Examining the Hydrologic Properties of the Missouri River Basin

https://github.com/cwatson1013/Hydrologic_Data_Analysis_Final_Proj

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1 Rationale and Research Questions

The Missouri River is the largest river in North America (2,540 miles) and has the second largest watershed (529,000 mi^2/339 acres, U.S.-Canada, (Kammerer 1990)). Its watershed covers portions of ten states, which account for approximately one-sixth of the continental United States, as well as a small part of Canada (Engineers Missouri River Basin Water Management Division 2018). The headwater is located in the Bitterroot Mountains River of northwestern Wyoming and southwestern Montana (Council 2002). Demands for managing the river for the benefit of human livelihood has resulted in drastic modification in the river and the floodplains. Numerous reservoirs and dams have been constructed, of which six major dams were built on the mainstream(Council 2002). Now, the river is used intensively in multiple ways, including municipal, agricultural, hydropower, recreation, flood control etc. (Reclamation 2016b).

Within the 328 million acres of the basin's total area in the United States, 64.2% (218 acres) are related to agricultural uses, while the rest dedicated for recreation, fish and wildlife, and urban (Reclamation 2016b, @usace2018). 37.1% of the total basin area is pasture and range grassland primarily for grazing, and cropland consists of almost 92 million acres (Engineers Missouri River Basin Water Management Division 2018). As of 2012, irrigated land comprises 14.2 million acres, and required a delivery of about 13 million acre-feet of surface water annually (Engineers Missouri River Basin Water Management Division 2018). Wetlands and Water bodies, on the other hand, cover 3.7 and 1.8 million acres, respectively (Engineers Missouri River Basin Water Management Division 2018). In spite of the low proportion of water areas (2.3%), they are the pivotal foundation for agricultural or other usages, and thus critical to the whole region's economy.

Along with the agricultural, urban, and industrial development in the region is nutrient loading and enrichment in water bodies, especially for nitrogen (N) and phosphorus (P). Agricultural input through fertilizer is the predominant anthropogenic source for nutrient in water bodies in the whole basin (Council 2002). Regardless of the major anthropogenic source, nutrient enrichment is considered nationally as one of the leading factors for water quality impairment. According to USEPA 303(d) lists, more than 160 stream reaches, lakes, or reservoirs were reported by USEPA to suffer nutrient-related impairment in 2006 (Council 2002).

In addition to change in nutrient concentration, discharge appears to be highly variable in the basin, and both severe drought and flooding events occurred in the basin in the past. For example, in the spring and summer of 2011, an unprecedented flooding event caused over \$2 billion damage and 5 fatalities, leading to FEMA disaster declaration made in all states along the Missouri River (Oceanic and Administration 2012). During the flooding event, around 11,000 people evacuated Minot, North Dakota owing to high water level in Souris River, which flooded 4,000 homes (Oceanic and Administration 2012). In 2012, a drought even struck the Central Great Plain, including the basin, and inflicted at least \$12 billion of loss before July, 2012 (Force 2013). Recently, another flooding event occurred in the spring of 2019.

Given all the background information above, we would like to know the current state of Missouri River and its tributaries, with a focus on the changing patterns in discharge and nutrient levels. Water bodies along the downstream are more likely to be impaired by nutrients accumulated from the upstream, and more croplands and pastures which can further load nutrients into streams are distributed in the lower basins (Figure 1). Therefore, in the present project, study sites were concentrated in the southeast of the whole Missouri Basin. By analyzing data retrieved from these sites, we first revealed the general yearly discharge pattern and changes in variability over years. Then we investigated how the dramatic change in discharge (i.e. water quantity) could potentially interact with nutrient enrichment (i.e. water quality). We examined a few specific flooding and drought events, during which changes in both water quality and quantity were well recorded, so that we could make inference on the interplay between quantity and quality. The effect of population on nutrient enrichment was also examined to illustrate potential non-agricultural impact from human activities. Finally, based on the pattern in the past and the best model we could fit, we attempted to predict the likely future conditions and trends in the Missouri River Basin. Our research questions and acccompanying hypotheses are below:

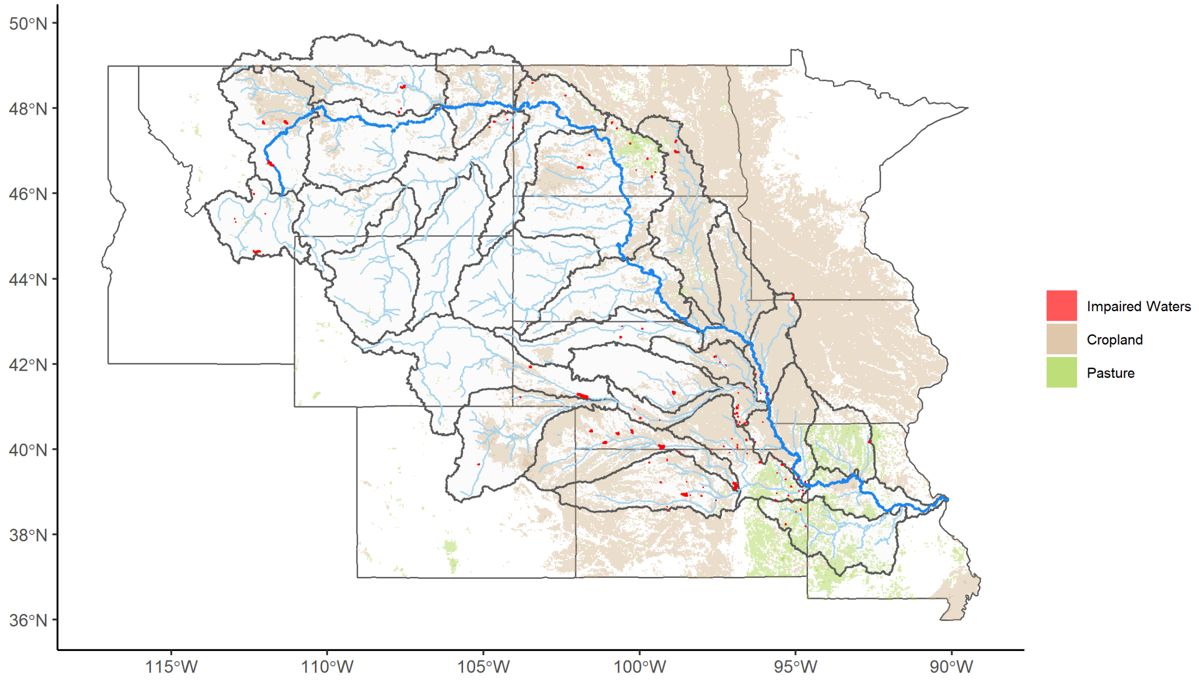

Figure 1: Map of agricultural lands and impaired waters in the Missouri River Basin. Row and Close Grain Crop Cultural Formation shown by tan-colored areas, pasture and hay field shown by yellowgreen areas, imparied water bodies according to Clean Water Act Section 303(d) (EPA 2015) denoted by red areas, and all HUC4 watersheds in the Missouri River Basin (1001-1030) delineated by gray polygons. The thin light-blue lines outline all streams of a Strahler order higher than 2, and the thick blue line represents the mainstem of Missouri River.

1. How have changes in discharge (i.e. water quantity) interacted with nutrient enrichment (i.e. water quality) in the Missouri River Basin?
    a) Nutrient levels have increased over time - Keqi
    b) Discharge has become more variable over time - Hubert
    c) Nutrient levels increase with discharge - Rachel
2. What effects do specific flood and drought events have on the water quality and quantity of rivers in the Missouri River Basin areas of interest?
    a) Rivers will exhibit a flushing behavior due to the land use and type of flow during storms - Rachel
    b) Discharge will decrease during drought due to decreased overland flow. - Caroline
3. What factors contribute to the variability of total nitrogen in the rivers?
    a) Land use, year, discharge, phosphorus, and HUC region will contribute to the variability of total nitrogen across sites - Rachel
4. Given past and current data, what can we predict about the future state of water in the Missouri River Basin?
    a) Total flow in the Missouri River Basin is decreasing (non-stationary) over time - Keqi
    b) The future situation of the river basin will see the continuation of current trends of decreasing overall volume of flow. - Keqi

2 Dataset Information

The data we are analyzing comes from the United States Geological Survey (USGS) database called the National Water Information System interface, or NWIS. We pulled data from the interface using the R package `dataRetrieval`. Because we are interested in the lower Missouri River basin, we pulled sites from each HUC4 subbasin from 1020 to 1030. We chose these subbasins because they had a variety of tributaries that all flowed into the Missouri River, representing a variety of river sizes and lengths. We filtered these subbasin queries to only show us sites that contained discharge, nitrogen, and phosphorus data. Once we found the sites with all of this data, we chose 2 sites from each HUC sub basin for a total of 22. We chose the two sites from each HUC sub basin by comparing the periods of records for each of our chosen variables and finding the sites with the longest periods of records. We chose to look at two sites per HUC region (for a total of 22) in order to maintain a digestable scope. We retrieved data on water quantity, water quality (N, P concentrations) (Table 1).

Only seven sites within our HUC subbasin boundary contained any high frequency nitrogen data. Therefore, we also looked at these 6 sites in order to do analyses and answer our research question about flooding. Since flooding and droughts can be thought of as opposites, we looked at the same 6 sites for droughts as we did for flooding (Table 2).

We have two main datasets:

- The daily values dataset containing discharge, nitrogen, and phosphorus data for 22 sites.
- The high freqency dataset containing high frequency data for nitrogen and discharge for 6 sites.

Variable	Unit	Number of Sites
Discharge	cfs or m^3/s	22
Time	UTC	22
Nitrogen	mg/L	22 with daily values, 6 with high frequency values
Phosphorus	mg/L	22

Table 1: Table showing information about the dataset used for this analysis.

<Add a table that summarizes your data structure (variables, units, ranges and/or central tendencies, data source if multiple are used, etc.). This table can be made in markdown text or inserted as a `kable` function in an R chunk. If the latter, do not include the code used to generate your table.>

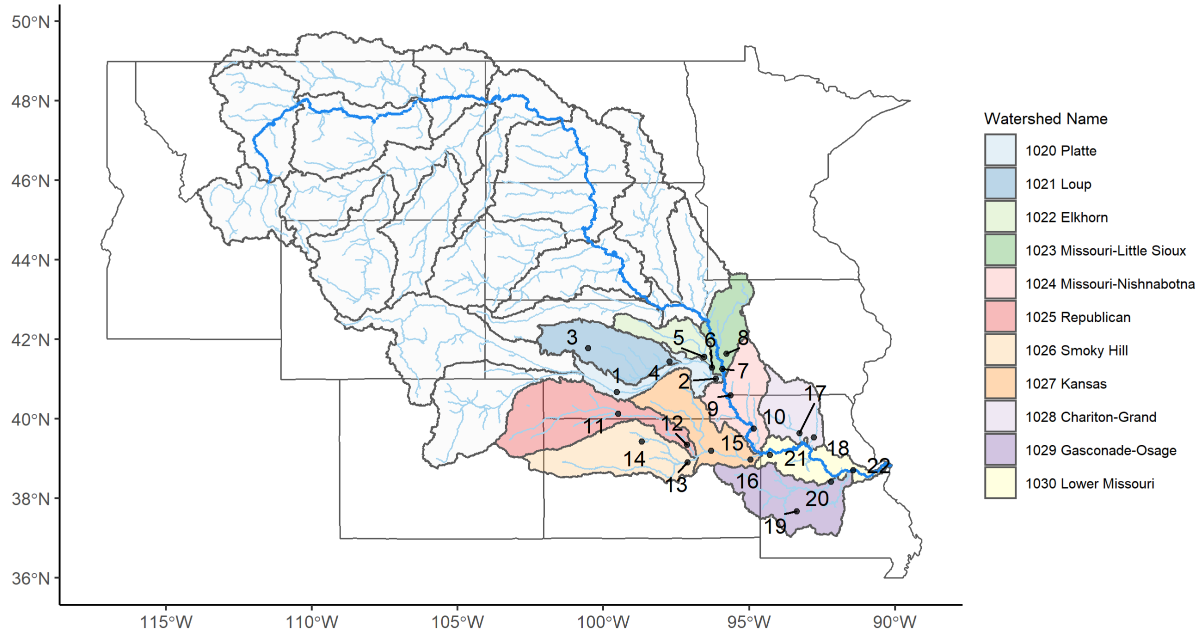

Figure 2: Map of USGS sites used for long term analysis.

3 Exploratory Analysis

3.1 Exploration of variables

Basic data wrangling was needed in order to obtain all variables of interest. After obtaining all pertinent data, each variable was visualized in order to see the shape of the data and the range of values (Figure 3). Any necessary transformation or cleaning was completed after this step.

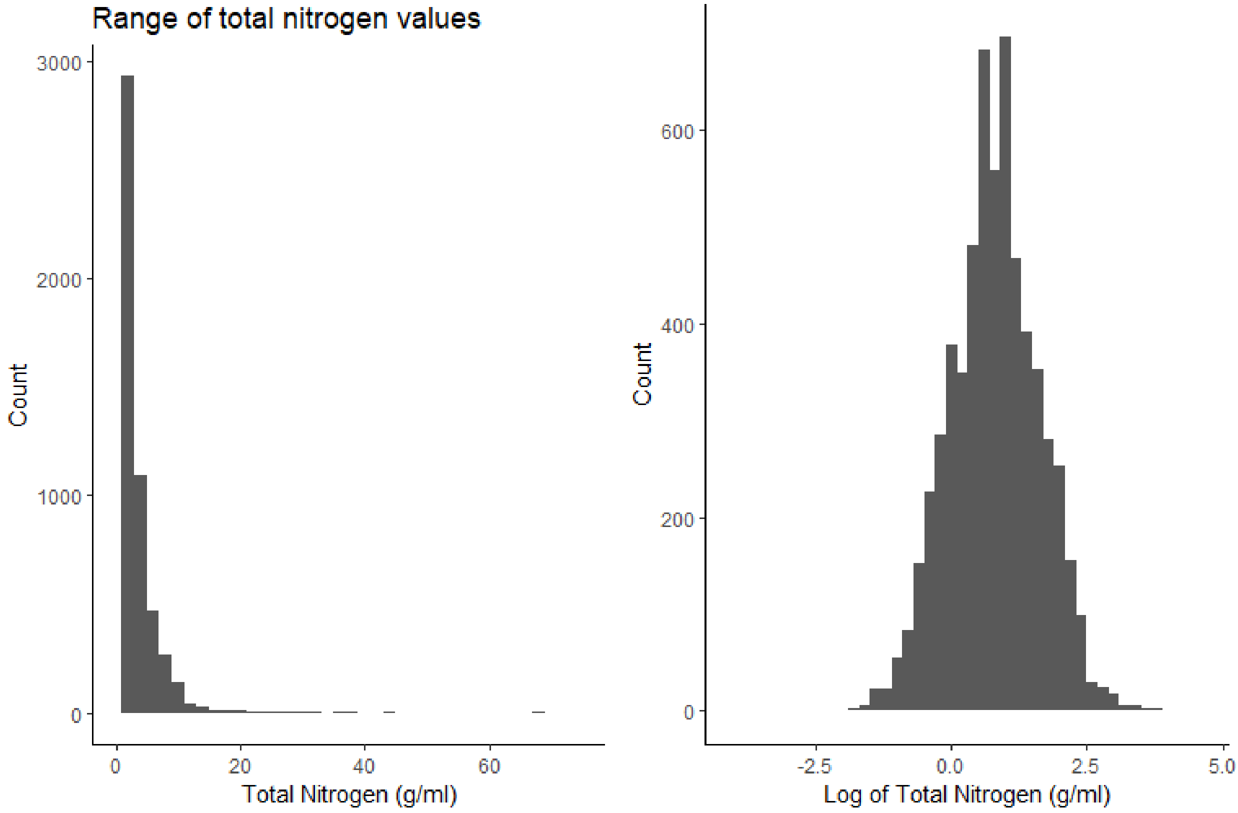

Figure 3: Histograms showing the range of total nitrogen values obtained from all sites during the total period of record. Raw (left) and logged (right) nitrogen data are shown to show that any analysis requiring normally distributed data will use the log transformed nitrogen data.

Discharge, nitrogen, and phosphorus were plotted for each site and examined together in order to see if there were any obvious patterns or trends (Figure 4).

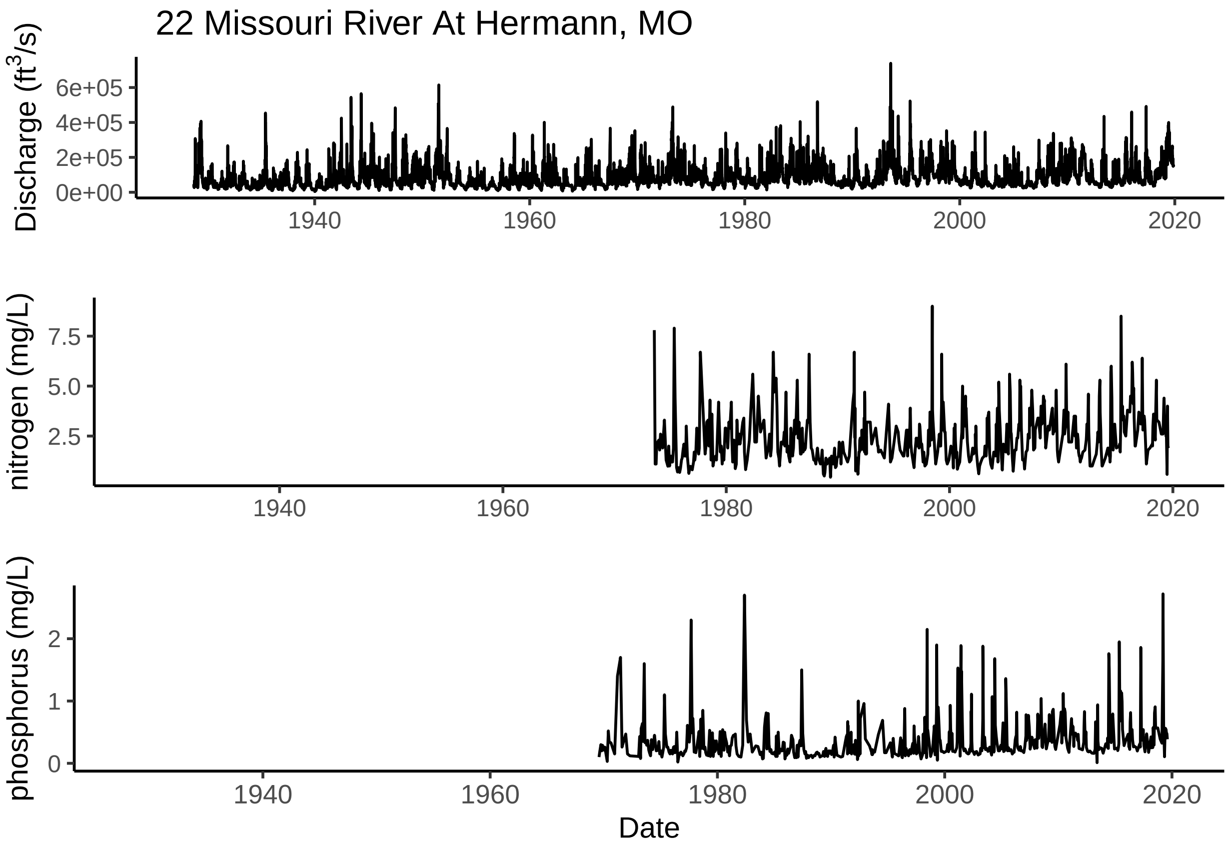

Figure 4: Discharge, Nitrogen, Phosphorus daily data of site No. 22 Missouri River At Hermann, MO.

3.2 Yearly Discharge Pattern

Typical discharge patterns within a year for each HUC4 watershed from 1020 to 1030 were generated by compiling all available discharge data at the 22 selected USGS site (Figure 5). Generally, discharge reaches its peak during the summer and falls to minima during the winter, and most of the sites exhibit rather high variations across years, as indicated by the large difference between the medians and the first or the third quartiles. Furthermore, highest variations in discharge appear to occur in the summer, whereas discharge in the winter varies less among years. The large variability within a year and the seasonal pattern is only obvious in larger streams and rivers but not in small creeks (e.g. site 5 Maple Creek near Nickerson, site 8 Boyer River, site 21 Small Blue River). Exceptions to the generalization are three sites with medium discharge (site 1 Platte River, NE; site 3 Dismal River, NE; site 11 Republican River, NE). They have fairly constant discharge and variation across years, and the the first and the third even have slightly lower discharge during the summer. Platte River forms by the confluence of North Platte and South Platte Rivers, and both two have snowmelt as their water source, resulting in the observed higher discharge during the spring and low in the summer. Dismal River forms by two forks that arise from groundwater (Ogallala Aquifer), which is supposed to be more stable than precipitation. The majority of Republican River basin is underlain by Ogallala Aquifer (Reclamation 2016a), and a plausible high proportion of water source from groundwater could explain the little variation across years.

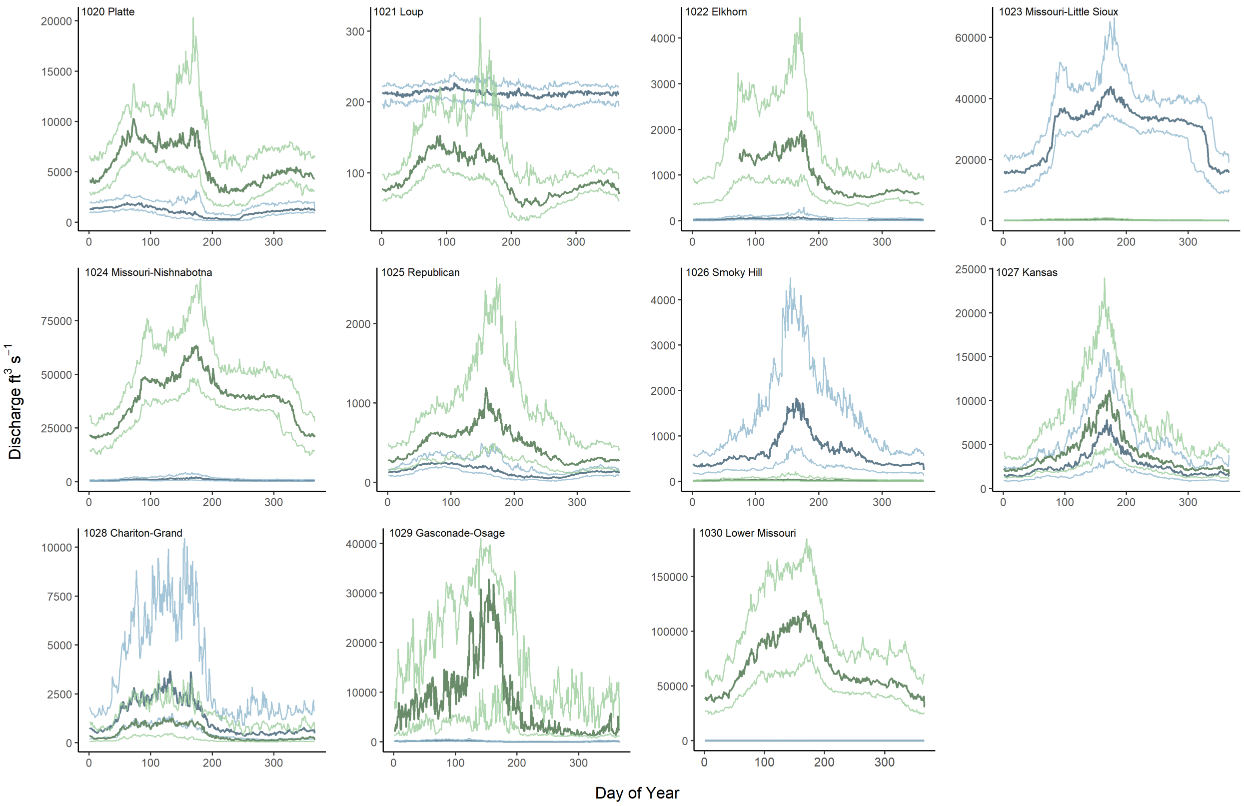

Figure 5: Yearly discharge pattern for the lower Missouri HUC4 watersheds. Thick, dark lines are the median of all discharge records on a day of year, while light, thin lines are the 25th and 75 discharge quantiles on that day. The blue lines represent the first site in a HUC4 watershed, while the green lines represent the second site.

3.3 Change in Discharge Variations over Years

To reveal how variability of discharge has changed over time, we analyzed the relationship between standard deviation of discharge within a year and years, using linear models (Figure 6; Table 2). Among all the 22 sites, 14 sites suggest increasing SD over time, and 4 of them show statistically significant increase. By contrast, only 8 sites suggest declining SD trends, and 2 of them exhibit statistically significant rising in SD. Despite that only data from six sites (around 27%) yield conclusive results, within these sites the number of streams that have become more variable are two times as many as those with decreasing variability. Thus, our results suggest that the whole Missouri Basin appear to have become more variable over years since around the mid-19th century. The low percentage of significant results could result from the small effect size, and/or the short time span of available data for some sites. Hence, more monitoring on discharge in the basin are required in the future to reach a more definitive conclusion.

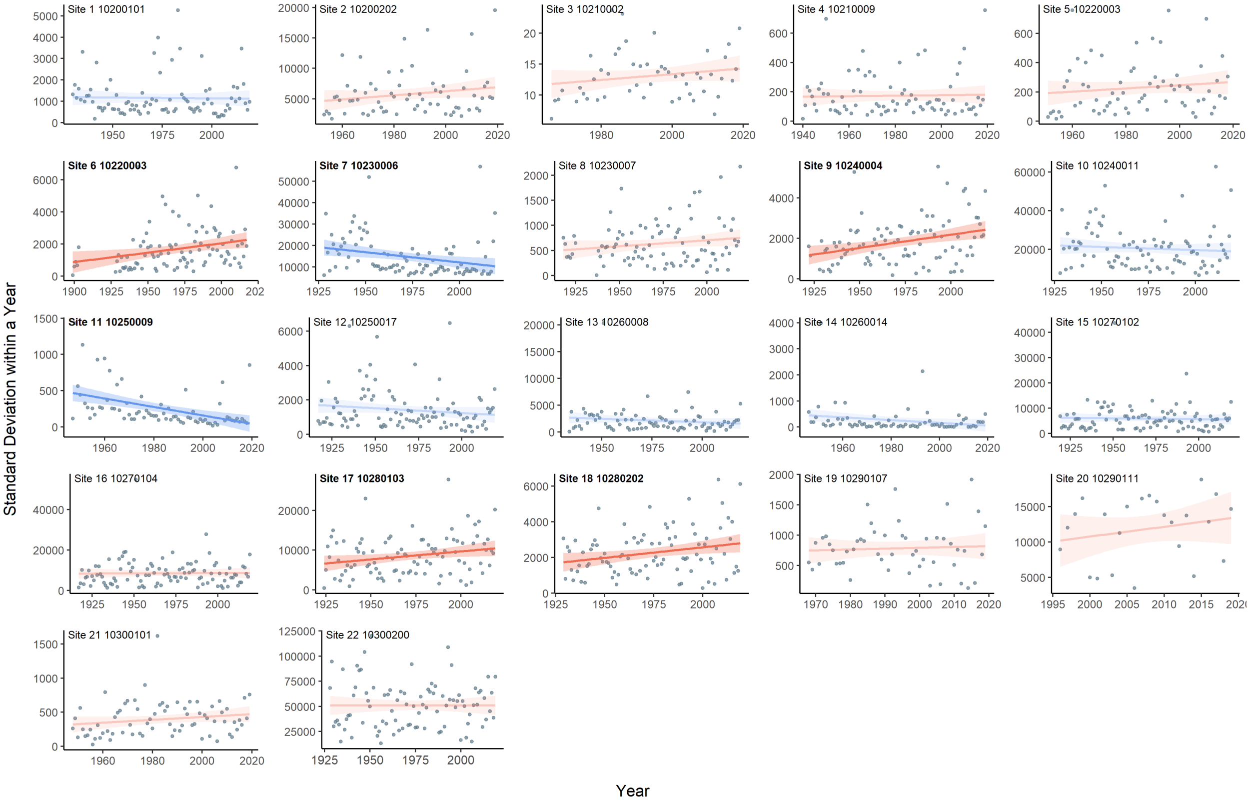

Figure 6: Changes in the standard deviations (SD) of discharge within a year at 22 sites over the whole time span of available data. Red regression lines and confidence intervals suggest increasing SD, whereas blue for decreasing SD over time. Bolded site labels and HUC8, and colors with higher saturation indicate statistically significant results ($\alpha = 0.05$).

Table 2: Slopes of linear regression between year and standard deviation of discharge at 22 sites.

	Site Name	HUC4	β_1	P
1	Platte River Near Overton, NE	1020	-0.805	0.83
2	Platte River At Louisville, NE	1020	33.7	0.144
3	Dismal River Near Thedford, NE	1021	0.047	0.196
4	Beaver Creek At Genoa, NE	1021	0.168	0.812
5	Maple Creek Near Nickerson, NE	1022	1.1	0.314
6	**Elkhorn River At Waterloo, NE**	**1022**	**11.7**	**0.009**
7	**Missouri River At Omaha, NE**	**1023**	**-95.2**	**0.0093**
8	Boyer River At Logan, IA	1023	2.4	0.134
9	**Nishnabotna River Above Hamburg, IA**	**1024**	**13**	**0.0018**
10	Missouri River At St. Joseph, MO	1024	-32.1	0.452

	Site Name	HUC4	β_1	P
11	**Republican River Near Orleans, NE**	**1025**	**-5.86**	**1e-04**
12	Republican R At Clay Center, KS	1025	-5.58	0.157
13	Smoky Hill R At Enterprise, KS	1026	-12.9	0.226
14	Sf Solomon R At Osborne, KS	1026	-5.27	0.0716
15	Kansas R At Wamego, KS	1027	-6.68	0.714
16	Kansas R At Desoto, KS	1027	2.56	0.91
17	**Grand River Near Sumner, MO**	**1028**	**40.4**	**0.0264**
18	**Chariton River Near Prairie Hill, MO**	**1028**	**11.9**	**0.0199**
19	Pomme De Terre River Near Polk, MO	1029	1.39	0.704
20	Osage River Below St. Thomas, MO	1029	138	0.311
21	Little Blue River Near Lake City, MO	1030	2.1	0.141
22	Missouri River At Hermann, MO	1030	0.657	0.994

4 Analysis

<Insert visualizations and text describing your main analyses. Format your R chunks so that graphs are displayed but code and other output is not displayed. Instead, describe the results of any statistical tests in the main text (e.g., "Variable x was significantly different among y groups (ANOVA; df = 300, F = 5.55, p < 0.0001)"). Each paragraph, accompanied by one or more visualizations, should describe the major findings and how they relate to the question and hypotheses. Divide this section into subsections, one for each research question.>

<Each figure should be accompanied by a caption, and each figure should be referenced within the text>

4.1 Question 1: How have changes in discharge interacted with nutrient enrichment in the Missouri River Basin?

We analyzed discharge, nitrogen and phosphorus trends at 22 sites using daily value data. The results are listed in the following table. In our analysis, discharge of 18 sites increase while 4 sites show the decreasing trend of discharge. However, these four sites all locate in HUC 1025 and 1026, away from the main stem of the Missouri River. Therefore, overall, the discharge in Missouri River is increasing. The trend of nitrogen and phosphorus concentration of 22 sites are quite different. But generally, the trend of nitrogen and the trend of phosphorus are similar, which indicates that there is high possiblity that nitrogen and phosphorus come from the same sources. If we focus on the sites located at the main stem of the Missouri River (06610000 Missouri River at Omaha, NE; 06818000 Missouri River at St. Joseph, MO; 06934500 Missouri River at Hermann, MO), we can see significant increasing trend of nitrogen and phosphorus. The water quality in Missouri River is still deteriorating and protection is urgently needed.

Site Name	Site Number	Discharge Trend	Discharge Trend Significance	Nitrogen Trend	Nitrogen Trend Significance	Phosphorus Trend	Phosphorus Trend Significance
Platte River near Overton, Nebr.	06768000	Increase		Decrease	*	Decrease	***
Platte River at Louisville, Nebr.	06805500	Increase	***	Increase	***	Increase	***
Dismal River near Thedford, Nebr.	06775900	Increase	***	Decrease	***	Decrease	
Beaver Creek at Genoa, Nebr.	06794000	Increase		Increase		Increase	
Maple Creek near Nickerson, Nebr.	06800000	Increase	***	Increase	***	Increase	***
Elkhorn River at Waterloo, Nebr.	06800500	Increase	***	Increase	*	Increase	

Site Name	Site Number	Discharge Trend	Discharge Trend Significance	Nitrogen Trend	Nitrogen Trend Significance	Phosphorus Trend	Phosphorus Trend Significance
Missouri River at Omaha, NE	06610000	Increase	***	Increase	**	Increase	***
Boyer River at Logan, IA	06609500	Increase	***	Decrease		Increase	
Nishnabotna River above Hamburg, IA	06810000	Increase	***	Decrease		Increase	
Missouri River at St. Joseph, MO	06818000	Increase	***	Increase	.	Increase	
Republican River near Orleans, Nebr.	06844500	Decrease	***	Increase	.	Decrease	**
REPUBLICAN R AT CLAY CENTER, KS	06856600	Decrease	**	Decrease	**	Decrease	***

Site Name	Site Number	Discharge Trend	Discharge Trend Significance	Nitrogen Trend	Nitrogen Trend Significance	Phosphorus Trend	Phosphorus Trend Significance
SMOKY HILL R AT ENTERPRISE, KS	06877600	Decrease		Decrease	.	Increase	
SF SOLOMON R AT OSBORNE, KS	06874000	Decrease	.	Decrease	***	Decrease	***
KANSAS R AT WAMEGO, KS	06887500	Increase		Increase	***	Increase	***
KANSAS R AT DESOTO, KS	06892350	Increase	.	Increase	**	Increase	***
Grand River near Sumner, MO	06902000	Increase	*	Decrease	***	Increase	
Chariton River near Prairie Hill, MO	06905500	Increase	*	Decrease		Increase	
Pomme de Terre River near Polk, MO	06921070	Increase		Decrease	.	Decrease	

Site Name	Site Number	Discharge Trend	Discharge Trend Significance	Nitrogen Trend	Nitrogen Trend Significance	Phosphorus Trend	Phosphorus Trend Significance
Osage River below St. Thomas, MO	06926510	Increase		Decrease	***	Increase	***
Little Blue River near Lake City, MO	06894000	Increase	**	Decrease	***	Decrease	***
Missouri River at Hermann, MO	06934500	Increase	***	Increase	***	Increase	***

Note: *** p-value < 0.001 ** 0.001 <= p-value < 0.01 * 0.01 <= p-value < 0.05 . 0.05 <= p-value < 0.1 otherwise 0.1 <= p-value < 1

4.2 Question 2: What effects do specific flood and drought events have on the water quality and quantity of rivers in the Missouri River Basin areas of interest?

4.2.1 Flooding

Population of each county (from the 2010 census) in the four states that make up our region area of interest (Kansas, Nebraska, Missouri, and Iowa) were found using the "counties" database from R's `noncensus` package. We decided that population could be used as a proxy for land cover, as a greater population would indicate more development and fewer agricultural fields or open spaces.

Baseflow and quickflow from each site were determined with the `EcoHydRology` package. After linearly interpolating the instantaneous discharge data in order to account for gaps, total baseflow volume was found and the percent of discharge exported as baseflow was calculated. We predicted that a site within a county with a large population would have a lower percent of its discharge exported as baseflow, because quickflow would be more common in areas with a lot of development. Similarly, we also predicted that a site within a county with a small population would have a greater percentage of its discharge coming from baseflow. More developed areas often have flashier floods, and so we were curious to see whether we can relate population to an element of flashiness - the percentage of discharge exported as quickflow.

Contrary to our hypotheses, greater county population does not contribute to a decrease in percent of discharge as baseflow ($p = 0.4199$, $F = 0.8067$) in our sites of interest. This may be due to our small sample size of sites, or perhaps the size of the rivers in our study.

High frequency nitrogen data was only available for seven sites within our region. In order to better understand the behavior of rivers during floods, we examined dygraph plots of discharge and nitrogen, and created hysteresis plots. Storms from the fall of 2018 (September - December) were examined for each river site with data from that time period. We chose to only look at storms that occurred in the second half of the year in order to avoid conflating snowpack melt and precipitation affects.

We predicted that most rivers in the area would behave the same way, and that rivers would exhibit flushing behavior. We thought that flushing rivers would be more prevalent because of the many agricultural fields in our region of study, and any overland flow to the rivers would bring with it a high concentration of nutrients (nitrogen being one of them) from the fertilized fields. Our results say otherwise (Table 2). Our sites of interest had both positive and negative slopes in the hysteresis plots, and also exhibited both clockwise and counter clockwise directions of flow (**??**). The same river was analyzed multiple times throughout the year, and even the same river showed different slopes and directions in the hysteresis plots for different storm events.

Site Name	Site Number	Time Period	Direction	Slope
West Nishnabotna River in Randolph, IA	06808500	Oct 7 - 13, 2018	counter clockwise	negative (Figure xx)
Nodaway River at Clarinda, IA	06817000	Oct 8 - 12, 2018	clockwise	negative
Kansas River in Desoto, KS	06892350	Nov 30 - Dec 5, 2018	counter clockwise	positive
Missouri River at Hermann, MO	06934500	Oct 7 - 20, 2018	counter clockwise	negative
Mill C at Johnson Drive, Shawnee, KS	06892513	Nov 27 - Dec 4, 2018	clockwise	negative

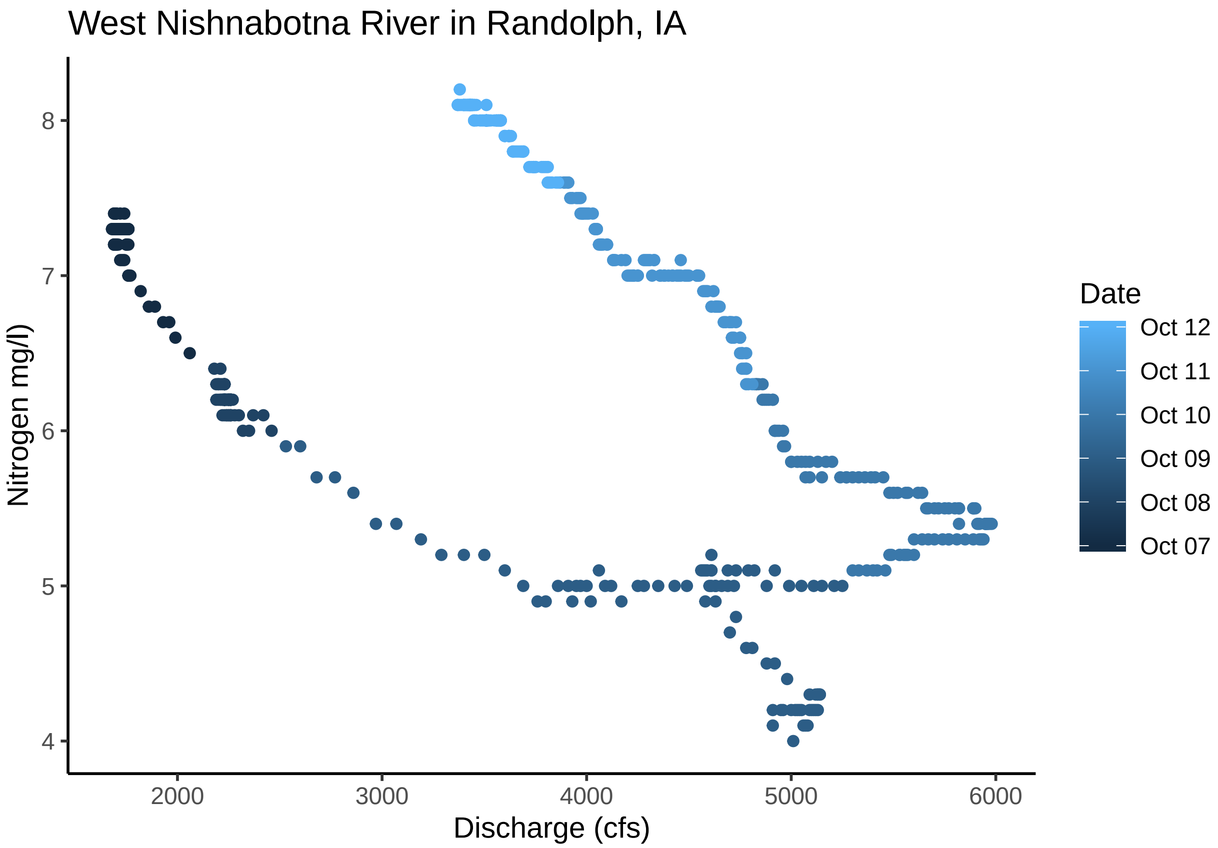

Figure 7: Hyteresis plot for site in Randolph, IA that shows a negative slope (diluting behavior) in a counter clockwise direction.

Site Name	Site Number	Time Period	Direction	Slope
Grand River, Sumner MO	06902000	Sep 6 - 10, 2018	clockwise	positive

4.2.2 Droughts

Droughts in the Missouri River Basin were known to occur throughout the years and six sites were analyzed for drought information. The six sites were chosen based off what was examined for floods.

Drought was defined as determining the 7Q10, which is the minimum 7-day average flow that will occur every 10 years (probability of 10%) (EPA, 2019). The 7Q10 measurement is used to determine streamflow limits, allocate water resources, dilution rates in watersheds, and more (USGS, 2019). 7Q10 is calculated by determining the recurrence interval, which is the past recurrence of an event, which for droughts would be the minimum 7-day average discharge. The recurrence interval can then be used to calculate the probability, which would be the probability or likelihood of having a minimum 7-day average flow of this magnitude or greater. In this case, the minimum 7-day average flow that has a 10% chance of going below that value in a given year.

The recurrence interval is calculated using the following equation:

$T = (n + 1)/m$

where T is the recurrence interval, n is the number of years of data, and m is the ranking of the event within the years of data.

Exceedance probability is calculated to determine the probability of having a discharge event of a given size or greater in a year. The equation is:

$P = 1/T$

where P is the exceedance probability, and T is the recurrence interval.

The 7Q10 was calculated for each of the six sites by first filtering the discharge data to only include the selected site. The 'rollmean' function was then used to calculate the average flow every 7 days for said site. Once the 7-day average flow was calculated, the data was grouped by the year so that it could then be summarized to obtain the minimum 7-day average flow. After grouping and summarizing the data, there was one value, the minimum 7-day average flow, for each year of data obtained. From here, the recurrence interval and probability were calculated in each data frame.

The 7Q10 value was then determined from the probability column by filtering the data to show the minimum 7-day average discharge with probability less than or equal to 0.1 (Table 3).

Table summarizing the 7Q10 values for each of the streams that were analyzed for droughts.

Site Name	Site Number	7Q10 Minimum Discharge (cfs)
West Nishnabotna River in Randolph, IA	06808500	41.3
Nodaway River at Clarinda, IA	06817000	5.93
Kansas River in Desoto, KS	06892350	562
Missouri River at Hermann, MO	06934500	12414
Mill C at Johnson Drive, Shawnee, KS	06892513	1.47
Grand River, Sumner MO	06902000	39.1

In addition to calculating the 7Q10 values for the 6 sites, the sites were analyzed to determine the 7-day moving average flow over a period of years. The 25th, 50th, and 75th quantiles were calculated to determine the minimum, median, and maximum values for discharge in a given year. The 7-day moving average flow over a period of years was then plotted with the 25th, 50th, and 75th quantiles representing normal drought conditions, drought watch, drought warning, and drought emergency (Figure ______). This information about what flow would constitute a drought is extremely useful for water managers.

4.3 Question 3: What factors contribute to the variability of total nitrogen in the rivers?

In order to better understand what contributes to the variability of nitrogen concentration in our study area of interest, we created a linear model with fixed effects and random effects. By considering the HUC 4 region each site is in as a random effect, we can estimate the amount of variation of nitrogen between each HUC 4. In order to better model the interaction, I chose to divide the year variable by 10 and the population by 1000 so that rescaling is not an issue. The model chosen is below:

```
lmer(data, log(total.nitrogen) ~ Year + population  + (1|huc4))
```

Year and population are fixed effects while the grouping of the HUC 4 region is a random effect. This means we take the HUC 4 region variance into account when modeling the effect of year and population on total nitrogen. Using log transformed nitrogen data and HUC 4 region as a random effect, there is a significant difference in total nitrogen across each decade and every 1000 people ($p < 2e\text{-}16$). The regression equation is below:

$$log(TotalNitrogen) = -3.68 + 0.0229(Year/10) - 9.95e - 04(population/1000)$$

Because we used a log transformed data set, we have to exponentiate the coefficients in the model to interpret them. The intercept is 0.025, which is the mean of total nitrogen when year is 0 and population is 0. When exponentiating the Year coefficient, we can conclude that every decade has a 1.02 multiplicative effect on nitrogen. When exponentiating the population coefficient, we can conclude that every 1000 people have a 0.99 multiplicative effect on nitrogen. The model demonstrates the the level of decade and population affected the total nitrogen in each HUC 4 region. Residuals are evenly distributed, and the R^2 value = 0.514, indicating that 51.4% of the variation in nitrogen is explained by this model.

4.4 Question 4: Given past and current data, what can we predict about the future state of water in the Missouri River Basin?

Site Name	Site Number	Dec. 2019	Jan. 2020	Feb. 2020	Mar. 2020	Apr. 2020	May 2020	June 2020	July 2020	Aug. 2020	Sept. 2020	Oct. 2020	Nov. 2020
Platte River near Overton, Nebr.	06768000	2019.992	1942.129	1929.812	2040.172	2032.186	1990.873	2023.824	2008.551	1928.585	1996.895	1979.332	2026.699

Site Name	Site Number	Dec. 2019	Jan. 2020	Feb. 2020	Mar. 2020	Apr. 2020	May 2020	June 2020	July 2020	Aug. 2020	Sept. 2020	Oct. 2020	Nov. 2020
Platte River at Louisville, Nebr.	06805500	14060.7	12802.12	22845.87	23729.41	15056.78	16585.18	16430.86	15168.09	15216.91	14719.46	13635.72	12780.16
Dismal River near Thedford, Nebr.	06775900	239.2082	238.9823	238.3112	239.5916	240.5232	242.5456	242.0362	241.6402	242.0486	242.2382	241.9548	240.2764
Beaver Creek at Genoa, Nebr.	06794000	148.0349	129.4563	139.6963	127.3795	165.0577	190.15	189.022	172.7318	157.0474	146.7917	151.0374	146.0562
Maple Creek near Nickerson, Nebr.	06800000	173.1581	150.6924	141.7453	113.545	159.0779	199.5598	187.1167	149.6111	148.6135	149.6721	146.2639	136.3859
Elkhorn River at Waterloo, Nebr.	06800500	2607.337	2598.626	2172.196	3208.066	3341.663	3977.737	3785.948	2912.286	2434.121	2091.352	2733.932	2520.393
Missouri River at Omaha, NE	06610000	70976.66	60591.75	76874.04	73723.59	81113.58	83595.91	70800.98	85219.7	78593.88	80467.92	78227.7	70854.33
Boyer River at Logan, IA	06609500	708.6843	691.4864	645.5966	1176.8074	714.8702	814.9989	890.516	733.6069	650.3336	655.3034	724.2968	689.9273

Site Name	Site Number	Dec. 2019	Jan. 2020	Feb. 2020	Mar. 2020	Apr. 2020	May 2020	June 2020	July 2020	Aug. 2020	Sept. 2020	Oct. 2020	Nov. 2020
Nishnabotna River above Hamburg, IA	06810000	2422.32	2391.72	2377.85	3204.07	2417.13	2731.8	3104.86	2650.79	2460.29	2777.40	3156.36	2595.649
Missouri River at St. Joseph, MO	06818000	90011.3	77760.7	76549.0	116938.2	120927.1	130362.1	116671.1	110560.9	79105.4	103960.1	121688.9	90403.96
Republican River near Orleans, Nebr.	06844500	154.954	145.28	147.940	228.287	171.878	166.030	184.050	321.398	164.374	150.460	149.705	158.701
REPUBLICAN R AT CLAY CENTER, KS	06856000	2212.68	2012.94	1966.35	2354.77	2052.39	2615.52	2571.78	2483.55	2404.83	2283.90	2196.92	2458.036
SMOKY HILL R AT ENTERPRISE, KS	06877600	1999.59	1814.09	1788.58	1807.76	1634.91	2308.79	2034.46	1885.74	1831.55	1777.79	1663.05	1556.348
SF SOLOMON R AT OSBORNE, KS	06874000	174.320	140.658	123.454	114.662	110.169	107.871	106.699	106.099	105.792	105.636	105.556	105.5151

Site Name	Site Number	Dec. 2019	Jan. 2020	Feb. 2020	Mar. 2020	Apr. 2020	May 2020	June 2020	July 2020	Aug. 2020	Sept. 2020	Oct. 2020	Nov. 2020
KANSAS R AT WAMEGO, KS	06887500	14398.71	10484.57	7084.95	6938.43	5800.96	7571.28	9826.41	11052.98	9796.39	7676.54	6316.07	7846.2
KANSAS R AT DESOTO, KS	06892350	17433.74	13064.97	8272.79	9534.90	7730.84	11531.10	7710.27	12100.02	7099.49	6399.50	8509.62	2945.916
Grand River near Sumner, MO	06902000	9634.729	9456.48	10440.13	13753.19	10392.48	12326.17	17156.89	13890.93	9517.49	10274.17	12340.84	7456.777
Chariton River near Prairie Hill, MO	06905500	1946.37	2523.67	2763.86	3701.26	2556.85	3142.34	2904.04	2597.21	3511.39	2678.03	2898.12	2629.494
Pomme de Terre River near Polk, MO	06921070	302.197	290.196	335.346	317.866	267.663	404.104	462.339	255.162	247.383	250.406	269.61	287.8386
Osage River below St. Thomas, MO	06926510	12184.39	13730.13	11039.61	12564.51	14026.31	14174.26	13191.61	16801.41	15671.6	14122.21	13155.12	12236.42

Site Name	Site Number	Dec. 2019	Jan. 2020	Feb. 2020	Mar. 2020	Apr. 2020	May 2020	June 2020	July 2020	Aug. 2020	Sept. 2020	Oct. 2020	Nov. 2020
Little Blue River near Lake City, MO	06894000	181.666	206.497	263.724	206.725	214.545	320.452	250.681	228.437	209.844	231.759	198.791	190.647
Missouri River at Hermann, MO	06934500	189461.1	194893.1	242122.8	215398.2	212735.2	230589.2	240828.8	227848.2	213285.9	216789.2	230480	210515

5 Summary and Conclusions

<Summarize your major findings from your analyses in a few paragraphs. What conclusions do you draw from your findings? Relate your findings back to the original research questions and rationale.>

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