Lower Great Miami River Nutrient Management Project

GMRWN Seminar: Nutrient Impairment of Surface Waters

September 11, 2019

Derek Schlea,
LimnoTech

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Lower Great Miami River Nutrient Management Project

Agenda:

- Project Goal
- Overview of Work Completed
  - Original Model Development and Application
  - Supplemental Modeling
- Nutrient Reduction Scenarios
  - Overview
  - Summary of Results
- Findings

Project Goal:

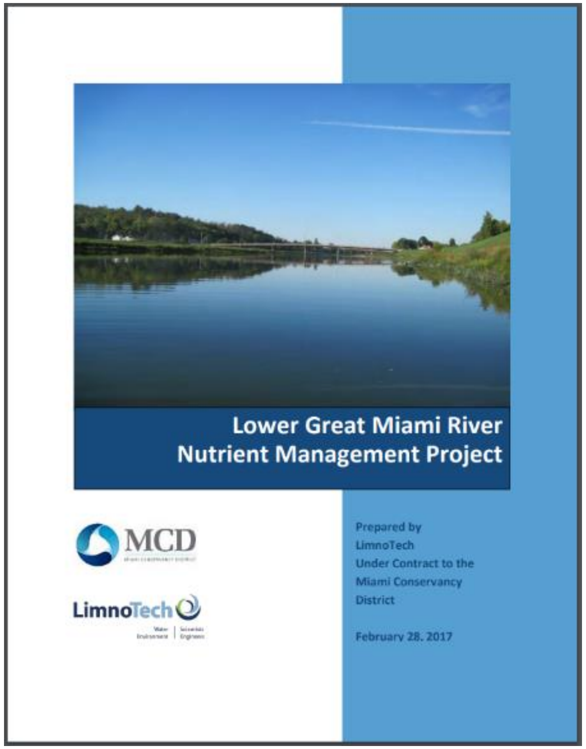
- "…**develop a water quality model** that builds on…sampling by the WRRFs, MCD, OEPA and others…"
  - Include "…**nutrient sources**…and the necessary water quality and **nutrient transport dynamics**…"
  - Scientifically sound
- Use model to estimate the effect of nutrient reduction on dissolved oxygen and algal growth in the river

Overview of Work Completed

Lower Great Miami River Nutrient Management Project

Original Work Completed:

- Data compilation and review
- Model selection
- Model development & calibration
  - Watershed model
  - River hydrodynamic model
  - River water quality model
- Apply model to nutrient reduction scenarios

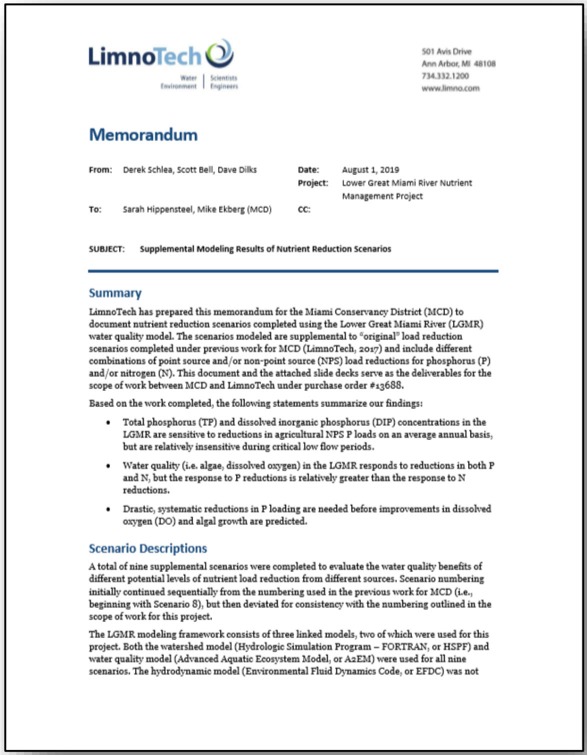


Report available on MCD web site: https://www.mcdwater.org/water-studies/

Lower Great Miami River Nutrient Management Project

Supplemental Scenarios:

- Apply model to additional nutrient reduction scenarios
  - What nutrient load reduction is needed to move the water quality needle?
  - Evaluate the potential benefits of reducing non-point source and point source phosphorus loads
  - Evaluate the effect of nitrogen load reductions



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Memorandum

From:	Derek Schlea, Scott Bell, Dave Dilks	**Date:**	August 1, 2019
		Project:	Lower Great Miami River Nutrient Management Project
To:	Sarah Hippensteel, Mike Ekberg (MCD)	**CC:**	

SUBJECT: **Supplemental Modeling Results of Nutrient Reduction Scenarios**

Summary

LimnoTech has prepared this memorandum for the Miami Conservancy District (MCD) to document nutrient reduction scenarios completed using the Lower Great Miami River (LGMR) water quality model. The scenarios modeled are supplemental to "original" load reduction scenarios completed under previous work for MCD (LimnoTech, 2017) and include different combinations of point source and/or non-point source (NPS) load reductions for phosphorus (P) and/or nitrogen (N). This document and the attached slide decks serve as the deliverables for the scope of work between MCD and LimnoTech under purchase order #13688.

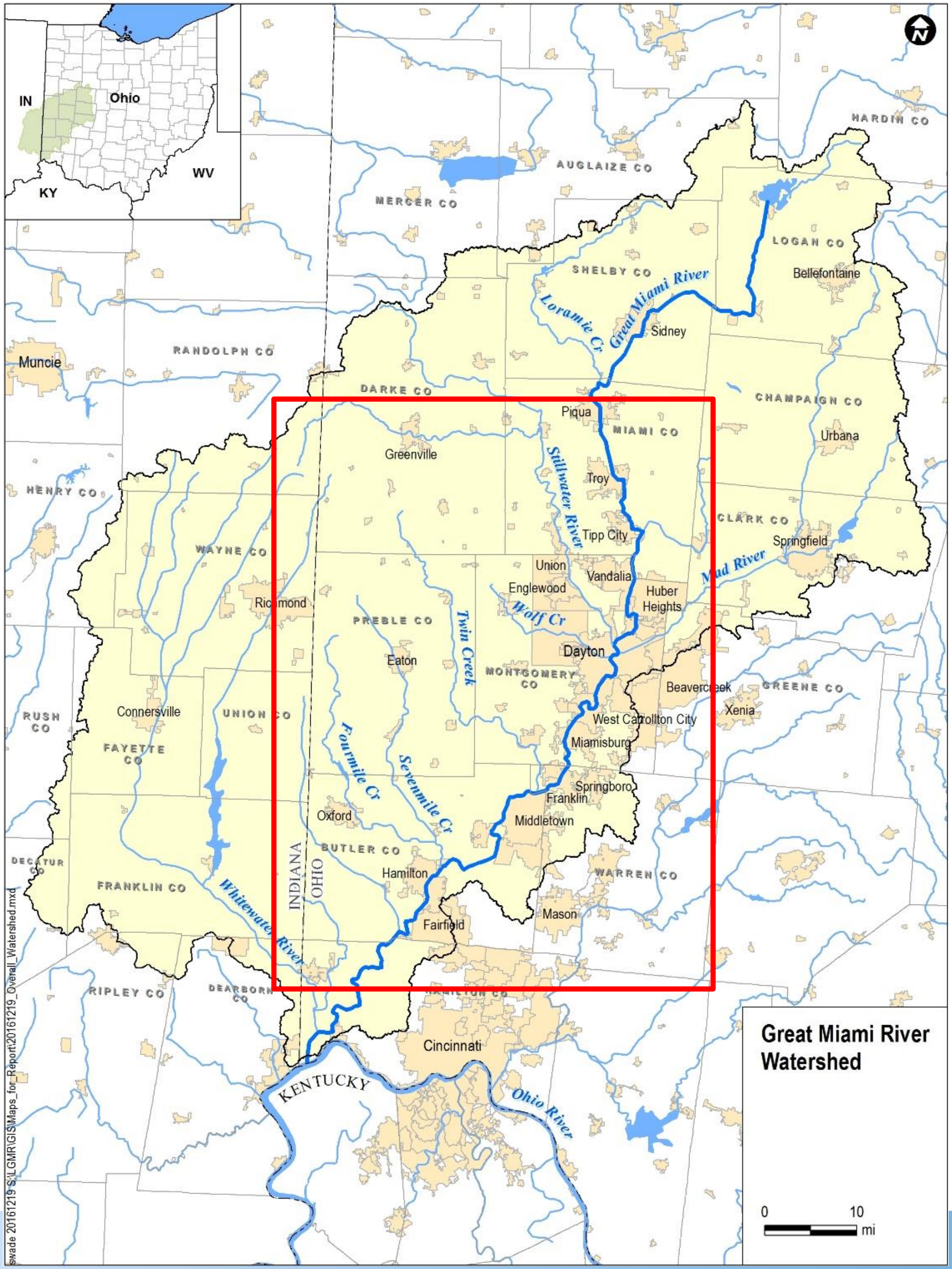
Based on the work completed, the following statements summarize our findings:

- Total phosphorus (TP) and dissolved inorganic phosphorus (DIP) concentrations in the LGMR are sensitive to reductions in agricultural NPS P loads on an average annual basis, but are relatively insensitive during critical low flow periods.
- Water quality (i.e. algae, dissolved oxygen) in the LGMR responds to reductions in both P and N, but the response to P reductions is relatively greater than the response to N reductions.
- Drastic, systematic reductions in P loading are needed before improvements in dissolved oxygen (DO) and algal growth are predicted.

Scenario Descriptions

A total of nine supplemental scenarios were completed to evaluate the water quality benefits of different potential levels of nutrient load reduction from different sources. Scenario numbering initially continued sequentially from the numbering used in the previous work for MCD (i.e., beginning with Scenario 8), but then deviated for consistency with the numbering outlined in the scope of work for this project.

The LGMR modeling framework consists of three linked models, two of which were used for this project. Both the watershed model (Hydrologic Simulation Program – FORTRAN, or HSPF) and water quality model (Advanced Aquatic Ecosystem Model, or A2EM) were used for all nine scenarios. The hydrodynamic model (Environmental Fluid Dynamics Code, or EFDC) was not


Great Miami River Watershed
0 10 mi
IN
Ohio
KY
WV
HARDIN CO
AUGLAIZE CO
MERCER CO
LOGAN CO
Bellefontaine
SHELBY CO
Great Miami River
Loramie Cr
Sidney
RANDOLPH CO
Muncie
DARKE CO
CHAMPAIGN CO
Piqua
MIAMI CO
Urbana
Greenville
Stillwater River
Troy
HENRY CO
CLARK CO
Tipp City
Springfield
WAYNE CO
Union
Vandalia
Mad River
Englewood
Huber Heights
Richmond
PREBLE CO
Twin Creek
Wolf Cr
Dayton
Eaton
MONTGOMERY CO
Beavercreek
GREENE CO
Xenia
RUSH CO
Connersville
UNION CO
West Carrollton City
FAYETTE CO
Fourmile Cr
Sevenmile Cr
Miamisburg
Springboro
Franklin
Oxford
Middletown
DECATUR CO
BUTLER CO
INDIANA
OHIO
Hamilton
WARREN CO
FRANKLIN CO
Whitewater River
Mason
Fairfield
RIPLEY CO
DEARBORN CO
HAMILTON CO
Cincinnati
KENTUCKY
Ohio River
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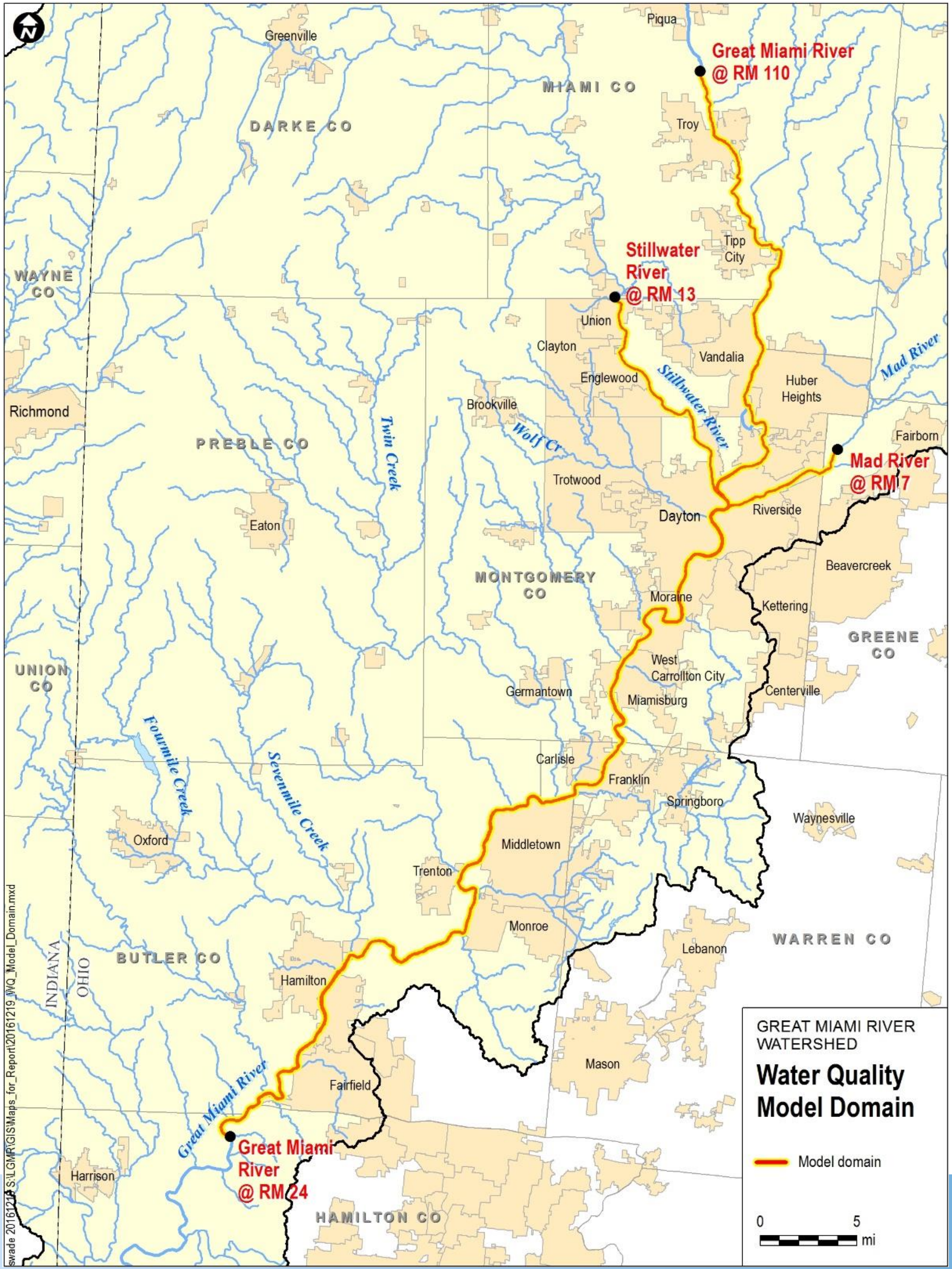

GREAT MIAMI RIVER
WATERSHED
Water Quality
Model Domain
Model domain
0
5
mi
Great Miami River
@ RM 110
Stillwater
River
@ RM 13
Mad River
@ RM 7
Great Miami
River
@ RM 24
Piqua
Greenville
MIAMI CO
DARKE CO
Troy
Tipp
City
WAYNE
CO
Union
Clayton
Vandalia
Englewood
Huber
Heights
Mad River
Richmond
Brookville
Stillwater River
Fairborn
PREBLE CO
Twin Creek
Wolf Cr
Trotwood
Dayton
Riverside
Eaton
Beavercreek
MONTGOMERY
CO
Moraine
Kettering
GREENE
CO
UNION
CO
West
Carrollton City
Germantown
Miamisburg
Centerville
Fourmile Creek
Sevenmile Creek
Carlisle
Franklin
Springboro
Waynesville
Oxford
Middletown
Trenton
Monroe
WARREN CO
BUTLER CO
Lebanon
Hamilton
INDIANA
OHIO
Mason
Fairfield
Great Miami River
Harrison
HAMILTON CO
swade 20161219 S:\LGMR\GIS\Maps_for_Report\20161219_WQ_Model_Domain.mxd

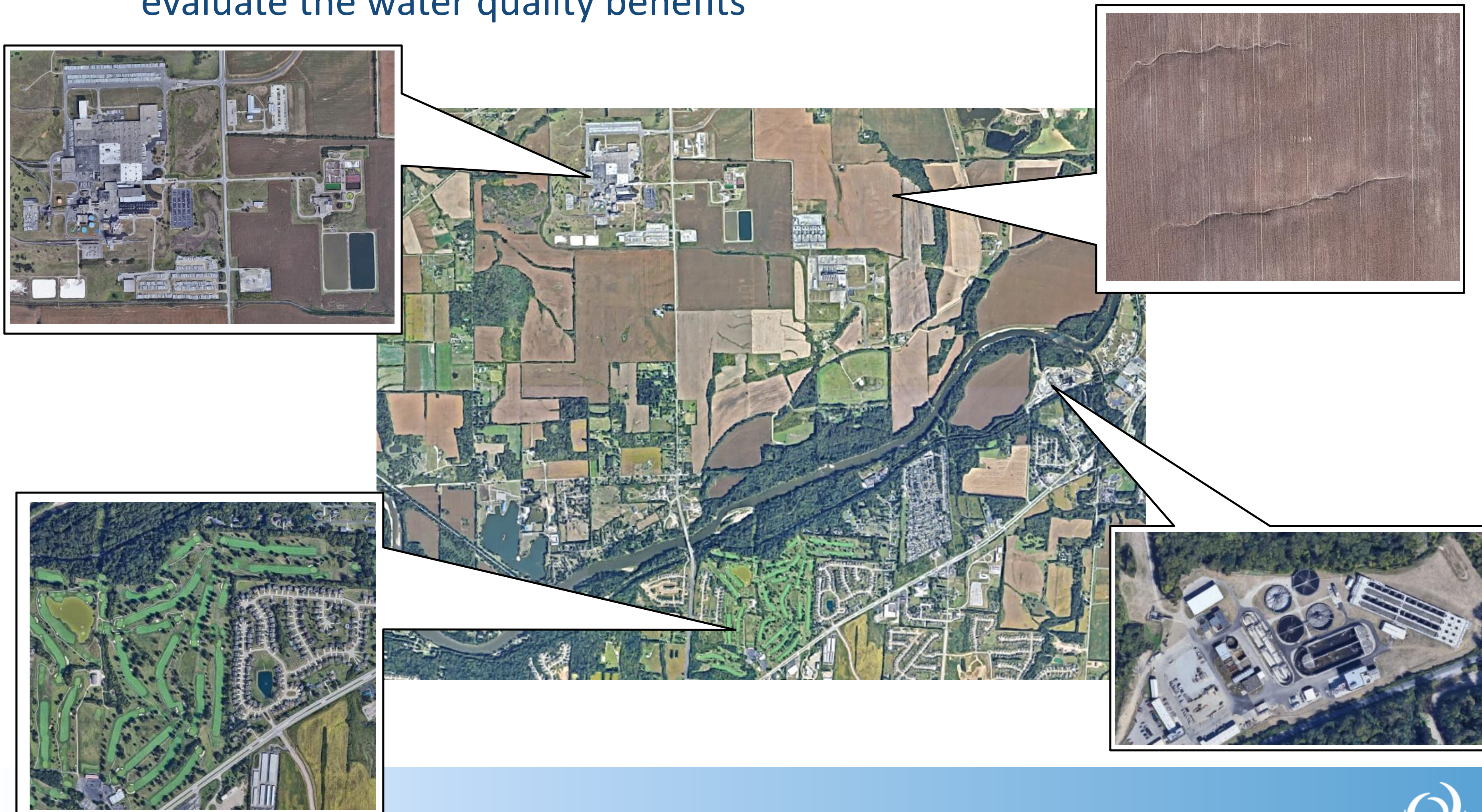
Nutrient Reduction Scenarios

Overview

Lower Great Miami River Nutrient Management Project

Nutrient Reduction Scenarios:

- Simulate potential real-world management actions to comparatively evaluate the water quality benefits



Lower Great Miami River Nutrient Management Project

Nutrient Reduction Scenarios

Point Sources	Agricultural Non-Point Source Load Reductions				
	No change	15% P	25% P	40% P	75% P & N
No change	*Baseline*	✓	✓	✓	
Dayton & Montgomery Co. effluent 0.75 mg-P/l	✓				
Dayton & Montgomery Co. effluent 0 mg-P/l	✓				
All major WRRFs *in WQ domain* effluent 0.75 mg-P/l	✓	✓			
All major WRRFs *in WQ domain* effluent 0 mg-P/l	✓				
All major and minor WRRFs effluent 0.75 mg-P/l	✓		✓	✓	
All major and minor WRRFs 60% TN reduction	✓				
All major and minor WRRFs 60% TN reduction <u>and</u> All major and minor WRRFs effluent 0.75 mg-P/l	✓				✓
All major and minor WRRFs effluent 0 mg-P/l	✓				

Original Scenarios

Supplemental Scenarios

Details:

- TP limit of 1 mg/l was simulated assuming 0.75 mg/l (53% ortho-P)
    - Applied July-October only; historical conditions for November-June
- Point source TN reductions were applied the entire year

Average Annual TP Load Reduction *into* the LGMR

Point Sources	Agricultural Non-Point Source Load Reductions				
	No change	15% P	25% P	40% P	75% P & N
No change	-	*8.7%*	*15%*	*23%*	
Dayton & Montgomery Co. effluent 0.75 mg-P/l	*1.5%*				
Dayton & Montgomery Co. effluent 0 mg-P/l	*2.5%*				
All major WRRFs *in WQ domain* effluent 0.75 mg-P/l	*2.8%*	*12%*			
All major WRRFs *in WQ domain* effluent 0 mg-P/l	*4.8%*				
All major and minor WRRFs effluent 0.75 mg-P/l	*5.0%*		*20%*	*28%*	
All major and minor WRRFs 60% TN reduction	-				
All major and minor WRRFs 60% TN reduction and All major and minor WRRFs effluent 0.75 mg-P/l	*5.0%*				*49%*
All major and minor WRRFs effluent 0 mg-P/l	*7.9%*				

Original Scenarios
Supplemental Scenarios

Average Jul-Oct TP Load Reduction *into* the LGMR

Point Sources	Agricultural Non-Point Source Load Reductions				
	No change	15% P	25% P	40% P	75% P & N
No change	*-*	*3.6%*	*6.0%*	*9.6%*	
Dayton & Montgomery Co. effluent 0.75 mg-P/l	*11%*				
Dayton & Montgomery Co. effluent 0 mg-P/l	*17%*				
All major WRRFs *in WQ domain* effluent 0.75 mg-P/l	*20%*	*23%*			
All major WRRFs *in WQ domain* effluent 0 mg-P/l	*33%*				
All major and minor WRRFs effluent 0.75 mg-P/l	*34%*		*40%*	*44%*	
All major and minor WRRFs 60% TN reduction	*-*				
All major and minor WRRFs 60% TN reduction and All major and minor WRRFs effluent 0.75 mg-P/l	*34%*				*52%*
All major and minor WRRFs effluent 0 mg-P/l	*55%*				

Original Scenarios
Supplemental Scenarios

Nutrient Reduction Scenarios

Results

Nutrient Reduction Scenario Results

- Model results are shown in two ways:
  - Time series plots for Fairfield, 2011 – 2013
    - Results shown are monthly average values.

plots for the
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the simulation
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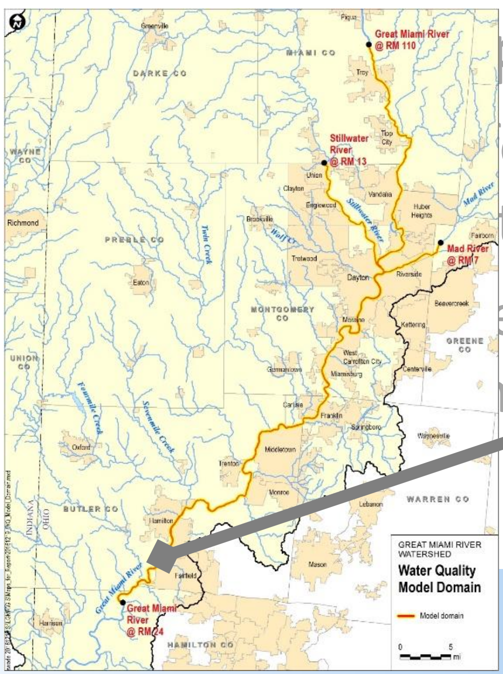
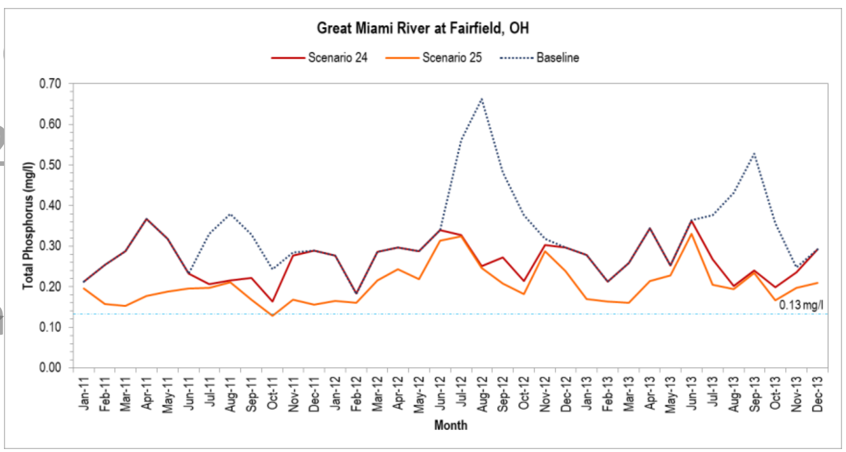
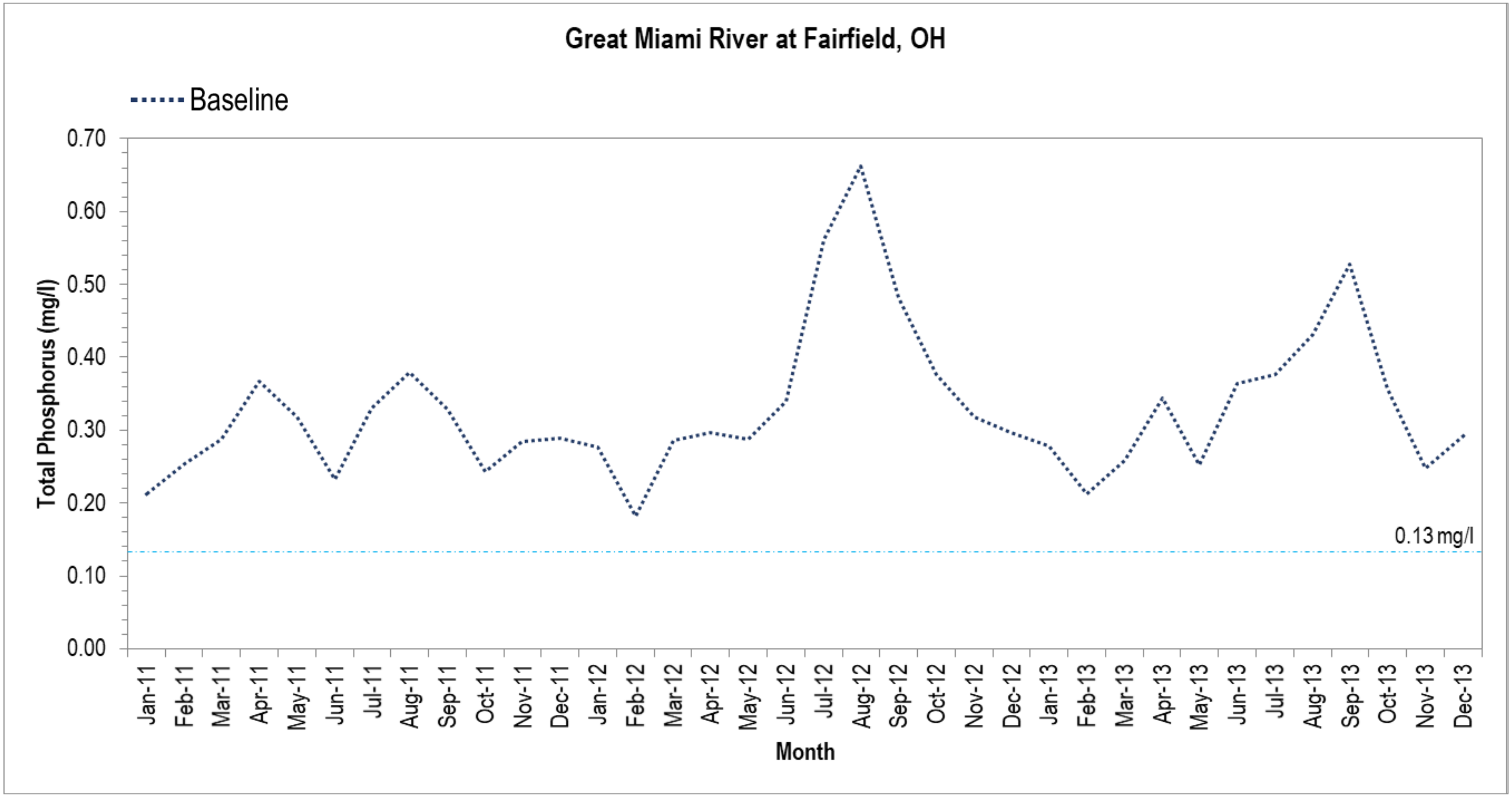
n on the right.



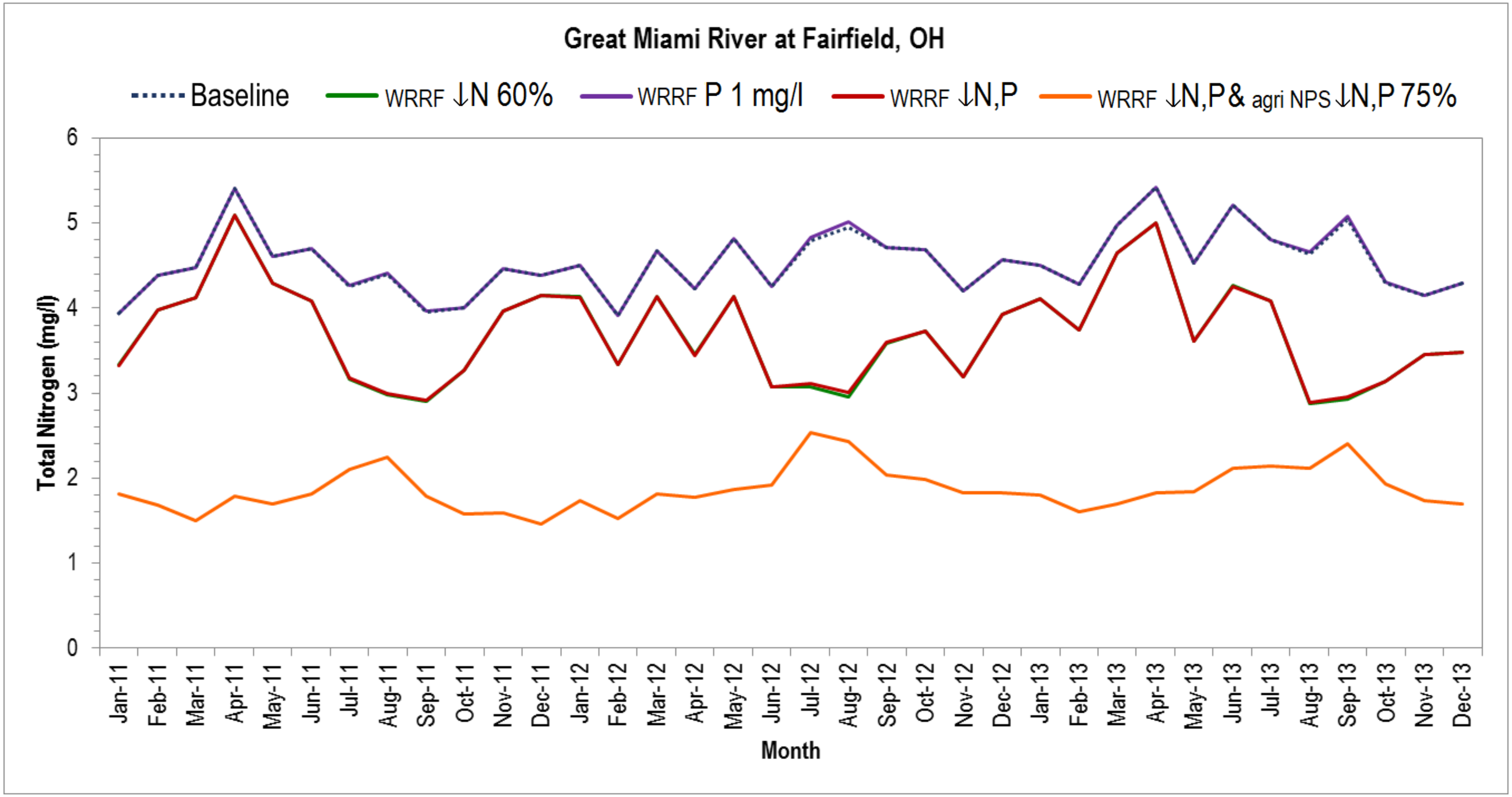


TP Time Series Plot

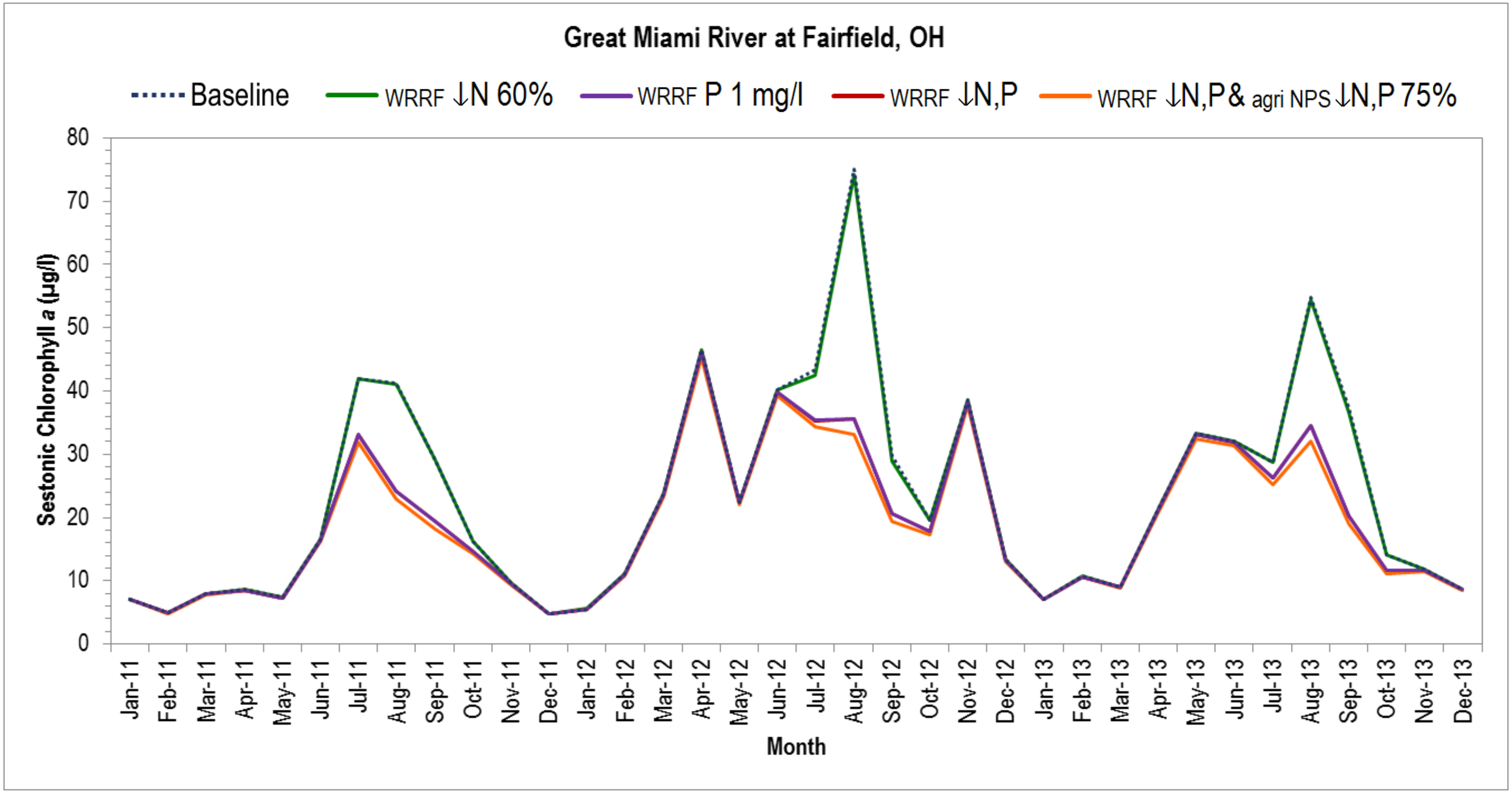


TP=0.13 mg/l suggested as a potential management target for over enriched waters
R.J. Miltner, 2018, Eutrophication endpoints for larger rivers in Ohio, USA. *Environ Monit Assess.*

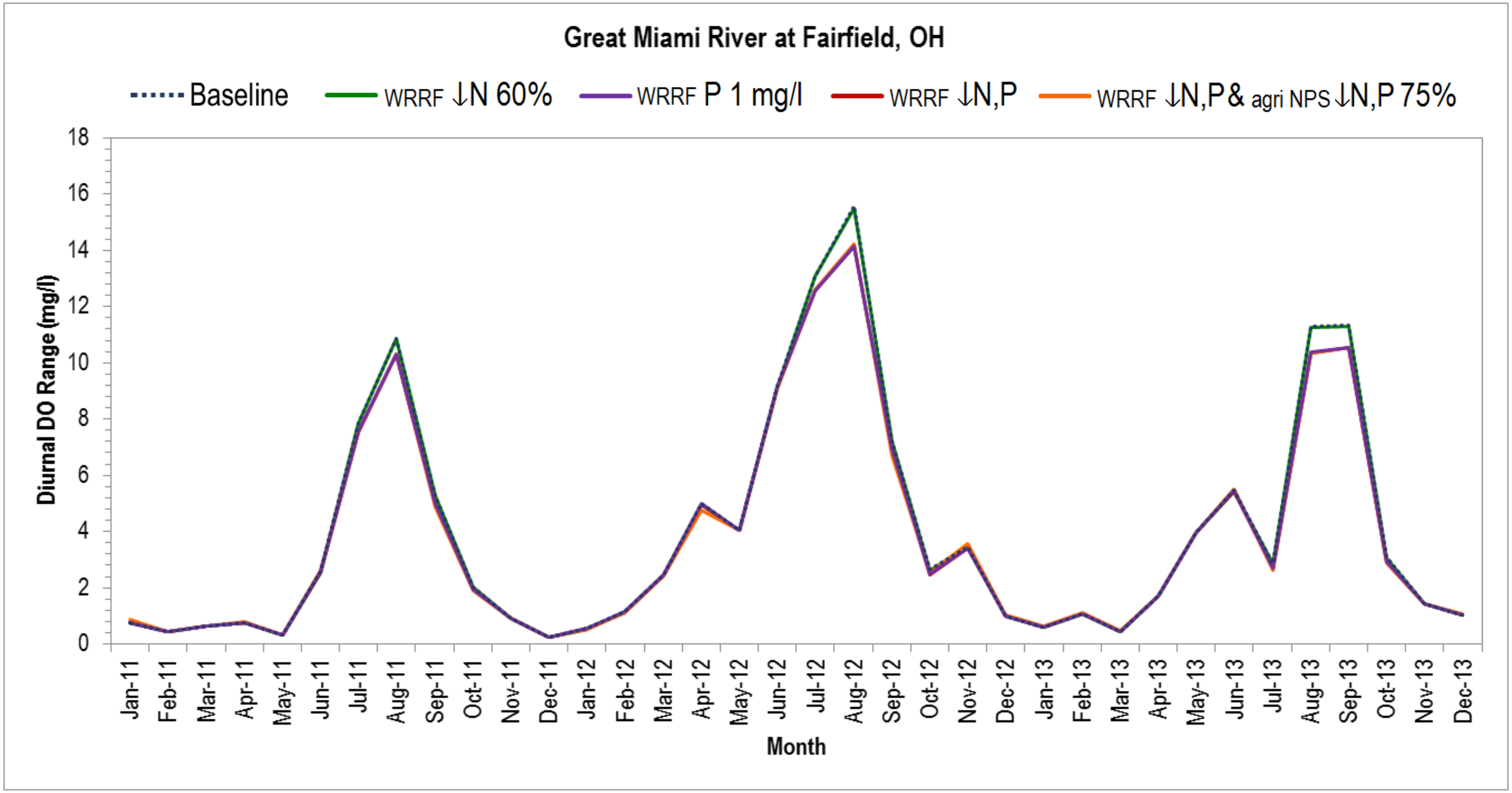
TN Time Series Plot



Sestonic Algae Time Series Plot



Diurnal DO Time Series Plot

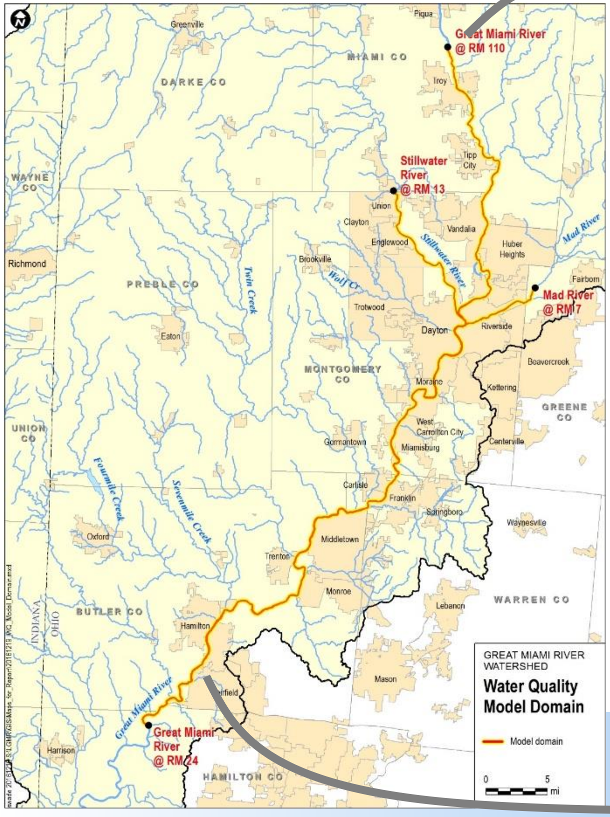


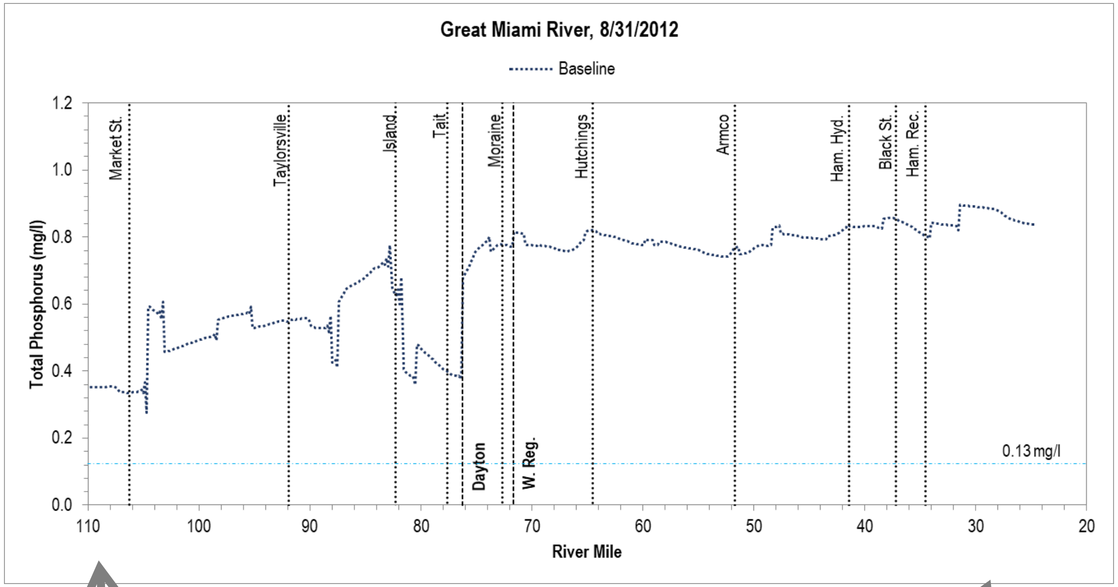
Nutrient Reduction Scenario Results

- Model results are shown in two ways:
  - Time series plots for Fairfield, 2011 – 2013
    - Results shown are monthly average values.
  - Longitudinal plots for the entire LGMR model domain
    - Results are for August 31, 2012, which was the lowest flow date during the simulation period (460 cfs).
    - The plots are oriented with upstream on the left, downstream on the right.

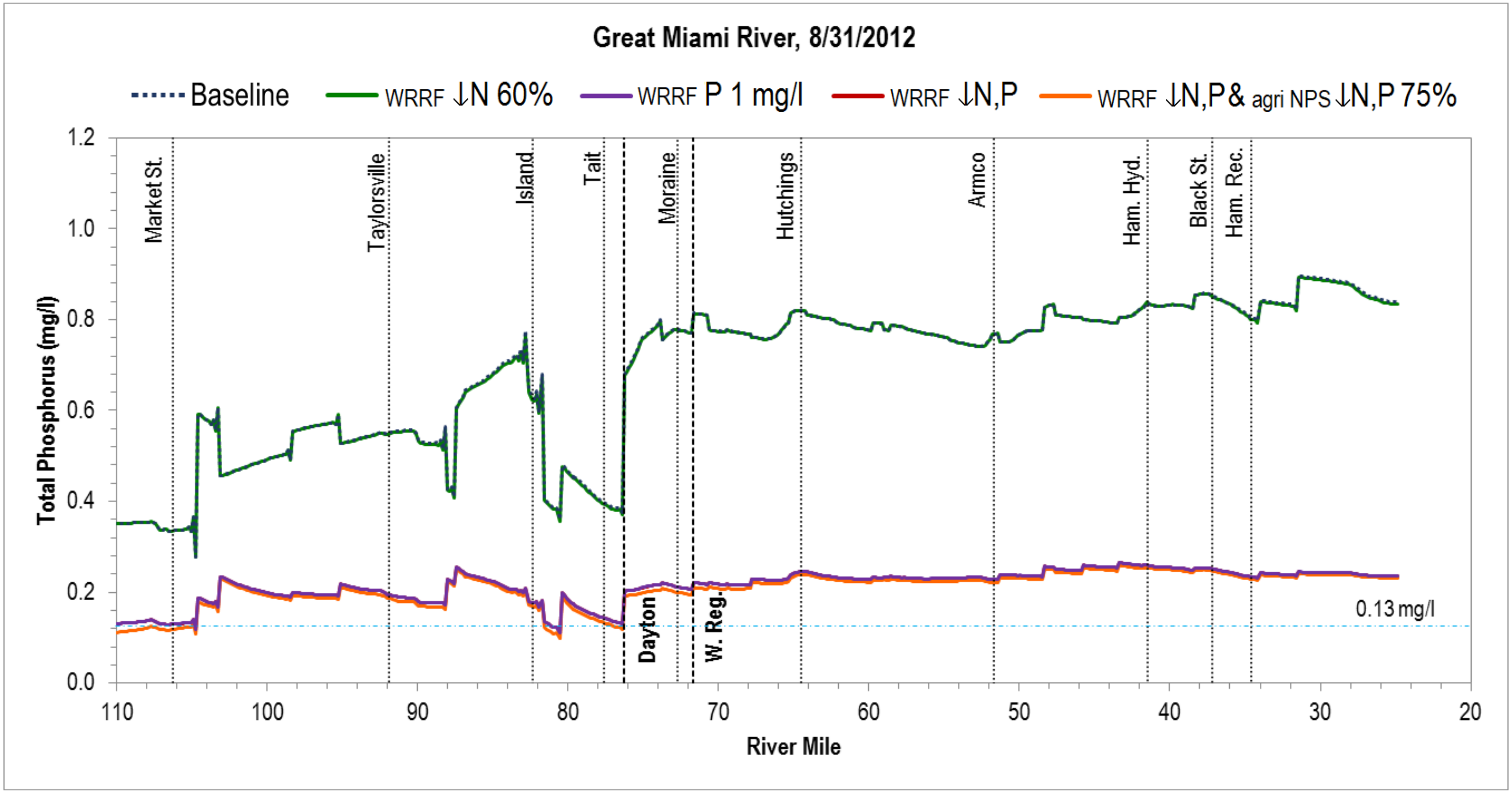
Nutrient Reduction Scenario Results

- Longitudinal plots for the 8/31/12 low flow date
- Key locations shown as vertical lines

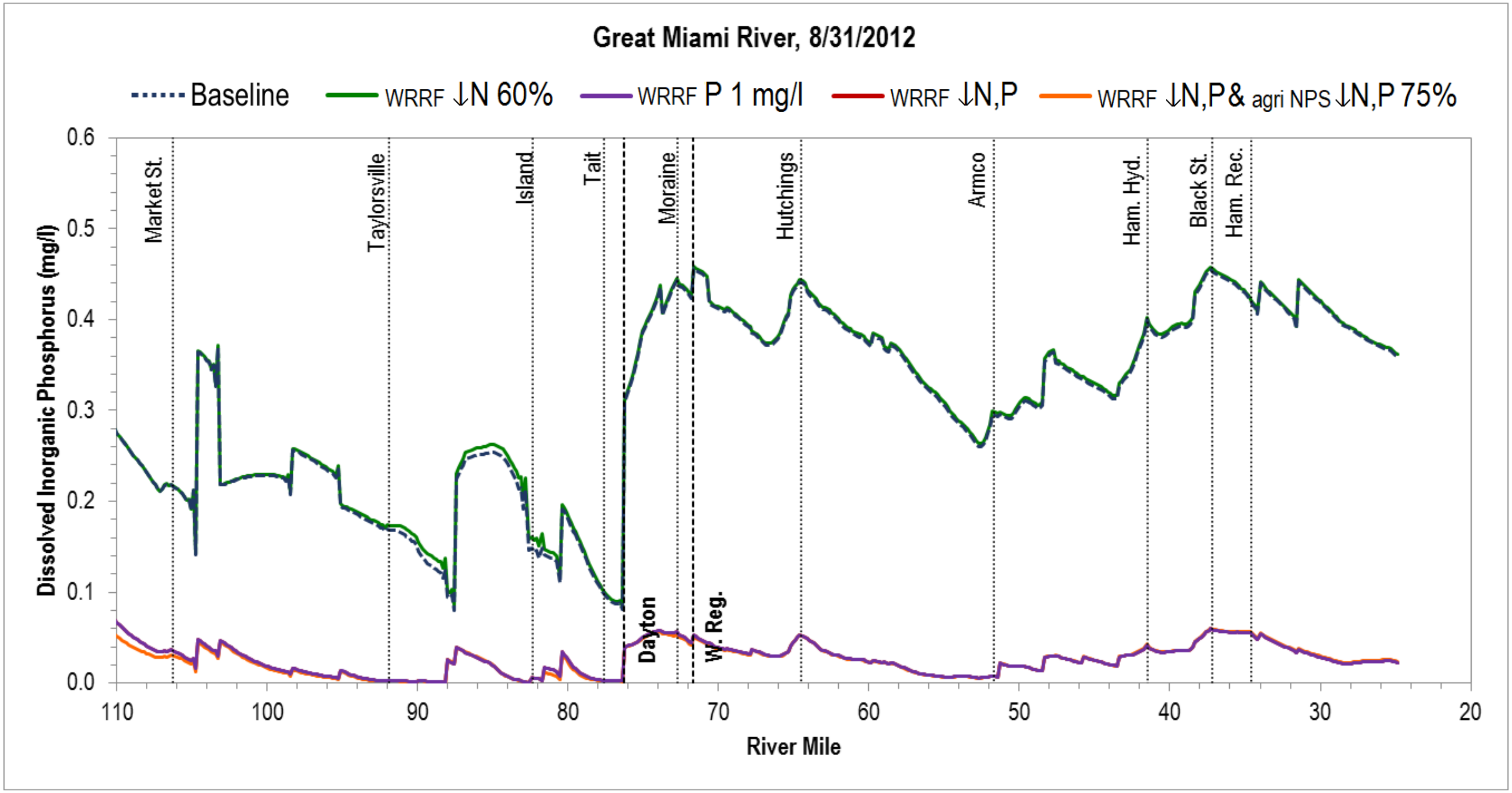




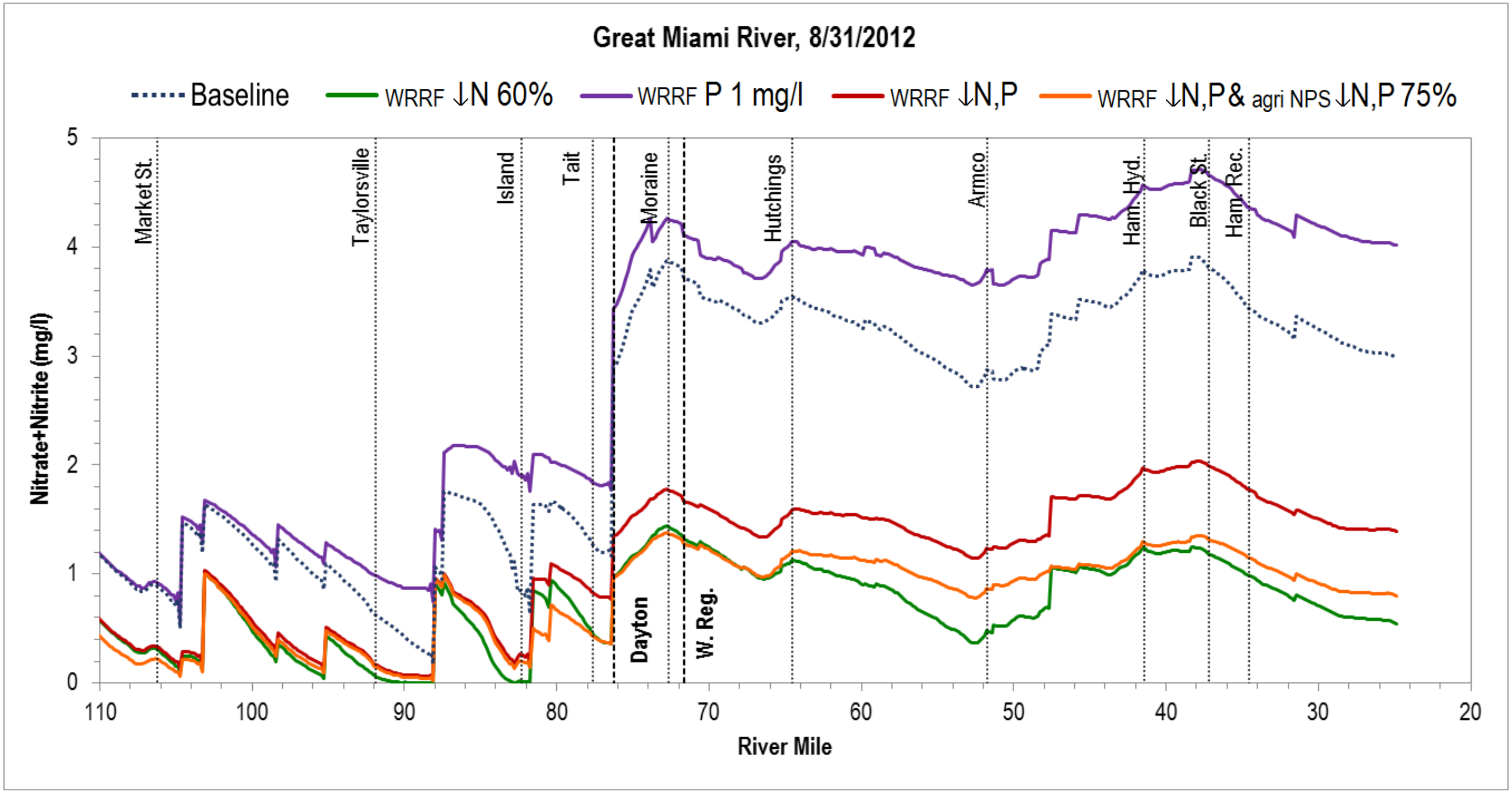
TP Longitudinal Plot



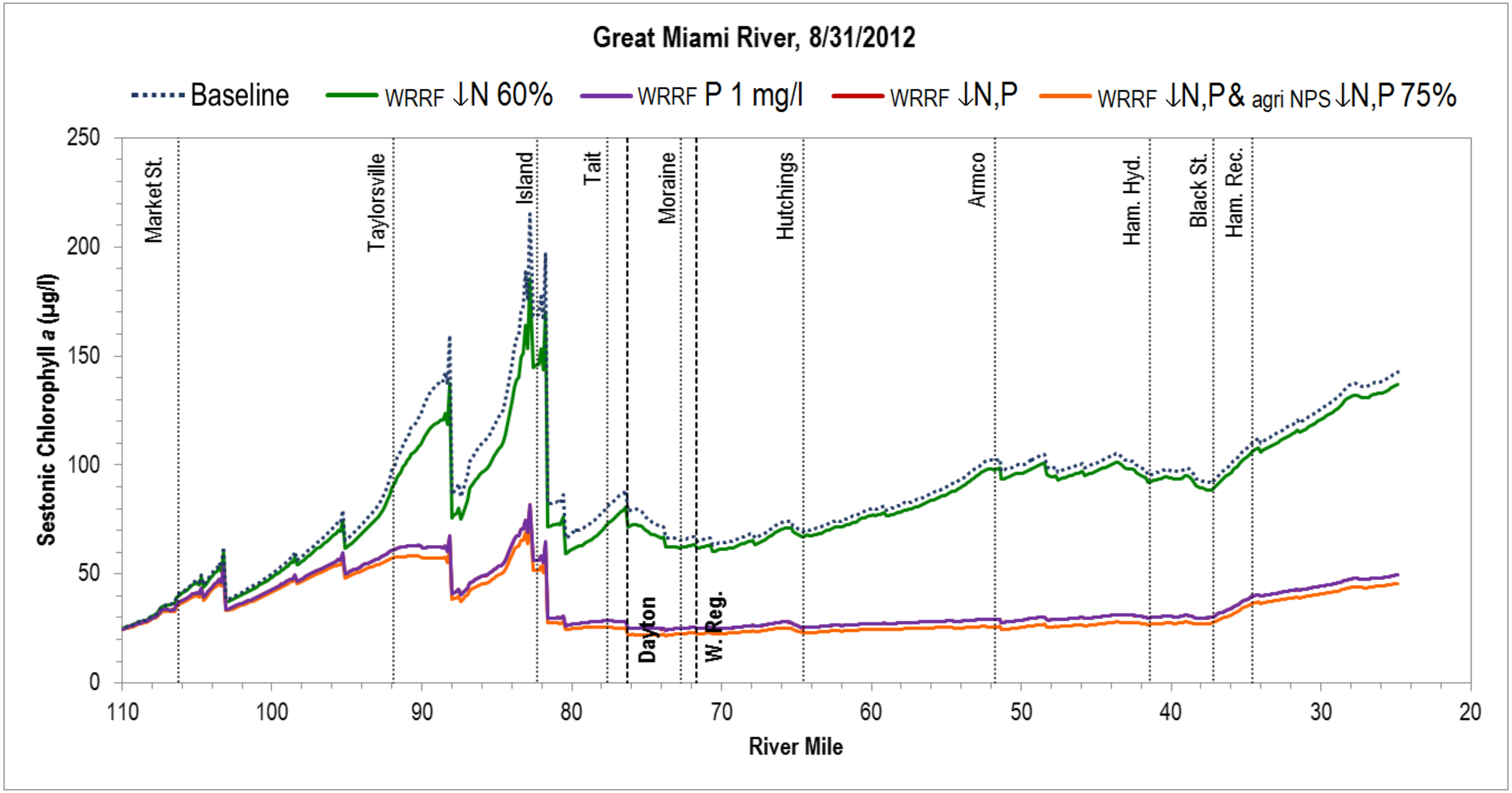
DIP Longitudinal Plot



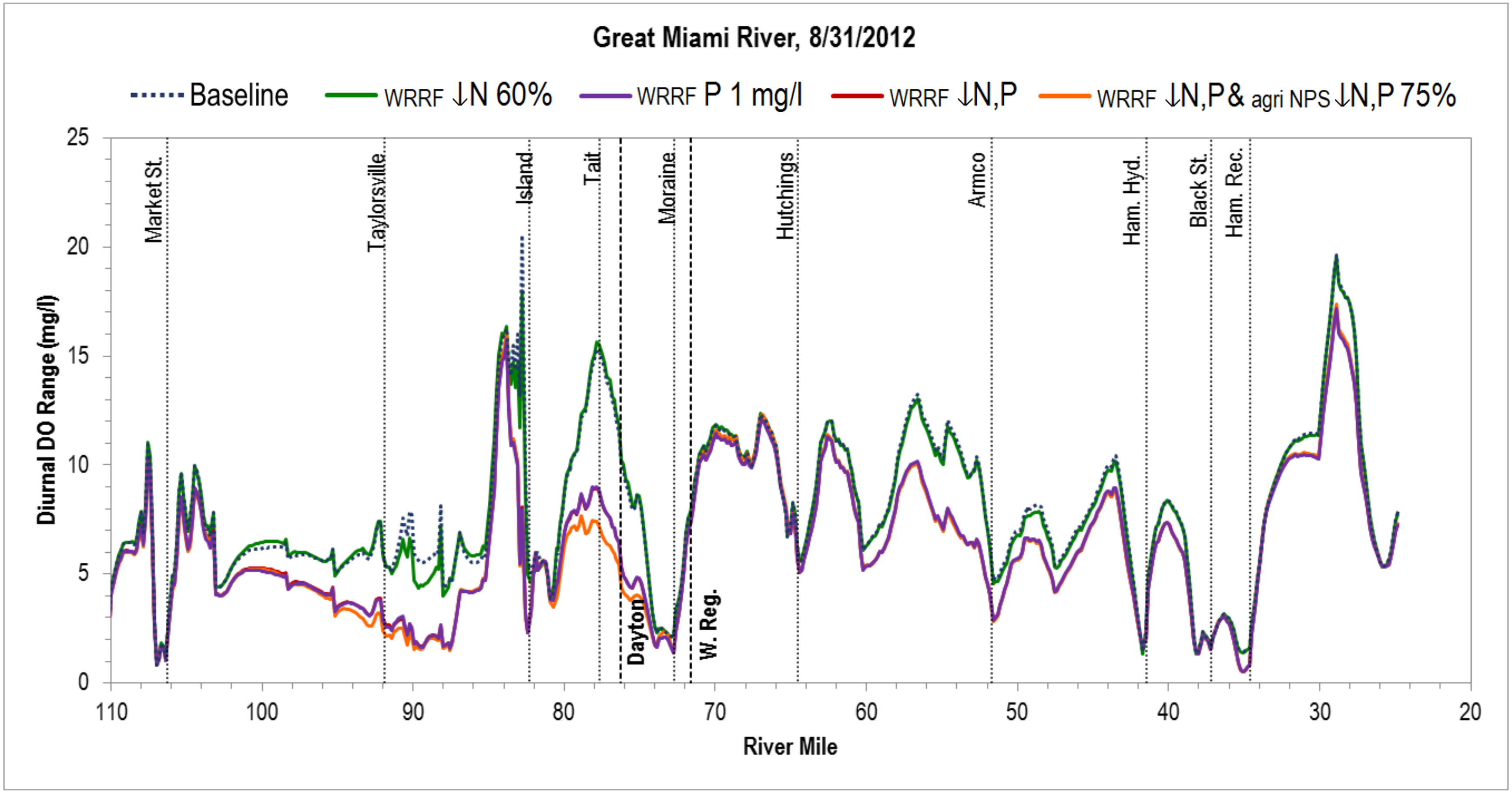
NO2+NO3 Longitudinal Plot



Sestonic Algae Longitudinal Plot



Diurnal DO Longitudinal Plot



Findings:

- Drastic, systematic reductions in phosphorus loading are needed before noticeable improvements in dissolved oxygen and algal growth are predicted.

Findings:

- Water quality (i.e., algae, dissolved oxygen) in the LGMR responds to reductions in both phosphorus and nitrogen, but the response to phosphorus reductions is relatively greater than the response to nitrogen reductions.

Findings:

- Phosphorus concentrations in the LGMR are sensitive to reductions in agricultural non-point source phosphorus loads on an average annual basis, but are relatively insensitive during critical low flow periods.

Questions?

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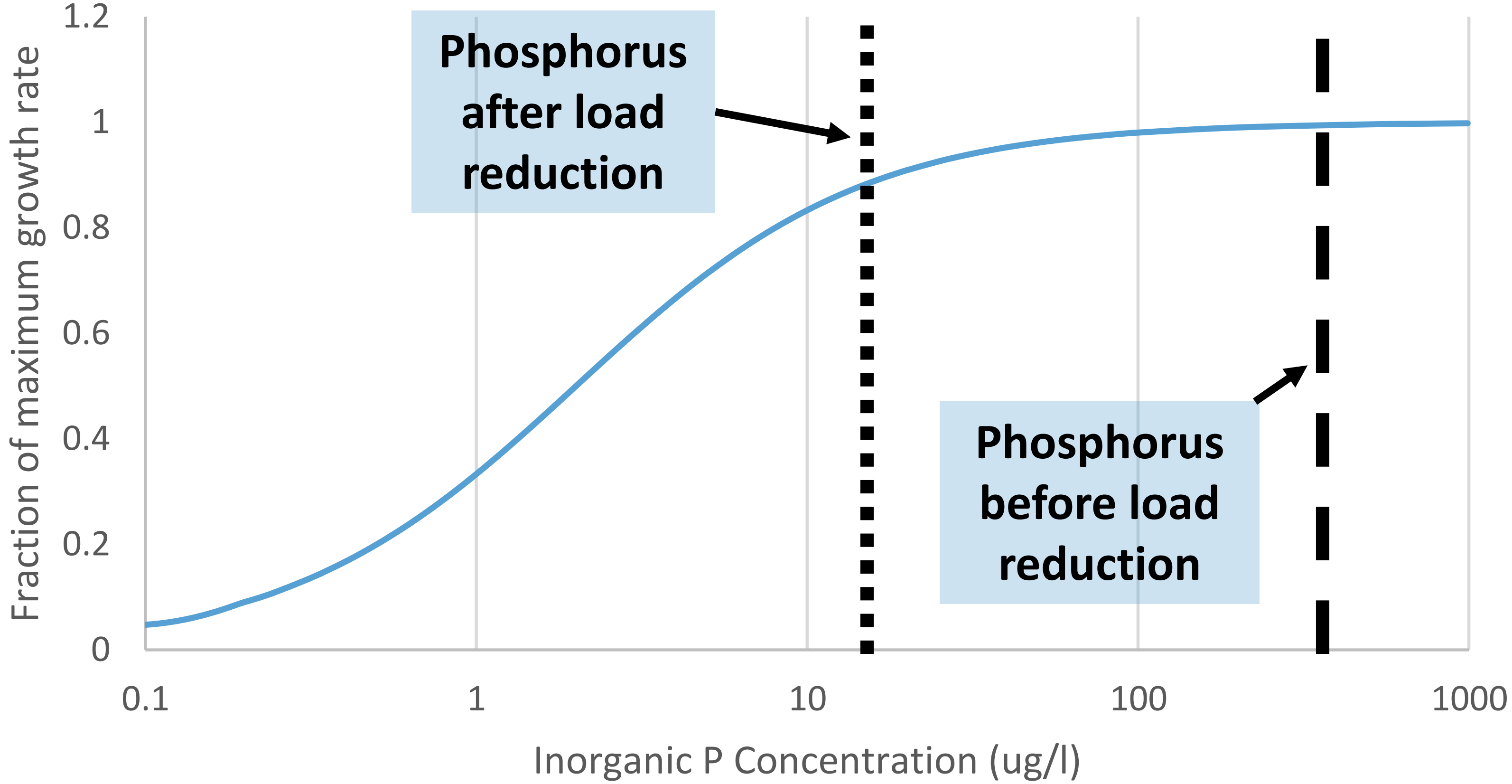
Discussion

Limitation on the Effects of TP Load Reductions

- Phosphorus is still too high to limit algal growth

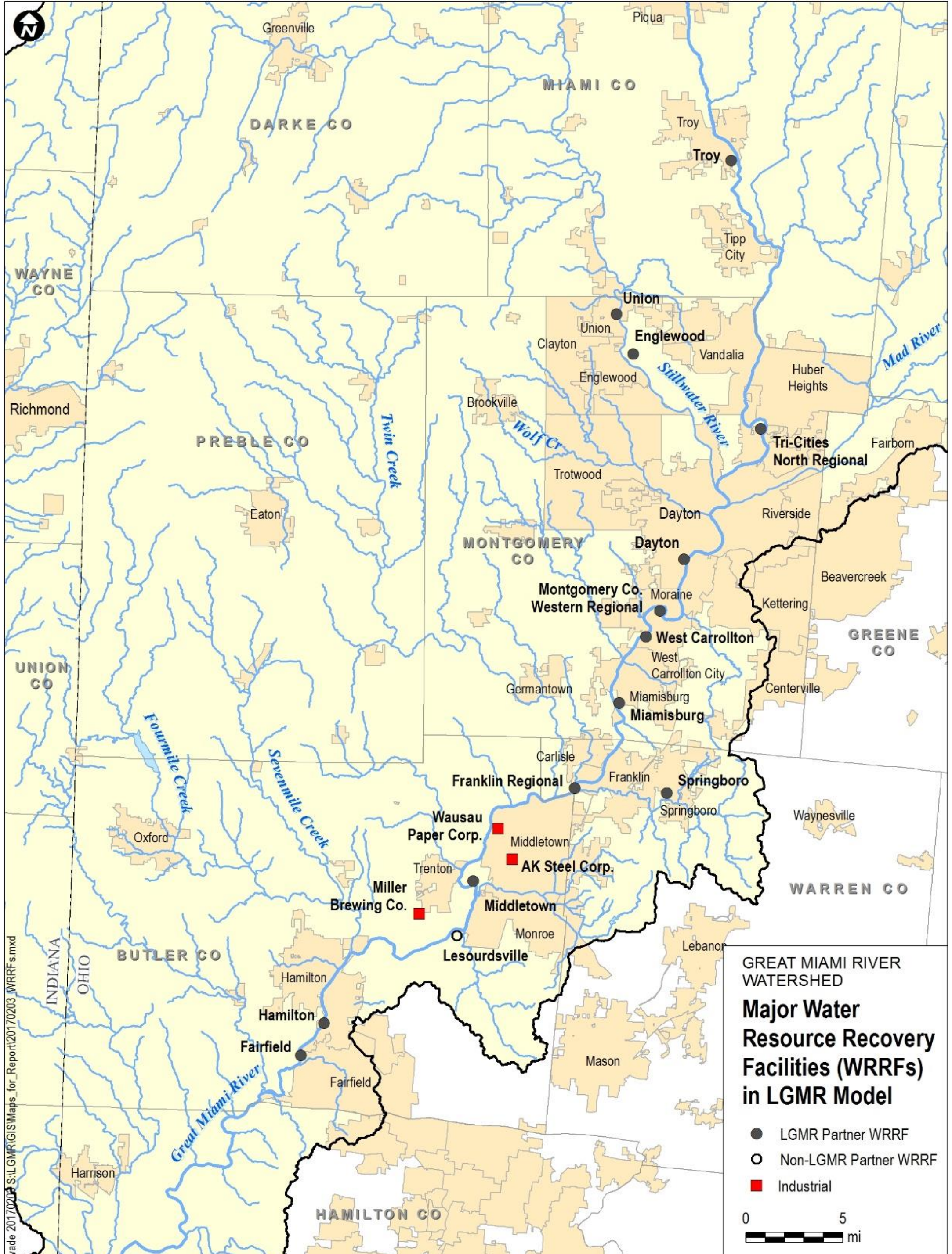


Limiting Nutrients: Liebig's Law of the Minimum

- Growth is dictated not by total resources available, but by the scarcest resource
  – Based on observations that increasing the amount of plentiful nutrients did not increase plant growth
- Water quality management ramifications
  – Often* most efficient to control algal growth by reducing one nutrient to limiting levels
  – Site-specific determination of whether N or P is the most cost-effective to limit**

*Not meant to imply that co-limitation doesn't exist, just that it is typically more economical to control a single nutrient

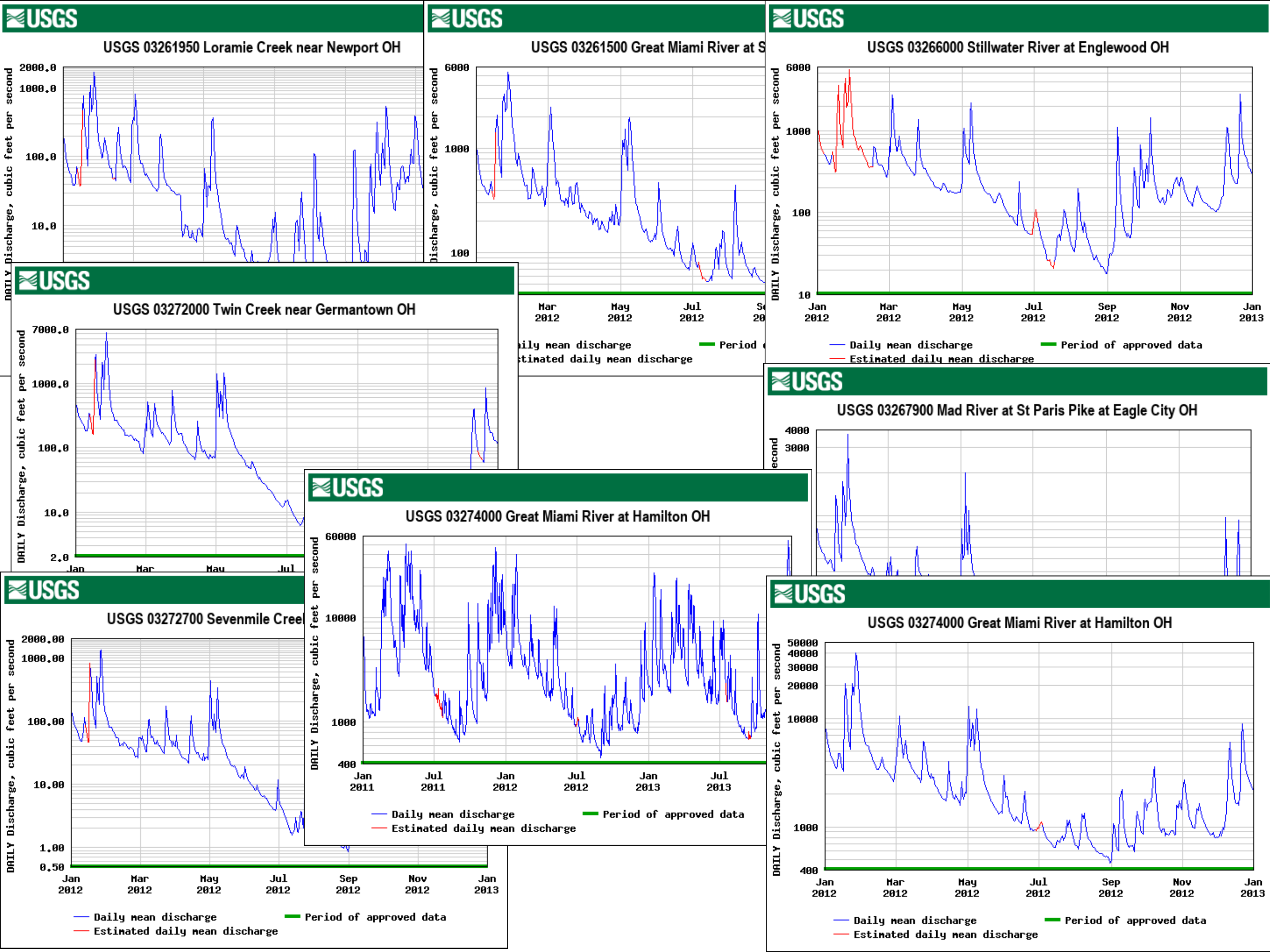
**As a general rule, P has been the most economical to limit in the Midwest. N is more economical to limit in the western US and estuarine waters, due to the relative abundance of naturally-occurring P in those area.



GREAT MIAMI RIVER WATERSHED
Major Water Resource Recovery Facilities (WRRFs) in LGMR Model
LGMR Partner WRRF
Non-LGMR Partner WRRF
Industrial
0
5
mi
Greenville
Piqua
MIAMI CO
DARKE CO
Troy
Troy
Tipp City
WAYNE CO
Union
Union
Clayton
Englewood
Englewood
Vandalia
Huber Heights
Mad River
Stillwater River
Richmond
Brookville
Wolf Cr
Twin Creek
PREBLE CO
Tri-Cities North Regional
Fairborn
Trotwood
Dayton
Riverside
Eaton
Dayton
MONTGOMERY CO
Beavercreek
Montgomery Co. Western Regional
Moraine
Kettering
West Carrollton
West Carrollton City
GREENE CO
UNION CO
Germantown
Miamisburg
Miamisburg
Centerville
Fourmile Creek
Sevenmile Creek
Carlisle
Franklin Regional
Franklin
Springboro
Springboro
Waynesville
Wausau Paper Corp.
Middletown
Oxford
Trenton
AK Steel Corp.
Miller Brewing Co.
Middletown
WARREN CO
Monroe
Lesourdsville
Lebanon
INDIANA
OHIO
BUTLER CO
Hamilton
Hamilton
Fairfield
Fairfield
Mason
Great Miami River
Harrison
HAMILTON CO
swade 20170203 S:\LGMR\GIS\Maps_for_Report\20170203_WRRFs.mxd

Lower Great Miami River Nutrient Management Project

Symbol	Description	Initial value(s)	Calibrated value(s)	Recommended Range (or Value)	Units	Reference(s)
General Water Quality Parameters						
K_{89C}	Mineralization rate of LDOP	0.10	0.10	0.1	/day	QEA, 2009
K_{1415C}	Nitrification rate at 20°C	0.075	0.30	0.1 – 1.0	/day	Brown and Barnwell, 1987
K_{150C}	Denitrification rate at 20°C	0.10	0.05	0.03	/day	QEA, 2009
K_{1921C}	Hydrolysis rate of LPOC	0.10	0.10	0.08	/day	QEA, 2009
K_{210C}	Oxidation rate of LDOC	0.10	0.10	0.10	/day	QEA, 2009
Sestonic Algae						
K_C	Saturated growth rate	2.0-2.3	2.2-2.6	1.5-2.5	/day	Thomann & Mueller 1987
I_S	Saturating algal light intensity	150-200	50	100-400	ly/day	Chapra 1997
K_{mN}	Half saturation constant for N	0.005-0.020	0.010-0.020	0.010-0.020	mg-N/L	Chapra 1997
K_{mP}	Half saturation constant for P	0.005	0.005	0.001-0.005	mg-P/L	Chapra 1997
Benthic Algae						
GRMAXBA	Zero-order maximum growth rate	250	400-1000	15-500	mg-Chla/m^2/day	Flynn et al. 2013
KMPBA	External P half-saturation constant	0.125	0.125	0.005-0.175	mgP/L	Flynn et al. 2013
KQPBA	Intercellular P half-saturation constant	0.00325	0.00325	0.000625-0.0125	mgP/mgC	Flynn et al. 2013
RMAXBA	Maximum respiration rate	0.2	0.4	0.02-0.8	/day	Flynn et al. 2013
EXCBA	Excretion rate	0	0.2	0-0.8	/day	Flynn et al. 2013
DTHBA	Death rate	0.3	0.2	0-0.5	/day	Flynn et al. 2013
KMLBA	Light half-saturation constant	100	50	30-90	ly/day	Flynn et al. 2013



USGS
USGS 03261950 Loramie Creek near Newport OH
DAILY Discharge, cubic feet per second
2000.0
1000.0
100.0
10.0
USGS
USGS 03261500 Great Miami River at S
6000
1000
100
Mar 2012
May 2012
Jul 2012
USGS
USGS 03266000 Stillwater River at Englewood OH
6000
1000
100
10
Jan 2012
Mar 2012
May 2012
Jul 2012
Sep 2012
Nov 2012
Jan 2013
Daily mean discharge
Period of approved data
Estimated daily mean discharge
USGS
USGS 03272000 Twin Creek near Germantown OH
7000.0
1000.0
100.0
10.0
2.0
USGS
USGS 03267900 Mad River at St Paris Pike at Eagle City OH
4000
3000
USGS
USGS 03274000 Great Miami River at Hamilton OH
60000
10000
1000
400
Jan 2011
Jul 2011
Jan 2012
Jul 2012
Jan 2013
Jul 2013
Daily mean discharge
Period of approved data
Estimated daily mean discharge
USGS
USGS 03272700 Sevenmile Creek
2000.00
1000.00
100.00
10.00
1.00
0.50
Jan 2012
Mar 2012
May 2012
Jul 2012
Sep 2012
Nov 2012
Jan 2013
Daily mean discharge
Period of approved data
Estimated daily mean discharge
USGS
USGS 03274000 Great Miami River at Hamilton OH
50000
40000
30000
20000
10000
1000
400
Jan 2012
Mar 2012
May 2012
Jul 2012
Sep 2012
Nov 2012
Jan 2013
Daily mean discharge
Period of approved data
Estimated daily mean discharge

Lower Great Miami River Nutrient Management Project

This report documents work related to the development, calibration and initial application of a water quality model of the lower Great Miami River (LGMR), Ohio. This work was conducted by LimnoTech under contract to the Miami Conservancy District (MCD), on behalf of a partnership of Water Resource Recovery Facilities (WRRFs). The partnership includes: the cities of Dayton, Englewood, Fairfield, Franklin, Hamilton, Miamisburg, Middletown, Springboro, Troy, Union, and West Carrollton; Tri-Cities Wastewater Authority on behalf of the cities of Huber Heights, Vandalia, and Tipp City; and Montgomery County. The purpose of this work was to conduct a scientifically sound evaluation of the potential effects of nutrient load reduction on water quality in the LGMR.

As a result of a water quality investigation of the LGMR conducted by the Ohio Environmental Protection Agency (OEPA) and policy set forth in the 2013 Ohio Nutrient Reduction Strategy, the OEPA notified NPDES permittees in the LGMR that the OEPA was planning to write numeric phosphorus limits into permits starting with the next permit renewal cycle. Although extensive data collection up to this point had defined conditions in the LGMR that were potentially attributed to excessive nutrient loading, specifically large diurnal DO variation and high sestonic chlorophyll, a model had not been developed to evaluate that relationship and estimate the effect of reducing phosphorus loading on these conditions. Several of the WRRFs that would be subject to phosphorus limits in their NPDES permits decided to fund the development of such a model.

The primary purpose of the LGMR water quality model is to comparatively evaluate the water quality benefits of different potential levels of nutrient load reduction, reduction of nutrients from different sources and/or other potential actions, such as dam removal. As part of this project, seven scenarios were run, each of which involved some aspect of potential nutrient load reduction. Those scenarios and their results are described in this section.

Lower Great Miami River Nutrient Management Project

Watershed model

- Used existing HSPF models from MCD
  - Orig. dev. for flood eval.
- Repurposed models by recalibrating hydrology
- Calibrated for nutrients