Clark Fork River Nutrient Water Quality Status and Trends Report, 1998—2017

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EXECUTIVE SUMMARY

This Nutrient Water Quality Status and Trends Report for the Clark Fork River was completed for the Clark Fork River Water Quality Monitoring Committee (CFRWQMC) under contract with Montana Department of Environmental Quality (DEQ) and Avista. This report evaluates the completion of the fourth five-year monitoring period and twenty years of nutrient monitoring in the basin by the program for the years 1998 to 2017. The report provides background and details of the monitoring program and summarizes nutrient reduction activities that have taken place in the Clark Fork River basin of Montana in recent years. The primary purpose of this report is to address the following Clark Fork River water quality monitoring program monitoring objectives:

1. Evaluate time trends in nutrient concentrations in the mainstem Clark Fork River and selected tributaries (Silver Bow Creek)
2. Evaluate time trends for benthic algae chlorophyll-a in the Clark Fork River
3. Monitor compliance with established summer nutrient and benthic algae chlorophyll-a target levels in the Clark Fork River
4. Estimate nutrient loading rates to Lake Pend Oreille from the Clark Fork River.

Additionally, this report summarizes efforts in the Clark Fork River basin in Montana to reduce point source and nonpoint source nutrient loading to the Clark Fork River and its tributaries.

The time trends analysis for nutrient constituents was conducted on data from twelve long-term monitoring stations in the Clark Fork River basin extending from the headwaters at the Clark Fork River confluence with Silver Bow Creek to the Clark Fork River below Cabinet Gorge Dam. Nutrients evaluated include total nitrogen as N (TN), total soluble inorganic nitrogen as N (TSIN), total phosphorus as P (TP), and soluble reactive phosphorus as P (SRP). The time trends analysis for benthic algae included seven monitoring stations in the upper and middle Clark Fork River, extending from the Clark Fork River at Deer Lodge, to the Clark Fork River above the Flathead River. Time trends analysis for benthic algae evaluated mean and maximum benthic chlorophyll-a. The analyses were completed for the summer season months of July, August, and September from data collected from 1998–2017.

Prior to conducting the time trend analysis and loading evaluation, data reduction activities were completed for the DEQ-provided dataset and the data were reviewed for quality assurance. The nonparametric Mann-Kendall trend test was used to detect trends in the reduced data. The time trend analyses employed two-sided tests with significance level of alpha=0.1 and a null hypothesis, H_0, that no trend was present in the series. Consistent with previous work (Suplee, et al. 2012) site by site analyses showed that total nutrients were influenced by mean monthly summer discharge (or stream flow). TN concentrations generally decreased with increasing stream flow, while TP concentrations generally increased with increasing stream flow. Dissolved constituents (TSIN and SRP) generally followed similar patterns as the total nutrients. Therefore prior to conducting time trend analyses nutrient concentration data were first regressed against flow utilizing the locally weight scatterplot smoothing (LOWESS) method to remove variation in concentration related to stream discharge. Consistent with current

statistical guidance (Helsel and Hirsch 2002), temporal nutrient trends for TN, TSIN, TP and SRP were assessed with the seasonal Mann-Kendall trend test on flow-adjusted concentrations (residuals from the LOWESS regression) against time. Time trends of mean and maximum annual chlorophyll-a values were assessed with the Mann-Kendall trend test on algae levels against time. TP and TN nutrient loadings were evaluated using the U.S. Army Corps of Engineers (USACE) FLUX32 Load Estimation Software model (version 3.10).

This report also assesses standards threshold exceedance rates from State of Montana numeric nutrient water quality standards thresholds for Clark Fork River monitoring stations in the upper and middle Clark Fork River. Exceedance of numeric nutrient standards threshold for the Clark Fork River were evaluated and compared over two time periods: 1998 to 2007 and 2008 to 2017.

Additionally, nutrient loading estimates for TP and TN were estimated and compiled for the Clark Fork River into Lake Pend Oreille from with data from monitoring Station CFR-30, Clark Fork River below Cabinet Gorge Dam, in Idaho, from 1998–2017.

The Clark Fork River nutrient and chlorophyll-a time trends analysis, 1998—2017, detected trends with varying degrees of significance and direction within the dataset. Findings of the time trends analysis are tabulated and provided graphically in Section 6 and Attachment B of this report.

Results and conclusions of this work include:

- Overall, summertime TN concentrations appear to be holding relatively steady at most monitoring stations in the basin. No trends in TN were detected in eight of twelve monitoring stations.
- Notably, highly significant decreasing trends for both TN and TSIN concentrations were detected at monitoring station CFR-2.5, Silver Bow Creek at Opportunity. The decreases in TN and TSIN found at CFR-2.5 are likely responses to nutrient reduction activities that have occurred at the Butte wastewater treatment facility and from restoration efforts in the headwaters area.
- The trend analysis detected a significant increasing trend in TSIN concentrations station CFR-25, Clark Fork River above Flathead. This was the only increasing time trend in TSIN in this work.
- Overall decreasing trends of TP concentrations were detected throughout the basin during the summer months. Decreasing trends in TP concentrations were detected at nine of twelve monitoring stations. Only at CFR-2.5, Silver Bow Creek at Opportunity, was an increasing trend in TP detected.
- While the Butte wastewater treatment plant has demonstrated significant reduction in TP loading (effluent TP concentrations have been reduced about 80%) this work found highly significant increasing trends of TP and SRP at Station CFR-2.5, Silver Bow Creek at Opportunity. DEQ is investigating a number of potential sources of this increasing trend.
- Nutrient reduction activities do not appear to have been successful at controlling or reducing total and soluble phosphorus concentrations in Silver Bow Creek at station CFR-2.5, as this work found highly significant increasing trends in TP and SRP at this station.
- Summertime SRP concentrations since 1998 appear to be decreasing in the middle Clark Fork River. Highly significant decreasing trends in SRP concentrations were detected at three monitoring stations in the middle river.

- The highly significant decreasing time trends found for all nutrients at station CFR-18, Clark Fork River at Missoula, demonstrate that nutrient reduction activities taken by the City of Missoula and Missoula County have been very effective in reducing the concentration of instream nutrients and benthic algae levels in the river below Missoula.
- Exceedances of numeric nutrient standards thresholds were evaluated over two time periods, 1998 to 2007 and 2008 to 2017.
    - The number of samples exceeding the Clark Fork River TN threshold decreased for all but one monitoring station, CFR-9, Clark Fork River at Deer Lodge, when comparing the two time periods. That station also had the highest percentage of samples that exceed the TN standard at over 70% in the more recent time period. Seven of eight monitoring stations had a decreasing percentage in the number of samples exceeding the TN threshold over the two time periods.
    - The number of samples exceeding the numeric TP standard increased in the upper river (Stations CFR-7, Clark Fork River below Warm Springs Creek; CFR-9, Clark Fork River at Deer Lodge; CFR-10, Clark Fork River above Little Blackfoot River; and CFR-12, Clark Fork River at Bonita) and decreased at the stations in the middle river (CFR-15.5, Clark Fork River above Missoula; CFR-18, Clark Fork River below Missoula; and CFR-22, Clark Fork River at Huson) over the two time periods. Station CFR-25, Clark Fork River above Flathead, has had no sample result greater than the numeric TP standard in 122 samples spanning 20 years. Stations CFR-7, Clark Fork River below Warm Springs Creek, and CFR-9, Clark Fork River at Deer Lodge, had the largest, nearly 20%, increases (18% and 19%, respectively) in the number of samples exceeding the numeric TP standard over the two time periods. Station CFR-18, Clark Fork River below Missoula had the largest decrease in the number of samples exceeding the numeric TP standard at 21%. While the number of samples exceeding numeric TP standards in the upper river is greater in the recent time period (2008 to 2017), the results of the time trend analysis found decreasing trends in TP concentration at stations in the upper river including CFR-9, Clark Fork River at Deer Lodge; CFR-10, Clark Fork River above Little Blackfoot River; and CFR-12, Clark Fork River at Bonita. The reason for this disparity may be attributed to the influence of stream flow on TP instream concentrations, which is taken into account in the trends test. There were very few exceedances of TP standard threshold in the middle part of the river during the later period (0% to 3%).
- In the lower Clark Fork River, TSIN concentrations appear to be decreasing with highly significant decreasing trends at CFR-29, Clark Fork River at Noxon Bridge, and CFR-30, Clark Fork River below Cabinet Gorge Dam. This, however, is contrasted with significantly increasing trends in TN detected at CFR-28, Clark Fork River below Thompson Falls, and CFR-29, Clark Fork River at Noxon Bridge found. The authors believe that these two increasing trends may be biased based on a change in TN laboratory analysis about half way through the monitoring period and should be reevaluated in the future.
- This work found decreasing trends of TSIN, TP, and SRP at station CFR-30, Clark Fork River below Cabinet Gorge Dam, which suggests that the compounding efforts of nutrient reduction activities within the basin have, overall, improved nutrient water quality in the watershed over the twenty-year monitoring period.
- Time trends analysis found benthic algal levels to be holding steady or decreasing at the seven stations monitored for algae. No increasing trends in chlorophyll-a were found. Upstream of

Missoula one marginally significant decreasing trend was detected at CFR-12, Clark Fork River at Bonita. Below Missoula, chlorophyll-a concentrations have been generally declining since 1998, with decreasing trends in mean or maximum concentrations detected at three stations.

- In regard to numeric nutrient standard thresholds for chlorophyll-a, this work found a decreasing percentage of samples that exceeded the mean and maximum summer chlorophyll-a standard for most monitoring stations when comparing the two time periods.
- The estimated TP load to Lake Pend Oreille exceeded the allocated target load five times since 1998. The allocated target load exceedances occurred in 2006, 2008, 2011, 2012, and 2014. There was no short-term TP load exceedance in any consecutive three-year period since 1998. TN loads were also evaluated, but no target load exists for TN since Lake Pend Oreille is considered to be P limited.

The following recommendations are made to the CFRWQC to further assess nutrient water quality status in the Clark Fork River basin:

- Evaluate factors for the significantly increasing trend found in TSIN concentrations at station CFR-25, Clark Fork River above Flathead
- Compile and tabulate basin-wide nutrient loads from permitted point sources and estimates of non-point source contributions
- Estimate summer and/or annual nutrient loads at select stations in the upper and middle river
- Review and evaluate stream discharge changes and other hydrologic factors and assess their potential effect on nutrient and algae levels
- Review and discuss changes in nitrogen to phosphorus ratios at select monitoring stations throughout the river
- Continue the water quality monitoring program as it serves a critical component in evaluating status of the watershed and informing management decisions.
- Consider additional nutrient trends analysis with a truncated dataset. The truncated dataset for TN could range from 2009 to 2017 to remove potential bias of differing analytical methods completed in years 1998 to 2008. Additional data review and data reduction should be considered for the dataset for a number of potential outliers and suspect values that may be present in the earlier data (generally pre-2009).
- Summarize available summertime temperature and dissolved oxygen data since these parameters interact with algae levels to affect habitat quality. Where little data exist, add some stations with temperature and dissolved oxygen monitors.
- Collaborate with Idaho Department of Environmental Quality (IDEQ) to evaluate effects of estimated annual nutrient loading to Lake Pend Oreille on water quality in the lake.

Much work has been done in the Clark Fork River basin to reduce and control nutrient impacts to water quality. Point source and non-point source nutrient reduction activities have occurred across the basin, more are planned and some are already in progress. Nutrient reduction activities in Missoula have resulted in highly significant decreasing trends for all nutrients at the monitoring station below Missoula. Decreasing trends in TP concentrations were found throughout the river. Despite these gains, summer concentrations of TN and TP continue to exceed numeric water quality standard thresholds especially in the upper river. The basin-wide nutrient water quality monitoring program that has been in place since 1998, continues to be a critical tool to evaluate effectiveness of nutrient reduction activities. Basin-wide nutrient water quality monitoring should continue into the future so that cumulative, long-term impacts of nutrient reduction activities can be evaluated. The nutrient water quality monitoring program must continue to regularly assess the status, trends and influences of water quality in the Clark Fork River basin so that planners and managers are better able to direct and focus nutrient reduction efforts in the Clark Fork River basin.

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ACRONYMS

AFDM	Ash-free Dry Mass
ARM	Administrative Rules of Montana
BNR	Biological Nutrient Removal
CFRWQMC	Clark Fork River Water Quality Monitoring Committee
DEQ	Montana Department of Environmental Quality
DO	Dissolved Oxygen
EPA	Environmental Protection Agency (U.S.)
IDEQ	Idaho Department of Environmental Quality
LOWESS	Locally Weighted Scatterplot Smoothing
MDL	Method Detection Limit
mV	Millivolts
NTU	Nephelometric Turbidity Units
ORP	Oxidation Reduction Potential
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RC	Result Condition
SAP	Sampling and Analysis Plan
SC	Specific Conductance
SRP	Soluble Reactive Phosphorus
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TPN	Total Persulfate Nitrogen
TSIN	Total Soluble Inorganic Nitrogen
USACE	U.S. Army Corps of Engineers
USGS	United States Geological Survey
VNRP	Voluntary Nutrient Reduction Program

1.0 INTRODUCTION

This Nutrient Water Quality Status and Trends Report for the Clark Fork River is a joint effort sponsored by the Montana Department of Environmental Quality (DEQ), Avista. The report has been prepared on behalf of the Clark Fork River Water Quality Monitoring Committee (CFRWQMC) to evaluate the completion of the fourth five-year nutrient water quality monitoring period and twenty years of nutrient monitoring in the Clark Fork River basin by the program for the years 1998 to 2017. The CFRWQMC has been managed by the Clark Fork Coalition (CFC) since 2015, and includes the members DEQ, Idaho DEQ (IDEQ), Avista, City of Missoula, and the University of Montana.

This report is the result of decades of collaboration between public, private, and nonprofit entities working together to reduce nutrient impacts to the Clark Fork River and to methodically monitor their progress. A comprehensive Clark Fork River basin-wide nutrient water quality monitoring program was started in 1998 and continues today under the direction of the CFRWQMC. The nutrient water quality monitoring program was established by the Clark Fork-Pend Oreille Basin Management Plan (Basin Management Plan; EPA 1993), which was prepared by the states of Montana, Idaho, and Washington, in conjunction with the U.S. Environmental Protection Agency (EPA) Regions 8 and 10. The Basin Management Plan was based on studies mandated by U.S. Congress because of citizen concerns regarding increased aquatic weeds and algae in the Clark Fork River and Pend Oreille Lake.

The Basin Management Plan was adopted in 1993 and was last updated in 2007, and focuses efforts on controlling eutrophication and associated water use impairment problems that were identified as the most important interstate water quality problem. The goal of the Basin Management plan is to restore and protect designated beneficial water uses. The Management Plan further identifies water quality objectives and emerging new water quality challenges.

To that end this report is intended to meet stated priority water quality monitoring program objectives including:

1. Evaluate time trends in nutrient concentrations in the mainstem Clark Fork River and selected tributary streams (Silver Bow Creek)
2. Evaluate time trends for benthic algae chlorophyll-a in the Clark Fork River
3. Monitor compliance with established summer nutrient and benthic algae chlorophyll-a target levels in the Clark Fork River
4. Estimate nutrient loading rates to Lake Pend Oreille from the Clark Fork River.

Additionally, this report provides a summary of recent and ongoing nutrient point source and non-point source reduction activities in the Clark Fork River basin in Montana.

The time trends analysis for nutrient constituents was conducted on monitoring program data, 1998–2017, from 12, long-term monitoring stations in the Clark Fork River basin, extending from the River's headwaters at Silver Bow Creek to the Clark Fork River below Cabinet Gorge Dam. The time trends analysis was completed for the summer season months of July, August, and September.

Project sponsors DEQ and Avista contracted with HydroSolutions Inc (HydroSolutions) to complete this Nutrient Water Quality Status and Trends Report for the Clark Fork River. Work was authorized under DEQ contract number 217041, signed on June 27, 2017, and included one contract modification (Modification 1). Avista contract number R-41716 was signed on November 11, 2017.

2.0 BACKGROUND

The Clark Fork River drains about 22,000 square miles including most of Montana west of the Continental Divide. The Clark Fork River is a vital resource and critical lifeline for human and aquatic communities living in its basin. According to the 2010 US Census, the Clark Fork River basin in Montana has a population of about 339,800 people, contains 334 named streams with a total of over 5,200 miles in stream length, has five major dams, and supports over 350,000 irrigated acres (USGS 2015). The Clark Fork River has long-term average annual flow of almost 22,000 cubic feet per second (CFS) leaving Montana (USGS 2018). The Clark Fork River provides water to support a wide array of beneficial uses, including drinking water, irrigation, industry, hydro-electric power generation, and recreation. It also supports a diverse assemblage of aquatic life uses including several threatened and endangered species. The upper Clark Fork River from headwaters to the former Milltown Dam has undergone major restoration and cleanup efforts to remove contaminated heavy metals sediments that washed downstream from mine tailings. U.S. Environmental Protection Agency (EPA) Superfund Program, DEQ and the Montana Natural Resource Damage Program have large scale restoration efforts in the upper Clark Fork River to restore streambeds, streambanks, and the floodplain. For these many reasons the Clark Fork River is considered a critical resource that multiple citizen and watershed groups, businesses, municipalities, and state and federal agencies work together to monitor, protect, and improve.

2.1 HISTORY

The current monitoring program on the Clark Fork River is a continuation of a program that was initially developed in 1998 by the Tri-State Water Quality Council (Council). The Council was established in 1993 as a partnership of citizens, businesses, industry, tribes, government, and environmental groups with the goal of collaboratively addressing the problem of excess nutrients and algae, as identified in the Clark Fork-Pend Oreille Basin Management Plan (Basin Management Plan) (EPA 1993). One of the first tasks of the Council was to create a Monitoring Committee to oversee and implement a long-term, basin-wide monitoring strategy. The monitoring program was started in 1998 and continues today. The Council disbanded in 2012 and DEQ assumed the overall responsibility for administering the monitoring program in the Clark Fork basin in Montana. Today, former members of the Council, including DEQ, Avista, City of Missoula, University of Montana, IDEQ, and Clark Fork Coalition (CFC) collaborate as the CFRWQMC and continue monitoring and data collection efforts for the Clark Fork River.

Beginning in spring of 2015, DEQ contracted with the CFC to manage the CFRWQMC water quality monitoring program in Montana. In addition, Avista's Water Resources Technical Advisory Council (WRTAC) serves in an advisory capacity. WRTAC is a subcommittee that was formed during the relicensing process in 1999 to make decisions about how to spend Avista's protection, mitigation, and enhancement measure money to offset effects from operation of Noxon Rapids Dam and Cabinet Gorge Dam on waters of the Clark Fork-Pend Oreille Basin.

The 2013-2017 monitoring program represents the first five-year monitoring program managed by the CFRWQMC. The Council managed the previous five-year monitoring programs from 1998-2002, 2003-2007, and 2008-2012. Consistent data collection and management, a rigorous data quality assurance oversight process, and methodical data review and validation completed through the life of the program provides the basis for statistical analysis of water quality time trends for the Clark Fork River. This nutrient time trends analysis report builds on the efforts of the monitoring committee to incorporate data collected in the 2013-2017 monitoring period.

2.2 PURPOSE

In order to improve water quality and to work to achieve objectives identified in the Basin Management Plan (EPA 2007), the Council established four primary water quality management goals and seven associated water quality monitoring program objectives for the Clark Fork-Pend Oreille basin. This report both provides a means to evaluate effectiveness of certain management goals and responds directly to a number of program monitoring objectives. This report builds on previously completed Clark Fork River water quality trends reports (Tri-State Water Quality Council 2009) (HydroSolutions 2014) to assess the status of water quality in the Clark Fork River. This report will be used by state agencies and the CFRWQMC to evaluate effectiveness of nutrient reduction activities in the Clark Fork River basin and help guide future management decisions.

The following management goals were identified by the Council and conform to specific basin management goals originally identified in the Basin Management Plan:

- Control nuisance algae in the Clark Fork River by reducing nutrient concentrations
- Protect Lake Pend Oreille water quality by maintaining or reducing current rates of nutrient loading from the Clark Fork River
- Reduce near-shore eutrophication in Lake Pend Oreille by reducing nutrient loading from local sources
- Improve Pend Oreille River water quality through macrophyte management and tributary non-point source controls

The Council established seven priority water quality program monitoring objectives for the Clark Fork – Pend Oreille basin. These monitoring objectives are:

1. Evaluating time trends in nutrient concentrations in the mainstem Clark Fork River and selected tributaries
2. Evaluating time trends for benthic algae chlorophyll in the Clark Fork River
3. Monitoring compliance with established summer nutrient and benthic algae chlorophyll target levels in the Clark Fork River
4. Estimating nutrient loading rates to Lake Pend Oreille from the Clark Fork River
5. Evaluating time trends for benthic algae chlorophyll densities in near-shore areas of Lake Pend Oreille
6. Evaluating time trends for Secchi transparency in Lake Pend Oreille
7. Evaluating time trends for nutrient concentrations in the Pend Oreille River.

The CFRWQMC has adopted monitoring objectives numbers one through four. The purpose of this report is to evaluate nutrient water quality and chlorophyll-a levels and identify time trends in the program's dataset. This report addresses the first four monitoring objectives. The other monitoring objectives continue to be evaluated by others, primarily the IDEQ and Washington Department of Ecology through separate monitoring programs.

2.3 NUTRIENT STANDARDS

Because the Clark Fork mainstem was determined to be impaired by nutrients, the Clean Water Act required that a Total Maximum Daily Load analysis be performed. Hence, the Council helped enact The Clark Fork River Voluntary Nutrient Reduction Program (VNRP) to reduce nutrient loading to the river (Envronmental Quality Council 1999). The VNRP included instream nutrient target concentrations for the mainstem Clark Fork River June 21st to September 21st. In 2002 the state of Montana subsequently adopted the VNRP targets as nutrient standards for TP, TN, and mean and maximum benthic algal chlorophyll-a in the Administrative Rules of Montana (ARM) 17.30.631, the first nutrient standards in the state. The EPA accepted the VNRP targets as TMDL for the river.

Today, nutrient standards for the Clark Fork River monitoring program fall under two authorities. For Silver Bow Creek at Opportunity, the standards are listed in DEQ Department Circular DEQ-12A. This circular contains information pertaining to the base numeric nutrient standards for wadeable streams (§75-5-301(2), MCA) and their implementation. Silver Bow Creek is located within the Middle Rockies ecoregion, thus the standards apply from July 1 to September 30, and are as follows:

- Total phosphorus as P: 30 µg/L
- Total Nitrogen as N: 300 µg/L

For the mainstem Clark Fork River from below the Warm Springs Creek confluence (N46º11'17", W112º46'03") to the confluence with the Blackfoot River (N46º52'19", W113º53'35"), ARM 17.30.631 applies. The numeric water quality standards for Total Nitrogen, Total Phosphorus, and benthic algal chlorophyll-a, applicable from June 21 to September 21, are as follows:

- Total Phosphorus as P: 20 µg/L
- Total Nitrogen as N: 300 µg/L
- (Summer mean) - Benthic 100 mg/square meter algal chlorophyll-a
- (Maximum) - Benthic 150 mg/square meter algal chlorophyll-a

For the mainstem Clark Fork River from the confluence with the Blackfoot River (N46º52'19", W113º53'35") to the confluence with the Flathead River (N47º21'45", W114º46'43"), ARM 17.30.631 (2002) applies. The numeric water quality standards for Total Nitrogen, Total Phosphorus, and benthic algal chlorophyll-a, applicable from June 21 to September 21, are as follows:

- Total Phosphorus as P: 39 µg/L
- Total Nitrogen as N: 300 µg/L
- (Summer mean) - Benthic 100 mg/square meter algal chlorophyll-a
- (Maximum) - Benthic 150 mg/square meter algal chlorophyll-a

These nutrient standards are used as a benchmark by the CFRWQMC to evaluate water quality monitoring data collected by the program each year during annual data reporting activities.

2.4 Nutrient Load Agreement

On the lower Clark Fork River, nutrient load thresholds were established by The Montana and Idaho Border Nutrient Load Memorandum of Agreement (Border Agreement) in 2002 to protect Lake Pend Oreille from accelerated cultural eutrophication. The Border Agreement, which was also championed by the Council, directs the completion of an annual nutrient loading analysis and developed nutrient loading thresholds to protect water quality in the open waters of Lake Pend Oreille from the mouth of the Clark Fork River to the Long Bridge (Highway 95). Nutrient targets established in section VII of the Border Agreement include:

- An area-weighted euphotic-zone average concentration of 7.3 micrograms per liter (µg/L) TP for Lake Pend Oreille
- Total TP loading to Lake Pend Oreille of 328,651 kilograms per year (kg/year)
- TP loading from Montana of 259,500 kg/year, as measured at the Clark Fork River at the Montana/Idaho state line, below Cabinet Gorge Dam
- TP loading from Lake Pend Oreille watershed in Idaho of 69,151 kg/year

- Greater than 15:1 TN to TP ratio

The Border Agreement established short-term and long-term exceedances of the nutrient load targets. The Border Agreement states that an exceedance of the nutrient targets exist when either of the following conditions are documented:

(a) A short-term exceedance of the nutrient targets consisting of three consecutive years of TP load increases at the border that are above the targets by greater than 10 percent

(b) A long-term exceedance of the nutrient targets consisting of a ten-year average TP concentration in the lake greater than 7.3 µg/L.

Avista completes annual estimates of nutrient loading from the Clark Fork River to Lake Pend Oreille. These estimates are compared to the nutrient targets in the Border Agreement to evaluate short-term exceedances of the targets. Other nutrient targets are evaluated by IDEQ.

3.0 NUTRIENT REDUCTION ACTIVITIES

The Council was a catalyst for nutrient reduction activities in the Clark Fork River basin through the creation of the Basin Management Plan and the VNRP. The VNRP was a landmark agreement in place from 1998 to 2008 to reduce nutrient discharges in the upper and middle Clark Fork River. The agreement was a commitment to reduce nutrient discharge into the river between three municipal wastewater treatment plants (Butte, Deer Lodge, and Missoula) and one industrial discharger (Smurfit-Stone). In addition, Missoula County connected over 3,000 septic systems to a piped sewer system for treatment, and municipalities banned phosphate containing laundry detergents (McDowell 2000). Additional information on this significant program can be found in a final report prepared by the Council (2009). The report is a comprehensive account of the nutrient reduction activities implemented during the VNRP and their impacts.

The following sections provide an account of recent point and non-point nutrient reduction activities that have taken place in the Clark Fork River basin.

3.1 POINT SOURCE NUTRIENT REDUCTION ACTIVITIES

Point sources are those that release nutrients from discrete conveyances, such as discharge pipes at factories or wastewater treatment plants. The following are considered the most noteworthy point source nutrient reduction activities that have occurred in the Clark Fork River Basin since 1998.

Nutrient Source	Nutrient Reduction Activity
Missoula wastewater facility	**~2013:** launched a large-scale tree plantation irrigation project. Irrigates 160 acres of hybrid poplar trees May 1 to September 30. During that period about 10% of total effluent is diverted for irrigation. On average this is about 0.77 million gallons per day (MGD) of 7.45 MGD total. The amount diverted for irrigation is optimized to match evapotranspiration rates. **2009**: Launched a pilot project to irrigate 1.6 acres of poplar trees with treated effluent. **2004-2005**: Upgraded and expanded the facility's biological nutrient removal (BNR) system, and fermenter. The City first started using biological treatment with activated sludge in 1974. IN 1982 a new solids handling facility, and a new headworks building were constructed to improve treatment processes.
Deer Lodge wastewater facility	**2018:** Alum was added to the process in July and August to enhance phosphorus removal. Effluent sampling results showed 4.5 mg/L or less for total nitrogen and 0.4 mg/L or less for total phosphorus. Based on the effluent data from the new facility, it appears that TN loads to the Clark Fork River were reduced by approximately 45%, whereas phosphorus loads, while slightly lower, were essentially unchanged. A major challenge for optimizing nutrient removal at the Deer Lodge

Nutrient Source	Nutrient Reduction Activity
	facility is the significant infiltration of groundwater into the collection system that results in very dilute influent concentrations. **2017**: The lagoon system was upgraded to a basic BNR mechanical treatment plant. The process design is called an MLE (Modified Ludzack-Ettinger). The design target effluent concentrations are 0.8 mg/l TP and 8 mg/l TN. The facility is designed for biological nitrogen removal but not biological phosphorus removal. Alum dosing during July, August, and September will be utilized for phosphorus removal when the numeric nutrient standards are in effect. This plant was put on line in the fall of 2017. **2009**: Replaced old leaking sewer lines by slip lining them. **2008**: Developed a land application system for effluent to reduce direct July–September discharge to the river to zero (Note: Reductions occurred only up to 2008, as facility returned temporarily to direct discharge in 2008).
Smurfit-Stone Container Corporation	**2010**: Mill was closed. The paper mill operated along the banks of the Clark Fork River downstream of Missoula for over 50 years and processed up to 25 million gallons of water per day during peak production. **Pre-2010**: Reduced nutrient additions to treatment systems; no direct discharge to river July-August (used storage ponds).
Hamilton wastewater treatment plant	**2010**: Upgraded facility (headworks, flow meters, transfer switch for generator, computer system), added a dissolved air floatation unit, upgraded the return activated sludge pumps, and added a screw press.
Stevensville wastewater facility	**2011**: Replaced unlined polishing lagoons with a UV disinfection as a final clarifier.
Missoula County	**1998-2012**: Connected thousands of existing home septic systems to the central sewer.
Butte wastewater facility	**2016**: Plant was upgraded from a conventional activated sludge (secondary mechanical treatment) plant to a membrane BNR plant. The design target effluent limits are 0.3 mg/l TP and 3 mg/l TN. **2011**: Constructed stormwater detention basins to reduce stormwater overflow to the sanitary sewers; reduced industrial loads; grew sod with effluent in summer; updated facilities headworks, and installed influent and effluent Parshall flumes, and two vertical turbine effluent pumps for sod farm.

Nutrient Source	Nutrient Reduction Activity
Lolo Wastewater Facility	**2014:** Plant staff, DEQ and Water Planet technicians visited to plant to engage in optimization discussions. Based on operational changes to the aeration basins, TN in the effluent was reduced from 28 mg/L to 21 mg/L resulting in a 25% reduction. TP remained essentially unchanged with the operational changes, but was reduced from an average concentration of 4.6 mg/L to 4.4 mg/L.
Polson Wastewater Facility	**2018:** Replacement of an existing lagoon system with a sequencing batch reactor (SBR) mechanical plant. New plant startup date will be February 2019. Plant operates under an NPDES discharge permit administered by the EPA. Design target effluent concentrations are 8 mg/L TN and 1.5 mg/L TP.

3.2 Non-Point Source Nutrient Reduction Activities

Non-point nutrient sources include those that come from a large area rather than from specific identifiable sources. Non-point source nutrient reduction activities typically include projects to reduce sediment loading (e.g. bank stabilization, channel restoration, and mine reclamation). Because sediments contain nutrients, a reduction in sediment loads will also reduce nutrient loads to the Clark Fork River.

Each year, the state of Montana receives funding from EPA through Section 319 of the Clean Water Act to distribute throughout the state to groups interested in implementing projects to reduce non-point source pollution. DEQ's Watershed Protection Section has developed an interactive map that details restoration projects funded by the 319 Grant Program. This tool offers a current and detailed visual display of non-point source nutrient reduction activities in the Clark Fork River Basin. The interactive map can be accessed online through DEQ's website (Montana DEQ 2018).

The following is a list of current non-point source nutrient reduction activities funded through the 319 Grant Program that have generally occurred since the last trends report. The listed activities are distributed across the entire basin, but do not necessarily represent a comprehensive list. Projects are typically funded through a variety of sources.

Date	Waterbody/Project Name	Project Sponsor or Organization
2018—Present	Tramway Creek Mine Reclamation	Trout Unlimited
Activity Description: Water quality in Tramway Creek, a tributary to the Little Blackfoot River, will be improved by removing ~30,000 cubic yards of mine waste from multiple sites, hauling the material to an existing repository, and regrading and revegetating streambanks.		
2018—Present	Cow Creek Restoration Project	Flathead Conservation District
Activity Description: Restoration along Cow Creek, a tributary to the Whitefish River, will reduce pollutants to downstream impaired waterbodies. Riparian fencing, hardened water crossings, and water gaps will protect streambanks from trampling, and stream channel function will improve by reestablishing native riparian and woody vegetation and floodplain connection.		
2018—Present	Granite Creek Sediment Reduction	Clark Fork Coalition

Date	Waterbody/Project Name	Project Sponsor or Organization
Activity Description: Sediment input to Upper Lolo Creek will be reduced by completing 100% recontouring of 8.5 miles of forest roads and removing at least 9 culverts. Work is anticipated to reduce sediment in Granite Creek by up to 175 tons/year.		
2018—Present	Fencing and Riparian Improvements on Miller Creek	Bitter Root Water Forum
Activity Description: The Water Forum is working with the Oxbow Cattle Co. to rebuild a healthy riparian area with exclosure fencing, appropriately sized water gaps, beaver mimicry, and riparian plantings.		
2017—Present	Middle and Upper Blackfoot Stream Restoration	Blackfoot Challenge
Activity Description: Sediment and nutrient inputs will be reduced along a 3,700-foot reach of Nevada Creek, a tributary to the Blackfoot River, by stabilizing banks, reconnecting the floodplain, and improving riparian and instream habitat. Grazing management plans will also be established at sites along Nevada and Chimney Creeks.		
2017—Present	Temperature and Sediment Reduction on the East Fork of the Bitterroot	Bitter Root Water Forum
Activity Description: This project's goal is to reduce pollutant inputs to the East Fork of the Bitterroot River by stabilizing stream banks. 2,000 feet of fencing was installed to protect streambanks and the reestablishment of nursery plants and live shrub transplants.		
2017—Present	Ontario and Monarch Creek Floodplain Project	Helena National Forest
Activity Description: This project will reduce sediment loading to the Little Blackfoot River and its tributaries by removing 7,800 feet of road segments and associated crossing structures. This will require rerouting Ontario Creek away from a road and into a historic channel.		
2017—Present	Lower Swan Valley Road Sediment Reduction Project	Swan Valley Connections
Activity Description: Road decommissioning and stream restoration projects in Squeezer Creek, Whitetail Creek, and Woodward Creek watersheds will reduce sediment delivery. Project activities include removing culverts and abandoned bridge abutments, obliterating roads, creating alternate roads with best management practices in place, stabilizing road slopes with terracing and vegetation, and restoring channel geometry and floodplain connection.		
2017—Present	Mud Creek Stream and Wetland Restoration Project	Lincoln Conservation District
Activity Description: This site was a timber milling operation from 1954 - 1973, during which time a cooling pond was installed and Mud Creek was straightened and channelized. Restoration of Mud Creek includes improving riparian and floodplain conditions by reconnecting the floodplain, creating a matrix of wetlands, and creating complex aquatic habitat.		
2013—Present	Ninemile Creek Reclamation	Trout Unlimited
Activity Description: By the end of 2018, Trout Unlimited and partners will have restored over 1.5 miles of stream channel and associated floodplain of Ninemile Creek and tributaries. This watershed was heavily impacted by historical placer and hardrock mining. Restoration included the removal of over 150,000 cubic yards of sediment from remnant placer piles in the historical floodplain.		
2014—Present	Bull River Sediment Reduction and Revegetation	Lower Clark Fork Watershed Council

Date	Waterbody/Project Name	Project Sponsor or Organization
Activity Description: This will replace invasive reed canary grass, which covers most of the banks along the Bull River, with deeply-rooted riparian shrubs and trees. 11,000 feet of fencing was used to build exclosures that were revegetated with native plants.		
2012—Present	Watershed Restoration Plans	Local watershed groups
Activity Description: Since 2012, 13 watershed groups within the Clark Fork River basin completed a Watershed Restoration Plan and more are in development. Watersheds with approved Watershed Restoration Plans include the Bitterroot River, Blackfoot River, Flathead Lake, Flathead-Stillwater, Flint Creek, Kootenai Basin, Little Blackfoot, Lolo Creek, Lower Clark Fork, Ninemile Creek, Swan Lake, Rock Creek, Miller Creek, Thompson River, and Upper Clark Fork River Tributaries. These documents guide planning and implementation of restoration activities and make watershed groups eligible for grant funding through the Clean Water Act Section 319 program.		
2015-2017	Telegraph Creek Restoration	Trout Unlimited
Activity Description: Three waste rock piles were removed from the Lily/Orphan Boy abandoned mine site, including one that spanned Telegraph Creek. Additional contaminated sediment was removed from the floodplain, 400 feet of stream channel was restored to natural conditions, and floodplain wetland acreage increased. The project resulted in decreases of long-term sediment and metals loading.		
2015-2017	Upper Lolo Creek Sediment Reduction Project	Clark Fork Coalition
Activity Description: 12 miles of forest roads were 100% recontoured. At 19 sites where culverts were removed, recontouring matches natural stream geomorphology, and large woody debris and boulders were placed to control the grade. The project reduced pollutants in Upper Lolo Creek and opened 7-10 miles of stream to fish for spawning and cold water refugia.		
2016	Flathead Ripples of Change Project	Flathead Lakers
Activity Description: 2,650 feet of the riparian area along Ashley Creek was fenced off from livestock and a water gap was built to limit stream access by livestock. Additionally, a lakefront lawn was converted to a vegetated riparian buffer.		
2012-2016	Watershed Improvement through Sediment Reduction in Upper Sleeping Child Creek and Rye Creek	Bitter Root Water Forum
Activity Description: Pollutant inputs to Rye and Sleeping Child Creeks were reduced by installing 250 feet of bioengineered, fabric-wrapped soil lifts to help stabilize eroding banks. One woody debris pile was built, and one was rebuilt, to stop erosion and avulsion.		
2015-2017	Sediment Reduction in Lolo Creek Watershed	Lolo Watershed Group
Activity Description: Primarily in burned riparian areas, 840 feet of streambank along Highway 12 were improved by planting ~900 trees to serve as a riparian buffer between the road and the creek.		
2012-2015	Browns Gulch Restoration Project	Watershed Restoration Coalition for the Upper Clark Fork River
Activity Description: This project was designed to restore water quality and wetland and aquatic habitat in the largest tributary to Silver Bow Creek. It reduced sedimentation from streambanks and roads by stabilizing banks and improving drainage on 9 miles of county road. Funding also supported reconstruction of livestock corrals, installation of an all-season livestock water tank, and fencing off the creek to protect the banks from cattle.		
2012-2014	Swan Watershed TMDL Implementation	Swan Ecosystem Center
Activity Description: By 2010, landownership of 93% of the Jim Creek watershed had been transferred from private timberlands to public lands. This grant contract funded an assessment of forest roads		

Date	Waterbody/Project Name	Project Sponsor or Organization
and a design for restoration based on the assessment's results. Best management practices were installed along 7.3 miles of road along lower Jim Creek to reduce pollutant inputs to streams and lakes. In 2018, sediment was removed as an impairment cause on Jim Creek.		
2013-2017	Lost Horse Creek Streamflow Enhancement	Clark Fork Coalition
Activity Description: Irrigation from Lost Horse Creek was formerly provided by excavating an earthen dam. This project funded construction of a siphon to provide irrigation water instead. Flows in Lost Horse Creek increased by more than 10 cfs and reconnected the creek to the Bitterroot River. Additionally, because yearly excavations are no longer necessary, this project decreased sediment inputs. Increased flows lowered stream temperature and restored connectivity for migratory fish, especially rare westslope cutthroat trout.		
2013-2014	Realign Clear Creek Road	Lolo National Forest
Activity Description: The goal of the project was to improve water quality by reducing or eliminating the frequency of road washout and streambank failure at several locations. Objectives focused on realigning the road further from Clear Creek and creating floodplain.		
2013-2014	East Fork Bitterroot River Watershed Improvement	Trout Unlimited
Activity Description: This project fully decommissioned 10 miles of forest roads along tributaries to the East Fork Bitterroot River. Activities included decompaction, recontouring, seeding, fertilizing, mulching, removing culverts, and re-grading the stream channel to match historic contours.		
2012	Revegetation on East Fork Bitterroot	Bitter Root Water Forum
Activity Description: Volunteers revegetated 380 feet of streambank to increase the size and quality of the riparian buffer between Highway 93 and the East Fork Bitterroot River. This small-scale effort accomplished 1 of 5 designs aimed at revegetating 5,000 feet of bank within a 2 mile stretch of road.		
2012-2014	Blackfoot Watershed Water Quality and Native Fish Restoration	Blackfoot Challenge
Activity Description: Restoration projects along ~9,000 feet of Cottonwood, South Fork Poorman, and Ashby creeks improved water quality by stabilizing and revegetating eroding streambanks. The restoration included obliterating roads, reconstructing stream channels, replacing culverts with bridges, and removing four fords.		
2010-2014	Conservation Advisor for Livestock Operations	Soil and Water Conservation Districts of Montana
Activity Description: This project reduced nonpoint source pollution associated with animal feeding operations by providing an on-site assessment tool to determine risk of impacting water quality. Based on these assessments, consulting and funding for best management practices implementation was provided. 28 assessments were conducted, and 3 resulted in on-the-ground projects (2 in the Stillwater basin). 3,000 copies of the on-site assessment tool were published and distributed to conservation districts and posted electronically on the Montana Association of Conservation District's website (www.macdnet.org).		
2011-2013	Haskill Creek Floodplain Renovation	Flathead Conservation District
Activity Description: This project created a riparian buffer for agricultural land. Floodplain renovation along 1,222 feet of Haskill Creek included lowering high banks to floodplain elevation, installing woody debris jams and conifer/willow fascines, and implementing a rigorous floodplain revegetation plan. The project successfully provided bank stability and reduced erosion in the project reach by 74%.		
2010-2011	Bigfork Stormwater Project	Flathead County

Date	Waterbody/Project Name	Project Sponsor or Organization
Activity Description: The Bigfork Stormwater Project improved water quality in Bigfork Bay and Flathead Lake by developing successful stormwater management strategies. Flathead County installed a stormwater conveyance and filtration systems and pet waste bins to reduce nutrient, sediment, and *E. coli* pollution.		
2007-2012	Upper Clark Fork Activities	Deer Lodge Valley Conservation District
Activity Description: Multiple projects completed under this grant contract reduced metals, nutrients, sediment, and temperature pollution from private ranches in the upper Clark Fork basin. Installation of projects concluded in 2011 and included new pivot irrigation, stockwater pipelines, corrals, and riparian fencing along Gold Creek. On Peterson Creek, over 6 miles of 3-strand high tensile electric fence was installed to protect 3 miles (the majority) of Peterson Creek from livestock impact. Additionally, an 18,000-foot stock water pipeline was installed to supply 5 tanks with seasonal stock water.		

Additionally, EPA, DEQ and the Montana Department of Justice Natural Resource Damage Program (NRDP) have and are completing multiple cleanup and restoration activities in the upper Clark Fork River and its headwaters. Projects have focused on removal of metals-contaminated sediments and extensive stream bank restoration to establish floodplain connectivity. Many of these activities may have long-term impacts on nutrient loads and levels. While the NRDP has not conducted any restoration activities specifically targeting nutrient reduction in the upper Clark Fork River Basin they are currently developing a nutrient/water quality working group to guide investigations to address algal blooms and other issues in certain reaches of the river. The investigations are joint projects with Montana Fish Wildlife and Parks and University of Montana to understand why the Clark Fork River between Flint Creek and Rock Creek has lower trout densities relative to other reaches of the river. The investigations have identified the Dutchman wetland area as a potential significant source of nutrients to the river, specifically TN (Martin, Doug, Personal Comm., December 27, 2018).

4.0 MONITORING PROGRAM

The Council initiated and coordinated a Clark Fork-Pend Oreille basin-wide monitoring program. The Council's Monitoring Committee directed and oversaw a consistent water quality monitoring program, which consisted of a dedicated network of state agencies including DEQ, IDEQ, and Washington Department of Ecology; industry and business partners including Avista, Plum Creek Timber Company, Montana Rail Link; the City of Missoula; the University of Montana; and a technical consultant. The U.S. Forest Service and EPA also provided regular funding and other assistance for the monitoring program. Generally, the monitoring program consisted of measuring field parameters and collecting water quality samples at monitoring locations on the Clark Fork River and selected tributaries, Lake Pend Oreille, and the Pend Oreille River within the Clark Fork-Pend Oreille watershed of western Montana, northern Idaho, and northeastern Washington. Key to the program was developing and maintaining a consistent set of methods, sample stations, sampling personnel, and data quality control measures. Dedicated long-term monitoring stations were established and divided among the multiple organizations and agencies that formed the Council's Monitoring Committee. Under the direction of the Council, the monitoring program was consistently completed beginning in 1998 and on an annual basis until 2012.

Clark Fork River water quality monitoring is now managed at the state level by the CFRWQMC. Many members that served with the Council now serve on the CFRWQMC. The CFRWQMC has carried over many of the same monitoring protocols to direct their efforts in order to maintain consistent long-term water quality monitoring objectives. Separate project-specific sampling programs and associated quality assurance project plans (QAPPs) have been developed as guidance for the individual participants of the sampling program. These plans are collectively managed by the CFRWQMC and published through DEQ. Program QAPPs provide a consistent and scientifically acceptable approach to data collection and management that facilitates achievement of program objectives, provides framework for conducting the activity, and establishes the guidelines for reviewing analytical results and assures quality data. Program sampling and analysis plans (SAPs) are developed for each activity to provide the structure and protocol of the activity, defining what, where, when, and the protocols for accomplishing the monitoring activity. Program QAPPs and SAPs are regularly reviewed and updated by members of the CFRWQMC at an annual meeting.

The following list summarizes relevant Clark Fork River water quality monitoring program activities completed for use in this report. Currently, the Clark Fork River water quality monitoring program includes:

- Clark Fork River Monthly Monitoring (monthly monitoring): Avista collects monthly nutrient samples and field constituents at three lower Clark Fork River stations in July, August, and September. Monthly monitoring and nutrient data collection at Station 30 (below Cabinet Gorge Dam) occurs each month of the year March through November.
- Clark Fork River Peak Flow Monitoring (peak flow monitoring): Avista collects nutrient samples at Station 30 (below Cabinet Gorge Dam) during spring runoff. This consists of six sampling events spread over about a one-month period during the rising limb of the hydrograph and at the peak, typically in May and June.
- Clark Fork River Summer Nutrient Monitoring (summer monitoring): The Clark Fork Coalition and University of Montana collect nutrient samples and field constituents in summer months (July-September) at eight Clark Fork River stations, one station on Silver Bow Creek, and one Station on the lower Flathead River (not included in this trends report).

- Clark Fork River Benthic Algae Monitoring (benthic algae monitoring): The University of Montana collects summer benthic algae samples for chlorophyll-a and ash-free dry weight at seven Clark Fork River sites in August and September.

4.1 Monitoring Network

The locations selected for water quality monitoring provide distributed spatial coverage for evaluating the effects of point and non-point pollution sources and the influences of major population centers and tributary inflows. Although numerous monitoring stations have been sampled through the course of the monitoring program, consistent data collection has occurred at twelve locations since 1998 to the present day. Data generated from sampling at these twelve locations are selected for inclusion in this trends report. This design provides for a cost effective and scientifically-based assessment of nutrient inputs and effects throughout the watershed. Monitoring stations are distributed throughout the upper, middle, and lower reaches of the Clark Fork River watershed. The upper Clark Fork River extends from the headwaters at Silver Bow Creek to the confluence with the Blackfoot River, upstream of Missoula. The middle Clark Fork River extends from the confluence with the Blackfoot River to the confluence with the Flathead River. The lower Clark Fork River in Montana extends downstream from the confluence with the Flathead River to below Cabinet Gorge Dam. Note the monitoring stations include eleven stations on the Clark Fork River and one station on Silver Bow Creek. Collectively these stations are referred to as "Clark Fork River Stations" in this report. The twelve Clark Fork River nutrient monitoring stations included in this report are listed in **Table 4-1** and shown on the map in **Attachment A**. Also shown in **Table 4-1** are the river reach, the paired USGS stream gaging station, and monitoring type for each monitoring station.

Table 4-1. Clark Fork River Watershed Monitoring Stations included in the Nutrient Trends Report

Reach	Station ID	Monitoring Station Name	USGS Gage Number	Monitoring Type
Upper CFR	CFR-2.5	Silver Bow Creek at Opportunity	12323600 Silver Bow Creek at Opportunity	SN6
	CFR-07	CFR below Warm Springs Creek	12323800 CFR at Galen	SN6
	CFR-09	CFR at Deer Lodge	12324200 CFR at Deer Lodge	P2, SN6
	CFR-10	CFR above Little Blackfoot River	12324200 CFR at Deer Lodge	P2, SN6
	CFR-12	CFR at Bonita	12331800 CFR near Drummond	P2, SN6
Middle CFR	CFR-15.5	CFR above Missoula	12340500 CFR above Missoula	P2, SN6
	CFR-18	CFR below Missoula	12340500 CFR above Missoula	P2, SN6
	CFR-22	CFR at Huson	12353000 CFR below Missoula	P2, SN6
	CFR-25	CFR above Flathead	12354500 CFR at St. Regis	P2, SN6
Lower CFR	CFR-28	CFR below Thompson Falls	12389000 CFR near Plains	N3
	CFR-29	CFR at Noxon Bridge	12391400 CFR below Noxon Rapids Dam	N3
	CFR-30	CFR below Cabinet Gorge Dam	12391950 CFR below Cabinet Gorge Dam	N15

Notes:

CFR	*Clark Fork River*
SN6	*Summer monitoring for nutrient and field constituents, 6 samples collected in July, August, and September*
P2	*Periphyton collected in August and September by University of Montana Watershed Health Clinic*
N3	*Monthly monitoring for nutrients and field constituents, 3 monthly samples collected in July, August, and September*
N15	*Monthly monitoring for nutrients and field constituents, 9 monthly samples (excludes December, January and February) and 6 peak flow samples for nutrients and field constituents*

4.2 Monitored Constituents

The current monitoring program consists of the collection of the following nutrient constituents, benthic algae data, and field parameter measurements. Additional nutrient constituents such as total Kjeldahl nitrogen (TKN) have been included in the past but are no longer part of the current program. Select metals constituents have also been monitored in past years, but are no longer part of the current monitoring program.

Nutrient Constituents

- Total (persulfate) nitrogen (TPN), or total nitrogen (TN) (monitored from 2009–present)
- Total Kjeldahl nitrogen (TKN) (monitored from 1998–2008)
- Soluble nitrate and nitrite as N (NO_2+NO_3 as N), or also called inorganic nitrogen as N (dissolved)
- Soluble ammonia nitrogen as N (NH_3+NH_4 as N), or also called total ammonia nitrogen as N (dissolved)
- Total phosphorus (TP), or phosphate-phosphorus as P
- Soluble reactive phosphorus (SRP), or Orthophosphate as P

Benthic Algae (or periphyton)

- Benthic algae samples were analyzed for chlorophyll-a in milligrams per square meter (mg/m^2) and ash-free dry mass (AFDM) in grams per square meter (g/m^2).

Field Parameters

- Water temperature in degrees Celsius (˚C)
- Dissolved oxygen (DO) in milligrams per liter (mg/L)
- pH (standard units)
- Oxidation reduction potential (ORP) in millivolts (mV)
- Specific conductance (SC) in microSiemens per centimeter (µS/cm)
- Total dissolved solids (TDS) in mg/L
- Turbidity in Nephelometric Turbidity Units (NTU)

Stream flow (CFS) and river stage (feet) data recorded by the USGS are also part of the data used in this report.

4.3 Sampling and Analytical Methods

Specific methods of sample collection, preservation, and handling currently followed by each of the monitoring program activities can be found in the CFRWQMC program QAPP (Montana DEQ 2018). Sampling and analytical methods are consistent with DEQ Water Quality Planning Bureau water quality monitoring standard operating procedures (Montana DEQ 2013). All nutrient analyses were performed by state-certified laboratories using EPA-approved analytical methods. Details of these methods can be found in Standard Methods for the Examination of Water and Wastewater, 20th Ed (APHA/AWWA/WEF 1998) and in the laboratories' quality assurance plans which are part of respective monitoring activity QAPPs.

Throughout the history of the monitoring program, various analytical methods and detection limits have been applied to generate the dataset used in this report. **Table 4-2** summarizes the constituents, analytical methods, and detection limits of the nutrient and chlorophyll-a analyses used to generate the source data.

Table 4-2. Summary of Analytical Constituents, Analytical Methods, and Detection Limits for the Clark Fork River Monitoring Program, 1998-2017		
Constituent	**Analytical Method(s)**	**Range of Detection Limits**
Ammonia nitrogen (NH3+NH4 as N)	350.1, 4500-NH3(H), SM 4500-NH_3(G)	10 µg/L
Inorganic nitrogen (NO_2+NO_3 as N)	353.2, 353.3, 4500-NO3(I)	2-20 µg/L
Kjeldahl nitrogen (TKN)	351.1, 351.2	100 µg/L
Nutrient-nitrogen (TPN) or Total Nitrogen (TN)	4500-N (C)	10-100 µg/L
Orthophosphate (SRP)	365.1, 365.3, 4500-P-G, 4500-P (F)	1-4 µg/L
Phosphate-phosphorus or Total Phosphorus (TP)	365.2, 365.3, 365.4, 4500-P-H, 4500-P (B)	1-8 µg/L
Algal chlorophyll-a (chl-*a*)	(University of Montana Watershed Health Clinic 2009), A 10200H	0.1-7 mg chl-*a*/m^2
Algal ash-free dry mass (AFDM)	(University of Montana Watershed Health Clinic 2009), A 10300 C (5)	0.01-0.8 g/m^2

Notes:

1 *Detection Limits shown are equivalent to the lower reporting limits in the dataset used*

2 *Analytical Methods reference:* (APHA/AWWA/WEF 1998)

3 *g/m^2* *grams per square meter*

4 *mg/m^2* *milligrams per square meter*

5 *µg/L* *micrograms per liter*

6 *UM-WHC* *University of Montana Watershed Health Clinic*

7 *The range of detection limits for the algal parameters is due to different sampling methods that sample different size areas. The limit of detection (LOD) for hoop samples 0.01 mg/m^2 chlorophyll-a, 0.01 g/m^2AFDM; template samples 0.4 mg/m^2 chlorophyll-*a*, 0.4g/m^2 AFDM. The limit of required quantitation (LORQ) is about 10 times these levels. In the past DEQ used the LORQ as the LOD. But now uses both.*

Detection limits shown in **Table 4-2** are based on the laboratory lower reporting limits recorded in the source data. Laboratory lower reporting limits were established by the laboratories for each constituent as the lowest concentration that could be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions. Method detection limits (MDLs) are calculated by the laboratories and are a value less than the lower reporting limit. MDLs were not consistently provided by the laboratories in the dataset provided by DEQ. Results detected greater than the MDL, but less than the lower reporting limit indicates the presence of the analyte, but the concentration could not be accurately quantified. Therefore, those results in the database were qualified as an estimated value and were used in the trends analysis. Lower reporting limits for each monitored constituent met project required quantitation limits for Clark Fork River monitoring activities established in the QAPP. Note that the range of detection limits for the algal parameters is due to different sampling methods that sample different size areas. The laboratory limit of detection (LOD) for hoop samples is 0.01 mg/m^2 chlorophyll-a, 0.01 g/m^2 AFDM; template samples 0.4 mg/m^2 chlorophyll-a, 0.4g/m^2 AFDM. The laboratory limit of required quantitation (LORQ) is about 10 times these levels.

Table 4-3 details the current approved analytical methods and minimum lower reporting limit concentrations (referred to as project required quantitation limit) necessary to effectively evaluate the project data to the project objectives, as determined in the most recent project QAPP (Montana DEQ 2018). Note the methods and limits apply generally to data collected during the recent five-year monitoring cycle. Not all of the data included in the trends analysis conform to these limits, however all data used was reviewed through a quality assurance quality control process and approved for this intended use.

Table 4-3. Current Monitoring Program Analytical Methods and Detection Limits

Analyte	Method	Alternate Method	Project Required Quantitation Limit
Total Phosphorus (TP)	SM 4500-P-H	SM 4500-P(B) &(F)	2 µg/l
Total Persulfate Nitrogen (TPN)	SM 4500-N (C)	SM 4500-N (C)	50 µg/l
Nitrate + Nitrite-Nitrogen (NO_2+NO_3-N)	SM 4500-NO_3(I)	SM 4500-NO_3 (F)	2 µg/l
Total Ammonia-Nitrogen (NH_3+NH_4-N)	SM 4500-NH_3(H)	SM 4500-NH_3(G)	10 µg/l
Soluble Reactive Phosphorus (SRP)	SM 4500-P-G	SM 4500-P (F)	2 µg/l
Chlorophyll-a *hoop vs template*	A 10200H		0.1 vs 4 mg/m^2
Ash- Free Dry Mass hoop vs template	A 10300 C (5)		0.1 vs 4 g/ m^2

Source: (Montana DEQ 2018)

4.4 Data Quality Assurance

The program's water quality data undergoes rigorous quality assurance/quality control (QA/QC) review and reporting as directed by the program QAPP (Montana DEQ 2018) prior to final approval and upload. The QAQC procedures includes a review of documentation associated with sampling and measurement and laboratory analytical results to verify data quality. It also includes a review of the data quality objectives (DQOs) and data quality indicators (DQIs) as outlined in the program QAPP. Documentation of this review is provided by the CFRWQMC in an annual report.

Data generated through this program are submitted annually to DEQ as an electronic data deliverable (EDD) file that is uploaded to the Montana EQuIS Water Quality Exchange (MT-eWQX). Data from MT-eWQX is submitted to EPA's data warehouse, the National Water Quality Portal. Data uploaded through this QA/QC process form the basis for the dataset used in this report. The data quality assurance processes assure the data can be used for the intended program purposes, including this water quality trends report.

5.0 Data Analysis Methods

This section describes the methods used in this report including methods to reduce the raw dataset into a useable format, statistical analysis methods used to assess trends in the data, and methods used to estimate nutrient loading. The data reduction methods, statistical methods, and loading evaluation methods are consistent with previous work (Tri-State Water Quality Council 2009) (Suplee, et al. 2012) (HydroSolutions 2014) and were approved by DEQ.

5.1 Data Reduction

The dataset used in this report was retrieved by DEQ from the Water Quality Portal (WQP) and provided electronically to HydroSolutions. DEQ extracted all available nutrient data from the Clark Fork River monitoring program and other sources at the same monitoring stations through 2017. DEQ had previously removed all data prior to 1998 for inconsistencies in data and laboratory MDL or lower reporting limit reporting (HydroSolutions 2014).

The 1998-2012 dataset was reduced and analyzed by HydroSolutions, as described in the previous trends analysis report (HydroSolutions 2014). Data covering the period from 2013 through 2017 was reduced into a similar format and incorporated into the overall 1998-2017 dataset. The following provides a list of data reduction activities that were completed for 2013-2017 dataset.

1. Data associated with sampling stations on tributaries including the Bitterroot River, Flathead River and Thompson River were removed. Data from the Thompson River (CFR-27.5) was analyzed as part of the previous trends report, but data collection at that station has ceased since that time.
2. Quality control duplicate and blank sample data were removed.
3. Extreme outliers were removed at the direction of DEQ (this applied to two values in the 1998-2012 data set and was addressed in the previous trends analysis). There were no extreme outliers identified by DEQ in the 2013-2017 data set.
4. Data discrepancies identified by HydroSolutions were corrected through coordination with DEQ. This included 20 text field errors in the database for data 2012 and 2013.
5. Data collected in months other than July, August, and September were removed.
6. Variations in nomenclature were categorized for analysis. (For example, total phosphorous, is also reported as phosphate-phosphorous and total nitrogen is also reported as nutrient-nitrogen.)
7. Rejected data were removed from the data set. This included TP and SRP results from station 9 collected on 8/24/2016.
8. Results reported as non-detect were assigned a quantity one-half the lower reporting limit reported in the database.
9. TN concentrations were calculated by summing concentrations of TKN and NO_2+NO_3 as N collected concurrently at each monitoring station for the years 1998 to 2008 (this was completed as part of the previous trends analysis).
10. TSIN concentrations were calculated by summing concentrations of nitrate and nitrite (NO_2+NO_3 as N) and Ammonia (NH_3 as N) collected concurrently at each monitoring station for the dataset 2013-2017. The TSIN concentration values from 2013-2017 were then merged with the TSIN concentration values from 1998-2012, which were generated in the previous time trend analysis.

11. Where multiple sample results at one station existed within a calendar month, the results were averaged to provide one monthly value.
12. Monthly average stream flow at USGS gaging stations identified in **Table 4-1** were extracted from the USGS National Water Information System and paired to respective monitoring stations.
13. Monthly average stream flow data provided by Avista for Noxon Rapids Dam was paired with site CFR-29 after September 2014, when USGS gage 12391400 CFR below Noxon Rapids Dam was taken out of service.

Reduced datasets are provided electronically in Attachment E.

5.2 STATISTICAL TREND ANALYSES

Prior to conducting the trends analysis, the sample population size (N) and number of values that were non-detect or had a result condition (RC) were compiled and evaluated. This was done to better understand if non-detect values could affect or bias trends results. Compiled sample population size number of values with a result condition are presented in **Table 5-1**. The sample population shown in **Table 5-1** represents the entire number of samples collected during the monitoring period (excluding quality control samples) at each monitoring station in the reduced dataset. Monthly average concentrations were computed, which reduced the actual N used in the time trend analysis. The maximum possible reduced N used for the trends analysis is 60 (3 monthly average concentrations per year x 20 years). RC represents a reported non-detect value of the sample parameter or a non-detect value of one or more of the additive components of the parameter(s), in the case of TN (from 1998-2008) and TSIN. In completing the trend analysis, direct measure of TN, which began in 2009, is assumed to be comparable to the previously calculated TN values, as described in bullet point number nine in the list above (Suplee, et al. 2012). The sample population for chlorophyll-a mean and maximum was 20 each, respectively, at each monitoring station.

Table 5-1. Sample Population Count (N) and Number of Values with Sample Result Conditions (RC) [1] of the Clark Fork River Nutrient Trends Analysis Dataset 1998–2017

Station ID	TN [2]		TKN		TSIN [3]		NO3-NO2		NH3		TP		SRP [4]	
	N	RC	N	RC	N	RC	N	RC	N	RC	N	RC	N	RC
CFR-2.5	149	1	85	1	150	13	150	0	150	13	149	0	141	0
CFR-07	149	28	85	3	150	54	150	25	150	41	150	0	141	0
CFR-09	120	0	57	0	122	40	122	1	122	40	121	0	113	1
CFR-10	149	49	85	1	150	88	150	58	150	60	150	0	142	1
CFR-12	121	20	57	3	122	56	122	21	122	44	121	0	114	4
CFR-15.5	121	25	57	10	122	50	122	27	122	36	122	0	114	7
CFR-18	147	8	83	5	149	26	148	3	149	24	149	0	141	2
CFR-22	148	13	84	5	149	59	148	8	149	56	149	0	140	4
CFR-25	122	22	58	16	122	61	122	8	122	60	122	0	114	16
CFR-28	58	18	32	15	59	48	59	8	59	45	59	0	45	18
CFR-29	58	12	32	11	59	18	59	2	59	17	59	0	45	2
CFR-30	63	16	37	15	64	42	64	4	64	40	64	0	61	11

Notes:

1	Sample Result Condition (RC) is the number of sample results reported as a non-detect value (less than the method detection limit). For calculated constituents, TN (1998-2008) and TSIN (1998-2017), RC is counted one time if either component was a non-detect value.
2	TN sample count from 1998-2017 is the sum of measured TN samples plus calculated TN, which is the sum of paired TKN (1998-2008) plus NO3-NO2 as N samples. TN was analyzed beginning in 2009. TKN is no longer analyzed.
3	TSIN sample count is the sum of paired NH3+NH4 as N and NO_2+NO_3 as N samples.
4	SRP was not monitored at Stations CFR-28 and CFR-29 from 2008 to 2012.

Based on review of literature (Helsel and Hirsch 2002) and previous work (Suplee, et al. 2012) (HydroSolutions 2014), and consultation with DEQ, the nonparametric Mann-Kendall trend test was selected as the appropriate method to detect trends in the selected dataset. The R statistical programming language was used to run the trends analysis (R Core Team 2018). Prior to execution of the time trends analysis, code was written in R to prepare the data into a useable format. This process consisted of cleaning, transforming, and pre-processing the reduced dataset into consistent and usable number formats. The *rkt* package for R (Marchetto 2017) was used to calculate time-series trend analyses for each parameter of interest using the Mann-Kendall and Seasonal Mann-Kendall tests.

The time trend analyses employed two-sided tests with significance level α; also known as the false positive rate, of 0.1 and a null hypothesis, H_0, that there was no trend in the series. An α value of 0.1 means that there is at most a 10 percent chance of a false positive (trend identified when one does not exist) in the results. When using a false positive rate of 0.1, results with a reported p-value less than 0.1 exhibit a statistically significant trend in the data. The direction of the trend is indicated by the Mann-Kendall statistic score (S), with positive values indicating an increasing trend and negative S values indicating a decreasing trend.

Previous work concluded that discharge influenced total monthly nutrient levels at all sites (Suplee, et al. 2012). Consistent with previous work (Suplee, et al. 2012) site by site analyses showed that total nutrients were influenced by mean monthly summer discharge (or stream flow). TN concentrations generally decreased with increasing stream flow, while TP concentrations generally increased with increasing stream flow. Dissolved constituents (TSIN and SRP) generally followed similar patterns as the total nutrients. Because of this relationship, nutrient concentration data were first regressed against flow utilizing the LOWESS method. Consistent with current statistical guidance (Helsel and Hirsch 2002), and that of DEQ, this study assessed time nutrient trends for TN, TSIN, TP, and SRP with the Seasonal Mann-Kendall trend test on flow-adjusted concentrations (residuals from the LOWESS regression) against time. This method is able to distinguish time trends in water quality beyond those due to variation caused by time changes in discharge, and to correct for seasonality (Hirsch, Slack and Smith 1982) (Helsel and Hirsch 2002) (Suplee, et al. 2012). For this study the Seasonal Mann-Kendall test with a period of three, for the months of July, August, and September accounted for monthly trends within the dataset.

Previous analyses in the area determined chlorophyll-a concentrations were not clearly tied to discharge (Suplee, et al. 2012); therefore, no flow adjustment was made prior to the time trends analysis of chlorophyll-a. This study assessed time trends of the mean and maximum annual chlorophyll-a values with the Mann-Kendall trend test on concentration against time.

5.3 Evaluation of Numeric Nutrient Standards Thresholds Exceedance Comparison

This section describes the method used to assess attainment or exceedance of State of Montana numeric nutrient water quality standards for Clark Fork River monitoring stations in the upper and middle Clark Fork River over time. Attainment or exceedance of numeric nutrient standard thresholds for the Clark Fork River were evaluated for the complete dataset 1998 to 2017. This twenty-year dataset was broken into two ten-year sets: 1998 to 2007 and 2008 to 2017. This break out provided a nearly equal distribution of data for both time periods and importantly, provided a comparison between the earlier period when nutrient reduction activities we just beginning to the later period when the nutrient reduction activities were afforded time to work, all the while additional nutrient reduction activities had taken place. For each set, individual sample results (i.e. not the averaged and flow-adjusted dataset used for trends analysis) for TN, TP, mean chlorophyll-a, and maximum chlorophyll-a were tabulated and compared to numeric standards. The number of samples exceeding the numeric standard were tabulated and computed into a percentage for both time periods. This analysis does not constitute a clean water act beneficial use assessment but may assist DEQ in updating nutrient related beneficial assessments for specific segments of the Clark Fork River.

5.4 Nutrient Loading Estimation Method

Clark Fork River nutrient loading (TP and TN) into Lake Pend Oreille is evaluated on an annual basis using the U.S. Army Corps of Engineers (USACE) FLUX32 Load Estimation Software model (version 3.10). The FLUX32 model is one of three USACE models that comprise the BATHTUB Eutrophication model (Walker 1999). The model uses grab-sample nutrient concentrations, corresponding discharge measurements, and complete discharge records to calculate annual nutrient loading. The FLUX32 model provides six methods to synthesize the discharge-nutrient concentration relationship from individual sample records and impute them onto the entire flow record. Method 6, *Regression Applied to Individual Flows,* has been used in previous work and is used in this report to maintain consistency and because the coefficient of variation reported for this method is generally low and is adequate for use in mass-balance modeling (Tri-State Water Quality Council 2009) (Montana DEQ 2018). Method 6 is generally preferred over the other regression-based methods when the discharge-nutrient concentration relationship is well defined. Method 6, *Regression Applied to Individual Flows*, is defined by Walker (1999).

Nutrient loads are estimated using the record of mean daily discharge from USGS station 12392000, Clark Fork River at Whitehorse Rapids, which operated from 1929 to 2014. This station was located downstream of Cabinet Gorge Dam and is no longer operated. Consistent with USGS guidance, discharge at this station is now calculated from the sum of measured flow at USGS station 12391950, Clark Fork River below Cabinet Gorge dam and an estimated 600 CFS groundwater inflow derived from seepage around the dam (USGS 2018).

For the loading analysis, the FLUX32 model converts nutrient concentrations from micrograms per liter (µg/L) to miligrams per cubic meter (mg/m^3) and discharge values from cubic feet per second (cfs) to cubic hectometers per year (hm^3/yr). The number of stratified discharge regimes calculated by the model is limited by the number of sample results available to impute onto the complete discharge record. The model develops a separate regression equation for each stratification. In most years, there were three separate stratum: one half the mean discharge, mean discharge, and two times the mean discharge. In some years there were fewer samples collected and the model utilized two stratum: less than mean daily flow, and greater than the mean daily flow. For each stratum, the regression equation is applied individually to each daily flow value. The sum of daily loads provides the annual estimate.

The nutrient loading results presented in this report are a compilation of previous completed work. Nutrient loading estimates were compiled from previous annual reports and individual technical memorandums prepared by Avista on file with the CFRWQMC and DEQ.

6.0 NUTRIENT WATER QUALITY TIME TREND RESULTS

This section presents results of the time trends analysis of TN, TSIN, TP, SRP, mean chlorophyll-a, and maximum chlorophyll-a for each of twelve monitoring stations in the Clark Fork River 1998–2017 dataset. **Table 6-1** summarizes numerical results of the trends tests, interpretation of those results, corresponding trend direction and relative significance or magnitude by monitoring station. The following is a description of the results reported in **Table 6-1:**

Numerical Results

$p - value =$ The risk to reject H_0 while it is true (represented as a decimal in the results, can also be represented as a percentage).

$S =$ The statistical value representing the monotonic dependence of y on x; in this case study the statistic represents the tendency of the constituent values to decrease or increase as time progresses; where the seasonal Mann-Kendall test is implemented, the S statistic is represented by S' which is equal to the sum of the S statistic for each season

Interpretation

Null hypothesis, H_0 : there is no trend in the series

Alternate hypothesis, H_a : there is a trend in the series

If $p > 0.1$ then H_0 cannot be rejected (a trend is not detected)

If $p < 0.1$ then reject H_0, and accept H_a (a trend is detected)

Trend Direction

If $p > 0.1$, then trend not detected
If $p < 0.1$ and If $S < 0$, then decreasing trend
If $p < 0.1$ and If $S > 0$, then increasing trend

Trend Magnitude

The magnitude of trends were ranked based on guidance in USGS publication "Statistical Methods in Water Resources," (Helsel and Hirsch 2002). Interpretation of the presence and magnitude and of a significant trend, evaluated at a significance level of $\alpha = 0.1$ was interpreted as follows:

Marginally Significant: $0.05 < p \leq 0.1$
Significant: $0.01 < p \leq 0.05$
Highly Significant: $p < 0.01$

Graphical display of trend results are presented in the maps provided in **Attachment B**. Each map symbolically represents the trend findings for a single constituent at each monitoring station. Symbology for each monitoring station falls into one of three categories, 1) not sampled, 2) no significant trend detected, and 3) trend detected. For all stations where a trend was detected, the stations are symbolized with graduated arrows, with the direction and size of the symbol indicating the direction and magnitude of the trend calculated.

6.1 Nutrient Trend Results by Monitoring Station

Results of the seasonal Mann-Kendall trend test for TN, TSIN, TP, SRP, and Mann-Kendall trend test for maximum and mean benthic chlorophyll-a stations in the Clark Fork River 1998–2017 dataset are presented in **Table 6-1** and **Figure 6-1**. Program outputs and plots from R of these results are provided in **Attachment C.** Results of the nutrient trends analysis for Clark Fork River monitoring stations in the 1998-2017 dataset include:

- Monitoring Station CRF-2.5: a highly significant decreasing trend in TN and TSIN; a highly significant increasing trend in TP and SRP
- Monitoring Station CFR-07: no trends detected for TN, TSIN, TP, SRP, maximum benthic chlorophyll-a or mean benthic chlorophyll-a
- Monitoring Station CFR-09: a marginally significant decreasing trend in TP; no trend for TN, TSIN, SRP, maximum benthic chlorophyll-a or mean benthic chlorophyll-a
- Monitoring Station CFR-10: a marginally significant decreasing trend in TP and SRP; no trend for TN, TSIN, maximum benthic chlorophyll-a or mean benthic chlorophyll-a
- Monitoring Station CFR-12: a marginally significant decreasing trend in TP, maximum benthic chlorophyll-a, and mean benthic chlorophyll-a; no trend for TN, TSIN, or SRP
- Monitoring Station CFR-15.5: a marginally significant decreasing trend in TSIN and TP; a highly significant decreasing trend in SRP; no trend for TN, maximum benthic chlorophyll-a or mean benthic chlorophyll-a
- Monitoring Station CFR-18: a highly significant decreasing trend in TN, TSIN, TP, SRP, and mean benthic chlorophyll-a; a marginally significant decreasing trend in maximum benthic chlorophyll-a
- Monitoring Station CFR-22: a highly significant decreasing trend in TP and SRP; a marginally significant decreasing trend in mean benthic chlorophyll-a and maximum benthic chlorophyll-a; no trend in TN or TSIN
- Monitoring Station CFR-25: a significant increasing trend in TSIN; a marginally significant decreasing trend in TP; a significant decreasing trend in maximum benthic chlorophyll-a; no trend in TN, SRP, or mean benthic chlorophyll-a
- Monitoring Station CFR-28: a significant increasing trend in TN; a significant decreasing trend in TP; no trend in TSIN or SRP
- Monitoring Station CFR-29: a significant increasing trend in TN; a highly significant decreasing trend in TSIN; no trend in TP or SRP
- Monitoring Station CFR-30: a highly significant decreasing trend in TSIN; a marginally significant decreasing trend in TP and SRP; no trend in TN

Table 6-1. Results and Findings of Seasonal Mann-Kendall Trend Test for TN, TSIN, TP, SRP and Mann-Kendall Trend Test for Mean Benthic Chlorophyll-a, and Maximum Benthic Chlorophyll-a for $\alpha = 0.1$ at all Monitoring Stations, 1998-2017

Nutrient	$p-value$ (Two-tailed)	Interpretation H_0 : There is no trend in the series H_a : There is a trend in the series	S'	Trend Direction	Trend Magnitude
Monitoring Station CFR-2.5, Silver Bow Creek at Opportunity					
TN	0.0000	$p < 0.1$, Reject H_0 and Accept H_a	-220	Decreasing	Highly Significant
TSIN	0.0005	$p < 0.1$, Reject H_0 and Accept H_a	-188	Decreasing	Highly Significant
TP	0.0042	$p < 0.1$, Reject H_0 and Accept H_a	154	Increasing	Highly Significant
SRP	0.0000	$p < 0.1$, Reject H_0 and Accept H_a	251	Increasing	Highly Significant
Monitoring Station CFR-07, Clark Fork River below Warm Springs Creek					
TN	0.9851	$p > 0.1$, Cannot reject H_0	2	Not Detected	-
TSIN	0.1601	$p > 0.1$, Cannot reject H_0	-76	Not Detected	-
TP	0.5615	$p > 0.1$, Cannot reject H_0	32	Not Detected	-
SRP	0.1350	$p > 0.1$, Cannot reject H_0	75	Not Detected	-
Monitoring Station CFR-09, Clark Fork River at Deer Lodge					
TN	0.5870	$p > 0.1$, Cannot reject H_0	-30	Not Detected	-
TSIN	0.2095	$p > 0.1$, Cannot reject H_0	68	Not Detected	-
TP	0.0537	$p < 0.1$, Reject H_0 and Accept H_a	-104	Decreasing	Marginally Significant
SRP	0.6278	$p > 0.1$, Cannot reject H_0	25	Not Detected	-
Mean Chlorophyll-a	0.6265	$p > 0.1$, Cannot reject H_0	16	Not Detected	-
Maximum Chlorophyll-a	0.5376	$p > 0.1$, Cannot reject H_0	20	Not Detected	-
Monitoring Station CFR-10, Clark Fork River above Little Blackfoot River					
TN	0.7219	$p > 0.1$, Cannot reject H_0	-20	Not Detected	-
TSIN	0.7502	$p > 0.1$, Cannot reject H_0	-18	Not Detected	-
TP	0.0883	$p < 0.1$, Reject H_0 and Accept H_a	-92	Decreasing	Marginally Significant
SRP	0.0684	$p > 0.1$, Cannot reject H_0	-89	Decreasing	Marginally Significant

Table 6-1. Results and Findings of Seasonal Mann-Kendall Trend Test for TN, TSIN, TP, SRP and Mann-Kendall Trend Test for Mean Benthic Chlorophyll-a, and Maximum Benthic Chlorophyll-a for $\alpha = 0.1$ at all Monitoring Stations, 1998-2017

Nutrient	$p - value$ (Two-tailed)	Interpretation H_0: There is no trend in the series H_a: There is a trend in the series	S'	Trend Direction	Trend Magnitude
Mean Chlorophyll-a	0.4751	$p > 0.1$, Cannot reject H_0	16	Not Detected	-
Maximum Chlorophyll-a	0.3468	$p > 0.1$, Cannot reject H_0	20	Not Detected	-
Monitoring Station CFR-12, Clark Fork River at Bonita					
TN	0.4651	$p > 0.1$, Cannot reject H_0	-40	Not Detected	-
TSIN	0.8368	$p > 0.1$, Cannot reject H_0	-12	Not Detected	-
TP	0.0815	$p < 0.1$, Reject H_0 and Accept H_a	-94	Decreasing	Marginally Significant
SRP	0.1961	$p > 0.1$, Cannot reject H_0	-65	Not Detected	-
Mean Chlorophyll-a	0.0855	$p < 0.1$, Reject H_0 and Accept H_a	-54	Decreasing	Marginally Significant
Maximum Chlorophyll-a	0.0855	$p < 0.1$, Reject H_0 and Accept H_a	-54	Decreasing	Marginally Significant
Monitoring Station CFR-15.5, Clark Fork River above Missoula					
TN	0.9254	$p > 0.1$, Cannot reject H_0	-6	Not Detected	-
TSIN	0.0692	$p < 0.1$, Reject H_0 and Accept H_a	-98	Decreasing	Marginally Significant
TP	0.0637	$p < 0.1$, Reject H_0 and Accept H_a	-100	Decreasing	Marginally Significant
SRP	0.0060	$p < 0.1$, Reject H_0 and Accept H_a	-137	Decreasing	Highly Significant
Mean Chlorophyll-a	0.4751	$p > 0.1$, Cannot reject H_0	-23	Not Detected	-
Maximum Chlorophyll-a	0.8710	$p > 0.1$, Cannot reject H_0	6	Not Detected	-
Monitoring Station CFR-18, Clark Fork River below Missoula					
TN	0.0000	$p < 0.1$, Reject H_0 and Accept H_a	-262	Decreasing	Highly Significant
TSIN	0.0000	$p < 0.1$, Reject H_0 and Accept H_a	-312	Decreasing	Highly Significant
TP	0.0000	$p < 0.1$, Reject H_0 and Accept H_a	-262	Decreasing	Highly Significant
SRP	0.0000	$p < 0.1$, Reject H_0 and Accept H_a	-221	Decreasing	Highly Significant
Mean Chlorophyll-a	0.0058	$p < 0.1$, Reject H_0 and Accept H_a	-86	Decreasing	Highly Significant
Maximum Chlorophyll-a	0.0855	$p < 0.1$, Reject H_0 and Accept H_a	-54	Decreasing	Marginally Significant

Table 6-1. Results and Findings of Seasonal Mann-Kendall Trend Test for TN, TSIN, TP, SRP and Mann-Kendall Trend Test for Mean Benthic Chlorophyll-a, and Maximum Benthic Chlorophyll-a for $\alpha = 0.1$ at all Monitoring Stations, 1998-2017

Nutrient	$p - value$ (Two-tailed)	Interpretation H_0 : There is no trend in the series H_a : There is a trend in the series	S'	Trend Direction	Trend Magnitude
Monitoring Station CFR-22, Clark Fork River and Huson					
TN	0.3394	$p > 0.1$, Cannot reject H_0	-52	Not Detected	-
TSIN	0.4425	$p > 0.1$, Cannot reject H_0	-42	Not Detected	-
TP	0.0000	$p < 0.1$, Reject H_0 and Accept H_a	-222	Decreasing	Highly Significant
SRP	0.0000	$p < 0.1$, Reject H_0 and Accept H_a	-221	Decreasing	Highly Significant
Mean Chlorophyll-a	0.0688	$p < 0.1$, Reject H_0 and Accept H_a	-57	Decreasing	Marginally Significant
Maximum Chlorophyll-a	0.0736	$p < 0.1$, Reject H_0 and Accept H_a	-56	Decreasing	Marginally Significant
Monitoring Station CFR-25, Clark Fork River above Flathead					
TN	0.3208	$p > 0.1$, Cannot reject H_0	54	Not Detected	-
TSIN	0.0450	$p < 0.1$, Reject H_0 and Accept H_a	108	Increasing	Significant
TP	0.0883	$p < 0.1$, Reject H_0 and Accept H_a	-92	Decreasing	Marginally Significant
SRP	0.4671	$p > 0.1$, Cannot reject H_0	-37	Not Detected	-
Mean Chlorophyll-a	0.1350	$p > 0.1$, Cannot reject H_0	-47	Not Detected	-
Maximum Chlorophyll-a	0.0348	$p < 0.1$, Reject H_0 and Accept H_a	-66	Decreasing	Significant
Monitoring Station CFR-28, Clark Fork River below Thompson Falls					
TN	0.0280	$p < 0.1$, Reject H_0 and Accept H_a	113	Increasing	Significant
TSIN	0.4898	$p > 0.1$, Cannot reject H_0	37	Not Detected	-
TP	0.0460	$p < 0.1$, Reject H_0 and Accept H_a	-105	Decreasing	Significant
SRP	0.6892	$p > 0.1$, Cannot reject H_0	-15	Not Detected	-
Monitoring Station CFR-29, Clark Fork River at Noxon Bridge					
TN	0.0341	$p < 0.1$, Reject H_0 and Accept H_a	109	Increasing	Significant
TSIN	0.0004	$p < 0.1$, Reject H_0 and Accept H_a	-185	Decreasing	Highly Significant
TP	0.9084	$p > 0.1$, Cannot reject H_0	7	Not Detected	-
SRP	0.7317	$p > 0.1$, Cannot reject H_0	13	Not Detected	-

Table 6-1. Results and Findings of Seasonal Mann-Kendall Trend Test for TN, TSIN, TP, SRP and Mann-Kendall Trend Test for Mean Benthic Chlorophyll-a, and Maximum Benthic Chlorophyll-a for $\alpha = 0.1$ at all Monitoring Stations, 1998-2017					
Nutrient	$p - value$ **(Two-tailed)**	**Interpretation** H_0 **: There is no trend in the series** H_a **: There is a trend in the series**	S'	**Trend Direction**	**Trend Magnitude**
Monitoring Station CFR-30, Clark Fork River below Cabinet Gorge Dam					
TN	0.2092	$p > 0.1$, Cannot reject H_0	65	Not Detected	-
TSIN	0.0010	$p < 0.1$, Reject H_0 and Accept H_a	-173	Decreasing	Highly Significant
TP	0.0504	$p < 0.1$, Reject H_0 and Accept H_a	-103	Decreasing	Marginally Significant
SRP	0.0975	$p < 0.1$, Reject H_0 and Accept H_a	-81	Decreasing	Marginally Significant

6.2 Summary of Nutrient Trends

The results of the Clark Fork River nutrient and chlorophyll-a time trends analysis, 1998–2017, found some discernable trends with varying degrees of significance and direction within the dataset. Findings of the trends analysis are provided graphically as maps in **Attachment B** for all analyzed constituents at all monitoring stations. **Figure 6-1** summarizes the results of the Clark Fork River nutrient time trends analyses, including an indication of directionality and magnitude for detected trends.

The trend analysis for summertime TN found no trend detected at eight of the twelve Clark Fork River monitoring stations. Highly significant decreasing trends were detected at CFR-2.5 and CFR-18. Significant increasing trends were detected at CFR-28 and CFR-29.

The trend analysis for summertime TSIN found no trend detected at six of the twelve Clark Fork River monitoring stations. Highly significant decreasing trends were detected at CFR-2.5, CFR-18, CFR-29, and CFR-30. A marginally significant decreasing trend was detected at CFR-15.5. There was a significant increasing trend detected at CFR-25.

The trends analysis for summertime TP yielded the most trends and the most decreasing trends. Trends were detected at ten of the twelve Clark Fork River monitoring stations, including nine decreasing and one increasing trends. Of the decreasing trends, two were highly significant (CFR-18 and CFR-22), one was significant (CFR-28), and six were marginally significant (CFR-09, CFR-10, CFR-12, CFR-15.5, CFR-25, and CFR-30). A highly significant increasing trend was detected at CFR-2.5.

The trends analysis for summertime SRP detected trends at six monitoring locations. Highly significant decreasing trends were detected at CFR-15.5, CFR-18, and CFR-22. Marginally significant decreasing trends were detected at CFR-10 and CFR-30. One highly significant increasing trend was detected at CFR-2.5. SRP was not monitored at Station CFR-28 and CFR-29 from 2008-2012.

The trend analysis for mean and maximum chlorophyll-a detected no trends at three of the seven monitoring stations. Marginally significant decreasing trends for chlorophyll-a summertime mean and maximum were detected at CFR-12 and CFR-22. At Station CFR-18, the trend analysis found a highly significant decreasing trend in mean chlorophyll-a and a marginally significant decreasing trend in maximum chlorophyll-a. At Station CFR-25, a significant decreasing trend in maximum chlorophyll-a was detected, but no trend in mean chlorophyll-a. There were no increasing trends detected for chlorophyll-a.

Spatially, the five monitoring stations in the upper Clark Fork River (headwaters to confluence with Blackfoot River), represented by stations CFR-2.5 to CFR-12, were found to have eight decreasing nutrient and chlorophyll-a trends and two increasing nutrient time trends. The four monitoring stations in the middle Clark Fork River (confluence Blackfoot River to confluence Flathead River), represented by stations CFR-15.5 to CFR-25, were found to have 15 decreasing nutrient and chlorophyll-a time trends and one increasing time trend. Eight of the decreasing time trends in the middle Clark Fork River are considered to be highly significant decreasing trends. Notably, Station CFR-18, Clark Fork River below Missoula, had decreasing time trends for all constituents analyzed, including highly significant decreasing trends for TN, TSIN, TP, SRP and mean chlorophyll-a. The three monitoring stations in the lower Clark Fork River (confluence with Flathead River to below Cabinet Gorge Dam), represented by stations, CFR-28 to CFR-30, were found to have five decreasing and two increasing nutrient time trends.

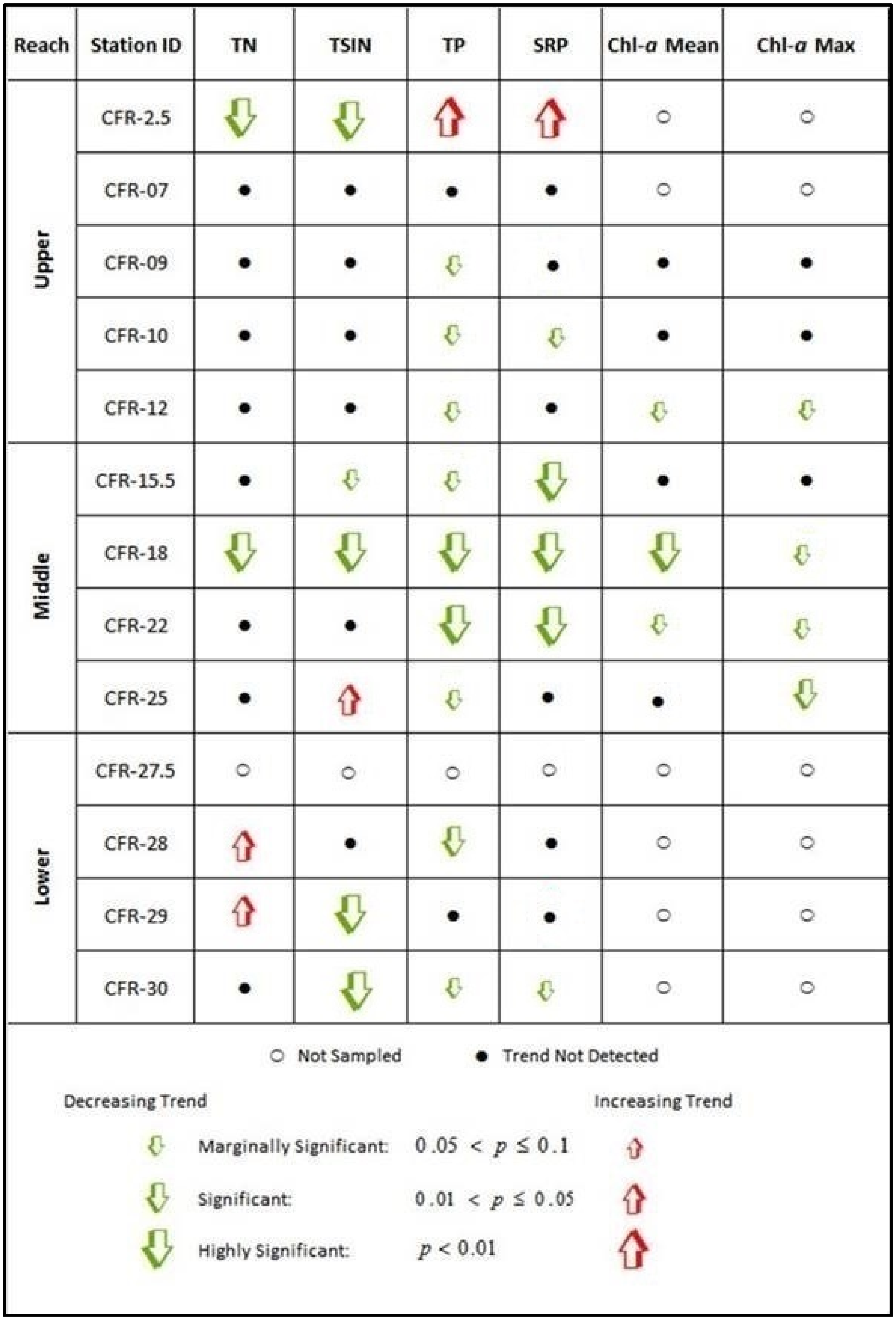

Figure 6-1. Summary of Nutrient and Chlorophyll-a Trends for the Clark Fork River Dataset, 1998–2017, with Respective Significance Levels (Helsel and Hirsch 2002)**. Note: Data collection at Monitoring Station CFR-27.5 ceased in 2012. SRP was not collected at CFR-28 or CFR-29 from 2008-2012.**

6.3 Discussion

The nutrient time trends analysis provides a means by which to evaluate the effectiveness of nutrient reduction activities in the basin. Since the effectiveness of point source nutrient reduction activities are more straight forward to evaluate than non-point source nutrient reduction activities they are the focus of this discussion.

Multiple nutrient reduction activities have taken place in the upper Clark Fork River and its headwaters. These activities include construction of stormwater detention basins at the Butte wastewater treatment facility in 2011 and recent wastewater treatment upgrades at the Butte (2016) and City of Deer Lodge (2017) facilities. Additionally, extensive stream bank restoration efforts to remove contaminated sediments and restore floodplain connectivity have occurred along the upper river through state and federal programs. The most significant trends in the upper river were found in Silver Bow Creek at station CFR-2.5. While all nutrient levels remain high, this work found highly significant decreasing trends in TN and TSIN, which may be attributed to activities completed at the Butte wastewater treatment facility, which reduced TN and TP effluent concentrations by about 80%, and restoration efforts in the headwaters area upper river. The cause of the highly significant increasing trends for TP and SRP at the same site is unclear. DEQ is investigating a number of potential sources of TP and SRP above this station. At stations from Deer Lodge downstream to Bonita (Beavertail Hill), TP was found to have a decreasing trend. It is unclear if the decrease in TP at these sites is due to any specific nutrient reduction activity or if it is a cumulative effect. The City of Deer Lodge wastewater treatment facility became operational in 2017 and will need additional monitoring to evaluate its effectiveness.

In the middle Clark Fork River, the highly significant decreasing trends for all nutrients at station CFR-18, Clark Fork River at Missoula, demonstrate that nutrient reduction activities taken by the City of Missoula and Missoula County have been very effective in reducing the concentration of instream nutrients and benthic algae levels. The activities primarily include upgrades at the Missoula wastewater treatment facility and the connection of thousands of individual septic systems to municipal treatment. The decreasing trends in TP and SRP at Huson (station CFR-22) are likely due to the improvements made at the Missoula wastewater treatment facility as well as the 2010 closure of Smurfit Stone. Downstream at station CFR-25, at the Clark Fork River above the Flathead River, this work found an increasing trend for TSIN. Beyond this trend recent TSIN values in the last year or two are notably higher than the previous record. It is unclear what may be causing these higher concentrations.

No major point source nutrient reduction activities have taken place in the lower Clark Fork River, although multiple non-point source projects have been completed or are in progress. Water quality and hydrology in this reach of the river is largely influenced by the inflow of a major tributary, the Flathead River, and three hydroelectric dams at Thompson Falls, Noxon Rapids, and Cabinet Gorge. This work found increasing trends of TN at stations CFR-28 and CFR-29. These were the only increasing trends for TN found among all of the monitoring stations and authors believe these results should be regarded with caution, as discussed further below. This work found decreasing trends of TSIN, TP, and SRP at station CFR-30, which suggests that the compounding efforts of nutrient reduction activities within the basin have, overall, improved nutrient water quality in the watershed over the twenty-year monitoring period.

There are a number of factors that have potential to affect the results of the time trends analysis. These factors include sample size, number and proportion of non-detect results, changes in analytical methods, methods of data reduction, analytical detection and reporting limits, and data outliers. To the extent possible, measures were taken by the monitoring program to assemble a reliable dataset for this report. These measures include consistent monitoring program sampling and analysis protocols, standard analytical methods, and a thorough data quality assurance-quality control review and data validation process prior to approval and upload of data. The data set provided by DEQ underwent quality review process that involved numerous interested parties to assure a reliable basis for statistical analysis. Guidance was provided by DEQ during this trends analysis regarding how to handle non-detect results, methods of data reduction, review of analytical limits, and evaluation and treatment of data outliers. Methods of data reduction and the trends analysis followed guidance provided by the DEQ project manager and other staff. Additionally, methods of data reduction and trends analysis were consistent with USGS methods (Helsel and Hirsch 2002) and with previous work (Suplee, et al. 2012).

Similar to previous work (Suplee, et al. 2012), non-detect values were assigned values at one-half the lower reporting limit. There is potential for this assumption to skew or bias results of the time trend analysis, particularly if there is a high proportion of non-detect values and/or a wide range of lower reporting limits for a constituent. The previous trends analysis determined that this methodology was unlikely to bias the trends results. In addition, the Mann Kendall test is resistant to non-detects because it is not parametric and uses ranking of values, not the values themselves. For the 1998-2017 dataset, the constituents that may be most affected by this type of bias are TN (calculated values from 1998-2008) and TSIN because they include analytical data with a higher proportion of non-detect results, as presented in **Table 5-1**. Comparatively, the TP and SRP dataset contained relatively few non-detect values. TKN, NO2+NO3 as N, and NH3+NH4 as N were the three constituents with the highest proportions of non-detect values as shown **Table 5-1**. The calculated TN values for the time period 1998-2008 may be influenced by such bias, because since the inception of measuring TN directly (TPN analysis) in 2009, there have been no non-detect results in the reported data. It is unlikely that non-detect values affected trend results for most constituents and most sample sites with the exception noted below for stations CFR-28 and CFR-29.

Laboratory lower reporting limits for all constituents generally remained consistent throughout the monitoring period, as detailed in **Table 4-2** and **Table 4-3**. The largest change in lower reporting limit came from change in TN analysis. From 1998 through 2008 TKN and NO2+NO3 as N were used to calculate TN. Beginning in 2009 the program changed to direct measurement of TN through TPN analysis. For most samples the lower reporting limit was 100 µg/L for TKN and 50 µg/L for TPN. Since most TN results throughout the monitoring period were greater than 100 µg/L, the change in reporting limit alone is not thought to have skewed trend findings for most stations. This is consistent with findings of previous work (Suplee, et al. 2012). Since 2012, efforts to improve consistency in laboratory reporting have been made and it is anticipated that the effects of any past inconsistencies will lessen over time.

Given the discussion above, the authors observed after further investigation, that the program change in how total nitrogen is analyzed and reported may be cause for bias in the trend analysis results for TN especially at stations with overall lower levels of total nitrogen. This is a likely factor in the detected increasing TN trends at CFR-28 and CFR-29. The factors that may contribute to the bias at these stations include: the change in laboratory methods from TKN to TPN, change in laboratory lower reporting limits, and the higher proportion of non-detect values in earlier data where TN was calculated at these particular sites. This bias is evident in review of scatter plots of nutrients versus time provided in **Attachment C** (note stations CFR-28 and CFR-29) which appear to show a shift in the TN data beginning around 2009 to 2010. Even though increasing trends for TN were found at the two stations, the TN concentrations at these stations remain relatively low (<300 µg/l).

Since data were validated through quality assurance and quality control processes directed by the monitoring program prior to inclusion in the dataset provided by DEQ, testing for outliers was not completed as part of this trends analysis. There were two TN values from 1998 that were removed from the dataset after consultation with DEQ. These values were one to two orders of magnitude greater that the rest of the dataset. With consultation with DEQ, TP and SRP values from 2016 at CFR-9 were rejected and excluded from the trends analysis because they failed the logic test (dissolved fraction greater than total concentration). Additionally, the trend analysis used average monthly values, so anomalous values would be smoothed out to reduce the potential of bias of the trend results. Only one monthly sample was collected in the lower Clark Fork River stations (CFR-28 to CFR-30), so the average value was represented by one grab sample. Two to three monthly samples were collected at stations in the upper and middle Clark Fork River (CFR-2.5 to CFR-25).

There is potential that outliers and suspect data may affect a small number of results of the trends analysis. Outliers include data points that greatly exceed the typical values at a station. Suspect values include occurrences where the dissolved fraction (i.e. TSIN or SRP) exceeded the total concentration (i.e. TN or TP) for a given set. Outliers and suspect values can be identified in the scatter plots of nutrients versus time provided in **Attachment C** and in review of tabulated data used in the trend analysis. In general, it appears that most of the outliers and suspect data occurs in the first half of the dataset (1998 to 2007). Removal of these outliers and suspect data may result in a trend being detected where one was not previously detected, or may result a no trend being detected where one previously was. It is thought that only a few trend results may have been affected had this been done.

7.0 Numeric Nutrient Standards Threshold Exceedance Rate Evaluation

7.1 Total Nitrogen

Results of the numeric nutrient standards threshold exceedance rate comparisons for TN over time periods 1998 to 2007 and 2008 to 2017 are shown below in **Table 7-1** and **Figure 7-1**. The table shows the number of samples collected and the number of samples that exceeded numeric nutrient standard thresholds applicable to the site. The number of samples exceeding the numeric standard dropped from the earlier time period to the later time period at every station except at station CFR-9, Clark Fork River at Deer Lodge. This station had a small (2%) increase in the number of samples exceeding the numeric standard. Stations CFR-10, CFR-12, CFR-15.5, CFR-18, and CFR-22 each had change of at least 25% fewer number of samples that exceeded the numeric standard. Station CFR-18, Clark Fork River below Missoula, had the largest drop (47%); decreasing from 50% of samples exceeding the standard in 1998 to 2007 to 3% of samples exceeding the standard from 2008 to 2017. Notably, these changes do not correlate to the results of the time trends analyses discussed above, except for Station CFR-18.

Table 7-1. Summary Table of Clark Fork River Total Nitrogen Numeric Nutrient Standard Exceedance 1998 to 2017

	TN (Numeric Nutrient Standard: 300 µg/l all stations)						
	1998-2007			2008-2017			
Station	# samples	# samples > standard	% > standard	# samples	# samples > standard	% > standard	Change
CFR-2.5	77	77	100%	72	72	100%	0%
CFR-7	77	39	51%	72	25	35%	-16%
CFR-9	49	34	69%	71	51	72%	2%
CFR-10	77	52	68%	72	30	42%	-26%
CFR-12	49	25	51%	72	16	22%	-29%
CFR-15.5	49	11	22%	72	2	3%	-20%
CFR-18	76	38	50%	71	2	3%	-47%
CFR-22	76	24	32%	72	3	4%	-27%
CFR-25	50	4	8%	72	2	3%	-5%
Total	**580**	**304**	**52%**	**646**	**203**	**31%**	**-21%**

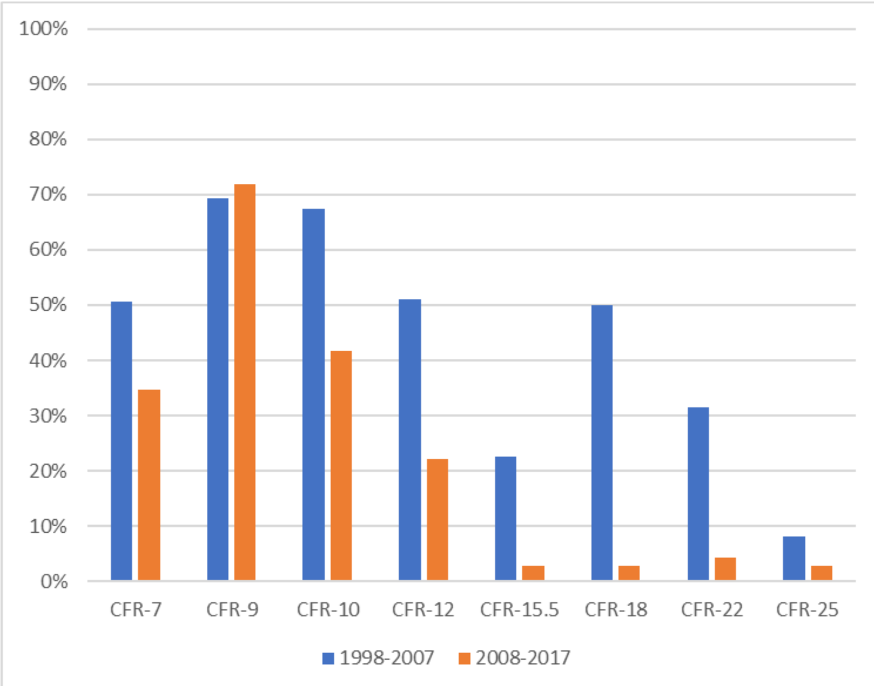

Figure 7-1. Percent Samples Exceeding Total Nitrogen Numeric Nutrient Standard in Clark Fork River

7.2 Total Phosphorus

Results of the numeric nutrient standards assessment for TP over time periods 1998 to 2007 and 2008 to 2017 are shown below in **Table 7-2** and **Figure 7-2**. The number of samples exceeding the numeric standard increased in the upper river (Stations CFR-7, CFR-9, CFR-10, and CFR-12) and decreased at the stations in the middle river (CFR-15.5, CFR-18, and CFR-22) from the earlier time period to the later time period. Station CFR-25, Clark Fork River above Flathead, has had no sample result greater than the numeric TP standard in 122 samples spanning 20 years. Note the numeric TP standard is less stringent in the middle river (CFR-15.5 to CFR-25) at 39 µg/l compared to 20 µg/l in the Clark Fork River above station CFR-15.5. Stations CFR-7 and CFR-9 had the largest increases (18% and 19%, respectively) in the number of samples exceeding the numeric TP standard over the two time periods. Station CFR-18 had the largest decrease in the number of samples exceeding the numeric TP standard at 21%.

Table 7-2. Summary Table of Clark Fork River Total Phosphorus Numeric Nutrient Standard Exceedance 1998 to 2017

Station	TP (Numeric Nutrient Standard: 30 µg/l CFR-2.5, 20 µg/l CFR-7 to CFR-12, 39 µg/l CFR 15.5 to CFR-25)						
	1998-2007			2008-2017			
	# samples	# samples > standard	% > standard	# samples	# samples > standard	% > standard	Change
CFR-2.5	78	78	100%	71	71	100%	0%
CFR-7	78	64	82%	72	72	100%	18%
CFR-9	50	23	46%	72	47	65%	19%
CFR-10	78	64	82%	72	66	92%	10%
CFR-12	49	32	65%	72	49	68%	3%
CFR-15.5	50	4	8%	72	2	3%	-5%
CFR-18	77	18	23%	72	2	3%	-21%
CFR-22	77	3	4%	72	1	1%	-3%
CFR-25	50	0	0%	72	0	0%	0%
Total	587	286	49%	647	310	48%	-1%

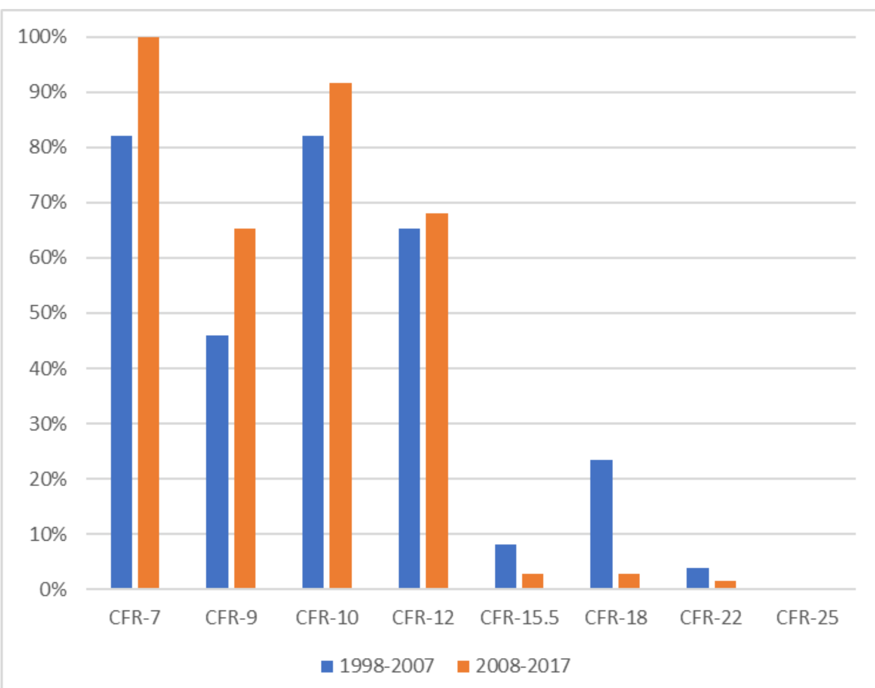

Figure 7-2. Percent Samples Exceeding Total Phosphorus Numeric Nutrient Standard in Clark Fork River

7.3 Chlorophyll-a Summer Mean

Results of the numeric nutrient standards assessment for chlorophyll-a summer mean over time periods 1998 to 2007 and 2008 to 2017 are shown below in **Table 7-3** and **Figure 7-3**. The number of occurrences that the chlorophyll-a summer mean exceeded the numeric standard decreased at six of the seven stations monitored for that parameter. The remaining station, CFR-25, Clark Fork River above Flathead, did not exceed the numeric standard in either time period, so had no change. The two stations with the greatest decrease in the number of occurrences exceeding the chlorophyll-a summer mean numeric standard were stations CFR-15.5 and CFR-18, at decreases of 40% and 50% respectively. The overall number of occurrences exceeding the chlorophyll-a summer mean numeric standard decreased by 26% over the two time periods. Despite this decrease the three upper stations (CFR-9, CFR-10, and CFR-12) exceeded the standard in the majority of the results (90%, 60%, and 70% respectively) in the 2008 to 2017 time period.

Table 7-3. Summary Table of Clark Fork River Chlorophyll-a Summer Mean Numeric Nutrient Standard Exceedance 1998 to 2017

	Chlorophyll-a Summer Mean (Numeric Nutrient Standard: 100 mg/m^2)						
	1998-2007			2008-2017			
Station	# samples	# samples > standard	% > standard	# samples	# samples > standard	% > standard	Change
CFR-9	10	10	100%	10	9	90%	-10%
CFR-10	10	9	90%	10	6	60%	-30%
CFR-12	10	9	90%	10	7	70%	-20%
CFR-15.5	10	5	50%	10	1	10%	-40%
CFR-18	10	9	90%	10	4	40%	-50%
CFR-22	10	3	30%	10	0	0%	-30%
CFR-25	10	0	0%	10	0	0%	0%
Total	70	45	64%	70	27	39%	-26%

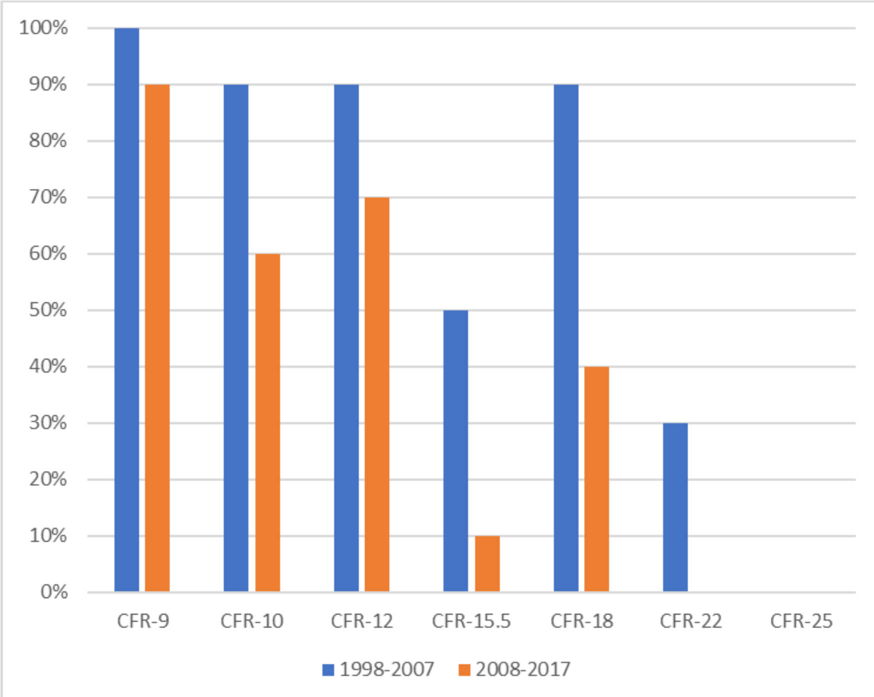

Figure 7-3. Percent Samples Exceeding Chlorophyll-a Summer Mean Numeric Nutrient Standard in Clark Fork River

7.4 Chlorophyll-a Summer Maximum

Results of the numeric nutrient standards assessment for chlorophyll-a summer maximum over time periods 1998 to 2007 and 2008 to 2017 are shown below in **Table 7-4** and **Figure 7-4**. The number of occurrences that the chlorophyll-a summer maximum exceeded the numeric standard decreased at five of the seven stations monitored for that parameter. Station CFR-9 exceeded the chlorophyll-a summer maximum standard nine out of ten times in the 2008 to 2017 period, which is one greater than the 1998 to 2007 period. Station CFR-25 did not exceed the numeric standard in either time period, so had no change. The two stations with the greatest decrease in the number of occurrences exceeding the chlorophyll-a summer mean numeric standard were stations CFR-10 and CFR-18, at decreases of 40% each. Overall the number of occurrences exceeding the chlorophyll-a summer maximum numeric standard at all stations decreased 16% over the two time periods. In the recent time period 2008 to 2017 the chlorophyll-a summer maximum was exceeded in 90% of the results at station CFR-9, 60% at station CFR-12, and 50% at station CFR-18. Stations CFR-15.5 and CFR-22 has each exceeded the chlorophyll-a summer maximum standard only once in twenty years of monitoring.

Table 7-4. Summary Table of Clark Fork River Chlorophyll-a Summer Maximum Numeric Nutrient Standard Exceedance 1998 to 2017

Station	Chlorophyll-a Summer Maximum (Numeric Nutrient Standard: 150 mg/m^2)						
	1998-2007			2008-2017			
	# samples	# samples > standard	% > standard	# samples	# samples > standard	% > standard	Change
CFR-9	10	8	80%	10	9	90%	10%
CFR-10	10	7	70%	10	3	30%	-40%
CFR-12	10	8	80%	10	6	60%	-20%
CFR-15.5	10	1	10%	10	0	0%	-10%
CFR-18	10	9	90%	10	5	50%	-40%
CFR-22	10	1	10%	10	0	0%	-10%
CFR-25	10	0	0%	10	0	0%	0%
Total	70	34	49%	70	23	33%	-16%

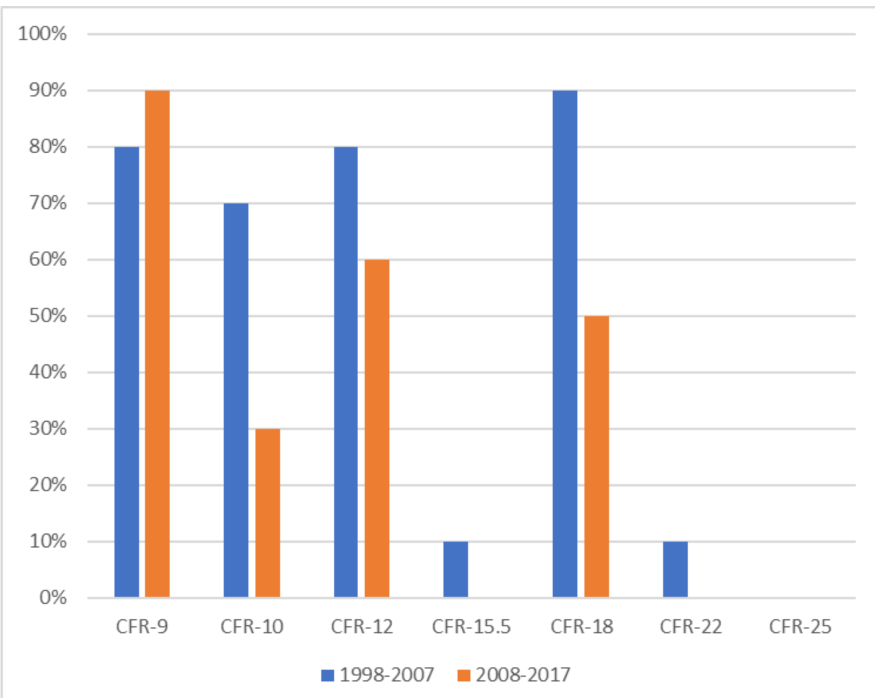

Figure 7-4. Percent Samples Exceeding Chlorophyll-a Summer Maximum Numeric Nutrient Standard in Clark Fork River

7.5 Discussion

In general, the results of this evaluation are consistent with the results of the trends analysis. However, while the number of samples exceeding numeric TP standards in the upper river is greater in the recent time period (2008 to 2017), the results of the time trend analyses discussed above found decreasing trends at stations in the upper river including CFR-9, CFR-10, and CFR-12. Possible explanations for this disparity or others that exist include:

- The potential influence of variations in stream flow on instream nutrient concentrations between the two periods. Review of station specific data showed that TN concentrations generally decreased with increasing stream flow, while TP concentrations generally increased with increasing stream flow (Suplee, et al. 2012).
- Differences in methods of evaluation for nutrient concentrations. The trends analysis is a statistical methodology that used average monthly concentrations and average monthly stream flow, whereas the nutrient standards thresholds evaluation assessed individual sample results which were a function of instantaneous stream flow at the time of sample collection.

8.0 NUTRIENT LOADING RESULTS

Nutrient loading estimates for TP and TN to Lake Pend Oreille from the Clark Fork River from 1998—2017 are presented below in **Table 8-1**. FLUX model input discharge and nutrient concentration files are provided in **Attachment E**.

Included in **Table 8-1** are the annual daily mean flow rate, percent of the average daily mean flow rate at USGS station 12392000, Clark Fork River at Whitehorse Rapids, for the published period of record (1929—2013), and annual inflow volume. Both U.S. customary units and the International System of Units (S.I.) are provided for convenience. Charts of estimated TP and TN loading from the Clark Fork River, 1998—2017, are provided in **Attachment D**. The chart of the estimated TP load also compares annual TP load from Clark Fork River and the Border Agreement TP allocated target load.

Table 8-1. Estimated Total Phosphorus and Total Nitrogen Loads to Lake Pend Oreille from the Clark Fork River 1998–2017, includes Annual Daily Mean Flow Rate, and Annual Inflow Volume

Year	Daily Mean Flow Rate		Inflow Volume		TP Loading		TN Loading	
	CFS	% of Average	hm^3	ac-ft x 1000	Kg x 1000	lbs x 1000	Kg x 1000	lbs x 1000
1998	19,627	89%	17,530	14,212	170.2	375.2	1,955	4,311
1999	22,534	103%	20,125	16,316	229.0	504.9	3,055	6,734
2000	18,584	85%	16,644	13,493	122.8	270.7	1,900	4,189
2001	11,505	52%	10,276	8,331	90.9	200.4	1,535	3,384
2002	23,158	106%	20,683	16,768	235.4	519.0	2,525	5,567
2003	17,576	80%	15,697	12,726	179.2	395.1	2,882	6,354
2004	17,695	81%	15,847	12,847	139.7	308.0	1,848	4,075
2005	17,869	81%	15,959	12,938	159.2	351.1	1,813	3,997
2006	22,417	102%	20,021	16,231	**285.1**	**628.6**	3,401	7,498
2007	18,661	85%	16,667	13,512	158.8	350.2	2,587	5,704
2008	23,101	105%	20,689	16,773	**307.6**	**678.2**	4,050	8,928
2009	19,484	89%	17,402	14,108	215.4	474.8	2,482	5,471
2010	17,996	82%	16,072	13,030	150.4	331.5	2,254	4,969
2011	32,491	148%	29,018	23,525	**528.1**	**1,164.4**	4,842	10,676
2012	26,219	119%	23,481	19,036	**312.0**	**687.8**	3,966	8,743
2013	19,535	89%	17,447	14,144	148.9	328.2	2,279	5,025
2014	25,598	117%	22,799	18,483	**260.5**	**574.3**	3,720	8,200
2015	17,764	81%	15,865	12,862	132.3	291.6	2,179	4,803
2016	18,752	85%	16,794	13,615	141.2	311.3	2,355	5,193
2017	26,461	121%	23,633	19,160	258.5	569.8	3,347	7,379

Notes:
CFS - cubic feet per second *lbs -- pound mass* *TP - Total Phosphorus*
ac-ft - acre feet *hm^3 - cubic hectometer* *Kg - Kilogram* *TN - Total Nitrogen*
Average of mean daily flow rate at USGS gaging station 12392000 Clark Fork at Whitehorse Rapids near Cabinet Idaho for published record 1929-2013 (21,950 CFS)
***Bolded** TP loading values indicate exceedance of the allocated target load of 259,500 kilograms per year*

Nutrient load estimates of TP and TN from the Clark Fork River to Lake Pend Oreille varies from year to year and is related to the mean annual discharge and total volume of inflow from the watershed. As expected, nutrient loads increase with increased mean annual discharge. According to loading estimates, the annual TP load has exceeded the allocated target load of 259,500 kilograms per year, five times since 1998. The allocated target load exceedances occurred in 2006, 2008, 2011, 2012 and 2014. In each of these cases, the mean annual discharge was greater than the long-term mean annual discharge. 2017 was the first year since 2002 when the estimated TP load was been below the target threshold, despite mean annual discharge exceeding the long-term average.

The Border Agreement identifies a short-term exceedance as three consecutive years greater than 110 percent of the target load. No short-term TP load exceedance in any consecutive three-year period since 1998 was identified. Nutrient loading targets have not been established for Clark Fork River TN loading to Lake Pend Oreille.

9.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the results presented above, this report makes the following conclusions:

- Overall, TN concentrations appear to be holding relatively steady at monitoring stations throughout the basin. No trends in TN were detected in eight of twelve monitoring stations. Notably, highly significant decreasing trends for both TN and TSIN concentrations were detected at monitoring stations CFR-2.5, Silver Bow Creek at Opportunity and CFR-18, Clark Fork River below Missoula. The decreases found at CFR-2.5 are likely responses to nutrient reduction activities that have occurred at the Butte wastewater treatment facility and from restoration efforts in the headwaters area.
- With the exception of CFR-2.5, Silver Bow Creek at Opportunity, this work found decreasing trends in summertime TP concentrations throughout the basin.
- While the Butte wastewater treatment plant has demonstrated significant reduction in TP loading (effluent TP concentrations have been reduced about 80%) this work found highly significant increasing trends of TP and SRP at Station CFR-2.5, Silver Bow Creek at Opportunity. DEQ is investigating a number of potential causes of this increasing trend.
- Summertime SRP concentrations since 1998 appear to be decreasing in the middle Clark Fork River.
- The highly significant decreasing trends found for all nutrients at station CFR-18, Clark Fork River at Missoula, demonstrate that nutrient reduction activities taken by the City of Missoula and Missoula County have been very effective in reducing the concentration of instream nutrients and benthic algae levels in the river below Missoula. The effects of these activities appear to extend downstream to station CFR-22, Clark Fork River at Huson, which exhibited highly significant decreasing trends in TP and SRP concentration and marginally significant decreasing trends in chlorophyll-a levels. The 2010 closure of Smurfit Stone may also have contributed to the trend at Huson.
- This work evaluated numeric nutrient standards threshold exceedances over two time periods, 1998 to 2007 and 2008 to 2017. In general, over the two time periods the TN standard threshold exceedance decreased at 20%, while the TP standard threshold exceedance remained about the same (1% increase). Standards threshold exceedance is greatest in the upper river and much less to nearly negligible in the middle river. At the headwaters, Station CFR-2.5, Sliver Bow Creek at Opportunity, every water quality sample collected, 1998 to 2017, has exceeded the current numeric nutrient standards for TN and TP.
- Overall chlorophyll-a mean and maximum standards threshold exceedances decreased 26% and 16%, respectively, over the two time periods in the seven monitoring stations in the upper and middle Clark Fork River.
- In the lower Clark Fork River TSIN concentrations appear to be decreasing with highly significant decreasing trend in TSIN at CFR-29, Clark Fork River at Noxon Bridge, and CFR-30, Clark Fork River below Cabinet Gorge Dam. This, however, is contrasted with significantly increasing trends in TN detected at CFR-28, Clark Fork River below Thompson Falls, and CFR-29, Clark Fork River at Noxon Bridge. The authors believe that these two increasing trends may be biased due to a change in TN laboratory analysis about half way through the monitoring period and should be reevaluated.

- This work found decreasing trends of TSIN, TP, and SRP at station CFR-30, Clark Fork River below Cabinet Gorge Dam, which suggests that the compounding efforts of nutrient reduction activities within the basin have, overall, improved nutrient water quality in the watershed over the twenty-year monitoring period.
- Time trends analysis found benthic algal levels to be holding steady or decreasing at the seven stations monitored for chlorophyll-a.
- Nutrient loading from the Clark Fork River to Lake Pend Oreille varies from year to year and is proportional to the volume of inflow from the watershed. Generally, in years when inflow is in excess of the annual average, the TP load exceeds the allocated target load of 259,500 kilograms per year of Montana-Idaho Border Agreement. The estimated TP load exceeded the allocated target load five times since 1998. The allocated target load exceedances occurred in 2006, 2008, 2011, 2012, and 2014, but there has been no short-term TP load exceedance during the monitoring period.

The following recommendations are made to the CFRWQC to further assess nutrient water quality status in future studies or as part of the next 5-year trends analysis:

- Evaluate factors of the significantly increasing trend found in TSIN concentrations at station CFR-25, Clark Fork River above Flathead.
- Compile and tabulate basin-wide nutrient loads from permitted point sources and estimates of non-point source contributions.
- Estimate summer and/or annual nutrient loads at select stations in the upper and middle river.
- Review and evaluate stream discharge changes and other hydrologic factors and assess their potential effect on nutrient and chlorophyll-a levels.
- Review and discuss changes in nitrogen to phosphorus ratios at select monitoring stations throughout the river.
- Continue the water quality monitoring program as it continues to serve a critical component in evaluating status of the watershed and informing management decisions.
- Consider additional nutrient trends analysis with a truncated dataset. The truncated dataset for TN could range from 2009 to 2017 to remove potential bias of differing analytical methods completed in years 1998 to 2008. Additional data review and data reduction should be considered for the dataset for a number of potential outliers and suspect values that may be present in the earlier data (generally pre-2009).
- Summarize available summertime temperature and dissolved oxygen data since these parameters interact with algae levels to affect habitat quality. Where little data exist, add some stations with temperature and dissolved oxygen monitors.
- Collaborate with IDEQ to evaluate effects of estimated annual nutrient loading to Lake Pend Oreille on water quality in the lake.

Much work has been done in the Clark Fork River basin to reduce and control nutrient impacts to water quality. Point source and non-point source nutrient reduction activities have occurred across the basin, more are planned, and some are already in progress. Nutrient reduction activities in Missoula have resulted in highly significant decreasing trends in all nutrients at the monitoring station below Missoula. Decreasing trends in TP concentrations were found throughout the river. Despite some gains, summer concentrations of TN and TP continue to exceed numeric water quality standards especially in the upper river. The basin-wide nutrient water quality monitoring program that has been in place since 1998 continues to be a critical tool to evaluate effectiveness of nutrient reduction activities. Basin-wide nutrient water quality monitoring should continue into the future so that cumulative, long-term impacts of nutrient reduction activities can be evaluated. The nutrient water quality monitoring program should continue to regularly assess the status and trends of water quality in the Clark Fork River basin so that planners and managers may better direct and focus nutrient reduction efforts in the Clark Fork River basin.

10.0 REFERENCES

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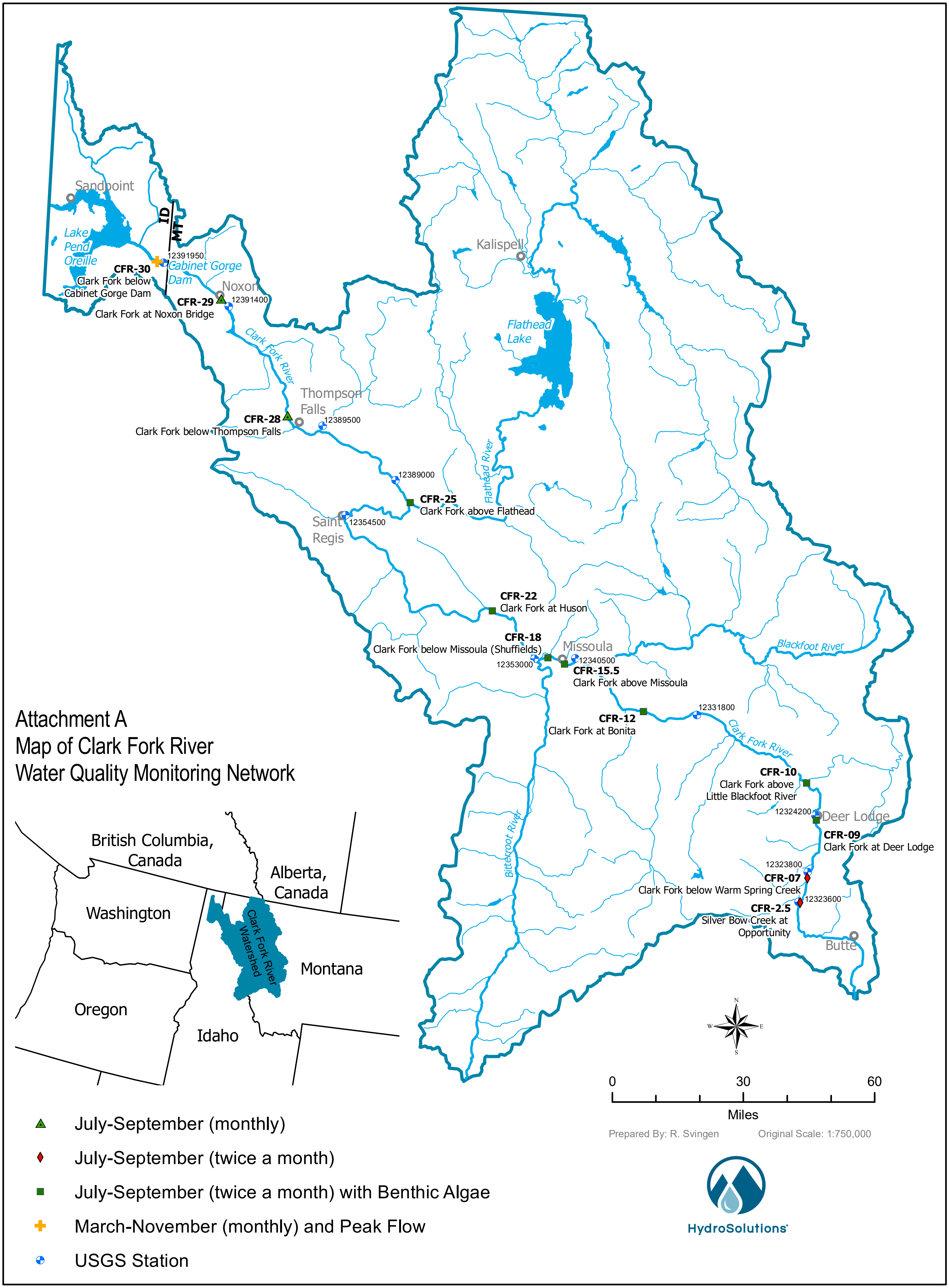
ATTACHMENT A:

Map of Clark Fork Water Quality Monitoring Network

Attachment A
Map of Clark Fork River Water Quality Monitoring Network



ATTACHMENT B:

Clark Fork River, 1998-2017, Time Trend Findings Maps:

Attachment B-1: 1998–2017 Time Trend Findings for Total Nitrogen at Clark Fork River Monitoring Stations

Attachment B-2: 1998–2017 Time Trend Findings for Total Soluble Inorganic Nitrogen at Clark Fork River Monitoring Stations

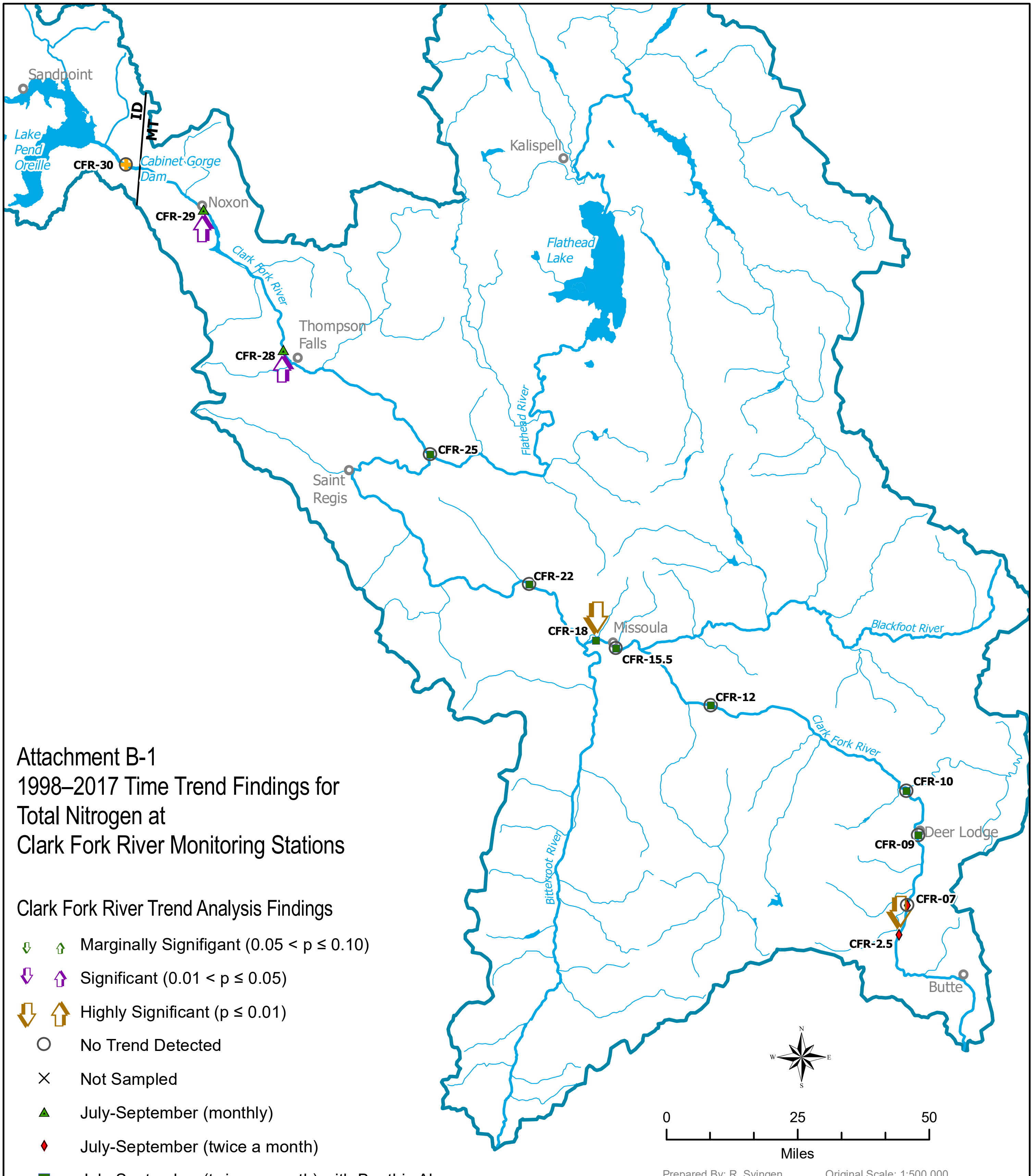
Attachment B-3: 1998–2017 Time Trend Findings for Total Phosphorus at Clark Fork River Monitoring Stations

Attachment B-4: 1998–2017 Time Trend Findings for Soluble Reactive Phosphorus at Clark Fork River Monitoring Stations

Attachment B-5: 1998–2017 Time Trend Findings for Mean Chlorophyll-*a* at Clark Fork River Monitoring Stations

Attachment B-6: 1998–2017 Time Trend Findings for Maximum Chlorophyll-*a* at Clark Fork River Monitoring Stations

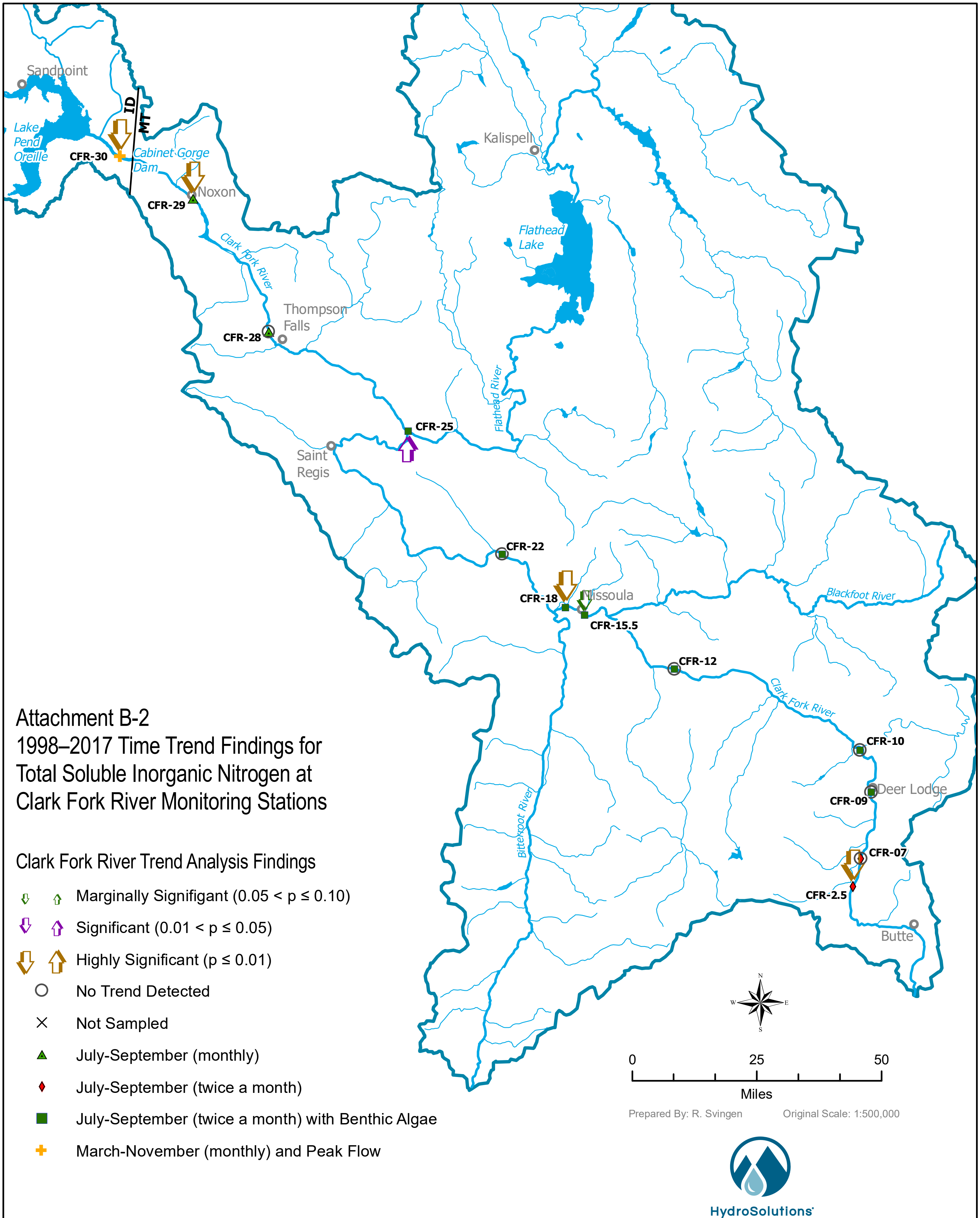
Attachment B-1
1998–2017 Time Trend Findings for Total Nitrogen at Clark Fork River Monitoring Stations



HydroSolutions

Trend findings based on Seasonal Kendall test on residuals from Locally Weighted Scatterplot Smoothing (LOWESS) of average monthly summertime (July-Sept) concentration, plotted against corresponding mean monthly discharge at paired USGS gaging stations. Significance level (alpha) = 0.1. Clark Fork River nutrient dataset, 1998-2017, from Montana Department of Environmental Quality.

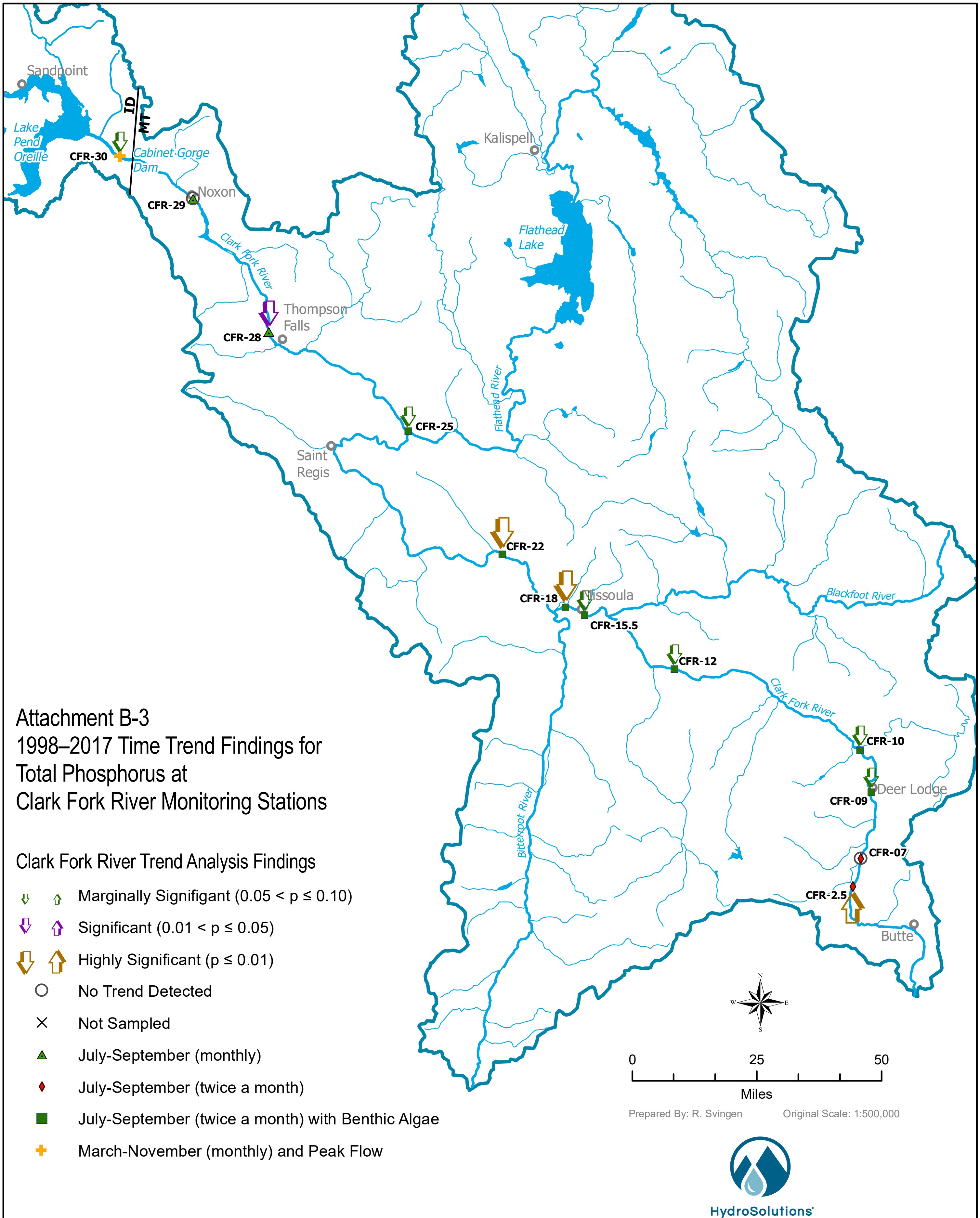
Method Reference: Helsel, D R, and R M Hirsch. Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, chapter A3. USGS, 2002.



Attachment B-2
1998–2017 Time Trend Findings for Total Soluble Inorganic Nitrogen at Clark Fork River Monitoring Stations

Trend findings based on Seasonal Kendall test on residuals from Locally Weighted Scatterplot Smoothing (LOWESS) of average monthly summertime (July-Sept) concentration, plotted against corresponding mean monthly discharge at paired USGS gaging stations. Significance level (alpha) = 0.1. Clark Fork River nutrient dataset, 1998-2017, from Montana Department of Environmental Quality.

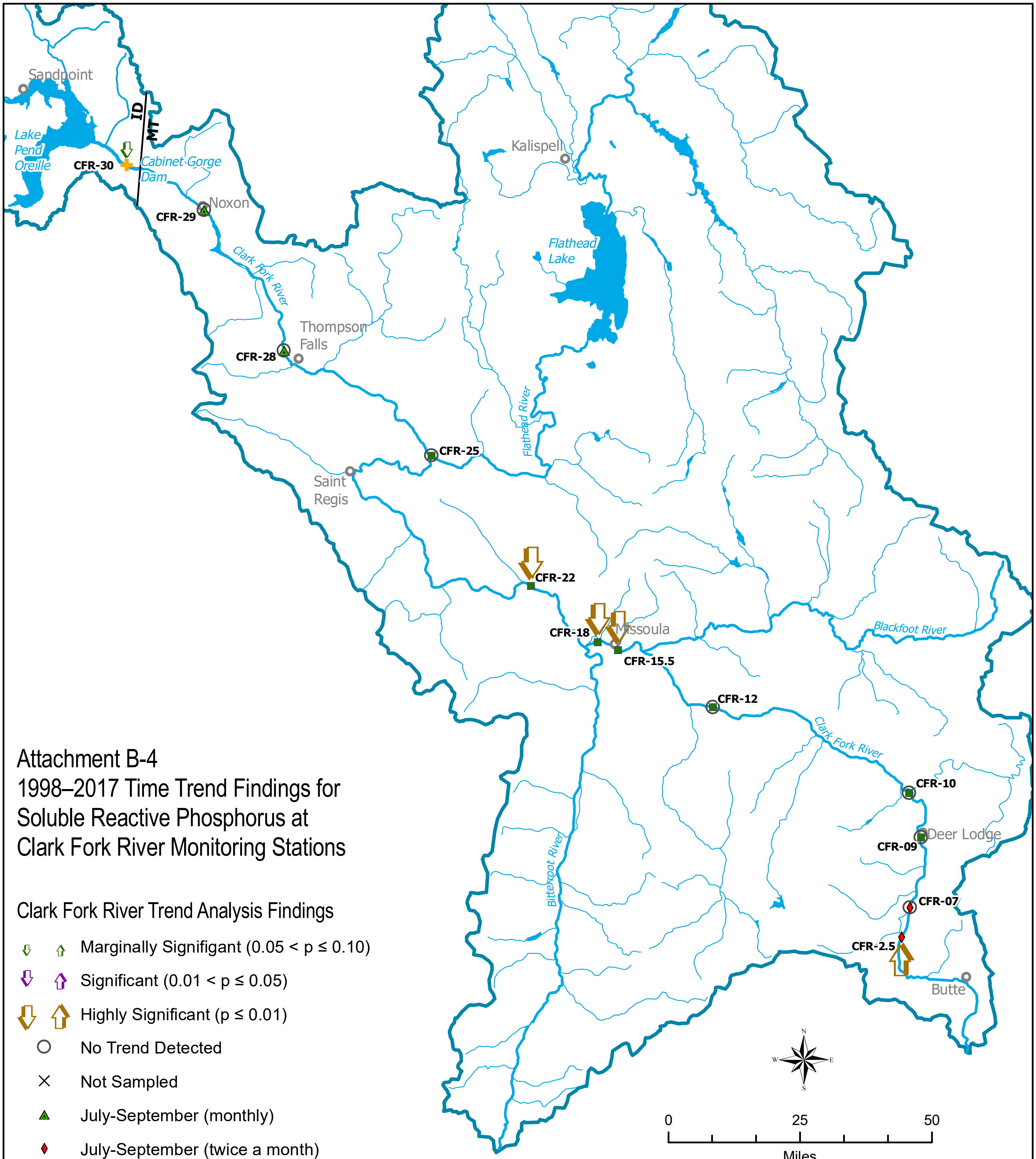
Method Reference: Helsel, D R, and R M Hirsch. Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, chapter A3. USGS, 2002.



Attachment B-3
1998–2017 Time Trend Findings for Total Phosphorus at Clark Fork River Monitoring Stations

Trend findings based on Seasonal Kendall test on residuals from Locally Weighted Scatterplot Smoothing (LOWESS) of average monthly summertime (July-Sept) concentration, plotted against corresponding mean monthly discharge at paired USGS gaging stations. Significance level (alpha) = 0.1. Clark Fork River nutrient dataset, 1998-2017, from Montana Department of Environmental Quality.

Method Reference: Helsel, D R, and R M Hirsch. Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, chapter A3. USGS, 2002.



Attachment B-4
1998–2017 Time Trend Findings for Soluble Reactive Phosphorus at Clark Fork River Monitoring Stations

Clark Fork River Trend Analysis Findings

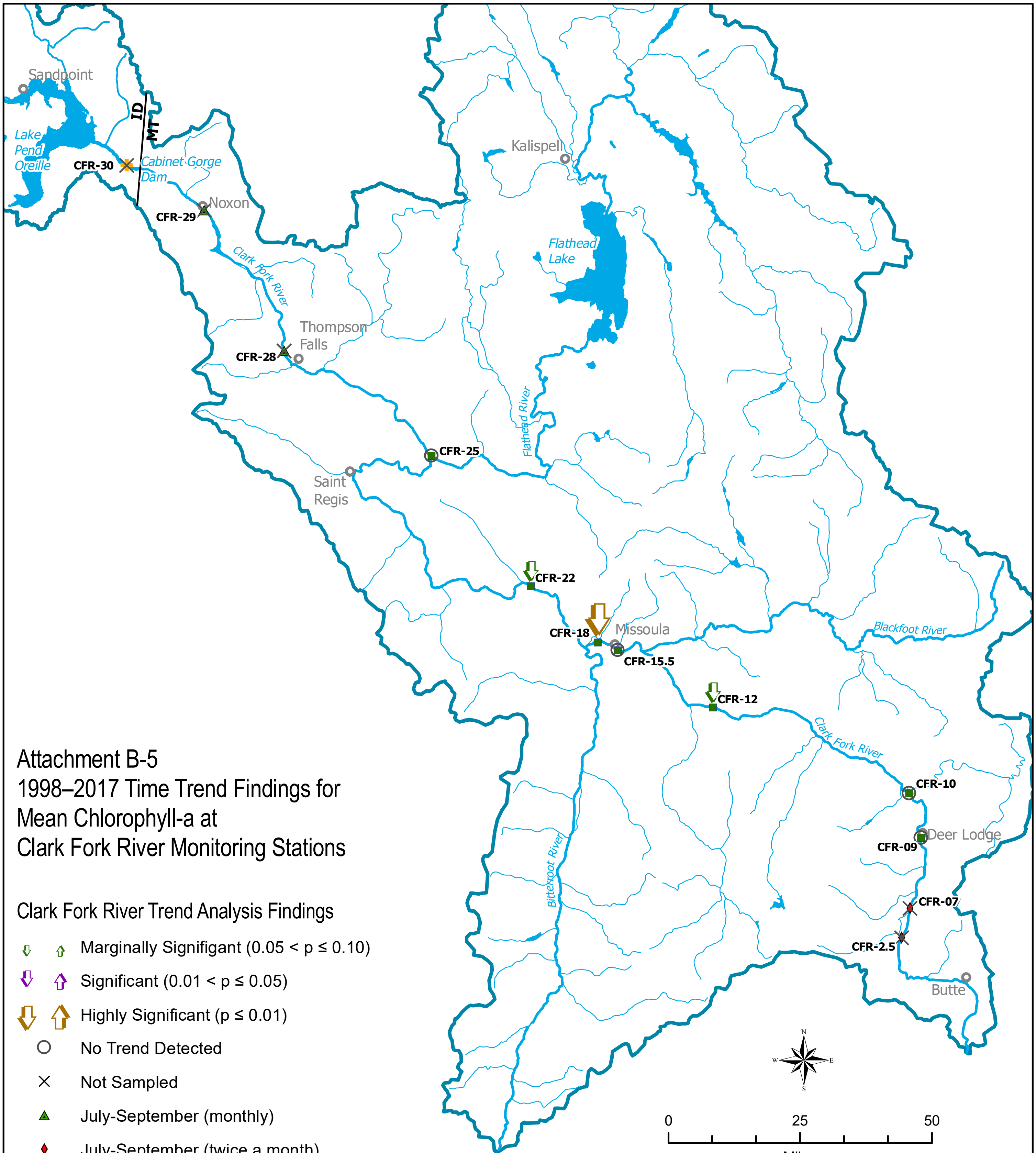
- Marginally Signifigant (0.05 < p ≤ 0.10)
- Significant (0.01 < p ≤ 0.05)
- Highly Significant (p ≤ 0.01)
- No Trend Detected
- Not Sampled
- July-September (monthly)
- July-September (twice a month)
- July-September (twice a month) with Benthic Algae
- March-November (monthly) and Peak Flow

Prepared By: R. Svingen Original Scale: 1:500,000

HydroSolutions

Trend findings based on Seasonal Kendall test on residuals from Locally Weighted Scatterplot Smoothing (LOWESS) of average monthly summertime (July-Sept) concentration, plotted against corresponding mean monthly discharge at paired USGS gaging stations. Significance level (alpha) = 0.1. Clark Fork River nutrient dataset, 1998-2017, from Montana Department of Environmental Quality.

Method Reference: Helsel, D R, and R M Hirsch. Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, chapter A3. USGS, 2002.



Attachment B-5
1998–2017 Time Trend Findings for Mean Chlorophyll-a at Clark Fork River Monitoring Stations

Clark Fork River Trend Analysis Findings

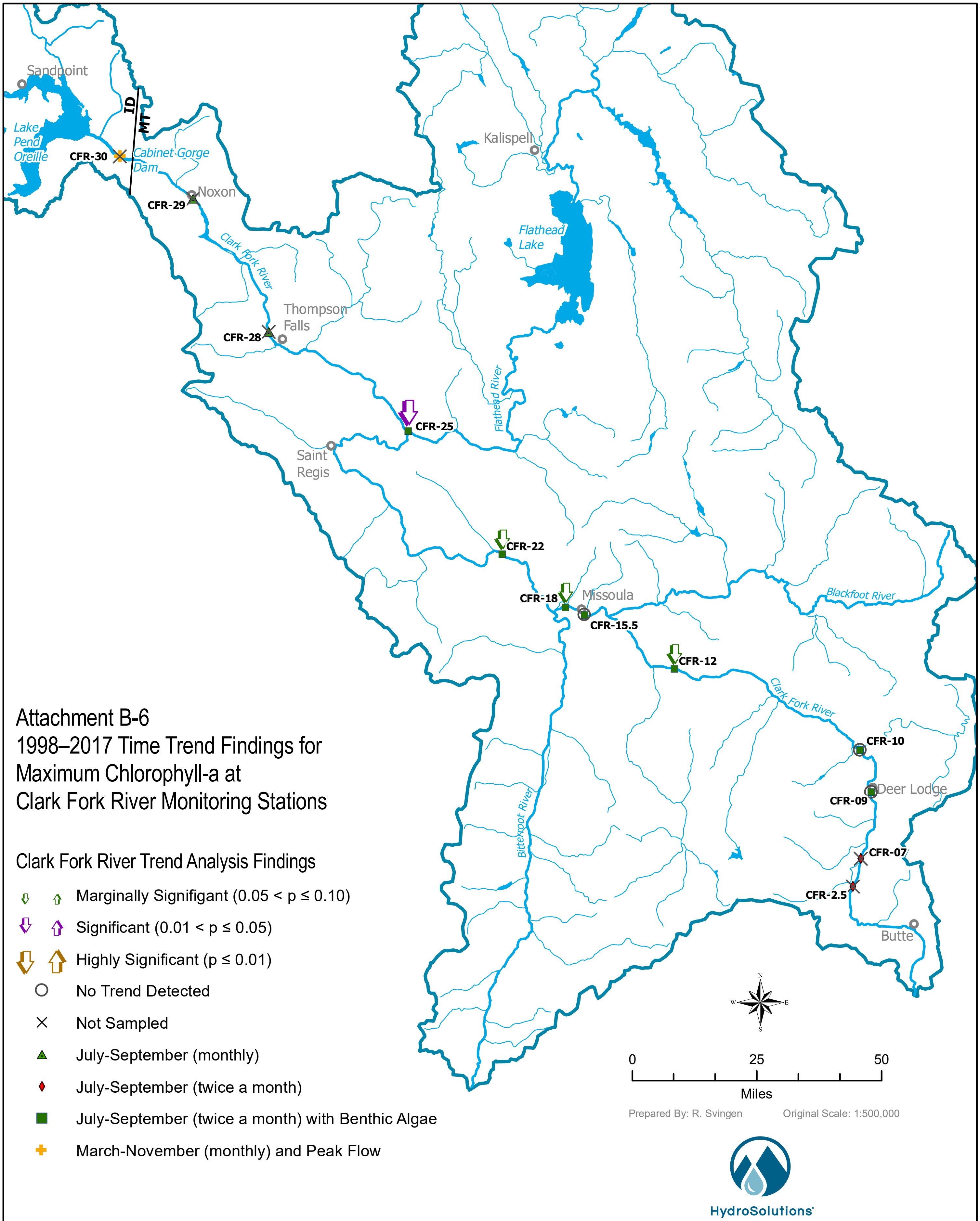
- Marginally Signifigant (0.05 < p ≤ 0.10)
- Significant (0.01 < p ≤ 0.05)
- Highly Significant (p ≤ 0.01)
- No Trend Detected
- Not Sampled
- July-September (monthly)
- July-September (twice a month)
- July-September (twice a month) with Benthic Algae
- March-November (monthly) and Peak Flow

HydroSolutions

Trend findings based on Seasonal Kendall test on residuals from Locally Weighted Scatterplot Smoothing (LOWESS) of average monthly summertime (July-Sept) concentration, plotted against corresponding mean monthly discharge at paired USGS gaging stations. Significance level (alpha) = 0.1. Clark Fork River nutrient dataset, 1998-2017, from Montana Department of Environmental Quality.

Method Reference: Helsel, D R, and R M Hirsch. Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, chapter A3. USGS, 2002.

Attachment B-6
1998–2017 Time Trend Findings for Maximum Chlorophyll-a at Clark Fork River Monitoring Stations



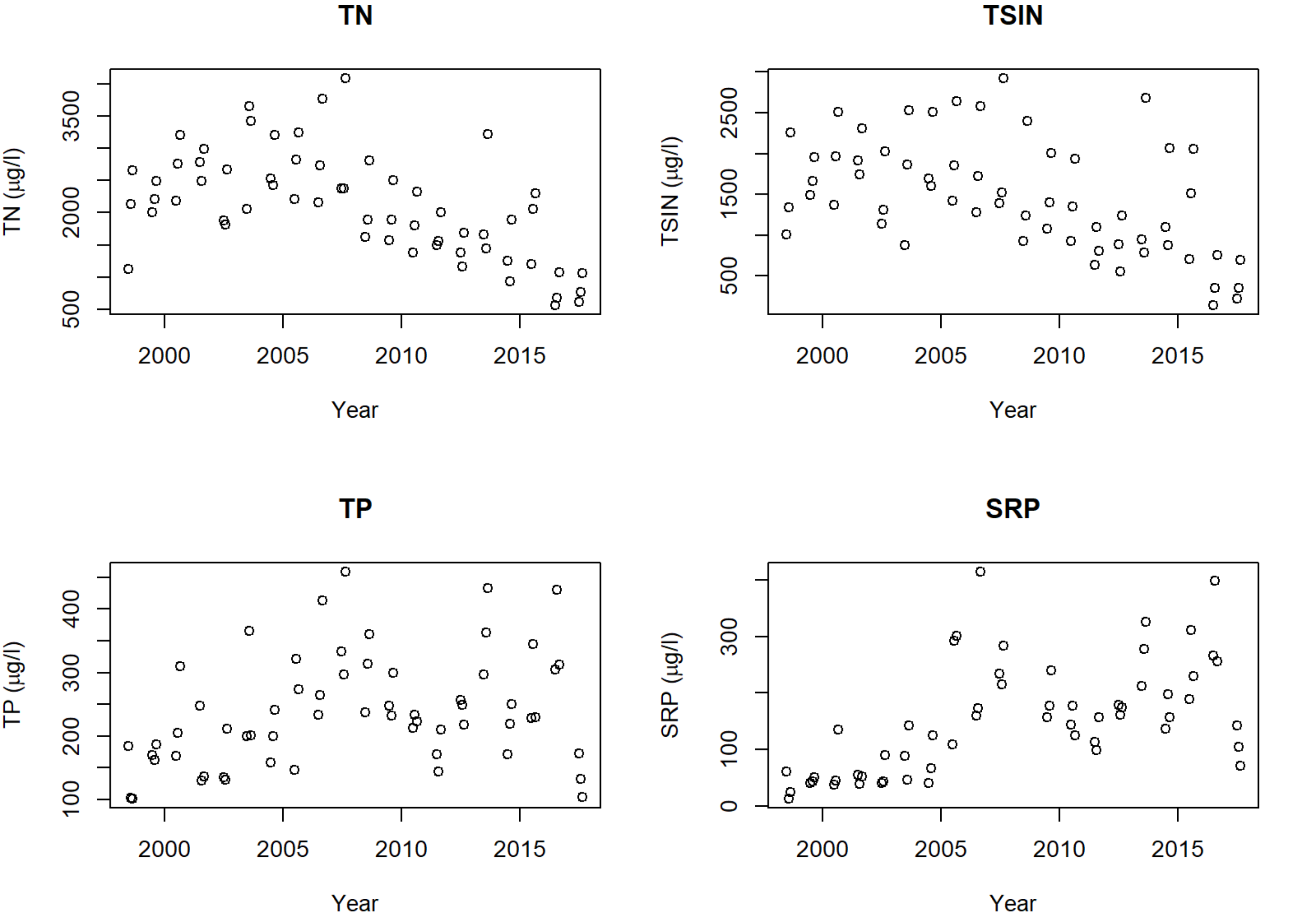
Trend findings based on Seasonal Kendall test on residuals from Locally Weighted Scatterplot Smoothing (LOWESS) of average monthly summertime (July-Sept) concentration, plotted against corresponding mean monthly discharge at paired USGS gaging stations. Significance level (alpha) = 0.1. Clark Fork River nutrient dataset, 1998-2017, from Montana Department of Environmental Quality.

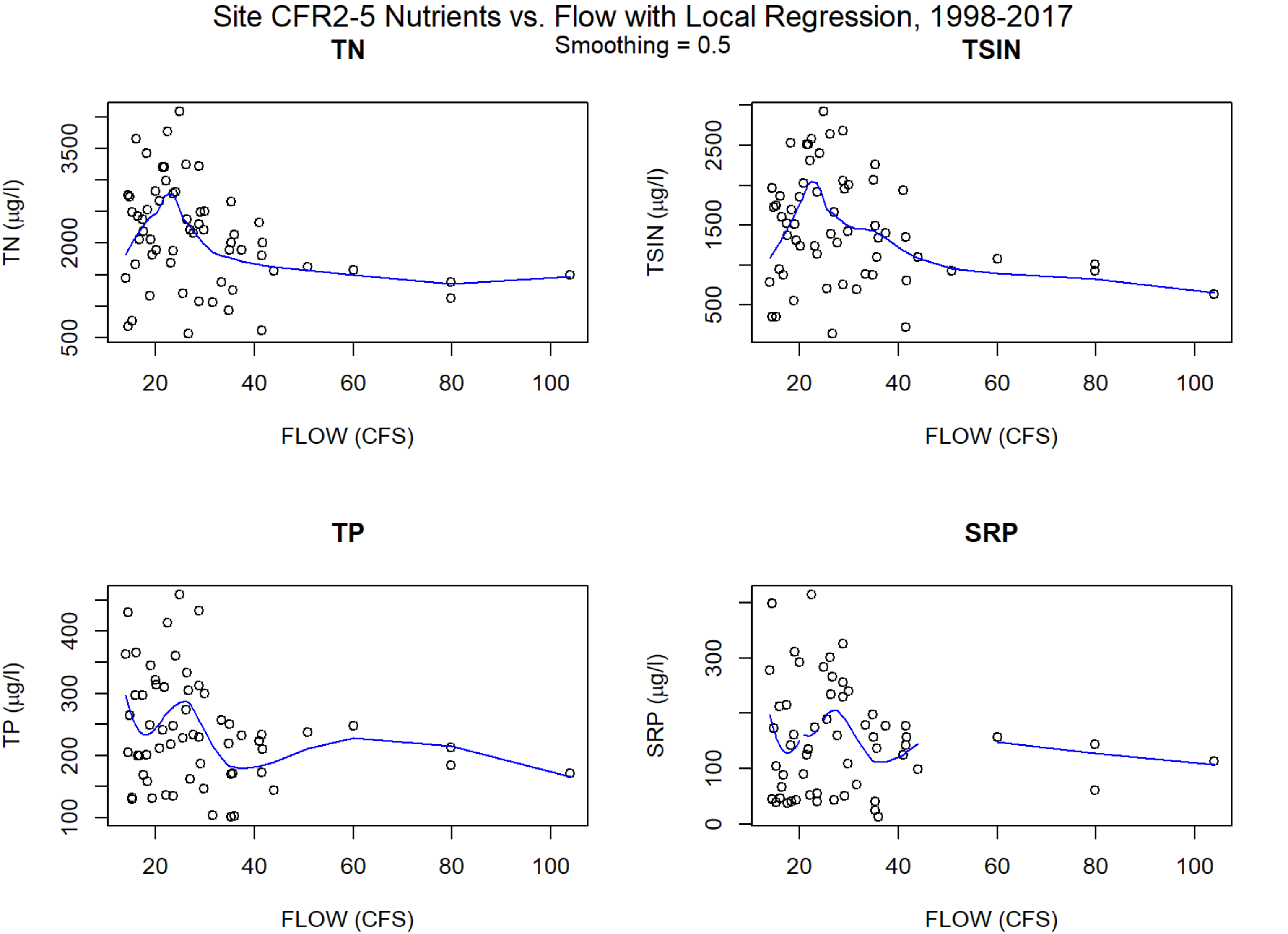
Method Reference: Helsel, D R, and R M Hirsch. Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, chapter A3. USGS, 2002.

ATTACHMENT C:

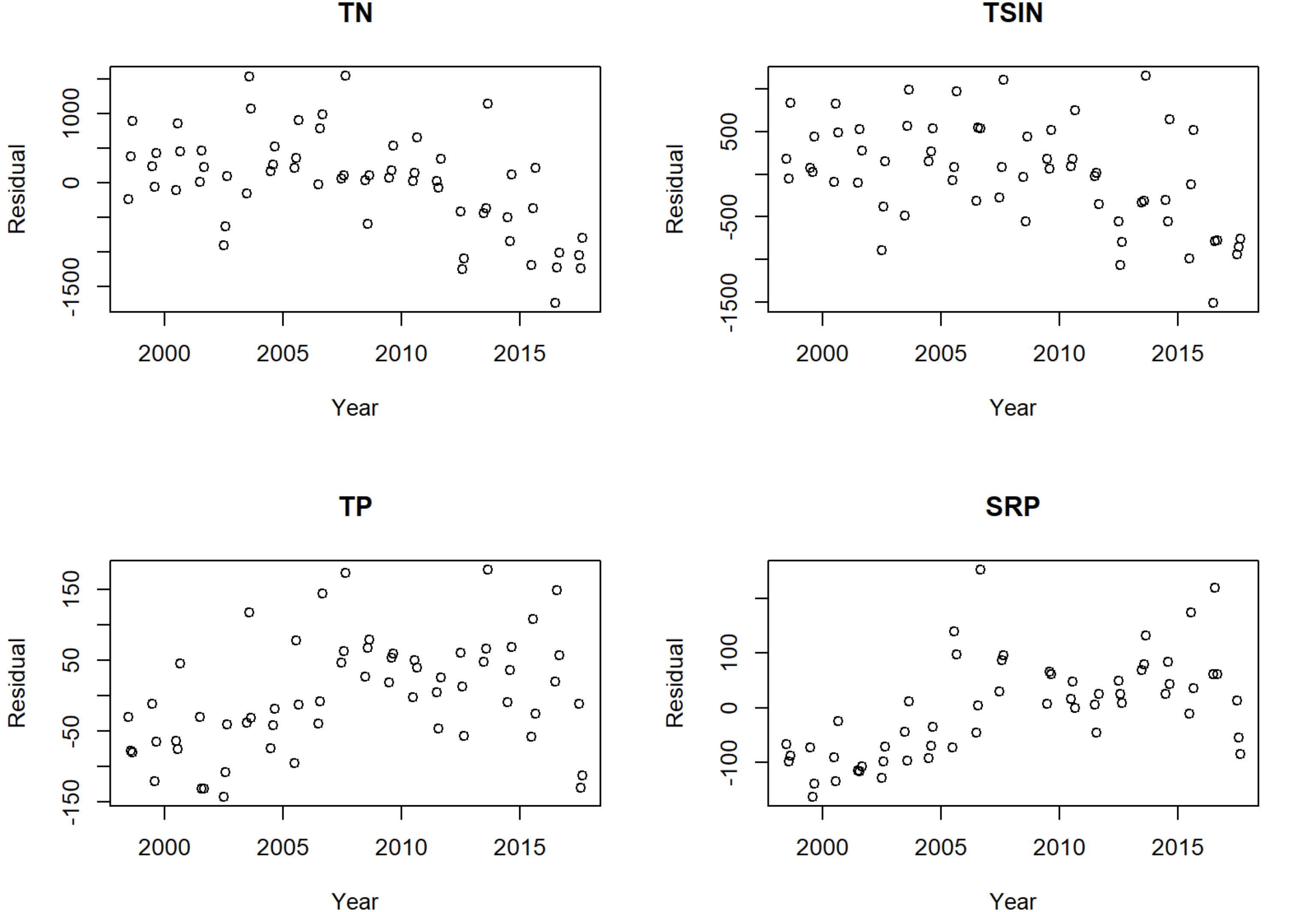
Statistical Program Outputs

Site CFR2-5 Nutrients vs. Time, 1998-2017

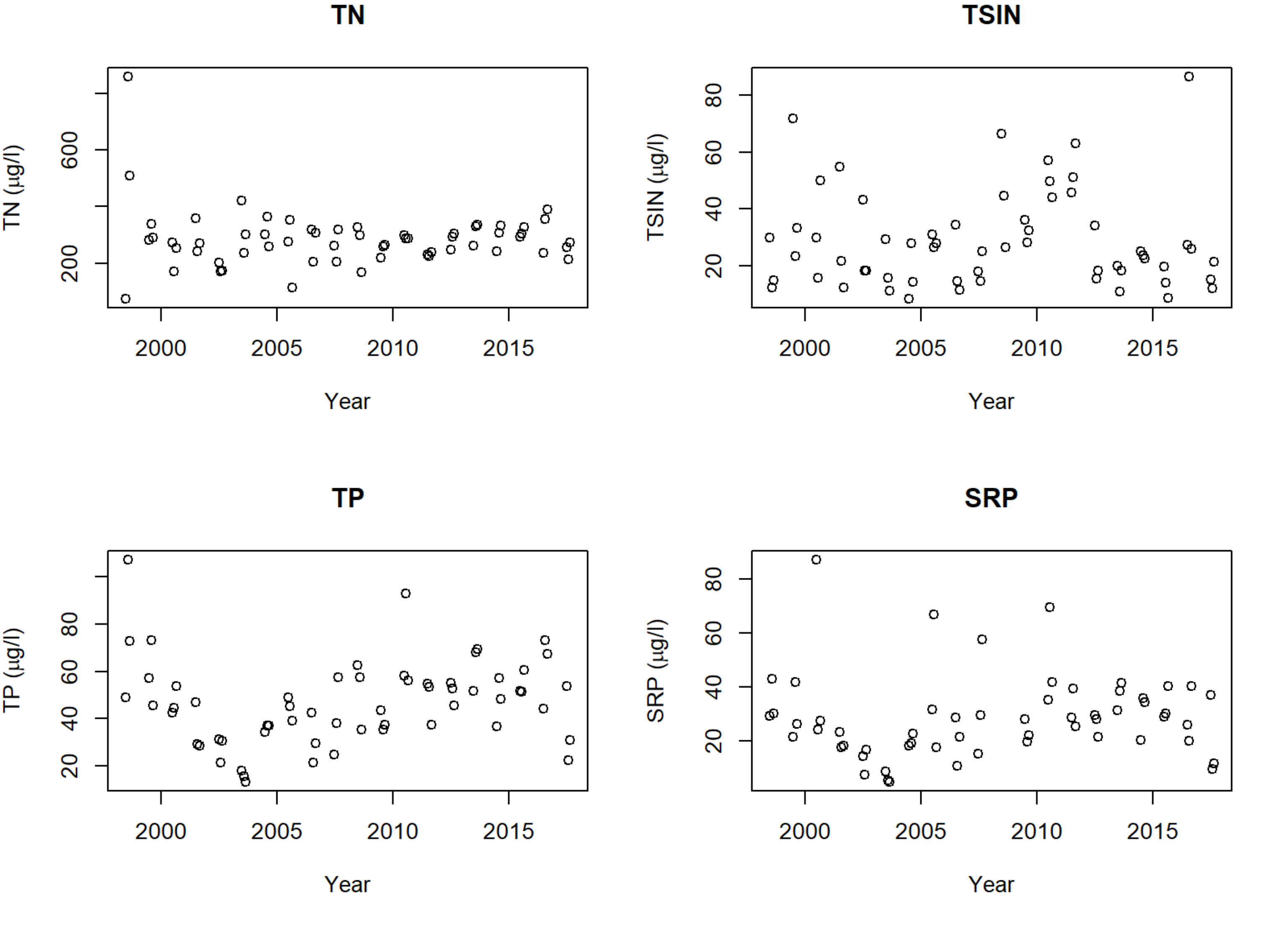


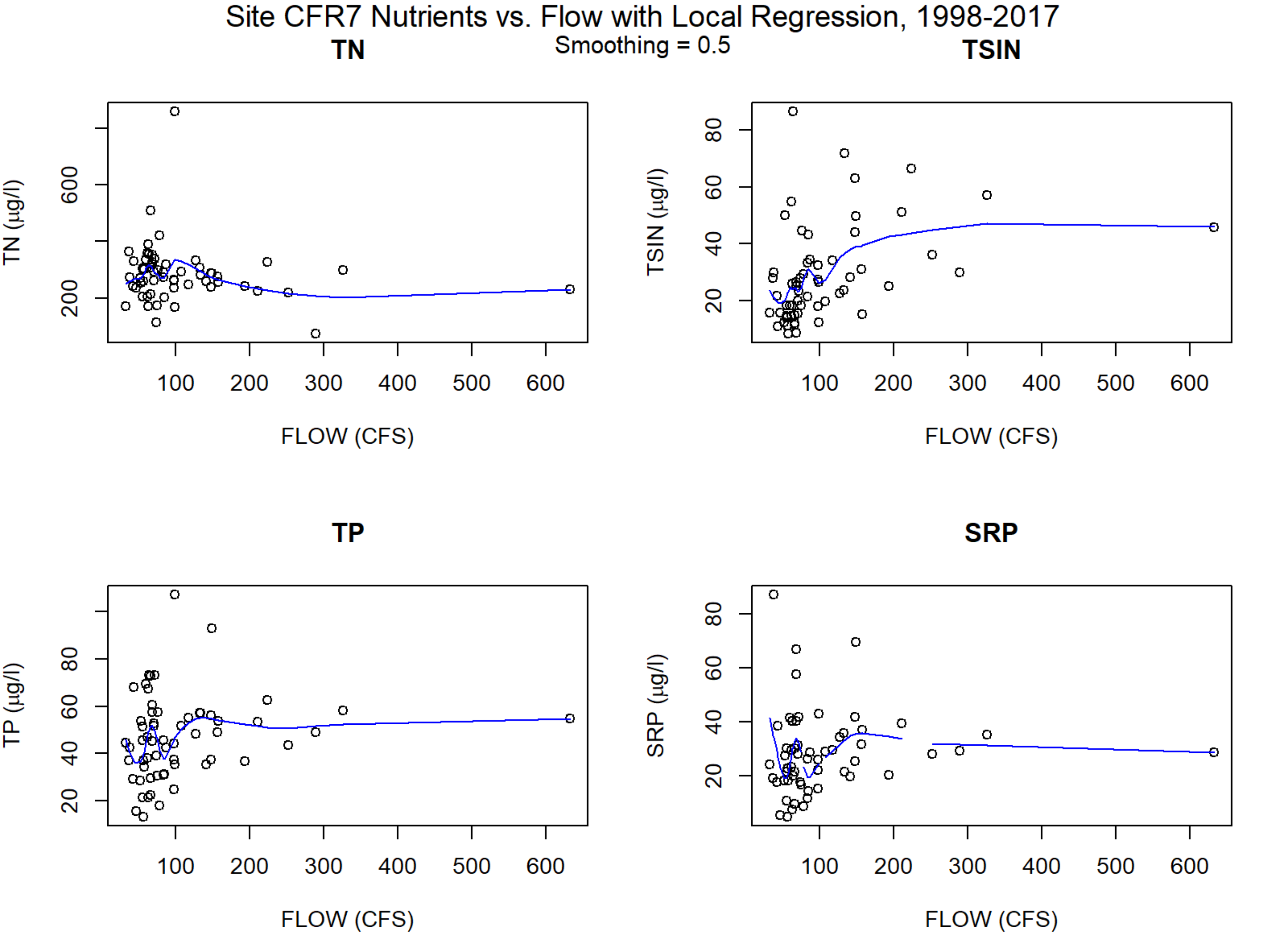

Site CFR2-5 Nutrients vs. Flow with Local Regression, 1998-2017
Smoothing = 0.5
TN
TN (µg/l)
500
2000
3500
20
40
60
80
100
FLOW (CFS)
TSIN
TSIN (µg/l)
500
1500
2500
20
40
60
80
100
FLOW (CFS)
TP
TP (µg/l)
100
200
300
400
20
40
60
80
100
FLOW (CFS)
SRP
SRP (µg/l)
0
100
300
20
40
60
80
100
FLOW (CFS)

Site CFR2-5 Residuals vs. Time, 1998-2017

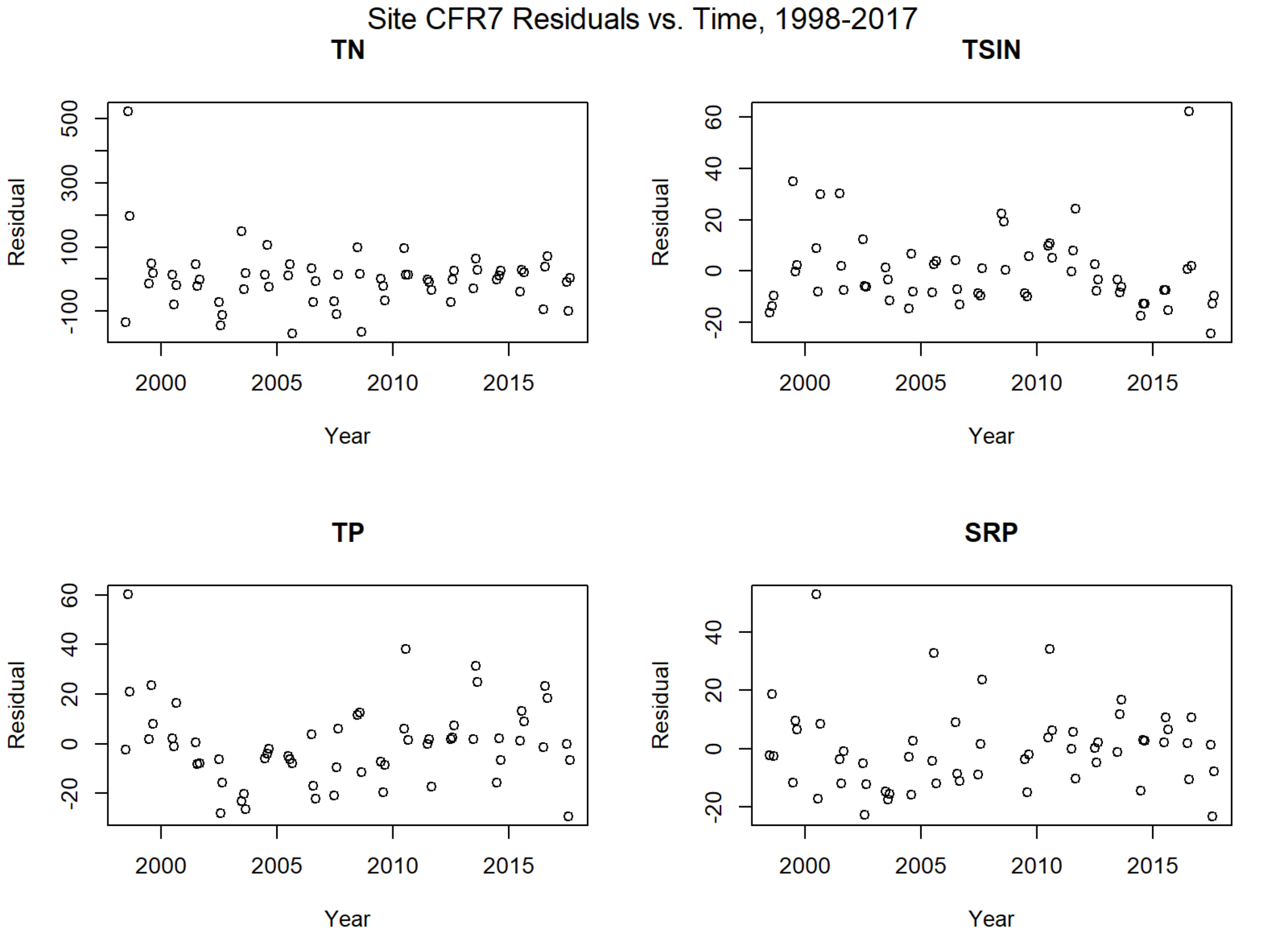


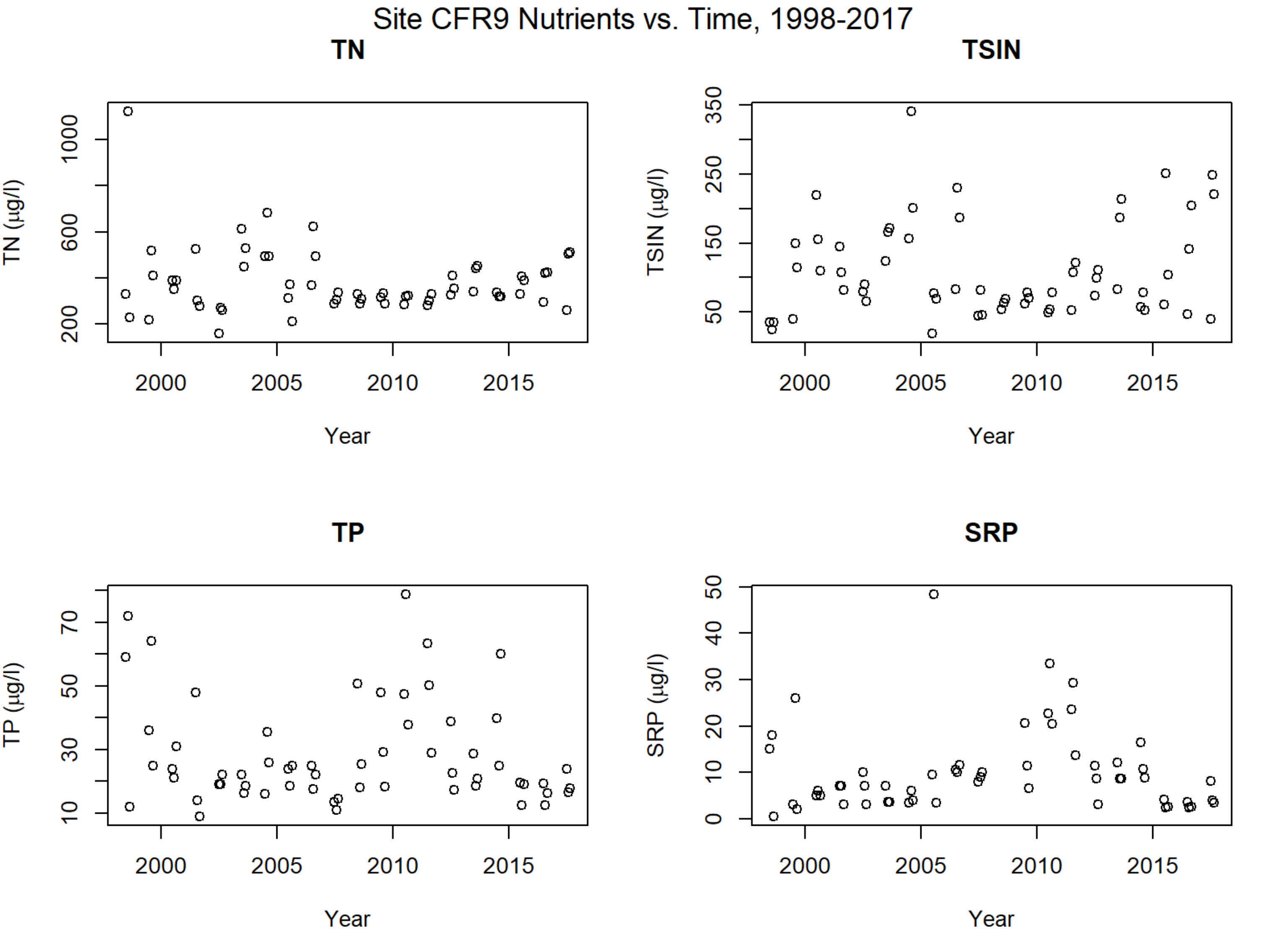
Site CFR7 Nutrients vs. Time, 1998-2017



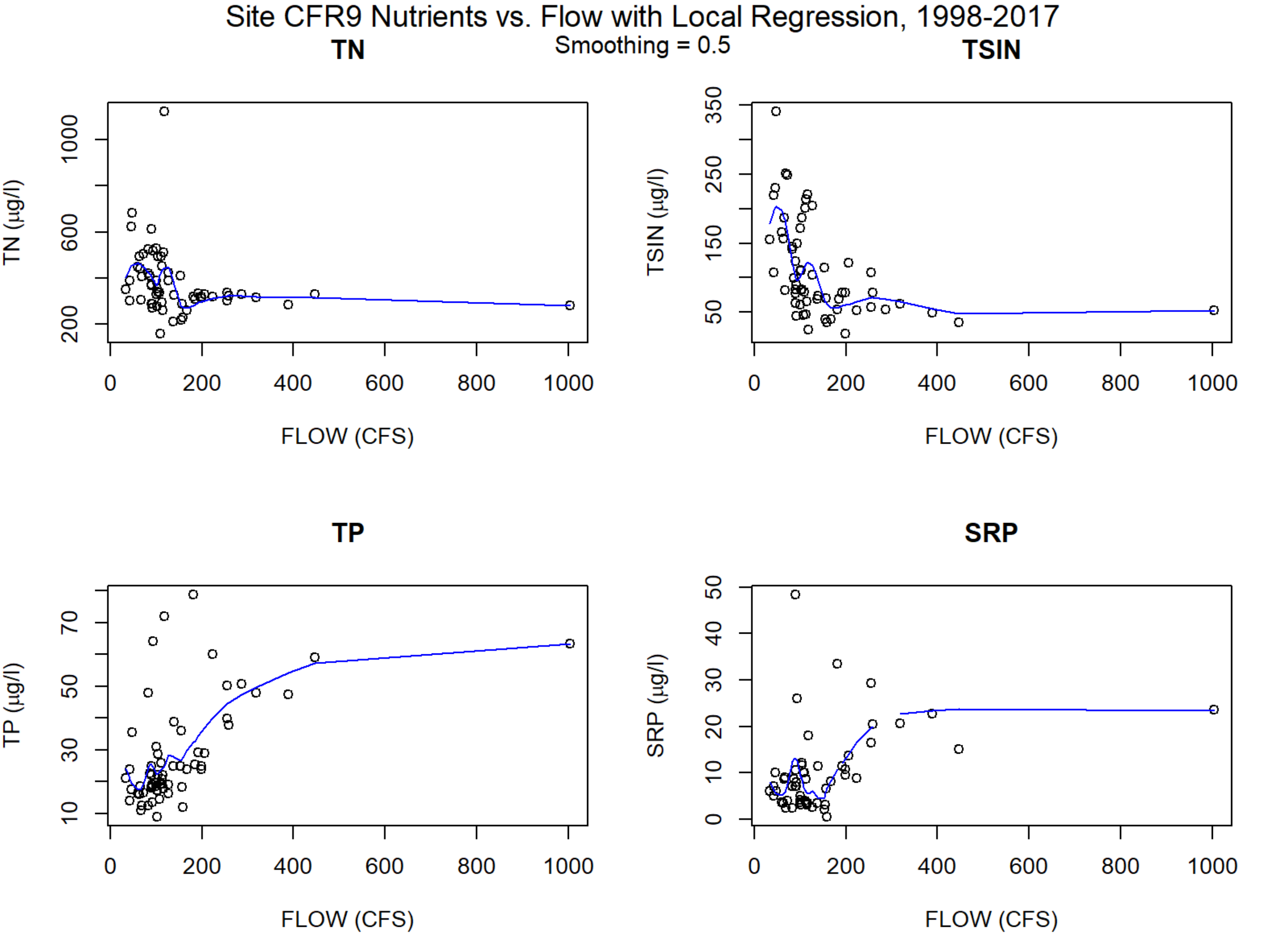


Site CFR7 Nutrients vs. Flow with Local Regression, 1998-2017
Smoothing = 0.5
TN
TN (µg/l)
200
600
100
200
300
400
500
600
FLOW (CFS)
TSIN
TSIN (µg/l)
20
40
60
80
FLOW (CFS)
TP
TP (µg/l)
20
40
60
80
FLOW (CFS)
SRP
SRP (µg/l)
20
40
60
80
FLOW (CFS)

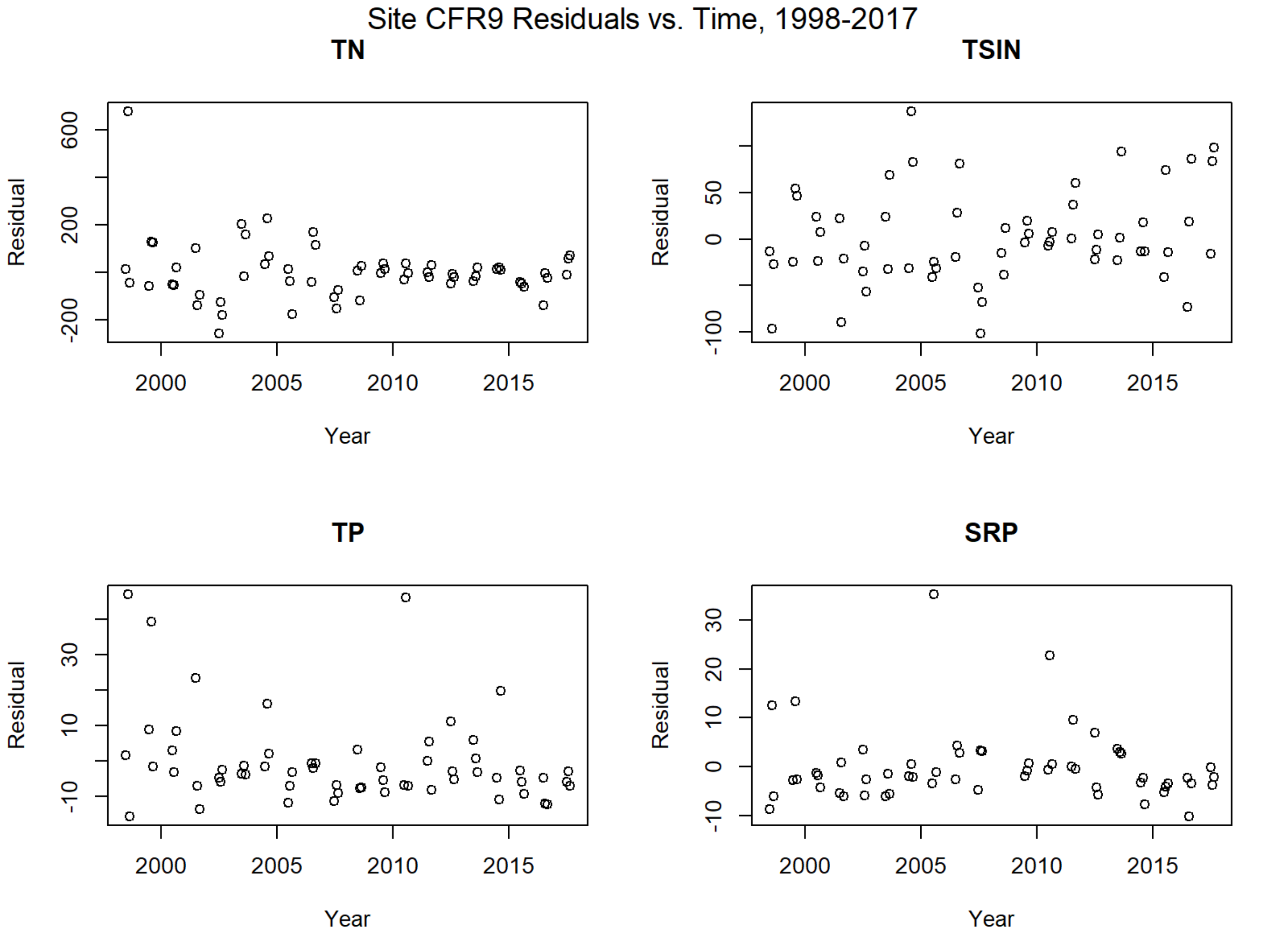

Site CFR7 Residuals vs. Time, 1998-2017
TN
TSIN
TP
SRP
Residual
Year
-100
100
300
500
-20
0
20
40
60
2000
2005
2010
2015

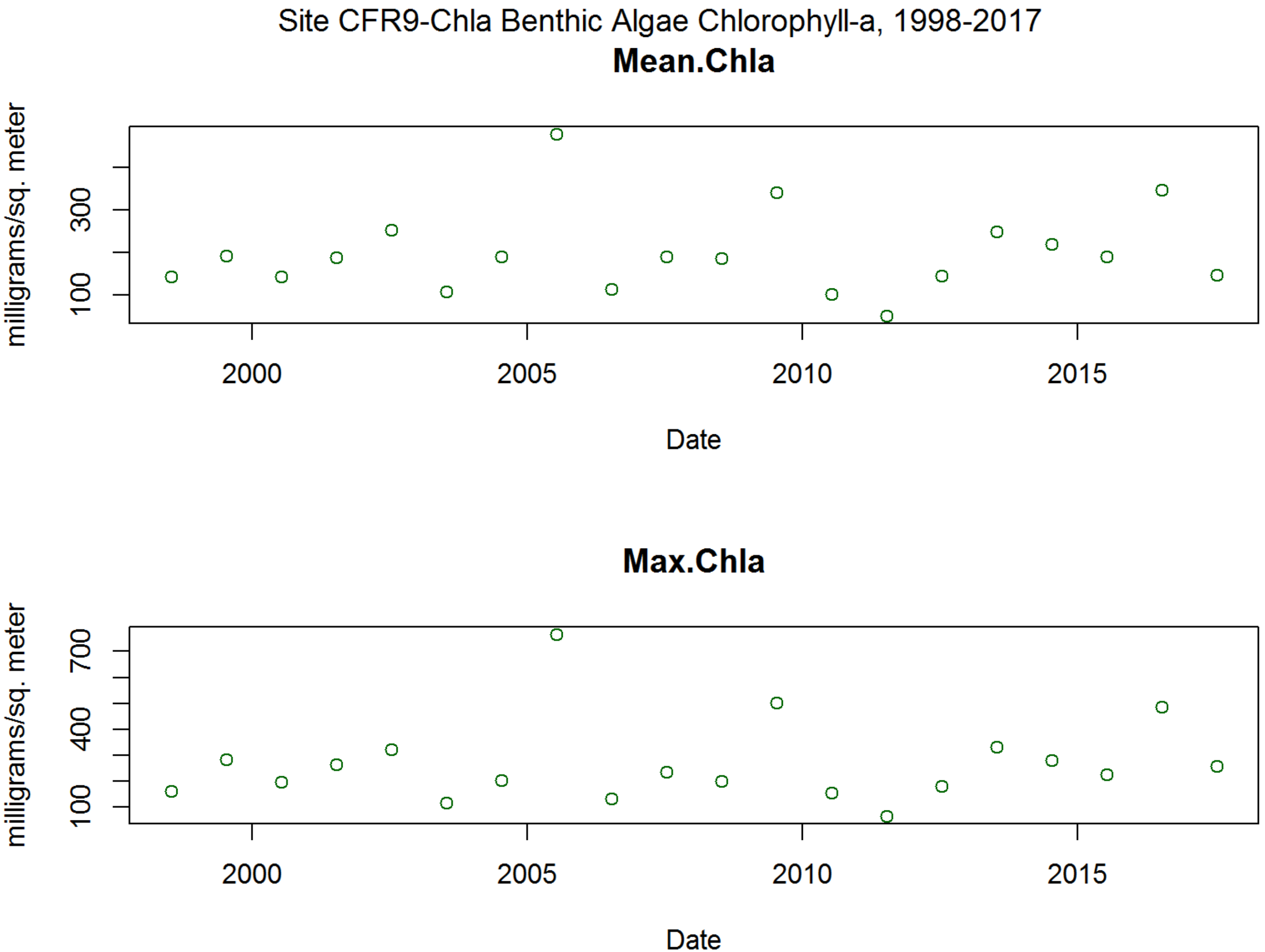


Site CFR9 Nutrients vs. Time, 1998-2017
TN
TN (µg/l)
200
600
1000
2000
2005
2010
2015
Year
TSIN
TSIN (µg/l)
50
150
250
350
2000
2005
2010
2015
Year
TP
TP (µg/l)
10
30
50
70
2000
2005
2010
2015
Year
SRP
SRP (µg/l)
0
10
20
30
40
50
2000
2005
2010
2015
Year

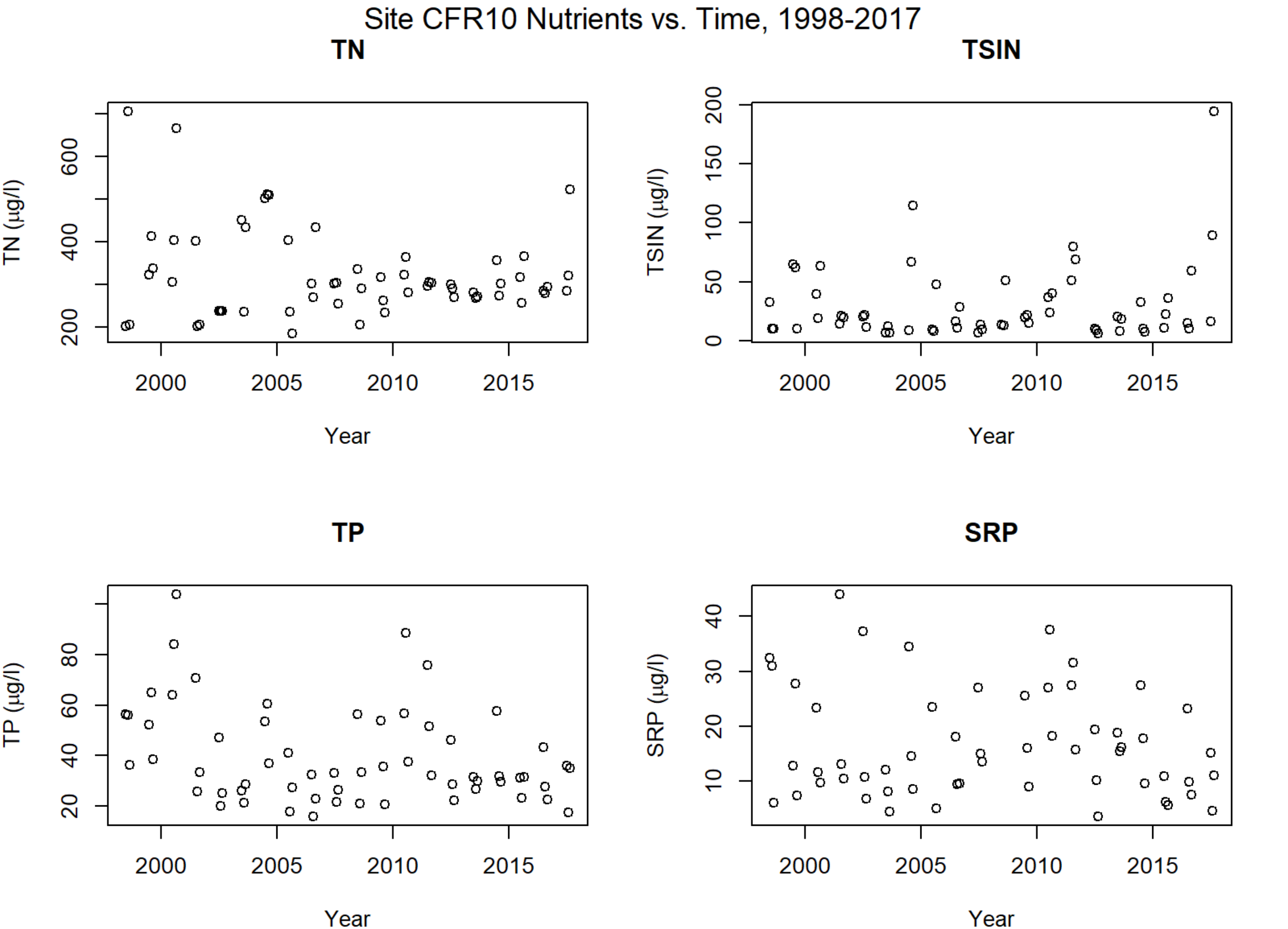


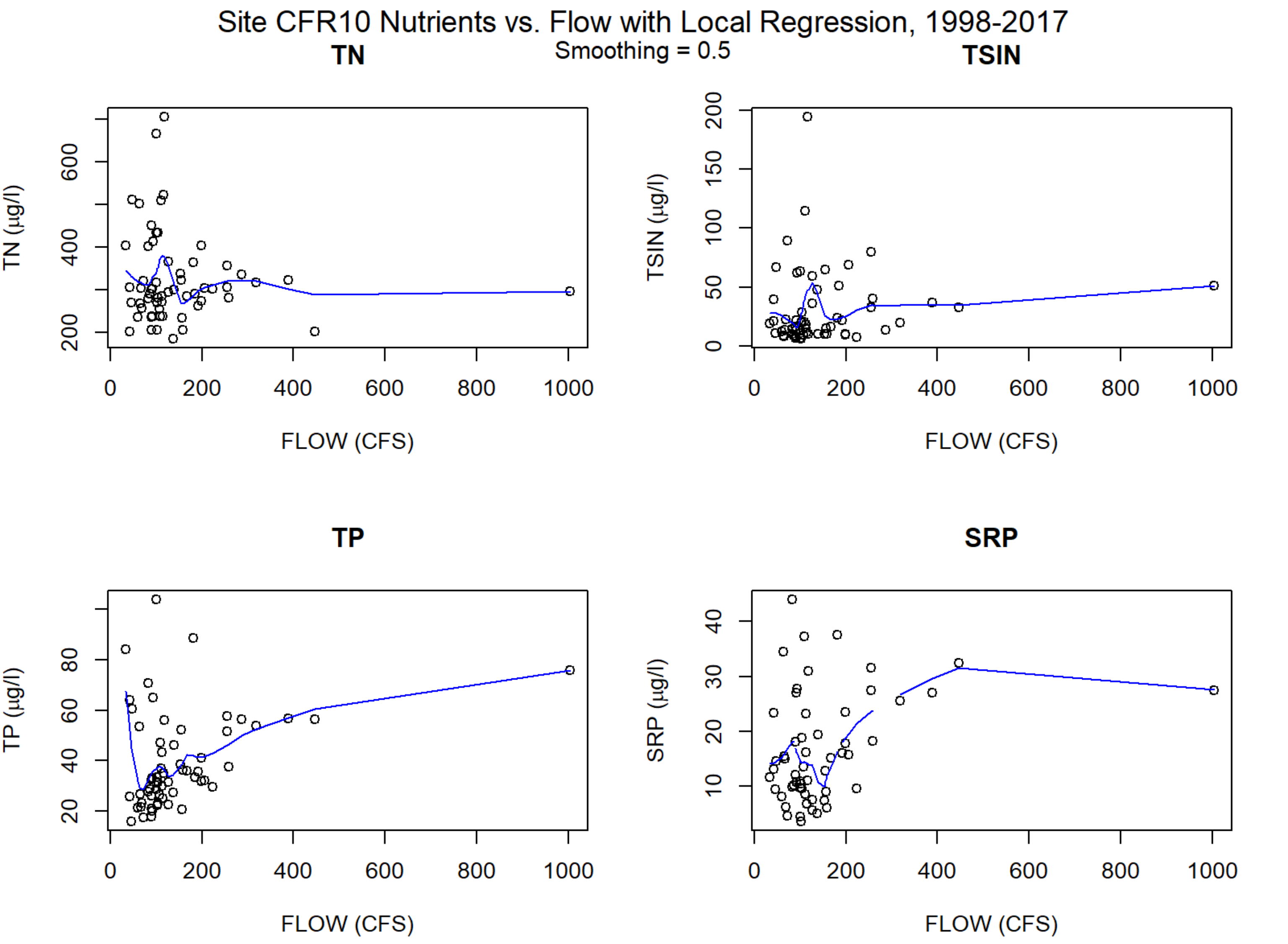
Site CFR9 Nutrients vs. Flow with Local Regression, 1998-2017
Smoothing = 0.5
TN
TSIN
TP
SRP
TN (µg/l)
TSIN (µg/l)
TP (µg/l)
SRP (µg/l)
FLOW (CFS)

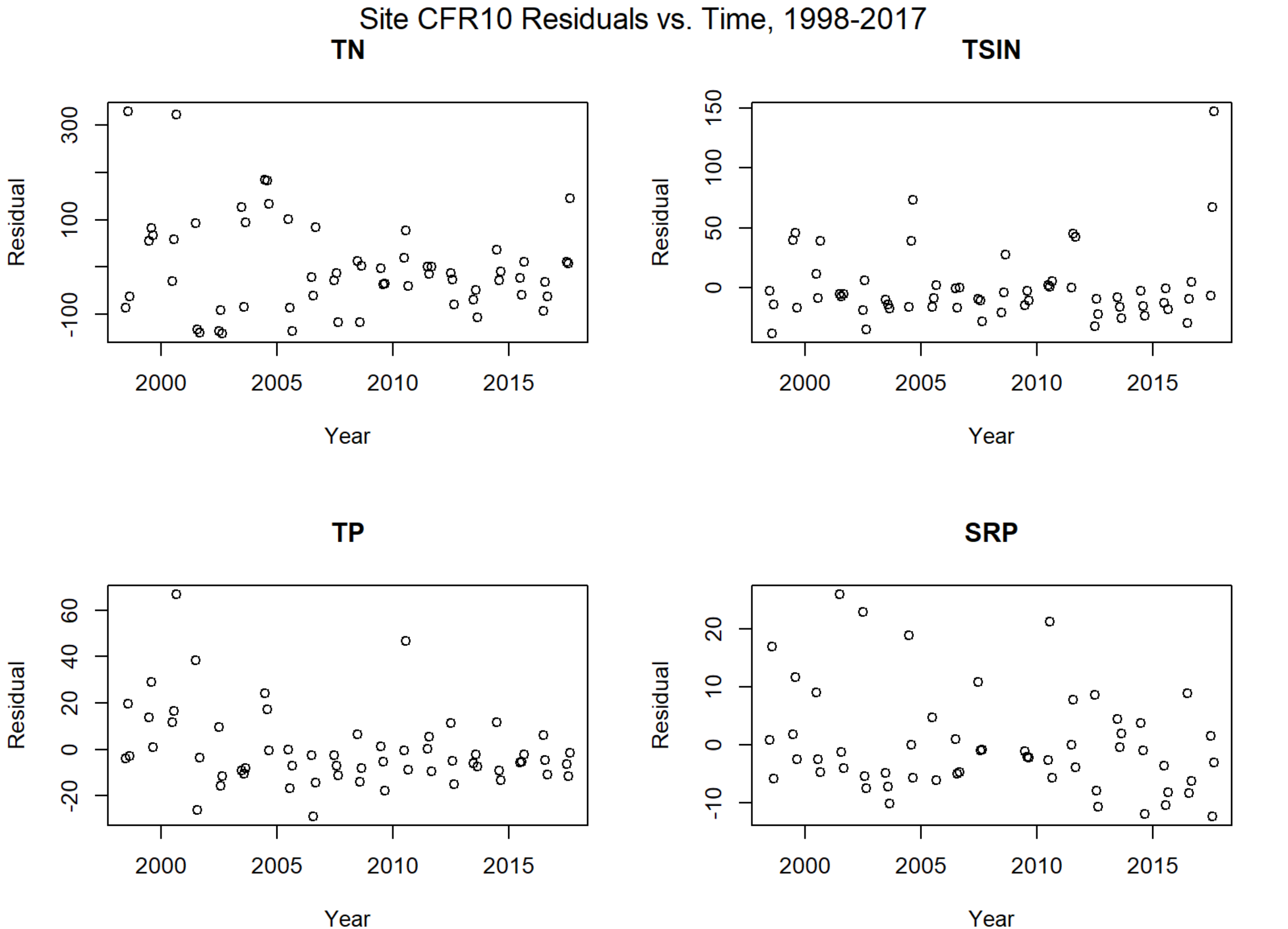

Site CFR9 Residuals vs. Time, 1998-2017
TN
TSIN
TP
SRP
Residual
Year
600
200
-200
50
0
-100
30
10
-10
30
20
10
0
-10
2000
2005
2010
2015

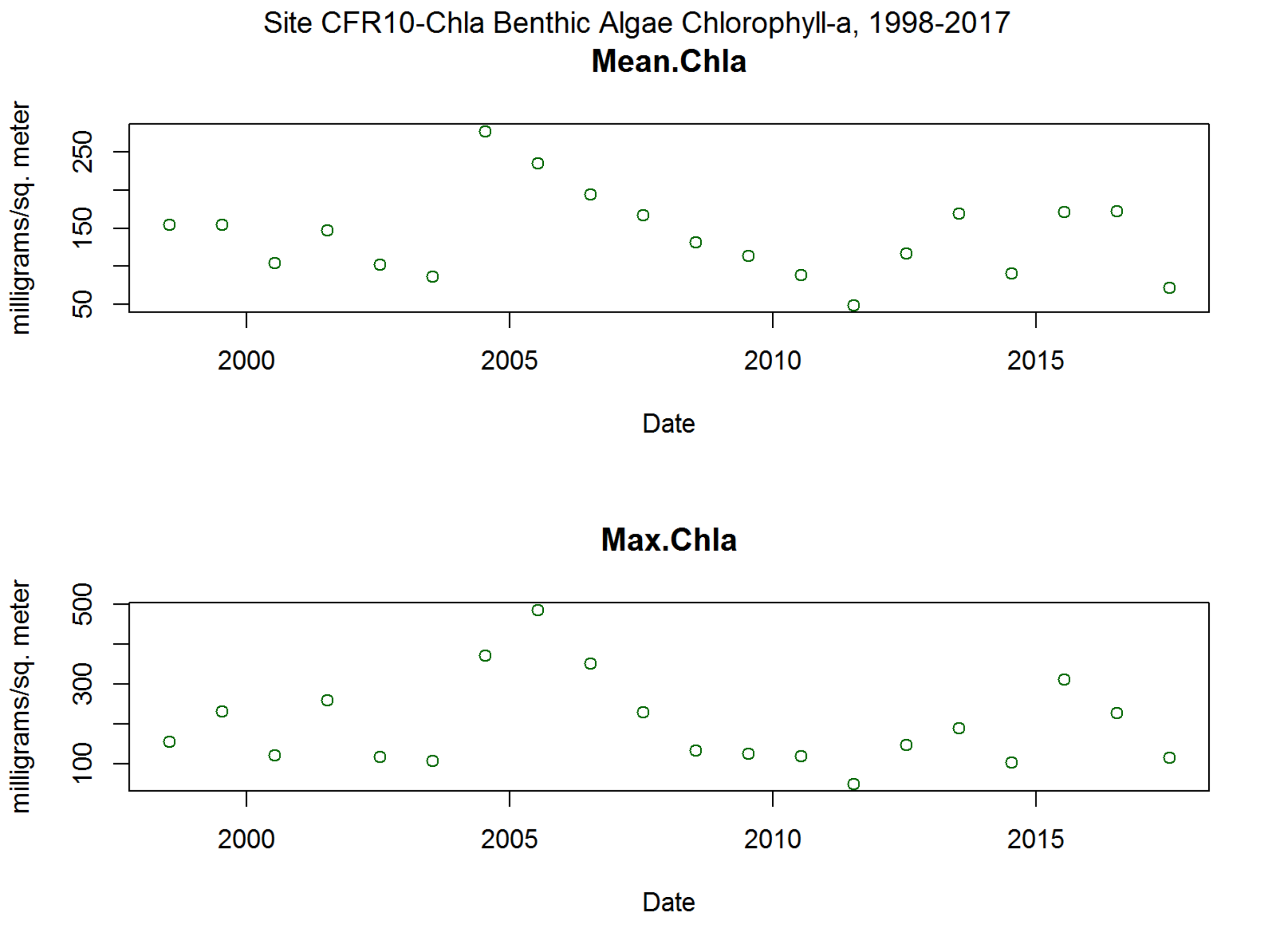


Site CFR9-Chla Benthic Algae Chlorophyll-a, 1998-2017
Mean.Chla
milligrams/sq. meter
100
300
2000
2005
2010
2015
Date
Max.Chla
milligrams/sq. meter
100
400
700
2000
2005
2010
2015
Date

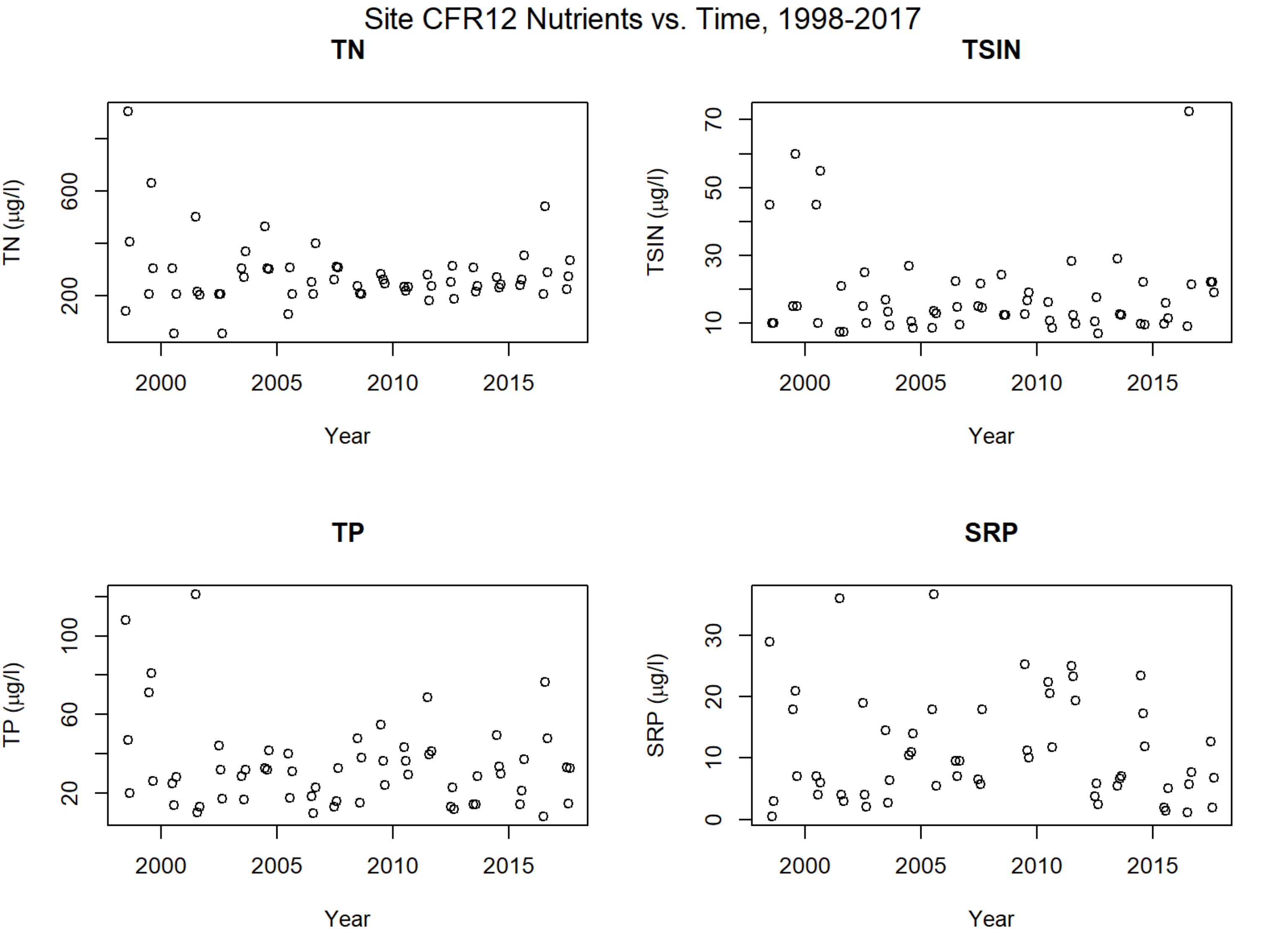

Site CFR10 Nutrients vs. Time, 1998-2017
TN
TN (µg/l)
200
400
600
Year
2000
2005
2010
2015
TSIN
TSIN (µg/l)
0
50
100
150
200
Year
2000
2005
2010
2015
TP
TP (µg/l)
20
40
60
80
Year
2000
2005
2010
2015
SRP
SRP (µg/l)
10
20
30
40
Year
2000
2005
2010
2015

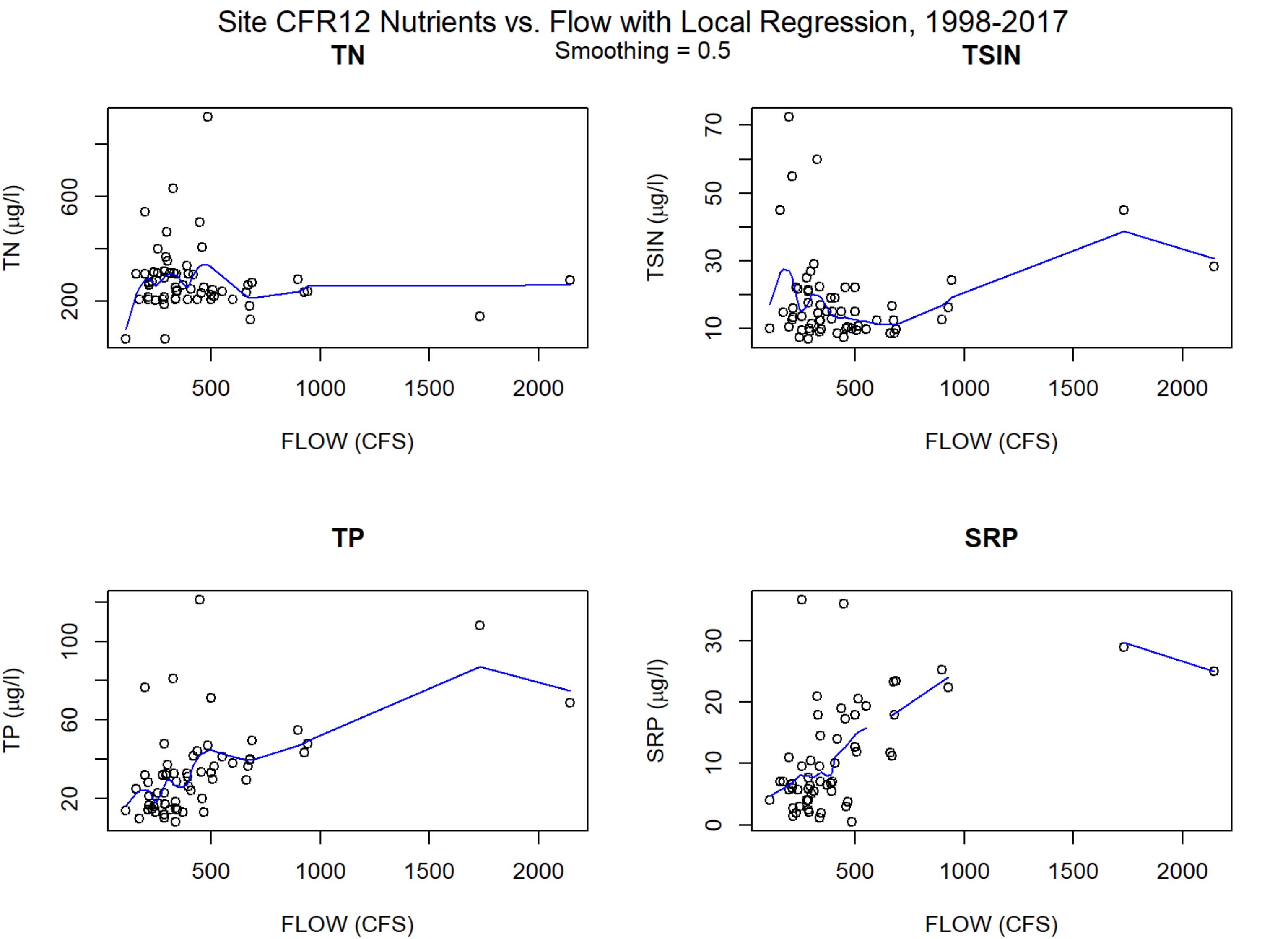

Site CFR10 Nutrients vs. Flow with Local Regression, 1998-2017
Smoothing = 0.5
TN
TSIN
TP
SRP
TN (µg/l)
TSIN (µg/l)
TP (µg/l)
SRP (µg/l)
FLOW (CFS)
FLOW (CFS)
FLOW (CFS)
FLOW (CFS)

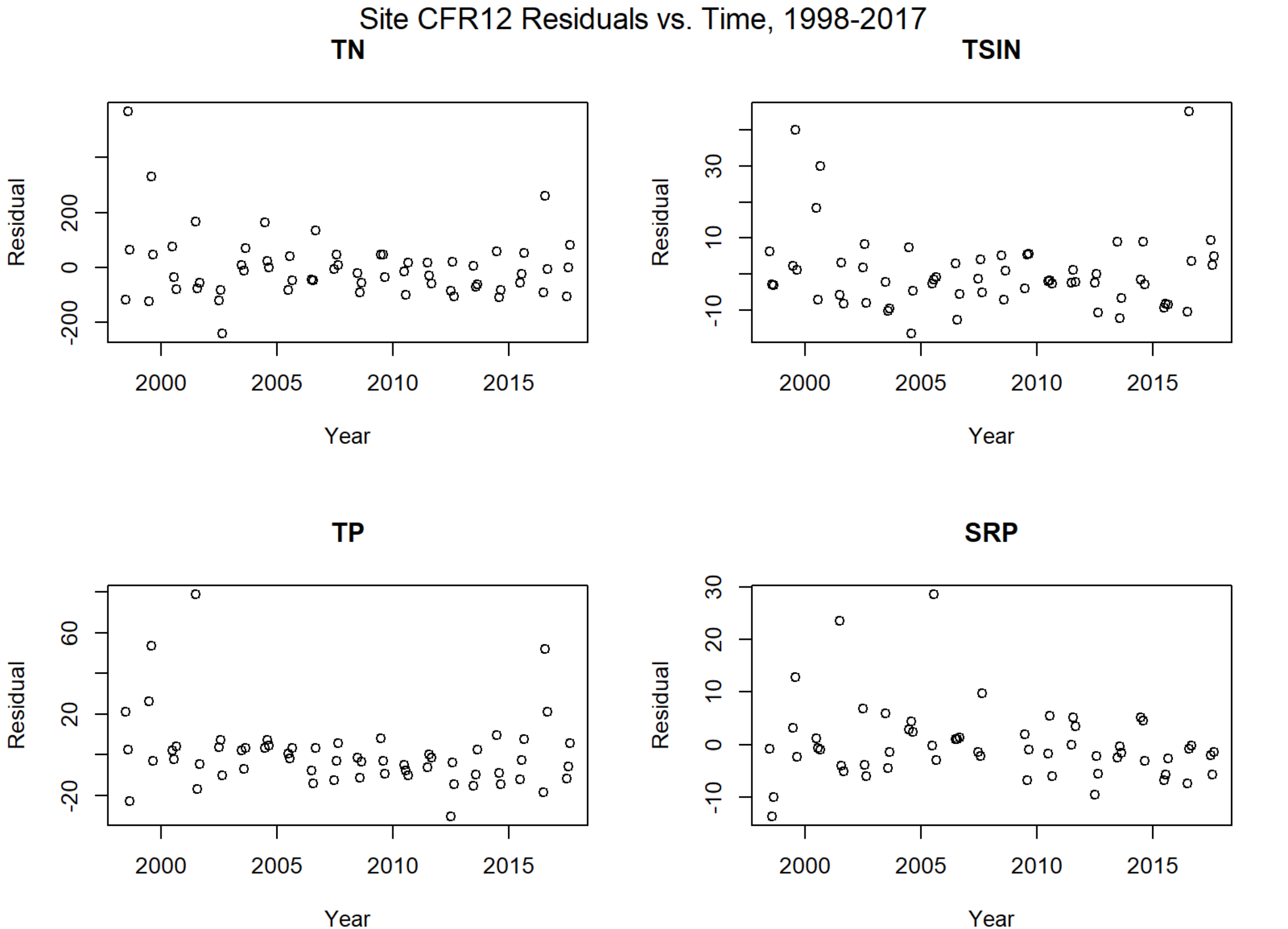

Site CFR10 Residuals vs. Time, 1998-2017
TN
TSIN
TP
SRP
Residual
Year
300
100
-100
150
100
50
0
60
40
20
0
-20
20
10
0
-10
2000
2005
2010
2015



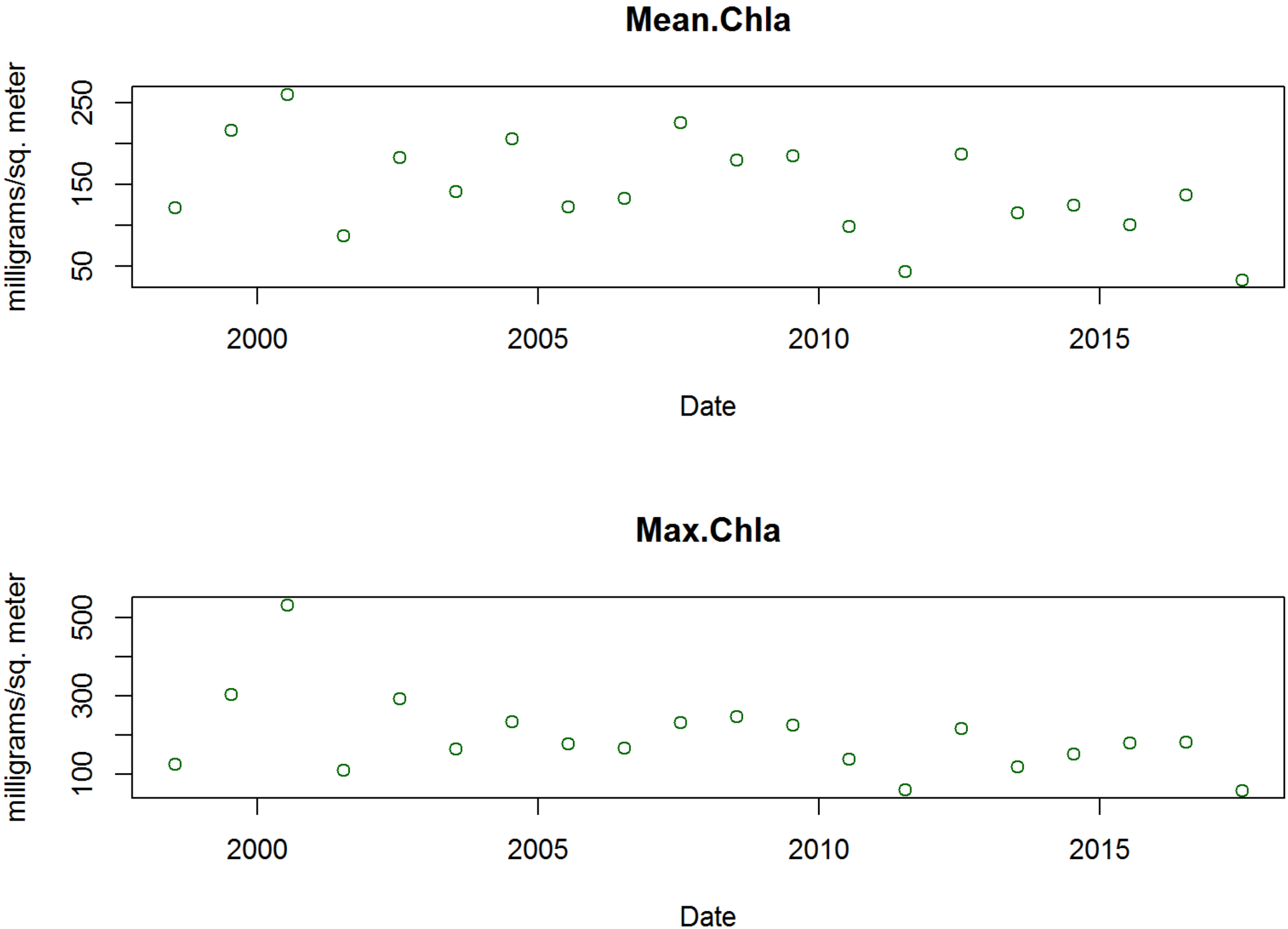
Site CFR10-Chla Benthic Algae Chlorophyll-a, 1998-2017
Mean.Chla
milligrams/sq. meter
50
150
250
2000
2005
2010
2015
Date
Max.Chla
milligrams/sq. meter
100
300
500
2000
2005
2010
2015
Date

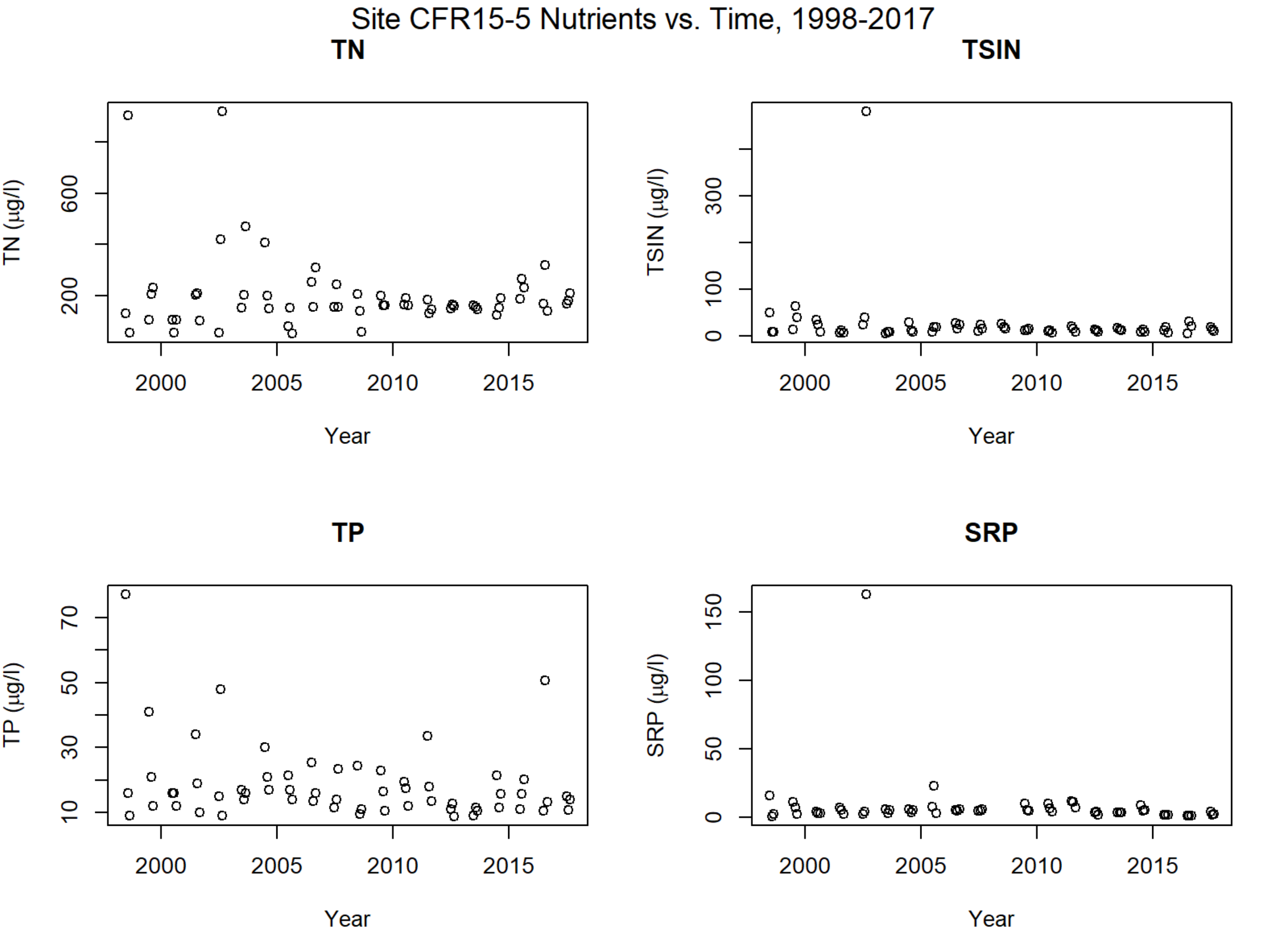

Site CFR12 Nutrients vs. Time, 1998-2017
TN
TN (µg/l)
200
600
2000
2005
2010
2015
Year
TSIN
TSIN (µg/l)
10
30
50
70
2000
2005
2010
2015
Year
TP
TP (µg/l)
20
60
100
2000
2005
2010
2015
Year
SRP
SRP (µg/l)
0
10
20
30
2000
2005
2010
2015
Year

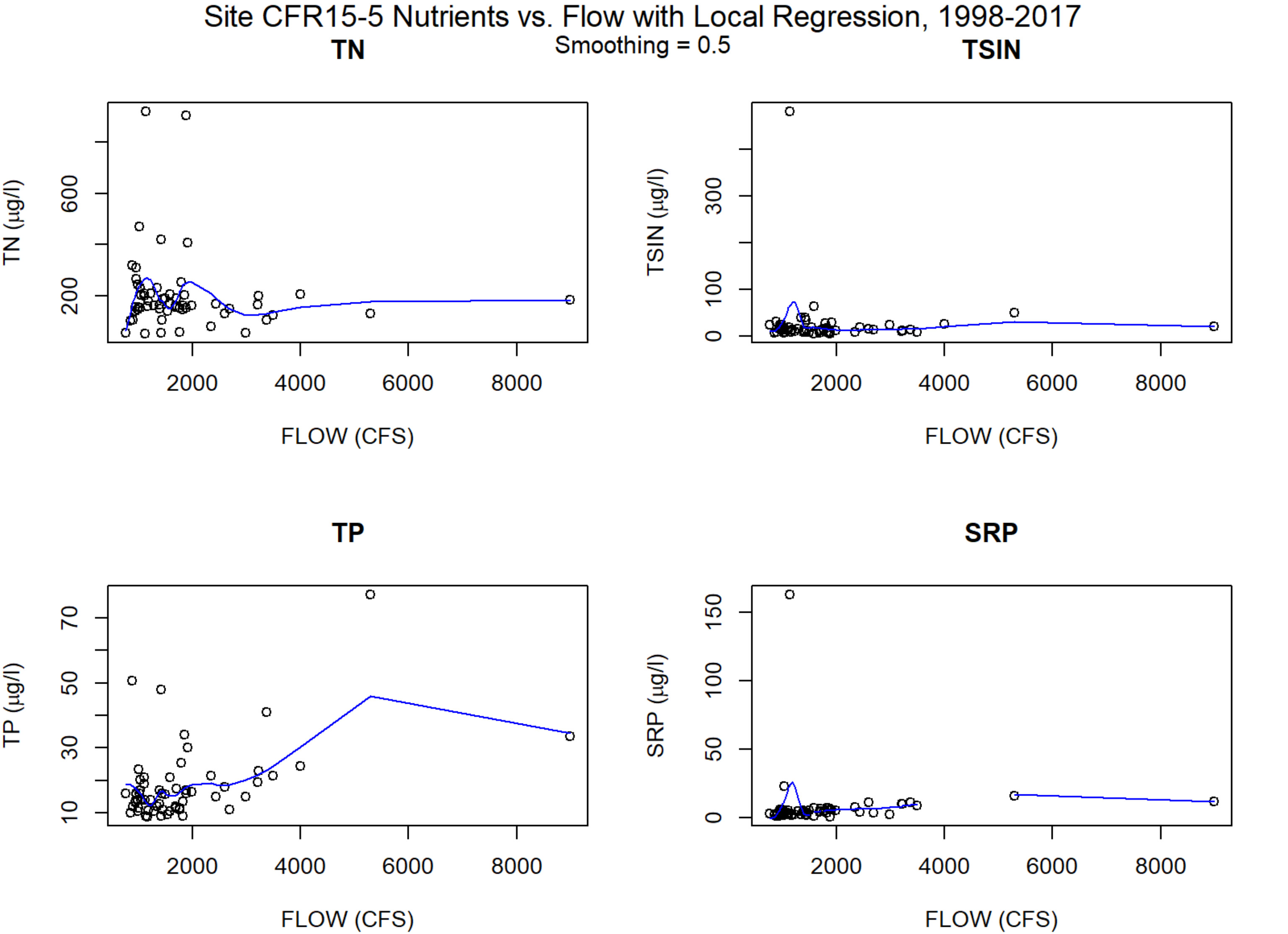

Site CFR12 Nutrients vs. Flow with Local Regression, 1998-2017
Smoothing = 0.5
TN
TN (µg/l)
200
600
500
1000
1500
2000
FLOW (CFS)
TSIN
TSIN (µg/l)
10
30
50
70
500
1000
1500
2000
FLOW (CFS)
TP
TP (µg/l)
20
60
100
500
1000
1500
2000
FLOW (CFS)
SRP
SRP (µg/l)
0
10
20
30
500
1000
1500
2000
FLOW (CFS)

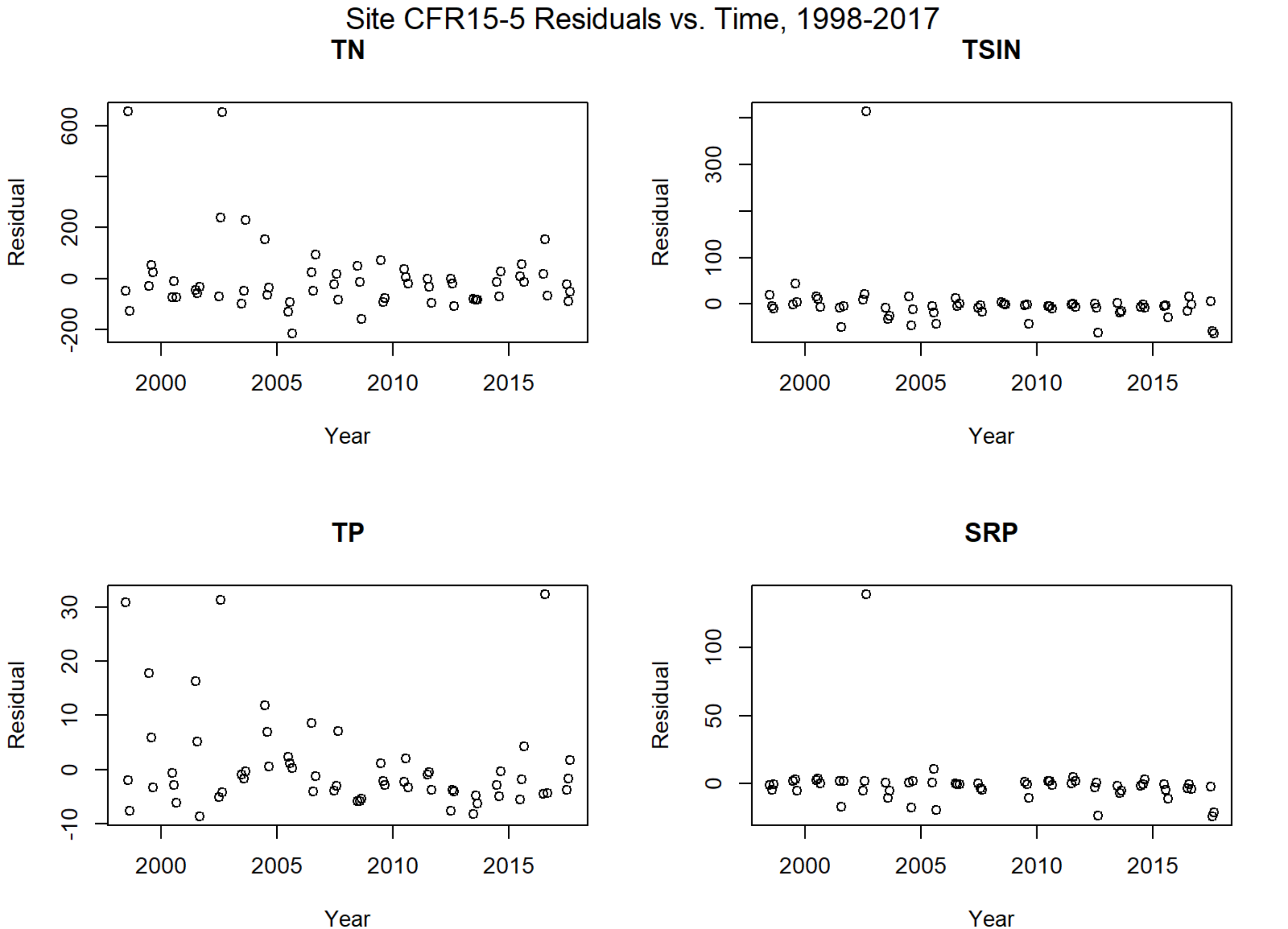

Site CFR12 Residuals vs. Time, 1998-2017
TN
TSIN
TP
SRP
Residual
Year
200
0
-200
30
10
-10
60
20
-20
30
20
10
0
-10
2000
2005
2010
2015

Site CFR12-Chla Benthic Algae Chlorophyll-a, 1998-2017

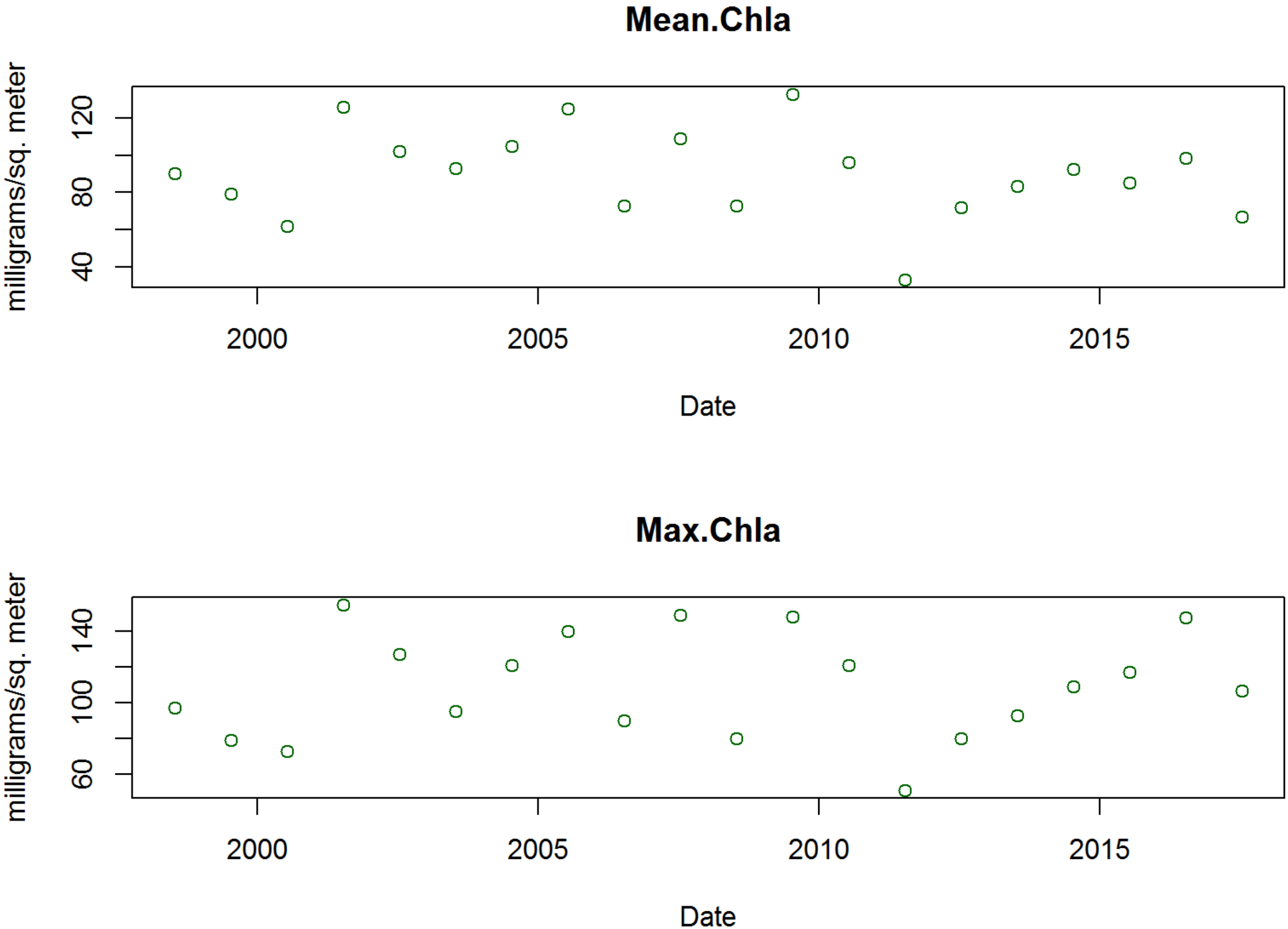


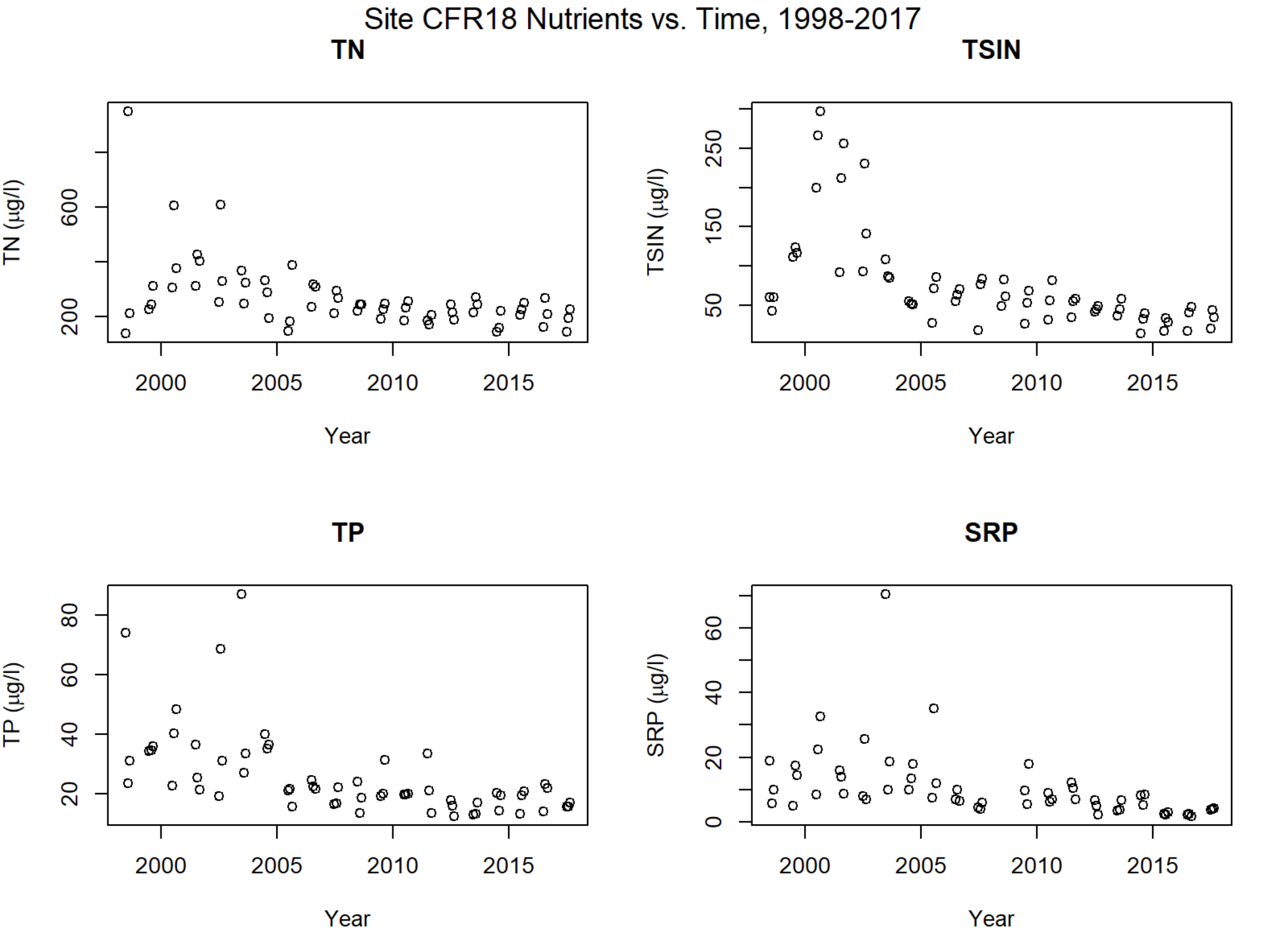

Site CFR15-5 Nutrients vs. Time, 1998-2017
TN
TN (µg/l)
200
600
Year
2000
2005
2010
2015
TSIN
TSIN (µg/l)
0
100
300
Year
2000
2005
2010
2015
TP
TP (µg/l)
10
30
50
70
Year
2000
2005
2010
2015
SRP
SRP (µg/l)
0
50
100
150
Year
2000
2005
2010
2015

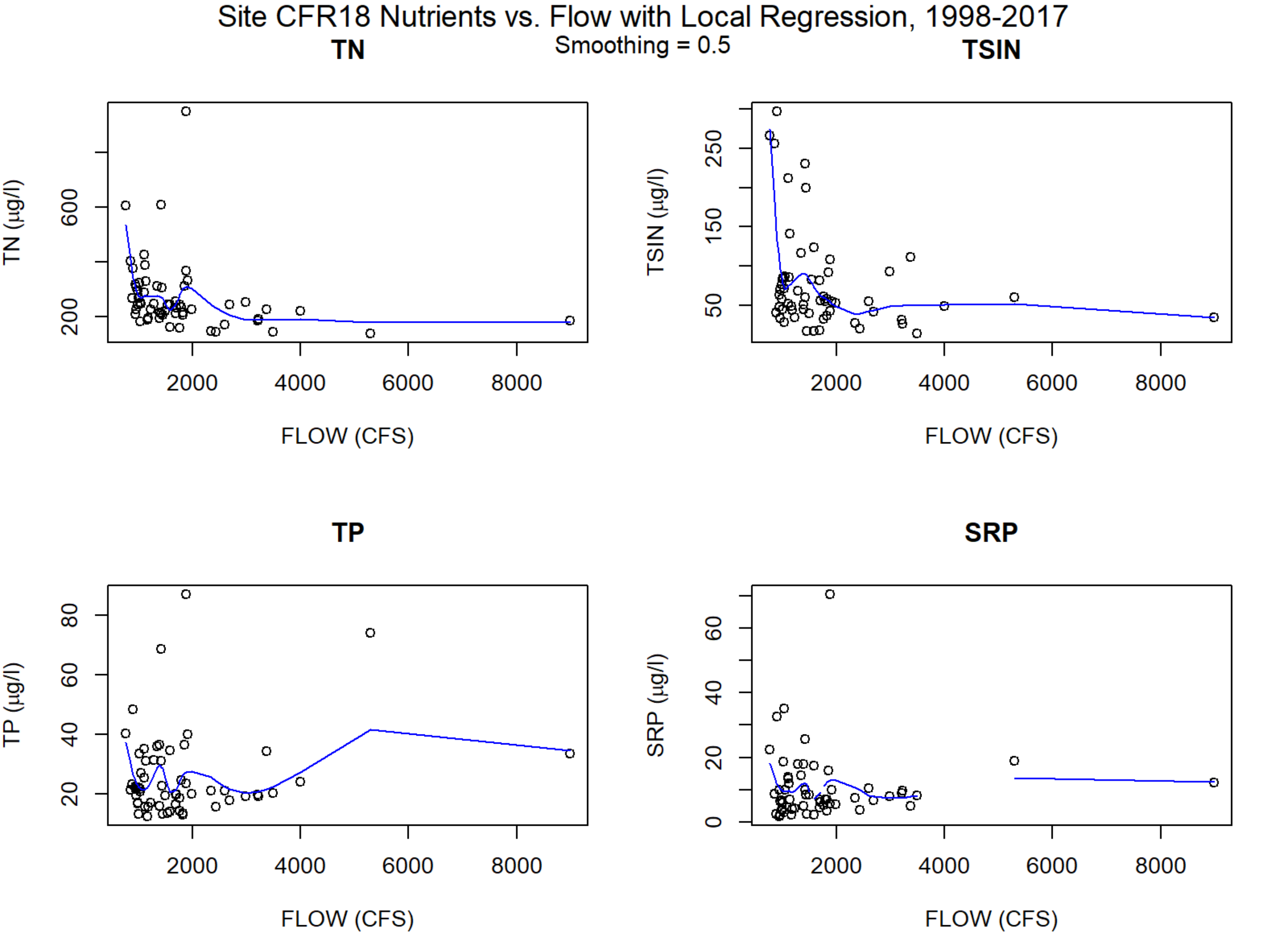

Site CFR15-5 Nutrients vs. Flow with Local Regression, 1998-2017
Smoothing = 0.5
TN
TN (µg/l)
200
600
2000
4000
6000
8000
FLOW (CFS)
TSIN
TSIN (µg/l)
0
100
300
2000
4000
6000
8000
FLOW (CFS)
TP
TP (µg/l)
10
30
50
70
2000
4000
6000
8000
FLOW (CFS)
SRP
SRP (µg/l)
0
50
100
150
2000
4000
6000
8000
FLOW (CFS)

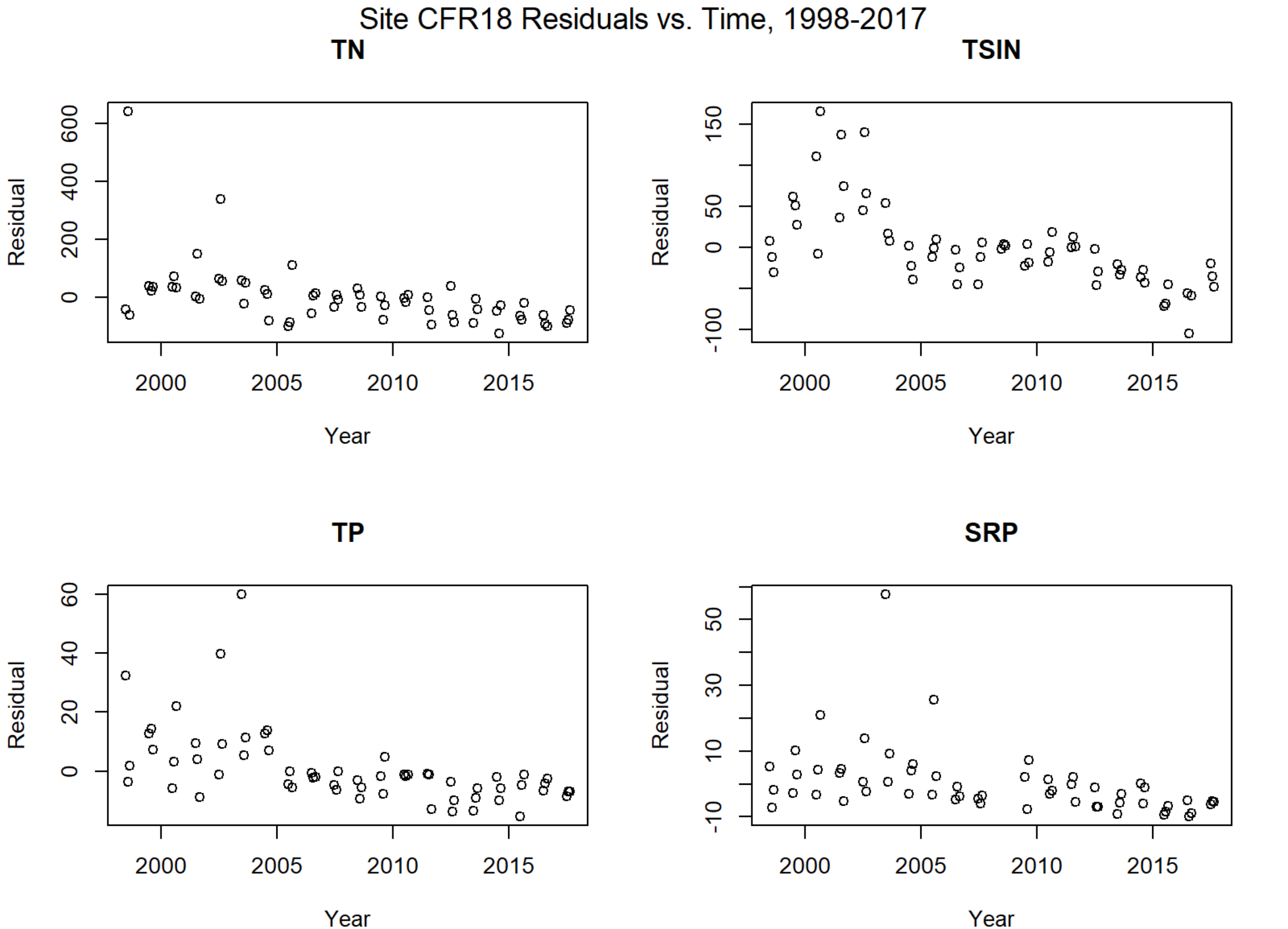

Site CFR15-5 Residuals vs. Time, 1998-2017
TN
TSIN
TP
SRP
Residual
Year
600
200
0
-200
300
100
30
20
10
-10
50
2000
2005
2010
2015

Site CFR15.5-Chla Benthic Algae Chlorophyll-a, 1998-2017

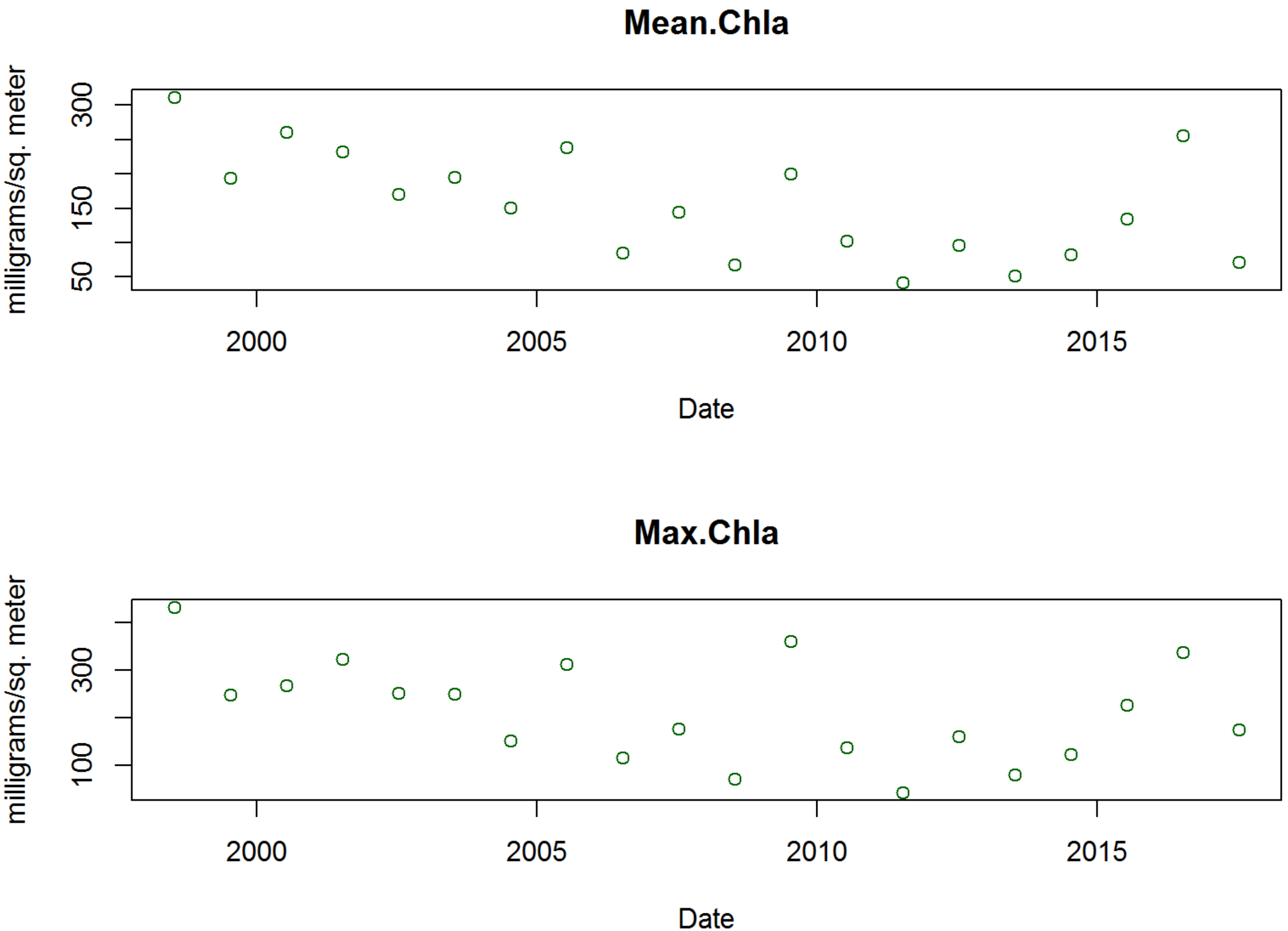


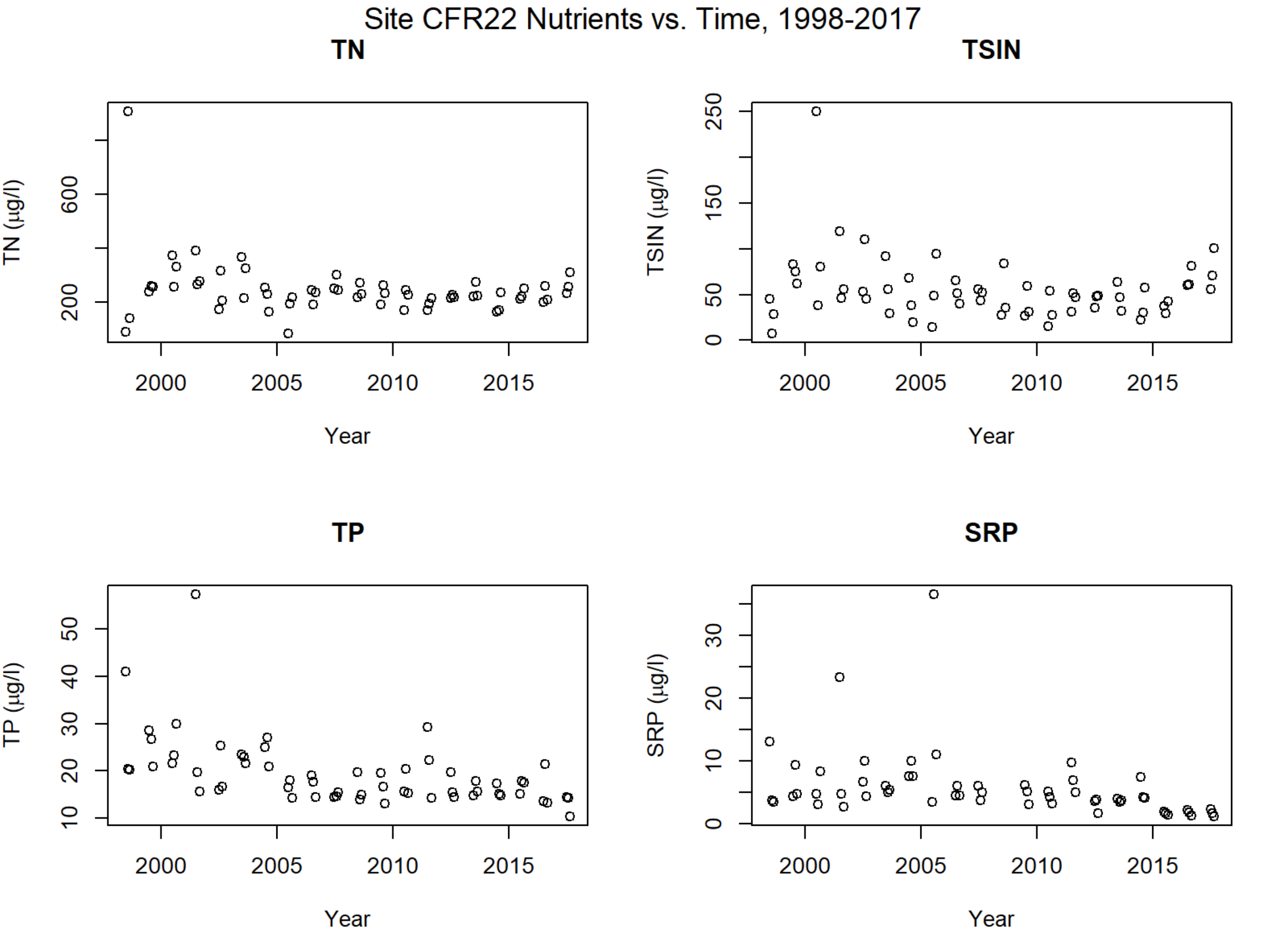

Site CFR18 Nutrients vs. Time, 1998-2017
TN
TN (µg/l)
200
600
TSIN
TSIN (µg/l)
50
150
250
TP
TP (µg/l)
20
40
60
80
SRP
SRP (µg/l)
0
20
40
60
2000
2005
2010
2015
Year

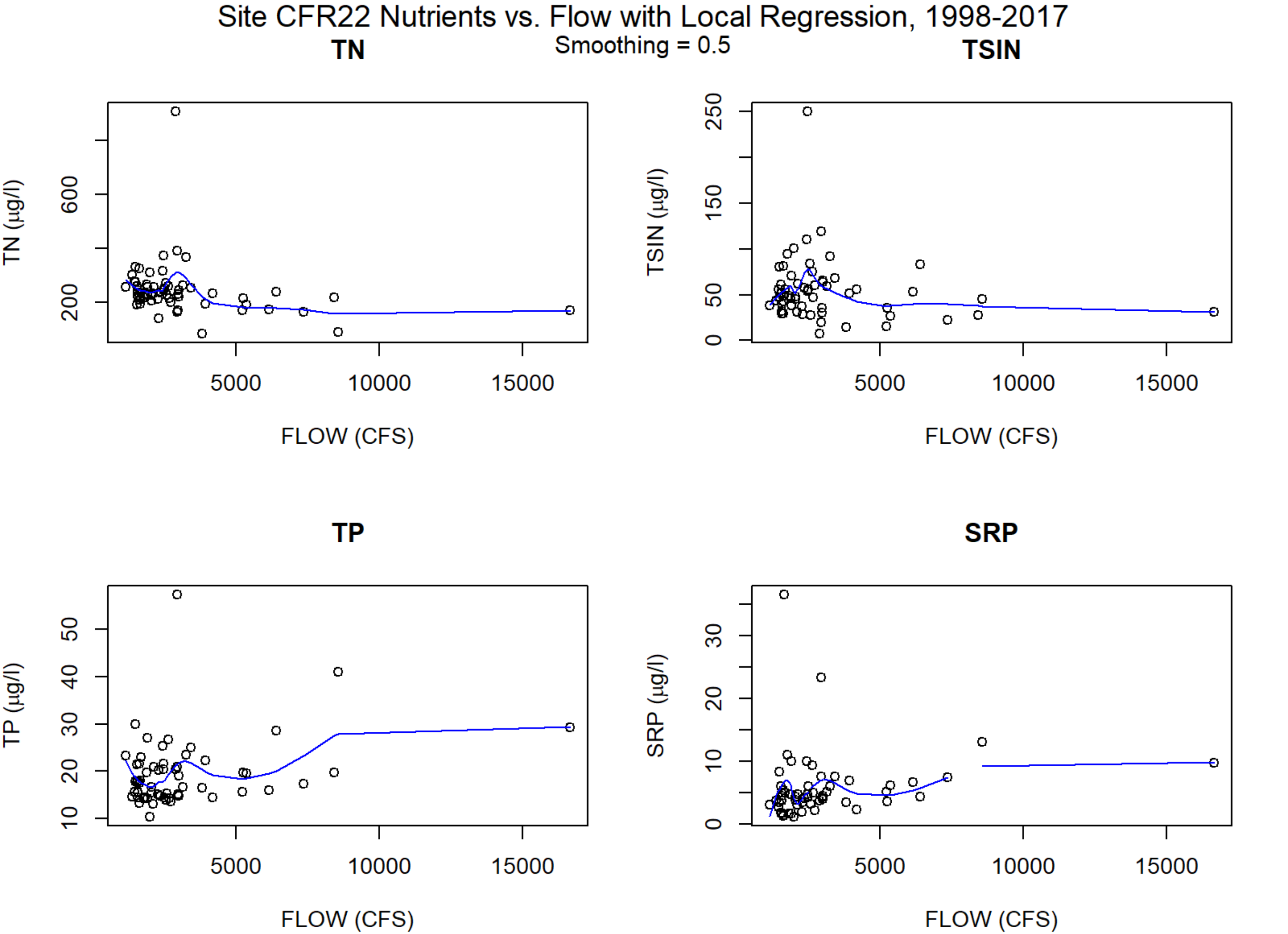

Site CFR18 Nutrients vs. Flow with Local Regression, 1998-2017
Smoothing = 0.5
TN
TSIN
TP
SRP
TN (µg/l)
TSIN (µg/l)
TP (µg/l)
SRP (µg/l)
FLOW (CFS)
2000
4000
6000
8000
200
600
50
150
250
20
40
60
80
0

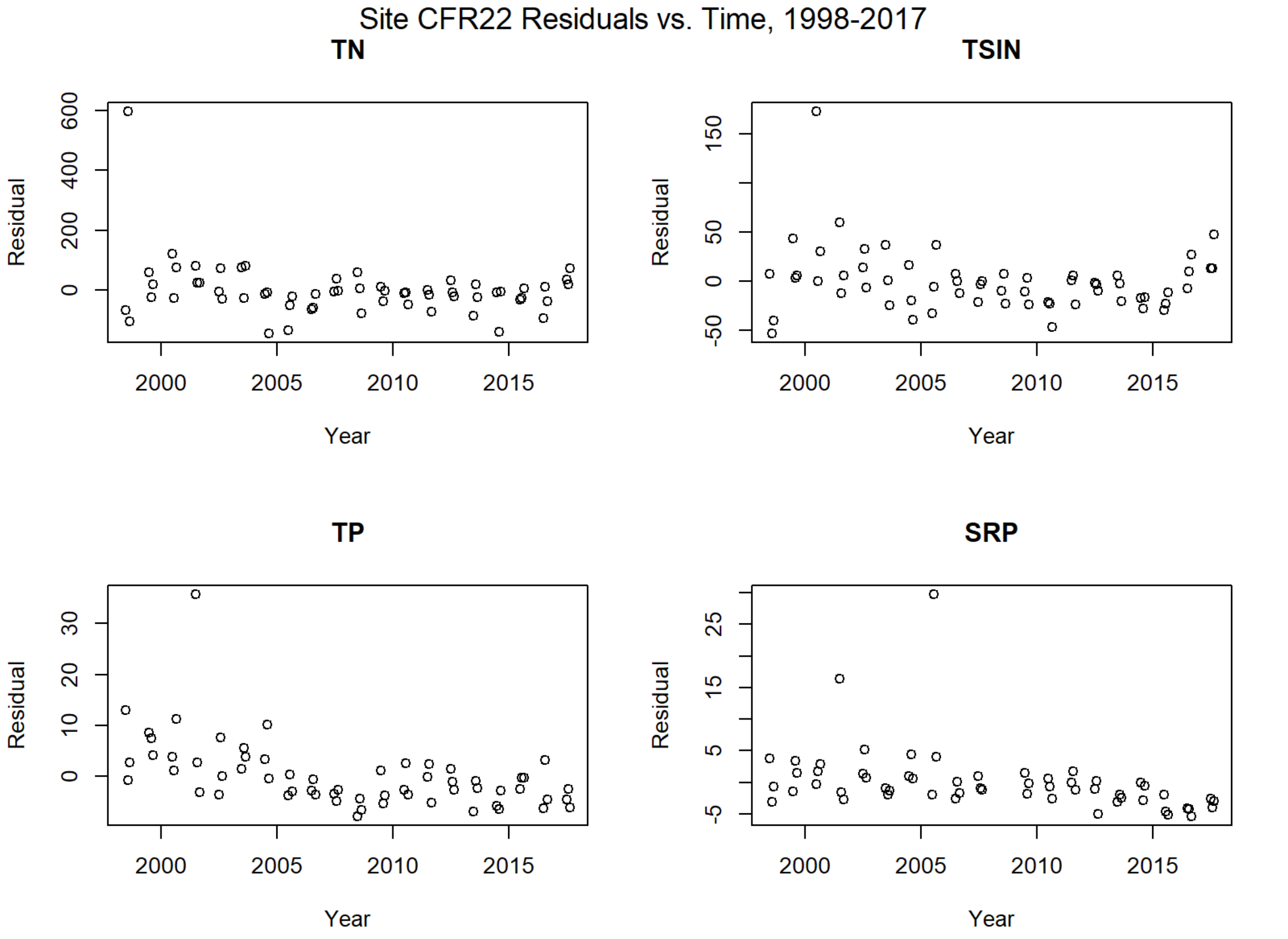

Site CFR18 Residuals vs. Time, 1998-2017
TN
TSIN
TP
SRP
Residual
Year
600
400
200
0
150
50
0
-100
60
40
20
0
50
30
10
-10
2000
2005
2010
2015

Site CFR18-Chla Benthic Algae Chlorophyll-a, 1998-2017

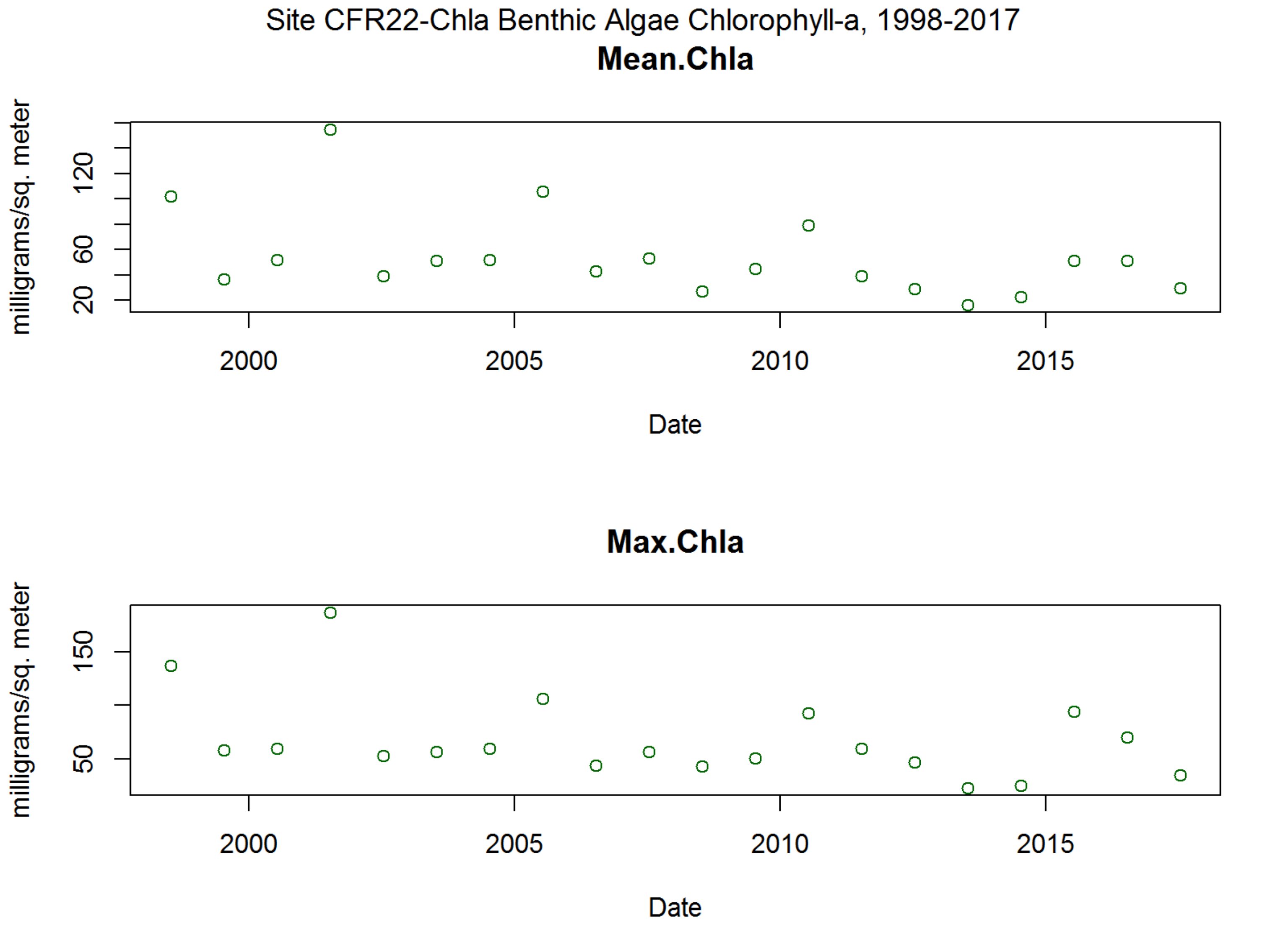


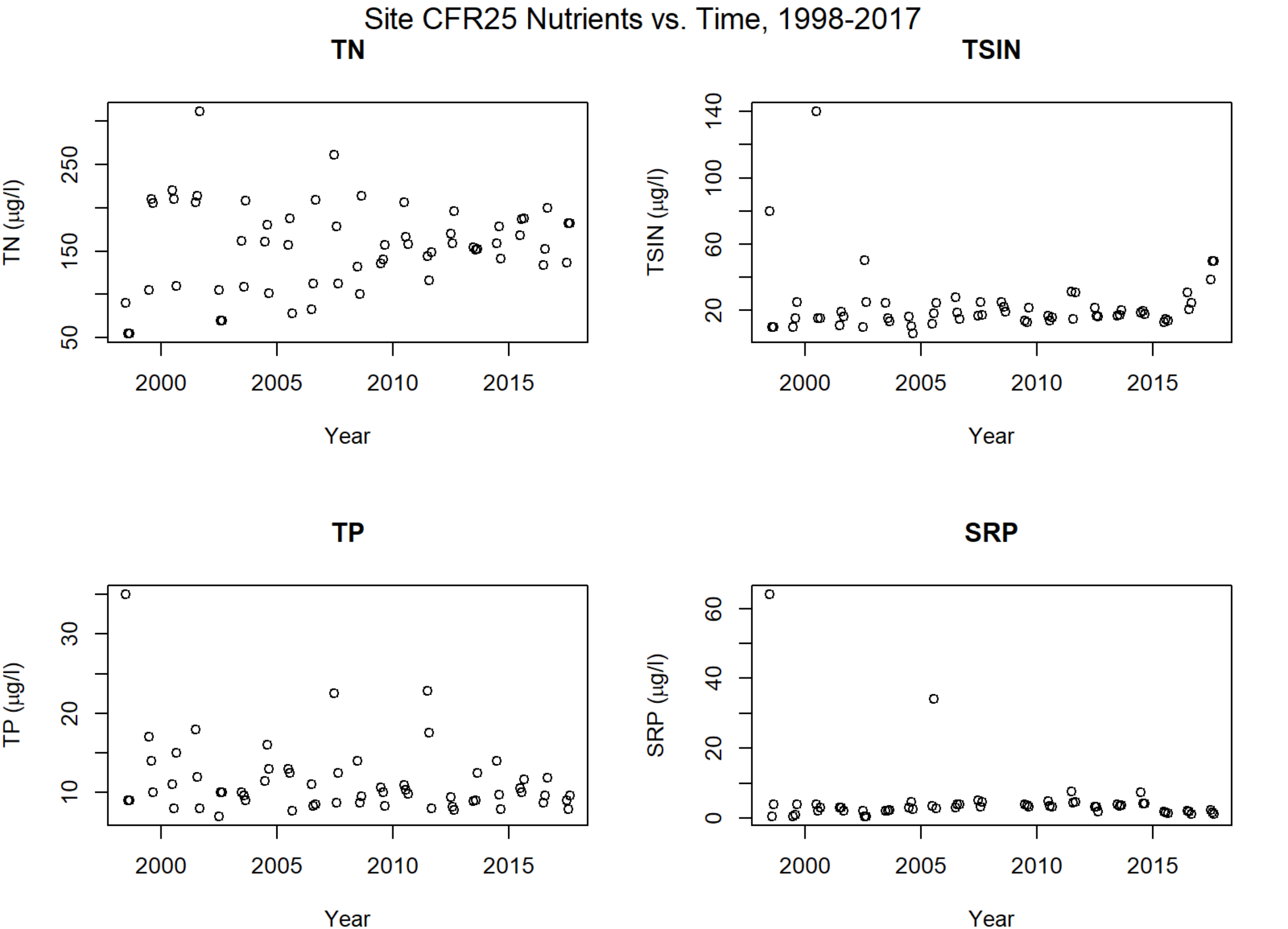

Site CFR22 Nutrients vs. Time, 1998-2017
TN
TN (µg/l)
200
600
2000
2005
2010
2015
Year
TSIN
TSIN (µg/l)
0
50
150
250
2000
2005
2010
2015
Year
TP
TP (µg/l)
10
20
30
40
50
2000
2005
2010
2015
Year
SRP
SRP (µg/l)
0
10
20
30
2000
2005
2010
2015
Year


Site CFR22 Nutrients vs. Flow with Local Regression, 1998-2017
Smoothing = 0.5
TN
TN (µg/l)
200
600
FLOW (CFS)
5000
10000
15000
TSIN
TSIN (µg/l)
0
50
150
250
FLOW (CFS)
5000
10000
15000
TP
TP (µg/l)
10
20
30
40
50
FLOW (CFS)
5000
10000
15000
SRP
SRP (µg/l)
0
10
20
30
FLOW (CFS)
5000
10000
15000

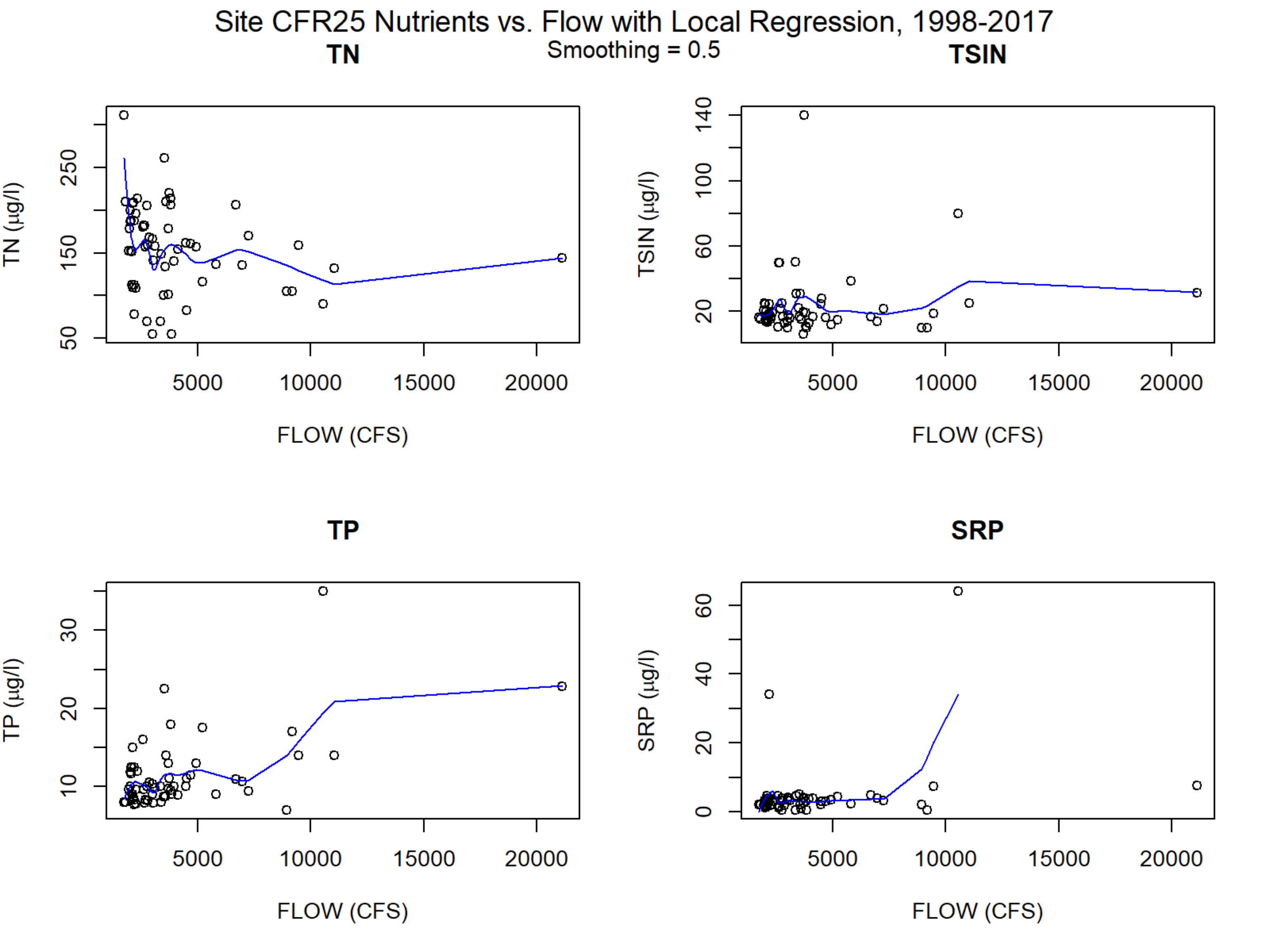


Site CFR22 Residuals vs. Time, 1998-2017
TN
TSIN
TP
SRP
Residual
Year

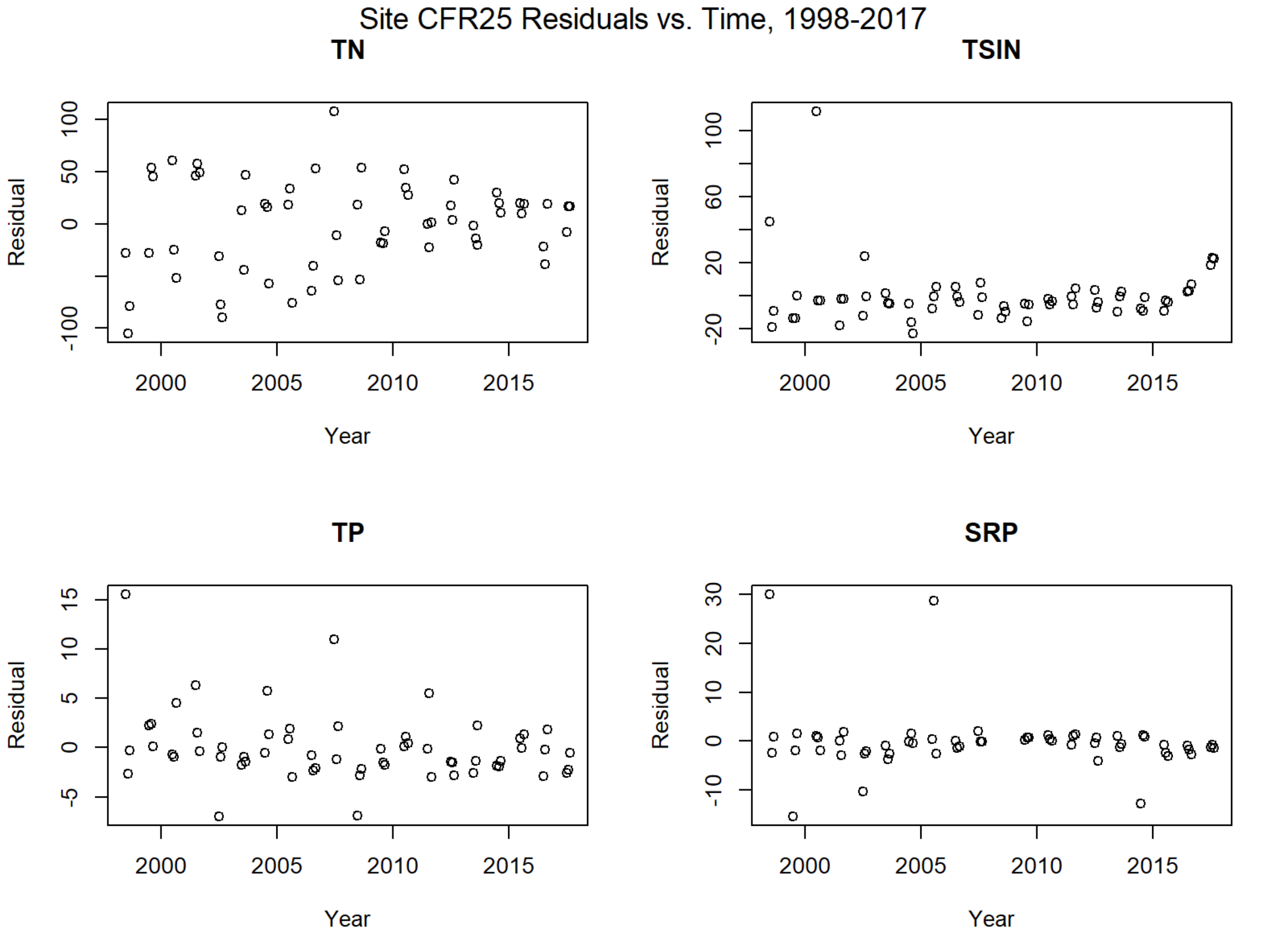

Site CFR22-Chla Benthic Algae Chlorophyll-a, 1998-2017
Mean.Chla
milligrams/sq. meter
20
60
120
2000
2005
2010
2015
Date
Max.Chla
milligrams/sq. meter
50
150
2000
2005
2010
2015
Date



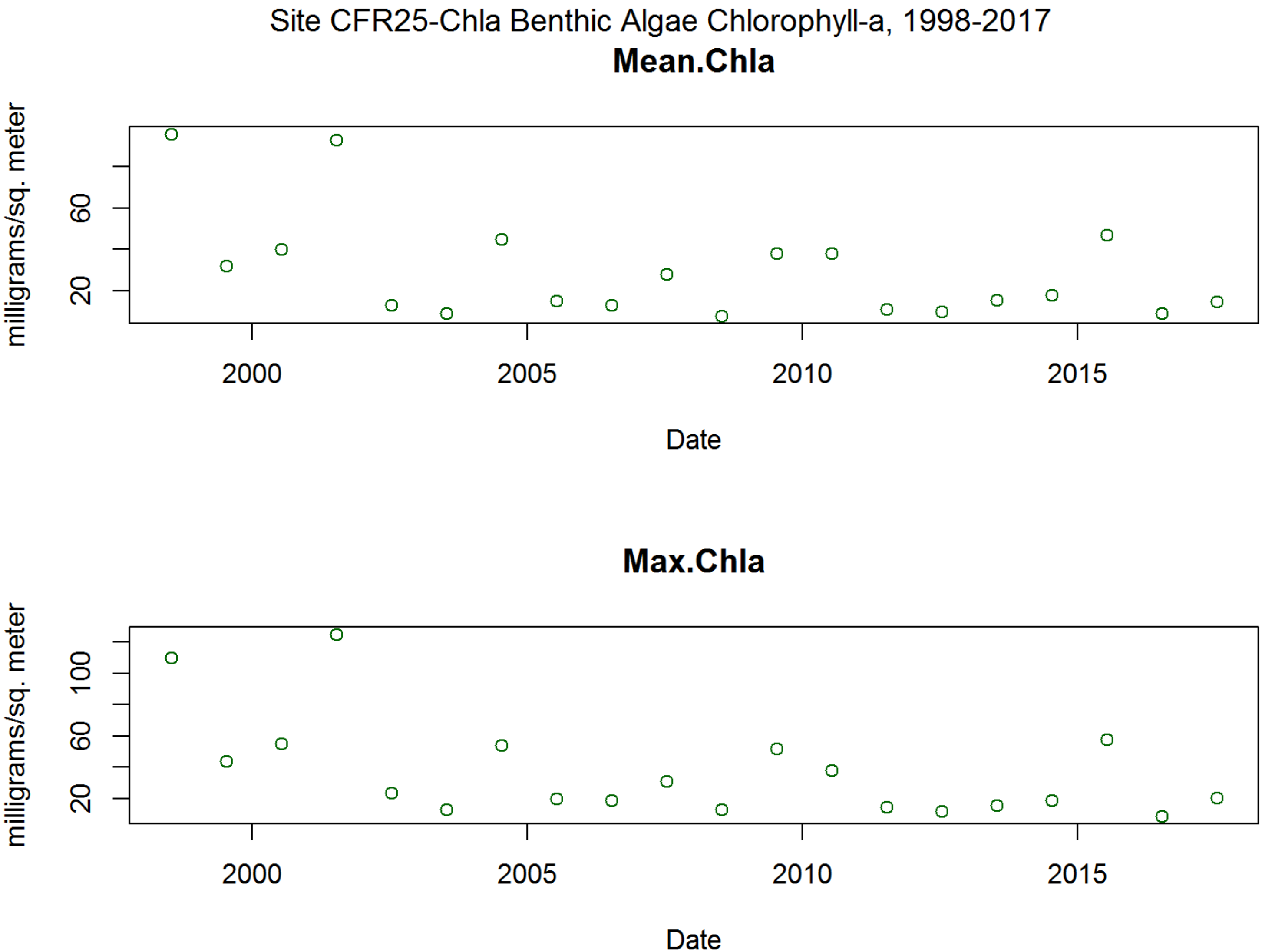
Site CFR25 Nutrients vs. Time, 1998-2017
TN
TN (µg/l)
50
150
250
2000
2005
2010
2015
Year
TSIN
TSIN (µg/l)
20
60
100
140
2000
2005
2010
2015
Year
TP
TP (µg/l)
10
20
30
2000
2005
2010
2015
Year
SRP
SRP (µg/l)
0
20
40
60
2000
2005
2010
2015
Year

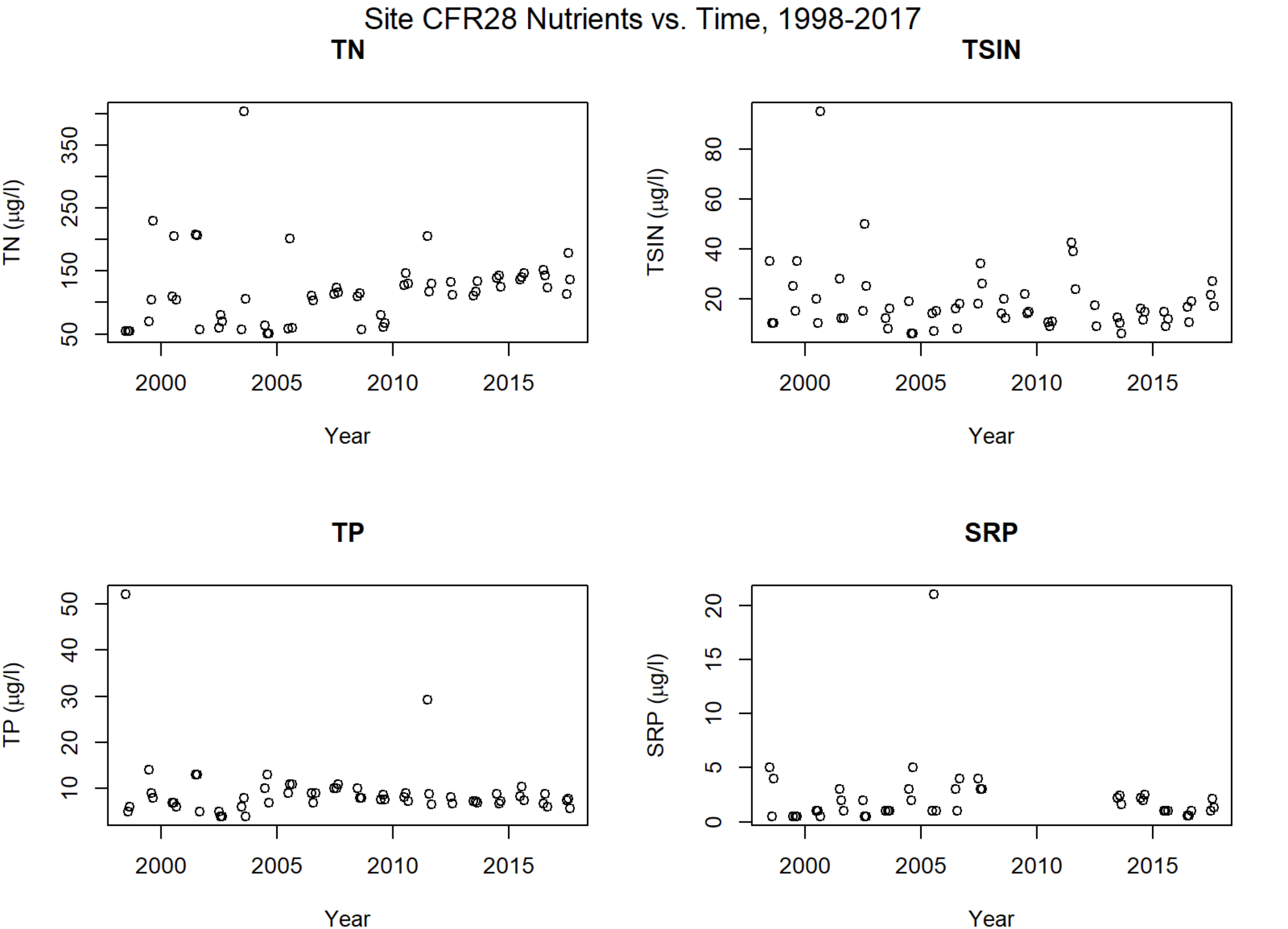


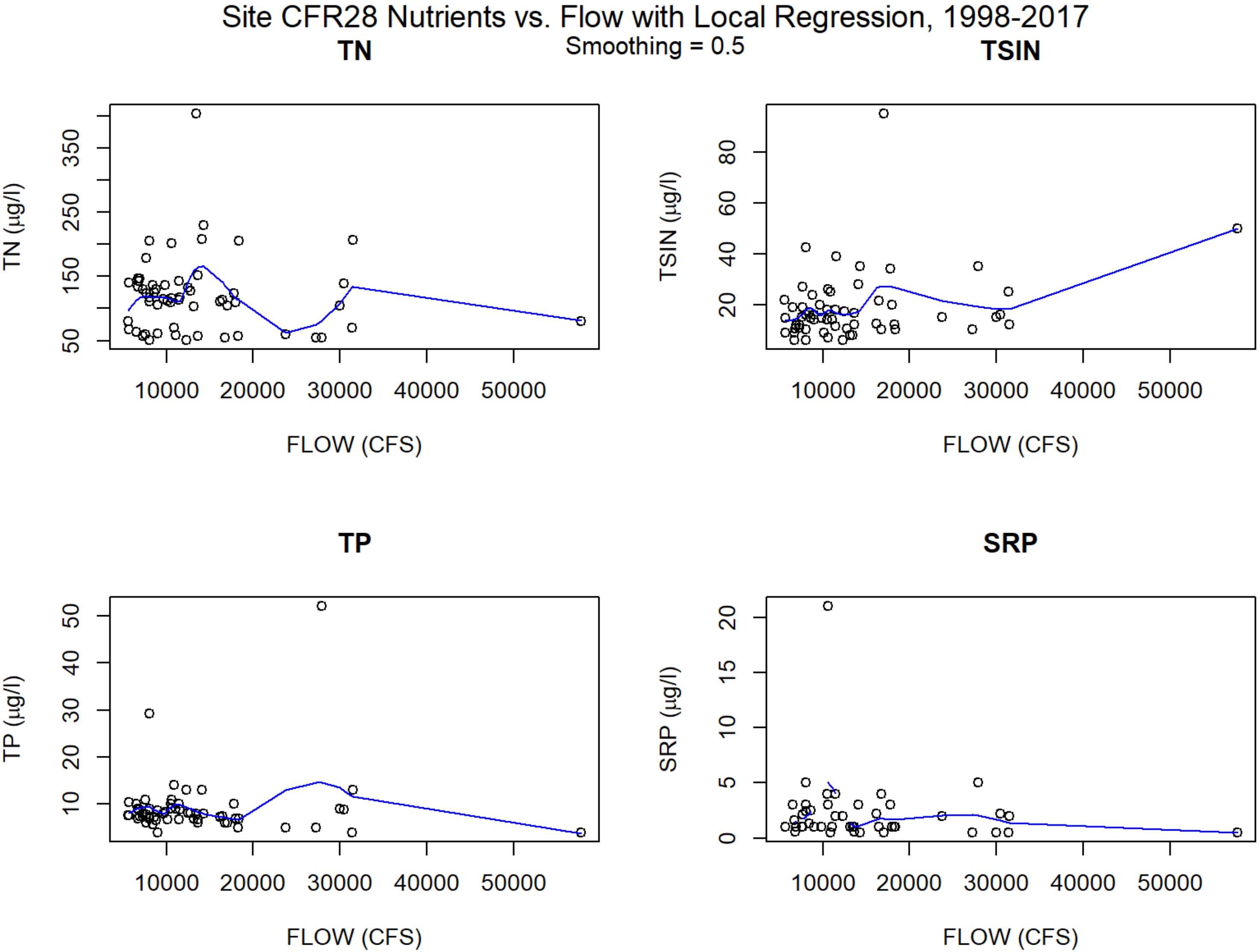
Site CFR25 Nutrients vs. Flow with Local Regression, 1998-2017
Smoothing = 0.5
TN
TN (µg/l)
50
150
250
5000
10000
15000
20000
FLOW (CFS)
TSIN
TSIN (µg/l)
20
60
100
140
5000
10000
15000
20000
FLOW (CFS)
TP
TP (µg/l)
10
20
30
5000
10000
15000
20000
FLOW (CFS)
SRP
SRP (µg/l)
0
20
40
60
5000
10000
15000
20000
FLOW (CFS)

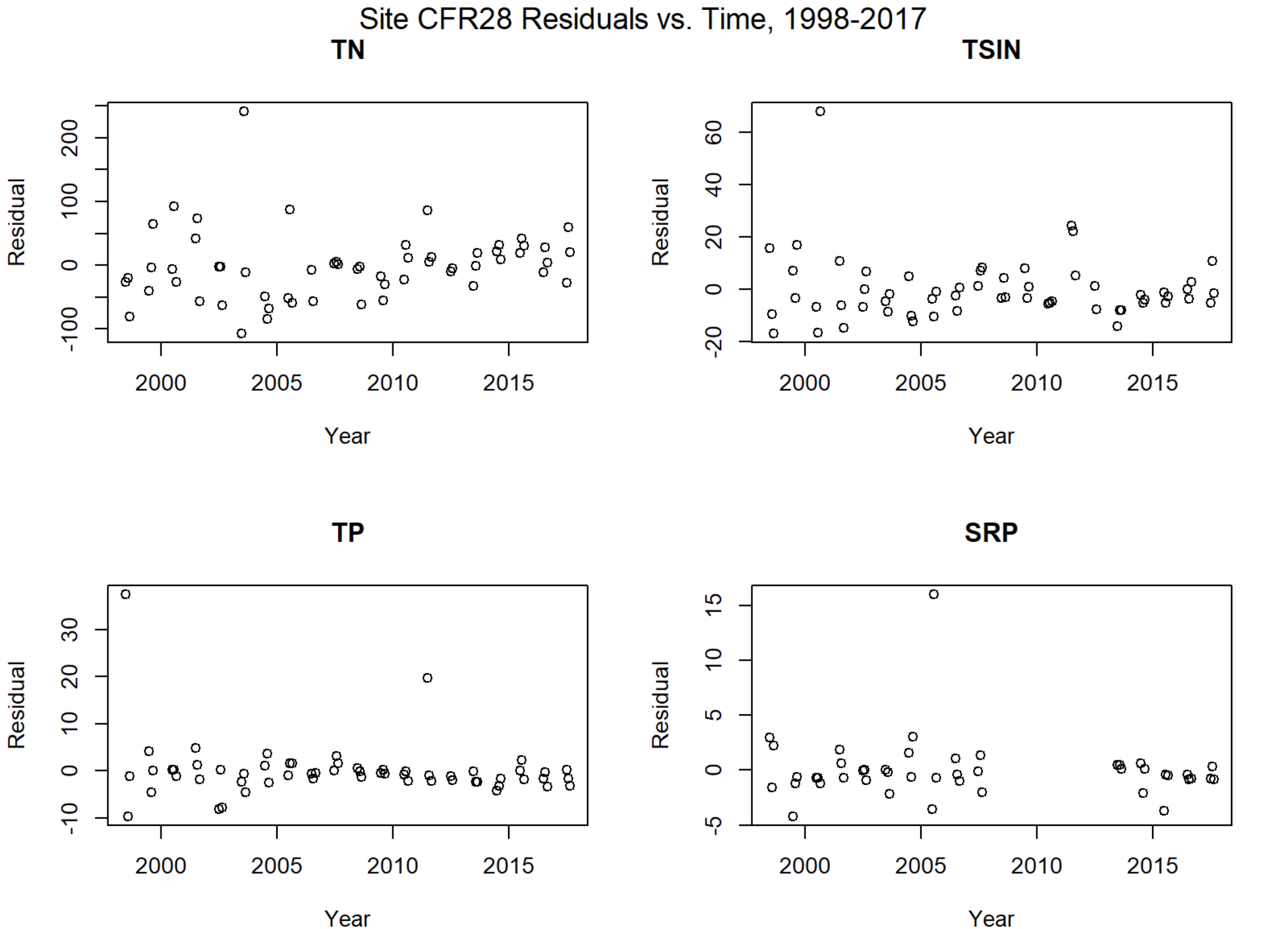


Site CFR25 Residuals vs. Time, 1998-2017
TN
TSIN
TP
SRP
Residual
Year
100
50
0
-100
60
20
-20
15
10
5
-5
30
-10
2000
2005
2010
2015

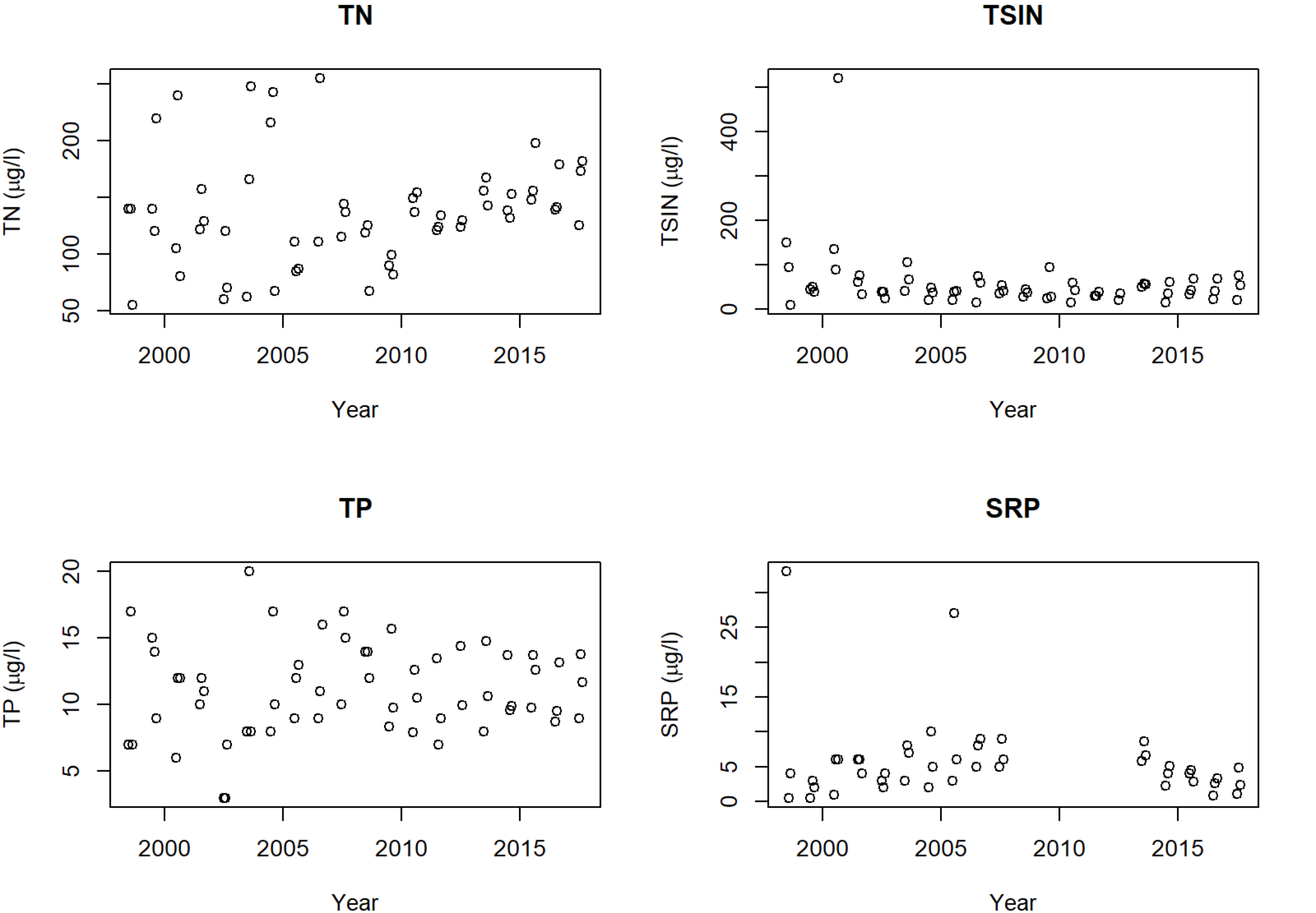

Site CFR25-Chla Benthic Algae Chlorophyll-a, 1998-2017
Mean.Chla
milligrams/sq. meter
20
60
2000
2005
2010
2015
Date
Max.Chla
milligrams/sq. meter
20
60
100
2000
2005
2010
2015
Date

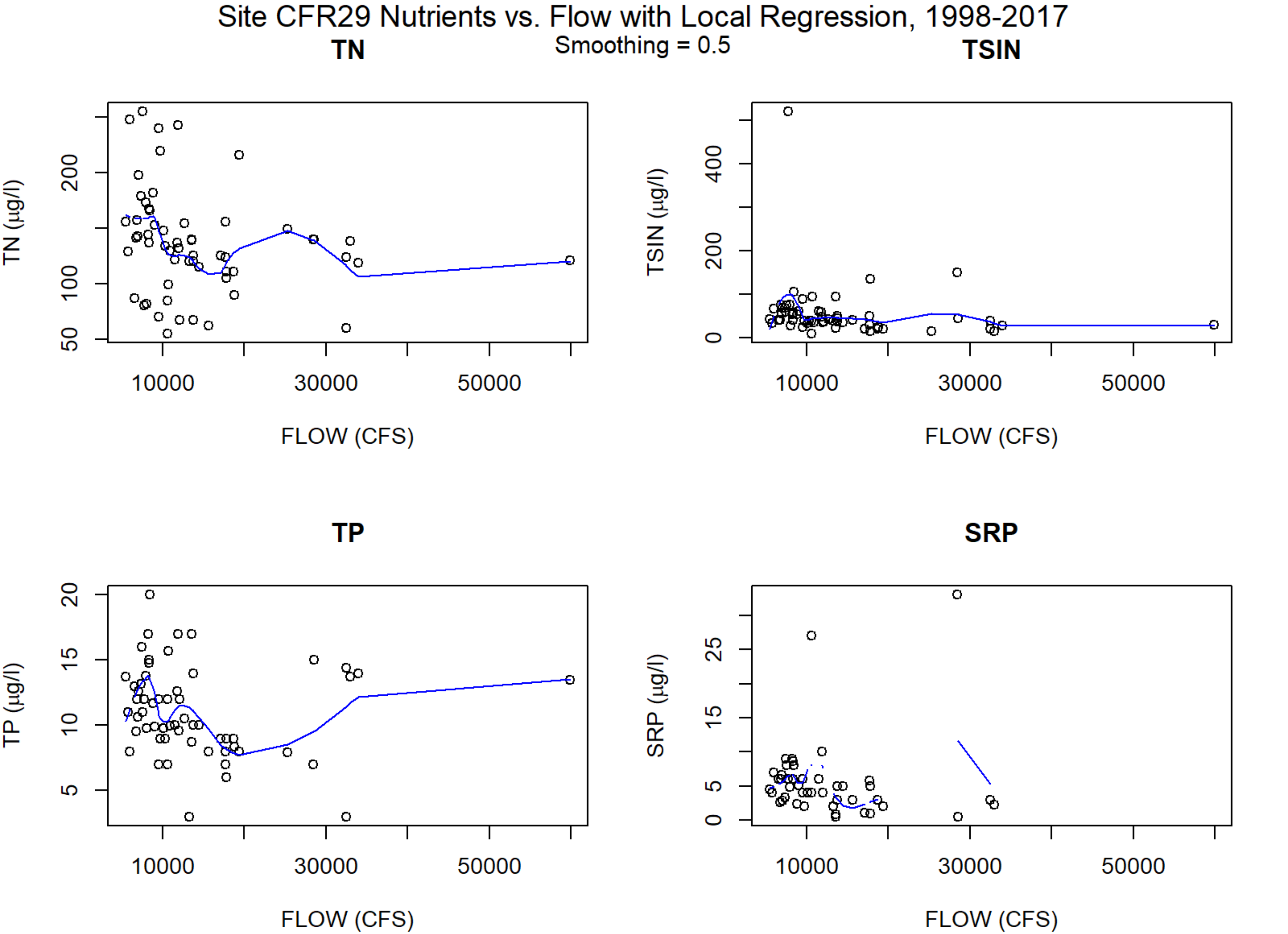

Site CFR28 Nutrients vs. Time, 1998-2017
TN
TN (µg/l)
50
150
250
350
2000
2005
2010
2015
Year
TSIN
TSIN (µg/l)
20
40
60
80
2000
2005
2010
2015
Year
TP
TP (µg/l)
10
20
30
40
50
2000
2005
2010
2015
Year
SRP
SRP (µg/l)
0
5
10
15
20
2000
2005
2010
2015
Year

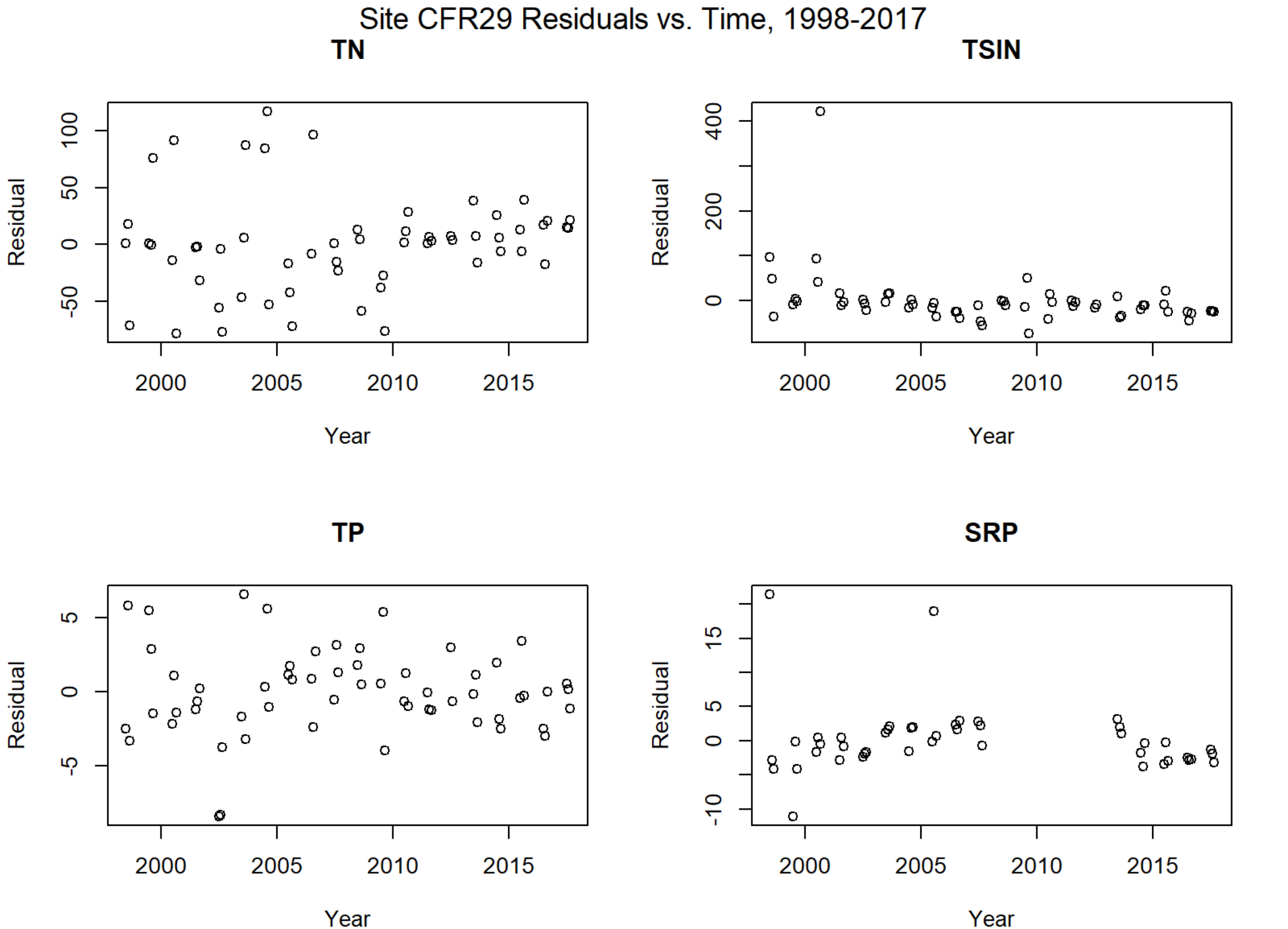

Site CFR28 Nutrients vs. Flow with Local Regression, 1998-2017
Smoothing = 0.5
TN
TSIN
TP
SRP
TN (µg/l)
TSIN (µg/l)
TP (µg/l)
SRP (µg/l)
FLOW (CFS)
FLOW (CFS)
FLOW (CFS)
FLOW (CFS)
10000
20000
30000
40000
50000

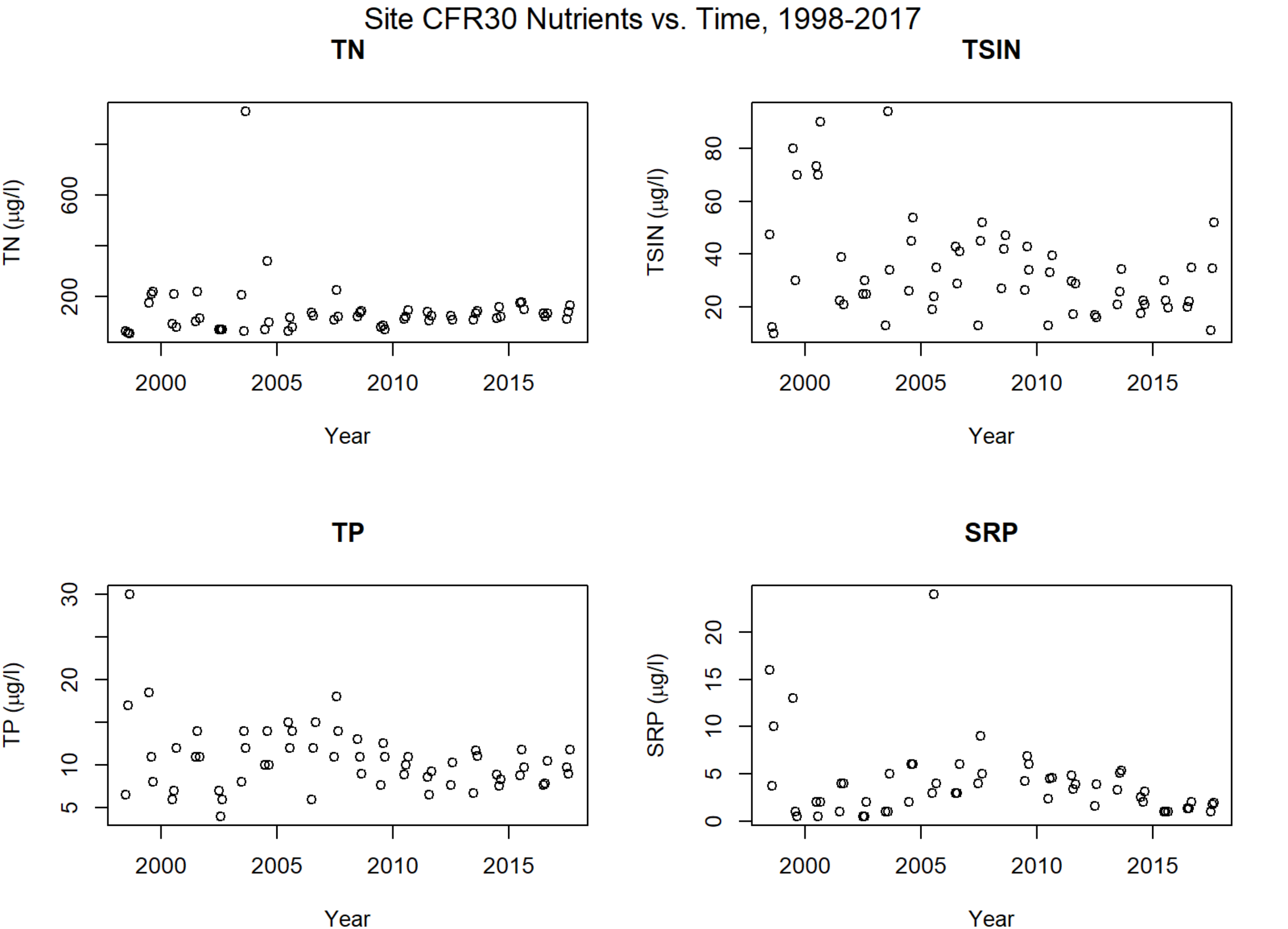

Site CFR28 Residuals vs. Time, 1998-2017
TN
TSIN
TP
SRP
Residual
Year
-100
0
100
200
-20
0
20
40
60
-10
0
10
20
30
-5
0
5
10
15
2000
2005
2010
2015

Site CFR29 Nutrients vs. Time, 1998-2017

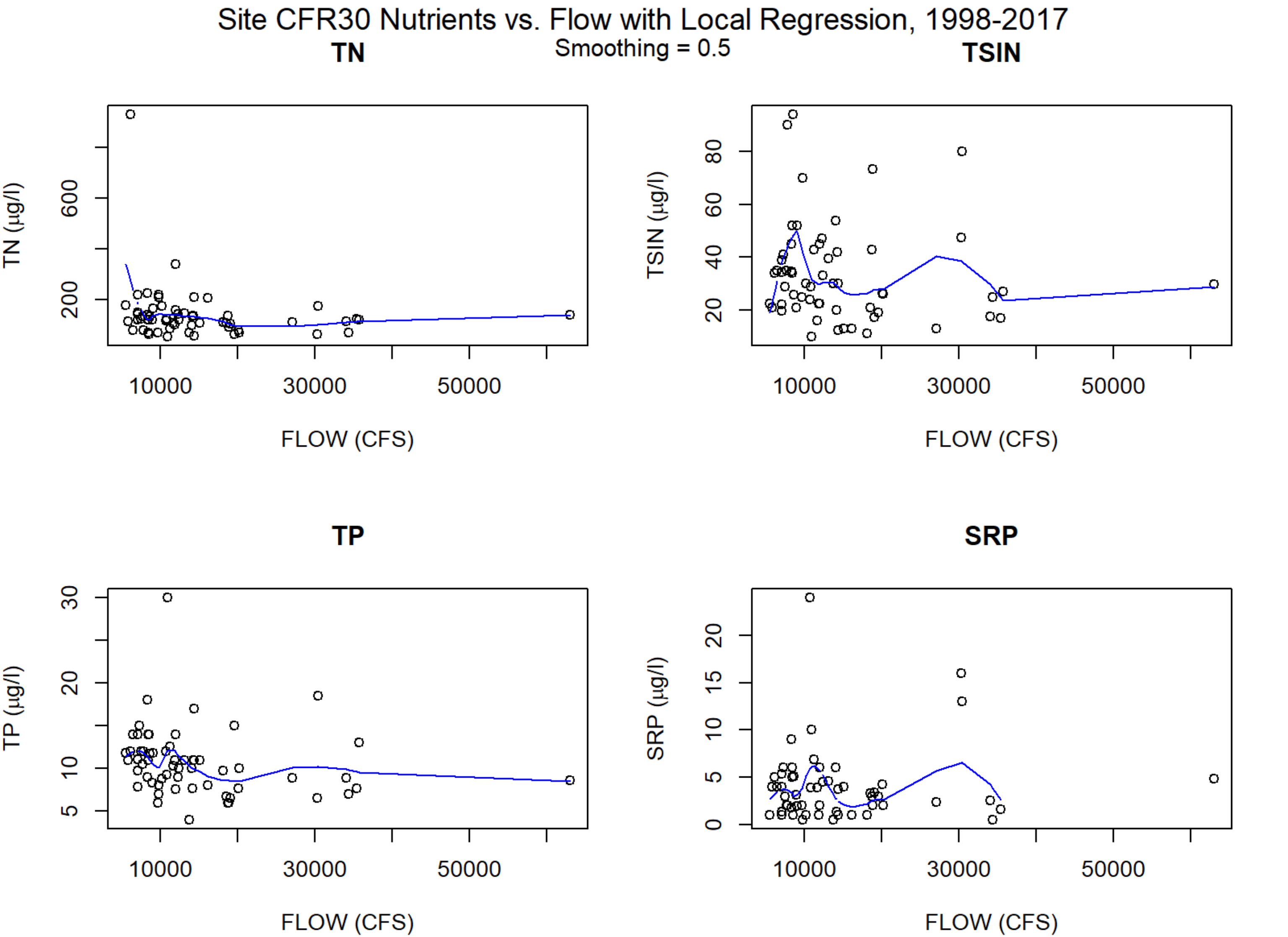


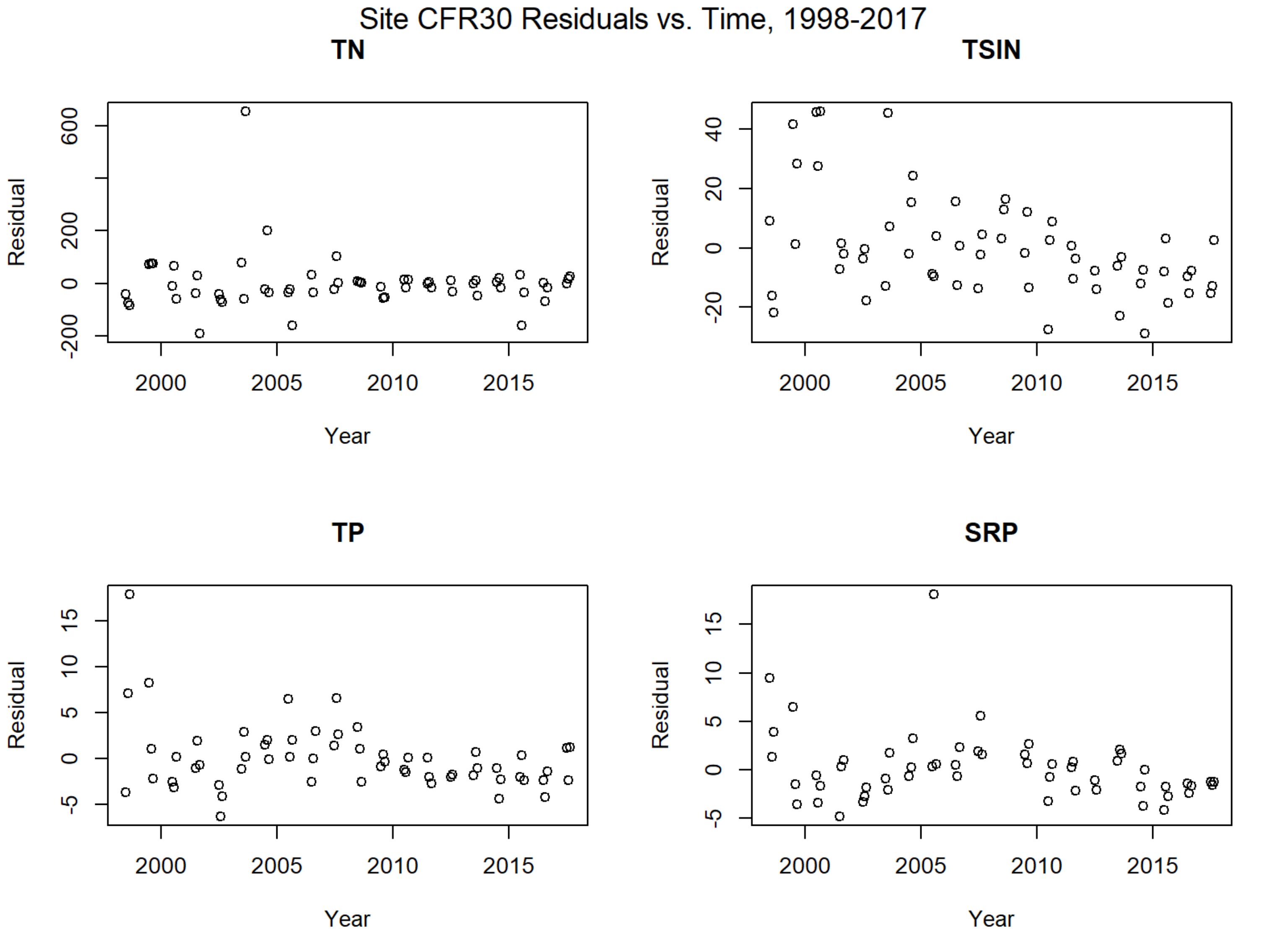

Site CFR29 Nutrients vs. Flow with Local Regression, 1998-2017
Smoothing = 0.5
TN
TN (µg/l)
50
100
200
10000
30000
50000
FLOW (CFS)
TSIN
TSIN (µg/l)
0
200
400
10000
30000
50000
FLOW (CFS)
TP
TP (µg/l)
5
10
15
20
10000
30000
50000
FLOW (CFS)
SRP
SRP (µg/l)
0
5
15
25
10000
30000
50000
FLOW (CFS)


Site CFR29 Residuals vs. Time, 1998-2017
TN
TSIN
TP
SRP
Residual
Year
100
50
0
-50
400
200
15
5
-5
-10
2000
2005
2010
2015



Site CFR30 Nutrients vs. Time, 1998-2017
TN
TN (µg/l)
200
600
TSIN
TSIN (µg/l)
20
40
60
80
TP
TP (µg/l)
5
10
20
30
SRP
SRP (µg/l)
0
5
10
15
20
2000
2005
2010
2015
Year

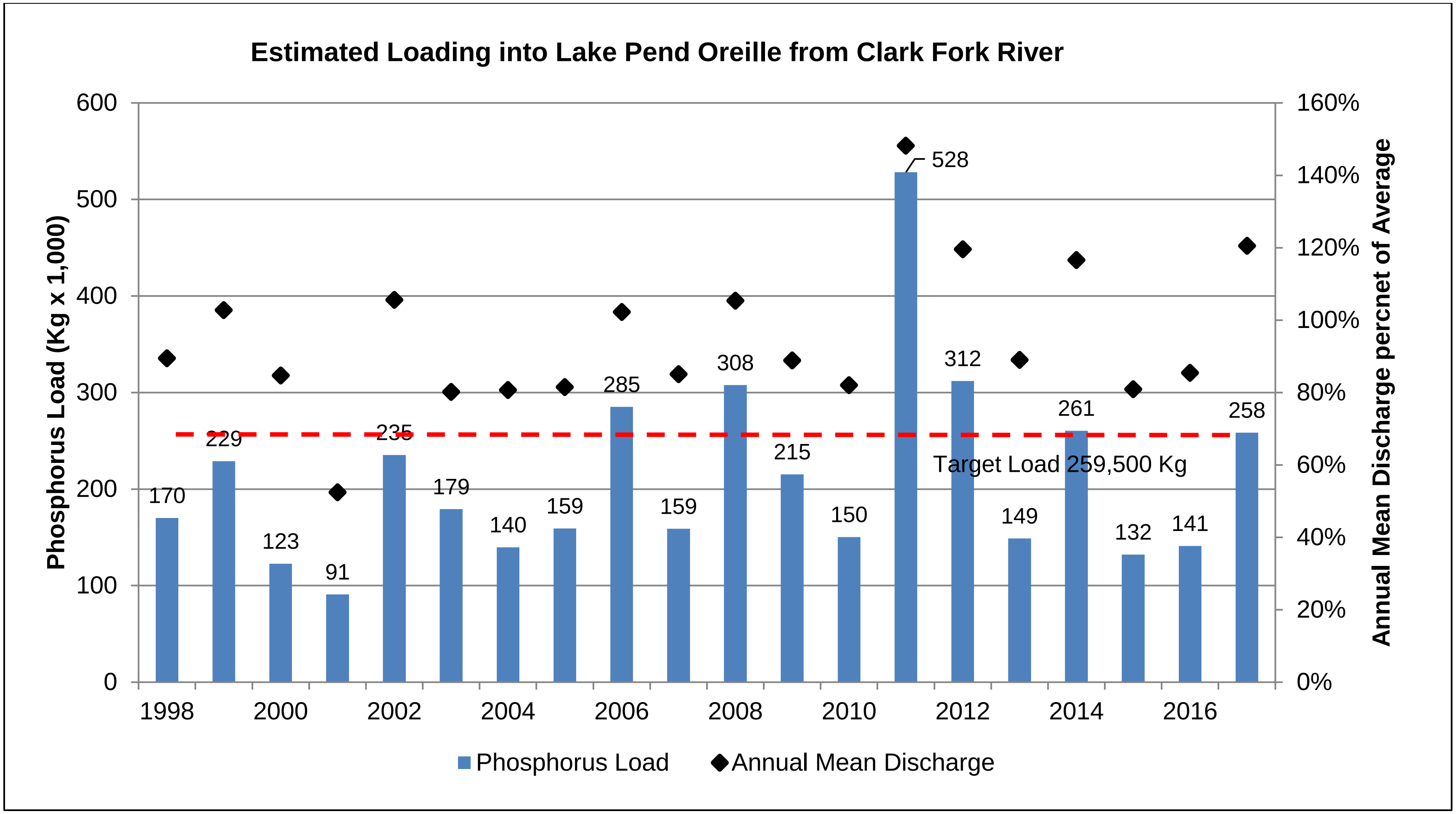

Site CFR30 Nutrients vs. Flow with Local Regression, 1998-2017
Smoothing = 0.5
TN
TN (µg/l)
200
600
10000
30000
50000
FLOW (CFS)
TSIN
TSIN (µg/l)
20
40
60
80
10000
30000
50000
FLOW (CFS)
TP
TP (µg/l)
5
10
20
30
10000
30000
50000
FLOW (CFS)
SRP
SRP (µg/l)
0
5
10
15
20
10000
30000
50000
FLOW (CFS)



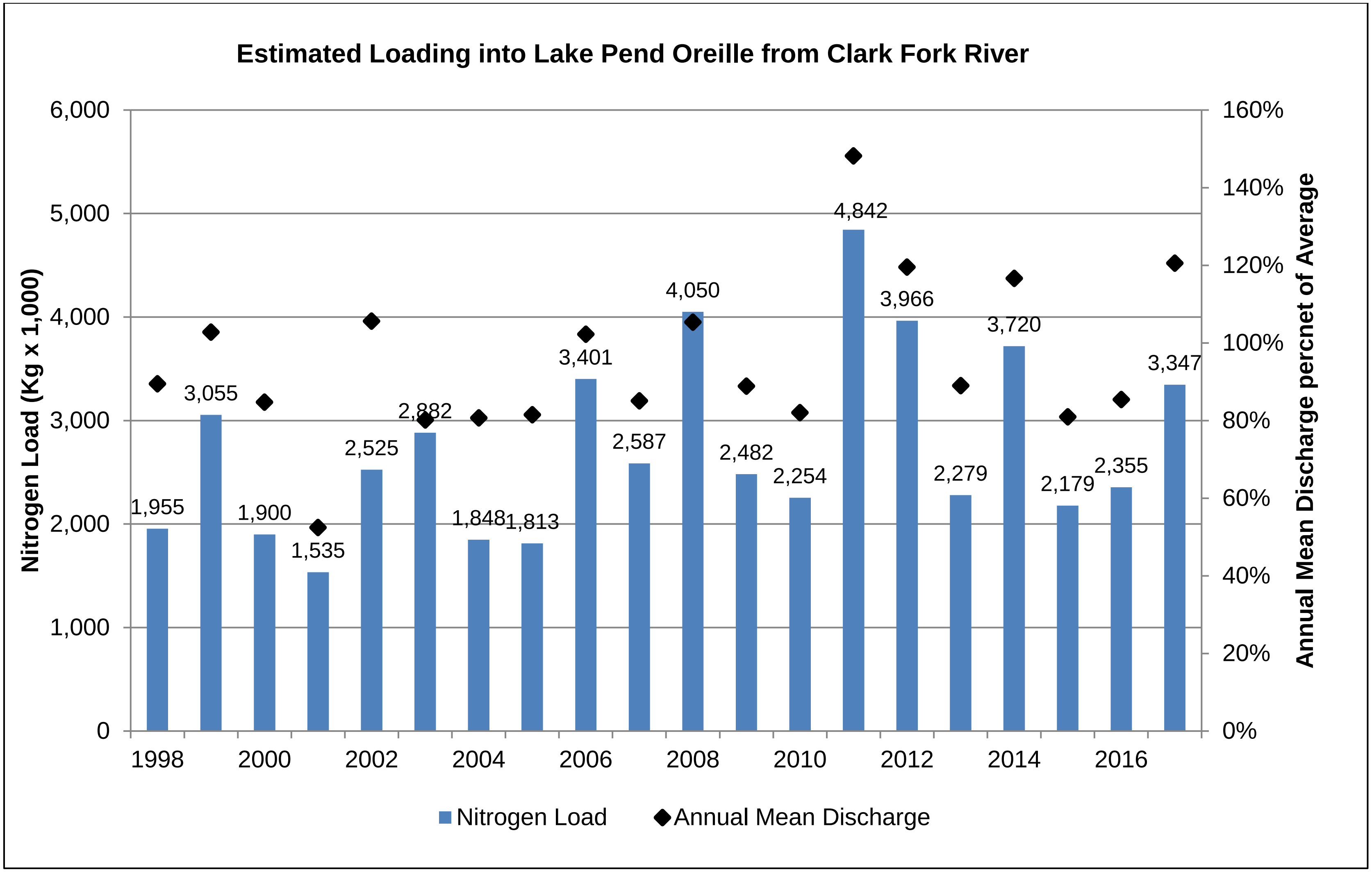
Site CFR30 Residuals vs. Time, 1998-2017
TN
TSIN
TP
SRP
Residual
Year
2000
2005
2010
2015
600
200
0
-200
40
20
0
-20
15
10
5
0
-5

ATTACHMENT D:

Charts of Estimated Nutrient Loading from the Clark Fork River 1998-2017



Attachment D-1. Estimated Total Phosphorus Loading from the Clark Fork River 1998 to 2017, based on U.S. Army Corps of Engineers FLUX model, with Method 6 regressions stratified on two or three regimes, according to the number of sample results. Water quality sample results were generated from monitoring station Clark Fork River below Cabinet Gorge Dam (CFR-30) and inflow from USGS gaging station 12392000, Clark Fork at Whitehorse Rapids, Idaho. Target Load is based on Montana-Idaho Nutrient Border Agreement, Clark Fork River annual allocation.



Attachment D-2. Estimated Total Nitrogen Loading from the Clark Fork River 1998 to 2017, based on U.S. Army Corps of Engineers FLUX model, with Method 6 regressions stratified on two or three regimes, according to the number of sample results. Water quality sample results were generated from monitoring station Clark Fork River below Cabinet Gorge Dam (CFR-30) and inflow from USGS gaging station 12392000, Clark Fork at Whitehorse Rapids, Idaho.