Preserving

Nutrient Concentrations in the Upper Great Miami River near Taylorsville Dam

2007 - 2024 Report

THE MIAMI CONSERVANCY DISTRICT

Abstract

The Miami Conservancy District (MCD) has conducted automated water quality monitoring of the Upper Great Miami River since 2006 to assess nutrient trends in a predominantly agricultural watershed. This study evaluates long-term patterns in nitrate-nitrogen and total phosphorus concentrations from 2007–2024 using the U.S. Geological Survey's EGRET software, which accounts for flow, time, and seasonality.

Findings indicate that stream flows have steadily increased since 1960, potentially influencing nutrient dynamics. Nitrate concentrations remained relatively stable over time but consistently exceeded Ohio EPA's 1.5 mg/L threshold for biological over-enrichment. Total phosphorus concentrations declined through 2017, then increased—especially at low flows—remaining above the 0.13 mg/L EPA benchmark throughout the study period.

Persistent nutrient enrichment suggests ongoing risks to aquatic ecosystem health in the Upper Great Miami River and contributes to nutrient exports downstream. These results underscore the importance of continuous monitoring to inform watershed management and nutrient reduction efforts.

Background

The Miami Conservancy District is a conservancy district - a political subdivision of the State of Ohio. Miami Conservancy District works as a regional government agency throughout the Great Miami River Watershed (see figure 1). Since formed in 1915, Miami Conservancy District provides flood protection, water stewardship, and recreation.

To track natural water resource conditions, Miami Conservancy District operates automated and observer precipitation stations as well as extensive stream gaging and observation well networks to record precipitation, streamflow, and groundwater levels. Miami Conservancy District operates the stream gaging network with the U.S. Geological Survey (USGS) under a cooperative agreement that has been in place since 1931. Partnering with a variety of federal, state, and local governments, Miami Conservancy District conducts surface water and groundwater quality and quantity studies.

Nutrient Enrichment in the Great Miami River Watershed

Nutrients such as nitrogen and phosphorus are essential for aquatic life, supporting the growth of algae and aquatic plants and sustaining biological communities in rivers and streams. However, excessive concentration can impair ecosystem health by altering food webs, increasing algal and macrophyte growth, reducing water clarity, depleting dissolved oxygen, and shifting aquatic communities toward degraded species compositions (Ohio EPA, 1999).

Human activities over the past century—including wastewater discharges, fertilizer runoff, and atmospheric deposition—have significantly increased nutrient inputs to aquatic systems (Puckett, 1995). In the Great Miami River Watershed, nutrient enrichment has been well documented by the Ohio EPA and other researchers. Notably, algal blooms were observed in 1995 and 2011, and nutrient pollution remains one of the most common causes of stream impairment in the region (Ohio EPA, 2011). Runoff from the watershed also contributes to hypoxia in the Gulf of Mexico, with some of the highest nutrient yields in the Mississippi-Atchafalaya River Basin (Goolsby et al., 1999; Loftus, 2004).

Monitoring

To monitor and respond to these concerns, the Miami Conservancy District (MCD) established an automated water quality sampling station downstream of Taylorsville Dam in 2006. The station collects daily samples for analysis of nitrate-nitrogen, total phosphorus, ammonia, nitrite, total Kjeldahl nitrogen, soluble reactive phosphorus, and total suspended solids. Samples are analyzed by the City of Dayton Water Reclamation Laboratory, with data stored in MCD's AQUARIUS Cloud database.

The sheltered enclosure station includes a pump, located about seven meters from the riverbank, that delivers water to a flow-through tank (see figure 2). A refrigerated sampler connected to the tank uses pre-programmed timing to fill bottles, which are stored in a carousel, for weekly collection and laboratory analysis (see figure 3).

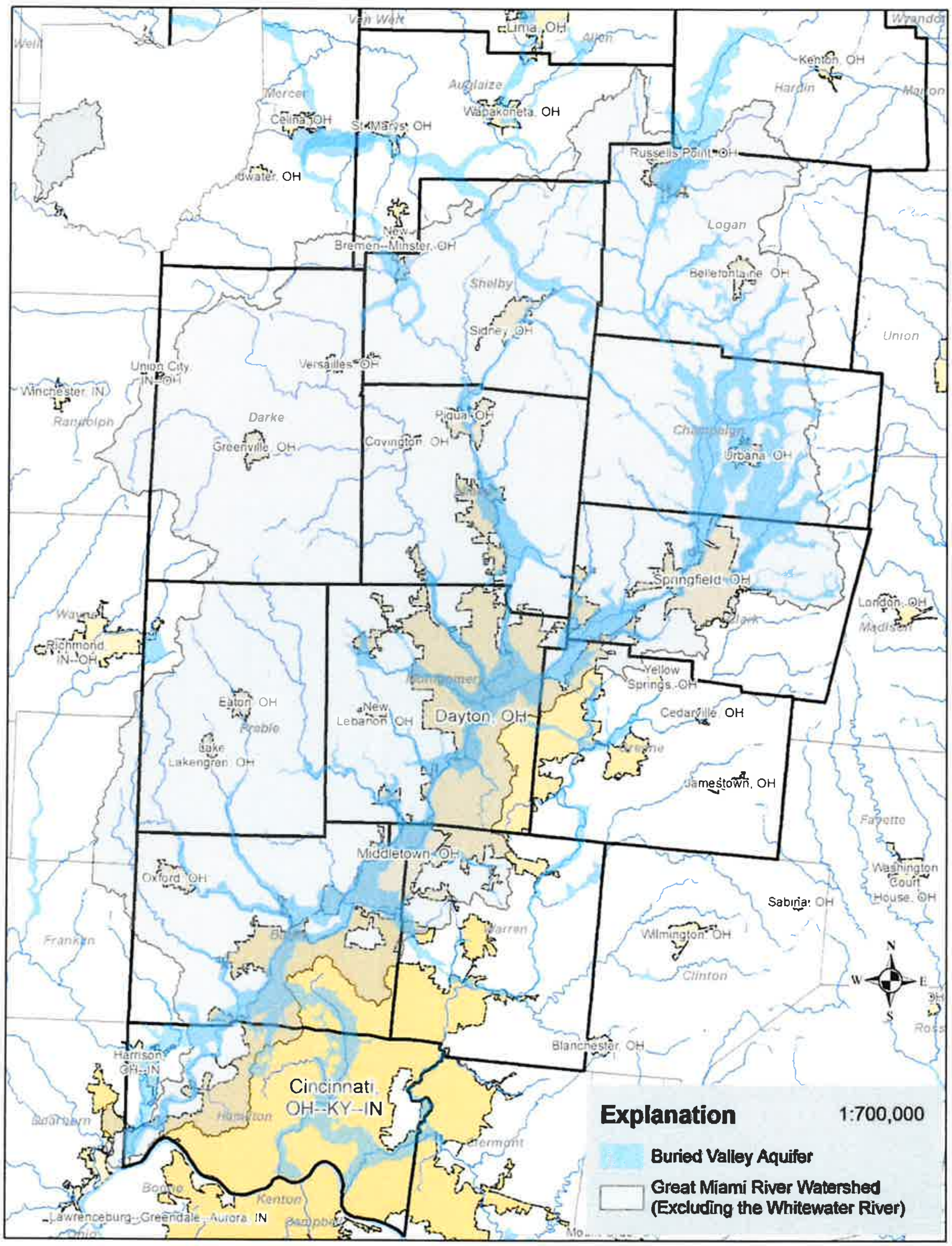
This report summarizes the trend analyses of nitrate and total phosphorus concentrations collected from 2007 through 2024. To analyze the data, U.S. Geological Survey EGRET software was used. These nutrients were selected based on their ecological significance and alignment with Ohio EPA thresholds for over-enrichment. The analysis explores long-term trends in relation to seasonal variation and streamflow, offering insight into watershed nutrient dynamics and informing regional management strategies.

Laboratory Analysis

Samples are collected by the Miami Conservancy District and sent to the City of Dayton Water Reclamation Laboratory to perform analysis using the following analytical methods.

Parameter	Analytical Method
Ammonia	EPA 350.2
Nitrite as N	SM 4500 NO3-F
Nitrate as N	SM 4500 NO3-F
Phosphorus, Total Reactive	SM 4500 P-F
Total Phosphorus	EPA 200.7/6010
Total Kjeldahl Nitrogen	EPA 351.2
Total Suspended Solids	EPA 160.2

Figure 1 – Map of the Great Miami River Watershed, Ohio.



Results from the laboratory analysis are provided back to MCD electronically. The results are uploaded to an AQUARIUS Cloud database where data is managed for quality assurance and quality control as well as storage and retrieval.

Figure 1. Schematic of the sampling station on the Upper Great Miami River.

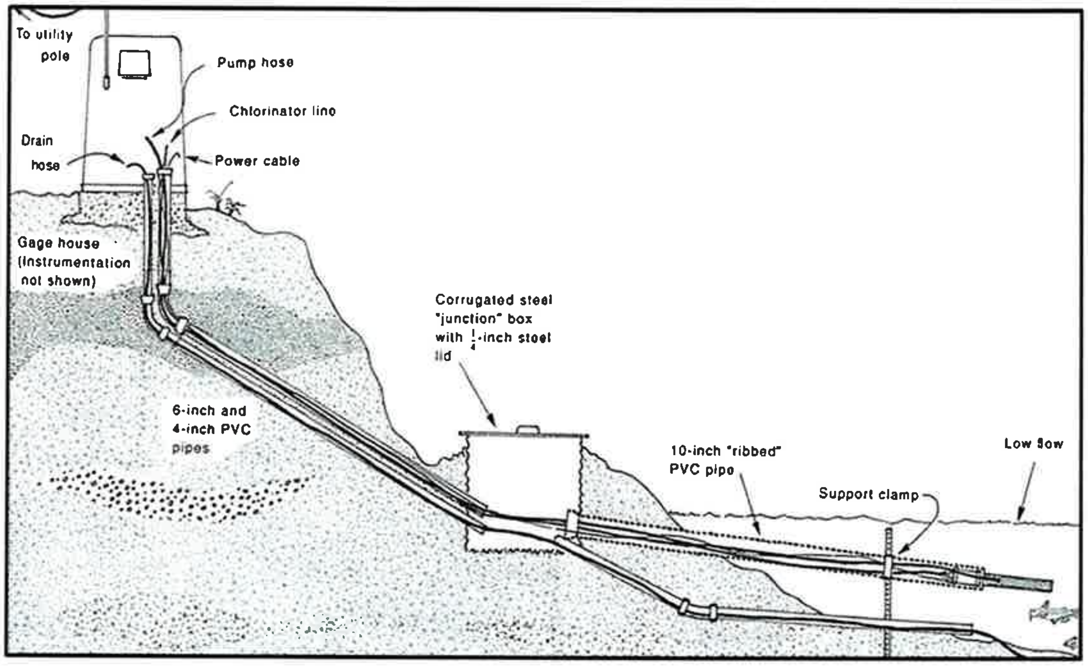


Figure 2. Inside of the shelter for the sampling station showing the flow through tank on the left and refrigerated sampler on the right.

Exploration and Graphics for River Trends (EGRET) Analysis

To analyze time series data, the United States Geological Survey (USGS) software package Exploration and Graphics for River Trends (EGRET) is used for discharge, nitrate – nitrogen (nitrate), and total phosphorus data collected. Nitrate and total phosphorus were selected because Ohio EPA has published nutrient over-enrichment criteria.

During this study, the discharge record for the USGS streamgage at Taylorsville Dam (Great Miami River at Taylorsville OH - 03263000) was used to approximate river flows at the sampling station.

EGRET is an R package for analyzing long-term changes in streamflow statistics (high flow, mean flow, and low flow) as well as changes in water quality (Hirsch, Moyer, and Archer, 2010) and (Hirsch and De Cicco, 2015). For analysis of trends in streamflow, EGRET uses a method based on locally weighted scatterplot smoothing (lowess). The method produces graphical curves through data points that show patterns of change over time spans of a decade or more.

For analysis of water quality data, EGRET uses weighted regressions on time, discharge, and season. The weighted regressions describe long-term changes in concentration and the mass of a chemical constituent flowing through a system or flux.

Flow History Analysis

The streamflow record for the Great Miami River at Taylorsville (Taylorsville) streamgage was analyzed for the period of 1922 – 2024 (see figure 4). Lowess curves for the maximum, mean, and median daily flows as well as the 7-day minimum flow are shown in figure 5. The curves in the plots all show increasing trends for streamflow across the entire range of flows. The curves tend to have relatively flat slopes showing neither an upward nor downward trend in flow up to the year 1960. After 1960, all the curves show a positive slope or increasing trend in flow through the year 2000. The curves for the median daily and 7-day minimum flatten out after 2000 while the curves for the maximum and mean daily flows continue to increase.

EGRET analysis of the long-term flow record for the Upper Great Miami River suggests that flows have increased over time and the increases could impact water quality. For example, higher flows could in some cases result in dilution of nutrients originating from point sources. Higher flows could also cause increased streambank erosion resulting in higher concentrations of nutrients bound to sediment particles.

Water Quality Analysis

The time series data was analyzed for nitrate and total phosphorus using a weighted regression model. The time series data spanned the period of 2007 through 2024. Flow data from the Great Miami River at Taylorsville streamgage was paired with the water quality data for analysis of chemical flux. Flow duration statistics for the period of analysis are summarized in the following table.

Percentile	**Discharge** (m^3/sec)
5th	3
10th	4
25th	6
50th	16
75th	39
90th	96
95th	165
Max	719

Nitrate

Time series data for nitrate consists of 2,603 samples collected between June 19, 2007, and October 21, 2024. Figure 6 shows plots of how nitrate concentrations in the dataset vary with flow, time, and by month. In general, the highest nitrate concentrations measured in samples tended to occur at higher river flows. The months of December, January, and March had the highest median nitrate concentrations while the months of August and September had the lowest median concentrations. Finally, the range of flows for days on which samples were collected closely matches the range of flows for all the days in the analysis period. This indicates the samples are representative of all flow conditions that occurred during the period of interest.

Time, flow, and seasonal weighted regression analysis of the nitrate time series data shows annual, and flow normalized mean concentrations lack much of a trend over the period of analysis. Flow normalized mean concentrations started out at approximately 2.8 mg/L in 2008 and decreased to approximately 2.6 mg/L by 2024 (see Figure 7). Annual mean concentrations for nitrate tended to fluctuate between 3.0 and 2.5 mg/L.

To more fully characterize how changes in nitrate concentrations measured in water samples may have occurred EGRET generates contour plots with discharge range on the vertical axis and time on the horizontal axis (see Figure 8). The pair of black lined curves superimposed on the plot show the 5th and 95th percentile flows (low and high flow) for the Taylorsville streamgage. These curves have a period of 1 year and represent seasonal variations in the 5th and 95th percentile flows. The stacked vertical legend on the right-hand side of the plot shows the color palette corresponding to different contour levels for concentrations of nitrate. The period of the plot is 2008 to 2022, spanning almost the entire sample record. The plot shows a consistent pattern in contours from 2008 through 2022 indicating a lack of significant changes in nitrate concentrations with time, flow, and season. The highest nitrate concentrations occur at flows above 50 m^3/sec. The purple contours showing the highest nitrate concentrations seem to increase in size at flows above 200 m^3/sec for the period of 2014 – 2018 but then decrease in size after 2018. There does not appear to be much change in nitrate concentrations for flows below 50 m^3/sec.

The final step in the weighted regression analysis is to use the weighted regression model to estimate nitrate concentrations that one would expect to occur for low flow, intermediate flow, and high flow centered on June 1 (see Figure 9). June 1 was selected because it is a time of year when nitrate concentrations measured in water samples tend to be high during runoff events. The different flows used in this analysis were 5, 15, and 165 cubic meters per second, corresponding with approximately the 20^{th}, 50^{th}, and 95^{th} flow percentiles. The analysis shows the greatest change in nitrate concentrations for high flows (165 cubic meters per second). For example, the expected nitrate concentration on June 1, 2008, for a high flow (green line) is around 4.6 mg/L. In comparison the expected nitrate concentration for the same flow on June 1, 2023, decreases to about 4 mg/L. There are no significant changes in nitrate concentrations for intermediate and low flows for the period of analysis.

According to Ohio EPA, nitrate concentrations above 1.5 mg/L in large rivers designated as exceptional warmwater habitat (EWH) are excessive and have the potential to cause over-enrichment (Ohio EPA, 1999). The Upper Great Miami River is designated by Ohio EPA as meeting Exceptional Warmwater Habitat standards, and the watershed size classifies the Upper Great Miami as a "large river". Mean and flow normalized mean nitrate concentrations from the weighted regression model exceeded 1.5 mg/L throughout the period of analysis.

Total Phosphorus

Time series data for total phosphorus consisted of 2,634 samples collected between June 19, 2007, and October 21, 2024. Figure 10 shows plots of how total phosphorus concentrations vary with flow, time, and by month. In general, total phosphorus concentrations tend to increase at the low and high flow extremes. The months of August and September had the highest median total phosphorus concentrations while the months of January, February, March, and April had the lowest median concentrations. The range of flows for days on which samples were collected closely matches the range of flows for all the days in the analysis period. This indicates the samples are representative of all flow conditions that occurred during the period of interest.

Time, flow, and seasonal weighted regression analysis of the total phosphorus time series data shows that annual mean and annual flow normalized concentrations decreased from around 0.3 mg/L in 2008 to 0.25 mg/L in 2017. After 2017, annual mean and flow normalized total phosphorus concentrations increased to about 0.35 mg/L in 2024. Overall, the weighted regression analysis showed little net change in total phosphorus concentrations from 2008 through 2024 (see Figure 11).

To more fully characterize total phosphorus concentration variations across time, discharge, and season EGRET generated a contour plot like the one generated for nitrate (see Figure 12). The plot shows there was some increase in phosphorus concentrations for low flows but no significant changes in phosphorus concentrations at intermediate and higher flows.

Weighted regression analysis of total phosphorus concentration trends for low, intermediate, and high flows centered on June1 shows an upward trend for low flows (see Figure 13). Total phosphorus concentrations remained constant across time for intermediate flows. However, there was a significant decrease in total phosphorus concentrations at higher flows. The expected concentration of total phosphorus on June 1, 2008 at a flow of 165 cubic meters per second is approximately 0.55 mg/L according to the weighted regression model. However, by June 1, 2024 the concentration decreased to 0.40 mg/L for the same flow conditions.

According to Ohio EPA, total phosphorus concentrations above 0.13 mg/L in large rivers are excessive and have the potential to cause over-enrichment (Ohio EPA, 2023). Mean and flow normalized mean total phosphorus concentrations from the weighted regression model exceeded 0.13 mg/L throughout the period of analysis.

Conclusions

The Miami Conservancy District's long-term monitoring of the Upper Great Miami River has yielded several important insights into nutrient trends and their implications for regional water quality:

- **Streamflow has increased over time.**
  Since 1960, high, median, and low flows at the Taylorsville USGS streamgage have all shown a steady upward trend. These changes in hydrology may influence nutrient transport and sediment dynamics, with implications for both dilution and erosion.
- **Nitrate concentrations have remained elevated and stable.**
  Weighted regression analysis shows that nitrate concentrations have remained relatively consistent between 2007 and 2024, with only a slight decline at high flows. Mean concentrations consistently exceed Ohio EPA's 1.5 mg/L threshold for over-enrichment in large rivers, suggesting persistent nutrient loading and the potential for biological impacts.
- **Total phosphorus concentrations show a mixed trend.**
  Total phosphorus concentrations declined through 2017 but increased thereafter, especially during low-flow periods. Despite some improvements at high flows, overall

concentrations remain well above Ohio EPA's benchmark of 0.13 mg/L, indicating ongoing enrichment.

- **Nutrient levels remain a concern for aquatic health.**
  Both nitrate and total phosphorus levels in the Upper Great Miami River consistently exceed thresholds associated with ecological impairment. These elevated concentrations are likely contributing to observed water quality challenges in the watershed and downstream—potentially fueling algal blooms, reducing dissolved oxygen, and contributing to hypoxia in the Gulf of Mexico.
- **Long-term data is essential to guide nutrient management.**
  This 18-year dataset demonstrates the value of continuous, high-quality monitoring for understanding nutrient dynamics and evaluating the impact of land use and watershed management practices over time.

References

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Figure 4. Map showing the locations of the sampling station and USGS streamgage in relation to the Upper Great Miami River Watershed.

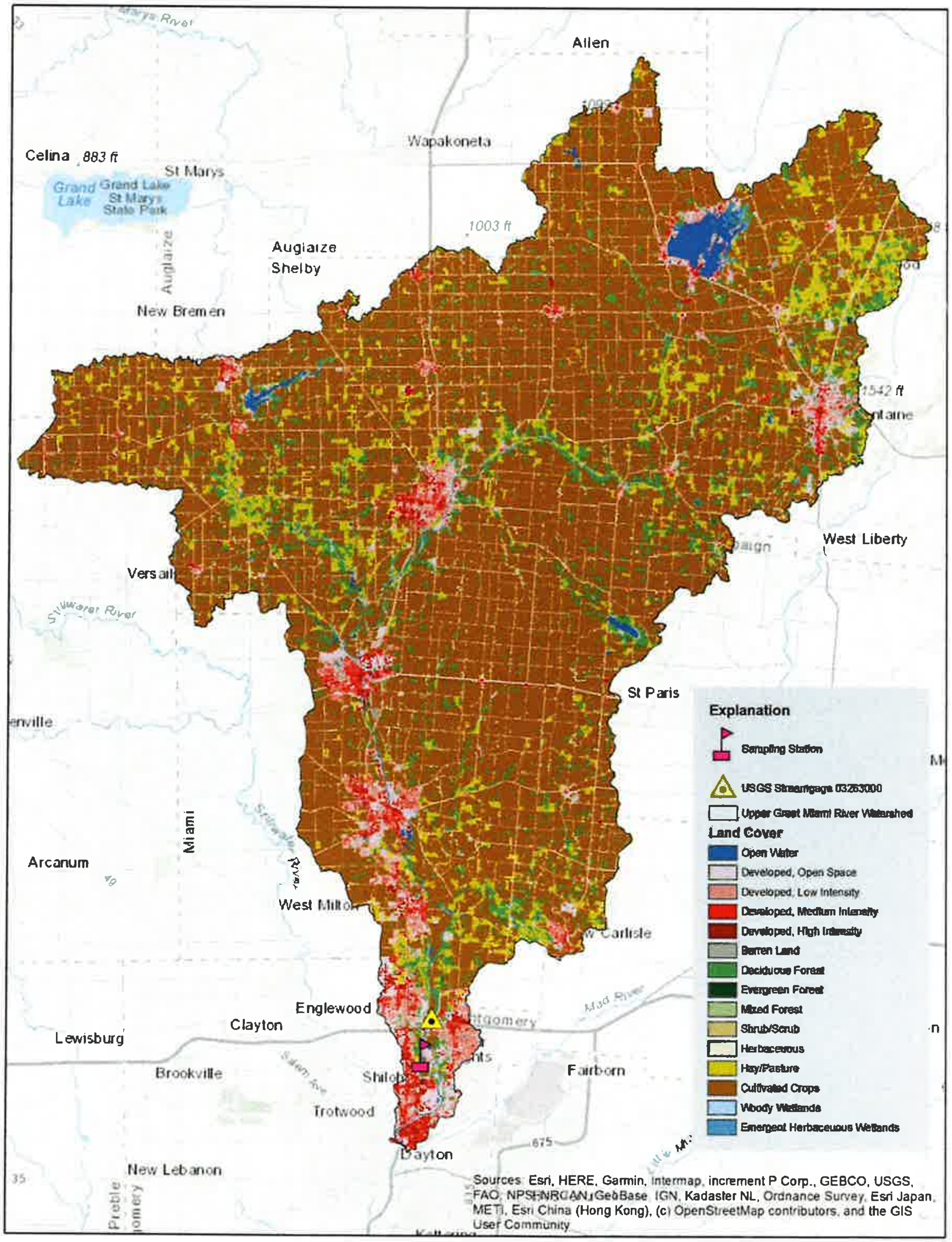


Figure 5. Plots showing changes in maximum, mean, and median daily flows as well as 7-day minimum flow for the Upper Great Miami River.

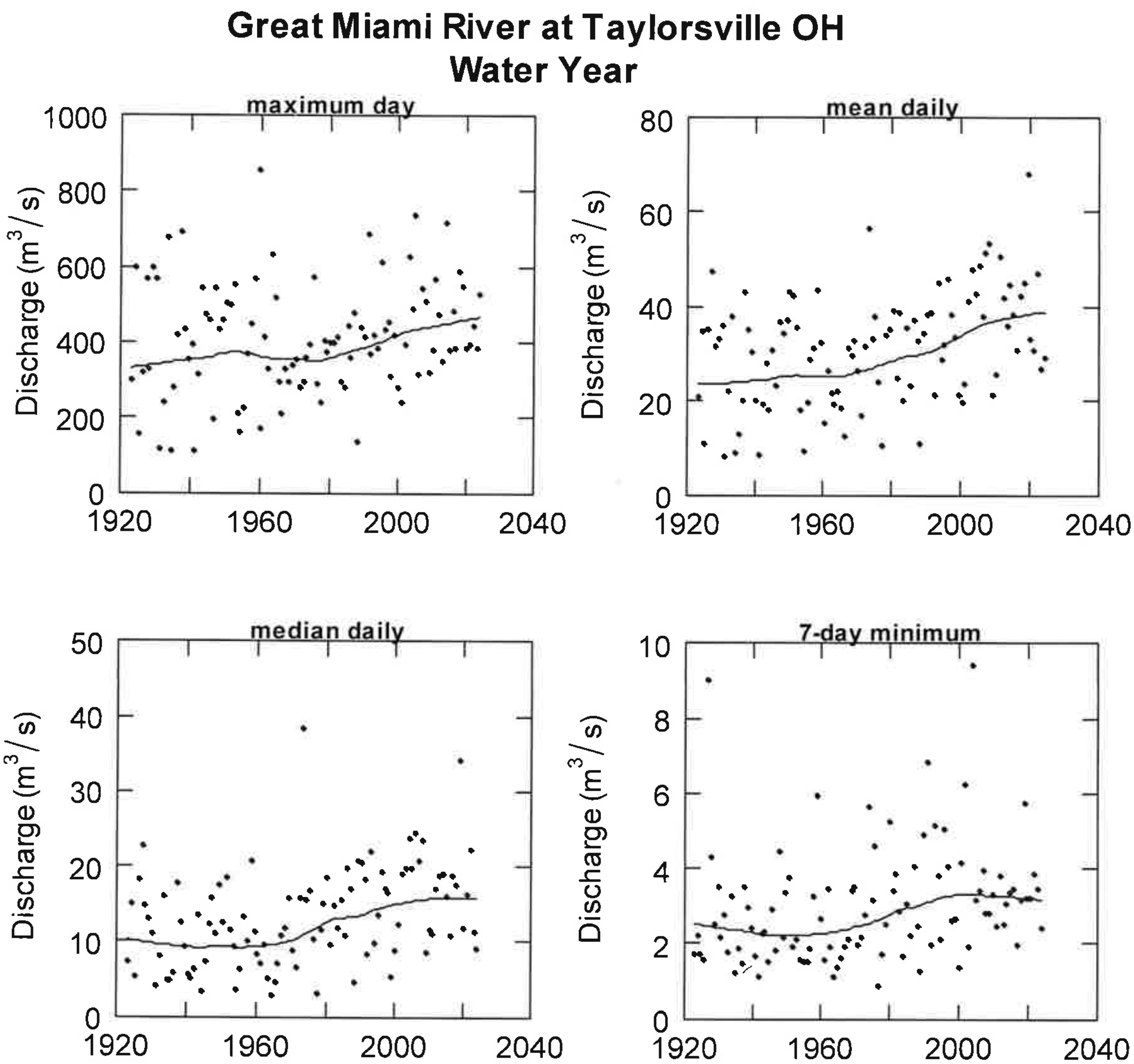


Figure 6 Plots showing how nitrate concentrations vary by discharge, with time, and by month. The plot in the lower right-hand corner shows the range of flows for which samples were collected in comparison to all flows for the period of analysis.

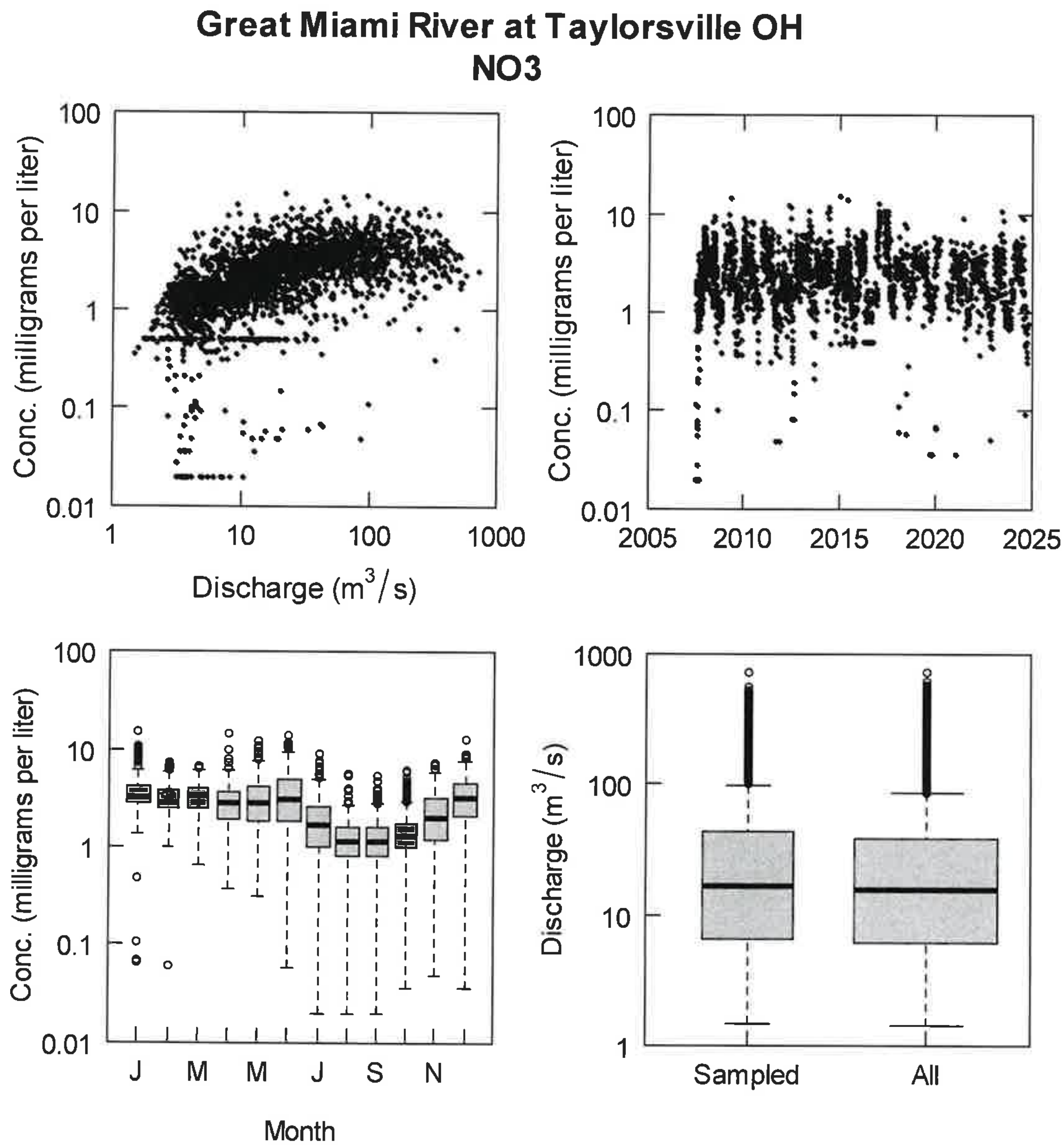


Figure 7 Plot showing annual average concentrations (dots) and the annual flow-normalized concentration (green line) computed from the weighted regression analysis.

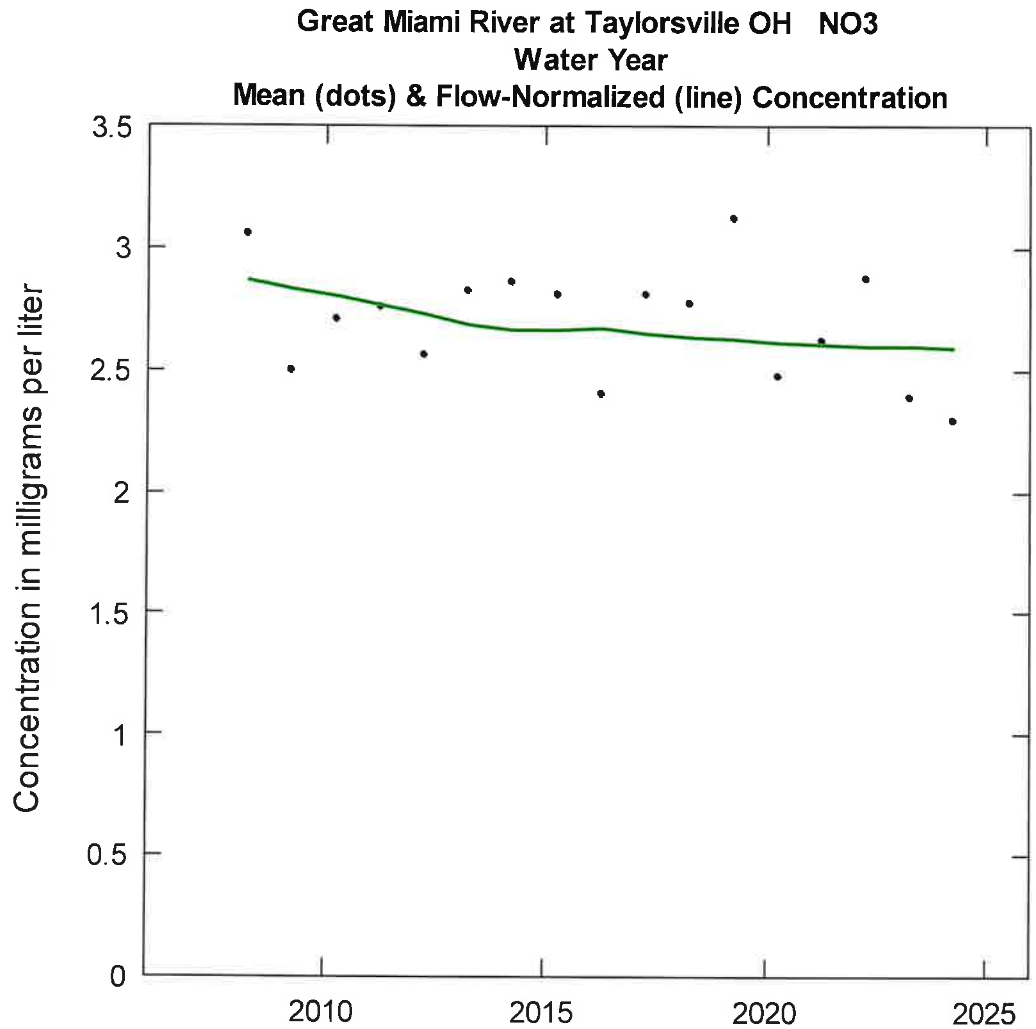


Figure 8. Contour plot showing changes in concentration of nitrate as a function of time, discharge, and season.

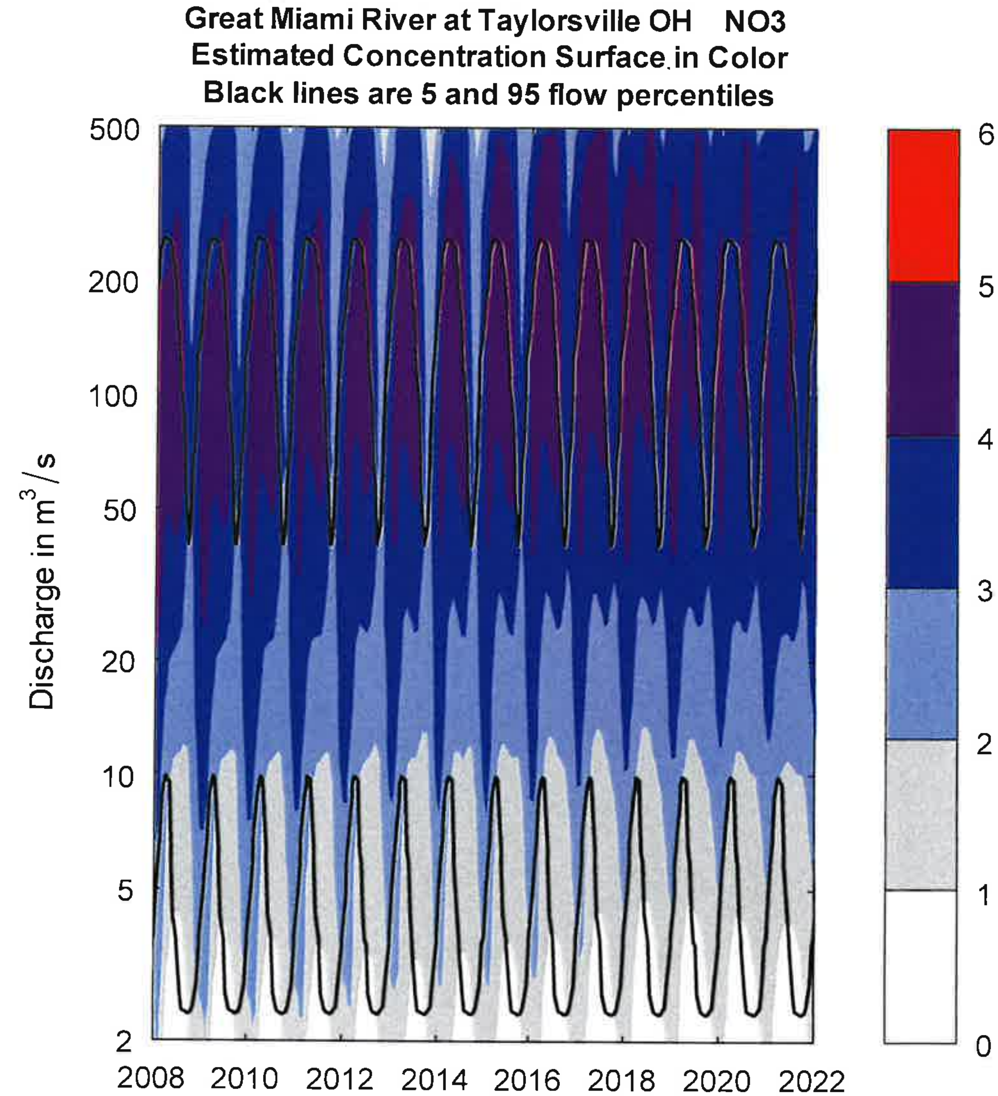


Figure 9. Plot showing the weighted regression model estimated concentration of nitrate for three different flows (low, median, and high) over time. The plot is centered on June 1.

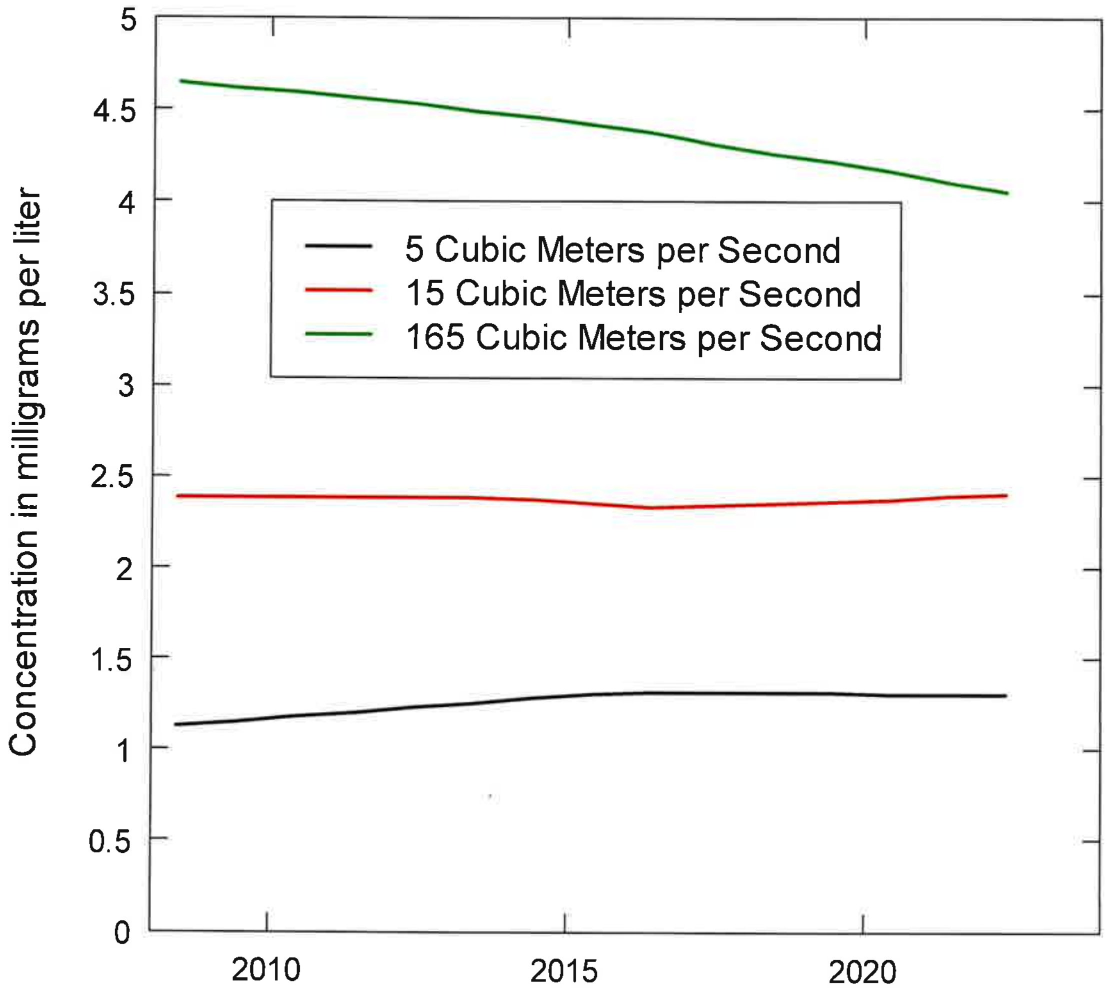


Figure 10. Plots showing how total phosphorus concentrations vary by discharge, with time, and by month. The plot in the lower right-hand corner shows the range of flows for which samples were collected in comparison to all flows for the period of analysis.

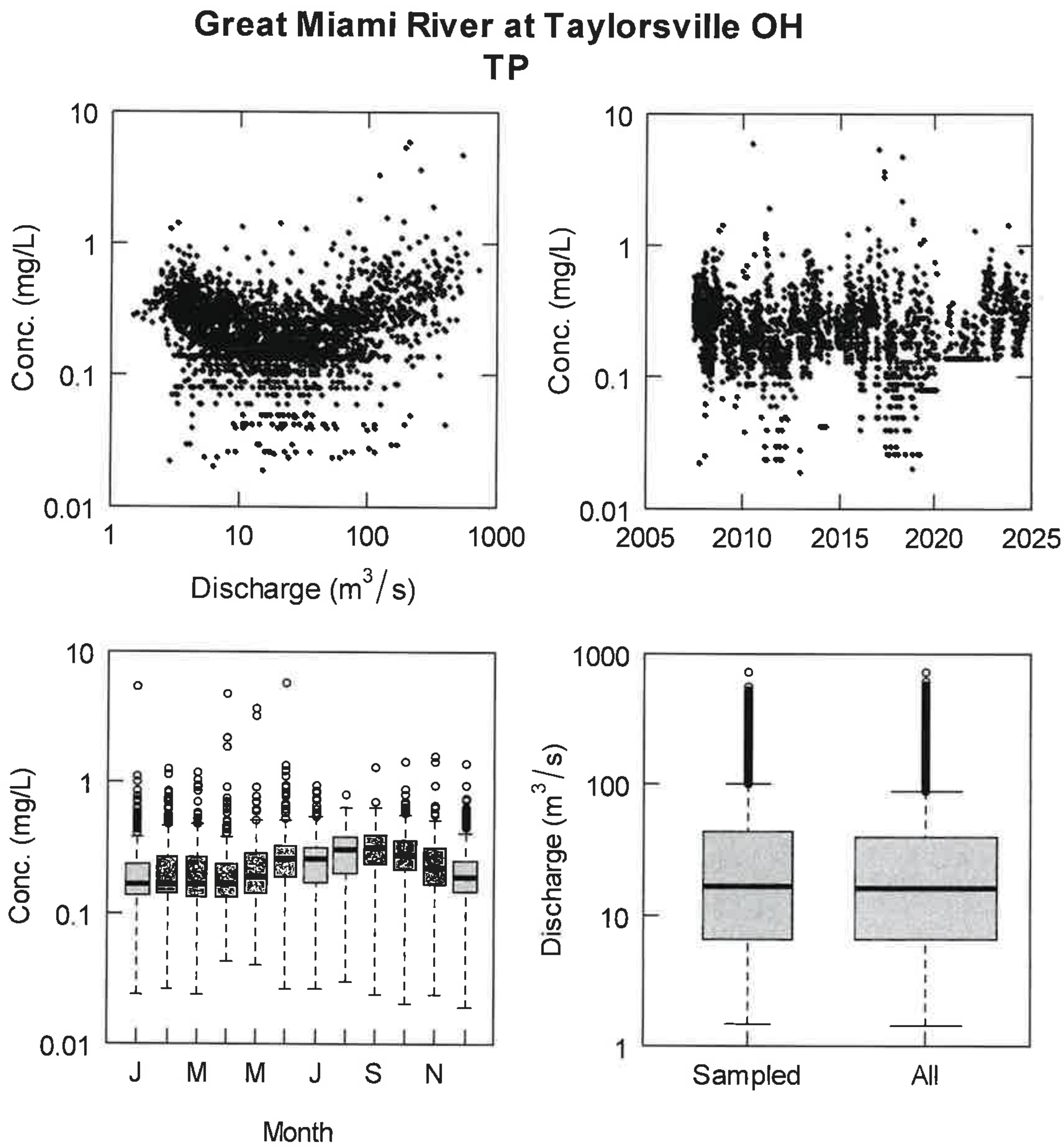


Figure 31. Plot showing annual average concentrations (dots) and the annual flow-normalized concentration (green line) computed from the weighted regression analysis

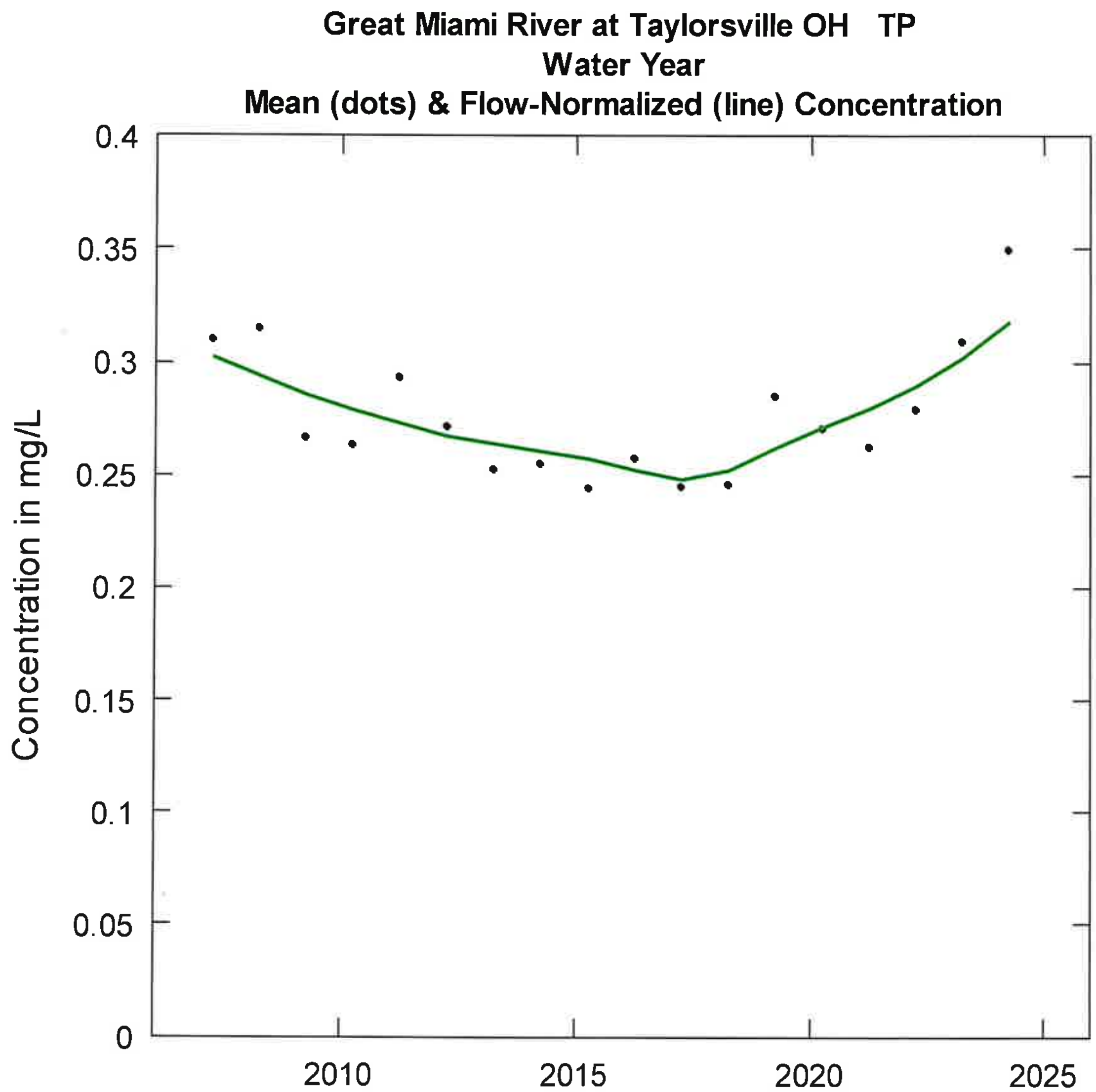


Figure 42. Contour plot showing changes in concentration of total phosphorus as a function of time, discharge, and season.

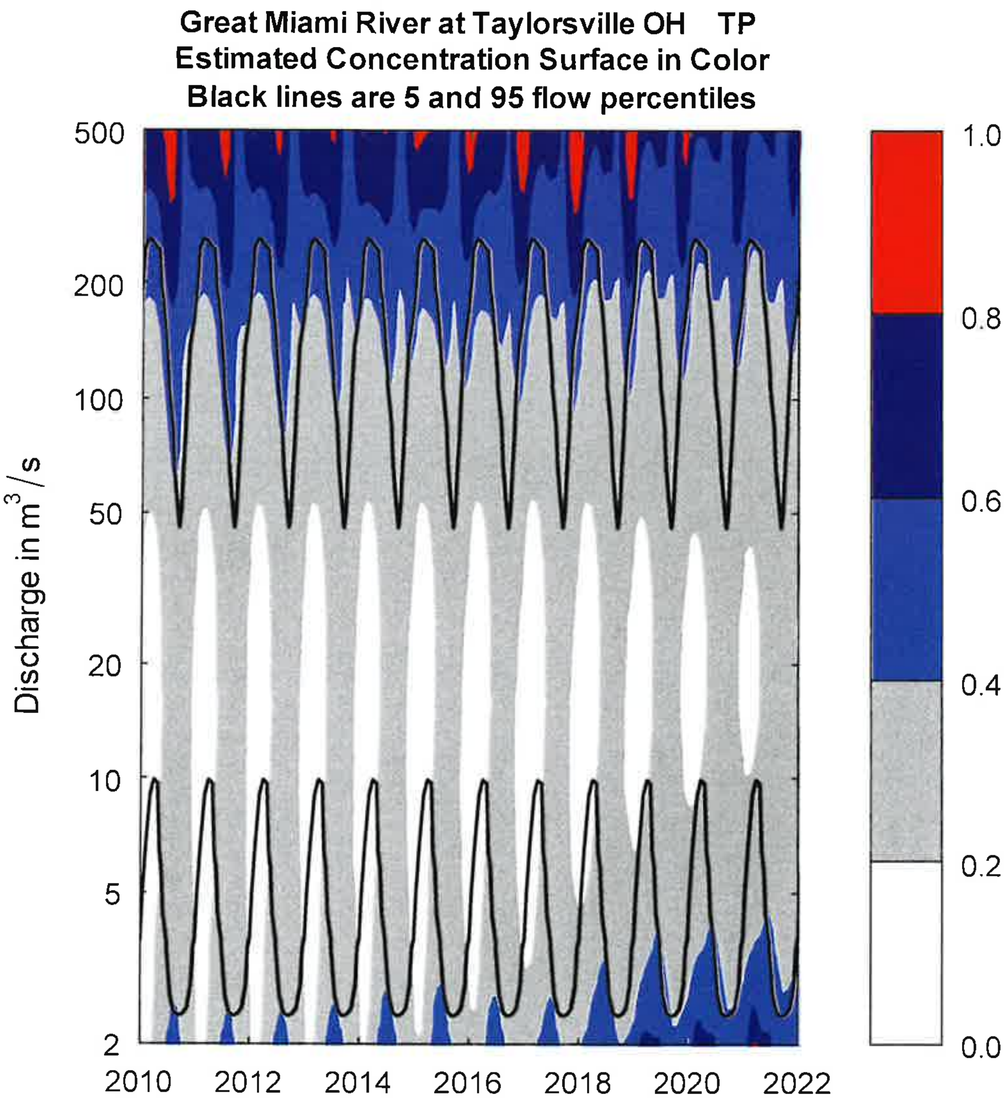
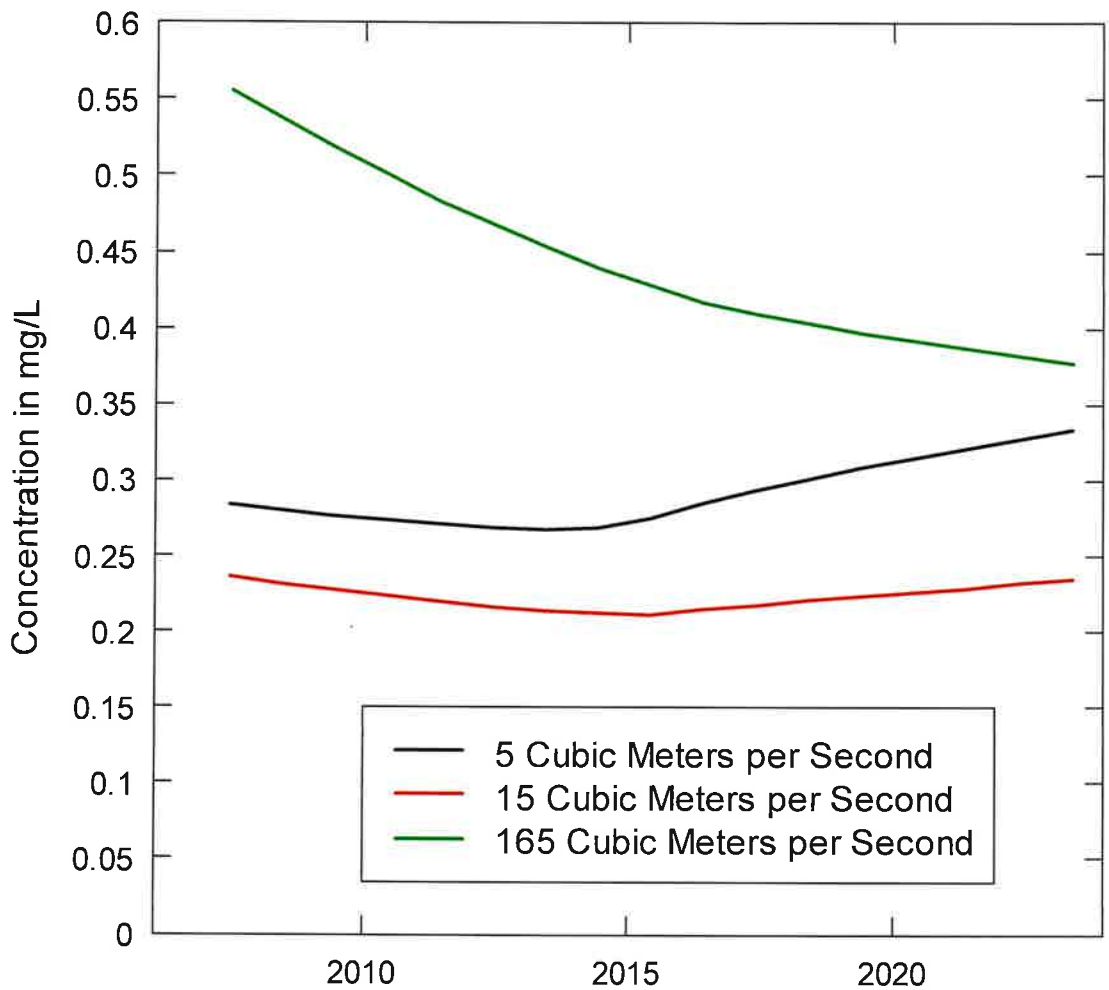


Figure 53. Plot showing the weighted regression model estimated concentration of total phosphorus for three different flows (low, median, and high) over time. The plot is centered on June 1.



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