Water Quality of Oak Creek and Fossil Creek, Arizona

A look into the quality near Oak Creek's headwaters (2019),
Lower Oak Creek (2018-2019),
Fossil Creek (2018-2019)

OAK CREEK
WATERSHED COUNCIL

Oak Creek Watershed Council

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Special thanks to:

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Abstract

This report presents health and water quality information of Oak Creek in northern Arizona. Oak Creek stretches 50 miles beginning in Oak Creek Canyon, flowing through Sedona, Page Springs and Cornville until it reaches its confluence with the Verde River. The report contains six sets of data. The first set is data collected during the summer of 2019 from the near headwaters of Oak Creek and West Fork, a major tributary. Second are data collected throughout the summers of 2018 and 2019 in sites along lower Oak Creek Canyon. Next are the datasets from the summers of 2018 and 2019 from Fossil Creek. These data show the relationship of water quality in different spring-fed streams that see high amounts of recreation. Both Oak and Fossil Creeks receive high amounts of visitors who come to recreate, which results in massive increases of littering, wildlife disruption, habitat degradation, and microbial contamination. Since the introduction of the permit system on Fossil Creek, many of the previously stated effects have been mitigated, however, Oak Creek is listed as impaired because it fails to meet water quality standards. The data presented here, specifically the most recent data, shows that during baseflow conditions on Oak Creek, there are no exceedances of *Escherichia coli (E. coli)*.

Introduction

The data is primarily focused around the amount of *Escherichia coli* found within Oak Creek. Although this bacteria plays a critical role in all natural water bodies, the lower stretch of Oak Creek is listed as impaired by the Arizona Department of Environmental Quality. Therefore, it was important to gather data on the upstream conditions of Oak Creek. This study examines exceedances in *E. coli*, when and where they occur, and known patterns about *E. coli* exceedances. In low-use months, or the winter season, there are less frequent exceedance events than in high-use months. This is because the amount of recreation declines as both air and water temperatures decline. Spring snowmelt increases incoming flow to the creek, which can increase the amount of *E. coli* concentrations by carrying fecal matter into streams. However, due to the rate of snow melt, springtime conditions do not often result in exceedances.

It is during the summertime that the most exceedances are seen. This is for a few reasons: recreation, weather, and human behavior influencing animal behavior. Recreation increases as early as the beginning of March, when Spring Break begins, peaking around the Fourth of July until the beginning of August, when schools start their fall semester. Recreation often continues at high rates well into autumn at places like West Fork because of the foliage changing colors. Increased recreation throughout the warm season leads to exceedances in *E. coli*, but the Arizona monsoon season also plays a role.

Monsoon season usually begins at the end of June and lasts until September. These storms have the potential to create massive flood events that carry sediment, fecal matter, litter and other waste like plant debris into creeks and streams. Snowmelt slowly introduces fine amounts of waste into streams. In contrast, monsoon floods occur rapidly and can significantly lower the water quality for extended periods of time due to increased turbidity. Lastly, because of the increase in recreation, the behavior of humans changes the behavior of animals. When recreators leave their trash and waste behind, it encourages animals, especially scavengers, to venture into areas that they would not normally go. This can increase the rates of fecal matter that are directly introduced into the stream system. Because exceedances occur most frequently in the summer, the data in this report were collected from the months of May - September.

Summary of *Escherichia coli* in Oak Creek

Statistics from the city of Sedona website states that Sedona gets over 3 million tourists every year, but Sedona only houses 10,300 permanent residents. This influx of visitors puts stress on the city, roads, trails, and Oak Creek. The ever so popular creek destinations in the canyon such as Midgley Bridge, Grasshopper Point draws the attention of visitors who may not understand how finite these resources are. On a sunny, warm weekend, the pullouts along Highway 89a are often full of illegally parked cars, trash including diapers, drive-through food and packaging, and people walking dangerously close to traveling vehicles. Overcrowding creates problems like pollution, erosion, and sedimentation, destruction of land, and puts wildlife and their habitats at risk. Illegally parked cars in the pullouts cause erosion into the creek and encourages people to take social trails down to the creek and furthers erosion.

As freshly eroded sediment makes its way into the creek, the clear spring-fed water of Oak Creek becomes turbid. This is often seen after a monsoon or big flood, when normally clear water resembles chocolate milk because the sediment is entrained in the water instead of settled at the bottom. When water is more turbid, the bacteria *E. coli* is more likely to bind to the sediment and produce more colony forming units, further impairing the water. This is a problem because Oak Creek is already listed as impaired, which means that it fails to meet water quality standards.

E. coli is naturally found in the intestines of humans and animals, and therefore, found in natural bodies of water where fish and other animals reside. There are additional increases in *E. coli* when people or animals scat in or near the creek. Because people often go to the creek to recreate bringing food and drinks with them, it is sometimes left behind as trash. This can change behavior of scavenger animals like skunks. In turn, skunks will be more prone to find the residual food scraps left behind by humans and then scat near the creek. The increase of human use in and around Oak Creek has led to increased concentrations of *E. coli* in Oak Creek. Concentrations and measurements of *E. coli* are explained in the next section.

Oak Creek's Water Quality Status

Oak Creek is listed as impaired by ADEQ because it fails to meet water quality standards for *E. coli*. The standard for a single sample maximum value of *E. coli* is 235 colony forming units per 100 milliliter sample. When a sample goes above this value it is an exceedance. As discussed in the introduction, exceedances are most common in the summer, however, year-round lower Oak Creek sees exceedances due to the

accumulation of nonpoint source pollution. There was seldom data collected in upper Oak Creek so that played into the decision factor when selecting where to sample water quality along Oak Creek.

Methods

Pertaining to the samples collected by Oak Creek Watershed Council

Preparing and collecting *E. coli* samples:

First, the ambassadors put on a fresh pair of gloves for each sample and labeled each 100 mL sample bottle with the following information: sample date, location/site ID, time sample was collected, and if it was a duplicate. When the sample was ready to be collected, the sampler would stand over the sampling spot and face upstream to ensure that they were not contaminating the sample. The sample was collected over riffles, with a faster flow being ideal. To gather the sample, the plastic seal around the 100 mL bottle was ripped off, and the mouth of the bottle collected the flow. The sample was then placed in an ice chest until transferred to the lab.

Turbidity sample:

First, the vial was cleaned by filling it full and rinsing it three times before collecting new samples. Then, filled with flowing water at the same time and location as the *E. coli* sample was collected. It was critical that the vial was not scratched or dirty, so the turbidity samples were placed in a box until they could be read. To process the turbidity sample, the turbidity meter was calibrated with the gel sample that most closely resembled the sample collected. Once calibrated, the sample was inverted three times and measured with a turbidity meter.

Other procedures:

Before leaving each site, air and water temperature were recorded. As well as fact sheets including site, stream, and sampling conditions.

Results

Upper Oak Creek & West Fork (2019)

This section of the report presents the results from sampling in Upper Oak Creek over the course of the summer months (June-September) in 2019. This sampling effort was supported by the Sedona Chamber of Commerce under the Sedona Sustainable Tourism Plan.

The ambassadors of the Oak Creek Watershed Council, Elise Guzman and Emma Harries, collected water samples throughout the 2019 summer season. Specifically, they sampled towards the headwaters of Oak Creek at three different sites: Pine Flats Crossing on Oak Creek and two sites along West Fork, a major tributary near the headwaters of Oak Creek. Samples were collected every Tuesday morning for 14 consecutive weeks.

The locations for sampling were chosen by OCWC and ADEQ for determining if bacteria such as *E. coli* were present at the confluence site and farther upstream near the headwaters of Oak Creek. In the past, data from West Fork has been inconclusive. Additionally, there was seldom data collected for Upper Oak Creek from Pumphouse Wash to Spring Creek, excluding the data collected by Slide Rock State Park since the 1990's. This effort is crucial in understanding exceedance trends and potential problem areas like Pumphouse Wash and West Fork.

West Fork above confluence with Oak Creek (34.987638, -111.746342)

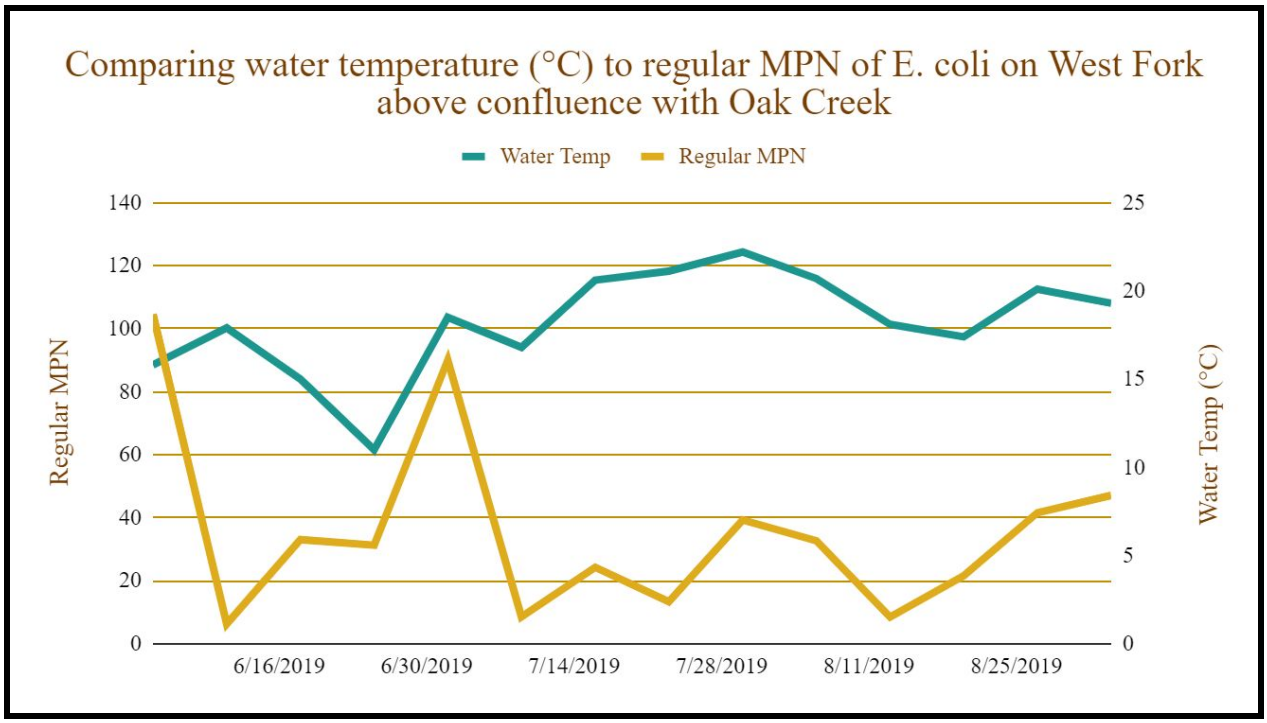

Figure 1: Water temperatures of samples with regular MPN of *E. coli* measured.

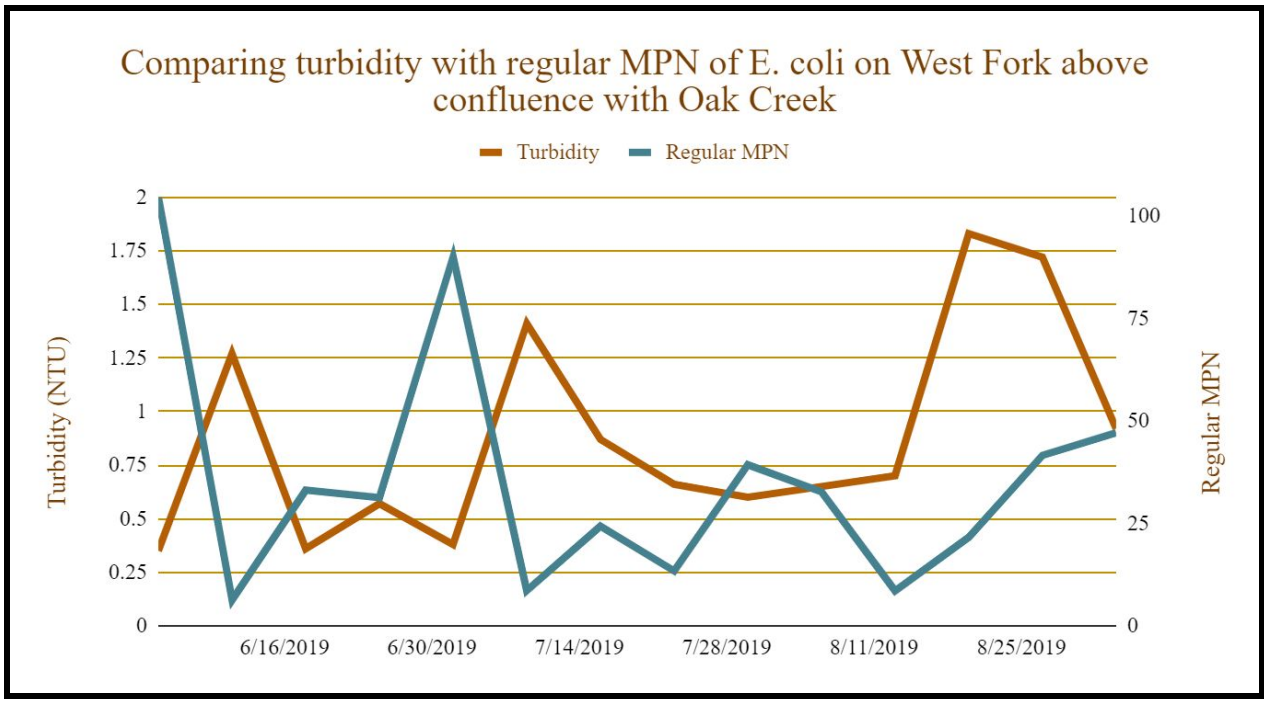

Figure 2: Comparison of turbidity (NTU) with *E. coli* concentrations.

Table 1: Compilation of West Fork above confluence data

	West Fork Above Confluence		
Date	Water Temp (°C)	*E. coli* (MPN)	Turbidity (NTU)
6/4/19	15.8	104.6	0.35
6/11/19	17.9	6.3	1.27
6/18/19	15	33.1	0.36
6/25/19	11	31.3	0.57
7/2/19	18.5	90	0.38
7/9/19	16.8	8.6	1.41
7/16/19	20.6	24.3	0.87
7/23/19	21.12	13.4	0.66
7/30/19	22.2	39.3	0.6
8/6/19	20.7	32.7	0.65
8/13/19	18.1	8.5	0.7
8/20/19	17.4	21.6	1.83
8/27/19	20.1	41.6	1.72
9/3/19	19.3	47.1	0.92

Referring to Figure 1, the last week in June to the first week in July shows a corresponding trend in temperature and *E. coli*. In this sample, *E. coli* spiked at the same time as the water temperature increased from 11°C to 19°C in one week. The first sample collected (Fig. 1) shows the highest amount of *E. coli,* 104.6 MPN. The only other time that the amount of *E. coli* was comparably high was in the fifth sample taken on July 2 with 90 MPN per 100 mL of water (Fig. 1). After July 2, the water temperature stayed within a three degree range of temperature through the end of the samples (Fig. 1). However, from July 30 to August 13, the temperature was decreasing, meanwhile the amount of *E. coli* was decreasing (Fig. 1). When the temperature began increasing in the middle of August, the amount of *E. coli* per sample increased as well (Fig. 1).

Figure 2 does not clearly show a relationship between turbidity and the amount of *E. coli* per sample. The two highest values of *E. coli* were 104.6 and 90 MPN taken on June 4 and July 2. However, these samples had low values for turbidity at 0.35 and 0.38 NTU, respectively (Fig. 2).

West Fork at the second crossing (34.989629, -111.747732)

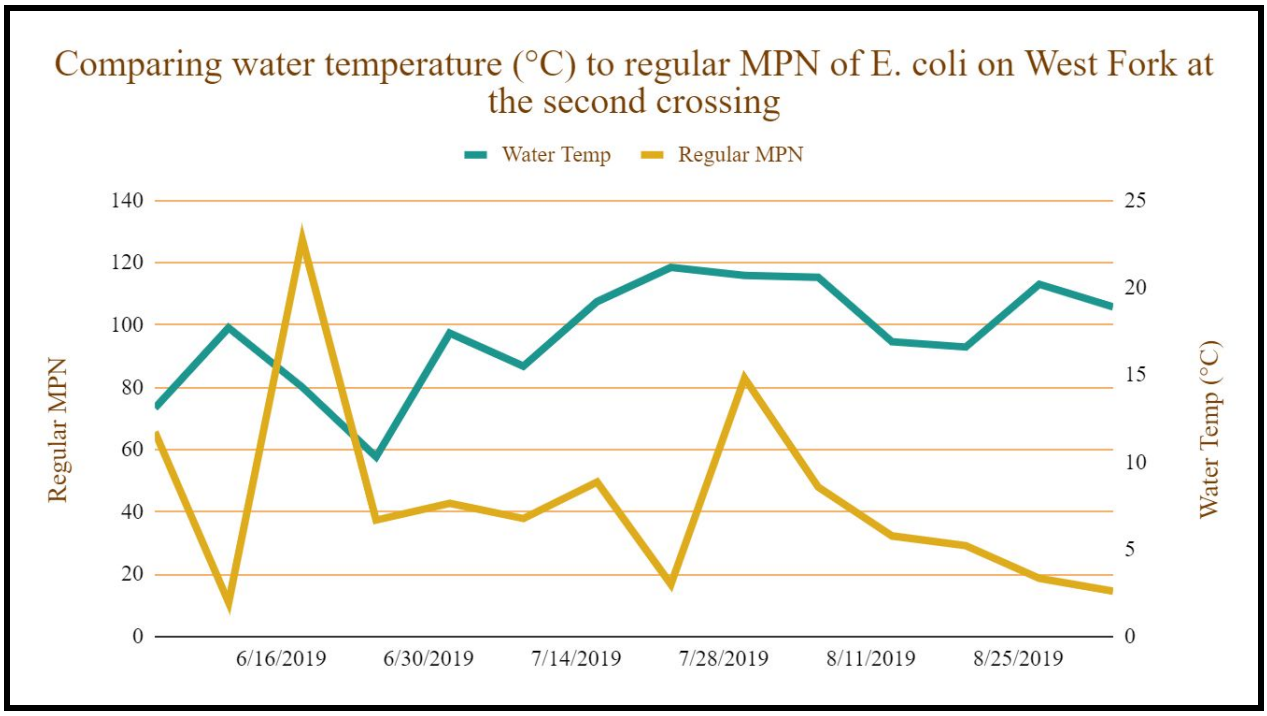

Figure 3: Water temperatures of samples with regular MPN of *E. coli* measured.

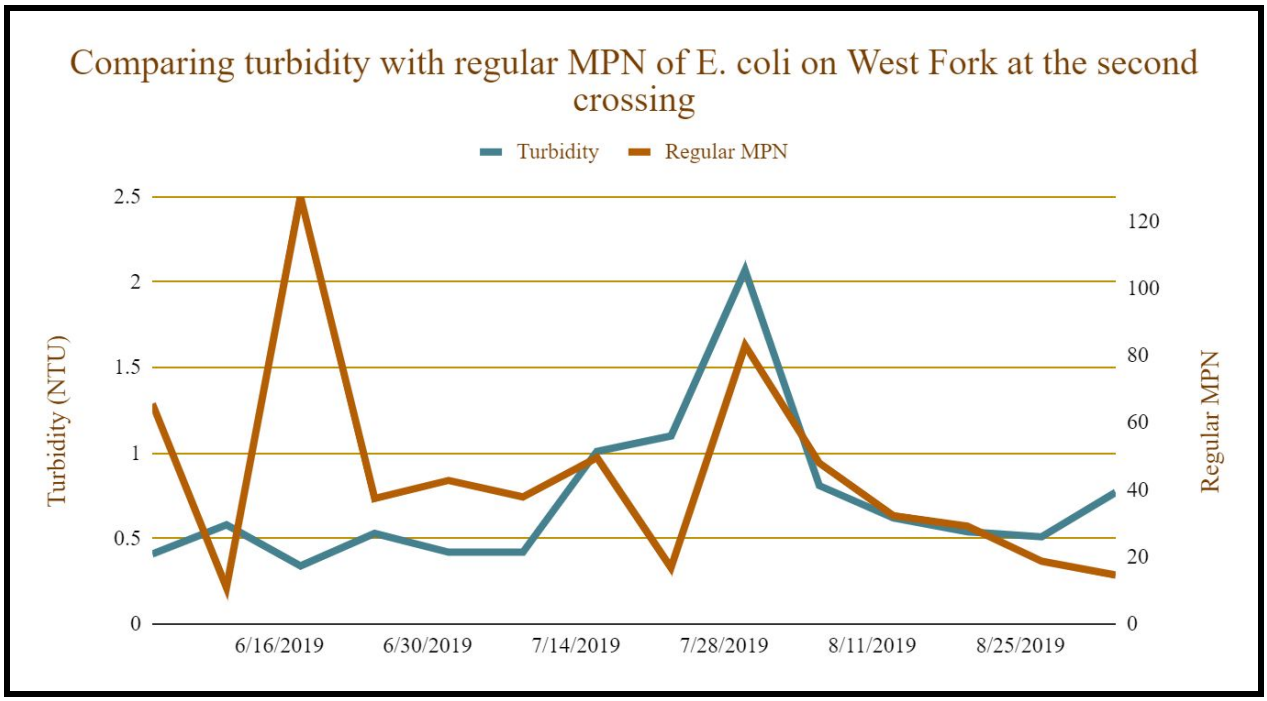

Figure 4: The comparison of turbidity with *E. coli* concentrations.

Table 2: Compilation of West Fork second crossing data

	West Fork Second Crossing		
Date	Water Temp (°C)	*E. coli* (MPN)	Turbidity (NTU)
6/4/19	13.1	65.7	0.41
6/11/19	17.7	10.9	0.58
6/18/19	14.3	127.4	0.34
6/25/19	10.3	37.4	0.53
7/2/19	17.4	42.8	0.42
7/9/19	15.5	37.9	0.42
7/16/19	19.2	49.6	1.01
7/23/19	21.17	16.8	1.1
7/30/19	20.7	83	2.07
8/6/19	20.6	48	0.81
8/13/19	16.9	32.3	0.62
8/20/19	16.6	29.2	0.54
8/27/19	20.2	18.7	0.51
9/3/19	18.9	14.6	0.77

Figure 3 shows a less clear relationship between water temperature and turbidity than Figure 1. *E. coli* peaks on June 18 with 127.4 MPN but the water temperature was on the low end at 14.3°C (Fig. 3). In contrast, on July 23, the warmest water temperature was seen at 21.17°C but the amount of *E. coli* was only 16.8 MPN (Fig. 3). The second highest *E. coli* peak was 83 MPN on July 30 (Fig. 4). This date had the highest value for turbidity at 2.07 NTU (Fig. 4). As the value for *E. coli* decreased through August, the turbidity values followed along (Fig. 4).

Pine Flats Crossing (35.008022, -111.747732)

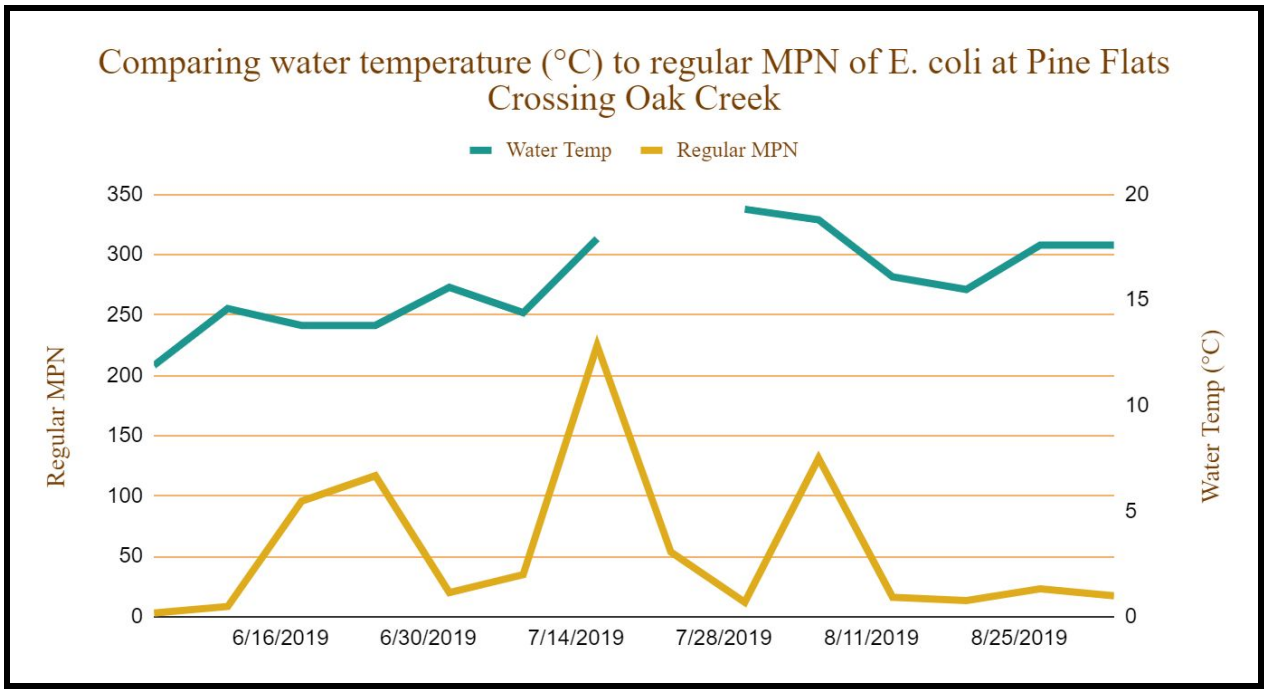

Figure 5: Water temperature compared to amount of *E. coli*

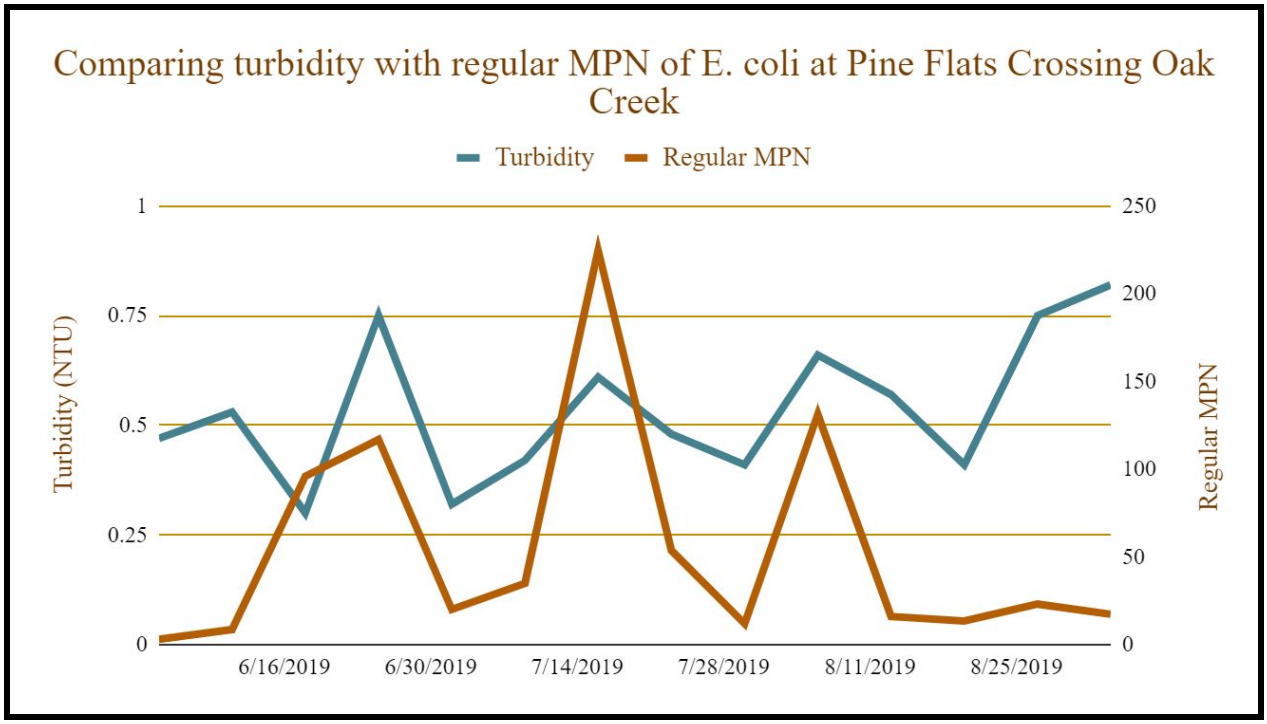

Figure 6: Turbidity compared to the amount of *E. coli*

Table 3: Compilation of Pine Flats crossing data

	Pine Flats Crossing		
Date	Water Temp (°C)	*E. coli* (MPN)	Turbidity (NTU)
6/4/19	11.9	3.1	0.47
6/11/19	14.6	8.6	0.53
6/18/19	13.8	95.9	0.3
6/25/19	13.8	116.9	0.75
7/2/19	15.6	20.1	0.32
7/9/19	14.4	35	0.42
7/16/19	17.9	224.7	0.61
7/23/19		53.7	0.48
7/30/19	19.3	12	0.41
8/6/19	18.8	131.3	0.66
8/13/19	16.1	16.1	0.57
8/20/19	15.5	13.5	0.41
8/27/19	17.6	23.1	0.75
9/3/19	17.6	17.3	0.82

The recorded water temperatures at Pine Flats stayed cooler than the other locations (Fig. 1, 3, and 5). Temperature appears to be slowly increasing throughout the months but does not appear to have an effect on the concentration of *E. coli* (Fig. 5). The highest amount of *E. coli* was seen at this location on July 16 at 224.7 MPN, just below the exceedance standard. On July 23rd, temperature was not recorded.

Figure 6 appears to show a trend between turbidity and the amount of *E. coli* per sample. Yet, the turbidity value never went above 1 NTU at this location. Therefore, even at the highest recorded spike of *E. coli*, the value for turbidity was 0.61 NTU.

Oak Creek (2018-2019)

This section presents data from the summers of 2018 and 2019. Samples were collected at the following sites: Above Slide Rock State Park, Grasshopper Point, Midgley Bridge, Chavez Ranch, and Crescent Moon. All samples were collected on Tuesday mornings between 7-11 a.m.

Above Slide Rock State Park

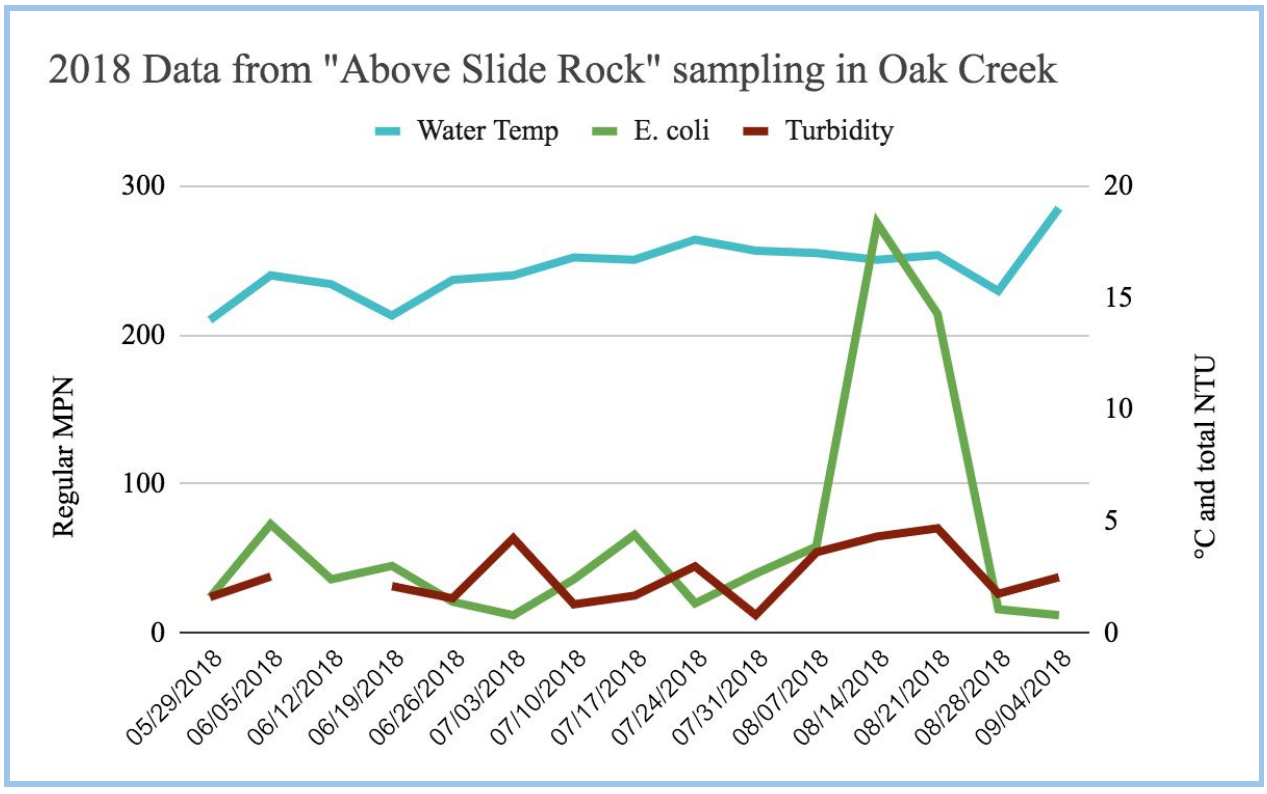

Figure 7: 2018 Water quality from above Slide Rock State Park comparing water temperature, *E. coli* concentration, and turbidity.

Table 4: Compilation of Above Slide Rock data 2018

	Above Slide Rock		
Date	Water Temp (°C)	*E. coli* (MPN)	Turbidity (NTU)
05/29/2018	14	24	1.61
06/05/2018	16	73	2.53
06/12/2018	15.6	36	
06/19/2018	14.2	45	2.1
06/26/2018	15.8	21	1.56
07/03/2018	16	12	4.24
07/10/2018	16.8	36	1.29
07/17/2018	16.7	66	1.67
07/24/2018	17.6	20	2.98
07/31/2018	17.1	40	0.81
08/07/2018	17	58	3.61
08/14/2018	16.7	275	4.32
08/21/2018	16.9	214	4.69
08/28/2018	15.3	16	1.76
09/04/2018	19	12	2.5

Figure 7 has a noticeably steep increase in *E. coli* on August 14, 275 MPN. The following week there was another exceedance in *E. coli* concentration at 214 MPN (Fig. 7). The turbidity values for each of these exceedances are 4.32 and 4.69 NTU, respectively. On June 12th, Turbidity was not recorded (Tab. 4). Water temperature stayed consistent with the samples and other than the two collected exceedance samples, the concentration of *E.coli* was low (Tab. 4)

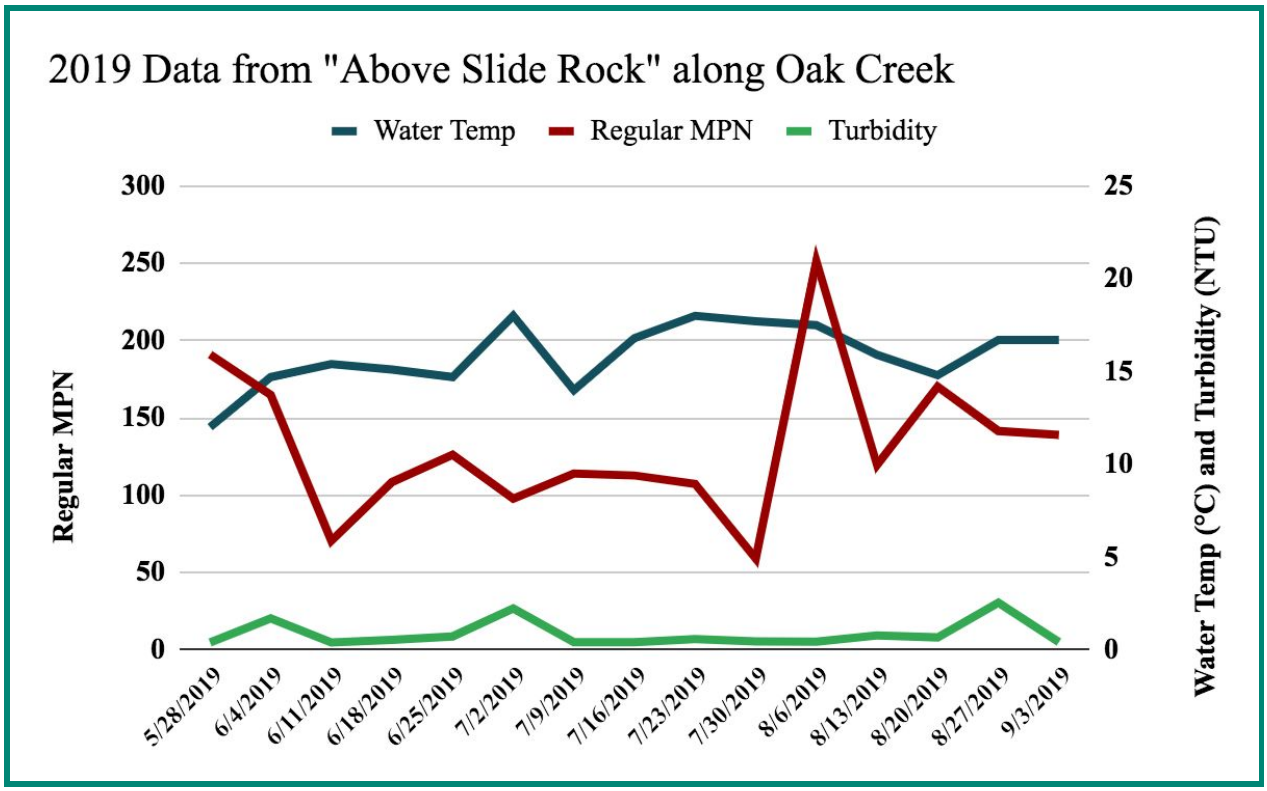

Figure 8: 2019 Water quality from above Slide Rock State Park comparing water temperature (Right Y-axis), *E. coli* concentration (Left Y-axis), and turbidity (Right Y-axis).

Table 5: Compilation of Above Slide Rock data 2019

	Above Slide Rock		
Date	Water Temp (°C)	*E. coli* (MPN)	Turbidity (NTU)
5/28/2019	12	191	0.4
6/4/2019	14.7	164.8	1.7
6/11/2019	15.4	70.5	0.4
6/18/2019	15.1	108.5	0.53
6/25/2019	14.7	126.1	0.72
7/2/2019	18	97.8	2.23
7/9/2019	14	113.9	0.41
7/16/2019	16.8	112.7	0.41
7/23/2019	18	107.3	0.58
7/30/2019	17.7	59	0.45
8/6/2019	17.5	251.3	0.44
8/13/2019	15.9	119.6	0.78
8/20/2019	14.8	170.2	0.67
8/27/2019	16.7	141.5	2.54
9/3/2019	16.7	139	0.42

Figure 8 shows one exceedance of *E. coli* on August 6, 2019 (Fig. 8). The data shows *E. coli* concentrations ranged from 59 to 251.3 MPN with only one exceedance (Tab. 5). Water temperature ranged from 12°C to 18°C (Tab. 5). Turbidity samples never increased beyond 2.54 NTU (Tab. 5). Figure 8 shows a nearly constant rate of *E. coli* concentrations with a range of 59 to 164.8 MPN (Fig. 8). All 15 samples were collected during baseflow conditions.

Grasshopper Point

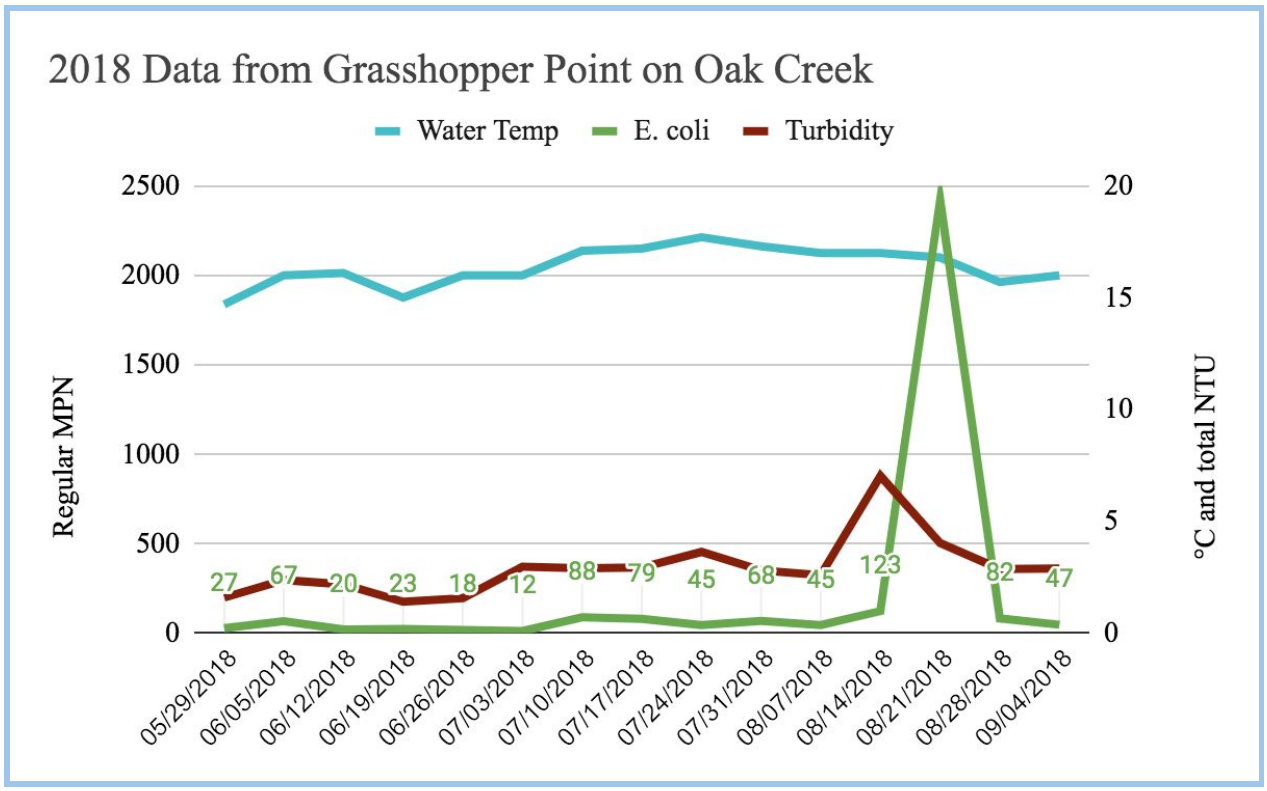

Figure 9: Grasshopper Point water quality data. Note, the peak of 2,419 MPN of E. coli skews the line.

Table 6: Compilation of Grasshopper Point data 2018.

	Grasshopper Point		
Date	Water Temp (°C)	*E. coli* (MPN)	Turbidity (NTU)
05/29/2018	14.7	27	1.59
06/05/2018	16	67	2.37
06/12/2018	16.1	20	2.18
06/19/2018	15	23	1.4
06/26/2018	16	18	1.56
07/03/2018	16	12	2.97
07/10/2018	17.1	88	2.9
07/17/2018	17.2	79	2.93
07/24/2018	17.7	45	3.63
07/31/2018	17.3	68	2.8
08/07/2018	17	45	2.59
08/14/2018	17	123	7.03
08/21/2018	16.8	2419.5	4.03
08/28/2018	15.7	82	2.87
09/04/2018	16	47	2.89

Figure 9 shows the most dramatic spike in *E. coli* measured of all sampling locations. On August 21, *E. coli* was 2,419.5 MPN (Tab. 6), while the turbidity of the sample collected was 4.03 NTU. Water temperature remained consistent from sample to sample (Fig. 9), and the other samples collected all had low values for *E. coli*.

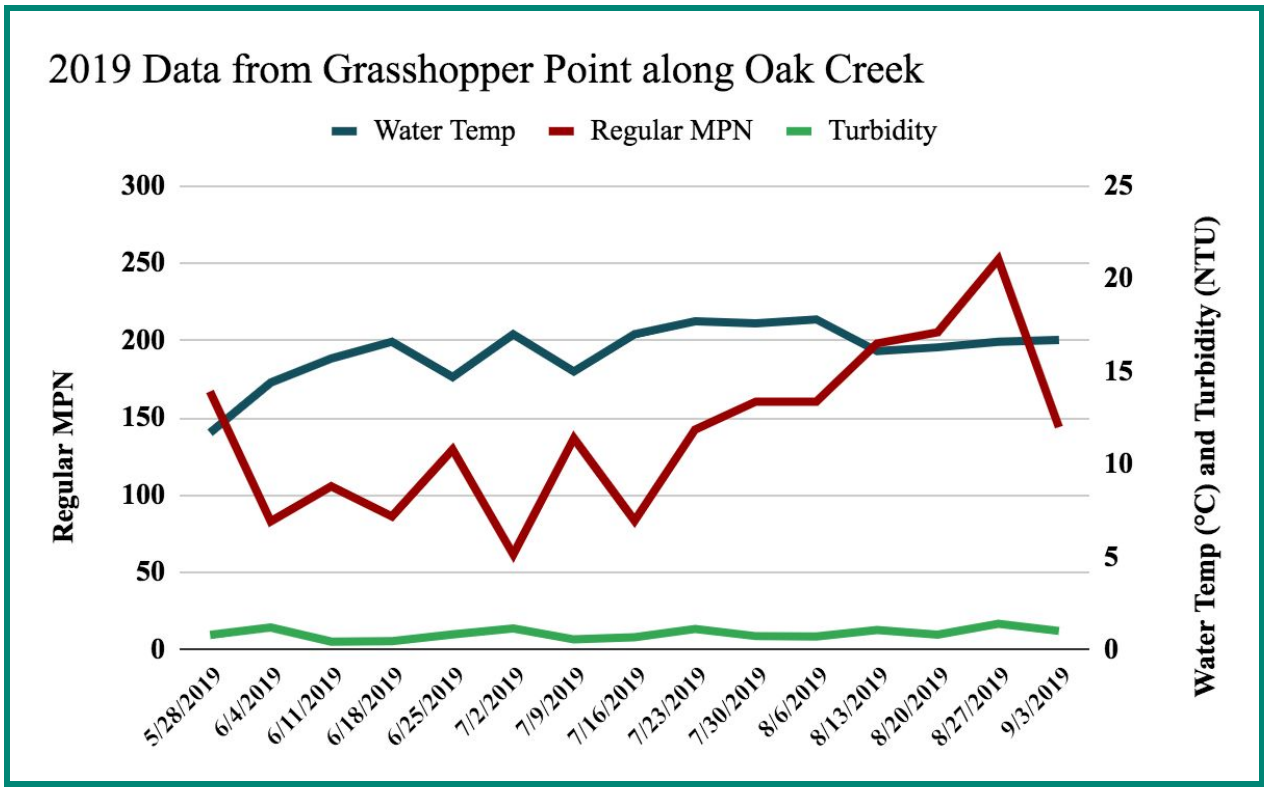

Figure 10: 2019 Water quality from Grasshopper Point comparing water temperature (Right Y-axis), *E. coli* concentration (Left Y-axis), and turbidity (Right Y-axis).

Table 7: Compilation of Grasshopper Point data 2019.

	Grasshopper Point		
Date	Water Temp (°C)	*E. coli* (MPN)	Turbidity (NTU)
5/28/2019	11.7	167.1	0.8
6/4/2019	14.4	83.1	1.2
6/11/2019	15.7	105.7	0.44
6/18/2019	16.6	86.3	0.46
6/25/2019	14.7	129.5	0.83
7/2/2019	17	61.7	1.15
7/9/2019	15	136.7	0.56
7/16/2019	17	83.5	0.68
7/23/2019	17.7	142.4	1.12
7/30/2019	17.6	160.5	0.74
8/6/2019	17.8	160.5	0.72
8/13/2019	16.1	198.1	1.06
8/20/2019	16.3	205.3	0.82
8/27/2019	16.6	252.5	1.4
9/3/2019	16.7	144	1.02

Figure 10 shows *E. coli* concentrations slowly increasing from July to August with the peak measuring at an exceedance of 252.5 MPN on August 27, 2019 (Fig. 10). At the measured exceedance, the turbidity has a value of 1.4 NTU (Tab. 7) The turbidity line shown in Figure 10 is nearly constant with values ranging from 0.4 to 1.4 NTU with the highest value occurring the same time as the exceedance was measured. Water temperature appears to be slowly increasing from May until the beginning of August then appears to stabilize until samples ceased (Tab. 7)

Midgley Bridge

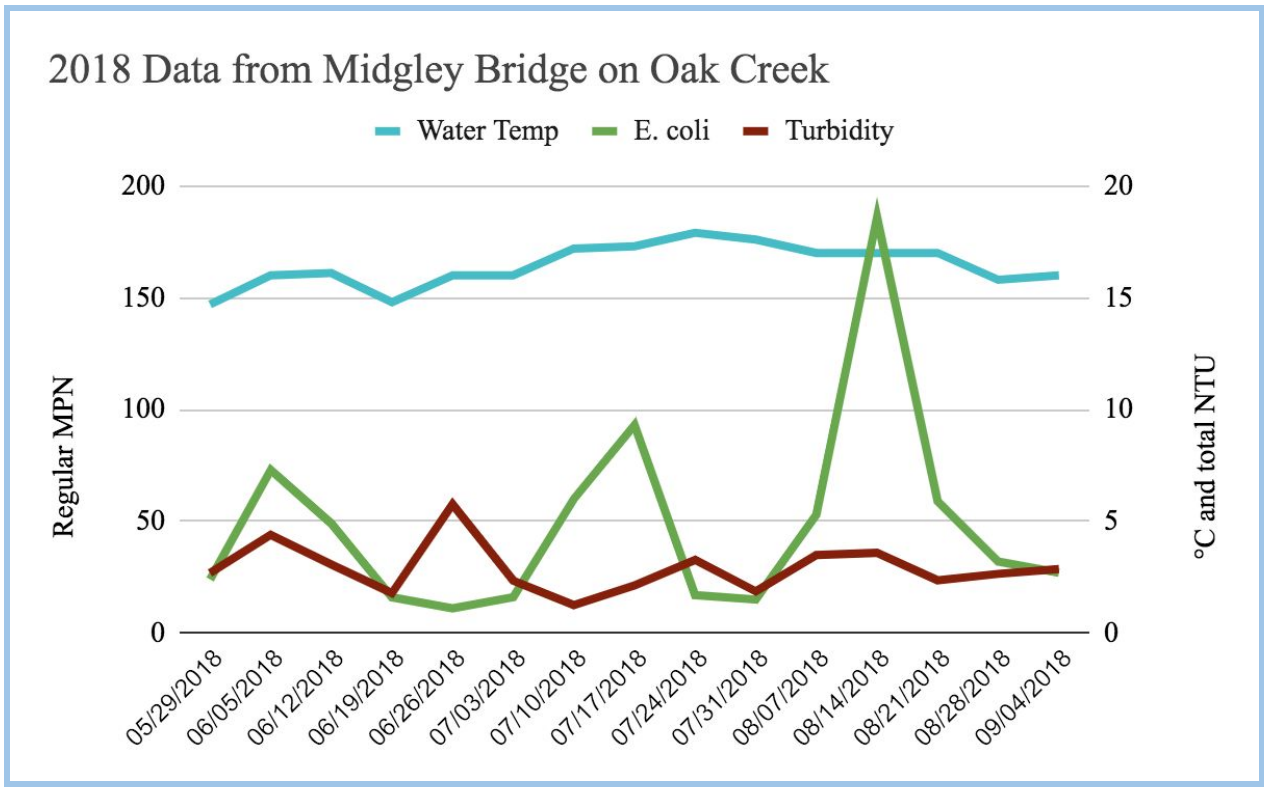

Figure 11: Midgley Bridge water quality data 2018.

Table 8: Compilation of Midgley Bridge data 2018.

	Midgley Bridge		
Date	Water Temp (°C)	*E. coli* (MPN)	Turbidity (NTU)
05/29/2018	14.7	24	2.68
06/05/2018	16	73	4.39
06/12/2018	16.1	49	3.07
06/19/2018	14.8	16	1.79
06/26/2018	16	11	5.77
07/03/2018	16	16	2.35
07/10/2018	17.2	60	1.25
07/17/2018	17.3	93	2.13
07/24/2018	17.9	17	3.27
07/31/2018	17.6	15	1.87
08/07/2018	17	53	3.49
08/14/2018	17	186	3.59
08/21/2018	17	59	2.36
08/28/2018	15.8	32	2.65
09/04/2018	16	27	2.87

Midgley Bridge does not see the same exceedances as the upstream locations did in August (Fig. 11). There is one *E. coli* peak in August, measuring 186 MPN. And although not an exceedance, it did occur on August 14, the same day as the Slide Rock exceedance mentioned above (Tab. 4 and 8). The turbidity values fluctuated slightly from a low of 1.25 NTU to a high of 5.77 NTU (Tab. 8). The peak turbidity value was in late June and the amount of MPN in that sample was the lowest captured by the data at 11 MPN (Tab. 8). Water temperatures remain constant (Fig. 11).

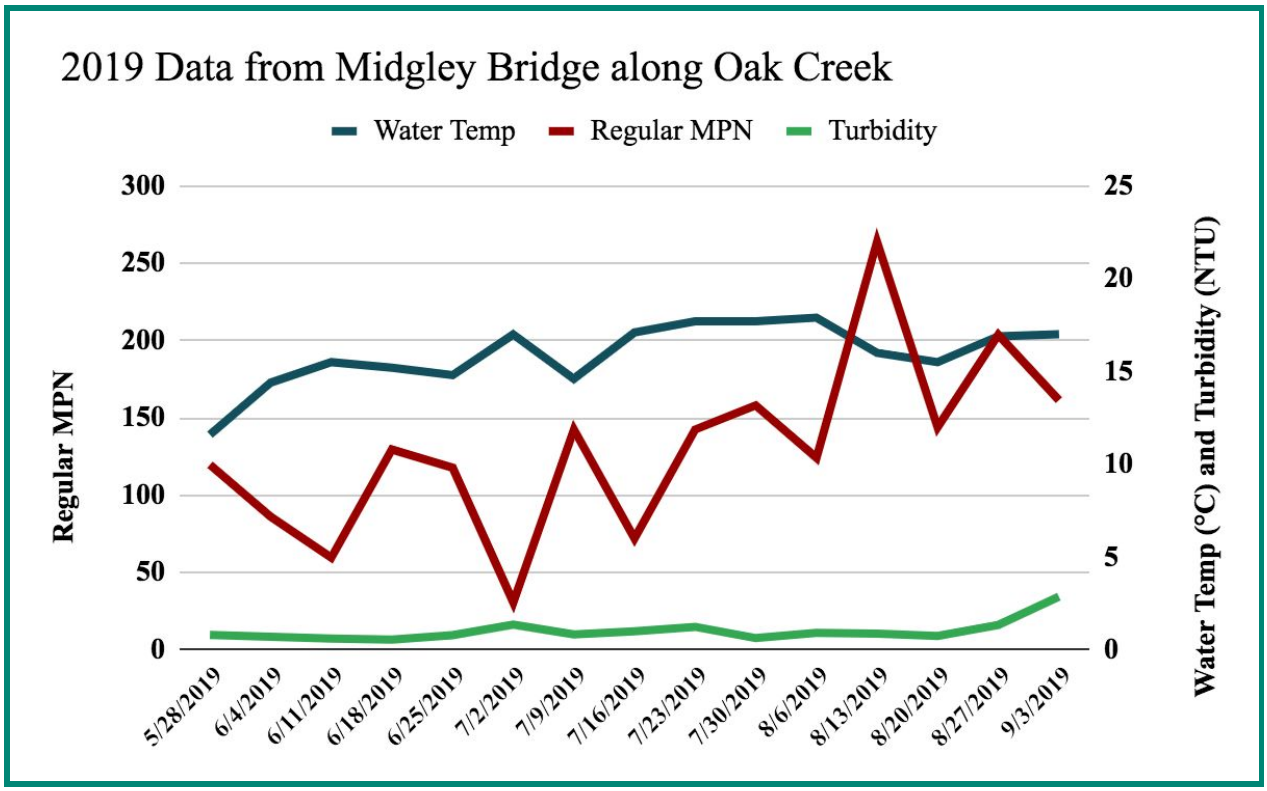

Figure 12: Midgley Bridge water quality data 2019.

Table 9: Compilation Midgley Bridge data 2019.

	Midgley Bridge		
Date	Water Temp (°C)	*E. coli* (MPN)	Turbidity (NTU)
5/28/2019	11.6	119.7	0.8
6/4/2019	14.4	86.1	0.7
6/11/2019	15.5	59.6	0.6
6/18/2019	15.2	129.5	0.55
6/25/2019	14.8	117.8	0.79
7/2/2019	17	30.7	1.36
7/9/2019	14.6	142.4	0.83
7/16/2019	17.1	72	1
7/23/2019	17.7	142.4	1.24
7/30/2019	17.7	158	0.63
8/6/2019	17.9	124.2	0.92
8/13/2019	16	263.8	0.87
8/20/2019	15.5	144	0.75
8/27/2019	16.9	203.7	1.34
9/3/2019	17	161.5	2.86

Figure 12 shows one exceedance in August on different dates than both upstream exceedances (Fig. 8, 10, and 12). The exceedance shown in Figure 12 was on August 13, 2019 and measures 263.8 MPN (Fig. 12) The turbidity value corresponding with the exceedance was 0.87 NTU (Tab. 9). On July 2, 2019 the *E. coli* measured was the lowest measurement collected at 30.7 MPN (Tab. 9) with a turbidity measurement of 1.36 NTU and water temperature recorded at 17°C.

Chavez Crossing

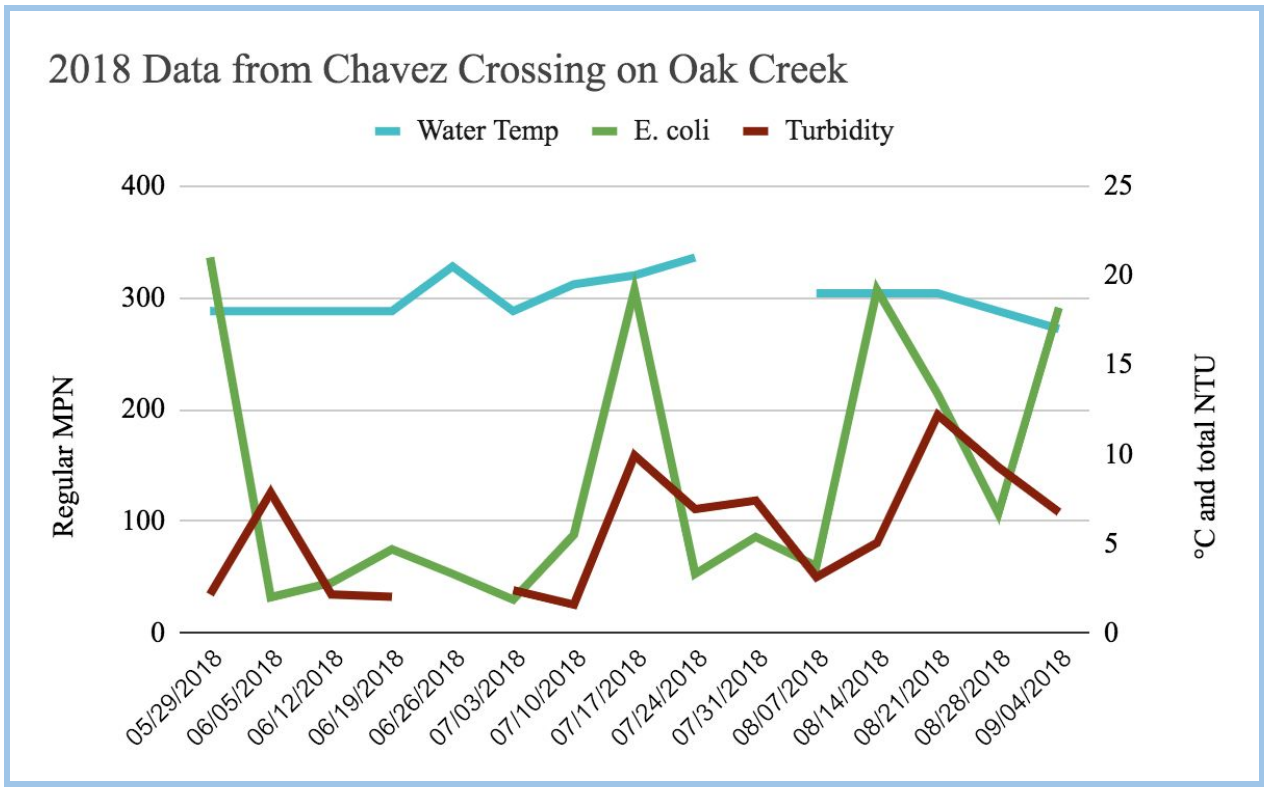

Figure 13: Chavez Crossing water quality data 2018. Note one missing temperature reading and one missing turbidity reading.

Table 10: Compilation of Chavez Crossing data 2018.

	Chavez Crossing		
Date	Water Temp (°C)	*E. coli* (MPN)	Turbidity (NTU)
05/29/2018	18	336	2.16
06/05/2018	18	32	7.86
06/12/2018	18	45	2.16
06/19/2018	18	75	2.03
06/26/2018	20.5	53	
07/03/2018	18	30	2.4
07/10/2018	19.5	88	1.59
07/17/2018	20	307	9.93
07/24/2018	21	53	6.93
07/31/2018		86	7.41
08/07/2018	19	60	3.13
08/14/2018	19	307	5.04
08/21/2018	19	214	12.2
08/28/2018	18	107	9.28
09/04/2018	17	291	6.76

Chavez Crossing saw four recorded exceedances (Fig. 13). These exceedances were 336, 307, 307, and 291 MPN, respectively (Tab. 10). At the second and third exceedances, the values for turbidity were 9.93 and 5.04 NTU, respectively (Tab. 10). The highest turbidity value collected was 12.2 NTU on August 21. The last four weeks of data all saw relatively high values for *E. coli* as compared to other locations (Tab. 10).

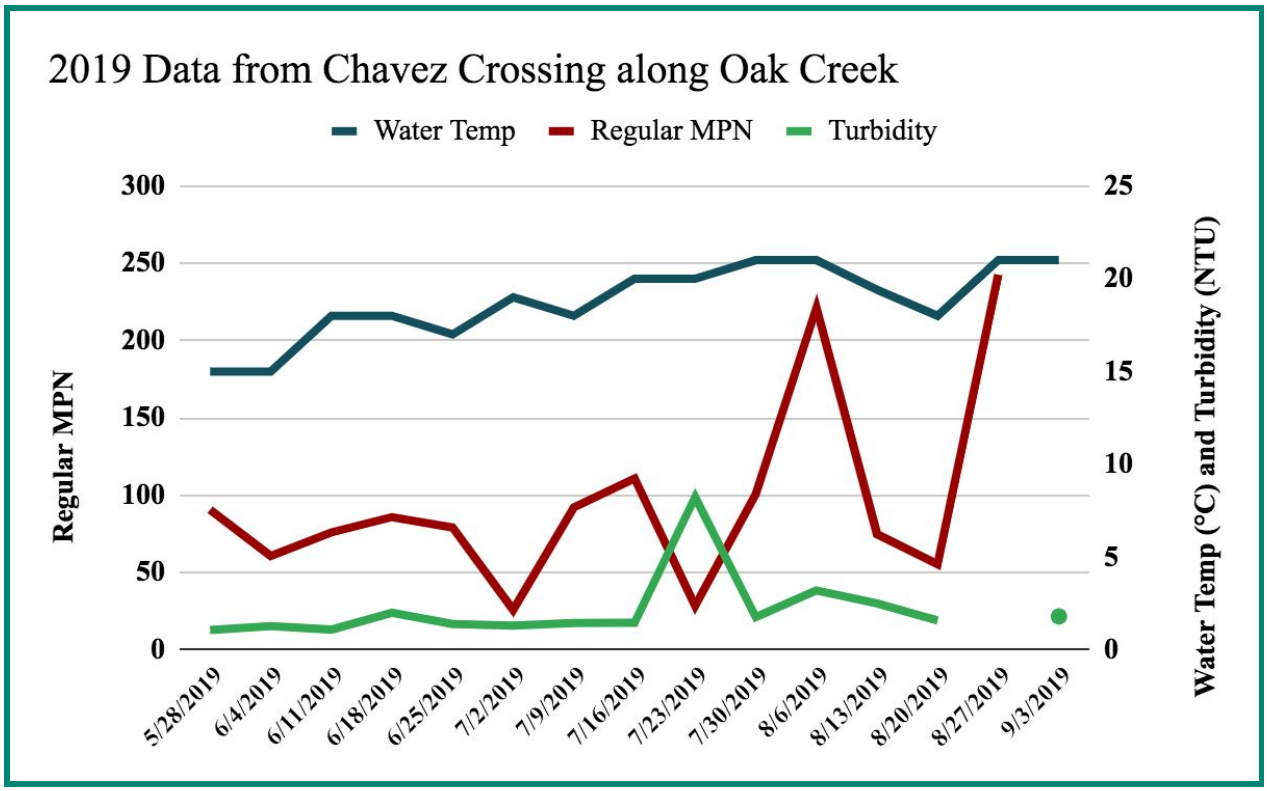

Figure 14: Chavez Crossing water quality data 2019.

Table 11: Compilation of Chavez Crossing data 2019.

	Chavez Crossing		
Date	Water Temp (°C)	*E. coli (MPN)*	Turbidity (NTU)
5/28/2019	15	90.6	1.07
6/4/2019	15	60.7	1.28
6/11/2019	18	75.9	1.09
6/18/2019	18	85.8	2
6/25/2019	17	79.1	1.39
7/2/2019	19	25.8	1.3
7/9/2019	18	92.1	1.45
7/16/2019	20	110.8	1.46
7/23/2019	20	28.4	8.23
7/30/2019	21	100.7	1.77
8/6/2019	21	221.1	3.2
8/13/2019	19.4	74.8	2.5
8/20/2019	18	55.3	1.58
8/27/2019	21	242.7	
9/3/2019	21		1.8

Figure 14 shows one exceedance of *E. coli* on August 27, 2019 with a value of 242.7 MPN (Fig. 14). There was no recorded turbidity reading for that exceedance. The second highest *E. coli* measurement found 221.1 MPN on August 6, 2019. At this location the data shows relatively low values for *E. coli* (Tab. 11). The highest recorded turbidity value was 8.23 NTU on July 23, 2019 and the *E. coli* concentration was the second lowest recorded value at 28.4 MPN (Tab. 11). The exceedance shown here is also seen downstream at the Crescent Moon sampling site on the same date, August 27, 2019 (Fig. 16).

Crescent Moon

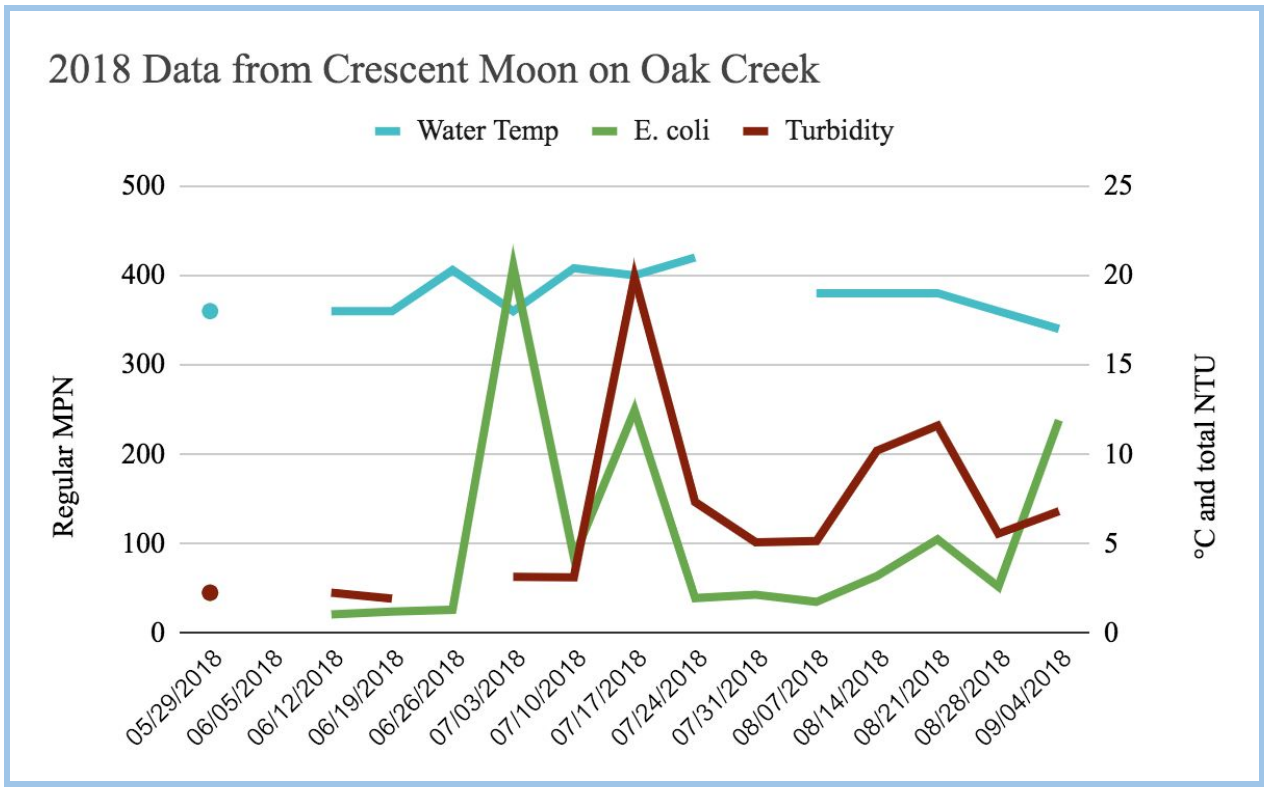

Figure 15: Crescent Moon water quality data 2018.

Table 12: Compilation of Crescent Moon data 2018.

	Crescent Moon		
Date	Water Temp (°C)	*E. coli* (MPN)	Turbidity (NTU)
05/29/2018	18	45	2.26
06/05/2018			
06/12/2018	18	21	2.26
06/19/2018	18	24	1.93
06/26/2018	20.3	26	
07/03/2018	18	410	3.14
07/10/2018	20.4	85	3.12
07/17/2018	20	249	19.9
07/24/2018	21	39	7.33
07/31/2018		43	5.08
08/07/2018	19	35	5.15
08/14/2018	19	64	10.2
08/21/2018	19	105	11.6
08/28/2018	18	52	5.56
09/04/2018	17	238	6.81

The Crescent Moon samples show the most turbid water with a maximum of 19.9 NTU (Fig. 15). The turbidity for the 14th and 21st days of August were 10.2 NTU and 11.6 NTU, respectively (Tab. 12). The samples from these dates, however, did not have exceedances to match those seen farther upstream. There were three exceedances in this dataset: 410 MPN on July 3, 249 MPN on July 17, and 238 MPN on September 4 (Tab. 12). The exceedances on July 17 and September 4 were seen both here and Chavez Crossing.

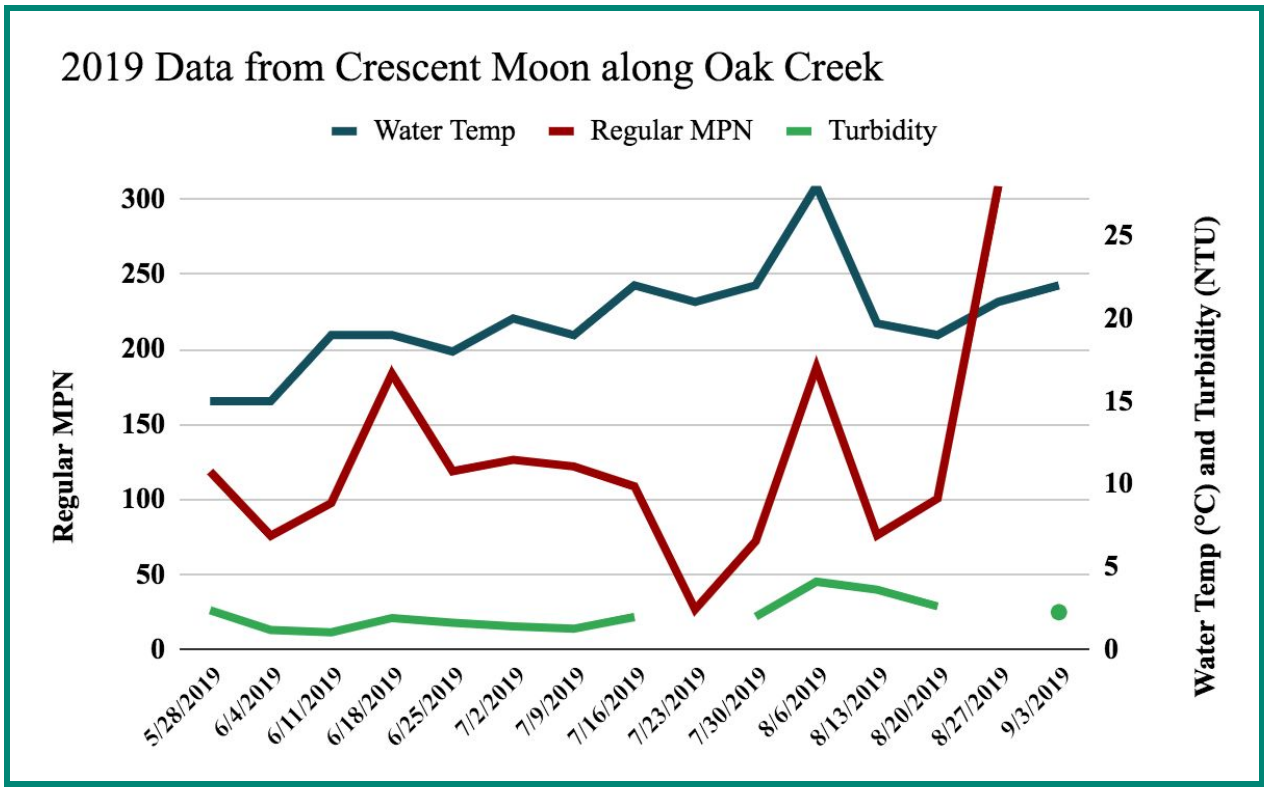

Figure 16: Crescent Moon water quality data 2019.

Table 13: Compilation of Crescent Moon data 2019.

	Crescent Moon		
Date	Water Temp (°C)	*E. coli* (MPN)	Turbidity (NTU)
5/28/2019	15	118.7	2.39
6/4/2019	15	75.9	1.19
6/11/2019	19	97.7	1.06
6/18/2019	19	183.7	1.92
6/25/2019	18	118.9	1.63
7/2/2019	20	126.4	1.42
7/9/2019	19	122.1	1.27
7/16/2019	22	108.8	1.98
7/23/2019	21	26.9	
7/30/2019	22	72.3	2
8/6/2019	28	188	4.11
8/13/2019	19.7	76.2	3.63
8/20/2019	19	100.7	2.62
8/27/2019	21	308.8	
9/3/2019	22		2.27

In Figure 16 there appears to be a relationship between the water temperature and the count of *E. coli* MPN from July 30 through August 13, 2019 (Fig. 16). In the peak between those three weeks, the water temperature is at the highest measured sample but the count for *E. coli* was not at the highest measured sample (Tab. 13). There was one exceedance for *E. coli* in this dataset on August 27, 2019 measured at 308.8 MPN (Tab. 13). The exceedance shown here was also seen at the Chavez Crossing sampling site just upstream on the same day (Fig. 14).

Fossil Creek (2018-2019)

This section presents data from Fossil Creek, a similar stream system as Oak Creek. Samples in 2018 were collected from the following sites: Irving, Bridge, Sally Mae, and Purple Mountain. In 2019, samples were collected from Irving, Bridge, Homestead, Sally Mae, and Purple Mountain. No samples were collected near the waterfall trail in either year. All samples lack turbidity data. Sampling occurred on Tuesdays, once a month, during July, August, and September 2018. In 2019, sampling dates doubled with samples sometimes occurring twice a month from April through September.

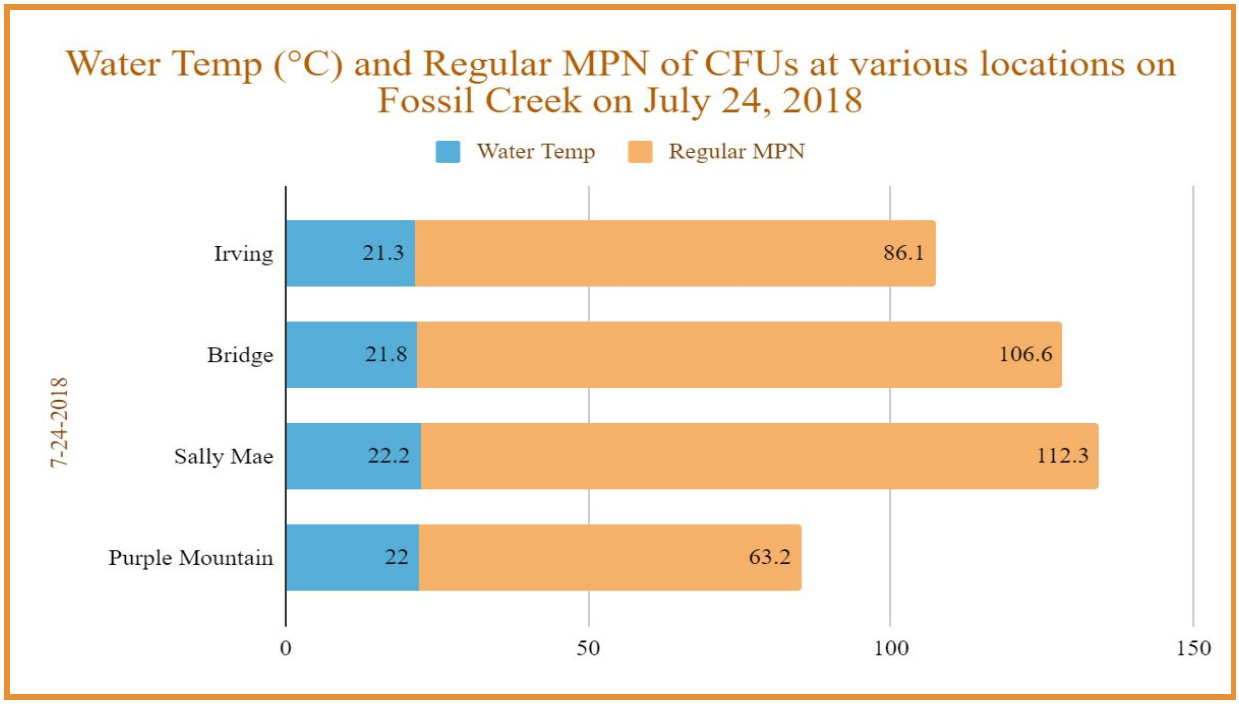

Figure 17: The water temperature compared to MPN of *E. coli* at the various sample sites along Fossil Creek on one Tuesday in July.

The samples collected in July 2018 show the concentration of *E. coli* to be increasing farther downstream. Until the last sampling site where the value no longer followed the trend (Fig. 17). Water temperature increased farther downstream but remained between 21.3°C and 22.2°C (Fig. 17).

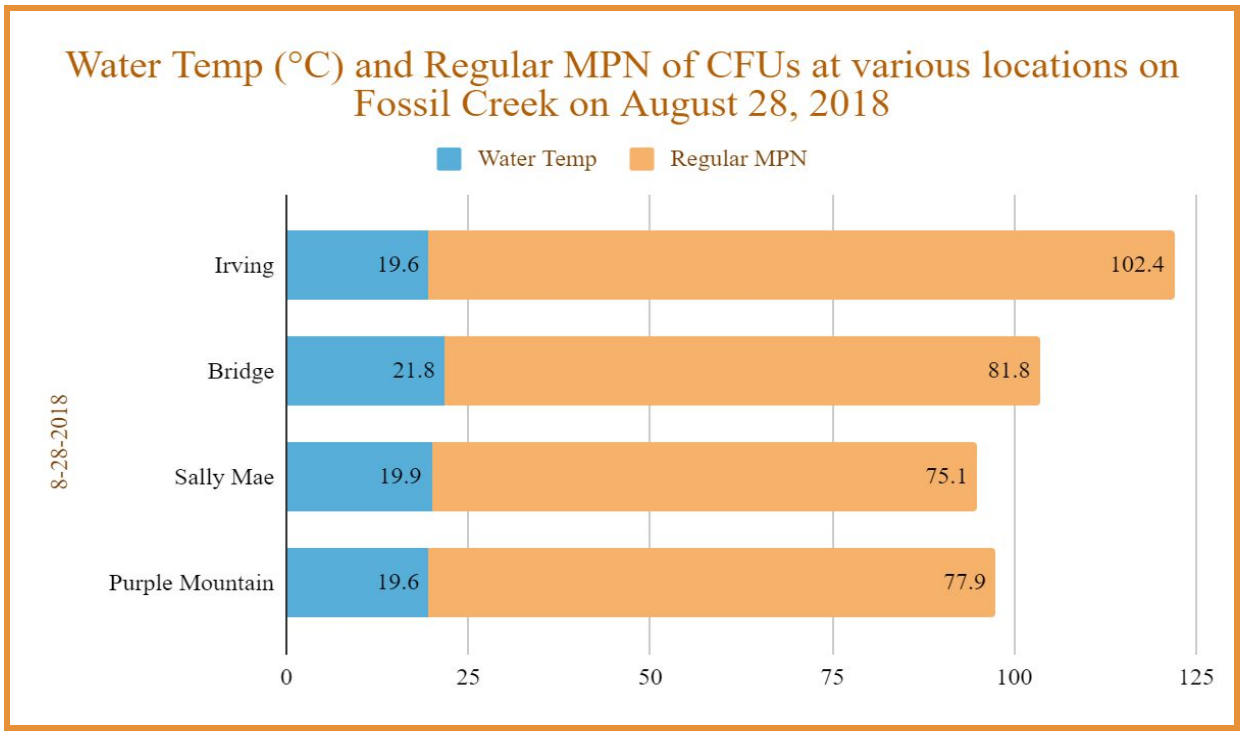

Figure 18: The water temperature compared to MPN of *E. coli* at the various sample sites along Fossil Creek on one Tuesday in August.

Samples collected in August show no exceedances for *E. coli* (Fig. 18). The sample closest to the waterfall, Irving, saw the highest concentration, 102.4 MPN (Fig. 18). Water temperature stayed between 19.6°C and 21.8°C at each location (Fig. 18).

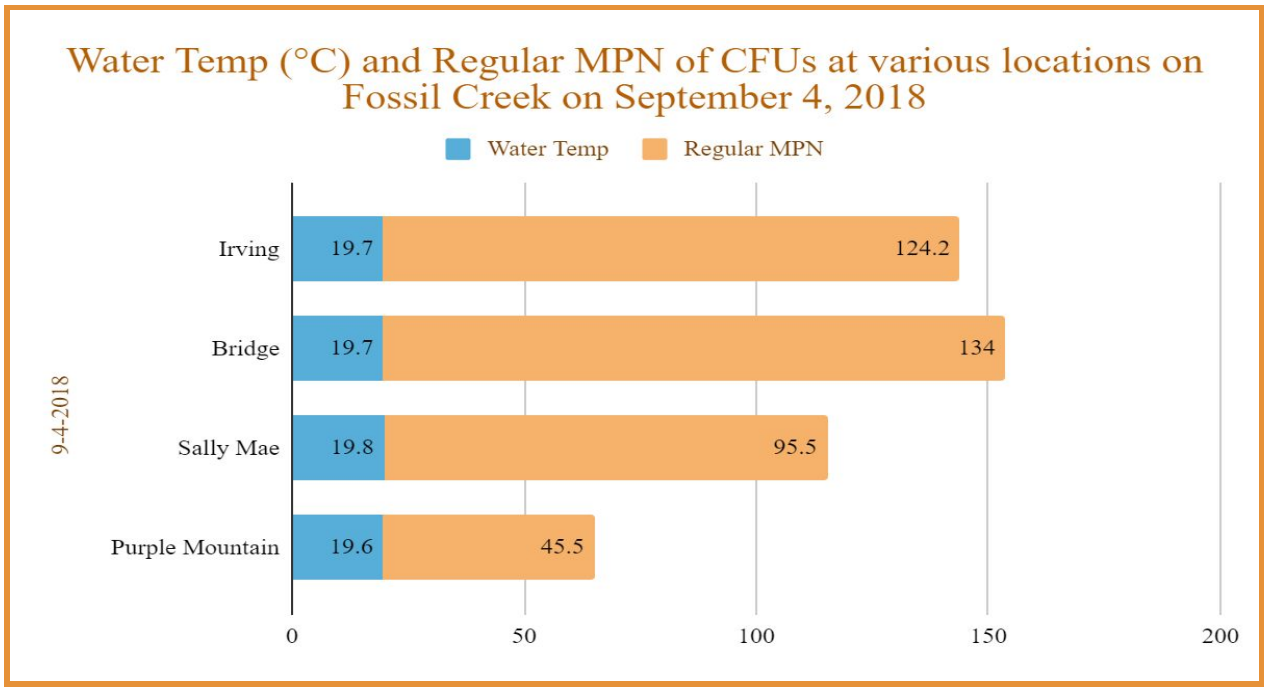

Figure 19: The water temperature compared to MPN of *E. coli* at the various sample sites along Fossil Creek on one Tuesday in September.

September 4 saw the highest recorded amount of *E. coli,* 134 MPN, at the bridge sampling site. (Fig. 14). Purple Mountain remains low as it did in July (Fig. 17 and 18). Water temperature was resistant to change in September (Fig. 19).

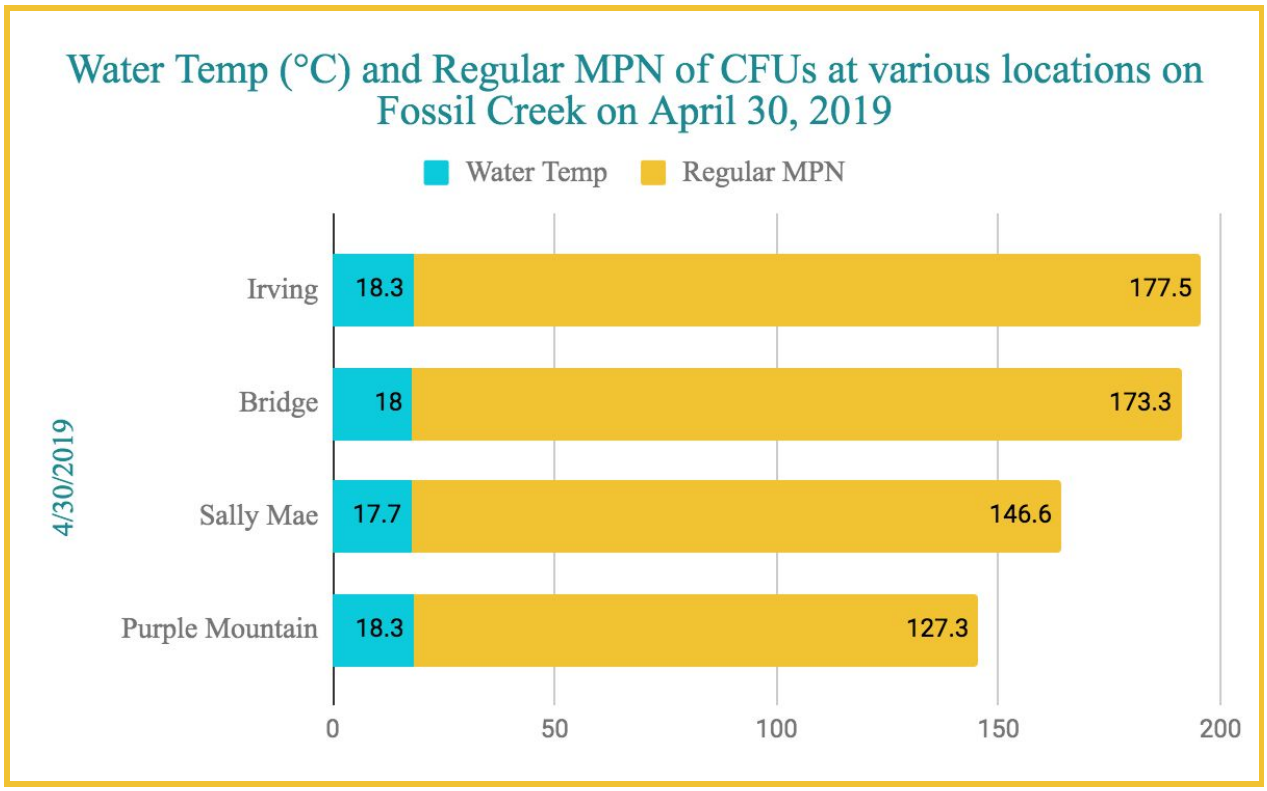

Figure 20: Water temperature compared to *E. coli* concentration on April 30, 2019 along Fossil Creek.

The samples along Fossil Creek taken in April show that the farther downstream one travels there is less counted *E. coli* (Fig. 20). There are no exceedances measured from this dataset. The temperature ranges from 17.7°C to 18.3°C in April (Fig. 20).

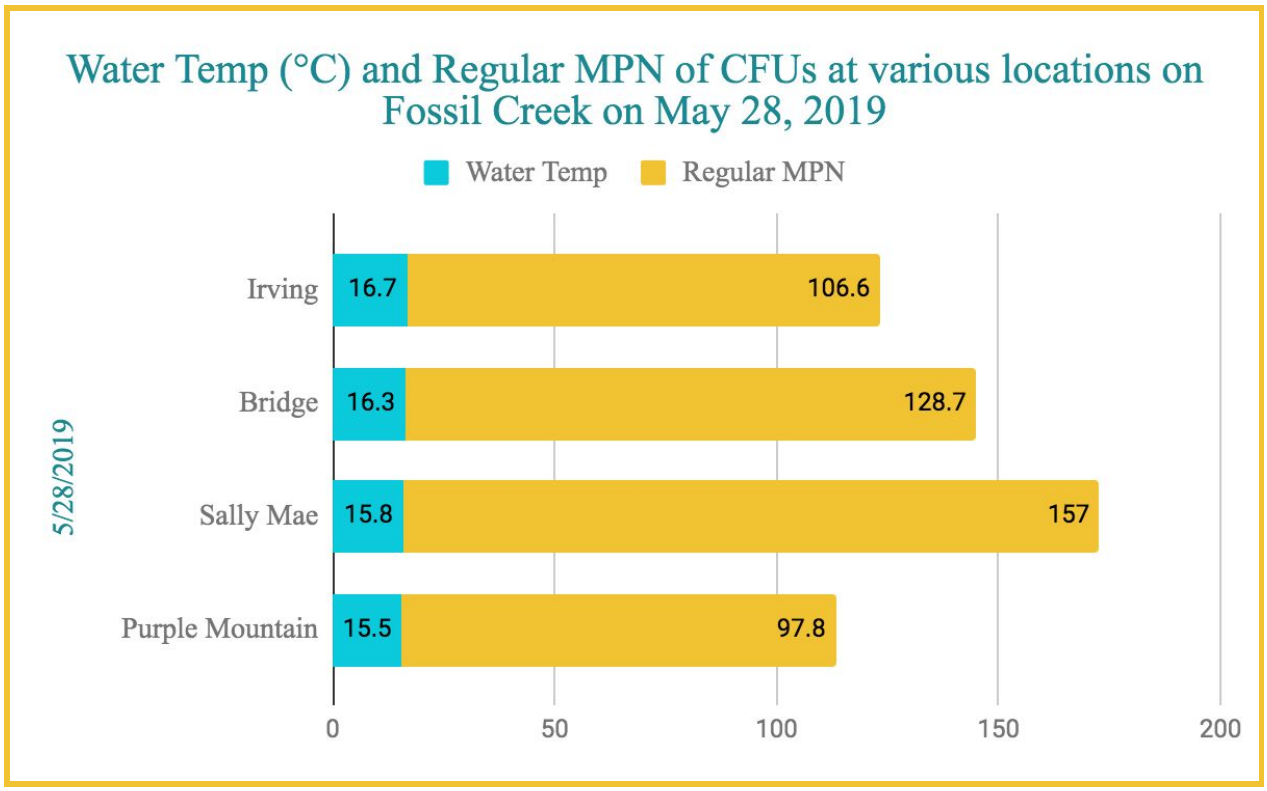

Figure 21: Water temperature compared to *E. coli* concentration on May 28, 2019 along Fossil Creek.

Conversely to Figure 20, Figure 21 appears as though the *E. coli* concentrations increase further downstream until the last sample where the measured *E. coli* count is the lowest sampled for this date (Fig. 21) Figure 21 shows the temperature is colder downstream than upstream with a range of temperatures from 15.5°C to 16.7°C (Fig. 21).

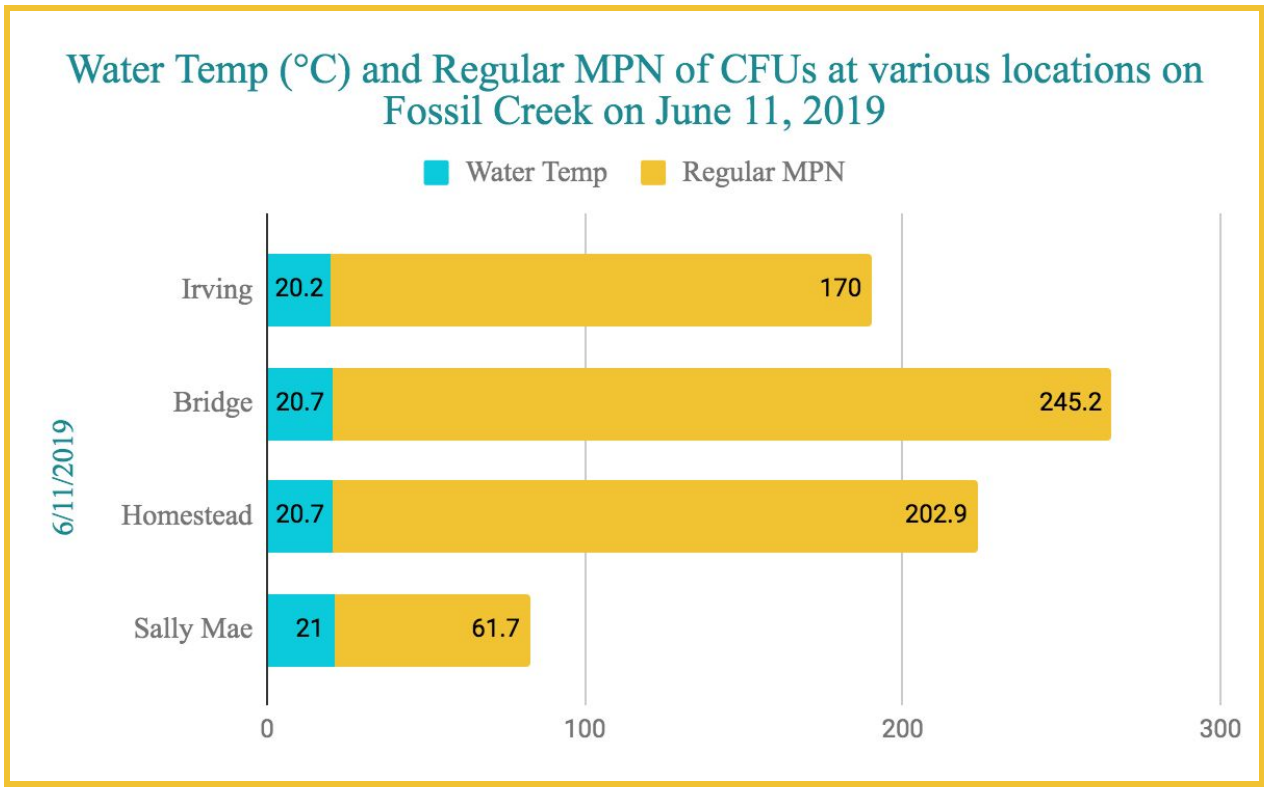

Figure 22: Water temperature compared to *E. coli* concentration on June 11, 2019 along Fossil Creek.

Figure 22 shows an exceedance of *E. coli* at the Bridge sampling site with counted *E. coli* concentrations at 245.2 MPN (Fig. 22). Upstream of the exceedance, the concentration of *E. coli* showed 170 MPN (Fig. 22). Downstream of the exceedance, at the sampling site called Homestead, the concentration showed 202.9 MPN, and finally the concentration was minimal at the Sally Mae sampling site with a measurement of 61.7 MPN (Fig. 22). The temperature remained relatively constant across all four sampling sites on June 11, 2019 (Fig. 22).

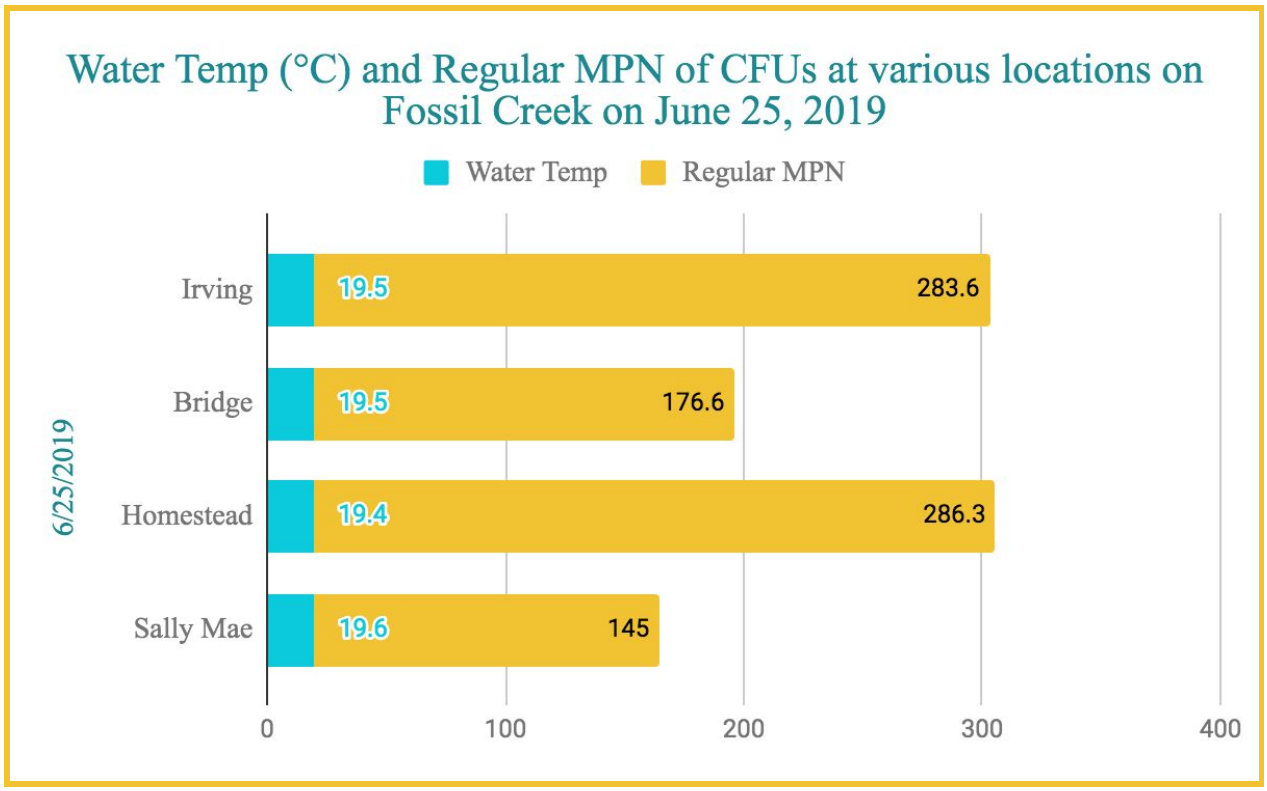

Figure 23: Water temperature compared to *E. coli* concentration on June 25, 2019 along Fossil Creek.

Figure 23 shows two exceedances with counts of *E. coli* concentrations of 283.6 MPN and 286.3 MPN, respectively (Fig. 23). These exceedances occurred at the upstream most site, Irving, and the third out four sampling sites, Homestead. In between these two exceedances were samples that do not show exceedances (Fig.23). The temperature remained between 19 and 20°C for all four locations on June 25, 2019 (Fig. 23).

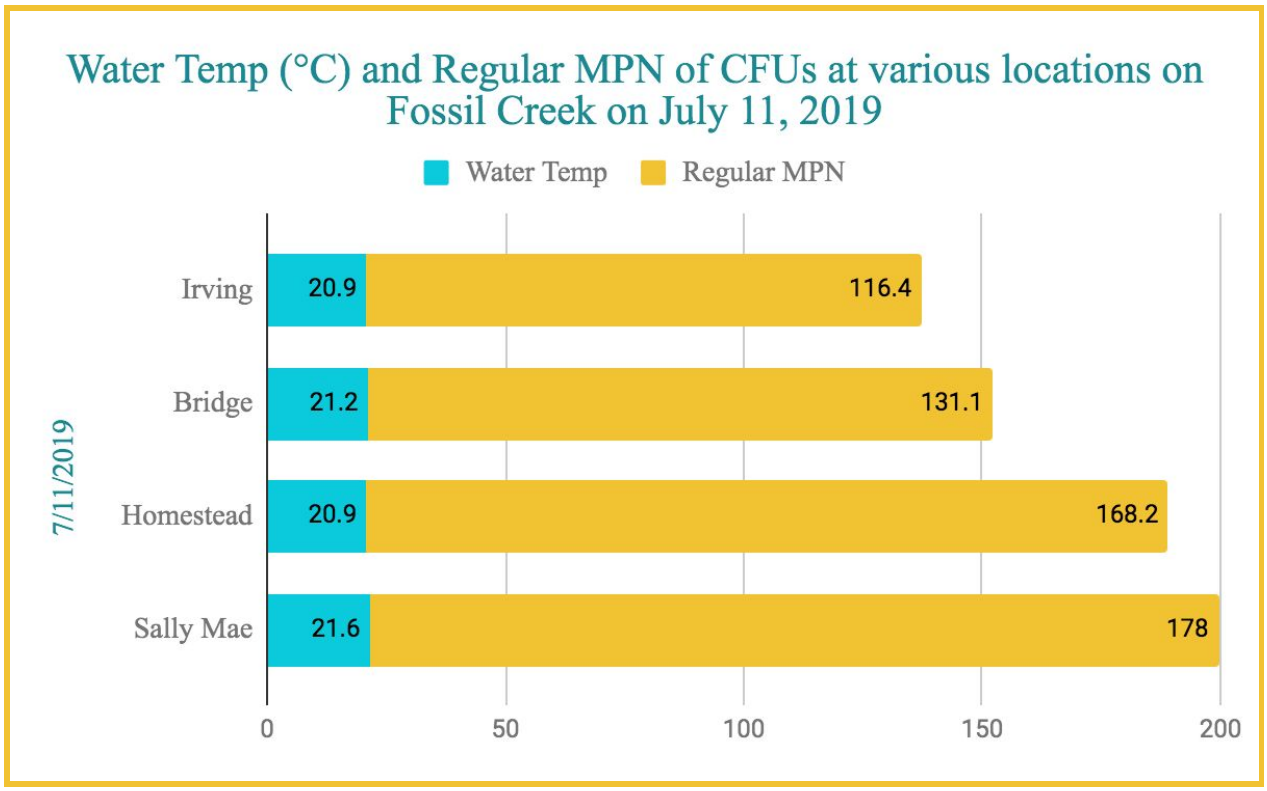

Figure 24: Water temperature compared to *E. coli* concentration on July 11, 2019 along Fossil Creek.

Figure 24 is similar to Figure 21 because it shows a slight trend of increasing *E. coli* concentrations farther downstream (Fig. 21 and Fig. 24). There are no recorded exceedances in the data shown in Fig. 24 for July 11, 2019. Temperature remains relatively constant across the four samples.

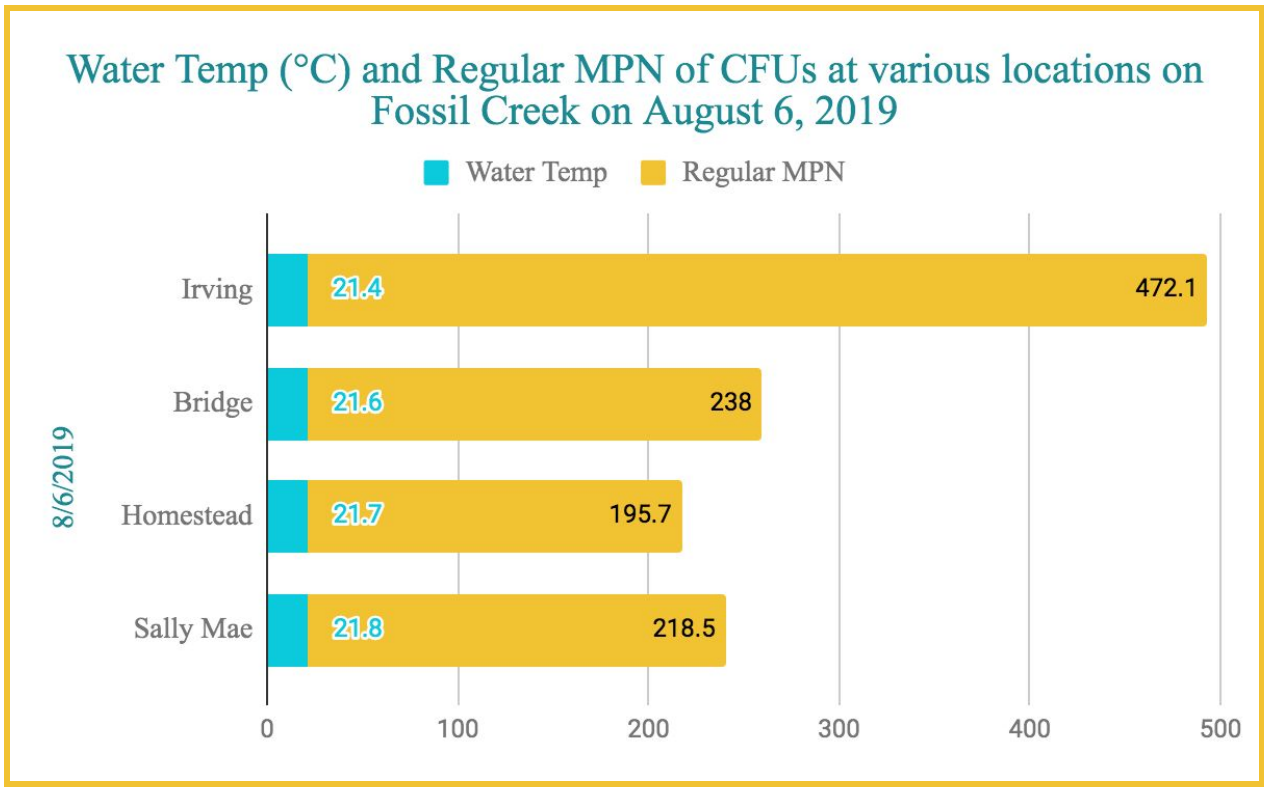

Figure 25: Water temperature compared to *E. coli* concentration on August 6, 2019 along Fossil Creek.

Figure 25 shows a large exceedance at the farthest upstream sampling site with concentrations at 472.1 MPN (Fig. 25). Downstream, at the Bridge sampling site there is also an exceedance with concentrations at 238 MPN. Homestead and Sally Mae do not show exceedances though Sally Mae does come close to exceedance concentrations. The temperature remained constant across all four sampling sites.

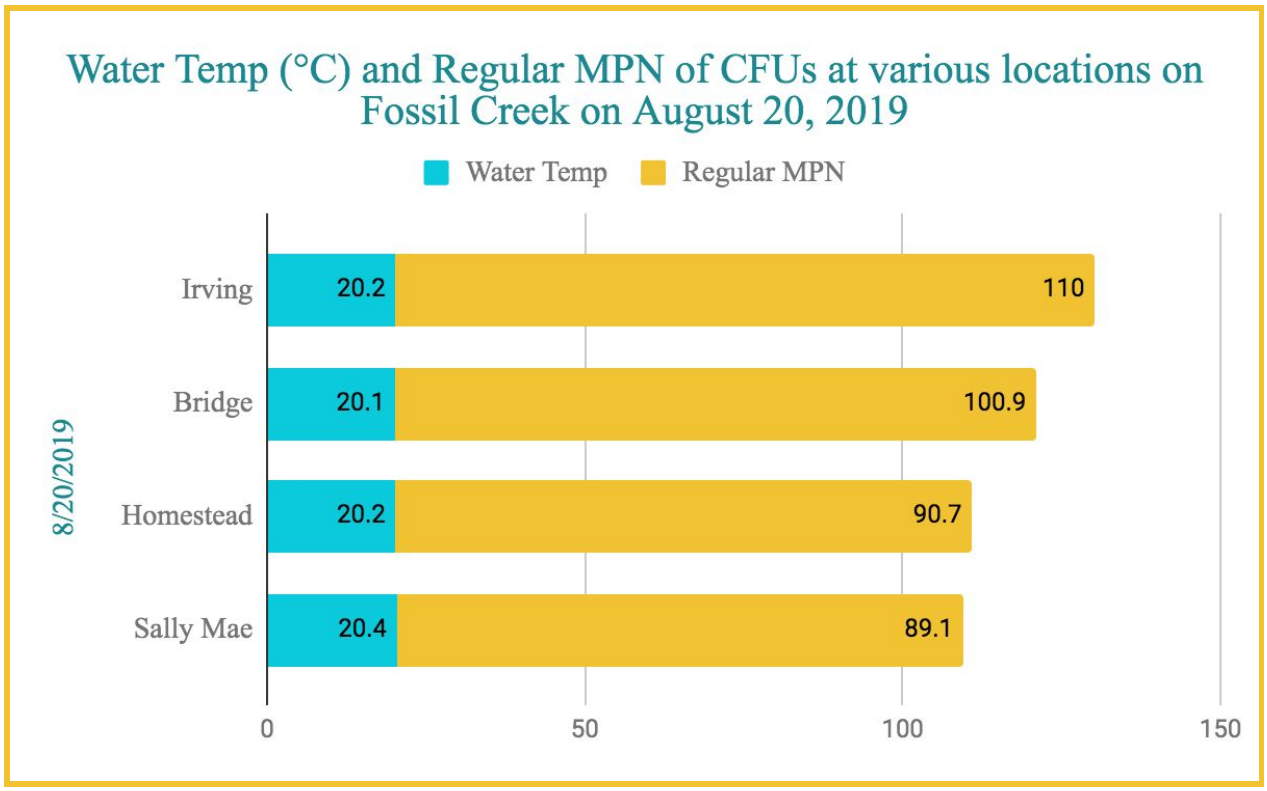

Figure 26: Water temperature compared to *E. coli* concentration on August 20, 2019 along Fossil Creek.

Figure 26 shows decreasing concentrations of *E. coli* as the samples go downstream (Fig. 26). The temperatures remain constant across the four samples. There are no exceedances collected from this date of sampling.

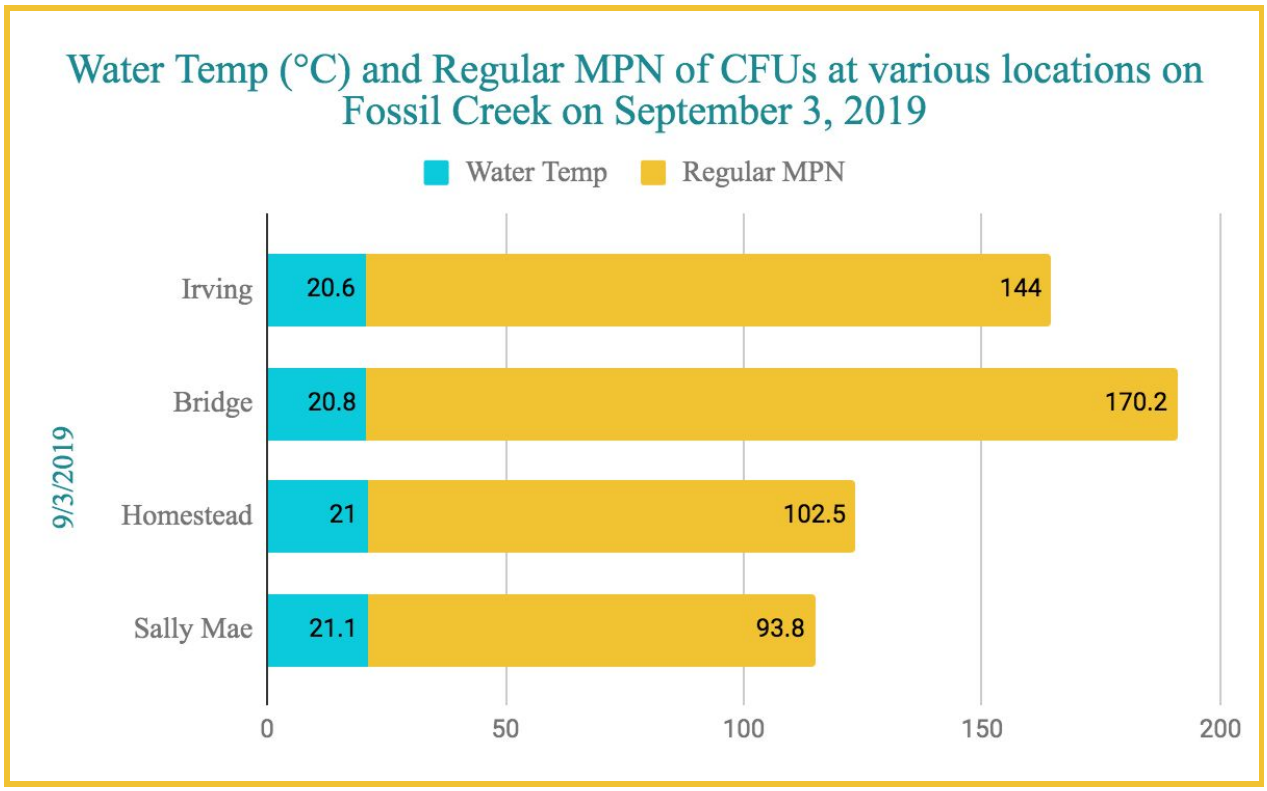

Figure 27: Water temperature compared to *E. coli* concentration on September 3, 2019 along Fossil Creek.

Figure 27 shows no exceedances with *E. coli* samples taken. The highest recorded sample was at the Bridge sampling site and measured 170.2 MPN (Fig. 27). Water temperature showed little change.

Discussion

The data in this report covers six different data sets and cannot easily be compared. However, there are some issues that go across the board. First, is the sampling time and date. In order to gather data on the possible impacts that recreation has on either Oak Creek or Fossil Creek, it would be ideal to have samples collected when recreation is occurring. A suggestion would be to change the sampling date and time from Tuesday morning to Saturday afternoon. This could possibly capture the effect that recreation has on the water quality as it is happening. However, we recognize that accessibility through parking and staffing availability during high-visitation days are a factor in this.

Furthermore, it is difficult to compare sampling sites in lower Oak Creek and Fossil Creek because the order in which samples were collected is unknown. The recommendation moving forward is to first sample upstream then move downstream mimicking the streamflow and therefore, easier to compare the data.

Also, it is difficult to understand and explain why one sampling site showed an exceedance while the sites both upstream and downstream do not show the same exceedance. However, it is very likely that nonpoint and point source pollution aid in this issue. Further issues include not having a large enough sampling set, as well as not following up on any exceedances the day after, instead of the week after. Please see our future planned sampling efforts to monitor visitor-use in Oak Creek Canyon on page 48.

Upper Oak Creek and West Fork (2019)

In summary, this data represents a baseline flow of Oak Creek. There was not a single exceedance gathered in the data collected, nor did the water ever become disturbed enough to cause a high turbidity value. While the goal of this data was to be able to show trends in temperature, turbidity, and *E. coli*, it doesn't show said trends. There are a few instances where the data resembles a relationship. However, taking into account the lack of sampling, it is unclear if the relationships can be confirmed. This data was collected at entirely baseflow conditions, meaning that no single storm or monsoon occurred prior to samples being taken. Although this data does not satisfy the initial goal, it is good to have as baseline data, so that future samples have something to be compared to.

Oak Creek (2018-2019)

2018

Throughout the data collected there was likely a storm event or multiple storm events from the middle of August to the beginning of September. Beginning with the site above Slide Rock State Park, there were two exceedances a week apart from August 14 to August 21. Directly downstream, at Grasshopper Point, there was an enormous exceedance on August 21. Midgley Bridge didn't have an exceedance but does suggest a storm on the same date. The remaining two sites downstream appear to have been affected by a different storm several weeks later, as shown by the exceedances on September 4. Exceedances shown in these datasets are most likely due to storm or monsoon events.

2019

Similar to the 2018 Oak Creek data, we can assume that there could have been storm events between August 6-27, although 2019 was one of the drier years for monsoon events. Out of the five sites sampled, all sites showed one exceededence during these dates. Grasshopper point, Chavez Crossing, and Crescent Moon all had exceedances on August 27, 2019, alluding to the point that these sites may have had a high amount of use the previous weekend and/or a stormwater event. Samples above Slide Rock State Park peaked on August 6, 2019 at 251.3 MPN while Midgley Bridge peaked on August 13, 2019 at 263.8 MPN. Furthermore, turbidity readings were relatively consistent, except on July 23, 2019 at Chavez Crossing where turbidity read at over 8 NTU. This is inconsistent with the guideline that the level of *E. coli* increases as turbidity increases, yet the data shows otherwise (Fig. 14). Overall, we cannot conclude whether or not any exceedances in this dataset is due to high recreation use and/or stormwater events.

Fossil Creek (2018-2019)

2018

The data from Fossil Creek is inconclusive because there were only three samples. It could be hypothesized that if samples were taken more consistently, and taken closer to the waterfall trail then there would be more exceedances.

2019

Data from Fossil Creek increased from only three sampling dates in 2018 to eight sampling dates in 2019. These samples were still collected on Tuesday mornings and do not show consistent exceedances from upstream sites to downstream sites. Samples began at the end of April and went through the beginning of September. In June there were two exceedances that were separated by two other non-exceedance samples. It is likely that at the two samples there were a few recreators in the water causing the exceedances that then were diluted so the exceedances were not seen at the downstream locations. Similarly, in August there was one relatively high exceedance over 400 MPN that has an unknown attribution. Ultimately, the water quality samples collected along Fossil Creek showed few exceedances and the exceedances shown have no definitive cause. The temperature stayed consistent throughout the four months of sampling and there were no turbidity readings taken.

Future Sampling in Oak Creek Canyon (2020+)

In the years following, Oak Creek Watershed Council will continue to work with key partners to assess water quality in the Oak Creek Watershed. In 2020, we increased our sampling sites to several locations in Oak Creek Canyon. We also changed our primary sampling date from Tuesday to occur over high-use times, from mid-March-September, during the weekend. Thanks to a grant from the Arizona Department of Environmental Quality, we can work to understand how visitor-use and poor recreation practices play a role in water quality impairment. In 2020, we continue to work with the Arizona Department of Environmental Quality and the Sedona Chamber of Commerce to monitor water quality in Oak Creek. By continuing to sample at Oak Creek Canyon sites during each Tuesday in the summer season, we can compare baseline data to samples collected over high-use times on the weekend.