NUTRIENT ASSESSMENT REDUCTION PLAN FOR THE UPPER DES PLAINES RIVER

Prepared for

Des Plaines River Watershed Workgroup

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Project MOW5554

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ACRONYMS AND ABBREVIATIONS

%	percent
µg/L	micrograms per liter
DO	dissolved oxygen
DRWW	Des Plaines River Watershed Workgroup
GIMS	Green Infrastructure Model and Strategy
Illinois EPA	Illinois Environmental Protection Agency
mg/L	milligrams per liter
mm	millimeters
MS4	Municipal Separate Storm Sewer System
NARP	Nutrient Assessment Reduction Plan
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source
POTW	publicly owned treatment works
SMC	Stormwater Management Commission
SWAT	Soil and Water Assessment Tool
TMDL	total maximum daily load
TP	total phosphorous
TSS	total suspended solids
WBP	watershed-based plan
WDNR	Wisconsin Department of Natural Resources

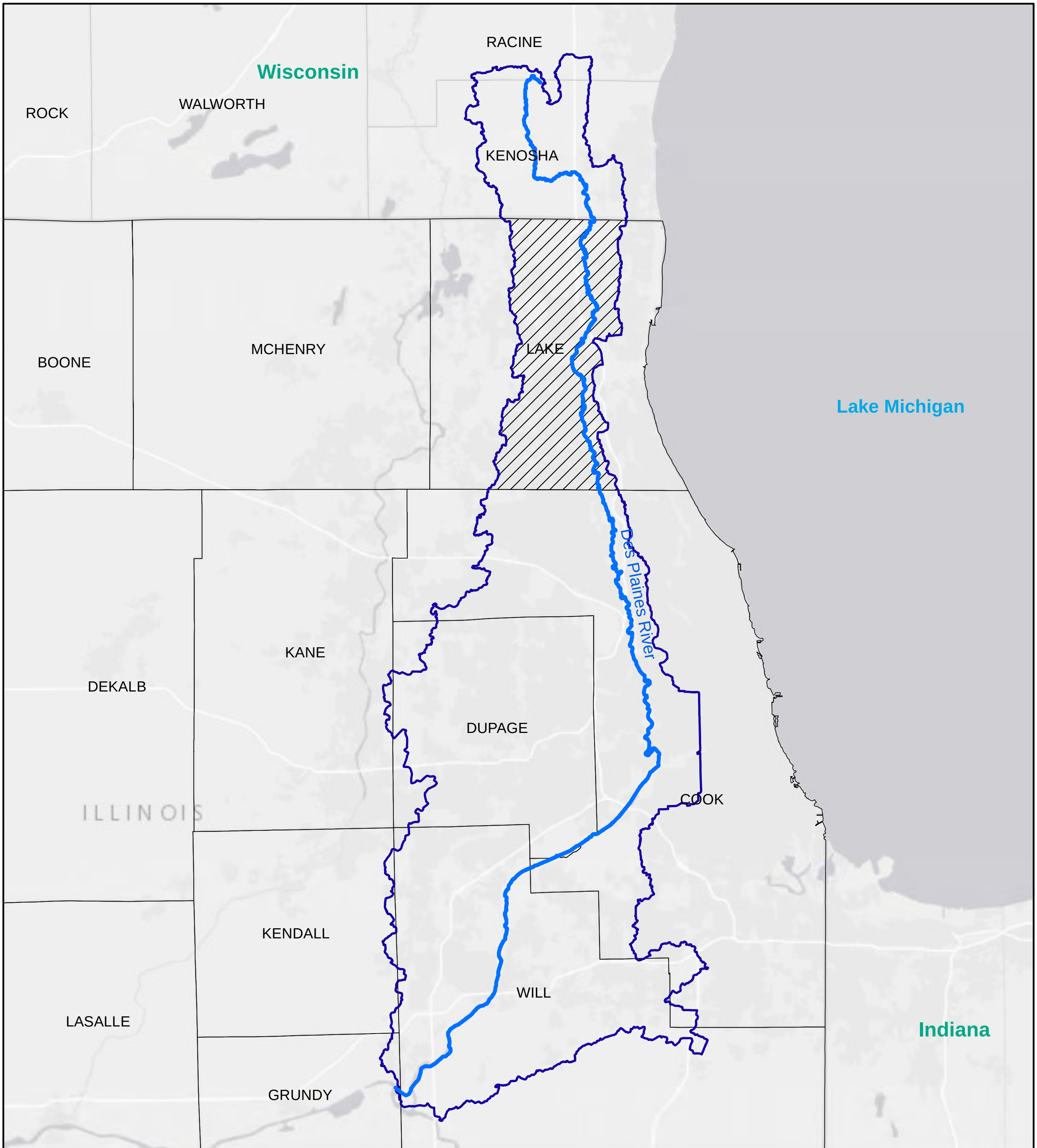
1. INTRODUCTION

1.1 Study Area

The Des Plaines River originates near Union Grove, Wisconsin and drains an area of 1,455 square miles through Racine and Kenosha counties in southeastern Wisconsin and through Lake, Cook, and Will counties in northeastern Illinois (**Figure 1**). The river joins the Chicago Sanitary and Ship Canal in Lockport, Illinois and then flows west through Joliet before converging with the Kankakee River to form the Illinois River. The Study Area for the Upper Des Plaines River Watershed Nutrient Assessment Reduction Plan (NARP) focuses on the 36.3-mile stretch of the Des Plaines River between Russell Road in Lake County (at the Wisconsin and Illinois boundary) and its confluence with Wheeling Ditch in Cook County (**Figure 1**). This section of the river drains a watershed area of 235 square miles, which is referred to as the Study Area in this report henceforth.

Land use in the Study Area is predominantly residential (31.2 percent); agriculture (18.4 percent); and transportation, utility, and waste facility (10.3 percent) with the remaining area being institutional, industrial, commercial, public and private open space based on the 2015 Chicago Metropolitan Agency data (**Figure 2**). Most of the soil in the Study Area consists of sand clay loam, which is classified as Hydrologic Soil Group C. This type of soil is poorly drained and has a high runoff potential. The NARP Study Area has a warm continental climate with warm summers and cold winters. The polar jet stream creates low-pressure systems that bring clouds, wind, and precipitation. Impervious surfaces such as buildings, roads, parking lots, and industrial activities result in increased temperatures in the urban area. Lake Michigan moderates the temperatures in winter and summer seasons.

According to the 2020 United States Census, the population in the Study Area is 281,514. The population is anticipated to increase by 20% by 2050 (Lake County Stormwater Management Commission [SMC] 2018).



Des Plaines River Watershed
Des Plaines River
Study Area
Illinois County Boundary
Wisconsin County Boundary

N

0 15 Miles

Des Plaines River Watershed

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Figure 1

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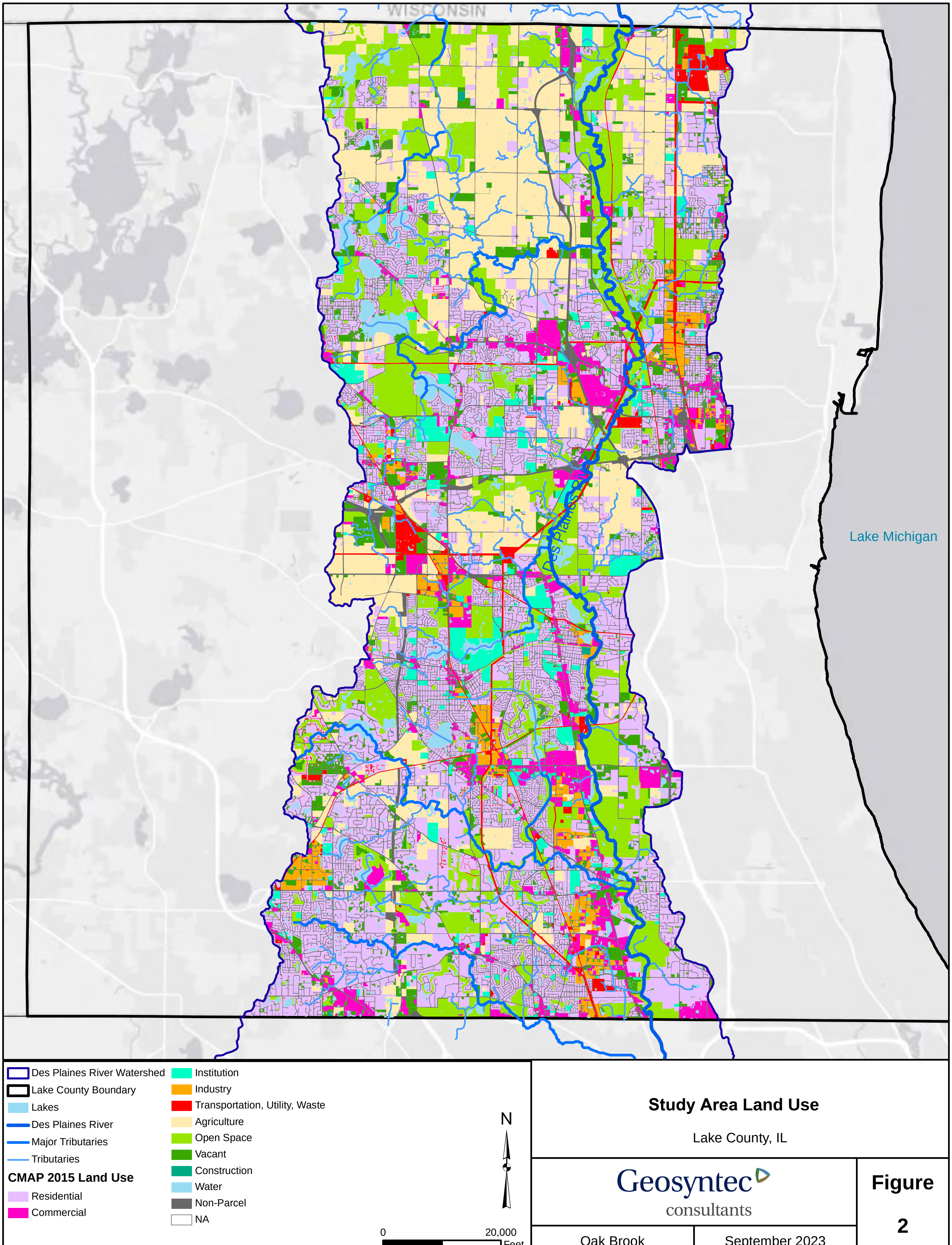

Study Area Land Use

Lake County, IL

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Figure 2

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Z:\prj1\WATER RESOURCES - 1840\MOW5554 - DRWW NARP Development\3.0 GIS\MXDs\Report\2023(0817)_Figure2_DRWW NARP Land Use.mxd 9/1/2023 9:10:35 AM

1.2 Purpose of the NARP

The Illinois EPA has incorporated a special condition requirement to develop a NARP in many Illinois National Pollutant Discharge Elimination System (NPDES) permits for major POTWs. The NARP requirements apply to POTWs discharging upstream of water bodies that are determined to have a phosphorus-related impairment[1] or to be at "risk of eutrophication"[2]. In addition, there are conditions in the Municipal Separate Storm Sewer System (MS4) general permit that require permittees to provide a schedule for meeting waste load allocations in total maximum daily loads (TMDLs) or watershed management plans.

The purpose of the NARP is to identify phosphorus input reductions and other measures necessary to address the phosphorus-related impairment. Illinois EPA recognizes that other measures (such as dam removal, stream restoration, riparian buffers, or constructed wetlands) may be needed to eliminate impairments. Therefore, Illinois EPA has encouraged POTWs to develop NARPs on a watershed-wide basis with input from MS4s and other stakeholders

1.3 Watershed Group

The Des Plaines River Watershed Workgroup (DRWW) is a voluntary, dues-collecting organization whose mission is to meet Illinois EPA requirements by making cost-effective improvements to water quality in the Upper Des Plaines River and its tributaries in Lake County. The DRWW brings together a diverse coalition of stakeholders: members include communities, POTWs, and other interested parties. A complete list of participants can be found on the DRWW website (DRWW 2023).

The DRWW is developing a NARP for the Study Area. There are eight major POTWs in the Study Area (**Figure 3**) with design flows ranging from 4 to 24 million gallons per day **(Table 1**). The NPDES permits for these POTWs include the NARP special conditions because the POTWs are located upstream of a reach that Illinois EPA has identified as impaired due to phosphorus (Illinois EPA 2022). Among these eight POTWs, the Village of Mundelein Sewage Treatment Plant is not currently a member of the DRWW, and this report does not satisfy their NPDES special condition requirement.

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[1] A water body with a phosphorus-related impairment means is listed by Illinois EPA as impaired because of the presence of dissolved oxygen or "offensive conditions" (e.g., algae or aquatic plant growth).
[2] A water body is determined to be at "risk at eutrophication" if the levels of sestonic chlorophyll, pH, and dissolved oxygen are above the thresholds set by Illinois Risk of Eutrophication Committee.

Table 2: Publicly Owned Treatment Works in the Nutrient Assessment Reduction Plan Study Area

Publicly Owned Treatment Works	Design Average Flow (MGD)	Receiving Water Body
North Shore Water Reclamation District (NSWRD) - Gurnee Water Reclamation Facility (WRF)	23.6	Des Plaines River
NSWRD - Waukegan WRF	22.0	Des Plaines River
Des Plaines River STP	16.0	Des Plaines River
New Century Town WRF	6.0	Des Plaines River
*Village of Mundelein STP**	*4.95*	*Des Plaines River*
Village of Libertyville STP	4.0	Des Plaines River
Mill Creek WRF	2.1	Mill Creek
Lindenhurst Sanitary District Sewage Treatment Plant (STP)	2.0	Hastings Creek

** Not part of the Des Plaines River Watershed Workgroup*
MGD: million gallons per day

DRWW hired Geosyntec Consultants, Inc. (Geosyntec) to develop a work plan to identify the scope, schedule, and budget for subsequent work required to produce the NARP (Geosyntec 2020). The work plan was submitted by DRWW to Illinois EPA to meet the special condition in the NPDES permit of POTWs. DRWW did not receive any specific feedback on the work plan from Illinois EPA.

1.4 Report Organization

DRWW hired a project team consisting of Geosyntec (prime consultant), Kieser & Associates, and The Conservation Fund to develop the NARP. The project team worked closely with the DRWW Monitoring Committee in the development of the NARP. This report documents the work that the project team conducted to execute the work plan for the Study Area NARP (Geosyntec 2020).

Chapter 2 of the report provides an overview of water quality impairments, nutrient sources, and other factors impacting water quality and previous water quality studies. The NARP development process, which included collecting data and analyzing, modeling, and evaluating management scenarios, is described in Chapter 3. Chapter 4 recommends an implementation plan and schedule to address phosphorus-related impairments.

2. WATER QUALITY STATUS

2.1 Phosphorus-Related Impairments

To fulfill the requirements of Section 303(d) of the federal Clean Water Act, every two years the Illinois EPA prepares a list of impaired waterbodies not meeting their intended uses (fishing, swimming, drinking water supply, etc.) and the criteria used as basis of the impairment. The criteria can be numeric or non-numeric (Section 303[d] List). The 2022 Section 303(d) List includes the following waterbodies in the Study Area for phosphorus-related impairments (Illinois EPA 2022) (**Table 2**):

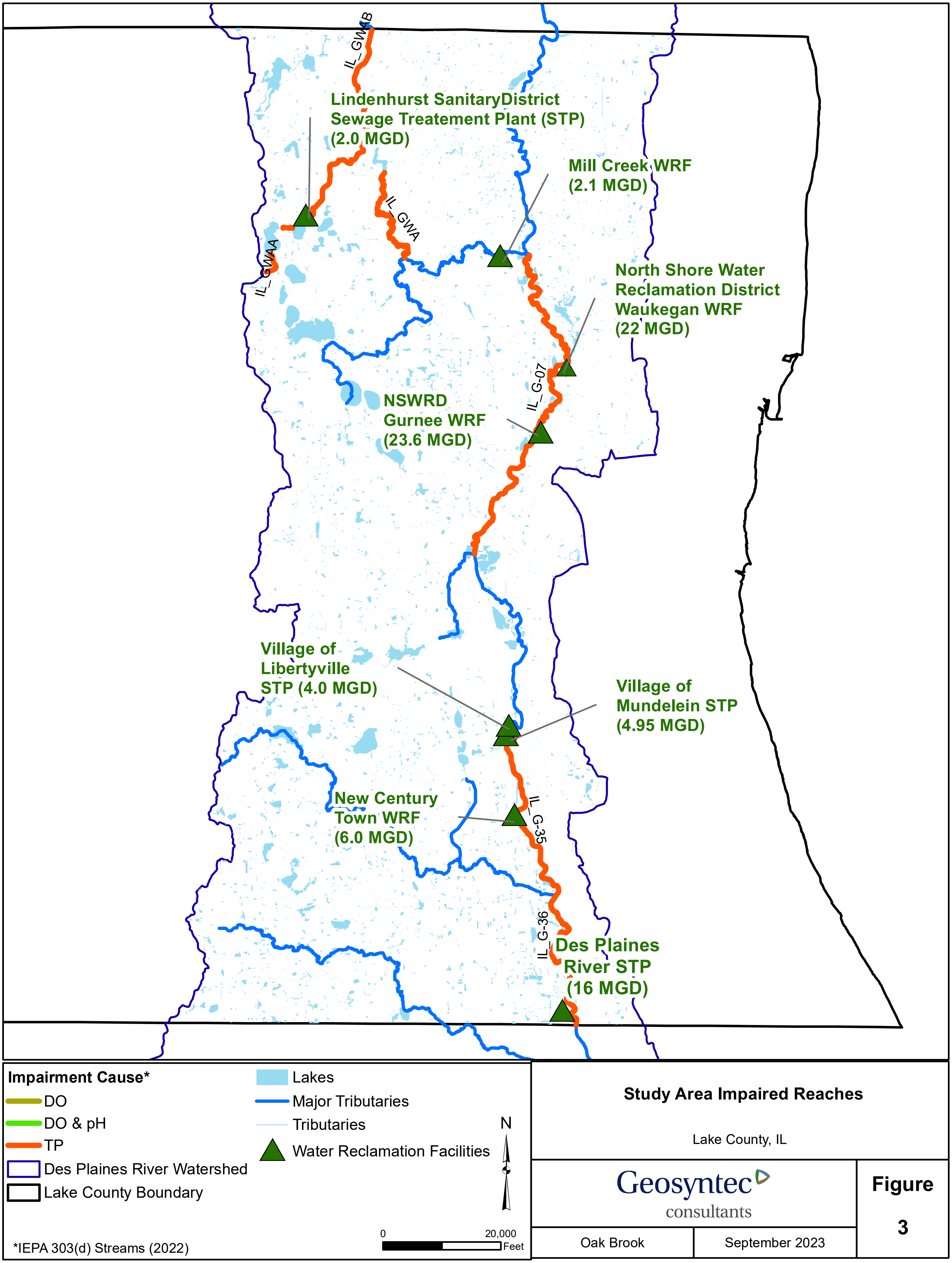
1. Des Plaines River segments IL_G-35, IL_G-36, and IL_G-07
2. North Mill Creek segment IL_GWA
3. Dutch Gap Canal segment IL_GWAB
4. Hastings Creek segment IL_GWAA

Figure 3 shows the location of these reaches. Segments of the Des Plaines River (IL_G-25, IL_G-08), Mill Creek (IL_GW-02), and Indian Creek (IL_GU-02) were listed for phosphorus-related impairment in the 2016 Section 303(d) List (Illinois EPA 2016) but were delisted in the 2022 Section 303(d) List.

Table 3: Phosphorus-Related Impaired Reaches (Illinois EPA 2022)

Water Body	Segment	Length (miles)	Cause of Impairment by Designated Use	
			Aquatic Life	Aesthetic Quality
Des Plaines River	IL_G-35	5.00	Cause Unk, Total Phosphorus (**TP**)	F
Des Plaines River	IL_G-36	7.22	**Algae**, CauseUnk, FlowMod, **TP**	F
Des Plaines River	IL_G-07	10.78	As, Cause Unk, Nitrogen, Stream Alt, **TP**	F
North Mill Creek	IL_GWA	5.48	As, Cause Unk, Flow Alt, Flow Mod, Sed/Silt, **TP**	F
Dutch Gap Canal	IL_GWAB	1.1	As, Flow Alt, Flow Mod, Manganese, Sed/Silt, **TP**	X
Hastings Creek	IL_GWAA	4.04	As, Flow Mod, Sed/Silt, Stream Alt, **TP**	X

As: arsenic
CauseUnk: Cause Unknown
F: Fully Supporting
FlowAlt: Flow Alteration – Changes in Depth and Flow Velocity
FlowMod: Flow Regime Modification
Sed/Silt: Sedimentation/Siltation
StreamAlt: Alteration in Stream-side or littoral vegetative covers
X: Not Assessed



Study Area Impaired Reaches

Lake County, IL

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Figure 3

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2.2 Water Quality Goals and Load Reductions Targets

The DRWW has identified within their Bylaws the following goal:

> "The goal of the Workgroup is to improve water quality in the Des Plaines River and its tributaries through monitoring, project and best practices implementation, and education and outreach that will achieve attainment of water quality standards and designated uses for the watershed."

These Bylaws, originally established in 2018, and further revised in 2022, demonstrate a willingness by the DRWW to actively address the identified water quality impairments identified by the Illinois EPA and develop a reasonable framework as part of this NARP to accomplish the implementation necessary to achieve this goal. The segments of Des Plaines River and its tributaries impaired for phosphorus-related impairments (dissolved oxygen [DO] and nuisance algae impairment) are identified in Section 2.1. A summary of water quality standards in the Des Plaines River and its tributaries for DO and nuisance algae is provided below.

Dissolved Oxygen: Numeric criteria for DO are described in Illinois Administrative Code (Ill. Adm. Code or IAC) rules for water quality standards (35 Ill. Adm. Code 302). The DO criteria are dependent on the time of the year and include three components: (1) an instantaneous criterion, (2) a daily mean averaged over seven days, and (3) a daily mean averaged over 30 days. **Table 3** presents the DO standards for reaches in the Study Area.

Table 4: Dissolved Oxygen Water Quality Standards

DO Standard	March through July	August through February
Instantaneous (mg/L)	5.0	3.5
Daily mean averaged over seven days (mg/L)	6.0	4.0
Daily mean averaged over 30 days (mg/L)	N/A	5.5

Nuisance Algae: There are no numeric standards for nuisance algae in Illinois. The provisions of IAC Section 302.203 are a narrative description for the offensive condition in streams that is applicable to the reaches in the Study Area: "*Waters of the State shall be free from sludge or bottom deposits, floating debris, visible oil, odor, plant or algal growth, color or turbidity of other than natural origin*". The Illinois EPA uses a visual assessment by a trained biologist to determine whether a stream complies with these provisions. The biologist documents the visual results assessment in a field form along with the offensive condition such as excessive plant or algal growth.

The Illinois EPA 303(d) list identifies total phosphorus (TP) as a cause of impairment for several of the Des Plaines River and its tributaries' reaches associated with nuisance algae or plant growth. There are no numeric or narrative water quality criteria for TP in rivers and streams in Illinois.

From 2015 to 2018, a Nutrient Science Advisory Committee (NSAC) met and developed recommendations for numeric nutrient criteria for non-wadeable streams and rivers and wadeable streams for Illinois' southern and northern ecosystems. The NSAC recommended TP, total nitrogen, benthic chlorophyll *a*, and water column chlorophyll-a criteria (Illinois NSAC, 2018). The recommended TP criterion for non-wadeable streams in a northern Illinois ecosystem like the Des Plaines River was 113 micrograms per liter (µg/L). The Illinois EPA has not acted on the NSAC recommendations. Hence, this recommended criterion was not used for the NARP.

The Illinois Nutrient Loss Reduction Strategy recommends statewide TP load reduction targets of 45 % from the Year 2011 baseline loading for the period by 2045 (Illinois EPA et al., 2015). This load reduction target was used a reference for the Study Area as the NARP goal of meeting water quality standards and addressing phosphorus related impairments would need to be ongoing and adaptive in nature to verify the impact of implemented projected

2.3 Nutrient Sources

The nutrient sources in the NARP Study Area include point-source loading from major POTWs, loadings from the upstream area, and nonpoint-source (NPS) loading from surface runoff. NPS loading can be grouped into three major categories:

1. Agricultural
2. Urban (developed and open space in urban areas)
3. Other (forest, rural grassland, surface water, and wetlands)

The distribution of these land uses within the NARP Study Area is shown in **Figure 2.**

As part of NARP development, the project team developed a Soil and Water Assessment Tool (SWAT) model to quantify the TP loading. Annual TP loads were calculated based on the 2013 to 2020 modeling results for the NARP Study Area. **Figure 4** provides the annual average percentage contribution of TP from different sources for the NARP Study Area from 2013 to 2020. The total simulated annual average TP load for the entire Study Area from 2013 to 2020 is 441,850 pounds. Approximately 71% of this load is estimated to be from POTWs, while 37% is estimated to originate from the upstream area in Wisconsin. Urban runoff accounts for approximately 10% of the TP load, while other NPS contribute approximately 1% of total load.

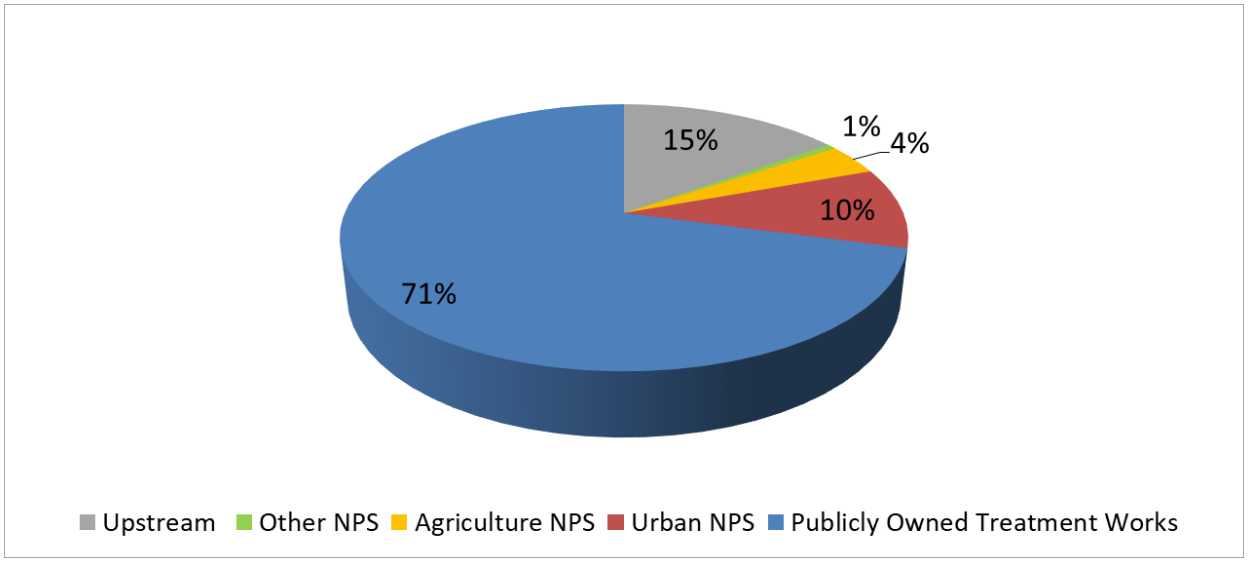


Figure 4: Estimated Annual Average Total Phosphorus Loading, 2013 to 2020

2.4 Other Factors

Streambank erosion is another factor that impacts water quality. The Lake County SMC conducted a stream inventory of the Des Plaines River and its tributaries. The results indicated that reaches of the mainstem of the Des Plaines River and the North Mill Creek are moderately eroded for 89% and 59% of miles assessed, respectively (Lake County SMC 2018).

2.5 Water Quality Studies

There have been extensive water quality studies and management plans for the Des Plaines River and its tributaries. Summaries of relevant studies and management plans are provided below.

2.5.1 Des Plaines River Watershed-Based Plan

The Lake County SMC developed a nine-element WBP for the Des Plaines River watershed planning area (Lake County SMC 2018). The plan identified nutrients, organic enrichment, and sedimentation and siltation as the major causes of impairments in the river and streams. The WBP included estimation of current and future annual average TP and total nitrogen loads from NPS based on existing and future conditions. The pollutant loading was estimated using the Spatial Watershed Assessment and Management Model. The model predicted an increase of 82% and 54% for TP and total nitrogen, respectively, for the future condition as compared to the existing condition. The WBP recommended several actions to reduce pollution entering the watershed, including investing in POTWs, upgrading stormwater management systems, and reducing the use of pesticides and fertilizers. The WBP also recommends using green infrastructure such as rain gardens and bioswales to manage stormwater runoff and reduce flooding and loading from urban sources.

2.5.2 Monitoring Studies

The DRWW and Illinois EPA have performed water quality monitoring in the Study Area, which is briefly described below.

2.5.2.1 DRWW Monitoring

Since September 2015, the DRWW has undertaken a comprehensive monitoring program to collect physical, chemical, and biological data in the mainstem Des Plaines River and its tributaries. The goals of the monitoring program as stated in the DRWW monitoring strategy documents are (1) to "develop and implement a comprehensive monitoring program that will include chemical, physical, and biological components that will accurately identify the quality of stream and river ecosystems as well as stressors associated with non-attainment of water quality standards and designated uses" and (2) to "assist the NPDES permittees including the POTWs and MS4 in meeting monitoring requirements" (DRWW 2015, 2017, 2018, 2020).

The comprehensive water quality monitoring undertaken by DRWW leveraged a tiered site design, which allowed for more frequent monitoring of sites with greater flow and tributary area while still providing comprehensive coverage of the watershed. The numbers of stations in each tier varied each year. Tier 1 included monitoring stations on Des Plaines River and Mill Creek. Monitoring of Tier 1 sites included biological assessment, sestonic and benthic chlorophyll a studies, and water column and sediment monitoring programs. Tier 2 consists of stations located on Des Plaines River and tributary streams, which were sampled for biological assessment and water column and sediment chemistry every 6 years. The 18 tributary stations were sampled for biological assessment and water column data every six years. The location of monitoring stations is shown in **Figure 5**

The components of monitoring included:

1. **Biological monitoring**. Biological monitoring includes sampling fish and macroinvertebrate habitat assessment. Biological monitoring was conducted for 69 sites in 2016 and then on a rotating basis for a minimum of 20 out of 70 total sites in the following years.
2. **Water column and sediment chemistry monitoring**. The water column and sediment data were collected using tiered monitoring strategy described above. The monitoring locations are shown in **Figure 5**. Water column monitoring consisted of both continuous monitoring of DO, pH, temperature, and conductivity and grab sample collection for DO, DO saturation, ammonia, nitrogen, TP, organic carbon, total suspended solids (TSS), pH, conductivity, and chlorine. Sediment samples were analyzed for metals and organics.
3. **Flow monitoring**. DRWW hired Burns & McDonnell Engineering Company, Inc. to install a network of 15 stage data loggers and measured flow data monitors to develop flow rating curves in the mainstem Des Plaines River and its tributaries.

DRWW also hired Midwest Biodiversity Institute to develop an Integrated Prioritization System tool to identify the most limiting stressors in receiving streams based on the above-described comprehensive monitoring program (MBI, 2022).

2.5.2.2 Illinois EPA Monitoring

Illinois EPA collected continuous and discrete water quality monitoring data in the watershed in 2013 and 2018 as part of its Intensive River Basin Survey program. Additional data were collected in the watershed as part of Illinois EPA's Ambient Water Quality Monitoring Network Program and Facility Stream Survey programs (Illinois EPA 2023).

2.5.3 Lake County Green Infrastructure Model and Strategy

The Lake County Green Infrastructure Model and Strategy (GIMS) is a framework for identifying land conservation and restoration opportunities for the county's major native landscape types: woodland/forest, prairie/grassland/savanna, wetlands, and freshwater aquatic systems (LCFD, 2016). The GIMS was developed by the Lake County Forest Preserve District. It builds on the previous efforts of the Chicago Wilderness regional Green Infrastructure Vision and on the assessment of ecosystem service valuation in Lake County and six other Illinois counties that was conducted by the Chicago Metropolitan Agency for Planning with support from the Conservation Fund.

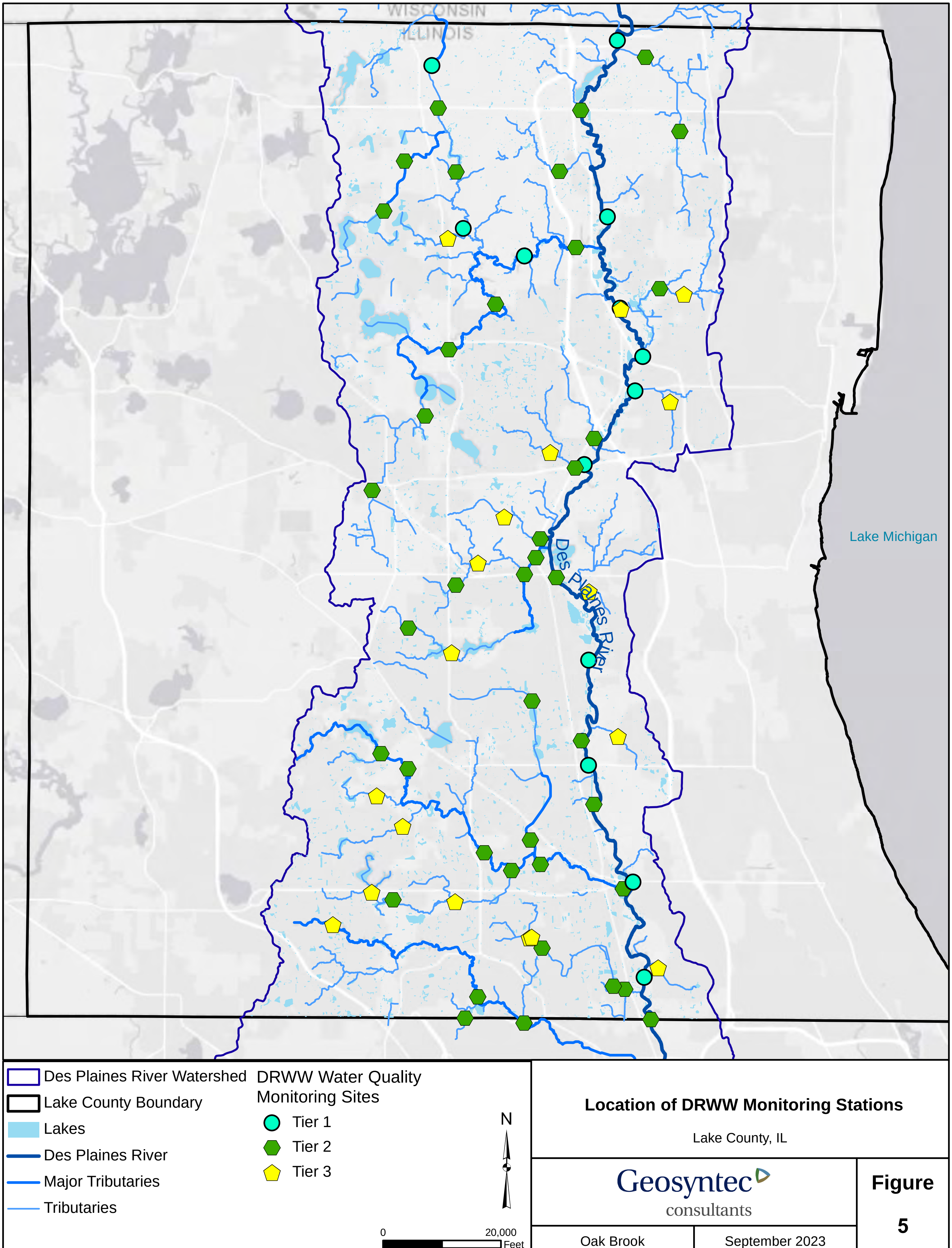
The GIMS is a valuable tool for land conservation and restoration in Lake County. It can be used to identify priority areas for conservation, develop restoration plans, and assess the advantages of green infrastructure. The GIMS is also a valuable resource for the public, providing information about the county's green infrastructure network and the benefits of conservation. Among its major recommendations, the GIMS proposes to protect and restore core areas and functional connections, increase the connectivity of the green infrastructure network, expand the use of green infrastructure to manage stormwater runoff, and educate the public about the benefits of green infrastructure.

2.5.4 Wisconsin Des Plaines River Studies

The upstream load to the Study Area includes loading from the Des Plaines River watershed in southeastern Wisconsin, with a drainage area of 133 square miles. Although upstream of the NARP Study Area, this area is relevant because upstream water quality (e.g., nutrients, algae, and DO) impacts the water quality in the DRWW NARP Study Area.

The Southeastern Watershed Regional Planning Commission developed a comprehensive regional plan for the Des Plaines River watershed in southeastern Wisconsin (SEWRPC, 1978). The plan identifies the major water quality, flooding, and land use issues in the watershed and outlines strategies for addressing them. The plan also includes a set of goals and objectives for the watershed, as well as a list of actions that need to be taken to achieve these goals.

The Wisconsin Department of Natural Resources (WDNR) is developing a TMDL for the Fox Illinois River Basin (WDNR 2023). The study area for this TMDL includes the Des Plaines River watershed in Wisconsin. The mainstem Des Plaines River segments in Wisconsin are listed as being impaired on Wisconsin's Section 303(d) List (WDNR, 2022). The TMDL and subsequent implementation plan will provide a framework to address the impairments in these segments.



Location of DRWW Monitoring Stations

Lake County, IL

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Figure 5

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3. NARP DEVELOPMENT PROCESS

3.1 Data Collection and Analysis

DRWW conducted NARP–focused monitoring in 2020, which consisted of the following components:

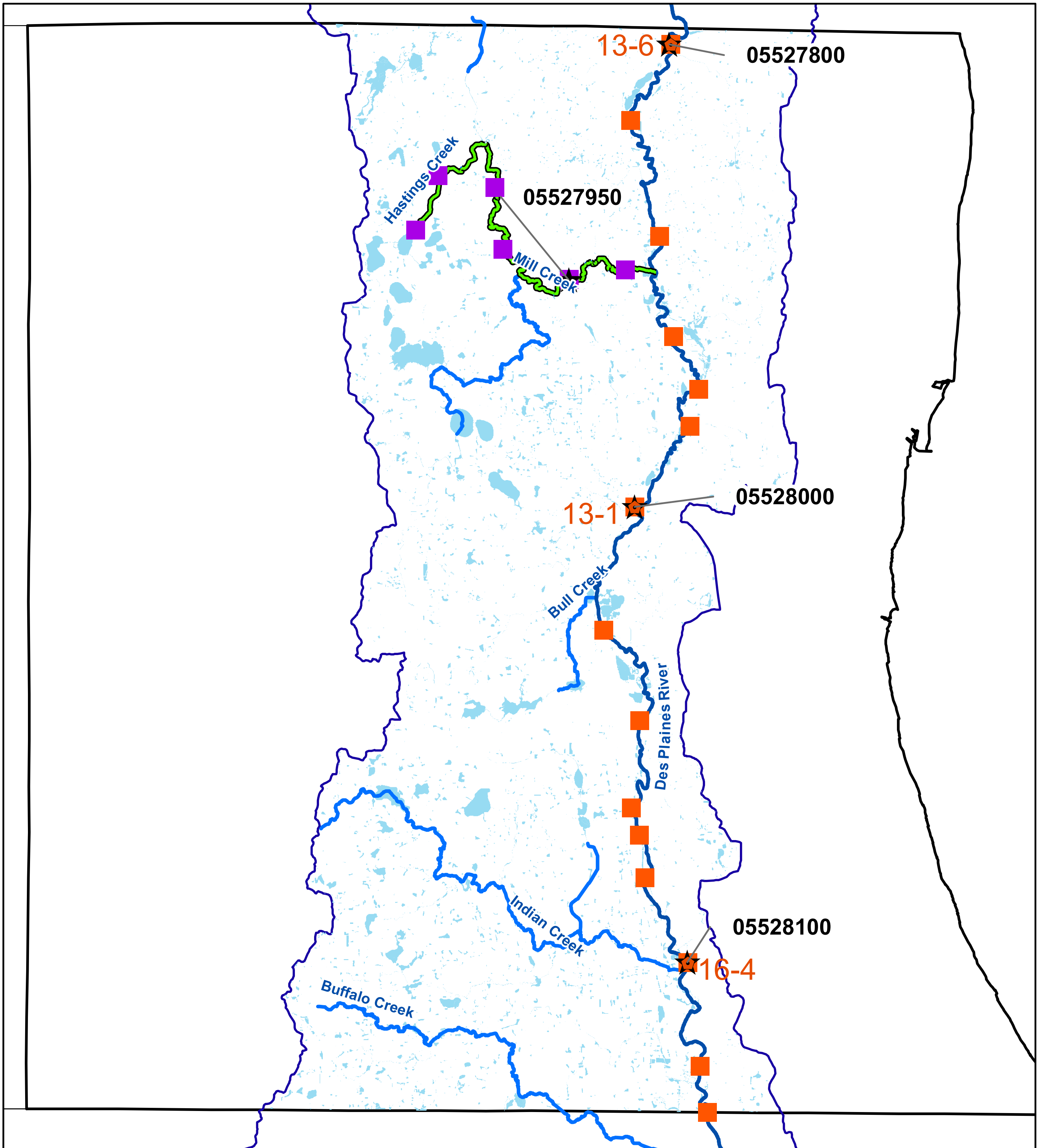
1. **Continuous monitoring**. Three sondes on the mainstem of the Des Plaines River (**Figure 6**) measured DO, temperature, TSS, pH, chlorophyll *a*, and conductivity.
2. **Discrete sampling**. Discrete measurements were taken for DO, temperature, pH, nutrients, sestonic chlorophyll *a*, and benthic algae at 15 Tier 1 sites on the mainstem of the Des Plaines River and three (3) tier sites on the Mill Creek. Samples were taken monthly during the summer period.

Data for the growing season (May to October) from 2017 to 2020 were analyzed to assess the longitudinal trends along the mainstem of the Des Plaines River. **Figure 7** shows the longitudinal box-and-whisker plots for measured instream TP.[3] The *x* axis on the graph represents miles on the Des Plaines River, decreasing from left to right in the direction of flow. The plot shows that the instream TP increased with inputs from POTWs but decreased shortly after.

Figure 8 shows a similar plot for sestonic chlorophyll *a*. Instream chlorophyll *a* is high (greater than 15 µg/L) at the upstream boundary at the Illinois-Wisconsin border, and it decreases downstream due to dilution from discharge inputs from POTWs.

This trend is also apparent in **Figure 9**, which shows high chlorophyll *a* levels at upstream station 13-1 (Rusell Road) and decreased levels at downstream station 16-4 (Rt 120). The high chlorophyll *a* levels at the upstream boundary resulted in large variability in DO at the upstream boundary (**Figure 10** and **Figure 11**). Downstream, the variability in DO is reduced by discharge inputs from POTWs, which are high in DO, and reduced instream chlorophyll *a* levels. The data analysis shows that the chlorophyll *a* levels at the upstream boundary have a large impact on downstream water quality.

[3] Whiskers represent the minimum and maximum values, the edges of the box represent the 25th and 75th percentile values, and the central lines represents the median values. Text on top of each box shows the numbers of samples available



Des Plaines Watershed
Lake County Boundary
Lakes
Mill Creek Model Extent
Des Plaines River
Major Tributaries
Mainstem WQ Stations
Mill Creek Model WQ Stations
USGS Stations
Continuous WQ Stations

N

0 20,000 Feet

2020 Nutrient Assement Reduction Plan Monitoring Stations

Lake County, IL

Geosyntec consultants

Oak Brook | September 2023

Figure 6

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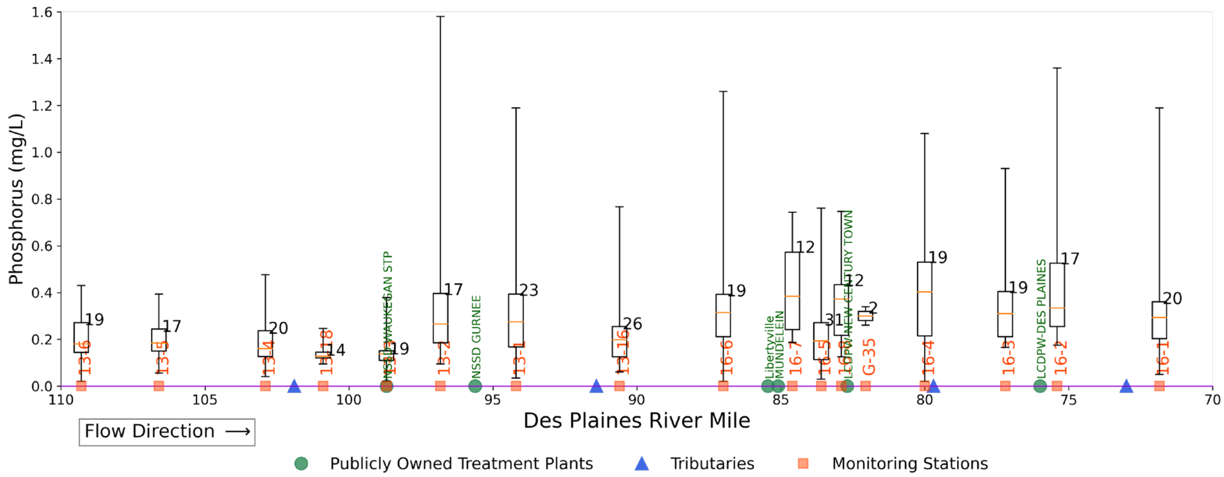

Figure 7: Longitudinal Plot of Measured Total Phosphorus in the Des Plaines River for the Growing Season (May to October), 2017 to 2020

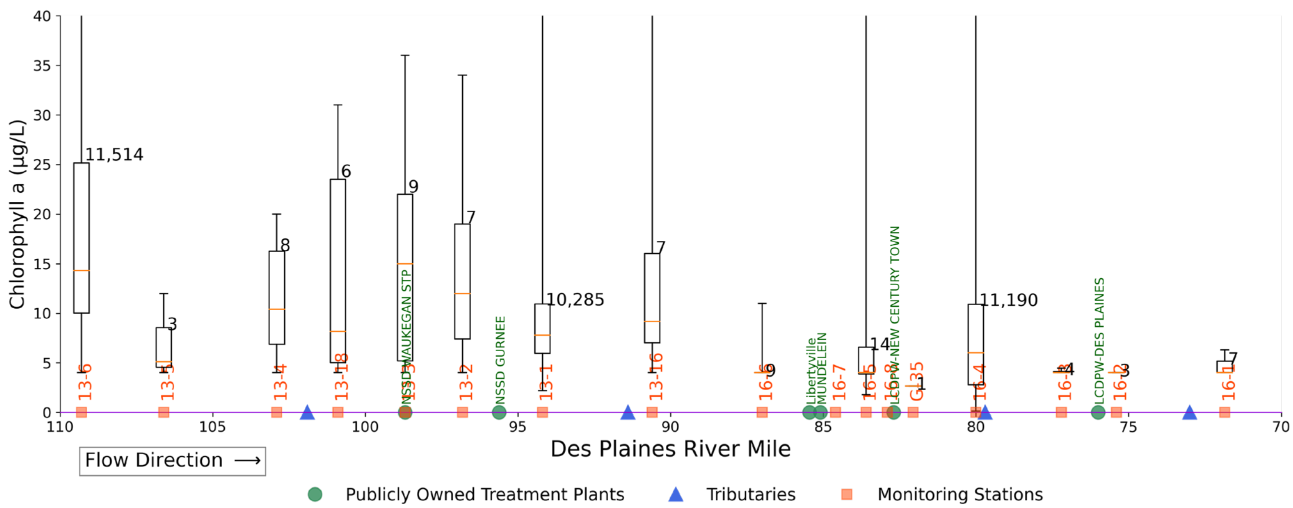

Figure 8: Longitudinal Plot of Measured Sestonic Chlorophyll *a* in the Des Plaines River for the Growing Season (May to October), 2017 to 2020

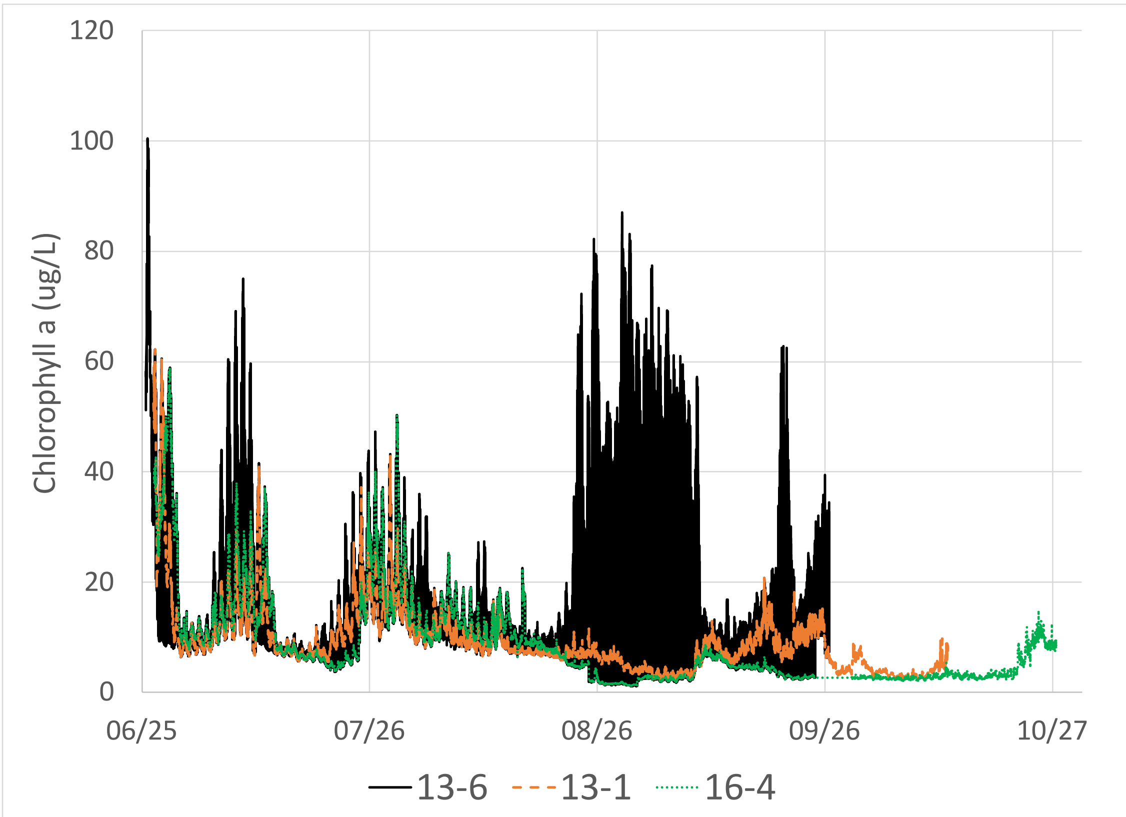

Figure 9: Time Series of Measured Continuous Sestonic Chlorophyll *a* at Three Stations on the Des Plaines River Mainstem in 2020

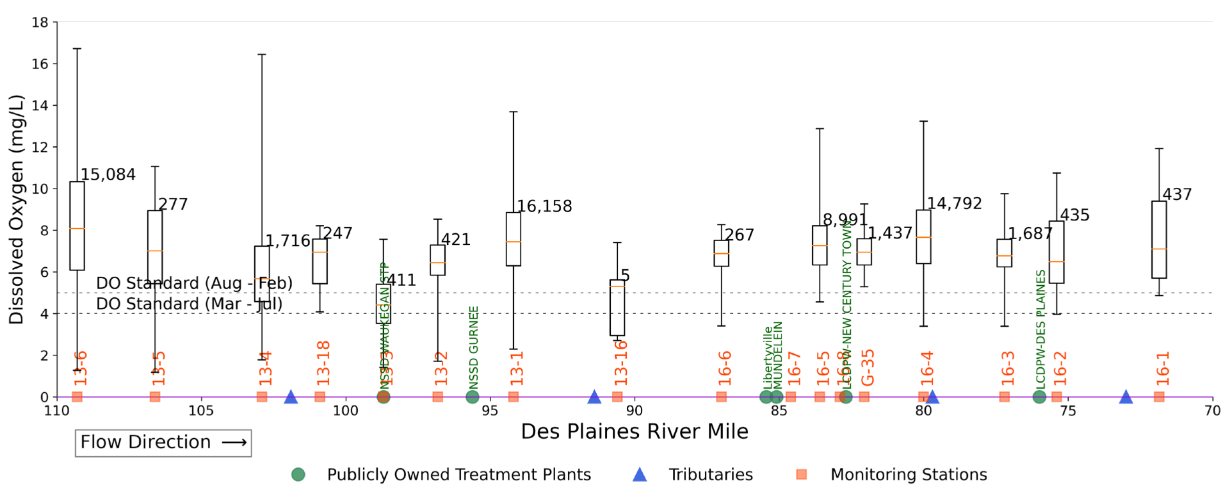

Figure 10: Longitudinal Plot of Measured Dissolved Oxygen in the Des Plaines River for the Growing Season (May to October), 2017 to 2020

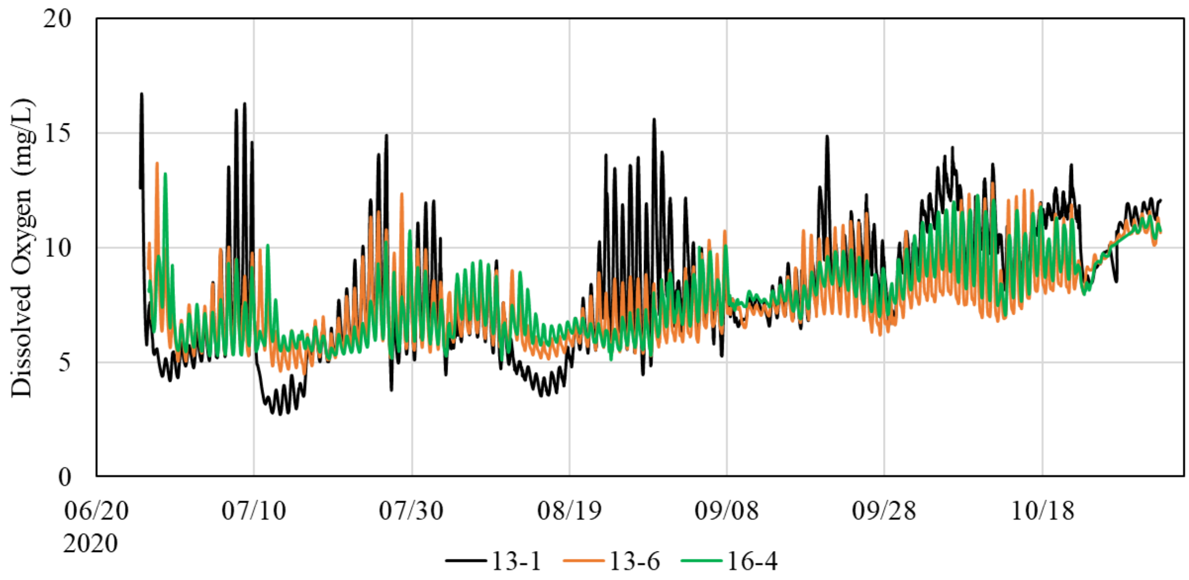

Figure 11: Time Series of Measured Continuous Dissolved Oxygen at Three Stations on the Des Plaines River Mainstem in 2020

3.2 Modeling

The NARP requires identification of phosphorus input reductions by point-source and NPS discharges, among other necessary measures to remove phosphorus-related impairments in the watershed. Models can be used to define the linkage between the phosphorus inputs and related impairments such as DO and nuisance algae, evaluate the effectiveness of different watershed management scenarios in reducing or removing impairments, and provide useful information to decision-makers as they decide which projects to prioritize in implementing NARP recommendations.

A linked numerical modeling framework was developed for the NARP, as recommended in the DRWW NARP work plan (Geosyntec 2020). The linked modeling framework consists of two components: a watershed model and two instream models with hydraulic and water-quality components (**Figure 12**). The development and calibration of the two models are briefly summarized below, and further details are included with the appendices.

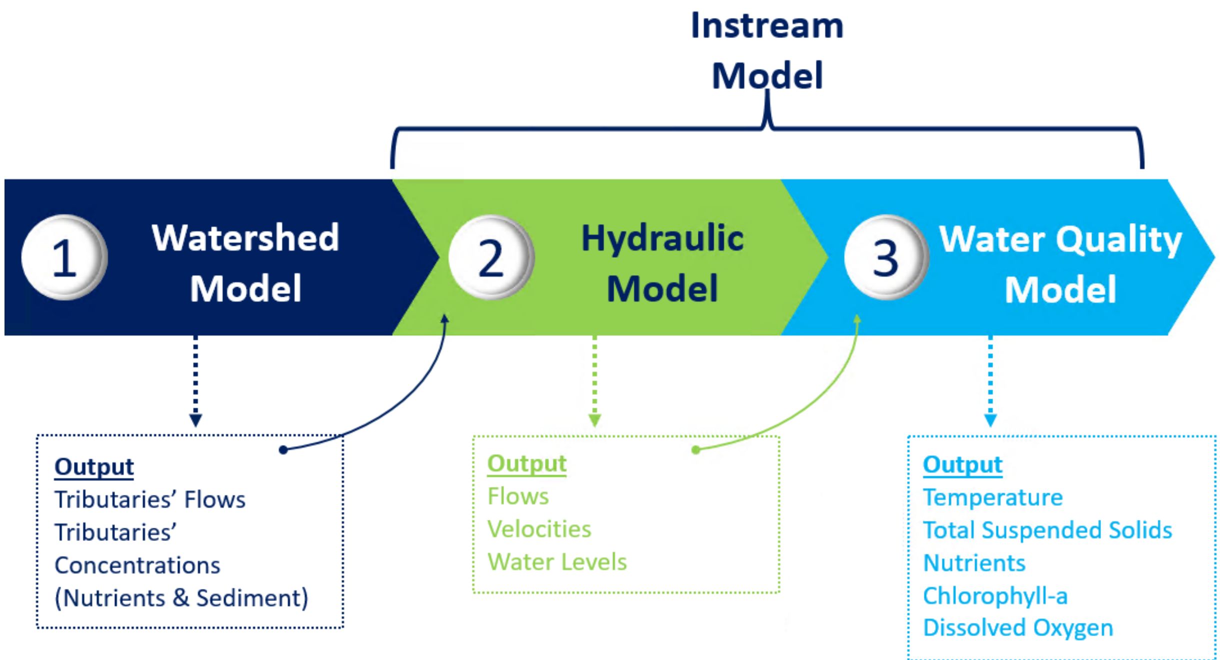

Figure 12: Model Framework

3.2.1 Watershed Model

The watershed model was developed using the Soil & Water Assessment Tool (SWAT) which is a river-basin-scale model originally developed by the United States Department of Agriculture's Agricultural Research Service (Texas A&M 2006, Neitsch et al. 2011). The extent of the SWAT model developed for the NARP includes the drainage area in Wisconsin and the NARP Study Area. The drainage area of 231,534 acres was delineated into the 89 subwatersheds based on elevation data for developing the model. The inputs into the model included data on elevation, soil, land use, stream network, and meteorology.

The SWAT model was calibrated to measured flow and available water quality data to enable the model to simulate reality reasonably well. **Figure 13** shows the daily time series comparison of simulated values and measured data at the four United States Geological Survey gages for the period of 2013 to 2018. The model simulates the daily flows reasonably well compared to the measured data except for Mill Creek. In general, the model underestimated the peaks of the biggest storms for Mill Creek, which resulted in a slight underestimation of total flow volumes from Mill Creek. For the Des Plaines River watershed, WWTP loading constitutes more than 70% of loading under the current existing conditions. Hence, the underestimation of loading from Mill Creek is unlikely to impact the water quality in the mainstem of the Des Plaines River

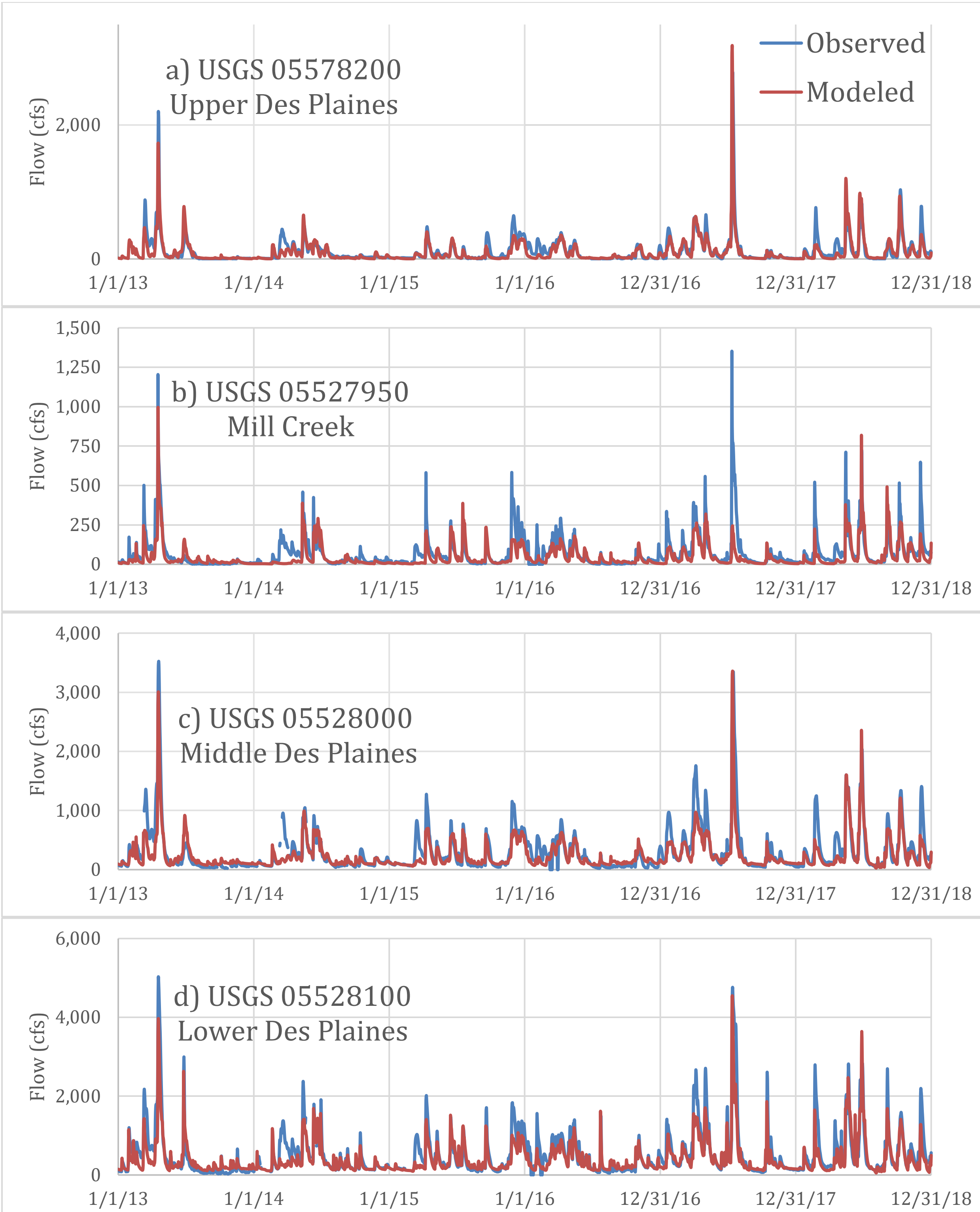

Figure 13: Times Series Comparison of Simulated and Measured Flows in Des Plaines River

The SWAT model was used to generate time series of flows and concentrations of TP, total nitrogen, and TSS from the land segments, including the POTW loads, to the instream models. A comparison of measured and simulated instream TP concentrations is shown in **Figure 14**. The model simulates TP concentrations in the measured data reasonably well.

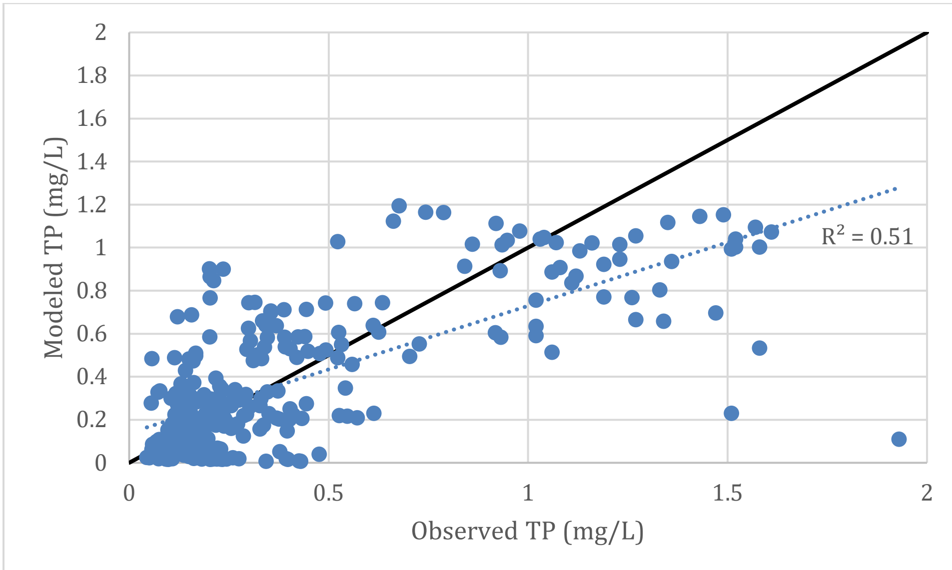

Figure 14: Overall Modeled Stream Total Phosphorus Concentrations versus Observed Data

Figure 15 illustrates estimated annual TP loads from 2013 to 2020 for the NARP Study Area. POTW loads constitute the majority of TP load for all years. POTW loads show a generally declining trend from 2013 to 2020, except in 2019. Precipitation in 2019 (46.4 inches) average for the 10 utilized precipitation stations) was higher than in any year from the 2011 to 2020 period (36.2 in average, 25–46.4 mm range, *Appendix A: DRWW NARP Watershed Modeling*). If any excess inflow and infiltration was handled by POTWs, it could have contributed to the increased effluent TP load for that year. The NPS loads are largely driven by stormwater runoff and correlate strongly with precipitation totals. The annual precipitation totals from 2017 to 2020 were higher than the annual totals from 2013 to 2016, and the NPS loads for these years follow this trend as well.

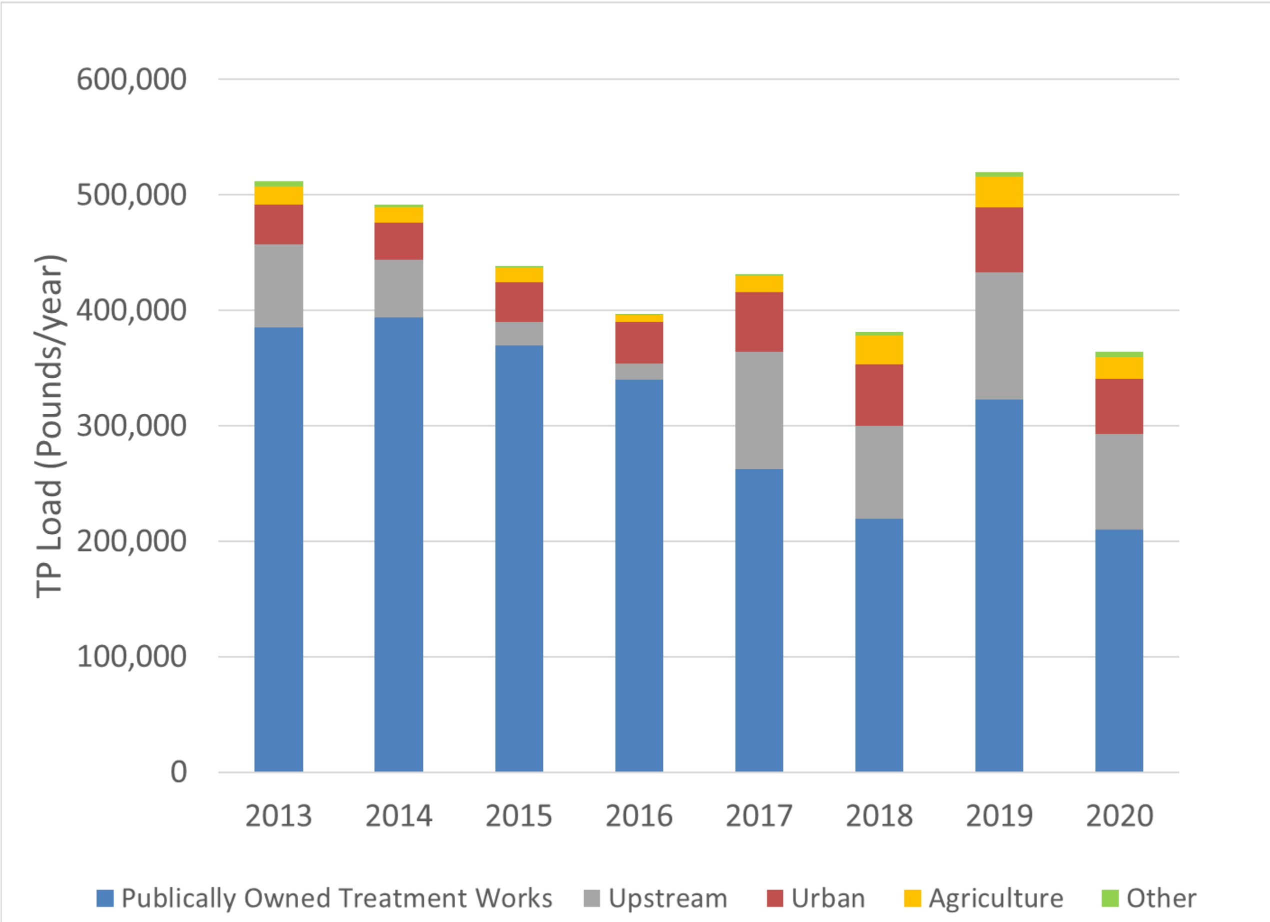

Figure 15: Simulated Annual Total Phosphorus Loads from Different Sources from 2013 to 2020

The SWAT model was also run for two additional theoretical management scenarios in which POTW effluent TP concentrations were capped at 1 milligram per liter (mg/L) and 0.5 mg/L. **Figure 16** compares the existing annual average loads with TP loads and two scenarios with POTW effluent TP limits of 1.0 mg/L and 0.5 mg/L, respectively. The two effluent limit scenarios predicted large load decreases as compared to the baseline scenarios that used observed data. For the baseline annual average scenario, POTWs accounted for 71% of the modeled TP. The percent contributions of POTWs to TP average annual loading would decrease to 38% and 25% under the 1.0 mg/L limit and 0.5 mg/L limit scenarios, respectively.

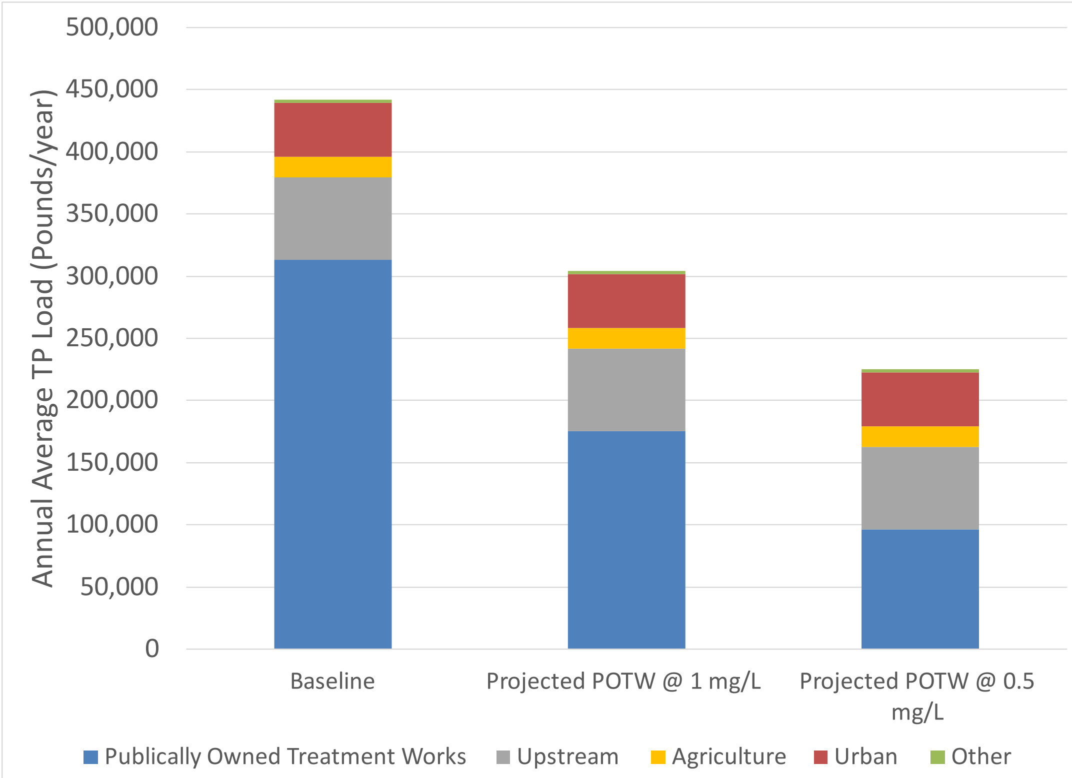

Figure 16: Estimated Quantity of Annual Average Total Phosphorus Load, 2013 to 2020

The watershed model development and calibration are described in detail in Appendix A (DRWW NARP Watershed Modeling).

3.2.2 Instream Model

The instream model was developed using the QUAL2Kw framework (Pelletier et al. 2006). QUAL2Kw can perform a continuous simulation of flow and water quality. The QUAL2Kw framework provided the DRWW with a tool to inform management decisions concerning water quality under varying flow conditions over the growing season.

The modeled reaches include the Des Plaines River mainstem and the tributaries that receive discharges from POTWs shown in **Figure 2**. The modeled tributaries are as follows:

1. Hastings Creek, downstream of Hasting Lake (receives effluent from Lindenhurst Sanitary District STP)
2. North Mill Creek, downstream of the confluence with Hastings Creek (downstream of Hastings Creek)
3. Mill Creek, downstream of the confluence with North Mill Creek (receives the effluent discharge from Mill Creek water reclamation facility or WRF)

QUAL2Kw cannot model branched tributaries. Therefore, two QUAL2kw models were developed to simulate the reaches above using the same parameterization: the Mainstem Model, which includes thirty-five miles on the mainstem of the Des Plaines River, and the Tributary Model, which includes thirteen miles on the three tributary segments listed above.

The instream model development and calibration are described in detail in Appendix B (DRWW Instream Model) and are summarized below.

3.2.2.1 Development

The inputs into the instream model included meteorology, channel characteristics, and time series of flows and water quality constituents from the upstream boundary, NPS, and point sources.

3.2.2.2 Calibration

The instream model was calibrated to available flow and water quality data for the growing season of May to October 2020. This period was chosen because it provides the most available instream water quality data (including concurrent continuous and discrete water quality). The flow in the mainstem of the Des Plaines River was high in May 2020 and very low from June to October 2020.

Figure 17 compares simulated and measured TP at the Route 120 station in the Des Plaines River (river mile 20.8). The model does a reasonable job of representing the measurements. **Figure 18** compares simulated and measured discrete and continuous chlorophyll *a* data at the Route 120 station in the Des Plaines River (river mile 20.8). The Mainstem Model simulations captured the overall trend of measured chlorophyll *a* reasonably well. However, the model significantly underpredicts peaks for chlorophyll *a*, especially in late August and late September. The underprediction is linked to an underprediction of chlorophyll *a* from the Mill Creek tributary. **Figure 19** compares simulated and measured DO in the Des Plaines River at Route 120 (river mile 20.8) for July 1 to August 15, 2020. The model captures the DO diurnal fluctuations reasonably well during this period.

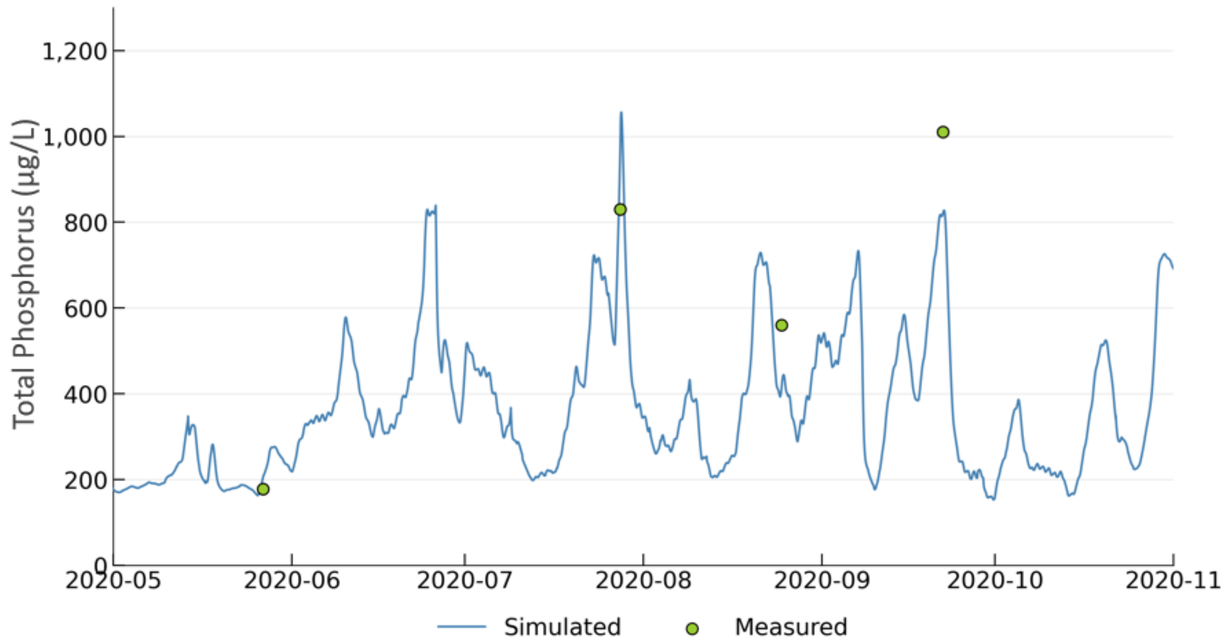

Figure 17: Simulated and Measured Total Phosphorus on the Des Plaines River at Route 120 (River Mile 20.8)

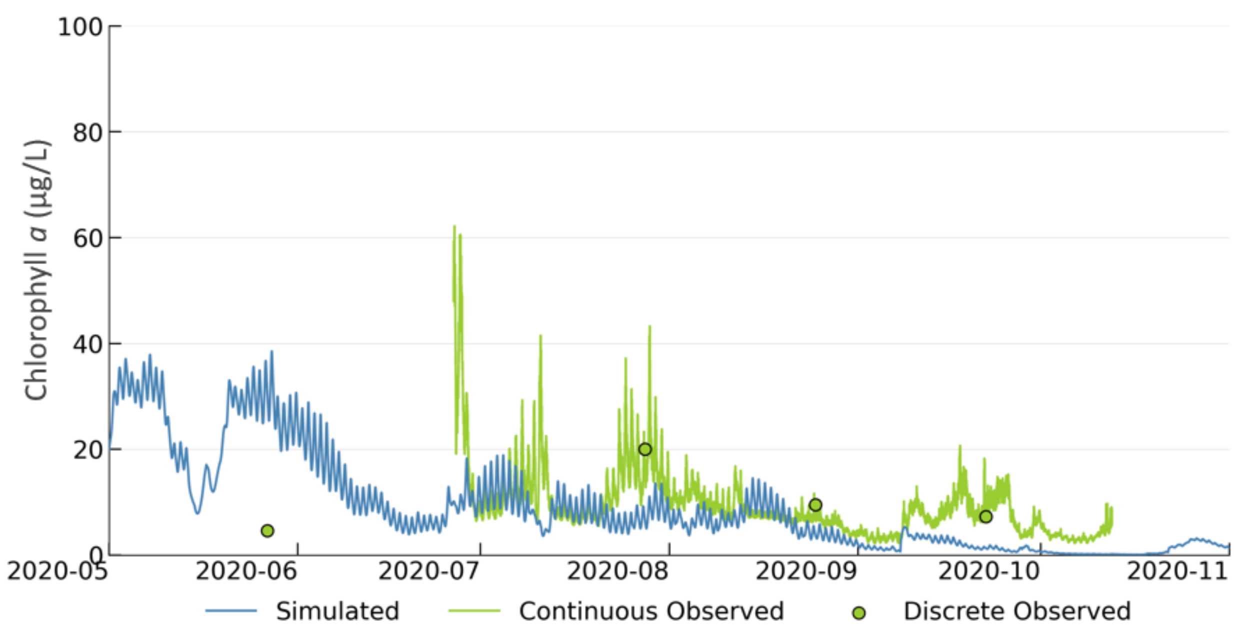

Figure 18: Simulated and Measured Sestonic Chlorophyll *a* in the Des Plaines River at Route 120 (River Mile 20.8)

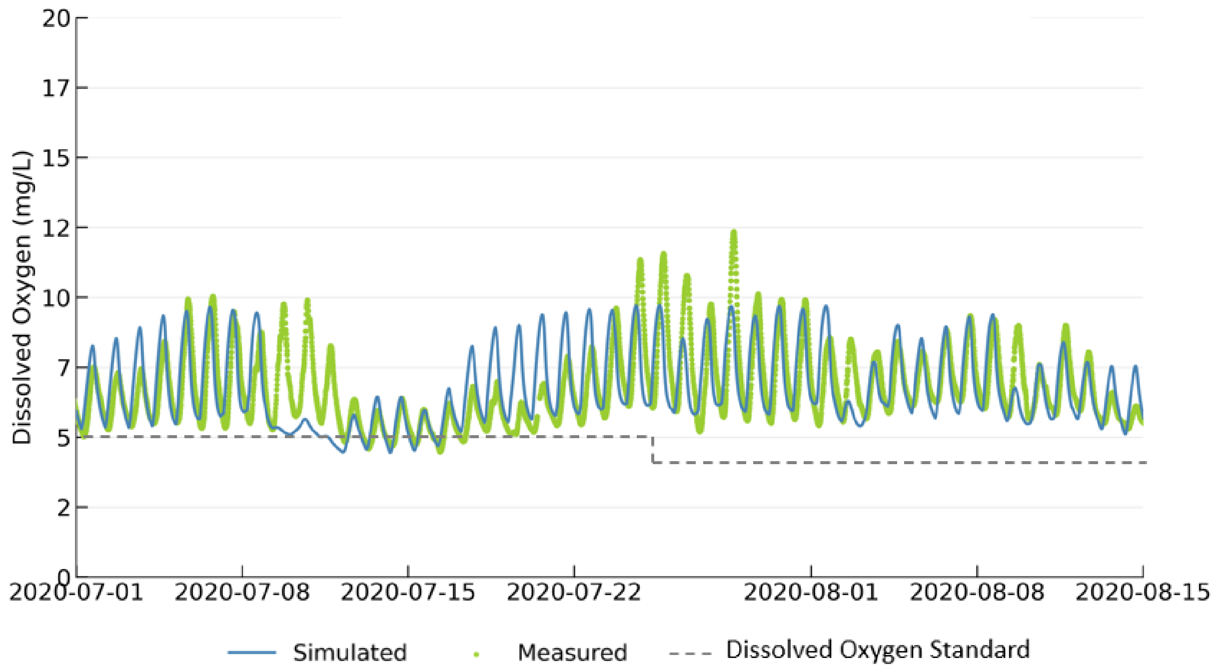

Figure 19: Simulated and Measured Dissolved Oxygen in the Des Plaines River at Route 120 (River Mile 20.8), July to August 2020

3.3 Management Scenarios

The models were used to simulate several scenarios to evaluate the effectiveness of watershed-based strategies in improving the water quality in the Upper Des Plaines River. These scenarios were compared with the baseline scenario, which represents the existing condition of the system. The instream calibrated model for the growing season of May to October 2020 was used as the baseline scenario for evaluating watershed management actions.

The watershed management scenarios are described briefly below.

3.3.1 Load Reduction from POTWs

The TP concentrations for POTWs in the baseline scenario range from 0.1 to 6.8 mg/L. The instream model was run to simulate the impact of POTW TP load reduction scenarios by capping the TP effluent concentrations to constant values of 0.5 mg/L and 0.1 mg/L.

3.3.2 Load Reduction from Upstream Sources

The upstream load constitutes approximately 20% of the total TP load into the Study Area for the period of May to October 2020. The instream model was run for a scenario with a 75% reduction in upstream TP load. The reduction was simulated by proportionally reducing the upstream concentrations of organic phosphorus, inorganic phosphorus, and internal phosphorus within sestonic algae (i.e., algae suspended in the water column). The upstream boundary sestonic chlorophyll *a* values for the baseline scenario ranged from 9 to 96 µg/L over the growing season. For the 75% reduction scenario, the upstream sestonic chlorophyll *a* boundary ranged from 2 to

24 µg/L. It is unknown at this time whether this load reduction can be realized with the TMDL for the Des Plaines River in Wisconsin, which is currently under development.

3.3.3 Load Reduction from Nonpoint sources

The contribution of tributary loads varies by river mile and is simulated with the SWAT model. The instream model was run for a scenario with a reduction of 75% of the tributary load.

3.3.4 Combined Scenario

The watershed management scenarios described above were grouped into two combined scenarios based on the Monitoring/Water Quality Improvements Committee's review of the results of the management scenarios described above. The two combined scenarios are as follows:

1. **Combined Scenario #1:** 25% upstream TP reduction, 25% tributaries TP reduction, and 0.5 mg/L POTW effluent TP
2. **Combined Scenario #2:** 50% upstream TP reduction, 25% tributaries TP reduction, and 0.5 mg/L POTW effluent TP

3.3.5 Other Measures

The Des Plaines River at the Illinois-Wisconsin border is very sluggish and has very low DO at times (**Figure 11**). This part of the river could benefit from a stream restoration project, which would involve creating riffles and pools to increase natural aeration. The impact of this stream restoration project was simulated in the model by increasing the velocity by 2.5 times[4] and reducing the depth of upstream reach by the same factor.

3.4 Evaluation of Management Scenarios

The models were used to evaluate the watershed management actions and combined scenarios by comparing the results to the baseline scenarios for the three selected periods:

1. Growing Season Period (May to October 2020)
2. High-Flow Period (May 1 to May 31, 2020)
3. Low DO Period (July 1 to July 7, 2020, when the upstream DO was below the water quality criteria)

The modeling results and key findings are summarized below and are described in detail in Appendix B (DRWW Instream Model).

3.4.1 Key Takeaway #1: POTW total phosphorus reductions beyond 0.5 mg/L have minimal impact on water quality.

The impact of load reductions associated with more stringent effluent TP limits for POTWs was simulated by capping the POTW effluent concentrations to 0.5 mg/ L and 0.1 mg/L in the model.

[4] The factor of 2.5 was chosen arbitrarily to assess the impact increased velocity and decreased depth on stream reaeration

Simulated results for the baseline scenario (**Figure 20**, black solid line) were compared with a scenario with POTW effluent TP capped at 0.5 mg/L and a scenario with POTW effluent TP capped at 0.1 mg/L for the growing season (May to October 2020). The results show that decreasing POTW TP effluent substantially reduces instream TP downstream of river mile 23. For the scenario with a POTW TP effluent concentration at 0.5 mg/L, the TP loading transported through the system would be reduced by approximately 29% (**Figure 20)**. Even after the POTW TP effluent load reduction of 0.1 mg/L, the reduced instream TP concentrations are still above the critical thresholds to cause nutrient limitation for algae. Therefore, the reduction in POTW TP effluent concentration beyond 0.5 mg/L has no major impact on instream sestonic chlorophyll *a* or DO.

3.4.2 Key Takeaway #2: Upstream total phosphorus reduction reduces sestonic chlorophyll *a* and improves dissolved oxygen during high flows.

The scenarios for the upstream TP load reduction included a modeled reduction in upstream sestonic chlorophyll *a*, because a portion of TP is also bound up as internal phosphorus in sestonic chlorophyll *a*. Simulated results for the baseline scenario (**Figure 21**, black solid line) were compared with a scenario with a 75% upstream reduction (blue dashed line) for the high-flow period (May 1 to May 31, 2020). The results show that reducing the upstream TP load reduces the instream TP and sestonic chlorophyll *a*. The reduction in instream chlorophyll *a* improves DO because of reduced DO swings and increased benthic algae activity after wet events.

3.4.3 Key Takeaway #3: Tributary total phosphorus reductions reduce sestonic chlorophyll *a* in the mainstem river but have minimal impact on dissolved oxygen.

The impact of reducing tributary loads on the mainstem Des Plaines River was assessed by running scenarios with 75% reductions in simulated tributary TP loadings. Simulated results for the baseline scenario (**Figure 22**, black solid line) were compared with a scenario with a 75% tributary TP load reduction (green dashed line) for the high-flow period (May 1 to May 31). The results show that reducing the tributary TP load slightly reduces the instream TP and sestonic chlorophyll *a*, mostly following wet events. Tributary phosphorus load reductions have a minimal impact on the instream DO.

3.4.4 Key Takeaway #4: A combined reduction in the load from POTWs, nonpoint sources, and upstream improves the water quality in the Des Plaines River.

The impact of combined management actions that reduce the load from POTWs, nonpoint sources, and upstream was assessed by running two additional modeling scenarios. Modeling results were compared during the growing season (May to October 2020) for the baseline scenarios, Combined Scenario #1 (25% upstream TP reduction, 25% tributaries TP reduction, and 0.5 mg/L POTW effluent TP), and Combined Scenario # 2 (50% upstream TP reduction, 25% tributaries TP reduction, and 0.5 mg/L POTW effluent TP) (**Figure 23**). The results show that combining the POTW load reduction with load reduction from NPS and from upstream sources results in improved DO due to the reduction in instream TP, sestonic chlorophyll *a,* and benthic algae. This combined strategy is recommended to address the phosphorus-related impairment in the Study Area.

3.4.5 Key Takeaway #5: Improving upstream dissolved oxygen addresses the impairment in upper reaches of the Des Plaines River.

The impact of a stream restoration project in the Des Plaines River near the Illinois-Wisconsin border was simulated in the model by increasing the velocity and decreasing the depth each by a factor of 2.5. The modeling results show that increased velocity and reduced depth would result in increased reaeration, which would address the DO impairment in upper reaches of the NARP Study Area (**Figure 24**).

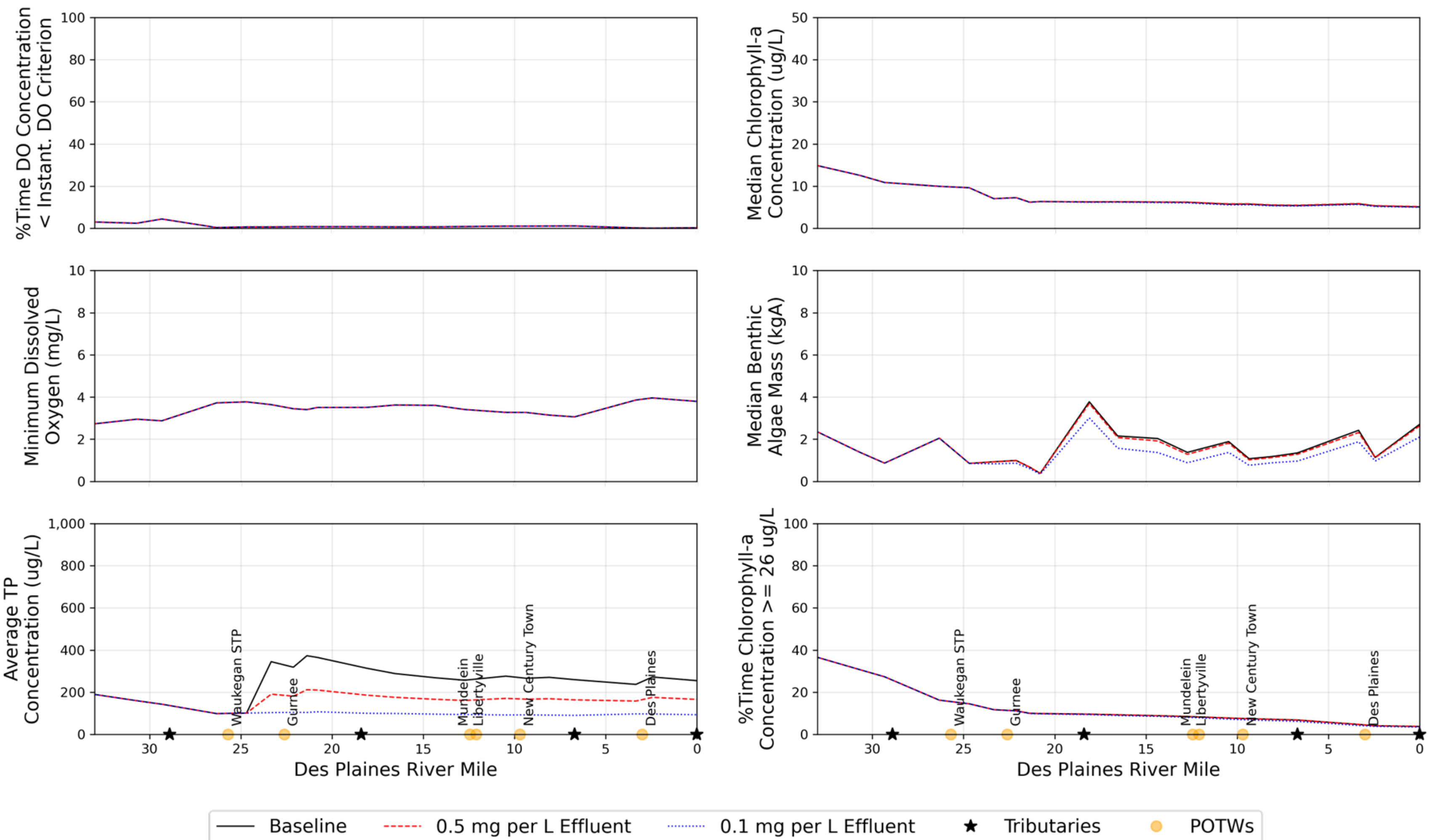

Figure 20:Comparison of Baseline Scenario and Scenarios with POTW Effluent Discharge at 0.5 mg/L and 0.1 mg/L Total Phosphorus (May 1 to October 31, 2020)

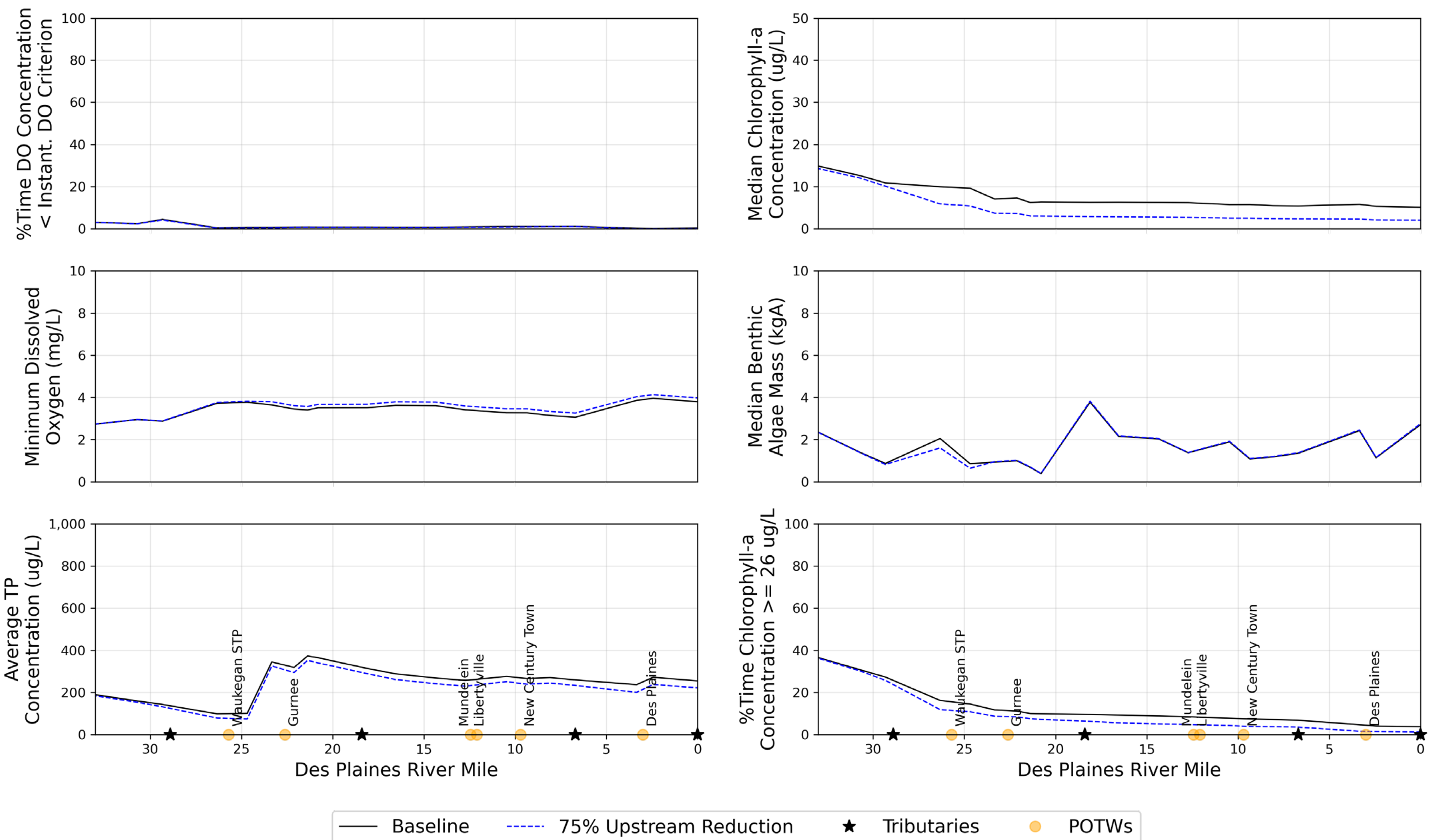

Figure 21: Comparison of Baseline Scenario and Scenario with Upstream Total Phosphorus Reduced by 75% (May 1 to May 31, 2020)

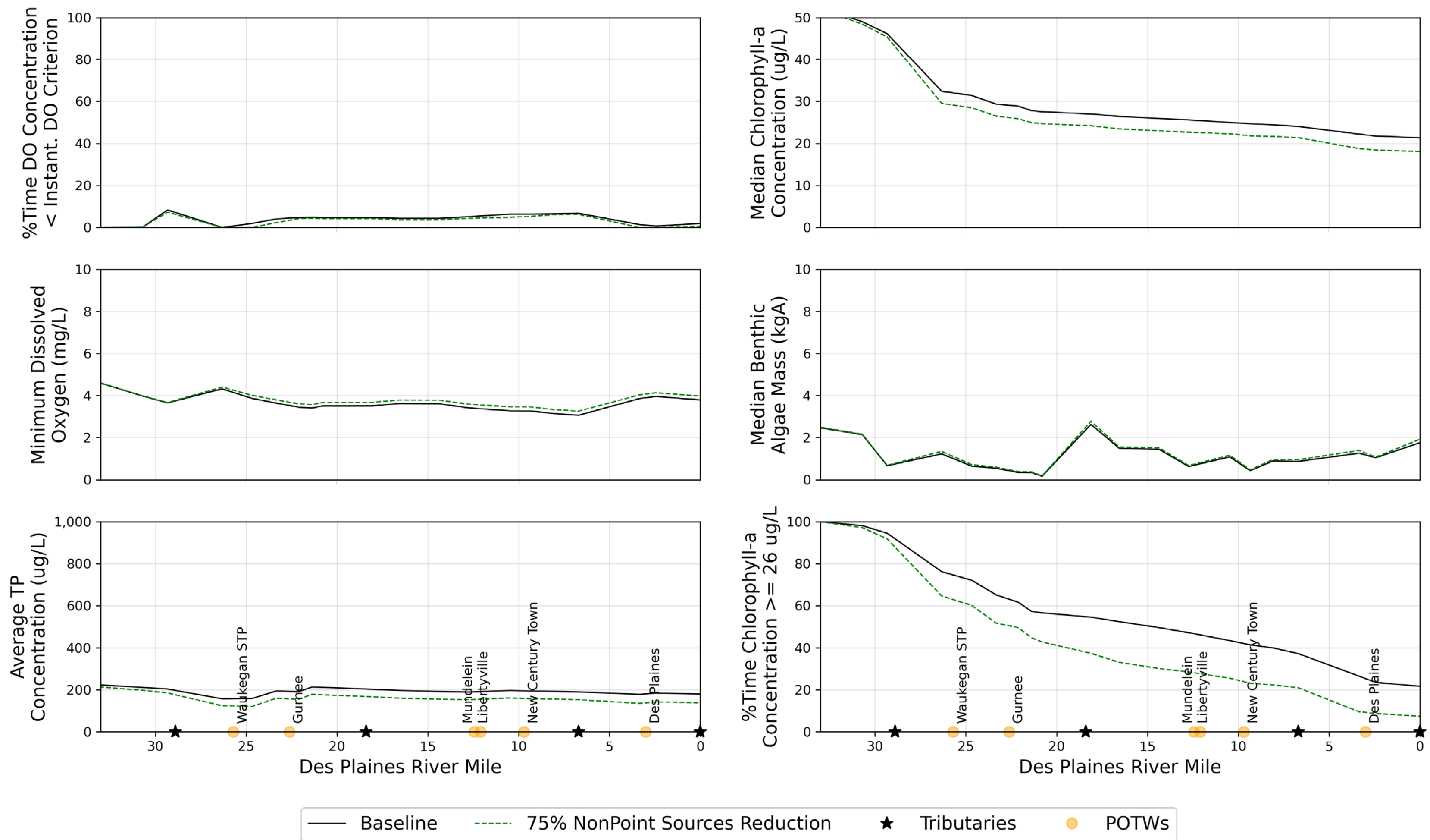

Figure 22: Comparison of Baseline Scenario and Scenario with Nonpoint Sources Total Phosphorus Reduced by 75% (May 1 to May 31, 2020)

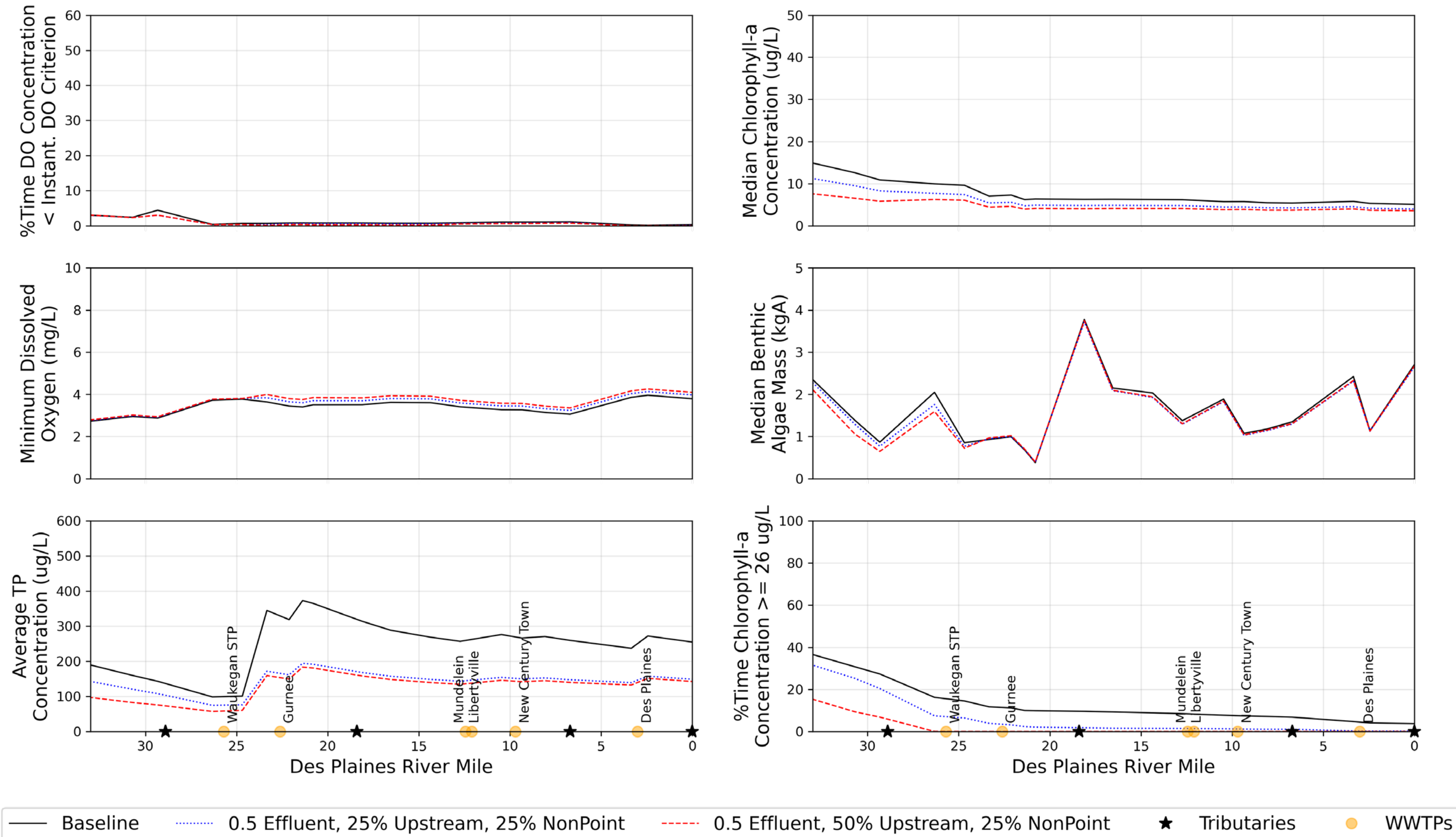

Figure 23: Comparison of Baseline Scenario, Combined Scenario #1, and Combined Scenario #2

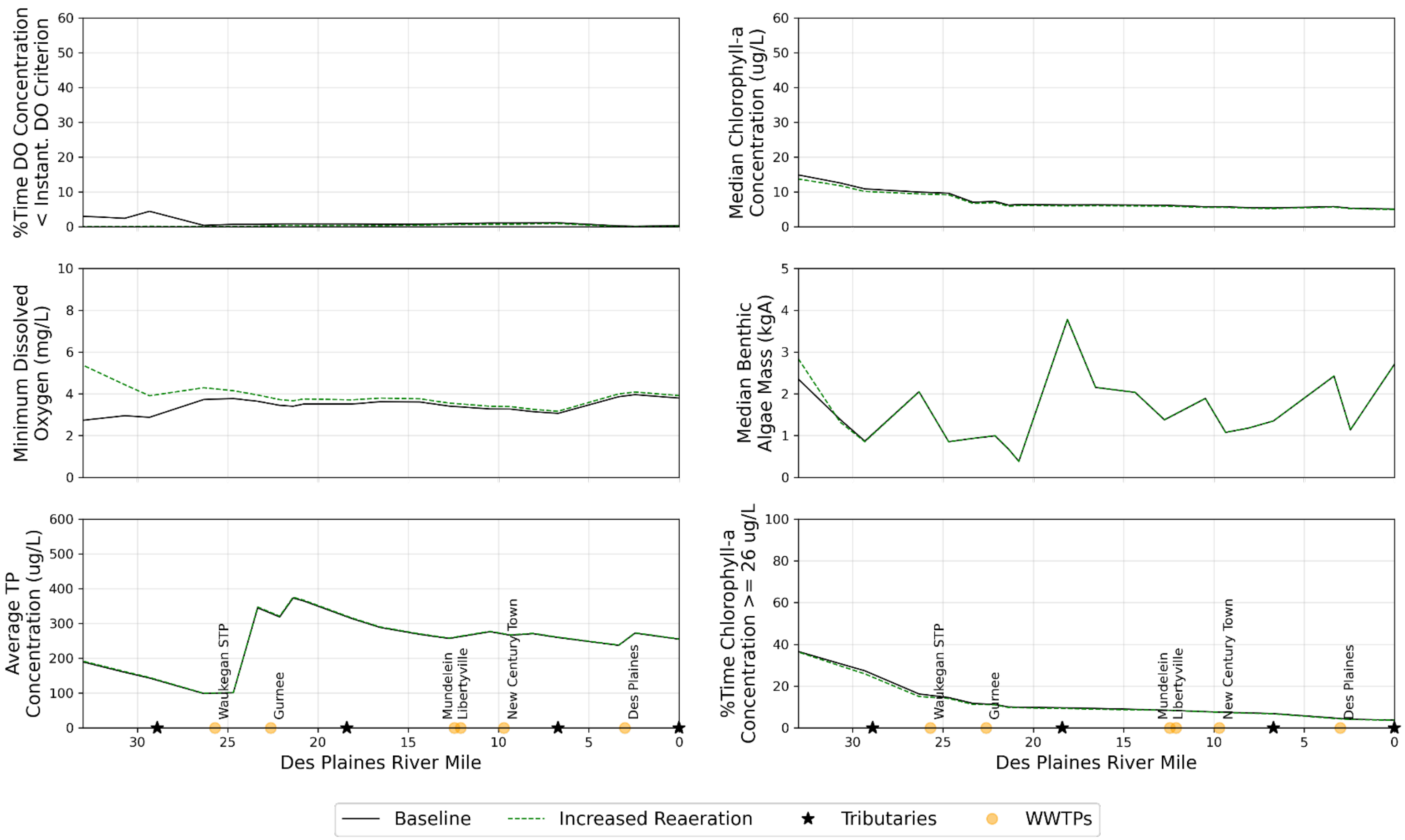

Figure 24: Comparison of Baseline Scenario and Scenario with Increased Reaeration at the Upstream Boundary (May to October 2020)

4. IMPLEMENTATION PLAN AND SCHEDULE

The work completed for the NARP focused on identifying management actions to eliminate DO and nuisance algae impairments. Future work would continue these efforts but may also expand to study other impairments or issues, such as sedimentation and hydromodification. This section presents the recommended management actions for addressing phosphorus-related impairments in the Study Area. Recommended actions fall under the following categories:

1. Administrative actions
2. Actions to address DO and nuisance algae impairments
3. Actions to provide other ancillary benefits
4. Monitoring and modeling studies

The recommended actions include shorter-term actions that can be implemented prior to 2033 and longer-term priorities for implementation after 2033. An implementation schedule with realistic milestones has been developed to allow the DRWW and other watershed stakeholders to pursue and utilize funds from public and private sources more effectively. The pre- and post-2033 recommended actions, along with key stakeholders and potential funding sources, are summarized in **Table 4** and described in detail below.

Table 5: Nutrient Assessment Reduction Plan Recommended Actions

Category	Subcategory	Pre-2033	Post-2033	Key Stakeholders	Potential Funding Sources
Administrative		Evaluate the role of the Des Plaines River Watershed Workgroup (DRWW) in addressing impairments related to the Nutrient Assessment Reduction Plan (NARP)	TBD based on evaluation	DRWW	DRWW, Applicable local, state and federal funding sources'
		Continue DRWW monthly meetings and annual newsletters	Assess meeting frequency	DRWW	DRWW
Actions to address dissolved oxygen (DO) and nuisance algae impairments	Upstream Sources	Engage with the Wisconsin Department of Natural Resources (WDNR) on the development of a total maximum daily load (TMDL) for the Des Plaines River (DPR) and its tributaries in Wisconsin.	Continue to work with WDNR as a key stakeholder, including evaluating the potential for interstate program implementation such as the Regional Conservation Partnership Program (RCPP)	Illinois Environmental Protection Agency (Illinois EPA); DRWW; WDNR	WDNR, Applicable local, state and federal funding sources
	Major Publicly Owned Treatment Works (POTW) Upgrades	Meet a 0.5 milligram-per-liter (mg/L) total phosphorus effluent limit (12-month rolling geometric mean, calculated monthly) or alternate limit by January 1, 2030	Monitor the impact of 0.5 mg/L effluent attainment of mainstem DO swings and algal growth	Major POTWs; Illinois EPA; DRWW	POTW capital budgets; Illinois EPA; State Revolving Fund loans; User rates

Category	Subcategory	Pre-2033	Post-2033	Key Stakeholders	Potential Funding Sources
Actions to provide ancillary benefits	Urban	Consider policy recommendations on numeric total suspended solids (TSS) capture and impervious area percentage restriction per Watershed Based Plan recommendation	Support appropriate policy change in the watershed	DRWW; Lake County SMC; Lake County Technical Advisory Committee (TAC); Local Communities	N/A
		Encourage and distribute educational materials focused on the impacts of phosphorus.	Update and continue	DRWW; Lake County SMC	DRWW
		Encourage/support and distribute educational materials focused on the impacts of hydromodification.			
		Explore/study the potential for nutrient credit or trading program	Update and or implement strategy if feasible and membership supports	DRWW; Illinois EPA; Chicago Metropolitan Agency for Planning (CMAP)	Illinois EPA 604B; CMAP Local Technical Assistance; DRWW
		Look for ways to increase funding program expenditures within the DPR watershed.	Increase expenditures on beneficial stormwater projects as appropriate	DRWW; Local Communities; Lake County SMC; Public Private Partnership (P3) Collaborator	DRWW; Lake County Watershed Management Board (WMB); Lake County SMC; P3

Category	Subcategory	Pre-2033	Post-2033	Key Stakeholders	Potential Funding Sources
Actions to provide ancillary benefits	Urban	In accordance with pending Illinois EPA guidance, review opportunities to enhance current maintenance and monitoring requirements with member communities.	Consider establishing annual maintenance and monitoring reporting from all new developments.	DRWW; Local Communities; Lake County SMC;	DRWW; Local Communities; Lake County SMC
		Review communal practices in relation to seasonal street sweeping and leaf litter pickup.	Encourage a targeted leaf collection program.		
		Continue to promote the retrofitting of stormwater detention facilities consistent with the Watershed-Based Plan (WBP).	Encourage tracking of detention facility retrofits and dead pool storage maintenance.		
		Promote Lake County SMC's "Guide to Maintaining Stormwater Best Management Practices" for homeowners' associations and property owners, including ways to enhance it at the community level.	Continue to promote homeowner association engagement; consider inclusion of homeowner association guidance as part of Special Service Area (SSA) establishment.		

Category	Subcategory	Pre-2033	Post-2033	Key Stakeholders	Potential Funding Sources
Actions to provide ancillary benefits	Agriculture	Explore relationships with the local Natural Resources Conservation Service (NRCS) office and the Lake County Farm Bureau.	Consider engagement with identified agricultural producers	DRWW; NRCS; Illinois Farm Bureau; Lake County Farm Bureau; Local Communities	DRWW NRCS
		Explore opportunities to engage in bi-state agricultural implementation programs like RCPP and Soil and Water Outcomes Fund.			
	Stream & Wetland Restoration	Explore stream restoration opportunities for improving stream reaeration and maintenance of baseflow.	Support stream restoration measures	DRWW; Local Communities; Illinois EPA; Lake County SMC	Section 319 grants, Other applicable local, state and federal funding sources
		Explore wetland restoration projects in consultation with Lake County Forest Preserve District	Support wetland restoration measures	DRWW; Local Communities; Illinois EPA; Lake County SMC	Section 319 grants, Other applicable local, state and federal funding sources
		Explore project opportunities to remove hydraulic impediments to flow on tributaries	Support projects to remove hydrologic impediments to flow on tributaries		
Monitoring and Modeling Studies		Establish a monitoring program for implementation post-2033 to assess the impact of POTW upgrades.	Implement monitoring program	DRWW; Local communities; POTWs	DRWW

Category	Subcategory	Pre-2033	Post-2033	Key Stakeholders	Potential Funding Sources
Monitoring and Modeling Studies		Monitoring to meet the requirements of NPDES permit requirements for POTWs and municipal separate storm sewer systems (MS4s)	Assess data and continue monitoring as needed	DRWW; POTWs; MS4s	DRWW
		Work with watershed partners to develop a watershed-wide tracking program of development and restoration projects.	Use project tracking to evaluate whether loading from site development has outpaced DRWW's ability to implement phosphorus-load-reducing projects.	DRWW; Local communities; Lake County SMC	Lake County SMC; WMB
		Work with the United States Geological Survey (USGS) and other stakeholders to consider establishing a Next Generation Water Observing Station on Des Plaines River at IL-WI border		DRWW; USGS; WDNR; Illinois EPA; Lake County SMC	DRWW; USGS; WDNR; Illinois EPA; Lake County SMC

4.1 Administrative Actions

The DRWW will continue to work on its goal to "*improve water quality in the Des Plaines River and its tributaries through monitoring, project and best practices implementation, and education and outreach that will achieve attainment of water quality standards and designated uses for the watershed*." Key to achieving this goal is the upgrades at the POTWs to achieve the 0.5 mg/L TP effluent limit and for the POTWs to continue to participate in the DRWW. Other actions need to remain voluntary for the DRWW to leverage potential resources outside of the workgroup members. The DRWW will continue to evaluate its role in its implementation of NARP recommendations in 2024 and beyond. Specific action items for the workgroup will be based on that evaluation. The workgroup will continue holding regular meetings to bring watershed stakeholders together. It will also continue to develop annual newsletter and other educational materials.

4.2 Actions for Addressing DO and Nuisance Algae Impairments

The recommended actions for eliminating low DO and nuisance algae impairments in the Study Area include POTW upgrades and upstream load reductions. These are described below.

4.2.1 POTW Upgrades

The POTW load reduction targets of 0.5 mg/L TP are believed to be achievable through a combination of biological phosphorus reduction combined with (in some instances) chemical addition. All DRWW POTWs are in the process of upgrading facilities to meet the 0.5 mg/L TP effluent limits. The technologies being utilized to meet these targets include biological phosphorus removal, chemical (ferric chloride) dosing, and alum treatments. A detailed description of these technologies is included in the phosphorus optimization feasibility reports and the annual progress reports submitted to Illinois EPA by each facility.

SWAT modeling results show that reducing POTW effluent concentrations of TP to 0.5 mg/L by 2033 will reduce annual average loading by more than 50% from the existing average baseline condition (**Figure 16)**. Due to the significance of this reduction, the potential implications of other sources should be evaluated once sufficient data have been collected after 2033. The water quality model simulations indicate that further reductions at the POTW beyond 0.5 mg/L will not provide significant benefits to the mainstem of the Des Plaines River. The stream response based on such significant nutrient reductions could require recalibration with additional data points to sufficiently diagnose the impact or benefit of POTW load reductions.

The NPDES permits for the POTWs required that the facilities meet the monthly average TP effluent limit of 1.0 mg/L by 2022. All POTWs are already meeting this requirement. These POTWs must also meet a 0.5 mg/L effluent limit (12-month rolling geometric mean, calculated monthly) by January 1, 2033. The Lindenhurst Sanitary District STP, New Century Town WRF, and Mill Creek WRF are already meeting the 0.5 mg/L TP limit. A summary of progress made by POTWs in reducing TP is provided in **Table 5.**

Special conditions within NPDES permits for POTW's in the watershed require identifying and providing adequate justification of any exception or circumstance to meeting an effluent limit of 0.5 mg/L TP 12-month rolling geometric mean by January 1, 2030. This justification is required to be submitted to the Illinois EPA at the time of renewal of the permits or by December 31, 2023, whichever date is first. North Shore Water Reclamation District indicated that they've submitted such a report to Illinois EPA on November 30, 2023, for its Waukegan (IL0035092, December 1, 2020) and Gurnee POTWs (IL0035092, December 1, 2020) identifying two exceptions which may apply to their facilities. During a virtual meeting with the DRWW on December 7, 2023, Illinois EPA staff stated that they would review NSWRD and any other submissions for permit renewals, but the NARP may supersede these conditions. Illinois EPA also stated they may be open to a TP limit that is higher than 0.5 mg/L if POTW's were to undertake watershed projects that would reduce the phosphorus loading by a differential amount between the higher limit and 0.5 mg/L TP. POTW's within the watershed may elect to engage with Illinois EPA regarding this approach after the NARP submission.

Table 6: Publicly Owned Treatment Works Upgrade Progress

POTW	Meeting Monthly Average Total Phosphorus (TP) of 1.0 mg/L?	Annual Average TP (mg/L)	Meeting Annual Geometric Mean of 0.5 mg/L TP?	Current Process	Planned Upgrades
North Shore Water Reclamation District (NSWRD) -Waukegan Water Reclamation Facility (WRF)	Y	0.68	N	Biological phosphorus removal (BPR) with some ferric chloride is used to ensure compliance with 1.0 mg/l monthly average limit	More robust chemical system is under construction now with expectation to meet future limits of 0.5 mg/l rolling geomean in 2030.
NSWRD - Gurnee WRF	Y	0.85	N	BPR with some ferric chloride is used to ensure compliance with 1.0 mg/l monthly average limit	More robust chemical system is under construction now with expectation to meet future limits of 0.5 mg/l rolling geomean in 2030.
Lindenhurst Sanitary District Sewage Treatment Plant (STP)	Y	0.479	Y	BPR along with alum for summer months	N/A
New Century Town WRF	Y	0.3	Y	BPR with alum as a back-up treatment when needed	N/A
Mill Creek Water Reclamation Facility (WRF)	Y	0.1	Y	BPR with alum as a back-up treatment when needed	N/A
Des Plaines River STP	Y	0.6	N	BPR with alum as a back-up treatment when needed	N/A
Village of Libertyville STP	Y	0.9	N	Chemical feed system with PAC alum based	Engineering study completed and construction planned for 2028-2029

4.2.2 Upstream Load Reduction

Once the POTWs achieve compliance with the TP effluent limit of 0.5 mg/L, loading from upstream sources (i.e., Wisconsin tributaries) will be the largest contributor of phosphorus to the Study Area. The WDNR is taking the lead in developing a TMDL for the Wisconsin contribution. Upon completion of the modeling effort, the WDNR will undertake an extensive planning process with stakeholder input to help shape TMDL implementation.

DRWW should identify individuals who will remain engaged as the process unfolds. This may include attending meetings (in person or virtual) to provide input. The TMDL process is anticipated to take 2–3 years to complete. The Wisconsin state standard for TP in streams is 0.075 mg/L, but the anticipated timeline to reach compliance with the TMDL would likely take much longer. For this reason, DRWW should continue to engage with WDNR as a downstream recipient. The Des Plaines River corridor has continued to develop in Wisconsin along Interstate 43 in Racine and Kenosha Counties and is expected to continue to grow, even without the rapid growth originally anticipated with the proposed Foxconn facility.

4.2.2.1 Potential Practices

Anticipated practices will likely be a combination of agricultural and stormwater NPS practices; however, implementation will be dictated by the WDNR through the stakeholder meeting engagement process.

4.3 Actions for Providing Other Ancillary Benefits

Other impairments in the Study Area include sedimentation and siltation, habitat degradation, hydromodification, and impacts from other contaminants. Sedimentation, habit degradation, and hydromodification can be addressed by reducing the impact of stormwater runoff and other NPS in agricultural and urban tributary watersheds.

Recommendations for reducing phosphorus loading from agricultural and urban areas are provided below. The Project Team also evaluated the specific project recommendations for stream and wetland restoration and hydraulic impediment removal in the DPR WBP to improve water quality in the Des Plaines River. These recommendations are not meant to specifically address the NARP-related DO and nuisance related impairments but are meant to identify potential, voluntary opportunities for project implementation by stakeholders in the watershed.

4.3.1 Non-Point Source Load Reduction

4.3.1.1 Agricultural

Significant agricultural activity takes place in the upper portion of the Study Area (**Figure 2**). Agriculture is expected to continue to contribute a notable amount of phosphorus to the watershed after 2033. Agricultural runoff might warrant a select group of best management practices (BMPs) more conducive to capturing water in a rural field setting. Engaging agricultural communities in collaborative efforts to reduce NPS pollution is a strategy that has been widely adopted to aid instream water quality improvements. Although attribution and quantification remain challenging, field-level research documents the benefit of implementing in-field, edge-of-field, and structural practices to decrease field runoff.

Farmers make decisions to implement conservation practices based on multiple considerations, including bottom-line cost, land tenure, soil productivity, and peer norms, beliefs, and attitudes. Access to information can also affect how these decisions are made. Programs to increase conservation adoption should consider how all these factors come together to affect land management decisions and associated practices. Financial assistance has traditionally been offered to incentivize farmers to change their work practices or try something new. Recent research suggests that additional tactics that can successfully address NPS agricultural runoff include working in localized, smaller watersheds, aligning cost-share incentives to target the highest contributors, and promoting adoption of conservation systems (e.g., by adopting graduated cost-share rate that supports multi-practice adoption). A targeted and tailored outreach and engagement strategy is equally important.

Potential Practices

Advancements in agriculture, a better understanding of the use of cover crops, and the implementation of no-till farming techniques have been highly successful in reducing agricultural runoff. Other options for edge-of-field practices, such as field borders, saturated buffers, and agricultural runoff treatment systems, exist. However, because much of the remaining farmland in the watershed is leased, there can be resistance to placing any land in long-term easements, considering the potential for conversion to future residential, commercial, or industrial uses.

Lake County still maintains an active United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) office and county farm bureau. DRWW may look for opportunities to coordinate with active farmland owners who have concerns about easements and dedicating land to runoff controls. By working with agricultural agencies, DRWW may consider using creative language to convert “agricultural runoff controls” to “developmental stormwater management controls,” thus assuaging land conversion concerns and preempting resistance to temporary agricultural runoff controls.

4.3.1.2 Urban Sources

Stormwater runoff from urban areas in many member communities will continue to be a source of sediment and nutrients in the watershed. As agricultural areas in the watershed are redeveloped for urban land uses, impervious surfaces become more prevalent. Approaches to urban stormwater management might be better evaluated by distinguishing between new and existing developments.

New Development

Improvements to the Lake County Watershed Development Ordinance (WDO) in 2013 were successful in establishing programmatic controls such as runoff volume reduction requirements and water quality volume requirements for new development. Additionally, improved efforts were made to enhance and encourage communities to better enforce maintenance of stormwater facilities through the recording of easements and maintenance agreements. It is still incumbent on those communities to follow through on inspections and enforcement. If the designed BMPs are not maintained according to the recorded agreement, they provide little value in protecting against water quality degradation.

DRWW was identified as the lead entity for two policy considerations in the DPR WBP (Lake County SMC, 2018) that could provide significant beneficial returns on stormwater water quality in the watershed:

1. Development of standards for TSS: In compliance with Illinois EPA, standards for TSS or other numeric water quality performance standards can be established for new development and redevelopment in the DPR planning area. The State of Wisconsin requires new developments to remove an annual average of 80% of TSS from stormwater. The State of Minnesota utilizes a 75% average annual total phosphorus (TP) load reduction requirement for new development. TSS and TP have a strong relationship due to phosphorus's association with sediment. The Lake County WDO has reference TSS values for 140 water bodies in Lake County, primarily lakes. Similarly, the DRWW could develop a baseline TSS value for the Des Plaines River that could be leveraged in developing a target stormwater runoff threshold.

2. Impervious surface coverage regulations: Increase education and political desire to provide funding and technical analysis for improving local and countywide regulations pertaining to impervious surface stormwater runoff and BMPs. Impervious surface coverage regulations could be considered at appropriate scales (such as parcels or catchments) to reduce runoff volumes for new development or redevelopment. The NRCS curve number method, commonly applied for stormwater design criteria throughout northeastern Illinois and the wider Midwest, assumes a threshold for the percentage of impervious surfaces for development. These percentages are rarely enforced or audited. Additionally, it is common for residential property owners to expand their impervious footprint with yard amenities; there may be a cumulative impact that is generally not tracked at the community level. Offsets for property additions or lot restrictions could help to reduce system volume, which can, in turn, reduce other system inputs and phosphorus load.

Existing Development

The Lake County SMC inventoried 2,303 stormwater detention basins in 2016 as part of the Des Plaines River WBP development process. The purpose of the inventory was to evaluate opportunities for stormwater detention basin retrofits, which could enhance water-quality performance. Enhancements for retrofits typically include nativizing shorelines to reduce bank erosion potential and converting turf or dry basins into wet basins to enhance the capture of particulates. The inventory did not assess the maintenance for facility dead pool storage that would be required to effectively capture the desired sediment and associated nutrients. As dead pool storage is lost and sediment volume increases, aged detention ponds, instead of providing effective capture as originally intended, can become nutrient sources. Lake County SMC recommends the depth contours for stormwater facilities be checked every two years (Lake County SMC, 2002) to ensure the function of the facility remains consistent with the original design intent. Sediment storage availability can be highly dependent on the original design, upstream tributary area, and tributary land use. Lake County SMC also suggests that dredging in an "eventual cost." A lifetime of 15-20 years is very typical.

It is also necessary to maintain the function and storage associated with any on-site BMP practices, which the WDO now requires to be recorded and maintained in a stormwater easement. It is incumbent upon the communities within the watershed to regulate these areas to ensure that they performing as designed.

DRWW can facilitate a process to track the maintenance of stormwater detention basins in the Study Area. This could be an initiative among member communities and a beneficial addition to the MS4 program language. Most backup Special Service Areas and other maintenance improvement requirements are not triggered until an issue develops. Proactive language targeted to address dead pool storage will preserve the capability of sediment and nutrient storage. Suggested improvements include surveying sediment buildup within wet detention facilities on a minimum 10-year basis and maintaining a permanent set dead pool storage volume. The DRWW may wish to investigate a pilot program focused on required maintenance and monitoring to determine the financial implications on a select group of property or business owners.

4.3.2 Stream and Wetland Restoration

Stream restoration, hydraulic impediment removal, and wetland restoration may not necessarily impact nutrient levels in the stream but help to mitigate conditions that promote low DO and nuisance algae impairments. These are briefly described below and discussed in detail in *Appendix C: Project Recommendations*

4.3.2.1 Stream Restoration

Streams sections with low velocities result in low natural reaeration and provide conditions for algae growth due to large travel times. It is recommended to add stream riffles and pools on suitable stream sections to improve natural reaeration and reduce algae growth due to faster velocity. Example stream restoration projects based on stakeholder input and DPR WBP are provided in *Appendix C: Project Recommendations.*

4.3.2.2 Hydraulic Impediment Removal

Impediments such as beaver dams, nonfunctional dams, and blocked culverts can slow down water, which promotes algae and reduces aeration. The removal of these hydrologic impediments would improve DO and reduce algae growth. For example, the North Mill Creek dam impounded Rasmussen Lake, which was listed by Illinois EPA as being impaired for a phosphorus-related impairment due to low DO. Water quality was greatly improved in the stream when the North Mill Creek dam was removed, and the Lake County Forest Preserve District undertook a stream restoration project.

Restored North Mill Creek after Removal of North Mill Creek Dam. Photo Courtesy: Interfluve

4.3.2.3 Wetland Restoration

Wetland restoration adjoining the stream improves the stream's water quality. Wetland restoration can help to maintain stream baseflow, provide waterway shading, promote retention of sediment and other particulates, stabilize shorelines and stream banks, and support nutrient uptake. The Lake County Wetland Restoration and Preservation Plan (WRAPP) identifies and assesses the functional significance of existing and potentially restorable wetlands in Lake County, Illinois (Lake County SMC 2020). The WRAPP identifies several potentially restorable wetlands adjoining the six stream segments listed as impaired for phosphorus. The Lake County Forest Preserve District is currently working with US Armey Corps Engineers on Dutch Gap Canal wetland restoration project over a 785-acre site in the Village of Antioch, Lake County. The development of plans and specifications will begin upon receipt of funding, with the goal of awarding a construction contract in Fiscal Year 2024 (USACE, 2023)

4.3.3 Project Recommendations

A total of 597 projects from DPR WBP were assessed for TP load reduction potential and cost-effectiveness. Of these, 29 projects were identified with a potential phosphorus reduction greater than 50 pounds per year, while eight (8) projects were identified with a potential phosphorus reduction greater than 100 pounds per year.

Field borders, grass waterways, sediment forebays, streambank stabilization, and wetland creation/restoration were the only project categories identified with the potential to provide a potential phosphorus reduction greater than 100 pounds per year. Of these, grass waterways provide the most cost-effective benefit ($65/lb P), while wetland creation/restoration was the least cost-effective ($4,266/lb P).

When looking at projects with the potential to reduce phosphorus loads by 50 pounds per year or greater, there was a more diverse set of project types. Grass waterways, ponds, and stormwater management BMPs (Best Management Practices) are more cost-effective on a per-pound basis than practices such as streambank restoration and wetland creation but typically have smaller impacts. Grass waterways are substantially more efficient than other practices, making up the top four (5) options when analyzing the most efficient qualifying projects. Details on the project are included in *Appendix C: Recommended Projects for the NARP.*

4.4 Monitoring Studies

The DRWW will undertake the following actions to assess the impact of implemented projects for adaptive watershed management:

1. Update monitoring strategy based on the NARP results and recommendations. Implement updated monitoring recommendations.
2. Establish a monitoring program for implementation post-2033 to assess the impact of WWTP plant upgrades. Execute monitoring programs post 2033.
3. Work with watershed partners to develop a watershed-wide tracking program for development and restoration projects.
4. Work with the United States Geological Survey (USGS) and other stakeholders to consider establishing a Next Generation Water Observing Station on Des Plaines River at the IL-WI border.

4.5 Budgeting and Funding

The DRWW currently consists of 30 community, township, and agency members, along with a number of private associate members (DRWW 2023). The potential revenue needed to confront the water quality impairment and reach the goal of use attainment will be best addressed as a group, provided the challenge can be approached from an incremental and adaptable standpoint. Any approach will require an assessment of the financial resources of the group and a means to utilize them in a fiscally responsible way that demonstrates progress based on membership consensus.

Because the amount of effort needed to make measurable progress is not easily assessed, DRWW will be well suited to establish reasonable milestones that are complemented with monitoring. Projects for consideration may also be shared among members to maximize financial resources wherever possible.

Before the amount of money necessary to reach the desired nutrient reductions is determined, it is first necessary to understand whether ongoing improvement projects are providing the necessary beneficial returns needed to improve the baseline phosphorus conditions assessed as part of the NARP. If the impact of new watershed development projects negates the beneficial reduction of phosphorus or phosphorus-related impairments, additional funding will need to be provided by member communities or through the DRWW to offset the increase in loading due to new developments.

4.5.1 Member Fees

The revenue generated by DRWW membership fees for fiscal years 2022 and 2023 was $271,400 and $260,500, respectively. A significant amount of these dues was utilized for the data and NARP development. Once the NARP has been completed, DRWW may choose to modify membership fees based on the DRWW's desired involvement at the implementation level. These fees can be used in several ways based on the workgroup's ultimate approach to project implementation. Member fees can be used, for example, to initiate pilot projects, continue monitoring efforts, or provide matching funds for grants.

4.5.2 Grants

The Study Area is wholly within Lake County, which currently has programs that can assist in water quality improvement projects. The Des Plaines River WBP provides an extensive list of potential grant funding sources; however, the programs listed below in **Table 6** have a proven track record within the region of use and applicability in the watershed. The Lake County SMC grants specifically are a unique opportunity to implement small- to medium-level projects that may not qualify for Section 319 funding. The chance of grant application success is typically improved by having any project preidentified in an appropriate planning document, such as a watershed plan or similar. While Section 604B is typically associated with watershed planning activities, it could be leveraged to ascertain the viability of programmatic avenues for improvement, such as alternative project delivery, credit programs, or trading. CMAP also provides a local unique funding source to evaluate a wide source of topics and supports sustainability objectives in northeastern Illinois.

Table 6: Recommended Grant Programs for Project Implementation

Entity	Program	Typical Award	Due Date
Lake County SMC	Watershed Management Board (WMB) Program Grants	\$5K-\$30K	October
Lake County SMC	Stormwater Infrastructure Repair Program (SIRF)	\$100K	October
Illinois EPA	Section 319 Program	\$200K	August (can vary)
Illinois EPA	Green Infrastructure Grant Opportunity (GIGO)	\$50K+	October
Illinois EPA	Section 604B Program	\$200K+	December
CMAP	Local Technical Assistance Program	\$100K+	February

CMAP: Chicago Metropolitan Agency for Planning
Illinois EPA: Illinois Environmental Protection Agency
SMC: Stormwater Management Commission

4.5.3 Alternative Source Funding

4.5.3.1 Private-Public Partnerships (P3)

Another innovative funding source for programmatic implementation or retrofit of green infrastructure is a public-private partnership (P3). P3s provide an opportunity to leverage private industry to capture scale efficiencies and coordinated maintenance. A P3 is an agreement between one or more public- and private-sector entities to accomplish goals more efficiently than what can be accomplished individually. This involves a private entity developing or maintaining stormwater infrastructure on behalf of public partners. The P3 shares the risk and cost so that no one organization bears the full burden. This cooperation helps to drive innovation and build strong, long-term relationships. For example, the Milwaukee Metropolitan Sewerage District is currently implementing green infrastructure to reduce overflows into Lake Michigan through a P3 program. P3s are an alternative funding option that the DRWW and its members could explore to expand green infrastructure in the Study Area.

4.5.3.2 Water Quality Trading

In 2023, Wisconsin approved the Water Quality Trading Clearinghouse, designed to provide flexibility in trading and better visibility of potential trading partners. While DRWW does not need as diverse a platform to facilitate such activity, dialogue targeted at working across the watershed can help to address phosphorus-related impairments where the return on investments provides the largest benefit. At the moment, this could suggest a simple peer-to-peer system that would enable members to work as partners in implementing in-the-ground projects on available land rather than forcing unmaintainable projects at undesirable locations. To develop such a program, DRWW would likely have to develop a study to assess feasibility and interest.

4.5.3.3 USDA Regional Conservation Partnership Program (RCPP)

Administered by the USDA-NRCS, the Regional Conservation Partnership Program (RCPP) is a competitive program authorized for $1.5 billion under the 2018 federal Farm Bill, plus an additional $4.95 billion through the Inflation Reduction Act. Through RCPP, a group of partners in a specific place combine their resources and capacity to collectively address a natural resource concern, such as water quality. NRCS will coinvest in the local or regional collaborative effort by awarding a federal commitment of at least $1 to $1 over the course of a 5-year agreement. The federal dollars are delivered directly to farmers to cover costs associated with implementing conservation practices or permanently protecting their farmland from development. RCPP award sizes range from $250,000 to $25 million and can be bi-state.

A good example of a successful RCPP is the Milwaukee River Watershed Conservation Partnership (MRWCP). The MRWCP consists of 13 partners, led by the Milwaukee Metropolitan Sewerage District, working in the Milwaukee River Watershed to address water quality and flood control by engaging and paying farmers to implement conservation practices. County land and water conservation department staff and NRCS staff, working with producer-led watershed groups, identify priority projects and help operators implement practices that achieve the needed pollution reduction but are also acceptable from the farm management perspective. Since the first RCPP in 2016, the group has deployed $9.3 million of federal cost-share across the watershed.

A new producer-led watershed group in Kenosha County, Kenosha County Regenerative Producers, would make an excellent partner on an RCPP proposal. This group received a 2023 grant from the Wisconsin Department of Agriculture, Trade, and Consumer Protection, which provides funding to producer-led groups that focus on NPS pollution abatement activities. The Kenosha County group provides peer support and technical assistance to encourage innovative regenerative farming techniques that keep nutrients on the farm.

With a producer-led watershed group already organizing around conservation adoption, there is an excellent opportunity for DRWW to support the effort with supplemental cost-share or additional watershed capacity (or both) through an RCPP proposal. A small group could be assembled to discuss the opportunity and potential; this group might include Mark Jenks, Kenosha County Conservationist, and Kirsten Jurcek with Glacierland Resource Conservation & Development.

4.5.3.4 Wisconsin Wetland Conservation Trust In-Lieu Fee Program

Wetland mitigation funding in Wisconsin can be used to restore and enhance wetlands that provide a water quality benefit. The WDNR's Wisconsin Wetland Conservation Trust (WWCT) program provides grants for wetland restoration and enhancement projects. The WWCT account currently holds $850,000 for use in the Upper Illinois District (which includes Kenosha County) for one or more wetland projects that generate 15 or more credits. The ILF program provides one credit per acre for hydrology and vegetation restoration in effectively drained wetlands and about 0.5 credits per acre for vegetation enhancement in existing wetlands. WWCT dollars can be used for acquisition, restoration, monitoring, and stewardship. The Wetlands and Watersheds Explorer mapping tool identifies multiple areas that have strong wetland restoration potential in the Upper Des Plaines River watershed in Wisconsin.

Potential partners for a project like this would be Seno K/RLT Conservancy, a long-term holder of the land (Stacy Santiago, Executive Director), and RES, a project developer (Erin Delawalla, Project Manager).

RES develops projects focused on nature-based solutions for 404 mitigation, wastewater and stormwater permit compliance, and community resiliency. RES has worked extensively on wetland and stream restoration projects in southeast Wisconsin and northeastern Illinois. RES might have projects already identified to improve DO levels or reduce phosphorus and nitrogen conditions. RES owns and manages the Wisconsin Water Quality Trading Clearinghouse for water quality trading in Wisconsin. NPS activities in the Upper Des Plaines would not be good candidates for the water quality trading program because there is no Wisconsin discharger downstream who could use credits; however, the clearinghouse is a way to identify potential projects because farmers can register a potential project independently. The clearinghouse could be helpful in identifying projects located in the Des Plaines watershed in Wisconsin, which would provide the most cost-effective nutrient reductions for downstream Illinois communities in the Des Plaines watershed.

4.5.3.5 Soil and Water Outcomes Fund

The Soil and Water Outcomes Fund, currently active in Illinois and Wisconsin, could be a source of leverage for any investments DRWW seeks to undertake in those areas. The Outcomes Fund provides a bridge between (1) corporations, government, and utilities interested in seeing quantified environmental uplift and (2) farmers who transition to on-farm conservation practices that yield positive environmental outcomes like water quality improvement. The Outcomes Fund provides financial assistance and new revenue streams for farmers by selling environmental outcomes to public and private beneficiaries to meet regulatory and voluntary sustainability goals. Beneficiaries' resources are often stacked with USDA and other funding sources, including RCPP, to provide cost-competitive environmental outcomes.

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APPENDIX A
Watershed Model

APPENDIX B
Instream Model

APPENDIX C
Project Recommendations