SPANISH CREEK WATER QUALITY

by

Carolyn Ruth Nealen

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DEDICATION

I would like to dedicate this paper to three very important people: Sharon Benjey, Richard Grannis, and Dr. Laura Eidietis. Sharon Benjey, my mother, was my very first science instructor. Everywhere we went she constantly pointed out and identified the various flowers, trees, birds, and insects. It is entirely her fault that I love nature, particularly insects, so much and I am eternally grateful for the early education which sparked a love of science. Richard Grannis nurtured that love through his Advanced Biology class during high school. During fourth quarter we had to stake out an area in the outdoor lab, identify every living organism that we could, and create a guidebook for our plot. That project whetted my appetite for field work. Finally, I would like to thank Dr. Laura Eidietis for storming into my Biology for Elementary School teachers at Eastern Michigan University, in the spring of 2006, and stating that she needed a research assistant. My experience collecting crayfish and benthic macroinvertebrates, running predation experiments, and participating Eastern Michigan University's Undergraduate Research Symposium have been invaluable.

ACKNOWLEDGEMENTS

First and foremost, I need to express my gratitude to my family for helping me with this research project. Thank you so much to my husband, son, and mother for spending hours with me at Spanish Creek, regardless of the weather. Thank you for helping to carry equipment, recording flow measurements I yelled to you, and helping with many other miscellaneous tasks. Thank you to my in-laws and father for the moral support you provided.

I would like to thank Dr. Graves and Amber Kirkpatrick for their guidance on this research project. Thank you for being so willing to jump on board when I needed to switch projects and for the invaluable advice you both provided.

A giant thank you to Adam Sigler and Holly Kreiner at the Montana State University Water Quality Extension Office for teaching me how to use a flow meter and lending me one for the duration of this project.

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ABSTRACT

Spanish Creek's water quality was monitored over several months, through collection of data from nine parameters. Specific data from two sites were compared to determine the impact of recreational use upon overall stream health. Macroinvertebrates were also sampled. Data was graphed and analyzed for patterns. Results suggest that Spanish Creek's water quality is Good and that recreational use does not negatively impact stream health.

INTRODUCTION AND BACKGROUND

Spanish Creek

Spanish Creek is a first order stream the source of which is Summit Lake, in the Bear Basin area of the Spanish Peaks, a branch of the Madison Range. It flows into the Gallatin River near Gallatin Gateway, Montana, approximately 80 miles from the Gallatin's source in the northwest corner of Yellowstone National Park. The Gallatin River flows through the Gallatin Valley, which is an intermontane basin covering an area of about 540 square miles. Spanish Creek is part of the Missouri region (10), Missouri headwaters subregion (1002), and Greater Gallatin watershed (10020008). Hydrological unit code numbers (HUC), found after each region, are used to identify the geographical location of a waterway. The section of Spanish Creek sampled for this study is located in the Spanish Peaks unit of The Lee Metcalf Wilderness Area (Figure 1). Two sampling sites were established above and below the foot bridge used by Spanish Creek Trail to ; downstream (DS) at 45°26'54.31"N, 111°22'41.61"W and upstream (US) at 45°26'53.18"N, 111°22'41.72"W (Hackett, Vishner, McMurtrey, & Steinhilber, 1960; Hydrological Unit Maps, 2018; Google Earth, 1995).

Figure 1. Map of Spanish Creek sampling sites

History of Water Quality in Montana

The state of Montana began publishing water quality reports in 1992, but until 1997 there was much confusion regarding which agency was responsible for monitoring water quality. This was also complicated by the lack of defined methodology and insufficient staff resources. In 1997, new legislation created the Department of Environmental Quality (DEQ) which was to be responsible for monitoring water quality in the state of Montana. It is also important to note that until 2000, water quality reports contained data on some water bodies under federal and tribal jurisdiction. The 303(d) List for 2000 notes the EPA determination that, while states could monitor up to federal and tribal boundaries, they were to exclude waters within federal and tribal boundaries. For example, Montana DEQ only monitors the non-tribal portions of Flathead Lake. (Montana 303(d) list Parts A and B, 2000).

In 1989, a gauging station was placed just above the confluence of Spanish Creek into the Gallatin River, to measure monthly and yearly runoff. Though Hacket et al. reported data for this station, through 1954, the United States Geological Society (USGS) website has no data prior to 1994. The USGS does have a stream site on Spanish Creek (USGS-452700111223201) found at 45.4499285 degrees latitude and -111.3763487 degrees longitude. The only data available on the USGS website for this station was collected between April 30, 1987 and October 28, 1987 (Hackett, et al., 1960; "*USGS Current Conditions," 2018; "Water Quality Samples for USA," 2018*).

Chemical analysis of surface water was collected by USGS just above Spanish Creek's confluence into the Gallatin River, in August 1949 and September of 1951, and just below the confluence, in June and October of 1949. Data from the USGS stream site was not accessible online, other than a brief statement of what type of data was collected: temperature, water temperature, discharge, water conductance, and an unspecified water sample (Hackett, et al.; *"Water Quality Samples for USA," 2018*). In 2017, I inquired of the Greater Gallatin Watershed Council whether they had any chemical analysis or other data from Spanish Creek and was told they did not.

Although water quality assessment in Montana has been sporadic, it has been moving in a positive direction. By 1998, the 303d report stated that 17,874 stream miles and 789,583 lake acres had been assessed. For the 2010 Integrated Water Quality Report, the state moved from medium resolution NHD (National Hydrography Dataset) to high resolution NHD, which provided a more accurate picture of Montana's waterbodies. For example, medium resolution NHD showed 40,826 perennial stream miles while high resolution NHD showed 49,099 perennial stream miles.

Insufficient funding and personnel have made citizen monitoring and assessment of streams important.

CONCEPTUAL FRAMEWORK

Chemical analysis of water samples is necessary to determine the health of a body of water, a stream in this case. This data is used to calculate a water quality index or WQI. Nine parameters are used to determine a WQI; dissolved oxygen, fecal coliform, pH, biochemical oxygen demand (BOD), temperature, total phosphates (PO^3), nitrates (NO^3), turbidity, and total dissolved solids (TDS). Macroinvertebrates can also be used, to some extent, as indicators of stream health. Flow has a direct impact on all the previously mentioned, as well as on macroinvertebrate populations (Mitchell & Stapp, 2008).

Dissolved oxygen (DO), is the amount of free oxygen dissolved in water that is usable by aquatic organisms. Dissolved oxygen levels are directly affected by water temperature, altitude, and barometric pressure. Warmer water temperatures lead to increased plant life which, through the decay process, leads to lower dissolved oxygen levels. Oxygen is more readily dissolvable in water at higher altitudes because of the increase in atmospheric pressure. Powers (1929) notes that lower temperatures and higher altitudes can lead to oxygen supersaturation, where DO levels can exceed 100%. (Mitchell & Stapp, 2008)

Fecal coliform bacteria are found in the feces of warm-blooded animals, such as humans, dogs, and horses, and while they are not pathogens in and of themselves, there is a direct relationship between the number of colonies in a water source and the likelihood of contracting disease. Spanish Creek is a recreation area with numerous multi-use trails popular with hikers and horseback riders; a large percentage of which are accompanied by a dog or two. The main stream crossing is a foot bridge with a cobbled horse crossing directly upstream. In their article, Flack, Medine, and Hansen-Bristow (1988) reference a study done in a recreation area in Utah that found an increase in fecal coliform colonies during peak recreational season, with a sharp decrease directly afterwards. (Mitchell & Stapp, 2008).

The pH of water is the negative log of hydrogen ions present, ranging from 0-14; 7 is considered neutral while above is alkaline and below is acidic. Sutcliffe and Carrick (1973) noted that macroinvertebrate diversity in English streams increased when the pH of a stream rose over 5.7. Streams in the United States generally have a pH range of 6.5 to 8.5. Most aquatic organisms have a very narrow tolerable pH range, which is around the pH range for the US. Higher or lower pH values lead to death. Dead organisms are then fed on by bacteria which, at high concentration levels, increase the BOD, turbidity, and temperature of water (Mitchell & Stapp, 2008).

Biochemical oxygen demand (BOD), is, “a measure of the amount of oxygen consumed by organic matter and associated microorganisms in the water over a five-day period” (Mitchell & Stapp, 2008, pg. 63). Lee, Lee, Yu, and Rhew (2016) state that BOD is used worldwide to determine organic pollutants in water. High BODs indicate that oxygen is being consumed at a great rate, which is generally due to excessive organic nutrients, such as nitrates and phosphates. Such nutrients increase plant growth. Bacteria feed upon decaying plant matter, leading to increased oxygen usage. Excessive oxygen consumption by bacteria decreases the amount of oxygen available for other aquatic organisms, such as benthic macroinvertebrates and fish, to use. Agricultural run-off, sewage, and many other human industries can add excessive organic nutrients to water systems, causing an increase in BOD (Mitchell & Stapp, 2008).

Temperature directly affects DO levels, macroinvertebrate diversity and bacteria levels. Mitchell and Stapp state that temperature affects plant and microbe photosynthesis and metabolic rates. Xiangpeng and Shuhong (2014) noted in their study of Liaodong Bay that bacteria count increases with warmer temperatures. Bacterial increase leads to greater consumption of dissolved oxygen.

Organic phosphates and nitrates are essential for plant growth and generally occur in low amounts. These nutrients commonly enter a water system through animal waste, decomposing plant and animal matter, and fertilizer. Mitchell and Stapp (2008) note that sewage is the main avenue by which humans contribute excess nitrogen to rivers. Naturally occurring phosphates generally originate from forest fires and volcanic ash, while human added phosphates originate from fertilizers, animal waste, and detergents. Unusually high nitrate and /or phosphate levels can lead to an increase in plant and algae production. The additional algae deplete oxygen, cloud the water, raise water temperature and lower DO/BOD; resulting in algal blooms and eutrophication (dead zones). (Mitchel & Stapp, 2008).

Turbidity measures the transparency of a body of water, or lack thereof. Suspended materials in a body of water reduce clarity, which in turn reduces the amount of sunlight available to plants and other organisms. Suspended matter absorbs heat, resulting in warmer water and decreased dissolved oxygen levels. Excessive particulate matter can also pose a threat to fish as it can clog gills, causing suffocation, and smother eggs. Increases in turbidity can be caused by heavy stream flow, construction, and runoff eroding stream banks, which increase sediment load. In slower moving streams, algal growth can increase turbidity (Mitchell & Stapp, 2008).

Total Dissolved Solids (TDS) refers to the amount of dissolved inorganic solids found in a water source. Calcium, bicarbonate, nitrogen, and phosphorus are a few examples of inorganic solids that may be dissolved in water. Nitrogen and phosphates are necessary for life to flourish, but a careful balance must be maintained. If TDS is too high the stream can become choked with vegetation whereas, if it is too low, aquatic life will be restricted. Possible sources of dissolved solids include agricultural (nitrates and phosphates from fertilizer) and urban runoff (road salts and fertilizer). Higher levels of certain dissolved solids can lead to increased plant and algal growth. If the increases are significant, they can raise BOD and temperature, in addition to increasing turbidity. TDS and electrical conductivity (EC) are directly related as EC increases with the increase of salts in water (Mitchell & Stapp, 2008).

A stream’s flow, though not used to calculate a WQI, has a direct impact upon the factors that are used for such a calculation. Streams with higher flow rates are more easily able to self-clean, meaning that contaminants and particulate matter do not remain in them long. They also tend to have higher DO levels because more atmospheric oxygen is able to be mixed in.

Macroinvertebrates, while not a parameter needed for calculating a water quality index, can provide valuable information about the health of a stream. Invertebrate groups have different pollution tolerance levels. Stoneflies, mayflies, caddisflies, and riffle beetles are some of the most pollution intolerant, making them highly sensitive to changes in stream health. Mitchell and Stapp (2008) note that dragonflies, damselflies and crane flies are generally indicators of good water quality, while midges, black flies, and water mites can indicate poor water quality because they are generally more tolerant of contaminants. Additionally, tubifex and blood midges are quite tolerant of pollution. A sampling of the macroinvertebrate population can therefore give one a general idea of a body's water quality. Richards (1996) notes that the use of macroinvertebrates as water quality indicators may have begun as early as 1848, when Kolenati noted that the pollution of a European stream destroyed a downstream population of caddisflies.

As humans and other organisms are so dependent upon fresh water, it is extremely important to monitor sources such as streams, rivers, ponds, and lakes. Changes in the health of fresh water bodies have a significant impact upon our lives and the lives of organisms we are dependent upon. As previously noted, Spanish Creek flows into the Gallatin River. Farming and ranching are very large industries in the Gallatin Valley. According to Hackett, et al., 75% of water used for irrigation comes from the Gallatin River. Richards (1960) cites Montana 305(b) Report in his thesis, which states that only 10% of Montana's streams have been monitored for water quality. Monitoring the water sources feeding into the Gallatin River is extremely important because their health impacts that of the river and everything downstream (Montana Water Quality Division, 1994).

METHODOLOGY

Site Selection

When choosing a reach for sampling it is important to find a relatively straight stretch of stream with no major obstructions. The upstream sample site met these criteria (Figure 1). It was also far enough away from the foot bridge to ensure that the samples taken would accurately represent the health of Spanish Creek. The downstream sampling site was established to determine if the stream crossing was impacting stream health, so data was collected for biochemical oxygen demand (BOD), temperature, and fecal coliform. Sampling would have been better if conducted immediately downstream of the horse crossing, but that was not feasible due to high traffic. All samples were taken on either Friday or Saturday.

Sampling & Testing Procedures

In addition to the nine factors used to calculate the water quality index (WQI), data was gathered on macroinvertebrates, electrical conductivity (EC) and stream discharge (flow). EC is related to total dissolved solids (TDS), making collecting both a good idea, and flow directly impacts the nine factors used to calculate a WQI. Dissolved oxygen (DO), biochemical oxygen demand (BOD), nitrates (NO^3), and phosphates (PO^3) were measured using CHEMetrics test kits. Temperature, pH, EC, and TDS were all measured used a Hanna meter, which was calibrated prior to use (Model HI98129). Fecal coliform counts were obtained using the Coliscan® Easygel method. Turbidity was measured using a 60 cm turbidity tube. Stream discharge was measured with a Marsh McBirney flow meter. To ensure accurate comparisons, all tests were performed between 1000 and 1300 on either Friday or Saturday, due to those days having higher traffic. All data was graphed and analyzed for trends.

Dissolved Oxygen

DO was measured at both sites because it was one of the factors used to determine the impact of recreational traffic on Spanish Creek. A 25 mL sample cup was immersed, swirled, and dumped out MS two times. A 25 mL sample was taken on a third immersion. The DO test kit ampoule was inserted into the sample cup, the tip broken off, and several seconds allowed for the ampoule to fill with stream water. It was inverted three times to mix reagent and sample. After two minutes the ampoule's color was compared to a color chart to determine DO level, in mg/L.

In order to calculate percent saturation, a corrected value was determined based on altitude. Spanish Creek's altitude was closest to 6,065 feet, the reading was multiplied by a correction factor of 0.80. The corrected value and site water temperature were used with Mitchell and Stapp's (2008, pg. 59) Level of Oxygen Saturation Chart to determine saturation.

Fecal Coliform

Fecal coliform tests were run at both sites, as this was one of the factors being used to determine impacts of recreational use on Spanish Creek. A three mL sample was taken MS at each site, using a sterile pipette, and transferred into a thawed Coliscan® Easygel media bottle labeled with site name, date, and time, and placed on ice. Upon returning home each bottle was carefully poured into a prepared petri dish, which were labeled in the same way as the bottles. To reduce chances of contamination, lids were only opened as far as necessary to transfer the media. Petri dishes sat at room temperature until the sample had solidified, then the dishes were carefully taped closed, inverted, and stored at room temperature for a period of 48 hours. After 48 hours the number of fecal coliform colonies (dark purple dots) were counted. The number of colonies was then multiplied by 33.3 to calculate the number of colonies in a 100 mL sample and reported in CFUs (colony forming units).

Hanna Meter Calibration

To calibrate pH, the pH calibration setting on the meter was chosen. Per the directions on the meter, it was first placed in the 4.0 pH solution, then rinsed with spring water, and finally placed in the 7.0 pH solution. To calibrate the EC, the EC calibration setting was selected, and the meter was placed in the 1413 µS/cm solution packet. In both cases the meter was left in the solution until the CAL text stopped blinking, indicating calibration was complete.

Temperature, pH, Total Dissolved Solids, and Electrical Conductivity

To measure temperature, pH, TDS, and EC, the Hanna meter was immersed two inches below the stream surface for about 20 seconds. This was done three times for each factor, and readings were recorded. Temperature was used to determine recreational impact on SC, so readings were taken at both sites; LB, RB and MS and as close to the same time of day as possible to ensure accurate comparison. EC, TDS, and pH were only measured MS at the upstream site because they were not used in determining recreational traffic impacts on Spanish Creek.

Temperature, TDS, and EC data were averaged, and the median pH value was used as pH cannot be averaged because the scale is logarithmic.

Biological Oxygen Demand

In order to measure BOD an 800 mL container was immersed twice MS at the upstream site. Each time water was swirled and then dumped back into the stream. During a third immersion the container was placed fully under water and allowed to fill. The lid was carefully placed on the container, while still underwater, to avoid air bubbles. The sample container was wrapped in tin foil and placed at room temperature for 5 days. On day five, DO was measured and used to determine BOD; the difference in DO from day one to day five.

Phosphates

Phosphate levels were measured with a CHEMetrics phosphate test kit. A 25 mL sample cup was immersed, swirled, and dumped out MS two times at the upstream site. A 25 mL sample was taken on a third immersion. The PO^3 test kit ampoule was inserted into the sample cup, the tip broken off, and several seconds allowed for ampoule to fill. It was inverted three times to mix reagent and sample. After two minutes the ampoule's color was compared to the color standards to determine PO^3 in ppm.

Nitrates

Nitrate levels were measured with a CHEMetrics nitrate test kit, utilizing the zinc reduction method. A 25 mL sample cup was immersed, swirled, and dumped out MS two times at the upstream site. A 25 mL sample of the stream was taken on the third immersion and a 15 mL portion was then poured into the reaction tube. Into this container one zinc foil packet was emptied. The lid was secured, and the reaction tube shaken vigorously, from shoulder to hip and back, for two minutes. Ten drops of acidifier solution were placed into a 25 mL sample cup and the contents of the capped cylinder carefully transferred, so as to allow as few zinc particles as possible. The sample cup was swirled to mix, the ampoule was inserted, the tip was broken and the ampoule was allowed to fill. It was inverted three times to mix reagent and sample. After ten minutes the ampoule's color was compared to the color standards to determine NO^3 in ppm.

Turbidity

A 60 cm turbidity tube was used to measure water clarity (Figure 2). I approached the MS location of my upstream site from downstream, so as to not contaminate my first water sample. The turbidity tube was rinsed with stream water. While one generally then pours a water sample into the tube until the disc at the bottom is obscured, the water from Spanish Creek was so clear that the disc was still visible when the tube was completely full. For the second and third water samples I disturbed the bed of the stream and repeated the process of pouring water into the tube. The disc at the bottom of the tube was still visible even with the disturbance. According to a personal correspondence with Amber Kirkpatrick, the fact that the disc was visible with the tube full meant that the turbidity measurement was less than 5 NTUs (nephelometric turbidity units).

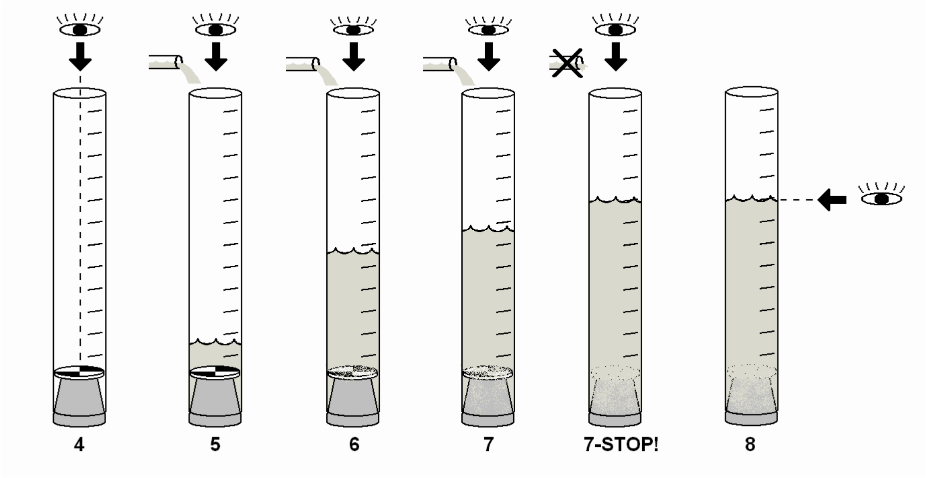

Figure 2. Using a Turbidity Tube. Obtained from The Turbidity Tube: Simple and Accurate Measurement of Turbidity in the Field PDF by Elizabeth Myre & Ryan Shaw of Michigan Technical University.

Stream Flow

A Marsh McBirney flow meter borrowed from Montana State University's Extension Water Quality program was used to measure stream flow from August to September.

To transect the stream, a fiberglass measuring tape was stretched tightly across a relatively straight, smooth portion of the stream. Stream beds are not uniform, and their depth varies, so dividing the stream into sections gives a more accurate picture. Current protocol is to divide the wetted width (the width of a stream's wet area) by 20 or 21 and round the result down to the nearest tenth of a foot. Depth and velocity readings were taken at each of the 20 or 21 divisions.

To take depth and velocity readings, I stood downstream from the tape measure and placed the top setting rod upstream with sensors facing upstream. The top setting rod was placed on the bottom of the stream and the depth measured to the nearest tenth of a foot (Figure 3). I called measurements out to an assistant on the bank who recorded the depth measurement and repeated the number back to me. The top setting rod was adjusted so the measurement bulb was at the correct depth. As Spanish Creek was less than two and a half feet in depth at the deepest point, the measurement was taken at 60% depth (60% of the way down from the surface). The on button was pressed and the rod held steady for 40 seconds while stream velocity (ft/second) was measured. Velocity was called to my assistant who then repeated and recorded the number. This procedure was repeated for each of the cross sections. Flow data was used to create a rating curve, which shows the relationship between flow and depth when plotted. A rating curve can be used to create an equation that allows you to estimate velocity based on water depth (Water Quality SOP for Discharge Measurement with Marsh McBirney Flow Meter, 2016).

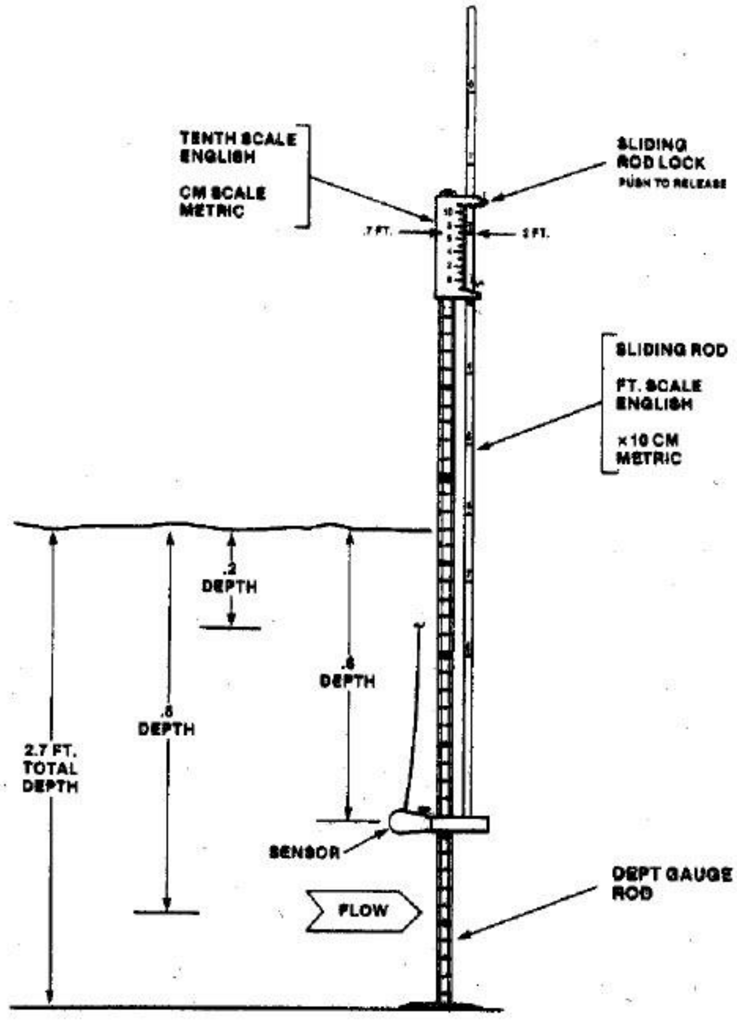

Figure 3. Top Setting Rod – Obtained from Holly Kreiner at the MSU Extension, from the Water Quality SOP for Discharge Measurement with Marsh McBirney Flow Meter, 2016).

Benthic Macroinvertebrate Sampling

Macroinvertebrates can provide a snapshot image of a stream's overall health and can be used to corroborate a WQI. To sample benthic macroinvertebrates an aquatic D-net, two white ice cube trays, a white utensil tray, and a pipette were employed. Three samples were taken during each trip to the stream: two kick net samples and one rock rub sample. To ensure randomness, my assistant called out how far up or downstream and towards which bank I was to move, via a number of steps. All benthic macroinvertebrates from both sample methods were returned to the stream following identification and sample identifications were recorded in a table, along with their tolerance to pollution.

For kick net sampling, a shallow gravely bank of Spanish Creek was selected, along the upstream reach. I approached chosen locations from downstream and placed the D-net downstream from my location in the stream, flat side down. Sediment was vigorously kicked up for approximately one minute, over a five-foot area, while the D-net was moved back and forth. The net was lifted up, transported to the RB of the upstream site and emptied into the white utensil tray. Stream water was used to rinse any clinging sediment off the net and the sample allowed to settle. After settling the different orders of macroinvertebrates were noted. A cut-off pipette was used as needed to transfer specimens to individual ice cube sections for better visibility. Identification was made via previous experience, J. Reese Voshell, Jr.'s (2002) A Guide to Common Freshwater Invertebrates of North America, and the Entomology Facebook group (several members work with aquatic invertebrates professionally).

Rock rub samples were done by randomly selecting a rock from the stream and rinsing it with stream water. The rock was examined for macroinvertebrates as was the stream water that had washed over the rock.

Calculation of Water Quality Index

To calculate WQI for Spanish Creek, I followed protocol outlined in Mitchell & Stapp (2008). Q-values for each of the nine parameters were multiplied by a weighting factor. Weighting factors are based on the importance of each parameter to the overall water quality. Resulting numbers were added together to determine the WQI. I then used Mitchell & Stapp's (2008) Water Quality Index Range chart to determine Spanish Creek's health; excellent, good, medium, poor, or very poor. In event of missing data, the protocol for calculating a WQI without all parameters was followed; the inverse of the factors weight was calculated and the sum of the other factors multiplied by it.

Recreational Impact on Spanish Creek

To evaluate impacts on Spanish Creek from the recreational crossing, the upstream and downstream readings for temperature, DO, and fecal coliforms were graphed. Data was averaged and data sets for each parameter compared to see if there were significant differences between the two sites.

DATA AND ANALYSIS

Figure 4 is a graph of percent saturation of dissolved oxygen (DO) downstream (DS) and upstream (US). Saturation percentages DS range from 35 to 65, with an average of 54%. Average saturation levels of US DO were 52%, with a data range of 35 to 65%. The corrected overall averages for DO were 6.5 ppm for DS and 6.3 ppm for US.

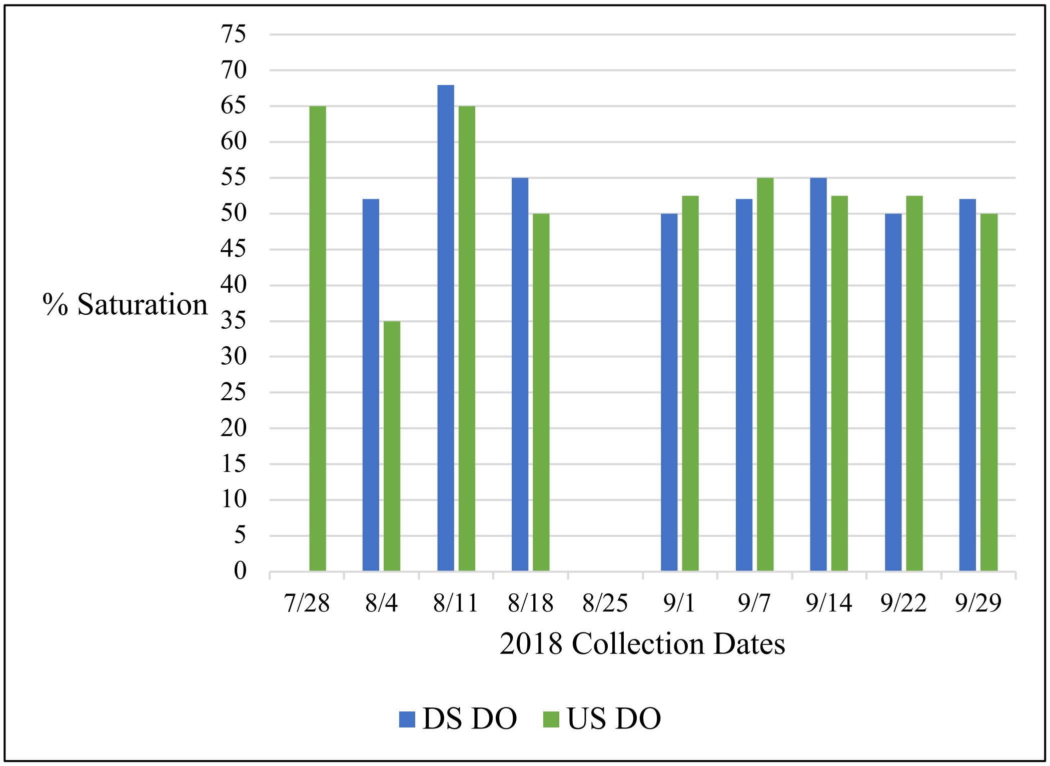

Figure 4. Downstream (DS) vs. Upstream (US) Dissolved Oxygen.

Figure 5 is a graph of fecal coliforms for both sites. Fecal coliforms were detected twice at the DS site and once at the US site.

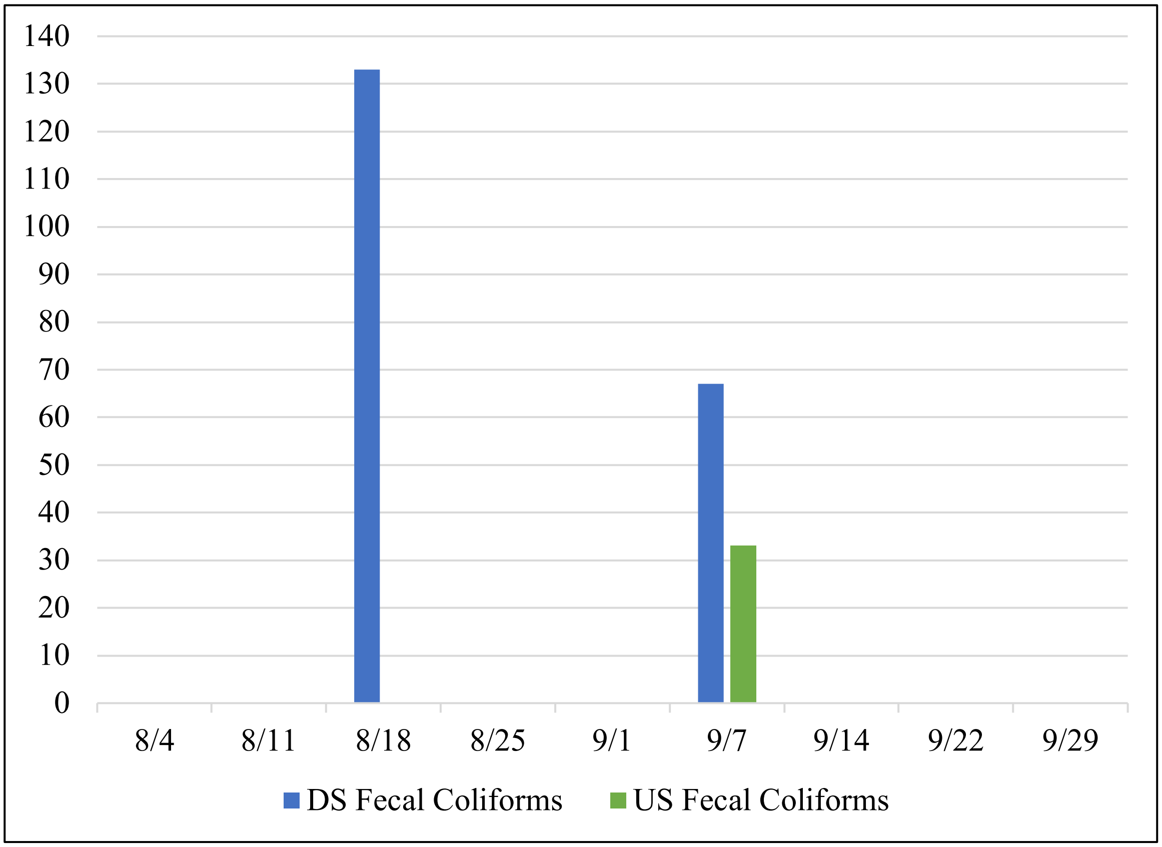

Figure 5. Fecal Coliforms: Downstream (DS) vs. Upstream (US).

Figure 6 shows temperature trends for both sites. Averages were 8.2. and 8.6°C, respectively. The average Δ was 0.3°C.

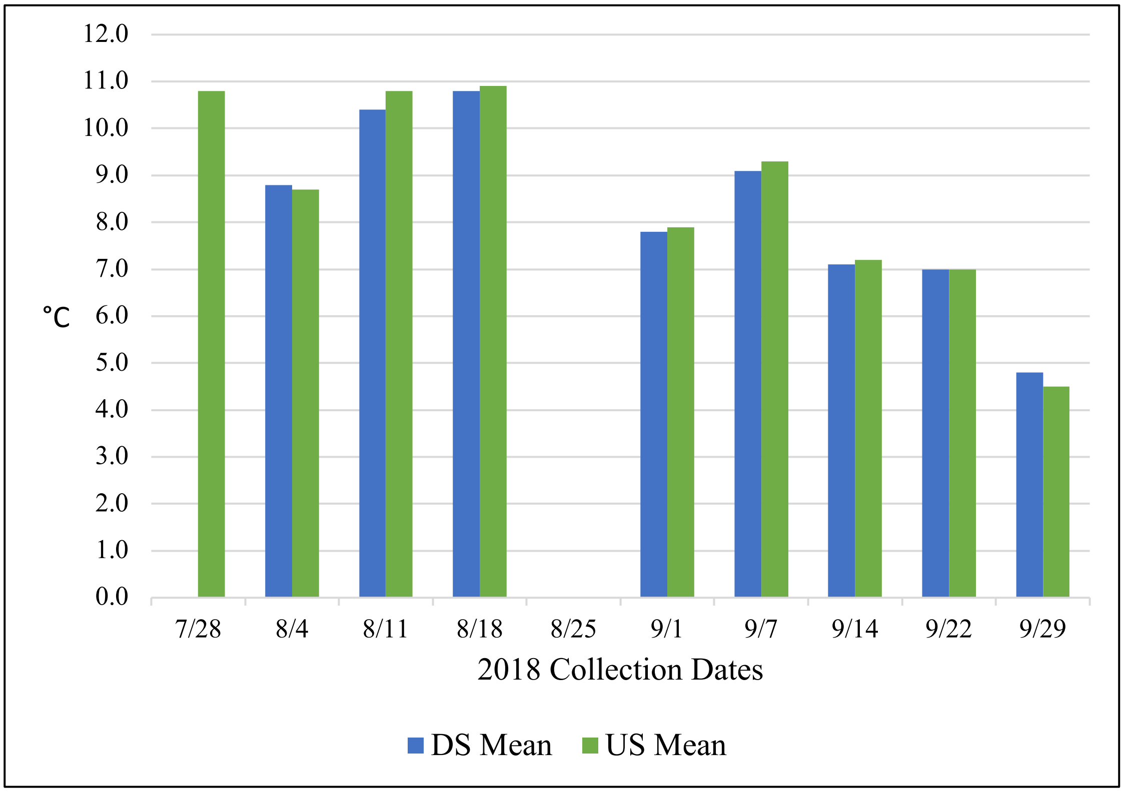

Figure 6. Downstream (DS) vs. Upstream (US) Temperatures.

Figure 7 is a graph showing median pH values for the US site. Readings ranged from 5.82 to 7.40, with an overall median of 7.2.

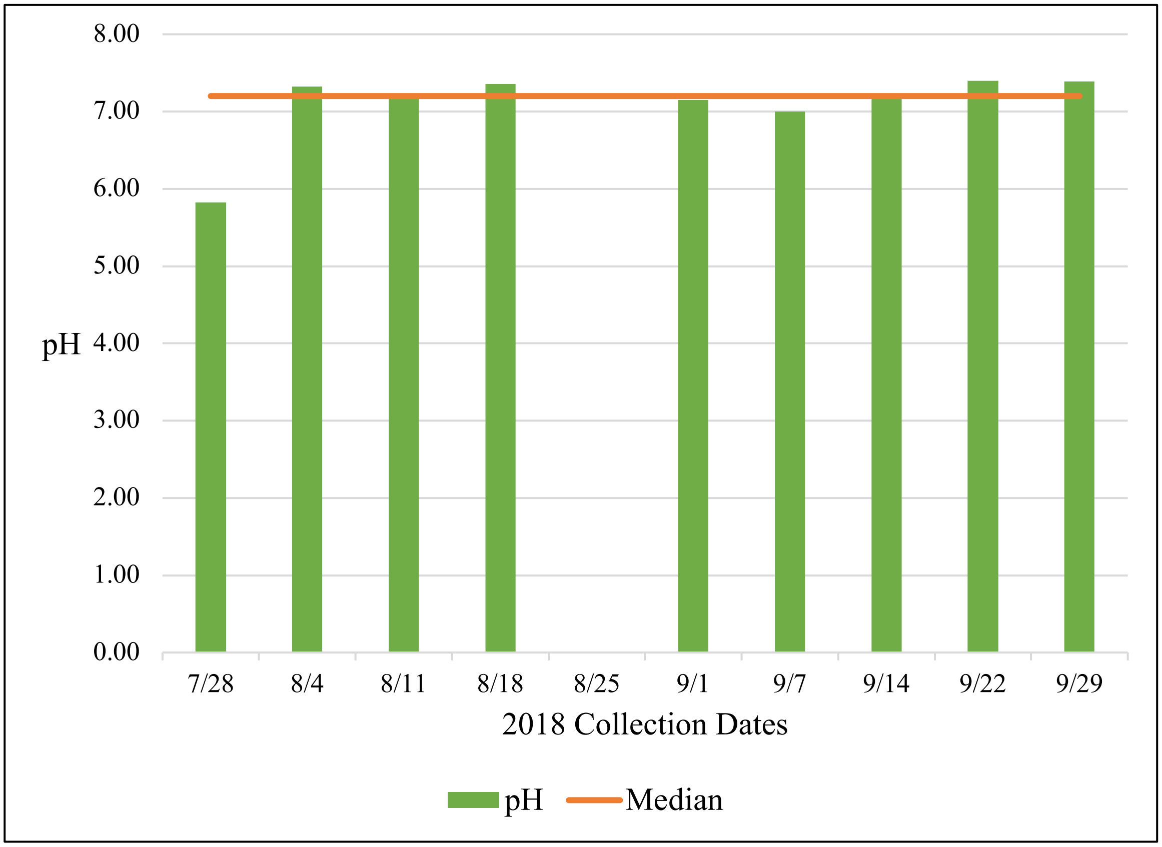

Figure 7. Upstream (US) Ph.

Figure 8 is a graph of TDS levels at the US site. Levels ranged from 26 to 35ppm, with an average TDS level of 33ppm. Figure 9 is a graph showing electrical conductivity (EC) at the US site. EC ranged from 53 to 71 µS/cm, with the average being 63µS/cm.

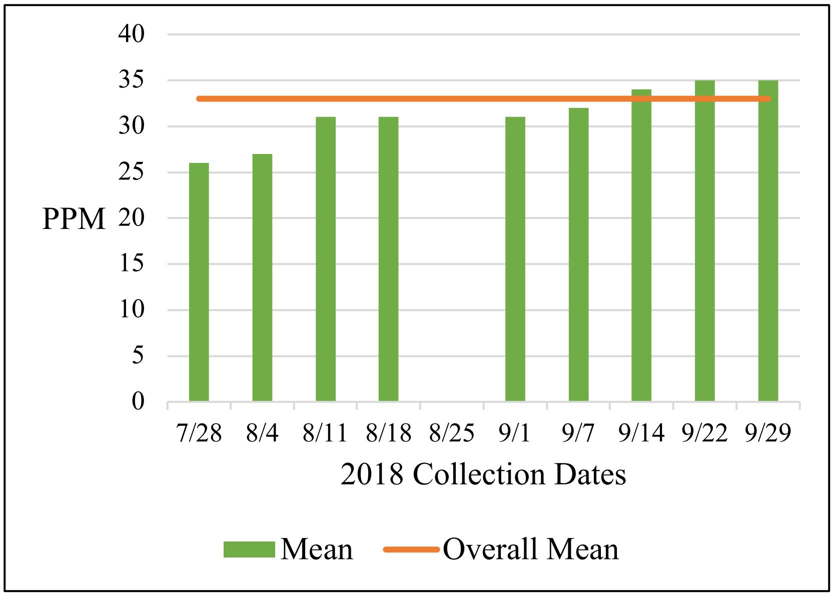

Figure 8. Upstream (US) Total Dissolved Solids (TDS).

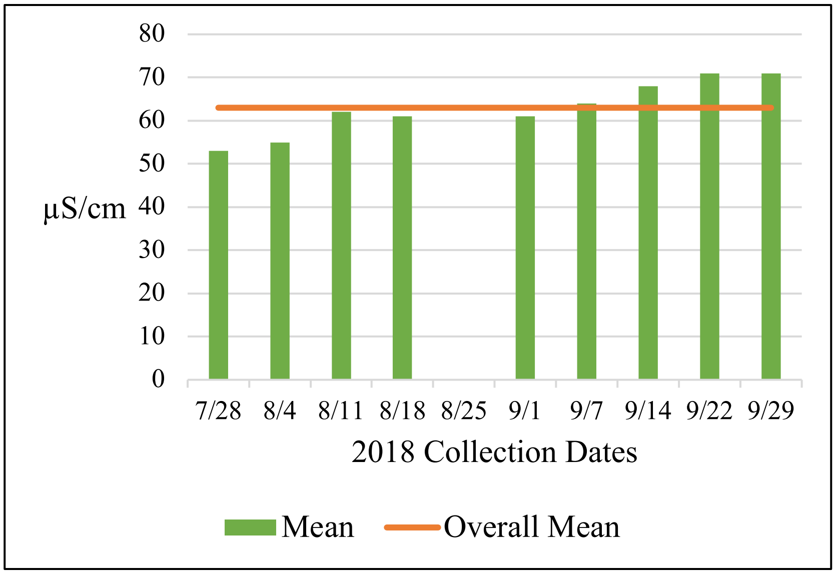

Figure 9. Upstream (US) Electrical Conductivity (EC).

Figure 10 is a graph of BOD at the US site. Values ranged 1.3 to 2.1 ppm, with an average of 1.3 ppm.

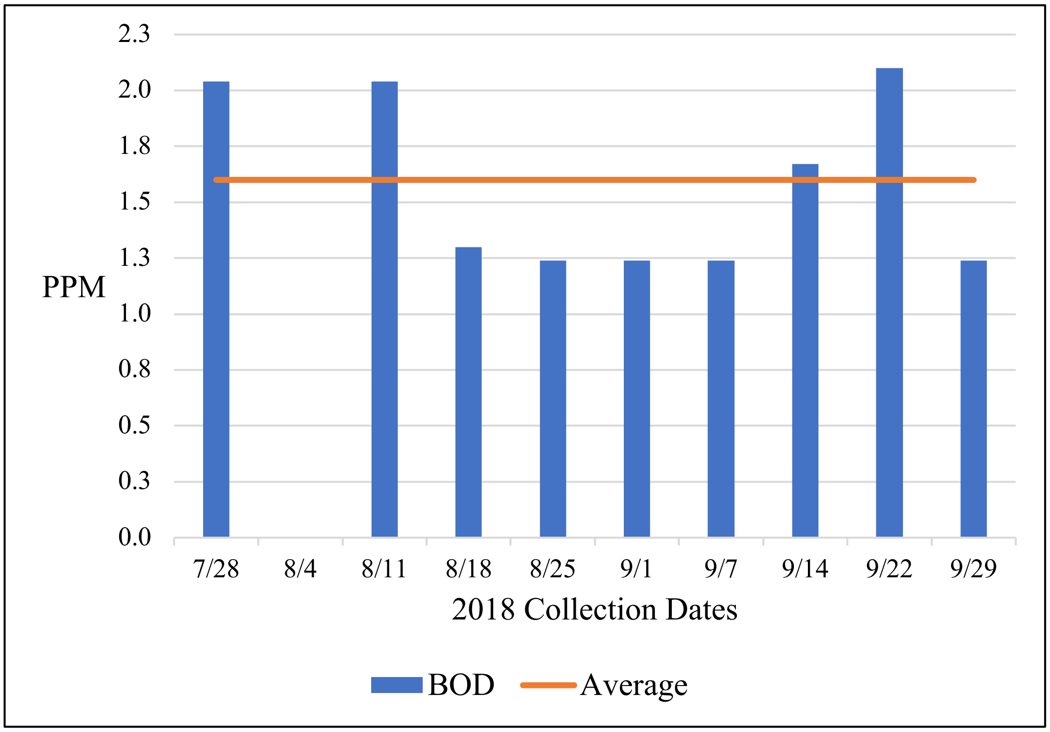

Figure 10. Upstream (US) Biochemical Oxygen Demand (BOD).

Table 3 shows phosphate (PO^3) and nitrate (NO^3) levels. PO^3 and NO^3 levels registered as 0 ppm through the course of data collection, with a few exceptions for NO^3.

Table 3
Spanish Creek Nitrate and Phosphate Levels

2018 Collection Date	PO^3 in ppm	NO^3 in ppm
7/28	0	0.05
8/4	0	0.05
8/11	0	0.05
8/18	0	0.05
8/25	0	0
9/1	0	0
9/7	0	0
9/14	0	0
9/22	0	0
9/29	0	0

Turbidity registered at less than 5 NTUs for each sample collection on every collection date.

Table 4 contains flow measurements. Average depth of Spanish Creek ranged from 0.36 to 0.43 ft (Table 4). Average flow varied from 7.19 to 14.38 cfs. Figure 11 is a graph showing the relationship between flow and depth. This is what is used to develop the rating curve. The R^2 shows how well a line fits to a data set.

Table 4
Spanish Creek Flow Data

Date	Time	Depth (ft)	Flow (cfs)
8/25/18	1115 to 1150	0.43	14.78
9/1/2018	1137 to 1224	0.39	9.74
9/7/2018	1217 to 1239	0.36	7.19
9/14/18	1140 to 1200	0.41	11.14
9/23/18	1112 to 1151	0.36	9.06
9/29/18	1205 to ~1235	0.41	9.61

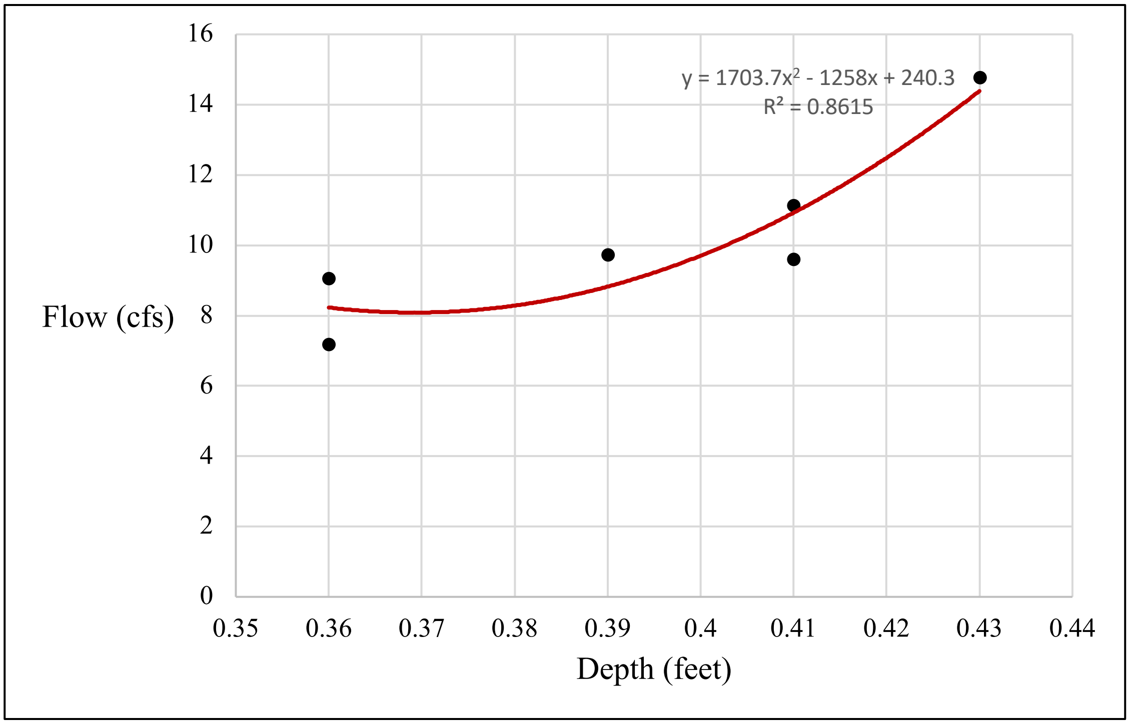

Figure 11. Spanish Creek Flow Curve 2018: Flow x Depth Curve – Polynomial.

Figure 12 is a graph showing Spanish Creek's PTI for each collection date. PTI ranged from 16 to 23, with the average being 19. A complete data table may be found in Appendix C.

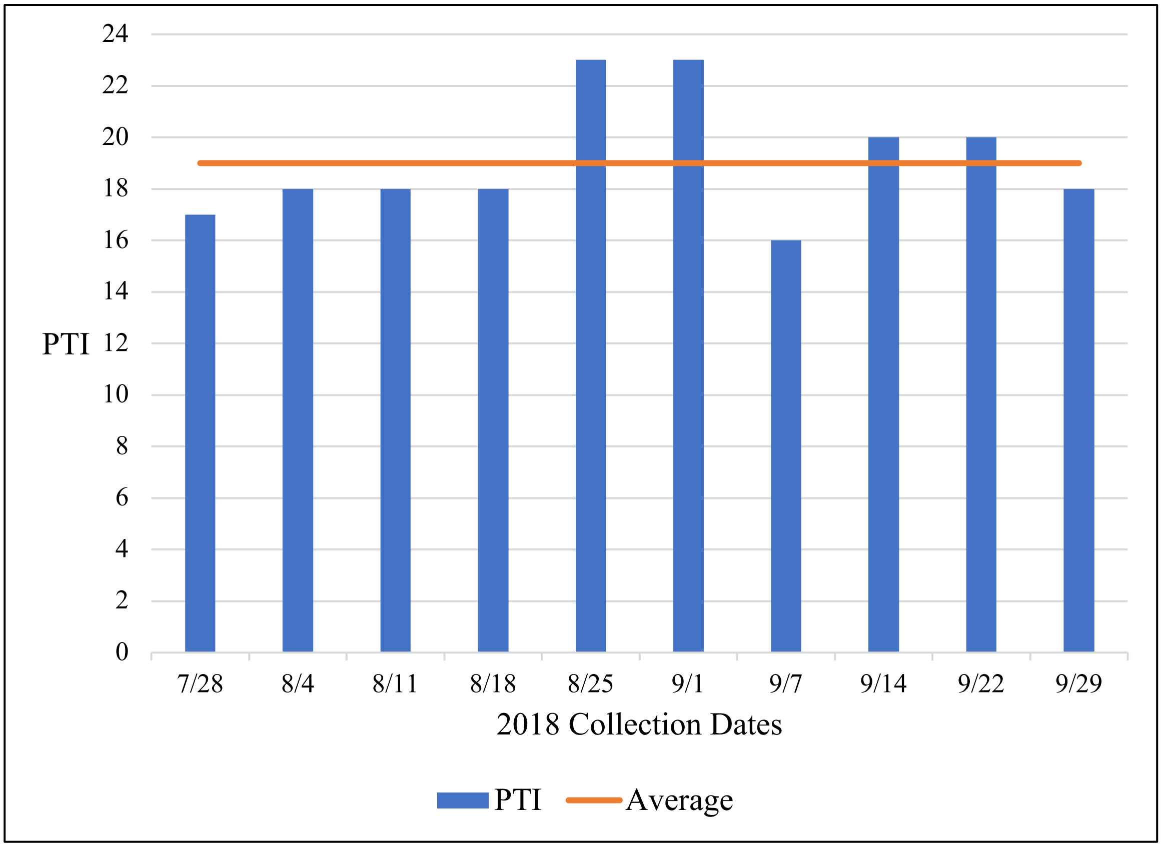

Figure 12. Spanish Creek Pollution Tolerance Index (PTI).

Figure 13 is a graph of Spanish Creek's WQI and Table 6 shows details for each parameter. WQI was in the 80s for each of the nine collection dates it was calculated. A data gap occurred on August 25.

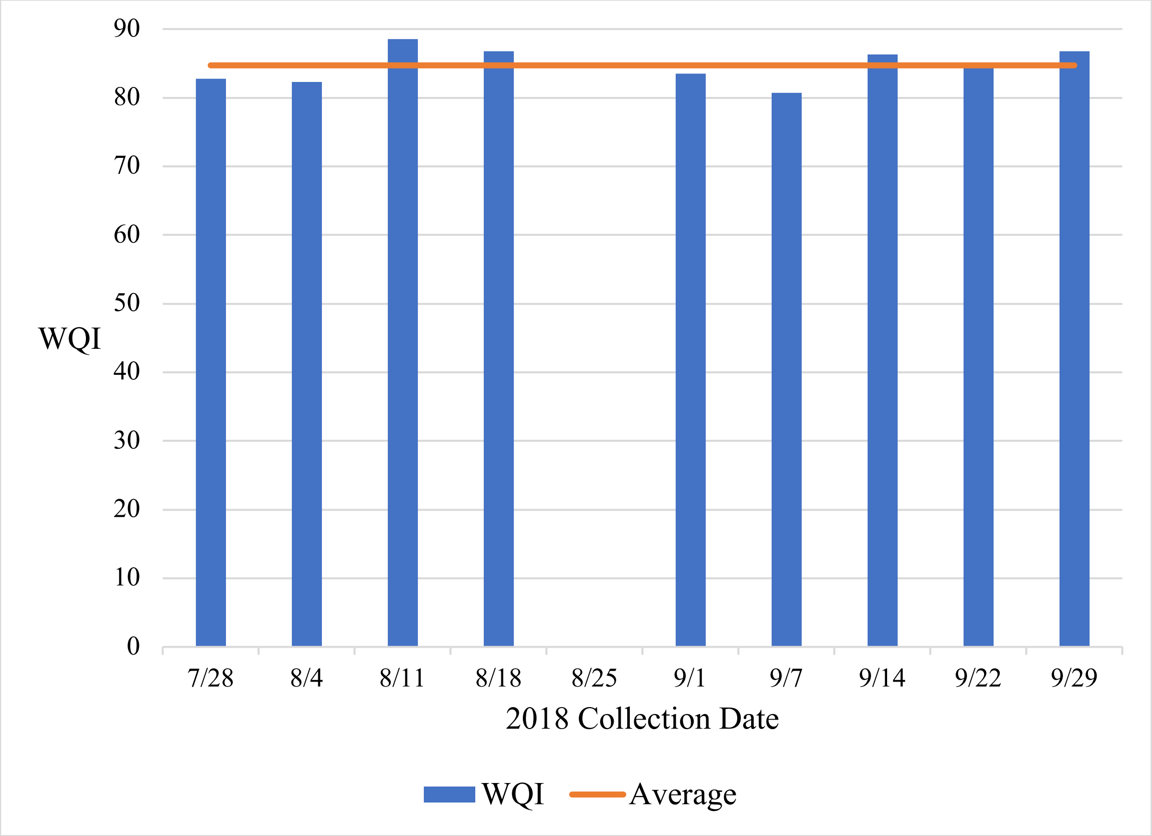

Figure 13. Spanish Creek Upstream (US) Water Quality Index (WQI).

Table 6.

Spanish Creek WQI

Parameter	7/28	8/4	8/11	8/18	8/25	9/1	9/7	9/14	9/22	9/29
DO	11.05	4.25	11.22	7.65	[redacted]	7.14	8.5	7.14	7.14	7.65
F.Coliform	16	16	16	16	16	[redacted]	9.28	16	16	16
pH	5.28	10.12	10.01	10.12	[redacted]	10.01	9.9	10.01	10.01	10.01
BOD	8.25	[redacted]	8.25	9.9	9.9	9.9	9.9	9.9	8.25	9.9
Temperature	[redacted]	9.2	9.15	9.2	[redacted]	9.2	9.2	9.2	9.2	9.2
PO	10	10	10	10	10	10	10	10	10	10
NO	9.99	9.99	9.99	9.99	10	10	10	10	10	10
Turbidity	8	8	8	8	8	8	8	8	8	8
TDS	5.95	5.95	5.95	5.95	[redacted]	5.95	5.95	6.02	6.02	6.02
WQI	82.72	82.33	88.57	86.81	[redacted]	83.54	80.73	86.27	84.62	86.78

INTERPRETATION AND CONCLUSION

Dissolved Oxygen

Percent saturation for DO and corrected average DO values were much lower than expected. With the exception of the US reading on August 4, which was Poor, all other DS and US readings fell into the Fair category of 51-71%, according to Mitchell and Stapp. The lower DO saturation and values might generally be suggestive of warmer water and/or lower altitude but neither of these is the case. Another possible reason for the lower DO levels may be the lateness of the season. Spanish Creek's depth and flow decrease as the summer passes.

It is important to note that there is no DS DO or other data for July 28 as all DS data collection began after that date. The data gap on August 25 is due to the loss of my first Hanna meter. Said loss meant that, though both DS and US DO were measured for the day though, I could not take water temperature. Water temperature is needed to calculate % saturation. You can get corrected values without temp, but you can't get % saturation.

Fecal coliform

Fecal coliform colonies were only observed on three occasions, once US and twice DS. The US reading of 33 cfu (colony forming units) is considered excellent by Mitchell and Stapp, as are all the other reading that were zero (both US and DS). DS results of 67 and 133 cfu are considered good. I had expected to have more collection dates with F. coliform DS though not necessarily higher than 133 cfu. Spanish Creek's average flow of 10.25 cfs seems to be enough to dilute any contamination currently present.

There is a data gap on September 1 because I forgot to bring my cooler; samples must be placed on ice afterwards.

Temperature

The change in temperature between DS and US was considered excellent according to Mitchell and Stapp (2008). Such a small change suggests there is no thermal pollution between the two sites monitored in this section of Spanish Creek. Although the average site temperatures of 8.2 and 8.6°C, respectively, may be considered lower than optimal for the larva of several macroinvertebrate species, there did not seem to be any negative effects upon their populations. Mayflies, stoneflies, and caddisflies were the most abundant types of macroinvertebrates found when the stream was sampled.

As noted in the section on dissolved oxygen, there is a data gap on August 25. This data gap also affects pH, TDS, and EC.

pH

Except for one reading, pH levels at Spanish Creek were excellent. The median pH on July 28 was 5.82, which Mitchell and Stapp consider good. All other readings were between 7.0 and 7.4, with the average being 7.2. This pH range is within the narrow window in which macroinvertebrates thrive.

Total Dissolved Solids & Electrical Conductivity

According to the chart in Mitchell and Stapp (2008, pg. 92) the range of Spanish Creek's TDS reading was excellent. There are enough dissolved solids to not restrict life in the stream, but not high enough to cause plant life to choke the stream. Plant life was minimal until later in the season. I observed more aquatic vegetation, especially mid-stream as stream flow and depth decreased and temperatures increased. Slower stream flow allows dissolved solids to stay in an area for longer, which allows nutrients to be better used by plants. Decreased depth allows sunlight to warm the water more, as do the increase in dissolved solids. Warmer water temperature encourages more aquatic plant life.

The range of EC readings corroborate this finding, as the more salts there are dissolved in water the higher the EC readings will be. Higher levels of salts allow for greater electrical conductivity.

Biochemical Oxygen Demand

Spanish Creek has a low BOD with an average of 1.6 ppm. This indicates oxygen is not being consumed at a high rate by plants, animals, and other organisms. As noted in the Literature Review, high BOD levels generally indicate the presence of excessive nutrients (primarily nitrates and phosphates), which generally encourage excessive plant growth. Spanish Creek's excellent BOD suggests that nutrient levels are healthy, which is supported by TDS and EC readings.

A data gap does occur on August 4 because I forgot to take a BOD sample.

Nitrates and Phosphates

Nitrates and phosphates occur in very small amounts in Spanish Creek. The test I used was not able to measure any phosphates and, only on four occasions, registered nitrates. I would like to send samples of both off to a lab as there must be at least trace amounts in order for plant growth to occur. The low readings are no surprise considering that this portion of Spanish Creek is in a wilderness area. There is no agricultural run-off and the stream appears to move fast enough dilute waste from the horse crossing. While Montana does have many forest fires, I cannot recall one burning recently near the data collection area. It would be interesting to see what the nitrate and phosphate levels are a various part of the stream lower down, where is passes through ranchland.

Turbidity

Turbidity measurements for Spanish Creek were always excellent. Even when I kicked up sediment and then sampled, I could always see the disk at the bottom of the turbidity tube. Flow played a large part in the excellent turbidity readings, as did the location. There are no agricultural areas or construction sites close by that would cause sediment to enter the stream because of the designated land use in this area. The lack of suspended material in the water allows Spanish Creek's temperature to be cooler and to have more dissolved oxygen. It would be interesting to see what the readings are very early in the season, when the snow melt increases the depth, flow and erosion.

Flow

Spanish Creek's flow is fast enough to maintain stream health even with seasonal fluctuations. The stream flows very fast and is quite deep in the early spring but start to slow and decrease in depth throughout the summer and into the fall. Fluctuations are due to snow melt, precipitation, and evaporation. Slower flow allows contaminants, sediment, and other materials to remain in the stream longer. Fecal coliform cultures and turbidity readings suggest that Spanish Creek flows fast enough to dilute fecal coliform from the waste of horse and other animals, as well to remove any sediment that is disturbed, even with decreased depth and slower velocity.

Macroinvertebrates

Most benthic macroinvertebrates sampled belonged to Group 1, which is considered pollution intolerant, suggesting Spanish Creek is quite healthy. Though average temps were lower than Mitchell and Stapp consider optimal for mayflies, stoneflies, and caddisflies, these macros comprised the bulk of my samples. I often found three to four different species of both mayflies and caddisflies. Riffle beetles were the fourth type of Group 1 organism commonly found in samples, both in larval and adult forms. Water mites and midges, both Group 3, also made an appearance, as did crane flies (Group 2), though not with the same richness or abundance as the organisms in Group 1.

When the PTI for each collection date was calculated, most dates fell into Mitchell and Stapp's Good category, but two days were excellent, one was fair. The PTI may have been better if the macroinvertebrate population was more abundant. There were only seven types of macroinvertebrates noted in samples, due to sampling protocol. The two days with excellent PTI's had all seven macros in samples. Areas of the stream with slower flow and more plant life may have had a higher abundance, and I would like to sample them in the future.

Water Quality Index

A WQI was calculated for all collection dates except August 25, as there were too many missing factors on that date for me to feel comfortable doing so. All calculated

WQIs fell within the Good category, though I had expected to see Excellent. The DO saturation levels were lower than expected and the weighing factor was the heaviest (0.17). As all other factors fell, on average, into the Excellent category this one factor appears to have had an impact upon the WQI falling into the Good rather than Excellent category.

Recreation Impact

After comparing temperature, DO, and fecal coliform for DS and US, it does not appear that the recreational crossing has any negative impact on stream health. Temperature readings for both sites were similar, as were DO levels and fecal coliform counts. The flow of the stream may be fast enough to mitigate any issues arising from such use, but data was only collected on a few dates during one season. Further research is needed to really determine if recreation has an impact.

VALUE

Implications for Personal Practice & Teaching Science

While science can be learned from reading, some aspects are best learned by doing. There’s a big difference between reading a procedure and actually doing it. During an online, field-based course I took two summers ago, I learned many of the various methods for data collection that I put into practice in this project. I was able to more fully develop my understanding of water quality monitoring, in addition to polishing my data collection, recording, and analysis skills. In doing so I feel that I will be better equipped to help students learn proper data collection techniques, recording of data, and analysis of data. Additionally, I have a valuable vehicle through which to teach many different subject areas in the future as this particular topic can easily be incorporated into math, social studies, writing, and many other fields.

Even though I was somewhat familiar with the data collection techniques used, there were times when problem-solving was needed or new skills sets needed to be learned. What do you do when your d-net starts falling apart mid-collection? Whoops, your writing implement just floated off downstream! How do you use a flow meter? What can I use to keep everything I need on hand, when I'm standing midstream? These are all great topics that can aid students increase their problem solving and analysis skills.

Data collection techniques used, and data analysis would be relatively simple for many different grade levels to do, though there would be some modifications needed depending on age. Children of any age can use a Hanna meter, but the chemical tests would be better left for middle school and older. Younger students would have difficulty using the glass ampules and there would be safety concerns regarding the zinc used for the nitrates test and possibly with being in stream. With the introduction of background knowledge, students from first grade on up should be able to analyze data. My son, who was headed into first grade, liked to come help with data collection and understood many of the implications of certain readings. He, like many younger students, would need help with the math but would be able to determine what the final WQI numbers meant.

Implications for the Community

Now that I have a better understanding of water quality I can be more of an asset to my community. I understand why monitoring is important and know there are many different Stream Teams in the area that I could join in order to help monitor various water bodies. It is also possible in the future, when I have my own classroom again, that my class could adopt a stream to monitor, in order to provide valuable data to watershed councils, local, and state governments.

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APPENDICES

APPENDIX A

PERCENTAGE OF WATER BODIES ASSESSED IN STATE OF MONTANA

Table 1

Percentage of Water Bodies Assessed in the State of Montana by Year

Year	# of stream miles assessed	% of perennial stream miles assessed	# of lake/reservoir acres assessed	% of lake/reservoir acres assessed
2018	20,686	38.0	493,343	74.0
2016	20,300	35.0	493,236	70.0
2014	20,278	44.0	493,237	86.0
2012	22,373	37.5	595,597	76.3
2010 High Res. NHD	22,079	45.0	566,313	88.9
2010 Medium Res. NHD	no data	no data	no data	no data
2008	20,457	50.1	603,692	94.4
2006	20,549	50.3	606,291	94.8
2004	19,476	47.7	606,275	94.8
2002	20,099	40.5	604,761	87.4
2000	no data	no data	no data	no data
1998	17,874	no data	798,583	95.8
1996	no data	no data	no data	no data

Note. Water quality report years contain data from the previous two years. Additionally, water bodies in federal and tribal jurisdiction were included in the water quality reports of 1996 and 1998. This table was created from data found in Montana's Integrated Water Quality Reports and 303d reports from 1996 to 2018.

APPENDIX B

TOTAL STREAM MILES AND WATERBODY ACRES

Table 2

Total Stream Miles and Waterbody Acres in the State of Montana

Year	Total perennial stream miles	Total intermittent and ephemeral stream miles	Total streams (all types)	Total ditches and canals in miles	Total lakes, reservoir, and wetland acres
2018	58200	307000	365200	no data	730000
2016	58200	307000	365200	no data	577000
2014	45971	272389	318360	11386	564986
2012	59600	274400	334000	11200	780300
2010 High Res. NHD	49099	272463	321562	11317	636911
2010 Medium Res. NHD	40826	95850	136676	6087	639466
2008	40826	95850	136676	6087	639466
2006	40826	95850	136676	6087	639466
2004	40825	104646	145471	6088	639466
2002	49643	117065	166708	7094	691826
2000	no data	no data	no data	no data	no data
1998	no data	no data	no data	no data	833964
1996	no data	no data	no data	no data	no data

Note. Water quality report years contain data from the previous two years. Additionally, water bodies in federal and tribal jurisdiction were included in the water quality reports of 1996 and 1998. This table was created from data found in Montana's Integrated Water Quality Reports and 303d reports from 1996 to 2018.

APPENDIX C

SPANISH CREEK PTI TABLE

Table 5

Spanish Creek PTI

	7/28	8/4	8/11	8/18	8/25	9/1	9/7	9/14	9/22	9/29
GROUP 1 (x4)										
Gill snail										
Stonefly	x	x	x	x	x	x	x	x	x	x
Mayfly	x	x	x	x	x	x	x	x	x	x
Riffle beetle		x	x	x	x	x	x	x	x	x
Caddisfly	x	x	x	x	x	x		x	x	x
Dobsonfly										
Water penny										
G1 Total	12	16	16	16	16	16	12	16	16	16
GROUP 2 (x3)										
Sowbug										
Scud										
Dragonfly										
Damselfly										
Crane fly	x				x	x				
Clam										
G2 Total	3	0	0	0	3	3	0	0	0	0
GROUP 3 (x2)										
Leech										
Midge	x	x			x	x	x	x	x	
Flatworm										
Black fly										
Water mite			x	x	x	x	x	x	x	x
G3 Total	2	2	2	2	4	4	4	4	4	2
GROUP 4 (x1)										
Pouch snail										
Rat-tailed maggot										
Aquatic worm										
Blood midge										
G4 Total	0	0	0	0	0	0	0	0	0	0
PTI	17	18	18	18	23	23	16	20	20	18