Comparing the Effects of Precipitation and Select Water Quality Parameters in Two Different Suburban Watersheds

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March. 9, 2020

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Abstract:

Evaluating the water quality of a stream is essential in determining potential sources of impairment and effects of flooding. The amount of precipitation that falls in Dearborn Heights varies depending on the type of weather front producing the rain and how widespread the system is. The Rouge River and the Ecorse Creek are two suburban rivers located in North and South Dearborn Heights. This research sought to investigate the correlation between rainfall type and amount and select water parameters. The water parameters measured included dissolved oxygen, turbidity, conductivity, water temperature and salinity. 40 sets of measurements were taken throughout a period of 5 months, extending from the beginning of July, 2019 to the end of October, 2019. During the investigation period, rainfall amounts often varied with heavy precipitation dropped from thunderstorms to steady rain falling from warm front rain. There were also several periods of extended dry weather. At each river Vernier probes were used to determine conductivity, dissolved oxygen, water temperature, and salinity. However, a water sample from both rivers was taken home to measure turbidity using a Vernier turbidity probe. Comparing rainfall to the water parameters, correlation fluctuated between inverse, direct, or no correlation at all. With much of the turbidity, conductivity, and water temperature measurements, there was a direct correlation between precipitation and the levels of those parameters in the water. However, DO had an inverse relationship with rainfall while salinity had a more variable relationship. Moving forward, we recommend that more areas where rainwater can soak into the ground be created to benefit the health of the rivers and the communities surrounding them.

Key Words: oxygen, salinity, temperature, precipitation, turbidity

Background:

Water quality and urban flooding are important and pressing concerns for Southeastern Michigan and many places around the globe as well. In recent years urban and suburban areas in Michigan are experiencing more extreme amounts and periods of rain than at any time in past 100 years. Occasional flooding that might have occurred at the 50, 100, or 500 year extreme is now occurring several times a year or every other year. An increase in storms with record precipitation along with more impervious surfaces has led to extreme surface runoff into both of our local rivers. The Middle Branch of the Rouge River is very prone to flooding because the highly developed region surrounding it has few places for water to soak in and the topography is rather flat. Its adjacent roadway is often closed throughout the year because of flooding for extended periods of time. The Ecorse Creek, a small stream that runs through the south part of Dearborn Heights has also seen an increase in yearly flooding that is deep enough to swallow cars and good portions of houses. The Middle Branch of the Rouge River and the Ecorse Creek both have United States Geological Survey (USGS) hydrographic stations that measure river levels. Little research within these watersheds has specifically looked at the effect of river levels on associated water quality parameters. The flooding issue clearly needs continued research to determine the best course of action to solve a problem that affects hundreds to thousands of individuals and families living in our area. This research hopes to fill a missing gap in the public record for how specific rainfall events affect particular concerns of water quality. Over a 5-month period - we tested salinity, conductivity, dissolved oxygen, turbidity, and temperature as well as the amount of precipitation at each site in order to develop an understanding of how each parameter affects the other. We also looked at river water levels in both rivers to see how the water quality parameters fluctuate with the rising and falling levels of the height of the river. Using the data from testing, we worked to develop an understanding of how each river behaves as a result of a storm or other significant rainfall event.

Figure 1 (Left) and Figure 2 (Right): Flooding in South Dearborn Heights near the Ecorse Creek.

Research Questions:

-Initial Research Questions:

To what extent can salinity, conductivity, and turbidity measurements be correlated with precipitation totals, stream discharge, and stream velocity? How does the type rainfall an area experiences affect the turbidity and conductivity? How do water levels of a stream affect turbidity and dissolved oxygen after a rainfall event?

-Null Hypotheses:

Null Hypothesis 1: Salinity, conductivity, and turbidity measurements cannot be correlated with precipitation totals, stream discharge, and stream velocity. Null Hypothesis 2: The type of rainfall in an area does not affect the amount of turbidity or the conductivity. Null Hypothesis 3: Water levels of a stream do not affect turbidity or dissolved oxygen after a rainfall event.

-Why this is important / Research Implications:

In the heavily developed regions of Michigan where a high percentage of impervious surfaces are present, the amount and type of rainfall can have significant implications for the people living there. EPA research indicates that with our changing climate the frequency of floods is likely to increase because of increased spring and annual rainfall and the intensity of storms (United States Environmental Protection Agency). The two rivers and watersheds present in Dearborn Heights, MI drain the surface runoff from the homes and businesses of nearly 60,000 people. These streams also move the water of nearby communities of similar population and development density that are both upstream and downstream from the two study sites in this research. Without a plan to properly manage the infiltration and runoff of storm events, houses and businesses in the floodplains near the rivers will experience continued flooding during these predicted and likely extreme precipitation events with subsequent high personal and economic losses. Studying local water quality parameters during and after different amounts of rainfall fall will help to determine what water quality parameters are most impacted by large rainfall events. This is a very important issue for citizens living in Dearborn Heights because they are directly impacted by flooding in both the northern and southern portions of our city. In North Dearborn Heights citizens are inconvenienced by an important transportation corridor closing during flood events and the people living in South Dearborn Heights have to contend with damage and losses related to the repeated flooding of their homes and vehicles. Currently very little longitudinal water quality monitoring is taking place within our city. Creating a database of information useful to city and regional planners can help provide much needed information to take future action that may help to alleviate the ecological, economic, and personal effects of frequent flooding. Analyzing connections between the different water quality parameters and precipitation events in our watersheds will make it possible to have evidence to show to state and federal agencies (with possible funding) to help find solutions to the flooding parts of our city has been experiencing. Right now the city is looking into a multimillion way to channelize the Ecorse River in South Dearborn Heights. The research completed in this investigation points the way to a possible cheaper, more ecological sound, and more effective way to manage runoff. One long-term solution would be to reduce impermeable surfaces by buying back a few homes in region and constructing small wetlands in appropriate areas that can be created to allow the runoff to soak in rather than runoff. The Ecorse River in South Dearborn Heights begins near a large regional airport but picks up more water volume as it enters the Southwestern portion of the city near a large parcel of land the city already owns. Rather than selling and or developing this property, it might be better to look into ways this area could serve both city recreational purposes and more carefully designed areas to retain water during storm events.

Introduction and Review of Literature:

This project monitored two separate watersheds existing within the city of Dearborn Heights, MI. It is essential to continue testing these rivers to determine the sources of pollution running off into the streams and affecting their health. The two watersheds present affect hundreds of thousands of people and recently, increased precipitation and flooding is becoming a larger problem and climate change has been implicated as the primary reason why (United States Environmental Protection Agency). This research sought to study which parameters had a correlation with the amount of rainfall that was collected and what its relationship was to rainfall amounts. Water quality parameters such as turbidity, dissolved oxygen, and water temperature had a close relationship. When water becomes more turbid, sunlight is absorbed at a higher amount because of is reduced albedo. This in turn causes the water temperature to increase. With warmer temperatures, the levels of dissolved oxygen decrease due to the water's inability to hold oxygen gas dissolved in solution. A major cause of turbidity is urban development and the sediment that can run off into the water from construction sites (Neupane). Increased runoff also increases the erosive ability of the water flowing through a river's channel. Both the Rouge and Ecorse Rivers flow through areas rich in fine sand and clay. These two particle sizes do not take much river velocity to keep them suspended in the water, leading to high turbidity.

The Rouge River is surrounded by both permeable and impermeable surfaces. With impermeable surfaces facing the north, once it rains, the rain travels south towards the river, the runoff carrying sediments which increases the turbidity in the water. Flooding impacts many different areas including loss of life, damage to property, ecosystems can be destroyed, and much more (National Academies of Sciences, Engineering, and Medicine). More rain gardens or wetlands would help prevent this issue because the rainwater would soak into the ground instead of running off into rivers and sewers, overflowing them and causing extensive flooding.

Research Methods:

1. Locate a safe site on two local rivers (running through residential areas) to collect water samples from. All water samples were taken from a bridge over the river(s). Determine GPS location of each monitoring site.
2. Install two rain gauges (using GLOBE protocols) near the desired rivers in order to monitor daily precipitation totals.

3. Monitor each site in the late afternoon from + or - one hour from 4:00 P.M. (only time to get consistent transportation to sample sites). Collect and test water samples from each site three times a week from July to the end of October, 2019.
4. Follow GLOBE protocols and to measure the water quality parameters of salinity, conductivity, dissolved oxygen, and turbidity. Use GLOBE certified Vernier technology to measure each protocol making sure to calibrate instruments prior to use when necessary.
5. A Nasco Swing Sampler (extends to 3.66 meters) with a 1000-mL plastic bottle allowed water samples to be taken from the main current and below the water surface.
6. All water quality testing was completed immediately after collecting the water sample with the exception of turbidity. Each water quality parameter was tested three times and the results averaged to obtain the final reported value.
7. The water remaining in the sample bottle was allowed to reach room temperature and the Vernier turbidity sensor was calibrated prior to testing. If condensation on the sampling vial occurs, an inaccurate turbidity reading will result.
8. Input all data into the GLOBE website.
9. Analyze and interpret data.

Both research sites, the Rouge River and Ecorse River Creek, are located in Dearborn Heights, MI. The Rouge River is located near Edwards Hines Drive and Hillcrest Elementary School, while the Ecorse River Creek was located on Beech Daly and Amherst, near main roads. Salinity, conductivity, dissolved oxygen, and water temperature were all taken on site, starting with the Rouge River at 4:00 pm and the Ecorse Creek immediately after. However, due to a lag time (15-20 minutes depending on traffic) we weren't able to take the measurements at the same exact time. Precipitation was measured near both sites using installed rain gauges, in which readings of rainfall were measured daily in mm. Salinity was tested directly at the site, using a Vernier Probe connected to a Lab Quest. Conductivity was also tested directly at the site, using the Conductivity Vernier Probe connected to a LabQuest acquisition device. Water temperature was tested this way as well. However, dissolved oxygen was measured with a Bluetooh optical DO probe connected to a phone with the Vernier Graphical GW App downloaded. Dissolved oxygen was measured in mg/L and as percent saturation. Water samples to measure turbidity with were taken at home immediately, where the Vernier Turbidity Sensor was used. Afterwards, the data was entered into the GLOBE data entry portal and then into an Excel spreadsheet to create the graphs comparing various measurements taken at both the Rouge River and the Ecorse Creek (40 graphs). This research benefits those individuals and organizations who are looking to find a solution to the increased community flooding our city has been experiencing recently. Solving the excess amounts of runoff and flooding that take place in Dearborn Heights is not beneficial from an ecological standpoint, it also reduces economic impacts on our city and its residents.

THE GLOBE PROGRAM SCIENCE Data Entry

Data Entry Home / Crestwood High School / Rouge River - Parr Wayside / Integrated Hydrology

Past Observations for Integrated Hydrology

From 2019-07-01 To 2019-10-31

	Measured at time in UTC
1	2019-07-02 08:15 UTC
2	2019-07-05 07:57 UTC
3	2019-07-06 08:30 UTC
4	2019-07-09 15:36 UTC
5	2019-07-11 15:47 UTC
6	2019-07-13 09:05 UTC
7	2019-07-15 15:47 UTC
8	2019-07-17 15:46 UTC
9	2019-07-19 16:04 UTC
10	2019-07-22 16:06 UTC
11	2019-07-24 08:35 UTC
12	2019-07-27 08:03 UTC

THE GLOBE PROGRAM SCIENCE Data Entry

Data Entry Home / Crestwood High School / Ecorse River-Beech/Van Born / Integrated Hydrology

Past Observations for Integrated Hydrology

From 2019-07-01 To 2019-10-31

	Measured at time in UTC
1	2019-07-02 08:40 UTC
2	2019-07-06 08:50 UTC
3	2019-07-09 16:05 UTC
4	2019-07-11 16:10 UTC
5	2019-07-13 09:29 UTC
6	2019-07-15 16:10 UTC
7	2019-07-17 16:30 UTC
8	2019-07-19 16:44 UTC
9	2019-07-22 16:56 UTC
10	2019-07-24 09:08 UTC
11	2019-07-27 08:43 UTC
12	2019-07-31 15:35 UTC

Table 1-2: Globe Data Entry that has been entered from July 2, 2019 to October 28, 2019.

Figure 3 (Left) and Figure 4 (Right): Figures 3 and 4 show the sites that these water parameters were taken at. Figure 3 (left) shows the Rouge River site while Figure 4 (right) shows the Ecorse River Creek site. Exact location of the Rouge River: 42.347143 N, -83.276759 W and Exact location the Ecorse River Creek: 42.269461 N, -83.289944 W.

Results:

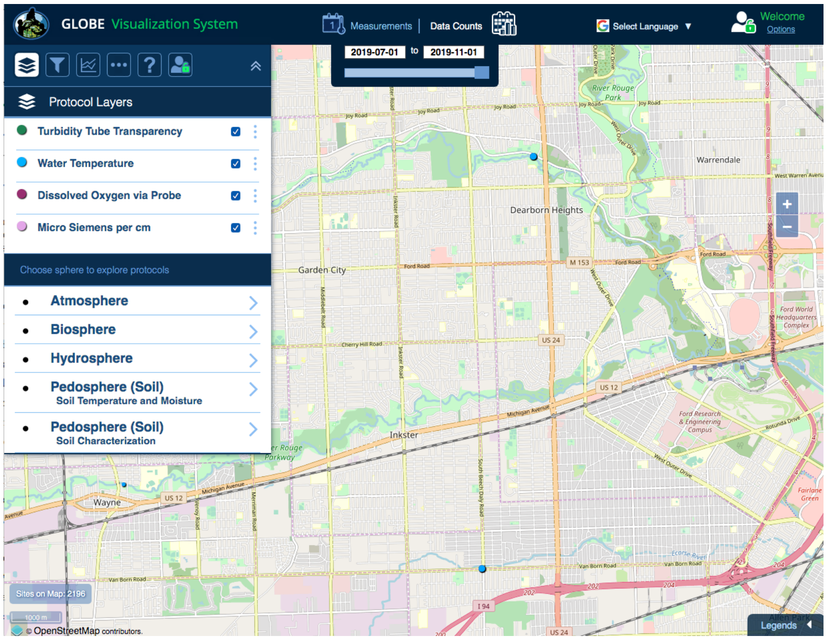
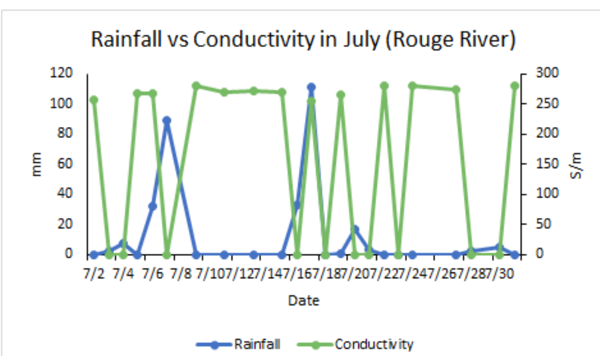


Figure 5: Visualization. The two points shown were our testing sites and during our four-month research there were no schools in the area who tested any of the same parameters.



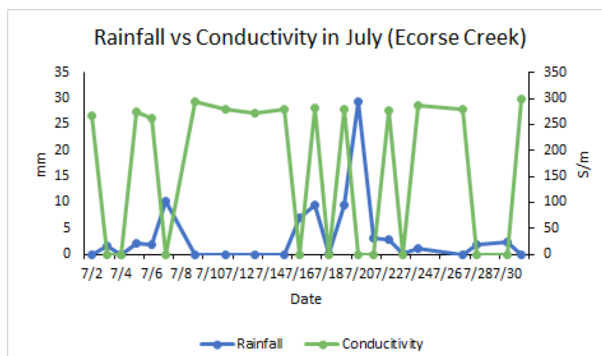
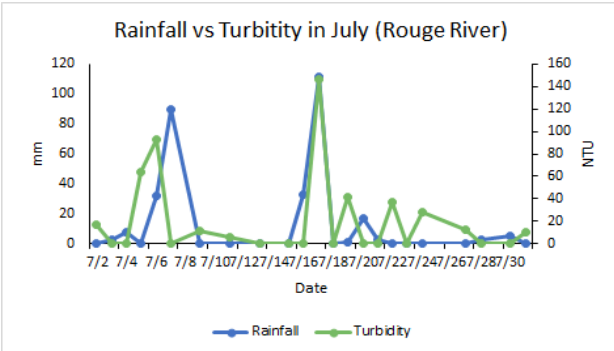


Figure 6 (Left) and Figure 7 (Right): Rainfall vs Conductivity in July. Rainfall and Conductivity in both the Rouge River and the Ecorse Creek showed almost identical patterns. In this case, conductivity was used as a substitution for total solids as in our previous research there was found to be a correlation between the two. These infographics show that with increased rainfall, there was an increase in conductivity immediately afterwards.



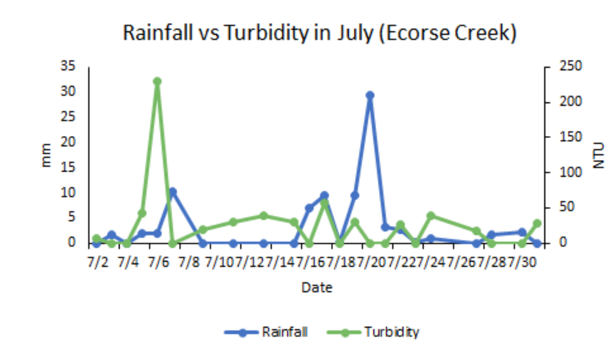
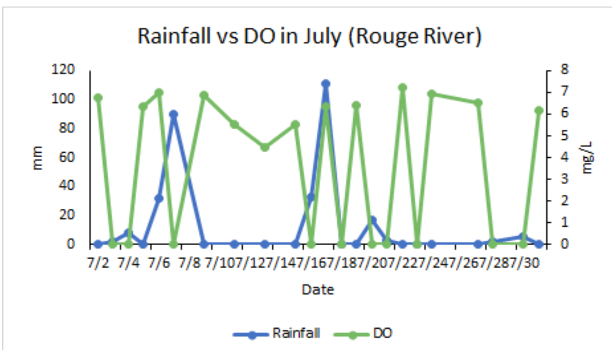


Figure 8 (Left) and Figure 9 (Right): Rainfall vs Turbidity in July. Turbidity showed a direct correlation with Rainfall, meaning immediately after rainfall occurred, both rivers became more turbid.



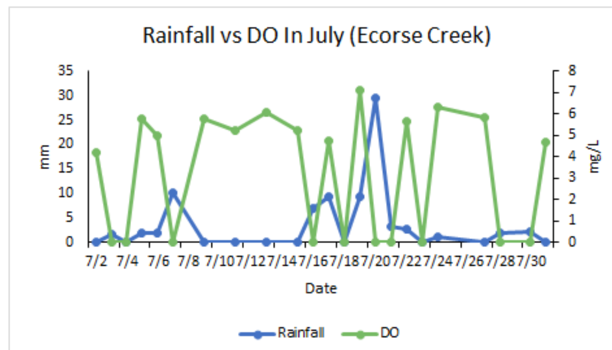
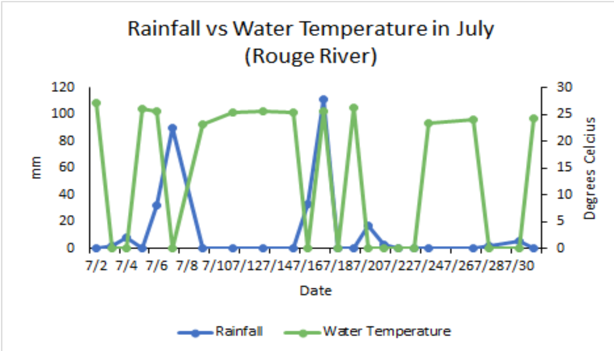


Figure 10 (Left) and Figure 11 (Right): Rainfall vs Dissolved Oxygen in July. Dissolved oxygen varies greatly with temperature and rainfall. So, looking at this in the summer, dissolved oxygen levels were lower when it rained due to an increase of temperature in the water. As temperature levels increase, dissolved oxygen levels decrease due to the water's inability to hold oxygen.



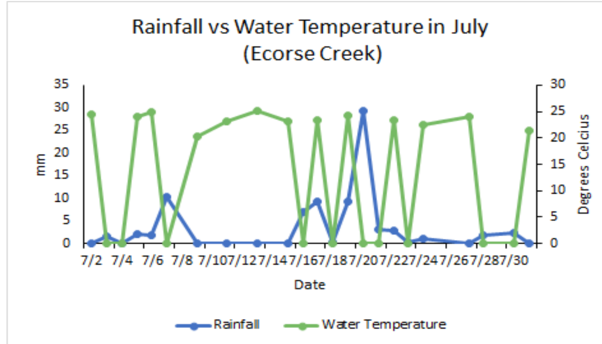


Figure 12 (Left) and Figure 13 (Right): Rainfall vs Water Temperature in July. Water temperature and Rainfall have an inverse correlation between the two. This means that as it rains more and more, the water temperature decreases and as it rains less, water temperature increases.

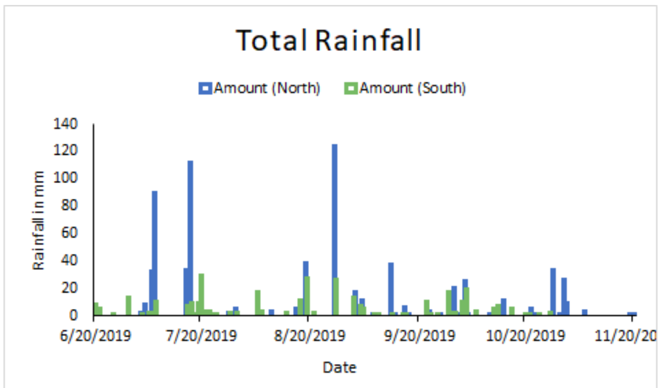
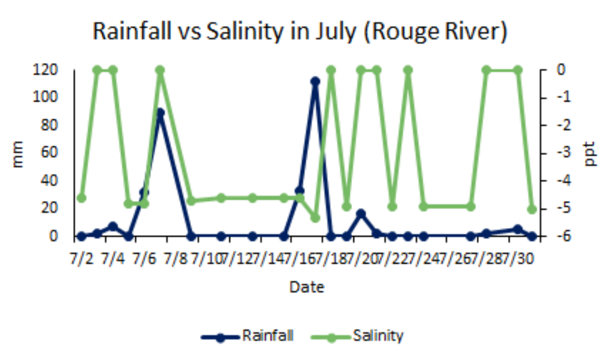


Figure 14: Total Rainfall. This infographic shows the amount of rainfall collected in both Northern and Southern Dearborn Heights. This shows that there was more rain received in the north rather than the south.



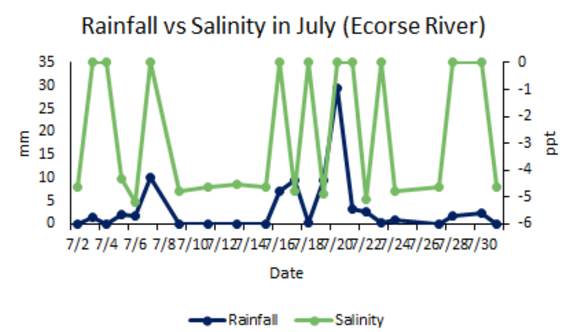


Figure 15 (Left) vs Figure 16 (Right): Salinity vs Rainfall in July. Looking at salinity, it was found that with rainfall, salinity had a direct correlation with it. This means that once rainfall spiked, so did salinity, and once rainfall lowered, so did the number of salt ions.

Discussion:

Unfortunately, there were some testing conditions that we didn't have control over during our research period. Ideally it would have been better to test every day at the same time. However, transportation and other responsibilities made this not possible. In addition, it would have been better to have a larger dataset of additional water quality parameters to test. Testing of additional parameters such as nitrates, phosphates, coliform bacteria, etc. was not possible this past summer as our school lab was not available to us because of construction. Luckily, a USGS (United States Geological Survey) stream gauge located adjacent to the South Dearborn Heights study site provided us with accurate stream height and discharge data. Even so, there was no comparably close USGS stream gauge on the study site in the north part of Dearborn Heights. Flooding at this location made it hazardous to study at times. It would have been best to test the water at both sites simultaneously but because of equipment limitations and the lag time present when travelling from one site to another, this was simply not possible. We also tried to compare our data to other schools, but not many were testing during the same time period we were. One such school was located in Thailand. Sadly, their school was out so we couldn't contact them when we needed to as well as the fact that there was a drought there and there wouldn't have been enough data regarding precipitation to compare. Vernier instruments were utilized in this research and although they provide accurate data, it is not as precise as what more advanced instrumentation would provide. Although not as precise, the values we obtained do show trends that can be used to predict outcomes. We learned that when rainfall spiked, river levels raised.

Conclusion:

During our four-month study period, rainfall appears to have a correlation with the water quality parameters that we have tested. These water quality parameters include dissolved oxygen, water temperature, turbidity, conductivity, and salinity. Of these parameters, dissolved oxygen and conductivity have an inverse relationship while turbidity, water temperature, and salinity have a direct correlation to rainfall. Along with these parameters, we also looked at the differentiating height of the two rivers compared to rainfall. We primarily focused on the correlations between water temperature, conductivity, turbidity, dissolved oxygen, and rainfall. We found that these selected parameters have a tight correlation between them. Between water temperature and dissolved oxygen, as temperature increases dissolved oxygen decreases due to the water's inability to hold oxygen. The rivers became more turbid due to run off, which darkened the river. Once the rivers darken, more heat is absorbed due to albedo, which increases the water temperature.

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Badges:

Be a Data Scientist: Over the summer and fall, we tested two urban rivers in our area and analyzed our data by importing it into an Excel spreadsheet. Using this we were able to make graphs showing how the different parameters examined correlated to one another. We found that water temperature and turbidity have a strong direct relationship while dissolved oxygen is inversely connected. To improve accuracy, more parameters would have to be looked at and studied.

Make an Impact: We observed that the flooding in our city was negatively affecting many different aspects of the community and environment and wanted to look further into it to determine what the effects were. Understanding the relationships between precipitation and specific water quality parameters could be very beneficial to us as junior watershed commissioners to show the importance of implementing increased water testing.