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Assessing Variability in Nutrient Transport from the Mississippi Watershed

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Introduction

The Mississippi River begins in Minnesota from Lake Itasca and runs a course of 2,350 miles until it reaches the Gulf of Mexico. Through this journey, hundreds of different tributaries join the Mississippi River creating water sources from 31 states and 2 Canadian provinces; which are high agricultural and human sources of nutrients to the watershed. Far downstream, the Mississippi River and the Atchafalaya River become interconnected, and they both discharge freshwater into the Gulf of Mexico. This system becomes what is known as the Mississippi/Atchafalaya River Basin (MARB), and the entire system is the third largest in the world, covering approximately 15% of North America and 41% of the contiguous United States[1]. It has been estimated that the combination of these rivers account for approximately 80% of the freshwater input into the Gulf of Mexico from the United States, as well as 90% of the total nitrogen that is inputted into the Gulf of Mexico on an annual basis. This input of nitrogen, as well as other major nutrients, can stimulate algal growth within the Gulf, being one of the main causes of the very large hypoxic zone (i.e., the "Dead Zone") found in the northern shelf of the Gulf[2].

Hypoxic areas have the potential to become spatially extensive, with oxygen levels dropping too low (<30% saturation; i.e., hypoxia) to support marine macro-organisms such as fish, crabs, and clams, resulting in mass mortality events[3]. In this system, the decrease in dissolved oxygen begins during the late months of spring due to the increase in flux of freshwater (imposing stratification) and nutrients, reaching a maximum during the late summer. Between the years of 1985 and 1992, the average size of this dead zone was between 7,000 and 9,000 square kilometers[2].

Due to a rise in concern from the public regarding coastal hypoxia, scientific assessments began in 1997 after a task force was initiated in order to fully understand the situation[4]. The goals of the task force were to assess why eutrophication was occurring, and the effects it has on the system as well as potential mitigation strategies. Being able to understand the sources of these nutrients and how their fluxes have varied temporally within the Mississippi Watershed is extremely important for understanding the trends, future predictions, and consequences for the Gulf of Mexico Hypoxic Zone.

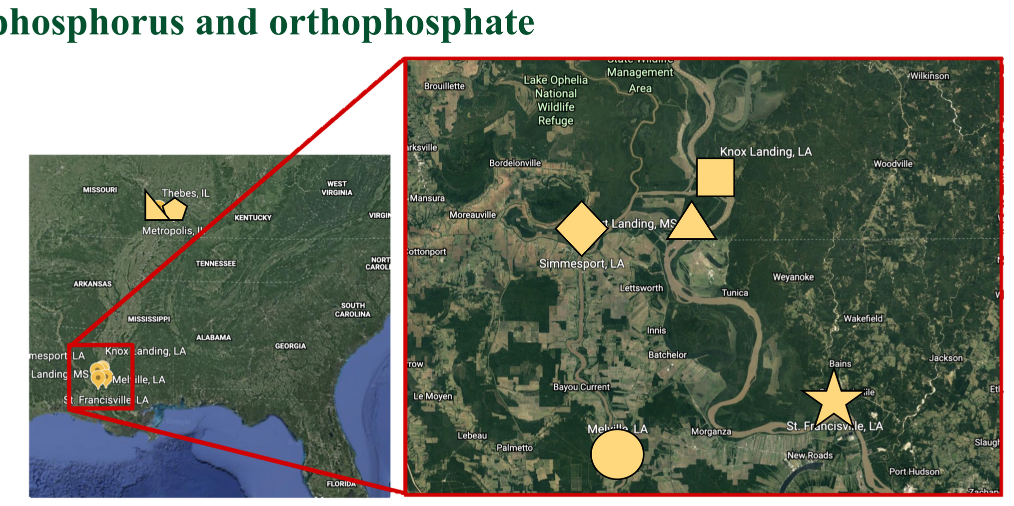
Image Source: https://www.epa.gov/ms-htf/mississippiatchafalaya-river-basin-marb

Methods

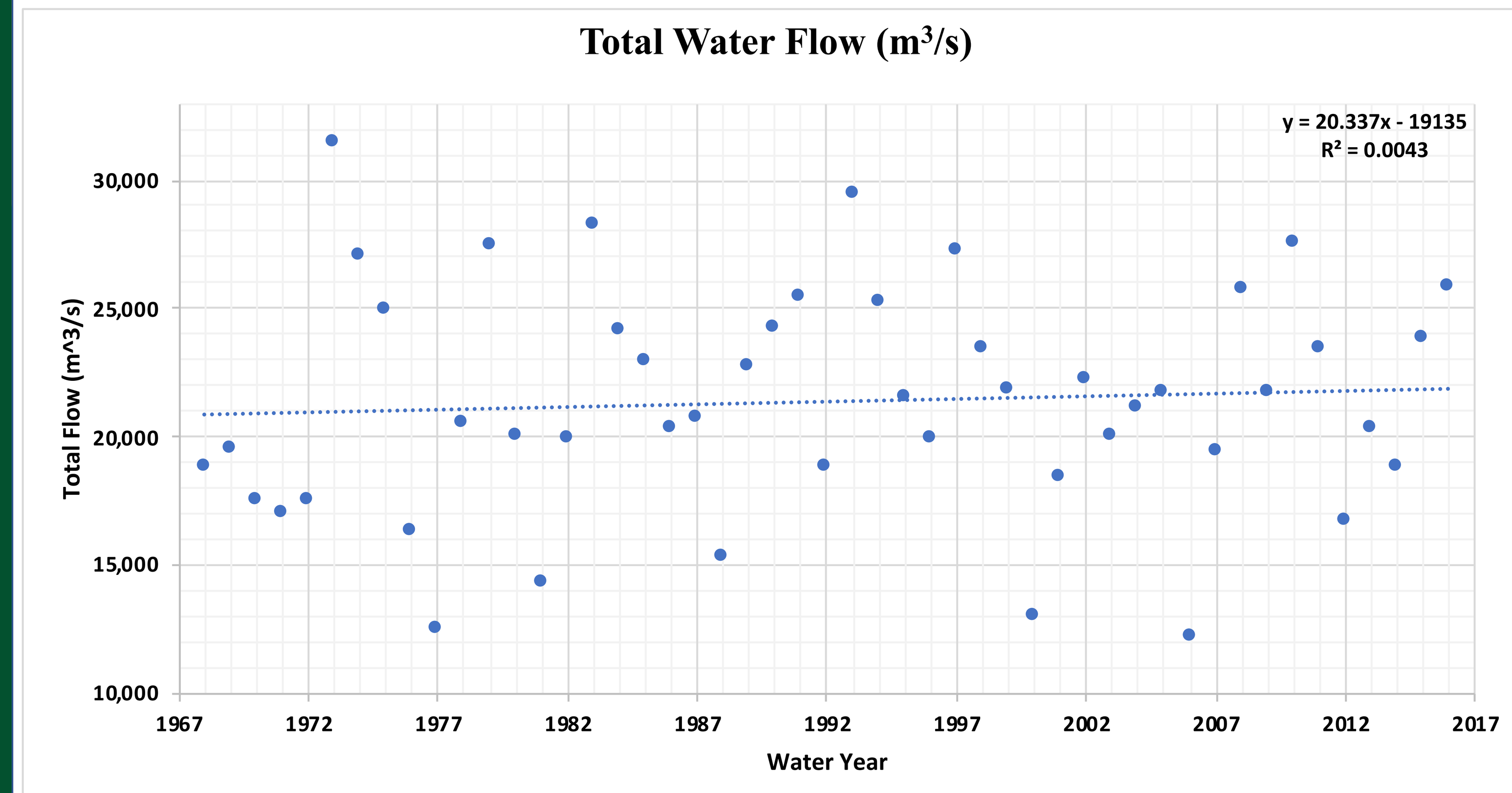
Data of mean river flow and nutrient load delivery from the total Mississippi-Atchafalaya River Basin into the Gulf of Mexico were taken from the United States Geological Survey (USGS)[5]. Nutrient flux in the Mississippi River was calculated using water quality data from ☆ and discharge data from △. Nutrient flux in the Atchafalaya River was calculated using water quality data from ○ and discharge data from ◇. Water flow at three other stations were taken into consideration when calculating nutrient delivery. Measurements for the water flow diverging from the Mississippi River to the Atchafalaya River was from □, whereas flow from upstream in the Mississippi River was from ⬠ and ◺. To calculate these flux estimates, the USGS used the regression-model method[5], which estimates values for continuous nutrient flux over time. This regression-model was used to calculate the fluxes in the LOADEST software program. For the set of data used in this analysis, the adjusted maximum likelihood estimates (AMLE) are used[5].

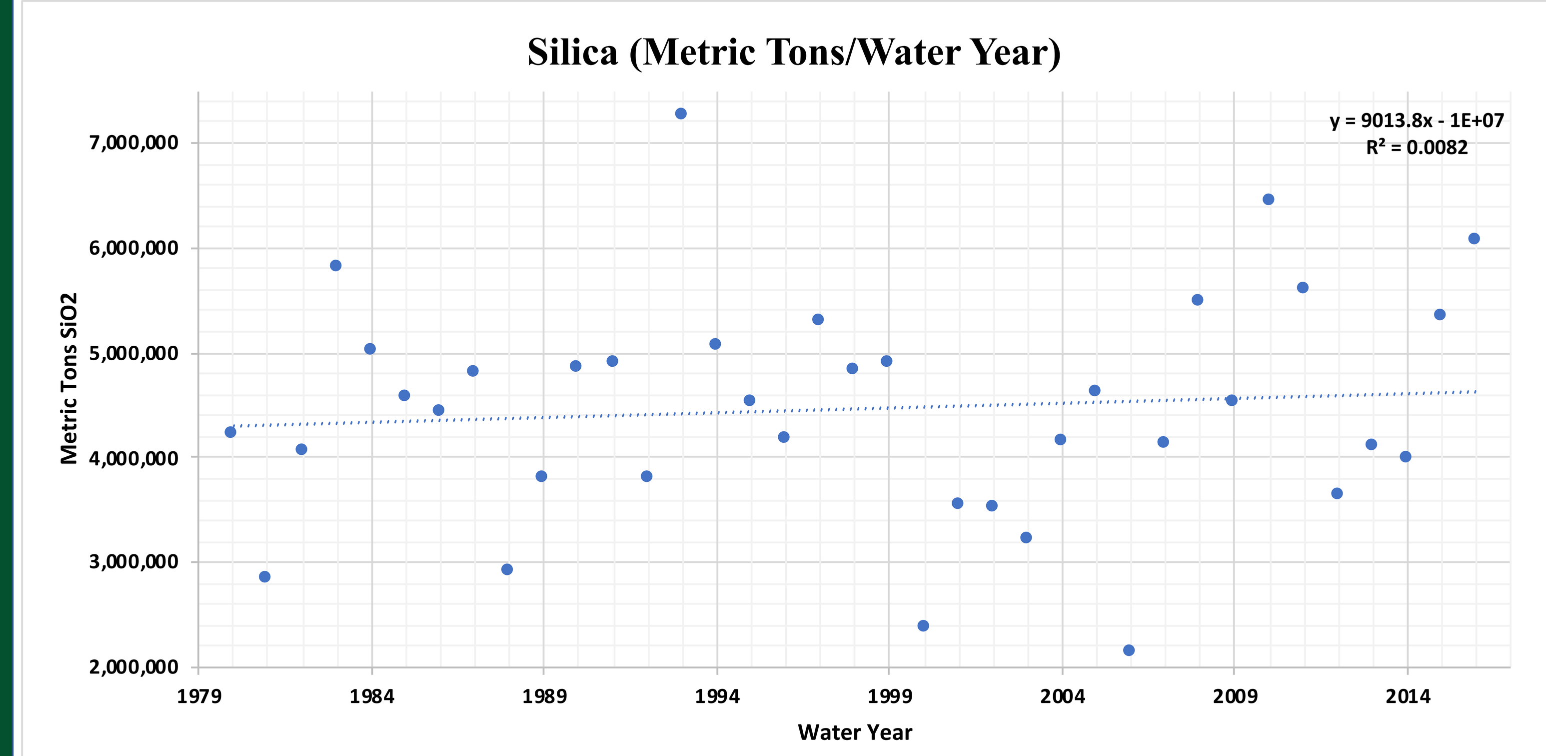
The nutrient fluxes assessed in this analysis are:

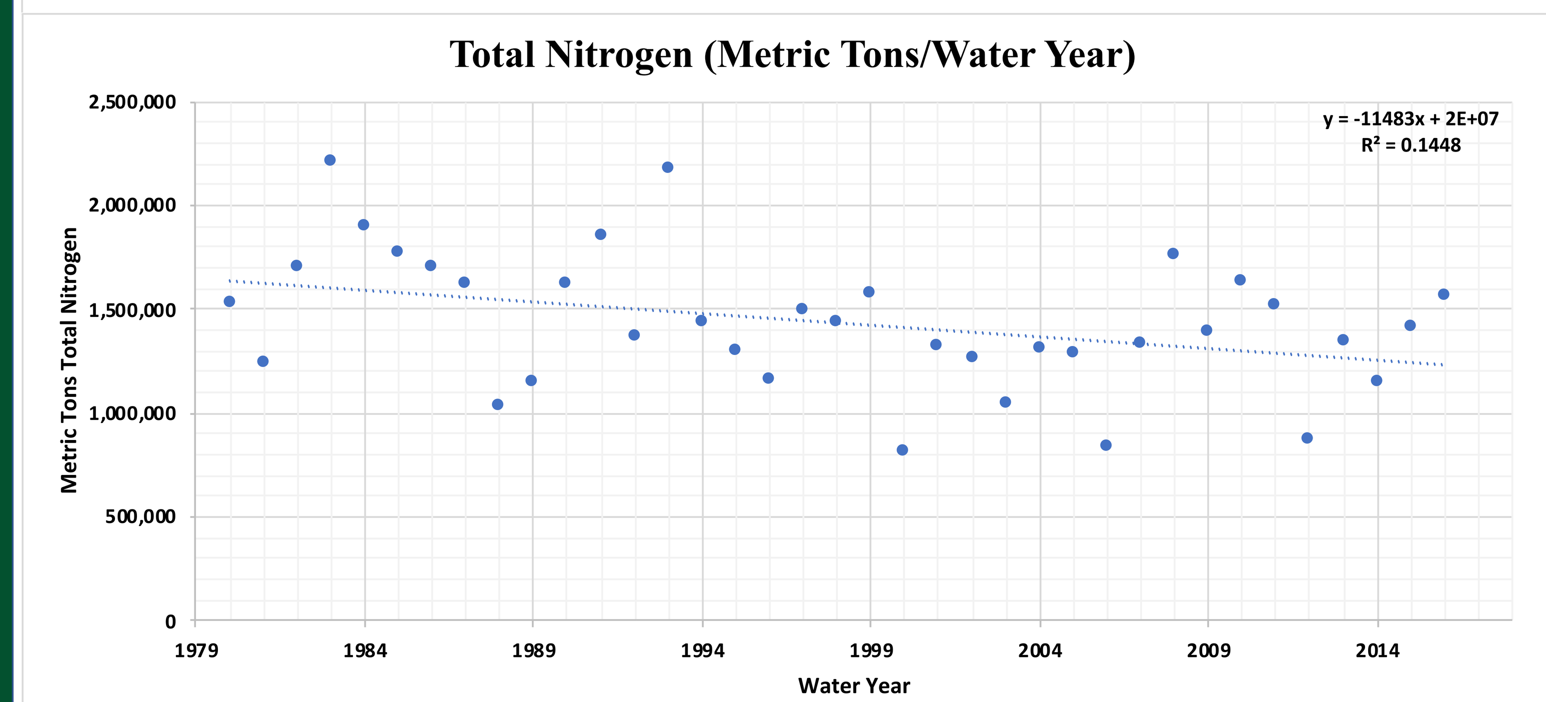
- **Nitrate + nitrite, ammonium and organic nitrogen**
- **Organic phosphorus and orthophosphate**

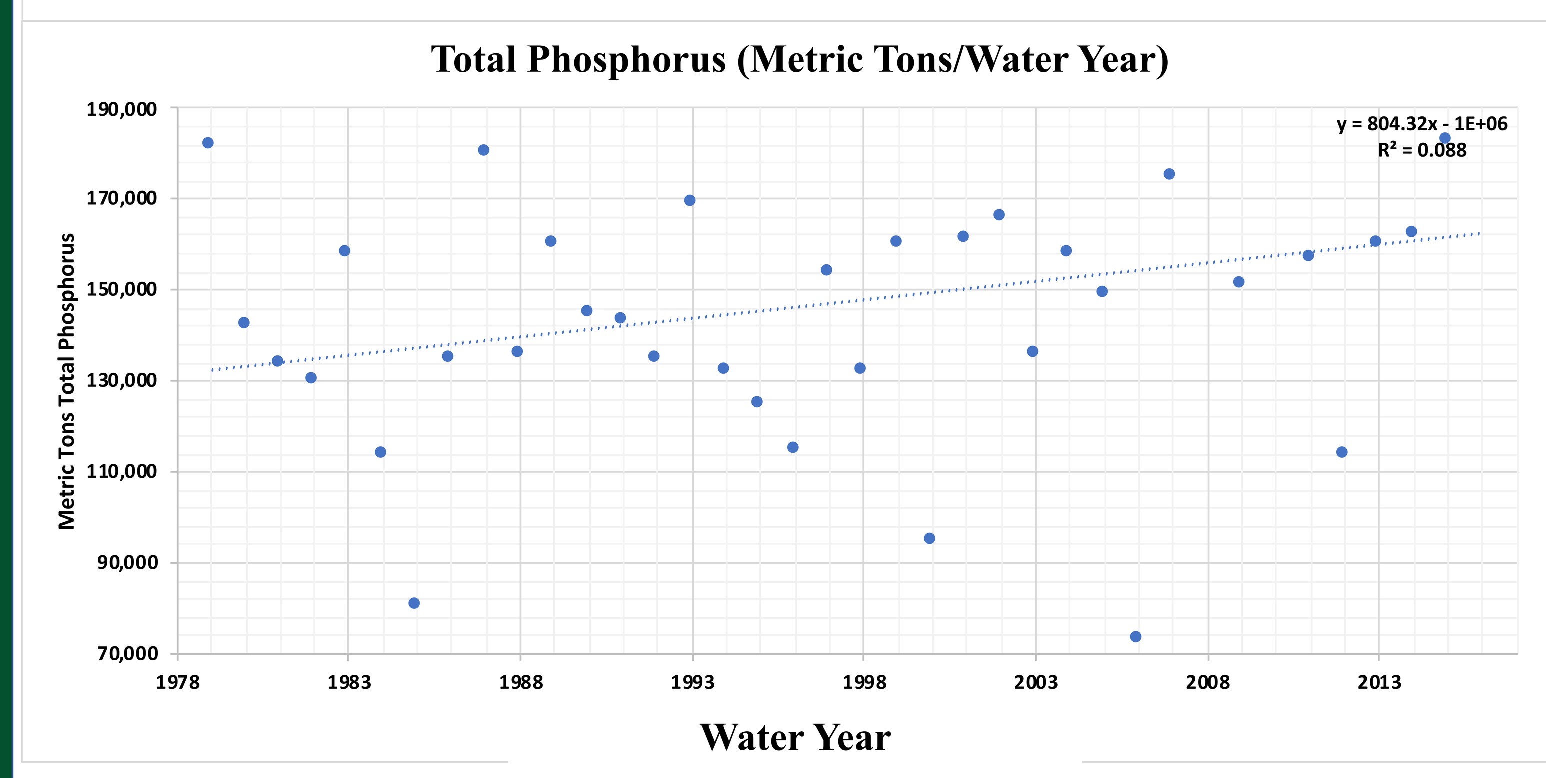


Results: The figures below show the total flow (m^3/s) and nutrient flux per water year for silica, total nitrogen and total phosphorus as a function of time.



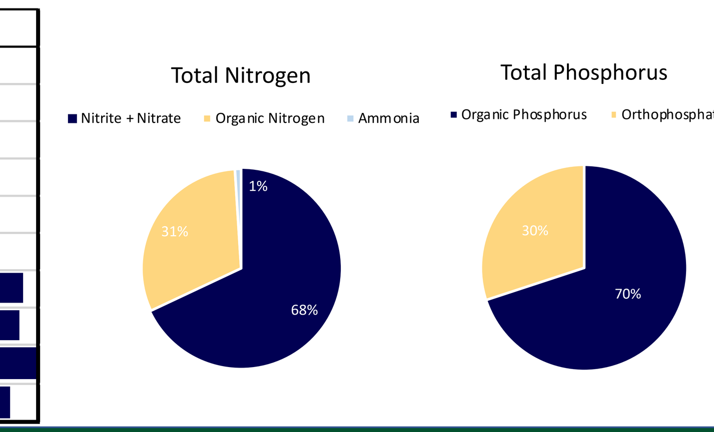






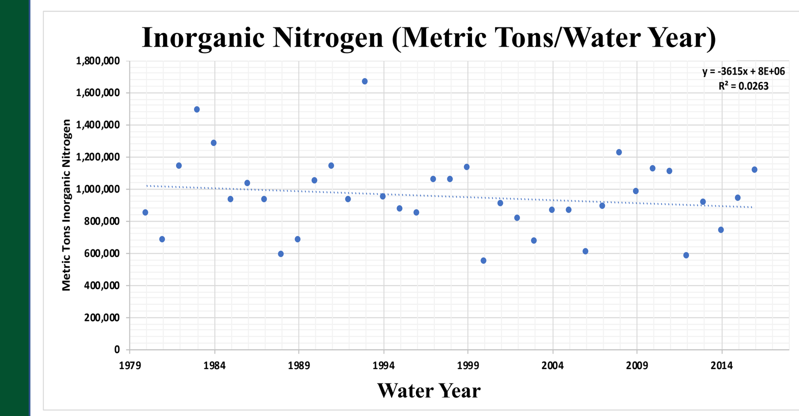
Results: The table shows the percent changes in nutrient flux during the specific time periods. The charts show the components making up total nitrogen and total phosphorus.

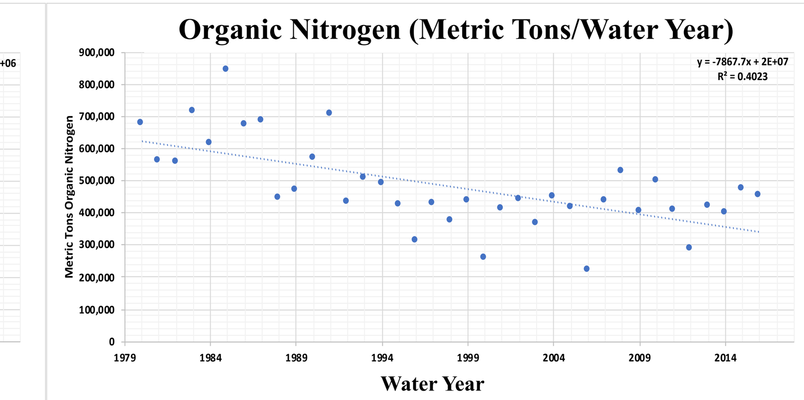
Nutrient	Starting Record	Ending Record	% Change
Total Water Flow	1969 - 1977	2007 - 2016	+ 10.17
Total Nitrogen	1980 - 1989	2007 - 2016	-12.13
Nitrite + Nitrate	1979 - 1988	2007 - 2016	-0.84
Inorganic Nitrogen	1980 - 1989	2007 - 2016	+ 0.13
Ammonia	1980 - 1989	2007 - 2016	-79.85
Organic Nitrogen	1980 - 1989	2007 - 2016	-30.95
Total Phosphorus	1979 - 1988	2007 - 2016	+ 22.73
Organic Phosphorus	1982 - 1991	2007 - 2016	+ 21.09
Orthophosphate	1982 - 1991	2007 - 2016	+ 29.92
Silica	1980 - 1989	2007 - 2016	+ 16.11



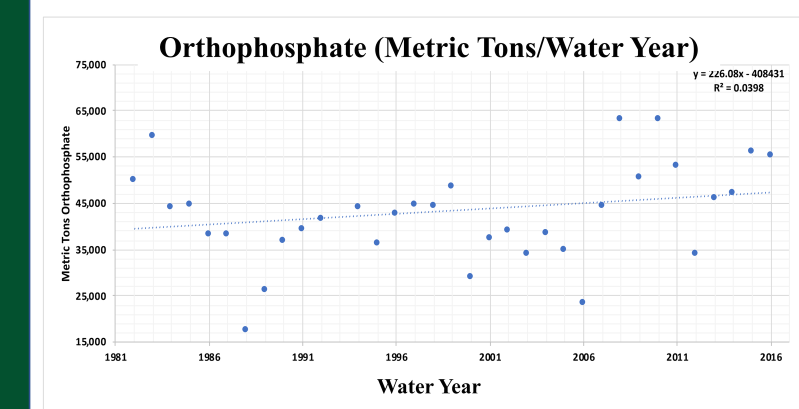
Discussion

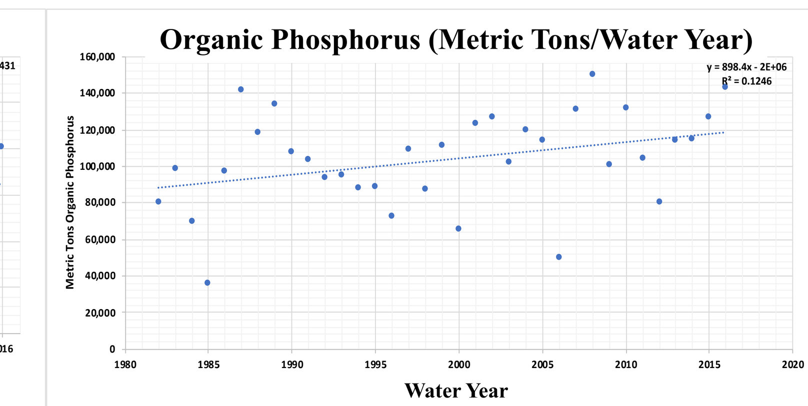
- There was a small increase in the **total flow**, where the percent change in the 10-year average from the start to the end of the record is +10.17%.
- For this analysis, **silicic acid** was used as a non-anthropogenic conservative tracer of nutrient transport. The other nutrient fluxes have a large anthropogenic influence.
- The changes in **total nitrogen** flux (-12.13%) can be explained by the decrease in organic nitrogen flux (-30.95%), whereas inorganic nitrogen remains effectively unchanged.
  - **Organic nitrogen** decreased over time, but the cause remains unknown.
  - Some of the reasons that changes may not be seen for **inorganic nitrogen** is due to legacy nitrogen sources, differences between groundwater systems for their capacity to store nitrogen, the balances between an increase and decrease in nitrate usage in certain areas, and the timescale of the usage of inorganic nitrogen fertilizer[6].





- **Total phosphorus** (+22.73%), organic phosphorus and orthophosphate changes in fluxes coincide with increased usage of fertilizers and population growth.
  - Further, when land is cultivated, erosion increases, and phosphorus will be discharged into nearby water sources[7].
  - These factors, combined with the usage of phosphate fertilizer, help explain the linear increase in organic phosphorus and orthophosphate throughout history.





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Acknowledgements

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