Water Quality along the San Juan River

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Abstract

The San Juan River is valued as a source of water to the Colorado River, a spot for recreation and cultural significance, and a home to many native species. Everything and everyone dependent on the river relies on the quality of the river being safe to use. It is important that water quality is continuously monitored to understand the health and composition of the river, and for further research to be conducted to best understand how to preserve the San Juan and other rivers. This study looks at the effect of a summer monsoon on levels of turbidity, dissolved oxygen, nitrate, phosphate, pH, coliform, and water temperature compared to water quality seen in normal weather and flow conditions. These water quality assessments were completed using a Lamotte Low Cost Water Quality Monitoring kit, and were completed along the Lower San Juan over a seven day period. The results show an increase in turbidity, nitrate, and water temperature, a decrease in dissolved oxygen and phosphate, and stagnant trends in pH and coliform. These results suggest that the monsoon event, although only lasting for a few hours, had a substantial impact on the water quality of the river.

Introduction

The San Juan River is a major tributary of the Colorado River, and originates as snowmelt from the San Juan Mountains in southwest Colorado. It flows for approximately 355 miles, traveling through northwest New Mexico into southeast Utah and ending at Lake Powell. As the San Juan moves through the states, it turns from a mountain river to an incising alluvial river meandering through desert plains that becomes more silty and filled with sediment (Aton et al., 2000). In addition to the significant cultural and environmental impact the river has created, the San Juan continues to be an important source of water and power for over 4 million people (*EPA*, 2020).

Water quality assessments are important to conduct on a regular basis as they help build an understanding of the expected chemical and physical properties of a river, monitor and regulate a river's health for recreational, consumptive uses, and preserve wildlife habitat (*EPA,* 2014). Common indicators for these assessments are: presence of coliform bacteria, dissolved oxygen (DO), nitrate, pH, phosphorus or phosphate, temperature, and turbidity. Assessments conducted during normal conditions can be used to understand water quality trends when there are sudden changes in the weather that affect the water.

As the San Juan River journeys through the desert regions of Utah, it is exposed to arid conditions and weather patterns. The North American Monsoon (NAM) is an important component of the Southwestern US' climate, as it is a huge precipitation event that takes place from July to September. It is marked by increased winds, thunderstorms, and increased flows in rivers affected by the monsoon. The NAM presents extreme changes in weather conditions when compared to expected weather and flow conditions the San Juan region has for most of the year, and has potential to change the water quality of the river. Studies on water quality after monsoons and subsequent increased, sometimes scouring, flows in a mountainous watershed found that turbidity and total suspended solids increased while pH and DO both experienced a drop (Lee et al., 2015). Concerning sediment loads, Ta et al. 2013 and Wang et al. 2016 show that strong wind events and thunderstorms can lead to a threefold increase in suspended sediment loading, leading to channel narrowing and destructive effects on downstream ecology. Hass et al. 2001 notes an increase in dissolved organic matter with strong rainstorms in Southwestern US rivers which indicates an increase in nitrate levels.

When considering normal flows and weather conditions on the San Juan, the river exhibits an average of 10.61 ppm of DO, 0.51 ppm of nitrate, 0.6 ppm of phosphate, an average pH of 8.0, an average water temperature of 18.4 degrees Celsius, and an average turbidity of 744 FNU (Hornewer, 2014; *USGS Water Data*, 2018). We chose to look at water quality data for the calendar year of 2010 and the calendar year of 2018, as these years had flow levels and regimes expected for the regulated San Juan River as represent expected water quality levels for the river.

This observational study explores the changes in water quality of the San Juan River after a monsoonal event, specifically looking at the indicators of nitrate, phosphate, DO, water temperature, turbidity, coliform and pH. From the results of this study, we hope to build an understanding of changes in river systems after sudden meteorological events and what this implies for water quality, ecology, and human use of that system.

Methods

Study location

This water quality assessment took place on a 83-mile reach of the Lower San Juan river from Sand Island campgrounds to Clay Hill Crossing in Utah. Sampling was taken at campsites we set up at, and sampling sites were set up near cobble bars and relatively shallow areas of flowing water. The campsites we sampled are in the order of: Sand Island campground, River House camp, Pontiac Wash camp, Honaker camp, Slickhorn camp B, and Oljeto camp. We collected samples and conducted tests on coliform, DO, nitrate, pH, phosphate, temperature, and turbidity at one sampling site at all these locations except for Oljeto camp. At Oljeto, we sampled from two sites -- one in the flowing river and one in the pool of clear, standing water located behind the camp site. We tested for the seven indicators from these two sites, and have a total of 14 results from the Oljeto camp.

Sampling was conducted from June 16th, 2022 to June 22nd, 2022, with the exception of June 18th, 2022. The thunderstorm that we will analyze the effects of occurred on the 18th, and due to those conditions we were unable to sample that day. Sampling at all campsites started between 2:30 pm and 4:30 pm as this was the only time feasible for us, and sampling at this same time range at each campsite avoided any changes that would occur based on the time of day (such as temperature and DO). There was one exception to this -- on June 21st, sampling was not done until 9:15pm.

Sampling procedure

Water quality tests were conducted using the Lamotte low cost water monitoring kit. The following procedure was done at each testing site. The sampling container was rinsed two times with the stream water, submerged and pointed into the current for 30 seconds, capped underwater, and removed from the river.

The first test was for coliform. Water was poured up to 10 milliliters in a test tube containing a coliform testing tablet. The test tube was then supposed to be stored at room temperature, out of direct sunlight, and remain unshaken for 48 hours. However, maintaining room temperature and preventing shaking was unattainable on the river. In order to account for this, a sample was taken using tap water from Davis, California. This sample was shaken over the following 48 hours to attempt to mimic the conditions on the river. After 48 hours, the samples were observed by looking at the color and clarity of the water. A cloudy, yellow, and bubbly sample would indicate a positive test meaning at least 20 coliform colonies were present per 100 milliliters of water. If the sample was red or a clear yellow, this would indicate a negative test meaning less than 20 coliform colonies were present per 100 milliliters of water.

There are three different groups of coliform bacteria. Total coliform includes multiple kinds of bacteria, many of which are commonly found in the environment. Fecal coliform is nested within total coliform and is found within the guts and feces of warm blooded animals. E-coli is one type of fecal coliform. The test kit used in this study detects total coliform. Not all strains of coliform bacteria are harmful. However, if there is a sign of contamination it could mean that pathogens were also able to enter the system. Drinking water standards state that total coliform and E. coli should be absent, negative, or zero colony forming units per 100 milliliters. Coliform tests are important because they can be used to find and eliminate any sources of contamination.

The second test conducted was dissolved oxygen. A small tube was submerged in the water sample and filled to the top. Two DO test tablets were dropped into the tube. The cap was screwed on and the tube was repeatedly inverted to mix the sample until the tablets had disintegrated, this took approximately four minutes. Then, the tube was left to sit for five minutes to allow the color to develop. The color of the sample was compared to the provided DO color chart in order to get a measurement of the DO in ppm.

Dissolved oxygen levels are affected by both seasons and daily temperatures, and the inverse relationship between temperature and oxygen levels. DO affects the water quality through the health of all aquatic species that require oxygen to live. According to EPA standards, DO should be between 6.5-8 ppm to be considered healthy drinking water.

The third test was for nitrate. A test tube was filled to the 5 milliliters line with the water sample and one nitrate wide range CTA test tablet was added. The test tube was inserted into a protective sleeve. Then it was capped and inverted for two minutes, allowing the tablet to disintegrate. An additional 5 minutes were needed for the color to develop. Lastly, the tube was removed from the protective shield and its color was compared to a nitrate color chart which used measurements of ppm.

Some concentration of nitrate is necessary and beneficial as it provides nutrients to plants. However, too high of concentrations can lead to accelerated growth of algae and plants which can deplete dissolved oxygen and limit light penetration. According to the EPA, concentrations below 10ppm are considered safe to drink. High concentrations of nitrate can be caused by air pollution or runoff from agriculture or sewage. It is important to detect and remove any sources of contamination.

The fourth test was for pH. A test tube was filled to the 10 milliliters line with the water sample and one wide range pH test tablet was added. It was then capped and inverted until the tablet disintegrated. The color of the sample was compared to the pH color chart.

pH is an important quality of water because it controls both the form and amount of chemicals found in the water. It also affects wildlife because most species have an ideal pH range for survival. The EPA recommends drinking water to be between 6.5 and 8.5.

The fifth test was for phosphate. A test tube was filled to the 10 milliliters line with the water sample and one phosphorus test tablet was added. The tube was capped and inverted until the tablet disintegrated. The tube was allowed to sit for 5 minutes to allow the color to develop. Then it was compared to the phosphate color chart which used measurements of ppm.

Similar to nitrate, phosphate is necessary in small quantities to provide nutrients to living organisms. However, concentrations that are too high can lead to accelerated growth of algae and plants. EPA recommends phosphate levels to be below 0.05ppm for streams discharging into reservoirs.

The sixth test was for temperature. A thermometer was placed four inches below the water surface for one minute. The thermometer was then removed and the temperature was indicated by whichever number had a green display.

Temperature is an important cue for many species and affects growth, reproduction, and migration. It can also limit the ranges that species are able to survive in and affect water chemistry. Water can be unnaturally heated up from sources such as power plants or pavement before entering a stream, negatively affecting the wildlife that are accustomed to certain temperatures.

The seventh and final test conducted was turbidity. A Secchi disk icon sticker was previously placed on the bottom of the water testing kit container. The container was filled to the turbidity fill line. The jar was looked down into and the appearance of the secchi disk icon through the water was compared to the icons on the turbidity chart. The measurements of turbidity were recorded in JTU.

Turbidity is a good measurement for water quality because it affects light penetration which can reduce ecological productivity and harm aquatic species. In addition, suspended particles can act as shelter for bacteria. The EPA requires drinking water to be no higher than 0.3NTU.

Results

All the coliform tests along the San Juan River came back positive, indicating that at least 20 coliform colonies per 100 milliliters were present in the water at each campsite. However, the samples had varying shades of yellow for unknown reasons. The control sample taken at Davis, CA came back negative so it is assumed that shaking the vials does not result in a false positive result. DO samples from the San Juan were 3ppm on June 16th, decreased to 2ppm on June 17th, further increased to 1.5ppm on the day after the storm, then went back to 2ppm for the next two days before decreasing again to 1.5ppm on the last day. The pool behind Oljeto camp had a low DO of 1ppm. Nitrate levels remained relatively stable, beginning at 5ppm on June 16th, decreasing to 4ppm, then rising back to 5ppm two days after the thunderstorm before dropping slightly again. pH was also relatively stable throughout the river, beginning at 8 on June 17th, rising to 8.5 following the thunderstorm, then dropping back to 8 on June 21st and remaining at 8 for the rest of the time range. Phosphate was 2ppm on June 16th, then dropped to 0.5 ppm the following day and remained below 1ppm for the remaining days after the storm, eventually reaching 0ppm on the final day. An exception to this was the pool behind Oljeto camp on June 22nd, where phosphate was 1ppm. Water temperature began at 26°C on June 16th, then dropped to 24℃ on June 17th and remained at that temperature till June 19th. After that, the temperature continued to drop over the next two days to 22°C and 21.5℃ respectively. June 22nd saw an increase in temp back to 24°C, and the pool behind Oljeto camp was noticeably warmer, measuring at 30℃. Turbidity started at 20 JTU/ 380 FNU on June 16th, increased slightly to 40 JTU/760 FNU on June 17th, then remained above 100 JTU/ 1900 FNU for all the days after the storm. The pool behind Oljeto camp was an exception with a turbidity of 50 JTU / 950 FNU.

Notes were taken on the color of the water during the sampling time period of June 16 to June 22. For the first two days, the water was green and clear. June 18th was the day of the storm, yet the water remained green and clear. On the morning of June 19th, the river was still slightly green but by the afternoon it had become red and sandy-silty. On the morning of June 20, the river was a vivid red-brown color and silty, by afternoon it had changed color to gray-brown. By June 21st, the water was brown-yellow, opaque, and extremely silty. The conditions remained the same on June 22nd, with the same opacity and level of suspended sediment.

The table below shows the water quality assessments results from our sampling period:

Date	Location	Time of Sampling	Weather conditions	Nitrate (ppm)	Phosphate (ppm)	Coliform	Turbidity (JTU)	DO (ppm)	Water temp (°C)	pH
06/16/22	Sand Island put-in	14:30	Clear, sunny, 32.2°C	5	2	positive	20	3	26	8
06/17/22	River House campground	16:00	80% cloud cover, 33.4°C	4	0.5	positive	40	2	24	8.5
06/19/22	Pontiac campground	16:30	Sunny, 15% cloud cover, extremely windy, 29°C (day after thunderstorm)	4	--	positive	>100	1.5	24	8.5
06/20/22	Honaker camp	16:30	Clear, sunny, 29.4 - 32.2°C	5	<1	positive	>100	2	22	8.5
06/21/22	Slickhorn camp B	21:15	Clear, dark, 27.2°C	5	<1	positive	>100	2	21.5	8
06/22/22	Oljeto camp (in flowing river)	15:00	70% cloud cover, 31.6°C	4-5	0	positive	>100	1.5	24	8
06/22/22	Oljeto camp (pool behind camp)	14:45	60% cloud cover, 31.6°C	<5	1	positive	50	1	30	8

One interesting trend to depict visually is the relationship between turbidity and streamflow, as seen in the graph below. The columns represent how turbid the river was in percent out of 1900 FNU (as that was the highest turbidity measurement we observed during the sampling period), and the line graph shows the stream flow during our sampling time period. It is clear that after the thunderstorm on 6/18 (no data was collected on that day), turbidity increases to the highest measurement (1900 FNU/100 JTU) and does not decrease for the rest of the sampling period.

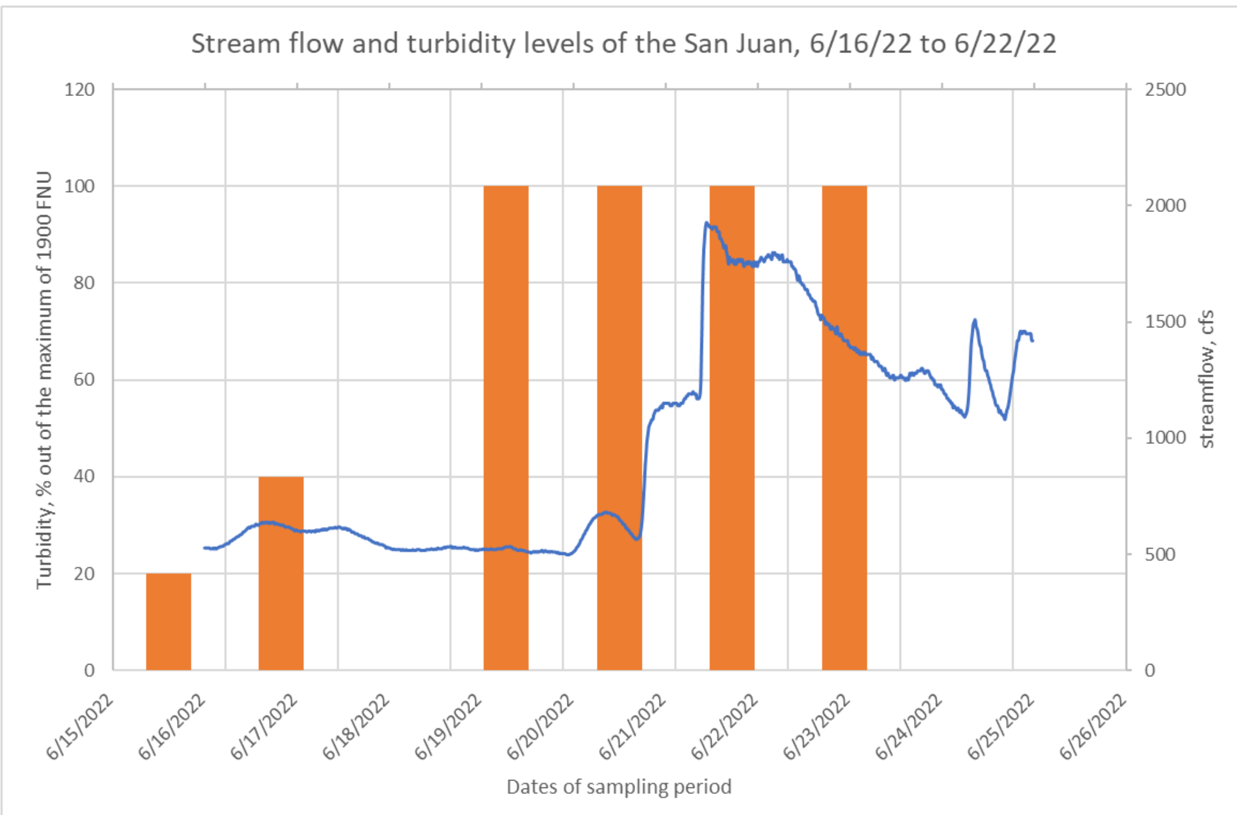

Figure 1: This graph shows the streamflow of the San Juan river from 6/16/22 to 6/22/22 along with the turbidity levels during that time period.

Discussion

Expected monsoon-caused variations in water quality

Our results show expected variations in turbidity, temperature, and nitrate levels, and showed unexpected trends in phosphate, DO, and coliform. An increase in turbidity was observed after the rainstorm; this was expected due to sediment from the river's surrounding environment being eroded and entering the river through surface runoff. Although there is no data from the day of the thunderstorm, Lee et al., 2015, Ta et al., 2013, and Wang et al., 2016 all indicate increases in sediment load and nutrient concentrations, and these were the observed conditions in the days following the thunderstorms. Notes on the color of the river during the thunderstorm and the days after support this reasoning; the day and night of the thunderstorm, the San Juan was slightly green and comparatively clear to the following days where the river turned opaque shifting through the colors of red and brown while being full of sediment. Not all sample sites had the same physical appearance; the pool behind Oljeto camp that was sampled was a clear, light green-blue color, and was shallow, still water. Any sediment that had been flushed into that pool from the thunderstorm had most likely settled onto the bottom of the pool, and explains the turbidity measurement of 50 JTU/ 950 FNU from the site.

There was a definite decrease in temperature after the rainstorm; this trend was expected as the river received a high influx of water from the rain, seen both through increases in volume and flow rate. The increased volume of water allows the river to stay colder for longer as the river now needs more time to warm up its increased water flow. This trend in temperature correlates with the increase in DO levels seen after the thunderstorm, as colder temperatures can keep dissolved oxygen in a water body longer compared to warmer temperatures (Butcher et al., 1995).

Nitrate levels before and after the thunderstorm were higher than what is expected during normal weather conditions in the San Juan, but it is not as high as was expected when considering the large presence of cattle and other mammals utilizing the riparian vegetation along the river. Measurements after the thunderstorm show increased nitrate levels from 4 ppm to 5 ppm, but nitrate levels fall back down in the days following the storm. We were not able to find probable time ranges in which we would continue to detect increased nitrate levels after a monsoonal event. The increase in nitrate after a thunderstorm is not unusual; the storm and the strong winds of the storm aided in erosion and sent more sediment into the river. The influx of sediment into the river can include the influx of nitrate-rich sediment; this nitrate-rich sediment being a by-product of human uses and cattle activity on the river banks (Galloway et al., 2003). Additionally, thunderstorms can bring in dissolved organic matter (DOM) from terrestrial sources or through disturbing the water column, and nitrate is a commonly found molecule in DOM (Haas et al., 2001).

Unexpected monsoon-influenced trends

When compared to nitrate, phosphate exhibited the opposite trend of being relatively low and decreasing further after the thunderstorm. Most inputs of phosphate into a water system are from agricultural and urban sources, as natural phosphorus additions come from inorganic materials and are in the form of elemental phosphorus. Phosphate, and phosphorus in general, are necessary for plant growth but an overdose can create a eutrophic water system with plants overtaking the water way, increasing the nutrient load of a system, and reducing DO for other aquatic organisms to utilize (Mainstone et al., 2002). Seeing the low phosphate levels is a strong sign that the river is not very polluted, and that agricultural and urban runoff seem to not make up significant parts of the pollution the San Juan may be receiving, but it does not make sense when compared with the levels of nitrate increasing after the thunderstorm or with the consistently positive coliform samples taken throughout the reach of the San Juan we rafted. These phosphate measurements could indicate minimal pollution from agricultural run-off, or could indicate that the test for phosphate was flawed, either by human or instrument error.

The trend of the DO measurements was another unexpected variation, as it decreased slightly after the storm and increased after that day. This is an unexpected result, as the temperature of the water was colder, and colder water is expected to hold more DO compared to warmer water. When measuring warmer waters on June 16th, the DO is at its highest level at 3 ppm, and for all the lower water temperatures measurements the DO measurement fluctuates around 1.5 to 2 ppm. This result seems to be in accordance with Lee et al., 2015, as that study took place in a river that was going through drought conditions (defined as when the flow is less than normal (by hundreds of cfs) for that particular system) and then a monsoonal event increased flows temporarily; this is a similar condition the San Juan is currently experiencing as the flows well before the monsoon were around 300 to 550 cfs and the San Juan was reported to be in a drought, and well below the expected flows of above 1000 cfs. When considering the unique conditions of drought and a sudden monsoonal event, this trend of DO decreasing is not unexpected but is hard to explain.

Another surprising trend found along the river was with the coliform measurements. All coliform tests throughout the sampling period along the river were positive. Although these tests were positive, it does not mean all the colonies detected were of harmful coliform. Coliform is a type of bacteria naturally present in the environment and there are many different strains of coliform, and only certain strains are fecal coliform. The positive coliform tests could be present because of the high recreational activity the San Juan sees during the summer time or it could be due to other mammals such as cows and wild horses using the river for long periods of time. There is no identifiable trend with the coliform samples and how those levels vary throughout the river or vary due to storms as the test only shows the presence of 20 or more colonies per 100 ml of water. From trends of nitrate increase, it is expected to see increases in coliform colonies found after the storm event due to potentially contaminated surface runoff from nearby agricultural and range lands. Even though the tests were positive, they seemed to vary in color and opacity as they were all different shades of yellow and seemed to either be clear or cloudy with some tissue-like substance forming in the sample. This was an interesting change in the samples, and could indicate something about the coliform strains found in various points of the river.

One trend that did not seem to be affected by any event was that of the pH. pH remained relatively the same throughout the sampling period, with values only changing between 8 and 8.5. After the storm, the pH became a little more basic at 8.5 but soon returned to a value of 8.

This indicated that there were more hydroxyl ions in the water compared to free hydrogen ions, but even this difference may not be noticeable as the "neutral" on the pH scale is 7 (*Water Science School,* 2019). There were no other physical or chemical changes that seem to be related to the trend of pH, although the nitrate and phosphate levels could have had some influence over the pH but none of which are noticeable with our testing kit.

Compared to their expected trends during normal weather conditions and flows of or above 1000 cfs, all indicators expect pH strayed from these expected conditions after the monsoonal event. Nitrate levels, water temperatures, and turbidity are all increasing; these indicators seemed to be elevated before and after the thunderstorm. DO and phosphate seem to have always been decreased, and were lower after the thunderstorm. These trends make some sense when considering that conditions before the thunderstorm were drought conditions, as seen with flows hitting as low as 300 cfs and being artificially raised to 586 cfs during the time of our sampling period (*USGS Water Data, 2020).* With lower water flows, this can mean increased concentrations of nutrients such as nitrates and increased presence of sediment loads that are unable to be diluted due to the low volume of water. Lower volumes also mean higher water temperatures as a river can warm up much quicker, and there is more risk of evaporation that can further deplete water levels. Warmer and less water also means lowering DO levels, and the physical decrease of habitat for aquatic organisms to exist in.

Even with these drought conditions, the sudden monsoonal changes to the system can be beneficial to some organisms. The sudden thunderstorm increased the turbidity of the San Juan, and this made the river much more opaque and silty. The San Juan river has always been a silty river regardless of drought conditions, and bringing back this environment has potential to positively benefit the native suckers and minnows present in the river (Aton et al., 2000). Conversely, Hedden et al. 2020 points out that the low oxygen levels present after flash floods that increased turbidity of the river have led to Flannelmouth Suckers dying by the thousands and Channel Catfish benefitting from these turbid conditions as their prey are caught unaware. More research into the dynamics between native and non-native fish and understanding the conditions that will increase and curb the respective species is much needed.

Even though some of the indicators exhibited strong trends, there were some limitations in sampling that may have affected the results. First, the water quality kit was low cost and had many imprecise measurements. Phosphate, nitrate, DO, and pH all required the use of a color chart. These charts had three main numerical categories and a color associated with them and the researchers had to assess whether the color of the sample fell on the specific category or estimate a value somewhere in between. Estimates tended to be whole numbers, when in reality they may not be. Second, the number of samples taken was limited. Only one sample was taken at each site. With the missed sampling on the day of the thunderstorm, this led to only 7 samples total over a 7 day period. By not sampling on the day of the thunderstorm, valuable data was left out about how water quality is affected during rainfall. In addition, the fact that this survey was only a week long makes it difficult to assess long term impacts of the thunderstorm. A third source of limitation is bias and inconsistencies. Each sample was usually done by a new group of people.

This could bias the results due to different methods of data collection and different perspectives about where a certain color falls on the color charts. Another limitation that should be mentioned are possible confounding variables. The goal of this study was to assess the impact of the thunderstorm on water quality. However, samples were not only taken on different days, they were also taken at different sites longitudinally along the river. It is possible that changes in water quality could be due to different locations rather than different times after the storm.

Despite the above-mentioned limitations, the trends these water quality indicators show after the monsoon further identifies the impact monsoonal weather has on the San Juan River and other desert watersheds. Even if the impact of the thunderstorm may not benefit the stakeholders on the river, these changes in water quality should be studied, expected, and mitigated for if necessary.

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