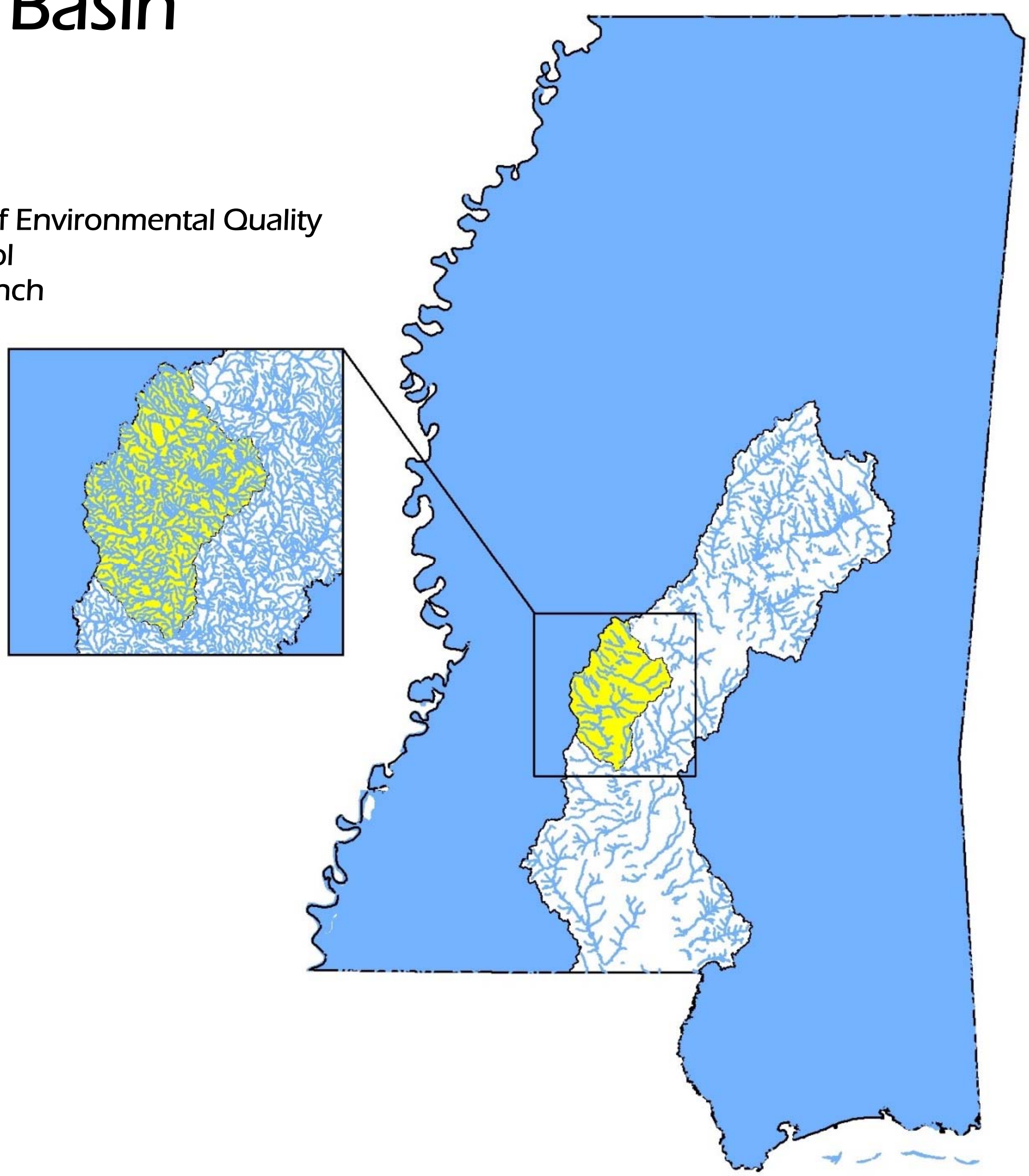
FINAL
April, 2015

Total Maximum Daily Load Total Nitrogen and Total Phosphorus For the Pearl River from Ross Barnett Reservoir to the Strong River Hinds, Rankin, Simpson, and Copiah Counties Pearl River Basin



Prepared By

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FOREWORD

This report contains one or more Total Maximum Daily Loads (TMDLs) for water body segments with previously completed TMDLs. The implementation of the TMDLs contained herein will be prioritized within Mississippi's basin management approach.

As additional information becomes available, the TMDLs may be updated again. Such additional information may include water quality and quantity data, changes in pollutant loadings, modifications to the water quality standards or criteria, or changes in landuse within the watershed. In some cases, additional water quality data may indicate that no impairment exists.

Table 1 Conversion Factors

From	To	multiply by	From	To	multiply by	From	To	multiply by
mi^2	$feet^2$	27,878,400	$meter^3$	liter	1,000	miles	feet	5,280
km^2	$feet^2$	10,763,911	$Feet^3$/sec	gallons/min	448.8312	km	feet	3,280.84
hectares	$feet^2$	107,639	$meter^3$	gallons	264.1721	miles	meters	1,609.34
acre	$feet^2$	43,560	$meter^3$	$Feet^3$	35.3147	meters	feet	3.2808
mi^2	acre	640	$Feet^3$	Liter	28.3168	km	miles	0.6214
km^2	acre	247.1044	$Yard^3$	$Feet^3$	27	days	seconds	86,400
km^2	hectares	100	$Feet^3$	gallons	7.4805	mg/l * MGD	lbs./day	8.3454
hectares	acre	2.4710	$Yard^3$	$meter^3$	0.7646	µg/l * cfs	gm/day	2.4500
km^2	mi^2	0.3861	$Feet^3$/sec	MGD	0.6463	tonnes	ton	1.1

Table 2 Prefix Symbols

Fraction	Prefix	Symbol	Multiple	Prefix	Symbol
10^{-1}	deci	d	10	deka	da
10^{-2}	centi	c	10^2	hecto	h
10^{-3}	milli	m	10^3	kilo	k
10^{-6}	micro	µ	10^6	mega	M
10^{-9}	nano	n	10^9	giga	G
10^{-12}	pico	p	10^{12}	tera	T
10^{-15}	femto	f	10^{15}	peta	P
10^{-18}	atto	a	10^{18}	exa	E

The fonts used in this document are ink saving fonts based on Inkfarm.com ink-usage calculator. Century Schoolbook was selected for the body text. Eras Medium ITC was used for subheadings, and Goudy Old Style was used for headings.

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Table 3 Listing Information

Name	ID	County	Pollutant
Pearl River	MSUMPRLR1E	Hinds, Rankin, Simpson, and Copiah	Total Phosphorus and Total Nitrogen
Location: From Ross Barnett Reservoir to the confluence with the Strong River			

Table 4 Water Quality Standards

Parameter	Beneficial use	Water Quality Criteria
Nutrients Total Phosphorus Total Nitrogen	Aquatic Life Support	Waters shall be free from materials attributable to municipal, industrial, agricultural, or other dischargers producing color, odor, taste, total suspended solids, or other conditions in such degree as to create a nuisance, render the waters injurious to public health, recreation, or to aquatic life and wildlife, or adversely affect the palatability of fish, aesthetic quality, or impair the waters for any designated uses.

Table 5 Total Maximum Daily Load for the Pearl River at Hopewell

	WLA lbs. per day	WLA sw lbs. per day	LA lbs. per day	MOS	TMDL lbs. per day
Total Phosphorus	1,827	381	2,000	implicit	4,208
Total Nitrogen	10,717	10,396	54,620	implicit	75,733

EXECUTIVE SUMMARY

Figure 1 Pearl River

This TMDL updates the 2009 Pearl River Nutrient TMDL for the segment of the river from the Ross Barnett Reservoir to the confluence with the Strong River. This segment is the county boundary between Hinds and Rankin Counties and Copiah and Simpson Counties. It includes several point source discharges. The pollutants of concern are total phosphorus (TP) and total nitrogen (TN).

The previous 2014 Draft TMDL went to public notice March 20, 2014. MDEQ received several comments on that version and in response, prepared this 2014 revised draft version of the TMDL. This revised draft will be sent for public review as well. The 2009 TMDL for the Pearl River utilizes a mass balance approach for TMDL development. It called for a 56% reduction in the TP load to the river. This revised draft updated 2014 TMDL uses dynamic computer model simulations to provide more accurate estimates of the TMDL for this segment of the Pearl River. The modeling allows simulation of the nutrients available in the river and the response variables of dissolved oxygen, dissolved oxygen saturation, and chlorophyll-a. By manipulating the nutrient level reductions, the corresponding responses can be studied to predict expected outcomes. This TMDL provides an estimate of the TN and TP allowable in this river to produce the predicted outcomes.

The limited nutrient information and estimated existing concentrations indicate reductions of nutrients can be accomplished with implementation of best management practices (BMPs) and discharge limitation of TP from the point sources.

The new water quality modeling available for this TMDL indicates an overall reduction of 70% TP will restore water quality in this segment. The TN TMDL will be set based on the reduction of TP. Algal Growth Potential Tests (AGPT) indicate the river is nutrient limited therefore a reduction of the over abundant TP is appropriate and will reduce the combined nutrient pollution in the river.

The nonpoint source loads dominate the loading of nutrients in the river. Modeling indicates that if all of the point source loads were removed, the river would remain impaired. Figure 2 below shows that the complete removal of the TP load from the point sources would not significantly impact the chlorophyll-a in the Pearl River at low flow.

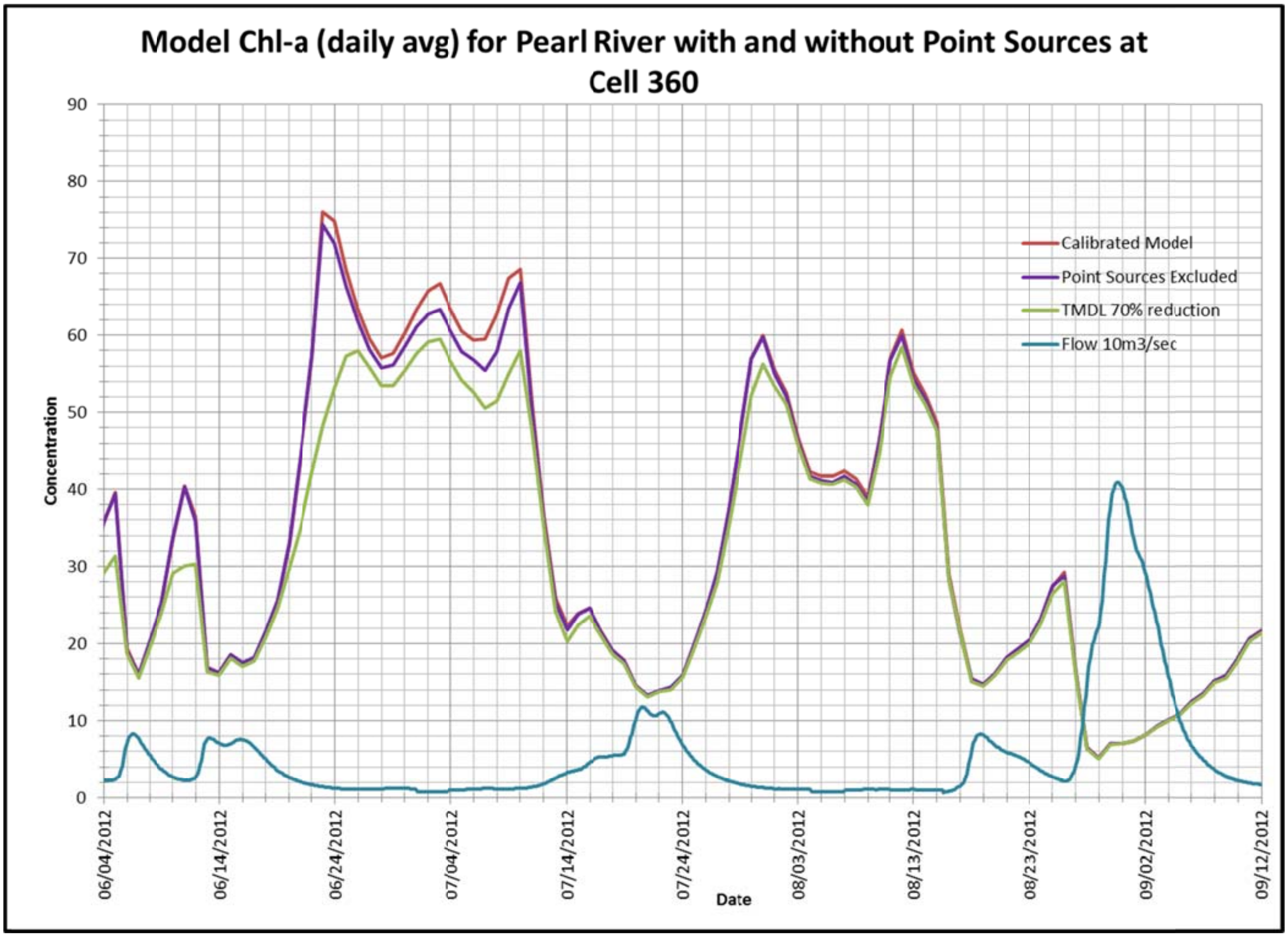

Figure 2 Model Chl-a (daily avg) for Pearl River with and without Point Sources at Cell 360

This TMDL will support voluntary Best Management Practices (BMP) designed to reduce the nonpoint source load of TN and TP as well as apply appropriate TN and TP limitations on the existing and future point sources. Restoration of the water quality depends on the reduction of the nonpoint source loads to this watershed.

INTRODUCTION

1.1 Background

The identification of water bodies not meeting their designated use and the development of total maximum daily loads (TMDLs) for those water bodies are required by Section 303(d) of the Clean Water Act and the Environmental Protection Agency's (EPA) Water Quality Planning and Management Regulations (40 CFR part 130). The TMDL process is designed to restore and maintain the quality of those impaired water bodies through the establishment of pollutant specific allowable loads. This TMDL covers a portion of the 2008 §303(d) listed segments shown in Figure 3, specifically the Pearl River from the Ross Barnett Reservoir to the confluence with the Strong River.

This segment already has an approved nutrient TMDL (2009) that was developed utilizing a mass balance approach for the entire River. This 2014 TMDL uses dynamic computer model simulations (EFDC and WASP) to provide computer simulated causal and response loading for this segment of the Pearl River. This allows for the study of the fate and transport of TN and TP and the response variable chlorophyll-a. The model also has the capability to study the reduction of TN or TP, and select the most efficient pathway toward nutrient pollution control.

1.2 Listing History

The segment was originally listed by evaluating the basin for water bodies that were potentially impaired due to activities within the watersheds. There are no state numeric criteria in Mississippi for nutrients. These numeric criteria are currently being developed by MDEQ. The 2009 TMDL utilized a mass balance approach to determine the TMDL values for TN and TP. Literature values were used to establish the NPDES Permit limits for the major POTWs included in the 2009 TMDL. A second effort began in 2011 to update the 2009 TMDL. That effort was abandoned after determining that better computer modeling would be available in 2013. This 2014 Revised Draft TMDL effort is based on that newer 2013 computer modeling.

1.3 Applicable Water Body Segment Use

The water use classifications are established by the State of Mississippi in The Administrative Procedures Act Rules Title 11, Part 6, Chapter 2: Mississippi Commission on Environmental Quality Regulations for Water Quality Criteria For Intrastate, Interstate, And Coastal Waters Rules 2.2 and 2.4 (MDEQ, 2014).[1] The designated beneficial use for this segment of the Pearl River is Recreation and Aquatic Life Use Support (fish & wildlife classification).

1 Source: Miss. Code Ann. §§ 49-2-1, et seq. and 49-17-1, et seq.

1.4 Applicable Water Body Segment Standard

The water quality standard applicable to the use of the water body and the pollutant of concern is defined in The Administrative Procedures Act Rules Title 11, Part 6, Chapter 2: Mississippi Commission on Environmental Quality Regulations for Water Quality Criteria For Intrastate, Interstate, And Coastal Waters Rule 2.3 (MDEQ, 2014).2

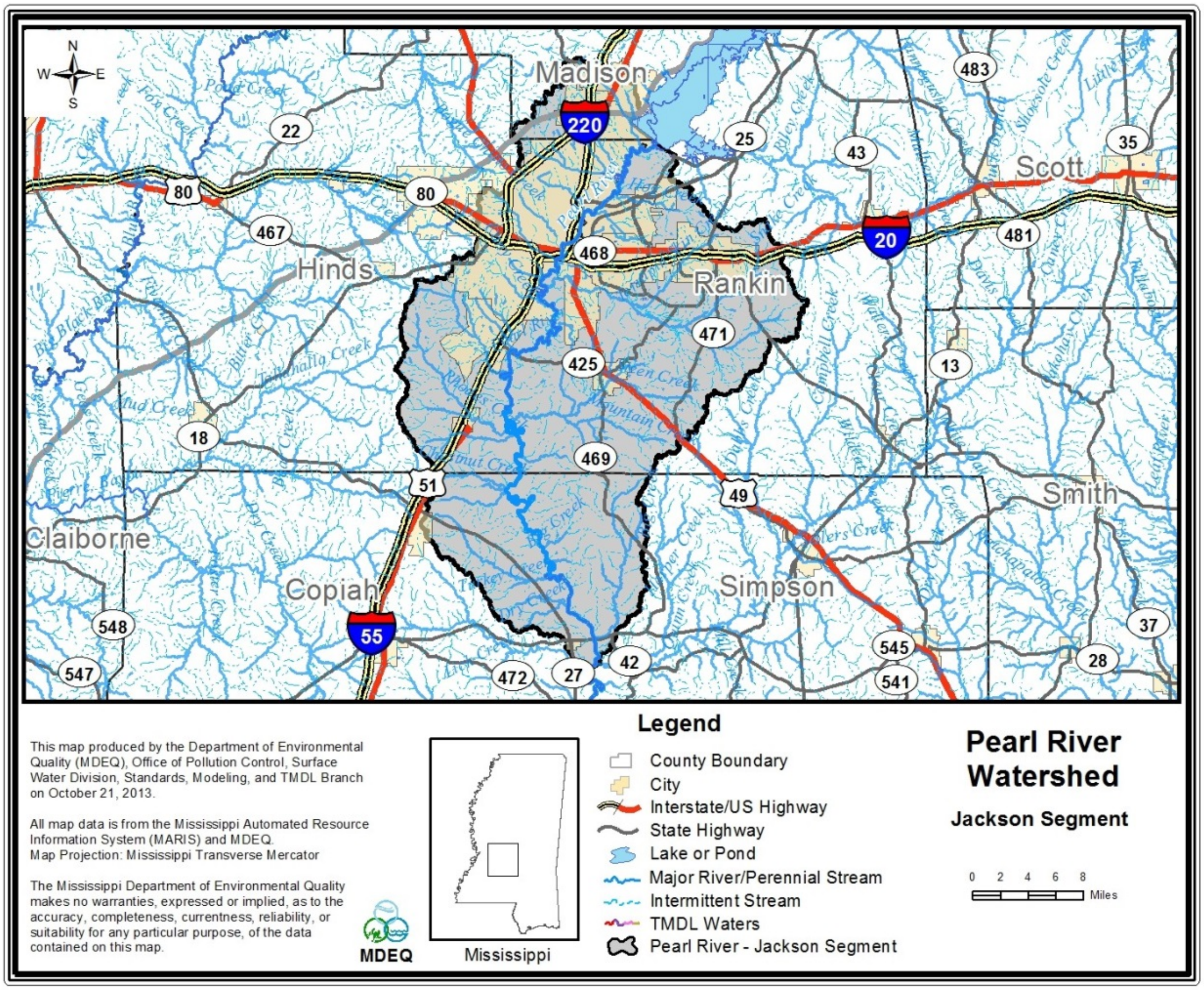

Figure 3 TMDL Segment of the Pearl River

Mississippi's water quality standards contain a narrative criteria that can be applied to nutrients which states "*Waters shall be free from materials attributable to municipal, industrial, agricultural, or other discharges producing color, odor, taste, total suspended or*

2 Ibid.

dissolved solids, sediment, turbidity, or other conditions in such degree as to create a nuisance, render the waters injurious to public health, recreation, or to aquatic life and wildlife, or adversely affect the palatability of fish, aesthetic quality, or impair the waters for any designated use. (MDEQ, 2014)." 3

1.5 Selection of a TMDL Endpoint

One of the major components of a TMDL is the establishment of instream numeric endpoints, which are used to evaluate the attainment of acceptable water quality. Instream numeric endpoints, therefore, represent the water quality goals that are to be achieved by meeting the load and wasteload allocations specified in the TMDL. The endpoints allow for a comparison between observed instream conditions and conditions that are expected to restore designated uses.

Excessive nutrient concentrations in a large river can produce an overabundance of algae that create eutrophic conditions in the river. The algae, through photosynthesis, produce oxygen when exposed to sunlight, and take up oxygen during the night. This diurnal swing in oxygen levels in the stream could lead to an aquatic life impact due to the lack of oxygen available instream. The EFDC / WASP models can simulate this natural phenomenon and predict chlorophyll-a levels as a response to the nutrients (TN and TP) available in the stream.

The WASP model was calibrated to several data sets where dissolved oxygen levels and chlorophyll-a levels were monitored instream during critical climactic conditions in 2012. By calibrating the model to known critical conditions, other less critical conditions can be predicted by the model. (See Appendix A.) The critical cell location determined by the model output for this segment is near Hopewell, MS shown in Figure 5 below (Cell 360). This is also shown in Figure 4 on the previous page which shows the entire model cell structure. The highlighted cell is the critical cell in the model.

The critical cell was identified by reviewing the model output for all of the cells and by comparison identifying the area that was most impacted by the pollutant loading in the model. The comparisons are made both in time and space as the critical condition could be in a different location based on the conditions in the model inputs of weather, flows, pollutant loads, etc.

This TMDL is based on a reaction to reducing nutrient concentrations and studying the corresponding chlorophyll-a and dissolved oxygen levels in the river. Model studies were completed to evaluate which nutrient reduction provided the best control of the response variables in the stream. The model was run with a series of reductions to TP, then with a series of reductions to TN, and finally with combinations of reductions to both nutrients.

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3 Title 11, Part 6, Chapter 2, Rule 2.2.A.(3)

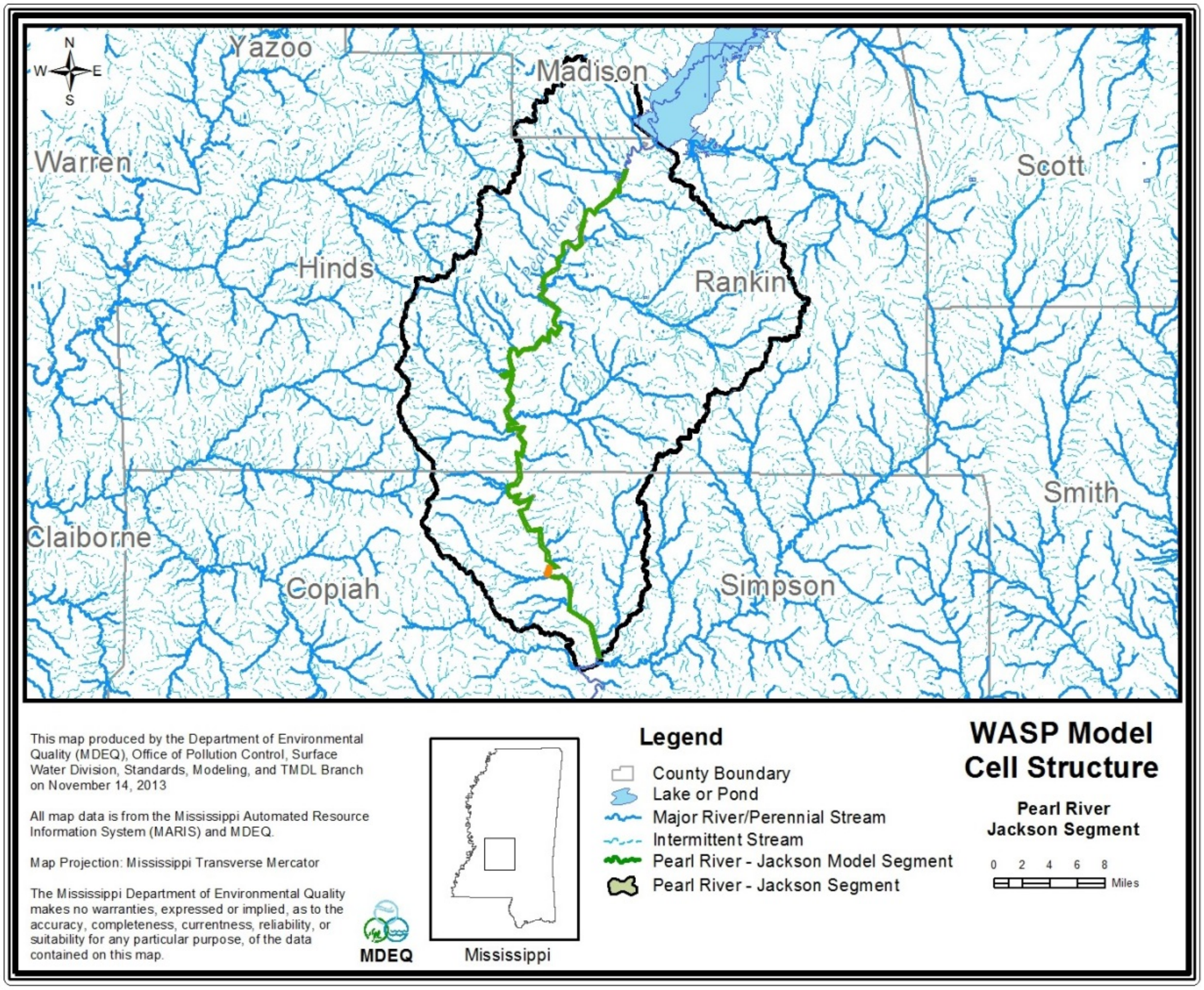


Figure 4 WASP Model Cell Structure (Critical Cell Highlighted)

The most efficient result was obtained with a reduction of TP. The BMPs employed will control both TN and TP from nonpoint sources. The point sources primarily use a chemical addition, usually alum, to settle out TP in the clarifier, but have to use a biological process controlling the dissolved oxygen levels to remove TN thru denitrification. The physical settling of TP is more efficient and less costly than TN removal in the wastewater treatment process. The TP physical process does increase the waste sludge because the TP is chemically attached to the added alum, and this is then sent to the landfill. The denitrification process converts the organic species of nitrogen in the wastewater to nitrogen gas which is reintroduced to the atmosphere. This TMDL will focus on the TP reduction scenario to control the response variables in the watershed and store the excess TP in the landfill.

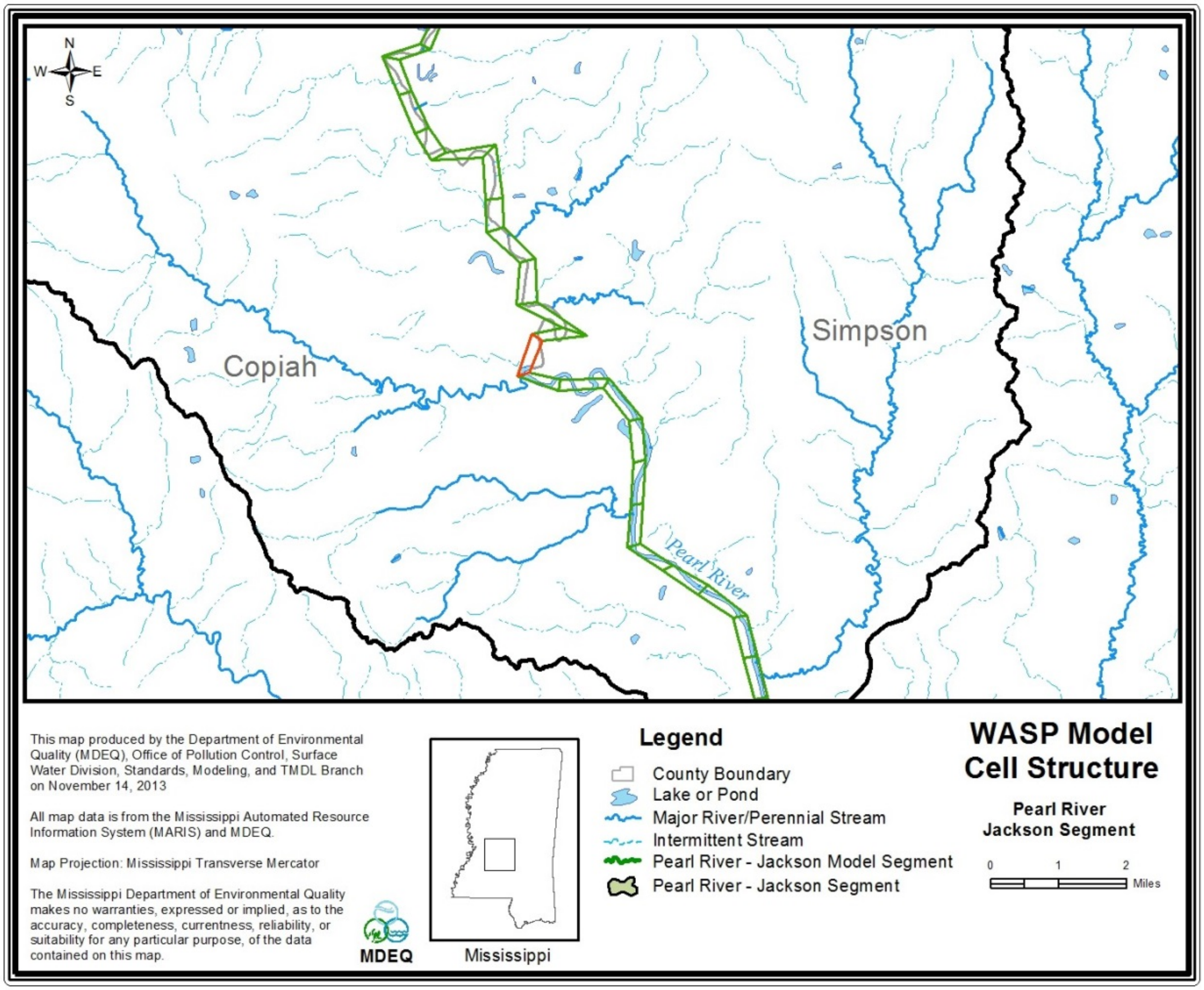


Figure 5 Critical Cell in WASP Model

The endpoint for the TMDL is based on the analysis of corresponding reactions to varying levels of TP reduction. Once the reduction level is selected, the TMDL nutrient load is calculated based on the model prediction for flow and concentration of TP. The overall reduction will provide a total TMDL which will then be divided between point and nonpoint sources (WLA and LA components of the TMDL).

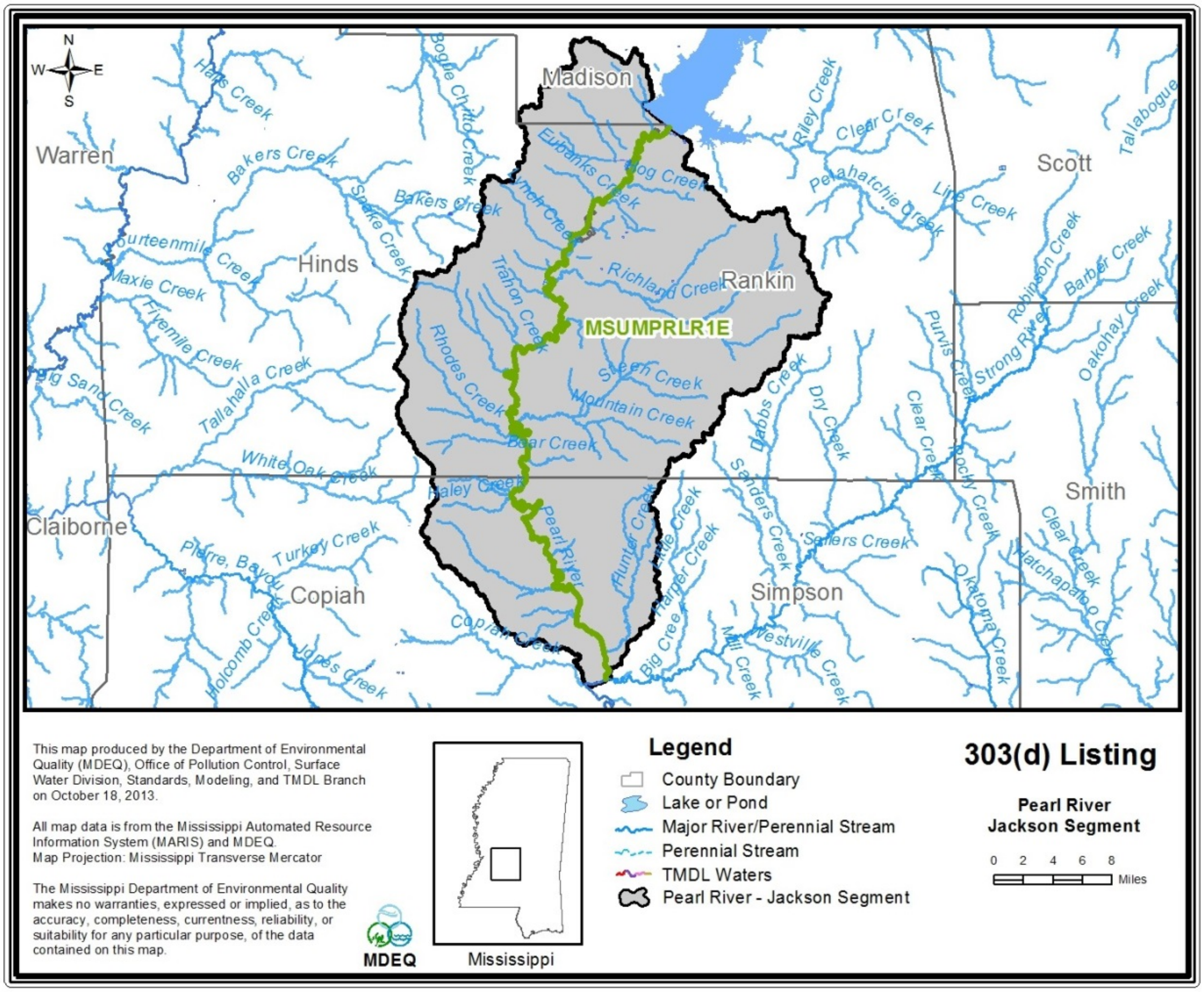


Figure 6 Pearl River 2008 303(d) Listing

WATER BODY ASSESSMENT

2.1 Water Quality Data

Figure 7 2012 Pearl River Monitoring Station

The Pearl River has had ongoing intensive water quality studies by MDEQ, EPA Region 4, Georgia Pacific, Inc., and LDEQ over the past decade. EPA Region 4 and MDEQ jointly studied the Pearl River above and at the Jackson POTWs in 2006. In 2006, 2008, and 2012 MDEQ completed algal growth potential tests on five locations throughout the watershed. Georgia Pacific Inc. studied the Pearl River in Lawrence County above and below their discharge point in 2010. In 2012, EPA Region 4 and MDEQ jointly studied the Pearl River in Copiah and Simpson Counties. All of these data sets were used in the preparation of the EFDC and WASP dynamic computer models of the Pearl River. Tetra Tech, Inc. created the models and calibrated and validated the model results to the monitoring data collected. The model development report and the data are included in this TMDL in Appendix A.

2.2 Nutrient Enrichment found in the Pearl River

2.2.1 Modeling Critical Location

During the 2012 monitoring period EPA Region 4 and MDEQ found an over-enrichment of TP and TN in the Pearl River. The critical condition, which was identified by modeling, was at the Pearl River Station 3 at Hopewell, MS. The model result of dissolved oxygen was super saturated in ranges of 150% to 160%. This is not a water quality standard in Mississippi, but other states in EPA Region 4 use this indicator for stream impairment.

2.2.2 Modeling Response Variables

The model results for diurnal flux between the minimum and maximum dissolved oxygen concentrations was approximately 8 mg/l. Ohio and Minnesota environmental departments use this indicator for stream impairment. TP model results were greater than 250 µg/l. Chlorophyll-a model results were as high as 80 µg/l. See Figure 8 below. Figure 98 on page 55 of Appendix A in the model report shows the comparison of the measured dissolved oxygen to the model output at this station. Figures 64 and 67 on pages 38-39 show the TN and TP comparison between model prediction and measured values for this area.

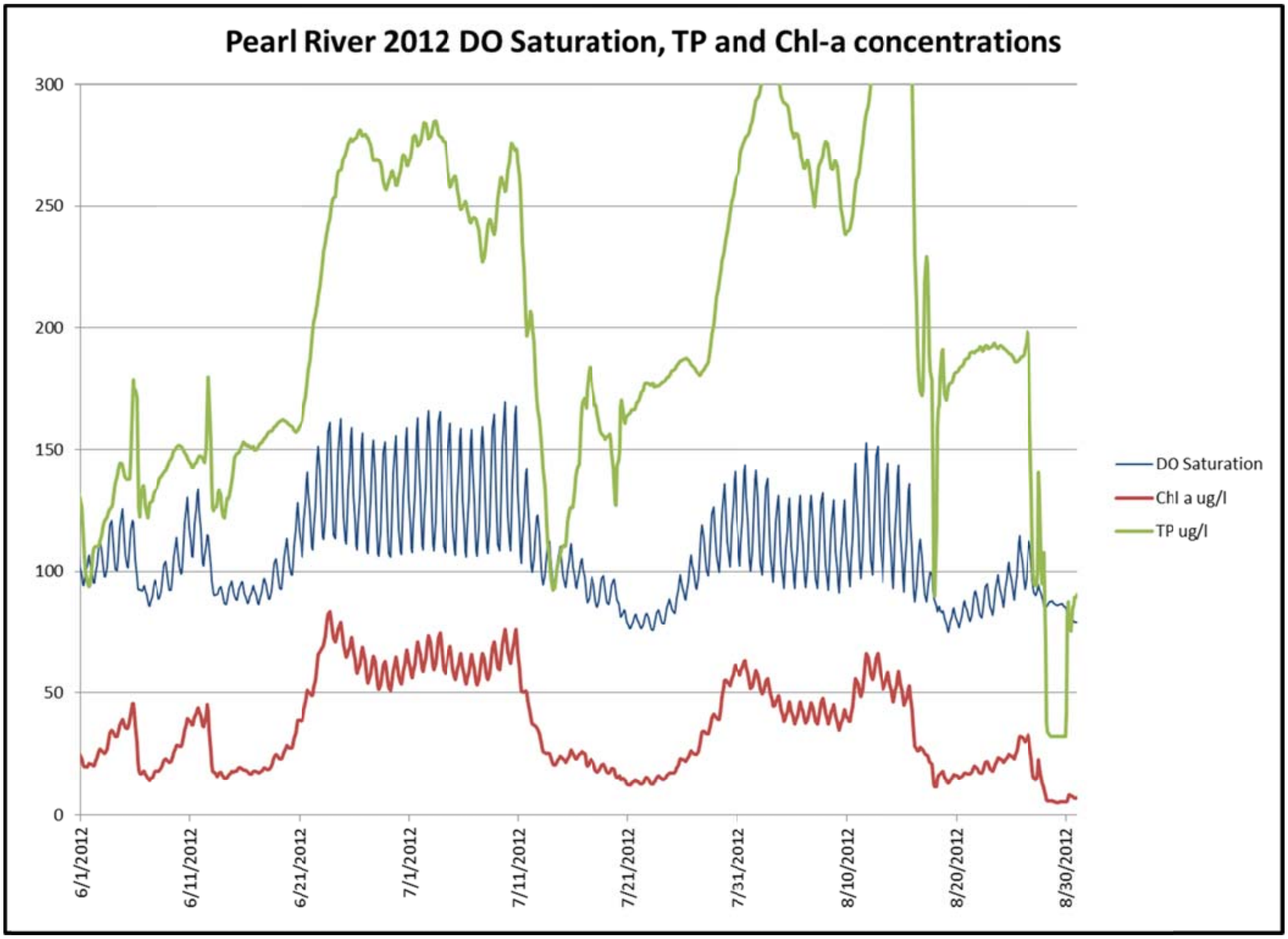


Figure 8 Calibrated Model Output Critical Cell Growing Season, 2012

2.2.3 Algal Growth Potential Tests

AGPT tests were completed on the Pearl River in 2006, 2008, and 2012. All of the tests indicate that nitrogen is the limiting nutrient. The test takes three water samples. One is the control sample, nothing is added. One sample has phosphorus added, and the third sample has nitrogen added. The growth rate of an algal species is measured in the laboratory in each sample. The samples are dried and weighed to show which nutrient is limiting and which has an overabundant supply. The nutrient in shortest supply controls growth.4

4 Chapra, pg. 608.

The AGPT results indicate that the river is nitrogen limited and needs to be driven back to being phosphorous limited. While this TMDL does not recommend a reduction to point source loading of TN, it does recommend quarterly monitoring of TN and applying the TN WLA load at these facilities.

The 2012 AGPT results are shown below. The 2008 and 2006 nutrient data and AGPT results are shown is Tables 7 and 8.

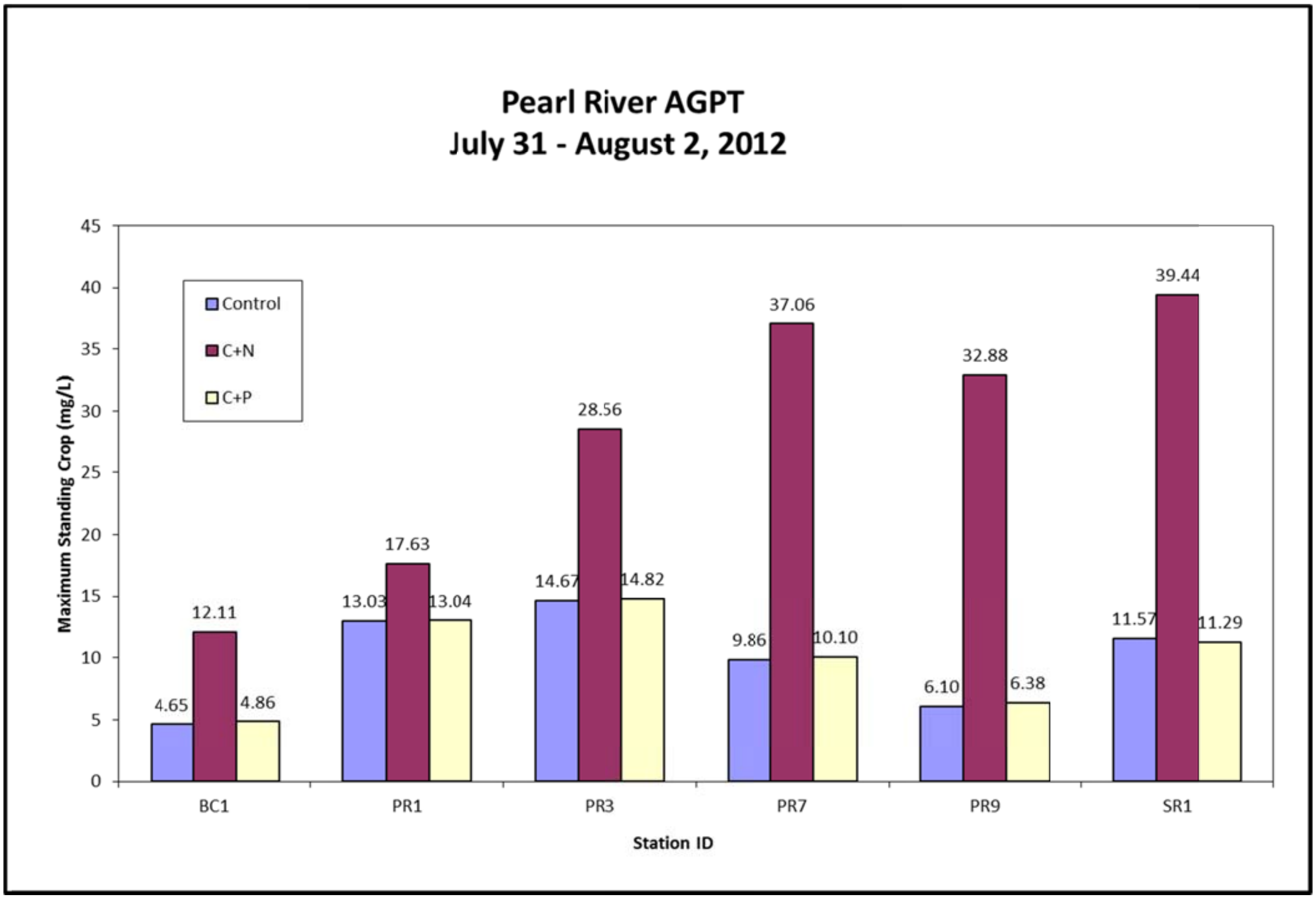


Figure 9 Chart showing AGPT Results 2012

Table 6 AGPT Test Results 2012
Pearl River
July 31-August 2, 2012

Station	Maximum Standing Crop, Dry Weight (mg/L) Control	C+N	C+P	Limiting Nutrient
BC1	4.65	12.11	4.87	Nitrogen
PR1	13.04	17.64	13.04	Nitrogen
PR3	14.68	28.57	14.83	Nitrogen
PR7	9.86	37.07	10.10	Nitrogen
PR9	6.10	32.89	6.38	Nitrogen
SR1	11.58	39.45	11.29	Nitrogen

Freshwater AGPT using *Selenastrum capricornutum* as test alga

C+N = Control + 1.0 mg/L Nitrate-N

C+P = Control + 0.05 mg/L Phosphate-P

Table 7 Nutrient and AGPT Test Results 2008

Station Number	Station Location	Date	TN (mg/l)	TP (mg/l)	AGPT (mg/l)	Limiting Nutrient
A0450019	Pearl River at Pearlington	4/30/2008	0.95	0.10	6.3	Nitrogen
		5/28/2008	0.96	0.12		
A0490019	Pearl River at Rosemary Rd near Terry	4/22/2008	1.44	0.17	9.5	Nitrogen
		5/12/2008	1.45	0.25		
A0770166	Pearl River near Monticello	4/30/2008	1.58	0.16	9.2	Nitrogen
		5/27/2008	1.76	0.18		
A0910168	Pearl River near Columbia	4/30/2008	1.53	0.19	13	Nitrogen
		5/28/2008	1.18	0.15		
A1090004	Pearl River near Bogalusa	4/30/2008	1.11	0.12	3.2	Nitrogen
		5/28/2008	1.31	0.20		
A1210162	Pearl River at Florence Byrum Rd near Byram	4/25/2008	1.25	0.14	10	Nitrogen
		5/21/2008	1.14	0.15		
Site 2	Pearl River at Hwy 28 near Georgetown	4/30/2008	1.43	0.16	9.9	Nitrogen
		5/27/2008	1.55	0.15		

Table 8 Nutrient and AGPT Test Results 2006

Station Number	Station Location	Date	TN (mg/l)	TP (mg/l)	AGPT (mg/l)	Limiting Nutrient
A0490016	Pearl River at Jackson at Impound Lot	8/23/2006	1.06	0.06		
		8/22/2006			3.5	Nitrogen
A0490017	Pearl River at Jackson WWTP above discharge	8/23/2006	058	0.05		
		8/25/2006			3.0	Nitrogen
A0490018	Pearl River at Jackson WWTP below discharge	8/23/2006	1.57	0.39		
		8/25/2006			20	Nitrogen
A0490019	Pearl River near Terry at Rosemary Rd	8/23/2006	2.43	0.14	NA	NA

A1210162	Pearl River at Florence Byrum Rd near Byram	8/23/2006	2.42	0.36		
		8/24/2006			38	Nitrogen
C0490033	Pearl River at Jackson at Water Works	8/23/2006	1.10	0.06	NA	NA

2.3 Assessment of Point Sources

An important part of the TMDL analysis is the identification of individual sources, source categories, or source subcategories of nutrients in the watershed and the amount of pollutant loading contributed by each of these sources. Under the CWA, sources are broadly classified as either point or nonpoint sources. Under 40 CFR §122.2, a point source is defined as a discernible, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters.

The NPDES program regulates point source discharges. Point sources can be described by two broad categories: 1) NPDES regulated municipal and industrial wastewater treatment plants (WWTPs) and 2) NPDES regulated activities, which include construction activities and municipal storm water discharges (Municipal Separate Storm Sewer Systems [MS4s]). For the purposes of this TMDL, all sources of nutrient loading not regulated by NPDES permits are considered nonpoint sources.

2.3.1 Primary Point Source Loads

Point source dominated freshwater systems are generally nitrogen limited. By controlling the phosphorous loads with a TP reduction, the streams can be converted to a phosphorus limited stream which is typical of unimpaired streams. (Thomann and Mueller, 1987).

The wastewater was characterized based upon the best available information. Discharge Monitoring Reports (DMRs) and direct effluent sampling provided the loading rates used in the models to represent the point sources. Where DMRs or direct sampling were not available, estimated concentrations of TN and TP were selected for different treatment types (USEPA 1997).

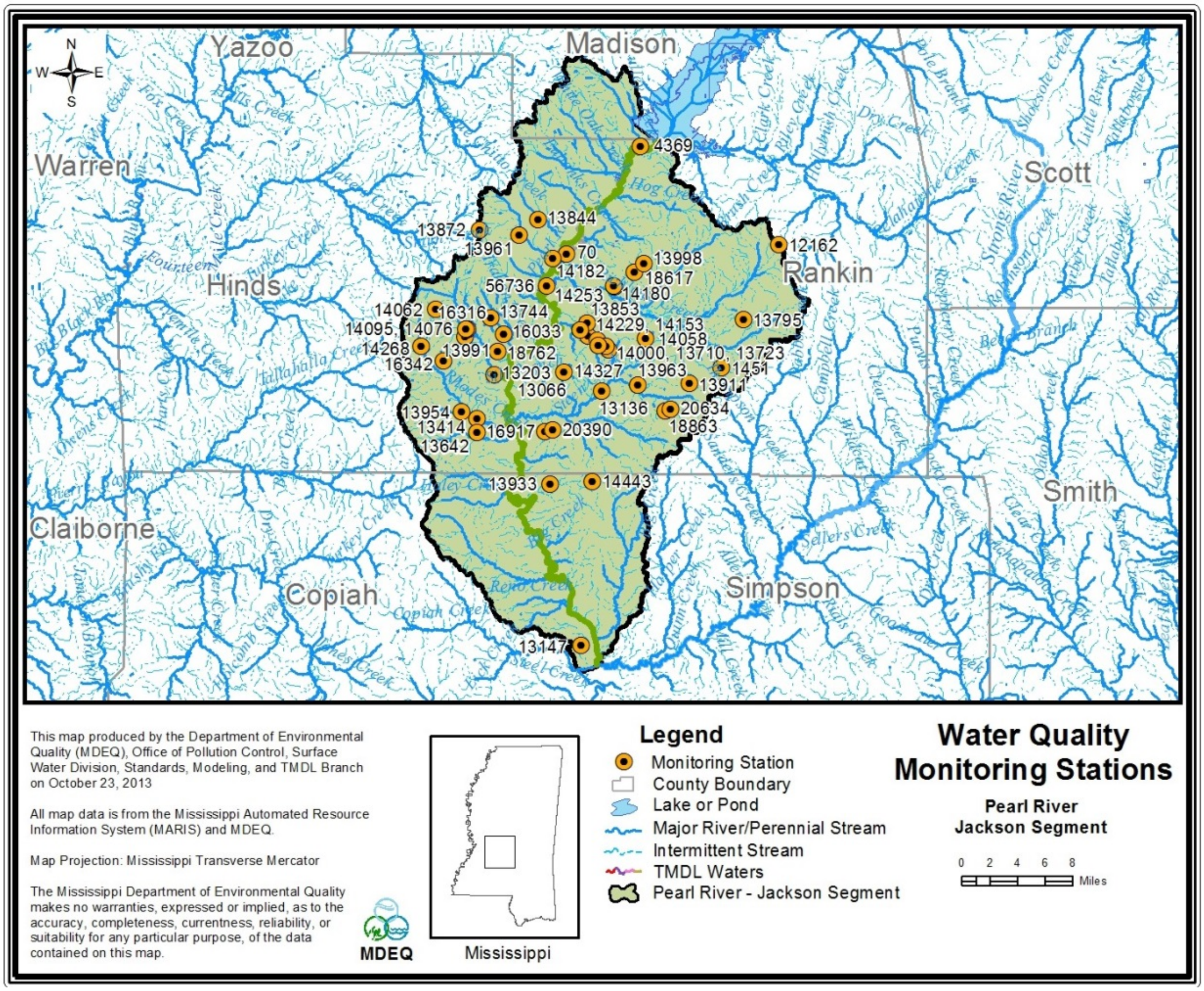


Figure 10 Point Source Locations in the Pearl River Jackson Watershed

Table 9 Point Sources in the Watershed

Master AI	Facility Name	City	County	Lat.	Long.	NPDES Permit
70	Pilot Travel Centers LLC, Pilot Travel Center Number 077	Jackson	Hinds	32.273611	-90.192778	MS0054861
1451	Pursue Energy Corporation, Thomasville Gas Plant	Brandon	Rankin	32.160244	-89.984519	MS0033987
4369	OB Curtis Water Treatment Plant	Ridgeland	Hinds	32.391008	-90.0845	MS0046906
12162	Southern Natural Gas Company LLC, Rankin Compressor Station	Brandon	Rankin	32.288728	-89.914053	MS0051039
13066	Cleary Heights POTW	Florence	Rankin	32.155589	-90.177678	MS0036307
13136	Florence POTW	Florence	Rankin	32.135694	-90.131444	MS0025275

13147	Georgetown POTW	Georgetown	Copiah	31.869875	-90.155583	MS0020605
13203	Jackson POTW, Trahon and Big Creek	Jackson	Hinds	32.152164	-90.263889	MS0044059
13414	Terry POTW	Terry	Hinds	32.10595	-90.285008	MS0025224
13642	Autumn Light Personal Care Home	Terry	Hinds	32.091997	-90.285086	MS0023493
13710	Briar Hill Rest Home LLC	Florence	Rankin	32.182747	-90.126528	MS0029726
13723	Total Environmental Solutions Inc., Woodland Acres Subdivision	Florence	Rankin	32.178553	-90.123139	MS0030252
13744	B and G Utilities Inc., Brookwood Subdivision	Jackson	Hinds	32.211417	-90.268167	MS0031194
13795	TMJ LLC	Brandon	Rankin	32.210611	-89.956972	MS0033006
13844	Chukstop Car Wash	Jackson	Hinds	32.314278	-90.210833	MS0034991
13853	Wilson Enterprises, Quicky Car Wash	Richland	Rankin	32.206175	-90.150042	MS0035408
13872	N C Carwash	Jackson	Hinds	32.3035	-90.282528	MS0036471
13911	Rankin County School District, McLaurin Attendance Center	Florence	Rankin	32.143975	-90.023778	MS0038466
13933	High Place Retreat, The	Florence	Simpson	32.038414	-90.194889	MS0038971
13954	Poole Subdivision	Terry	Hinds	32.113639	-90.303944	MS0039845
13961	Ultimate Shine Car Wash	Jackson	Hinds	32.297806	-90.233639	MS0040096
13963	Rolling Hills Wastewater Inc., Rolling Hills Subdivision	Florence	Rankin	32.141531	-90.087181	MS0040134
13991	Hinds County School District, Gary Road Elementary	Byram	Hinds	32.191806	-90.299658	MS0042099
13998	Daily Equipment Company	Pearl	Rankin	32.268847	-90.079803	MS0042277
14000	Restoration Community Fellowship Church	Florence	Rankin	32.183161	-90.135514	MS0042579
14058	Friends of Children of Mississippi Inc., New Hope Headstart Center	Pearl	Rankin	32.190911	-90.077503	MS0044547
14062	Ridge Park, Wakeland Hills and Wildwood Subdivisions	Jackson	Hinds	32.220361	-90.336306	MS0044792
14076	Child Care Management Group, The Child Development Center	Byram	Hinds	32.198742	-90.297744	MS0045161
14095	Corporate Child Care Services Inc., Child Development Center	Terry	Hinds	32.199464	-90.297139	MS0045837
14153	Raworth and Harvel LLC, Country View Estates Mobile Home Park	Florence	Rankin	32.192861	-90.148583	MS0047856
14180	Ks Kids Learning Center Inc.	Pearl	Rankin	32.244492	-90.115678	MS0048488

14229	Pine Ridge Mobile Home Park	Florence	Rankin	32.199306	-90.158389	MS0050482
14253	Haney Commercial Building	Pearl	Rankin	32.245278	-90.117414	MS0051063
14268	Siwell Utility Company Inc., Owens Road Subdivision	Terry	Hinds	32.181694	-90.353611	MS0051781
14327	G and J Enterprises LLC	Florence	Rankin	32.188469	-90.137306	MS0053821
14443	First Presbyterian Church, Twin Lakes Conference Center	Florence	Rankin	32.040983	-90.142356	MS0056600
14812	H and E Equipment Services LLC	Pearl	Rankin	32.278778	-90.175203	MS0056936
16033	McInnis Electric Company	Byram	Hinds	32.194167	-90.2525	MS0057711
16316	David K May Office Building	Jackson	Hinds	32.199358	-90.299136	MS0057819
16342	Oakview Utility Company Inc., Rowan Oak S/D	Jackson	Hinds	32.1665	-90.326269	MS0057835
16917	King Rental Properties Inc.	Florence	Rankin	32.0926	-90.20065	MS0058220
18617	AAAG Mississippi LLC, dba Rea Brothers Mid-South Auction	Pearl	Rankin	32.259458	-90.091689	MS0059846
18762	W G Yates and Sons Construction Company, Heavy Division Office	Jackson	Hinds	32.176722	-90.260111	MS0059323
18863	Star View Mobile Home Park	Florence	Rankin	32.115297	-90.053061	MS0059382
20390	Craig Estates Mobile Home Park	Florence	Rankin	32.09445	-90.191953	MS0059927
20634	Eddie Williams Mobile Home Park	Florence	Rankin	32.117131	-90.046886	MS0043621

2.3.2 EPA Enforcement on City of Jackson POTWs

Ongoing enforcement proceedings on the City of Jackson POTWs have resulted in a $400 Million consent decree between the City of Jackson and EPA. This consent decree deals with improvements required for the wastewater treatment plants and sewer collection systems. The collection system has for the past several years been discharging directly into the Pearl River prior to treatment which allowed excessive pollutant loads in the river. It is believed that this source is a primary source of nutrients in the watershed. MDEQ anticipates that as these collection and treatment system improvements occur during the next several years, the water quality will improve.

2.3.3 Stormwater Point Source Loading

Nutrient loadings from NPDES regulated construction activities and MS4s are considered point sources to surface waters. These discharges occur in response to storm events and are included in the WLAsw portion of this TMDL. As of March 2003, discharge of storm water from construction activities disturbing more than one acre must obtain an NPDES permit. The purpose of the NPDES permit is to eliminate or minimize the discharge of pollutants from construction activities. Since construction activities at a site are of a temporary, relatively short term nature, the number of construction sites covered by the general permit varies. The target for these areas is the same range as the TMDL target for the watershed. The WLAs provided to the NPDES regulated construction activities and MS4s will be implemented as best management practices (BMPs) as specified in Mississippi's General Storm Water Permits for Small Construction, Construction, and Phase I & II MS4 permits. Properly designed and well-maintained BMPs are expected to provide attainment of water quality standards.

There are 9 MS4 permits within the Pearl River Jackson Segment. These MS4 permits are listed in Table 7.

Table 10 MS4 Permits in Watershed

Permit ID #	MS4 Name
MSRMS4026	City of Brandon, MS4 Storm Water Management Program
MSRMS4028	City of Flowood, MS4 Storm Water Management Program
MSRMS4019	Hinds County, MS4 Storm Water Management Program
MSRMS4024	MDOT, MS4 Storm Water Management Program
MSRMS4031	Madison County, MS4 Storm Water Management Program
MSRMS4025	City of Pearl, MS4 Storm Water Management Program
MSRMS4035	Rankin County, MS4 Storm Water Management Program
MSRMS4029	City of Richland, MS4 Storm Water Management Program
MSS049786	City of Jackson, MS4 Storm Water Management Program

2.3 Assessment of Non-Point Sources

Non-point loading of nutrients and organic material in a water body results from the transport of the pollutants into receiving waters by overland surface runoff, groundwater infiltration, and atmospheric deposition. Total nitrogen is a combination of many forms of nitrogen found in the environment. Inorganic nitrogen can be transported in particulate and dissolved phases in surface runoff. Dissolved inorganic nitrogen can be transported in groundwater and may enter a water body from groundwater infiltration. Finally, atmospheric gaseous nitrogen may enter a water body from atmospheric deposition.

Unlike nitrogen, phosphorus is primarily transported in surface runoff when it is sorbed by eroding sediment. Phosphorus may also be associated with fine-grained particulate matter in the atmosphere and can enter streams as a result of dry fallout and rainfall (USEPA, 1999). However, phosphorus is typically not readily available from the atmosphere or the natural water supply (Davis and Cornwell, 1988). As a result, phosphorus is typically the limiting nutrient in most non-point source dominated rivers and streams, with the exception of watersheds which are dominated by agriculture and have high concentrations of phosphorus contained in the surface runoff due to fertilizers and animal excrement or watersheds with naturally occurring soils which are rich in phosphorus (Thomann and Mueller, 1987).

2.4 Watershed Landuse

The Pearl River Basin contains different landuse types, including urban, water, forest, pasture, cropland, and wetlands. The landuse information is based on the 2006 National Land Cover Dataset (NLCD). The landuse distribution for the Pearl River Jackson Segment is shown in Table 11 and Figure 11.

Table 11 Landuse in Watershed

Pearl-Jackson	Water	Urban	Forest	Scrub/Barren	Pasture	Cropland	Wetland
area	5,251.85	91,496.57	102,880.97	35,059.21	45,619.19	10,407.86	45,475.52
%area	1.6%	27.2%	30.6%	10.4%	13.6%	3.1%	13.5%

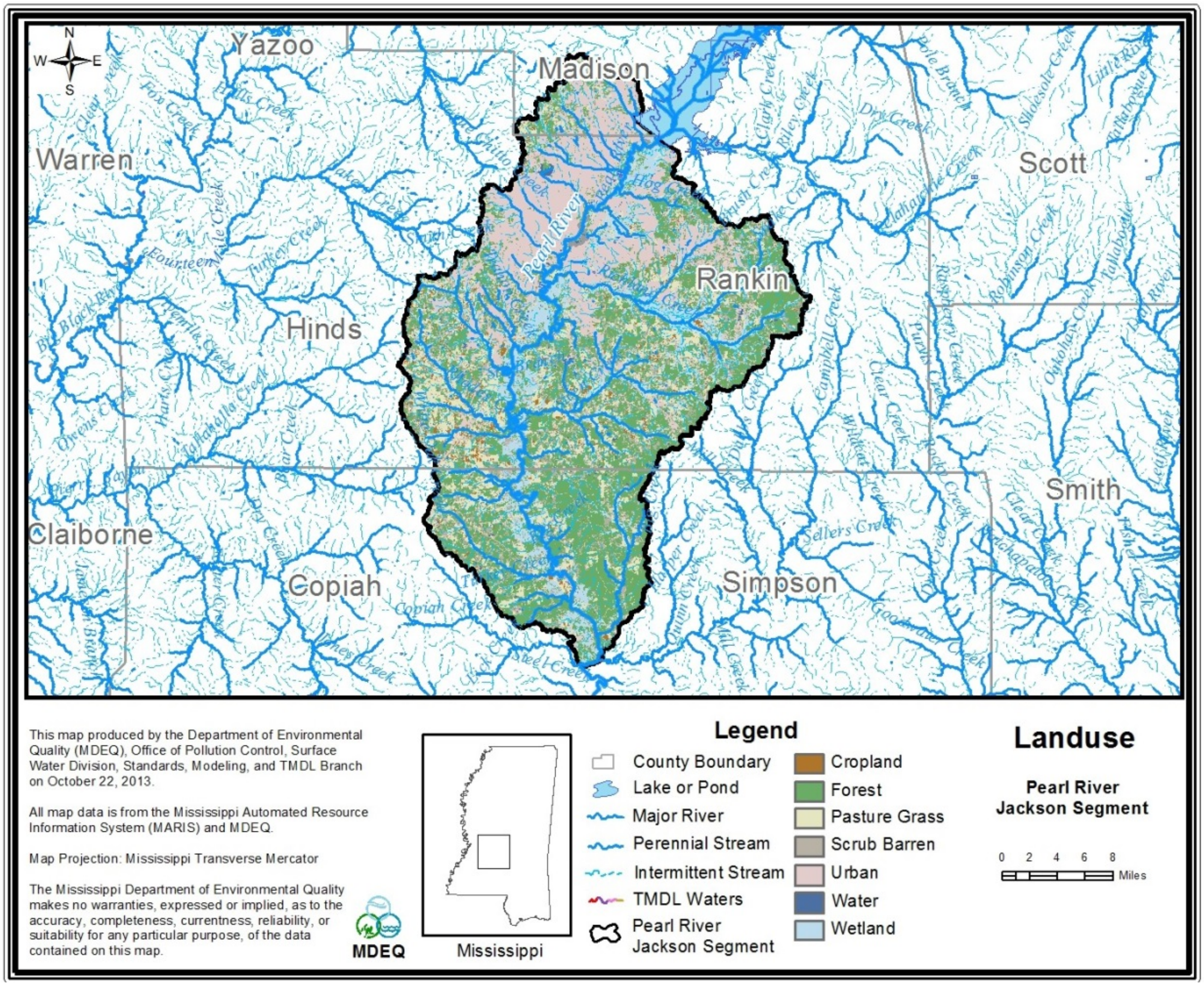


Figure 11 Landuse in the Pearl River Jackson Segment (2006 image)

Pearl River Nutrient TMDL Development

3.1 Historical TMDL Efforts

MDEQ completed the nutrient TMDL for TN and TP for the Pearl River Watershed in June 2009. This 2009 TMDL used a mass balance approach and was not specific to watershed segments. MDEQ also completed a wasteload allocation (WLA) for the City of Jackson Savanna Street POTW which provided TN and TP limits based on the 2009 TMDL. MDEQ used the STREAM model to set $CBOD_5$ and ammonia permit limits. The STREAM model is a steady state Streeter-Phelps Dissolved Oxygen equation based model. The NPDES permit limits provided in the WLA were 7-2-6 ($CBOD_5$-NH_3-N-DO) mg/l and 1,128 lbs./day TP and 5,126 lbs./day TN.

This simplified method for TMDL and WLA development fails to consider the dynamic nature of water quality modeling. The 2013 EFDC / WASP model overcomes this limitation and offers MDEQ an opportunity to express more scientifically defensible permit limits based not on a mass balance limit, but based on the study of the reactions to decreased levels of nutrients in the stream.

The Figure 12 below shows all of the dissolved oxygen output for the segments. There are no violations of the water quality standards for dissolved oxygen according to the model.

The dissolved oxygen levels in the Pearl River maintained levels well above the minimum water quality standard for dissolved oxygen. Typically this standard is used as the target for water quality modeling due to the diurnal minimums falling below the concentration allowed by the standard. The dissolved oxygen standard is usually a suitable target for TMDL development. Unfortunately, this approach is not applicable to this river due to the eutrophication and very high dissolved oxygen levels found during the critical period. Therefore this TMDL will study other causes and responses to the high nutrient content during low flows in the river.

3.2 Causal and Reaction Parameters

The reduction of available TN and/or TP produces a reaction within the stream. The chlorophyll-a growth is slowed which reduces the oxygen production during sun light hours due to photosynthesis, and the reduction also reduces the oxygen demand during night time. The flux between the minimum and maximum dissolved oxygen should also reduce as a response.

The WASP model is capable of exploring these reactions and determine the appropriate TN and TP level to simulate the desired result in water quality; that is the response of chlorophyll-a in the river to reduced loads of TN and/or TP.

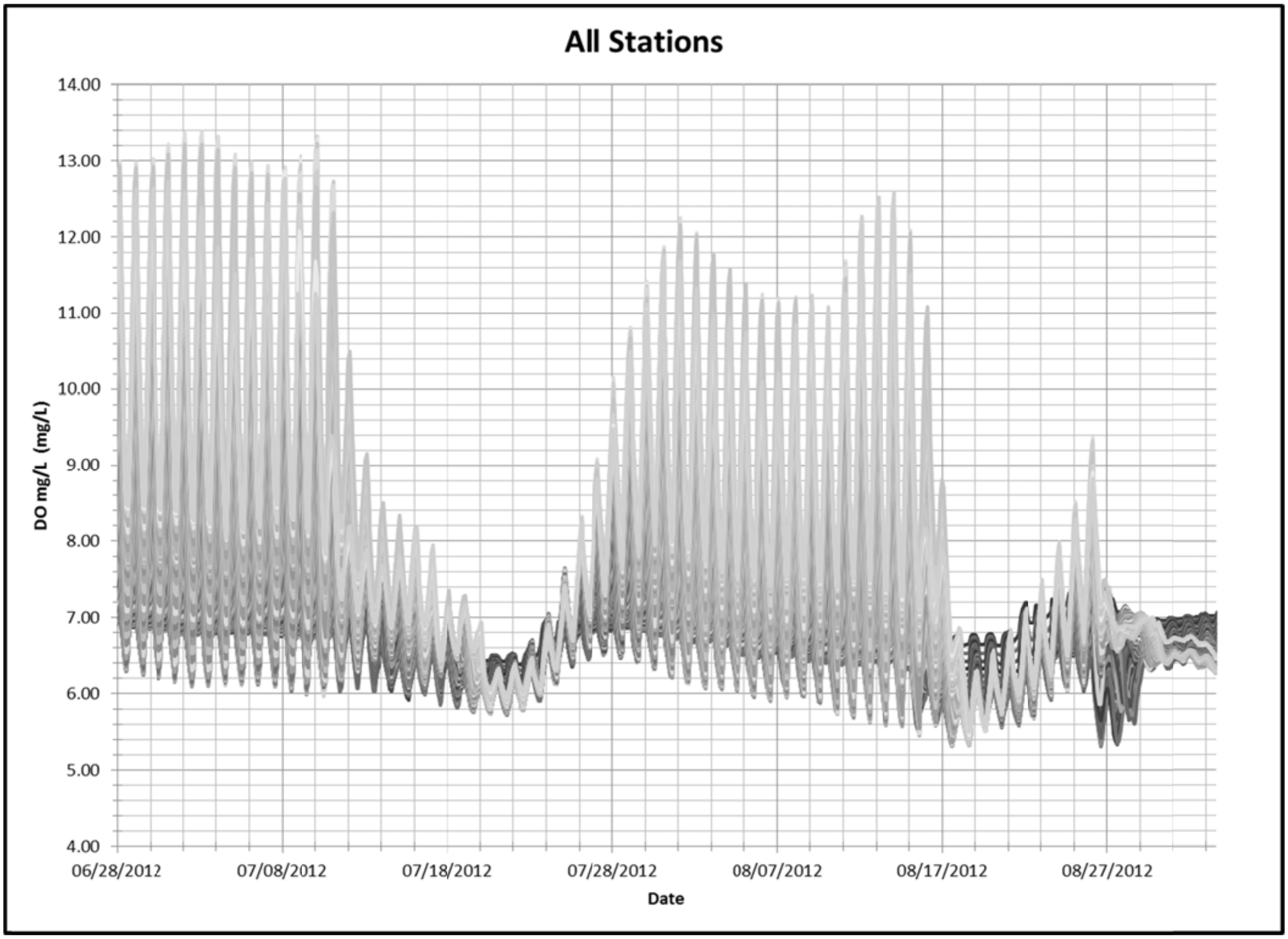


Figure 12 All Cells DO Model Output Critical Condition

3.3 WASP Model Output and Reaction Relationships

The WASP model provides a simulation of the water quality relationships and gives output for study. It is important to remember that this output is just that, a modeled simulation, not water quality data. The calibration of the model will adjust specific parameters to make the match between the data and the model output. Figures 13 - 16 show the comparison of the data and model output at different segments.

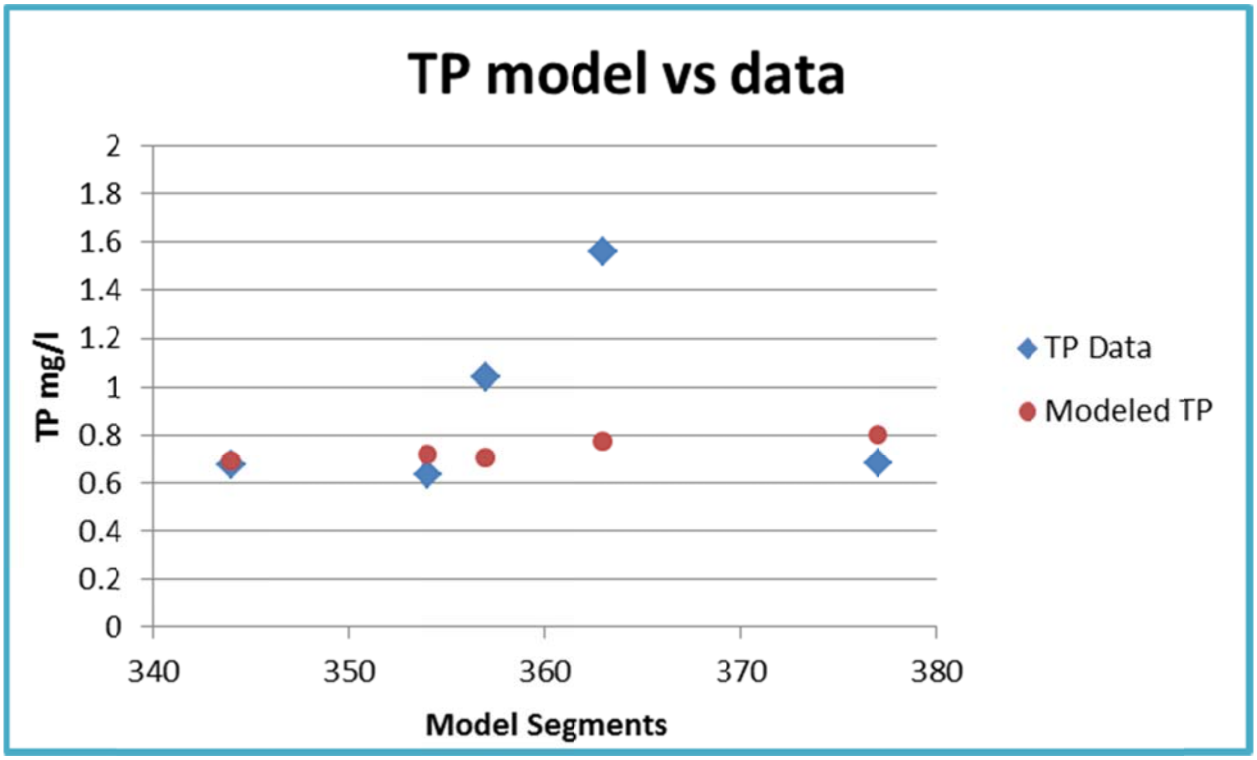


Figure 13 Total Phosphorus Data compared to Model Output

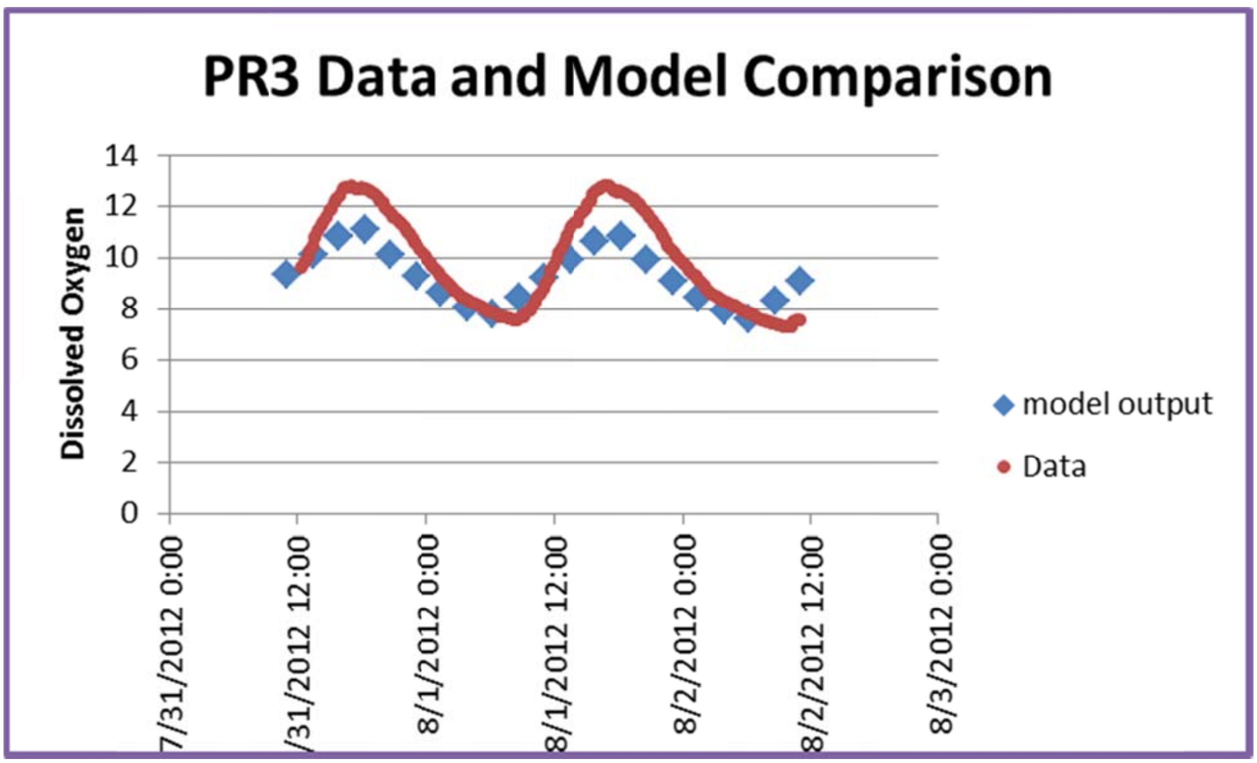
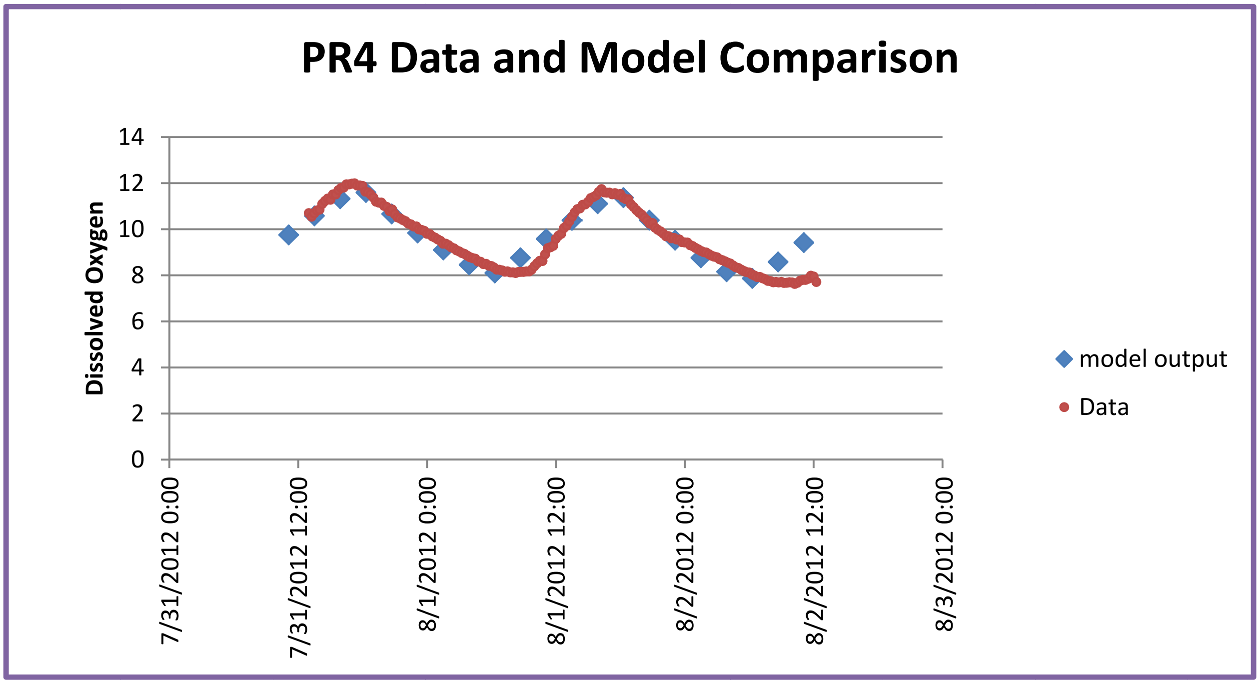


Figure 15 Dissolved Oxygen Data compared to Model Output



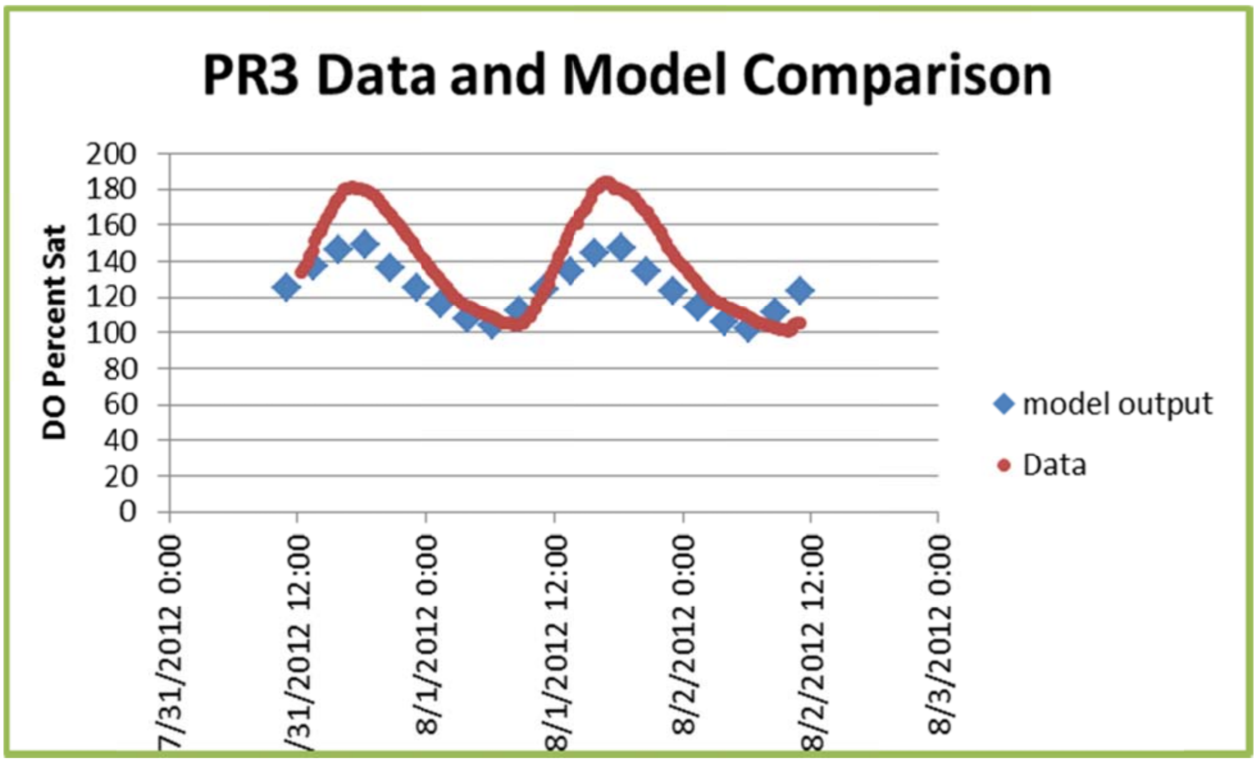


Figure 16 DO % Saturation Data compared to Model Output

However, this simulation is important to understanding the causal relationships ongoing in the water chemistry. For example Figure 17 below shows the model output of chlorophyll-a and flow plotted. This chart shows that all of the higher chlorophyll-a results occur during periods of very low flow. This makes sense because higher flows have increased turbidity which reduces the available sunlight reaching the algae. To generate the eutrophic supersaturated situation the algae need time to sit and generate oxygen.

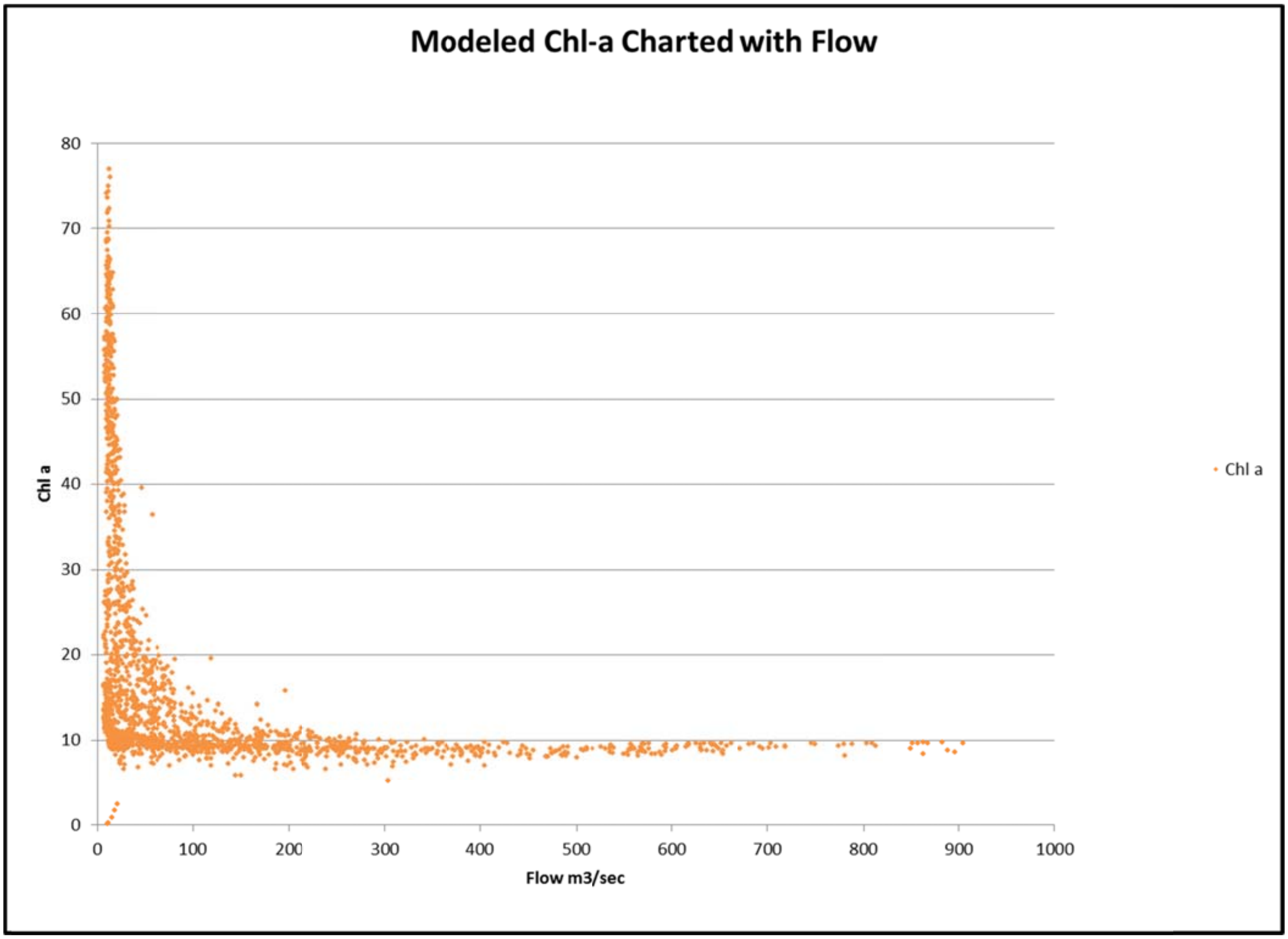


Figure 17 Model Output Chlorophyll-a vs. Flow Model Cell 360

An additional relationship seen in the model output is between chlorophyll-a and temperature. The higher temperatures of the summer are in the growing season for the algae. This could be because of the increased number of sunlight hours which would generate more photosynthesis and increase the ambient temperatures. This is also when the flows are reduced and critical conditions arrive.5

5 Modeling Note: Chloraphyll-a was adjusted higher than measured to calibrate the dissolved oxygen saturation. The measured chloraphyll-a values are lower than what is represented by the model.

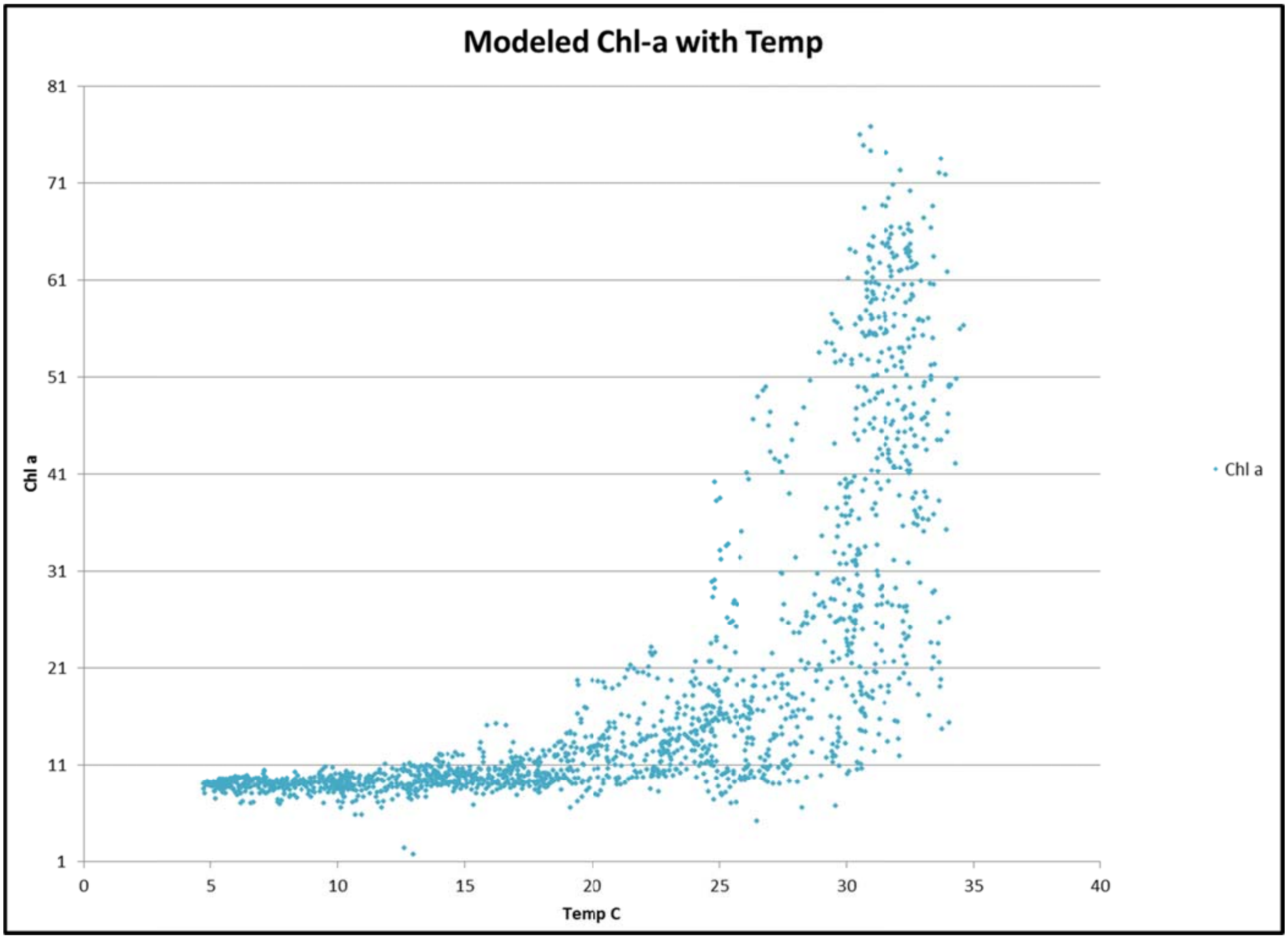


Figure 18 Model Output Chlorophyll-*a* vs. Temperature Model Cell 360

3.3 TP and TN Reduction Scenarios

The WASP model allows consideration of many variable reduction scenarios. The model output can show the best path forward to water quality restoration based on the model output. To set the nutrient reduction needed for restoration of the river, several nutrient reduction scenarios were considered.

3.3.1 Growing Season

The chlorophyll-a model output indicates this response variable is primarily a concern to water quality during the summer growing season. In Figure 19, the chlorophyll-a results are shown for 7 model runs. In each of these model runs, TP was reduced by an overall percentage. There was no significant change in the output until the TP reduction exceeded 50%. There was only minor change in chlorophyll-a in each of the model runs during the non-growing season. Based on this observation, this TMDL will focus on the summer growing season to establish seasonal nutrient NPDES permit limits.

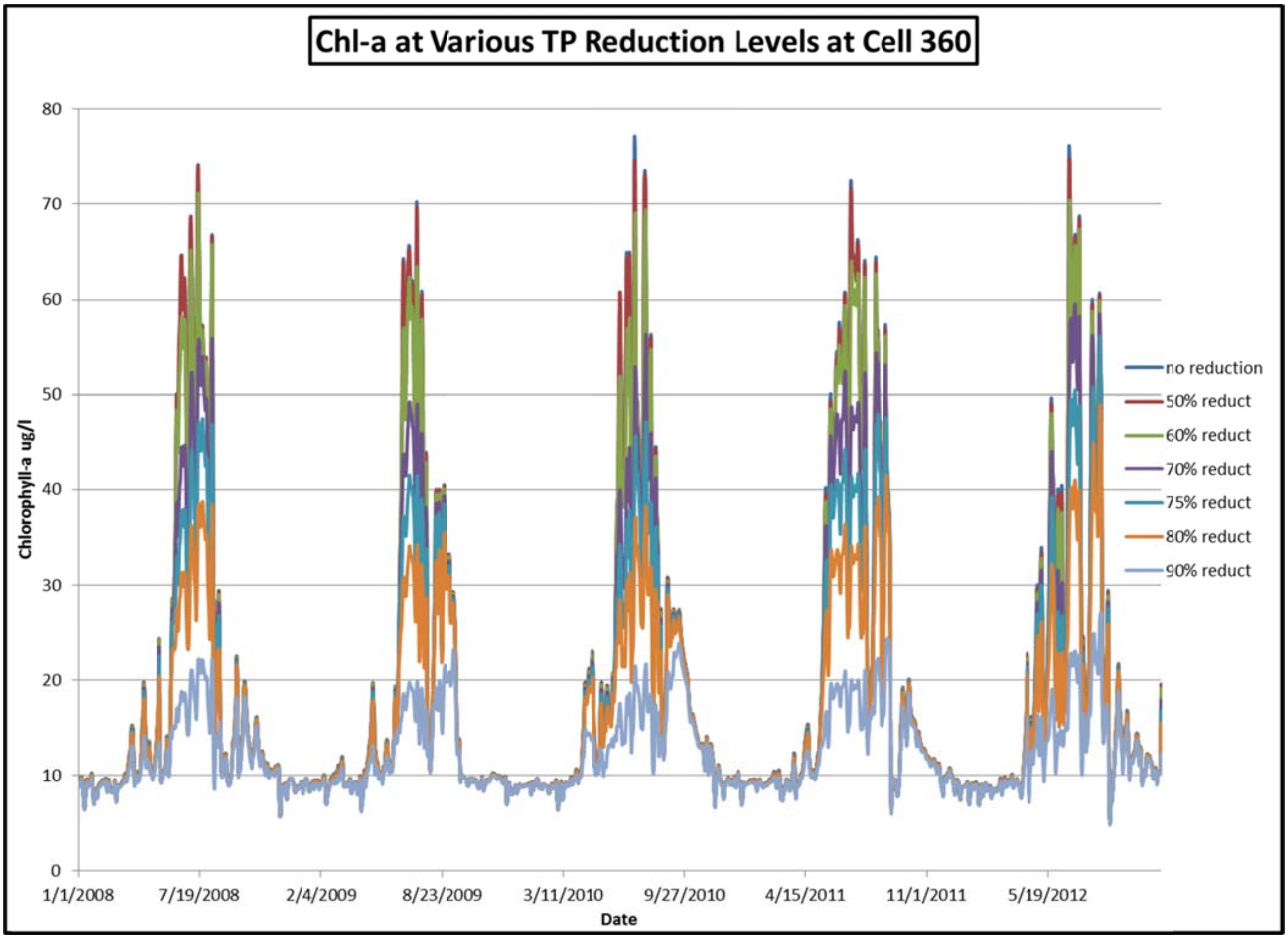


Figure 19 Model Output Chlorophyll-a at various TP reductions Model Cell 360, 2008 - 2012

This figure shows the five years of the model run. Figure 20 below shows the focus of the critical condition during 2012. Similar to Figure 2 on page 11, the algal response in the model is associated with low flows. When the river flow quantity and velocity elevate, the chlorophyll-a response variable is not evident.

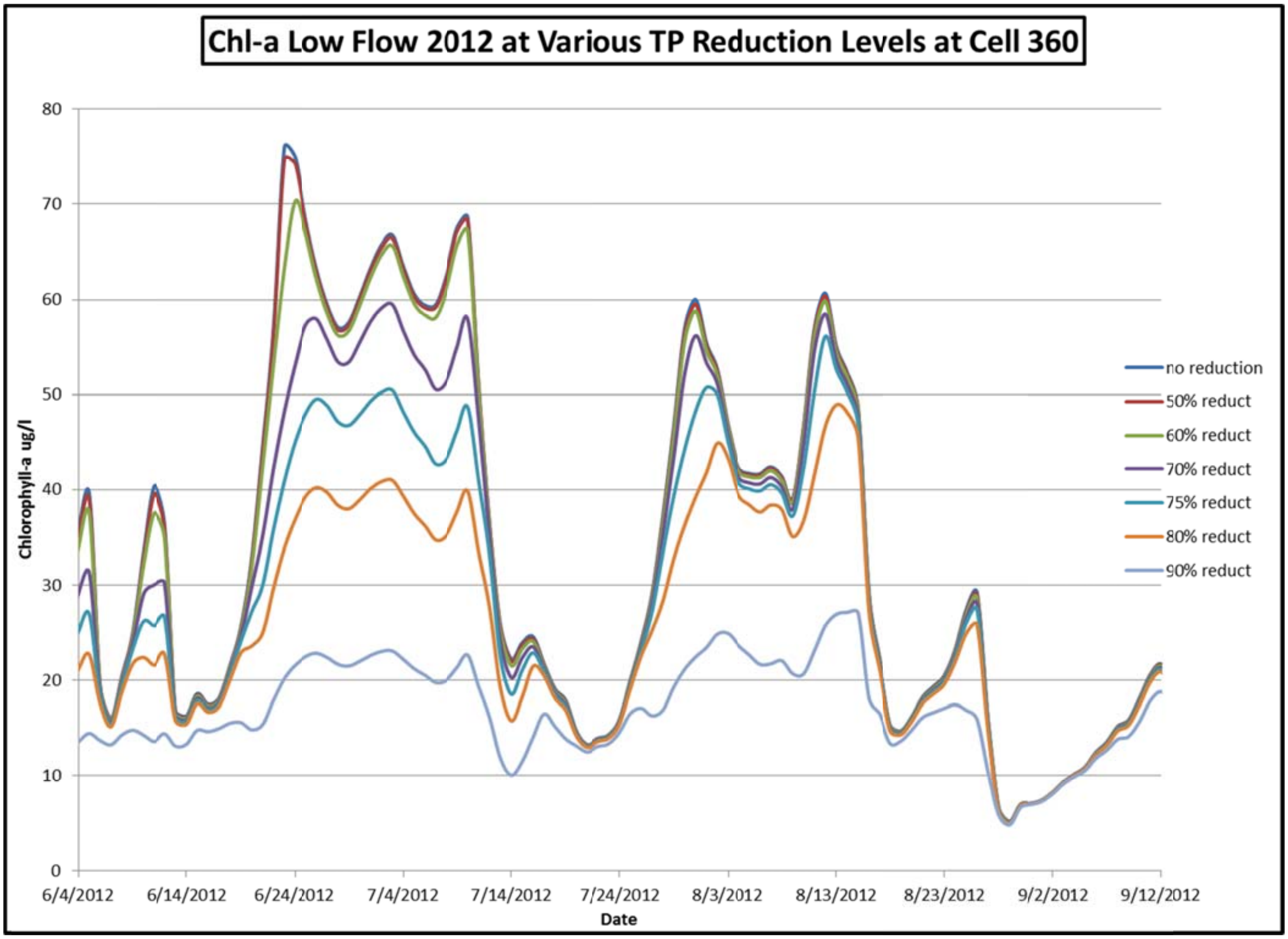


Figure 20 Focus of Critical Condition, 2012

3.3.2 Consider the Maximum Chlorophyll-a Levels

One consideration was the maximum chlorophyll-a response with each of the nutrient reduction scenarios. To observe this, the chart in Figure 19 above was converted to show the maximum to minimum results for each model run. Figure 21 shows these results.

Again, in the lower levels (non-growing season), there is minimal difference in all of the reduction scenarios. That is, the winter non-growing season is not impacted by a change in TP. On the left side of the chart, the reductions are more easily seen in the maximum chlorophyll-a values for each model run. For example, the TP model reduction scenario of 0.3; that is a 70% reduction to TP in the watershed, will limit the maximum chlorophyll-a to less than 60 µg/l.

The State of Florida Department of Environmental Protection (FPED) developed the St. Johns River Nutrient TMDL in 2008. They established a site-specific threshold for nutrient impairment for the freshwater zone based on chlorophyll a values. FDEP evaluated the maximum algal biomass levels that would (1) maintain the diversity of the plankton community, (2) facilitate the upward transfer of primary production to higher trophic levels (and maintain zooplankton diversity), and (3) minimize the potential dominance of detrimental algal species and the production of algal toxins. FDEP used a chlorophyll-a target of 40 µg/L, not to be exceeded more than 10 percent of the time which would protect the aquatic flora and fauna of the St. Johns River. FDEP studies show that when chlorophyll a levels rise above 40 µg/L for an extended period of time, a shift in algal types occurs: blue-green algae begin to dominate the system in Florida, toxic algal species begin to increase, and zooplankton communities begin to decline. FDEP along with the community stakeholders proposed the use of this target threshold for the St Johns River TMDL, and recommended that the threshold be applied over a long-term period (several years representing slightly drier than average conditions), rather than a worst-case, dry year. The TMDL was established and approved by EPA R4 using the alternative chlorophyll a threshold and long-term average model output, rather than model predictions for a worst-case year.6

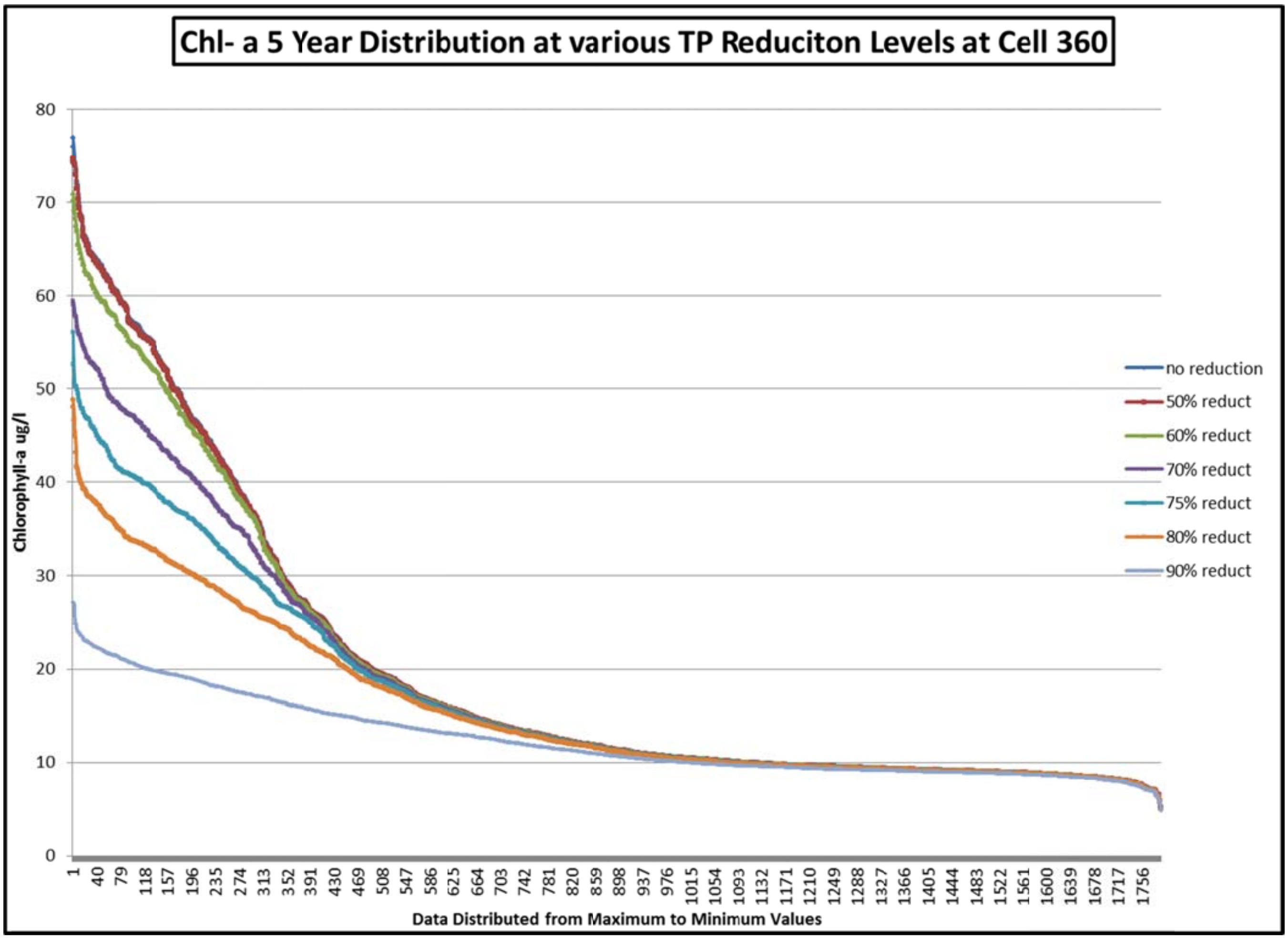


Figure 21 Regression of Chlorophyll-a Model Output at various TP Reductions Model Cell 360

6 FDEP St Johns River TMDL, http://www.lsjr.org/pdf/LSJRTMDLFinal_edited_7-9-08.pdf, page 11

MDEQ reviewed the St. Johns River TMDL target process and applied the concept to the model output results obtained in this study. The chlorophyll-a model values were plotted in Figure 21 from maximum to minimum. The 90th percentile of these model scenarios were gathered and plotted. A trend analysis was then used to predict the percent reduction needed to achieve a 40 µg/l chlorophyll-a target with a limit of 10% exceedance. The results are shown in Figure 22 below. The 70% reduction run selected for this TMDL provided a 90th percentile value of 41.7. To find the percentage to meet the target of 40 the equation for the trend line was produced, and a calculated reduction scenario to meet the FDEP target is a reduction of 70.8%. MDEQ believes this comparison to an EPA R4 approved TMDL process shows similar results, and the TMDL target 70% reduction will protect the Pearl River.

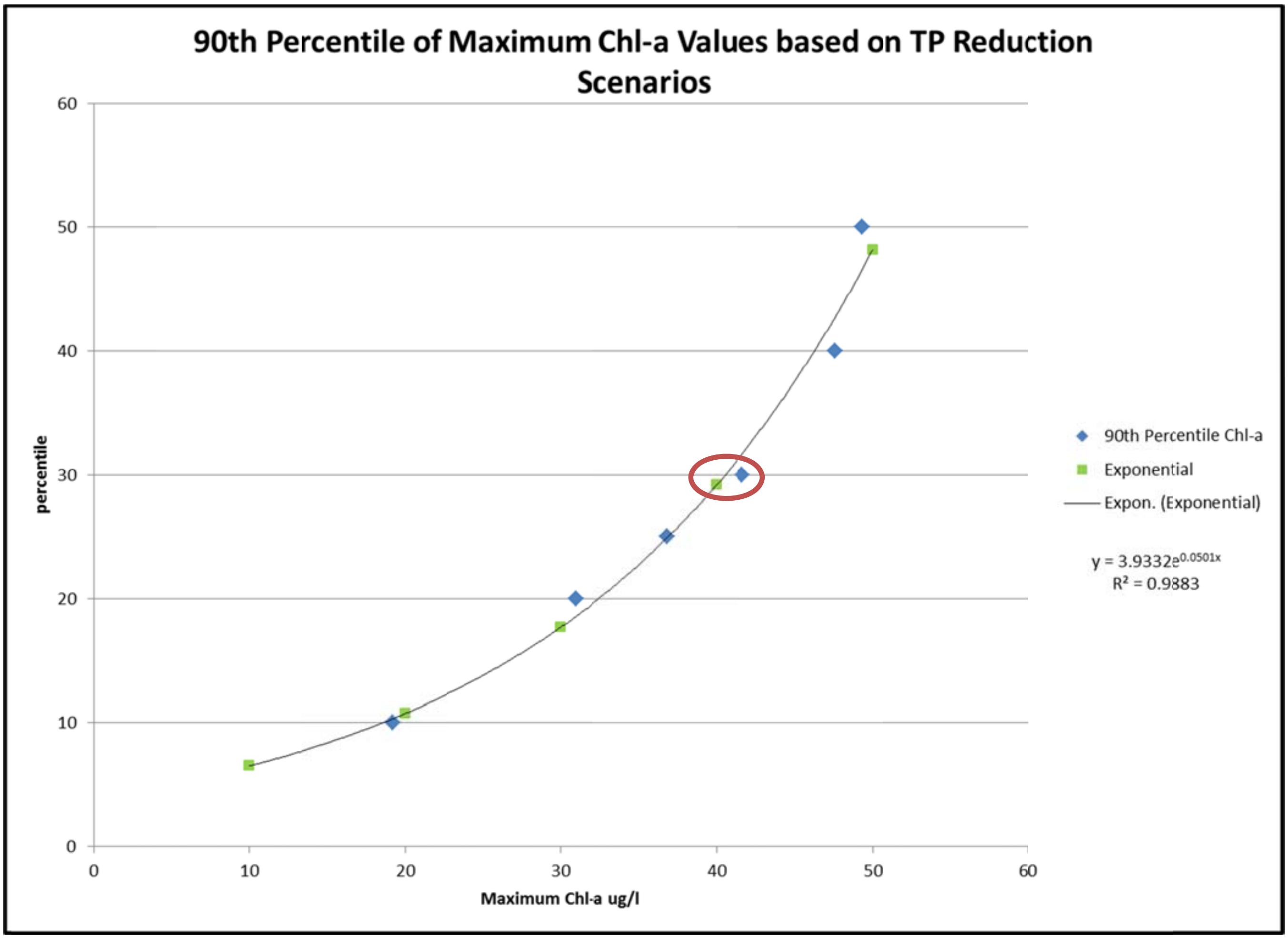


Figure 22 90th Percentile of Maximum Chl-a Model Output

3.3.3 Consider Seasonal Geometric Mean for Chlorophyll-a

Another consideration is to calculate the seasonal geometric mean of chlorophyll-a. By using a geometric mean calculation, the high variability in the response variable is tampered. The error that could be associated with high flux swings is accounted for by dampening those curves with a geometric mean calculation.

Figure 23 below shows each of the seasonal geometric means within the model output and their reductions as the TP was reduced. As in the maximum charts above, there is no significant reduction seen in geometric means until a 50% reduction is achieved.

This chart also displays the variability in seasons. The 2010 and 2011 geometric means are higher than the other years. These years were during a significant drought, and the flows are much lower than in the other model runs. The 2008 season appears to be the average year for the model output. A TP reduction of 70% generated a geometric mean of 23 µg/l response for 2008.

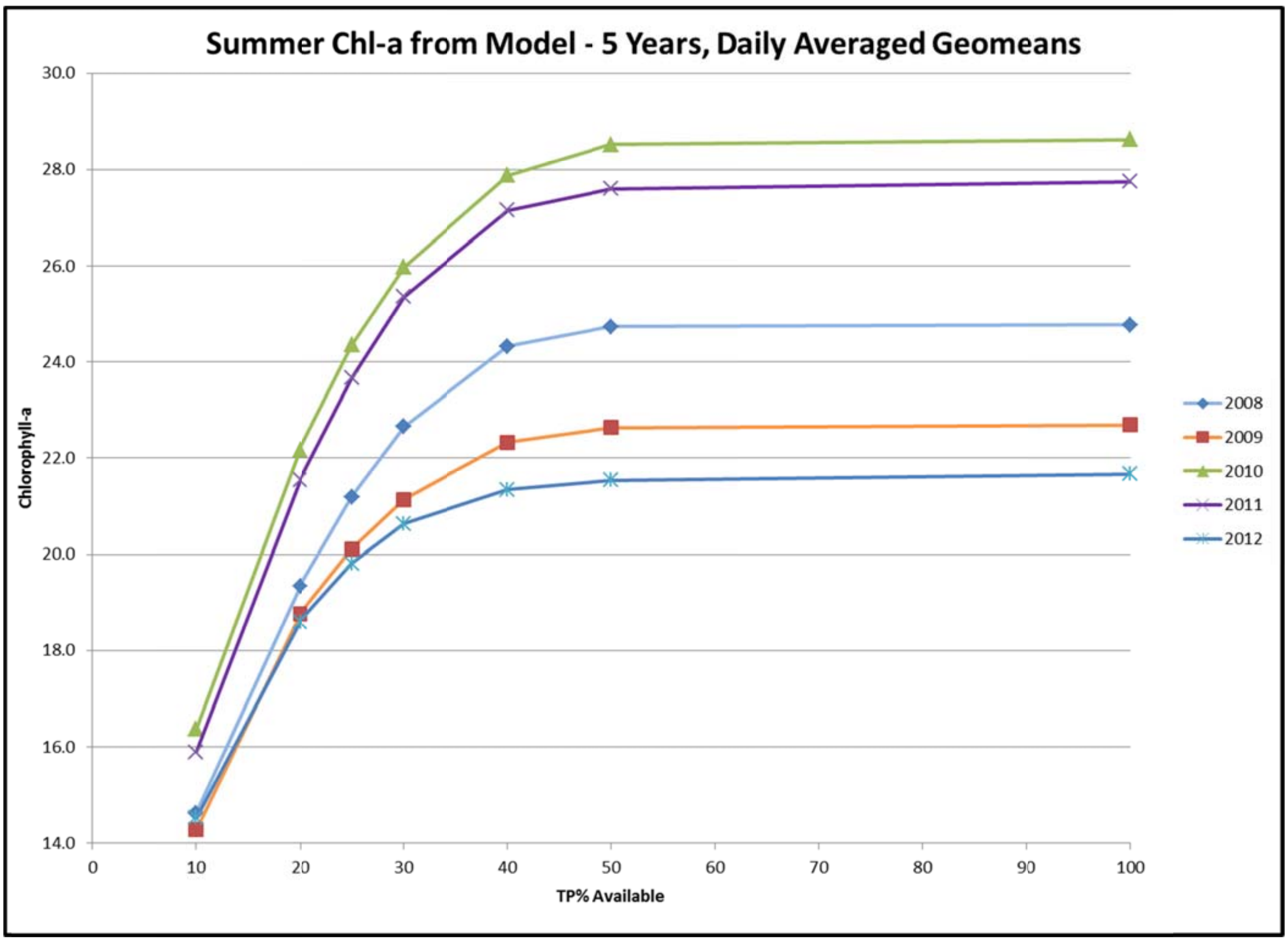


Figure 23 Geometric Means Chl-a at Various TP% Available

3.3.4 Consider Dissolved Oxygen Diurnal Flux

Ohio Environmental Protection Agency published *A Method and Rationale for Deriving Nutrient Criteria for Small Rivers and Streams in Ohio*. This paper describes an analysis of the dissolved oxygen flux as a response to nutrient reduction. The difference between the minimum dissolved oxygen at night and the maximum dissolved oxygen during the afternoon provides the Diurnal Flux. The greater the flux, the more impact nutrients are having on the stream. If one targets a flux reduction, a nutrient limit could be derived.

Minnesota Pollution Control Agency published *Establishing Relationships Among In-stream Nutrient Concentrations, Phytoplankton Abundance and Composition, Fish IBI and Biochemical Oxygen Demand in Minnesota*. This paper addressed sestonic chlorophyll-a targets for large rivers. The paper recommends DO flux ranges for less than 3 to 4.5 mg/l for the southern more enriched region of Minnesota. These are based on regression models of DO ranges vs. chlorophyll-a.

MDEQ did not adopt these methods for this TMDL, but included this comparison in the TMDL to show the reduction scenario would address this method.

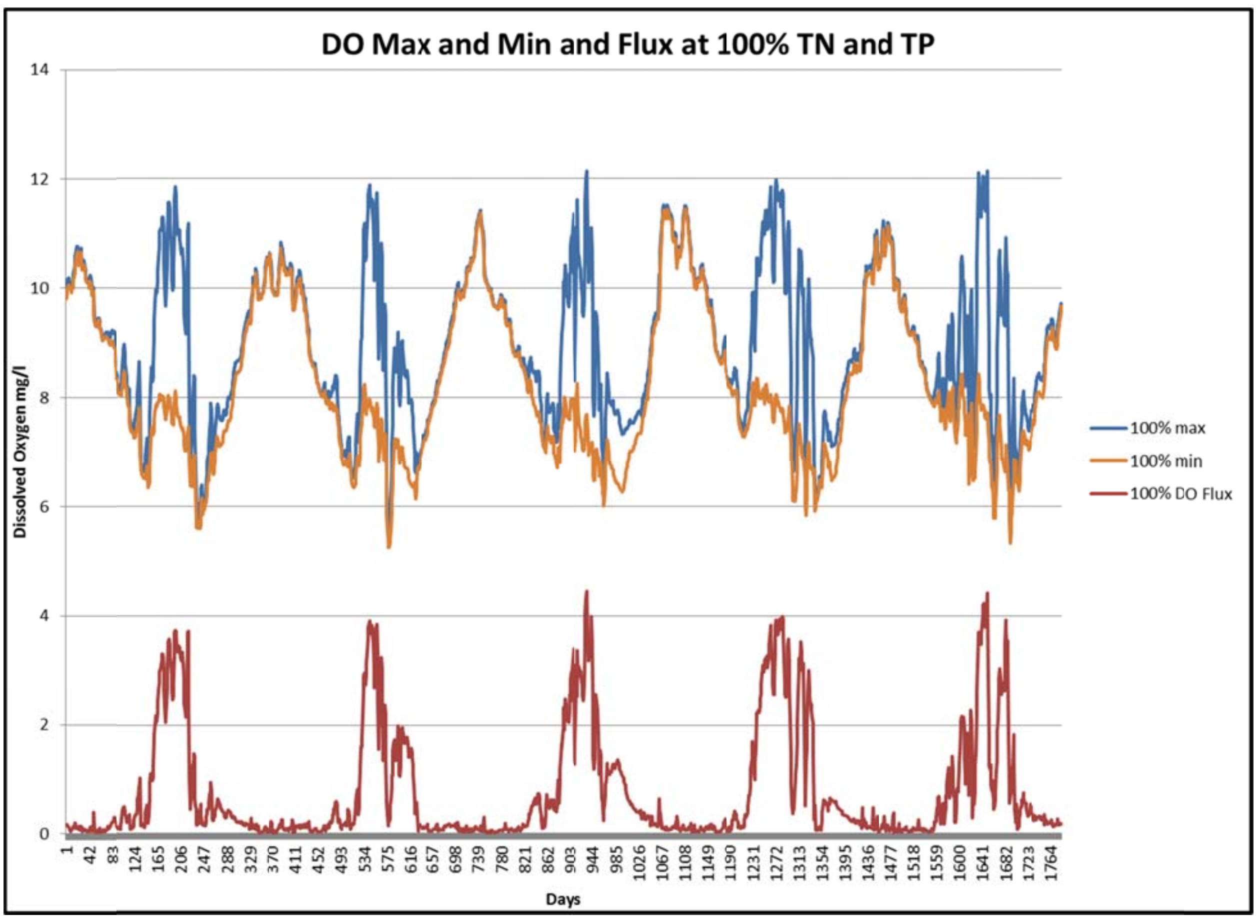


Figure 24 DO Flux at 100% TN and TP

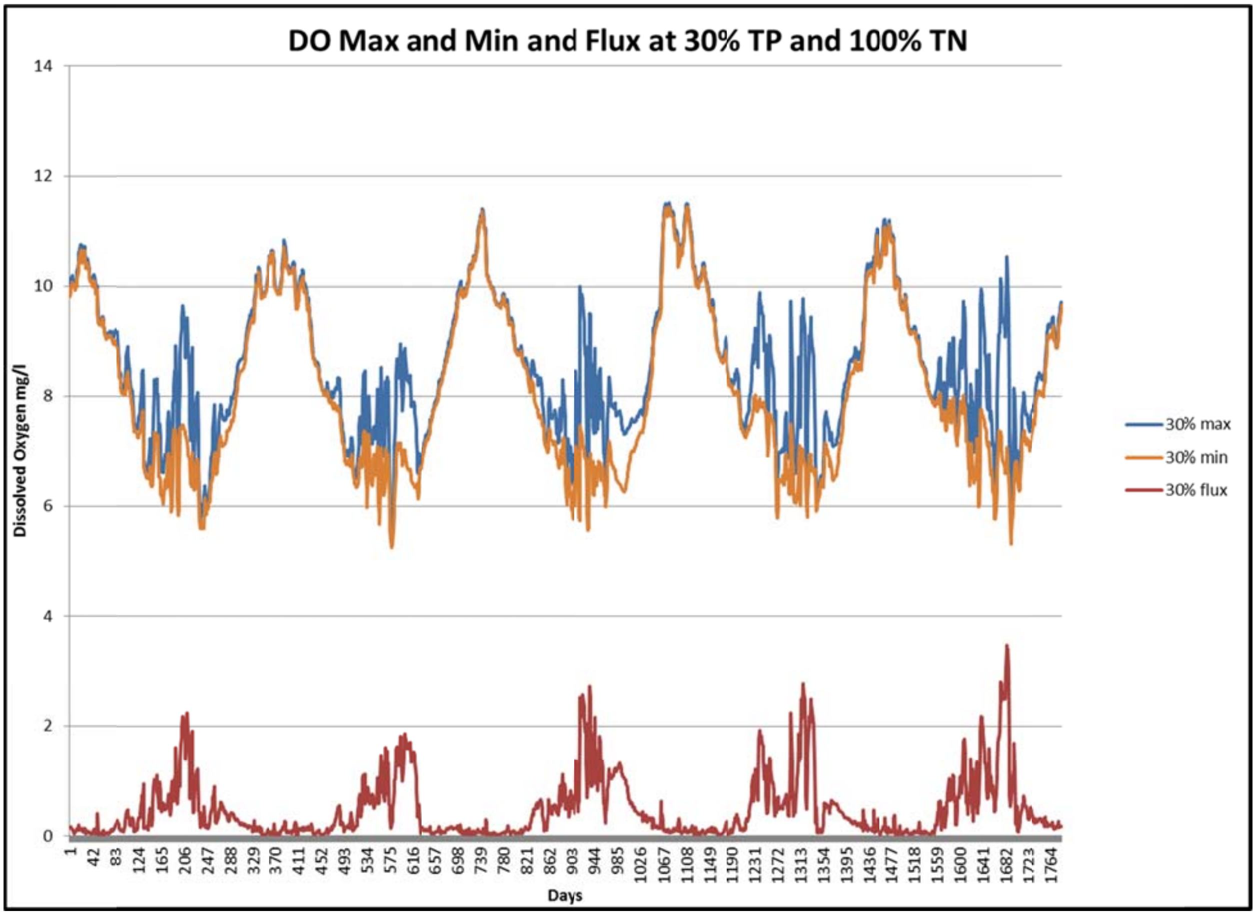


Figure 25 DO Flux at 30% TP Available

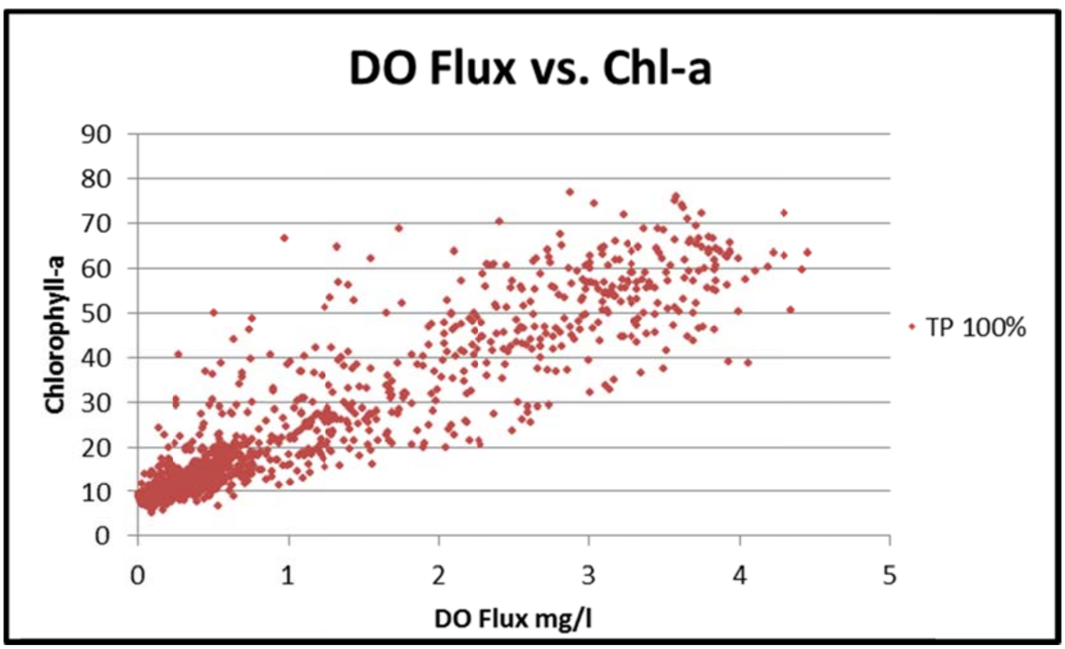


Figure 26 DO Flux vs. Chl-a TN and TP 100%

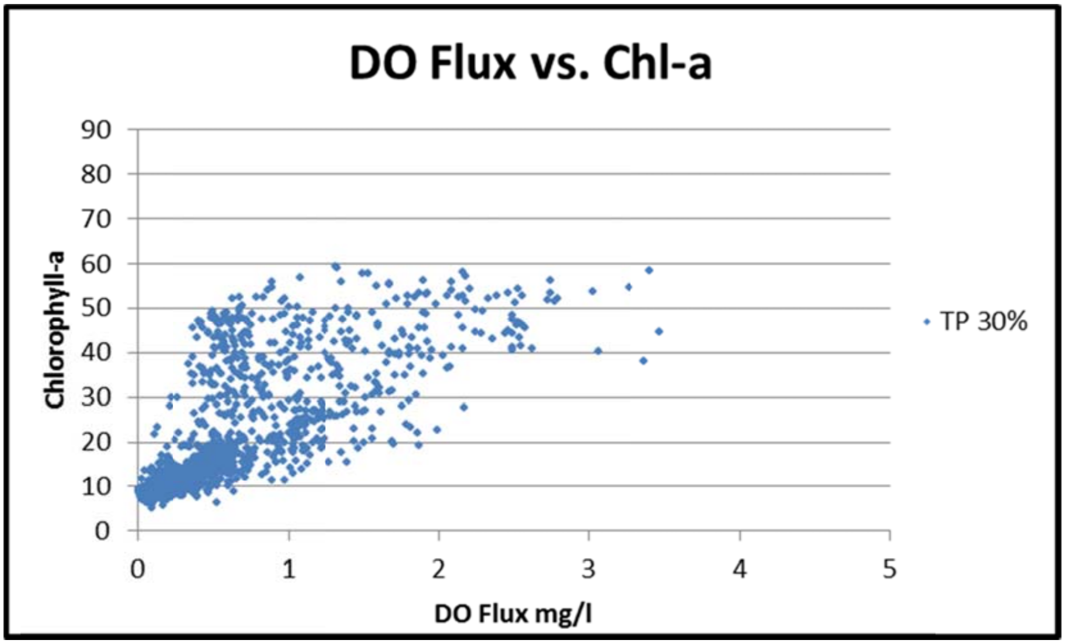


Figure 27 DO Flux vs. Chl-a TP 30%

Figures 24 and 25 show the maximum and minimum DO as well as the DO flux for the model output for the 100% and 30% TP available models. Figures 26 and 27 show the relationship of DO flux to chlorophyll-a for both models. The DO flux maximum value dropped from 4.45 to 3.47. The average DO flux dropped from 0.79 to 0.48. The chlorophyll-a maximum dropped from 76.9 to 59.5 µg/l.

3.4 TMDL Target Selection

Several pathways were considered for development of the TMDL target both in the causal and in the response variables. Model output shows a 70% reduction in TP provides a chlorophyll-a maximum below 60 µg/l and a 90th percentile maximum of 41.7 µg/l. The seasonal geometric mean for the average year of 2008 was 23 µg/l. The DO flux was below 3.5 mg/l. This 70% reduction of TP is an aggressive reduction goal. The existing 2009 TMDL sets the reduction target to 56%. Modeling indicates there will be an improvement to water quality as a response to this reduction target.

The 70% TP reduction target is an overall reduction for total (point and nonpoint) load within the WASP model. The next chapter will discuss the allocation of the LA and WLA to the point and non-point sources in the watershed.

Figure 28 shows model results for TP for the calibrated model and the 2009 and 2014 TMDL reduction targets.

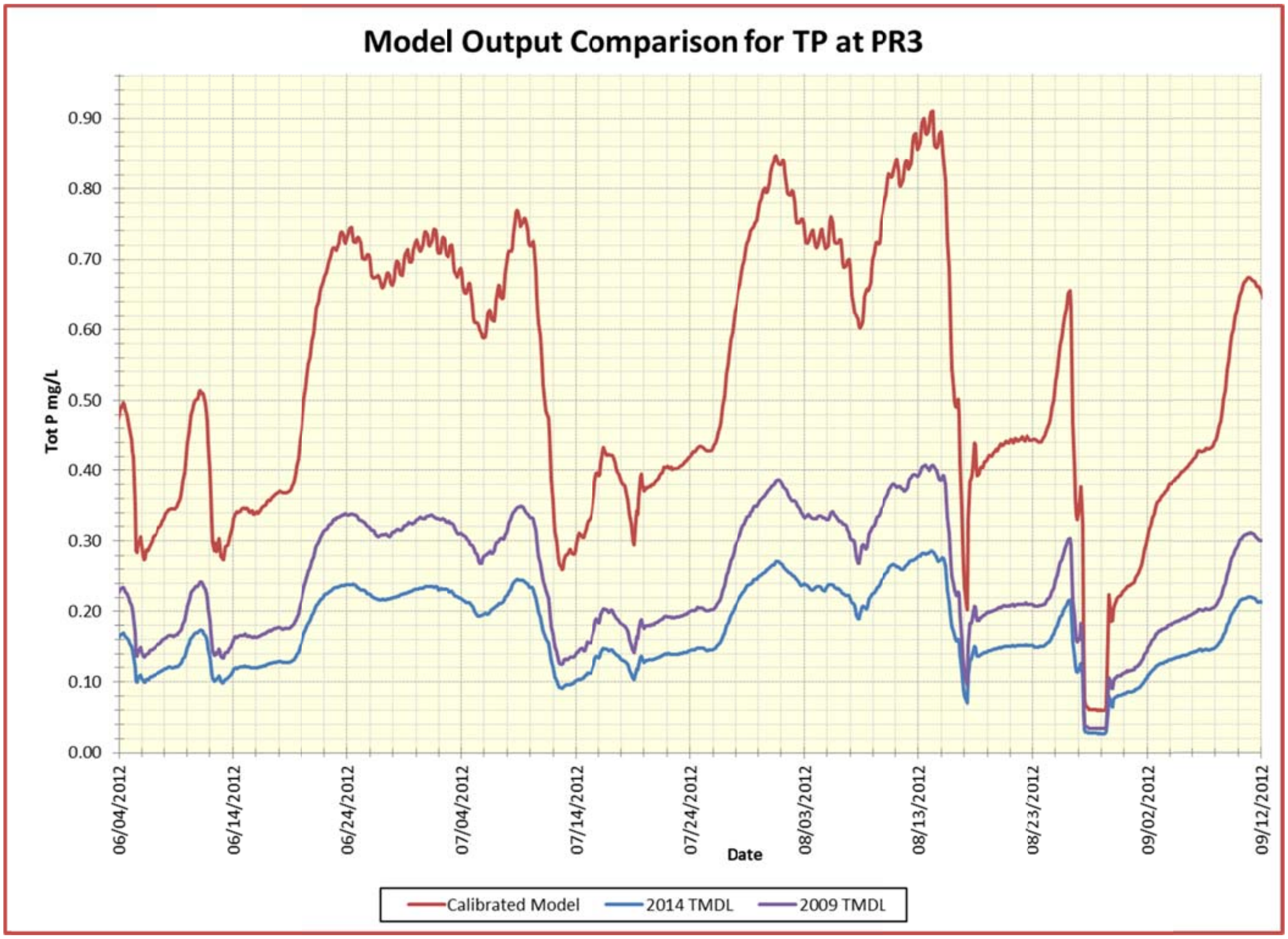


Figure 28 Compares Model Results with 2014 and 2009 TMDL values

3.5 Nonpoint Source Dominant Loads

One further consideration is the anthropogenic loading of nutrients for the watershed. To review this, the WASP model was set with all of the TN and TP from the point sources completely removed. The resulting model output indicates continued impairment with the point sources removed. This means that the complete elimination of all of the point sources will not restore water quality. The restoration is dependent on controlling the nonpoint source loads to the implementation of BMPs. Concurrently, new permit limits will be established to further improve the quality of the nutrient loads in the watershed.

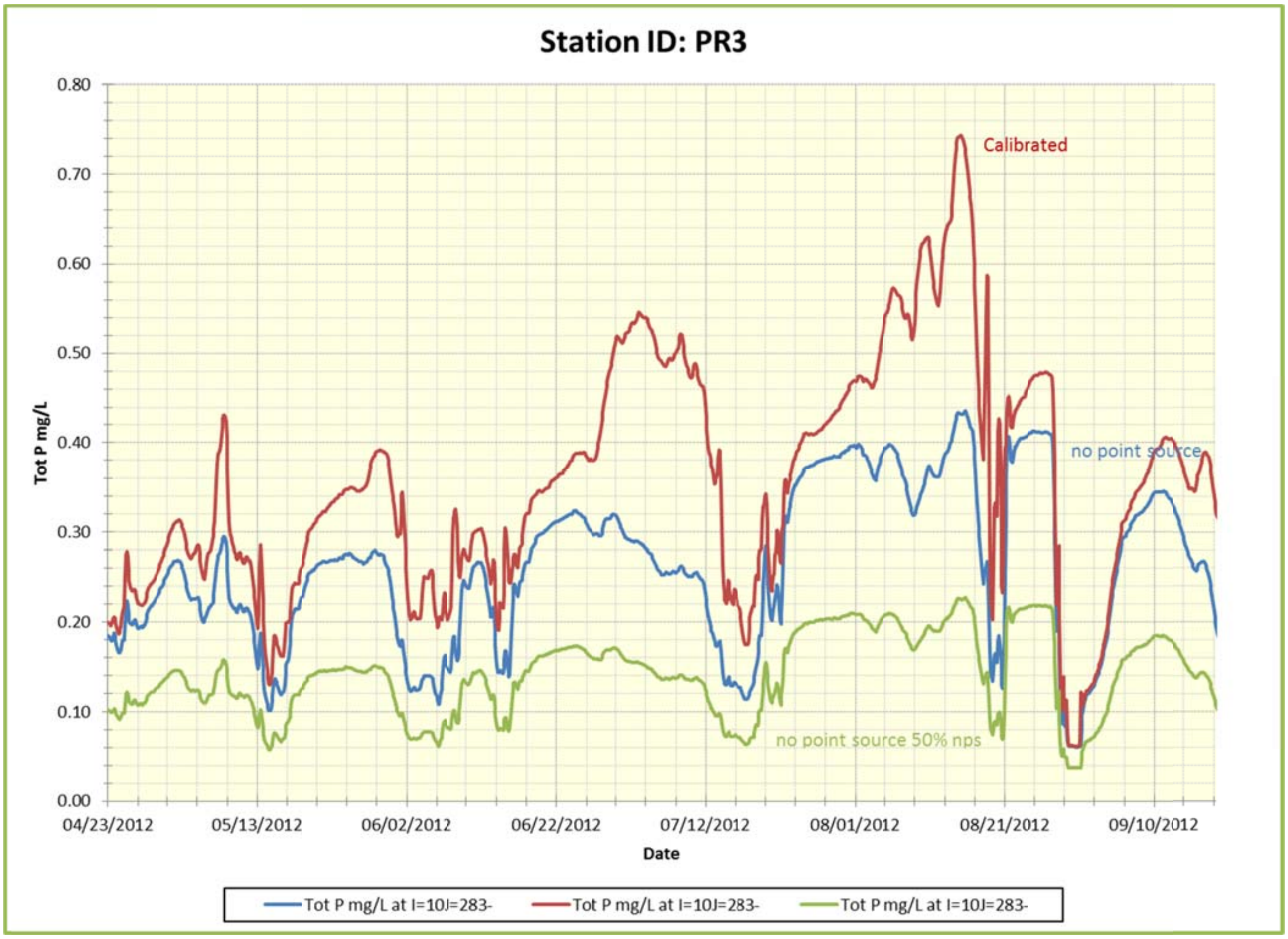


Figure 29 Model Output of TP with and without point sources

TP ALLOCATION

4.1 TMDL Calculation for Total Phosphorus

The TMDL is calculated based on the following equation.

$$TMDL = WLA + WLAsw + LA + MOS$$

where WLA is the Wasteload Allocation, WLAsw is Wasteload Allocation from stormwater activities, LA is the Load Allocation, and MOS is the Margin of Safety.

The TMDL for TP will be based on reducing the overall TP load by 70%. To determine this load, the model output was charted for both the 100% available and 30% available TP. The TP concentration for each day was multiplied by the flow that day and converted to a daily load.

Extreme flow events can drive the outcome. Figure 30 shows the flows modeled based on the USGS flow gages in the river. The peaks shown are the result of hurricanes and tropical storms which impacted the watershed during the 5 years studied. The largest peak was from Tropical Storm Lee which provided 7 to 10 inches of rainfall over most of the watershed over a 4 day period in September, 2011. (NOAA, 2011) To account for these outliers, the 90th percentile of the loads was selected as the TMDL for TP. This is a conservative assumption that sets the TMDL based on regular critical conditions and does not allow for a higher TMDL based on tropical storm flows.

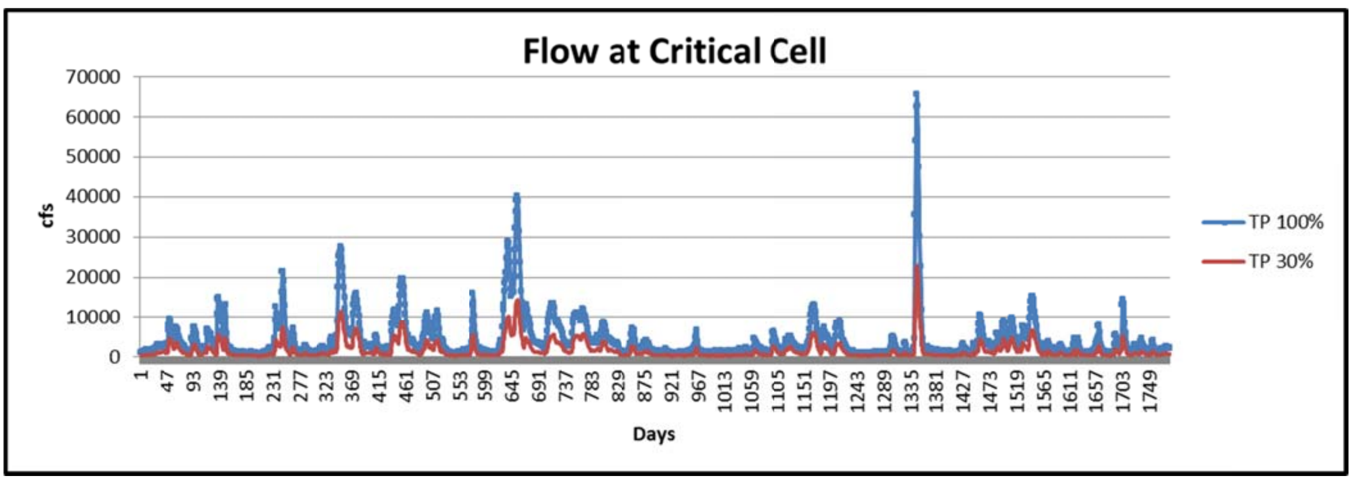


Figure 30 Flow at Model Cell 360

Figure 31 below shows the TP load in pounds per day for both 100% available and 30% available regressed from the lowest to the highest values. When the 90th percentile is selected from the 70% reduction, the TMDL is reduced from 10,045 lbs. to 4,208 lbs. This is an overall reduction in load of 58.1%.

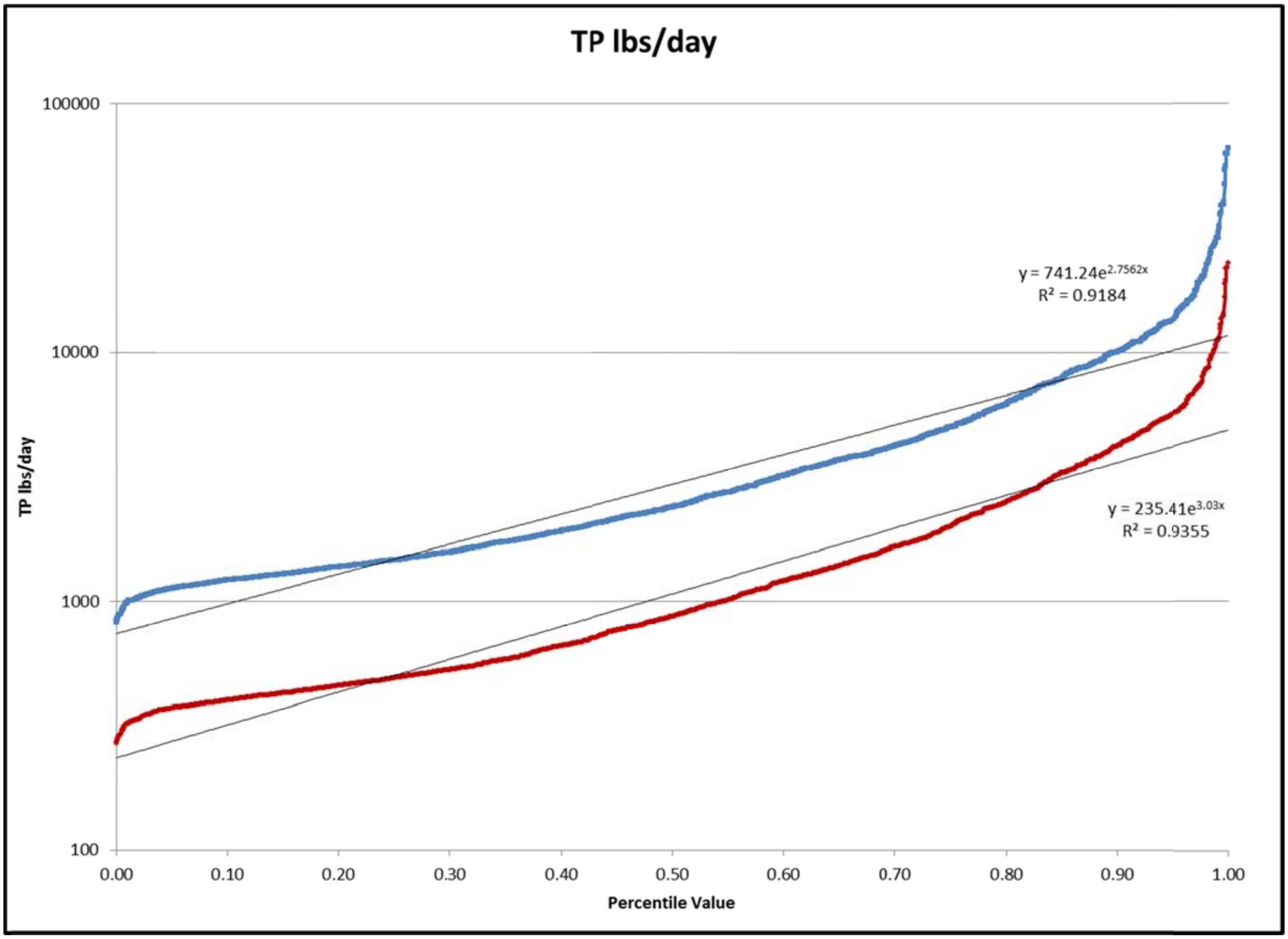


Figure 31 TP Load Regression

4.2 Waste Load Allocation

This model provided for the direct calculation of the TP TMDL at 4,208 lbs. per day during the growing season. This TMDL value must be allocated between point and non-point sources. To achieve this allocation, the TMDL will be divided between the WLA and LA portions. The LA portion will also be allocated between non-point source load and WLAsw to determine the overall allocations for the TMDL. See Table 9 below for the calculations.

4.2.1 City of Jackson POTW - Savanna Street Facility

The City of Jackson POTW, Savanna Street Facility, had seasonal flow limits of 46 MGD in the summer (May – October) and 120 MGD in the winter (November – April) in the previous NPDES permit. This permitted flow was changed to match the technical capacity of the treatment plant at 46 MGD year round at the last permit reissuance. The average flow of this facility, taken from their NPDES permit application based on 777 samples, is 48.14 MGD. This figure was used in the calibration modeling; however, 46

MGD was used in the permit limit models. The TP and TN loads for this facility were calculated based on the new annual flow at 46 MGD and are to be applied as a 30-day average load in the permit. The nutrient limits are seasonal based on the growing season of chlorophyll-a and the WASP model output. The TP allocation for this facility is 1131.7 lbs. per day during the growing season. The 2009 TMDL allocated 1128 lbs. per day.

4.2.2 West Rankin County POTW Future Facility

West Rankin County applied for a NPDES permit to build a new wastewater treatment plant to discharge just north of the current Savanna Street POTW. This wastewater is currently being treated at the Savanna Street POTW. The flow requested would be permitted at 20 MGD. To coordinate with this TMDL, the TP limit would be 439.3 lbs. per day during the growing season. As this permit is currently in the development and planning phase, the allocation cannot be assigned before the permit is approved. Therefore, MDEQ will show this allocation as future assimilative capacity available in this TMDL. Should the West Rankin County POTW NPDES permit not be issued, this future allocation will be held for other point source allocation in the future.

4.2.3 City of Jackson POTW - Trahon Facility

The City of Jackson POTW, Trahon Facility has an NPDES permit limit of 4.5 MGD. The TP allocation for this facility is 110.7 lbs. per day during the growing season.

4.2.4 O.B. Curtis Water Treatment Plant, City of Jackson

The O.B. Curtis Water Treatment Plant discharges 3.12 MGD into the Pearl River. The allocation for TP is 76.8 lbs. per day during the growing season. The City of Jackson has 3 facilities in this point source allocation. They will be given the opportunity to adjust these 3 loads in combination to achieve the most efficient treatment available while maintaining the overall limit of the sum of the three plants at 1297 lbs. per day during the growing season.

4.2.5 Florence POTW

The Florence POTW discharges 0.5 MGD. The TP allocation from this TMDL will be 23.4 lbs. per day during the growing season.

4.2.6 Other Small Communities and *de minimis* Facilities

The rest of the point sources are less than 6 lbs. per day and lower. The TP limits will be set by allowing a TP concentration of 5.6 mg/l in these permits. The allocations are shown in Table 12 below.

4.3 Wasteload Allocation Storm Water

MDEQ has established a method to estimate the storm water waste load allocation (WLAsw). The WLAsw is calculated according to the equation below. The intent of the storm water NPDES permit is not to treat the water after collection, but to reduce the exposure of storm water runoff to pollutants by implementing various controls. Storm water NPDES permits require the establishment of controls or BMPs to reduce the pollutants entering the environment.

Waste Load Allocation Storm Water (WLAsw) = LA * % Urban Area in MS4 within watershed * 70%

WLAsw = LA * 27.2% * 70% = 19.04% * LA to proportion the Stormwater WLA

WLAsw = 2,000 lbs. per day * 27.2% * 70% = 381 lbs. per day

4.4 Load Allocation

This TMDL recommends a nonpoint source reduction of TN and TP. Best management practices should be encouraged in the watersheds to reduce potential TN and TP loads from non-point sources.

For land disturbing activities related to silviculture, construction, and agriculture, it is recommended that practices, as outlined in "Mississippi's BMPs: Best Management Practices for Forestry in Mississippi" (MFC, 2008), "NPS Field Manual For Erosion And Sediment Control Version 2." (MDEQ, et. al, 2011), and "Field Office Technical Guide" (NRCS, 2012), be followed, respectively.

Figure 32 below shows the existing BMPs in the watershed presently.

4.5 Incorporation of a Margin of Safety

The margin of safety is a required component of a TMDL and accounts for the uncertainty about the relationship between pollutant loads and the quality of the receiving water body. The two types of MOS development are to implicitly incorporate the MOS using conservative model assumptions or to explicitly specify a portion of the total TMDL as the MOS. The MOS selected for this model is implicit.

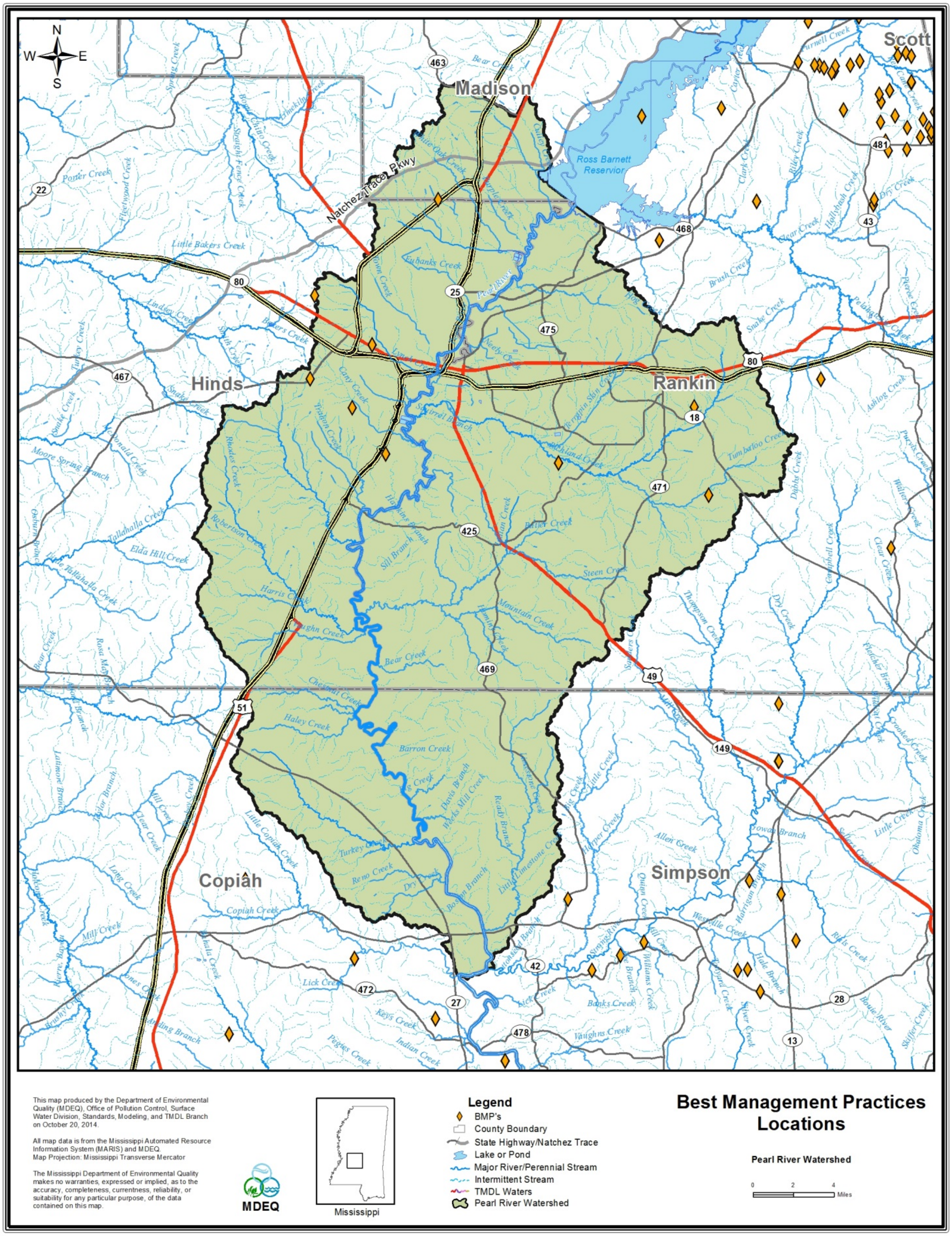


Figure 32 BMPs in the Watershed

4.6 TP TMDL Allocations

Table 12 shows the WLA, WLAsw, and LA allocations for TP in the segment. These are specific to the results of the modeling at cell 360 near Hopewell and are based on the critical conditions found in the model output. The *de minimis* point sources are grouped into one listing.

Table 12 TP TMDL Allocations

Facility	AI No.	Discharge (MGD)	TP Concentration (mg/l)	TP Load (lbs./day)
City of Jackson POTW- Savanna Street	13201	46	2.95	1131.7
Future growth	56736	20	2.52	439.3
City of Jackson POTW- Trahon	13203	4.5	2.95	110.7
O.B. Curtis Water Treatment Plant	4369	3.12	2.95	76.8
City of Florence POTW	13136	0.5	5.6	23.4
City of Terry POTW	13414	0.12	5.6	5.6
City of Georgetown POTW	13147	0.11	5.6	5.1
Red River Utility Company	14062	0.1144	5.2	5.0
Cleary Heights S/D	13066	0.1	5.6	4.7
Rowan Oaks S/D	16342	0.088	5.6	4.1
Other de minimis Facilities		0.442	5.6	20.1
WLAsw				381.0
Load Allocation				2000.0
Total TMDL				**4,207.5**

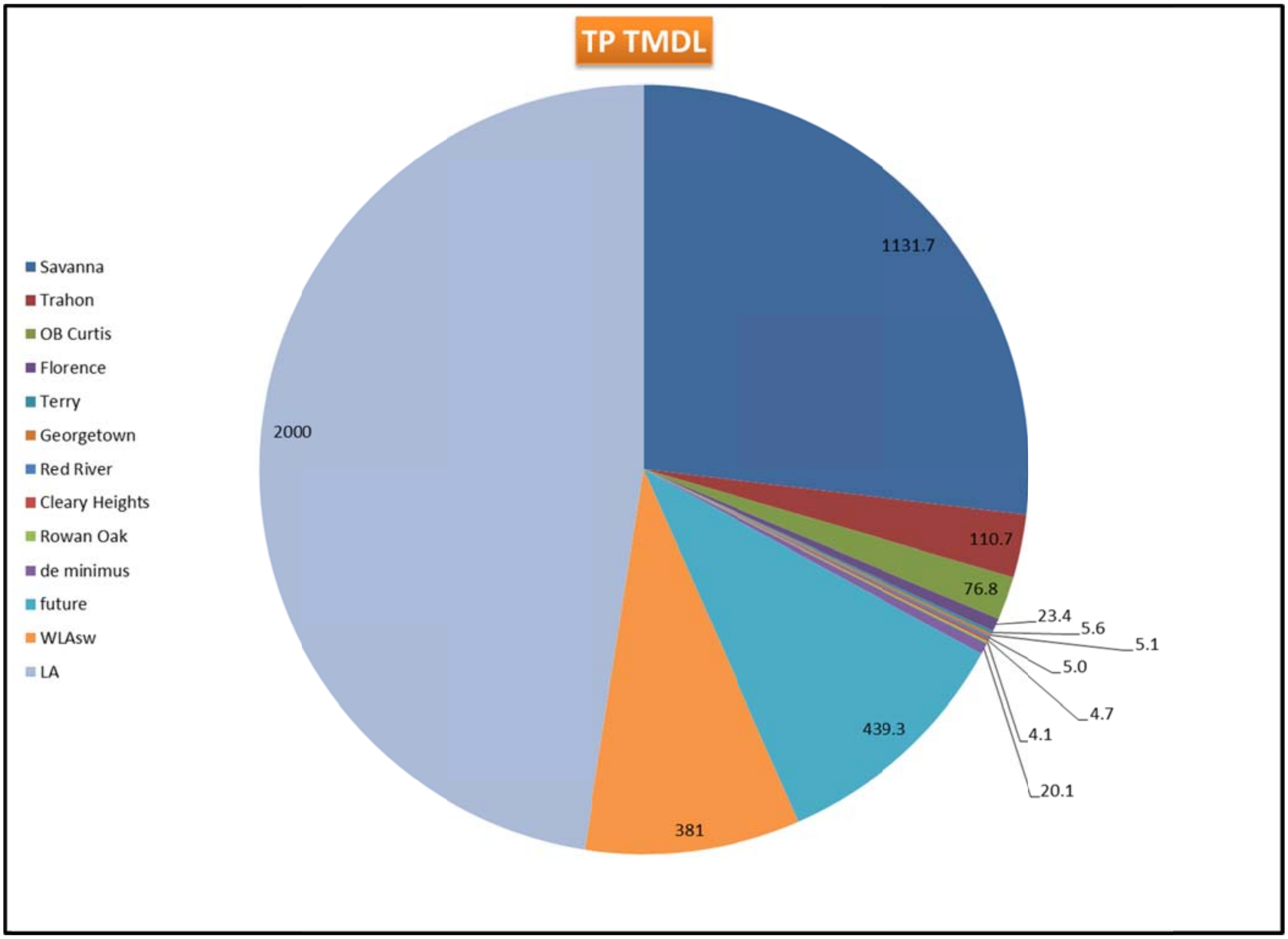


Figure 33 TP TMDL Allocations

4.7 Seasonality and Critical Condition

This TMDL accounts for seasonal variability by requiring allocations that ensure growing season protection of water quality standards, which is during critical conditions.

TN Allocation

5.1 TMDL Established for Nitrogen

The TMDL for TN was established in the same manner as in TP. The model output for the 30%TP available run was used to establish the TN TMDL. Again the 90th percentile value was used to provide a conservative value for TN based on avoiding tropical storm flows.

The 90th percentile of TN in pounds per day in the 30%TP available model run is 75,733 pounds per day. This TMDL proposes to set the TN concentration in point source permits at 13.6 to 11.5 mg/l based on literature values of adequate WWTP TN treatment. The goal of the TMDL is to achieve water quality restoration through limiting TP. However, the same BMPs that will control the TP contribution from nonpoint sources will also control TN from that source.

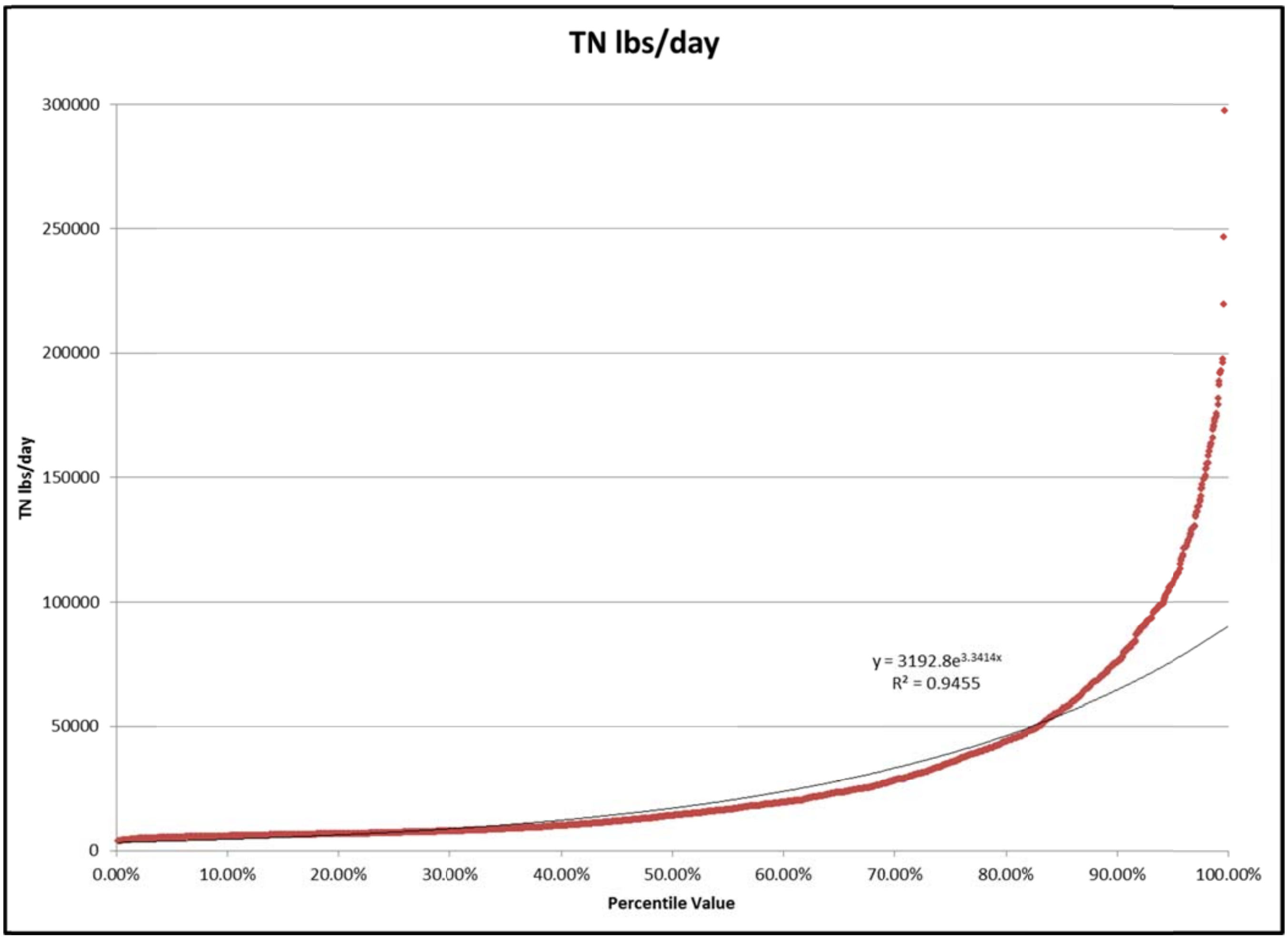


Figure 34 TN Pounds per Day Regression

5.2 Waste Load Allocation

The WLA is based on an overall allowable concentration of 13.6 to 11.5 mg/l from each point source. Table 13 below shows the individual point sources, their permitted flow, and the corresponding TN load allowed in pounds per day. This total load is less than the WLA for this pollutant and will be allocated for future growth.

Table 13 TN Loads from Point Sources

Agency Interest ID	Flow MGD	TN mg/l	TN Lbs./Day
13201	46	13.6	5220.9
56736	20	11.5	1919.4
13203	4.5	13.6	510.7
4369	3.12	11.5	299.4
13136	0.5	11.5	48.0
13414	0.12	11.5	11.5
13147	0.11	11.5	10.6
14062	0.1144	11.5	11.0
13066	0.1	11.5	9.6
16342	0.088	11.5	8.4
13744	0.08	11.5	7.7
13963	0.07	11.5	6.7
14443	0.035	11.5	3.4
14268	0.033	11.5	3.2
13911	0.03	11.5	2.9
14229	0.023	11.5	2.2
13710	0.0225	11.5	2.2
20634	0.02	11.5	1.9
13795	0.015	11.5	1.4
13933	0.015	11.5	1.4
18863	0.015	11.5	1.4
13991	0.0139	11.5	1.3
13723	0.011	11.5	1.1
13642	0.01	11.5	1.0
14153	0.007	11.5	0.7
20390	0.006	11.5	0.6
18617	0.005	11.5	0.5
16917	0.002	11.5	0.2
13872	0.0018	11.5	0.2
13954	0.0016	11.5	0.2
13853	0.0015	11.5	0.1
14000	0.0015	11.5	0.1
14058	0.0015	11.5	0.1
14095	0.0015	11.5	0.1
14180	0.0015	11.5	0.1

13844	0.001	11.5	0.1
13998	0.001	11.5	0.1
14076	0.001	11.5	0.1
14253	0.001	11.5	0.1
18762	0.0006	11.5	0.1
16033	0.0005	11.5	0.0
16316	0.0005	11.5	0.0
70	0.00043	11.5	0.0
13961	0.0004	11.5	0.0
12162	0.00004	11.5	0.0
14327	0.012	11.5	1.2
1451	0	11.5	0.0
14812	0	11.5	0.0
Total	**76.5**		**8828.4**

5.3 Wasteload Allocation Storm Water

The same stormwater calculation used for TP has been applied to TN.

Waste Load Allocation Storm Water (WLAsw) = LA * % Urban Area in MS4 within watershed * 70%

WLAsw = LA * 27.2% * 70% = 19.04% * LA to proportion the Stormwater WLA

WLAsw = 54,602 lbs. per day * 27.2% * 70% = 10,396 lbs. per day

5.4 Load Allocation and Margin of Safety

These loads are also constructed as in the TP TMDL. There is sufficient assimilative capacity in TN such that reduction is not required by this TMDL.

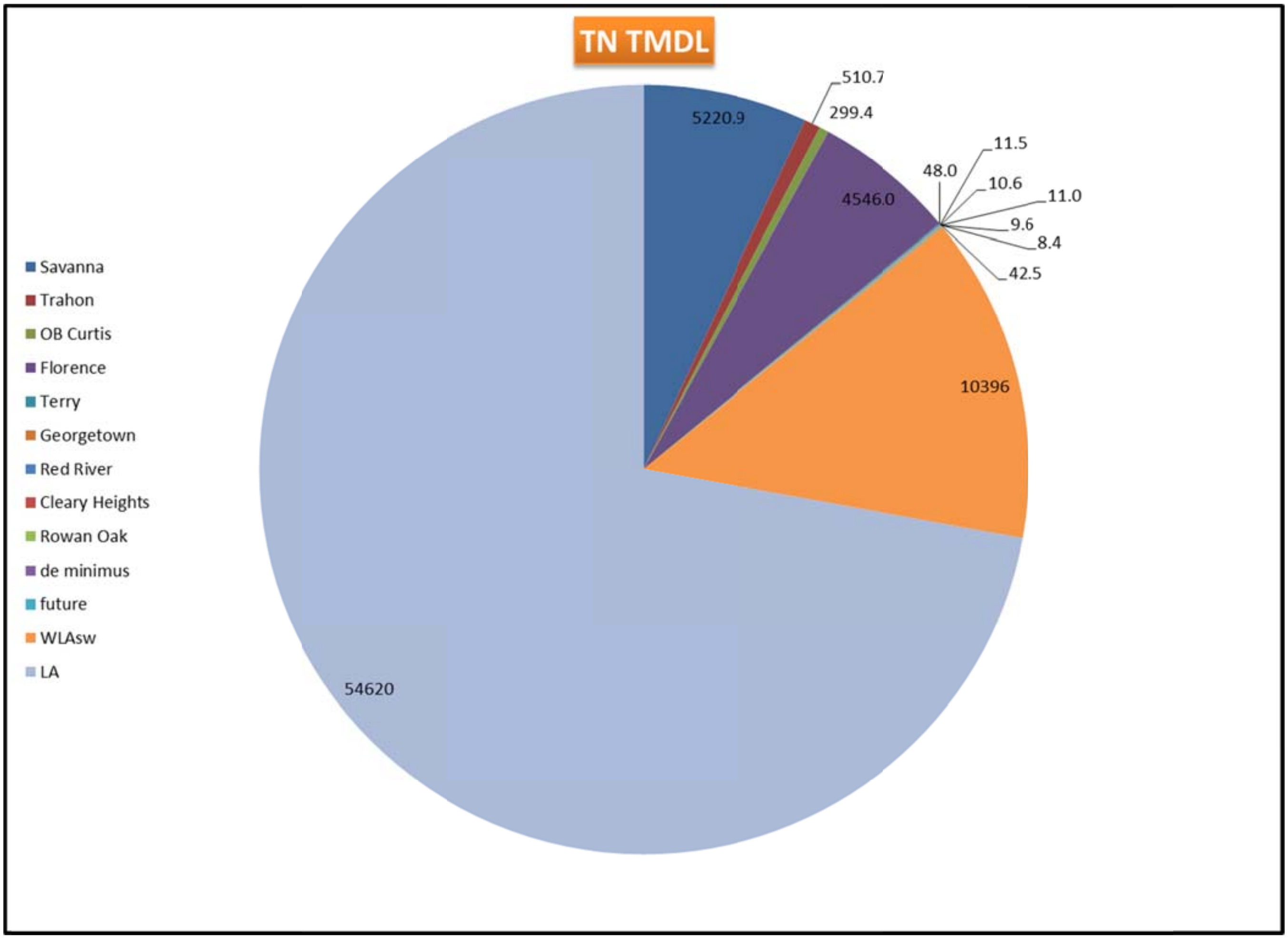


Figure 35 TN TMDL Distribution

CONCLUSION

The implementation of BMP activities should continue to reduce the nutrient loads entering the Pearl River. The limiting of TN and TP from the waste water treatment plants and the restoration of the Savanna St. POTW will also provide for improved water quality from the point sources. This will provide improved water quality for the support of aquatic life in the water bodies, and will result in the attainment of the applicable water quality standards.

6.1 Next Steps

MDEQ's Basin Management Approach and Nonpoint Source Program emphasize restoration of impaired waters with developed TMDLs. During the watershed prioritization process to be conducted by the Pearl River Basin Team, this TMDL will be considered as a basis for implementing possible restoration projects. The Pearl River and the Ross Barnett Reservoir are both actively receiving coverage in basin management projects. The basin team is made up of state and federal resource agencies and stakeholder organizations and provides the opportunity for these entities to work with local stakeholders to achieve quantifiable improvements in water quality. Together, basin team members work to understand water quality conditions, determine causes and sources of problems, prioritize watersheds for potential water quality restoration and protection activities, and identify collaboration and leveraging opportunities. The Basin Management Approach and the Nonpoint Source Program work together to facilitate and support these activities.

The Nonpoint Source Program provides financial incentives to eligible parties to implement appropriate restoration and protection projects through the Clean Water Act's Section 319 Nonpoint Source (NPS) Grant Program. This program makes available around $1.6M each grant year for restoration and protections efforts by providing a 60% cost share for eligible projects.

Mississippi Soil and Water Conservation Commission (MSWCC) is the lead agency responsible for abatement of agricultural NPS pollution through training, promotion, and installation of BMPs on agricultural lands. USDA Natural Resource Conservation Service (NRCS) provides technical assistance to MSWCC through its conservation districts located in each county. NRCS assists animal producers in developing nutrient management plans and grazing management plans. MDEQ, MSWCC, NRCS, and other governmental and nongovernmental organizations work closely together to reduce agricultural runoff through the Section 319 NPS Program.

Mississippi Forestry Commission (MFC), in cooperation with the Mississippi Forestry Association (MFA) and Mississippi State University (MSU), has taken a leadership role in the development and promotion of the forestry industry Best Management Practices (BMPs) in Mississippi. MDEQ is designated as the lead agency for implementing an urban polluted runoff control program through its Storm Water Program. Through this program, MDEQ regulates most construction activities. Mississippi Department of Transportation (MDOT) is responsible for implementation of erosion and sediment control practices on highway construction.

Due to this TMDL, projects within this watershed will receive a higher score and ranking for funding through the basin team process and Nonpoint Source Program described above.

6.2 Public Participation

This TMDL will be published for a 30-day public notice. During this time, the public will be notified by publication in the statewide newspaper. The public will be given an opportunity to review the TMDLs and submit comments. MDEQ also distributes all TMDLs at the beginning of the public notice to those members of the public who have requested to be included on a TMDL mailing list. Anyone wishing to become a member of the TMDL mailing list should contact Greg_Jackson@deq.state.ms.us.

All comments should be directed to Greg Jackson at MDEQ, PO Box 2261, Jackson, MS 39225. All comments received during the public notice period and at any public hearings become a part of the record of this TMDL and will be considered in the submission of this TMDL to EPA Region 4 for final approval.

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Appendix A – Tetra Tech Pearl River Model Report

Pearl River Nutrient Modeling Report

Prepared By

Tetra Tech, Inc.
Atlanta, GA 30339

For

Georgia Pacific – Monticello Mill

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1.0 INTRODUCTION

1.1 Objectives

The Office of Pollution Control (OPC), Mississippi Department of Environmental Quality (MDEQ), has concerns about nutrient enrichment of the Pearl River. Through the nutrient criteria development process, MDEQ is evaluating how to establish nutrient criteria for large rivers. One option, expressed by MDEQ, is to use a calibrated water quality model as a tool for evaluating nutrient and Biochemical Oxygen Demand (BOD) impacts on key water quality variables, such as dissolved oxygen (DO) and/or chlorophyll (Chl a).

The Georgia-Pacific Monticello LLC (GP) Mill, located near Monticello, Mississippi, has an interest in the Pearl River and how the future nutrient criteria may impact the mill. To assist MDEQ in this process, GP Monticello contracted development of a Pearl River calibrated water quality model that can be used for TMDL development as a tool for developing nutrient criteria. GP Monticello is providing this model to MDEQ for their use. This report documents the calibration and development of the Pearl River hydrodynamic and water quality model. Initially the model was only going to cover the Pearl River from Monticello to Columbia, but with assistance and data provided by MDEQ the Pearl River model extends from Jackson, Ms. to Bogalusa, La. The Pearl River model includes water quality parameters and kinetics that can assess both BOD/DO impacts and Chl a/nutrient impacts on the river. The time period for this model is 2008 – 2012, which includes the 2008 critical summer low flow high temperature period for evaluating the BOD/DO impacts and a range of summer flow conditions for evaluating nutrient/Chl a impacts.

1.2 Study Area Description

The Pearl River model starts below Ross Barnett Reservoir near Jackson, Mississippi and extends past Monticello to the City of Bogalusa along the Mississippi and Louisiana border. The river then continues downstream to the Mississippi Gulf Coast.

The GP Mill is located adjacent to the Pearl River near Monticello, Mississippi. The Mill is a containerboard facility producing Kraft linerboard that is used to make the strong outer and inner layer of corrugated containers. Effluent from the Mill is treated via primary and secondary treatment systems before being released into the Pearl River.

1.3 Summary

The hydrodynamic model Environmental Fluid Dynamics Code (EFDC) was selected to simulate hydrodynamics, temperature, and transport processes for this study. The Pearl River EFDC model was used to simulate the flow and temperature for the Pearl River Study Area. A one dimensional grid was setup from 2000 through 2012. The EFDC hydrodynamic simulation is used to drive the Water Quality Analysis Simulation Program (WASP) Version 6.5 water quality model. The WASP model was operated on the same one dimensional grid used for the EFDC. For the water quality model calibration, the five-year time period of 2008 through 2012 was used. In consultation with MDEQ, this was determined to be the best representative time period for the model calibration and the final TMDL model.

There are numerous sources of data for the Pearl River for the time period 2008 to 2012, which were used to calibrate the model. Overall the model does a good job in replicating the nutrient concentrations, BOD5, Chl a and DO levels measured in the Pearl River. The model is adequate for nutrient and DO TMDL development.

Although this model covers the Pearl River from Jackson down past Bogalusa, the specific concern of this report is modeling GP Monticello's impact on water quality. The main area of focus is Pearl River near Monticello and parameters of concern are low DO levels and high DO levels that exceed the DO saturation due to high Chl a levels. Summer 2008 represents a low flow high temperature period when DO levels are expected to be the lowest values. For all 6 years the minimum daily average DO was above the MDEQ DO water quality standard of 5.0 mg/l downstream of the GP Monticello Mill.

A nutrient sensitivity analysis was run comparing existing conditions to no GP Monticello discharge conditions. The downstream DO levels with the GP Monticello discharge had fewer days that were above the DO saturation levels. The downstream summer Chl a with the GP Monticello discharge were about 5 ug/l or 10 percent higher with the existing GP Monticello discharge than with no discharge. Comparing upstream and downstream of GP Monticello's discharge, the DO levels upstream of the discharge exceed the DO saturation more than the levles downstream while the Chl a levels upstream are higher than the Chl a levels downstream.

2.0 Available Data for the Pearl River

There are numerous sources of data for the Pearl River for the time period 2008 to 2012. Following is a description of the various data collection activities. The data are graphically presented in the model calibration section of this report.

2.1 USGS Flow Gages

There are five, United States Geological Survey (USGS) flow gages in this section of the Pearl River – the Jackson, Rockport, Monticello, Columbia, and Bogalusa USGS gages. The locations for these gages are illustrated in Figure 1. The flow data for the gages is summarized in Table 1.

USGS Gage #	Location	Parameter	Units	Mean	Min	Max
2486000	Jackson	Flow	cfs	3696	148	49800
2488000	Rockport	Flow	cfs	6803	375	61000
2488500	Monticello	Flow	cfs	6047	438	62800
2489000	Columbia	Flow	cfs	6922	799	64400
2489500	Bogalusa	Flow	cfs	9116	1140	76800

Table 14 USGS Pearl River Gages and Flow Rates (cubic feet per second (cfs))

Figure 36 Pearl River USGS Gages

2.2 MDEQ and EPA Water Quality Studies

2.2.1 EPA and MDEQs' 2012 Pearl River Intensive Water Quality Study

EPA and MDEQ collected water quality data for the Pearl River and tributaries August 30 to September 1, 2012 (EPA 2012). The Pearl River section started at Moncure Road and ended below Rockport Road. The study included sampling locations at 8 sites on the Pearl River (PR1 – PR9) and four tributary stations (SR1, BC1 and CC1); station details are listed in the EPA report. See Figure 2 for map of the study area and sampling locations. Data collection included:

- Reaeration data
- Sediment Oxygen Demand (SOD)
- Chlorophyll a concentrations and rates.
- Samples for Algal Growth Potential (AGP) test
- Samples for limiting nutrient test
- *Insitu* DO and Temperature data
- Time of travel measurements

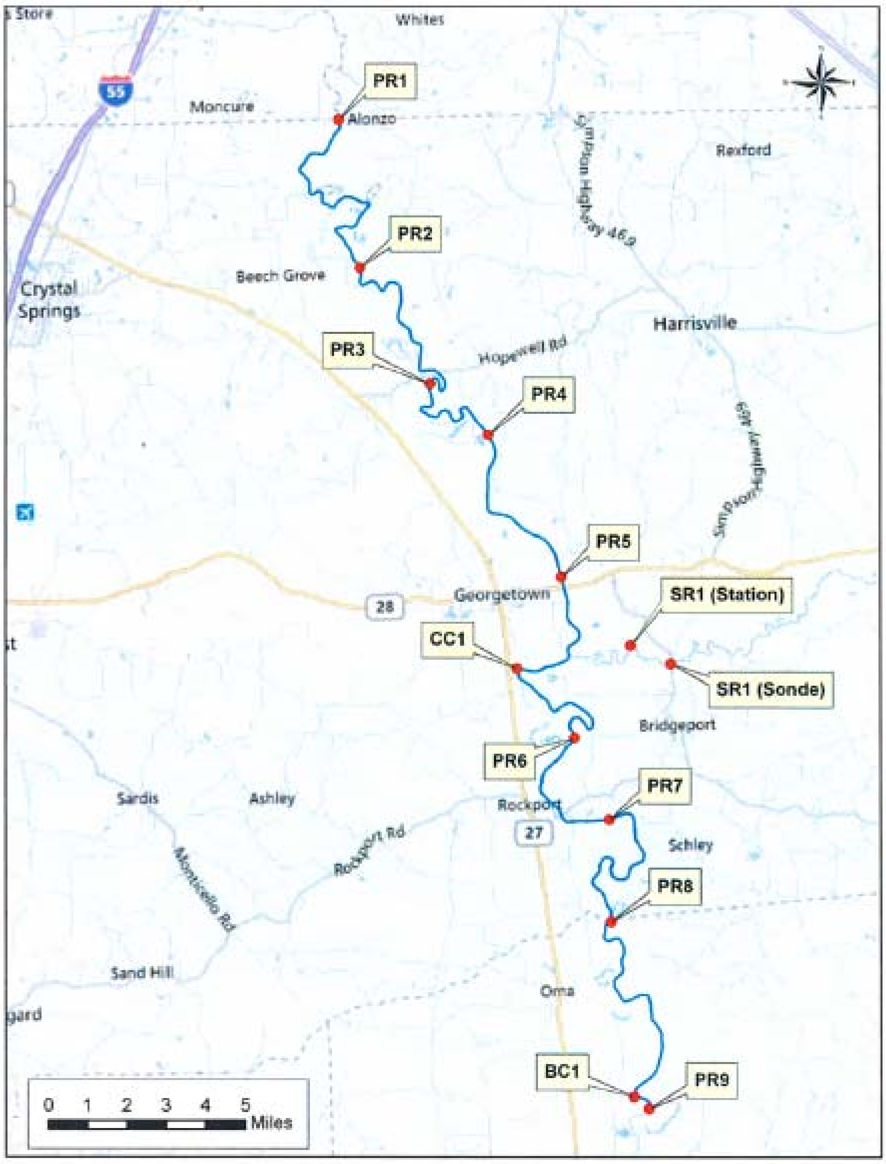

Figure 37 2012 EPA and MDEQ Study Area and Sampling Stations

Insitu DO and Temperature sampling was also completed at the stations from July 31 to August 2, 2012. A data summary for the DO and temperature data is provided in Table 2.

Table 15 DO and Temperature Summary, August 30 – September 1, 2012 Study

Station	Parameter Name	Units	Mean	Min	Max
PR1	Dissolved oxygen	mg/l	8.97	6.00	11.93
PR2	Dissolved oxygen	mg/l	9.05	6.62	12.14
PR3	Dissolved oxygen	mg/l	9.95	7.25	12.80
PR4	Dissolved oxygen	mg/l	9.54	7.57	11.95
PR5	Dissolved oxygen	mg/l	9.41	7.27	11.30
PR6	Dissolved oxygen	mg/l	9.07	6.53	11.62
PR7	Dissolved oxygen	mg/l	9.21	7.02	11.93
PR8	Dissolved oxygen	mg/l	9.60	7.11	13.01
PR1	Temperature, water	deg C	33.21	31.73	34.52
PR2	Temperature, water	deg C	33.28	31.55	35.18
PR3	Temperature, water	deg C	33.26	32.23	34.74
PR4	Temperature, water	deg C	33.18	32.56	33.86
PR5	Temperature, water	deg C	32.91	32.23	33.60
PR6	Temperature, water	deg C	32.57	31.70	33.21
PR7	Temperature, water	deg C	32.51	31.55	34.00
PR8	Temperature, water	deg C	32.55	31.42	33.93

mg/l – milligrams per liter, deg C – degrees Celsius

2.2.2 MDEQ September 2010 Study

MDEQ, in September 2010, collected *insitu* WQ data, chemical WQ data and long-term biochemical oxygen demand (BOD) data in the Pearl River near Monticello (MDEQ 2010). The sampling locations included four Pearl River Stations (PR1 – PR4), GP Mill Effluent (GP) and Hall Creek (HC1-HC3). Figure 3 shows the study area and sampling stations.

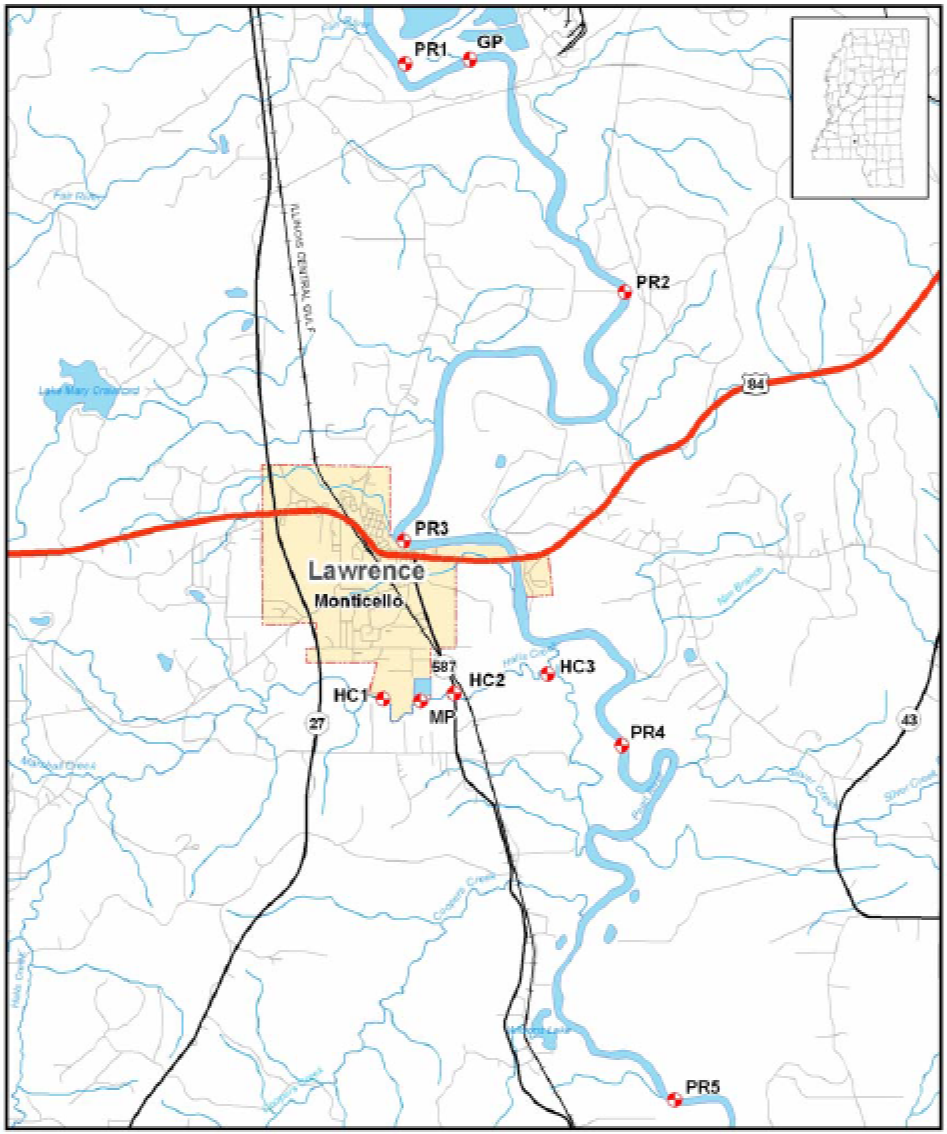

Figure 38 MDEQ 2010 Study Area and Sampling Stations.

2.2.3 MDEQ Pearl River Nutrient Monitoring

MDEQ has a long-term Pearl River nutrient monitoring station at Byram, located on Highway 29 below Jackson. The nutrient values for the various monitoring stations are provided in Table 3.

Table 16 Nutrient Sampling - Pearl River at Byram at Old Swinging Bridge

Parameter Name	Units	No. Obs.	Mean	Min	Max
Ammonia as NH3	mg/l	57	0.19	0.04	1.28
Nitrate-Nitrite	mg/l	63	0.59	0.07	2.12
Orthophosphate	mg/l	1	0.1	0.1	0.1
Kjeldahl nitrogen	mg/l	62	0.96	0.12	2.1
Total Nitrogen	mg/l	48	1.5	0.49	3.23
Organic Phosphorous	mg/l	1	0.05	0.05	0.05
Phosphorus	mg/l	63	0.27	0.05	1.12

mg/l – milligrams per liter

2.2.4 MDEQ Pearl River April and May 2008 Special TMDL Nutrient Study

In April and May 2008, MDEQ collected Chl a and nutrient data at the seven monitoring stations shown in Figure 4. This provided the most comprehensive snapshot of the distribution of nutrients and Chl a throughout the Pearl River system. This data are summarized in Tables 4 - 6.

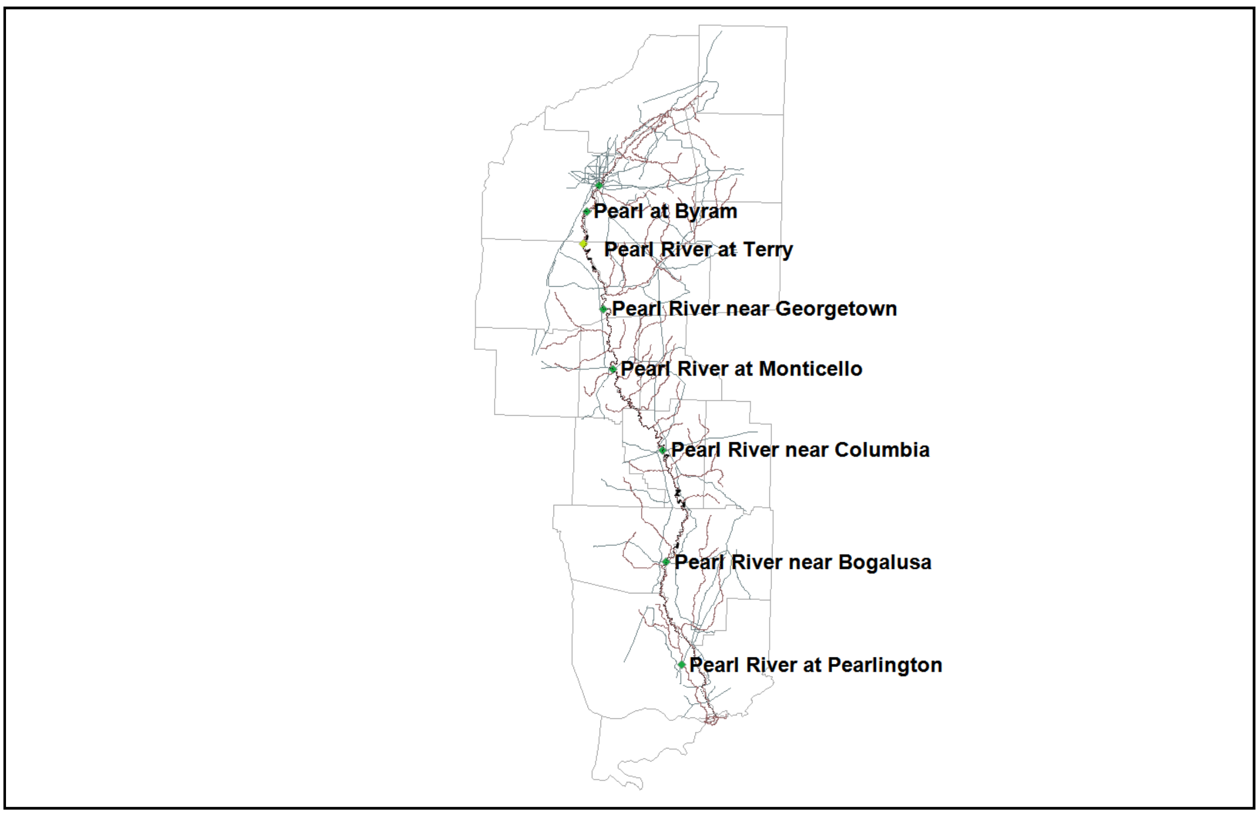

Figure 39 MDEQ 2008 TMDL Study Sampling Stations

Table 17 MDEQ 2008 Dissolved Oxygen and Chl a Data

Station Name	Parameter Name	Units	Mean	Min	Max
Pearl River at Byram	Chlorophyll A	ug/l	16.5	11.3	21.7
Pearl River near Terry	Chlorophyll A	ug/l	32.5	26.7	38.3
Pearl River at Georgetown	Chlorophyll A	ug/l	24.15	20	28.3
Pearl River near Monticello	Chlorophyll A	ug/l	21.8	13.1	30.5
Pearl River at Columbia	Chlorophyll A	ug/l	16.15	14	18.3
Pearl River at Bogalusa	Chlorophyll A	ug/l	15.3	2.9	27.7
Pearl River at Pearlington	Chlorophyll A	ug/l	6.9	4.7	9.1
Station Name	**Parameter Name**	**Units**	**Mean**	**Min**	**Max**
Pearl River at Byram	Dissolved Oxygen	mg/l	8.61	8.55	8.67
Pearl River near Terry	Dissolved Oxygen	mg/l	8.5	7.6	9.39
Pearl River at Georgetown	Dissolved Oxygen	mg/l	7.77	7.77	7.77
Pearl River near Monticello	Dissolved Oxygen	mg/l	7.34	7.34	7.34
Pearl River at Columbia	Dissolved Oxygen	mg/l	7.67	7.27	8.07
Pearl River at Bogalusa	Dissolved Oxygen	mg/l	7.74	6.62	8.85
Pearl River at Pearlington	Dissolved Oxygen	mg/l	6.86	5.84	7.88

mg/l – milligrams per liter, µg/l – micrograms per liter

Table 18 MDEQ 2008 Nitrogen Series Data

Station Name	Parameter Name	Units	Mean	Min	Max
Pearl River at Byram	Ammonia	mg/l	0.09	0.04	0.13
Pearl River near Terry	Ammonia	mg/l	0.14	0.04	0.23
Pearl River at Georgetown	Ammonia	mg/l	0.04	0.04	0.04
Pearl River near Monticello	Ammonia	mg/l	0.04	0.04	0.04
Pearl River at Columbia	Ammonia	mg/l	0.04	0.04	0.04
Pearl River at Pearlington	Ammonia	mg/l	0.14	0.04	0.19
Station Name	**Parameter Name**	**Units**	**Mean**	**Min**	**Max**
Pearl River at Byram	Nitrate-Nitrite	mg/l	0.26	0.19	0.33
Pearl River near Terry	Nitrate-Nitrite	mg/l	0.4	0.17	0.72
Pearl River at Georgetown	Nitrate-Nitrite	mg/l	0.25	0.15	0.35
Pearl River near Monticello	Nitrate-Nitrite	mg/l	0.27	0.17	0.37
Pearl River at Columbia	Nitrate-Nitrite	mg/l	0.37	0.34	0.4
Pearl River at Pearlington	Nitrate-Nitrite	mg/l	0.16	0.14	0.17
Station Name	**Parameter Name**	**Units**	**Mean**	**Min**	**Max**
Pearl River at Byram	TKN	mg/l	0.96	0.87	1.14
Pearl River near Terry	TKN	mg/l	1.02	0.73	1.38
Pearl River at Georgetown	TKN	mg/l	1.24	1.2	1.28
Pearl River near Monticello	TKN	mg/l	1.4	1.39	1.41
Pearl River at Columbia	TKN	mg/l	0.99	0.84	1.13
Pearl River at Bogalusa	TKN	mg/l	1.01	1	1.02
Pearl River at Pearlington	TKN	mg/l	0.8	0.79	0.81
Station Name	**Parameter Name**	**Units**	**Mean**	**Min**	**Max**
Pearl River at Byram	Total Nitrogen	mg/l	1.22	1.06	1.47
Pearl River near Terry	Total Nitrogen	mg/l	1.47	1.44	1.55
Pearl River at Georgetown	Total Nitrogen	mg/l	1.49	1.43	1.55
Pearl River near Monticello	Total Nitrogen	mg/l	1.67	1.58	1.76
Pearl River at Columbia	Total Nitrogen	mg/l	1.36	1.18	1.53
Pearl River at Bogalusa	Total Nitrogen	mg/l	1.21	1.11	1.31
Pearl River at Pearlington	Total Nitrogen	mg/l	0.96	0.95	0.96

mg/l – milligrams per liter, µg/l – micrograms per liter

Table 19 MDEQ 2008 Phosphorous Series Data

Station Name	Parameter Name	Units	Mean	Min	Max
Pearl River at Byram	Total Phosphorous	mg/l	0.14	0.13	0.15
Pearl River near Terry	Total Phosphorous	mg/l	0.2	0.16	0.25
Pearl River at Georgetown	Total Phosphorous	mg/l	0.16	0.15	0.16
Pearl River near Monticello	Total Phosphorous	mg/l	0.17	0.16	0.18
Pearl River at Columbia	Total Phosphorous	mg/l	0.17	0.15	0.19
Pearl River at Bogalusa	Total Phosphorous	mg/l	0.16	0.12	0.2
Pearl River at Pearlington	Total Phosphorous	mg/l	0.11	0.1	0.12
Station Name	**Parameter Name**	**Units**	**Mean**	**Min**	**Max**
Pearl River at Byram	Organic Phosphorous	mg/l	0.05	0.05	0.05
Pearl River near Terry	Organic Phosphorous	mg/l	0.01	0.01	0.01
Pearl River at Georgetown	Organic Phosphorous	mg/l	0.06	0.06	0.06
Pearl River near Monticello	Organic Phosphorous	mg/l	0.09	0.09	0.09
Pearl River at Columbia	Organic Phosphorous	mg/l	0.12	0.12	0.12
Pearl River at Bogalusa	Organic Phosphorous	mg/l	0.14	0.14	0.14
Pearl River at Pearlington	Organic Phosphorous	mg/l	0.05	0.05	0.05
Station Name	**Parameter Name**	**Units**	**Mean**	**Min**	**Max**
Pearl River at Byram	Ortho-Phosphorous	mg/l	0.1	0.1	0.1
Pearl River near Terry	Ortho-Phosphorous	mg/l	0.26	0.26	0.26
Pearl River at Georgetown	Ortho-Phosphorous	mg/l	0.09	0.09	0.09
Pearl River near Monticello	Ortho-Phosphorous	mg/l	0.09	0.09	0.09
Pearl River at Columbia	Ortho-Phosphorous	mg/l	0.12	0.12	0.12
Pearl River at Pearlington	Ortho-Phosphorous	mg/l	0.07	0.07	0.07

mg/l – milligrams per liter, µg/l – micrograms per liter

2.3 GP Monticello Data

GP Monticello routinely collects temperature and flow data at their water intake and effluent discharge structure located in the Pearl River, as well as temperature, BOD5 and DO data upstream above their water intake and downstream of the Mill's discharge near the USGS gage.

2.3.1 GP Monticello Effluent Data

GP Monticello collects discharge effluent data on a routine basis. Table 7 summarizes the GP Monticello effluent data collected from 2008 to 2012.

Table 20 GP Monticello Efflunet Data

Parameter	Units	Mean	Min	Max
FLOW	mgd	28.1	0.0	50.8
BOD5	mg/l	42.1	0.0	106.0
Ammonia	mg/l	1.7	0.0	9.0
Ntrate-Nitrite	mg/l	0.1	0.1	0.1
Organic Nitrogen	mg/l	9.5	9.5	9.5
Phosphate	mg/l	0.1	0.0	2.2
Total Phosphorus	mg/l	1.3	0.4	3.6

mgd – million gallons per day, mg/l – milligrams per liter

2.3.2 GP Monticello Pearl River Sampling

GP Monticello routinely collects Pearl River water quality data both upstream and downstream of their effluent discharge. Table 8 summarizes these data.

Table 21 GP Monticello River Sampling Data

Station Name	Parameter Name	Units	No. Obs.	Mean	Min	Max
Pearl River Upstream GP Monticello	BOD5	mg/l	4243	2.42	0.5	8
Pearl River Upstream GP Monticello	DO	mg/l	4256	8.64	5	12
Pearl River Upstream GP Monticello	Temperature, water	deg C	4259	19.99	6	32
Pearl River Downstream of GP Monticello	BOD5	mg/l	4247	3.02	0.5	9.5
Pearl River Downstream of GP Monticello	DO	mg/l	4254	7.4	5	14

BOD5 – 5-day biochemical oxygen demand, DO – dissolved oxygen, mg/l – milligrams per liter, deg C – degrees Celsius

2.3.3 GP Monticello Contracted Reaeration Study

GP Monticello contracted with HYDRO2 consultants to measure the reaeration in the Pearl River below their discharge site providing a more scientifically defensible value. The river reach of interest extends from the point of discharge downstream to below the city of Monticello, Mississippi. The measured reaeration rates ranged from 1.16 to 1.62 (grams oxygen/meter^2/day).

2.3.4 GP Monticello Long Term BOD Analysis

NCASI and MDEQ, in 2010, conducted long term BOD analysis of the GP Monticello effluent. Based on these long term analyses, an *f-ratio* (effluent BOD ultimate carbonaceous to BOD5 ratio) of 7 was determined as an appropriate value.

3.0 Hydrodynamic Modeling

The hydrodynamic model Environmental Fluid Dynamics Code (EFDC) was selected to simulate hydrodynamics, temperature and transport processes for this study. EFDC is a general purpose modeling package for simulating 1-D, 2-D, and 3-D flow and transport in surface water systems including rivers, lakes, estuaries, reservoirs, wetlands, and near shore to shelf-scale coastal regions. The EFDC model originally developed at the Virginia Institute of Marine Science for estuarine and coastal applications, has been extensively tested and documented, and is considered public domain software (Hamrick, 1992).

The Pearl River EFDC model was used to simulate the flow and temperature for the Pearl River Study Area. A one dimensional grid was setup using, 1) the USGS National Hydrography stream flow lines for the length; 2) satellite photos for stream width; and 3) USGS gage field sampling data for depth, velocity, surface elevation (to determine slopes) and widths. The Pearl River EFDC model consisted of 442 grids, each nearly approximately 1000 meters long. The time period of the hydrodynamic modeling was from 2000 through 2012.

The full model grid extent is shown in Figure 5 and Figure 6 provides more detail of the model grid in the vicinity of GP Monticello.

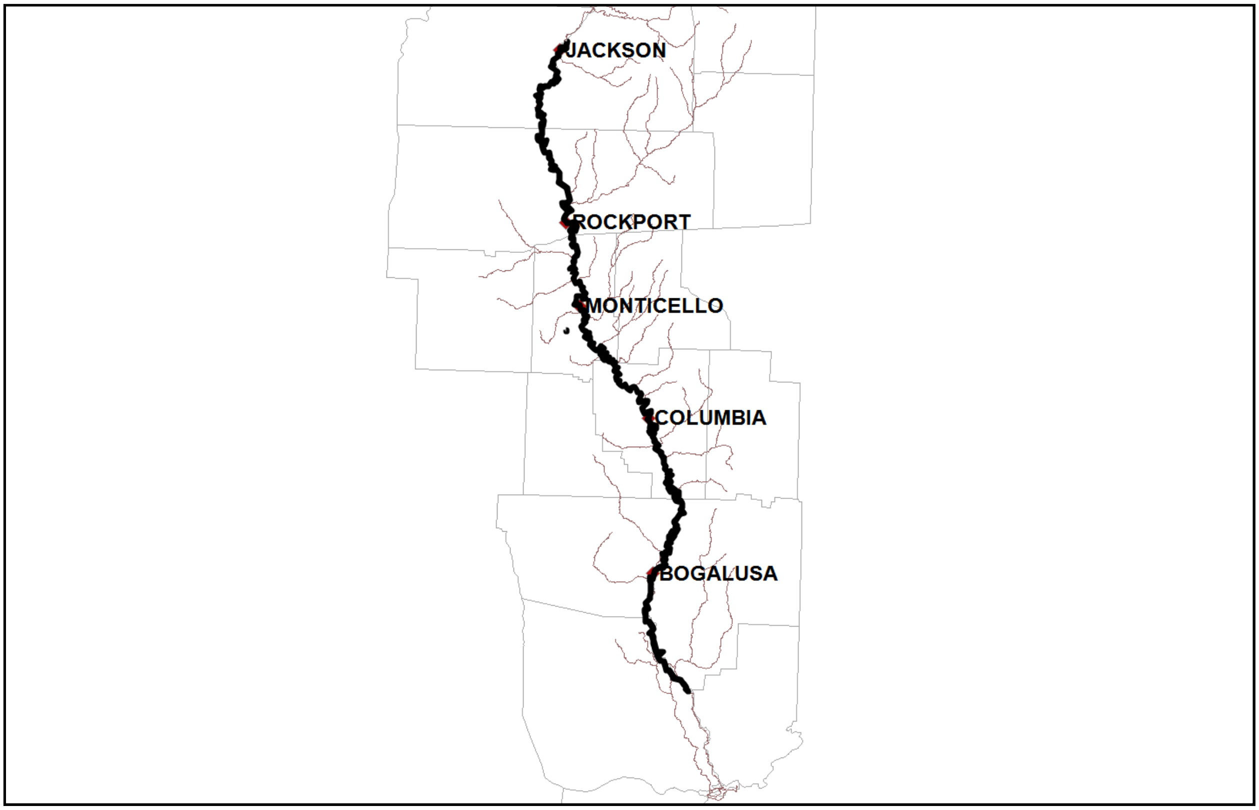

Figure 40 Pearl River Model Grid Full Extent

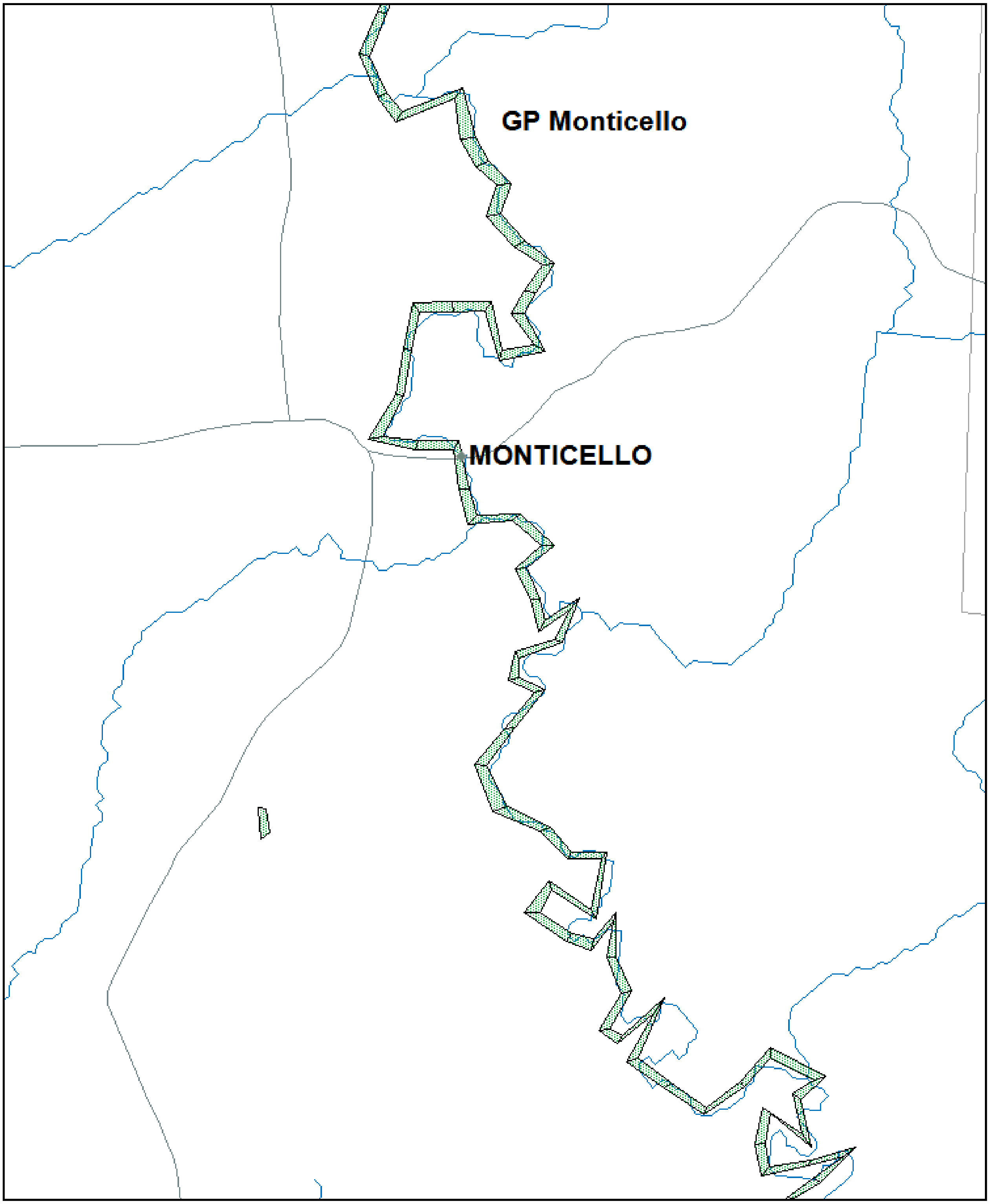

Figure 41 Model Grid near Monticello

3.1 Flows

The USGS Highway 80 Jackson gage flow was used as the headwater boundary flow for the Pearl River model. The tributary and groundwater inflows between the USGS gages were estimated using the difference of flow between the gages (for example USGS Monticello gage flows minus USGS Jackson gage flows). This difference in flow was distributed to the tributary and ground water flow inputs. The groundwater was estimated to be a total of 100 cubic feet per second (cfs) distributed 10 cfs every 10 kilometers. The remaining delta flow was distributed between the major tributaries proportional to their drainage area size. The measured GP Monticello water withdrawal and effluent discharge was also included in the model.

Table 9 shows the magnitude and R-squared correlation coefficient of flows at the USGS gages and Figures 7 through 11 illustrate the time series comparison between measured and simulated flows. For Figure 8 (USGS Gage at Rockport Road) only a partial flow record was available, the gage was out of use in 2002 and discontinued in 2004.

Table 22 EFDC Flow Calibration Statistics

Station	Measured Flow (cfs)			Simulated Flow (cfs)			Correlation Coefficeint
	Mean	5 Percentile	95 Percentile	Mean	5 Percentile	95 Percentile	
Jackson	3689	15700	216	3729	15717	219	0.99
Rockport	6809	25860	425	6976	27689	416	0.93
Monticello	6033	24600	549	6053	24192	549	0.93
Columbia	6907	25700	986	7175	26659	1050	0.91
Bogalusa	9098	35200	1510	9658	35973	1616	0.95

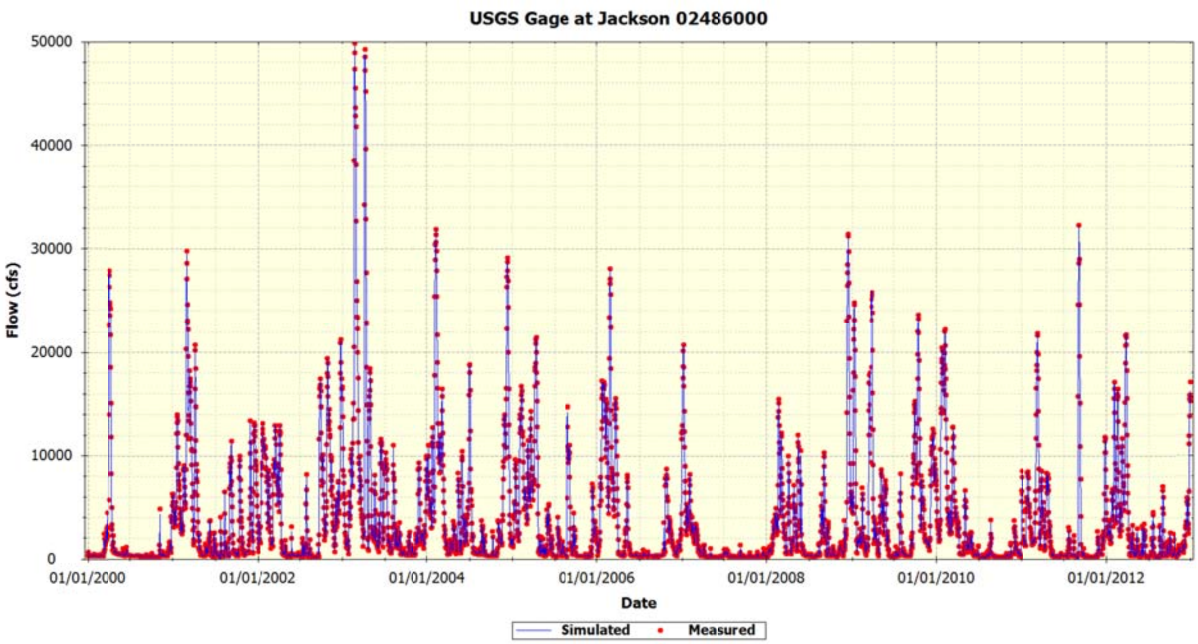

Figure 42 Simulated and Measured Flows – USGS Gage at Jackson

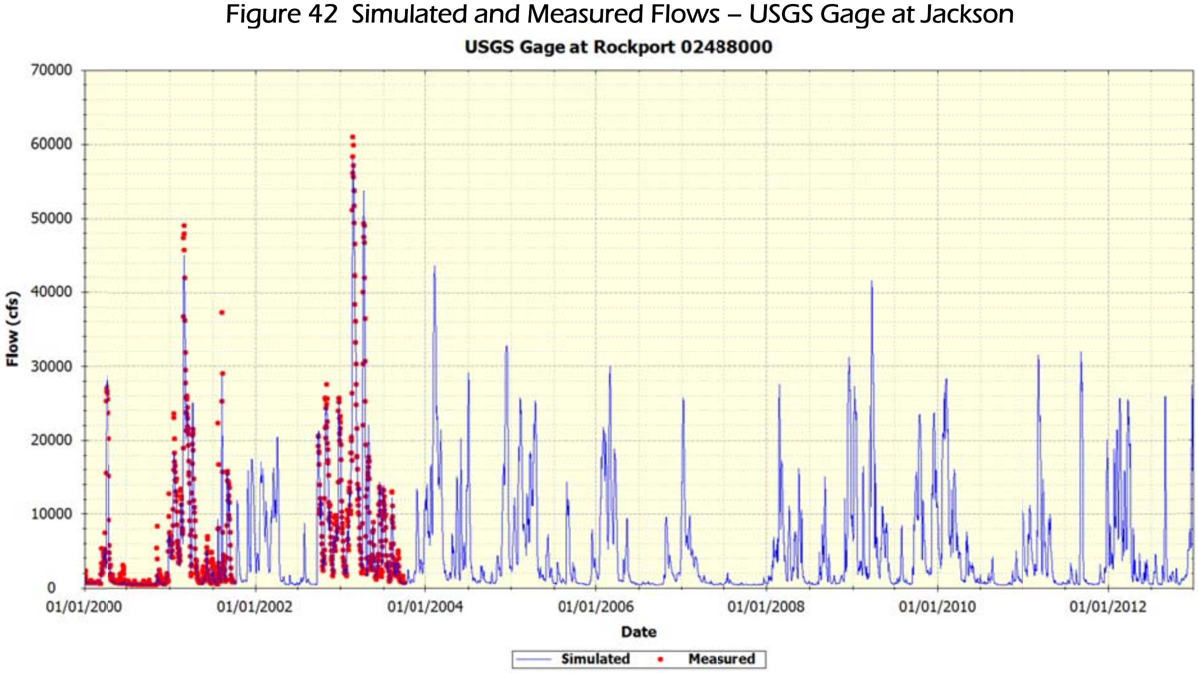

Figure 43 Simulated and Measured Flows – USGS Gage at Rockport

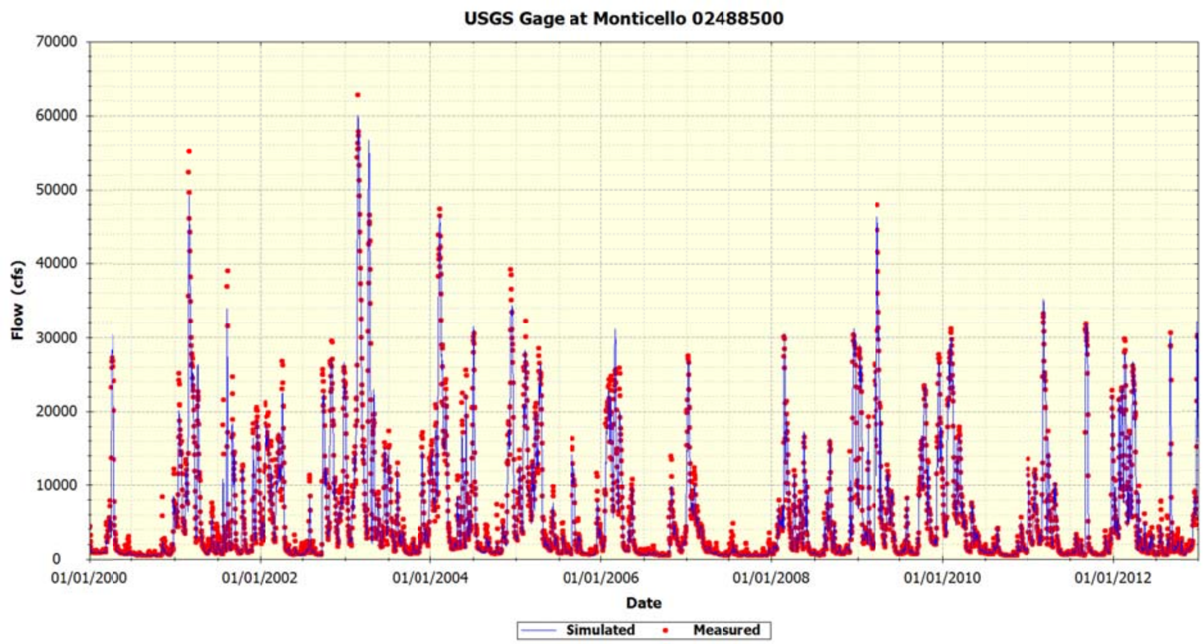

Figure 44 Simulated and Measured Flows – USGS Gage at Monticello

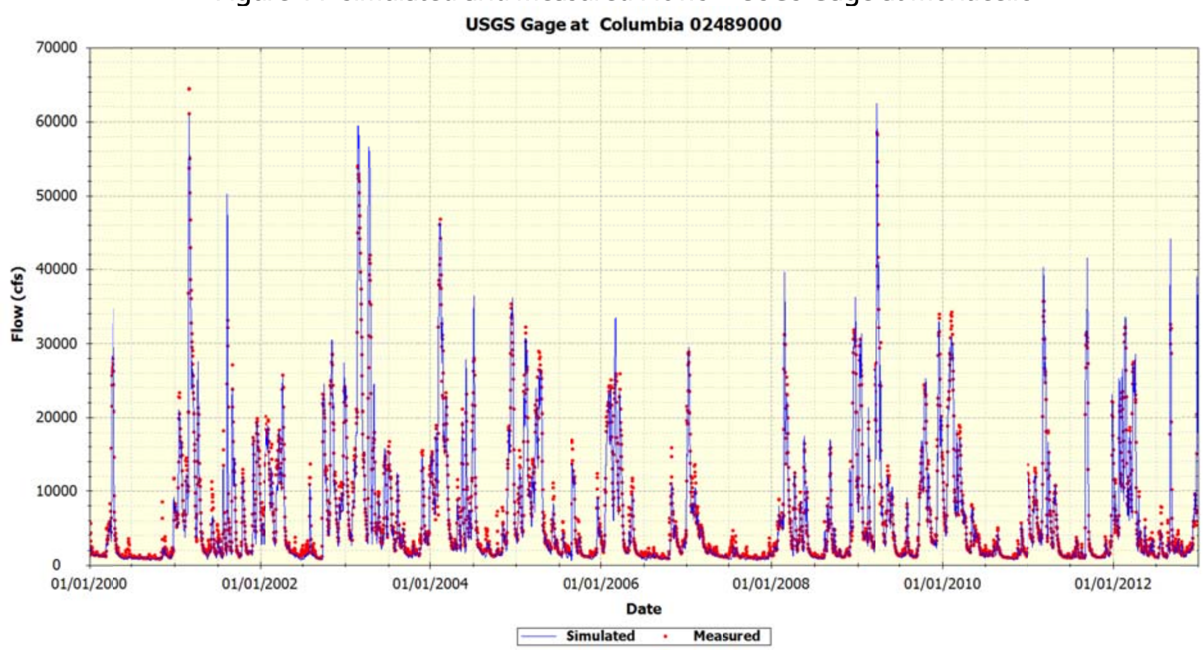

Figure 45 Simulated and Measured Flows – USGS Gage at Columbia

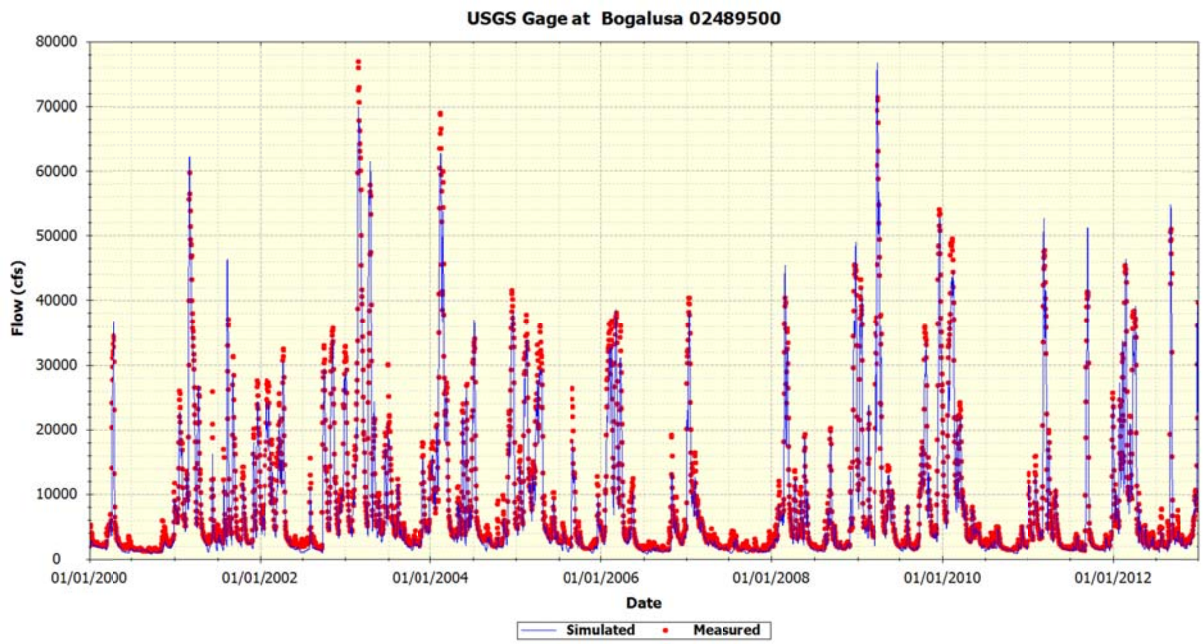

Figure 46 Simulated and Measured Flows – USGS Gage at Bogalusa

3.2 Meteorological Data

Daily air temperatures, atmospheric pressure, and cloud cover were obtained from weather stations near Hattiesburg, Mississippi. Solar radiation was calculated from equations using the River latitude and longitude coordinates. Appendix A provides the time series graphs of these meteorological inputs.

3.3 River Temperature Modeling

Limited long-term temperature monitoring data were available for the Pearl River. For the period of 2001 -2012, GP Monticello collected temperature data in the Pearl River above their effluent discharge. Figure 12 plots the measured Pearl River temperature data and the EFDC Pearl River hydrodynamic model temperature simulations for this site.

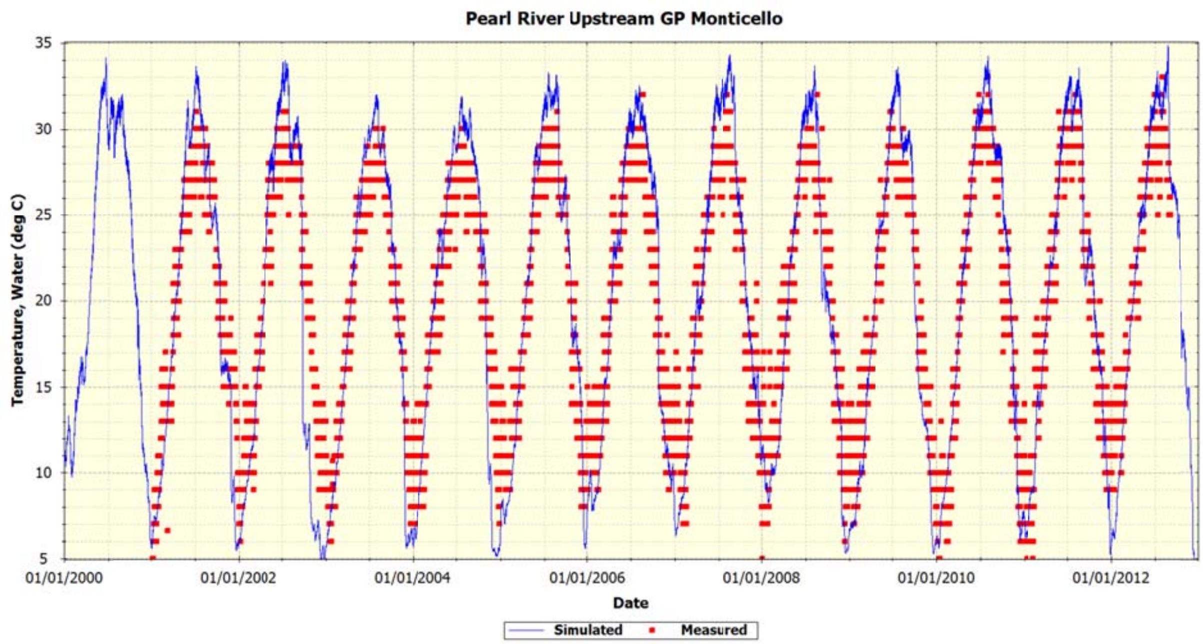

Figure 47 Pearl River Temperature Upstream GP Effluent Discharge

Tributary inflow temperatures had to be estimated since no long term temperature data are available for the tributaries. Tributary temperatures were estimated by fitting a sine curve to the measured values from a variety of temperature sampling sites in nearby watersheds. The temperature sine curve represents the seasonal change in temperature throughout the year. The resultant estimated temperature time series is shown in Figure 13, with temperatures ranging from 8 to 28 degrees Celsius.

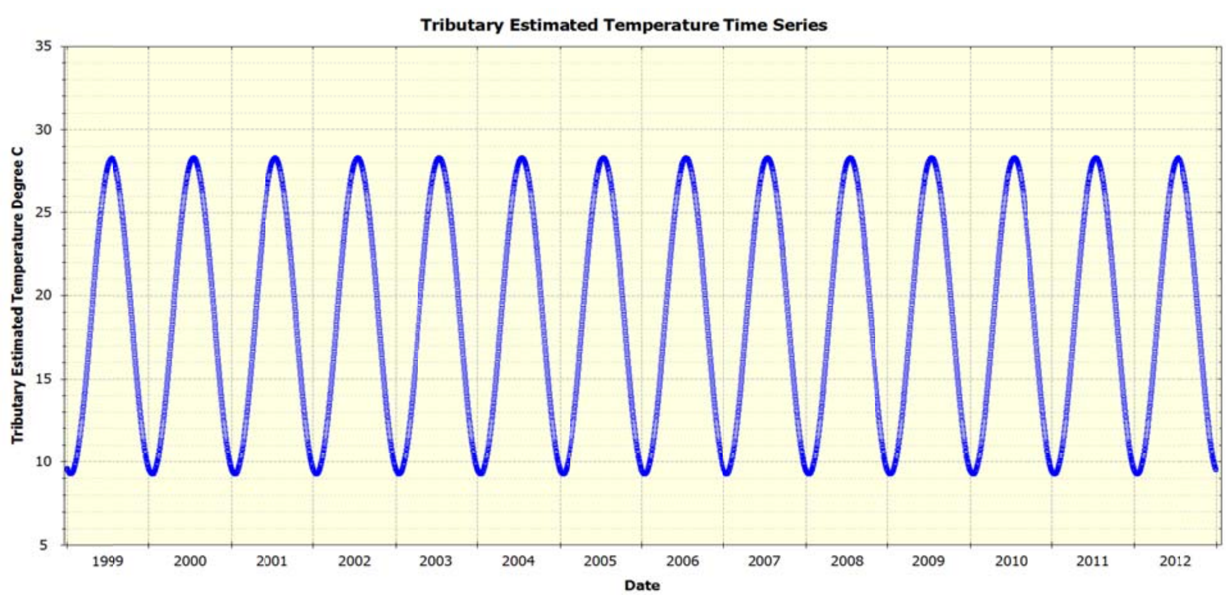

Figure 48 Tributary Temperatures

The groundwater temperature was input as a constant 12 degrees C.

4.0 WATER QUALITY MODEL DEVELOPMENT

The EFDC hydrodynamic simulation is used to drive the Water Quality Analysis Simulation Program (WASP) Version 6.5 water quality model. The WASP model was operated on the same one dimensional grid used for the EFDC. For the water quality model calibration, the five-year time period of 2008 through 2012 was used. In consultation with MDEQ, this was determined to be the best representative time period for the model calibration and the final TMDL model.

4.1 WASP Model

The EPA WASP Model, Version 6.5, (WASP) was used to model water quality. The WASP model was calibrated to the available data which included nutrients, DO, BOD, and Chl a. WASP simulates the transport and transformation reactions of up to eight state variables related to eutrophication. They can be considered as four interacting systems: phytoplankton kinetics, the phosphorus cycle, the nitrogen cycle, and the dissolved oxygen balance. The general WASP mass balance equation is solved for each state variable. For all variables modeled, boundary concentrations must be specified for segments receiving input, output, or exchange flows from outside the model. The eight variables within WASP utilized in the instream water quality simulation are:

- Nitrate-Nitrite
- Ammonia
- Organic Nitrogen
- Organic Phosphorus
- Orthophosphate
- Carbonaceous Ultimate Biochemical Oxygen Demand (BODuc)
- Phytoplankton (Chl a)
- Dissolved Oxygen

4.1.1 EFDC WASP Data Transfer

An external hydrodynamic file (".hyd" file) output by EFDC was used to input different hydrodynamic parameters, including volume, depth, velocity, and flow at each cell. This provides the flow, velocity, and temperature values required by WASP.

4.1.2 Meteorological Conditions

WASP uses air temperature, wind, length of day, and solar radiation time series as meteorological inputs. Graphs of these times series are included in Appendix A.

4.1.3 Light Extinction

WASP models the light available for photosynthesis from the incident solar radiation at the water surface and the rate of light attenuation or "extinction" in the water column. Light extinction is represented by an extinction coefficient (*Ke*), such that light remaining at depth *z* is equal to:

$$I_o * e^{-Ke \cdot z},$$

where I_o is the light penetration at the surface. Using the depth of the water, the average *Ke* value can be calculated and used in the WASP model.

The model estimates *Ke* as the combined effects of algal self-shading, which can be important under bloom conditions, and a non-algal component, represented through a user-supplied extinction coefficient. Light extinction coefficient estimations were obtained from the 2012 EPA and MDEQ water quality study. Water column *Ke* values ranged from 2 to 3.5 per meter. Basically, the light penetrated trough the water column and reached the bottom.

4.1.4 Sediment Oxygen Demand

The decomposition of organic material in bottom sediment can lower the concentrations of oxygen in the overlying waters. The decomposition of organic material results in the exertion of an oxygen demand at the sediment-water interface called sediment oxygen demand (SOD). Measured Pearl River SOD values during the 2012 study ranged from 0.8 to 1.3 grams oxygen/meter^2/day, measured rates adjusted to 20 degrees C.

4.1.5 Reaeration

Two reaeration studies were conducted on different stretches of the Pearl River. In 2011, GP Monticello contracted with HYDRO2 to conduct a reaeration study for the Pearl River around Monticello (2011 HYDRO2). The reaeration rates ranged from 0.8 to 1.3 grams oxygen/meter^2/day. In 2012, EPA conducted a reaeration study on the Pearl River around Rockport. The reaeration rates ranged from 0.4 to 2.0 grams oxygen/meter^2/day. WASP can use either reaeration input directly or various reaeration formulations that varies reaeration with change of river's velocity and depth. The WASP model's O'Connor Dobbins reaeration formulation was used as the O'Connor Dobbins reaeration formulation represented the actual reaeration measurements for the time periods they were selected.

For the Pearl River below GP Monticello the measured reaeration rate (August 29 – 31, 2011, was 1.62 grams oxygen/meter^2/day. Figure 14 illustrates the simulated reaeration rate for the Pearl River below GP Monticello and Figure 15 compares the measured and simulated reaeration rates for August 29 – 31, 2012.

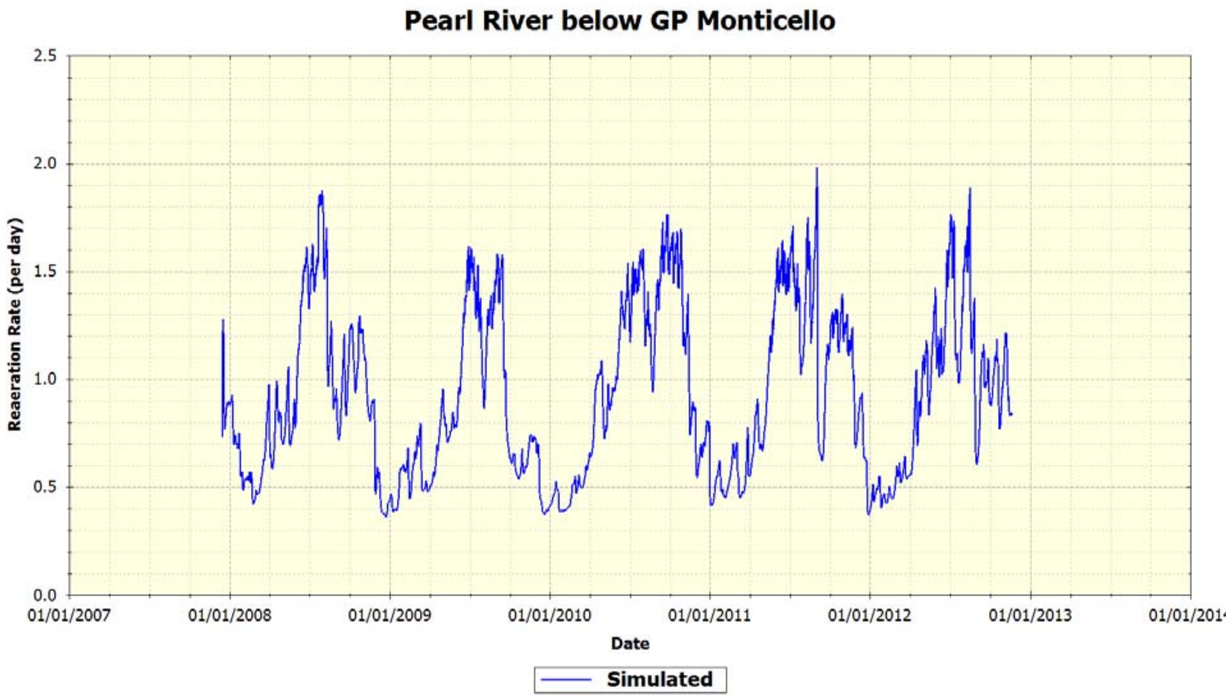

Figure 49 2008 – 2012 Simulated Reaeration Rates Pearl River below GP Monticello

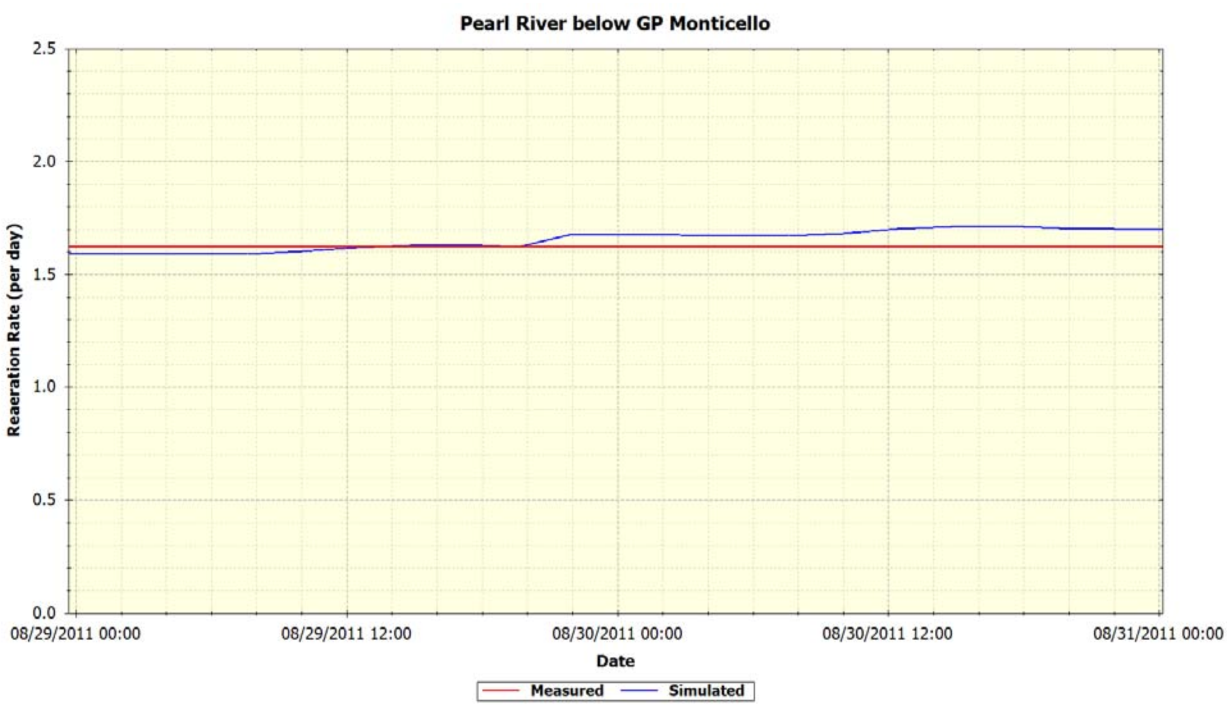

Figure 50 Simulated and Measured Reaeration Rates for Pearl River below GP Monticello

4.1.6 BOD, Nutrient, and Algal Rates and Kinetics

Normal rate and kinetic values as modeled in other southeast water quality models were used as the starting values for the Pearl River model. However the BOD decay rate, BOD ultimate to BOD_5 ratio, the algal growth rate, and the carbon to Chl a ratio were adjusted based on the available data. These rates and kinetic values are provided in Appendix B.

The MDEQ long-term BOD measurements provide an *f ratio* (ultimate carbonaceous BOD (BODuc) to BOD_5 day ratio) range of 3 to 3.7. The Pearl River WASP model used an average ratio of 3.5 for all the BOD inputs and a river BODuc decay rate of 0.07 per day. The exception was the GP Monticello effluent, where a *f ratio* (BODuc to BOD_5 ratio) of 7.0 was used based on the long-term BOD data.

The algal growth rates and algal carbon to Chl a ratio was adjusted to match the available Chl a measurements and the measured diurnal DO. An algal growth rate of 1.5 per day and carbon to Chl a ratio of 100 were used as the final values.

4.1.7 Wastewater Discharges

There are seven (7) major wastewater discharges (five publicly owned treatment facilities (POTW) discharges and two industrial discharges) included in the Pearl River WASP Model. These are:

- GP Monticello Industrial
- Savannah Street, City of Jackson POTW
- Trahon, City of Jackson POTW
- Monticello POTW
- Copiah POTW
- Columbia POTW
- Sanderson Farms WWTP
- Hazlehurst POTW

GP Monticello effluent discharge parameters were based on available data and were summarized in Section 2.3.1. To illustrate the variation in the GP Monticello effluent data, Figures 16 – 19 show the actual flow, BOD5, nitrogen series, and phosphorous series time-series used in the WASP model.

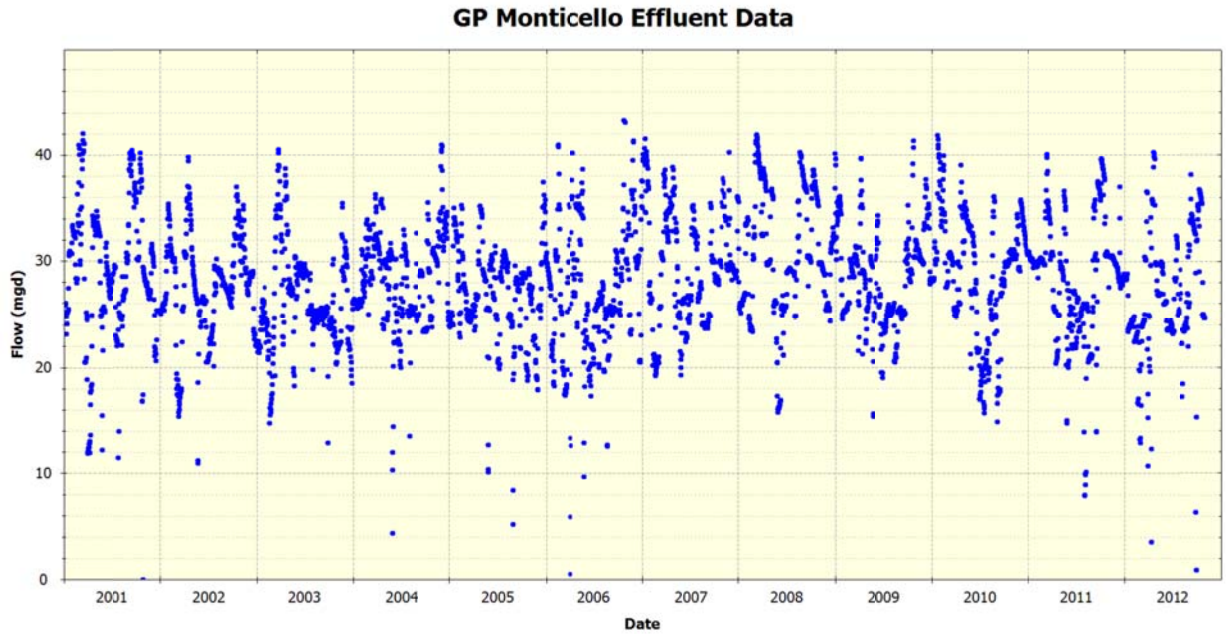

Figure 51 GP Monticello Effluent Discharge Flow Data

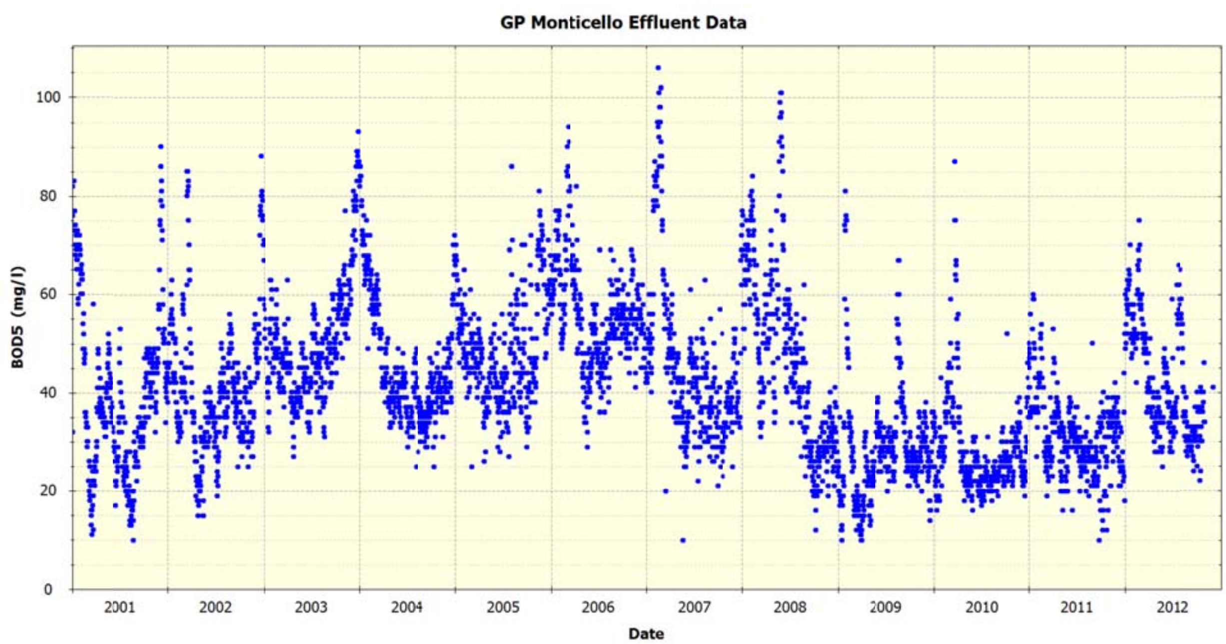

Figure 52 GP Monticello Effluent Discharge BOD5 Data

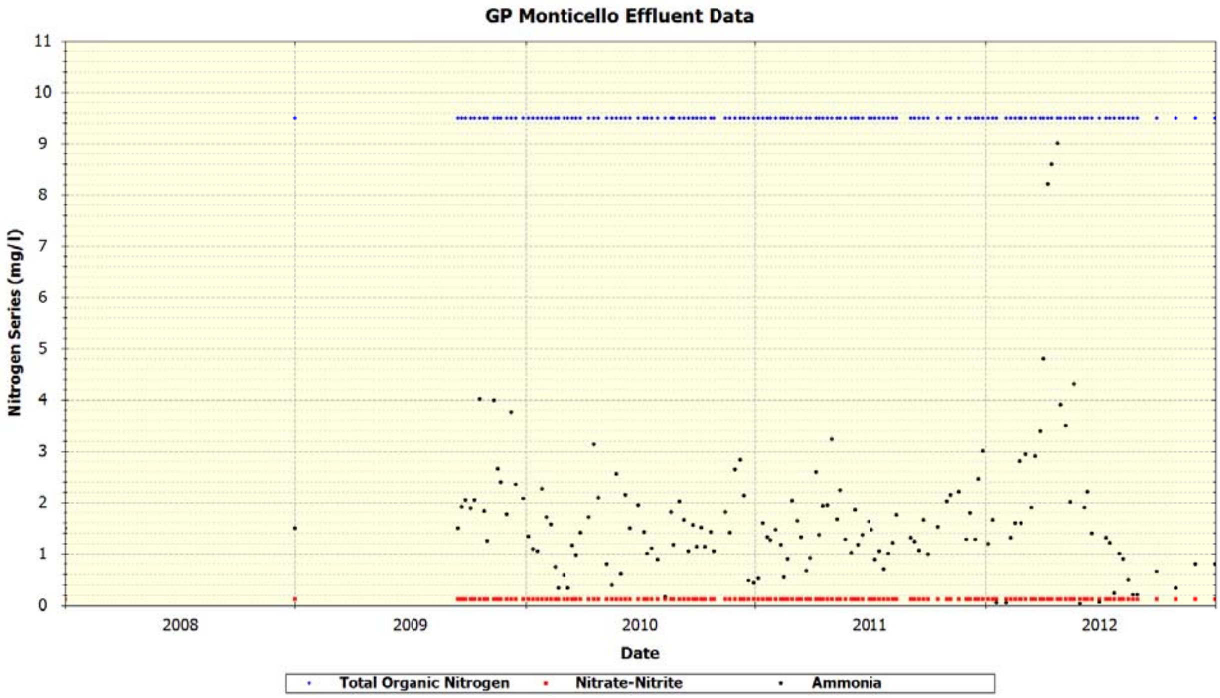

Figure 53 GP Monticello Effluent Discharge Nitrogen Series Data

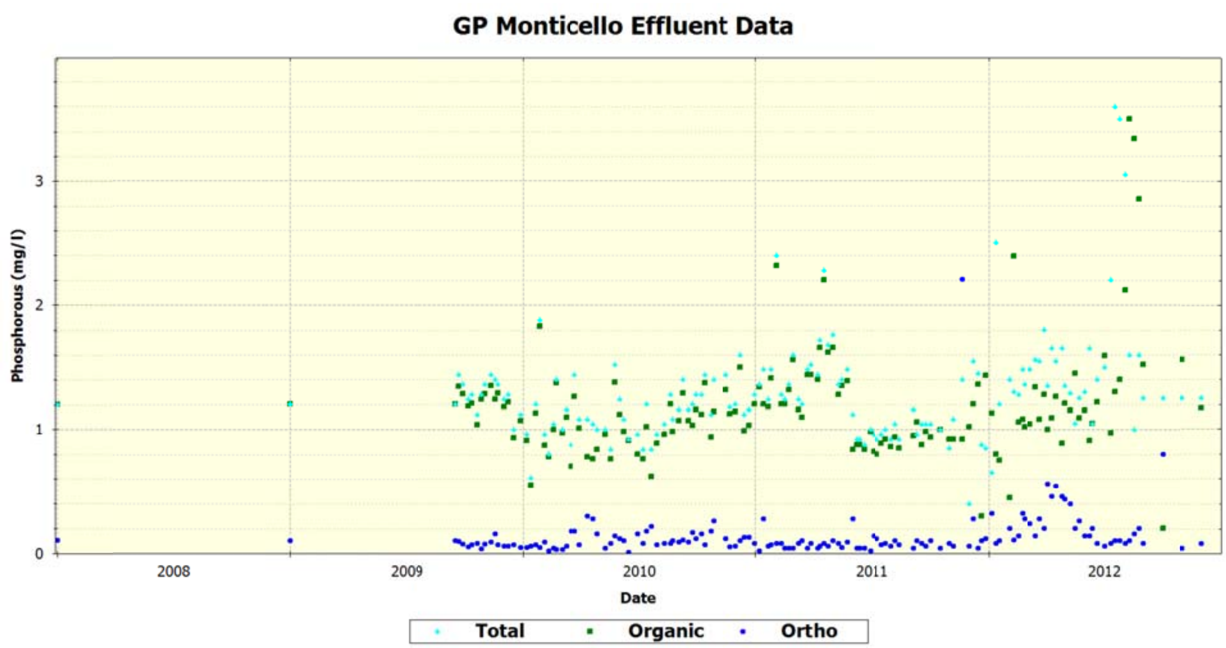

Figure 54 GP Monticello Effluent Discharge Phosphorous Series Data

Savannah Street, City of Jackson POTW effluent parameters are summarized in Table 10. The measure effluent parameter time series were input in to the WASP model.

Table 23 Savannah Street, City of Jackson POTW Effluent Parameters

Parameter	Units	Mean	Min	Max
FLOW	mgd	43.1	29.0	73.0
CBOD5	mg/l	5.6	2.0	12.7
Ammonia	mg/l	2.4	0.2	17.3
Ortho-phospharous	mg/l	1.0	0.7	1.2
Ntrate-Nitrite	mg/l	1.6	1.9	0.9
Total Organic Nitrogen	mg/l	6.9	5.8	9.1
Total Organic Phosphorous	mg/l	1.5	1.0	1.8

For the five other major dischargers, permit information was input in to the WASP model. Table 11 shows the effluent parameters for each of these dischargers.

Table 24 Effluent Parameters for Columbia, Monticello, Trahon, Copiah and Hazelhurst POTWs and Sanderson Farms Discharges

POTW	Columbia	Monticello	Trahon	Copiah	Sanderson	Hazelhurst
Flow (mgd)	1.7	0.5	3.3	0.5	1.5	0.5
BOD5 (mg/l)	16	16	16	10	16	10
Ammonia (mg/l)	4	4	4	2	4	2
TN (mg/l)	15	15	15	15	103	15
NOx (mg/l)	4	4	4	2	4	2
Organic N (mg/l)	7	7	7	11	95	11
TP (mg/l)	40	40	40	5	40	5
OrthoP (mg/l)	20	20	20	2.5	20	2.5
Organic P	20	20	20	2.5	20	2.5
DO	6	6	6	6	6	6

4.1.8 Headwater Data

The headwater of the Pearl River model is located below the Ross Barnett Reservoir. The time series data used at this boundary were taken initially from the reservoir sampling and then adjusted based on the long-term data MDEQ collected at Byram. Seasonal patterns were determined for each input parameter.

Based on information from MDEQ, overflows from the Savannah Street POTW holding ponds discharged into the Pearl River during the 2010 to 2012 time period. These overflows were not measured. Based on the Pearl River data collected at Byram, these overflows added measurable nitrogen loadings to the Pearl River. For modeling purposes the estimated additional nitrogen was include in the headwater Nitrate-Nitrite time series. For the TMDL model the nitrate-nitrite time series will be returned to its normal time pattern that was measured during 2008 -2009.

Figure 20 illustrates both the nitrate-nitrite time series used for the calibrated model and the expected normal time series used in the TMDL model. Figures 21 to 25 illustrate the data time series for other nitrogen, phosphorous, BOD5, and DO headwater parameters.

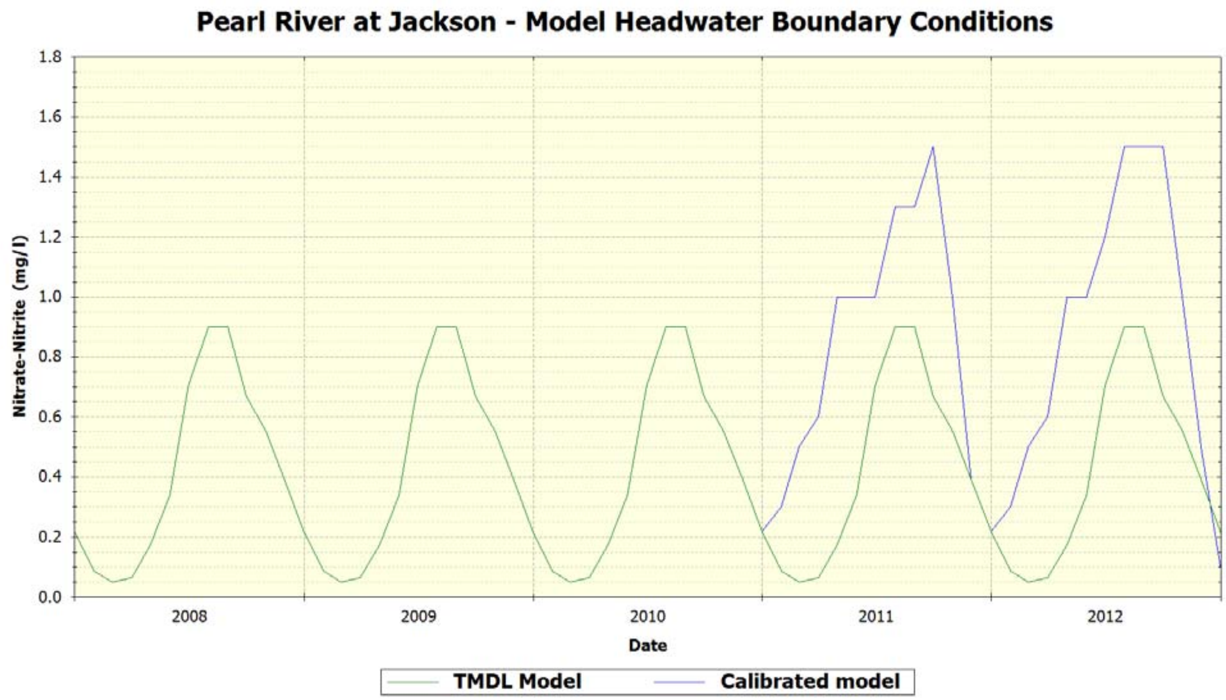

Figure 55 Model Headwater Conditions - Nitrate-Nitrite

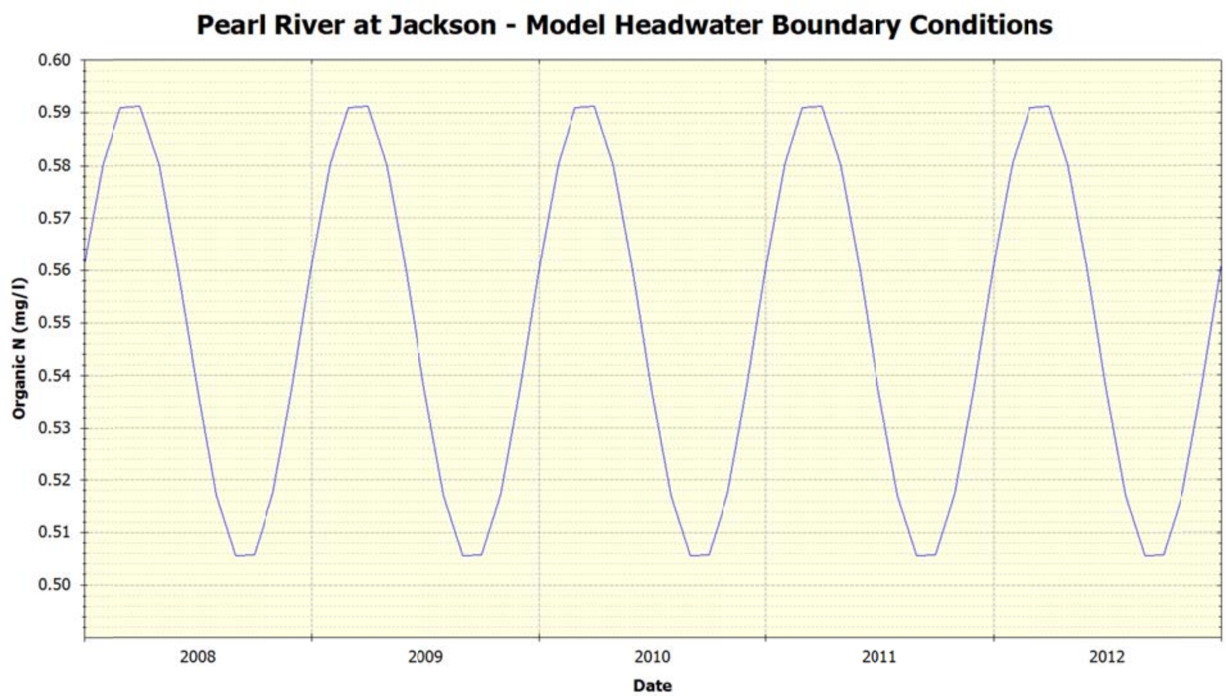

Figure 56 Model Headwater Conditions – Organic Nitrogen

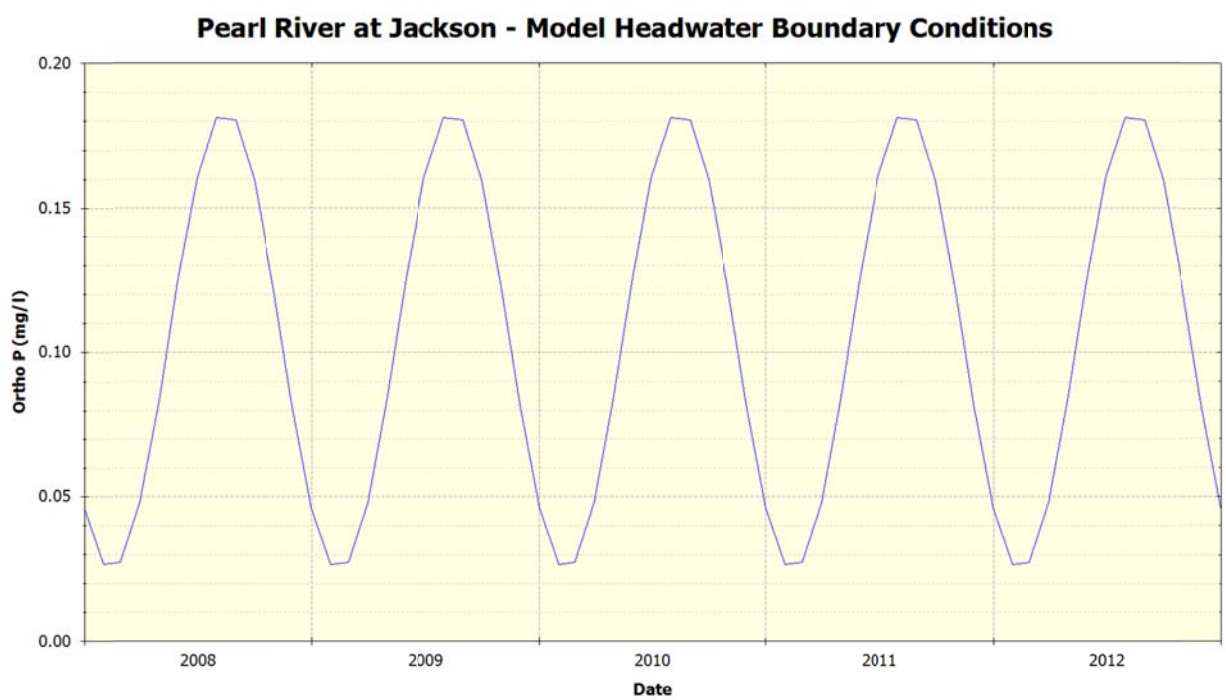

Figure 57 Model Headwater Conditions – Ortho-Phosphorous

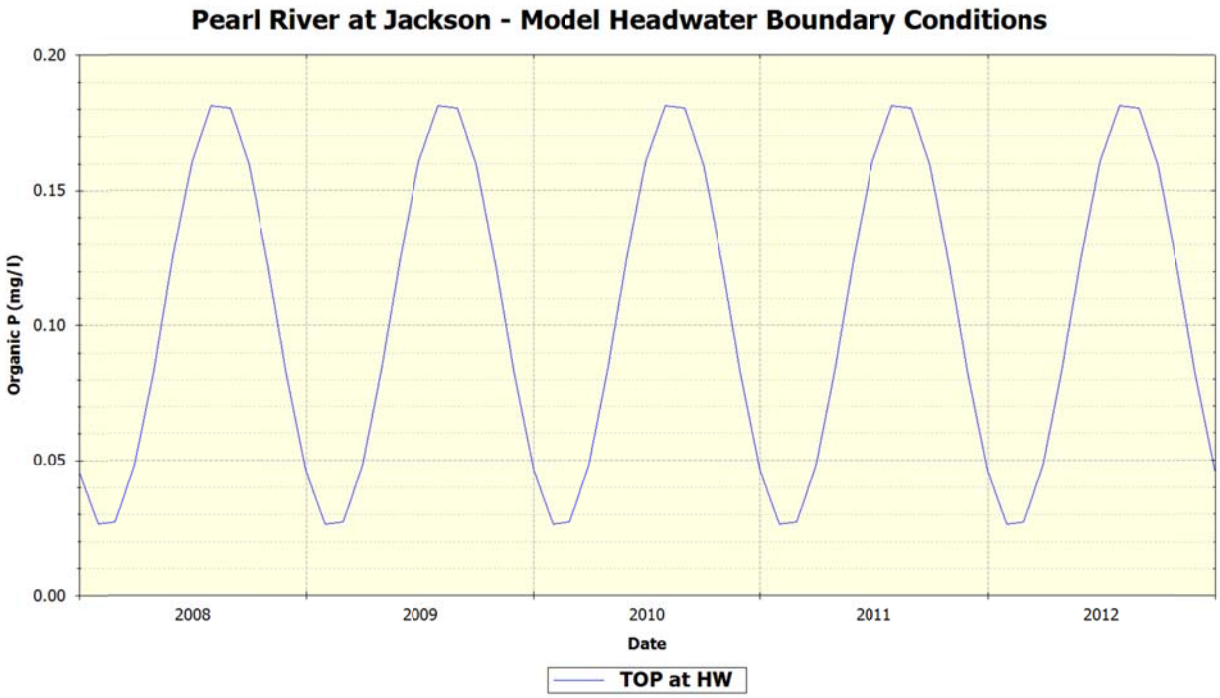

Figure 58 Model Headwater Conditions – Organic Phosphorus

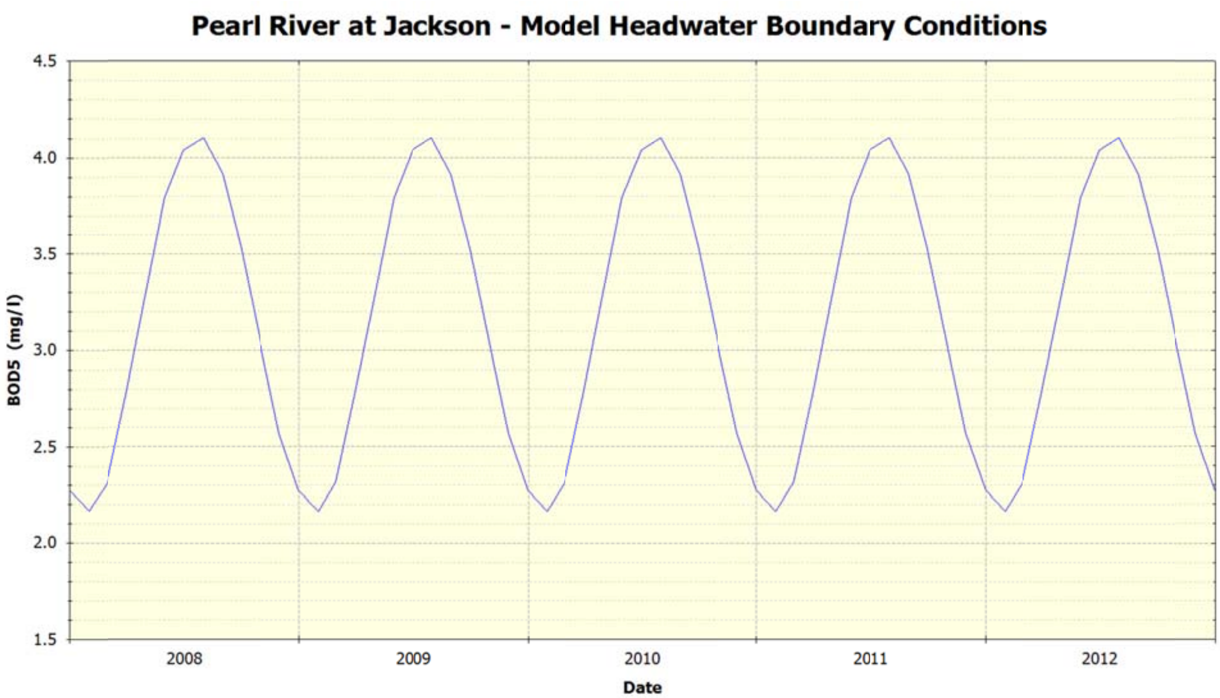

Figure 59 Model Headwater Conditions – BOD5

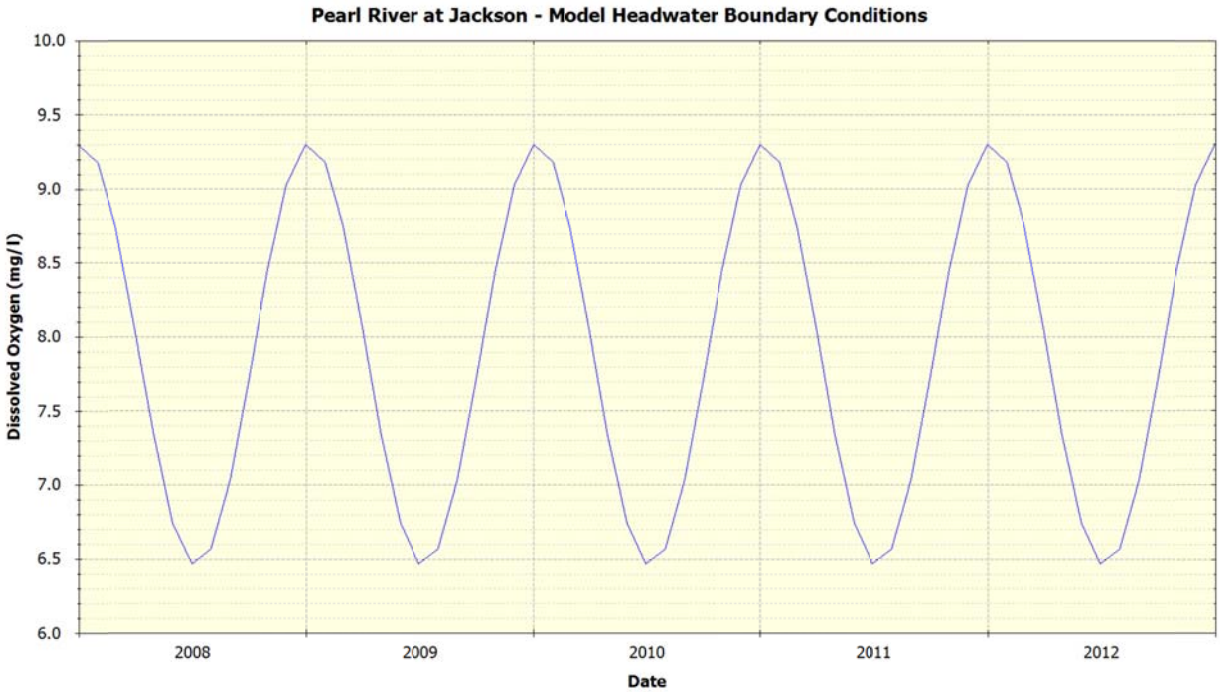

Figure 60 Model Headwater Conditions – Dissolved Oxygen

4.1.9 Tributary Data

There are a number of tributaries that discharge into the Pearl River. The time series data used at these tributaries were determine from the limited water quality data available. Seasonal patterns were estimated for each input parameter, except BOD5 which was set to a constant 2 mg/l. Figures 26 - 28 illustrate the tributary inputs in to the WASP model.

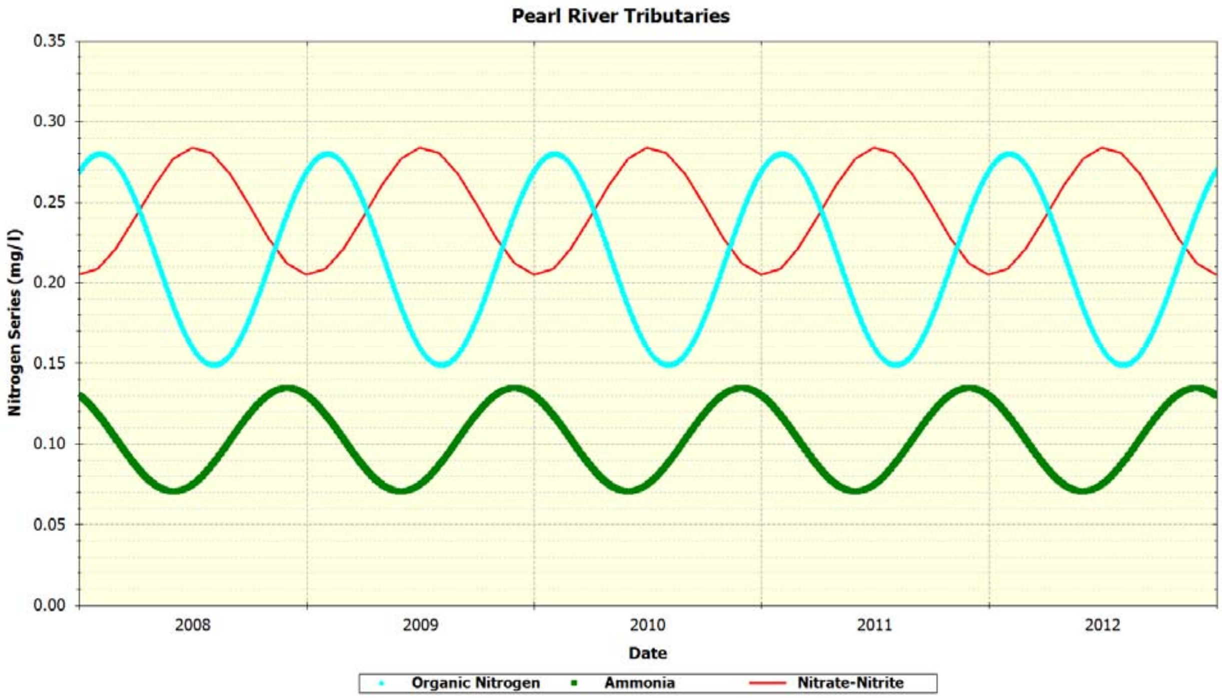

Figure 61 Pearl River Tributary – Nitrogen Series

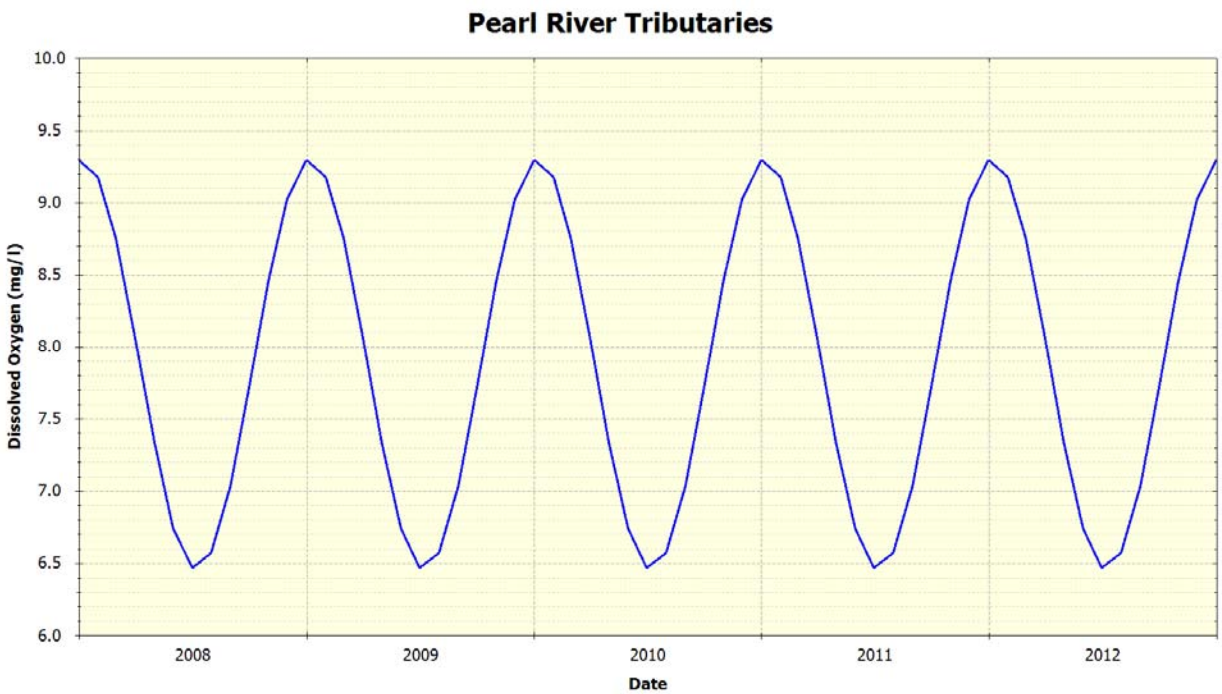

Figure 62 Pearl River Tributary – Dissolved Oxygen Series

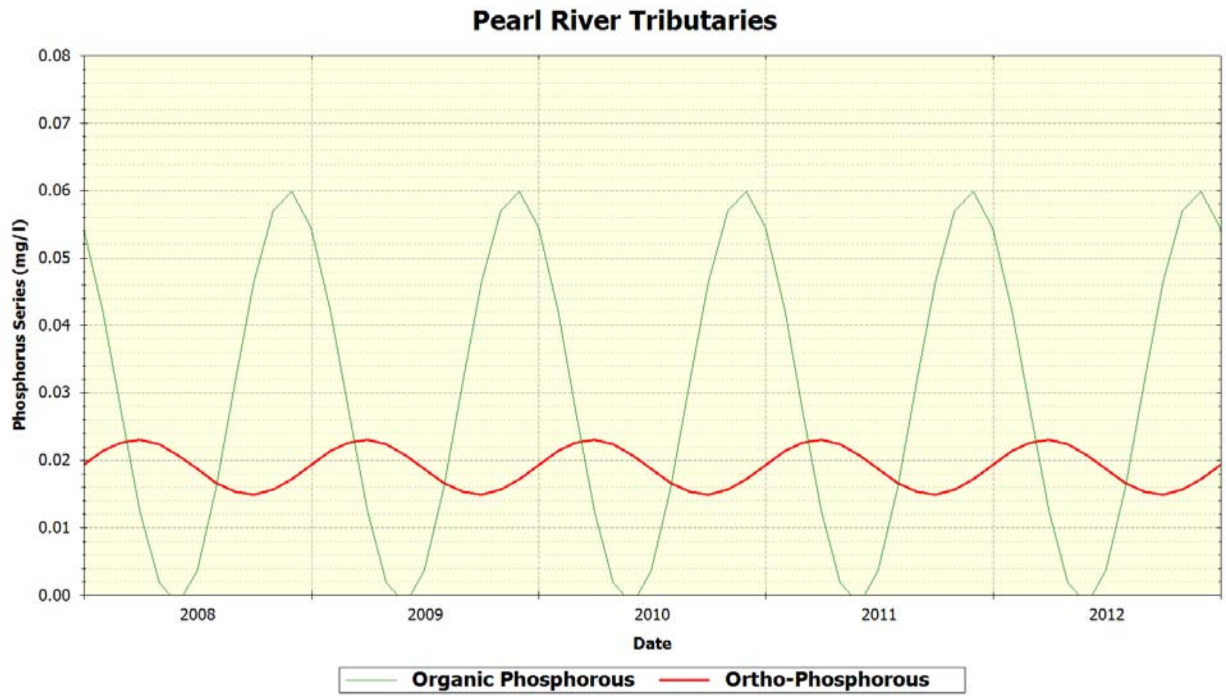

Figure 63 Pearl River Tributary – Phosphorous Series

4.3 WASP Model Calibration

The Pearl River WASP model was calibrated to the available 2008 – 2012 stream data. These data were collected through a series a stream sampling studies previously discussed in Section 2, which included the data summaries. The following sections illustrate the model simulations verses the measured data for each of the stream studies. Overall the calibrated model does a good job of simulating the available data and can be used for future DO/BOD and nutrient/Chl a TMDL development.

4.3.1 Pearl River at Byram

The Pearl River at Byram at the Old Swinging Bridge sampling location is one of MDEQ's long-term water quality monitoring station and provides the only available long-term data for the river. Figures 29 through 33 illustrate the 2008 – 2012 measured data and the model simulated values for nitrogen and phosphorous.

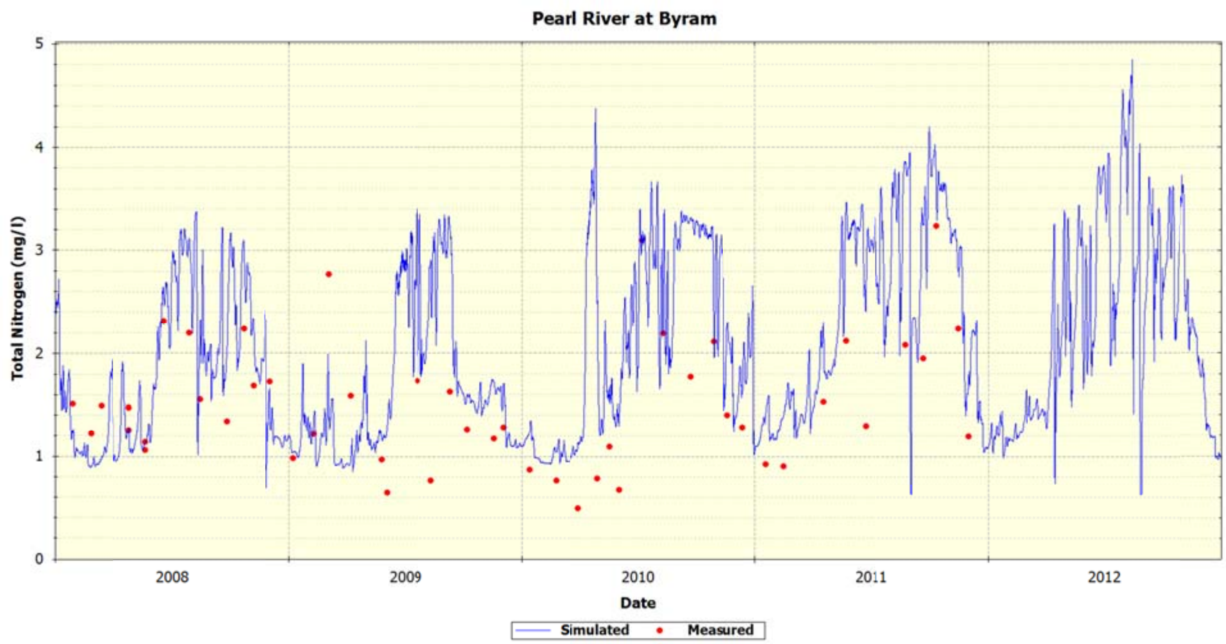

Figure 64 Pearl River at Byram – Simulated vs Measured Total Nitrogen

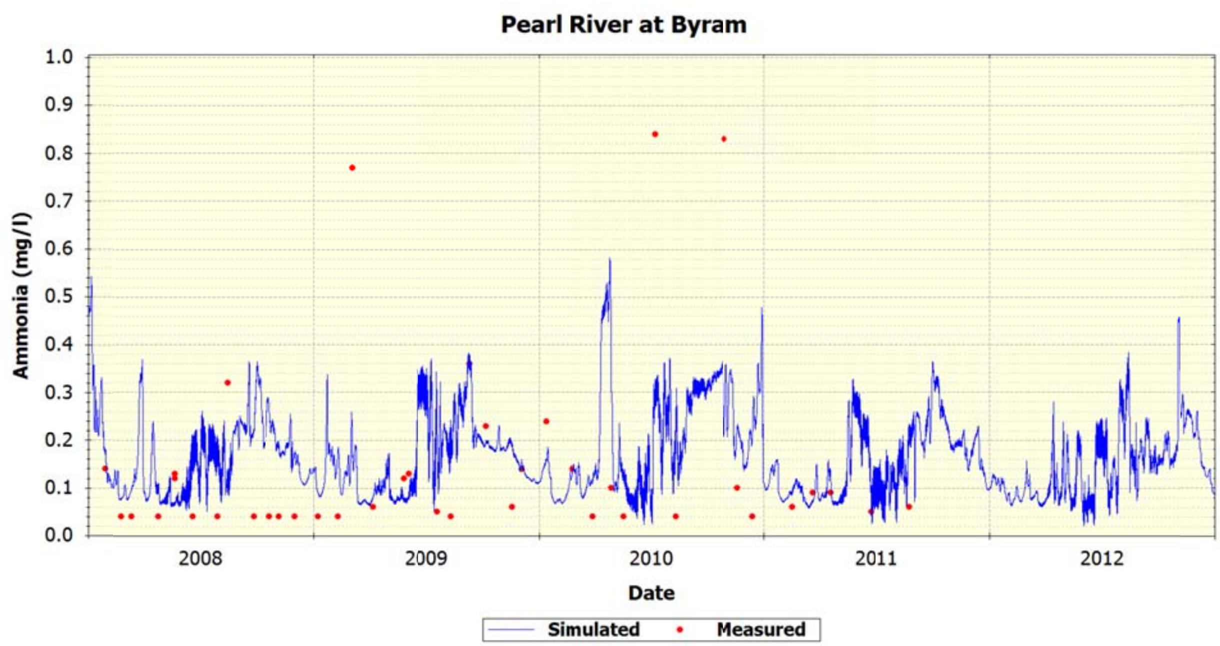

Figure 65 Pearl River at Byram – Simulated vs Measured Ammonia

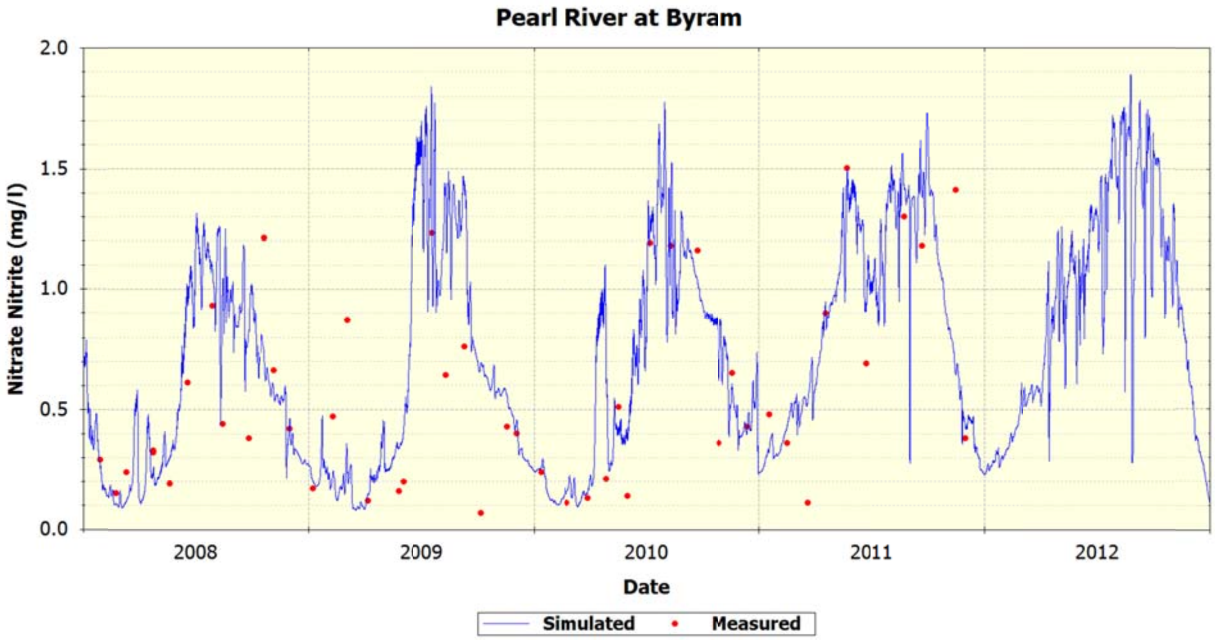

Figure 66 Pearl River at Byram – Simulated vs Measured Nitrate-Nitrite

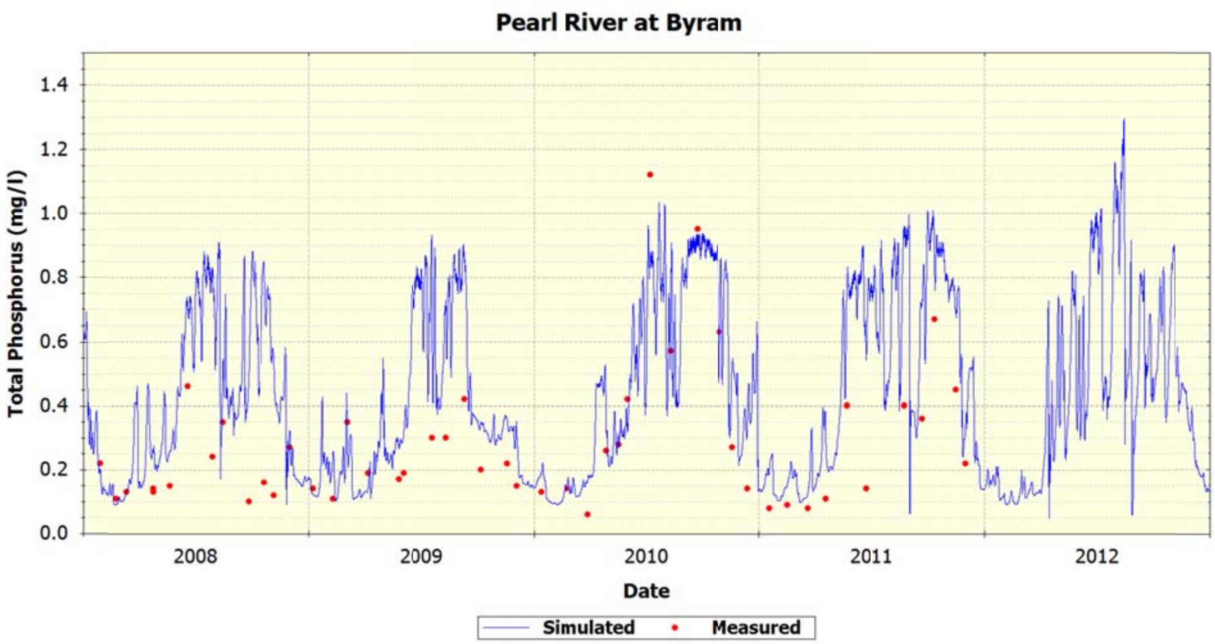

Figure 67 Pearl River at Byram – Simulated vs Measured Total Phosphorus

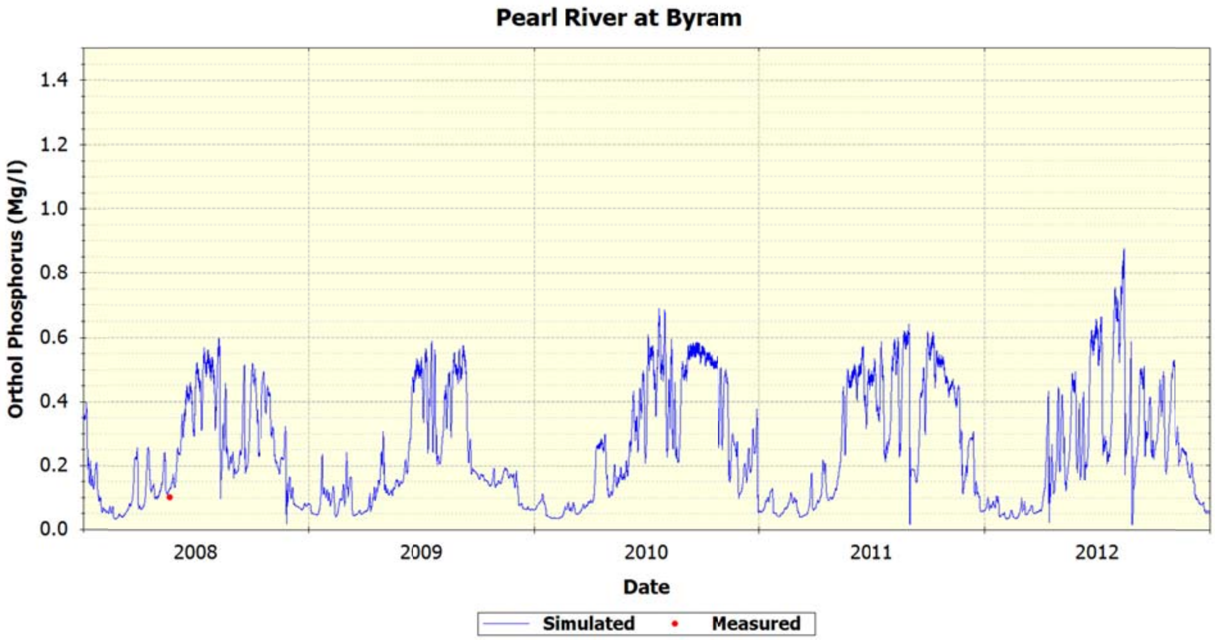

Figure 68 Pearl River at Byram – Simulated vs Measured Ortho-Phosphorous

4.3.2 Pearl River MDEQ 2008 Nutrient TMDL Study

In April and May 2008, MDEQ conducted a nutrient snapshot sampling study of the Pearl River from Jackson to Pearlington, Mississippi near the mouth of the Pearl River. Figures 34 through 54 illustrate the model predictions against measured data for TN, TP, and Chl a.

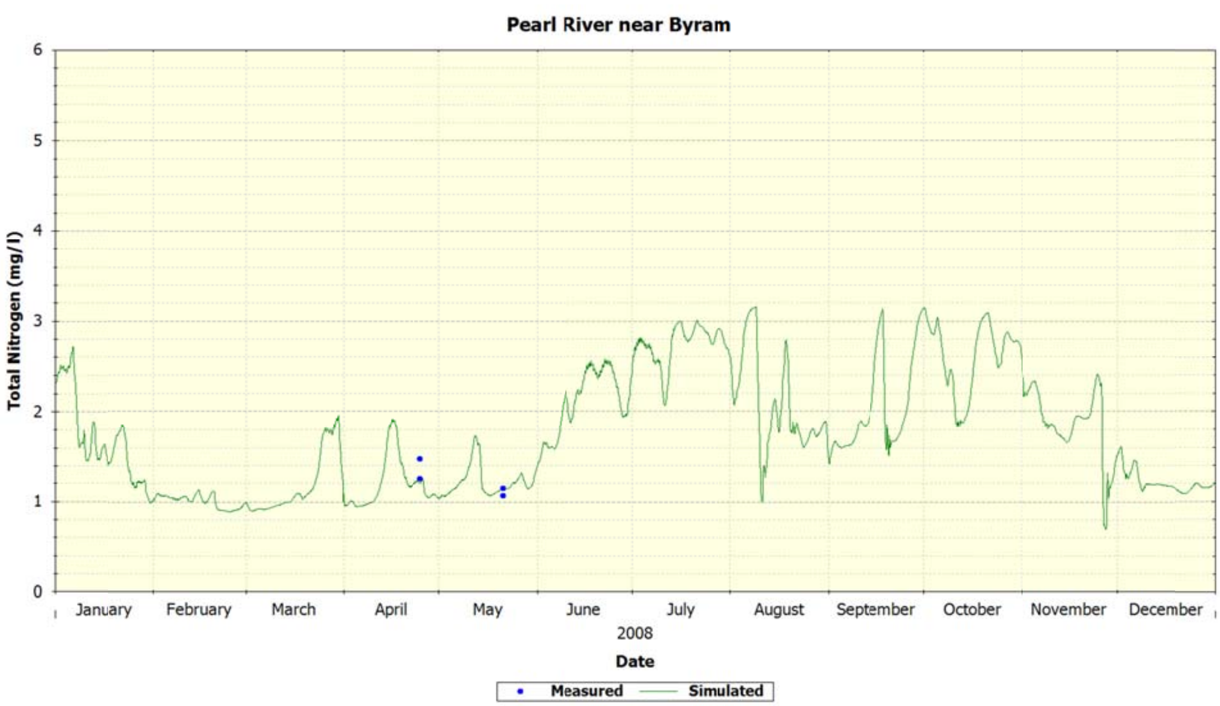

Figure 69 MDEQ Station Pearl River at Byram – Total Nitrogen

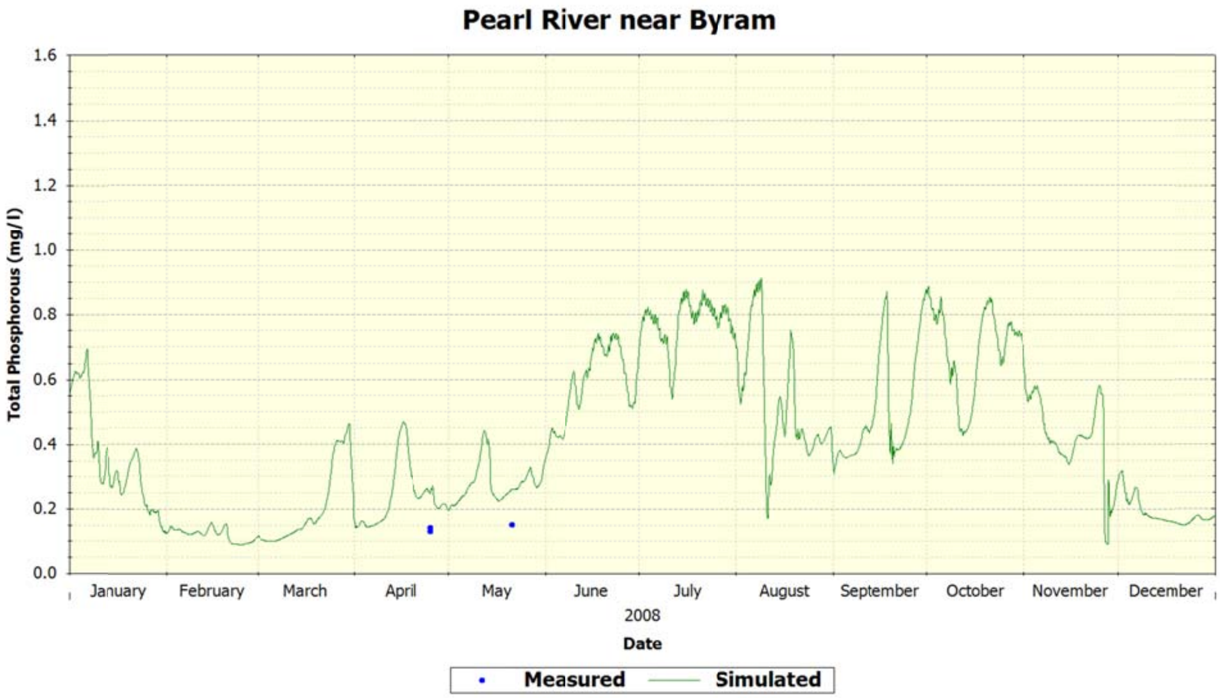

Figure 70 MDEQ Station Pearl River at Byram – Total Phosphorous

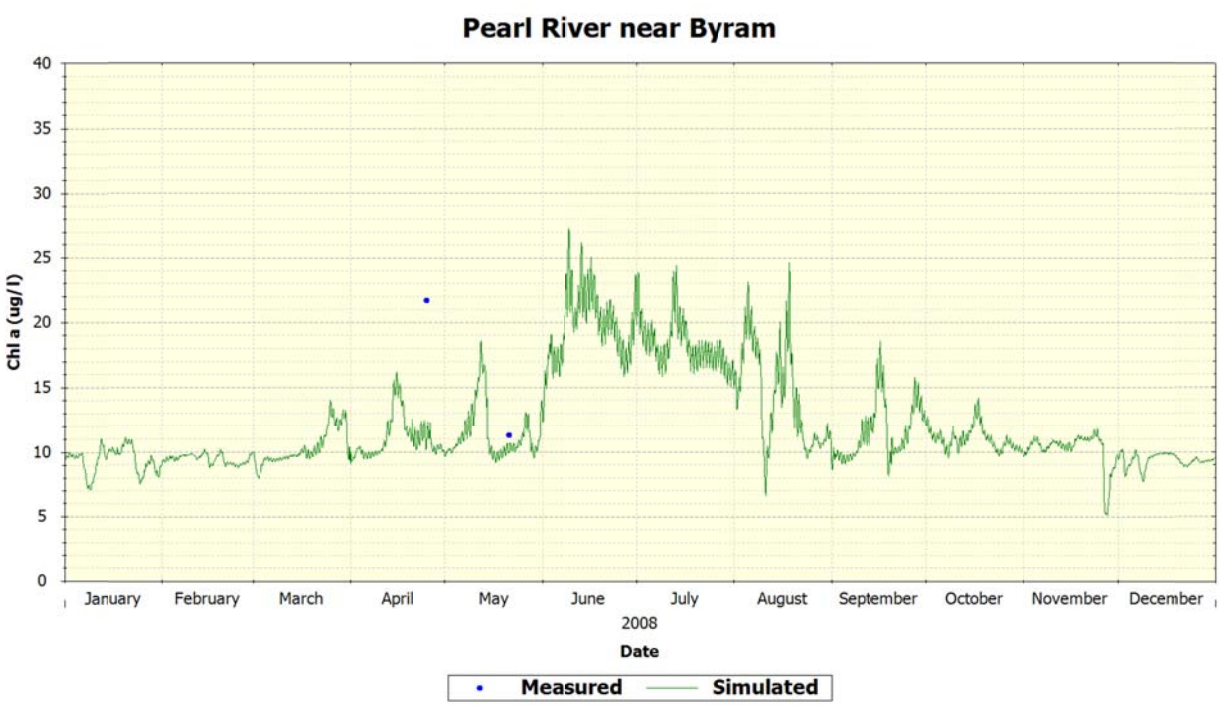

Figure 71 MDEQ Station Pearl River at Byram – Chl a

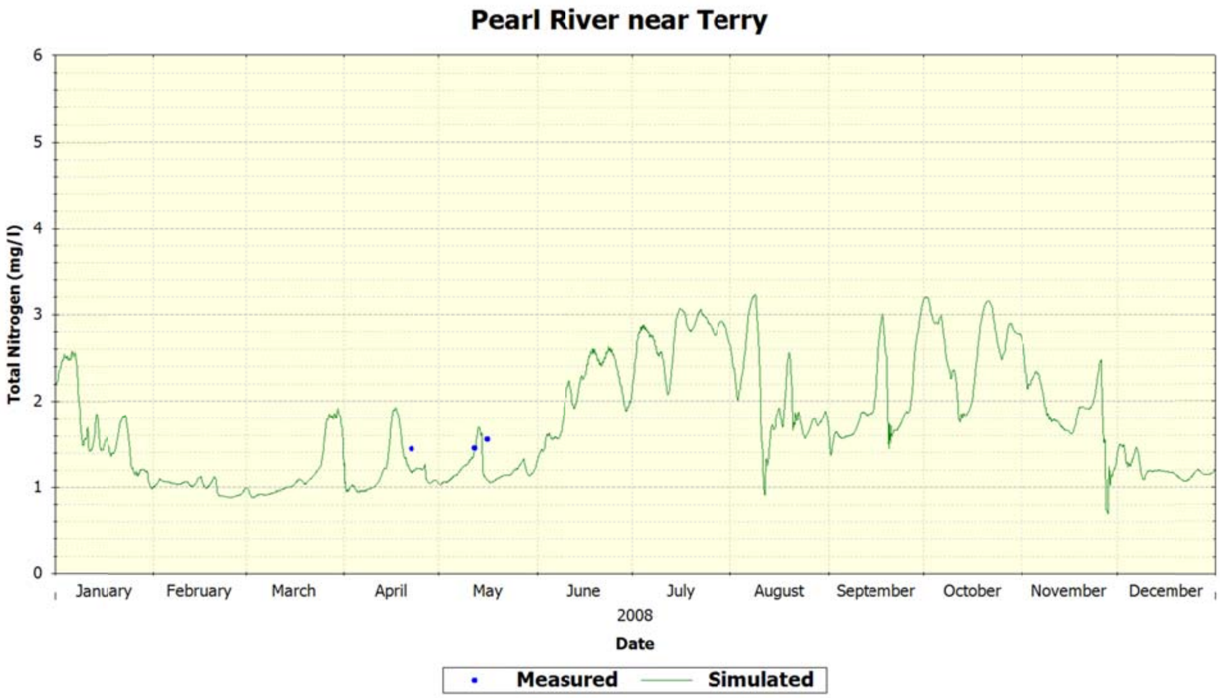

Figure 72 MDEQ Station Pearl River near Terry – Total Nitrogen

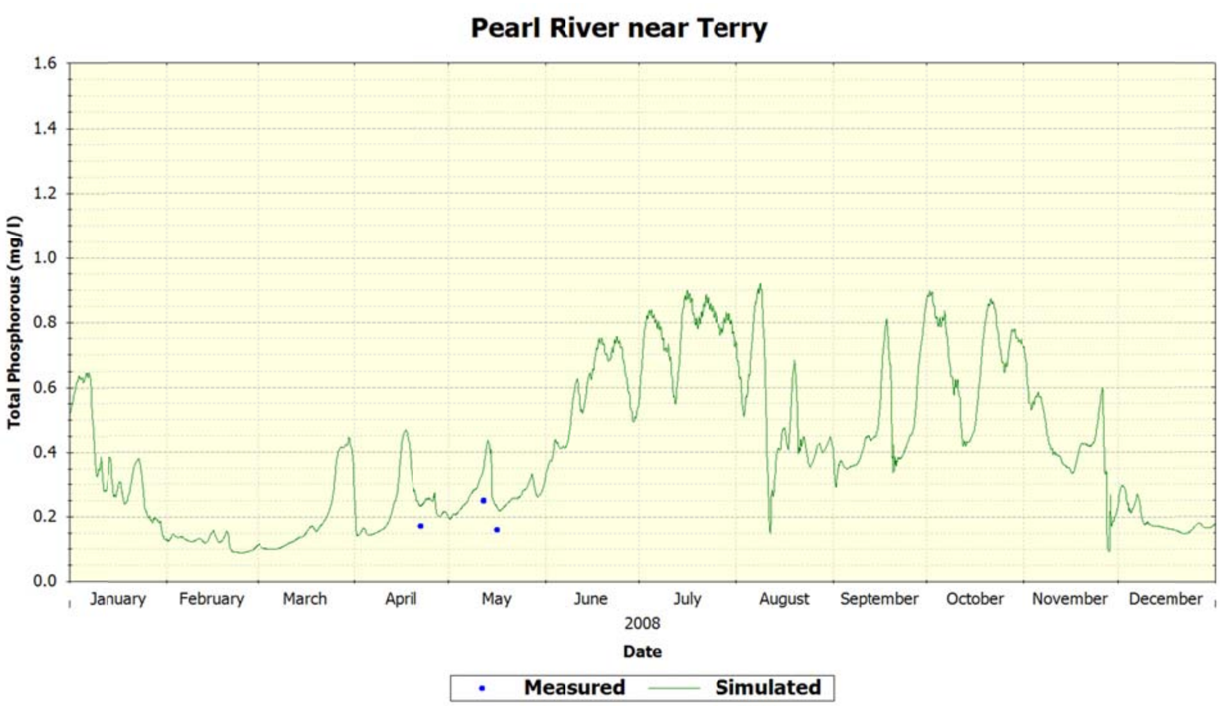

Figure 73 MDEQ Station Pearl River near Terry – Total Phosphorous

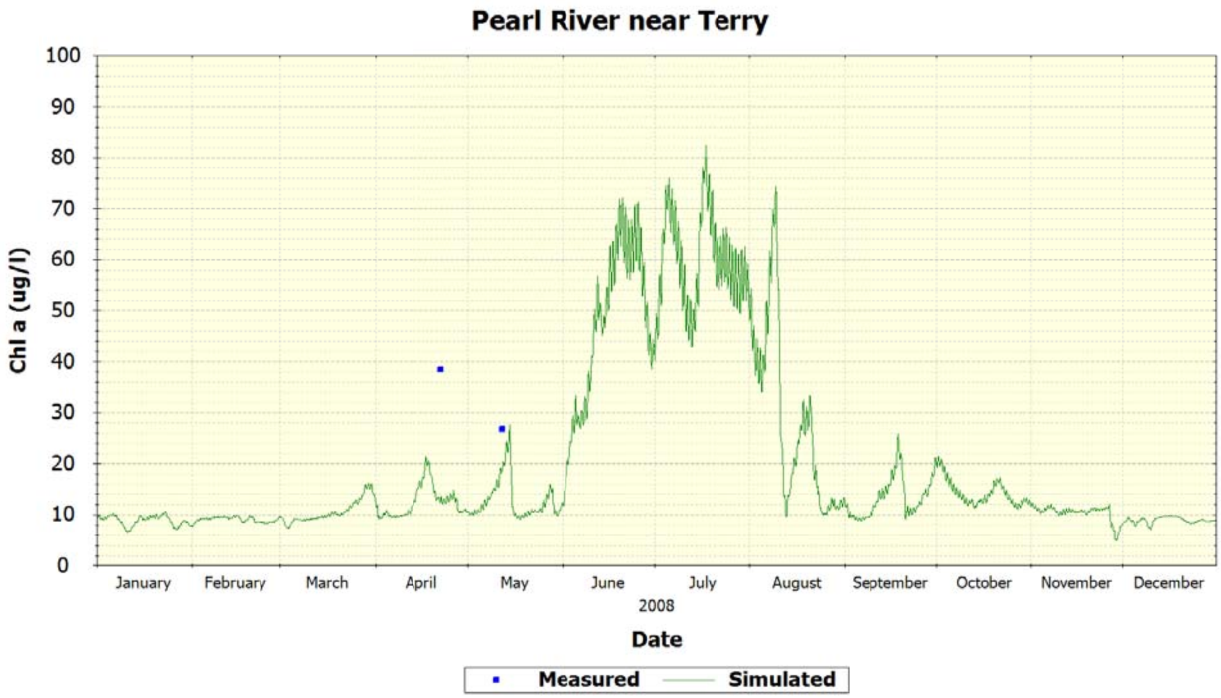

Figure 74 MDEQ Station Pearl River near Terry – Chl a

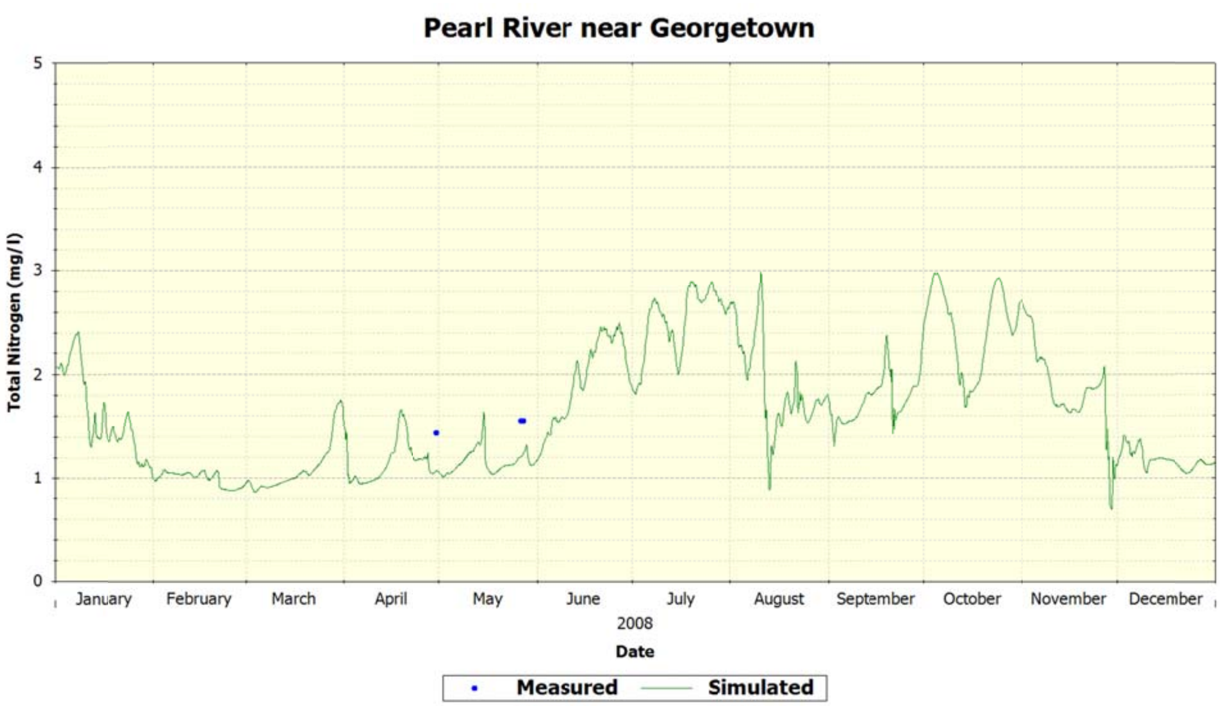

Figure 75 MDEQ Station Pearl River near Georgetown – Total Nitrogen

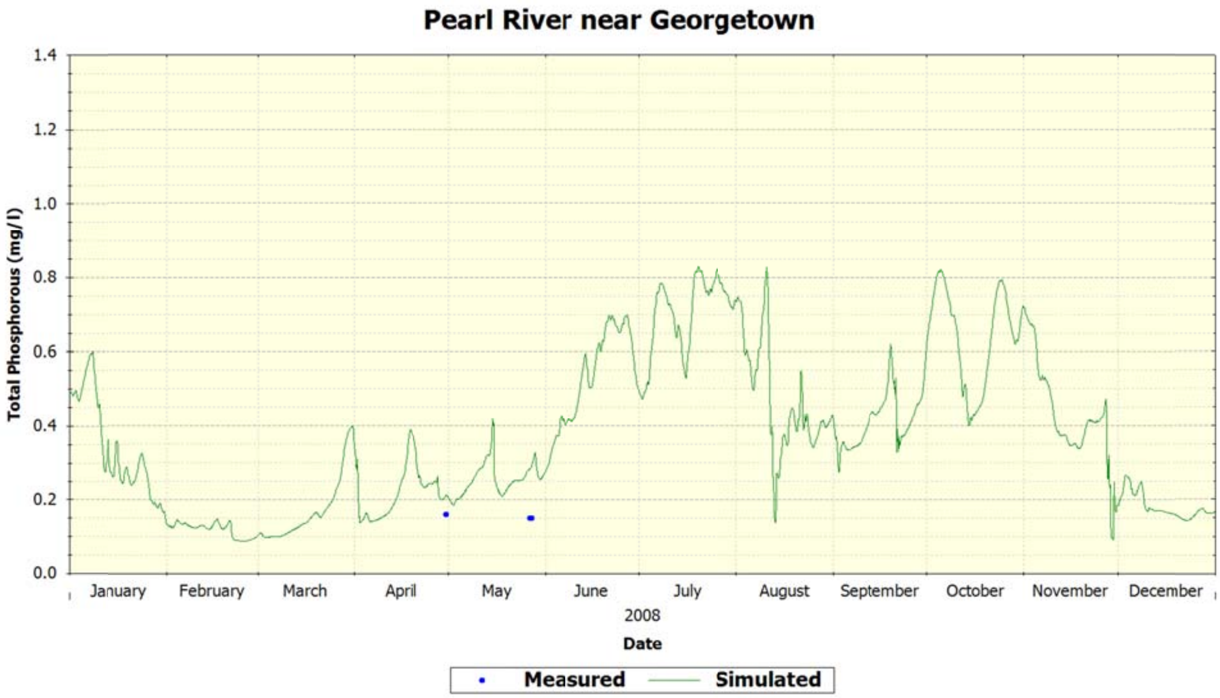

Figure 76 MDEQ Station Pearl River near Georgetown – Total Phosphorous

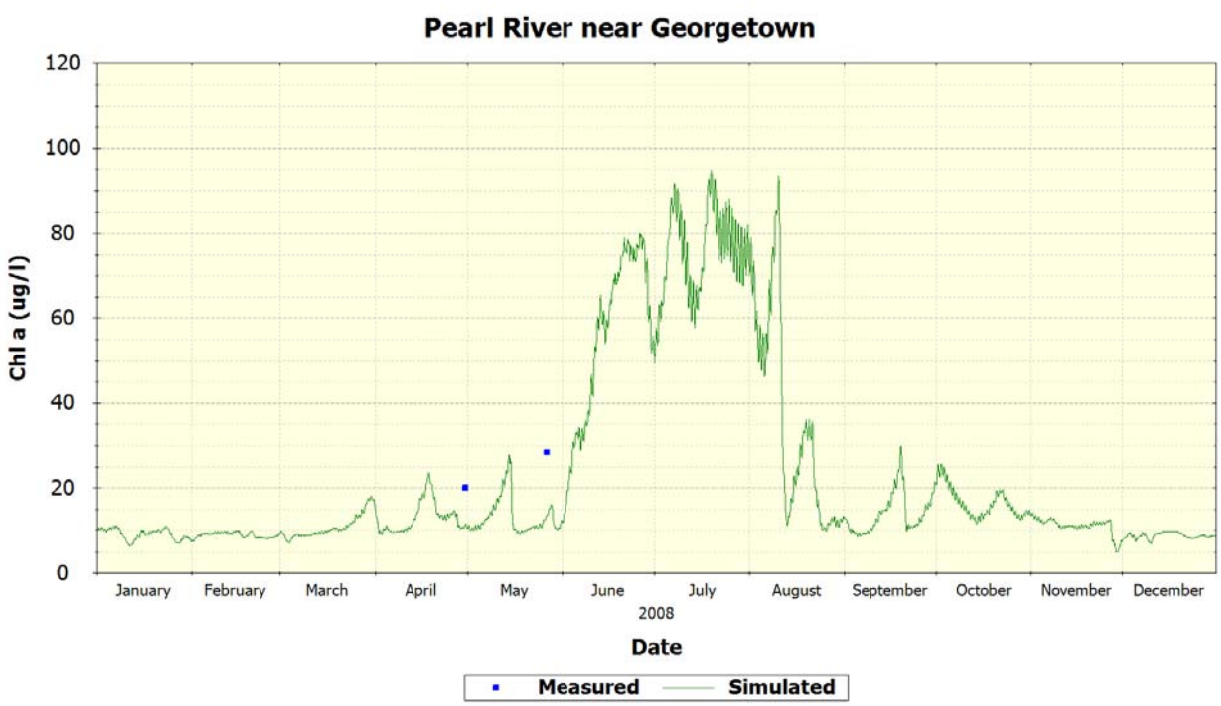

Figure 77 MDEQ Station Pearl River near Georgetown – Chl a

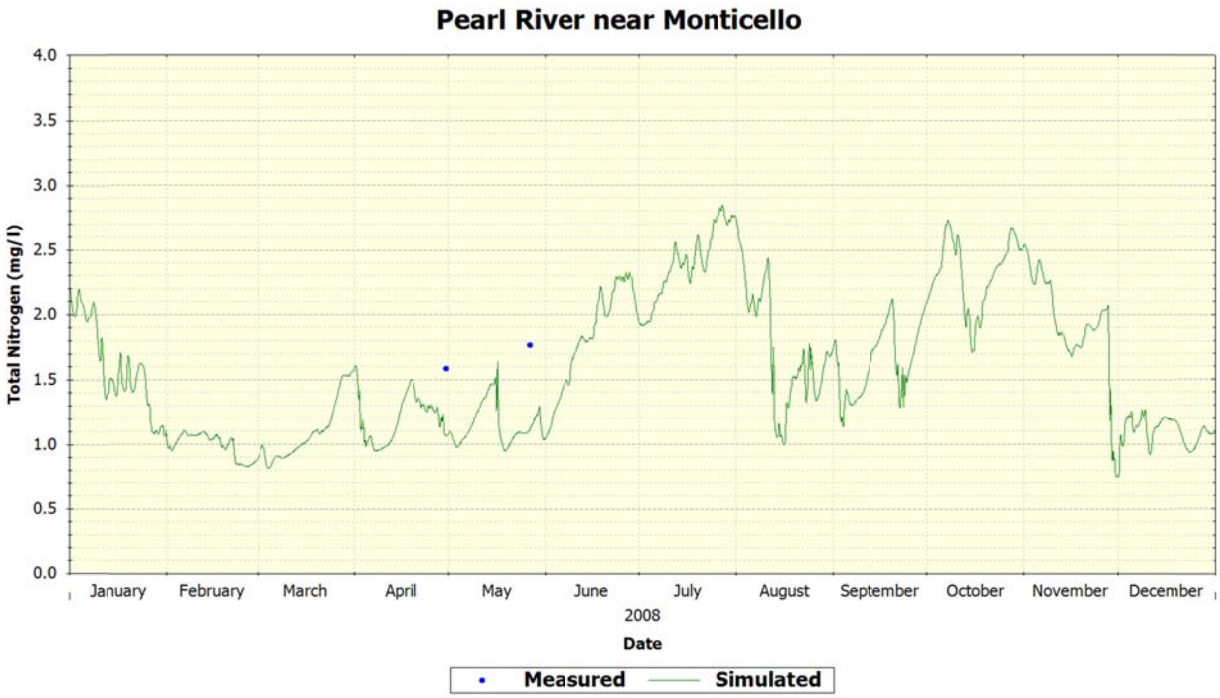

Figure 78 MDEQ Station Pearl River near Monticello – Total Nitrogen

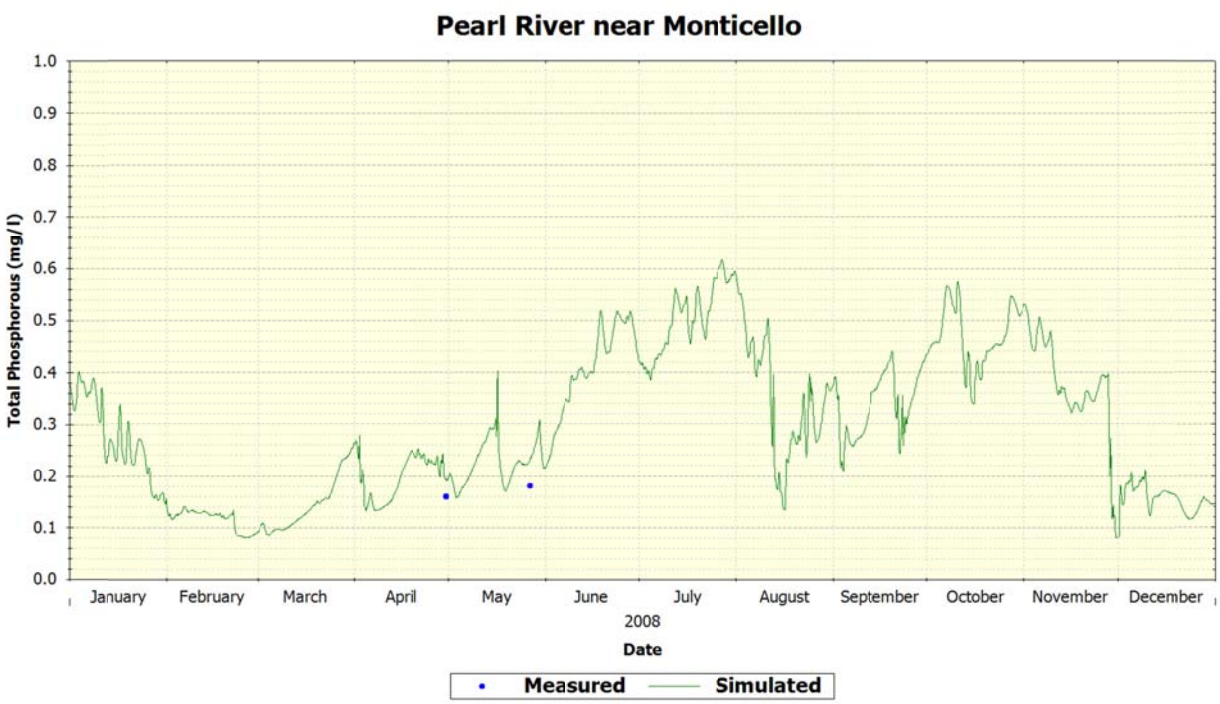

Figure 79 MDEQ Station Pearl River near Georgetown – Total Phosphorus

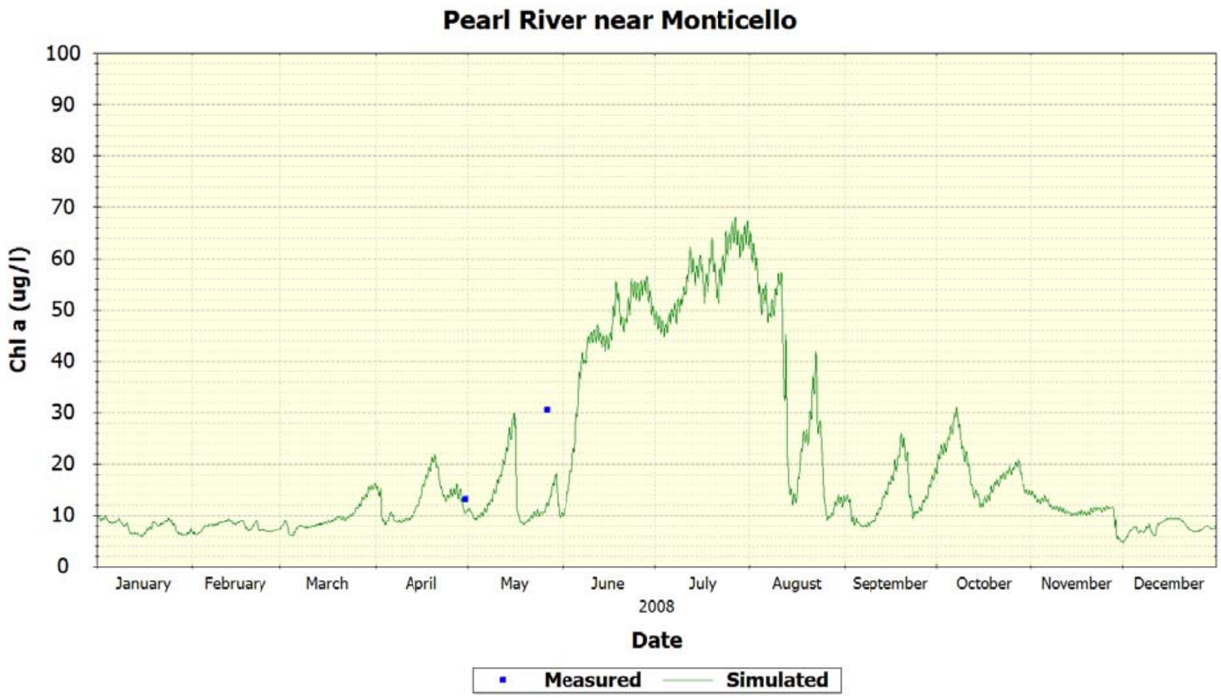

Figure 80 MDEQ Station Pearl River near Georgetown – Chl a

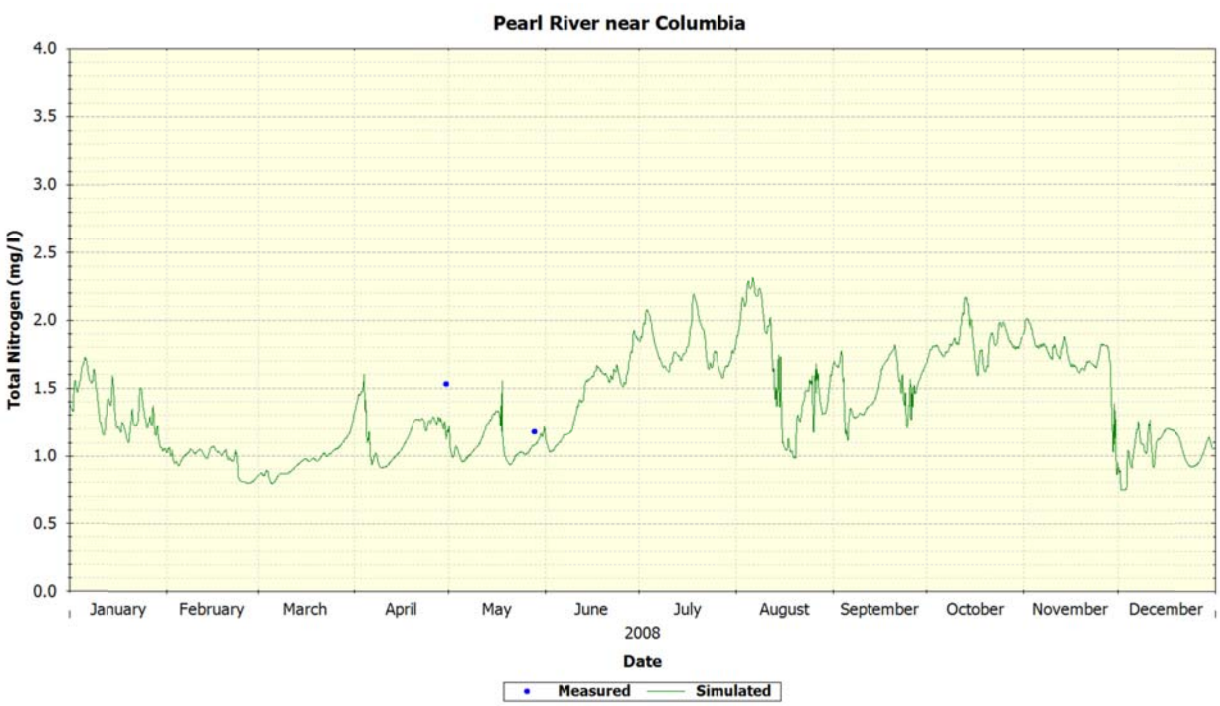

Figure 81 MDEQ Station Pearl River near Columbia – Total Nitrogen

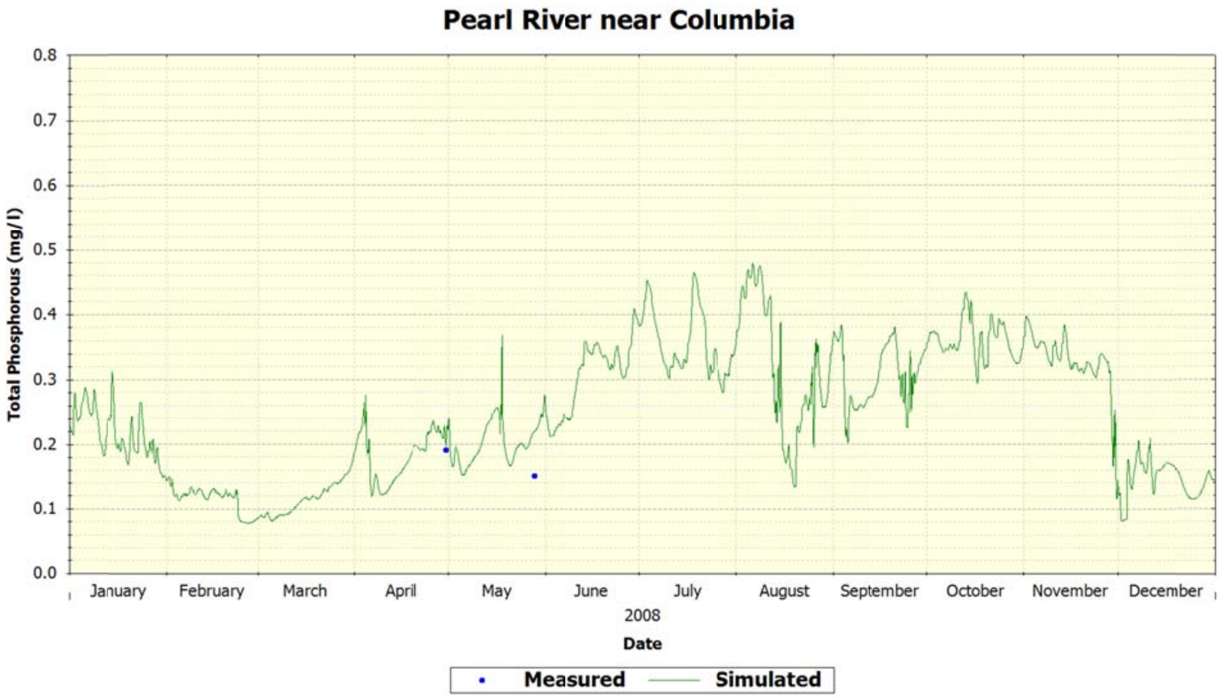

Figure 82 MDEQ Station Pearl River near Columbia – Total Phosphorus

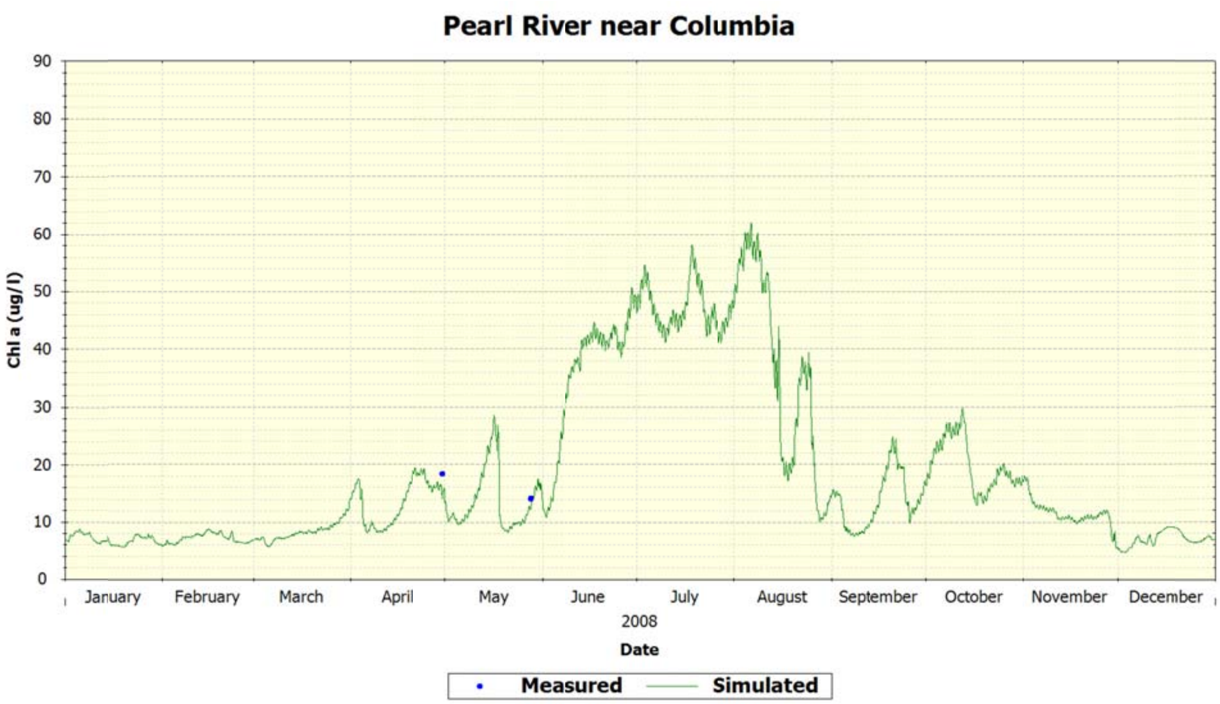

Figure 83 MDEQ Station Pearl River near Columbia – Chl a

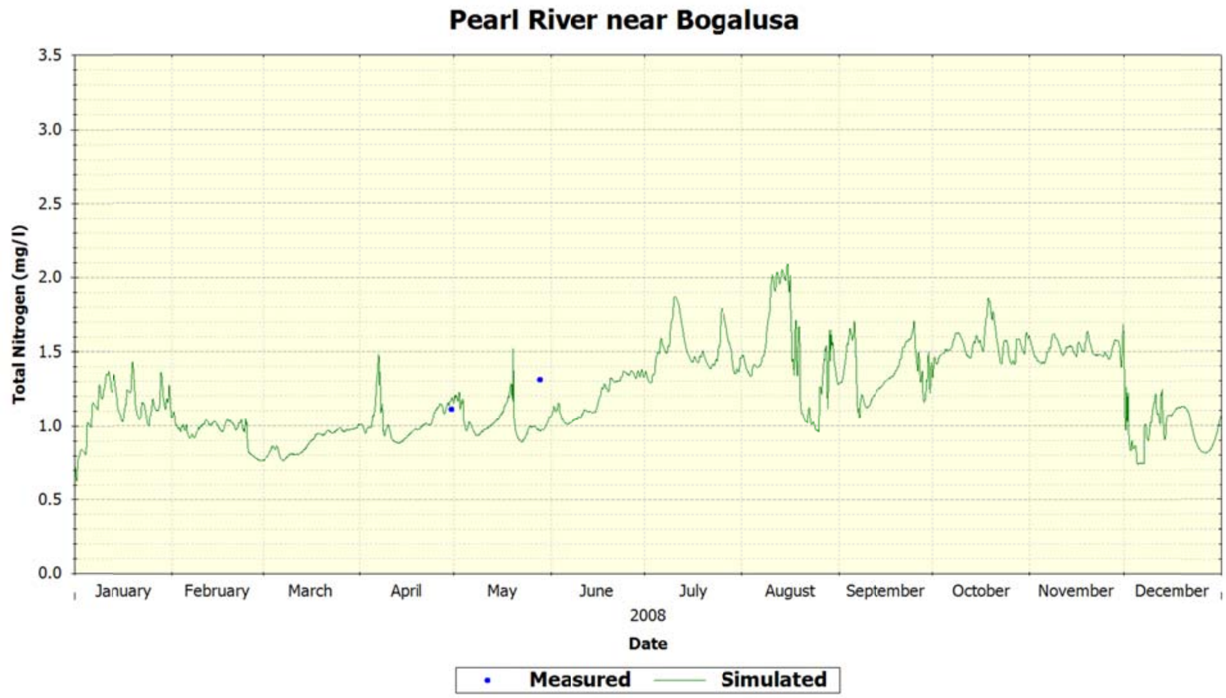

Figure 84 MDEQ Station Pearl River near Bogalusa – Total Nitrogen

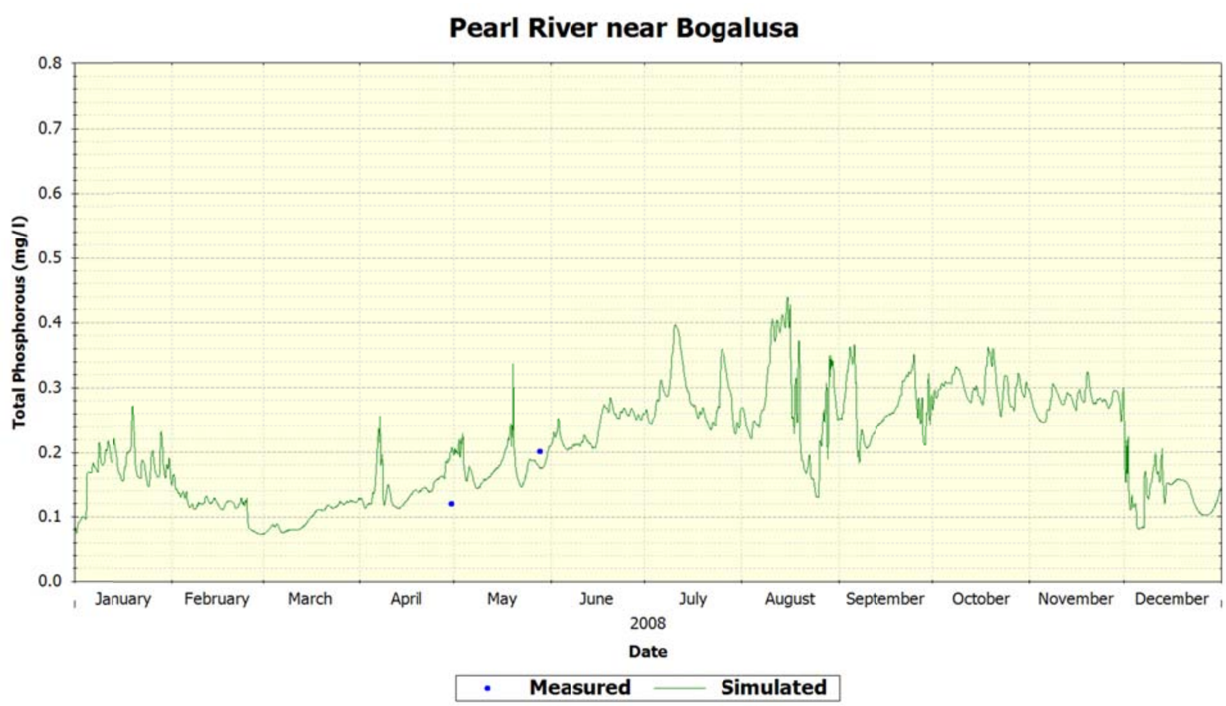

Figure 85 MDEQ Station Pearl River near Bogalusa – Total Phosphorus

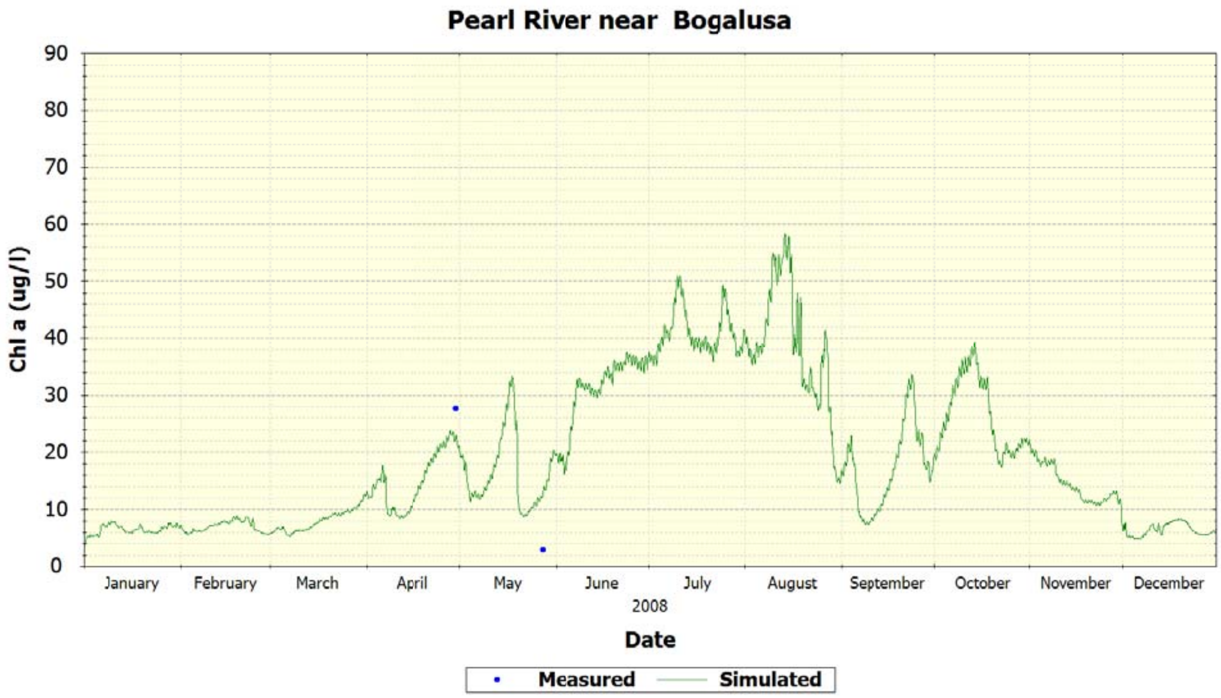

Figure 86 MDEQ Station Pearl River near Bogalusa – Chl a

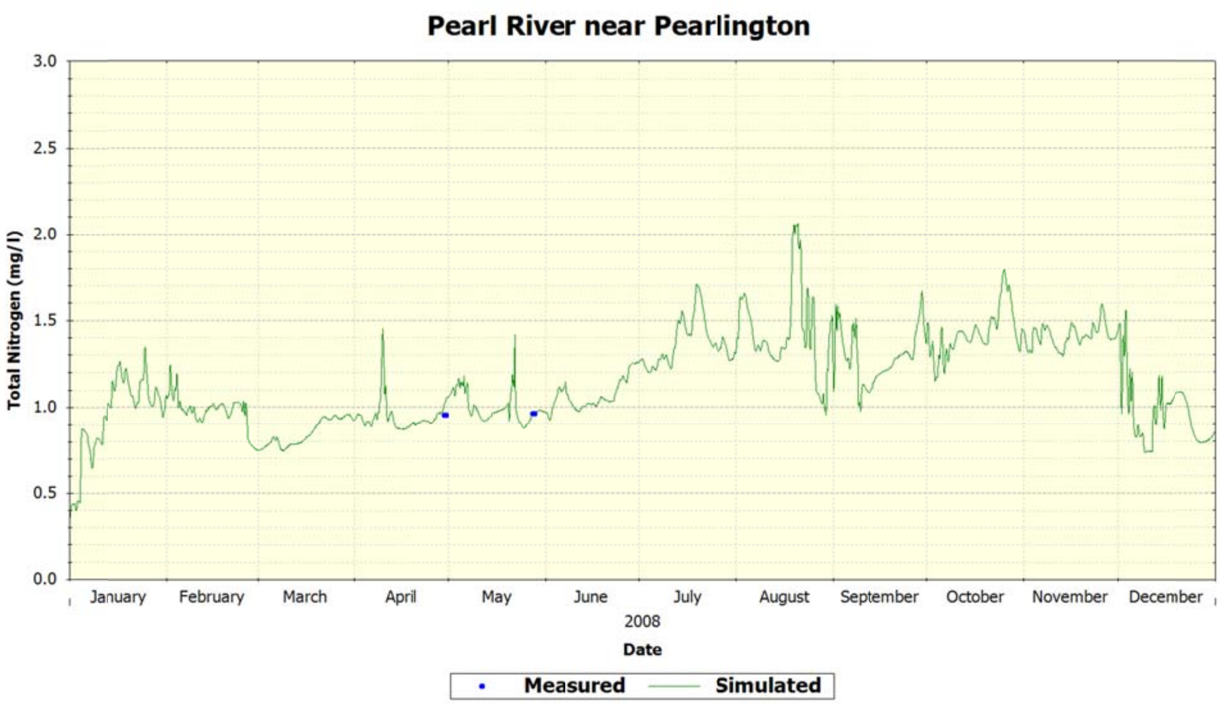

Figure 87 MDEQ Station Pearl River near Pearlington – Total Nitrogen

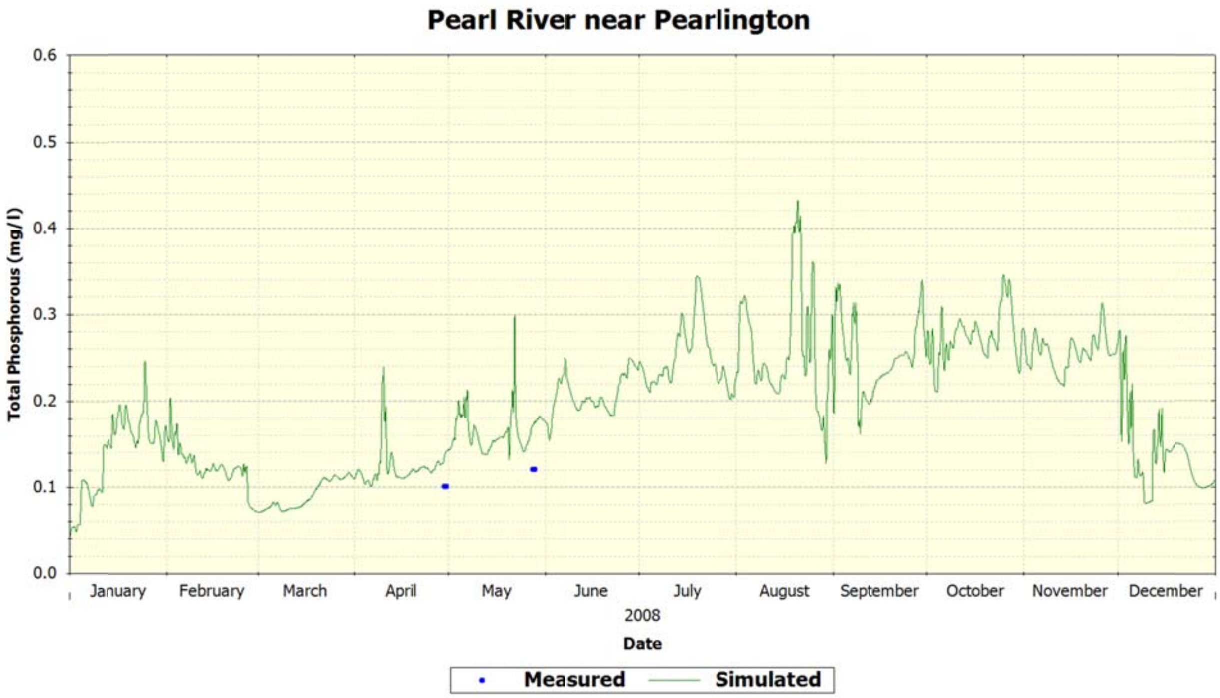

Figure 88 MDEQ Station Pearl River near Pearlington– Total Phosphorous

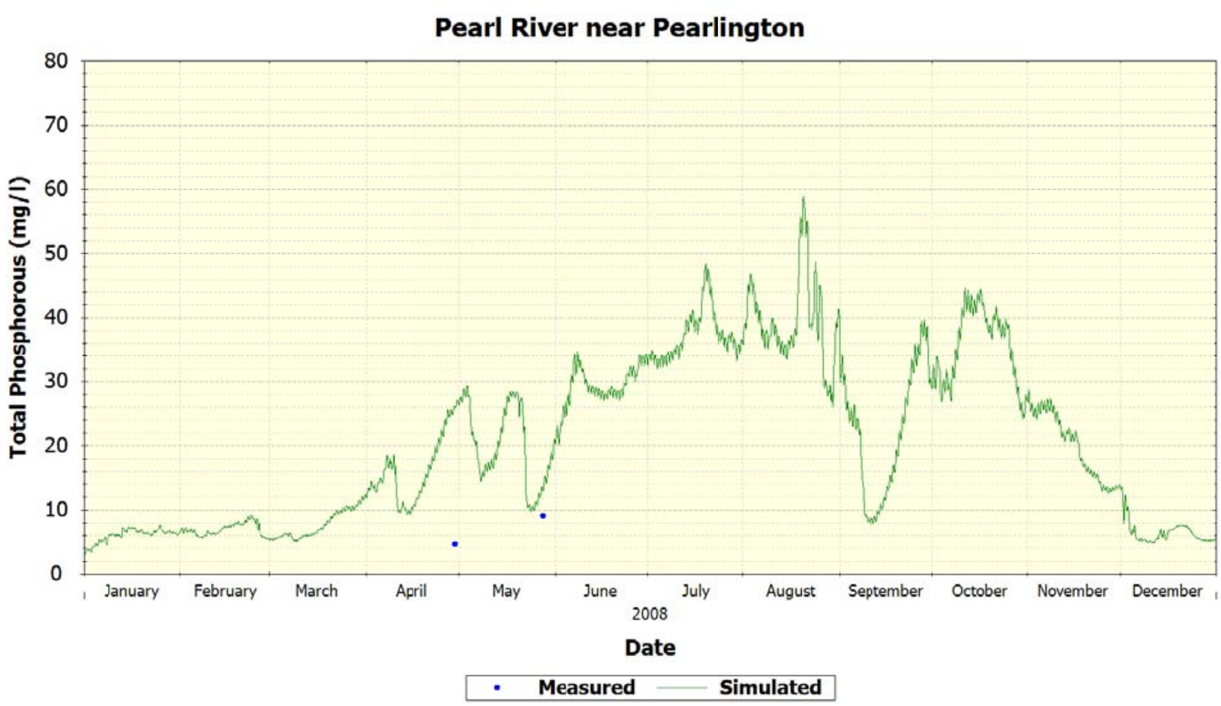

Figure 89 MDEQ Station Pearl River near Pearlington– Chl a

4.3.3 Pearl River near Monticello

GP Monticello has an ongoing river monitoring program, sampling BOD_5 and DO upstream and downstream of their discharge as discussed in Section 2. Figures 55 through 58 illustrate the model predictions against measured data for DO and BOD5.

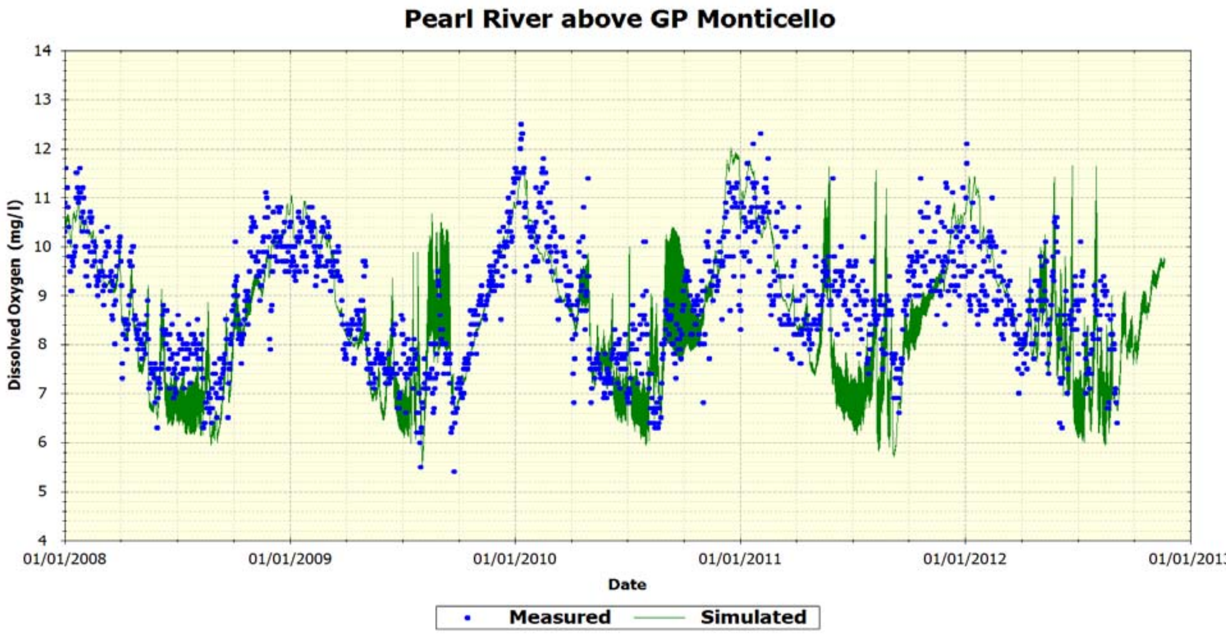

Figure 90 Pearl River above GP Monticello – Dissolved Oxygen

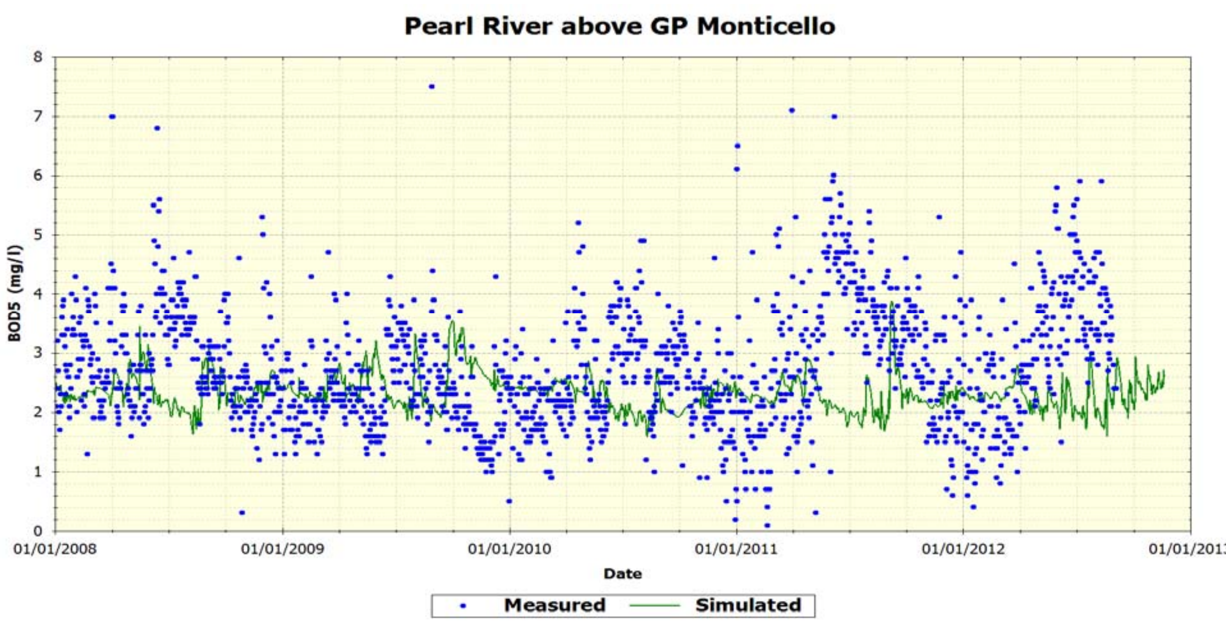

Figure 91 Pearl River above GP Monticello – BOD5

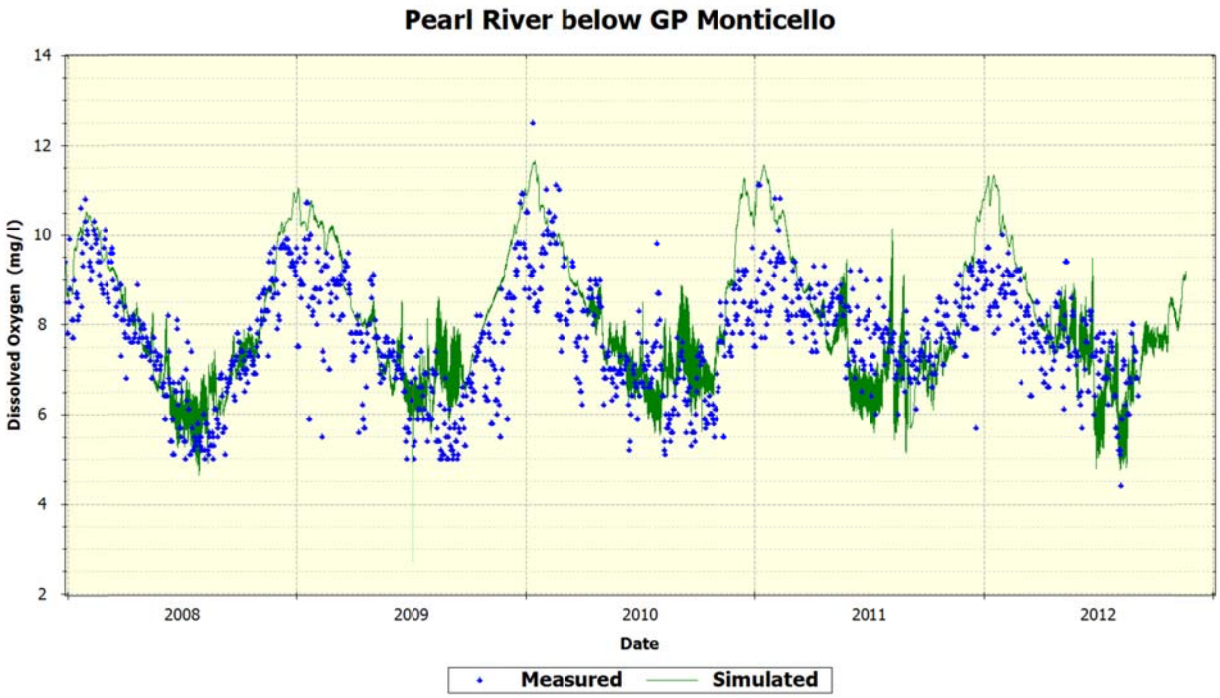

Figure 92 Pearl River below GP Monticello – Dissolved Oxygen

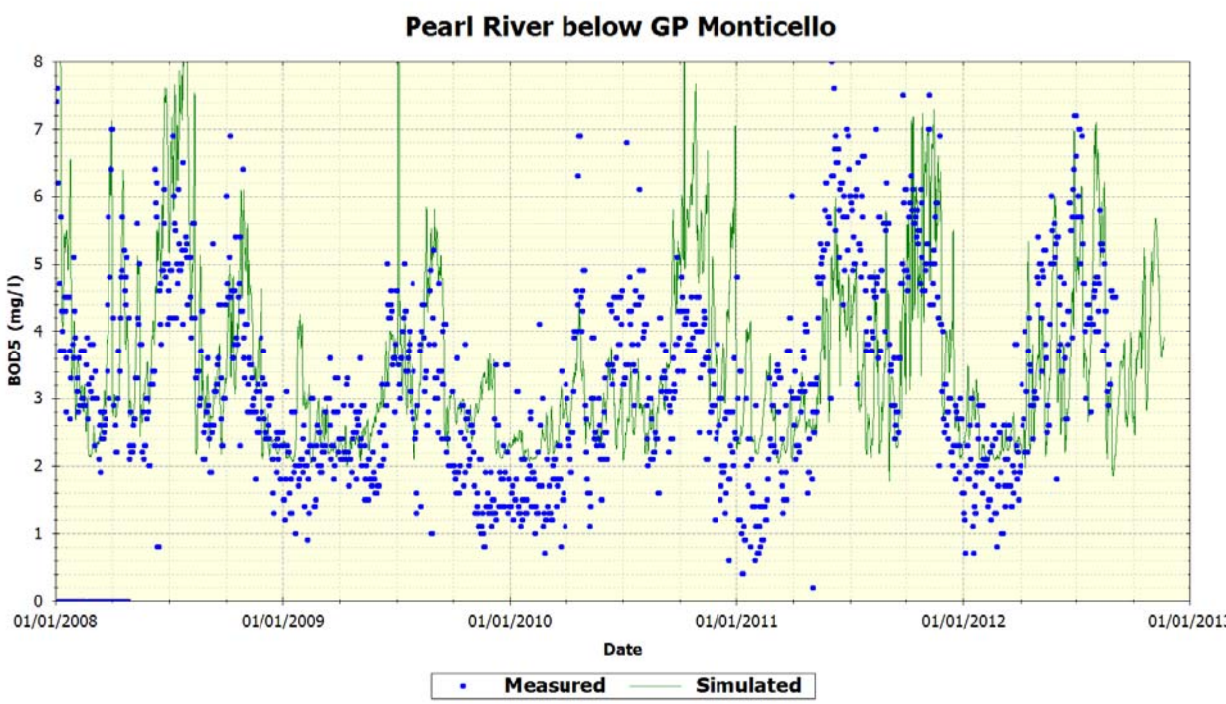

Figure 93 Pearl River below GP Monticello – BOD5

4.3.4 Pearl River 2012 MDEQ Study

MDEQ collected *insitu* DO data during the 2012 EPA and MDEQ Water Quality Study at Stations PR1 – PR8. The water quality data collected during this study and location map are in Section 2. MDEQ *insitu* DO data provided a two to three day diurnal DO measurements, showing the day to night DO swing mostly due to the high Chl a concentrations in the river. These diurnal DO measurements were well above the DO saturation levels, which indicated to MDEQ, a potential DO and Chl a problem. Figures 59 to 74 illustrate measured and simulated DO levels for this time period, along with the modeled graphs of the predicted Chl a levels.

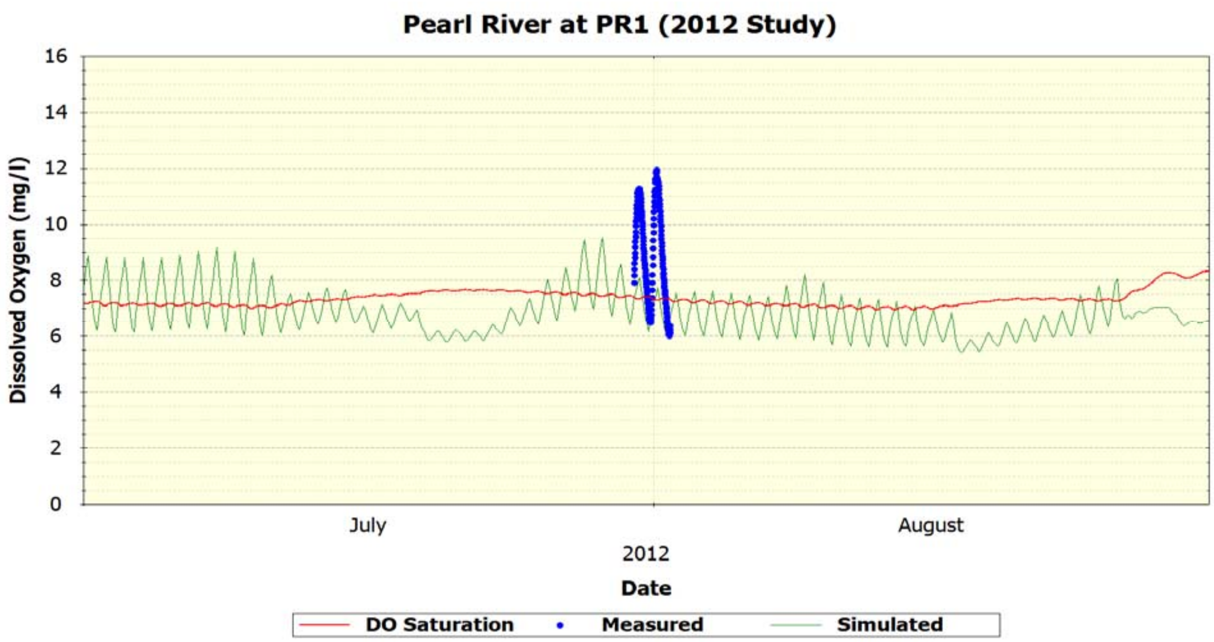

Figure 94 Pearl River Station PR1 – Dissolved Oxygen

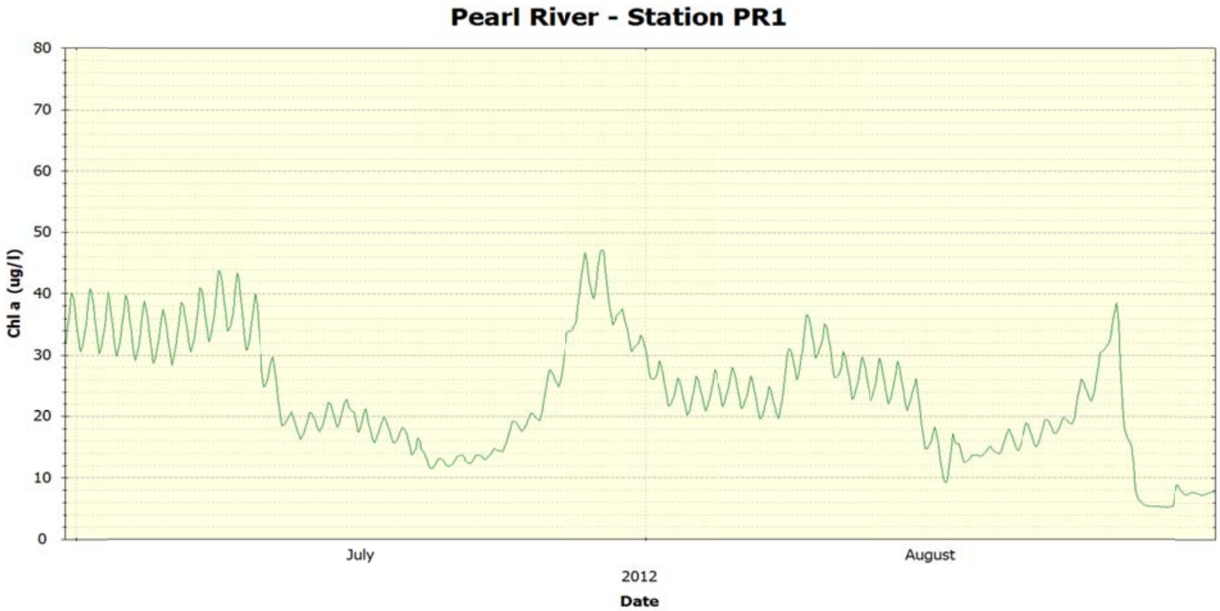

Figure 95 Pearl River Station PR1 – Chl a

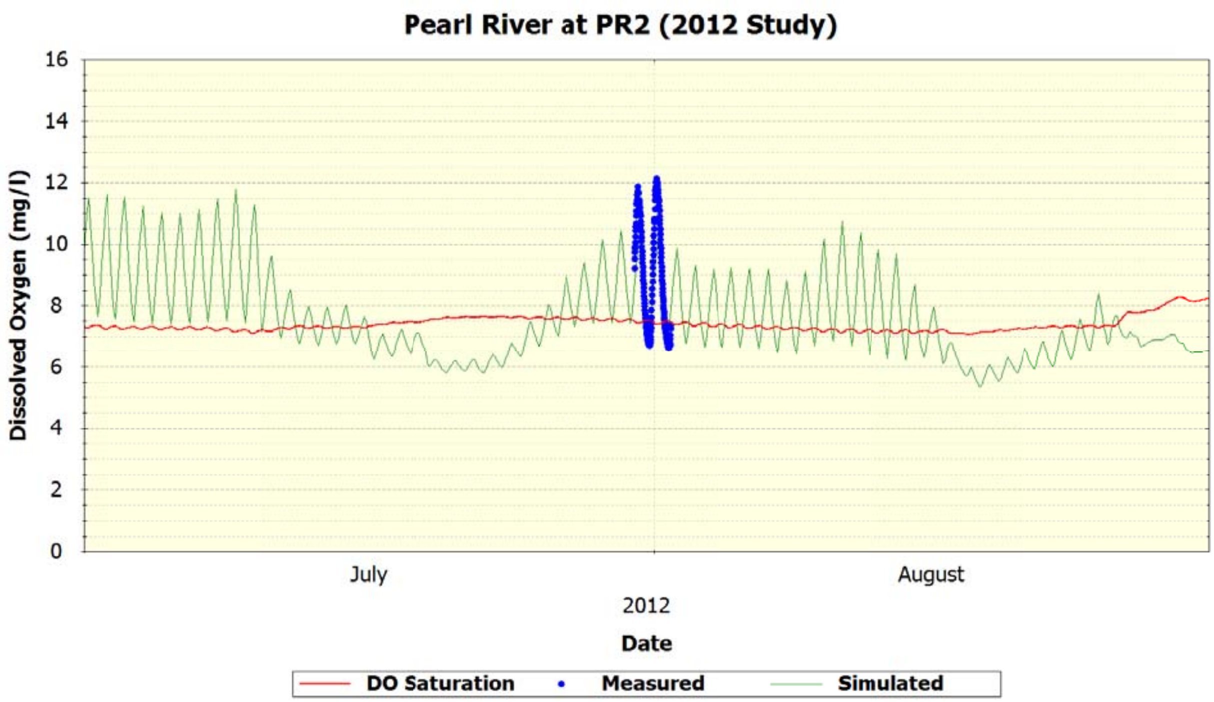

Figure 96 Pearl River Station PR2 – Dissolved Oxygen

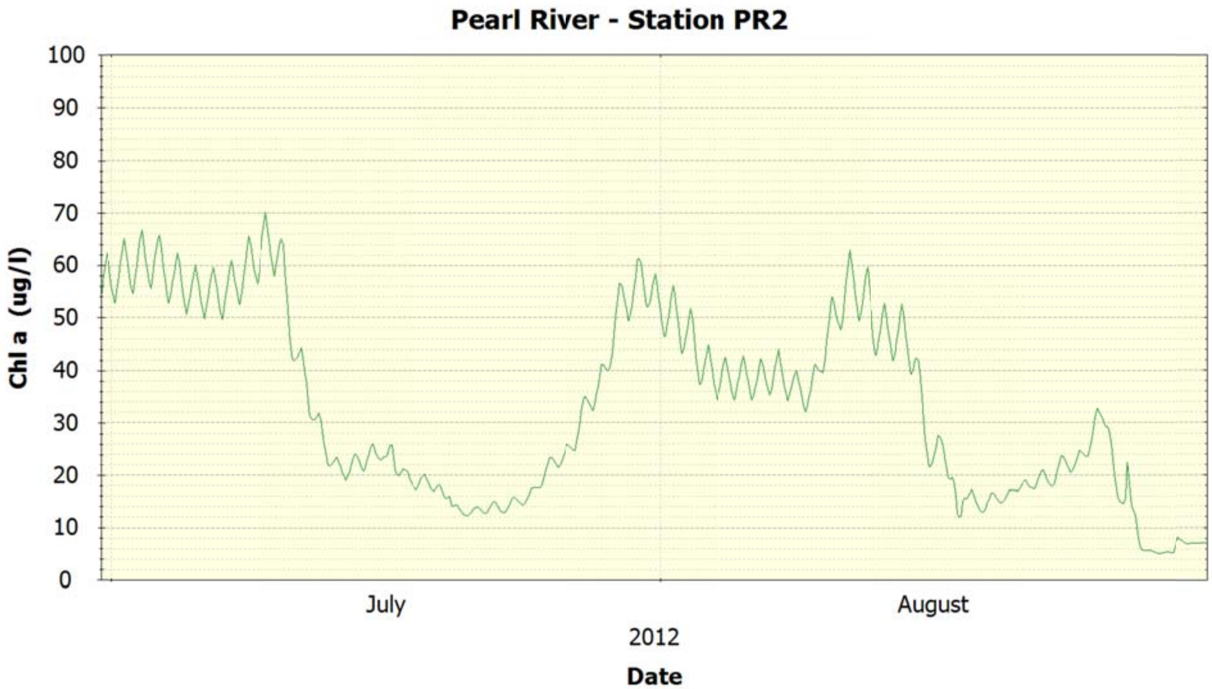

Figure 97 Pearl River Station PR2 – Chl a

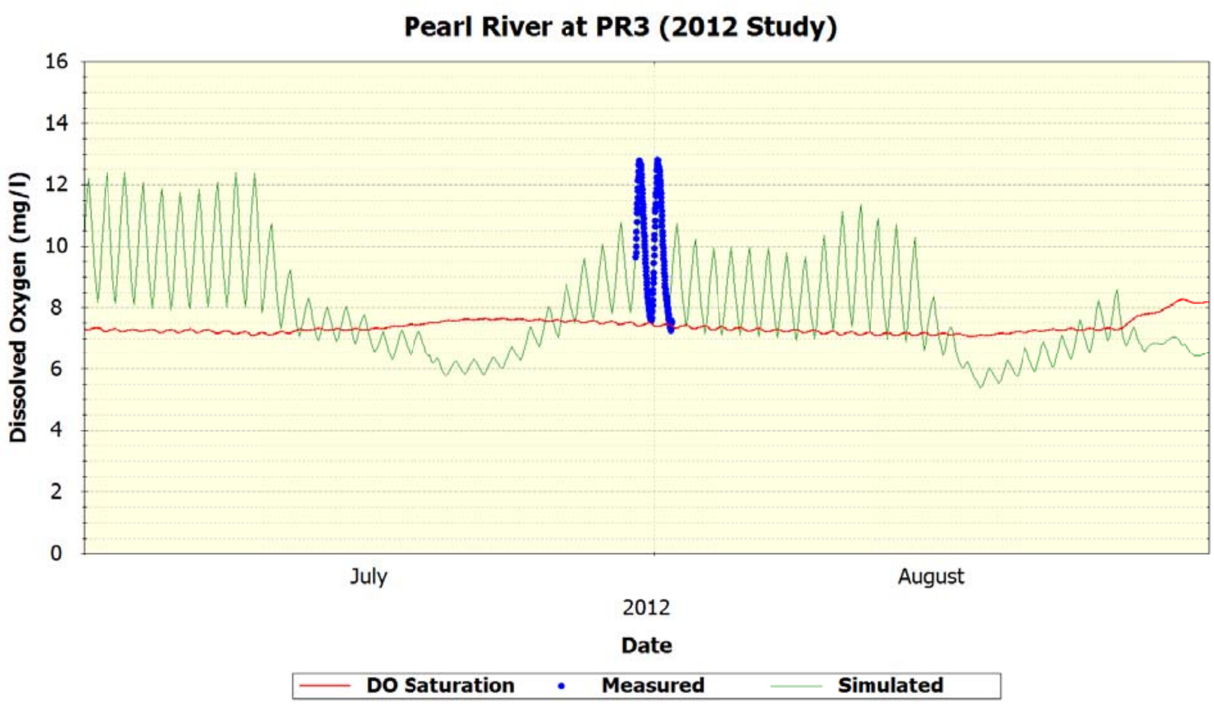

Figure 98 Pearl River Station PR3 – Dissolved Oxygen

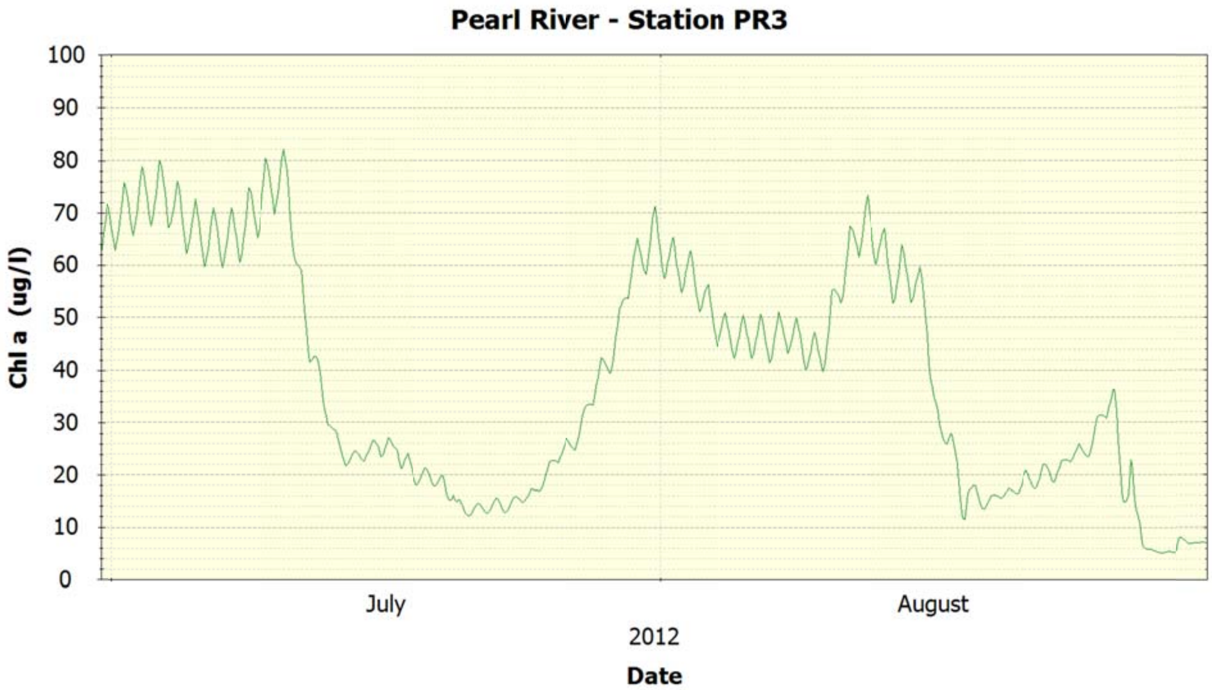

Figure 99 Pearl River Station PR3 – Chl a

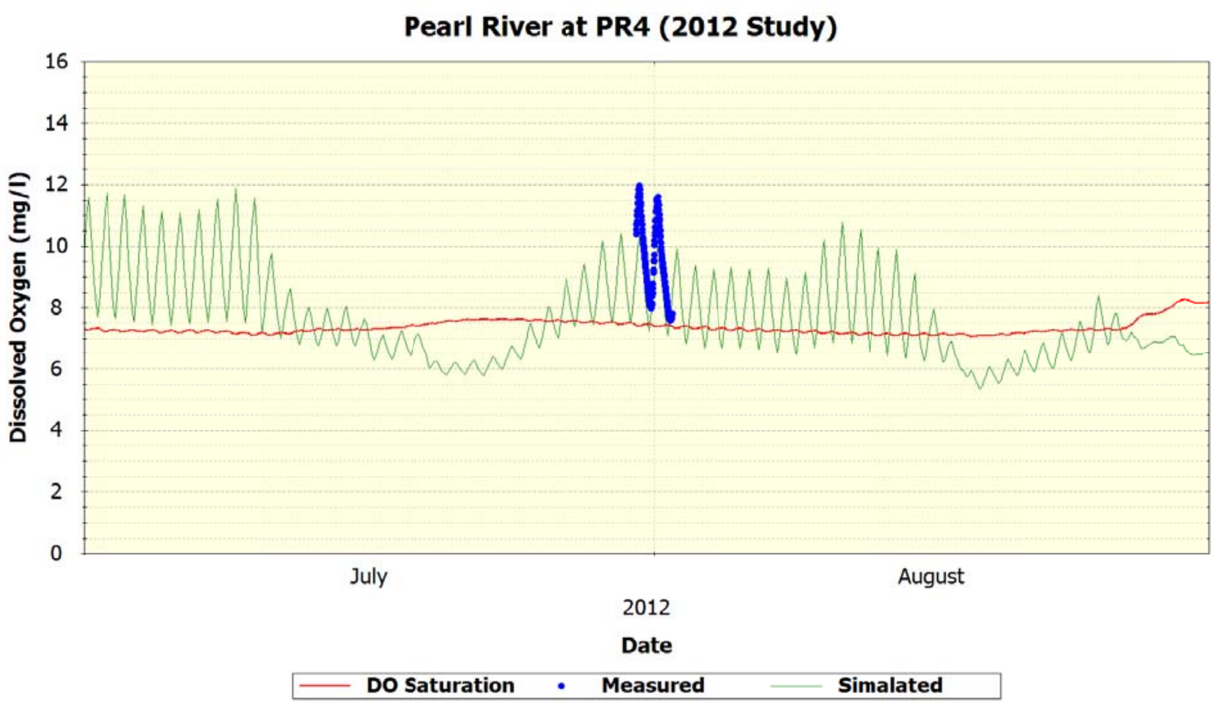

Figure 100 Pearl River Station PR4 – Dissolved Oxygen

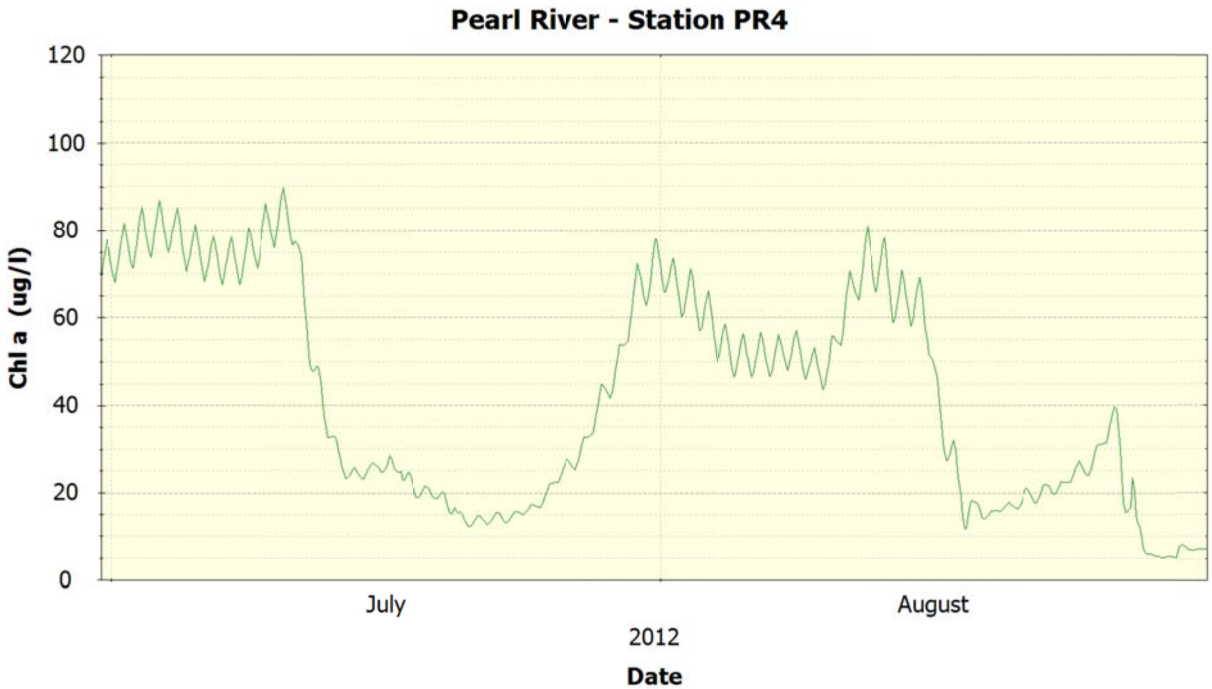

Figure 101 Pearl River Station PR4 – Chl a

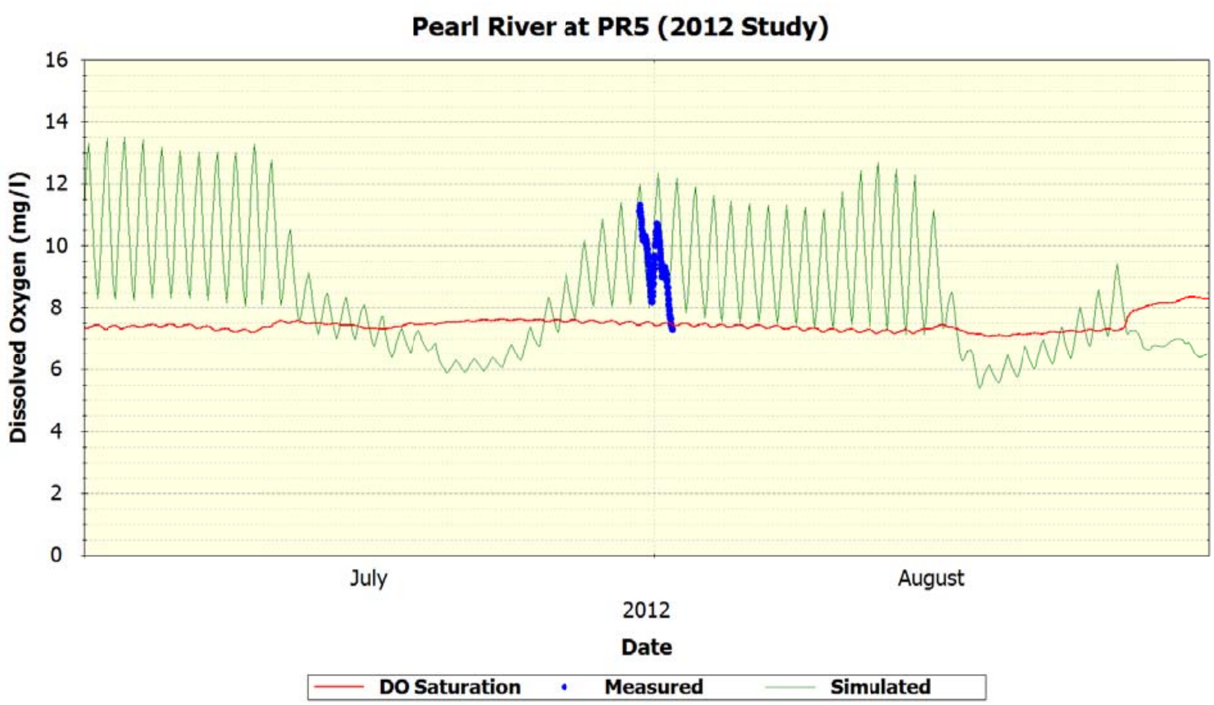

Figure 102 Pearl River Station PR5 – Dissolved Oxygen

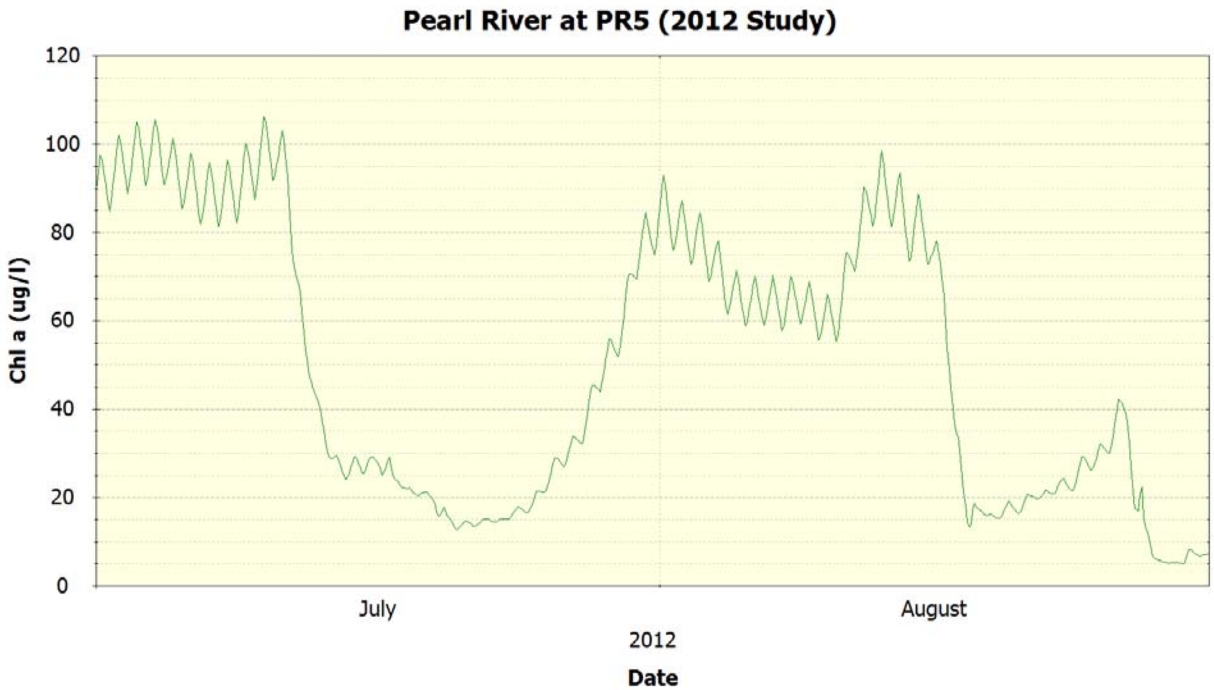

Figure 103 Pearl River Station PR5 – Chl a

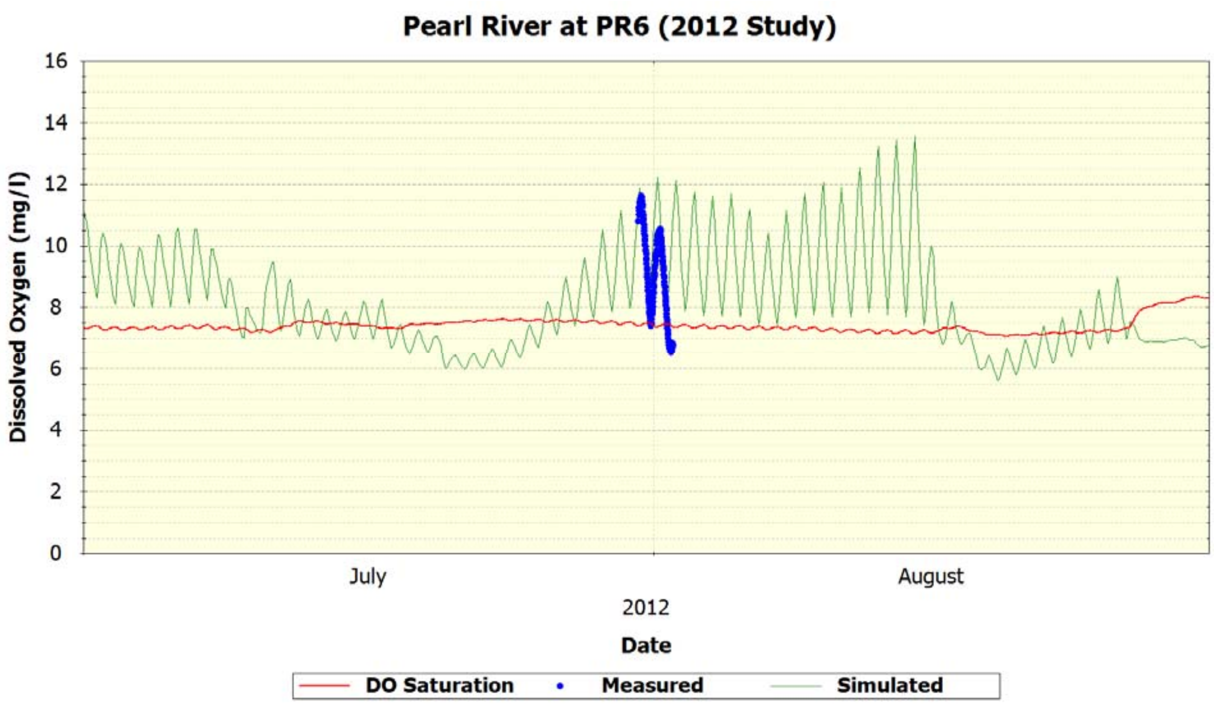

Figure 104 Pearl River Station PR6 – Dissolved Oxygen

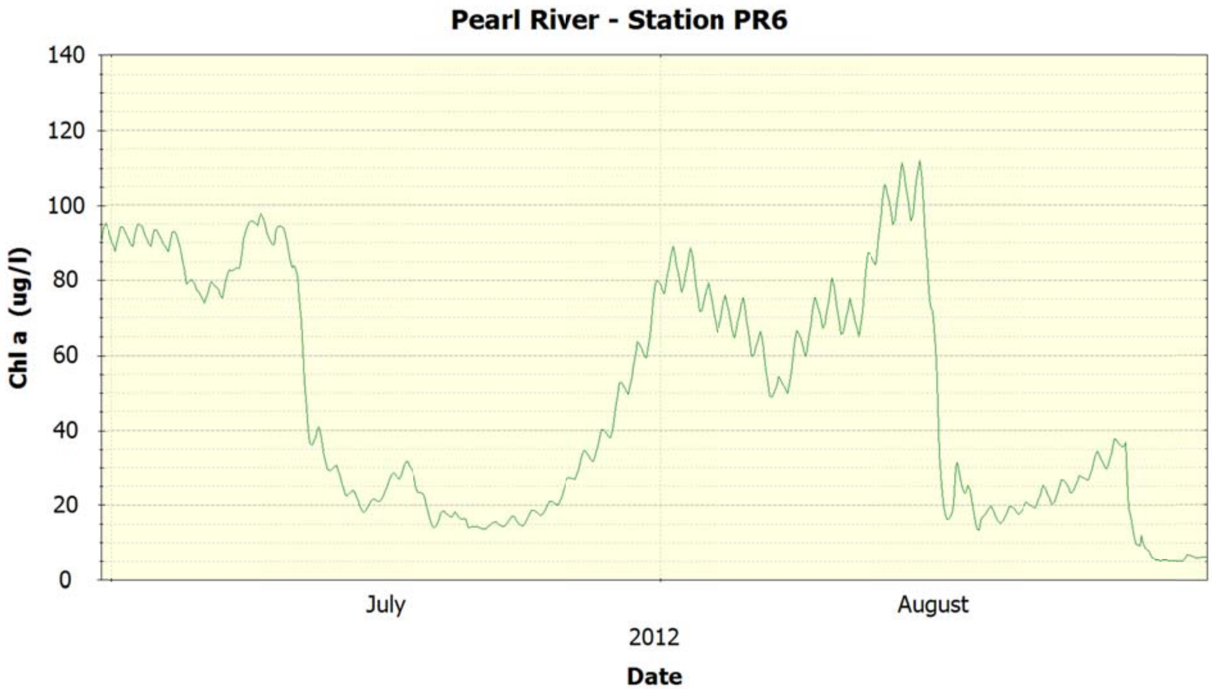

Figure 105 Pearl River Station PR6 – Chl a

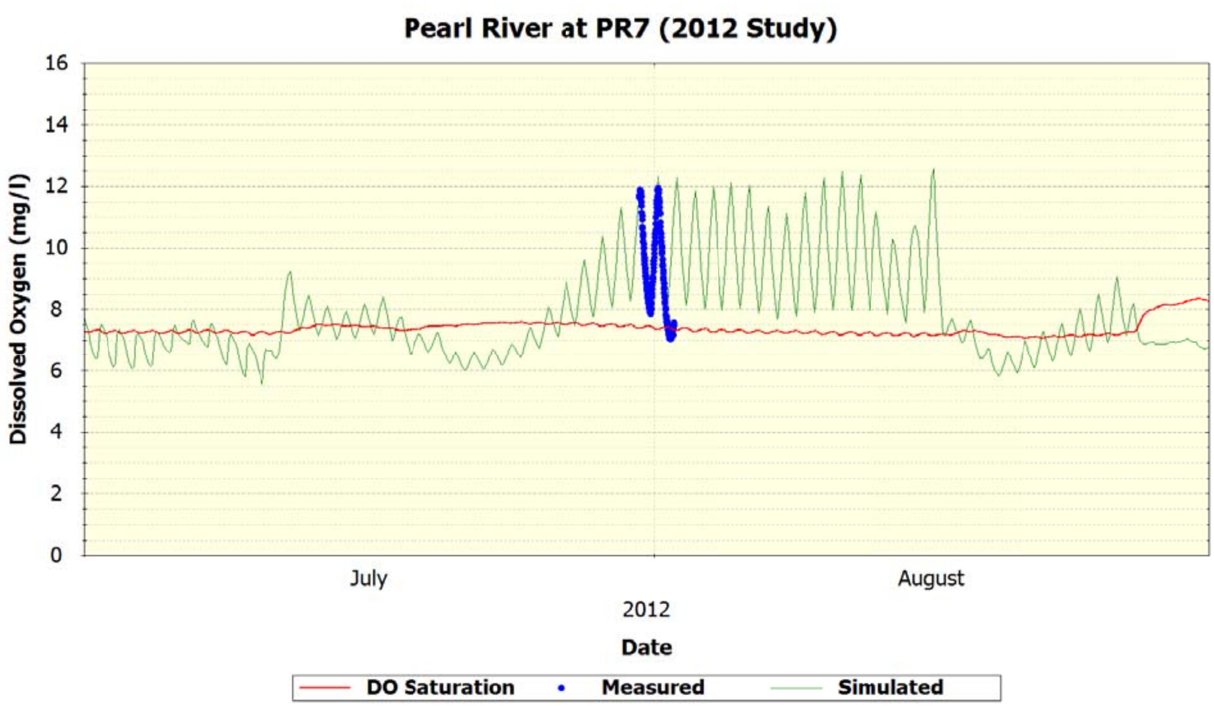

Figure 106 Pearl River Station PR7 – Dissolved Oxygen

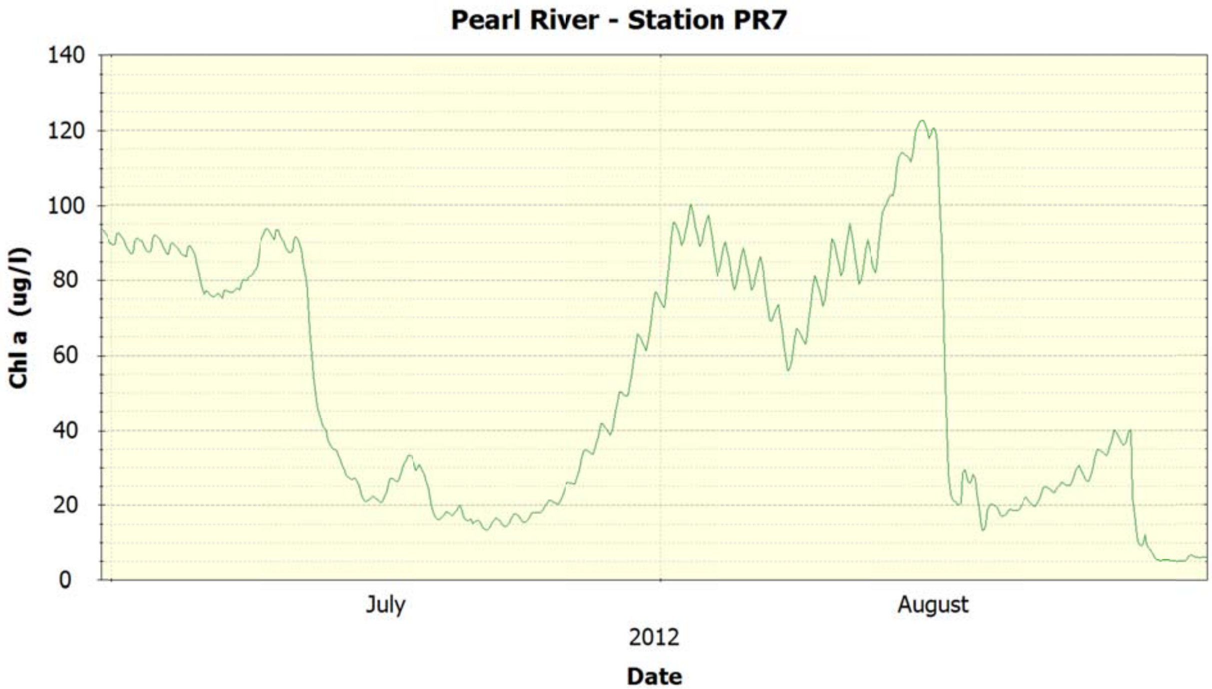

Figure 107 Pearl River Station PR7 – Chl a

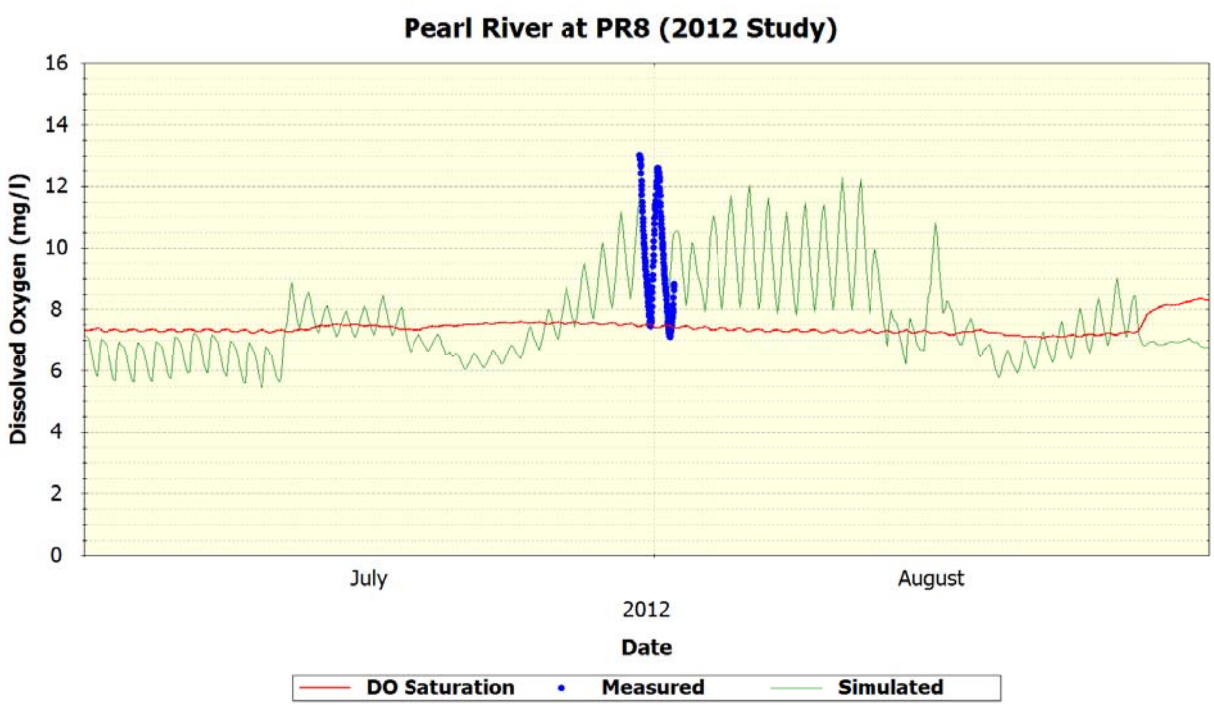

Figure 108 Pearl River Station PR8 – Dissolved Oxygen

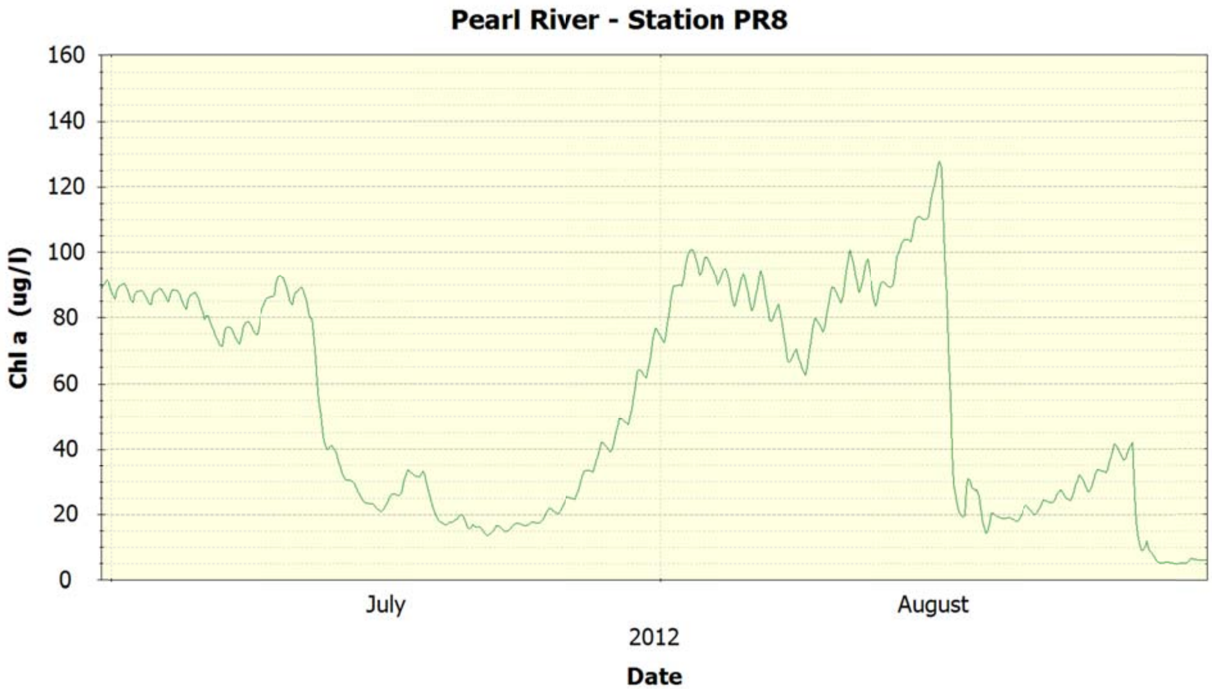

Figure 109 Pearl River Station PR8 – Chl a

4.3.4 Pearl River 2010 Study Model Calibration

MDEQ collected *insitu* DO data during the 2010 MDEQ Water Quality Study at four stations, PR1 –PR4. The water quality data summary and location map are in Section 2. MDEQ *insitu* DO data provided a two day diurnal DO measurements, showing the day to night DO swing mostly due to the high Chl a concentrations in the river. These diurnal DO measurements were at times above the DO saturation levels, which indicated to MDEQ, a potential DO and Chl a problem. Figures 75 to 82 illustrate measured and simulated DO levels for this time period, along with the modeled graphs of the predicted Chl a levels.

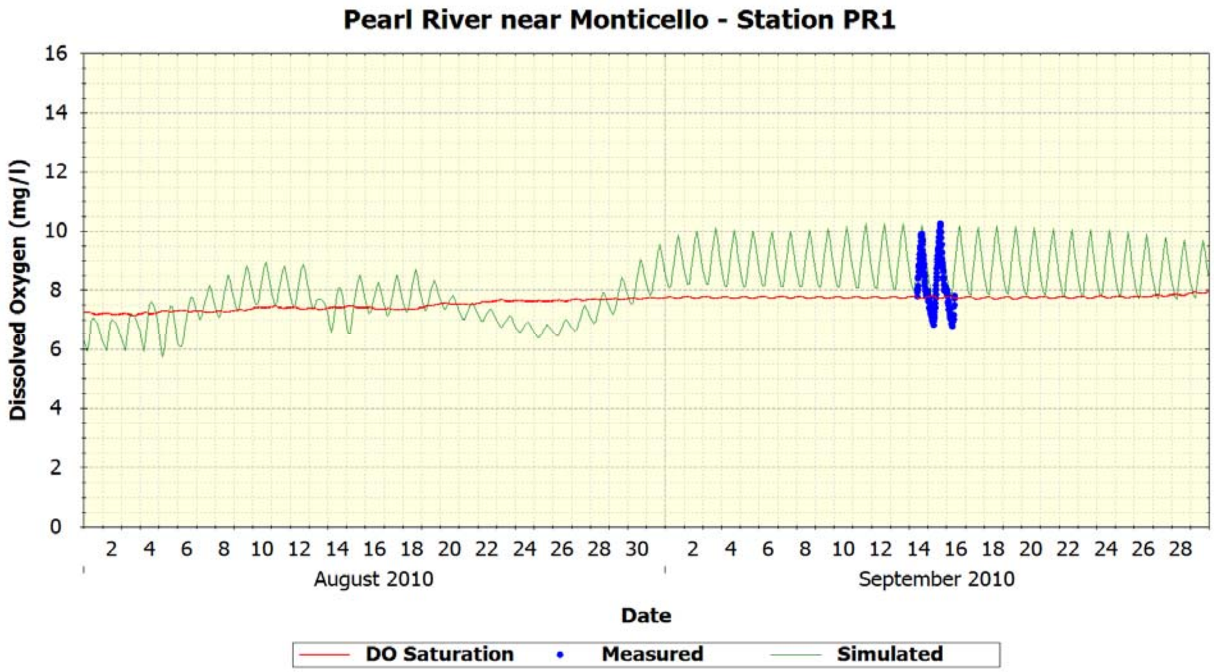

Figure 110 Pearl River near Monticello Station PR1 – Dissolved Oxygen

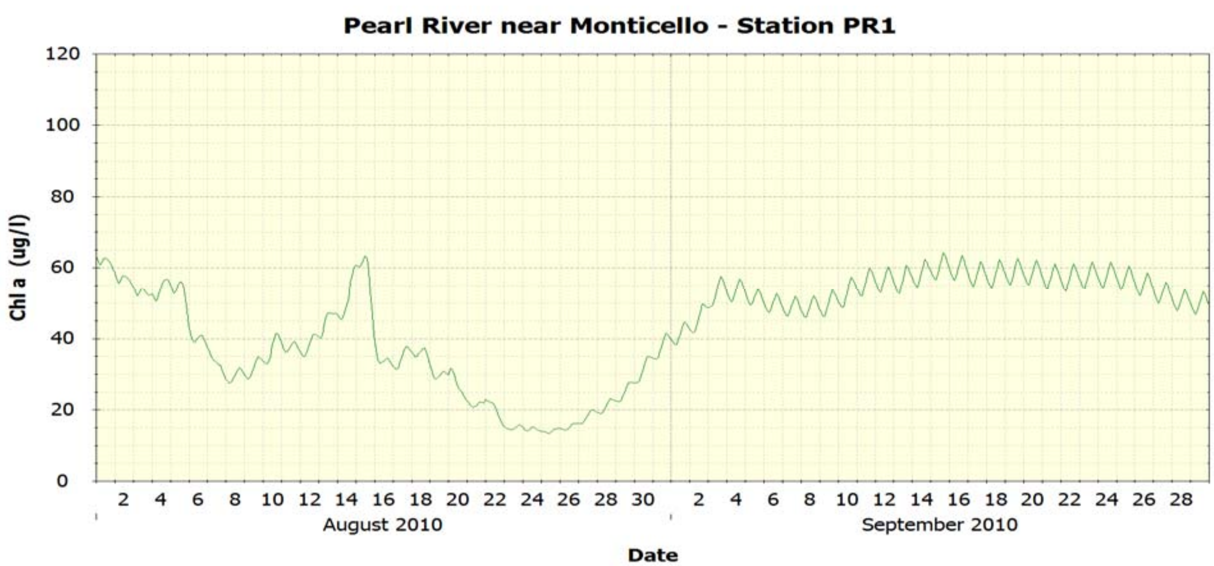

Figure 111 Pearl River near Monticello Station PR1 – Chl a

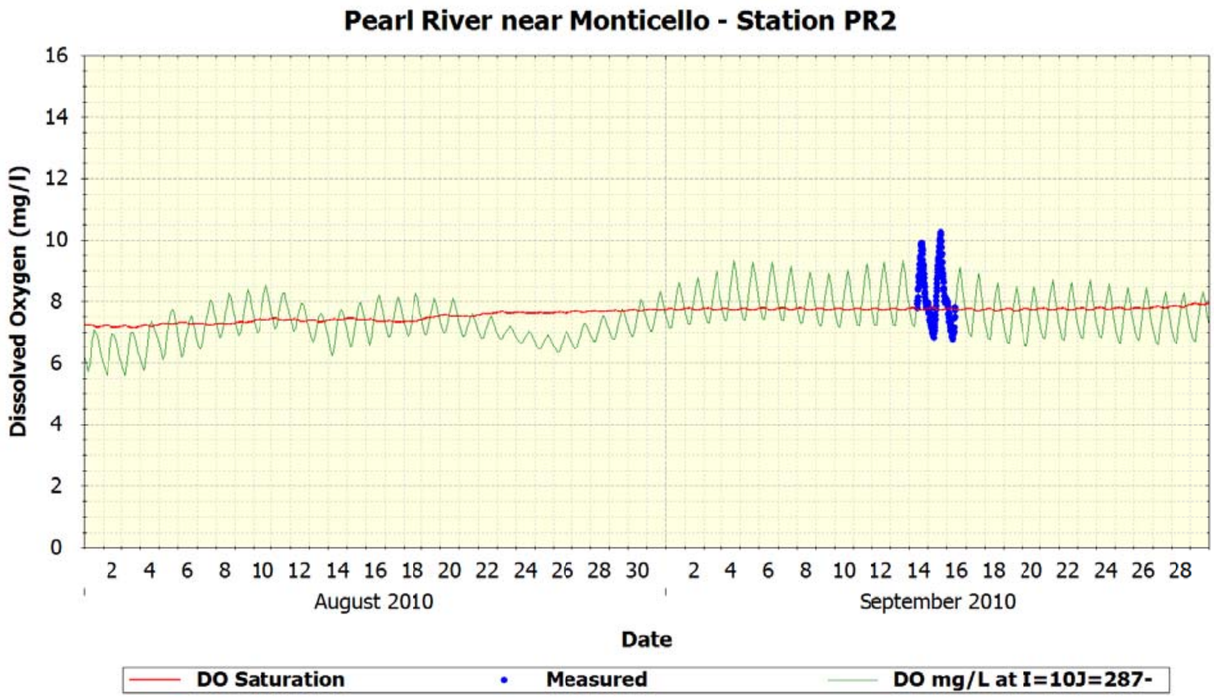

Figure 112 Pearl River near Monticello Station PR2 – Dissolved Oxygen

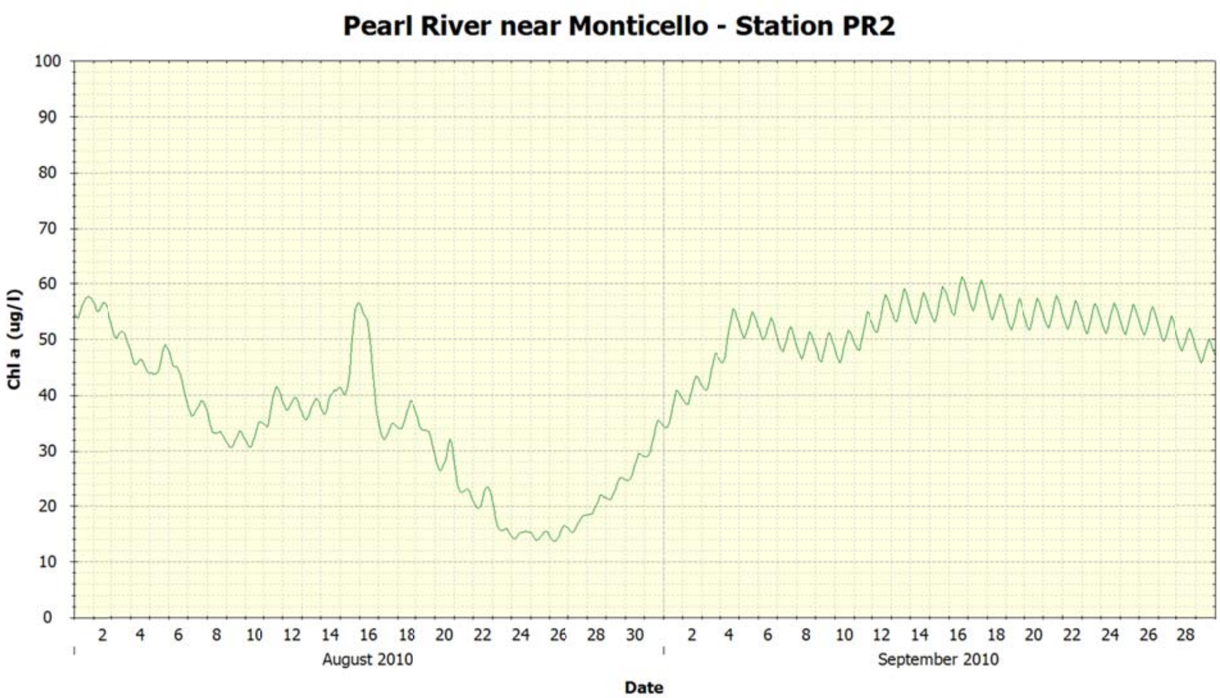

Figure 113 Pearl River near Monticello Station PR2 – Chl a

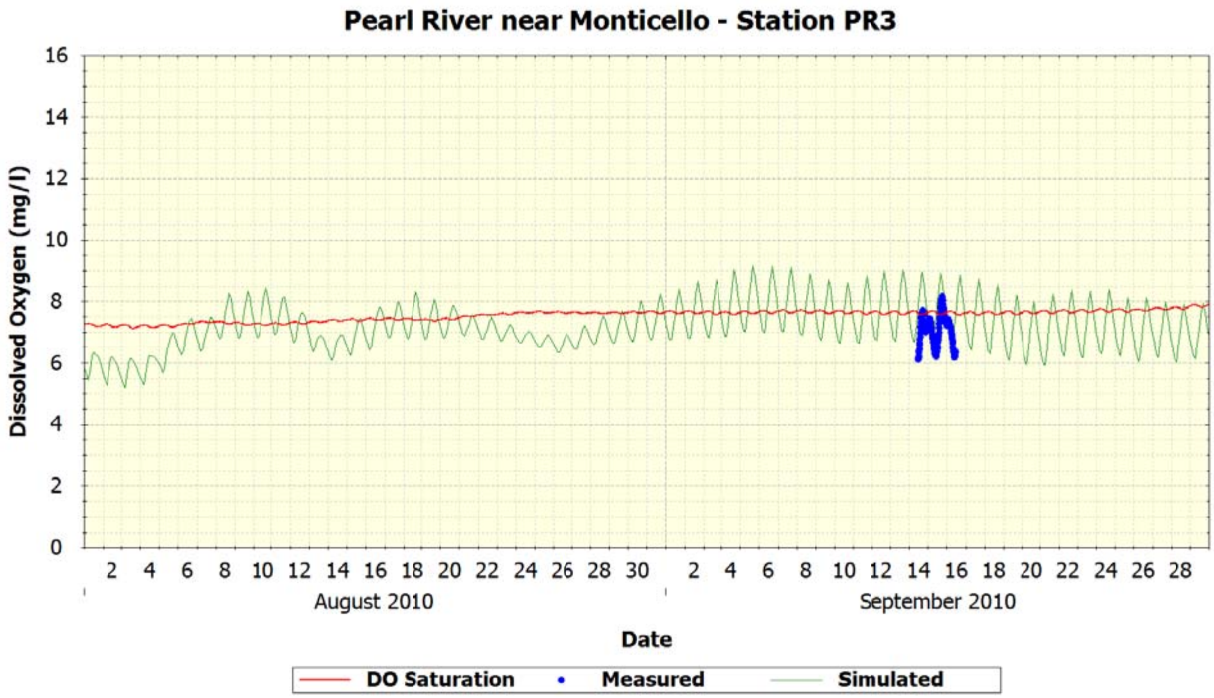

Figure 114 Pearl River near Monticello Station PR3 – Dissolved Oxygen

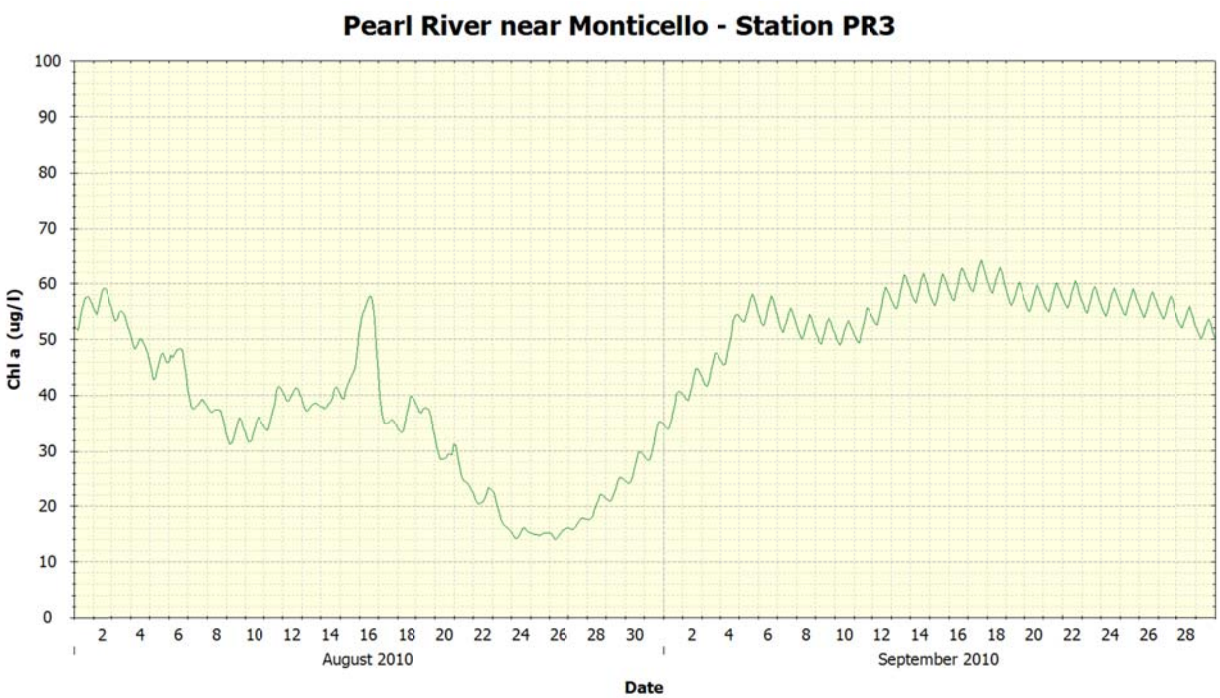

Figure 115 Pearl River near Monticello Station PR3 – Chl a

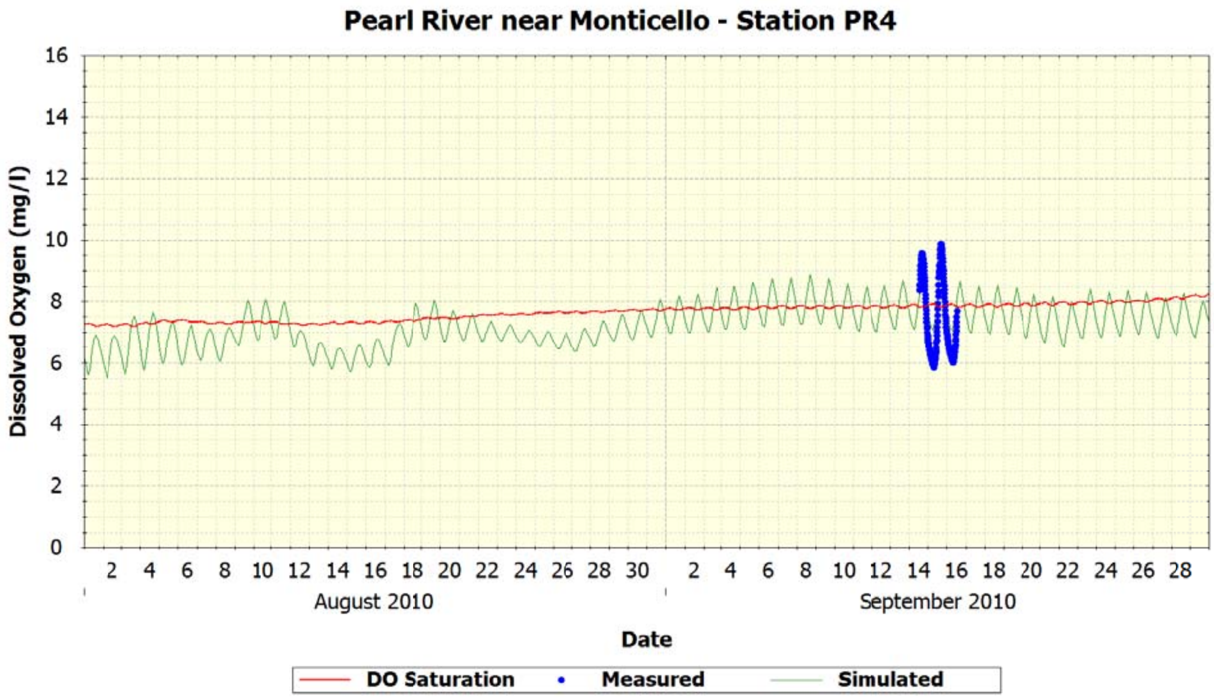

Figure 116 Pearl River near Monticello Station PR4 – Dissolved Oxygen

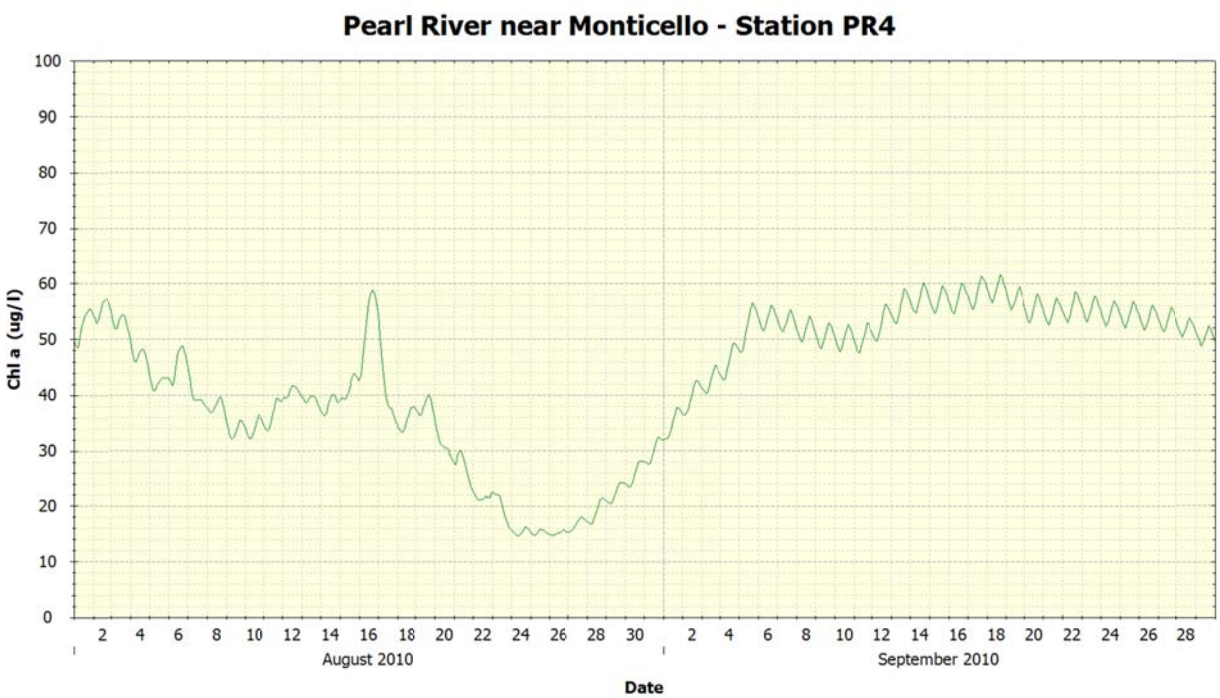

Figure 117 Pearl River near Monticello Station PR4 – Chl a

5.0 Pearl River TMDL Model

The 2008 – 2012 Pearl River model is calibrated as good as possible with the available data. Overall the model does a good job in replicating the nutrient concentrations, BOD5, Chl a, and DO levels measured in the Pearl River.

In discussions with MDEQ, the time frame, 2008 – 2012, is a good time frame for TMDL development, in that these years encompass a variety of flow ranges, especially low flow during the critical 2008 summer months. Therefore with the minor correction to the headwater nitrate-nitrite time series discussed previously in Section 4, the model is adequate for nutrient and DO TMDL development.

Although this model covers the Pearl River from Jackson down past Bogalusa, the specific concern of this report is modeling GP Monticello's impact on water quality. The main area of focus is Pearl River near Monticello and parameter of concern is low DO levels due to the discharge of BOD5 and ammonia from GP Monticello's effluent. Also of concern is what impact GP Monticello nutrient discharge has on diurnal DO levels that exceed the DO saturation due to high Chl a levels.

5.1 Pearl River Dissolved Oxygen Low Flow Model

Summer 2008 represents a low flow high temperature period when DO levels are expected to be at the lowest values. MDEQ noted that during their 2010 study the DO levels in the Pearl River continued to drop as they sampled further downstream of GP Monticello's discharge. The DO TMDL model confirms this observation and the area of the DO sag or lowest predicted DO values is about 30 kilometers downstream of the discharge. For all 6 years the minimum daily average DO was above the MDEQ DO water quality standard of 5.0 mg/l. Figures 83 to 87 illustrate the daily average DO concentrations at five sites on the Pearl River – upstream and 10, 20 25, and 30 kilometers (km) downstream of GP Monticello's discharge. The DO sag area or area of lowest DO is at 25 km below GP Monticello as illustrated in Figure 86.

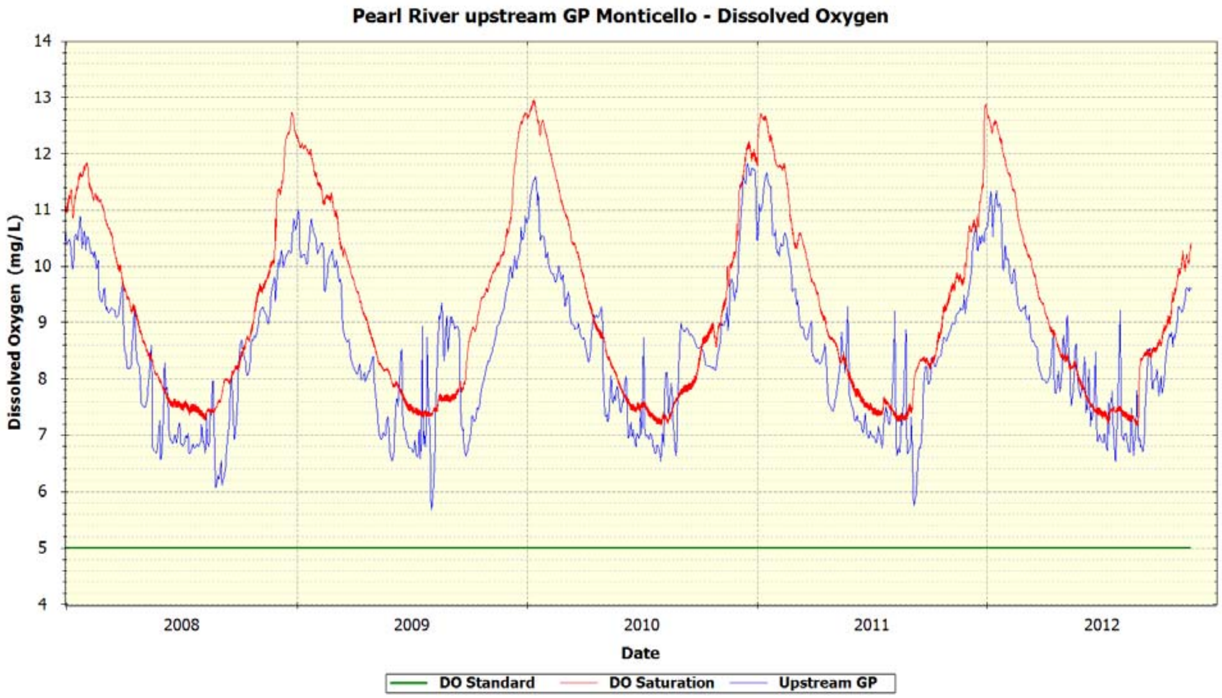

Figure 118 Pearl River upstream GP – Dissolved Oxygen

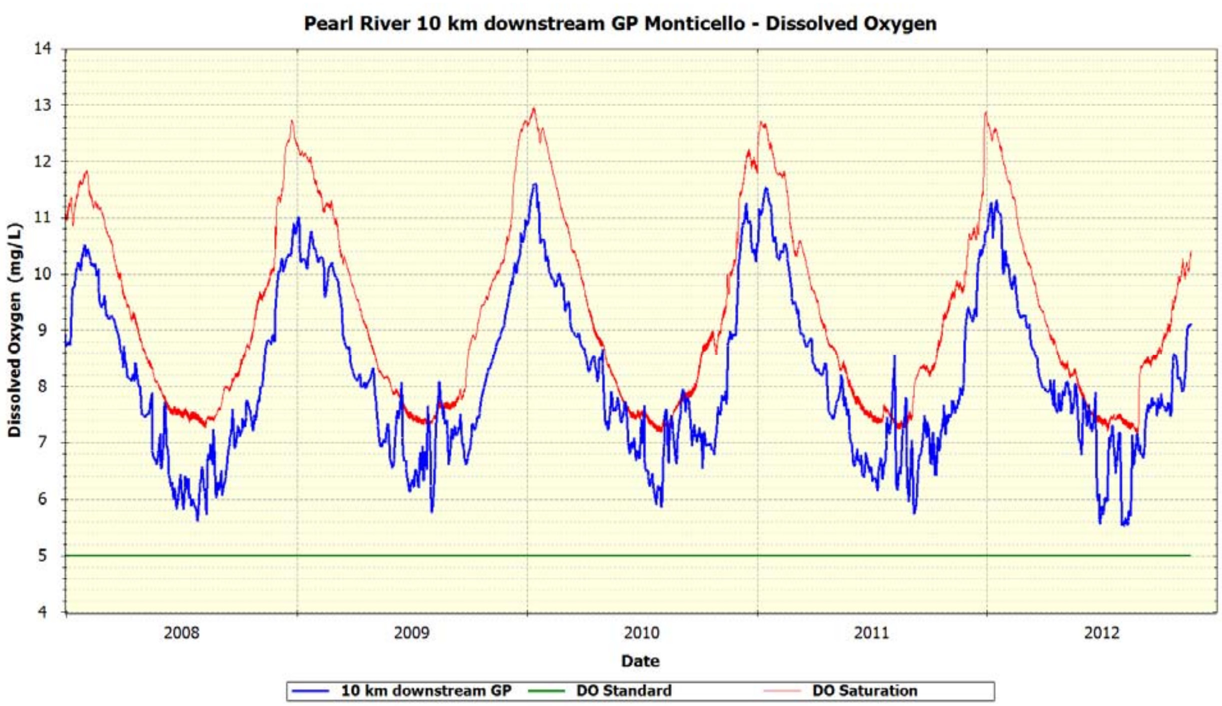

Figure 119 Pearl River 10 km downstream GP – Dissolved Oxygen

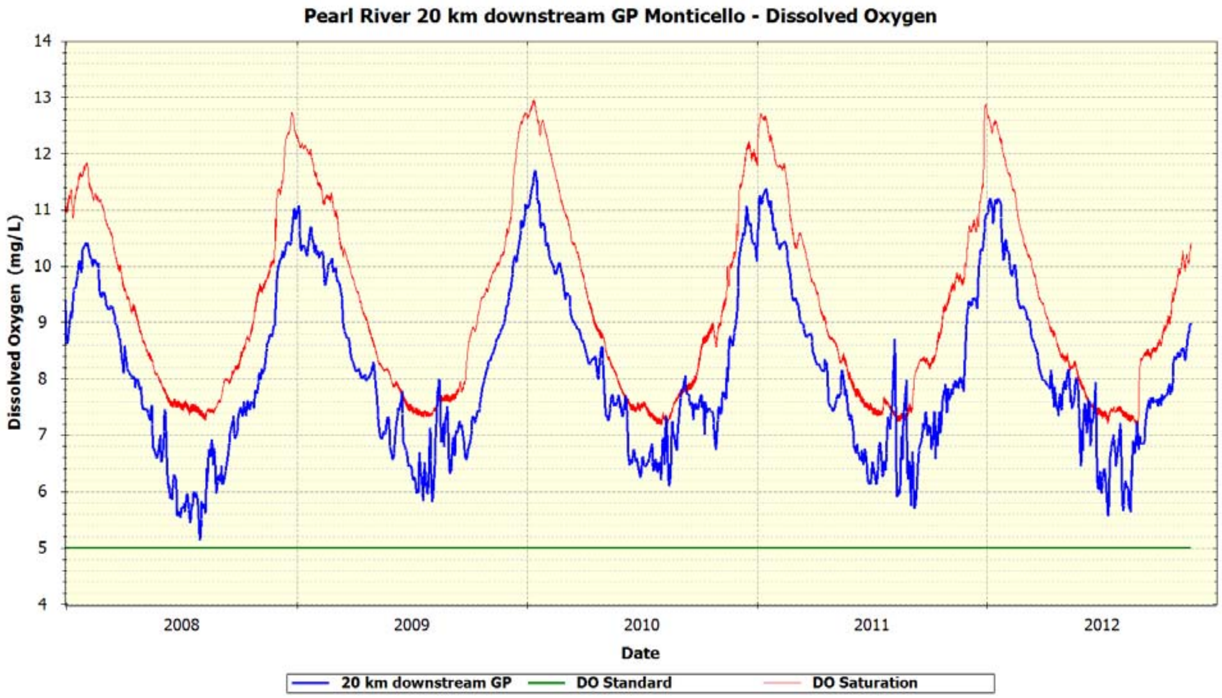

Figure 120 Pearl River 20 km downstream GP – Dissolved Oxygen

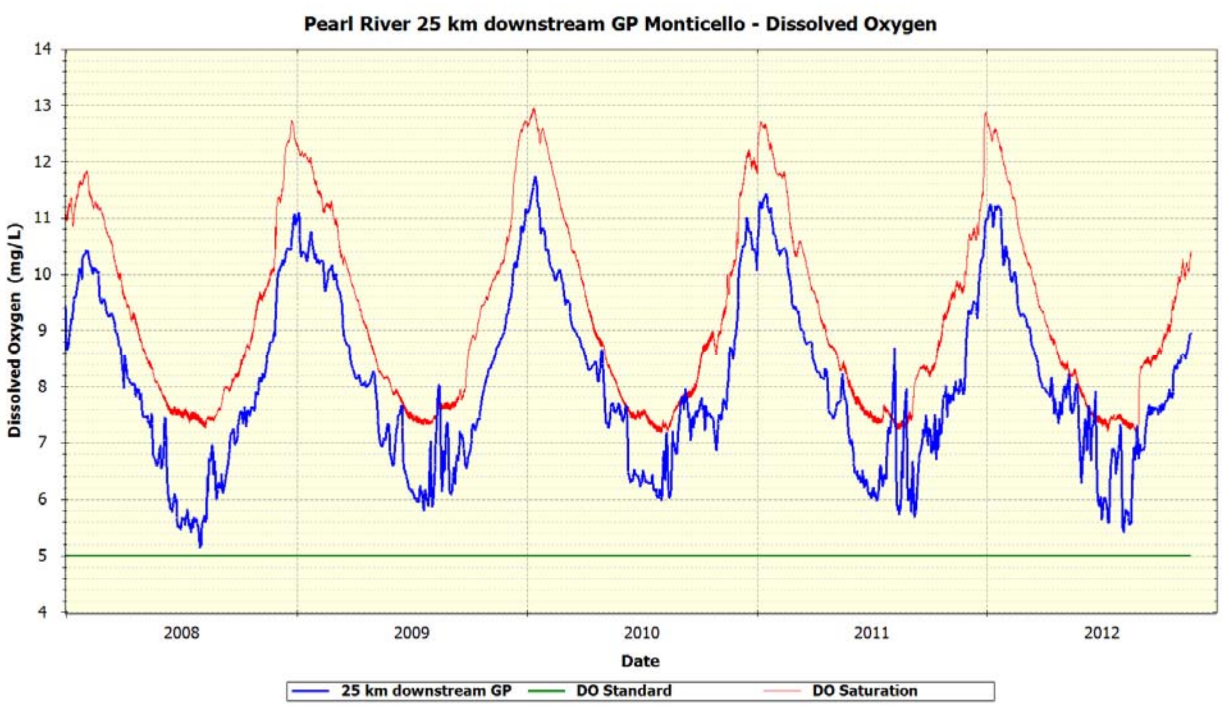

Figure 121 Pearl River 25 km downstream GP – Dissolved Oxygen – DO Sag Area

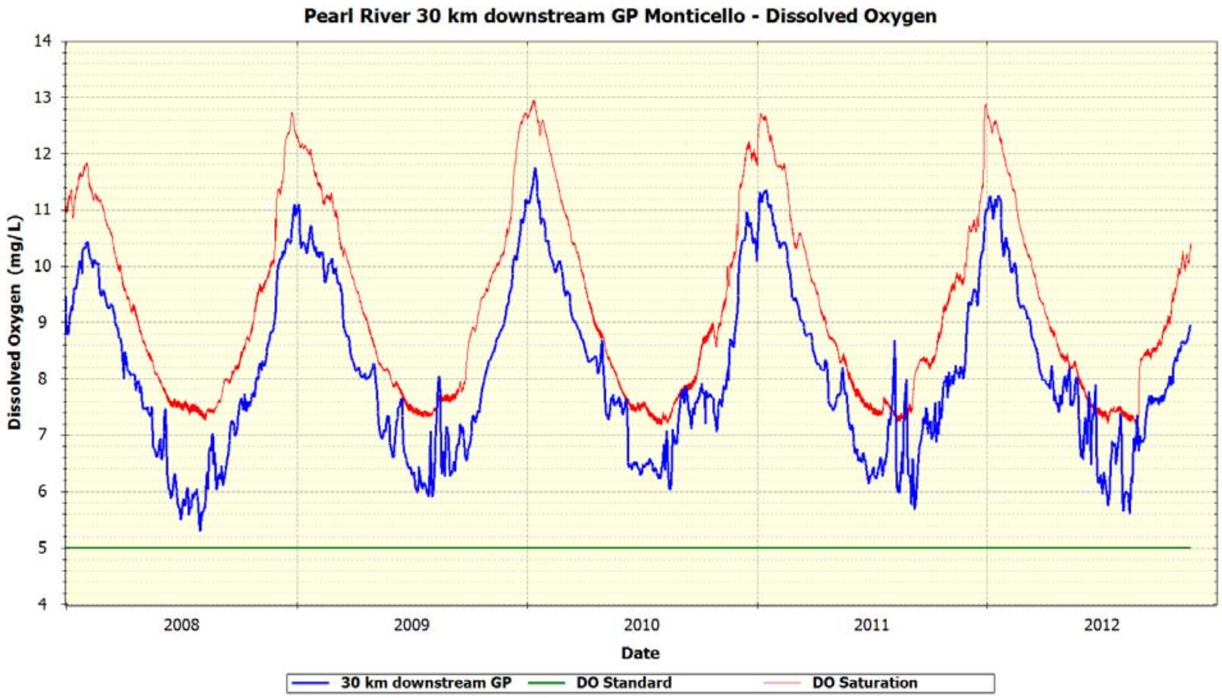

Figure 122 Pearl River 30 km downstream GP – Dissolved Oxygen

5.2 Pearl River near Monticello Nutrient Model

The Pearl River Nutrient Model was used to evaluate GP Monticello's nutrient discharge impact on the Pearl River DO and Chl a levels. The USGS Monticello gage location was selected to compare existing condition 2008 – 2012 model predictions and model predictions with no GP Monticello discharge.

The DO levels with the GP Monticello discharge were lower than without the discharge and there were fewer days that were above the DO saturation levels, while, as previously stated, the low DO levels stayed above 5.0 mg/l. The summer Chl a with the GP Monticello discharge were about 5 ug/l or 10 percent higher with the existing GP Monticello discharge than with no discharge. Figures 88 and 89 illustrate the DO and Chl a levels with and without GP Monticello's discharge.

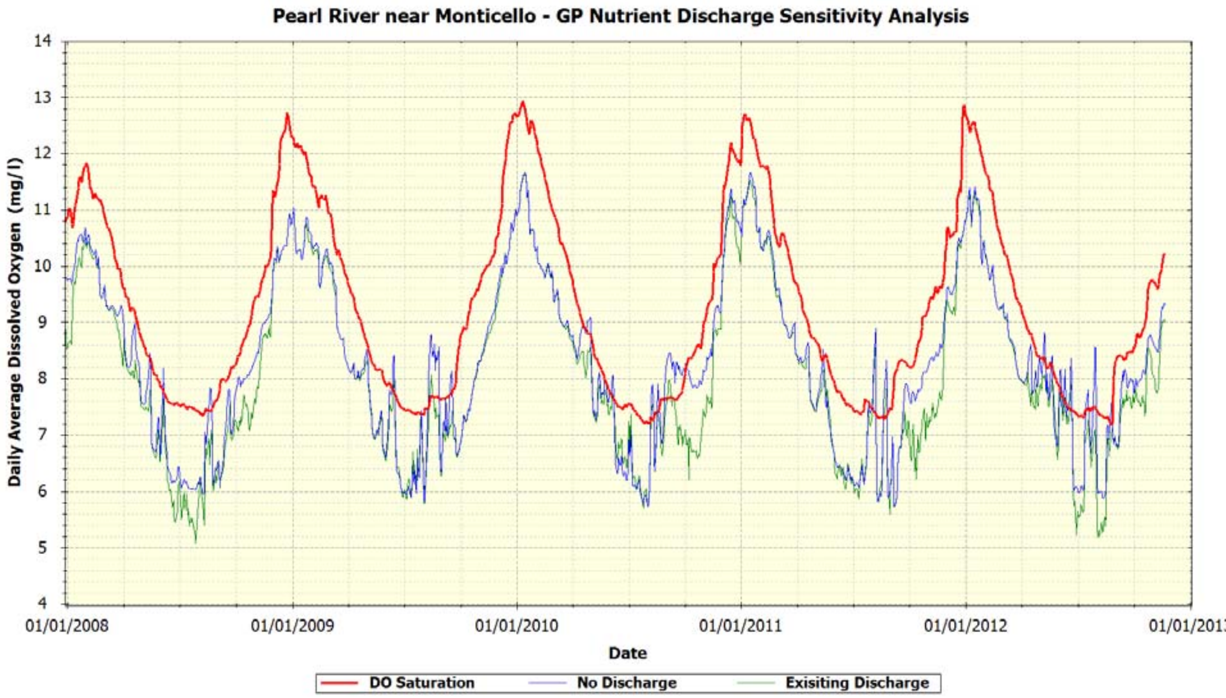

Figure 123 Pearl River Nutrient Sensitivity Analysis – Daily Average Dissolved Oxygen

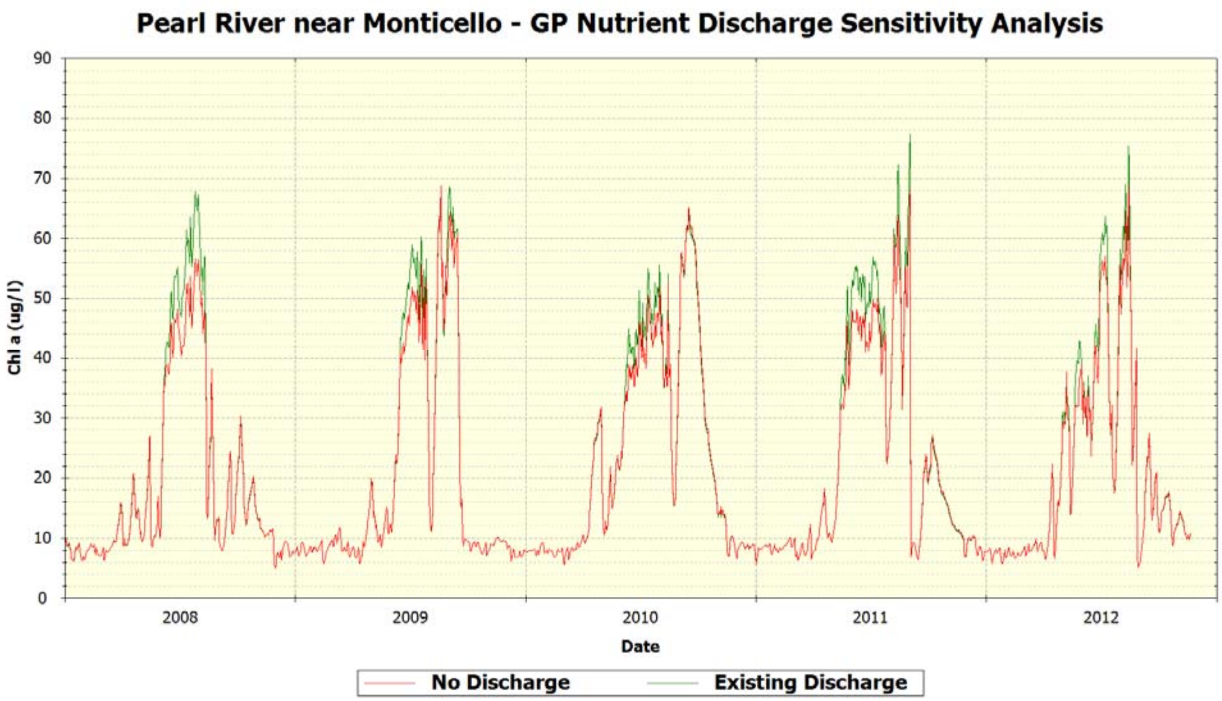

Figure 124 Pearl River Nutrient Sensitivity Analysis – Daily Average Chl a

Comparing upstream and downstream of GP Monticello's discharge, the DO levels upstream of the discharge exceed the DO saturation more than the levels downstream while the Chl a levels upstream are higher than the Chl a levels downstream. See Figures 90 and 91.

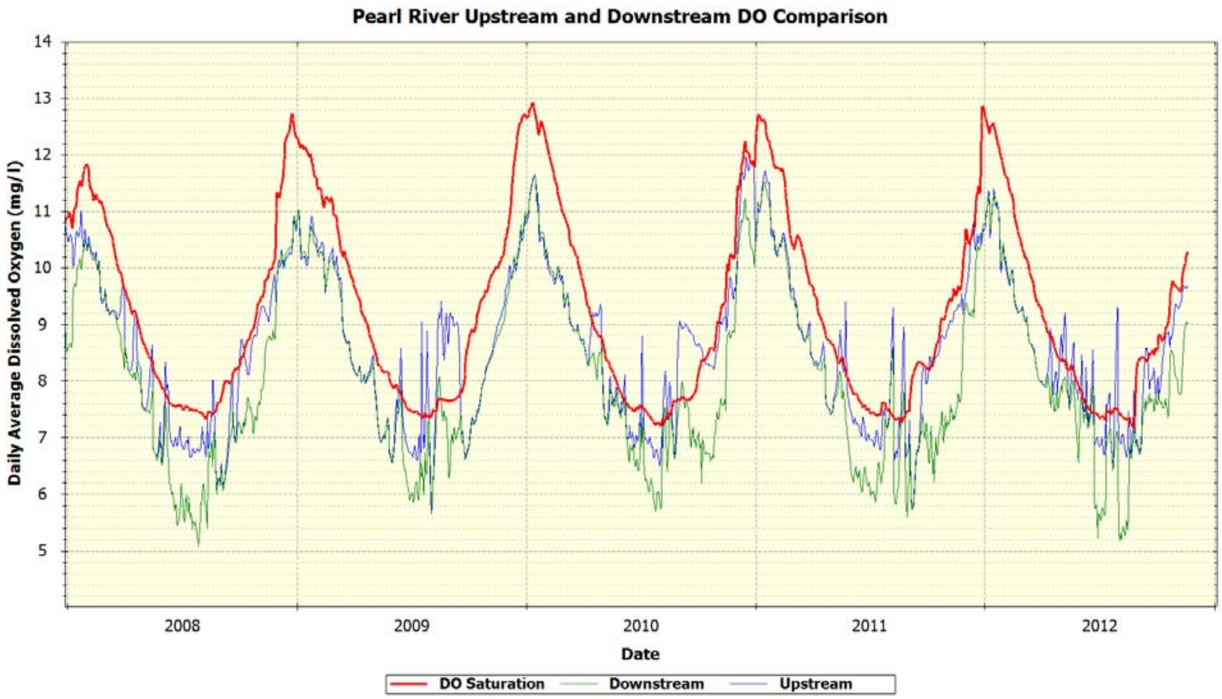

Figure 125 Pearl River Upstream and Downstream Analysis – Daily Average Dissolved Oxygen

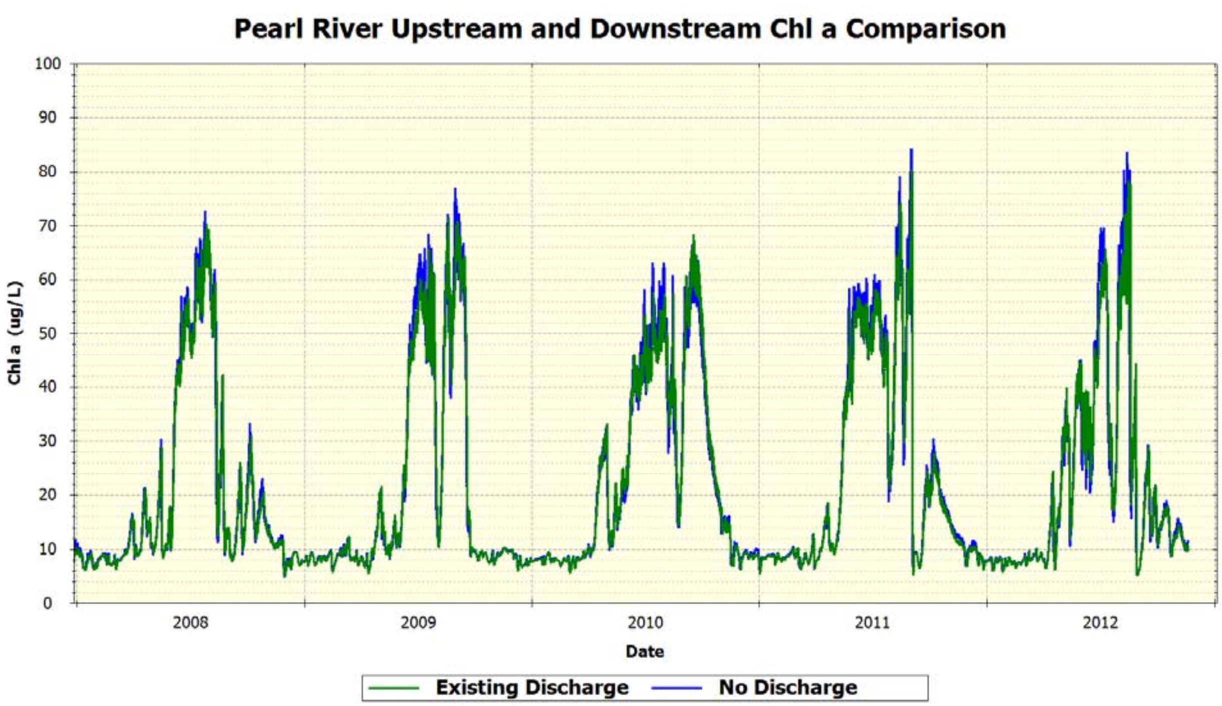

Figure 126 Pearl River Upstream and Downstream Analysis – Daily Average Chl a

6.0 REFERENCES

Ambrose, R. B., T. A. Wool, and J. L. Martin. 1993. The water quality analysis simulation program, WASP5. U. S. Environmental Protection Agency, Environmental Research Laboratory, Athens, GA, 210.

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Appendix A: Pressure, Air Temperature, Cloud Cover and Solar Radiation Graphs

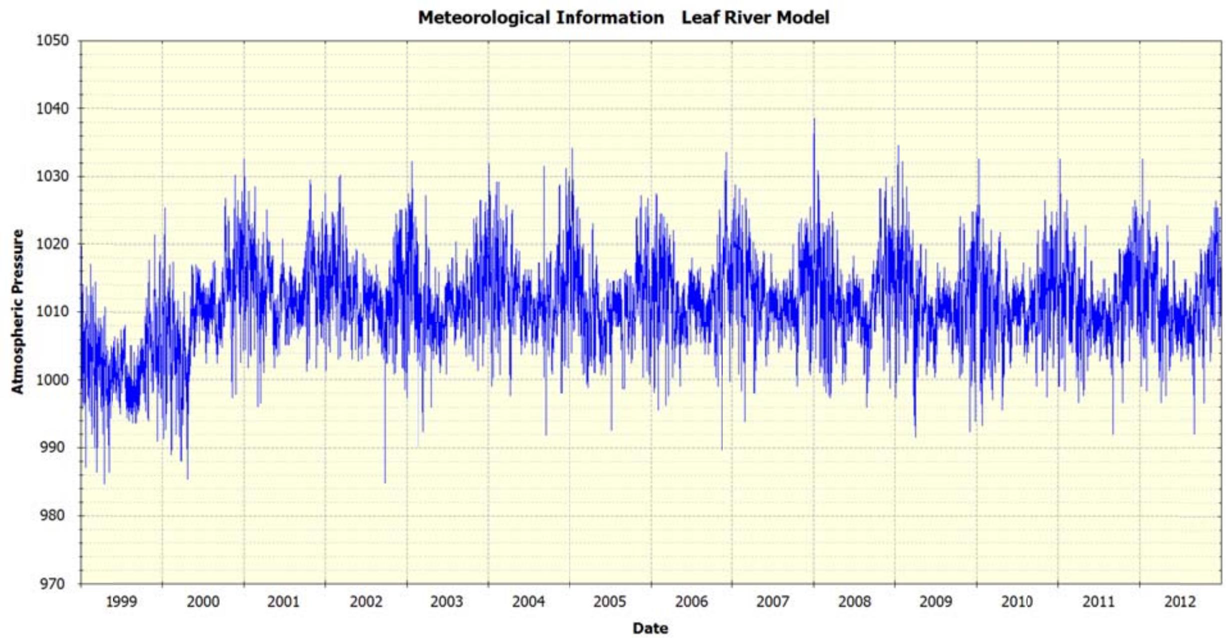

Figure 127 Atmospheric Pressure

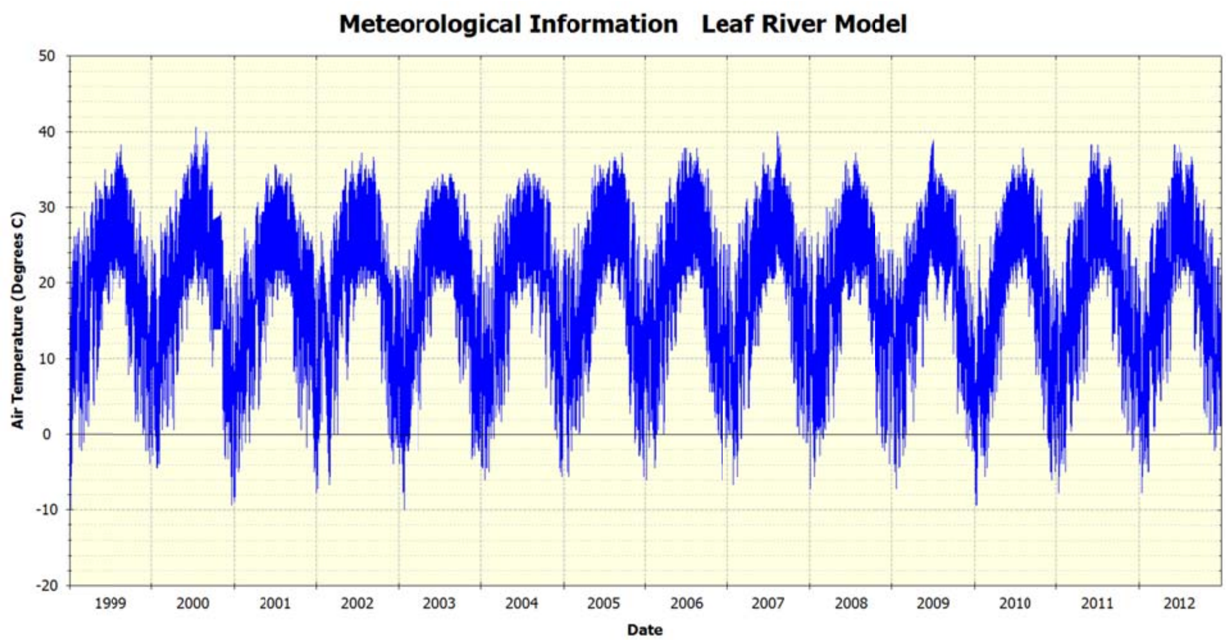

Figure 128 Air Temperature

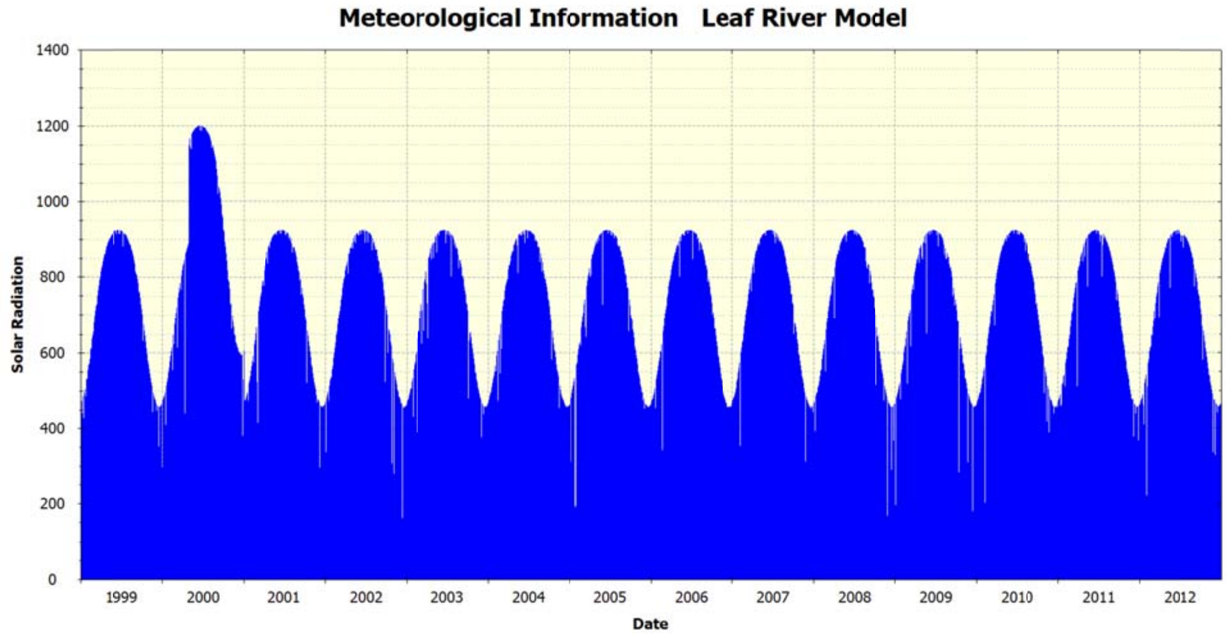

Figure 129 Solar Radiation

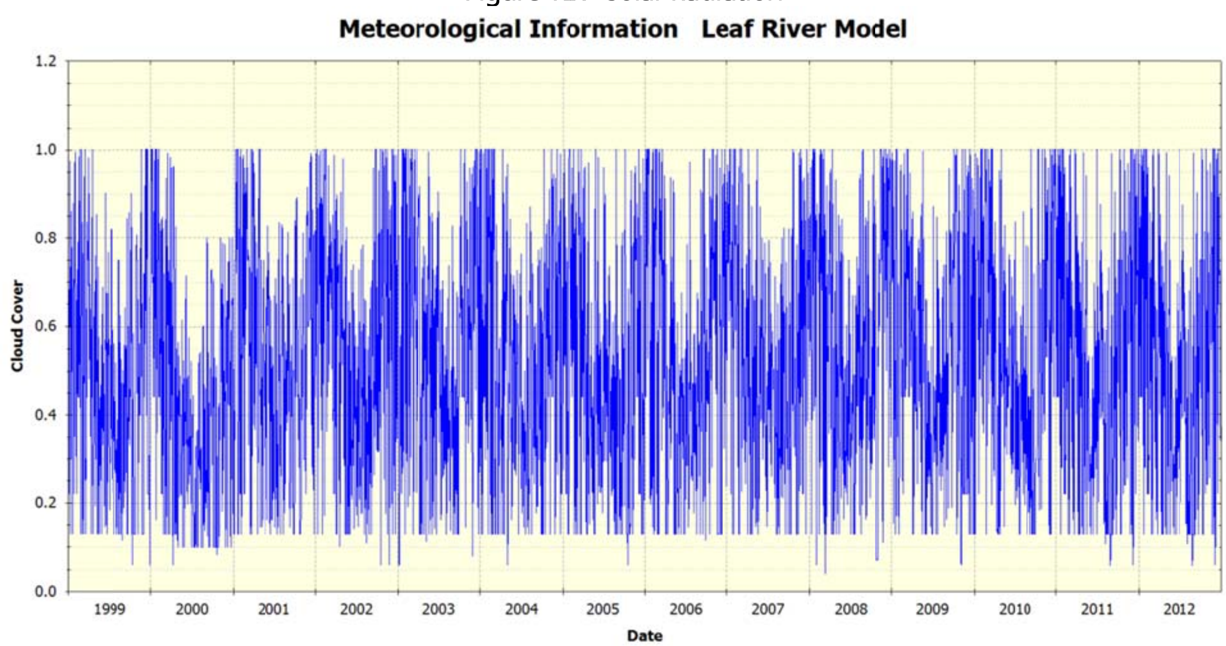

Figure 130 Cloud Cover