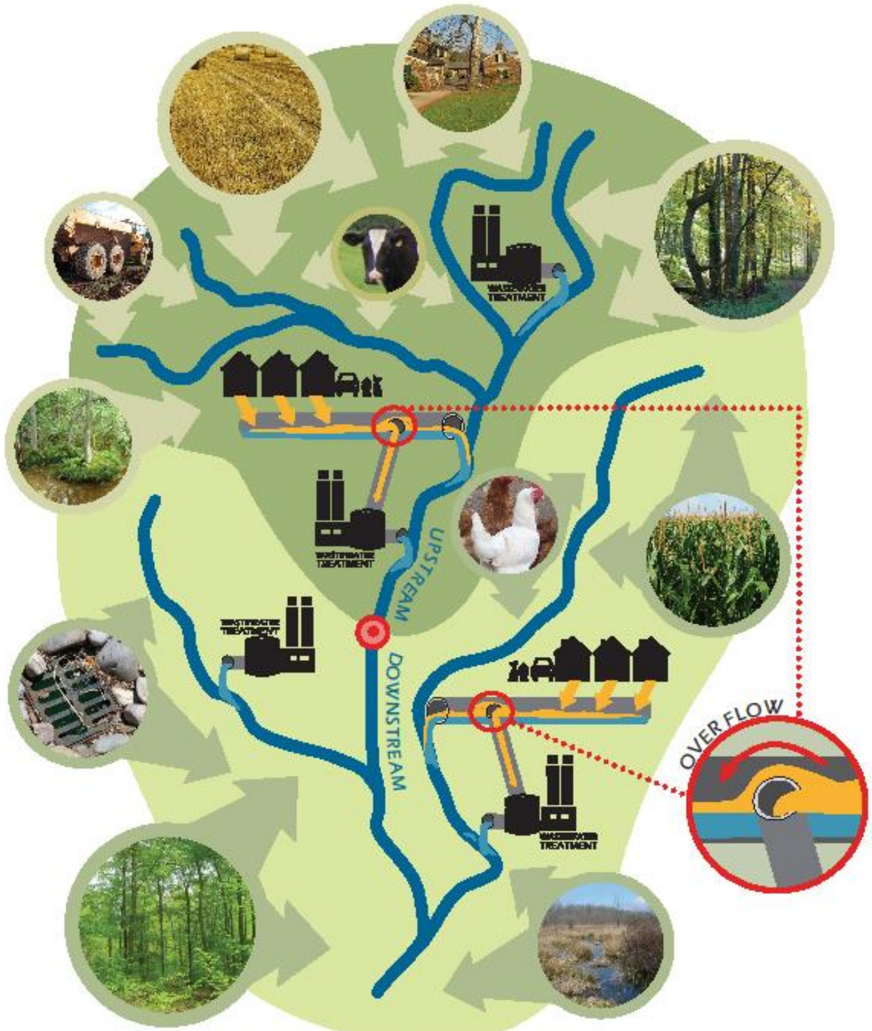
Nutrient Mass Balance Study for Ohio's Major Rivers 2024



Division of Surface Water
Modeling and Assessment Section
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Executive Summary

This study analyzes annual total nitrogen (N) and total phosphorus (P) loads by watersheds across Ohio. By summarizing these loads, Ohio EPA can identify excess nutrient sources and prioritize resources for reduction efforts. This research and other studies serve as a tool for guiding investments and policy decisions aimed at reducing nutrient loading in the Lake Erie watershed and the Ohio River basin.

The nutrient mass balance study includes the Maumee, Portage, Cedar-Toussaint, Sandusky, Huron, Old Woman Creek, Vermilion, Cuyahoga, Great Miami, Little Miami, Scioto, Hocking, and Muskingum watersheds, covering 72% of Ohio's land area.

This 2024 edition reports loadings and adds water years 2022 and 2023, covering 11 years for most watersheds (water years 2013-2023).

This report classifies nutrient sources into three categories:

1) Point source loads - calculated using detailed self-monitoring data by regulated sources with individual National Pollutant Discharge Elimination System (NPDES) permits
2) Household sewage treatment systems (HSTS) - estimated loads from residential sewage
3) Nonpoint source (NPS) nutrients - originate from various land uses, including urban, agricultural, and natural areas

Water quality monitoring data for the Vermilion River for water years 2022 and 2023 were unavailable at publication. Consequently, updated values for the watershed are not included in this report. Ohio EPA intends to release an addendum once the data becomes available.

Significant state and federal funding is being directed toward nutrient reduction efforts, focusing on both point and nonpoint sources, particularly in the western Lake Erie Basin. Monitoring programs are in place to assess water quality improvements due to these actions. However, a delay is expected in observing load reductions as the impact of legacy nutrient management practices wanes over time.

Important Findings

Key findings include the watersheds with the highest absolute total P and total N loads, the relative contributions of each source, and the watersheds with the highest yield per unit area.

The Maumee and Scioto watersheds had the highest average annual total P loads over the past five water years (2019-2023), with 2,695 and 2,152 metric tons per annum (mta), respectively. Despite draining the largest area, the Muskingum watershed ranked fourth in total P load, averaging 1,461 metric tons per annum, likely due to in-stream reservoirs and a high proportion of natural land cover.

Water year 2019 was extremely wet, leading to maximum total P and N loads in most watersheds studied. The nonpoint source yield for both nutrients was also the highest this year for most watersheds, highlighting the significant role of hydrology in total loads.

Nonpoint sources were the largest contributors to total P loads in the Huron (95%), Sandusky (94%), Portage (91%), and Maumee (90%) watersheds. Note that all of these are within the Lake Erie watershed. In contrast, the Cuyahoga watershed, also in this Lake Erie watershed but with different characteristics, had the lowest nonpoint source contribution of total P at 51%.

The Cuyahoga River basin had the highest NPDES total P load at 41%. The three watersheds with next highest proportion of NPDES total P load were in the Ohio River basin, Great Miami (28%), Scioto (25%), and Muskingum (21%).

Loading from HSTS accounted for an average of 6% of the total P load across examined watersheds, with the highest proportions in the Muskingum (10%) and Cuyahoga (8%) watersheds and the lowest in the Maumee, Portage, and Sandusky watersheds (3%).

Total N patterns of load magnitude are similar to total P. The Maumee watershed had the highest average total N load at 39,064 mta, followed by the Scioto watershed with an average of 24,383 mta.

Regarding total N relative sources, NPDES loads contributed 11-17% of total N load across Ohio River basin watersheds and about 7% in the Lake Erie watershed, excluding the Cuyahoga watershed, which was an outlier at 77%. In the Lake Erie watersheds, excluding the Cuyahoga, nonpoint sources dominated total N with more than 88%, while in Ohio River watersheds with five years of data, nonpoint sources comprised an average of 79% of the total N load.

HSTS contributed an average of 4% to total N across the watersheds, making it most often the smallest load source.

Nonpoint source yields for total P ranged from 0.37 to 1.44 pounds per acre, with the highest yields found in northwest Ohio, where about 80% of the land is used for agriculture. Similar patterns were observed for total N when adjusted for watershed area.

Human waste loads (NPDES + HSTS) were higher in the Ohio River basin, averaging 0.69 pounds per person, compared to 0.37 pounds per person in the Lake Erie basin. This difference is due to stricter phosphorus treatment requirements for major NPDES plants in the Lake Erie watershed. However, there has been a steady decline in total P loads to the Muskingum watershed within the Ohio River basin, attributed to new treatment limits on several major plants since wy13. Total N per capita loads were similar across all watersheds, averaging 6.1 pounds per person.

Future Actions

The next edition (2026) will provide computed loadings for the subsequent two water years (13 years).

Ohio EPA is considering adding new watersheds in the next edition using data from its ambient water quality monitoring program. The nutrient loading calculation method for these watersheds would differ from the existing methods, relying on less frequent samples collected by Ohio EPA rather than more frequent third-party samples. This may introduce greater uncertainty in the loading results, and statistics on these uncertainties will be reported if these methods are used.

Ohio EPA and potential partners are considering reporting water quality trends for monitored watersheds using the USGS' WRTDS methodology (Hirsch and De Cicco, 2015), made possible by USGS' recent workflow publication (Loken et al., 2023).

1 Introduction

This study aims to measure total nitrogen (N) and total phosphorus (P) nutrient loads and annually evaluate the contributions of point and nonpoint sources to Lake Erie and the Ohio River. Excess nutrients promote algal growth, harming the health of aquatic ecosystems.

Load sources originating from all known major contributors (municipal wastewater, industrial wastewater, HSTS, nonpoint sources) were identified to calculate total loads. This report computes loading totals on a water-year[1] basis. Eleven total water years are reported in this edition; 2013 through 2023 (designated herein as wyNN where NN is the water year, e.g., wy18).

Conducting this study has several benefits. Identifying the sources of nutrient loads helps determine the most environmentally beneficial and cost-effective strategies for nutrient reduction. For instance, if nonpoint source nutrients are found to be the primary contributors to total P loads downstream, it would not be practical or efficient to focus efforts on reducing point source nutrients.

Additionally, this study supports national and regional goals outlined in the 2012 Great Lakes Water Agreement Annex 4 (Great Lakes Water Quality Agreement, 2015) and the Gulf of Mexico Hypoxia Task Force 2008 Action Plan (U.S. EPA, 2008). Annex 4 specifically targets issues related to nuisance algal blooms and hypoxia in Lake Erie. This study's findings could also assist in managing nuisance algal blooms in the Ohio River and other near field impacts in Ohio.

The Point Source and Urban Runoff Nutrient Workgroup (Ohio EPA, 2012) identified the need to assess Ohio's nutrient sources and loads as part of Ohio EPA's Nutrient Reduction Strategy. In 2015, the Ohio General Assembly mandated a study of the nutrient mass balance under ORC 6111.03 (T).

> The director of environmental protection may do any of the following:
>
> (T) Study, examine, and calculate nutrient loading from point and nonpoint sources in order to determine comparative contributions by those sources and to utilize the information derived from those calculations to determine the most environmentally beneficial and cost-effective mechanisms to reduce nutrient loading to watersheds in the Lake Erie basin and the Ohio river basin. In order to evaluate nutrient loading contributions, the director or the director's designee shall conduct a study of the nutrient mass balance for both point and nonpoint sources in watersheds in the Lake Erie basin and the Ohio river basin using available data, including both of the following:
>
> > (1) Data on water quality and stream flow;
> >
> > (2) Data on point source discharges into those watersheds.
>
> The director or the director's designee shall report and update the results of the study to coincide with the release of the Ohio integrated water quality monitoring and assessment report prepared by the director.

[1] A water year (wy) is a 12-month period that starts on Oct. 1 of each year and is named for the year of its September-ending date. The beginning of a water year differs from the calendar year so that precipitation and its associated subsequent runoff are accounted for in the same 12-month period. Late autumn and winter snowfall that may accumulate in the ensuing months will not drain and discharge until the following spring (or summer) snowmelt.

The National Center for Water Quality Research (NCWQR) at Heidelberg University monitors eight major Ohio watersheds daily. The data can be found on their ***monitoring data portal***.

USGS monitors nutrient loading regularly for two watersheds and sub-hourly discharge (streamflow) for all 11 watersheds in this study. USGS streamflow, nutrient concentration, and load data are available through the ***National Water Dashboard***.

The Ohio Department of Natural Resources (ODNR) monitors water quality daily at Old Woman Creek. Results collected by ODNR are available from Ohio EPA upon request.

These data sources are critical in developing a meaningful procedure for a biennial analysis of loading sources. The monitored watersheds include the Maumee River, Portage River, Sandusky River, Huron River, Old Woman Creek, and Cuyahoga River of the Lake Erie tributary system and the Great Miami River, Scioto River, Little Miami River (including the East Fork Little Miami River), Hocking River, and Muskingum River of the Ohio River tributary system.

This report includes a greater proportion of Lake Erie's drainage area than the Ohio River, emphasizing the need to document nutrient contributions to Ohio's waters in support of the Great Lakes Water Quality Agreement. This importance results in two additional Lake Erie watersheds. The area in this report referred to as Cedar Toussaint (Lake Erie) uses nonpoint source loads from adjacent Portage River monitoring. The USGS monitors water quality and flow in the Vermilion River (Lake Erie), but samples are collected less frequently than in the other watersheds, requiring different loading calculation methods.

The 2024 nutrient mass balance study examines nutrient loads from 13 watersheds. Figure 1 shows these watersheds.

A key assumption in assessing nutrient loads is that there is no loss from source to outlet. While some nutrient loss can occur through assimilation into floodplains, substrates, or plant uptake, this assumption is reasonable for evaluating total nutrient quantity, such as total P, over a year. Over longer time intervals, sources and sinks of nutrients generally balance out. However, permanent losses may occur through denitrification or fish harvest. Further research on nutrient processing in streams can be found in works by King et al. (2022), Casillas-Ituarte (2020), Jarvie (2011, 2012, 2013), Marcê (2009), and Withers (2008).

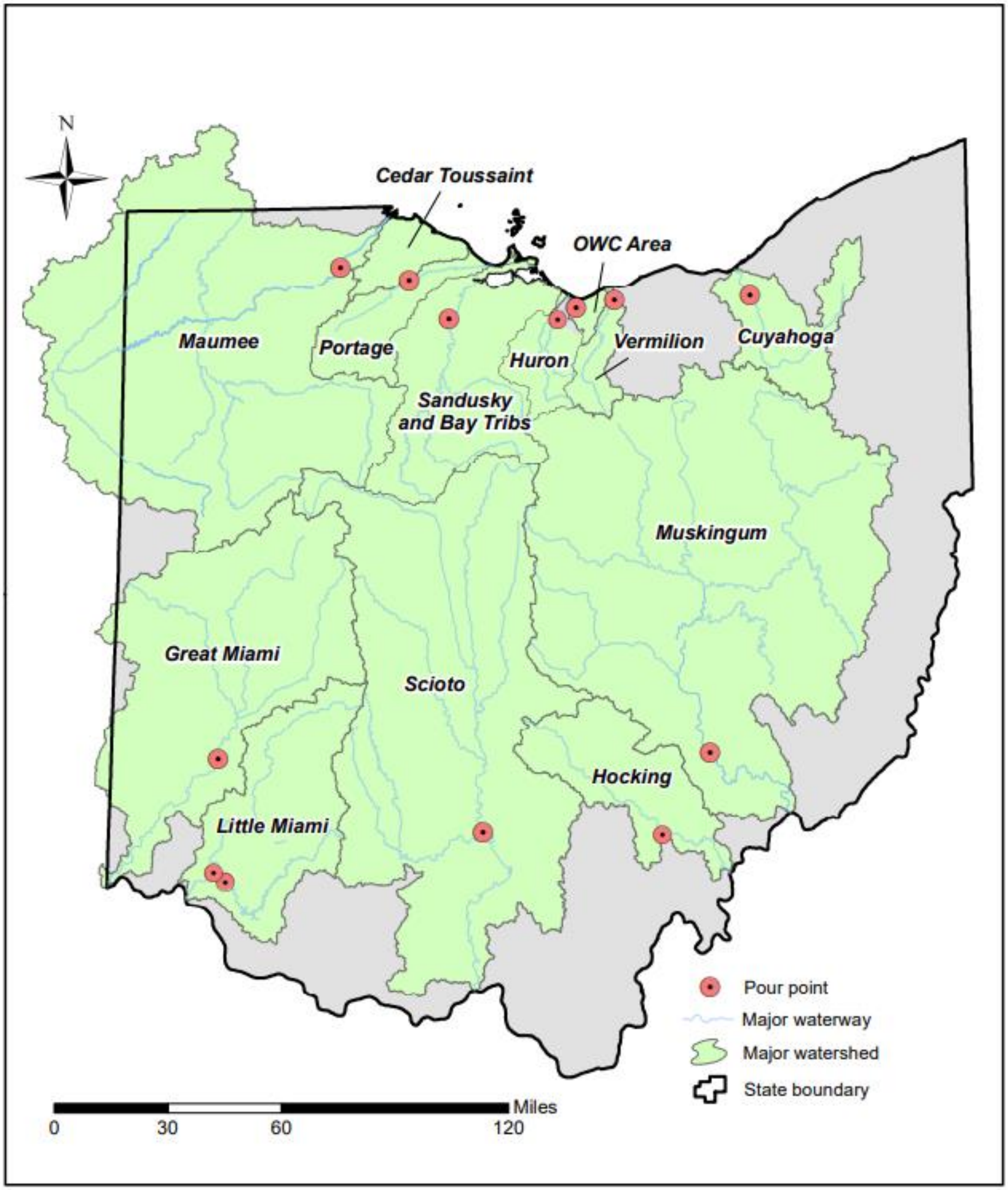


Figure 1 - Map of nutrient mass balance watersheds and associated pour points

2 Methods

2.1 Overall Loading Calculation

The mass balance equation used to calculate watershed loading is presented as Equation 1 below.

$$Total\ Load = NPDES + HSTS + NPS_{upst} + NPS_{dst}\ (1)$$

The load discharged by entities with NPDES permits, which are within the regulatory authority of Ohio EPA, is represented as the point source load (named NPDES) in Equation 1. HSTS contributions are estimated separately. The NPS loads are separated into two categories: nonpoint source calculated upstream from the monitoring point (NPS_{upst}) and nonpoint source calculated downstream of the monitoring point (NPS_{dst}). The timing, location, duration, and amounts of precipitation, especially rainfall, are important variables influencing stream discharges that affect source loads, especially from nonpoint sources. However, point sources may also be affected. These variables are discussed in Section 3.1, subsection Relationship of Annual Water Yield to Annual Load.

2.2 Point Source Loading

The NPDES program requires permittees to report operational data to Ohio EPA via discharge monitoring reports (DMR). All facilities are required to report flow volume. To varying degrees, nutrient concentrations are also monitored and reported. This depends on factors such as the reasonable potential of elevated concentrations and facility size. Because reporting varies across facilities, a flexible method is needed to estimate loads and accommodate for missing data.

Equation 2 estimates the generic loading from an NPDES-permitted facility.

$$Annual\ Load = Q(in\ MG) * [Nutrient] * cf\ (2)$$

In Equation 2, Q represents a facility’s flow volume in million gallons (MG). The conversion factor (cf) term, equal to 3.78451, is a conversion factor used to convert MG and nutrient concentration from milligrams per liter into kilograms per day.

To estimate the nutrient concentration, denoted [Nutrient], in Equation 2, each facility is categorized into one of four groups based on the type of plant and nutrient monitoring data available. The groups and methods for calculating nutrient concentrations include:

1) Industrial facilities reporting nutrient concentrations – utilize the median concentration of nutrients reported during the calculation period.
2) Industrial facilities not reporting nutrient concentrations – assume a *de minimis* nutrient concentration set to 0.
3) Sewage treatment facilities reporting nutrient concentrations – apply the median nutrient concentration from the calculation period.
4) Sewage treatment facilities not reporting nutrient concentrations – use the median nutrient concentration from similar facilities.

In this document, sewage treatment facilities are referred to as municipal. Nutrient concentrations are estimated for three size classes of municipal effluent, as defined in Table 1. It’s important to note that the 2016 edition had five size classes for municipal effluent; however, the three-size class breakdown presented here is more aligned with Ohio EPA's management of its NPDES program.

Table 1 - Facility classes by design flow

Group	Type	Design Flow (million gallons per day)
Industrials	All Industrial Permits	--
Major Municipal	Sewage Treatment	≥ 1.0
Minor Municipal	Sewage Treatment	0.1 to 1.0
Package Plant	Sewage Treatment	< 0.1

Nutrient loads in this report are estimated as total P and total N. Facilities with phosphorus monitoring typically report total P, which can be used directly for loading estimates. Of note, all major municipal facilities have monitoring requirements for total P. However, estimates are needed for ammonia, nitrite + nitrate, and organic N to determine total N. Most facilities, however, are only required to report ammonia and nitrite + nitrate, with limited data available for organic N. In the approach used here, organic N is estimated as the difference between Total Kjeldahl Nitrogen (TKN) and ammonia. A statewide analysis of paired TKN and ammonia samples from NPDES sewage treatment facilities from wy11 – wy15 (9,110 samples) was performed to estimate organic N. This analysis found similar results despite different sized facilities. Therefore, the median of the statewide dataset of 1.37 mg/L is used for an organic N estimate for all sewage treatment facilities.

Wet-weather events often result in increased wastewater flows within collection networks, either by design in combined sewer communities or as increased flows to sanitary sewers through inflow and infiltration (I&I). The result of increased flows is reduced treatment at the plant (usually a bypass of secondary treatment), wastewater bypasses at the plant headworks (raw bypasses), overflows of combined sewers (CSOs), and overflows of sanitary sewers (SSOs).

Loads are estimated at NPDES facilities reporting discharge for these wet-weather events at assigned stations. This report uses a wet-weather loading nutrient concentration of 0.73 mg/L for total P, the median concentration of 131 samples reported from September 2014 to August 2017 by two sewer districts that are required to monitor TP at select CSO outfalls in their NPDES permit. For total N, 20 mg/L was used at stations designated as SSOs, CSOs, and raw bypasses (U.S. Environmental Protection Agency, 2004; Tchobanoglous et al., 2003). For bypasses that pass through primary treatment, 15% removal is assumed to account for settling and sludge removal. For those that pass through secondary treatment, 40% removal is assumed. These removal rates are applied to the concentrations listed above in this paragraph to calculate these loads. Note that SSOs are only included in these calculations when overflow volume is reported.

One watershed analyzed in the mass balance study, the Maumee, has NPDES sources contributing to it from outside Ohio. Data on monthly loads is available from the Integrated Compliance Information System (ICIS) maintained by U.S. EPA. These monthly loads are summed for each facility within the watershed and are reported as out-of-state (OOS) NPDES loads. Facilities identified as controlled dischargers are excluded from the OOS analysis because the data maintained in ICIS is an average of discharge on days a discharge occurred. There is no associated count of days that discharge occurred. This OOS load contains a CSO load estimate where the overflow volumes are reported, and combined sewer systems were assumed to have the same concentration as those within Ohio.

2.3 HSTS Loads

The population served by HSTS was updated in the 2022 iteration of the nutrient mass balance report via the geospatial reporting tool GIS. For this analysis, dasymetric mapping and raster data were utilized. The dasymetric system uses quantitative aerial data and creates boundaries that divide the mapped areas into zones of relative sameness (for example water features or forested area). This tool is helpful when calculating populations and performing land use analysis. To estimate HSTS populations, a dasymetric density raster based on U.S. Census block data from 2020 was created to estimate the watershed area populations. An overlay of potentially sewered areas for Ohio was then created, based on sewered areas provided by areawide agencies, census place boundaries of municipalities, and incorporated areas with sewer services in areas not covered by areawide or regional agencies. Census place and municipal boundaries were adjusted to best match known sewered areas. The estimation of the population in unsewered areas was then calculated by subtracting the estimate of the sewered area population from the estimate of the total population in each watershed. For additional details on this methodology, see Appendix B of the 2022 edition of this report.

Two watersheds did not use the above method to determine the HSTS population. In the Maumee, the Toledo Metropolitan Area Council of Governments (TMACOG) estimated the HSTS population as part of a Water Quality §604(b) Work Program (TMACOG, 2018). This estimate was used for the Maumee. There is no areawide agency for the Scioto watershed that delineates sewered areas, likely leading to an overestimate of the HSTS population in the Scioto in past versions of this report. For the Scioto, the HSTS population was calculated by subtracting the population served by NPDES wastewater treatment plants from the total census population within the watershed boundary.

The HSTS load is calculated using Equation 3 below.

$$Load_{HSTS} = Pop_{HSTS} * Nut_{Yield} * \left[percentPop_{discharge} * DR_{discharge} + percentPop_{onsite-working} * DR_{onsite-working} + percentPop_{onsite-failed} * DR_{onsite-failed} \right] \quad (3)$$

where,

Pop_{HSTS} = Total population served by HSTS in watershed (persons)

Nut_{Yield} = Annual yield of nutrient per person $\left(\frac{\frac{lb}{year}}{person}\right)$

$percentPop_{discharge}$ = percent of population served by discharging HSTS

$DR_{discharge}$ = nutrient delivery ratio for discharging systems

$percentPop_{onsite-working}$ = percent of population served by onsite working HSTS

$DR_{onsite-working}$ = nutrient delivery ratio for onsite working systems

$percentPop_{onsite-failing}$ = percent of population served by onsite failing HSTS

$DR_{onsite-failing}$ = nutrient delivery ratio for onsite failing systems

A literature review determined the per capita nutrient yield in household wastewater. A study by Lowe and others (2009) reported a median nutrient yield as 0.511 kg-P/capita/year and 3.686 kg-N/capita/year. In a similar effort to this mass balance study, the Minnesota Pollution Control Agency (MPCA) estimated the annual per capita nutrient yield to be 0.8845 kg-P/capita/year and 9.1 kg-N/capita/year (Wilson and Anderson, 2004). The MPCA study used estimated values based on different household water use activities, while the Lowe study reported statistics on data measured on actual systems. The Lowe study median concentrations were used because the methodology uses actual sampling data of septic tank effluents.

Phosphorus delivery ratios for three different system types were also estimated by literature review. One system type is properly operating soil absorption systems. In these systems, wastewater percolates through the soil matrix, where physical, chemical, and biological processes treat pollutants. Phosphorus is usually considered to be effectively removed in these systems. Beal and others (2005) reviewed several studies and reported varied findings suggesting very efficient P removal of up to >99%. In a nutrient balance study, MPCA assumed that HSTS with soil absorption systems removed phosphorus at 80% efficiency (MPCA, 2004). For this study, 80% efficiency will be used because the studies reviewed by Beal used fresh soil columns and did not consider a reduction in efficiency with system age.

Another category of systems included in the mass balance study is soil absorption systems failing to function as designed. A myriad of problems causes failure of systems, so literature values are not available for phosphorus removal. For this mass balance study, the assumption is made that failing systems still involve some level of soil contact; therefore, total P removal will be in between the value of a direct discharge and a soil absorption system. The value used for the mass balance study was 40% total P removal for failing soil adsorption systems, or half that is assumed for properly working systems.

A third group of HSTS is systems designed to discharge directly to a receiving stream. These systems use mechanical treatment processes to treat wastewater and discharge directly to streams. Like septic tanks, they are designed to remove suspended solids, but sludge removal is limited to periodic pumping. Lowe and others (2009) studied septic tank influent and effluent and determined a 6% reduction in total P. This study will use the same 6% reduction observed by Lowe and others (2009).

Nitrogen delivery ratios are different from phosphorus delivery ratios and, like phosphorus, are estimated by literature review. Soil type and flow path affect nitrogen delivery from soil absorption systems. Beal and others (2005) reviewed several studies and reported nitrogen removal from 0 to 80%. This mass balance study uses 40% nitrogen removal in working soil absorption systems. Again, since failing soil absorption systems are considered failing for many reasons, they are not well studied relative to the removal efficiency of different pollutants. However, since soil contact and lateral water movement are still involved, this nutrient mass balance study will use the same, yet moderate, 40% removal efficiency used for working soil absorption systems. As noted above, discharging HSTS are not designed to remove sludge from the system. Instead, they mineralize organic material; therefore, the median total N outflow of septic tanks is not significantly different from the inflow (Lowe, 2009). For this reason, the discharging HSTS will not be considered to provide any reduction of total N in the mass balance study.

The final component needed to estimate HSTS loading is the relative proportion of system types split into three categories: 1) working soil absorption systems, 2) failing soil absorption systems, and 3) systems designed to discharge. The Ohio Department of Health (ODH) is the state agency tasked with regulating household sewage treatment. In 2013, ODH published the results of a survey of county health districts in 2012 as an inventory of existing HSTS in the state by Ohio EPA district (Table 2). The district with the largest area overlap with a watershed is used to determine the relative proportions of different system types.

Table 2 - Proportions of total HSTS systems grouped into categories for nutrient mass balance study

Adapted from the 2012 ODH statewide inventory (ODH, 2013).

Ohio EPA District	Working Soil Adsorption (%)	Failing Soil Adsorption (%)	Discharging (%)
Northwest	41.5	26.5	32
Northeast	44	27	29
Central	42.8	25.2	32
Southwest	64	14	22
Southeast	61.2	10.8	28

2.4 Nonpoint Source Loading

Central to estimating the nonpoint source load is a monitoring point, herein the pour point, where the NCWQR or USGS collect near-continuous data. Data collected at a fine temporal resolution can calculate a very accurate annual load at that location. The nonpoint source load is separated into two categories based on the nonpoint source load upstream of the pour point (NPS_{up}) and downstream of the pour point (NPS_{dn}). Different assumptions were made to estimate the nonpoint source load up and downstream of the pour point. The NPS_{up} is estimated as the residual load at the pour point. The residual load is the difference between the total pour point load and the sum of the NPDES and HSTS loads upstream of the pour point. Conversely, NPS_{dn} is calculated by multiplying the upstream yield (NPS_{up} relative to watershed area) by the downstream area.

There is no pour point for the Cedar Toussaint watershed. The NPS_{up} yield is applied from the adjacent Portage River watershed's pour point load. Also, the Old Woman Creek area watershed's pour point monitoring is expanded to other adjacent Lake Erie frontal zones.

It was important to separate the two types of nonpoint source loads (NPS_{up} and NPS_{dn}) because the load downstream is estimated with the assumption of having the same areal yield as the upstream load. Yield equivalency is a less precise assumption than mass conservation (discussed below). Watersheds with a larger proportion of drainage area downstream from the pour point are subject to more influence from the assumption of yield equivalency. Excluding the Cedar Toussaint and Old Woman Creek watersheds, the percent of total area downstream of the pour point, from highest to lowest, for the watersheds is: Scioto (41); Sandusky (31); Great Miami (30); Portage (27); Hocking (21); Cuyahoga (13); Huron (9); Muskingum (8); Little Miami (4); Maumee (4); and Vermilion (2). In the Old Woman Creek area watershed included in this report, 75% of the area is either downstream of the pour point or in a different adjacent frontal Lake Erie watershed. Therefore, the nonpoint source load calculation is less precise for some watersheds versus others. Deviations in the yield assumption are compounded when the land use distribution between the up and downstream of the pour point is considerably different (e.g., the Maumee).

A key assumption of the mass balance method is conservation of nutrient mass being transported through the watershed. Consequently, the nonpoint source load includes both nonpoint sources and sinks of nutrients. Nutrient sources included within the nonpoint source estimate include: agricultural sources; stormwater runoff from developed lands; MS4 (municipal separate storm sewer system) areas; mining activities; natural sources and others. Nutrient sinks could include: wetlands (total P and total N); biomass – both terrestrial and aquatic (total P and total N); sedimentation (total P); atmospheric losses (total N); and others. Some nutrients assimilated within nonpoint sinks are undoubtedly from point sources or HSTS. Because the point source and HSTS terms in Equation 1 are computed directly at their source and no assimilation is considered, the mass balance method will overestimate the annual delivery of the load from these sources.

2.5 Pour Point Load Estimation

Monitoring loads for wy13 to wy23, except for the Vermilion River watershed, were provided to Ohio EPA by NCWQR or USGS. Old Woman Creek data is collected by ODNR and calculated by NCWQR. The COVID-19 pandemic affected monitoring resources in 2020, and gaps were filled using LoadFlex or manual interpolation by NCWQR.

The Vermilion River is monitored less frequently, with monthly samples collected by USGS. Loads from wy13 to wy19 were estimated using a regression-based method (LOADEST, Runkel et al., 2004), while loads from wy20 to wy23 were calculated using the WRTDS tool (Hirsch and De Cicco, 2015). Water quality data for wy22 and wy23 for the Vermilion are unavailable for this report, but Ohio EPA intends to publish an addendum when data is accessible.

2.6 Contributing Populations

This report defines the contributing population as the source population for nutrient loading to a watershed. This value varies from the total population living within a watershed's boundary, as many wastewater treatment plants serve populations outside of the watershed where the plant discharges. It is important to differentiate when calculating per capita load as it relates to load calculations and sourcing.

A new methodology was developed and utilized to increase the accuracy of contributing population data for the 2022 report. Originally, for this report's 2016 – 2020 iterations, spatial analysis in GIS was conducted to assign sewered populations on watershed divides to the watershed where the wastewater treatment plant discharged. In the 2022 report and this 2024 edition, the total contributing population for each watershed is calculated as the summation of the HSTS populations (as described in Section 2.3) and population served by the watershed's wastewater treatment plants. The latter value is available because NPDES permit applications require wastewater treatment plants to report the population served. A study conducted by the Toledo Metropolitan Area Council of Governments (TMACOG) in 2018 specifying HSTS breakdowns was utilized specifically for the Maumee watershed (TMACOG, 2018).

3 Results and Discussion

3.1 Statewide Analysis

The five most recent water years' average total P loading is presented as total load grouped by the major source on Figure 2. Average nonpoint source and per capita yields are shown on Figure 3. The LMR/EFLMR and Hocking River basin results are not presented in Figure 2 and Figure 3 because five years of data are unavailable for these watersheds. Additionally, the Vermilion is not part of this statewide analysis due to the unavailability of loading data for wy22 and wy23. The tabular results used to create Figure 2 and Figure 3 are in Appendix A – Summary Tables for Mass Balance Calculations.

The source categories are nonpoint source, total NPDES, and HSTS. Nutrient yields are reported to standardize the load by watershed area and human population count. The yield indicates the intensity of the load. The annual nonpoint source yield is calculated by dividing the annual nonpoint source load by the watershed area, both assessed at the pour point. For per capita yield, the sum of NPDES and HSTS loads is divided by the total human population contributing waste in the watershed, calculated at the watershed outlet. The per capita yield reflects the human sewage-sourced nutrient load and, for the NPDES portion of the load, includes all populations residing in each facility's service (collection) area. The total N loads and yields are presented similarly (Figure 4 and Figure 5).

Sections 3.2-3.14 contain more detailed discussion of relative differences *within* each watershed. The following discussion focuses on differences in total and relative load *among* the watersheds throughout the state concerning watershed area, annual water yield, nonpoint source nutrient yield, per capita nutrient yield, and population density.

Watershed Area

Larger watershed areas can produce greater absolute nonpoint source loads (see Figures 2 and 4). Therefore, it is essential to consider watershed area when comparing watersheds of different sizes. For instance, although the Maumee and Portage watersheds exhibit similar land use and nutrient yields, the Maumee watershed drains more than 10 times the area of Portage, resulting in a significantly higher total load. Reviewing nonpoint source nutrient yields and per capita yields is advisable for more accurate comparisons.

The Muskingum watershed is an exception to the trend of larger watersheds resulting in greater loads. Despite having the largest drainage area, it delivers a smaller total load than the Maumee, Scioto, or Great Miami watersheds due to specific watershed characteristics.

Relationship of Annual Water Yield to Annual Load

As the product of flow and concentration determines load, it is essential to understand flow variability for effective load comparisons. Larger watersheds usually exhibit higher stream flows, so water yield—annual discharge normalized by watershed area, expressed as height over time (e.g., 14 inches per water year)—is a useful metric for comparison. Annual streamflow discharge is primarily affected by fluctuations in precipitation from year to year and regional precipitation patterns. The water yield for each watershed is presented in Table 3, and the median of the last 20 years of discharge data, with some date range exceptions.

The median water yield is generally lower for northwest Ohio (14.1 – 15.1 in) compared to the Ohio River watershed (16.1 – 17.9 in) but highest in the Cuyahoga watershed (22.0). Hence, for equivalent nutrient yields across watersheds in a typical year, those with higher water yields will have lower flow-weighted mean concentrations (FWMC). The Cuyahoga watershed demonstrates this dilution effect.

Two water years, wy16 and wy23, were dry statewide, with only a few exceptions, these years were in the bottom quarter annual water yields of nearly every watershed of this 20-year period. The wettest year included in this analysis was wy19 when all watersheds, except for the Vermillion, exceeded their 75^{th} percentile of this 20-year period.

When extending this discussion to loads, the total P load in wy16 is the lowest loading year for all watersheds, excluding the Huron (wy21) and Scioto (wy23), whereas wy19 is the highest loading year for all (Table 4). The total N loadings reflected similar trends with the exception that wy23 was the minimum in several watersheds (Table 5). These tables do not include LMR and Hocking median and averages because there are too few years of observations. These observations highlight the importance of considering the annual flows when evaluating nutrient loads.

FWMC is a way to (partially) normalize the influence of flow from year to year. FWMC can be calculated differently, which is equivalent to the annual load divided by the total annual flow. This provides a concentration somewhat dampened by the impact of flow when interpreting results, allowing for a more comparable statistic to investigate differences between watersheds. The “somewhat” qualifier is used because a positive relationship typically exists between flow and concentration. This tends to increase the FWMC in wet years. FWMC is calculated within Sections 3.2-3.14 to discuss inter-annual variability for each of the specific regions examined.

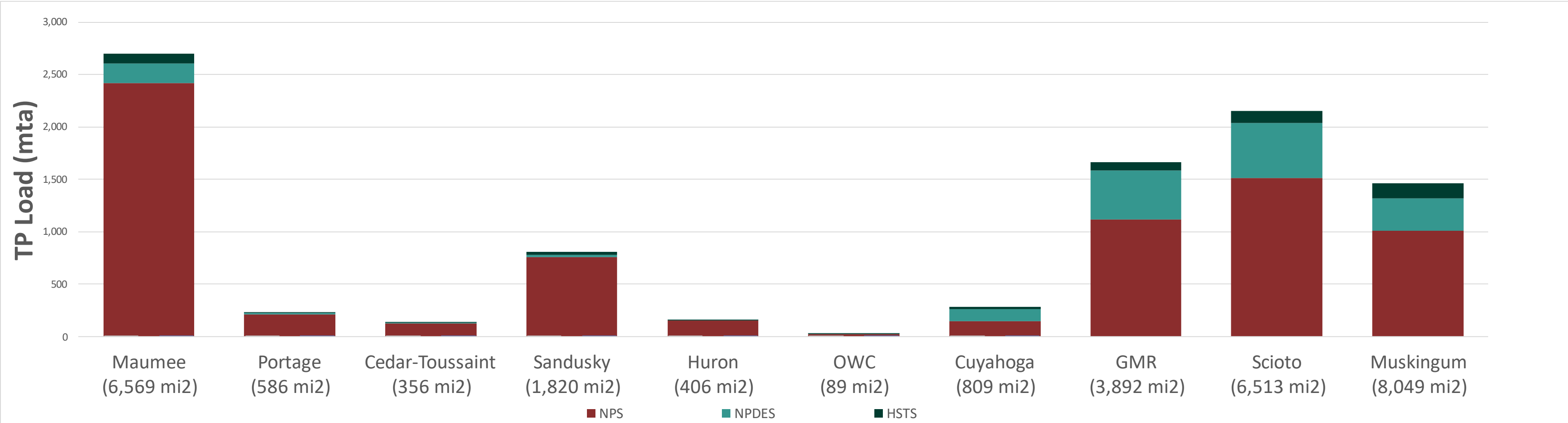


Figure 2 - Total phosphorus loading using nutrient balance methods as the average of the loads calculated from water year 2019-2023

"GMR" denotes Great Miami River.

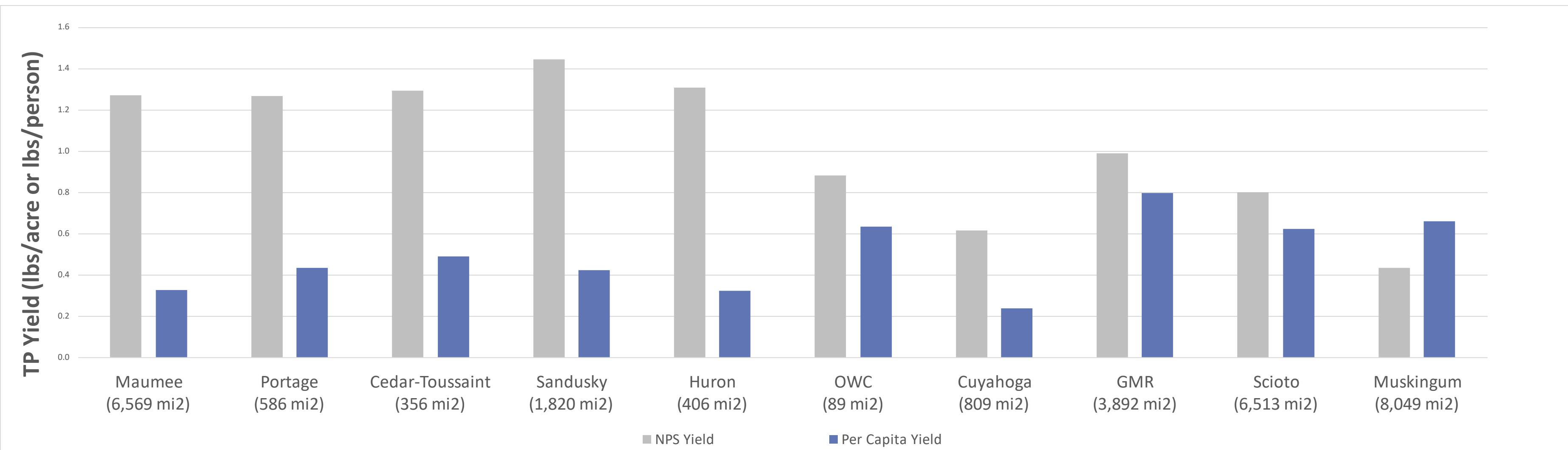


Figure 3 - Total phosphorus yields as the average of the loads calculated from water year 2019-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

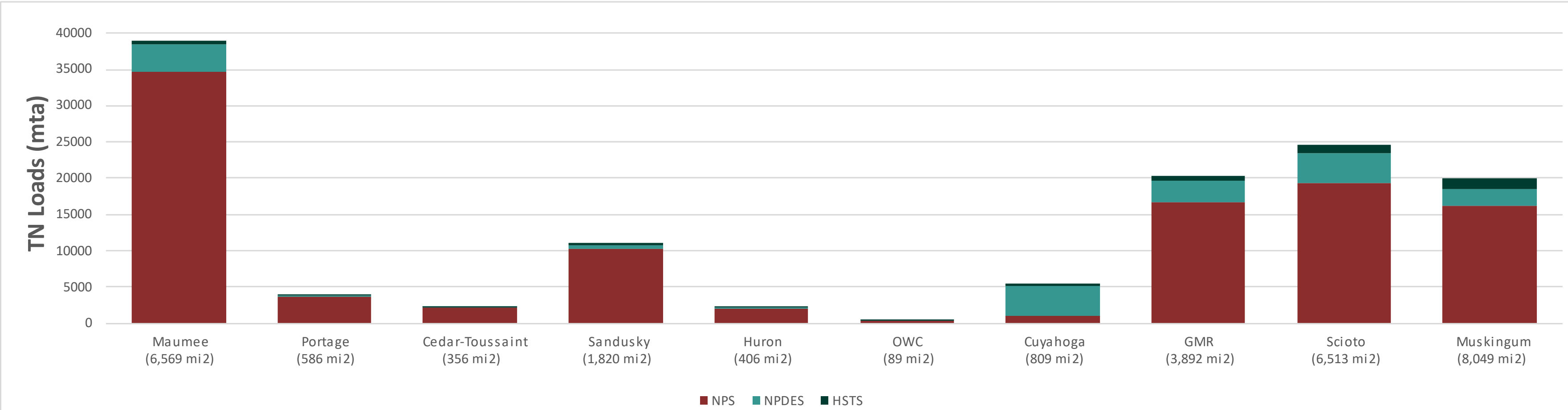


Figure 4 - Total nitrogen loading using nutrient balance methods as the average of the loads calculated from water year 2019-2023

"GMR" denotes Great Miami River.

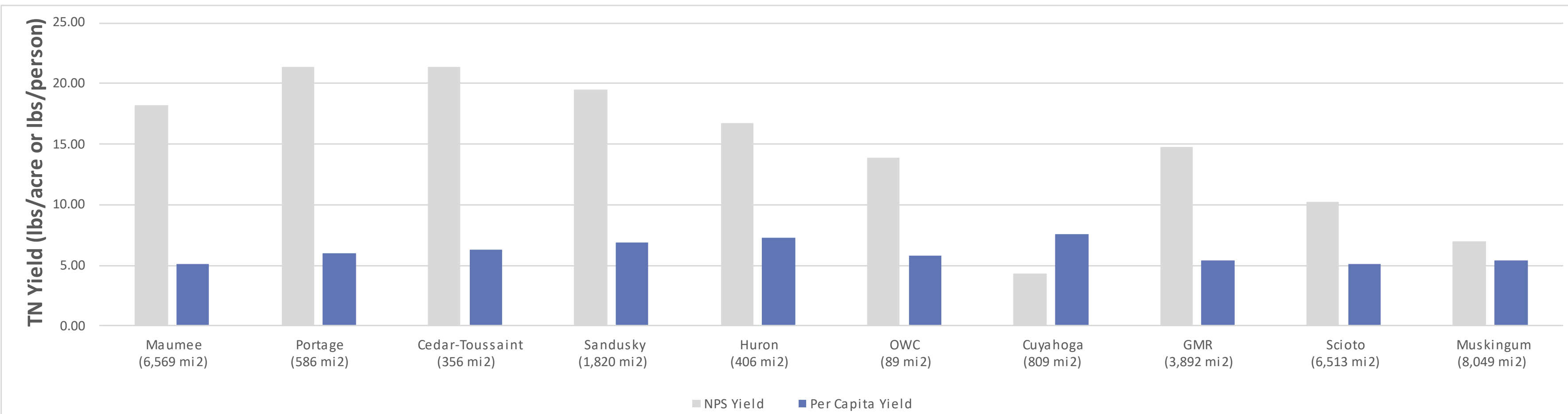


Figure 5 - Total nitrogen loading as the average of the loads calculated from water year 2019-2021

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

Table 3 - Annual water yield (in) and median long-term water yield (in/yr), for the watersheds calculated at the pour point (PP) of each

		Water Yield (in)									
Watershed	Median (2004-2023)	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Maumee	14.1	14.0	16.0	9.5	16.5	14.1	21.5	13.8	9.7	16.0	10.1
Portage	14.8	15.6	15.6	10.7	14.0	15.7	24.0	13.3	11.2	15.7	9.4
Cedar Toussaint	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sandusky	15.1	17.2	12.9	10.5	14.3	16.0	21.9	11.7	11.2	14.0	10.1
Huron	15.4	17.8	11.4	11.7	12.7	16.4	21.0	13.1	15.0	14.6	11.0
Old Woman Ck	15.4	16.7	14.3	11.4	13.0	17.6	23.7	11.7	11.5	12.3	11.1
Vermilion	16.1	18.3	11.3	10.8	13.7	16.2	21.1	12.8	15.2	16.0	13.7
Cuyahoga	22.0	22.4	20.9	16.1	23.9	23.2	29.0	21.6	19.2	21.2	19.1
Great Miami	17.1	18.2	15.6	13.3	15.2	19.8	27.2	14.9	13.2	20.1	10.7
LMR/EFLMR	17.9	17.9	16.5	16.8	17.8	23.3	31.3	16.4	15.5	19.7	12.5
Scioto	17.1	17.7	15.0	13.2	15.4	21.9	27.9	16.6	12.5	19.5	11.9
Hocking	16.1	15.0	12.3	11.3	15.4	23.3	28.0	19.3	10.6	18.8	11.8
Muskingum	17.1	18.7	15.0	11.6	14.5	20.9	26.5	18.4	12.6	20.1	13.4

Table 4 - Annual total phosphorus load in metric tons per year (by water year and average of five years) for the watersheds examined in this study

Watershed	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23	5 yr. Average
Maumee	2,288	2,102	2,346	1,268	3,054	2,668	3,897	2,980	1,575	2,741	2,286	2,696
Portage	163	226	170	143	185	254	364	199	149	258	204	235
Cedar-Toussaint	96	133	101	86	108	150	213	115	87	157	125	139
Sandusky	951	833	533	449	801	844	1,226	706	563	936	605	807
Huron	NA	NA	NA	NA	NA	202	217	159	118	195	122	162
Old Woman Creek	NA	NA	NA	21	27	27	38	26	24	17	23	26
Vermilion	141	146	84	68	87	125	156	80	123	TBD	TBD	TBD
Cuyahoga	313	354	298	206	325	321	398	243	266	266	246	284
Great Miami	1,218	1,762	1,722	878	1,397	1,803	2,475	1,464	1,189	2,165	1,026	1,664
LMR/EFLMR	NA	NA	NA	NA	NA	NA	NA	NA	685	900	581	722[a]
Scioto	2,015	2,402	1,969	1,486	2,117	2,797	3,783	2,103	1,320	2,340	1,026	2,152
Hocking	NA	NA	NA	NA	NA	NA	NA	NA	133	276	113	174[a]
Muskingum	1,330	1,632	1,545	885	1,316	1,799	2,209	1,237	936	1,783	1,041	1,441

a: 3-year average from 2021-2023

Table 5 — Annual total nitrogen load in metric tons per year (by water year and average of five years) for the watersheds examined in this study

Watershed	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23	5 yr. Average
Maumee	43,630	37,609	44,962	30,953	49,551	40,327	49,461	35,471	37,495	42,143	30,749	39,064
Portage	3,915	3,116	4,032	3,226	5,358	4,357	5,415	3,258	4,180	3,973	2,773	3,920
Cedar-Toussaint	2,195	1,718	2,247	1,818	3,109	2,502	3,126	1,837	2,362	2,404	1,655	2,277
Sandusky	15,165	10,853	9,474	8,678	13,092	12,008	14,759	9,553	10,642	11,574	8,697	11,045
Huron	NA	NA	NA	NA	NA	2,046	2,679	1,856	2,416	2,174	1,665	2,158
Old Woman Creek	NA	NA	NA	313	465	368	627	292	352	308	344	385
Vermilion	1,510	1,571	899	917	1,199	1,425	2,065	792	1,188	TBD	TBD	TBD
Cuyahoga	5,952	5,750	4,921	4,738	5,612	6,062	6,561	5,605	5,148	5,045	4,613	5,394
Great Miami	18,083	20,458	21,111	14,550	21,791	20,203	28,367	18,282	16,667	24,340	14,258	20,383
LMR/EFLMR	NA	NA	NA	NA	NA	NA	NA	NA	4,836	5,615	3,566	4,673[a]
Scioto	22,729	27,711	23,949	17,819	28,077	27,961	36,707	24,578	16,778	26,957	18,105	24,625
Hocking	NA	NA	NA	NA	NA	NA	NA	NA	1,282	2,513	1,325	1,707[a]
Muskingum	18,706	22,159	18,067	12,587	18,767	23,432	29,414	21,736	14,172	21,131	13,472	19,985

a: 3-year average from 2021-2023

Nonpoint Source Nutrient Yield

The Muskingum and Cuyahoga watersheds show the lowest nonpoint source nutrient yields (see gray bars in Figure 3 and Figure 5) – for the total P and total N averages over five years (2019 - 2023). The highest nonpoint source yields are found in the Lake Erie watersheds (excluding Cuyahoga). In the Muskingum and Scioto watersheds, the presence of large run-of-river reservoirs may be a confounding factor for nonpoint source yields. In-stream reservoirs can trap nonpoint source sediment with associated nutrients and prevent their movement downstream to the pour point. The Huron River, LMR/EFLMR, and Hocking River are absent from these statewide figures due to not having five years of data available. Also, the Vermilion is not included due to recent years' loadings data not available at the time of publication.

Natural land cover including wetlands, forests, shrubs, herbaceous land, and open water, makes up more than 48% of the Muskingum and contributes minimally to nonpoint nutrient loads (Figure 6). The Cuyahoga watershed is a low generator of nonpoint source N yield (Figure 5) and, to some extent, showed a low P yield (Figure 3). Natural land cover was also high for the Cuyahoga and Vermilion watersheds, comprising more than 38% and 27% of their total area, respectively. Yet the Vermilion watershed nonpoint P yield was among the highest among the watersheds (not shown in Figure 3 due to data availability, but evident in Section 3.8). While Vermilion approaches the Cuyahoga in terms of natural land cover, it is also similar to the Cuyahoga in that it receives more annual precipitation than other Lake Erie watersheds (Table 3). The higher precipitation combines with its higher percentage of agricultural land than the Cuyahoga (Figure 6).

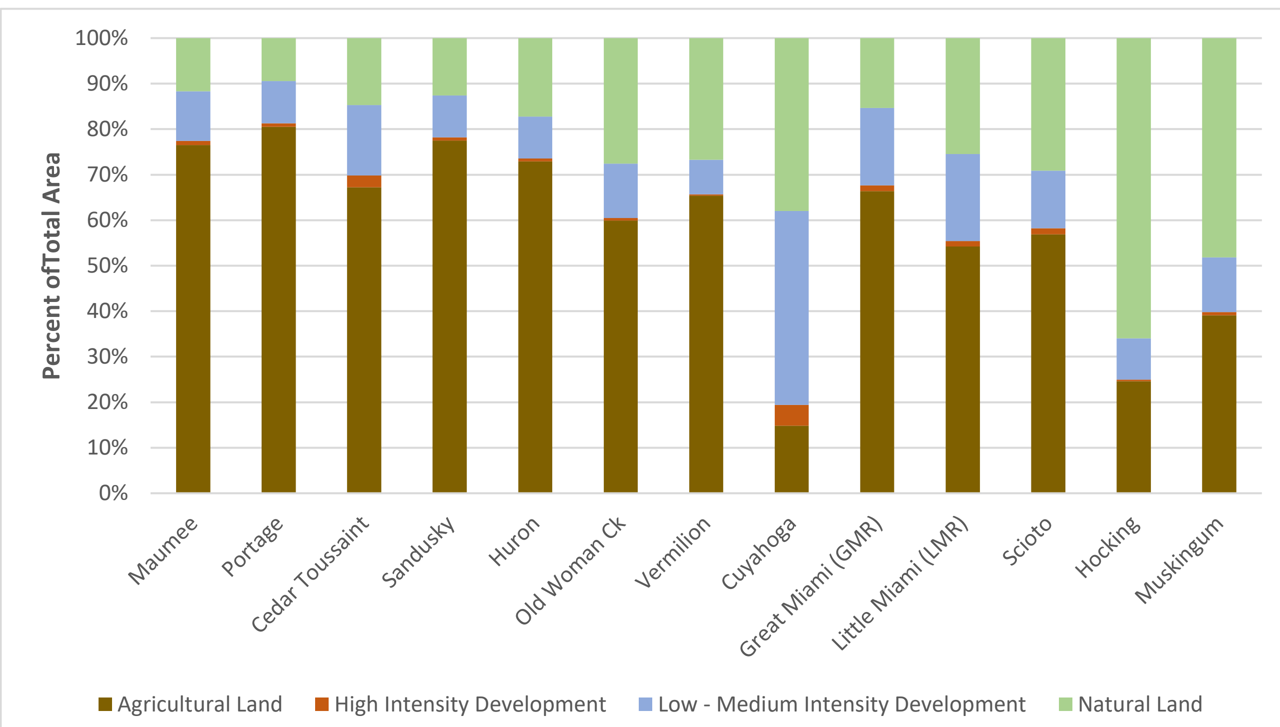


Figure 6 - Distribution of major land use and land cover categories by major watershed

Shown as percent of total watershed area. Land use/cover data taken from National Land Cover Dataset for year 2021 (NLCD 2021).

Per Capita Nutrient Yield

The per capita yield of sewage-sourced nutrient load is calculated by dividing the sum of NPDES and HSTS loads by the total human population in the watershed. The highest per capita total P yield, more than 0.6 lbs./person, is found in the GMR, Scioto, and Muskingum watersheds (blue bars in Figure 3), where major WWTPs typically lack total P concentration limits. In contrast, despite being primarily urban, the Cuyahoga watershed has the lowest per capita total P yield due to a high treatment level from WWTPs. The remaining Lake Erie watersheds have moderate per capita total P yields, influenced by the presence of HSTS and smaller WWTPs, which provide less treatment before discharge. Total N per capita yield differences across the study watersheds are less distinct (blue bars in Figure 5).

Population Density

Estimates of population density were made using the contributing population and the total watershed area (Table 6). The Cuyahoga watershed has the highest density, more than double that of the next highest watersheds, the Great Miami and Scioto. It's important to note that the contributing population may reside outside the watershed but still impacts it, such as residents from Toledo contributing to the Maumee watershed.

When exploring the highest relative contribution of total NPDES and HSTS load to total watershed load, the Cuyahoga watershed has the highest total N load (greater than 80% of total load). No other watershed is close to this proportion contribution of NPDES and HSTS to total N load. For total P, the Cuyahoga watershed also has the highest proportion of load, greater than half the total load, contributed by NPDES and HSTS. The Ohio River watersheds also had higher combined NPDES and HSTS total P loads. The Muskingum's relatively higher NPDES proportion is more of a reflection of its reduced NPS load due to all the natural area versus elevated population density.

Table 6 - Population density calculated as the contributing watershed population divided by watershed area

Watershed	Contributing Population (# persons)	Population Density (contributing population/sq. mi)
Maumee	1,380,434	210
Portage	101,550	173
Cedar-Toussaint	59,846	168
Sandusky	269,014	148
Huron	55,811	137
OWC	10,563	119
Vermilion	33,500	125
Cuyahoga	1,143,142	1,413
GMR	1,517,842	390
LMR	629,775	359
Scioto	2,156,599	331
Hocking	216,503	181
Muskingum	1,477,592	184

3.2 Maumee River

The Maumee River drains 6,569 sq. mi. across northwestern Ohio, southeastern Michigan, and northeastern Indiana (Figure 7). The NCWQR operates a water quality sampling station at a USGS gaging station near Waterville, Ohio, serving as the pour point for nutrient mass balance calculations. The watershed area upstream of this point is 6,300 sq. mi., with 269 sq. mi. downstream.

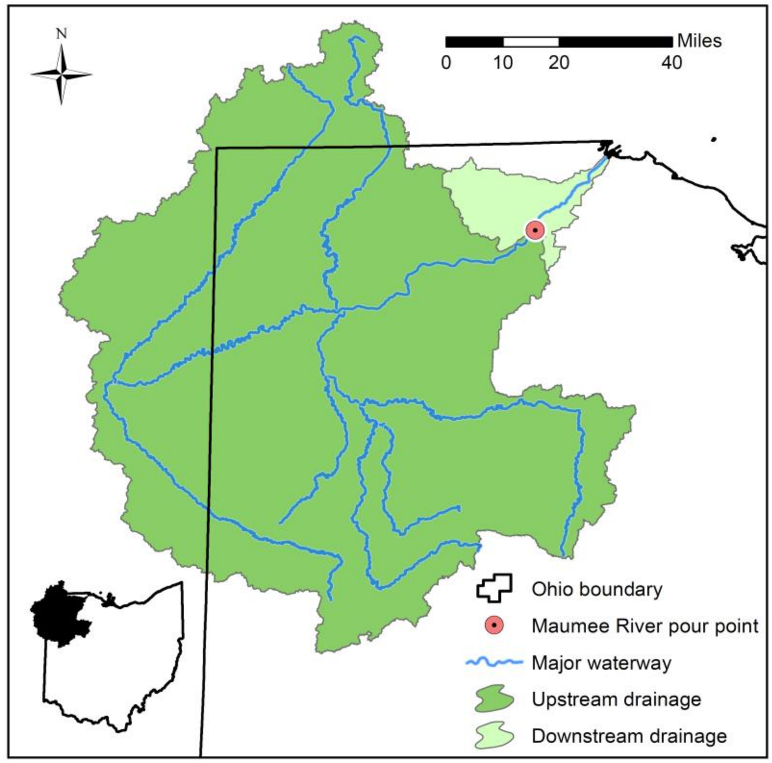


Figure 7 - Project area represented in Maumee River mass balance. The pour point, up, and downstream drainage areas are shown.

Agricultural production dominates the watershed, covering 77% of the land, including the fertile historic Great Black Swamp. Land use shifts significantly as the river moves into the Toledo metropolitan area, with agricultural production decreasing from 78% upstream of the pour point to 46% downstream. In contrast, natural and developed land increases downstream (21% natural and 33% developed, compared to 11% each upstream).

Total P loads from the Maumee River were a maximum of 3,897 metric tons per year (mta) in wy19 and a minimum of 1,268 mta for wy16 (Figure 8 and Table 7). Total N loads from the Maumee River were a maximum of 49,551 mta in wy17 and a minimum of 30,749 mta for wy23 (Figure 10 and Table 7). Total P and total N yields are presented on Figure 9 and Figure 11.

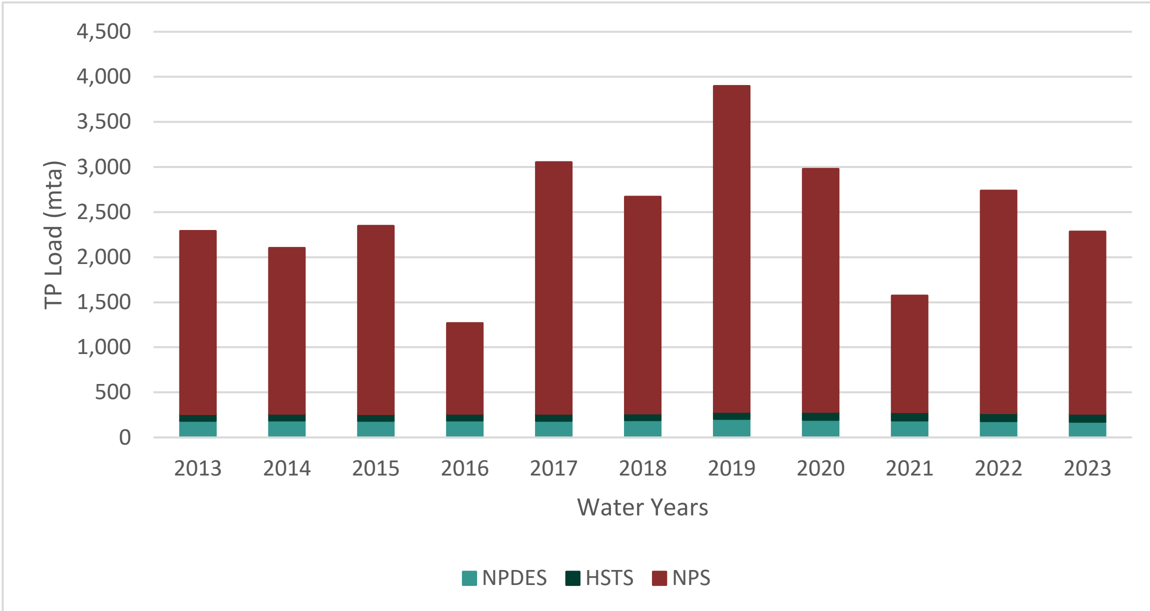


Figure 8 - Total phosphorus loads for the Maumee River for water year 2013-2023

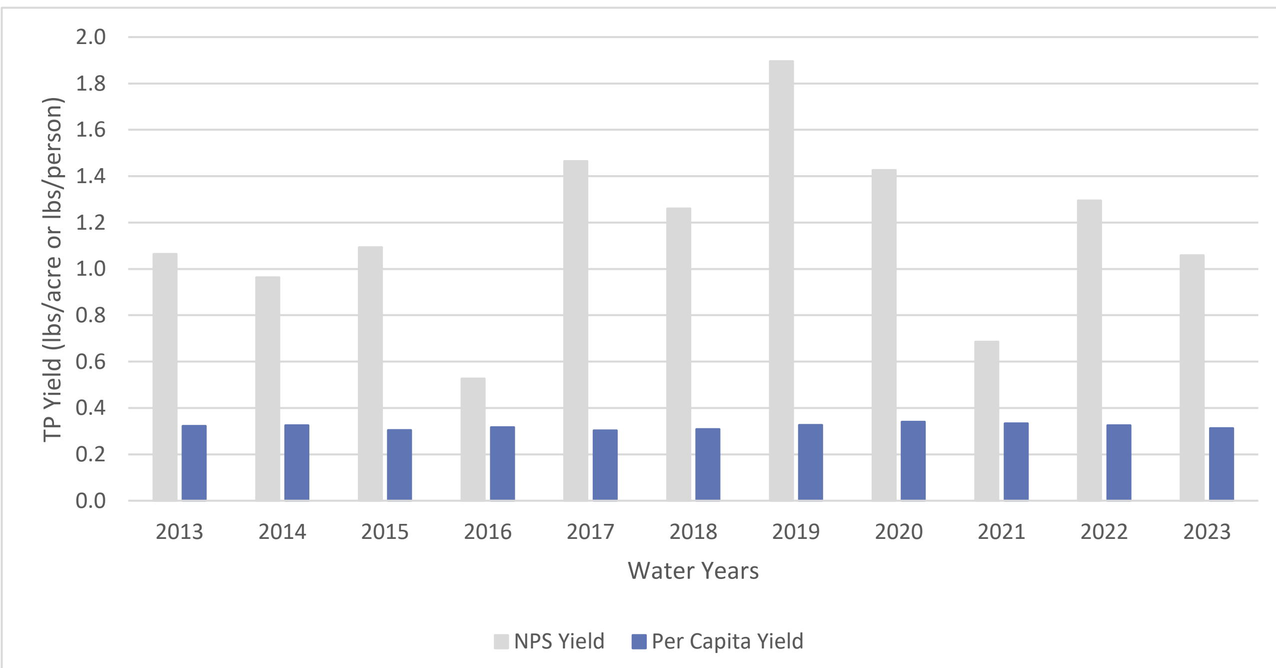


Figure 9 — Total phosphorus yields for the Maumee River for water year 2013-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS.

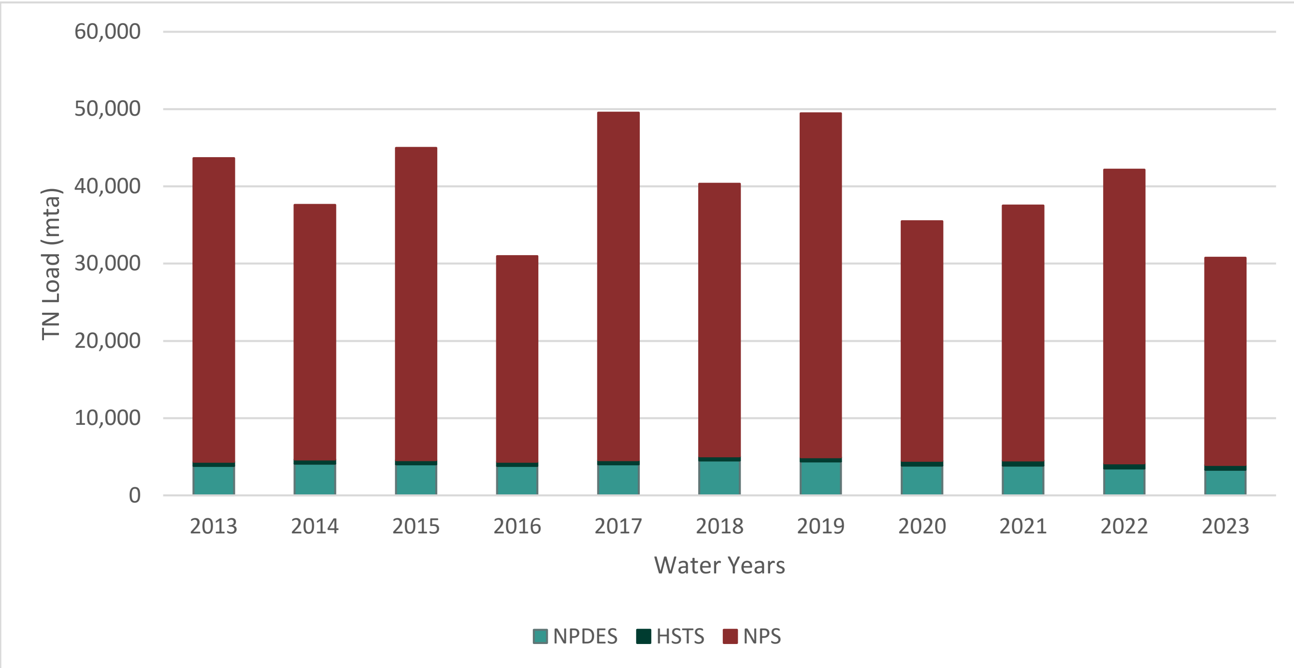


Figure 10 — Total nitrogen loads for the Maumee River for water year 2013-2023

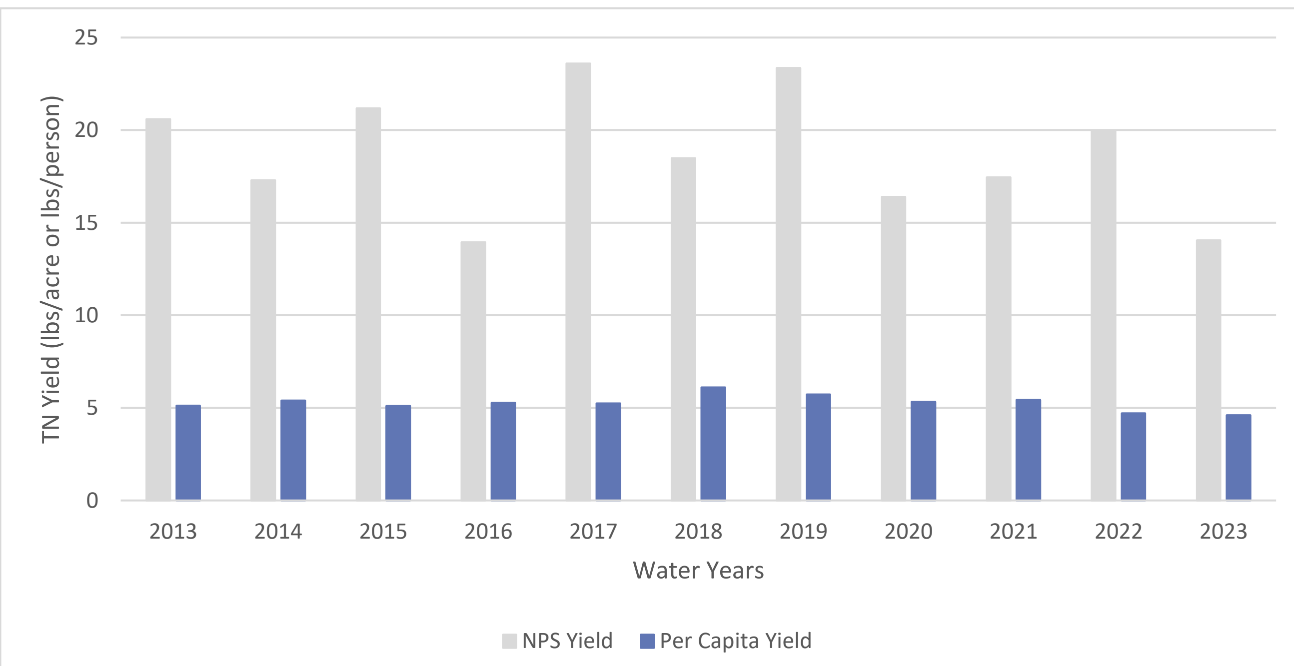


Figure 11 -- Total nitrogen yields for the Maumee River for water year 2013-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

The importance of total discharge is highlighted in the observed data where the two highest loading years, wy17 and wy19, are also the highest discharging years. Due to very high precipitation, the wy19 loads are larger than in other years. Wy23 was comparatively a much drier year (as observed by the water yield on Table 7), and experienced lower than average total loads for both P and N.

Table 7 — Annual flow-weighted mean concentration (FWMC), total load, and water yield for wy13 through wy21

Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and water yield are calculated at the pour point and do not include downstream drainage area.

Parameter	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Water Yield (in/yr)	12.1	14.0	16.0	9.5	16.5	14.1	21.5	13.8	9.7	16.0	10.1
20-yr Median Water Yield (in) – 14.1											
Total P											
FWMC (mg/L)	0.42	0.34	0.33	0.29	0.42	0.39	0.41	0.47	0.34	0.37	0.49
Annual Load (mta)	2,288	2,102	2,346	1,268	3,054	2,668	3,897	2,980	1,575	2,739	2,284
Total N											
FWMC (mg/L)	8.05	5.89	6.05	6.93	7.38	6.26	5.11	5.50	8.40	5.79	6.55
Annual Load (mta)	43,630	37,609	44,962	30,953	49,551	40,327	49,461	35,470	37,495	42,123	30,749

The average proportions of nonpoint source, NPDES, and HSTS loads for total P and total N over the past five years, presented in Figure 12, show that nonpoint sources account for 90% of total P and 89% of total N in the Maumee River. NPDES sources comprise 7% of total P and 10% of total N, while HSTS contributes 3% of total P and 1% of total N.

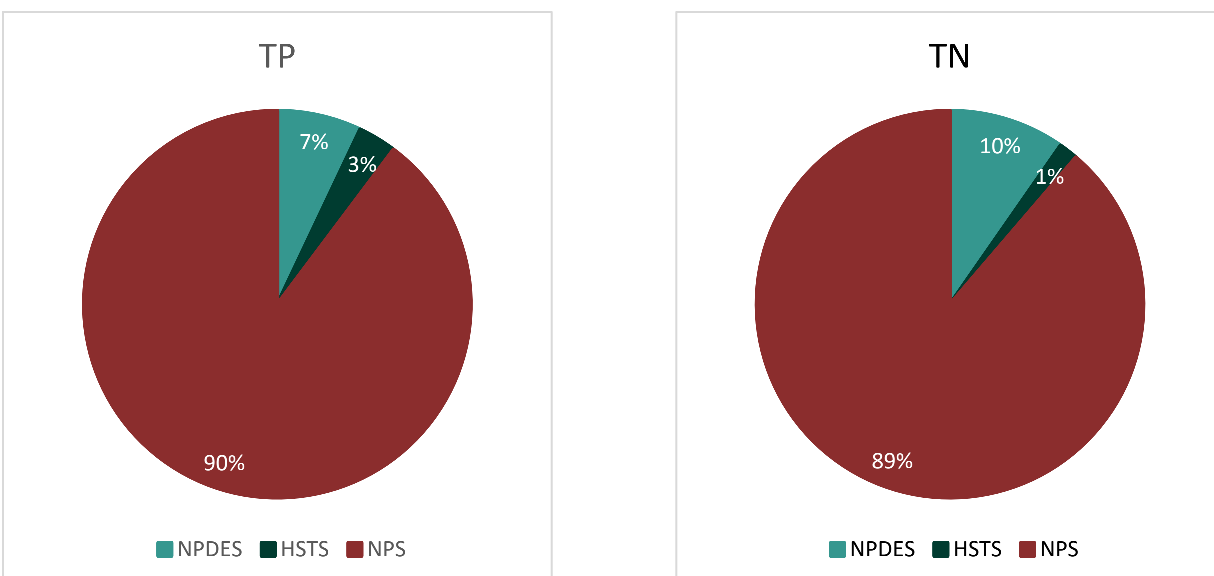


Figure 12 — Proportion of total phosphorus and nitrogen load from different sources for the Maumee watershed, an average of five years (wy19-wy23)

The Maumee watershed is significant in Ohio as the largest tributary to Lake Erie and the top nutrient contributor statewide. Both federal and state efforts have been made to control nutrients, including the Maumee Watershed Nutrient TMDL (Ohio EPA, 2023a). The international Great Lakes Water Quality Agreement also prioritizes this watershed to address Lake Erie ecosystem issues.

3.3 Portage River

The Portage River drains 586 sq. mi. in northwest Ohio, with a watershed area of 429 sq. mi. upstream and 158 sq. mi. downstream of a USGS gaging station and NCWQR water quality station in Woodville (Figure 13).

Agricultural production occupies 81% of the land, while natural areas and development account for 9% and 10%, respectively. Downstream, the pour point natural land use area is 14%, compared to 6% upstream.

Maximum total P loads of 364 mta were observed in wy19 and a minimum of 143 mta in wy16 (Figure 14 and Table 8). Total N loads maximum of 5,415 mta occurred in wy19, while the minimum was 2,773 mta in wy23 (Figure 16 and Table 8). Total P and total N yields are presented in Figures 15 and 17, respectively.

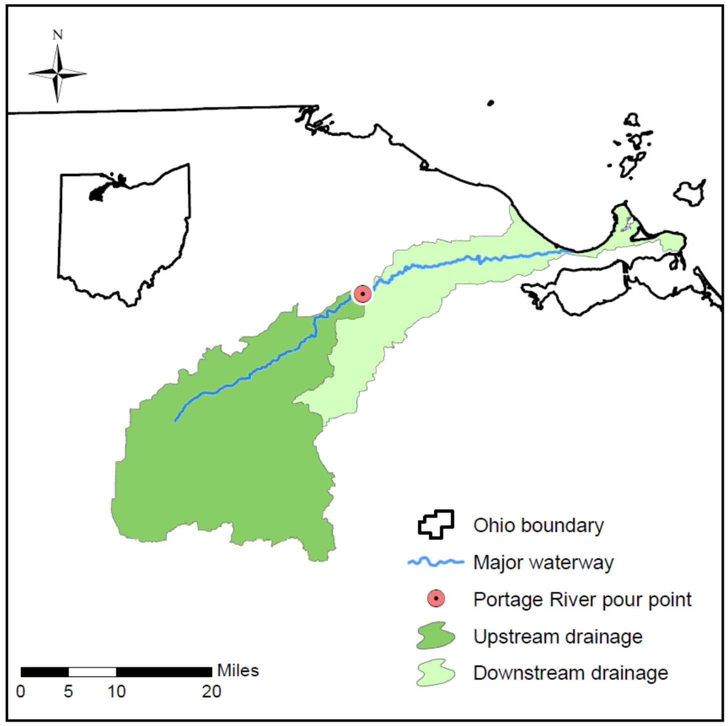


Figure 13 - Project area represented in the Portage River mass balance. The pour point, up, and downstream drainage areas are shown.

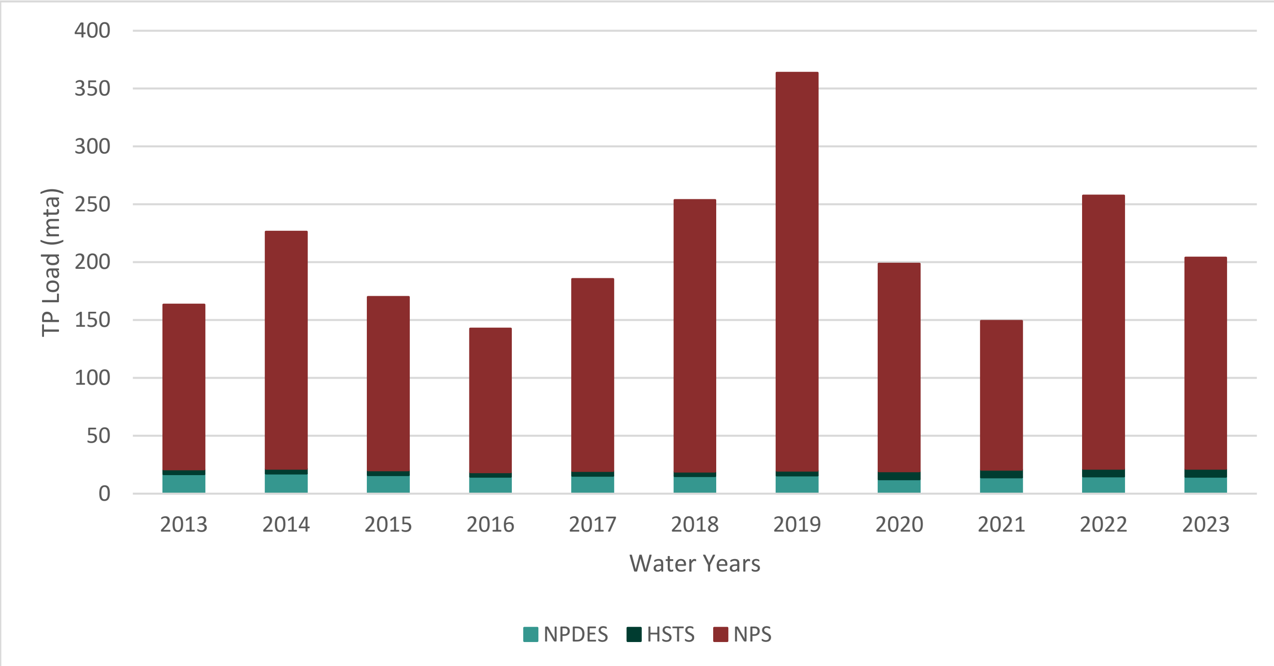


Figure 14 — Total phosphorus loads for the Portage River for water year 2013-2023

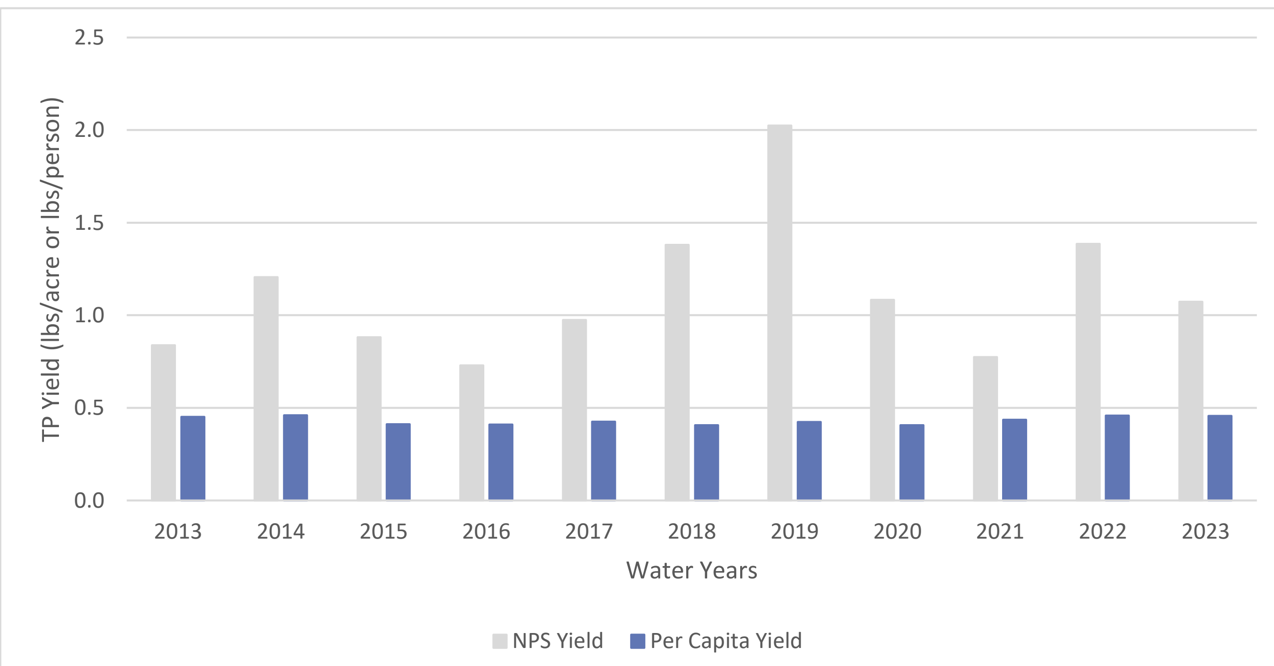


Figure 15 — Total phosphorus yields for the Portage River for water year 2013-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

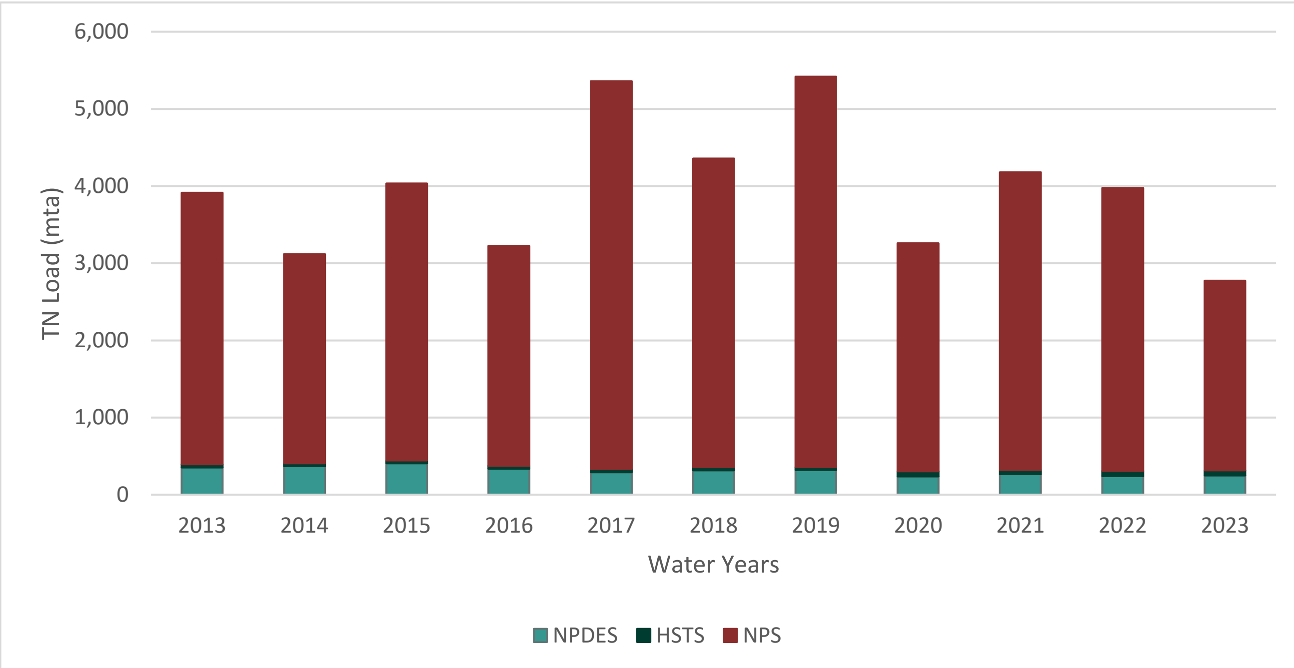


Figure 16 — Total nitrogen loads for the Portage River for water year 2013-2023

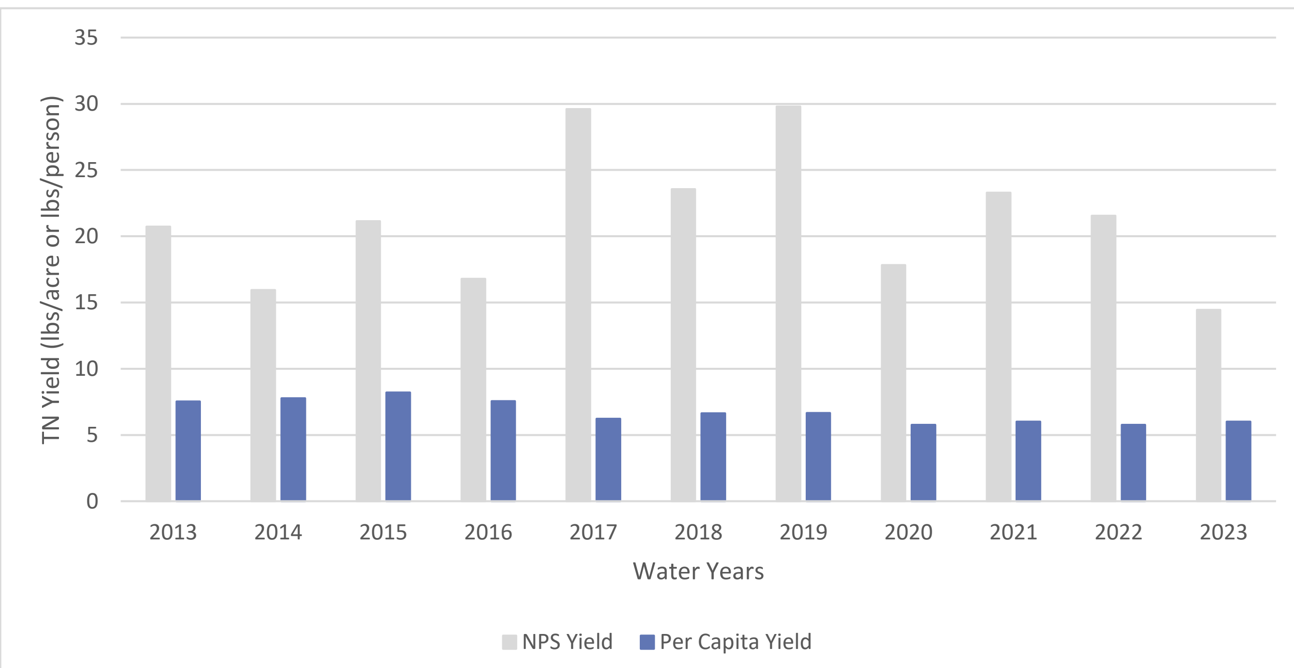


Figure 17 — Total nitrogen yields for the Portage River for water year 2013-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

Table 8 — Annual flow-weighted mean concentration (FWMC), total load, and water yield annual flow-weighted mean concentration (FWMC), total load, and water yield for wy13 through wy23 for the Portage watershed.

Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and water yield are calculated at the pour point and do not include downstream drainage area.

Parameter	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Water Yield (in/yr)	13.3	15.6	15.6	10.6	14	15.6	24	13.3	11.20	15.7	9.4
20-yr Median Water Yield (in) – 14.8											
Total P											
FWMC (mg/L)	0.31	0.37	0.28	0.34	0.34	0.41	0.39	0.38	0.34	0.42	0.55
Annual Load (mta)	163	226	170	143	185	254	364	199	149	258	204
Total N											
FWMC (mg/L)	7.79	5.22	6.82	7.97	9.45	7.17	5.82	6.30	9.63	6.52	7.52
Annual Load (mta)	3,915	3,116	4,032	3,226	5,358	4,357	5,415	2,358	4,180	3,973	2,773

The average load over the last five years indicates that nonpoint sources account for 91% of total annual P and 92% of total annual N in the Portage River (Figure 18). NPDES sources contribute 6% of total P and 7% of total N, while HSTS contributes 3% and 1% for total P and total N, respectively.

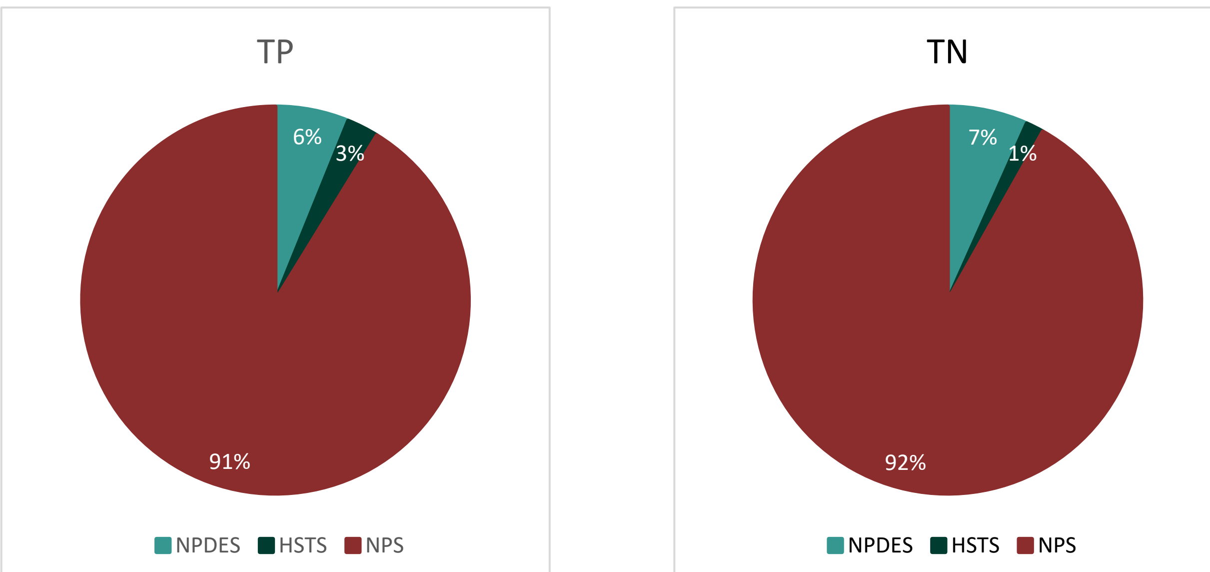


Figure 18 — Proportion of total phosphorus and nitrogen load from different sources for the Portage watershed, average of five years (water year 2019-2023)

The Portage River is a priority watershed for nutrient reduction to the western basin of Lake Erie, as outlined in the 2012 Great Lakes Water Quality Agreement. Despite its smaller size (less than 10% of the Maumee River watershed), this report, including its previous iterations, shows its nutrient loads are similar to those of the Maumee when adjusted for area. Thus, the Portage River plays a significant role in nutrient reduction efforts for Lake Erie.

3.4 Cedar Toussaint

The Cedar-Toussaint watershed in northwestern Ohio covers 358 sq. mi. and combines several Lake Erie tributaries (Figure 19). Together, this area drains primarily agricultural land, which accounts for 67% of its land use. There is no pour point within this watershed. Rather, the load yields determined from the adjacent Portage River watershed are applied to the Cedar-Toussaint watershed area.

The maximum total P load calculated for this watershed was 213 mta in wy19, and the minimum was 86 mta in wy16, while the total N loads maximum was 3,126 mta in wy19 and a minimum of 1,655 mta in wy23 (see Figures 20 and 22, Table 9).

The watershed includes areas served by Toledo and Bowling Green WWTPs; however, those plants discharge to other watersheds. Because of this, adjustments were made to account for this watershed's populations for yield calculations (Figures 21 and 23).

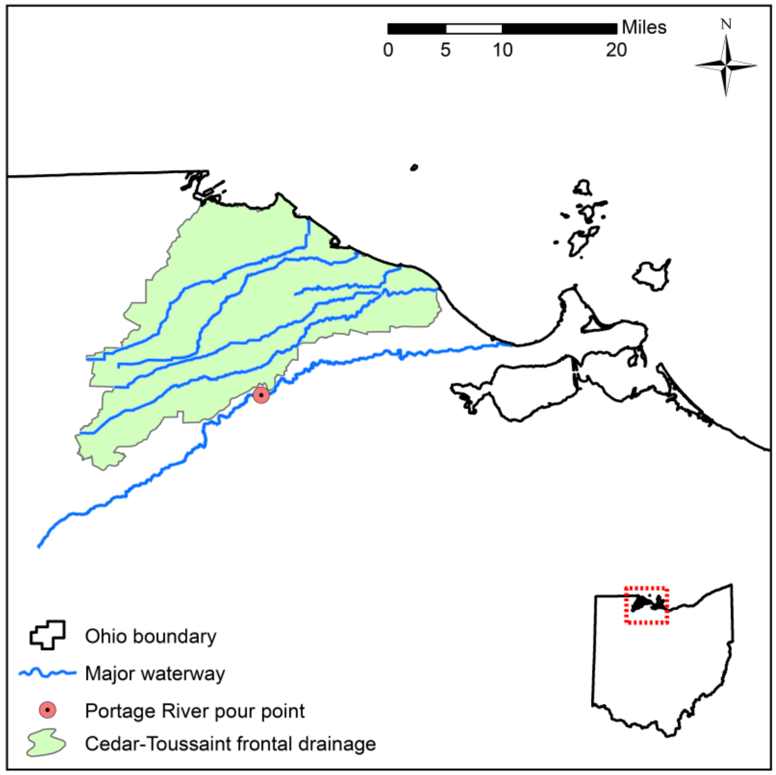


Figure 19 — Project area represented in the Cedar-Toussaint Lake Erie tributaries mass balance. The Portage River pour point used for this watersheds' calculations is shown.

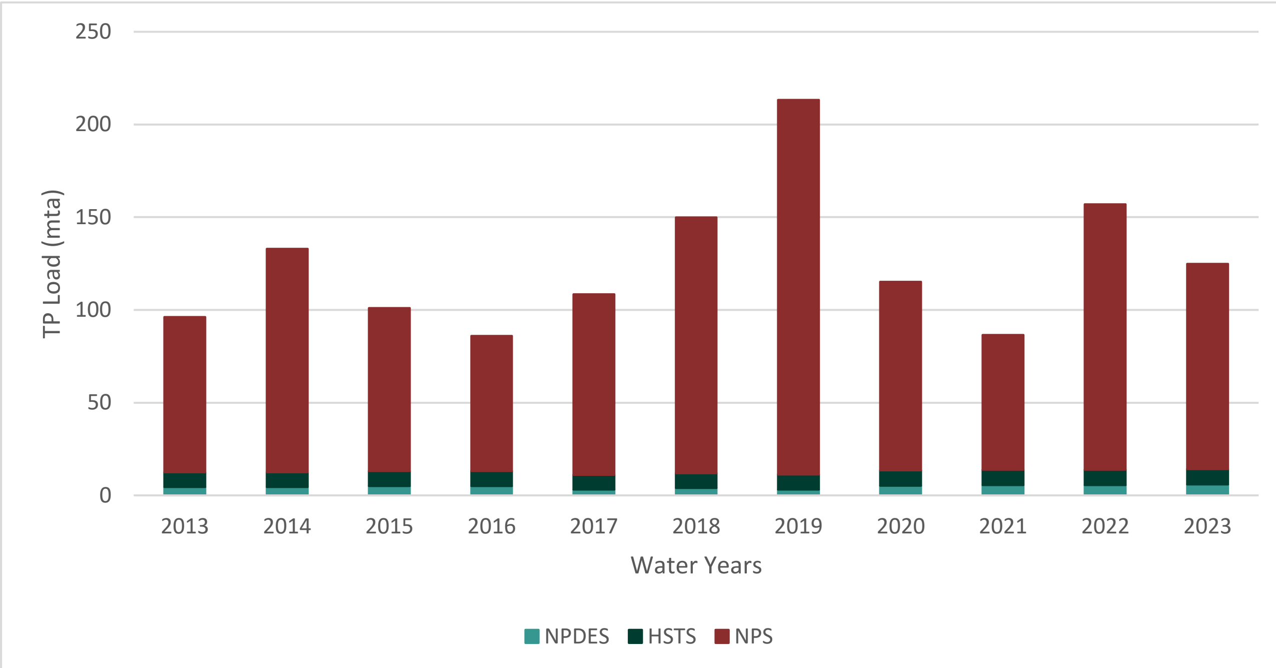


Figure 20 — Total phosphorus load for Cedar-Toussaint for water year 2013-2023

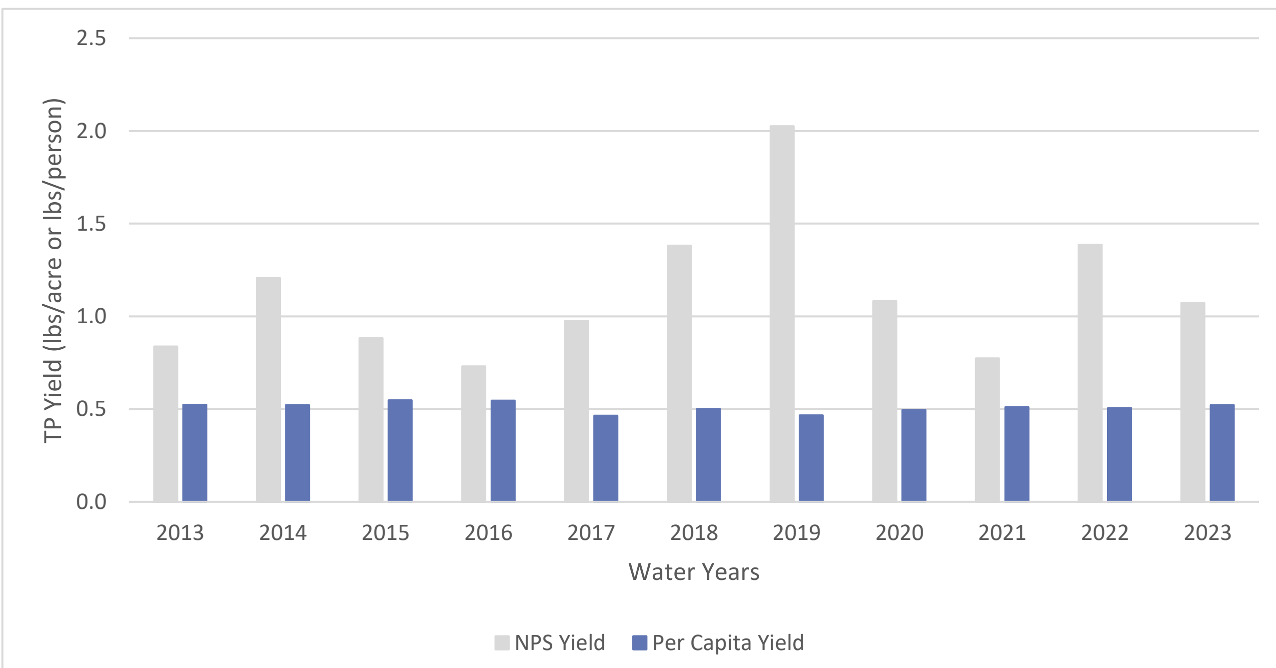


Figure 21— Total phosphorus yields for Cedar-Toussaint for water year 2013-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

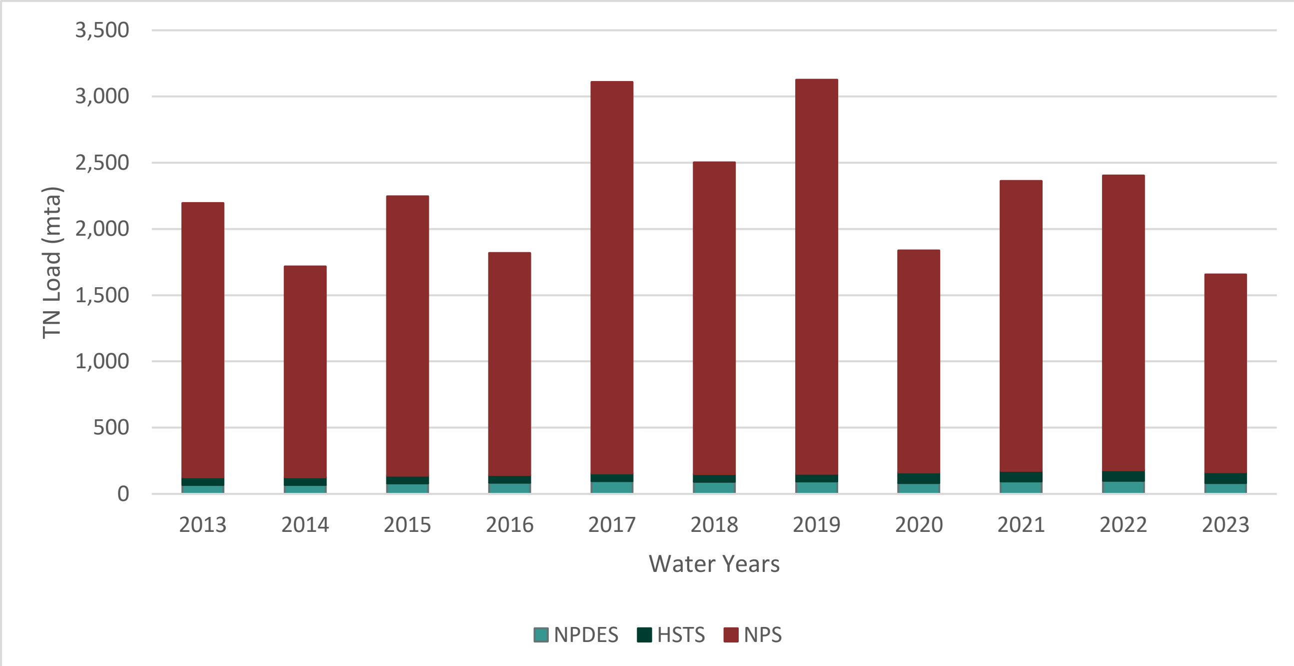


Figure 22 — Total nitrogen loads for Cedar-Toussaint for water year 2013-2023

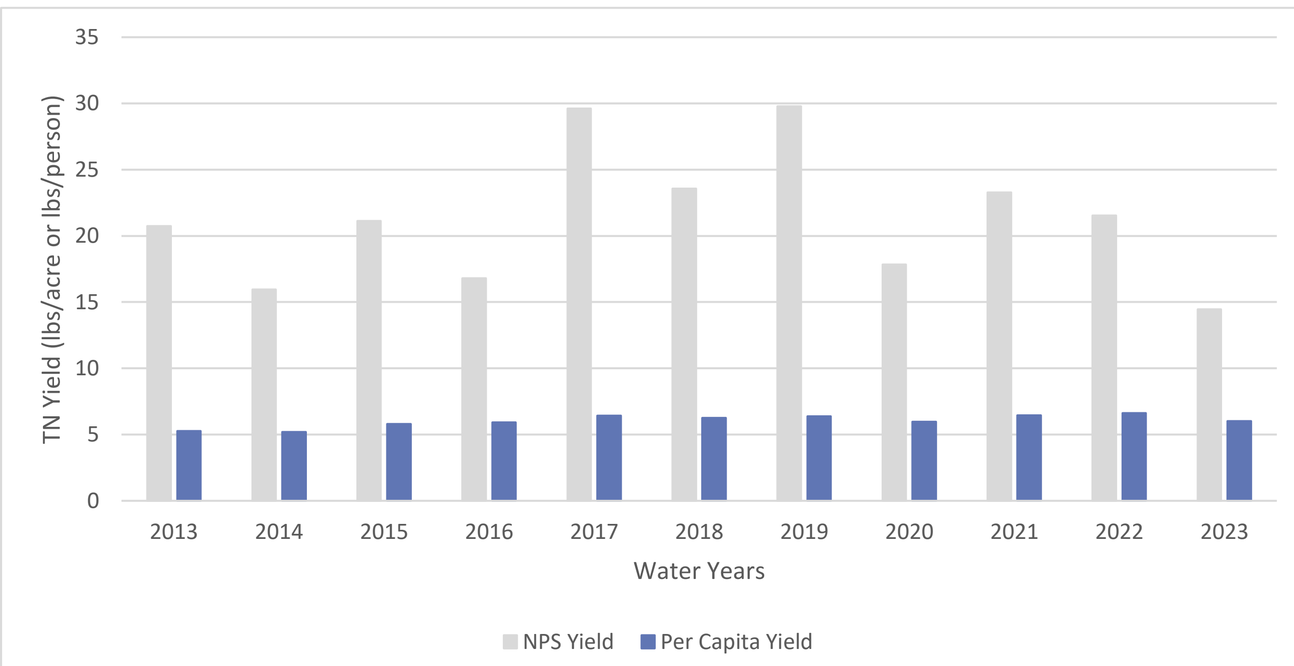


Figure 23 — Total nitrogen yields for Cedar-Toussaint for water year 2013-2023

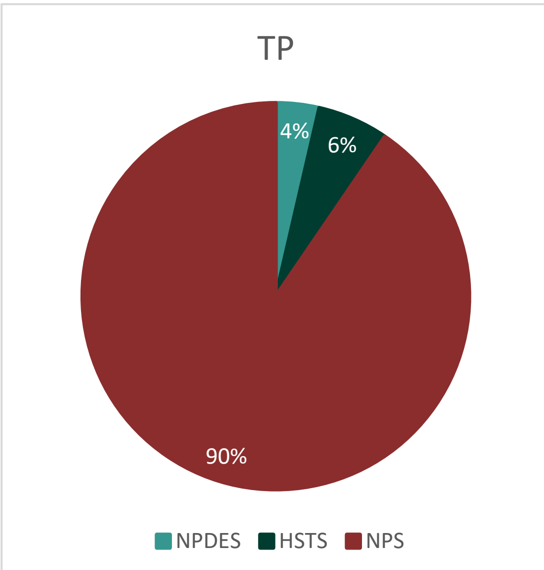
Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

Table 9 — Annual total loads for wy13 through wy23 for the Cedar-Toussaint watershed

Since this watershed uses the Portage River monitoring point, no water yields and FWMCs are available.

Parameter	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Total P											
Annual Load (mta)	96	133	101	86	108	150	213	115	87	157	125
Total N											
Annual Load (mta)	2,195	1,718	2,247	1,818	3,109	2,502	3,126	1,837	2,362	2,404	1,655

As shown on Figure 24, nonpoint sources account for 90% of total P and 93% of total N in the Cedar-Toussaint watershed. NPDES sources contribute 4% to the annual total P and total N, while HSTS contributes 6% to the total P and 3% to the total N.



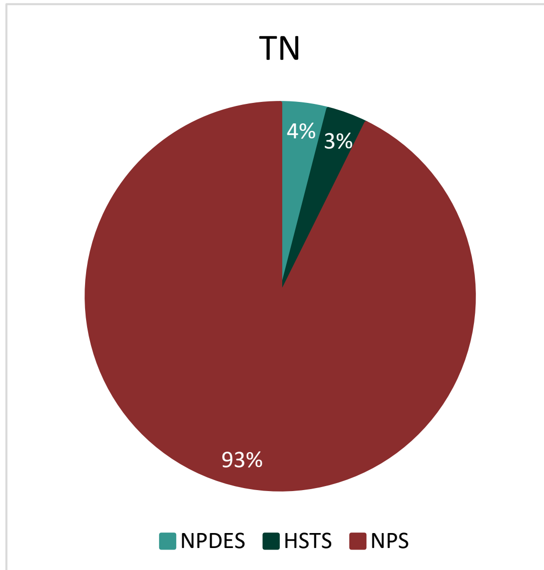


Figure 24 — Proportion of total phosphorus and nitrogen load from different sources for the Cedar-Toussaint watershed, average of five years (wy19-wy23)

3.5 Sandusky River and Sandusky Bay Tributaries Watershed

The Sandusky River and Sandusky Bay tributaries drain 1,820 sq. mi. in north-central Ohio (Figure 25). The NCWQR monitors water quality at the USGS station on the Sandusky River in Fremont, Ohio, which serves as a pour point for nutrient calculations. The watershed area upstream of the pour point is 1,250 sq. mi. Downstream of the pour point is 568 sq. mi. and includes the areas draining directly to Sandusky Bay (i.e., not the Sandusky River).

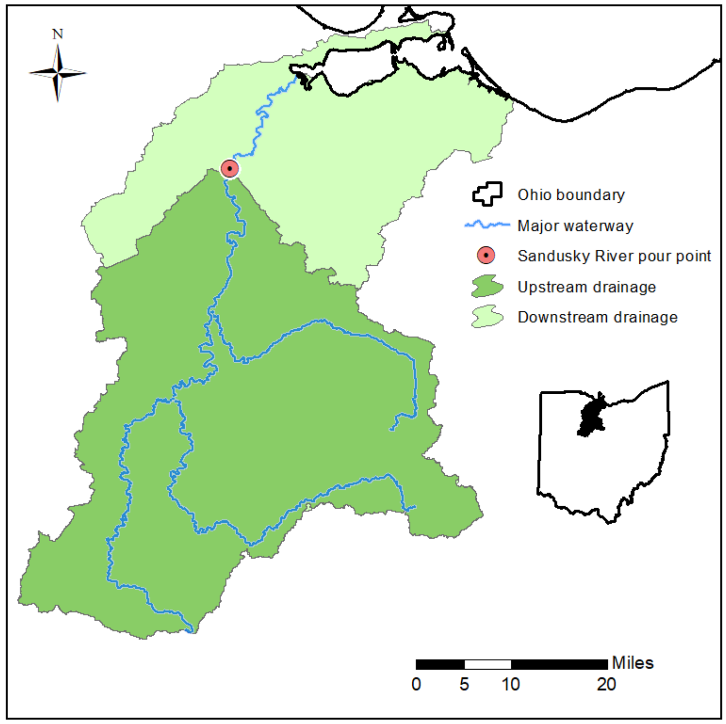


Figure 25 - Project area represented in the Sandusky River and Sandusky Bay tributaries mass balance. The pour point, up, and downstream drainage areas are shown.

Agricultural production is predominant, occupying 78% of the land, with natural areas at 13% and developed lands making up the small remainder.

Maximum total P loads of 1,226 mta were observed in wy19 and minimum of 449 mta in wy16 (Figure 26 and Table 10). Total N loads maximum of 15,165 mta was observed in wy13, with a minimum of 8,678 mta in wy16 and a near-minimum of 8,697 mta in wy23 (Figure 28 and Table 10). Total P and total N yields are presented on Figures 27 and 29, respectively.

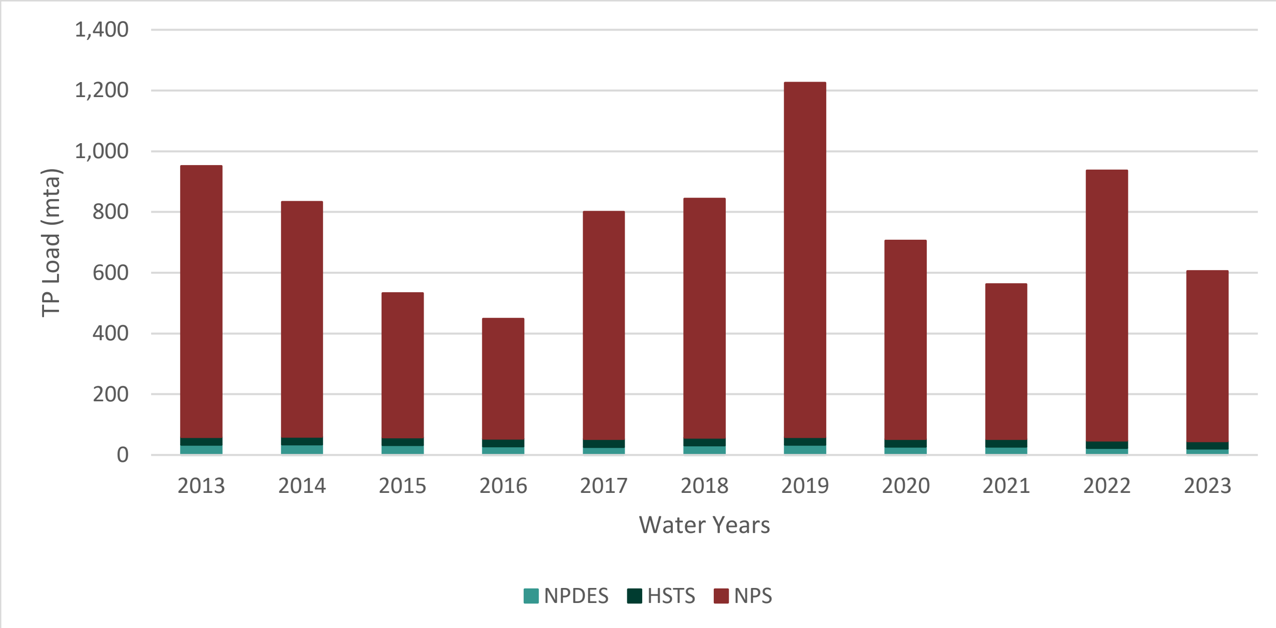


Figure 26 — Total phosphorus loads for the Sandusky River and Sandusky Bay tributaries for water year 2013-2023

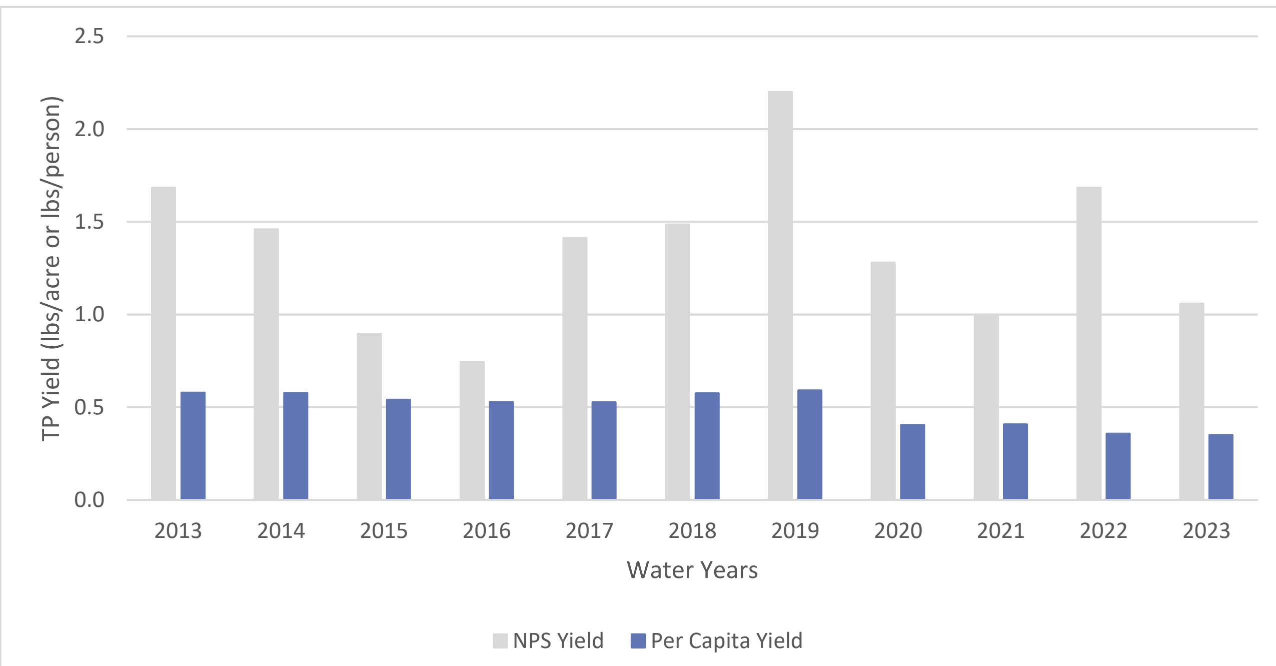


Figure 27 — Total phosphorus yields for the Sandusky River and Sandusky Bay tributaries for water year 2013-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

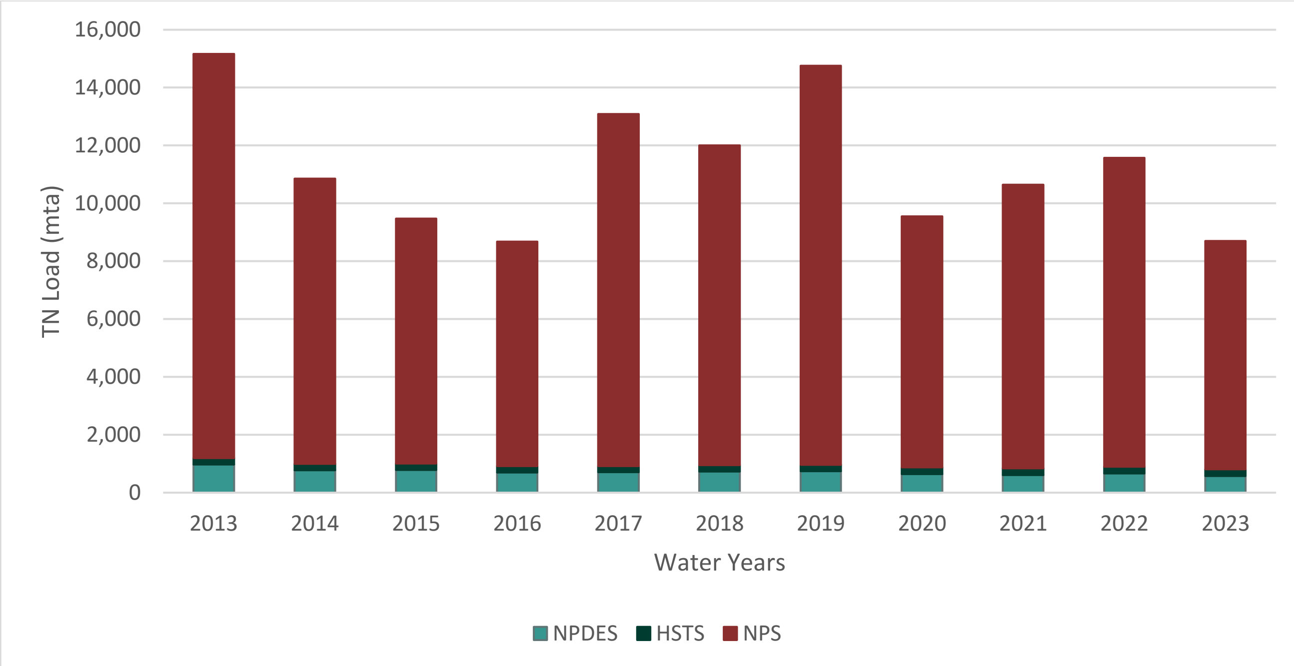


Figure 28 — Total nitrogen loads for the Sandusky River and Sandusky Bay tributaries for water year 2013-2023

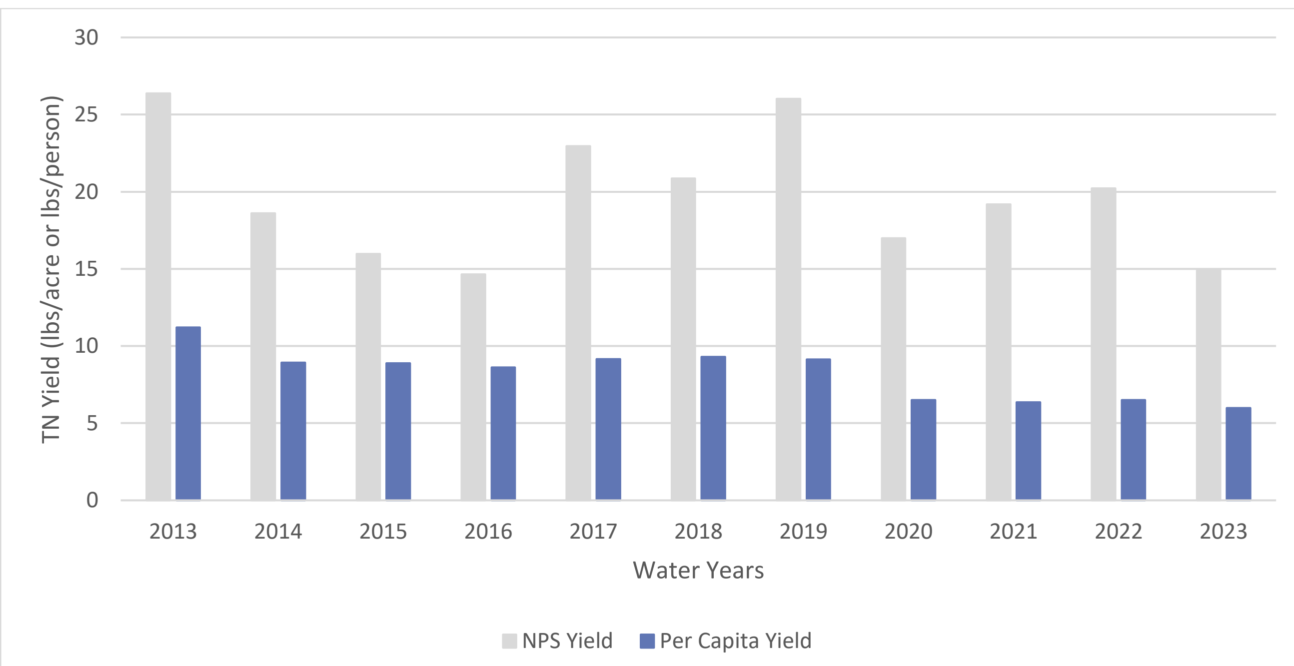


Figure 29 — Total nitrogen yields for the Sandusky River and Sandusky Bay tributaries for water year 2013-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

Table 10 - Annual flow-weighted mean concentration (FWMC), total load, and water yield annual flow-weighted mean concentration (FWMC), total load, and water yield for wy13 through wy23 for the Sandusky watershed

Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and water yield are calculated at the pour point and do not include downstream drainage area.

Parameter	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Water Yield (in/yr)	18.1	17.2	12.9	10.5	14.3	16.0	21.9	11.7	11.2	14.0	10.1
20-yr Median Water Yield (in) – 15.1											
Total P											
FWMC (mg/L)	0.43	0.39	0.33	0.34	0.46	0.44	0.39	0.51	0.42	0.55	0.49
Annual Load (mta)	951	833	533	449	801	844	1,226	706	563	936	605
Total N											
FWMC (mg/L)	6.73	5.12	6.53	6.59	7.75	6.02	5.44	6.73	7.85	14.0	10.1
Annual Load (mta)	15,165	10,853	9,474	8,678	13,092	12,008	14,759	9,553	10,642	11,574	8,697

The average proportion of loads for total P and total N over the last five years shows that nonpoint sources dominate in the Sandusky River, accounting for 94% and 92%, respectively (Figure 30). NPDES sources contribute 3% for total P and 6% for total N, while HSTS contributes 3% for total P and 2% for total N.

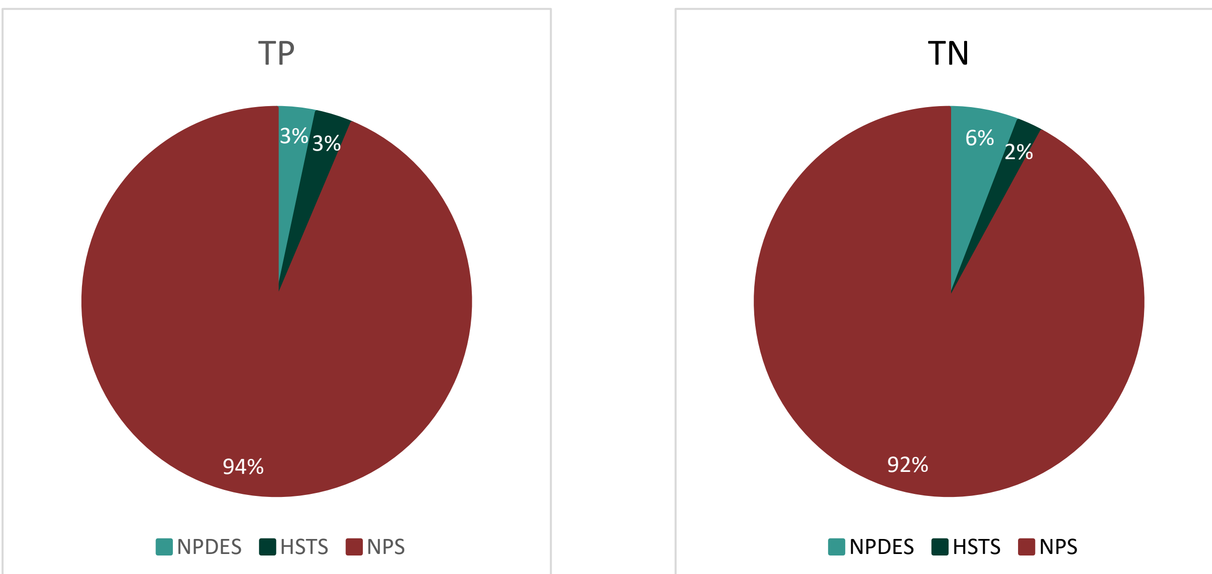


Figure 30 - Proportion of total phosphorus and nitrogen load from different sources for the Sandusky River and Sandusky Bay tributaries watershed, average of five years (wy19-wy23)

The Sandusky River is a central Lake Erie basin tributary and is targeted for a 40% reduction in annual total P loads to curb central basin hypoxia. There is also a watershed target of 40% reduction of spring total and dissolved phosphorus to address nearshore cyanobacteria blooms (Annex 4 of the 2012 Great Lakes Water Quality Agreement).

The NCWQR is located in Tiffin, Ohio in the center of the Sandusky River watershed and the river has been central to many of their loading studies. A NCWQR study estimated that only 4% of the annual phosphorus export in the Sandusky River was from point sources (Baker, 2006). Baker and others (2006) also presented a FWMC for total P as being the highest amongst the watersheds the Ohio EPA mass balance study. The results identified highlight the importance of nonpoint source loadings in a watershed that has 80% of its land use dedicated to agricultural production.

3.6 Huron River

The Huron River drains 406 sq. mi. in northwestern Ohio (Figure 31). The NCWQR monitors water quality at the USGS gaging station in Milan, Ohio, which serves as a pour point for nutrient calculations. The watershed area upstream is 370 sq. mi., while 35 sq. mi. is downstream. Agriculture dominates the entire watershed, making up 73% of the land use. Land use in the small area downstream of the pour point shifts to 28% natural land, 15% developed, and 57% agricultural.

With six years of available loading data, the maximum total P load was 217 mta in wy19, and the minimum was 118 mta in wy21 (Figure 32 and Table 11). Total N loads ranged from 1,665 mta in wy23 to 2,679 mta in wy19 (Figure 34 and Table 11). The total P and total N yields are presented on Figures 33 and 35.

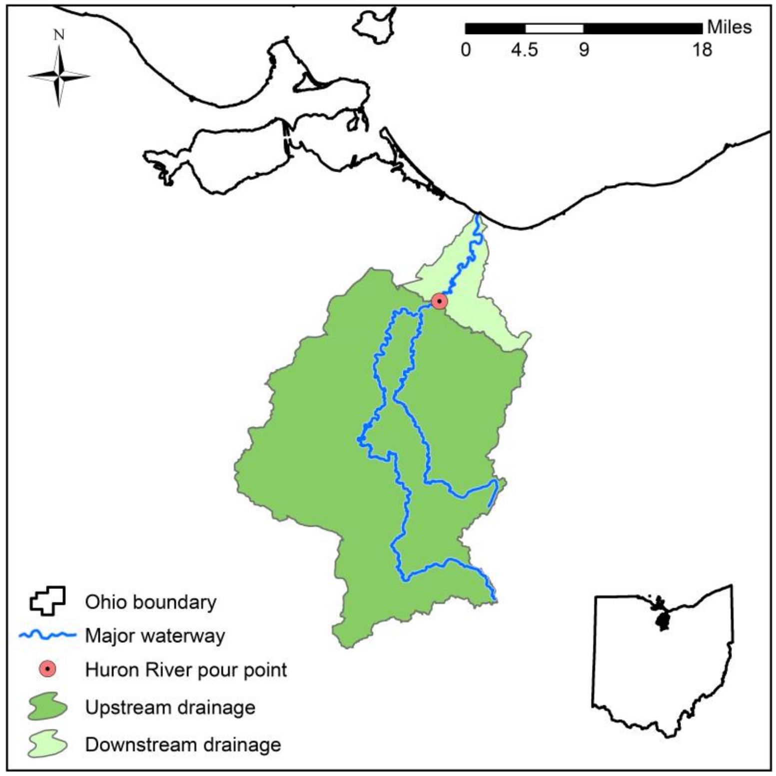


Figure 31 - Project area represented in the Huron River mass balance. A pour point is identified in one of the watersheds and yield calculations were used in the other two watershed areas

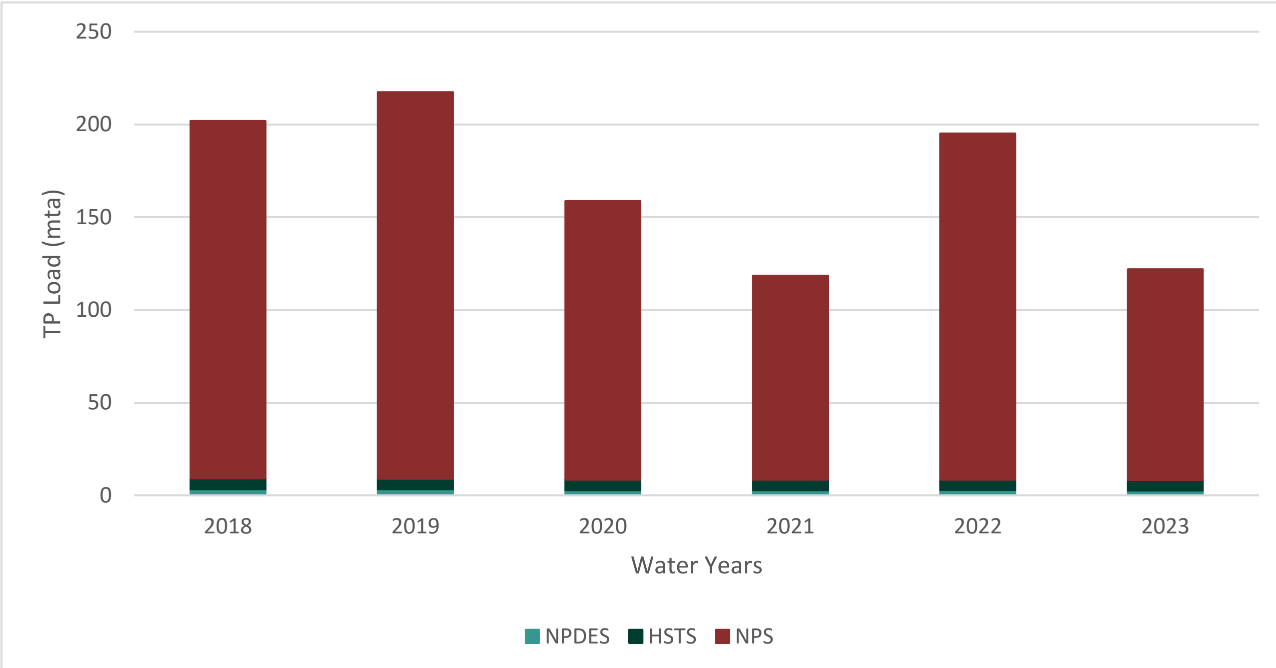


Figure 32 — Total phosphorus loads for Huron River for water year 2018-2023

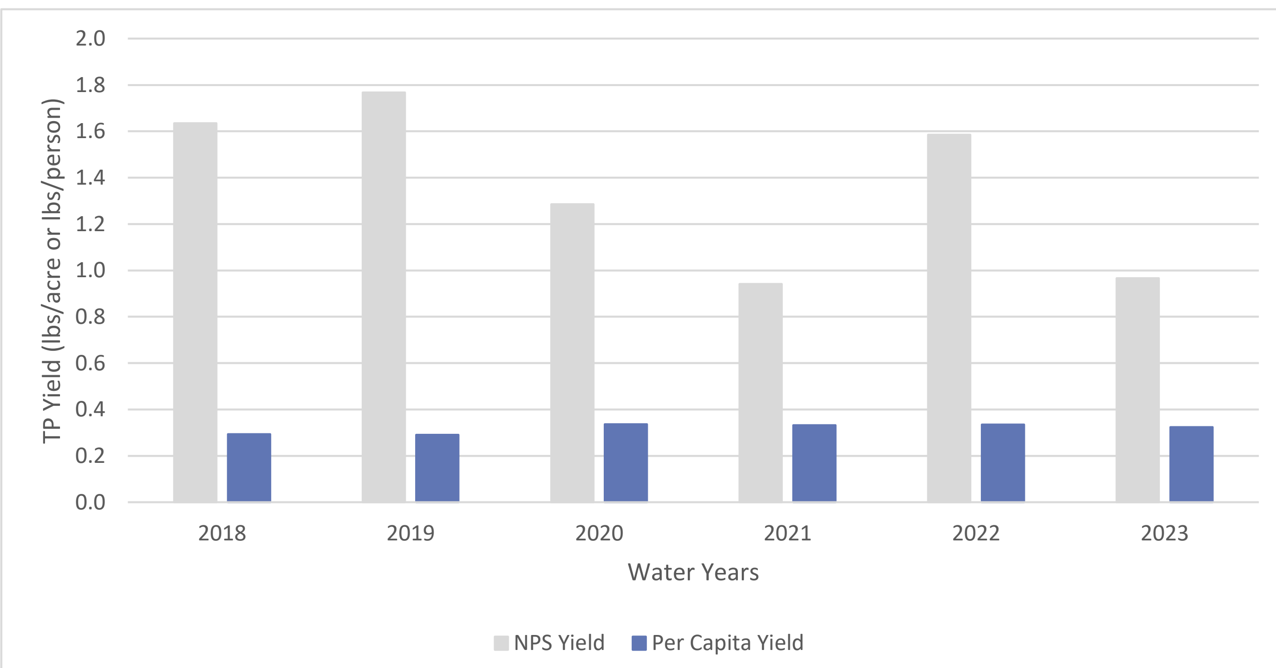


Figure 33 — Total phosphorus yields for Huron River for water year 2018-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

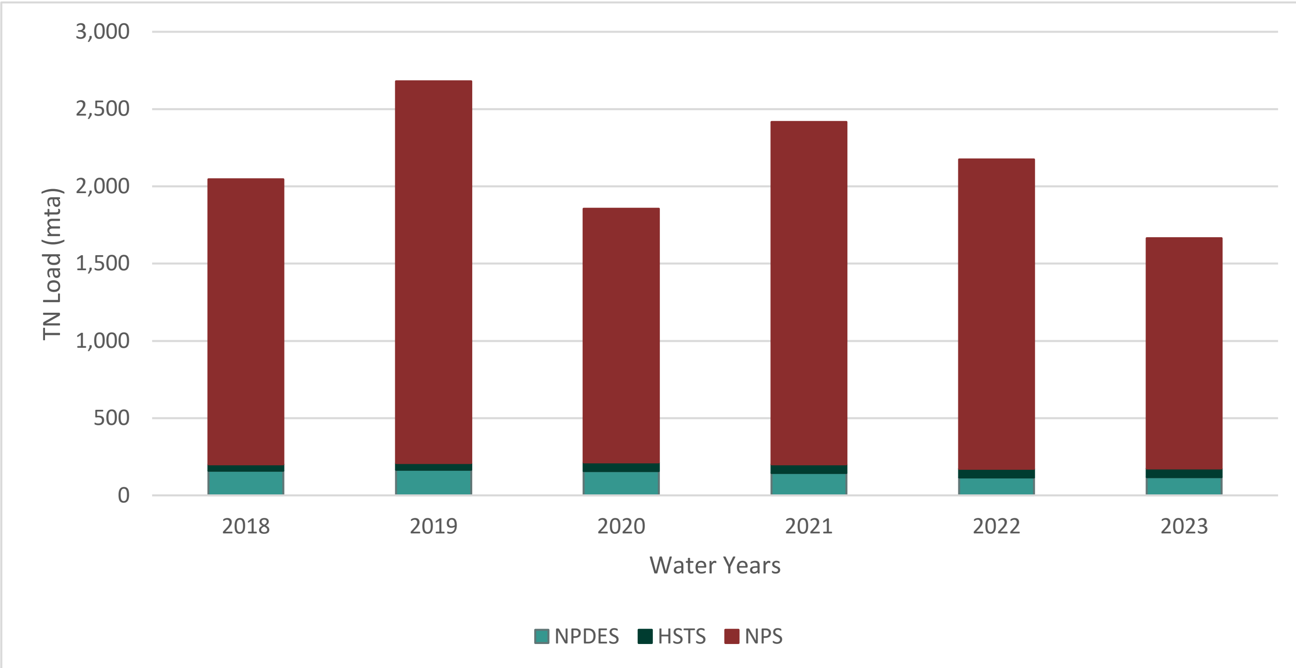


Figure 34 — Total nitrogen loads for Huron River for water year 2018-2023

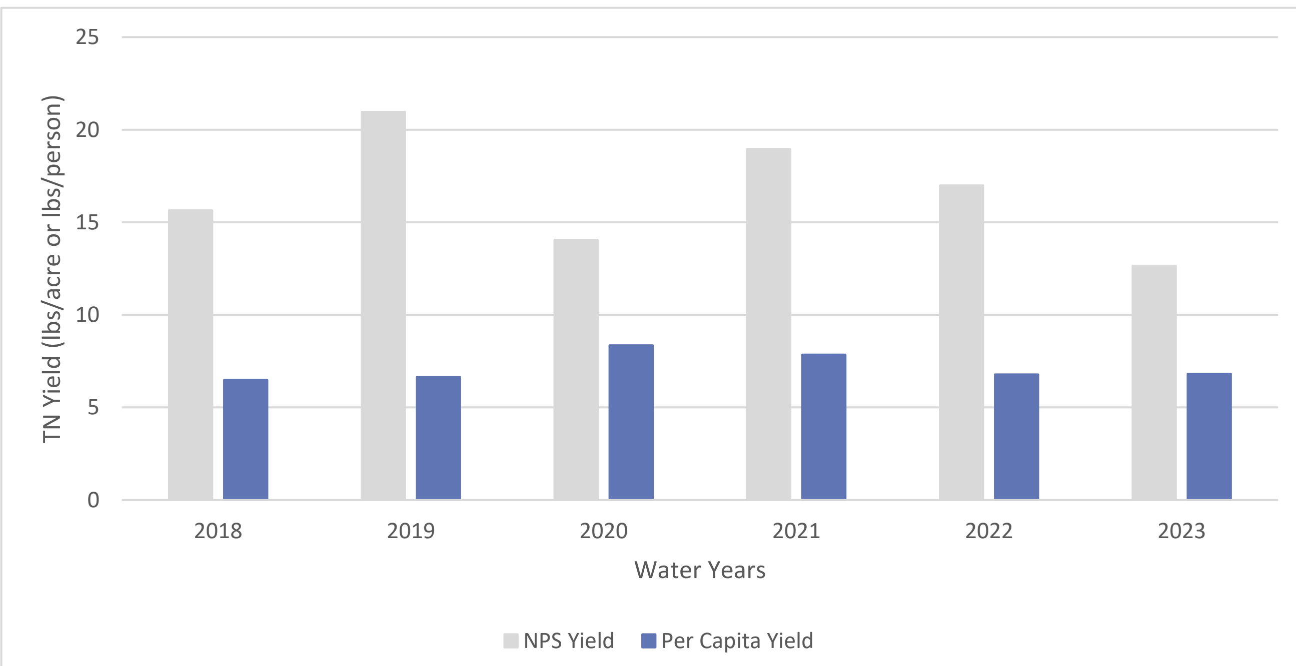


Figure 35 — Total nitrogen yields for Huron River for water year 2018-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

Table 11 — Annual flow-weighted mean concentration (FWMC), total load, and water yield for wy18 through wy23 for the Huron River

Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and water yield are calculated at the pour point and do not include downstream drainage area.

Parameter	wy18	wy19	wy20	wy21	wy22	wy23
Water Yield (in/yr)	16.4	21.0	13.1	15.0	14.6	11.0
20-yr Median Water Yield (in) – 15.4						
Total P						
FWMC (mg/L)	0.44	0.39	0.45	0.29	0.50	0.41
Annual Load (mta)	202	217	159	118	195	122
Total N						
FWMC (mg/L)	4.58	4.70	5.10	5.90	5.46	5.52
Annual Load (mta)	2,046	2,679	1,856	2,416	2,174	1,665

Over the past five years, nonpoint sources accounted for most P (95%) and total N (91%) loads in the Huron River (Figure 36). NPDES sources contributed 2% of total P and 7% of total N, while HSTS contributed 3% of total P and 2% of total N.

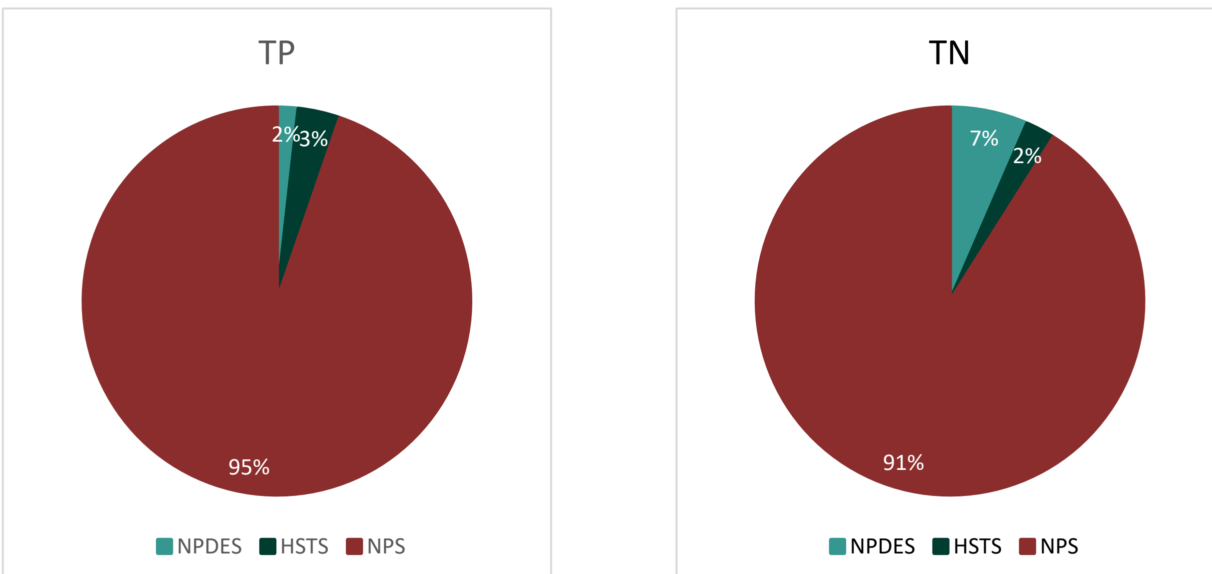


Figure 36 — Proportion of total phosphorus and nitrogen load from different sources for the Huron River watershed, average of two years (wy19-wy23)

3.7 Old Woman Creek

The Old Woman Creek area in northwestern Ohio drains 89 sq. mi. (Figure 37). The USGS monitors water quality at a gaging station on Old Woman Creek near Huron, which serves as the pour point for nutrient mass balance calculations. ODNR oversees daily sample collection as part of the Old Woman Creek National Estuarine Research Reserve, with loading data available starting from wy16.

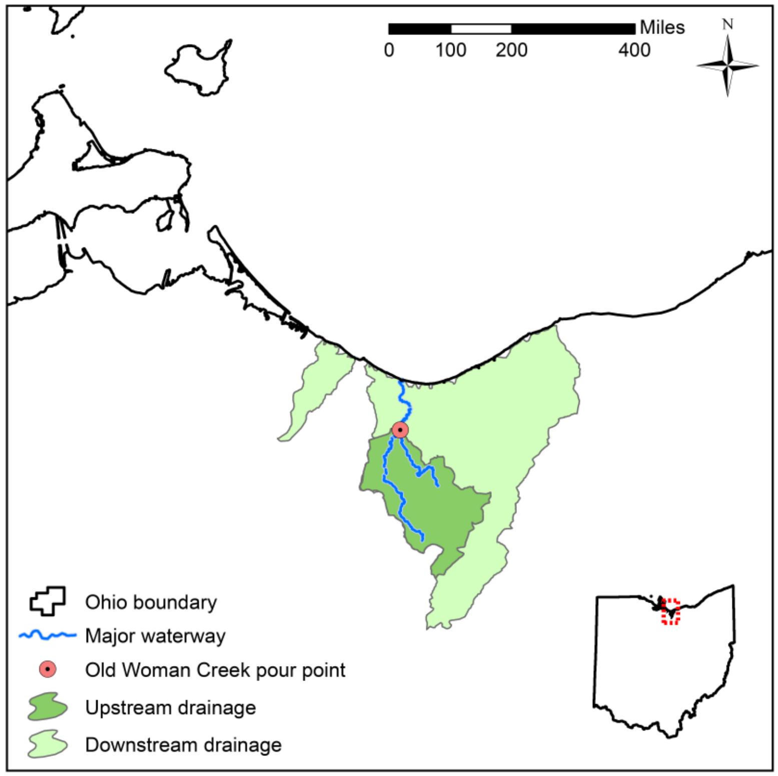


Figure 37— Project area represented in the Old Woman Creek area mass balance. A pour point was identified in one of the watersheds, and yield calculations were used in the other two watershed areas.

The watershed area upstream the pour point is 22 sq. mi. The area considered downstream the pour point drains 67 sq. mi., some of which includes watersheds of direct Lake Erie tributaries. Agricultural land accounts for 60% of the area's land use, while downstream the pour point has a higher percentage of natural land (30%) compared to upstream (19%).

From wy16 to wy23, the maximum total P loads was 38 metric tons per year (mta) in wy19 and minimum of 17 mta in wy22 (Figure 38 and Table 12). Total N loads reached a maximum of 627 mta in wy19 and a minimum of 292 mta in wy20 (Figure 40 and Table 12). Total P and total N yields are presented on Figures 39 and 41.

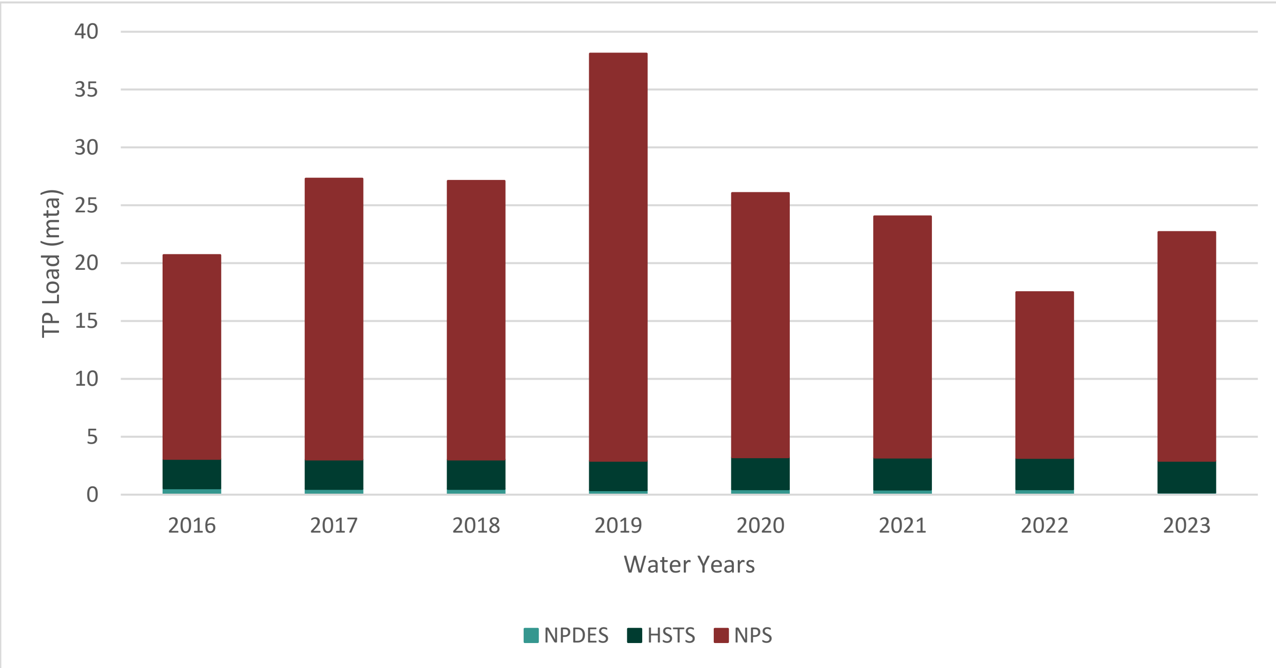


Figure 38 — Total phosphorus loads for Old Woman Creek for water year 2016-2023

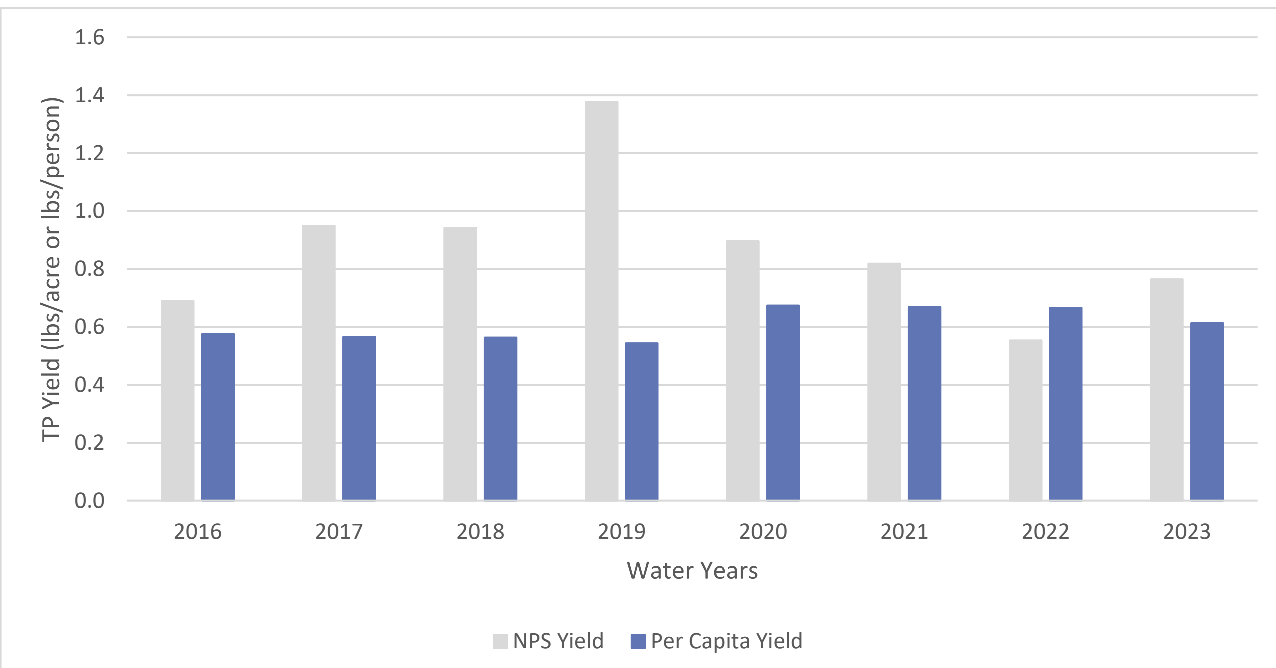


Figure 39 — Total phosphorus yields for Old Woman Creek for water year 2016-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

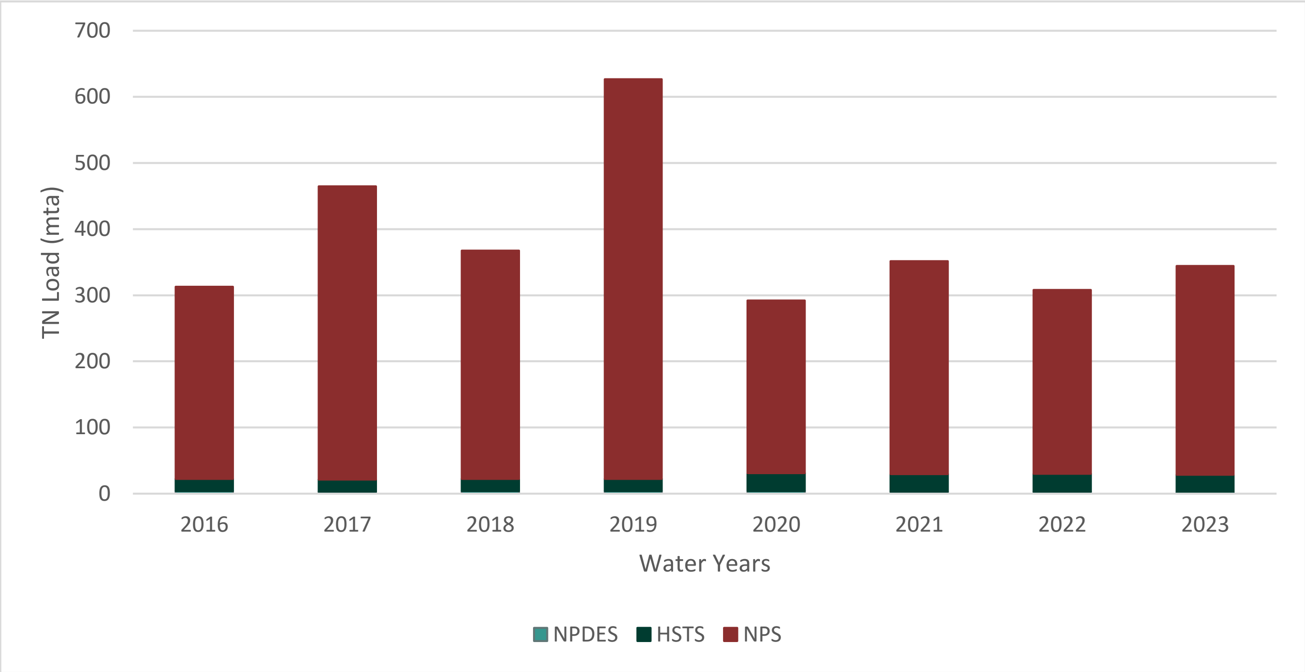


Figure 40 — Total nitrogen loads for Old Woman Creek for water year 2016-2023

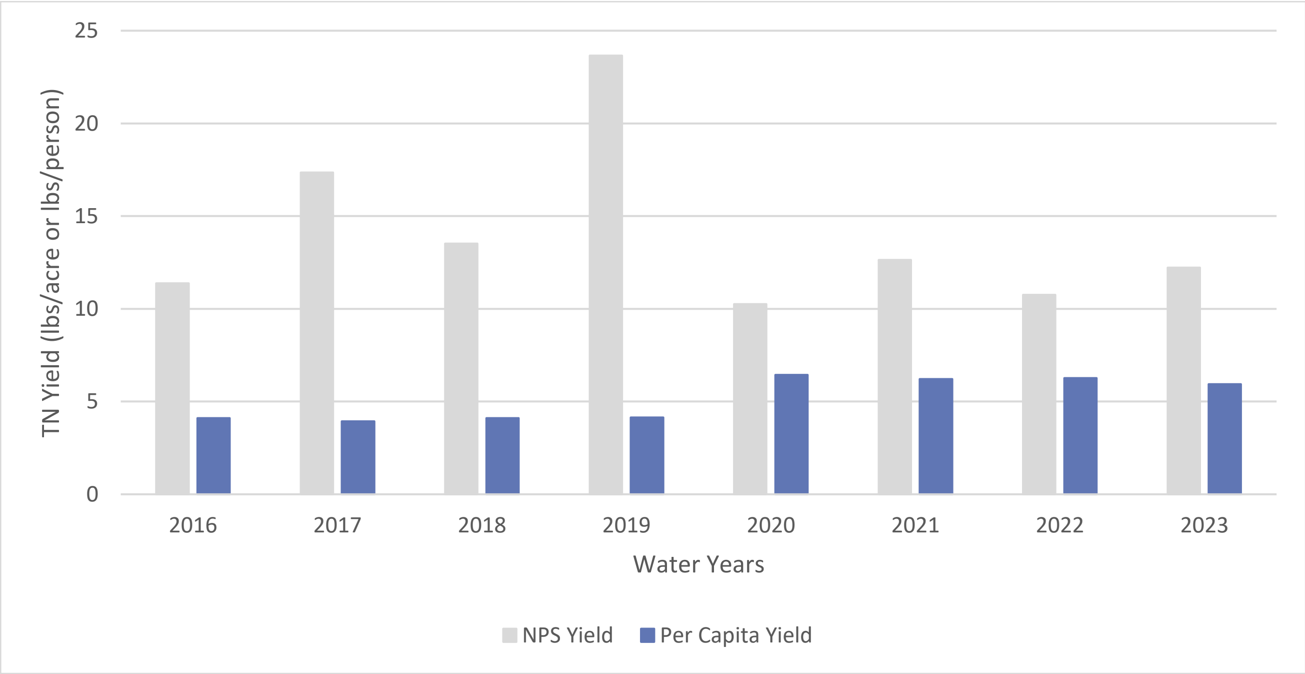


Figure 41 — Total nitrogen yields for Old Woman Creek for water year 2016-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

Table 12 — Annual flow-weighted mean concentration (FWMC), total load, and water yield for wy16 through wy23 for Old Woman Creek

Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and water yield are calculated at the pour point and do not include downstream drainage area.

Parameter	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Water Yield (in/yr)	16.5	16.7	14.3	11.4	13.0	17.6	23.7	11.7	11.5	12.3	11.1
20-yr Median Water Yield (in) – 15.4											
Total P											
FWMC (mg/L)	NA	NA	NA	0.30	0.36	0.26	0.28	0.36	0.34	0.23	0.33
Annual Load (mta)	NA	NA	NA	21	27	27	38	26	24	17	23
Total N											
FWMC (mg/L)	NA	NA	NA	4.67	6.13	3.57	4.55	4.11	5.11	4.11	5.14
Annual Load (mta)	NA	NA	NA	313	465	368	627	292	351	308	344

The analysis of the last five years of data shows that nonpoint sources account for the majority of total P (88%) and total N (93%) loads in Old Woman Creek (Figure 42). NPDES sources contribute 2% of total P and 1% of total N, while HSTS sources account for 10% of total P and 6% of total N.

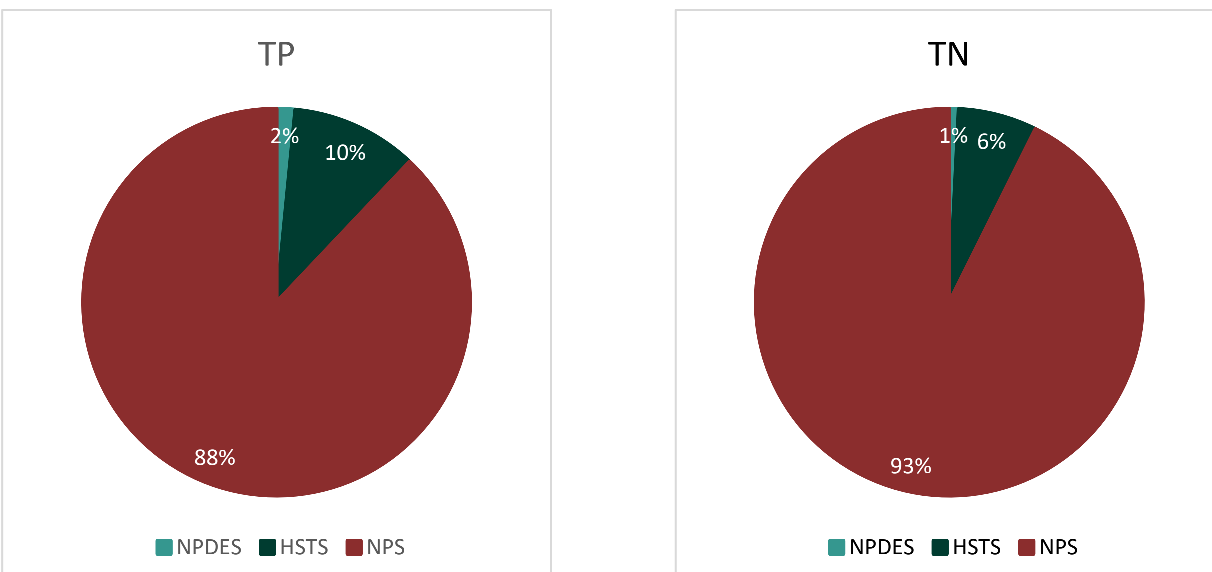


Figure 42 — Proportion of total phosphorus and nitrogen load from different sources for Old Woman Creek, an average of five years (wy19-wy23)

3.8 Vermilion River

The Vermilion River drains 267 sq. mi. in north-central Ohio, with a USGS water quality station in Vermilion used for nutrient mass balance calculations (Figure 43). Agriculture dominates the watershed's land use at 65%. There are only 7 sq. mi. downstream of the pour point. Natural areas increase to 42% of land use in the small downstream zone compared to 26% upstream of the pour point.

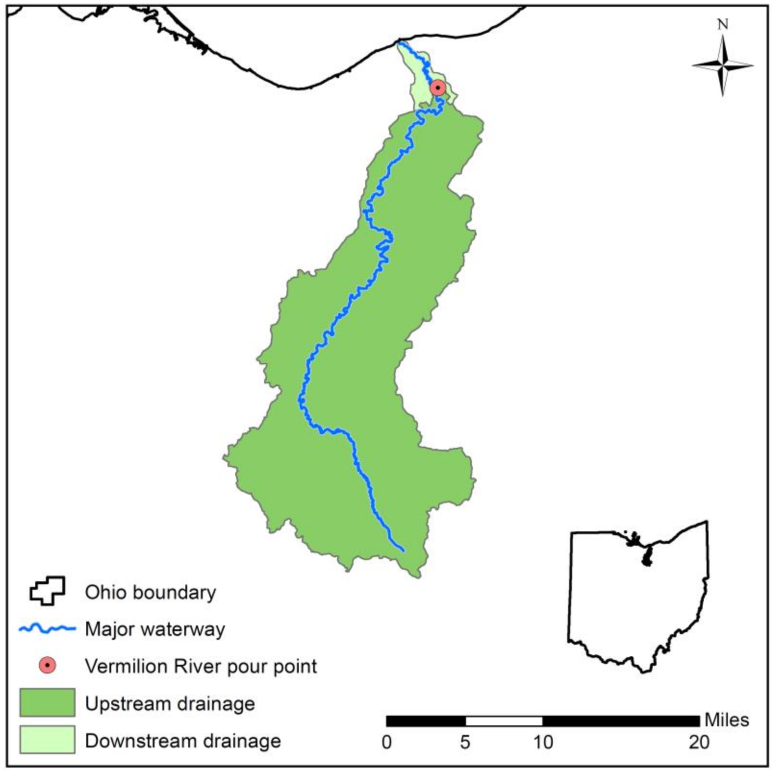


Figure 43 — Project area represented in the Vermilion River mass balance. The pour point, up, and downstream drainage areas are shown.

USGS collects monthly water quality samples at this gage and computes loads from this monitoring. This is a different load calculation method from all the other watersheds in this report.

Nutrient load data for wy22 and wy23 are not yet available and Ohio EPA intends to include these in an addendum to this report. For wy13 to wy22, the maximum total P loads were 156 metric tons per year (mta) in wy19, and the minimum was 68 mta in wy16 (Figure 44 and Table 13). Total N loads reached a maximum of 2,065 mta in wy19 and a minimum of 792 mta in wy20 (Figure 46 and Table 13). Total P and total N yields are presented in Figures 45 and 47.

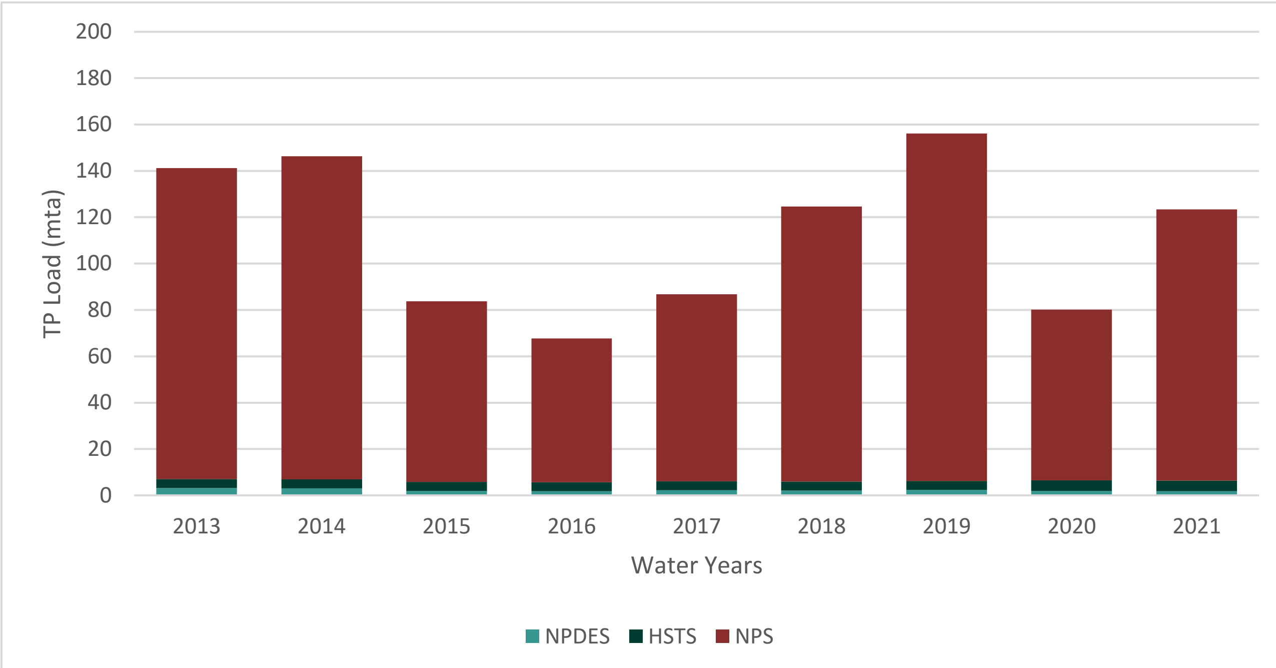


Figure 44 — Total phosphorus loads for the Vermilion River for water year 2013-2021

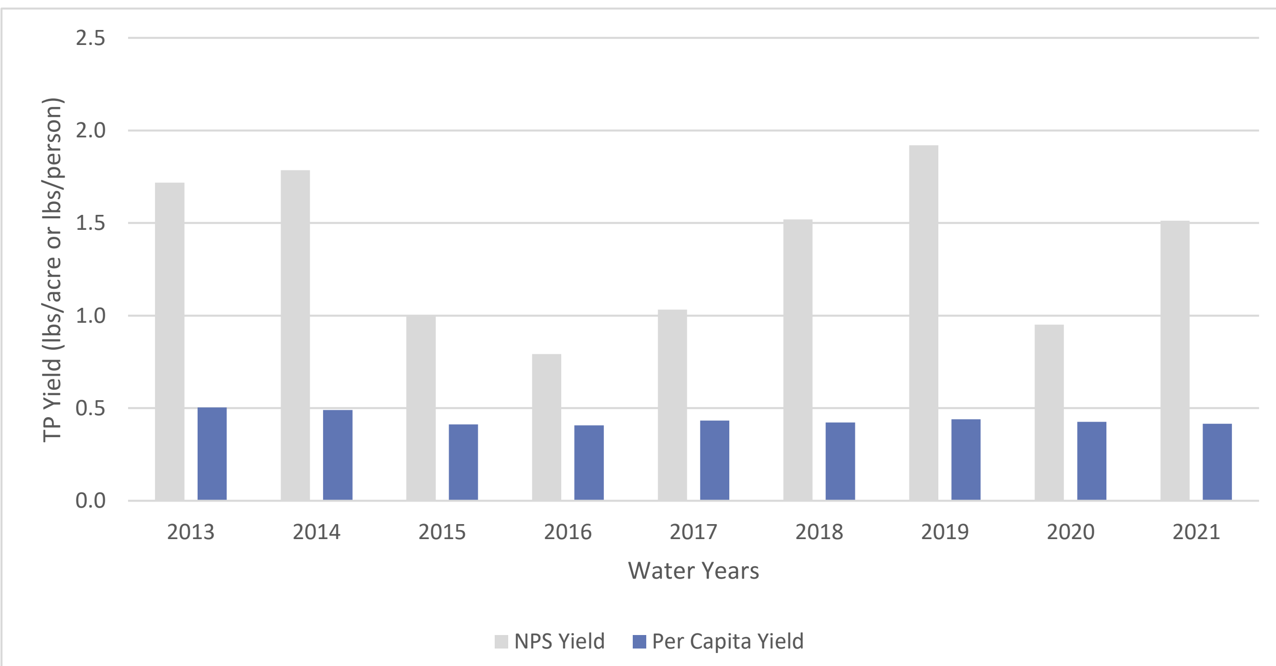


Figure 45 — Total phosphorus yields for the Vermilion River for water year 2013-2021

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

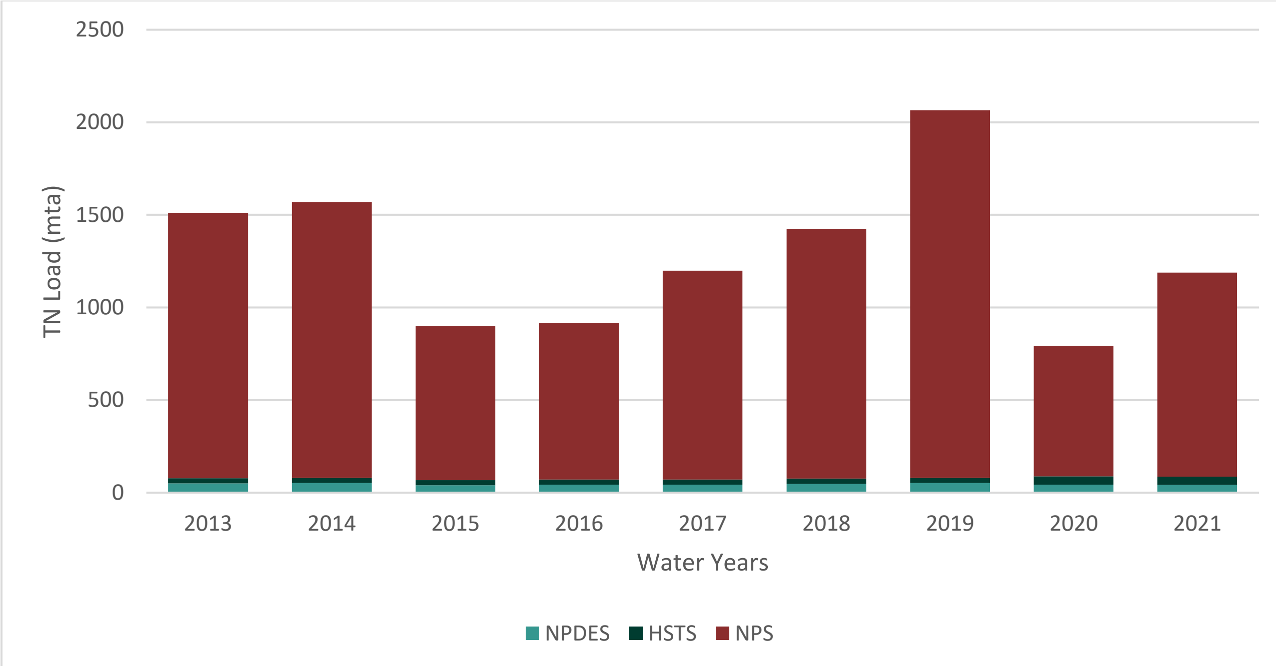


Figure 46 — Total nitrogen loads for the Vermilion River for water year 2013-2021

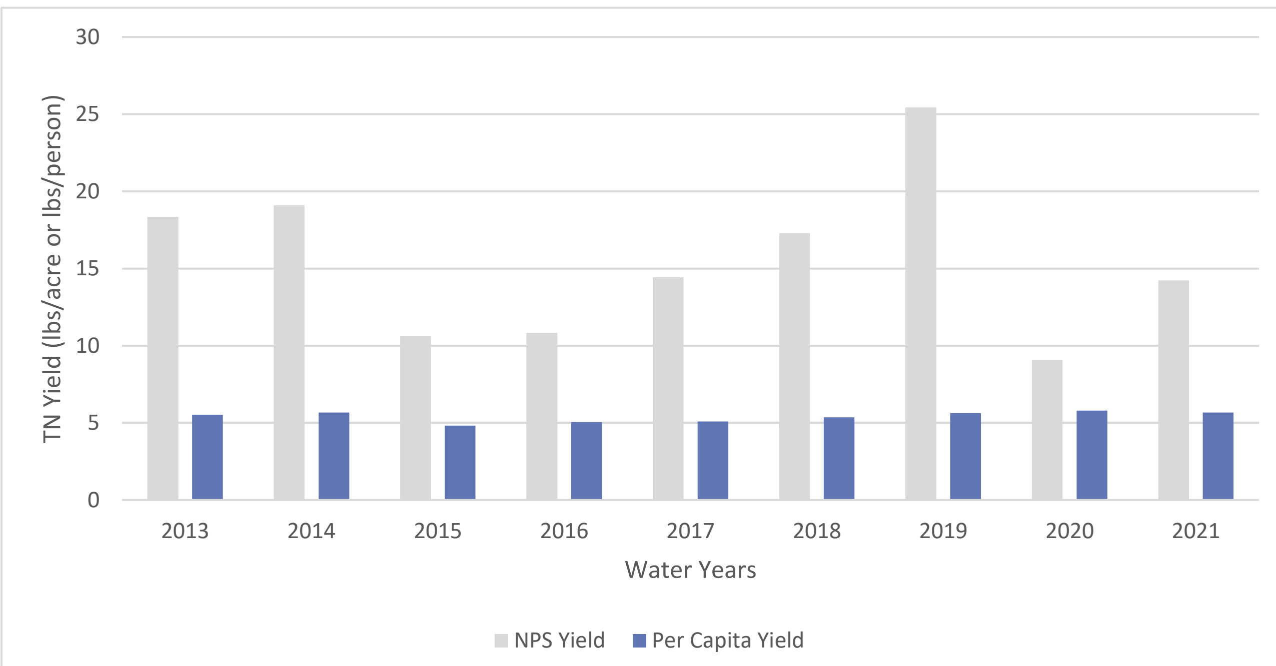


Figure 47 — Total nitrogen load yields for the Vermilion River for water year 2013-2021

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

Table 13 — Annual flow-weighted mean concentration (FWMC), total load, and water yield for wy13 through wy21 for the Vermilion watershed

Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and water yield are calculated at the pour point and do not include downstream drainage area.

Parameter	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Water Yield (in/yr)	16.9	18.3	11.3	10.8	13.7	16.2	21.1	12.8	15.2	16.0	13.7
20-yr Median Water Yield (in) – 16.1											
Total P											
FWMC (mg/L)	0.47	0.45	0.42	0.35	0.35	NA	NA	NA	NA	TBD	TBD
Annual Load (mta)	141	146	84	68	87	125	156	80	123	TBD	TBD
Total N											
FWMC (mg/L)	4.95	4.75	4.38	4.69	4.85	NA	NA	NA	NA	TBD	TBD
Annual Load (mta)	1,510	1,571	899	917	1,199	1,425	2,065	792	1,188	TBD	TBD

The recent five-year averages of total P and total N loads in the Vermilion River show that nonpoint sources account for 94% of both (Figure 48). NPDES sources contribute 2% of total P and 3% of total N, while HSTS sources account for 2% of total P and 3% of total N.

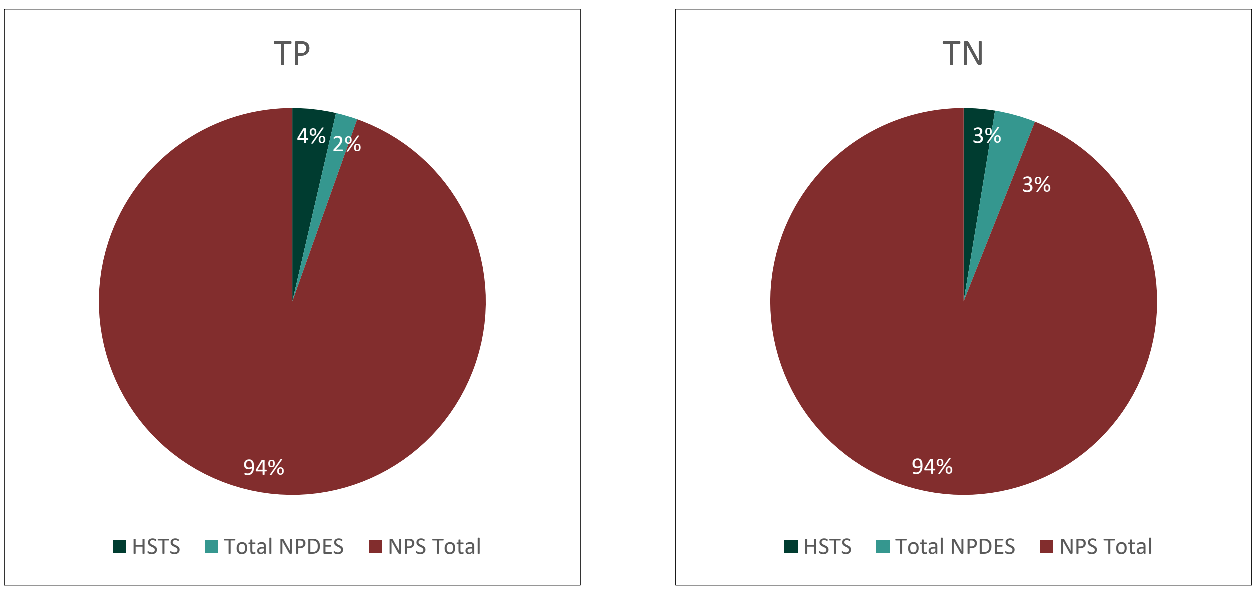


Figure 48 — Proportion of total phosphorus and nitrogen load from different sources for the Vermilion watershed, an average of five years (wy17-wy21)

The data collected by the USGS was robust enough to allow for a load estimate to be derived; however, in part due to the watershed's size, it has not been widely studied outside of the USGS's current effort. The Vermilion River is a central Lake Erie basin tributary and is targeted for a 40% reduction in annual loads to curb central basin hypoxia (Annex 4 of the 2012 Great Lakes Water Quality Agreement).

3.9 Cuyahoga River

The Cuyahoga River drains 809 sq. mi. in northeast Ohio (Figure 49). The NCWQR maintains a water quality station at the USGS gaging station in Independence. The watershed area upstream of the pour point is 704 sq. mi., while 105 sq. mi. is downstream.

Land use in the watershed comprises 38% natural areas and 47% development, with a significant increase in development downstream of the pour point (from 41% upstream to 90% downstream) due to the Cleveland metro area.

Maximum total P loads were 398 mta in water year 2019 and a minimum of 206 mta in 2016 (Figure 50 and Table 14). Total N loads reached a maximum of 6,561 mta in 2019 and 4,613 mta in 2023 (Figure 52 and Table 14). Total P and total N yields are presented in Figures 51 and 53.

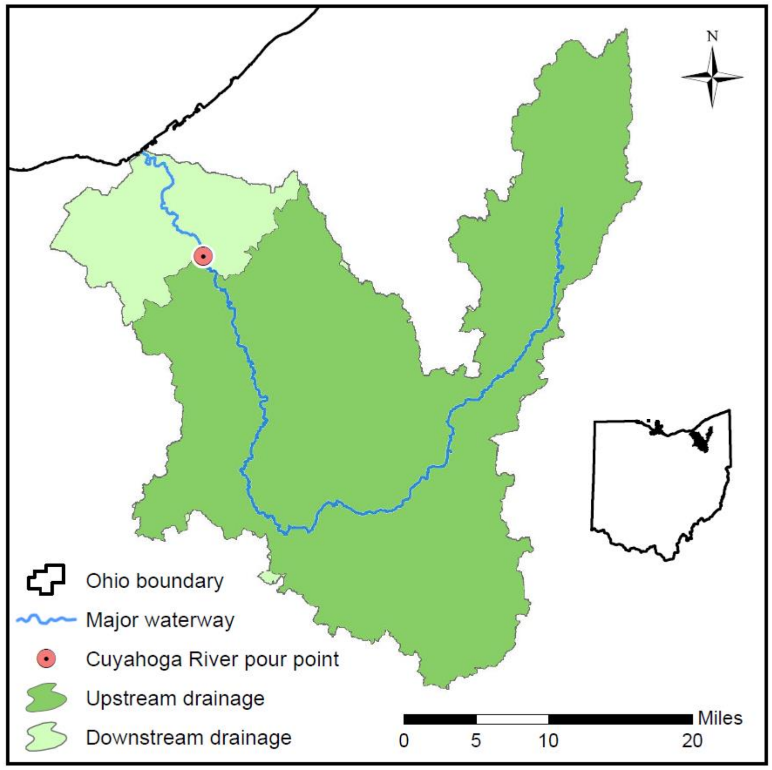


Figure 49— Project area represented in the Cuyahoga River mass balance. The pour point, up, and downstream drainage areas are shown.

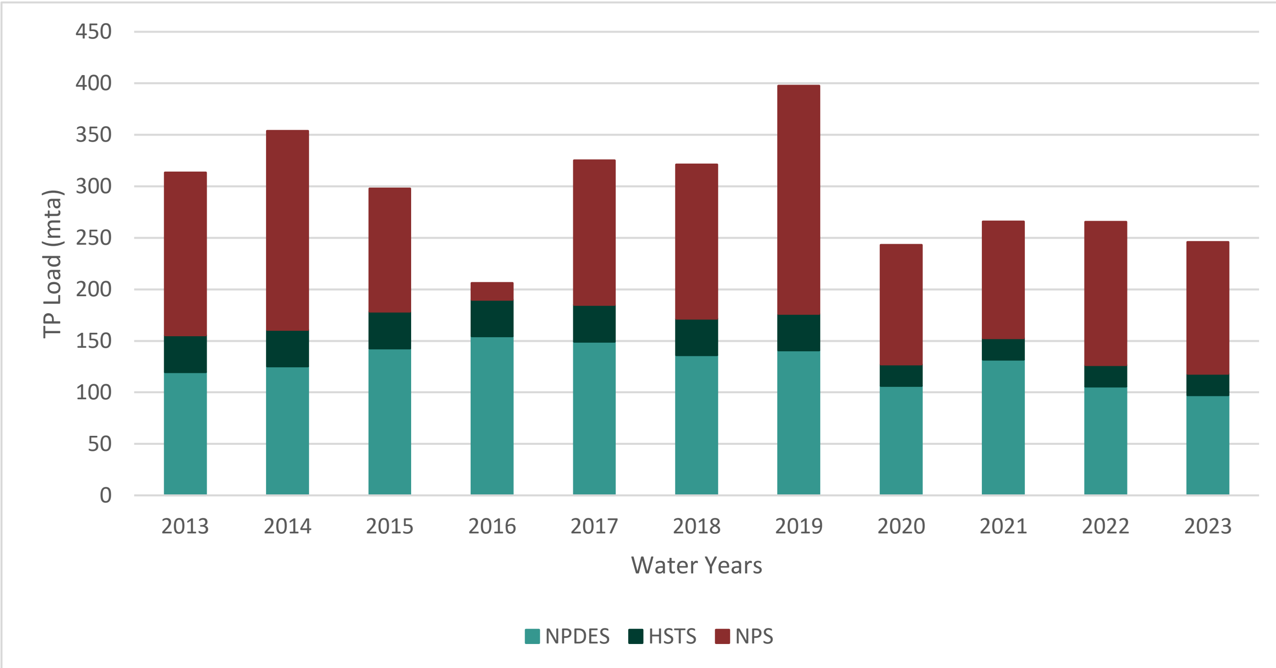


Figure 50 — Total phosphorus loads for the Cuyahoga River for water year 2013-2023

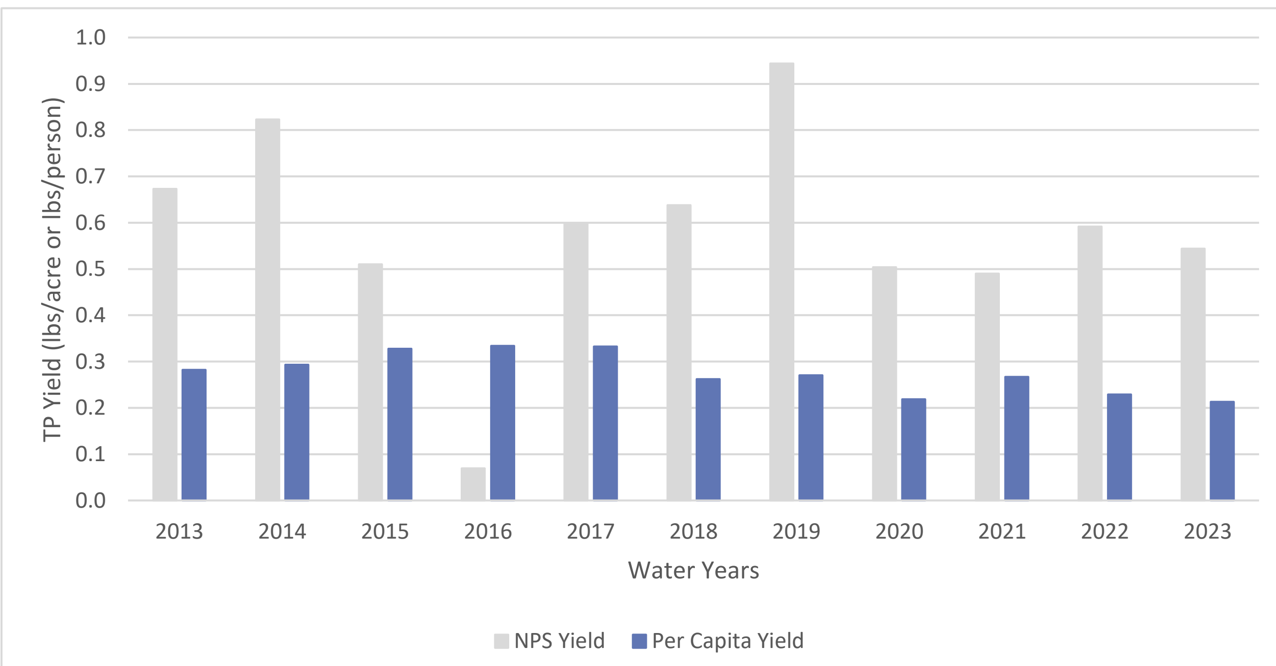


Figure 51 — Total phosphorus yields for the Cuyahoga River for water year 2013-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

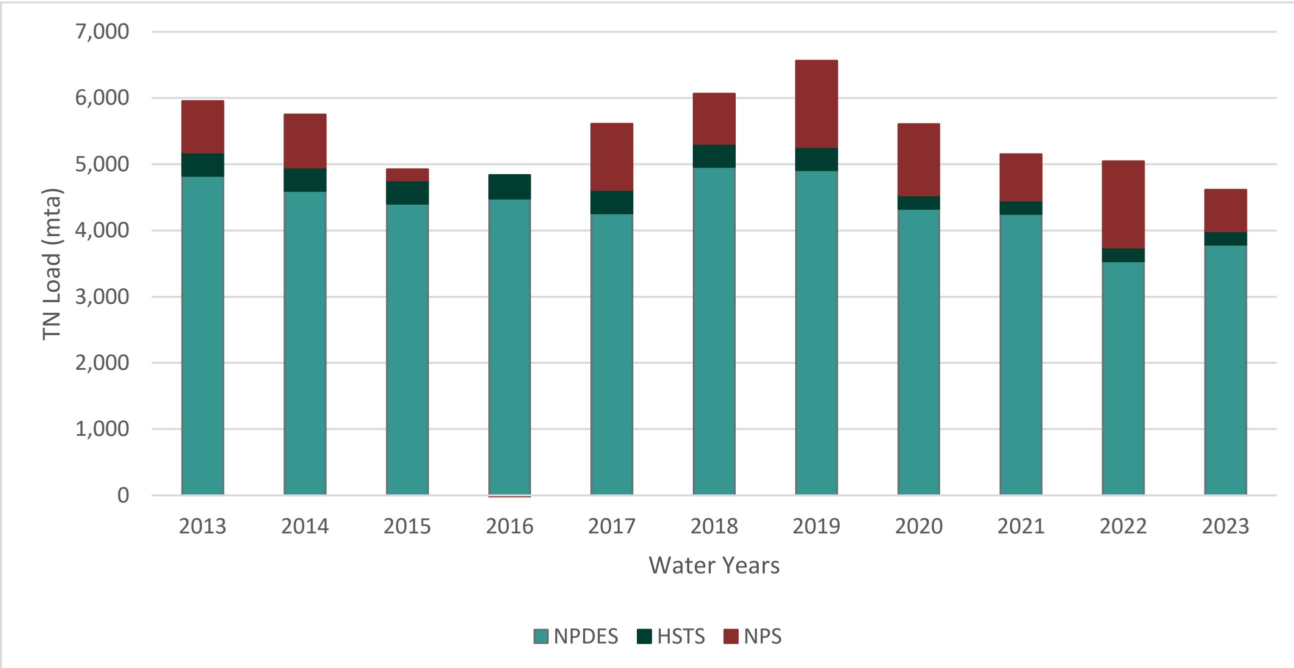


Figure 52 — Total nitrogen loads for the Cuyahoga River for water year 2013-2023

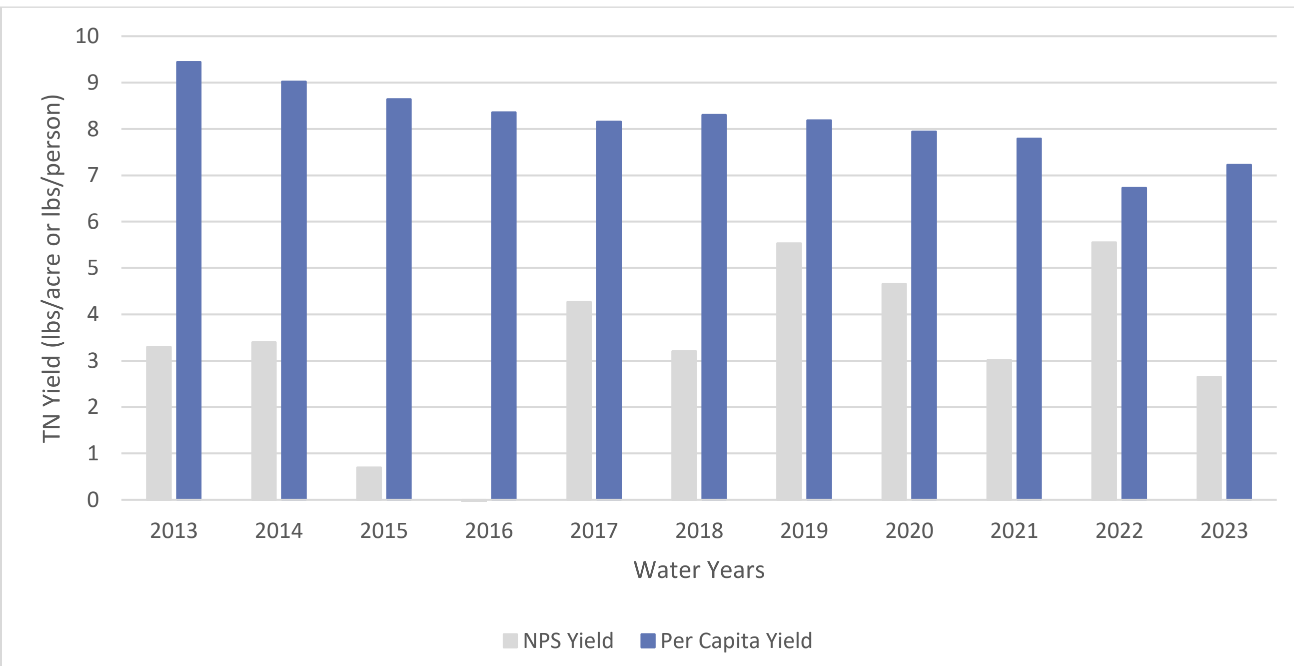


Figure 53 — Total nitrogen yields for the Cuyahoga River for water year 2013-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

Table 14 — Annual flow-weighted mean concentration (FWMC), total load, and water yield for wy13 through wy23 for the Cuyahoga watershed

Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and water yield are calculated at the pour point and do not include downstream drainage area.

Parameter	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Water Yield (in/yr)	21.3	22.4	20.9	16.1	23.9	23.2	29.0	21.6	19.2	21.2	19.1
20-yr Median Water Yield (in) – 22.0											
Total P											
FWMC (mg/L)	0.24	0.25	0.20	0.15	0.19	0.20	0.20	0.16	0.19	0.19	0.19
Annual Load (mta)	313	354	298	206	325	321	398	243	266	266	246
Total N											
FWMC (mg/L)	2.73	2.81	2.43	2.69	2.63	2.41	2.29	2.90	2.80	3.01	2.69
Annual Load (mta)	5,952	5,750	4,921	4,738	5,612	6,062	6,561	5,605	5,148	5,045	4,613

Over the last five water years, nonpoint sources contributed 51% of the total P load and 19% of the total N load (Figure 54). NPDES sources accounted for 41% of the total P and 77% of the total N loads, marking the highest proportions of these sources among the watersheds studied. HSTS communities contributed 8% to the total P and 4% to the total N loads.

The mass balance methods indicate that some landscape areas act as sources while others serve as sinks for total P and N. In wy16, nonpoint sources exhibited a net negative yield for total N, the only instance of such a result in the studied watersheds.

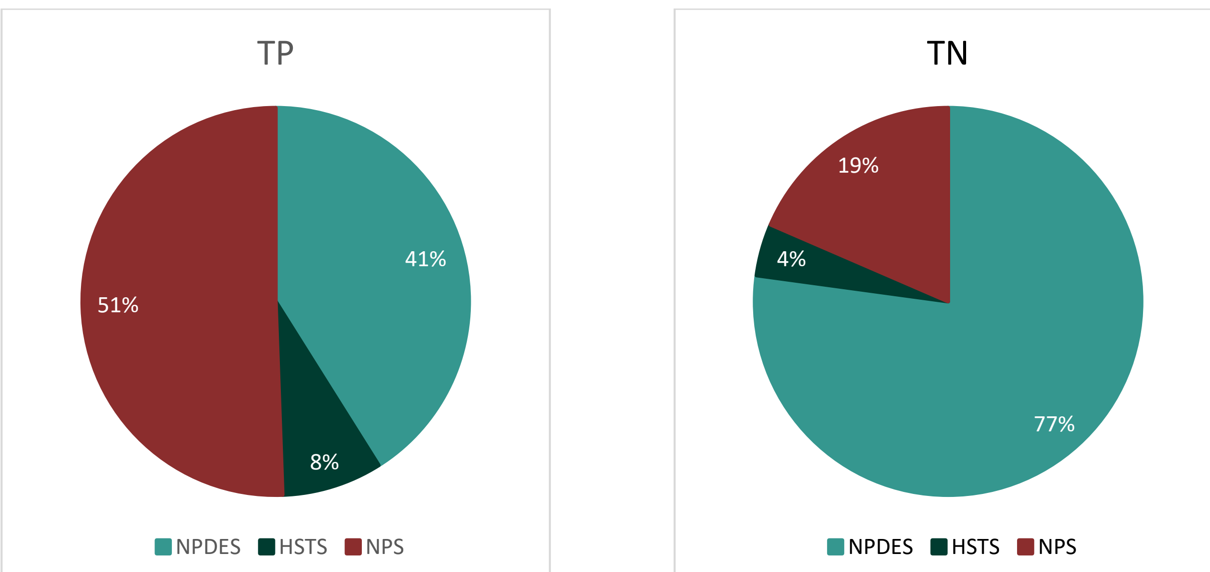


Figure 54— Proportion of total phosphorus and nitrogen load from different sources for the Cuyahoga watershed, average of five years (wy19-wy23)

The Cuyahoga River is one of Ohio's most urbanized watersheds, with more than 1,440 people per square mile, leading to high point source loading (Table 6). However, the relative loading of total P is lower than that of total N, indicating the effectiveness of phosphorus control limits at wastewater treatment plants discharging flow rates of one million gallons a day or more. Despite higher flow from point sources, the time-weighted mean concentration of total P is lower than that of the Scioto and Great Miami rivers (Baker et al., 2006).

3.10 Great Miami River

The Great Miami River drains 3,892 sq. mi. in southwest Ohio and southeast Indiana (Figure 55). This report excludes the drainage area for the Whitewater River tributary that primarily drains land within Indiana. The NCWQR operates a water quality station at the USGS gaging station in Miamisburg, Ohio, which serves as a pour point for nutrient mass balance calculations.

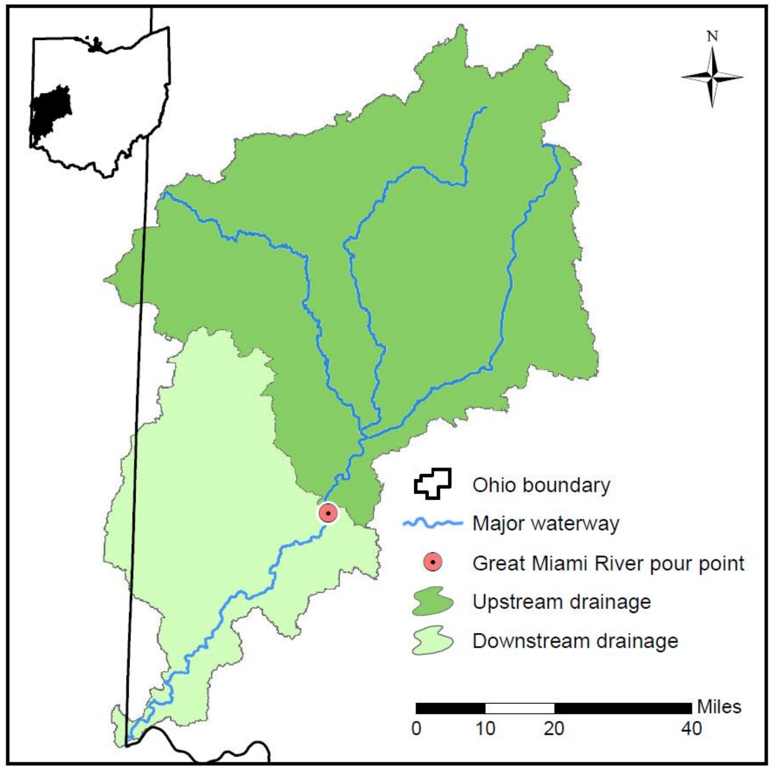


Figure 55— Project area represented in the Great Miami River mass balance. The pour point, up, and downstream drainage areas are shown.

The upstream watershed area is 2,712 sq. mi., while downstream it is 1,180 sq. mi. The watershed is predominantly agricultural, with 66% in production; however, there is a notable shift to natural areas downstream of the pour point.

Maximum total P loads were observed at 2,475 mta in water year 2019 and a minimum of 883 mta in water year 2016 (Figure 56 and Table 15). Total N loads reached a maximum of 28,367 mta in water year 2019 and a minimum of 14,258 mta in water year 2023 (Figure 58 and Table 15). Total P and total N yields are presented on Figures 57 and 59.

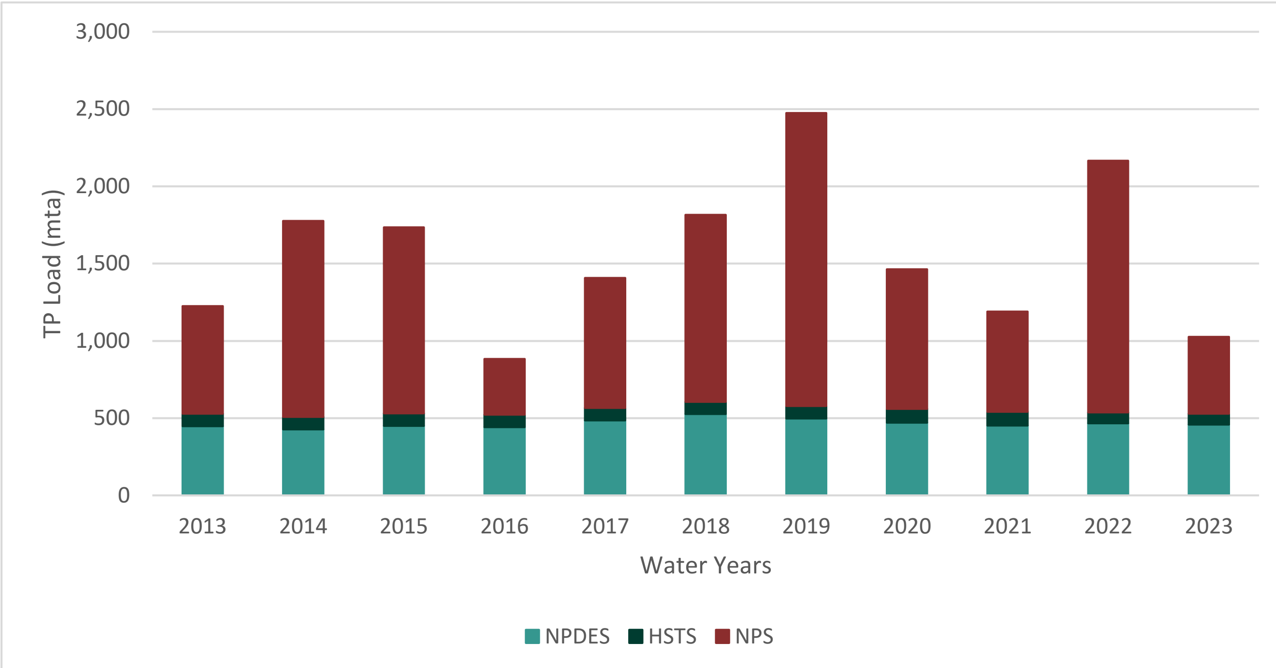


Figure 56 — Total phosphorus loads for the Great Miami River for water year 2013-2023

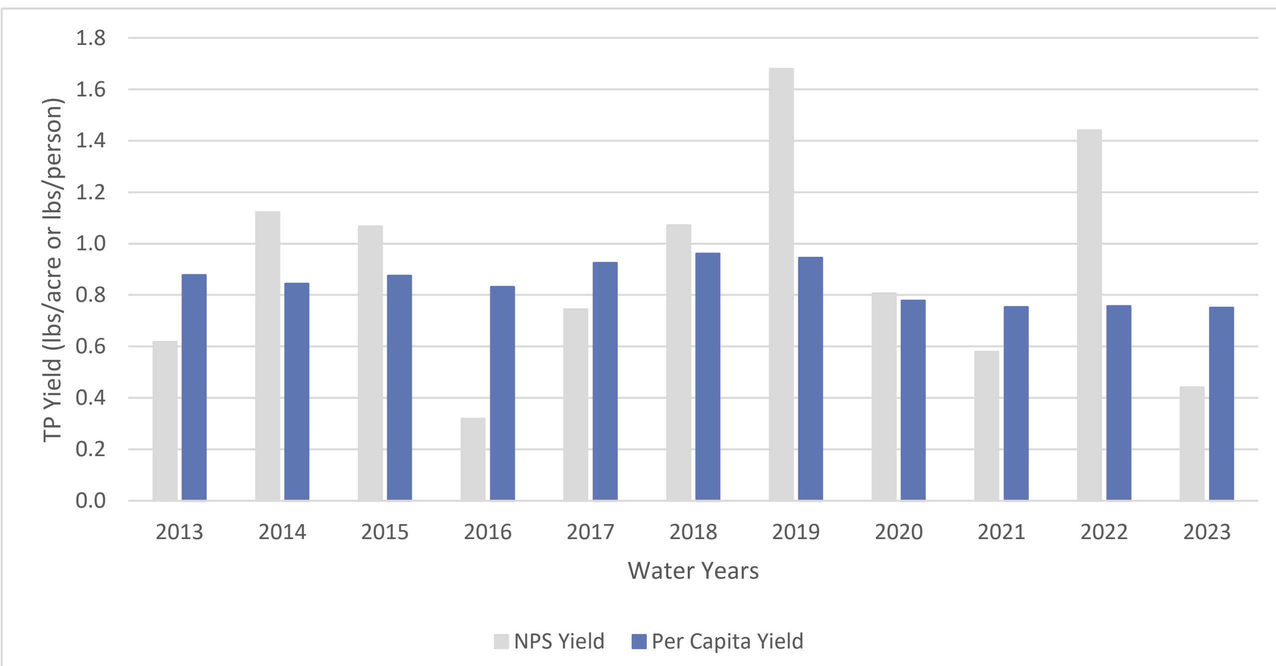


Figure 57 — Total phosphorus yields for the Great Miami River for water year 2013-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

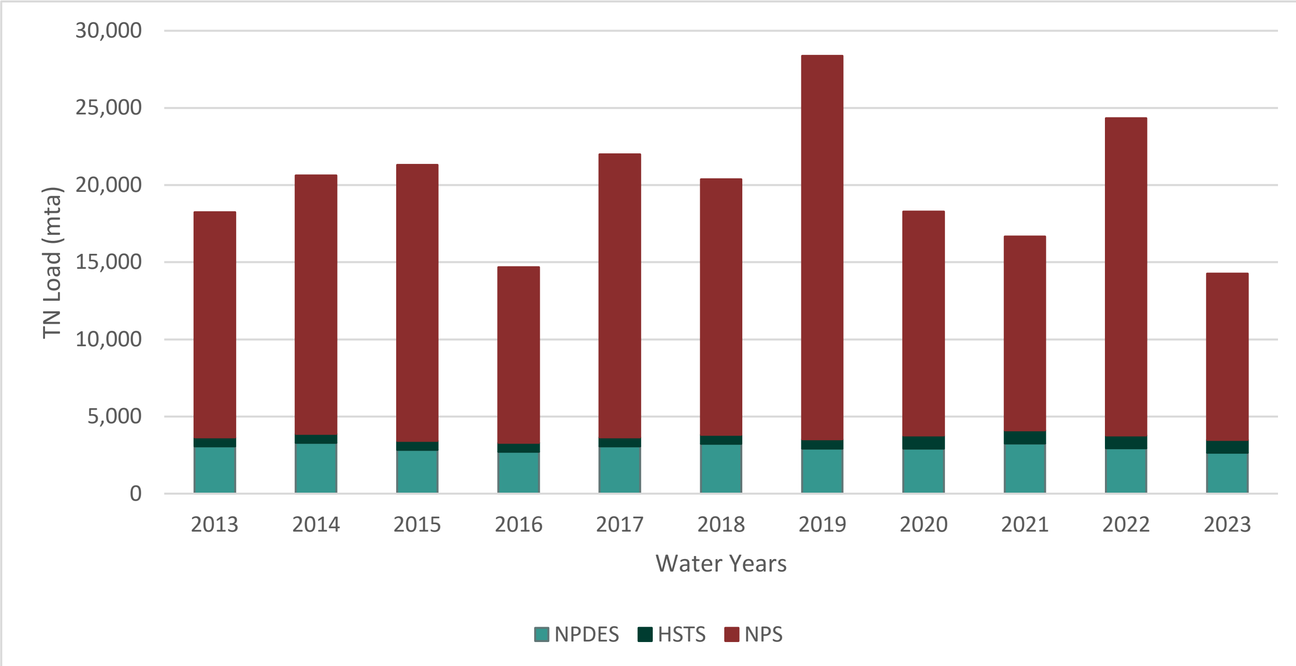


Figure 58 — Total nitrogen loads for the Great Miami River for water year 2013-2023

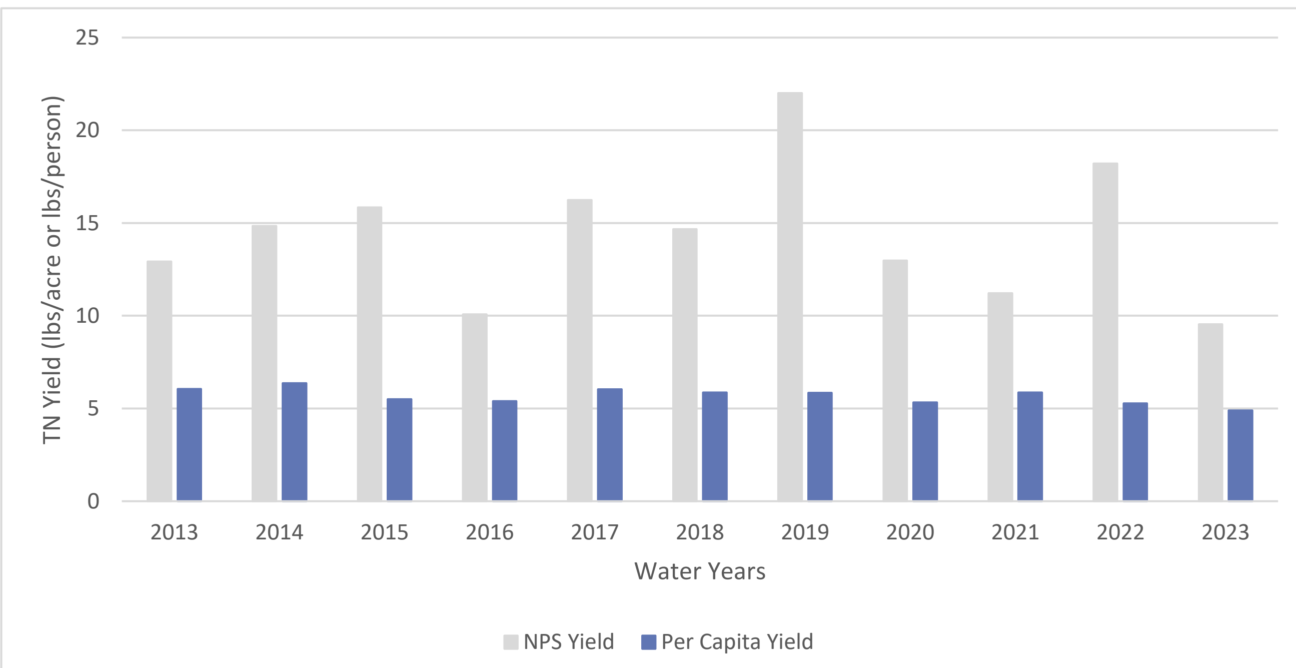


Figure 59 — Total nitrogen yields for the Great Miami River for water year 2013-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

Table 15 — Annual flow-weighted mean concentration (FWMC), total load, and water yield for wy13 through wy23 for the Great Miami watershed

Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and water yield are calculated at the pour point and do not include downstream drainage area.

Parameter	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Water Yield (in/yr)	13.6	18.2	15.6	13.3	15.2	19.8	27.2	14.9	13.2	20.1	10.7
20-yr Median Water Yield (in) – 17.1											
Total P											
FWMC (mg/L)	0.37	0.39	0.64	0.25	0.37	0.37	0.36	0.39	0.36	0.42	0.38
Annual Load (mta)	1,226	1,775	1,734	883	1,407	1,816	2,475	1,464	1,189	2,165	1,026
Total N											
FWMC (mg/L)	5.33	4.68	5.29	4.02	6.20	4.04	4.05	4.80	5.00	4.74	5.24
Annual Load (mta)	18,234	20,631	21,295	14,669	21,980	20,373	28,367	18,282	16,667	24,340	14,258

The relative proportions of nonpoint source, NPDES, and HSTS loads for total P and total N over the last five years are as follows: nonpoint sources account for 67% of total P and 82% of total N in the Great Miami River (Figure 60). NPDES sources contribute 28% of total P and 14% of total N, while HSTS contributes 5% of total P and 4% of total N.

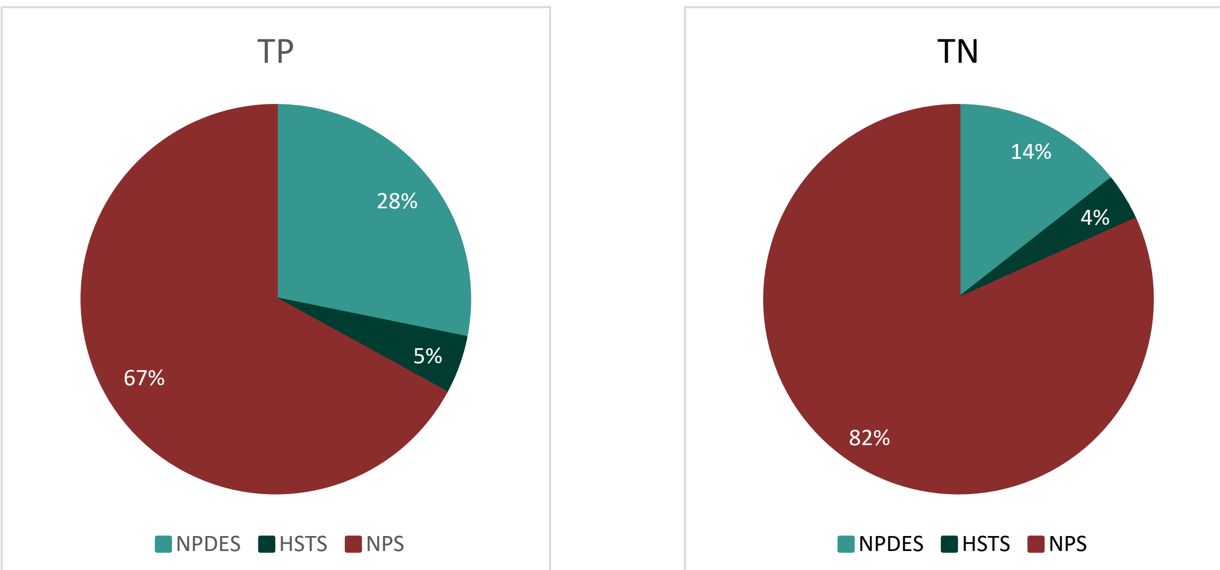


Figure 60 — Proportion of total phosphorus and nitrogen load from different sources for the Great Miami watershed, average of five years (wy19-wy23)

The Great Miami River has been identified as a major nutrient contributor to the Gulf of Mexico. A NOAA study (Goolsby, 1999) indicated this watershed had one of the highest total P and dissolved phosphorus yields among 42 watersheds in the Mississippi-Atchafalaya River basin. Additionally, an NCWQR study found the river had the highest soluble reactive phosphorus concentrations among 10 Ohio streams (Baker, 2006). A study by the Miami Conservancy District (MCD, 2012) revealed that dissolved orthophosphate made up 63% of total P, with total P concentrations rising at both high and low flows. These findings highlight increased NPDES sources for total P, supporting Ohio EPA mass balance efforts.

3.11 Little Miami River

The Little Miami River drains an area of 1,317 square miles in southwest Ohio, including the East Fork Little Miami River subwatershed (Figure 61). This watershed has two pour points, one on the Little Miami River and the other on its East Fork tributary. USGS monitors water quality at both pour at streamflow gages. The watershed area upstream of the Little Miami River pour point is 1,202 sq. mi., while upstream of the East Fork pour point covers 476 sq. mi. The area downstream of both pour points is 78 sq. mi.

The overall watershed is predominantly agricultural (54%). Downstream of the pour points, the land use shifts to more developed land, which accounts for 57% of the area.

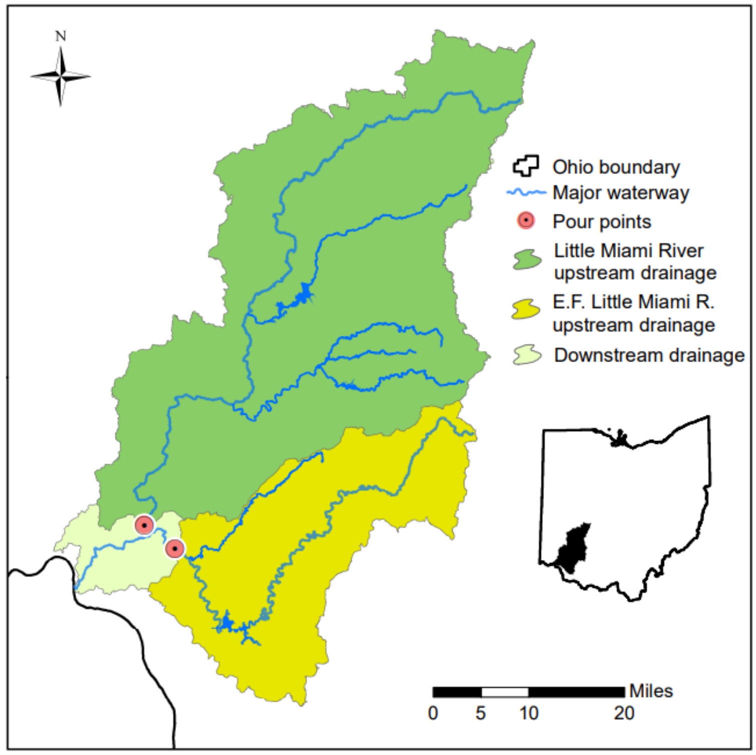


Figure 61 — Project area represented in the Little Miami River mass balance. The pour point, up, and downstream drainage areas are shown.

For the 2022 nutrient mass balance study, the Little Miami and East Fork monitoring stations were new, with the first complete year of data available from wy21. Examining the three years of available data for this report, total P loads for the LMR system varied from 581 mta in wy23 to 900 mta in wy22 (Figure 62), while total N loads ranged from 3,566 mta in wy23 to 5,615 mta in wy22 (Figure 64 and Table 16). Total P and total N yields are presented on Figures 63 and 65.

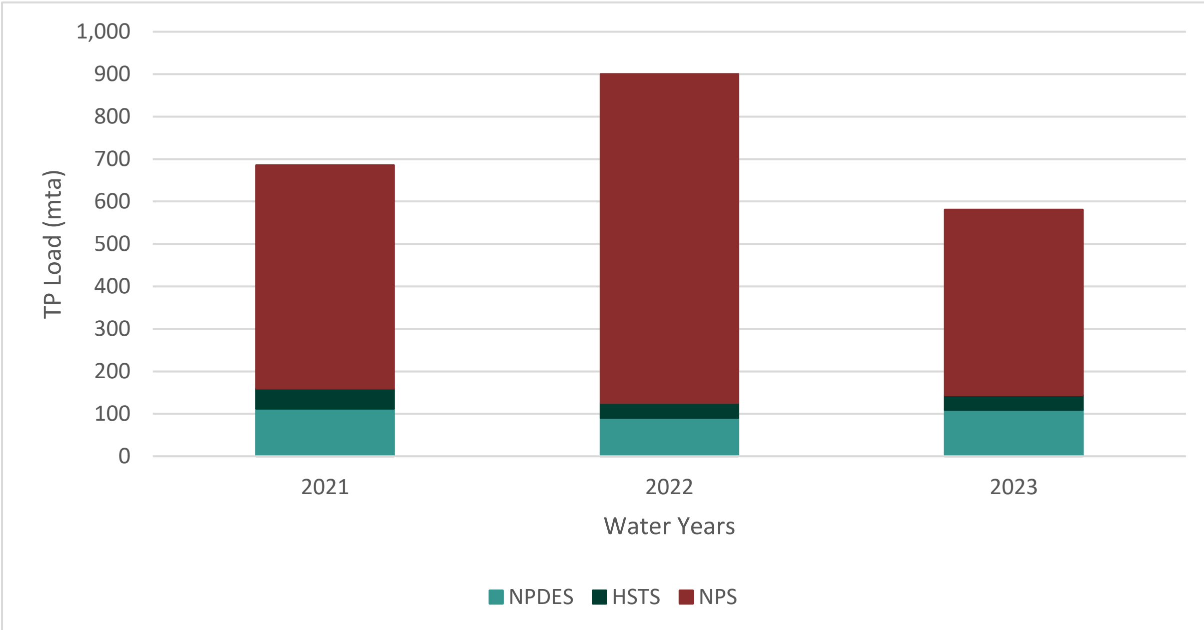


Figure 62 — Total phosphorus loads for the Little Miami River for water years 2021-2023

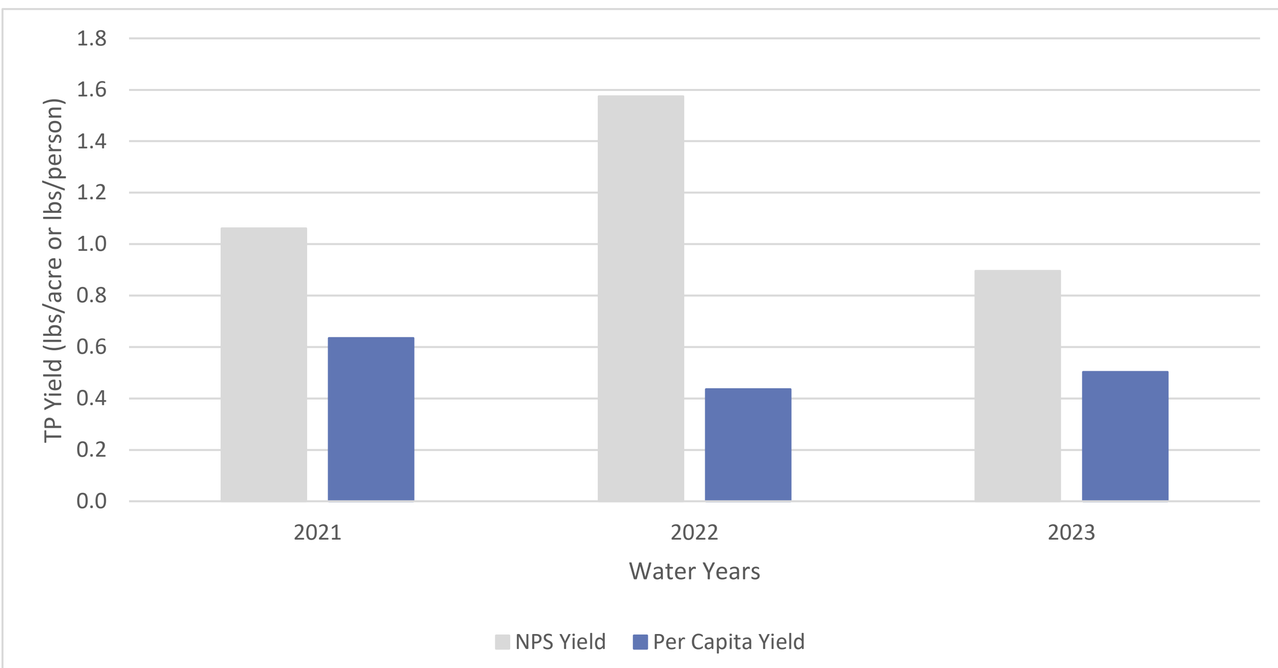


Figure 63 — Total phosphorus yields for the Little Miami River for water years 2021-2023

Nonpoint source yields are calculated using the total measured load at the pour points and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

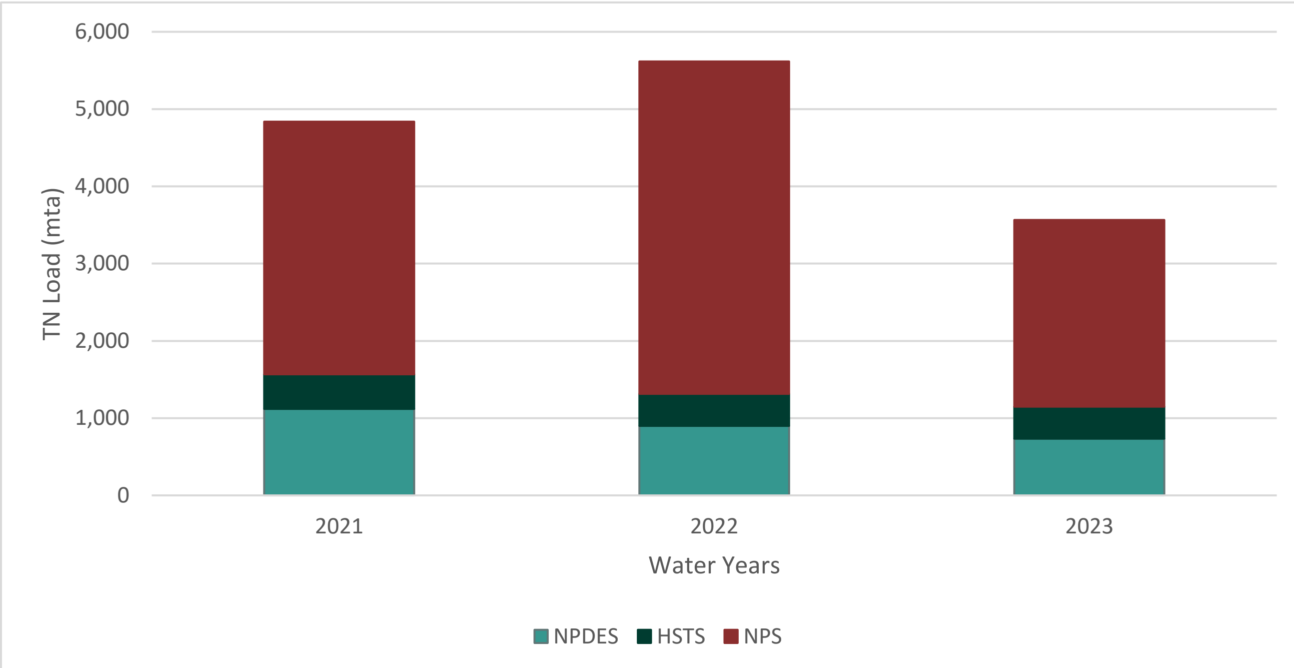


Figure 64 — Total nitrogen loads for the Little Miami River for water years 2021-2023

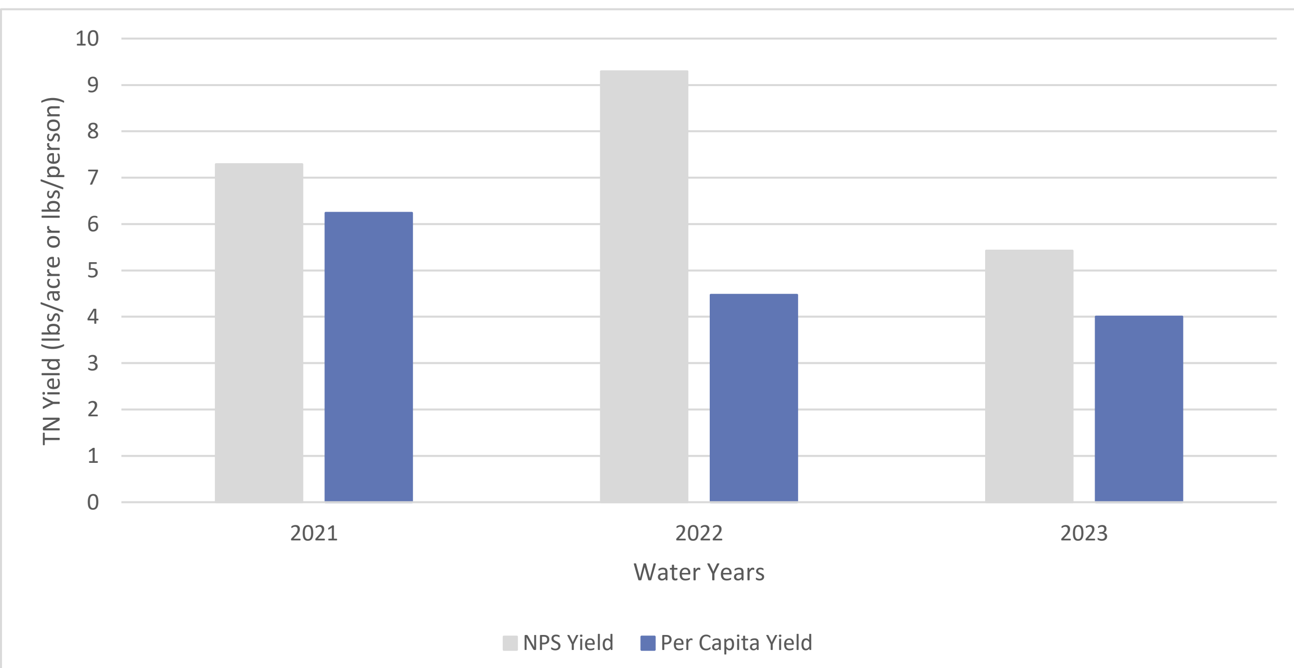


Figure 65 — Total nitrogen yields for the Little Miami River for water years 2021-2023

Nonpoint source yields are calculated using the total measured load at the pour points and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

Table 16 — Annual flow-weighted mean concentration (FWMC) and total load wy2021-2023 for the Little Miami River

FWMC is calculated at the pour points and does not include downstream drainage area.

Parameter	wy21	wy22	wy23
Water Yield (in/yr)	15.5	19.7	12.5
20-yr Median Water Yield (in) – 17.9			
Total P			
FWMC (mg/L)	0.36	0.39	0.38
Annual Load (mta)	685	900	581
Total N			
FWMC (mg/L)	2.6	2.4	2.4
Annual Load (mta)	4,836	5,615	3,566

In wy21, nonpoint sources contributed 80% of the total P load and 71% of the total N load (Figure 66). NPDES sources accounted for 14% of total P and 20% of total N, while HSTS contributed 6% of total P and 9% of total N.

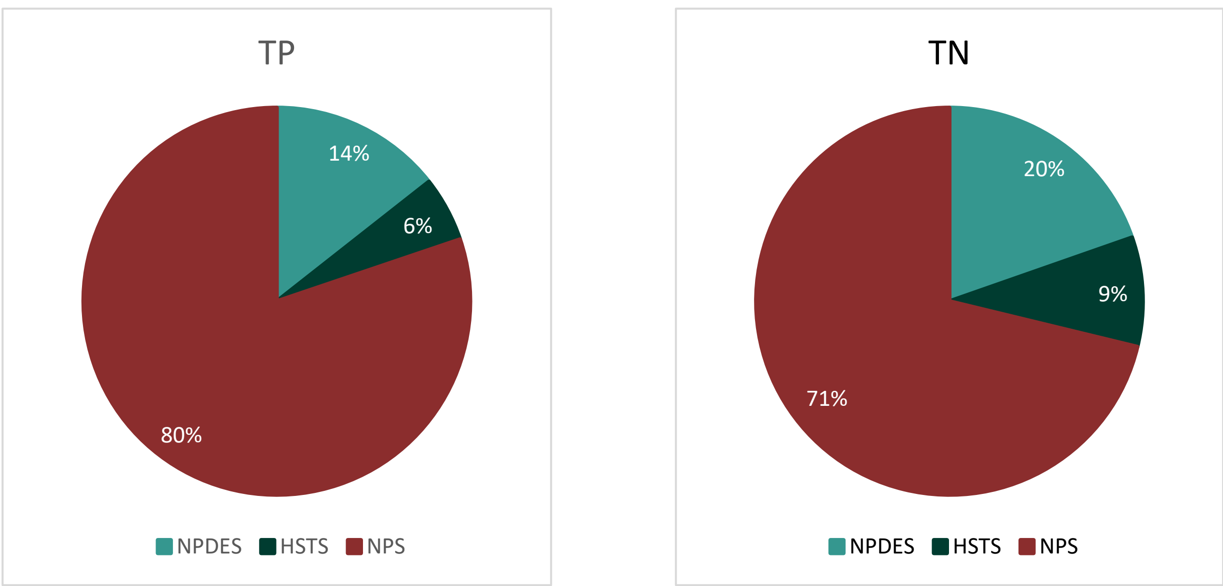


Figure 66 — Proportion of total phosphorus and nitrogen load from different sources for the Little Miami watershed, average of three years (wy21-wy23)

3.12 Scioto River

The Scioto River drains 6,512 sq. mi. in central and south-central Ohio (Figure 67). The NCWQR monitors water quality at a USGS gaging station in Chillicothe, which serves as a pour point for nutrient mass balance calculations. The watershed area upstream of the pour point is 3,851 sq. mi., while 2,662 sq. mi. is downstream.

Agricultural land comprises 57% of the Scioto watershed. The proportion of natural area significantly shifts from 13% upstream of the pour point to 52% downstream.

Maximum total P loads of 3,783 mta occurred in wy19 and minimum of 1,212 mta in wy23 (Figure 68 and Table 17). Total N loads reached a maximum of 36,707 mta in wy19 and a minimum of 16,778 mta in wy21 (Figure 70 and Table 17). The total P and total N yields are presented on Figures 69 and 71.

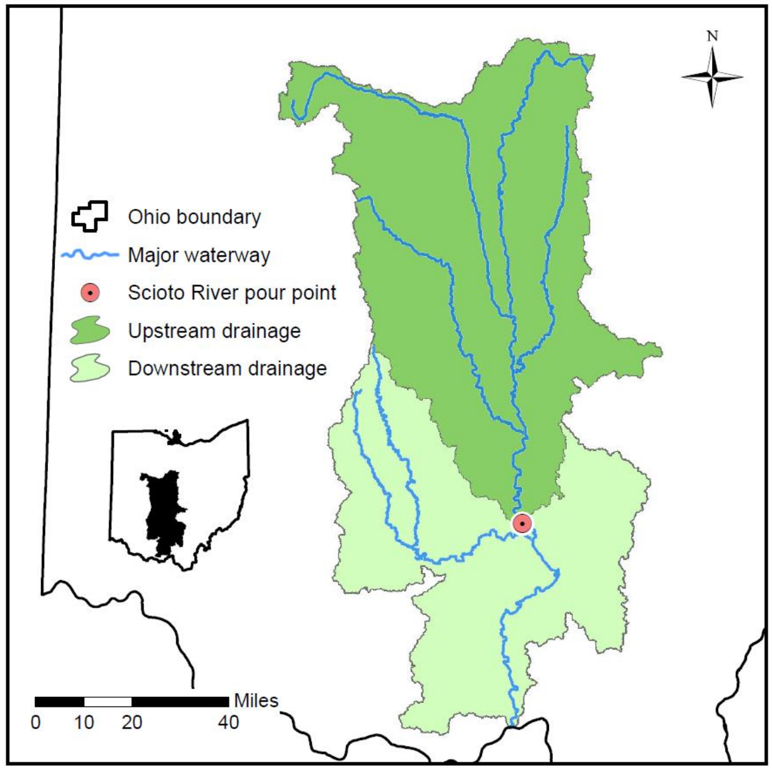


Figure 67— Project area represented in the Scioto River mass balance. The pour point, up, and downstream drainage areas are shown.

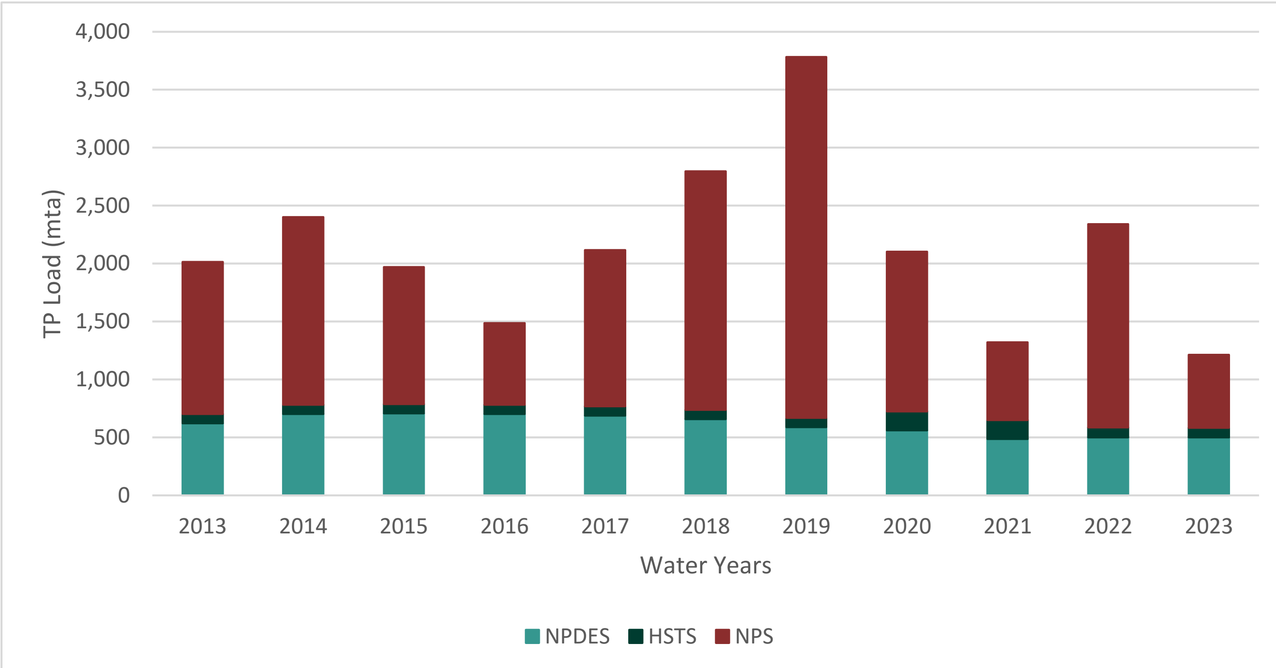


Figure 68 — Total phosphorus loads for the Scioto River for water year 2013-2023

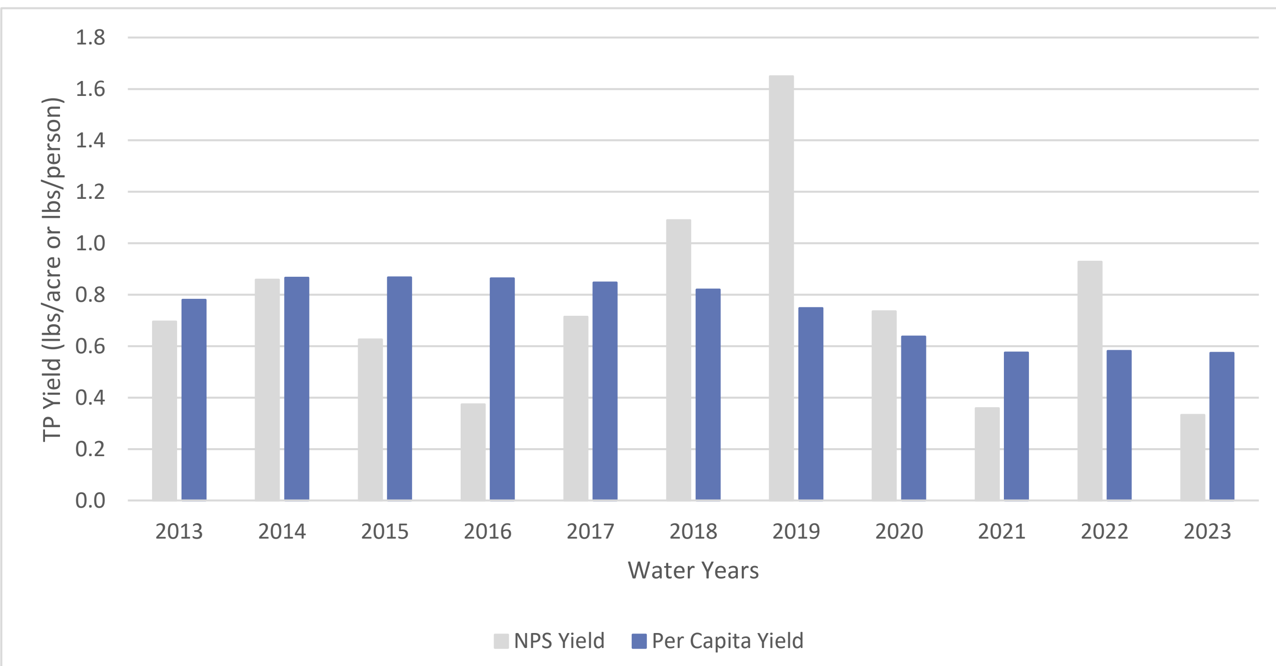


Figure 69 — Total phosphorus yields for the Scioto River for water year 2013-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

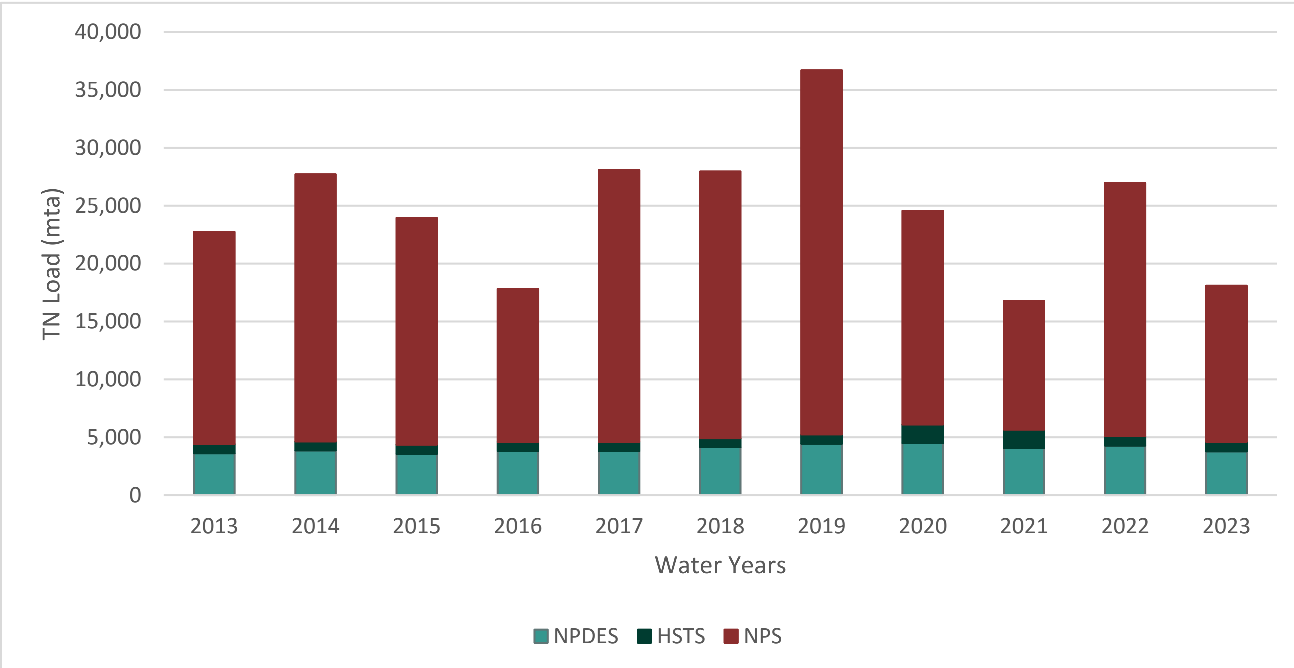


Figure 70 — Total nitrogen loads for the Scioto River for water year 2013-2023

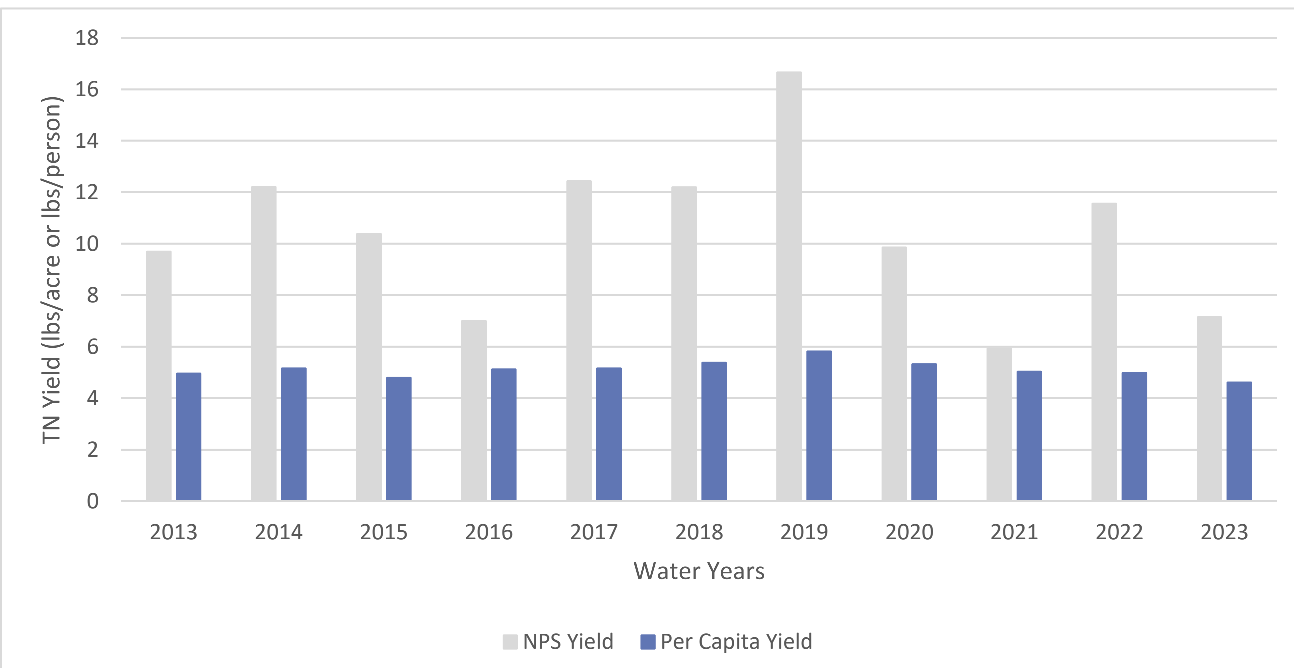


Figure 71 — Total nitrogen yields for the Scioto River for water year 2013-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

Table 17 — Annual flow-weighted mean concentration (FWMC), total load, and water yield for wy13 through wy23 for the Scioto watershed

Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and water yield are calculated at the pour point and do not include downstream drainage area.

Parameter	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Water Yield (in/yr)	14.0	17.7	15.0	13.2	15.4	21.9	27.9	16.6	12.5	19.5	11.9
20-yr Median Water Yield (in) – 17.1											
Total P											
FWMC (mg/L)	0.38	0.37	0.36	0.33	0.37	0.34	0.34	0.35	0.30	0.31	0.28
Annual Load (mta)	2,015	2,402	1,969	1,486	2,117	2,798	3,783	2,103	1,320	2,340	1,212
Total N											
FWMC (mg/L)	4.08	3.85	4.00	3.98	4.72	3.23	3.29	3.90	3.67	3.51	3.95
Annual Load (mta)	22,729	27,711	23,949	17,819	28,077	27,961	36,707	24,578	16,778	26,957	18,105

Over the last five years, nonpoint sources accounted for 70% of the total P load and 78% of the total N load (Figure 72). NPDES sources contributed 25% of total P and 17% of total N, while HSTS communities contributed 5% for total P and 4% for total N.

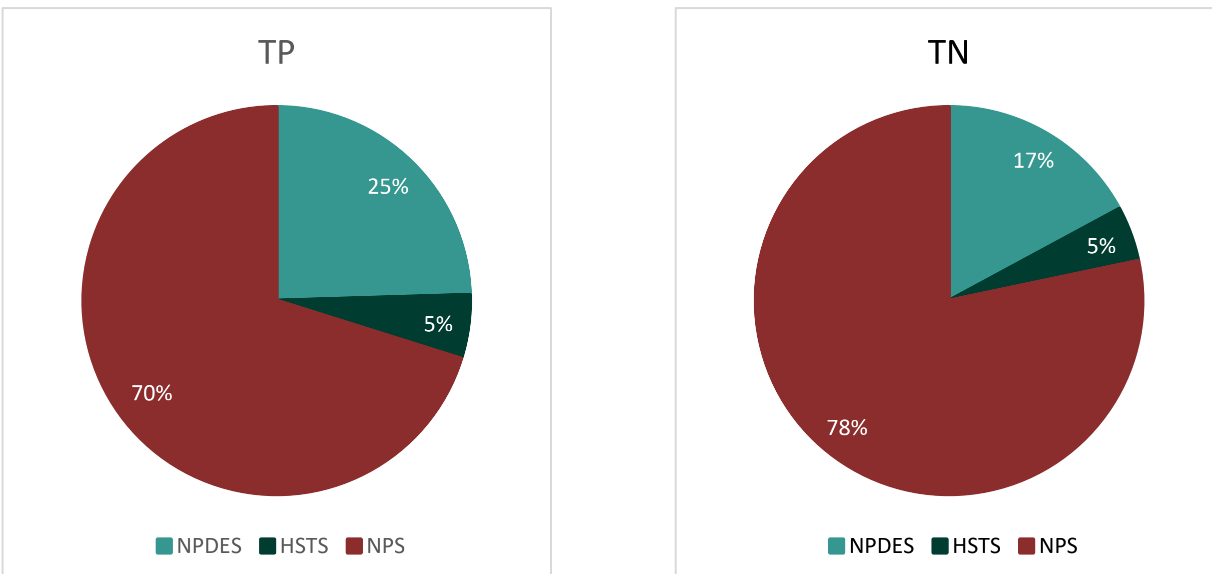


Figure 72 - Proportion of total phosphorus and nitrogen load from different sources for the Scioto watershed, average of five years (wy19-wy23)

The Scioto River is Ohio's second largest watershed, draining to the Ohio River. Baker et al. (2006) found that total P contributions were higher in a time-weighted mean than a flow-weighted mean, indicating a significant influence from point sources, which aligns with findings from Ohio EPA.

3.13 Hocking River

The Hocking River drains 1,197 sq. mi. in southeast Ohio, with a watershed area of 942 sq. mi. upstream and 255 sq. mi. downstream of the pour point at the Hocking River gage in Athens (Figure 73). The USGS monitors the water quality and streamflow at this pour point.

The watershed is primarily dominated by natural (66%) and agricultural (25%) land use. Land use downstream of the pour point has greater natural lands (80%) compared to upstream (62%).

The 2022 nutrient mass balance study introduced the water quality gage, with wy21 data being the first full year available. Total P loads varied from 276 mta in wy22 to 113 mta in wy23 (Figure 74, while total N loads ranged from 1,281 mta (wy21) to 2,513 mta (wy22) (Figure 76 and Table 18). Total P and total N yields are presented on Figures 75 and 77.

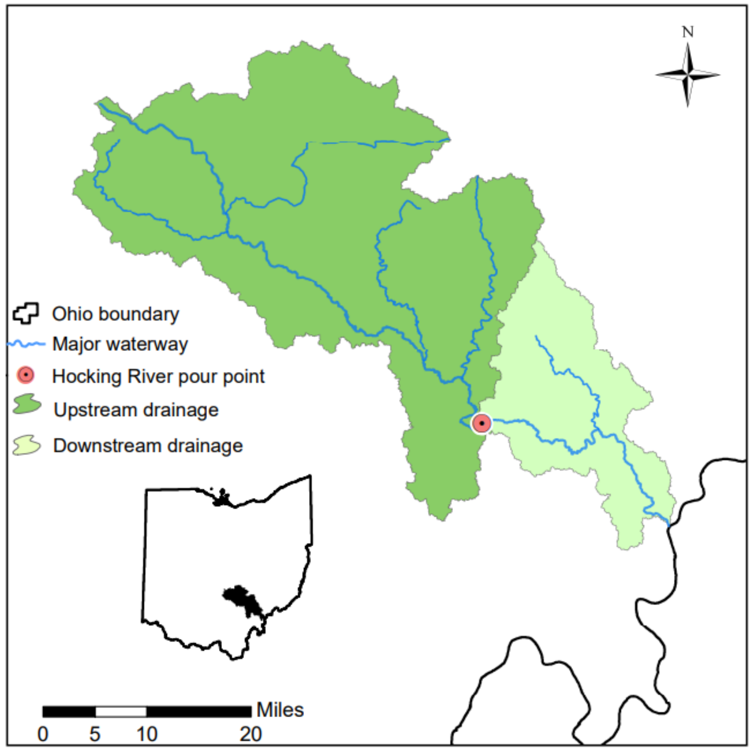


Figure 73 — Project area represented in the Hocking River mass balance. The pour point, up, and downstream drainage areas are shown.

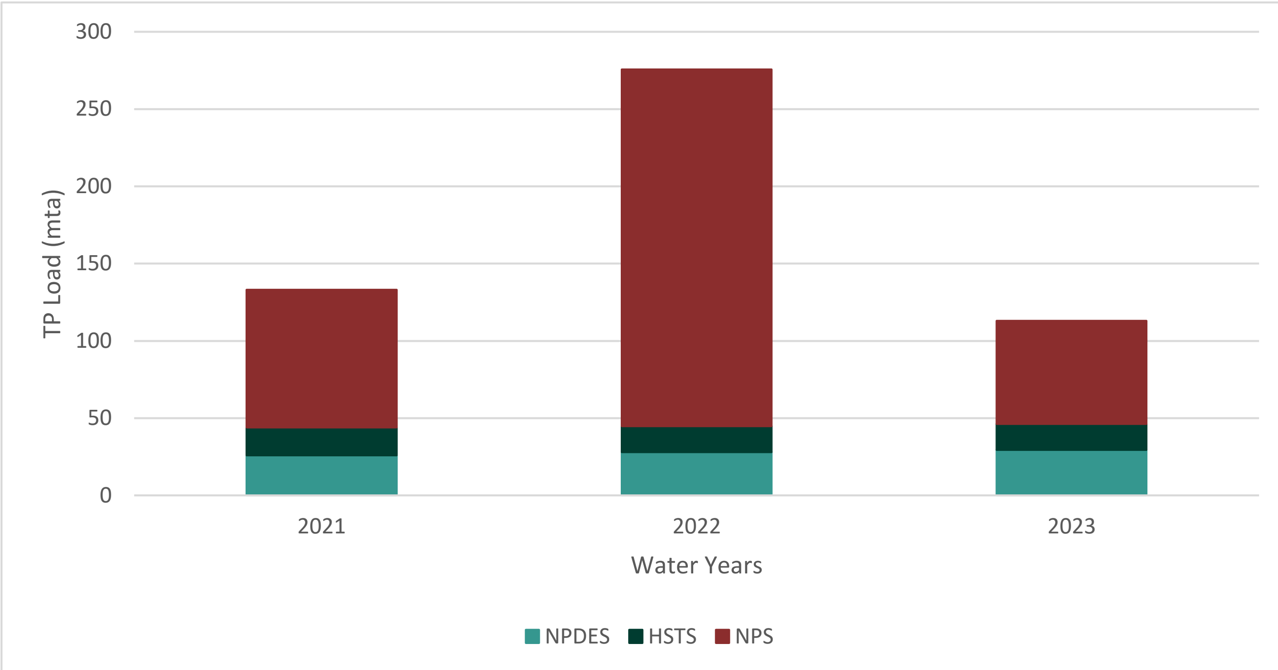


Figure 74 — Total phosphorus loads for the Hocking River for water years 2021-2023

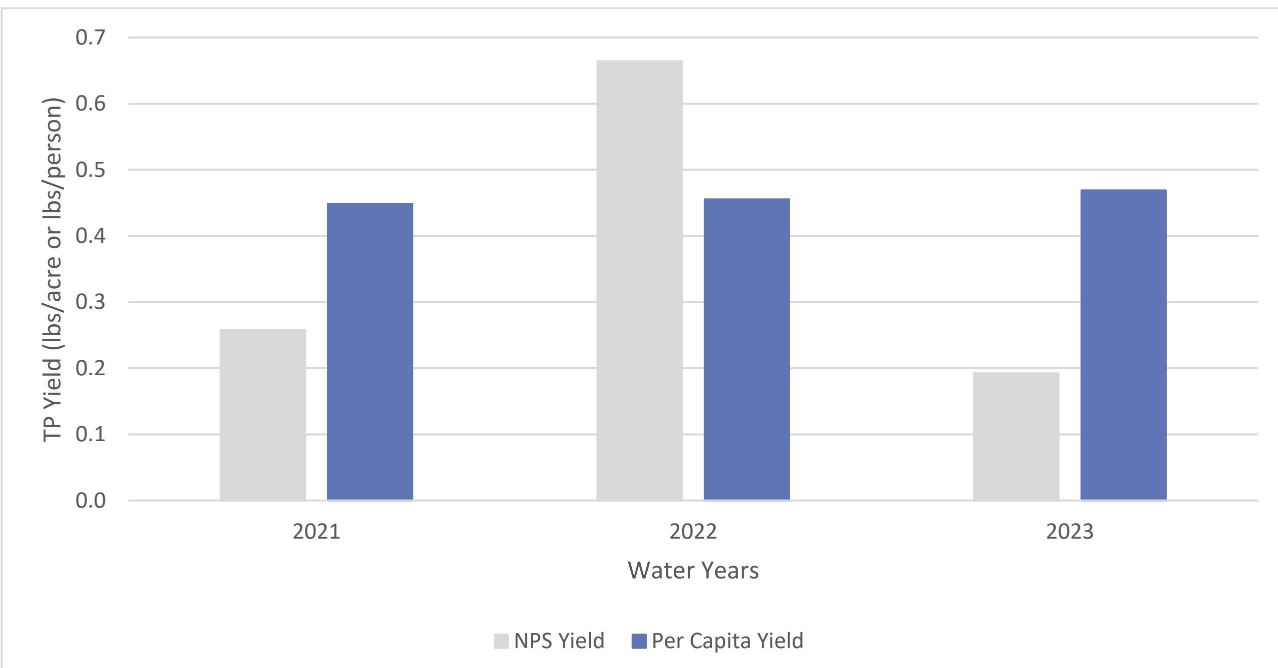


Figure 75 — Total phosphorus yields for the Hocking River for water years 2021-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

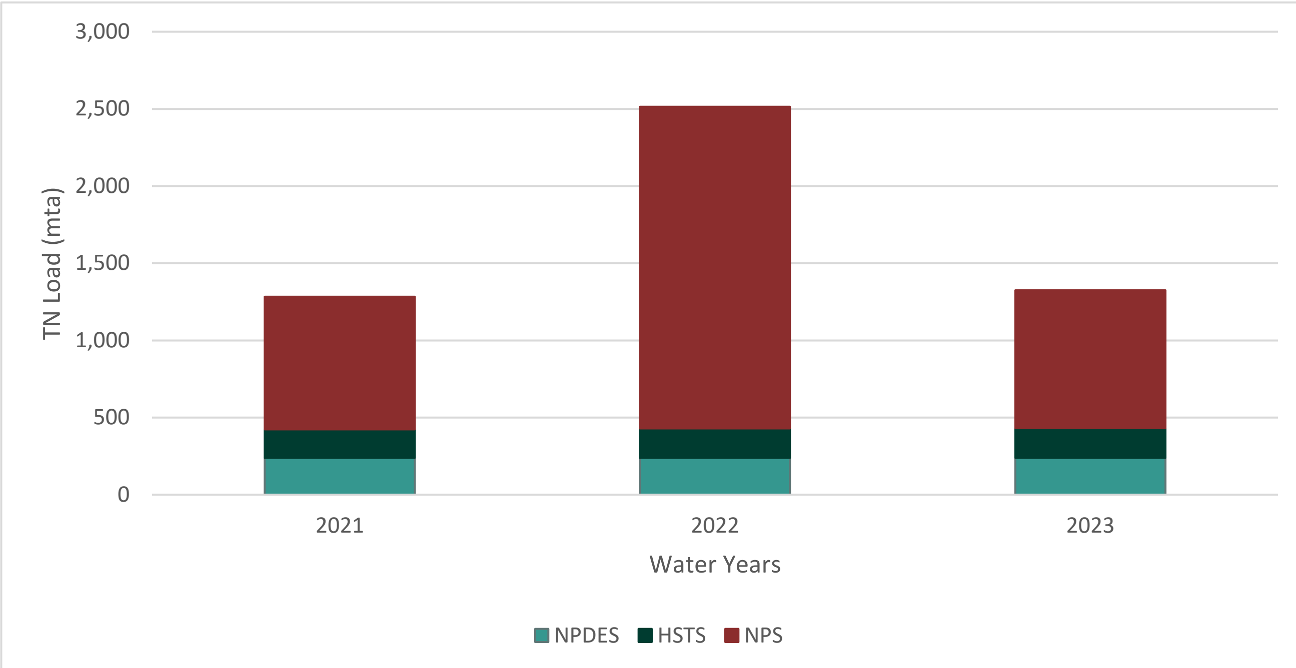


Figure 76 — Total nitrogen loads for the Hocking River for water years 2021-2023

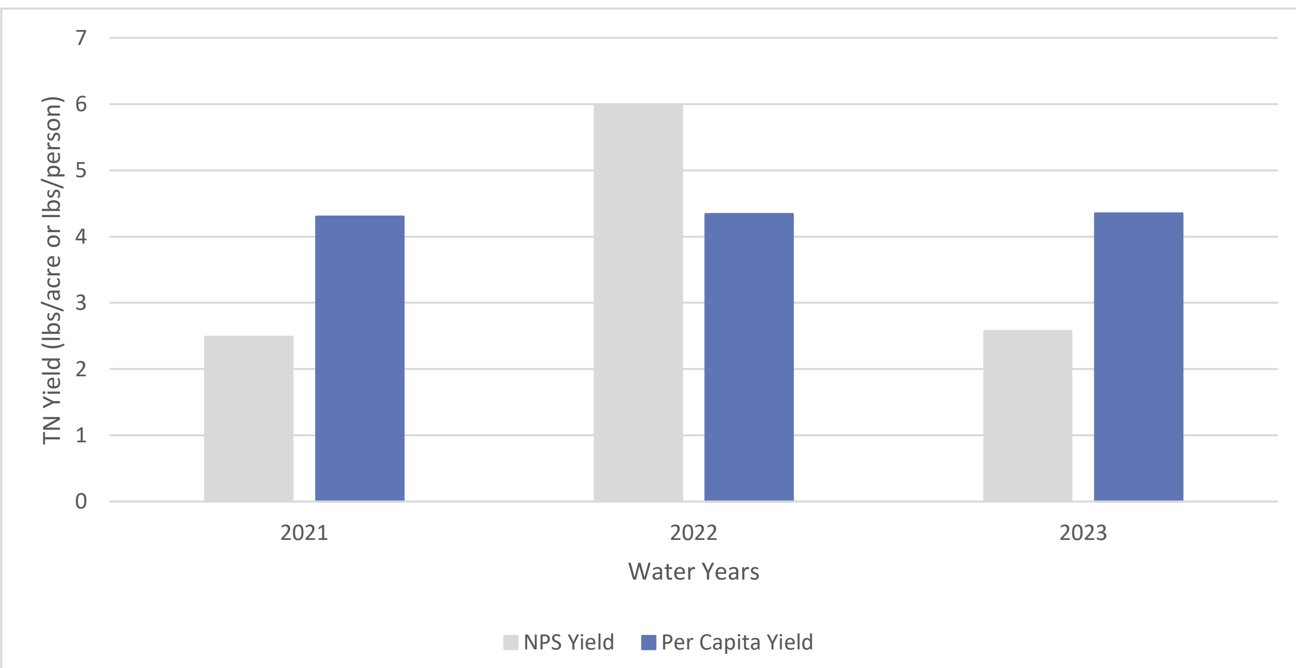


Figure 77 — Total nitrogen yields for the Hocking River for water years 2021-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

Table 18 — Annual flow-weighted mean concentration (FWMC), total load and water yield for wy21-wy23 for the Hocking watershed

Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and water yield are calculated at the pour point and do not include downstream drainage area.

Parameter	wy21	wy22	wy23
Water yield (in/yr)	10.6	18.8	11.8
20-yr Median Water Yield (in) – 16.1			
Total P			
FWMC (mg/L)	0.16	0.19	0.12
Annual Load (mta)	133	276	113
Total N			
FWMC (mg/L)	1.57	1.72	1.47
Annual Load (mta)	1,282	2,513	1,325

The average of wy21 to wy23 loads indicate that nonpoint sources accounted for 74% of total P and 75% of total N, while NPDES sources contributed 16% of total P and 14% of total N (Figure 78). HSTS communities made up 10% of total P and 11% of total N. The higher HSTS contribution in the Hocking watershed is likely due to a larger proportion of the population relying on HSTS compared to other watersheds with central sewage systems.

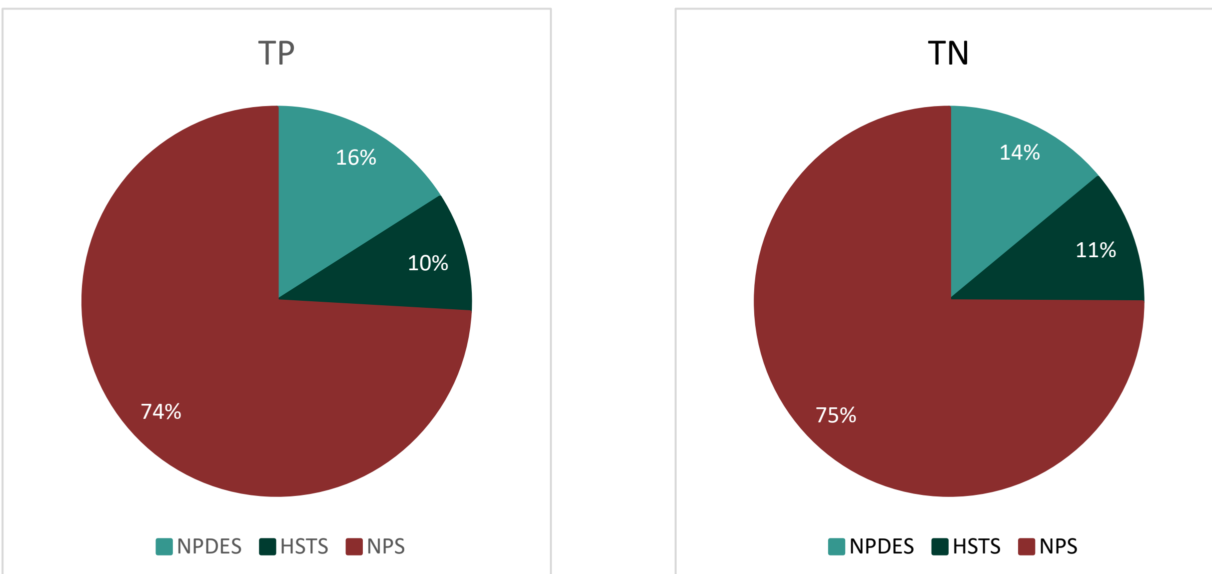


Figure 78 - Proportion of total phosphorus and nitrogen load from different sources for the Hocking watershed, average of three years (wy21-wy23)

3.14 Muskingum River

The Muskingum River drains 8,049 sq. mi. in northeast and southeast Ohio (Figure 79). A water quality station maintained by the NCWQR at the USGS gaging station in McConnelsville is used for nutrient mass balance calculations. The pour point's watershed area is 7,421 sq. mi., and there is 628 sq. mi. downstream of the pour point.

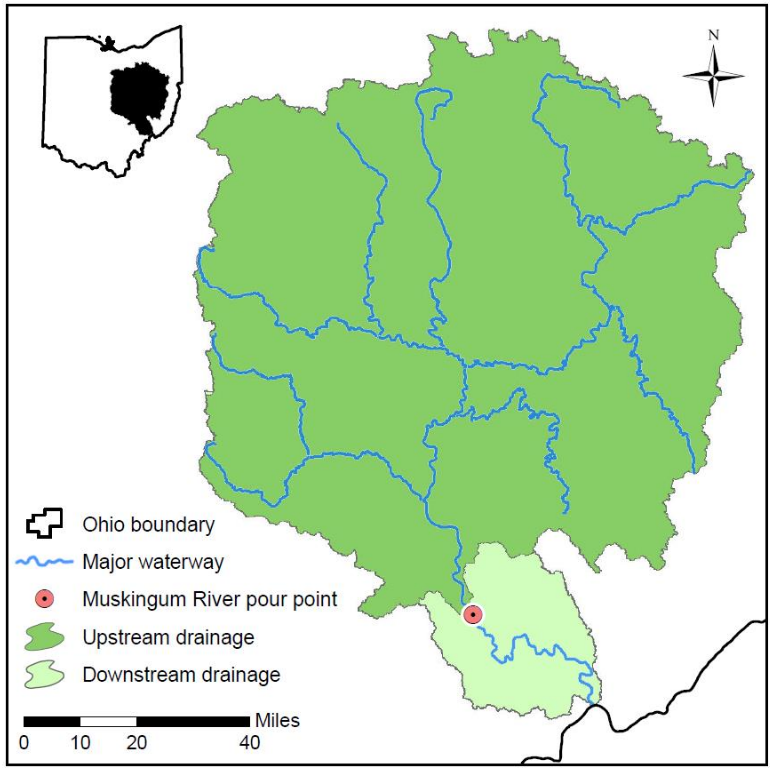


Figure 79— Project area represented in the Muskingum River mass balance. The pour point, up, and downstream drainage areas are shown.

Land use in the watershed is predominantly natural (48%) and agricultural (39%). Agricultural land decreases from 40% to 25% downstream of the pour point, while natural areas increase from 47% to 68%.

Maximum total P loads were 2,209 mta in wy19 and at a minimum of 885 mta in wy16 (Figure 80 and Table 19). Total N loads reached a maximum of 29,414 mta in wy19 and a minimum of 12,587 mta in wy16 (Figure 82 and Table 19. Total P and total N yields are presented on Figures 81 and 83.

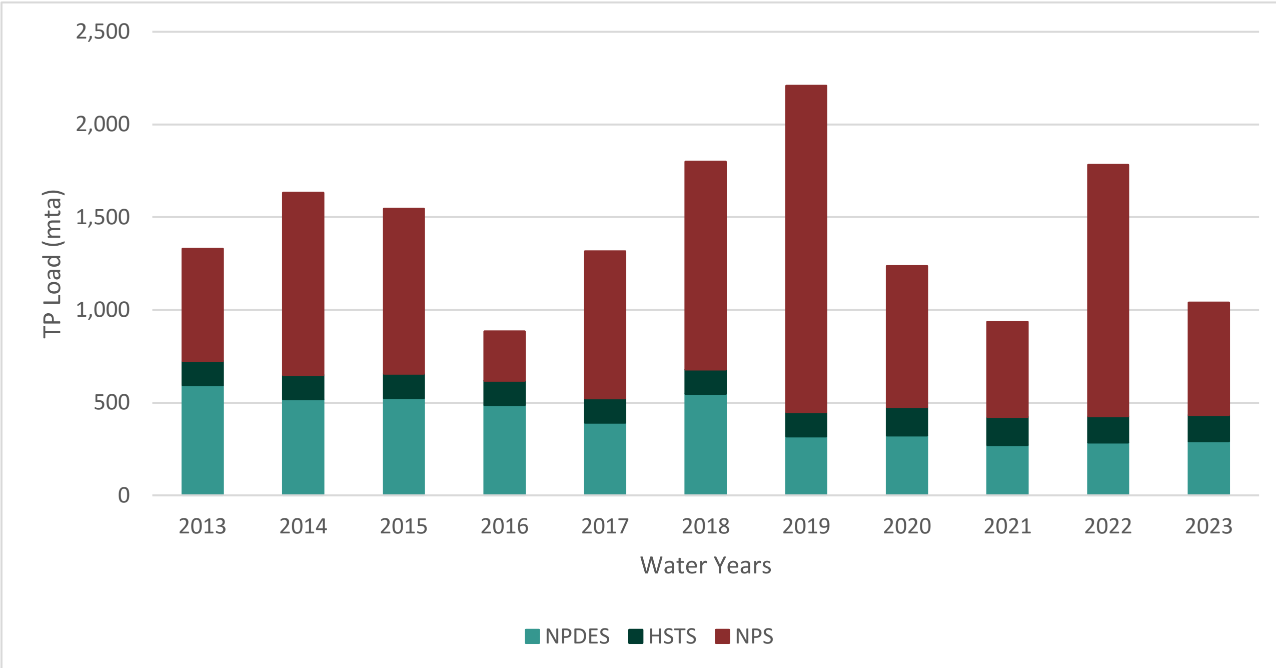


Figure 80 — Total phosphorus loads for the Muskingum River for water year 2013-2023

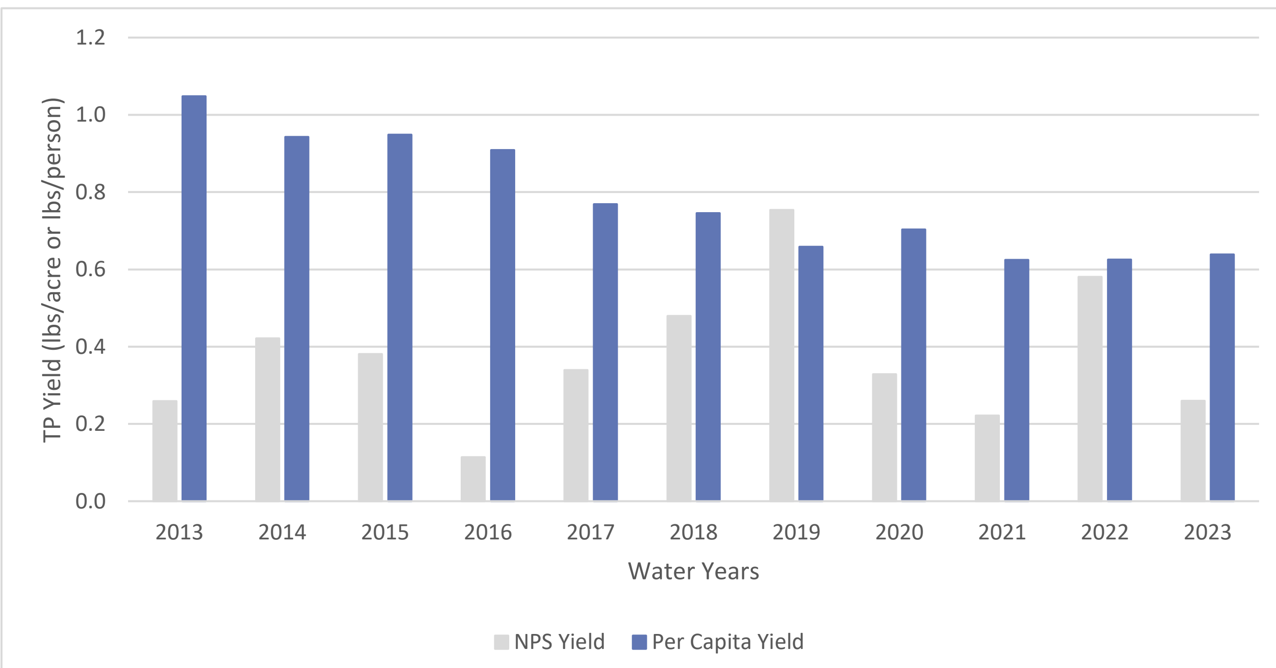


Figure 81 — Total phosphorus yields for the Muskingum River for water year 2013-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

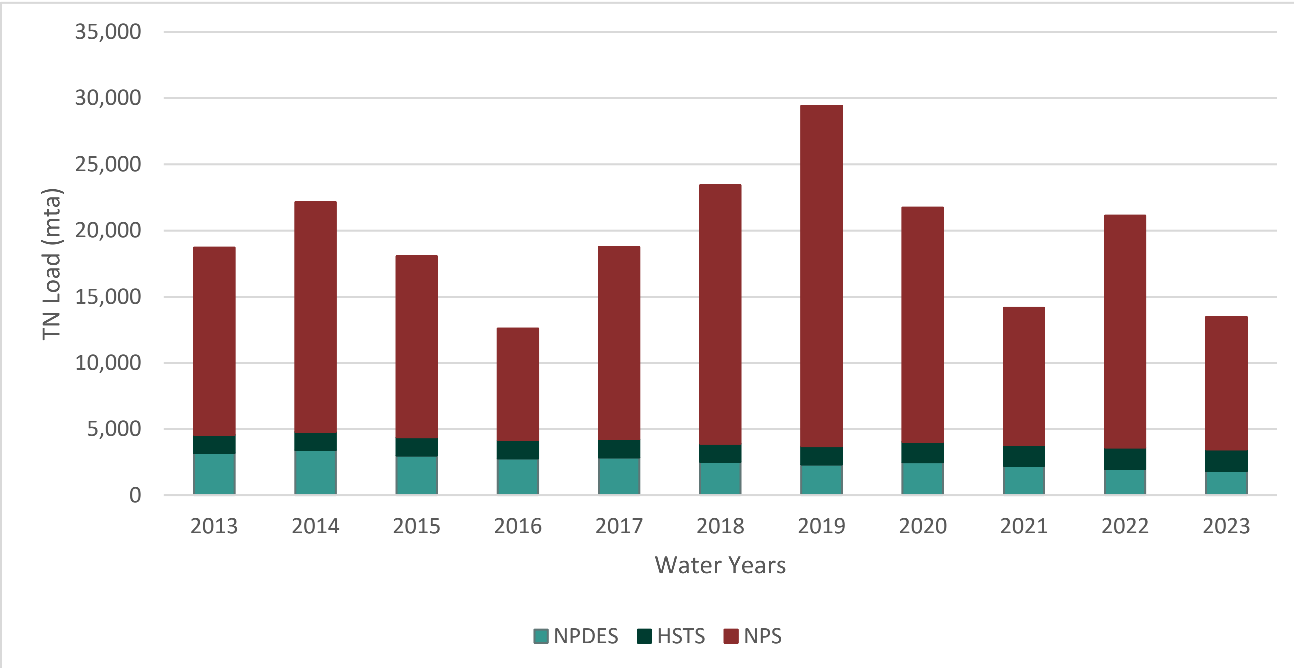


Figure 82 — Total nitrogen loads for the Muskingum River for water year 2013-2023

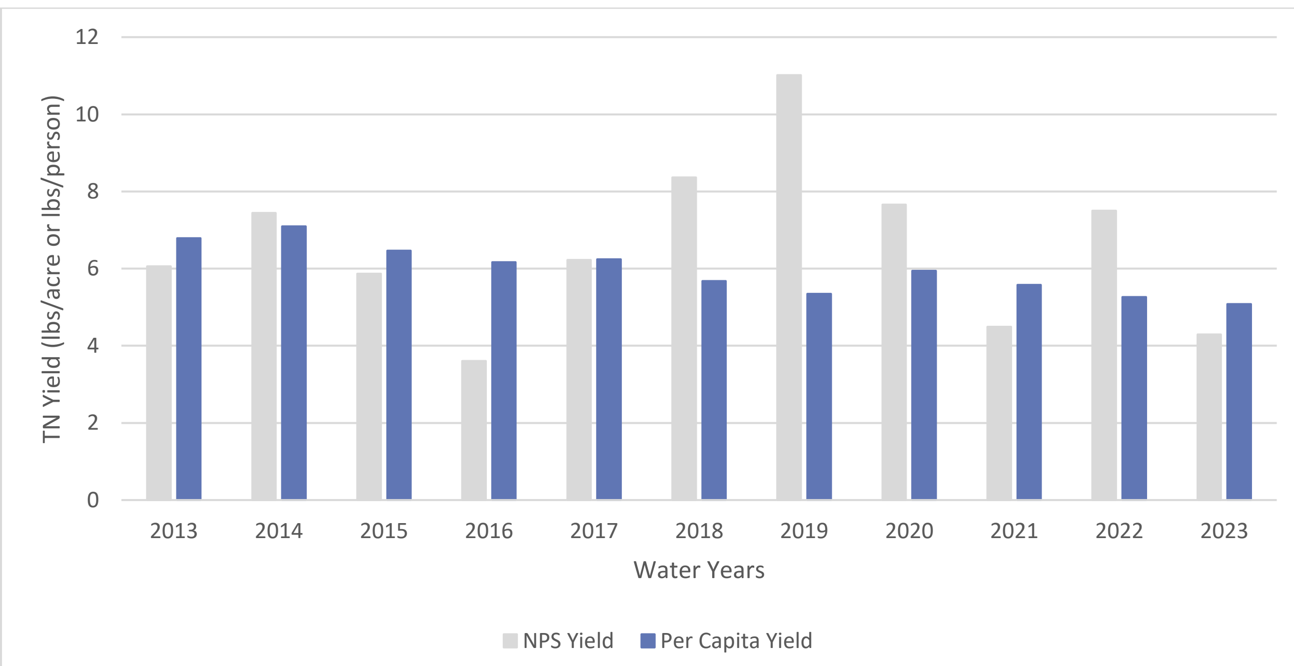


Figure 83 — Total nitrogen yields for the Muskingum River for water year 2013-2023

Nonpoint source yields are calculated using the total measured load at the pour point and the upstream area. Per capita yields are calculated as the sum of the NPDES load and HSTS load divided by the contributing population.

Table 19 — Annual flow-weighted mean concentration (FWMC), total load, and water yield for wy13 through wy23 for the Muskingum watershed

Water yield is annual discharge normalized by watershed area (in units of inches/yr). FWMC and water yield are calculated at the pour point and do not include downstream drainage area.

Parameter	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Water Yield (in/yr)	14.9	18.7	15.0	11.6	14.5	20.9	26.5	18.4	12.6	20.1	13.4
20-yr Median Water Yield (in) – 17.1											
Total P											
FWMC (mg/L)	0.17	0.17	0.2	0.15	0.18	0.17	0.16	0.13	0.15	0.17	0.15
Annual Load (mta)	1,330	1,632	1,545	885	1,316	1,799	2,209	1,237	936	1,783	1,041
Total N											
FWMC (mg/L)	2.42	2.26	2.3	2.09	2.54	2.14	2.11	2.3	2.2	2.01	1.93
Annual Load (mta)	18,706	22,159	18,067	12,587	18,767	23,041	29,414	21,736	14,172	21,131	13,472

The observed data emphasizes the significance of total discharge in total P levels, as years ranked by flow correspond with total P rankings. However, this pattern was less evident for total N, indicating different loading mechanisms for P and N. The loads for wy19 are anticipated to be higher due to increased precipitation, a trend seen for both total P and N. In contrast, drier years like wy21 and wy23 experienced lower total P and N loads.

Notably, the per capita yield from point sources has decreased since the report's first iteration, with total P loading dropping to nearly half of the contributions seen in wy13. This decline is linked to reduced total P loads from major municipal wastewater treatment plants that have received stricter treatment limits since wy13.

In an average of the five-year study, nonpoint sources contributed 69% of annual total P and 81% of total N loads (Figure 84). NPDES sources accounted for 21% of total P and 11% of total N loads, while HSTS communities contributed 10% of total P and 11% of total N. The Muskingum River watershed has many natural areas and has recorded the lowest nonpoint source yield for total P over the past five years.

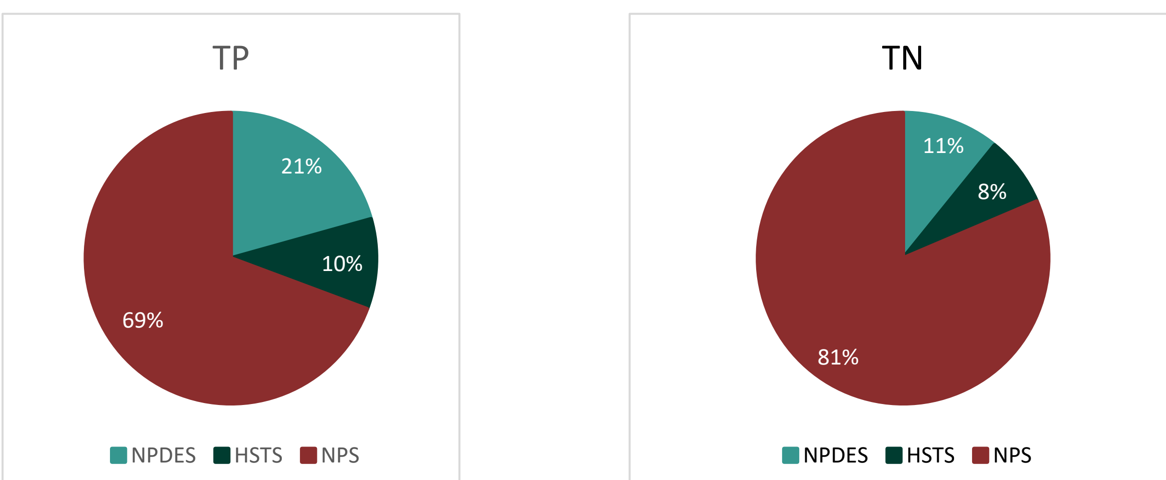


Figure 84 — Proportion of total phosphorus and nitrogen load from different sources for the Muskingum watershed, average of five years (wy19-wy23)

4 Summary and Future Work

Nutrient loads (total P and total N) were estimated from 13 Ohio watersheds, covering 72% of the state's land area. Factors influencing these loads include watershed size, annual water yield, nonpoint source yield, land use, per capita yield, and population density. The study found variations in total loads and source contributions among the watersheds, which is important for guiding nutrient reduction efforts to meet national and international goals for the Gulf of Mexico and Lake Erie.

In line with ORC 6111.03 (T), Ohio EPA will update this study biennially alongside the integrated report. Feedback has led to valuable suggestions for improving future biennial nutrient balance reports. Future editions aim to cover more areas, incorporating data from Ohio EPA's Statewide Ambient Water Quality Monitoring (Ohio EPA, 2023b) program and utilizing additional load estimation methods. Enhanced analytical assessments of nutrient trends over time will also be provided, thanks to improved access to resources like USGS' WRTDS methodology.

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Appendix A – Summary Tables for Mass Balance Calculations

Table 20 — Summary of total P loading components for calculating the nutrient mass balance in the Maumee River watershed

Source	TP Load (mta)										
	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Upstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	32.7	39.5	36.3	34.2	35.0	36.1	34.0	35.5	34.6	32.3	29.2
NPDES 2 – Municipal 0.1-1.0 mgd	17.3	19.7	17.1	20.8	17.9	19.3	20.5	19.2	15.7	17.0	14.8
NPDES 3 – Municipal <0.1 mgd	8.2	8.9	8.2	7.4	8.5	9.4	12.6	7.4	7.8	7.7	8.5
NPDES – Industrial	11.9	11.8	11.8	12.7	13.0	10.8	12.7	11.7	13.4	12.1	12.8
Wet Weather UPST Pour Point	1.7	1.7	3.0	1.6	2.6	2.6	2.9	1.8	1.7	1.7	1.3
Total NPDES UPST Pour Point	112.5	125.8	129.1	124.8	131.0	134.5	143.2	133.7	126.9	121.7	118.7
HSTS UPST Pour Point	72.2	72.2	72.2	72.2	72.2	72.2	72.2	0.0	0.0	0.0	0.0
Load @ Pour Point	2,130.0	1,960.0	2,200.0	1,160.0	2,880.0	2,510.0	3,680.0	2,720.0	1,370.0	2,490.0	2,056.0
NPS UPST Pour Point	1,945.3	1,762.1	1,998.7	963.1	2,676.9	2,303.3	3,464.7	2,586.3	1,243.1	2,368.3	1,937.3
Downstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	68.4	60.3	54.3	61.7	54.2	53.8	63.4	60.9	60.6	56.0	52.4
NPDES 2 – Municipal 0.1-1.0 mgd	1.7	1.6	0.7	0.6	0.4	0.3	0.5	0.6	0.4	0.7	0.8
NPDES 3 – Municipal <0.1 mgd	0.2	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.5
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.6
Wet Weather DST Pour Point	1.1	1.1	1.5	0.4	0.6	1.4	0.6	0.3	1.7	0.6	1.9
Total NPDES DST Pour Point	71.4	63.2	56.8	63.0	55.5	55.8	64.8	62.1	63.1	58.6	56.2
HSTS DST Pour Point	3.1	3.1	3.1	3.1	3.1	3.1	3.1	0.0	0.0	0.0	0.0
NPS DST Pour Point	83.7	75.8	86.0	41.4	115.2	99.1	149.1	108.4	52.1	101.0	82.6
Totals											
HSTS	75.3	75.3	75.3	75.3	75.3	75.3	75.3	89.4	89.4	89.4	89.4
Total NPDES	183.9	189.0	185.9	187.8	186.4	190.3	207.9	195.8	189.9	180.2	175.0
NPS Total	2,029.0	1,837.9	2,084.7	1,004.5	2,792.1	2,402.5	3,613.8	2,694.7	1,295.3	2,469.3	2,019.8
Total Load	2,288.2	2,102.1	2,345.9	1,267.6	3,053.8	2,668.0	3,897.0	2,979.9	1,574.5	2,738.9	2,284.2
% HSTS	3%	4%	3%	6%	2%	3%	2%	3%	6%	3%	4%
% NPDES	8%	9%	8%	15%	6%	7%	5%	7%	12%	7%	8%
% of NPDES – Municipal ≥ 1.0 mgd	55.0%	52.8%	48.7%	51.1%	47.8%	47.2%	46.8%	49.2%	50.1%	49.0%	46.6%
% of NPDES – Municipal 0.1-1.0 mgd	10.3%	11.2%	9.6%	11.4%	9.8%	10.3%	10.1%	10.1%	8.4%	9.8%	8.9%
% of NPDES – Municipal <0.1 mgd	4.5%	4.9%	4.5%	4.1%	4.7%	5.1%	6.2%	4.0%	4.3%	4.5%	5.1%
% of NPDES – Industrial	6.5%	6.3%	6.3%	6.8%	7.0%	5.7%	6.1%	6.0%	7.0%	7.2%	7.7%
% of NPDES – Wet Weather	1.5%	1.5%	2.5%	1.1%	1.7%	2.1%	1.7%	1.1%	1.8%	1.3%	1.8%
% NPS	89%	87%	89%	79%	91%	90%	93%	90%	82%	90%	88%
Yield UPST Pour Point (lb/acre)	1.06	0.96	1.09	0.53	1.46	1.26	1.90	1.43	0.69	1.30	1.06
Per Capita Yield (lb/person)	0.32	0.33	0.30	0.32	0.30	0.31	0.33	0.34	0.33	0.32	0.31

Table 21 — Summary of total N loading components for calculating the nutrient mass balance in the Maumee River watershed

	TN Load (mta)										
Source	**wy13**	**wy14**	**wy15**	**wy16**	**wy17**	**wy18**	**wy19**	**wy20**	**wy21**	**wy22**	**wy23**
Upstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	794.2	797.9	776.5	803.0	889.2	984.3	943.4	805.4	800.5	731.8	586.4
NPDES 2 – Municipal 0.1-1.0 mgd	141.9	132.0	137.1	146.1	124.2	138.6	146.1	149.4	121.3	104.1	89.5
NPDES 3 – Municipal <0.1 mgd	67.7	54.2	52.4	53.8	53.8	57.8	98.0	42.7	42.4	40.2	43.3
NPDES – Industrial	54.0	52.5	57.6	58.4	56.9	48.1	39.6	31.3	31.3	48.5	51.0
Wet Weather UPST Pour Point	47.3	45.9	83.1	43.8	71.1	70.0	79.6	49.9	46.9	45.2	34.4
Total NPDES UPST Pour Point	2,105.2	2,193.9	2,287.3	2,020.8	2,316.3	2,376.1	2,495.2	2,137.1	2,034.4	2,050.4	1,741.4
HSTS UPST Pour Point	520.6	520.6	520.6	520.6	520.6	520.6	520.6	0.0	0.0	0.0	0.0
Load @ Pour Point	40,275.8	34,323.6	41,520.8	28,042.2	45,958.5	36,690.0	45,700.0	31,874.0	33,690.0	38,500.0	27,440.0
NPS UPST Pour Point	37,649.9	31,609.1	38,712.9	25,500.8	43,121.5	33,793.3	42,684.2	29,736.9	31,655.6	36,449.6	25,698.6
Downstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	1,667.3	1,860.0	1,698.4	1,765.4	1,683.2	2,107.1	1,869.8	1,684.0	1,773.3	1,409.8	1,492.4
NPDES 2 – Municipal 0.1-1.0 mgd	12.9	11.6	9.7	12.4	12.1	13.6	14.6	12.0	12.1	11.8	17.6
NPDES 3 – Municipal <0.1 mgd	1.3	1.4	2.0	2.1	2.2	2.4	1.4	1.3	1.5	1.8	2.7
NPDES – Industrial	0.2	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.2	4.2	3.5
Wet Weather DST Pour Point	29.5	29.7	42.3	11.5	16.5	37.2	15.8	8.0	46.2	16.7	52.2
Total NPDES DST Pour Point	1,711.1	1,902.7	1,752.5	1,791.4	1,714.1	2,160.3	1,901.7	1,705.2	1,833.3	1,444.2	1,568.4
HSTS DST Pour Point	22.4	22.4	22.4	22.4	22.4	22.4	22.4	0.0	0.0	0.0	0.0
NPS DST Pour Point	1,620.3	1,360.3	1,666.1	1,097.5	1,855.8	1,454.3	1,837.0	1,246.9	1,327.4	1,554.0	1,095.7
Totals											
HSTS	543.0	543.0	543.0	543.0	543.0	543.0	543.0	644.5	644.5	644.5	644.5
Total NPDES	3,816.3	4,096.6	4,039.7	3,812.2	4,030.5	4,536.4	4,396.9	3,842.3	3,867.6	3,494.7	3,309.8
NPS Total	39,270.3	32,969.5	40,379.0	26,598.3	44,977.3	35,247.6	44,521.2	30,983.8	32,983.0	38,003.6	26,794.3
Total Load	43,629.6	37,609.1	44,961.7	30,953.5	49,550.8	40,327.1	49,461.1	35,470.7	37,495.2	42,142.8	30,748.6
% HSTS	1%	1%	1%	2%	1%	1%	1%	2%	2%	2%	2%
% NPDES	9%	11%	9%	12%	8%	11%	9%	11%	10%	8%	11%
% of NPDES – Municipal ≥ 1.0 mgd	64.5%	64.9%	61.3%	67.4%	63.8%	68.1%	64.0%	64.8%	66.5%	61.3%	62.8%
% of NPDES – Municipal 0.1-1.0 mgd	4.1%	3.5%	3.6%	4.2%	3.4%	3.4%	3.7%	4.2%	3.4%	3.3%	3.2%
% of NPDES – Municipal <0.1 mgd	1.8%	1.4%	1.3%	1.5%	1.4%	1.3%	2.3%	1.1%	1.1%	1.2%	1.4%
% of NPDES – Industrial	1.4%	1.3%	1.4%	1.5%	1.4%	1.1%	0.9%	0.8%	0.8%	1.5%	1.6%
% of NPDES – Wet Weather	2.0%	1.8%	3.1%	1.4%	2.2%	2.4%	2.2%	1.5%	2.4%	1.8%	2.6%
% NPS	90%	88%	90%	86%	91%	87%	90%	87%	88%	90%	87%
Yield UPST Pour Point (lb/acre)	20.60	17.29	21.18	13.95	23.59	18.49	23.35	16.39	17.45	19.93	14.05
Per Capita Yield (lb/person)	5.12	5.39	5.10	5.27	5.24	6.10	5.73	5.33	5.42	4.70	4.59

Table 22 — Summary of total P loading components for calculating the nutrient mass balance in the Portage River watershed

	TP Load (mta)										
Source	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Upstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	6.0	6.3	6.8	6.6	6.9	5.7	5.1	4.6	5.2	5.6	5.3
NPDES 2 – Municipal 0.1-1.0 mgd	1.8	1.8	1.4	1.1	2.0	1.8	1.8	1.3	0.9	1.2	0.9
NPDES 3 – Municipal <0.1 mgd	0.8	0.7	0.7	0.7	0.7	0.8	1.3	0.6	0.7	1.0	0.7
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet Weather UPST Pour Point	1.4	1.3	1.6	0.9	1.2	1.1	1.3	0.4	0.6	0.4	0.3
Total NPDES UPST Pour Point	9.9	10.1	10.5	9.3	10.8	9.4	9.5	6.9	7.5	8.2	7.2
HSTS UPST Pour Point	3.0	3.0	3.0	3.0	3.0	3.0	3.0	4.4	4.4	4.4	4.4
Load @ Pour Point	117.0	163.0	123.0	103.0	135.0	184.0	264.0	143.0	106.0	185.0	145.0
NPS UPST Pour Point	104.1	149.9	109.6	90.7	121.2	171.6	251.6	131.7	94.2	172.4	133.5
Downstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	0.5	0.4	0.3	0.4	0.3	0.4	0.4	0.4	0.2	0.3	0.3
NPDES 2 – Municipal 0.1-1.0 mgd	3.1	3.4	3.2	3.5	3.3	3.6	4.3	3.0	3.4	3.6	4.2
NPDES 3 – Municipal <0.1 mgd	3.2	3.1	1.3	1.2	1.1	1.1	1.3	2.1	2.8	2.7	2.8
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet Weather DST Pour Point	0.2	0.5	0.8	0.2	0.1	0.5	0.4	0.1	0.1	0.2	0.2
Total NPDES DST Pour Point	7.0	7.3	5.6	5.2	4.8	5.7	6.4	5.6	6.6	6.7	7.5
HSTS DST Pour Point	1.1	1.1	1.1	1.1	1.1	1.1	1.1	2.4	2.4	2.4	2.4
NPS DST Pour Point	38.2	55.0	40.2	33.3	44.5	62.9	92.3	47.8	34.1	63.5	49.2
Totals											
HSTS	4.1	4.1	4.1	4.1	4.1	4.1	4.1	6.8	6.8	6.8	6.8
Total NPDES	16.8	17.5	16.0	14.5	15.6	15.1	15.8	12.5	14.1	14.9	14.7
NPS Total	142.3	204.9	149.7	124.0	165.7	234.5	343.8	179.5	128.3	235.9	182.6
Total Load	163.2	226.4	169.8	142.6	185.3	253.7	363.7	198.8	149.1	257.6	204.1
% HSTS	2%	2%	2%	3%	2%	2%	1%	3%	5%	3%	3%
% NPDES	10%	8%	9%	10%	8%	6%	4%	6%	9%	6%	7%
% of NPDES – Municipal ≥ 1.0 mgd	38.5%	38.4%	44.3%	48.1%	46.1%	40.3%	34.9%	39.8%	38.8%	39.6%	37.7%
% of NPDES – Municipal 0.1-1.0 mgd	28.8%	29.6%	28.5%	31.2%	33.7%	35.8%	38.1%	34.2%	30.8%	32.0%	35.1%
% of NPDES – Municipal <0.1 mgd	23.5%	22.0%	12.1%	13.5%	11.4%	12.7%	16.2%	21.6%	25.1%	24.7%	24.2%
% of NPDES – Industrial	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
% of NPDES – Wet Weather	9.1%	10.0%	14.9%	7.1%	8.7%	11.1%	10.7%	4.3%	5.3%	3.7%	3.0%
% NPS	87%	90%	88%	87%	89%	92%	95%	90%	86%	92%	89%
Yield UPST Pour Point (lb/acre)	0.84	1.21	0.88	0.73	0.98	1.38	2.02	1.08	0.77	1.39	1.07
Per Capita Yield (lb/person)	0.45	0.46	0.41	0.41	0.43	0.41	0.42	0.41	0.44	0.46	0.46

Table 23 — Summary of total N loading components for calculating the nutrient mass balance in the Portage River watershed

Source	TP Load (mta)										
	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Upstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	192.4	206.1	225.8	202.4	142.7	152.7	140.5	117.8	135.7	125.2	123.1
NPDES 2 – Municipal 0.1-1.0 mgd	20.5	21.1	16.7	16.4	16.6	18.4	19.7	14.7	13.7	15.5	19.6
NPDES 3 – Municipal <0.1 mgd	6.6	6.0	5.8	3.4	3.4	3.6	3.8	2.4	2.7	3.3	3.1
NPDES – Industrial	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Wet Weather UPST Pour Point	37.3	35.2	45.0	23.8	33.4	31.4	36.3	11.2	17.4	10.0	6.9
Total NPDES UPST Pour Point	256.8	268.5	293.2	246.2	196.2	206.2	200.4	146.1	169.5	154.1	152.6
HSTS UPST Pour Point	28.9	28.9	28.9	28.9	28.9	28.9	28.9	42.2	31.5	42.2	42.2
Load @ Pour Point	2,861.4	2,279.4	2,947.1	2,360.9	3,903.4	3,163.0	3,930.0	2,358.0	3,033.0	2,876.0	1,992.0
NPS UPST Pour Point	2,575.8	1,982.1	2,625.1	2,085.9	3,678.4	2,927.9	3,700.7	2,169.7	2,832.0	2,679.7	1,797.2
Downstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	37.0	34.2	39.8	38.4	35.7	37.5	47.9	38.0	38.6	31.1	34.5
NPDES 2 – Municipal 0.1-1.0 mgd	17.1	16.9	17.1	17.2	21.1	24.3	23.2	16.3	20.1	15.7	19.8
NPDES 3 – Municipal <0.1 mgd	10.7	9.9	7.7	7.5	8.3	9.4	11.5	11.6	11.5	9.3	10.9
NPDES – Industrial	28.2	25.3	26.2	21.4	26.2	24.0	24.8	20.9	24.2	26.2	25.7
Wet Weather DST Pour Point	4.9	12.5	20.6	4.6	3.7	14.6	9.9	3.7	3.1	4.9	5.2
Total NPDES DST Pour Point	97.9	98.8	111.4	89.2	95.1	109.7	117.3	90.5	97.5	87.2	96.0
HSTS DST Pour Point	10.6	10.6	10.6	10.6	10.6	10.6	10.6	23.1	23.1	23.1	23.1
NPS DST Pour Point	944.8	727.1	962.9	765.1	1,349.3	1,074.0	1,357.5	786.4	1,026.4	986.9	661.9
Totals											
HSTS	39.5	39.5	39.5	39.5	39.5	39.5	39.5	65.3	54.6	65.3	65.3
Total NPDES	354.6	367.3	404.6	335.3	291.3	315.9	317.7	236.6	266.9	241.3	248.5
NPS Total	3,520.6	2,709.1	3,588.0	2,851.0	5,027.7	4,002.0	5,058.2	2,956.1	3,858.5	3,666.6	2,459.1
Total Load	3,914.7	3,115.9	4,032.0	3,225.8	5,358.4	4,357.4	5,415.4	3,258.0	4,180.0	3,973.2	2,773.0
% HSTS	1%	1%	1%	1%	1%	1%	1%	2%	1%	2%	2%
% NPDES	9%	12%	10%	10%	5%	7%	6%	7%	6%	6%	9%
% of NPDES – Municipal ≥ 1.0 mgd	64.7%	65.4%	65.6%	71.8%	61.3%	60.2%	59.3%	65.9%	65.3%	64.8%	63.4%
% of NPDES – Municipal 0.1-1.0 mgd	10.6%	10.3%	8.4%	10.0%	12.9%	13.5%	13.5%	13.1%	12.7%	12.9%	15.8%
% of NPDES – Municipal <0.1 mgd	4.9%	4.3%	3.3%	3.3%	4.0%	4.1%	4.8%	5.9%	5.3%	5.2%	5.6%
% of NPDES – Industrial	8.0%	6.9%	6.5%	6.4%	9.0%	7.6%	7.8%	8.8%	9.1%	10.9%	10.3%
% of NPDES – Wet Weather	11.9%	13.0%	16.2%	8.5%	12.7%	14.6%	14.5%	6.3%	7.7%	6.2%	4.8%
% NPS	90%	87%	89%	88%	94%	92%	93%	91%	92%	92%	89%
Yield UPST Pour Point (lb/acre)	20.73	15.96	21.13	16.79	29.61	23.57	29.79	17.84	23.29	21.54	14.45
Per Capita Yield (lb/person)	7.54	7.77	8.20	7.56	6.22	6.64	6.66	5.78	6.01	5.76	6.00

Table 24 — Summary of total P loading components for calculating the nutrient mass balance in the Cedar-Toussaint watershed

	TP Load (mta)										
Source	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Downstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	2.3	1.7	2.5	2.5	0.9	1.9	1.1	3.5	3.6	4.1	4.5
NPDES 2 – Municipal 0.1-1.0 mgd	1.3	1.7	1.6	1.5	1.2	1.1	1.2	0.8	0.9	0.3	0.4
NPDES 3 – Municipal <0.1 mgd	0.9	1.1	0.9	1.1	0.9	0.9	0.9	0.9	1.0	1.1	1.0
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet Weather DST Pour Point	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total NPDES DST Pour Point	4.5	4.5	5.1	5.0	3.1	4.0	3.1	5.1	5.6	5.5	5.8
HSTS DST Pour Point	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.3	8.3	8.3	8.3
NPS DST Pour Point	83.6	120.4	88.0	72.9	97.4	137.8	202.1	101.7	72.7	143.1	110.8
Totals											
HSTS	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.3	8.3	8.3	8.3
Total NPDES	4.5	4.5	5.1	5.0	3.1	4.0	3.1	5.1	5.6	5.5	5.8
NPS Total	83.6	120.4	88.0	72.9	97.4	137.8	202.1	101.7	72.7	143.1	110.8
Total Load	96.2	132.9	101.1	86.0	108.5	149.8	213.2	115.2	86.6	156.9	124.9
% HSTS	8%	6%	8%	9%	7%	5%	4%	7%	10%	5%	7%
% NPDES	5%	3%	5%	6%	3%	3%	1%	4%	6%	3%	5%
% of NPDES – Municipal ≥ 1.0 mgd	50.6%	37.3%	50.0%	48.9%	30.3%	48.1%	34.0%	67.9%	64.9%	74.0%	76.7%
% of NPDES – Municipal 0.1-1.0 mgd	29.3%	38.6%	32.1%	29.8%	39.7%	28.3%	37.9%	15.3%	16.9%	5.1%	6.4%
% of NPDES – Municipal <0.1 mgd	20.1%	24.1%	17.9%	21.3%	29.9%	23.5%	28.0%	16.8%	18.2%	20.2%	16.8%
% of NPDES – Industrial	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.7%	0.1%
% of NPDES – Wet Weather	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% NPS	87%	91%	87%	85%	90%	92%	95%	88%	84%	91%	89%
Yield UPST Pour Point (lb/acre)	0.84	1.21	0.88	0.73	0.98	1.38	2.02	1.08	0.77	1.39	1.07
Per Capita Yield (lb/person)	0.52	0.52	0.55	0.55	0.46	0.50	0.47	0.50	0.51	0.51	0.52

Table 25 — Summary of total N loading components for calculating the nutrient mass balance in the Cedar-Toussaint watershed

	TN Load (mta)										
Source	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Downstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	57.4	55.9	71.6	74.1	85.6	80.7	85.4	72.7	85.7	93.9	77.1
NPDES 2 – Municipal 0.1-1.0 mgd	4.0	5.3	3.6	3.5	4.7	4.3	4.5	3.2	3.2	0.5	0.8
NPDES 3 – Municipal <0.1 mgd	7.0	5.3	5.5	6.3	5.7	6.9	5.0	5.9	5.6	5.2	5.2
NPDES – Industrial	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet Weather DST Pour Point	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total NPDES DST Pour Point	68.4	67.5	80.6	83.9	96.0	91.9	94.9	81.8	94.5	99.6	83.1
HSTS DST Pour Point	58.0	58.0	58.0	58.0	58.0	58.0	58.0	80.4	80.4	80.4	80.4
NPS DST Pour Point	2,069.1	1,592.2	2,108.7	1,675.6	2,954.9	2,352.0	2,972.8	1,675.2	2,186.6	2,224.4	1,491.9
Totals											
HSTS	58.0	58.0	58.0	58.0	58.0	58.0	58.0	80.4	80.4	80.4	80.4
Total NPDES	68.4	67.5	80.6	83.9	96.0	91.9	94.9	81.8	94.5	99.6	83.1
NPS Total	2,069.1	1,592.2	2,108.7	1,675.6	2,954.9	2,352.0	2,972.8	1,675.2	2,186.6	2,224.4	1,491.9
Total Load	2,195.5	1,717.7	2,247.4	1,817.5	3,108.9	2,502.0	3,125.7	1,837.4	2,361.5	2,404.4	1,655.4
% HSTS	3%	3%	3%	3%	2%	2%	2%	4%	3%	3%	5%
% NPDES	3%	4%	4%	5%	3%	4%	3%	4%	4%	4%	5%
% of NPDES – Municipal ≥ 1.0 mgd	83.9%	82.7%	88.7%	88.3%	89.1%	87.8%	90.0%	88.9%	90.6%	94.3%	92.8%
% of NPDES – Municipal 0.1-1.0 mgd	5.9%	7.9%	4.4%	4.2%	4.9%	4.7%	4.7%	4.0%	3.4%	0.5%	0.9%
% of NPDES – Municipal <0.1 mgd	10.2%	7.9%	6.8%	7.5%	6.0%	7.5%	5.3%	7.2%	6.0%	5.2%	6.3%
% of NPDES – Industrial	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% of NPDES – Wet Weather	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% NPS	94%	93%	94%	92%	95%	94%	95%	91%	93%	93%	90%
Yield UPST Pour Point (lb/acre)	20.73	15.96	21.13	16.79	29.61	23.57	29.79	17.84	23.29	21.54	14.45
Per Capita Yield (lb/person)	5.28	5.20	5.79	5.93	6.43	6.26	6.38	5.97	6.44	6.63	6.02

Table 26 — Summary of total P loading components for calculating the nutrient mass balance in the Sandusky River watershed

	TP Load (mta)										
Source	**wy13**	**wy14**	**wy15**	**wy16**	**wy17**	**wy18**	**wy19**	**wy20**	**wy21**	**wy22**	**wy23**
Upstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	12.8	9.9	8.1	6.7	8.2	9.3	9.7	8.2	7.9	5.4	4.9
NPDES 2 – Municipal 0.1-1.0 mgd	2.0	2.4	2.5	2.3	2.1	2.2	2.0	1.4	1.2	1.4	0.9
NPDES 3 – Municipal <0.1 mgd	1.0	1.0	1.0	0.9	1.0	1.1	1.0	1.1	1.4	1.0	1.0
NPDES – Industrial	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1
Wet Weather UPST Pour Point	1.8	1.9	1.8	1.6	1.6	2.0	3.0	2.0	1.9	3.3	1.9
Total NPDES UPST Pour Point	17.7	15.3	13.5	11.6	13.0	14.7	15.9	12.7	12.5	11.3	8.8
HSTS UPST Pour Point	13.2	13.2	13.2	13.2	13.2	13.2	13.2	12.8	12.8	12.8	12.8
Load @ Pour Point	642.0	558.0	352.0	295.0	539.0	567.0	828.0	486.0	385.0	635.0	406.0
NPS UPST Pour Point	611.0	529.5	325.3	270.2	512.7	539.0	798.9	460.5	359.7	611.0	384.4
Downstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	10.9	12.9	11.6	12.3	10.5	13.4	14.6	12.5	12.9	9.9	9.6
NPDES 2 – Municipal 0.1-1.0 mgd	0.4	0.4	0.3	0.4	0.4	0.4	0.7	0.3	0.4	0.0	0.0
NPDES 3 – Municipal <0.1 mgd	1.2	1.4	1.1	1.1	1.3	1.6	1.5	1.5	1.5	1.4	1.9
NPDES – Industrial	0.1	0.4	1.2	0.9	0.6	0.2	0.1	0.1	0.1	0.1	0.0
Wet Weather DST Pour Point	3.7	4.0	5.0	2.5	1.1	1.2	1.3	0.9	0.5	0.4	1.1
Total NPDES DST Pour Point	16.3	19.1	19.2	17.2	13.9	16.8	18.2	15.2	15.4	11.8	12.6
HSTS DST Pour Point	12.1	12.1	12.1	12.1	12.1	12.1	12.1	11.7	11.7	11.7	11.7
NPS DST Pour Point	281.0	243.5	149.6	124.3	235.8	247.9	367.4	192.7	150.5	277.9	174.8
Totals											
HSTS	25.4	25.4	25.4	25.4	25.4	25.4	25.4	24.4	24.4	24.4	24.4
Total NPDES	34.0	34.4	32.7	28.8	27.0	31.5	34.0	28.0	27.9	23.0	21.5
NPS Total	892.0	773.0	474.8	394.5	748.5	786.9	1,166.3	653.2	510.2	888.9	559.2
Total Load	951.4	832.7	532.9	448.6	800.9	843.8	1,225.7	705.6	562.5	936.3	605.1
% HSTS	3%	3%	5%	6%	3%	3%	2%	3%	4%	3%	4%
% NPDES	4%	4%	6%	6%	3%	4%	3%	4%	5%	2%	4%
% of NPDES – Municipal ≥ 1.0 mgd	69.7%	66.5%	60.1%	66.1%	69.3%	72.0%	71.3%	74.1%	74.6%	66.5%	67.4%
% of NPDES – Municipal 0.1-1.0 mgd	7.1%	8.2%	8.7%	9.3%	9.1%	8.2%	7.8%	5.8%	5.7%	6.0%	4.3%
% of NPDES – Municipal <0.1 mgd	6.5%	6.9%	6.7%	6.8%	8.6%	8.6%	7.4%	9.1%	10.2%	10.4%	13.5%
% of NPDES – Industrial	0.5%	1.2%	3.8%	3.5%	3.0%	1.3%	0.7%	0.5%	0.7%	0.9%	0.7%
% of NPDES – Wet Weather	16.3%	17.3%	20.6%	14.4%	10.0%	10.1%	12.8%	10.6%	8.7%	16.2%	14.1%
% NPS	94%	93%	89%	88%	93%	93%	95%	93%	91%	95%	92%
Yield UPST Pour Point (lb/acre)	1.68	1.46	0.90	0.74	1.41	1.48	2.20	1.28	1.00	1.68	1.06
Per Capita Yield (lb/person)	0.58	0.58	0.54	0.53	0.53	0.58	0.59	0.40	0.41	0.36	0.35

Table 27 — Summary of total N loading components for calculating the nutrient mass balance in the Sandusky River watershed

	TN Load (mta)										
Source	**wy13**	**wy14**	**wy15**	**wy16**	**wy17**	**wy18**	**wy19**	**wy20**	**wy21**	**wy22**	**wy23**
Upstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	165.6	152.7	138.2	124.7	138.3	124.4	115.6	128.9	102.6	85.4	91.1
NPDES 2 – Municipal 0.1-1.0 mgd	19.1	19.0	20.7	23.6	15.4	19.2	16.1	15.4	16.1	12.8	14.7
NPDES 3 – Municipal <0.1 mgd	7.4	7.5	7.7	6.8	7.9	10.0	8.6	8.5	7.6	6.6	7.9
NPDES – Industrial	0.2	0.2	0.2	0.2	0.4	0.5	0.5	0.7	0.7	0.3	0.2
Wet Weather UPST Pour Point	49.6	53.0	48.4	44.2	44.7	53.5	83.5	55.8	52.2	91.6	53.0
Total NPDES UPST Pour Point	241.9	232.4	215.2	199.6	206.7	207.5	224.4	209.3	179.1	196.6	167.0
HSTS UPST Pour Point	128.1	128.1	128.1	128.1	128.1	128.1	128.1	123.7	123.7	123.7	123.7
Load @ Pour Point	9,943.2	7,116.2	6,141.6	5,646.8	8,670.6	7,910.0	9,800.0	6,450.0	7,210.0	7,660.0	5,710.0
NPS UPST Pour Point	9,573.1	6,755.7	5,798.2	5,319.0	8,335.7	7,574.3	9,447.5	6,117.1	6,907.2	7,339.7	5,419.3
Downstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	591.6	401.6	405.5	386.4	425.0	442.9	434.4	362.2	366.5	429.4	354.6
NPDES 2 – Municipal 0.1-1.0 mgd	13.3	7.4	13.5	14.7	12.9	15.2	23.0	16.3	20.7	0.0	0.0
NPDES 3 – Municipal <0.1 mgd	21.1	19.0	18.8	23.0	28.9	31.3	28.4	26.4	26.2	22.4	24.6
NPDES – Industrial	0.2	0.1	0.2	0.1	0.1	0.4	0.2	0.2	0.7	0.3	0.2
Wet Weather DST Pour Point	101.8	109.4	136.4	69.0	29.4	33.3	36.3	25.5	14.3	10.4	30.1
Total NPDES DST Pour Point	728.0	537.6	574.5	493.2	496.3	523.1	522.2	430.7	428.4	462.6	409.4
HSTS DST Pour Point	92.0	92.0	92.0	92.0	92.0	92.0	92.0	112.8	112.8	112.8	112.8
NPS DST Pour Point	4,402.3	3,106.7	2,666.4	2,446.0	3,833.3	3,483.1	4,344.5	2,559.8	2,890.5	3,338.5	2,465.0
Totals											
HSTS	220.1	220.1	220.1	220.1	220.1	220.1	220.1	236.4	236.4	236.4	236.4
Total NPDES	969.9	770.0	789.7	692.8	703.1	730.7	746.6	639.9	607.6	659.2	576.4
NPS Total	13,975.4	9,862.4	8,464.5	7,765.1	12,168.9	11,057.4	13,792.0	8,676.9	9,797.6	10,678.2	7,884.3
Total Load	15,165.4	10,852.5	9,474.3	8,678.0	13,092.1	12,008.2	14,758.7	9,553.3	10,641.6	11,573.8	8,697.1
% HSTS	1%	2%	2%	3%	2%	2%	1%	2%	2%	2%	3%
% NPDES	6%	7%	8%	8%	5%	6%	5%	7%	6%	6%	7%
% of NPDES – Municipal ≥ 1.0 mgd	78.1%	72.0%	68.9%	73.8%	80.1%	77.6%	73.7%	76.7%	77.2%	78.1%	77.3%
% of NPDES – Municipal 0.1-1.0 mgd	3.3%	3.4%	4.3%	5.5%	4.0%	4.7%	5.2%	5.0%	6.0%	1.9%	2.6%
% of NPDES – Municipal <0.1 mgd	2.9%	3.4%	3.4%	4.3%	5.2%	5.7%	5.0%	5.4%	5.6%	4.4%	5.6%
% of NPDES – Industrial	0.0%	0.0%	0.1%	0.0%	0.1%	0.1%	0.1%	0.2%	0.2%	0.1%	0.1%
% of NPDES – Wet Weather	15.6%	21.1%	23.4%	16.4%	10.5%	11.9%	16.0%	12.7%	10.9%	15.5%	14.4%
% NPS	92%	91%	89%	89%	93%	92%	93%	91%	92%	92%	91%
Yield UPST Pour Point (lb/acre)	26.37	18.61	15.97	14.65	22.96	20.86	26.02	16.99	19.18	20.22	14.93
Per Capita Yield (lb/person)	11.20	8.92	8.89	8.62	9.15	9.31	9.13	6.51	6.36	6.50	5.98

Table 28 — Summary of total P loading components for calculating the nutrient mass balance in the Huron watershed

	TP Load (mta)					
Source	**wy18**	**wy19**	**wy20**	**wy21**	**wy22**	**wy23**
Upstream of Pour Point						
NPDES 1 – Municipal ≥1.0 mgd	1.8	1.9	1.3	1.2	1.4	1.0
NPDES 2 – Municipal 0.1-1.0 mgd	0.8	0.5	0.5	0.4	0.5	0.4
NPDES 3 – Municipal <0.1 mgd	0.2	0.1	0.2	0.1	0.1	0.1
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.0
Wet Weather UPST Pour Point	0.1	0.1	0.0	0.1	0.0	0.0
Total NPDES UPST Pour Point	2.8	2.6	2.0	1.8	2.1	1.6
HSTS UPST Pour Point	5.3	5.3	4.6	4.6	4.6	4.6
Load @ Pour Point	184.0	198.0	144.0	107.0	177.0	110.0
NPS UPST Pour Point	175.9	190.1	137.4	100.6	170.4	103.9
Downstream of Pour Point						
NPDES 1 – Municipal ≥1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0
NPDES 2 – Municipal 0.1-1.0 mgd	0.5	0.7	0.7	0.8	0.7	0.8
NPDES 3 – Municipal <0.1 mgd	0.0	0.0	0.1	0.1	0.2	0.2
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.0
Wet Weather DST Pour Point	0.0	0.0	0.0	0.0	0.0	0.0
Total NPDES DST Pour Point	0.5	0.7	0.8	0.9	0.8	1.0
HSTS DST Pour Point	0.5	0.5	1.1	1.1	1.1	1.1
NPS DST Pour Point	16.8	18.2	12.9	9.4	16.2	9.9
Totals						
HSTS	5.8	5.8	5.7	5.7	5.7	5.7
Total NPDES	3.3	3.3	2.9	2.8	2.9	2.6
NPS Total	192.7	208.3	150.2	110.0	186.6	113.8
Total Load	201.8	217.4	158.8	118.5	195.2	122.0
% HSTS	3%	3%	4%	5%	3%	5%
% NPDES	2%	2%	2%	2%	1%	2%
% of NPDES – Municipal ≥ 1.0 mgd	53.4%	57.1%	46.8%	44.8%	49.5%	40.5%
% of NPDES – Municipal 0.1-1.0 mgd	39.1%	34.6%	43.7%	45.3%	39.6%	46.5%
% of NPDES – Municipal <0.1 mgd	5.5%	4.2%	8.0%	8.1%	9.2%	11.1%
% of NPDES – Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% of NPDES – Wet Weather	1.9%	4.1%	1.5%	1.8%	1.7%	1.9%
% NPS	95%	96%	95%	93%	96%	93%
Yield UPST Pour Point (lb/acre)	1.64	1.77	1.29	0.94	1.59	0.97
Per Capita Yield (lb/person)	0.29	0.29	0.34	0.33	0.34	0.32

Table 29 — Summary of total N loading components for calculating the nutrient mass balance in the Huron watershed

Source	TN Load (mta) wy18	wy19	wy20	wy21	wy22	wy23
Upstream of Pour Point						
NPDES 1 – Municipal ≥1.0 mgd	100.9	97.7	86.5	77.2	62.2	67.0
NPDES 2 – Municipal 0.1-1.0 mgd	10.3	9.8	8.2	7.4	6.2	4.7
NPDES 3 – Municipal <0.1 mgd	1.7	1.0	0.9	1.1	0.9	0.9
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.0
Wet Weather UPST Pour Point	1.8	3.7	1.2	1.4	1.3	1.3
Total NPDES UPST Pour Point	114.6	112.3	96.8	87.1	70.6	73.9
HSTS UPST Pour Point	38.0	38.0	45.0	45.0	45.0	45.0
Load @ Pour Point	1,836.0	2,405.0	1,644.0	2,158.0	1,942.0	1,480.0
NPS UPST Pour Point	1,683.4	2,254.7	1,502.3	2,025.9	1,826.4	1,361.1
Downstream of Pour Point						
NPDES 1 – Municipal ≥1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0
NPDES 2 – Municipal 0.1-1.0 mgd	44.9	54.2	59.6	56.3	45.2	42.9
NPDES 3 – Municipal <0.1 mgd	0.3	0.3	0.4	0.8	1.2	1.4
NPDES – Industrial	0.1	0.1	0.1	0.0	0.0	0.0
Wet Weather DST Pour Point	0.0	0.0	0.0	0.0	0.0	0.0
Total NPDES DST Pour Point	45.2	54.6	60.2	57.1	46.5	44.3
HSTS DST Pour Point	3.6	3.6	10.9	10.9	10.9	10.9
NPS DST Pour Point	160.8	215.4	140.6	189.6	174.1	129.8
Totals						
HSTS	41.6	41.6	55.9	55.9	55.9	55.9
Total NPDES	159.8	166.9	156.9	144.3	117.1	118.2
NPS Total	1,844.2	2,470.1	1,642.9	2,215.5	2,000.5	1,490.9
Total Load	2,045.7	2,678.6	1,855.7	2,415.7	2,173.5	1,665.0
% HSTS	2%	2%	3%	2%	3%	3%
% NPDES	8%	6%	8%	6%	5%	7%
% of NPDES – Municipal ≥ 1.0 mgd	63.1%	58.6%	55.2%	53.5%	53.1%	56.7%
% of NPDES – Municipal 0.1-1.0 mgd	34.5%	38.4%	43.2%	44.2%	43.8%	40.2%
% of NPDES – Municipal <0.1 mgd	1.2%	0.8%	0.8%	1.4%	1.9%	1.9%
% of NPDES – Industrial	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
% of NPDES – Wet Weather	1.1%	2.2%	0.7%	1.0%	1.1%	1.1%
% NPS	90%	92%	89%	92%	92%	90%
Yield UPST Pour Point (lb/acre)	15.65	20.96	14.05	18.95	16.99	12.66
Per Capita Yield (lb/person)	6.49	6.65	8.36	7.85	6.78	6.82

Table 30 — Summary of total P loading components for calculating the nutrient mass balance in the Old Woman Creek watershed

	TP Load (mta)							
Source	**wy16**	**wy17**	**wy18**	**wy19**	**wy20**	**wy21**	**wy22**	**wy23**
Upstream of Pour Point								
NPDES 1 – Municipal ≥1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NPDES 2 – Municipal 0.1-1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NPDES 3 – Municipal <0.1 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet Weather UPST Pour Point	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total NPDES UPST Pour Point	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HSTS UPST Pour Point	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5
Load @ Pour Point	5.1	6.7	6.7	9.5	6.2	5.7	4.0	5.4
NPS UPST Pour Point	4.4	6.0	6.0	8.8	5.7	5.2	3.5	4.8
Downstream of Pour Point								
NPDES 1 – Municipal ≥1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NPDES 2 – Municipal 0.1-1.0 mgd	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.0
NPDES 3 – Municipal <0.1 mgd	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.2
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet Weather DST Pour Point	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total NPDES DST Pour Point	0.6	0.5	0.5	0.4	0.5	0.4	0.5	0.2
HSTS DST Pour Point	1.9	1.9	1.9	1.9	2.2	2.2	2.2	2.2
NPS DST Pour Point	13.2	18.2	18.0	26.3	17.2	15.7	10.8	14.9
Totals								
HSTS	2.6	2.6	2.6	2.6	2.7	2.7	2.7	2.7
Total NPDES	0.6	0.5	0.5	0.4	0.5	0.5	0.5	0.2
NPS Total	17.6	24.2	24.1	35.2	22.8	20.8	14.3	19.7
Total Load	20.7	27.3	27.1	38.1	26.1	24.0	17.5	22.7
% HSTS	12%	9%	9%	7%	11%	11%	16%	12%
% NPDES	3%	2%	2%	1%	2%	2%	3%	1%
% of NPDES – Municipal ≥ 1.0 mgd	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% of NPDES – Municipal 0.1-1.0 mgd	58.7%	55.7%	60.8%	55.0%	63.3%	75.7%	69.7%	6.3%
% of NPDES – Municipal <0.1 mgd	41.3%	44.3%	39.2%	45.0%	36.7%	24.3%	30.3%	93.7%
% of NPDES – Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% of NPDES – Wet Weather	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% NPS	85%	89%	89%	92%	88%	87%	82%	87%
Yield UPST Pour Point (lb/acre)	0.69	0.95	0.94	1.38	0.90	0.82	0.55	0.76
Per Capita Yield (lb/person)	0.57	0.57	0.56	0.54	0.67	0.67	0.67	0.61

Table 31 — Summary of total N loading components for calculating the nutrient mass balance in the Old Woman Creek watershed

	TN Load (mta)							
Source	**wy16**	**wy17**	**wy18**	**wy19**	**wy20**	**wy21**	**wy22**	**wy23**
Upstream of Pour Point								
NPDES 1 – Municipal ≥1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NPDES 2 – Municipal 0.1-1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NPDES 3 – Municipal <0.1 mgd	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet Weather UPST Pour Point	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total NPDES UPST Pour Point	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
HSTS UPST Pour Point	4.6	4.6	4.6	4.6	5.4	5.4	5.4	5.4
Load @ Pour Point	77.6	116.0	91.4	156.5	70.1	85.1	73.4	82.6
NPS UPST Pour Point	73.0	111.4	86.8	151.8	64.7	79.7	68.0	77.3
Downstream of Pour Point								
NPDES 1 – Municipal ≥1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NPDES 2 – Municipal 0.1-1.0 mgd	1.6	1.5	2.0	2.2	2.5	1.8	2.0	0.1
NPDES 3 – Municipal <0.1 mgd	2.2	1.4	1.8	1.7	1.3	0.9	1.0	1.3
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet Weather DST Pour Point	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total NPDES DST Pour Point	3.8	2.9	3.8	3.9	3.8	2.7	3.0	1.4
HSTS DST Pour Point	13.8	13.8	13.8	13.8	21.6	21.6	21.6	21.6
NPS DST Pour Point	217.6	332.1	258.7	452.6	196.5	242.2	210.0	238.6
Totals								
HSTS	18.4	18.4	18.4	18.4	27.0	27.0	27.0	27.0
Total NPDES	3.8	2.9	3.8	4.0	3.8	2.7	3.0	1.5
NPS Total	290.6	443.4	345.5	604.4	261.2	321.9	278.0	315.9
Total Load	312.8	464.7	367.6	626.8	292.0	351.6	308.0	344.3
% HSTS	6%	4%	5%	3%	9%	8%	9%	8%
% NPDES	1%	1%	1%	1%	1%	1%	1%	0%
% of NPDES – Municipal ≥ 1.0 mgd	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% of NPDES – Municipal 0.1-1.0 mgd	40.9%	50.6%	52.8%	54.7%	64.1%	65.9%	65.7%	6.4%
% of NPDES – Municipal <0.1 mgd	59.1%	49.4%	47.2%	45.3%	35.9%	34.1%	34.3%	93.6%
% of NPDES – Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% of NPDES – Wet Weather	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% NPS	93%	95%	94%	96%	89%	92%	90%	92%
Yield UPST Pour Point (lb/acre)	11.38	17.36	13.53	23.66	10.25	12.64	10.76	12.22
Per Capita Yield (lb/person)	4.12	3.94	4.10	4.14	6.44	6.21	6.27	5.94

Table 32 — Summary of total P loading components for calculating the nutrient mass balance in the Vermilion River watershed

	TP Load (mta)										
Source	**wy13**	**wy14**	**wy15**	**wy16**	**wy17**	**wy18**	**wy19**	**wy20**	**wy21**	**wy22**	**wy23**
Upstream of Pour Point										**TBD**	**TBD**
NPDES 1 – Municipal ≥1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
NPDES 2 – Municipal 0.1-1.0 mgd	2.1	2.0	0.9	0.8	0.9	1.1	1.2	0.9	0.7		
NPDES 3 – Municipal <0.1 mgd	0.6	0.6	0.7	0.5	0.5	0.6	0.7	0.6	0.7		
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Wet Weather UPST Pour Point	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Total NPDES UPST Pour Point	2.7	2.5	1.6	1.3	1.4	1.7	1.9	1.5	1.4		
HSTS UPST Pour Point	3.8	3.8	3.8	3.8	3.8	3.8	3.8	4.3	4.3		
Load @ Pour Point	137.1	142.1	81.2	65.4	83.8	121.0	151.7	77.7	119.9		
NPS UPST Pour Point	130.6	135.8	75.9	60.3	78.6	115.5	146.1	71.8	114.3		
Downstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	0.5	0.5	0.4	0.6	0.8	0.4	0.5	0.4	0.5		
NPDES 2 – Municipal 0.1-1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
NPDES 3 – Municipal <0.1 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Wet Weather DST Pour Point	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Total NPDES DST Pour Point	0.5	0.5	0.4	0.6	0.8	0.4	0.5	0.4	0.5		
HSTS DST Pour Point	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2		
NPS DST Pour Point	3.5	3.6	2.0	1.6	2.1	3.1	3.9	1.8	2.8		
Totals											
HSTS	3.9	3.9	3.9	3.9	3.9	3.9	3.9	4.5	4.5		
Total NPDES	3.2	3.0	1.9	1.9	2.2	2.1	2.3	2.0	1.8		
NPS Total	134.1	139.4	77.9	61.9	80.7	118.6	150.0	73.6	117.1		
Total Load	141.2	146.3	83.7	67.7	86.8	124.6	156.2	80.1	123.4		
% HSTS	3%	3%	5%	6%	4%	3%	2%	6%	4%		
% NPDES	2%	2%	2%	3%	3%	2%	1%	2%	1%		
% of NPDES – Municipal ≥ 1.0 mgd	15.1%	16.6%	19.6%	30.6%	36.3%	19.9%	20.1%	21.9%	25.0%		
% of NPDES – Municipal 0.1-1.0 mgd	64.7%	64.6%	45.8%	42.4%	42.6%	52.0%	50.6%	48.5%	38.2%		
% of NPDES – Municipal <0.1 mgd	20.2%	18.8%	34.6%	27.0%	21.1%	28.1%	29.3%	29.6%	36.8%		
% of NPDES – Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
% of NPDES – Wet Weather	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
% NPS	95%	95%	93%	92%	93%	95%	96%	92%	95%		
Yield UPST Pour Point (lb/acre)	1.72	1.79	1.00	0.79	1.03	1.52	1.92	0.95	1.51		
Per Capita Yield (lb/person)	0.50	0.49	0.41	0.41	0.43	0.42	0.44	0.43	0.42		

Table 33 — Summary of total N loading components for calculating the nutrient mass balance in the Vermilion River watershed

	TN Load (mta)										
Source	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Upstream of Pour Point										TBD	TBD
NPDES 1 – Municipal ≥1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
NPDES 2 – Municipal 0.1-1.0 mgd	13.7	15.2	12.6	14.0	15.0	15.3	15.3	14.7	12.3		
NPDES 3 – Municipal <0.1 mgd	5.3	5.7	5.3	5.9	4.7	5.5	4.5	3.7	5.1		
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Wet Weather UPST Pour Point	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
OOS Point Source	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
OOS Wet Weather	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Total NPDES UPST Pour Point	19.0	20.9	18.0	19.9	19.7	20.8	19.8	18.3	17.4		
HSTS UPST Pour Point	27.3	27.3	27.3	27.3	27.3	27.3	27.3	42.2	42.2		
Load @ Pour Point	1,441.6	1,500.0	854.8	871.1	1,144.9	1,362.6	1,980.9	747.6	1,134.5		
NPS UPST Pour Point	1,395.2	1,451.7	809.4	823.9	1,097.9	1,314.5	1,933.7	687.1	1,074.9		
Downstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	30.9	31.0	21.9	23.3	23.9	26.7	31.5	25.4	24.3		
NPDES 2 – Municipal 0.1-1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
NPDES 3 – Municipal <0.1 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Wet Weather DST Pour Point	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Total NPDES DST Pour Point	30.9	31.0	21.9	23.3	23.9	26.7	31.5	25.4	24.3		
HSTS DST Pour Point	0.7	0.7	0.7	0.7	0.7	0.7	0.7	2.2	2.2		
NPS DST Pour Point	37.3	38.8	21.6	22.0	29.3	35.1	51.7	17.0	26.6		
Totals											
HSTS	28.1	28.1	28.1	28.1	28.1	28.1	28.1	44.4	44.4		
Total NPDES	49.9	51.9	39.9	43.2	43.6	47.5	51.2	43.7	41.7		
NPS Total	1,432.5	1,490.5	831.1	845.9	1,127.2	1,349.6	1,985.4	704.1	1101.6		
Total Load	1,510.5	1,570.5	899.0	917.2	1,198.9	1,425.2	2,064.7	792.0	1,187.7		
% HSTS	2%	2%	3%	3%	2%	2%	1%	6%	4%		
% NPDES	3%	3%	4%	5%	4%	3%	2%	6%	4%		
% of NPDES – Municipal ≥ 1.0 mgd	61.9%	59.7%	54.9%	54.0%	54.8%	56.2%	61.4%	58.1%	58.4%		
% of NPDES – Municipal 0.1-1.0 mgd	27.4%	29.2%	31.7%	32.3%	34.3%	32.2%	29.8%	33.5%	29.4%		
% of NPDES – Municipal <0.1 mgd	10.7%	11.1%	13.4%	13.7%	10.8%	11.7%	8.8%	8.4%	12.2%		
% of NPDES – Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
% of NPDES – Wet Weather	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
% NPS	95%	95%	92%	92%	94%	95%	96%	89%	93%		
Yield UPST Pour Point (lb/acre)	18.35	19.09	10.64	10.83	14.44	17.29	25.43	9.09	14.22		
Per Capita Yield (lb/person)	5.52	5.67	4.81	5.05	5.08	5.36	5.62	5.80	5.67		

Table 34 — Summary of total P loading components for calculating the nutrient mass balance in the Cuyahoga River watershed

	TP Load (mta)										
Source	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Upstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	64.7	58.8	53.6	59.4	57.2	53.0	37.0	30.0	45.4	38.4	32.7
NPDES 2 – Municipal 0.1-1.0 mgd	1.1	1.1	1.1	1.2	1.4	0.9	1.2	1.2	1.1	1.3	1.2
NPDES 3 – Municipal <0.1 mgd	1.8	1.2	1.4	1.4	1.4	1.5	1.5	1.6	1.2	1.2	1.2
NPDES – Industrial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet Weather UPST Pour Point	3.1	2.9	2.2	1.8	2.2	2.6	2.4	0.8	0.6	0.7	0.4
Total NPDES UPST Pour Point	70.8	64.0	58.3	63.7	62.1	58.1	42.2	33.7	48.4	41.7	35.5
HSTS UPST Pour Point	31.1	31.1	31.1	31.1	31.1	31.1	31.1	20.5	20.5	20.4	20.4
Load @ Pour Point	240.0	264.0	194.0	109.0	216.0	220.0	267.0	155.0	167.0	183.0	167.0
NPS UPST Pour Point	138.2	168.9	104.6	14.2	122.8	130.9	193.7	100.8	98.1	120.9	111.1
Downstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	41.1	53.0	75.8	73.2	74.3	42.8	62.7	59.5	70.0	56.9	54.6
NPDES 2 – Municipal 0.1-1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NPDES 3 – Municipal <0.1 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NPDES – Industrial	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Wet Weather DST Pour Point	8.0	8.2	8.7	17.5	12.9	35.2	35.7	13.0	13.4	7.2	7.3
Total NPDES DST Pour Point	49.1	61.2	84.5	90.7	87.3	78.1	98.6	72.6	83.6	64.2	62.0
HSTS DST Pour Point	4.4	4.4	4.4	4.4	4.4	4.4	4.4	0.3	0.3	0.3	0.3
NPS DST Pour Point	19.7	24.1	14.9	2.0	17.5	18.7	27.7	15.3	14.9	18.0	16.6
Totals											
HSTS	35.5	35.5	35.5	35.5	35.5	35.5	35.5	20.9	20.9	20.8	20.8
Total NPDES	119.8	125.2	142.8	154.4	149.4	136.2	140.7	106.3	131.9	105.9	97.4
NPS Total	157.9	193.0	119.6	16.2	140.3	149.5	221.4	116.1	112.9	138.9	127.7
Total Load	313.3	353.8	297.9	206.1	325.2	321.2	397.7	243.2	265.7	265.5	245.9
% HSTS	11%	10%	12%	17%	11%	11%	9%	9%	8%	8%	8%
% NPDES	38%	35%	48%	75%	46%	42%	35%	44%	50%	40%	40%
% of NPDES – Municipal ≥ 1.0 mgd	88.3%	89.3%	90.6%	85.8%	88.0%	70.4%	70.9%	84.2%	87.4%	90.1%	89.6%
% of NPDES – Municipal 0.1-1.0 mgd	0.9%	0.9%	0.8%	0.8%	0.9%	0.7%	0.9%	1.1%	0.9%	1.2%	1.2%
% of NPDES – Municipal <0.1 mgd	1.5%	1.0%	1.0%	0.9%	0.9%	1.1%	1.1%	1.5%	0.9%	1.1%	1.2%
% of NPDES – Industrial	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
% of NPDES – Wet Weather	9.2%	8.9%	7.6%	12.5%	10.1%	27.8%	27.1%	13.1%	10.7%	7.5%	7.9%
% NPS	50%	55%	40%	8%	43%	47%	56%	48%	43%	52%	52%
Yield UPST Pour Point (lb/acre)	0.67	0.82	0.51	0.07	0.60	0.64	0.94	0.50	0.49	0.59	0.54
Per Capita Yield (lb/person)	0.28	0.29	0.33	0.33	0.33	0.26	0.27	0.22	0.27	0.23	0.21

Table 35 — Summary of total N loading components for calculating the nutrient mass balance in the Cuyahoga River watershed

	TN Load (mta)										
Source	**wy13**	**wy14**	**wy15**	**wy16**	**wy17**	**wy18**	**wy19**	**wy20**	**wy21**	**wy22**	**wy23**
Upstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	1,604.6	1,796.9	1,754.0	1,641.7	1,395.3	1,488.1	1,499.4	1,707.1	1,653.1	1,563.9	1,581.0
NPDES 2 – Municipal 0.1-1.0 mgd	52.0	51.6	56.0	50.4	50.0	46.1	46.2	43.7	43.1	40.6	40.7
NPDES 3 – Municipal <0.1 mgd	26.2	25.1	28.6	28.6	28.2	29.7	28.8	27.9	17.5	13.6	13.4
NPDES – Industrial	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4
Wet Weather UPST Pour Point	84.6	78.5	60.9	48.6	59.5	70.8	67.0	23.2	17.2	20.0	10.3
Total NPDES UPST Pour Point	1,767.7	1,952.2	1,899.7	1,769.6	1,533.2	1,635.0	1,641.8	1,802.2	1,731.3	1,638.6	1,645.8
HSTS UPST Pour Point	307.3	307.3	307.3	307.3	307.3	307.3	307.3	202.0	202.0	202.0	202.0
Load @ Pour Point	2,751.3	2,957.3	2,349.8	1,991.2	2,715.7	2,600.0	3,085.0	2,936.0	2,536.0	2,975.0	2,390.0
NPS UPST Pour Point	676.4	697.9	142.9	-85.6	875.3	657.8	1,136.0	931.8	602.7	1,134.4	542.2
Downstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	2,790.7	2,384.6	2,222.6	2,198.8	2,342.0	2,325.2	2,253.9	2,136.1	2,121.0	1,663.5	1,904.8
NPDES 2 – Municipal 0.1-1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NPDES 3 – Municipal <0.1 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NPDES – Industrial	51.3	38.8	46.4	38.2	31.4	34.5	36.6	31.7	28.3	37.4	34.9
Wet Weather DST Pour Point	217.9	225.3	237.8	478.3	353.4	964.7	979.2	357.0	368.4	196.9	199.5
Total NPDES DST Pour Point	3,060.0	2,648.7	2,506.9	2,715.3	2,726.9	3,324.5	3,269.7	2,524.7	2,517.6	1,897.8	2,139.1
HSTS DST Pour Point	43.9	43.9	43.9	43.9	43.9	43.9	43.9	3.1	3.1	3.1	3.1
NPS DST Pour Point	96.6	99.7	20.4	-12.2	125.0	94.0	162.3	141.3	91.4	169.2	80.9
Totals											
HSTS	351.2	351.2	351.2	351.2	351.2	351.2	351.2	205.1	205.1	205.1	205.1
Total NPDES	4,827.7	4,600.9	4,406.5	4,484.8	4,260.1	4,959.4	4,911.4	4,326.9	4,249.0	3,536.4	3,784.9
NPS Total	773.0	797.6	163.3	-97.8	1,000.3	751.7	1,298.3	1,073.1	694.1	1,303.6	623.1
Total Load	5,951.8	5,749.6	4,921.0	4,738.1	5,611.6	6,062.3	6,560.9	5,605.1	5,148.2	5,045.1	4,613.1
% HSTS	6%	6%	7%	7%	6%	6%	5%	4%	4%	4%	4%
% NPDES	81%	80%	90%	95%	76%	82%	75%	77%	83%	70%	82%
% of NPDES – Municipal ≥ 1.0 mgd	91.0%	90.9%	90.2%	85.6%	87.7%	76.9%	76.4%	88.8%	88.8%	91.3%	92.1%
% of NPDES – Municipal 0.1-1.0 mgd	1.1%	1.1%	1.3%	1.1%	1.2%	0.9%	0.9%	1.0%	1.0%	1.1%	1.1%
% of NPDES – Municipal <0.1 mgd	0.5%	0.5%	0.6%	0.6%	0.7%	0.6%	0.6%	0.6%	0.4%	0.4%	0.4%
% of NPDES – Industrial	1.1%	0.8%	1.1%	0.9%	0.7%	0.7%	0.8%	0.7%	0.7%	1.1%	0.9%
% of NPDES – Wet Weather	6.3%	6.6%	6.8%	11.7%	9.7%	20.9%	21.3%	8.8%	9.1%	6.1%	5.5%
% NPS	13%	14%	3%	-2%	18%	12%	20%	19%	13%	26%	14%
Yield UPST Pour Point (lb/acre)	3.30	3.40	0.70	-0.42	4.27	3.21	5.54	4.66	3.01	5.55	2.65
Per Capita Yield (lb/person)	9.44	9.02	8.64	8.36	8.16	8.30	8.18	7.95	7.79	6.72	7.22

Table 36 — Summary of total P loading components for calculating the nutrient mass balance in the Great Miami River watershed

	TP Load (mta)										
Source	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Upstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	313.8	291.2	323.2	297.0	357.3	377.7	361.7	335.8	324.9	322.9	325.8
NPDES 2 – Municipal 0.1-1.0 mgd	17.8	16.9	15.5	17.0	17.1	16.2	22.3	18.7	17.3	16.1	14.9
NPDES 3 – Municipal <0.1 mgd	2.8	2.5	2.5	2.9	2.7	2.8	2.3	2.3	2.7	2.6	2.5
NPDES – Industrial	1.6	1.4	2.8	3.3	3.6	2.2	4.7	2.1	1.6	1.8	1.2
Wet Weather UPST Pour Point	1.4	3.1	2.4	2.2	1.2	11.5	0.9	0.8	0.4	2.4	1.8
Total NPDES UPST Pour Point	337.5	315.0	346.4	322.4	381.9	410.3	391.9	359.7	346.8	345.7	346.2
HSTS UPST Pour Point	56.2	56.2	56.2	56.2	56.2	56.2	56.2	51.3	51.3	39.8	39.8
Load @ Pour Point	879.5	1,254.7	1,242.2	629.5	1,023.8	1,310.0	1,770.0	1,040.0	849.0	1,520.0	733.0
NPS UPST Pour Point	485.8	883.4	839.6	250.9	585.7	843.4	1,321.9	629.1	450.9	1,134.5	347.1
Downstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	84.4	89.8	79.0	79.4	75.4	76.9	77.1	75.5	72.3	98.7	91.4
NPDES 2 – Municipal 0.1-1.0 mgd	15.4	14.2	12.3	10.5	9.9	9.2	10.4	11.1	9.1	7.1	8.2
NPDES 3 – Municipal <0.1 mgd	3.4	3.6	3.6	3.4	3.3	3.9	3.6	3.4	3.6	3.7	3.9
NPDES – Industrial	7.4	4.0	5.4	25.6	14.6	24.5	14.3	19.9	18.6	10.5	6.1
Wet Weather DST Pour Point	0.3	0.5	2.6	0.6	0.7	0.7	0.7	1.6	1.5	1.4	1.8
Total NPDES DST Pour Point	110.8	112.1	102.9	119.5	103.9	115.2	106.1	111.4	105.1	121.5	111.4
HSTS DST Pour Point	24.4	24.4	24.4	24.4	24.4	24.4	24.4	37.8	37.8	30.4	30.4
NPS DST Pour Point	211.1	383.9	364.8	109.0	254.5	366.5	574.4	274.7	196.9	493.5	151.0
Totals											
HSTS	80.7	80.7	80.7	80.7	80.7	80.7	80.7	89.1	89.1	70.2	70.2
Total NPDES	448.3	427.2	449.2	441.9	485.8	525.6	498.0	471.0	452.0	467.1	457.6
NPS Total	696.9	1,267.3	1,204.4	359.9	840.2	1,209.9	1,896.3	903.8	647.8	1,628.0	498.0
Total Load	1,225.9	1,775.2	1,734.4	882.5	1,406.6	1,816.2	2,475.0	1,463.9	1,188.8	2,165.3	1,025.7
% HSTS	7%	5%	5%	9%	6%	4%	3%	6%	7%	3%	7%
% NPDES	37%	24%	26%	50%	35%	29%	20%	32%	38%	22%	45%
% of NPDES – Municipal ≥ 1.0 mgd	88.8%	89.2%	89.5%	85.2%	89.1%	86.5%	88.1%	87.3%	87.9%	90.2%	91.2%
% of NPDES – Municipal 0.1-1.0 mgd	7.4%	7.3%	6.2%	6.2%	5.5%	4.8%	6.6%	6.3%	5.8%	5.0%	5.0%
% of NPDES – Municipal <0.1 mgd	1.4%	1.4%	1.3%	1.4%	1.2%	1.3%	1.2%	1.2%	1.4%	1.4%	1.4%
% of NPDES – Industrial	2.0%	1.2%	1.8%	6.5%	3.8%	5.1%	3.8%	4.7%	4.5%	2.6%	1.6%
% of NPDES – Wet Weather	0.4%	0.9%	1.1%	0.6%	0.4%	2.3%	0.3%	0.5%	0.4%	0.8%	0.8%
% NPS	57%	71%	69%	41%	60%	67%	77%	62%	54%	75%	49%
Yield UPST Pour Point (lb/acre)	0.62	1.12	1.07	0.32	0.74	1.07	1.68	0.81	0.58	1.44	0.44
Per Capita Yield (lb/person)	0.88	0.84	0.87	0.83	0.92	0.96	0.95	0.78	0.75	0.76	0.75

Table 37— Summary of total N loading components for calculating the nutrient mass balance in the Great Miami River watershed

	TN Load (mta)										
Source	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Upstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	2,121.5	2,001.5	1,731.0	1,569.2	2,090.0	1,874.1	1,932.7	1,911.2	2,338.9	1,978.0	1,855.2
NPDES 2 – Municipal 0.1-1.0 mgd	106.7	114.7	136.0	144.9	133.3	150.6	161.0	163.7	149.4	131.0	104.2
NPDES 3 – Municipal <0.1 mgd	17.7	17.0	17.7	20.4	18.8	18.0	17.8	15.2	16.4	14.6	14.0
NPDES – Industrial	0.7	1.1	3.2	3.9	5.3	4.1	3.9	4.8	4.4	2.4	2.0
Wet Weather UPST Pour Point	37.9	84.9	65.8	60.2	33.0	315.0	24.9	21.5	10.1	65.4	49.9
Total NPDES UPST Pour Point	2,284.5	2,219.1	1,953.7	1,798.7	2,280.3	2,361.8	2,140.2	2,116.4	2,519.2	2,191.3	2,025.2
HSTS UPST Pour Point	405.7	405.7	405.7	405.7	405.7	405.7	405.7	488.0	488.0	471.5	471.5
Load @ Pour Point	12,858.5	14,297.9	14,822.0	10,136.7	15,468.3	14,310.0	19,870.0	12,710.0	11,750.0	17,000.0	10,010.0
NPS UPST Pour Point	10,168.3	11,673.0	12,462.5	7,932.3	12,782.3	11,542.5	17,324.1	10,105.6	8,742.8	14,337.1	7,513.2
Downstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	646.1	923.1	677.6	789.6	643.5	722.5	656.5	606.4	585.4	579.8	497.1
NPDES 2 – Municipal 0.1-1.0 mgd	78.6	92.2	75.2	59.3	76.7	92.4	76.4	84.3	67.2	66.2	48.7
NPDES 3 – Municipal <0.1 mgd	25.8	26.6	24.5	19.5	16.5	20.1	22.7	39.8	26.9	27.8	20.2
NPDES – Industrial	23.0	27.3	32.4	23.7	25.5	17.4	19.8	26.1	19.7	31.0	4.6
Wet Weather DST Pour Point	7.3	15.0	72.0	16.7	18.7	19.2	17.9	42.6	40.2	39.2	49.7
Total NPDES DST Pour Point	780.7	1,084.2	881.7	908.9	780.9	871.7	793.2	799.2	739.4	744.0	620.2
HSTS DST Pour Point	176.3	176.3	176.3	176.3	176.3	176.3	176.3	359.4	359.4	360.0	360.0
NPS DST Pour Point	4,418.4	5,072.2	5,415.3	3,446.8	5,554.2	5,015.5	7,527.8	4,413.6	3,818.4	6,235.9	3,267.9
Totals											
HSTS	582.0	582.0	582.0	582.0	582.0	582.0	582.0	847.4	847.4	831.5	831.5
Total NPDES	3,065.2	3,303.3	2,835.4	2,707.5	3,061.2	3,233.4	2,933.5	2,915.6	3,258.6	2,935.4	2,645.4
NPS Total	14,586.7	16,745.3	17,877.8	11,379.1	18,336.5	16,558.1	24,851.8	14,519.2	12,561.2	20,573.0	10,781.1
Total Load	18,233.9	20,630.6	21,295.3	14,668.6	21,979.8	20,373.5	28,367.3	18,282.2	16,667.2	24,339.9	14,258.1
% HSTS	3%	3%	3%	4%	3%	3%	2%	5%	5%	3%	6%
% NPDES	17%	16%	13%	18%	14%	16%	10%	16%	20%	12%	19%
% of NPDES – Municipal ≥ 1.0 mgd	90.3%	88.5%	84.9%	87.1%	89.3%	80.3%	88.3%	86.4%	89.7%	87.1%	88.9%
% of NPDES – Municipal 0.1-1.0 mgd	6.0%	6.3%	7.4%	7.5%	6.9%	7.5%	8.1%	8.5%	6.6%	6.7%	5.8%
% of NPDES – Municipal <0.1 mgd	1.4%	1.3%	1.5%	1.5%	1.2%	1.2%	1.4%	1.9%	1.3%	1.4%	1.3%
% of NPDES – Industrial	0.8%	0.9%	1.3%	1.0%	1.0%	0.7%	0.8%	1.1%	0.7%	1.1%	0.2%
% of NPDES – Wet Weather	1.5%	3.0%	4.9%	2.8%	1.7%	10.3%	1.5%	2.2%	1.5%	3.6%	3.8%
% NPS	80%	81%	84%	78%	83%	81%	88%	79%	75%	85%	76%
Yield UPST Pour Point (lb/acre)	12.92	14.83	15.84	10.08	16.24	14.67	22.02	12.97	11.22	18.21	9.54
Per Capita Yield (lb/person)	6.06	6.36	5.49	5.39	6.03	5.86	5.84	5.33	5.86	5.27	4.90

Table 38 — Summary of total P loading components for calculating the nutrient mass balance in the Little Miami River watershed

Source	TP Load (mta) wy21	wy22	wy23
Upstream of Pour Points			
NPDES 1 – Municipal ≥1.0 mgd	37.4	28.7	33.7
NPDES 2 – Municipal 0.1-1.0 mgd	19.2	18.5	22.4
NPDES 3 – Municipal <0.1 mgd	1.1	2.4	2.4
NPDES – Industrial	0.0	0.0	0.0
Wet Weather UPST Pour Point	0.0	0.0	0.0
Total NPDES UPST Pour Point	57.7	49.6	58.6
HSTS UPST Pour Point	30.0	23.1	23.1
Load @ Pour Point	454.5	622.4	394.3
NPS UPST Pour Point	366.9	549.7	312.6
Downstream of Pour Points			
NPDES 1 – Municipal ≥1.0 mgd	23.6	20.3	24.2
NPDES 2 – Municipal 0.1-1.0 mgd	1.9	3.0	3.3
NPDES 3 – Municipal <0.1 mgd	0.3	0.2	0.2
NPDES – Industrial	0.0	0.0	0.0
Wet Weather DST Pour Point	0.0	1.4	0.2
Total NPDES DST Pour Point	25.7	24.9	28.0
HSTS DST Pour Point	5.0	2.4	2.4
NPS DST Pour Point	38.8	35.6	20.3
Totals			
HSTS	47.3	35.0	35.0
Total NPDES	112.2	90.7	109.0
NPS Total	525.9	774.1	436.8
Total Load	685.4	899.9	580.8
% HSTS	7%	4%	6%
% NPDES	16%	10%	19%
% of NPDES – Municipal ≥ 1.0 mgd	54.3%	54.0%	53.2%
% of NPDES – Municipal 0.1-1.0 mgd	18.8%	23.7%	23.6%
% of NPDES – Municipal <0.1 mgd	1.2%	2.9%	2.4%
% of NPDES – Industrial	0.0%	0.1%	0.1%
% of NPDES – Wet Weather	0.0%	1.6%	0.2%
% NPS	77%	86%	75%
Yield UPST Pour Points (lb/acre)	1.06	1.58	0.90
Per Capita Yield (lb/person)	0.63	0.44	0.50

Table 39 — Summary of total N loading components for calculating the nutrient mass balance in the Little Miami River watershed

Source	TN Load (mta) wy21	wy22	wy23
Upstream of Pour Points			
NPDES 1 – Municipal ≥1.0 mgd	464.5	399.8	335.1
NPDES 2 – Municipal 0.1-1.0 mgd	151.4	140.5	160.0
NPDES 3 – Municipal <0.1 mgd	7.3	20.6	15.5
NPDES – Industrial	0.0	0.0	0.0
Wet Weather UPST Pour Point	0.0	0.1	0.8
Total NPDES UPST Pour Point	623.3	560.9	511.5
HSTS UPST Pour Point	284.9	273.8	273.8
Load @ Pour Point	3,426.9	4,077.7	2,679.0
NPS UPST Pour Point	2,518.7	3,243.0	1,893.7
Downstream of Pour Points			
NPDES 1 – Municipal ≥1.0 mgd	148.6	117.1	90.6
NPDES 2 – Municipal 0.1-1.0 mgd	5.1	17.2	10.7
NPDES 3 – Municipal <0.1 mgd	2.9	1.3	0.9
NPDES – Industrial	0.5	0.4	0.4
Wet Weather DST Pour Point	0.0	38.6	5.2
Total NPDES DST Pour Point	157.2	174.7	107.7
HSTS DST Pour Point	47.7	28.9	28.9
NPS DST Pour Point	266.6	210.2	122.8
Totals			
HSTS	449.6	415.2	415.2
Total NPDES	1,119.1	901.0	734.8
NPS Total	3,267.4	4,299.4	2,416.1
Total Load	4,836.2	5,615.5	3,566.1
% HSTS	9%	7%	12%
% NPDES	23%	16%	21%
% of NPDES – Municipal ≥ 1.0 mgd	54.8%	57.4%	57.9%
% of NPDES – Municipal 0.1-1.0 mgd	14.0%	17.5%	23.2%
% of NPDES – Municipal <0.1 mgd	0.9%	2.4%	2.2%
% of NPDES – Industrial	0.0%	0.0%	0.1%
% of NPDES – Wet Weather	0.0%	4.3%	0.8%
% NPS	68%	77%	68%
Yield UPST Pour Points (lb/acre)	7.29	9.29	5.43
Per Capita Yield (lb/person)	6.24	4.47	4.00

Table 40 — Summary of total P loading components for calculating the nutrient mass balance in the Scioto River watershed

Source	TP Load (mta) wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Upstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	528.4	599.1	604.1	604.6	584.8	566.2	493.4	454.2	386.0	384.4	383.4
NPDES 2 – Municipal 0.1-1.0 mgd	26.1	27.0	24.9	26.1	29.5	27.2	27.6	34.2	35.8	34.1	32.9
NPDES 3 – Municipal <0.1 mgd	13.1	15.0	13.2	13.0	12.9	12.9	12.6	12.9	11.1	13.2	12.1
NPDES – Industrial	0.2	0.3	0.2	0.2	0.1	0.1	0.2	0.2	0.3	2.8	2.2
Wet Weather UPST Pour Point	1.7	3.9	4.2	3.6	2.3	7.0	4.4	5.8	1.4	4.4	1.0
Total NPDES UPST Pour Point	569.5	645.2	646.6	647.5	629.6	613.4	538.2	507.3	434.6	438.8	431.6
HSTS UPST Pour Point	47.4	47.4	47.4	47.4	47.4	47.4	47.4	129.2	129.2	53.5	53.5
Load @ Pour Point	1,394.8	1,652.4	1,393.9	1,112.2	1,476.0	1,880.0	2,430.0	1,450.0	960.0	1,530.0	857.0
NPS UPST Pour Point	777.9	959.7	699.9	417.3	799.0	1,219.2	1,844.4	813.5	396.2	1,037.7	371.9
Downstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	25.9	27.6	28.8	22.3	25.5	21.2	29.5	32.3	31.5	38.2	33.0
NPDES 2 – Municipal 0.1-1.0 mgd	6.3	6.5	6.1	6.6	6.1	6.3	7.6	6.9	7.6	6.8	7.5
NPDES 3 – Municipal <0.1 mgd	5.8	5.9	5.4	5.9	5.6	6.9	7.0	8.3	7.5	8.3	8.6
NPDES – Industrial	13.9	15.5	19.9	18.7	20.2	9.9	5.5	7.3	5.8	5.1	16.4
Wet Weather DST Pour Point	0.2	0.2	0.0	0.0	0.0	0.0	0.1	0.3	0.0	4.2	2.5
Total NPDES DST Pour Point	52.0	55.6	60.3	53.4	57.5	44.2	49.7	55.2	52.4	62.5	68.0
HSTS DST Pour Point	32.7	32.7	32.7	32.7	32.7	32.7	32.7	33.1	33.1	30.4	30.4
NPS DST Pour Point	535.9	661.1	482.2	287.5	550.4	839.9	1,270.6	564.6	275.0	717.3	257.1
Totals											
HSTS	80.1	80.1	80.1	80.1	80.1	80.1	80.1	162.3	162.3	83.9	83.9
Total NPDES	621.5	700.9	706.8	700.9	687.1	657.6	587.9	562.5	487.0	501.4	499.6
NPS Total	1,313.8	1,620.9	1,182.1	704.8	1,349.4	2,059.0	3,115.0	1,378.1	671.1	1,755.0	629.0
Total Load	2,015.4	2,401.8	1,969.0	1,485.8	2,116.6	2,796.8	3,783.0	2,102.9	1,320.5	2,340.2	1,212.5
% HSTS	4%	3%	4%	5%	4%	3%	2%	8%	12%	4%	7%
% NPDES	31%	29%	36%	47%	32%	24%	16%	27%	37%	21%	41%
% of NPDES – Municipal ≥ 1.0 mgd	89.2%	89.4%	89.5%	89.4%	88.8%	89.3%	89.0%	86.5%	85.7%	84.3%	83.3%
% of NPDES – Municipal 0.1-1.0 mgd	5.2%	4.8%	4.4%	4.7%	5.2%	5.1%	6.0%	7.3%	8.9%	8.2%	8.1%
% of NPDES – Municipal <0.1 mgd	3.0%	3.0%	2.6%	2.7%	2.7%	3.0%	3.3%	3.8%	3.8%	4.3%	4.1%
% of NPDES – Industrial	2.3%	2.2%	2.8%	2.7%	3.0%	1.5%	1.0%	1.3%	1.2%	1.6%	3.7%
% of NPDES – Wet Weather	0.3%	0.6%	0.6%	0.5%	0.3%	1.1%	0.8%	1.1%	0.3%	1.7%	0.7%
% NPS	65%	67%	60%	47%	64%	74%	82%	66%	51%	75%	52%
Yield UPST Pour Point (lb/acre)	0.70	0.86	0.63	0.37	0.71	1.09	1.65	0.74	0.36	0.93	0.33
Per Capita Yield (lb/person)	0.78	0.87	0.87	0.86	0.85	0.82	0.75	0.64	0.57	0.58	0.57

Table 41 — Summary of total N loading components for calculating the nutrient mass balance in the Scioto River watershed

	TN Load (mta)										
Source	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Upstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	2,870.3	2,978.0	2,710.8	2,984.3	3,011.0	3,176.1	3,598.8	3,586.9	3,382.4	3,404.4	3,068.2
NPDES 2 – Municipal 0.1-1.0 mgd	272.5	298.1	263.8	279.3	305.0	327.2	319.9	335.2	287.9	275.7	248.0
NPDES 3 – Municipal <0.1 mgd	113.7	121.7	116.6	120.1	121.7	129.6	114.6	107.3	92.4	106.9	94.7
NPDES – Industrial	0.3	0.6	1.0	1.2	0.5	0.4	0.3	1.7	1.3	0.7	0.3
Wet Weather UPST Pour Point	45.8	106.0	115.3	98.1	64.2	192.5	120.5	157.6	37.1	119.2	26.7
Total NPDES UPST Pour Point	3,302.6	3,504.3	3,207.4	3,482.9	3,502.4	3,825.8	4,154.1	4,188.6	3,801.1	3,906.9	3,437.9
HSTS UPST Pour Point	463.3	463.3	463.3	463.3	463.3	463.3	463.3	1,277.5	1,277.5	522.5	522.5
Load @ Pour Point	14,609.1	17,621.0	15,273.1	11,769.5	17,864.5	17,930.0	23,250.0	16,370.0	11,640.0	17,350.0	11,940.0
NPS UPST Pour Point	10,843.3	13,653.4	11,602.4	7,823.4	13,898.8	13,640.9	18,632.6	10,903.8	6,561.4	12,920.6	7,979.6
Downstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	216.0	253.0	242.7	221.2	196.4	186.0	184.0	175.5	141.9	157.2	169.6
NPDES 2 – Municipal 0.1-1.0 mgd	43.3	47.9	43.6	50.1	48.0	62.6	56.0	66.8	61.4	54.0	46.7
NPDES 3 – Municipal <0.1 mgd	57.9	50.0	47.8	56.1	59.4	60.7	52.1	58.3	48.0	48.7	54.7
NPDES – Industrial	9.5	8.4	29.1	13.2	14.6	5.8	6.0	5.6	4.8	4.8	11.3
Wet Weather DST Pour Point	4.2	5.4	1.1	0.5	0.0	0.1	3.7	7.1	0.6	114.3	69.6
Total NPDES DST Pour Point	330.8	364.7	364.3	341.0	318.3	315.2	301.8	313.2	256.7	378.9	351.9
HSTS DST Pour Point	319.2	319.2	319.2	319.2	319.2	319.2	319.2	327.0	327.0	296.7	296.7
NPS DST Pour Point	7,469.9	9,405.8	7,992.8	5,389.5	9,574.8	9,397.2	12,835.9	7,568.1	4,554.1	8,931.5	5,515.9
Totals											
HSTS	782.5	782.5	782.5	782.5	782.5	782.5	782.5	1,604.6	1,604.6	819.3	819.3
Total NPDES	3,633.4	3,869.0	3,571.8	3,823.9	3,820.7	4,140.9	4,456.0	4,501.8	4,057.8	4,285.8	3,789.8
NPS Total	18,313.1	23,059.2	19,595.2	13,212.8	23,473.5	23,038.1	31,468.5	18,472.0	11,115.5	21,852.1	13,495.5
Total Load	22,729.0	27,710.7	23,949.5	17,819.2	28,076.7	27,961.5	36,706.9	24,578.4	16,777.9	26,957.1	18,104.6
% HSTS	3%	3%	3%	4%	3%	3%	2%	7%	10%	#DIV/0!	#DIV/0!
% NPDES	16%	14%	15%	21%	14%	15%	12%	18%	24%	#DIV/0!	#DIV/0!
% of NPDES – Municipal ≥ 1.0 mgd	84.9%	83.5%	82.7%	83.8%	83.9%	81.2%	84.9%	83.6%	86.9%	83.1%	85.4%
% of NPDES – Municipal 0.1-1.0 mgd	8.7%	8.9%	8.6%	8.6%	9.2%	9.4%	8.4%	8.9%	8.6%	7.7%	7.8%
% of NPDES – Municipal <0.1 mgd	4.7%	4.4%	4.6%	4.6%	4.7%	4.6%	3.7%	3.7%	3.5%	3.6%	3.9%
% of NPDES – Industrial	0.3%	0.2%	0.8%	0.4%	0.4%	0.2%	0.1%	0.2%	0.1%	0.1%	0.3%
% of NPDES – Wet Weather	1.4%	2.9%	3.3%	2.6%	1.7%	4.7%	2.8%	3.7%	0.9%	5.4%	2.5%
% NPS	81%	83%	82%	74%	84%	82%	86%	75%	66%	81%	75%
Yield UPST Pour Point (lb/acre)	9.69	12.21	10.37	6.99	12.42	12.19	16.66	9.85	5.93	11.56	7.14
Per Capita Yield (lb/person)	4.96	5.16	4.79	5.11	5.15	5.38	5.81	5.31	5.03	4.97	4.60

Table 42 — Summary of total P loading components for calculating the nutrient mass balance in the Hocking River watershed

Source	TP Load (mta) wy21	wy22	wy23
Upstream of Pour Point			
NPDES 1 – Municipal ≥1.0 mgd	11.6	11.8	13.7
NPDES 2 – Municipal 0.1-1.0 mgd	3.9	5.4	5.6
NPDES 3 – Municipal <0.1 mgd	2.8	2.6	2.5
NPDES – Industrial	0.0	0.0	0.0
Wet Weather UPST Pour Point	0.0	0.1	0.1
Total NPDES UPST Pour Point	18.3	20.0	22.0
HSTS UPST Pour Point	16.2	15.1	15.1
Load @ Pour Point	104.5	216.7	89.6
NPS UPST Pour Point	70.0	181.6	52.6
Downstream of Pour Point			
NPDES 1 – Municipal ≥1.0 mgd	7.6	8.0	7.3
NPDES 2 – Municipal 0.1-1.0 mgd	0.0	0.0	0.0
NPDES 3 – Municipal <0.1 mgd	0.1	0.1	0.2
NPDES – Industrial	0.0	0.0	0.0
Wet Weather DST Pour Point	0.0	0.0	0.0
Total NPDES DST Pour Point	7.7	8.1	7.4
HSTS DST Pour Point	1.8	1.7	1.7
NPS DST Pour Point	18.9	49.1	14.2
Totals			
HSTS	18.1	16.8	16.8
Total NPDES	26.0	28.1	29.4
NPS Total	88.9	230.7	66.8
Total Load	133.0	275.6	112.9
% HSTS	14%	6%	15%
% NPDES	20%	10%	26%
% of NPDES – Municipal ≥ 1.0 mgd	73.9%	70.5%	71.3%
% of NPDES – Municipal 0.1-1.0 mgd	14.8%	19.4%	19.1%
% of NPDES – Municipal <0.1 mgd	11.1%	9.6%	9.1%
% of NPDES – Industrial	0.0%	0.0%	0.1%
% of NPDES – Wet Weather	0.1%	0.5%	0.4%
% NPS	67%	84%	59%
Yield UPST Pour Point (lb/acre)	0.26	0.66	0.19
Per Capita Yield (lb/person)	0.45	0.46	0.47

Table 43 — Summary of total N loading components for calculating the nutrient mass balance in the Hocking River watershed

	TN Load (mta)		
Source	**wy21**	**wy22**	**wy23**
Upstream of Pour Point			
NPDES 1 – Municipal ≥1.0 mgd	132.6	144.0	132.4
NPDES 2 – Municipal 0.1-1.0 mgd	39.5	32.9	40.7
NPDES 3 – Municipal <0.1 mgd	18.3	17.5	15.6
NPDES – Industrial	0.2	0.1	0.1
Wet Weather UPST Pour Point	0.8	3.5	3.4
Total NPDES UPST Pour Point	191.4	198.0	192.0
HSTS UPST Pour Point	166.2	172.0	172.0
Load @ Pour Point	1,033.4	2,010.0	1,068.3
NPS UPST Pour Point	675.8	1,640.0	704.2
Downstream of Pour Point			
NPDES 1 – Municipal ≥1.0 mgd	46.1	39.4	46.2
NPDES 2 – Municipal 0.1-1.0 mgd	0.0	0.0	0.0
NPDES 3 – Municipal <0.1 mgd	1.0	1.2	1.0
NPDES – Industrial	0.0	0.0	0.0
Wet Weather DST Pour Point	0.0	0.0	0.0
Total NPDES DST Pour Point	47.1	40.6	47.2
HSTS DST Pour Point	18.8	19.4	19.4
NPS DST Pour Point	182.6	442.9	190.2
Totals			
HSTS	185.0	191.5	191.5
Total NPDES	238.5	238.6	239.3
NPS Total	858.5	2,082.9	894.4
Total Load	1,282.0	2,512.9	1,325.1
% HSTS	14%	8%	14%
% NPDES	19%	9%	18%
% of NPDES – Municipal ≥ 1.0 mgd	74.9%	76.9%	74.6%
% of NPDES – Municipal 0.1-1.0 mgd	16.6%	13.8%	17.0%
% of NPDES – Municipal <0.1 mgd	8.1%	7.8%	6.9%
% of NPDES – Industrial	0.1%	0.1%	0.0%
% of NPDES – Wet Weather	0.3%	1.5%	1.4%
% NPS	67%	83%	67%
Yield UPST Pour Point (lb/acre)	2.49	6.00	2.57
Per Capita Yield (lb/person)	4.31	4.34	4.35

Table 44 — Summary of total P loading components for calculating the nutrient mass balance in the Muskingum River watershed

	TP Load (mta)										
Source	**wy13**	**wy14**	**wy15**	**wy16**	**wy17**	**wy18**	**wy19**	**wy20**	**wy21**	**wy22**	**wy23**
Upstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	504.6	433.5	440.4	416.8	315.5	296.9	245.0	259.3	200.4	212.8	220.7
NPDES 2 – Municipal 0.1-1.0 mgd	53.3	53.0	50.5	50.8	56.3	59.0	52.5	48.6	52.9	50.9	52.3
NPDES 3 – Municipal <0.1 mgd	9.6	10.3	10.4	7.5	9.4	9.8	9.4	8.2	10.0	10.9	10.3
NPDES – Industrial	23.5	17.6	20.7	10.6	9.0	7.4	5.2	4.2	5.0	6.5	5.4
Wet Weather UPST Pour Point	0.5	0.8	1.0	0.8	1.1	172.6	3.6	1.4	0.6	1.1	0.3
Total NPDES UPST Pour Point	591.6	515.2	523.0	486.5	391.3	545.6	315.6	321.6	268.8	282.2	289.0
HSTS UPST Pour Point	121.0	121.0	121.0	121.0	121.0	121.0	121.0	148.0	148.0	137.6	137.6
Load @ Pour Point	1,270.8	1,543.4	1,464.4	852.7	1,243.2	1,700.0	2,060.0	1,170.0	889.0	1,670.0	986.0
NPS UPST Pour Point	558.2	907.1	820.4	245.2	730.9	1,033.3	1,623.4	700.4	472.2	1,250.2	559.4
Downstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NPDES 2 – Municipal 0.1-1.0 mgd	1.5	1.7	1.2	1.1	1.3	1.4	2.3	2.0	2.1	2.2	2.2
NPDES 3 – Municipal <0.1 mgd	0.2	0.5	0.3	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.2
NPDES – Industrial	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.1
Wet Weather DST Pour Point	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total NPDES DST Pour Point	1.8	2.3	1.5	1.5	1.6	1.7	2.5	2.1	2.2	2.4	2.5
HSTS DST Pour Point	10.2	10.2	10.2	10.2	10.2	10.2	10.2	5.0	5.0	4.7	4.7
NPS DST Pour Point	46.9	76.3	69.0	20.6	61.5	86.9	136.5	59.4	40.1	105.9	47.4
Totals											
HSTS	131.2	131.2	131.2	131.2	131.2	131.2	131.2	153.1	153.1	142.3	142.3
Total NPDES	593.4	517.5	524.5	488.0	392.9	547.3	318.1	323.6	271.0	284.7	291.4
NPS Total	605.1	983.4	889.4	265.8	792.3	1,120.2	1,759.9	759.8	512.2	1,356.0	606.8
Total Load	1,329.7	1,632.1	1,545.1	885.0	1,316.4	1,798.8	2,209.2	1,236.5	936.3	1,783.0	1,040.5
% HSTS	10%	8%	8%	15%	10%	7%	6%	12%	16%	8%	14%
% NPDES	45%	32%	34%	55%	30%	30%	14%	26%	29%	16%	28%
% of NPDES – Municipal ≥ 1.0 mgd	85.0%	83.8%	84.0%	85.4%	80.3%	54.3%	77.0%	80.1%	73.9%	74.8%	75.7%
% of NPDES – Municipal 0.1-1.0 mgd	9.2%	10.6%	9.8%	10.6%	14.7%	11.0%	17.2%	15.6%	20.3%	18.7%	18.7%
% of NPDES – Municipal <0.1 mgd	1.6%	2.1%	2.0%	1.6%	2.4%	1.8%	3.0%	2.6%	3.7%	3.9%	3.6%
% of NPDES – Industrial	4.0%	3.4%	4.0%	2.2%	2.3%	1.3%	1.7%	1.3%	1.8%	2.3%	1.9%
% of NPDES – Wet Weather	0.1%	0.2%	0.2%	0.2%	0.3%	31.5%	1.1%	0.4%	0.2%	0.4%	0.1%
% NPS	46%	60%	58%	30%	60%	62%	80%	61%	55%	76%	58%
Yield UPST Pour Point (lb/acre)	0.26	0.42	0.38	0.11	0.34	0.48	0.75	0.33	0.22	0.58	0.26
Per Capita Yield (lb/person)	1.05	0.94	0.95	0.91	0.77	0.75	0.66	0.70	0.62	0.63	0.64

Table 45 — Summary of total N loading components for calculating the nutrient mass balance in the Muskingum River watershed

	TN Load (mta)										
Source	wy13	wy14	wy15	wy16	wy17	wy18	wy19	wy20	wy21	wy22	wy23
Upstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	2,684.6	2,848.2	2,470.7	2,321.3	2,306.0	1,893.6	1,709.4	1,971.9	1,732.3	1,502.4	1,430.9
NPDES 2 – Municipal 0.1-1.0 mgd	364.9	405.0	356.5	361.5	385.0	411.3	395.0	361.4	351.1	307.1	261.0
NPDES 3 – Municipal <0.1 mgd	91.2	93.3	94.7	45.0	85.2	90.1	77.3	72.9	72.9	80.4	75.5
NPDES – Industrial	17.9	18.6	20.1	23.9	29.9	26.1	24.4	28.1	29.8	40.5	33.8
Wet Weather UPST Pour Point	14.9	21.7	26.5	22.3	29.4	78.7	98.6	37.0	15.6	31.3	9.0
Total NPDES UPST Pour Point	3,173.4	3,386.7	2,968.5	2,774.0	2,835.4	2,499.7	2,304.8	2,471.2	2,201.6	1,961.7	1,810.3
HSTS UPST Pour Point	1,273.6	1,273.6	1,273.6	1,273.6	1,273.6	1,273.6	1,273.6	1,516.1	1,516.1	1,569.0	1,569.0
Load @ Pour Point	17,488.0	20,687.1	16,877.0	11,812.0	17,515.3	21,790.0	27,300.0	20,290.0	13,290.0	19,690.0	12,620.0
NPS UPST Pour Point	13,041.0	16,026.9	12,634.9	7,764.5	13,406.3	18,016.7	23,721.6	16,302.7	9,572.3	16,159.4	9,240.7
Downstream of Pour Point											
NPDES 1 – Municipal ≥1.0 mgd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NPDES 2 – Municipal 0.1-1.0 mgd	12.2	14.8	15.4	11.9	13.7	16.2	9.4	8.9	14.3	15.4	12.0
NPDES 3 – Municipal <0.1 mgd	1.5	0.9	1.8	1.1	1.7	1.8	1.3	1.0	1.6	1.8	2.0
NPDES – Industrial	0.1	1.6	2.9	1.8	1.7	1.9	1.4	1.5	1.7	1.9	1.9
Wet Weather DST Pour Point	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total NPDES DST Pour Point	13.8	17.2	20.1	14.8	17.2	19.9	12.1	11.4	17.6	19.1	15.9
HSTS DST Pour Point	107.1	107.1	107.1	107.1	107.1	107.1	107.1	51.7	51.7	53.5	53.5
NPS DST Pour Point	1,096.7	1,347.8	1,062.6	653.0	1,127.4	1,515.2	1,994.9	1,383.4	812.3	1,368.4	782.5
Totals											
HSTS	1,380.7	1,380.7	1,380.7	1,380.7	1,380.7	1,380.7	1,380.7	1,567.8	1,567.8	1,622.5	1,622.5
Total NPDES	3,187.2	3,403.9	2,988.6	2,788.7	2,852.6	2,519.6	2,316.9	2,482.6	2,219.3	1,980.8	1,826.1
NPS Total	14,137.7	17,374.7	13,697.4	8,417.4	14,533.8	19,531.9	25,716.6	17,686.0	10,384.5	17,527.8	10,023.2
Total Load	18,705.6	22,159.3	18,066.7	12,586.9	18,767.1	23,432.1	29,414.2	21,736.5	14,171.6	21,131.1	13,471.9
% HSTS	7%	6%	8%	11%	7%	6%	5%	7%	11%	8%	12%
% NPDES	17%	15%	17%	22%	15%	11%	8%	11%	16%	9%	14%
% of NPDES – Municipal ≥ 1.0 mgd	84.2%	83.7%	82.7%	83.2%	80.8%	75.2%	73.8%	79.4%	78.1%	75.8%	78.4%
% of NPDES – Municipal 0.1-1.0 mgd	11.8%	12.3%	12.4%	13.4%	14.0%	17.0%	17.5%	14.9%	16.5%	16.3%	15.0%
% of NPDES – Municipal <0.1 mgd	2.9%	2.8%	3.2%	1.7%	3.0%	3.6%	3.4%	3.0%	3.4%	4.2%	4.2%
% of NPDES – Industrial	0.6%	0.6%	0.8%	0.9%	1.1%	1.1%	1.1%	1.2%	1.4%	2.1%	2.0%
% of NPDES – Wet Weather	0.5%	0.6%	0.9%	0.8%	1.0%	3.1%	4.3%	1.5%	0.7%	1.6%	0.5%
% NPS	76%	78%	76%	67%	77%	83%	87%	81%	73%	83%	74%
Yield UPST Pour Point (lb/acre)	6.06	7.44	5.87	3.61	6.22	8.37	11.01	7.66	4.50	7.50	4.29
Per Capita Yield (lb/person)	6.78	7.10	6.46	6.17	6.24	5.68	5.35	5.94	5.58	5.27	5.08