Water Quality and Stream Flow Monitoring in the Blackfoot River Watershed

"By leveraging community volunteers, it puts the power of monitoring in citizen's hands and it reduces the cost of collecting high quality information. The data collected allows community members to track changes in their streams through time and it provides a connection to the ecosystems in which they live. It can provide highly valuable information for water stewards, fisheries biologists, help guide management actions, and emphasize the sensitivity of the systems to changes in climate and management." - SWCC

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With technical support from Joann Wallenburn, Clearwater Resource Council
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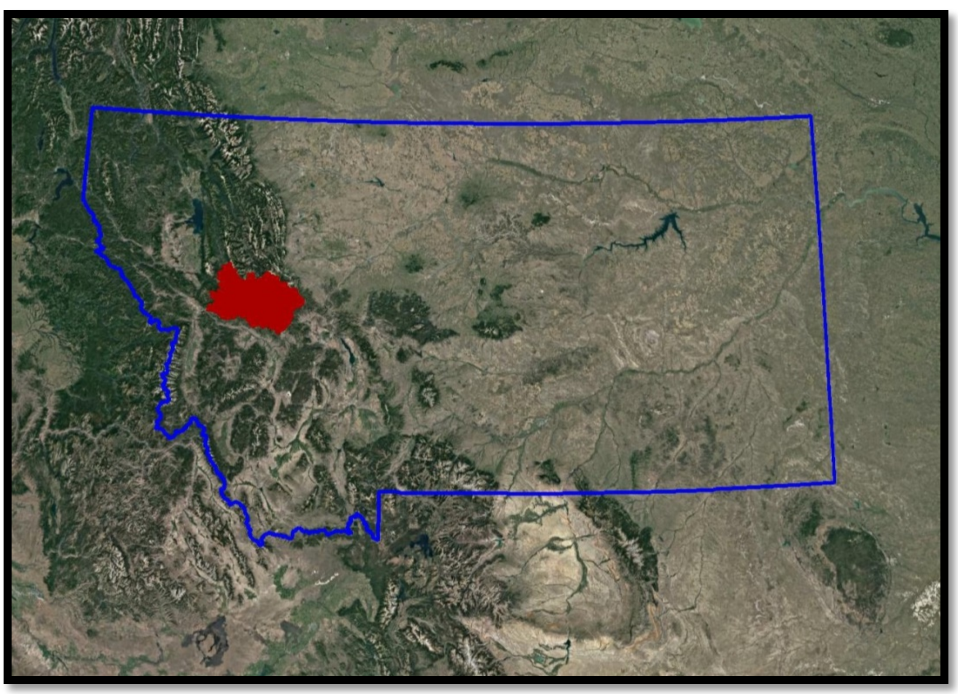
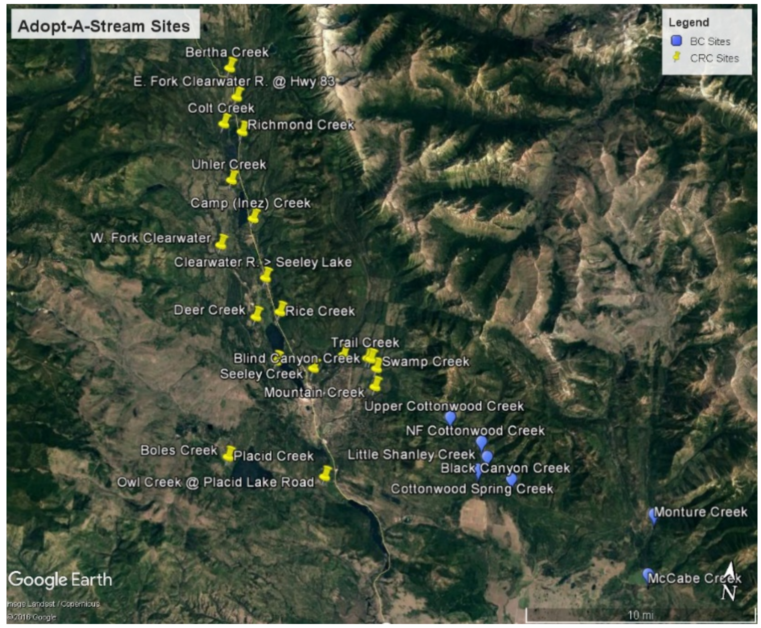


Map 1 - The Blackfoot Watershed marked in solid red within the state of Montana, outlined in blue.

Introduction

The Blackfoot Challenge, Clearwater Resource Council, and the Southwest Crown Collaborative have partnered for the past five years to characterize flow patterns and run-off period water quality dynamics of headwater streams. The data collected provides baseline knowledge of stream health in proposed Collaborative Forest Landscape Restoration (CFLR) project areas – the Center Horse and Stonewall projects, both of which have been delayed due to litigation and altered by the 2017 wildfires. On July 24, 2017, five weeks after our 2017 monitoring season was completed, the Rice Ridge wildfire started approximately 11 miles northwest of our monitoring area. Over the next two and a half months, the wildfire burned across a 160,000-acre area to the south and east, encompassing the headwaters (as well as some sample sites) of six of the seven streams we monitored at that time. Monitoring in 2018 provided the opportunity to compare water quality parameters post wildfire with the baseline data already collected in 2016 and 2017. In addition, the stream data collected supports goals outlined in the Blackfoot Watershed Restoration Plan adopted by the Montana Department of Environmental Quality in 2014. This monitoring program engages youth and local citizens in better understanding ecosystem processes and how resource management decisions might impact their public lands. The data synthesized also supports planning for partner stewardship work, such as fisheries habitat restoration and Blackfoot Drought Response coordination.



Map 2 – Stream monitoring sites throughout the Blackfoot Challenge and Clearwater Resource Council project area

Map 3 – Rice Ridge wildfire perimeter (red boundary) overlaid on map of monitored stream drainages. Note: Cottonwood Spring Creek drainage location, marked with blue dot, outside of wildfire perimeter.

The Blackfoot Challenge (Challenge) involved youth from local schools in our monitoring of flow rates for two primary streams. Ovando school studied East Warren Creek in Upper Warren Basin, (12 Digit HUC: 170102030904) and Lincoln School students and Helena High School students, through a continued partnership between the Challenge and the Youth Forest Monitoring Program sponsored by the Helena-Lewis and Clark National Forest, helped study Poorman Creek in Poorman Basin (12 Digit HUC: 170102030302): see Map 4 for site locations. The Challenge


Photo 1 – Ovando School students take a flow measurement in E. Warren creek during spring run-off.

extended our youth education and involvement to the Potomac and Helmville Schools who studied two secondary streams: Union Creek and Nevada Creek, respectively.

Photo 2 – Blackfoot Challenge citizen science volunteer collects water samples from Upper Cottonwood Creek.

In 2016-2017 the Challenge also worked with citizen science volunteers to monitor five perennial headwater streams in the Cottonwood sub-drainage (12 Digit HUC: 170102030909) and two additional streams in the Dick Creek and Monture Creek Basins (12 Digit HUCs: 170102030803 and 170102030801, respectively). The following streams are included in our study: Black Canyon Creek (2nd order), Little Shanley Creek (1st order), North Fork of Cottonwood Creek (3rd order), Upper Cottonwood Creek (2nd order), Cottonwood Spring Creek (3rd order), Monture Creek (4th order), and McCabe Creek (2nd order). In 2018 sample sites on Dunham Creek (3rd order) in Monture Creek Basin and Shanley Creek (1st order), in Cottonwood Creek Basin were added to our monitoring area. All stream drainages except for Cottonwood Spring Creek were burned at varying severity in the Rice Ridge wildfire.

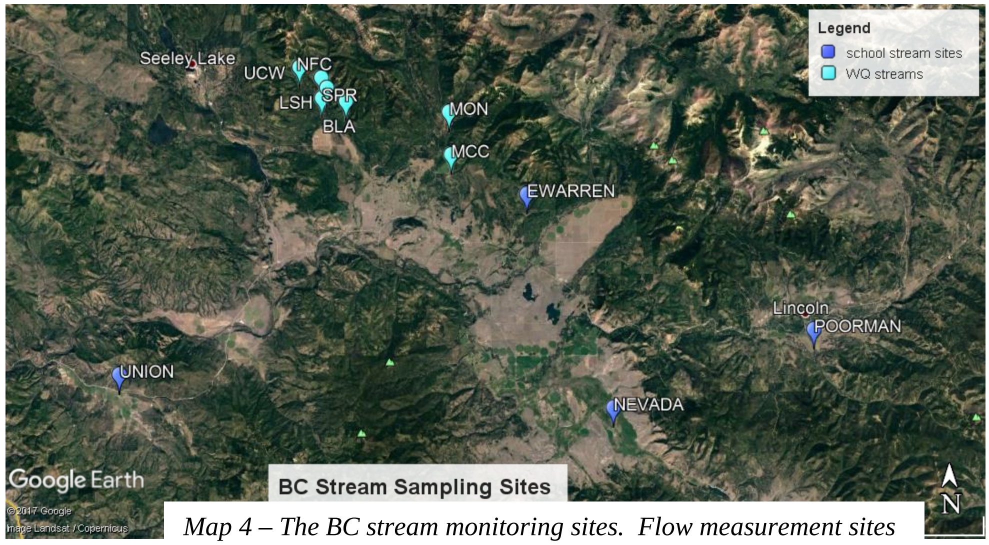
The U.S. Forest Service is the primary land manager in the study area, with some state and private land ownership in the foothills. Land cover consists of predominantly coniferous forest and some agricultural pastureland. In 2018, grab samples for turbidity, nutrients and total suspended solids (TSS), stream stage data (water depth), and subjective visual assessments of water color and water clarity were collected on a weekly basis from mid-March through June, every other week in July and a post-season sample in August and October. The number of monitoring events increased from 15 sample rounds in 2016 and 2017 to 19 sample rounds in 2018 in an effort to increase chances of capturing effects of the wildfire. Year-to-year data are compared in this report.

Photo 3, left – Blackfoot Challenge citizen science volunteer collects nutrient samples from North Fork Cottonwood Creek.

Photo 4, right – Helmville School students take a flow measurement in Nevada Creek and learn about what their data signifies for late season flows.

Methods and Materials

HOBO MX 2001-04 data loggers were installed in E. Warren Creek and Poorman Creek at permanent staff gages (previously established by Trout Unlimited in 2014 to monitor water leases), to collect water depth and temperature data every two hours from April or May until October or November. The site monitored in each stream was a cross-section through a run, with relatively defined banksides. Data from these loggers were downloaded at least twice over the monitoring season. Flow measurements were taken once every 3-4 weeks by a Swoffer 2100 current meter with 3.7' topset wading rod. These established measuring sites have been used for all measurements beginning in 2015, with only minor deviations when flow became too low to be registered by the instrument. In these instances the sample site was relocated downstream to an area of visible current.



Map 4 – The BC stream monitoring sites. Flow measurement sites are shown in indigo and water quality sites are shown in teal.

Five flow measurements were attempted in East Warren Creek between April and September 2018, although the flow was too low to measure on the September date. The logger collected data from April 23 through November. We used data from 2017 and 2018 flow measurements (due to the low number of viable measurements in 2018) to derive a rating curve and used that rating to convert depth measurements taken by the logger into flow rates for the entire logger collection period.

Seven flow measurements were taken in Poorman Creek from April to October, with the HOBO logger installed from end of April to early November. A rating curve was derived from the seven flow measurements collected, and then used to convert logger depths, measured and interpolated, into flow rates for the entire logger collection period. From this interpolation plot we noticed abnormal trends in the data and sent the information to the DNRC hydrologist for the Blackfoot watershed, Aaron Fiaschetti, for review. Fiaschetti confirmed that the trend looked irregular and the depth reader in our logger most likely malfunctioned, while the barometric pressure readings seemed okay. Thus, all depth data was nullified, while the barometric pressure data was retained. Using the manual flow measurements and USGS stream gage #12335500 depths from Nevada Creek we calculated a linear regression curve to estimate flows in Poorman Creek for the 2018 season.

For the Cottonwood, Monture, and Dick creek basin study areas, the Challenge recruited volunteers and trained them on how to properly collect water samples for turbidity, nutrients, and TSS analyses. Volunteers were also trained to record stream stage information and take visual assessments on stream color and clarity. A volunteer-staff pair collected samples and processed them for analyses once a week for a total of 19 collections. Seven volunteers participated in the water quality sampling over the course of the monitoring season.

All samples were collected in accordance with the Montana Department of Environmental Quality approved Sampling and Analysis Plan that was created for this project by the Clearwater Resource Council. Water samples to be analyzed for TSS and nutrients were packed in a cooler on ice and shipped to the Flathead Lake Biological Station. Nutrient analysis documented total nitrogen (TN) and total phosphorus (TP). TSS readings are reported in mg/L, TN and TP readings are reported in ug/L. Turbidity measurements were analyzed by Blackfoot Challenge personnel with a HACH 2100Q Surface Scatter Turbidimeter with readings reported in terms of nephelometric turbidity units (NTUs). Staff gage measurements were recorded to the nearest quarter inch.

Results

Flow Monitoring – all figures located in Appendix A

Flow levels and patterns varied substantially from year to year. Flows estimated from data collected by Trout Unlimited in 2014 are also shown. Also note that for clarity the graphs reflect logger data only from the 1200 hour each day, while accumulated discharge and average and maximum temperatures are from the entire data set of readings every two hours*.

East Warren Creek flows (Table 1, Figure 2) were generally high in 2014, with peak flows occurring in May and a high of 37 CFS on 5/25/14. 2015 and 2016 flows were much lower, peaking in March and April at 9 CFS and 6 CFS respectively. 2017 flows were moderate with a high flow of 15 CFS on 5/7. Flow levels were significantly higher in 2018 than in all previous years, with a peak flow of 95 CFS recorded on 4/29, and much higher estimated total discharge. Flows remained well above 10 CFS throughout most of May 2018. The highest temperatures occurred in 2015, with several days of temperatures above 12ºC in July and August (Figure 3). Temperatures rose above 15º for at least a few days each year except for 2017, when the high was 14.8 (Table 1). The mean temperature between May 1 and October 10 was highest in 2015 and lowest in 2018.

Poorman Creek flows were much higher in 2018 than in previous years (Table 1, Figure 4). The flow pattern was similar to those of 2014 and 2017, albeit with a large increase in total amount of water moving through the system. In 2014 the highest flow occurred in late May at 67 CFS. 2015 data depicts a low flow year with no significant peaks. The highest flow rate recorded was on 6/10, with a rate of 15 CFS. 2016 data also depicts a relatively low flow year, although run-off did have a distinct peak from end of April to early May with a maximum flow rate 25 CFS on 4/24. Flow data for 2017 show much greater values than those for 2015 and 2016 and similar values to 2014. A first peak occurred on 5/8 at 57 CFS and a second, higher peak on 6/13, with a rate of 62 CFS. In 2018 the highest flow rate occurred on 5/11 at 249 CFS, by far the greatest recorded amount in the five year study. Similar to East Warren Creek, the highest temperatures were recorded in 2015, with several days above 12ºC (Table 1, Figure 5), and a maximum temperature of almost 19ºC. Temperatures reached above 15ºC in 2014 and 2016 as well. Temperatures were lowest in 2018, averaging only 8.5 ºC and dropping several degrees lower than in 2015 on some dates.

Table 1. Water-year discharge and temperatures for East Warren and Poorman creeks 2014-2018

	East Warren			Poorman		
Year	Accumulated Discharge, CFS	Avg. temp, C	Max. temp, C	Accumulated Discharge, CFS	Avg. temp, C	Max. temp, C
2014	110,814,402	9.20	15.86	593,656,042	9.20	15.86
2015	24,590,922	10.19	16.52	148,833,180	8.87	18.81
2016	20,176,367	9.28	15.76	119,430,151	9.93	18.71
2017	49,475,619	9.21	14.80	340,229,356	8.75	13.96
2018	173,740,458	8.34	15.00	919,041,526	8.5	13.77

*Due to a sensor malfunction in 2017 and 2018 a regression curve was used to estimate data for Poorman Creek. The regression was calculated using the 1200 hour reading of flow data from Nevada Creek USGS stream gage #12335500. Because the 1200 hour reading was used for the compared stream only the 1200 hour flow rate was calculated for the Poorman Creek dataset and thus accumulated discharge is calculated over every 24 hours rather than every 2 hours.

Water Quality Monitoring – all graphs located in Appendix B

<u>Turbidity</u>

Turbidity levels in 2018 were substantially higher in most streams than in 2016 and 2017, and peaked in all streams between 4/27 – 5/17, when peak run-off also occurred for each stream (Figure 6). For example, the maximum turbidity reading in Monture Creek in 2018 was 33.85 NTU on 4/27/18, compared to a maximum of 12.48 in Monture Creek on 5/12/17. In 2016, turbidity in Monture Creek never exceeded 5 NTU. Also in contrast to 2018, 2017 data show two distinct peak turbidity dates – the first occurring around 3/15, and the second occurring around 5/12, eight weeks apart

(Figure 7). Lowest stage and turbidity values occurred in 2016, (Figure 8), with only one significant peak during run-off. However, the peak turbidity date in 2016 occurred much earlier than in 2018, on around 4/7/16.

Turbidity levels varied more in 2018 than in 2017 and 2016 (Figures 9, 10, and 11). With the exception of Monture and Dunham creeks in 2018, 75% of all turbidity values for all three years are less than or equal to 6 NTU, with 2016 values not exceeding 4 NTU. The primary differences among years are seen in the upper 25% of turbidity values for each stream, indicating the effects of the respective year's peak flow. 2018 turbidity values are condensed in the lower 50th percentile and spread out in the upper 50th percentile, indicating a consistent rise and fall around the peak of runoff. In contrast, 2017 turbidity values were generally more spread out over all percentiles, indicating a more gradual run-off period throughout the monitoring season. The plot for 2016 turbidity values shows major outliers with the two middle quartiles very close to the mean turbidity value.

These relationships are also seen in Table 2. All streams with the exception of Black Canyon and Upper Cottonwood creeks showed maximum turbidity values in 2018 far exceeding those of 2017 and 2016. However, median turbidity values were greatest in 2017 across all streams, reflecting more variability within the middle 50% of values in 2017 compared to 2018. The Black Canyon Creek maximum turbidity value was much greater than in 2017 but slightly less than the 2016 result, which was an outlier within that year's dataset. Considerable variation within individual streams was evident each year, and showed some correlation with gage height (Figures 12-41).

Table 2. Maximum and median turbidity values measured over the monitoring period

Maximum	BLA	LSH	NFC	UCW	SPR	MCC	MON	DUN	SHA
2018	11.6	16.7	16.2	6.4	10.8	10.6	33.9	29.2	4.5
2017	3.05	6.73	7.11	11.34	6.47	9.29	12.48	NA	NA
2016	11.93	6.88	3.01	2.34	5.86	2.07	4.84	NA	NA
Median									
2018	0.79	1.89	1.16	1.33	1.60	0.96	2.21	2.71	3.15
2017	0.88	3.96	1.98	1.63	4.29	1.41	2.12	NA	NA
2016	0.37	0.84	0.71	0.62	1.70	0.53	0.78	NA	NA

2018 and 2017 Nutrient levels and Total Suspended Solids

Total Nitrogen (TN) levels for all streams peaked in late April 2018, as seen in Figure 42 and Table 3 (Shanley Creek's first sample was taken on 5/17 because there was no running water at the site until that time). We measured the highest TN value of the entire monitoring season in Dunham Creek at 455ug/L, with N. Fork Cottonwood Creek the next highest at 435ug/L. Maximum values for TN were greater for all streams in 2018 compared to 2017, when all levels were less than 250ug/L except for in Cottonwood Spring Creek. In 2017, the Cottonwood Spring Creek maximum TN value of 473ug/L was twice as much or more than that of all other streams throughout the 2017 monitoring period (Figure 43). All TN levels for 2017 peaked in mid-March, about five weeks earlier than peak levels occurred in 2018. Median TN values were greater for four out of seven streams in 2018 compared to 2017; the exceptions were Cottonwood Spring, McCabe, and Monture creeks, although the differences were slight in the latter two streams.

Table 3. Maximum and median values for Total Nitrogen measured for all streams over the course of the monitoring period.

Maximum	BLA	LSH	NFC	UCW	SPR	MCC	MON	DUN	SHA
2018 TN	318	401	435	199	348	260	372	455	99
2017 TN	156	220	213	155	473	142	159	NA	NA
Median									
2018 TN	132	162	197	102	172	70.5	89.25	157	74.95
2017 TN	116	128	96.6	66.5	226	79.5	90.6	NA	NA

Total Phosphorus (TP) levels for all streams also peaked in late April 2018 with the exception of McCabe and Shanley creeks, which peaked later in May (Figure 44 and Table 4); this was also when the first sample was taken from Shanley). Dunham Creek exhibited the overall highest maximum TP value followed by Little Shanley Creek. Similar to the TN data, 2018 TP maximum values exceeded those from 2017, with the exception again of Cottonwood Spring Creek, and each creek's peak value for 2018 was two to three times more than it was in 2017. Median TP values in 2018 were almost twice as much as those in 2017 for most streams. Black Canyon and Little Shanley creeks were only slightly greater in 2018 than 2017 and Cottonwood Spring Creek median value was less in 2018 than 2017.

Table 4. Maximum and median values for Total Phosphorus measured for all streams over the course of the monitoring period.

Maximum	BLA	LSH	NFC	UCW	SPR	MCC	MON	DUN	SHA
2018 TP	39.5	81.7	80.3	30.7	26.4	28.4	77.9	96.2	25.5
2017 TP	17.1	28.4	24.5	15.8	39.9	13.6	26.1	NA	NA
Median									
2018 TP	12.8	14.4	14.6	9.3	14.1	6.7	12.5	17.65	13.7
2017 TP	11.8	14.6	7.2	4.1	18.7	3.2	8.2	NA	NA

Total Suspended Solid (TSS) levels for all streams peaked around late April to mid-May 2018 (Figure 46, Table 5). Monture and Dunham creeks show the highest maximum TSS levels. Outside of the peak period, TSS levels for most streams remained between 0 and 10mg/L. Maximum TSS values for all streams in 2017 (Figure 47), are less than those measured in 2018 with the exception of Cottonwood Spring Creek, which was only 0.2ug/L less in 2018 than 2017. Black Canyon, N. Fork Cottonwood, and Monture creeks maximum TSS 2018 values were all more than three times greater than those in 2017. Median TSS values were fairly similar for both years. All of these parameters varied throughout the sampling seasons in individual streams (Figures 48-74).

Table 5. Maximum and median values for Total Suspended Solids measured for all streams over the course of the monitoring period.

Maximum	BLA	LSH	NFC	UCW	SPR	MCC	MON	DUN	SHA
2018 TSS	19.0	17.6	38.0	9.4	8.9	15.9	67.9	58.2	22.7
2017 TSS	3.3	16.0	10.9	6.4	9.1	10.9	22.4	NA	NA
Median									
2018 TSS	0.6	1.65	1.85	1.55	1.2	1.35	4.1	5.6	0.6
2017 TSS	1.1	2.5	1.2	1.1	3.6	1.4	3.7	NA	NA

Note that Dunham and Shanley creeks were not monitored in 2016 or 2017 for nutrient or TSS parameters.

<u>2018 Parameter Correlations</u>

In 2018, data showed positive linear associations between turbidity vs. TP (R^2 value = 0.7377) and turbidity vs. TSS (R^2 value = 0.864), while showing a weaker correlation with TN (R^2 value = 0.367) (Figures 75-77). A weaker positive association occurred in 2017 between turbidity and TP, and turbidity and TSS (R^2 values = 0.326 and 0.3672, respectively); and even lesser correlation was shown between turbidity and TN (R^2 value = 0.2384) (Figures 78-80).

Discussion

Flow and Temperature Monitoring: East Warren Creek and Poorman Creek

2018 completes the fourth consecutive year for stream flow and temperature monitoring by the Challenge in East Warren Creek, with student participation from the Ovando School each year. The data show substantial variation in flow among years, including when peak flow occurred and amount of annual discharge. Five years of consecutive flow and temperature monitoring have been completed on Poorman Creek. Poorman Creek flow data also show variation among years and patterns within years similar to those in East Warren, albeit with much higher levels of flow in Poorman. Flows in both streams were highest by far in 2018, followed by 2014 and 2017. Flows were lowest in 2015 and 2016 in both creeks, and runoff also peaked earlier in these years compared to the years of higher flows.

Stream temperatures were roughly inversely correlated with flows, with higher mean temperatures in the lower flow years and lower mean temperatures in 2018. However, all years saw maximum temperatures above 14.8ºC in both streams, with some temperatures in Poorman reaching above 18ºC in 2015 and 2016. Temperatures in 2015 and 2016 also rose above 10ºC much earlier in the season (early to mid-June) in both streams than in the higher flow years.

Native bull trout and cutthroat trout numbers decline at temperatures above 10ºC and these species are essentially absent in waters above 18ºC. Efforts to conserve native fisheries in these Blackfoot tributaries may need to include maintaining higher flows when possible and improving stream habitat to create cold-water refugia within streams. As climate change creates warmer summers in western Montana, high flow levels may be more important than ever to maintain lower temperatures.

The SNOTEL data collected by the United States Geological Survey (USGS) and Natural Resources Conservation Service (NRCS) from the five stations in the Blackfoot watershed show the 2018 snow water equivalent (SWE) maximum value reaching over 12 in. more than that of 2017 and the 30-year normal (Figure 1). The five years of streamflow data show the oscillations of discharge rate and annual amounts from year to year, with 2018 and 2017 the only recorded years to remain above 3 CFS during the monitoring period. The discharge variation from year to year, shown by data from both East Warren and Poorman Creeks, seems to reflect differences in amount of snow pack for those respective winters.

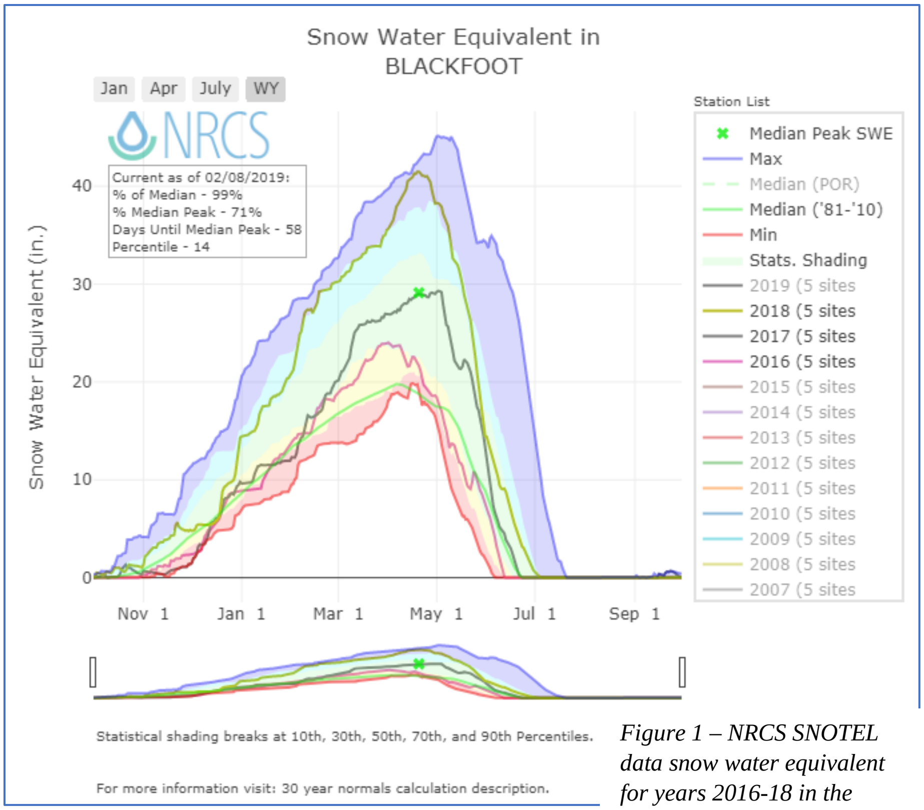


Figure 1 – NRCS SNOTEL data snow water equivalent for years 2016-18 in the Blackfoot watershed.

Water Quality Monitoring: Cottonwood and Monture Basins

Dedicated volunteers ensured the success of the Challenge's third water quality monitoring season. The data collected this season corresponds across parameters to show a single peak run-off period occurring around April 27 through May 17. Data values for turbidity, TP, and TSS leading up to the beginning of peak run-off show minimal variation week-to-week. After the peak run-off period, the values from each parameter all appear to return to their low level equilibrium. Data values for TN show more variability throughout the monitoring season – exhibiting greater differences across streams and an immediate increase towards the peak from the first sample tested. After the peak, TN values fell to lower levels by early July.

Correlations of both TP and TSS with turbidity levels indicate that turbidity analyses may be a relatively inexpensive, simple indicator of water quality that can direct where more in-depth monitoring is warranted. While additional years of data would help confirm these associations, it appears that they may be stronger in years of high flow and high turbidities.

All parameter values were overall the highest in 2018 for all streams and lowest in 2016, with some variations in timing. Gage heights indicated greater water levels for five of the seven streams in 2018 that can be compared to previous years. Gage levels this season were measured to the best of our ability as during peak run-off five out of eight stream gages were washed out by high waters and stream morphology most likely altered. Upper Cottonwood and Cottonwood Spring creeks are the two streams whose water levels stayed fairly consistent from year to year. Both of these streams' gages were washed out, but we did our best to maintain accuracy by noting gage location when installed at the beginning of the season and continuing to measure as close to that location as possible after wash out and recalibrating depth when gage was re-installed. The increased amount of snowpack and SWE in 2018, as seen in the SNOTEL data, had a direct relationship with the majority of parameters measured that monitoring season, indicating that with more water moving through the system come more sediment and nutrients. However, increased snowpack in 2018 may not have been the sole cause for the increased parameter values we saw in our results.

Of the seven streams with data measured prior to 2018, five of those streams saw remarkable increases in turbidity, nutrients, and TSS in 2018 compared to 2017 and 2016. Cottonwood Spring Creek is the only stream in our monitoring area that flows completely outside of the Rice Ridge wildfire perimeter (see Map 3 above). Cottonwood Spring Creek was one of the streams with the overall highest levels in turbidity, TN, TP, and TSS in 2017. In contrast, the 2018 data showed Cottonwood Spring Creek most often in the mid-level ranking for all parameters, indicating its lower level of increase relative to the other streams.

Upper Cottonwood Creek also exhibited little change from 2017 to 2018 despite its location within the wildfire perimeter. North Fork Cottonwood Creek, the next drainage to the south and east from Upper Cottonwood Creek, as well as Monture Creek saw the most extreme increases in TN, TP, and TSS values from 2017 to 2018, primarily in the upper 50^{th} percentile of each stream's respective values. These two streams present a contrast to Upper Cottonwood Creek despite all being within the wildfire perimeter. The contrast could imply that less severe burning occurred upstream in the Upper Cottonwood drainage compared to greater fire intensity in both the North Fork Cottonwood and Monture drainages. The forest surrounding the monitoring sites at Upper Cottonwood, North Fork Cottonwood, Little Shanley, Black Canyon, Shanley, and Dunham creeks were all charred from the wildfire. Monture and McCabe creeks sites were not immediately surrounded by burned areas, but were burned over upstream.

Given only two years of pre-fire data and one year post-fire, with high variability of flow levels, burn severity, topography, and other factors as well as collecting samples only once per week; this dataset is likely missing important components. Sifting apart cause and effect to water quality is difficult. Flow levels and fire very likely interacted to increase sediment and nutrient levels in these streams. Increased sampling to more than once per week could potentially provide important information about sediment and nutrient levels.

After Rice Ridge wildfire, the US Forest Service began salvage logging with the plan to remove 76,241 tons of logs across 1,829 acres. Continued sampling through the 2019 run-off season will allow us to monitor water quality as timber removal occurs. The original goal to obtain baseline data for the Collaborative Forest and Landscape Restoration projects has now grown into invaluable data collected pre- and post-wildfire. Analysis of water quality post-wildfire and subsequent salvage logging is fundamental information for evaluating the health of this resource for downstream irrigators, fisheries, and recreationists.

Acknowledgments

The Challenge would like to thank Martha Swanson, Brie Guilmette, Judy DeNoyer, Joe Raible, Mike Mayernik, Steve Holden, McKenzie Schessl, and Elaine Caton for volunteering to help collect stream samples for our water quality analysis work. A special thank you to the Lolo National Forest and the SWCC CFLR program coordinator, Cory Davis, for providing funding to support our water quality monitoring program and involvement with citizen scientist volunteers. Thank you to the Helena-Lewis and Clark National Forest for their continued partnership through the Youth Forest Monitoring Program, and to our DNRC area hydrologist, Aaron Fiaschetti, and retired USFS emeritus fisheries scientist, Bruce Rieman, for their help with organizing and interpreting our stream flow data. The Challenge would also like to thank the teachers at Ovando, Hemlville, and Potomac schools for their help in taking the science classroom outside and into the water, and their assistance in providing consistent flow measurements.

For more information on the Blackfoot Challenge monitoring program, please visit www.blackfootchallenge.org, call us at (406) 793- 3900, or stop by our office 405 Main Street, Ovando MT 59854

Appendix A:

Compared Years: Flow Monitoring

Upper Warren Creek Basin: **East Warren Creek** 3rd order tributary.

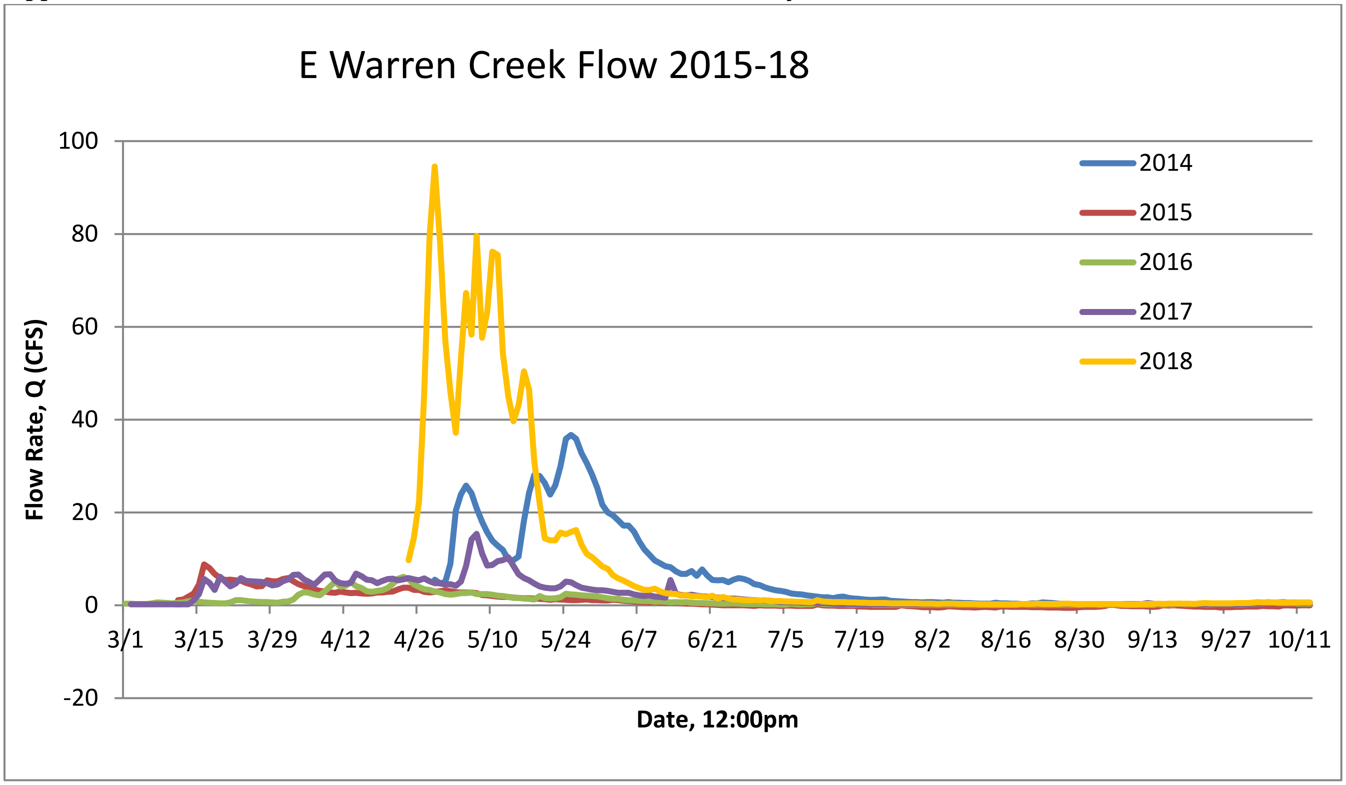


Figure 2 – Flow rates over time for years 2014-2018. Rates are derived from logger depths entered in to a rating curve created by manual flow measurements. A separate rating curve was created from data for each year, except for 2018 which used data from 2017 and 2018.

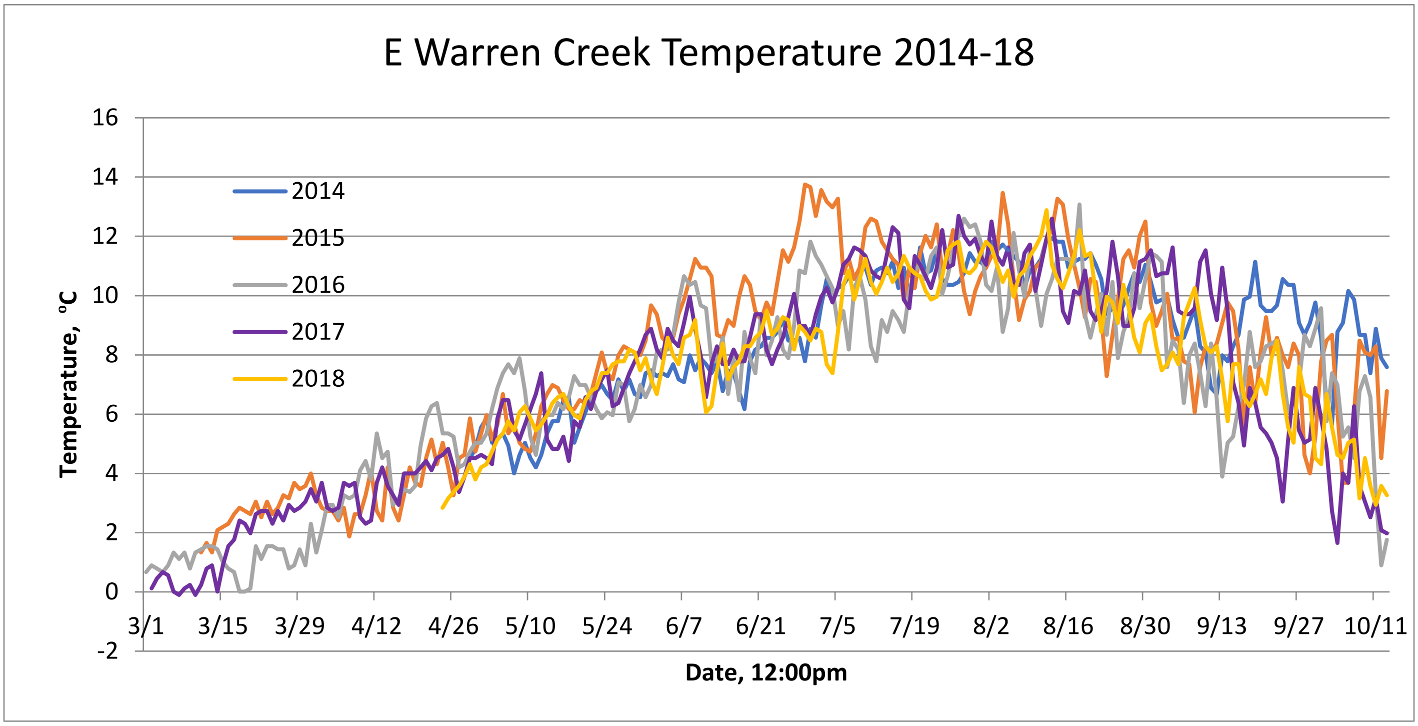


Figure 3 – Temperature readings taken by a data logger 2014-2018.

Poorman Creek Basin: **Poorman Creek** 4th order tributary

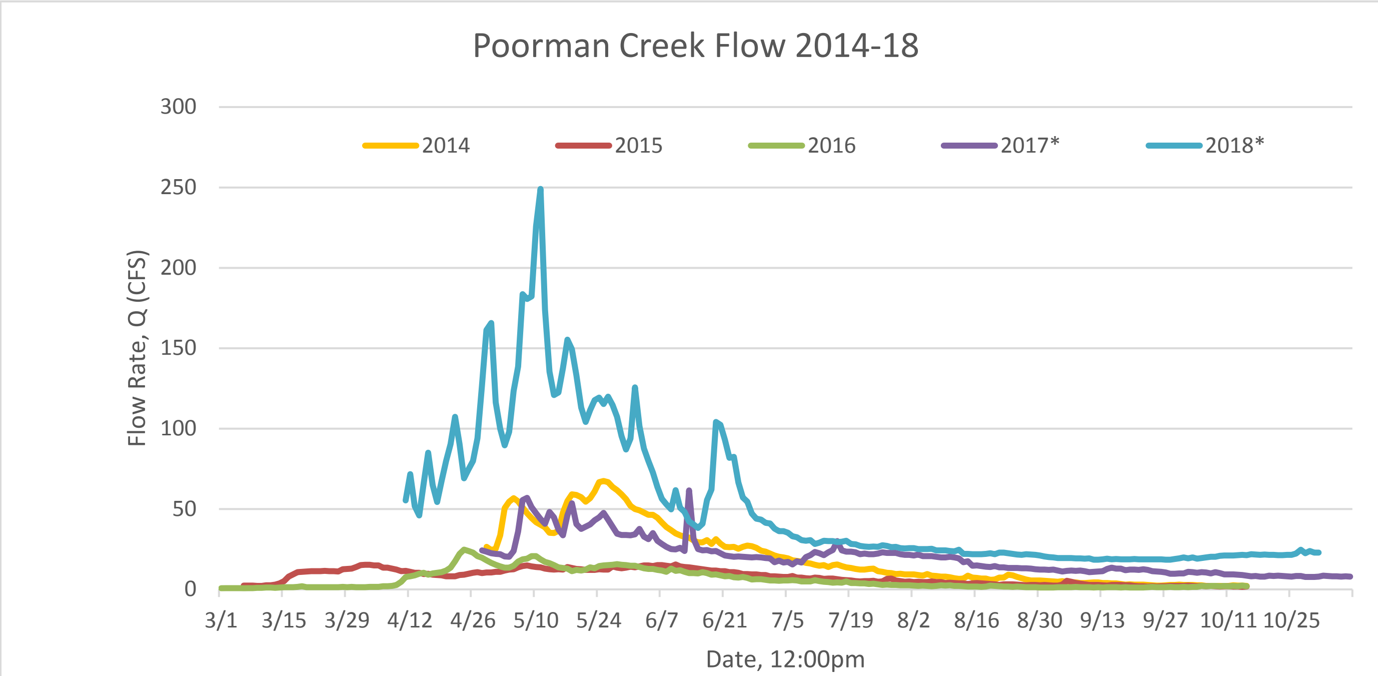


Figure 4 – Flow rates over time for years 2014, 2015, 2016, 2017, and 2018*. Rates are derived from logger depths entered in to a rating curve created by manual flow measurements. A separate rating curve was created for each year from that year's respective data.*

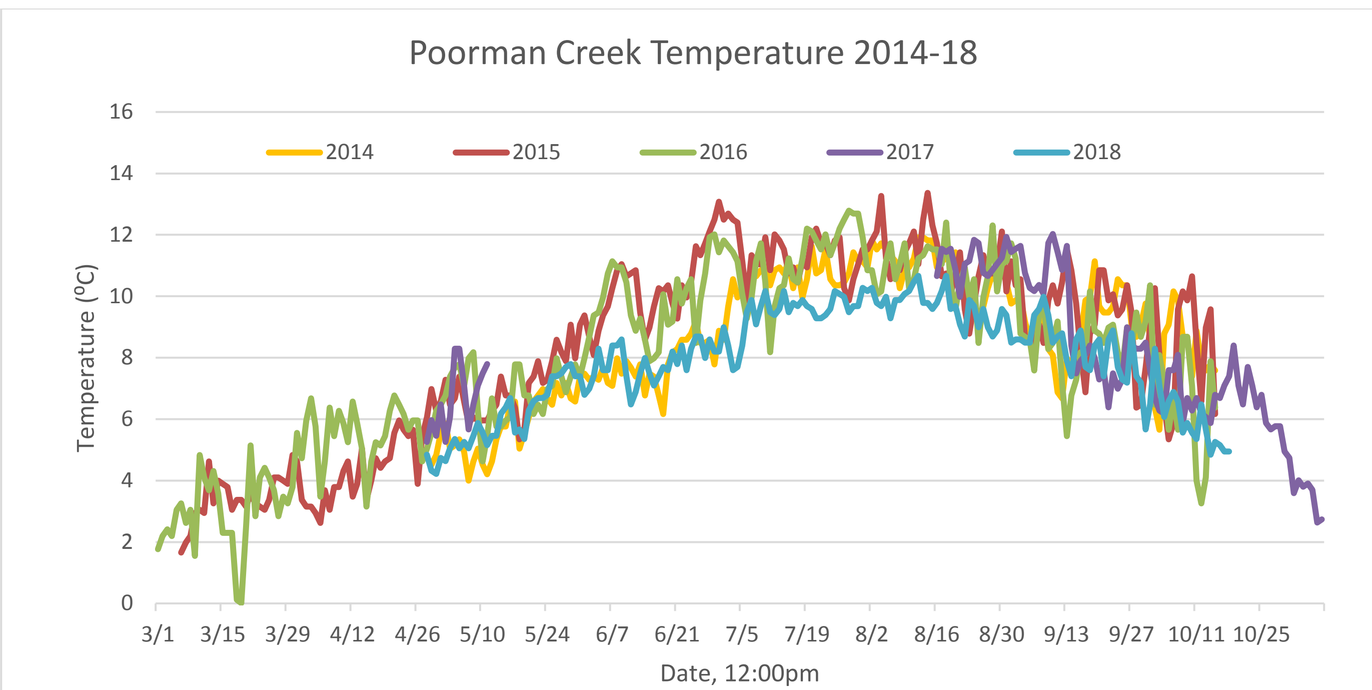


Figure 5 – Temperature readings taken by a data logger 2014- 2018.

*Due to a technical malfunction, the 2017 logger only collected data for two weeks before shutting down. The malfunction was not identified until mid-August when it was corrected, allowing the logger to begin collecting data again. The logger continued to collect accurate data from mid-August until it was manually shut-off in early November. A linear regression curve for stream depth was created by using the four staff gage measurements taken manually while the logger was down, logger data collected before and after the malfunction, and data from a USGS stream gage #12335500 located in Nevada Creek above the reservoir near Helmville, MT. Lost temperature readings were not able to be determined due to no temperature data collected by the USGS Nevada Creek stream gage
*Due to a technical malfunction, the 2018 logger failed to collect accurate stream depth data for the entire season. Data was estimated by creating a linear regression curve using the seven flow and staff gage measurements taken manually throughout the season and the depth measurements from the USGS stream gage #12335500. The barometric pressure gage on the device was apparently unaffected by the malfunction of depth reader and collected seemingly accurate data from April through October.

NOTE: Stream acronyms are as follows: Black Canyon Creek- **BLA**, Little Shanley Creek- **LSH**, North Fork Cottonwood Creek- **NFC**, Cottonwood Spring Creek- **SPR**, Upper Cottonwood Creek- **UCW**, McCabe Creek- **MCC**, Monture Creek- **MON**, Dunham Creek- **DUN**, and Shanley Creek- **SHA**

Compared Years: 2018, 2017 and 2016 Turbidity

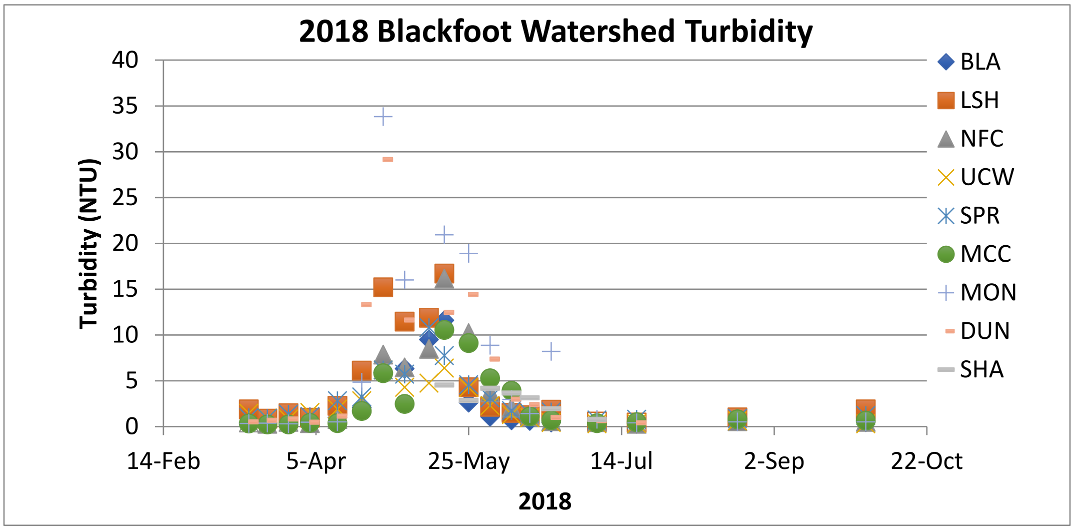


Figure 6 – Turbidity analysis results for all streams in our study over the entire sampling period of 2018. ***Note the extended monitoring season in 2018 (difference in x-axis)***

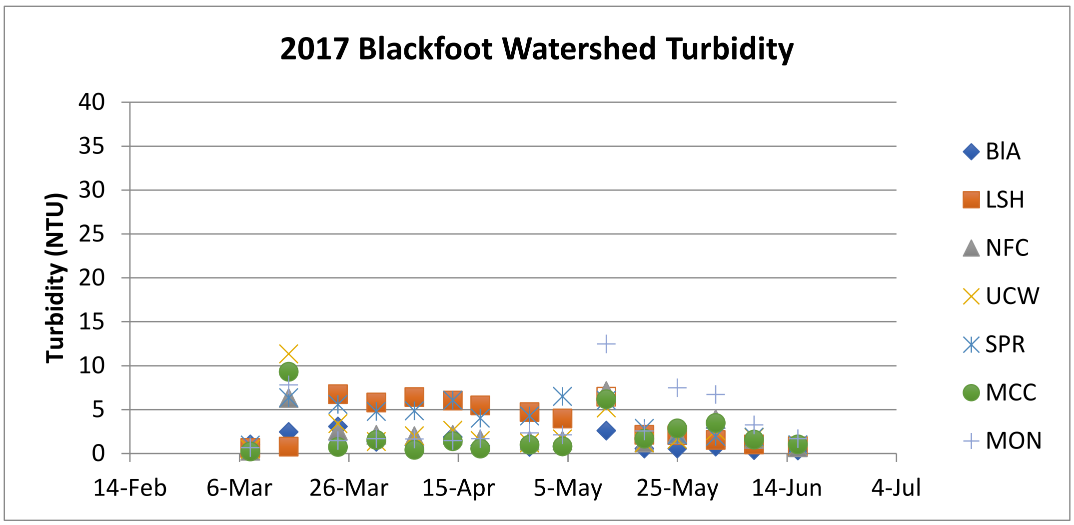


Figure 7 – Turbidity analysis results for all streams in our study over the entire sampling period of 2017.

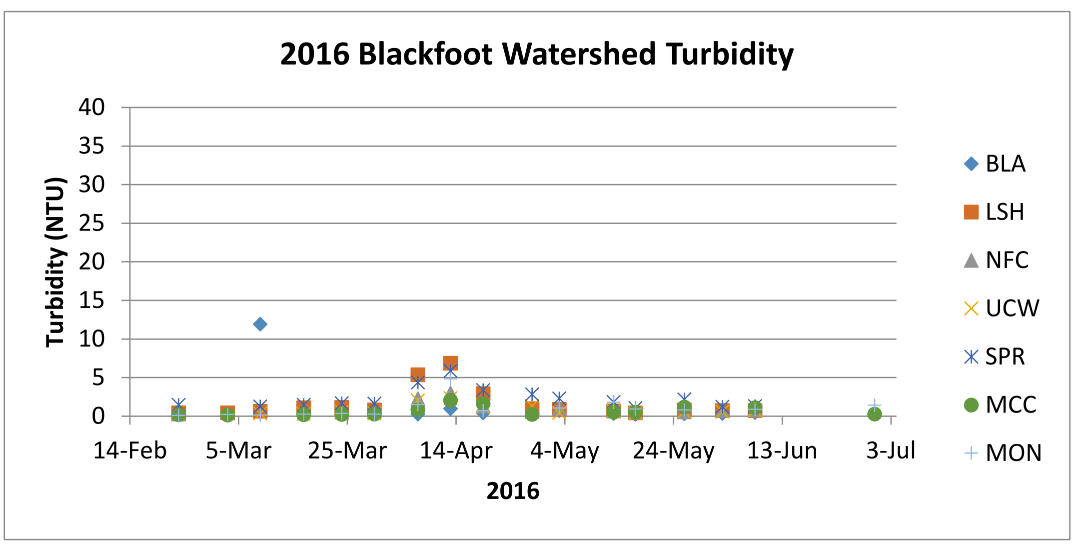


Figure 8 – Turbidity analysis results for all streams in our study over the entire sampling period of 2016.

Figures 9, 10 and 11 – A comparison of turbidity analysis results from 2018, 2017, and 2016 monitoring seasons. Data is formatted here as a Box and Whiskers plot to better express averages and outliers. The "Box" represents the middle 50% of the data, with the center line being the mean value. The top "Whisker" represents the upper quartile (25%) and the bottom "Whisker" represents the lower quartile of data.*

Note the difference in units on the y-axis between sampling years in order to retain detail from 2017 and 2016 data.

Note Dunham and Shanley creeks were not sampled in 2017 and 2016.

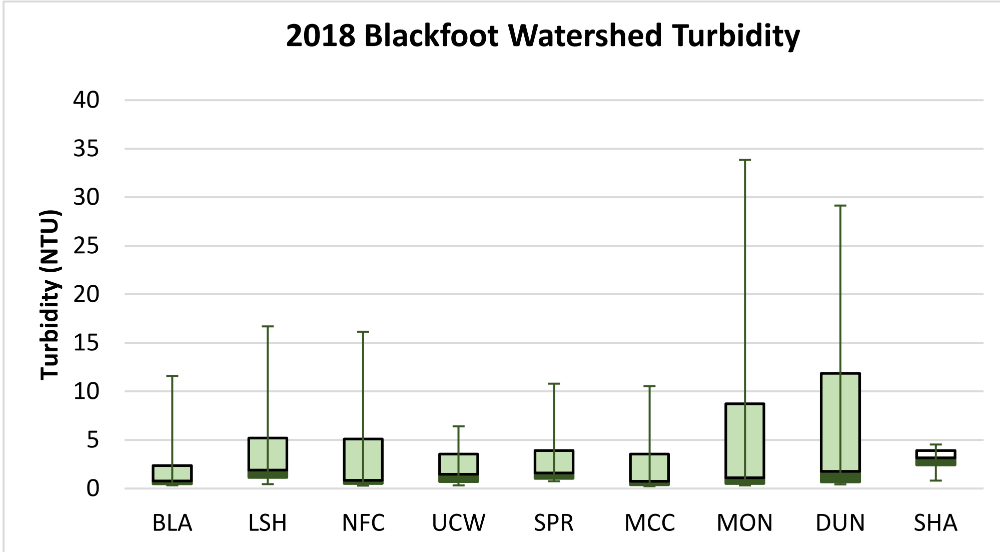


Figure 9

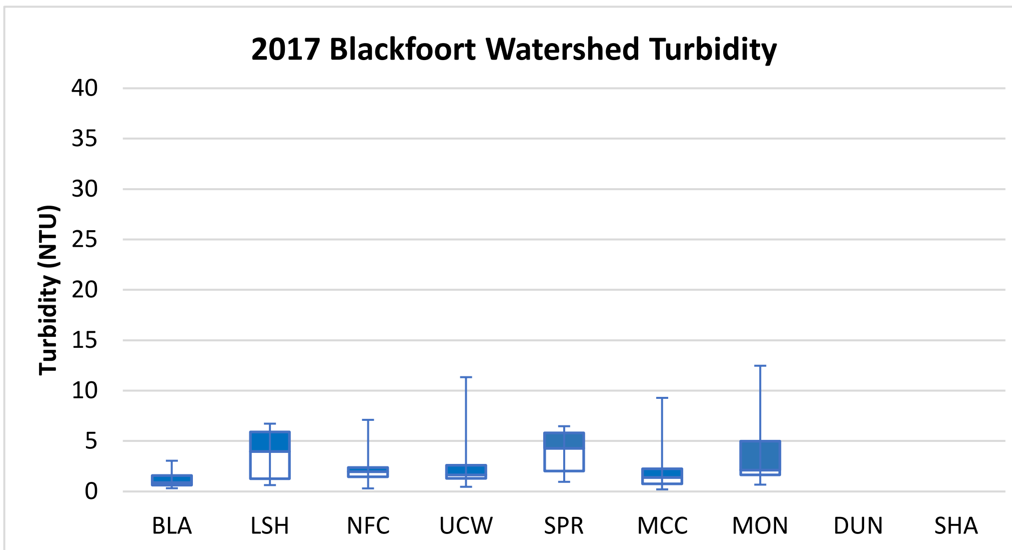


Figure 10

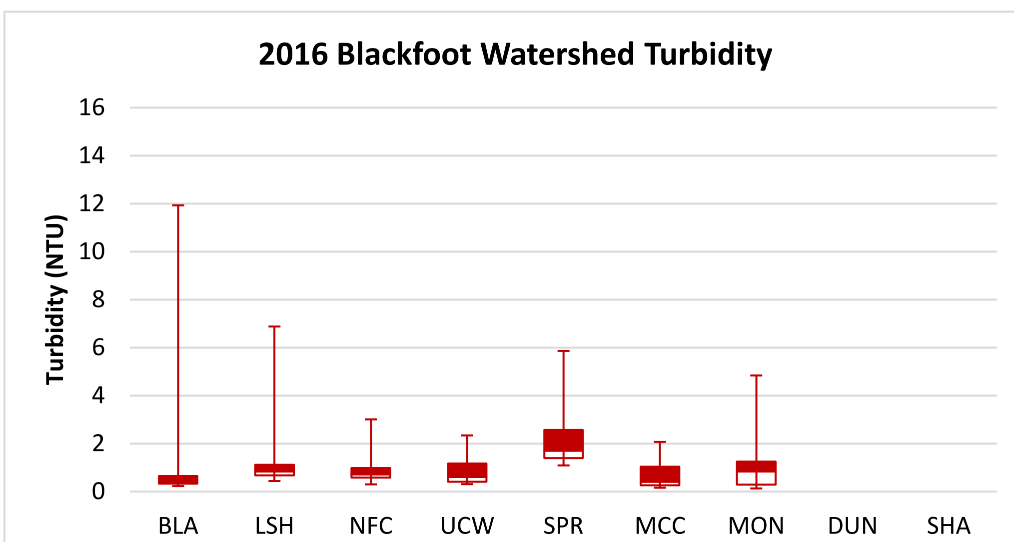


Figure 11

2018, 2017, and 2016 Turbidity Comparisons: Individual streams

Each stream has one graph comparing all three years that turbidity was monitored: 2018, 2017, and 2016. Each stream also has a graph depicting gage height and turbidity measurements for each year; the y-axes are made to be the same for both years to ease comparison

Cottonwood Basin: **Black Canyon Creek** 2nd order tributary.

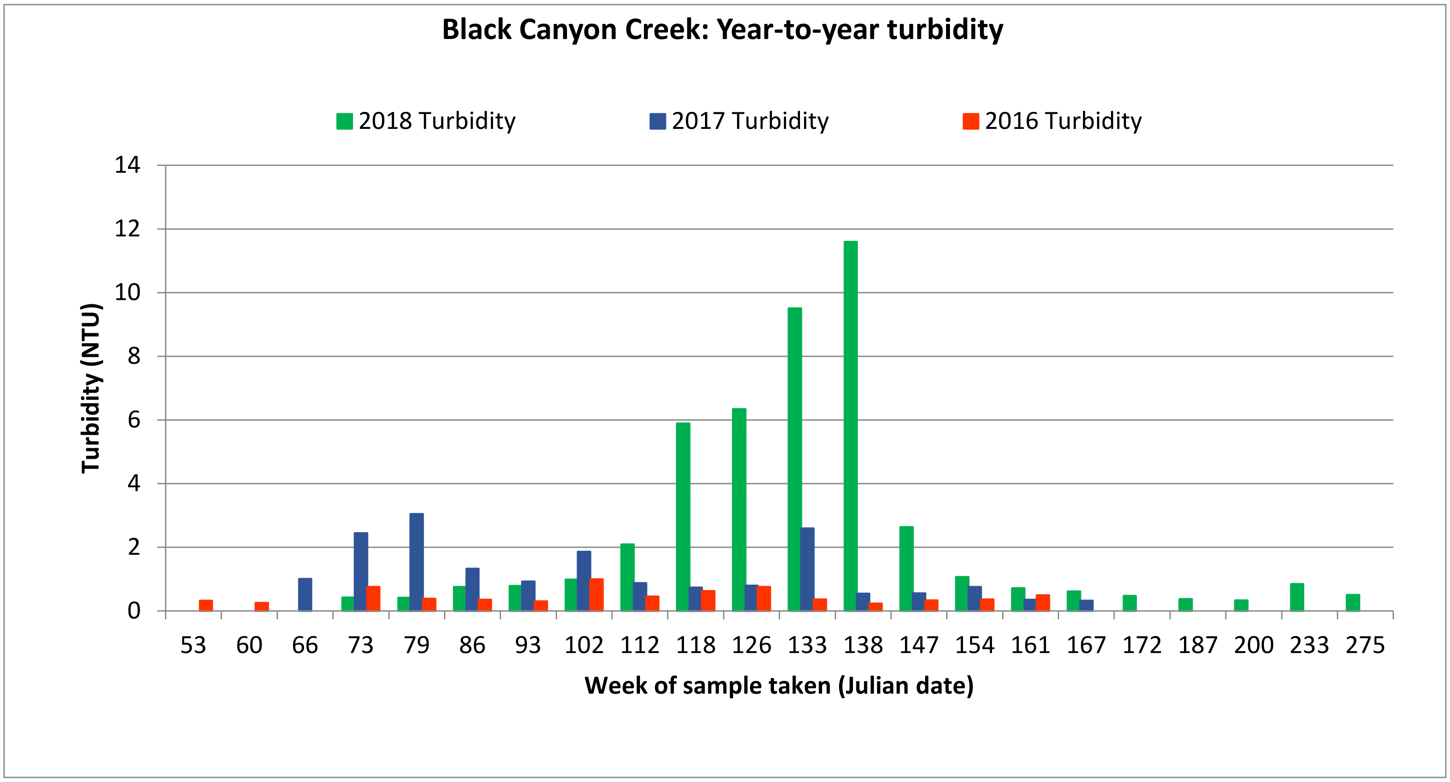
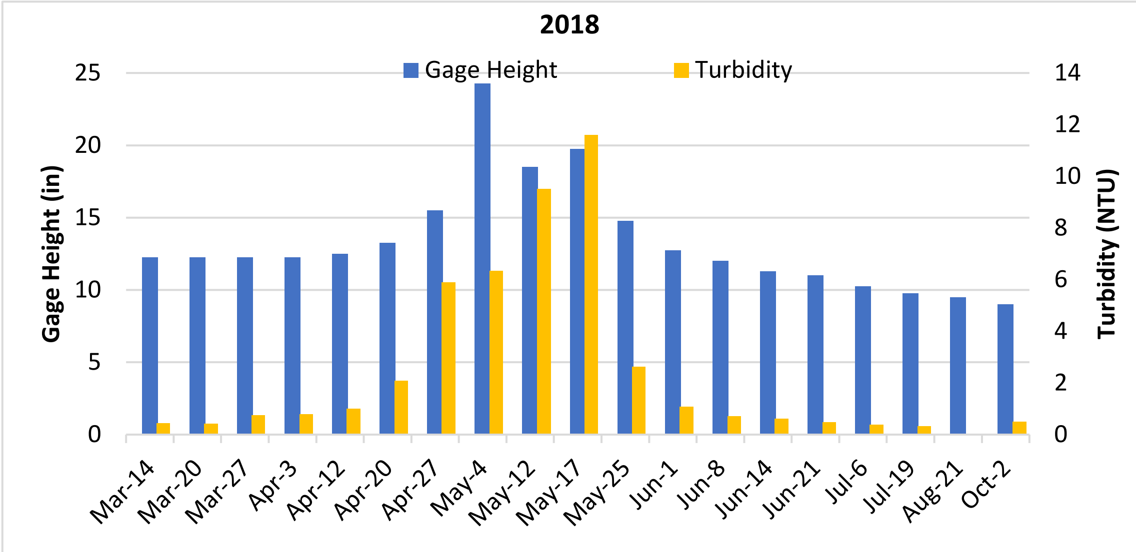
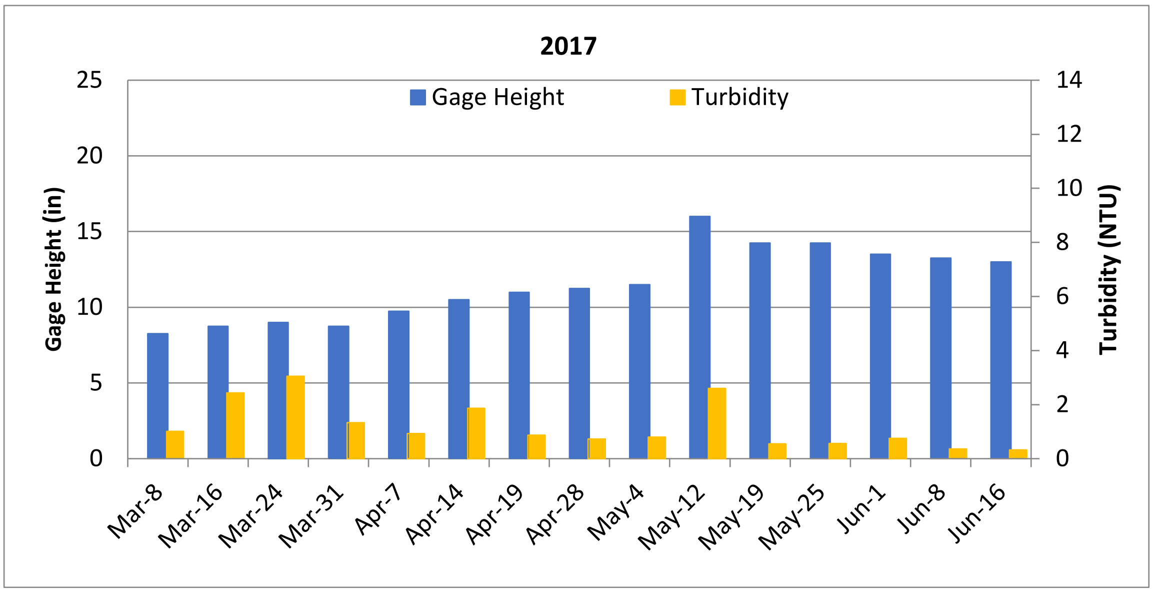
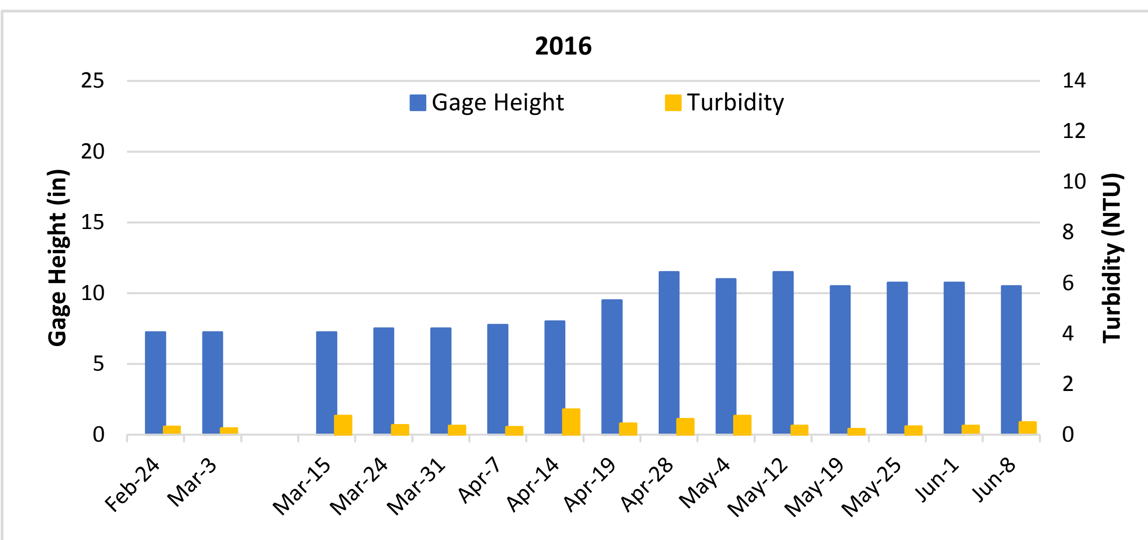


Figure 12 – Turbidity results for each week of sampling during years 2018, 2017 and 2016

Figures 13, 14, and 15– Gage height (water level) relative to turbidity results for each week of sampling during years 2018, 2017, and 2016







Cottonwood Basin: **Little Shanley Creek** 1st order tributary.

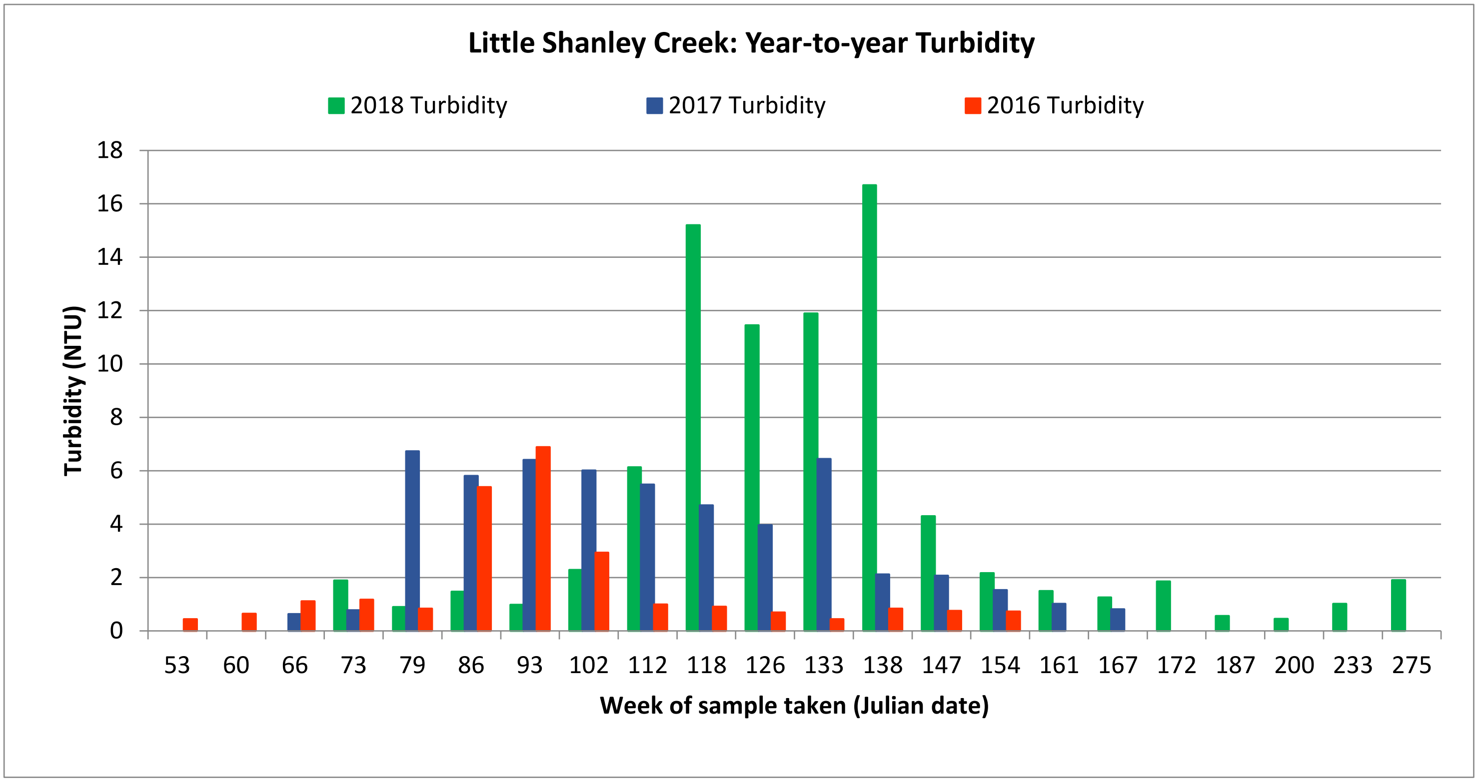
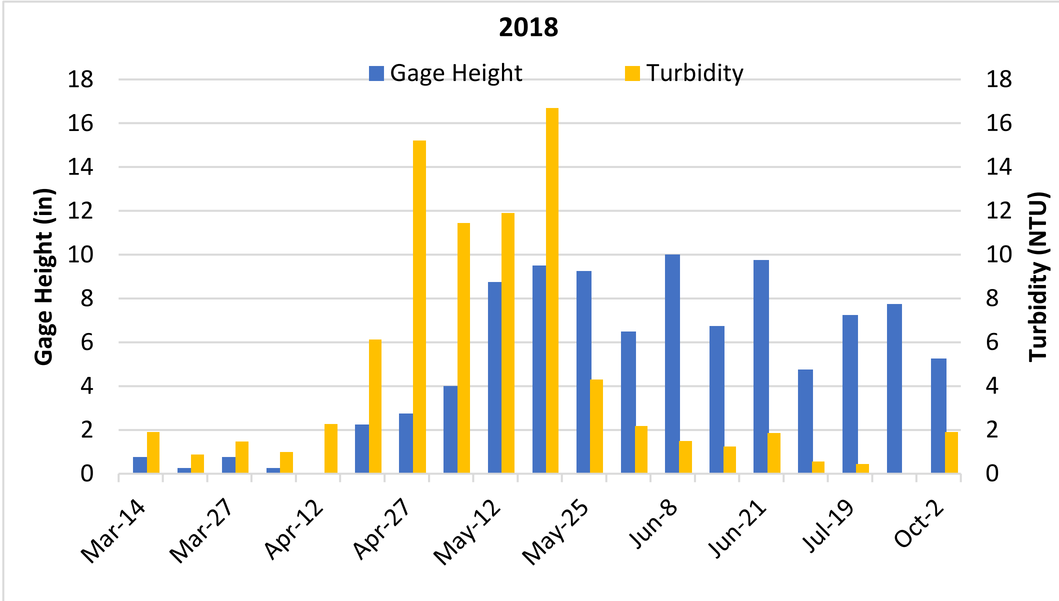
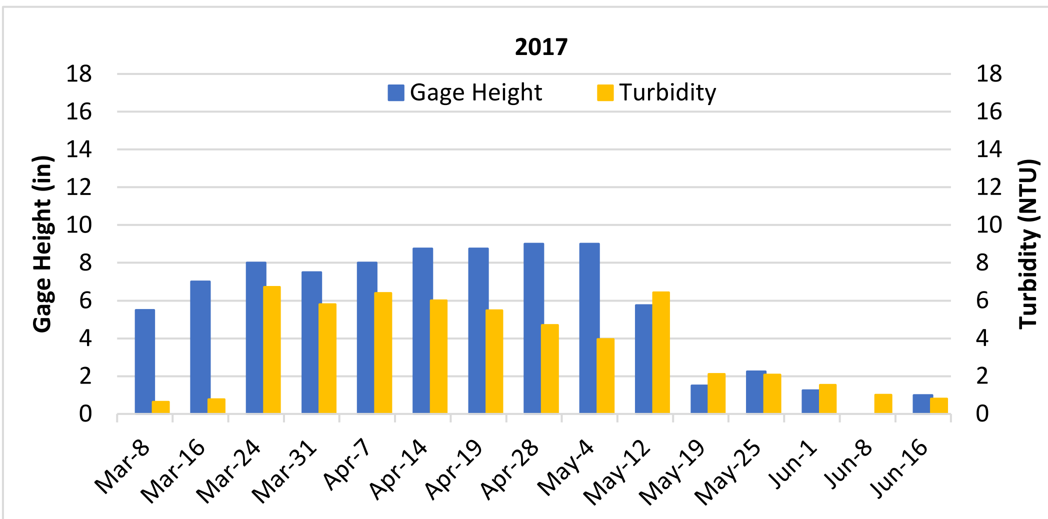


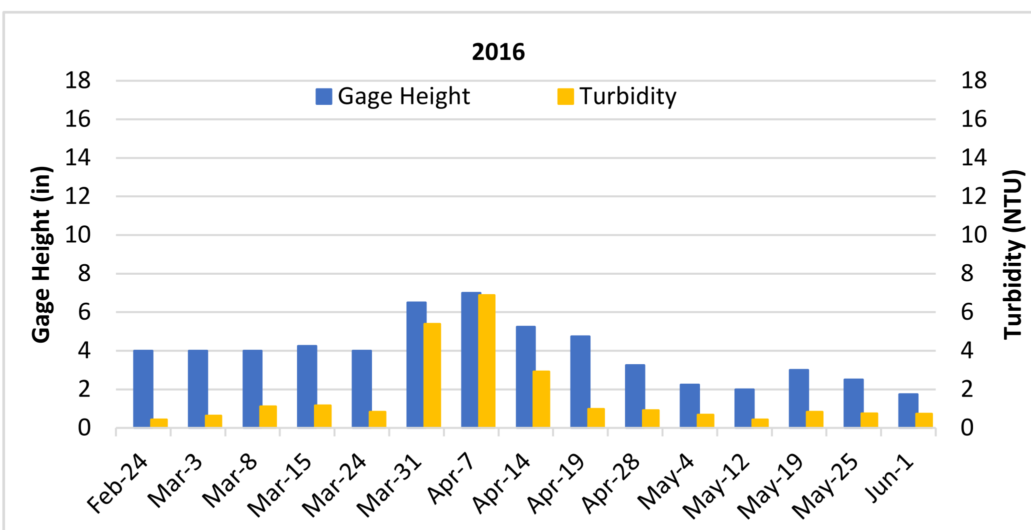
Figure 16 – Turbidity results for each week of sampling during years 2018, 2017 and 2016

Little Shanley Creek

Figures 17, 18, and 19– Gage height (water level) relative to turbidity results for each week of sampling during years 2018, 2017, and 2016







Cottonwood Basin: **N. Fork Cottonwood Creek** 3rd order tributary.

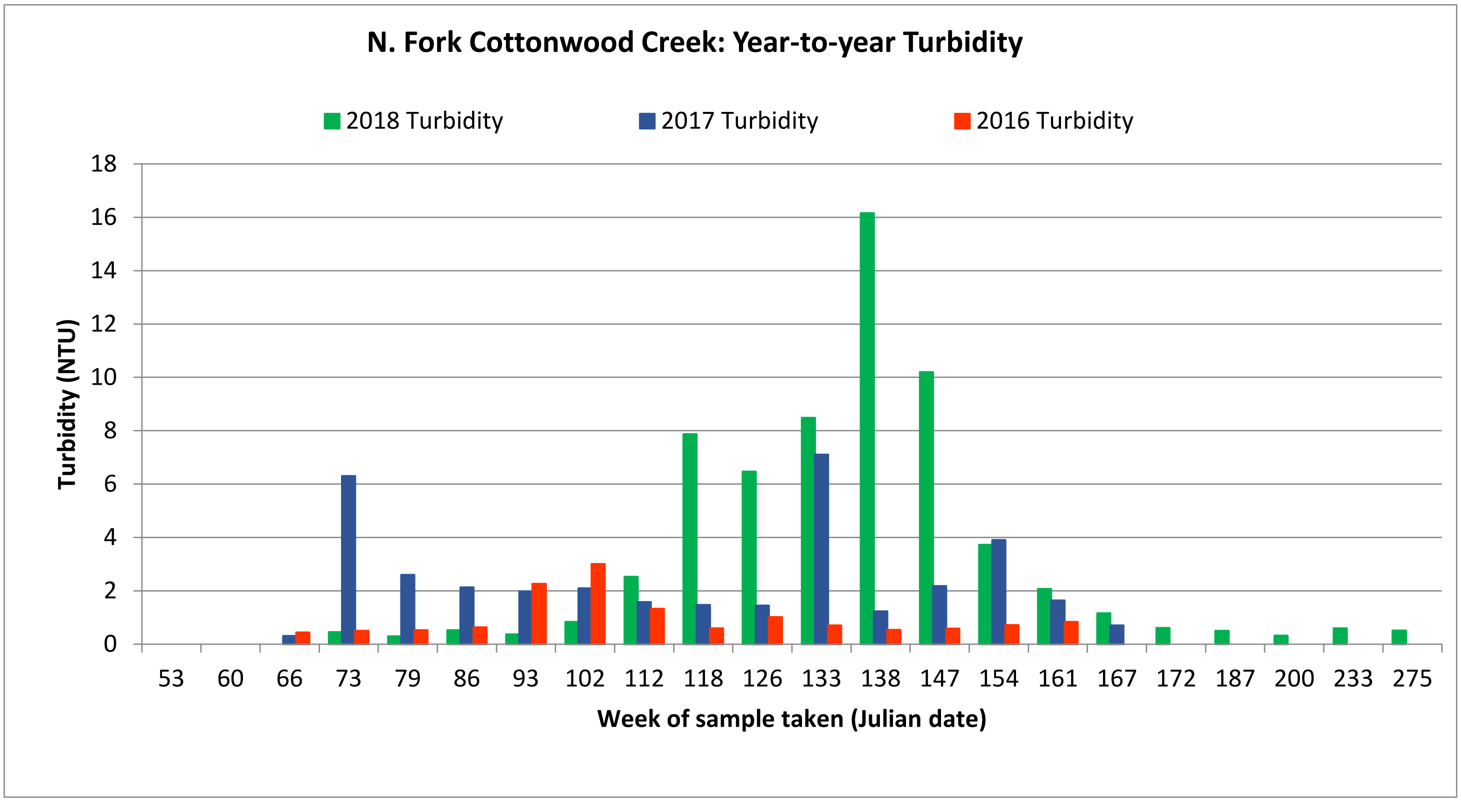
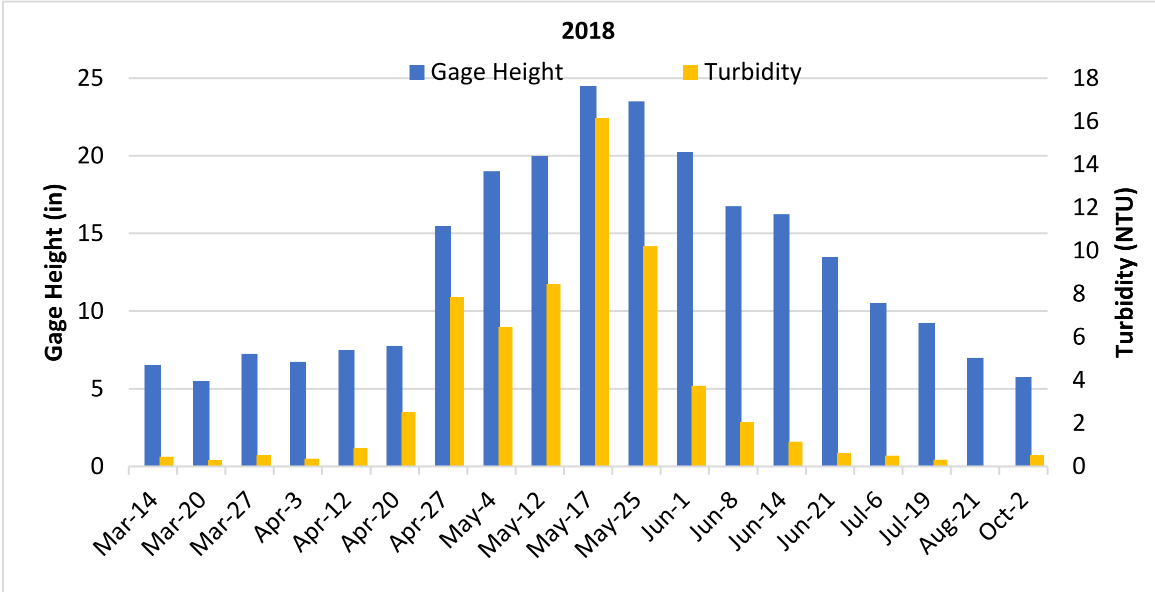
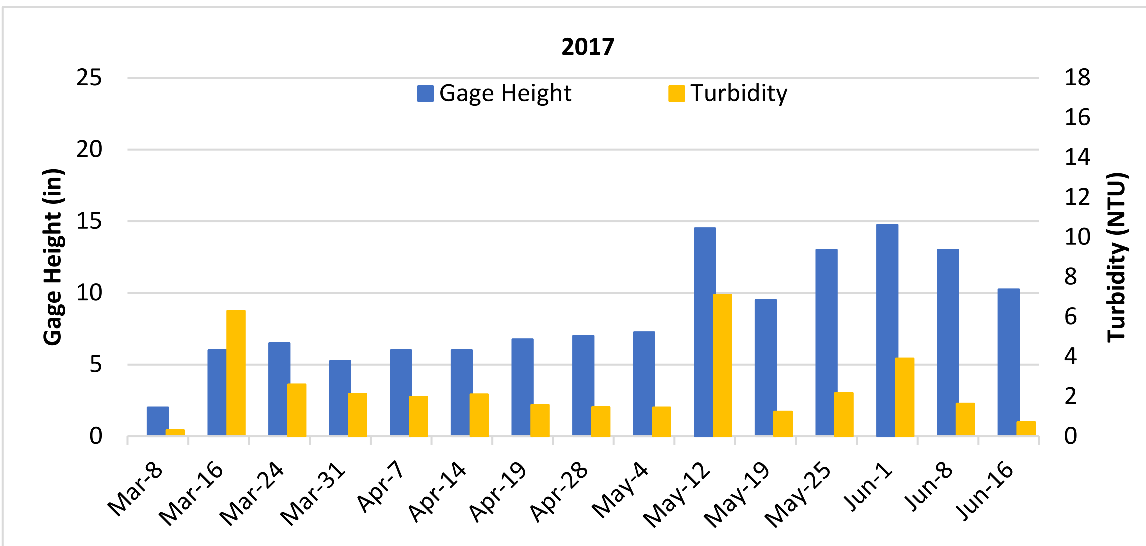


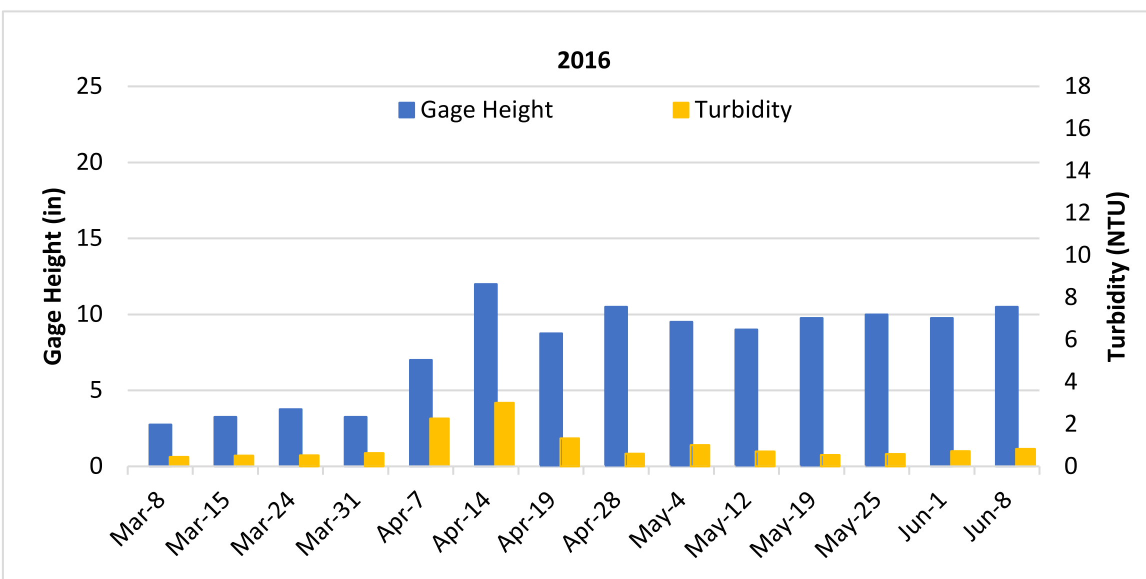
Figure 20 – Turbidity results for each week of sampling during years 2018, 2017 and 2016

N. Fork Cottonwood Creek

Figures 21, 22, and 23 – Gage height (water level) relative to turbidity results for each week of sampling during years 2018, 2017, and 2016







Cottonwood Basin: **Upper Cottonwood Creek** 2nd order tributary.

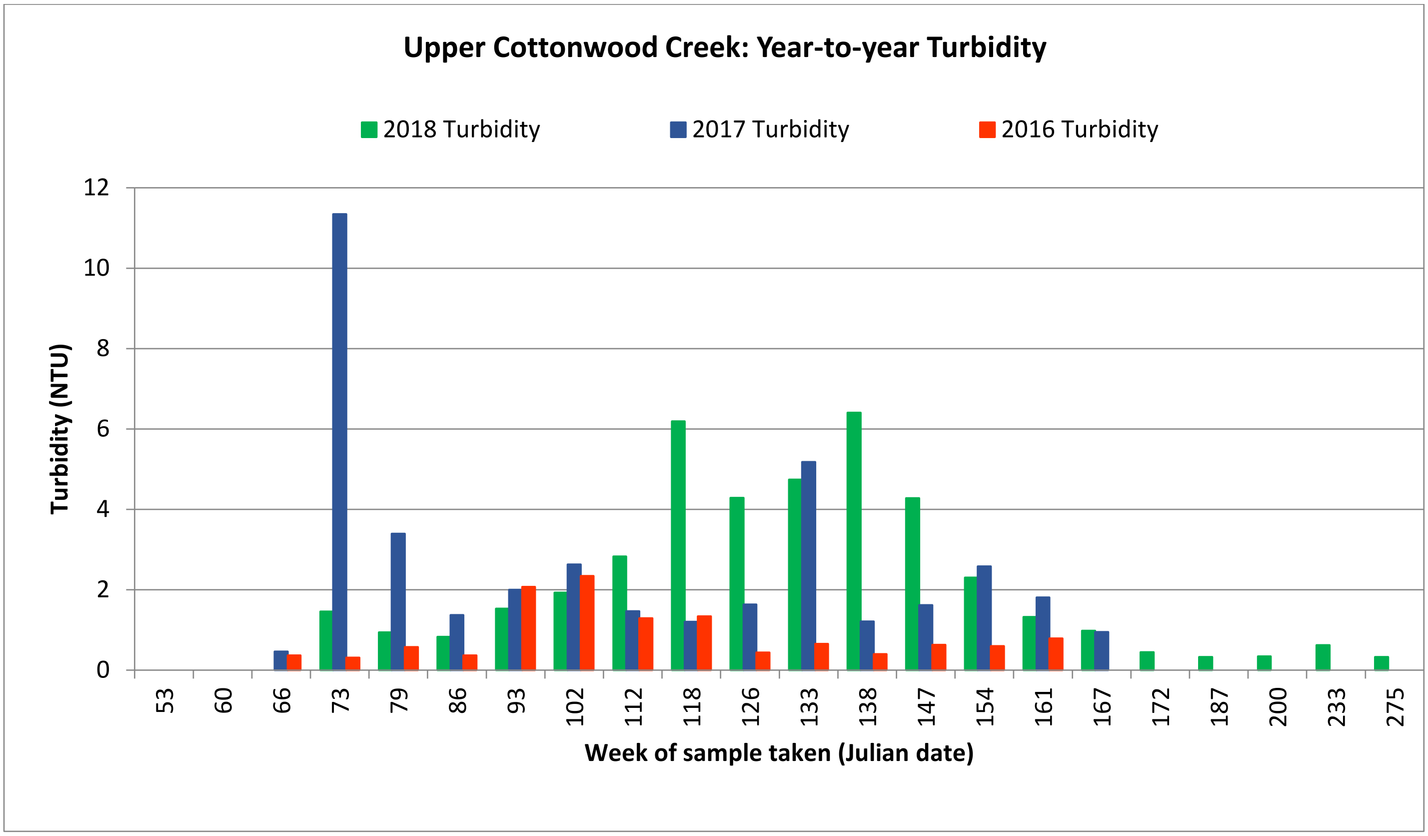
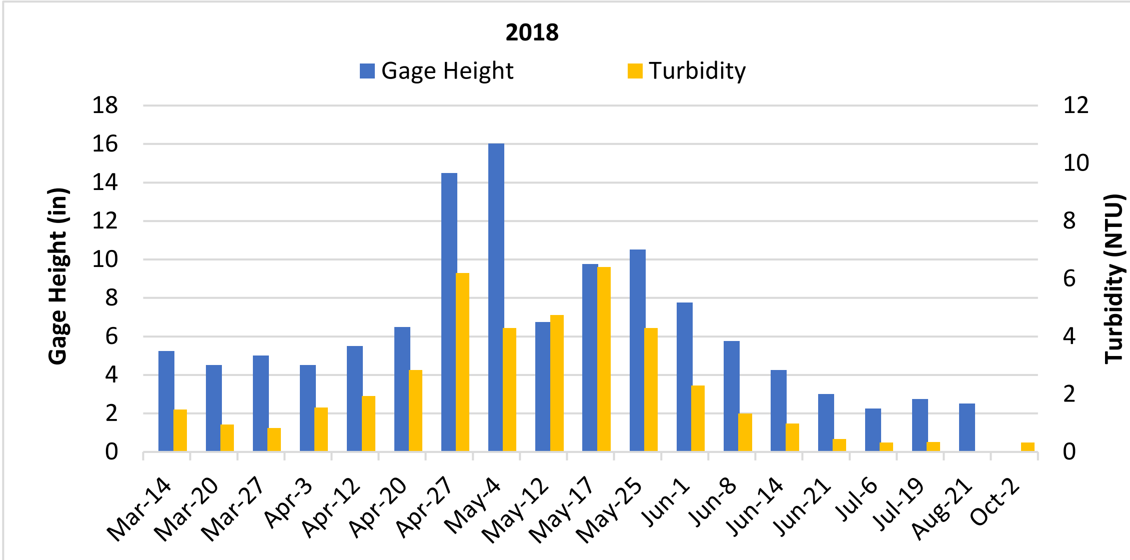
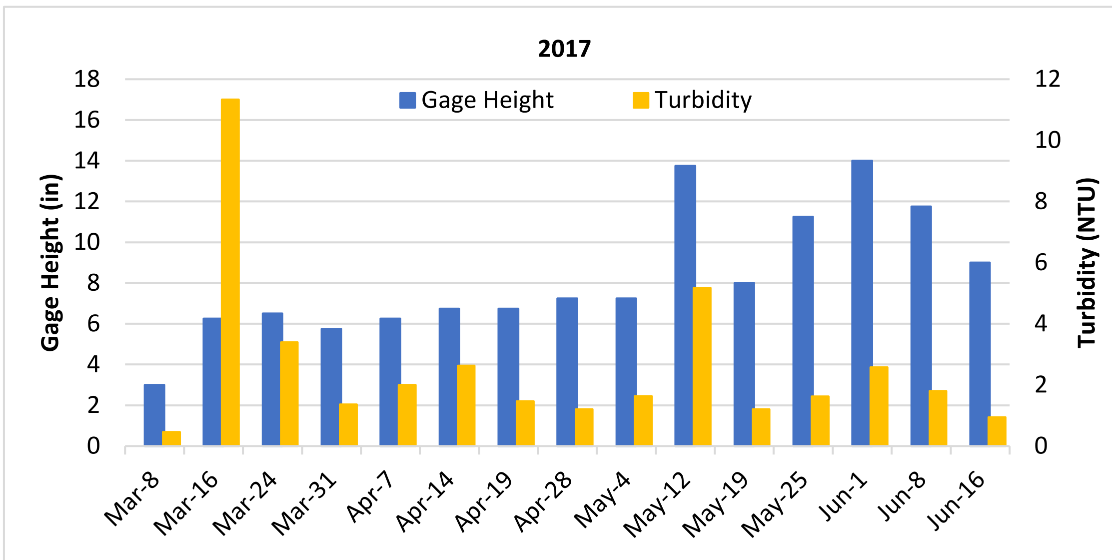


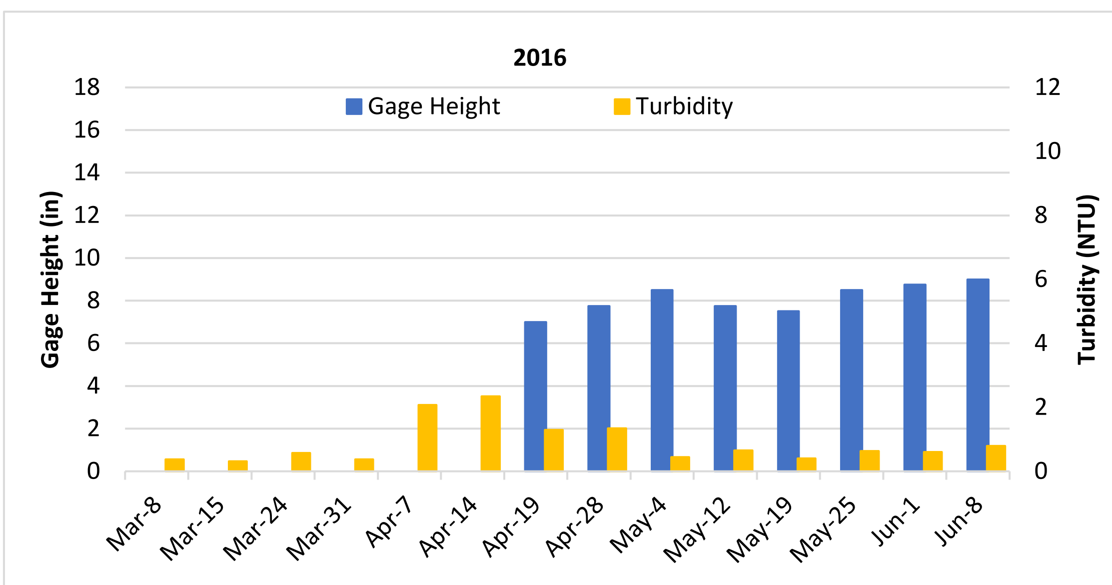
Figure 24 – Turbidity results for each week of sampling during years 2018, 2017 and 2016

Upper Cottonwood Creek

Figures 25, 26, and 27 – Gage height (water level) relative to turbidity results for each week of sampling during years 2018, 2017, and 2016







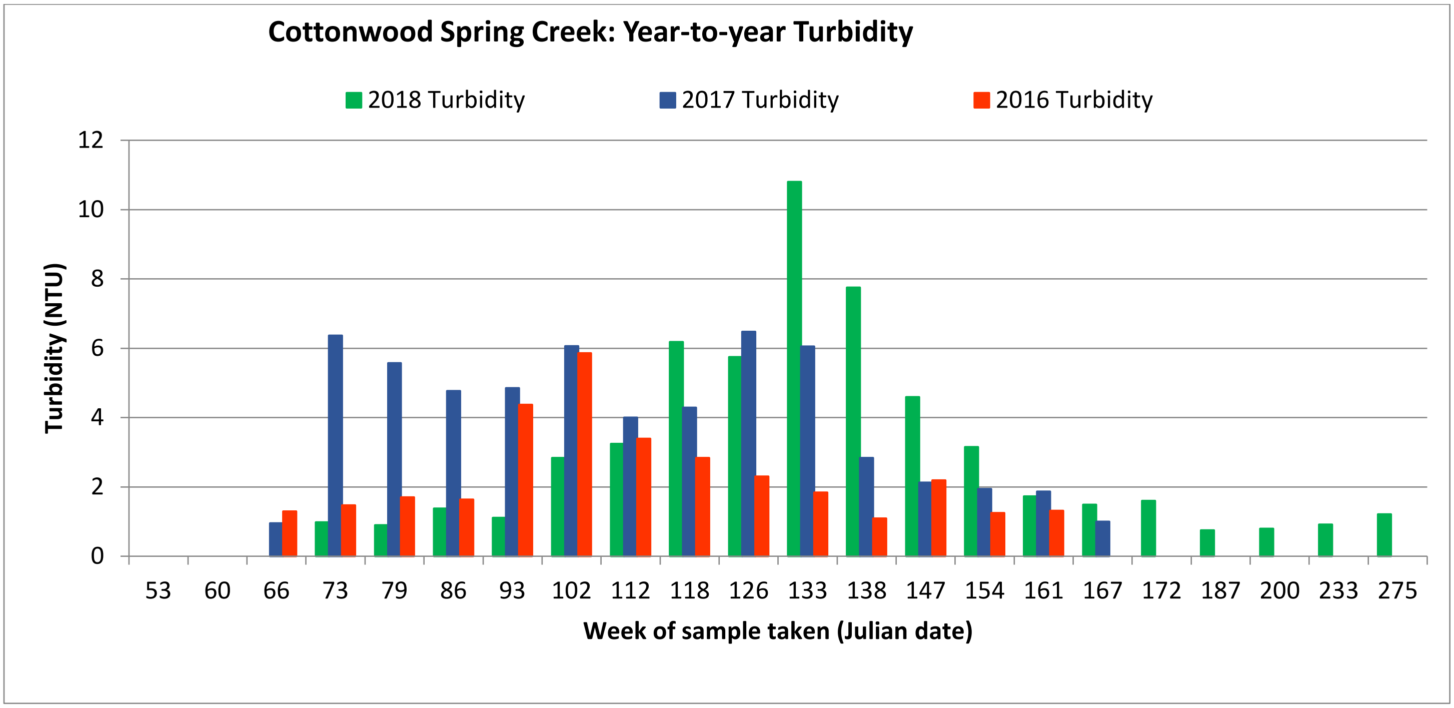
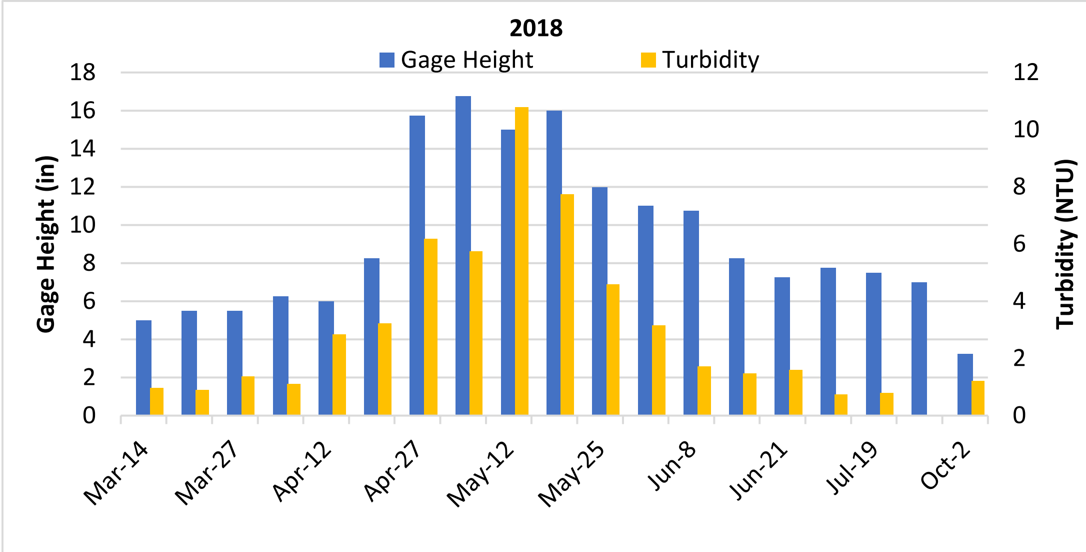
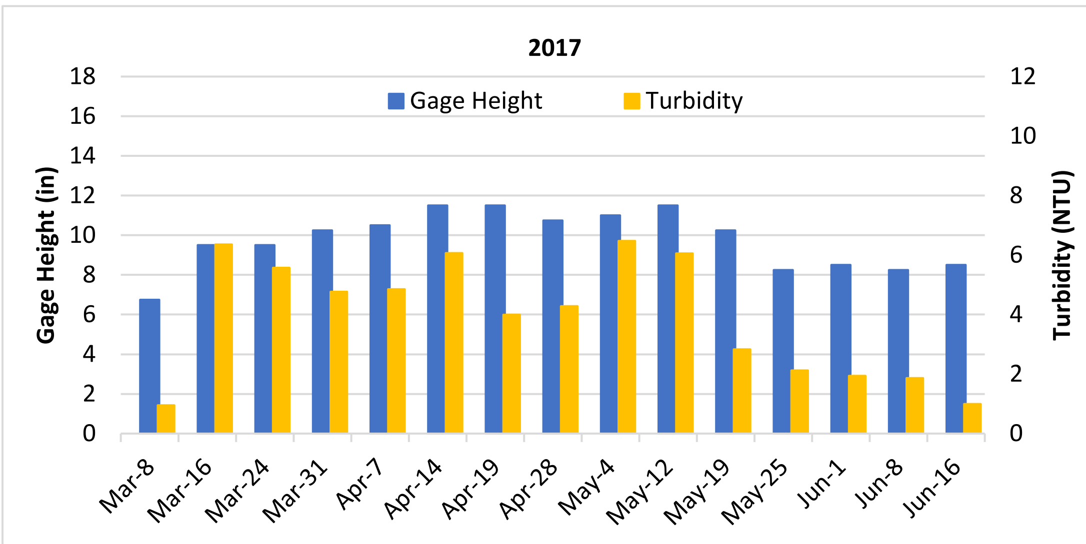


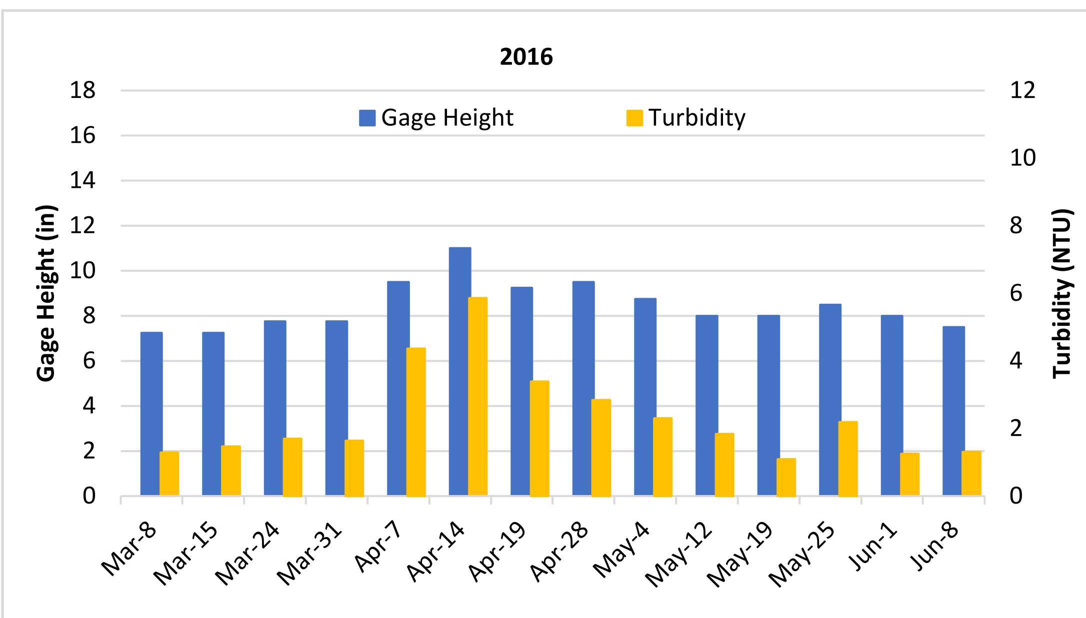
Figure 28 – Turbidity results for each week of sampling during years 2018, 2017 and 2016

Cottonwood Spring Creek

Figures28, 29, and 30 – Gage height (water level) relative to turbidity results for each week of sampling during years 2018, 2017, and 2016







Dick Creek Basin: **McCabe Creek** 3rd order tributary

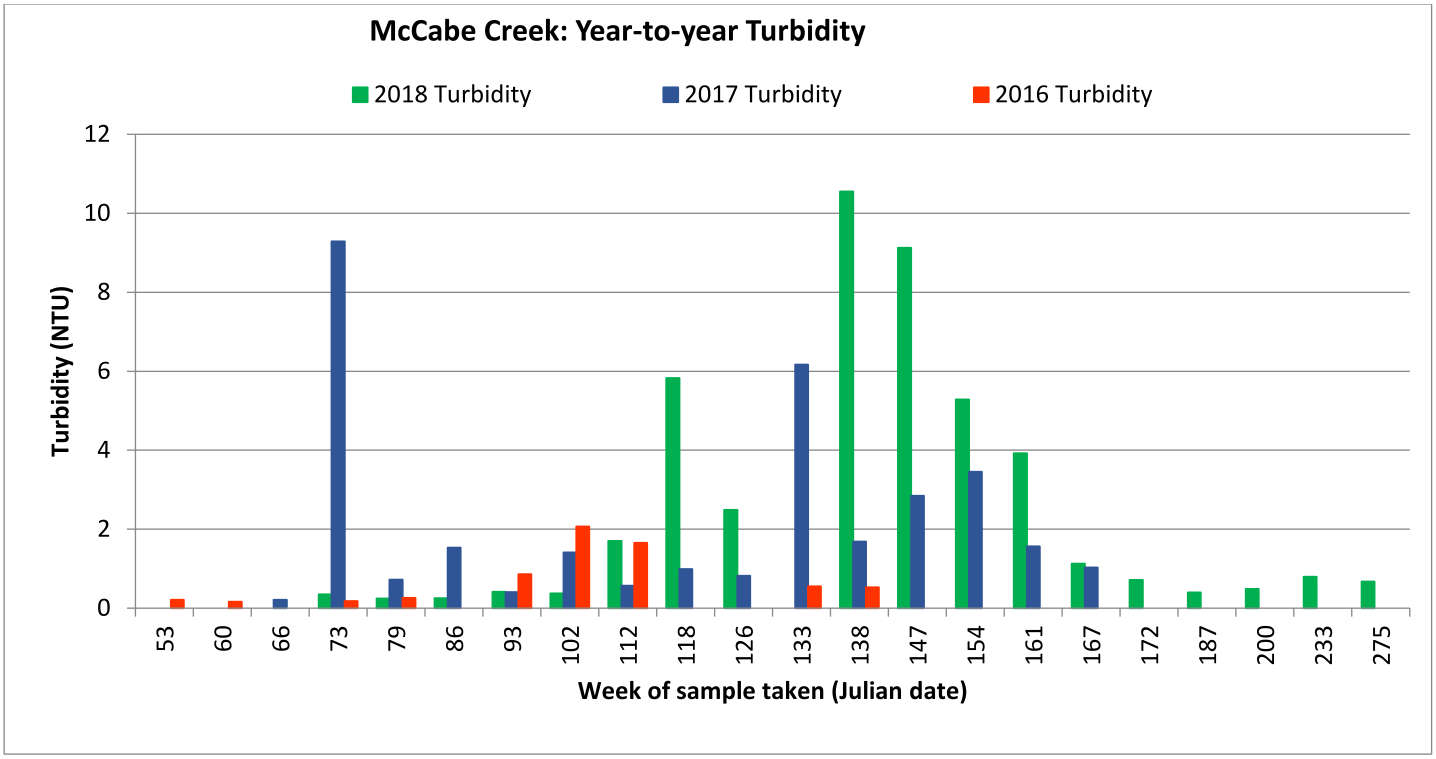
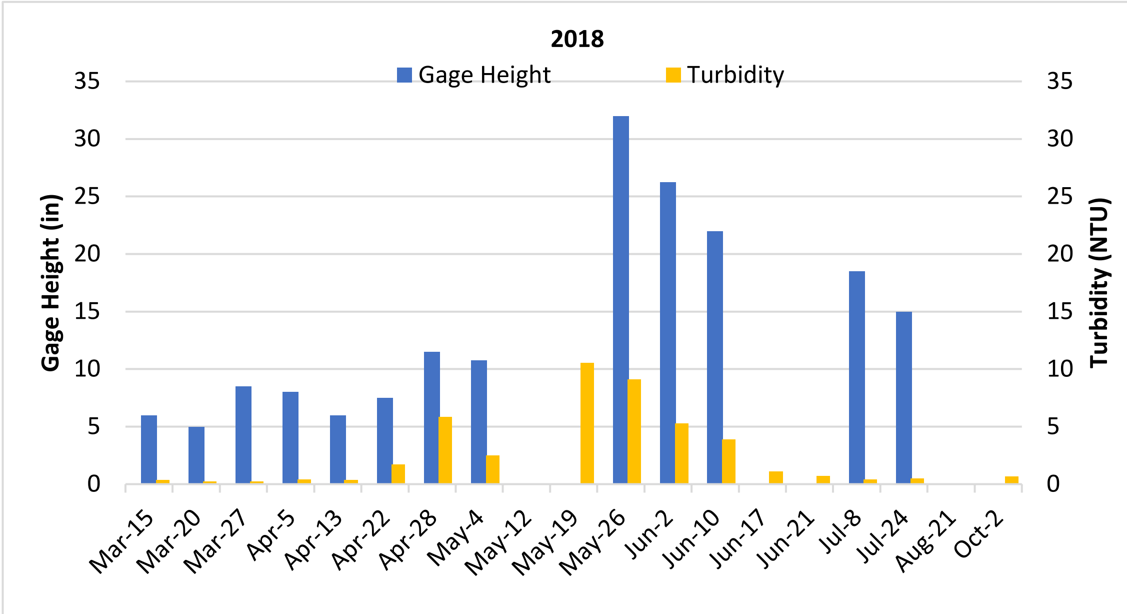


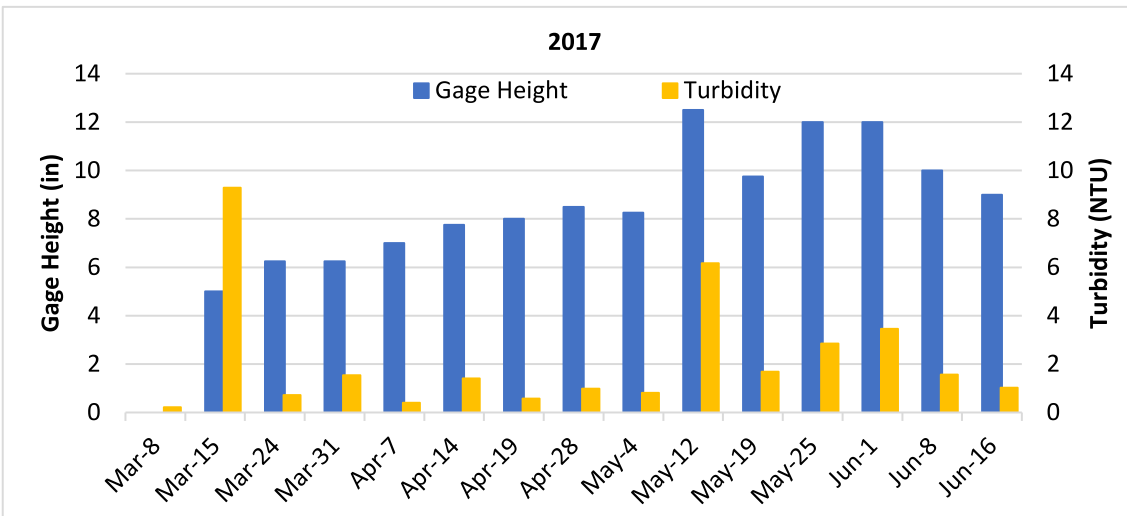
Figure 31 – Turbidity results for each week of sampling during years 2018, 2017 and 2016

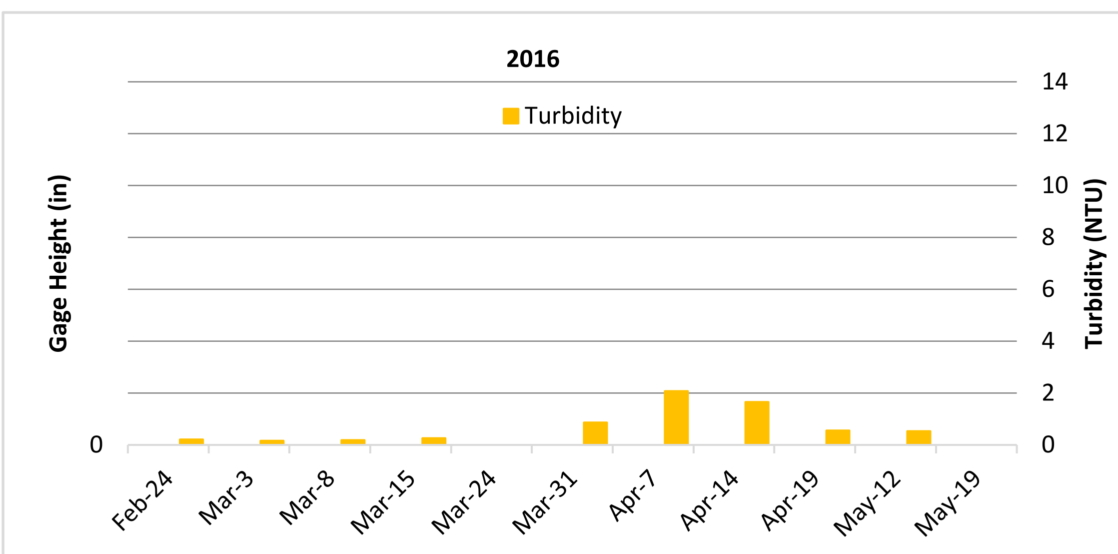
McCabe Creek

Figures 33, 34, and 35 – Gage height (water level) relative to turbidity results for each week of sampling during years 2018, 2017, and 2016 ***Note that no gage height data was collected in 2016 for McCabe Ck***



Note the difference in y-axis for 2018 to allow for more detail in 2017 and 2016.





Monture Basin: **Monture Creek** 4th order tributary

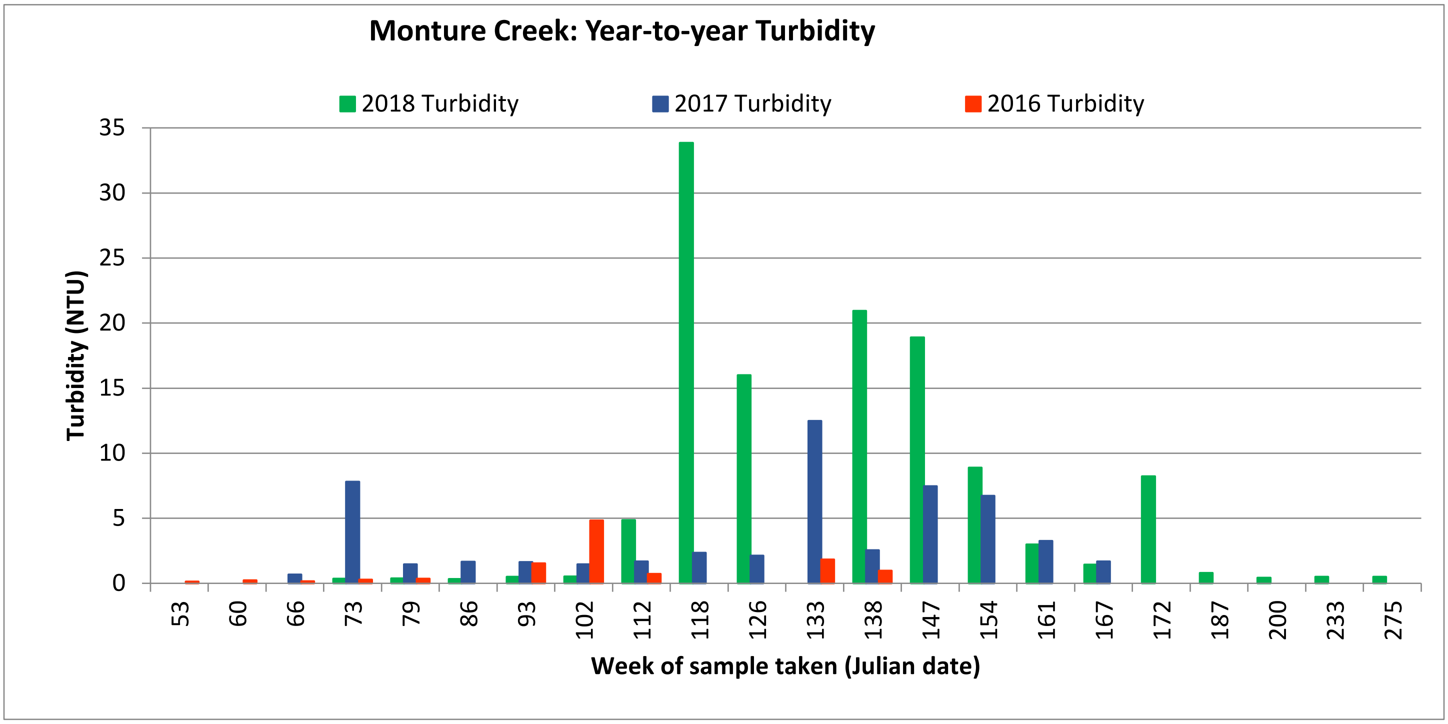
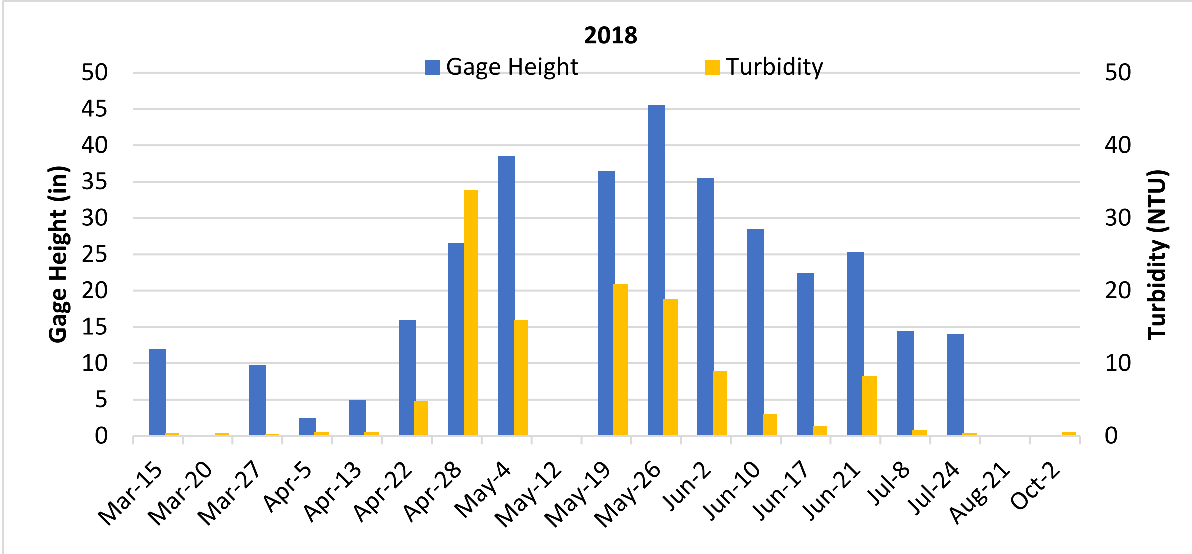
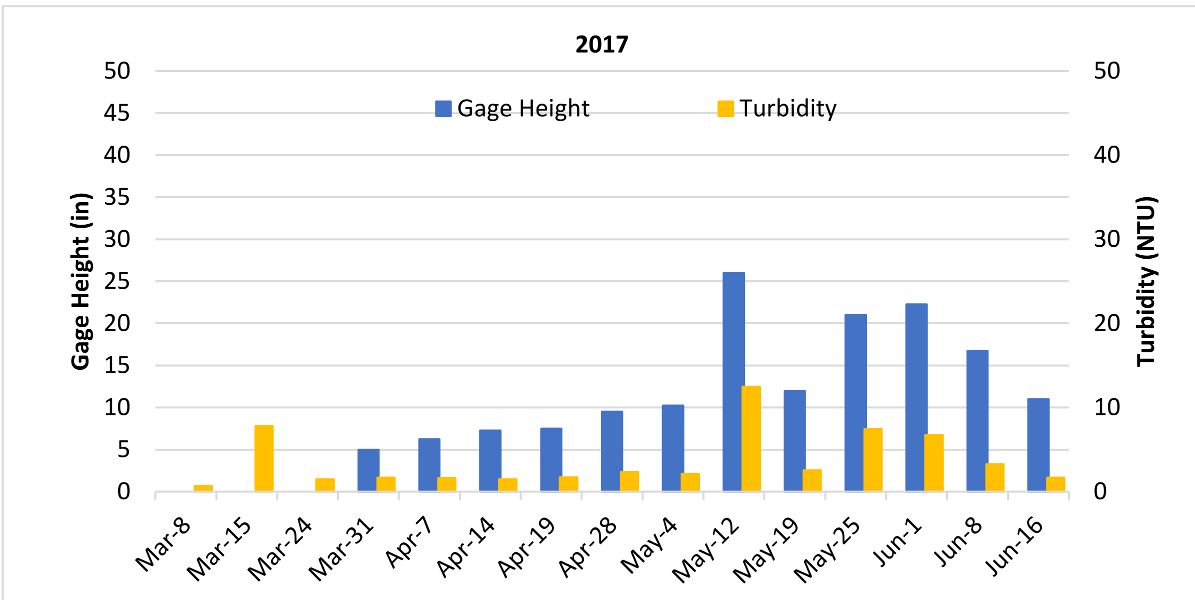


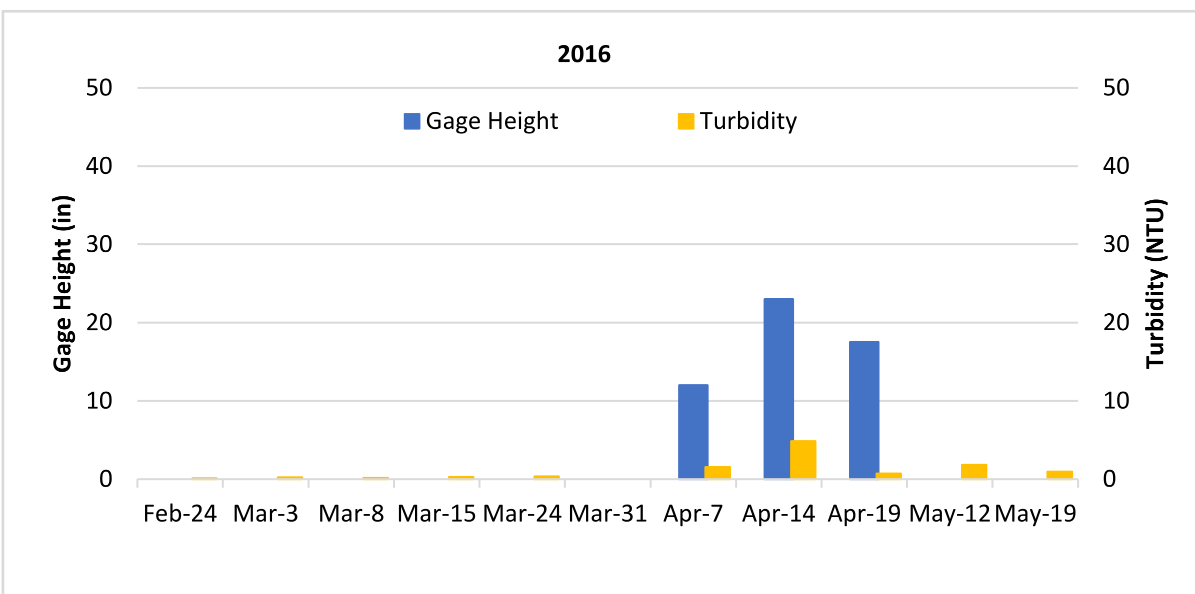
Figure 36 – Turbidity results for each week of sampling during years 2018, 2017 and 2016

Monture Creek

Figures 37, 38, and 39 – Gage height (water level) relative to turbidity results for each week of sampling during years 2018, 2017, and 2016
Note that in 2016 gage height data was only collected 4/7, 4/14, and 4/19 for Monture Ck.







Monture Basin: **Dunham Creek** 3rd order tributary

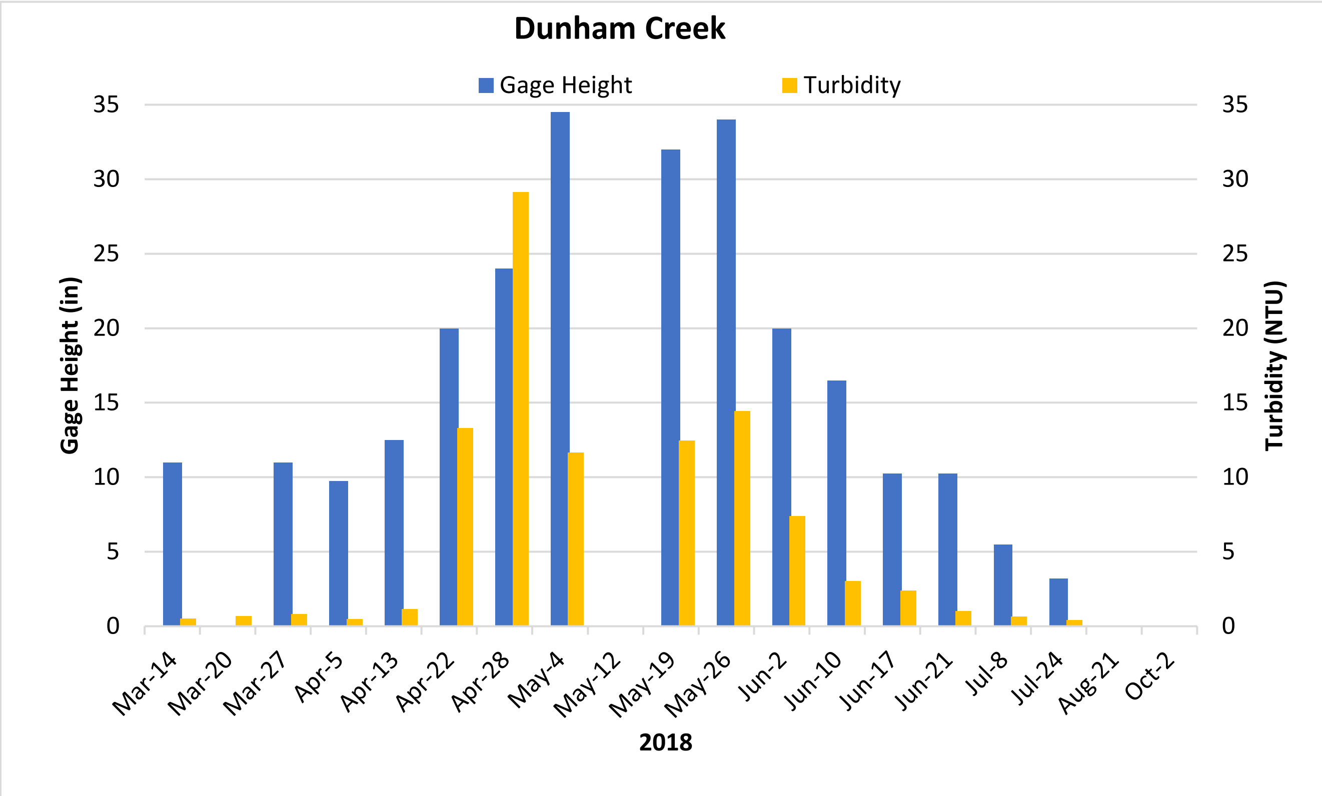


Figure 40

Cottonwood Basin: **Shanley Creek** 1st order tributary

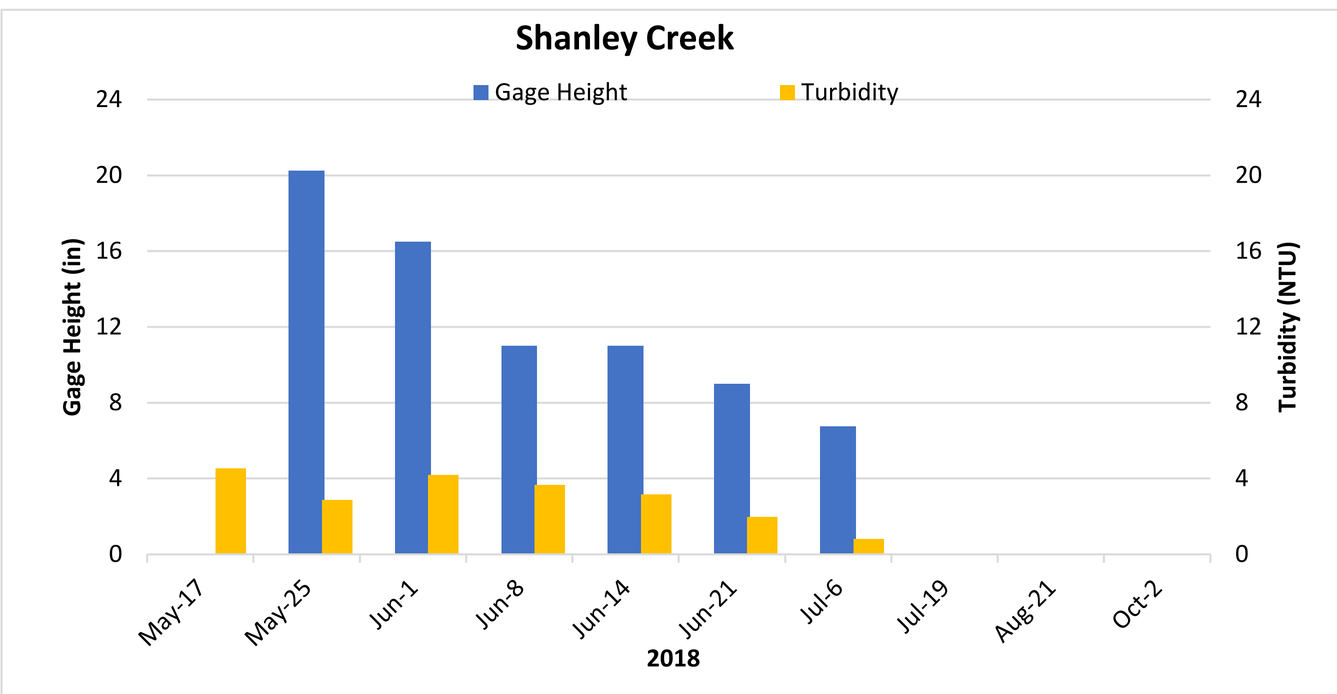


Figure 41

NOTE: Stream acronyms are as follows: Black Canyon Creek- **BLA**, Little Shanley Creek- **LSH**, North Fork Cottonwood Creek- **NFC**, Cottonwood Spring Creek- **SPR**, Upper Cottonwood Creek- **UCW**, McCabe Creek- **MCC**, and Monture Creek- **MON**

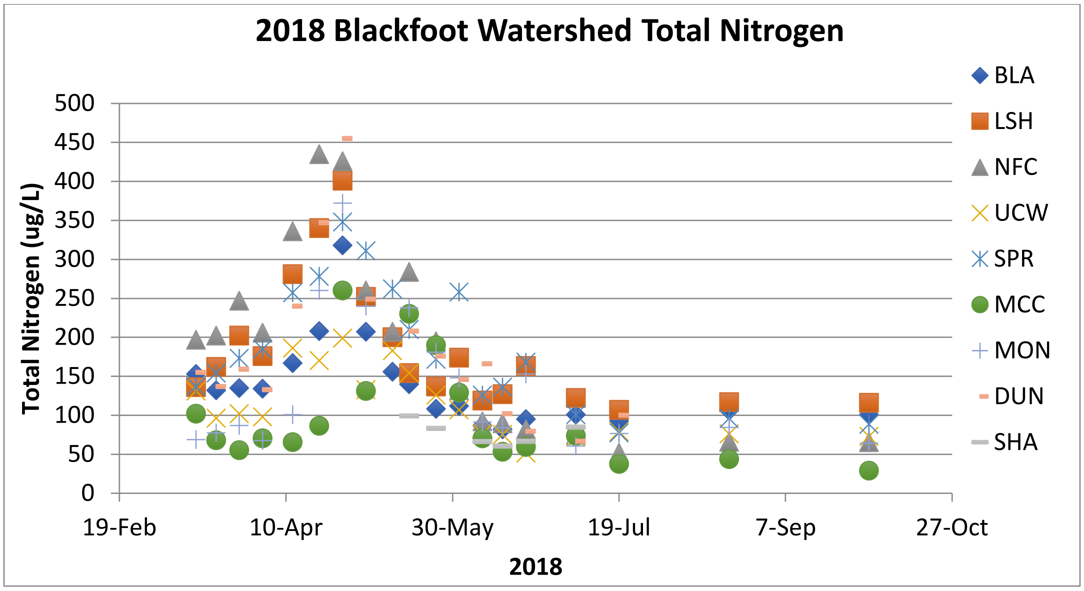


Figure 42 – Total Nitrogen amounts for each stream over the 2018 sampling period

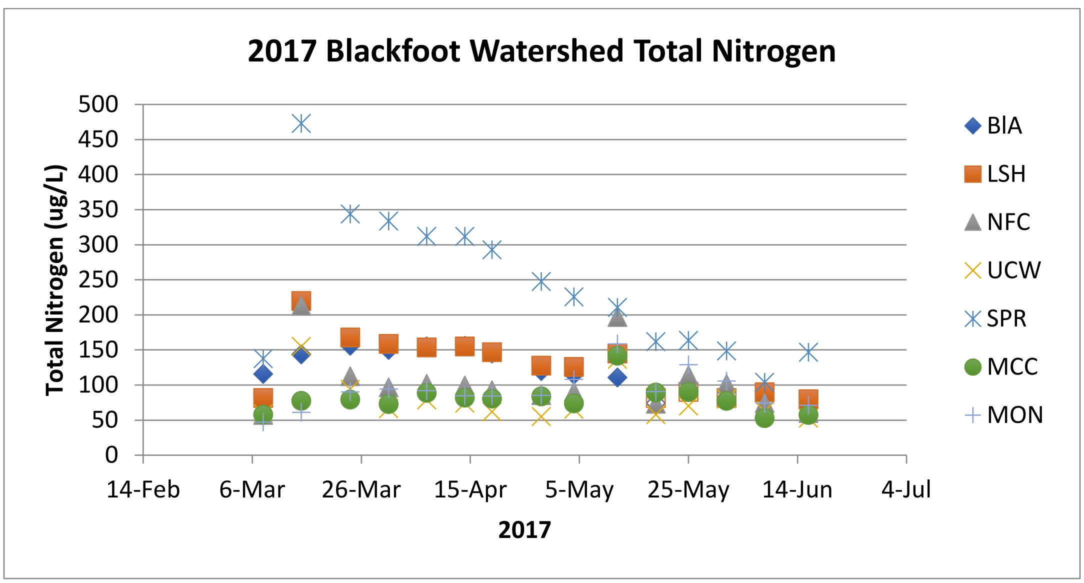


Figure 43 – Total Nitrogen amounts for each stream over the 2017 sampling period

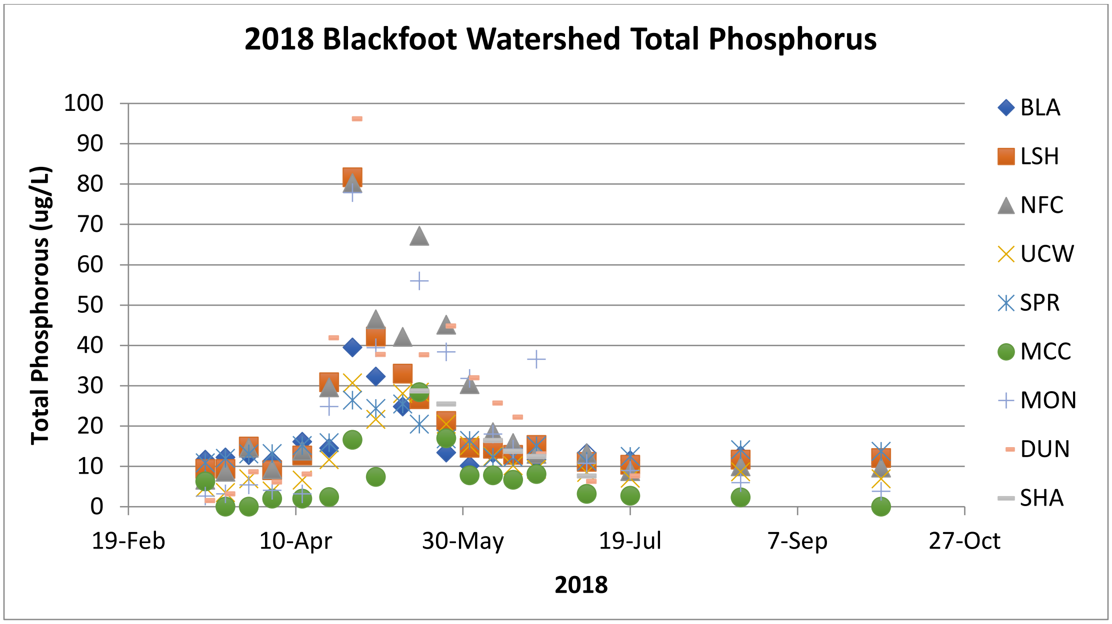


Figure 44 – Total Phosphorus amounts for each stream over the 2018 sampling period

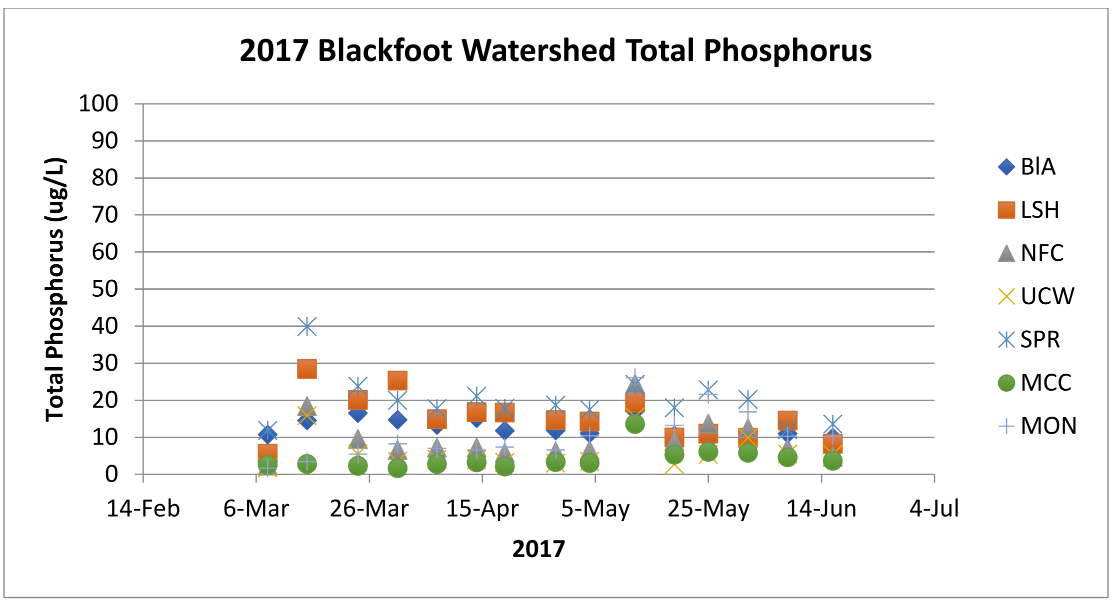


Figure 45– Total Phosphorus amounts for each stream over the 2017 sampling period

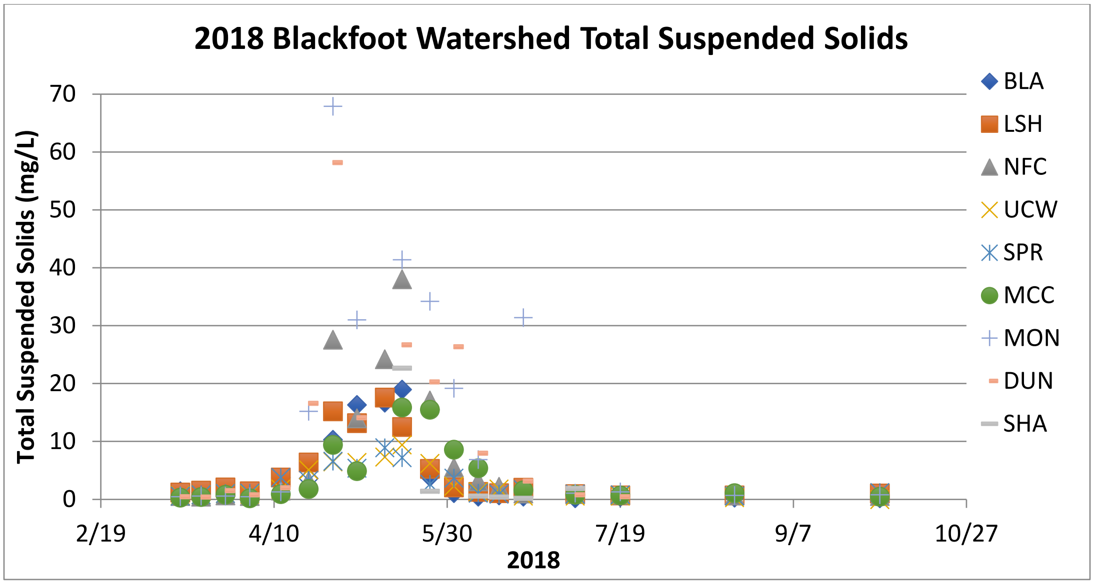


Figure 46 – Total Suspended Solids for each stream over the 2018 sampling period

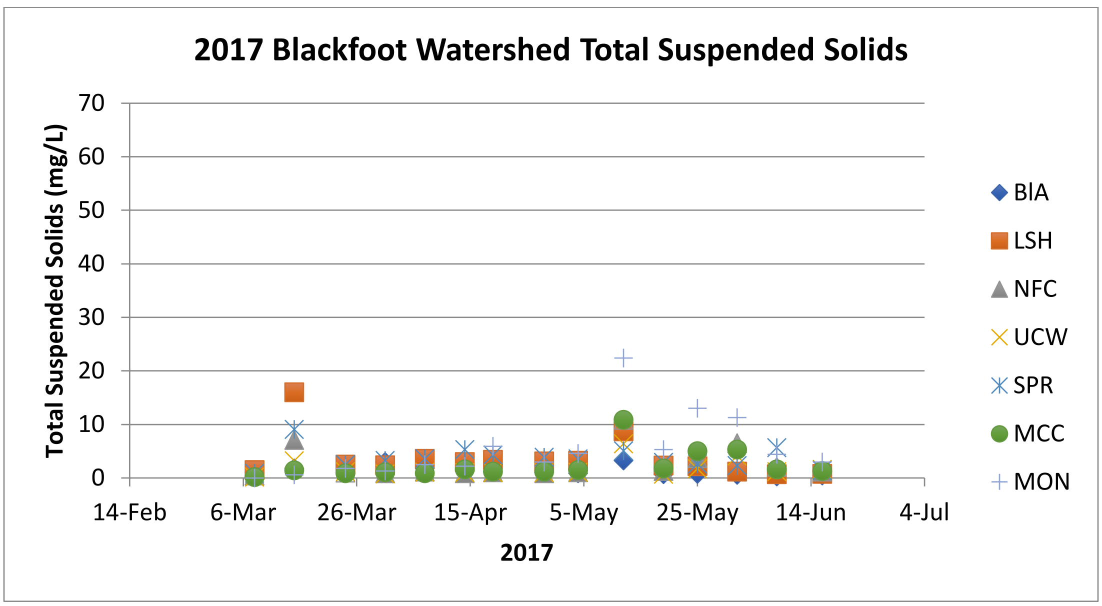


Figure 47 – Total Suspended Solids for each stream over the 2017 sampling period

2018 and 2017 Compared Individual Stream Data: Water Quality Monitoring

Cottonwood Basin: **Black Canyon Creek** 2nd order tributary, 19 samples in 2018 and 15 samples in 2017.

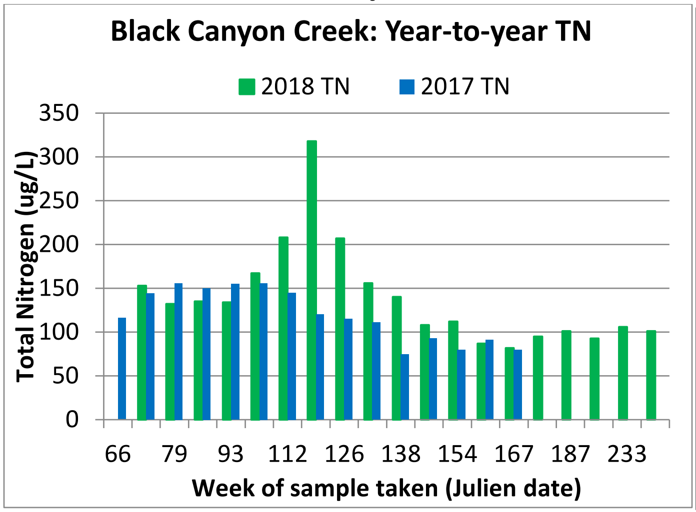


Figure 48 – TN = Total Nitrogen results for each week of sampling for years 2018 and 2017.

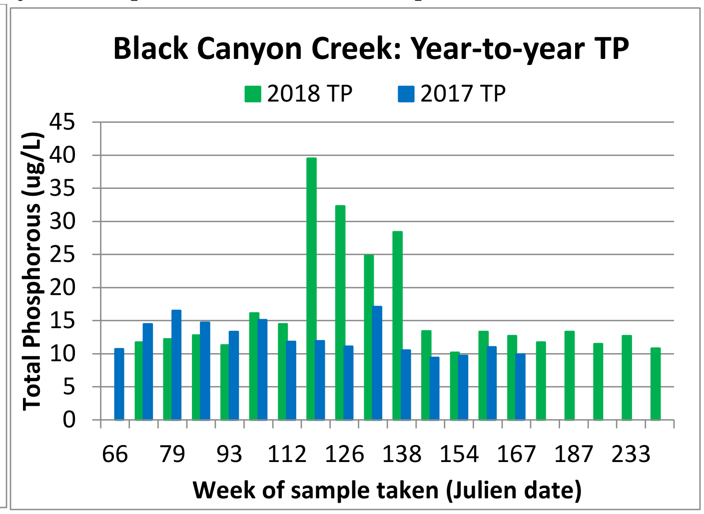


Figure 49– TP = Total Phosphorus results for each week of sampling for years 2018 and 2017.

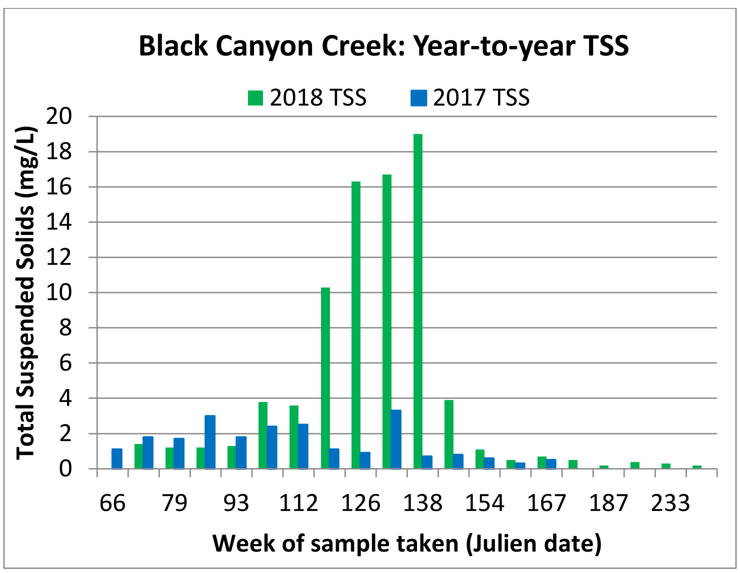


Figure 50 – TSS = Total Suspended Solids results for each week of sampling for 2018 and 2017.

Cottonwood Basin: **Little Shanley Creek** 1st order tributary, 19 samples in 2018 and 15 samples in 2017.

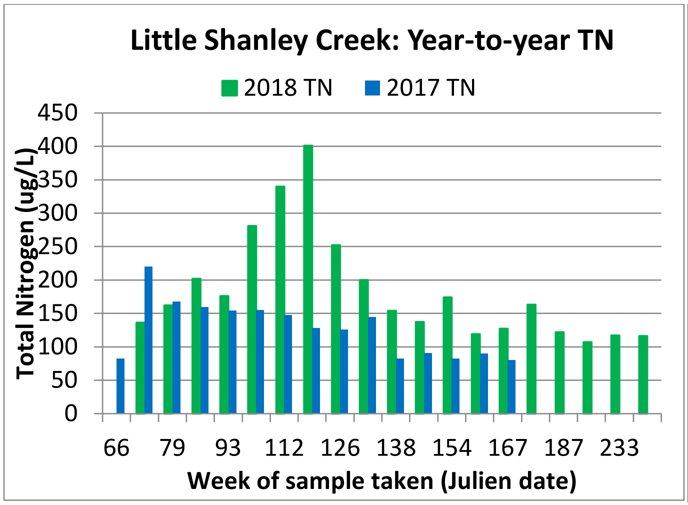


Figure 51 –TN = Total Nitrogen results for each week of sampling for 2018 and 2017.

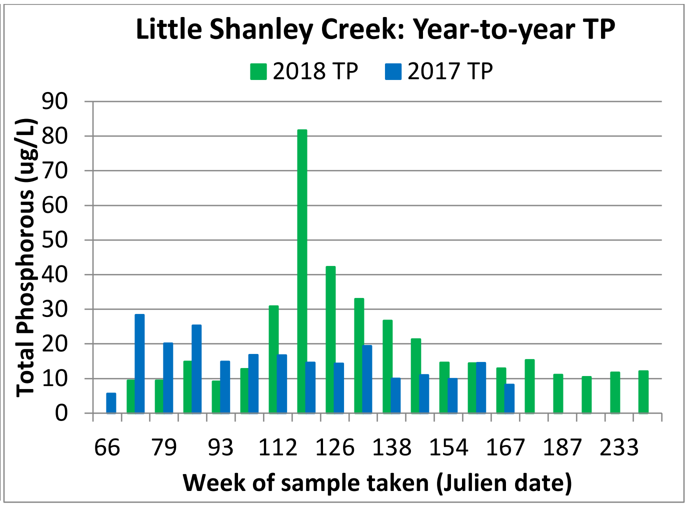


Figure 52 –TP = Total Phosphorus results for each week of sampling for 2018 and 2017.

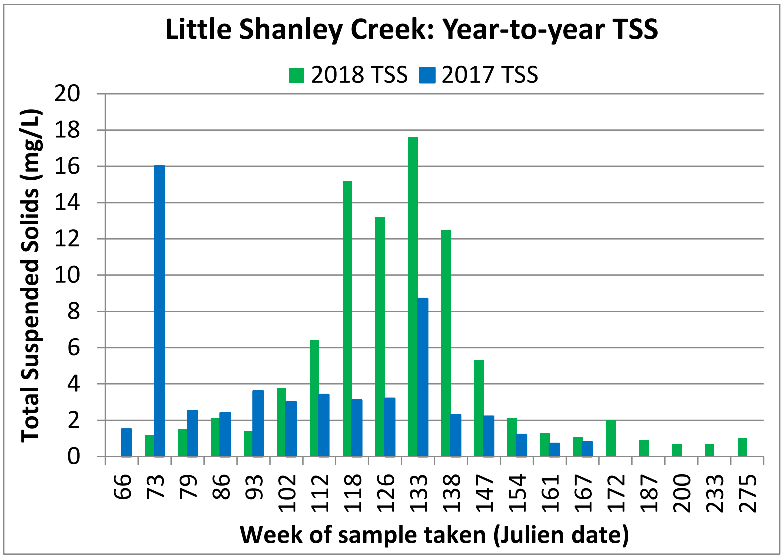


Figure 53 –TSS = Total Suspended Solids results for each week of sampling for 2018 and 2017.

Cottonwood Basin: **North Fork Cottonwood Creek** 3rd order tributary, 19 samples in 2018 and 15 samples in 2017.

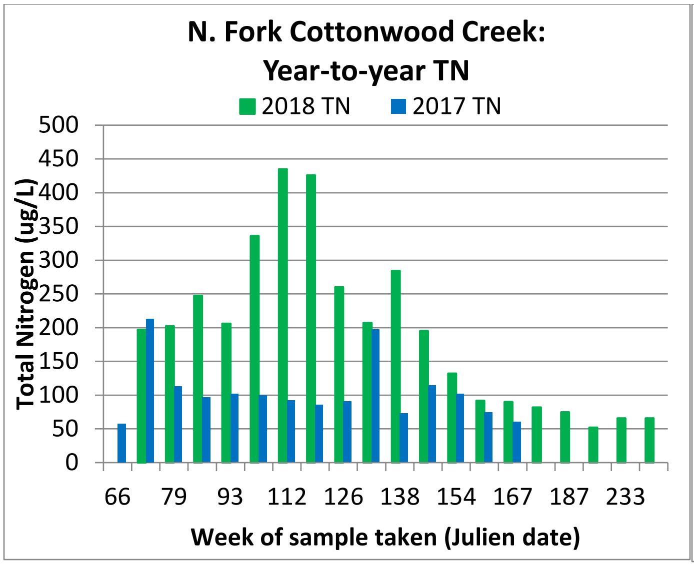


Figure 54 – TN = Total Nitrogen results for each week of sampling for 2018 and 2017.

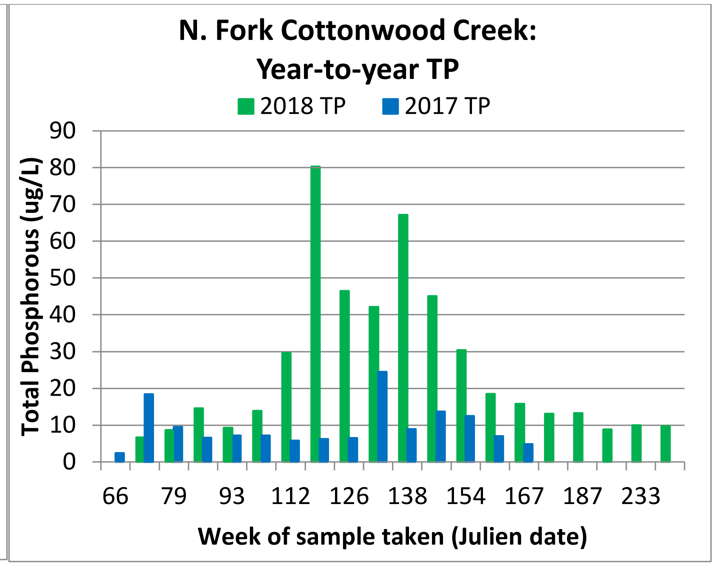


Figure 55 – TP = Total Phosphorus results for each week of sampling for 2018 and 2017.

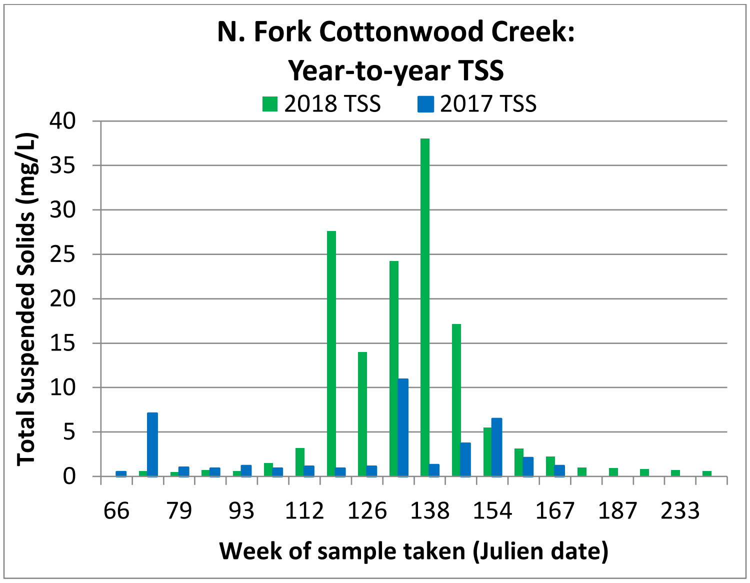


Figure 56 – TSS = Total Suspended Solids results for each week of sampling for 2018 and 2017.

Cottonwood Basin: **Cottonwood Spring Creek** 3rd order tributary, 19 samples in 2018 and 15 samples in 2017.

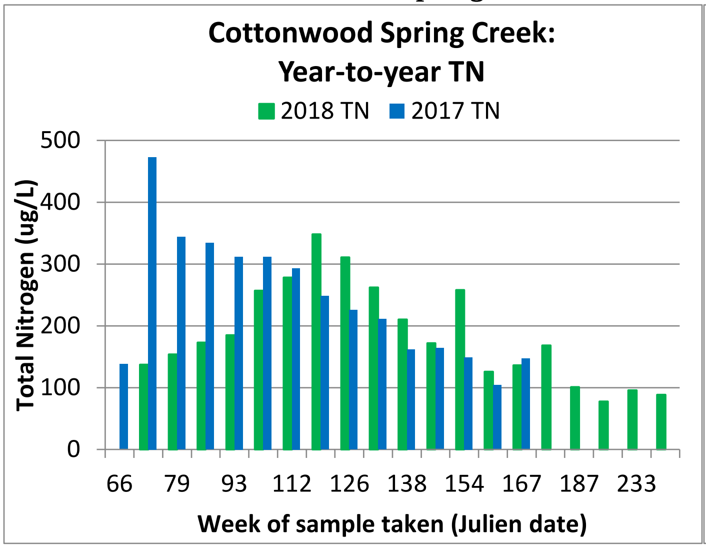


Figure 57 – TN = Total Nitrogen results for each week of sampling for 2018 and 2017.

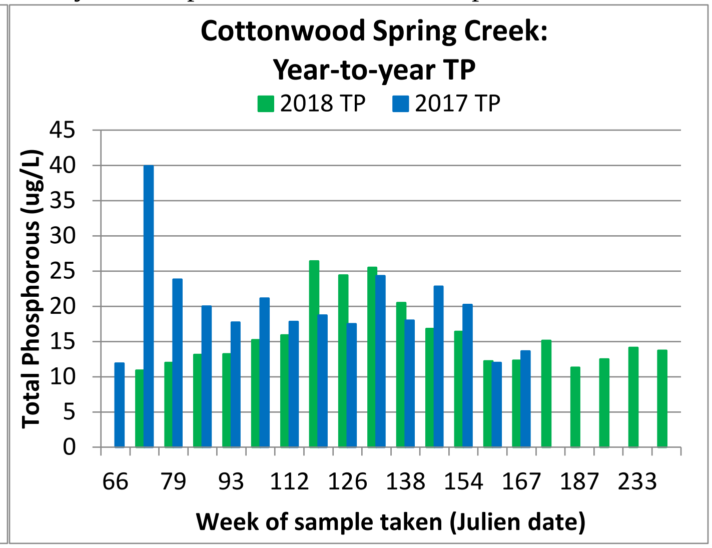


Figure 58 – TP = Total Phosphorus results for each week of sampling for 2018 and 2017.

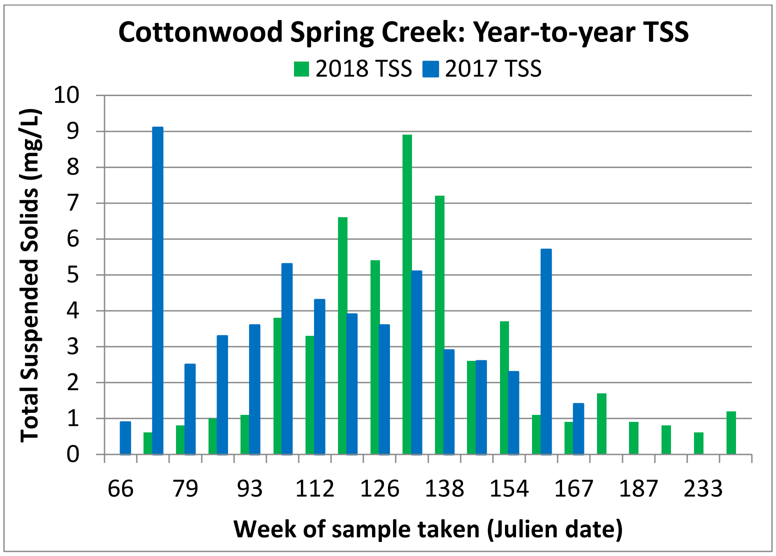


Figure 59 – TSS = Total Suspended Solids results for each week of sampling for 2018 and 2017.

Cottonwood Basin: **Upper Cottonwood Creek** 2nd order tributary, 19 samples in 2018 and 15 samples in 2017.

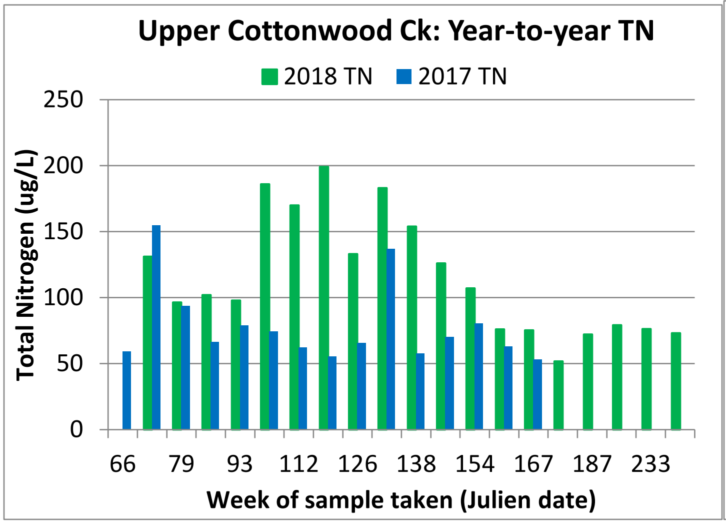


Figure 60 – TN = Total Nitrogen results for each week of sampling for 2018 and 2017.

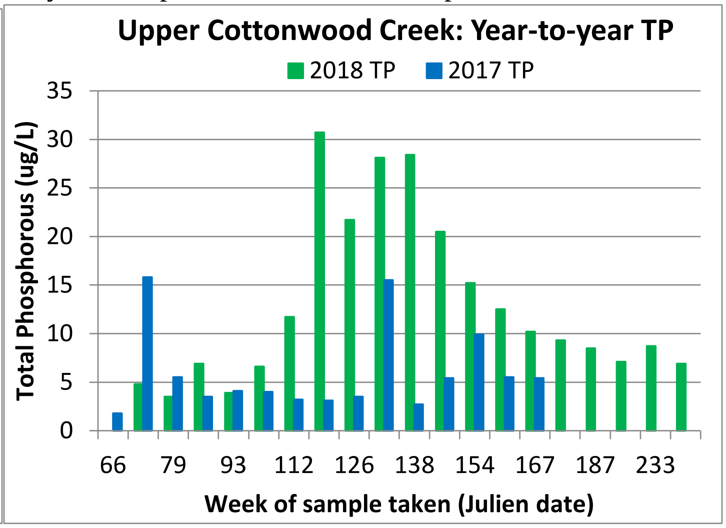


Figure 61 – TP = Total Phosphorus results for each week of sampling for 2018 and 2017.

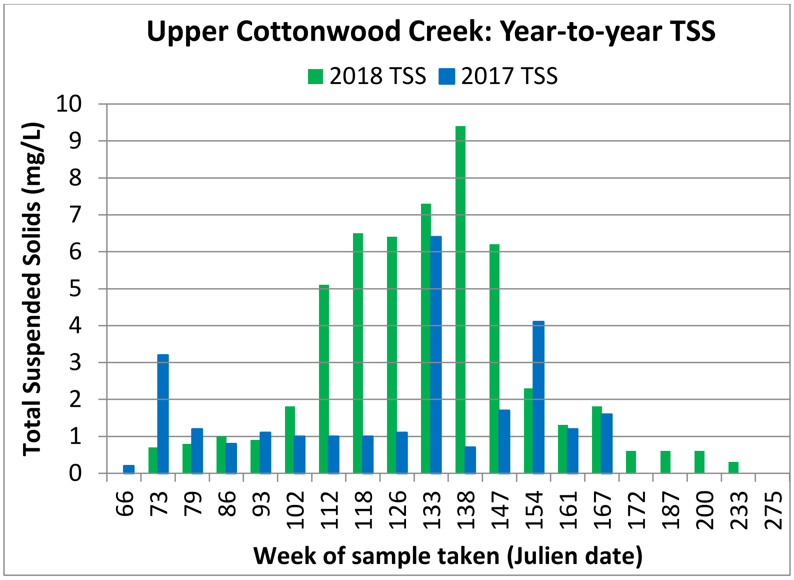


Figure 62 – TSS = Total Suspended Solids results for each week of sampling for 2018 and 2017.

Dick Creek Basin: **McCabe Creek** 2nd order tributary, 18 samples in 2018 and 15 samples in 2017.

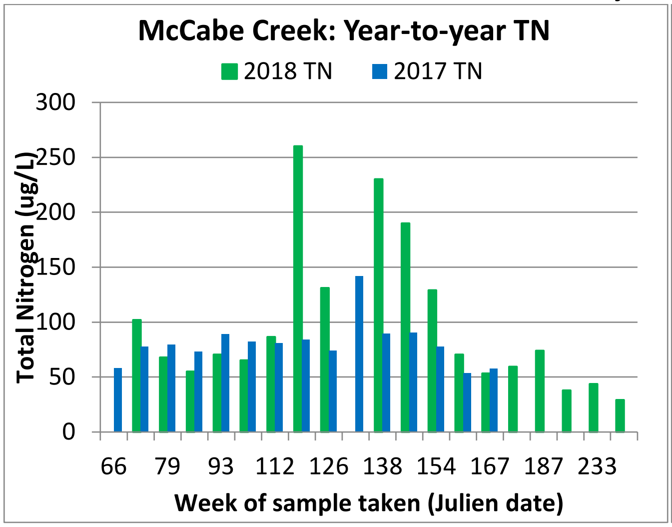


Figure 63 – TN= Total Nitrogen results for each week of sampling for 2018 and 2017.

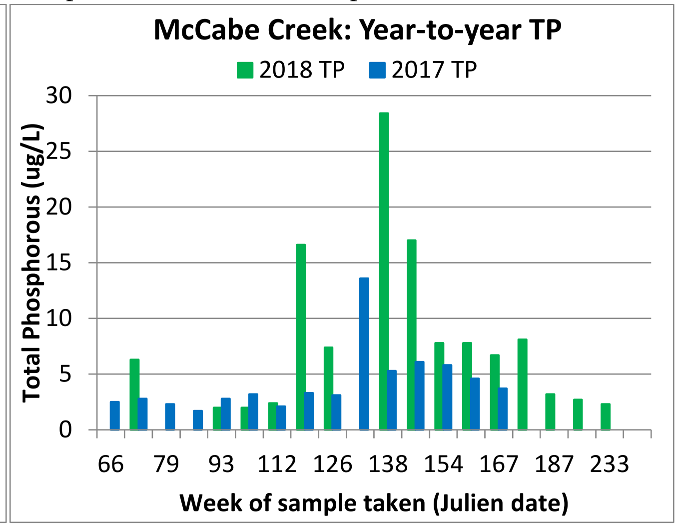


Figure 64 – TP = Total Phosphorus results for each week of sampling for 2018 and 2017.

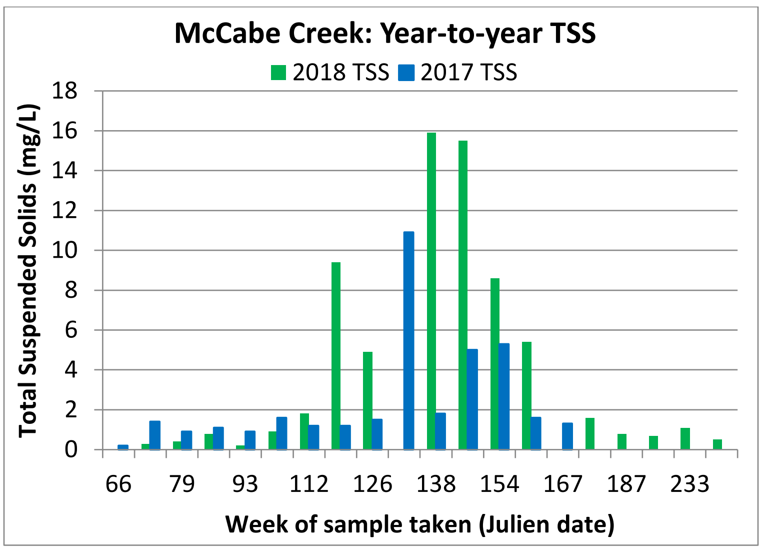


Figure 65 – TSS = Total Suspended Solids results for each week of sampling for 2018 and 2017.

Monture Basin: **Monture Creek** 4th order tributary, 18 samples in 2018 and 15 samples in 2017.

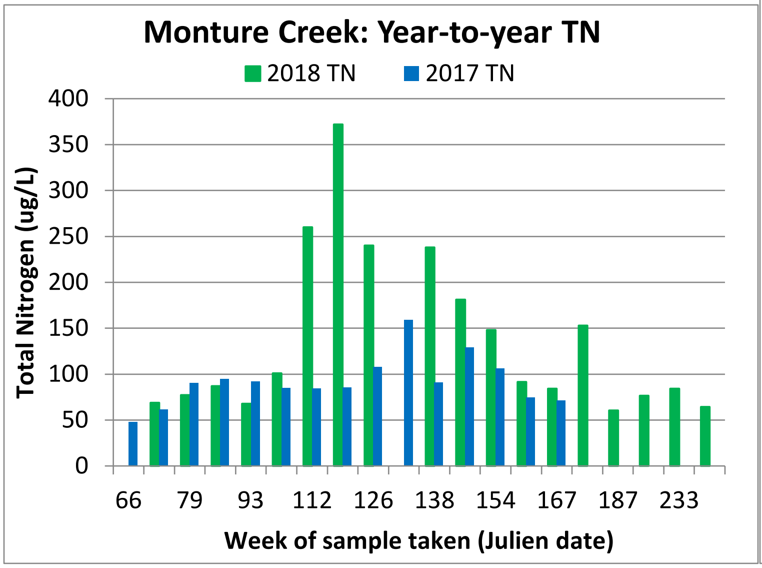


Figure 66 – TN = Total Nitrogen results for each week of sampling for 2018 and 2017.

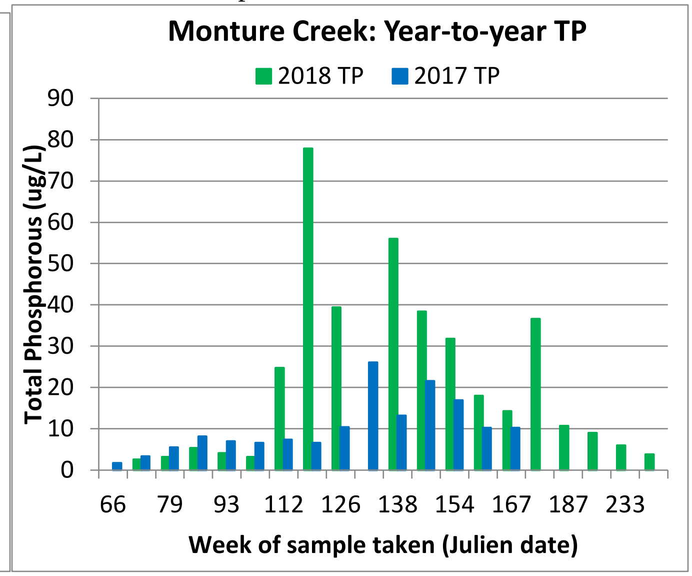


Figure 67 – TP = Total Phosphorus results for each week of sampling for 2018 and 2017.

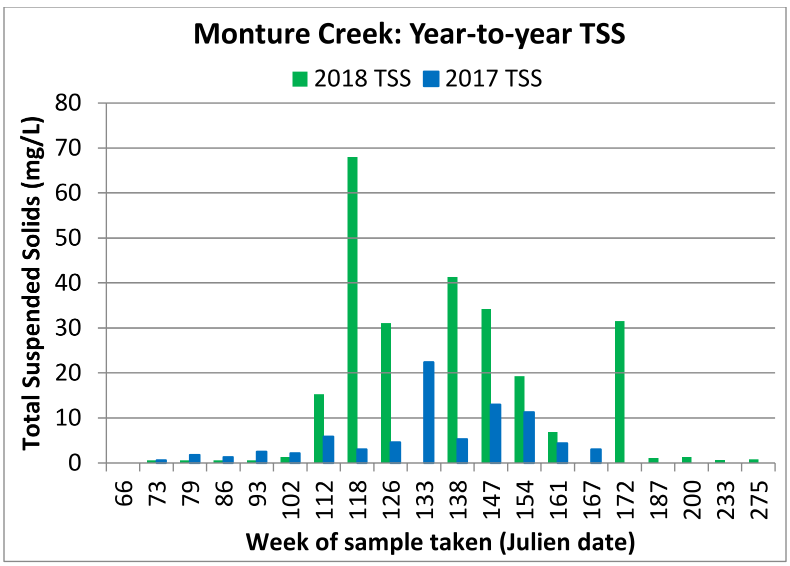


Figure 68 – TSS = Total Suspended Solids results for each week of sampling for 2018 and 2017.

Monture Basin: **Dunham Creek** 3rd order tributary, 16 samples in 2018 and 0 samples in 2017.

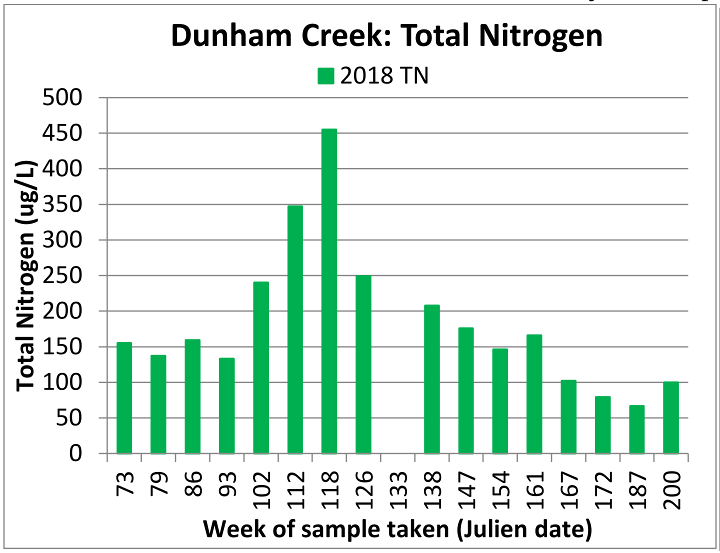


Figure 69 – Total Nitrogen results for each week of sampling.

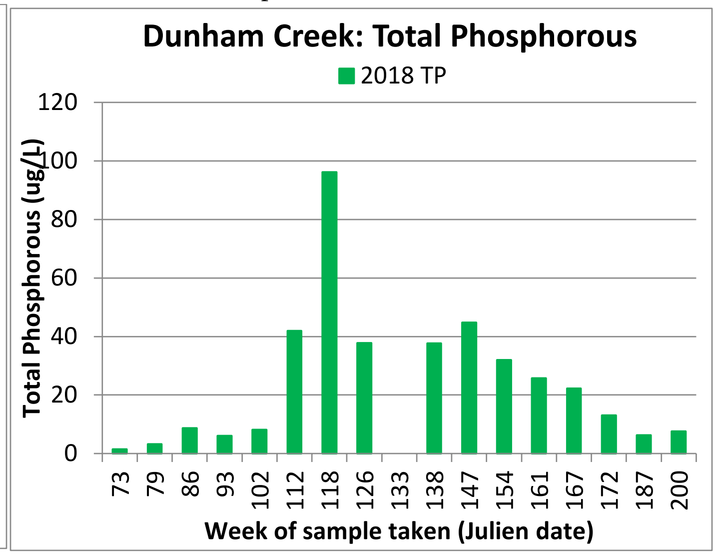


Figure 70 – Total Phosphorus results for each week of sampling.

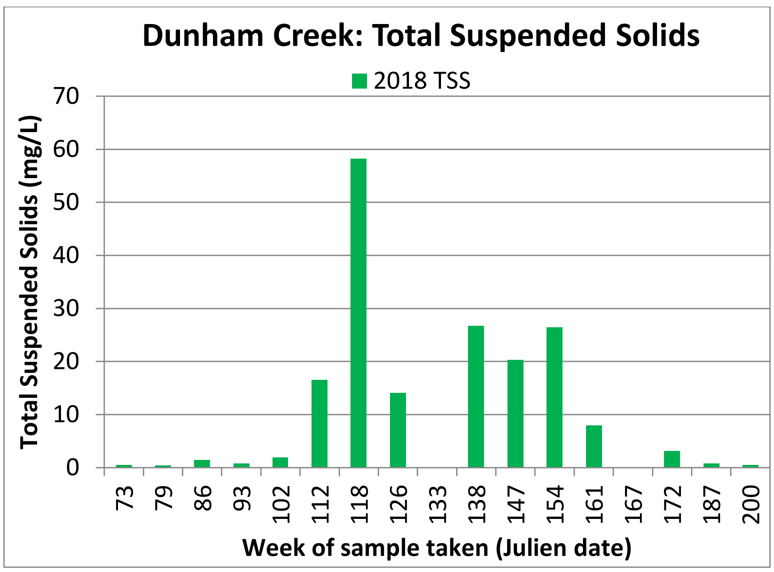


Figure 71 – Total Suspended Solids results for each week of sampling.

Cottonwood Basin: **Shanley Creek** 1st order tributary, 6 samples in 2018 and 0 in 2017.

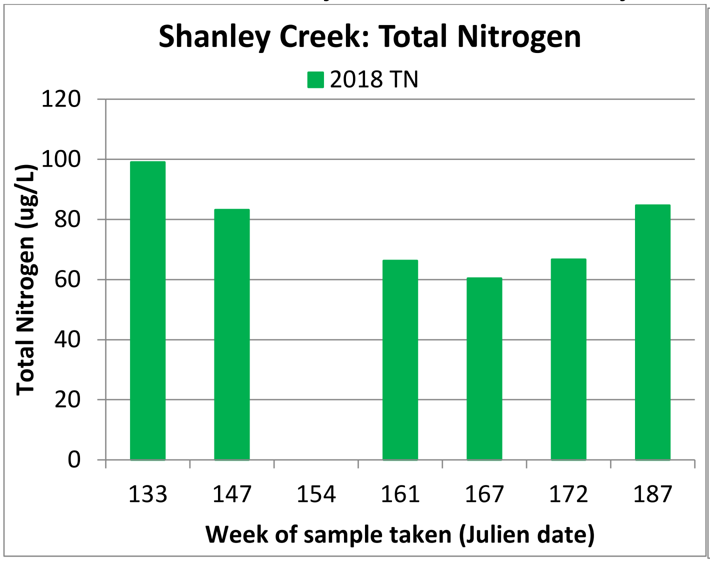


Figure 72– Total Nitrogen results for each week of sampling.

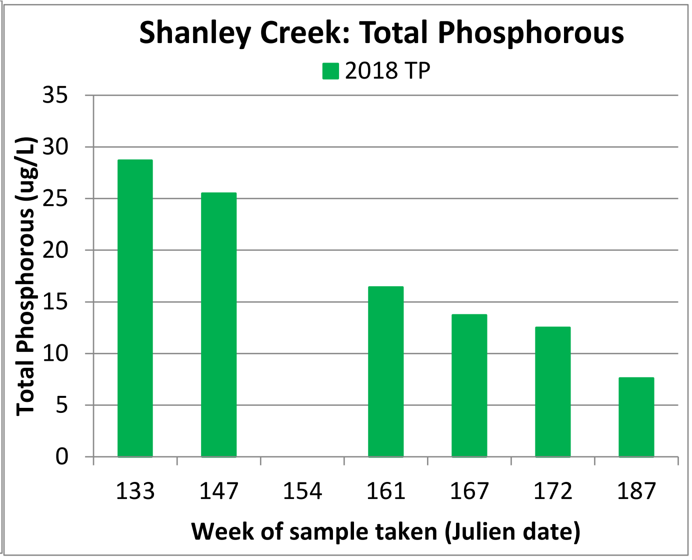


Figure 73 – Total Phosphorus results for each week of sampling.

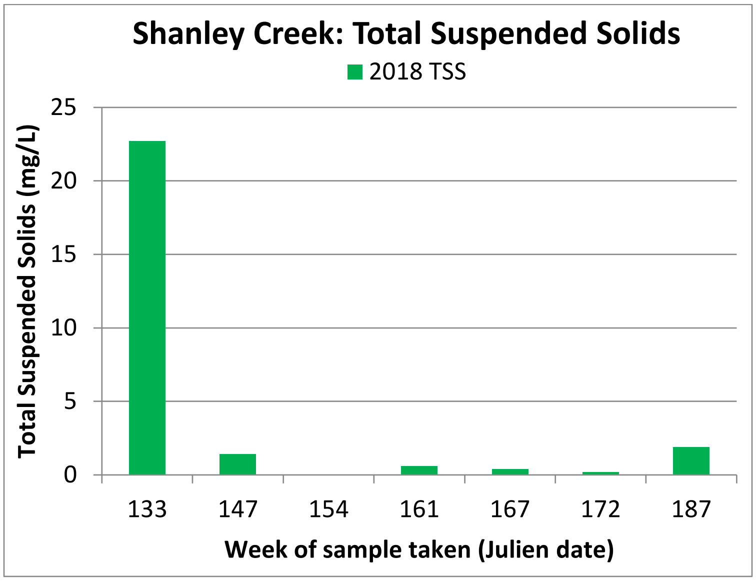


Figure 74 – Total Suspended Solids results for each week of sampling.

Parameter correlations

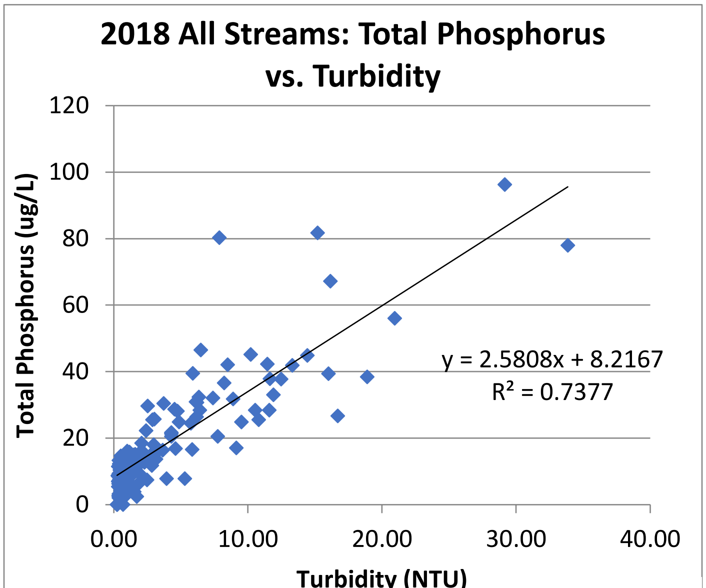


Figure 75

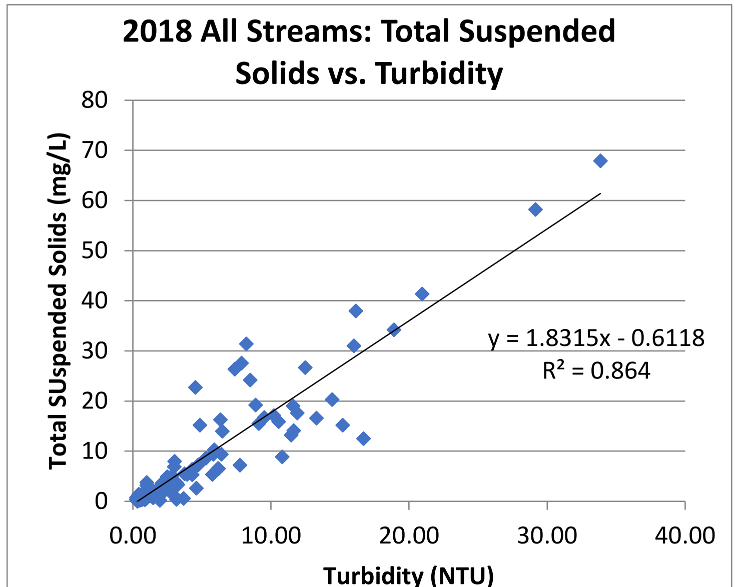


Figure 76

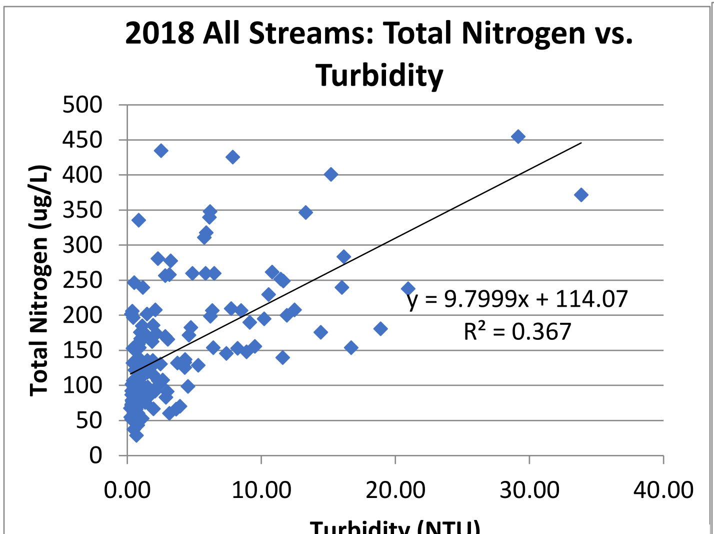


Figure 77

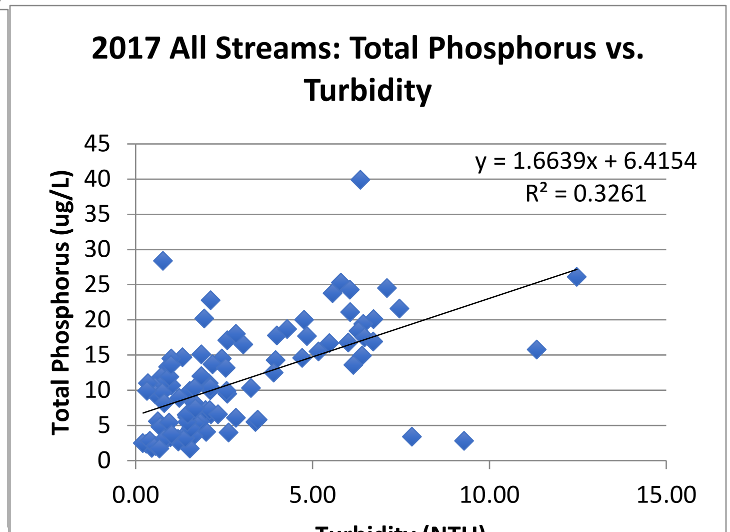


Figure 78

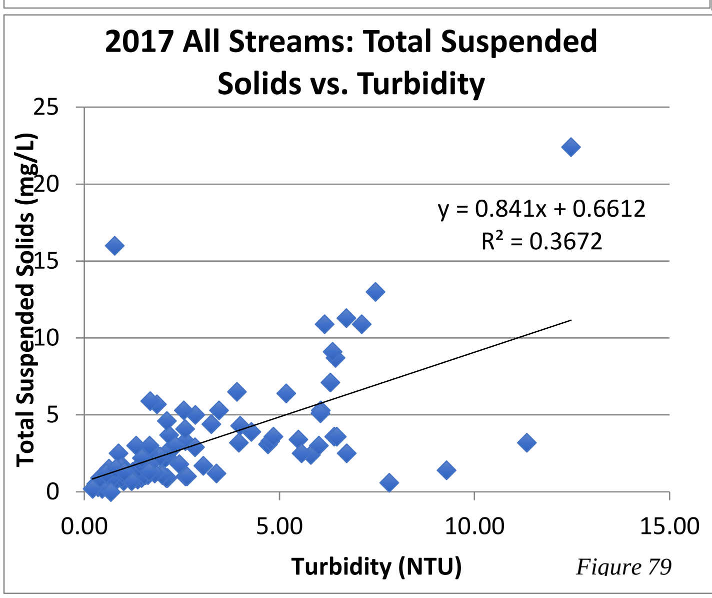


Figure 79

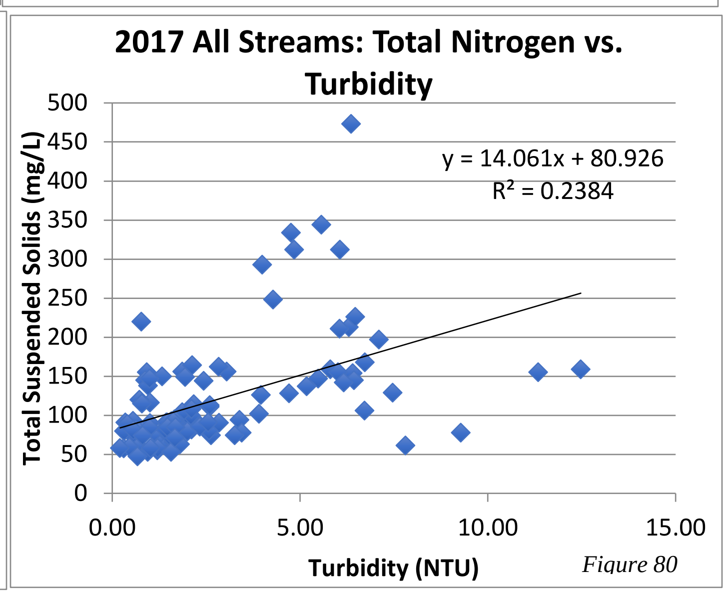


Figure 80