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Melching Water Solutions, LLC

Phosphorus Assessment & Reduction Plan

Prepared for

Metropolitan Water Reclamation District of Greater Chicago

Prepared by

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ACRONYMS AND ABBREVIATIONS

AOC	Areas of Concern
AP	Aquatic Plants
BMP	Best Management Practice
BUI	Beneficial Use Impairment
CARE	Citizens Advisory for the Remediation of the Environment
CAWS	Chicago Area Waterway System
CCD	Chicago City Datum
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMAP	Chicago Metropolitan Agency for Planning
CPR	Chemical Phosphorus Removal
CPVC	chlorinated polyvinyl chloride
CSC	Calumet-Sag Channel
CSO	Combined Sewer Overflow
CSSC	Chicago Sanitary and Ship Canal
CWRP	Calumet Water Reclamation Plant
DO	Dissolved Oxygen
S2EBPR	Sidestream Enhanced Biological Phosphorus Removal
EFDC	Environmental Fluid Dynamics Code
EPA	Environmental Protection Agency
FRP	Fiberglass Reinforced Plastic
GCR	Grand Calumet River
GIGO	Green Infrastructure Grant Opportunities

IDEM	Indiana Department of Environmental Management
IJC	International Joint Commission
IL	Illinois
IWS	Integrated Water Science
LCRN	Little Calumet River North
LTA	Local Technical Assistance
MMSD	Milwaukee Metropolitan Sewerage District
MN	Minnesota
MPCA	Minnesota Pollution Control Agency
MWRD	Metropolitan Water Reclamation District of Greater Chicago
NBCR	North Branch Chicago River
NGWOS	Next Generation Water Observation System
NOC	Nutrient Oversight Committee
NPDES	National Pollutant Discharge Elimination System
NSC	North Shore Channel
PARP	Phosphorus Assessment and Reduction Plan
RAPS	Racine Avenue Pumping Station
RFP	Request for Proposal
SWMM	U.S. Environmental Protection Agency (EPA) Storm Water Management Model
TARP	Tunnel and Reservoir Plan
TN	Total Nitrogen
TP	Total Phosphorus
USACE	United States Geological Survey
USGS	U.S. Geological Survey

WI	Wisconsin
WIFIA	Water Infrastructure Finance and Innovation Act
WMO	Watershed Management Ordinance
WRP	Water Reclamation Plants
WWTP	Wastewater Treatment Plant

1. INTRODUCTION

1.1 Purpose

Metropolitan Water Reclamation District of Greater Chicago (MWRD) owns and operates seven Water Reclamation Plants (WRPs) in the Greater Chicago area. These WRPs treat an average of 1.4 billion gallons of wastewater each day, with a total wastewater treatment capacity of 2.0 billion gallons per day. Four of the seven WRPs (O'Brien, Stickney, Calumet, and Lemont) discharge treated effluent into the Chicago Area Waterway System (CAWS). MWRD developed the Phosphorus Assessment and Reduction Plan (PARP) as part of a negotiated agreement for the National Pollutant Discharge Elimination System (NPDES) permits for three of these WRPs (O'Brien, Stickney, and Calumet).

This PARP is the result of a detailed study to identify possible implementation measures to reduce excess phosphorus levels, potentially resulting in unnatural plant or algal growth in the CAWS. This report presents the study methodology and results, implementation recommendations, and proposed schedule to reduce or eliminate unnatural growth.

The study was conducted by a Project Team in collaboration with MWRD and the Nutrient Oversight Committee (NOC), a multi-stakeholder advisory group. The NOC is comprised of three members: one from MWRD, one from the Illinois Environmental Protection Agency (EPA), and one representing several environmental groups (**Table 1**). The Project Team was led by Geosyntec Consultants Inc. (Geosyntec, **Table 2**). The NOC has been involved in the process from the beginning, reviewing research and data gaps and providing feedback on study findings. The project team has held six formal meetings with the NOC throughout the project.

Table 1: PARP Nutrient Oversight Committee

Representative	Position	Agency
Jennifer Wasik	Assistant Director, Monitoring and Research Department	Metropolitan Water Reclamation District of Greater Chicago
Scott Twait	Manager, Water Quality Standards Section, Bureau of Water	Illinois Environmental Protection Agency
Cindy Skrukrud		Several Environmental Groups[1]

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[1] Environmental groups include Environmental Law & Policy Center, Friends of the Chicago River, Gulf Restoration Network, Natural Resources Defense Council, Prairie Rivers Network, and Sierra Club

Table 2: PARP Project Team

Organization	Role on Consultant Team
Geosyntec Consultants, Inc.	Consultant Team Lead
Melching Water Solutions, LLC	Consultant Team Member
University of Illinois, Urbana-Champaign	Consultant Team Member
Dynamic Solutions International, LLC	Consultant Team Member
Green Metro Planning	Consultant Team Member
Bravo Engineering Company	Consultant Team Member
Metro Strategies Group	Consultant Team Member
Kaletech, LLC	Consultant Team Member

1.2 Study Area

The CAWS consists of approximately 80 miles of urban waterways and channels, 75 percent of which are human-made canals. The remaining 25 percent has been dredged, straightened, widened, and realigned for navigation, flood control, and conveyance of flow from numerous sources. These sources include treated effluent from four of the WRPs previously listed, 240 combined sewer overflows (CSOs), three CSO pumping stations, industrial discharges, and runoff from numerous tributary streams. MWRD controls flow and water levels in the CAWS to provide drainage, prevent discharge into Lake Michigan, facilitate commercial and recreational navigation, and maintain water quality.

The following reaches of the CAWS were included as a part of this study[2] (**Figure 1**):

1. North Shore Channel (NSC)
2. North Branch Chicago River (NBCR) from its confluence with the NSC to its confluence with the South Branch Chicago River
3. Chicago River
4. South Branch Chicago River
5. Bubbly Creek (south fork of the South Branch of the Chicago River)
6. Chicago Sanitary and Ship Canal (CSSC)
7. Calumet River from the O'Brien Lock & Dam to the Grand Calumet River

[2] The segment of the Calumet River from Lake Michigan to the O'Brien Lock & Dam was excluded from the study based on discussion with the NOC as it has not experienced flow reversals in recent years

8. Grand Calumet River from the Indiana state line to its confluence with the Calumet River
9. Little Calumet River from its junction with the Grand Calumet River to the Calumet-Sag Channel (i.e., the Little Calumet River North [LCRN])
10. Calumet-Sag Channel (CSC)

The project team further subdivided the NSC, CSSC, LCRN, and Calumet-Sag Channel for the purpose of assessing unnatural growth as follows:

- **North Shore Channel (NSC):** Upper and Lower NSC separated by the O'Brien WRP
- **Chicago Ship and Sanitary Canal (CSSC):** Upper CSSC (north of the Stickney WRP), Lower CSSC before the junction with the Calumet-Sag Channel (south of the Stickney WRP), Lower CSSC after the junction with the Calumet-Sag Channel
- **Little Calumet River North (LCRN):** Upper and Lower LCRN separated by the Calumet WRP
- **Calumet-Sag Channel**: Upper, Middle, and Lower Calumet-Sag Channel separated by junctions with Mill Creek and Tinley Creek.

The major sources of phosphorus load into the CAWS include the following:

- Four WRPs – O'Brien, Stickney, Calumet, and Lemont
- Upstream areas, which include the North Branch Chicago River and Grand Calumet River watersheds
- Tributary areas which include the Calumet-Sag Channel and Little Calumet River watersheds, which discharge into the CAWS through surface streams or stormwater outfalls
- CSOs

The location of these sources is shown in **Figure 2.**

1.3 Plan Overview

The overall goal of the study was to determine if there is unnatural plant or algal growth in the CAWS due to excess phosphorus[3] and, if so, establish an implementation plan and schedule for measures to eliminate unnatural growth. The study consisted of three primary tasks:

Task 1 – Identify which reaches of the CAWS had unnatural plant or algal growth

Task 2 – Identify the measures needed to eliminate unnatural algal growth

[3] Unnatural plant or algal growth is defined in the District's NPDES permits as recurring diurnal pre-dawn excursions from dissolved oxygen water quality standards, supersaturation in dissolved oxygen levels and chlorophyll-a levels indicating the presence of unnatural plant or algal growth."

Task 3 – Develop an implementation plan for identified measures

Chapter 2 presents the Task 1 findings and methodology for determining where unnatural growth is likely in the CAWS system. Chapter 3 discusses the project team's approach to identifying and evaluating the measures required to eliminate or reduce unnatural plant or algal growth and summarizes key recommendations. The findings from both tasks informed the implementation plan developed as part of Task 3, which is presented in Chapter 4. Finally, Chapter 5 provides recommendations for adaptive management practices for ongoing evaluation and implementation of measures to maintain water quality in the CAWS over the longer term.

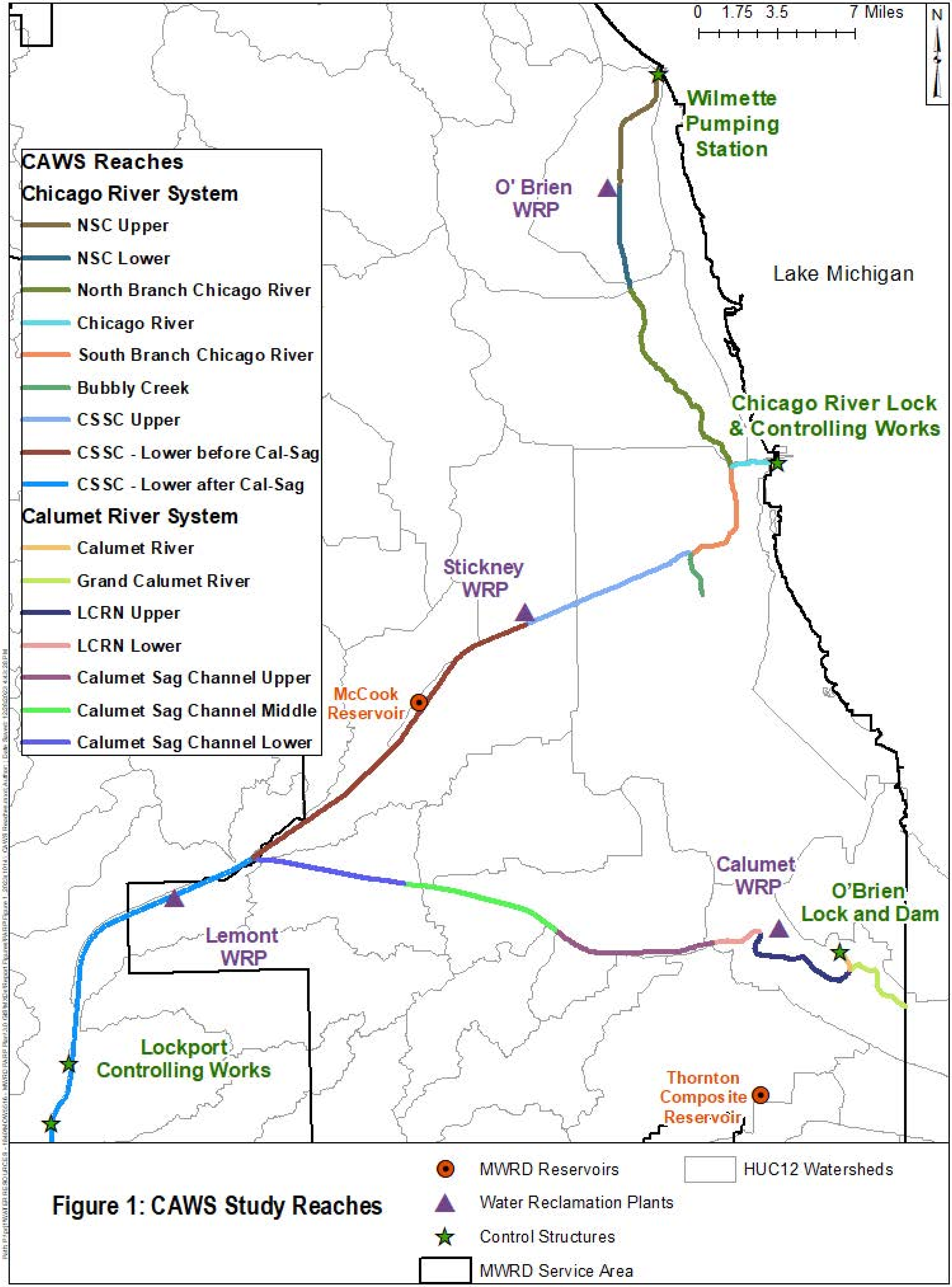

Figure 1: CAWS Study Reaches

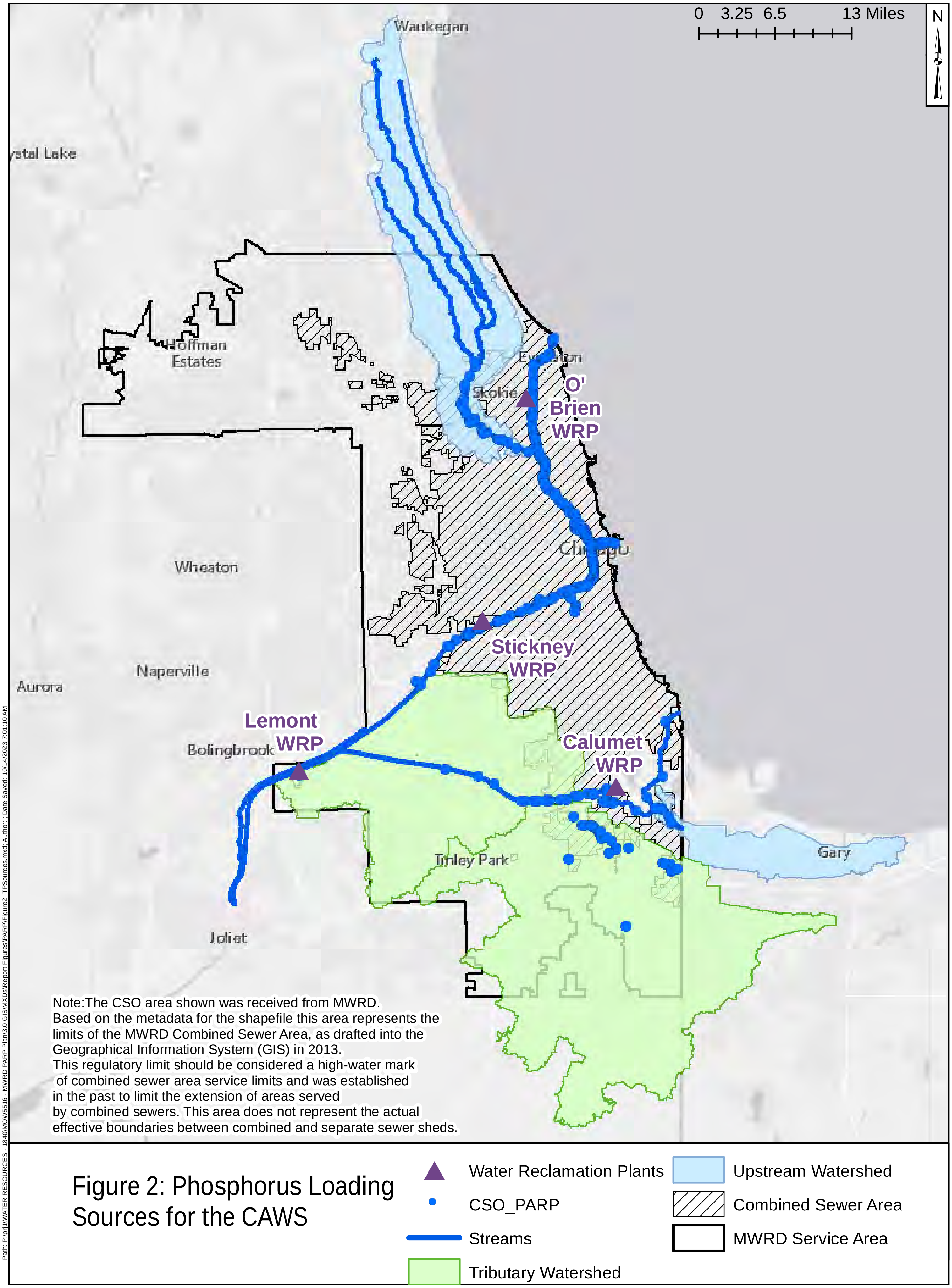

Figure 2: Phosphorus Loading Sources for the CAWS

2. UNNATURAL GROWTH ASSESSMENT

The goal of Task 1 is to determine the CAWS reaches exhibiting unnatural plant or algal growth. The project team reviewed existing water quality data that could indicate the presence of unnatural plant or algal growth. This included evaluating water quality data against several thresholds, including Illinois water quality standards (dissolved oxygen [DO] and pH), parameters included in Illinois EPA's risk of eutrophication criteria (DO, pH, and sestonic algae), and stream metabolism.

2.1 Methodology

Task 1 involved reviewing available water quality data that could indicate the presence of unnatural plant or algal growth. Water quality datasets were obtained from MWRD and Illinois EPA monitoring stations. The time period selected for analysis was March to September based on the higher than typical chlorophyll-a levels historically reported for these months, with the exception of Upper NSC. The project team also reviewed each CAWS reach to select data sets that most closely matched current conditions:

- For the Chicago River system reaches, data from 2018 to 2019 reflected the completion of the McCook Stage I Reservoir in December 2017, which reduced the number of CSOs in the Chicago River System.
- For the reaches in the Calumet River System (Calumet-Sag Channel, Little Calumet River North, and Grand Calumet River), data from 2016 to 2019 reflected the completion of the Thornton Reservoir in December 2015, which reduced the number of CSOs into the Calumet River System.
- For the Grand Calumet River, data from 2017 to 2019 reflected the completion of a major dredging project in January 2017.

The team evaluated data sets utilizing three different approaches or lines of evidence to confirm and determine which reaches of the CAWS experienced unnatural growth:

LINE OF EVIDENCE 1
Data analysis
(pre-dawn excursions from DO water quality standards, DO supersaturation, high chlorophyll-a levels)

LINE OF EVIDENCE 2
Risk of eutrophication criteria

LINE OF EVIDENCE 3
Stream metabolism

The three lines of evidence are briefly described below with the details included in *Appendix A: PARP Task 1 report.*

The first line of evidence, data analysis, evaluated the co-occurrence of pre-dawn DO excursions, supersaturation in DO levels, and high chlorophyll-a levels as the primary indicators for unnatural growth in a reach. The other two lines of evidence, risk of eutrophication criteria and stream metabolism, were utilized to confirm the data analysis findings.

The second line of evidence was adapted from the Illinois EPA's risk of eutrophication assessment framework developed for natural streams, which uses numeric thresholds for chlorophyll-a, pH, and DO saturation to determine if there is a likelihood of unnatural growth. The Illinois EPA risk of eutrophication criteria could not be applied to the CAWS, which is a completely unique system that is impacted by artificial aeration and diversions of cool, high DO water from Lake Michigan. As an alternative, the project team established a chlorophyll-a threshold of 7.5 micrograms per liter (µg/L) for risk of eutrophication specifically for the CAWS, based on the findings from data analysis. This threshold was established to distinguish between reaches with Likely and Unlikely unnatural growth and should not be used as a water quality criterion or otherwise as a threshold for impairment since this level cannot be correlated with detrimental biological or water quality endpoints. For nearly 50 years since the U.S. Environmental Protection Agency published a preliminary analysis of National Eutrophication Survey Data (USEPA, 1974), the generally accepted definition of a eutrophic water body is one with 10 µg/L or more of chlorophyll-a. This conclusion was based on the National Academy of Science and the National Academy of Engineering, 1972. Hence, the 7.5 µg/L threshold represents a near eutrophic condition and provides a safety factor in the current ecological evaluation.

The last line of evidence, stream metabolism, measures gross primary production, ecosystem respiration, and net ecosystem production as key indicators of stream health. The application of stream metabolism requires a number of river conditions to be met. The project team evaluated all reaches for applicability and measured stream metabolism only for those reaches that fully or partially met the conditions.

Based on the findings from all three lines of evidence, each CAWS reach was classified in one of three categories: unnatural growth likely, unnatural growth unlikely, and needs further investigation.

UNNATURAL GROWTH LIKELY
If at least two out of three lines of evidence indicated unnatural growth was likely to occur

UNNATURAL GROWTH UNLIKELY
If at least two out of three lines of evidence indicated unnatural growth was unlikely to occur

NEEDS FURTHER INVESTIGATION
If there was inconsistency between the lines of evidence or sufficient data did not exist for determination of unnatural growth

The project team also developed a supplemental monitoring and sampling plan to address gaps in the data analysis. The team worked with MWRD to develop monitoring recommendations and a field monitoring sheet for documenting visual observations of potential indicators of unnatural growth. MWRD conducted additional monitoring from July to September 2020 and March to September 2021 based on the monitoring recommendations. The additional data were analyzed to determine whether unnatural growth was likely or unlikely for the reaches that required further investigation, as well as to confirm the findings for the remaining reaches. The findings from Task 1 on unnatural algae and aquatic plant growth are summarized below with the details described in *Appendix A: PARP Task 1 report.*

2.2 Algae Unnatural Growth

The final determination for the CAWS reaches experiencing unnatural algae growth are listed below and are shown in the map in **Figure 3**.

Unnatural Growth Likely

- North Shore Channel – Upper
- Bubbly Creek
- Grand Calumet River
- Little Calumet River North – Upper
- Little Calumet River North - Lower
- Calumet Sag Channel- Upper
- Calumet Sag Channel – Middle
- Calumet Sag Channel – Lower
- CSSC-Lower after Cal-Sag Junction to Lemont WRP

Unnatural Growth Unlikely

- North Shore Channel – Lower
- North Branch Chicago River
- Chicago River
- South Branch Chicago River
- CSSC – Upper
- CSSC – Lower before Cal-Sag
- CSSC – Lower after Cal-Sag Junction D/S Lemont WRP

The reaches of the CAWS determined to have unnatural growth are located in the Calumet River System, with the exception of Bubbly Creek and the Upper NSC. Bubbly Creek and Upper NSC were found to exhibit unique conditions based on data analysis, which are described briefly below.

The water quality data in the Upper NSC showed high chlorophyll-a and supersaturated DO during the period of November to April when no water is diverted from Lake Michigan. This phenomenon also occurs in the Upper North Branch Chicago River upstream of the junction with NSC. This seems to indicate that such phenomena may be a naturally occurring thing in the region. In consultation with the NOC, it was determined that the level of effort to fully identify the causes of phenomenon will require additional study outside of the PARP scope.

The water quality in Bubbly Creek is impacted by the nutrient fluxes from the historically contaminated sediment bed and CSO discharges from the Racine Avenue Pumping Station. The reported chlorophyll-a concentrations in Bubbly Creek range from 3.8 to 109 µg/L from 2016 to 2019, which were considerably higher than the other CAWS reaches. The DO in Bubbly Creek dropped to zero during CSO discharges from the Racine Avenue Pumping Station. In addition, very high diurnal swings occurred during periods with no CSO discharge. Similar to Upper NSC, it was determined in consultation with the NOC that additional investigations are warranted for Bubbly Creek. The recommendations for additional studies for the Upper NSC and Bubbly Creek, are discussed in Chapter 4. As a result, identifying and evaluating potential measures to eliminate unnatural growth as a part of the PARP study focused on the Calumet River System.

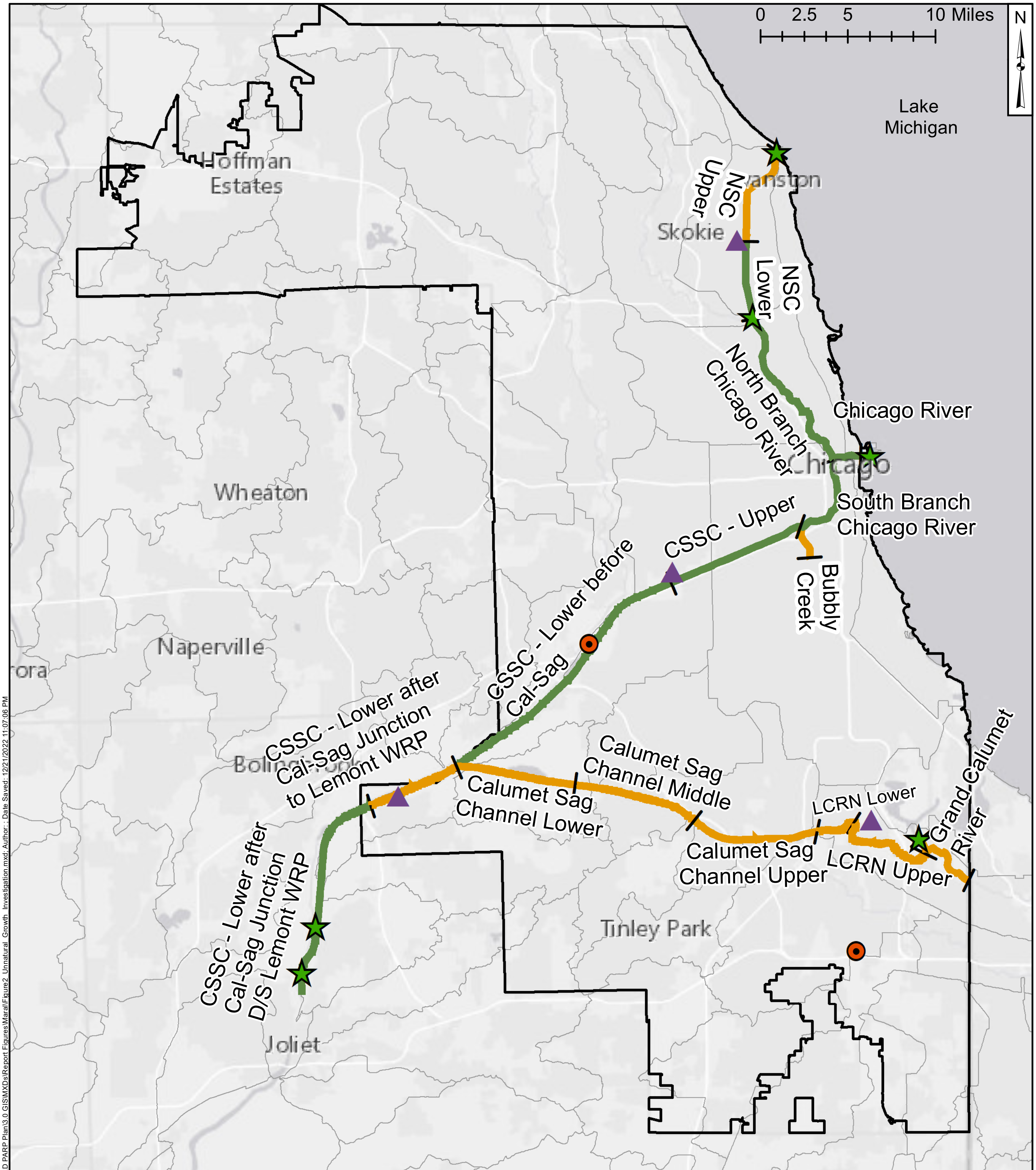

Figure 3: Algal Unnatural Growth Assessment

MWRD Reservoirs

Water Reclamation Plants

Control Structures

Unnatural Growth Assessment

Unnatural Growth Likely

Unnatural Growth Unlikely

2.3 Unnatural Aquatic Plant Growth

The presence of aquatic plants in the CAWS were assessed using field observations. These field observations were conducted to determine if the measured diurnal DO variations could have been partially caused by aquatic plants or were solely related to algae represented by the high chlorophyll-a measured in the Calumet River System.

Geosyntec worked with MWRD to develop a field form to document aquatic plant (AP) coverage. This form was used by MWRD field staff to document unnatural plant growth in the CAWS for several stations in 2020 and 2021. **Table 3** summarizes aquatic plant coverage reported for reaches in the Calumet River System. The field observations indicate that there is limited aquatic plant coverage in the Calumet River System except for the Grand Calumet River. An emergent plant coverage of 15 percent was reported for only one observation on the Calumet-Sag Channel at 104th Street. The remaining 13 observations reported no coverage of emergent APs at the same location. Based on these data it was concluded that aquatic plants have a very limited impact on the CAWS water quality.

Table 3: Observations of Aquatic Plant Coverage in the Calumet River System made by MWRD Field Staff in 2021.

MWRD Station ID	Station Name	Number of observations	Maximum reported percentage coverage of		
			Submergent Aquatic Plant[1]	Emergent Aquatic Plant[2]	Floating Aquatic Plant[3]
55	Calumet River at 130th Street	14	10	0	0
122	Grand Calumet River at Columbia Avenue	14	25	25	20
86	Grand Calumet River at Burnham Avenue	20	30	25	40
121	Grand Calumet River at Torrence Avenue	14	50	10	25
56	Little Calumet River at Indiana Avenue	1	0	0	0
76	Little Calumet River at Halsted Avenue	1	0	5	0
59	Cal Sag Channel at Cicero Avenue	1	0	0	0
119	Cal Sag Channel River Mile 311.7	14	0	5	5
118	Cal Sag Channel at 104th Street	14	0	15	5
120	Cal Sag Channel at Southwest Highway	14	0	5	5
43	Cal-Sag Channel at Route #83	1	0	0	0
42	CSSC at Route #83 Bridge	14	0	5	0
116	CSSC at River Mile 302.6	14	0	0	0
117	CSSC at Romeoville Road	14	0	0	0

[1] Plants that grow entirely under the water surface
[2] Plants that grow in water, but part of plant remains above the water surface
[3] Plants that have roots attached to river bottom and leaving floating on water surface

3. MEASURES TO ADDRESS UNNATURAL GROWTH

Task 2 of the PARP involved identifying measures to address unnatural growth in the Calumet River System reaches. The project team first developed an integrated model to determine existing conditions and evaluate various scenarios that could result in reducing unnatural algal growth and phosphorus levels.

3.1 Modeling Tool Development

Models can serve to define the linkages between phosphorus loading in the watershed and related impairments such as DO and nuisance algae in the CAWS. Models can also be used to evaluate the effectiveness of different watershed management scenarios in reducing or removing impairments. Models help to identify appropriate measures for load reductions and results can be used to prioritize projects for implementation.

Measured data and models were used to quantify the loading from different sources and assess impacts on water quality in the CAWS. The project team developed an integrated modeling framework (**Figure 4**) to simulate phosphorus loading from different sources and its impacts on water quality in the CAWS. The framework consists of the CAWS instream model with inputs from additional models and measured data, specifically:

1. Watershed model to quantify the tributary flow and concentrations
2. CSO model to calculate CSO flows into the CAWS
3. Measured data to estimate upstream loading, WRP loading, and CSO concentrations

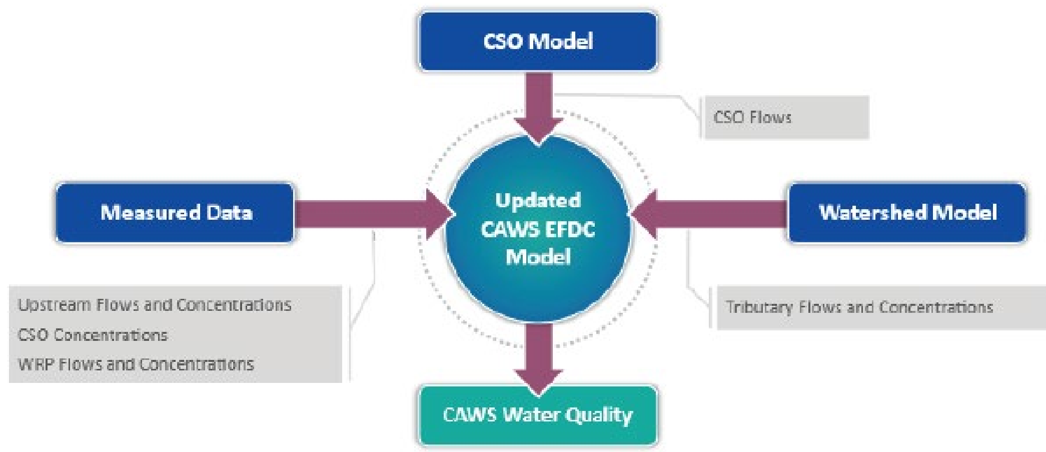

Figure 4: Modeling Framework Developed for the Phosphorus Assessment Reduction Plan (PARP) Study

3.1.1 Watershed Model

The Little Calumet River and Calumet-Sag Channel reaches of the CAWS receive minimal CSO discharges after the completion of the Thornton Reservoir in late 2015. For these reaches, stormwater runoff is a significant source of nutrient loading, in addition to loading from the Calumet WRP. The lack of a continuous nutrient monitoring program for the tributaries requires watershed modeling to fill in temporal and spatial gaps in nutrient loading estimates.

The project team developed a watershed model using the U.S. Environmental Protection Agency (EPA) Storm Water Management Model (SWMM) platform. Inputs for the watershed model included meteorological, land use, topography, soil, imperviousness, conveyance system, CSO, and Thornton Creek Basin Sanitary District wastewater treatment plant (WWTP) data. The model was calibrated to match flow data measured by the U.S. Geological Survey (USGS) and water quality data measured by the Illinois EPA and MWRD.

The watershed model was used to simulate series of flow and pollutant loads for total nitrogen (TN) and total phosphorus (TP) from the Little Calumet River and Calumet-Sag Channel watersheds. The details of the watershed modeling are described in Section 3 of *Appendix B: Task 2A report*.

3.1.2 Combined Sewer Overflow Model

The completion of the Thornton Composite Reservoir in 2015 and the McCook Stage I Reservoir in 2017 resulted in a significant reduction in CSOs in the Calumet River and Lower Chicago River systems. An existing hydrologic and hydraulic model of the combined sewer system was updated to simulate CSO flows into the Chicago River System reaches served by the Mainstream Branch of MWRD’s Tunnel and Reservoir Plan (TARP) system. The CSO model is an integrated TARP model comprised of two separate original InfoWorks models: the Chicago Trunk Sewer Model and the Connecting Structure Mainstream & Des Plaines Tunnel (CS-TARP) model.

The CSO model was updated to represent current conditions and included updates to the hydraulic model components, precipitation data, and boundary conditions. The details of the CSO model are described in Section 4 of *Appendix B: Task 2A report*.

3.1.3 CAWS Model

The CAWS model was developed to simulate the impacts of nutrient loading from various sources based on inputs from the watershed model, CSO model, and measured data. The project team leveraged the Environmental Fluid Dynamics Code (EFDC) Plus (EFDC+) modeling framework (DSI 2020) to develop the CAWS model, building upon the previous modeling efforts by the University of Illinois at Urbana-Champaign (Zhu et al., 2016, 2017; Sinha et al., 2012, 2013; Quijano et al., 2017) and Marquette University (Shrestha & Melching, 2003; Alp & Melching, 2006) for MWRD. The CAWS model uses inputs of bathymetry, flow and water quality boundary conditions, and hydraulic structure operations to simulate changes in the hydrodynamics (flow, velocity, water surface elevation, and temperature) and water quality (nutrients, chlorophyll-a, and DO).

The CAWS model was calibrated and verified to available measured data for water surface elevation, flow, temperature, nutrients, chlorophyll-a, and DO for the periods of January to September 2020 and January to September 2021, respectively. The calibration and verification results show that the model is capable of simulating DO concentrations reasonably well. The calibrated model predictions for water surface elevation, flow, temperature, total phosphorus, ammonia, nitrite and nitrate, total organic carbon, and chlorophyll-a also are reasonably close to the measured data. The CAWS model development is described in Section 5 of the Task 2A report.

3.1.4 Modeling Results and Discussion

The data collection and modeling provided important insights into the hydrodynamics and water quality in the CAWS, which are briefly discussed below.

Total Phosphorus Loading Distribution

The results of the watershed and CSO models and measured data were used to quantify the phosphorus loading from different sources into the CAWS reaches. **Figure 5** shows the distribution of loading into the Calumet River System for the periods of March to September 2020 and March to September 2021, where March to September denotes the growing season. The Calumet WRP constitutes more than 80 percent of the TP loading into the Calumet River System during the growing season. The loading from the Little Calumet River and Cal-Sag Channel tributaries constitutes about 16 to 17 percent of total TP loading into the Calumet River System. The upstream watershed of the Grand Calumet River contributes approximately three to four percent of total TP loading to the Calumet River System.

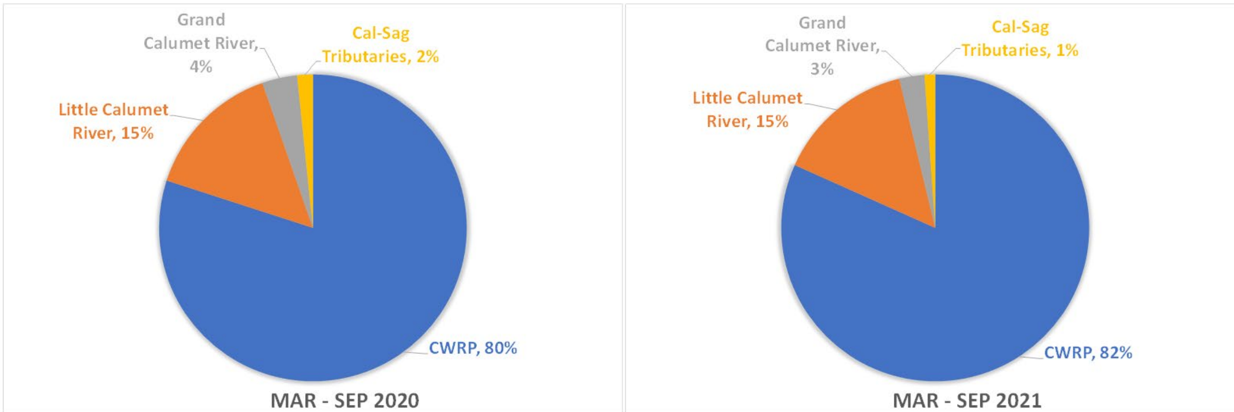

Figure 5: Pie Chart Showing Relative Contribution of Total Phosphorus to the CAWS During the Growing Season of March to September 2020 (note: CWRP denotes the Calumet Water Reclamation Plant)

Bi-directional Nature of Flows

In most river systems, water reclamation plant effluent moves downstream and has no effect on the water quality and aquatic ecosystem upstream of the effluent outfall. Thus, if the CAWS were like most river systems, the North Shore Channel Upper, Little Calumet River North Upper, and CSSC Upper would be unaffected by effluent from the O'Brien, Calumet, and Stickney WRPs, respectively. However, because of the low gradients in the bathymetry and water surface elevation, the large discharge rates from the WRPs into the CAWS can sometimes raise the water surface elevation or the hydraulic head locally, causing the energy head at a WRP discharge location (outfall) to be higher than the energy head upstream of the discharge outfall. As a result of the locally elevated energy head during periods of large discharges from the WRPs, there is bidirectional flow in the CAWS near the WRP outfall location. Thus, particularly during periods when no discretionary diversion is taken at the Wilmette Pumping Station or the O'Brien Lock and Dam, water quality and the aquatic ecosystem in the Upper NSC or LCRN Upper can be affected by discharge from the O'Brien or Calumet WRPs, respectively.

The CAWS EFDC+ model simulates the bidirectional flow near the WRP outfalls during periods of no discretionary diversion from Lake Michigan. The model results show that flow reversal near the Calumet WRP discharge for water year 2020 and 2021 does not extend much upstream. Hence, this flow reversal is not anticipated to impact algae growth in the Little Calumet River North Upper (upstream of Calumet WRP). This phenomenon is described in more detail in *Section 6.1 of Appendix B: Task 2A report*

Limiting Factors for Algae Growth

The model results were analyzed to assess the limiting factor for unnatural growth in the CAWS. A detailed description of algae limiting factors in the model is provided in Section 6.2 of the Appendix B: Task 2A report (Appendix B).

The modeling results showed that algal growth in the CAWS was limited by the availability of light for more than 90 percent of the simulation time under the existing conditions. Phosphorus was not a limiting factor in the CAWS reaches under the existing conditions. Reducing the TP concentration in the Calumet WRP to 0.5 mg/L would result in phosphorus becoming a limiting factor for algae growth for less than three percent of the time. These results indicate that algal growth in the CAWS is limited by light since nutrients are generally available in abundance even with the substantial reduction in effluent TP to 0.5 mg/L. The model results match the field studies done by Wasik et al. (2008) in which the effluent TP concentration at MWRD's John E. Egan WRP was reduced to 0.5 mg/L to study the stream responses.

Impact of Grand Calumet Algae Input

The Grand Calumet River from Indiana contributes approximately three to four percent of the total TP loading to the Calumet River System. However, the Grand Calumet River is the only upstream boundary providing a high concentration of chlorophyll-a levels into the CAWS. **Figure 6** shows the measured chlorophyll-a levels in the Grand Calumet River near the Illinois-Indiana border. MWRD also documented more than 50 percent aquatic plant coverage in the river at this location, which is shown in **Figure 7**. The modeling results showed that simulated algae concentrations in Calumet River System are very sensitive to the chlorophyll-a input from the Grand Calumet River.

An independent modeling study conducted by UIUC showed that high Lake Michigan water levels between 1.5 ft and 5.0 ft, Chicago City Datum (CCD) will cause the discharges from Hammond Sanitary District, East Chicago Sanitary District and Gary Sanitary District to flow the CAWS through the Grand Calumet River (Wang et. al 2021). This phenomenon occurred during 2020 when the measured Lake Michigan water levels were between +3 ft and + 4 ft CCD (Wang et al., 2022).

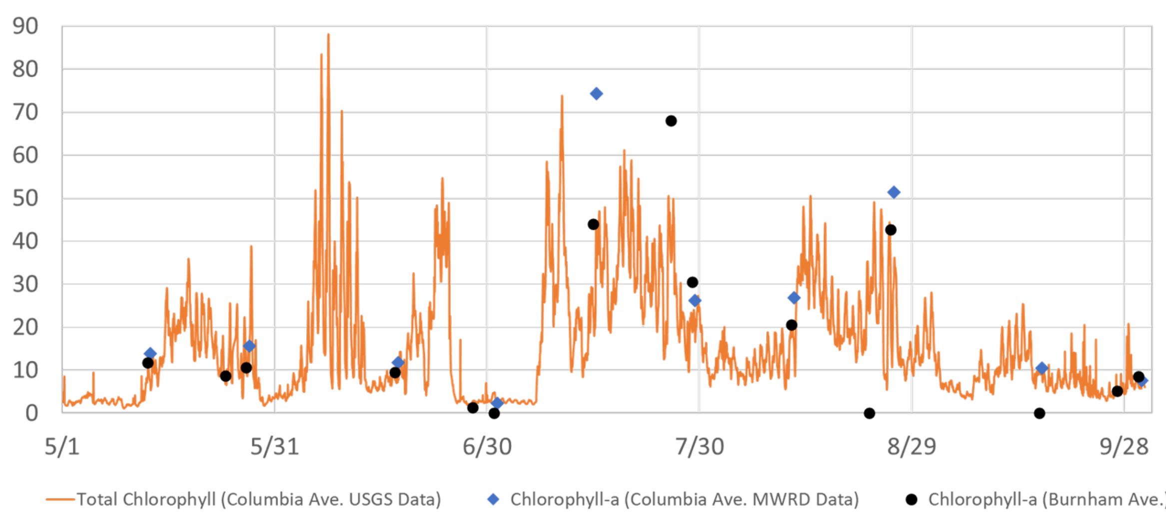

Figure 6: Measured Chlorophyll in the Grand Calumet River near the Illinois-Indiana Border in 2021

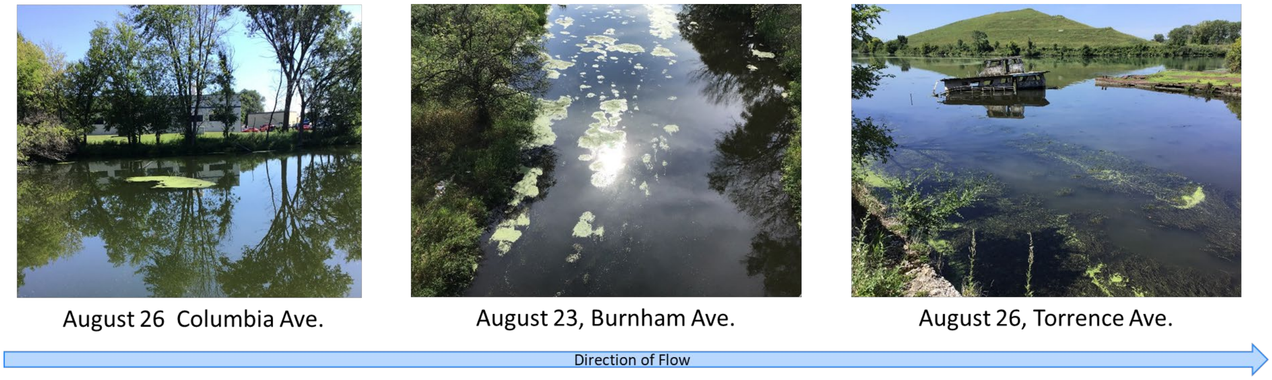

Figure 7: Visual documentation of the unnatural growth in Grand Calumet River in August 2021

3.2 Management Actions

The model was used to evaluate possible management actions to address unnatural algal growth in the Calumet River System. Existing conditions scenarios were simulated using the calibrated model for March to September 2020 and March to September 2021 to quantify the impact of phosphorus loads from different sources on CAWS water quality.

Various management actions were then modeled to evaluate the impact on existing conditions and the effectiveness of different strategies to reduce phosphorus levels. These scenarios focused on TP load reductions from the Calumet WRP, stormwater runoff, and upstream watersheds, and a combination of these strategies. The simulated model scenarios are summarized in **Table 4**. The effectiveness of watershed management strategies was then evaluated by comparing simulated timeseries of TP, chlorophyll-a, and DO with the results of the existing conditions scenarios at key locations in the Calumet River System.

Table 4: Modeled Management Action Scenarios

Scenario	Description
Calumet Water Reclamation Plant (WRP) Total Phosphorus (TP) Reduction	Maximum effluent TP concentration capped at 1 mg/L, 0.5 mg/L, 0.3 mg/L, and 0.1 mg/L respectively
Tributary TP Load Reduction	Load reductions of 25 percent
Upstream TP and Chlorophyll-a Reduction	Load reductions of 50 percent
Thorn Creek Basin Sanitary District Sewage Treatment Plant TP Reduction	Maximum effluent TP concentration capped at 0.5 mg/L
Combined Scenario – Calumet WRP TP Reduction plus Upstream Load Reduction	WRP maximum effluent TP concentration capped at 0.5 mg/L Load reductions of 50 percent for TP and Chl-a

3.3 Evaluation of Management Actions

The CAWS model was used to evaluate the foregoing scenarios including the combined scenario. The key findings are summarized below and described in detail in *Appendix C: Task 2B report.*

Key Finding 1: Reduction of Calumet TP has limited impact on unnatural algal growth (pre-dawn DO excursions, DO oversaturation, and chlorophyll-a levels)

The daily TP concentrations for the Calumet WRP in the existing conditions scenario ranged from 1.4 to 5.9 milligrams per liter (mg/L) for 2020 and 1.2 to 8.9 mg/L for 2021 The impact of reducing these concentrations on the CAWS instream water quality was simulated by running model scenarios with the Calumet WRP maximum effluent TP concentration capped at one to 0.1 mg/L.

Modeling results for the existing conditions scenario (orange solid) and scenarios with maximum Calumet WRP TP concentrations set to 1 mg/L (blue dashed), 0.5 mg/L (grey dashed), 0.3 mg/L (green dashed), and 0.1 mg/L (yellow dashed) in the Calumet-Sag Channel at Route 83 are shown in **Figure 8** to **Figure 10**. Reductions in the Calumet WRP effluent TP concentrations significantly reduce instream TP as shown in **Figure 8**. However, the reduction in Calumet WRP TP has an insignificant impact on the simulated instream chlorophyll-a and DO **(Figure 9 and Figure 10 ,** respectively). This is because the relatively high chlorophyll-a concentration (and consequently pre-dawn DO excursions and DO supersaturation) in the Calumet River System is driven by chlorophyll-a loading from the Grand Calumet River and Little Calumet River South.

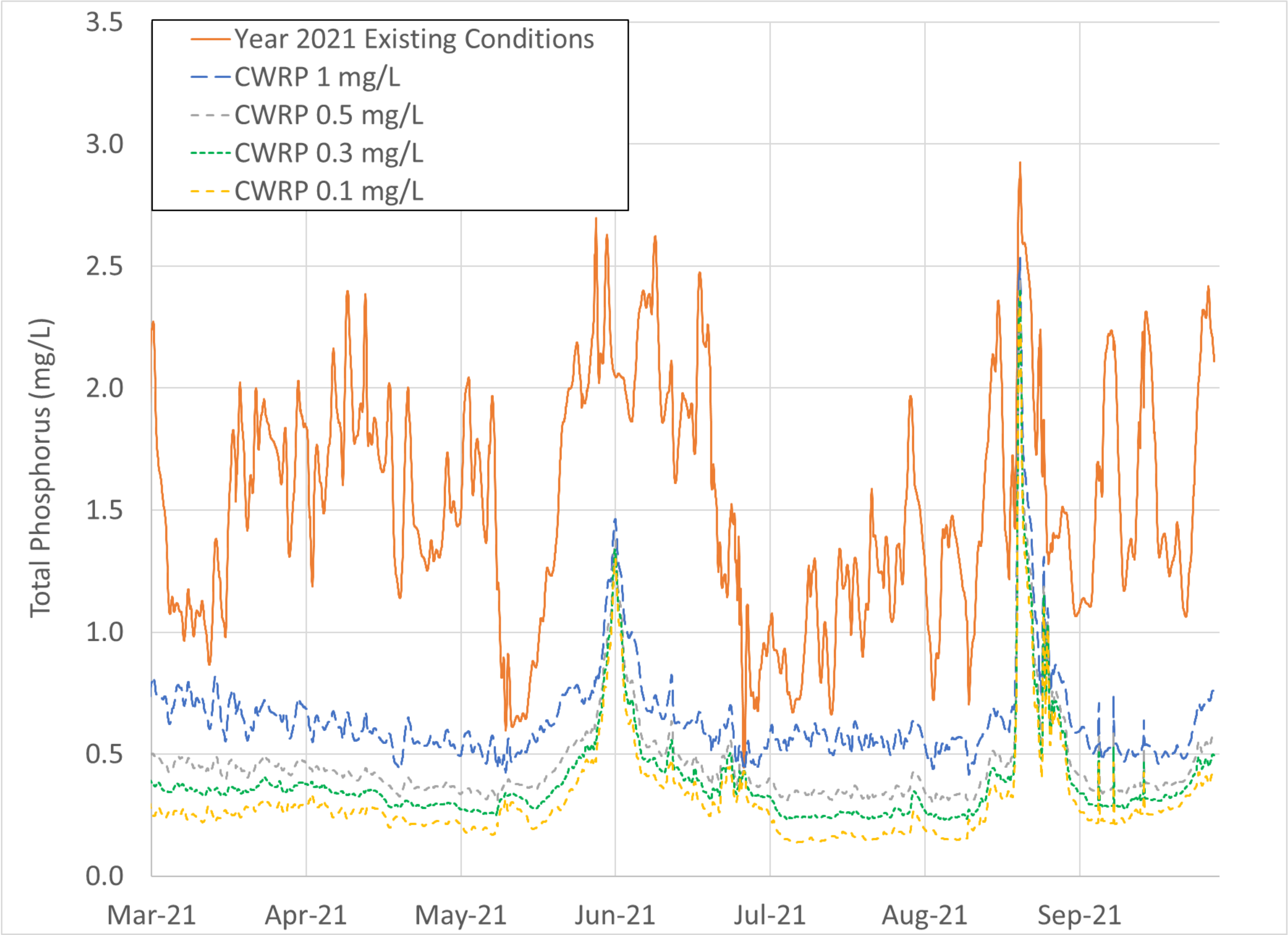

Figure 8: Comparison of Simulated Total Phosphorus in the Calumet Sag Channel at Route 83 for the Existing Condition Scenario (orange solid) and Scenarios with Calumet Water Reclamation Plant Effluent Discharge at 1.0 (blue dashed), 0.5 (gray dashed), 0.3 (green dashed), and 0.1 (yellow dashed) mg/L Total Phosphorus

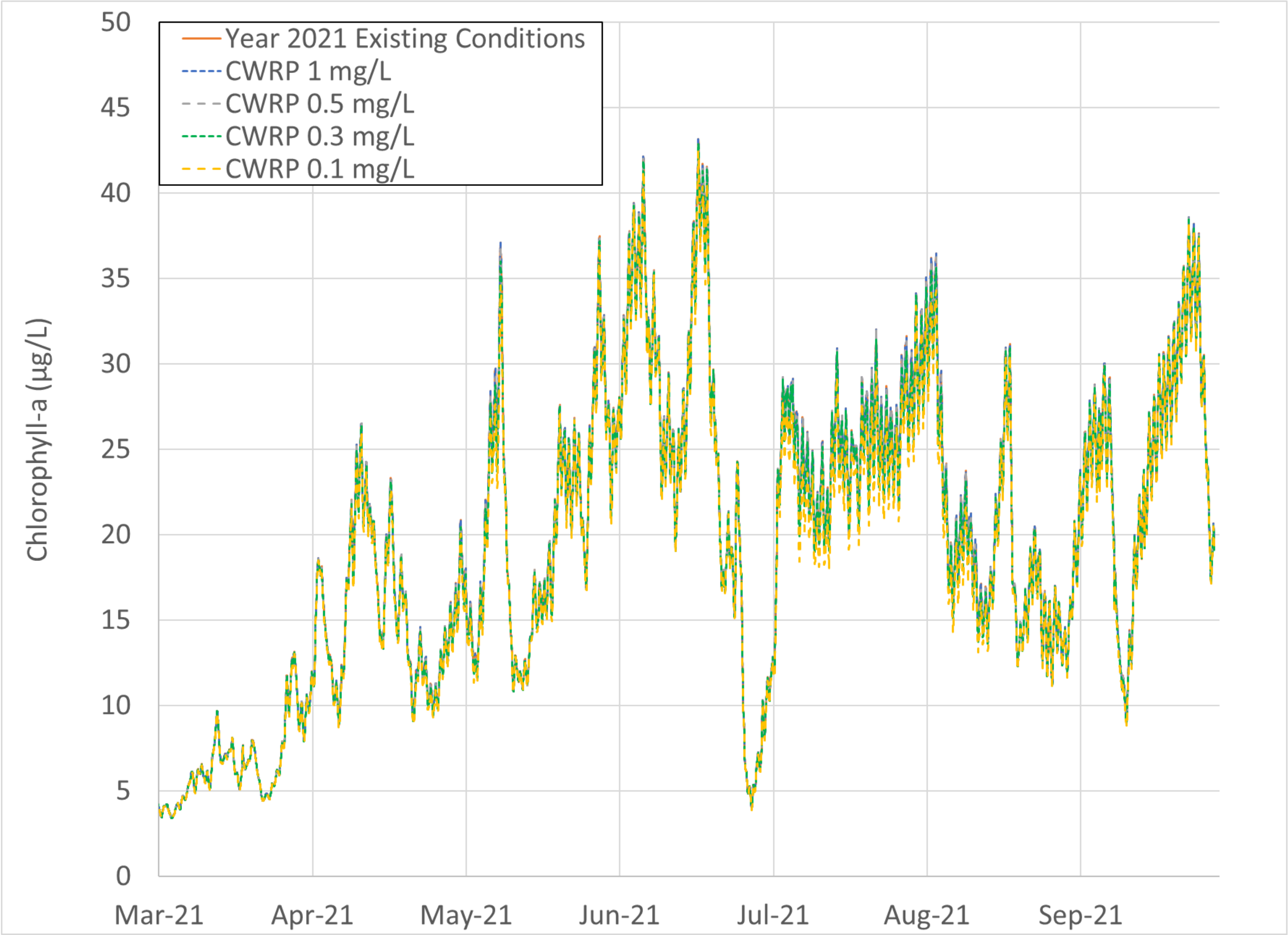

Figure 9: Comparison of Simulated Chlorophyll-a in the Calumet-Sag Channel at Route 83 for the for the Existing Condition Scenario (orange solid) and Scenarios with Calumet Water Reclamation Plant Effluent Discharge at 1.0 (blue dashed), 0.5 (grey dashed), 0.3 (green dashed), and 0.1 (yellow dashed) mg/L Total Phosphorus

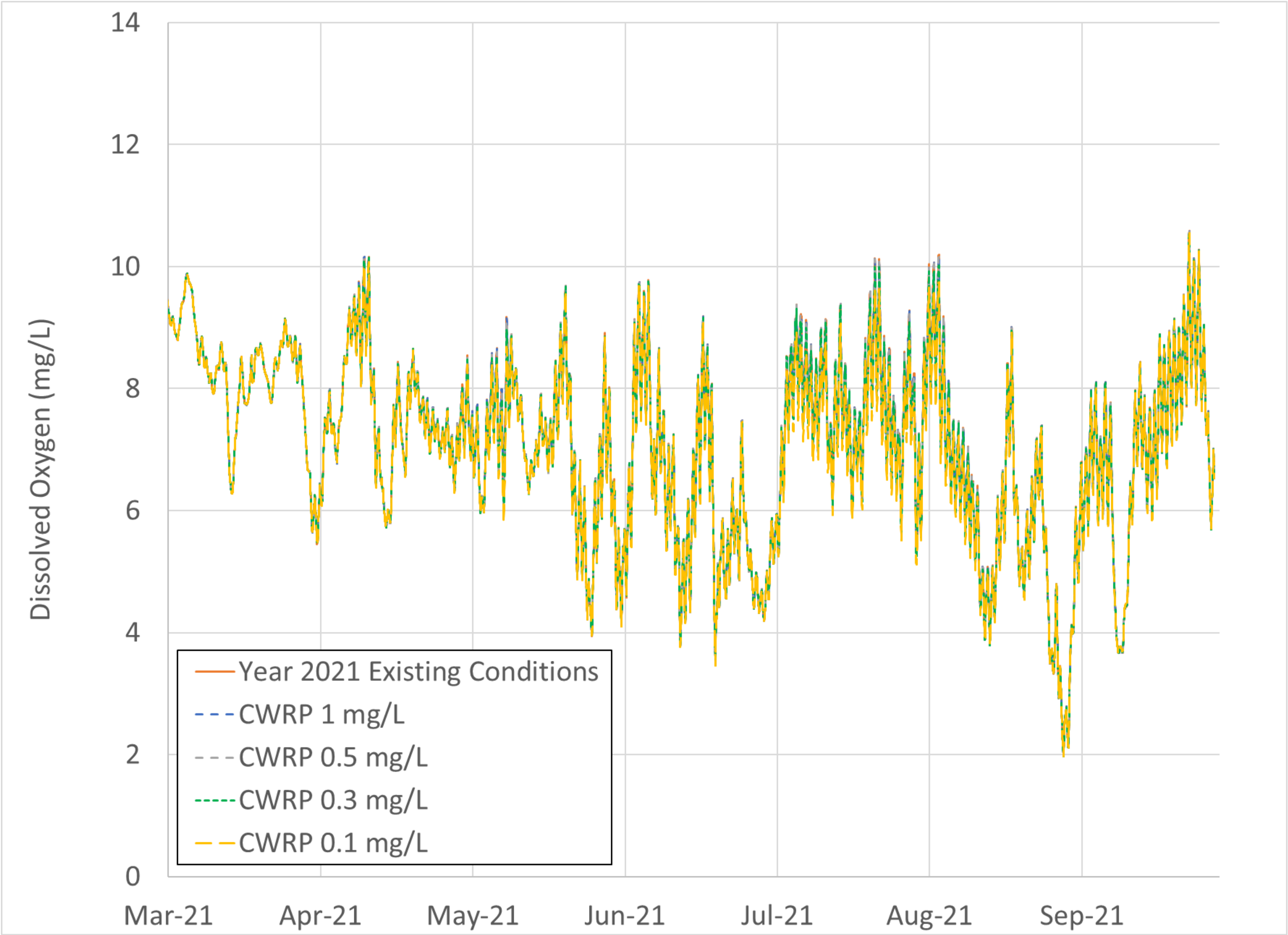

Figure 10: Comparison of Simulated Dissolved Oxygen in the Calumet-Sag Channel at Route 83 for the Existing Condition Scenario (orange solid) and Scenarios with Calumet Water Reclamation Plant Effluent Discharge at 1.0 (blue dashed), 0.5 (grey dashed), 0.3 (green dashed), and 0.1 (yellow dashed) mg/L Total Phosphorus

Key Finding 2: Reduced algae levels from Grand Calumet River would result in reduction of unnatural algae growth

The Grand Calumet River (GCR) is a source of TP and chlorophyll-a into the CSC. The impact of reducing these concentrations on instream water quality was simulated by running model scenarios with the TP and chlorophyll-a from the GCR reduced by 50 percent.

Figure 11 and **Figure 12** show the results of simulated chlorophyll-a and DO, respectively, in the Calumet River System at Route 83 for the existing conditions scenario (orange solid) and the modeled scenario with a 50 percent reduction in GCR TP and chlorophyll-a inputs (gray dashed). TP concentrations at Route 83 are minimally impacted by reductions of upstream TP and chlorophyll-a **(**as shown in *Appendix C: Task 2B Report – Watershed Management Actions Evaluation*). However, the chlorophyll-a levels show a notable decrease at the same location (**Figure 11**). This decrease is primarily due to a decrease in the upstream chlorophyll-a boundary condition. As a result of the reduction in chlorophyll-a, the diurnal fluctuations in DO are slightly reduced which results in a slightly reduced average DO (**Figure 12**) because the algal photosynthetic production of DO is greater overall than the DO uptake during algal respiration.

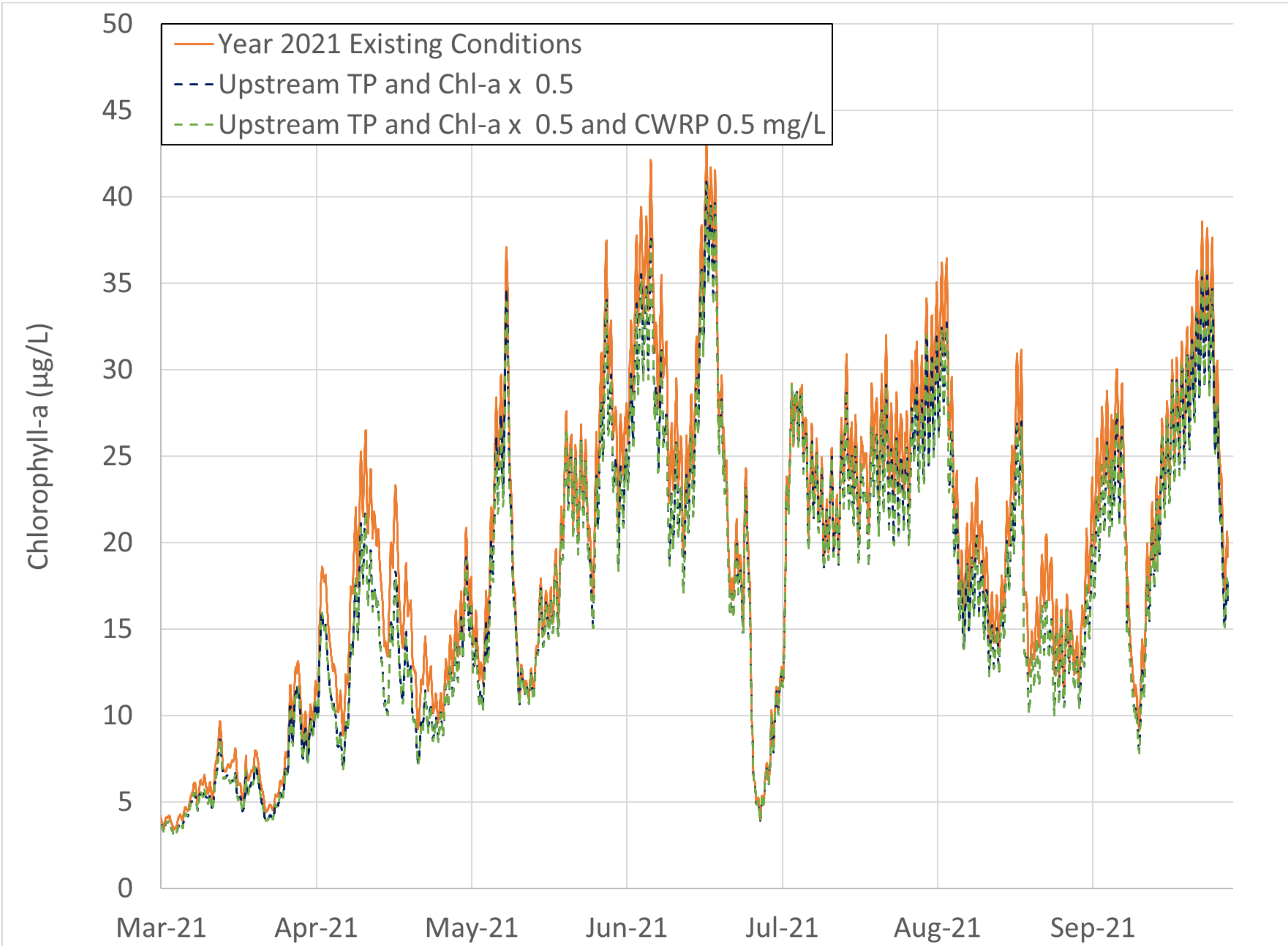

Figure 11: Comparison of Simulated Chlorophyll-a in the Calumet-Sag Channel at Route 83 for the Existing Condition Scenario (orange solid), Scenario with Grand Calumet River TP and chlorophyll-a concentrations reduced by 50 percent (blue dashed), and scenario with Calumet Water Reclamation Plant Effluent Discharge at 0.5 mg/L TP and Grand Calumet River and Little Calumet River South TP and chlorophyll-a concentrations reduced by 50 percent (green dashed)

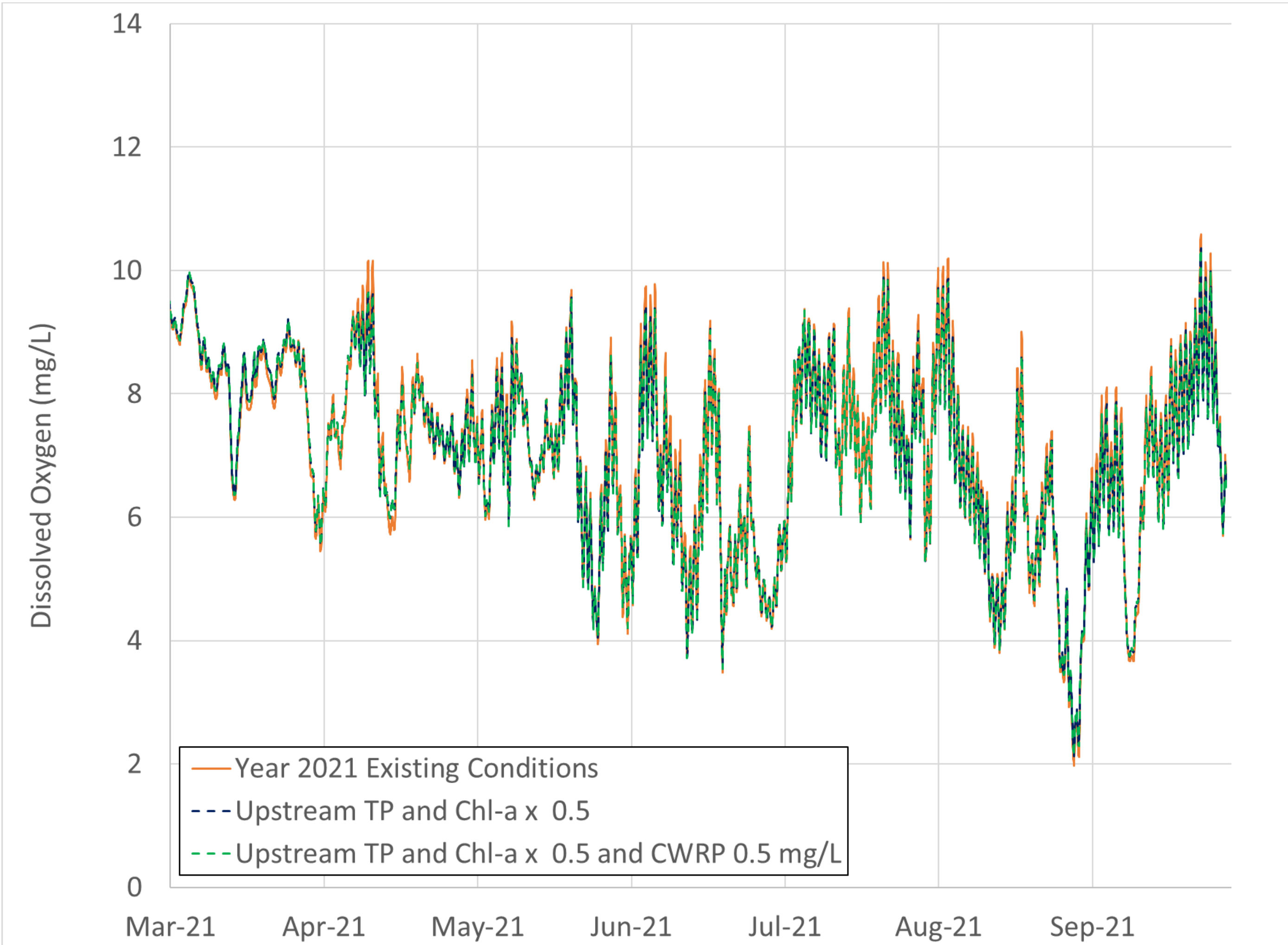

Figure 12: Comparison of Simulated Dissolved Oxygen in the Calumet-Sag Channel at Route 83 for the Existing Condition Scenario (orange solid), Scenario with Grand Calumet River and Little Calumet River South Total Phosphorus (TP) and Chlorophyll-a Concentrations Reduced by 50 Percent (blue dashed), and Scenario with Calumet Water Reclamation Plant Effluent Discharge at 0.5 mg/L TP Scenario and Grand Calumet River and Little Calumet River South TP and chlorophyll-a Concentrations Reduced by 50 Percent (green dashed)

Key Finding 3: Reduction in tributary loading has limited impacts on unnatural growth

The Calumet-Sag and Little Calumet River tributary watersheds contribute approximately seven to eight percent of the total TP loading to the CAWS during the simulation periods. The impact of reducing the tributary TP loading was simulated by reducing the input of estimated tributary TP loading into the Calumet River System by 25 percent.

Figure 13 to **Figure 15** show the comparison of simulated existing condition model results (orange solid) with the scenario with a 25 percent tributary load reduction (black dotted). These results indicate that a reduction in tributary TP loading has negligible benefits to the Calumet River System water quality.

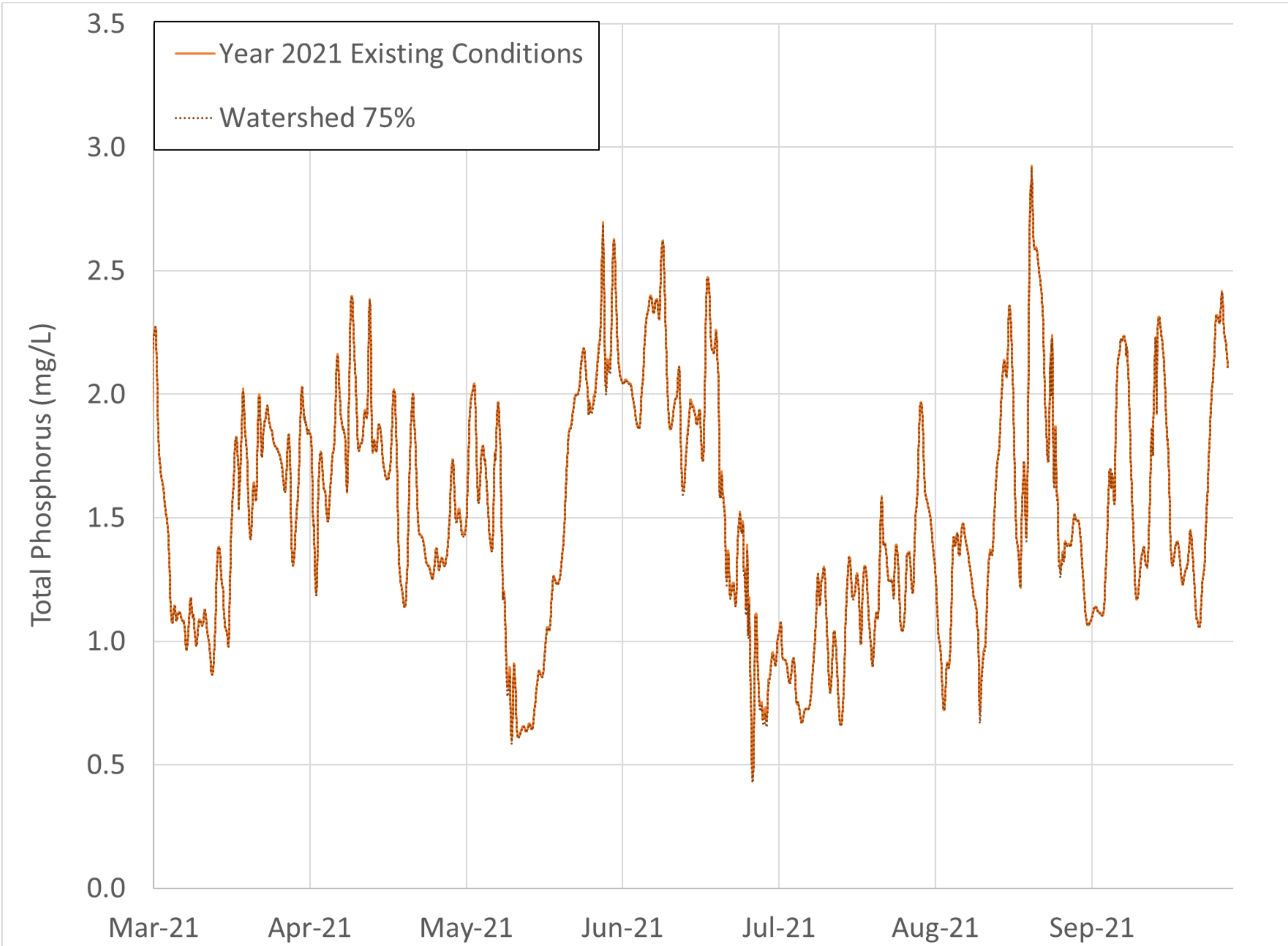

Figure 13: Comparison of Simulated Total Phosphorus in the Calumet-Sag Channel at Route 83 for the Existing Condition Scenario (orange solid) and Scenario with the Calumet-Sag and Little Calumet River Watershed TP Loads Reduced by 25 Percent (black dotted)

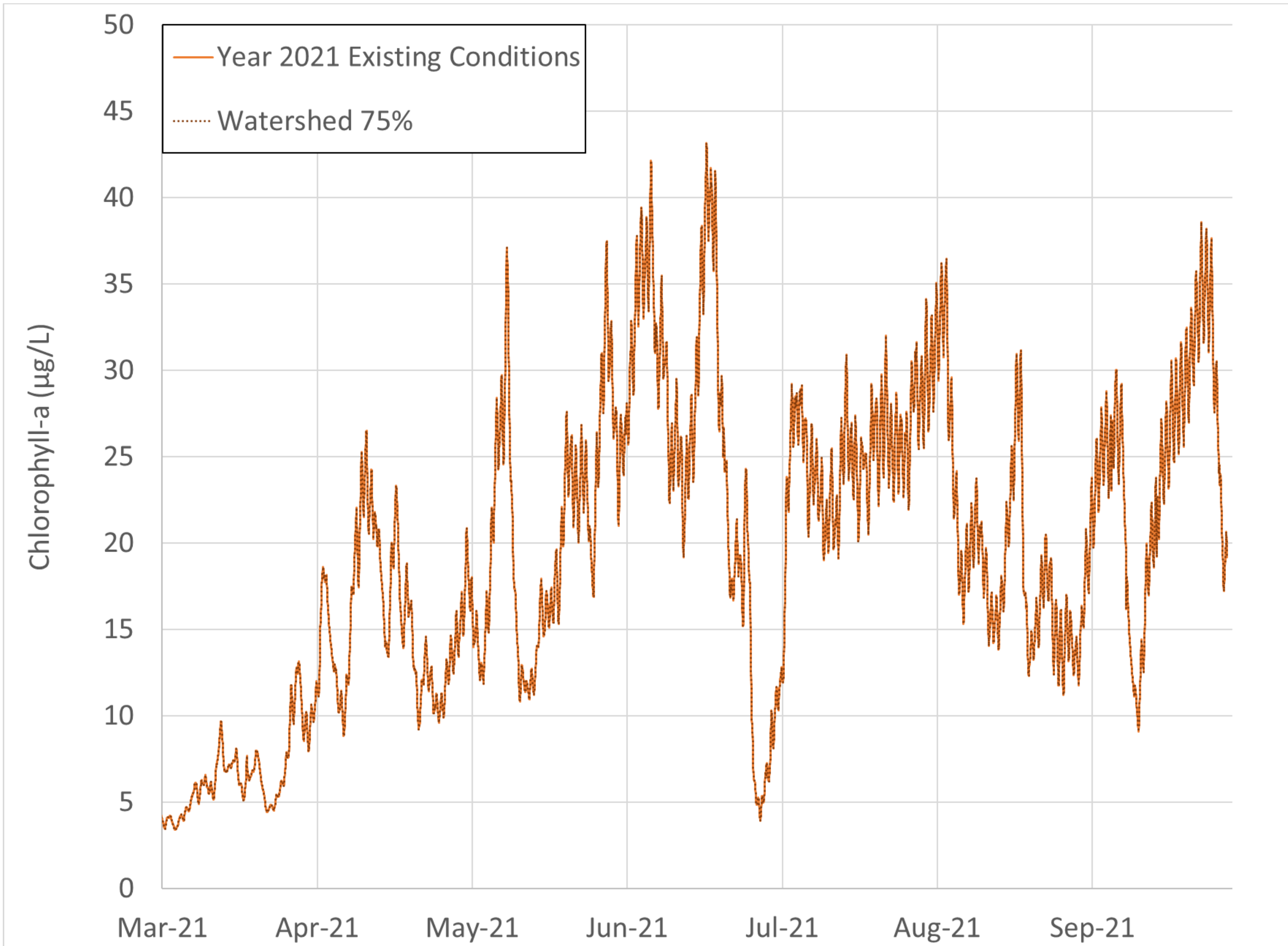

Figure 14: Comparison of Simulated Chlorophyll-a in the Calumet-Sag Channel at Route 83 for the Existing Condition Scenario (orange solid) and Scenario with the Calumet-Sag and Little Calumet River Watershed TP Loads Reduced by 25 percent (black dotted)

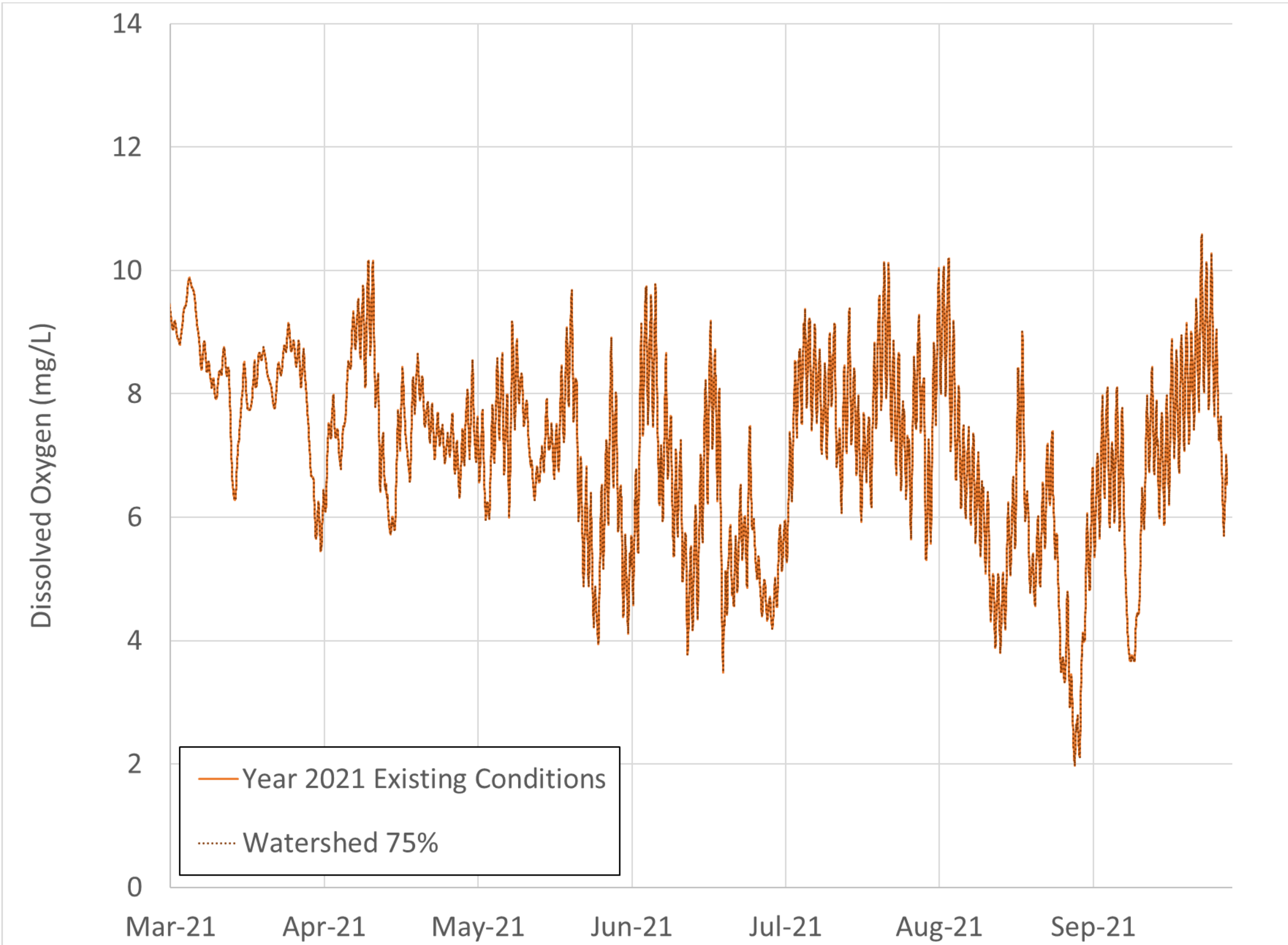

Figure 15: Comparison of Simulated Dissolved Oxygen in the Calumet-Sag Channel at Route 83 for the Existing Condition Scenario (orange solid) and Scenario the Calumet-Sag and Little Calumet River Watershed Total Phosphorus Loads Reduced by 25 Percent (black dotted)

Key Finding 4: Combined Calumet WRP TP reduction (@ 0.5 mg/L) and upstream algae reduction results in slightly larger reduction in algae levels

A combined model scenario was run to assess the combined impact of upstream TP and chlorophyll-a reduction with the Calumet WRP TP set to 0.5 mg/L. The model results show that this would result in slightly larger reduction in algae levels (**Figure 11)** , but only minimal impact on DO as shown by green dashed line in **Figure 12.** This combined strategy is recommended for addressing the unnatural plant and algae growth and reducing the overall TP load transported from the Calumet River System to the downstream CSSC, Des Plaines River, and Illinois River.

3.4 Summary of Findings

Various scenarios were modeled to evaluate the effectiveness of watershed management strategies to address unnatural algal growth (represented by chlorophyll-a) in the Calumet River System of the CAWS. Results of these scenarios show that Calumet WRP TP effluent reductions have a significant impact on instream TP concentrations but do not impact the DO and chlorophyll-a levels in the system. Reducing chlorophyll-a input from the Grand Calumet River results in the reduction of chlorophyll-a in the CAWS and small reductions in DO in the summer growing season. Reducing tributary TP loads from the Calumet-Sag and Little Calumet River South watershed has minimal impact on water quality in the CAWS. A combination of watershed management strategies, which includes limiting the Calumet WRP TP concentrations to 0.5 mg/L and reducing TP and chlorophyll-a concentrations from the Grand Calumet River is a preferred strategy to address unnatural algal growth in the CAWS and downstream reaches.

3.5 Recommended Management Actions

The following management actions are recommended to reduce the unnatural algal growth in the CAWS.

1. WRP Plant Upgrades: This management action is well underway to meet the TP effluent limit of 0.5 mg/L (rolling annual geometric mean) by 2030 at Calumet, Stickney, and O'Brien WRPs
2. Grand Calumet River Algae Reduction: This management action, while potentially having a significant impact on unnatural growth, includes significantly different stakeholders, processes for completion, and funding complexities. Collaboration with stakeholders in Indiana stakeholders will be necessary to achieve the reduction in algae from the Grand Calumet River.
3. Future Studies and Projects: This management action is recommended for continued future work on addressing unnatural growth in the CAWS. This includes undertaking studies and projects to fully identify the causes of impairment and the measures needed to eliminate the unnatural growth in Bubbly Creek and Upper NSC.

The modeling results indicate the stormwater load reduction would not significantly impact the unnatural growth in the CAWS. However, this management action could result in ancillary benefits beyond addressing unnatural growth and TP load reduction and could be considered by MWRD. The implementation plan for these recommended actions is described in Chapter 4.

4. IMPLEMENTATION PLAN

The work completed for the PARP focused on identifying the recommended management actions to address unnatural algae growth in the Calumet River System. The work also identified that additional investigation was needed for the Upper NSC and Bubbly Creek. This section describes the recommended management actions for addressing unnatural growth in the CAWS. Recommended actions fall under the following categories:

1. Actions to Address Unnatural Growth
2. Actions to Provide Ancillary Benefits
3. Planned and Recommended Studies

The recommended actions are described in detail in the following sections, along with stakeholder engagement, potential funding sources, and evaluation of success (where appropriate). The role of MWRD in the PARP implementation is discussed in **Section 4.4**.

4.1 Actions to Address Unnatural Growth

The actions to address unnatural growth in the CAWS include WRP plant upgrades and GCR algae reduction. These are described below.

4.1.1 WRP Plant Upgrades

Overview

The NPDES permits for the Calumet, Stickney and O'Brien WRPs have TP effluent limits, including a monthly average of 1 mg/L and an annual geometric mean of 0.5 mg/L that will need to be met by a specific timeframe provided in **Table 5.**

The results of modeling scenarios show that reducing the Calumet WRP effluent TP beyond a TP effluent limit of 0.5 mg/L would not address the unnatural algae growth. Hence, achieving the 0.5 mg/L TP limit is recommended for the Calumet WRP.

Table 5: Total Phosphorus Effluent Limit Compliance Schedule for Water Reclamation Plants Discharging to the CAWS

Water Reclamation Plant (NPDES Permit Number)	TP effluent limit of monthly average of 1 mg/L	TP effluent limit of annual geometric mean of 0.5 mg/L
Calumet (IL0028061)	January 1, 2024	January 1, 2030
Stickney (IL0028053)	August 6, 2021	January 1, 2030
O'Brien (IL0028088)	August 1, 2027	January 1, 2030

A summary of current progress made by each WRP in reducing TP is in *Appendix D: WRP Upgrades Progress*. A brief description of the planned upgrades at the Calumet WRP, which is the most relevant for the PARP, is provided in the following paragraphs:

The Phosphorus Removal Feasibility Study conducted for the Calumet WRP indicated that chemical phosphorus removal (CPR) is more feasible than enhanced biological phosphorus removal to meet required TP effluent limits (Greeley and Hansen, 2019). The study noted that Sidestream Enhanced Biological Phosphorus Removal (S2EBPR) was promising but that more studies are needed.

MWRD conducted a pilot study on S2EBPR at the Calumet WRP to understand the potential reduction in chemical cost and achievement of stable and sustainable phosphorus removal. The pilot study demonstrated that S2EBPR is a promising method to help meet the current TP permit limit of a monthly average of 1.0 mg/L and the future limit of an annual geomean of 0.5 mg/L. S2EBPR may also provide additional economic and environmental benefits, but further study is necessary. The effluent orthophosphate in the pilot battery averaged 0.16 mg/L during the study's optimized period, while the control battery (no S2EBPR) averaged 3.42 mg/L. This study showed the need for additional carbon (average of 54,259 pounds per day of chemical oxygen demand) could be reduced by 40 to 69 percent when comparing S2EBPR to conventional EBPR. However, the implementation of S2EBPR would require building additional fermentation tanks to maintain the current treatment capacity of Calumet WRP. MWRD staff currently are using the information learned from the S2EBPR pilot study to perform an engineering evaluation of different phosphorus removal strategies for the Calumet WRP. The evaluation will include conceptual designs and cost estimates including capital and operation and maintenance (O&M) costs. This evaluation is expected to be completed by the end of 2023.

A CPR facility is currently under construction at the Calumet WRP to meet the effluent limits of 1 mg/L (monthly average by January 2024) and 0.5 mg/L (rolling annual geomean by January 2030) to ensure permit compliance at the Calumet WRP. The contract includes installation of fourteen (14) fiberglass reinforced plastic (FRP) chemical storage tanks with heat panels and insulation, two (2) foundations each with concrete secondary containment walls for the storage tanks, two (2) pump buildings, twenty (20) chemical dosing pumps on the ten (10) separate skids, and chlorinated polyvinyl chloride (CPVC) and double-wall CPVC piping, valves, and heat tracing for outdoor portions of the plant.

Stakeholder Engagement

The stakeholders for WRP upgrades include MWRD, its ratepayers, and Illinois EPA. It will be important to communicate information about needed upgrades with these stakeholders to help ensure that the required upgrades get funded.

Potential Funding Sources

MWRD capital budget would account for the facility upgrades required to the effluent limits. MWRD has already budgeted a total of approximately $400 million for fiscal years 2022-2027 to upgrade the Calumet, Stickney, and O'Brien WRPs to meet the TP effluent limits of 1 mg/L (monthly average) and 0.5 mg/L (12-month geomean rolling average, calculated monthly) by the timeframes specified in **Table 5**.

Evaluation of Success

The success of WRP upgrades will be measured by reported TP effluent data. MWRD makes this data available on its website (MWRD, 2023a). In addition, MWRD will continue to measure instream water quality in the CAWS at the existing monitoring stations per the CDOM Quality Assurance Project Plan (QAPP, MWRD, 2016) and AWQMN QAPP (MWRD, 2019) in next permit cycle, which is also made available on MWRD website (MWRD, 2023b). These data can be used to assess the impact of TP load reductions on the instream water quality in the CAWS

4.1.2 Grand Calumet River Algae Reduction

Overview

The PARP study determined that algal input from the GCR in Indiana has a significant impact on the unnatural growth in the Calumet River System. The GCR is currently listed on Indiana’s Section 303(d) List as being impaired for DO and nutrients (IDEM, 2022). The GCR quality also impacts the water quality in the Great Lakes through its connection at the Indiana Harbor. The International Joint Commission (IJC), consisting of representatives from the United States and Canada, has listed the GCR as one of the 43 designated Areas of Concern (AOC) within the Great Lakes Basin. The Unites States and Canada are required under the 1987 Great Lakes Water Quality Agreement to develop Remedial Action Plans to address the beneficial use impairments (BUI) in the AOCs which includes eutrophication or undesirable algae (BUI8). The water quality in the GCR in Indiana is impacted by wastewater treatment plants and CSO discharges from the Hammond Sanitary District, East Chicago Sanitary District and Gary Sanitary District. The TP effluent limit for the three wastewater treatment plants is 1 mg/L monthly average. Hammond, Gary, and East Chicago are currently implementing long-term control plans (LTCPs) to reduce CSO discharges.

The Indiana Department of Environmental Management (IDEM) has been working to address the impairment in the GCR with input from a diverse group of stakeholders represented by the Citizens Advisory for the Remediation of the Environment (CARE) Committee (IDEM, 2023). IDEM is currently collaborating with USGS and USEPA on a multi-year study to evaluate algal impairment conditions and establishing baseline trends. This study includes continuous monitoring of DO and temperature (10 sites), chlorophyll (4 sites), and total algae (1 site) on the GCR. The study also includes a genomic based assessment for algae species characterization. The samples for genomic assessment were collected during four events from April to September 2021 at four locations (including two locations on the GCR). The USGS has released preliminary data from the sampling events (USGS, 2023). The dominant algae species reported in GCR at Columbia Avenue are Chrysophyceae (golden algae), Bacillariophyta (Diatoms-Dinoflagellates) and Viridiplantae (green algae). These findings are based on four sampling events and additional data may need to be collected to develop management actions. The USGS is planning to publish results of the study by the end of 2023[4].

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[4] Personal Communication D. Lampe, USGS (2022)

The following actions are recommended to reduce the impact of GCR algae input on CAWS water quality:

- Request the Illinois EPA to work with IDEM to reduce TP loading from upstream WWTPs and CSO communities.
- Request the Illinois EPA and environmental groups to work with IDEM and other stakeholders in Indiana to reduce unnatural growth of algae in Indiana's portion of the GCR. The USGS results would help inform the actions that need to be taken. IDEM is currently working on scoping a two-year project to augment the population of native mussels for reducing algae and TP concentration in the GCR.
- Continued monitoring of the GCR. It is recommended that MWRD conduct CDOM monitoring in Grand Calumet River at Torrence Avenue every three years. The USGS started operating a Next Generation Water Observation System (NGWOS) gage in 2021 on the GCR at the Columbia Avenue (USGS 05536356). This location includes continuous measurement of discharge, DO, nitrate, orthophosphate, pH, chlorophyll fluorescence (fChl), phycocyanin fluorescence (fPC), stream temperature, and turbidity. The data from the station for 2021 was utilized for the PARP study. In addition, MWRD collects monthly grab samples at Burnham Ave. station. which is located downstream of IL-IN State Border. MWRD could utilize the data from the USGS Columbia Avenue, MWRD Torrence Avenue and Burnham Avenue stations to assess TP and algae input from GCR

Stakeholder Engagement

The stakeholders for reducing the algal input include environmental groups, Illinois EPA, IDEM, the CARE Committee, and wastewater and CSO communities discharging to the GCR. It is recommended the Illinois EPA and environmental groups engage with the Indiana stakeholders to address unnatural growth in the GCR.

Potential Funding Sources

The potential sources of funding include federal and state grants such as the Great Lakes Protection fund, Chi-Cal Rivers Fund and IDEM Section 319 funding. The grant funding opportunities would need be to be led by Indiana based entity with support from MWRD. The improvements to the wastewater treatment facilities and CSO communities should be funded by the capital operating budget of the respective communities. This can be supplemented with long term and low-cost loans authorized under the Water Infrastructure Finance and Innovation Act (WIFIA) Program of 2014.

Evaluation of Success

The data that USGS is currently collecting at the NGWOS Columbia Ave. station can be used to track the success of implemented projects. Currently, the funding for the station is available through the end of 2030 as part of USGS Integrated Water Science (IWS) Illinois River basins study (USGS, 2021).

4.2 Actions to Provide Other Ancillary Benefits through Stormwater Load Reduction

4.2.1 Overview

The results of modeled management scenarios showed that a reduction in stormwater loading from the Little Calumet and Calumet-Sag watersheds would have a minimal impact on the Calumet River System water quality. However, the reduction in stormwater loading would provide ancillary benefits such as reducing hydromodification. The Project Team worked with MWRD Stormwater Planning Division to develop site-specific and programmatic recommendations to reduce phosphorus loading from the Little Calumet and Cal-Sag watersheds. The recommendations are not meant to address the unnatural growth in the CAWS but are meant to identify potential opportunities for project implementation by stakeholders in the watershed. These are briefly described in the following subsections.

4.2.2 Site-Specific Recommendations

Site-specific recommendations for reducing stormwater TP loading from the Little Calumet and Calumet-Sag watersheds include two types of potential projects. The first include retrofitting existing stormwater facilities into facilities that remove phosphorus more effectively. The second include building new multi-benefit stormwater facilities incorporating TP removal capabilities. Site-specific recommendations were developed using the following steps:

- Evaluate stormwater best management practices (BMPs) effective for reducing TP loading and appropriate for implementation in CAWS tributary watersheds;
- Identify priority areas with high TP reduction potential;
- Identify potential sites for retrofitting existing BMPs through desktop screening in prioritized areas;
- Conduct site visits to evaluate the potential sites for retrofitting;
- Develop example recommendations of site-specific projects for retrofitting existing BMP projects based on site visit observations; and
- Develop recommendations for design of new BMPs to incorporate phosphorus removal.

Evaluate BMPs for Phosphorus Removal

The treatment of urban stormwater runoff to reduce TP loading requires a treatment train approach, in which various technologies are implemented throughout the transport pathway of phosphorus from stormwater (MPCA, 2023). Stormwater BMPs were evaluated based on effectiveness for reduction of particulate-bound phosphorus, operation and maintenance (O&M) requirements, capital and O&M costs, and adverse effects on the environment. The BMPs were also evaluated with consideration of the characteristics of the tributary watersheds of the CAWS, which are mostly comprised of flat urban/suburban land uses with a lot of existing detention features. The literature reviewed include repository resources such as the International Stormwater BMP Database (Clary et al., 2020), and the Minnesota Stormwater Manual (MPCA, 2023), and case studies on individual treatment technologies such as filtration media, street sweeping, leaf collection, and pretreatment devices.

The review of the “International Stormwater BMP Database: 2020 Summary Statistics” (Clary et al., 2020) was done to inform the selection of BMPs that are effective in phosphorus removal from stormwater. As of December 2019, the BMP Database contains data sets collected over four decades from over 700 BMP studies throughout the U.S. and several other countries. Many BMPs result in statistically significant reductions for phosphorus, but grass swales, grass strips, and bioretention show phosphorus export, which is likely due to the presence of phosphorus rich soils and planting media (e.g., containing compost) for many studies in the BMP database. The performance of BMPs for phosphorus are documented in Table 4-3 of Clary et al., 2020 and are summarized below:

- The best performing BMPs for TP reduction are media filters (mostly sand filters), high rate biofiltration (manufactured devices with high-rate infiltration media that supports plants), and high-rate media filtration (manufactured devices with high rate infiltration media consisting of a variety of inert and sorptive media types and configurations [e.g., cartridge filters, upflow filters, membrane filters, vertical bed filters]).
- The best performing BMPs for orthophosphate in the analysis data set are retention ponds and media filters.
- Because phosphorus in stormwater runoff is generally highly particulate-bound, BMPs with unit processes for removing particulates (i.e., sedimentation and filtration) will generally provide good removal for TP.
- In particular, BMPs with permanent pools appear to be effective at reducing the major forms of phosphorus.
- Retention ponds also show reductions for dissolved phosphorus.
- Most practices do not show statistically significant reductions for dissolved phosphorus.

Based on the literature review, the recommended BMPs for reducing TP loading from stormwater are briefly described:

Pretreatment

Pretreatment devices are components in the storm drain system designed and installed upstream of the regional stormwater facilities to intercept a portion of the sediment before stormwater enters the main facilities. Typical pretreatment devices include sedimentation forebays and hydrodynamic separators, both of which remove TP by settling and storing the sediment in stormwater. Inclusion of pretreatment not only improves TP treatment performance but also reduces the O&M burdens on the main facilities. Pretreatment can be retrofitted into existing regional stormwater facilities and their tributary areas, where the addition of pretreatment devices will not significantly impact the flood reduction of the stormwater facility.

Example of Pretreatment device: Sedimentation Forebay

Retention Basins

Retention basins are designed to retain stormwater to achieve longer residence time (usually greater than 24 hours) and improve pollutant removal by allowing settling to occur. Based on the MWRD's Watershed Management Ordinance Permit Database, several stormwater detention facilities exist in the identified priority areas, which present cost-effective opportunities to convert

Example of a Retention Pond (Left) with a Retrofitted Outlet Structure (Right) into retention facilities by altering the existing outlet structures. Flood control facilities also provide potential opportunities for improved pollutant removal. Some flood control facilities such as Tinley Park reservoir and Deer Creek reservoir receive inflow during large events. For these facilities, retrofitting the inlets such that runoff from small to medium size storms can be routed into the basins and the existing volume of the facility can be utilized for retention treatment. This retrofit would increase the percentage of annual runoff being treated by an existing facility. Similar to pretreatment, these BMPs are recommended in locations where the retrofit will not significantly impact the flood reduction of the stormwater facility.

Filtration

Filtration BMPs reduce phosphorus loading by passing stormwater through porous media consisting of either natural or engineered media and retaining pollutants by sieving and adsorption. Typical filtration BMPs include green streets, filtration basins, and distributed planter boxes. Although vegetated filtration BMPs (swales, filter strips, and basins) can provide water quality benefits, they are ineffective for TP removal due to leaching of phosphorus from the natural or compost-based filtration media. Replacement of TP-leaching media in existing infiltration practices with phosphorus-free sand-based and perlite-based filtration media with sorbents including biochar, iron, or activated alumina improves the TP removal efficiency through existing BMPs.

Example of a Filtration Basin with Engineered Media for Phosphorus Removal

Compact Agricultural Phosphorus Treatment Structure

The Compact Agricultural Phosphorus Treatment Structure, or CAPTure™, is a modular technology solution for removing soluble phosphorus from agricultural tile drainage and overland runoff before it discharges to local surface waters. This practice calls for detention basin capacity to control a 10-year storm. If area is limited, control of a 2-year storm is adequate for the purposes of serving a CAPTure™ installation.

Identify Priority Areas

The priority areas for implementation of recommended BMPs were identified based on three factors:

Stormwater TP Loading: The annual average TP load per unit areas was estimated based on the watershed model. The areas with highest 50% TP loading per acre were prioritized.

Density of Existing Stormwater Facilities: The density of existing stormwater facilities and associated stormwater storage volumes were assessed based on MWRD's Watershed Management Ordinance Permit Database. The areas with lowest 50% detention volume provided by existing stormwater facilities per acre were identified.

Other Co-Benefits: The areas where BMP implementation could also provide additional co-benefits such as reducing flooding, driving equitable investments and opportunities to create multi-benefit facilities such as parks and trails were prioritized. The areas identified using these three factors were overlaid to define the priority areas for BMP implementation.

The priority areas are shown in **Figure 16**. The results of this analysis show that eight communities should be prioritized for site-specific stormwater BMP project considerations: Hickory Hills, Burbank, Chicago Ridge, Oak Lawn, Evergreen Park[5], Alsip[5], Midlothian, and Oak Forest. Phosphorus loading from these areas can be reduced by implementing recommended BMPs such as pretreatment devices, retention basins and filtration described above. The priority areas include home lawns, golf course, industrial/office parks etc. where overfertilization of ornamental vegetation may lead to phosphorus wash off to the streams. Consideration should be given to reduction of phosphorus in lawn fertilizers, which can significantly reduce the phosphorus loading from agricultural non-point sources.

The results of the priority analysis were shared with MWRD Staff. MWRD may consider incorporating factors such as the potential for phosphorus reduction when evaluating applications for projects submitted by local municipalities and other governmental organizations through its Stormwater Partnership Programs.

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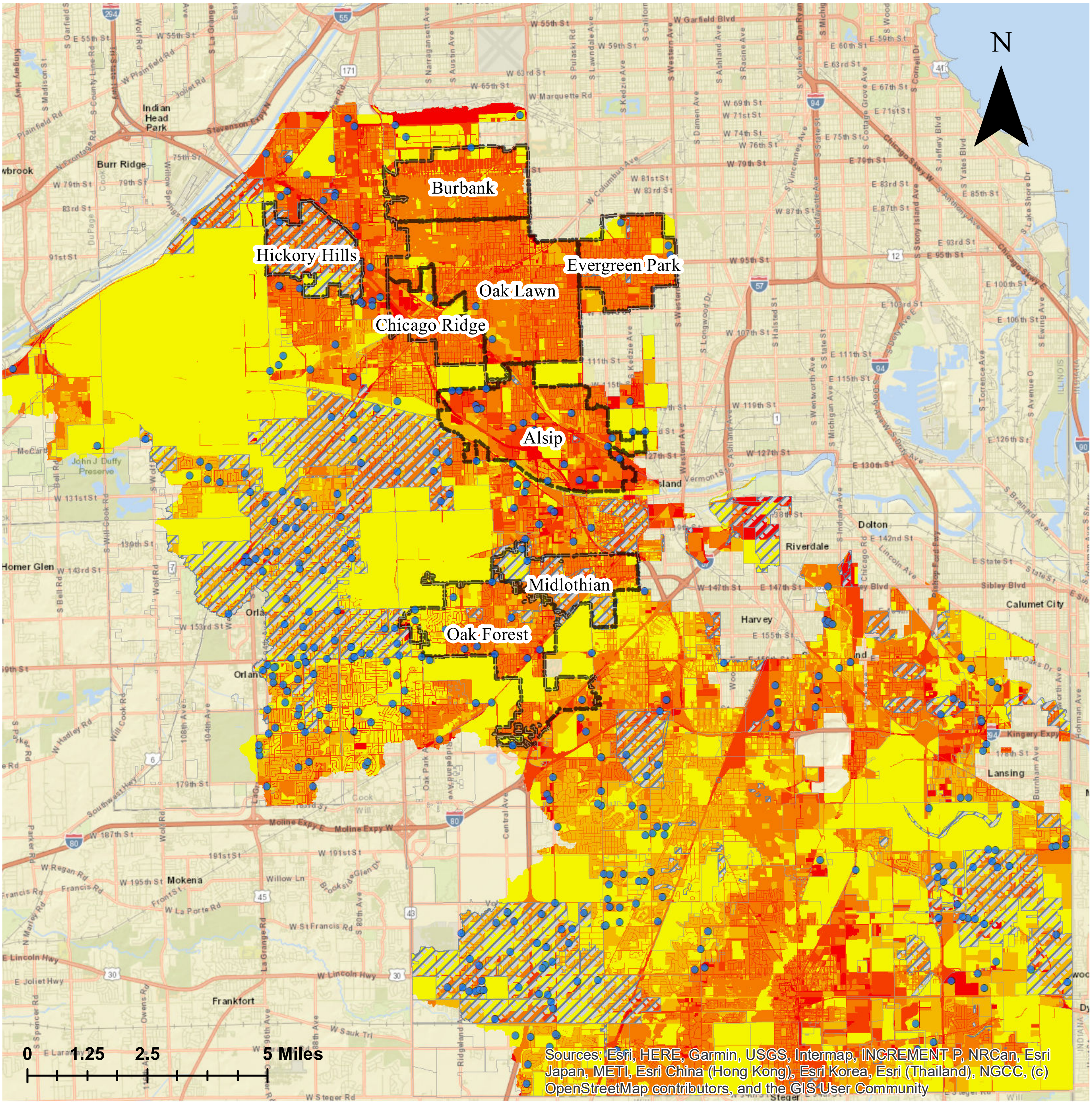
[5] Small areas of Evergreen Park and Alsip have stormwater conveyed to MWRD interceptor and eventually to Calumet Water Reclamation Plant



Legend

Stormwater TP load (grams per acre per growing season)

- 0 - 100
- 101 - 200
- 201 - 400
- 401 - 600
- 601 - 2400

Municipality

- Prioritized
- Others

Existing Wet Ponds

Flood-prone Areas (Identified in Stormwater Masterplan)

Figure 16: Priority Area for BMP Implementation

Phosphorus Assessment and Reduction Plan

February 2023

Geosyntec consultants

Recommended Projects

Retrofit Project Recommendations

Twenty-five existing stormwater facilities were identified within and near the prioritized areas for site investigation based on the retrofit potential for TP removal. These facilities were selected based on several factors including ownership, alternative use, estimated TP loading from the tributaries, existing size, and outlet structure through desktop analysis. Subsequently, the Project Team conducted site visits to these facilities in late 2022 – early 2023. Seven facilities were chosen for the example conceptual retrofit design for enhancing TP removal based on results from the site investigations. The implementation feasibility of these projects (or similar projects) would need to be assessed based local partnerships, funding, and other factors. These conceptual project design are provided as examples that can be replicated for similar facilities in the watershed. The feasibility of the recommended examples projects would need to be assessed for implementation in consultation with the municipalities. The project located on public property are most likely to get implemented in collaboration with MWRD and local communities. The details on the proposed project examples are summarized in *Appendix E1: Retrofit Stormwater Project Recommendations.*

Table 6 provides a basic summary of the sites visited and a preliminary assessment of the potential for additional phosphorus removal at these sites. 13 of the 25 sites showed potential for additional phosphorus removal. It must be emphasized that the preliminary assessment is at the screening level and detailed designs and assessments of the sites are needed to determine whether any of these sites can actually be retrofitted to achieve additional phosphorus reduction without adversely affecting the flood management functions of these facilities. It is important also to note that most of the wet retention ponds are likely to have already achieved their maximum reduction potential because they already have restrictive outlets and/or substantial detention times (see **Figure 17** for examples). It is likely that most of the existing wet retention basins in the study area are functioning similarly. The best potential might be to convert dry detention basins to wet retention basins.

Seven facilities were chosen for the example conceptual retrofit design for enhancing TP removal based on results from the site investigations. The implementation feasibility of these projects (or similar projects) would need to be assessed based local partnerships, funding, and other factors. These conceptual project design are provided as examples that can be replicated for similar facilities in the watershed. The feasibility of the recommended examples projects would need to be assessed for implementation in consultation with the municipalities. The project located on public property are most likely to get implemented in collaboration with MWRD and local communities. The details on the proposed project examples are summarized in *Appendix E1: Retrofit Stormwater Project Recommendations.*

Table 6: Stormwater management facilities visited in the Little Calumet and Calumet-Sag watersheds and a preliminary assessment of the potential for further phosphorus reduction at these sites.

Location	Subdivision/Facility Name	Facility Type	Phosphorus Reduction Potential
Alsip	Coca Cola Building	Wet retention pond	No potential for further phosphorus control
Alsip	Laramie Square	Dry detention pond	Restrictive outlet has already been installed (see **Figure 17**)
Alsip	Wilkins Park	Dry detention pond	Lower bottom to receive runoff from smaller events and possibly convert to wet retention pond
Alsip	Deer Park PUD Subdivision	Dry detention pond	Pond is relatively small, and modifications may not provide much benefit
Country Club Hills	Woodland Hills Phase 1	Wet retention pond	No potential for further phosphorus control
Country Club Hills	Village West Development	Wet detention basin	No potential for further phosphorus control
Crestwood	Rivercrest	Wet retention pond	No potential for further phosphorus control
Evergreen Park	Washtenaw Detention Basin	Regional flood control	Change in pond bottom could be regraded to increase detention times
Justice	Miroballi's Steeple Hill	Dry detention pond	Inlet needs to be modified to receive runoff from smaller events
Matteson	Butterfield Place (South)	Dry detention pond	Restrictive outlet has already been installed
Matteson	Butterfield Place (North)	Wet retention pond	Restrictive outlet has already been installed (see **Figure 17**)

Location	Subdivision/Facility Name	Facility Type	Phosphorus Reduction Potential
Oak Forest	Midlothian Reservoir	Regional flood control	No potential for further phosphorus control
Oak Forest	The Avenues of Oak Forest	Dry detention pond	Drains directly to Midlothian Reservoir, so no potential for further phosphorus control
Oak Forest	Oak Forest Detention	Regional flood control	Modifications to capture runoff from smaller storms could be cost prohibitive
Oak Lawn	Hartz Eagle Ridge Wolfe Wildlife	Wet retention pond with porous pavement and bioretention pre-treatment	Restrictive outlet has already been installed
Oak Lawn	Foxwoods Subdivision	Dry detention pond	Lower bottom to receive runoff from smaller events and possibly convert to wet retention pond
Orland Hills	Detention Pond A (Lake Lorin)	Wet retention pond	No potential for further phosphorus control
Orland Park	Meadows Park Estates	Dry detention pond	Possibly could add a restrictor at the outlet to increase detention time or convert to wet pond
Orland Park	Silver Lake Gardens Unit #8	Dry detention pond	Possibly could add a restrictor at the outlet to increase detention time or convert to wet pond
South Holland	Carrington Cove Subdivision	Dry detention pond	Feasibility evaluation on retrofit
Tinley Park	Tinley Park Reservoir	Regional flood control	Modify pump out operations to extend retention time

Location	Subdivision/Facility Name	Facility Type	Phosphorus Reduction Potential
Tinley Park	Phase Chase	Dry detention pond	Convert to wet retention pond
Tinley Park	Mansfield Court Townhomes (West)	Wet retention pond	No potential for further phosphorus control
Tinley Park	Mansfield Court Townhomes (East)	Dry detention pond	Possibly could modify the restrictor at the outlet to increase detention time
Tinley Park	Tinley Meadows	Dry detention pond	Possibly could modify the restrictor at the outlet to increase detention time or convert to wet pond

(a) (b)

Figure 17: Examples of restrictive outlets added to wet- and dry-ponds in the Little Calumet and Calumet-Sag watersheds (a) outlet of the Butterfield Place (North) wet pond in Matteson, and (b) outlet of the Laramie Square dry pond in Alsip.

New Project Recommendations

The Project Team developed general recommendations for MWRD and local communities to incorporate TP removal in stormwater facility design. These recommendations are summarized as follows:

1. **Target Phosphorus Hotspot**: The phosphorus loading estimated by the watershed model can be leveraged by MWRD and local communities to identify locations of planned stormwater facilities for targeting areas with high TP loading. Sampling and observation records should also be used as confirmation of phosphorus hotspots.

2. **Choose Effective Stormwater BMPs**: The three categories of BMPs listed in the retrofit recommendations (pretreatment, retention, and filtration) are generally more effective than dry detention ponds and vegetated facilities in removing TP.

3. **Promote Multi-Benefit Facilities**: The design of new stormwater projects should incorporate improvement in water quality (including phosphorus removal), reduction in flooding risk, and other recreational or educational benefits when possible. This design strategy can potentially engage more stakeholders and increase funding sources when identifying local partner-led projects for MWRD Stormwater Partnerships.

Additional site-specific recommendations can be incorporated into the design for improving TP removal. MWRD is partnering with the Village of Oak Lawn to design and construct a stormwater detention facility at Polaris Park. MWRD requested the Project Team to provide recommendations on the 60% design for improving TP removal. These recommendations from the Project Team on improving the Polaris Park design to incorporate TP removal are included in *Appendix E2: Polaris Park Design Recommendations.* It should be noted that MWRD Stormwater staff and the Project Team agreed that the recommended technology for a treatment device installed at the end of a retention structure would not be a good fit for the proposed dry detention pond in Oak Lawn.

4.2.3 Programmatic Recommendations

The Project Team developed the following programmatic recommendations for reducing stormwater phosphorus loading into the CAWS.

Enhanced Street Sweeping and Leaf Collection

Street sweeping and leaf collection are a form of pre-treatment or source control for phosphorus. Several studies have been done to evaluate nutrient reduction on an annual basis resulting from leaf collection and subsequent street sweeping primarily in the Minneapolis-St. Paul, MN, and Madison, WI, areas (see *Appendix F: Street Sweeping Effectiveness in Reducing TP Loads* for details). These studies also sought to develop guidance for effective nutrient reduction in runoff. As experiences in Minneapolis-St. Paul and Madison and a recent survey of communities and agencies in Du Page County (McCracken, 2022) indicate there is room to further improve the phosphorus reduction through improved leaf collection and street sweeping practices in the fall. In Madison, Selbig (2016) found that it is very important to prevent nutrient leaching resulting from leaves contacting rainfall in the gutters or other direct drainage pathways. If leaf collection can be done prior to rainfall events and street sweeping can be performed immediately follow leaf collection (i.e., within 24 hours as in Selbig's (2016) study), a 10% annual reduction in phosphorus load may be achieved (perhaps more in areas with high canopy cover of streets). Further, if a nutrient credit system is established, communities might be incentivized to apply these practices (such credit systems have been developed for Minnesota and are under development for DuPage County, IL [McCracken, 2022]). Thus, improved street sweeping and leaf collection practices in the fall could be an implementable phosphorus management practice. The developments in DuPage County should be monitored by MWRD and Illinois EPA. Communities in the Little Calumet and Calumet-Sag watersheds should be encouraged to develop enhanced street sweeping and leaf collection programs along the lines of those recommended in Selbig (2016).

Alignment with MWRD Stormwater Management Program

The Project Team recommends that MWRD explore and review opportunities to align PARP recommendations with the District's Stormwater Program. In 2020, Geosyntec was engaged to assist MWRD by providing stormwater master planning program management services in the combined sewer service area. Through the analysis of utilizing a volumetric standard of one inch of rainfall to capture site imperviousness through Stormwater BMPs that promote infiltration, it was estimated that an average of 93% of the average annual stormwater volume could be captured for 15 years of events extending from 2000-2015. Although this does not reflect total site runoff volume, it demonstrates the potential value of integrating the PARP recommendations into the planning for future Stormwater BMPs by advancing landscape scale BMPs can also provide additional phosphorus capture. Identifying a neighborhood level pilot study could help demonstrate this value in conjunction with modeled phosphorus hotspots intersected with flood prone areas.

Maintenance of Stormwater Facilities

The Project Team recommends that MWRD continue to work with communities on long-term maintenance of stormwater facilities as part of MWRD Stormwater Management Program regulatory function. MWRD jurisdiction has an ever-growing inventory of permitted stormwater infrastructure, of which the majority is maintained privately, but tracked at the local (municipal) level. While this infrastructure is intended to be placed in protected tracts of land and maintained accordingly, maintenance and monitoring programs are largely observational in nature causing maintenance to be driven by notable citing of necessary repair resulting from issues such as erosion, flooding, or failure. Properly functioning BMPs, particularly stormwater management facilities, need to maintain sediment capture volume (dead pool storage) to effectively guard against phosphorus release. Incorporating language that proactively requires volumetric measurement of BMP storage in addition to traditionally observed reports may better protect against sediment and phosphorus resuspension and flushing into local receiving waterbodies. It is recommended to conduct pilot studies at a few stormwater facilities to assess whether nutrient removal every five years may be sufficient to achieve the desired capture efficiency. Furthermore, facilities that capture additional offsite drainage should be prioritized.

Development of Technical Assistance Resources

The Project Team recommends that MWRD work with regional agencies such as the Chicago Metropolitan Agency for Planning (CMAP) on technical assistance resources for communities such as a developing guide for ordinance updates. Local communities rely on numerous ordinances to facilitate development within their respective municipal boundaries. Adoption of the WMO by Cook County communities represents the incorporation of the latest stormwater and floodplain regulations, however communities also rely on any number of additional codes and ordinances to facilitate the development process. Depending on the community, these may identify with zoning, subdivision development, landscaping, roadways, rights of way, or others. Within these community specific regulations are numerous areas of overlap and depending on the date of the previous local ordinance update, be outdated in terms of effectiveness.

When executed from a development standpoint, these outdated ordinances or codes can lead to indirect impacts and maintenance issues. For example, subdivision codes typically establish minimum landscaping guidelines. To meet these requirements, developers often occupy and or encroach upon floodplain and stormwater management areas. While this is typically allowable by code, open landscaping near open stormwater ponds or stormwater features tends to clog inlets, overload catch basin sumps, and ultimately serve as a direct phosphorus input. Minimum separation could provide significant reduction of phosphorus inputs. Similarly, outdated roadway standards may require curb and gutter design with open drainage. This tends to concentrate flows and provide little filtering capability for urban stormwater runoff. These inconsistencies can lead to missed opportunities which unintentionally undermine the intent of stormwater water quality controls in the WMO. MWRD can explore with collaborators such as CMAP, non-profit organizations, watershed advocacy groups, and The Conservation to develop guidance on review of local ordinances to better accommodate green infrastructure practices.

Promote Educational Material

MWRD has recently developed educational material for general public on the benefits of green infrastructure. These include the 'Green Neighbor Guide' and 'Green Neighborhood Guides'. It is recommended that MWRD continue to develop and promote these educational materials to encourage wide-scale adoption of green infrastructure that reduces P-loading to surface waters.

4.2.4 Stakeholder Engagement

The stakeholders for implementing projects are MWRD, Cook County, municipalities, townships, park districts, school districts, other public entities and environmental groups. A detailed list of stakeholders is included in *Appendix G: PARP Stakeholder Engagement Plan and Survey Results* Municipalities likely have the greatest opportunities for identifying and implementing green infrastructure retrofit projects and reviewing ordinances.

The Project Team worked with MWRD to conduct a survey for requesting information from the communities in the Little Calumet and Cal-Sag watersheds in July 2021. The survey was sent out to 66 communities and 13 responses were received. The detailed survey responses are included in *Appendix G: PARP Stakeholder Engagement Plan and Survey Results* with a summary provided below.

Two streambank restoration and three green infrastructure projects were currently underway or planned that have the potential to reduce phosphorus loading. Eleven communities reported to have a dedicated street sweeping program. Seven (7) of these 11 communities reported that street sweeping operations were modified due to increase of leaf litter in the Fall. Six communities reported having a dedicated leaf collection program for residents. Among these six communities, five communities followed leaf collection with street sweeping.

The Project Team presented the stormwater recommendations to the community stakeholders at the Little Calumet and Cal-Sag Watershed Council meetings on April 20 and April 26, 2023, respectively. The Project Team did not receive additional feedback from the community stakeholders for the two presentations.

4.2.5 Funding Sources

There are several funding and technical assistance sources that can support local governments and landowners in the implementation of the foregoing actions. These are briefly described as follows:

MWRD Green Infrastructure Program

MWRD works with local government organizations to implement stormwater BMPs through its Green Infrastructure Partnership Program (MWRD, 2023c).

Grant Funding

The Illinois EPA has funding programs available for the planning and implementation of urban BMPs including green infrastructure, stream restoration, wetland restoration, and other water quality improvement projects. These include Section 319, Section 604 (b), and Green Infrastructure Grant Opportunities (GIGO) programs.

CMAP's Local Technical Assistance (LTA) program has been used to support local governments and watershed groups in reviewing and updating local development ordinances. The LTA program provides access to public policy experts from CMAP staff or outside contractors. Local watershed groups and municipalities have already used the LTA program to review ordinances in the DuPage and Kane Counties.

Public Private Partnerships (P3s)

Another innovative funding source for programmatic implementation or retrofit of green infrastructure is Public Private Partnerships (P3s). 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 has to bear the full burden. This cooperation helps to drive innovation and build strong long-term relationships. For example, the Milwaukee Metropolitan Sewerage District (MMSD) is currently implementing green infrastructure to reduce overflows into Lake Michigan through a P3 program. P3s are an alternative funding option that MWRD and local communities could explore to expand green infrastructure in the Little Calumet and Calumet-Sag watersheds.

4.3 Planned and Recommended Studies

This section describes planned and recommended studies and projects for continued future work on addressing unnatural growth in the CAWS are described below

4.3.1 Calumet Phosphorus Source Characterization Study

One of the challenges to utilizing biological phosphorus removal at the Calumet WRP is that the raw wastewater is higher in phosphorus than typical domestic wastewater and, therefore, requires costly chemical treatment to remove. This is likely due to a large commercial/industrial user base that may be discharging much higher phosphorus loads. To determine the source of the biggest contributors, a comprehensive mass balance of phosphorus loads to Calumet WRP is being conducted by measuring the flows and phosphorus concentrations of the intercepting sewers (four of them), TARP pumpback, internal plant recycles (gravity concentration tank overflow and lagoon pumpback), and WRP mainstream flows (influent and effluent). These will be measured for 30 days in 2023 to determine the phosphorus load contribution from each of these sources to the WRP over this extended period. Additionally, two large commercial industrial users (LCIUs), previously identified as significant phosphorus load contributors, are being sampled during the same period to determine their relative contribution. By determining what contribution each interceptor has to the Calumet WRP phosphorus load, the list of potential bigger LCIUs can be narrowed and their potential contribution better quantified.

4.3.2 North Shore Channel Upper Monitoring Planned Study

The water quality data in the Upper NSC showed high chlorophyll-a and supersaturated DO during the period of November to April when no water is diverted from Lake Michigan. The Project Team developed recommendations for additional data collection to understand the cause of this unnatural growth. The Project Teams recommendations for Upper NSC monitoring study are described in detail in *Appendix E3: Study Recommendations for Upper North Shore Channel and Bubbly Creek*.

Based on the Project Team's recommendations, MWRD plans to collect additional data in the Upper NSC to assess the unnatural growth. Data collection will begin in late 2023 and end in 2025. Water quality meters will be deployed at Sheridan Road and Church Street on the upper Upper NSC and will collect hourly data for DO, specific conductivity, temperature, chlorophyll a, turbidity, and pH. Water samples will be collected for phytoplankton and zooplankton taxonomy, and low-level nutrient analysis (Total Nitrogen, Nitrate-Nitrite, Total Phosphorus, Orthophosphate), in each of the following months: December through April, July, and October. Algae and aquatic macrophyte abundance, ice presence, and snow cover depth, will be noted and documented with photographs. MWRD has acquired equipment to open a sampling hole in the ice cover if conditions allow for safe sample collection.

4.3.3 Bubbly Creek Planned Restoration

Bubbly Creek exhibits the largest unnatural algal growth in the CAWS due to nutrient fluxes from the historically contaminated sediment bed and CSO discharges from the Racine Avenue Pumping Station (RAPS). The U.S. Army Corps of Engineers (USACE) has developed a restoration plan to address poor quality sediments that support tolerant and invasive aquatic life, lack of in-stream and riparian habitat, and lack of diverse native aquatic and riparian plant communities (USACE, 2020). The restoration plan recommends restoration of 40 acres including 30.7 acres of substrate restoration, 9.3 acres of riparian plant restoration, one acre of emergent plant restoration, 3.3 acres of submergent plant restoration and woody debris restoration at 10 locations within the channel. The United States Congress has authorized funding of the proposed project under the Water Resources Development Act of 2020. The estimated project cost is $17,934,000 with approximately 65% coming from federal funding and the remaining from the City of Chicago, which is the non-federal sponsor. The USACE is currently in the process of negotiating an interagency agreement with the City of Chicago for the cost sharing of the design. The project implementation would require that the USACE and the City of Chicago receive protection from liability claims under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Therefore, CERCLA liability protection would have to be legislated prior to implementation. The project implementation is anticipated to substantially improve the water quality in Bubbly Creek. The Project Team also provided some additional recommendations for monitoring and modeling of Bubbly Creek which are included in *Appendix E3: Monitoring Study Recommendations for Upper North Shore Channel and Bubbly Creek*

4.3.4 McCook Reservoir Stage II

The McCook Reservoir will provide more than $143 million per year in flood damage reduction benefits to 3.1 million people in 37 communities, along with a total capacity of 10 billion gallons once Stage 2 is completed in 2029. McCook Reservoir Stage I was completed in 2017, providing 3.5 billion gallons of storage. The United States Army Corps of Engineers Integrated Feasibility Report and Environmental Assessment for Bubbly Creek estimates that the average number of Racine Avenue Pump Station discharge events to Bubbly Creek will be reduced to twice per year following Stage 2 coming online, based on modeled future conditions. That is compared to modeled average of 26 events/year before Stage I came online and 6 events/year since Stage I came online. In addition, lower volume discharges are expected when there are CSO events. While these modeled estimates do not account for increased high intensity rain events brought about by climate change, significant reductions of discharges to Bubbly Creek are anticipated.

4.3.5 Grand Calumet River Pilot Studies

MWRD could explore the potential for collaborating with Illinois EPA, IDEM, the CARE Committee, and others to consider piloting instream algae reduction technologies at the mouth of the GCR in Illinois. The potential for grant funding should be explored. The Project Team evaluated available ecological and technological approaches for algae reduction in the GCR. Ecological approaches include use of filter feeding organisms, macrophytes, barley straws, and competing bacteria, which reduce algae growth. However, these ecological approaches are not recommended due to the potential to cause an undesirable shift in ecosystem composition. The use of barley straws is recommended for GCR since it is cost effective, easy to maintain, and works in shallower waters.[6] Technological approaches include use of algaecides; coagulation and precipitation; coagulation, flotation, and harvesting; mixing and aeration; and ultrasound. Most of

[6] Requires a minimum depth of 7 inches

the technological approaches have been reported to work well in deeper lakes and reservoirs. The technological approach recommended for GCR is ultrasound. A study at the mouth of the GCR could be piloted to test and evaluate this technology.

4.4 Role of MWRD in PARP Implementation

The implementation actions to be undertaken by MWRD for the PARP are:

- Upgrade the Calumet, O'Brien, and Stickney facilities by January 1, 2030, to meet the TP effluent limit of an annual geometric mean of 0.5 mg/L
- Continue Continuous Dissolved Oxygen Monitoring (CDOM) in the CAWS per the Illinois EPA-approved Quality Assurance Project Plan (QAPP), dated July 1, 2016 (MWRD, 2016)
- Conduct CDOM monitoring in Grand Calumet River at Torrence Avenue every three years for the period of March to September
- Conduct Ambient Water Quality Monitoring in the CAWS per the Illinois EPA-approved QAPP dated April 1, 2019 (MWRD, 2019)
- Collaborate with IDEM and other stakeholders in Indiana to reduce the unnatural growth of algae in Indiana's portion of the GCR
- Conduct a special monitoring study in the Upper NSC to determine the cause of high chlorophyll-a and supersaturation DO during the period of November to April when no water is diverted from Lake Michigan
- Work with the US Army Corps of Engineers to complete the McCook Reservoir Stage II Project

Additional actions that MWRD may consider include:

- Collaborate with regional agencies such as the Chicago Metropolitan Agency for Planning (CMAP) on technical assistance resources for communities, such as a developing guide for ordinance updates
- Encourage communities in Little Calumet and Calumet-Sag watersheds to develop enhanced street sweeping and leaf collection practices
- Develop educational material for the public on the benefits of green infrastructure
- Work with communities on long-term maintenance of stormwater facilities as part of the MWRD Stormwater Management Program regulatory function
- Consider incorporating factors such as the potential for phosphorus reduction when evaluating applications for projects submitted by local municipalities and other governmental organizations through MWRD Stormwater Partnership Programs.

5. ADAPTIVE MANAGEMENT

The PARP provides a flexible and adaptable roadmap for addressing unnatural algal growth in the CAWS. This section outlines an adaptive management framework to reasonably accommodate potential challenges. This section is provided for future consideration for MWRD and Illinois EPA

Adaptive management is an iterative process that involves continual monitoring to assess the performance of management actions and enable responsiveness to potential challenges. It promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood.

An adaptive management protocol for the PARP should account for needed changes as information becomes available, environmental and land use conditions change, or the policy environment changes. The protocol should be based on a fixed recurring time period of ten years for assessing outcomes and future actions. This fixed schedule will support a planning and decision-making process to account for trends that need to be considered for the next 10-year endpoint. The review and assessment should consider cumulative changes resulting from project implementation, land use changes, regulatorily driven change, and the anticipated 10-year water quality outcomes. Documentation of significant management actions for watershed-based changes is essential to provide a historical record that can be reviewed if conditions change, and additional corrective actions are needed.

The major areas warranting review and documentation for adaptive management are WRP upgrades, improvement in Grand Calumet River (GCR) water quality, and construction of the McCook Stage 2 Reservoir.

WRP Upgrades: MWRD is currently upgrading the Stickney, O'Brien, and Calumets WRPs to meet the TP effluent annual geometric mean target limit of 0.5 mg/L by January 2030. The assessment of the reduction in unnatural algal growth will be an important benchmark for the PARP implementation. This assessment can be conducted using the instream discrete and continuous water quality data collected by MWRD every year.

GCR Water Quality Improvements: Illinois EPA and environmental groups should continue to engage with the IDEM on the implementation of projects to address unnatural algal growth in the GCR in Indiana. The impact of future improvements in GCR water quality in Indiana can be assessed using the data collected at the Next Generation Water Observation System (NGWOS) USGS 05536356.

McCook Stage 2 Reservoir Construction: The completion of the McCook Stage 2 Reservoir is anticipated to significantly reduce CSOs into Bubbly Creek, which significantly impact DO under existing conditions. Pre- and post-monitoring of Bubbly Creek is recommended to assess the impact of McCook Stage 2 reservoir construction on unnatural algal growth in Bubbly Creek.

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