Effects of forest stand density reduction on nutrient transport at the Caspar Creek Watershed

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Helen E. Dahlke

Department of Land, Air and Water Resources
One Shields Ave
University of California, Davis
Davis, CA 95616-8627

Phone: 530-302-5358
Fax: 530-752-1552
Email: hdahlke@ucdavis.edu

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1 Executive Summary

Healthy headwater streams are critical to protecting downstream water quality for many natural ecosystems and societal water uses. Attention to the critical role that headwater watersheds play in providing clean surface water for ecosystems and human consumption has been magnified in recent years as threats to their sustainability continue to intensify through land use change, urbanization, timber harvesting, and climate change induced extreme events and wildfires. Many of the headwater catchments in the United States and across the world are forested, with forests providing several functions to their aquatic ecosystems such as shade, nutrients, soil moisture storage, erosion and flood control, and buffers for extreme events. Yet, many forests also provide food, fuel and fiber for humans, hence, timber harvest is a frequent management activity and ecological disturbance event in many headwater watersheds.

Decades of research on the impact of timber harvest or deforestation on downstream aquatic ecosystems have shown that timber harvest in general increases total water yield (Fulton and West, 2002). However, there is less agreement on how timber harvest affects biogeochemical processes, nutrient export, and stream water chemistry. Previous studies have shown that biogeochemical trends observed after timber harvest are often confounded by specific watershed characteristics, such as watershed area, forest and vegetation types, soil types, slope, aspect, and light availability, to name a few (Lamontagne et al., 2000; Bernhardt et al., 2003). Determining the relationship between stand density reduction, streamflow, and fluxes of major nutrients and water chemistry parameters across a range of harvest intensities allowed identifying relationships and thresholds at which reducing stand density may begin to affect biogeochemical processes to the extent that nutrient export and stream chemistry are significantly affected.

The goal of this study was to quantify the effect of different levels of stand density reduction on the mass balance of major nutrients (carbon, nitrogen, and phosphorus) and base cations and anions in the South Fork Caspar Creek. Our main hypothesis was that stand density reduction will increase export of total N, total P, nitrate, and dissolved organic carbon from the treated watersheds immediately following the timber harvest, with greater effects observed with greater stand density reduction. The increased export of nutrients and base cations/anions is further hypothesized to be facilitated by rapid flow pathways and increased hydrologic connectivity associated with macropore flow and fast subsurface stormflow above the clay-rich, argillic soil horizon present in the watershed. This study is addressing the following specific research questions:

1) What are the temporal (annual, seasonal) variations and patterns of nutrient and base cation/anion fluxes from coast redwood forests?

2) How do different stand density reductions change the patterns, concentrations and fluxes of nutrients and base cations and anions compared to pre-harvest conditions?

Between fall 2016 and June 2020 almost 2000 water samples were collected at the outlets of four sub-watersheds (WIL, TRE, UQL, and ZIE) representing timber stand reductions of 0%, 35%, 55%, and 75% and the South Fork Caspar Creek watershed during storm events and during the summer baseflow period. Concentrations and fluxes of major nutrients (total nitrogen, NH_4^+-N, NO_3^--N, dissolved organic nitrogen, total phosphorus, phosphate, and dissolved organic carbon) and electrical conductivity, pH, and turbidity were observed. Concentrations and fluxes were compared across the five sampling points and through time (pre- and post-harvest, water year, water year type, and season) to determine single or compound effects of forest harvest management practices and naturally occurring disturbance events such as extreme wet or dry years. All differences were analyzed using ANOVA and post-hoc Tukey's honestly significant difference test.

Hydrology and Climate

In summary we found, the four study years exhibited extreme variability in annual precipitation, which varied between 534 mm in HY2020 and 1632 mm in 2017 (the second largest annual precipitation in the last 100 years). Because of the high and low annual precipitation amounts, mean daily streamflow and total annual water yield from SFC and the four study sub-watersheds varied widely from year to year, creating large differences in stream water nutrient concentrations and nutrient fluxes of N, P and DOC. Despite the natural variation in streamflow due to variable precipitation inputs, water yield increased in the sub-watersheds the two years following the timber removal in summer and fall of 2018. Water yield increased at an average rate of about 31.5 mm/year for every 10% of timber removed from the watershed in HY2019 and at a rate of about 18 mm/yr for every 10% of timber removed from the watershed in HY2020. However, increase in water yield in UQL and ZIE following the timber removal event was not large enough to prevent cessation of streamflow in these sub-watersheds during the dry summer months and particularly the drought year of HY2020.

Nutrient concentrations

Stream water solute concentrations were similar between the control and treatment sub-watersheds, but elemental concentrations were generally higher in the four sub-watersheds compared to the concentrations measured at the outlet of South Fork Caspar Creek. Across all studied watersheds, the timber removal caused a clear increase in stream water DOC and TP concentrations. These increases are likely due to increased availability and transport of biomass and organic matter from the harvested areas to the stream as well as an increased suspended sediment influx from disturbed forest soils (and generally higher risk of erosion after vegetation is removed) during storm events, and associated increased transport of particulate P attached to sediment grains. Sub-watersheds subject to timber removal also showed a statistically significant increase in DON as well as NH_4^+-N and NO_3^--N (in ZIE only), which is likely due to increased availability of organic nitrogen from the timber harvest, and enhanced mineralization and nitrification or organic-N in the forest soils and streams. The increased availability of DON in the forest soils combined with the increase in water yield likely results in increased subsurface lateral flow above the clay-rich, argillic horizon and macropore flow, which delivers DON-enriched waters from the hillslope areas to the stream during storm events. In contrast to the second experimental study conducted in the North Fork of Caspar Creek, we did not find a clear increase in NO_3^--N across all treatment watersheds. However, some of these processes might have been subdued due to the fact that HY2020 was an extreme dry year and most N cycling processes require substantial soil moisture for mineralization of organic N to NH_4^+, and nitrification of NH_4^+ to NO_3^- to occur. In addition, some of the N transported from the sub-watersheds where timber was removed to the stream might have been consumed in-stream for example by algal communities that strived under the increased light availability and large input of organic-N and wordy debris, which might have increased inorganic nitrogen processing in streams.

Nutrient Fluxes

Fluxes of N, P and C from the sub-watersheds subject to timber removal as well as the entire South Fork Caspar Creek watershed were generally 1.3 to 9 times greater than those from the control sub-watershed WIL. The increased nutrient fluxes were a combination of both increased solute concentrations (e.g. DOC, TP, DON) and increased water flux (due to reduction in evapotranspiration). The loss of N from the sub-watersheds where 35-75% of the timber stand was removed increased in the two years following the harvest event. However, the magnitude of the increase in N flux following the timber removal overall was smaller than the N export observed during the very wet HY2017. This indicates that naturally occurring hydrologic extreme events can transport as much or more N from coastal forested watersheds as would occur in response to 75% timber removal during a normal precipitation year. In contrast to the N fluxes, DOC export did show the strongest response to the implemented timber harvest treatments, resulting in the case of ZIE (75% timber removal) an almost 2.3-fold increase in load. Together the results indicate that management of the residual biomass from the timber harvest is key in keeping the DOC loads in stream water at or near the same levels as observed prior to the timber harvest event.

Acknowledgments

We acknowledge the valuable guidance and logistical support from Elizabeth Keppeler, Joe Wagenbrenner, Pete Cafferata and Salli Dymond in scoping and conducting this research project. Field and laboratory assistance by S. McLaughlin, Kerri Steenwerth, Cristina Prieto Garcia, Shulamit Shroder, and Kira Waldman, and the entire field staff of the USDA Forest Service/Jackson State Forest Caspar Creek Research Team is greatly appreciated.

2 Introduction

Healthy headwater streams are critical to protecting downstream water quality for many natural ecosystems and societal water uses (Battin et al., 2008). Attention to the critical role that headwater watersheds play in providing clean surface water for ecosystems and human consumption has been magnified in recent years as threats to their sustainability continue to intensify through land use change, urbanization, timber harvesting, and climate change induced extreme events and wildfires (Elmore & Kaushal, 2008; Poff et al., 2011). Headwater streams originate from extensive networks of first-order stream channels and spring seeps, and it is their small relative size, and often fragmented or ephemeral nature, that make them exceptionally vulnerable to landscape disturbances (Battin et al., 2008).

Within headwater watersheds, several functional landscape units are distinguished including hillslopes, riparian zones, stream channels, upland areas or variable source areas that are characterized by different hydrological and biophysical dynamics and mechanisms. Based on decades of watershed research, it is widely recognized that forested riparian zones are crucial to sustaining the health of headwater streams. Energy, water, nutrients, and environmental pollutants are regulated by forested riparian buffer zones (Battin et al., 2008; Kreutzweiser et al., 2008; Poff et al., 2011; Richardson & Danehy, 2007), whereby various biogeochemical processes control exchanges between terrestrial and aquatic ecosystems. Riparian zones are characterized by high biodiversity; in the western US. They take up less than 2% of the total land area, but provide habitat to approximately one third of all plant species (Poff et al., 2011). Because headwater watersheds often have low or ephemeral flow regimes, stream reaches are often disconnected for periods of the year and therefore they do not typically support fish or other larger aquatic species, which creates a refuge for certain communities who would otherwise be subject to predation(Richardson & Danehy, 2007). Canopy closure and low light availability regulate stream temperatures in headwater watersheds and produce higher humidity environments suited to specific plants and organisms adapted to these conditions (Richardson & Danehy, 2007). Allochthonous organic matter and organic byproducts originating in headwater streams are the drivers of primary production, downstream food webs, uniquely adapted aquatic communities, and higher organisms, as described in the River Continuum Concept (Vannote et al., 1980).

Forest management strategies such as thinning, logging, and timber harvesting are often implicated as having adverse effects on nutrient cycling, sediment transport and hydrological processes in forested watersheds. Timber harvest in particular has been shown to impact downstream ecosystems and water quality through changes in hydrologic response, increased sedimentation and erosion, changes in stream temperature and dissolved oxygen content, and changes in biogeochemical processes and trends (Troendle & King 1985; Stednick 1996; Gravelle et al. 2009; Boggs et al. 2016). Over the past 60 years, several studies have investigated the effects of forest disturbance on hydrologic parameters including base flow, stream flow, and depth to the water table. Many of these studies agree that forest disturbance generally increases total water yield (Fulton & West, 2002), however, reported effects on biogeochemical processes and water quality remain quite variable and site-specific in the published studies. Natural variations in nutrient concentrations in stream water can be due to differences in geology and weathering, precipitation, streamflow, and biological processes. In the western U.S., differences in stream chemical concentrations, especially phosphorus (P), tends to be dominated by geology (Dethier, 1979, Gravelle et al., 2018), while exports in organic and inorganic nitrogen are rather related to in-stream and soil processes. Previous studies in the western U.S. have also found large seasonal variations in nitrogen (N) and P concentrations. Seasonal variability can be due to geochemical weathering, as observed in western Montana (Nagorski et al., 2003), or snowmelt runoff (Sickman et al., 2003, Stottlemyer and Troendle, 1992). Primary producers remove N and P (Minshall et al., 2001, Mulholland et al., 2000), and there can be a high demand for N species, especially during the summer (Peterson et al., 2001). However, compared with other land uses, forested watersheds generally have relatively low N and P concentrations (Omernik, 1977, Clark et al., 2001, Ice and Binkley, 2003).

Because of the natural variability in geology, atmospheric inputs, and vegetation between watersheds, but particularly climate and forest management practices that can be applied, the effects of timber harvesting on nutrient concentrations described in previous studies are highly variable (Lovett et al., 2000) and often non-transferable to watersheds in other physiographic settings (Feller, 2005). Although the majority of studies indicate that timber harvest has, by and large, little or no effect on soil carbon (C) and nitrogen (N) (Johnson and Curtis 2001; Martin and Harr, 1989), some studies in the U.S. and southern Canada (Binkley and Brown, 1993), Idaho (Snyder et al., 1975), British Columbia (Feller and Kimmins, 1984), and Oregon (Harr and Fredriksen, 1988) did observe a general increase in nitrate (NO_3^-) concentrations. Most studies also observed a muted response in phosphorus concentrations following logging activities, but in general they were not observed to increase after harvest, possibly due to fixation in soils (Tiedemann et al., 1988, Salminen and Beschta, 1991).

In addition, while forest thinning is expected to reduce aboveground biomass formation of a C-rich litter layer (Jandl et al. 2003) there is so far insufficient evidence on how the reduction of the C pool on the forest floor is influencing the C pool in the mineral soil and subsequent export of dissolved carbon with subsurface storm flow. The reduction in the humus layer associated with forest harvesting has been observed to cause a reduction in base saturation and depletions of exchangeable pools of base cations (e.g. K, Ca, Mg), Mn and Zn (Olsson et al. 1996, Dahlgren 1998). Other studies (e.g. Lamontagne et al. 2000) have observed increases in K, total N, total P and dissolved organic C export in response to forest harvest. Elevated N leaching immediately following the disturbance of the forest ecosystem after harvest can acidify streams and cause eutrophication in estuaries and coastal waters (Vitousek et al. 1997; Fenn et al. 1998; Murdoch and Stoddard 1992). Although large variability in N export from forested watersheds has been observed (Mattson et al. 2015, Sugimoto et al. 2016), some studies (e.g. Lovett et al. 2002) have concluded that NO_3^- leaching and total N export from forested watersheds is more closely related to rates of soil N transformation controlled by the soil-microbe-root complex (Williard et al.

1997), the soil C:N ratio of the watershed soils, and the variation in tree species composition than instream N cycling processes (Lovett et al. 2000). In contrast, Bernhardt et al. (2005) hypothesized in response to a recent decline in NO_3^- export from the Hubbard Brook Experimental Forest (Aber et al. 2002) that increased assimilative uptake by microbes in streams and transformation of stream NO_3^- into its gaseous components play an increasing role in the overall export of NO_3^- from watersheds. They suggested that additional research is needed to provide accurate measures of denitrification for forested streams, as it appears that denitrification is the largest sink for NO_3^- once it reaches the stream.

Forest management can have profound impacts on rainfall-runoff generation processes, water yields and flow pathways that water takes to the watershed outlet. Paired watershed studies of different forest management strategies conducted in the boreal forests of northern Sweden, for example, have shown that runoff can increase by up to 30% during both baseflow and peak flow periods following timber harvest (Laudon et al. 2009). In addition, it can cause a rise in groundwater table (due to lower evapotranspiration after harvest), which in the case of the boreal catchments studied by Laudon et al. (2009) increased the transport of dissolved organic carbon (DOC) from the organic matter and carbon rich riparian zones surrounding boreal rivers.

Based on paired watershed studies conducted at the Hubbard Brook Experimental Forest (HBEF) in New Hampshire, where stream water chemical analyses have been conducted since 1963, it has been observed that nitrate (NO_3^-) export to streams will increase after deforestation as a result of reduced plant uptake, as well as higher rates of N mineralization and nitrification processes (Bernhardt et al. 2003). The experimental forest experienced for example an ice storm in January 1998, which resulted in an average estimated canopy damage of 30% in two of the south-facing watersheds. Bernhardt et al. (2003) studied NO_3^- concentrations after the disturbance event and observed a significant increase in stream water NO_3^- concentrations, with greatest effects observed in the second growing season after the disturbance. They also showed that the degree to which NO_3^- concentrations increased was positively correlated with the type and intensity of the disturbance. Additionally, Bernhardt et al. (2003) were able to confirm that these observed increases in NO_3^- were mitigated by in-stream metabolic processes before they reached the watershed outlet. Their most compelling findings show that before the ice storm NO_3^- exports at the gauging stations were usually equal to or higher than those at the upper reaches of the watersheds, whereas after the ice storm damage, the ratios of NO_3^- flux between the gauging stations and the damage zones were consistently lower, meaning a greater proportion of NO_3^- export was being attenuated over the stream reach after the disturbance compared to before the disturbance occurred.

Export of dissolved inorganic nitrogen (DIN; e.g. NO_3^- and NH_4^+), an important macro nutrient for flora and fauna, with stream water is influenced by both terrestrial and aquatic processes including watershed geomorphology (Creed and Band 1998), soil characteristics (Gundersen et al. 1998; Seely et al. 1998), land-use or fire history (Pardo et al. 1995), vegetation type or successional stage (Vitousek and Reiners 1975; Wigington et al. 1998), and atmospheric deposition (Stoddard 1994). N uptake by vegetation or soil microfauna may also influence seasonal patterns of stream DIN export (Likens 2013; Vitousek 1977; Foster et al. 1989). In-stream processes, such as denitrification, cycling of N through biota, organic matter storage and particulate matter transport, can also modify stream DIN concentrations (Meyer et al. 1998; Burns 1998, Vanderbilt et al., 2003). Hydrological processes, in particular, are frequently correlated with stream water DIN concentrations as shown in the Hubbard Brook study (Bernhardt et al. 2003). Several other studies have documented seasonal NO_3-N concentration-discharge relationships (Bond 1979; Foster et al. 1989; Hill 1986; Newbold et al. 1995) and spikes in NO_3-N concentration associated with high discharge events (Hill 1993; Newbold et al. 1995).

On the other hand, much less is known about the processes influencing dissolved organic carbon (DON) concentrations and fluxes in stream water. Stream discharge was found to be positively correlated with DON concentrations in five of nine watersheds studied in New England (Campbell et al. 2000) and five out of ten streams in the Lake Tahoe Basin (Coats and Goldman 2001). Peaks in DON concentrations were observed during storm events in an Appalachian stream (Buffam et al. 2001). McHale et al. (2000) found that DON concentrations were positively related to stream discharge in both dormant and growing seasons, and concluded that biotic controls seem to have a greater impact on NO_3-N concentrations than on DON concentrations. They concluded that due to differences in sorption behavior in soils and microbial lability between organic and inorganic forms of N, controls on DON in streams may differ substantially from controls on inorganic nitrogen species. A paired watershed study conducted at H.J. Andrews Experimental Forest in the Central Cascade Mountains of Oregon found that both NO_3^- and DON were positively correlated to discharge, whereby DON concentrations peaked early in the rainy season, likely due to flushing of decomposition products (Vanderbilt et al. 2003). However, they also concluded that inorganic nitrogen fluxes were highly variable in space and time and often obscured by various biotic processes and controls.

Goodale et al. (2000) questioned the assumption that ecosystem N retention and N fluxes are mainly controlled by biotic processes and instead hypothesized that terrestrial nitrogen retention is a direct result of varying degrees of N limitation, or excesses. They found stream water NO_3^- concentrations to be clearly seasonal, with higher concentrations in the dormant season, and lower values observed during the growing season. In their study, total dissolved nitrogen (TDN) concentrations followed a similar pattern as NO_3^-, which was hypothesized to be due to low overall NH_4^+ contributions, and the fact that they did not find significant seasonal differences in DON. However, they observed that DON concentrations remained mostly stable throughout the year. They also found DOC export to be slightly higher during the growing season, which resulted in higher DOC:DON ratios during the growing season. They concluded that the observed DON patterns do not necessarily correspond to biotic N demands, and that significant nitrogen losses in the form of DON can instead co-occur along with organic matter losses to streams.

Olsson et al. (1996) examined changes in soil C and N in four coniferous forested watersheds in Sweden, 15-16 years after the implementation of three different harvesting intensities. The harvesting treatments included a “conventional” treatment where all residue was left onsite, a treatment that harvested all tree residue except needles, and a whole-tree harvest, where no residue was left on the ground. Their results demonstrated that, independent of harvesting intensity, there were significant changes in C and N content in soil humus and mineral layers in the whole-tree harvest treatment. Soil C pools were not found to have clear trends in response to harvest treatment intensity, while soil N pools did exhibit varying trends, between the experimental sites, suggesting more of a site effect, than a harvest intensity effect. In general, they were not able to determine distinguishable differences between harvest intensities and net C storage, but they did note that in the conventional treatments, there was still considerable coarse woody debris visible on the ground 15 years after harvesting, which was hypothesized to have a continued (long-term) impact on N and C trends in these watersheds. Many studies have found that forest disturbance increases watershed nitrogen losses in the short term, mostly in the form of NO_3^--N as a result of a reduced plant uptake, increased mineralization of organic materials, and increased nitrification (Bernhardt et al., 2003). In studies that have reported higher stream nutrient export after disturbance, many find these increases within the first 5 years after harvest. Other studies have found no significant increase in nutrient export shortly after disturbance events, but have observed lower nutrient export in the long-term (>5 years after harvest) (Kreutzweiser et al., 2008).

A large scale paired watershed study comparing timber harvest and controlled burning conducted by Lamontagne et al. (2000) in the Boreal Shield of Quebec showed similar results as observed by Olsson et al. (1996) and Bernhardt et al. (2003). Lamontagne et al. (2000) found that nutrient export increased both in the burned and harvested basins, compared to the reference watersheds. DOC, total phosphorus (TP) and NO_3^- exhibited the greatest increase in export rates in all scenarios (both harvested and burned basins) amongst the measured analytes (Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^-, NO_3^-, SO_4^{2-}, DOC, TP, and TN). In all harvested basins, TP, TN, and DOC export was 1.5-fold to several fold higher than in reference watersheds. They also observed higher DOC export amongst the harvested watersheds compared to the burned watersheds. Similar to the results found in Hubbard Brook Experimental Forest, Lamontagne et al. (2003) also found a positive correlation between export rate and percentage of drainage area cut for certain analytes in harvested basins, which included Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^-, and TP.

The above mentioned studies highlight that nutrient export (N, P, C) from forested watersheds is influenced by several physiographic factors including geology, climate but mostly by hydrological and watershed-specific factors that directly affect the chemical, physical and microbially mediated processes of these nutrient cycles. When investigating watershed response to a disturbance event, all of these factors will have a cumulative impact, often intensifying or amplifying certain trends. In this study, the fluxes of C, P and N and its major species were studied in response to different timber harvest treatments and across variable hydro-climatological conditions to determine quantitative relationships between nutrient export and hydrology in response to forest management practices and naturally occurring disturbance events such as extreme events such as floods or droughts.

3 Research objectives

The goal of this research study was to examine changes in the mass balance of major nutrients (C, N, P) and base cations/anions across the main functional watershed units (e.g. whole watershed vs. sub-watersheds) of South Fork Caspar Creek watershed in response to different stand density reductions. The hypothesis of the project is that stand density reduction will increase export of total N, total P, NO_3^-, and particulate/dissolved organic C from the treated watersheds immediately following the forest harvest, with greater impacts observed with greater stand density reduction. It is further hypothesized that stand density reduction will increased stormflow either in the form of overland flow, macropore flow, or subsurface stormflow above the clay-rich, argillic soil horizon that promote rapid pathways for runoff and nutrient transport from hillslopes to streams. The proposed research attempted to address these hypotheses through the following specific objectives:

1) What are the temporal (annual, seasonal) variations and patterns of nutrient and base cation/anion fluxes from coast redwood forests?

2) How do different stand density reductions change the patterns, concentrations and fluxes of nutrients and base cations and anions compared to pre-harvest conditions?

Between fall 2016 and June 2020 over 1800 water samples were collected at the outlets of four sub-watersheds (TRE, WIL, UQL, and ZIE) and at the South Fork weir during storm events and during the summer baseflow period. Samples were analyzed for electrical conductivity, pH, and concentrations of total nitrogen, NH_4^+, nitrate (NO_3^--N), dissolved organic nitrogen, total phosphorus, PO_4-P, dissolved organic carbon, and base cations and anions. Analysis of samples for major cations (Ca^{2+}, Mg^{2+}, Na^+, K^+) and anions (Cl^-, F^-, NO_3^-, SO_4^{2-}, PO_4^{3-}) is still ongoing and are therefore not discussed in this report. N species, P, DOC concentrations and loads were compared across the five sampling points and through time (pre- and post-harvest, water year, water year type, and season) to determine if and to what extent stand density reductions resulted in shifts or significant changes in transport of these nutrients from the watershed.

3.1 Changes to project timeline and objectives

Harvest treatments according to original project timeline were expected to take place during the spring and summer of 2017, and analysis of postharvest geochemistry to take place between summer 2017 and June 2020. Timber harvest occurred in spring and summer 2017 as a joint effort between the California Department of Forestry and Fire Protection (CAL FIRE) and the US Forest Service, as well as contracted loggers. Logging at Caspar Creek South Fork watershed took longer than anticipated due to contracting and permitting matters in addition to shifting of schedules due to the weather-dependent nature of forest harvesting activities. To avoid erosion, the ground had to be sufficiently dry in order for logging to take place in spring 2017, which was the second wettest year on record in northern California in over 100 years. In addition, harvest was influenced in the fall of 2017 by the start of the fire season in California. Priorities of agency staff have consequently been directed toward the many wildfires that have occurred in the area during 2017 and 2018. Fire response has taken precedence over some of the planned harvesting in Caspar Creek (Liz Keppler, USFS pers. Communication). Timber market prices, limitations on available loggers, and a yearly mandatory survey for spotted owls in this area have further impacted the initial project timeline.

The delay in harvest allowed collection of an extensive baseline water chemistry dataset from the four sub-watersheds. Sample collection at the outlet of South Fork Caspar Creek was impacted by restoration activities in the main stem that occurred just upstream of the gage and therefore SFCC samples could only be collected for the period 3/21/2017-6/30/2020 with a data gap occurring from 8/7-10/13/2017. The baseline data collected from the sub-watersheds provided us with a better understanding of the pre-harvest conditions, and even more certainty in the normal ranges of ion and nutrient concentrations and fluxes that are characteristic of the South Fork of Caspar Creek.

In summer 2017, matrix harvest of trees started in the South Fork Caspar Creek watershed in the area surrounding the sub-watersheds of interest in this study. The matrix harvest consisted mainly of a thinning of the forest. This harvest is a routine management practice, designed to reduce tree density to maintain forest health. The matrix harvest was not intended or expected to affect the stream water chemistry in any of the sub-watersheds to any significant degree, as it was conducted around the entire South Fork study area. Documentation of the location based timeline of the matrix harvest, as well as the ongoing harvest treatments are kept by CAL FIRE staff. Currently this documentation is in the process of being digitized and will eventually be available as GPS data.

In March 2020, the global outbreak of the SARS-CoV-2 (short COVID) virus caused immediate closure of university facilities for 6 months. Students and staff were asked to work from home and only essential (agricultural, medical, animal) research was permitted to continue on a minimal staff basis. The effect of this temporary closure was that research staff on this project were not allowed to use university facilities to continue non-essential research. In addition, analysis of water samples for major cations and anions was reliant on a ThermoFisher Dionex ion chromatograph that is owned by a USDA employee who did not allow access to her lab and the instrument until spring 2021. By the time access was given, the machine had been neglected for 12 months and needed replacement of several parts and extensive maintenance. As of December 2021 the instrument is in working order but the project has no funding left for personnel to analyze samples on the machine. The student who was employed on the project left the project in March 2021 without finishing her MSc degree.

4 Methods

4.1 Study Site and Experimental Design

4.1.1 History of Experimental Research in Caspar Creek watershed

The Caspar Creek Experimental Watershed has been continuously studied since its establishment in 1962 as a collaboration between CAL FIRE and the U.S. Forest Service Pacific Southwest Research Station (PSW). The Caspar Creek Experimental Watershed has conducted thus far, two long-term research experiments. The primary goal of the first two experiments (1962-85, 1985-present) was to understand the effect of timber harvest on streamflow and suspended sediment concentrations in coastal-forested watersheds. The first experiment was set up as a classic paired watershed study. Cumulative effects (e.g. sediment, discharge) of removing 60-70% of the timber stand volume were studied in South Fork Caspar Creek and compared to the North Fork Caspar Creek watershed, which served as control. In the second experiment (1985-present) modern California Forest Practice Rules (FPRs) were tested in different sub-watersheds of the North Fork Caspar Creek and effects were compared among the different sub-watersheds.

In 2016, the PSW's postdoctoral Research Hydrologist Dr. Salli Dymond designed a third experiment with the goal to expand upon the findings of the first two experiments to investigate the effect that different reductions in stand density (e.g. reduction in the quantity of trees) might have on the interconnected hydrological, geomorphic, and ecological processes in coastal redwood forests (Dymond, 2016). To improve this understanding several research projects were set up that study these processes at the tree, plot, hillslope, sub-watershed and watershed scale. Table 1 lists the experimental sub-watersheds in South Fork Caspar Creek and stand reductions researched during the first experiment in the sub-watersheds of South Fork Caspar Creek.

Table 1: South Fork Caspar Creek sub-watershed names, stand reductions researched during the first experiment, and planned treatments for the third experiment.

Watershed name	Watershed ID	% Leaf area reduction	Area (ha)	Year of last harvest	% Volume logged (Exp. 1)
South Fork Caspar Creek	SFC*	35	424	1971-1973	65%
Ogilvie	OGI	45	18	1971	60%
Porter	POR	25	32	1971	60%
Quetelet	QUE	35	394	1971-1973	65%
Richards	RIC	0	49	1972	70%
Sequoyah	SEQ	65	17	1972	70%
Treat	TRE*	35	14	1972	70%
Uqlidisi	UQL*	55	13	1973	65%
Williams	WIL*	0	26	1973	65%
Yocom	YOC	47	53	1973	65%
Ziemer	ZIE*	75	25	1973	65%

* Sub-watershed outlets sampled for stream water chemistry analysis.

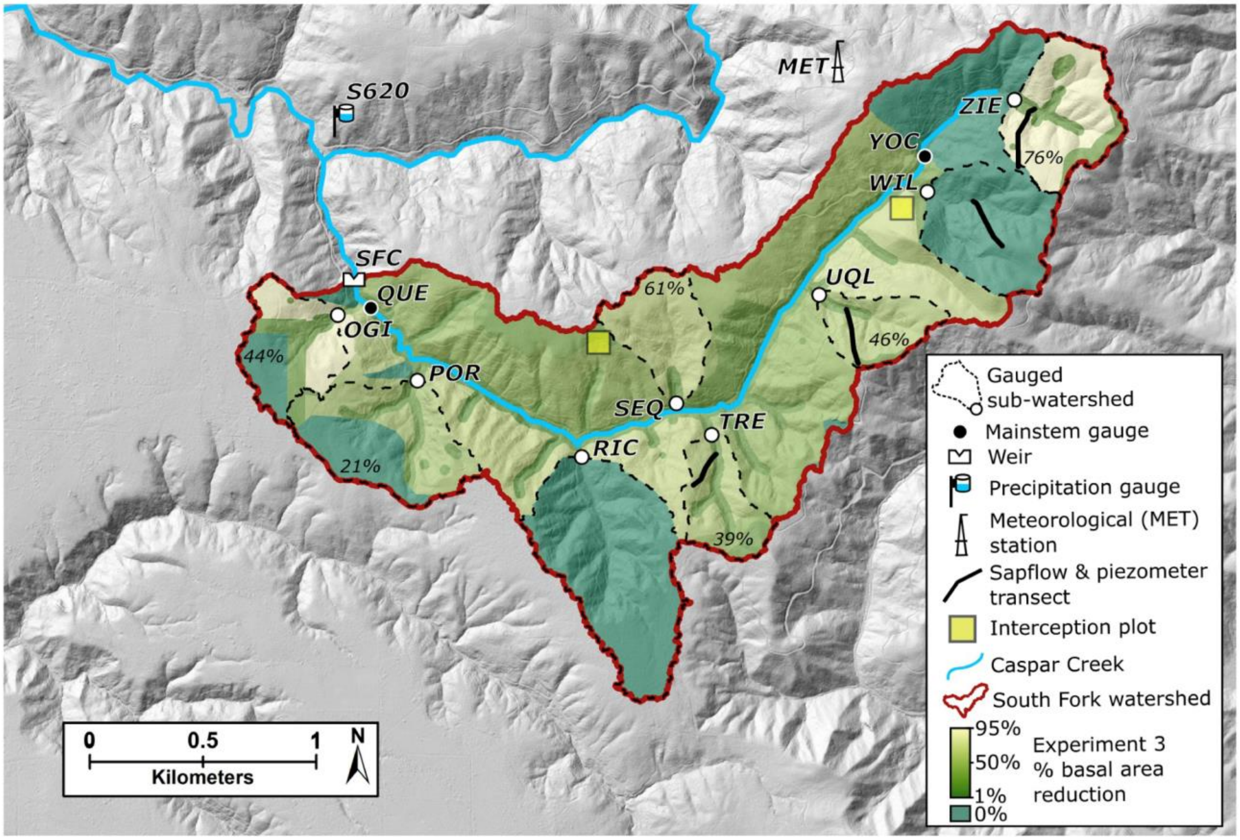

Figure 1: The South Fork Caspar Creek watersheds and its ten sub-watersheds (from Dymond et al. 2021, Fig. 3).

4.1.2 Caspar Creek Experimental Watershed

The Caspar Creek experimental watershed is located in coastal northern California in Mendocino County inside the Jackson Demonstration State Forest, at approximately 39° 21' N, 123° 44' W. The watershed is located about 7 km from the Pacific Coast and 14 km southeast of Fort Bragg, CA. The Caspar Creek watershed has a total drainage area of 2,167 ha, of which 897 ha are included in the experimental watershed study area (Henry 1998). The study area contains two main drainage basins, the North Fork and the South Fork of Caspar Creek, with basin areas of 473 ha and 424 ha, respectively (Dymond, 2016). The North Fork drainage basin is divided into thirteen sub-watersheds ranging in individual drainage areas from 10 ha to 384 ha. Within the South Fork, there are 10 sub-watersheds, which range in drainage areas from 13 ha to 394 ha (Table 2). The South and North Forks drain into the main branch of Caspar Creek, which, from their confluence point, flows northeast into the Pacific Ocean.

Jackson Demonstration State Forest is the largest (19,689 ha) of eight demonstration forests in the state, and is managed and operated by CAL FIRE. The main land use in Jackson Demonstration State Forest is the growth and harvest of timber, revenue from which goes to fund a variety of the Department's Resource Management programs, while providing research and demonstration opportunities in natural resource management, which include wildlife habitat and watershed protection and restoration. The forest stands in the South Fork of Caspar Creek were approximately 95 years old when they were last harvested during the First Experiment at Caspar Creek. Harvest began with the eastern portion of the South Fork in 1971, and the final northwestern portion was completed in 1973. During this experiment, all ten sub-watersheds in the South Fork were harvested, with stand volume reduction ranging from 60-70%. Results from the First Experiment have been reported by Rice et al. (1979) and Ziemer (1998).

Forest vegetation in Caspar Creek is dominated by coast redwood (*Sequoia sempervirens* (D. Don) Endl.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), with some associated grand fir (*Abies grandis* (Doug. ex D. Don) Lindl.), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), and minor amounts of hardwoods, including tanoak (*Lithocarpus densiflorus* (Fook. and Arn. Rohn) and red alder (*Alnus rubus* Bong.). The understory vegetation is comprised of evergreen huckleberry (*Vaccinum ovatum* Pursh), Pacific rhododendron (*Rhododendron macrophyllum* D. Don), and sword fern (*Polystichum munitum* (Kaulf.) Presl.) (Henry 1998).

The northwest Pacific Coast of California has a Mediterranean climate regime, characterized by mild, moist winters of low-intensity rainfall. Summers are typically cool and dry, with coastal fog frequently observed, which can have a significant contribution to the total annual precipitation in some coastal redwood forest ecosystems in the form of fog drip (Burgess & Dawson, 2004). This has not, however, been shown to be the case for the Caspar Creek watershed (Keppeler, 2007). The monthly air temperature measured near the South Fork weir from 1989 to 2018 averaged 6.1 °C in December and 13.7 °C in August (Dymond et al., 2021). The 30-year mean annual precipitation, measured near the confluence of the South Fork and North Fork from 1989 to 2018, was 1168 mm, about 90% of which occurs between the months of October through April (Dymond et al., 2021).

Elevation in the South Fork of Caspar Creek ranges from 46 to 329 m, with average sub-watershed slopes ranging from about 26 to 50%. In certain areas within the watershed, slopes can reach an excess of 65% (Dymond, 2016). The geomorphology of this coastal system consists of uplifted marine terraces, which have been significantly incised by stream processes (Henry 1998). The soils in the Caspar Creek watershed are predominantly Alfisols and Ultisols, which have been derived from residuum of Franciscan sandstone and Cretaceous Age shale (Henry 1998). Soils in the watershed have been found to consistently exhibit thick argillic horizons, which are suspected to influence hydrologic processes occurring in response to storm events, specifically subsurface lateral flow (Dahlgren 1998). Dominant soil subgroups are identified in Table 2. Soil data for the initial soil assessment of South Fork watershed was obtained from the USDA-NRCS Web Soil Survey using the South Fork watershed boundary file provided by the Caspar Creek Experimental Watersheds project staff.

The South Fork Caspar Creek watershed is divided into ten sub-watersheds, each of which has a direct outlet to the main stem of the South Fork (Figure 1). In 2000, each of the sub-watershed outlets was instrumented with a gaging station to monitor streamflow in preparation for the Third Experiment. Since spring of 2016, all of the ten sub-watersheds have been sampled for water chemistry baseline analysis. For the nutrient study presented here, sampling and data analysis focused on four of these ten sub-watersheds (TRE, UQL, WIL, and ZIE), which have been more intensively sampled between summer 2016 and summer 2020. In March of 2017, a fifth sampling location was added at the South Fork weir, in order to capture the integrated response of the entire South Fork Caspar Creek watershed. The four sub-watersheds selected for this study encompass a gradient in stand density reductions as well as a control (no timber harvest). The WIL watershed serves as a control (0% vegetation removal), the TRE watershed will demonstrate a light harvest (35% reduction in stand density), the UQL watershed is a moderate harvest (55% reduction) and the ZIE watershed represents a high harvest (75% reduction) treatment.

Table 2: Physical characteristics of the South Fork sub-watersheds.

Sub-watershed name	% Leaf Area Reduction	Area (hectares)	Average slope (%)	Elevation range (m)	Dominant soil subgroups
SFC*	TBD	424	60	46-329	Ultic hapludalf
QUE	TBD	394.3	50	48-329	Mollic/Ultic hapludalf
RIC	0	48.8	42	73-198	Mollic/Ultic hapludalf
YOC	47	52.9	48	146-329	Typic haplohumult
WIL*	0	26.5	51	146-323	Typic haplohumult
OGI	25	18.3	26	58-174	Mollic/Ultic hapludalf
TRE*	35	14.1	47	98-244	Mollic/Ultic hapludalf
POR	45	31.7	34	61-186	Ultic hapludalf
UQL*	55	12.5	49	122-323	Typic haplohumult
SEQ	65	16.8	38	79-207	Ultic hapludalf
ZIE*	75	25.3	43	213-329	Typic haplohumult

*Subwatershed outlets sampled/monitored for stream water chemistry analysis

4.1.3 Treatments

Two of the ten South Fork sub-watersheds were designated as long-term reference watersheds (WIL and RIC) and did not receive a harvest treatment. The seven other sub-watersheds were assigned harvest treatments ranging from 25% to 75% reduction in leaf area (Table 2). Forest managers typically prescribe stand harvest intensity based on basal area (the surface area of stems at a height of 4.5 feet (1.37 m) above ground per unit ground area), as opposed to overstory density (leaf area), partially due to the difficulty of obtaining leaf area measurements. However, leaf-area-index (LAI) plays a large role when examining regrowth processes in coast redwood ecosystems due to stump resprouting (O'Hara and Berril 2010). Therefore, for the purpose of examining forest response to stand reduction, harvest reductions percentages will be calculated by leaf area index (the ratio of leaf area per unit of ground area) in the Third Experiment. Harvesting of the matrix area (i.e. remaining area surrounding the sub-watersheds in South Fork Caspar Creek) began in the summer of 2017, and harvest treatments of the seven sub-watersheds began in May of 2018. Hydrologic calculations (i.e. discharge and runoff calculations) were determined based on Felling dates (to account for reduced plant uptake), whereas nutrient budget calculations (i.e. analyte concentrations and loads/fluxes) were determined using yarding dates (to account for increased erosional/disturbance components). Tree felling and yarding dates for each sub-watershed are summarized in Figures 2 & 3. For the statistical analysis conducted in this study only the yarding dates were considered to distinguish pre- and post-treatment effects on nutrient flux in each sub-watershed since yarding imposes more disturbance on the forest floor than the felling. For the streamflow analysis felling dates were used to define pre- and post-harvest periods. Period dates used in our analysis are listed in Table 3. It should also be noted that the hydrologic year (HY) for the Caspar Creek watershed begins August 1st and ends July 31st in the following year, as opposed to the USGS designated water year (Oct. 1st – Sept. 30th).

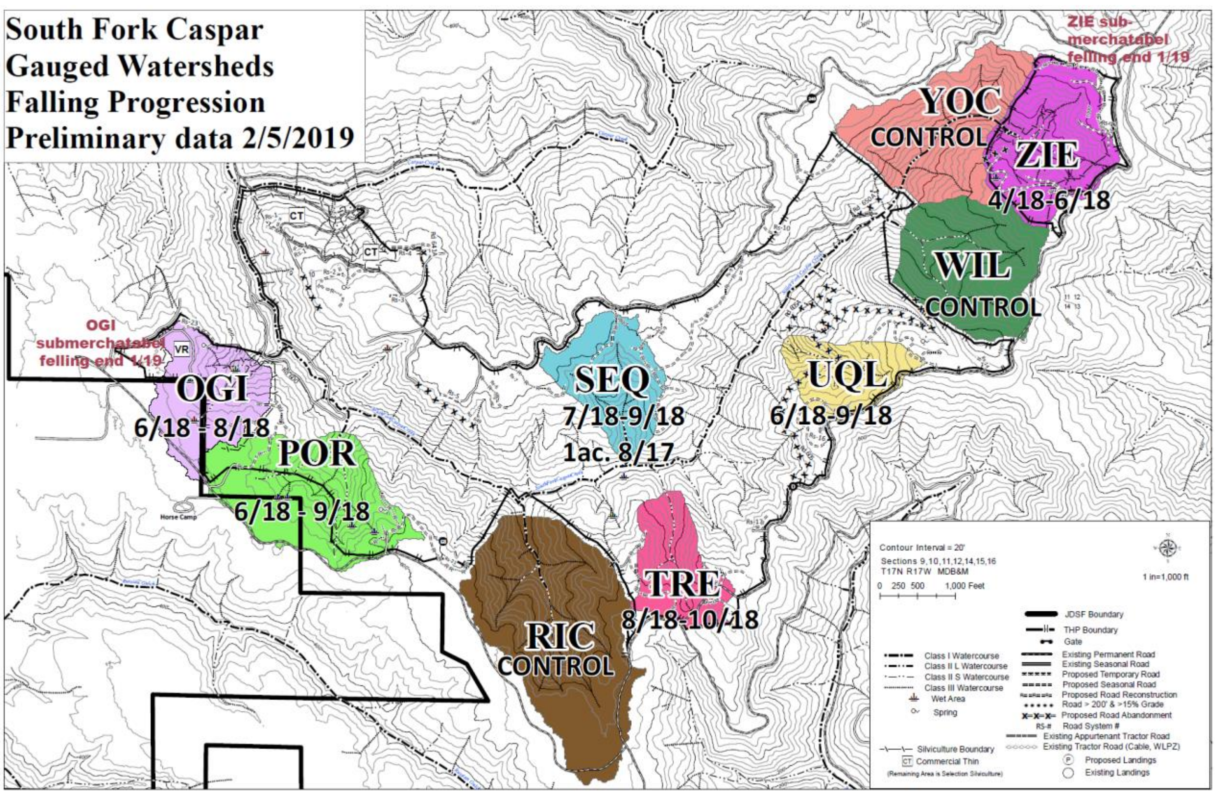

Figure 2: South Fork Caspar Creek felling dates for the four sub-watersheds studied.

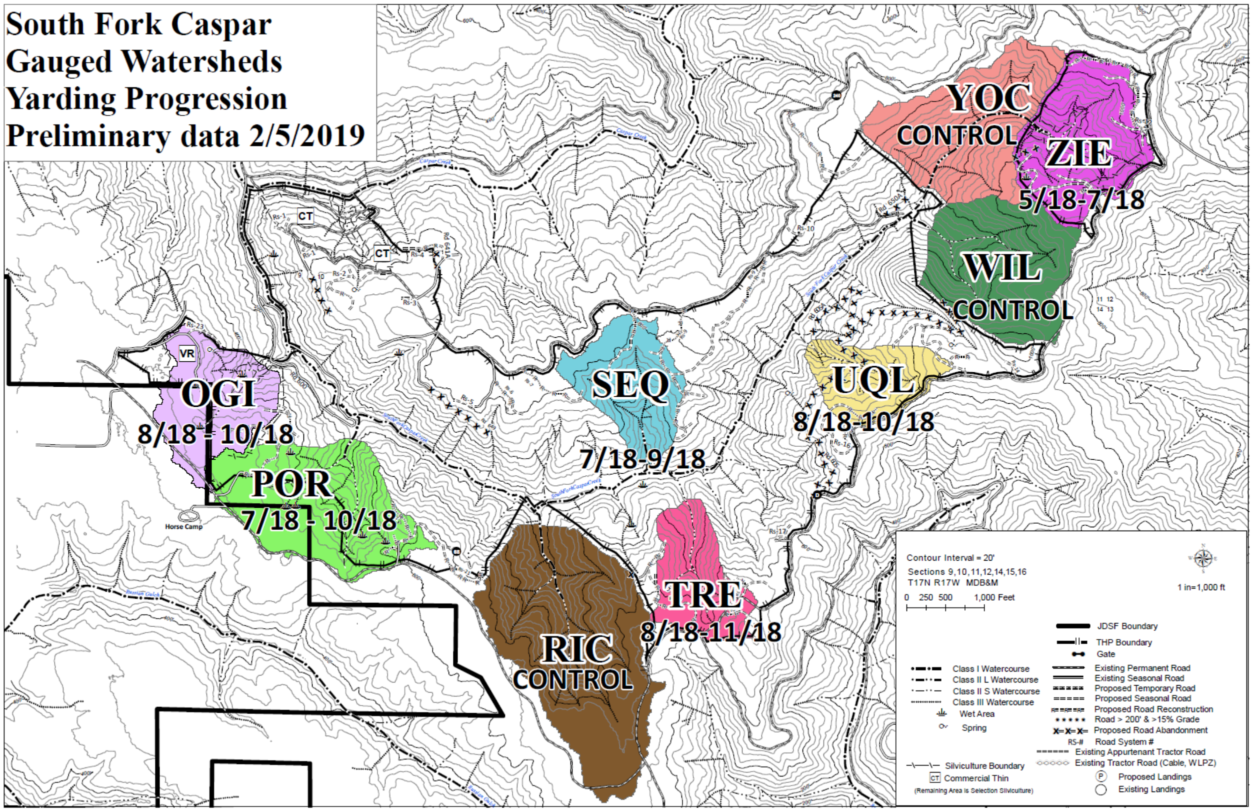

Figure 3: South Fork Caspar Creek yarding dates for the four sub-watersheds studied.

Table 3: Time periods considered in the statistical analysis of the stream water chemistry data.

Period	SFC	WIL	TRE	UQL	ZIE
Pre yarding	8/1/15-4/30/18	8/1/15-4/30/18	8/1/15-7/31/18	8/1/15-7/31/18	8/1/15-7/31/18
Post yarding	5/1/18-6/30/20	5/1/18-6/30/20	8/1/18-6/30/20	8/1/18-6/30/20	8/1/18-6/30/20
HY17	8/1/16-7/31/17	8/1/16-7/31/17	8/1/16-7/31/17	8/1/16-7/31/17	8/1/16-7/31/17
HY18	8/1/17-7/31/18	8/1/17-7/31/18	8/1/17-7/31/18	8/1/17-7/31/18	8/1/17-7/31/18
HY19	8/1/18-7/31/19	8/1/18-7/31/19	8/1/18-7/31/19	8/1/18-7/31/19	8/1/18-7/31/19
HY20	8/1/19-7/31/20	8/1/19-7/31/20	8/1/19-7/31/20	8/1/19-7/31/20	8/1/19-7/31/20
Dry years	HY 16, 18, 20	HY 16, 18, 20	HY 16, 18,20	HY 16, 18, 20	HY 16, 18, 20
Wet years	HY 17, 19	HY 17, 19	HY 17, 19	HY 17, 19	HY 17, 19

4.2 Data Collection and Analysis

4.2.1 Sampling Methods

The outlet of the South Fork main stem is equipped with a compound weir with a 120° v-notch weir for stages up to 2 feet, and a 20-foot rectangular weir for stages above 2 feet. Turbidity is recorded at the South Fork weir using an FTS DTS-12 temperature/turbidity sensor (FTS Inc., Victoria, BC, Canada). All sub-watershed outlets are equipped with Montana flumes, and turbidity is recorded using Campbell Scientific OBS-3 turbidity sensors (Campbell Scientific Inc., Logan, UT, USA). Stage is measured at all flume and weir locations with Campbell Scientific pressure transducers. Stage and turbidity are recorded on a 10-minute interval. Stage was converted to discharge from a developed, site-specific stage-discharge relationship. Stream water samples were collected with ISCO 6712 automated samplers (Teledyne ISCO Inc., Lincoln, NE, USA), as well as by PSW Caspar Creek staff, who manually collected grab samples during storm events from May 2016 until June 2020. All samples were collected mid-stream where sufficient mixing is assumed to occur. Unfiltered, non-acidified samples were collected in 125 ml HDPE bottles and stored in a refrigerator at 4°C until samples were shipped on ice from Caspar Creek to UC Davis for laboratory analysis. During storm events, ISCO auto samplers collected samples on an hourly basis. From these hourly samples, two samples two samples on the rising limb, one near the peak, and two samples on the falling limb were chosen for laboratory analysis to reduce the overall number of samples considered in this study. In addition, several grab samples of precipitation were collected.

4.2.2 Laboratory Analysis

Samples were shipped in insulated packaging and upon arrival at UC Davis were stored at 4°C until analysis. Unfiltered sub-samples were used for Total Nitrogen (TN), Total Phosphorous (TP), turbidity, pH and EC analyses. Prior to analysis for NO_3^--N, NH_4^+-N, and orthophosphate (PO_4), samples were vacuum filtered through 0.2-micron pore diameter membranes. pH and EC were measured potentiometrically using a combination electrode. NO_3-N was determined colorimetrically using an adapted Vanadium(III) Chloride reduction (Doane & Horwath, 2003; Miranda et al., 2001). Orthophosphate or "dissolved reactive phosphorous" (DRP), which includes PO_4-P plus any other compounds that might give PO_4-P during reaction conditions or react as PO_4-P were determined using the Phosphomolybdate blue/ascorbic acid method (Kovar & Pierzynski, 2009; Murphy & Riley, 1962). TN and TP were digested using Peroxodisulfate oxidation followed by the above-mentioned methods for NO_3^--N and PO_4-P colorimetric determination. Dissolved organic nitrogen (DON) was calculated as DON = TN – (NO_3^--N + NH_4^+-N). NH_4^+-N analysis used an adapted method using the Berthelot reaction/salicylate analog of indophenol blue (Forster, 1995; Verdouw et al., 1978). DOC was analyzed with UV-persulfate oxidation, on a Phoenix 8000 total organic carbon analyzer (Teledyne Instruments, Mason, OH). Anion concentrations (Cl^- and SO_4^-) and cation concentrations (Mg^{2+}, Ca^+, K^+ and Na^+) are determined by ion chromatography using a Dionex ICS-2000 Ion Chromatograph. Concentrations are reported as mg/L.

4.2.3 Statistical Analysis

4.2.3.1 Paired Watershed Study

Paired watersheds have been widely used in hydrological and biogeochemical research to study long-term trends in forested systems (Hornbeck 1973, King 2008, Dahlgren & Driscoll, 1994). This is partly due to the time it takes for forest stands to return to pre-treatment conditions, as well as difficulties in attributing effects to treatments as opposed to other time-dependent variables. The paired watershed design has been employed in both long-term experiments previously conducted at Caspar Creek (First and Second Experiments). The Third Experiment will also employ a paired watershed design, aiming to compare treatment effects between sub-watersheds in the South Fork. In order to employ the effective use of the paired watershed design, the ten South Fork sub-watersheds have been assessed in terms of their physical, hydrologic, and stream water chemical characteristics. The four sub-watersheds that will provide the majority of the water chemistry data (TRE, UQL, WIL and ZIE) are being closely monitored in order to validate this study design. Qualitative assessments of drainage area, watershed slope, topography, soil characteristics, and riparian zone characteristics will form the basis for sub-watershed compatibility. Climate and precipitation parameters have been assumed to be identical among South Fork sub-watersheds.

Since summer 2016, monthly baseflow samples and more frequent winter storm water samples have been collected at the outlet of the four sub-watersheds and the outlet of South Fork Caspar Creek to understand baseline conditions in flow and nutrient export from these watersheds. The baseline samples were used to characterize the flow regime and biogeochemistry of Caspar Creek at near-pristine conditions and to evaluate whether all sub-watersheds behave hydrologically and biogeochemically in a similar manner. To validate the criteria for a paired watershed design, similarity in characteristics between watersheds, simple linear regression analysis was employed for a subset of water chemistry and hydrologic (stream discharge) variables to determine the degree of correlation present between watersheds.

4.2.3.2 Estimation of nutrient loads

Nutrient loads/fluxes (kg/ha) were calculated for each sub-watershed by multiplying the mean analyte concentration (mass per Liter) of two consecutive sampling events with the total discharge (Liters per time) over the sampling interval:

$$Load\ (kg/ha) = \frac{\sum_{t}^{t-1} Q_i * \frac{1}{2}(C_{t-1} + C_t)}{10^6}\frac{1}{A}$$

Where t and t_{-1} denote the time step of the current and previous water sample, Q is discharge in L/s, C is the nutrient concentration in stream water in mg/L, and A is the watershed area in ha. The estimation of nutrient loads is based on the assumption that collected water samples are representative over the time duration of the sampling interval. Due to the irregular sampling interval used in this study, this assumption had the effect that estimated loads are rather large for some of the summer samples when the sampling interval was one month.

4.2.3.3 Statistical Analyses

Analysis of Variance (ANOVA) and Tukey's Honestly Significant Difference test (Tukey's HSD) were used to determine statistically significant differences in hydrology and chemistry, between a number of spatial and temporal comparisons. For each sub-watershed discharge and nutrient concentrations were compared between:

1) pre-yarding vs. post-yarding periods;
2) hydrologic years (HYs 2017, 2018, 2019, and 2020);
3) water-year types (i.e. wetter than average HYs; "wet years", compared to drier than average HYs; "dry years");
4) seasons within the pre- and post-yarding periods (e.g. pre-yard spring seasons vs. post-yard spring seasons); and
5) seasons of wet and dry years (e.g. dry-year winter seasons vs. wet-year winter seasons.)

To determine harvest treatment effects, ANOVA and Tukey's HSD were also used to compare all five experimental sub-watersheds to one another for each of the previously mentioned time periods. Statistical tests were run at a significance level of $\alpha = 0.05$.

5 Results and Discussion

5.1 Validity of paired watershed assumption

Qualitative and quantitative comparison of the South Fork sub-watersheds suggests that the four sub-watersheds are moderately well correlated in terms of slope and soil characteristics. Table 4 shows the percent difference in watershed slopes between each treatment sub-watershed and the control (0% harvest) sub-watershed. In general, average watershed slope ranges between 43% (ZIE) and 60% (SFC), with the four smaller sub-watersheds varying around 45-50%. Soil characteristics are similar between all sub-watersheds, at the subgroup level, and are listed in Table 4. Soil data from the NRCS Web Soil Survey indicate that there are nine major soil units mapped in the South Fork watershed area. Of these nine soil units, the Dehaven-Hotel complex, the Irmulco-Tramway complex, and the Vandamme loam cover about 35.6%, 31.3% and 19.1% respectively. Figure 4 shows the soil map units and their distribution within the South Fork watershed, which is largely uniform and slope dependent.

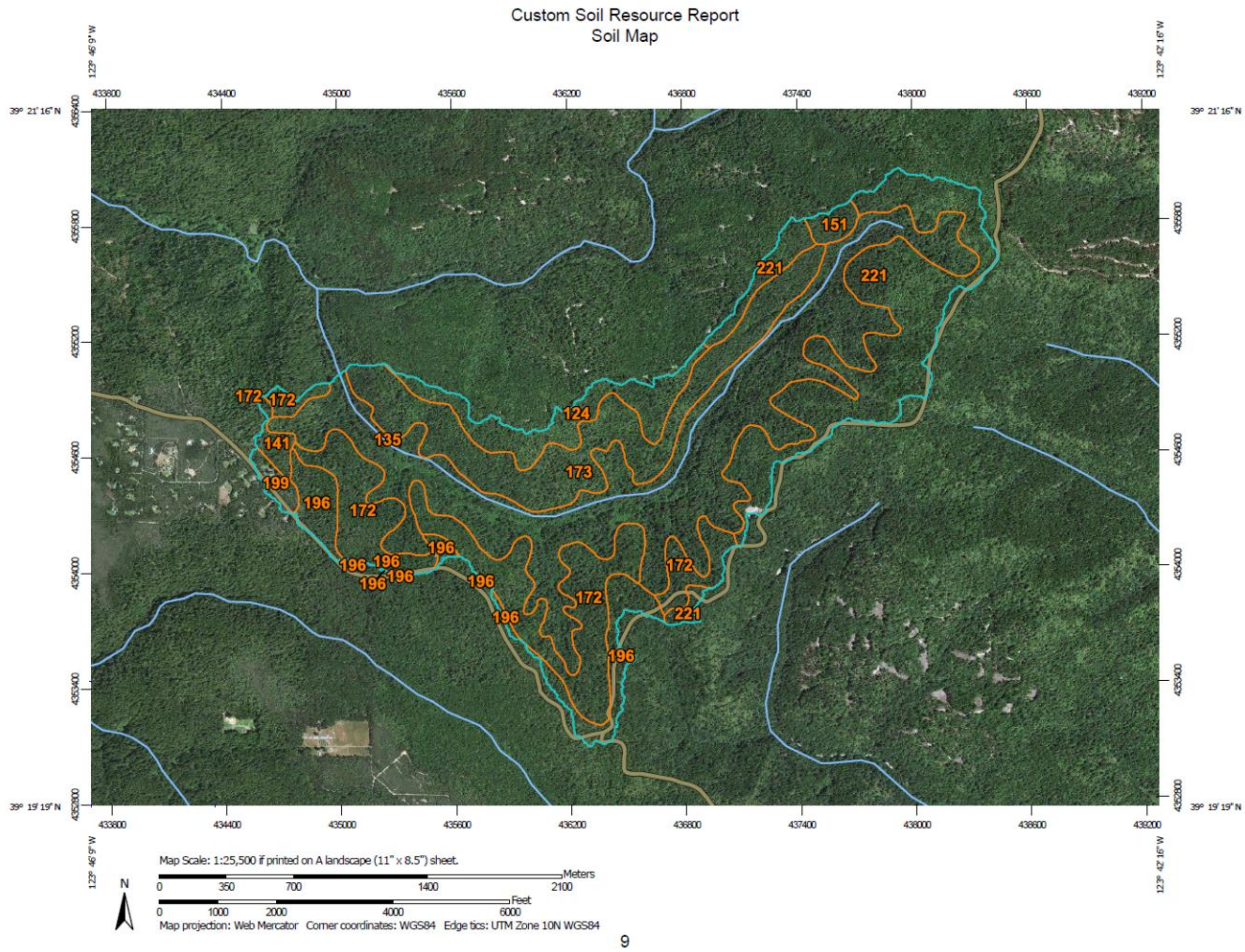

Figure 4: Soil map units within South Fork Caspar Creek watershed. Dominant map units include 135: Dehaven-Hotel complex, 172/173: Irmulco-Tramway complex, and 221: Vandamme loam.

Table 4: Percent differences in slope between treatment sub-watersheds compared with reference watersheds.

Sub-watershed ID	Reduction %	Average slope (%)	% difference to WIL
SFC*	TBD	60	18.0
WIL*	0	51	0.0
TRE*	35	47	7.9
UQL*	55	49	4.0
ZIE*	75	43	14.9

* Sub-watershed outlets intensively monitored for stream water chemistry analysis.

To evaluate the hydrologic compatibility of the sub-watersheds receiving timber reduction treatments (TRE, UQL and ZIE) to the control sub-watershed (WIL), a simple linear regression of the watersheds' discharges was conducted for the pre-harvest period. All treatment watersheds show a high degree of correlation with the control watershed WIL over the course of the pre-treatment period (2016-2018) (Figure 5). Similarity in discharge magnitude and high coefficients of determination for both years are indicative of a strong basis for comparison for each treatment sub-watershed (TRE, UQL, and ZIE) to the reference (WIL) and between the treatment sub-watersheds (Figure 5). As indicated by Figure 5, the slopes of the discharge correlations between the individual sub-watersheds are not always 1:1. Although discharge was corrected for watershed area, the correlations indicated that the discharge in the three treatment sub-watersheds (TRE, UQL, ZIE) is greater than in the control by about 6.4% (TRE), 18% (ZIE) and 20% (UQL). These differences cannot be explained by the watershed slope or watershed area since WIL has the largest watershed slope (51%) and largest watershed area (26.5 ha) of all four sub-watersheds analyzed here. Potential sources for the differences in slope could be the position and aspect of the sub-watersheds within South Fork Caspar Creek and potential differences in the amount of precipitation the sub-watersheds receive as well as the storage capacity of the watershed.

To examine the storage capacity of watersheds, rainfall-runoff ratios were calculated for each sub-watershed for major storm events that occurred during HY2017 and HY2018 between November and March (Tables 5 and 6). Runoff ratios represent the total amount of runoff generated for each individual storm event, normalized by sub-watershed area. The amount of runoff (in mm) is divided by the precipitation accumulated over the same time period, which gives a ratio of cumulative event runoff to cumulative event precipitation.

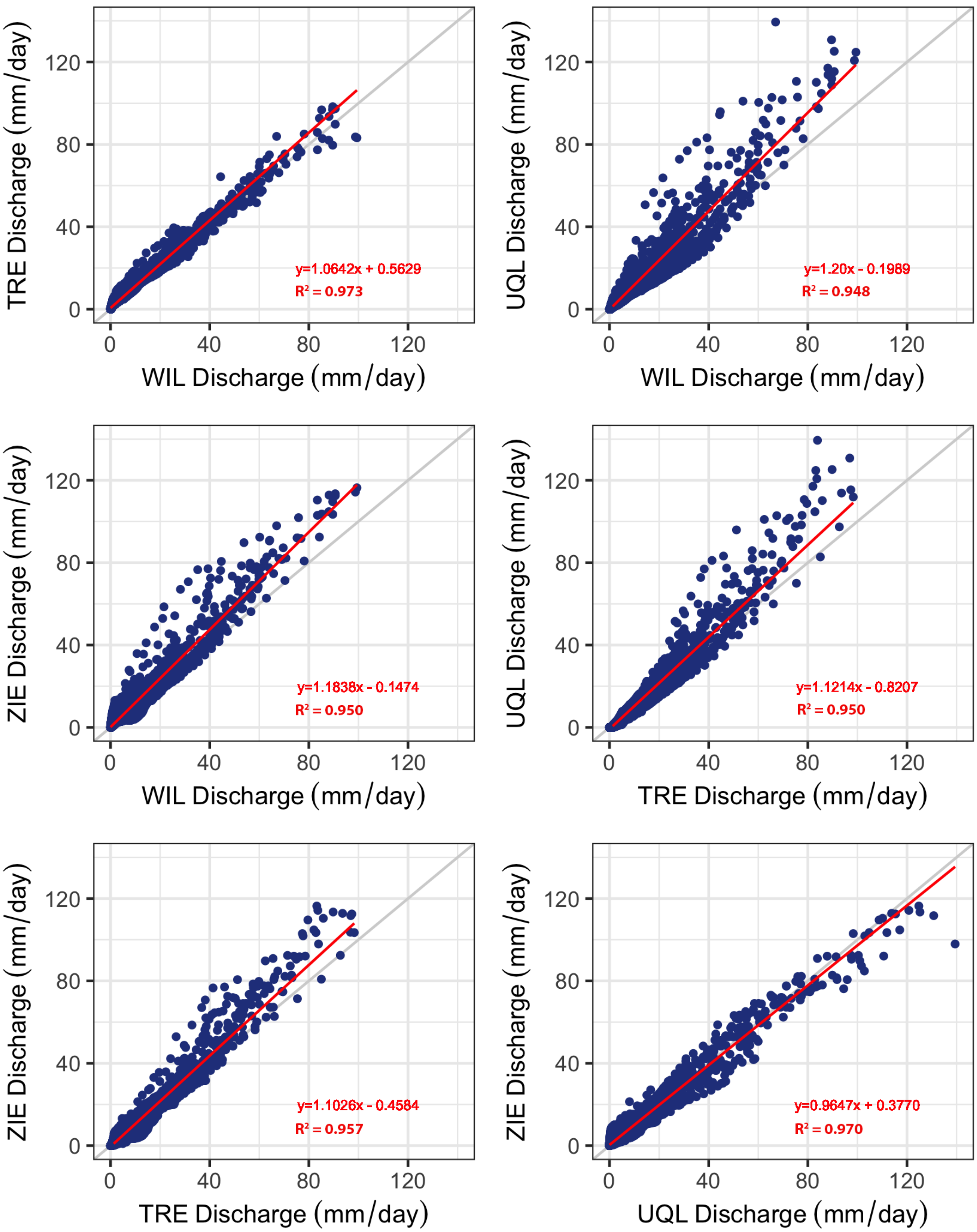

Figure 5: Correlation plots of runoff yield (in mm/day) for each combination of the four sub-watersheds studies in this project.

During the fall wetting-up period runoff ratios in all watersheds were lower than at the height of the winter rainy season, indicating that a greater fraction of the observed event precipitation was used to wet-up the watershed. The antecedent precipitation in early October 2016 was 103.1 mm, reaching 295.4 mm by mid-November. The 2016 fall wetting-up period (early October through mid-October) was identified based on sub-watershed hydrographs and cumulative precipitation totals calculated for these periods. The 2017 fall-wetting up period (early October-end of December) was much longer in duration than it took for each watershed to saturate during the previous year. The antecedent precipitation period is the amount of time it takes for enough precipitation to accumulate to fully saturate the soil profile. The first hydrologic response for the water year is typically not observed until antecedent moisture conditions are met. Tables 5 and 6 display rainfall-runoff coefficients for both years. The relative changes observed amongst runoff ratios of each sub-watershed indicate similarity and predictability in watershed behavior. It is clear that HY2017 and HY2018 were very different in terms of the timing, magnitude, and frequency of precipitation events and storm events. However, the observed rainfall-runoff values are consistent with one another on a relative basis, which indicates that even during variable precipitation/climatic conditions, these four sub-watersheds behave predictably, and should be able to serve as an adequate basis for comparison among treatment levels.

Table 5: HY2017 runoff-rainfall ratios and antecedent moisture conditions for sub-watersheds TRE, UQL, WIL, and ZIE.

2016-2017 Storm Events		WIL	TRE	UQL	ZIE	Event Average
Antecedent Precipitation	(10/2/16-11/17/16)	0.08	0.17	0.06	0.12	**0.11**
Wetting Period	(10/2/16-11/23/16)	0.04	0.1	0	0.03	**0.04**
1	(10/23/16-11/17/16)	0.1	0.21	0.09	0.16	**0.14**
2	(11/17/16-12/5/16)	0.34	0.49	0.47	0.43	**0.43**
3	(12/5/16-12/20/16)	0.59	0.68	0.67	0.69	**0.66**
4	(12/20/16-1/16/17)	0.62	0.73	0.67	0.68	**0.68**
5	(1/16/17-1/31/17)	0.7	0.81	0.71	0.76	**0.75**
6	(1/31/17-2/14/17)	0.73	0.82	0.76	0.8	**0.78**
7	(2/14/17-3/17/17)	0.8	1	0.85	0.85	**0.88**
8	(3/17/17-4/5/17)	0.56	0.77	0.57	0.58	**0.62**
9	(4/5/17-4/23/17)	0.38	0.56	0.38	0.41	**0.43**
Annual Average		**0.45**	**0.59**	**0.47**	**0.50**	

Based on Tables 5 & 6, it is evident that rainfall-runoff ratios in HY2017 were higher than in HY2018. HY2017 was a wet year with above-normal precipitation (1632 mm), which resulted in rainfall-runoff ratios well in exceedance of 0.7 for most storm events at the peak of the rainy season. Season average rainfall-runoff ratios reached 0.45 (WIL), 0.59 (TRE), 0.47 (UQL) and 0.5 (ZIE) compared to the season averages of 0.35 (WIL), 0.51 (TRE), 0.38 (UQL) and 0.4 (ZIE) in HY2018. Total precipitation in HY2018 was 947 mm, about 58% of the HY2017 precipitation. Antecedent precipitation needed to wet up the watersheds in HY2017 and HY2018 was 287.8 mm and 253.5 mm, respectively. The higher antecedent precipitation observed in HY2017 was likely due to the fact that HY2017 followed a 4-year extended drought and deep moisture in the vadose zone was depleted and more precipitation was required to connect flow pathways from the watershed's hillslopes to the riparian zone. Despite these inter-annual differences the data indicate that each sub-watershed requires approximately 27 cm (10.5 inches) of antecedent precipitation to initiate a significant hydrologic response.

A careful comparison of the rainfall-runoff ratios across the four sub-watersheds also indicates subtle differences in rainfall-runoff response. Across both years, the control sub-watershed WIL had consistently the lowest rainfall-runoff ratios (0.45 in HY2017, 0.35 in HY2018) indicating a larger watershed storage and ability to absorb precipitation before runoff is initiated. In contrast, Treat had consistently the largest rainfall-runoff ratios (0.59 in HY2017 and 0.51 in HY2018) indicating a relatively smaller watershed storage and ability to buffer against large precipitation inputs. UQL and ZIE had rainfall-runoff ratios slightly higher than WIL but not as extreme as TRE.

Table 6: HY2018 runoff-rainfall ratios and antecedent moisture conditions for sub-watersheds TRE, UQL, WIL, and ZIE.

YTD 2017-2018 Storm Events		WIL	TRE	UQL	ZIE	Event Average
Antecedent Precipitation	10/2/17-1/1/18	0.08	0.20	0.03	0.06	**0.09**
1	1/1/18-1/13/18	0.12	0.28	0.14	0.16	**0.18**
2	1/13/18-1/20/18	0.16	0.31	0.21	0.21	**0.22**
3	1/20/18-1/23/18	0.36	0.48	0.48	0.44	**0.44**
4	1/23/18-2/4/18	0.64	0.96	0.70	0.71	**0.75**
5	3/11/18-3/19/18	0.29	0.47	0.35	0.36	**0.37**
6	3/19/18-4/1/18	0.52	0.72	0.49	0.60	**0.58**
7	4/4/18-4/10/18	0.60	0.62	0.64	0.66	**0.63**
Annual Average		**0.35**	**0.51**	**0.38**	**0.40**	

5.2 Hydrology and climate

Hydrologic years 2017-2020 were quite different in terms of annual and seasonal precipitation and rainfall-runoff response. Figures 6 and 7 show the daily precipitation and discharge observed within South Fork Caspar Creek and the four study sub-watersheds. Quantitative summary statistics for flow and precipitation are also shown in Tables 7 & 8 including Tukey's HSD test statistics.

As shown in Figure 6 and Table 7, HY2017 and HY 2019 were wetter with 1632 mm and 1372 mm of rainfall while HY 2018 and 2020 were drier with 947 mm and 534 mm, respectively. While HY2017 had the most rainfall days (N=132), daily precipitation amounts were modest, not exceeding 70 mm/day. The highest single day precipitation observed in the 4-year study period was 114.55 mm/day and occurred on April 6, 2018. Both HY2018 and HY2019 had large storm events late in the rainy season, which mainly influenced nitrogen export from the watershed as well as N cycling processes within each sub-watershed.

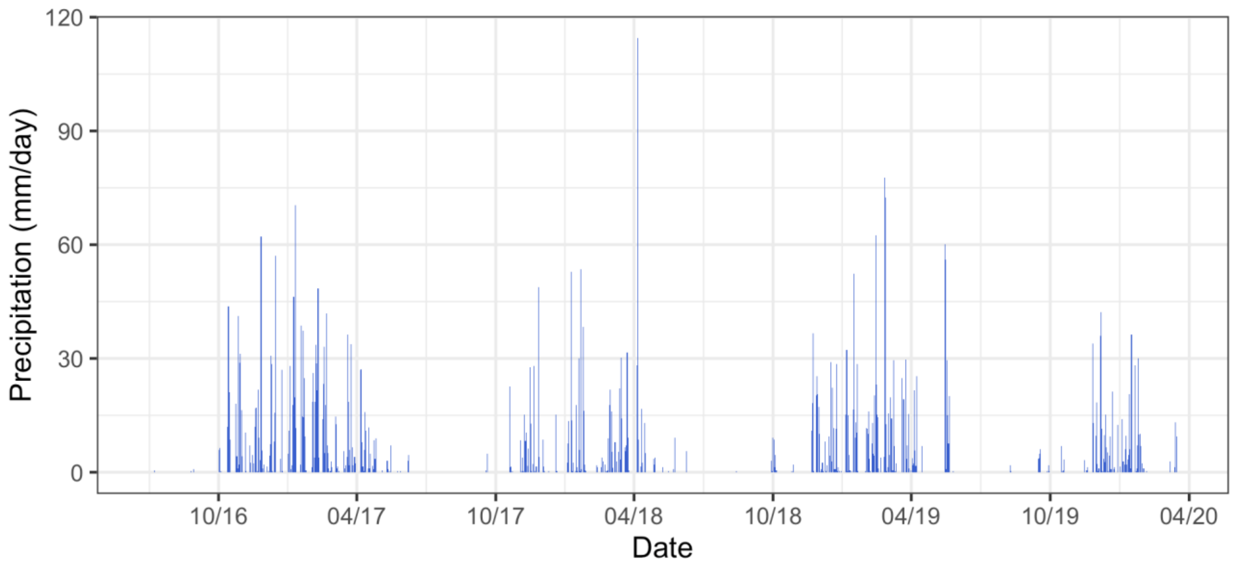

Figure 6: Daily precipitation observed during the study period (7/1/2016 – 6/30/2020).

In response to variable precipitation inputs, rainfall-runoff response in South Fork Caspar Creek watershed and the four sub-watersheds was variable (Figure 7). Average daily discharge was highest in HY2017 and lowest in HY2020, the wettest and driest year within the study period, respectively. Average discharge was significantly different ($p < 0.001$) for most time periods compared in this study (Table 7). Average discharge at the South Fork Caspar Creek watershed outlet was similar to the discharge observed in the control sub-watershed WIL for most periods of time. For example, average discharge in HY2017 at SFC and WIL were 2.61 and 2.6 mm/day respectively, while TRE, UQL and ZIE each had a higher runoff yield of 3.39, 3.2 and 2.96 mm/day, respectively.

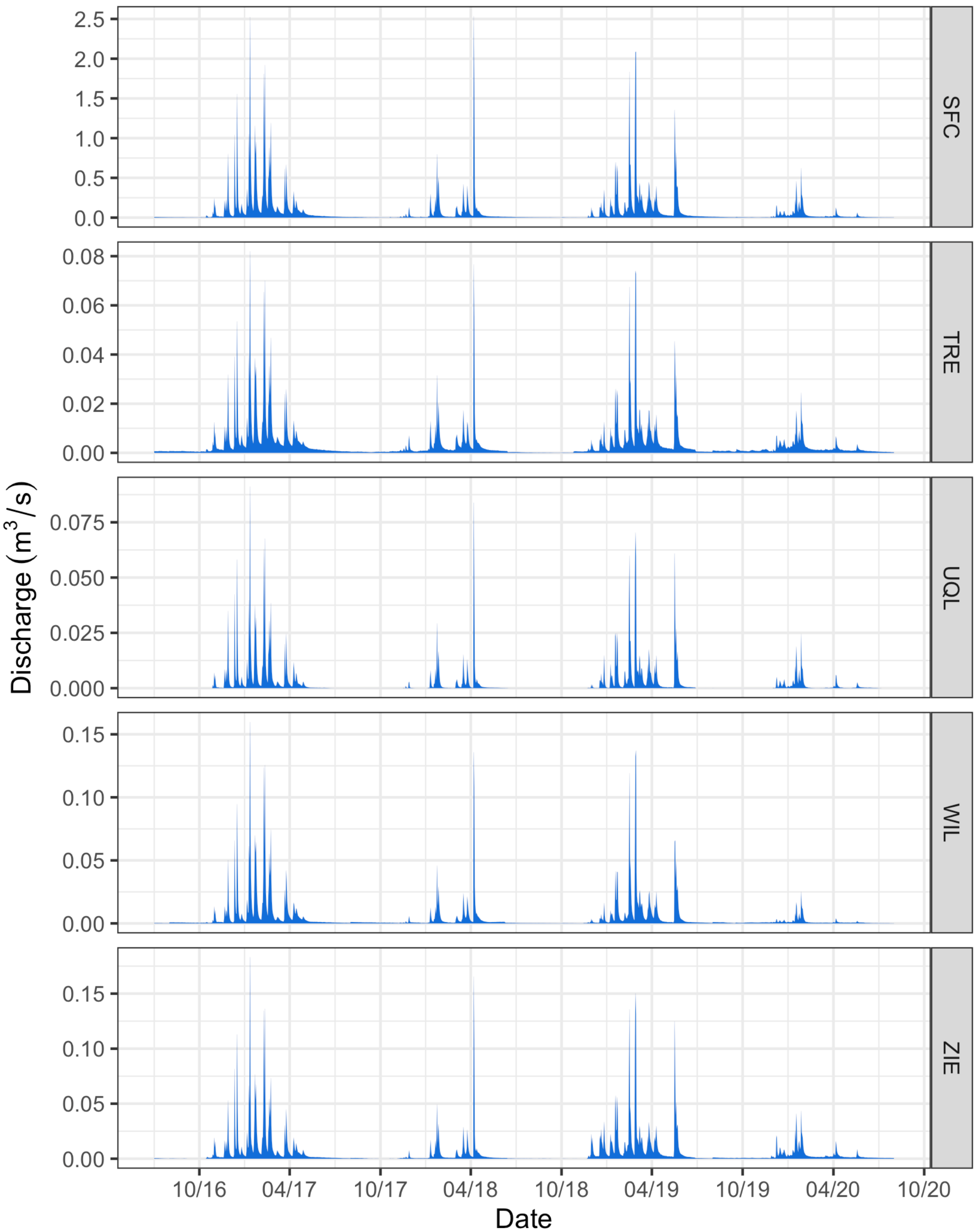

Figure 7: Hydrographs of daily discharge for South Fork Caspar Creek gage and the four sub-watersheds compared in the nutrient study.

Streamflow was consistently highest during the winter season followed by spring, fall and summer (Table 7). Both UQL and TRE had zero flow periods during the summer and early fall months during the dry years (HY2018, HY2020) while WIL and ZIE maintained minimal flows during the same periods. Comparison of average flows between the pre-felling and post-felling period and wet and dry years show very similar results, indicating that timber harvest treatment effects on the hydrologic response of the sub-watersheds was heavily influenced by the extreme variability in precipitation between the hydrologic years both in the pre- and post-felling period (Figure 8, Table 8). Pre-felling flows varied between 25 and 120 mm/day. The high baseflow in the pre-felling period is mainly the result of the wet HY2017 (Figure 8). In contrast, post-felling flows were much lower, varying between 0 and 95 mm/day with long periods of flow not exceeding 1 mm/day.

Average daily flow during dry years was about 50%, 66%, 70%, 39% and 52% of wet year average flow for SFC, WIL, TRE, UQL, and ZIE, respectively. When comparing flows between HY2018 (a dry year) and HY2017 (the wettest year), these percentages change to 36%, 56%, 40%, 26% and 34% for SFC, WIL, TRE, UQL, and ZIE, respectively. In contrast, when comparing average daily flows between the pre-felling and post-felling period, post-felling average flows were on average lower than pre-felling flows (Figure 8) but the percent difference in the ratios increased, indicating that despite the drier post-felling hydrologic years runoff for a given amount of rainfall increased in the sub-watersheds subject to timber harvest treatments (Table 7). Average daily flows in the post-felling period were 67%, 59%, 71%, 62% and 74% for SFC, WIL, TRE, UQL, and ZIE, respectively, indicating that runoff yield particularly increased in TRE, UQL and ZIE but also overall flow from the South Fork Caspar Creek watershed increased in the post-felling period compared to the comparison of wet and dry years or HY2017 and HY2018.

Table 7: Results of Tukey's HSD test for streamflow and total precipitation across different annual analysis periods and sub-watersheds. Values show mean flow (mm/day) during the analysis period ± one standard deviation. Precipitation is shown as total (in mm) over a given period. Please see Table 3 for the dates considered in each analysis period.

	SFC		**WIL**		**TRE**		**UQL**		**ZIE**		**Precip.**
	mm/day		***mm/day***		***mm/day***		***mm/day***		***mm/day***		***mm***
Pre-fell	1.9 ± 5.4	**a**	2 ± 5.6	**a**	2.56 ± 6.0	**a**	2.25 ± 7.2	**a**	2.43 ± 6.7	**a**	2579
Post-fell	1.28 ± 4.7	**b**	1.18 ± 4.5	**b**	1.83 ± 4.5	**b**	1.4 ± 4.5	**b**	1.8 ± 5.9	**b**	1906
p-value	<0.001		<0.001		<0.001		<0.001		<0.001		
HY17	2.61 ± 6.3	**d**	2.6 ± 6.4	**c**	3.39 ± 6.6	**c**	3.2 ± 8.1	**c**	2.96 ± 7.6	**b**	1632
HY18	0.95 ± 4.3	**a**	1.46 ± 4.8	**a**	1.38 ± 4.1	**a**	0.85 ± 4.8	**a**	1.02 ± 4.8	**a**	947
HY19	2.1 ± 5.8	**b**	1.98 ± 5.6	**a**	2.62 ± 6.1	**a**	3.07 ± 8.1	**b**	2.9 ± 7.6	**b**	1372
HY20	0.5 ± 1.2	**c**	0.38 ± 0.8	**b**	1.05 ± 1.5	**b**	0.85 ± 1.7	**a**	0.95 ± 1.8	**a**	534
p-value	<0.001		<0.001		<0.001		<0.001		<0.001		
Dry years	1.17 ± 4.4	**a**	1.51 ± 4.9	**a**	2.11 ± 5.5	**a**	1.2 ± 5.2	**a**	1.55 ± 5.2	**a**	1481
Wet years	2.35 ± 6.1	**b**	2.29 ± 6.1	**b**	3.01 ± 6.4	**b**	3.1 ± 8.1	**b**	2.93 ± 7.6	**b**	3004

p-value	<0.001		<0.001		<0.001		<0.001		<0.001	

Relative increases in streamflow in the sub-watersheds subject to timber harvest treatments are also evident in Figure 9, which shows correlation plots of runoff yield between each sub-watershed pair for the pre-felling and post-felling season. In comparison to the control watershed WIL, daily water yield in TRE, UQL and ZIE increased by 5.9%, 5.2% and 11.8%, respectively in the post-felling season. Timber reduction of 35% and 55% in TRE and UQL seem to have a similar effect on streamflow as indicated by the identical slopes of the linear regressions of pre-felling and post-felling TRE vs. UQL runoff (Figure 9). In comparison to the control sub-watershed WIL, both sub-watersheds increased their flow in the post-felling period, but maintained a nearly identical slope of 1.1246 (pre-felling) and 1.1265 (post-felling) when correlated against each other. Among all three sub-watersheds subject to timber harvest, ZIE showed the most pronounced increase in flow. Average daily flow increased by 11.8% compared to the control sub-watershed WIL, by 7.3% compared to TRE (35% reduction in leaf area), and by 6.2% compared to UQL (55% reduction in leaf area). However, timber reduction had the most effect on high-magnitude flows in UQL and only modest effects on peak flows in ZIE (Figure 9).

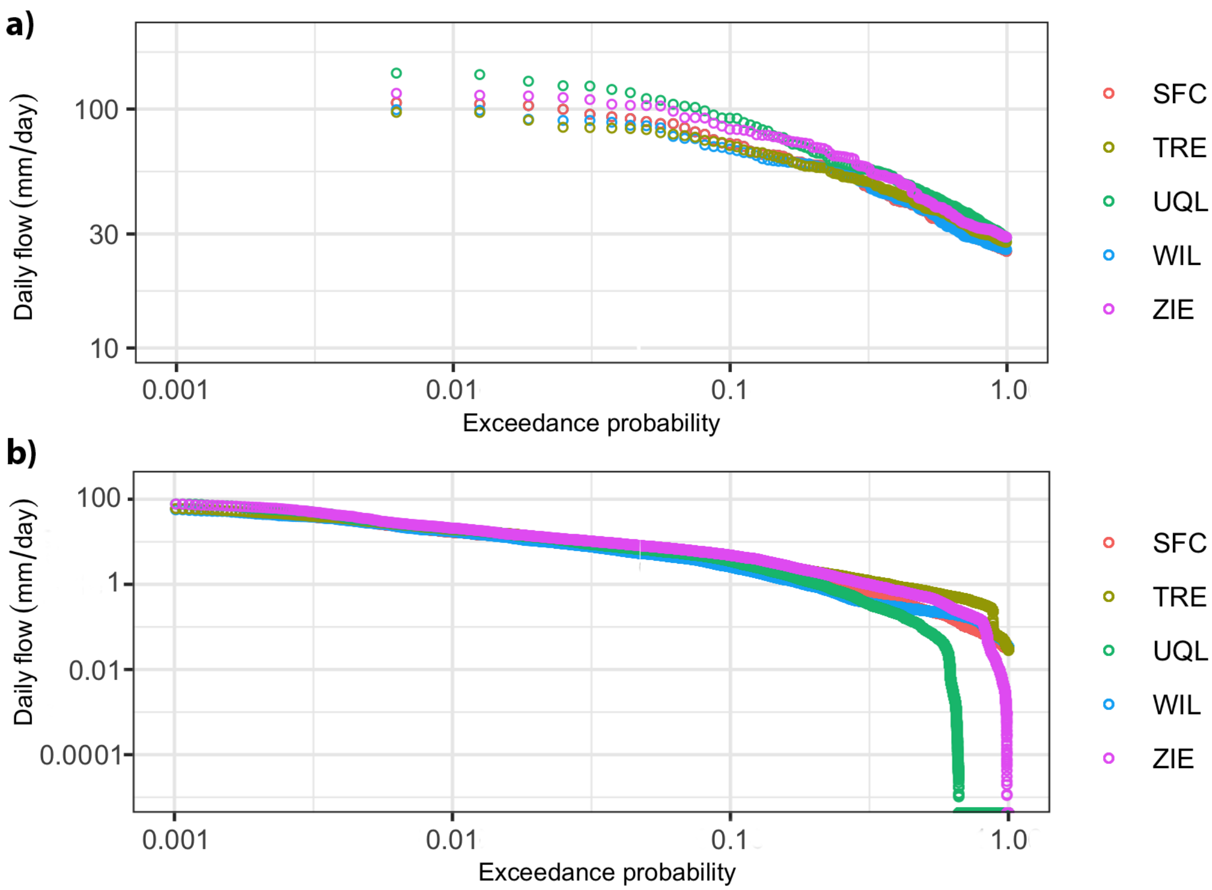

Figure 8: Flow duration curves of sub-watershed daily flow (mm/day) for the pre-felling (a) and post-felling (b) period. Exceedance probability was estimated with the Weibull plotting position (p_e = rank/(N+1)).

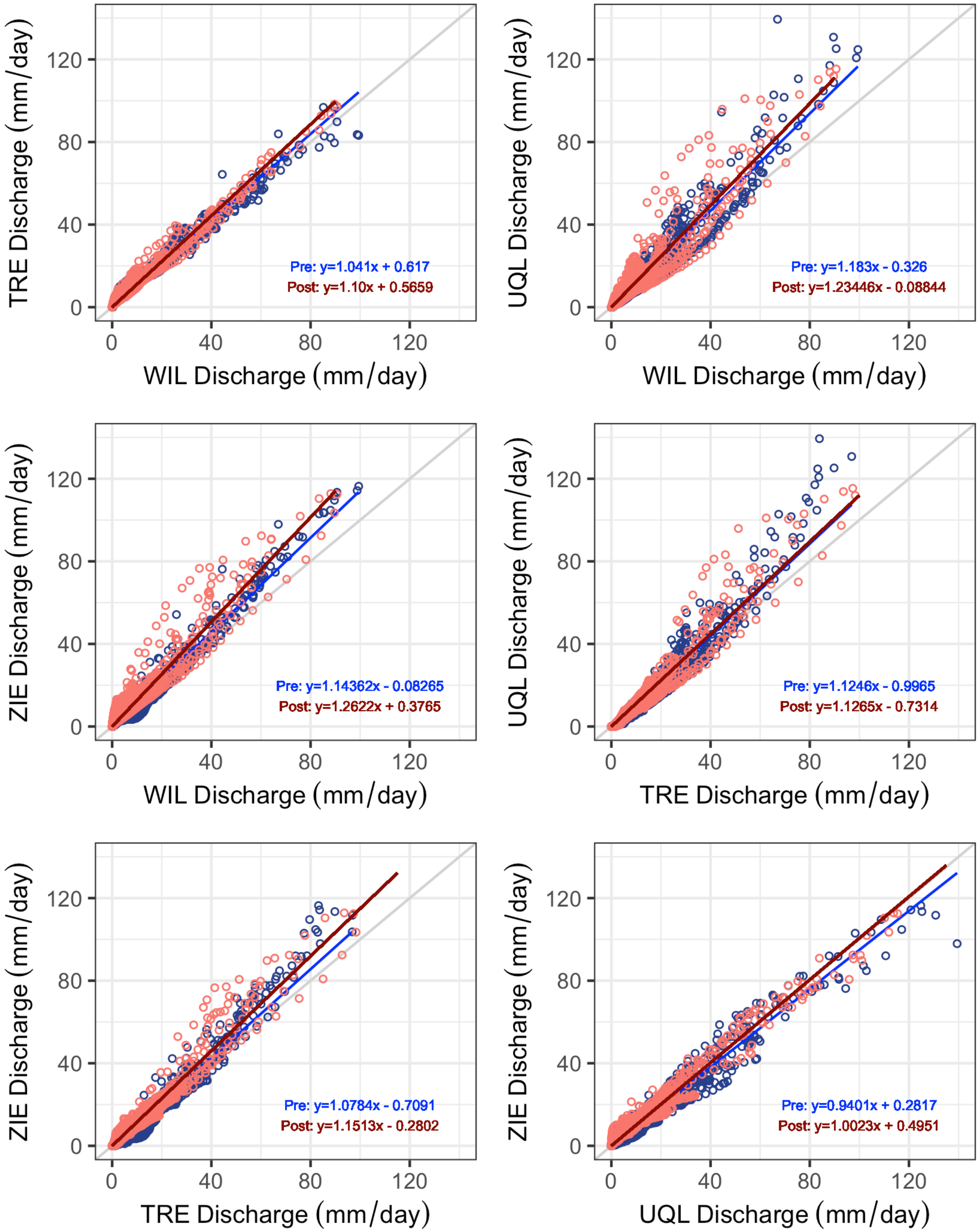

Figure 9: Correlation plots of pre-felling (blue) and post-felling (orange) runoff yield (in mm/day) for each combination of the four sub-watersheds studies in this project.

When looking at seasonal changes between the pre-felling and post-felling period, we can observe that the post-felling fall, winter and spring seasons' average flows are lower than the pre-felling flows, again likely due to the extreme wet year observed in HY2017 during the pre-felling season (Table 8). However, average Summer flows are higher at the SFC, TRE, UQL and ZIE gages and lower at the WIL gage (the control) during the post-felling period, indicating that timber harvest reduced plant water demand in these sub-watersheds leading to increased water yield during the summer period (Table 8). In addition, the average spring flow in ZIE in the post-felling period is nearly identical to the pre-felling flow, indicating the 75% reduction in leaf area in this watershed significantly increased spring season flow, likely due to reduced plant water demand.

Table 8: Results of Tukey's HSD test for streamflow and total precipitation across different seasonal analysis periods and sub-watersheds. Values show mean flow (mm/day) during the analysis period ± one standard deviation. Precipitation is shown as total (in mm) over a given period. Please see Table 3 for the dates considered in each analysis period.

	SFC		**WIL**		**TRE**		**UQL**		**ZIE**		**Precip.**
	mm/day		***mm/day***		***mm/day***		***mm/day***		***mm/day***		***mm***
Pre-Fall	0.36 ± 1.5	**a**	0.46 ± 1. 5	**a**	0.78 ± 1.9	**a**	0.55 ± 2. 6	**a**	0.57 ± 2.0	**a**	636
Post-Fall	0.09 ± 0.2	**b**	0.15 ± 0.1	**b**	0.4 ± 0.4	**b**	0.28 ± 0.3	**b**	0.22 ± 0.7	**b**	273
p-value	<0.001		<0.001		<0.001		<0.001		<0.001		
Pre-Winter	4.39 ± 8.4	**a**	4.4 ± 8.5	**a**	5.52 ± 8.7	**a**	4.45 ± 9.9	**a**	5.2 ± 10.2	**a**	1223
Post-Winter	2.97 ± 7.3	**b**	2.25 ± 6.6	**b**	3.89 ± 7.6	**b**	2.93 ± 7.0	**b**	4.5 ± 9.2	**b**	1149
p-value	<0.001		<0.001		<0.001		<0.001		<0.001		
Pre-Spring	2.45 ± 4.9	**a**	2.3 ± 5.0	**a**	3.18 ± 6.3	**a**	2.11 ± 6.9	**a**	2.68 ± 6.1	**a**	706
Post-Spring	2.03 ± 5.7	**b**	2.1 ± 5.7	**b**	2.65 ± 4.0	**b**	1.63 ± 4.0	**b**	2.66 ± 7.0	**a**	482
p-value	<0.001		<0.001		<0.001		<0.001		0.7		
Pre-Summer	0.15 ± 0.1	**a**	0.21 ± 0.1	**a**	0.38 ± 0.2	**a**	0.02 ± 0.03	**a**	0.17 ± 0.1	**a**	13.5
Post-Summer	0.18 ± 0.2	**b**	0.18 ± 0.1	**b**	0.41 ± 0.3	**b**	0.15 ± 0.2	**b**	0.21 ± 0.2	**b**	2.0
p-value	<0.001		<0.001		<0.001		<0.001		<0.001		
Dry-Fall	0.14 ± 0.06	**a**	0.16 ± 0.1	**a**	0.36 ± 0.5	**a**	0.04 ± 0.2	**a**	0.166 ± 0.3	**a**	306
Wet-Fall	0.49 ± 1.8	**b**	0.49 ± 1.7	**b**	0.87 ± 2.2	**b**	1.56 ± 4.2	**b**	0.67 ± 2.2	**b**	603
p-value	<0.001		<0.001		<0.001		<0.001		<0.001		
Dry-Winter	2.39 ± 5.5	**a**	3.24 ± 7.6	**a**	3.86 ± 6.7	**a**	2.42 ± 6.5	**a**	3.09 ± 6.5	**a**	740
Wet-Winter	5.98 ± 10.4	**b**	5.94 ± 10.5	**b**	7.14 ± 10.8	**b**	6.18 ± 12.1	**b**	7.65 ± 12.8	**b**	1633
p-value	<0.001		<0.001		<0.001		<0.001		<0.001		
Dry-Spring	1.86 ± 6.2	**a**	2.17 ± 5.1	**a**	3.36 ± 7.5	**a**	1.69 ± 6.7	**a**	2.26 ± 7.0	**a**	428
Wet-Spring	2.76 ± 3.9	**b**	2.55 ± 3.7	**b**	3.63 ± 4.1	**b**	2.6 ± 5.1	**b**	3.28 ± 5.4	**b**	760
p-value	<0.001		<0.001		<0.001		<0.001		<0.001		
Dry-Summer	0.12 ± 0.06	**a**	0.17 ± 0.1	**a**	0.3 ± 0.1	**a**	0.03 ± 0.04	**a**	0.2 ± 0.1	**a**	27

Wet-Summer	0.24 ± 0.2	**b**	0.23 ± 0.1	**b**	0.46 ± 0.3	**b**	0.09 ± 0.2	**b**	0.21 ± 0.2	**b**	10
p-value	<0.001		<0.001		<0.001		<0.001		<0.001		

Table 9 and Figure 10 are summarizing the water yields for each sub-watershed and SFC for the four hydrologic years monitored in this study. Despite similar precipitation inputs, water yields varied between the sub-watersheds. Water yields were generally lowest in WIL, the control sub-watershed for a given precipitation input and highest in TRE, indicating that each sub-watershed has a slightly different watershed storage, whereby WIL is capable of absorbing more rainfall (and releasing less runoff for a given rainfall input) and TRE is least capable of holding on to rainfall. Although water yields are adjusted for the differing sizes of the watershed, the different water yields clearly indicate dominance of different flow pathways in these watersheds. Infiltrating rainfall in WIL is likely taking a deeper route to the stream compared to TRE despite the fact that the watershed slope of both sub-watersheds is similar (51 and 47% respectively). Both UQl and WIL show water yields similar to those observed at the watershed outlet of South Fork Caspar (see annual rainfall-runoff ratios in Table).

Table 9: Annual precipitation and water yield (mm/yr) for the four treatment sub-watersheds and the South Fork Caspar Creek gauge for hydrologic years 2017-2020.

	Precipitation mm/year	**Water yield mm/year**				
		SFC	**WIL**	**TRE**	**UQL**	**ZIE**
HY 2017	1632	936.7	929.3	1229.5	957.4	1025.9
HY 2018	947	340.1	331.4	498.7	300.6	352.9
HY 2019	1372	753.1	709.2	950.8	797.1	1004.6
HY 2020	534	178.6	134.0	379.8	181.9	323.2
		Rainfall-Runoff Ratio				
HY 2017		57%	57%	75%	59%	63%
HY 2018		36%	35%	53%	32%	37%
HY 2019		55%	52%	69%	58%	73%
HY 2020		33%	25%	71%	34%	61%

A comparison of the water yields between individual hydrologic years indicates that all sub-watersheds and SFC have comparable water yields in HY2017 and HY2018 (the pre-harvest period) but show a clear increasing trend with the percent of timber removed in HY 2019 and 2020. In HY2019, the water yield from ZIE, one of the treatment sub-watersheds where 75% of the timber stand was removed, was almost 300 mm higher than in the control WIL. HY2019 was a fairly wet year. However, the same increasing trend can be observed in HY2020, with ZIE yielding 323.2 mm/yr compared to 134 mm/yr from WIL. A regression of percent timber removed vs. annual water yield for both years shows clear positive slopes for both hydrologic years and an average increase of 31.5 mm per 10% timber removed in HY2019 and an increase of 17.9 mm per 10% timber removed in HY2020.

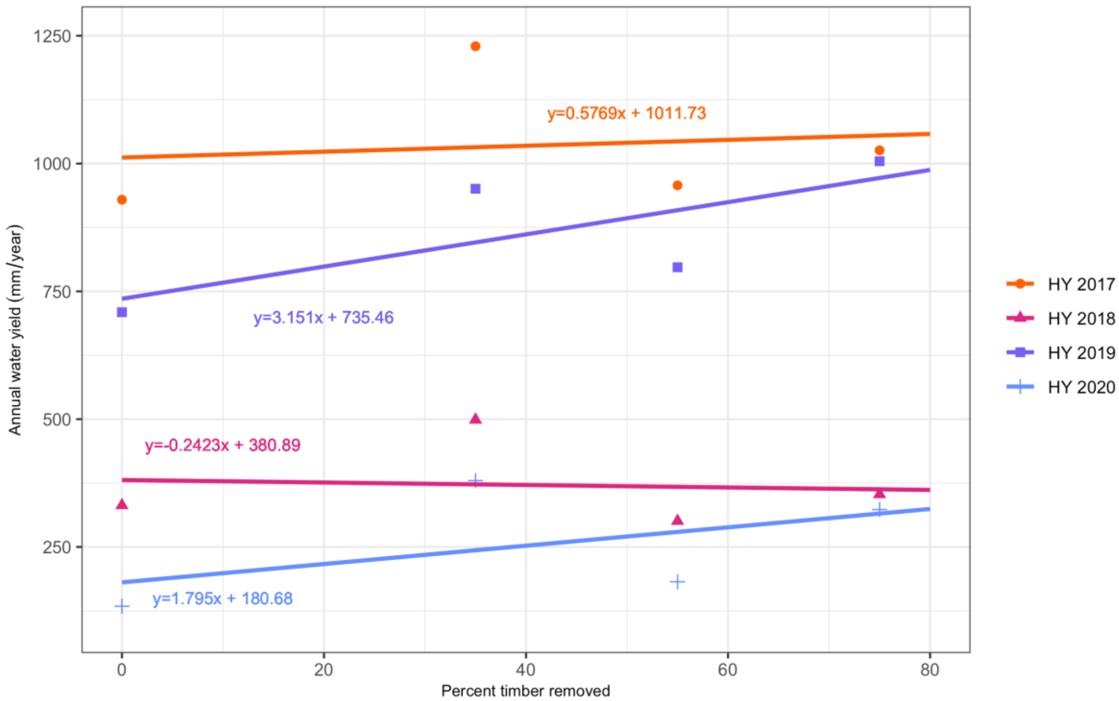

Figure 10: Annual water yield vs. percent timber removed in each watershed comparing hydrological years 2017 – 2020. Hydrologic years 2019 and 2020 are the post-harvest years, while HY 2017 was the wettest year within the 4-year study period.

5.3 Water Chemistry

Timber was harvested in different phases throughout the South Fork Caspar Creek watershed starting as early as June 2016 in the southeastern part of the watershed and commencing as late as November 2018 in some of the experimental watersheds. While specific treatments were imposed in some of the study sub-watersheds, the forest in the hillslope areas surrounding the treatment sub-watersheds was also thinned as part of the so called 'matrix harvest'. Thus, comparison of streamflow and nutrient fluxes from the three sub-watersheds receiving timber harvest (TRE, UQL, ZIE) with the control sub-watershed WIL and the outlet of South Fork Caspar Creek (SFC) allows examining the effects of harvest and post-harvest management practices on nutrient cycling across the entire watershed continuum. The export of nutrients in stream water is one of the primary processes responsible for nutrient losses from forested ecosystems (Dahlgren, 1998). In the following sections we will describe the general dynamics in nutrient concentrations (TN, NO_3^--N, NH_4^+-N, DON, TP, PO_4-P, DOC) and selected water chemistry parameters (pH, EC, turbidity), their relationship to streamflow, and evaluate whether statistically significant differences in nutrient concentrations exist when comparing sub-watersheds, different management periods, seasons, or hydrologic periods. In addition, we will examine nutrient fluxes and total nutrient loads exported from the study watersheds across the same time periods.

The following section summarize nutrient concentrations and selected water chemistry parameters for the entire study period of July 1, 2016 to June 30, 2020. As mentioned in section 5.1, timber harvest occurred in phases impacting the starting dates of when management practices influenced the streamflow and nutrient flux response in the study sub-watersheds. While felling was expected to have an immediate effect on the hydrologic response of the sub-watersheds, this study assumed that nutrient fluxes mainly changed after logs were removed from the sub-watersheds, which often causes substantial disturbance of the forest floor.

5.3.1 Watershed comparisons

We started our water chemistry analysis by comparing nutrient concentrations (TN, NO_3^--N, NH_4^+-N, DON, TP, PO_4-P, DOC) and selected water chemistry parameters (pH, EC, turbidity) between the four sub-watersheds (WIL, TRE, UQL, ZIE) and SFC (South Fork Caspar Creek) for different annual and seasonal comparison periods. For each water chemistry parameters, main dynamics are summarized in graphical form and tables, which provide post-hoc Tukey's HSD test scores from an Analysis of Variance. In each table, statistical results were analyzed at a significance level of $\alpha = 0.05$. However, since concentrations or water chemistry parameters are compared between five watersheds, the adjusted p-value is $\alpha_{test} = 0.05/10 = 0.005$ (considering 10 tests are performed to compare five groups). Hence, p-values < 0.005 indicate significant differences.

5.3.1.1 Turbidity

Turbidity in SFC and the four sub-watersheds was generally low during dry flow periods and slightly elevated during rainy season storm events (Figure 11). Turbidity rarely exceeded 200 NTU (Nephelometric Turbidity Units) except during a handful of storm events in January 2017, April 2018, and March 2019. Turbidity was highest in all four sub-watersheds on April 6, 2018 when the watershed received 114.5 mm of rainfall within 24-hours. A rain event of such intensity often exceeds the water storage capacity of shallow forest soils resulting in shallow subsurface storm flow in the more porous A horizons of the forest soils, macropore flow and eventually saturation excess overland flow. The latter, which often originates from saturated areas connected to the riparian zone and ephemeral stream network has the potential to transport high loads of suspended sediment to streams. In addition, forest roads often serve as concentrated flow pathways during storm events providing more suspended sediments to streams than most natural forest area because of tire ruts and generally low vegetation cover observed on forest roads (Beschta, 1978; Reid and Dunne, 1984; Bilby et al., 1989).

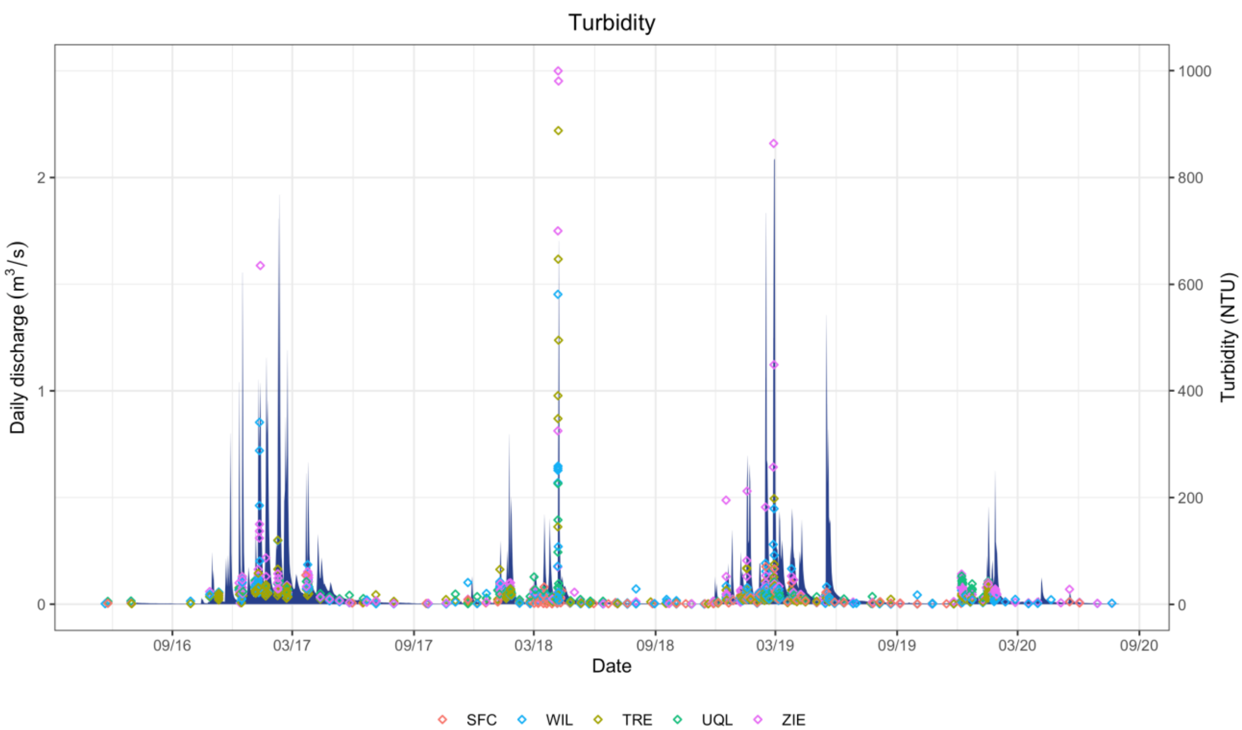

Figure 11: Variation in turbidity (diamonds) at the outlet of each sub-watershed and South Fork Caspar Creek. Streamflow is shown as blue filled areas. Felling was completed in fall 2018 in the sub-watersheds. Turbidity was measured automatically at stream gages using an FTS DTS-12 temperature/turbidity sensor.

Comparison of mean pre-harvest and post-harvest stream water turbidity between the four sub-watersheds and SFC indicates very similar dynamics. As shown in Tables 10 & 11, most comparison periods did not show a significant difference in turbidity between sub-watersheds or SFC, with exception of the post-harvest period, wet years, and HY2019 and HY2020. During the post-harvest period, turbidity was significantly elevated in ZIE and TRE, which both had timber reductions of 75% and 55%, respectively. At a seasonal basis, post-harvest mean winter turbidity was significantly higher in ZIE compared to the other sub-watersheds but also fourfold the turbidity measured at SFC. During dry-years, turbidity only varied in winter between sub-watersheds, while sub-watershed differences in EC were significant during all four seasons of wet years. Again, turbidity measured at the outlet of SFC was often three or four times lower than turbidity measured at the outlets of the treatment sub-watersheds, indicating that the main stem of South Fork Caspar Creek allows settling of suspended solids before it exits the south branch of Caspar Creek watershed.

Table 10: ANOVA and post-hoc Tukey's HSD test scores for mean differences in pre- and post-harvest and other annual stream water turbidity (NTU) trends comparing sub-watersheds. ANOVA and Tukey's HSD were calculated at a significance level of $\alpha = 0.05$. N is the number of samples considered in each group. Since 5 watersheds are compared, $\alpha_{test} = 0.05/10 = 0.005$. Hence, p-values < 0.005 indicate significant differences.

	SFC	WIL	TRE	UQL	ZIE	*p-value*
N **Pre-yarding**	34 8.39 ± 11.4 a	106 39.13 ± 62.8 a	104 45.67 ± 124.3 a	95 29.26 ± 27.8 a	106 62.48 ± 160.3 a	*0.057*
N **Post-yarding**	54 11.01 ± 15.7 a	134 13.78 ± 20 a	119 15.8 ± 21.3 a	105 22.37 ± 12.1 ab	143 34.26 ± 85.9 b	***<0.001***
N **HY 2017**	7 12 ± 19 a	53 42 ± 62 a	47 24 ± 20 a	41 29 ± 10 a	56 49 ± 85 a	*0.116*
N **HY 2018**	30 7 ± 9 a	57 34 ± 62 a	55 66 ± 168 a	52 30 ± 36 a	54 72 ± 208 a	*0.116*
N **HY 2019**	40 14 ± 17 a	69 17 ± 26 a	63 18 ± 28 a	50 17 ± 10 a	67 50 ± 123 b	***0.006***
N **HY 2020**	9 2 ± 2 c	60 11 ± 9 ac	56 13 ± 9 a	55 28 ± 11 b	70 21 ± 13 d	***<0.001***
N **Dry years**	41 5.51 ± 7.6 a	118 21.98 ± 44.9 a	113 38.49 ± 119.9 a	109 28.4 ± 26.4 a	126 42.94 ± 138.4 a	*0.131*
N **Wet years**	47 13.91 ± 17.2 a	122 27.87 ± 47 a	110 20.73 ± 24.9 a	91 22.34 ± 12.1 a	123 49.68 ± 107.1 b	***0.002***

Table 11: ANOVA and post-hoc Tukey's HSD test scores for mean differences in seasonal stream water turbidity (NTU) comparing sub-watersheds. ANOVA and Tukey's HSD were calculated at a significance level of $\alpha = 0.05$. N is the number of samples considered in each group. Since 5 watersheds are compared, $\alpha_{test} = 0.05/10 = 0.005$. Hence, p-values < 0.005 are significant.

		SFC	WIL	TRE	UQL	ZIE	p-value
Pre-yarding vs. Post-yarding	**N**	1	8	10	4	8	
	Pre-Fall	NA	12.9 ± 13.7	9.26 ± 6.5	14.03 ± 9.5	12.7 ± 8.2	*0.875*
		a	a	a	a	a	
	N	7	57	49	48	57	
	Pre-Winter	6.25 ± 6.4	39.66 ± 59.9	25.43 ± 19.6	28.35 ± 8.1	47.47 ± 84	*0.105*
		a	a	a	a	a	
	N	22	38	38	39	37	
	Pre-Spring	10 ± 13	47 ± 74	89 ± 198	34 ± 41	103 ± 247	*0.095*
		a	a	a	a	a	
	N	4	3	7	4	4	
	Pre-Summer	2 ± 0	3 ± 4	4 ± 6	7 ± 2	4 ± 2	*0.539*
		a	a	a	a	a	
	N	7	8	9		16	
	Post-Fall	1.02 ± 1.4	1.13 ± 0.9	1.84 ± 2		11 ± 10	*0.504*
		a	a	a		ab	
	N	18	88	84	79	98	
	Post-Winter	21.16 ± 21.5	18 ± 23	20 ± 24	26 ± 12	46 ± 102	***0.006***
		ab	a	a	ab	b	
	N	16	25	18	21	23	
	Post-Spring	11 ± 10	8 ± 7	8 ± 6	14 ± 6	16 ± 14	***0.025***
		ab	a	ab	ab	b	
	N	10	14	9	5	13	
	Post-Summer	2 ± 1	1 ± 1	3 ± 3	7 ± 5	3 ± 2	***<0.001***
		a	a	a	b	a	
Dry vs. Wet years	**N**	5	7	8	2	7	
	Dry-Fall	3 ± 3	7 ± 15	3 ± 3	10 ± 13	3 ± 3	*0.709*
		a	a	a	a	a	
	N	8	69	66	71	77	
	Dry-Winter	6 ± 6	16 ± 9	17 ± 10	28 ± 9	24 ± 10	***<0.001***
		c	ac	a	b	b	
	N	20	33	29	31	33	
	Dry-Spring	8 ± 10	44 ± 80	109 ± 224	34 ± 47	106 ± 262	*0.095*
		a	a	a	a	a	
	N	8	9	10	5	9	
	Dry-Summer	2 ± 1	1 ± 1	3 ± 3	4 ± 2	2 ± 1	***0.028***
		ab	b	ab	a	ab	
	N	24	38	37	31	37	
	Wet-Fall	11 ± 13	15 ± 16	12 ± 10	20 ± 11	21 ± 18	*0.016*
		a	a	a	a	a	
	N	17	76	67	56	78	
	Wet-Winter	22 ± 22	37 ± 57	27 ± 29	25 ± 12	68 ± 131	***0.003***
		ab	ab	a	a	b	
	N	18	30	27	29	27	
	Wet-Spring	14 ± 14	17 ± 17	13 ± 11	20 ± 12	25 ± 19	***0.047***
		ab	ab	a	ab	b	
	N	6	8	6	4	8	

	Wet-Summer	2 ± 1 b	2 ± 3 b	5 ± 6 ab	10 ± 3 a	4 ± 2 b	***0.004***

5.3.1.2 Electrical conductivity

EC showed a strong temporal pattern at both the seasonal and storm-event scale (Figure 12). Seasonally, maximum EC occurred during the summer period of low streamflow reaching up to 500 µS/cm in the control sub-watershed WIL. During storm events EC was reduced by up to 400 µS/cm as a result of dilution and changes in hydrologic flow pathways. The decrease in EC during peak streamflows is in complete contrast to the nutrient concentrations (C, N, P), which peak during high flow events.

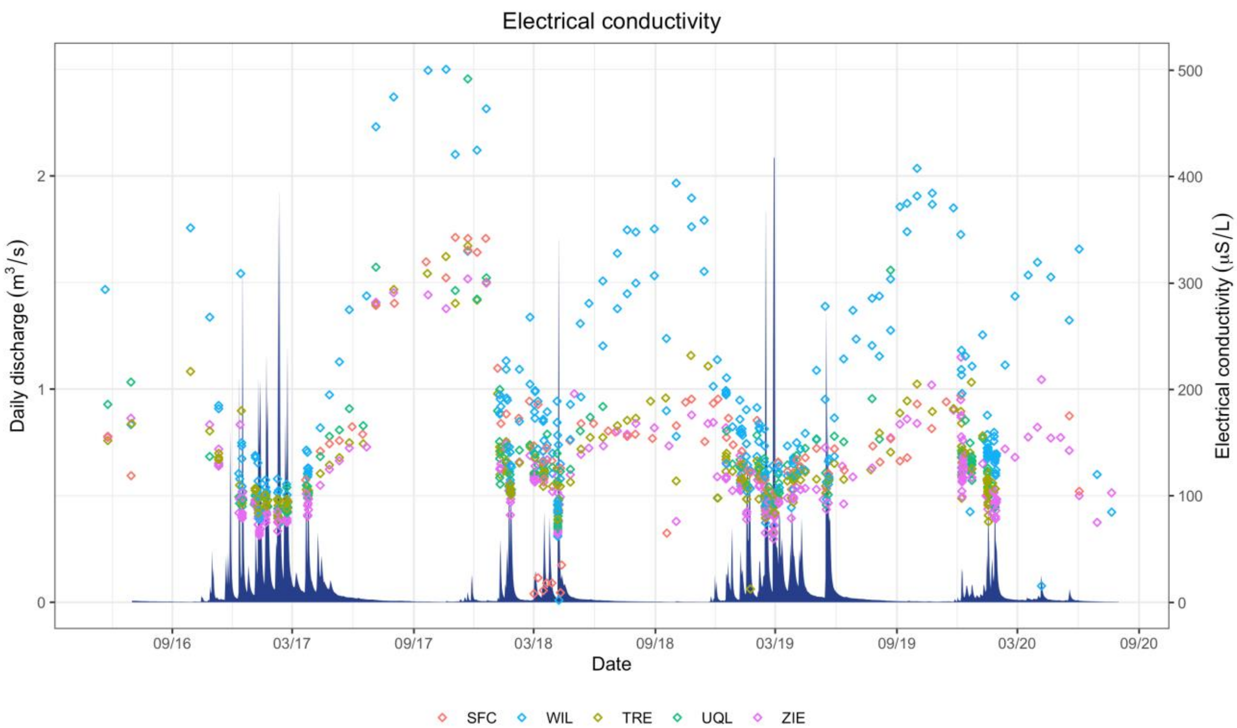

Figure 12: Variation in electrical conductivity (EC) at the outlet of each sub-watershed and South Fork Caspar Creek. Streamflow is shown as blue filled areas. Felling was completed in fall 2018 in the sub-watersheds. Grab samples were collected bi-weekly during baseflow periods while autosamplers were used to collect samples during storm events.

Interestingly, EC in the control sub-watershed was generally 100-200 µS/cm higher during the dry season low flow periods and about 30-50 µS/cm higher during storm events. ANOVA and post-hoc Tukey's HSD test scores indicate that mean EC was significantly different in WIL compared to the other three treatment watersheds in the pre-harvest and post-harvest periods, in wet and dry years and in each hydrologic year ($p<0.001$, Table 12). The higher EC observed in WIL can be interpreted as an indicator for deeper flow pathways and longer residence times of water within the watershed, particularly if co-occurring with high base cation and silica and low DOC concentrations (James and Roulet, 2006).

EC concentrations in the three treatment sub-watersheds and SFC were comparable but lower than in WIL, varying between 250-350 µS/cm in summer 2017 and 50 – 150 µS/cm at the height of the winter rainy season. As shown in Figure 12, EC was consistently lowest in ZIE during storm events indicating a higher dilution effect from rainfall (Table 12). EC was exceptionally high in the summer of 2017 (Table13), which is not surprising given that baseflow in summer 2017 was greater in all four watersheds compared to the other, often drier years. The high EC values observed in summer 2017are likely an effect of the intense winter rainy season and its effect on groundwater recharge and return flow to streams. 2017 was the second wettest year on record in northern California. The high precipitation likely resulted in a deep flushing effect in all sub-watersheds, whereby larger fractions of the infiltrating precipitation traveled along deeper flow pathways, reconnecting mountain recharge and deeper groundwater with the watershed outlets.

Table 12: ANOVA and post-hoc Tukey's HSD test scores for mean differences in pre- and post-harvest and other annual stream water electrical conductivity (µS/cm) trends comparing sub-watersheds. ANOVA and Tukey's HSD were calculated at a significance level of $\alpha = 0.05$. N is the number of samples considered in each group. Since 5 watersheds are compared, $\alpha_{test} = 0.05/10 = 0.005$. Hence, p-values < 0.005 indicate significant differences.

	SFC	WIL	TRE	UQL	ZIE	*p-value*
N	34	106	104	95	106	
Pre-yarding	148 ± 91	170 ± 98	132 ± 56	129 ± 61	114 ± 51	***<0.001***
	ab	b	a	a	a	
N	55	137	123	107	145	
Post-yarding	141 ± 31	185 ± 81	121 ± 34	123 ± 30	118 ± 33	***<0.001***
	b	c	ab	ab	a	
N	7	53	47	41	56	
HY 2017	166 ± 52	143 ± 74	114 ± 37	109 ± 42	97 ± 36	***<0.001***
	bc	c	ab	ab	a	
N	30	57	55	52	54	
HY 2018	146 ± 94	204 ± 111	146 ± 65	141 ± 70	134 ± 57	***<0.001***
	a	b	a	a	a	
N	40	69	63	50	66	
HY 2019	134 ± 31	171 ± 70	116 ± 32	117 ± 24	107 ± 27	***<0.001***
	b	c	ab	ab	a	
N	10	63	60	57	73	
HY 2020	157 ± 30	190 ± 87	127 ± 35	129 ± 34	124 ± 34	***<0.001***
	ab	b	a	a	a	
N	42	121	117	111	129	
Dry years	148 ± 81	198 ± 99	137 ± 52	136 ± 54	129 ± 45	***<0.001***
	a	b	a	a	a	
N	47	122	110	91	122	
Wet years	139 ± 36	159 ± 73	115 ± 34	113 ± 33	102 ± 32	***<0.001***
	b	b	a	a	a	

On average, EC was higher during dry years than during wet years (except for summer 2017). Both HY2018 and HY2020 averaged around 140 and 125 (µS/cm) in the three treatment sub-watersheds (TRE, WIL, ZIE), respectively. Given that HY2020 was the driest year within the 4-year study period it is however interesting to observe that EC was lower in HY2020 than in HY2018, possibly indicating shallower flow pathways of rainfall-runoff to streams and less return flow of groundwater to streams. For many comparison periods stream water EC was also significantly different at the outlet of South Fork Caspar Creek. Often EC was more elevated at SFC than observed in the three sub-watersheds, but generally stream water EC at SFC was lower than observed in WIL.

Seasonal dynamics shown in Table 13 more or less reflect the same trends as observed at the annual or pre-harvest and post-harvest scale. Stream water EC was often highest in summer and fall and lowest in spring. Mean seasonal EC varied by about 100 µS/cm in most sub-watersheds, except for WIL, which showed a greater variability in mean seasonal EC values of about 103 to 403 µS/cm. Again, at the seasonal scale stream water EC in WIL was significantly different from stream water EC in TRE, UQL and ZIE ($p<0.001$) both during wet and dry year and when comparing the pre-harvest and post-harvest seasons.

Table 13: ANOVA and post-hoc Tukey's HSD test scores for mean differences in seasonal stream water electrical conductivity (µS/cm) comparing sub-watersheds. ANOVA and Tukey's HSD were calculated at a significance level of α = 0.05. N is the number of samples considered in each group.

		SFC	WIL	TRE	UQL	ZIE	*p-value*
Pre-yarding vs. Post-yarding	**N**	1	8	10	4	8	
	Pre-Fall	NA	342 ± 127	217 ± 86	263 ± 170	196 ± 79	*0.055*
		a	a	a	a	a	
	N	7	57	49	48	57	
	Pre-Winter	228 ± 75	146 ± 75	119 ± 44	116 ± 46	98 ± 36	***<0.001***
		c	b	ab	a	a	
	N	22	38	38	39	37	
	Pre-Spring	102 ± 62	151 ± 54	115 ± 20	121 ± 30	107 ± 23	***<0.001***
		a	b	a	a	a	
	N	4	3	7	4	4	
	Pre-Summer	209 ± 83	403 ± 101	198 ± 62	218 ± 67	223 ± 74	***0.007***
		a	b	a	a	a	
	N	10	7	8	0	9	
	Post-Fall	162 ± 39	358 ± 52	188 ± 36	NA	162 ± 36	***<0.001***
		a	b	a		a	
	N	18	88	84	79	97	
	Post-Winter	133 ± 35	155 ± 44	114 ± 26	117 ± 22	110 ± 28	***<0.001***
		b	c	ab	ab	a	
	N	16	26	21	23	25	
	Post-Spring	133 ± 22	175 ± 78	113 ± 28	129 ± 24	123 ± 35	***<0.001***
		a	b	a	a	a	
	N	11	16	10	5	14	
	Post-Summer	144 ± 18	287 ± 84	145 ± 36	195 ± 68	133 ± 32	***<0.001***
		a	b	a	a	a	
Dry vs. Wet years	**N**	5	7	8	2	7	
	Dry-Fall	200 ± 76	415 ± 65	249 ± 70	393 ± 141	227 ± 60	***<0.001***
		b	c	ab	ac	ab	
	N	8	69	66	71	77	
	Dry-Winter	224 ± 71	173 ± 66	129 ± 39	129 ± 36	119 ± 34	***<0.001***
		c	b	a	a	a	
	N	20	34	32	33	35	
	Dry-Spring	102 ± 66	169 ± 79	115 ± 29	125 ± 32	122 ± 34	***<0.001***
		a	b	a	a	a	
	N	9	11	11	5	10	
	Dry-Summer	156 ± 51	303 ± 112	164 ± 52	204 ± 64	154 ± 59	***<0.001***
		a	b	a	ab	a	
	N	24	38	37	31	37	
	Wet-Fall	137 ± 30	181 ± 79	128 ± 35	123 ± 22	113 ± 28	***<0.001***
		a	b	a	a	a	
	N	17	76	67	56	77	
	Wet-Winter	129 ± 33	132 ± 41	103 ± 21	102 ± 20	92 ± 22	***<0.001***
		b	b	a	a	a	
	N	18	30	27	29	27	
	Wet-Spring	130 ± 17	152 ± 44	113 ± 13	122 ± 23	102 ± 17	***<0.001***
		ac	c	ab	a	b	
	N	6	8	6	4	8	
	Wet-Summer	170 ± 55	309 ± 70	172 ± 60	206 ± 75	153 ± 58	***<0.001***

		a	b	a	ab	a	

5.3.1.3 pH

The pH of stream water varied between 6 and 9.2 during the study period across all watersheds. pH was highest at the beginning of the measurement period which coincided with the end of a 4-year extended drought in California (Figure 13). Seasonally, stream water pH was slightly more basic during the summer period of low streamflow. pH generally decreased to neutral (pH=7) or even slightly acidic during the winter rainy season and storm events. Similarly to the EC trends, the control sub-watershed WIL showed generally a higher pH than the other sub-watersheds or South Fork Caspar Creek, again confirming that less runoff is passing through the forest soil in the form of shallow subsurface flow or even overland flow. Due to the high organic matter often present in the O and A horizons of forest soils, humic acids are being mobilized during rainfall-runoff events leading to lower pH in streamflow from forested watersheds (Lynch et al. 1985; Laudon et al. 2004). In many boreal or forested watersheds, pH has been found to generally increase with increasing flowpath length due to decreasing organic matter concentrations and increasing HCO_3^- concentrations (Neubauer et al. 2013).

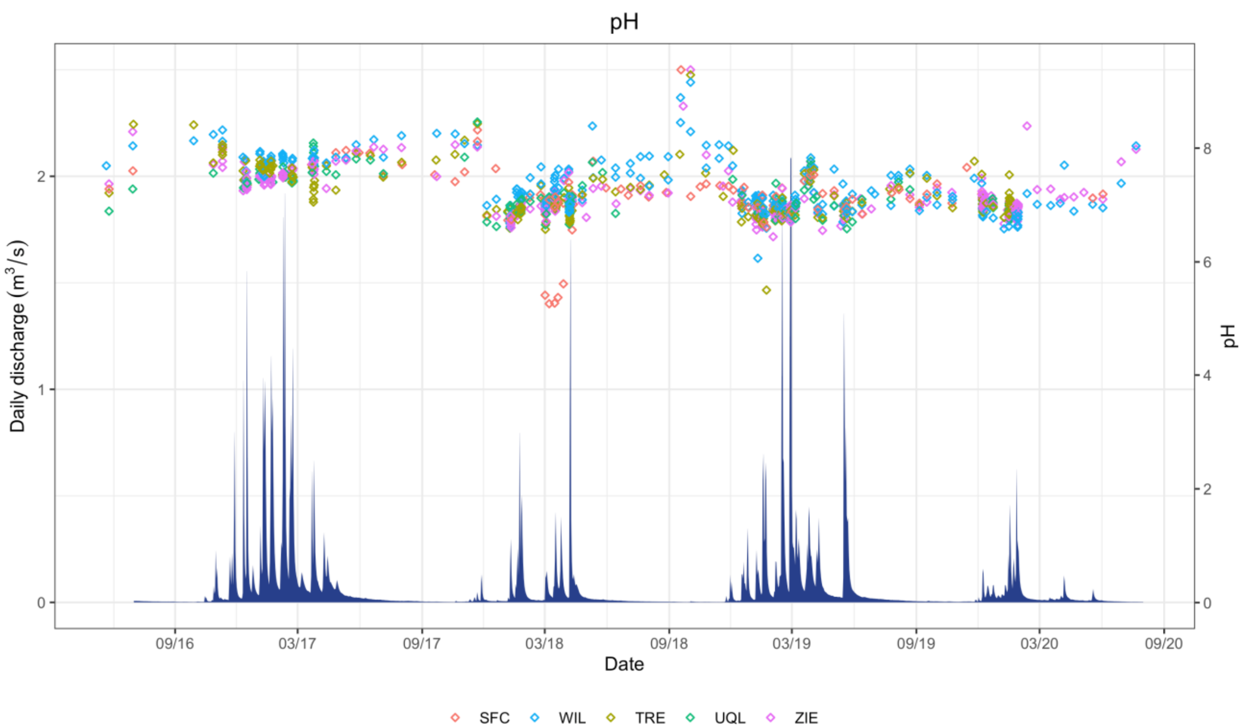

Figure 13: Variation in pH (diamonds) at the outlet of each sub-watershed and South Fork Caspar Creek. Streamflow is shown as blue filled areas. Felling was completed in fall 2018 in the sub-watersheds. Grab samples were collected bi-weekly during baseflow periods while autosamplers were used to collect samples during storm events.

Stream water pH showed a slightly declining trend over the 4-year study period. pH was highest and slightly basic during HY2017 and more neutral during HY2018-HY2020 (Table 14). During the felling year (2018) and the first year following the timber harvest pH reached values as low as 5.3 in some of the stormflow samples, possibly indicating higher amounts of organic-matter-rich runoff contributing to streamflow. This is particularly evident during post-harvest storm events, when pH lowered to values between 6.5 and 7.5 compared to the higher pH values observed in HY2017 (Table 14). The decrease in pH during high flow events probably reflects incomplete neutralization due to the decreased contact time of runoff with the soil. However, disturbance of the forest floor during yarding likely increased influx of organic matter into streams during storm events, which slightly lowered the pH.

Table 14: ANOVA and post-hoc Tukey's HSD test scores for mean differences in pre- and post-harvest and other annual stream water pH (moles H^+/L) trends comparing sub-watersheds. ANOVA and Tukey's HSD were calculated at a significance level of $\alpha = 0.05$. N is the number of samples considered in each group. Since 5 watersheds are compared, $\alpha_{test} = 0.05/10 = 0.005$. Hence, p-values < 0.005 indicate significant differences.

	SFC	WIL	TRE	UQL	ZIE	*p-value*
N	34	106	104	95	106	
Pre-yarding	7 ± 0.8	7.5 ± 0.4	7.3 ± 0.4	7.3 ± 0.4	7.3 ± 0.4	***<0.001***
	b	c	a	ab	ac	
N	55	137	123	107	145	
Post-yarding	7.2 ± 0.4	7.1 ± 0.4	7.1 ± 0.4	7 ± 0.2	7.5 ± 5.9	*0.587*
	a	a	a	a	a	
N	7	53	47	41	56	
HY 2017	7.81 ± 0.2	7.76 ± 0.2	7.61 ± 0.2	7.59 ± 0.2	7.57 ± 0.2	***<0.001***
	bc	c	ab	ab	a	
N	30	57	55	52	54	
HY 2018	6.87 ± 0.8	7.28 ± 0.4	7.05 ± 0.4	7.01 ± 0.3	7.05 ± 0.3	***<0.001***
	a	b	a	a	a	
N	40	69	63	50	66	
HY 2019	7.14 ± 0.4	7.21 ± 0.4	7.04 ± 0.5	6.97 ± 0.3	7.04 ± 0.5	***0.019***
	ab	b	ab	a	ab	
N	10	63	60	57	73	
HY 2020	7.22 ± 0.2	6.95 ± 0.3	7.12 ± 0.3	6.99 ± 0.2	8.03 ± 8.2	*0.583*
	a	a	a	a	a	
N	55	121	117	111	129	
Dry years	7.18 ± 0.4	7.11 ± 0.4	7.1 ± 0.3	7 ± 0.2	7.62 ± 6.2	*0.521*
		a	a	a	a	
N	47	122	110	91	122	
Wet years	7.2 ± 0.5	7.4 ± 0.4	7.3 ± 0.5	7.2 ± 0.4	7.3 ± 0.4	***0.004***
	ab	b	a	a	a	

When comparing individual sub-watersheds, pH was slightly more elevated in WIL compared to the other three sub-watersheds, again indicating that runoff in WIL was taking slightly deeper flow pathways allowing more contact time of subsurface flow with bedrock or the lower soil profile. This trend becomes particularly obvious during wet years and wet seasons when mean stream water pH in WIL was 0.2-0.5 moles H^+/L higher than during other periods (Table 15).

This is also reflected in Table 15, which shows stream water pH only significantly differs between the four sub-watersheds and SFC during the winter and spring season of wet and dry years but not during the post-harvest seasons.

Overall, however, stream water pH did not reach values that could increase the mobility of iron (Fe), which often occurs at pH of less than 6. Although not measured in this study, the observed pH values rather support the precipitation of iron (oxy)hydroxides, which can occur when Fe-rich anoxic groundwater mixes with oxic stream water at pH > 5. Fe(III) that was previously bound to natural organic matter can also precipitate as iron (oxy)hydroxides when the pH of the water increases due to the strong hydrolytic tendency of Fe(III) (Neubauer et al. 2013). In-stream iron (oxy)hydroxide can affect the fate of many metals and metalloids such as lead (Pb), chromium (Cr), and arsenic oxyanions (As) that are bound to iron (oxy)hydroxides. However, many of these processes are not well studied in forested watersheds.

Table 15: ANOVA and post-hoc Tukey's HSD test scores for mean differences in seasonal stream water pH (moles H^+/L) comparing sub-watersheds. ANOVA and Tukey's HSD were calculated at a significance level of α = 0.05. N is the number of samples considered in each group.

		SFC	WIL	TRE	UQL	ZIE	*p-value*
Pre-yarding vs. Post-yarding	**N**	1	8	10	4	8	
	Pre-Fall	NA	8.18 ± 0.1	8.03 ± 0.2	7.97 ± 0.4	7.84 ± 0.2	***0.075***
		ab	a	ab	ab	b	
	N	7	57	49	48	57	
	Pre-Winter	7.02 ± 0.3	7.46 ± 0.4	7.29 ± 0.4	7.2 ± 0.3	7.28 ± 0.3	***<0.001***
		a	b	ab	a	a	
	N	22	38	38	39	37	
	Pre-Spring	6.86 ± 0.9	7.35 ± 0.4	7.1 ± 0.3	7.24 ± 0.4	7.24 ± 0.3	***0.034***
		b	a	ab	a	a	
	N	4	3	7	4	4	
	Pre-Summer	7.68 ± 0.2	8.07 ± 0.2	7.62 ± 0.4	7.37 ± 0.4	8.08 ± 0.1	***0.002***
		ab	ab	ab	a	b	
	N	10	7	8	0	9	
	Post-Fall	7.5 ± 0.7	7.8 ± 0.5	7.6 ± 0.8	NA	15.5 ± 23.2	*0.445*
		a	a	a		a	
	N	18	88	84	79	97	
	Post-Winter	6.98 ± 0.2	6.9 ± 0.2	6.9 ± 0.3	6.9 ± 0.2	7 ± 0.2	*0.741*
			a	a	a	a	
	N	16	26	21	23	25	
	Post-Spring	7.2 ± 0.3	7.3 ± 0.4	7.2 ± 0.3	7.1 ± 0.3	7.1 ± 0.3	*0.046*
		a	a	a	a	a	
	N	11	16	10	5	14	
	Post-Summer	7.18 ± 0.1	7.5 ± 0.4	7.4 ± 0.4	7.2 ± 0.2	7.2 ± 0.3	*0.094*
		a	a	a	a	a	
Dry vs. Wet years	**N**	5	7	8	2	7	
	Dry-Fall	7.44 ± 0.5	7.77 ± 0.5	7.64 ± 0.5	8.15 ± 0.4	17.49 ± 26.4	*0.579*
		a	a	a	a	a	
	N	8	69	66	71	77	
	Dry-Winter	7.04 ± 0.3	6.92 ± 0.2	6.99 ± 0.2	6.93 ± 0.1	6.98 ± 0.2	*0.085*
		a	a	a	a	a	
	N	20	34	32	33	35	
	Dry-Spring	6.69 ± 0.8	7.21 ± 0.3	7.03 ± 0.3	7.06 ± 0.2	7.08 ± 0.2	***<0.001***
		b	a	a	a	a	
	N	9	11	11	5	10	
	Dry-Summer	7.32 ± 0.2	7.58 ± 0.4	7.54 ± 0.4	7.16 ± 0.2	7.49 ± 0.5	*0.226*
		a	a	a	a	a	
	N	24	38	37	31	37	
	Wet-Fall	7.42 ± 0.5	7.64 ± 0.4	7.48 ± 0.5	7.37 ± 0.5	7.51 ± 0.6	*0.211*
		a	a	a	a	a	
	N	17	76	67	56	77	
	Wet-Winter	6.97 ± 0.2	7.33 ± 0.4	7.16 ± 0.4	7.17 ± 0.3	7.17 ± 0.3	***0.001***
		a	b	a	ab	a	
	N	18	30	27	29	27	
	Wet-Spring	7.35 ± 0.4	7.49 ± 0.4	7.29 ± 0.3	7.34 ± 0.5	7.33 ± 0.4	*0.347*
		a	a	a	a	a	
	N	6	8	6	4	8	
	Wet-Summer	7.31 ± 0.4	7.58 ± 0.4	7.43 ± 0.3	7.39 ± 0.3	7.33 ± 0.4	*0.647*

5.3.1.4 Dissolved organic carbon

DOC concentrations in stream water were comparable in all four sub-watersheds and SFC prior to timber harvest. Concentrations were highest in fall during the first 'fall flush' events when the watersheds wetted up after a long dry season (Figure 14). DOC concentrations ranged between 0.5 and 9.5 mg/L during the rainy season of HY2017 and between 1 and 3 mg/L during the summer period of low streamflow. Although HY2018 was a below normal precipitation year, fall flush DOC concentrations were approximately 30% higher than observed during the Fall of HY2017. This increase in fall 2017 DOC concentration could be an indication that organic carbon export in South Fork Caspar Creek watershed was already altered in fall of 2017 due to the matrix harvest that started in some parts of the watershed in June and August 2017. During the post-harvest period, DOC concentrations show a clear increase in all treatment watersheds but particularly in ZIE (75% reduction in basal area), while the control sub-watershed maintained DOC concentrations as low as 0.9 mg/L. Base DOC concentrations in the three treatment sub-watersheds TRE, UQL and ZIE increase by about 0.5 mg/L during low flow periods between winter storm events and increase by as much as 2-3 mg/L during the low flow period of the dry summer months following the 2018/2019 rainy season. Although HY2020 was the driest year in the study period, DOC concentrations nearly doubled during the fall flush and early winter storm events while low flow concentrations stayed at about 3 mg/L (Table 16 & 17).

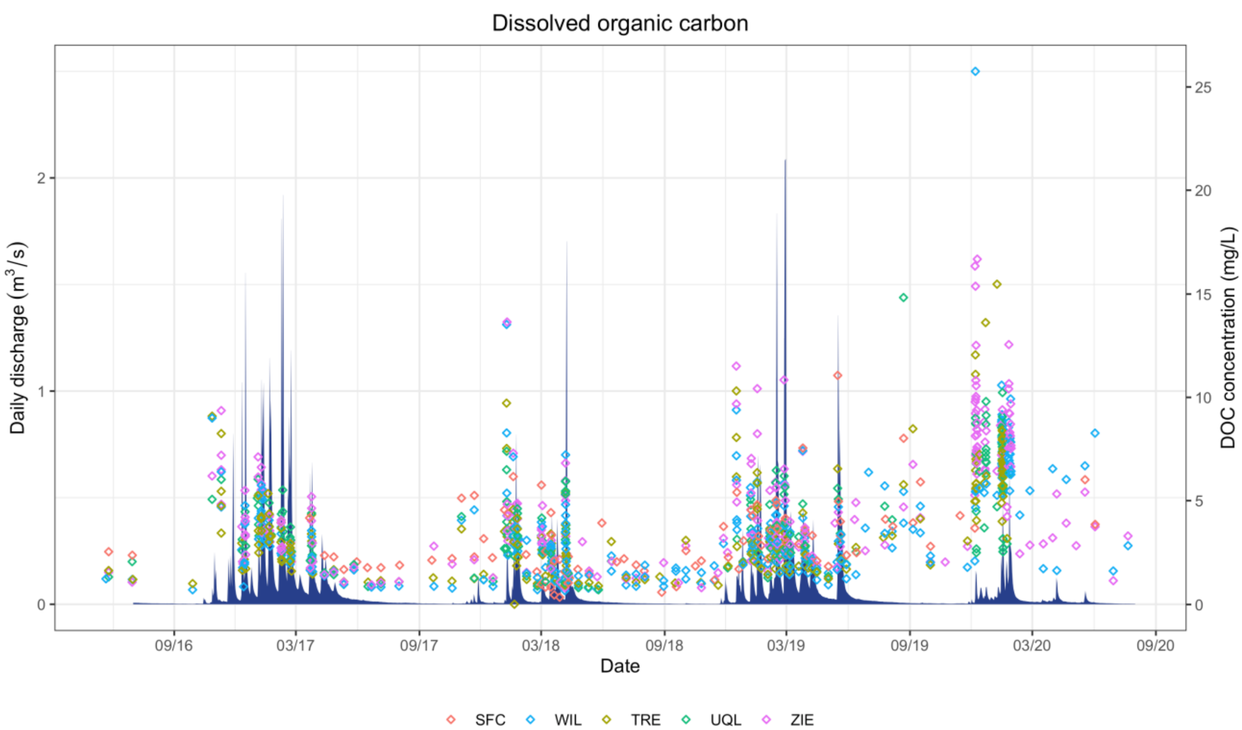

Figure 14: Concentrations of dissolved organic carbon (DOC) (diamonds) at the outlet of each sub-watershed and South Fork Caspar Creek. Streamflow is shown as blue filled areas. Felling

was completed in fall 2018 in the sub-watersheds. Grab samples were collected bi-weekly during baseflow periods while autosamplers were used to collect samples during storm events.

When comparing the mean pre-harvest and post-harvest DOC concentration measured at SFC and the outlet of the four sub-watersheds it is obvious that all five landscape units behave significantly different. As indicated by the post-hoc Tukey's HSD test scores in Table 16, stream water DOC concentration was significantly different in the pre-harvest and post-harvest periods, in both wet and dry years, and in HY2019 and HY2020. Particularly the annual means of the hydrologic years shown in Table 16 show a clear increasing trend from average DOC concentrations of around 3 mg/L in HY2017 to 3.5-4 mg/L in HY2019 and 5-7.5 mg/L in HY2020. The largest year-to-year increase in DOC can be observed in UQL and particularly in ZIE, which each had a 55% and 75% reduction in timber in 2018. Interestingly, DOC concentrations were also elevated in WIL in HY2020, while HY2017-HY2019 DOC concentrations in WIL were steady at around 3 mg/L. The increase in DOC observed in HY2020 in WIL could be the result of atmospheric deposition of ash from wildfires over the entire Caspar Creek watershed. HY2020 was an extreme dry year and several fires burnt for months in the California coast range, particularly the LNU Lightning Complex fires caused severe smoke just south of the Caspar Creek watershed.

Seasonal comparison of DOC concentrations between sub-watersheds and SFC highlight that most of the significant differences in mean annual DOC concentrations are driven by significant differences in mean winter and spring concentrations. Although DOC concentrations do not show any significant differences between sub-watersheds and SFC during the pre-harvest seasons, DOC concentrations differ significantly during the winter and spring seasons of the post-harvest period, as well as during wet and dry years (Table 17). Mean post-winter DOC concentration in ZIE was 7.013 ± 3.14 while mean DOC concentration at SFC was only 3.683 ± 1.05. In general, mean seasonal DOC concentrations in the treatment sub-watersheds 1.5 times or double the DOC concentration observed at the outlet of South Fork Caspar Creek. This is indicating that some of the DOC exported from the sub-watersheds is likely metabolized within the main fork of South Fork Caspar Creek since DOC where it serves as an important source of allochthonous energy for heterotrophs (Raymond and Saiers, 2010). The increase in stream water DOC observed in TRE and ZIE following the timber harvest is particular noteworthy since HY2019 and HY2020 were comparable average or below-average precipitation years that did not yield high streamflow responses. In general one would expect the DOC export and concentrations to be even higher during a post-harvest wet year, since it is well established that DOC concentrations increase with stream discharge (Hornberger et al. 1994, Raymond & Saiers, 2010) as the watershed becomes more connected and more runoff is generated from a larger fraction of the watershed area.

Increased concentrations of DOC in stream water after clearcutting or partial timber removal is a common observation (McLaughlin et al. 1996). However, the magnitude of DOC transport varies appreciably between sites. Increase in DOC concentration in stream water following timber harvest is often delayed, dependent on organic matter decomposition and C mineralization. In addition, hydrologic transport mechanisms play a large role in controlling when and how much of organic matter is reaching the stream by way of vertical and lateral subsurface or surface transport. These general trends were clearly corroborated in this study. The sub-watershed with the highest percentage in timber removal experienced the largest increase in DOC concentrations during the post-harvest period. However, at the same time the extreme variability in precipitation between the four study years with HY2017 being the second wettest year in 100-years and HY2020 being the third driest year on record, highlights that DOC export from watersheds is also very dependent on the overall capacity of the watershed to produce runoff as well as many interconnected biochemical, soil physical and climatic processes that control soil OC mineralization, litterfall, DOC leaching, and organic matter decomposition. As shown in this study, rainy seasons with above-normal precipitation can increase the DOC concentration in stream water on average three to five-fold. Hence, the overall magnitude of DOC export from harvested watersheds depends tightly on the climate regime immediately following the harvest. Although an increase in DOC export can be expected, DOC export could be much reduced or dampened if harvest is followed by below-normal or dry precipitation years.

Table 16: ANOVA and post-hoc Tukey's HSD test scores for mean differences in pre- and post-harvest and other annual stream water dissolved organic carbon (mg/L) trends comparing sub-watersheds. ANOVA and Tukey's HSD were calculated at a significance level of $\alpha = 0.05$. N is the number of samples considered in each group. Since 5 watersheds are compared, α_{test} = 0.05/10 = 0.005. Hence, p-values < 0.005 indicate significant differences.

	SFC	WIL	TRE	UQL	ZIE	*p-value*
N	34	106	104	95	106	
Pre-yarding	2.48 ± 1.49	3.082 ± 1.91	2.778 ± 1.7	3.117 ± 1.51	3.565 ± 1.98	***0.005***
	a	ab	a	ab	b	
N	54	136	119	106	144	
Post-yarding	3.506 ± 1.85	4.466 ± 3.08	4.432 ± 2.71	4.992 ± 2.5	5.659 ± 3.31	***<0.001***
	b	ab	ab	ac	c	
N	7	53	47	41	56	
HY 2017	2.299 ± 0.87	3.109 ± 1.62	3.091 ± 1.69	3.361 ± 1.39	3.804 ± 1.79	*0.051*
	a	a	a	a	a	
N	30	57	55	52	54	
HY 2018	2.496 ± 1.57	2.905 ± 2.17	2.559 ± 1.69	2.98 ± 1.6	3.199 ± 2.11	*0.34*
	a	a	a	a	a	
N	40	69	63	49	66	
HY 2019	3.387 ± 1.86	2.939 ± 1.63	2.914 ± 1.71	3.514 ± 1.41	4.041 ± 2.36	***0.003***
	ab	a	a	ab	b	
N	9	62	56	57	72	
HY 2020	4.697 ± 1.63	6.446 ± 3.22	6.139 ± 2.62	6.262 ± 2.53	7.469 ± 3.14	*0.014*
	a	a	a	a	a	
N	41	120	113	111	128	
Dry years	2.977 ± 1.78	4.72 ± 3.28	4.313 ± 2.84	4.642 ± 2.7	5.571 ± 3.48	***<0.001***
	b	ac	ab	ac	c	
N	47	122	110	90	122	
Wet years	3.225 ± 1.79	3.013 ± 1.62	2.99 ± 1.69	3.444 ± 1.4	3.932 ± 2.11	***<0.001***
	ab	a	a	ab	b	

Table 17: ANOVA and post-hoc Tukey's HSD test scores for mean differences in seasonal stream water DOC concentration (mg/L) comparing sub-watersheds. ANOVA and Tukey's HSD were calculated at a significance level of α = 0.05. N is the number of samples considered in each group.

		SFC	WIL	TRE	UQL	ZIE	*p-value*
Pre-yarding vs. Post-yarding	**N**	1	8	10	4	8	
	Pre-Fall	NA	3.884 ± 2.99	3.928 ± 2.97	4.153 ± 2.06	5.124 ± 2.67	*0.88*
		a	a	a	a	a	
	N	7	57	49	48	57	
	Pre-Winter	3.503 ± 1.62	3.582 ± 1.96	3.19 ± 1.62	3.611 ± 1.35	3.994 ± 1.9	*0.228*
		a	a	a	a	a	
	N	22	38	38	39	37	
	Pre-Spring	2.124 ± 1.34	2.339 ± 1.14	2.195 ± 1.06	2.569 ± 1.42	2.839 ± 1.52	*0.159*
		a	a	a	a	a	
	N	4	3	7	4	4	
	Pre-Summer	1.95 ± 0.29	0.847 ± 0.03	1.413 ± 0.72	1.495 ± 0.67	1.04 ± 0.07	*0.088*
		a	a	a	a	a	
	N	9	6	7	0	9	
	Post-Fall	2.595 ± 1.22	1.541 ± 0.51	2.79 ± 2.68	NA	2.559 ± 1.77	*0.579*
		a	a	a		a	
	N	18	88	81	78	96	
	Post-Winter	3.683 ± 1.05	5.487 ± 3.15	5.126 ± 2.83	5.468 ± 2.35	7.013 ± 3.14	***<0.001***
		a	a	a	a	b	
	N	16	26	21	23	25	
	Post-Spring	3.948 ± 2.48	2.478 ± 1.65	2.78 ± 1.33	3.168 ± 1.19	3.169 ± 1.42	***0.066***
		b	a	ab	ab	ab	
	N	11	16	10	5	14	
	Post-Summer	3.317 ± 2.14	3.176 ± 2.17	3.424 ± 1.5	5.952 ± 5.02	2.819 ± 1.35	*0.131*
		a	a	a	a	a	
Dry years vs. Wet years	**N**	4	6	7	2	7	
	Dry-Fall	4.071 ± 1.02	2.399 ± 1.6	2.96 ± 2.62	2.755 ± 2.1	2.935 ± 1.73	*0.766*
		a	a	a	a	a	
	N	8	69	63	71	76	
	Dry-Winter	3.525 ± 1.5	6.183 ± 3.37	5.626 ± 2.96	5.463 ± 2.52	7.404 ± 3.24	***<0.001***
		a	ab	a	a	b	
	N	20	34	32	33	35	
	Dry-Spring	2.281 ± 1.65	2.679 ± 1.68	2.462 ± 1.19	2.887 ± 1.54	3.031 ± 1.53	*0.35*
		a	a	a	a	a	
	N	9	11	11	5	10	
	Dry-Summer	3.551 ± 2.14	3.12 ± 2.34	3.039 ± 1.71	5.326 ± 5.38	2.38 ± 1.45	*0.314*
		a	a	a	a	a	
	N	24	38	37	31	37	
	Wet-Fall	3.193 ± 2.18	2.32 ± 1.59	2.732 ± 1.95	2.867 ± 1.33	3.288 ± 2.01	*0.18*
		a	a	a	a	a	
	N	17	76	67	55	77	
	Wet-Winter	3.684 ± 1.08	3.426 ± 1.47	3.24 ± 1.54	3.854 ± 1.26	4.392 ± 2.09	***<0.001***
		ab	a	a	ab	b	
	N	18	30	27	29	27	
	Wet-Spring	3.572 ± 2.35	2.075 ± 0.79	2.333 ± 1.2	2.682 ± 1.15	2.896 ± 1.43	***0.005***
		b	a	a	ab	ab	
	N	6	8	6	4	8	
	Wet-Summer	2.055 ± 1.18	2.38 ± 1.97	1.783 ± 0.95	2.278 ± 1.81	2.479 ± 1.44	*0.924*

		a	a	a	a	a	

5.3.1.5 Total Nitrogen

Total nitrogen in stream water was low throughout the study period, averaging about 0.2 to 0.3 mg/L in all sub-watersheds and SFC throughout the pre-harvest period and about 0.13 to 0.25 mg/L throughout the post-harvest period (Figure 15). TN concentrations were generally low during baseflow or low flow conditions and generally increased during storm events. However the timing, when these peak concentrations occurred differed between wet and dry years. During wet years, we saw generally higher TN concentrations during storm events occurring in the spring season (e.g. March/April 2017) while TN concentrations in stream water were higher during the fall flush events of dry years (e.g. October/November 2018, 2020). High TN concentrations in exceedance of 1 mg/L were observed during the largest precipitation event of the study period (April 6, 2018), as well as during the summer and fall season of the post-harvest hydrologic year of 2020.

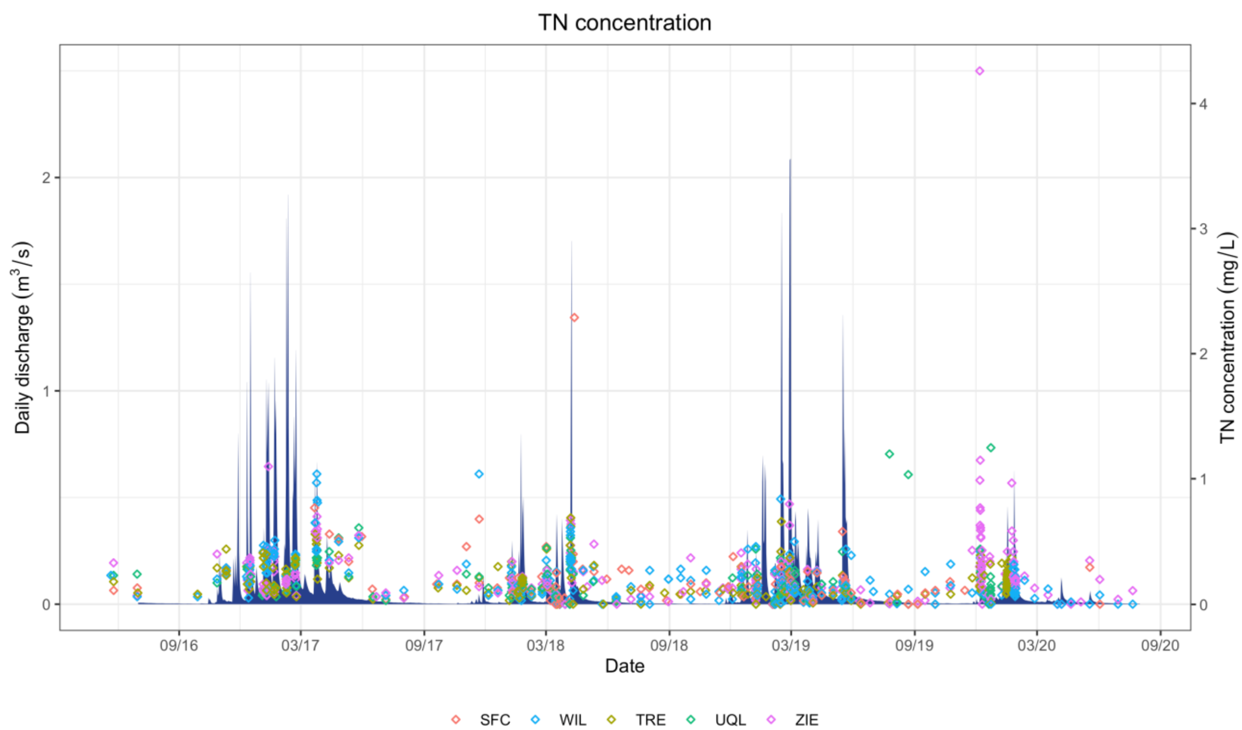

Figure 15: Concentrations of total nitrogen (TN) in stream water in each sub-watershed and South Fork Caspar Creek.

TN concentrations were not significantly different between the sub-watersheds and SFC in the pre-harvest period but TN concentrations were significantly higher in UQL (55% reduction) and ZIE (75% timber reduction) in the post-harvest period as indicated in Table 18. TN concentrations were also significantly in TRE (35% reduction), UQL, and ZIE in HY2020, which was the second hydrologic year following the harvest in South Fork Caspar Creek. The average TN concentration in ZIE in HY2020 was 0.346 ± 0.53 mg/L compared to 0.239 ± 0.25 mg/L in UQL, 0.187 ± 0.13 mg/L in TRE, and 0.101 ± 0.09 mg/L at SFC. TN concentration in ZIE was almost 0.2 mg/L higher than the average HY2020 concentration in the control sub-watershed, indicating a clear increase as a result of the timber harvest. TN concentrations were also significantly different between sub-watersheds during dry years, with higher concentrations observed in UQL, ZIE and SFC compared to the control sub-watershed WIL (Table 18).

Table 18: ANOVA and post-hoc Tukey's HSD test scores for mean differences in pre- and post-harvest and other annual stream water total nitrogen (mg/L) trends comparing sub-watersheds. ANOVA and Tukey's HSD were calculated at a significance level of α = 0.05. N is the number of samples considered in each group. Since 5 watersheds are compared, α_{test} = 0.05/10 = 0.005. Hence, p-values < 0.005 indicate significant differences.

	SFC	WIL	TRE	UQL	ZIE	*p-value*
N	9	11	5	9	10	
Pre-yarding	0.283 ± 0.41	0.273 ± 0.21	0.213 ± 0.16	0.206 ± 0.14	0.252 ± 0.18	***0.055***
	a	a	a	a	a	
N	24	37	31	38	37	
Post-yarding	0.153 ± 0.11	0.137 ± 0.13	0.151 ± 0.13	0.199 ± 0.22	0.254 ± 0.4	***0.001***
	ab	a	a	ab	b	
N	10	8	7	9	7	
HY 2017	0.413 ± 0.26	0.347 ± 0.21	0.263 ± 0.14	0.249 ± 0.15	0.301 ± 0.2	***0.26***
	a	a	a	a	a	
N	49	48	57	57	15	
HY 2018	0.254 ± 0.41	0.191 ± 0.18	0.173 ± 0.16	0.171 ± 0.12	0.192 ± 0.15	***0.444***
	a	a	a	a	a	
N	76	62	65	95	22	
HY 2019	0.158 ± 0.12	0.141 ± 0.14	0.113 ± 0.12	0.166 ± 0.19	0.161 ± 0.15	***0.321***
	a	a	a	a	a	
N	38	39	39	37	16	
HY 2020	0.101 ± 0.09	0.134 ± 0.12	0.187 ± 0.13	0.239 ± 0.25	0.346 ± 0.53	***0.007***
	ab	a	ab	ab	b	
N	34	104	95	107	106	
Dry years	0.211 ± 0.36	0.168 ± 0.16	0.18 ± 0.14	0.202 ± 0.19	0.278 ± 0.41	***0.019***
	ab	a	a	ab	b	
N	6	6	4	8	8	
Wet years	0.198 ± 0.17	0.234 ± 0.2	0.182 ± 0.15	0.204 ± 0.18	0.227 ± 0.19	***0.22***
	a	a	a	a	a	

Seasonal comparison of TN concentrations between sub-watersheds and SFC highlight that most of the significant differences in mean seasonal TN concentrations are driven by significant differences in mean winter and summer concentrations (Table 19). For example, in the pre-harvest period, mean winter TN concentrations were significantly higher in the control sub-watershed WIL, TRE and ZIE with TN concentrations > 0.2 mg/L. During the post-harvest period, mean winter TN concentrations were significantly higher (almost double) in ZIE compared to the other sub-watersheds and SFC, while mean summer TN concentrations were significantly higher in UQL compared to the other sub-watersheds. The same seasonal trends were observed during dry years, whereby mean winter TN concentrations were significantly higher in ZIE in winter and in UQL during summer.

Increased concentrations of TN in stream water after clearcutting or partial timber removal has been observed in other forested watersheds (Thiffault et al. 2011, Prescott, 2002, Devine et al. 2012) and is mainly attributed to the increased rates of nitrogen mineralization (the conversion of organic nitrogen from the organic matter pool to NH_4^+) and nitrification of NH_4^+ to inorganic nitrite and NO_3^-. Most of these processes are occurring on the forest soil, hence the increase in stream water TN concentrations is reliant on the hydrologic export of excess nitrogen into creeks and rivers. Organic matter removal associated with timber harvest (particularly if whole trees are removed without any recycling byproducts) has been identified as being mainly detrimental to forest productivity in young stands and the drier, continental forests of the Inland Northwest about 15-25 years following clearcutting (Jurgensen et al. 1997). However, more recent studies have found that ten years after harvesting and replanting, varying levels of organic matter removal had only marginal effects on tree productivity (Egnell, 2011; Thiffault et al., 2011; Ponder et al., 2012), but substantial short- and long-term effects on soil microbial communities. A meta-analysis of forest perturbation studies found that harvesting reduces microbial biomass by 19% on average (Holden &Treseder, 2013), with stronger effects on fungal than on bacterial populations (27% vs. 14% reductions, respectively). Molecular ecology studies of Long-Term Soil Productivity Study sites in multiple ecozones showed that harvesting caused long-term changes in the overall soil microbial community structure (Hartmann et al. 2012, 2009), and in hemicellulolytic populations (Leung et al., 2015). Many of these changes were attributed to forest harvest practices, whereby aboveground impacts resulting from timber harvest such as change in plant cover, niche availability, and microclimate can affect the composition and activity of the soil communities and both the quantity and quality of organic inputs, which directly and indirectly can alter soil chemistry, including increases in pH and reductions the C/N ratio, and the soil carbon, nitrogen, and phosphorus pools (Cardenas et al., 2018). Likewise water availability (e.g. precipitation) can limit many of these processes since mineralization and nitrification are aerobic processes that occur at optimal rates only if the water content is at 70% of soil water capacity. Hence, it makes sense that most of the spikes in TN (as well as NO_3^- and NH_4^+) were observed during storm events in the post-harvest period when soil moisture was sufficiently elevated to promote mineralization and nitrification in the soil as well as export of soil NO_3^- and NH_4^+ to streams with surface or subsurface storm flow.

Table 19: ANOVA and post-hoc Tukey's HSD test scores for mean differences in seasonal stream water TN concentration (mg/L) comparing sub-watersheds. ANOVA and Tukey's HSD were calculated at a significance level of α = 0.05. N is the number of samples considered in each group.

		SFC	WIL	TRE	UQL	ZIE	*p-value*
Pre-yarding vs. Post-yarding	**N**	8	66	56	50	77	
	Pre-Fall	NA	0.304 ± 0.31	0.217 ± 0.11	0.23 ± 0.05	0.264 ± 0.07	*0.184*
		a	a	a	a	a	
	N	18	27	29	30	27	
	Pre-Winter	0.156 ± 0.06	0.238 ± 0.13	0.2 ± 0.11	0.166 ± 0.08	0.218 ± 0.16	***0.029***
		ab	b	ab	a	ab	
	N	14	59	54	72	75	
	Pre-Spring	0.34 ± 0.49	0.334 ± 0.27	0.259 ± 0.21	0.265 ± 0.18	0.321 ± 0.21	*0.573*
		a	a	a	a	a	
	N	20	30	31	34	33	
	Pre-Summer	0.088 ± 0.04	0.08 ± 0.03	0.057 ± 0.04	0.088 ± 0.1	0.068 ± 0.02	*0.855*
		a	a	a	a	a	
	N	19	21	25	0	23	
	Post-Fall	0.114 ± 0.05	0.137 ± 0.13	0.088 ± 0.07	NA	0.162 ± 0.15	*0.504*
		a	a	a		a	
	N	5	8	2	7	7	
	Post-Winter	0.19 ± 0.11	0.173 ± 0.15	0.167 ± 0.12	0.192 ± 0.18	0.32 ± 0.47	***0.003***
		ab	a	a	a	b	
	N	4	7	4	3	4	
	Post-Spring	0.185 ± 0.14	0.083 ± 0.08	0.155 ± 0.18	0.133 ± 0.1	0.143 ± 0.12	*0.118*
		a	a	a	a	a	
	N	11	10	5	14	14	
	Post-Summer	0.094 ± 0.1	0.06 ± 0.07	0.073 ± 0.05	0.571 ± 0.56	0.05 ± 0.06	***<0.001***
		a	a	a	b	a	
Dry years vs. Wet years	**N**	52	113	88	111	141	
	Dry-Fall	0.216 ± 0.27	0.293 ± 0.35	0.111 ± 0.08	0.23 ± 0.01	0.174 ± 0.15	*0.631*
		a	a	a	a	a	
	N	1	10	4	8	8	
	Dry-Winter	0.155 ± 0.05	0.154 ± 0.1	0.181 ± 0.09	0.192 ± 0.17	0.339 ± 0.5	***0.002***
		ab	a	a	a	b	
	N	42	115	94	100	127	
	Dry-Spring	0.276 ± 0.49	0.196 ± 0.17	0.235 ± 0.23	0.187 ± 0.15	0.223 ± 0.18	*0.745*
		a	a	a	a	a	
	N	44	102	89	118	120	
	Dry-Summer	0.114 ± 0.1	0.041 ± 0.05	0.07 ± 0.04	0.381 ± 0.43	0.06 ± 0.06	***0.003***
		a	a	a	b	a	
	N	7	47	41	53	56	
	Wet-Fall	0.236 ± 0.21	0.257 ± 0.28	0.209 ± 0.16	0.252 ± 0.17	0.275 ± 0.2	*0.723*
		a	a	a	a	a	
	N	10	58	40	41	71	
	Wet-Winter	0.193 ± 0.11	0.238 ± 0.15	0.178 ± 0.14	0.168 ± 0.11	0.222 ± 0.18	*0.227*
		a	a	a	a	a	
	N	30	55	52	58	54	
	Wet-Spring	0.274 ± 0.23	0.281 ± 0.31	0.213 ± 0.17	0.253 ± 0.18	0.29 ± 0.22	*0.741*
		a	a	a	a	a	
	N	37	55	48	65	64	
	Wet-Summer	0.058 ± 0.05	0.089 ± 0.07	0.06 ± 0.06	0.325 ± 0.58	0.046 ± 0.04	*0.227*

		a	a	a	a	a

5.3.1.6 Nitrate

Stream water NO_3^- (reported as NO_3^--N in figures and tables) concentrations were generally less than our detection limit of 0.01 mg/L, however, NO_3^- concentrations typically ranged between the detection limit and 0.2 mg/L during storm events (Figure 16). NO_3^- concentrations were alike in all sub-watersheds and SFC during the pre-harvest season but significantly higher in ZIE (75% timber reduction) during the post-harvest period (Table 20). NO_3^- concentrations in ZIE peaked at around 0.48 mg/L during the first storm event of HY2020 and were generally elevated during the summer low flow period (Figure 16). A comparison of the stream water NO_3^- concentrations with the TN concentration (Figure 15) reveals very similar patterns. This is because the majority of the total inorganic nitrogen exported from the watershed is in the form of NH_4^+ and NO_3^- with very minor and negligible contributions in the form of dissolved organic nitrogen.

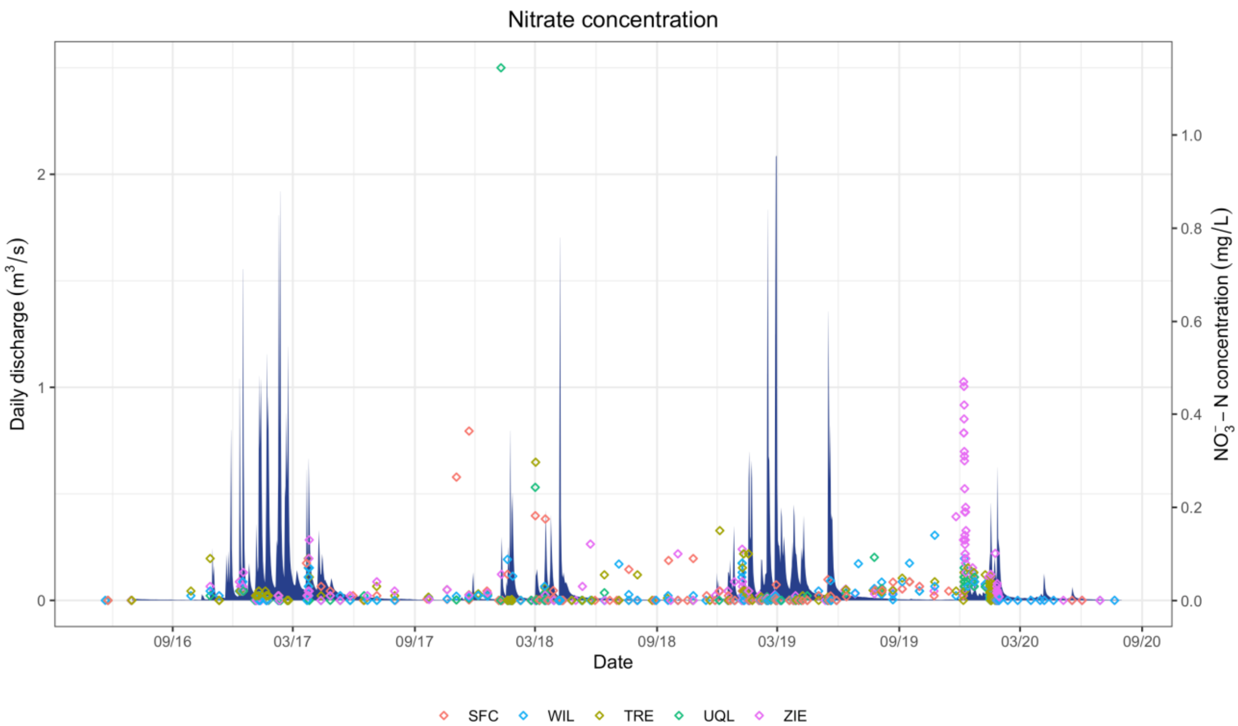

Figure 16: Concentrations of nitrate-nitrogen ($\boldsymbol{NO_3^-}$-N) in stream water in each sub-watershed and South Fork Caspar Creek.

These visual trends are supported by the ANOVA as indicated by the post-hoc Tukey's HSD test scores in Table 20. Stream water NO_3^- concentrations were significantly higher in ZIE during the post-harvest period, and particularly HY2020, when mean NO_3^- concentration was four times the concentration observed in other sub-watersheds and SFC. Sub-watersheds also showed significant differences during dry years, with generally lower NO_3^- concentrations in the control sub-watershed WIL and TRE (35% reduction) and slightly higher concentrations in UQL, ZIE and SFC (Table 20).

A look at the mean seasonal stream water NO_3^- concentrations shown in Table 21 indicates that most of the annual differences are driven by the winter and summer NO_3^- concentrations in the post-harvest period. Stream water NO_3^- was significantly higher in ZIE during the post-winter seasons and during the winters of dry years. In addition, NO_3^- was also significantly elevated in UQL (55% reduction) during the post-summer season. Both statistics indicate similar processes as discussed for the TN dynamics in the previous section. Since NO_3^- is mainly produced by soil microbial communities through mineralization of organic-N to NH_4^+ and nitrification of NH_4^+ to NO_3^-, the process is not only influenced by the availability of organic-N but also soil temperature and soil moisture. Organic matter availability was likely the highest in ZIE post-harvest after 75% of the stand was removed. This organic matter availability combined with elevated moisture (due to reduced plant water uptake) provided ideal conditions for the increased production of soil NO_3^-.

The fact that maximum NO_3^- concentrations occurred in the second year following timber harvest and in the watershed with the highest removal percentage is in agreement with findings from the second Caspar Creek experiment conducted in the 1990s. Dahlgren (1998) similarly observed that stream water NO_3^- concentrations peaked during the second year following clear cutting. He likewise attributed the delayed spike in NO_3^- to the microbial immobilization of N during the decomposition of woody litter with high C/N ratios that effectively immobilize nitrogen and limit its release to the environment. At C/N ratios greater than 30, nitrogen becomes limiting and the mineralized nitrogen goes preferentially into microbial biomass, while at ratios less than 20, nitrogen is used for catabolism, resulting in loss of gaseous nitrogen species and leaching of NO_3^- (Cardenas et al., 2018). In forest soils, several studies have observed a low C:N ratio in soil samples following timber harvest or clearcutting, which is generally seen as being indicative of nitrogen loss (both due to change in microbial community and hydrologic transport and loss) (Cardenas et al., 2018). However, since no soil samples were collected during the post-harvest period, it remains speculative how much NO_3^- might have been produced due to increased mineralization and nitrification and how much NO_3^- is effectively lost because of increased hydrologic transport (due to increased water yield). However, given the steep slopes within the Caspar Creek watershed, it is hypothesized that once sufficient rainfall occurred, mineralization and nitrification increased in the forest soils with the increased input of organic matter from the harvest, resulting in a build-up of soil NO_3^- that was then flushed from the profile during larger storm events. Since timber was reduced by 75% in ZIE, this increased soil NO_3^- pool was not substantially depleted by tree or plant N uptake and therefore available for hydrologic transport during the winter rainy season.

Table 20: ANOVA and post-hoc Tukey's HSD test scores for mean differences in pre- and post-harvest and other annual stream water $\boldsymbol{NO_3^-}$-N concentration (mg/L) trends comparing sub-watersheds. ANOVA and Tukey's HSD were calculated at a significance level of α = 0.05. N is the number of samples considered in each group. Since 5 watersheds are compared, α_{test} = 0.05/10 = 0.005. Hence, p-values < 0.005 indicate significant differences.

	SFC	WIL	TRE	UQL	ZIE	*p-value*
N	34	107	104	95	106	
Pre-yarding	0.029 ± 0.07	0.008 ± 0.02	0.012 ± 0.03	0.017 ± 0.12	0.009 ± 0.02	0.414
	a	a	a	a	a	
N	55	137	123	107	146	
Post-yarding	0.012 ± 0.02	0.01 ± 0.02	0.016 ± 0.02	0.017 ± 0.03	0.049 ± 0.1	**<0.001**
	a	a	a	a	b	
N	7	53	47	41	56	
HY 2017	0.023 ± 0.03	0.012 ± 0.02	0.016 ± 0.02	0.004 ± 0.01	0.015 ± 0.02	**0.012**
	ab	ab	a	b	ab	
N	30	58	55	52	54	
HY 2018	0.03 ± 0.08	0.005 ± 0.02	0.008 ± 0.04	0.028 ± 0.16	0.005 ± 0.02	0.374
	a	a	a	a	a	
N	40	69	63	50	67	
HY 2019	0.01 ± 0.02	0.006 ± 0.02	0.01 ± 0.03	0.008 ± 0.02	0.009 ± 0.02	0.882
	a	a	a	a	a	
N	10	63	60	57	73	
HY 2020	0.019 ± 0.01	0.013 ± 0.02	0.022 ± 0.02	0.024 ± 0.03	0.089 ± 0.12	**<0.001**
	a	a	a	a	b	
N	42	122	117	111	129	
Dry years	0.026 ± 0.07	0.009 ± 0.02	0.015 ± 0.03	0.026 ± 0.11	0.053 ± 0.1	**<0.001**
	ab	a	a	ab	b	
N	47	122	110	91	123	
Wet years	0.012 ± 0.02	0.009 ± 0.02	0.013 ± 0.02	0.006 ± 0.02	0.011 ± 0.02	0.195
	a	a	a	a	a	

Table 21: ANOVA and post-hoc Tukey's HSD test scores for mean differences in seasonal stream water $\boldsymbol{NO_3^-}$-N concentration (mg/L) comparing sub-watersheds. ANOVA and Tukey's HSD were calculated at a significance level of α = 0.05. N is the number of samples considered in each group.

		SFC	WIL	TRE	UQL	ZIE	*p-value*
Pre-yarding vs. Post-yarding	**N** **Pre-Fall**	1 NA b	8 0.008 ± 0.01 a	10 0.015 ± 0.03 a	4 0.003 ± 0.01 a	8 0.009 ± 0.01 a	***<0.001***
	N **Pre-Winter**	7 0.013 ± 0.02 a	57 0.008 ± 0.02 a	49 0.007 ± 0.01 a	48 0.026 ± 0.17 a	57 0.009 ± 0.01 a	*0.41*
	N **Pre-Spring**	22 0.025 ± 0.05 a	39 0.008 ± 0.02 a	38 0.017 ± 0.05 a	39 0.008 ± 0.04 a	37 0.009 ± 0.03 a	*0.45*
	N **Pre-Summer**	4 0.003 ± 0.01 a	3 0 ± 0 a	7 0.013 ± 0.02 a	4 0.008 ± 0.01 a	4 0.018 ± 0.02 a	*0.734*
	N **Post-Fall**	10 0.027 ± 0.03 a	7 0.026 ± 0.05 a	8 0.016 ± 0.02 a	0 NA	9 0.04 ± 0.06 a	*0.744*
	N **Post-Winter**	18 0.007 ± 0.01 a	88 0.009 ± 0.02 a	84 0.02 ± 0.03 a	79 0.018 ± 0.02 a	98 0.067 ± 0.11 b	***<0.001***
	N **Post-Spring**	16 0.004 ± 0.01 a	26 0.002 ± 0.01 a	21 0.001 ± 0 a	23 0.001 ± 0 a	25 0.008 ± 0.02 a	*0.367*
	N **Post-Summer**	11 0.018 ± 0.02 a	16 0.021 ± 0.03 a	10 0.017 ± 0.02 a	5 0.073 ± 0.08 b	14 0.009 ± 0.01 a	***0.004***
Dry years vs. Wet years	**N** **Dry-Fall**	5 0.088 ± 0.15 a	7 0.027 ± 0.05 a	8 0.021 ± 0.02 a	2 0 ± 0 a	7 0.04 ± 0.06 a	*0.518*
	N **Dry-Winter**	8 0.013 ± 0.02 ab	69 0.01 ± 0.02 a	66 0.018 ± 0.02 a	71 0.033 ± 0.14 a	77 0.081 ± 0.12 b	***<0.001***
	N **Dry-Spring**	20 0.02 ± 0.06 a	35 0.001 ± 0.01 a	32 0.01 ± 0.05 a	33 0.008 ± 0.04 a	35 0.005 ± 0.02 a	*0.487*
	N **Dry-Summer**	9 0.019 ± 0.03 a	11 0.016 ± 0.03 a	11 0.013 ± 0.02 a	5 0.055 ± 0.09 a	10 0.008 ± 0.01 a	*0.139*
	N **Wet-Fall**	24 0.017 ± 0.03 a	38 0.01 ± 0.02 a	37 0.012 ± 0.02 a	31 0.003 ± 0.01 a	37 0.014 ± 0.03 a	*0.194*
	N **Wet-Winter**	17 0.006 ± 0.01 a	76 0.007 ± 0.01 a	67 0.013 ± 0.03 a	56 0.007 ± 0.02 a	78 0.01 ± 0.02 a	*0.304*
	N **Wet-Spring**	18 0.012 ± 0.02 a	30 0.011 ± 0.02 a	27 0.012 ± 0.02 a	29 0.002 ± 0.01 a	27 0.013 ± 0.03 a	*0.325*
	N **Wet-Summer**	6 0.007 ± 0.01	8 0.019 ± 0.03	6 0.02 ± 0.02	4 0.03 ± 0.04	8 0.014 ± 0.01	*0.577*

5.3.1.7 *Ammonium*

Similar to the stream water NO_3^- concentrations, NH_4^+ concentrations were near or below the detection limit of 0.01 mg/L most of the time during the study period. NH_4^+ concentrations increased generally during storm events and peaked late in the rainy season (end of winter, early spring) during wet years and early in the rainy season during dry years (Figure 17). NH_4^+ concentration in HY2019 (the first year following the timber harvest) were lower than during the wet pre-harvest HY2017 but visually elevated in HY2020, the second year following timber harvest. Comparison of mean annual NH_4^+ concentrations in stream water shown in Table 22 indicates that all four sub-watersheds have comparable NH_4^+ concentrations during most analysis periods except during wet years. During wet years, stream water NH_4^+ was significantly higher in UQL and significantly lower in ZIE compared to the other sub-watersheds and SFC. A comparison of the stream water NH_4^+ concentrations with the TN concentration (Figure 15) reveals very similar seasonal and annual patterns. This is because the majority of the total inorganic nitrogen exported from the watershed is in the form of NH_4^+, which makes up about 10-20% of the TN observed in stream water. Higher NH_4^+ concentrations could be due to atmospheric wet deposition of NH_4^+ (Argerich et al., 2013), or indicate weak or incomplete nitrification of NH_4^+ to NO_3^-, which could be due to a lack of Nitrosomonas and Nitrobacter bacteria, the two most frequently identifies genera associated with nitrification.

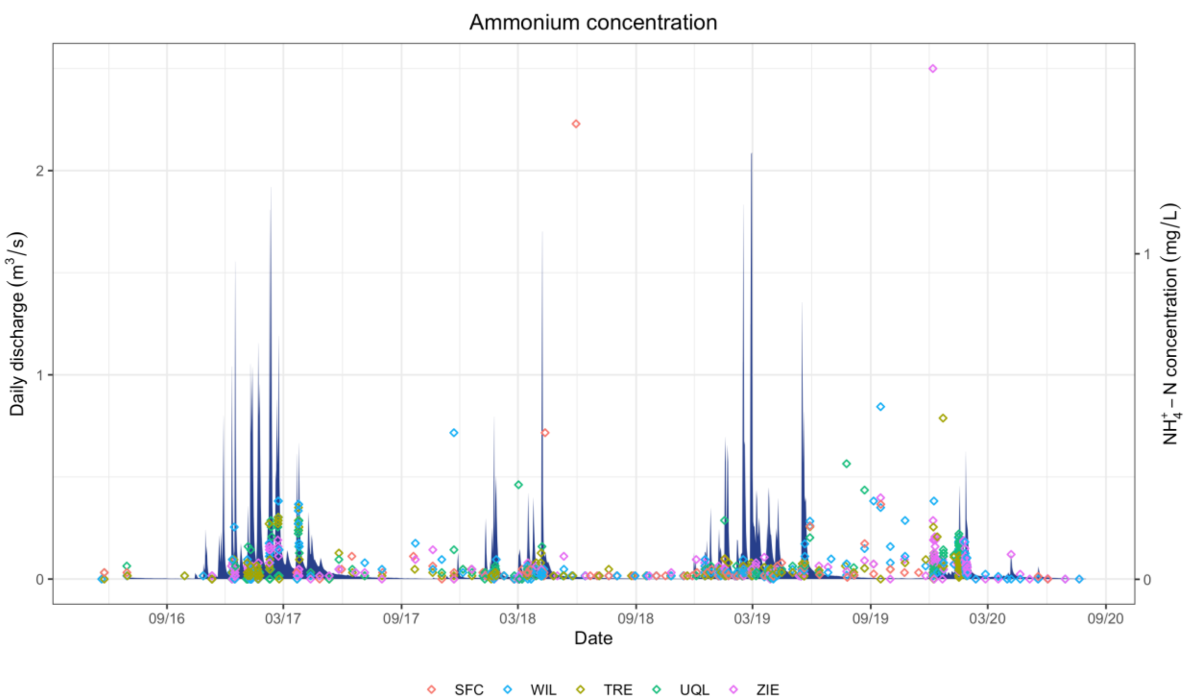

Figure 17: Concentrations of ammonium-nitrogen (NH_4^+-N) in stream water in each sub-watershed and South Fork Caspar Creek.

Although not measured in this study, Dahlgren (1998) studied nitrogen fluxes in precipitation for 5-years during the 2nd Caspar Creek watershed experiment. He found that nitrogen fluxes in bulk precipitation were very low, ranging between 0.1 and 0.4 kg N per hectare and year but also regulated to a large degree by the precipitation amount and canopy interception. Dahlgren (1998) hypothesized that atmospheric nitrogen inputs were higher than what was measured in preciptiation since tree canopies have a much higher efficiency in capturing atmopsheric gasses, aerosols and particulate matter than is possible to capture with a single location rain gauge. He also suggested that atmospheric N deposition might be spatially heterogeneous, with clearcut areas receiving less deposition than densily forested areas, since removal of the canopy greatly attenuates the capture effciciency.

These visual trends shown in Figure 17 are supported by the ANOVA as indicated by the post-hoc Tukey's HSD test scores in Table 22 and Table 23. Stream water NH_4^+ concentrations were significantly different between UQL and ZIE in wet years, whereby mean NH_4^+ concentration in ZIE was about half the concentration observed in UQL. A look at the mean seasonal stream water NH_4^+ concentrations shown in Table 23 for all four sub-watersheds and SFC indicate that there are no statistically significant differences in mean seasonal NH_4^+ concentrations except for the dry spring seasons, which shows a significant difference in mean NH_4^+ stream water concentration between SFC and ZIE. Similar to the annual statistics overall stream water NH_4^+ concentrations in ZIE are very low (about one third) of the NH_4^+ concentrations observed at the South Fork Caspar Creek watershed outlet. This could be due to a number of factors. First, the SFC gauge location reflects the integrated stream water chemistry signal from the entire South Fork Caspar Creek watersheds, which is not only reflecting the effect of different degrees of timber removal in the sub-watersheds of South Fork Caspar Creek but also potential in-stream or hyporheic biogeochemical processes. Inamdar (2007) for example observed that most dissolved NH_4^+ in the stream water of a glaciated, forested watershed in Western New York, USA originated from wetlands or riparian water during baseflow (i.e. non-stormflow) periods and from throughfall and litter leachate during storm events. Similar to the patterns observed in this study, Inamdar (2007) observed that NH_4^+ concentrations in streamflow were much greater during storm events than baseflow conditions and showed a consistent temporal pattern with an increase in concentrations on the hydrograph rising limb, a peak at or before the discharge peak, followed by a decline in concentrations. Stottlemyer (2001) similarly observed that NO_3^- and NH_4^+ export from forested watersheds appeared to be dependent on the seasonal change in hydrologic flowpath, soil freezing, seasonal forest-floor inorganic N pools resulting from mineralization, spatial variation in watershed forest-floor inorganic N pools, and gross soil N mineralization rates. Hong et al. (2005) likewise concluded that most of the long-term pattern of NO_3^- and NH_4^+ export from watershed 6 at Hubbard Brook Experimental Forest in New Hampshire could be reproduced from inorganic N inputs to the soil, from both atmospheric N deposition and N mineralization. They also observed that NO_3^- flux in stream water was significantly higher during periods of high streamflow than in low periods. More recently, Webster et al. (2016) observed a major increase in inorganic N (NH_4^+, NO_3^-) export from a forested watershed at Coweeta Hydrologic Laboratory, NC following experimental clearcutting. They hypothesized that the increase in dissolved inorganic N (DIN) export from the watershed was the result of an initial pulse of organic matter input, reduced vegetation uptake, increased mineralization of soil organic N, and N fixation by black locust-associated bacteria following clearcut logging. They also observed a shift in the timing of DIN export. In their control watershed DIN export was greatest during the summer baseflow period while the clear cut watersheds shifted to a pattern of maximum winter DIN concentration. The seasonal pattern of DIN concentration and export from reference watersheds were explained by terrestrial and in-stream processes, but following clearcutting and the fact that elevated DIN availability saturated both terrestrial and in-stream uptake, which caused the entire N export regime to become dominated by hydrologic transport. Streams with either winter or summer peak NO_3^- concentration have been observed to have a decline in concentration after fall leaf abscission, attributable to in-stream uptake of N by leaf-decomposing fungi and bacteria (e.g. Mulholland and Hill 1997; Burns 1998; Goodale et al. 2009; Bernal and others 2012; Sebestyen et al. 2014) as this is a time of maximum heterotrophic production and N immobilization in forest-covered streams (also see Roberts and Mulholland 2007; Roberts et al. 2007; Valett et al. 2008). Modeling studies have also suggested that in-stream biotic uptake and subsequent mineralization can significantly modify N concentrations in forested watershed streams (Webster et al. 2009, 2016). In some cases, N inputs to stream following forest disturbance can exceed the uptake capacity of in-stream processes (e.g. even during fall when low DIN groundwater flow persists), causing a shift in magnitude and seasonal timing of watershed N export (Lin et al. 2015). Bernhardt et al. (2003) observed an increase in in-stream inorganic N uptake and nitrogen-processing efficiency in Hubbard Brook Experimental Forest, New Hampshire following a forest disturbance event. They concluded that the canopy damage that resulted from an ice storm led to increased light availability and large inputs of woody debris to streams, which increased algal production, and storage and processing of terrestrial litter in the stream, which increased inorganic nitrogen processing in streams. They estimated that, without in-stream processing, export of NO_3^- from the damaged watersheds would have been 80-140% higher than was observed, indicating that both the increased influx of N to streams can increase in-stream N processing but also saturate the system with N leading to increased N export at the same time.

Table 22: ANOVA and post-hoc Tukey's HSD test scores for mean differences in pre- and post-harvest and other annual stream water $\boldsymbol{NH_4^+}$-N concentration (mg/L) trends comparing sub-watersheds. ANOVA and Tukey's HSD were calculated at a significance level of $\alpha = 0.05$. N is the number of samples considered in each group. Since 5 watersheds are compared, $\alpha_{test} = 0.05/10 = 0.005$. Hence, p-values < 0.005 indicate significant differences.

	SFC	WIL	TRE	UQL	ZIE	*p-value*
N	34	106	104	95	106	
Pre-yarding	0.031 ± 0.08 a	0.041 ± 0.07 a	0.034 ± 0.05 a	0.04 ± 0.06 a	0.022 ± 0.03 a	*0.1*
N	55	137	123	107	145	

Post-yarding	0.053 ± 0.19	0.035 ± 0.04	0.069 ± 0.44	0.051 ± 0.05	0.048 ± 0.13	*0.838*
	a	a	a	a	a	
N	7	53	47	41	56	
HY 2017	0.021 ± 0.02	0.057 ± 0.07	0.055 ± 0.07	0.06 ± 0.07	0.027 ± 0.03	*0.024*
	a	a	a	a	a	
N	30	57	55	52	54	
HY 2018	0.077 ± 0.26	0.024 ± 0.06	0.017 ± 0.02	0.024 ± 0.04	0.017 ± 0.02	*0.06*
	a	a	a	a	a	
N	40	69	63	50	66	
HY 2019	0.024 ± 0.03	0.023 ± 0.03	0.023 ± 0.02	0.034 ± 0.05	0.022 ± 0.01	*0.242*
	a	a	a	a	a	
N	10	63	60	57	73	
HY 2020	0.051 ± 0.07	0.051 ± 0.05	0.117 ± 0.64	0.066 ± 0.04	0.074 ± 0.18	*0.827*
	a	a	a	a	a	
N	42	121	117	111	129	
Dry years	0.068 ± 0.22	0.038 ± 0.06	0.068 ± 0.46	0.046 ± 0.05	0.049 ± 0.14	*0.868*
	a	a	a	a	a	
N	47	122	110	91	122	
Wet years	0.024 ± 0.03	0.038 ± 0.06	0.037 ± 0.05	0.046 ± 0.06	0.024 ± 0.02	***0.007***
	ab	ab	ab	a	b	

Table 23: ANOVA and post-hoc Tukey's HSD test scores for mean differences in seasonal stream water NH_4^+-N concentration (mg/L) comparing sub-watersheds. ANOVA and Tukey's HSD were calculated at a significance level of α = 0.05. N is the number of samples considered in each group.

		SFC	WIL	TRE	UQL	ZIE	*p-value*
Pre-yarding vs. Post-yarding	**N**	1	8	10	4	8	
	Pre-Fall	NA	0.084 ± 0.15	0.009 ± 0.01	0.033 ± 0.04	0.023 ± 0.03	*0.423*
		a	a	a	a	a	
	N	7	57	49	48	57	
	Pre-Winter	0.016 ± 0.01	0.037 ± 0.06	0.036 ± 0.05	0.039 ± 0.05	0.027 ± 0.03	*0.539*
		a	a	a	a	a	
	N	22	38	38	39	37	
	Pre-Spring	0.037 ± 0.09	0.038 ± 0.06	0.041 ± 0.06	0.044 ± 0.06	0.016 ± 0.01	*0.279*
		a	a	a	a	a	
	N	4	3	7	4	4	
	Pre-Summer	0.03 ± 0.03	0.033 ± 0.02	0.014 ± 0.01	0.023 ± 0.02	0.013 ± 0.01	*0.251*
		a	a	a	a	a	
	N	10	7	8	0	9	
	Post-Fall	0.019 ± 0.02	0.029 ± 0.02	0.031 ± 0.03	NA	0.022 ± 0.02	*0.66*
		a	a	a		a	
	N	18	88	84	79	98	
	Post-Winter	0.02 ± 0.01	0.037 ± 0.04	0.089 ± 0.54	0.054 ± 0.04	0.058 ± 0.16	*0.737*
		a	a	a	a	a	
	N	16	26	21	23	25	
	Post-Spring	0.121 ± 0.34	0.025 ± 0.04	0.026 ± 0.04	0.025 ± 0.03	0.024 ± 0.02	*0.134*
		a	a	a	a	a	
	N	11	16	10	5	13	
	Post-Summer	0.038 ± 0.07	0.047 ± 0.07	0.022 ± 0.02	0.131 ± 0.14	0.034 ± 0.07	*0.097*
		a	a	a	a	a	
Dry years vs. Wet years	**N**	5	7	8	2	7	
	Dry-Fall	0.03 ± 0.02	0.116 ± 0.15	0.035 ± 0.02	0.055 ± 0.05	0.041 ± 0.04	*0.286*
		a	a	a	a	a	
	N	8	69	66	71	77	
	Dry-Winter	0.016 ± 0.01	0.041 ± 0.04	0.106 ± 0.61	0.054 ± 0.04	0.066 ± 0.18	*0.748*
		a	a	a	a	a	
	N	20	34	32	33	35	
	Dry-Spring	0.108 ± 0.32	0.01 ± 0.01	0.016 ± 0.02	0.025 ± 0.05	0.017 ± 0.02	***0.032***
		b	a	ab	ab	a	
	N	9	11	11	5	10	
	Dry-Summer	0.047 ± 0.08	0.055 ± 0.09	0.018 ± 0.02	0.067 ± 0.07	0.033 ± 0.08	*0.656*
		a	a	a	a	a	
	N	24	38	37	31	37	
	Wet-Fall	0.027 ± 0.03	0.047 ± 0.07	0.044 ± 0.06	0.048 ± 0.05	0.019 ± 0.02	*0.059*
		a	a	a	a	a	
	N	17	76	67	56	78	
	Wet-Winter	0.02 ± 0.01	0.034 ± 0.05	0.034 ± 0.04	0.04 ± 0.05	0.027 ± 0.03	*0.337*
		a	a	a	a	a	
	N	18	30	27	29	27	
	Wet-Spring	0.033 ± 0.04	0.058 ± 0.07	0.059 ± 0.07	0.051 ± 0.05	0.022 ± 0.02	*0.069*
		a	a	a	a	a	
	N	6	8	6	4	7	
	Wet-Summer	0.02 ± 0.02	0.031 ± 0.02	0.02 ± 0.01	0.103 ± 0.17	0.023 ± 0.01	*0.203*

5.3.1.8 Dissolved organic nitrogen

Dissolved organic nitrogen concentrations in stream water were not directly measured but calculated as the residual of TN minus NO_3^- and NH_4^+. As such DON was highly variable in stream water ranging between 0.01 and 1 mg/L most of the time during the study period. DON concentrations were generally elevated during storm events and peaked late in the rainy season (end of winter, early spring) during wet years and early in the rainy season during dry years (Figure 18). DON concentration were typically lower during the summer dry flow period, except for the first summer of the timber harvest when DON concentrations were visually elevated throughout the year.

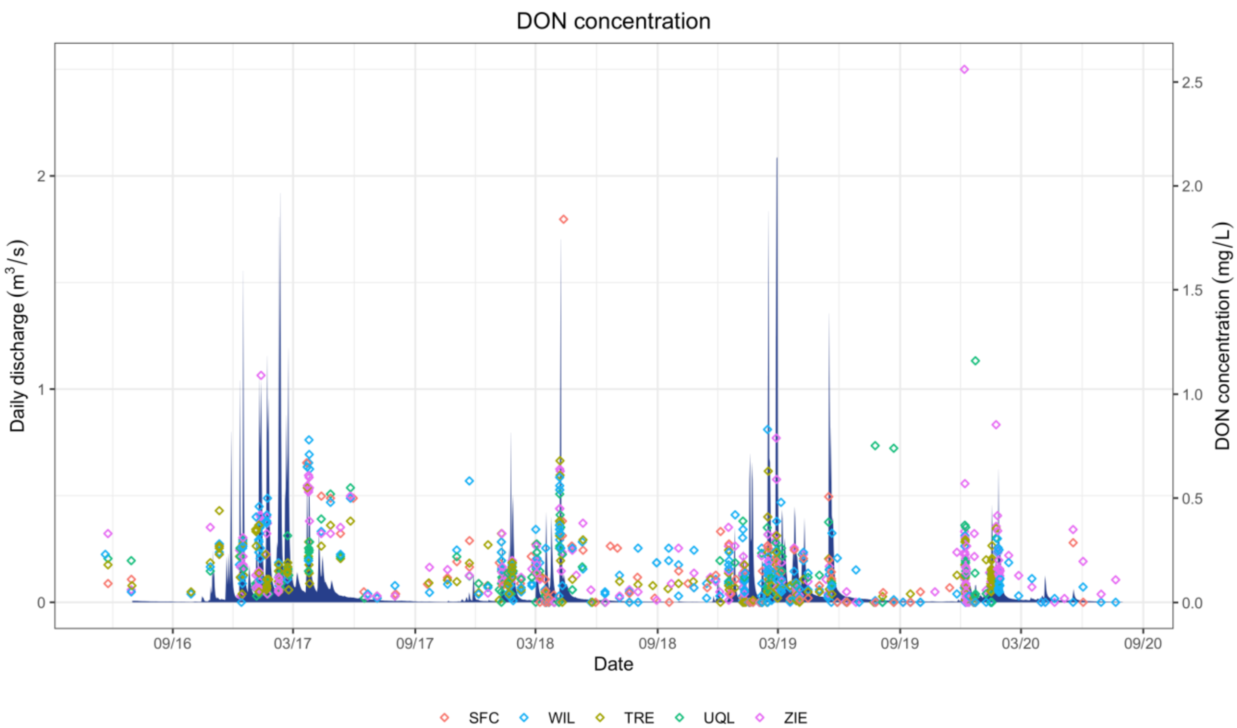

Figure 18: Concentrations of dissolved organic nitrogen (DON) in stream water in each sub-watershed and South Fork Caspar Creek.

Comparison of mean annual DON concentrations in stream water shown in Table 24 indicates that all four sub-watersheds have comparable DON concentrations during most analysis periods except during wet years, HY 2020 and the post-yarding period in general. During wet years, stream water DON was significantly higher in higher in ZIE compared to TRE (35% removal). DON concentrations in ZIE were also significantly higher than DON concentrations in WIL (control) in HY2020 and significantly higher than DON concentrations in WIL and TRE in the post-yarding period (Table 24). These results are not surprising since timber removal in ZIE was 75% resulting in an increased organic matter (containing both elevated C and organic-N) flux into the stream. Comparison of the stream water DON concentrations with the TN concentration (Figure 15) reveals very similar seasonal and annual patterns. This is because the majority of the total nitrogen exported from the South Fork Caspar Creek watershed was in the form of DON, which makes up about 80% of the TN observed in stream water.

These visual trends shown in Fig. 18 are supported by the ANOVA as indicated by the post-hoc Tukey's HSD test scores in Table 25. Seasonal stream water DON concentrations were significantly different in the pre-yarding winter season, the post-yarding winter and summer seasons, and the winter and summer season of dry years. In most cases the mean seasonal DON concentration in stream water was significantly higher in one or several of the treatment sub-watersheds in the post-yarding seasons compared to the control sub-watershed or SFC. Post-yarding DON concentration was particularly elevated in UQL during the summer season and ZIE during the winter season following the timber removal. Both sub-watersheds had more than 50% of its timber stand removed. However, stream water DON was also significantly elevated in UQL and ZIE during the summer and the winter season of dry years, respectively, indicating that some water chemistry differences may exist between the sub-watersheds irrespective of timber removal status.

Table 24: ANOVA and post-hoc Tukey's HSD test scores for mean differences in pre- and post-harvest and other annual stream water dissolved organic nitrogen concentration (mg/L) trends comparing sub-watersheds. ANOVA and Tukey's HSD were calculated at a significance level of $\alpha = 0.05$. N is the number of samples considered in each group. Since 5 watersheds are compared, $\alpha_{test} = 0.05/10 = 0.005$. Hence, p-values < 0.005 indicate significant differences.

	SFC	WIL	TRE	UQL	ZIE	*p-value*
N	34	107	104	95	106	
Pre-yarding	0.224 ± 0.34	0.226 ± 0.18	0.171 ± 0.14	0.16 ± 0.13	0.222 ± 0.18	0.019
	a	a	a	a	a	
N	55	137	123	107	146	
Post-yarding	0.115 ± 0.11	0.086 ± 0.12	0.097 ± 0.12	0.117 ± 0.17	0.156 ± 0.25	**0.01**
	ab	a	a	ab	b	
N	7	53	47	41	56	
HY 2017	0.37 ± 0.2	0.28 ± 0.2	0.19 ± 0.1	0.18 ± 0.1	0.26 ± 0.2	0.006
	a	a	a	a	a	
N	30	58	55	52	54	
HY 2018	0.19 ± 0.3	0.16 ± 0.2	0.15 ± 0.2	0.14 ± 0.1	0.17 ± 0.1	0.76
	a	a	a	a	a	
N	40	69	63	50	67	
HY 2019	0.12 ± 0.1	0.11 ± 0.1	0.08 ± 0.1	0.13 ± 0.1	0.13 ± 0.1	0.219
	a	a	a	a	a	
N	10	63	60	57	73	
HY 2020	0.07 ± 0.1	0.06 ± 0.1	0.12 ± 0.1	0.11 ± 0.2	0.18 ± 0.3	**0.017**
	ab	a	ab	ab	b	
N	42	122	117	111	129	
Dry years	0.157 ± 0.29	0.11 ± 0.1	0.134 ± 0.14	0.12 ± 0.2	0.18 ± 0.3	0.068
	a	a	a	a	a	
N	47	122	110	91	123	
Wet years	0.16 ± 0.2	0.18 ± 0.2	0.13 ± 0.1	0.15 ± 0.1	0.19 ± 0.2	**0.035**
	ab	ab	a	ab	b	

The observed patterns in DON concentrations are comparable to concentrations found in other forested watersheds along the US west coast. For example, similar to Vanderbilt et al. (2002), who studies long-term organic and inorganic nitrogen inputs and outputs in six watersheds at H.J. Andrews Experimental Forest in the central Cascade Mountains of Oregon, DON is the predominant form of N exported from all watersheds, followed by PON, NH_4^+-N and NO_3-N. They also noted that DON had consistent seasonal concentration patterns in all watersheds with peak stream water DON concentrations occurring in November-December after the onset of fall rains but before the peak in the hydrograph, probably due to flushing of products of decomposition that had built up during the dry summer. However, in contrast to this study we also saw a clear spike in DON concentration during the largest storm events during the 2016-2020 study period, which sometimes occurred at the end of the rainy season (e.g. spring). The elevated DON concentrations during these high-magnitude flow events could have been due to the larger hydrologic connectivity occurring during these events as a greater fraction of the watershed contributed direct runoff to streams via variable source areas or rapid subsurface stormflow. However, overall much less is known about the processes controlling DON concentrations and fluxes in stream water. While most studies do observe peaks in DON concentrations during storm events (Buffam et al. 2001), some studies suggest that the sorption behavior of soils and particularly the microbial lability between organic and inorganic forms of N represent major controls on DON in streams.

Table 25: ANOVA and post-hoc Tukey's HSD test scores for mean differences in seasonal stream water DON concentration (mg/L) comparing sub-watersheds. ANOVA and Tukey's HSD were calculated at a significance level of α = 0.05. N is the number of samples considered in each group.

		SFC	WIL	TRE	UQL	ZIE	*p-value*
Pre-yarding vs. Post-yarding	**N**	1	8	10	4	8	
	Pre-Fall	NA	0.21 ± 0.2	0.19 ± 0.1	0.2 ± 0.1	0.23 ± 0.1	0.897
		a	a	a	a	a	
	N	7	57	49	48	57	
	Pre-Winter	0.13 ± 0.1	0.19 ± 0.1	0.16 ± 0.1	0.12 ± 0.1	0.18 ± 0.2	**0.019**
		ab	b	ab	a	ab	
	N	22	39	38	39	37	
	Pre-Spring	0.28 ± 0.4	0.29 ± 0.2	0.21 ± 0.2	0.21 ± 0.2	0.3 ± 0.2	0.261
		a	a	a	a	a	
	N	4	3	7	4	4	
	Pre-Summer	0.06 ± 0	0.05 ± 0	0.04 ± 0	0.06 ± 0.1	0.04 ± 0	0.937
		a	a	a	a	a	
	N	10	7	8	0	9	
	Post-Fall	0.08 ± 0.1	0.09 ± 0.1	0.06 ± 0.1	NA	0.11 ± 0.1	0.594
		a	a	a		a	
	N	18	88	84	79	98	
	Post-Winter	0.14 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.11 ± 0.2	0.19 ± 0.3	**0.006**
		ab	a	a	a	b	
	N	16	26	21	23	25	
	Post-Spring	0.14 ± 0.1	0.06 ± 0.1	0.12 ± 0.2	0.1 ± 0.1	0.11 ± 0.1	0.235
		a	a	a	a	a	
	N	11	16	10	5	14	
	Post-Summer	0.07 ± 0.1	0.03 ± 0.1	0.05 ± 0	0.36 ± 0.4	0.04 ± 0.1	**<0.001**
		a	a	a	b	a	
Dry years vs. Wet years	**N**	5	7	8	2	7	
	Dry-Fall	0.11 ± 0.1	0.16 ± 0.2	0.08 ± 0.1	0.18 ± 0.1	0.11 ± 0.1	0.737
		a	a	a	a	a	
	N	8	69	66	71	77	
	Dry-Winter	0.13 ± 0.1	0.09 ± 0.1	0.12 ± 0.1	0.1 ± 0.2	0.19 ± 0.3	**0.007**
		ab	a	ab	a	b	
	N	20	35	32	33	35	
	Dry-Spring	0.21 ± 0.4	0.18 ± 0.2	0.2 ± 0.2	0.15 ± 0.1	0.19 ± 0.2	0.811
		a	a	a	a	a	
	N	9	11	11	5	10	
	Dry-Summer	0.09 ± 0.1	0.02 ± 0	0.05 ± 0	0.25 ± 0.3	0.05 ± 0.1	**0.009**
		ab	a	a	b	a	
	N	24	38	37	31	37	
	Wet-Fall	0.2 ± 0.2	0.2 ± 0.2	0.16 ± 0.1	0.2 ± 0.2	0.25 ± 0.2	0.382
		a	a	a	a	a	
	N	17	76	67	56	78	
	Wet-Winter	0.14 ± 0.1	0.19 ± 0.2	0.12 ± 0.1	0.12 ± 0.1	0.18 ± 0.2	0.013
		a	a	a	a	a	
	N	18	30	27	29	27	
	Wet-Spring	0.24 ± 0.2	0.22 ± 0.3	0.15 ± 0.1	0.2 ± 0.2	0.26 ± 0.2	0.354
		a	a	a	a	a	
	N	6	8	6	4	8	
	Wet-Summer	0.04 ± 0	0.05 ± 0.1	0.04 ± 0	0.2 ± 0.4	0.02 ± 0	0.274

5.3.1.9 Total phosphorus

Total phosphorus (TP) concentrations were very low and near the detection limit of 0.05 mg/L most of the time during the study period. TP concentrations were generally higher during dry years and lower during wet years indicating a clear relationship to flow and geogenic sources (e.g. mineral weathering). Stream water TP concentrations typically peaked during storm events however there were also elevated TP concentrations during the summer and fall of 2018 and 2019, possibly indicating disturbance of the forest floor from logging activities, which might have resulted in an increased influx of suspended sediments and particulate phosphorus into streams (Figure 19). TP was particularly elevated during the April 6, 2018 peak flow event, which also had the highest sediment flux of all storm events monitored between 2016 and 2020.

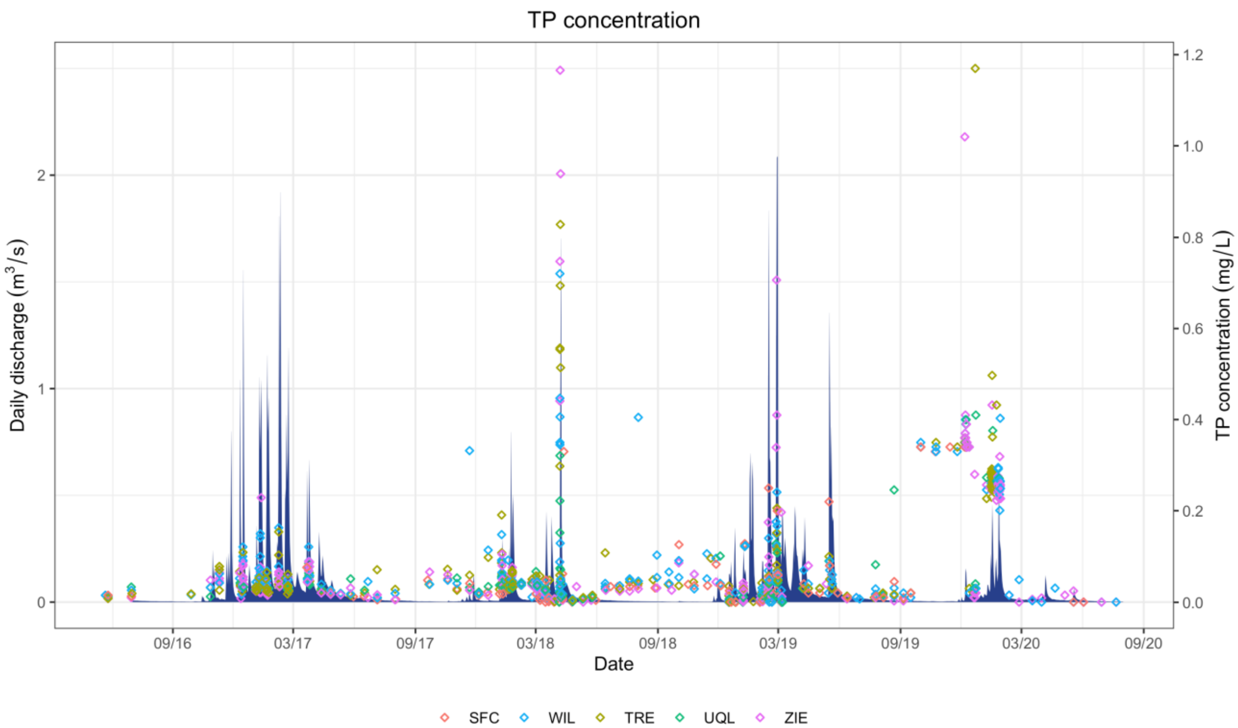

Figure 19: Concentrations of total phosphorus (TP) in stream water in each sub-watershed and South Fork Caspar Creek.

Post-hoc Tukey's HSD test scores from the ANOVA shown in Table 26 indicate that TP concentrations were significantly lower in both UQL and SFC than in the control (WIL) in HY2017, however, TRE and ZIE were not significantly different from either WIL or SFC. Higher TP flux from the control sub-watershed could be explained by the longer and deeper flow pathways that are hypothesized for WIL, which were also supported by the higher EC values in comparison to the other sub-watersheds and SFC. Deeper flow pathways would allow more contact time of water with the bedrock, allowing more weathering byproducts to dissolve and being transported with subsurface flows. Sub-watersheds also showed significant differences in stream water TP concentrations during dry years (Table 26). Stream water TP was significantly higher in WIL, TRE and UQL during dry years than observed at SFC, but on average, ZIE showed the highest TP concentration in streamflow during dry years (0.18 mg/L). These higher TP concentrations observed in ZIE could be due to higher groundwater contributions to streamflow but mainly due to disturbance created with the timber harvest, which expectedly would increase the sediment flux and particulate P flux from hillslopes to streams. This is also supported by the increase in turbidity observed in ZIE during the post-harvest period and the high correlation coefficient between TP and turbidity.

Comparison of mean seasonal TP concentrations between sub-watersheds and SFC reveal no significant differences between all five watersheds with exception of the post-summer seasons (Table 27). Mean TP concentration in stream water was significantly higher in UQL than all other treatment sub-watersheds but not significantly different from SFC. As indicated by the phosphate concentrations shown in the next section, the majority of TP exported from South Fork Caspar Creek and the four treatment sub-watersheds is in the form of particulate or sediment bound phosphorus. These dynamics are consistent with other forested watershed studies that have observed a soluble reactive phosphorus (SRP) SRP/TP ratio of 0.37 or 0.16 (Ostrofsky et al. 2018). In addition, the TP fluxes from South Fork Caspar Creek overall seem very low compared to other studies that have observed mean TP concentrations of 100-300 mg/L or more (Ryan et al. 2018). Most of the TP reported in these studies originates from sediment (e.g. soils, back erosion) in close proximity to streams, however, atmospheric deposition of P in bulk precipitation has also been found in some studies to exceed P export by discharge (Cole and Rapp, 1981; Sohrt et al., 2017, 2019).

Table 26: ANOVA and post-hoc Tukey's HSD test scores for mean differences in pre- and post-harvest and other annual stream water total phosphorus concentration (mg/L) trends comparing sub-watersheds. ANOVA and Tukey's HSD were calculated at a significance level of $\alpha = 0.05$. N is the number of samples considered in each group. Since 5 watersheds are compared, $\alpha_{test} = 0.05/10 = 0.005$. Hence, p-values < 0.005 indicate significant differences.

	SFC	WIL	TRE	UQL	ZIE	*p-value*
N **Pre-yarding**	34 0.031 ± 0.06	106 0.067 ± 0.08 a	104 0.075 ± 0.13 a	95 0.042 ± 0.04 a	106 0.072 ± 0.16 a	0.162
N **Post-yarding**	34 0.031 ± 0.06 a	107 0.067 ± 0.08 a	104 0.075 ± 0.13 a	95 0.042 ± 0.04 a	106 0.072 ± 0.16 a	0.082
N **HY 2017**	7 0.026 ± 0.03 a	53 0.058 ± 0.03 b	47 0.046 ± 0.03 ab	41 0.039 ± 0.01 a	56 0.048 ± 0.03 ab	**0.005**
N **HY 2018**	30 0.031 ± 0.06 a	58 0.073 ± 0.1 a	55 0.102 ± 0.18 a	52 0.045 ± 0.05 a	54 0.093 ± 0.22 a	0.11

N **HY 2019**	33 0.055 ± 0.06 a	58 0.045 ± 0.05 a	48 0.046 ± 0.05 a	42 0.03 ± 0.04 a	58 0.063 ± 0.11 a	0.216
N **HY 2020**	10 0.143 ± 0.17 a	42 0.188 ± 0.14 a	58 0.243 ± 0.19 a	40 0.196 ± 0.15 a	71 0.245 ± 0.17 a	0.12
N **Dry years**	42 0.057 ± 0.11 c	101 0.12 ± 0.13 abc	115 0.172 ± 0.19 ab	94 0.109 ± 0.13 ac	127 0.177 ± 0.21 b	**<0.001**
N **Wet years**	40 0.05 ± 0.06 a	111 0.051 ± 0.04 a	95 0.046 ± 0.04 a	83 0.034 ± 0.03 a	114 0.056 ± 0.08 a	0.097

Table 27: ANOVA and post-hoc Tukey's HSD test scores for mean differences in seasonal stream water TP concentration (mg/L) comparing sub-watersheds. ANOVA and Tukey's HSD were calculated at a significance level of α = 0.05. N is the number of samples considered in each group.

		SFC	WIL	TRE	UQL	ZIE	*p-value*
Pre-yarding vs. Post-yarding	**N**	1	8	10	4	8	
	Pre-Fall	NA	0.076 ± 0.1	0.051 ± 0.02	0.04 ± 0.03	0.053 ± 0.01	0.817
		a	a	a	a	a	
	N	7	57	49	48	57	
	Pre-Winter	0.029 ± 0.01	0.061 ± 0.03	0.051 ± 0.03	0.039 ± 0.01	0.048 ± 0.03	**0.002**
		ab	b	ab	a	ab	
	N	22	39	38	39	37	
	Pre-Spring	0.035 ± 0.07	0.077 ± 0.11	0.118 ± 0.21	0.046 ± 0.06	0.119 ± 0.27	0.151
		a	a	a	a	a	
	N	4	3	7	4	4	
	Pre-Summer	0.01 ± 0	0.027 ± 0.02	0.046 ± 0.03	0.025 ± 0.01	0.013 ± 0.01	0.088
		a	a	a	a	a	
	N	10	7	8	0	9	
	Post-Fall	0.139 ± 0.14	0.173 ± 0.15	0.158 ± 0.16	NA	0.148 ± 0.14	0.971
		a	a	a		a	
	N	15	64	76	62	95	
	Post-Winter	0.079 ± 0.1	0.135 ± 0.13	0.191 ± 0.18	0.134 ± 0.15	0.2 ± 0.18	0.004
		a	a	a	a	a	
	N	12	18	12	15	17	
	Post-Spring	0.044 ± 0.06	0.024 ± 0.02	0.027 ± 0.03	0.027 ± 0.03	0.036 ± 0.05	0.66
		a	a	a	a	a	
	N	11	16	10	5	14	
	Post-Summer	0.023 ± 0.01	0.024 ± 0.02	0.018 ± 0.02	0.072 ± 0.1	0.013 ± 0.01	**0.02**
		ab	a	a	b	a	
Dry years vs. Wet years	**N**	5	7	8	2	7	
	Dry-Fall	0.212 ± 0.17	0.21 ± 0.16	0.155 ± 0.16	0.04 ± 0.01	0.167 ± 0.16	0.691
		a	a	a	a	a	
	N	8	49	66	56	77	
	Dry-Winter	0.068 ± 0.11	0.164 ± 0.13	0.215 ± 0.18	0.151 ± 0.14	0.224 ± 0.16	**0.005**
		b	a	a	a	a	
	N	20	34	30	31	33	
	Dry-Spring	0.031 ± 0.07	0.071 ± 0.12	0.133 ± 0.24	0.044 ± 0.07	0.118 ± 0.28	0.178
		a	a	a	a	a	
	N	9	11	11	5	10	
	Dry-Summer	0.02 ± 0.01	0.022 ± 0.02	0.027 ± 0.03	0.066 ± 0.1	0.01 ± 0.01	0.117
		a	a	a	a	a	
	N	20	31	30	25	31	
	Wet-Fall	0.053 ± 0.05	0.045 ± 0.03	0.045 ± 0.03	0.037 ± 0.03	0.055 ± 0.04	0.325
		a	a	a	a	a	
	N	14	72	59	54	75	
	Wet-Winter	0.061 ± 0.08	0.057 ± 0.05	0.047 ± 0.04	0.033 ± 0.03	0.06 ± 0.1	0.167
		a	a	a	a	a	
	N	14	23	20	23	21	
	Wet-Spring	0.049 ± 0.06	0.045 ± 0.03	0.041 ± 0.02	0.037 ± 0.02	0.053 ± 0.04	0.611
		a	a	a	a	a	
	N	6	8	6	4	8	
	Wet-Summer	0.018 ± 0.01	0.028 ± 0.02	0.033 ± 0.02	0.033 ± 0.03	0.016 ± 0.01	0.417

5.3.1.10 Phosphate

Similar to the stream water TP concentrations, phosphate concentrations were near or below the detection limit of 0.005 mg/L most of the time during the study period. Phosphate concentrations increased slightly during storm events but stayed for the most part below 0.015 mg/L in the pre-yarding season (Figure 20). The low phosphate concentrations observed are not surprising. Elevated phosphate in stream water would indicate anthropogenic sources (e.g. septic systems, detergents etc.) but since the Caspar Creek watersheds contains no settlements and only a few houses, anthropogenic input of phosphate is expected to be negligible. Although Figure 20 does not suggest large differences in phosphate concentrations between the sub-watershed and SFC, Table 28 shows that there were significant differences in HY2017 (wettest year), wet years, and HY2019. In HY2017, stream water phosphate concentrations were significantly higher in WIL and TRE compared to the other watersheds, while UQL and ZIE showed the lowest concentrations. Similar patterns were observed for HY 2019 and also wet years, which combine data from HY2017 and HY2019.

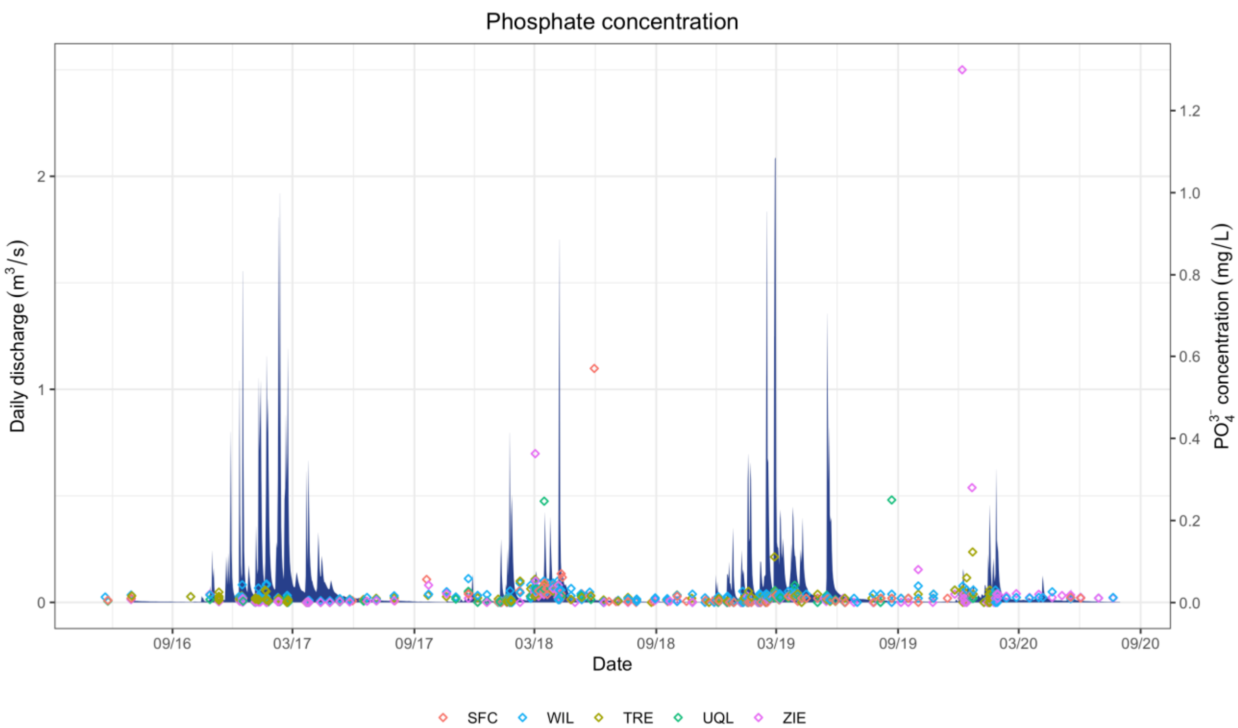

Figure 20: Concentrations of phosphate ($\boldsymbol{PO_4^{3-}}$) in stream water in each sub-watershed and South Fork Caspar Creek.

Comparison of mean seasonal phosphate concentrations indicates that all sub-watersheds and SFC had similar phosphate concentrations during most seasons except for the pre-yarding and wet year winter seasons (Table 29). In both cases, UQL and ZIE showed near-zero phosphate concentrations in stream water while WIL showed the highest phosphate concentrations among sub-watersheds. However, because concentrations overall were very low and near detection limit it would be prudent no to over-interpret these statistical differences observed between watersheds.

Table 28: ANOVA and post-hoc Tukey's HSD test scores for mean differences in pre- and post-harvest and other annual stream water phosphate concentration (mg/L) trends comparing sub-watersheds. ANOVA and Tukey's HSD were calculated at a significance level of α = 0.05. N is the number of samples considered in each group. Since 5 watersheds are compared, α_{test} = 0.05/10 = 0.005. Hence, p-values < 0.005 indicate significant differences.

	SFC	WIL	TRE	UQL	ZIE	*p-value*
N	34	107	104	95	106	
Pre-yarding	0.018 ± 0.02	0.016 ± 0.01	0.011 ± 0.01	0.009 ± 0.03	0.01 ± 0.04	0.11
	a	a	a	a	a	
N	55	137	123	107	146	
Post-yarding	0.017 ± 0.08	0.012 ± 0.01	0.022 ± 0.11	0.01 ± 0.02	0.019 ± 0.11	0.757
	a	a	a	a	a	
N	7	53	47	41	56	
HY 2017	0.003 ± 0	0.011 ± 0.01	0.008 ± 0.01	0.001 ± 0	0.001 ± 0	**<0.001**
	bc	a	ab	c	c	
N	30	58	55	52	54	
HY 2018	0.039 ± 0.1	0.021 ± 0.02	0.014 ± 0.01	0.016 ± 0.04	0.019 ± 0.05	0.175
	a	a	a	a	a	
N	40	69	63	50	67	
HY 2019	0.006 ± 0.01	0.013 ± 0.01	0.011 ± 0.02	0.009 ± 0.01	0.006 ± 0.01	**<0.001**
	bc	a	ab	abc	c	
N	10	63	60	57	73	
HY 2020	0.009 ± 0	0.012 ± 0.01	0.033 ± 0.16	0.011 ± 0.03	0.033 ± 0.15	0.645
	a	a	a	a	a	
N	42	122	117	111	129	
Dry years	0.031 ± 0.09	0.016 ± 0.01	0.024 ± 0.11	0.013 ± 0.03	0.027 ± 0.12	0.633
	a	a	a	a	a	
N	47	122	110	91	123	
Wet years	0.006 ± 0.01	0.012 ± 0.01	0.01 ± 0.01	0.005 ± 0.01	0.004 ± 0.01	**<0.001**
	bc	a	ab	c	c	

Table 29: ANOVA and post-hoc Tukey's HSD test scores for mean differences in seasonal stream water phosphate concentration (mg/L) comparing sub-watersheds. ANOVA and Tukey's HSD were calculated at a significance level of α = 0.05. N is the number of samples considered in each group.

			SFC	WIL	TRE	UQL	ZIE	*p-value*
Pre-yarding vs. Post-yarding	**Pre-Fall**	**N**	1	8	10	4	8	
			NA	0.021 ± 0.02	0.016 ± 0.01	0.013 ± 0.01	0.013 ± 0.01	0.685
			a	a	a	a	a	
	Pre-Winter	**N**	7	57	49	48	57	
			0.007 ± 0.01	0.013 ± 0.01	0.008 ± 0.01	0.001 ± 0	0.001 ± 0	**<0.001**
			abc	c	a	b	b	
	Pre-Spring	**N**	22	39	38	39	37	
			0.024 ± 0.02	0.021 ± 0.02	0.015 ± 0.01	0.019 ± 0.04	0.025 ± 0.06	0.789
			a	a	a	a	a	
	Pre-Summer	**N**	4	3	7	4	4	
			0.005 ± 0.01	0.013 ± 0.01	0.01 ± 0.01	0.003 ± 0.01	0.003 ± 0.01	0.05
			a	a	a	a	a	
	Post-Fall	**N**	10	7	8	0	9	
			0.006 ± 0.01	0.02 ± 0.01	0.015 ± 0.01	NA	0.013 ± 0.03	0.328
			a	a	a		a	
	Post-Winter	**N**	18	88	84	79	98	
			0.005 ± 0.01	0.011 ± 0.01	0.027 ± 0.13	0.006 ± 0.01	0.024 ± 0.13	0.531
			a	a	a	a	a	
	Post-Spring	**N**	16	26	21	23	25	
			0.046 ± 0.14	0.016 ± 0.01	0.012 ± 0.01	0.014 ± 0.01	0.012 ± 0.01	0.263
			a	a	a	a	a	
	Post-Summer	**N**	11	16	10	5	14	
			0.004 ± 0.01	0.01 ± 0.01	0.01 ± 0	0.052 ± 0.11	0.004 ± 0.01	**0.053**
			b	ab	ab	a	b	
Dry years vs. Wet years	**Dry-Fall**	**N**	5	7	8	2	7	
			0.01 ± 0.01	0.03 ± 0.02	0.018 ± 0.01	0.02 ± 0.01	0.024 ± 0.03	0.364
			a	a	a	a	a	
	Dry-Winter	**N**	8	69	66	71	77	
			0.008 ± 0.01	0.01 ± 0.01	0.029 ± 0.15	0.005 ± 0.01	0.028 ± 0.15	0.553
			a	a	a	a	a	
	Dry-Spring	**N**	20	35	32	33	35	
			0.056 ± 0.12	0.026 ± 0.01	0.02 ± 0.01	0.025 ± 0.04	0.03 ± 0.06	0.208
			a	a	a	a	a	
	Dry-Summer	**N**	9	11	11	5	10	
			0.006 ± 0.01	0.011 ± 0.01	0.011 ± 0	0.054 ± 0.11	0.004 ± 0.01	0.103
			a	a	a	a	a	
	Wet-Fall	**N**	24	38	37	31	37	
			0.008 ± 0.01	0.011 ± 0.01	0.009 ± 0.01	0.008 ± 0.01	0.006 ± 0.01	0.099
			a	a	a	a	a	
	Wet-Winter	**N**	17	76	67	56	78	
			0.005 ± 0.01	0.013 ± 0.01	0.01 ± 0.02	0.004 ± 0.01	0.003 ± 0.01	**<0.001**
			bc	a	ab	c	c	
	Wet-Spring	**N**	18	30	27	29	27	
			0.008 ± 0.01	0.011 ± 0.01	0.008 ± 0.01	0.009 ± 0.01	0.007 ± 0.01	0.405
			a	a	a	a	a	
	Wet-Summer	**N**	6	8	6	4	8	
			0.002 ± 0	0.01 ± 0.01	0.008 ± 0	0 ± 0	0.003 ± 0	**0.001**
			bc	a	ab	c	bc	

5.3.2 Temporal comparison

The tables presented in this section summarize the temporal differences in nutrient concentrations and water chemistry parameters within each sub-watershed (WIL, TRE, UQL, ZIE) and SFC. To a large extent, these statistics reflect some of the dynamics already discussed in section 6.3.1, hence, we will highlight only significant differences for the different statistical comparisons that were made.

5.3.2.1 Pre-harvest vs post-harvest period

Table 30 summarizes the post-hoc Tukey's HSD test scores comparing the pre- and post-harvest water chemistry in each of the five watersheds studied in this project. Overall, the ANOVA results and post-hoc analysis indicate that all four sub-watersheds (WIL, TRE, UQL, ZIE) show significant differences in at least five or more water chemistry parameters, while SFC, the outlet of South Fork Caspar Creek only shows significant differences in two parameters. Both TP and DOC are significantly elevated at SFC in the post-yarding period, indicating an increased carbon and particulate phosphorus flux.

Among the sub-watersheds, surprisingly the control sub-watershed WIL showed significant differences in pH, turbidity, TN, TP, phosphate, DOC and DON between the pre- and post-harvest period. In most cases concentrations or values decreased in the post-harvest period, likely due to the fact that both HY2019 and HY2020 had less precipitation than for example HY2017 in the pre-harvest period, which could mean that a smaller fraction of the watershed contributed flow to streams during storm events, thereby reducing the influx of soil nutrients and sediment into the stream. However, similar to the treatment sub-watersheds, DOC increased in WIL in the post-harvest period possibly corroborating the hypothesis that atmospheric deposition of ash from wildfires in HY2019 and HY2020 might have caused an influx of C to streams.

Among the treatment sub-watersheds (TRE, UQL, ZIE), statistical results indicate similar dynamics. Mean DOC, DON and TP stream water concentrations were all significant different between the pre- and post-harvest period in all three sub-watersheds. DOC and TP significantly increased in the post-harvest period in all three sub-watersheds while DON significantly decreased. These dynamics again can be explained by the increased influx of sediment from soil disturbance and the increased influx of organic matter from the timber harvest. A close look at Table 30 even reveals that mean DOC concentrations gradually increase with the percentage of timber removed in each sub-watershed in the post-harvest period. Mean post-harvest DOC concentrations are 4.43 ± 2.7, 4.99 ± 2.5, and 5.66 ± 3.3 mg/L in TRE, UQL and ZIE, respectively. However, among the three treatment sub-watersheds, ZIE is the only one that also shows significant differences in NH_4^+ and NO_3^- between the pre- and post-harvest period. NH_4^+ and NO_3^- are both significantly higher in the post-harvest period, indicating that the organic-N contained in the biomass that is left behind (e.g. roots) is mineralized to NH_4^+ and nitrified to NO_3^- thereby elevating the inorganic nitrogen flux from the watersheds to the stream.

Table 30: ANOVA and post-hoc Tukey's HSD test scores for mean differences in pre-harvest vs. post-harvest stream water chemistry in each sub-watershed and South Fork Caspar Creek. ANOVA and Tukey's HSD were calculated at a significance level of α = 0.05. N is the number of samples considered in each group.

		N	EC	pH	Turbidity	TN	NH_4^+-N	NO_3^- - N	TP	PO_4	DOC	DON
			mS	Moles H^+/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
SFC	Pre	34	148 ± 91	7.02 ± 0.8	8 ± 11	0.283 ± 0.41	0.031 ± 0.08	0.029 ± 0.07	0.031 ± 0.06	0.018 ± 0.02	2.48 ± 1.5	0.224 ± 0.34
	Post	55	141 ± 31	7.18 ± 0.4	11 ± 16	0.153 ± 0.11	0.053 ± 0.19	0.012 ± 0.02	0.07 ± 0.1	0.017 ± 0.08	3.51 ± 1.8	0.115 ± 0.11
	p-value		0.67	0.301	0.368	0.08	0.456	0.181	**0.025**	0.906	**0.005**	0.073
WIL	Pre	107	170 ± 98	7.49 ± 0.4	39 ± 63	0.273 ± 0.21	0.041 ± 0.07	0.008 ± 0.02	0.067 ± 0.08	0.016 ± 0.01	3.08 ± 1.9	0.226 ± 0.18
	Post	137	185 ± 81	7.11 ± 0.4	14 ± 20	0.137 ± 0.13	0.035 ± 0.04	0.01 ± 0.02	0.101 ± 0.12	0.012 ± 0.01	4.47 ± 3.1	0.086 ± 0.12
	p-value		0.203	**<0.001**	**<0.001**	**<0.001**	0.497	0.449	**0.015**	**0.009**	**<0.001**	**<0.001**
TRE	Pre	104	132 ± 56	7.32 ± 0.4	46 ± 124	0.213 ± 0.16	0.034 ± 0.05	0.012 ± 0.03	0.075 ± 0.13	0.011 ± 0.01	2.78 ± 1.7	0.171 ± 0.14
	Post	123	121 ± 34	7.08 ± 0.4	16 ± 21	0.151 ± 0.13	0.069 ± 0.44	0.016 ± 0.02	0.154 ± 0.17	0.022 ± 0.11	4.43 ± 2.7	0.097 ± 0.12
	p-value		0.088	**<0.001**	**0.017**	**0.002**	0.387	0.262	**<0.001**	0.293	**<0.001**	**<0.001**
UQL	Pre	95	129 ± 61	7.26 ± 0.4	29 ± 28	0.206 ± 0.14	0.04 ± 0.06	0.017 ± 0.12	0.042 ± 0.04	0.009 ± 0.03	3.12 ± 1.5	0.16 ± 0.13
	Post	107	123 ± 30	6.98 ± 0.2	22 ± 12	0.199 ± 0.22	0.051 ± 0.05	0.017 ± 0.03	0.111 ± 0.14	0.01 ± 0.02	4.99 ± 2.5	0.117 ± 0.17
	p-value		0.419	**<0.001**	**0.027**	0.805	0.141	0.982	**<0.001**	0.83	**<0.001**	**0.045**
ZIE	Pre	106	114 ± 51	7.33 ± 0.4	62 ± 160	0.252 ± 0.18	0.022 ± 0.03	0.009 ± 0.02	0.072 ± 0.16	0.01 ± 0.04	3.56 ± 2	0.222 ± 0.18
	Post	145	118 ± 33	7.54 ± 5.9	34 ± 86	0.254 ± 0.4	0.048 ± 0.13	0.049 ± 0.1	0.157 ± 0.17	0.019 ± 0.11	5.66 ± 3.3	0.156 ± 0.25
	p-value		0.461	0.669	0.102	0.962	**0.022**	**<0.001**	**<0.001**	0.352	**<0.001**	**0.014**

5.3.2.2 Hydrologic Years

Table 31 summarizes the post-hoc Tukey's HSD test scores comparing the water chemistry in each of the five watersheds studied in this project between the four hydrologic years. Overall, the ANOVA results and post-hoc analysis indicate similar patterns as was observed in the pre-harvest vs. post-harvest comparison and watershed comparison (section 6.3.1) SFC only showed significant differences between hydrologic years in the mean pH, TP and DOC concentrations. Again, DOC was significantly higher in the post-harvest period, which corresponds to HY2019 and HY2020. TP was only significantly higher in HY2020.

Among the four sub-watersheds (WIL, TRE, UQL, ZIE), WIL, the control, showed significant differences in all water chemistry parameters except NO_3^- when comparing hydrologic years. This is somewhat surprising and likely related to the huge variability in precipitation and streamflow between the four study years. As indicated by Tukey's HSD test scores, many of the nutrient concentrations were elevated during HY2017, the wettest year in the study period (e.g. TN, DON, NH_4^+), while DOC was mainly elevated in HY2020, likely due to the fire season.

In contrast, all three treatment sub-watersheds only showed significant differences in EC, TP and DOC (both of which showed significant increases in HY2020) and some sub-watersheds showed significant changes in NH_4^+ (UQL & ZIE) or turbidity (TRE & UQL) suggesting relationships to the timber harvest activities. However in some instances significant changes were related to drastic differences in flow as were observed in HY2017 vs. HY2020.

Table 31: ANOVA and post-hoc Tukey's HSD test scores for mean differences in stream water chemistry in each sub-watershed and South Fork Caspar Creek comparing the hydrologic years of 2017-2020. ANOVA and Tukey's HSD were calculated at a significance level of α = 0.05. N is the number of samples considered in each group.

		N	EC		pH		Turbidity		TN		NH_4^+-N		NO_3^- - N		DON		TP		PO_4		DOC	
			mS		Moles H^+/L		NTU		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L	
SFC	HY17	7	166 ± 52	a	7.81 ± 0.2	b	12 ± 19	a	0.413 ± 0.26	a	0.021 ± 0.02	a	0.023 ± 0.03	a	0.369 ± 0.25	b	0.026 ± 0.03	a	0.003 ± 0	a	2.3 ± 0.87	a
	HY18	30	146 ± 94	a	6.87 ± 0.8	a	6.8 ± 8.6	a	0.254 ± 0.41	a	0.077 ± 0.26	a	0.03 ± 0.08	a	0.189 ± 0.33	ab	0.031 ± 0.06	a	0.039 ± 0.1	a	2.5 ± 1.57	a
	HY19	40	134 ± 31	a	7.14 ± 0.4	a	14 ± 17	a	0.158 ± 0.12	a	0.024 ± 0.03	a	0.01 ± 0.02	a	0.119 ± 0.11	a	0.055 ± 0.06	a	0.006 ± 0.01	a	3.39 ± 1.9	ab
	HY20	10	157 ± 30	a	7.22 ± 0.2	ab	2 ± 2	a	0.101 ± 0.09	a	0.051 ± 0.07	a	0.019 ± 0.01	a	0.073 ± 0.09	a	0.143 ± 0.17	b	0.009 ± 0	a	4.7 ± 1.6	b
	p-value		0.496		**<0.001**		0.046		0.063		0.548		0.387		0.029		**0.002**		0.133		**0.004**	
WIL	HY17	53	143 ± 74	b	7.76 ± 0.2	c	42 ± 62	b	0.347 ± 0.21	b	0.057 ± 0.07	b	0.012 ± 0.02	a	0.278 ± 0.19	c	0.058 ± 0.03	a	0.011 ± 0.01	b	3.11 ± 1.6	a
	HY18	57	204 ±111	a	7.28 ± 0.4	a	34 ± 62	ab	0.191 ± 0.18	a	0.024 ± 0.06	a	0.005 ± 0.02	a	0.164 ± 0.15	a	0.073 ± 0.1	a	0.021 ± 0.02	a	2.9 ± 2.2	a
	HY19	69	171 ± 70	ab	7.21 ± 0.4	a	17 ± 26	ac	0.141 ± 0.14	a	0.023 ± 0.03	a	0.006 ± 0.02	a	0.109 ± 0.13	ab	0.045 ± 0.05	a	0.013 ± 0.01	b	2.94 ± 1.6	a
	HY20	63	190 ± 87	a	6.95 ± 0.3	b	11 ± 9	c	0.134 ± 0.12	a	0.051 ± 0.05	b	0.013 ± 0.02	a	0.063 ± 0.09	b	0.188 ± 0.14	b	0.012 ± 0.01	b	6.45 ± 3.2	b
	p-value		**0.002**		**<0.001**		**<0.001**		**<0.001**		**<0.001**		0.062		**<0.001**		**<0.001**		**<0.001**		**<0.001**	
TRE	HY17	47	114 ± 37	b	7.61 ± 0.2	b	24 ± 20	ab	0.263 ± 0.14	c	0.055 ± 0.07	a	0.016 ± 0.02	ab	0.192 ± 0.12	b	0.046 ± 0.03	a	0.008 ± 0.01	a	3.09 ± 1.7	a
	HY18	55	146 ± 65	a	7.05 ± 0.4	a	66 ± 168	a	0.173 ± 0.16	ab	0.017 ± 0.02	a	0.008 ± 0.04	a	0.154 ± 0.15	ab	0.102 ± 0.18	a	0.014 ± 0.01	a	2.56 ± 1.7	a
	HY19	63	116 ± 32	b	7.04 ± 0.5	a	18 ± 28	b	0.113 ± 0.12	a	0.023 ± 0.02	a	0.01 ± 0.03	ab	0.08 ± 0.11	c	0.046 ± 0.05	a	0.011 ± 0.02	a	2.91 ± 1.7	a
	HY20	60	127 ± 35	ab	7.12 ± 0.3	a	13 ± 9	b	0.187 ± 0.13	b	0.117 ± 0.64	a	0.022 ± 0.02	b	0.115 ± 0.13	ac	0.243 ± 0.19	b	0.033 ± 0.16	a	6.14 ± 2.6	b
	p-value		**<0.001**		**<0.001**		**0.005**		**<0.001**		0.328		0.032		**<0.001**		**<0.001**		0.359		**<0.001**	
UQL	HY17	41	109 ± 42	b	7.59 ± 0.2	b	29 ± 10	a	0.249 ± 0.15	a	0.06 ± 0.07	bc	0.004 ± 0.01	a	0.185 ± 0.14	a	0.039 ± 0.01	a	0.001 ± 0	b	3.36 ± 1.4	a
	HY18	52	141 ± 70	ab	7.01 ± 0.3	a	30 ± 36	a	0.171 ± 0.12	a	0.024 ± 0.04	a	0.028 ± 0.16	a	0.139 ± 0.12	a	0.045 ± 0.05	a	0.016 ± 0.04	a	2.98 ± 1.6	a
	HY19	50	117 ± 24	b	6.97 ± 0.3	a	17 ± 10	b	0.166 ± 0.19	a	0.034 ± 0.05	ab	0.008 ± 0.02	a	0.127 ± 0.14	a	0.03 ± 0.04	a	0.009 ± 0.01	ab	3.51 ± 1.4	a
	HY20	57	129 ± 34	ab	6.99 ± 0.2	a	28 ± 11	a	0.239 ± 0.25	a	0.066 ± 0.04	c	0.024 ± 0.03	a	0.108 ± 0.2	a	0.196 ± 0.15	b	0.011 ± 0.03	ab	6.26 ± 2.5	b
	p-value		**0.005**		**<0.001**		**0.004**		0.051		**<0.001**		0.427		0.107		**<0.001**		0.046		**<0.001**	
ZIE	HY17	56	97 ± 36	c	7.57 ± 0.2	a	49 ± 85	a	0.301 ± 0.2	ab	0.027 ± 0.03	a	0.015 ± 0.02	a	0.26 ± 0.2	b	0.048 ± 0.03	a	0.001 ± 0	a	3.8 ± 1.8	a
	HY18	54	134 ± 57	a	7.05 ± 0.3	a	72 ± 208	a	0.192 ± 0.15	a	0.017 ± 0.02	a	0.005 ± 0.02	a	0.171 ± 0.14	ab	0.093 ± 0.22	a	0.019 ± 0.05	a	3.2 ± 2.1	a
	HY19	66	107 ± 27	bc	7.04 ± 0.5	a	50 ± 123	a	0.161 ± 0.15	a	0.022 ± 0.01	a	0.009 ± 0.02	a	0.13 ± 0.15	a	0.063 ± 0.11	a	0.006 ± 0.01	a	4.04 ± 2.4	a
	HY20	73	124 ± 34	ab	8.03 ± 8.2	a	21 ± 13	a	0.346 ± 0.53	b	0.074 ± 0.18	b	0.089 ± 0.12	b	0.183 ± 0.32	ab	0.245 ± 0.17	b	0.033 ± 0.15	a	7.47 ± 3.1	b
	p-value		**<0.001**		0.523		0.15		**0.003**		**0.004**		**<0.001**		0.014		**<0.001**		0.158		**<0.001**	

5.3.2.3 Wet vs Dry years

Table 32 summarizes the post-hoc Tukey's HSD test scores comparing the water chemistry in each of the five watersheds between wet and dry years. Overall, the ANOVA results and post-hoc analysis indicate similar patterns as was observed in the pre-harvest vs. post-harvest comparison and watershed comparison (section 6.3.1) SFC only showed significant differences in turbidity between wet and dry, whereby (as expected) turbidity was significantly higher in wet years compared to dry years. Similar to the pre- vs. post-harvest and hydrologic year comparisons, WIL, the control sub-watershed exhibited the most number of water chemistry parameters with significant differences between wet and dry years. Except for turbidity, NH_4^+ and NO_3^-, all other parameters showed significant differences in WIL, with significantly higher concentrations in TP, phosphate, DOC and EC in dry years, and significantly higher concentrations in TN, DON and pH in wet years.

Similar to previous comparisons, the three treatment sub-watersheds showed significant differences in DOC, TP, phosphate, and EC when comparing wet and dry years. EC was significantly higher in dry years due to less dilution from rainfall-runoff, while TP was elevated in wet years, reflective of the increased influx of sediment and larger particulate P flux during storm events. In contrast, stream water phosphate was significantly higher in dry years, likely reflecting the atmospheric input of phosphate into the watershed and lower precipitation inputs (and therefore less of a dilution effect) observed during dry years.

Table 32: ANOVA and post-hoc Tukey's HSD test scores for mean differences in dry year vs. wet year stream water chemistry in each sub-watershed and South Fork Caspar Creek. ANOVA and Tukey's HSD were calculated at a significance level of α = 0.05. N is the number of samples considered in each group.

		N	EC	pH	Turbidity	TN	NH_4^+-N	NO_3^- - N	TP	PO_4	DOC	DON
			mS	Moles H^+/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
SFC	Dry years	42	148 ± 81	6.98 ± 0.7	6 ± 8	0.211 ± 0.36	0.068 ± 0.22	0.026 ± 0.07	0.057 ± 0.11	0.031 ± 0.09	2.98 ± 1.8	0.157 ± 0.29
	Wet years	47	139 ± 36	7.24 ± 0.5	14 ± 17	0.198 ± 0.17	0.024 ± 0.03	0.012 ± 0.02	0.05 ± 0.06	0.006 ± 0.01	3.22 ± 1.8	0.156 ± 0.16
	p-value		0.466	0.036	**0.004**	0.833	0.205	0.183	0.714	0.072	0.517	0.986
WIL	Dry years	122	198 ± 99	7.11 ± 0.4	22 ± 45	0.168 ± 0.16	0.038 ± 0.06	0.009 ± 0.02	0.12 ± 0.13	0.016 ± 0.01	4.72 ± 3.3	0.112 ± 0.13
	Wet years	122	159 ± 73	7.45 ± 0.4	28 ± 47	0.234 ± 0.2	0.038 ± 0.06	0.009 ± 0.02	0.051 ± 0.04	0.012 ± 0.01	3.01 ± 1.6	0.183 ± 0.18
	p-value		**<0.001**	**<0.001**	0.322	**0.008**	0.982	0.924	**<0.001**	**0.014**	**<0.001**	**<0.001**
TRE	Dry years	117	137 ± 52	7.1 ± 0.3	38 ± 120	0.18 ± 0.14	0.068 ± 0.46	0.015 ± 0.03	0.172 ± 0.19	0.024 ± 0.11	4.31 ± 2.8	0.134 ± 0.14
	Wet years	110	115 ± 34	7.28 ± 0.5	21 ± 25	0.182 ± 0.15	0.037 ± 0.05	0.013 ± 0.02	0.046 ± 0.04	0.01 ± 0.01	2.99 ± 1.7	0.128 ± 0.13
	p-value		**<0.001**	**0.001**	0.126	0.895	0.455	0.505	**<0.001**	0.188	**<0.001**	0.754
UQL	Dry years	111	136 ± 54	7 ± 0.2	28 ± 26	0.202 ± 0.19	0.046 ± 0.05	0.026 ± 0.11	0.109 ± 0.13	0.013 ± 0.03	4.64 ± 2.7	0.124 ± 0.16
	Wet years	91	113 ± 33	7.25 ± 0.4	22 ± 12	0.204 ± 0.18	0.046 ± 0.06	0.006 ± 0.02	0.034 ± 0.03	0.005 ± 0.01	3.44 ± 1.4	0.153 ± 0.14
	p-value		**<0.001**	**<0.001**	**0.034**	0.925	0.987	0.077	**<0.001**	**0.019**	**<0.001**	0.181
ZIE	Dry years	129	129 ± 45	7.62 ± 6.2	43 ± 138	0.278 ± 0.41	0.049 ± 0.14	0.053 ± 0.1	0.177 ± 0.21	0.027 ± 0.12	5.57 ± 3.5	0.178 ± 0.26
	Wet years	122	102 ± 32	7.28 ± 0.4	50 ± 107	0.227 ± 0.19	0.024 ± 0.02	0.011 ± 0.02	0.056 ± 0.08	0.004 ± 0.01	3.93 ± 2.1	0.189 ± 0.18
	p-value		**<0.001**	0.543	0.667	0.206	0.052	**<0.001**	**<0.001**	**0.035**	**<0.001**	0.704

5.3.2.4 Pre-harvest vs. post-harvest Seasons

Table 33 summarizes the post-hoc Tukey's HSD test scores comparing the seasonal (fall, winter, spring, summer) water chemistry in each of the five watersheds between the pre-harvest and post-harvest period. Overall, the ANOVA results and post-hoc Tukey's HSD analysis indicate that most of the significant differences show in the winter and spring seasons when comparing the pre-harvest and post-harvest seasons. At the outlet of South Fork Caspar Creek, EC was significantly higher in the winter seasons of the pre-harvest period compared to the post-harvest winter seasons (despite the fact that the pre-harvest seasons contained the wettest year), indicating a change in flow pathways of rainfall-runoff after the timber removal. As was documented in the previous forest disturbance or timber removal studies, a larger fraction of the rainfall-runoff is occurring along near-surface (e.g. shallow pathways) often because soil disturbance (e.g. erosion, compaction etc.) reduces the infiltration rate, forcing more rainfall to flow over land to streams. SFC, however, also shows a significant increase in DOC in the spring seasons of the post-harvest period, likely the result of increased organic matter or organic carbon transport from wet soils late in the rainy season to streams. SFC also showed a significant increase in TP in the post-harvest summer months, which is likely cause by the increased sediment flux from the yarding and felling activities.

Among the sub-watersheds, WIL, the control, showed a significant increase in DOC and TP in the post-harvest winter seasons, and a significant decrease in TP, DON, pH and turbidity in the post-harvest spring and summer seasons. Most of these dynamics are likely related to the drier precipitation regime that dominated the post-harvest period, often exhibited in higher groundwater contributions to streamflow often associated with higher concentrations of weathering byproducts.

Among the treatment sub-watersheds, all three (TRE, UQL, ZIE) sub-watersheds show a significant increase in stream water DOC concentration in the post-harvest winter seasons and summer seasons (TRE, ZIE only). Likewise, stream water pH was significantly lower in all three sub-watersheds in the post-harvest winter seasons, indicating higher amounts of organic-matter-rich runoff contributing to streamflow and incomplete neutralization due to the decreased contact time of runoff with the soil. TN was significantly lower in the post-harvest summer seasons in both UQL and ZIE, which could indicate increased in-stream consumption due to increased light availability (e.g. decrease in shaded stream sections as trees were removed). Some of the sub-watersheds also showed a decrease in stream water DON concentrations during the post-harvest spring or fall seasons, which could indicated an increased consumption of the biologically reactive nitrogen sourced from the dissolved organic matter pool by aquatic or benthic species in the stream channels. In addition, transport of DON from soils to streams might be decreased after the timber harvest, if less rainwater infiltrates into disturbed forest soils resulting in lower subsurface stormflow contributions (that move through the soil instead of on top of the soil) to streamflow.

Table 33: ANOVA and post-hoc Tukey's HSD test scores for mean differences in stream water chemistry parameters comparing seasonal trends in each sub-watershed between the pre-harvest and post-harvest period. ANOVA and Tukey's HSD were calculated at a significance level of α = 0.05. N is the number of samples considered in each group.

			N	EC mS	pH Moles H^+/L	Turbidity NTU	TN mg/L	NH_4^+-N mg/L	NO_3^- - N mg/L	TP mg/L	PO_4 mg/L	DOC mg/L	DON mg/L
SFC	Fall	Pre	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Post	10	162 ± 39	7.5 ± 0.7	1 ± 1	0.114 ± 0.05	0.019 ± 0.02	0.027 ± 0.03	0.139 ± 0.14	0.006 ± 0.01	2.6 ± 1.2	0.078 ± 0.05
		p-value											
	Winter	Pre	7	228 ± 75	7.02 ± 0.3	6 ± 6	0.156 ± 0.06	0.016 ± 0.01	0.013 ± 0.02	0.029 ± 0.01	0.007 ± 0.01	3.5 ± 1.6	0.127 ± 0.06
		Post	18	133 ± 35	6.98 ± 0.2	21 ± 21	0.19 ± 0.11	0.02 ± 0.01	0.007 ± 0.01	0.079 ± 0.1	0.005 ± 0.01	3.68 ± 1	0.138 ± 0.11
		p-value		**0.015**	0.798	**0.014**	0.332	0.429	0.499	0.082	0.685	0.791	0.745
	Spring	Pre	22	102 ± 62	6.86 ± 0.9	10 ± 13	0.34 ± 0.49	0.037 ± 0.09	0.025 ± 0.05	0.035 ± 0.07	0.024 ± 0.02	2.12 ± 1.3	0.283 ± 0.4
		Post	16	133 ± 22	7.2 ± 0.3	11 ± 10	0.185 ± 0.14	0.121 ± 0.34	0.004 ± 0.01	0.044 ± 0.06	0.046 ± 0.14	3.95 ± 2.5	0.142 ± 0.14
		p-value		0.039	0.105	0.765	0.167	0.355	0.088	0.695	0.536	**0.014**	0.141
	Summer	Pre	4	209 ± 83	7.68 ± 0.2	2 ± 0	0.088 ± 0.04	0.03 ± 0.03	0.003 ± 0.01	0.01 ± 0	0.005 ± 0.01	1.95 ± 0.3	0.055 ± 0.04
		Post	11	144 ± 18	7.18 ± 0.1	2 ± 1	0.094 ± 0.1	0.038 ± 0.07	0.018 ± 0.02	0.023 ± 0.01	0.004 ± 0.01	3.32 ± 2.1	0.069 ± 0.1
		p-value		0.216	**0.005**	0.728	0.873	0.751	0.056	**0.011**	0.703	0.063	0.707
WIL	Fall	Pre	8	342 ±127	8.18 ± 0.1	13 ± 14	0.304 ± 0.31	0.084 ± 0.15	0.008 ± 0.01	0.076 ± 0.1	0.021 ± 0.02	3.88 ± 3	0.213 ± 0.18
		Post	7	358 ± 52	7.8 ± 0.5	1 ± 1	0.137 ± 0.13	0.029 ± 0.02	0.026 ± 0.05	0.173 ± 0.15	0.02 ± 0.01	1.54 ± 0.5	0.09 ± 0.1
		p-value		0.755	0.115	**0.044**	0.195	0.346	0.383	0.188	0.875	0.063	0.117
	Winter	Pre	57	146 ± 75	7.46 ± 0.4	40 ± 60	0.238 ± 0.13	0.037 ± 0.06	0.008 ± 0.02	0.061 ± 0.03	0.013 ± 0.01	3.58 ± 2	0.192 ± 0.13
		Post	88	155 ± 44	6.93 ± 0.2	18 ± 23	0.173 ± 0.15	0.037 ± 0.04	0.009 ± 0.02	0.135 ± 0.13	0.011 ± 0.01	5.49 ± 3.2	0.104 ± 0.13
		p-value		0.382	**<0.001**	**0.013**	**0.01**	0.99	0.912	**<0.001**	0.21	**<0.001**	**<0.001**
	Spring	Pre	38	151 ± 54	7.35 ± 0.4	47 ± 74	0.334 ± 0.27	0.038 ± 0.06	0.008 ± 0.02	0.077 ± 0.11	0.021 ± 0.02	2.34 ± 1.1	0.291 ± 0.22
		Post	26	175 ± 78	7.33 ± 0.4	8 ± 7	0.083 ± 0.08	0.025 ± 0.04	0.002 ± 0.01	0.024 ± 0.02	0.016 ± 0.01	2.48 ± 1.7	0.059 ± 0.07
		p-value		0.182	0.826	**0.003**	**<0.001**	0.325	0.098	**0.007**	0.156	0.711	**<0.001**
	Summe r	Pre	3	403 ±101	8.07 ± 0.2	3 ± 4	0.08 ± 0.03	0.033 ± 0.02	0 ± 0	0.027 ± 0.02	0.013 ± 0.01	0.85 ± 0	0.047 ± 0.03
		Post	16	287 ± 84	7.49 ± 0.4	1 ± 1	0.06 ± 0.07	0.047 ± 0.07	0.021 ± 0.03	0.024 ± 0.02	0.01 ± 0.01	3.18 ± 2.2	0.031 ± 0.06
		p-value		0.173	**0.012**	0.499	0.433	0.519	**0.008**	0.837	0.469	**<0.001**	0.538
T	Fal	Pre	10	217 ± 86	8.03 ± 0.2	9 ± 7	0.217 ± 0.11	0.009 ± 0.01	0.015 ± 0.03	0.051 ± 0.02	0.016 ± 0.01	3.93 ± 3	0.193 ± 0.12

		Post	8	188 ± 36	7.6 ± 0.8	1 ± 1	0.088 ± 0.07	0.031 ± 0.03	0.016 ± 0.02	0.158 ± 0.16	0.015 ± 0.01	2.79 ± 2.7	0.061 ± 0.05
		p-value		0.349	0.165	**0.003**	**0.007**	**0.045**	0.913	0.096	0.804	0.423	**0.007**
	Winter	Pre	49	119 ± 44	7.29 ± 0.4	25 ± 20	0.2 ± 0.11	0.036 ± 0.05	0.007 ± 0.01	0.051 ± 0.03	0.008 ± 0.01	3.19 ± 1.6	0.156 ± 0.09
		Post	84	114 ± 26	6.95 ± 0.3	20 ± 24	0.167 ± 0.12	0.089 ± 0.54	0.02 ± 0.03	0.191 ± 0.18	0.027 ± 0.13	5.13 ± 2.8	0.1 ± 0.11
		p-value		0.495	**<0.001**	0.171	0.119	0.375	**<0.001**	**<0.001**	0.201	**<0.001**	**0.002**
	Spring	Pre	38	115 ± 20	7.1 ± 0.3	89 ± 198	0.259 ± 0.21	0.041 ± 0.06	0.017 ± 0.05	0.118 ± 0.21	0.015 ± 0.01	2.19 ± 1.1	0.208 ± 0.19
		Post	21	113 ± 28	7.23 ± 0.3	8 ± 6	0.155 ± 0.18	0.026 ± 0.04	0.001 ± 0	0.027 ± 0.03	0.012 ± 0.01	2.78 ± 1.3	0.122 ± 0.18
		p-value		0.864	0.166	**0.017**	0.057	0.226	0.069	**0.014**	0.244	0.091	0.093
	Summer	Pre	7	198 ± 62	7.62 ± 0.4	4 ± 6	0.057 ± 0.04	0.014 ± 0.01	0.013 ± 0.02	0.046 ± 0.03	0.01 ± 0.01	1.41 ± 0.7	0.037 ± 0.04
		Post	10	145 ± 36	7.42 ± 0.4	3 ± 3	0.073 ± 0.05	0.022 ± 0.02	0.017 ± 0.02	0.018 ± 0.02	0.01 ± 0	3.42 ± 1.5	0.052 ± 0.04
		p-value		0.076	0.324	0.624	0.479	0.333	0.665	0.071	0.872	**0.003**	0.463
UQL	**Fall**	Pre	4	263 ±170	7.97 ± 0.4	14 ± 10	0.23 ± 0.05	0.033 ± 0.04	0.003 ± 0.01	0.04 ± 0.03	0.013 ± 0.01	4.15 ± 2.1	0.195 ± 0.07
		Post	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		p-value											
	Winter	Pre	48	116 ± 46	7.2 ± 0.3	28 ± 8	0.166 ± 0.08	0.039 ± 0.05	0.026 ± 0.17	0.039 ± 0.01	0.001 ± 0	3.61 ± 1.3	0.121 ± 0.06
		Post	79	117 ± 22	6.94 ± 0.2	26 ± 12	0.192 ± 0.18	0.054 ± 0.04	0.018 ± 0.02	0.134 ± 0.15	0.006 ± 0.01	5.47 ± 2.3	0.106 ± 0.16
		p-value		0.972	**<0.001**	0.12	0.32	0.095	0.725	**<0.001**	**<0.001**	**<0.001**	0.464
	Spring	Pre	39	121 ± 30	7.24 ± 0.4	34 ± 41	0.265 ± 0.18	0.044 ± 0.06	0.008 ± 0.04	0.046 ± 0.06	0.019 ± 0.04	2.57 ± 1.4	0.215 ± 0.17
		Post	23	129 ± 24	7.09 ± 0.3	14 ± 6	0.133 ± 0.1	0.025 ± 0.03	0.001 ± 0	0.027 ± 0.03	0.014 ± 0.01	3.17 ± 1.2	0.102 ± 0.1
		p-value		0.232	0.106	**0.005**	**<0.001**	0.113	0.243	0.121	0.424	0.081	**0.002**
	Summer	Pre	4	218 ± 67	7.37 ± 0.4	7 ± 2	0.088 ± 0.1	0.023 ± 0.02	0.008 ± 0.01	0.025 ± 0.01	0.003 ± 0.01	1.5 ± 0.7	0.06 ± 0.09
		Post	5	195 ± 68	7.17 ± 0.2	7 ± 5	0.571 ± 0.56	0.131 ± 0.14	0.073 ± 0.08	0.072 ± 0.1	0.052 ± 0.11	5.95 ± 5	0.362 ± 0.37
		p-value		0.62	0.416	0.912	0.124	0.157	0.14	0.372	0.37	0.118	0.146
ZIE	**Fall**	Pre	8	196 ± 79	7.84 ± 0.2	13 ± 8	0.264 ± 0.07	0.023 ± 0.03	0.009 ± 0.01	0.053 ± 0.01	0.013 ± 0.01	5.12 ± 2.7	0.233 ± 0.08
		Post	9	162 ± 36	15.53 ± 23.2	2 ± 2	0.162 ± 0.15	0.022 ± 0.02	0.04 ± 0.06	0.148 ± 0.14	0.013 ± 0.03	2.56 ± 1.8	0.11 ± 0.09
		p-value		0.287	0.349	**0.007**	0.089	0.985	0.167	0.084	0.935	**0.04**	**0.009**
	Winter	Pre	57	98 ± 36	7.28 ± 0.3	47 ± 84	0.218 ± 0.16	0.027 ± 0.03	0.009 ± 0.01	0.048 ± 0.03	0.001 ± 0	3.99 ± 1.9	0.183 ± 0.16
		Post	97	110 ± 28	6.96 ± 0.2	46 ± 102	0.32 ± 0.47	0.058 ± 0.16	0.067 ± 0.11	0.2 ± 0.18	0.024 ± 0.13	7.01 ± 3.1	0.189 ± 0.29
		p-value		**0.04**	**<0.001**	0.913	0.055	0.058	**<0.001**	**<0.001**	0.092	**<0.001**	0.87

	Spring	Pre	37	107 ± 23	7.24 ± 0.3	103 ± 247	0.321 ± 0.21	0.016 ± 0.01	0.009 ± 0.03	0.119 ± 0.27	0.025 ± 0.06	2.84 ± 1.5	0.3 ± 0.2
		Post	25	123 ± 35	7.11 ± 0.3	16 ± 14	0.143 ± 0.12	0.024 ± 0.02	0.008 ± 0.02	0.036 ± 0.05	0.012 ± 0.01	3.17 ± 1.4	0.106 ± 0.11
		p-value		0.059	0.131	0.039	**<0.001**	0.093	0.872	0.075	0.191	0.387	**<0.001**
	Summer	Pre	4	223 ± 74	8.08 ± 0.1	4 ± 2	0.068 ± 0.02	0.013 ± 0.01	0.018 ± 0.02	0.013 ± 0.01	0.003 ± 0.01	1.04 ± 0.1	0.038 ± 0.02
		Post	14	133 ± 32	7.23 ± 0.3	3 ± 2	0.05 ± 0.06	0.034 ± 0.07	0.009 ± 0.01	0.013 ± 0.01	0.004 ± 0.01	2.82 ± 1.4	0.039 ± 0.06
		p-value		0.092	**<0.001**	0.419	0.334	0.281	0.385	0.929	0.674	**<0.001**	0.939

5.3.2.5 Dry-year vs. Wet-year Seasons

Table 34 summarizes the post-hoc Tukey's HSD test scores comparing the seasonal (fall, winter, spring, summer) water chemistry in each of the five watersheds between wet and dry years. Overall, the ANOVA results and post-hoc Tukey's HSD analysis indicate that most of the significant differences show in the winter and spring seasons when comparing wet and dry years. At the outlet of South Fork Caspar Creek, EC was significantly higher in the winter seasons of dry years compared to wet years (irrespective of whether timber harvest had occurred or not), indicating a clear difference in flow pathways between wet and dry years. During dry years, a larger fraction of streamflow is contributed from deeper flow pathways (groundwater flow, subsurface stormflow), which often allows a longer contact time of water with the soil matrix or bedrock, leading to a higher concentration of weathering byproducts in streamflow. SFC, also shows a significant increase in turbidity during the fall and winter seasons of wet years, which is expected as more frequent and high-magnitude precipitation events increase the antecedent wetness hydrologic connectivity in the watershed with larger stormflow or overland flow contributions to the stream that can cause bank erosion or wash-outs of forest roads.

Among the sub-watersheds, WIL, the control, showed significantly lower pH, turbidity, TN and DON concentrations but significantly higher DOC, EC and TP concentrations during the winter seasons of dry years. The observed dynamics in water chemistry parameters are consistent in such that the direction of trends observed in the individual water chemistry parameters suggest flow is travelling along deeper flow paths during dry years, with longer contact times of water with the soil matrix and bedrock, which increases EC and TP. At the same time the lack of shallow flow paths that water takes means that runoff has less opportunity to flow through or over the organic rich O and A horizons of the forest soils, which results in less transport of organic matter including organic and inorganic nitrogen to streams. This lack of hydrologic connectivity during drought years has also been observed in other forested watershed studies (e.g. Blaurock et al. 2021; Yang et al. 2021; Raymond & Saiers 2014), who observed disproportionally high DOC export from catchments following long dry periods (particularly during the first storm events) and in response to forest thinning. Raymond and Saiers (2014) hypothesized that the increase in DOC concentration and flux following low discharge periods is also temperature regulated, which mainly controls the size and reactivity of the organic matter pool. In addition, in-stream biogeochemical processes might quickly consume the existing N, thereby reducing the concentration of organic and inorganic N in stream water as indicated by the significantly lower stream water NO_3^- and NH_4^+ concentrations in the spring seasons of dry years in WIL (Table 34).

In comparison to WIL, N species (TN, DON, NO_3^--N, NH_4^+-N) in TRE, UQL and ZIE showed no or only very few significant differences when comparing seasonal concentrations between wet and dry years. This could be mainly due to the nature of these watersheds. As mentioned in previous sections, there are several indicators that flow in WIL is moving along deeper flow paths (higher EC values than all other sub-watersheds and SFC), which naturally would reveal drastic differences in water chemistry between dry and wet years, the latter which would likely have a more distinct shallow flow path signature. In contrast, TRE, UQL and ZIE seem to behave very similar hydrologically and hydro-chemically, in all cases suggesting shallower flow pathways year round (as indicated by lower and similar EC values) (Table 34). In contrast, all three sub-watersheds show a significantly higher TP concentration in stream water during the winter seasons of dry years, which could be mainly driven by the spikes in TP observed during the April 6, 2018 storm event, when suspended sediment load in the South Fork Caspar Creek watershed was very high and turbidity measurements reached the maximum detection limit of the sensor. Most of the TP transported during that storm was likely in the form of particulate or sediment-attached P, since phosphate concentrations remained very low (Table 34). Similar to WIL, all three treatment sub-watersheds also showed significantly higher DOC concentrations in stream water during the winter seasons of dry years, with ZIE averaging 7.4 mg/L compared to 5.6 and 5.4 mg/L observed in TRE and UQL, respectively. These elevated DOC concentrations could be the compound effect of the mechanisms controlling DOC export after dry periods described above for WIL and the increased influx of organic matter and biomass caused by the timber harvest that was observed in ZIE in HY2020 (2nd year after harvest).

Table 34: ANOVA and post-hoc Tukey's HSD test scores for mean differences in stream water chemistry parameters comparing seasonal trends in each sub-watershed between wet and dry years. ANOVA and Tukey's HSD were calculated at a significance level of α = 0.05. N is the number of samples considered in each group.

			N	EC	pH	Turbidity	TN	NH_4^+-N	NO_3^- - N	TP	PO_4	DOC	DON
				mS	Moles H^+/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
SFC	Fall	Dry	5	200 ± 76	7.44 ± 0.5	3 ± 3	0.216 ± 0.27	0.03 ± 0.02	0.088 ± 0.15	0.212 ± 0.17	0.01 ± 0.01	4.07 ± 1	0.114 ± 0.12
		Wet	24	137 ± 30	7.42 ± 0.5	11 ± 13	0.236 ± 0.21	0.027 ± 0.03	0.017 ± 0.03	0.053 ± 0.05	0.008 ± 0.01	3.19 ± 2.2	0.198 ± 0.2
		p-value		0.138	0.933	**0.01**	0.879	0.786	0.355	0.105	0.498	0.226	0.227
	Winter	Dry	8	224 ± 71	7.04 ± 0.3	6 ± 6	0.155 ± 0.05	0.016 ± 0.01	0.013 ± 0.02	0.068 ± 0.11	0.008 ± 0.01	3.52 ± 1.5	0.126 ± 0.05
		Wet	17	129 ± 33	6.97 ± 0.2	22 ± 22	0.193 ± 0.11	0.02 ± 0.01	0.006 ± 0.01	0.061 ± 0.08	0.005 ± 0.01	3.68 ± 1.1	0.139 ± 0.11
		p-value		**0.006**	0.579	**0.008**	0.284	0.458	0.452	0.881	0.553	0.793	0.697
	Spring	Dry	20	102 ± 66	6.69 ± 0.8	8 ± 10	0.276 ± 0.49	0.108 ± 0.32	0.02 ± 0.06	0.031 ± 0.07	0.056 ± 0.12	2.28 ± 1.7	0.212 ± 0.4
		Wet	18	130 ± 17	7.35 ± 0.4	14 ± 14	0.274 ± 0.23	0.033 ± 0.04	0.012 ± 0.02	0.049 ± 0.06	0.008 ± 0.01	3.57 ± 2.3	0.236 ± 0.21
		p-value		0.079	**0.003**	0.09	0.988	0.306	0.56	0.432	0.097	0.062	0.82
	Summer	Dry	9	156 ± 51	7.32 ± 0.2	2 ± 1	0.114 ± 0.1	0.047 ± 0.08	0.019 ± 0.03	0.02 ± 0.01	0.006 ± 0.01	3.55 ± 2.1	0.086 ± 0.11
		Wet	6	170 ± 55	7.31 ± 0.4	2 ± 1	0.058 ± 0.05	0.02 ± 0.02	0.007 ± 0.01	0.018 ± 0.01	0.002 ± 0	2.06 ± 1.2	0.035 ± 0.05
		p-value		0.626	0.94	0.504	0.187	0.352	0.213	0.816	0.13	0.106	0.235
WIL	Fall	Dry	7	415 ± 65	7.77 ± 0.5	7 ± 15	0.293 ± 0.35	0.116 ± 0.15	0.027 ± 0.05	0.21 ± 0.16	0.03 ± 0.02	2.4 ± 1.6	0.157 ± 0.2
		Wet	38	181 ± 79	7.64 ± 0.4	15 ± 16	0.257 ± 0.28	0.047 ± 0.07	0.01 ± 0.02	0.045 ± 0.03	0.011 ± 0.01	2.32 ± 1.6	0.204 ± 0.23
		p-value		**<0.001**	0.532	0.216	0.805	0.276	0.412	0.031	0.023	0.913	0.596
	Winter	Dry	69	173 ± 66	6.92 ± 0.2	16 ± 9	0.154 ± 0.1	0.041 ± 0.04	0.01 ± 0.02	0.164 ± 0.13	0.01 ± 0.01	6.18 ± 3.4	0.087 ± 0.09
		Wet	76	132 ± 41	7.33 ± 0.4	37 ± 57	0.238 ± 0.15	0.034 ± 0.05	0.007 ± 0.01	0.057 ± 0.05	0.013 ± 0.01	3.43 ± 1.5	0.186 ± 0.15
		p-value		**<0.001**	**<0.001**	**0.002**	**<0.001**	0.342	0.286	**<0.001**	0.198	**<0.001**	**<0.001**
	Spring	Dry	34	169 ± 79	7.21 ± 0.3	44 ± 80	0.196 ± 0.17	0.01 ± 0.01	0.001 ± 0.01	0.071 ± 0.12	0.026 ± 0.01	2.68 ± 1.7	0.182 ± 0.17
		Wet	30	152 ± 44	7.49 ± 0.4	17 ± 17	0.281 ± 0.31	0.058 ± 0.07	0.011 ± 0.02	0.045 ± 0.03	0.011 ± 0.01	2.07 ± 0.8	0.217 ± 0.25
		p-value		0.282	**0.002**	0.063	0.187	**0.001**	**0.011**	0.246	**<0.001**	0.067	0.519
	Summer	Dry	11	303 ± 112	7.58 ± 0.4	1 ± 1	0.041 ± 0.05	0.055 ± 0.09	0.016 ± 0.03	0.022 ± 0.02	0.011 ± 0.01	3.12 ± 2.3	0.02 ± 0.03
		Wet	8	309 ± 70	7.58 ± 0.4	2 ± 3	0.089 ± 0.07	0.031 ± 0.02	0.019 ± 0.03	0.028 ± 0.02	0.01 ± 0.01	2.38 ± 2	0.053 ± 0.08
		p-value		0.887	0.993	0.341	0.148	0.416	0.851	0.525	0.649	0.465	0.296

TRE	**Fall**	Dry	8	249 ± 70	7.64 ± 0.5	3 ± 3	0.111 ± 0.08	0.035 ± 0.02	0.021 ± 0.02	0.155 ± 0.16	0.018 ± 0.01	2.96 ± 2.6	0.076 ± 0.07
		Wet	37	128 ± 35	7.48 ± 0.5	12 ± 10	0.209 ± 0.16	0.044 ± 0.06	0.012 ± 0.02	0.045 ± 0.03	0.009 ± 0.01	2.73 ± 1.9	0.158 ± 0.13
		p-value		**0.001**	0.463	**<0.001**	**0.022**	0.478	0.192	0.088	**0.016**	0.833	**0.022**
	Winter	Dry	66	129 ± 39	6.99 ± 0.2	17 ± 10	0.181 ± 0.09	0.106 ± 0.61	0.018 ± 0.02	0.215 ± 0.18	0.029 ± 0.15	5.63 ± 3	0.121 ± 0.09
		Wet	67	103 ± 21	7.16 ± 0.4	27 ± 29	0.178 ± 0.14	0.034 ± 0.04	0.013 ± 0.03	0.047 ± 0.04	0.01 ± 0.02	3.24 ± 1.5	0.12 ± 0.13
		p-value		**<0.001**	**0.004**	**0.01**	0.887	0.337	0.247	**<0.001**	0.321	**<0.001**	0.93
	Spring	Dry	32	115 ± 29	7.03 ± 0.3	109 ± 224	0.235 ± 0.23	0.016 ± 0.02	0.01 ± 0.05	0.133 ± 0.24	0.02 ± 0.01	2.46 ± 1.2	0.202 ± 0.22
		Wet	27	113 ± 13	7.29 ± 0.3	13 ± 11	0.213 ± 0.17	0.059 ± 0.07	0.012 ± 0.02	0.041 ± 0.02	0.008 ± 0.01	2.33 ± 1.2	0.149 ± 0.14
		p-value		0.711	**0.003**	**0.029**	0.682	**0.004**	0.883	**0.043**	**<0.001**	0.681	0.271
	Summer	Dry	11	164 ± 52	7.54 ± 0.4	3 ± 3	0.07 ± 0.04	0.018 ± 0.02	0.013 ± 0.02	0.027 ± 0.03	0.011 ± 0	3.04 ± 1.7	0.051 ± 0.04
		Wet	6	172 ± 60	7.43 ± 0.3	5 ± 6	0.06 ± 0.06	0.02 ± 0.01	0.02 ± 0.02	0.033 ± 0.02	0.008 ± 0	1.78 ± 0.9	0.037 ± 0.04
		p-value		0.796	0.524	0.392	0.712	0.812	0.459	0.641	0.328	0.07	0.497
UQL	**Fall**	Dry	2	393 ± 141	8.15 ± 0.4	10 ± 13	0.23 ± 0.01	0.055 ± 0.05	0 ± 0	0.04 ± 0.01	0.02 ± 0.01	2.76 ± 2.1	0.175 ± 0.06
		Wet	31	123 ± 22	7.37 ± 0.5	20 ± 11	0.252 ± 0.17	0.048 ± 0.05	0.003 ± 0.01	0.037 ± 0.03	0.008 ± 0.01	2.87 ± 1.3	0.205 ± 0.16
		p-value		0.225	0.221	0.458	0.51	0.882	**0.009**	0.808	0.449	0.952	0.633
	Winter	Dry	71	129 ± 36	6.93 ± 0.1	28 ± 9	0.192 ± 0.17	0.054 ± 0.04	0.033 ± 0.14	0.151 ± 0.14	0.005 ± 0.01	5.46 ± 2.5	0.104 ± 0.16
		Wet	56	102 ± 20	7.17 ± 0.3	25 ± 12	0.168 ± 0.11	0.04 ± 0.05	0.007 ± 0.02	0.033 ± 0.03	0.004 ± 0.01	3.85 ± 1.3	0.121 ± 0.1
		p-value		**<0.001**	**<0.001**	0.055	0.372	0.103	0.119	**<0.001**	0.619	**<0.001**	0.441
	Spring	Dry	33	125 ± 32	7.06 ± 0.2	34 ± 47	0.187 ± 0.15	0.025 ± 0.05	0.008 ± 0.04	0.044 ± 0.07	0.025 ± 0.04	2.89 ± 1.5	0.145 ± 0.15
		Wet	29	122 ± 23	7.34 ± 0.5	20 ± 12	0.253 ± 0.18	0.051 ± 0.05	0.002 ± 0.01	0.037 ± 0.02	0.009 ± 0.01	2.68 ± 1.1	0.204 ± 0.17
		p-value		0.716	**0.005**	0.124	0.129	0.055	0.437	0.558	**0.035**	0.551	0.149
	Summer	Dry	5	204 ± 64	7.16 ± 0.2	4 ± 2	0.381 ± 0.43	0.067 ± 0.07	0.055 ± 0.09	0.066 ± 0.1	0.054 ± 0.11	5.33 ± 5.4	0.252 ± 0.31
		Wet	4	206 ± 75	7.39 ± 0.3	10 ± 3	0.325 ± 0.58	0.103 ± 0.17	0.03 ± 0.04	0.033 ± 0.03	0 ± 0	2.28 ± 1.8	0.198 ± 0.37
		p-value		0.976	0.307	**0.028**	0.879	0.71	0.579	0.526	0.329	0.288	0.819
ZIE	**Fall**	Dry	7	227 ± 60	17.49 ± 26.4	3 ± 3	0.174 ± 0.15	0.041 ± 0.04	0.04 ± 0.06	0.167 ± 0.16	0.024 ± 0.03	2.94 ± 1.7	0.106 ± 0.09
		Wet	37	113 ± 28	7.51 ± 0.6	21 ± 18	0.275 ± 0.2	0.019 ± 0.02	0.014 ± 0.03	0.055 ± 0.04	0.006 ± 0.01	3.29 ± 2	0.245 ± 0.19
		p-value		**0.002**	0.356	**<0.001**	0.154	0.158	0.311	0.113	0.142	0.64	**0.007**
	Winter	Dry	77	119 ± 34	6.98 ± 0.2	24 ± 10	0.339 ± 0.5	0.066 ± 0.18	0.081 ± 0.12	0.224 ± 0.16	0.028 ± 0.15	7.4 ± 3.2	0.194 ± 0.3
		Wet	78	92 ± 22	7.17 ± 0.3	68 ± 131	0.222 ± 0.18	0.027 ± 0.03	0.01 ± 0.02	0.06 ± 0.1	0.003 ± 0.01	4.39 ± 2.1	0.179 ± 0.18
		p-value		**<0.001**	**<0.001**	**0.004**	0.058	0.059	**<0.001**	**<0.001**	0.146	**<0.001**	0.718

	Spring	Dry	35	122 ± 34	7.08 ± 0.2	106 ± 262	0.223 ± 0.18	0.017 ± 0.02	0.005 ± 0.02	0.118 ± 0.28	0.03 ± 0.06	3.03 ± 1.5	0.194 ± 0.18
		Wet	27	102 ± 17	7.33 ± 0.4	25 ± 19	0.29 ± 0.22	0.022 ± 0.02	0.013 ± 0.03	0.053 ± 0.04	0.007 ± 0.01	2.9 ± 1.4	0.258 ± 0.21
		p-value		**0.003**	**0.007**	0.087	0.214	0.242	0.213	0.201	**0.027**	0.723	0.211
	Summer	Dry	10	154 ± 59	7.49 ± 0.5	2 ± 1	0.06 ± 0.06	0.033 ± 0.08	0.008 ± 0.01	0.01 ± 0.01	0.004 ± 0.01	2.38 ± 1.5	0.052 ± 0.06
		Wet	8	153 ± 58	7.33 ± 0.4	4 ± 2	0.046 ± 0.04	0.023 ± 0.01	0.014 ± 0.01	0.016 ± 0.01	0.003 ± 0	2.48 ± 1.4	0.021 ± 0.02
		p-value		0.987	0.449	**0.005**	0.55	0.688	0.382	0.198	0.467	0.888	0.16

5.3.3 Elemental Relationships

Relationships between water chemistry parameters and flow were evaluated through correlation matrices for each sub-watershed and the outlet of South Fork Caspar Creek. These assessed variables include stream discharge (Q), Electrical Conductivity (EC), pH, turbidity (TURB), total nitrogen (TN), nitrate (NO_3^--N), ammonium (NH_4^+-N), dissolved organic nitrogen (DON), Total Phosphorous (TP), Phosphate (PO4), and dissolved organic carbon (DOC). Correlation matrices of all variables are summarized for SFC and the sub-watersheds WIL, TRE, UQL, and ZIE in Figures 21-25 showing both the pre-harvest and post-harvest relationships. Correlation matrices displayed in Figures 21-25 were estimated using the Spearman Rank correlation coefficient and show relationships that are significant at the 0.001, 0.01, and 0.05 significance level, respectively.

High degrees of positive correlation (coefficients >0.6) are observed in all watersheds between turbidity and discharge, TN and DON, and in some sub-watersheds between turbidity and TP or DOC (mainly observed during the pre-harvest period). Negative correlation trends between discharge and EC, turbidity and EC, and in some watersheds pH and turbidity or TP or DOC are also observable. The high degree of negative or positive correlation between biogeochemical variables is a good indication that the selected sub-watersheds behave hydrologically and biogeochemically in a similar manner.

Relationships between individual nutrient species were somewhat surprisingly weak in all five watersheds. TN and DON were strongly positively correlated because DON is estimated as the difference between TN and the sum of NO_3^--N and NH_4^+-N and represented the largest fraction in TN concentrations. However, NO_3^--N and NH_4^+-N did not show significant relationships to TN, indicating that the observed DIN concentrations in stream water were not influenced by a common source or general hydrologic transport patterns in the watersheds.

Although visual inspection of nutrient concentrations in stream water showed generally an increase in N, P or C concentrations with discharge (particularly during some of the fall and spring storm events), most of the observed nutrient concentrations showed weak or no statistical relationships with discharge. Actual scatterplots of water chemistry parameters against discharge show a lot of scatter indicating that multiple transport processes might be involved at different seasons and that sources of the monitored nutrients change throughout the year.

One of the few obvious relationships that can be observed, is the clear negative correlation between discharge and EC, indicating a clear dilution trend of weathering byproducts in discharge during storm events. Likewise, pH was negatively correlated to discharge and was often dipping below the pH=7 level during storm events indicating shallower flow paths of runoff through the humus-rich and more acidic A and AB-horizons. These flow paths are further corroborated by the statistically significant, positive correlation between DOC and discharge, which indicates that export of particulate and dissolved organic carbon increased during storm events, as riparian zones were better hydrologically connected to adjacent hillslopes and overall the fraction of the watershed that contributed runoff to streamflow increased. Figures 21-25 also show significant positive correlations between TP, TN, turbidity, DOC and discharge. This is not surprising since higher discharge during storm events often means higher erosive forces acting on the stream channel, which can increase channel erosion and the concentration of suspended sediments. However, a large part of the higher suspended sediment load observed during storm events might actually come from runoff-generating areas adjacent to the stream that saturated during storm events. Such areas might be prone to overland flow or some form of concentrated runoff (e.g. subsurface stormflow or concentrated flow along forest roads) capable of eroding soil or litter, which can transport organic matter or particulate phosphorus attached to soil sediment to the stream. Many of the pre-harvest correlation plots also showed a negative correlation between discharge and phosphate, which indicates a clear dilution effect of phosphate during storm events, again caused by the shallow flow pathways and reduced contact time of water with bedrock minerals that could provide P-rich weathering byproducts.

A comparison of correlations between the pre-harvest and post-harvest periods indicates that most of the significant statistical correlations between discharge and water chemistry parameters did become weaker or not significant during the post-harvest period. This could be due to the timber harvest processes themselves (e.g. disturbance of litter and soil layers) or due to the generally drier hydrologic conditions observed in HY 2019 and HY2020 and associated overall reduction in flow and transport observed within the South Fork Caspar Creek watershed. The latter hypothesis is supported by the change in correlations observed in WIL, the control sub-watershed, which did not experience any timber harvest treatments but shows a clear reduction and sometimes reversal of correlation trends between the pre-harvest and post-harvest period. In the post-harvest period all sub-watersheds and SFC show significant correlations between discharge, EC, pH and turbidity and to a lesser extent between discharge and TN, DON and DOC. Again, since most of the TN observed in stream water at Caspar Creek is composed of DON, the increased availability of organic matter or biomass after the timber harvest is likely increasing the influx of organic carbon and organic-N into streams, resulting in higher concentrations of DOC and DON during storm events and therefore in a stronger statistical relationship between the two.

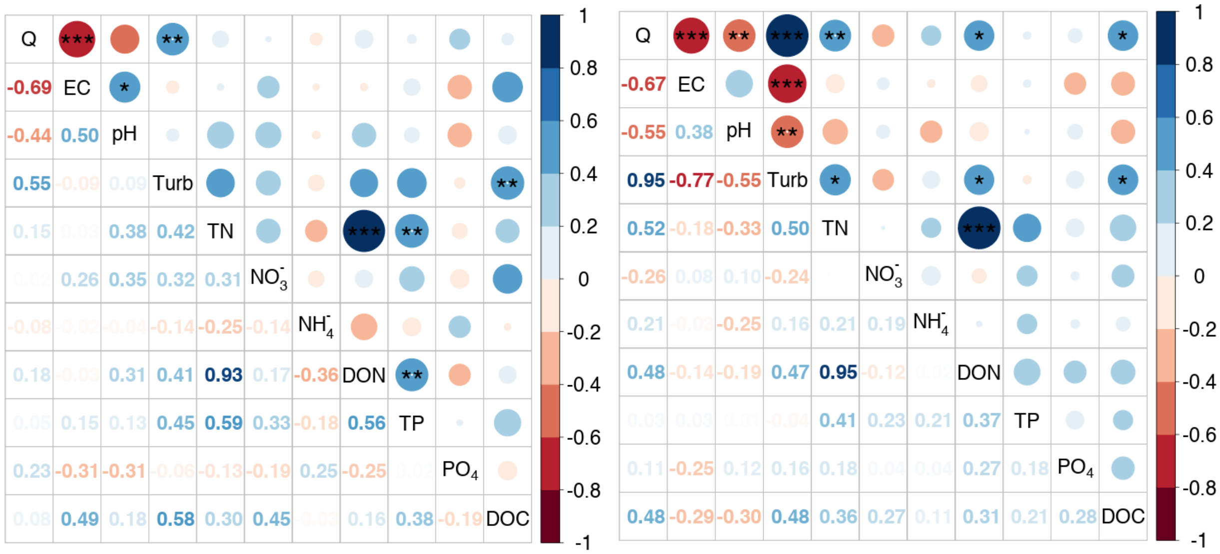

Figure 21: Correlation plot of flow and major water chemistry parameters at SFC for the pre-yarding (left) and post-yarding (right) periods. Three, two and one star indicate significant Pearson correlation coefficient at the 0.001, 0.01, and 0.05 significance level, respectively.

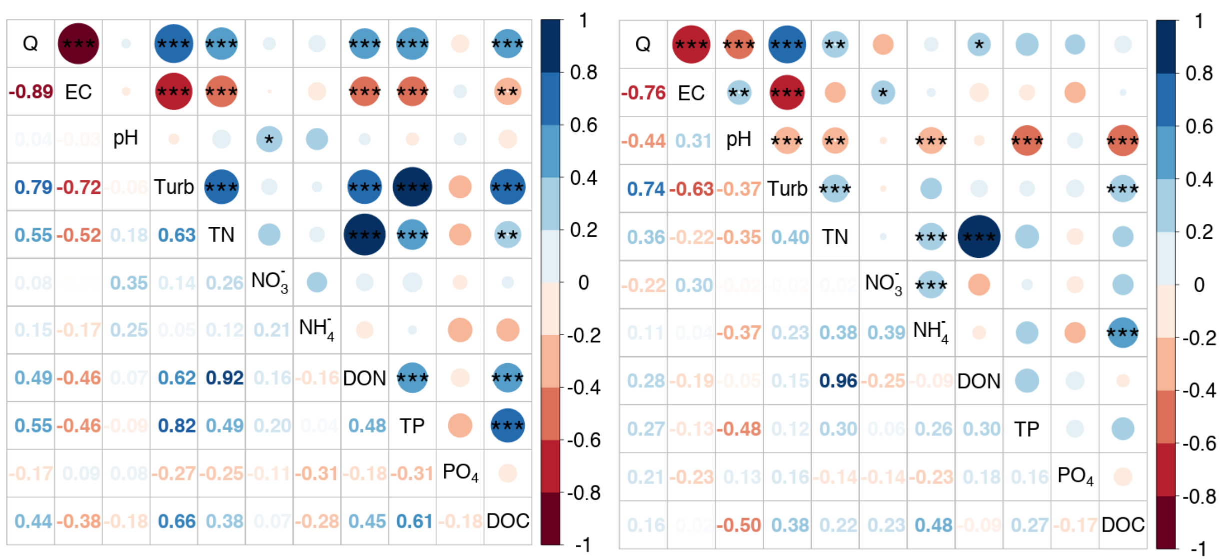

Figure 22: Correlation plot of flow and major water chemistry parameters at WIL for the pre-yarding (left) and post-yarding (right) periods. Three, two and one star indicate significant Pearson correlation coefficient at the 0.001, 0.01, and 0.05 significance level, respectively.

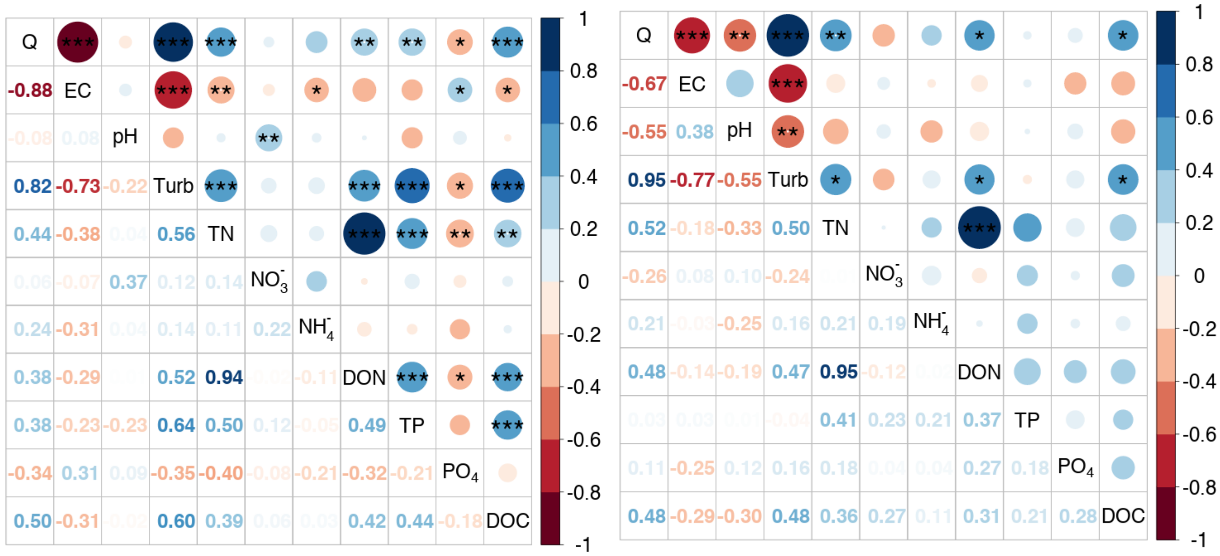

Figure 23: Correlation plot of flow and major water chemistry parameters at TRE for the pre-yarding (left) and post-yarding (right) periods. Three, two and one star indicate significant Pearson correlation coefficient at the 0.001, 0.01, and 0.05 significance level, respectively.

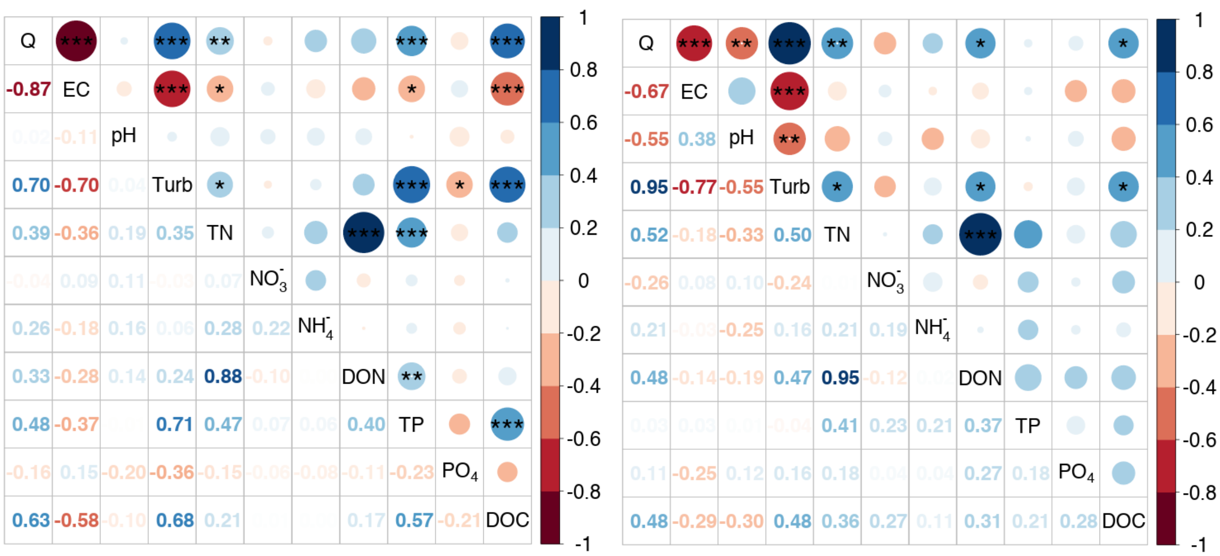

Figure 24: Correlation plot of flow and major water chemistry parameters at UQL for the pre-yarding (left) and post-yarding (right) periods. Three, two and one star indicate significant Pearson correlation coefficient at the 0.001, 0.01, and 0.05 significance level, respectively.

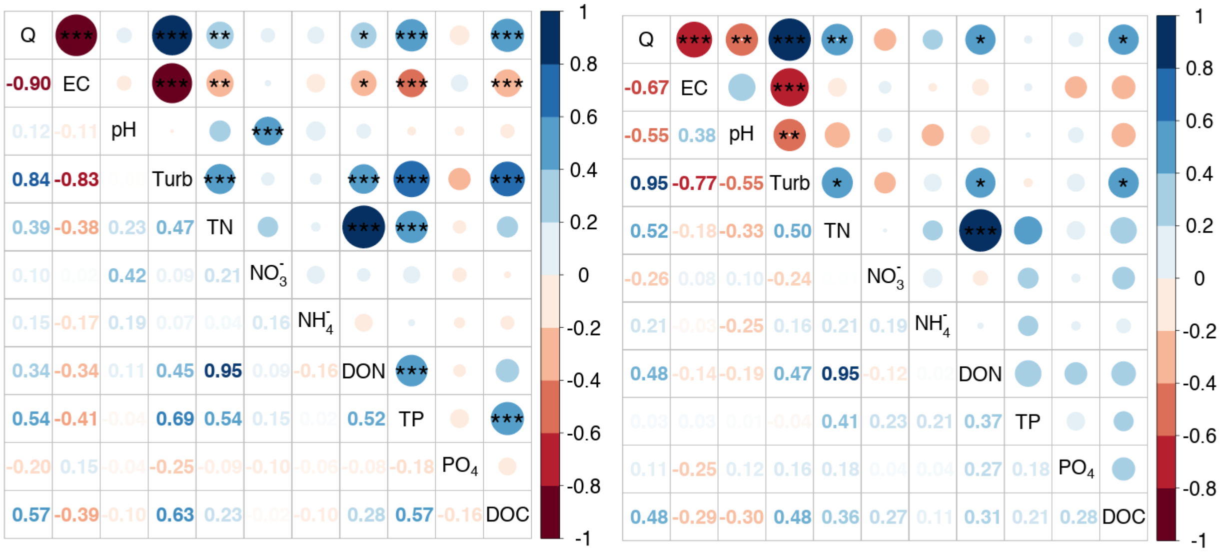

Figure 25: Correlation plot of flow and major water chemistry parameters at ZIE for the pre-yarding (left) and post-yarding (right) periods. Three, two and one star indicate significant Pearson correlation coefficient at the 0.001, 0.01, and 0.05 significance level, respectively.

5.4 Nutrient Fluxes in Stream Water

Using the elemental concentrations of N, P and C from the 4-year study period, nutrient fluxes were calculated by multiplying the stream discharge (L/s) with nutrient concentrations (mg/L) and integrating these observations over the sampling intervals. Since forest management practices do not only influence the source and transport of nutrients from the watersheds to streams but often also create significant changes in water yield (mm/day), estimated nutrient loads (kg/ha/period) provide unique insights into how forest management practices might influence overall nutrient export from forested watersheds under different hydrologic regimes.

Tables 35 and 36 show nutrient fluxes for the four treatment sub-watersheds and the outlet of South Fork Caspar Creek comparing the pre-harvest and post-harvest periods as well as hydrologic years. Estimates are only shown for nutrient fluxes in streamflow since constituents in precipitation were not monitored over the 4-year study period. Elemental fluxes of TP, PO4, NO_3^--N and NH_4^+-N were relatively low in comparison to DOC, TN and DON. NO_3^--N and PO_4-P varied between 0.05 and almost 0.45 kg/ha during the pre-harvest and post-harvest period, respectively (Table 35). NO_3^--N export was generally lower in the post-harvest period in all watersheds, except ZIE, which saw an increase in NO_3^--N flux post-harvest (from 0.12 to 0.18 kg/ha). SFC, UQL and WIL all averaged around 0.5-0.6 kg/ha during the post-harvest period (Table 35).

NH_4^+-N and TP fluxes were slightly higher than NO_3^--N and PO_4-P ranging between 0.26 and 0.66 kg/ha and 0.06 and 0.17 kg/ha respectively in the pre- and post-harvest periods. Similar to the NO_3^--N flux trends, NH_4^+-N load was lower in the post-harvest period than the pre-harvest period in all watersheds. NH_4^+-N at the outlet of South Fork Caspar Creek was in loading comparable to the control sub-watershed WIL, averaging around 0.26-0.29 kg/ha for the post-harvest period. In contrast, all other treatment sub-watersheds showed higher fluxes during the post-harvest period ranging between 0.33 and 0.37 kg/ha. TP load was lowest in the control sub-watershed in the post-harvest period, while all other treatment sub-watershed and SFC showed higher fluxes reaching in some cases 2.5 times the TP load exported from WIL (e.g. ZIE post-harvest TP load). These trends indicate a clear relationship between timber harvest treatment, discharge increase and likely a significant increase in particulate P attached to suspended sediments (since PO_4-P remained largely indifferent between watersheds). The TN and DON fluxes showed a clear decrease following the timber harvest treatments. In comparison to the pre-harvest period, TN fluxes decreased by a factor of 1.6 to 3.2 across the different treatment levels, with the smallest decrease observed in ZIE (75% stand reduction). TN and DON export was greatest in 2017, the wettest year of the 4-year study period, when TN and DON export was on average four times greater than during any of the other years. When comparing the TN and DON export among the treatment watersheds, both TRE and UQL show similar TN and DON fluxes as the control watershed WIL, while ZIE (75% stand reduction) and SFC (integrated watershed response) show TN and DON fluxes that are about 45% to 85% higher than the TN and DON fluxes from WIL (Table 35). DOC fluxes at the outlets of South Fork Caspar Creek watershed and the control sub-watershed WIL were comparatively low in the pre-harvest period (39.19 and 34.56 kg/ha respectively), compared to the three treatment sub-watersheds (TRE, UQL, ZIE), which averaged around 44 kg/ha in the pre-harvest period. WIL showed the lowest DOC flux of all measuring points during the pre-harvest period, which decreased even more (by 21%) during the post-harvest period, likely due to the drier conditions and associated lower streamflow. DOC fluxes increased substantially in UQL and ZIE (55% and 75% timber harvest) compared to the control watershed WIL by 54-102% with the highest increase observed in ZIE as indicated in Table 35. DOC flux also increased at the watershed outlet of South Fork Caspar Creek to an average flux of 37.85 kg/ha, which reflects an increase by 18%. The increase observed in DOC, TN and DON after timber harvest is consistent with other studies, who attribute these increased fluxes to increased availability of biomass and organic matter after the timber removal and increase transport of litters and biomass into streams. DOC fluxes could likely have been higher in the post-harvest period if Caspar Creek would have experienced a wet year like 2017. Despite the shorter pre-harvest period (pre-harvest: 8/1/2016 to 4/30 or 7/31/2018 which equals 637 and 729 days, post-harvest: 5/1 or 8/1/2018 to 7/31/2020 which equals 730 and 822 days, respectively), the total flow volume leaving the SFC watershed was 35% greater than during the post-harvest period (5.4 million m^3 vs 3.995 million m^3). In addition, there were more missing samples for the post-harvest period (due to COVID pandemic) which might have influenced total load estiamtes.

Table 35: Fluxes of major nutrients in stream water estimated for the outlet (SFC) and the four sub-watersheds (WIL, TRE, UQL and ZIE) within South Fork Caspar Creek for the pre-harvest

and post-harvest periods. Note that the pre-harvest values for SFC are not reflective of the full pre-harvest period since sampling at SFC did not start until Jan 2017.

		DOC	TN	NO_3^--N	$NH4^+$-N	DON	TP	PO_4-P
		Elemental Flux (kg/ha/period)						
SFC	pre-yard	39.19	5.16	0.45	0.29	4.44	0.50	0.11
	post-yard	37.85	1.65	0.06	0.29	1.42	0.65	0.11
WIL	pre-yard	34.56	3.72	0.09	0.59	3.04	0.72	0.15
	post-yard	27.40	1.17	0.05	0.26	0.98	0.48	0.11
TRE	pre-yard	44.98	3.77	0.20	0.66	2.94	1.06	0.17
	post-yard	36.49	1.38	0.11	0.37	1.03	0.86	0.17
UQL	pre-yard	43.39	2.81	0.05	0.54	2.23	0.55	0.06
	post-yard	34.17	1.30	0.05	0.33	1.00	0.51	0.09
ZIE	pre-yard	43.68	3.88	0.12	0.46	3.31	1.32	0.08
	post-yard	55.33	2.46	0.18	0.36	1.81	1.28	0.12

Table 36 and Figure 26 summarize the annual elemental fluxes for major nutrients (kg/ha/yr) for the four-year study period. The breakdown of elemental fluxes on a hydrological year basis reflects largely some of the dynamics discussed for Table 35. Nutrient fluxes were generally higher during wet years (e.g. HY2017, HY2019) than dry years. Considering that HY2017 was an extreme year, comparison of HY2017 and HY2019 provides some unique insights into the role that extreme hydrological events play in nutrient export compared to forest harvest disturbance events. Because sampling at SFC was hindered for several months in HY2017, many of the elemental fluxes listed for SFC in HY2017 are likely under-estimates. However, a comparison of WIL, the control watershed, with the three treatment sub-watersheds indicates clear differences in DOC, TN and TP.

Table 36: Fluxes of major nutrients in stream water estimated for the outlet (SFC) and the four sub-watersheds (WIL, TRE, UQL and ZIE) within South Fork Caspar Creek for the pre-harvest and post-harvest periods. Note that only partial data was available for SFC in HY2017, hence resulting in low loads.

		DOC	TN	NO_3^--N	$NH4^+$-N	DON	TP	PO_4^+-P
		Elemental Flux (kg/ha/yr)						
SFC	HY2017	29.89	4.39	0.37	0.18	3.83	0.41	0.04
	HY2018	9.54	0.80	0.08	0.17	0.62	0.10	0.09
	HY2019	29.10	1.25	0.04	0.19	1.07	0.36	0.06
	HY2020	8.43	0.37	0.01	0.03	0.33	0.29	0.02
WIL	HY2017	26.72	3.06	0.08	0.51	2.47	0.47	0.09
	HY2018	7.83	0.65	0.01	0.08	0.57	0.24	0.06
	HY2019	20.24	1.05	0.03	0.19	0.88	0.33	0.09
	HY2020	6.96	0.11	0.02	0.06	0.09	0.14	0.02
TRE	HY2017	34.57	2.91	0.18	0.58	2.15	0.48	0.09
	HY2018	9.79	0.82	0.02	0.08	0.75	0.58	0.08
	HY2019	23.58	1.00	0.05	0.26	0.81	0.30	0.13

	HY2020	12.93	0.39	0.06	0.11	0.23	0.56	0.04
UQL	HY2017	34.53	2.20	0.04	0.48	1.68	0.38	0.02
	HY2018	8.77	0.60	0.01	0.06	0.54	0.16	0.04
	HY2019	27.16	1.08	0.03	0.25	0.85	0.24	0.08
	HY2020	7.08	0.23	0.02	0.08	0.15	0.27	0.01
ZIE	HY2017	33.71	3.05	0.11	0.39	2.55	0.45	0.03
	HY2018	10.27	0.84	0.01	0.07	0.77	0.87	0.05
	HY2019	38.39	1.70	0.06	0.22	1.48	0.74	0.08
	HY2020	16.94	0.76	0.12	0.14	0.33	0.54	0.04

DOC export in WIL varied between 6.88 and 26.72 kg/ha/yr across the four hydrologic years and was on average 3-6 kg/ha lower every hydrologic year than the DOC flux observed in TRE, UQL and ZIE. Note, that several indicators (e.g. EC, pH) suggest that flow in the control sub-watershed WIL is following deeper flow pathways resulting in higher weathering byproduct loads in stream water (as indicated by higher EC and PO_4-P) compared to the other sub-watersheds. DOC load in TRE, UQL and ZIE is comparable during HY2017 and HY2018, varying around 34 and 8-10 kg/ha/yr, respectively. However, DOC fluxes increased substantially during HY2019 in all three treatment sub-watersheds, whereby the magnitude of the increase is clearly related to the treatment level (Figure 26). DOC export from WIL equaled 20.24 kg/ha in HY2019, but was 23.58, 27.16, and 38.39 kg/ha in TRE, UQL and ZIE respectively, representing an increase by a factor of 1.16, 1.34 and 1.89, respectively. As shown in Figure 26g, the DOC flux is linearly related to the percentage of timber removed in each sub-watersheds (R^2=0.82 for HY2019, R^2=0.50 for HY2020), indicating a clear dependence on the increased DOC flux to biomass and organic matter availability from the timber removal. As shown in Table 36, DOC export increased the most in the first year following the timber removal, but is still elevated in the second year after the timber removal compared to the pre-harvest DOC flux. However, even in HY2020, the second year after the timber removal, which was a low precipitation year with only 534 mm (compared to 1372 mm in HY2019), DOC export varied between 7.08 and 12.93 kg/ha/yr in the three treatment sub-watersheds (1.01-2.43-fold of the DOC export of WIL in HY2020). If precipitation would have been higher during HY 2020, DOC load could have easily exceeded the amounts estimated for HY2019.

Among the other elemental fluxes, TN likewise saw a clear increase across the treatment sub-watersheds for HY2019 and HY2020 in comparison to the control watershed WIL (Table 36, Figure 26). However, TN export was overall greatest during the very wet HY2017 and none of the three other years in the four year study period could exceed the TN flux observed in HY2017, despite the fact that some sub-watersheds had 75% of the timber stand removed. However, both HY2019 and HY2020 showed a clear increase in annual TN flux with the percent timber removed from the watershed. Most of the increase in TN flux observed in the sub-watersheds were timber was removed is due to an increase in DON export as indicated by Figure 26c, since about 60-80% of the total TN exported is contributed in the form of DON, but HY2019 saw a clear increase in NH_4^+-N export and HY2020 saw a clear increase in NO_3^--N export with increased timber removal (Figure 26b). The increase in NO_3^--N export two years after timber removal observed in this study is consistent with the findings of the 2nd Experiment of the Caspar Creek timber removal study (e.g. Dahlgren 1998) and other studies (e.g. Bernhardt et al. 2003). Trends in TP and PO_4-P vs. percent timber removal are less clear. Both elements show a dilution effect during the very wet HY2017, while TP shows an increase in TP vs. percent timber removed in all other HY and PO_4-P shows no conclusive trends for all other years. Together these results clearly indicate that hydrologic connectivity of the watershed and the larger runoff source area accessed during wet years, can substantially increase the transport of N from forest soils to streams.

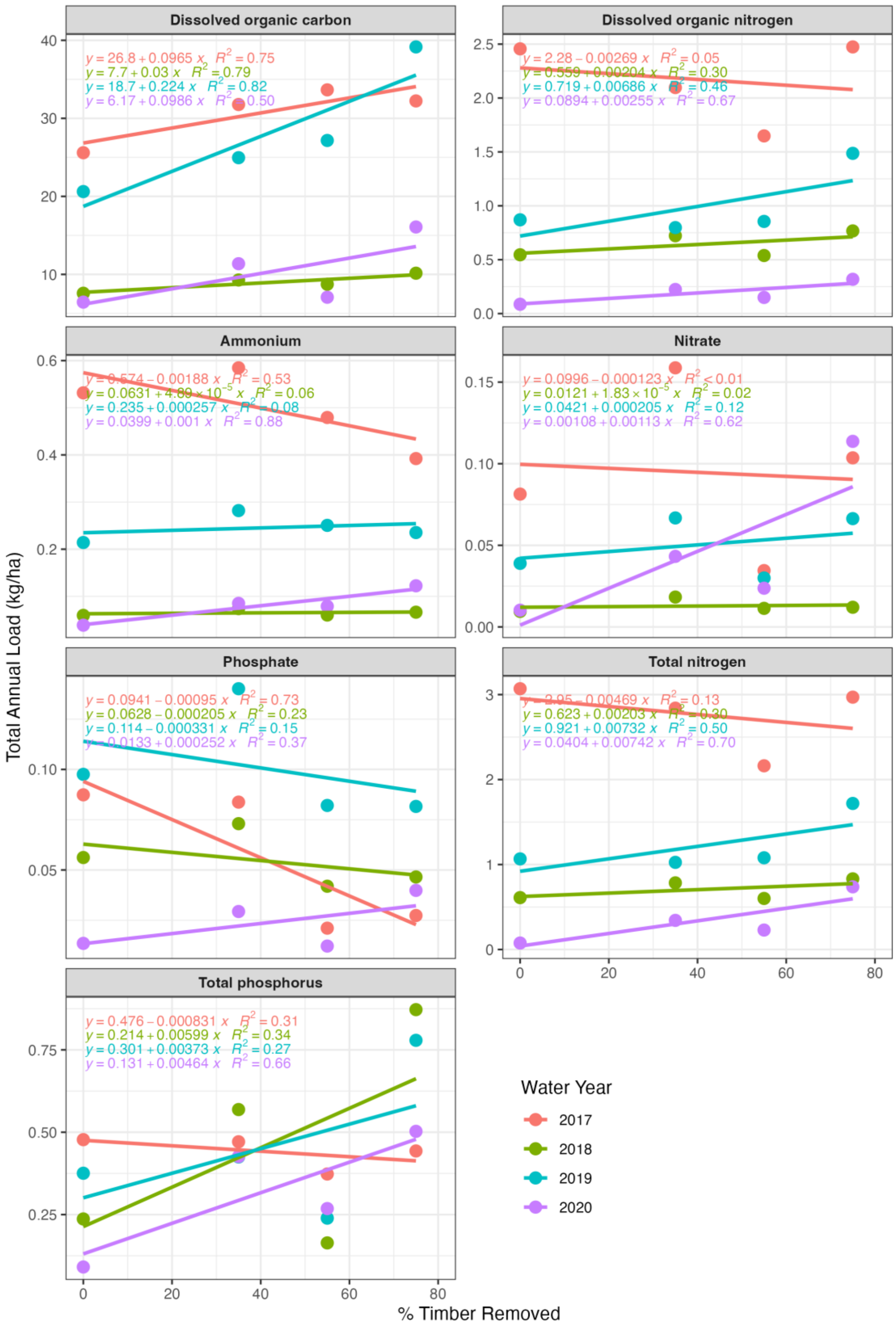

Figure 26: Annual elemental nutrient fluxes (kg/ha/yr) vs. percent timber removed in each sub-watershed for each hydrological year in the 4-year study period. Plots show TN (a), NO_3^--N (b), DON (c), NH_4^+-N (d), TP (e), PO_4-P (f), and DOC (g).

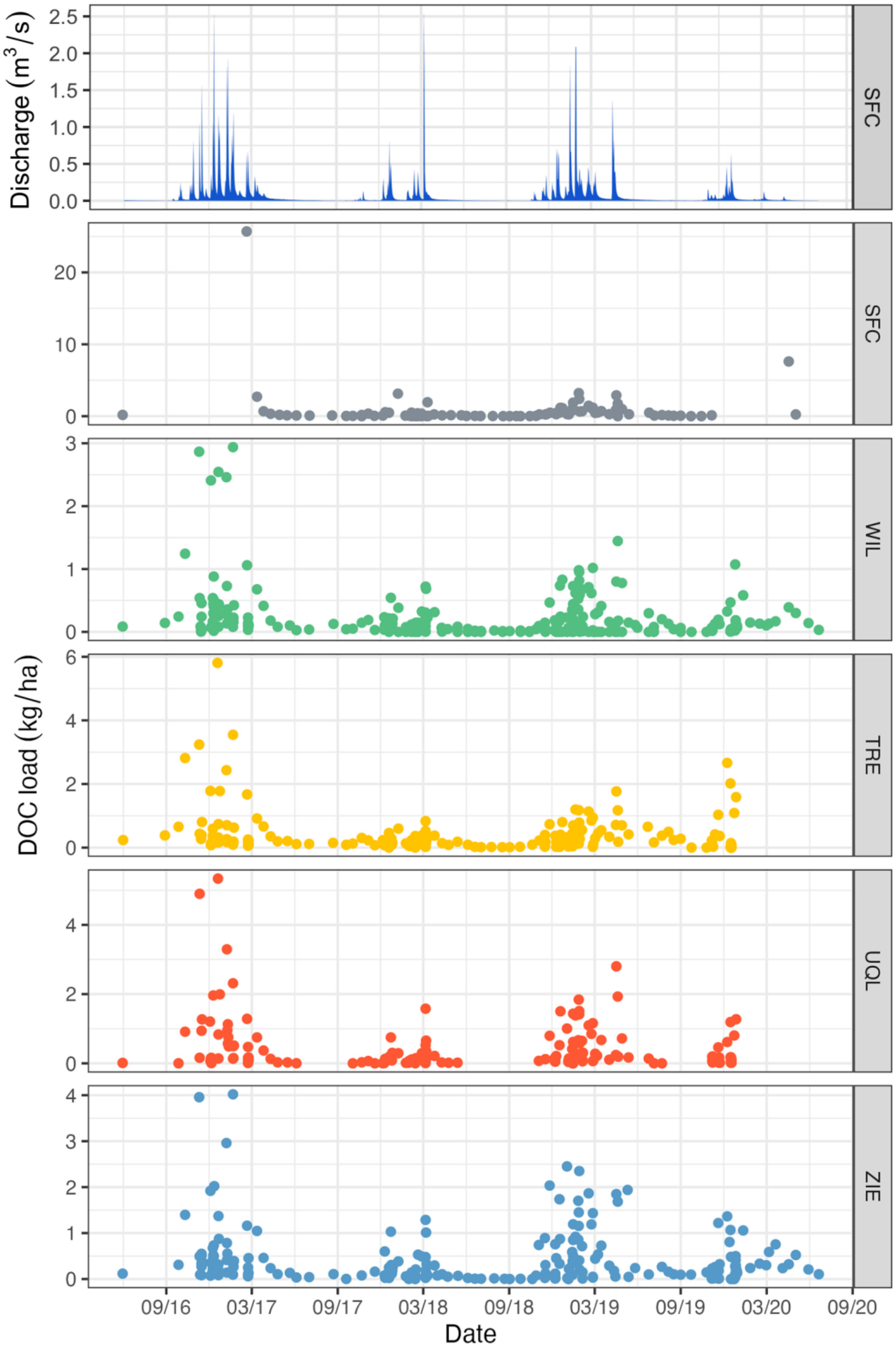

Figure 27: Dissolved Organic Carbon flux in stream water from the treatment sub-watersheds (WIL, TRE, UQL and ZIE) and South Fork Caspar Creek (SFC) for the four-year study period. Please note that y-axes differ in range.

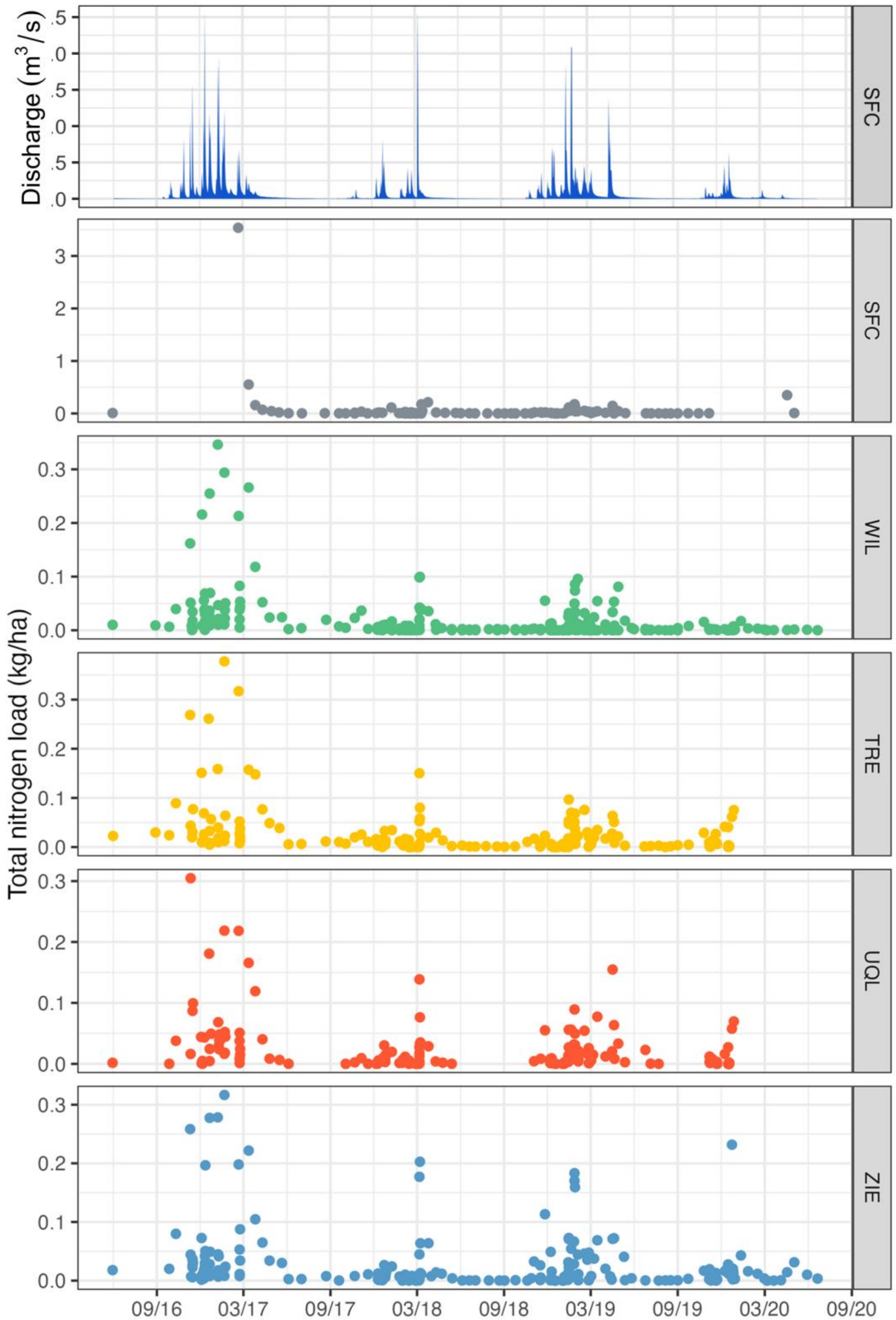

Figure 28: Total nitrogen flux in stream water from the treatment sub-watersheds (WIL, TRE, UQL and ZIE) and South Fork Caspar Creek (SFC) for the four-year study period. Please note that y-axes differ in range.

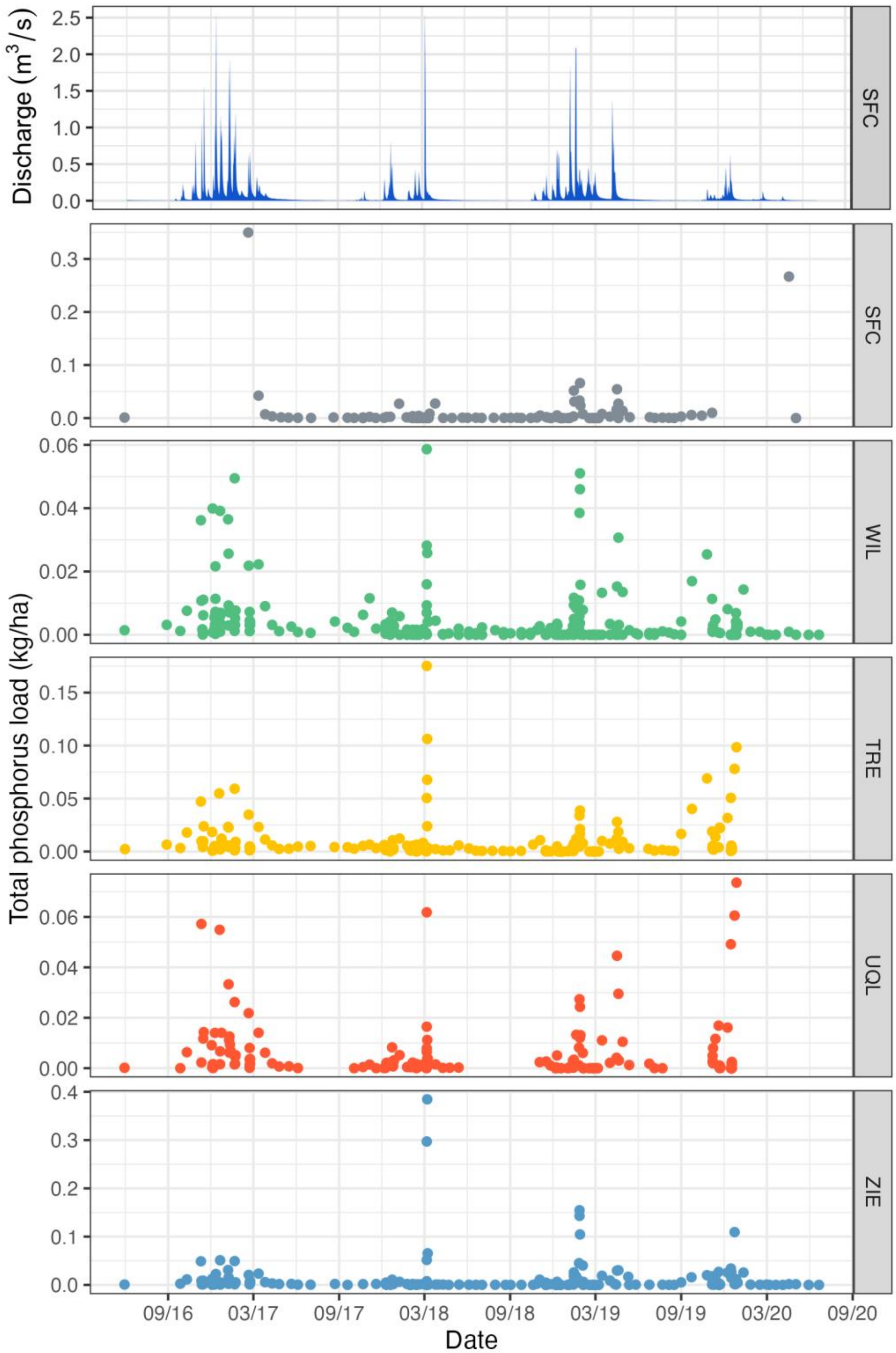

Figure 29: NO_3^- flux in stream water from the treatment sub-watersheds (WIL, TRE, UQL and ZIE) and South Fork Caspar Creek (SFC) for the four-year study period. Please note that y-axes differ in range.

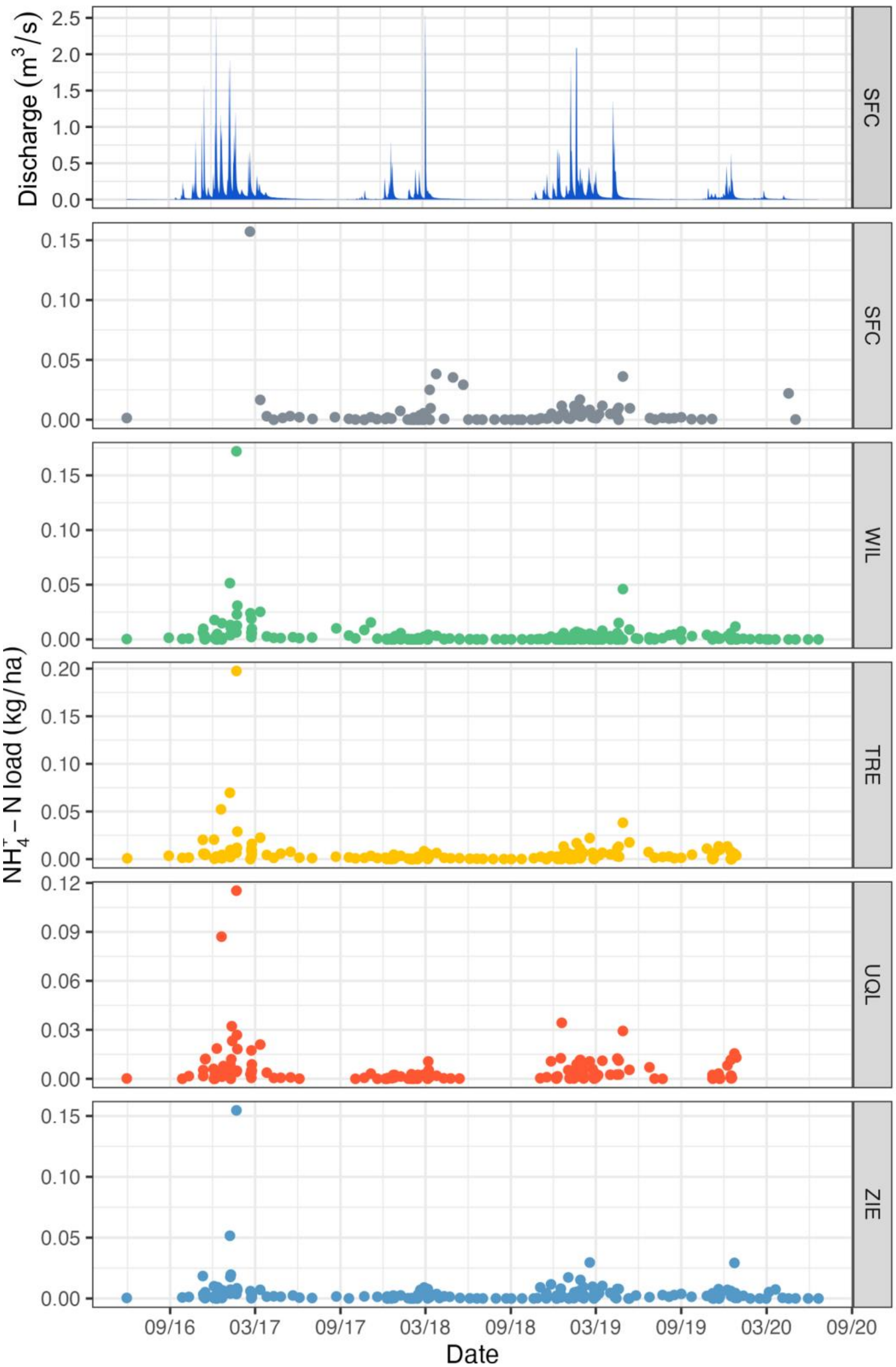

Figure 30: NH_4^+ flux in stream water from the treatment sub-watersheds (WIL, TRE, UQL and ZIE) and South Fork Caspar Creek (SFC) for the four-year study period. Please note that y-axes differ in range.

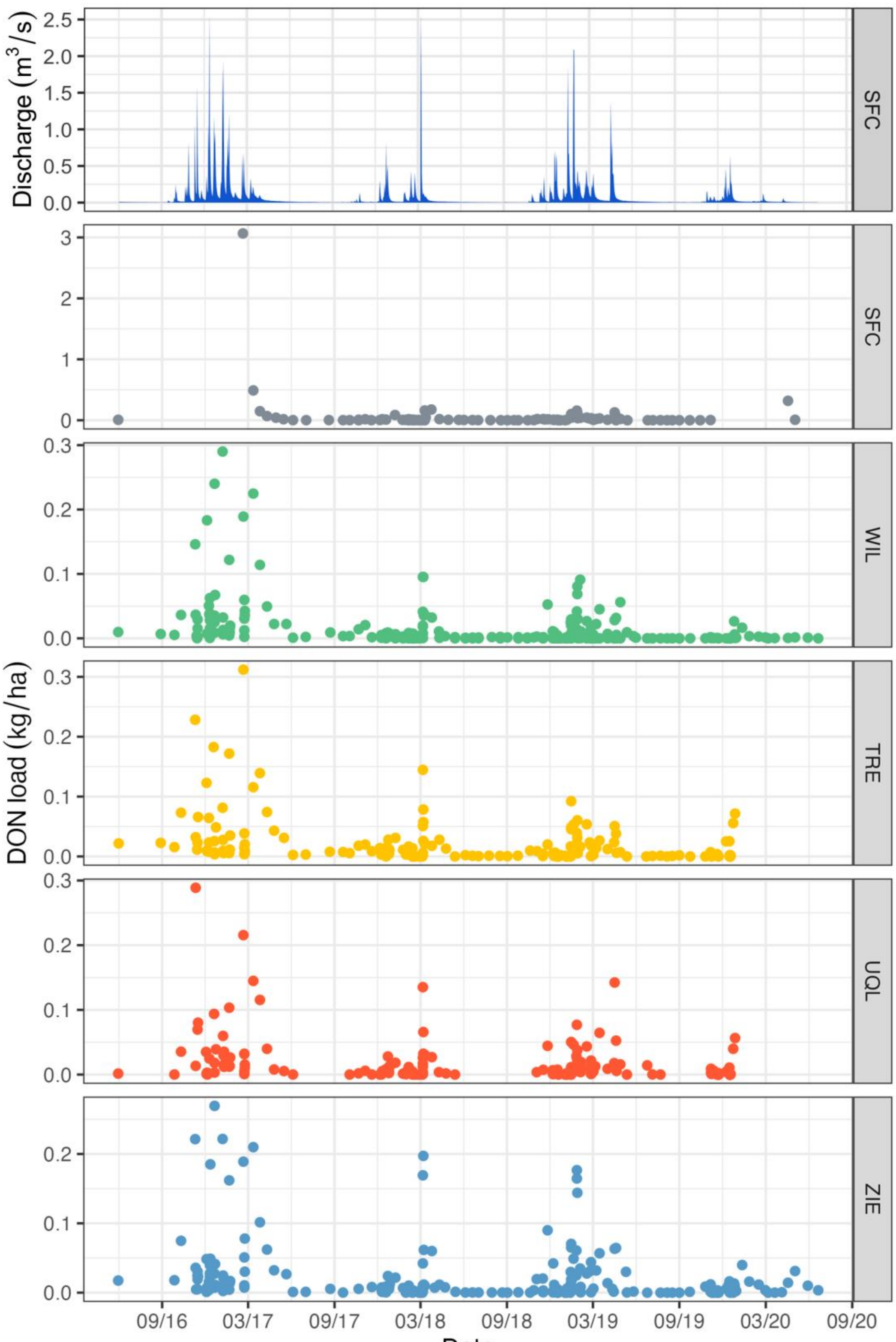

Figure 31: Dissolved Organic Nitrogen (DON) flux in stream water from the treatment sub-watersheds (WIL, TRE, UQL and ZIE) and South Fork Caspar Creek (SFC) for the four-year study period. Please note that y-axes differ in range.

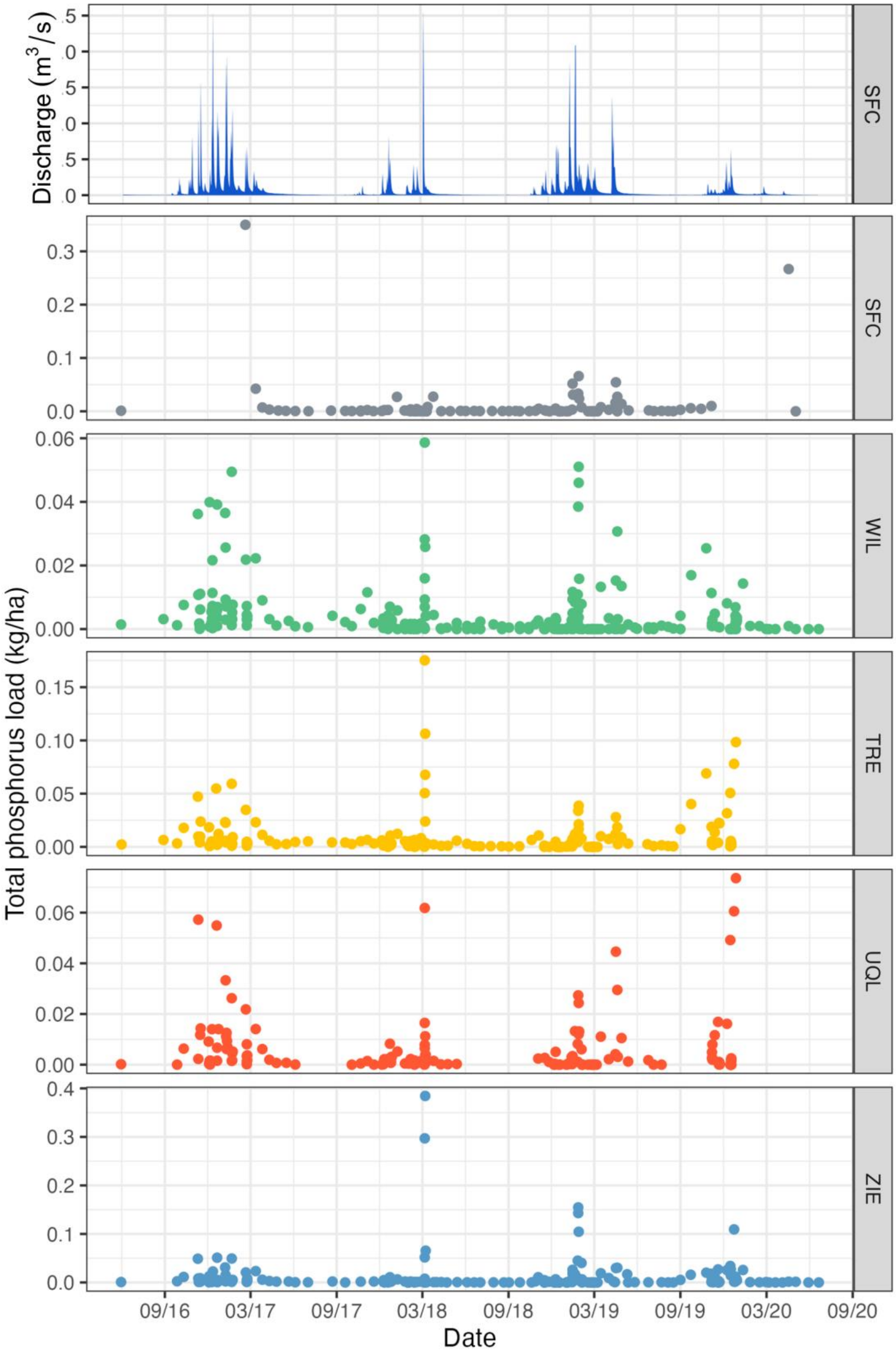

Figure 32: Total phosphorus flux in stream water from the treatment sub-watersheds (WIL, TRE, UQL and ZIE) and South Fork Caspar Creek (SFC) for the four-year study period. Please note that y-axes differ in range.

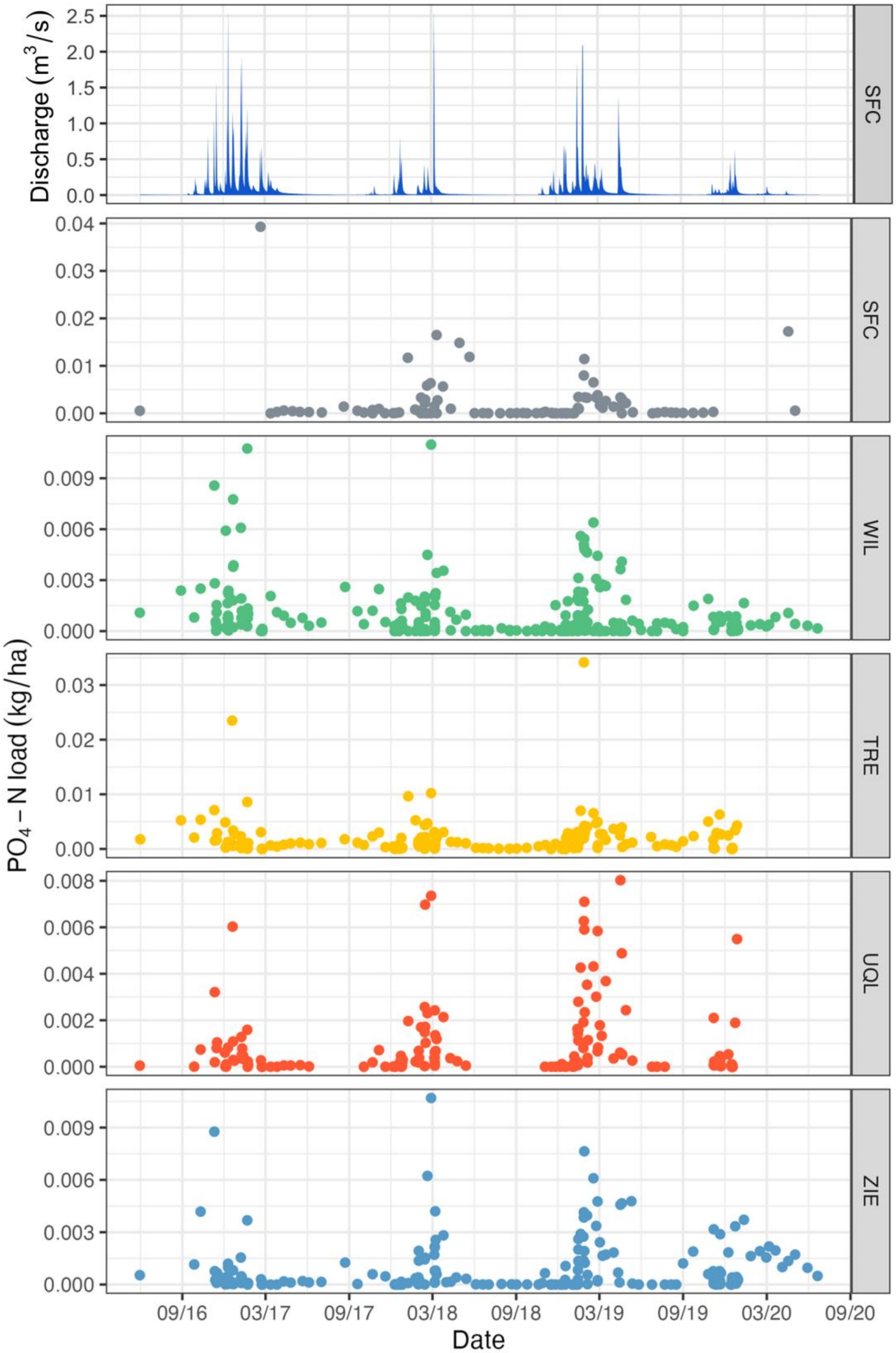

Figure 33: Phosphate flux in stream water from the treatment sub-watersheds (WIL, TRE, UQL and ZIE) and South Fork Caspar Creek (SFC) for the four-year study period. Please note that y-axes differ in range.

6 Conclusions

Concentrations and fluxes of major nutrients (N, P, C) were studied for four years (summer 2016 - summer 2020) at the outlets of four sub-watersheds (WIL, TRE, UQL, ZIE) located within the South Fork of Caspar Creek watershed and the outlet of South Fork Caspar Creek itself. Three of the sub-watersheds (TRE, WIL, UQL) had different percentages of its redwood timber removed, ranging from 35%, 55% to 75% starting in the summer of 2018. In this project, changes in nutrient concentrations, turbidity, pH, and electrical conductivity in stream water were analyzed over different comparison periods in order to determine single or compound effect of forest harvest management practices and naturally occurring disturbance events such as extreme wet or dry years. All differences were analyzed using ANOVA and post-hoc Tukey's honestly significant difference test.

Hydrology and Climate

The four study years exhibited extreme variability in annual precipitation, which varied between 534 mm in HY2020 and 1632 mm in 2017 (the second largest annual precipitation in the last 100 years). Because of the high and low annual precipitation amounts, mean daily streamflow and total annual water yield from SFC and the four study sub-watersheds varied widely from year to year, creating large differences in stream water nutrient concentrations and nutrient fluxes of N, P and DOC. Despite the natural variation in streamflow due to variable precipitation inputs, water yield increased in the sub-watersheds the two years following the timber removal in summer and fall of 2018. Water yield increased at an average rate of about 31.5 mm/year for every 10% of timber removed from the watershed in HY2019 and at a rate of about 18 mm/yr for every 10% of timber removed from the watershed in HY2020. However, increase in water yield in UQL and ZIE following the timber removal event was not large enough to prevent cessation of streamflow in these sub-watersheds during the dry summer months and particularly the drought year of HY2020.

Nutrient concentrations

Stream water solute concentrations were similar between the control and treatment sub-watersheds, but elemental concentrations were generally higher in the four sub-watersheds compared to the concentrations measured at the outlet of South Fork Caspar Creek. Across all studied watersheds, the timber removal caused a clear increase in stream water DOC and TP concentrations. These increases are likely due to increased availability and transport of biomass and organic matter from the harvested areas to the stream as well as an increased suspended sediment influx from disturbed forest soils (and generally higher risk of erosion after vegetation is removed) during storm events, and associated increased transport of particulate P attached to sediment grains. Sub-watersheds subject to timber removal also showed a statistically significant increase in DON as well as NH_4^+-N and NO_3^--N (in ZIE only), which is likely due to increased availability of organic nitrogen from the timber harvest, and enhanced mineralization and nitrification or organic-N in the forest soils and streams. The increased availability of DON in the forest soils combined with the increase in water yield likely results in increased subsurface lateral flow above the clay-rich, argillic horizon and macropore flow, which delivers DON-enriched waters from the hillslope areas to the stream during storm events. In contrast to the second experimental study conducted in the North Fork of Caspar Creek, we did not find a clear increase in NO_3^--N across all treatment watersheds. However, some of these processes might have been subdued due to the fact that HY2020 was an extreme dry year and most N cycling processes require substantial soil moisture for mineralization of organic N to NH_4^+, and nitrification of NH_4^+ to NO_3^- to occur. In addition, some of the N transported from the sub-watersheds where timber was removed to the stream might have been consumed in-stream for example by algal communities that strived under the increased light availability and large input of organic-N and wordy debris, which might have increased inorganic nitrogen processing in streams.

Nutrient Fluxes

Fluxes of N, P and C from the sub-watersheds subject to timber removal as well as the entire South Fork Caspar Creek watershed were generally 1.3 to 9 times greater than those from the control sub-watershed WIL. The increased nutrient fluxes were a combination of both increased solute concentrations (e.g. DOC, TP, DON) and increased water flux (due to reduction in evapotranspiration). The loss of N from the sub-watersheds where 35-75% of the timber stand was removed increased in the two years following the harvest event. However, the magnitude of the increase in N flux following the timber removal overall was smaller than the N export observed during the very wet HY2017. This indicates that naturally occurring hydrologic extreme events can transport as much or more N from coastal forested watersheds as would occur in response to 75% timber removal during a normal precipitation year. In contrast to the N fluxes, DOC export did show the strongest response to the implemented timber harvest treatments, resulting in the case of ZIE (75% timber removal) an almost 2.3-fold increase in load. Together the results indicate that management of the residual biomass from the timber harvest is key in keeping the DOC loads in stream water at or near the same levels as observed prior to the timber harvest event.

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Appendix A – Chemical Data

South Fork Caspar Creek sub-watersheds

Table 37: South Fork Caspar Creek (SFC).

Date	EC µS	pH mg/L	Turb mg/L	TN mg/L	NH_4^+-N mg/L	NO_3^--N mg/L	TP mg/L	PO_4 mg/L	DOC mg/L	DON mg/L
5/26/16 11:35	156	7.28	1.76	0.11	0.02	0	0.015	0.005	2.54	0.09
6/30/16 15:30	119	7.6	1.94	0.13	0.02	0	0.013	0.01	2.37	0.11
3/21/17 13:45	115	7.71	54.4	0.77	0.02	0.08	0.076	0	4.17	0.67
4/12/17 15:01	142	7.73	12.4	0.56	0.02	0.03	0.026	0	2.36	0.51
4/26/17 10:39	149	7.92	7.77	0.52	0	0.02	0.023	0.002	2.29	0.5
5/11/17 11:01	152	7.96	5.33	0.34	0	0.01	0.016	0.005	1.68	0.33
5/30/17 16:23	165	7.92	2.16	0.54	0.03	0.01	0.012	0.004	2.05	0.5
6/15/17 14:30	158	7.91	2.09	0.12	0.07	0	0.013	0.006	1.77	0.05
7/5/17 15:05	279	7.51	2.21	0.04	0.01	0.01	0.005	0.004	1.77	0.02
8/2/17 10:44	281	7.71	1.9	0.06	0.02	0	0.006	0.004	1.89	0.04
9/19/17 10:40	320	7.53	1.21	0.16	0.07	0.003	0.048	0.056	2.13	0.09
10/19/17 12:00	305	7.41	1.84	0.16	0.04	0.002	0.051	0.024	2.21	0.12
11/2/17 15:00	343	7.58	4.97	0.46	0	0.265	0.029	0.011	5.13	0.2
11/21/17 15:00	342	8.32	1.68	0.17	0	0.001	0.026	0.02	2.29	0.17
11/21/17 15:36	331	8.12	8.24	0.68	0.02	0.364	0.041	0.021	5.26	0.3
12/5/17 13:20	329	6.8	1.16	0.13	0.03	0.01	0.015	0.001	3.17	0.09
12/18/17 13:50	342	7.64	2.33	0.13	0.03	0.02	0.022	0.001	2.25	0.08
1/5/18 13:33	220	6.73	4.2	0.21	0.02	0	0.018	0.001	4.56	0.19
1/10/18 11:51	168	6.74	13.3	0.09	0.01	0	0.018	0	4.4	0.08
1/18/18 14:50	177	6.9	17.3	0.21	0.01	0.056	0.037	0.004	6.17	0.14
2/6/18 14:00	173	7.13	3.38	0.1	0.01	0	0.037	0.028	2.4	0.09
2/22/18 15:17	189	7.18	2.06	0.22	0	0	0.043	0.015	1.57	0.22
3/1/18 11:36	147	6.83	26.8	0.46	0	0.182	0.057	0.028	5.76	0.28
3/1/18 11:55	8	5.41	1.7	0.17	0	0	0.018	0.024	0.97	0.17
3/7/18 15:13	23	5.26	1.5	0.13	0.01	0	0.011	0.019	0.83	0.12
3/7/18 15:00	186	7.09	3.52	0.03	0.03	0.001	0.004	0.028	2.56	0
3/15/18 14:50	132	6.96	16.5	0.14	0.03	0	0.027	0.038	4.43	0.11
3/15/18 14:55	11	5.27	1.28	0	0.02	0	0	0.028	0.83	0
3/20/18 14:05	145	7.05	9.01	0.05	0.03	0	0.01	0.033	2.09	0.02
3/20/18 14:30	18	5.37	0.74	0	0.03	0	0.001	0.019	0.45	0
3/16/18 13:40	116	7.14	32.2	0.25	0.02	0.175	0.048	0.047	3.34	0.06
3/28/18 14:15	18	5.61	0.66	0.05	0.03	0.021	0	0.042	0.34	0
3/28/18 14:01	133	7.03	5.92	0.05	0.01	0.005	0.007	0.028	2.17	0.04

4/5/18 8:40	111	7.4	2.14	0.01	0.03	0	0	0.012	1.58	0
4/12/18 8:30	35	7.01	24.9	2.29	0.45	0	0.33	0.061	1.27	1.84
4/10/18 13:00	126	7.18	10.3	0.34	0.02	0	0.007	0.021	2.3	0.32
4/10/18 13:10	9	6.56	2.41	0.4	0.01	0	0.062	0.07	1.03	0.39
4/24/18 16:35	152	7.16	1.66	0.28	0.01	0	0	0.007	1.69	0.27
5/11/18 14:40	168	7.77	1.32	0.26	0.01	0	0.007	0.021	1.48	0.25
5/30/18 11:50	168	7.3	1.1	0.2	1.4	0	0.004	0.571	3.93	0
6/21/18 16:35	161	7.28	0.77	0.28	0.01	0	0.034	0.002	2.05	0.27
7/2/18 10:15	160	7.17	3.01	0.27	0.01	0	0.034	0.002	2.2	0.26
7/20/18 10:20	156	7.34	1.61	0.12	0.01	0.066	0.034	0.002	1.9	0.04
8/1/18 14:10	158	7.14	2.28	0.13	0.01	0	0.036	0	1.61	0.12
8/27/18 13:30	154	7.22	0.82	0.03	0.01	0	0.031	0.002	0.58	0.02
9/18/18 7:20	65	9.38	1.79	0.08	0.01	0.086	0.039	0.002	0.85	0
10/2/18 14:00	166	7.15	0.96	0.16	0.01	0	0.126	0.015	2.59	0.15
10/16/18 14:00	188	7.32	0.82	0.1	0.01	0	0.039	0.003	1.85	0.09
10/25/18 12:00	191	7.37	0.42	0.17	0.01	0.09	0.036	0.002	2.1	0.07
11/14/18 15:50	151	7.34	0.81	0.09	0.01	0.01	0.036	0.005	1.18	0.07
11/27/18 11:50	187	7.33	0.85	0.14	0.01	0	0.083	0.005	3.76	0.13
12/4/18 15:05	191	7.26	3.19	0.38	0.02	0.02	0.036	0.003	2.27	0.34
12/17/18 9:30	155	7.05	6.69	0.3	0.01	0.01	0.025	0	5.41	0.28
12/20/18 10:30	173	7.31	2.2	0.06	0.02	0	0	0	1.7	0.04
12/27/18 11:40	148	6.95	6.79	0.14	0.03	0	0	0	3.07	0.11
1/7/19 13:45	130	6.83	16.5	0.05	0.01	0.02	0.035	0	4.55	0.02
1/9/19 15:30	142	6.96	11.1	0.16	0.01	0	0.128	0	4.28	0.15
1/16/19 13:40	149	7.17	8.52	0	0.06	0.02	0	0	4.81	0
1/18/19 14:10	124	6.69	13.2	0	0.02	0	0	0	3.29	0
1/22/19 15:00	122	6.61	12.1	0	0.01	0	0	0	2.84	0
2/1/19 14:00	171	6.99	2.76	0	0.01	0	0	0	2.2	0
2/5/19 15:10	115.6	7.15	18.2	0.16	0.01	0	0.004	0	3.57	0.15
2/13/19 13:52	115	6.79	42.7	0.3	0.02	0.008	0.021	0.009	5.02	0.27
2/14/19 12:30	95	7.3	70.4	0.3	0.04	0.001	0.25	0.009	4.81	0.26
2/15/19 13:30	106.1	6.84	31.3	0.18	0.02	0	0.054	0	3.65	0.16
2/26/19 11:12	66.6	6.93	44.3	0.24	0.02	0.004	0.025	0.019	4.02	0.22
2/27/19 12:50	93.1	6.77	66.4	0.24	0.01	0.034	0.2	0.02	4.15	0.2
2/28/19 15:30	103.1	6.88	23	0.19	0.02	0	0.06	0.017	2.98	0.17
3/5/19 10:20	131.8	7.02	9.42	0.16	0.02	0	0	0.009	2.43	0.14
3/19/19 13:10	123	7.42	4.51	0.03	0.01	0	0	0.015	2.92	0.02
3/25/19 14:30	106	7.44	39.8	0.26	0.01	0	0	0.017	7.55	0.25
3/28/19 15:05	122	7.52	15.3	0.06	0.01	0	0	0.02	3.59	0.06
4/2/19 14:20	134	7.53	7.78	0.02	0.01	0	0	0.003	2.29	0.01

4/8/19 13:30	127.5	6.92	14.5	0.25	0.04	0	0.04	0.01	3.32	0.21
4/15/19 11:46	136	7.2	6.54	0.07	0.05	0	0.02	0.01	2.1	0.02
5/2/19 12:35	144.7	7.25	3.1	0.11	0.02	0.01	0.02	0.01	1.83	0.08
5/16/19 10:40	102.5	6.81	22.1	0.58	0.03	0.045	0.22	0.01	11.06	0.51
5/17/19 12:50	106.9	6.93	22.7	0.22	0.02	0	0.08	0.008	4.97	0.2
5/20/19 12:20	121	6.88	10.7	0.19	0.04	0.009	0.06	0.007	4	0.15
5/20/19 12:30	120.6	6.97	14.8	0.16	0.05	0	0.06	0.008	3.31	0.11
5/29/19 12:30	144.2	7.1	3.86	0.09	0.16	0	0.02	0.004	2.37	0
6/13/19 10:00	124.1	6.84	2.75	0.01	0.01	0.008	0.01	0	2.49	0
7/26/19 11:20	146.8	7.21	1.46	0.02	0.01	0.022	0.013	0	4.11	0
8/6/19 10:30	131.8	7.27	4.68	0.08	0.01	0.022	0.01	0.01	3.76	0.05
8/22/19 12:42	153.7	7.11	2.07	0	0.11	0.039	0.045	0.01	8.02	0
9/5/19 13:00	132.8	7.03	2.22	0	0.02	0.025	0.01	0.01	3.94	0
9/16/19 14:30	135.9	7.19	0	0.09	0.23	0.04	0.02	0.01	5.91	0
10/1/19 13:05	186.3	7.37	0.48	0.11	0.03	0.03	0.34	0	2.8	0.05
10/23/19 13:10	163.3	7.03	0.97	0.18	0.02	0.01	0.33	0.01	0	0
11/14/19 12:20	188.4	7.66	0.68	0.11	0.02	0.02	0.34	0.01	4.29	0.07
12/6/19 12:20	194.5	7.19	1.48	0.15	0.02	0.01	0.34	0.01	3.68	0.12
5/18/20 12:30	175.2	7.12	4.6	0.29	0.01	0	0	0.012	6.02	0.29
6/2/20 14:30	104.3	7.19	2.23	0	0	0	0	0.01	3.86	0
5/26/16 11:35	156	7.28	1.76	0.11	0.02	0	0.015	0.005	2.54	0.09

Table 38: Williams (WIL) sub-watershed.

Date	EC µS	pH mg/L	Turb mg/L	TN mg/L	NH_4^+-N mg/L	NO_3^--N mg/L	TP mg/L	PO_4 mg/L	DOC mg/L	DON mg/L
5/22/16 9:40	294	7.69	0.87	0.23	0	0	0.015	0.013	1.23	0.23
6/30/16 13:05	167	8.04	2.76	0.06	0.01	0	0.026	0.018	1.2	0.05
12/13/16 7:00	309	7.81	4.4	0.05	0.03	0.02	0.017	0.008	0.85	0
9/28/16 9:00	352	8.13	5.7	0.06	0.01	0.01	0.016	0.014	0.7	0.04
10/27/16 10:15	268	8.24	18.5	0.2	0.01	0.02	0.032	0.018	9	0.17
11/10/16 0:00	182	8.12	21.8	0.29	0	0.01	0.062	0.013	6.4	0.28
11/10/16 0:00	185	8.32	11.7	0.24	0	0	0.042	0.01	4.7	0.24
12/10/16 7:00	121	7.84	26.6	0.22	0.02	0.02	0.052	0.014	2.63	0.18
12/11/16 19:20	116	7.43	17.2	0.2	0.06	0.02	0.036	0.009	1.77	0.12
12/14/16 18:00	150	7.43	9.32	0.27	0.16	0.02	0.039	0.014	1.94	0.09
12/14/16 19:30	147	7.6	10.3	0.16	0.02	0.02	0.033	0.009	2.03	0.12
12/15/16 3:00	135	7.59	18.8	0.28	0	0.02	0.1	0.043	3.87	0.26
12/15/16 9:00	109	7.41	48.2	0.35	0.02	0.04	0.121	0.012	4.77	0.29
12/15/16 15:00	104	7.4	41	0.31	0	0.04	0.091	0.009	3.99	0.27

1/10/17 10:10	86	7.51	185	0.25	0.03	0.01	0.1	0.006	5.53	0.21
1/10/17 12:00	81	7.52	288	0.37	0	0.01	0.141	0.011	5.26	0.36
1/10/17 14:00	78	7.5	341	0.41	0.03	0.01	0.15	0.009	5.07	0.37
1/8/17 6:00	131	7.55	22.8	0.31	0	0.01	0.041	0.014	4.38	0.3
1/10/17 20:00	87	7.71	80.8	0.28	0.02	0	0.068	0.015	3.81	0.26
1/8/17 12:00	114	7.67	40.4	0.25	0	0.01	0.05	0.012	4.51	0.24
1/8/17 14:00	101	7.62	48.4	0.3	0	0.01	0.057	0.014	5.75	0.29
1/8/17 16:00	99	7.7	43.1	0.25	0	0.01	0.074	0.035	5.14	0.24
1/9/17 0:00	102	7.74	29.3	0.46	0	0	0.038	0.008	3.33	0.46
1/10/17 10:00	100	7.74	33.3	0.11	0	0	0.053	0.014	2.95	0.11
1/20/17 1:00	115	7.74	21.3	0.41	0.02	0	0.038	0.006	3.08	0.39
1/20/17 5:00	108	7.73	33.4	0.38	0	0	0.047	0.014	4.06	0.38
1/9/17 12:00	108	7.77	21.8	0.34	0.01	0	0.03	0.011	2.87	0.33
1/20/17 11:00	100	7.81	32	0.4	0	0.01	0.068	0.042	3.74	0.39
1/20/17 19:00	102	7.86	24.2	0.44	0.02	0	0.068	0.045	3.21	0.42
1/4/17 4:10	138	7.9	35.7	0.42	0.06	0.01	0.044	0.011	4.16	0.35
1/4/17 11:30	136	7.94	30.4	0.47	0.05	0.01	0.035	0.009	3.15	0.41
1/21/17 11:10	104	7.78	19.6	0.51	0	0.01	0.027	0.008	2.8	0.5
2/6/17 20:00	116	7.9	22	0.23	0.11	0	0.051	0.005	2.46	0.12
2/7/17 2:00	103	7.87	38	0.22	0.07	0	0.078	0.012	3.41	0.15
2/7/17 6:00	88	7.8	119	0.23	0.03	0.01	0.163	0.008	3.73	0.19
2/8/17 12:00	105	7.74	22	0.11	0.05	0	0.039	0.007	2.17	0.06
2/7/17 18:00	97	7.84	27.2	0.16	0.08	0	0.051	0.008	2.36	0.08
2/20/17 14:00	111	7.53	16.9	0.3	0.19	0	0.03	0.008	1.93	0.11
2/20/17 20:00	108	7.47	22.5	0.31	0.17	0	0.039	0.008	2.55	0.14
2/21/17 2:00	101	7.78	27	0.4	0.24	0	0.061	0.017	2.59	0.16
2/21/17 10:00	101	7.82	23.4	0.39	0.24	0	0.049	0.011	2.19	0.15
2/22/17 11:20	94	7.43	18.3	0.15	0.09	0	0.033	0	2.34	0.06
3/24/17 5:00	141	7.85	30.9	0.42	0.17	0.05	0.075	0.002	2.18	0.2
3/24/17 9:00	126	7.66	74.2	0.44	0.21	0.03	0.121	0.004	3.56	0.2
3/24/17 13:00	118	7.63	57.5	0.97	0.23	0.07	0.09	0.002	3.26	0.67
3/24/17 23:00	120	7.72	46.5	1.04	0.23	0.03	0.086	0	2.29	0.78
3/25/17 9:00	123	7.96	32.9	0.83	0.11	0.01	0.058	0	1.81	0.71
3/25/17 23:00	126	7.83	27.5	0.81	0.1	0.07	0.058	0.005	1.58	0.64
3/22/17 12:02	143	7.82	29.4	0.65	0	0	0.049	0	1.64	0.65
4/12/17 10:50	164	7.74	12.3	0.35	0.01	0	0.039	0.004	1.37	0.34
4/26/17 9:52	195	7.84	6.45	0.5	0.01	0.01	0.026	0.004	1.61	0.48
5/11/17 10:20	226	7.83	4.63	0.25	0.01	0.01	0.019	0.009	0.97	0.23
5/26/17 9:44	275	8.06	2.49	0.53	0.03	0	0.018	0.007	1.66	0.5
6/21/17 13:00	288	8.15	8.19	0.06	0.02	0	0.045	0.012	0.83	0.04

7/5/17 16:03	447	7.84	0.71	0.07	0.05	0	0.009	0.007	0.83	0.02
8/1/17 10:40	475	8.22	0.65	0.11	0.03	0	0.019	0.016	0.88	0.08
9/22/17 10:55	500	8.26	0.46	0.16	0.11	0.003	0.039	0.02	0.87	0.05
10/19/17 15:51	501	8.25	0.48	0.12	0.03	0.003	0.048	0.026	0.78	0.09
11/2/17 11:40	421	8.08	4.02	0.32	0.06	0.009	0.041	0.013	4.06	0.25
11/21/17 10:37	330	8.05	40.6	1.04	0.45	0.007	0.332	0.058	4.56	0.58
12/5/17 9:50	425	6.99	1	0.07	0.02	0.011	0.018	0.017	1.18	0.04
12/19/17 11:30	464	7.1	20.1	0.11	0.03	0.009	0.114	0.019	0.87	0.07
1/8/18 16:00	195	6.68	33.4	0.25	0.01	0	0.092	0	13.52	0.24
1/8/18 18:00	177	6.71	42.1	0.3	0.01	0	0.148	0	8.28	0.29
1/9/18 0:00	177	6.62	29.1	0.17	0.01	0	0.089	0	5.37	0.16
1/9/18 4:00	178	6.69	25.6	0.21	0.01	0	0.065	0	4.28	0.2
1/9/18 10:00	191	6.99	21.3	0.17	0.01	0	0.052	0.003	3.55	0.16
1/10/18 12:00	184	6.83	13.7	0.11	0.01	0	0.034	0.003	2.37	0.1
1/18/18 11:15	227	7.22	28.8	0.15	0.01	0	0.092	0.011	4.01	0.14
1/18/18 11:30	219	7.28	12.9	0.15	0.02	0.088	0.046	0.001	7.13	0.04
1/19/18 3:30	192	7.28	20.7	0.05	0.01	0	0.046	0.006	3.32	0.04
1/20/18 9:30	190	7.14	13.1	0.04	0.01	0	0.031	0.008	2.85	0.03
1/22/18 13:20	122	7.2	26.8	0.08	0	0	0.055	0.012	3.77	0.08
1/23/18 11:20	146	7.19	20.5	0.03	0.01	0	0.055	0.028	2.46	0.02
1/24/18 12:00	141	7.12	17.1	0.15	0.01	0	0.04	0.009	3.68	0.14
1/24/18 18:00	115	7.18	29	0.19	0.01	0	0.063	0.009	4.4	0.18
1/25/18 0:00	112	7.13	24	0.18	0.01	0	0.047	0.006	3.22	0.17
1/25/18 10:00	129	7.22	20.3	0.16	0.02	0	0.043	0.006	2.57	0.14
1/26/18 10:00	127	7.22	15.8	0.12	0.06	0.052	0.034	0	3.16	0.01
2/7/18 10:45	170	7.19	2.48	0.08	0.01	0	0.037	0.024	1.49	0.07
2/7/18 10:55	219	7.48	1.65	0.06	0.01	0	0.043	0.047	3.09	0.05
2/23/18 11:47	205	7.37	1.86	0.08	0	0	0.011	0.01	1.29	0.08
2/23/18 11:49	268	7.67	0.9	0.1	0.01	0	0.04	0.042	0.7	0.09
3/1/18 10:30				0.22	0	0	0.05	0.019	0	0
3/7/18 11:50	189	7.12	5.2	0.19	0	0	0.021	0.047	1.09	0.19
3/1/18 10:28	140	6.97	23.9	0.35	0	0	0.047	0.024	3.97	0.35
3/1/18 23:00	186	6.9	18.7	0.19	0	0	0.041	0.024	2.93	0.19
3/2/18 5:00	179	6.97	20	0.17	0.01	0	0.037	0.052	2.44	0.16
3/2/18 23:00	173	7.07	19.5	0.17	0	0	0.044	0.038	3.76	0.17
3/3/18 9:00	199	7.02	20.2	0.21	0	0	0.044	0.038	2.72	0.21
3/3/18 5:00	198	6.98	18.2	0.24	0	0	0.034	0.028	2.53	0.24
3/7/18 11:44	144	7.14	9.1	0.11	0	0	0.018	0.019	1.78	0.11
3/15/18 11:00	133	7.27	12.9	0.01	0.02	0	0.024	0.033	2.76	0
3/17/18 0:00	131	7.23	14.7	0.02	0.02	0	0.015	0.024	1.98	0

3/15/18 12:00	172	7.41	10.1	0.03	0.04	0	0.01	0.033	2.89	0
3/15/18 4:00	142	7.28	23.5	0.07	0.01	0	0.042	0.033	2.69	0.06
3/15/18 11:00	133	7.27	12.9	0.01	0.02	0	0.024	0.033	2.76	0
3/15/18 11:08	170	7.47	14.7	0.01	0.02	0.03	0.027	0.052	2.69	0
3/16/18 12:00	152	7.52	20.6	0.26	0	0	0.024	0.028	2.26	0.26
3/17/18 10:00	131	7.2	11.2	0.03	0.02	0	0.01	0.038	1.66	0.01
3/21/18 10:29	179	7.3	9.68	0	0	0	0.01	0.047	1.12	0
3/21/18 10:48	148	7.63	10.6	0	0	0	0.007	0.038	1.59	0
3/29/18 11:45	121	7.43	7.85	0	0.03	0	0.007	0.038	1.43	0
3/29/18 11:52	140	7.47	8.57	0	0.02	0	0.007	0.047	0.92	0
4/5/18 10:15	189	7.63	4.94	0.04	0.01	0	0.024	0.052	0.66	0.03
4/5/18 10:24	169	7.59	1.54	0	0.05	0	0.001	0.042	1.18	0
4/6/18 10:40	85	7.03	228	0.32	0.02	0	0.35	0.007	5.47	0.3
4/6/18 4:00	157	7.15	13.6	0.36	0.01	0	0.033	0.007	3.49	0.35
4/6/18 10:00	95	7.01	255	0.61	0.01	0	0.447	0.007	4.82	0.6
4/6/18 10:35	62	7.04	581	0.41	0.02	0	0.72	0.007	7.22	0.39
4/6/18 12:00	86	6.93	251	0.58	0.02	0	0.345	0.007	4.29	0.56
4/6/18 14:00	87	6.9	259	0.55	0.01	0	0.406	0.007	3.9	0.54
4/6/18 22:00	91	6.89	108	0.35	0.02	0	0.129	0.007	2.67	0.33
4/6/18 2:00	92	6.87	71.1	0.38	0.01	0	0.088	0.007	2.97	0.37
4/7/18 12:00	148	7	21.7	0.34	0.01	0	0.05	0.007	2.07	0.33
4/8/18 2:00	2	7.01	7.23	0.28	0.02	0	0.018	0.03	1.62	0.26
4/10/18 11:45	116	7.07	20.3	0.25	0.02	0	0.039	0.016	1.45	0.23
4/10/18 11:50	130	7.13	11.8	0.11	0.03	0	0.018	0.03	1.17	0.08
4/25/18 11:50	153	7.09	3.4	0.07	0.01	0	0.001	0.016	1.37	0.06
4/25/18 11:56	186	7.26	2.52	0.27	0.01	0	0.007	0.034	0.92	0.26
5/10/18 11:05	262	8.39	0.79	0.3	0.01	0	0.007	0.021	0.78	0.29
5/11/18 12:35	193	7.48	2.55	0.19	0.03	0	0.007	0.007	1.4	0.16
5/23/18 14:30	281	7.79	0.47	0	0.01	0	0.013	0.025	0.73	0
6/13/18 15:05	302	7.65	0.58	0.06	0.01	0	0.041	0.002	1.6	0.05
6/13/18 15:30	241	7.49	0.89	0.05	0.01	0	0.034	0	2.34	0.04
7/5/18 11:15	328	7.73	0.57	0.11	0.01	0.078	0.036	0.003	0.93	0.02
7/5/18 11:51	276	7.56	2.76	0.14	0.01	0	0.026	0.005	1.41	0.13
7/20/18 9:20	290	7.47	2.55	0.06	0.01	0	0.051	0.008	1.46	0.05
7/20/18 9:30	350	7.85	0.19	0.02	0.01	0.013	0.049	0.009	0.87	0
8/2/18 11:15	300	7.33	28.6	0.27	0.01	0	0.405	0.002	1.89	0.26
8/2/18 11:31	348	7.86	0.69	0	0.01	0	0.046	0.008	1.32	0
8/30/18 10:17	307	7.44	1.03	0.2	0.01	0	0.103	0.009	0.87	0.19
8/30/18 10:20	351	7.85	0.93	0.2	0.01	0	0.054	0.011	1.14	0.19
9/17/18 14:20	180	8.89	8.92	0.28	0.01	0.01	0.066	0.005	1.6	0.26

9/17/18 14:32	248	8.45	3.99	0.21	0.01	0	0.041	0.009	1.75	0.2
10/2/18 9:55	156	9.16	6.63	0.19	0.01	0	0.091	0.002	1.63	0.18
10/2/18 10:00	394	8.29	0.32	0.04	0.01	0	0.054	0.017	1.22	0.03
10/25/18 14:30	380	7.65	0.28	0.08	0.01	0	0.029	0	1.53	0.07
10/25/18 14:35	353	8.05	0.29	0.27	0.01	0.01	0.061	0.02	1	0.25
11/13/18 14:50	311	7.82	0.55	0.1	0.01	0	0.106	0.011	1.86	0.09
11/13/18 15:00	359	8.06	0.24	0.03	0.01	0	0.051	0	1.15	0.02
11/27/18 9:30	203	8.04	1.35	0.12	0.01	0	0.096	0	2.93	0.11
12/3/18 13:20	228	7.69	2.56	0.04	0.01	0	0.041	0.014	1.81	0.03
12/16/18 14:00	199	7.08	9.62	0.11	0.01	0	0.004	0	9.39	0.1
12/16/18 16:00	196	7.25	34.1	0.11	0.02	0	0	0.011	7.18	0.09
12/16/18 18:00	195	7.24	18.4	0.22	0.04	0	0.001	0	6	0.18
12/17/18 4:00	197	7.25	14.3	0.22	0.06	0	0.007	0	4.08	0.16
12/17/18 11:40	130	6.85	7.07	0.25	0.01	0	0	0	3.94	0.24
12/17/18 12:00	211	7.26	7.74	0.21	0.01	0	0.004	0.015	3.6	0.2
12/26/18 14:50	165	7.05	7.13	0.44	0.02	0	0.021	0.003	1.91	0.42
1/6/19 14:00	190	7.16	7.18	0.04	0.01	0	0.011	0	5.64	0.03
1/6/19 18:00	172	7.08	11.2	0.09	0.03	0.05	0.011	0	5.27	0.01
1/6/19 22:00	162	7.15	9.65	0.33	0.01	0.01	0.025	0	4.25	0.31
1/7/19 4:00	159	7	7.82	0.22	0.02	0.06	0.021	0.003	3.43	0.14
1/7/19 10:50	159	7.11	12.7	0.46	0.03	0.08	0.025	0.001	2.54	0.35
1/9/19 10:32	121	6.91	14.4	0.09	0.02	0.01	0.124	0	3.48	0.06
1/9/19 10:40	159	7.08	12.4	0.12	0.02	0	0.127	0.027	2.68	0.1
1/9/19 12:00	160	6.97	8.48	0.12	0.01	0	0.123	0.007	2.9	0.11
1/9/19 18:00	163	6.06	7.34	0.07	0.02	0	0.122	0	2.83	0.05
1/10/19 16:00	157	7.17	6.49	0.15	0.01	0	0.124	0	2.15	0.14
1/16/19 10:25	181	7.17	21.6	0	0.01	0.01	0	0.009	3.07	0
1/16/19 10:40	137	7.11	8.99		0.03	0		0.008	3.12	0
1/16/19 14:00	149	7.13	26.8	0	0.02	0	0	0.012	5.92	0
1/16/19 18:00	118	6.98	53.1	0	0.02	0.01	0	0.013	6.45	0
1/16/19 22:00	119	6.66	29.3	0	0.01	0	0	0	4.4	0
1/17/19 6:00	115	6.99	16.4	0	0.01	0	0	0.015	2.97	0
1/17/19 10:30	104	6.96	31.1		0.02	0		0	3.66	0
1/18/19 10:00	129	6.84	10.1	0	0.01	0	0	0.009	2	0
1/22/19 10:50	107	6.59	16.2		0.02	0		0	2.26	0
1/22/19 11:00	124	6.84	10.2	0	0.01	0	0	0	1.8	0
2/1/19 11:07	183	7.17	1.76	0	0.01	0	0	0	1.42	0
2/1/19 11:20	137	7.07	3.59	0	0.01	0.001	0.004	0.009	1.95	0
2/4/19 6:00	151	6.97	12.5	0.04	0.01	0	0.021	0.021	3.46	0.03
2/4/19 15:00	168	7.01	21.2	0.27	0.01	0	0.031	0	3.14	0.26

2/4/19 21:00	164	6.96	15.3	0.1	0.01	0	0.018	0.018	2.82	0.09
2/5/19 11:30			18.5	0	0.02	0	0.025	0	3.91	0
2/5/19 11:40	163	7.05	12.6	0	0.01	0	0.025	0.018	3.13	0
2/12/19 13:50	132	6.92	12.5	0.05	0.02	0	0.018	0.012	2.42	0.03
2/12/19 14:00	163	7.06	10.1	0	0.01	0.005	0.028	0.018	2.29	0
2/13/19 0:00	147	7.06	22.5	0.19	0.01	0	0.031	0.019	4.31	0.18
2/13/19 10:00	120	6.9	31.9	0.84	0.01	0	0.018	0.019	3.58	0.83
2/13/19 10:30	97	6.87	40	0.17	0.02	0	0.021	0.015	4.91	0.15
2/13/19 18:00	117.6	7.01	25.9	0.01	0.02	0.005	0.011	0.016	2.78	0
2/14/19 2:00	90.6	6.88	76.6	0.14	0.01	0.001	0.069	0.021	4.29	0.13
2/14/19 10:12	74.7	6.85	61.5	0.24	0.02	0	0.042	0.016	4.33	0.22
2/14/19 12:00	97.5	7.11	39.6	0.24	0.06	0	0.14	0.018	2.85	0.18
2/14/19 22:00	101.6	7.06	20.7	0.17	0.03	0	0.048	0.015	2.56	0.14
2/15/19 14:50	93.28	6.92	31.2	0.19	0.03	0	0	0.012	3.01	0.16
2/15/19 15:00	93.5	6.95	15.3	0.15	0.02	0	0.048	0.019	2.03	0.13
2/19/19 12:12	124.7	6.97	9.48	0.03	0.02	0.001	0	0.013	1.5	0.01
2/25/19 12:00	128.4	6.96	31	0.09	0.03	0.004	0.043	0.023	5.84	0.06
2/25/19 20:00	83.1	6.86	112	0.27	0.02	0.007	0.176	0.023	4.75	0.24
2/26/19 8:10	71.44	6.85	51.5	0.15	0.03	0.01	0.149	0.02	3.53	0.11
2/26/19 12:00	93.9	6.85	39	0.28	0.03	0.001	0.123	0.023	2.67	0.25
2/27/19 0:00	92.4	6.78	179	0.4	0.01	0.001	0.241	0.02	3.79	0.39
2/27/19 8:20	83.49	6.71	91.9	0.19	0.03	0	0.167	0.019	3.82	0.16
2/27/19 10:00	96.6	6.8	28.9	0.13	0.02	0	0.069	0.02	2.55	0.11
2/28/19 11:20	94.4	6.83	30.8	0.15	0.01	0	0.063	0.02	2.38	0.14
2/28/19 11:30	102.5	6.88	14.2	0.12	0.01	0	0.051	0.023	1.78	0.11
3/5/19 16:00	105.4	6.94	12.1	0.5	0.02	0	0	0.007	2.59	0.48
3/5/19 16:00	131.1	7.17	7.08	0.09	0.03	0	0.026	0.015	1.43	0.06
3/6/19 11:40	127.9	7.1	17.3	0.1	0.05	0	0	0.013	3.49	0.05
3/6/19 10:30	122.5	7.01	27.4	0.13	0.02	0	0.006	0.021	2.33	0.11
3/7/19 10:40	107.7	7.04	12.2	0.09	0.02	0	0	0.015	1.83	0.07
3/19/19 10:10	119	7.43	5.91	0.075	0.007	0		0.018	1.85	0.068
3/19/19 10:20	147	7.6	3.51	0.02	0.01	0	0	0.027	1.58	0
3/25/19 10:00	89	7.54	66.5	0.182	0.030	0.003		0.018	7.427	0.149
3/25/19 10:03	120	7.42	20.7	0.1	0.01	0	0	0.022	4.17	0.08
3/28/19 9:40	130	7.57	11	0.01	0	0	0	0.022	1.88	0.01
3/28/19 9:50	106	7.63	19.5	0.111	0.016	0		0.019	3.21	0.095
3/28/19 12:00	133	7.58	11.1	0.05	0.02	0	0	0.033	2.45	0.03
3/28/19 16:00	136	7.67	7.93	0.03	0	0.003	0	0.021	2.58	0.02
3/28/19 22:00	135	7.83	15.4	0.04	0.01	0.001	0	0.022	2.23	0.03
4/2/19 10:00	119	7.22	9.85	0.063	0	0		0.018	2.181	0.063

4/2/19 10:10	150	7.66	5.36	0.03	0	0	0	0.022	1.52	0.02
4/8/19 10:10	123.5	6.87	13.7	0.26	0.01	0.01	0.04	0.01	2.181	0.24
4/8/19 10:20	144	6.95	7.76	0.25	0.04	0.01	0.07	0	1.92	0.2
4/15/19 9:30	158.8	7.01	4.52	0.16	0.02	0	0.03	0.02	1.18	0.14
4/15/19 9:35	124.1	6.84	8.28	0.09	0.03	0	0.04	0.01	1.735	0.06
5/2/19 9:50	152.8	6.98	5.58	0.13	0.03	0.02	0.03	0	1.509	0.08
5/2/19 10:00	218	7.63	2.7	0.09	0.02	0.01	0.03	0.01	0.94	0.06
5/15/19 12:00	278.2	7.37	1.91	0.03	0.01	0	0.02	0.013	2.04	0.02
5/15/19 12:20	190.7	6.7	1.51	0.05	0.0178	0	0.02	0.007	1.674	0.032
5/17/19 9:40	113	7.02	14.4	0.15	0.02	0	0.07	0.015	3.05	0.13
5/17/19 9:50	96.86	6.96	32.9	0.18	0.024	0.001	0.09	0.013	4.70	0.15512
5/20/19 9:40	132.5	7.07	9.62	0.08	0.05	0.042	0.06	0.007	2.36	0
5/20/19 10:10	110.8	6.96	9.94	0.1	0.026	0	0.05	0.005	3.006	0.074
5/21/19 9:20	134.6	6.92	7.22	0.15	0.07	0	0.04	0.005	2.1	0.08
5/21/19 9:40	117.8	6.85	13.2	0.44	0.108	0	0.06	0.007	3.368	0.332
5/29/19 10:00	173.3	7.19	1.52	0.04	0.16	0	0.02	0.004	1.23	0
5/29/19 10:20	137.1	6.88	3.6	0.39	0.178	0	0.02	0.004	1.912	0.212
6/12/19 11:22	228.8	7	2.13	0.01	0.03	0.016	0.013	0.01	1.43	0
6/26/19 12:20	274.4	7.25	0.98	0.19	0.02	0.016	0.01	0.01	3.68	0.16
7/1/19 10:00	247.4	7.19	1.65	0.1	0.06	0.079	0.007	0	6.38	0
7/25/19 9:10	241.3	6.99	1.02	0.003	0.0119	0.024	0.017	0	5.72	0
7/25/19 11:10	285.7	7.52	0.78	0.08	0.05	0.025	0.029	0.02	3.43	0.01
8/5/19 11:00	287.8	7.52	0.56	0	0.02	0.013	0.017	0.02	3.52	0
8/5/19 11:40	231.3	7.46	1	0.014	0.0119	0.039	0.013	0	2.725	0
8/22/19 9:50	255.6	7.55	1.92	0.119	0.094	0.012	0.013	0	3.925	0.012
8/22/19 9:50	303.8	7.63	0.14	0	0.03	0.001	0.031	0.02	5.45	0
9/5/19 10:40	371.8	6.9	0	0	0.24	0.04	0.02	0.01	3.62	0
9/16/19 9:05	348.4	7.13		0.26	0.53	0.08	0.01	0.01	3.45	0
9/16/19 9:10	375	7.52	0	0	0.22	0.04	0.02	0.01	4.74	0
10/1/19 10:35	381.9	7	17.3	0.09	0.1	0.02	0.35	0.01	2.02	0
10/1/19 10:45	407.9	7.22	0.29	0	0.05	0.02	0.34	0.04	2.34	0
10/24/19 10:25	374.1	7.09	1.64	0.32	0.07	0.14	0.34	0.02	0	0
10/24/19 10:30	384.6	7.15	0.34	0.15	0.18	0.03	0.33	0.01		
11/25/19 9:45	370.7	7.47	0.4	0.09	0.04	0.01	0.33	0.03	1.79	0.04
12/6/19 11:20	345.7	7.38	2.84	0.1	0.02	0.01	0.35	0.02	2.09	0.07
12/7/19 8:00	218.8	6.93	25.8	0.37	0.06	0.04	0.37	0.01	25.75	0.27
12/7/19 12:00	236.9	6.95	7.13	0.42	0.07	0.03	0.36	0.04	5.44	0.32
12/7/19 16:00	213.6	6.82	3.87	0.19	0.01	0.07	0.4	0.02	4.67	0.11
12/8/19 8:00	196.3	6.79	3.04	0.09	0.24	0.09	0.39	0.01	5.48	0
12/13/19 14:30	231.4	6.88	15.3	0.08	0.02	0.03	0.02	0.03	5.61	0.03

12/20/19 11:55	85	7.09	3.53	0.01	0.02	0.06	0.02	0.02	5.39	0
12/23/19 11:50	221.9	6.77	8.22	0	0.05	0.04	0.03	0.03	5.82	0
1/15/20 8:00	144.8	6.72	30.8	0	0.13	0.011	0	0.01	8.82	0
1/15/20 10:00	149.5	6.9	37.7	0	0.09	0.009	0	0	10.59	0
1/15/20 12:00	157.7	6.88	25.8	0	0.09	0.002	0	0.01	7.83	0
1/15/20 14:00	140.7	6.86	30.5	0	0.03	0.001	0	0	8.91	0
1/15/20 16:00	140.6	6.86	31.5	0	0.11	0.009	0	0.01	8.13	0
1/15/20 18:00	137.2	6.93	23	0	0.04	0.008	0	0	6.82	0
1/15/20 20:00	134.9	6.94	16.6	0	0.11	0.004	0	0.01	8.05	0
1/15/20 22:00	137.7	6.92	20.9	0	0.02	0.002	0	0.01	9.16	0
1/16/20 0:00	140.5	6.9	18.7	0	0.09	0.009	0	0	6.1	0
1/16/20 2:00	144.7	6.92	15.2	0	0.12	0.01	0	0	7.37	0
1/16/20 4:00	140.9	6.84	14.6	0	0.06	0.009	0	0	6.61	0
1/16/20 6:00	141.3	6.86	14.8	0	0.03	0.002	0	0	5.34	0
1/16/20 8:00	139.7	6.81	17.3	0	0.04	0.008	0	0	6.69	0
1/16/20 10:00	140.2	6.8	13	0	0.08	0.001	0	0	6.69	0
1/16/20 12:00	142.4	6.82	13.3	0	0.09	0.008	0	0	6.16	0
1/16/20 14:00	143.4	6.79	12.4	0	0.08	0	0	0	5.7	0
1/16/20 16:00	145.5	6.87	11.5	0	0.03	0.009	0	0	5.24	0
1/16/20 18:00	149	6.82	11.7	0	0.07	0	0	0.02	7.18	0
1/16/20 20:00	137.7	6.77	12.1	0	0.02	0.009	0	0	5.37	0
1/8/20 11:40	251.3	6.58	2.77	0.07	0.05	0.035	0.246	0	5.26	0
1/15/20 14:58	175.8	6.62	12.1	0.18	0.01	0.027	0.26	0.01	6.78	0.14
1/25/20 12:00	151.5	6.75	4.87	0.42	0.11	0	0.26	0.01	7.08	0.31
1/25/20 18:00	159.7	6.77	7.53	0.29	0.05	0	0.268	0	8.55	0.24
1/26/20 0:00	156	6.78	11.6	0.32	0.08	0	0.295	0.03	8.8	0.24
1/26/20 6:00	138.9	6.85	19	0.28	0.03	0	0.292	0	7.28	0.25
1/26/20 12:00	134.1	6.8	14.9	0.32	0.05	0	0.273	0.02	8	0.26
1/26/20 18:00	131.2	6.8	13.2	0.09	0.03	0	0	0.02	6.94	0.06
1/27/20 0:00	137	6.85	12.3	0.09	0.03	0	0.244	0	6.3	0.07
1/27/20 6:00	135	6.82	10.5	0.09	0.03	0	0.246	0.01	6.38	0.06
1/27/20 12:00	133.4	6.85	10.3	0.07	0.02	0	0.254	0.02	5.48	0.05
1/27/20 18:00	137.4	6.81	10.4	0.1	0.01	0	0.268	0.01	6.79	0.09
1/28/20 0:00	121.4	6.83	8.79	0.28	0.03	0	0.236	0.01	8.01	0.25
1/28/20 6:00	119.2	6.79	9.8	0.12	0.03	0	0.249	0.01	7.26	0.09
1/28/20 12:00	138.6	6.61	10	0.06	0.01	0	0.201	0.01	6.66	0.05
1/28/20 18:00	124.4	6.64	10.3	0.22	0.07	0.006	0.249	0	9.92	0.15
1/29/20 0:00	139.2	6.75	10.3	0.15	0.04	0	0.403	0.01	7.84	0.11
1/29/20 6:00	137.5	6.8	9.19	0.09	0.01	0	0.265	0.01	6.27	0.08
1/29/20 12:00	139.6	6.87	9.93	0.13	0.01	0	0.249	0.02	6.43	0.11

2/11/20 10:58	223	7.2	4.29	0.19	0	0	0.015	0.01	4.31	0.19
2/26/20 11:04	287.7	7.01	9.1	0.05	0.01	0	0.049	0.012	5.49	0.03
3/17/20 9:10	307.5	6.99	0.84	0.12	0.01	0	0.003	0.01	1.72	0.11
3/31/20 9:00	319.6	7.03	1.45	0	0	0	0	0.012	6.55	0
4/6/20 11:50	15.4	7.7	0	0	0	0	0	0.012	1.63	0
4/20/20 13:47	305.7	6.89	8.41	0.02	0	0	0.031	0.026	6.03	0.02
5/18/20 9:40	265.1	7.01	5.06	0	0	0	0	0.009	6.69	0
6/2/20 9:23	332	6.95	3.43	0.07	0	0	0	0.012	8.27	0.07
6/29/20 12:40	120.1	7.38	1.36	0	0	0	0	0.01	1.61	0
7/21/20 11:40	84.7	8.04	1.84	0	0	0	0	0.012	2.83	0

Table 39: Treat (TRE) sub-watershed.

Date	EC μS	pH mg/L	Turb mg/L	TN mg/L	NH_4^+-N mg/L	NO_3^--N mg/L	TP mg/L	PO_4 mg/L	DOC mg/L	DON mg/L
5/26/16 9:50	152	7.21	1.83	0.18	0	0	0.008	0.005	1.63	0.18
7/1/16 10:55	168	8.42	0.8	0.09	0.01	0	0.019	0.016	1.2	0.08
12/14/16 7:00	180	7.78	2.5	0.12	0.06	0.02	0.024	0.016	2.17	0.04
9/28/16 10:25	217	8.41	1	0.08	0.01	0.02	0.018	0.014	1	0.05
10/27/16 10:10	161	7.74	15.6	0.29	0.01	0.09	0.032	0.018	9.09	0.19
11/10/16 0:00	140	8.06	19.9	0.26	0	0	0.078	0.015	8.25	0.26
11/10/16 0:00	136	8.01	15.7	0.27	0	0	0.071	0.01	5.46	0.27
11/10/16 0:00	136	7.88	12.2	0.44	0	0	0.078	0.025	4.76	0.44
11/10/16 0:00	134	7.93	7.93	0.23	0	0	0.026	0.005	3.44	0.23
12/10/16 11:30	99	7.6	30.7	0.3	0.04	0.04	0.067	0.009	2.95	0.22
12/11/16 12:20	110	7.44	18.5	0.16	0.02	0.02	0.036	0.007	1.64	0.12
12/16/16 12:20	104	7.35	16.1	0.18	0.03	0.02	0.039	0.011	1.72	0.13
12/15/16 12:00	93	7.42	51.9	0.3	0	0.02	0.109	0.007	3.29	0.28
1/3/17 20:30	107	7.68	24.9	0.41	0.05	0.01	0.033	0.008	5.25	0.35
1/4/17 4:40	105	7.79	25.8	0.37	0.02	0.01	0.033	0.011	3.55	0.34
1/4/17 12:50	105	7.69	21.4	0.3	0.02	0.01	0.027	0.008	2.87	0.27
1/4/17 21:00	107	7.72	20.5	0.37	0.01	0.01	0.024	0.008	2.49	0.35
1/8/17 8:40	97	7.65	30.1	0.4	0.02	0.01	0.033	0.006	4.14	0.37
1/8/17 16:10	84	7.62	58.1	0.17	0.01	0.02	0.053	0.008	4.23	0.14
1/8/17 21:10	89	7.61	31.4	0.11	0.04	0.02	0.033	0.006	3.55	0.05
1/20/17 1:00	101	7.62	15.3	0.08	0.01	0.01	0.024	0.008	3.01	0.06
1/20/17 7:00	90	7.64	36.4	0.15	0.03	0.01	0.065	0.027	4.37	0.11
1/20/17 11:00	90	7.68	31.6	0.11	0.02	0.01	0.03	0.006	3.75	0.08
1/20/17 19:00	93	7.77	22.2	0.08	0	0.01	0.024	0.006	3.29	0.07
1/23/17 12:10	96	7.69	19.9	0.13	0.01	0.01	0.021	0.004	3.29	0.11
1/18/17 17:00	101	7.56	20.2	0.29	0.04	0.02	0.051	0.03	5.35	0.23

2/6/17 20:00	97	7.53	16.1	0.28	0.17	0.01	0.039	0.002	3	0.1
2/7/17 4:00	82	7.54	65.7	0.2	0.04	0.01	0.103	0.002	3.96	0.15
2/7/17 6:00	79	7.5	120	0.24	0.05	0.01	0.154	0.004	3.68	0.18
2/7/17 18:00	91	7.48	21.2	0.09	0.03	0.01	0.034	0.004	2.18	0.05
2/8/17 4:00	95	7.5	25.2	0.13	0.06	0.01	0.051	0.01	2.06	0.06
2/20/17 12:00	97	7.41	11.1	0.31	0.17	0	0.018	0	2.07	0.14
2/20/17 18:00	93	7.65	19.6	0.32	0.17	0	0.033	0.001	2.73	0.15
2/21/17 0:00	88	7.52	33	0.37	0.18	0	0.061	0.003	2.93	0.19
2/21/17 4:00	88	7.53	23.9	0.36	0.19	0	0.036	0.001	2.52	0.17
2/22/17 13:20	95	7.49	13.7	0.06	0	0	0.024	0.006	1.6	0.06
3/24/17 5:00	104	7.1	16.5	0.48	0.17	0.09	0.052	0	3.4	0.22
3/24/17 9:00	98	7.05	40.4	0.51	0.18	0.07	0.085	0	4.33	0.26
3/24/17 15:00	98	7.31	35.2	0.52	0.22	0.01	0.058	0	3.05	0.29
3/25/17 1:00	100	7.23	25.1	0.35	0.15	0.02	0.041	0	2.2	0.18
3/25/17 11:00	103	7.35	31.7	0.33	0.16	0.03	0.064	0	1.52	0.14
3/25/17 23:00	105	7.43	19.5	0.2	0.06	0.05	0.046	0	1.46	0.09
3/22/17 10:13	106	7.66	27.3	0.56	0	0.01	0.044	0	1.67	0.55
4/12/17 13:05	121	7.69	9.62	0.29	0.01	0.01	0.026	0.002	1.39	0.27
4/26/17 10:00	129	7.26	6.82	0.39	0.01	0.01	0.026	0	1.67	0.37
5/11/17 10:50	136	7.79	5.64	0.21	0	0	0.019	0.006	1.09	0.21
5/26/17 11:40	150	7.91	3.73	0.47	0.08	0	0.015	0.008	1.67	0.39
6/16/17 12:30	149	7.87	3.27	0.04	0.02	0	0.02	0.007	1.07	0.02
7/5/17 8:32	281	7.49	17.7	0.07	0.01	0.03	0.071	0.01	1.14	0.03
8/1/17 14:20	294	7.75	5.34	0.05	0.01	0.01	0.028	0.011	1.09	0.03
9/21/17 11:45	309	7.79	0.97	0.13	0.03	0.007	0.039	0.017	1.28	0.09
10/19/17 9:10	325	7.89	8.76	0.15	0.02	0.023	0.072	0.014	1.12	0.11
11/2/17 13:40	281	8.14	7.04	0.11	0.01	0.001	0.026	0.013	3.64	0.1
11/21/17 12:32	335	8.43	3.49	0.21	0.01	0.012	0.059	0.024	1.24	0.19
12/5/17 11:40	284	6.82	2.46	0.09	0.03	0.014	0.018	0.011	1.45	0.05
12/19/17 14:28	301	6.92	10.4	0.3	0.01	0.014	0.098	0.001	1.28	0.28
1/5/18 12:00	196	6.89	8.87	0.03	0.02	0	0.028	0.008	3.52	0.01
1/8/18 14:00	146	6.59	25.8	0.31	0.02	0	0.086	0.003	9.72	0.29
1/8/18 18:00	142	6.93	65.1	0.34	0.01	0	0.191	0.004	7.53	0.33
1/8/18 22:00	142	6.8	38.1	0.25	0.01	0	0.108	0.001	4.96	0.24
1/9/18 4:00	120	6.76	28.1	0.16	0.01	0	0.062	0.001	3.65	0.15
1/9/18 10:00	139	6.75	21.9	0.19	0.02	0	0.052	0.001	3.27	0.17
1/10/18 12:00	145	6.73	18.3	0.12	0.01	0	0.043	0.003	2.38	0.11
1/18/18 11:00	151	7.01	10.5	0.09	0	0	0.028	0.008	3.98	0.09
1/18/18 11:20	133	6.87	12.9	0.09	0.01	0	0.037	0.001	4.58	0.08
1/19/18 3:20	124	6.86	18.9	0.11	0.01	0	0.049	0.004	3.02	0.1

1/20/18 7:20	122	6.74	13.6	0.05	0.01	0	0.028	0.004	0	0.04
1/23/18 14:15	110	6.99	18.1	0.16	0.02	0	0.04	0.009	1.86	0.14
1/24/18 12:00	111	6.96	26.8	0.21	0.02	0	0.069	0.006	4.16	0.19
1/24/18 18:00	107	6.91	28.1	0.17	0.02	0	0.063	0.006	3.64	0.15
1/24/18 22:00	102	6.85	27	0.19	0.02	0.002	0.066	0.003	2.9	0.17
1/25/18 8:00	105	6.95	18.7	0.21	0.02	0	0.043	0.003	2.28	0.19
1/25/18 22:00	101	6.96	17.1	0.13	0.01	0	0.034	0.004	2.27	0.12
2/7/18 12:50	131	7.19	3.49	0.07	0.01	0	0.037	0.052	1.2	0.06
2/23/18 11:58	146	7.34	4.68	0.12	0	0	0.05	0.033	1	0.12
3/1/18 10:20	121	7.08	26	0.18	0	0	0.057	0.015	3.23	0.18
3/7/18 11:35	118	7.05	21	0.13	0	0	0.057	0.015	1.37	0.13
3/1/18 23:00	122	6.57	22.7	0.44	0	0.297	0.057	0.056	2.64	0.14
3/2/18 21:00	114	6.69	18.8	0.2	0	0	0.044	0.028	2.61	0.2
3/3/18 7:00	136	6.84	16.1	0.14	0	0.002	0.031	0.019	2.39	0.14
3/16/18 13:00	132	6.98	11	0.07	0.03	0	0.024	0.028	2.94	0.04
3/15/18 19:00	129	7.01	15.9	0.03	0.03	0.027	0.03	0.028	2.62	0
3/15/18 13:00	121	6.98	13	0.02	0.03	0	0.013	0.024	1.8	0
3/17/18 3:00	123	6.91	13.3	0	0.05	0	0.007	0.024	1.95	0
3/17/18 11:00	121	6.96	10.5	0	0.03	0	0.01	0.028	1.5	0
3/21/18 13:20	134	7.03	5.38	0	0	0	0.048	0.033	1.3	0
3/15/18 12:50	109	6.98	14.5	0.06	0.01	0	0.027	0.042	3.4	0.05
3/29/18 12:55	109	7.13	4.69	0	0.05	0	0.001	0.028	0.99	0
4/5/18 11:00	126	7.3	2.14	0	0.05	0	0.001	0.042	0.92	0
4/6/18 12:10	72	7	391	0.38	0.03	0	0.554	0.012	3.47	0.35
4/6/18 8:00	91	6.8	145	0.34	0.02	0	0.298	0.012	5.39	0.32
4/10/18 10:15	109	6.9	10.9	0	0.03	0	0.01	0.012	1.33	0
4/6/18 4:00	110	6.93	18	0.47	0.08	0	0.059	0.007	3.84	0.39
4/6/18 12:00	78	6.82	348	0.55	0.01	0	0.557	0.007	3.42	0.54
4/6/18 22:00	88	6.73	647	0.69	0.01	0	0.694	0.007	2.46	0.68
4/7/18 2:00	87	6.69	888	0.62	0.01	0	0.828	0.007	2.34	0.61
4/7/18 10:00	92	6.76	495	0.39	0.01	0	0.514	0.007	1.87	0.38
4/7/18 18:00	96	6.72	13.2	0.21	0.01	0	0.018	0.007	1.59	0.2
4/25/18 14:15	113	7.18	3.57	0.12	0.01	0	0.004	0.007	1.01	0.11
5/11/18 13:05	144	7.47	2.04	0.31	0.01	0	0.01	0.012	1.05	0.3
5/25/18 11:15	155	7.45	1.65	0	0.01	0	0.015	0.016	0.89	0
6/13/18 13:30	155	7.23	0.99	0.04	0.01	0.055	0.108	0.006	3.03	0
7/5/18 13:45	166	7.31	0.95	0.11	0.01	0	0.029	0.003	1.29	0.1
7/20/18 8:40	171	7.27	0.43	0	0.03	0	0.044	0.012	1.07	0
8/2/18 9:00	173	7.35	0.62	0.15	0.01	0.055	0.041	0.005	1.19	0.09
8/24/18 15:30	189	7.53	4.29	0.09	0.01	0	0.049	0	1.33	0.08

9/16/18 12:40	192	7.89	1.55	0.08	0.01	0.005	0.039	0.006	1.03	0.07
10/2/18 9:30	114	9.29	3.04	0.1	0.01	0	0.036	0.018	3.09	0.09
10/24/18 14:50	232	7.56	0.36	0.11	0.01	0	0.044	0.01	1.05	0.1
11/19/18 14:20	222	7.15	0.63	0.12	0.01	0	0.096	0	0.92	0.11
12/4/18 12:40	98	7.96	1.79	0.09	0.02	0.15	0.036	0.009	1.85	0
12/16/18 14:00	123	6.7	13.4	0.15	0.01	0	0	0	10.31	0.14
12/16/18 16:00	134	7.03	26.1	0.3	0.03	0.02	0.035	0.003	8.06	0.25
12/16/18 18:00	137	6.98	26.5	0.09	0.01	0	0.014	0	6.16	0.08
12/17/18 13:50	140	6.94	7.85	0.07	0.01	0	0	0.003	2.79	0.06
12/26/18 14:22	123	6.79	7.87	0.08	0.01	0	0	0.003	1.99	0.07
1/7/19 14:15	115	6.81	14.8	0	0.02	0.07	0.028	0.003	2.43	0
1/9/19 6:00	117	6.93	9.2	0.15	0.02	0.02	0.124	0	2.98	0.11
1/9/19 13:15	116	7.03	14.6	0.08	0.03	0.1	0.122	0.003	2.5	0
1/9/19 18:00	116	6.77	9.99	0.21	0.03	0	0.123	0	2.88	0.18
1/11/19 14:00	130	6.75	8.14	0	0.02	0.02	0	0.011	2.09	0
1/16/19 11:50	118	6.95	8.11	0	0.02	0.01	0	0.005	4.76	0
1/16/19 14:00	111	6.88	15.5	0	0.02	0	0	0	6.36	0
1/16/19 18:00	97	6.62	67.9	0	0.02	0.1	0	0	5.87	0
1/16/19 20:00	97	6.66	66.5	0	0.06	0.02	0	0	4.6	0
1/17/19 2:00	97	6.93	28.5	0	0.01	0.01	0	0	3.02	0
1/18/19 4:00	107	6.76	12.4	0	0.01	0	0	0.027	2.44	0
1/18/19 13:40	108	6.7	12.9	0	0.01	0	0	0	1.89	0
1/22/19 13:55	12.4	5.5	8.76	0.06	0.05	0	0.001	0.013	1.73	0.01
2/1/19 11:24	133	6.9	5.25	0	0.01	0.001	0.001	0.013	1.45	0
2/4/19 3:00	126	6.87	9.35	0	0.01	0	0.018	0.012	3.04	0
2/4/19 9:00	97	6.92	12	0.01	0.01	0.005	0.042	0.012	3.65	0
2/4/19 15:00	127	6.72	15	0	0.01	0.008	0.021	0.013	3	0
2/5/19 11:35	119	6.94	11.4	0	0.01	0	0.025	0.015	2.27	0
2/12/19 13:30	115	6.92	6.99	0	0.01	0.001	0.021	0.013	1.71	0
2/13/19 0:00	118	7.04	11.3	0	0.01	0	0.021	0.01	3.45	0
2/13/19 10:00	101	6.84	18.8	0.06	0.01	0	0.014	0.015	3.08	0.05
2/13/19 18:00	98.4	6.86	14.7	0.42	0.01	0	0.007	0.013	2.31	0.41
2/14/19 2:00	86.1	6.72	41.9	0.25	0.01	0.001	0.014	0	3.75	0.24
2/14/19 12:00	79.5	6.88	23.8	0.66	0.03	0	0.057	0.012	2.82	0.63
2/14/19 22:00	98.8	7.13	16.4	0.15	0.04	0	0.043	0.015	2.7	0.11
2/19/19 11:50	104.7	6.85	7.56	0.1	0.02	0	0	0.01	1.58	0.08
2/26/19 10:00	84.4	6.93	25.5	0.08	0.02	0.001	0.12	0.111	2.59	0.06
2/26/19 14:00	99.6	6.88	32.6	0.2	0.02	0	0.081	0.019	2.76	0.18
2/26/19 20:00	84.9	6.85	50.7	0.26	0.02	0	0.152	0.019	3.44	0.24
2/27/19 2:00	83	6.78	198	0.37	0.05	0	0.206	0.02	3.84	0.32

2/27/19 6:00	89.4	6.79	74.7	0.19	0.04	0	0.114	0.019	3.13	0.15
2/27/19 18:00	96.2	6.82	34.9	0.07	0.01	0	0.069	0.025	2.34	0.06
2/28/19 13:10	84	6.92	12.3	0.03	0.01	0	0.048	0.019	1.85	0.02
3/5/19 18:00	98.2	6.82	9.76	0.11	0.03	0	0	0.006	1.56	0.08
3/19/19 11:00	114	7.55	2.83	0.12	0.04	0	0	0.014	1.84	0.08
3/25/19 12:00	98	7.6	26.5	0.1	0.01	0.001	0	0.021	4.42	0.09
3/28/19 8:00	94	7.41	14.7	0.05	0	0	0	0.017	2.75	0.05
3/28/19 12:00	117	7.61	11	0.09	0	0	0	0.024	2.47	0.08
3/28/19 20:00	114	7.59	9.41	0.03	0.03	0	0	0.014	2.4	0.01
3/29/19 16:00	116	7.6	7.14	0.07	0.03	0.001	0	0.017	2.38	0.04
4/2/19 11:20	122	7.62	4.7	0.01	0.01	0	0	0.021	1.75	0
4/8/19 10:22	114.9	6.78	7.67	0.14	0.02	0.01	0.03	0	1.73	0.11
4/15/19 10:55	122.4	6.77	4.21	0.07	0.02	0	0.03	0.01	1.55	0.05
5/2/19 13:00	115.7	7.16	5.49	0.07	0.02	0	0.03	0.02	1.23	0.05
5/16/19 8:00	109.3	6.89	12.9	0.23	0.01	0.007	0.1	0.007	6.55	0.21
5/17/19 9:50	103.2	6.97	11.4	0.11	0.05	0	0.05	0.012	2.92	0.06
5/20/19 9:05	113.8	7.04	5.94	0.11	0.01	0	0.03	0.005	2.14	0.1
5/21/19 9:15	116.1	6.76	4.64	0.09	0.05	0	0.03	0.002	2.16	0.04
5/29/19 9:30	130.5	6.89	1.65	0.03	0.16	0	0.02	0.002	1.7	0
6/12/19 14:40	115.5	7.04	3.1	0	0.03	0.023	0.013	0.01	2.75	0
7/23/19 12:55	124.5	7.28	1.39	0.01	0.04	0.022	0.01	0.01	3.22	0
8/5/19 13:40	159.1	7.31	2.81	0.07	0.02	0.018	0.02	0.01	3.31	0.03
8/22/19 10:20	141.1	7.56	9.33	0	0.03	0.022	0.017	0.01	5.78	0
9/5/19 9:30	177.9	7	0.68	0	0.05	0.048	0.006	0.01	8.48	0
9/16/19 10:10	189.3	7.47	0	0.08	0	0.04	0.02	0.01	4.13	0.04
10/1/19 9:30	205.1	7.16	0.52	0	0.03	0.02	0.34	0.02	1.9	0
10/24/19 10:10	179.3	6.95	1.7	0.08	0.05	0.04	0.35	0.02	0	0
11/25/19 14:50	182	7.77	0.56	0.21	0.06	0.02	0.34	0.03	3.06	0.13
12/6/19 13:15	179.4	7.54	6.11	0.14	0.01	0	0.35	0.03	4.97	0.13
12/7/19 8:00	136.2	7.1	16.1	0.25	0.02	0.05	0.35	0.01	12.05	0.18
12/7/19 12:00	146.6	7.14	19.2	0.3	0.16	0.06	0.36	0.02	11.11	0.08
12/7/19 16:00	168.3	7.02	16.5	0.19	0.03	0.03	0.36	0.02	6.47	0.13
12/7/19 20:00	97.7	7.09	5.08	0.33	0	0.04	0.35	0	5.57	0.29
12/8/19 0:00	146.4	6.88	20.1	0.14	0.06	0.03	0.35	0.02	4.99	0.05
12/8/19 4:00	140.1	6.9	14.9	0.39	0.05	0.04	0.35	0.03	7.01	0.3
12/8/19 8:00	118.3	6.9	16.8	0.22	0.06	0.04	0.34	0.02	5.82	0.12
12/8/19 12:00	131.7	6.87	15.6	0.18	0.08	0.02	0.34	0.01	5.63	0.08
12/8/19 16:00	130.6	6.89	14.1	0.11	0.07	0.03	0.34	0.02	5.85	0.01
12/8/19 20:00	142.2	6.94	13.5	0.11	0.03	0.04	0.34	0.01	6.88	0.04
12/9/19 0:00	122.9	6.92	13.1	0.14	0.05	0.02	0.34	0.02	4.05	0.07

12/13/19 12:45	140.3	7.03	9.17	0.23	0.13	0.07	0.03	0.06	7.24	0.03
12/20/19 13:40	140.6	7.04	4.39	0.11	0.04	0.05	0.02	0.02	5.86	0.02
12/22/19 12:00	206.8	7.05	11.1	0.32	4.95	0.06	1.17	1.23	13.61	0
12/23/19 11:10	125.4	6.97	10.7	0.01	0.04	0.04	0.03	0.02	6.19	0
1/8/20 13:25	156.5	6.78	4.3	0.33	0.07	0.055	0.227	0	15.47	0.2
1/15/20 10:00	116	6.92	12.9	0.08	0.01	0.017	0.284	0	4.9	0.05
1/15/20 11:00	115.2	6.87	12.7	0.17	0.05	0.031	0.254	0	7.23	0.09
1/16/20 0:00	115.9	6.84	12.6	0.13	0.01	0.041	0.252	0	5.73	0.08
1/16/20 2:00	113.1	6.83	12.5	0.2	0.01	0.032	0.23	0	6.94	0.16
1/16/20 4:00	114.3	7.21	11.3	0.09	0.01	0.032	0.287	0	4	0.05
1/16/20 6:00	113.8	7.53	11.6	0.16	0.01	0.042	0.257	0	8.42	0.11
1/16/20 8:00	111.7	7.12	19.2	0.2	0.01	0.04	0.281	0	7.94	0.16
1/16/20 10:00	104.6	7.05	39.7	0.14	0.02	0.038	0.292	0.02	7.32	0.08
1/16/20 12:00	107.3	7	38.3	0.22	0.03	0.029	0.276	0	8.37	0.16
1/16/20 14:00	106.8	7	32.9	0.24	0.05	0.053	0.254	0.01	8.02	0.14
1/16/20 16:00	91.9	7.01	30.5	0.31	0.07	0.036	0.252	0	7.97	0.2
1/16/20 18:00	103.2	7	23.2	0.19	0.03	0	0.252	0	0	0
1/16/20 20:00	91.1	7.06	24.3	0.27	0.05	0.008	0.276	0	0	0
1/16/20 22:00	102.3	7.02	19.8	0.2	0.05	0.02	0.497	0.01	6.48	0.12
1/17/20 0:00	104.1	7.02	23.3	0.18	0.03	0	0.252	0.01	0	0
1/17/20 2:00	101.6	7	17.8	0.18	0.05	0.018	0.245	0	7.5	0.11
1/17/20 4:00	81.7	7.07	15.2	0.19	0.04	0	0.254	0	6.12	0.15
1/17/20 6:00	102.2	7.01	17.2	0.33	0.06	0	0.263	0.02	6.56	0.27
1/17/20 8:00	75.6	7.07	16.3	0.25	0.04	0	0.254	0.03	6.85	0.21
1/17/20 10:00	93.5	7.1	17.7	0.16	0.03	0	0.362	0.01	5.71	0.13
1/17/20 12:00	106.3	6.99	17.8	0.23	0.06	0.02	0.263	0.01	6.81	0.14
1/17/20 14:00	94	7.09	15.7	0.12	0.03	0	0.271	0.02	5.22	0.09
1/17/20 16:00	107.4	7.07	14.3	0.15	0.04	0.006	0.263	0.02	6.74	0.1
1/17/20 18:00	121.5	7.09	13.7	0.17	0.03	0	0.249	0.02	6.32	0.13
1/23/20 13:12	112.1	6.92	9.49	0.37	0.02	0	0.432	0.01	3.18	0.35
1/27/20 14:25	106.7	6.97	13.5	0.16	0.01	0	0.254	0.02	7.89	0.15

Table 40: Uqlidisi (UQL) sub-watershed.

Date	EC µS	pH mg/L	Turb mg/L	TN mg/L	NH_4^+-N mg/L	NO_3^--N mg/L	TP mg/L	PO_4 mg/L	DOC mg/L	DON mg/L
5/26/16 9:13	186	6.89	5.22	0.23	0.02	0	0.012	0.003	1.32	0.21
6/30/16 10:08	207	7.28	6.03	0.24	0.04	0	0.033	0.01	2.06	0.2
10/27/16 9:28	137	7.56	13.7	0.17	0.01	0.01	0.012	0.007	5.07	0.15
11/10/16 0:00	130	8.03	22.7	0.29	0.01	0	0.065	0.002	6.03	0.28
12/11/16 1:40	99	7.3	29.9	0.28	0	0.02	0.042	0.004	3.13	0.26

12/11/16 14:00	93	7.31	25.1	0.3	0.06	0.02	0.039	0.003	2.57	0.22
12/15/16 11:20	90	7.48	31.2	0.35	0.03	0.02	0.049	0.003	4.47	0.3
12/16/16 11:50	96	7.38	23.5	0.22	0.04	0.02	0.033	0.003	2.81	0.16
1/3/17 20:50	94	7.63	44.7	0.09	0	0	0.03	0.001	6.04	0.09
1/4/17 5:00	100	7.56	41.4	0.09	0	0	0.044	0	4.76	0.09
1/4/17 13:10	101	7.54	37.9	0.09	0.01	0	0.044	0.001	3.85	0.08
1/5/17 3:10	106	7.51	30.4	0.13	0.1	0	0.03	0.004	3.31	0.03
1/5/17 3:50	94	7.47	36	0.08	0	0	0.033	0.001	5.33	0.08
1/9/17 4:40	89	7.48	28	0.13	0.09	0	0.035	0.003	4.19	0.04
1/23/17 11:30	90	7.4	23.9	0.06	0.02	0	0.03	0.001	3.36	0.04
1/19/17 23:00	97	7.47	26.3	0.14	0.04	0	0.047	0.006	3.78	0.1
1/20/17 5:00	97	7.44	28	0.14	0.04	0.01	0.05	0.012	4.9	0.09
1/2/17 17:00	92	7.45	31.9	0.07	0	0	0.027	0.001	5.13	0.07
1/20/17 19:00	85	7.5	26.8	0.13	0.01	0.01	0.024	0	4.31	0.11
2/8/17 11:40	87	7.57	30.4	0.13	0	0	0.039	0.002	3.11	0.13
2/7/17 10:10	81	7.67	38.5	0.1	0	0	0.048	0.002	4.36	0.1
2/9/17 11:00	74	7.57	45.1	0.17	0.03	0	0.057	0.004	5.52	0.14
2/9/17 14:00	74	7.54	40.8	0.25	0.18	0	0.051	0.002	4.48	0.07
2/10/17 0:00	79	7.49	38.4	0.26	0.16	0	0.048	0.002	3.51	0.1
2/11/17 0:00	87	7.49	27.1	0.22	0.13	0	0.039	0.004	2.58	0.09
2/20/17 12:00	91	7.39	24.4	0.33	0.16	0	0.027	0	3.24	0.17
2/20/17 20:00	108	7.39	23.6	0.33	0.01	0	0.033	0.009	2.12	0.32
2/21/17 0:00	86	7.53	28.6	0.37	0.18	0	0.033	0	3.73	0.19
2/21/17 10:00	84	7.47	28.9	0.35	0.19	0	0.03	0	3.1	0.16
2/22/17 12:40	89	7.41	27.1	0.14	0.01	0	0.027	0.001	2.54	0.13
3/24/17 5:00	121	8.09	31.1	0.37	0.14	0.02	0.041	0	2.06	0.21
3/24/17 7:00	109	8.03	31.9	0.31	0.15	0.01	0.041	0	2.83	0.15
3/24/17 11:00	98	7.92	45.4	0.44	0.17	0.01	0.064	0	4.4	0.26
3/24/17 23:00	98	7.8	46.1	0.35	0.1	0.01	0.061	0	2.96	0.24
3/25/17 11:00	101	7.79	42.1	0.43	0.18	0	0.055	0	2.38	0.25
3/25/17 23:00	103	7.68	32.6	0.37	0.08	0	0.038	0	2.05	0.29
3/22/17 9:40	110	7.57	42.6	0.65	0	0	0.052	0	2.11	0.65
4/12/17 11:20	137	7.59	19.8	0.42	0.02	0	0.029	0	1.52	0.4
4/26/17 9:36	156	7.53	13.8	0.53	0.01	0	0.02	0	1.43	0.52
5/11/17 10:00	162	7.81	10.3	0.22	0	0	0.016	0.001	0.96	0.22
5/26/17 10:45	182	7.81	16.7	0.61	0.06	0	0.051	0.004	1.92	0.55
6/16/17 10:11	166	7.79	10.6	0.06	0.03	0.01	0.026	0.003	0.86	0.02
7/5/17 15:42	315	7.55	6.12	0.03	0.01	0	0.01	0.004	0.98	0.02
11/2/17 12:40	293	7.84	18.9	0.24	0.02	0.001	0.053	0.008	4.24	0.22
11/21/17 11:38	492	8.46	0.82	0.22	0.09	0.004	0.032	0.027	1.27	0.13

12/5/17 10:50	285	6.7	14.2	0.13	0.03	0.01	0.022	0	1.19	0.09
12/19/17 14:00	305	6.62	11.6	0.11	0.02	0.011	0.034	0.004	1.1	0.08
1/5/18 11:10	180	6.87	26.1	0.07	0.01	0	0.037	0	2.69	0.06
1/8/18 16:00	135	6.76	31	0.22	0.02	0	0.055	0.004	6.5	0.2
1/8/18 18:00	117	6.67	29.1	0.22	0.02	1.145	0.055	0	7.39	0
1/8/18 20:00	200	6.95	39.7	0.1	0.01	0	0.052	0	3.98	0.09
1/9/18 2:00	125	6.6	39	0.16	0.01	0	0.058	0.001	4.96	0.15
1/9/18 10:00	111	6.67	35.7	0.13	0.01	0	0.058	0	3.37	0.12
1/10/18 12:00	142	6.7	29.3	0.13	0.01	0	0.04	0	2.47	0.12
1/8/18 10:18	151	6.99	18.8	0.05	0	0	0.037	0.001	2.7	0.05
1/18/18 10:20	131	7.01	19.4	0.15	0.01	0	0.031	0.003	3.27	0.14
1/19/18 4:20	140	6.95	24.9	0.1	0.01	0	0.043	0.003	3.66	0.09
1/20/18 8:20	147	6.88	22.9	0.1	0.01	0	0.031	0.004	2.32	0.09
1/22/18 14:00	109	6.87	30.4	0.16	0.01	0	0.04	0	4.11	0.15
1/23/18 12:00	123	6.89	26.6	0.06	0.02	0	0.031	0	2.74	0.04
1/24/18 12:00	120	7.08	21.2	0.15	0.03	0	0.03	0.001	3.32	0.12
1/24/18 18:00	104	6.88	29	0.18	0.04	0	0.037	0.001	4.62	0.14
1/24/18 22:00	103	6.92	26	0.2	0.03	0	0.04	0.001	4.39	0.17
1/25/18 10:00	103	6.95	24.2	0.18	0.03	0	0.037	0.003	3.3	0.15
1/26/18 10:00	106	7.1	20.7	0.16	0.01	0	0.034	0.004	2.8	0.15
2/7/18 11:25	143	7.06	8.52	0.12	0.01	0	0.04	0.024	1.36	0.11
2/23/18 11:18	148	7.12	14.5	0.13	0.01	0	0.041	0.015	0.88	0.12
3/1/18 9:45	115	7	51.1	0.22	0	0.243	0.067	0.024	3.32	0
3/7/18 11:07	129	7.14	18.6	0.15	0	0	0.037	0.024	1.09	0.15
3/2/18 22:00	122	6.69	23.2	0.28	0	0	0.034	0.033	3.06	0.28
3/2/18 0:00	121	6.65	23.9	0.45	0.29	0	0.031	0.038	4.17	0.16
3/3/18 8:00	139	6.84	27.3	0.24	0	0	0.037	0.033	2.58	0.24
3/16/18 9:00	120	7.04	25.3	0.08	0.04	0.017	0.015	0.024	2.68	0.02
3/21/18 12:03	158	7.08	16.5	0	0.01	0	0.004	0.028	1.19	0
3/16/18 23:00	118	6.94	20.5	0.05	0.04	0	0.013	0.033	2.08	0.01
3/15/18 21:00	126	6.99	21.7	0.07	0.04	0.014	0.015	0.247	2.81	0.02
3/15/18 13:00	142	7.08	14.3	0.1	0.04	0	0.027	0.028	2.56	0.06
3/17/18 11:00	124	6.95	21.4	0.03	0.03	0	0.01	0.024	1.93	0
3/15/18 12:20	118	7.13	25.5	0.06	0.03	0	0.027	0.033	2.45	0.03
3/29/18 12:28	127	7.21	15.5	0	0.01	0	0.007	0.028	1.03	0
4/5/18 10:20	140	7.04	7.19	0	0.03	0	0	0.016	1.03	0
4/6/18 11:30	69	6.95	158	0.34	0.02	0	0.222	0.007	5.95	0.32
4/10/18 9:43	123	7.15	19.5	0.24	0.01	0	0.015	0.016	1.5	0.23
4/6/18 4:00	114	6.66	13.7	0.27	0.01	0	0.021	0.007	3.12	0.26
4/6/18 8:00	91	7.04	31.2	0.34	0.01	0	0.074	0.007	5.32	0.33

4/6/18 10:00	74	7	97.5	0.28	0.01	0	0.152	0.007	5.93	0.27
4/6/18 12:00	71	6.97	226	0.53	0.01	0	0.321	0.007	5.47	0.52
4/6/18 22:00	81	6.96	31.7	0.27	0.01	0	0.036	0.007	3.64	0.26
4/7/18 2:00	77	6.9	29.5	0.43	0.01	0	0.045	0.007	3.83	0.42
4/7/18 12:00	84	6.85	38.6	0.36	0.1	0	0.071	0.007	2.97	0.26
4/8/18 2:00	97	7.06	17.7	0.37	0.01	0	0.01	0.007	2.21	0.36
4/25/18 12:58	125	7.34	6.75	0.07	0.01	0	0.001	0.007	0.8	0.06
5/10/18 10:25	161	7.75	8.91	0.18	0.01	0	0.007	0.016	0.83	0.17
5/25/18 10:00	174	7.57	5.85	0	0.01	0	0.01	0.007	0.7	0
6/13/18 14:00	184	6.85	5.63	0.02	0.01	0.016	0.029	0	2.08	0
12/3/18 16:30	98	7.45	5.1	0.21	0.01	0	0.101	0	1.76	0.2
12/17/18 12:40	161	7.17	7.71	0.13	0.03	0	0.007	0	3.14	0.1
12/26/18 13:20	130	6.96	7.19	0.23	0.04	0	0	0	2.06	0.19
1/6/19 14:00	129	6.79	7.1	0.14	0.01	0	0	0	5.25	0.13
1/6/19 20:00	127	6.99	9.27	0.1	0.03	0	0.004	0.003	5.06	0.07
1/7/19 0:00	134	6.83	9.28	0.05	0.01	0.08	0	0.003	4.8	0
1/7/19 8:00	105	6.78	11	0.44	0.01	0.04	0.021	0.001	3.64	0.39
1/7/19 12:15	112	6.79	15.7	0	0.02	0.02	0.011	0.003	3.08	0
1/9/19 8:00	127	6.87	10.5	0.13	0.04	0.04	0.128	0.003	2.91	0.05
1/9/19 12:20	127	6.86	14.5	0.24	0.02	0.1	0.123	0	2.47	0.12
1/9/19 18:00	126	6.76	11.5	0.1	0.01	0	0.123	0	2.73	0.09
1/10/19 10:00	126	6.82	9.38	0.13	0.02	0	0.122	0	3.02	0.11
1/16/19 11:15	146	7.04	12.8	0	0.01	0	0	0	2.54	0
1/16/19 12:00	109	6.85	8.34	0	0.18	0.02	0	0	5.84	0
1/16/19 14:00	121	6.91	12.3	0	0.04	0.02	0	0	4.99	0
1/16/19 18:00	101	6.72	25.2	0	0.03	0.02	0	0	7.64	0
1/16/19 20:00	93	6.71	25.2	0	0.02	0	0	0	7.06	0
1/17/19 4:00	87	6.75	17.1	0	0.04	0.01	0	0	4.23	0
1/18/19 10:00	110	6.8	10.4	0	0.01	0	0	0	2.5	0
1/22/19 13:20	111	6.85	11.7	0	0.02	0	0	0	2.09	0
2/1/19 10:30	157	6.93	5.54	0	0.01	0	0.004	0	1.28	0
2/4/19 6:00	130	7.12	18.6	0	0.04	0.005	0.014	0	4.82	0
2/4/19 12:00	119	6.72	18.7	0.25	0.01	0.005	0.018	0.009	3.57	0.24
2/4/19 18:00	125	6.73	18	0.02	0.02	0.001	0.004	0.009	3.29	0
2/5/19 10:35	116.4	7.38	15	0.01	0.02	0	0.014	0.01	2.71	0
2/12/19 14:00	135	6.83	12.1	0.08	0.02	0.001	0.021	0.009	2.1	0.06
2/13/19 0:00	123	6.89	15.3	0.37	0.01	0.001	0.007	0	3.76	0.36
2/13/19 6:00	99	6.85	26	0.08	0.01	0	0.014	0.012	5.87	0.07
2/13/19 18:00	98.1	6.76	23.1	0.13	0.02	0.008	0.014	0.01	0	0
2/14/19 0:00	82.7	6.88	40.2	0.35	0.02	0.005	0.014	0.01	6.47	0.33

2/14/19 10:00	82.5	6.79	24	0.09	0.02	0	0.007	0.012	4.81	0.07
2/14/19 22:00	91.8	7.06	19.3	0.11	0.02	0	0.04	0.01	3.81	0.09
2/19/19 11:10	108.3	6.9	12.4	0.14	0.02	0.004	0.019	0.009	2.36	0.12
2/25/19 12:00	101.5	6.86	26.1	0.23	0.02	0.007	0.013	0.014	5.31	0.2
2/25/19 18:00	63.9	6.74	65.9	0.32	0.03	0.004	0.128	0.019	6.2	0.29
2/26/19 10:00	90.4	6.97	25.6	0.15	0.03	0.001	0.016	0.014	3.49	0.12
2/27/19 0:00	83.2	6.82	41.7	0.15	0.04	0	0.057	0.029	5.66	0.11
2/27/19 10:00	82.7	6.9	24.2	0.06	0.02	0	0.108	0.011	3.94	0.04
2/28/19 12:10	93.1	6.88	17	0.03	0.01	0	0.043	0.016	2.71	0.02
3/5/19 16:00	120.3	6.89	11.6	0.12	0.03	0	0	0.009	1.9	0.09
3/6/19 11:10	111.9	6.76	13.8	0.27	0.01	0	0	0.009	2.83	0.26
3/6/19 14:50	104.9	6.98	21.3	0.16	0.01	0	0	0.01	3.37	0.15
3/7/19 11:40	102.7	7.03	16	0.24	0.02	0	0	0.012	2.49	0.22
3/19/19 9:53	129	7.26	7.28	0.05	0.04	0.001	0	0.011	3.26	0.01
3/25/19 10:30	98	7.33	20.7	0.11	0.02	0	0	0.018	4.85	0.09
3/28/19 12:00	118	7.49	16.2	0.07	0.01	0	0	0.024	3.5	0.07
3/28/19 22:00	119	7.77	17.1	0.03	0.01	0	0	0.042	2.83	0.02
3/29/19 12:00	119	7.7	16.4	0.08	0	0	0	0.017	2.82	0.08
4/2/19 9:45	138	7.1	11.5	0.02	0.01	0	0	0.015	2.08	0.01
4/6/19 9:30	126.9	7.15	17.9	0.26	0.03	0	0.03	0.01	2.06	0.23
4/15/19 10:00	144.7	6.73	9.72	0.16	0.03	0.01	0.03	0.01	1.6	0.12
5/2/19 12:00	153.6	6.99	14	0.18	0.04	0.01	0.03	0	1.35	0.13
5/16/19 7:20	121.6	6.98	18.1	0.42	0.04	0	0.09	0.018	5.6	0.38
5/17/19 8:30	91.5	6.81	14.2	0.17	0.01	0	0.08	0.013	5.08	0.16
5/20/19 7:35	101.2	6.89	9.29	0.11	0.04	0	0.05	0.008	3.42	0.07
5/21/19 7:40	114.9	6.58	12.1	0.13	0.04	0	0.04	0.007	2.17	0.09
5/29/19 8:30	156.1	6.7	3.66	0.06	0.13	0	0.02	0.007	1.94	0
6/12/19 14:20	150.8	7.1	10	0.01	0.02	0.016	0.013	0	2.53	0
7/25/19 9:40	191.4	7.1	14.3	1.2	0.35	0.093	0.082	0	4.74	0.75
8/5/19 13:00	153.3	7.4	4.14	0.02	0.04	0.025	0.017	0	4.08	0
8/22/19 9:10	312.2	7.27	1.25	1.04	0.27	0.022	0.246	0.25	14.82	0.74
12/7/19 12:00	142.3	7.01	52.7	0.44	0.02	0.05	0.36	0.01	9	0.37
12/7/19 16:00	136.5	7.08	43.5	0.39	0.03	0.07	0.35	0.01	8.74	0.29
12/8/19 8:00	122.1	6.91	39.6	0.26	0.04	0.05	0.35	0.01	8.69	0.17
12/8/19 8:00	139.4	6.95	35.2	0.27	0.04	0.03	0.35	0.01	7.28	0.2
12/8/19 12:00	143.1	6.88	45.9	0.26	0.04	0.03	0.35	0.01	4.48	0.19
12/8/19 16:00	142.2	6.91	40.9	0.19	0.04	0.02	0.35	0.01	6.8	0.13
12/8/19 20:00	139.5	6.9	40.3	0.43	0.03	0.04	0.39	0.01	2.67	0.36
12/8/19 20:00	127.5	6.94	37.7	0.24	0.06	0.03	0.4	0.01	2.49	0.15
12/13/19 11:20	171	7.04	17.7	0.06	0.04	0.04	0.34	0	6.41	0

12/20/19 12:30	149.8	7.07	20.2	0	0.03	0.04	0.03	0.01	3.69	0
12/22/19 18:00	121.6	7.11	29.8	0.22	0.05	0.03	0.04	0.01	7.32	0.14
12/22/19 20:00	130.1	7.03	22.4	0.13	0.07	0.03	0.03	0.01	6.9	0.03
12/22/19 22:00	136.6	7.04	28.1	0.08	0.09	0.03	0.03	0.01	7.12	0
12/23/19 0:00	132	7.03	27.2	0.08	0.05	0.03	0.03	0.01	6.32	0
12/23/19 2:00	133.8	7.01	26.9	0.11	0.08	0.04	0.03	0.01	8.7	0
12/23/19 4:00	129.1	7.04	28.4	0.07	0.07	0.04	0.03	0.01	9.8	0
12/23/19 6:00	137	7.01	27.8	0.04	0.04	0.04	0.03	0.01	7.5	0
12/23/19 8:00	114.6	6.97	38.1	1.25	0.04	0.05	0.41	0.02	9.13	1.16
12/23/19 10:35	132.4	6.95	27.8	0.16	0.08	0.04	0.03	0.01	6.85	0.04
1/15/20 22:00	123.2	7.03	36.5	0	0.09	0.001	0	0.01	7.75	0
1/16/20 0:00	121.2	6.99	26.3	0	0.13	0.008	0	0	6.45	0
1/16/20 2:00	123.2	7	24.4	0	0.1	0.009	0	0	5.62	0
1/16/20 4:00	126.1	6.93	23.1	0	0.11	0.001	0	0	7.01	0
1/16/20 6:00	116.3	6.94	24.5	0	0.14	0.009	0	0	7.61	0
1/16/20 8:00	108.6	6.92	31.3	0	0.08	0.01	0	0.01	8.17	0
1/16/20 10:00	107.9	6.92	36.2	0	0.09	0.003	0	0	8.68	0
1/16/20 12:00	103.7	6.94	34.9	0	0.12	0.002	0	0.01	9.06	0
1/16/20 14:00	100.7	6.94	32.9	0	0.09	0.01	0	0	8.2	0
1/16/20 16:00	93.8	6.99	43.1	0	0.11	0.003	0	0	10.23	0
1/16/20 18:00	101	6.97	35	0	0.1	0.014	0	0.01	8.43	0
1/16/20 20:00	99.6	6.92	32.8	0	0.07	0.002	0	0	8.14	0
1/16/20 22:00	106.4	6.73	34.1	0	0.09	0.011	0	0	8.63	0
1/17/20 0:00	102.1	6.79	33.4	0	0.06	0.002	0	0	7.41	0
1/17/20 2:00	99.5	6.75	30.4	0	0.04	0	0	0	6.24	0
1/17/20 4:00	91.9	7.09	29.8	0.13	0.05	0.033	0.273	0	5.74	0.06
1/17/20 6:00	103.1	6.96	24.6	0.22	0.06	0.025	0.26	0	3.17	0.13
1/17/20 8:00	102.4	6.86	29.8	0.23	0.11	0.029	0.284	0	2.54	0.09
1/17/20 10:00	99.3	6.85	32.3	0.19	0.08	0.025	0.276	0	2.72	0.09
1/17/20 12:00	92.1	6.83	27.3	0.18	0.08	0.035	0.249	0	2.54	0.07
1/17/20 14:00	101.8	6.78	26.7	0.19	0.09	0.029	0.265	0	6.31	0.08
1/17/20 16:00	106	6.81	25.8	0.21	0.09	0.036	0.265	0	5.5	0.09
1/17/20 18:00	102.9	6.79	27.9	0.26	0.09	0.032	0.263	0	5.76	0.14
1/17/20 20:00	103.6	6.76	30.2	0.24	0.1	0.024	0.376	0	5.6	0.11
1/8/20 12:43	154.2	6.78	12.8	0.14	0.07	0.029	0.273	0	4.71	0.04
1/15/20 10:10	114.4	6.89	31.6	0.16	0.05	0.026	0.273	0	8.53	0.08
1/23/20 12:06	109.5	6.9	18.7	0.37	0.07	0	0.265	0.02	2.92	0.31
1/27/20 13:25	89.3	6.92	22.5	0.13	0.03	0	0.271	0.02	6.35	0.1

Table 41: Ziemer sub-watershed.

Date	EC	pH	Turb	TN	NH_4^+-N	NO_3^--N	TP	PO_4	DOC	DON
	µS	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
5/26/16 8:30	155	7.37	2.67	0.33	0	0	0.008	0.005	1.55	0.33
6/30/16 8:55	173	8.29	2.6	0.07	0.01	0	0.01	0.007	1.07	0.06
12/12/16 7:00	167	7.76	2.5	0.11	0.05	0.03	0.008	0.008	1.95	0.03
10/27/16 9:15	167	7.71	23.6	0.4	0.01	0.03	0.048	0.02	6.2	0.36
11/10/16 0:00	144	8.02	21.3	0.29	0.01	0.01	0.065	0.003	9.36	0.27
11/10/16 0:00	131	7.98	17.2	0.27	0	0	0.052	0.002	7.2	0.27
11/10/16 0:00	129	7.77	16.1	0.28	0.01	0	0.046	0.002	6.5	0.27
11/10/16 0:00	128	7.66	10.2	0.23	0	0	0.042	0.013	4.83	0.23
12/10/16 13:30	84	7.25	39.8	0.33	0.04	0.04	0.064	0.006	3.75	0.25
12/11/16 14:00	97	7.43	22.6	0.19	0	0.02	0.033	0.003	2.06	0.17
12/15/16 7:00	80	7.58	37.9	0.37	0.02	0.04	0.079	0.001	5.5	0.31
12/15/16 19:30	84	7.47	31.2	0.24	0	0.02	0.055	0.001	3.37	0.22
12/15/16 12:00	82	7.38	51.8	0.33	0.03	0.03	0.088	0.004	4.21	0.27
12/15/16 15:00	79	7.34	45.6	0.35	0.01	0.03	0.082	0.001	4.03	0.31
12/15/16 21:00	103	7.27	20.4	0.22	0.02	0.02	0.049	0.009	3.29	0.18
12/16/16 10:23	98	7.31	22.6	0.24	0.01	0.06	0.039	0.001	2.4	0.17
1/8/17 8:00	87	7.5	28.9	0.13	0	0	0.03	0.003	5.5	0.13
1/3/17 20:20	96	7.5	35.5	0.12	0.04	0.01	0.024	0.001	7.12	0.07
1/8/17 12:00	79	7.51	44.8	0.15	0	0	0.033	0.001	5.83	0.15
1/8/17 14:00	73	7.45	65.3	0.15	0	0.01	0.035	0.001	6.62	0.14
1/8/17 16:00	73	7.47	54.3	0.11	0	0.01	0.033	0.001	5.54	0.1
1/20/17 4:30	78	7.43	86.9	0.42	0.01	0	0.041	0.001	4.23	0.41
1/20/17 10:30	75	7.36	52	0.34	0.01	0	0.027	0.001	4.28	0.33
1/10/17 12:00	65	7.35	137	0.25	0.03	0.01	0.071	0.001	5.56	0.21
1/9/17 0:00	81	7.44	35.4	0.07	0	0	0.047	0.017	3.83	0.07
1/9/17 18:00	87	7.45	23.6	0.07	0.01	0	0.021	0.001	3.39	0.06
1/4/17 21:10	95	7.5	25	0.1	0.03	0	0.024	0.001	3.16	0.07
1/10/17 10:00	67	7.49	124	0.43	0	0.01	0.066	0.003	5.4	0.42
1/11/17 20:00	69	7.38	635	1.1	0.01	0	0.229	0.003	3.54	1.09
1/20/17 0:30	86	7.38	35.4	0.26	0.02	0.01	0.021	0.001	3.18	0.23
1/21/17 6:30	82	7.48	24.2	0.1	0.05	0.01	0.018	0	3.55	0.04
1/10/17 14:00	63	7.46	150	0.4	0	0.01	0.077	0.003	5.32	0.39
1/3/17 23:40	92	7.51	39.1	0.16	0.02	0.01	0.03	0.001	6.15	0.13
1/11/17 10:00	78	7.62	27.5	0.45	0.04	0	0.021	0.001	3.42	0.41
1/21/17 13:20	83	7.51	23.2	0.38	0	0	0.015	0.001	3.02	0.38
2/6/17 22:00	85	7.56	28.9	0.16	0.1	0.01	0.045	0.002	2.72	0.05
2/7/17 2:00	75	7.56	40.3	0.16	0.09	0.01	0.06	0.002	3.93	0.06
2/7/17 6:00	67	7.48	57.1	0.18	0.05	0.01	0.066	0.002	4.07	0.12

2/7/17 16:00	76	7.51	48.8	0.2	0.1	0.01	0.066	0.002	2.58	0.09
2/8/17 16:00	76	7.54	29.2	0.2	0.09	0	0.034	0.002	2.78	0.11
2/20/17 12:00	89	7.67	25.5	0.23	0.12	0	0.033	0.003	2.68	0.11
2/20/17 18:00	79	7.61	28.2	0.25	0.1	0	0.039	0.001	2.98	0.15
2/21/17 2:00	75	7.61	35.5	0.25	0.09	0	0.052	0	3	0.16
2/21/17 10:00	77	7.61	26.4	0.2	0.07	0	0.036	0	2.4	0.13
2/22/17 10:00	85	7.64	21.9	0.07	0.01	0	0.024	0.001	2.06	0.06
3/24/17 7:25	91	7.77	52.2	0.64	0.02	0.01	0.069	0	4.03	0.61
3/24/17 9:25	82	7.59	60.8	0.56	0.01	0.02	0.089	0	5.2	0.53
3/24/17 11:25	81	7.62	50.8	0.58	0.03	0.01	0.069	0.002	4.64	0.54
3/25/17 17:25	87	7.63	54.5	0.6	0.03	0.02	0.078	0	2.96	0.55
3/25/17 5:25	93	7.54	42.9	0.7	0.01	0.09	0.049	0	2.02	0.6
3/25/17 17:25	97	7.77	49.7	0.53	0.01	0.13	0.088	0	2.11	0.39
3/22/17 10:55	102	7.72	33	0.58	0.01	0.01	0.044	0	1.75	0.56
4/12/17 9:30	110	7.29	13.7	0.33	0	0	0.02	0	1.43	0.33
4/26/17 9:05	125	7.77	9.67	0.35	0.01	0.01	0.017	0	1.56	0.33
5/11/17 9:12	133	7.79	6.93	0.37	0.01	0	0.016	0.002	1.07	0.36
5/26/17 8:20	145	7.95	2.98	0.55	0.03	0.01	0.031	0.001	1.78	0.51
6/21/17 11:50	146	8.02	3.67	0.06	0.02	0.01	0.01	0.003	0.94	0.03
7/5/17 14:45	282	7.98	6.51	0.09	0.02	0.04	0.016	0.004	1.05	0.03
8/1/17 9:30	291	8.01	1.49	0.05	0	0.02	0.005	0.004	1.1	0.03
9/22/17 10:04	289	7.5	1.81	0.23	0.06	0.002	0.066	0.042	2.81	0.17
10/19/17 15:31	276	8.06	2.19	0.27	0.09	0.023	0.06	0.021	1.94	0.16
11/21/17 10:30	304	8.02	9.16	0.14	0	0.011	0.026	0.01	2.15	0.13
12/19/17 10:35	300	6.8	3.95	0.09	0.03	0.016	0.015	0	1.28	0.04
5/1/18 9:57	196	6.78	22.4	0.14	0.01	0	0.034	0	3.02	0.13
1/9/18 9:39	126	6.8	38.6	0.21	0.01	0.056	0.105	0	13.64	0.14
1/9/18 13:39	125	6.72	26.5	0.34	0.01	0	0.08	0	4.84	0.33
1/9/18 21:39	125	6.65	25.6	0.11	0.01	0	0.049	0.001	4.27	0.1
1/10/18 3:39	126	6.7	20.1	0.18	0.01	0	0.034	0.001	3.55	0.17
1/10/18 9:38	130	6.6	16.9	0.11	0.01	0	0.034	0	3.06	0.1
1/18/18 9:50	144	6.89	23	0.12	0.01	0	0.04	0	2.91	0.11
1/18/18 14:40	149	6.89	26.8	0.12	0.02	0	0.049	0	7.3	0.1
1/19/18 2:40	128	6.81	24	0.13	0.01	0	0.043	0.001	4.46	0.12
1/19/18 8:40	125	6.86	18.5	0.09	0.01	0	0.028	0	3.75	0.08
1/22/18 11:10	105	6.9	39.1	0.13	0.01	0	0.062	0.001	4.82	0.12
1/23/18 9:10	112	7.01	23.3	0.1	0	0	0.037	0.003	3.07	0.1
1/24/18 13:18	103	6.92	33.4	0.19	0.02	0	0.059	0	4.63	0.17
1/24/18 19:18	82	7	40.1	0.22	0.02	0	0.076	0	4.87	0.2
1/24/18 23:18	94	6.89	26.8	0.22	0.02	0	0.047	0	4.13	0.2

1/25/18 9:18	97	6.92	24.8	0.17	0.02	0	0.04	0	3.12	0.15
1/26/18 9:18	103	7.05	18.4	0.16	0.02	0	0.034	0.001	3.08	0.14
2/7/18 10:05	132	6.93	5.09	0.13	0.01	0	0.043	0	1.54	0.12
2/23/18 11:02	138	6.98	7.56	0.16	0	0	0.037	0.015	0.95	0.16
3/1/18 9:22	120	6.88	27.7	0.19	0	0	0.044	0.028	3.59	0.19
3/7/18 10:18	116	7.01	10.6	0.11	0	0	0.018	0.015	1.11	0.11
3/1/18 10:00	118	6.93	21.3	0.2	0	0	0.037	0.024	3.69	0.2
3/2/18 18:42	113	6.87	18.9	0.17	0	0	0.027	0.024	2.9	0.17
3/2/18 2:42	116	6.98	25.3	0.2	0	0	0.037	0.033	2.99	0.2
3/2/18 0:06	115	7.02	22.8	0.17	0	0	0.034	0.024	3.31	0.17
3/2/18 8:42	135	6.88	21.4	0.27	0	0	0.041	0.363	2.89	0.27
3/3/18 4:42	128	6.93	20.2	0.18	0	0	0.037	0.028	2.97	0.18
3/3/18 0:42	114	6.71	20.5	0.15	0.01	0	0.031	0.052	4.77	0.14
3/15/18 10:12	142	7.1	13.5	0.05	0.04	0	0.013	0.019	2.78	0.01
3/16/18 9:21	113	6.89	15.3	0.08	0.05	0.011	0.007	0.024	3.09	0.02
3/21/18 9:25	134	7.16	12.9	0	0.02	0	0.004	0.038	2.19	0
3/15/18 9:55	118	7.25	17.6	0	0.03	0	0.018	0.028	1.72	0
3/29/18 10:10	104	7.43	9.97	0	0.04	0	0.007	0.033	1.07	0
4/5/18 11:05	119	7.57	4.22	0.01	0.02	0	0	0.028	0.8	0
4/6/18 9:00	63	7.11	325	0.36	0.03	0	0.441	0.042	5.98	0.33
4/10/18 9:25	99	7.09	13.3	0.26	0.02	0	0.004	0.016	1.39	0.24
4/6/18 5:22	103	7.1	22.3	0.47	0.02	0	0.042	0.012	5.27	0.45
4/6/18 7:22	84	7.05	69.7	0.41	0.02	0	0.088	0.012	6.82	0.39
4/6/18 11:22	65	7.03	700	0.67	0.03	0	0.747	0.007	5.01	0.64
4/6/18 19:22	67	6.97	1000	0.47	0.02	0	1.166	0.007	3.28	0.45
4/7/18 9:50	76	6.91	981	0.64	0.01	0	0.939	0.016	2.26	0.63
4/8/18 1:50	86	6.99	24.5	0.28	0.02	0	0.007	0.021	2.44	0.26
4/8/18 19:50	92	7.02	19.2	0.17	0.02	0	0.013	0.007	1.6	0.15
4/25/18 10:18	120	7.04	3.76	0.26	0.01	0	0.001	0.007	1.02	0.25
5/11/18 11:30	139	7.29	4.93	0.48	0.07	0.03	0	0.007	1.61	0.38
5/23/18 12:15	145	7.33	2.44	0.19	0.01	0.121	0.004	0.016	1.33	0.06
6/14/18 9:50	147	7.02	0.79	0	0.01	0	0.026	0	2.07	0
7/5/18 13:05	161	7.29	0.65	0.04	0.01	0	0.024	0.002	1.22	0.03
7/20/18 8:40	158	7.25	1.55	0.07	0.01	0	0.024	0	1.26	0.06
8/2/18 10:12	168	7.17	4.7	0.06	0.01	0	0.029	0.002	1.36	0.05
8/30/18 9:50	164	7.21	1.18	0.02	0.01	0	0.031	0.005	2.01	0.01
9/21/18 13:30	147	8.74	1.04	0.1	0.01	0	0.026	0.003	1.04	0.09
10/2/18 9:10	76	9.38	1.08	0.37	0.01	0.1	0.086	0.005	2.83	0.26
10/25/18 14:51	176	7.88	0.77	0.16	0.02	0	0.061	0	0.8	0.14
11/19/18 10:45	168	7.33	0.59	0.13	0.01	0	0.096	0	1.52	0.12

11/27/18 9:30	169	7.6	5.8	0.12	0.01	0.01	0.044	0.005	3.19	0.1
12/3/18 11:05	118	7.05	4	0.13	0.06	0.02	0.039	0	2.5	0.05
12/16/18 12:00	164	6.98	195	0.28	0.01	0	0.035	0	11.51	0.27
12/16/18 14:00	131	7.04	26.4	0.41	0.05	0	0	0	5.98	0.36
12/16/18 16:00	116	7.08	51.8	0.2	0.03	0.02	0.004	0	9.68	0.15
12/17/18 0:00	117	6.94	19.6	0.07	0.06	0	0.018	0	5.77	0.01
12/17/18 6:00	118	7.19	16.3	0.07	0.03	0	0.004	0	4.94	0.04
12/26/18 12:30	105	6.97	9.41	0.32	0.01	0.04	0.001	0	2.07	0.27
1/7/19 2:00	138	6.66	8.52	0.11	0.01	0	0.004	0	4.57	0.1
1/7/19 6:00	130	6.97	3.6	0.03	0.01	0.11	0.001	0	2.1	0
1/7/19 10:00	106	6.75	8.85	0.2	0.01	0.01	0.004	0	3.34	0.18
1/7/19 11:08	105	6.96	17.2	0.19	0.02	0.03	0.031	0	3.37	0.14
1/7/19 12:00	119	6.77	25.8	0.17	0.04	0	0.042	0	5.38	0.13
1/7/19 14:00	114	6.79	23.7	0.13	0.02	0.04	0.035	0.001	6.79	0.07
1/7/19 20:00	109	6.56	26.9	0.28	0.02	0.04	0.025	0	7.05	0.22
1/9/19 11:52	106	6.93	14.1	0.07	0.03	0	0.123	0	3.37	0.04
1/9/19 12:00	107	6.79	11.1	0.14	0.02	0.02	0.123	0	3.17	0.1
1/9/19 18:00	110	6.73	9.2	0.2	0.01	0.04	0.123	0	3.22	0.15
1/16/19 4:00	124	6.89	8.43	0	0.01	0.03	0	0	2.39	0
1/16/19 14:00	87	6.65	24.6	0	0.03	0.03	0	0	8.94	0
1/16/19 18:00	83	6.61	51.8	0	0.03	0	0	0	10.42	0
1/16/19 20:00	78	6.79	81.8	0	0.01	0	0	0.015	8.24	0
1/17/19 6:00	85	6.89	212	0	0.03	0.02	0	0	4.04	0
1/17/19 18:00	97	6.81	22.9	0	0.02	0	0	0	3.12	0
1/18/19 9:50	100	6.74	26.1	0	0.02	1.75	0	0	2.43	0
1/22/19 9:35	97	6.59	14.5	0	0.02	0	0	0	2.12	0
2/1/19 9:50	121	6.44	3.03	0	0.01	0	0	0	1.62	0
2/2/19 9:00	115	6.93	18.1	0	0.01	0.001	0.007	0	3.2	0
2/2/19 15:00	124	6.84	17.5	0	0.01	0.011	0.014	0	2.83	0
2/3/19 18:00	0	0	11.8	0	0.01	0	0.004	0	0	0
2/4/19 12:00	109	6.77	22.4	0.24	0.01	0.008	0.021	0	5.5	0.22
2/5/19 10:10	110	6.81	16.2	0.01	0.01	0	0.001	0	2.84	0
2/12/19 13:00	109	6.87	13.2	0	0.01	0.001	0.018	0	2.07	0
2/13/19 0:00	104	7.01	31.7	0.17	0.01	0.001	0.038	0	5.91	0.16
2/13/19 8:00	90	6.83	42	0.29	0.02	0	0.028	0.01	5.63	0.27
2/13/19 18:00	88.3	6.85	32.8	0.42	0.01	0	0.018	0.009	3.26	0.41
2/14/19 2:00	65.2	6.8	182	0.34	0.01	0.005	0.175	0.012	5.64	0.33
2/14/19 12:00	78.8	6.89	53.7	0.23	0.03	0.001	0.035	0.009	3.97	0.2
2/14/19 22:00	82.5	7.29	39.9	0.13	0.03	0.001	0.099	0.012	3.88	0.1
2/15/19 13:50	86.5	6.77	32.2	0.2	0.01	0	0.081	0.009	2.91	0.19

2/19/19 10:20	94.2	6.92	12.1	0.1	0.02	0	0.013	0.007	2.17	0.08
2/25/19 12:00	81.4	6.81	56.8	0.33	0.02	0.012	0.12	0.014	10.84	0.3
2/25/19 20:00	64.9	6.72	257	0.35	0.02	0.007	0.339	0.014	6.54	0.32
2/26/19 10:00	59.6	6.99	864	0.8	0.01	0.001	0.706	0.014	3.26	0.79
2/26/19 22:00	65.2	6.94	449	0.63	0.04	0	0.41	0.016	5.76	0.59
2/27/19 13:00	72.5	6.7	38	0.1	0.03	0	0.069	0.019	5.01	0.07
2/27/19 23:00	80	6.84	30.3	0.04	0.02	0	0.063	0.02	3.24	0.02
2/28/19 10:00	81.6	6.77	26.7	0.16	0.02	0	0.057	0.016	2.62	0.14
3/5/19 14:00	96.6	6.89	11.6	0.12	0.04	0	0.197	0.009	1.9	0.08
3/6/19 12:00	92.9	7.01	33.6	0.24	0.05	0	0.012	0.009	2.9	0.19
3/6/19 12:40	94.4	6.95	21.9	0.14	0.04	0	0	0.007	3.99	0.1
3/19/19 9:30	98	7.11	6.94	0.03	0.07	0	0	0.015	2.77	0
3/25/19 9:00	79	7.34	52.7	0.28	0.02	0	0	0.014	7.39	0.26
3/28/19 12:00	97	7.67	22.2	0.07	0.01	0	0	0.021	3.03	0.06
3/28/19 16:00	99	7.76	45.6	0.08	0	0.01	0	0.02	3.7	0.07
3/28/19 22:00	98	7.6	16.1	0.06	0.02	0	0	0.017	3.43	0.04
4/2/19 9:20	108	7.21	8.6	0.04	0	0	0	0.014	2.08	0.03
4/8/19 9:15	105.9	6.85	18.4	0.27	0.03	0.01	0.03	0	2.33	0.23
4/15/19 9:00	107.1	6.55	8.15	0.13	0.03	0	0.08	0.01	1.89	0.1
5/2/19 8:50	106.1	7.18	5.17	0.09	0.02	0.02	0.02	0.01	1.28	0.05
5/12/19 8:10	96.6	6.63	11.3	0.12	0.01	0	0.04	0.01	3.93	0.11
5/15/19 12:12	145.4	7	4.09	0.05	0.01	0	0.02	0.002	1.79	0.04
5/17/19 8:20	87.3	6.75	16.2	0.19	0.02	0	0.08	0.013	4.44	0.17
5/20/19 8:10	93.3	6.85	10.9	0.12	0.02	0	0.05	0.007	2.79	0.1
6/10/19 13:20	127.9	7.11	5.81	0.02	0	0.022	0.01	0.01	4.09	0
6/12/19 10:10	92.4	6.84	2.85	0.11	0.04	0.024	0.007	0	4.92	0.05
6/26/19 11:00	117.8	6.93	4.04	0.01	0.04	0.014	0.01	0	2.59	0
7/25/19 13:50	126.3	7.34	3.43	0	0.02	0.014	0.01	0	2.87	0
8/22/19 8:45	154.8	7.18	1.28	0	0.06	0.016	0.003	0	4.7	0
9/5/19 9:30	167.4	6.96	1.23	0.02	0.05	0.025	0.003	0	6.76	0
9/16/19 8:30	172.3	7.05	0	0.03	0.25	0.04	0.01	0	4.19	0
10/1/19 9:00	168.1	7.3	0.81	0	0	0.03	0.34	0.08	2.05	0
10/23/19 9:30	204.3	7.22	0.41	0.13	0.06	0.02	0.33	0	2.04	0.05
11/25/19 12:00	180.6	0	4.8	0.43	0.01	0.18	0.34	0.02	2.8	0.24
12/6/19 10:20	190.4	7.47	31.5	0.3	0.05	0.02	0.36	0.01	5.27	0.23
12/6/19 18:00	230.3	7.24	49.6	4.26	1.57	0.13	1.02	1.3	16.34	2.56
12/7/19 0:00	174.1	7.18	29.6	0.99	0.18	0.47	0.36	0.01	9.78	0.34
12/7/19 4:00	175.7	7.12	29.8	0.63	0.03	0.36	0.36	0.01	8.14	0.24
12/7/19 8:00	155.6	7.1	56.5	0.77	0.04	0.36	0.37	0.01	9.23	0.37
12/7/19 12:00	126.4	7.16	48.7	1.15	0.12	0.46	0.36	0.01	15.37	0.57

12/7/19 16:00	119.9	7.08	37.7	0.75	0.05	0.39	0.41	0.01	7.2	0.31
12/7/19 20:00	118.1	6.93	34.8	0.59	0.06	0.42	0.36	0.01	9.91	0.11
12/8/19 0:00	122.5	6.96	32.5	0.61	0.06	0.32	0.36	0.01	10.82	0.23
12/8/19 4:00	104.4	6.98	30.4	0.54	0.06	0.31	0.35	0.02	10.04	0.17
12/8/19 8:00	113.1	6.96	33.7	0.37	0.07	0.3	0.34	0.01	12.51	0
12/8/19 12:00	117.2	6.95	31	0.53	0.08	0.24	0.35	0.01	10.56	0.21
12/8/19 16:00	99.2	6.9	31.7	0.43	0.07	0.19	0.34	0.01	7.45	0.17
12/8/19 20:00	114.5	6.96	30.7	0.23	0	0.14	0.34	0.01	7.36	0.09
12/9/19 0:00	116.7	6.96	29.6	0.28	0.08	0.12	0.35	0.01	6.81	0.08
12/9/19 4:00	123.2	6.94	29.4	0.18	0.05	0.1	0.39	0.02	9.38	0.03
12/9/19 8:00	122.9	6.92	28.1	0.31	0.07	0.1	0.34	0.01	8.45	0.14
12/9/19 12:00	152.3	7.03	28.9	0.24	0.06	0.13	0.34	0.01	6.29	0.05
12/9/19 16:00	130.2	6.95	23.6	0.3	0.06	0.08	0.34	0.01	7.59	0.16
12/9/19 20:00	127.2	7	22.5	0.34	0.13	0.19	0.34	0.01	8.19	0.02
12/10/19 0:00	133.9	7.19	28.3	0.24	0.05	0.2	0.34	0.01	8.77	0
12/10/19 4:00	128.2	7.18	19.1	0.43	0.1	0.06	0.35	0.01	16.68	0.27
12/10/19 8:00	117.2	7.1	18.6	0.14	0.12	0.09	0.34	0.01	7.61	0
12/10/19 12:00	137.2	7.1	18.4	0	0.12	0.15	0.34	0	8.43	0
12/13/19 12:00	138	7.06	14.6	0.09	0.06	0.07	0.34	0	7.07	0
12/20/19 11:25	127	7.16	15.5	0.08	0.04	0.07	0.01	0.01	8.82	0
12/21/19 14:00	134	7.03	12.1	0.38	0	0.05	0.28	0.28	9.42	0.33
12/21/19 16:00	121.5	7.05	23.1	0.09	0.06	0.03	0.01	0.02	6.46	0
12/21/19 18:00	124.4	7.09	13	0.34	0.06	0.06	0.01	0.01	7.84	0.22
12/21/19 20:00	125.8	7.06	13.1	0.06	0.05	0.03	0.02	0.01	6.55	0
12/23/19 10:30	117.2	7.01	18	0.04	0.03	0.04	0.02	0.02	8.38	0
1/23/20 14:35	82.8	6.8	15.6	0.59	0.12	0.101	0.249	0	4.24	0.37
1/8/20 11:40	130.3	6.67	7.86	0.14	0.05	0.032	0.257	0	6.44	0.06
1/13/20 14:30	100	6.91	31.1	0.24	0.05	0.05	0.252	0	8.64	0.14
1/15/20 12:40	101.1	6.79	31.5	0.17	0.04	0.026	0.252	0	7.2	0.1
1/16/20 10:40	87.6	7.07	40.8	0.23	0.02	0.05	0.244	0.01	9.4	0.16
1/16/20 20:40	93.5	7.05	37.1	0.42	0.06	0.056	0.432	0	0	0
1/23/20 10:27	83.1	6.95	20.6	0.97	0.11	0.001	0.223	0.02	4.7	0.85
1/25/20 9:00	105.2	6.89	12	0.22	0.06	0	0.241	0.01	6.67	0.16
1/25/20 15:00	103.2	6.92	18.3	0.51	0.09	0	0.276	0.01	7.55	0.42
1/25/20 21:00	92.9	6.95	20.3	0.42	0.06	0.016	0.273	0	10.41	0.34
1/26/20 3:00	89.3	6.97	22.3	0.34	0.07	0.03	0.257	0.01	12.55	0.24
1/26/20 9:00	88.8	6.94	22.7	0.34	0.06	0.022	0.26	0.01	10.66	0.26
1/26/20 15:00	92.6	6.93	25.1	0.24	0.04	0.036	0.254	0.01	9.25	0.16
1/26/20 21:00	91.8	6.92	27.4	0.22	0.06	0	0.246	0.01	7.9	0.16
1/27/20 3:00	91.5	6.96	28.5	0.2	0.05	0.016	0.23	0.01	8.28	0.14

1/27/20 9:00	93.3	7.03	27	0.23	0.01	0.018	0.254	0.01	9.21	0.2
1/27/20 15:00	80.7	6.91	25.6	0.18	0.05	0	0.246	0.01	8.3	0.13
1/27/20 21:00	79.7	6.94	22.4	0.21	0.05	0.014	0.227	0.01	8.07	0.14
1/28/20 3:00	78.3	6.71	21.5	0.18	0.03	0.01	0.244	0.02	7.54	0.14
1/28/20 9:00	86.2	6.91	19.5	0.16	0.03	0	0.319	0.02	8.15	0.12
1/28/20 15:00	94.2	6.74	18.5	0.2	0.04	0	0.249	0.01	8.71	0.16
1/28/20 21:00	94.5	6.85	18.4	0.21	0.05	0	0.263	0.01	9.68	0.16
1/29/20 3:00	93.9	6.95	19	0.14	0.01	0	0.254	0.02	6.65	0.13
1/29/20 9:00	96	7.01	18.3	0.19	0.04	0.008	0.257	0.01	7.67	0.15
1/29/20 15:30	97	6.98	18.6	0.18	0.02	0.008	0.227	0.02	7.53	0.15
2/11/20 9:43	144.1	8.39	4.67	0.23	0	0	0.015	0.015	2.44	0.23
2/26/20 10:54	136.3	7.27	3.27	0.13	0	0	0	0.021	2.86	0.13
3/17/20 9:05	155.3	7.28	2.67	0.07	0	0	0.006	0.012	2.92	0.07
3/31/20 8:13	164.5	7.1	4.01	0	0	0	0.009	0.02	3.21	0
4/6/20 10:00	209.4	7.13	0	0	0.08	0	0	0.012	5.33	0
4/20/20 12:30	154.4	7.14	0	0	0.01	0	0	0.012	3.92	0
5/5/20 8:30	154.9	7.22	2.53	0.02	0	0	0.015	0.017	2.83	0.02
5/18/20 9:27	142.7	7.12	27.9	0.35	0	0	0.024	0.018	5.42	0.35
6/2/20 9:25	100.2	7.1	3.29	0.2	0	0	0	0.012	3.75	0.2
6/29/20 14:20	75.1	7.76	1.62	0.04	0	0	0	0.01	1.14	0.04
7/21/20 10:55	102.9	7.98	1.56	0.11	0	0	0	0.01	3.3	0.11

Table 42: Yocom (YOC) sub-watershed.

Date	EC µS	pH mg/L	Turb mg/L	TN mg/L	NH_4^+-N mg/L	NO_3^--N mg/L	TP mg/L	PO_4 mg/L	DOC mg/L	DON mg/L
5/26/16 9:00	170	6.91	3	0.36	0	0	0.005	0.001	1.89	0.36
6/30/16 10:10	197	7.43	11.5	0.09	0.01	0	0.055	0.009	1.28	0.08
10/27/16 10:00	213	7.4	10.9	0.14	0.01	0	0.01	0.009	6.54	0.13
3/22/17 11:43	115	7.76	41.1	0.5	0	0	0.052	0	1.91	0.5
4/12/17 10:14	124	7.33	17.2	0.34	0.01	0	0.026	0	1.53	0.33
4/26/17 9:34	139	7.48	14.5	0.46	0.04	0	0.048	0	1.9	0.42
5/11/17 9:50	141	7.81	12.9	0.27	0	0	0.041	0.001	1.3	0.27
5/26/17 9:10	160	7.68	4.91	0.51	0.01	0.01	0.028	0.001	1.62	0.49
6/21/17 12:50	167	8.01	21.7	0.08	0.02	0.01	0.057	0.003	1.24	0.05
7/5/17 15:07	305	7.98	2.03	0.2	0.08	0.03	0.005	0.004	1.47	0.09
8/1/17 10:10	313	7.92	0.9	0.04	0	0	0.005	0.003	1.6	0.04
11/21/17 12:15	307	7.87	9.86	0.16	0	0.002	0.026	0.008	3.16	0.16
12/5/17 9:40	296	6.81	5.04	0.03	0.01	0.012	0.015	0.001	1.91	0.01
12/19/17 11:00	312	7.07	1.69	0.17	0.02	0.01	0.015	0	1.64	0.14
1/5/18 11:30	225	6.82	9.53	0.12	0.01	0	0.015	0	2.9	0.11

1/10/18 12:20	137	6.83	23.3	0.09	0.01	0	0.034	0.001	3.26	0.08
1/18/18 10:40	151	6.94	20.7	0.09	0.01	0	0.043	0.004	4.38	0.08
2/7/18 10:39	139	7.13	9.47	0.14	0.01	0	0.047	0.001	1.83	0.13
2/23/18 11:34	148	7.11	5.95	0.18	0	0	0.04	0.015	1.15	0.18
3/1/18 10:15	122	7.07	43.9	0.28	0	0	0.057	0.019	4.66	0.28
3/7/18 11:35	116	7.18	16.1	0.14	0	0	0.027	0.015	1.73	0.14
3/21/18 10:00	131	7.13	12.8	0	0.01	0	0.007	0.019	1.61	0
3/15/18 10:52	119	7.08	19.7	0.06	0.01	0	0.027	0.033	2.85	0.05
3/29/18 10:55	107	7.4	12.7	0	0.02	0	0.004	0.033	1.41	0
4/6/18 10:30	60	7	534	0.47	0.03	0	0.811	0.028	7.11	0.44
4/5/18 10:41	136	7.07	9.14	0	0.04	0	0.004	0.021	1.27	0
4/10/18 10:25	107	7.15	16.8	0.17	0.01	0	0.007	0.007	1.47	0.16
4/25/18 11:00	128	7.01	6.65	0.19	0.01	0	0	0.007	1.29	0.18
5/11/18 12:05	145	7.28	3.56	0.15	0.02	0	0	0.007	1.34	0.13
5/23/18 13:40	161	7.31	2.84	0	0.01	0	0.004	0.016	0	0
6/13/18 15:40	170	7.39	0.78	0.06	0.01	0	0.026	0.002	2.22	0.05
12/17/18 11:00	121	6.82	9.87	0.08	0.01	0	0.004	0	3.7	0.07
12/26/18 13:50	108	6.9	11.6	0.17	0.02	0	0.031	0.001	2.45	0.15
1/7/19 12:20	110	6.94	22.4	0.01	0.01	0.01	0.021	0.003	3.55	0
1/9/19 12:22	110	6.76	18.1	0.13	0.01	0.03	0.123	0	3.29	0.09
1/16/19 11:00	118	7.01	10.9	0	0.02	0.01	0	0	3.4	0
1/17/19 10:10	97	6.88	35.3	0	0.02	0	0	0	3.67	0
1/18/19 10:15	103	6.78	22.4	0	0.01	0	0	0	2.63	0
1/22/19 10:20	103	6.97	21.5	0	0.02	0	0	0	2.27	0
2/1/19 10:35	117	6.61	7.13	0	0.01	0.005	0	0	1.91	0
2/5/19 11:00	115	6.82	20.8	0.01	0.01	0	0.042	0.012	3.1	0
2/12/19 13:35	118	6.89	16.2	0.2	0.02	0.001	0.014	0.009	2.25	0.18
2/13/19 10:15	94	6.82	47.3	0.4	0.01	0	0.038	0.015	4.7	0.39
2/14/19 10:02	75.8	6.81	69	0.22	0.02	0	0.031	0.015	4.38	0.2
2/15/19 14:20	91.1	6.91	36.7	0.19	0.02	0	0.04	0.01	2.93	0.17
2/26/19 9:22	68.9	6.94	52.8	0.23	0.04	0.01	0.12	0.017	3.16	0.18
2/27/19 9:50	77.8	6.85	78.1	0.28	0.02	0	0.105	0.019	3.45	0.26
2/28/19 11:00	91.2	6.85	52	0.23	0.02	0	0.096	0.017	3.48	0.21
3/5/19 14:00	102.9	6.95	15.4	0.08	0.03	0	0	0.012	2.08	0.05
3/19/19 10:00	105	7.21	9.6	0.02	0.04	0	0	0.014	2.23	0
3/25/19 9:30	86	7.37	71.1	0.21	0.02	0	0	0.015	6.71	0.19
3/28/19 9:30	105	7.42	20.1	0.09	0	0	0	0.017	2.71	0.09
4/2/19 9:50	138	7.1	12.2	0.03	0	0.001	0	0.017	1.88	0.03
4/8/19 9:57	118.3	6.78	24.2	0.31	0.03	0.01	0.05	0.01	2.31	0.27
4/15/19 10:00	121.9	6.77	9.87	0.11	0.02	0	0.03	0.01	1.61	0.09

5/2/19 9:30	127	6.99	10.2	0.14	0.02	0.01	0.04	0.01	1.64	0.11
5/15/19 12:30	142.2	6.65	6.24	0.07	0.02	0	0.03	0.007	2.2	0.05
5/17/19 9:20	92.7	6.83	19.8	0.17	0.02	0	0.09	0.012	4.13	0.15
5/20/19 9:00	114	7.4	10.5	0.11	0.01	0.056	0.05	0.008	3.54	0.04
5/20/19 9:00	112.9	7.01	14.2	0.14	0.04	0	0.05	0.012	2.94	0.1
5/29/19 10:20	125.4	6.8	8.78	0.13	0.16	0.001	0.04	0.005	1.6	0
6/12/19 10:38	133.2	6.79	9.89	0.03	0.03	0.022	0.023	0	4.48	0
6/26/19 11:40	137.3	6.94	4.46	0.02	0.02	0.014	0.01	0	2.34	0
7/25/19 12:00	158	7.31	2.62	0.02	0.06	0.024	0.01	0	5.64	0
8/5/19 10:30	142.1	6.85	2.69	0.05	0.03	0.022	0.01	0	3.65	0

Table 43: Sequoyah (SEQ) sub-watershed.

Date	EC µS	pH mg/L	Turb mg/L	TN mg/L	NH_4^+-N mg/L	NO_3^--N mg/L	TP mg/L	PO_4 mg/L	DOC mg/L	DON mg/L
5/26/16 10:49	183	7.38	2.46	0.26	0	0	0.005	0	2.75	0.26
8/13/16 13:50	246	8.07	11.6	0.12	0.06	0.05	0.02	0.011	3.23	0.01
9/28/16 11:40	261	8.79	3	0.11	0.01	0.04	0.018	0.013	2.22	0.06
10/27/16 10:40	224	8.13	26.3	2.43	0.01	1.58	0.032	0.01	13.5	0.84
11/10/16 0:00	193	8.21	21.9	0.39	0	0.14	0.049	0.002	7.05	0.25
3/22/17 10:50	111	7.83	42.4	0.78	0	0.02	0.055	0	3	0.76
4/12/17 13:26	129	7.73	21.5	0.48	0.01	0.03	0.039	0	2.26	0.44
4/26/17 10:32	148	7.33	17.9	0.34	0.01	0.05	0.045	0	2.66	0.28
5/11/17 11:24	159	7.97	9.93	0.31	0.01	0.03	0.022	0.005	1.77	0.27
5/26/17 12:40	172	7.92	4.86	0.6	0.01	0.03	0.031	0.004	2.4	0.56
6/16/17 13:00	170	7.9	4.21	0.18	0.05	0.04	0.039	0.004	1.94	0.09
7/5/17 9:25	315	7.46	11.8	0.1	0.02	0.05	0.041	0.008	1.95	0.03
8/1/17 14:45	332	7.68	2.57	0.09	0.01	0.05	0.009	0.007	2.1	0.03
9/21/17 11:07	427	7.66	1.71	0.17	0.06	0.011	0.036	0.014	2.5	0.1
10/19/17 9:40	448	7.8	7.3	0.16	0.03	0.013	0.075	0.016	2.41	0.12
11/2/17 13:56	480	8.63	0.47	0.18	0.02	0.033	0.026	0.016	3.66	0.13
11/21/17 14:12	349	7.89	7.53	0.49	0	0.248	0.029	0.005	4.05	0.24
12/5/17 13:00	354	6.76	2.5	0.12	0.01	0.016	0.009	0	2.77	0.09
12/19/17 14:48	386	7.75	1.54	0.25	0.01	0.01	0.037	0.001	2.24	0.23
1/5/18 13:15	234	6.88	12.6	0.56	0.03	0.372	0.037	0	6.29	0.16
1/18/18 11:53	191	6.91	38.6	0.45	0.01	0.333	0.083	0.003	7.4	0.11
2/7/18 13:56	200	7.38	1.5	0.07	0.01	0	0.034	0.019	1.61	0.06
2/23/18 12:40	196	7.29	9.3	0.23	0	0	0.076	0.019	2.16	0.23
3/1/18 10:55	148	6.89	47.8	0.43	0	0.013	0.087	0.033	6.37	0.42
3/7/18 12:33	154	7.15	13.3	0.15	0	0	0.024	0.015	2.27	0.15

3/21/18 14:05	169	7.26	12.1	0.03	0.03	0	0.01	0.024	2.77	0
3/15/18 13:28	140	7.06	52.6	0.34	0.02	0	0.147	0.028	5.89	0.32
3/29/18 13:30	126	7.22	13.5	0.03	0.01	0	0.01	0.033	2.07	0.02
4/6/18 12:45	62	6.91	309	0.42	0.02	0	0.432	0.016	7.58	0.4
4/5/18 11:58	131	7.28	6.93	0	0.01	0	0.004	0.012	2.18	0
4/10/18 11:45	113	7.22	16.9	0.26	0.05	0	0.018	0.007	2.58	0.21
4/25/18 15:07	147	7.28	5.99	0.06	0.02	0	0.004	0.007	1.96	0.04
5/11/18 13:40	176	8.84	2.92	0.12	0.01	0	0.001	0.007	1.74	0.11
5/25/18 12:30	182	7.63	2.4	0.26	0.01	0	0.007	0.007	1.82	0.25
6/15/18 12:10	200	7.36	2.65	0.01	0.01	0	0.111	0.003	2.4	0
7/5/18 14:35	226	7.33	0.66	0.05	0.01	0	0.021	0.002	2.29	0.04
7/20/18 9:55	234	7.77	0.57	0.08	0.01	0.055	0.034	0.003	2.13	0.02
8/2/18 9:10	250	7.51	1.35	0.1	0.03	0.009	0.039	0.005	2.33	0.06
8/29/18 14:35	274	8.03	0.58	0.03	0.01	0	0.044	0.002	1.73	0.02
9/16/18 14:00	309	7.35	18.8	0.71	0.01	0.066	0.106	0.006	1.46	0.63
10/2/18 10:30	377	7.71	1.39	0.17	0.01	0	0.076	0.038	6.14	0.16
10/24/18 15:06	381	7.45	14.3	0.66	0.01	0.02	0.123	0.056	3.38	0.63
11/19/18 15:05	444	7.6	1.18	0.15	0.01	0.02	0.101	0	1.19	0.12
11/19/18 15:20	378	7.94	0.27	0.09	0.01	0.01	0.046	0.008	2.62	0.07
12/4/18 11:20	108	8.78	4.69	0.26	0.01	0.04	0.039	0.003	3.28	0.21
12/17/18 14:10	166	7.21	10.7	0.15	0.01	0.03	0.124	0	5.42	0.11
12/26/18 15:20	132	7.08	5.56	0.17	0.04	0	0.014	0.001	4.15	0.13
1/7/19 14:25	121	6.84	22.4	0.09	0.02	0.08	0	0	5.29	0
1/9/19 13:30	127	6.82	17.1	0.14	0.01	0.05	0.123	0	4.99	0.08
1/16/19 13:08	136	7.09	51.1	0	0.04	0.34	0	0.002	9.15	0
1/17/19 12:00	117	6.9	28.5	0	0.02	0.03	0	0.009	4.4	0
1/17/19 12:20	101	6.75	33.8	0	0.02	0.01	0	0.009	6.73	0
1/22/19 14:35	103	6.73	19.4	0	0.01	0.01	0	0	3.88	0
2/1/19 11:55	144	7.05	9.62	0	0.01	0.005	0.014	0.016	2.78	0
2/5/19 12:50	115.2	6.85	28.4	0.07	0.01	0	0.042	0.01	5.2	0.06
2/13/19 12:00	99	6.8	49.1	0.13	0.01	0.005	0.031	0.009	6.87	0.12
2/14/19 10:45	75.4	6.83	75.5	0.23	0.02	0	0.069	0.016	4.63	0.21
2/15/19 10:30	89.2	7.06	34	0.22	0.02	0	0.057	0.012	5.64	0.2
2/26/19 10:20	72.3	6.9	46.5	0.32	0.05	0.004	0.06	0.017	0	0
2/27/19 11:30	72.3	6.75	49.2	0.17	0.05	0	0.131	0.017	6.32	0.12
2/28/19 13:40	84.5	7.31	30.3	0.19	0.01	0	0.084	0.019	4.46	0.18
3/5/19 0:00	107.2	7.01	18.5	0.1	0.02	0	0	0.013	3.34	0.08
3/19/19 12:00	110	7.59	13.9	0.07	0.02	0	0	0.014	3.08	0.05
3/25/19 12:15	95	7.4	65.1	0.3	0.02	0.002	0	0.018	9.12	0.27
3/28/19 12:10	107	7.55	22.4	0.12	0.01	0	0	0.015	4.23	0.11

4/2/19 12:25	120	7.5	14.4	0.06	0.02	0	0	0.017	3.24	0.04
4/8/19 10:40	113	6.9	27.4	0.17	0.04	0.01	0.04	0	3.82	0.12
4/15/19 12:10	118.4	7.2	14.6	0.13	0.01	0	0.03	0.01	2.47	0.12
5/2/19 13:20	138.1	7.3	9.22	0.1	0.02	0.01	0.03	0.01	2.14	0.07
5/16/19 8:30	96.8	6.89	54.9	0.25	0.01	0.099	0.28	0.008	12.95	0.14
5/17/19 10:50	95.7	6.72	23	0.26	0.04	0	0.08	0.012	6.98	0.22
5/20/19 10:10	100.7	7.02	35.3	0.19	0.04	0	0.12	0.008	4.35	0.15
5/21/19 9:50	94.9	6.94	33.7	0.25	0.08	0	0.11	0.008	5.94	0.17
5/29/19 10:00	131	6.97	5.8	0.15	0.14	0.007	0.03	0.005	2.72	0
6/12/19 15:10	140.6	7.05	10.5	0.11	0.02	0.03	0.023	0	2.94	0.06
6/26/19 13:30	129.8	7.27	12	0.31	0.04	0.028	0.017	0	3.22	0.24
7/23/19 12:15	173.2	7.14	4.22	0.02	0.03	0.091	0.017	0.01	5.72	0
8/5/19 14:10	184.3	7.3	5.48	0.11	0.04	0.053	0.013	0.01	3.21	0.01
8/22/19 11:30	187.8	7.36	1.72	0	0.03	0.019	0.003	0.01	6.11	0
9/5/19 10:20	176.2	7.01	1.13	0.15	0.04	0.036	0.024	0.01	7.06	0.08
9/16/19 10:35	195.5	7.28	0	0	0.22	0.04	0.01	0	6.54	0
10/1/19 10:30	240.7	6.99	20.5	0.26	0.04	0.02	0.35	0.01	2.92	0.2
10/24/19 10:40	231.7	7.28	30.3	0.34	0.11	0.03	0.34	0.01	0	0
11/25/19 15:30	265.4	7.65	0.6	0.14	0.22	0.01	0.34	0.02	4.02	0

Table 44: Richards (RIC) sub-watershed.

Date	EC	pH	Turb	TN	NH4+-N	NO3--N	TP	PO4	DOC	DON
	µS	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
6/10/16 13:35	163	8.36	1.7	0.13	0.02	0.02	0.016	0.01	1.87	0.09
8/13/16 14:30	162	7.74	2.6	0.06	0.02	0.04	0.013	0.011	1.97	0
9/28/16 12:15	175	8.2	1.6	0.11	0.01	0.04	0.021	0.012	1.84	0.06
10/27/16 11:15	165	7.87	29.2	0.73	0.01	0.31	0.04	0.013	10.02	0.41
11/10/16 0:00	154	7.51	37.3	0.95	0	0.13	0.305	0.006	11.12	0.82
11/10/16 0:00	153	7.58	23.6	0.57	0	0.21	0.192	0.009	9.65	0.36
11/10/16 0:00	148	7.78	10.8	0.73	0	0.36	0.075	0.009	8.21	0.37
3/22/17 11:23	120	7.65	25.4	0.65	0.01	0.02	0.044	0	2.6	0.62
4/12/17 14:00	126	7.66	16	0.44	0	0.01	0.058	0	2.14	0.43
4/26/17 11:07	134	7.56	5.76	0.34	0.02	0.02	0.029	0.004	2.55	0.3
5/11/17 11:55	135	7.84	5.23	0.23	0	0.01	0.026	0.006	1.55	0.22
5/26/17 13:23	145	7.69	2.67	0.51	0	0.01	0.015	0.005	1.84	0.5
6/16/17 13:20	131	7.92	5.83	0.07	0.02	0.02	0.042	0.006	1.57	0.03
7/5/17 10:35	273	7.5	1.83	0.04	0.01	0.03	0.005	0.004	1.63	0
8/1/17 15:20	279	7.61	2.69	0.09	0.01	0.03	0.016	0.007	1.69	0.05
9/21/17 11:15	285	7.61	1.79	0.19	0.09	0.023	0.039	0.016	1.91	0.08

10/19/17 8:30	268	7.58	2.11	0.18	0.03	0.025	0.054	0.018	2.07	0.13
11/2/17 14:10	287	7.6	3.68	0.26	0	0.082	0.022	0.003	4.56	0.18
11/21/17 13:21	306	8.11	1.58	0.18	0.02	0.016	0.022	0.014	1.98	0.14
12/5/17 14:10	283	6.73	1.41	0.09	0.02	0.012	0.009	0.001	2.16	0.06
12/19/17 15:12	294	6.7	1.75	0.07	0.02	0.009	0.012	0.006	1.86	0.04
1/5/18 13:45	193	6.94	6.42	0.18	0.01	0	0.025	0.001	4.8	0.17
1/10/18 9:51	136	6.81	11.4	0.1	0.01	0	0.028	0	3.83	0.09
1/18/18 12:42	131	6.84	15.4	0.14	0.02	0	0.046	0.001	6.1	0.12
2/7/18 14:38	122	7.1	2.48	0.11	0.01	0	0.037	0.01	2.22	0.1
2/23/18 13:18	146	7.28	2.36	0.12	0.01	0	0.04	0.019	1.44	0.11
3/1/18 11:30	129	6.82	13.9	0.23	0	0	0.034	0.015	4.52	0.23
3/7/18 13:23	131	7.07	11.6	0.15	0	0	0.041	0.019	1.8	0.15
3/21/18 14:29	153	7.12	4.5	0	0.03	0	0.001	0.024	2.2	0
3/15/18 13:51	121	7.06	24.3	0.16	0.02	0	0.059	0.042	4.84	0.14
3/29/18 14:05	122	7.22	4.22	0.02	0.02	0	0.001	0.038	1.56	0
4/5/18 12:25	143	6.95	1.63	0	0.02	0	0	0.012	1.43	0
4/6/18 13:30	78	6.79	411	0.41	0.04	0.052	0.601	0.012	5.23	0.32
4/10/18 12:50	118	7.09	4.73	0.13	0.01	0	0.001	0.007	1.93	0.12
4/25/18 16:02	130	7.14	5.17	0.23	0.01	0	0.018	0.007	1.41	0.22
5/11/18 14:30	151	8.08	1.32	0.25	0.01	0	0.001	0.012	1.37	0.24
5/25/18 13:30	140	7.28	1.19	0.11	0.01	0	0.01	0.007	1.38	0.1
6/15/18 9:40	140	7.16	0.87	0.1	0.01	0	0.036	0.003	2.14	0.09
7/5/18 16:10	144	6.99	0.9	0.02	0.01	0	0.029	0.003	1.8	0.01
7/20/18 10:55	145	7.22	0.86	0.09	0.01	0	0.029	0.002	1.83	0.08
8/2/18 10:30	151	7.13	1.11	0.01	0.01	0	0.034	0.003	1.79	0
8/29/18 14:50	151	7.51	0.87	0.09	0.01	0	0.039	0.003	0.72	0.08
9/17/18 9:30	156	7.3	1.36	0.09	0.01	0	0.034	0.003	1.02	0.08
10/2/18 11:50	192	7.3	1.54	0.25	0.01	0	0.034	0.009	2.79	0.24
10/24/18 15:35	191	7.5	0.59	0.12	0.01	0.07	0.101	0	2.03	0.04
11/14/18 9:15	158	7.53	9.5	0.37	0.01	0.05	0.173	0.021	0.51	0.31
11/19/18 15:05	165	6.98	0.46	0.11	0.01	0	0.096	0	1.94	0.1
12/4/18 10:50	143	7.37	1.18	0.15	0.01	0.04	0.029	0	2.52	0.1
12/17/18 13:25	150	7.15	3.84	0.26	0.01	0	0.014	0	3.85	0.25
12/27/18 10:00	135	7.05	5.07	0.09	0.05	0	0	0	2.54	0.04
1/7/19 15:10	128	6.93	8.57	0.01	0.04	0	0	0	3.85	0
1/9/19 14:10	126	6.53	6.73	0.17	0.01	0.06	0.122	0	3.98	0.1
1/16/19 13:52	119	6.82	36.5	0	0.03	0.06	0	0	8.96	0
1/17/19 11:15	113	7.14	12.6	0	0.01	0.02	0	0	4.12	0
1/22/19 15:15	118	6.52	6.43	0	0.01	0	0	0	2.49	0
2/1/19 12:55	133	6.82	14.9	0.19	0.01	0	0.049	0.013	2.12	0.18

2/3/19 12:45	103	6.92	22.6	0.04	0.01	0.008	0.007	0	4.56	0.02
2/5/19 13:30	127	7	10.8	0.04	0.01	0.001	0.025	0.01	3.5	0.03
2/14/19 11:50	91	6.87	29.9	0.18	0.02	0	0.021	0.012	4.27	0.16
2/15/19 11:50	112.4	7.1	15.6	0.15	0.02	0	0	0.012	3.6	0.13
2/27/19 12:30	93.3	6.72	28	0.18	0.01	0	0.099	0.016	3.81	0.17
2/28/19 14:40	95	6.92	11	0.2	0.01	0	0.099	0.019	2.91	0.19
3/5/19 9:30	115	6.97	5.07	0.1	0.05	0	0	0.015	2.27	0.05
3/19/19 13:00	114	7.35	2.62	0.02	0.03	0	0	0.014	2.67	0
3/25/19 13:00	106	7.52	13.8	0.16	0.01	0	0	0.015	5.96	0.15
3/28/19 13:00	116	7.57	7.22	0.05	0.01	0.001	0	0.022	3.21	0.04
4/2/19 13:23	121	7.36	7.49	0.06	0.02	0.005	0	0.017	2.66	0.04
4/8/19 11:45	117	6.77	13.7	0.16	0.04	0.01	0.04	0.01	3.61	0.11
4/15/19 13:10	142.3	7.25	3.57	0.16	0.02	0	0.02	0.01	1.88	0.14
5/2/19 13:40	124.7	7.24	2.64	0.06	0.03	0	0.02	0.01	1.94	0.03
5/16/19 9:05	107.1	6.89	18	0.47	0.01	0.07	0.18	0.008	9.09	0.39
5/17/19 11:50	109.2	6.82	10.7	0.14	0.06	0.001	0.07	0.004	4.36	0.08
5/20/19 10:55	115.9	7.03	6.83	0.11	0.05	0.052	0.04	0.005	2.79	0
5/21/19 10:25	117.9	6.83	6.16	0.1	0.05	0.001	0.04	0.007	3.38	0.05
5/29/19 11:00	130.2	6.93	2.32	0.07	0.17	0	0.02	0.004	2.01	0
6/12/19 15:40	115.2	7.09	3.48	0.02	0.03	0.019	0.023	0.01	4.06	0
6/26/19 14:20	117.4	7.3	1.67	0.02	0.03	0.021	0.013	0	5.52	0
7/23/19 11:00	138.5	7.24	1.25	0.02	0.02	0.021	0.01	0	4.53	0
8/6/19 13:40	111.8	7.19	1.28	0	0.03	0.007	0.007	0	3.04	0
8/22/19 12:12	145.5	7.13	1.9	0	0.03	0.042	0.01	0	4.1	0
9/5/19 11:00	135.3	7.3	1.62	0.04	0.06	0.059	0	0.01	5.7	0
9/16/19 11:50	163.5	7.31	0	0.04	0.18	0.04	0.03	0	3.61	0
10/1/19 11:00	163.8	7.57	38.2	0.1	0.05	0.03	0.41	0.02	2.87	0.02
10/24/19 11:20	106.3	7.74	6.88	0.15	0.05	0.03	0.34	0.01	5.83	0.07
11/25/19 15:50	169.4	7.79	7.73	0.19	0.11	0.01	0.34	0.01	3.37	0.07

Table 45: Quetelet (QUE) sub-watershed.

Date	EC μS	pH	Turb mg/L	TN mg/L	NH_4^+-N mg/L	NO_3^--N mg/L	TP mg/L	PO_4 mg/L	DOC mg/L	DON mg/L
5/26/16 12:40	182	7.52	1.26	0.21	0	0	0.015	0.007	2.47	0.21
6/30/16 15:30	155	8.55	1.56	0.05	0.01	0	0.016	0.01	1.7	0.04
11/10/16 0:00	149	8.16	19.1	0.73	0	0.38	0.122	0.016	8.61	0.35
3/21/17 14:00	115	7.64	55.6	0.66	0	0.08	0.075	0	3.94	0.58
4/12/17 14:51	146	7.65	12.1	0.33	0.01	0.03	0.029	0	2.26	0.29
4/26/17 10:58	156	7.91	8.92	0.42	0.01	0.03	0.033	0.002	2.58	0.38
5/11/17 10:32	166	7.87	5.5	0.17	0.01	0.01	0.016	0.006	1.76	0.15

6/21/17 16:42	176	8.01	1.91	0.09	0.02	0.01	0.016	0.007	1.79	0.06
7/5/17 16:00	308	7.46	1.04	0.03	0	0.01	0.013	0.011	1.78	0.02
8/2/17 9:30	318	7.5	2.03	0.07	0.02	0.03	0.019	0.013	1.91	0.02
12/5/17 14:08	347	6.72	0.89	0.14	0.03	0.011	0.015	0.001	2.57	0.1
12/18/17 15:05	372	6.65	3.16	0.17	0.02	0.011	0.034	0.001	2.17	0.14
1/5/18 13:50	262	6.8	5.41	0.33	0.02	0.164	0.025	0.001	6.17	0.15
1/10/18 12:28	140	6.78	17.1	0.19	0.01	0	0.034	0	4.11	0.18
1/18/18 14:10	174	6.84	20.5	0.36	0.01	0.092	0.049	0.004	6.76	0.26
2/22/18 15:37	201	7.22	2	0.16	0	0	0.037	0.019	1.63	0.16
2/15/18 12:15	201	7.24	2.91	0.17	0	0	0.047	0.015	1.5	0.17
3/1/18 13:05	149	6.92	28.3	0.39	0	0.099	0.057	0.019	3.27	0.29
3/1/18 14:00	144	6.83	87.5	0.43	0	0.135	0.132	0.024	5.25	0.3
3/2/18 18:00	142	6.98	26	0.26	0.02	0	0.054	0.033	3.73	0.24
3/3/18 6:00	163	6.97	24	0.28	0	0.016	0.044	0.024	3.99	0.26
3/3/18 12:00	161	7.1	22.1	0.25	0	0	0.044	0.033	3.4	0.25
3/3/18 0:00	166	6.95	23.3	0.3	0	0.027	0.047	0.038	3.79	0.27
3/7/18 14:35	163	7.24	8.41	0.09	0.03	0	0.018	0.024	2.22	0.06
3/22/18 12:01	146	7.2	6.69	0.01	0.02	0	0.007	0.033	3.24	0
3/15/18 15:00	132	7.05	12.9	0.29	0.04	0.082	0.018	0.038	6.57	0.17
3/15/18 23:00	124	6.93	19.3	0.2	0.04	0.014	0.039	0.047	4.63	0.15
3/16/18 9:00	122	6.91	17.1	0.14	0.02	0.017	0.024	0.038	4.38	0.1
3/16/18 23:00	118	6.99	21.2	0.12	0.02	0	0.024	0.042	3.55	0.1
3/17/18 13:00	123	6.9	14.8	0.1	0.04	0.053	0.018	0.028	3.5	0.01
3/15/18 14:30	131	6.95	22	0.23	0.02	0	0.059	0.042	5.04	0.21
3/29/18 14:35	142	7.35	5.7	0.01	0.04	0	0.004	0.028	1.7	0
4/5/18 9:20	59	7.24	1.51	0.54	0.04	0	0	0.012	1.54	0.5
4/6/18 4:00	129	7.18	32.6	0.52	0.02	0.189	0.071	0.007	5.83	0.31
4/6/18 8:00	95	7.05	225	0.93	0.01	0.53	0.461	0.012	8.13	0.39
4/6/18 10:00	78	7.03	737	0.83	0.03	0.121	1.018	0.021	8.31	0.68
4/6/18 22:00	84	7.02	190	0.38	0.01	0	0.292	0.012	33.9	0.37
4/7/18 4:00	85	7.11	199	0.31	0	0	0.278	0.025	6.01	0.31
4/7/18 14:00	98	6.95	134	0.66	0.03	0.288	0.208	0.007	3.29	0.34
4/8/18 2:00	105	7.01	49.4	0.32	0.02	0	0.08	0.007	3.05	0.3
4/12/18 9:40	128	7.07	13.5	0.18	0.03	0	0.015	0.012	2.77	0.15
4/10/18 14:51	135	7.21	11	0.26	0.01	0	0.01	0.007	2.2	0.25
4/26/18 10:20	163	7.24	1.32	0.26	0.02	0	0	0.007	1.55	0.24
5/11/18 14:05	157	9.63	0.76	0.01	0.01	0	0.004	0.007	1.45	0
5/30/18 11:10	181	7.46	1.15	0.26	0.01	0	0.013	0.012	2.62	0.25
6/21/18 16:40	189	7.46	0.34	0.07	0.01	0	0.041	0.003	2.37	0.06
7/19/18 15:35	192	7.3	0.63	0.04	0.02	0	0.024	0.002	1.98	0.02

8/1/18 14:50	193	7.38	0.86	0.04	0.01	0	0.009	0	1.47	0.03
8/27/18 14:00	202	7.43	1.56	0.11	0.01	0	0.044	0.006	0.88	0.1
9/17/18 13:22	186	7.31	1.74	0.15	0.01	0	0.113	0.005	2.62	0.14
10/2/18 12:40	262	7.37	0.61	0.14	0.01	0	0.071	0.045	4.74	0.13
10/26/18 15:36	224	7.62	0.41	0.33	0.01	0.02	0.116	0.003	0.57	0.3
11/14/18 17:00	156	7.27	2.48	0.22	0.06	0.03	0.103	0	2.37	0.13
11/19/18 16:30	230	7.54	0.48	0.14	0.01	0.08	0.046	0.006	1.89	0.05
11/27/18 12:40	219	7.21	3.08	0.23	0.01	0.05	0.083	0.003	6.25	0.17
12/4/18 15:30	207	7.37	1.05	0.08	0.03	0	0.031	0	3.06	0.05
12/17/18 11:50	162	7.25	9.51	0.43	0.01	0	0.055	0	4.66	0.42
12/27/18 13:50	156	7.09	4.34	0.03	0.02	0	0.001	0	2.91	0.01
1/7/19 14:35	131	6.89	17.8	0.06	0.05	0.08	0.014	0	4.37	0
1/9/19 4:00	138	7.07	9.52	0.05	0.01	0.01	0.124	0	4.23	0.03
1/9/19 15:30	135	6.85	13.1	0.1	0.01	0.01	0.122	0	4.19	0.08
1/9/19 16:00	138	6.85	11	0.19	0.02	0	0.125	0.009	4.43	0.17
1/10/19 10:00	138	6.91	8.85	0.11	0.03	0.01	0.123	0	3.61	0.07
1/16/19 14:00	132	6.96	21.7	0	0.07	0.14	0	0.001	7.53	0
1/16/19 18:00	102	6.63	124	0	0.04	0.14	0	0	9.94	0
1/16/19 20:00	97	6.83	165	0	0.01	0.06	0	0	9.46	0
1/17/19 0:00	105	6.93	38.1	0	0.02	0.04	0	0.009	6.75	0
1/17/19 8:00	112	6.97	30.8	0	0.02	0.01	0	0	4.96	0
1/18/19 14:40	124	6.51	11.6	0	0.01	0	0	0	3.39	0
1/22/19 14:55	122	6.7	10.7	0	0.02	0	0	0	2.8	0
2/1/19 13:20	169	7.03	2.78	0.09	0.02	0	0	0.009	2.21	0.07
2/4/19 6:00	119	6.93	10.4	0.17	0.01	0.011	0.014	0	5.63	0.15
2/4/19 15:00	148	6.83	18.9	0.13	0.02	0.02	0.025	0	5.16	0.09
2/4/19 21:00	139	6.99	19.8	0.1	0.01	0.008	0.001	0	4.51	0.08
2/5/19 14:25	107.3	7.49	16.3	0.03	0.02	0.001	0.035	0	3.94	0.01
2/12/19 9:40	145	6.94	12.6	0	0.01	0	0.007	0	2.84	0
2/13/19 0:00	133	6.94	22.3	0.14	0.02	0.001	0.025	0	4.97	0.12
2/13/19 8:00	108	6.8	39.1	0.46	0.02	0.001	0.035	0	6.95	0.44
2/13/19 14:20	108.8	6.81	36.8	0.18	0.02	0.005	0.042	0	4.6	0.16
2/13/19 18:00	105.7	6.88	37.5	0.12	0.02	0.008	0.031	0	4.17	0.09
2/14/19 0:00	78.8	6.83	219	0.73	0.03	0.005	0.158	0.01	7.31	0.7
2/14/19 12:00	92.6	6.92	63.1	0.94	0.02	0	0.332	0	4.84	0.92
2/14/19 22:00	106.7	7.18	39	0.19	0.02	0	0.054	0	4.21	0.17
2/15/19 13:10	102.6	7.1	29.8	0.19	0.03	0	0.066	0	3.73	0.16
2/19/19 14:55	123.4	6.9	15.2	0.1	0.01	0	0	0.012	2.44	0.09
2/25/19 12:00	109.6	6.95	30.6	0.35	0.01	0.004	0.057	0.011	7.27	0.34
2/25/19 20:00	48.3	6.91	251	0.52	0.02	0.01	0.336	0.014	7.93	0.49

2/26/19 12:00	90.1	6.97	52.3	0.27	0.02	0.012	0.108	0.014	4.16	0.24
2/27/19 2:00	84.5	6.79	350	0.42	0.04	0	0.22	0.022	5.99	0.38
2/27/19 10:00	86.8	6.6	72.1	0.19	0.02	0	0.173	0.016	4.41	0.17
2/28/19 15:30	109.6	6.79	25.5	0.1	0.01	0.001	0.126	0.019	2.94	0.09
3/5/19 6:00	123.4	7.02	11.3	0.12	0.05	0	0	0.015	2.51	0.07
3/6/19 11:50	118.5	7.07	29	0.22	0.05	0	0.006	0.007	3.48	0.17
3/6/19 14:30	108.7	7.01	39.2	0.44	0.09	0	0.032	0.01	3.89	0.35
3/7/19 10:30	110.7	7.07	14.5	0.12	0.02	0	0	0.012	3.23	0.1
3/19/19 12:40	131	7.48	5.3	0.13	0.03	0	0	0.015	2.59	0.09
3/25/19 14:00	106	7.42	37.4	0.19	0	0	0	0.017	6.73	0.18
3/28/19 12:00	122	7.76	17.4	0.13	0.01	0.014	0	0.024	3.42	0.11
3/28/19 22:00	125	7.67	19.2	0.07	0	0	0	0.021	3.72	0.06
3/29/19 14:00	126	7.65	20	0.07	0.01	0	0	0.018	3.38	0.06
4/2/19 13:30	137	7.65	8.58	0.04	0.01	0.01	0	0.004	2.26	0.02
4/8/19 12:30	126.1	6.88	14.7	0.11	0.04	0	0.04	0.01	3.48	0.07
4/15/19 11:56	142.4	7.2	6.06	0.13	0.01	0	0.02	0.01	2.01	0.12
5/2/19 13:40	158	7.37	3.79	0	0.01	0	0.02	0.02	1.69	0
5/16/19 10:30	104.1	6.83	20.4	0.33	0.01	0.106	0.26	0.01	10.97	0.21
5/17/19 12:45	108.3	6.91	20.1	0.2	0.05	0	0.09	0.01	5.21	0.15
5/20/19 11:35	121.7	6.88	11.6	0.22	0.03	0.016	0.06	0.007	3.34	0.18
5/29/19 12:30	150.9	7.14	3.34	0.09	0.16	0	0.02	0.005	2.38	0
6/13/19 8:55	158.5	6.85	2.98	0.01	0.02	0.013	0.02	0.01	3.23	0
7/26/19 8:40	177.8	7.16	1.93	0.11	0.03	0.017	0.017	0.01	4.34	0.07
8/6/19 12:40	169.5	7.2	4.9	0.05	0.03	0.014	0.01	0.01	4.64	0
8/22/19 12:00	165.1	7.35	0.85	0	0.04	0.027	0.01	0.02	4.32	0
9/5/19 13:10	199.9	7.07	0	0.05	0.23	0.05	0.01	0.01	5.85	0
9/16/19 14:10	205.4	7.07	0	0.08	0.24	0.05	0.03	0.02	9.04	0
10/1/19 12:15	233.2	7.38	0.91	0.07	0.02	0.03	0.41	0.02	2.77	0.02
10/23/19 12:40	243.8	6.97	8.37	0.28	0.02	0.01	0.33	0.01	0	0
11/26/19 15:12	190.8	7.42	10.3	0.25	0.02	0.01	0.43	0.24	5.78	0.22
12/6/19 12:10	243.6	7.62	1.79	0.14	0.1	0.02	0.35	0.02	3.75	0.02
12/6/19 20:00	219.2	7.12	19.7	0.78	0.07	0.37	0.35	0.01	10.86	0.34
12/7/19 8:00	143.4	7.1	16.5	1	0.03	0.44	0.36	0.01	9.32	0.53
12/7/19 12:00	152.7	7.03	30.5	0.84	0.04	0.55	0.36	0.02	9.57	0.25
12/7/19 16:00	73	7.19	28.9	0.84	0.02	0.46	0.36	0.01	9.65	0.36
12/7/19 20:00	146.6	6.86	21.4	0.6	0.02	0.37	0.35	0.01	9.51	0.21
12/8/19 0:00	169.9	6.81	25	0.7	0.02	0.32	0.36	0.01	0	0
12/8/19 4:00	161.1	6.83	20.6	0.47	0.14	0.32	0.35	0.01	9.8	0.01
12/8/19 8:00	148.2	6.89	21.2	0.68	0.02	0.3	0.35	0.01	9.33	0.36
12/8/19 10:00	171.3	6.88	18.1	0.37	0.06	0.19	0.34	0.02	6.8	0.12

12/8/19 12:00	166.9	6.86	19.5	0.54	0.12	0.26	0.35	0.01	8.53	0.16
12/8/19 16:00	142.3	6.82	17.8	0.43	0.14	0.2	0.34	0.01	7.72	0.09
12/9/19 0:00	163.5	6.87	15.5	0.37	0.1	0.13	0.34	0.01	7	0.14
12/20/19 15:22	181.8	6.97	5.78	0.14	0.03	0.12	0.02	0.01	6.39	0
1/15/20 22:00	119.3	7.01	49.8	0	0.1	0.012	0	0	10.89	0
1/16/20 0:00	103.7	7	58.8	0	0.11	0.01	0	0.01	11.77	0
1/16/20 2:00	118.8	7.01	53.3	0	0.08	0.002	0	0.01	9.03	0
1/16/20 4:00	117.6	6.97	36.9	0	0.11	0.011	0	0	8.12	0
1/16/20 6:00	113.1	6.93	37.5	0	0.08	0.002	0	0	10.18	0
1/16/20 8:00	111.5	6.91	31.7	0	0.09	0.003	0	0	8.79	0
1/16/20 10:00	116.4	6.91	34.7	0	0.11	0.002	0	0	8.12	0
1/16/20 12:00	114.8	6.86	35.5	0	0.08	0.002	0	0.01	7.97	0
1/16/20 14:00	117.4	6.88	30.6	0	0.04	0.011	0	0	7.22	0
1/16/20 16:00	118.5	6.89	28.7	0	0.09	0.01	0	0	7.29	0
1/16/20 18:00	119.7	6.9	29.9	0	0.07	0.008	0	0	8.15	0
1/16/20 20:00	121.8	6.86	27.4	0	0.05	0.011	0	0	7.19	0
1/16/20 22:00	118.6	6.57	23.6	0	0.04	0.013	0	0	6.56	0
1/17/20 0:00	120.2	6.74	26	0	0.06	0	0	0.01	7.72	0
1/17/20 2:00	128.8	6.86	23.4	0	0.02	0.002	0	0	5.74	0
1/17/20 4:00	128.4	6.74	26	0.19	0.03	0.002	0.276	0.01	6.14	0.16
1/17/20 6:00	95.3	6.94	21.6	0.22	0.02	0.054	0.26	0	5.16	0.14
1/17/20 8:00	128.7	6.77	23.2	0.28	0.02	0.05	0.303	0	2.95	0.21
1/17/20 10:00	110.9	6.81	23.2	0.36	0.1	0.059	0.281	0	3.24	0.2
1/17/20 12:00	125	6.81	21.2	0.31	0.07	0.043	0.287	0	2.91	0.19
1/17/20 14:00	132.1	6.6	22.7	0.3	0.09	0.044	0.287	0.01	5.16	0.17
1/17/20 16:00	130.6	6.7	25	0.29	0.06	0.057	0.268	0	5.44	0.17
1/17/20 18:00	129.8	6.68	20.9	0.38	0.07	0.052	0.273	0	5.01	0.27
1/17/20 20:00	133	6.69	23.5	0.26	0.01	0.053	0.284	0	5.37	0.2
12/23/19 14:10	164.4	6.6	5.19	0.16	0.06	0.032	0.244	0	5.98	0.07
1/8/20 15:45	176.9	6.74	5.02	0.2	0.04	0.036	0.265	0	0	0
1/15/20 16:00	137.2	6.74	23	0.3	0.05	0.065	0.252	0	8.7	0.18
1/16/20 2:00	114.2	6.76	45.3	0.39	0.05	0.065	0.26	0	11.22	0.27
1/16/20 13:45	116.1	6.95	66.1	0.46	0.05	0.093	0.26	0	0	0
1/23/20 12:42	120.7	6.84	15.7	0.64	0.08	0.038	0.29	0.02	4.85	0.52
1/25/20 8:00	150.7	6.79	9.61	0.47	0.06	0	0.287	0.01	4.59	0.41
1/25/20 14:00	144.6	6.83	9.52	0.5	0.12	0	0.265	0.01	8.43	0.38
1/25/20 20:00	132.7	6.84	19.4	0.56	0.09	0.13	0.229	0.02	10.38	0.34
1/26/20 8:00	111.8	6.86	30.5	0.44	0.06	0.105	0.281	0	10.73	0.28
1/26/20 14:00	110.7	6.88	24.5	0.26	0.03	0.065	0.271	0.02	9.45	0.17
1/26/20 20:00	121.8	6.85	22.7	0.28	0.07	0.04	0.265	0	9.21	0.17

1/27/20 2:00	100	6.91	22.2	0.22	0.04	0.026	0.236	0	8.91	0.15
1/27/20 8:00	119.1	6.91	20.5	0.2	0.04	0.001	0.257	0.01	9.53	0.16
1/27/20 14:00	118.5	6.94	19.8	0.24	0.02	0.004	0.254	0	7.49	0.21
1/27/20 20:00	122.3	6.81	18.3	0.22	0.05	0.001	0.241	0.01	9.02	0.17
1/28/20 2:00	109.1	6.6	16.5	0.22	0.05	0.006	0.241	0.01	7.77	0.16
1/28/20 8:00	112.1	6.87	16.3	0.23	0.03	0.012	0.236	0.01	7.5	0.19

Table 46: Porter (POR) sub-watershed.

Date	EC µS	pH mg/L	Turb mg/L	TN mg/L	NH_4^+-N mg/L	NO_3^--N mg/L	TP mg/L	PO_4 mg/L	DOC mg/L	DON mg/L
5/26/16 13:07	116	7.33	2.84	0.32	0	0	0.008	0.005	2.72	0.32
6/30/16 14:45	79	7.45	2.26	0.08	0.01	0	0.01	0.006	1.25	0.07
8/13/16 15:30	114	7.41	3.3	0.05	0.03	0.01	0.013	0.013	2.5	0.01
9/28/16 13:04	117	7.98	1.8	0.16	0.02	0	0.016	0.011	2.63	0.14
10/27/16 14:00	139	7.87	2	0.13	0.01	0	0.027	0.015	3.52	0.12
11/10/16 0:00	117	8.05	84.2	0.51	0	0.01	0.302	0.016	12.26	0.5
11/10/16 0:00	114	7.45	158	0.65	0	0	0.498	0.012	16.45	0.65
11/10/16 0:00	119	7.7	50.9	0.48	0	0.01	0.238	0.007	15.97	0.47
11/10/16 0:00	126	7.5	39.3	0.41	0	0	0.116	0.006	12.65	0.41
11/10/16 0:00	135	7.5	17.3	0.25	0	0	0.055	0.006	7.55	0.25
3/22/17 11:57	111	7.58	30.2	0.38	0.02	0.01	0.044	0	2.9	0.35
4/12/17 14:48	118	7.62	10	0.48	0.01	0.01	0.023	0	2.38	0.46
4/26/17 11:35	115	7.55	9.87	0.35	0	0.01	0.023	0	3.45	0.34
5/11/17 9:45	118	7.53	6.42	0.16	0.01	0	0.022	0.001	1.88	0.15
5/26/17 14:19	124	7.63	4.05	0.62	0.01	0	0.009	0.003	2.51	0.61
6/16/17 14:00	116	7.51	4.3	0.06	0.02	0	0.013	0.004	2	0.04
7/5/17 9:15	244	7.53	3.13	0.03	0.01	0	0.016	0.003	2.01	0.02
8/1/17 16:00	240	7.59	2.25	0.04	0.02	0	0.007	0.004	2.07	0.02
9/21/17 10:10	225	7.53	1.97	0.16	0.09	0.002	0.033	0.008	2.23	0.07
10/19/17 10:30	218	7.39	4.62	0.14	0.03	0.003	0.054	0.008	2.07	0.11
11/2/17 14:30	273	7.35	5.2	0.32	0	0	0.035	0.004	4.76	0.32
11/21/17 15:22	237	7.62	2.12	0.15	0.01	0.003	0.026	0.008	2.42	0.14
12/5/17 14:50	249	6.61	2.8	0.18	0.07	0.011	0.025	0.006	2.82	0.1
12/18/17 14:30	253	6.61	2.27	0.11	0.02	0.01	0.015	0.006	2.27	0.08
1/4/18 15:55	137	6.65	25.5	0.18	0.01	0	0.098	0.001	2.29	0.17
1/10/18 10:36	134	6.89	19.4	0.14	0.01	0	0.034	0	4.59	0.13
1/8/18 13:19	137	6.83	30.7	0.09	0.01	0	0.058	0.004	9.53	0.08
2/6/18 14:14	128	6.95	4.22	0.09	0.01	0	0.034	0.019	2.34	0.08
2/22/18 15:23	122	7.08	3.66	0.07	0	0	0.04	0.028	2.4	0.07

3/1/18 12:00	120	6.79	35	0.17	0	0	0.057	0.028	5.62	0.17
3/7/18 14:12	125	7.08	8.6	0.12	0	0	0.021	0.015	2.49	0.12
3/15/18 14:14	107	6.9	47.8	0.19	0.02	0	0.094	0.033	7.84	0.17
3/20/18 14:25	121	6.93	5.94	0.04	0.05	0	0.004	0.028	2.93	0
3/29/18 9:05	116	7.23	9.25	0	0.02	0	0.013	0.033	1.99	0
4/5/18 9:05	119	7.09	5.51	0.04	0.03	0	0.018	0.007	2.2	0.01
4/6/18 13:00	77	6.75	223	0.26	0.01	0	0.313	0.016	7.34	0.25
4/10/18 13:33	108	6.85	11.4	0.19	0.02	0	0.013	0.007	2.48	0.17
4/26/18 9:45	122	7.16	4.84	0.14	0.02	0	0.001	0.007	1.86	0.12
5/11/18 13:25	121	6.84	2.54	0.2	0.01	0	0.013	0.007	1.78	0.19
5/25/18 14:30	120	7.01	3.02	0.2	0.01	0	0.048	0.012	3.33	0.19
6/15/18 9:20	114	7.02	1.03	0.06	0.01	0	0.029	0.002	3.13	0.05
7/5/18 16:15	111	6.89	1.09	0.09	0.01	0.07	0.029	0.003	1.92	0.01
7/20/18 11:45	107	6.77	2.66	0.06	0.01	0	0.034	0.003	2.03	0.05
8/1/18 14:40	110	6.97	3.39	0.37	0.02	0.02	0.039	0	1.75	0.33
8/27/18 16:00	106	8.99	0.55	0.06	0.01	0.001	0.031	0.003	1.71	0.05
10/2/18 13:00	135	6.96	5.22	0.28	0.01	0	0.081	0.003	3.63	0.27
10/26/18 14:00	709	7.19	0.61	0.06	0.01	0.02	0.046	0.008	1.34	0.03
11/14/18 11:15	111	7.12	9.5	0.24	0.01	0	0.086	0	0.75	0.23
11/19/18 14:20	121	7.1	1	0.09	0.01	0.01	0.111	0.005	1.43	0.07
11/27/18 15:10	132	7.01	5.59	0.39	0.01	0.02	0.133	0.005	7.5	0.36
12/4/18 13:20	137	7.47	2.63	0.16	0.01	0	0.086	0	2.85	0.15
12/26/18 15:55	131	6.9	7.81	0.09	0.02	0	0.025	0.001	3.38	0.07
1/7/19 16:15	126	6.83	24.6	0.07	0.03	0.11	0.007	0.001	4.23	0
1/9/19 14:55	128	6.82	12.3	0.17	0.03	0	0.123	0.001	4.71	0.14
1/16/19 14:50	88	6.52	98.3	0	0.05	0	0	0	12.87	0
1/17/19 10:41	110	7.99	21.8	0	0.02	0	0	0	4.67	0
1/18/19 14:50	122	6.49	6.34	0	0.01	0.01	0	0	3.02	0
1/22/19 14:40	117	6.71	11.2	0	0.01	0	0	0	3.21	0
2/1/19 13:51	130	6.98	5.4	0.08	0.01	0	0.001	0.01	2.51	0.07
2/5/19 14:30	117.9	6.98	15.8	0.05	0.02	0	0.014	0.013	3.6	0.03
2/13/19 14:10	115.2	6.77	32.1	0.18	0.01	0.001	0.031	0.015	5	0.17
2/14/19 13:00	1117	7.29	29.8	0.3	0.04	0.001	0.093	0.012	5.6	0.26
2/15/19 12:35	107.1	6.89	18.8	0.14	0.02	0.001	0.078	0.01	4.33	0.12
2/26/19 12:00	97.5	6.97	30.5	0.24	0.03	0	0.075	0.017	5.63	0.21
2/27/19 11:50	87.1	6.69	30.1	0.19	0.02	0	0.105	0.016	5.46	0.17
2/28/19 15:03	97.2	6.77	16.7	0.16	0.01	0	0.06	0.016	3.74	0.15
3/5/19 11:00	100.7	6.73	9.2	0.06	0.04	0	0	0.012	2.79	0.02
3/19/19 14:20	102	7.24	5.18	0.05	0.02	0	0	0.014	3.29	0.03
3/25/19 13:30	106	7.5	37.9	0.25	0.02	0.001	0	0.03	8.9	0.22

3/28/19 13:30	113	7.68	13.9	0.06	0.01	0	0	0.02	4.66	0.05
4/2/19 14:35	114	7.55	6.67	0.03	0.01	0	0	0.009	2.55	0.02
4/8/19 12:55	111.7	6.89	15.8	0.15	0.04	0.01	0.09	0.01	5.68	0.1
4/15/19 12:10	110.9	7.05	5.38	0.08	0.04	0	0.02	0.01	2.25	0.04
5/2/19 11:10	100.6	7.35	4.63	0.1	0.02	0.01	0.02	0.01	1.98	0.07
5/2/19 12:50	74.4	7.35	4.79	0.11	0.01	0	0.02	0.01	1.81	0.1
5/16/19 10:00	94.9	6.9	24.5	0.41	0.03	0	0.13	0.015	11.61	0.38
5/17/19 11:50	108.8	6.88	16.6	0.17	0.1	0	0.06	0.008	5.58	0.07
5/20/19 10:30	116.1	6.91	13.4	0.11	0.03	0	0.07	0.025	4.05	0.08
5/21/19 11:15	111	6.86	8.63	0.13	0.14	0	0.04	0.005	4.1	0
5/28/19 14:45	118.1	6.84	2.8	0.06	0.14	0	0.02	0.004	2.47	0
6/13/19 8:35	93.4	7.09	5.42	0.05	0.03	0.014	0.017	0	2.9	0.01
7/23/19 14:20	97.8	7.37	3.54	0.02	0.04	0.022	0.01	0	5.55	0
8/22/19 13:12	120	7.33	2.57	0	0.02	0.019	0.006	0.01	4.85	0
9/5/19 12:20	115.3	7.2	2	0	0.03	0.039	0.01	0.01	2.88	0
9/16/19 12:20	106.6	7.27	0	0.06	0.26	0.04	0.02	0	5.99	0
10/1/19 10:42	109.1	7.51	0.75	0	0.07	0.02	0.34	0.01	2.89	0
10/23/19 12:15	134.5	7.29	1.53	0.09	0.04	0.01	0.34	0.01	2.63	0.04
10/23/19 13:55	91.5	7.31	5.22	0.13	0.05	0.03	0.34	0.01	0	0
11/25/19 16:20	116.6	7.85	12.6	0.16	0.04	0.01	0.34	0.01	3.26	0.11

Table 47: Ogilvie (OGI) sub-watershed.

Date	EC µS	pH mg/L	Turb mg/L	TN mg/L	NH_4^+-N mg/L	NO_3^--N mg/L	TP mg/L	PO_4 mg/L	DOC mg/L	DON mg/L
5/26/16 11:00	85	7.27	3.71	0.18	0	0	0.012	0	2.05	0.18
6/30/16 14:28	283	8.11	8.85	0.07	0.01	0	0.042	0.013	0.74	0.06
9/28/16 14:00	74	7.59	2.3	0.04	0.01	0	0.015	0.011	0.82	0.03
10/27/16 13:42	86	7.6	3	0.14	0.02	0	0.014	0.006	2.15	0.12
11/10/16 0:00	828	2.7	39.9	0.57	0.01	0	0.307	0.055	10.25	0.56
11/10/16 0:00	842	2.75	72.3	0.62	0.01	0	0.371	0.033	13.73	0.61
11/10/16 0:00	990	2.62	38.3	0.55	0.01	0	0.207	0.034	14.62	0.54
11/10/16 0:00	955	2.58	20.4	0.29	0.03	0.01	0.065	0.018	11.38	0.25
11/10/16 0:00	1029	2.55	13.6	0.32	0.04	0	0.068	0.013	8.57	0.28
3/22/17 12:40	93	7.51	17.8	0.41	0.01	0.01	0.024	0	2.88	0.39
4/26/17 10:31	93	7.38	10.3	0.22	0	0.01	0.02	0	2.96	0.21
5/11/17 9:20	87	7.37	7.88	0.22	0	0.01	0.016	0.001	1.5	0.21
5/26/17 15:57	87	7.79	4.4	0.49	0.01	0.01	0.012	0.001	1.87	0.47
6/22/17 9:40	83	7.44	5.31	0.07	0.02	0.01	0.01	0	1.52	0.04
7/5/17 8:55	206	7.8	4.73	0.03	0.01	0.01	0.01	0	1.44	0.01
8/1/17 8:20	186	7.82	4.95	0.04	0	0.01	0.022	0.001	1.29	0.03

9/21/17 9:28	157	7.67	4.38	0.13	0.08	0.005	0.027	0.001	1.36	0.05
10/19/17 11:30	156	7.52	3.44	0.12	0.01	0.004	0.03	0.003	1.19	0.11
11/6/17 9:06	193	7.82	2.13	0.14	0	0.01	0.019	0.005	1.49	0.13
11/21/17 14:00	219	7.64	5.64	0.14	0	0.01	0.022	0.003	3.55	0.13
12/5/17 11:52	203	6.8	3.9	0.15	0.07	0.01	0.018	0.001	1.89	0.07
12/18/17 14:03	204	6.72	2.54	0.1	0.01	0.01	0.012	0	1.49	0.08
1/4/18 15:35	102	6.67	7.03	0.14	0.01	0	0.015	0.001	1.39	0.13
1/10/18 11:14	132	6.63	18	0.09	0.01	0	0.034	0	4.26	0.08
1/18/18 13:00	135	7.01	38.1	0.18	0.01	0	0.068	0.004	9.64	0.17
2/6/18 13:47	98	6.88	7.54	0.1	0.01	0	0.053	0.038	1.91	0.09
2/22/18 14:50	90	6.85	5	0.16	0.01	0	0.043	0.015	0.93	0.15
3/1/18 13:31	111	6.83	27.2	0.2	0	0	0.047	0.028	3.91	0.2
3/7/18 14:45	100	6.82	4.6	0.13	0	0	0.014	0.015	1.44	0.13
3/15/18 14:29	102	7.09	43	0.95	0.04	0	0.082	0.028	6.36	0.91
3/20/18 14:15	103	7.07	5.88	0.2	0.04	0	0.004	0.033	1.58	0.16
3/29/18 8:55	100	7.35	6.74	0	0.03	0	0.004	0.028	1.35	0
4/5/18 8:45	97	7.3	2.43	0.03	0.02	0	0	0.024	1.09	0.01
4/6/18 12:15	63	6.99	201	0.38	0.03	0	0.292	0.033	9.31	0.35
4/10/18 13:45	95	7.04	7.24	0.4	0.03	0	0.004	0.012	2.07	0.37
4/24/18 16:05	91	6.97	2.87	0.11	0.02	0	0	0.007	1.16	0.09
5/11/18 12:45	91	6.79	2.4	0.13	0.01	0	0	0.007	0.87	0.12
5/30/18 8:50	85	6.77	2.55	0.23	0.01	0	0.004	0.007	0.97	0.22
6/15/18 16:00	76	7.35	1.58	0.01	0.01	0.016	0.019	0.005	1.54	0
6/22/18 8:00	77	7.14	1.46	0.04	0.01	0	0.021	0.003	1.22	0.03
7/5/18 15:16	73	7.2	1.57	0.03	0.01	0	0.024	0.009	1.27	0.02
7/20/18 11:10	72	7.03	4.54	0.06	0.01	0.009	0.036	0.003	1.36	0.04
8/1/18 15:40	71	7.38	1.79	0.06	0.01	0	0.029	0	0.84	0.05
8/27/18 14:30	76	7.2	1.65	0.01	0.01	0.032	0.026	0.002	1.6	0
10/2/18 11:40	90	7.39	3.54	0.8	0.01	0	0.029	0.002	1.73	0.79
10/26/18 13:10	74	7.65	2.01	0.12	0.02	0.04	0.054	0	1.26	0.06
11/14/18 13:30	71	6.93	4.69	0.14	0.01	0	0.081	0	0.78	0.13
11/20/18 11:00	76	7.25	5.55	0.15	0.01	0.03	0.036	0	1.13	0.11
11/27/18 14:40	120	7.14	9.93	0.17	0.01	0	0.093	0.002	7.59	0.16
12/4/18 14:30	108	7.25	4.5	0.06	0.01	0	0.071	0	2.18	0.05
12/17/18 10:20	129	6.91	8.72	0.12	0.02	0.01	0.018	0.002	3.76	0.09
12/17/18 11:10	136	6.83	6.58	0.27	0.02	0	0.011	0.002	4.89	0.25
12/27/18 11:20	115	6.76	6.74	0.71	0.02	0	0.011	0	2.68	0.69
1/7/19 15:30	117	6.9	18	0.1	0.04	0.04	0.014	0.007	3.75	0.02
1/9/19 13:50	118	6.82	13.8	0.1	0.01	0	0.124	0.006	3.65	0.09
1/16/19 12:20	104	6.84	91.4	0	0.02	0.02	0	0	11.79	0

1/17/19 10:10	103	6.89	25.1	0	0.02	0	0	0.012	5.41	0
1/22/19 14:10	107	6.79	10.9	0	0.02	0	0	0	3.01	0
2/1/19 12:50	95	6.78	5.03	0	0.01	0.112	0	0	1.93	0
2/5/19 13:35	63.7	6.75	18	0.08	0.02	0	0.025	0.01	3.49	0.06
2/13/19 13:45	107.1	6.72	37.6	0.34	0.02	0	0.042	0.016	5.74	0.32
2/14/19 11:12	84.1	6.78	32.7	0.21	0.04	0	0.295	0.012	7.91	0.17
2/15/19 14:05	84	6.73	21.3	0.1	0.02	0	0.025	0.012	4.79	0.08
2/26/19 9:52	64.5	6.98	33.9	0.16	0.02	0	0.134	0.019	5.97	0.14
2/27/19 10:55	79	6.86	30.3	0.16	0.01	0	0.072	0.017	6.86	0.15
2/28/19 15:20	78.9	6.8	19.5	0.11	0.01	0	0.054	0.016	4.1	0.1
3/5/19 4:00	95.2	6.92	7.93	0.11	0.03	0.01	0	0.009	2.65	0.07
3/18/19 15:05	87	7.59	15	0.06	0.04	0	0	0.017	5.69	0.03
3/19/19 12:00	82	7.53	4.86	0.03	0.02	0	0	0.014	2.78	0.01
3/25/19 14:36	88	7.47	35.5	0.14	0.01	0.001	0	0.021	7.87	0.13
4/2/19 12:55	90	7.3	5.65	0.03	0.01	0.003	0	0.012	2.72	0.02
4/8/19 11:30	89.8	6.83	15.1	0.13	0.02	0.01	0.03	0	4.66	0.1
4/15/19 11:00	89.1	7.19	4.37	0.09	0.04	0.01	0.02	0.01	2.11	0.04
5/16/19 9:30	91.9	6.98	20.3	0.44	0.02	0	0.13	0.013	13.52	0.42
5/17/19 11:20	91.5	6.63	15.3	0.17	0.04	0	0.06	0.008	6.03	0.13
5/20/19 11:30	103.3	6.85	8.41	0.1	0.04	0	0.04	0.007	4.33	0.06
5/21/19 11:30	96.2	6.84	9.62	0.12	0.04	0	0.03	0.005	4.69	0.08
5/28/19 14:25	93.5	6.96	3.23	0.06	0.14	0	0.02	0.004	2.39	0
6/13/19 7:45	84.5	7.17	9.14	0.07	0.02	0.014	0.013	0	2.68	0.03
6/26/19 15:10	75.9	7.16	4.15	0.02	0.04	0.022	0.01	0	6.25	0
7/23/19 15:20	79.8	7.33	5.88	0.06	0.03	0.019	0.02	0	3.49	0.01
8/22/19 10:50	69.4	7.71	4.92	0	0.03	0.016	0	0	4.66	0
9/5/19 12:30	85.4	7.35	4.42	0.04	0.04	0.045	0.006	0.01	6.14	0
9/17/19 13:00	70.6	7.18	0	0.03	0.2	0.04	0	0	5.6	0
10/1/19 12:30	95.1	7.81	4.16	0	0.03	0.03	0.34	0	1.86	0
11/26/19 14:20	100.4	7.83	0	0.71	0.06	0.01	0.4	0.03	6.9	0.64

Table 48: Sequoyah A (ASEQ) sub-watershed.

Date	EC µS	pH mg/L	Turb mg/L	TN mg/L	NH_4^+-N mg/L	NO_3^--N mg/L	TP mg/L	PO_4 mg/L	DOC mg/L	DON mg/L
1/5/18 13:10	239	6.88	8.2	0.21	0.02	0.00	0.025	0.000	5.76	0.19
2/7/18 14:26	172	7.31	5.8	0.13	0.01	0.00	0.05	0.019	2.36	0.12
3/1/18 10:50	145	7.19	32.0	0.35	0.00	0.00	0.064	0.024	5.47	0.35
3/7/18 12:30	167	7.21	7.8	0.10	0.00	0.00	0.018	0.019	1.90	0.10
3/21/18 14:10	176	7.14	5.1	0.05	0.02	0.00	0.007	0.019	1.91	0.03

3/15/18 13:20	135	7.08	21.2	0.15	0.01	0.00	0.045	0.033	5.06	0.14
4/5/18 11:55	179	7.57	1.6	0.00	0.02	0.00	0.001	0.033	1.31	0.00
4/6/18 12:35	71	6.68	502.0	0.41	0.02	0.00	0.776	0.016	5.98	0.39
4/10/18 11:41	132	7.2	14.0	0.25	0.02	0.00	0.015	0.007	1.95	0.23
4/25/18 15:00	174	7.36	1.6	0.19	0.01	0.00	0	0.016	1.42	0.18
5/11/18 13:30	198	7.56	0.8	0.28	0.01	0.00	0.004	0.025	1.33	0.27
5/25/18 13:00	214	7.64	0.8	0.00	0.01	0.00	0.007	0.016	1.23	0.00
6/15/18 12:50	240	7.4	0.7	0.03	0.01	0.00	0.029	0.002	1.95	0.02
7/5/18 14:10	271	7.35	0.5	0.20	0.01	0.00	0.021	0.003	1.57	0.19
7/20/18 9:45	282	7.47	0.5	0.02	0.01	0.00	0.026	0.002	1.37	0.01
8/2/18 9:05	297	7.38	1.1	0.04	0.02	0.02	0.029	0.003	1.50	0.00
8/29/18 15:15	315	7.31	0.5	0.04	0.01	0.00	0.041	0.003	1.37	0.03
10/2/18 11:40	422	7.21	10.7	0.00	0.11	0.06	0.096	0.000	3.40	0.00
10/24/18 14:55	439	7.54	0.5	0.09	0.01	0.00	0.024	0.003	1.04	0.08
12/4/18 11:10	171	8.23	1.4	0.17	0.01	0.00	0.088	0.000	2.19	0.16
12/17/18 14:30	157	7.28	10.1	0.27	0.01	0.01	0.025	0.000	4.15	0.25
12/26/18 16:00	142	7.02	8.1	0.08	0.02	0.00	0	0.000	2.95	0.06
1/7/19 14:55	131	7.02	18.5	0.00	0.03	0.01	0.014	0.000	3.90	0.00
1/9/19 13:45	135	6.87	13.6	0.15	0.01	0.00	0.125	0.001	3.73	0.14
1/16/19 12:55	138	6.93	13.5		0.02	0.01		0.000	6.78	0.00
1/22/19 14:15	122	6.8	13.6		0.02	0.00		0.016	2.69	0.00
2/1/19 12:00	182	6.85	2.3	0.00	0.01	0.00	0	0.010	1.97	0.00
2/5/19 13:00	138	6.94	19.2	0.00	0.01	0.00	0.035	0.013	3.41	0.00
2/13/19 11:55	108	6.89	39.5	0.25	0.01	0.00	0.042	0.018	4.70	0.24
2/14/19 10:40	83.1	6.82	52.4	0.30	0.03	0.00	0.042	0.015	7.68	0.27
2/15/19 10:15	108.2	7.09	34.8	0.02	0.02	0.00	0.054	0.009	3.49	0.00
2/25/19 10:15	79.5	6.94	43.4	0.20	0.06	0.00	0.037	0.019	3.73	0.14
2/27/19 10:50	90.76	6.73	68.7	0.24	0.01	0.00	0.12	0.019	3.77	0.23
2/28/19 13:40	95.19	6.93	25.7	0.07	0.01	0.00	0.066	0.019	2.70	0.06
3/5/19 18:00	125.3	6.97	17.0	0.14	0.01	0.00	0.026	0.010	2.36	0.13
3/19/19 12:00	140	7.51	6.2	0.03	0.02	0.00		0.021	2.39	0.02
3/25/19 12:05	97	7.4	48.2	0.18	0.02	0.00		0.021	7.00	0.16
3/28/19 12:10	126	7.56	17.8	0.07	0.02	0.01		0.025	3.42	0.04
4/2/19 12:15	144	7.44	8.7	0.05	0.02	0.00		0.018	2.35	0.02
4/8/19 10:30	132.8	6.84	13.7	0.28	0.02	0.02	0.04	0.010	2.67	0.24
4/15/19 12:15	149.8	7.26	7.5	0.14	0.03	0.01	0.04	0.020	1.88	0.10
5/2/19 13:15	173.3	7.29	2.3	0.08	0.02	0.01	0.02	0.010	1.55	0.05
5/16/19 8:45	107.8	6.86	22.6	0.68	0.02	0.00	0.24	0.010	10.59	0.66
5/17/19 10:25	106.4	6.9	15.3	0.18	0.05	0.01	0.09	0.007	4.98	0.12
5/20/19 9:40	123.5	6.9	15.6	0.11	0.06	0.00	0.06	0.010	3.42	0.05

5/21/19 9:40	120.3	6.89	12.9	0.19	0.10	0.00	0.06	0.008	4.61	0.09
5/29/19 10:00	162.2	6.9	2.4	0.06	0.16	0.00	0.02	0.002	1.77	0.00
6/12/19 15:10	188.4	6.95	2.6	0.02	0.02	0.02	0.007	0.000	2.93	0.00
7/23/19 12:30	234.5	7.14	10.9	0.01	0.03	0.02	0.01	0.000	3.74	0.00
8/5/19 14:00	229.5	7.27	1.7	0.08	0.03	0.02	0.007	0.000	3.46	0.03
8/22/19 10:50	225.4	7.31	0.4	0.00	0.02	0.02	0.00261398	0.010	4.15	0.00
9/5/19 10:20	281.8	7.26	0.3	0.00	0.04	0.03	0	0.010	6.24	0.00
9/16/19 10:30	294.4	7.13			0.26	0.05	0.02	0.000	3.56	0.00
10/1/19 10:00	351.4	6.95	2.3	0.00	0.01	0.01	0.34	0.010	1.83	0.00
10/24/19 10:30	264.9	7.21	4.6	0.32	0.03	0.03	0.34	0.000		

North Fork Caspar Creek sub-watersheds

Table 49: North Fork Caspar Creek (NFC).

Date	EC	pH	Turb	TN	NH_4^+-N	NO_3^--N	TP	PO_4	DOC	DON
	μS	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
5/26/16 14:19	157	7.34	0.7	0.22	0	0	0.012	0.007	1.58	0.22
7/1/16 9:38	167	7.84	1.34	0.05	0.01	0	0.01	0.003	0.8	0.04
4/12/17 10:50	127	7.74	7.65	0.4	0.03	0	0.023	0.004	1.22	0.37
4/27/17 13:22	136	7.73	6.36	0.32	0	0	0.029	0	1.18	0.32
5/30/17 14:15	156	7.87	1.67	0.71	0	0	0.015	0.008	1.57	0.71
6/15/17 13:20	160	7.91	1.17	0.03	0.01	0	0.023	0.009	0.93	0.02
7/3/17 13:14	287	7.84	1.24	0.07	0.01	0	0.013	0.008	1.09	0.06
8/1/17 15:10	295	7.93	0.86	0.05	0.01	0.04	0.007	0.005	1.1	0
9/18/17 12:50	318	7.91	18.8	0.43	0.13	0.003	0.072	0	3.62	0.3
10/23/17 13:40	300	7.58	1.14	0.12	0.02	0	0.036	0.013	1.32	0.1
11/3/17 12:20	314	7.84	1.31	0.14	0.02	0.002	0.022	0.016	1.14	0.12
11/20/17 13:30	289	7.95	2.69	0.14	0.02	0.003	0.022	0.023	2.49	0.12
12/4/17 11:40	230	6.49	0.64	0.05	0.06	0.01	0.009	0.012	1.43	0
12/18/17 10:40	310	6.68	0.82	0.04	0.02	0.014	0.012	0.004	1.01	0.01
1/4/18 11:15	197	6.86	1.9	0.22	0.01	0	0.015	0.001	1.23	0.21
1/10/18 10:00	147	6.92	11.8	0.06	0.01	0	0.031	0.006	2.58	0.05
1/8/18 14:24	172	6.83	5.32	0.01	0.01	0	0.018	0.011	3.14	0
1/19/18 14:38	153	6.95	13.2	0.13	0.01	0	0.034	0.006	2.88	0.12
2/6/18 10:32	153	7.14	1.73	0.11	0.01	0	0.034	0.005	1.04	0.1
2/22/18 11:03	155	7.36	0.99	0.07	0	0	0.034	0.038	0.81	0.07
3/1/18 14:25	139	7.21	15.2	0.14	0	0	0.037	0.024	5.27	0.14

3/8/18 11:36	116	7.17	39.5	0	0.05	0.03	0.004	0.038	1	0
3/8/18 13:25	129	7.1	3.97	0	0.03	0	0.004	0.042	1.13	0
3/28/18 12:54	12	5.73	0.66	0	0.02	0	0	0.038	0.1	0
3/28/18 12:40	112	7.2	5.3	0	0.02	0	0.004	0.038	1.04	0
4/6/18 9:45	92	6.52	93.9	0.34	0.02	0	0.211	0.007	5.53	0.32
4/9/18 9:45	101	6.97	17.6	0	0.03	0	0.018	0.012	1.39	0
4/25/18 14:25	113	7.73	0.71	0.16	0.01	0	0	0.016	1.02	0.15
5/30/18 13:50	155	7.47	0.76	0.03	0.01	0	0.033	0.021	1.87	0.02
6/15/18 15:10	160	7.39	0.39	0.17	0.01	0.028	0.039	0.003	1.52	0.13
7/3/18 15:50	169	7.28	0.76	0.03	0.01	0.101	0.036	0.003	1.36	0
7/19/18 14:05	174	7.3	0.91	0.02	0.01	0.02	0.029	0.002	1.26	0
8/1/18 12:20	176	7.18	1.33	0.02	0.01	0.016	0.039	0.003	1.3	0
8/29/18 11:15	150	9.14	3.71	0.04	0.01	0	0.036	0.002	0.88	0.03
10/25/18 10:45	238	7.58	0.33	0.27	0.01	0	0.101	0.008	1.41	0.26
11/15/18 15:00	131	7.38	0.47	0.09	0.01	0	0.098	0	0.69	0.08
11/21/18 11:10	57	7.03	1.04	0.07	0.01	0	0.041	0.041	1.19	0.06
12/6/18 13:30	50	7.93	1.63	0.04	0.01	0	0.026	0	1.89	0.03
12/18/18 11:40	160	7.22	3.73	0.07	0.02	0	0.011	0	2.31	0.05
12/27/18 13:10	148	7.01	4.3	0.16	0.02	0	0	0	1.83	0.14
1/8/19 13:25	130	7.03	8.84	0.03	0.01	0.01	0.123	0	2.79	0.01
1/17/19 13:10	115	6.77	25.8	0	0.02	0.01	0	0	4.65	0
1/17/19 14:10	101	6.92	23.1	0	0.03	0	0	0	2.6	0
1/22/19 11:30	104	6.75	10.6	0	0.01	0	0	0	1.56	0
1/30/19 13:40	134	6.83	1.55	0	0.01	0.03	0	0.015	1.35	0
2/4/19 12:00	121	6.94	6.13	0	0.01	0.001	0.007	0.013	2.99	0
2/13/19 12:35	102	6.98	33.4	0.35	0.01	0.005	0.035	0.015	3.23	0.34
2/14/19 15:00	84.1	7.29	104	0.05	0.02	0	0.167	0	2.4	0.03
2/15/19 14:55	90.4	6.87	25.1	0.13	0.01	0	0.057	0.013	1.91	0.12
2/20/19 14:40	92.2	6.92	7.53	0.09	0.05	0	0.072	0.009	1.39	0.04
2/26/19 12:30	88.5	6.85	50.7	0.05	0.01	0.015	0.105	0.022	2.46	0.03
2/27/19 14:40	86.3	6.64	102	0.03	0.04	0	0.155	0.032	2.78	0
2/28/19 14:00	94.5	6.97	24.7	0.03	0.01	0	0.075	0.014	1.68	0.02
3/6/19 14:10	104.4	7.13	15.3	0.23	0.03	0	0	0.007	2.11	0.2
3/25/19 10:10	101	7.58	17.4	0.22	0.02	0	0	0.02	3.2	0.2
3/28/19 10:10	112	7.58	7.9	0.02	0.03	0.003	0	0.028	3	0
4/4/19 9:40	124	7.62	3.34	0	0.01	0	0	0.003	1.5	0

4/11/19 12:46	117.6	7	6.25	0.1	0.05	0.01	0.04	0.02	1.51	0.04
4/18/19 11:55	123.9	7.23	2.96	0.06	0.09	0.01	0.03	0.02	1.08	0
5/1/19 11:15	121.4	7.32	1.88	0.06	0.03	0.01	0.02	0.02	1	0.02
5/15/19 9:10	158.4	6.99	1.14	0.02	0.01	0.012	0.02	0.004	1.29	0
5/17/19 12:40	102.8	7.02	15.6	0.15	0.03	0	0.08	0.01	3.08	0.12
5/22/19 12:40	110.4	6.94	6.62	0.07	0.05	0	0.04	0.005	1.47	0.02
5/28/19 13:58	133.1	6.98	2.81	0.04	0.12	0	0.03	0.002	1.3	0
6/12/19 9:50	143.1	6.76	1.66	0.17	0.01	0.016	0.01	0.01	2.02	0.15
7/2/19 9:30	130.7	7.39	0.92	0	0.04	0.025	0.007	0.01	5.68	0
7/17/19 13:00	131.4	7.25	0.91	0.01	0.01	0.021	0.01	0.01	3.8	0
7/26/19 12:10	159.4	7.01	0.82	0.03	0.03	0.018	0.007	0	3.49	0
8/1/19 10:10	140.2	6.96	0.77	0.14	0.07	0.027	0.007	0	7.88	0.04
8/22/19 14:00	174.1	6.81	0.7	0	0.06	0.03	0.013	0.01	6.83	0
9/5/19 11:50	181.4	7.18	0.72	0	0.06	0.013	0.01	0.02	6.02	0
9/17/19 12:00	170.5	7.1	0	0.1	0.2	0.04	0	0	4.8	0
10/2/19 11:45	196.8	7.2	1.07	0.12	0.1	0.03	0.33	0	1.71	0
10/23/19 10:30	215.5	7.21	0.72	0.27	0.21	0.03	0.33	0.01	3.35	0.03
11/14/19 11:30	224.4	7.54	0.23	0.12	0.13	0.01	0.34	0.01	2.03	0

Table 50: Iverson (IVE) sub-watershed.

Date	EC µS	pH mg/L	Turb mg/L	TN mg/L	NH_4^+-N mg/L	NO_3^--N mg/L	TP mg/L	PO_4 mg/L	DOC mg/L	DON mg/L
5/26/16 15:26	166	7.38	2.73	0.12	0	0	0.015	0.005	1.11	0.12
7/1/16 9:50	176	7.82	1.5	0.12	0.01	0	0.01	0	1.26	0.11
12/11/16 7:00	186	7.58	3.4	0.07	0.03	0.02	0.01	0.01	1.21	0.02
10/24/16 11:30	183	8.06	54.9	0.75	0.02	0.01	0.106	0.009	4.93	0.72
9/22/17 8:05	309	8.25	0.77	0.11	0.03	0.015	0.03	0.026	0.61	0.065

Table 51: Kjeldsen (KJE) sub-watershed.

Date	EC µS	pH mg/L	Turb mg/L	TN mg/L	NH_4^+-N mg/L	NO_3^--N mg/L	TP mg/L	PO_4 mg/L	DOC mg/L	DON mg/L
4/1/14 8:20	11	6.37	0.37	0.42	0.02	0	0.002	0	1.09	0.4
5/26/16 11:48	126	7.33	4.23	0.15	0	0	0.012	0.003	1.18	0.15
10/24/16 9:00	194	7.71	1	0.18	0.04	0	0.012	0.014	1.62	0.14
3/21/17 9:35	97	7.71	42.4	0.39	0	0	0.061	0	1.9	0.39
4/12/17 9:09	95	7.65	9.47	0.33	0.02	0	0.02	0	0.95	0.31
4/27/17 8:56	101	7.77	11.3	0.44	0.01	0	0.023	0	0.98	0.43

5/12/17 14:08	107	7.27	7.86	0.14	0.01	0	0.019	0.004	0.83	0.13
5/30/17 12:13	119	7.88	3.75	0.49	0	0	0.015	0.003	1.42	0.49
7/26/17 17:06	265	7.95	2.13	0.06	0	0.04	0.005	0.004	0.89	0.02
9/21/17 14:30	276	7.72	0.83	0.13	0.07	0.001	0.027	0.008	1.04	0.06
10/19/17 12:04	272	7.32	6.12	0.23	0.06	0	0.057	0.004	0.98	0.17
11/3/17 8:34	294	7.72	0.97	0.23	0.07	0	0.062	0.068	2	0.16
11/20/17 11:25	273	7.88	12.4	0.24	0.02	0.005	0.041	0.018	9.49	0.22
12/4/17 11:25	265	6.67	2.47	0.1	0.07	0.009	0.015	0	1.57	0.02
12/18/17 9:45	284	6.65	1.43	0.06	0.02	0.019	0.015	0.004	1.02	0.02
1/4/18 11:35	212	7	2.61	0.19	0.01	0	0.006	0	1.12	0.18
1/19/18 10:50	115	7.02	21.1	0.03	0.01	0	0.037	0.001	2.03	0.02
2/6/18 9:40	111	6.81	3.7	0.14	0.02	0	0.034	0.01	0.87	0.12
2/22/18 9:41	120	7.09	7.5	0.09	0.02	0	0.047	0.019	1.1	0.07
3/2/18 10:22	98	7.01	21.7	0.12	0	0	0.037	0.019	1.72	0.12
3/16/18 8:36	90	7.05	23.2	0	0.02	0	0.027	0.028	1.71	0
3/20/18 8:53	89	7.09	9.28	0	0.02	0	0.001	0.042	0.85	0
3/8/18 9:40	96	7.2	7.07	0.08	0.03	0	0.004	0.038	0.78	0.05
3/28/18 8:48	85	7	8.55	0	0.03	0	0.01	0.033	0.46	0
4/9/18 9:09	79	7.14	14.3	0.1	0.04	0	0.001	0.016	0.73	0.06
4/6/18 8:37	73	6.93	42.7	0.13	0.01	0	0.071	0.007	5.81	0.12
4/24/18 10:15	99	7.02	4.27	0.13	0.01	0	0.001	0.007	0.62	0.12
5/11/18 9:25	122	7.17	3.17	0.15	0.01	0	0	0.012	0.57	0.14
6/20/18 12:28	127	7.2	7.53	0.02	0.01	0	0.034	0.006	1.38	0.01
7/3/18 12:34	130	7.08	0.79	0.04	0.01	0	0.024	0.002	1.07	0.03
7/19/18 13:44	137	7.03	0.88	0.04	0.01	0.09	0.029	0.005	1.24	0
9/13/18 15:30	145	9.04	1.41	0.14	0.01	0.039	0.029	0.002	0.59	0.09
12/6/18 11:50	159	8.49	1.83	0.08	0.01	0	0.021	0	1.72	0.07
12/18/18 10:40	143	6.95	9.58	1.05	0.04	0	0.038	0	2.5	1.01
12/27/18 10:57	107	6.78	7.82	0.09	0.01	0	0	0	1.31	0.08
1/8/19 10:00	103	6.94	14.8	0	0.02	0.01	0.014	0.003	1.79	0
1/17/19 9:00	80	6.92	22.9	0	0.02	0.04	0	0.01	2.45	0
1/18/19 9:40	84	6.85	15.2	0	0.02	0	0	0	1.63	0
1/22/19 10:00	79	6.42	9.9	0	0.01	0	0	0	1.18	0
1/30/19 12:00	111	6.33	3.39	0.03	0.03	0	0.001	0	1.07	0
2/4/19 11:40	95	7.05	15.2	0	0.01	0	0.014	0.009	2.67	0
2/13/19 9:40	85	6.93	22.8	0.07	0.01	0	0.021	0.01	2.56	0.06
2/14/19 9:10	65.8	6.78	198	0.44	0.04	0	0.179	0.012	2.61	0.4

2/15/19 9:10	70.5	7.11	22.2	0.11	0.05	0.004	0.048	0.01	1.66	0.06
2/20/19 10:20	80.3	6.99	8.45	-0.04	0.02	0.001	0.054	0.007	1.03	0
2/26/19 8:30	37.6	6.95	32.8	0.18	0.03	0.007	0.084	0.014	1.65	0.14
2/27/19 8:40	65.1	6.87	209	0.13	0.02	0	0.206	0.054	2.06	0.11
2/28/19 14:00	56.8	6.96	31.2	0.14	0.01	0.001	0.009	0.015	1.32	0.13
3/6/19 13:25	85.7	6.98	11.8	0.08	0.05	0	0	0.012	1.47	0.03
3/12/19 13:20	83.4	7.08	6.29	0.15	0.01	0	0.003	0.007	1.02	0.14
3/25/19 9:31	76	7.4	21	0.06	0.02	0	0	0.015	3.77	0.05
3/28/19 8:51	78	7.57	10.4	0.03	0	0.001	0	0.017	1.82	0.03
4/4/19 9:45	95	7.67	5.76	0	0.01	0	0	0.001	1.21	0
4/11/19 9:40	85.8	6.85	7.24	0.07	0.04	0.01	0.02	0.01	1.31	0.02
4/18/19 9:45	92	7.05	6.17	0.12	0.01	0	0.03	0.01	0.92	0.11
5/15/19 10:45	121.4	6.89	4.88	0.07	0.01	0.005	0.03	0.007	2.39	0.05
5/16/19 7:45	89.6	6.95	15.2	0.09	0.02	0.04	0.11	0.008	7.59	0.03
5/17/19 8:40	79.6	6.9	32.1	0.1	0.02	0	0.09	0.005	2.37	0.08
5/20/19 8:10	81.4	6.97	7.83	0.07	0.02	0	0.03	0.007	1.77	0.05
5/22/19 9:50	84.9	6.86	6.87	0.07	0.07	0	0.03	0.005	1.5	0
5/28/19 8:50	98	6.81	2.57	0.01	0.16	0	0.02	0.004	1.2	0
6/12/19 8:20	97.6	6.87	4.75	0	0.04	0.065	0.01	0	1.7	0

Table 52: Munn (MUN) sub-watershed.

Date	EC μS	pH mg/L	Turb mg/L	TN mg/L	NH_4^+-N mg/L	NO_3^--N mg/L	TP mg/L	PO_4 mg/L	DOC mg/L	DON mg/L
4/1/14 8:45	75	8.04	3.01	0.26	0	0	0.015	0.003	2.32	0.26
4/1/14 9:10	107	8.09	2.57	0.29	0	0	0.026	0.007	1.23	0.29
4/1/14 9:00	133	7.71	0.95	0.26	0	0	0.005	0.001	1.09	0.26
4/3/14 8:30	10	7.26	0.39	0.03	0	0.01	0.003	0	1.21	0.02
3/4/14 4:50	73	7.3	0.58	0.38	0	0	0.005	0.003	2.71	0.38
4/1/14 8:35	80	7.87	1.84	0.31	0	0	0.008	0.003	2.22	0.31
3/4/14 9:50	63	7.69	0.74	0.33	0	0	0.008	0.003	3.19	0.33
5/26/16 11:55	125	7.26	7.96	0.06	0	0	0.037	0.001	0.96	0.06
10/24/16 9:00	185	7.81	1.2	0.02	0.01	0	0.018	0.014	0.6	0.01
3/21/17 9:30	105	7.7	44.6	0.53	0.01	0.01	0.061	0	2.2	0.51
4/12/17 9:06	113	7.62	8.14	0.35	0.01	0	0.023	0	0.77	0.34
4/27/17 8:58	119	7.62	9.93	0.55	0.02	0	0.02	0	0.94	0.53
5/11/17 14:11	116	7.29	6.08	0.13	0	0	0.013	0.001	0.63	0.13
7/26/17 17:05	240	7.77	2.48	0.1	0.02	0.03	0.01	0.007	0.66	0.05
9/21/17 14:28	274	7.53	2.28	0.29	0.26	0.021	0.027	0.008	0.85	0.01
11/3/17 8:33	283	7.64	1.94	0.18	0.02	0.012	0.026	0.017	1.12	0.15

11/20/17 11:20	251	7.75	15.6	0.23	0.02	0.005	0.05	0.018	6.28	0.21
12/4/17 11:23	281	6.68	1.5	0.13	0.11	0.011	0.009	0	1.12	0.01
12/18/17 9:40	295	6.64	3.9	0.07	0.02	0.011	0.015	0	0.72	0.04
1/4/18 11:45	216	6.96	1.77	0.07	0.01	0	0.009	0.001	0.76	0.06
1/19/18 10:49	127	6.87	25.3	0.04	0.01	0	0.04	0.001	2.37	0.03
2/6/18 9:45	115	7.04	4.74	0.13	0.02	0	0.05	0.015	0.59	0.11
2/22/18 9:36	126	7.17	6.43	0.13	0.01	0	0.053	0.019	0.52	0.12
3/2/18 10:20	107	7.01	30.2	0.15	0	0	0.044	0.015	1.85	0.15
3/20/18 8:50	110	7.06	7.06	0	0.01	0	0	0.028	0.61	0
3/16/18 8:31	96	7.01	26.7	0	0.01	0	0.024	0.028	1.55	0
3/8/18 9:37	108	7.15	2.12	0	0.05	0	0	0.033	0.52	0
3/28/18 8:45	100	7.03	6.84	0	0.02	0	0	0.028	0.52	0
4/9/18 9:05	89	7.04	11.1	0.93	0.04	0	0.004	0.007	0.78	0.89
4/6/18 8:37	77	6.8	133	0.23	0.02	0	0.272	0.012	5.64	0.21
4/24/18 10:10	109	6.87	1.19	0.14	0.01	0	0	0.007	0.76	0.13
5/11/18 9:21	145	7.34	6.86	0.18	0.01	0	0.01	0.021	0.39	0.17
6/20/18 12:30	131	7.07	0.31	0.09	0.01	0	0.024	0	1.17	0.08
7/3/18 12:30	127	7	0.78	0.02	0.01	0	0.019	0.002	0.91	0.01
7/19/18 13:47	130	7.11	0.48	0	0.2	0.039	0.031	0	0.69	0
9/13/18 15:40	87	8.96	41.2	0.44	0.01	0	0.113	0.002	0.84	0.43
12/6/18 11:20	92	7.16	0.72	0.08	0.02	0	0.091	0	1.28	0.06
12/18/18 10:30	149	6.85	3.86	0.35	0.02	0.05	0	0	1.88	0.28
12/27/18 10:55	114	6.86	5.73	0.09	0.02	0	0	0	1.2	0.07
1/8/19 10:15	113	6.9	10.8	0	0.01	0.01	0.014	0	1.77	0
1/17/19 9:00	88	6.85	20.5	0	0.02	0.02	0	0	2.37	0
1/18/19 9:40	97	6.94	11.7	0	0.01	0	0	0	1.61	0
1/22/19 10:00	80	6.19	9.38	0	0.01	0.01	0	0	1.26	0
1/30/19 12:05	95	6.48	4.98	0.05	0.01	0	0.004	0	1.1	0.04
2/4/19 11:45	103	6.77	34.1	0.13	0.01	0.005	0.045	0.012	4.07	0.12
2/13/19 9:37	93	7.01	29.8	0.16	0.02	0	0.007	0.01	2.87	0.14
2/14/19 9:10	76.7	6.84	31.3	0.15	0.01	0.007	0.025	0.01	2.53	0.13
2/15/19 8:55	93.3	6.96	14.2	0.1	0.02	0	0.037	0.009	1.66	0.08
2/20/19 10:10	97.7	6.93	6.43	0.08	0.02	0.001	0	0	1.01	0.06
2/26/19 8:30	87.2	6.82	19.1	0.11	0.04	0.004	0.084	0.011	1.82	0.07
2/27/19 8:40	79.9	6.84	29.8	0.06	0.01	0.001	0.054	0.013	2.02	0.05
2/28/19 12:00	67.8	6.91	12.6	0.13	0.06	0	0	0.009	1.27	0.07
3/6/19 13:50	96.6	6.88	15.7	0.15	0.01	0	0	0.012	1.59	0.14
3/12/19 12:30	97.8	7.06	10.8	0	0.01	0	0	0.01	1.02	0

3/25/19 9:33	92	7.58	46.1	0.07	0.03	0	0	0.011	3.33	0.04
3/28/19 8:53	85	7.47	8.89	0	0	0.004	0	0.021	1.89	0
4/4/19 9:45	111	7.64	4.35	0.02	0.01	0	0	0.004	1.03	0.01
4/11/19 9:30	105.7	6.93	6.85	0.11	0.04	0.01	0.03	0.01	1.34	0.06
4/18/19 9:40	106.5	7.01	5.04	0.1	0.05	0.01	0.02	0.01	0.96	0.04
5/15/19 10:40	127.3	6.72	3.66	0.04	0.01	0.023	0.02	0.001	1.63	0.01
5/16/19 7:40	110.8	6.94	40.1	0.07	0.01	0	0.12	0.01	4.93	0.06
5/17/19 8:40	91	6.82	15.5	0.11	0.01	0	0.06	0.007	2.55	0.1
5/20/19 8:10	100	6.85	7.15	0.07	0.06	0	0.03	0.008	1.63	0.01
5/22/19 9:40	103.9	6.88	5.5	0.09	0.09	0	0.03	0.008	1.87	0
5/28/19 8:40	110.3	6.61	1.5	0.03	0.13	0	0.01	0.089	1.11	0
6/12/19 9:10	124.4	6.86	5.8	0.23	0.03	0.022	0.007	0	2.72	0.17

Table 53: S640 sub-watershed.

Date	EC µS	pH mg/L	Turb mg/L	TN mg/L	NH_4^+-N mg/L	NO_3^--N mg/L	TP mg/L	PO_4 mg/L	DOC mg/L	DON mg/L
4/28/17 8:30	10	6.42	1.08	0.03	0	0.01	0.007	0	1.89	0.02
10/24/17 9:30	108	7.78	8.33	0.87	0.01	0	0.09	0.001	14.03	0.86
11/17/17 12:55	112	7.3	0.47	0.13	0.07	0.053	0	0.001	0.5	0.01
12/21/17 12:00	125	6.59	1.11	0.17	0.06	0.039	0.031	0	0.71	0.07
1/10/18 13:45	0	0	0.43	0.12	0.11	0	0	0	0.69	0.01
1/19/18 13:37	0	0	0.35	0.09	0.08	0	0.003	0.001	0.72	0.01
1/25/18 15:10	0	0	0.47	0.18	0.1	0.02	0.004	0	0.38	0.06
2/23/18 10:24	54	5.87	2.18	0.66	0.24	0.016	0.024	0.019	1.29	0.4
2/27/18 14:33	20	5.64	0.6	0.27	0.15	0.041	0.008	0.024	0.69	0.08
3/8/18 15:42	12	5.48	0.4	0.1	0.09	0.005	0	0.024	0.49	0.01
3/8/18 15:42	13	5.53	0.66	0	0.01	0	0.001	0.047	0.53	0
3/26/18 12:51	26	5.69	0.48	0.08	0.1	0.024	0	0.038	0.35	0
3/26/18 12:52	16	5.07	0.68	0	0.03	0.027	0.027	0.042	0.35	0
4/9/18 14:30	6	6.95	2.85	0.37	0.12	0	0.027	0.012	1.38	0.25
4/9/18 14:50	4	6.04	0.93	0.11	0.06	0	0	0.021	0.85	0.05
5/11/18 12:05	17	7.47	1.94	0.29	0.01	0	0.01	0.007	2.3	0.28
5/30/18 15:20	46	7.28	3.2	4.81	2.98	0.199	0.048	0.016	11.37	1.63
12/6/18 14:50	9	6.33	1.09	0.32	0.02	0.04	0.061	0.011	1.83	0.26
12/17/18 14:50	7	6.1	0.48	0.09	0.02	0.02	0	0	0.79	0.05
1/10/19 12:35	18	5.88	0.74	0.24	0.05	0.08	0.121	0	1.37	0.11
1/24/19 10:20	117.1	6.61	0.52	0.02	0.01	0	0	0	0.8	0.01

2/7/19 15:35	10	5.74	0.57	0.24	0.06	0.032	0.001	0	1.17	0.15
2/28/19 9:20	7	5.84	0.76	0.16	0.02	0.027	0.007	0.01	0.61	0.11
3/19/19 9:00	8	5.28	2.02	0.14	0.06	0.048	0	0.008	2.79	0.03
3/26/19 12:20	6	5.96	0.55	0.15	0.07	0.04	0	0.011	1.46	0.03
4/12/19 14:35	10.8	5.46	1.14	0.23	0.09	0.06	0.02	0	1.67	0.08
5/17/19 10:35	20.3	5.94	0.25	0.28	0.14	0.005	0.01	0.005	2.12	0.14
5/20/19 13:00	12.6	5.96	0.35	-0.11	0.14	0.028	0	0.004	1.06	0
5/23/19 13:58	18.8	5.44	0.64	0.27	0.16	0	0.03	0.004	2.9	0.11
9/18/19 11:20	20.3	7.47	0	0	0.87	0.07	0.05	0	6.57	0
10/23/19 12:00	49.7	7.54	1.59	1.99	0.95	0.06	0.37	0.11	11.15	0.98
12/30/19 15:00	10.8	7.51	1.38	0.19	0.13	0.09	0.01	0.01	6.4	0
1/22/20 14:00	12.8	7.59	0.22	0.31	0.1	0.01	0.268	0.01	5.58	0.2
1/28/20 11:11	9.2	7.28	0.48	0.18	0.02	0.026	0.236	0	5.47	0.14