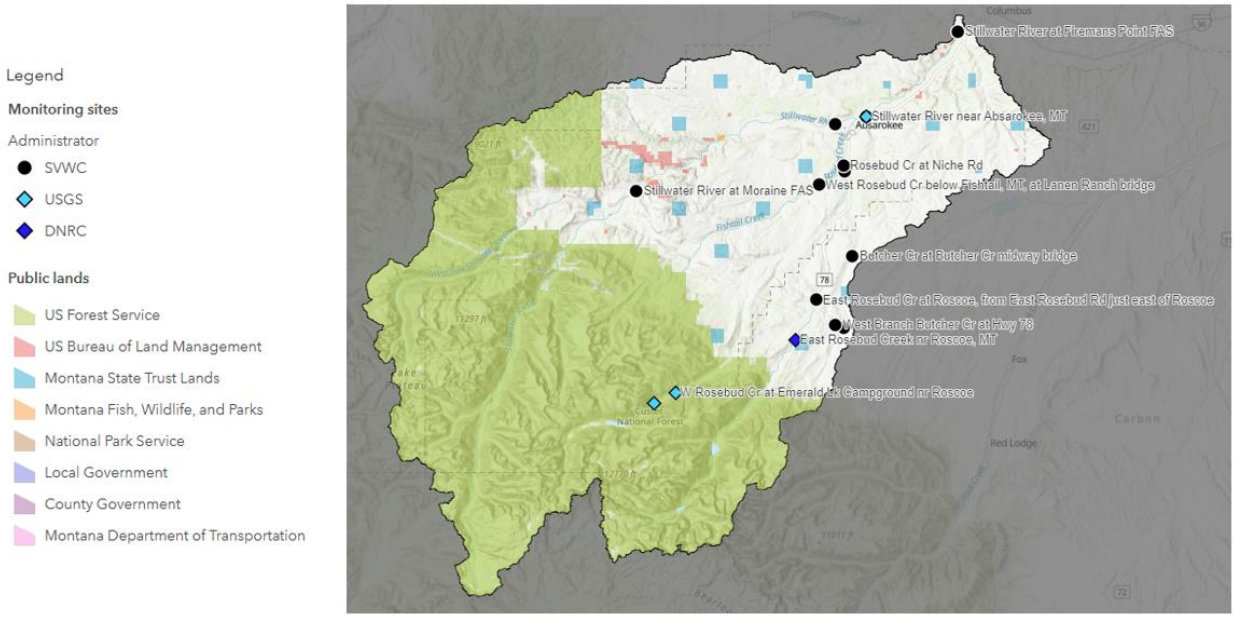


***Figure 1: Stillwater Watershed Map***. *The Stillwater watershed spans from the Beartooth Plateau through forested areas and across agricultural land before discharging into the Yellowstone River at Columbus, MT. Land ownership and sample locations are depicted according to the legend (black dots are the Stillwater Valley Watershed Council monitoring sites). An interactive version of this map can be accessed at https://arcg.is/1PyfjK.*

The Stillwater Watershed falls completely within the state of Montana, near the state's southern border with Wyoming. The Stillwater River begins at the peaks of the Beartooth Mountains in the Beartooth plateau and flows through forested lands before emerging onto the plains near Nye at an elevation of 5020 feet (Map Nye, 2024). The Stillwater Watershed (Figure 1) supports agriculture, prized trout fisheries, drinking water sources, rafting, and other primary contact recreation before flowing through Absarokee, and discharging into the Yellowstone River near Columbus. Rosebud Creek originates in the Beartooth Mountains near the Stillwater and is the main tributary of the Stillwater River. It flows through forested lands before emerging in the foothills near Roscoe. Rosebud Creek accounts for 45% of the Stillwaters's total discharge (Stillwater Valley Watershed Council, 2024). West Rosebud Creek, East Rosebud Creek, and Butcher Creek are main tributaries of Rosebud Creek. Land use along the banks of the Stillwater and tributaries include farms, ranches, housing developments, and industry. Stillwater-Sibanye is an active palladium and platinum mine located near the banks of the upper Stillwater River about 9 miles upstream from the Moraine fishing access site.

The Stillwater-Rosebud Water Quality Initiative (SRWQI) project launched in September 2020 and continues today. The project's goals include the collection and analysis of water samples at strategic monitoring sites to provide data to guide improvements in the river corridor and to promote river stewardship. Funding for monitoring has been provided by Montana Department of Environmental Quality, Montana Department of Natural Resources and Conservation, Trout Unlimited, the Flathead Lake Biological Station and by private donations. The Stillwater Valley Watershed Council (SVWC) supports coordination and training for the volunteer water monitoring group. This report includes data from laboratory analysis of volunteer-collected samples for Total Suspended Solids (TSS), Total Nitrogen (TN), Nitrate-N, and Total Phosphorus (TP) at nine sites along the Stillwater and Rosebud tributaries. The SVWC's water quality goals state, "Improve the quality and supply of water in the Stillwater River Watershed. Balance water needs and availability, both recreational and agriculturally, through shared sacrifice and water conservation and contamination prevention" (Stillwater Valley Watershed Council, 2024). Analysis of the data from the SRWQI project supports public outreach and education and water quality improvement projects.

# Methods

## Data Sources

The primary data analyzed in this report was collected under the SRWQI and is described in detail in annual sampling and analysis plan documents (Stillwater Valley Watershed Council, 2024). The SRWQI program uploads data to MDEQ's MT-eWQX, a national database for the long-term storage of volunteer data and associated metadata. The data for this report was downloaded from the National Water Quality Exchange (WQX) database through the national water quality portal (US EPA, 2019). Data uploaded to the WQX database must meet rigorous quality standards and structural requirements.

All historical data for monthly average discharge from USGS station 06205000 were downloaded (USGS Surface Water for USA) and the average flow for each month was calculated to plot flow data.

## Data Curation and Analysis

Primary data plotting for visualization was conducted in Excel. A series of Excel worksheets were used to track raw data, inventory sample sites and analytes, and clean and plot the data. Replicate and Quality Control samples were removed before plotting. Data from the monitoring group's nine sites were included in the analysis. The nine site names were shortened to clarify visual representations of the data, (Table 1). Two sites on Butcher

Creek are no longer monitored. Although they are listed in the site list (Table 1), they are not included in the Excel plots due to the limited period of record. Some additional plotting and analysis were conducted using R Statistical software. All Excel files and R related files supporting this report are available through an MSU website (MSUEWQ, 2024).

Nitrate-N is interpreted relative to a 0.1 mg/L threshold identified by MDEQ as a concentration above which nuisance algae is more common (MDEQ 2013). TN and TP are interpreted relative to the MDEQ numeric nutrient standards published in Circular DEQ-12A and its supporting scientific literature (MDEQ Circular DEQ-12A 2014). The standards in DEQ-12A are specific to ecoregion and values of 0.44 mg/L for TN and 0.033 mg/L for TP associated with the eco-region known as "Non-calcareous Foothill Grassland" were used. These thresholds are nutrient concentrations, above which there is a higher likelihood of nuisance algae issues. None of these thresholds are currently in policy as nutrient standards, but the science to identify these thresholds is the best available context for interpretation of nutrient concentrations. When the numeric nutrient standards were in place, they only applied for growing season months from July through September. However, it is useful to assess nutrients entering streams at all times of year to inform likely sources and possible solutions to mitigate nutrients entering streams. For this reason, nutrient concentrations collected across seasons are interpreted relative to these thresholds.

This report does not attempt to connect nutrient concentrations to specific sources. We focus on interpretation of nutrient patterns and provide the following general context for considering sources. The TN lab analyses accounts for all forms of nitrogen including particulate, dissolved organic, and dissolved inorganic forms (which includes nitrate and nitrite). Sources of nitrogen to water can include septic systems, residential fertilizer application, farming practices, livestock operations, and industrial facilities (US EPA, 2021). Nitrate is an inorganic form of nitrogen that is dissolved and commonly reaches streams through groundwater, making it useful as an indicator of groundwater based sources of nitrogen in some cases. Nitrate in groundwater can come from a variety of sources including septic tanks, animal waste, or farming practices (US EPA, 2021) and can also be generated from explosives used in mining operations (Dignazio, et al. 1998; Storb, et al., 2023). Phosphorus sources generally align with those listed above for nitrogen (except explosives) and are commonly tightly coupled with sediment that enters streams with soil and stream bank erosion (Novotny, 2003).

***Table 1. Site Name Abbriviations***. *The site names were shortened to increase the legibility of the plots, and the associated data field was named "Data Site Name". Each site was numbered in order of plotting from left to right, from 1 to 9.*

| Original Site Name | Data Site Name | MonitoringLocationIdentifier | Plot Order Left to Right |
|---|---|---|---|
| Stillwater River at Moraine FAS | StillwMoraine | MTVOLWQM_WQX-SRM-1 | 1 |
| Stillwater River near Johnson Bridge | StillwJohnBr | MTVOLWQM_WQX-SRJB-1 | 2 |
| West Rosebud Cr below Fishtail, MT, at Lanen Ranch bridge | WRoseFish | MTVOLWQM_WQX-WRBC-L | 3 |
| East Rosebud Cr at Roscoe, from East Rosebud Rd just east of Roscoe | ERoseRoscoe | MTVOLWQM_WQX-ERBC-R | 4 |
| East Rosebud Cr at Highway 419 | ERoseHwy419 | MTVOLWQM_WQX-ERBC-419 | 5 |
| Butcher Cr at Butcher Cr midway bridge | ButchCrMidBr | MTVOLWQM_WQX-BC-M | 6 |
| Butcher Cr at Hwy 78 | ButchCrHwy78 | MTVOLWQM_WQX-BC-78 | 7 |
| Rosebud Cr at Niche Rd | RoseNiche | MTVOLWQM_WQX-RBC-N | 8 |
| Stillwater River at Firemans Point FAS | StillwFirePt | MTVOLWQM_WQX-SRF-1 | 9 |
| West Branch Butcher Cr at Hwy 78 | WButchHwy78 | MTVOLWQM_WQX-BCWF-78 | NA |
| East Fork Butcher Cr at Hwy 78 | EButchHwy78 | MTVOLWQM_WQX-BCEF-78 | NA |
| Stillwater River at USGS Station 06205000 | StillUSGS | MTVOLWQM_WQX-SR-6205000 | NA |

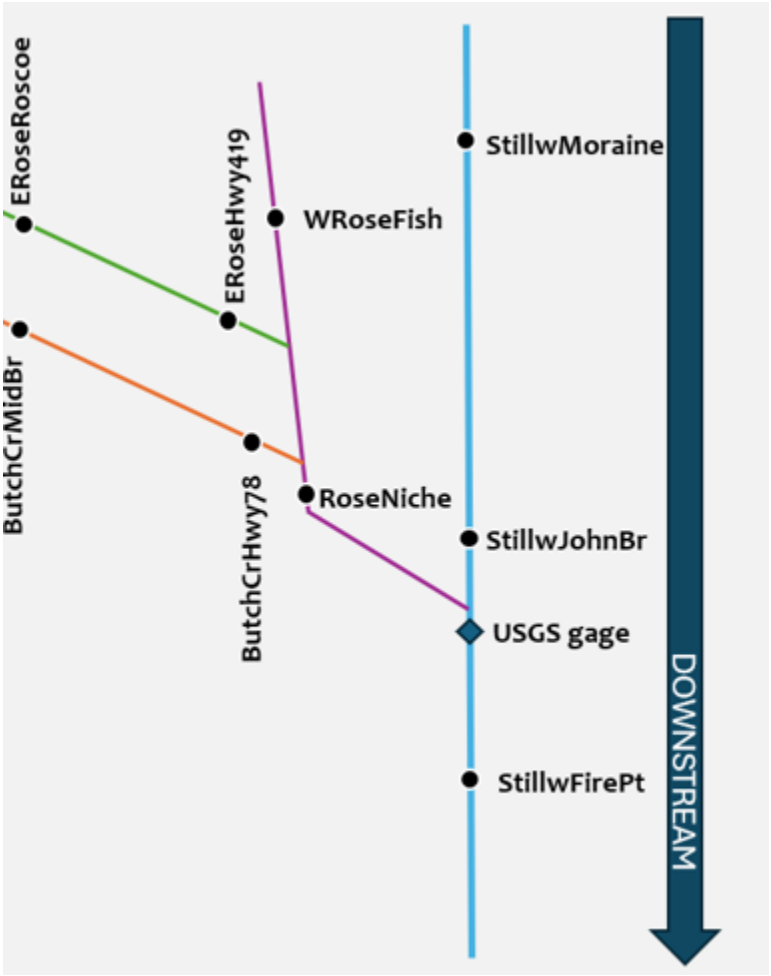


***Figure 1: Conceptual figure for the Stillwater River and its tributaries with orientation of site locations***. *The flow is from top to bottom and from left to right. The black dots are the SVWC monitoring sites, and the blue diamond is the USGS flow gage.*

# Results

## Total Nitrogen (TN)

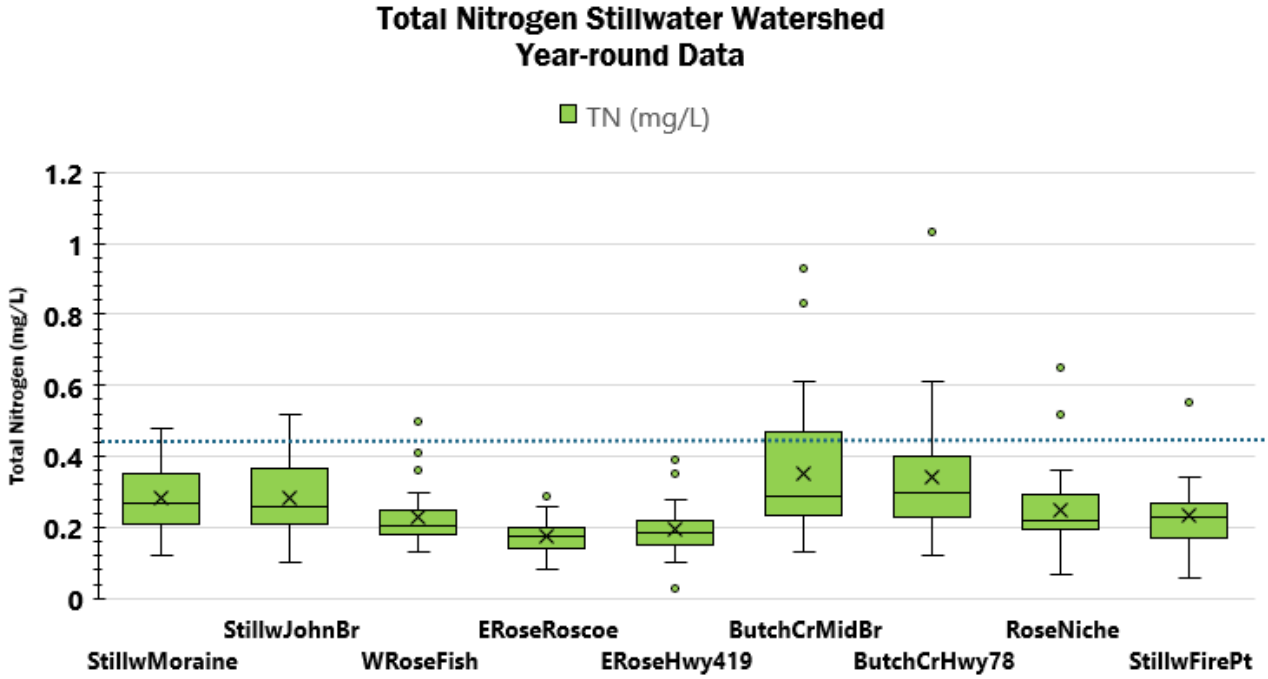


***Figure 2: Boxplots of Total Nitrogen concentrations organized by site.*** *TN concentrations are on the y-axis in mg/L. The sites on the x-axis are in order from upstream to downstream with the two uppermost mainstem Stillwater sites on the left followed by tributaries, and the most downstream mainstem Stillwater site on the right. See Figure 2 for site locations. The dashed line is the TN threshold of 0.440 mg/L for "Non-calcareous Foothill Grassland (43s)", the land type assigned to the Stillwater River watershed. The line inside each box represents the median TN concentration for each site, and the "X" represents the mean for each site. The area between the end of the lower whisker and the bottom of the box contains concentrations that fall within the first quartile excluding outliers. The distance from the bottom of the box and the median contains the values from the second quartile. The distance from the median to the top of the box contains all values within the third quartile, and the distance from the top of the box to the top whisker, excluding outliers, contains the values in the fourth quartile. Outliers are plotted outside of the whiskers if they lie greater than or equal to 1.5 times the length of the box from either end of the box (Team, T. M. 365 M., 2015).*

TN mean and median concentrations for all nine sites are below the MDEQ Circular 12A threshold of 0.440 mg/L (MDEQ, 2014; Figure 3). Of the nine sites, the two Butcher Creek sites tested highest for TN, ranging from 0.1 to 0.6 mg/L with a few outliers. The ButchCrMidBr site is the only site with an interquartile range that extends above the MDEQ threshold. TN means and medians were similar between Rosebud Creek, East Rosebud Creek, and West Rosebud Creek and were the lowest of all sites, ranging between 0.16 and 0.24 mg/L. The upstream Stillwater Moraine and Johnson Bridge sites have slightly higher mean TN concentrations than the downstream Fireman's Point site. The mean TN concentrations for all Stillwater mainstem sites range between 0.24 and 0.30 mg/L.

When data is assessed separately for the growing season, between July 1 and September 30, the mean TN concentration values are below the 0.44 mg/L threshold for all sites (Figure 4). The overall mean concentrations during the growing season months were slightly lower than the mean concentrations from the entire dataset, and fewer samples exceeded the threshold during the growing season.

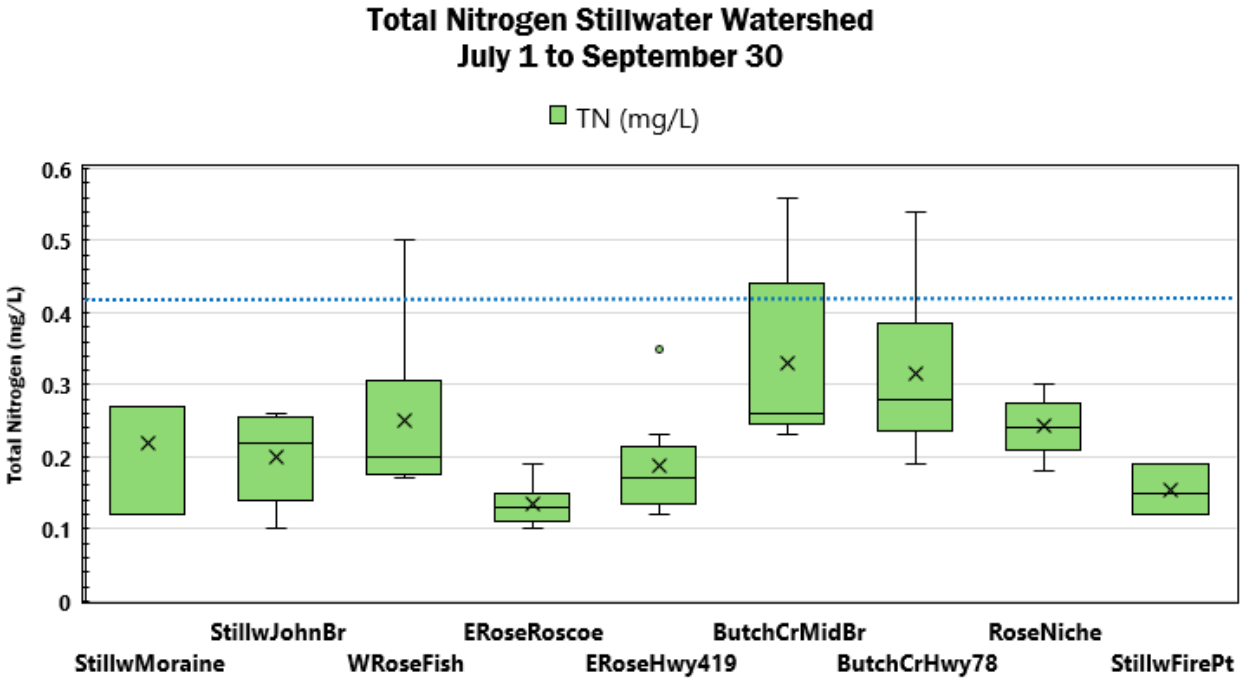


***Figure 3: Boxplots of Total Nitrogen concentrations of samples collected from July 1 to September 30 organized by site.*** *Total Nitrogen (TN) concentrations are on the y-axis in mg/L. The sites on the x-axis are in order from upstream to downstream with the two uppermost mainstem Stillwater sites on the left followed by tributaries, and the most downstream mainstem Stillwater site on the right. See Figure 2 for site locations. The dashed line is the TN threshold of 0.440 mg/L for "Non-calcareous Foothill Grassland (43s)", the land type assigned to the Stillwater River watershed. The line inside each box represents the median TN concentration for each site, and the "X" represents the mean TN concentration. The area between the end of the lower whisker and the bottom of the box contains concentrations that fall within the first quartile excluding outliers. The distance from the bottom of the box and the median contains the values from the second quartile. The distance from the median to the top of the box contains all values within the third quartile, and the distance from the top of the box to the top whisker, excluding outliers, contains the values in the fourth quartile. Outliers are plotted outside of the whiskers if they lie greater than or equal to 1.5 times the length of the box from either end of the box (Team, T. M. 365 M., 2015).*

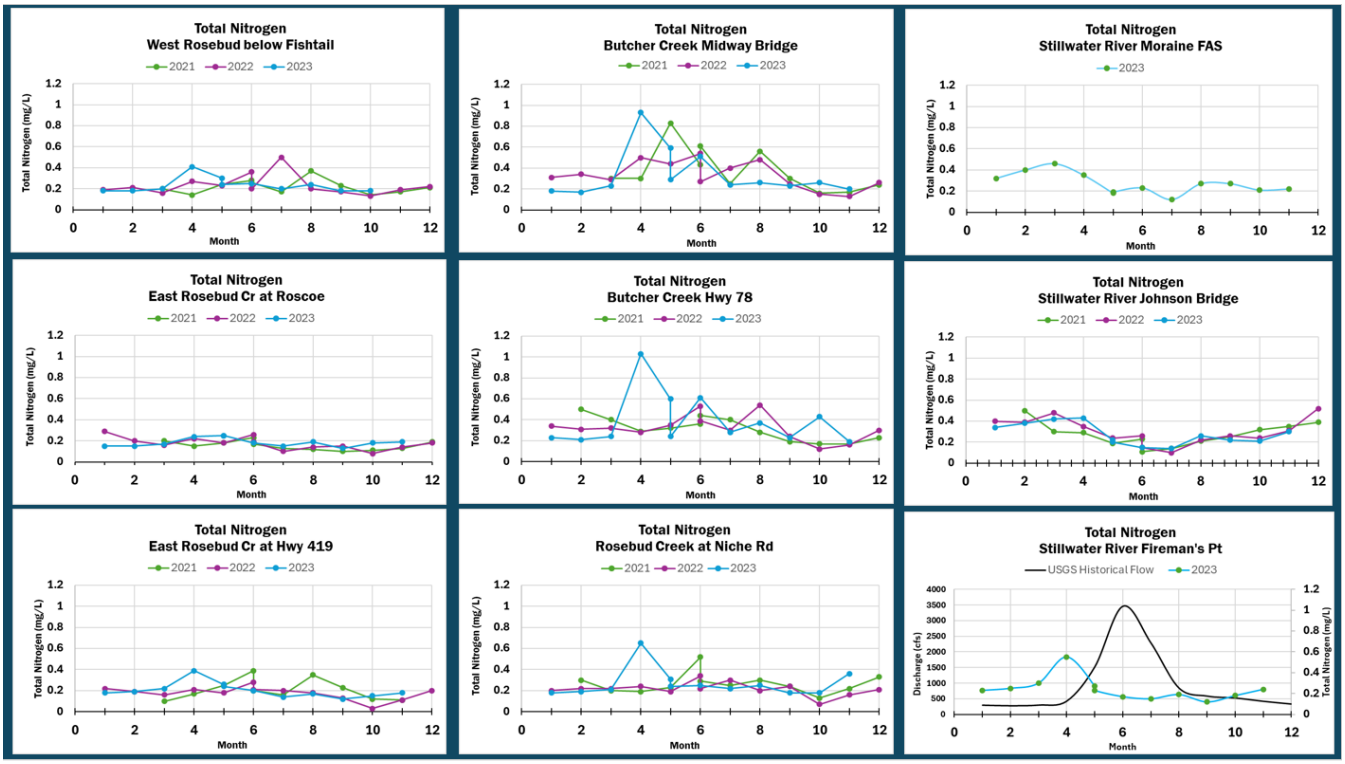


***Figure 4: Seasonal Trends for Total Nitrogen concentrations.*** *TN concentrations are on the y-axis in mg/L, and the months the samples were collected are numbered 1 to 12 on the x-axis. The black line on the Fireman's Point plot is the historic average monthly flow (cfs) from 1935 to present collected at the USGS gage #06205000 located upstream from Fireman's Point. Only 2023 data was available for the Moraine and Fireman's Point sites, while the 2021 to 2023 data was available for the rest of the sites with years depicted according to the legend.*

At Stillwater Fireman's Point, the highest measured peak concentration for TN was observed in April and exhibited a somewhat inverse relationship with flow. The peak measurement in April decreased as the flow increased from May to July. Peak measurements were observed in April for most sites. In April of 2023, TN concentrations at both Butcher Creek sites were higher than in the two previous years. TN concentrations at both East Rosebud sites and the Stillwater River Johnson River Bridge site were the most consistent over the three years. The highest TN concentrations in the watershed were observed at the Butcher Creek Midway Bridge site in May 2021, and May 2023, and the Butcher Creek Hwy 78 site in May 2023. Seasonal patterns are most noticeable at the Stillwater Johnson Bridge site with measured TN concentrations consistently peaking between October and March (Figure 5,6).

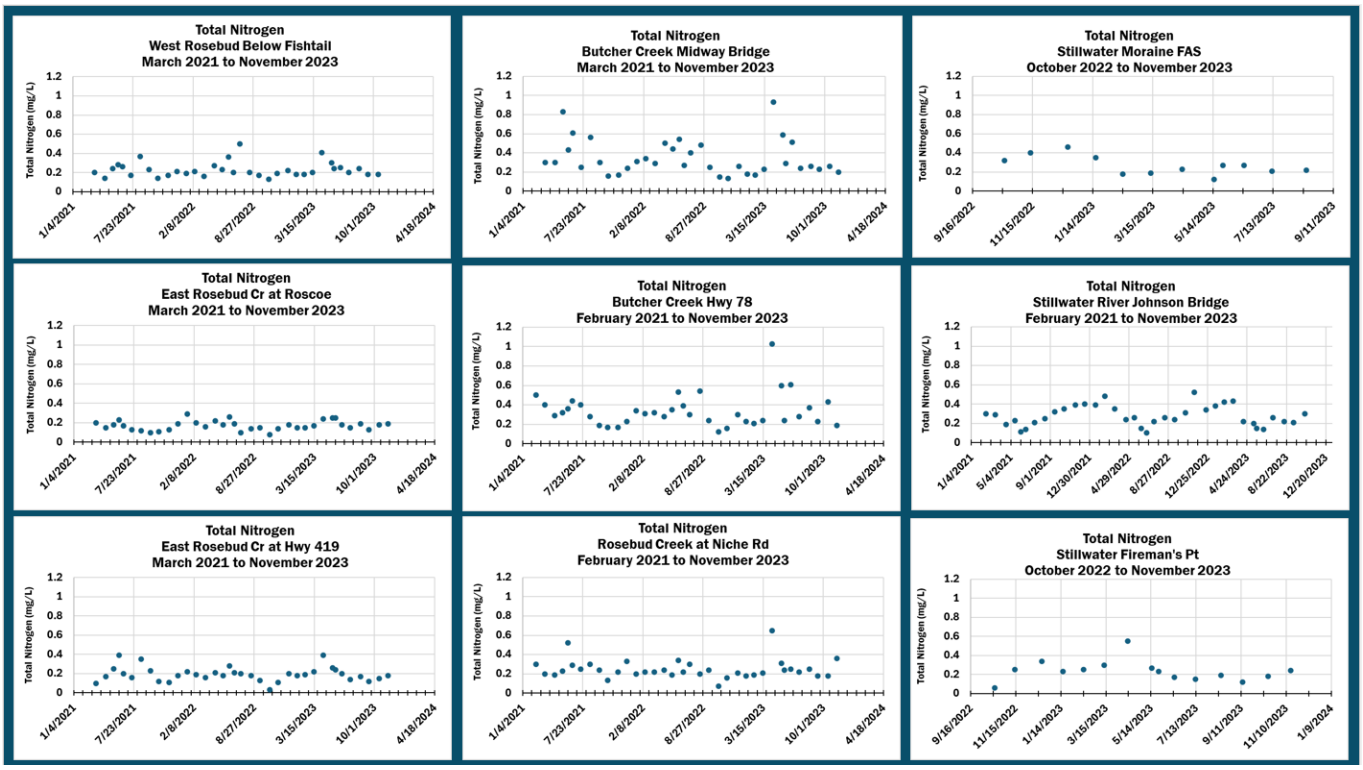


***Figure 5: Scatterplots for Total Nitrogen Concentrations.*** *TN concentrations are on the y-axis in mg/L, and the sample dates are on the x-axis. Only 2023 data was available for the Moraine and Fireman's Point sites, while 2021 to 2023 data was available for the rest of the sites.*

## Nitrate-N

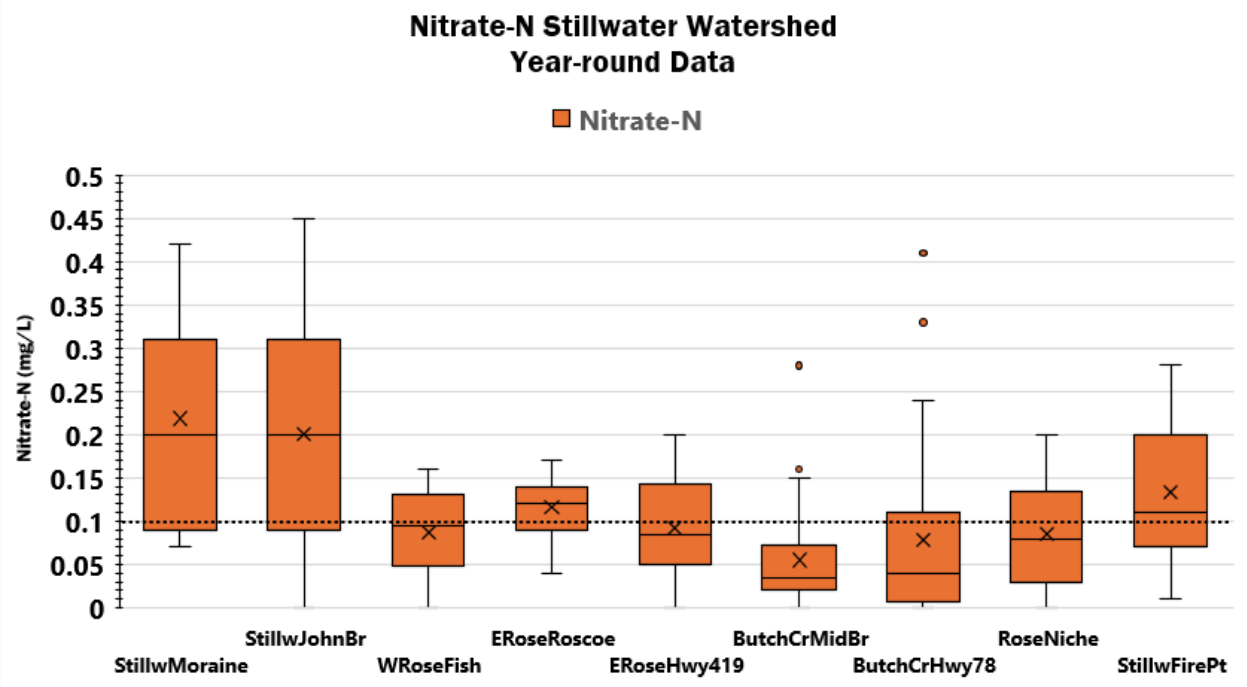


***Figure 6: Boxplots of Nitrate-N concentrations organized by site.*** *Nitrate-N concentrations are on the y-axis in mg/L. The sites on the x-axis are in order from upstream to downstream with the two uppermost mainstem Stillwater sites on the left followed by tributaries, and the most downstream mainstem Stillwater site on the right. See Figure 2 for site locations. The dashed line is the Nitrate-N threshold of 0.1 mg/L. The line inside each box represents the median Nitrate-N concentration for each site, and the "X" represents the mean. The area between the end of the lower whisker and the bottom of the box contains concentrations that fall within the first quartile excluding outliers. The distance from the bottom of the box and the median contains the values from the second quartile. The distance from the median to the top of the box contains all values within the third quartile, and the distance from the top of the box to the top whisker, excluding outliers, contains the values in the fourth quartile. Outliers are plotted outside of the whiskers if they lie greater than or equal to 1.5 times the length of the box from either end of the box (Team, T. M. 365 M., 2015).*

Nitrate-N concentrations were highest at the two most upstream sites on the Stillwater River (Moraine and Johnson Bridge), reaching concentrations of 0.2 to 0.22 mg/L, twice the 0.1 mg/L threshold above which nuisance algae may occur. Median concentrations for the Stillwater Fireman's Point site and East Rosebud at Roscoe site also exceeded the 0.1 mg/L threshold. The mean Nitrate-N concentration was lowest at the Butcher Creek Midway Bridge site (0.05 mg/L), but this site had two outlier concentrations above 0.15 and Butcher Creek at Highway 78 had two outliers above 0.3 mg/L.

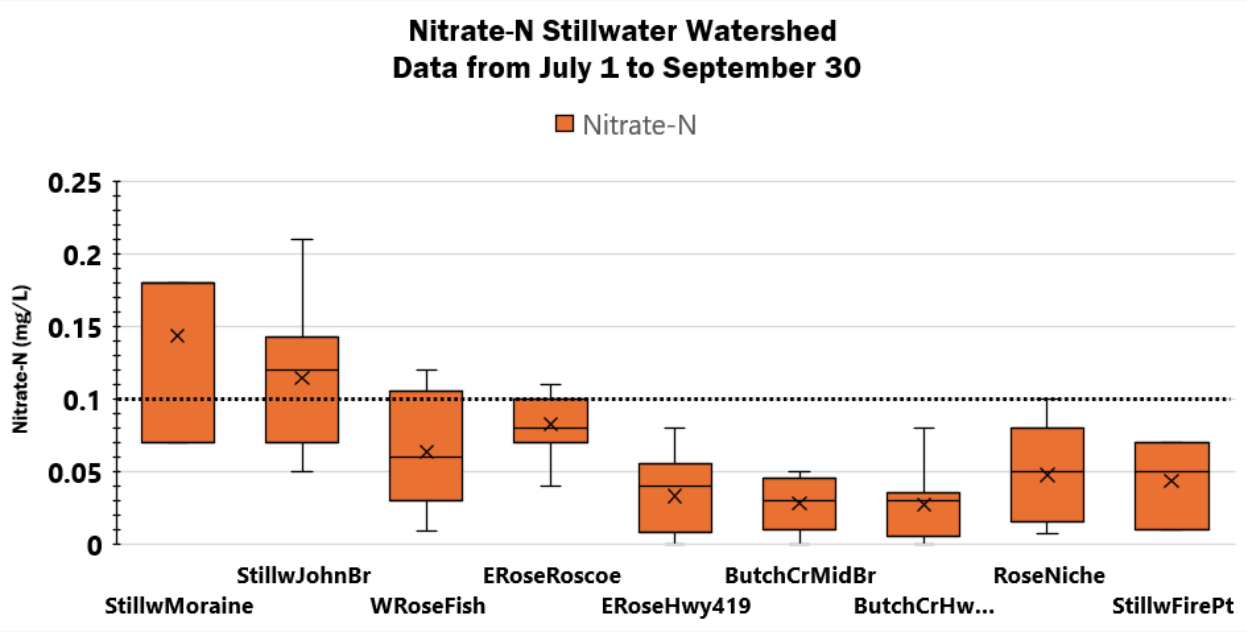


***Figure 8: Boxplots of Nitrate-N concentrations from July through September organized by site.*** *Nitrate-N concentrations are on the y-axis in mg/L. The sites on the x-axis are in order from upstream to downstream with the two uppermost mainstem Stillwater sites on the left followed by tributaries, and the most downstream mainstem Stillwater site on the right. See Figure 2 for site locations. The dashed line is the Nitrate-N threshold of 0.1 mg/L. The line inside each box represents the median Nitrate-N concentration for each site, and the "X" represents the mean. The area between the end of the lower whisker and the bottom of the box contains concentrations that fall within the first quartile excluding outliers. The distance from the bottom of the box and the median contains the values from the second quartile. The distance from the median to the top of the box contains all values within the third quartile, and the distance from the top of the box to the top whisker, excluding outliers, contains the values in the fourth quartile. Outliers are plotted outside of the whiskers if they lie greater than or equal to 1.5 times the length of the box from either end of the box.*

Nitrate concentrations for only the growing season, July 1-September 30, (Figures 4, 8, and 12) are presented parallel to that for total nutrients and indicate lower concentrations than the dataset across all months. Nitrate commonly enters streams with groundwater, so concentrations are highest when groundwater makes up the most streamflow, and lowest during spring runoff when snowmelt dilutes groundwater inflow. Runoff commonly extends into July for the Stillwater, and the primary algae growth season starts afterwards and extends through September. After runoff dilution winds down, a pattern of lower nitrate during the growing season can persist due to uptake of nitrate by aquatic plants/algae, which can mask the true concentration of nitrate entering a stream reach.

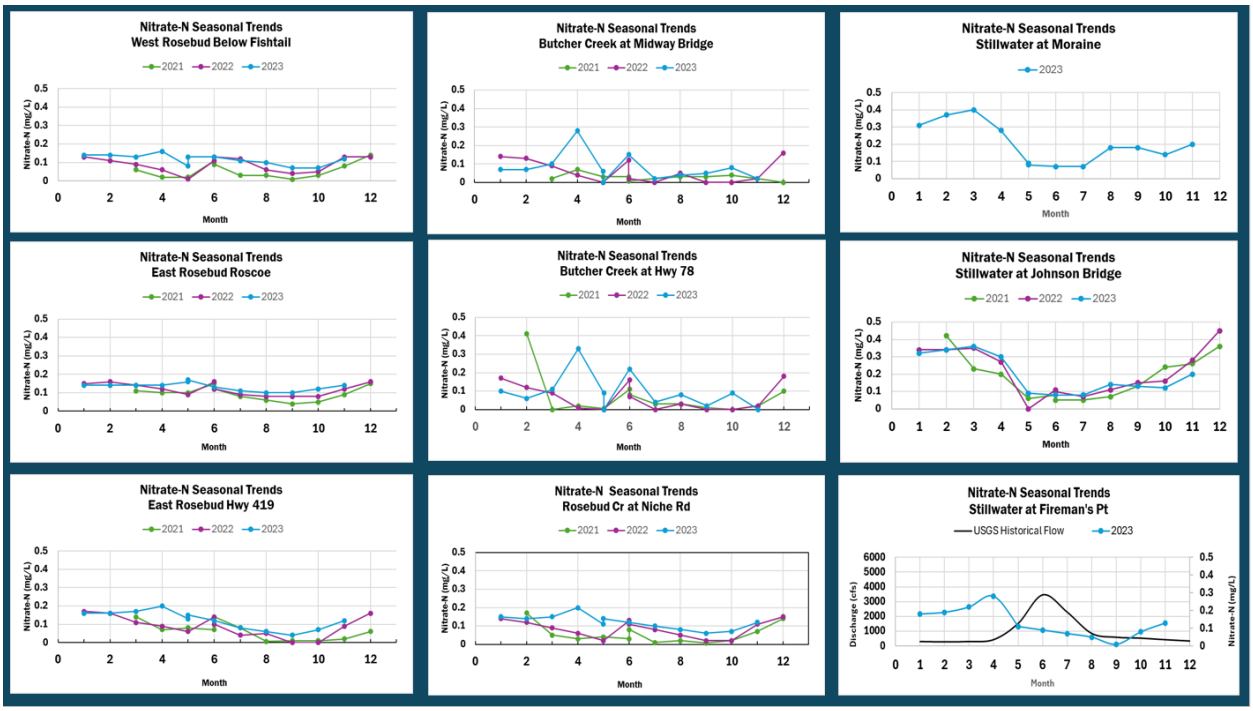


***Figure 7: Seasonal Trends for Nitrate-N concentrations.*** *Nitrate-N concentrations are on the y-axis in mg/L, and the months the samples were collected are numbered 1 to 12 on the x-axis. The black line on the Fireman's Point plot is the historic average monthly flow (cfs) collected at the USGS gage #06205000 located upstream from Fireman's Point representing data from 1935 to the present. Only 2023 data was available for the Moraine and Fireman's Point sites, while the 2021 to 2023 data was available for the rest of the sites.*

Measured nitrate-N concentrations were highest at the two most upstream Stillwater mainstem sites, Moraine, and Johnson Bridge, where peaks were measured in March and February at 0.4 and 0.45 mg/L respectively. Samples weren't available for the Moraine site and Fireman's Point sites in December, but measured peaks were observed in December at the Johnson Bridge site at 0.38 mg/L in 2021 and 0.45 mg/L in 2022. Nitrate-N concentrations exhibited more interannual variation at the two Butcher Creek sites which had measured peak concentrations in June and some relatively higher concentrations over winter and in April. At the Stillwater Fireman's Point site, the measured nitrate-N concentration peaked at about 0.25 mg/L in April 2023 and dropped to 0.1 in May as runoff increased flows from May to June. At the Stillwater Johnson Bridge site, the highest measured nitrate-N concentrations were observed between December and February 2021 and 2023 from 0.4 to 0.45 mg/L. (Figure 10). The concentrations in 2022 were lower, peaking at about 0.38 mg/L.

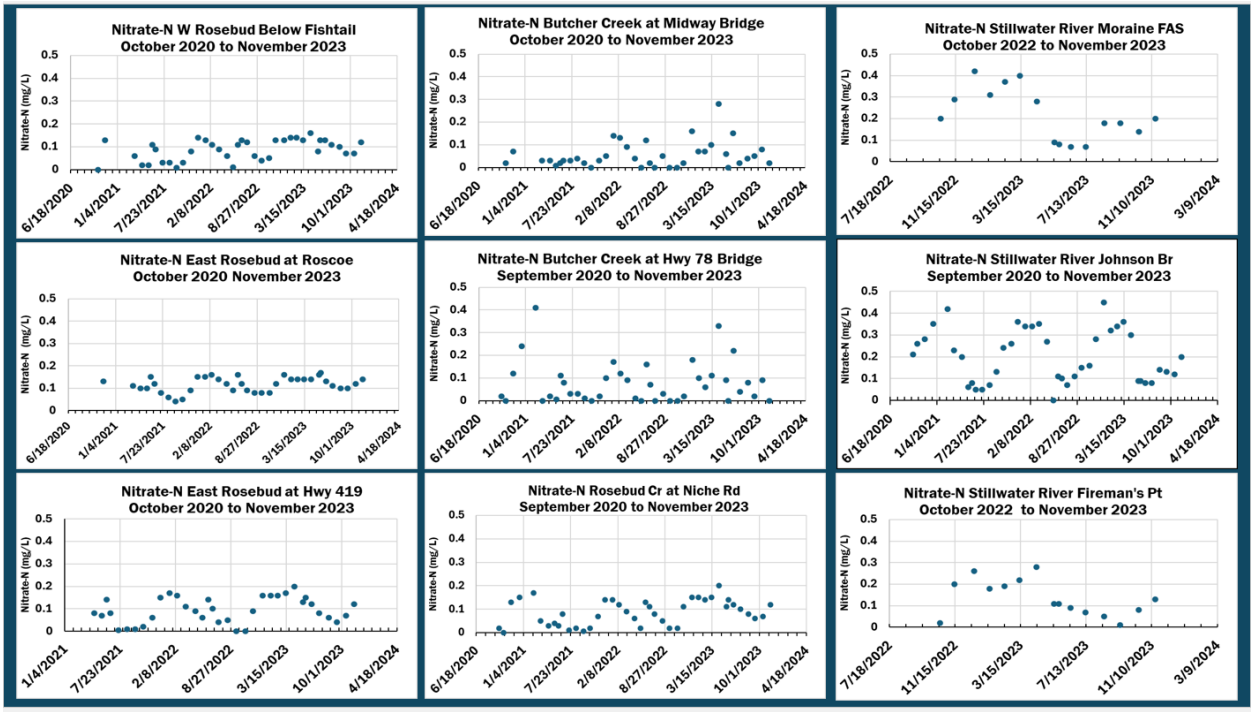


***Figure 8: Scatterplots for Nitrate-N Concentrations.*** *TN concentrations are on the y-axis in mg/L, and the sample dates are on the x-axis. Only 2023 data was available for the Moraine and Fireman's Point sites, while 2021 to 2023 data was available for the rest of the sites.*

## Total Phosphorus (TP)

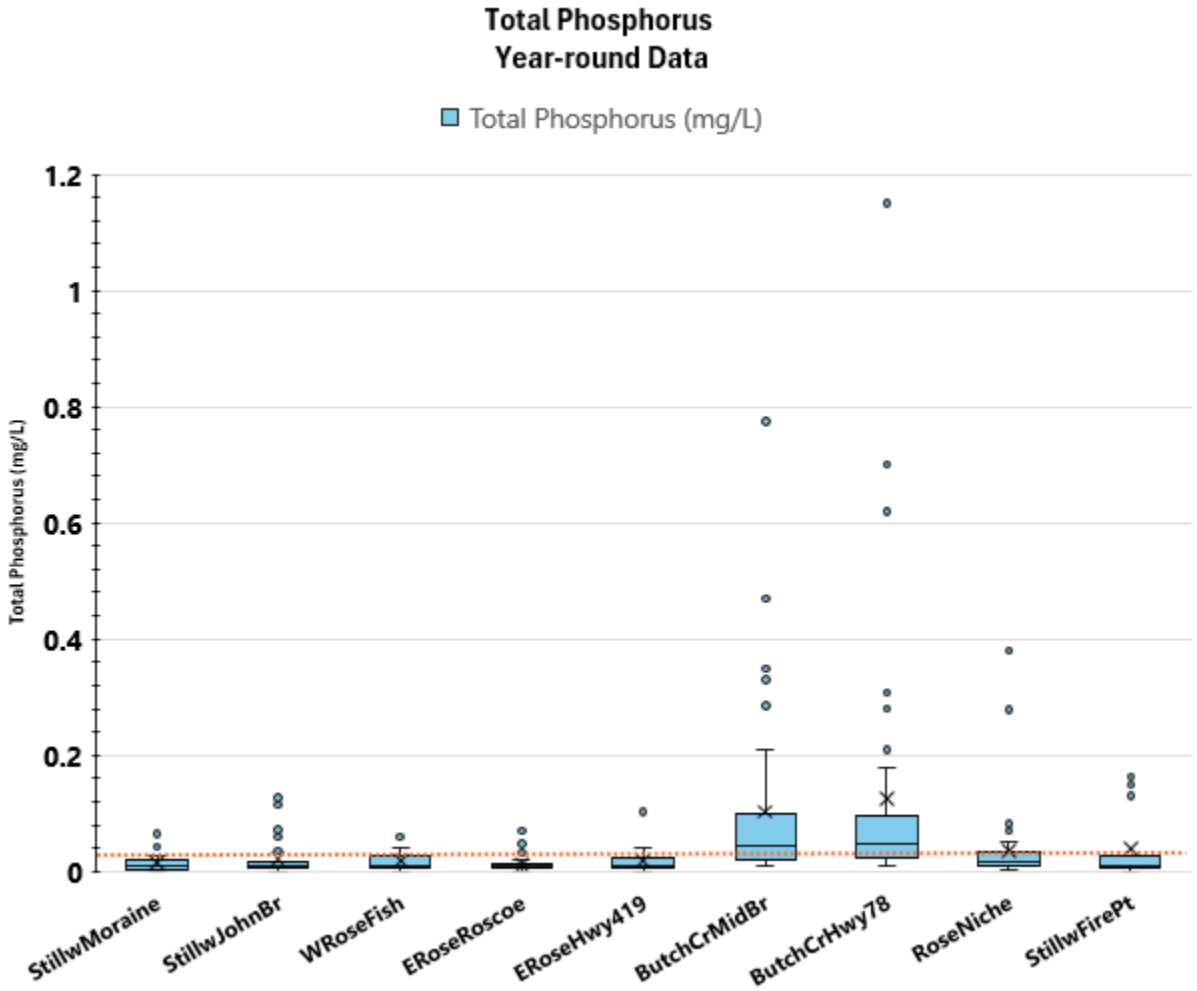


***Figure 9: Boxplots of Phosphorus concentrations organized by site.*** *Phosphorus concentrations are on the y-axis in mg/L. The sites on the x-axis are in order from upstream to downstream with the two uppermost mainstem Stillwater sites on the left followed by tributaries, and the most downstream mainstem Stillwater site on the right. See Figure 2 for site locations. The dashed line is the Phosphorus threshold of 0.033 mg/L. The line inside each box represents the median Phosphorus concentration for each site, and the "X" represents the mean. The area between the end of the lower whisker and the bottom of the box contains concentrations that fall within the first quartile excluding outliers. The distance from the bottom of the box and the median contains the values from the second quartile. The distance from the median to the top of the box contains all values within the third quartile, and the distance from the top of the box to the top whisker, excluding outliers, contains the values in the fourth quartile. Outliers are plotted outside of the whiskers if they lie greater than or equal to 1.5 times the length of the box from either end of the box. (Team, T. M. 365 M., 2015).*

Four sites exhibited mean Phosphorus concentrations exceeding the 0.033 mg/L MDEQ threshold: Butcher Creek at Midway Bridge (0.1 mg/L), Butcher Creek at Highway 78 (0.12 mg/L), Rosebud Creek at Niche Rd. (0.04 mg/L), and Stillwater River at Fireman's Point (0.04 mg/L) (Figure 11). The mean and median Phosphorus concentrations for the remaining five sites were below the 0.033 mg/L threshold. Phosphorus concentrations

were highest at the two Butcher Creek sites, with median values above the threshold and some concentrations as high as 10 times the threshold.

When data was assessed for only the growing season (July 1 to September 30), nearly all phosphorus sample concentrations for both Butcher Creek sites were above the threshold. Nearly all sample concentrations for the remaining sites were below the threshold (Figure 12).

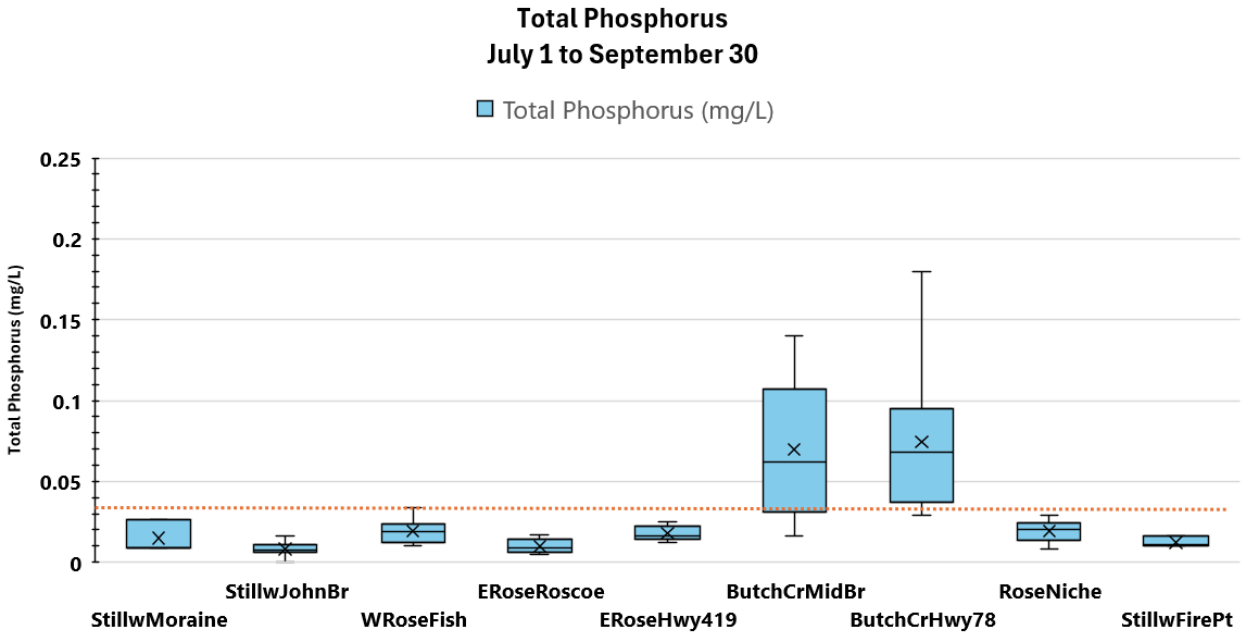


***Figure 10: Boxplots of Phosphorus concentrations from July through September organized by site.*** *Phosphorus concentrations are on the y-axis in mg/L. The sites on the x-axis are in order from upstream to downstream with the two uppermost mainstem Stillwater sites on the left followed by tributaries, and the most downstream mainstem Stillwater site on the right. See Figure 2 for site locations. The dashed line is the Phosphorus threshold of 0.033 mg/L. The line inside each box represents the median Phosphorus concentration for each site, and the "X" represents the mean. The area between the end of the lower whisker and the bottom of the box contains concentrations that fall within the first quartile excluding outliers. The distance from the bottom of the box and the median contains the values from the second quartile. The distance from the median to the top of the box contains all values within the third quartile, and the distance from the top of the box to the top whisker, excluding outliers, contains the values in the fourth quartile. Outliers are plotted outside of the whiskers if they lie greater than or equal to 1.5 times the length of the box from either end of the box. (Team, T. M. 365 M., 2015).*

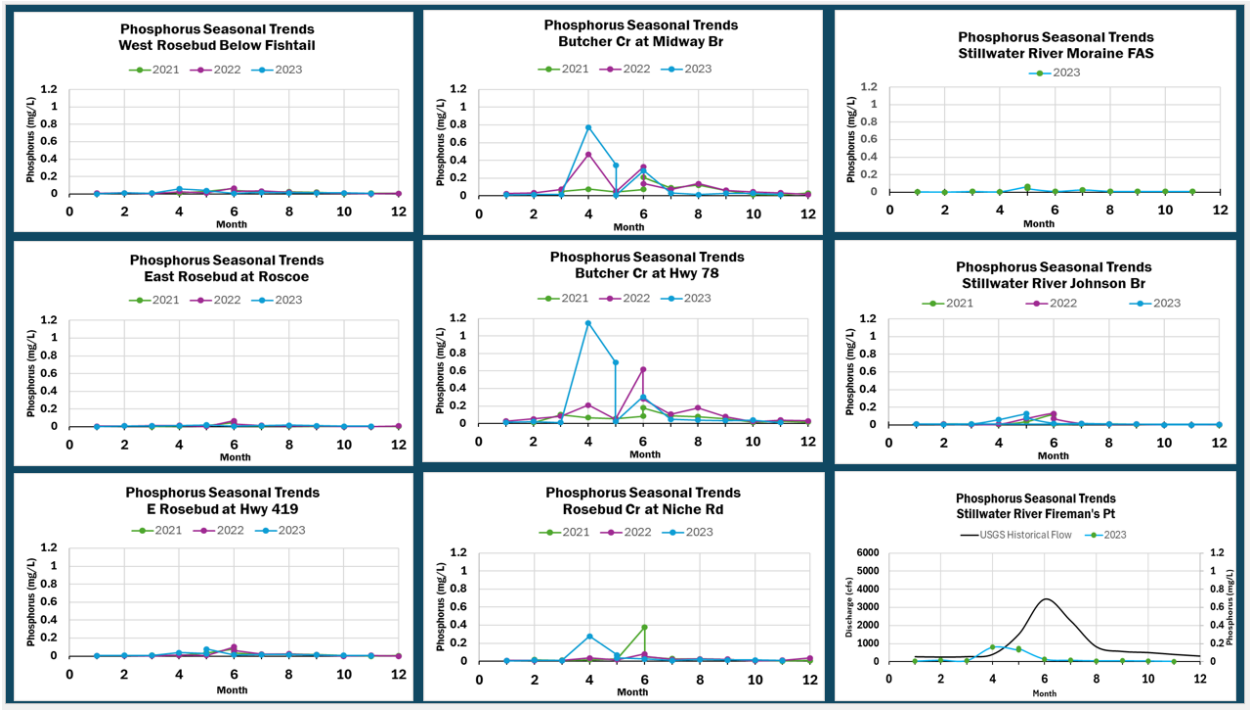


***Figure*13*: Seasonal Trends for Phosphorus concentrations.*** *Phosphorus concentrations are on the y-axis in mg/L, and the months the samples were collected are numbered 1 to 12 on the x-axis. The black line on the Fireman's Point plot is the historic average monthly flow (cfs) collected at the USGS gage #06205000 located upstream from Fireman's Point representing data from 1935 to the present. Only 2023 data was available for the Moraine and Fireman's Point sites, while the 2021 to 2023 data was available for the rest of the sites.*

Peak measured phosphorus concentrations were highest at the two Butcher Creek sites which were more than five times higher in 2023 (1.1 mg/L) than in 2021 (0.2 mg/L) at the Butcher Creek Highway 78 site (Figure 13, 14). These two sites exhibited progressively higher phosphorus concentrations from 2021 to 2023. Phosphorus concentrations were relatively low at the other sites. Phosphorus concentrations at Stillwater Fireman's Point show a positive correlation with flow with the highest measured concentration preceding peak flow by about two months. The lowest phosphorus concentrations occur at the lowest flows.

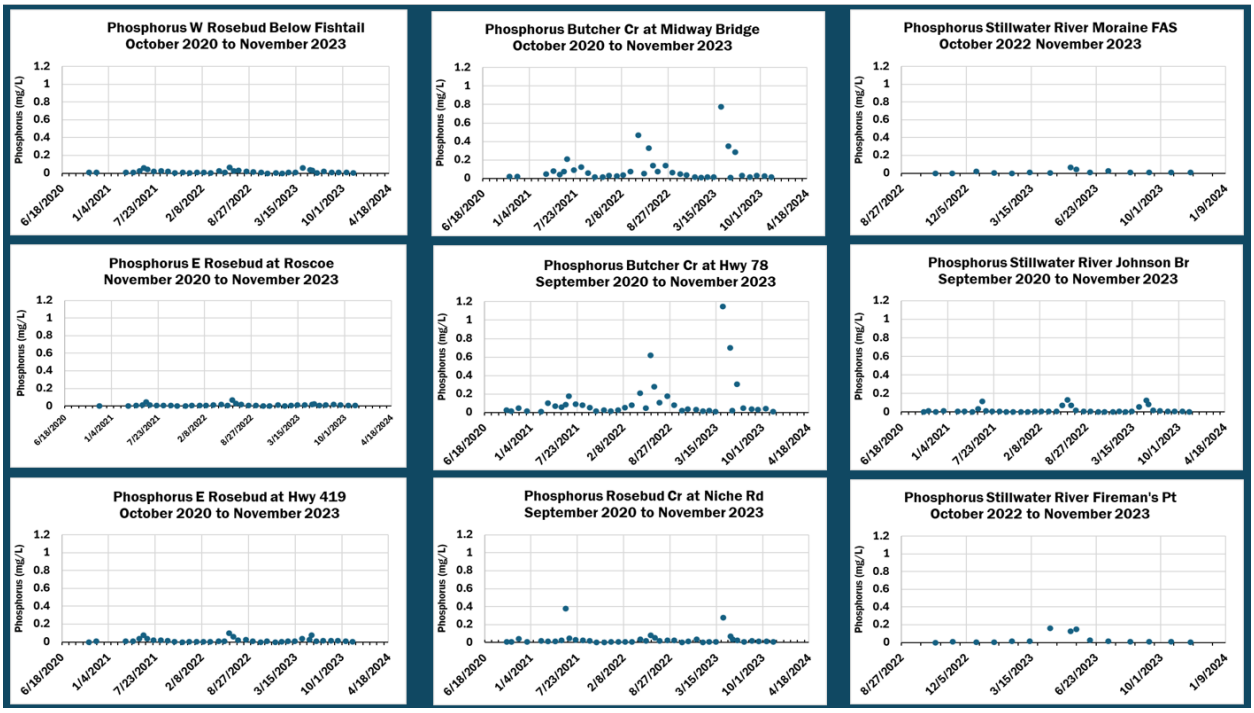


***Figure 14*: Scatterplots of Phosphorus Concentrations.** *Phosphorus concentrations are on the y-axis in mg/L, and the sample dates are on the x-axis. Only 2023 data was available for the Moraine and Fireman's Point sites, while data was available from 2021 through 2023 for the rest of the sites.*

# Relationships Between Parameters

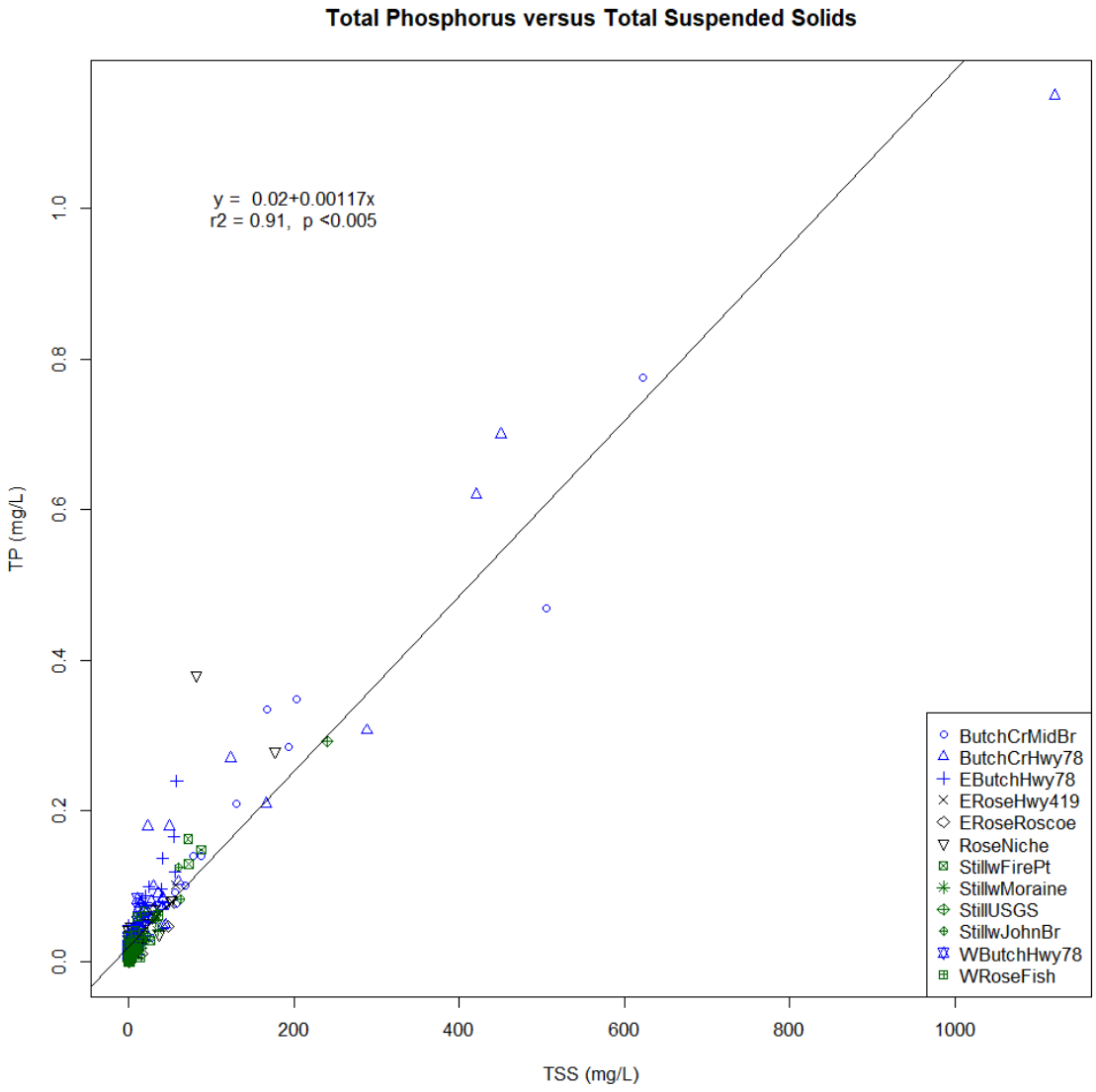


**Figure 15: Total Phosphorus versus Total Suspended Solids.** *TP plotted against TSS with samples for sites indicated according to symbology in the legend. The black line indicates a linear regression through all the points with the equation (Y = slope*X + intercept), $r^2$ value and p value for the relationship indicated on the plot. The closer an $r^2$ value is to 1, the better the line is doing at explaining the relationship between the parameters. A smaller $r^2$ value (closer to zero) indicates that parameters other than that on the X axis are playing an important role in controlling the values on the Y axis. The lower the p value, the more statistically significant the relationship is (a p value less than 0.005 indicates a highly significant statistical relationship).*

There is a correlation between TP and TSS, such that across all samples 91% of the variability in TP is explained by TSS. Based on the slope of this relationship, for every 1 kg of solids transported by the streams, approximately 1 mg of phosphorus is transported. This strong positive relationship was found across all sites with $r^2$ values ranging from 0.53 (WRoseFish) to 0.96 (StillwFirePt; Appendix A - Figure A1).

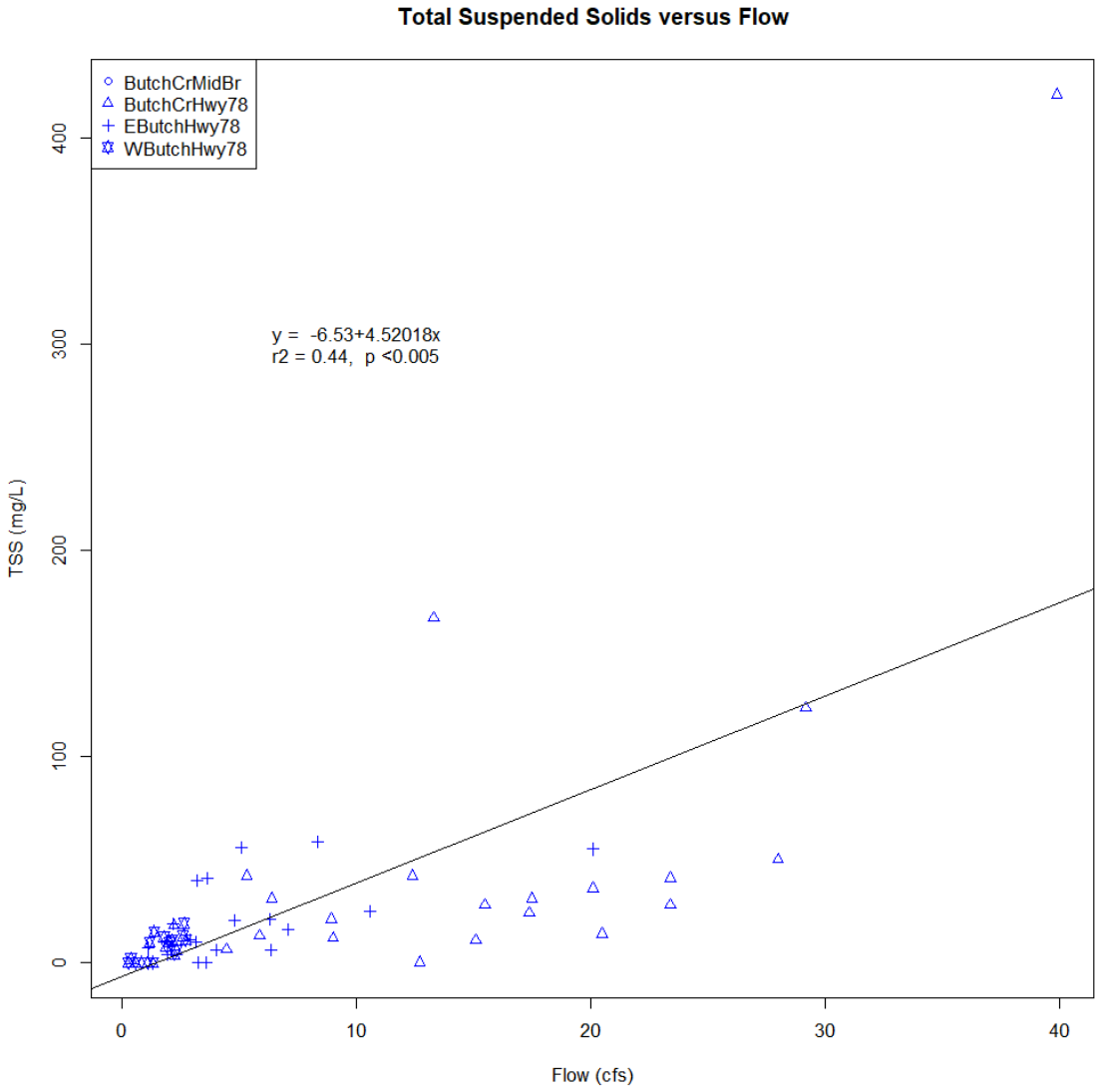


***Figure 16: Total Suspended Solids versus Flow.*** *Data is included for Butcher Creek sites where flow was measured on the same day as water quality sample collection. TSS is plotted against Flow with samples for sites indicated according to symbology in the legend. The black line indicates a linear regression through all the points with the equation (Y = slope*X + intercept), $r^2$ value and p value for the relationship indicated on the plot. The closer an $r^2$ value is to 1, the more accurate the line is at explaining the relationship between the parameters. A smaller $r^2$ value (closer to zero) indicates that parameters other than that on the X axis are playing an important role in controlling the values on the Y axis. The lower the p value, the more statistically significant the relationship is (a p value less than 0.005 indicates a highly significant statistical relationship).*

At the Butcher Creek sites, TSS concentrations are positively correlated with flow, such that 44% of variability in TSS concentration is explained by flow. While higher flow produces higher sediment concentrations, more than half (56%) of the variability in TSS is caused by conditions other than variability in flow. For individual sites the $r^2$ value ranges from 0.31 (EButchHwy78) to 0.53 (WButchHwy78; Appendix A - Figure A4).

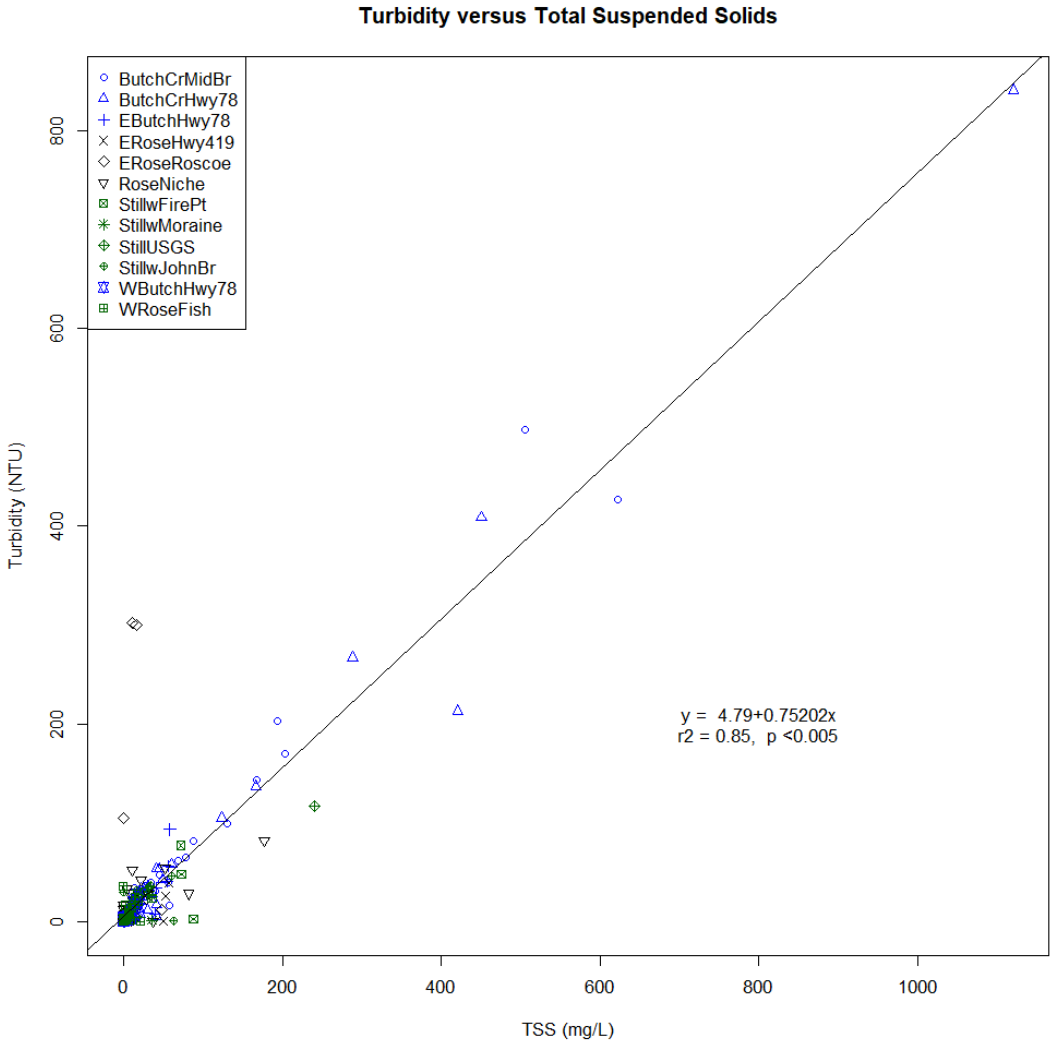


***Figure 17: Turbidity versus Total Suspended Solids.*** *Turbidity plotted against TSS with samples for sites indicated according to symbology in the legend. The black line indicates a linear regression through all the points with the equation (Y = slope*X + intercept), $r^2$ value and p value for the relationship indicated on the plot. The closer the $r^2$ value is to 1, the more accurate the line is at explaining the relationship between the parameters. A smaller $r^2$ value (closer to zero) indicates that parameters other than that on the X axis are playing an important role in controlling the values on the Y axis. The lower the p value, the more statistically significant the relationship is (a p value less than 0.005 indicates a highly significant statistical relationship).*

Turbidity can be useful as a surrogate measure for TSS. Across all sites and visits, turbidity explains 85% of the variability in TSS. For individual sites the $r^2$ values range from 0.06 (ERoseRoscoe) to 0.98 (ButchCrHwy78; Appendix A Figure, A6). For samples that fall particularly far off the regression line (notably two samples for ERoseRoscoe), the data should be assessed for possible errors or for unique circumstances that would result in high turbidity with low TSS (such as high concentrations of tannins or other causes of cloudiness besides suspended sediment).

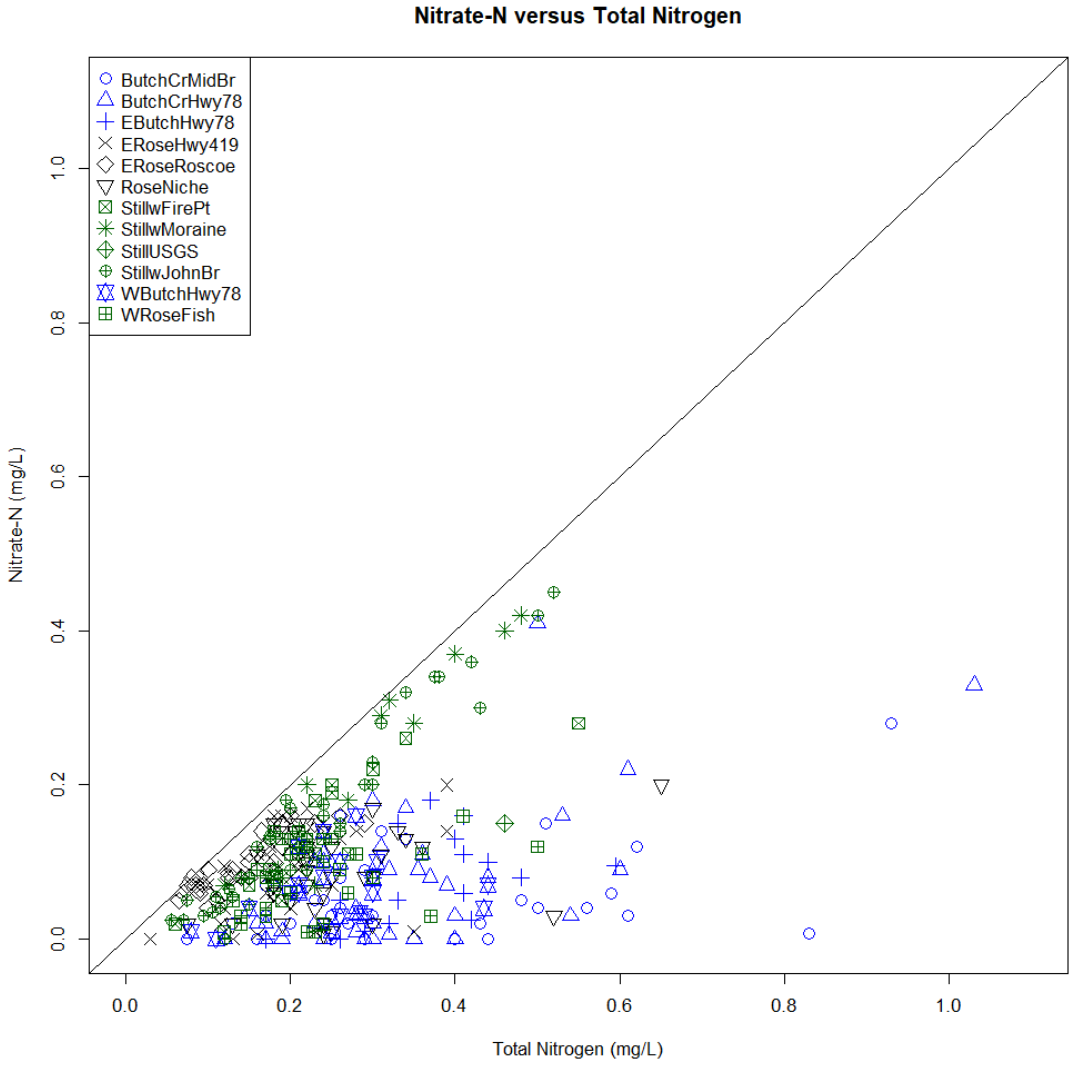


***Figure 18: Nitrate versus Total Nitrogen.*** *Nitrate-N plotted against TN with samples for sites indicated according to symbology in the legend. The black line is a 1 to 1 line. Nitrate-N is a component of TN, so it is not possible for values to fall above the 1 to 1 line. Points falling near the 1 to 1 line indicate that a large fraction of the TN is composed of nitrate.*

The fraction of total nitrogen made up by nitrate varies across sites and across time. While ButchCrMidBr consistently has a low fraction of TN made up by nitrate, StillwMoraine and StillwJohnBr consistently have close to 100% of TN made up by nitrate (Figure 18, Appendix A - Figure A8). Nitrate commonly enters streams through groundwater, so locations where nitrate makes up a-significant fraction of TN are areas to assess for possible groundwater sources.

# Discussion

Excess nutrients in waterways feed plant life, causing nuisance algae growth that endangers aquatic ecosystem health (US EPA, 2021.) The Stillwater River is listed by MDEQ as impaired, in part due to nutrient concentrations (MDEQ, 2020). The listing was made in 2006 and relied on the monitoring data available at that time.

MDEQ has indicated nitrate as a cause of impairment for the Stillwater River from the Absaroka-Beartooth Forest boundary to the mouth, which spans all three Stillwater monitoring locations based on monitoring data (MDEQ, 2020). The highest nitrate concentrations were measured at the most upstream sites on the Stillwater River during baseflow months, which indicates groundwater sourced inputs of nitrate as the most likely source of nitrogen inputs.

For Butcher Creek, TN concentrations were highest where nitrate-N fractions accounted for only 42% and 16% at the ButchCrHwy78 and ButchCrMidBr, respectively (Appendix A, Figure A8). The higher TN concentrations with lower nitrate-N concentration suggest possible organic nitrogen sources.

Phosphorus concentrations and sediment were listed as sources of impairment for the Butcher Creek tributary (MDEQ, 2020). Across all sites, measured phosphorus concentrations were highest at the Butcher Creek sites. Previous research has found that soils in the Butcher Creek watershed are prone to erosion and hence prone to mobilization of phosphorus bound to soil (USGS, 2018). Augmented flows in Butcher Creek diverted from East Rosebud Creek, and agricultural runoff through erosion-prone soils have been identified as sources of sedimentation in the Butcher Creek tributary separate from seasonal runoff (SVWC-a, 2024). TSS and TP loading to Butcher Creek from flow alterations is consistent with analysis indicating more than half of the variability in TSS concentration is independent of flow (Figure 16). Although phosphorus and TSS concentrations were much higher at the Butcher Creek sites than other tributaries, Butcher Creek TSS concentrations are much lower than those reported in the 1990s (SVWC-a, 2024), suggesting that TP levels are also lower than historically.

# Conclusions

Data analyzed for nutrient concentrations provided by the SRWQI project agrees with nitrate impairment listings by MDEQ on the Stillwater River, as well as phosphorus and sedimentation impairments on Butcher Creek (MDEQ, 2020).

Nitrate concentrations were highest at the upstream sites on the mainstem Stillwater (Moraine and Johnson Bridge). Concentrations were highest during winter baseflow months indicating groundwater sources of nitrate.

Rosebud tributary sites demonstrated TP and TN concentrations primarily below thresholds, while nitrate concentrations were more regularly found above the threshold for potential nuisance algae. Notably, the East Rosebud at Roscoe site had the lowest TN and TP concentrations among the Rosebud sites, while simultaneously having the highest nitrate concentrations among those sites, suggesting groundwater sources of nitrogen could be influencing that site.

TN concentrations were highest at the Butcher Creek sites where nitrate-N concentrations accounted for less than one-half of the TN concentrations, indicating likely overland flow and/or bank erosion sources of nitrogen are important contributors in this tributary.

The highest TP concentrations were observed in Butcher Creek. A strong correlation was found between TP and TSS, indicating sediment as the primary source of phosphorus to Butcher Creek, which is consistent with previous work identifying highly erodible soils in the Butcher Creek Watershed.

Turbidity looks very promising as a surrogate measurement to estimate TSS at the Butcher Creek sites. The relationship between turbidity and TSS is less robust, and variable at other sites.

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# Appendices

## Appendix A – Relationships between Parameters

Figure A1 - TP vs TSS (no stats)

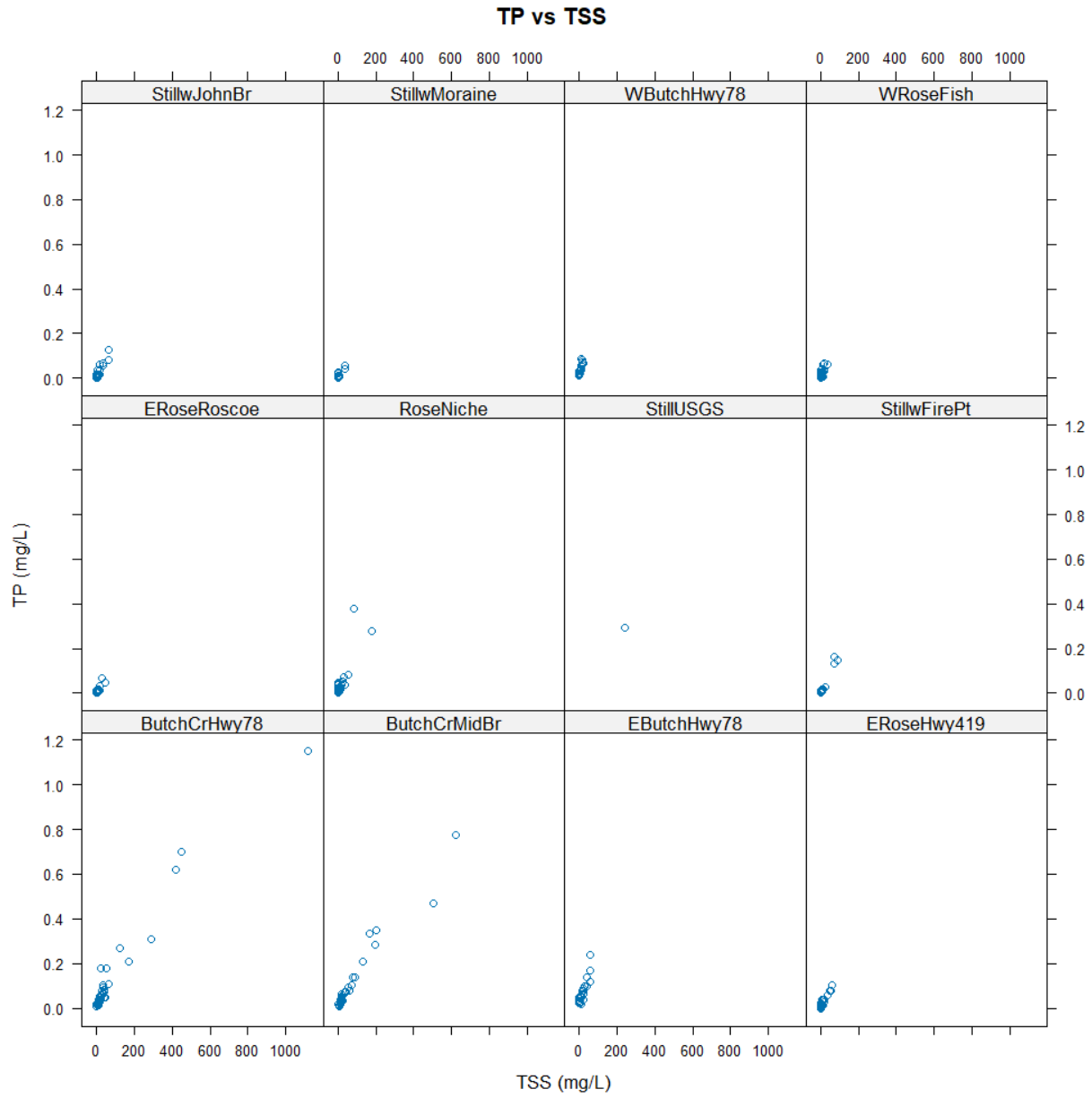


Figure A2 - TP vs TSS (with stats)

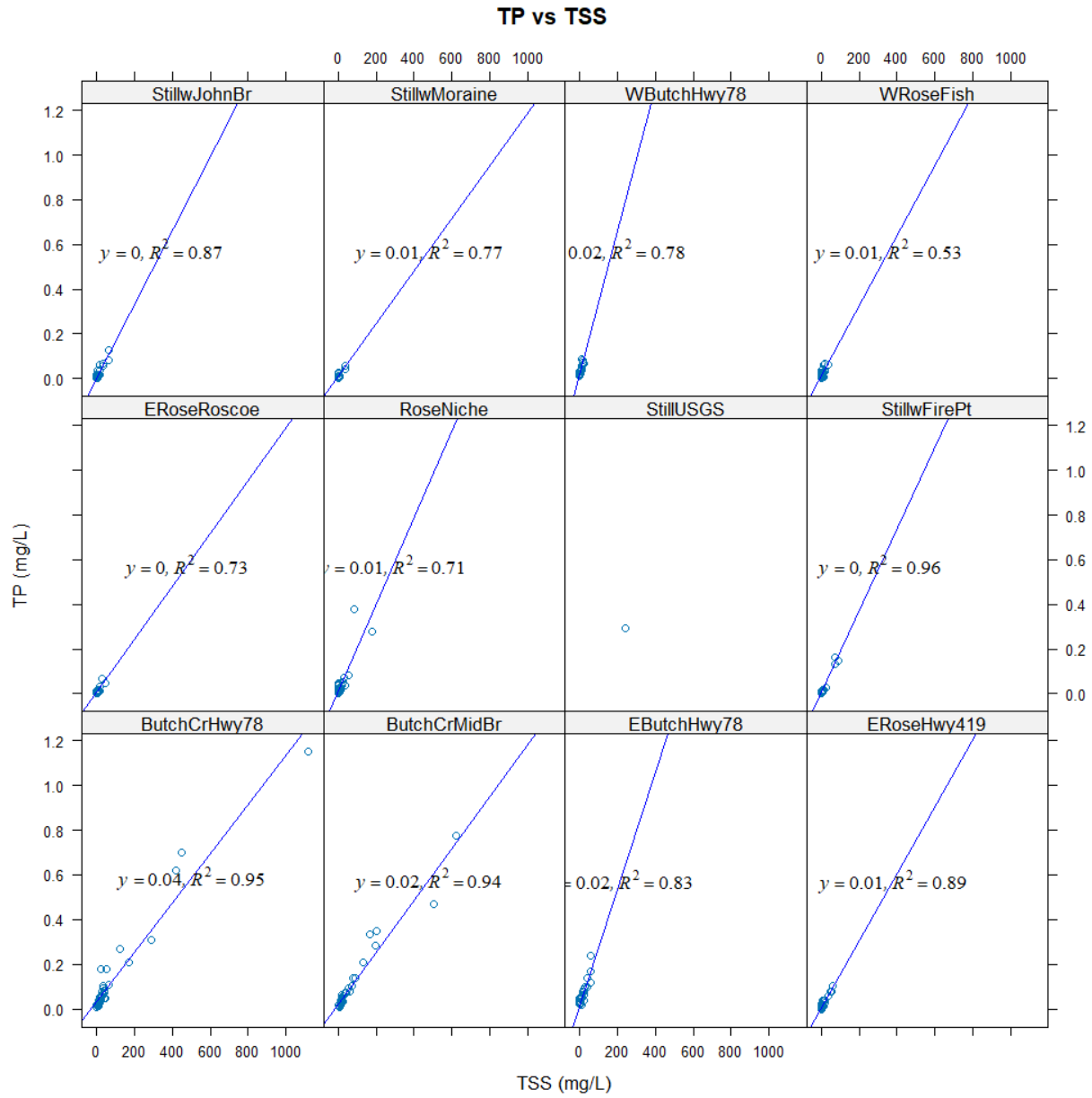


Figure A3 - TSS vs Flow (no stats)

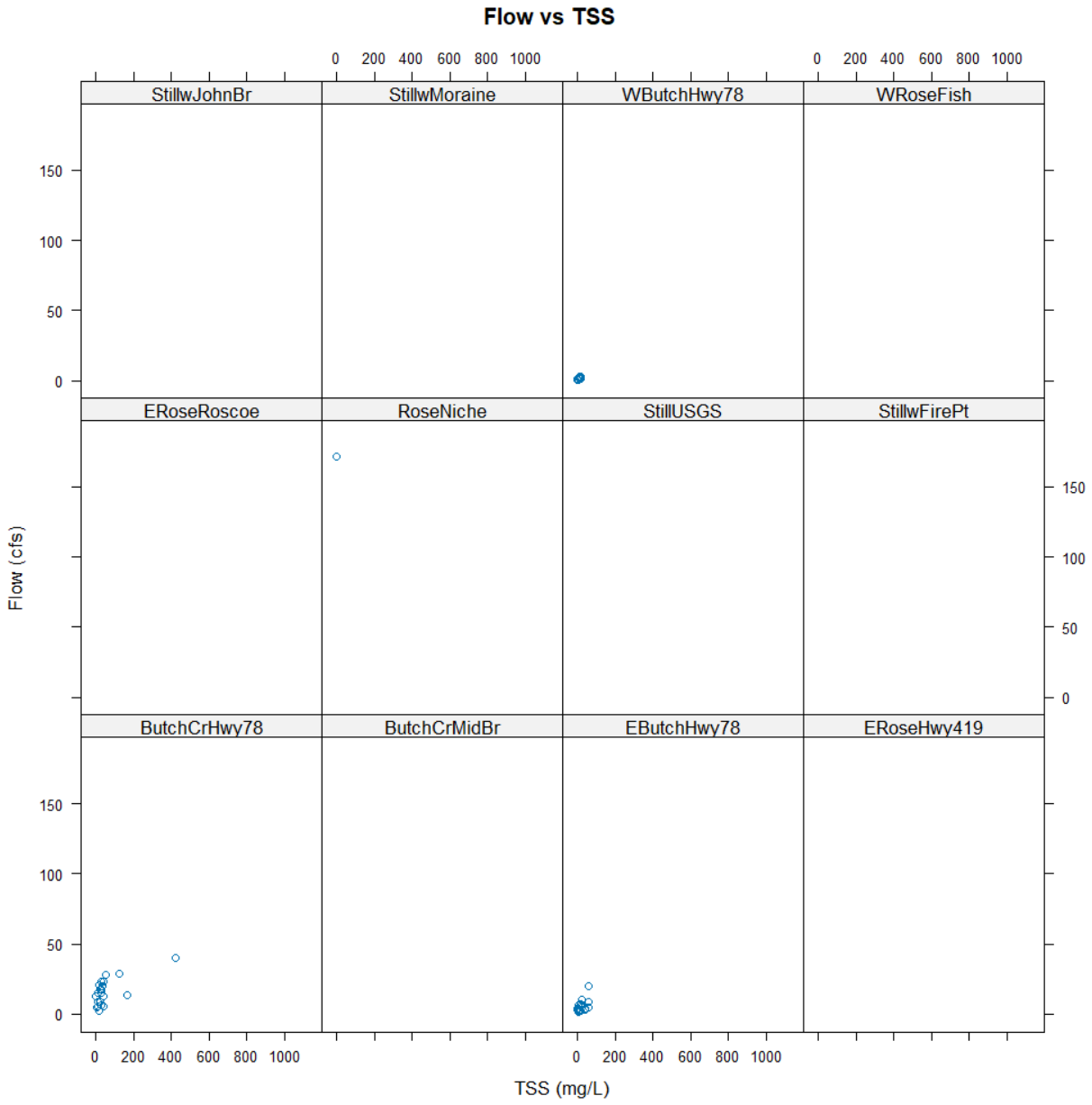


Figure A4 - TSS vs Flow (with stats)

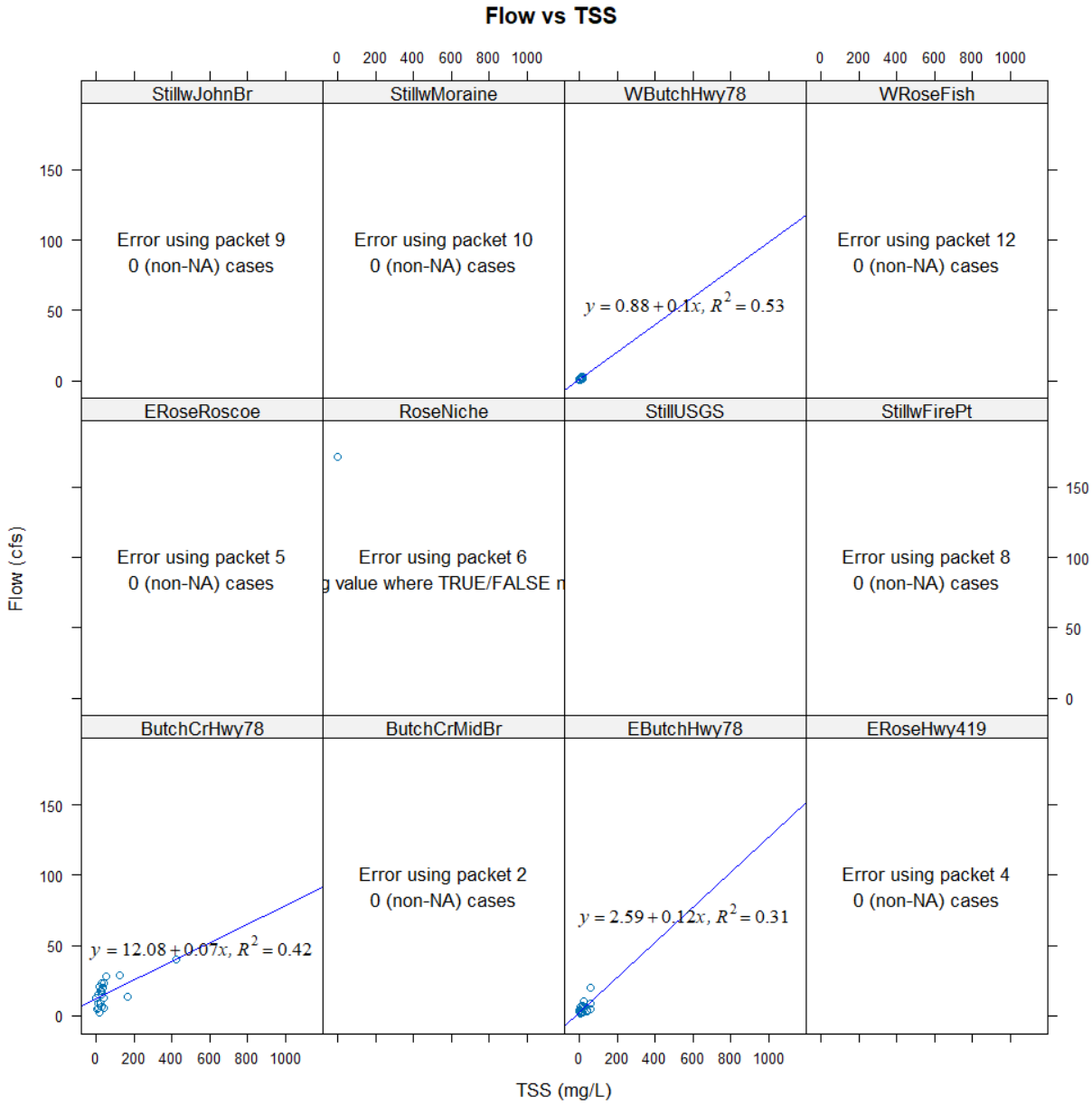


Figure A5 - TSS vs Turbidity (no stats)

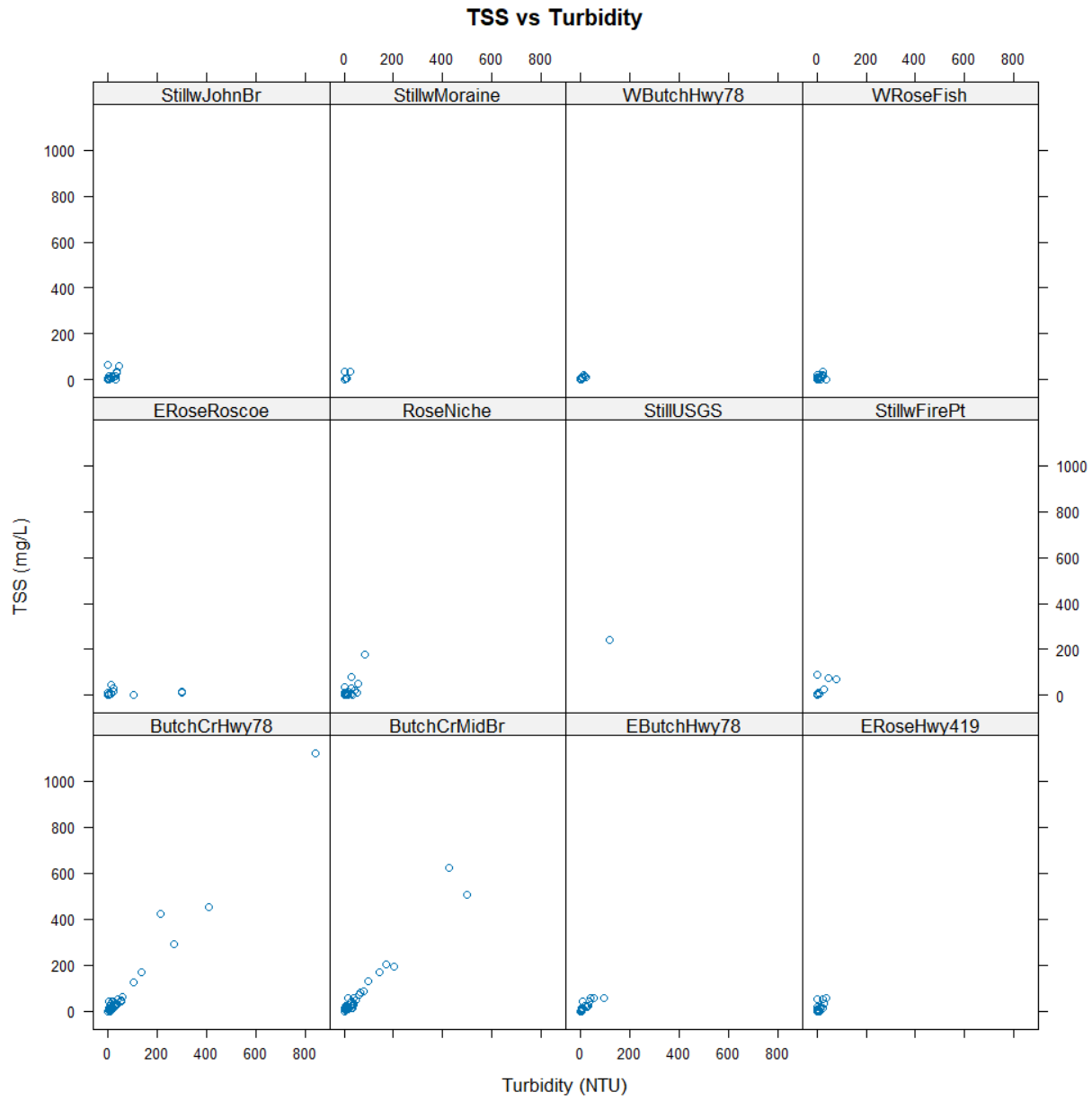


Figure A6 - TSS vs Turbidity (with stats)

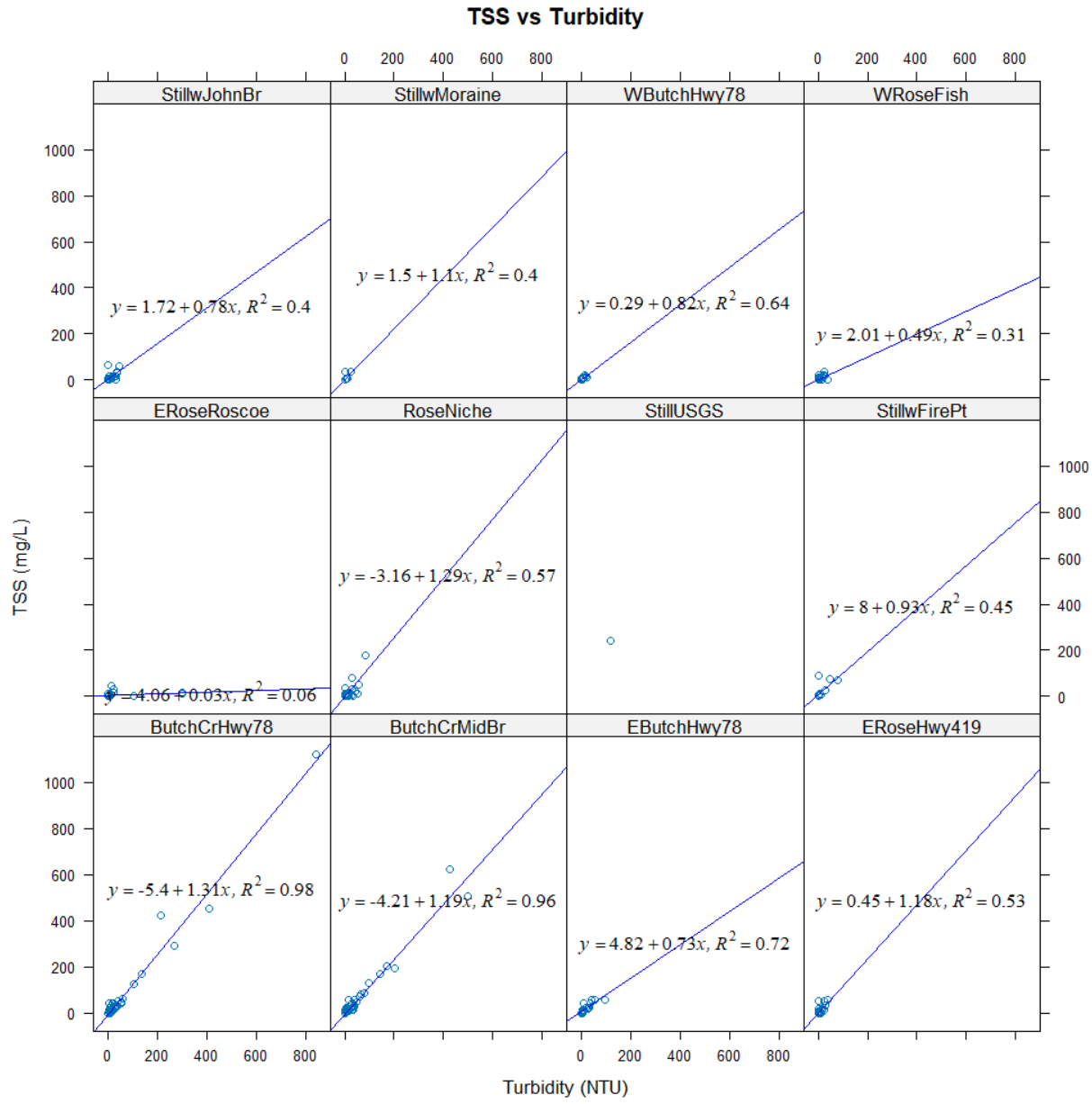


Figure A7 - Nitrate vs Total Nitrogen (no stats)

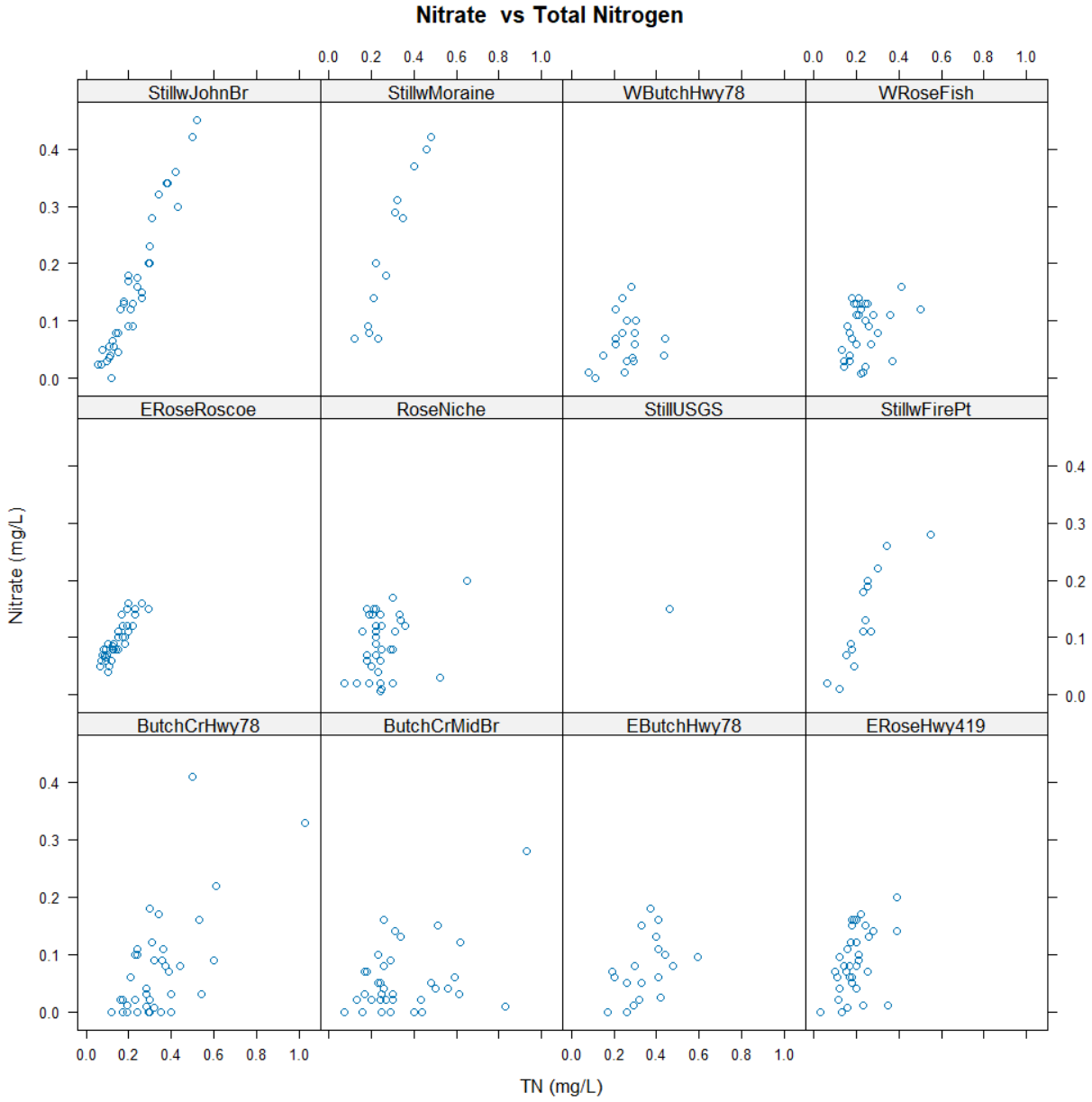
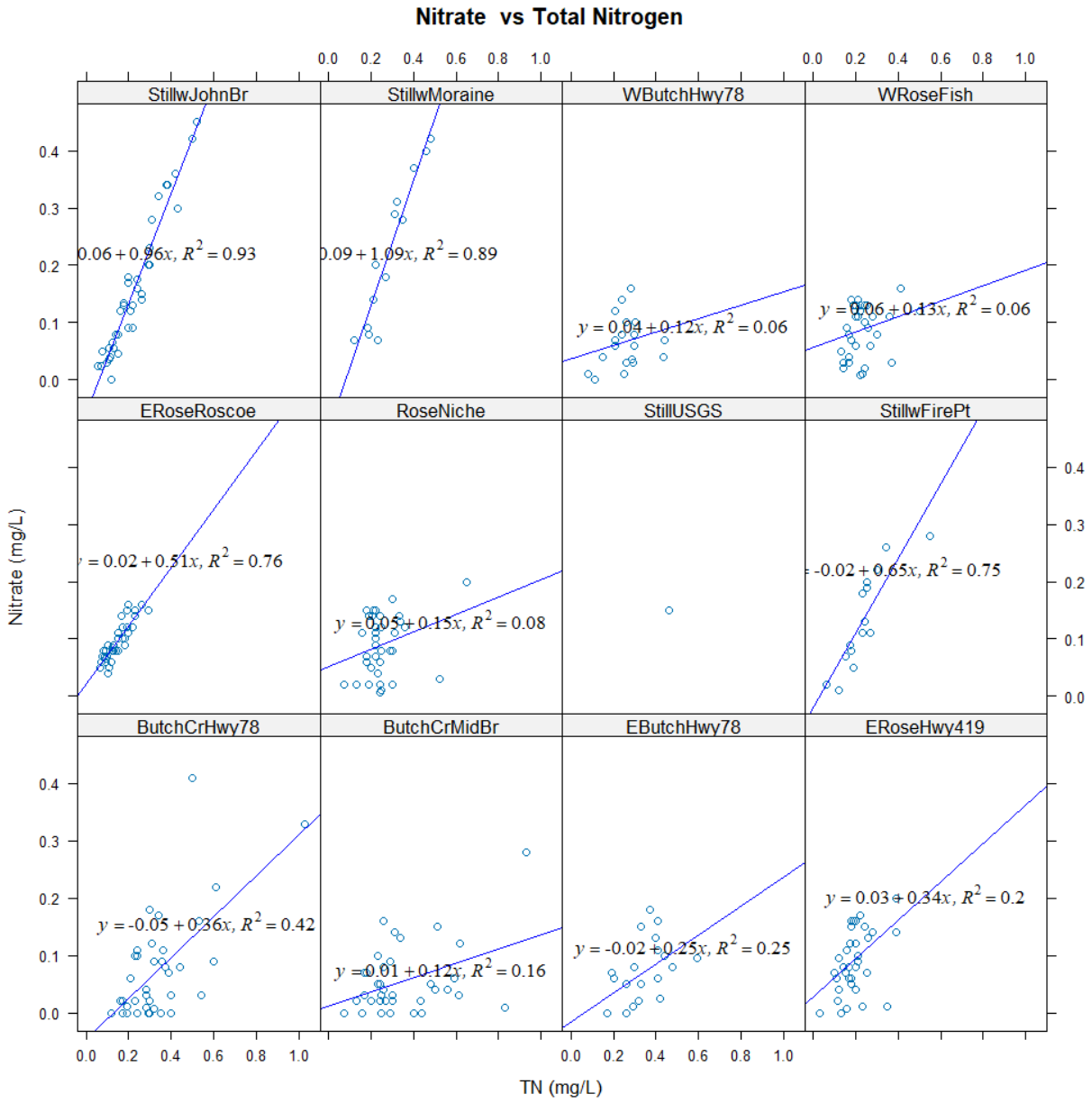


Figure A8 - Nitrate vs Total Nitrogen (with stats)



# Appendix B – Boxplots for Parameters

Figure B1 - Dissolved Oxygen

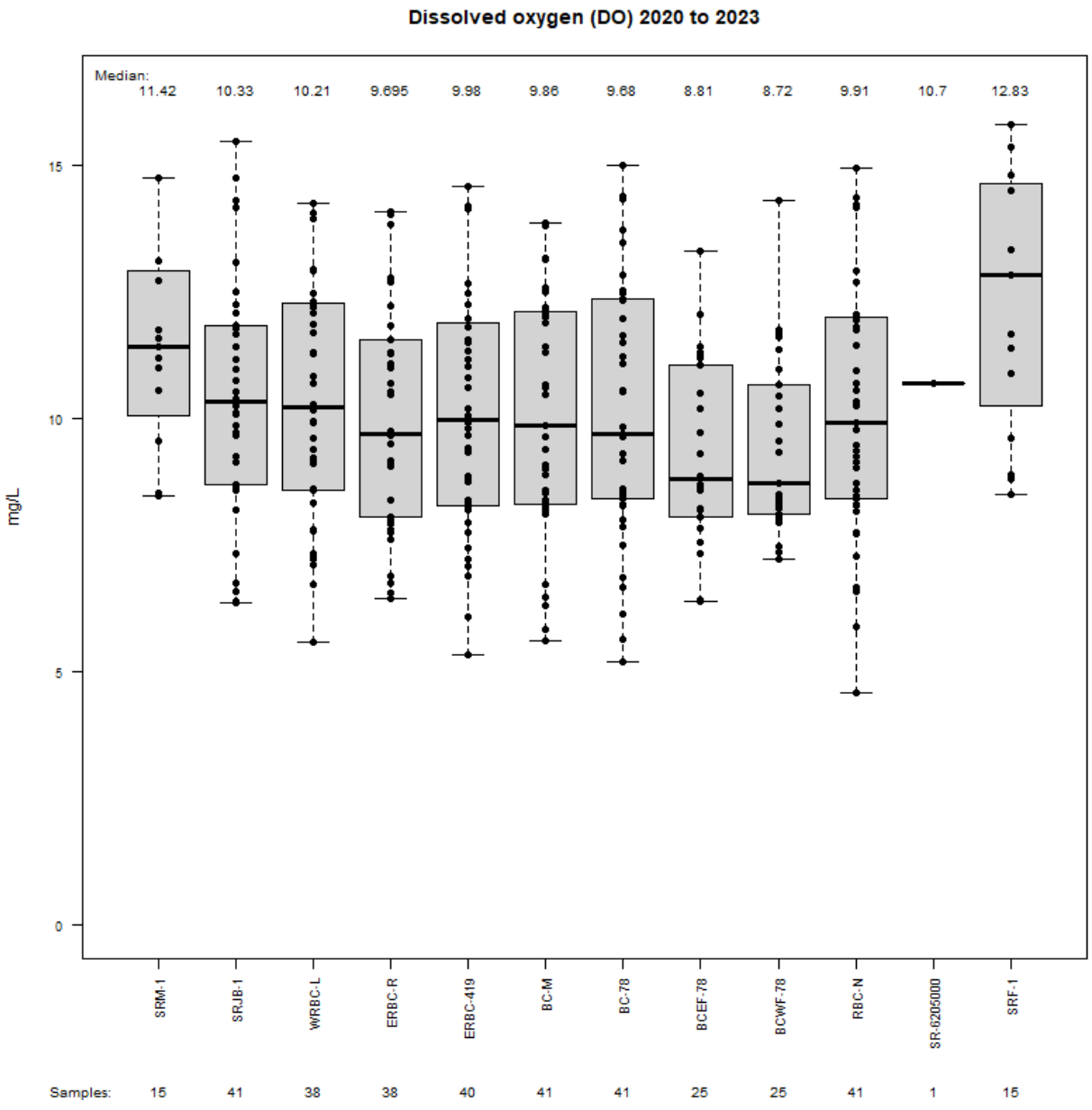


Figure B2 - Flow

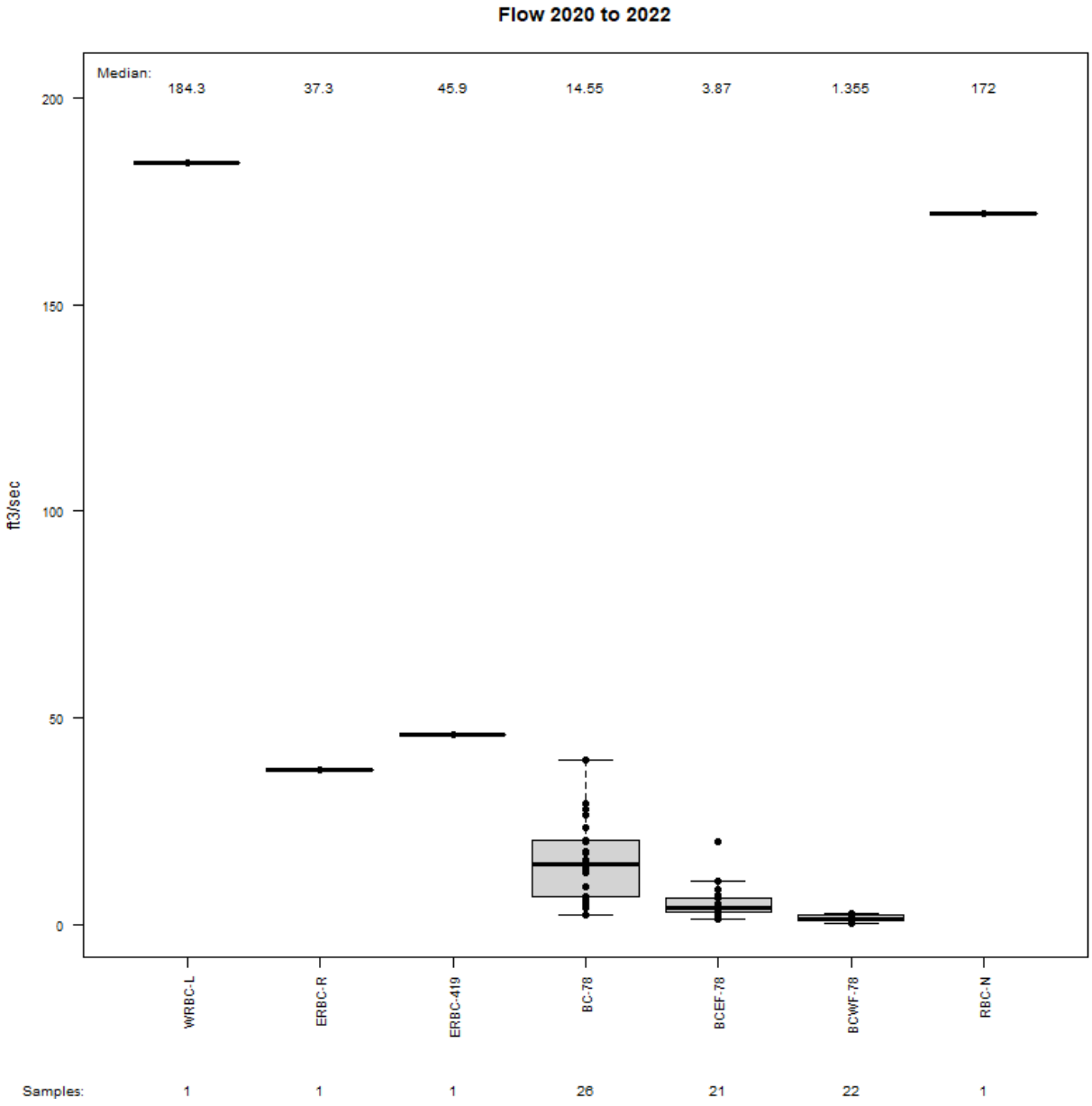


Figure B3 - Nitrate

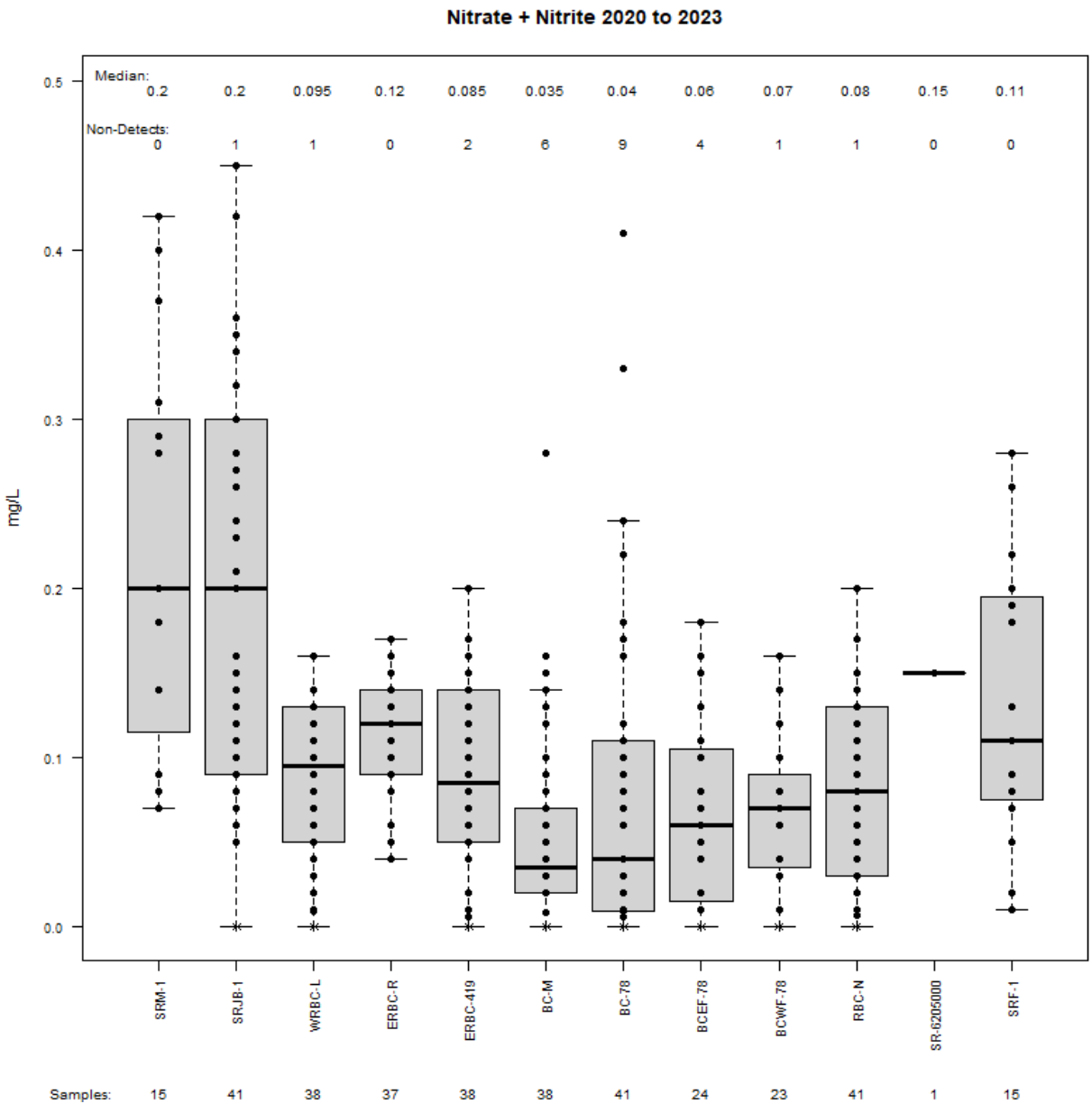


Figure B4 - pH

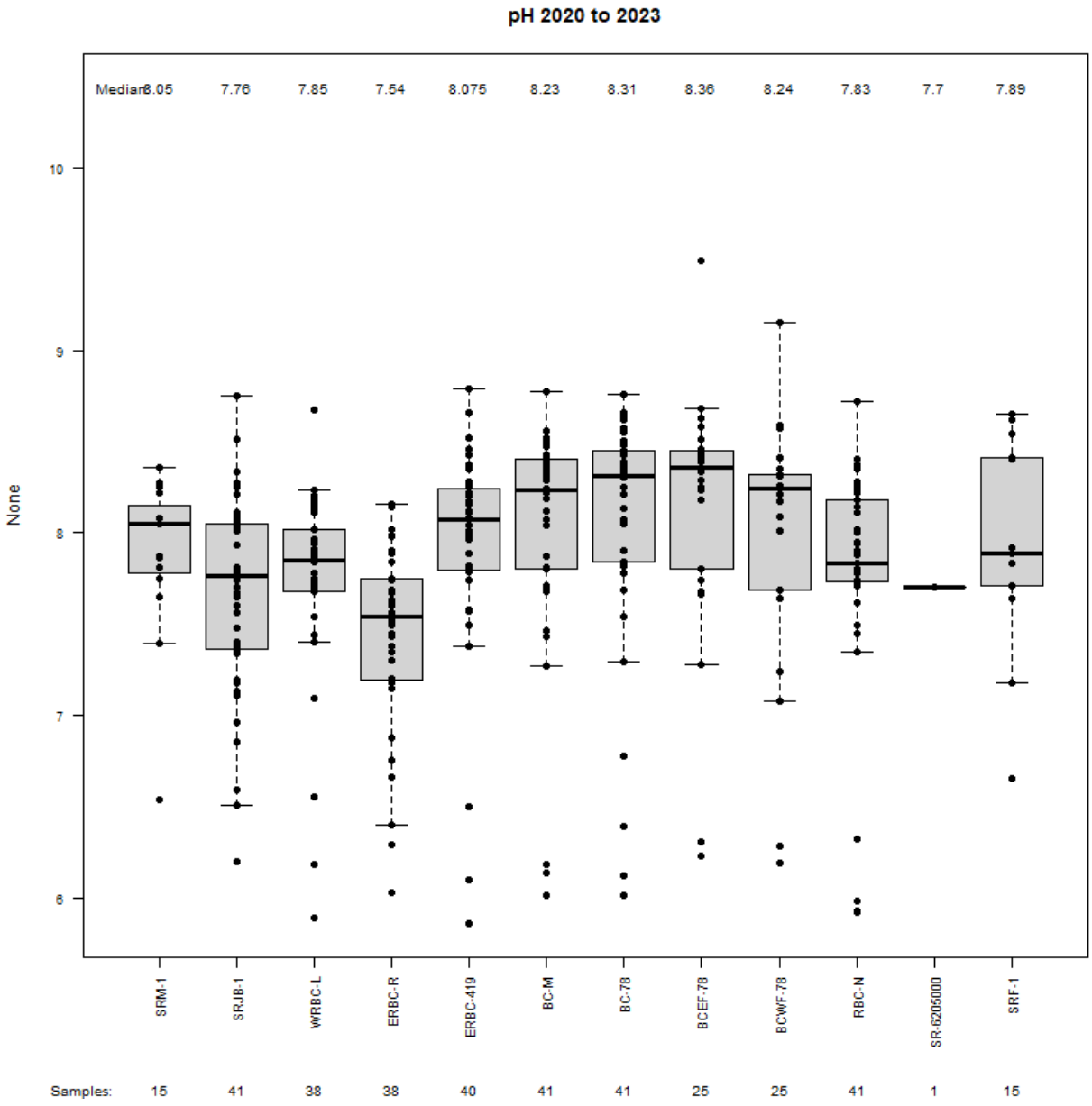

pH 2020 to 2023
Median 8.05 7.76 7.85 7.54 8.075 8.23 8.31 8.36 8.24 7.83 7.7 7.89
None
10
9
8
7
6
SRM-1
SRJB-1
WRBC-L
ERBC-R
ERBC-419
BC-M
BC-78
BCEF-78
BCWF-78
RBC-N
SR-6205000
SRF-1
Samples: 15 41 38 38 40 41 41 25 25 41 1 15

Figure B5 - Specific Conductance

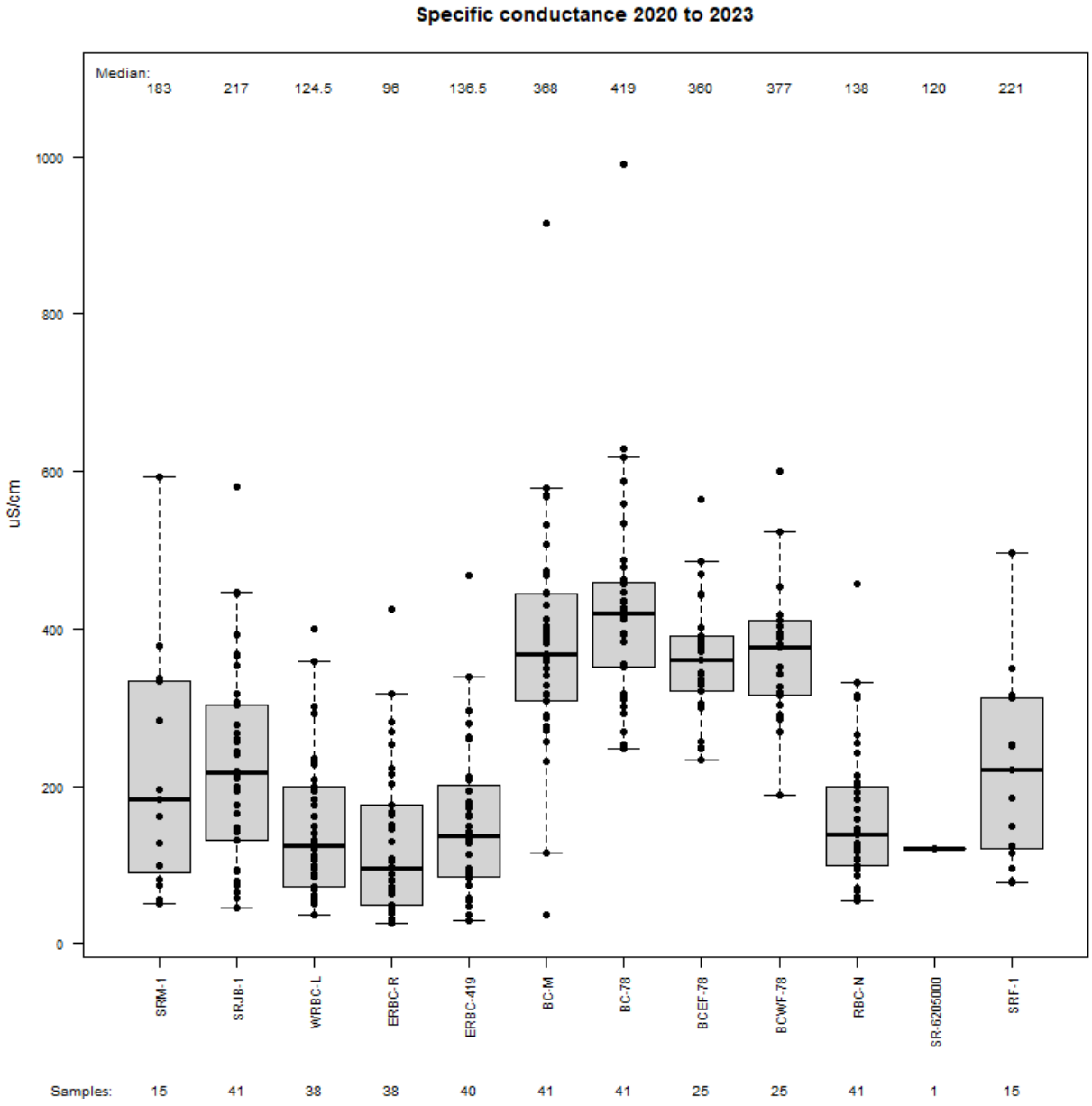


Figure B6 - Water Temperature

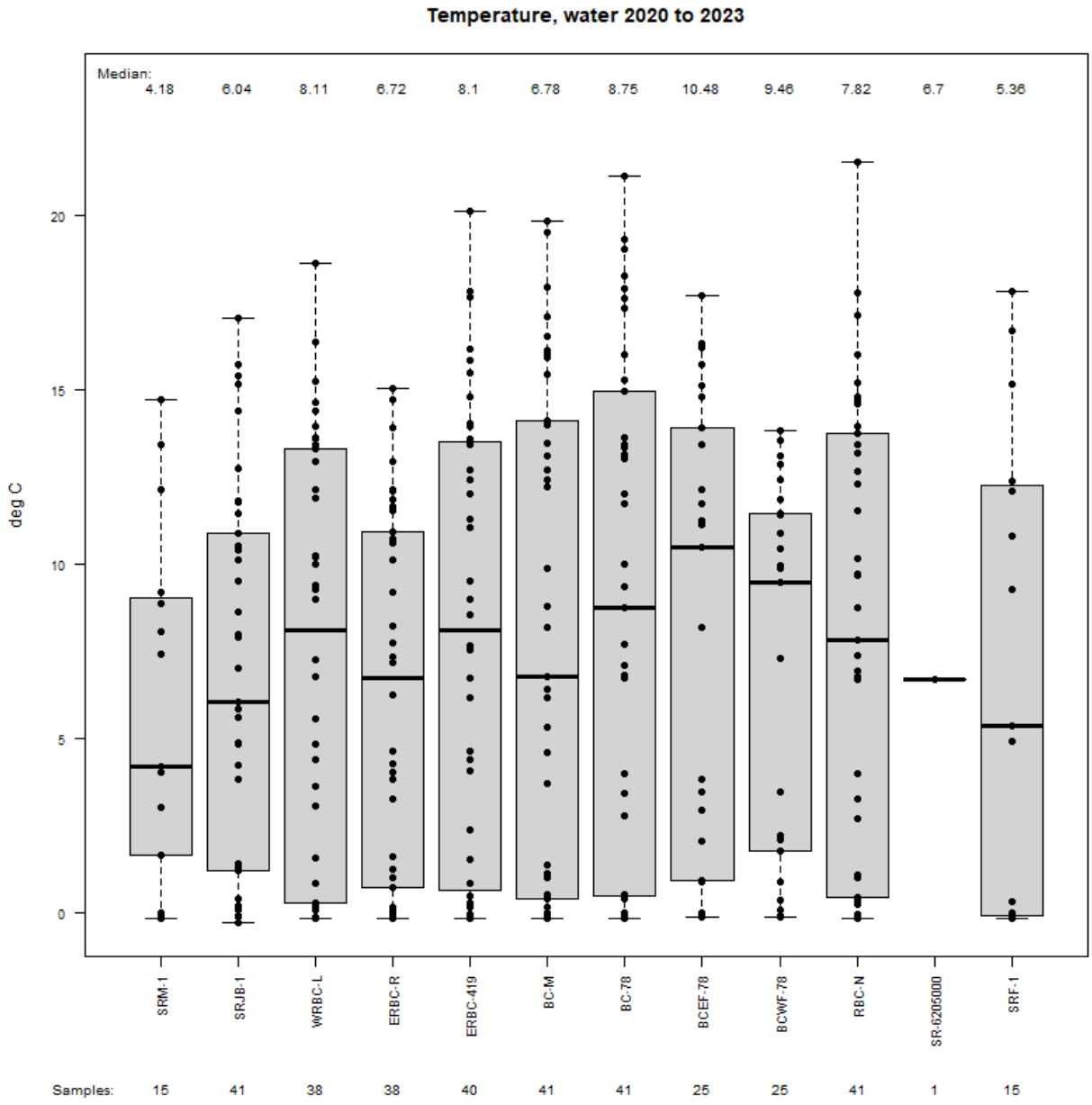


Figure B7 - Total Nitrogen

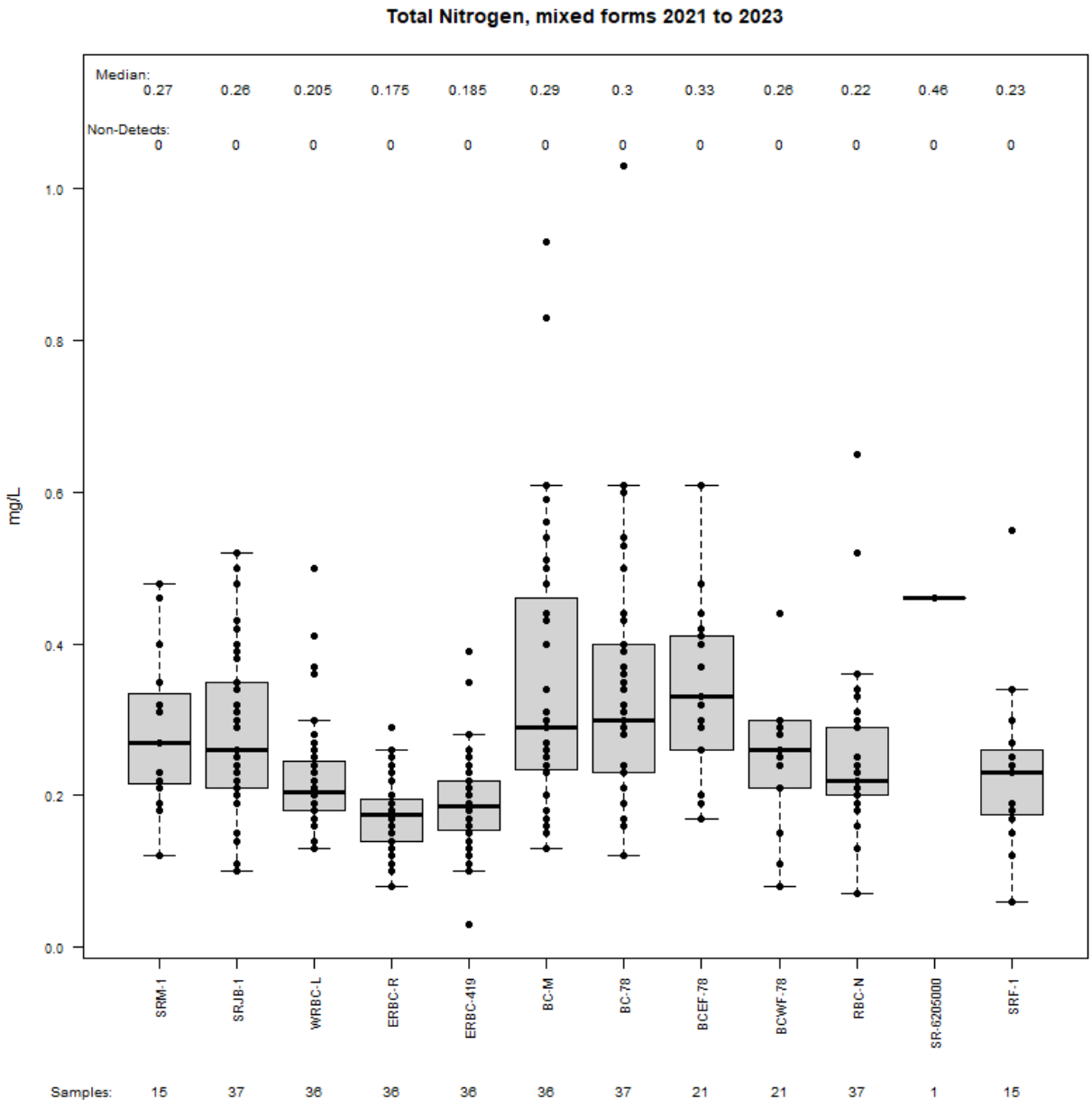


Figure B8 - Total Phosphorus

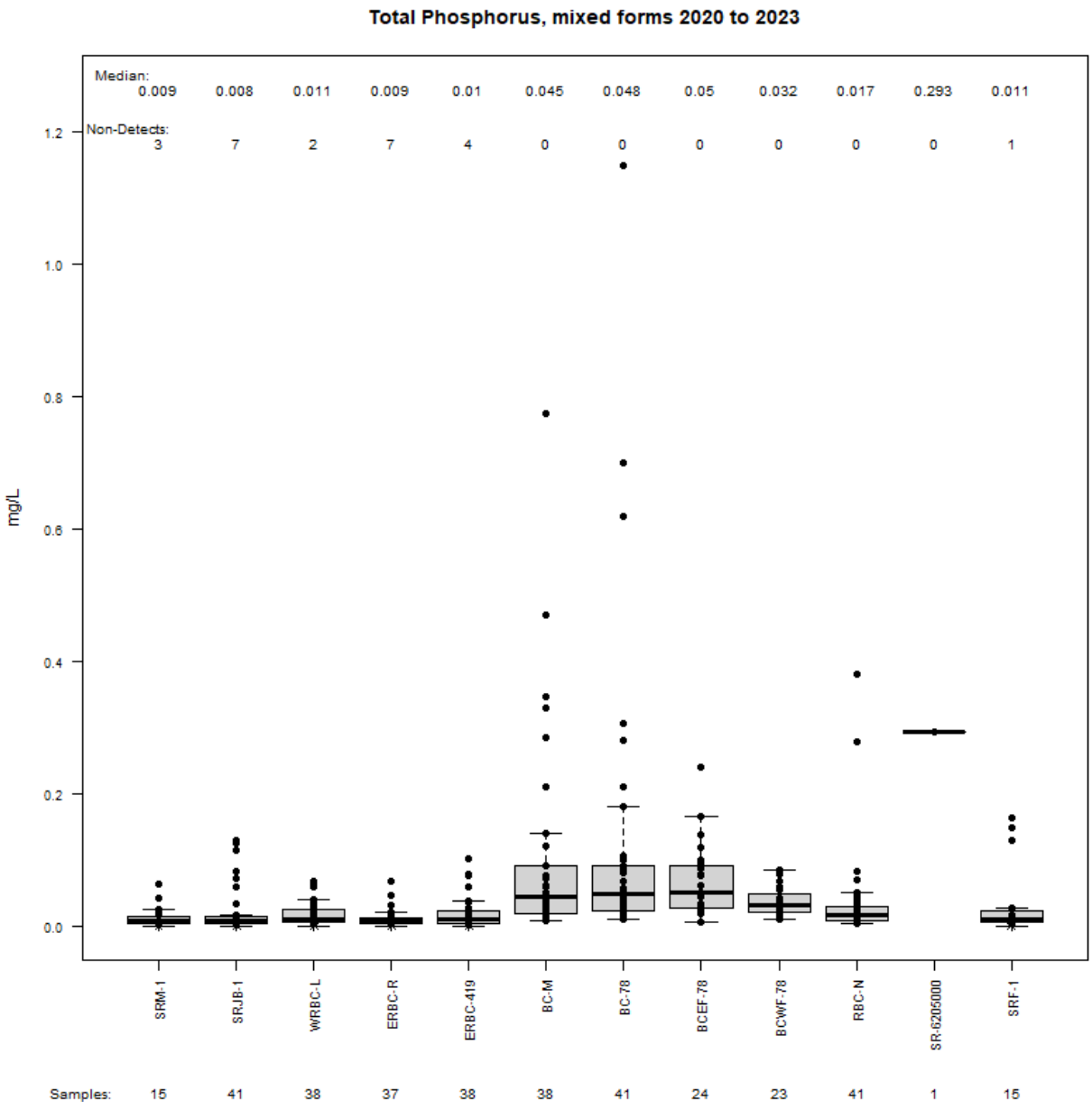


Figure B9 - Total Suspended Solids

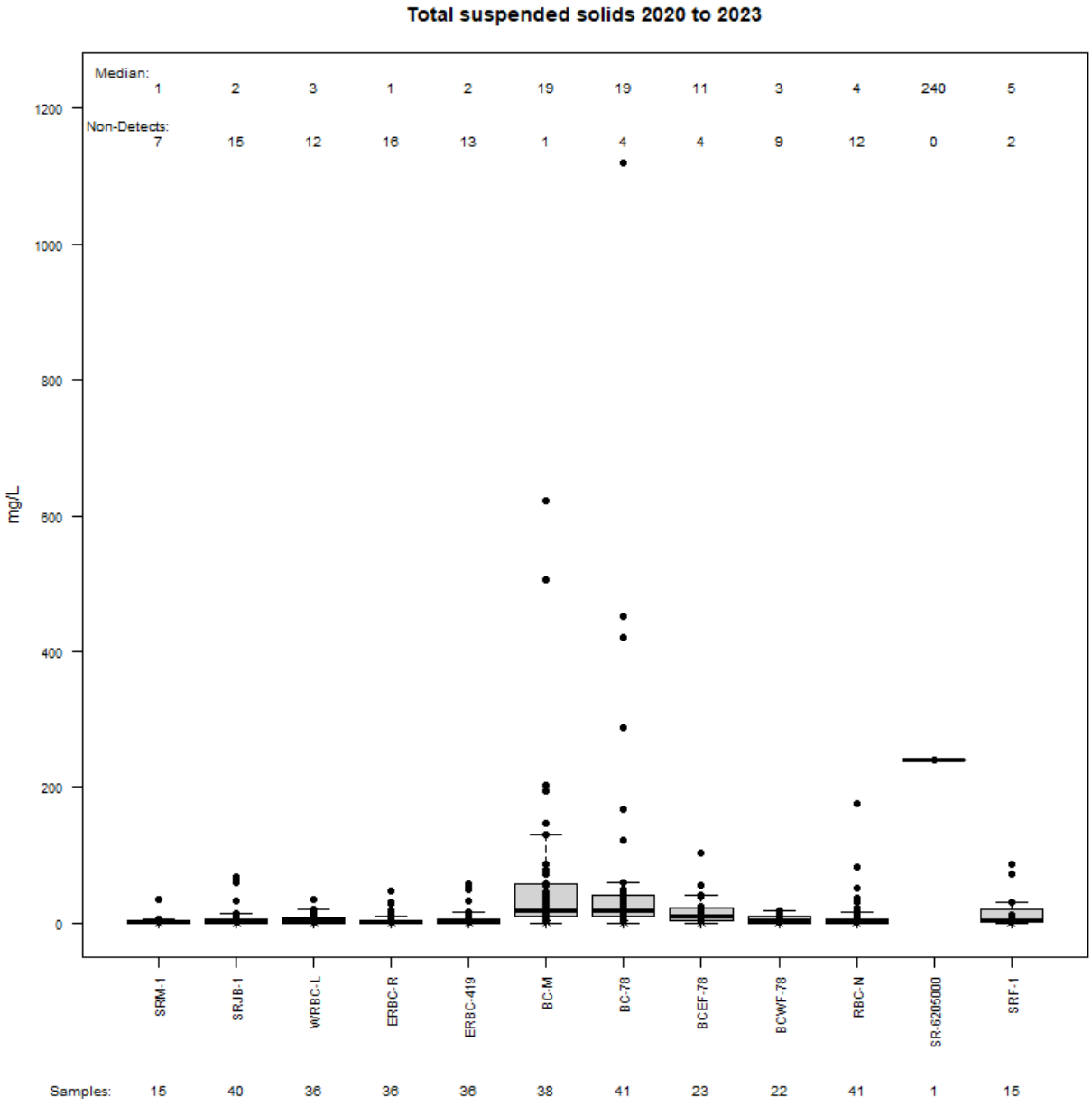
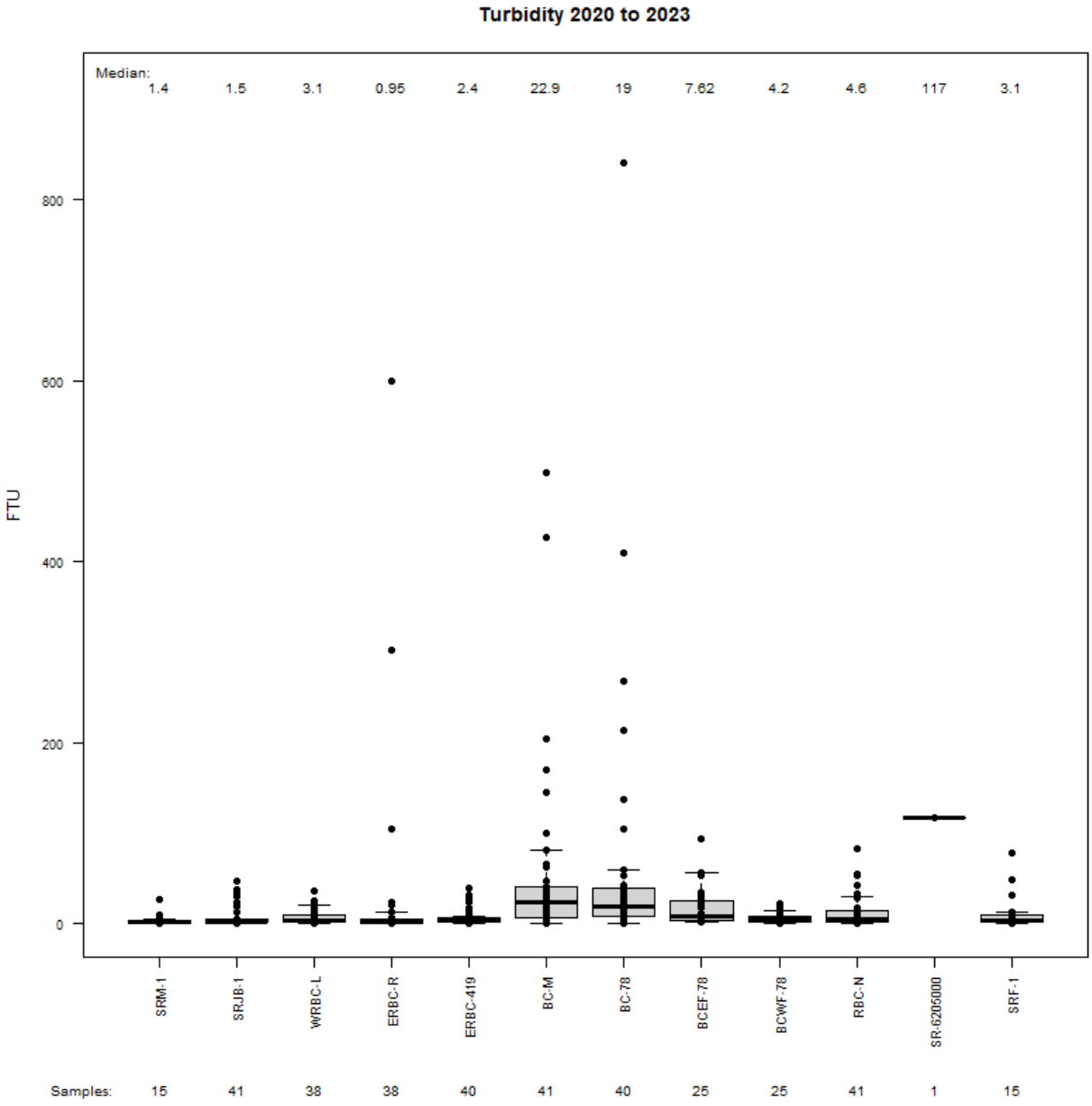


Figure B10 - Turbidity



# Appendix C – Corrections to be made in WQX

1. Most turbidity units are in NTUs, but all turbidity measurements from 2021 are reported in FTU. The MSU team was uncertain whether this was an error in units or if there were in fact data collected with different units.
2. Duplicate samples; same date, site, and parameter but none labeled as Quality Control

| ActivityTypeCode | ActivityStartDa | ActivitySta | MonitoringLocationName | Character | ResultMea | ResultMea |
|---|---|---|---|---|---|---|
| Field Msr/Obs | 8/16/2021 | 10:10:00 | East Fork Butcher Cr at Hwy 78 | Flow | 7.09 | ft3/sec |
| Field Msr/Obs | 8/16/2021 | 10:10:00 | East Fork Butcher Cr at Hwy 78 | Flow | 7.09 | ft3/sec |
| Field Msr/Obs | 8/16/2021 | 9:45:00 | West Branch Butcher Cr at Hwy 78 | Flow | 2.33 | ft3/sec |
| Field Msr/Obs | 8/16/2021 | 9:45:00 | West Branch Butcher Cr at Hwy 78 | Flow | 2.33 | ft3/sec |
| Field Msr/Obs | 10/14/2021 | 9:20:00 | Stillwater River near Johnson Bridge | Specific c | 267 | uS/cm |
| Field Msr/Obs | 10/14/2021 | 9:20:00 | Stillwater River near Johnson Bridge | Specific c | 194 | uS/cm |
| Field Msr/Obs | 4/20/2022 | 11:29:00 | East Rosebud Cr at Highway 419 | Dissolved | 10.81 | mg/L |
| Field Msr/Obs | 4/20/2022 | 11:29:00 | East Rosebud Cr at Highway 419 | Dissolved | 10.61 | mg/L |
| Field Msr/Obs | 4/20/2022 | 11:29:00 | East Rosebud Cr at Highway 419 | pH | 8.37 | None |
| Field Msr/Obs | 4/20/2022 | 11:29:00 | East Rosebud Cr at Highway 419 | pH | 8.08 | None |
| Field Msr/Obs | 4/20/2022 | 11:29:00 | East Rosebud Cr at Highway 419 | Specific c | 134 | uS/cm |
| Field Msr/Obs | 4/20/2022 | 11:29:00 | East Rosebud Cr at Highway 419 | Specific c | 96 | uS/cm |
| Field Msr/Obs | 4/20/2022 | 11:29:00 | East Rosebud Cr at Highway 419 | Temperatu | 7.67 | deg C |
| Field Msr/Obs | 4/20/2022 | 11:29:00 | East Rosebud Cr at Highway 419 | Temperatu | 4.65 | deg C |
| Field Msr/Obs | 4/20/2022 | 11:29:00 | East Rosebud Cr at Highway 419 | Turbidity | 5.8 | NTU |
| Field Msr/Obs | 4/20/2022 | 11:29:00 | East Rosebud Cr at Highway 419 | Turbidity | 3 | NTU |
| Field Msr/Obs | 6/6/2022 | 10:21:00 | East Fork Butcher Cr at Hwy 78 | Dissolved | 8.81 | mg/L |
| Field Msr/Obs | 6/6/2022 | 10:21:00 | East Fork Butcher Cr at Hwy 78 | Dissolved | 8.57 | mg/L |
| Field Msr/Obs | 6/6/2022 | 10:21:00 | East Fork Butcher Cr at Hwy 78 | pH | 8.45 | None |
| Field Msr/Obs | 6/6/2022 | 10:21:00 | East Fork Butcher Cr at Hwy 78 | pH | 8.25 | None |
| Field Msr/Obs | 6/6/2022 | 10:21:00 | East Fork Butcher Cr at Hwy 78 | Specific c | 486 | uS/cm |
| Field Msr/Obs | 6/6/2022 | 10:21:00 | East Fork Butcher Cr at Hwy 78 | Specific c | 328 | uS/cm |
| Field Msr/Obs | 6/6/2022 | 10:21:00 | East Fork Butcher Cr at Hwy 78 | Temperatu | 13.91 | deg C |
| Field Msr/Obs | 6/6/2022 | 10:21:00 | East Fork Butcher Cr at Hwy 78 | Temperatu | 10.48 | deg C |
| Field Msr/Obs | 6/6/2022 | 10:21:00 | East Fork Butcher Cr at Hwy 78 | Turbidity | 52.2 | NTU |
| Field Msr/Obs | 6/6/2022 | 10:21:00 | East Fork Butcher Cr at Hwy 78 | Turbidity | 29.5 | NTU |
| Field Msr/Obs | 6/6/2022 | 9:57:00 | West Branch Butcher Cr at Hwy 78 | Dissolved | 8.72 | mg/L |
| Field Msr/Obs | 6/6/2022 | 9:57:00 | West Branch Butcher Cr at Hwy 78 | Dissolved | 8.5 | mg/L |
| Field Msr/Obs | 6/6/2022 | 9:57:00 | West Branch Butcher Cr at Hwy 78 | pH | 8.26 | None |
| Field Msr/Obs | 6/6/2022 | 9:57:00 | West Branch Butcher Cr at Hwy 78 | pH | 8.01 | None |
| Field Msr/Obs | 6/6/2022 | 9:57:00 | West Branch Butcher Cr at Hwy 78 | Specific c | 411 | uS/cm |
| Field Msr/Obs | 6/6/2022 | 9:57:00 | West Branch Butcher Cr at Hwy 78 | Specific c | 316 | uS/cm |
| Field Msr/Obs | 6/6/2022 | 9:57:00 | West Branch Butcher Cr at Hwy 78 | Temperatu | 11.84 | deg C |

pdated

3. DO concentrations over 100 mg/L
    a. High DO concentrations on 10/10/2022 at 9 sites

| ActivityMe | ActivityStartDate | MonitoringLocationName | Character | ResultSampleF | ResultMea | ResultMea |
|---|---|---|---|---|---|---|
| Surface W | 10/18/2022 | Butcher Cr at Hwy 78 | Dissolved oxygen (DO) | 415 | mg/L | |
| Surface W | 10/18/2022 | Butcher Cr at Butcher Cr midway bridge | Dissolved oxygen (DO) | 368 | mg/L | |
| Surface W | 10/18/2022 | Stillwater River near Johnson Bridge | Dissolved oxygen (DO) | 245 | mg/L | |
| Surface W | 10/18/2022 | Stillwater River at Firemans Point FAS | Dissolved oxygen (DO) | 221 | mg/L | |
| Surface W | 10/18/2022 | Stillwater River at Moraine FAS | Dissolved oxygen (DO) | 195 | mg/L | |
| Surface W | 10/18/2022 | Rosebud Cr at Niche Rd | Dissolved oxygen (DO) | 159 | mg/L | |
| Surface W | 10/18/2022 | East Rosebud Cr at Highway 419 | Dissolved oxygen (DO) | 149 | mg/L | |
| Surface W | 10/18/2022 | West Rosebud Cr below Fishtail, MT, at Lanen Ranch bridge | Dissolved oxygen (DO) | 131 | mg/L | |
| Surface W | 10/18/2022 | East Rosebud Cr at Roscoe, from East Rosebud Rd just east of Roscoe | Dissolved oxygen (DO) | 104 | mg/L | |
| Surface W | 12/20/2022 | Stillwater River at Firemans Point FAS | Dissolved oxygen (DO) | 15.79 | mg/L | |
| Surface W | 12/20/2022 | Stillwater River near Johnson Bridge | Dissolved oxygen (DO) | 15.47 | mg/L | |