EXHIBIT 5

SUMMARY REPORT OF INVESTIGATIONS RELATED TO LAKE JESUP FLOW ENHANCEMENT AND WETLAND TREATMENT PROJECTS

Prepared for

St. Johns River Water Management District

4049 Reid Street
Palatka, Florida 32177

Prepared by

Jones Edmunds & Associates, Inc.
730 NE Waldo Road
Gainesville, Florida 32641

March 2019

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March 28, 2019

Ann B. Shortelle, PhD
Executive Director
St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32177

RE: St. Johns River Water Management District
Flow Restoration Feasibility Analysis for Lake Jesup
Jones Edmunds Project No.: 19750-068-01

Dear Dr. Shortelle,

Jones Edmunds, Tetra Tech, and ATM recently completed the Flow Restoration Feasibility Analysis for Lake Jesup (attached) to assist the District in evaluating potential water quality treatment alternatives for Lake Jesup. The report was completed in September 2018 and additional modeling was performed and provided to the District in October 2018. The District recently drafted a Technical Memorandum that applied the results of the Tetra Tech modeling to evaluate possible water quality and habitat changes in the lake and downstream (Lake Jesup Restoration Scenarios Assessment). Jones Edmunds has reviewed this Technical Memorandum and included it as an attachment as well.

We appreciate working with you on this effort and look forward to working with the District on similar efforts in the future.

If you have any questions or comments, please feel free to contact me at (352) 377-5821 or mnelson@jonesedmunds.com.

Sincerely,

Mark w Nelson

Mark Nelson, PE
Senior Consultant/Vice-President
730 NE Waldo Road
Gainesville, Florida 32641

Alan Foley, PE
Senior Project Manager
730 NE Waldo Road
Gainesville, Florida 32641

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Introduction

INTRODUCTION

Jones Edmunds, Applied Technology Management, and Tetra Tech performed a preliminary feasibility study to assess flow restoration scenarios for Lake Jesup along with the potential water quality benefits and construction costs associated each scenario. Between May and September 2018, the team performed the following Phase 1 tasks to assess the feasibility of restoring flow from the St. Johns River to Lake Jesup:

1. Refined existing hydrodynamic model of the Middle St. Johns River (MSJR) and Lake Jesup to create a baseline hydrodynamic model of existing conditions.
2. Used the refined hydrodynamic model to update an existing water quality model of Lake Jesup and create a baseline water quality model of existing conditions.
3. Used the models to assess the effects of three hydrologic reconnection configurations.
4. Evaluated potential wetland impacts using the Uniform Mitigation Assessment Method (UMAM) to determine construction and permitting constraints.
5. Developed an opinion of probable costs associated with all alternatives selected by SJRWMD staff.
6. Documented the tasks and results in a brief report and PowerPoint presentation.

Between September and November 2018, the team performed additional modeling (Phase 2) to help assess the potential impacts of the project on the downstream portions of the middle St. Johns River. We used the hydrodynamic and water quality models developed during Phase 1 to assess the following:

1. Changes to the downstream transport of nutrients to Lake Monroe.
2. Changes to the nutrients at the entrance of the Chub Creek canal.
3. Changes to the light regime within Lake Jesup.
4. Additional improvements to the light regime if this project is coupled with operation of a series of treatment ponds using water drawn from the lake through the Chub Creek canal.

Output from the Phase 2 models was provided to District staff as input for further analyses using District models. The District work is summarized in a technical memorandum *LAKE JESUP RESTORATION SCENARIOS ASSESSMENT*.

Flow Restoration Feasibility Analysis for Lake Jesup

JonesEdmunds

with

ATM DESIGN ENGINEERING CONSULTING

TETRA TECH

SEMINOLE COUNTY, FLORIDA
FLOW RESTORATION FEASIBILITY ANALYSIS FOR LAKE JESUP

St. Johns River Water Management District | September 2018

SEMINOLE COUNTY, FLORIDA
FLOW RESTORATION FEASIBILITY ANALYSIS FOR LAKE JESUP

Prepared for:

St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32178

Prepared by:

Jones Edmunds & Associates, Inc.
730 NE Waldo Road
Gainesville, Florida 32641
Certificate of Engineering Authorization #1841
Jones Edmunds Project No.: 19750-068-01

with

Applied Technology & Management, Inc.

and

Tetra Tech, Inc.

September 2018

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1 INTRODUCTION

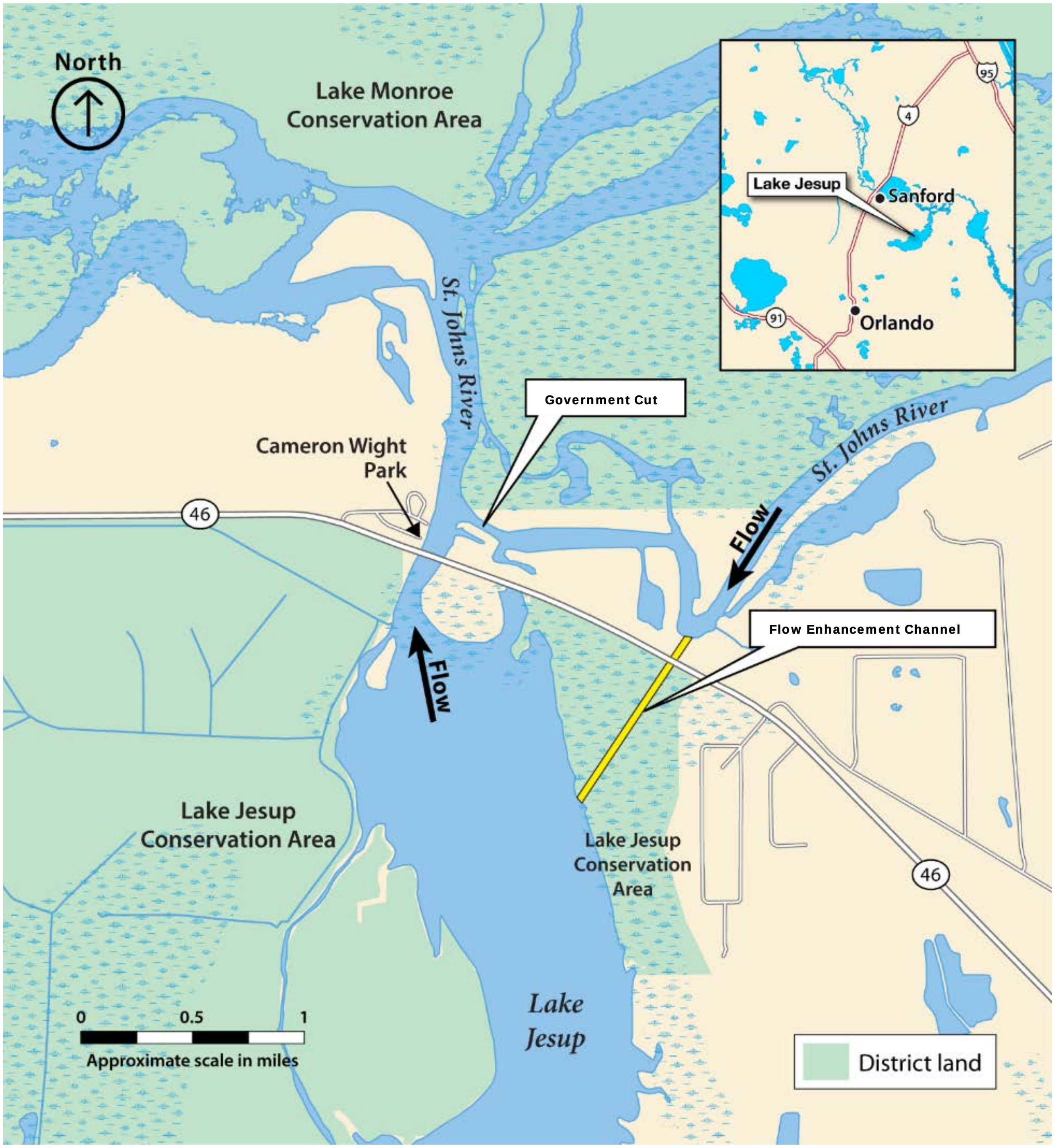
The Lake Jesup Flow Restoration Project was proposed to enhance water quality and habitat through improved water exchange between the St. Johns River and the east portion of Lake Jesup. This Report documents the findings of a Preliminary Feasibility Study to assess flow restoration scenarios and the potential water quality benefits and construction costs associated with each scenario.

Depending on water levels, Lake Jesup and its associated floodplain encompasses an area of about 10,000 to 16,000 acres. Hydrologic modifications to the confluence between the River and Lake date back to the steamboat era of the late 1800s. Local stakeholders have advocated for increasing riverine flow into the Lake for decades. In 2010, the Florida Department of Transportation (FDOT) completed a new 3,470-foot-high span-bridge over the confluence, thereby removing the State Road (SR) 46 earthen causeway. The new bridge creates the opportunity to enhance old flow-paths previously blocked by the causeway (Figure 1).

The ultimate goals of the flow enhancement project include:

- Enhance the historical hydrologic exchange between the east portion of Lake Jesup and the St. Johns River.
- Improve fish and wildlife habitat in the east portion of the Lake.
- Help restore potential habitat for submerged aquatic vegetation in the east portion of the Lake.

Figure 1 Lake Jesup Location and Proposed Project Features



2 FEASIBILITY ANALYSIS

The feasibility assessment was performed by the consulting team of Jones Edmunds, Applied Technology and Management (ATM), and Tetra Tech. ATM performed hydrodynamic modeling. Tetra Tech used the hydrodynamic modeling output as input to water quality modeling. Jones Edmunds evaluated wetland impacts, assessed permitting considerations, and developed a conceptual opinion of probable cost.

2.1 HYDRODYNAMIC MODEL

2.1.1 SOURCE MODEL

ATM used the Middle St. Johns River (MSJR) Environmental Fluid Dynamics Code (EFDC) baseline model provided by the St. Johns River Water Management District (SJRWMD) to simulate the hydrodynamics of the full MSJR system from Lake Harney to Satsuma. For the water quality simulations, ATM used a subset of the MSJR EFDC model hydrodynamics to drive the water quality model. The model subset included Lake Jesup and portions of the St. Johns River near the entrance to Lake Jesup.

2.1.2 NEW BASELINE MODEL

Following initial testing of the MSJR EFDC model, ATM made the following modifications to the EFDC model provided by SJRWMD:

- Converted SJRWMD's six-layer EFDC model to a single layer model to be compatible with the water quality model.
- Adjusted Channel B to represent the shallower, more restrictive channel reflected in available survey data.
- Increased the overall model grid resolution in the area near the entrance to Lake Jesup to accommodate inclusion of Channel C.

The reduction in the cross-sectional area of Channel B resulted in improved simulation of the flows passing through Channel A. Appendices A and B provide two Technical Memoranda that outline these changes and plots showing the improvement in the flow simulation through Channel A.

2.1.3 SIMULATION PERIOD

ATM executed simulations using the updated model for 2007 through 2014. This simulation period was selected based on available data to run the EFDC model and to match the simulation period of the water quality model. The 2007 portion of the simulation was used as a spin-up period for the water quality model; therefore, results are presented from 2008 through 2014.

2.1.4 BASELINE MODEL RESULTS

ATM reviewed the baseline model updates and results with SJRWMD staff. SJRWMD staff noted that the Channel B adjustment resulted in a better match to observed data than the previous SJRWMD model achieved. SJRWMD staff reviewed the results in the Technical Memoranda and deemed the revised model suitable for performing scenario analyses.

Appendices A and B contain the Technical Memoranda that outline the baseline model results.

2.1.5 SCENARIO MODELS

Using the baseline model outlined above, scenario runs were performed to quantify the changes in the hydrodynamics and to provide the hydrodynamic conditions for the water quality model. As previously stated, the full MSJR model was run for the hydrodynamics. To support the water quality model simulations, a subset of the MSJR hydrodynamics was clipped out to include Lake Jesup and the MSJR channel immediately upstream and downstream of the entrance. The clipped hydrodynamics were then provided to Tetra Tech to run the water quality model simulations.

Channel C was modeled with the following dimensions:

- A 165-foot top width to match the width of the MSJR upstream of the proposed entrance to Channel C.
- 4:1 (horizontal:vertical) side slopes.
- A channel invert elevation of -10 feet North American Vertical Datum of 1988 (NAVD 88) (approximately 9 feet deep).
- A length of 2,200 feet.

ATM simulated three scenarios to evaluate the potential impacts of changes in the entrance area of Lake Jesup. These scenarios are the following:

- Baseline: The baseline model as described earlier was executed for 2007 through 2014 with 2007 used as a spin-up year. The baseline model had Channels A and B open as their existing condition. This is the existing conditions model run for comparison against other scenarios to assess changes.
- Channels A, B, and C Open: This Scenario is the baseline model with Channel C open to the cross-sectional area (width and depth) as specified by SJRWMD.
- Channels A and C Open: This Scenario is the baseline model with Channel C open to the cross-sectional area (width and depth) as specified by SJRWMD with Channel B closed.

To compare the scenario results, ATM extracted the flows passing through the different channels from the hydrodynamic model. The four channels included:

- Channel A.
- Channel B.
- Channel C.
- Government Cut.

Figure 2a, 2b, and 2c present time series plots of the flows through the four channels for the simulation period 2008 through 2014. Table 1 presents the average annual flows for 2008 through 2014 for the four channels under each scenario.

Figure 2a **Time Series of Simulated Flow in the Channels at the Entrance to Lake Jesup (2008 to 2014) – Baseline**

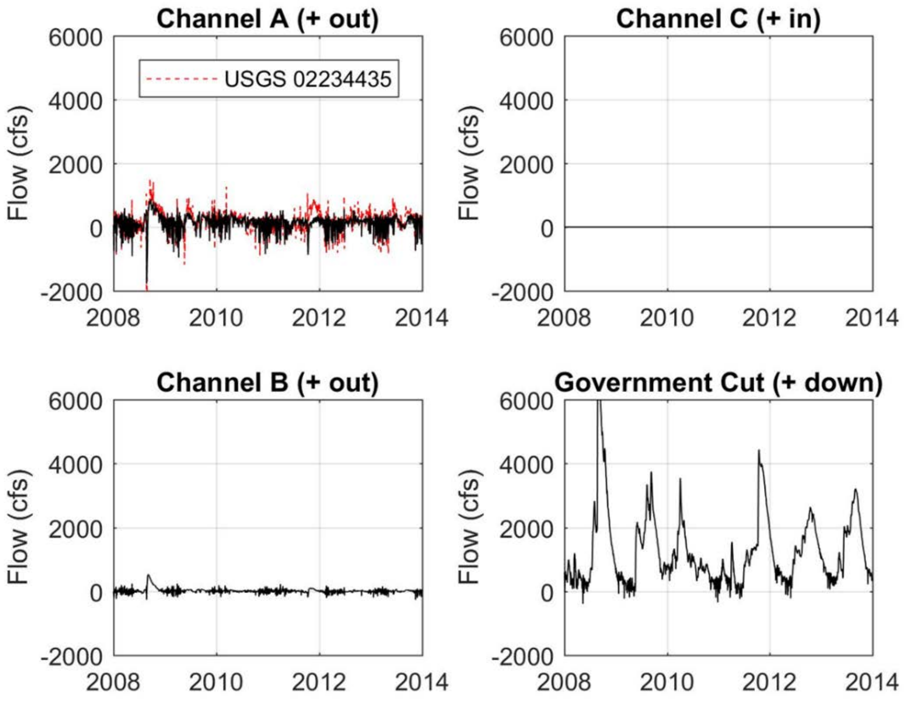


Figure 2b **Time Series of Simulated Flow in the Channels at the Entrance to Lake Jesup (2008 to 2014) – Channels A, B, and C Open**

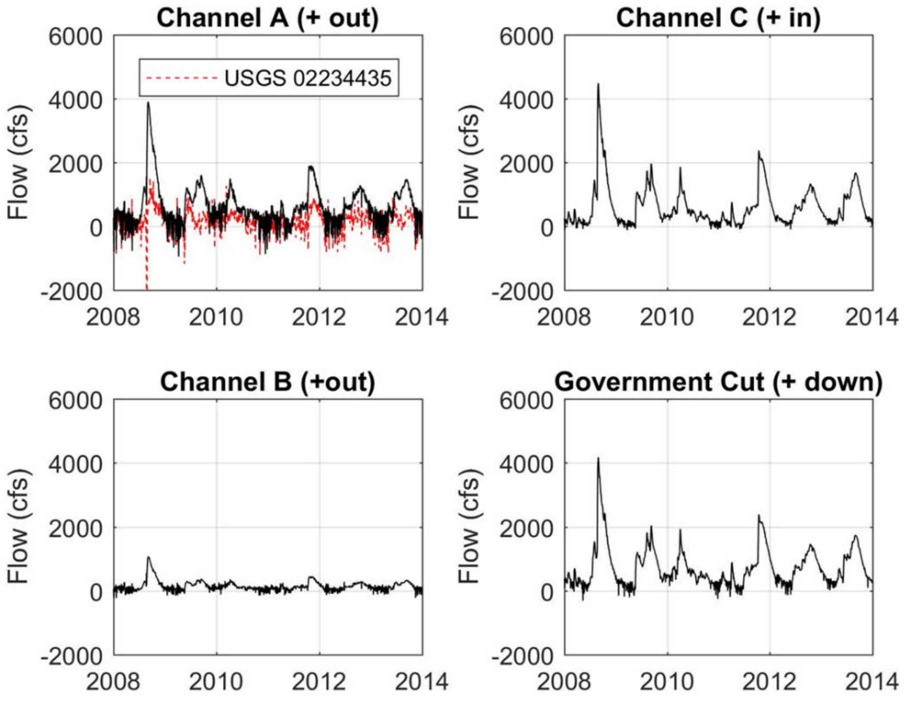


Figure 2c Time Series of Simulated Flow in the Channels at the Entrance to Lake Jesup (2008 to 2014) – Channels A and C Open

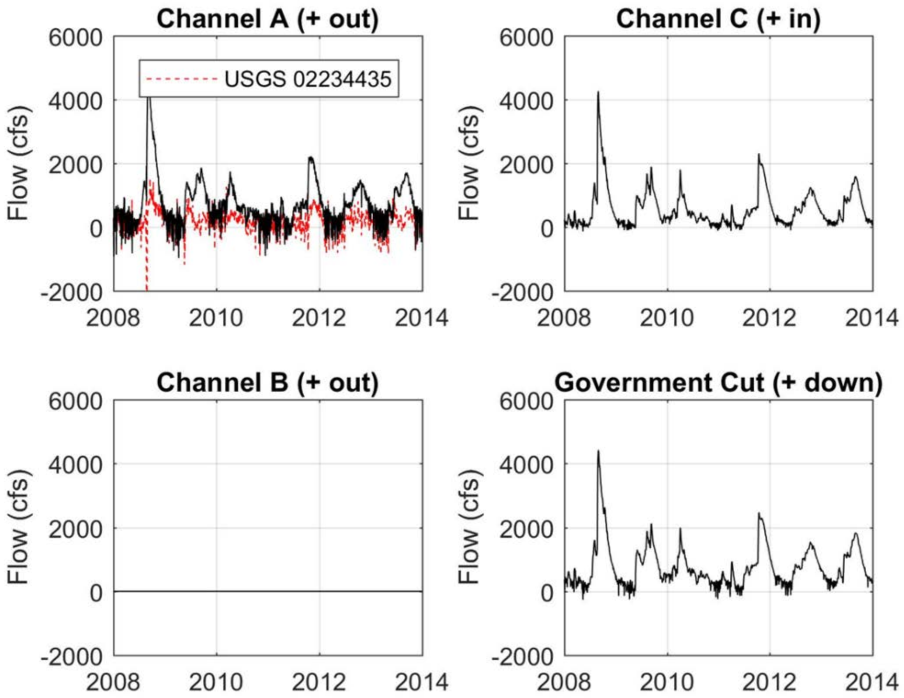


Table 1 Average Annual Flow in the Channels at the Entrance to Lake Jesup (2008 to 2014)

Channel	Annual Average Flows (cfs) - Existing Condition					
	2008	2009	2010	2011	2012	2013
A (flow out)	180	136	137	101	127	117
B (flow out)	66	15	6	16	-2	1
C (flow in)	0	0	0	0	0	0
Government Cut (flow downstream)	1713	1202	981	1269	1206	1272

Channel	Annual Average Flows (cfs) - Channels A, B, and C Open					
	2008	2009	2010	2011	2012	2013
A (flow out)	891	590	480	598	570	593
B (flow out)	228	138	108	138	124	128
C (flow in)	872	578	445	618	568	603
Government Cut (flow downstream)	957	686	578	720	693	731
Percent Original Flow Diverted to C	51%	48%	45%	49%	47%	47%
	1829	1264	1023	1338	1261	1334

Channel	Annual Average Flows (cfs) - Channel A and C Open, B Closed					
	2008	2009	2010	2011	2012	2013
A (flow out)	1045	683	550	691	652	679
B (flow out)	0	0	0	0	0	0
C (flow in)	799	532	408	573	527	560
Government Cut (flow downstream)	1036	734	617	767	736	776
Percent Original Flow Diverted to C	47%	44%	42%	45%	44%	44%

Looking first at the figures, the baseline condition shows that although there is some net push out of Lake Jesup, the bulk of the flow moving down the St. Johns River does not pass into Lake Jesup. In addition, the overall volume of flow passing through Channel B is small. Following the opening of Channel C, approximately 50 percent of the flow that was passing through Government Cut now passes into Lake Jesup through Channel C. This new flow that enters the Lake quickly turns and passes back out of Channels A and B (when B is open) and through Channel A (when B is closed). The results in Table 1 support this observation with the percent of flow passing into Channel C ranging from 42 to 51 percent depending on the year and if Channel B is closed.

Upstream of where Government Cut passes the entrance to Lake Jesup, the St. Johns River splits into a small channel that allows some of the river flow to bypass the Lake Jesup entrance area. The opening of Channel C provides a condition where some of the flow shown by the baseline model to be going through the bypass area now shifts down through Government Cut. This is not a large change, constituting approximately a 4- to7-percent increase in flow passing through this entrance area.

2.2 WATER QUALITY MODEL

2.2.1 SOURCE MODEL

In 2006, the Florida Department of Environmental Protection (FDEP) adopted a total maximum daily load (TMDL) for Lake Jesup that set limits for total phosphorus (TP) and total nitrogen (TN) to the Lake. In 2015, Tetra Tech began the process of updating the watershed and in-lake models originally prepared by SJRWMD so that FDEP could use the models to reevaluate the existing TMDL for Lake Jesup. The model updates were completed in 2017. For the Lake Jesup Flow Restoration Project, Tetra Tech started with the 2017 updated version of the in-lake water quality dynamics model, the Water Quality Analysis Simulation Program (WASP) model.

2.2.2 UPDATES

The 2017 WASP model was first updated to include the refined model grid that was developed by ATM using the MSJR EFDC model. Tetra Tech further refined the model to include a second upstream boundary condition to better represent the multiple connections between the Lake and River that were evaluated as part of this project.

2.2.3 SIMULATION PERIOD

Tetra Tech executed simulations using the updated model for 2007 through 2014, with 2007 as a model spin-up year. This simulation period was selected based on available data and to match the simulation period of the TMDL model.

2.2.4 BASELINE MODEL

The updated WASP model was run with the refined model grid and the hydrodynamic outputs from the MSJR EFDC model. The results were compared to the results from the TMDL modeling to ensure the modifications made to the model did not impact the model results. The water quality results from both models were similar, although the 2017 WASP model only included a connection with the River at Channel A and the updated model grid included an additional connection at Channel B resulting in some differences in the outputs.

Appendix C includes the Task 2 Technical Memorandum describing the comparison of the two models.

The final baseline model also included a second upstream boundary condition. The 2017 WASP model used data from SJRWMD Water Quality Station SJR-1 as the upstream boundary condition. The updated WASP model also included data from SJRWMD Water Quality Station SJR-415 as a second boundary condition. As shown in Figure 3 and Figure 4, the water upstream of Lake Jesup is of better quality than the water downstream of Lake Jesup. Bringing additional water into the Lake from upstream could help to improve water quality within the Lake. However, the in-lake water quality can only improve to the extent that the upstream water quality concentrations allow.

The WASP model does not extend beyond the boundaries of Lake Jesup; therefore, there is no water quality model for the Middle St. Johns River.

Figure 3 TN Concentrations at the SJRWMD Water Quality Stations Upstream and Downstream of Lake Jesup

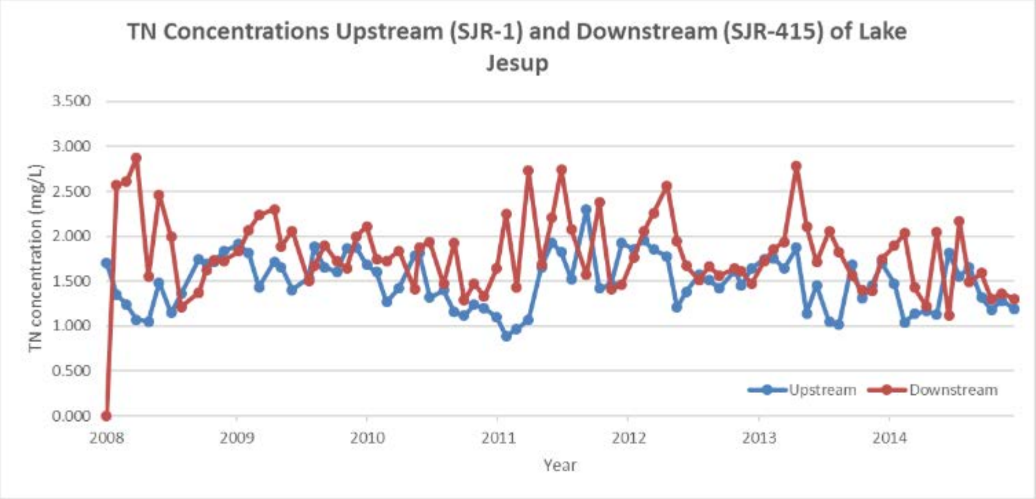
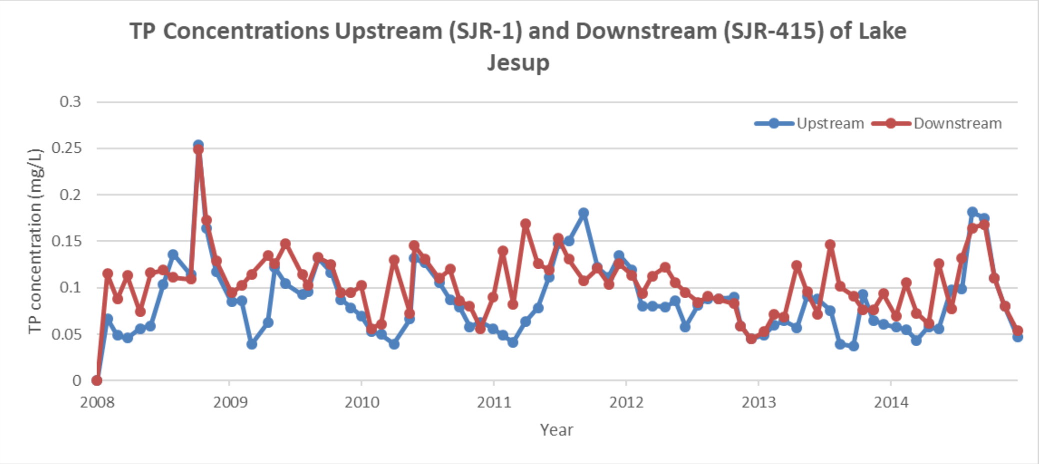


Figure 4 TP Concentrations at the SJRWMD Water Quality Stations Upstream and Downstream of Lake Jesup



2.2.5 SCENARIO MODELS

Tetra Tech executed the WASP model for two scenarios in addition to the baseline scenario: (1) Channels A, B, and C open, and (2) Channels A and C open and Channel B closed. The hydrodynamic output from the EFDC model for each scenario was used to drive the water quality model. Tetra Tech ran the model for each scenario until the internal model fluxes reached an equilibrium and the new in-lake water quality concentrations could be determined.

Figure 5 and Figure 6 show that there are improvements in the in-lake nutrient concentrations from the mouth of the Lake through a portion of the neck for each of these scenarios compared to the baseline condition. For TN concentrations, water quality improvements range from 9 to 45 percent in this area (Figure 5). For TP concentrations, water quality improvements range from 5 to 25 percent in this area (Figure 6). For TN and TP concentrations, there are slightly more water quality benefits from the scenario with all three channels open than with only Channels A and C open.

Appendix D includes additional details on the water quality benefits from each scenario.

Figure 5 Changes in TN Concentrations from the Baseline Condition for Scenarios Channels A, B, and C Open (left) and Channels A and C Open (right)

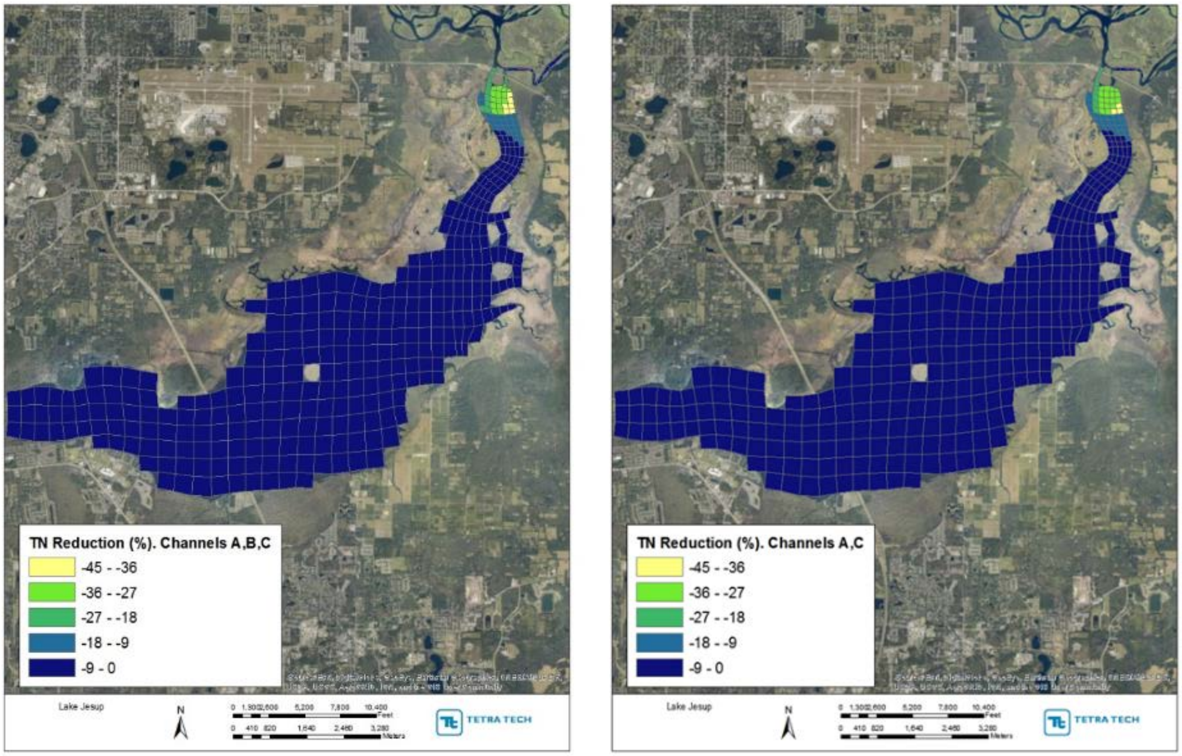
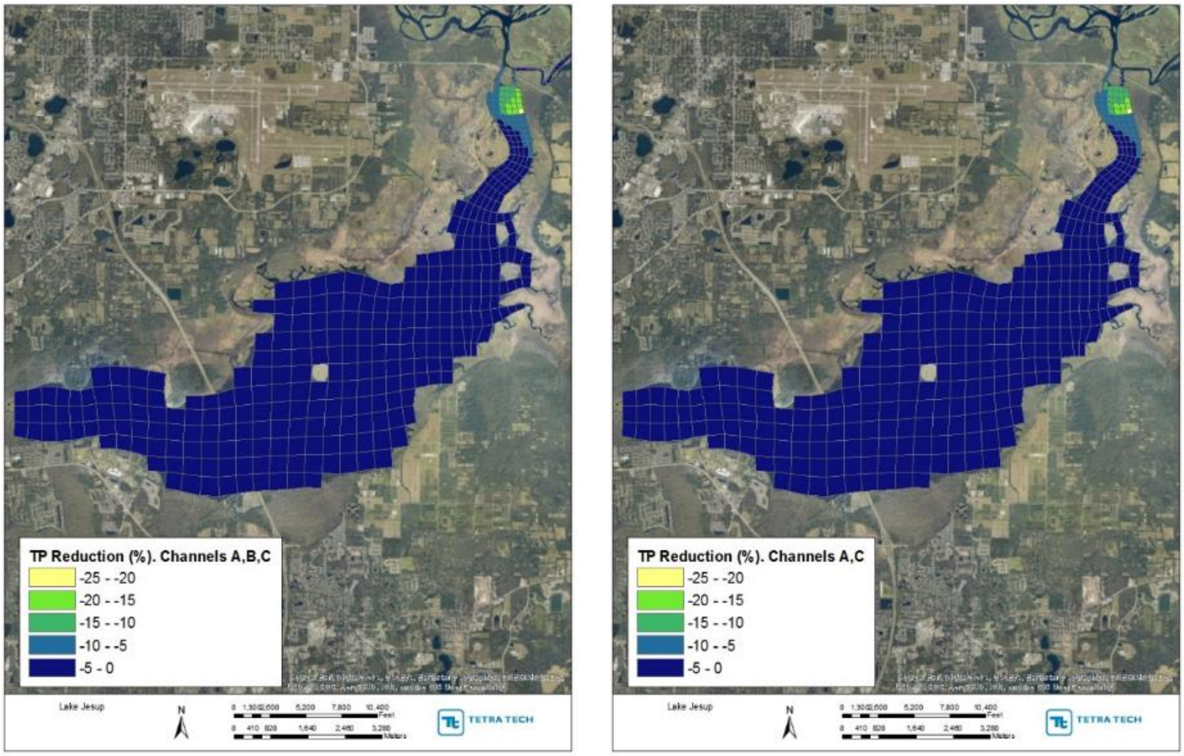


Figure 6 Changes in TP Concentrations from the Baseline Condition for Scenarios Channels A, B, and C Open (left) and Channels A and C Open (right)



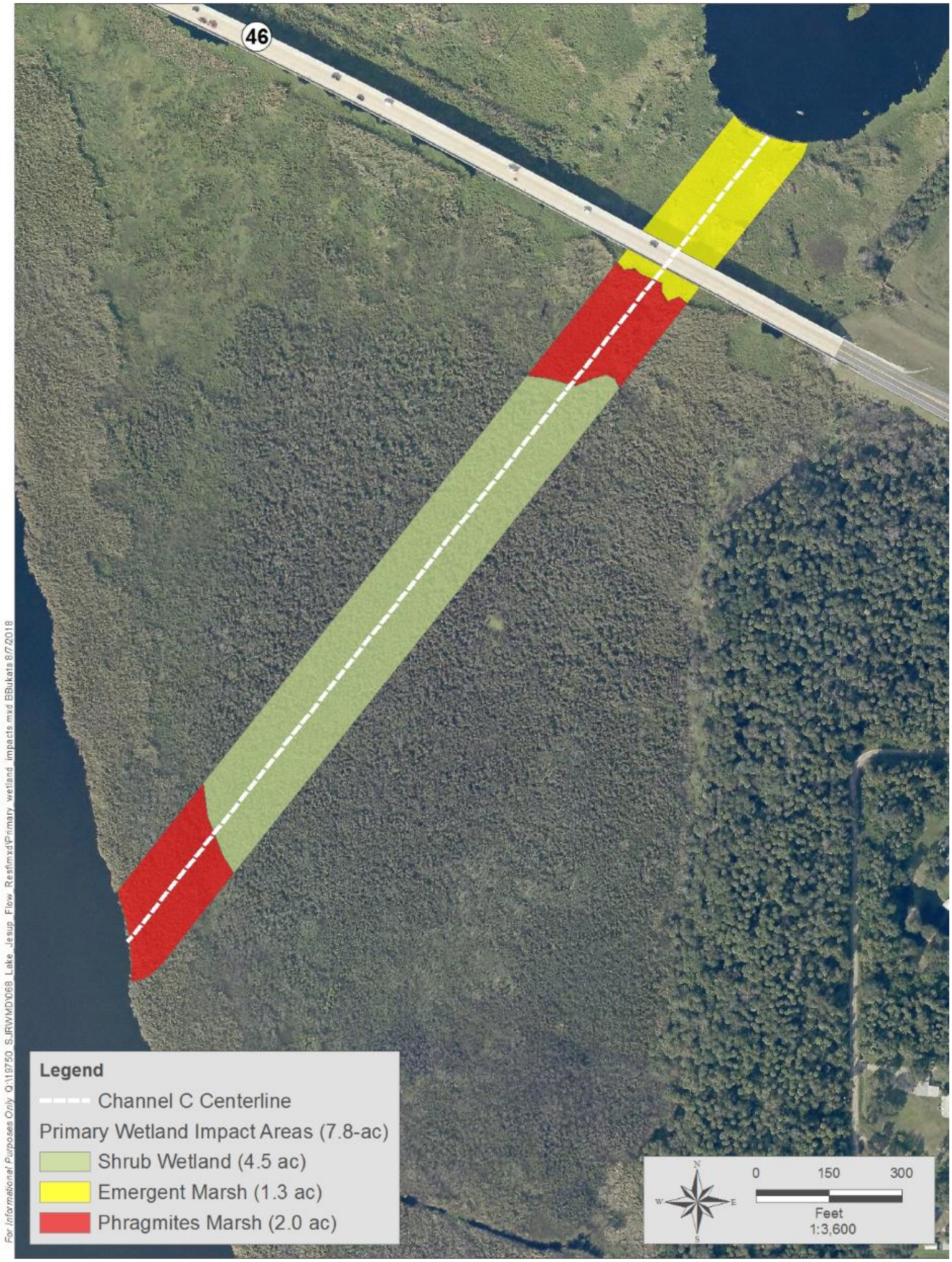
2.3 WETLAND EVALUATION

Jones Edmunds assessed the wetland vegetation community composition and quality, developed Uniform Mitigation Assessment Method (UMAM) scores, and assessed the potential impacts of the proposed Channel C to existing FDOT mitigation areas. The FDOT mitigation areas are associated with the FDOT SR 46 bridge replacement project.

2.3.1 WETLAND COMMUNITY ASSESSMENT

A Jones Edmunds' senior scientist assessed the wetland plant species composition and quality for the wetland areas that would be impacted by the proposed Channel C. The scientist reviewed Google Earth imagery, Google Earth Street View, Seminole County 2015 aerial imagery, and photographs and observations collected by SJRWMD staff during a site visit in June 5, 2018. Jones Edmunds and SJRWMD staff agreed that three primary wetland vegetation communities are found within the proposed Channel C – Shrub Wetland, Emergent Marsh, and Phragmites Marsh (Figure 7).

Figure 7 Wetland Communities Impacted by Proposed Channel C



2.3.1.1 Shrub Wetland

This wetland community comprises approximately 4.5 acres and is throughout the center of proposed Channel C. The community is dominated by Carolina willow (*Salix caroliniana*), buttonbush (*Cephalanthus occidentalis*), and likely other unconfirmed species such as wax myrtle (*Morella cerifera*), saltbush (*Baccharis halimifolia*), swamp rosemallow (*Hibiscus grandiflorus*), Virginia saltmarsh mallow (*Kosteletzkya pentacarpos*), and small red maple (*Acer rubrum*).

2.3.1.2 Emergent Marsh

This wetland community is at the north end of Channel C and comprises approximately 1.3 acres. The community is dominated by a diversity of native species such as phragmites (*Phragmites australis berlandieri*), denseflower knotweed (*Persicaria glabra*), maidencane (*Panicum hemitomon*), coast cockspur (*Echinochloa walteri*), marsh pennywort (*Hydrocotyle* spp.), *Kosteletzkya pentacarpos*, Carolina willow, spikerush (*Eleocharis* spp.), fireflag (*Thalia geniculata*), spatterdock (*Nuphar advena*), and buttonbush.

2.3.1.3 Phragmites Marsh

This wetland community comprises approximately 2.0 acres and is primarily along the margins of the large wetland south of SR 46 that Channel C will cut through. The wetland is dominated by a monoculture of phragmites, a native species.

2.3.2 BRIDGE REPLACEMENT MITIGATION ASSESSMENT

Jones Edmunds obtained copies of SJRWMD Permit No. 4-117-95925-1 and Technical Staff Report and US Army Corps of Engineers (USACE) Permit No. SAJ-2004-5426 (IP-AWP) to review the required wetland mitigation plan for primary and secondary wetland impacts associated with the FDOT SR 46 bridge replacement project. Mitigation for this project was consistent for SJRWMD and USACE and consisted of the following:

- Restore 5.565 acres of wetlands within the footprints of the Marina Isle Fish Camp and Tornado Tavern Fish Camp by removing the existing fill to an elevation of between 1.5 feet and 0.5 feet National Geodetic Vertical Datum (NGVD) 1929 (0.5 and –0.5 NAVD 88).
- Enhance 1.468 acres of wetlands on the slopes of the existing fill associated with the Marina Isle Fish Camp and Tornado Tavern Fish Camp by removing the fill to an elevation of between 1.5 feet and 0.5 feet NGVD 1929 (0.5 and –0.5 NAVD 88).
- Restore 6.787 acres of wetlands within the footprints of the existing boat basins of the Marina Isle Fish Camp and Tornado Tavern Fish Camp by filling the basins to an elevation of between 1.5 feet and 0.5 feet NGVD 1929 (0.5 and –0.5 NAVD 88).
- Restore 6.370 acres of wetlands within the footprint of the existing causeway by removing the causeway to an elevation of between 1.5 feet and 0.5 feet NGVD 1929 (0.5 and –0.5 NAVD 88).
- Enhance 3.306 acres of wetlands on the slope of the existing causeway by removing the causeway to an elevation of between 1.5 feet and 0.5 feet NGVD 1929 (0.5 and –0.5 NAVD 88).
- Preserve 30.26 acres of marsh. No wetland mitigation credit was provided for this preservation area.

Jones Edmunds rectified the Plan Sheets that depicted the above-referenced mitigation activities to quantify the acreage of each activity that will be impacted by Channel C. Much of the mitigation associated with the fish camps are west of the Channel C alignment. However, after rectifying the Mitigation Plan Sheets and digitizing the mitigation areas within Channel C, we estimate that Channel C will impact the following:

- 0.26 acre of Wetland Creation.
- 0.14 acre of Wetland Enhancement.
- 0.48 acre of Wetland Preservation (no mitigation credit provided).

2.3.3 UMAM ASSESSMENT

2.3.3.1 Channel C Impacts

A Jones Edmunds scientist assigned conservative UMAM scores to the Location and Landscape Support, Water Environment, and Community Structure categories for each wetland community. Overall, the wetland communities are high quality. Two distinctions were made in the UMAM analysis that resulted in different scores. The first was to Community Structure resulting from the prevalence of Carolina willow in the Shrub Wetland community since this species is considered a nuisance species by SJRWMD and USACE. The second was to Water Environment for the Phragmites community that fronts Lake Jesup and is exposed to lower water quality than interior wetlands. In total, an estimated 7.8 acres of wetlands would be impacted, resulting in an estimated functional loss (FL) of 6.7 units due to the construction of Channel C (Table 2).

Secondary impacts would also likely be assessed and were assumed to occur up to 100 feet away from the edge of the channel. Expected secondary impacts are that the new channel would create a barrier to some wildlife species and allow for boat traffic, which would create wave energy that would hit and erode adjacent wetlands and potentially lower water quality. To account for secondary impacts, we decreased UMAM scores for all three categories by 1 point (Table 2). This resulted in an additional 1.0 FL unit.

2.3.3.2 Previous SR 46 Mitigation Impacts

Using the mitigation acreages that fall within Channel C and their corresponding Relative Functional Gain values, we estimate that 0.28 FL unit will occur resulting from the construction of Channel C (Figure 8 and Table 2). The previous mitigation FL and primary wetland impacts associated with the construction of Channel C would need to be mitigated. We assume that both FDEP and USACE will require mitigation regardless of project benefit to offset impacts to these former mitigation areas.

2.3.4 ENVIRONMENTAL PERMITTING CONSIDERATIONS

Channel C crosses an SJRWMD-owned parcel referred to as the Little Cameron Ranch, which was purchased with Save Our River funds (SJRWMD, 2014). Referencing a July 25, 2018 email from Steven Miller, Bureau of Land Resources Chief, *there appears to be nothing in our acquisition, funding, nor management history that would preclude this project*. In addition, Jones Edmunds does not expect that listed wildlife species will negatively affect the ability to acquire a permit for this project.

Table 2 Summary of FL and Mitigation Costs for Channel C Impacts

Assessment Area	Location and Landscape Support		Water Environment		Community Structure		Delta	Acres	Functional Loss	Relative Functional Gain	Best Case Scenario Estimated Mitigation Cost[1]	Worst Case Scenario Estimated Mitigation Cost[2]
	Current	With Impacts	Current	With Impacts	Current	With Impacts						
Channel C Primary Impacts												
Carolina Willow Areas	9	0	9	0	7	0	0.833	4.5	3.75	NA	$ 75,000	$ 809,175
Emergent Marsh	9	0	9	0	9	0	0.900	1.3	1.17	NA	$ 23,400	$ 137,475
Phragmites Marsh	9	0	8	0	9	0	0.867	2.0	1.73	NA	$ 34,600	$ 203,275
							Subtotal=	**7.8**	**6.7**	**NA**	**$ 133,000**	**$ 1,149,925**
Channel C Secondary Impacts[3]												
Carolina Willow Areas	9	8	9	8	7	6	0.100	5.3	0.53	NA	$ 10,600	$ 62,275
Emergent Marsh	9	8	9	8	9	8	0.100	1.7	0.17	NA	$ 3,400	$ 19,975
Phragmites Marsh	9	8	8	7	9	8	0.100	2.7	0.27	NA	$ 5,400	$ 31,725
							Subtotal=	**9.7**	**1.0**	**NA**	**$ 19,400**	**$ 113,975**
Primary and Secondary Impact Total=								**17.5**	**7.6**	**NA**	**$ 152,400**	**$ 1,263,900**
Channel C Previous FDOT Mitigation Areas												
Wetland Creation	0	9	0	10	0	9	0.933	0.3	NA	0.24	$ 81,600	$ 81,600
Wetland Enhancement (Marsh)	6	9	6	10	7	9	0.300	0.1	NA	0.04	$ 13,600	$ 13,600
Wetland Enhancement (Fish Camp Shoreline)	6	9	8	10	6	9	NA	NA	NA	NA	NA	NA
Wetland Preservation							NA	0.5	NA	NA	NA	NA
							Subtotal=	**0.9**	NA	**0.28**	**$ 95,200**	**$ 95,200**
										TOTAL=	**$ 247,600**	**$ 1,359,100**

[1] Scenario assumes that FDEP does not require mitigation and only federal credits are required.

[2] Scenario assumes FDEP requires mitigation which must occur within the nested basin at a cost of $320,000/credit for the first 2.1 credits at Wildwood ROMA site and then $117,500/credit for remaining FL which is the mean cost of Farmton ($145,000/credit) and TM Econ ($90,000/credit) joint credits.

[3] Assumes 100' from limits of construction.

Figure 8 Channel C FDOT SR 46 Wetland Mitigation Areas

For Informational Purposes Only Q:\19750_SJRWMD\068_Lake_Jesup_Flow_Rest\mxd\Mitigation.mxd PStein 9/19/2018

Permits from FDEP and USACE would be required for the construction of Channel C. If analysis demonstrates that the creation of Channel C provides environmental benefits to Lake Jesup, the project could be presented as a restoration/enhancement project that may allow it to qualify for simpler, expedited permitting. Alternatively, the regulatory agencies could determine that the project does not provide a net environmental benefit and review the project through the standard permitting process. The regulatory agencies may determine that the proposed water quality and habitat benefits to the lake have less environmental benefit than the environmental impacts associated with converting the existing wetlands to an open water channel. Furthermore, the project benefits would occur to different communities than those impacted, which would not meet the requirement for type-for-type mitigation.

USACE is expected to require mitigation for primary and secondary wetland impacts resulting from the construction of Channel C due to the large acreage of impact, limited water quality enhancement, limited benefit to the wetlands in the region of impact, and the recommendation issued in USACE and SJRWMD (2011).

2.3.5 WETLAND MITIGATION COST

In the "best-case scenario," the project would qualify for a General Permit for environmental restoration which would not require mitigation, resulting in significant mitigation cost savings. However, the worst case would require both state and federal wetland mitigation. Following sections present cost estimates for both scenarios and for previous FDOT SR 46 mitigation areas that will be impacted.

2.3.6 STATE- AND FEDERAL-REQUIRED MITIGATION SCENARIO

Channel C lies within the Lake Jesup Nested Basin; therefore, wetland mitigation must occur within this basin. Wildwood is an SJRWMD-approved regional off-site mitigation area (ROMA) that is the only mitigation area/bank within the nested basin that can provide state credits. This mitigation area is managed by Bio-Tech Consulting, their broker is The Mitigation Banking Group, Inc., and credits cost $320,000/credit. However, only 2.1 credits are available from this mitigation area. SJRWMD will need to coordinate with FDEP to determine if credits can be purchased from a private wetland mitigation bank serving the area or if SJRWMD must provide permittee-sponsored mitigation. If FDEP does not approve this plan, SJRMWD would have to identify, design, and implement a wetland mitigation area within the basin that could involve wetland preservation, enhancement, restoration, and/or creation.

To generate a cost for permittee-sponsored mitigation for FL greater than the 2.1, a mean cost of $117,500/FL unit was used to estimate wetland mitigation cost beyond the 2.1 FL that can be mitigated at the Wildwood ROMA. This mean was derived using the cost/joint State and Federal credit at Farmton and TM Econ of $145,000 and $90,000, respectively, which both serve the project site. Regarding federal wetland mitigation credits, the Colbert Cameron wetland mitigation bank serves the project area and can provide USACE-only credits at a cost of $20,000/credit.

Jones Edmunds assumed that USACE and Wildwood ROMA credits would need to be purchased by SJRWMD for the 0.28 FL for impacts to the FDOT SR 46 mitigation areas resulting from Channel C at a total cost of $95,200 (Table 2).

Using the above-referenced methodology, the estimated wetland mitigation cost for this worst-case scenario is $1.36M (Table 2).

2.3.7 FEDERAL-REQUIRED BUT NO STATE-REQUIRED MITIGATION SCENARIO

If no mitigation is required by FDEP, approximately 7.6 and 0.28 USACE credits would need to be purchased from the Colbert Cameron wetland mitigation bank for Channel C impacts and impacts to the FDOT SR 46 mitigation areas, respectively. SJRWMD would also need to purchase 0.28 credit from the Wildwood ROMA. This results in an estimated wetland mitigation cost for the best-case scenario of $247,600 (Table 2).

2.4 OPINION OF PROBABLE COST

Jones Edmunds prepared a conceptual level opinion of probable construction cost based on similar recent projects and engineering judgement (Table 3).

No detailed information about the subsurface material or conditions along the proposed Channel C route is currently available. The composition of the subsurface material will affect the construction and material handling methods and costs. Should this project move forward, Jones Edmunds recommends performing subsurface investigations including soil cores and laboratory analyses to better inform construction decisions.

Jones Edmunds assumed construction would be performed using a hydraulic dredge and that material could be adequately dewatered at the construction site using geotextile tubes before hauling. A final placement site for the excavated material is not currently known; therefore, Jones Edmunds provided costs based on a short haul (a mile or less) and a long haul (up to 10 miles). Thin layer placement in the wetlands adjacent to Lake Jesup was not considered a viable placement method at this conceptual level because of the unknown nature of the material and the potential for the material to be unsuitable for successful use of thin layer placement.

Based on the channel dimensions, the volume of excavated material will be about 95,000 cubic yards. This could be placed on a 60-acre site at a depth of approximately 1 foot. The Seminole County Landfill is approximately 10 miles from the project site. This landfill may be interested in using the excavated material as daily cover.

Jones Edmunds investigated the potential for sediment maintenance needs in the excavated channel and Government Cut but was unable to collect adequate data to characterize the potential sediment accumulation. Insufficient sediment sampling data were available to quantify potential sediment transport in the St. Johns River at this site. The USACE Jacksonville office has no record of maintenance dredging for Government Cut. The lack of records may be indicative of no sediment accumulation in Government Cut, or Government Cut may have been over-excavated at the time of its construction.

Table 3 Conceptual Opinion of Probable Construction Cost

JonesEdmunds

PROJECT NAME: **LAKE JESUP DREDGING**

PROJECT No.: **19750-068-01**
DATE: **AUGUST 20, 2018**
SUBMITTAL: **CONCEPTUAL**

ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST

PROJECT SEGMENT:	LAKE JESUP DREDGING	CLIENT:	SJRWMD
		PREPARED BY:	BAT
ESTIMATE TYPE:	CONSTRUCTION COST	CHECKED BY:	WAN

FDOT ITEM NUMBER	**ITEM DESCRIPTION**	UNIT	QUANTITY	UNIT PRICE	COST
101-1	MOBILIZATION	%	10%	$280,037.00	$280,037.00
102-1	MAINTENANCE OF TRAFFIC	%	1%	$28,004.00	$28,004.00
	EROSION AND SEDIMENT CONTROL	%	2%	$56,007.00	$56,007.00
530-3-3	RIPRAP-RUBBLE, BANK AND SHORE	TN	2,100	$125.00	$262,500.00
	VEGETATION REMOVAL	AC	8	$35,000.00	$291,666.67
	DREDGING	CY	94,600	$15.00	$1,419,000.00
	DISPOSAL SITE CONSTRUCTION AND MANAGEMENT	EA	1	$50,000.00	$50,000.00
	RETURN WATER DISCHARGE STRUCTURE	EA	1	$5,000.00	$5,000.00
	MECHANICAL SEPARATOR	CY	94,600	$5.00	$473,000.00
	GEOTEXTILE TUBES	LF	4,400	$25.00	$110,000.00
	POLYMER TREATMENT - SETTLING IN CONTAINMENT BERM	CY	94,600	$2.00	$189,200.00
	DEWATERING	DAY		$400.00	$0.00
	CONTINGENCY	%	25%	$2,800,366.67	$700,091.67
	SUBTOTAL (ROUNDED)				**$3,864,500.00**
	SHORT HAUL (DISTRICT LANDS WEST SIDE OF LAKE JESUP)	CY	94,600	$10.00	$946,000.00
	ESTIMATE CONSTRUCTION CONTRACT PRICE (ROUNDED)				**$4,810,500**
	LONG HAUL (SITE TO BE DETERMINED)	CY	94,600	$18.00	$1,702,800.00
	ESTIMATE CONSTRUCTION CONTRACT PRICE (ROUNDED)				**$5,567,300**

3 SUMMARY OF RESULTS AND NEXT STEPS

The hydrodynamic and water quality modeling results indicate that the addition of Channel C would increase the water exchange between the MSJR and Lake Jesup. The hydrodynamic model results show that the additional flow entering Lake Jesup via Channel C would quickly turn upon entry into the Lake and discharge via Channel A. The water exchange and water quality benefits would be limited to an area of about 300 acres in the neck of Lake Jesup close to the point of connection with the MSJR. The water quality model results showed no significant water quality changes in the greater interior portion of Lake Jesup.

The sum of conceptual level mitigation and construction costs range from approximately $5M to almost $7M (Table 4).

Table 4 Summary of Conceptual Costs

	Low ($)	High ($)
Construction	4,810,500	5,567,300
Wetland Mitigation	247,600	1,359,100
Total	**5,058,100**	**6,926,400**

The hydrodynamic and water quality modeling were performed with existing calibrated models. These models do not characterize the project’s potential effects on the St. Johns River downstream of Lake Jesup. Additionally, the assessment of other potential natural system benefits resulting from anticipated water quality changes were not included within the scope of this analysis. To further explore the benefits and impacts of enhanced flow to the lake, SJRWMD may wish to consider additional modeling and analysis to assess the potential impacts on the river downstream of Lake Jesup as well as to assess other potential environmental benefits resulting from this project alone or in concert with other water quality improvement projects.

4 REFERENCES

U.S. Army Corps of Engineers and St. Johns River Water Management District. 2011. Lake Jesup Project Modification for Improvements to the Environment, Seminole and Volusia Counties, FL. Section 1135 Draft Ecosystem Restoration Report.

Appendix A

Initial Baseline Modeling Technical Memorandum

ATM | DESIGN ENGINEERING CONSULTING

2201 N.W. 40th TERRACE
GAINESVILLE, FLORIDA 32605-3574
386.256.1477

MEMORANDUM

To: Pete Sucsy

From: Steve Peene

CC: Alan Foley

Date : June 12, 2018

Re : MSJR Initial Baseline Modeling

Using the Middle St. Johns River (MSJR) Environmental Fluid Dynamics Code (EFDC) baseline model provided by the St. Johns River Water Management District (SJRWMD), a version of the MSJR model was developed to run using the Tetra Tech EFDC model code. The baseline model grid is shown in Figure 1. The baseline MSJR model extends from upstream of Lake Harney down to Buffalo Bluff. The baseline model simulation period chosen for this effort, based upon discussions with SJRWMD staff, was 2007 through 2013.

Initial model tests were performed to evaluate how the model run, using the Tetra Tech EFDC code, compared to available data for flows and water levels. For the purposes of this study, the primary area of concern is around Lake Jesup, at the connection to the St. Johns River (SJR). As such, the model-to-data comparisons were performed at stations in this area. Figure 2 shows the locations of the stations used for the model-to-data comparisons. The stations include:

- USGS 02234010 – St. Johns River at Osceola
- USGS 02234435 – Lake Jesup Outlet
- USGS 02234440 – St. Johns River at State Road 415
- HDS 01410650 – Lake Jesup at Oveido

Figures 3a and 3b present comparisons of the simulated and measured water levels at the four locations for the period of the simulation. The results are the daily averages of the simulations plotted against the measured daily data. The results show that the model captures the changes and the ranges of changes in water levels at the four stations. One difference appears to be that the measured and simulated water levels are shifted in mean water level. This may be a function of the definition of the vertical datum being utilized. This will need to be discussed with SJRWMD staff currently using the MSJR model. Figures 4a and 4b present simulated and measured flows at three of the stations, two along the SJR and one at the mouth of Lake Jesup. For the SJR stations, the agreement between the measured and simulated flows are good. At the entrance to Lake Jesup, there are some differences. This is believed to be a function of how the connection between Lake Jesup and the SJR is defined in the baseline model and is discussed further in the following paragraphs.

For this project, the desire is to examine the impacts of developing a new channel connection between the SJR and Lake Jesup. As such, the baseline model was modified to allow for inclusion of a connection between the SJR and Lake Jesup further upstream of the present connections. To facilitate this modeling, refinements were made to the existing baseline model grid to provide a more accurate representation of the existing channel conditions at the Lake Jesup and SJR connections and to facilitate introduction of a new connection, called Channel C. The other connections between Lake Jesup and the SJR, Channel A (the main and furthest west connection) and Channel B (a smaller connection just east of Channel A) are already in the baseline model. Figures 5a and 5b present a zoomed-in view of the connection between Lake Jesup and the SJR for the baseline and the refined model grids, respectively. This shows some of the minor modifications to the baseline grid (including a narrowing of the Channel B connection), some refinement of the SJRWMD channel, and the addition of grids at the northern end of Lake Jesup. Figure 5b also shows how the refined grid will represent the new channel connection (Channel C). This channel will be connected using the EFDC MAPGNS capabilities, which makes turning the channel on and off simple. For the simulation results presented below, which reflect present conditions, the channel connection was not turned on. The EFDC model was run using the refined grid with all the same freshwater inflows and the water level forcing function at Buffalo Bluff utilized for the baseline model. Figures 6a and 6b present the comparisons of the water levels. These comparisons are similar to those shown for the baseline model. Figures 7a and 7b present comparisons of the flows. For the SJR stations, the flow comparisons are similar. For the Lake Jesup connection, the results are better than those originally shown for the baseline model. This is most likely a function of changes to Channel B, such that Channel B is more restricted (which is the present condition) and, therefore, more of the flow passes out Channel A.

The results are presented to SJRWMD staff for review and discussion to determine if the model is sufficient to begin the baseline water quality simulations or to define changes that need to be made prior to advancing to the baseline water quality.

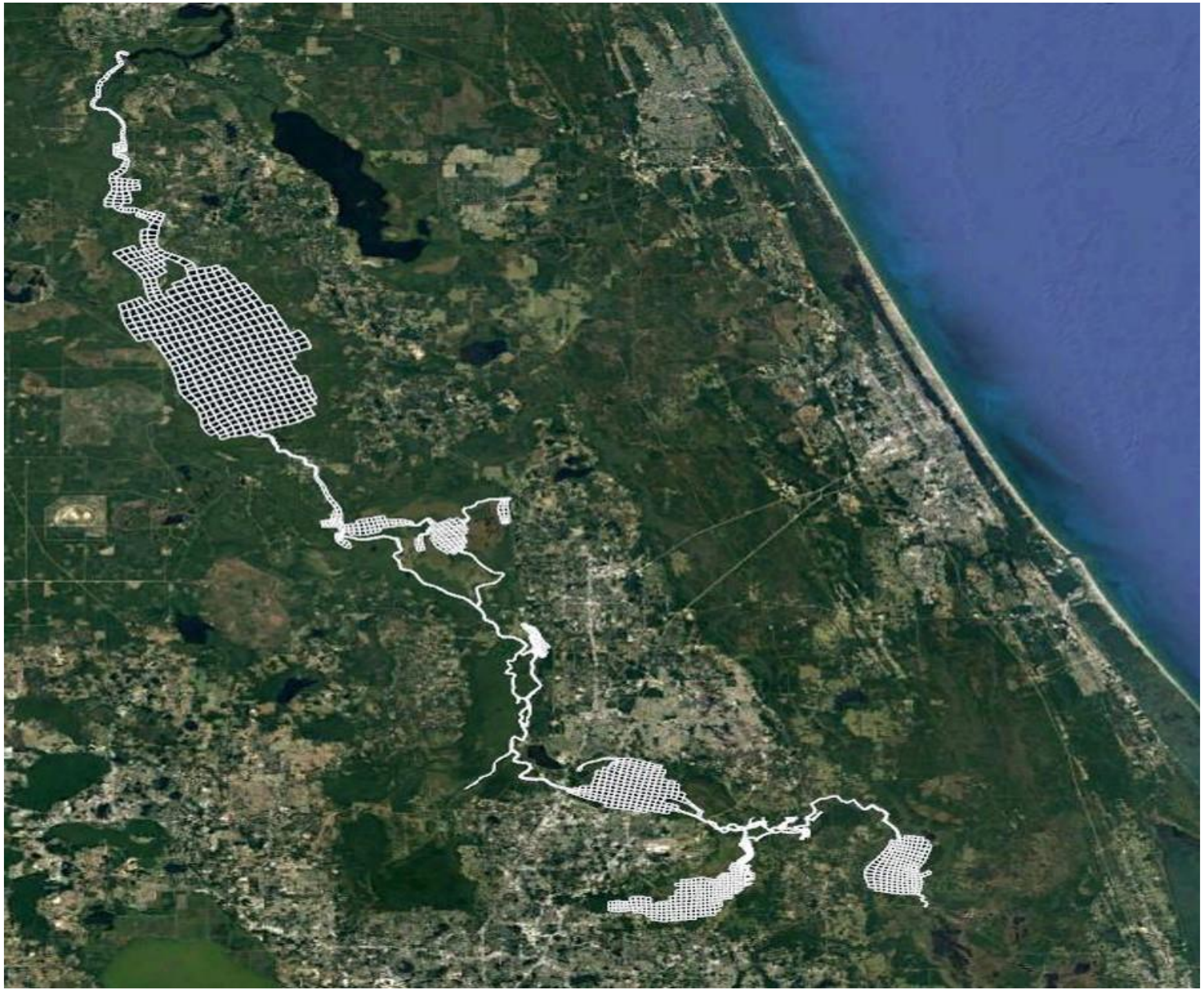


Figure 1

Figure 2

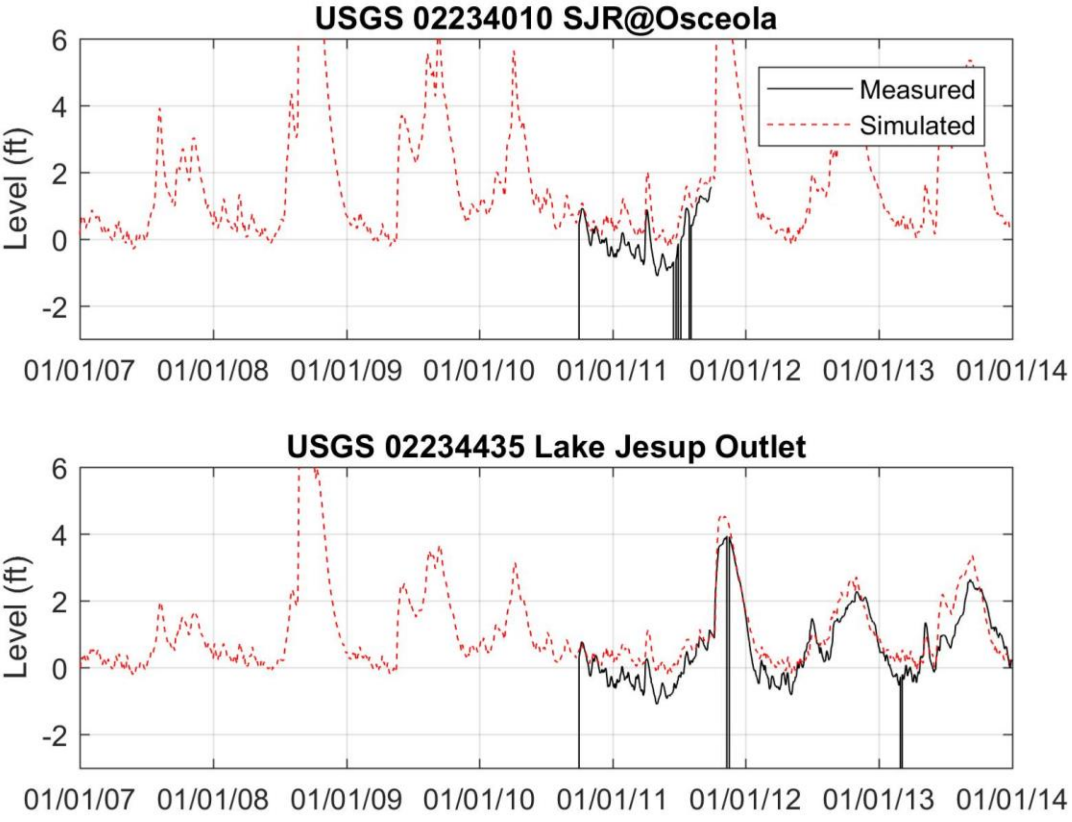


Figure 3a

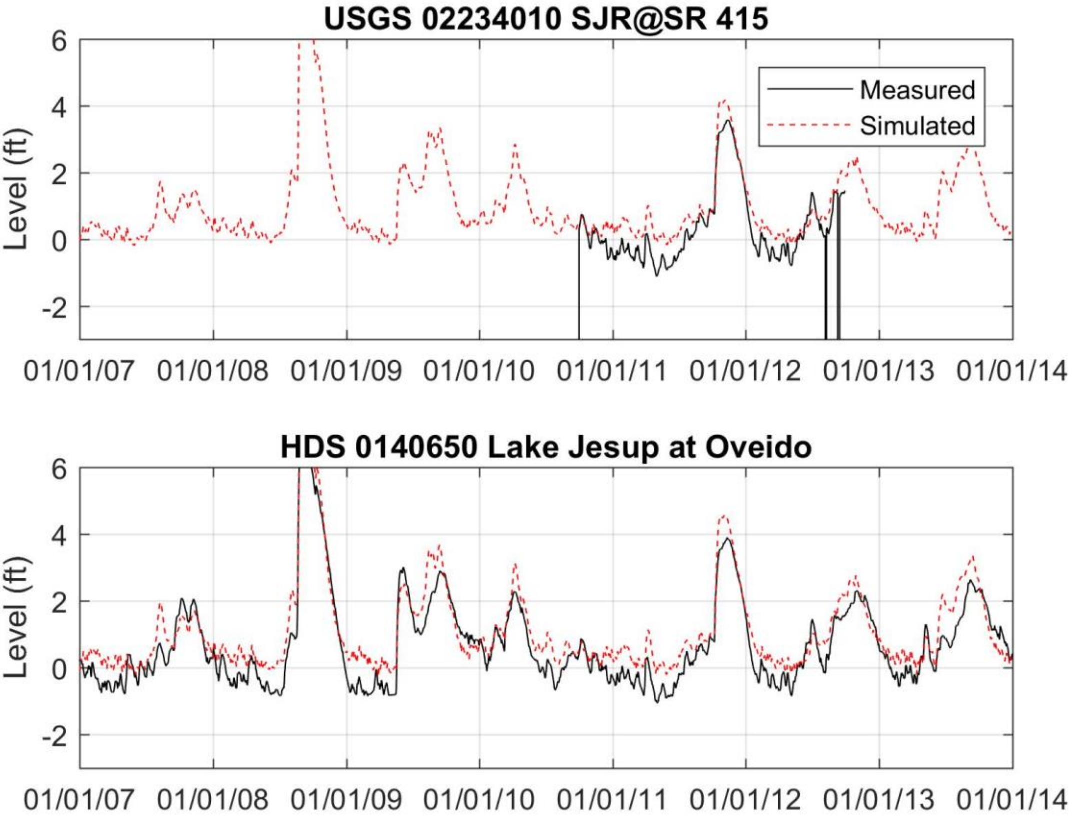


Figure 3b

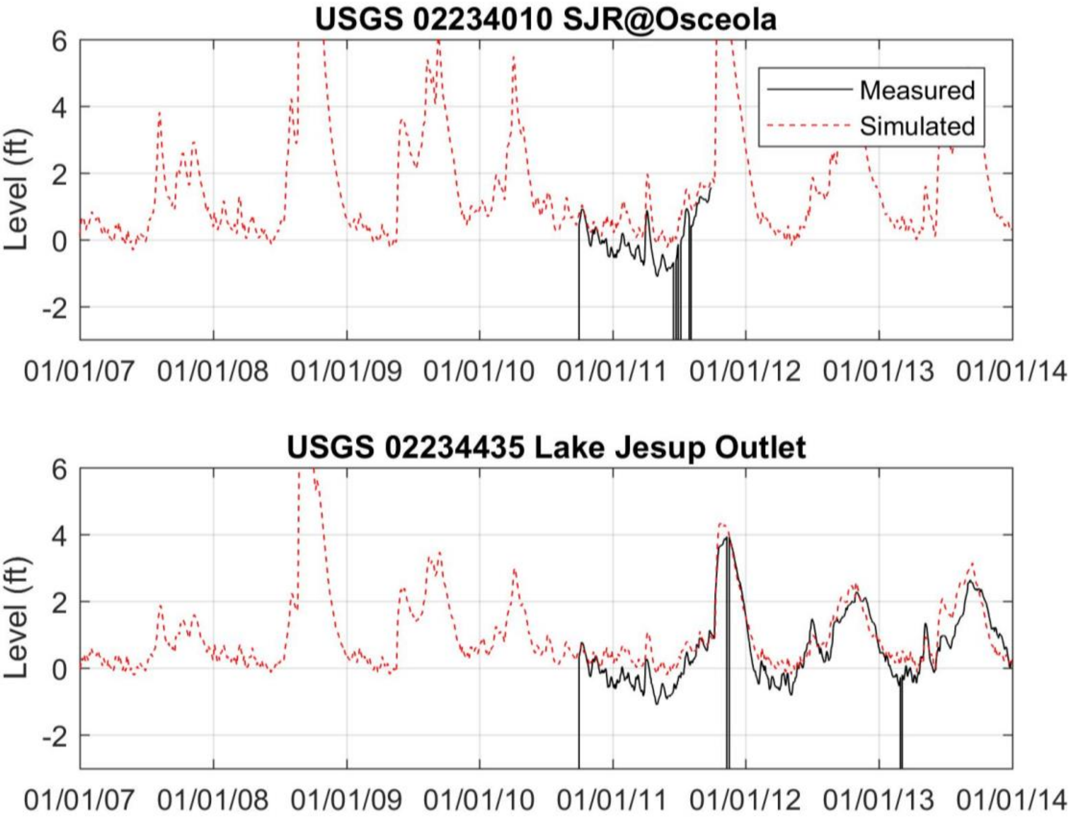


Figure 4a

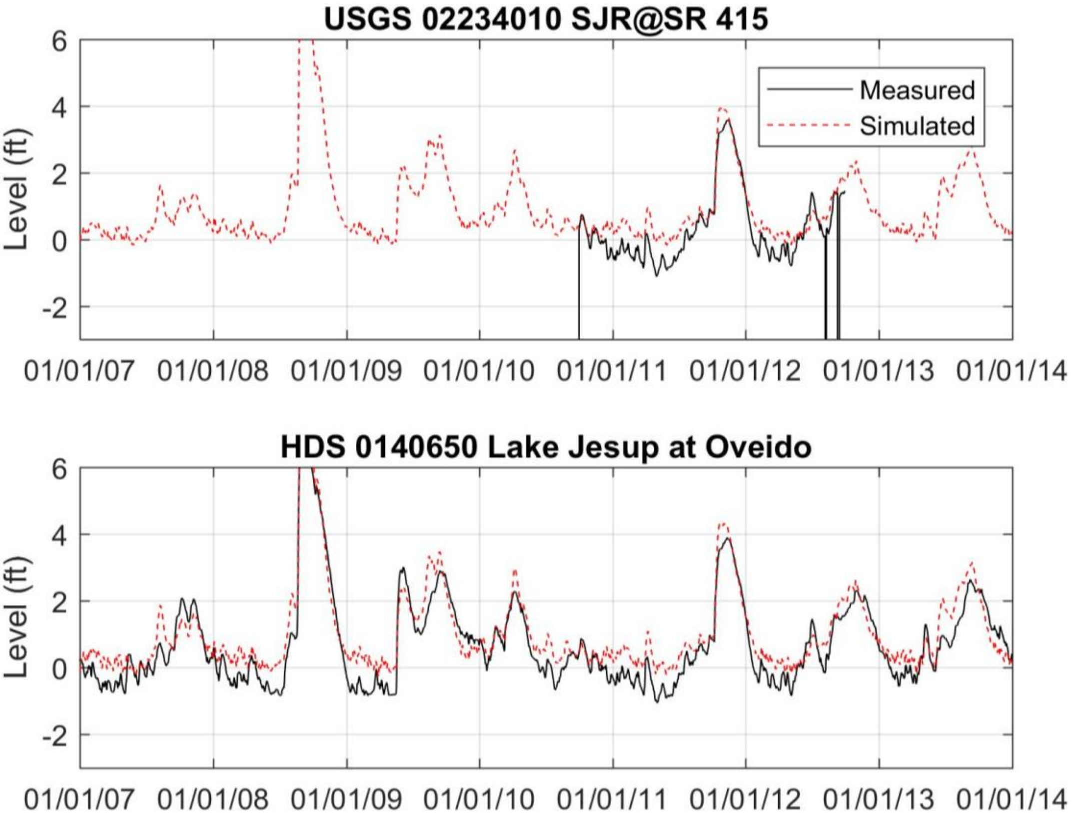


Figure 4b

Figure 5a

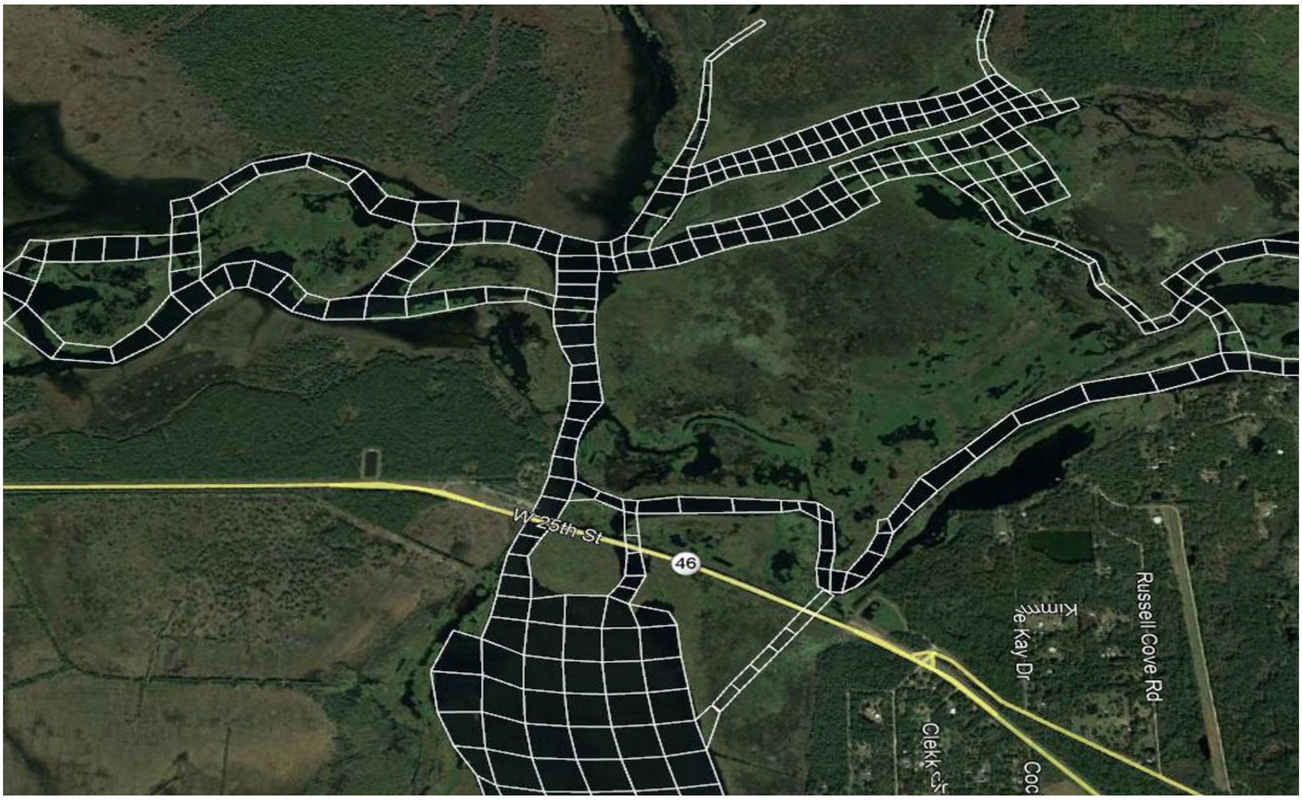


Figure 5b

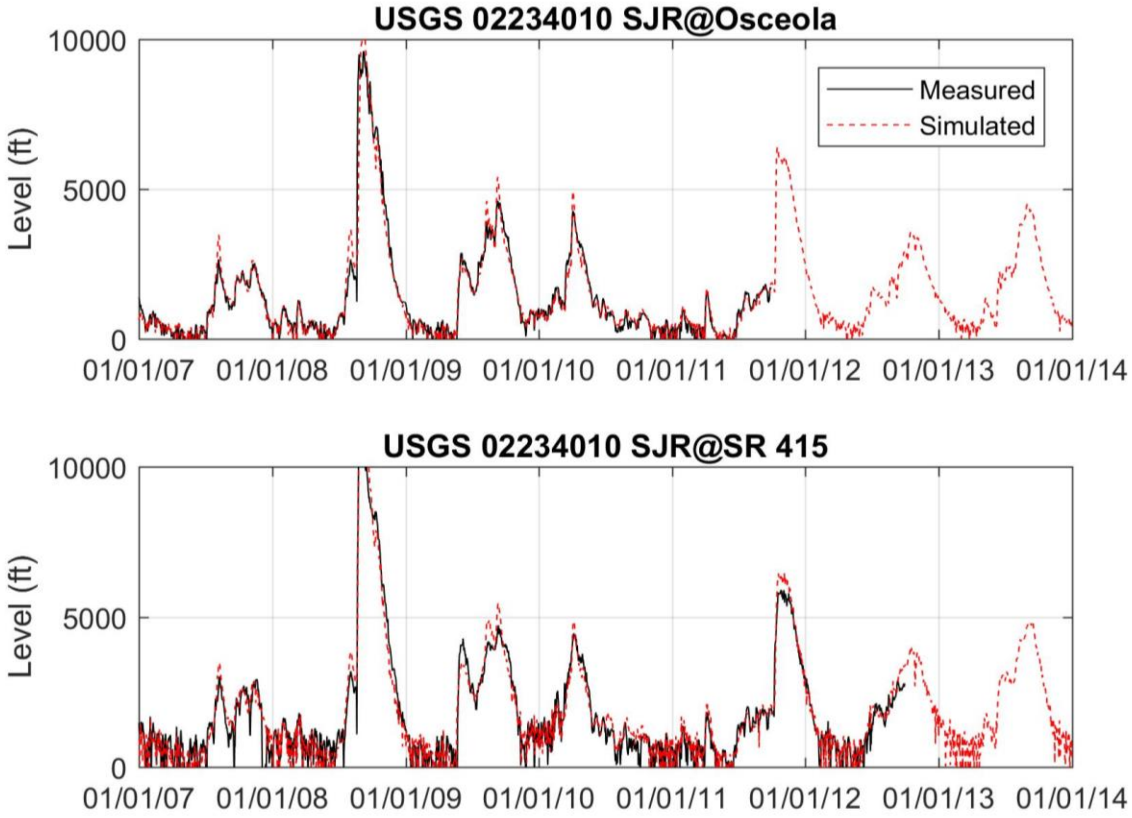


Figure 6a

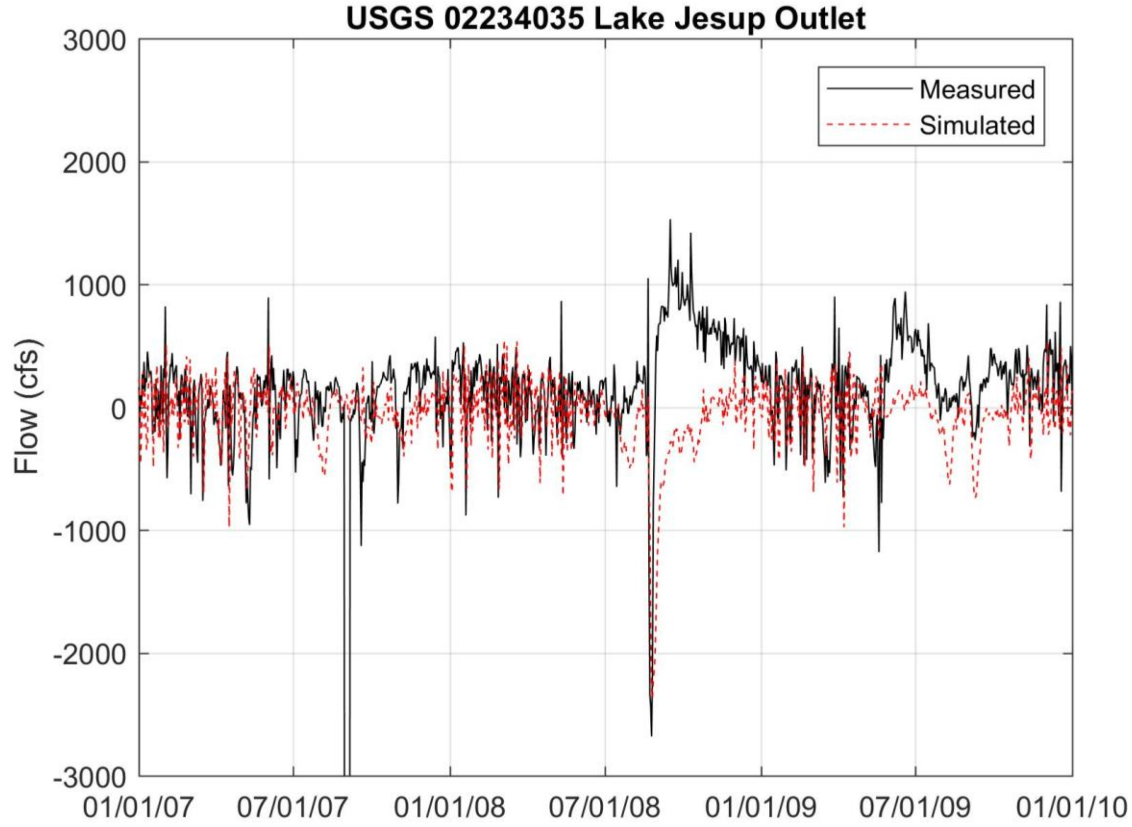


Figure 6b

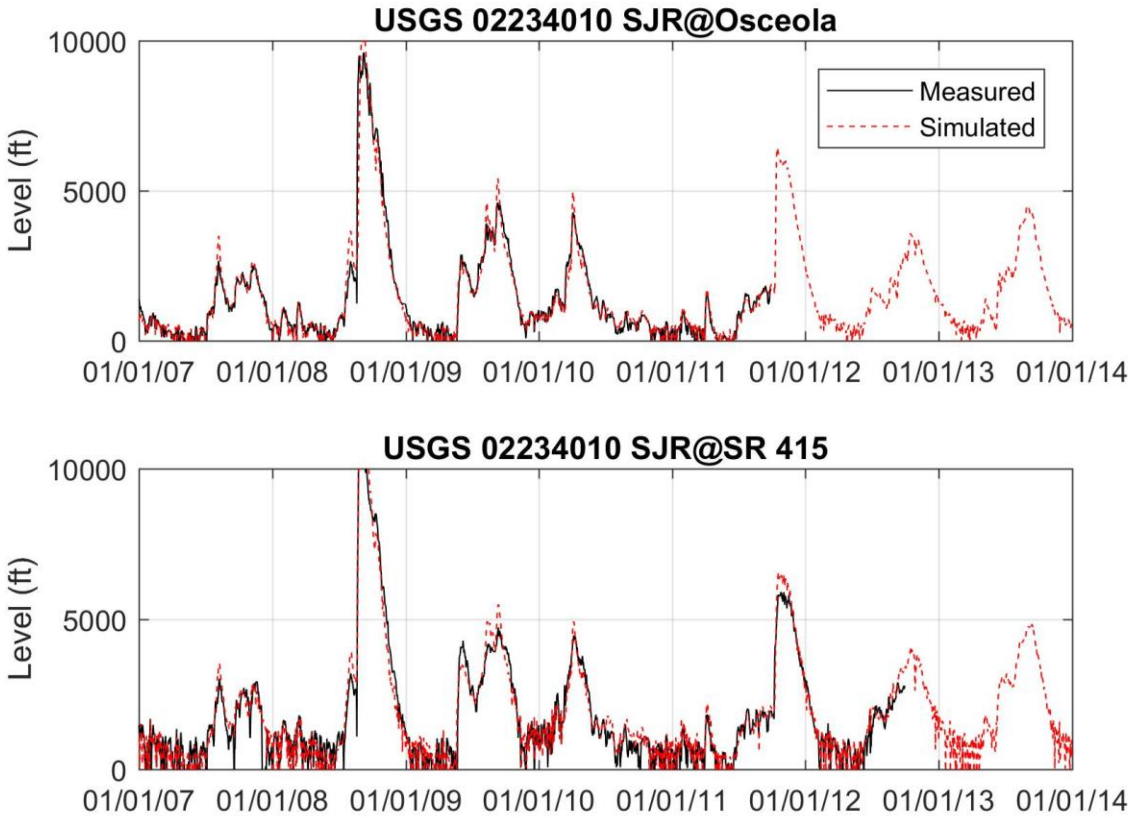


Figure 7a

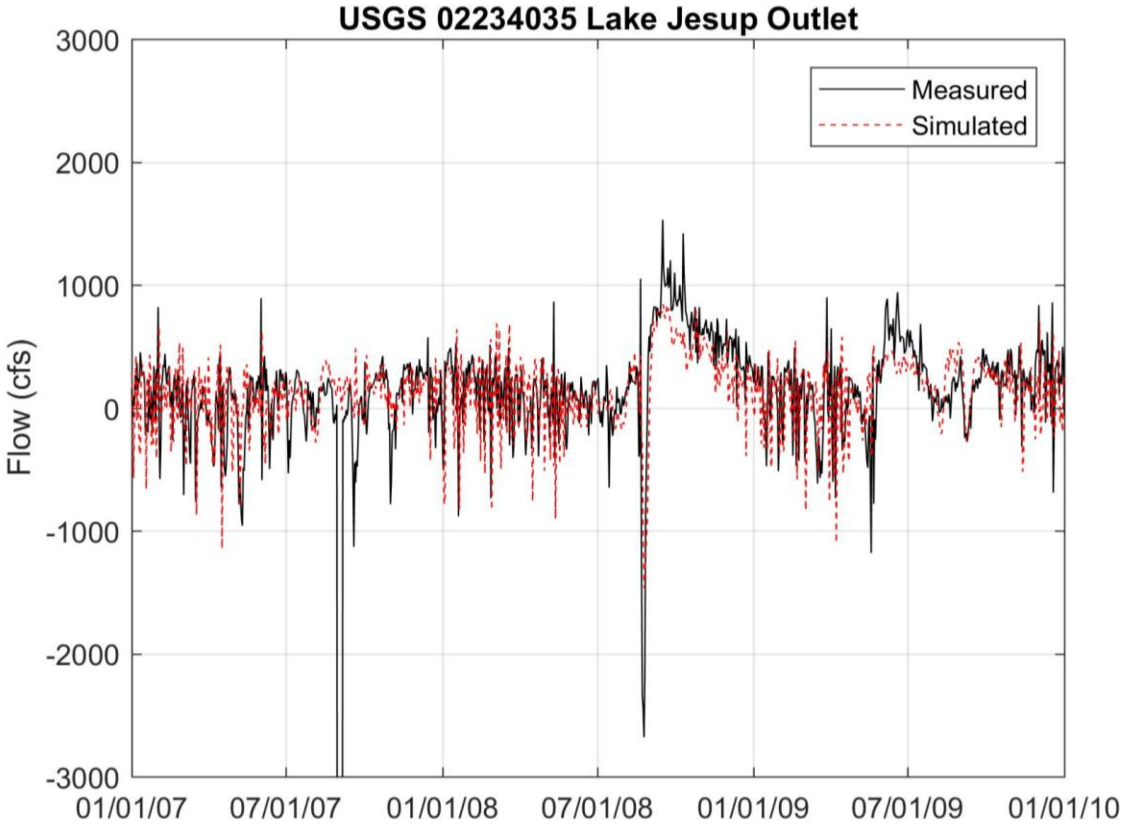


Figure 7b

Appendix B

Baseline Hydrodynamic Model Development Technical Memorandum

ATM | DESIGN ENGINEERING CONSULTING

MEMORANDUM

2201 N.W. 40th TERRACE
GAINESVILLE, FLORIDA 32605-3574
386.256.1477

To: Pete Sucsy, Derek Busby

From: Steve Peene

CC: Alan Foley

Date : August 31, 2018

Re : Final MSJR Baseline Hydrodynamic Model Development

On June 11, 2018 an initial Technical Memo Using the Middle St. Johns River (MSJR) Environmental Fluid Dynamics Code (EFDC) baseline model provided by the St. Johns River Water Management District (SJRWMD), a version of the MSJR model was developed to run using the Tetra Tech EFDC model code. The baseline model grid is shown in Figure 1. The baseline MSJR model extends from upstream of Lake Harney down to Buffalo Bluff. The baseline model simulation period chosen for this effort, based upon discussions with SJRWMD staff, was 2007 through 2013. An initial memo was provided to the District on June 11, 2018. This memo outlined the development of the hydrodynamic model to provide to Tetra Tech for the water quality simulation tests and demonstrated that the refined model matched or improved the simulations from the original MSJR model. The June 11 memo also presented how the original MSJR model grid was modified for use in the Lake Jesup Project simulations. Through the water quality model development, additional alterations to the hydrodynamic model were made. This memo outlines those changes and the final results from the hydrodynamic simulations.

In order to match the water quality model simulations conducted for Lake Jesup, the MSJR hydrodynamic model was modified. Two key modifications were made, these were;

- The flows into Lake Jesup were slightly different between the MSJR EFDC model and the Tetra Tech EFDC model for Lake Jesup. While the total flows were nearly identical, the Tetra Tech EFDC model had split some of the MSJR flows into sub-sets. The flows from the Lake Jesup EFDC model were input into the MSJR EFDC model.
- The MSJR model was run with 6 layers. The Tetra Tech EFDC model for Lake Jesup was run with 1 layer. The MSJR model was modified to run with 1 layer.

In addition to the changes in the flows and layers, the channel cross-section in Channel B was narrowed in order to better represent the flow distribution between Channel A and B. In the initial runs presented in the June 10, 2018 Technical Memo, it was shown that the flow out of Channel A was not accurately simulated in the original MSJR model. Based on this, Channel B was modified to better represent the flow out of Channel A.

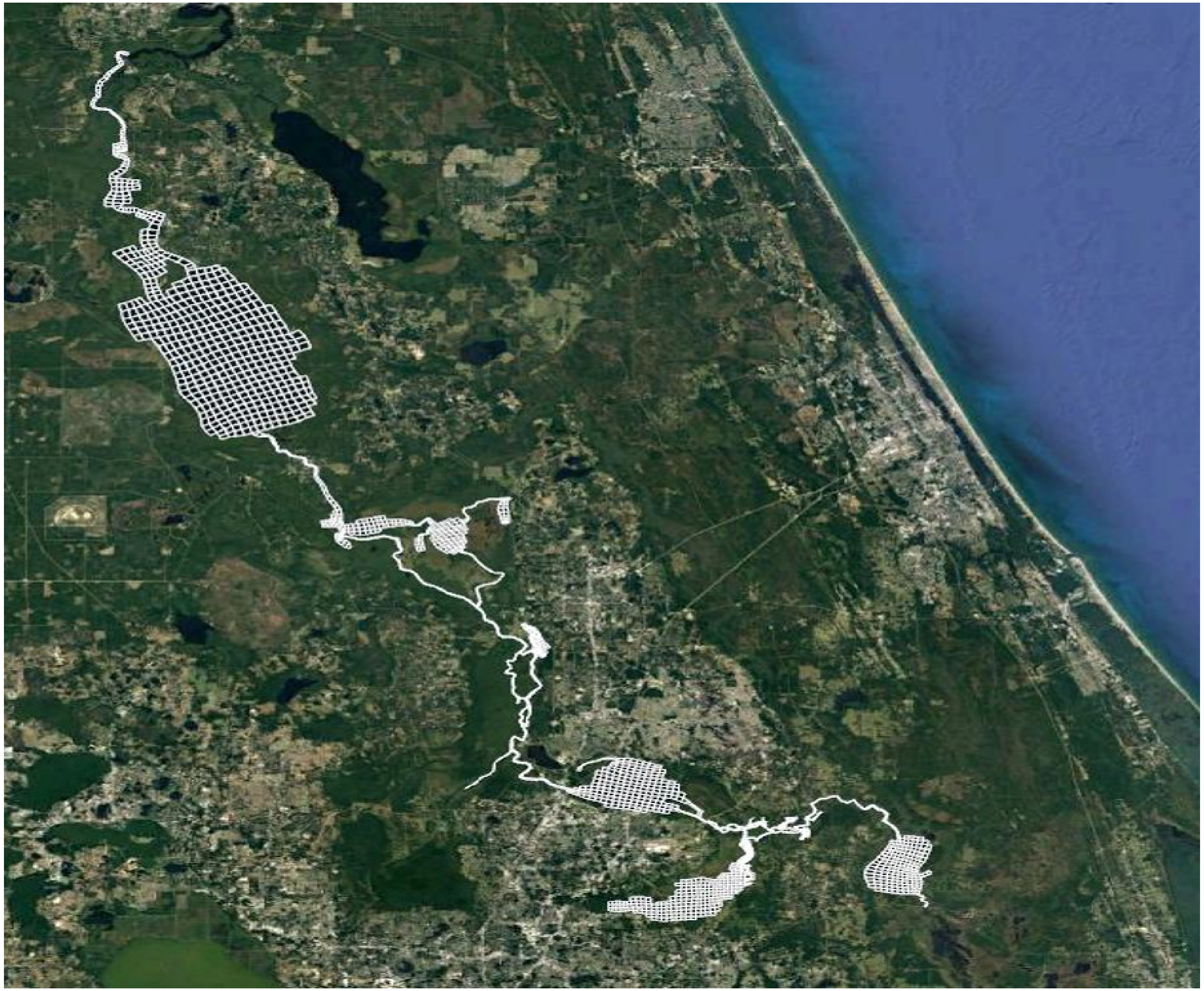


Figure 1

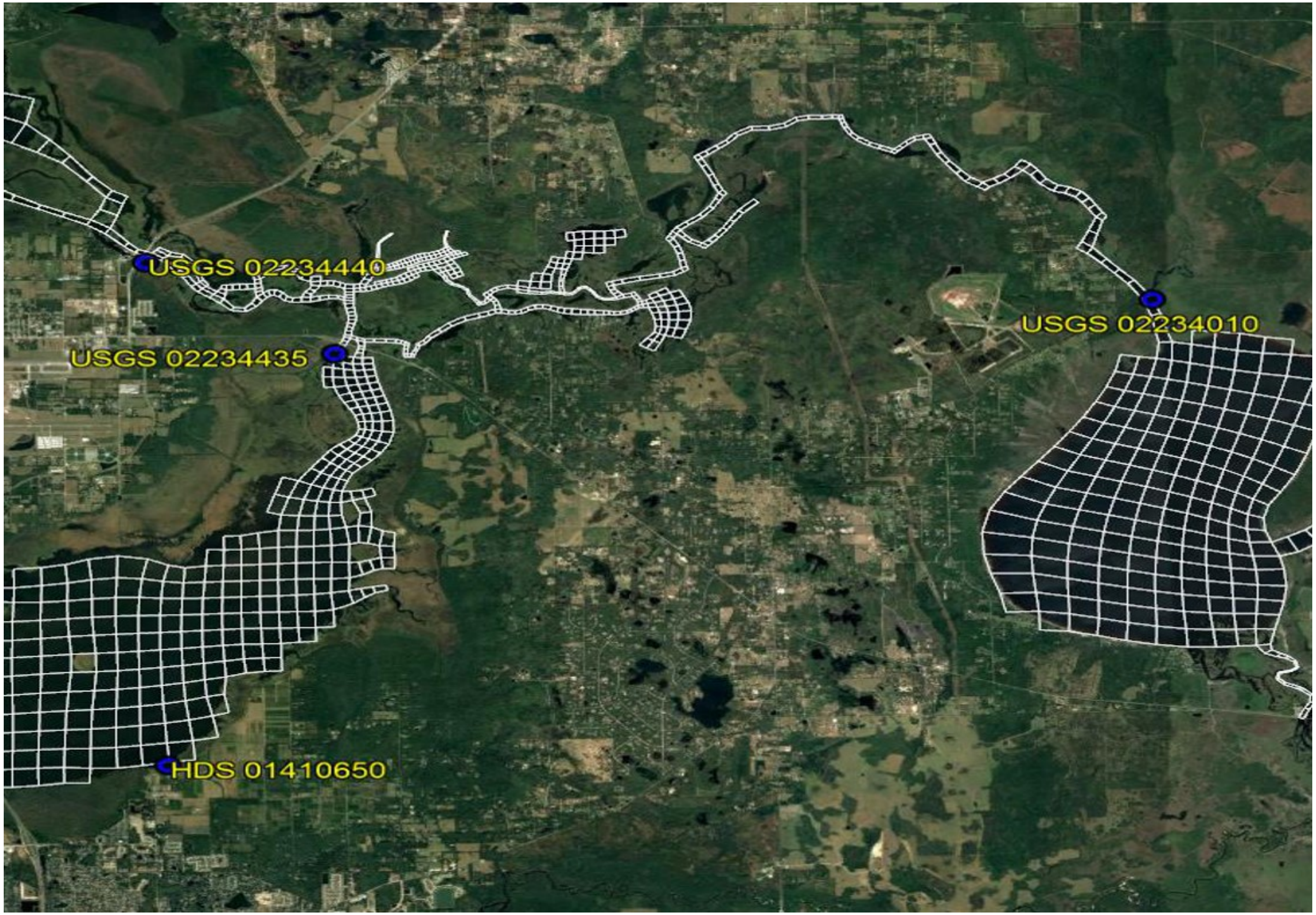


Figure 2

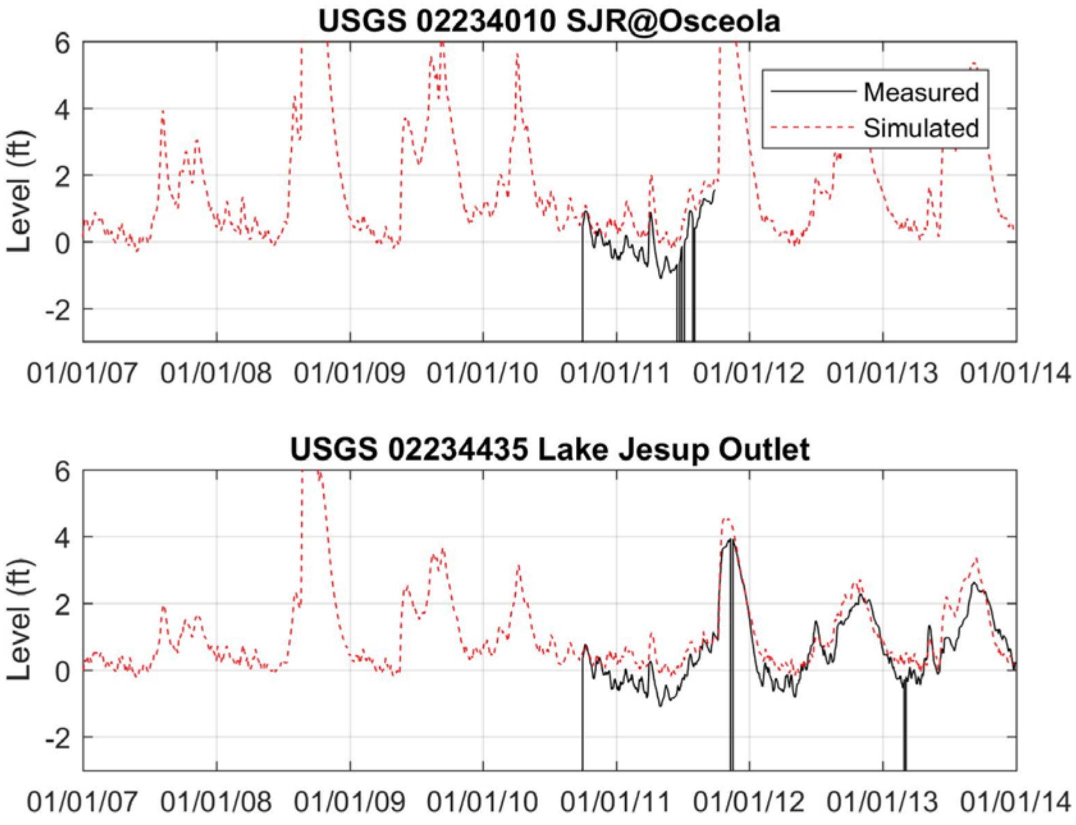


Figure 3a

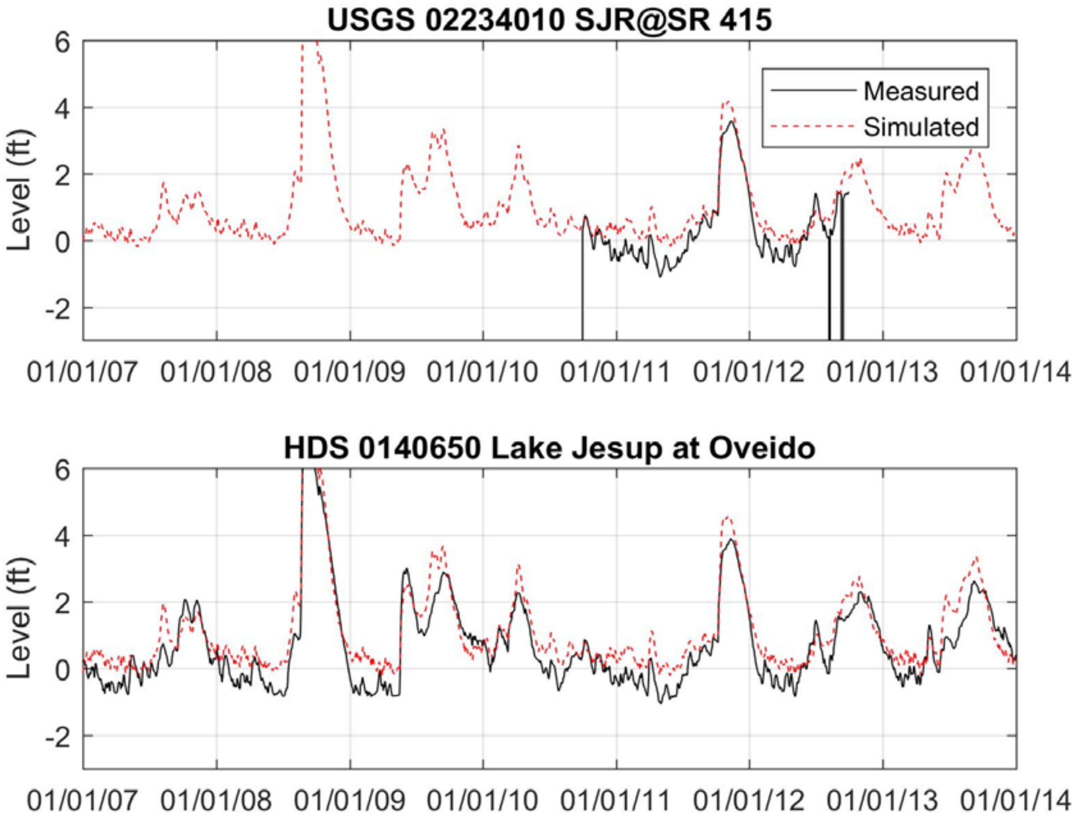
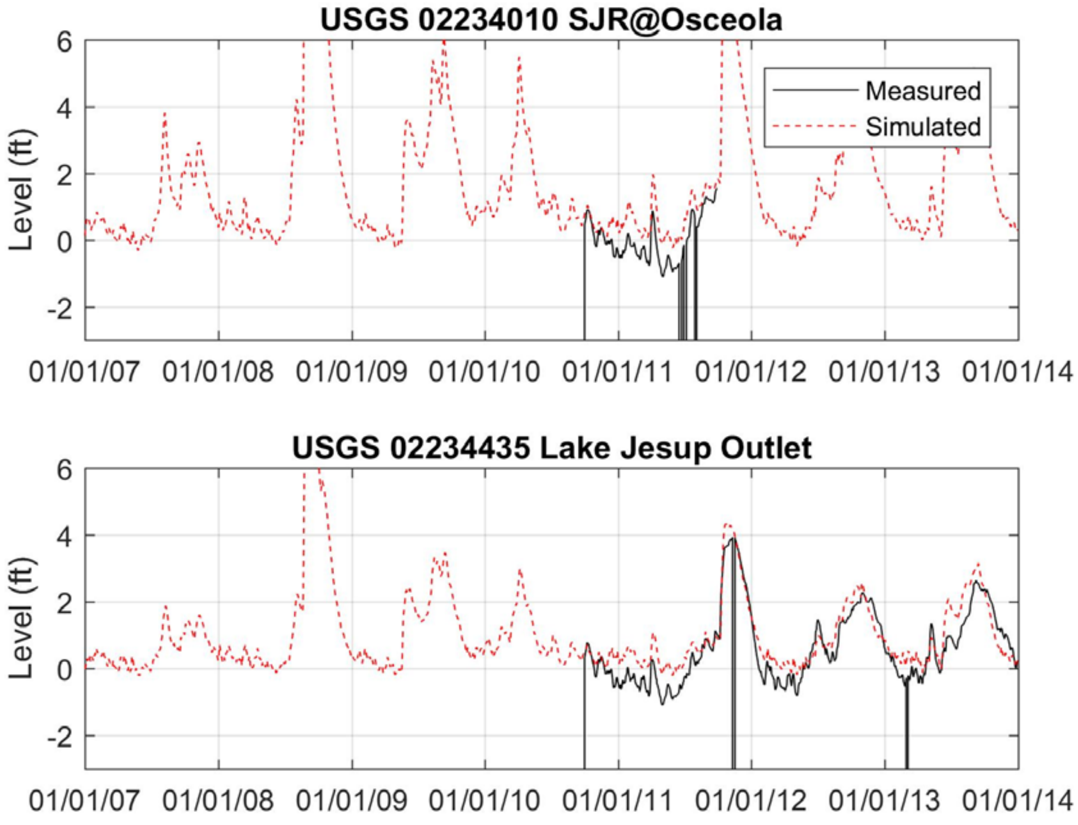
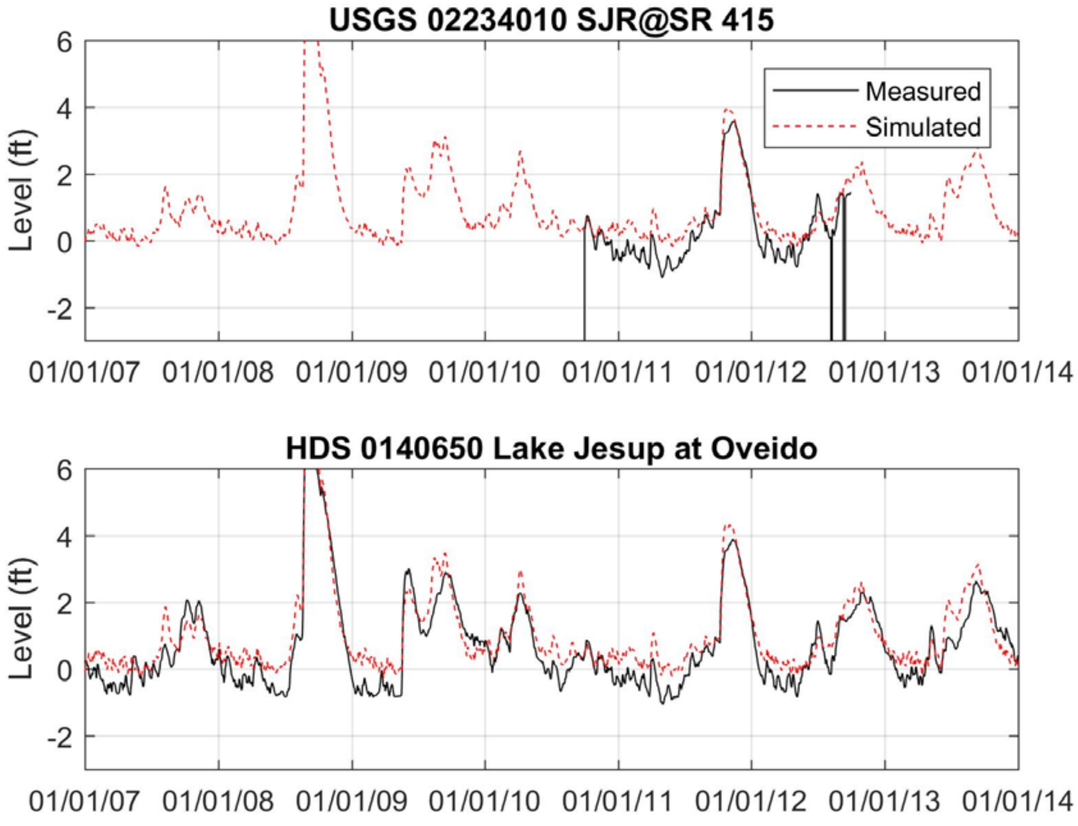


Figure 3b


USGS 02234010 SJR@Osceola

USGS 02234435 Lake Jesup Outlet

Figure 4a


USGS 02234010 SJR@SR 415

HDS 0140650 Lake Jesup at Oveido

Figure 4b

Figure 5a

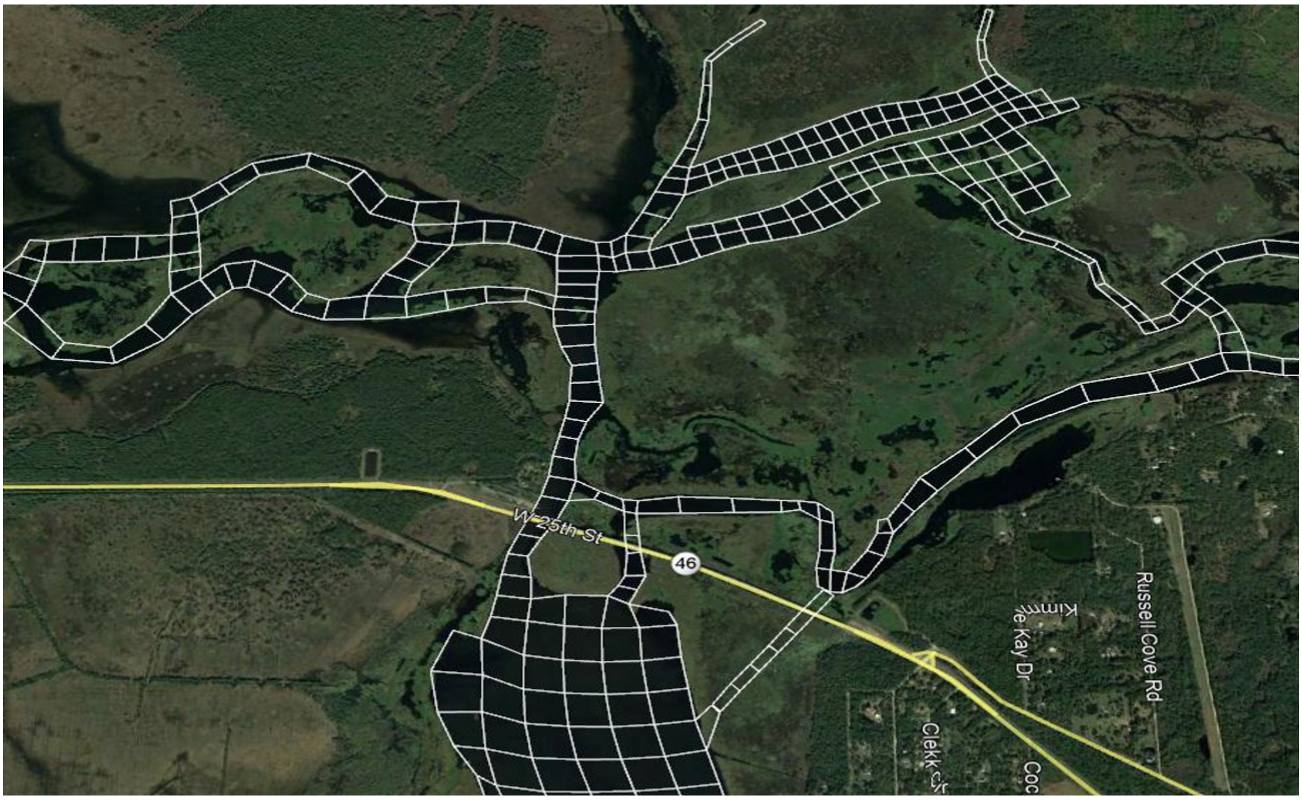
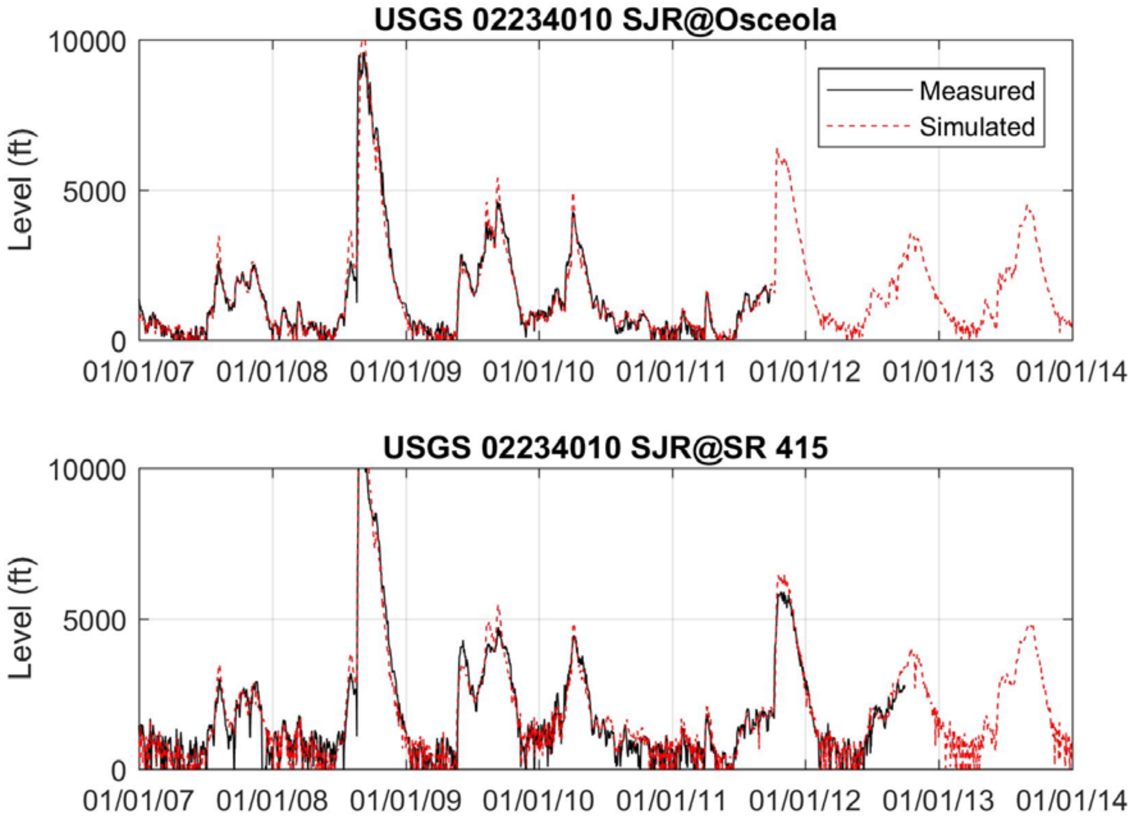


Figure 5b



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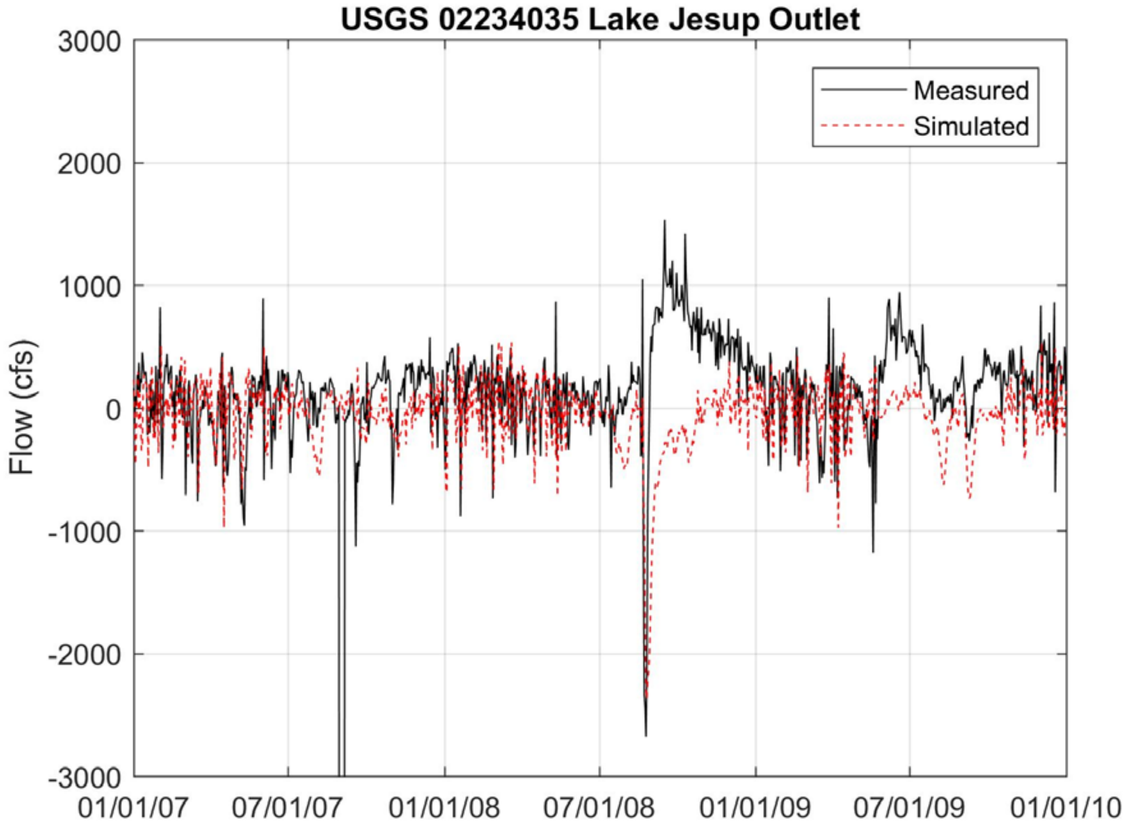

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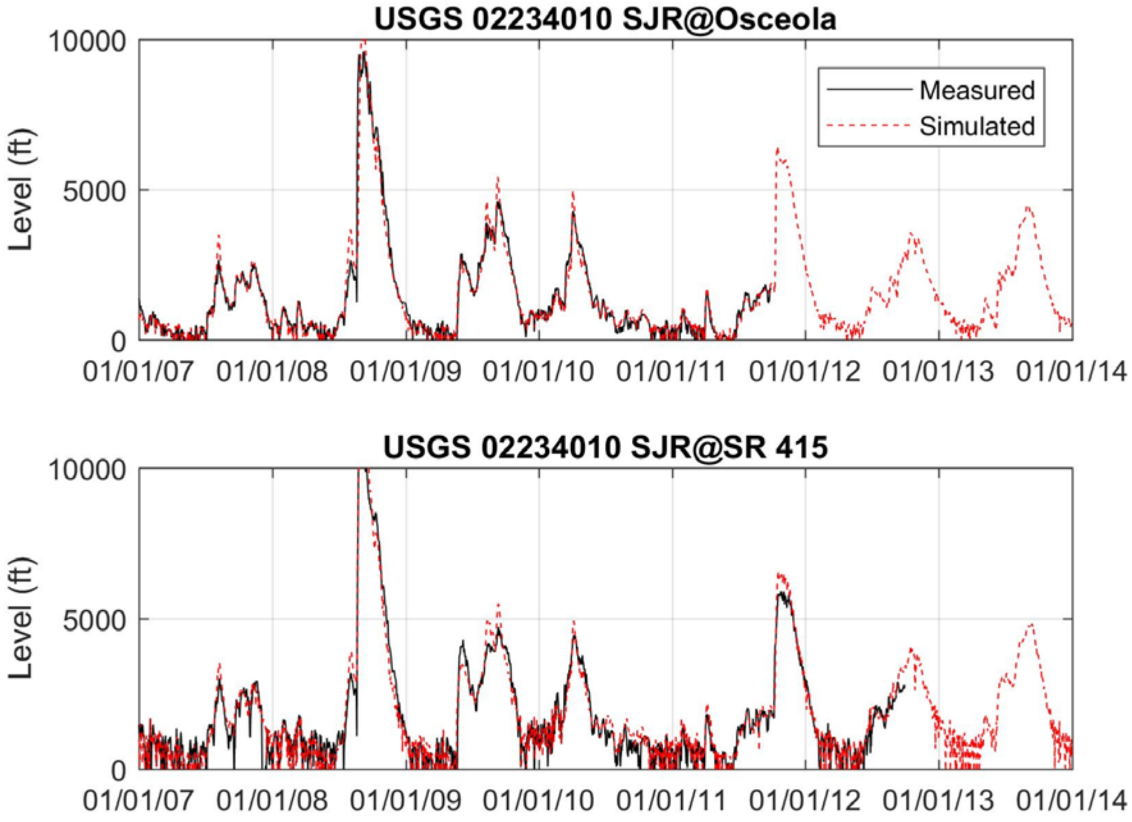

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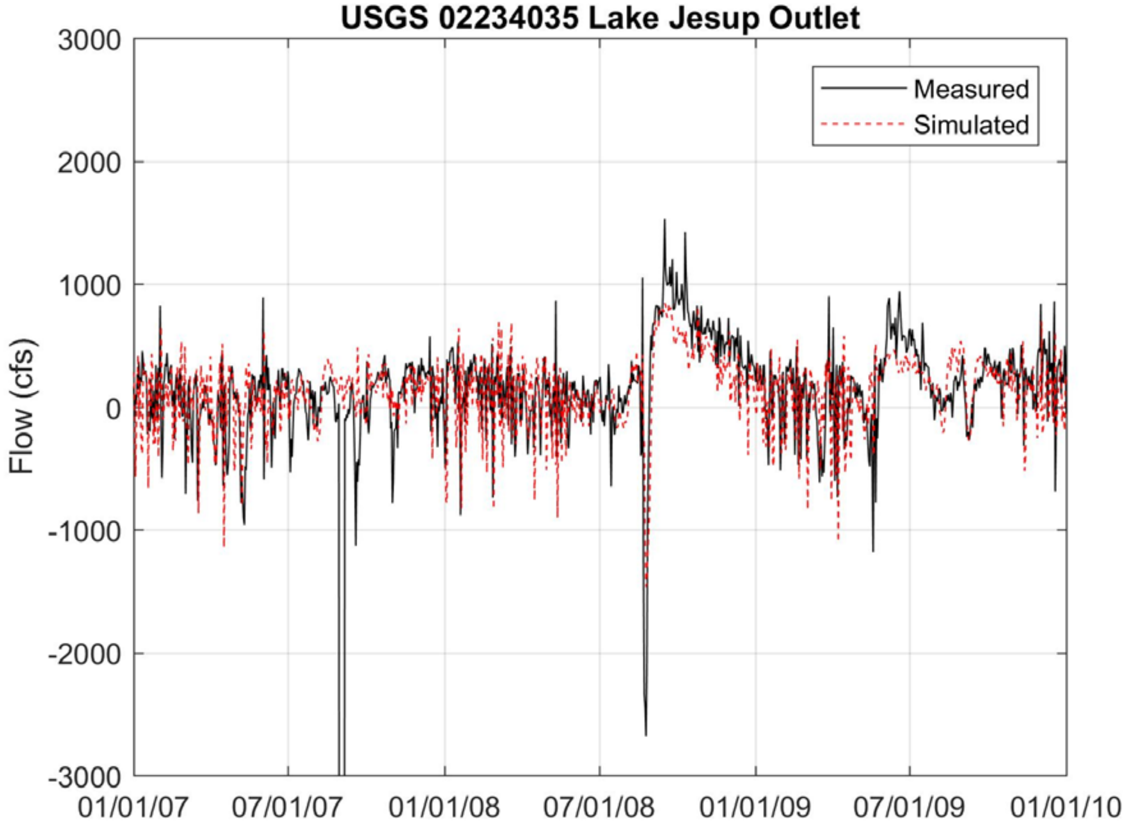


Figure 7b

Appendix C

Baseline Water Quality Model Development Technical Memorandum

TETRA TECH

MEMO

To:	Pete Sucsy, SJRWMD Derek Busby, SJRWMD
Cc:	Alan Foley, Jones Edmunds Steve Peene, ATM
From:	Rene Camacho, Tetra Tech Marcy Frick, Tetra Tech Brian Watson, Tetra Tech
Date:	July 6, 2018
Subject:	Flow Restoration Feasiblity Analysis for Lake Jesup, Seminole County, Florida Task 2: Water Quality Model Refinement and Baseline Simulation

1.0 SUMMARY

As part of the St. Johns River Water Management District (SJRWMD) efforts to investigate the potential impacts of a new channel connection between the St. Johns River (SJR) and Lake Jesup, an existing water quality model of the lake was updated to reflect the proposed connection and to facilitate the evaluation of different connection alternatives. The upgraded water quality model, hereafter known as the 2018 Lake Jesup Model (2018 LJM) was developed using the U.S. Environmental Protection Agency (USEPA) Water Quality Analysis Simulation Program (WASP). The baseline WASP model used was the Florida Department of Environmental Protection's 2017 Lake Jesup model (2017 LJM), which was updated by Tetra Tech as part of the Lake Jesup total maximum daily load reevaluation. The location of watershed boundaries and groundwater boundaries, as well as the time series of flows and water quality concentrations in the 2018 LJM are identical to those in the 2017 LJM. The only difference between the 2017 LJM and the 2018 LJM is that the latter includes a connection at Channel B, which was not shown as open in the 2017 LJM. The computational grid of the 2018 LJM is presented in **Figure 1**. The 2018 LJM is driven by hydrodynamic outputs from the Middle St. Johns River Environmental Fluid Dynamics model (MSJR-EFDC), which was updated by Applied Technology and Management as part of Task 1 of this project.

To demonstrate the functionality of the 2018 LJM, the model was executed from 1/31/2007 through 12/31/2014 using hydrodynamic outputs from the MSJR-EFDC for the same simulation period. The outputs of dissolved oxygen (DO), total nitrogen (TN), total phosphorus (TP), chlorophyll-a (Chla), and sediment nutrient fluxes from the 2018 LJM were then compared to the outputs from the 2017 LJM at selected monitoring stations (**Figure 1**). The purpose of the comparison was to ensure the 2018 LJM setup provided consistent results with the calibrated and validated 2017 LJM and, therefore, the 2018 LJM could be used as a predictive tool to evaluate the potential impacts of additional channel connections on the lake's water quality.

The comparison results are presented from **Figure 2** through **Figure 37** as follows: **Figure 2** through **Figure 7** show the comparison of TN model outputs, **Figure 8** through **Figure 13** show the comparison of TP model outputs, **Figure 14** through **Figure 19** show the comparison of Chla model outputs, **Figure 20** through **Figure 25** show the comparison of DO model outputs, and **Figure 26** through **Figure 37** show the comparison of sediment nutrient fluxes and sediment oxygen demand outputs.

The comparison results showed in general a good agreement between the 2018 LJM and the 2017 LJM outputs. Slight differences in model outputs were attributed to Channel B being open in the 2018 LJM. In particular, the mass exchanges occurring through this channel seem to cause a reduction in concentration for most of the simulated water quality variables in comparison with the results obtained from the 2017 LJM.

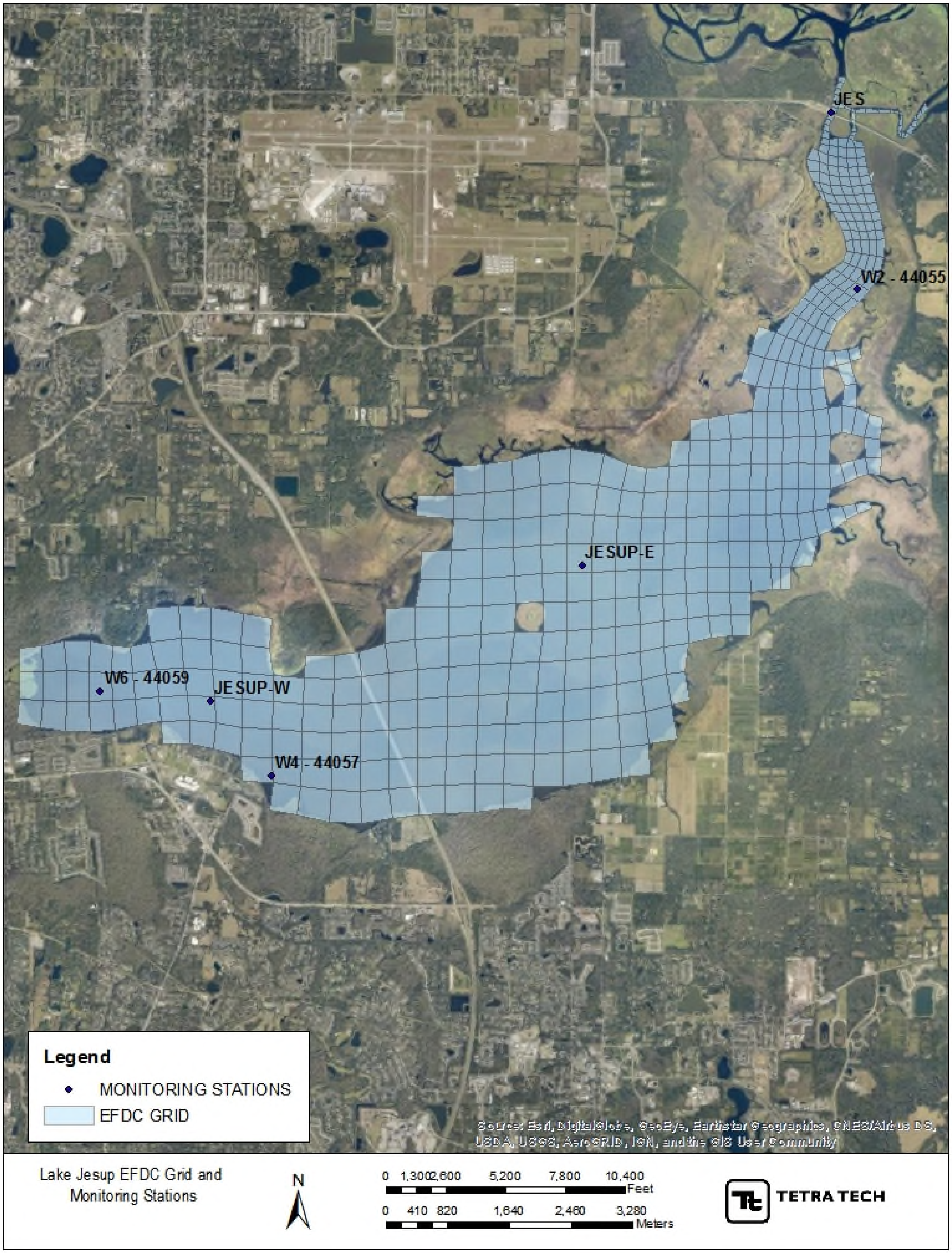


Figure 1. 2018 Lake Jesup model grid and location of selected monitoring stations for comparison analysis

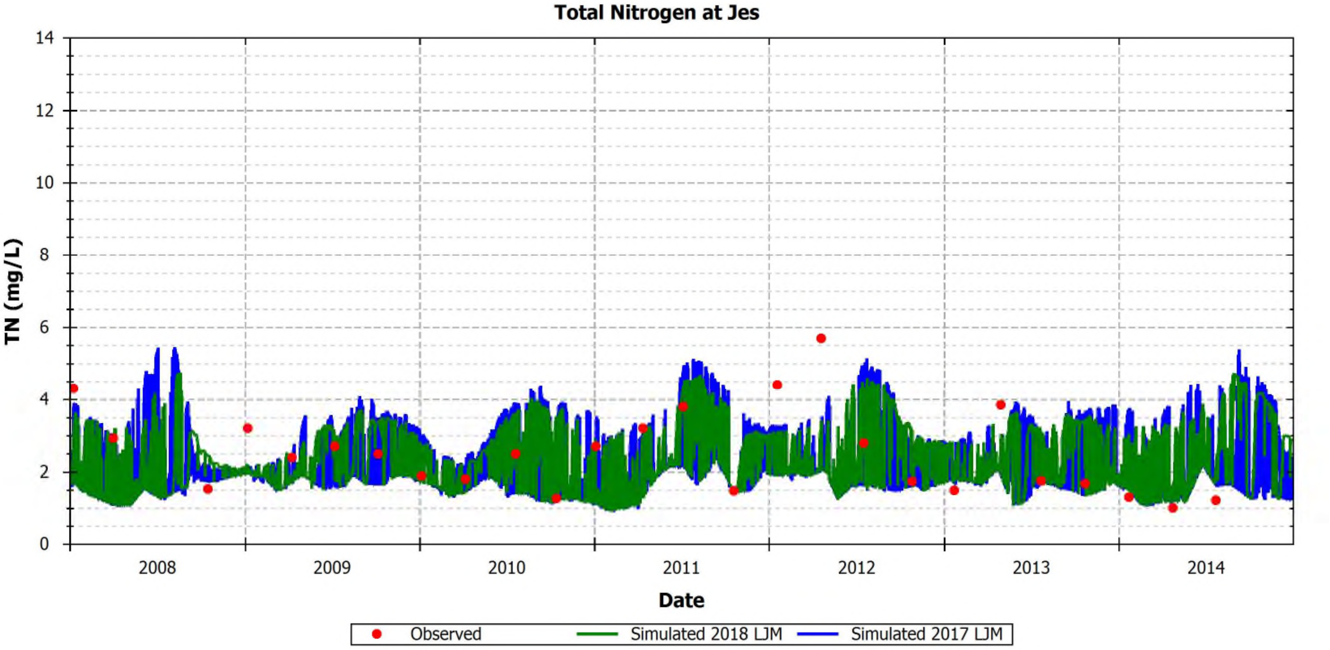


Figure 2. TN model comparison results at Jes

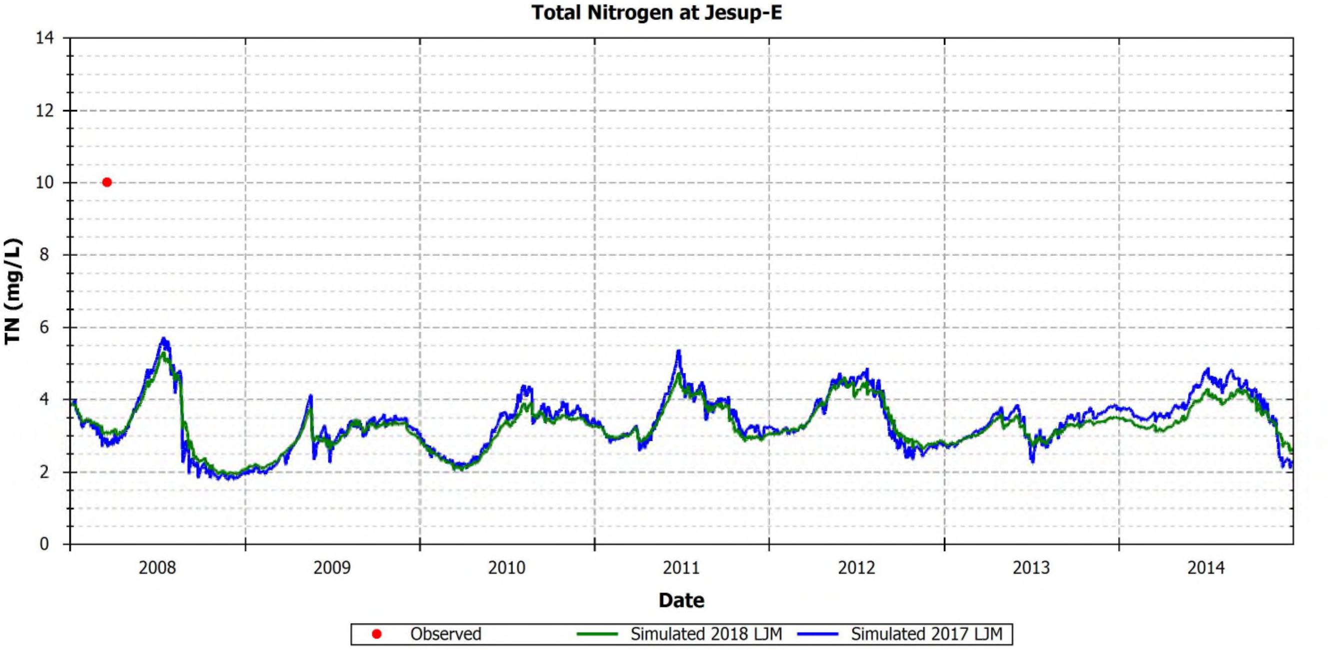


Figure 3. TN model comparison results at Jesup-E

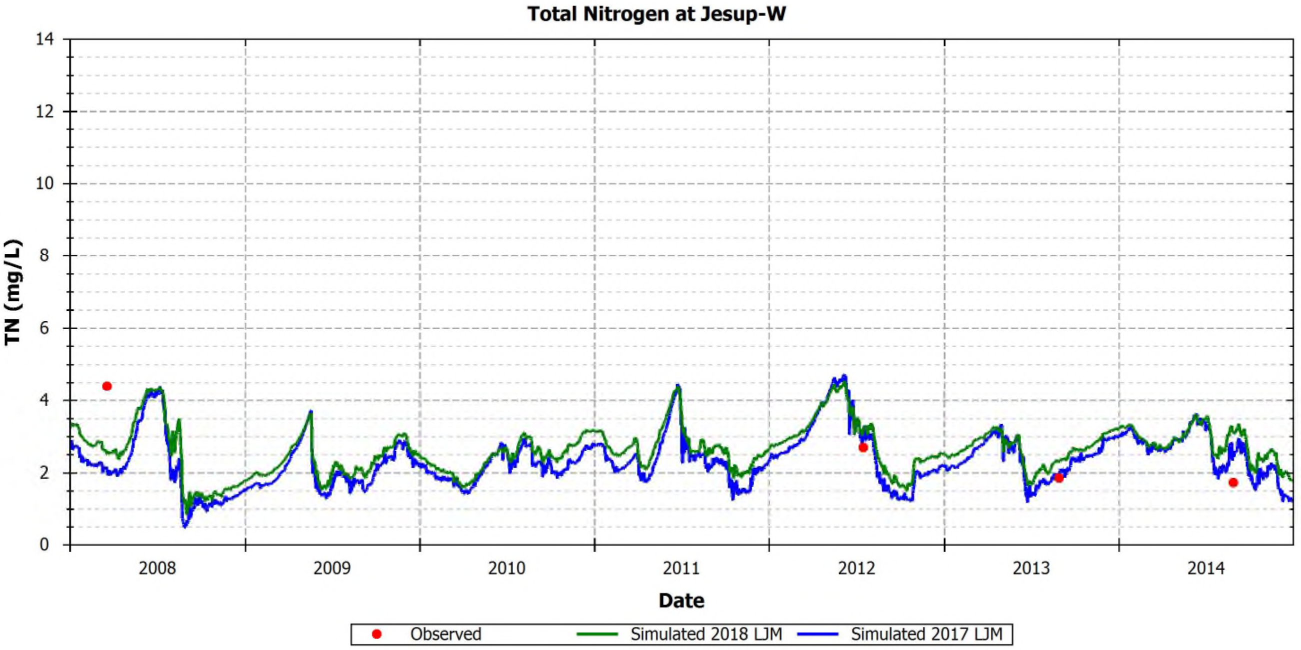


Figure 4. TN model comparison results at Jesup-W

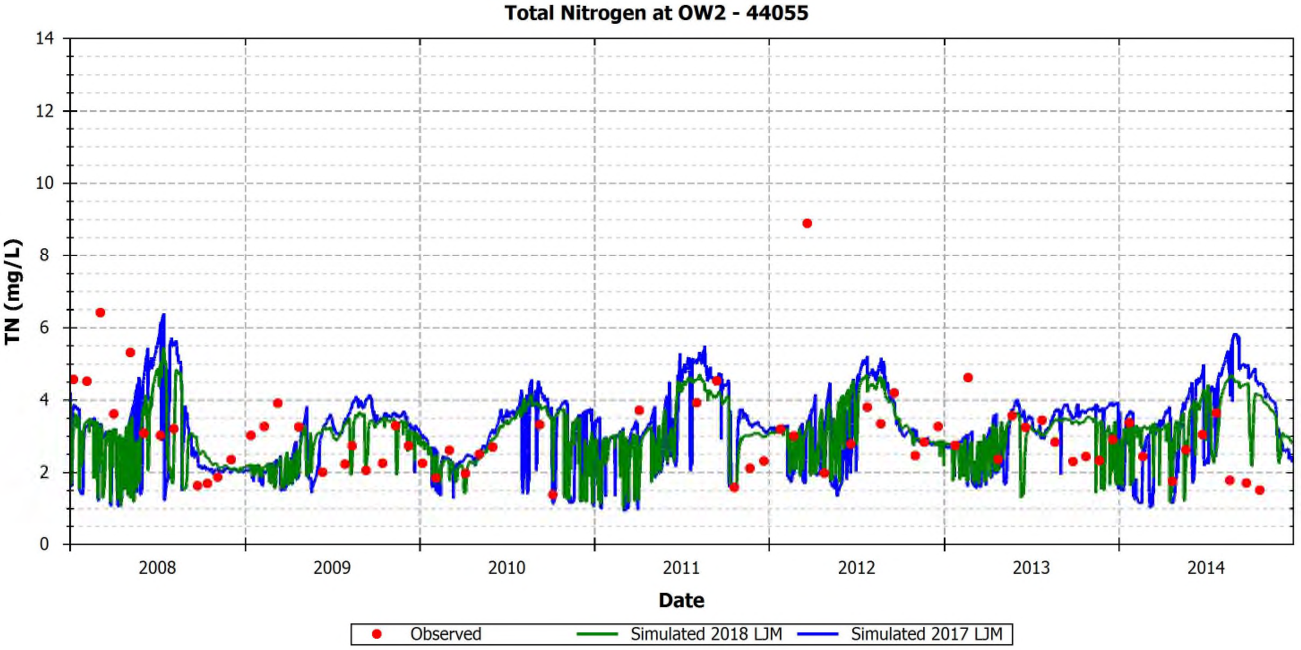


Figure 5. TN model comparison results at OW2 - 44055

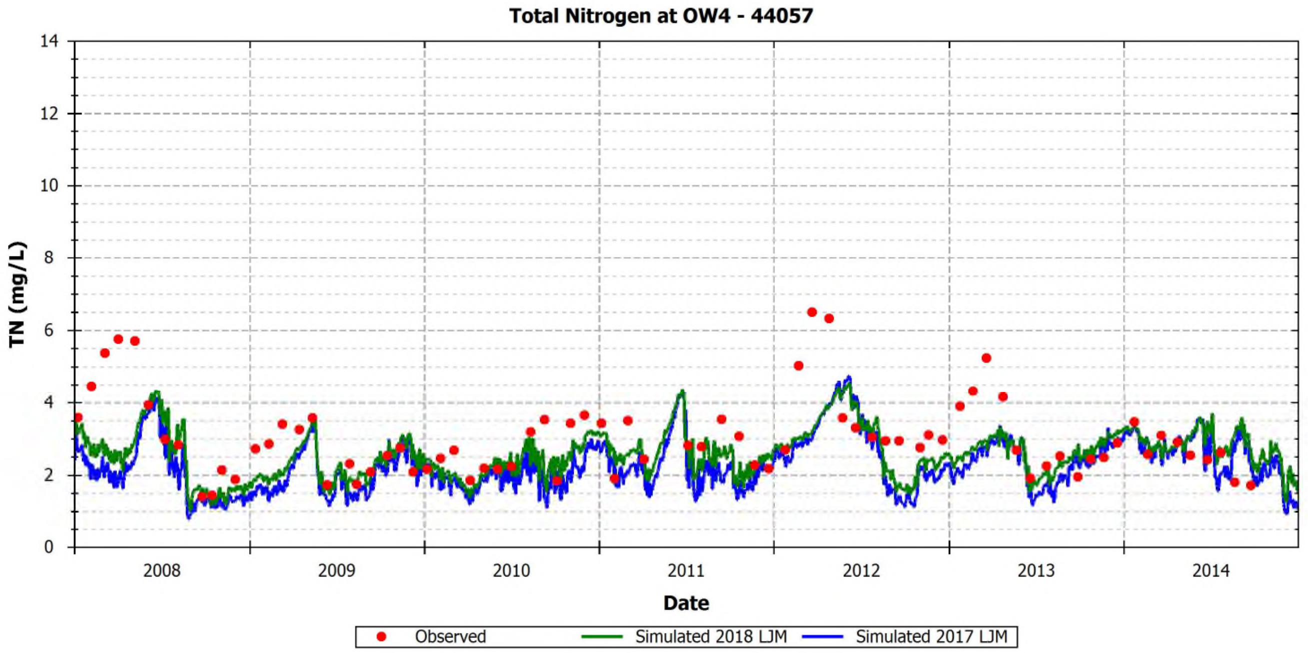


Figure 6. TN model comparison results at OW4 - 44057

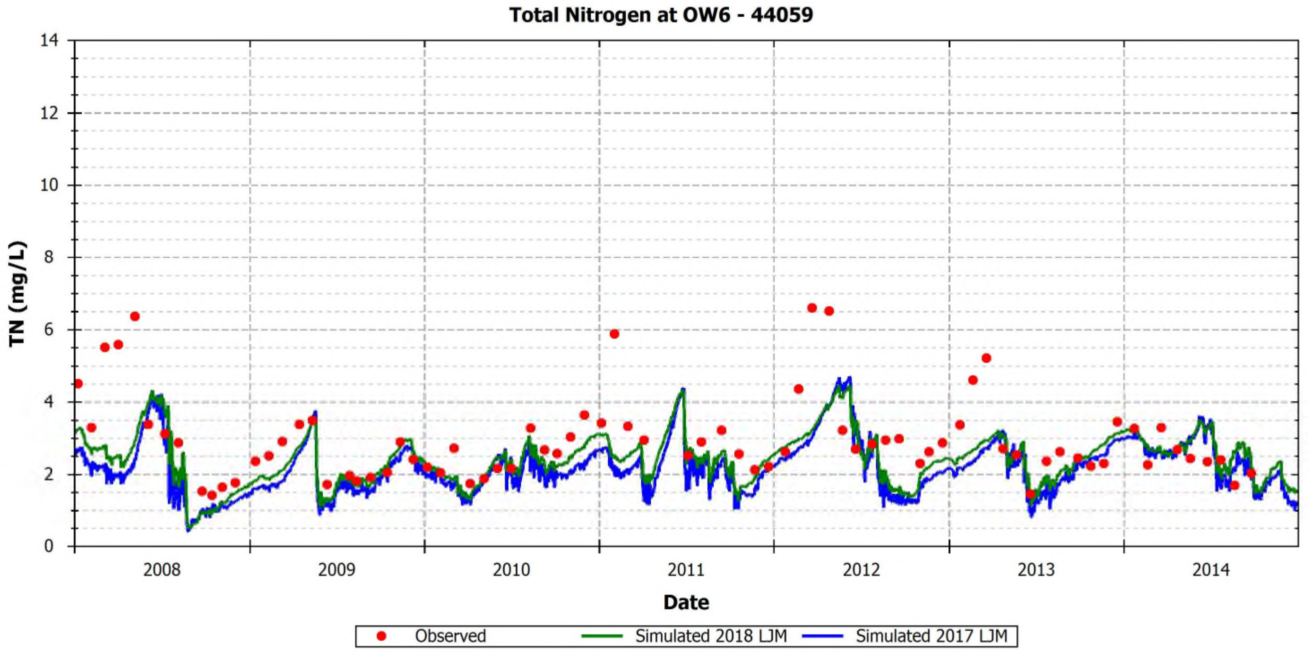


Figure 7. TN model comparison results at OW6 - 44059

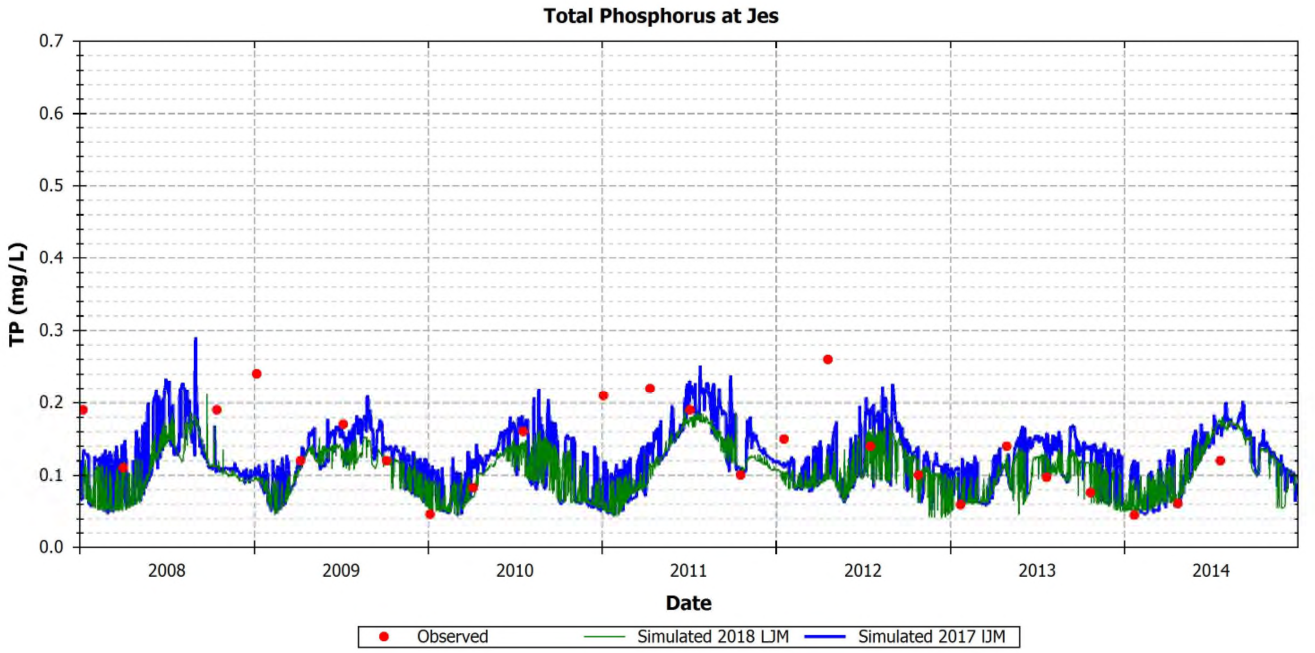


Figure 8. TP model comparison results at Jes

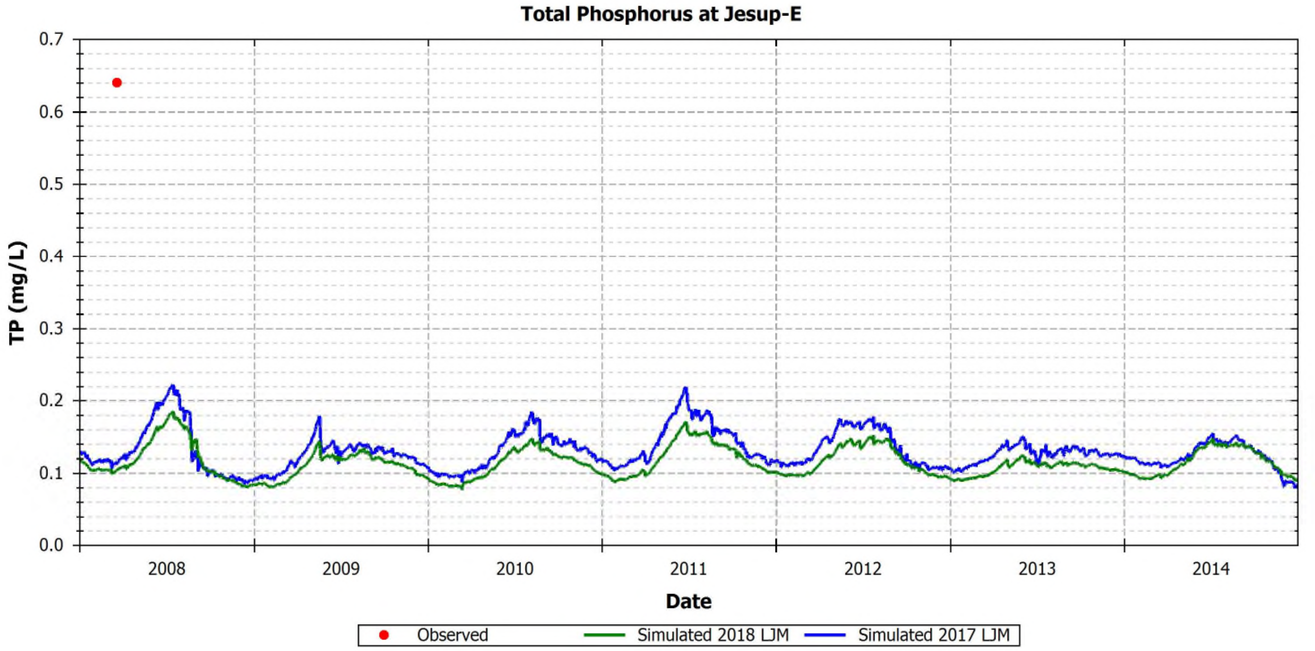


Figure 9. TP model comparison results at Jesup-E

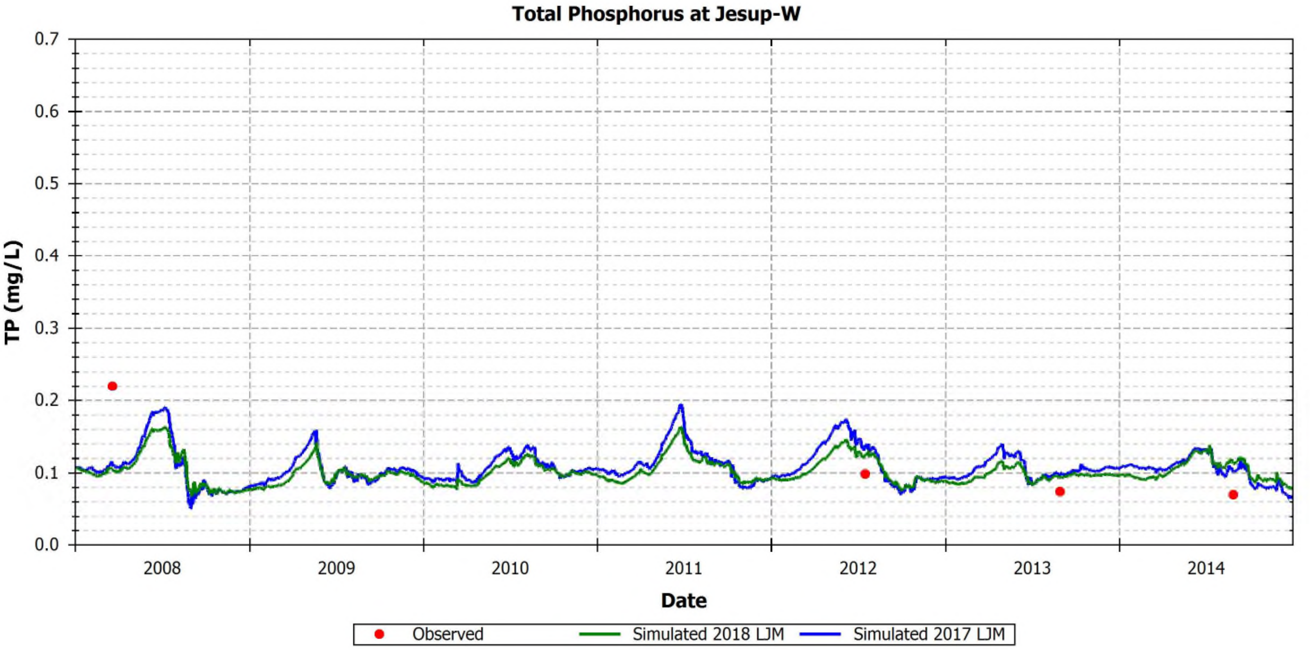


Figure 10. TP model comparison results at Jesup-W

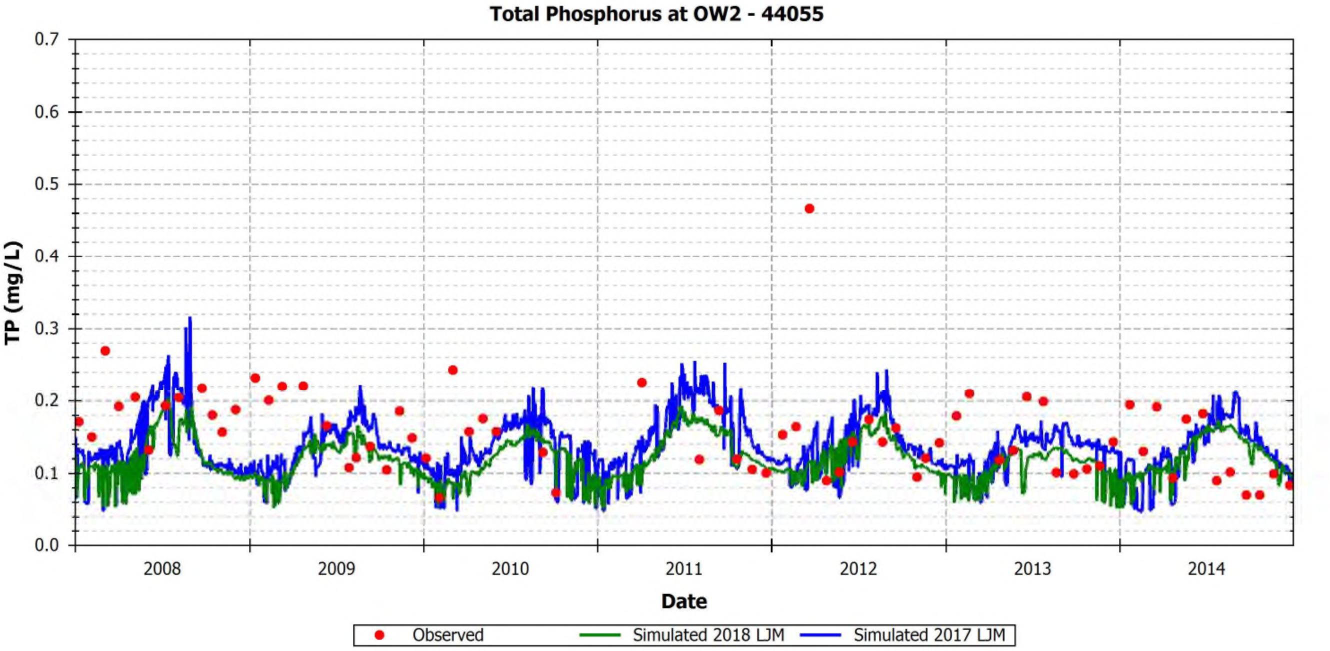


Figure 11. TP model comparison results at OW2 - 44055

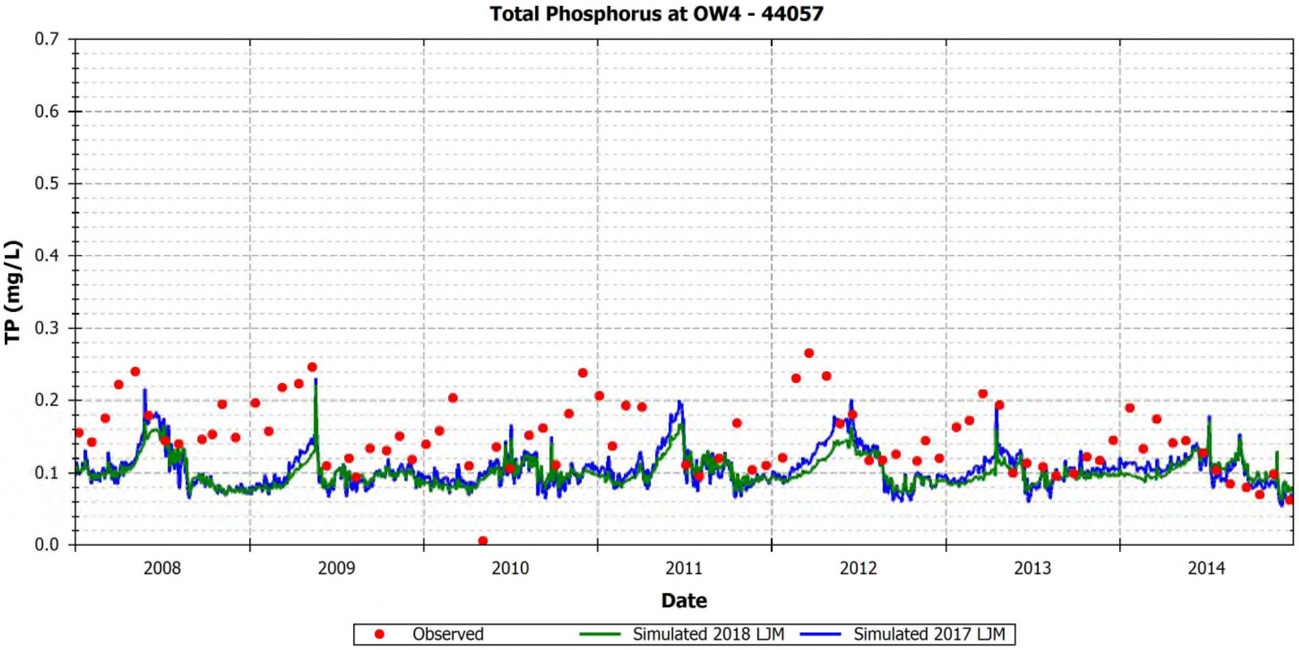


Figure 12. TP model comparison results at OW4 - 44057

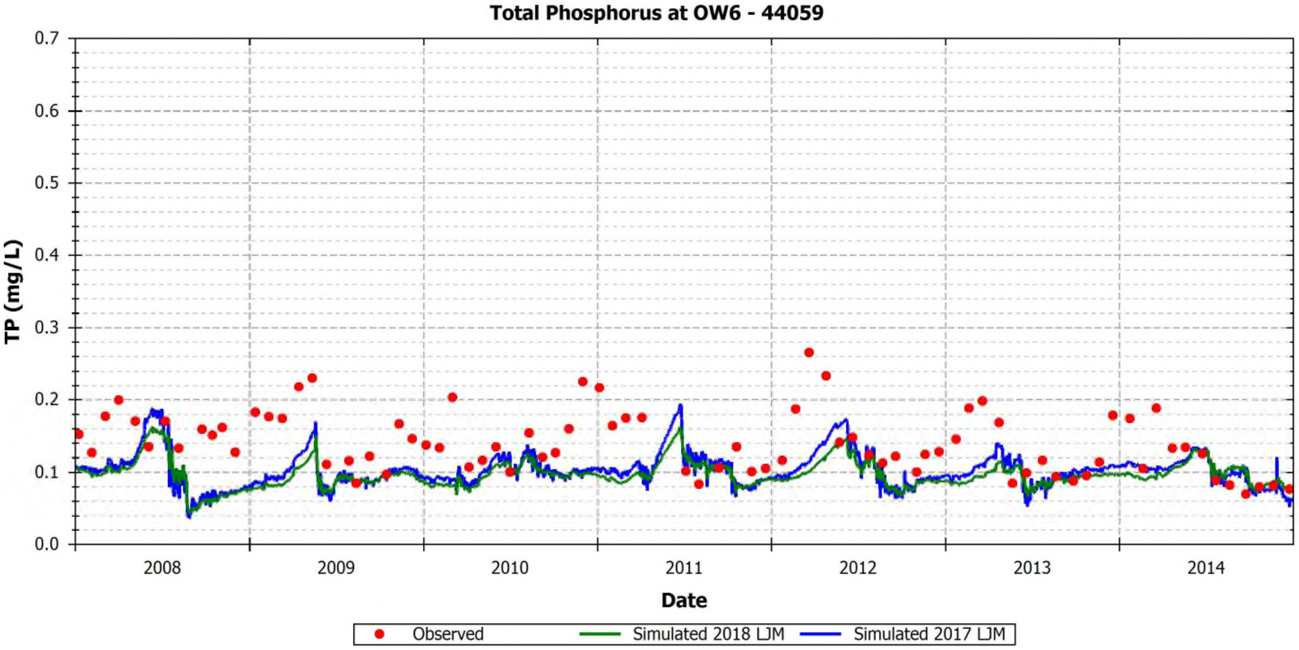


Figure 13. TP model comparison results at OW6 - 44059

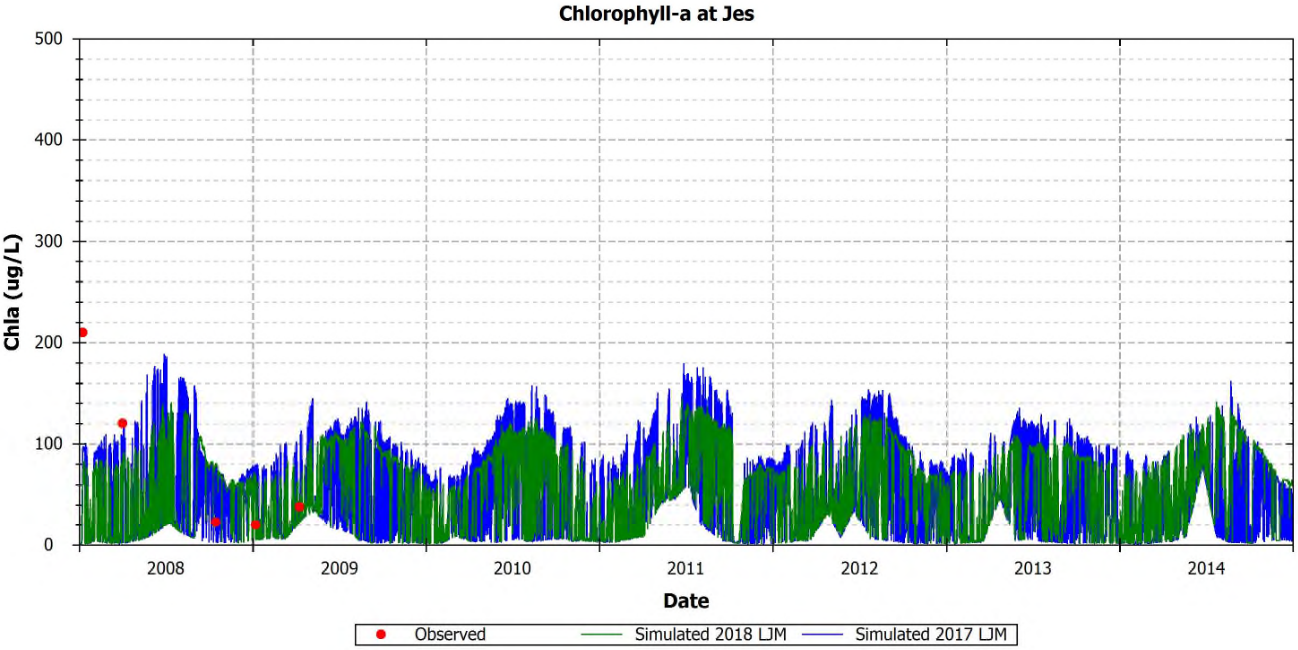


Figure 14. Chlorophyll-a model comparison results at Jes

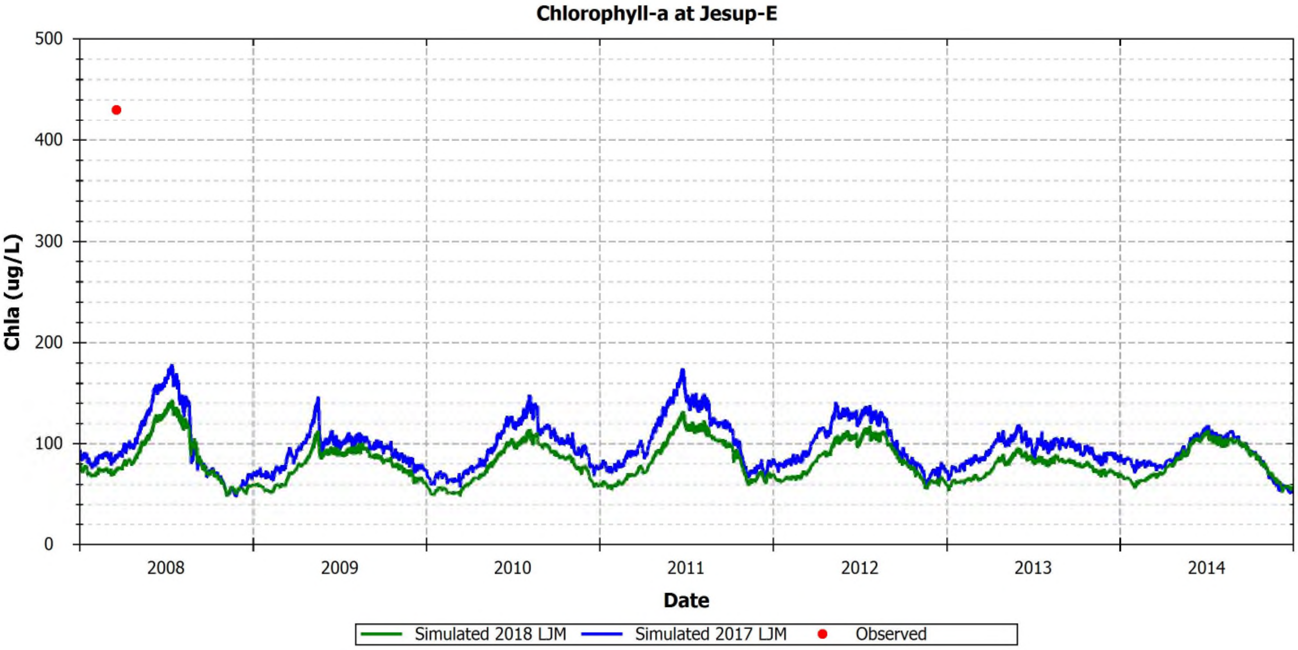


Figure 15. Chlorophyll-a model comparison results at Jesup-E

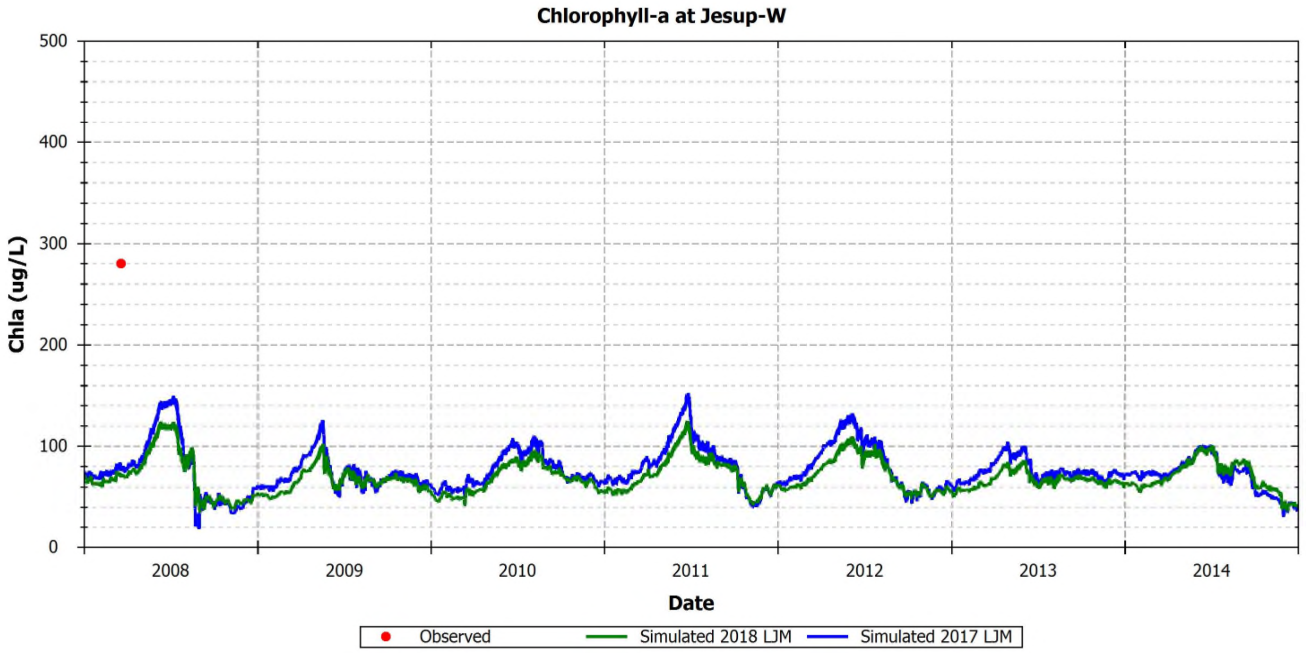


Figure 16. Chlorophyll-a model comparison results at Jesup-W

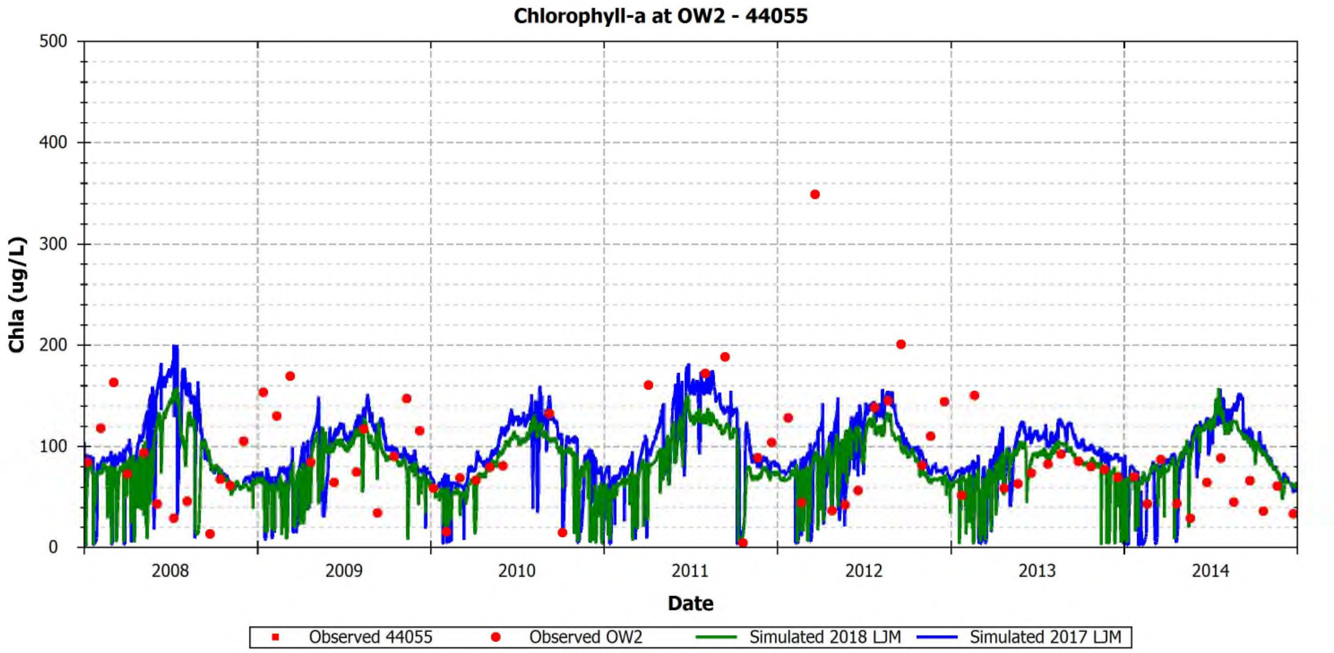


Figure 17. Chlorophyll-a model comparison results at OW2 - 44055

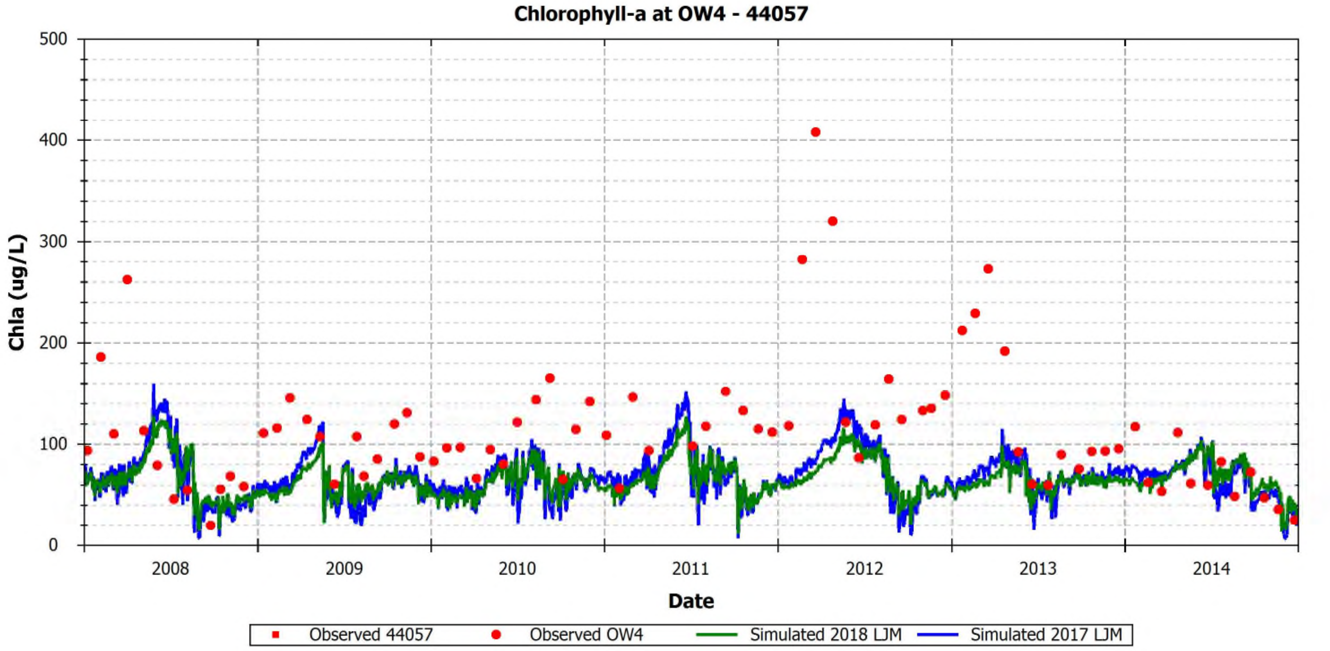


Figure 18. Chlorophyll-a model comparison results at OW4 - 44057

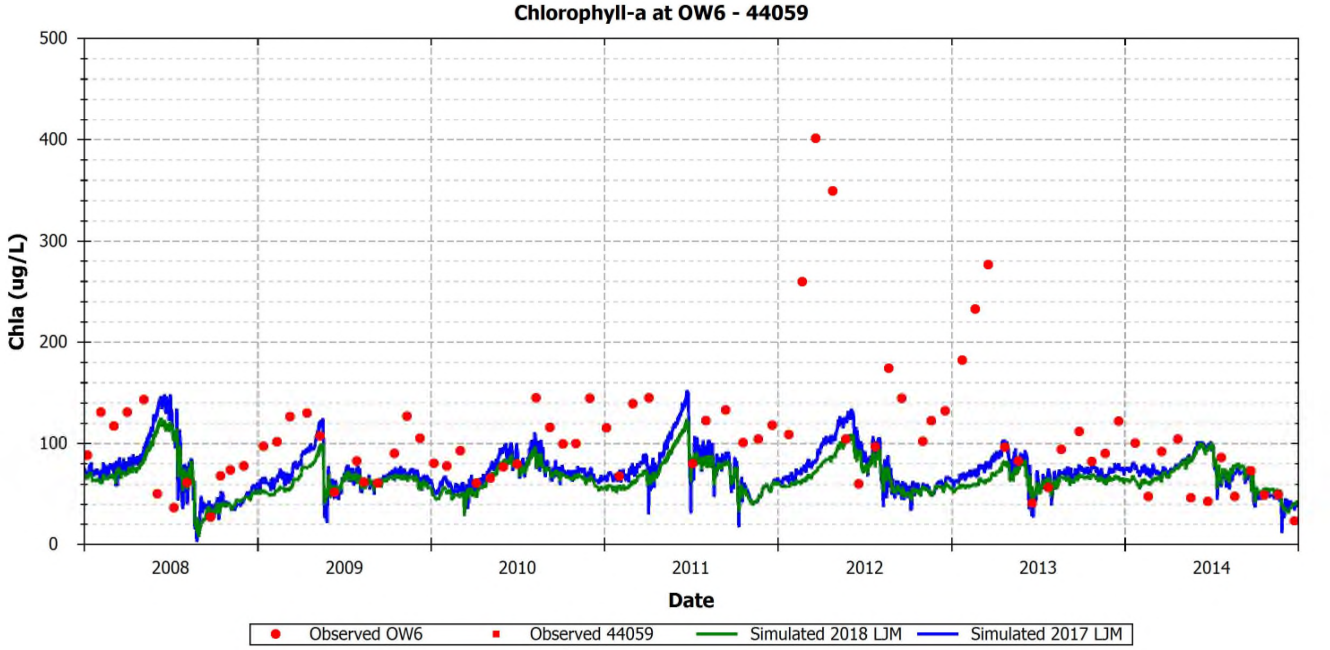


Figure 19. Chlorophyll-a model comparison results at OW6 - 44059

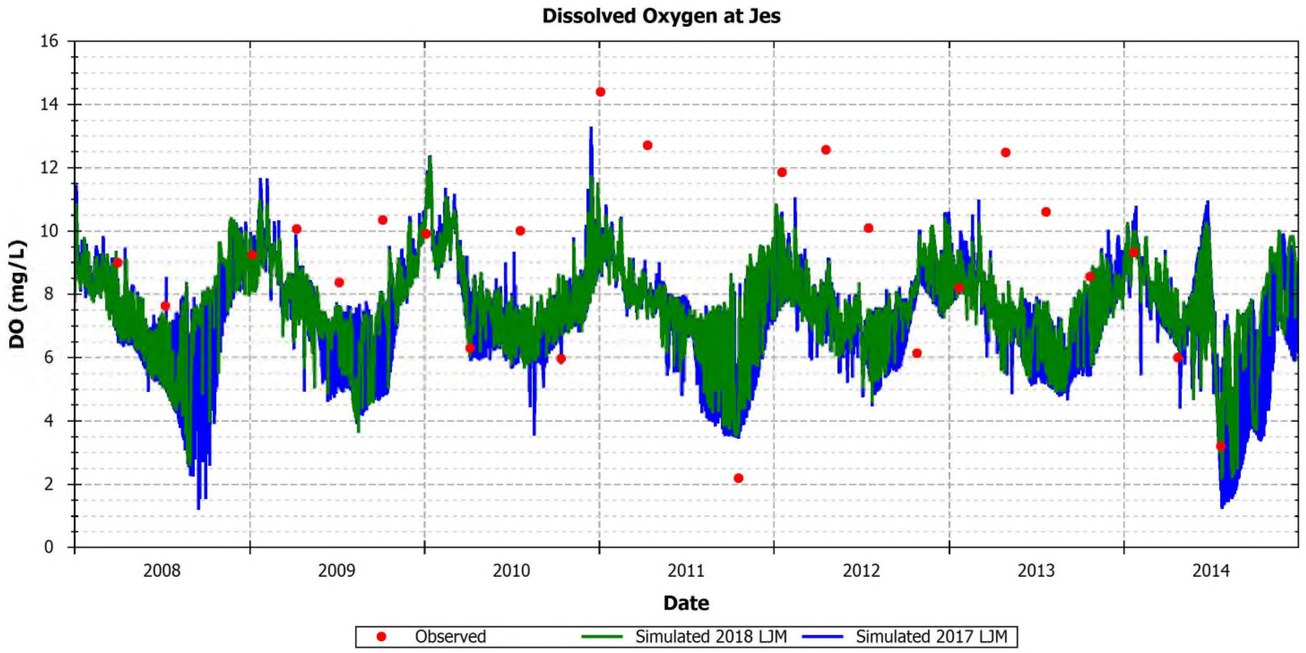


Figure 20. DO model comparison results at Jes

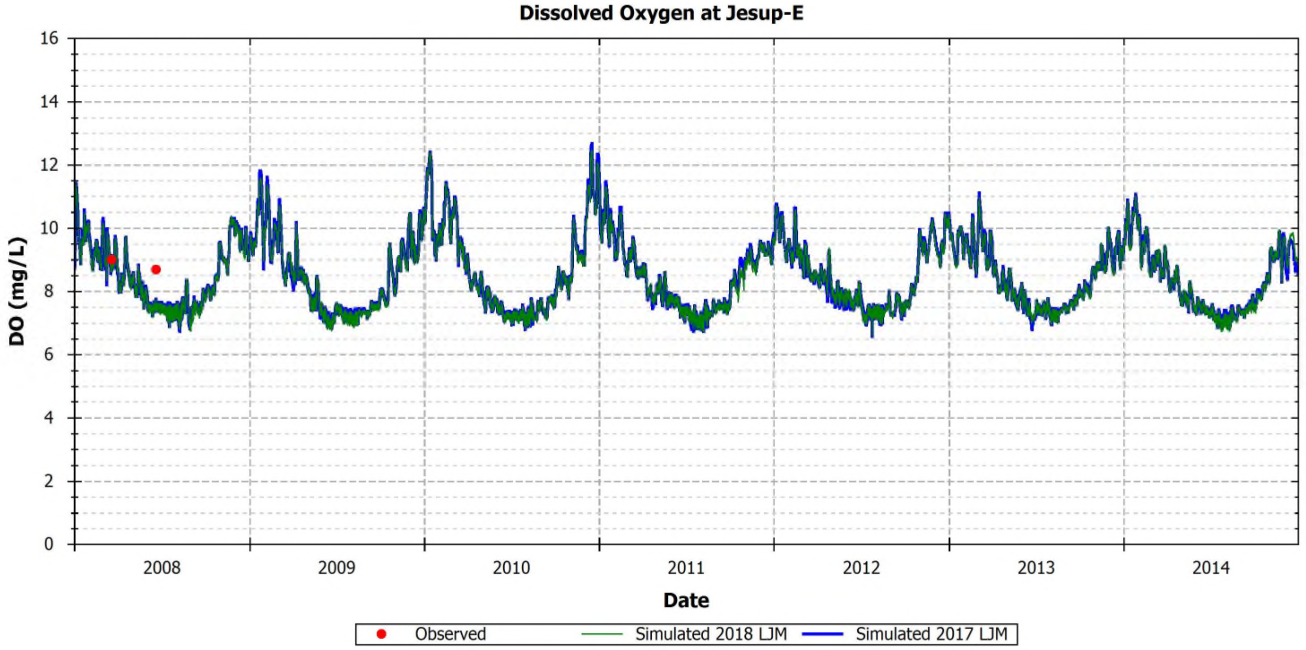


Figure 21. DO model comparison results at Jesup-E

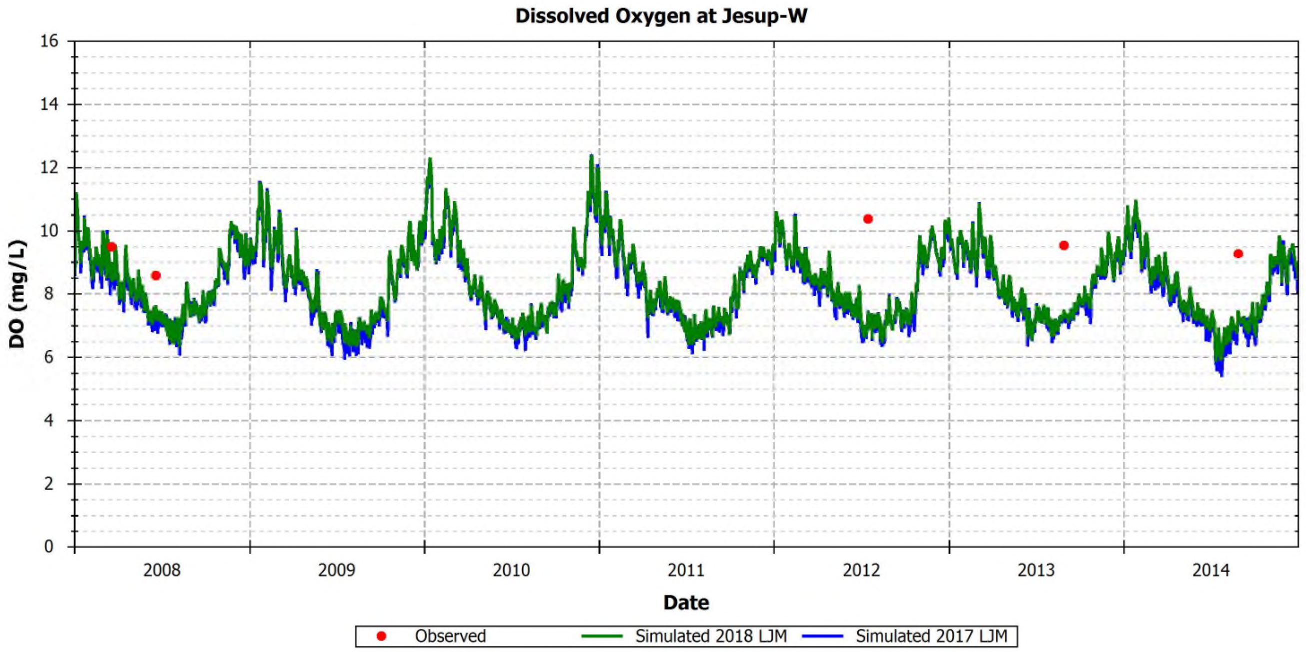


Figure 22. DO model comparison results at Jesup-W

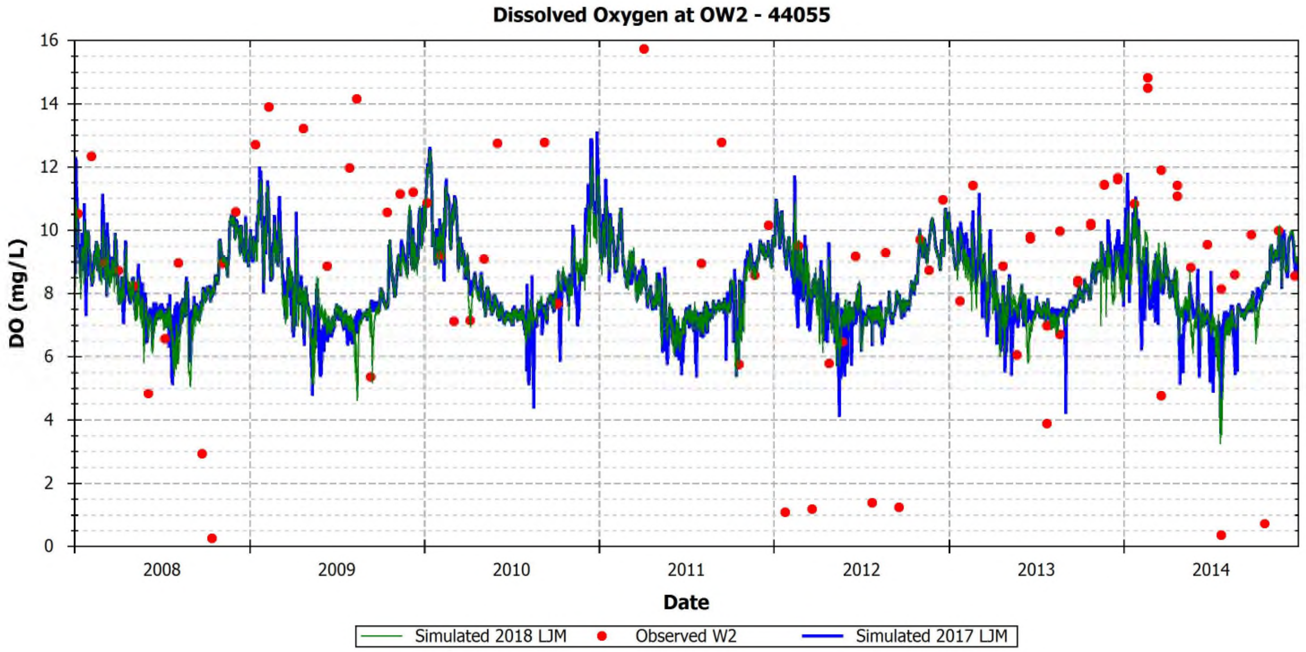


Figure 23. DO model comparison results at OW2 - 44055

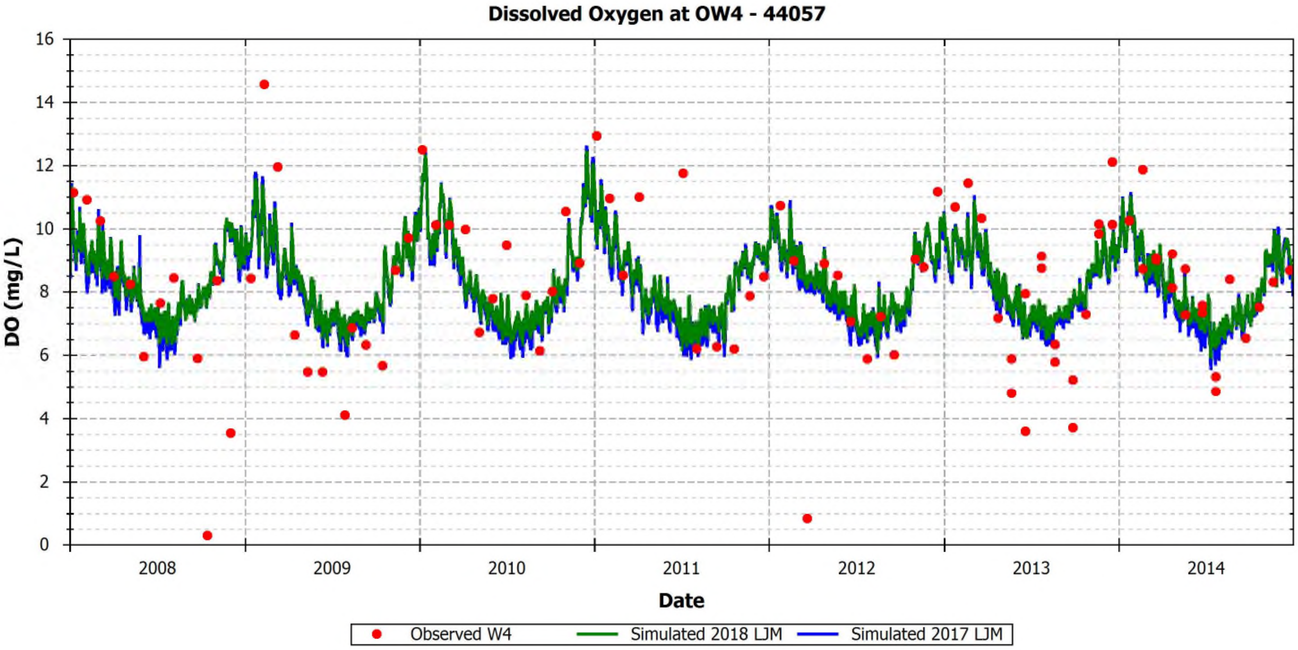


Figure 24. Dissolved Oxygen model comparison results at OW4 – 44057

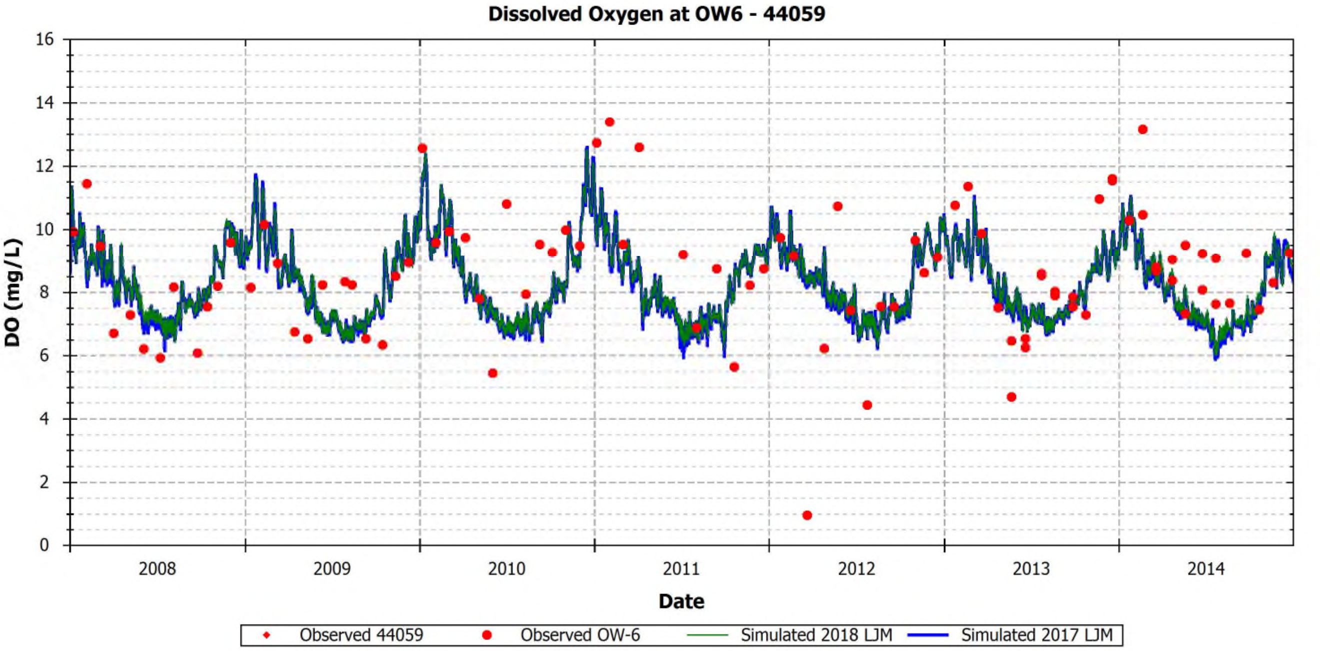


Figure 25. Dissolved Oxygen model comparison results at OW6 - 44059

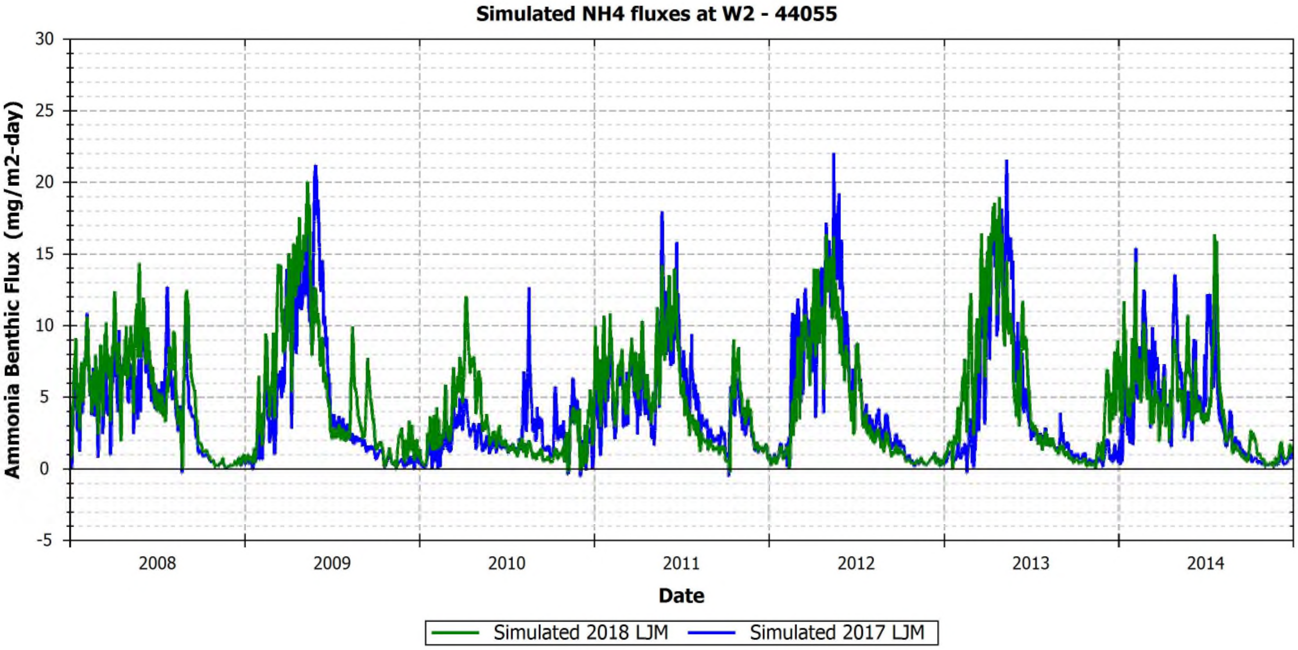


Figure 26. Ammonia/Ammonium sediment flux model comparison results at OW2 - 44055

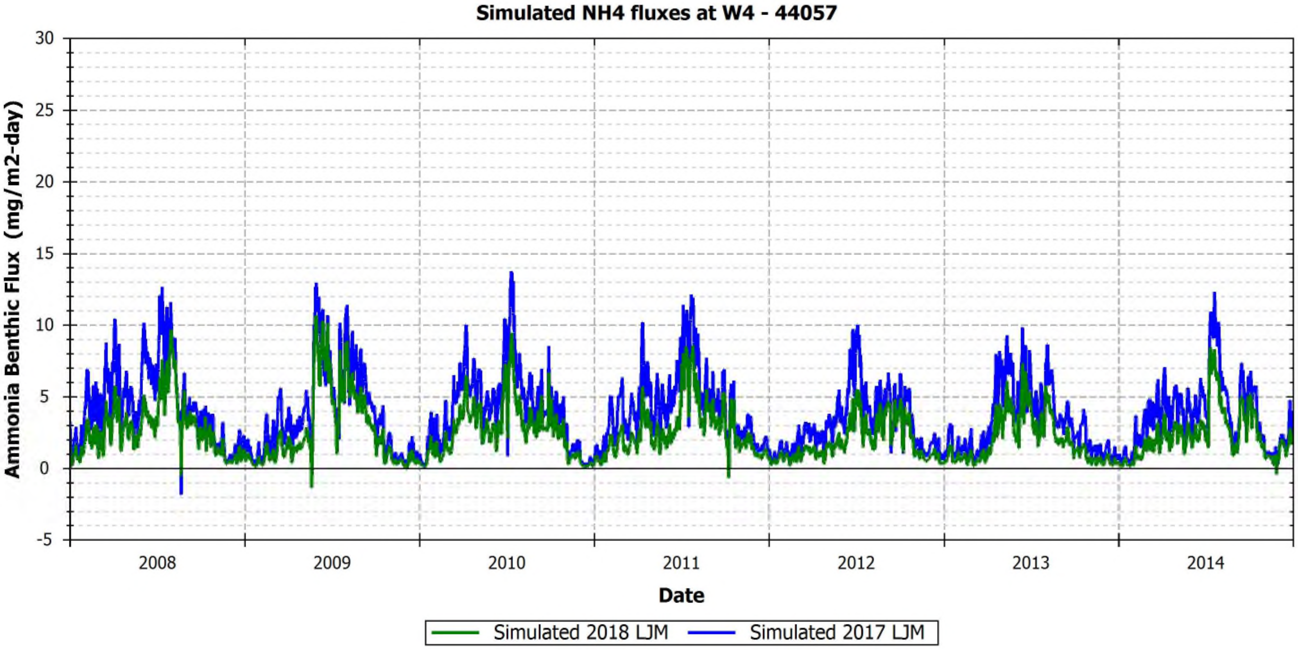


Figure 27. Ammonia/Ammonium sediment flux model comparison results at OW4 - 44057

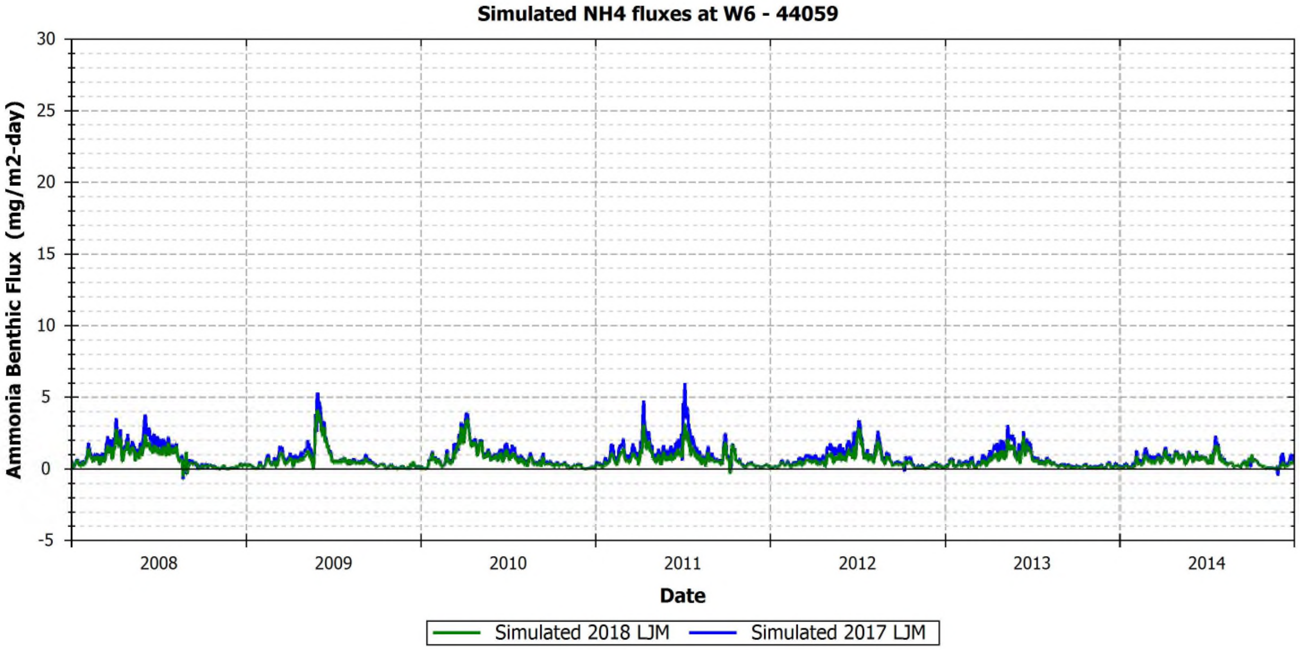


Figure 28. Ammonia/Ammonium sediment flux model comparison results at OW6 - 44059

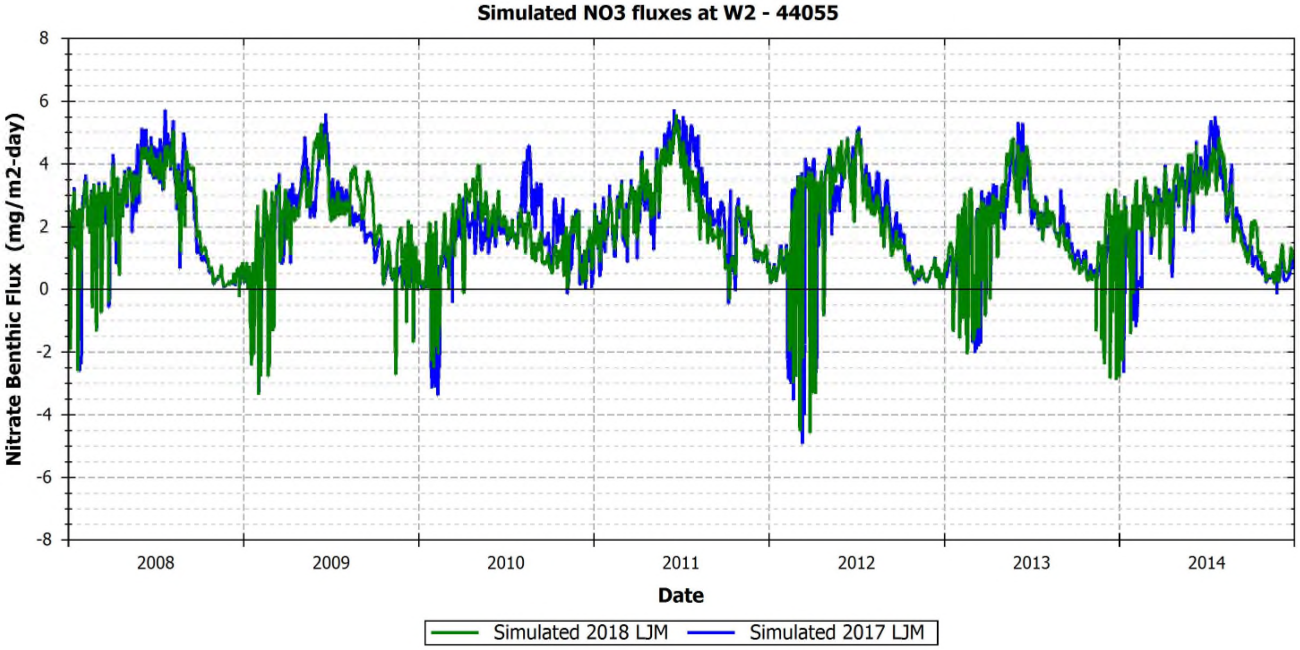


Figure 29. Nitrate sediment flux model comparison results at OW2 - 44055

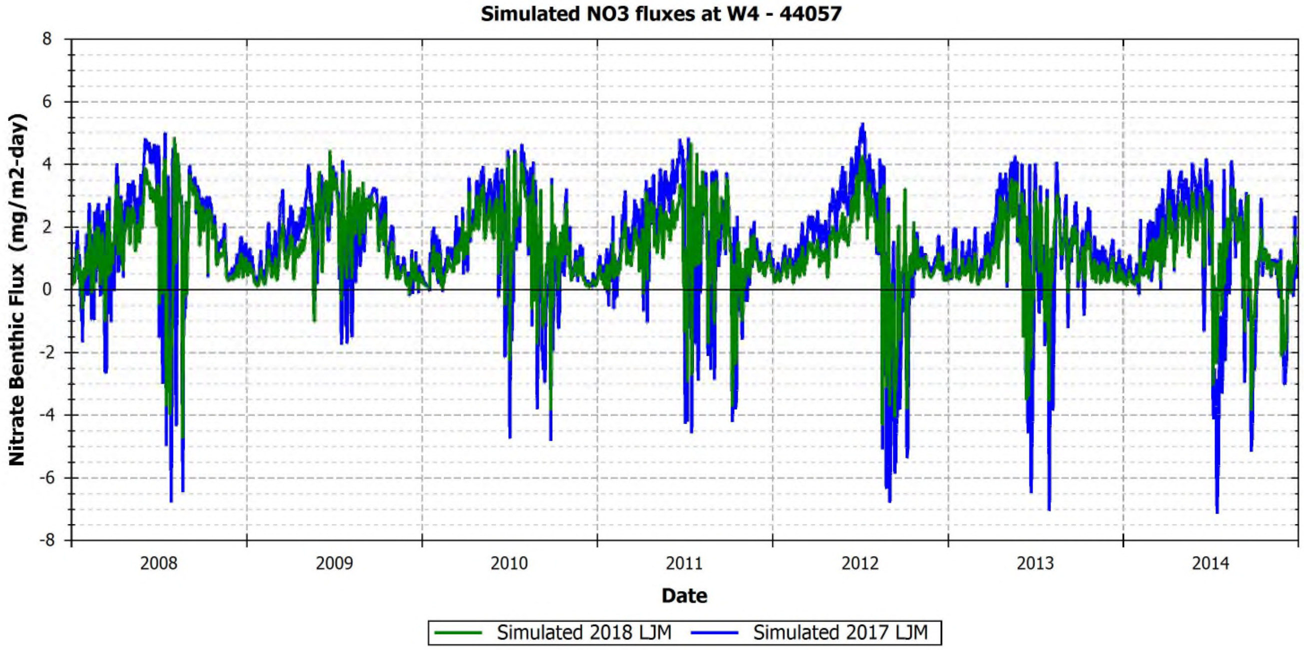


Figure 30. Nitrate sediment flux model comparison results at OW4 - 44057

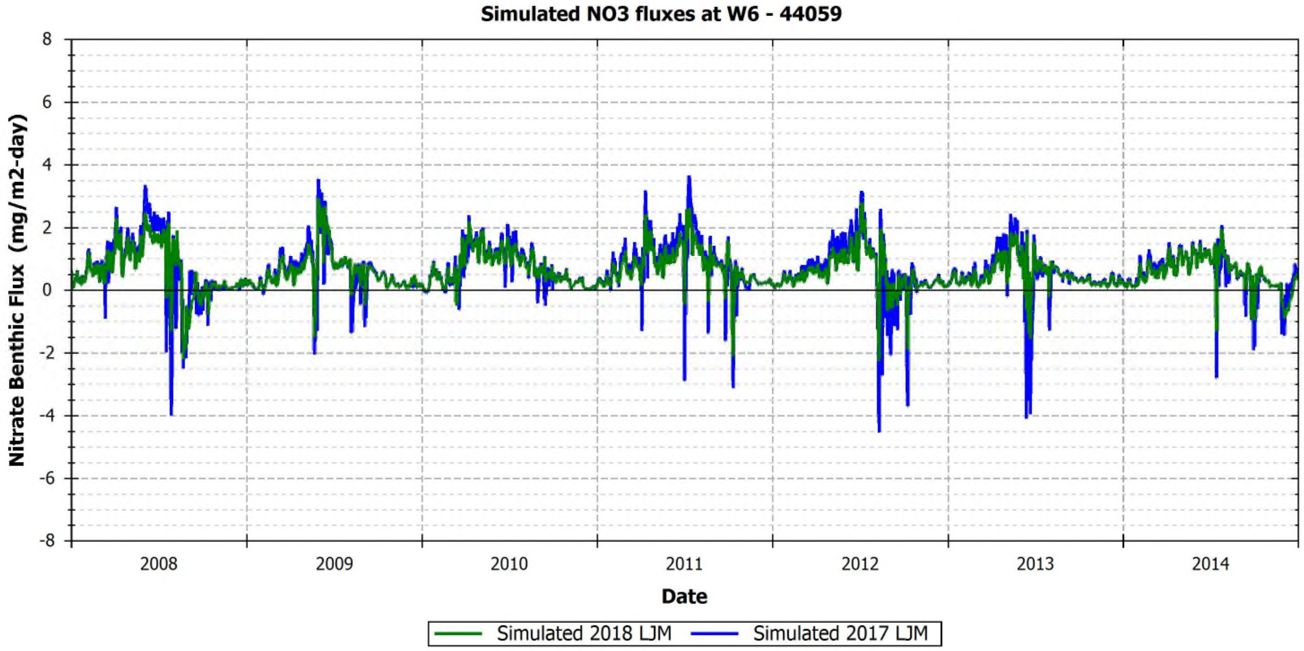


Figure 31. Nitrate sediment flux model comparison results at OW6 - 44059

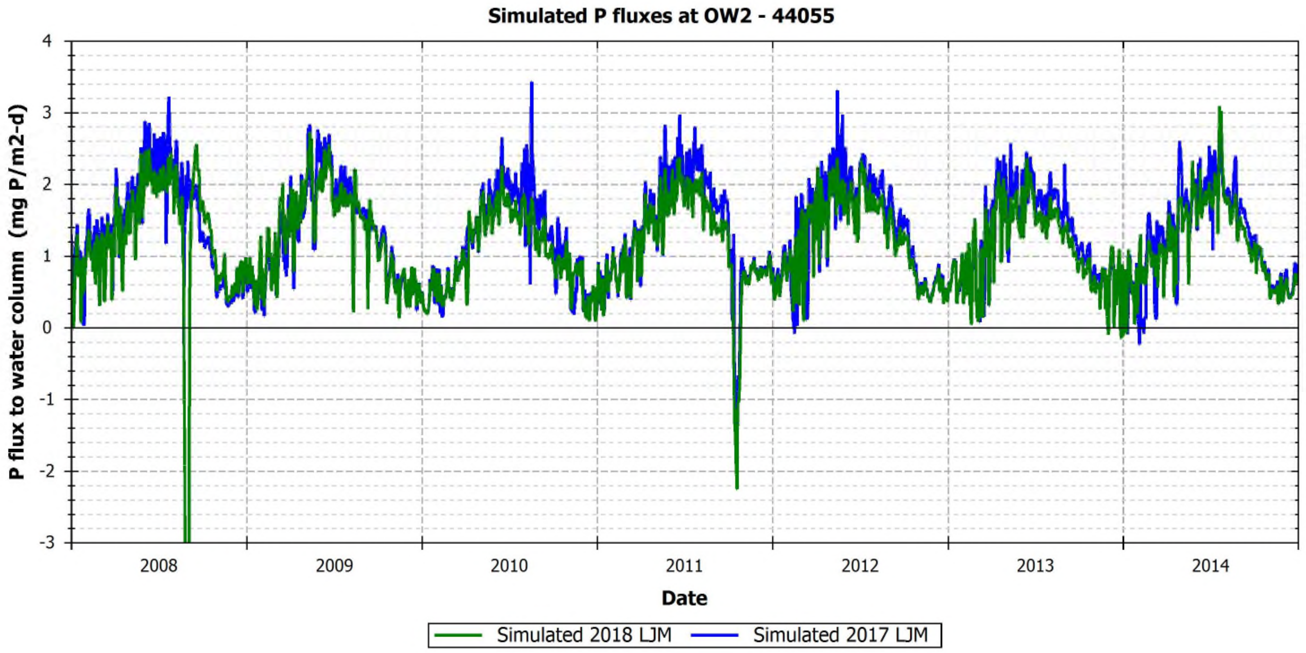


Figure 32. Phosphorus sediment flux model comparison results at OW2 - 44055

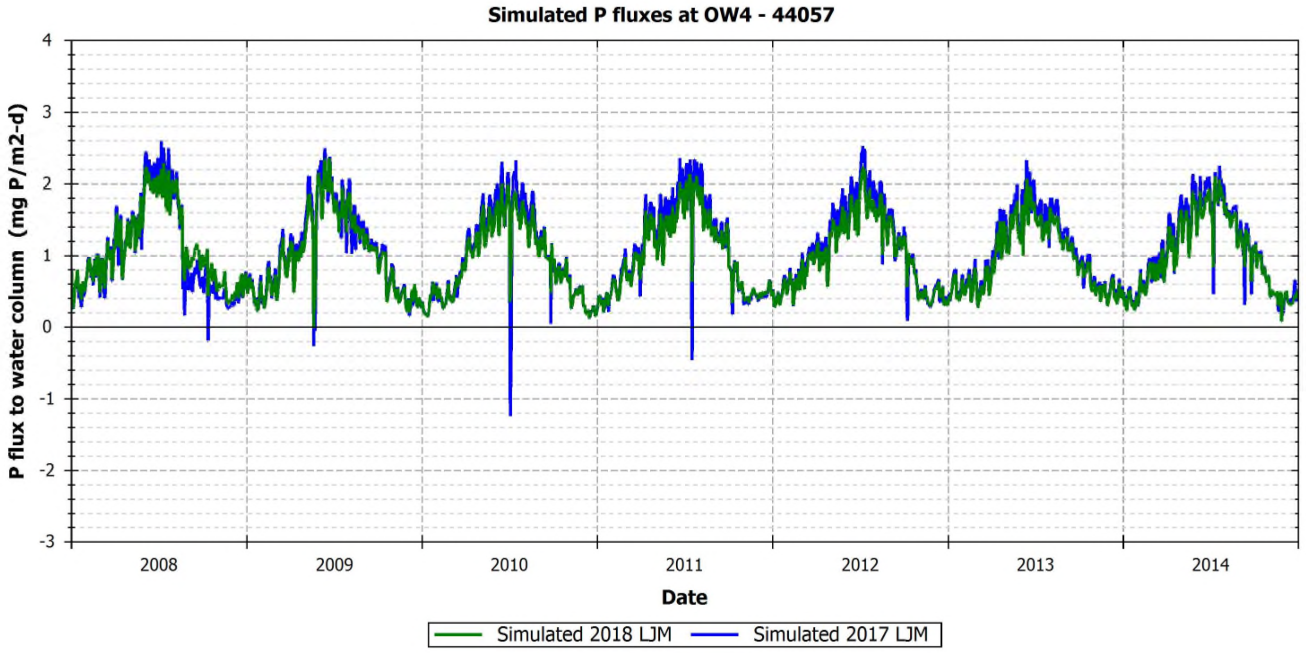


Figure 33. Phosphorus sediment flux model comparison results at OW4 - 44057

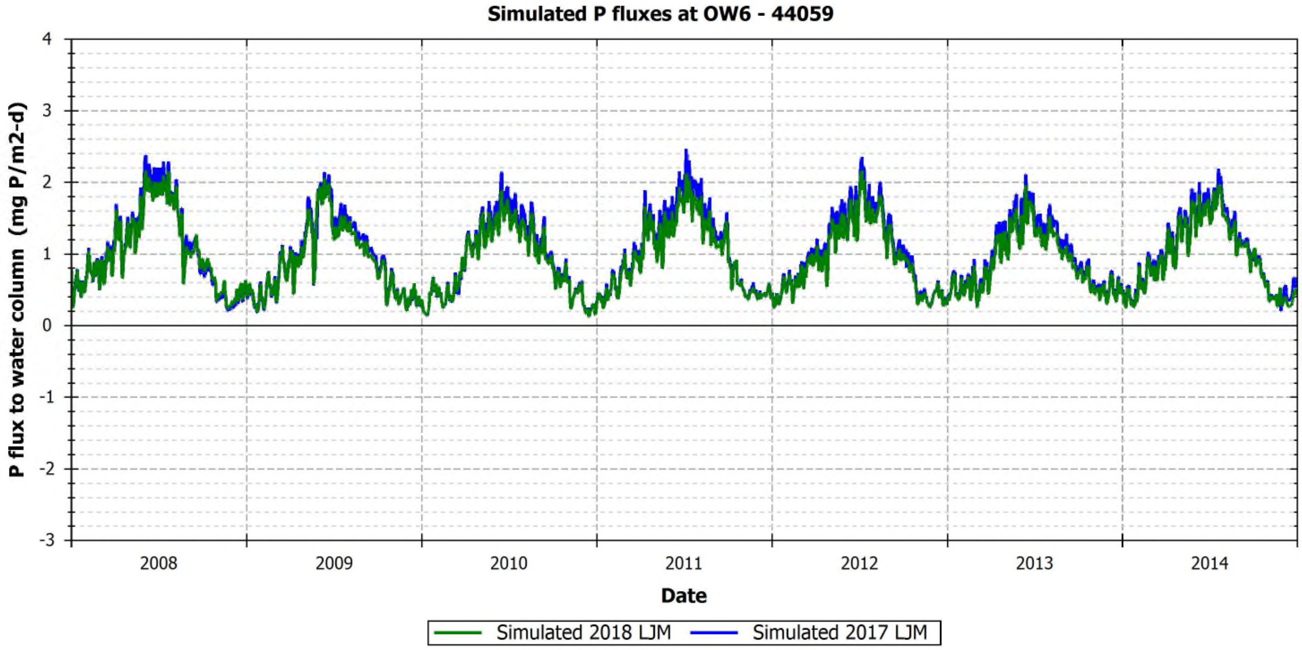


Figure 34. Phosphorus sediment flux model comparison results at OW6 - 44059

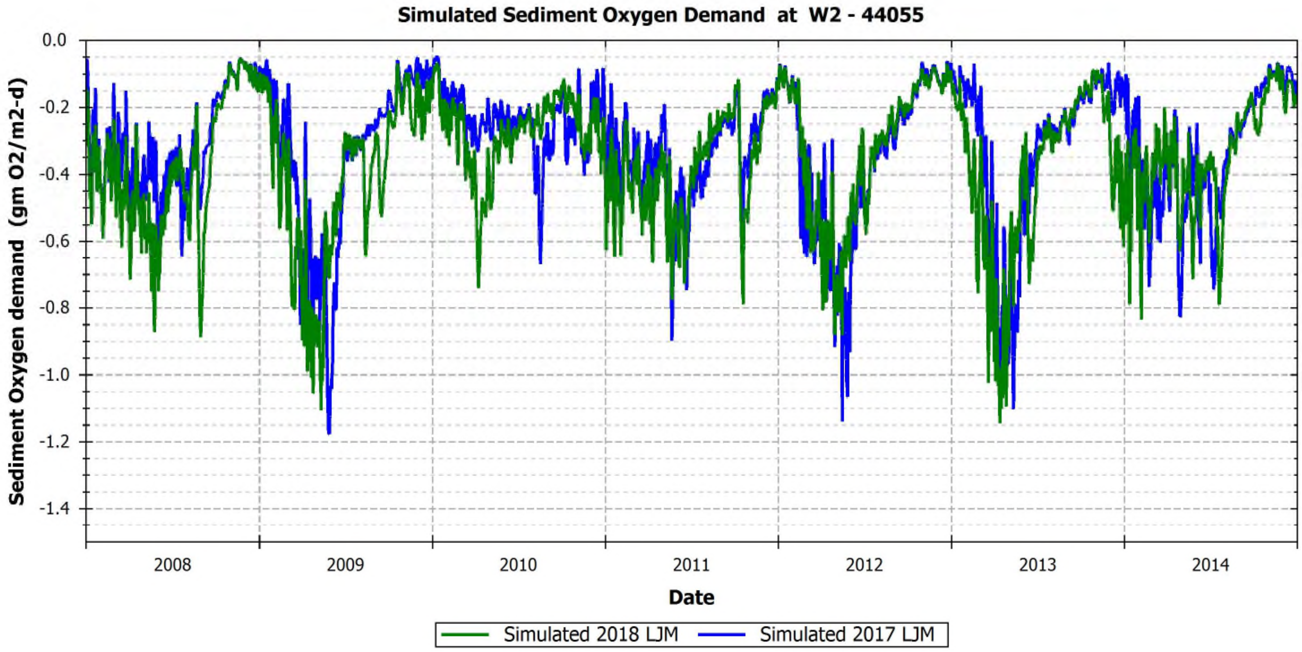


Figure 35. Sediment oxygen demand model comparison results at OW2 - 44055

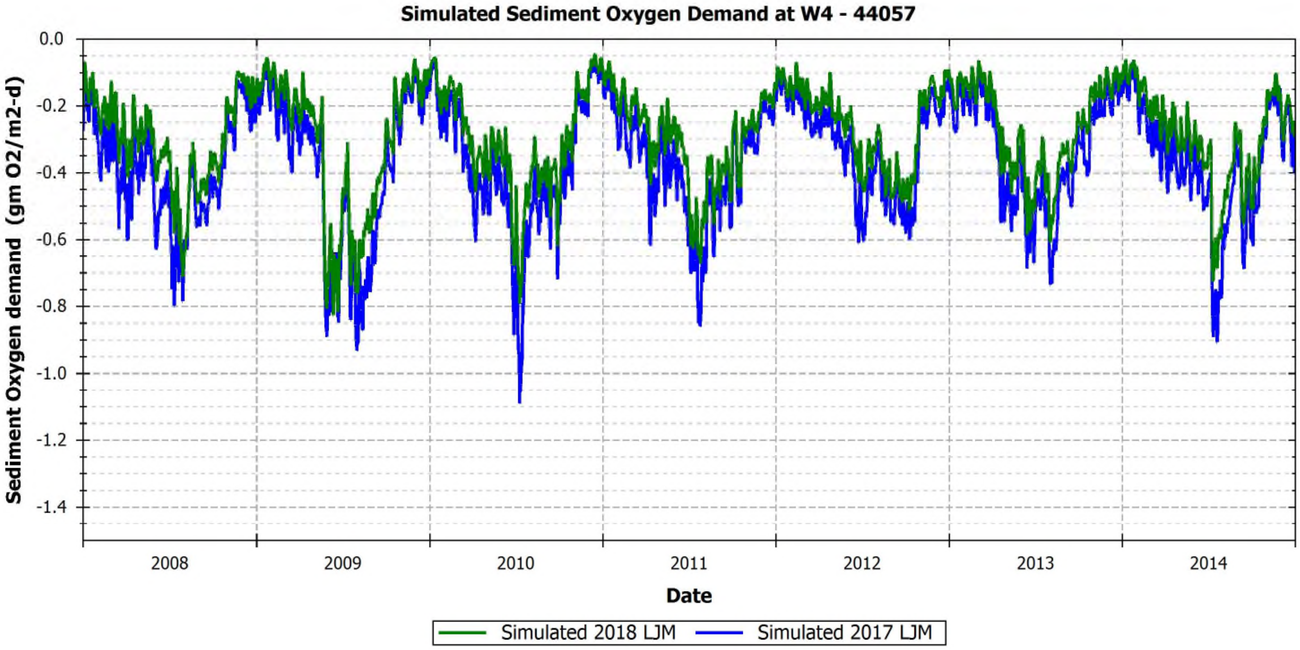


Figure 36. Sediment oxygen demand model comparison results at OW4 - 44057

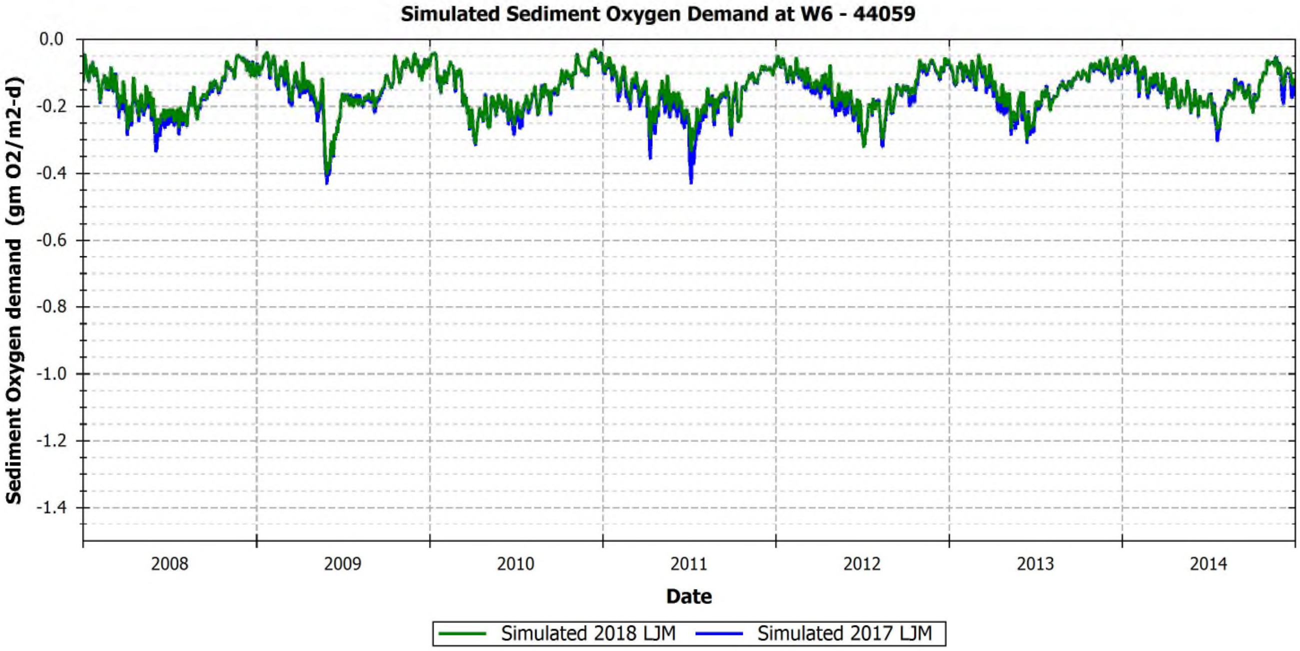


Figure 37. Sediment oxygen demand model comparison results at OW6 - 44059

2.0 REFERENCES

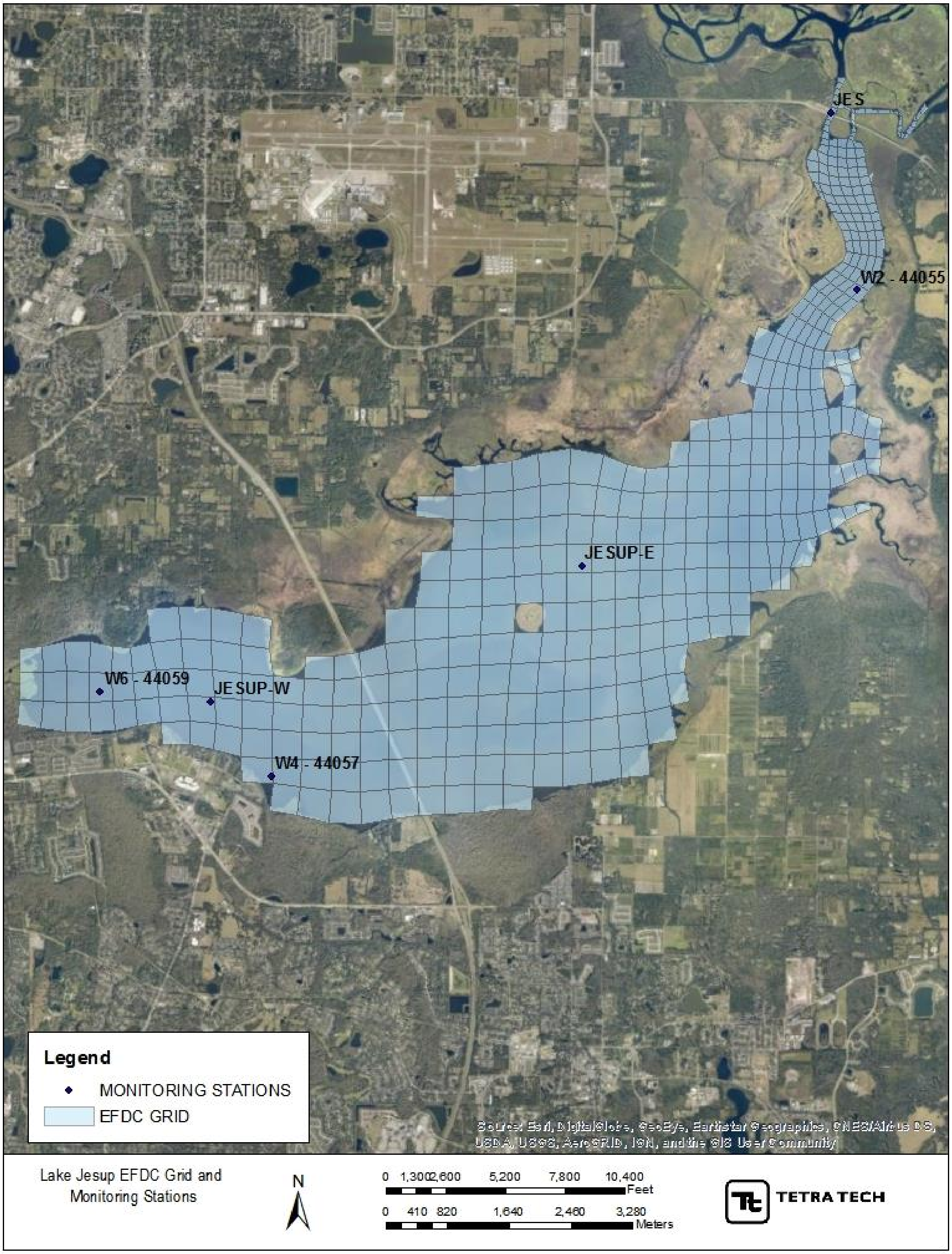
Applied Technology and Management 2018. MSJR Initial Baseline Modeling. Memorandum. Gainesville, Florida. 9pp.

Tetra Tech. 2017. Final Hydrology and Water Quality Modeling Report for the Lake Jesup Watershed, Florida. Atlanta, Georgia. 138pp.

Appendix D

Water Quality Model Results

Figure C-1 Location of Existing Water Quality Sampling Stations within Lake Jesup



Note: W2, W4, and W6 are sampling stations maintained by SJRWMD. JES, JESUP-E, and JESUP-W are sampling stations maintained by Seminole County and described in the Basin Management Action Plan document (https://floridadep.gov/sites/default/files/jesup-bmap.pdf).

SCENARIO 1: CHANNELS A, B, AND C OPEN – TN

Figure C-2 TN Concentrations at JES for Scenario 1

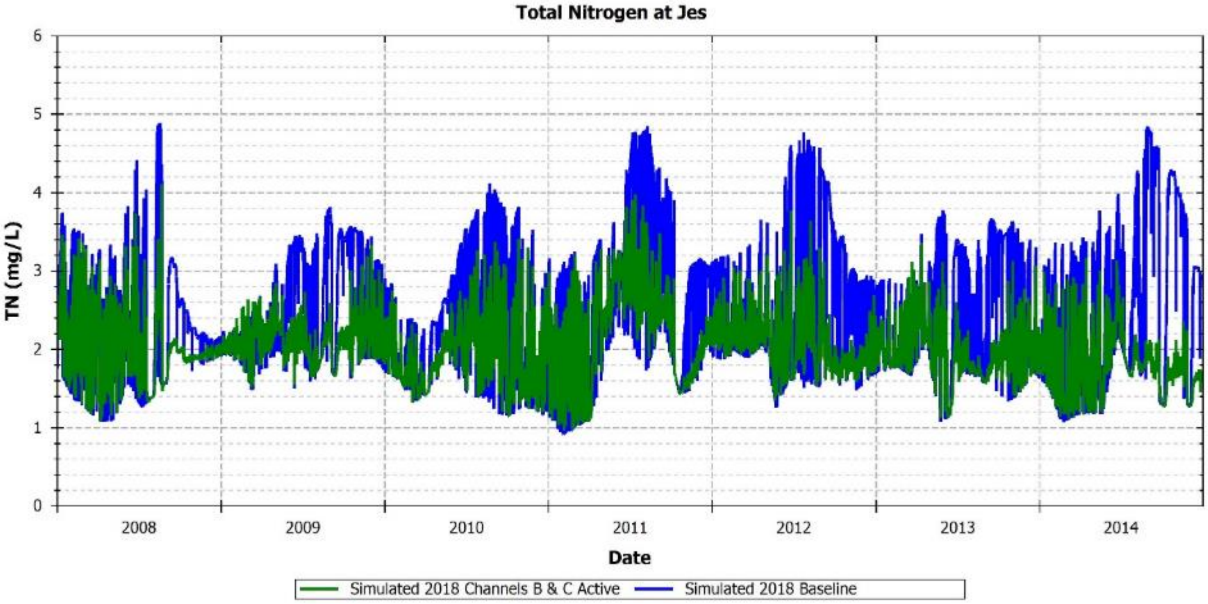


Figure C-3 TN Concentrations at OW2 – 44055 for Scenario 1

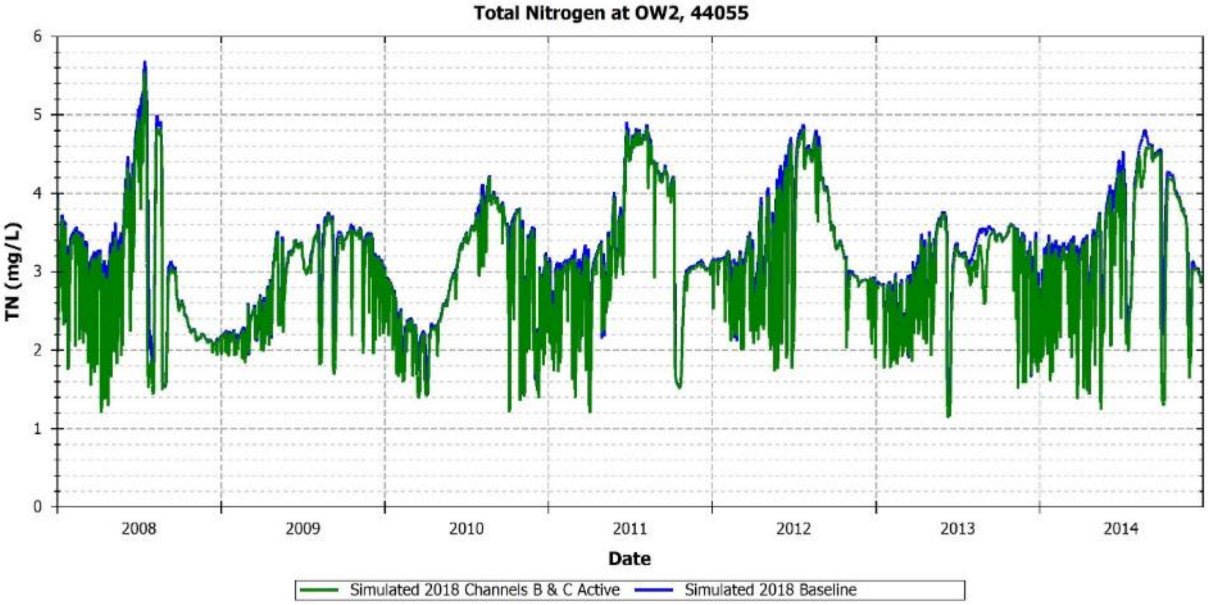


Figure C-4 TN Concentrations at Jesup-E for Scenario 1

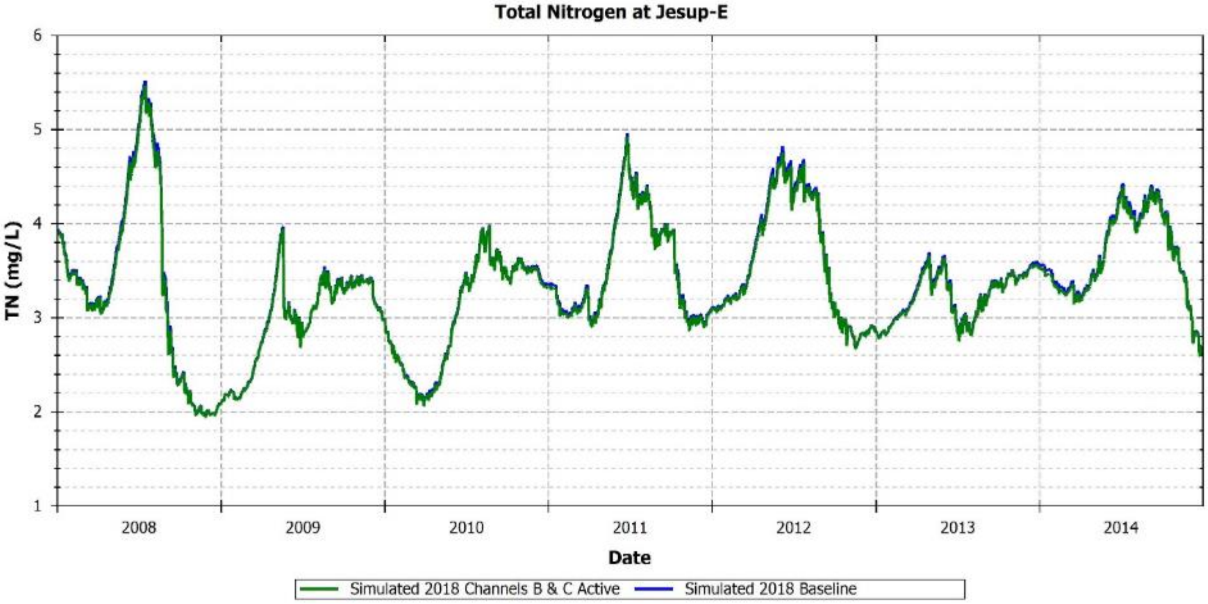


Figure C-5 TN Concentrations at OW4 – 44057 for Scenario 1

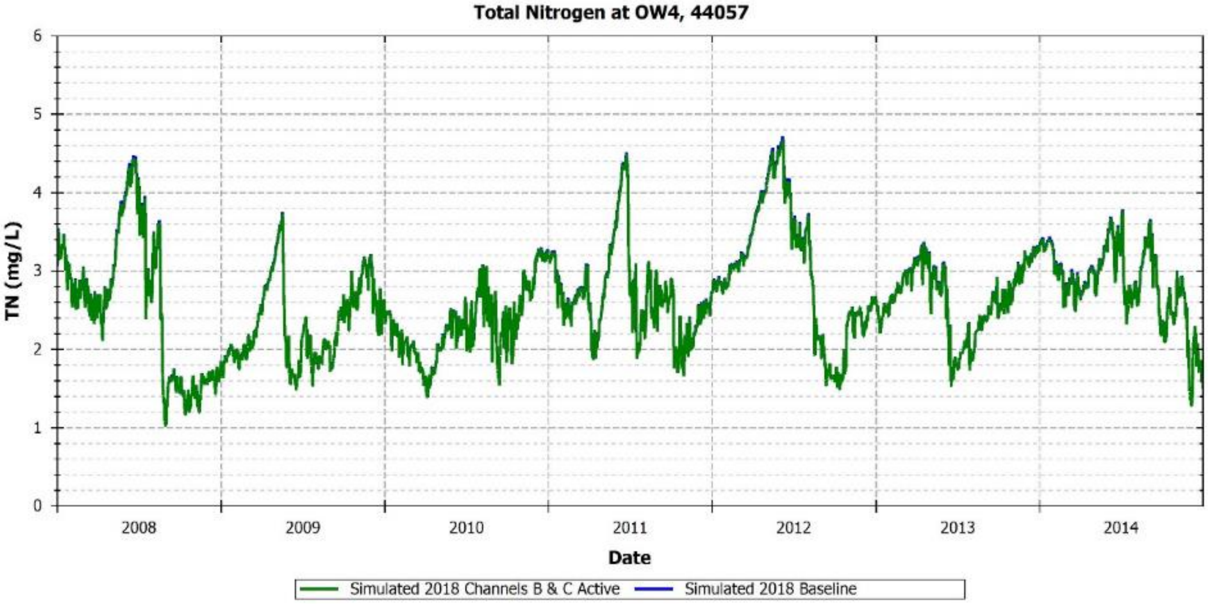


Figure C-6 TN Concentrations at Jesup-W for Scenario 1

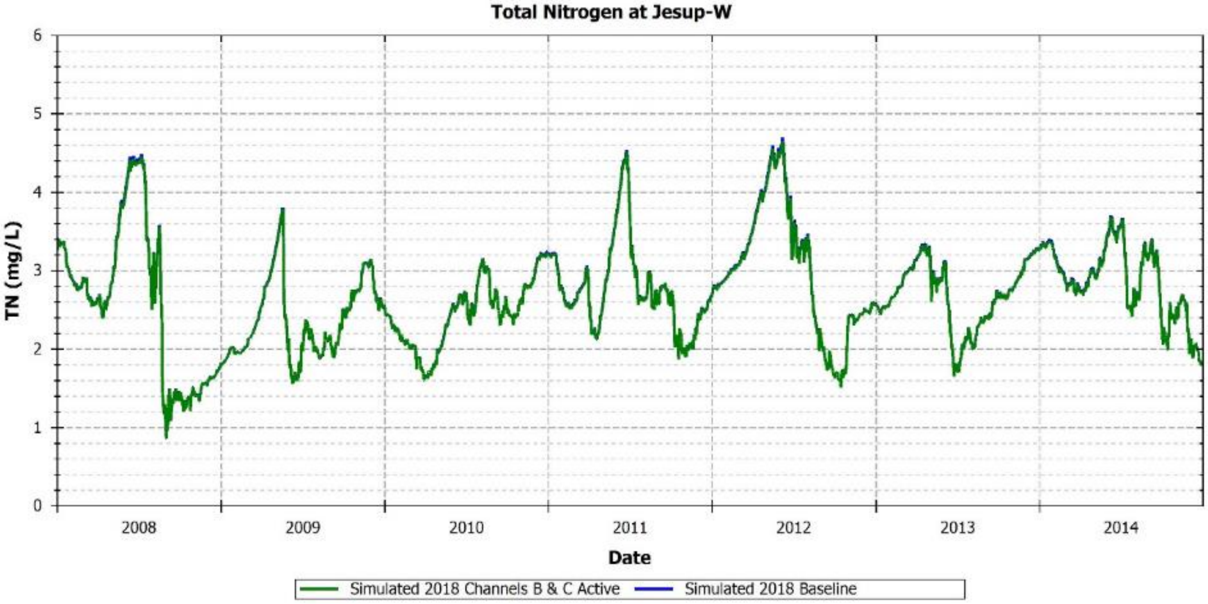


Figure C-7 TN Concentrations at OW6 – 44059 for Scenario 1

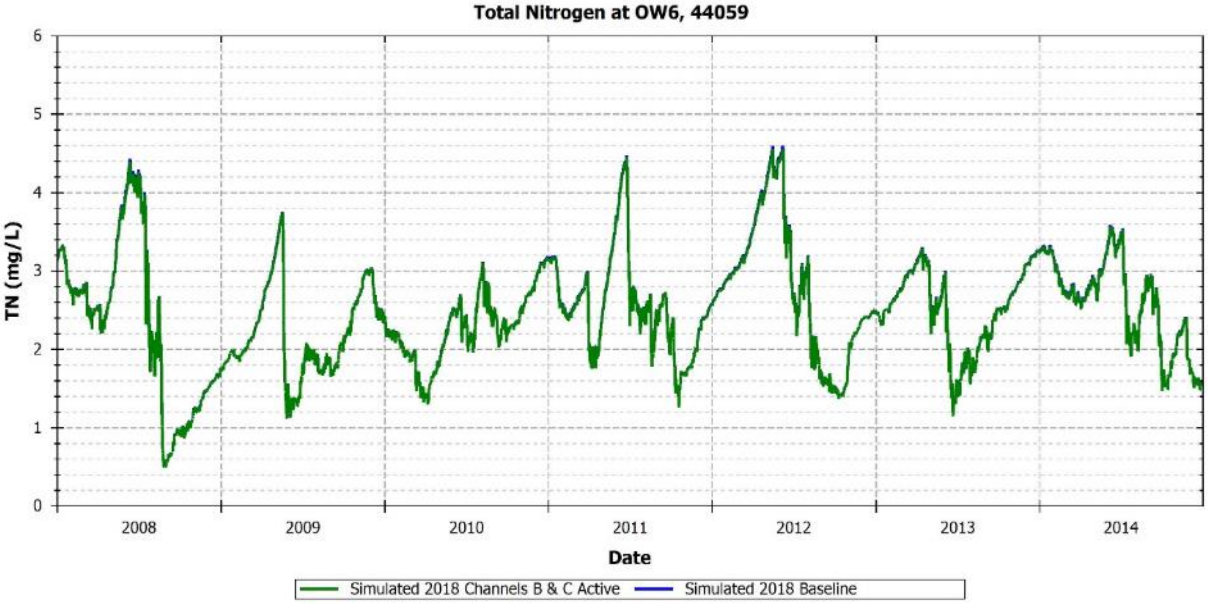


Table C-2: Changes in TN concentrations (mg/L) from baseline for Scenario 1

Year	W2			W4			W6		
	Baseline	A,B,C	% Change	Baseline	A,B,C	% Change	Baseline	A,B,C	% Change
2008	3.03	3.44	-13.5%	2.56	3.21	-25.4%	2.32	2.92	-26.0%
2009	2.93	2.83	3.3%	2.32	2.32	0.2%	2.20	2.20	0.2%
2010	2.92	2.76	5.4%	2.33	2.29	1.5%	2.28	2.25	1.4%
2011	3.40	3.24	4.4%	2.69	2.65	1.4%	2.55	2.51	1.4%
2012	3.44	3.26	5.1%	2.99	2.96	1.1%	2.77	2.74	1.0%
2013	3.01	2.87	4.7%	2.66	2.64	0.5%	2.52	2.51	0.5%
2014	3.50	3.23	7.7%	2.83	2.82	0.6%	2.58	2.57	0.5%

SCENARIO 1: CHANNELS A, B, AND C OPEN – TP

Figure C-8 TP Concentrations at Jes for Scenario 1

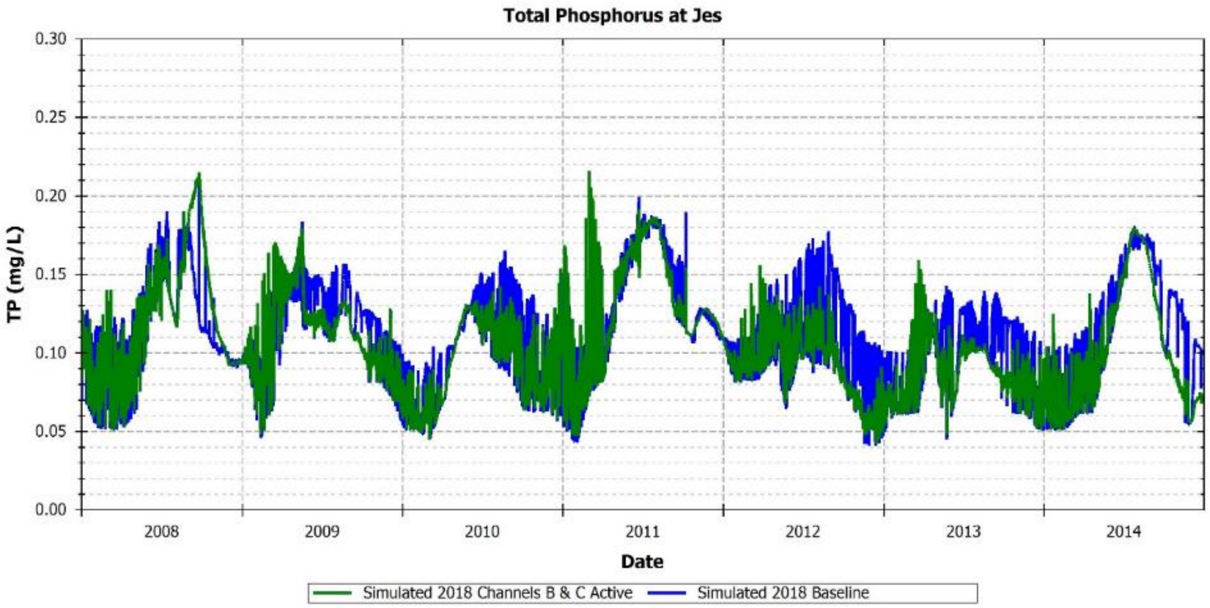


Figure C-9 TP Concentrations at OW2 – 44055 for Scenario 1

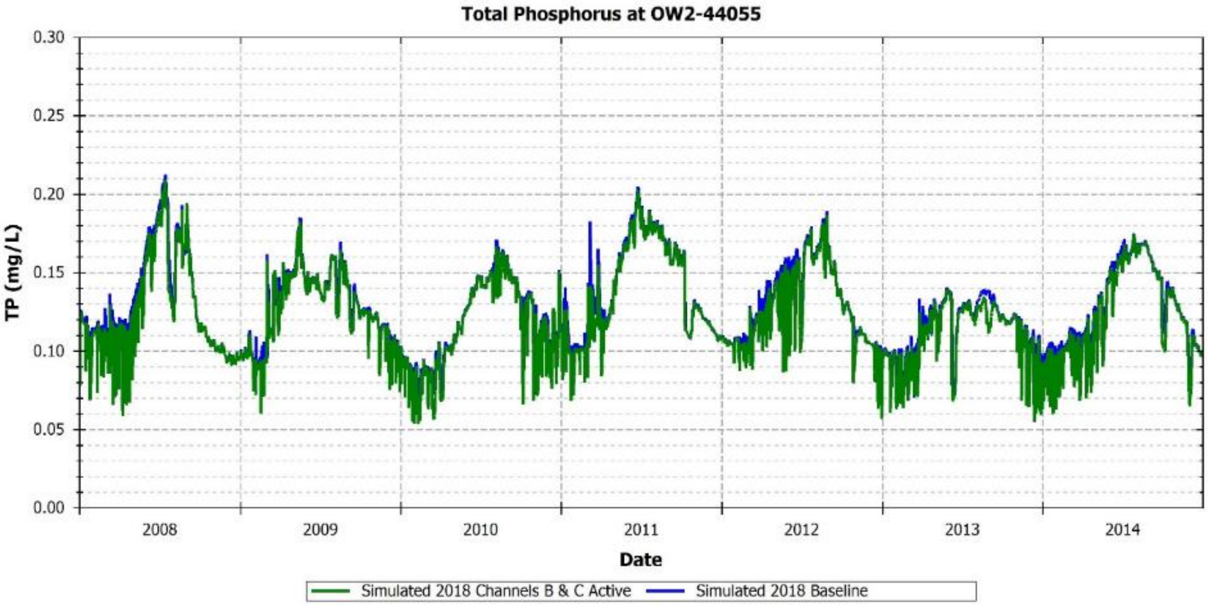


Figure C-10 TP Concentrations at Jesup E for Scenario 1

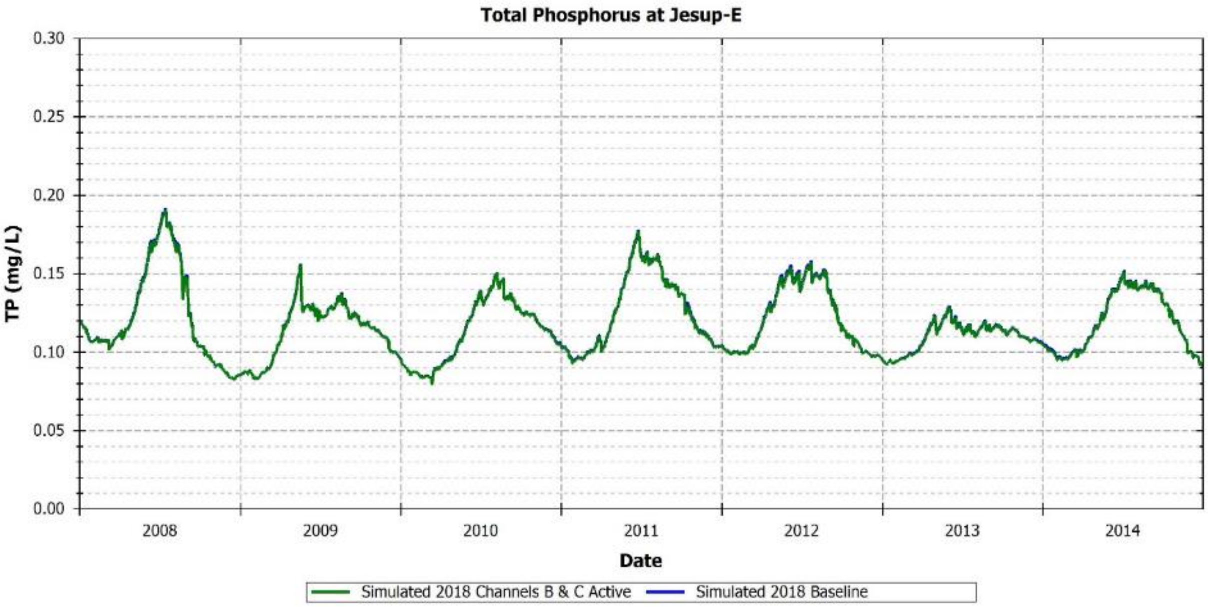


Figure C-11 TP Concentrations at OW4 44057 for Scenario 1

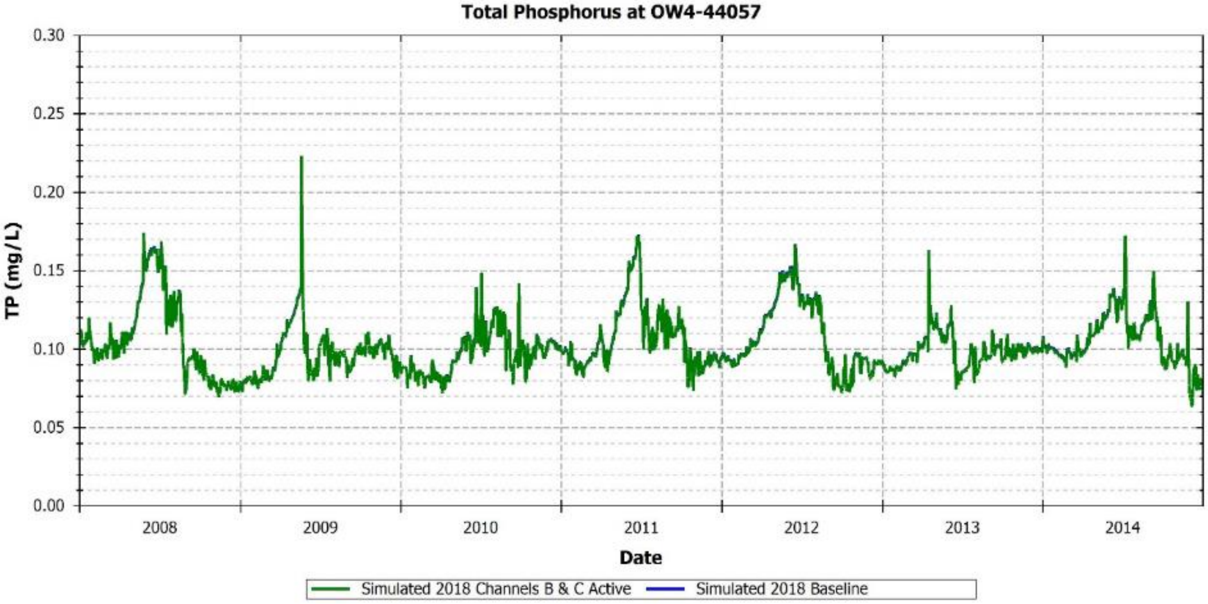


Figure C-12 TP Concentrations at Jesup-W for Scenario 1

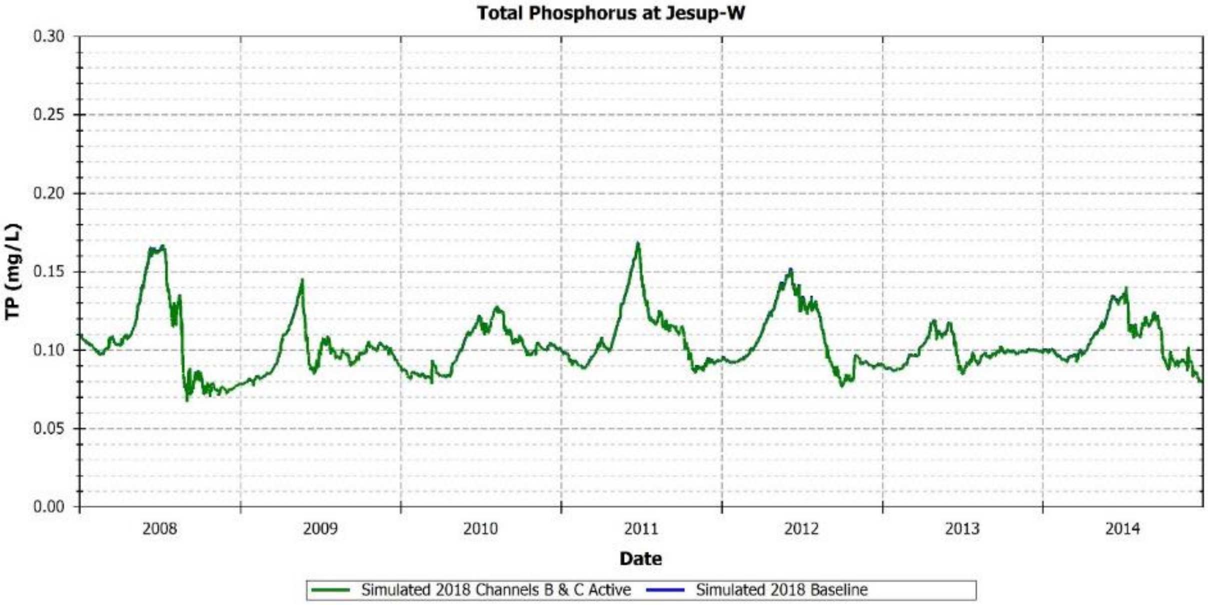


Figure C-13 TP Concentrations at OW6-44059 for Scenario 1

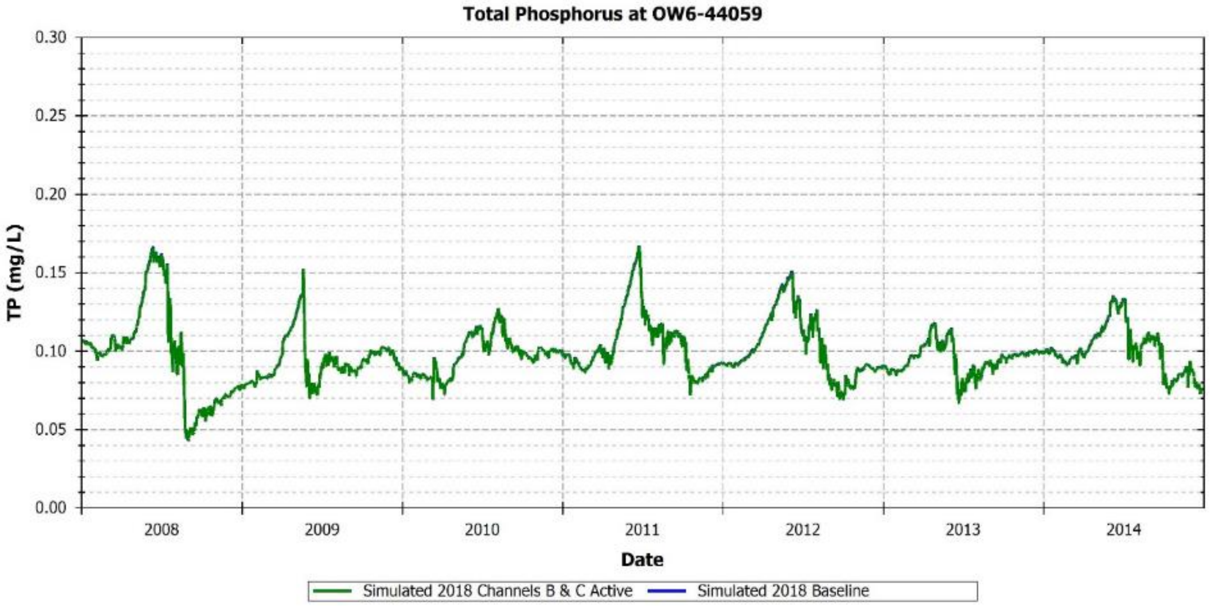


Table C-3: Changes in TP concentrations (mg/L) from baseline for Scenario 1

Year	W2			W4			W6		
	Baseline	A,B,C	% Change	Baseline	A,B,C	% Change	Baseline	A,B,C	% Change
2008	0.13	0.14	-9.7%	0.11	0.13	-17.0%	0.10	0.11	-16.8%
2009	0.13	0.12	2.7%	0.10	0.10	0.8%	0.09	0.09	0.9%
2010	0.12	0.11	4.9%	0.10	0.10	1.5%	0.10	0.10	1.5%
2011	0.14	0.14	3.4%	0.11	0.11	1.2%	0.10	0.10	1.1%
2012	0.13	0.13	4.2%	0.11	0.11	0.9%	0.10	0.10	0.8%
2013	0.11	0.11	3.9%	0.10	0.10	0.4%	0.09	0.09	0.4%
2014	0.13	0.12	4.4%	0.11	0.11	0.4%	0.10	0.10	0.3%

SCENARIO 1: CHANNELS A, B, AND C OPEN – CHLOROPHYLL-*A*

Figure C-14 Chlorophyll-*a* Concentrations at JES for Scenario 1

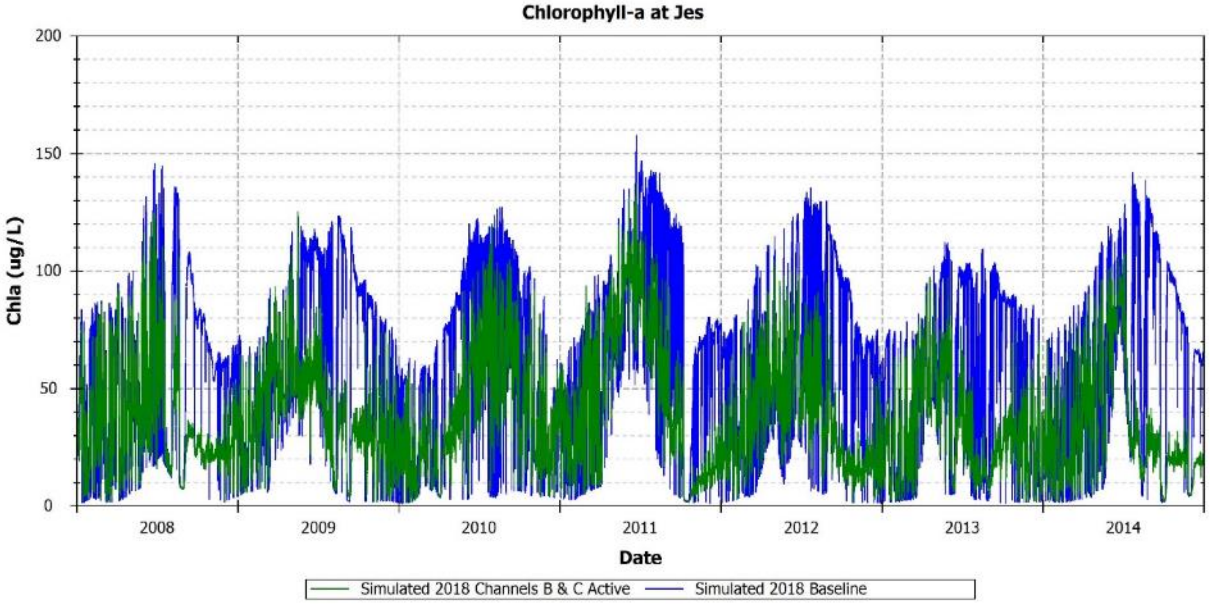


Figure C-15 Chlorophyll-*a* Concentrations at OW2 – 44055 for Scenario 1

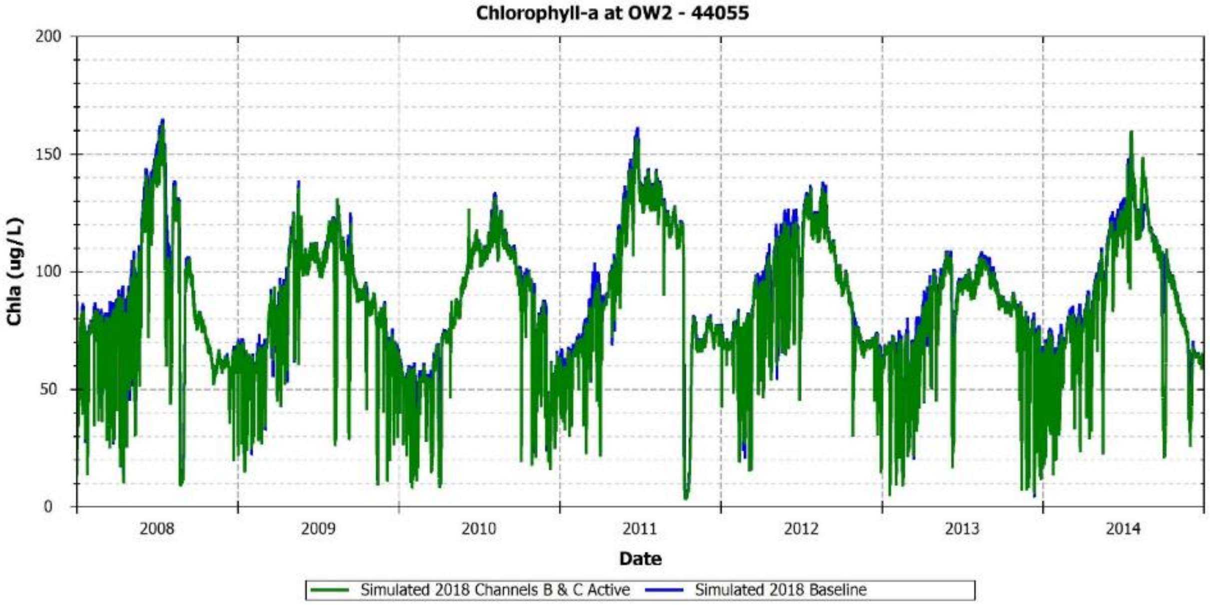


Figure C-16 Chlorophyll-*a* Concentrations at Jesup-E for Scenario 1

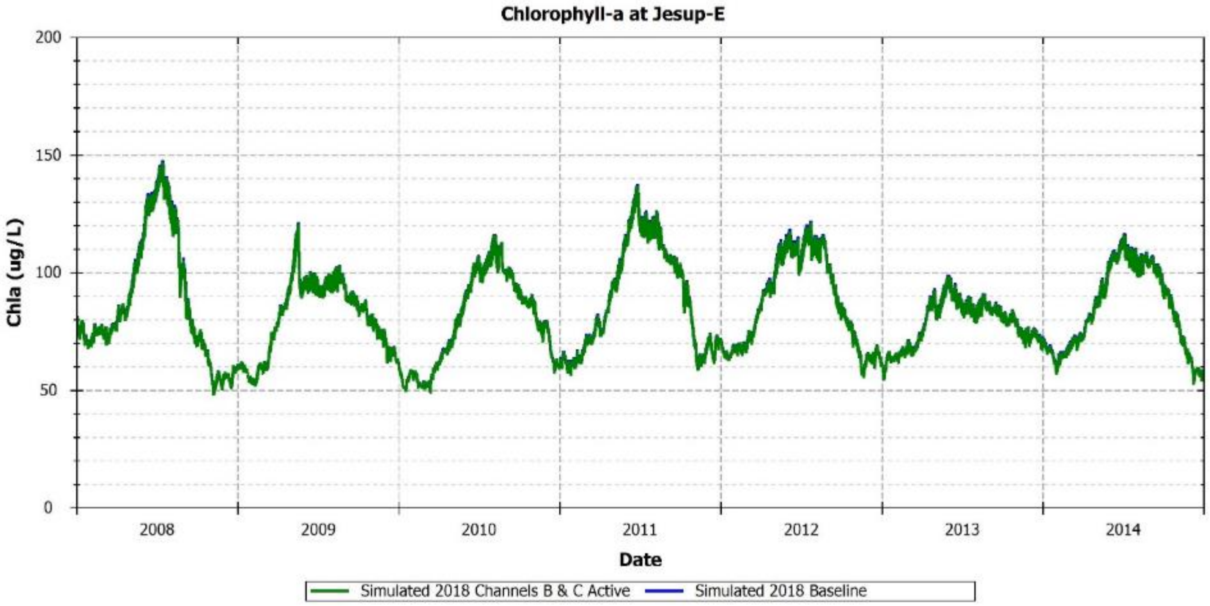


Figure C-17 Chlorophyll-*a* Concentrations at OW4 – 44057 for Scenario 1

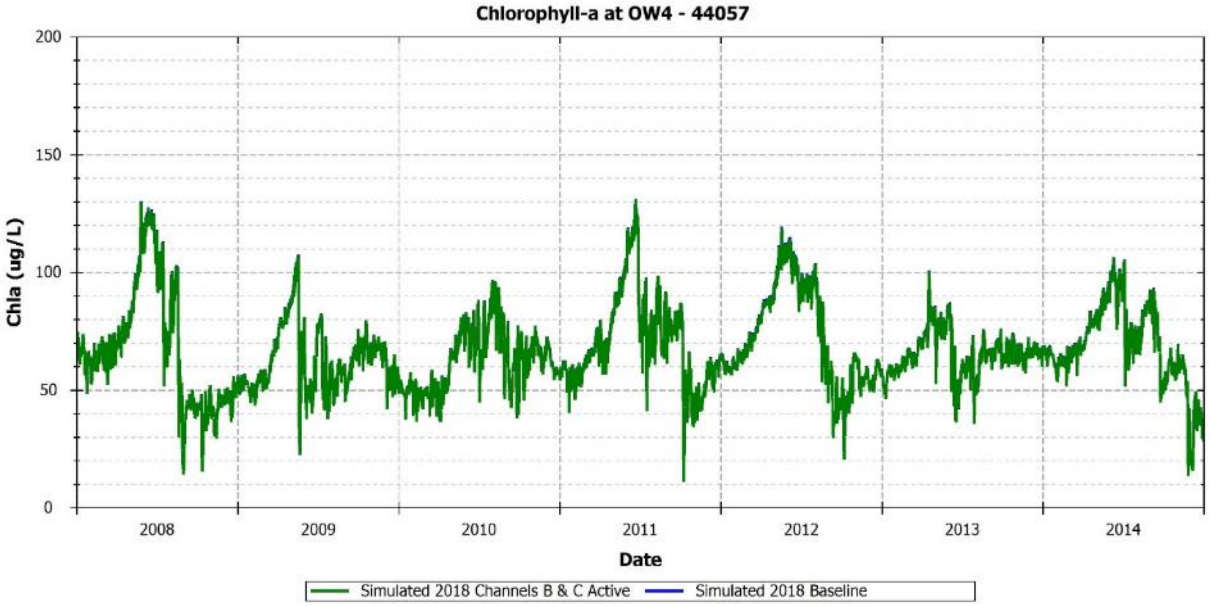


Figure C-18 Chlorophyll-*a* Concentrations at Jesup-W for Scenario 1

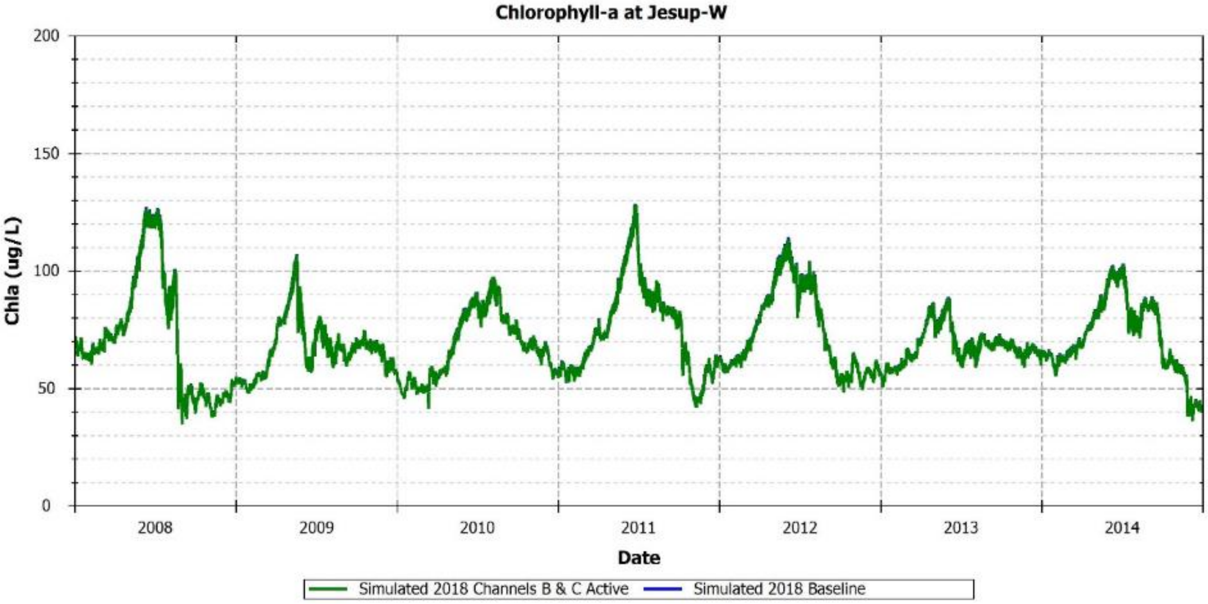
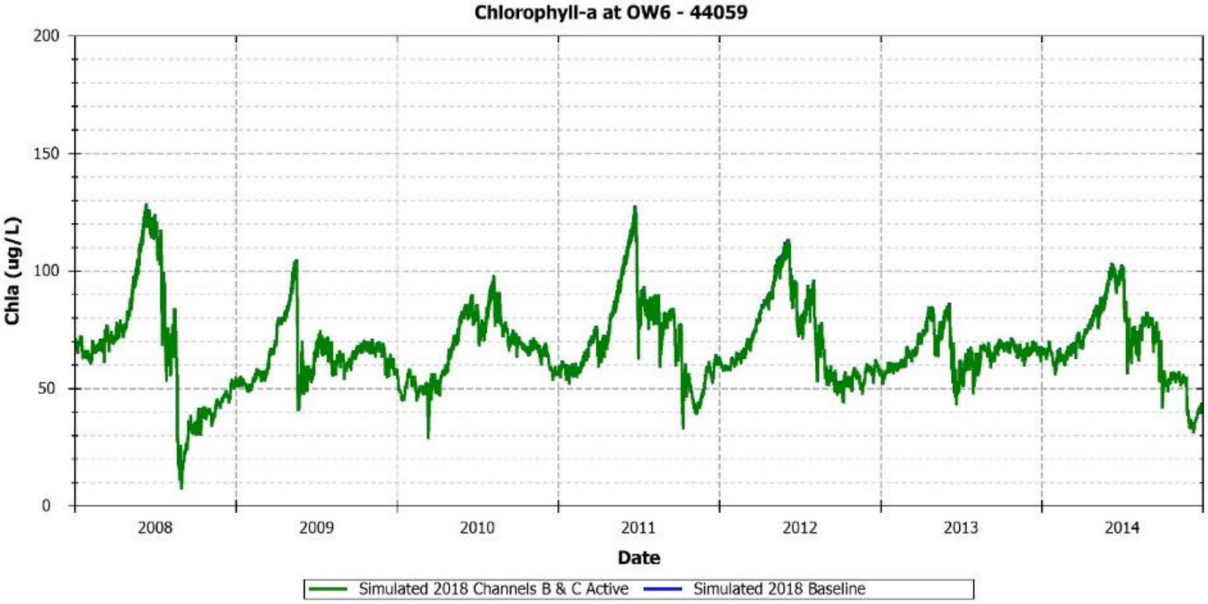


Figure C-19 Chlorophyll-*a* Concentrations at OW6 – 44059 for Scenario 1



SCENARIO 1: CHANNELS A, B, AND C OPEN – SEDIMENT FLUXES

Figure C-20 Ammonia Fluxes at OW2 – 44055 for Scenario 1

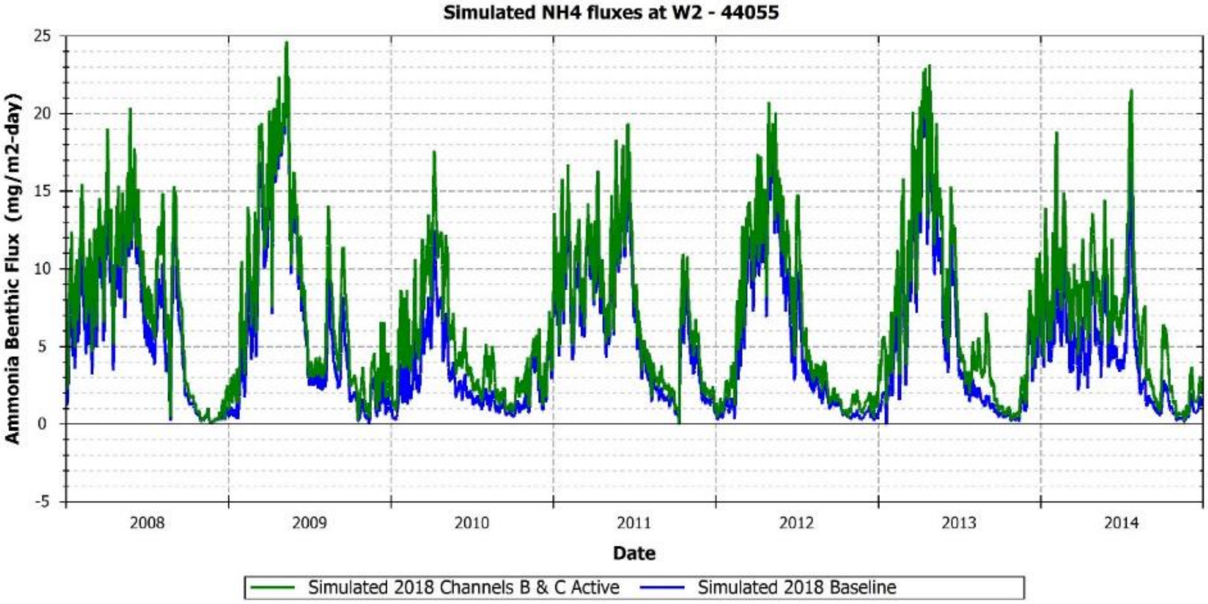


Figure C-21 Ammonia Fluxes at OW4 – 44057 for Scenario 1

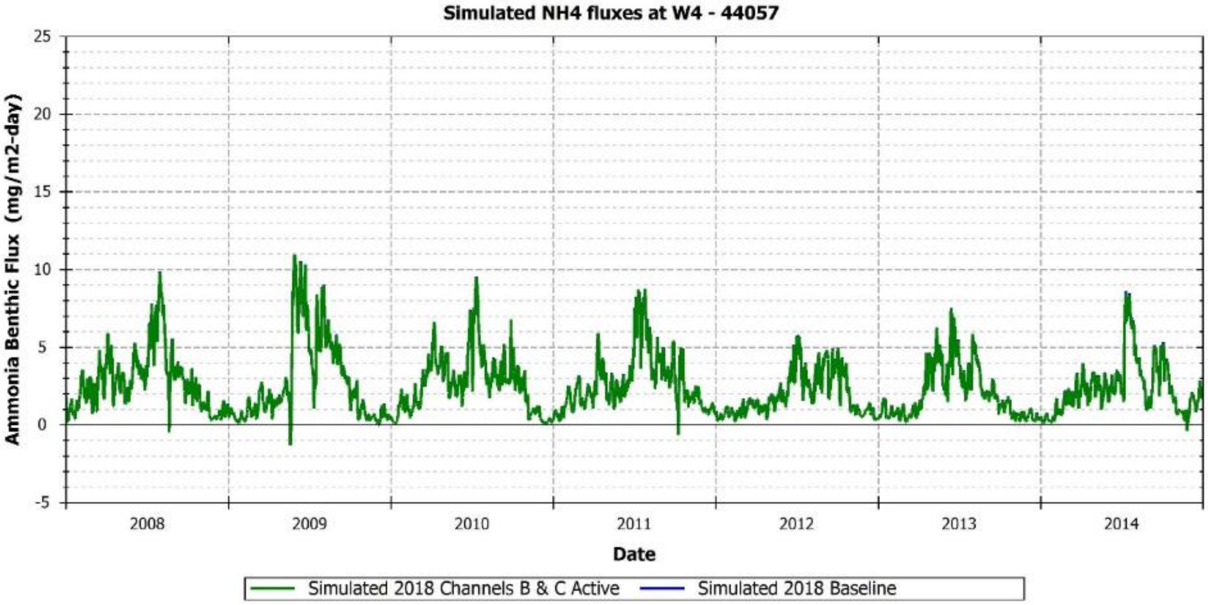


Figure C-22 Ammonia Fluxes at OW6 – 44059 for Scenario 1

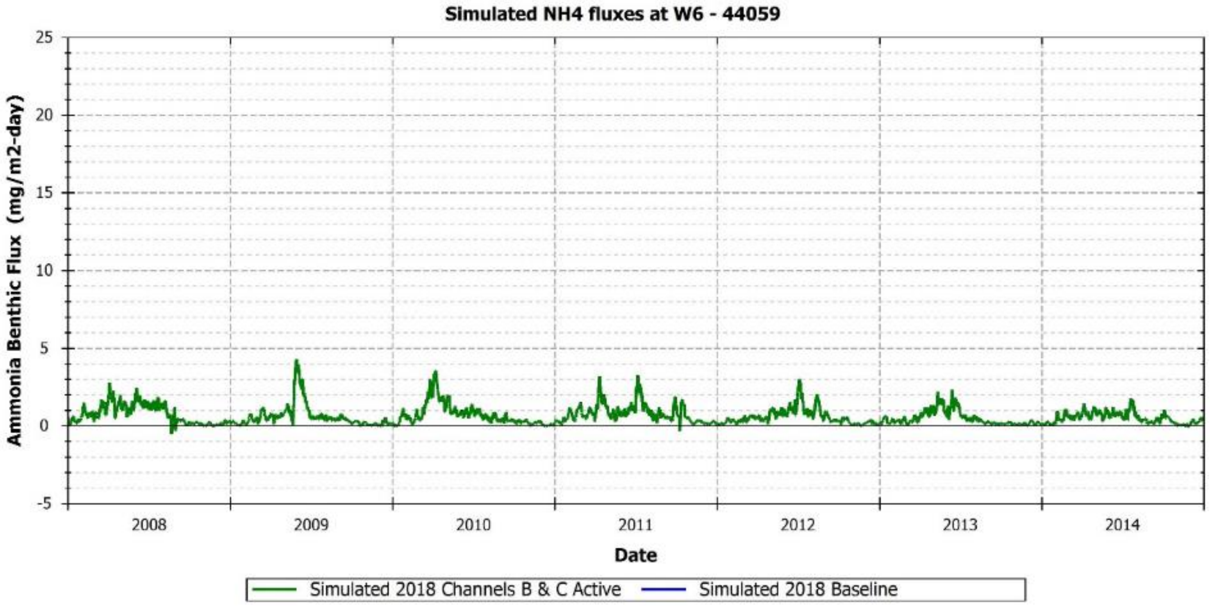


Figure C-23 Nitrate Fluxes at OW2 – 44055 for Scenario 1

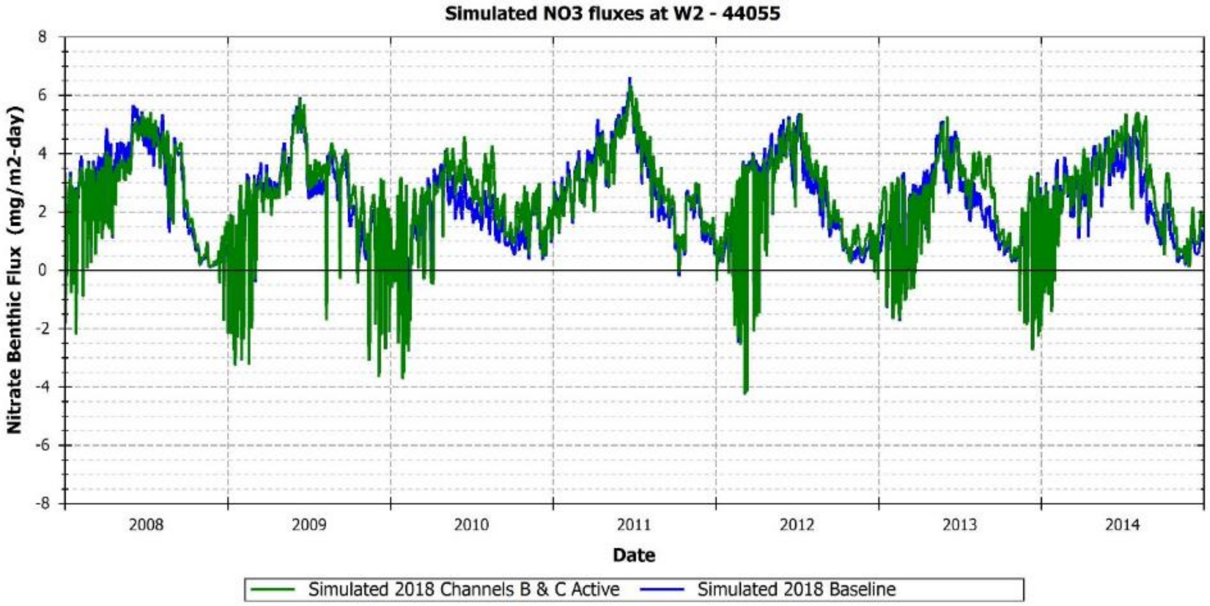


Figure C-24 Nitrate Fluxes at OW4 – 44057 for Scenario 1

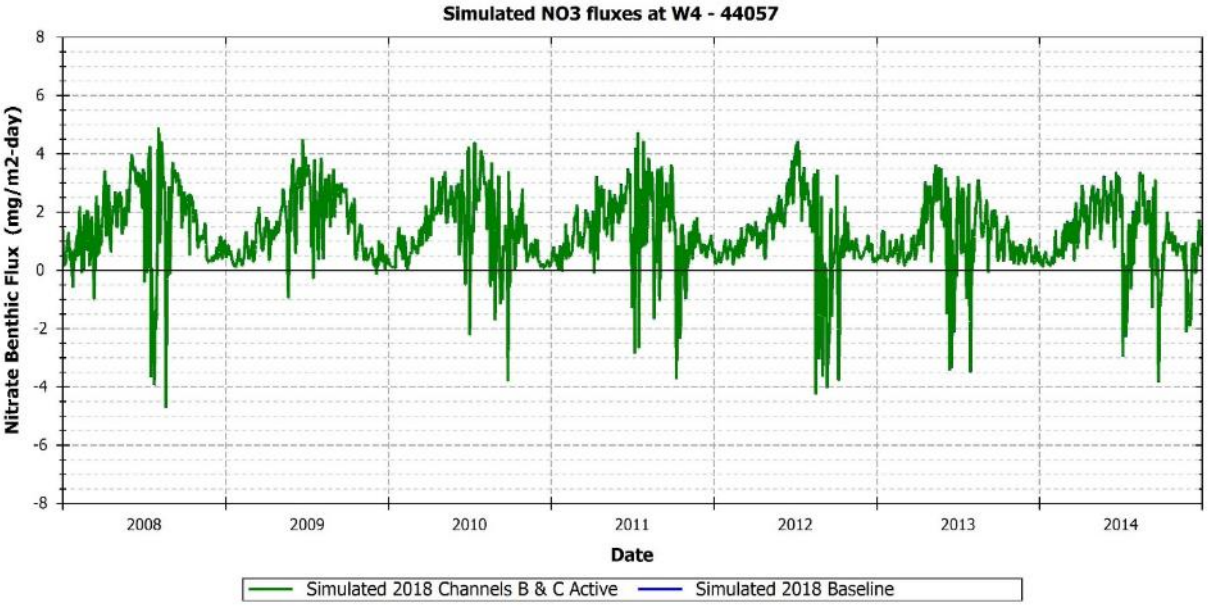


Figure C-25 Nitrate Fluxes at OW6 – 44059 for Scenario 1

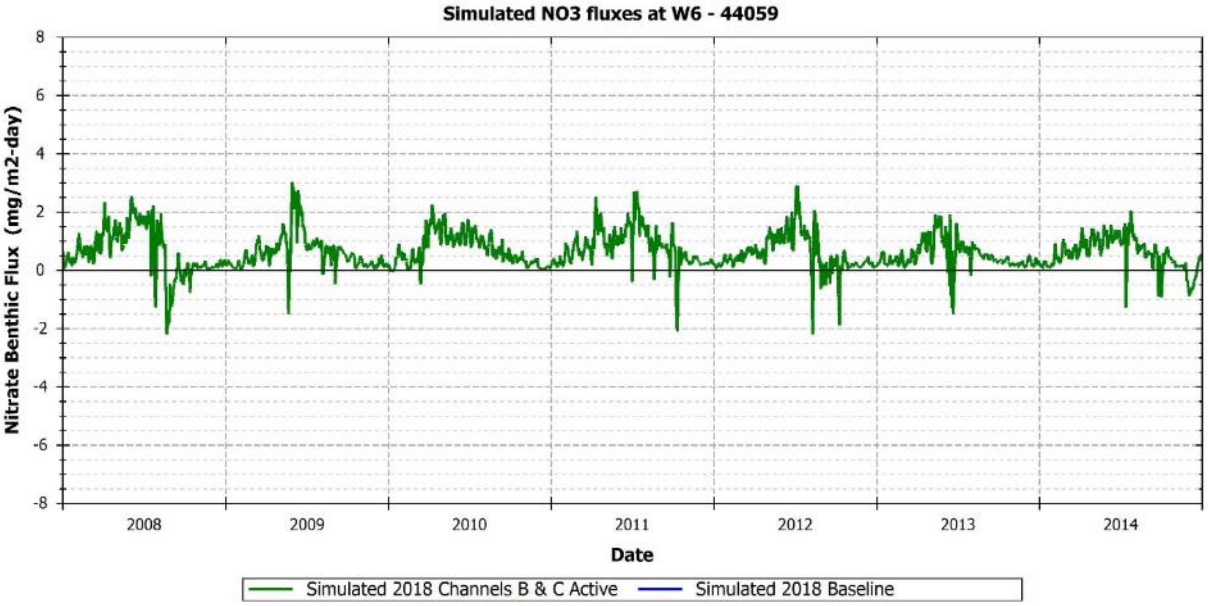


Figure C-26 Phosphorus Fluxes at OW2 – 44055 for Scenario 1

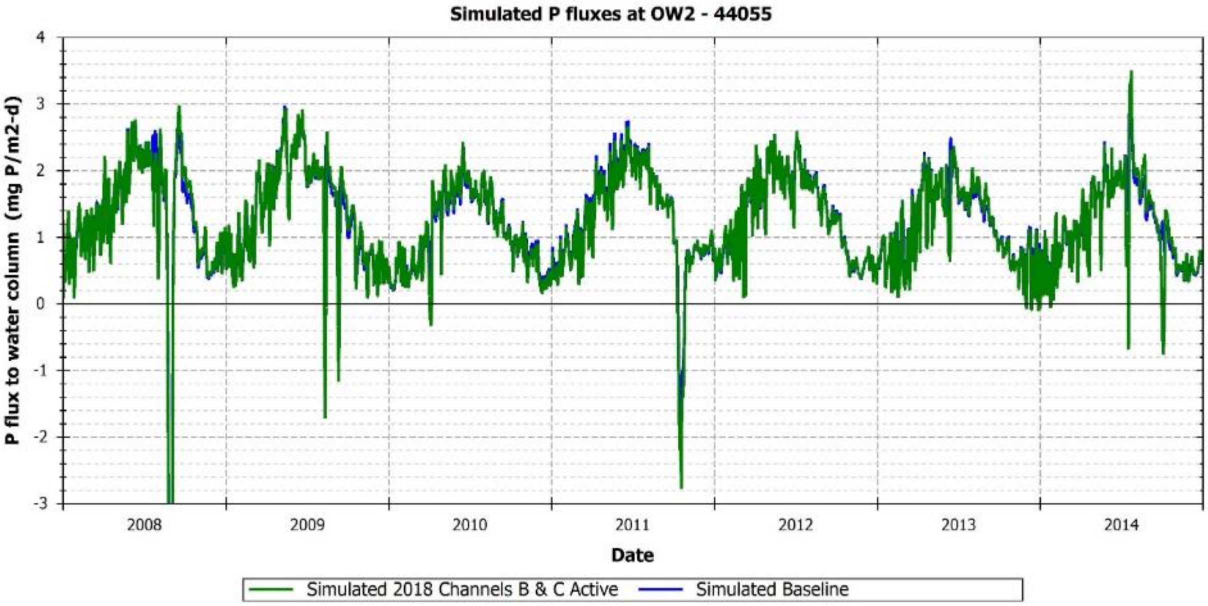


Figure C-27 Phosphorus Fluxes at OW4 – 44057 for Scenario 1

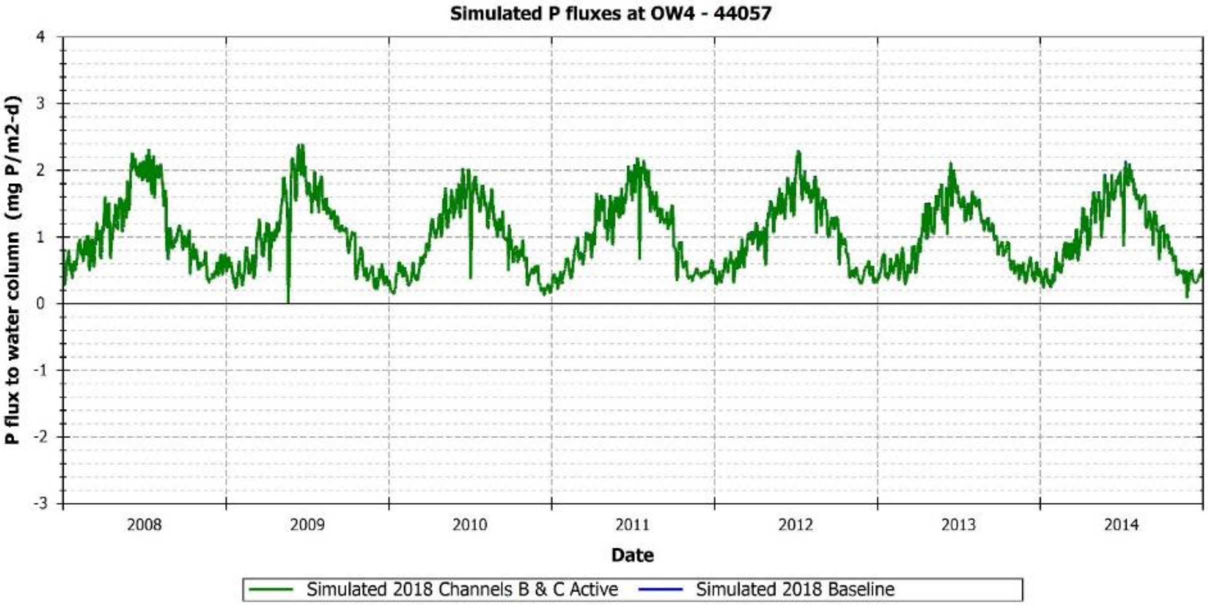


Figure C-28 Phosphorus Fluxes at OW6 – 44059 for Scenario 1

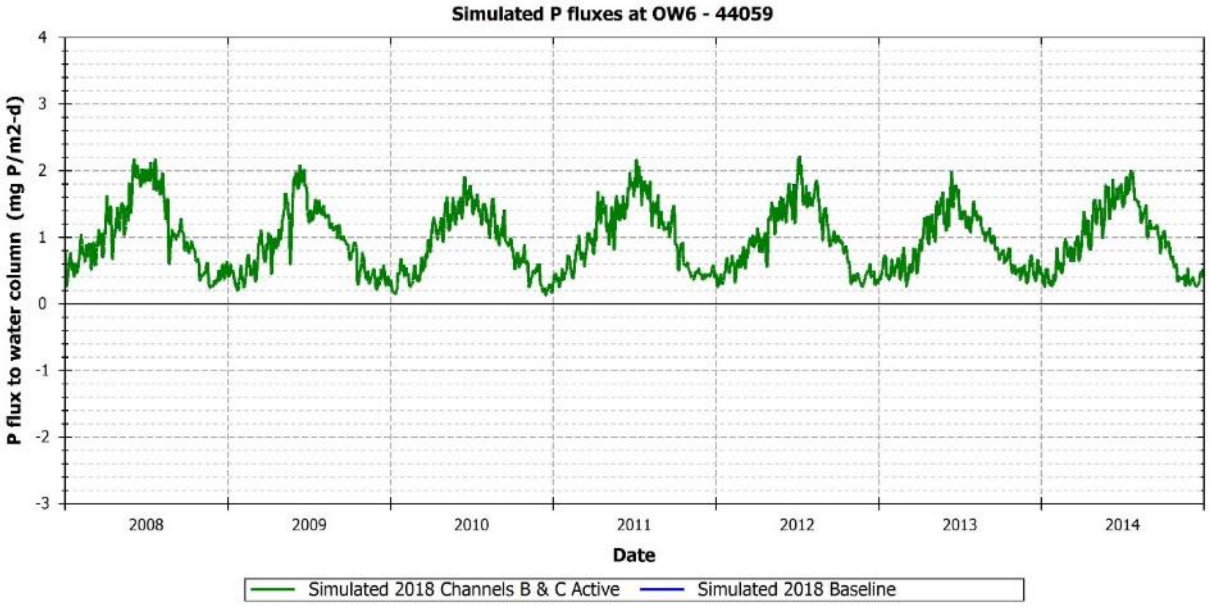


Figure C-29 Sediment Oxygen Demand at OW2 – 44055 for Scenario 1

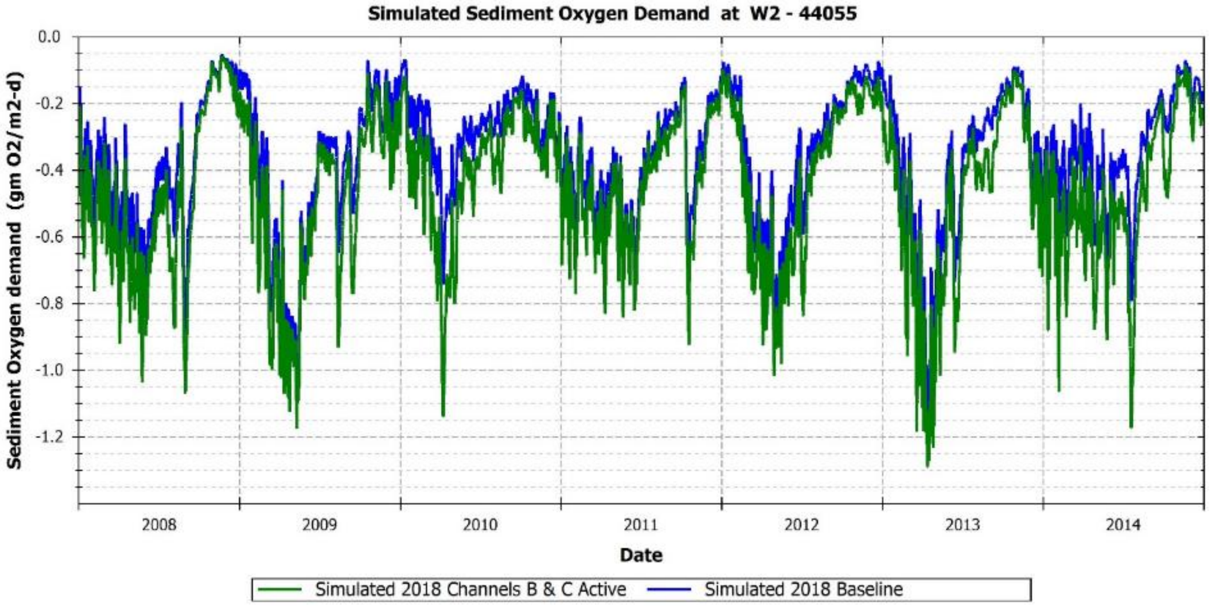


Figure C-30 Sediment Oxygen Demand at OW4 – 44057 for Scenario 1

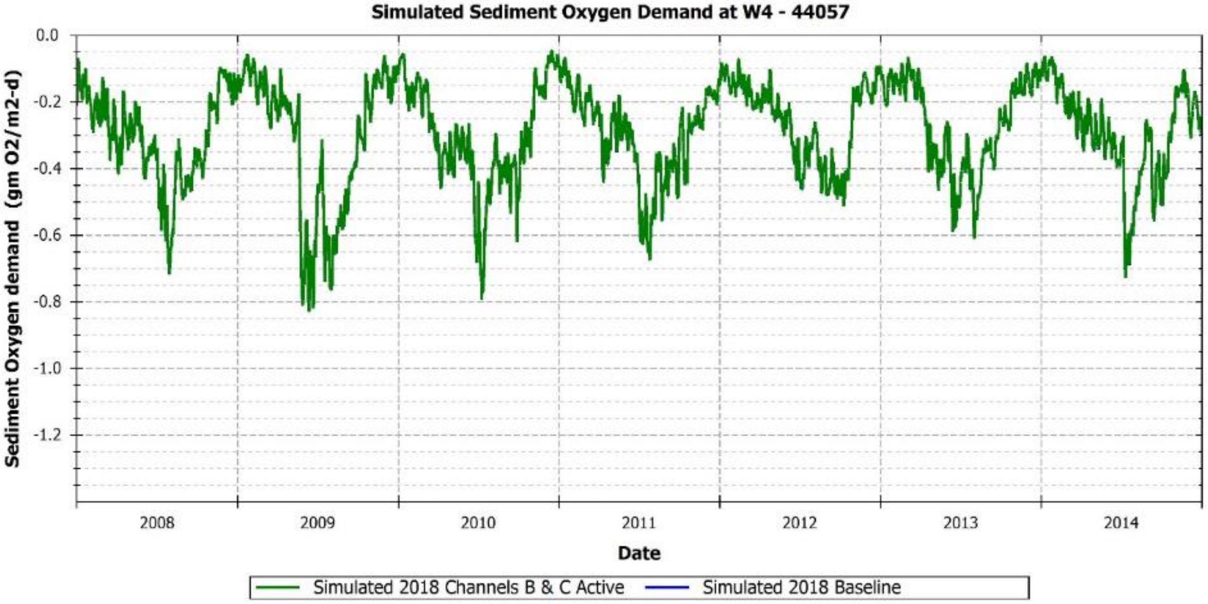
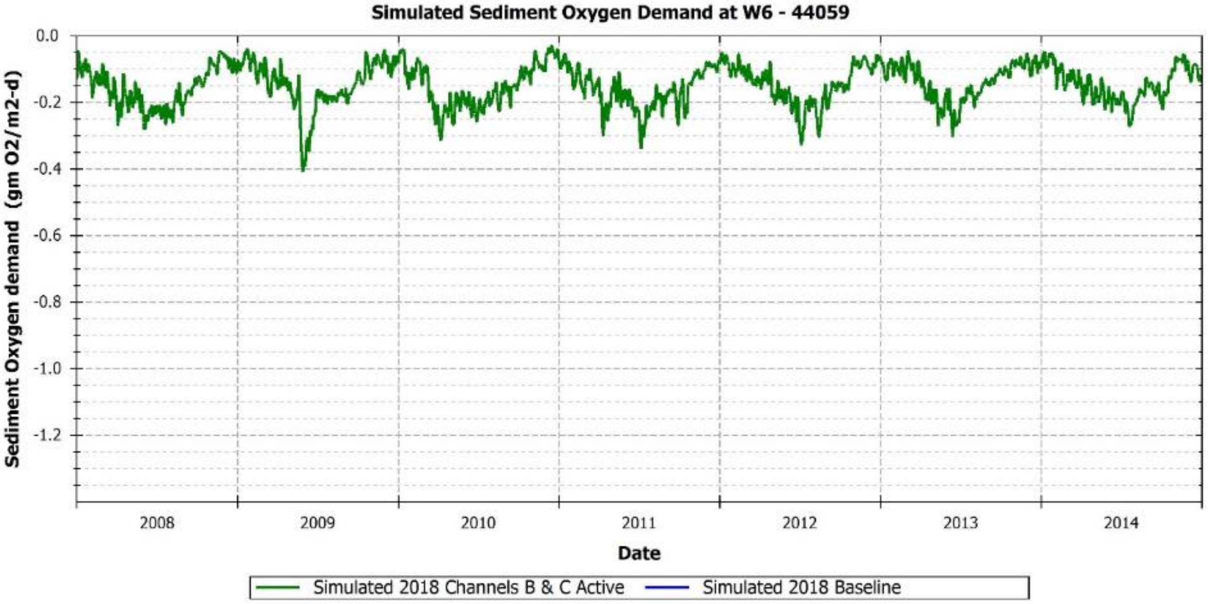


Figure C-31 Sediment Oxygen Demand at OW6 – 44059 for Scenario 1



SCENARIO 2: CHANNELS A AND C OPEN – TN

Figure C-32 TN Concentrations at JES for Scenario 2

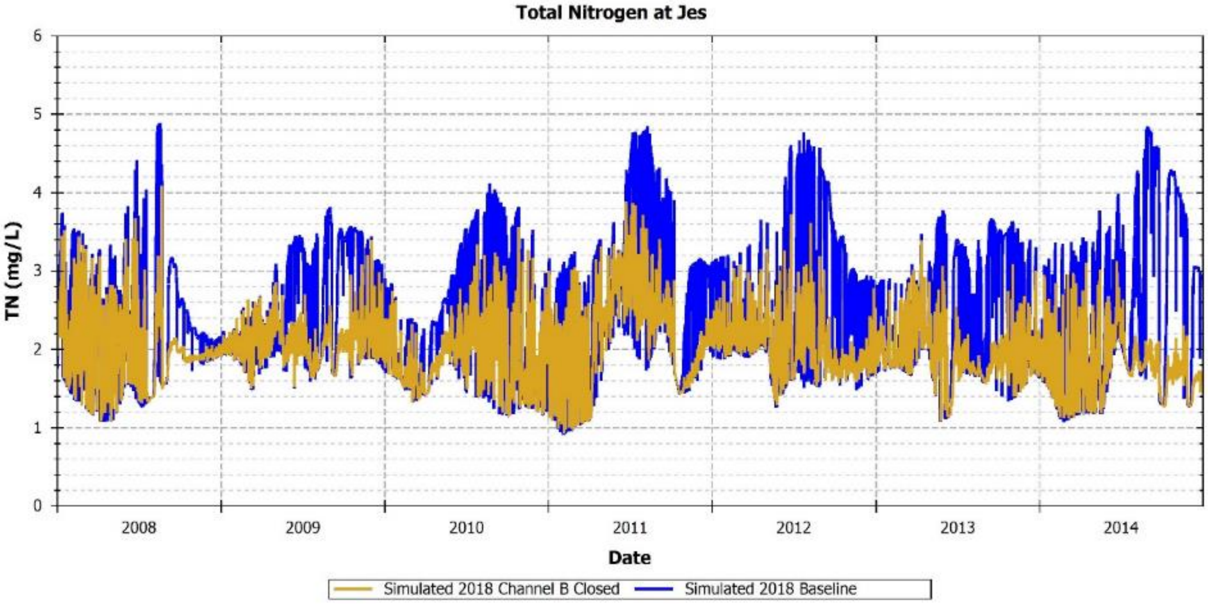


Figure C-33 TN Concentrations at OW2 – 44055 for Scenario 2

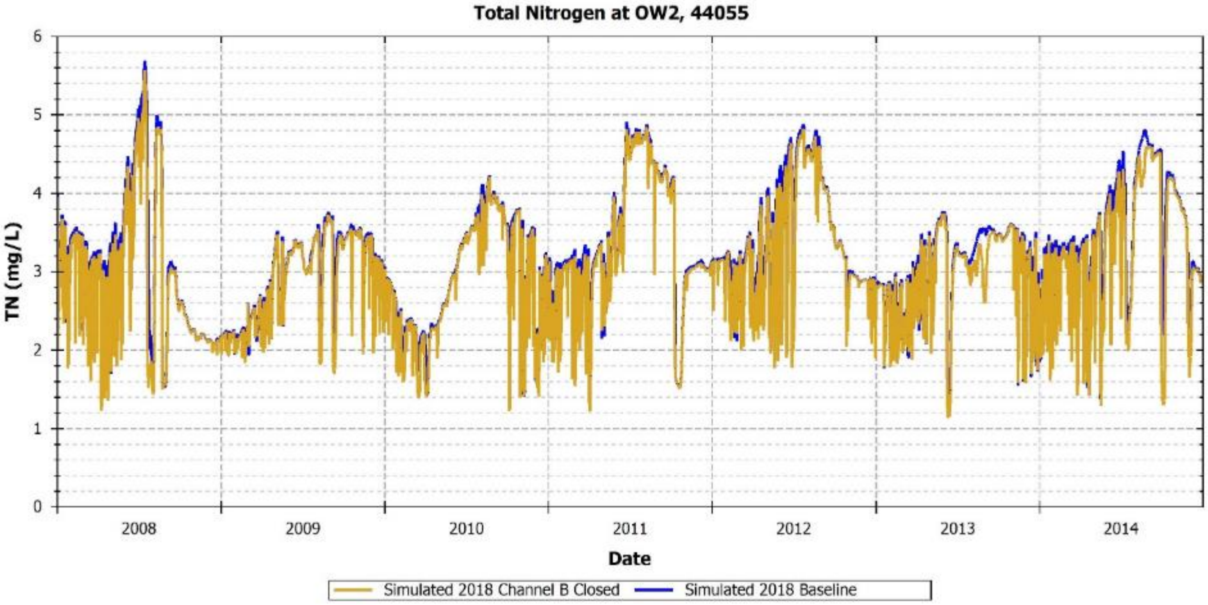


Figure C-34 TN Concentrations at Jesup E for Scenario 2

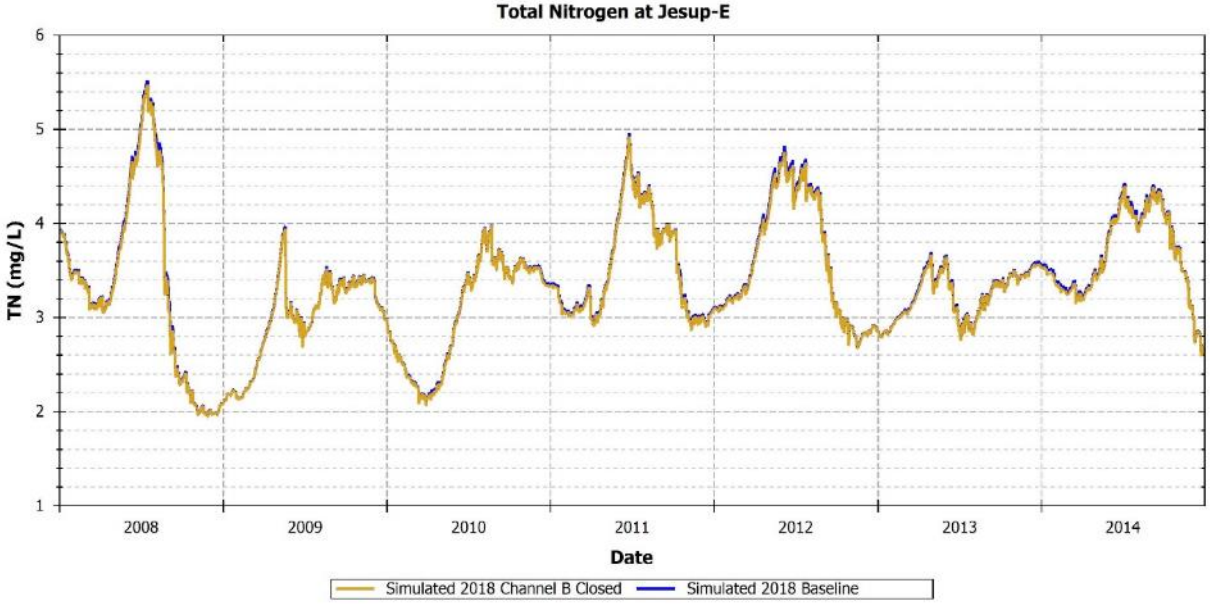


Figure C-35 TN Concentrations at OW4 – 44057 for Scenario 2

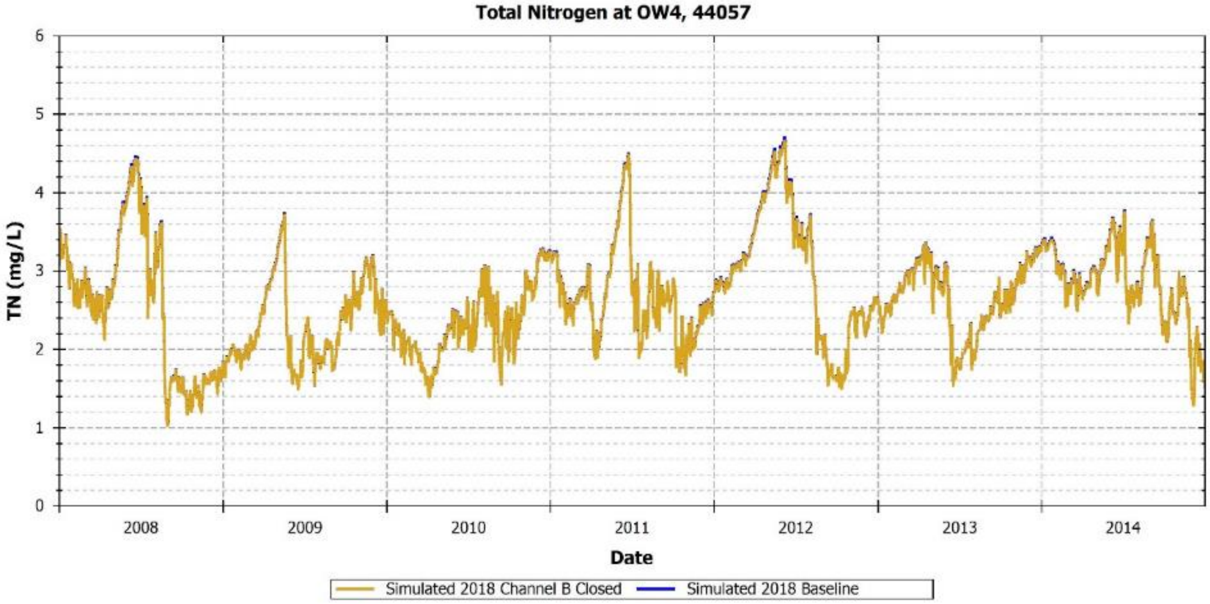


Figure C-36 TN Concentrations at Jesup-W for Scenario 2

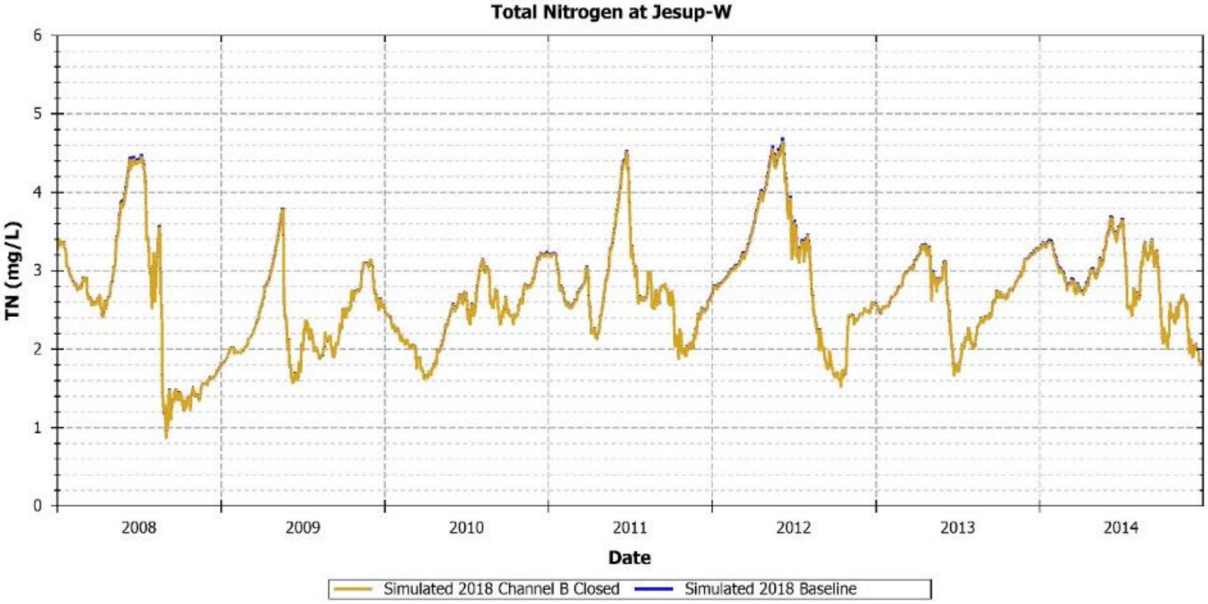


Figure C-37 TN Concentrations at OW6 – 44059 for Scenario 2

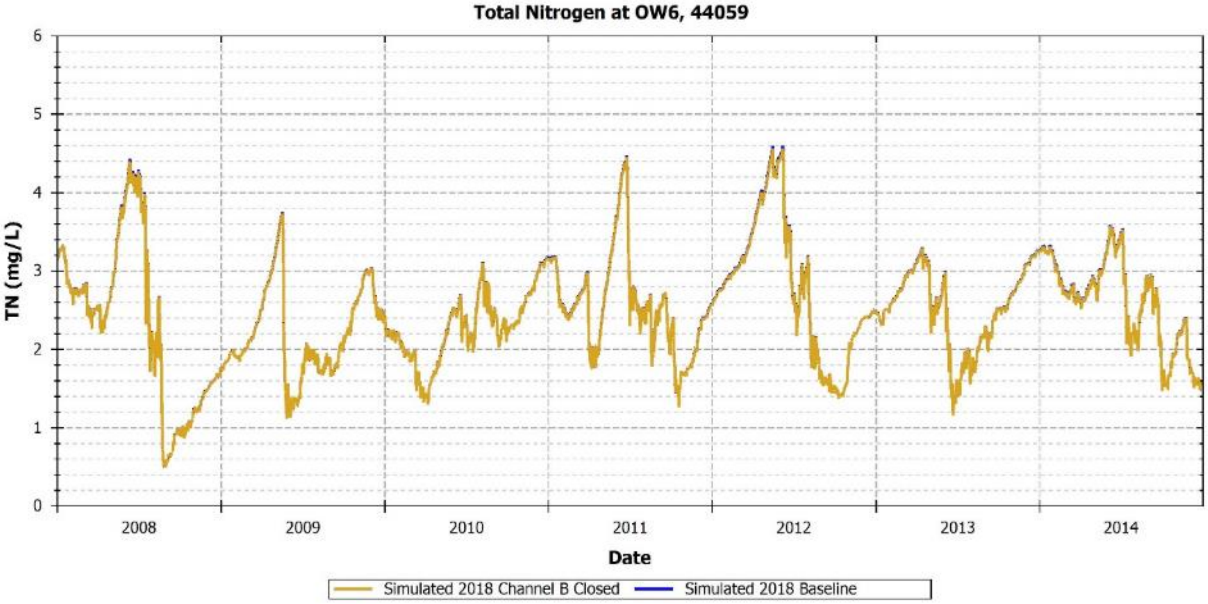


Table C-4: Changes in TN concentrations (mg/L) from baseline for Scenario 2

Year	**W2**			**W4**			W6		
	Baseline	A,C	% Change	Baseline	A,C	% Change	Baseline	A,C	% Change
2008	3.03	2.85	6.1%	2.56	2.55	0.4%	2.32	2.31	0.3%
2009	2.93	2.84	3.1%	2.32	2.32	0.2%	2.20	2.20	0.1%
2010	2.92	2.81	3.9%	2.33	2.32	0.2%	2.28	2.28	0.2%
2011	3.40	3.29	3.2%	2.69	2.68	0.4%	2.55	2.54	0.3%
2012	3.44	3.28	4.5%	2.99	2.97	0.5%	2.77	2.76	0.4%
2013	3.01	2.88	4.2%	2.66	2.65	0.3%	2.52	2.51	0.2%
2014	3.50	3.25	7.2%	2.83	2.82	0.4%	2.58	2.58	0.4%

SCENARIO 2: CHANNELS A AND C OPEN – TP

Figure C-38 TP Concentrations at JES for Scenario 2

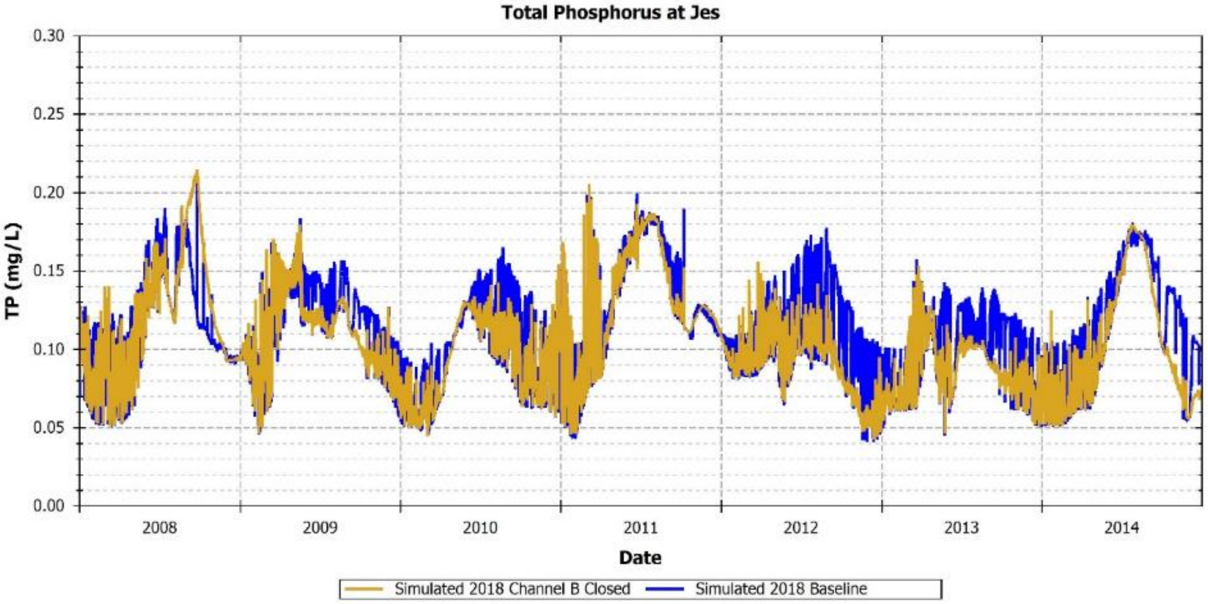


Figure C-39 TP Concentrations at OW2 – 44055 for Scenario 2

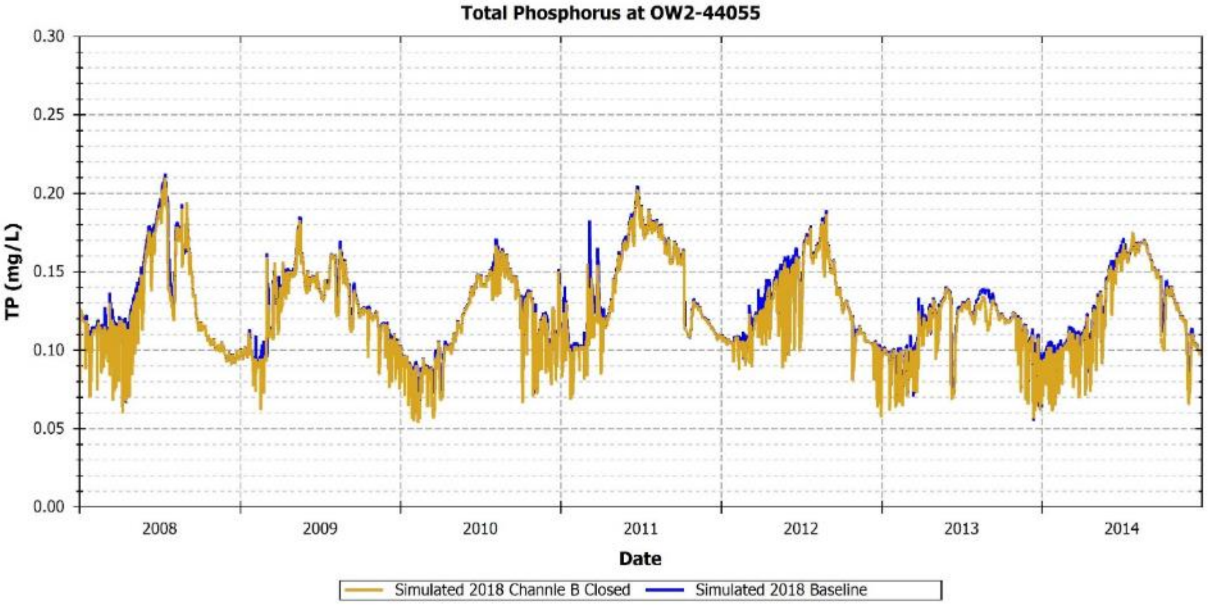


Figure C-40 TP Concentrations at Jesup-E for Scenario 2

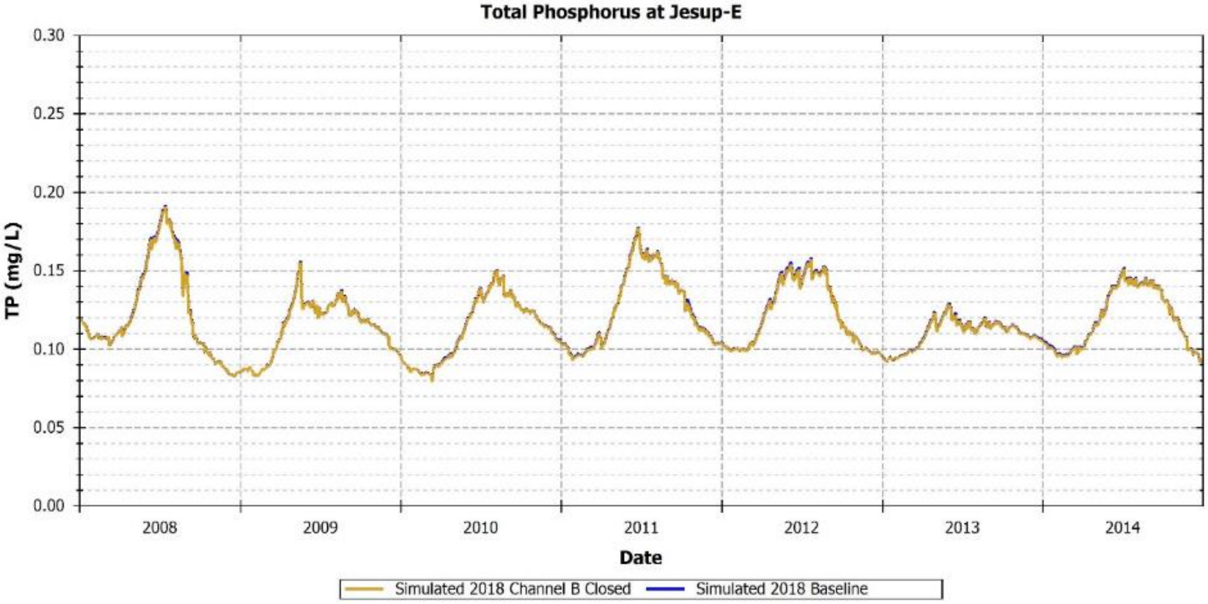


Figure C-41 TP Concentrations at OW4 – 44057 for Scenario 2

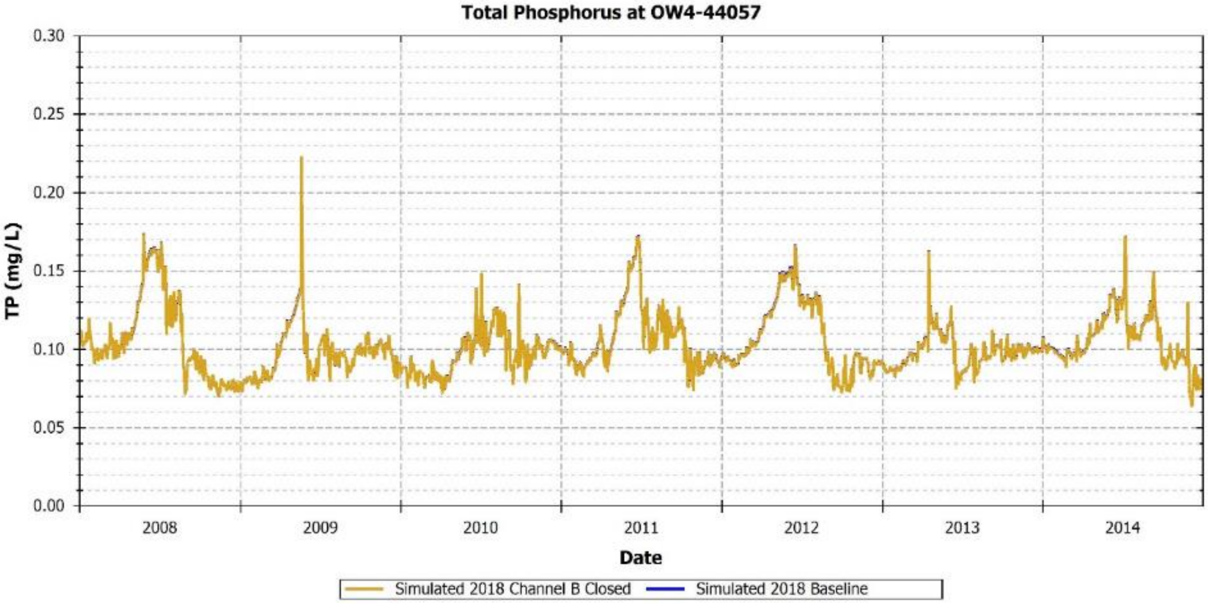


Figure C-42 TP Concentrations at Jesup-W for Scenario 2

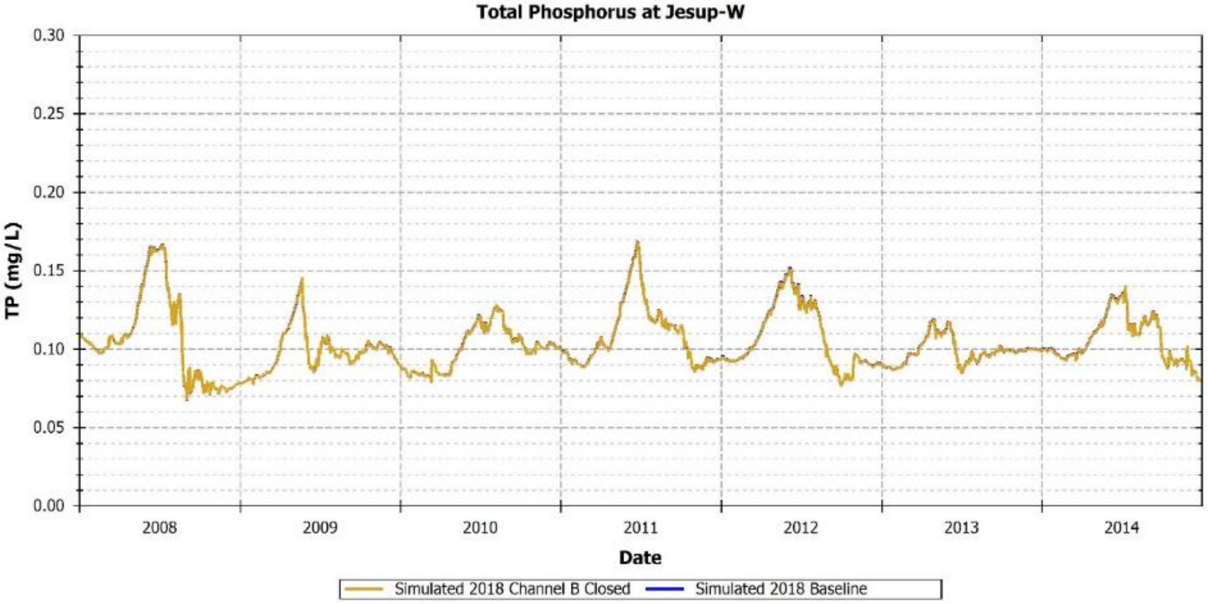


Figure C-43 TP Concentrations at OW6 – 44059 for Scenario 2

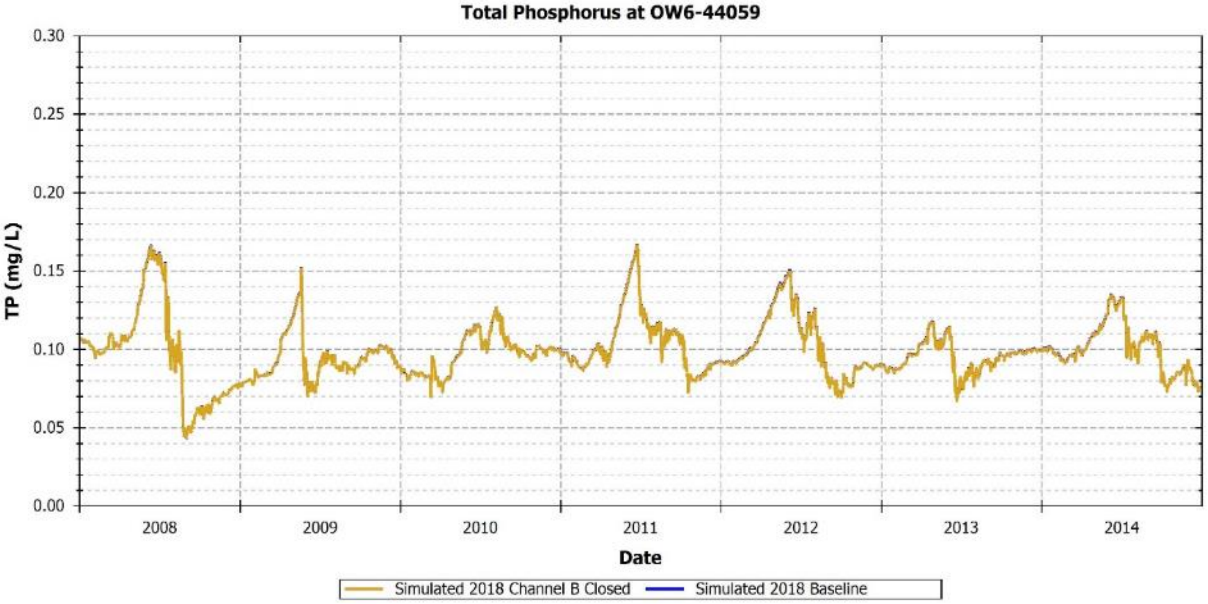


Table C-5: Changes in TP concentrations (mg/L) from baseline for Scenario 2

Year	**W2**			W4			W6		
	Baseline	A,C	% Change	Baseline	A,C	% Change	Baseline	A,C	% Change
2008	0.13	0.13	3.5%	0.11	0.11	0.2%	0.10	0.10	0.1%
2009	0.13	0.13	2.2%	0.10	0.10	0.1%	0.09	0.09	0.1%
2010	0.12	0.11	3.3%	0.10	0.10	0.2%	0.10	0.10	0.1%
2011	0.14	0.14	2.3%	0.11	0.11	0.3%	0.10	0.10	0.2%
2012	0.13	0.13	3.7%	0.11	0.11	0.3%	0.10	0.10	0.3%
2013	0.11	0.11	3.4%	0.10	0.10	0.2%	0.09	0.09	0.2%
2014	0.13	0.12	4.0%	0.11	0.11	0.3%	0.10	0.10	0.2%

SCENARIO 2: CHANNELS A AND C OPEN – CHLOROPHYLL-*A*

Figure C-44 Chlorophyll-*a* concentrations at JES for Scenario 2

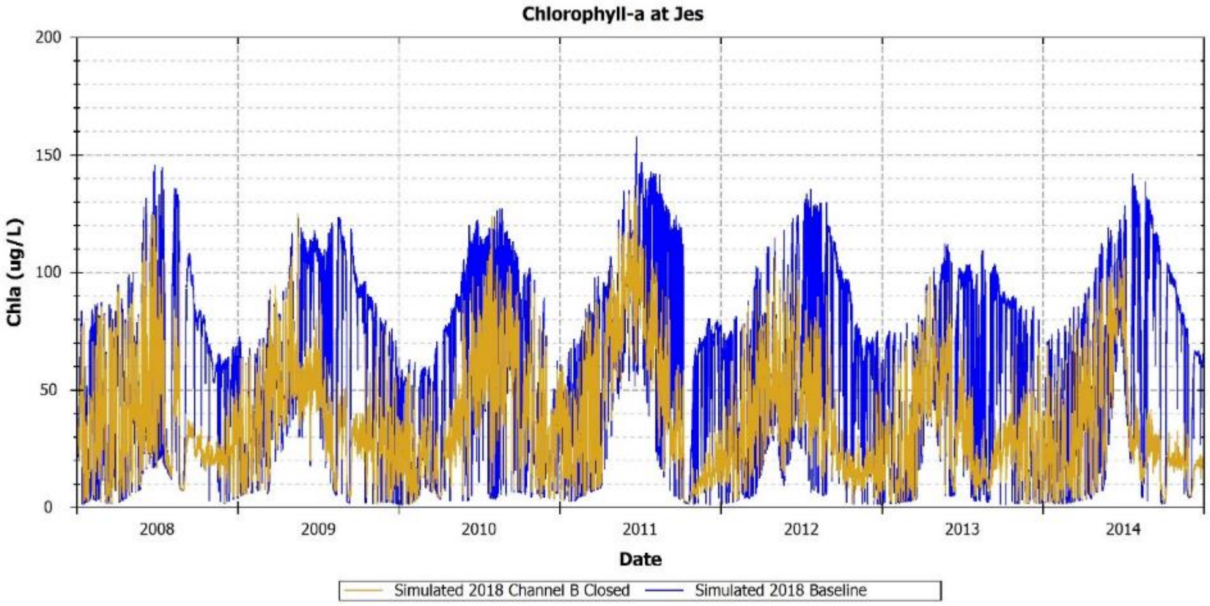


Figure C-45 Chlorophyll-*a* Concentrations at OW2 – 44055 for Scenario 2

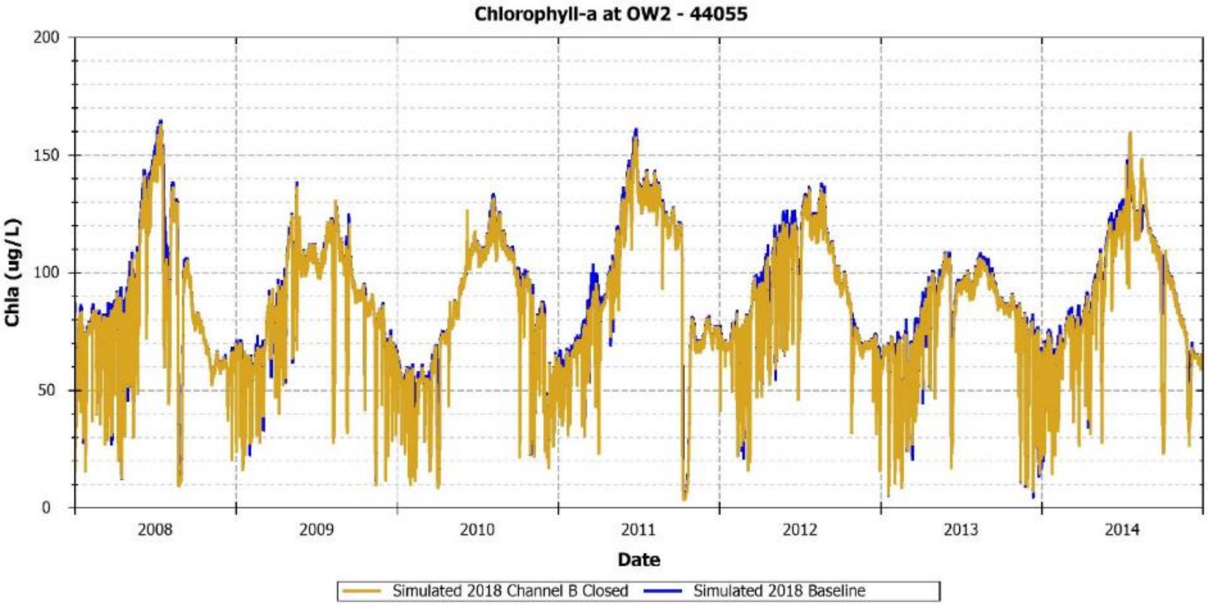


Figure C-46 Chlorophyll-*a* Concentrations at Jesup-E for Scenario 2

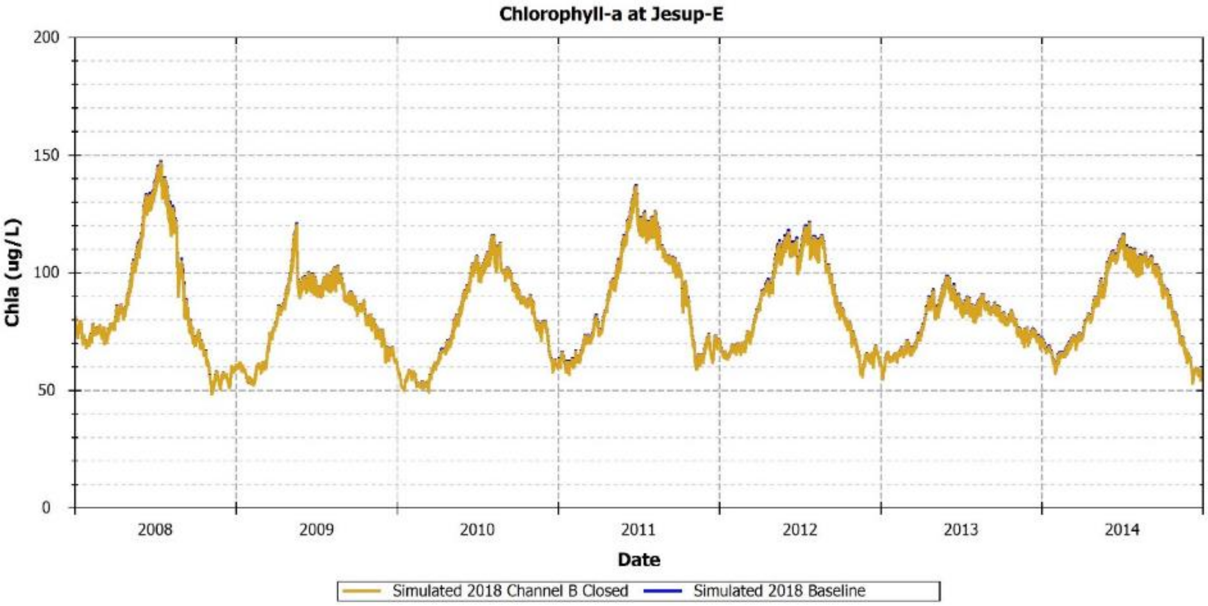


Figure C-47 Chlorophyll-*a* Concentrations at OW4 – 44057 for Scenario 2

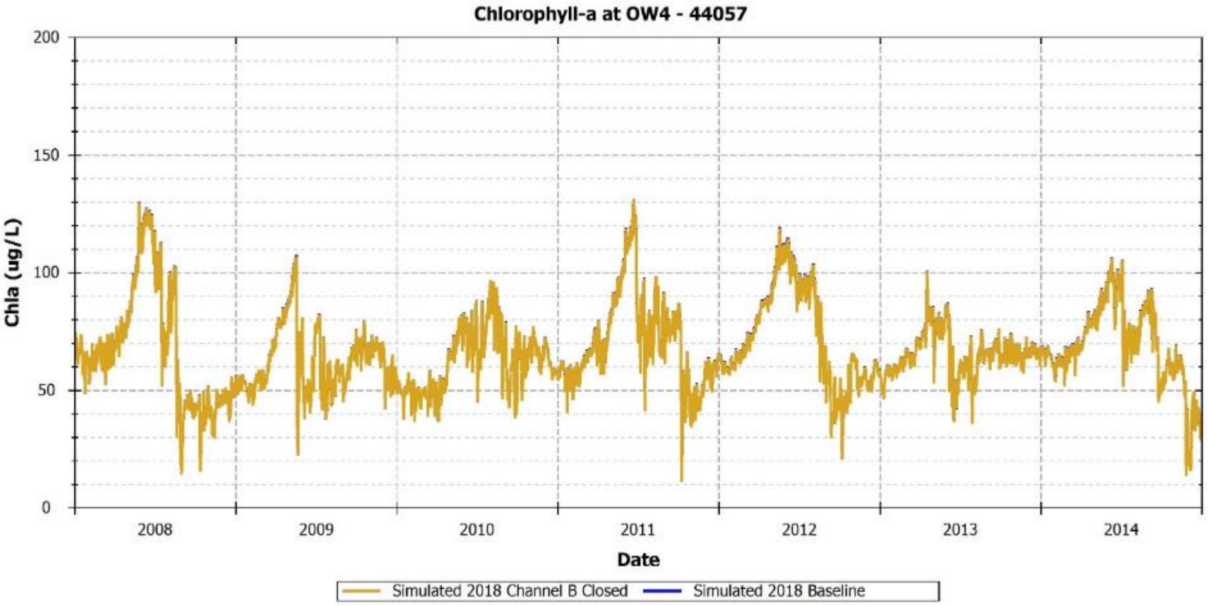


Figure C-48 Chlorophyll-*a* Concentrations at Jesup-W for Scenario 2

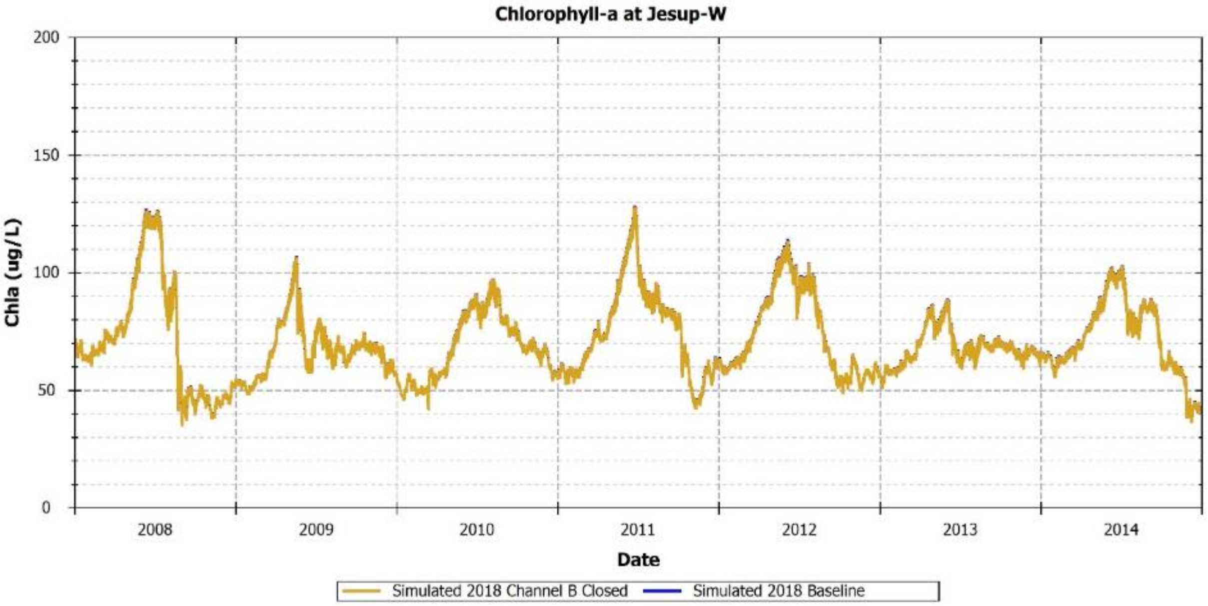
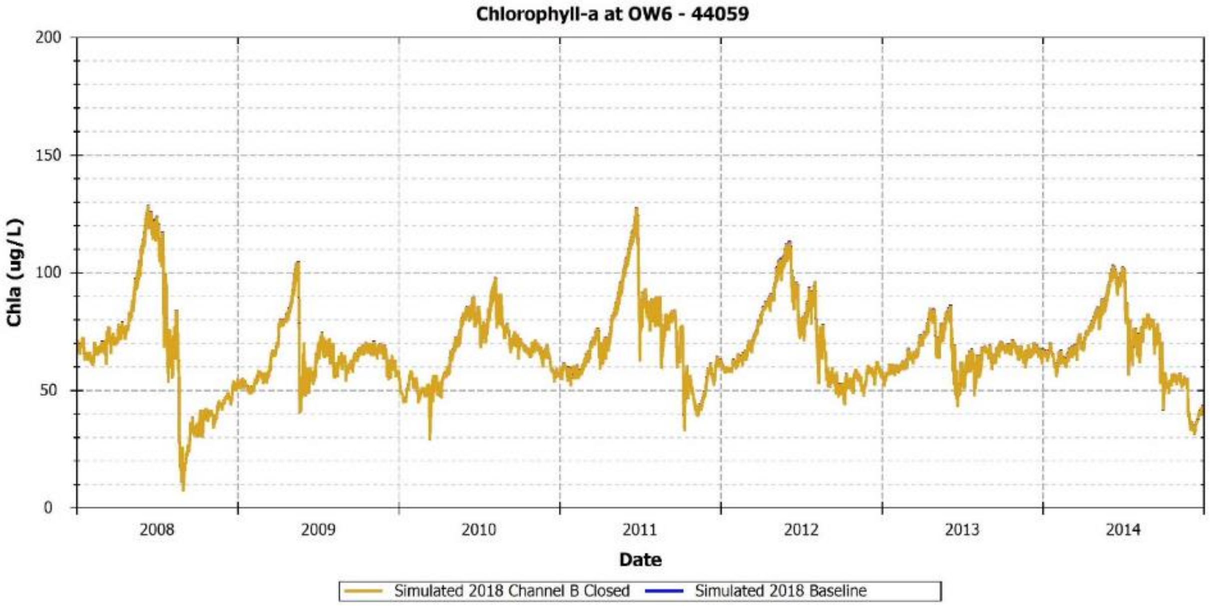


Figure C-49 Chlorophyll-*a* Concentrations at OW6 – 44059 for Scenario 2



SCENARIO 2: CHANNELS A AND C OPEN – SEDIMENT FLUXES

Figure C-50 Ammonia Fluxes at OW2 – 44055 for Scenario 2

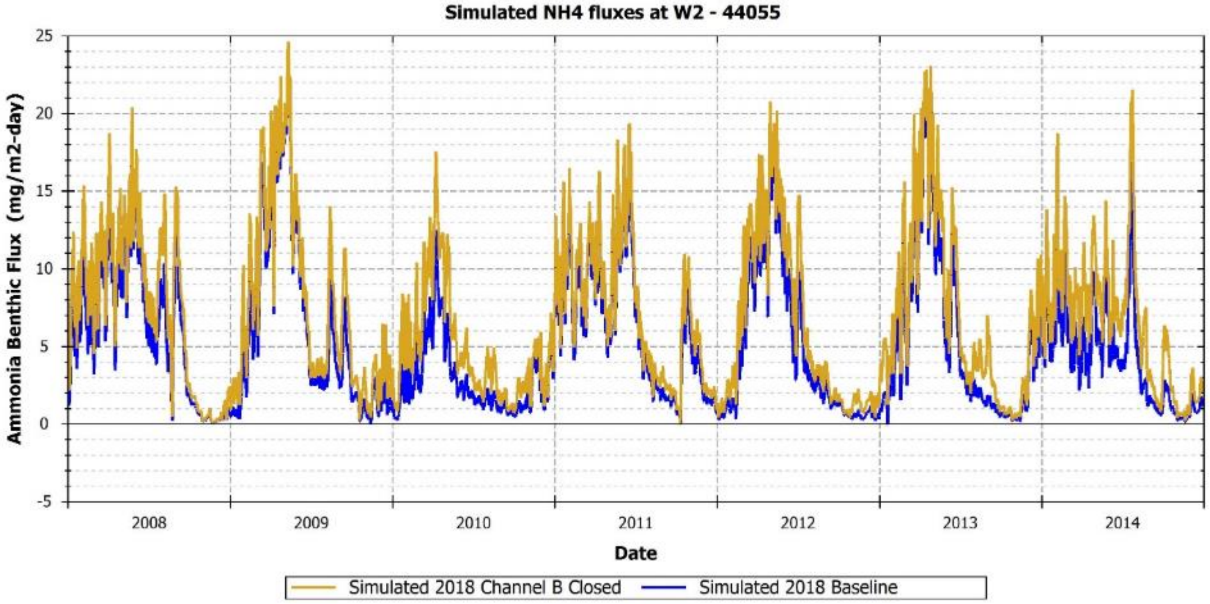


Figure C-51 Ammonia Fluxes at OW4 – 44057 for Scenario 2

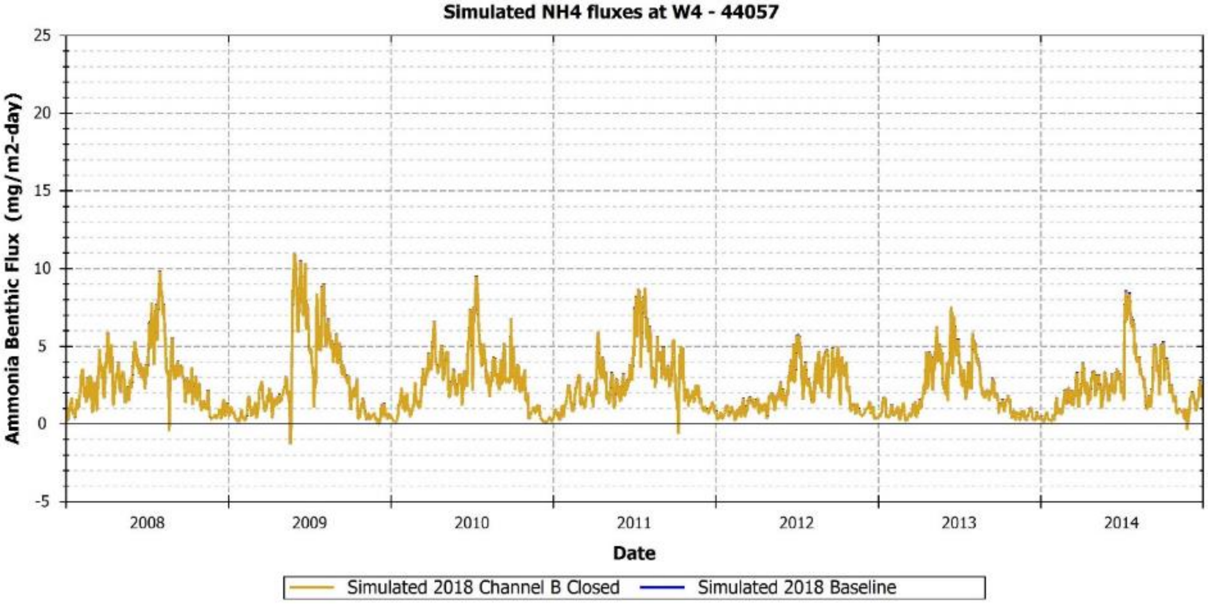


Figure C-52 Ammonia Fluxes at OW6 – 44059 for Scenario 2

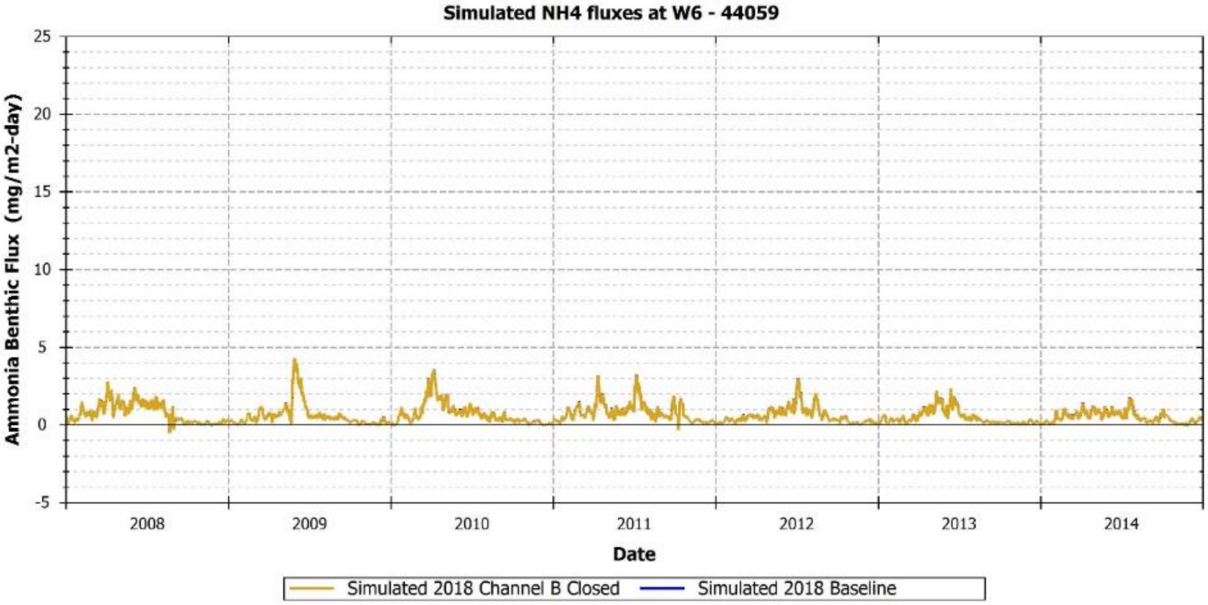


Figure C-53 Nitrate Fluxes at OW2 – 44055 for Scenario 2

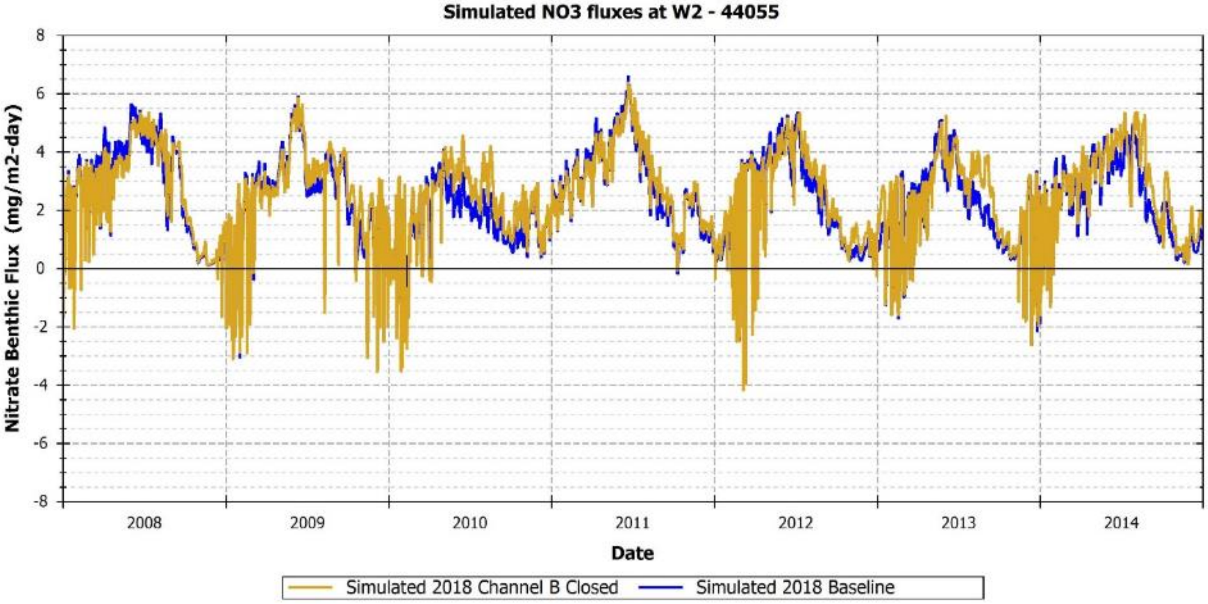


Figure C-54 Nitrate Fluxes at OW4 – 44057 for Scenario 2

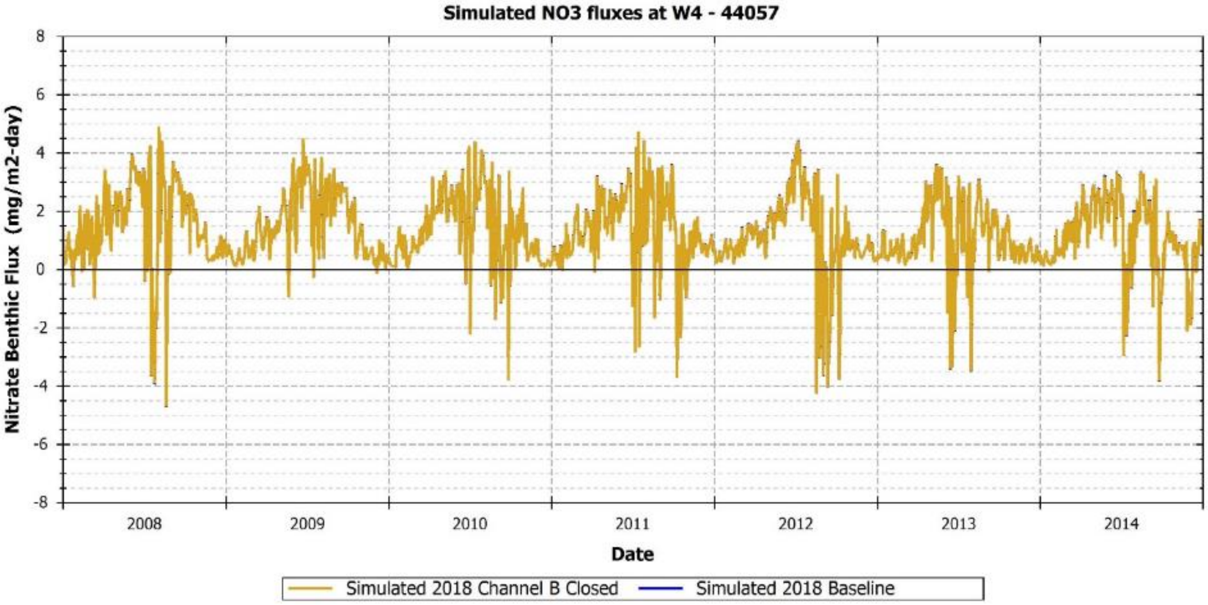


Figure C-55 Nitrate Fluxes at OW6 – 44059 for Scenario 2

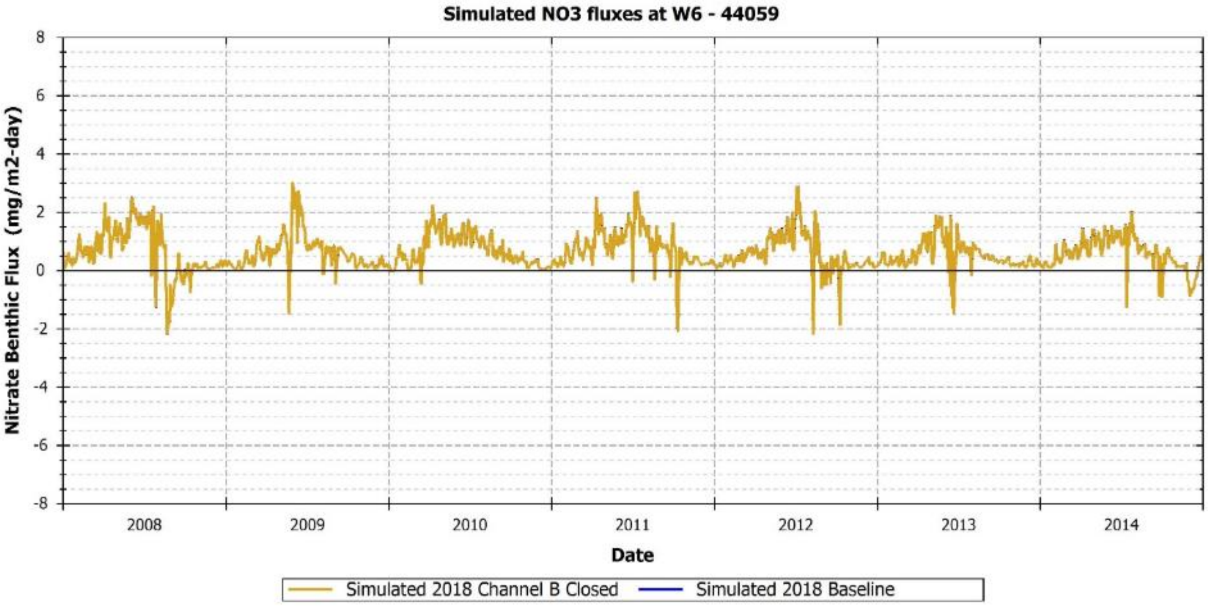


Figure C-56 Phosphorus Fluxes at OW2 – 44055 for Scenario 2

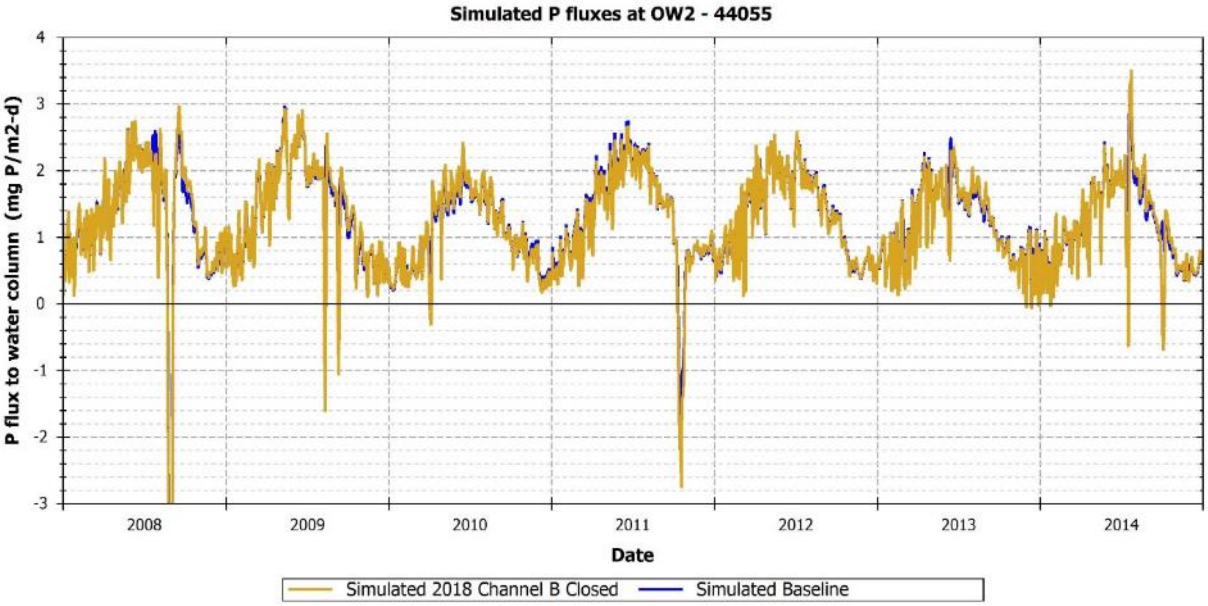


Figure C-57 Phosphorus Fluxes at OW4 – 44057 for Scenario 2

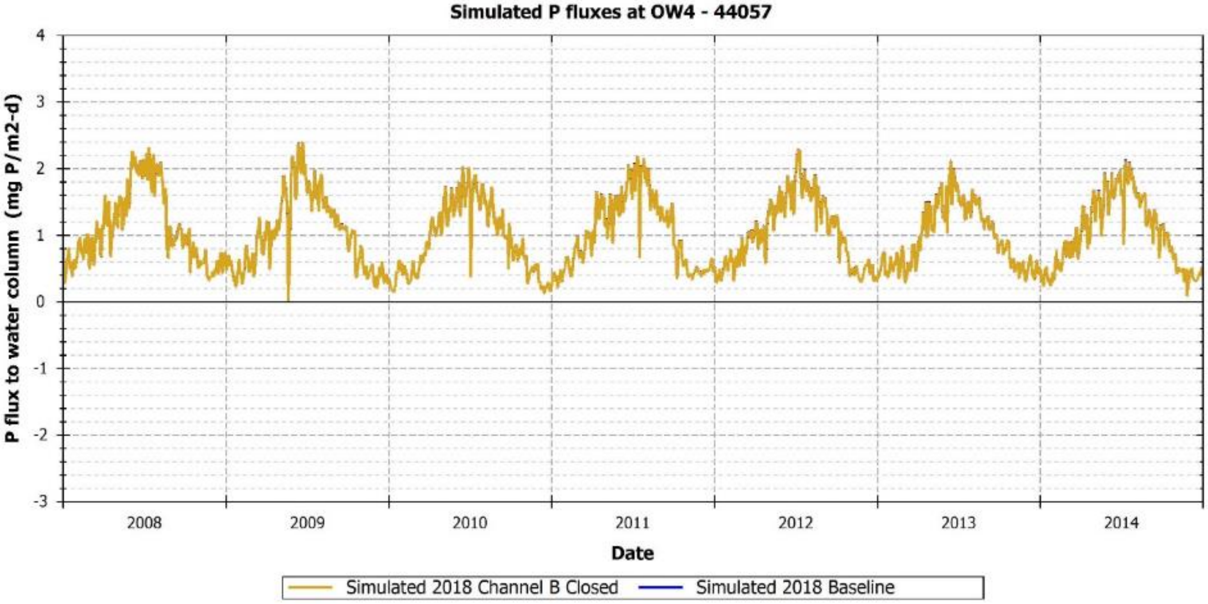


Figure C-58 Phosphorus Fluxes at OW6 – 44059 for Scenario 2

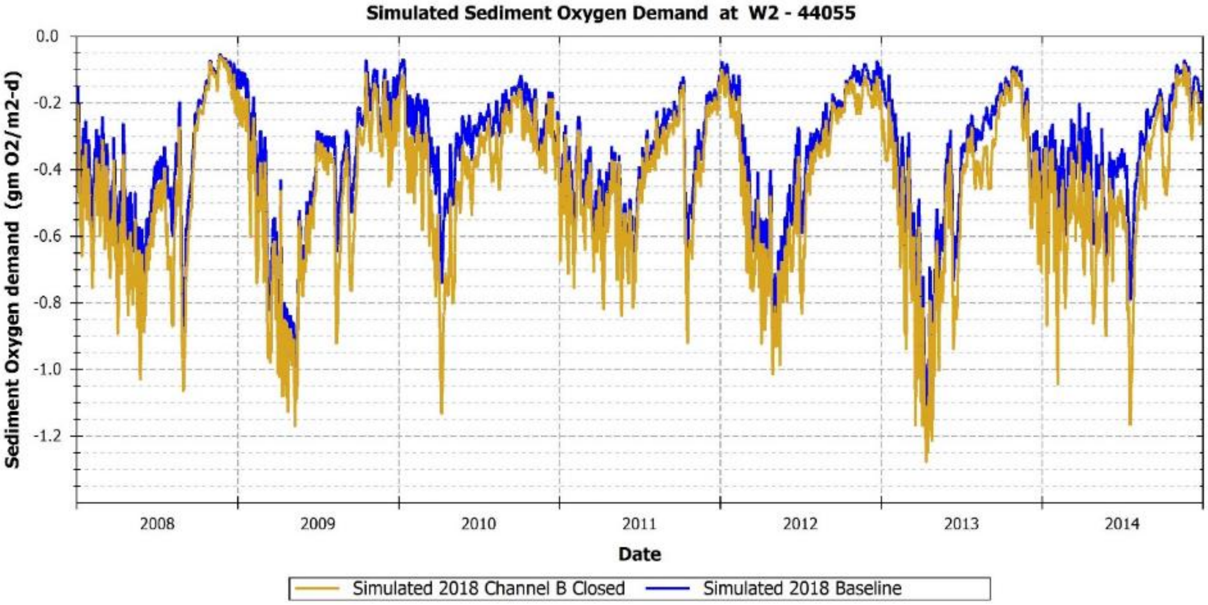


Figure C-59 Sediment Oxygen Demand at OW2 – 44055 for Scenario 2

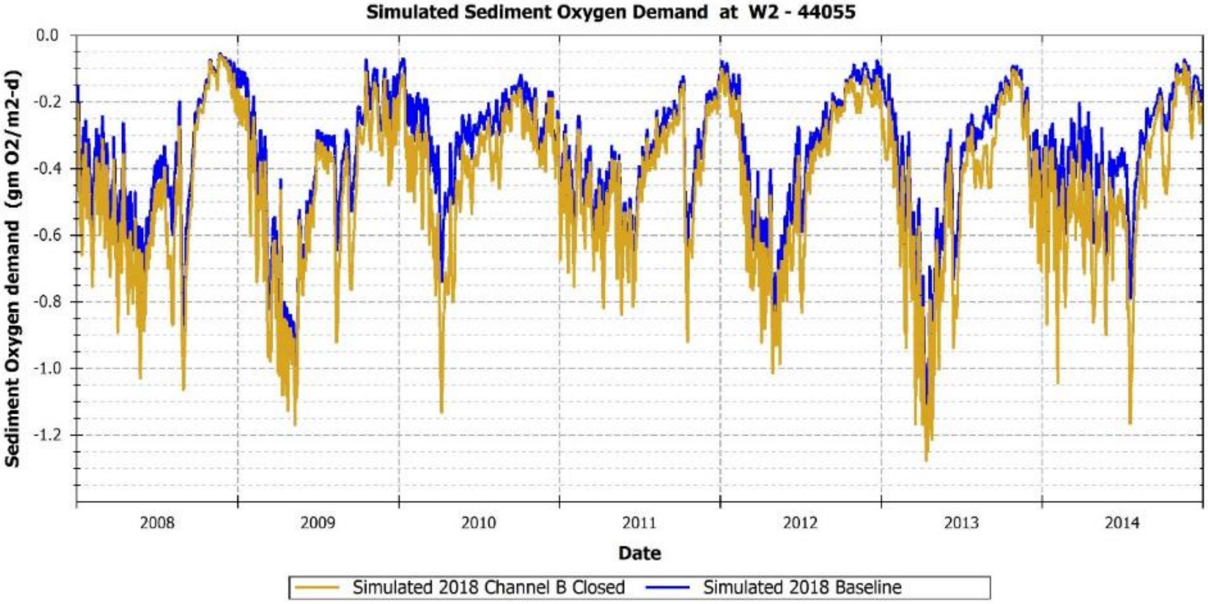


Figure C-60 Sediment Oxygen Demand at OW4 – 44057 for Scenario 2

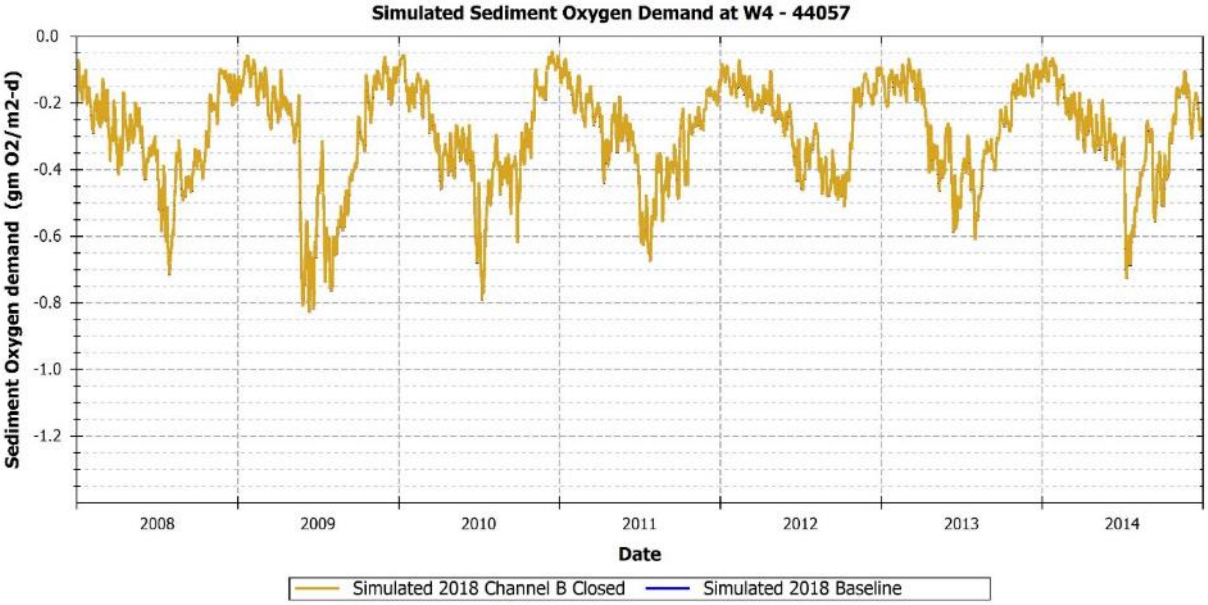
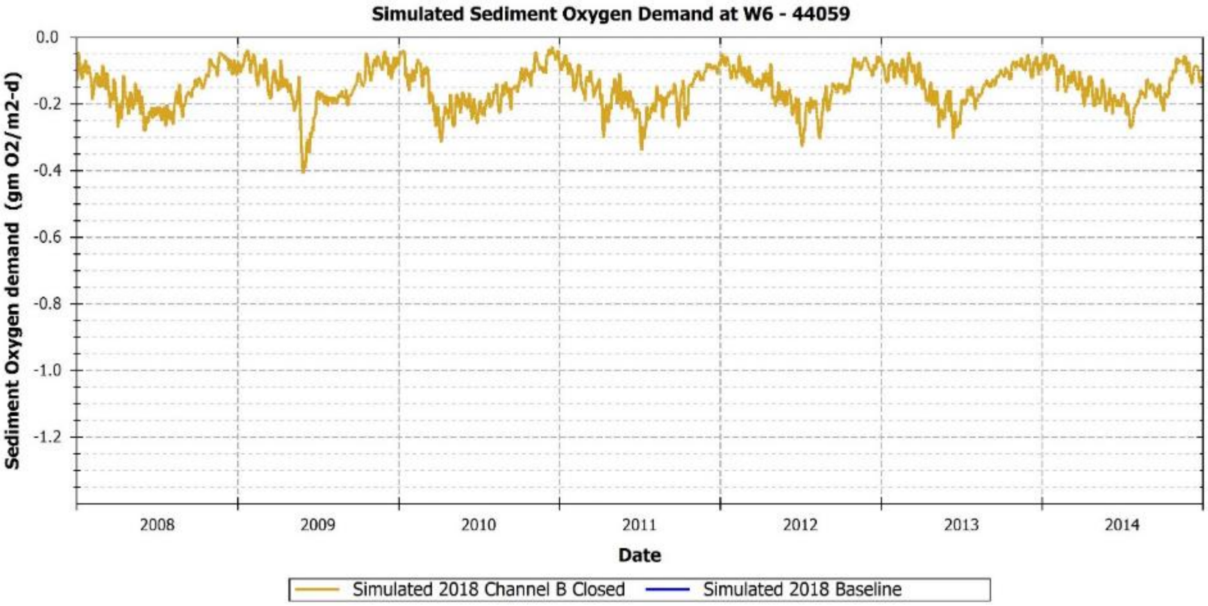
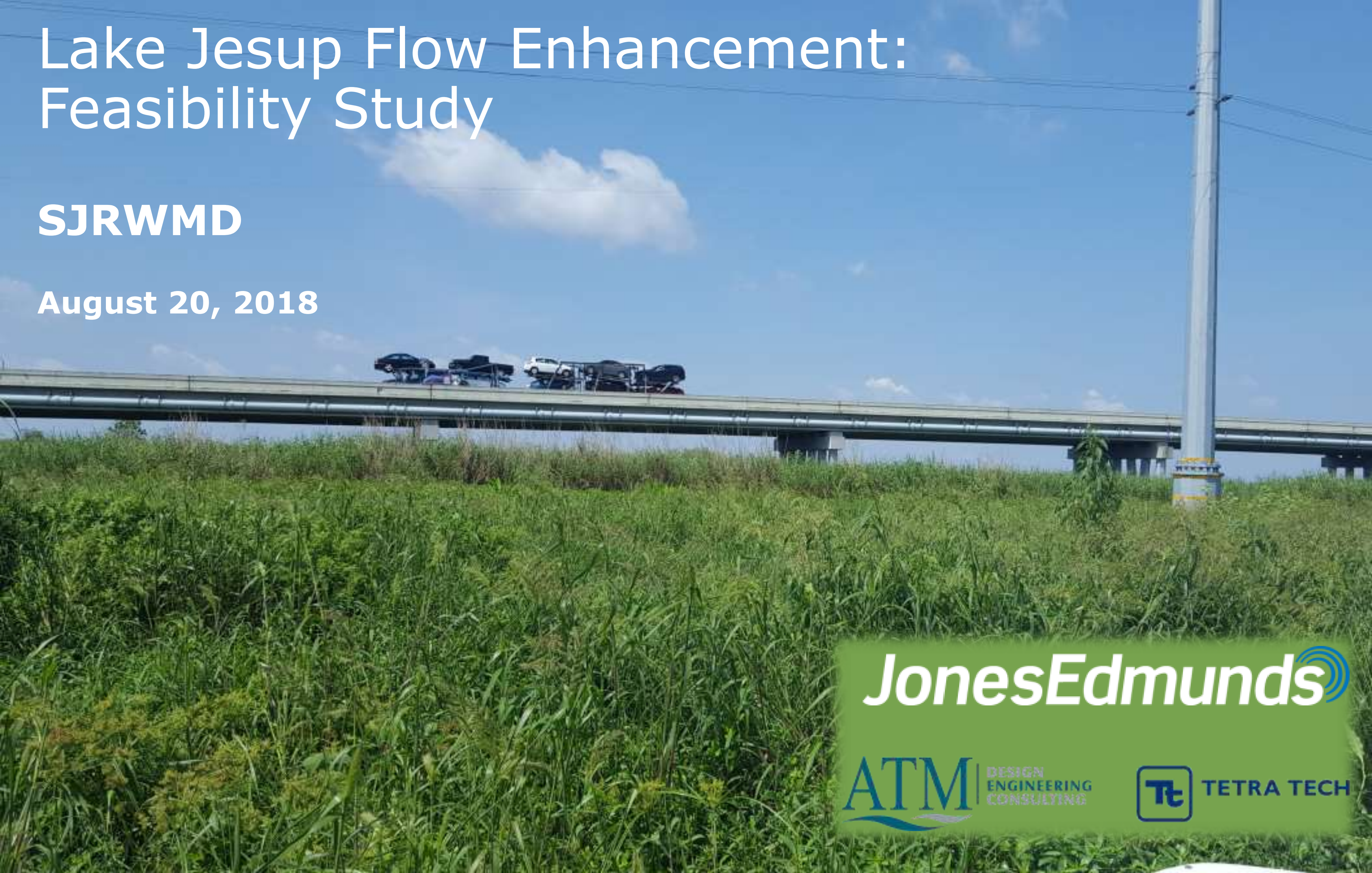


Figure C-61 Sediment Oxygen Demand at OW6 – 44059 for Scenario 2



Lake Jesup Flow Enhancement: Feasibility Study



Lake Jesup Flow Enhancement: Feasibility Study

SJRWMD

August 20, 2018

JonesEdmunds

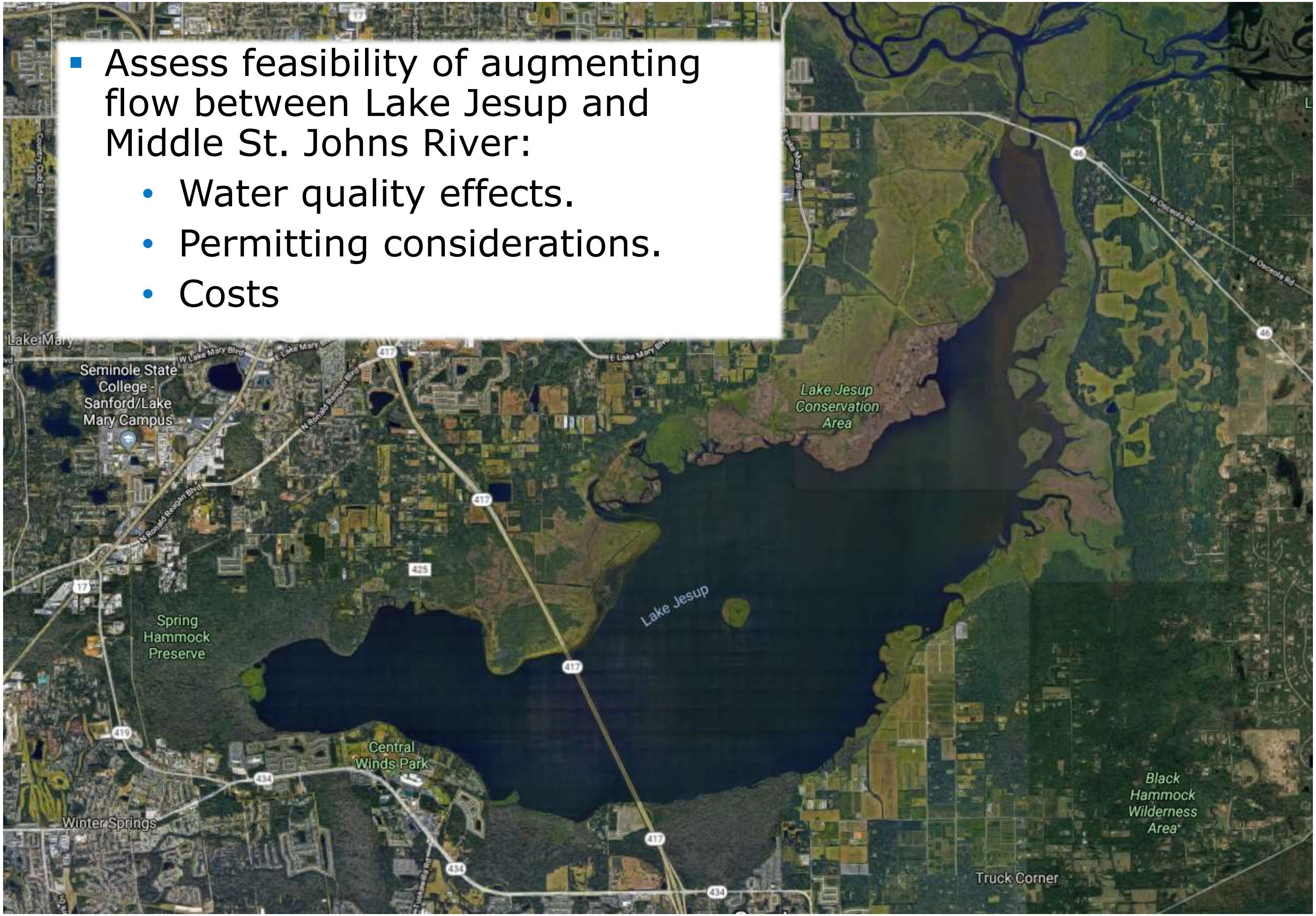
ATM DESIGN ENGINEERING CONSULTING

TETRA TECH

Overview

- Background, Goals, & Approach
- Scenarios Considered
- Hydrodynamic Modeling
- Water Quality Modeling
- Permitting Considerations
- Opinion of Cost
- Summary

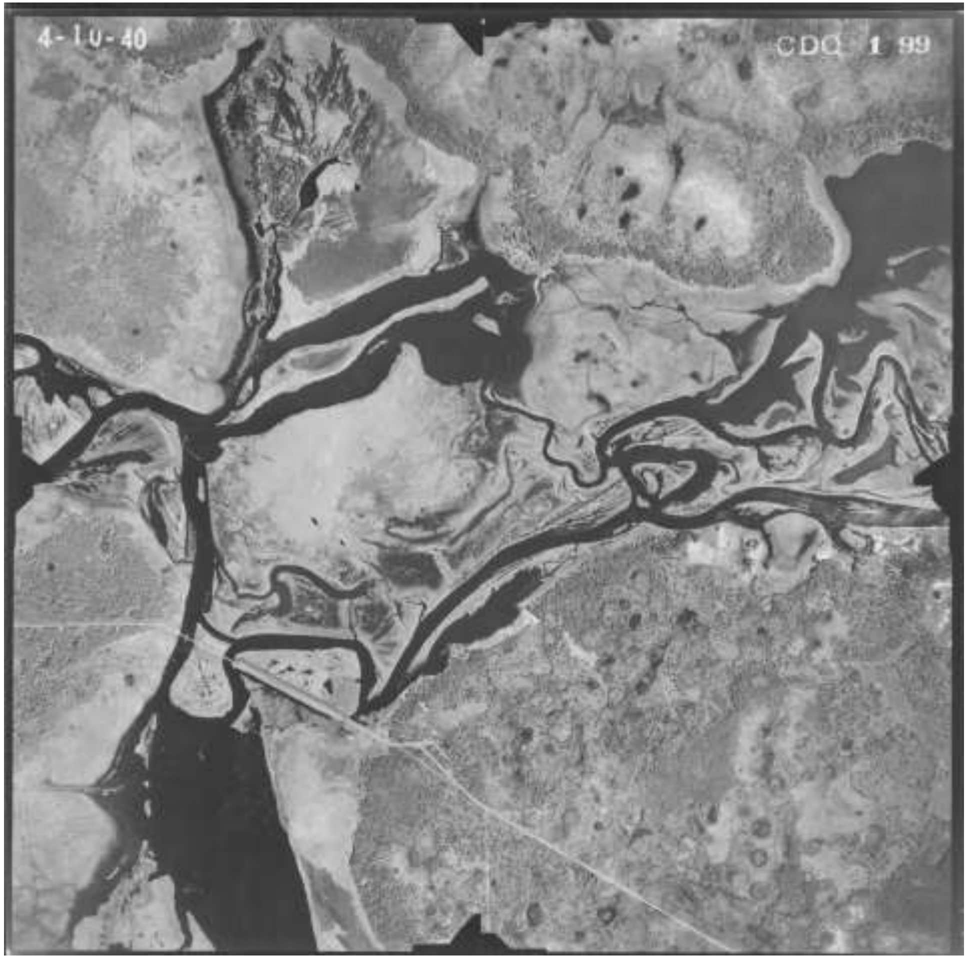
Background, Goals, & Approach



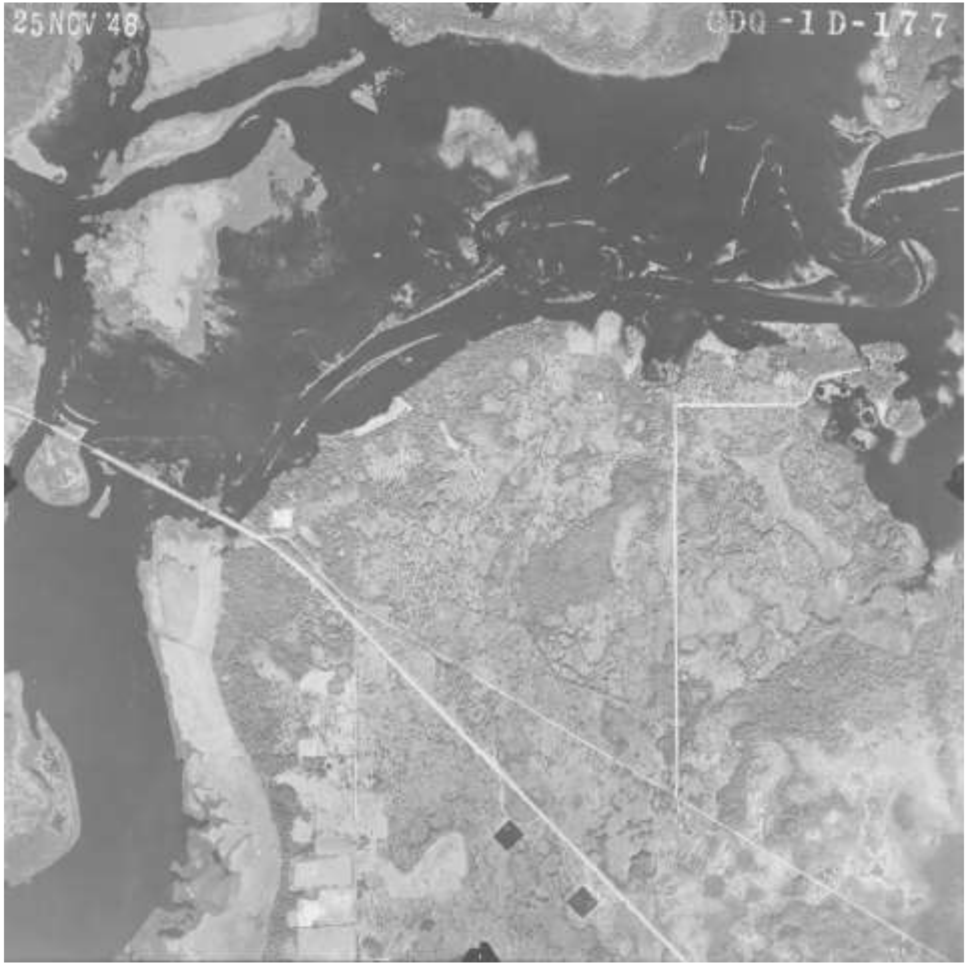
- Assess feasibility of augmenting flow between Lake Jesup and Middle St. Johns River:
  - Water quality effects.
  - Permitting considerations.
  - Costs

Background, Goals, & Approach

April 10, 1940 – normal water



November 25, 1948 – wet year



Hydrodynamic Modeling

- Start with SJRWMD MSJR model
- Clip out the portion including Lake Jesup
- Used existing model for relative comparison (minimal recalibration)

Scenarios Considered

1. Existing Conditions (Baseline) - A & B open.

2. A, B, & C open.

3. A & C open, B closed.

Hydrodynamic Modeling – Flow Summary

- Opening Channel C will divert almost half of the current flow through Government Cut into Lake Jesup
- Vector plots indicate that flow coming in C turns and flows out A and/or B
- Effect of that flow diversion is evaluated in the water quality model

Existing Conditions

Hydrodynamic Modeling – Flow Summary

- Opening Channel C will divert almost half of the current flow through Government Cut into Lake Jesup
- Vector plots indicate that flow coming in C turns and flows out A and/or B
- Effect of that flow diversion is evaluated in the water quality model

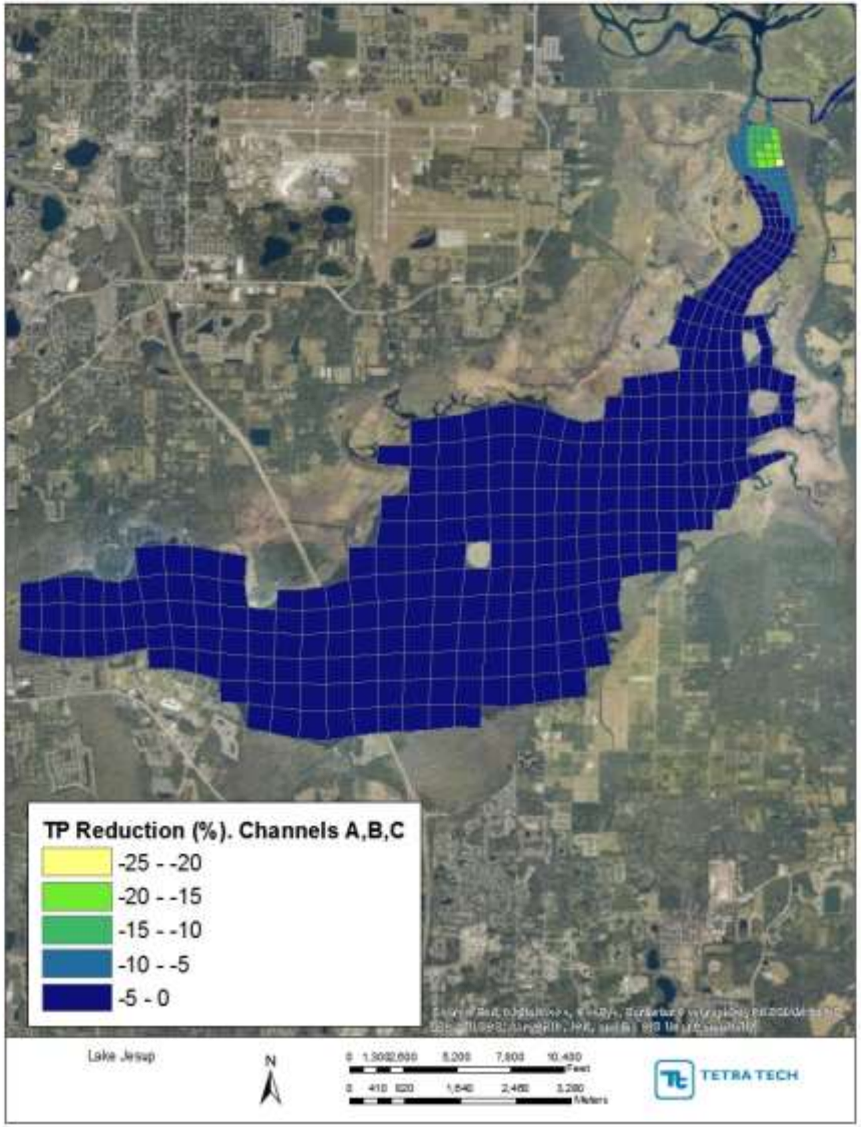
A, B, C Open

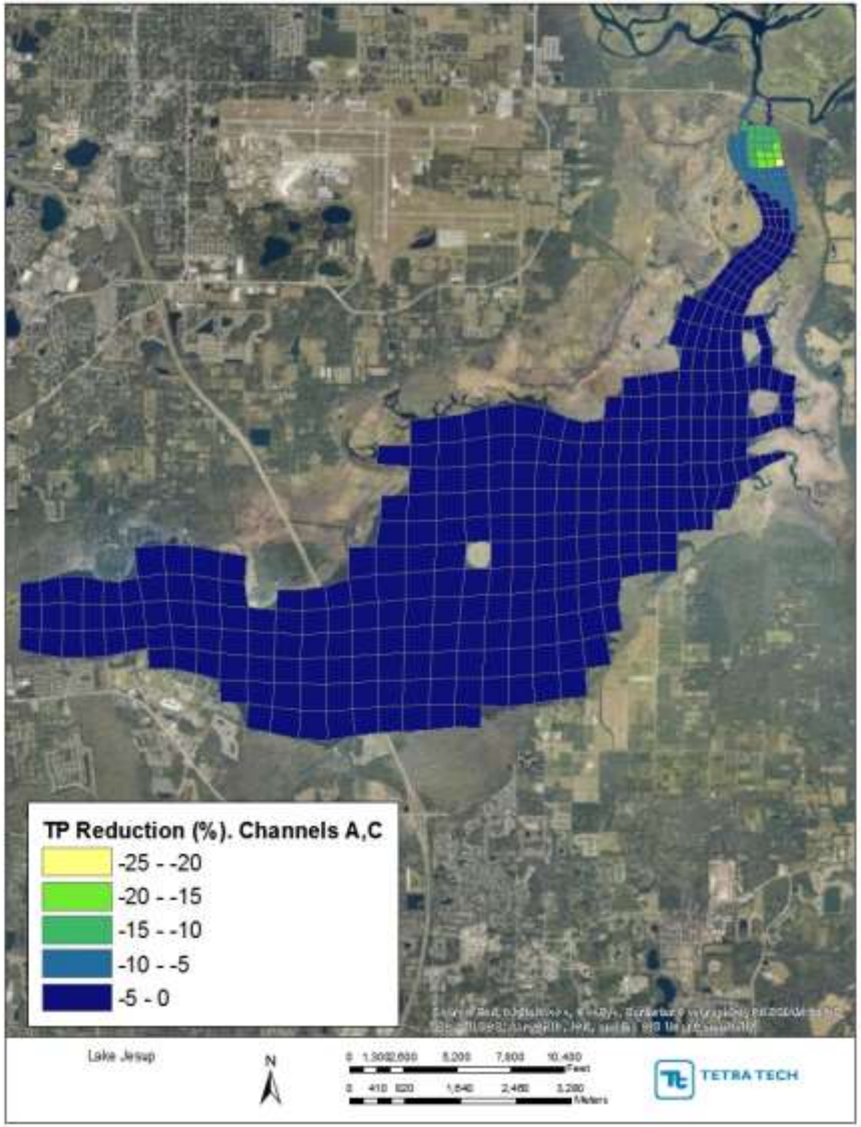
Hydrodynamic Modeling – Flow Summary

- Opening Channel C will divert almost half of the current flow through Government Cut into Lake Jesup
- Vector plots indicate that flow coming in C turns and flows out A and/or B
- Effect of that flow diversion is evaluated in the water quality model

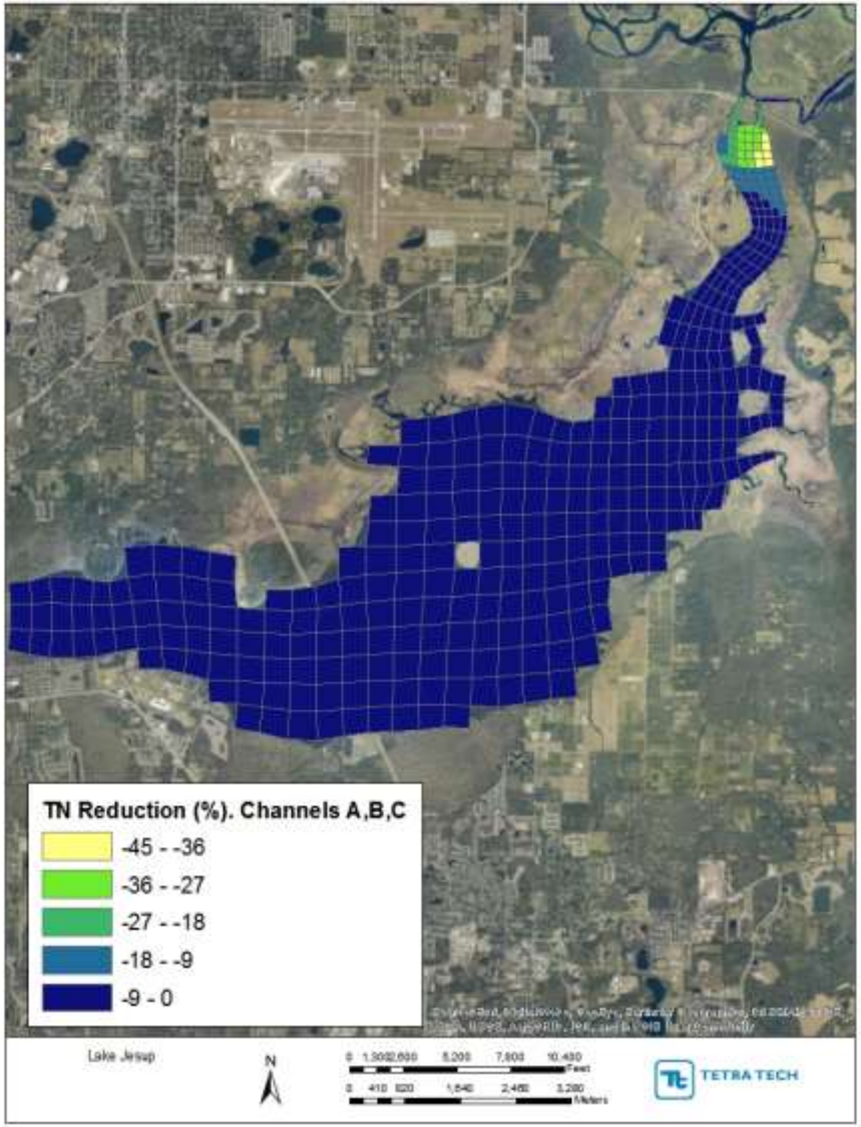
A & C Open, B Closed

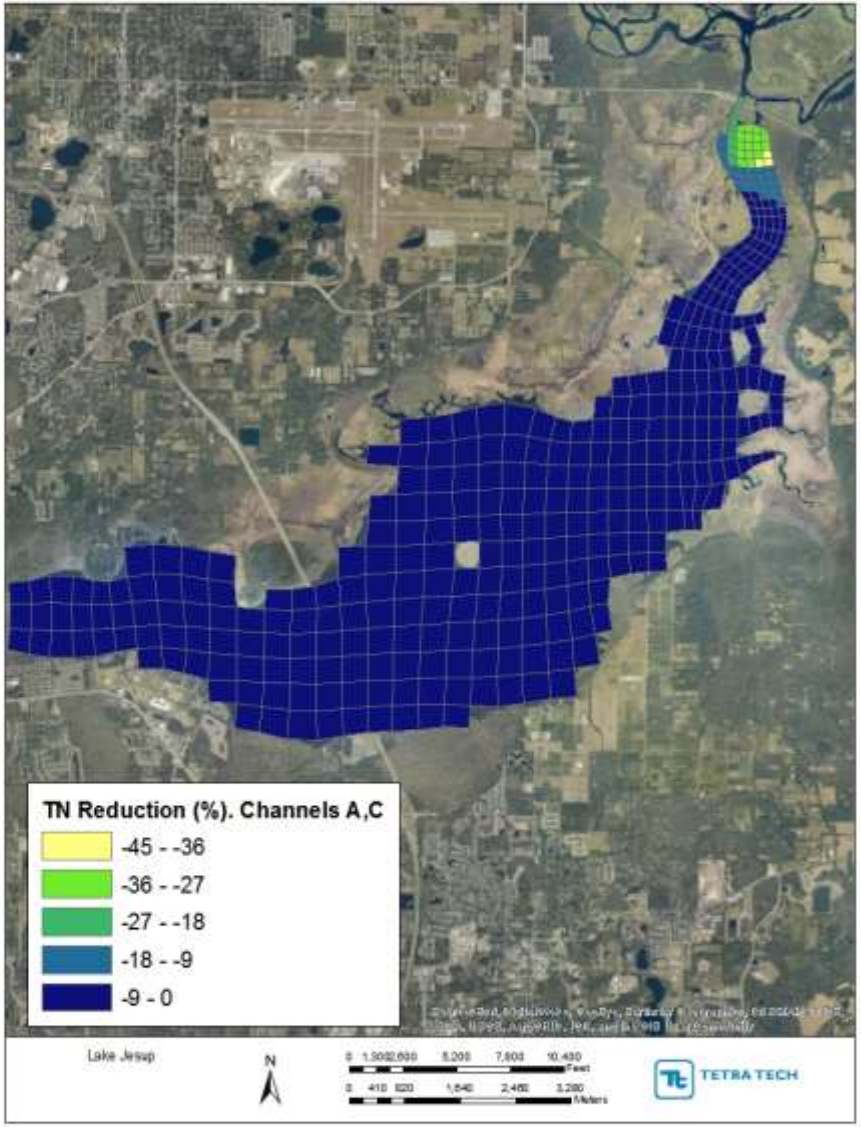
TP Changes in Water Quality





TN Changes in Water Quality





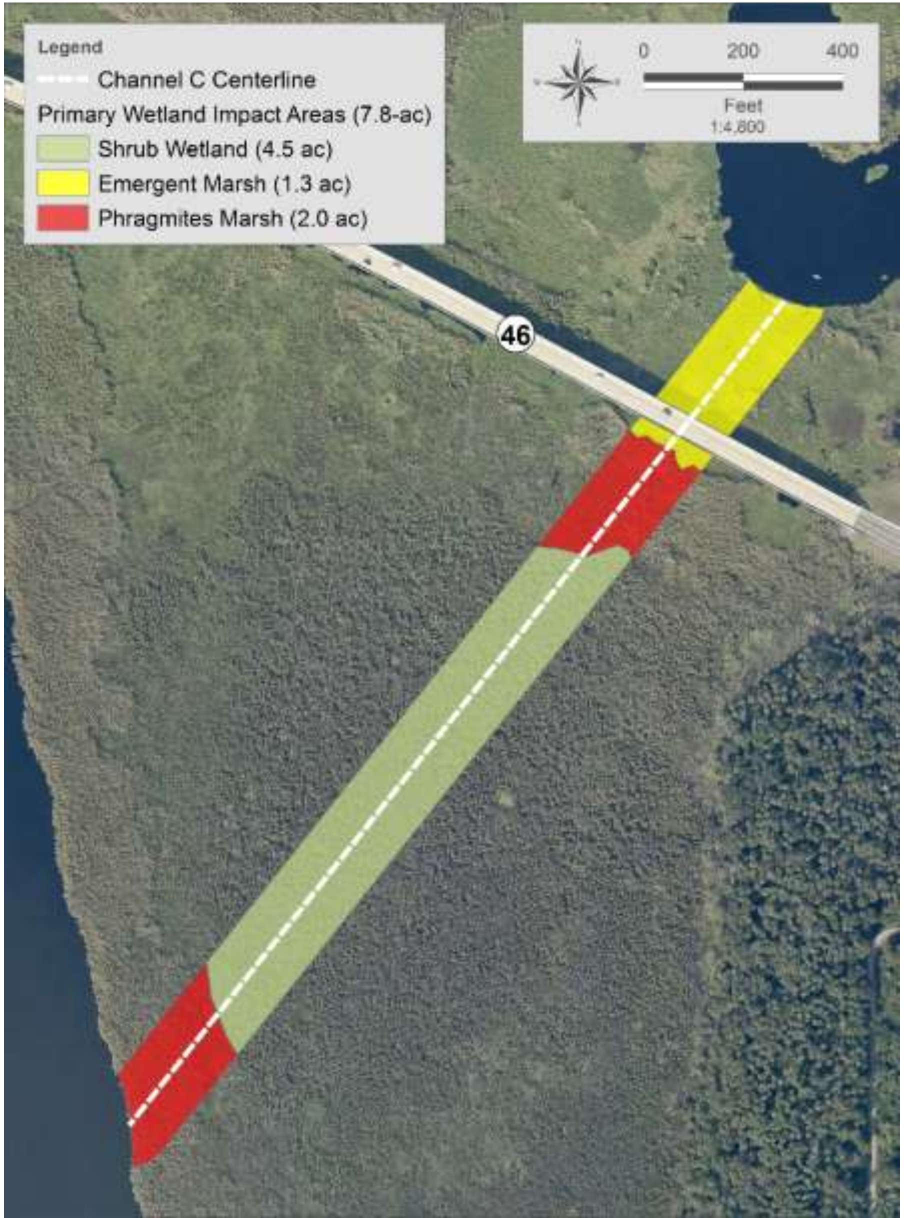
Permitting Considerations

- Natural/historic wetland communities

- Channel Impacts

  - 7.8 acres of primary impact (6.7 FL)

  - 9.7 acres of secondary impact (1.0 FL)



Permitting Considerations

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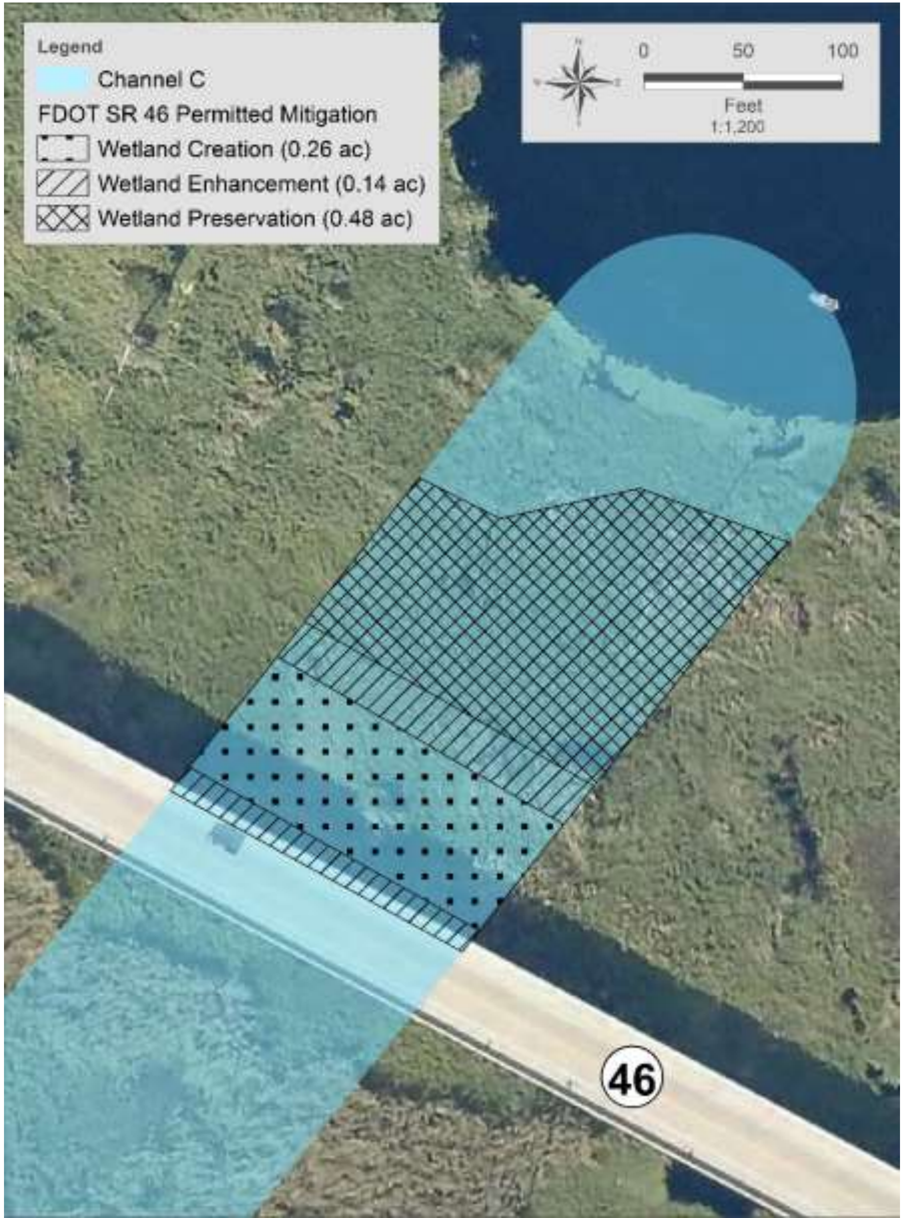
- Mitigation requirements
  - 0.9 acres of FDOT SR 46 mitigation (0.28 FL)
  - Nested Basin – requires mitigation in Lake Jesup basin
- Best Case - $220k
- Worst Case - $1.4M



Opinion of Cost

- Initial conceptual level costs based on similar projects and assumptions
- $4.8 - $5.6 M
  - Short haul < 1 mile
  - Long haul < 10 miles
- ~60 acre sediment placement site @ 1 ft. deep.

Summary

- Water Flow and Quality
  - Modeling indicates benefits are primarily in area adjacent to connection with MSJR.
  - Vector plots indicate that flow coming in C turns and flows out A and/or B
  - No significant water quality changes observed within lake interior.
- Costs

	Low	High
Construction	$4,810,500	$5,567,300
Mitigation	$ 220,000	$1,400,000
	$5,030,500	$6,967,300

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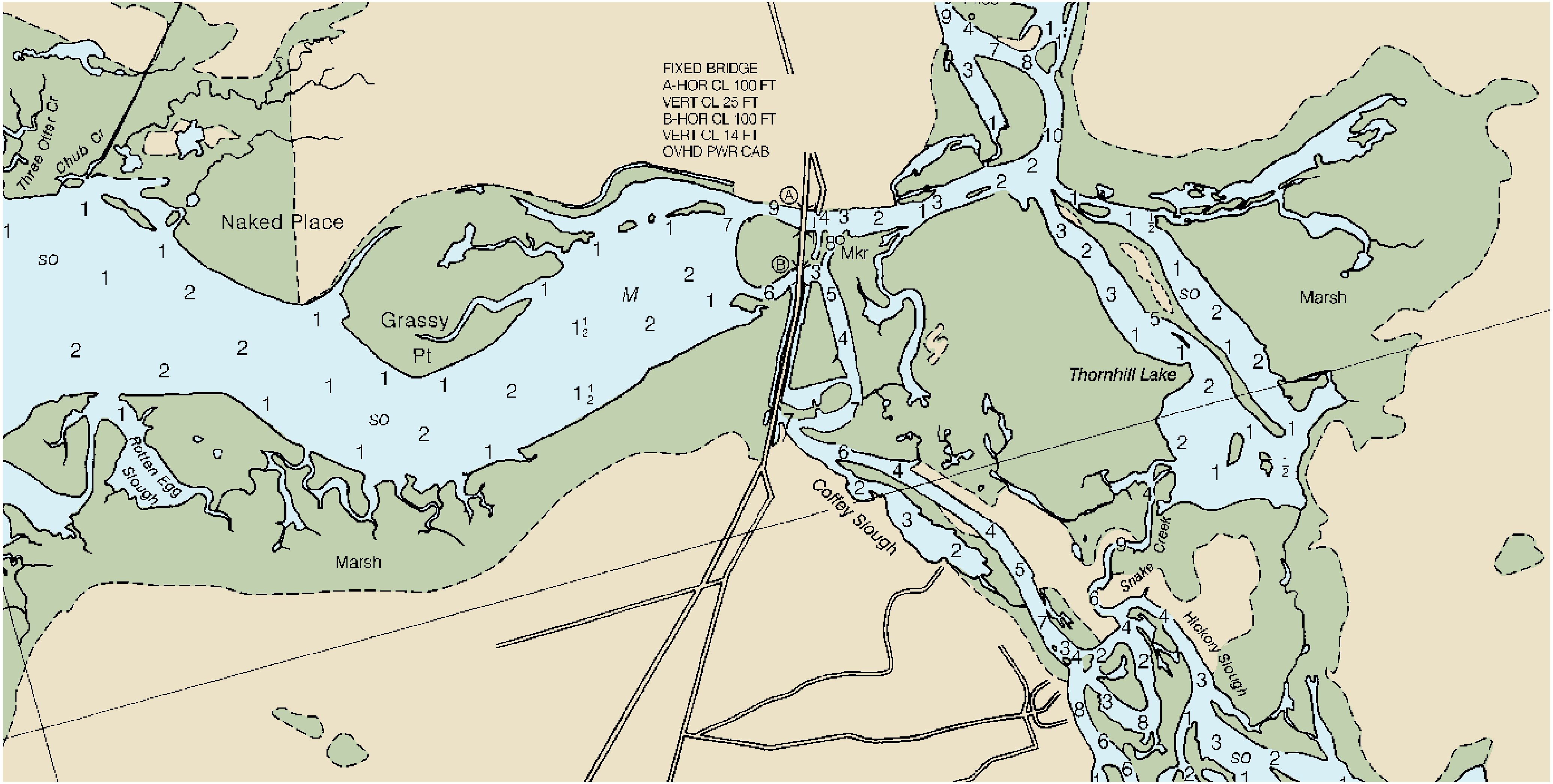
TETRA TECH

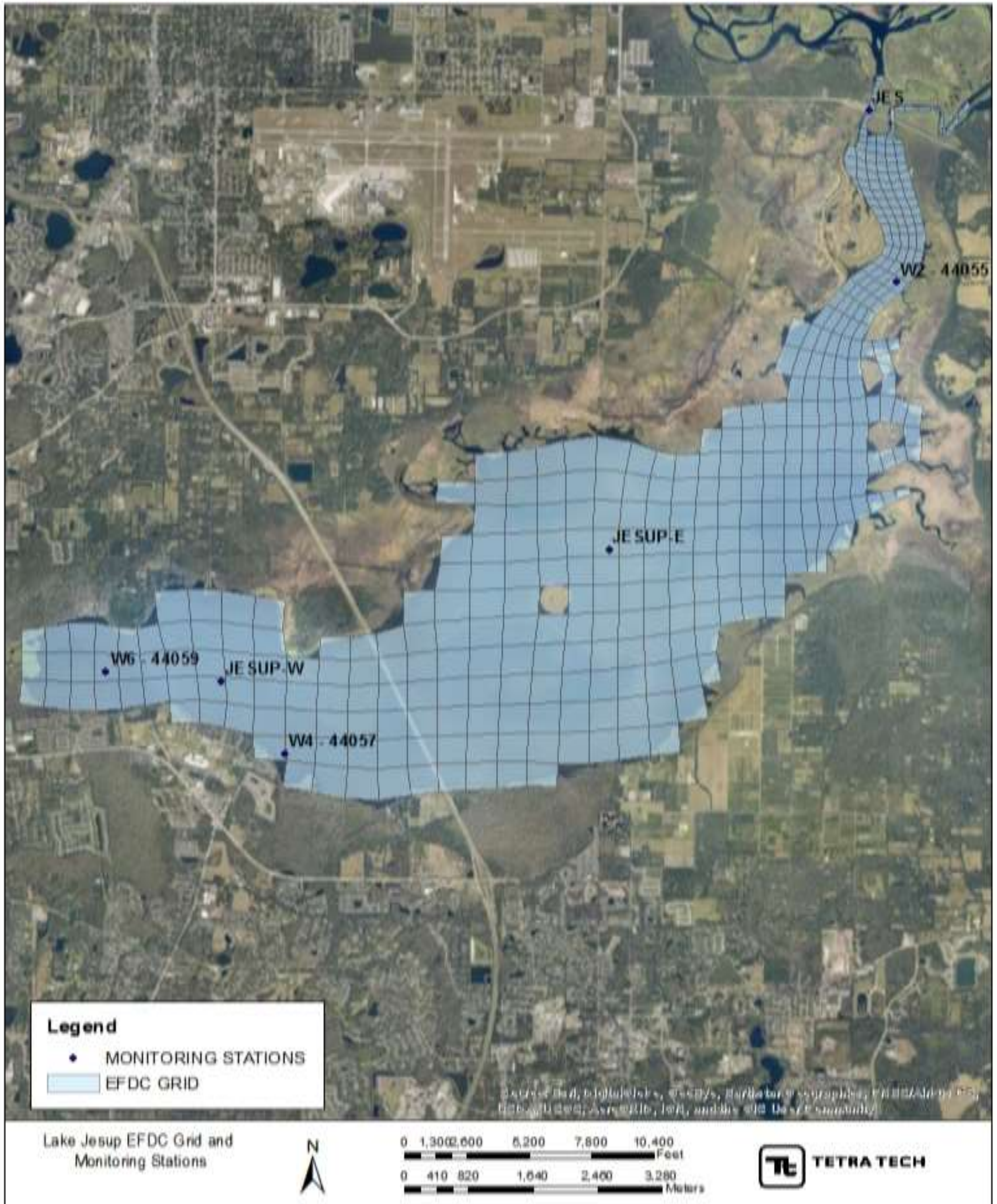
ATM
DESIGN
ENGINEERING
CONSULTING

NOAA Chart


FIXED BRIDGE
A-HOR CL 100 FT
VERT CL 25 FT
B-HOR CL 100 FT
VERT CL 14 FT
OVHD PWR CAB
Three Otter Cr
Chub Cr
Naked Place
Grassy Pt
Marsh
Rotten Egg Slough
Coffey Slough
Mkr
Thornhill Lake
Marsh
Snake Creek
Hickory Slough
so
M
A
B

Water Quality Monitoring – Station Locations

JonesEdmunds



TETRA TECH

Water Quality Modeling – TN % Change

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Year	W2				
	Baseline	A,B,C	% Change	A,C	% Change
2008	3.033	2.831	6.7%	2.848	6.1%
2009	2.932	2.837	3.2%	2.842	3.1%
2010	2.919	2.800	4.1%	2.807	3.9%
2011	3.396	3.276	3.5%	3.288	3.2%
2012	3.438	3.277	4.7%	3.283	4.5%
2013	3.009	2.872	4.5%	2.882	4.2%
2014	3.499	3.233	7.6%	3.246	7.2%
TMDL - TN	1.270				

Year	W4				
	Baseline	A,B,C	% Change	A,C	% Change
2008	2.561	2.549	0.5%	2.551	0.4%
2009	2.324	2.319	0.2%	2.320	0.2%
2010	2.326	2.321	0.2%	2.321	0.2%
2011	2.687	2.675	0.4%	2.677	0.4%
2012	2.990	2.973	0.6%	2.975	0.5%
2013	2.657	2.648	0.3%	2.650	0.3%
2014	2.833	2.819	0.5%	2.821	0.4%
TMDL - TN	1.270				

Year	W6				
	Baseline	A,B,C	% Change	A,C	% Change
2008	2.321	2.312	0.4%	2.314	0.3%
2009	2.200	2.197	0.2%	2.198	0.1%
2010	2.281	2.276	0.2%	2.277	0.2%
2011	2.547	2.537	0.4%	2.539	0.3%
2012	2.771	2.758	0.5%	2.759	0.4%
2013	2.521	2.514	0.3%	2.515	0.2%
2014	2.584	2.574	0.4%	2.575	0.4%
TMDL - TN	1.270				

Year	Lake-wide				
	Baseline	A,B,C	% Change	A,C	% Change
2008	2.924	2.789	4.6%	2.809	3.9%
2009	2.728	2.620	4.0%	2.631	3.6%
2010	2.735	2.606	4.7%	2.621	4.2%
2011	3.175	3.021	4.9%	3.040	4.2%
2012	3.257	3.084	5.3%	3.103	4.7%
2013	2.916	2.765	5.2%	2.782	4.6%
2014	3.242	3.008	7.2%	3.032	6.5%
TMDL - TN	1.270				

Water Quality Modeling – TP % Change

Year	W2				
	Baseline	A,B,C	% Change	A,C	% Change
2008	0.130	0.125	3.9%	0.125	3.5%
2009	0.128	0.125	2.3%	0.125	2.2%
2010	0.117	0.113	3.5%	0.114	3.3%
2011	0.141	0.137	2.5%	0.138	2.3%
2012	0.131	0.126	3.8%	0.126	3.7%
2013	0.113	0.109	3.8%	0.109	3.4%
2014	0.128	0.123	4.3%	0.123	4.0%
TMDL - TP	0.096				

Year	W4				
	Baseline	A,B,C	% Change	A,C	% Change
2008	0.107	0.107	0.2%	0.107	0.2%
2009	0.097	0.097	0.1%	0.097	0.1%
2010	0.097	0.097	0.2%	0.097	0.2%
2011	0.107	0.107	0.3%	0.107	0.3%
2012	0.108	0.107	0.4%	0.107	0.3%
2013	0.098	0.098	0.3%	0.098	0.2%
2014	0.106	0.105	0.3%	0.105	0.3%
TMDL - TP	0.096				

Year	W6				
	Baseline	A,B,C	% Change	A,C	% Change
2008	0.098	0.098	0.2%	0.098	0.1%
2009	0.094	0.093	0.1%	0.093	0.1%
2010	0.097	0.097	0.1%	0.097	0.1%
2011	0.105	0.104	0.2%	0.104	0.2%
2012	0.102	0.102	0.3%	0.102	0.3%
2013	0.095	0.094	0.2%	0.095	0.2%
2014	0.100	0.100	0.2%	0.100	0.2%
TMDL - TP	0.096				

Year	Lake-wide				
	Baseline	A,B,C	% Change	A,C	% Change
2008	0.122	0.121	1.0%	0.121	0.8%
2009	0.115	0.113	2.2%	0.113	2.1%
2010	0.110	0.106	3.1%	0.107	2.8%
2011	0.129	0.127	1.5%	0.127	1.4%
2012	0.119	0.115	4.1%	0.115	3.8%
2013	0.107	0.103	3.9%	0.104	3.5%
2014	0.119	0.115	3.3%	0.115	3.0%
TMDL - TP	0.096				

Lake Jesup Restoration Scenarios Assessment

Technical Memorandum SJ20XX-X

LAKE JESUP RESTORATION SCENARIOS ASSESSMENT

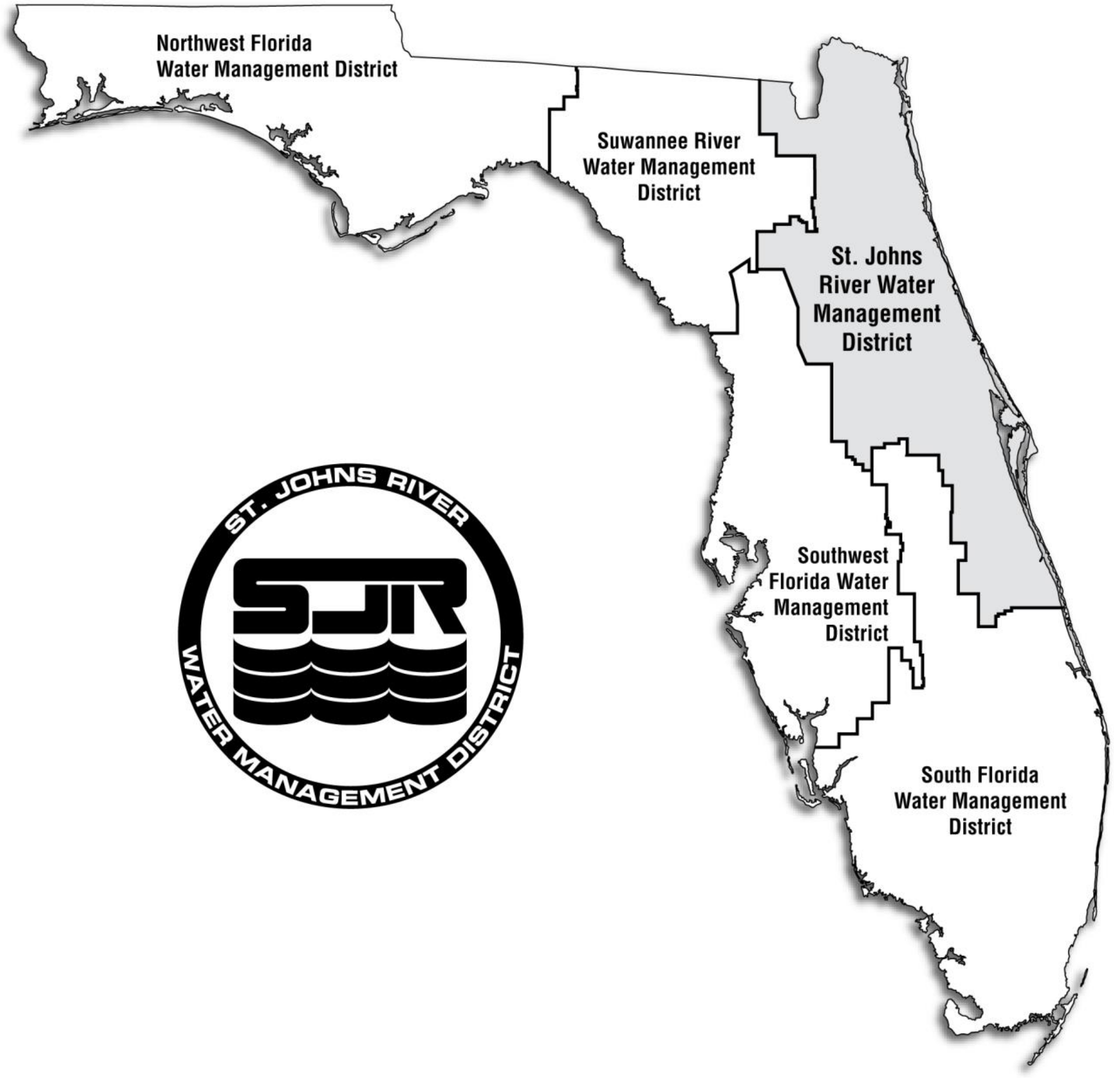
by

Bureau of Water Resources
Division of Water and Land Resources

DRAFT

St. Johns River Water Management District
Palatka, Florida

2019



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PLACEHOLDER

EXECUTIVE SUMMARY

This modeling analysis examines two projects for accelerating the restoration of Lake Jesup. Lake Jesup is an off-line lake of the Middle St. Johns River, located adjacent to the City of Sanford, with a 135 square mile watershed that encompasses urbanized areas of Orange and Seminole counties. Due to years of point and nonpoint source nutrient loading, and a naturally long hydraulic residence time, the lake has progressed to a hypereutrophic state. A TMDL was established for the lake in 2006, focusing on the reduction of phosphorus (FDEP, 2006).

This analysis is performed at a pivotal time for the lake. Stakeholders acting within the adopted Basin Management Action Plan (BMAP) (2010) have achieved the necessary external nutrient load reductions to result in meeting the Total Maximum Daily Load (TMDL). Unfortunately, recycling of legacy nutrients will delay achieving water quality goals for many decades. To accelerate the restoration process, it will be necessary to undertake additional projects to treat or remove nutrient enriched sediments, remove nutrients from the water column, or decrease the hydraulic residence time. To this end, the SJRWMD has prepared a work plan for the lake that proposes a number of projects and management actions to accelerate achievement of water quality and habitat goals.

Two potential restoration projects are examined in this study: The dredging of a channel that would improve circulation by improving connection to the St. Johns River, and a created flow-through treatment wetland that would filter nutrients and increase internal lake circulation. The dredging project would recreate historic flow paths that were closed by a series of actions initiated in the late 1800s. These two potential projects were examined, individually and in combination, with respect to the following water quality elements:

- Could either or both of these projects increase the nutrient load exported downstream to Lake Monroe, also an impaired water body with a TMDL and BMAP for nitrogen and phosphorus?

- Could the variations of the channel creation project direct St. Johns River water to the inlet of the flow-through treatment wetland proposed for the lake, reducing the system's efficiency of removing nutrients from the lake's water?

- Could either or both of these projects increase water clarity and light availability sufficiently to drive an appreciable increase in the area within the lake that could support beneficial submersed aquatic vegetation (e.g. SAV expansion)?

Four modeling scenarios, as well as a baseline simulation to represent current conditions, were prepared and run to address these questions.

- St. Johns River flow connection channels A, B and C

- St. Johns River flow connection channels A and C, without the B channel
- The treatment wetland alone, and
- The treatment wetland along with flow channels A, B and C

Changes to Downstream Nutrient Loading

The channel creation scenarios predicted annual average nitrogen and phosphorus load changes that were negligible, at 0.1 percent decrease for nitrogen, and 0.05 – 0.06 percent increases for phosphorus. However, the time series of downstream load differences indicates that for both nitrogen and phosphorus, when discharge is high, downstream load delivery is less than the current condition, and when river discharge is low, the downstream load is increased. The majority of the downstream nitrogen load reduction that accounts for the near-zero cumulative difference for the 7-year simulation occurs over 7 months, at the ends of 2008 (associated with TS Fay) and 2014. For the remainder of the simulation time span, downstream nutrient loading for the channel creation scenarios are increased over the current condition. Phosphorus exhibits a similar pattern, with the exception that with the very high discharge associated with Tropical Storm Fay, net downstream load increases, adding an additional ton of phosphorus between September and December above the baseline condition. One concern related low flow periods is the positive net load increase during a time when the lake's hydraulic residence time is greatest, which favors the development and intensity of algal blooms.

The treatment wetland scenario predicts an annual average net decrease in downstream nitrogen load of 59,719 lbs., and 1,928 lbs. of phosphorus, representing 0.9 percent decrease in annual average nitrogen load, and a 0.4 percent decrease in phosphorus load. Under the combined flow channel and wetland scenario, the annual average downstream nitrogen load decreases by 61,780 lbs., while the downstream phosphorus load decreases by 1,507 lbs. Neither of the wetland scenarios appear to create short-term oscillations in load that could lead to increases when downstream algal bloom susceptibility is high.

Influence on Flow Through Wetland Intake

A dye-tracer simulation was performed to estimate the increase in St. Johns River water that would reside adjacent to the intake of the proposed treatment wetland. This simulation predicted a minimal increase in St. Johns River water at this location, averaging 2.8 percent over the duration of the simulation, thus the channel project variations would not substantially reduce the treatment wetland's effectiveness.

SAV Expansion Potential

The simulations to assess SAV colonization potential relied upon predictions from the water quality model's predictions of light extinction coefficients, a parameter that describes the depth to which surface light will reach vertically through the water column. In water bodies that are high in algae and suspended solids, the light extinction coefficient is high, and light penetration is low. As both projects proposed in this study are expected to reduce both algae and suspended solids, and concomitantly decrease the light extinction coefficient in the portions of the lake that they influence, they will increase the depth of transmitted light, and thus potentially expand the area that could support rooted SAV. Based on research conducted in the Lower St. Johns River, a range in minimum light levels supporting SAV colonization of between 9 – 14 percent of surface light was used to assess potential areas for colonization. For each scenario, the area beyond the baseline condition for which depth was within the range to allow illumination of the sediments was considered as the increased area for potential SAV colonization.

Model results indicate that both projects will improve underwater light conditions, and hence may create additional area potentially suitable for SAV colonization. The location of the outflow of the flow-through wetland on the gently sloping littoral shelf of the northwest shoreline appears to impact a greater area conducive for SAV, by a range of 16 percent (139 acres) to 26 percent (285 acres). Under the channel creation scenarios, SAV-suitable areas are increased by 7 – 8 percent (60 – 70 acres) to 21 – 24 percent (230 – 260 acres). The increase in SAV-suitable area under the channel creation scenarios is located near the lake outlet, while the SAV area increased by the treatment wetland is distributed as a thin margin around much of the lake.

Modeling studies are extremely useful in the assessment of water body conditions and possible outcomes of management actions. Predictions from calibrated water quality models, even when not highly accurate in the sense that they closely match observed data, will track relevant ecosystem patterns and can unveil processes that would not be ascertained from observation of ambient water quality data alone, particularly when alternative scenarios to the current condition are posed. In this sense they often lead to follow on questions that invite additional study. In this analysis, the apparent inverse relationship between downstream loading and discharge is a potentially significant finding that should receive additional investigation with respect to its origin and downstream effects. It should be noted that the models in this study, which rely on grids that are fixed in planar extent, are being applied to a lake that is known to range between 10,000 – 16,000 acres as a function in water level. This could lead to artifacts that could create misleading discharge-concentration interactions. This limitation may also affect water level change processes and nutrient exchange related to floodplain rehydration and dehydration, which currently are not considered in the modeling. Furthermore, the estimates of light conditions supporting SAV developed in this study should be considered tentative and indirect, as other conditions not assessed in the model would need to be met for SAV colonization, including substrate quality, wind and wave sheltering, and fluctuating water level.

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INTRODUCTION AND BACKGROUND

Lake Jesup is one of the most hypereutrophic lakes in Central Florida. After a nutrient Total Maximum Daily Load (TMDL) and associated Basin Management Action Plan (BMAP) were established for the lake in 2006 and revised in 2010, stakeholders, including the state of Florida (FDEP), St. Johns River Water Management District (SJRWMD), Florida Fish and Wildlife Commission (FFWC) and local governments, have worked together to implement projects to reduce total phosphorus and sediment in surface runoff that contributes to the lake's poor water quality. Local and state leaders are interested in expanding efforts that will advance the recovery of the lake and restore water quality and habitat.

Increasing riverine flow through the lake has been advocated by local stakeholders as a means to improve circulation and water quality. Hydrologic modifications to the connection between the river and lake date back to the steamboat era of the late 1800s. In 2010, the Florida Department of Transportation completed a new 3,470-foot-long span bridge over the confluence, and in the process removed the State Road 46 earthen causeway. This created an opportunity to restore old previously blocked flow paths, and renewed stakeholders interest in a Lake Jesup Flow Restoration Project. A flow enhancement project was investigated in 2011 by the U.S. Army Corps of Engineers (USACE) to improve water quality and habitat by enhancing the exchange between the St. Johns River and the eastern portion of the lake.

A Flow Restoration Feasibility Assessment was initiated by the SJRWMD in 2018 to model the water quality effects of various reconnection scenarios and develop conceptual cost for each scenario. Working with the consulting team of Jones Edmonds, Applied Technology and Management, and Tetra Tech, the work was completed in 3 months, and a Feasibility Report finalized in September 2018. Three different scenarios were evaluated for their water quality effects:

1. **Existing Conditions (Baseline) – Channels A & B open**
2. **Channels A, B, and C open. Channel C is the proposed new channel.**
3. **Channels A & C open, B closed.**

The water quality modeling results from this analysis indicated that benefits are primarily contained to the area adjacent to the confluence with the St. Johns River. No changes were observed within the lake. Construction cost conceptual estimate range from $5M to $6M based on assumptions for hydraulic dredge and disposal site. Details of the Phase I work are described in the *Flow Restoration Feasibility Analysis for Lake Jesup Final Report.*

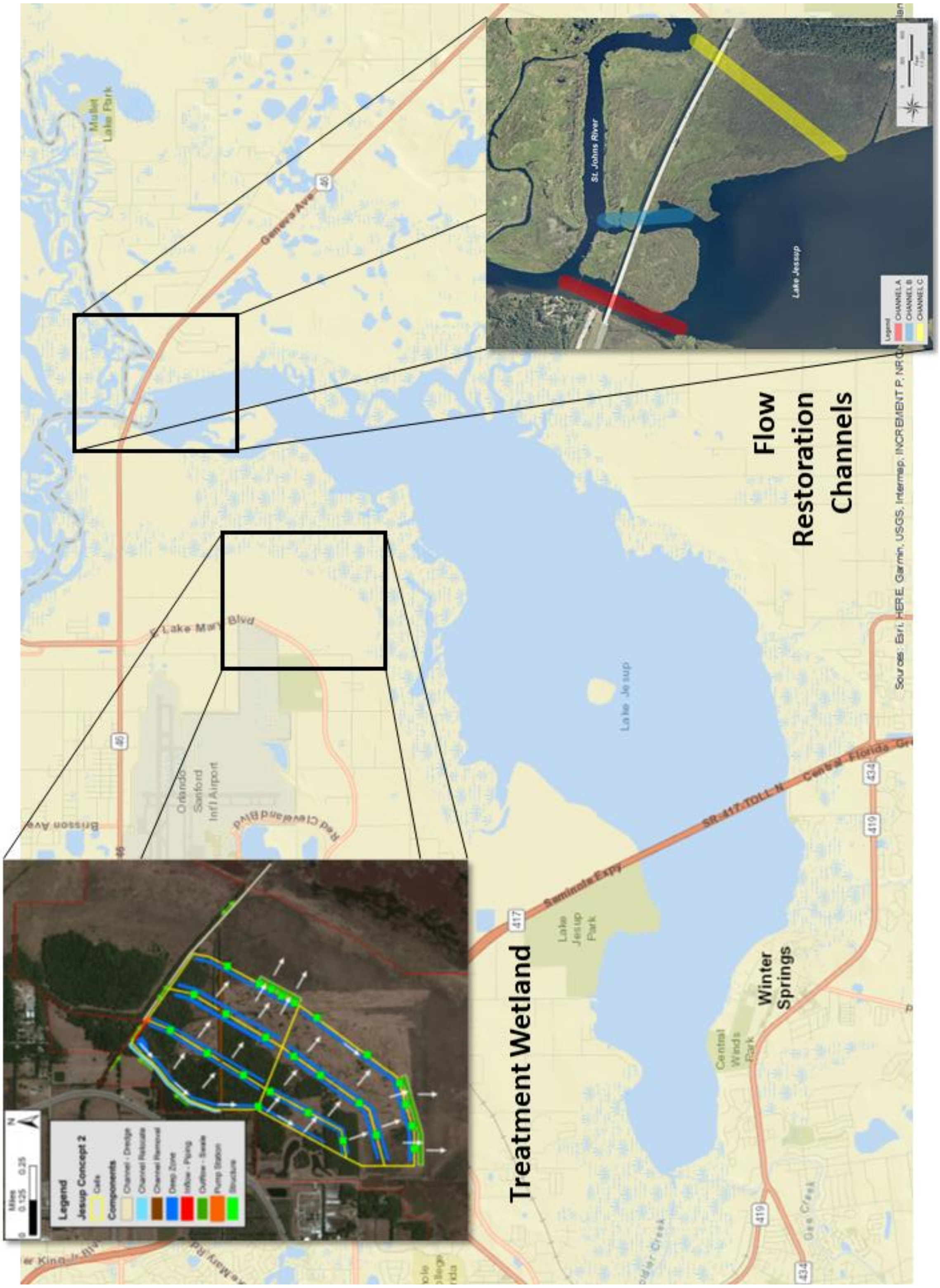


Figure 1. Lake Jesup Channel Proposed Project Locations

Following an internal review of the Phase I results, a Phase II investigation was conceived. The Phase I investigation focused on the water quality benefits associated with the flow restoration project but provided little insight how the project may benefit lake habitat. The Phase II investigation explores the secondary effects to the water resource areas impacted by the proposed project such as downstream changes in nutrient loading, and potential improvement to water column transparency that could enhance beneficial submersed aquatic vegetation (SAV) in the lake.

Downstream nutrient transport from the channel restoration project to Lake Monroe is a concern as Lake Monroe has a Total Maximum Daily Load (TMDL) that was established in 2009 and a Basin Management Action Plan (BMAP) that was approved in 2012. This presents obvious concerns such that the implementation of any upstream project not increase the downstream nutrient load. Any negative impact downstream to Lake Monroe would influence project rankings and prioritizing when compared to other potential SJRWMD projects in the Jesup basin.

Rooted submersed native plants contribute significantly to a lake’s healthy ecosystem providing a food source, habitat and production of oxygen. Field surveys indicate Lake Jesup’s ecosystem currently supports aquatic vegetation. The Seminole County Lake Management Program conducted vegetation surveys in 2013 and 2014, and documented a variety of submerged aquatic vegetation were documented including coontail and eelgrass (though also the invasive exotic hydrilla). These surveys indicate that SAV can grow in Lake Jesup, and suggests that improvement to underwater transparency can promote the expansion of this habitat.

The Phase II analysis also incorporates an evaluation of a previously-proposed treatment wetland project on the SJRWMD’s Cameron property north of the lake (Figure 1). Analysis conducted in 2014 by Environmental Consulting Technology, Inc. suggested that the Wetland Treatment System would be effective in reducing 1.29 MT/yr of phosphorus from entering Lake Jesup, and that the project could be cost effective at $120 per pound of phosphorus removed.

The following questions were explored in the Phase II work.

1. **What are possible impacts to the downstream transport of nutrients to Lake Monroe resulting from the Lake Jesup Flow Restoration project?**
2. **What would be the changes to the nutrients at the entrance of proposed intake location for the Cameron wetlands treatment project?**
3. **What are likely changes to water column transparence, and following from this, potential colonization by SAV within Lake Jesup resulting from the restoration channel and treatment wetland, individually and in combination?**

METHODS AND APPROACH

In this analysis, hydrodynamic and water quality models were applied to evaluate potential effects and benefits from the two proposed restoration projects for Lake Jesup. These models, the Environmental Fluid Dynamics Code (EFDC) hydrodynamic model and the Water quality Analysis Simulation Program (WASP) were set up and applied in previous investigations for water supply and TMDL determination, and were most recently utilized in the channel enhancement water quality assessment. For this phase II analysis, the models were configured to simulate five scenarios:

- **Baseline – The existing condition**
- **St. Johns River flow connection channels A, B and C**
- **St. Johns River flow connection channels A and C, with the B channel closed**
- **The treatment wetland alone, and**
- **The treatment wetland along with flow channels A, B and C**

These model scenarios were performed for the same simulation duration and boundary loads as those prepared for the phase I assessment. Scenarios with the EFDC model were performed to estimate circulation patterns under the proposed scenarios, while WASP simulations were performed to predict downstream export of nutrients and in-lake changes in transparency. Model output was provided for a spectrum of temporal and spatial intensities.

Model boundary conditions were based on measured water quality data. For the treatment wetland scenario, nutrient partitioning was based on Kim et al. (2011). The wetland was assumed to discharge mostly organic nutrients, with inorganic nutrients incorporated into the wetland, denitrified, or exported as organic nutrients. Specific TN and TP outlet concentrations were:

- TN = 2.18 mg/L, w/ TON = 2.1744, NH_4 = 0.005, and NO_x = 0.0003 mg/L
- TP = 0.103 mg/L, w/ Organic P = 0.1014 mg/L, and PO_4 = 0.00153 mg/L

EFDC dye simulations were performed to evaluate the potential for the flow channel enhancement configurations to direct upstream St. Johns River water to the inlet of a conceptual wetland treatment system for the lake, thereby reducing the efficiency of the system to treat degraded lake water. In the dye simulation format, the inflow points of interest are provided an arbitrary value of 100, while all other inputs are provided a zero value. The model is spun up to mix the "dye" to equilibrium, and then run through the simulation duration to assess the spatial distribution in proportions of the input of interest.

For the Lake Jesup SAV habitat projections, WASP model predictions of light attenuation coefficient were converted to mean depth of light transmission for 2 light levels, one based on a minimum light requirement of 9 percent of surface light, and another based on 14 percent. These two underwater light levels were selected because they were found to bracket the range of mean minimum surface light for water-ward edge of bed of SAV in the Lower St. Johns River

(Dobberfuhl, 2007). The mean depth predictions of the relatively coarse lake model grid were overlain onto a detailed bathymetry layer, created from a survey performed in 2009 for the Water Supply Impact Study (SJRWMD 2012). The resolution of this bathymetry layer for Lake Jesup is 10 square meters. The mean water level for Lake Jesup, 0.33m ASL, was added to the detailed bathymetry, to create a spatially-detailed average depth to sediment layer from the lake mean water level. These sediment depths were subtracted from the model predicted depths to 9 and 14 percent surface light for each scenario. Positive values were considered as potentially viable for SAV colonization based on available light, while negative values were considered unsuitable. To facilitate the GIS analysis and match the scale of the bathymetry data available, the values of the mean depth light transmissions predicted by the model were rounded to two significant digits and grouped into 10 cm bins.

RESULTS

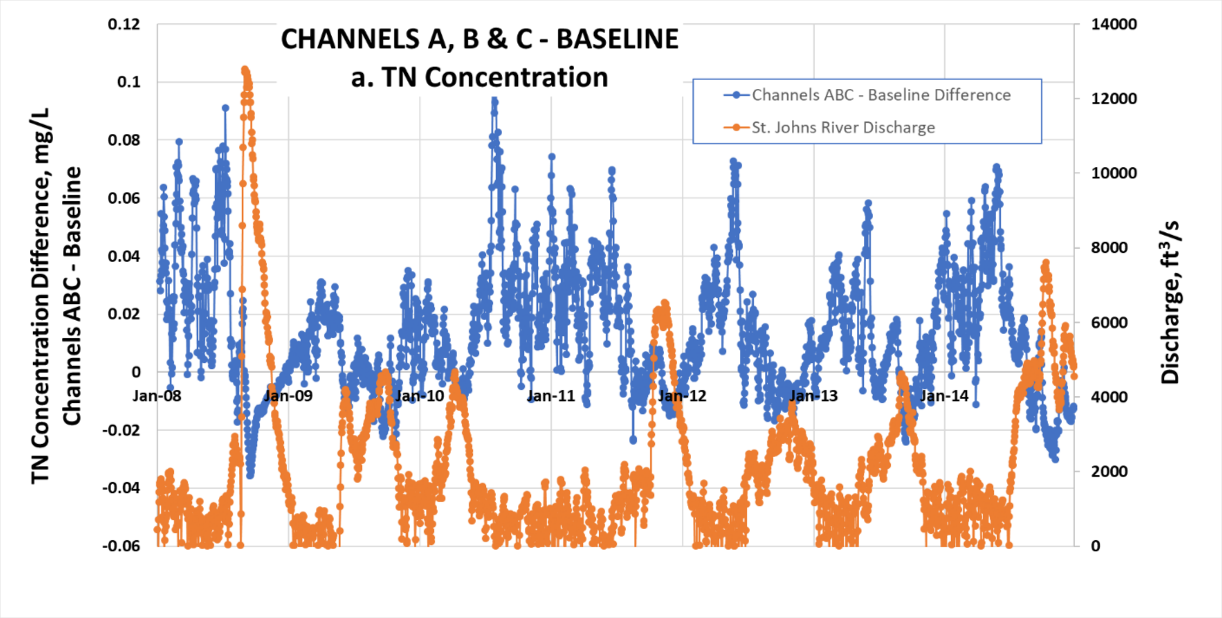
CHANGES TO THE DOWNSTREAM DELIVERY OF NUTRIENTS

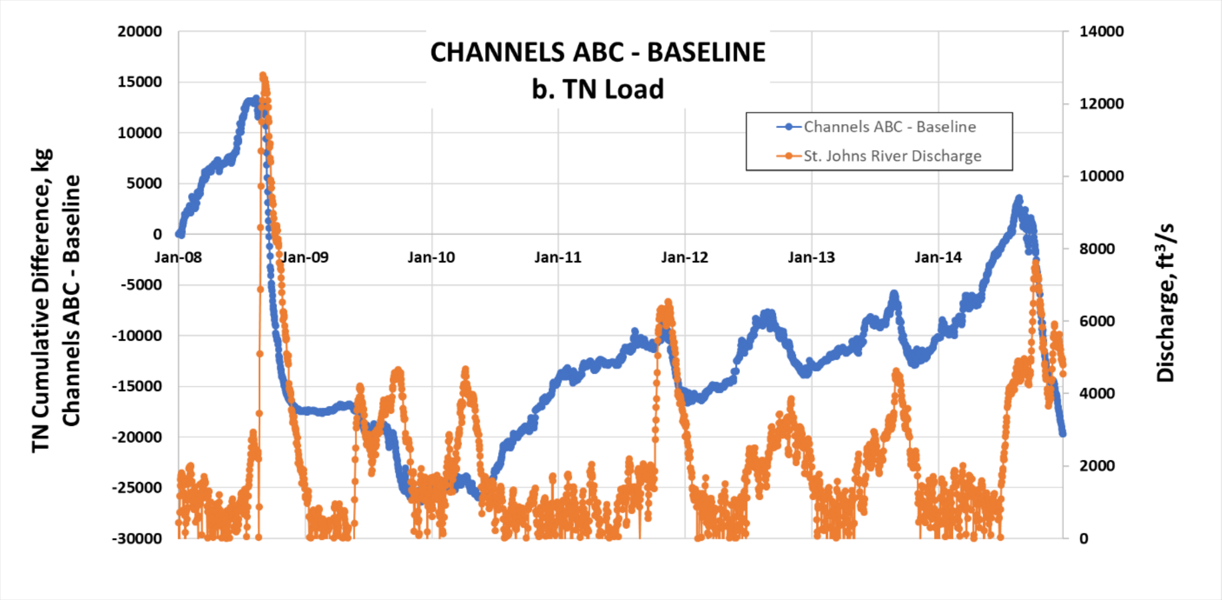
Nitrogen

Model results under the baseline condition estimate an average total nitrogen (TN) concentration in the St. Johns River downstream of Lake Jesup of 1.815 mg/L. Based on the mean discharge at the closest USGS discharge monitoring site at the outlet of Lake Monroe, this translates to an average TN load of 3119 MT/yr. It should be noted that this discharge monitoring site is downstream of several additional small inflows, and conversely, should also be slightly reduced due to evaporation that would occur from Lake Monroe.

With channels A, B and C open for circulation between Lake Jesup and the St. Johns River, model results indicate the average TN concentration delivered to Lake Monroe increases by 0.013 mg/L, to 1.828 mg/L. However, because of the interaction between concentration and discharge, the annual mean TN load decreases by 2.8 MT, to an overall annual mean value 3,116 MT. From the panels of concentration and load difference of Figure 2 it can be seen that this discrepancy arises from the inverse relationship between discharge and scenario concentration. When discharge is low to moderate, exported TN under the channel ABC scenario exceeds baseline concentration. Under high flow, the baseline TN tends to be greater than the channel ABC scenario concentration. The manifestation of this on load delivery to Lake Monroe is that under low flow, the channel ABC scenario net downstream load is positive, and under high flow the net downstream load is negative (Figure 2b). For example, under the low flow phase from January through July of 2008, the channel ABC scenario delivered a TN increase of 13 MT downstream, and during the extended dry cycle from June 2010 through June 2011, delivered an additional 17 MT of TN downstream. At the opposite extreme, during the high flow of Tropical Storm Fay fall of 2008, model results suggest that the channel ABC scenario decreased the downstream load by 31 MT. A similar high flow event in the last four months of the simulation resulted in a net decrease under the channel ABC scenario of 23 MT delivered downstream.

Figure 2. Channels A, B & C Minus Baseline Scenario TN Concentration and Load Differences from the WASP Model Simulations, in Blue, and USGS Discharge Site #02234500 at the Outlet of Lake Monroe, in Orange 2008-14. a. TN Concentration Difference. b. TN Cumulative Load Difference.





Under the channels A&C w/o B scenario, the mean downstream TN concentration is 1.826 mg/L, or 0.011 mg/L greater than the baseline mean. As is the case for the ABC scenario, the annual mean load is less for the A&C w/o B scenario, predicted to be 3.8 MT. Also, as with the three-channel scenario, downstream loads decline under high flow conditions, but increases during low flow. The largest downstream load increase was 15.3 MT between October 2013 through August 2014, followed by a 14 MT increase between June 2010 to October 2011.

Under the treatment wetland scenario, the modeled downstream mean TN concentration is 1.801 mg/L, or 0.014 mg/L below the mean baseline concentration. Examination of the time series pattern in concentration and load for the simulation duration shows that reduced concentrations are generally spread throughout the duration of the simulation, with only occasional intervals when the wetland scenarios results in concentrations greater than baseline (Figure 3a).

The overall annual mean TN load exported downstream under the wetland scenarios is 3,091 MT/yr, or 27.1 MT below the baseline annual mean load. Load reduction is generally uniform through the simulation duration, indicating a relatively constant reduction of downstream (Figure 3b).

For the scenario that combines both the channels ABC and wetland projects, the model predicts an average downstream TN concentration of 1.814 mg/L, a negligible change in the average baseline TN concentration (a 0.001 mg/L decrease). The temporal pattern in increases and decreases in TN concentration relative to the baseline condition is similar to that of the ABC? channels scenario, in that TN is greater in downstream export when discharge and lake residence time is low, and lower when discharge is high (Figure 4a).

Figure 3. Wetland Minus Baseline Scenario TN Concentration and Load Differences from the WASP Model Simulations, in Blue, and USGS Discharge Site #02234500 at the Outlet of Lake Monroe, in Orange 2008-14. a. TN Concentration Difference. b. TN Cumulative Load Difference.

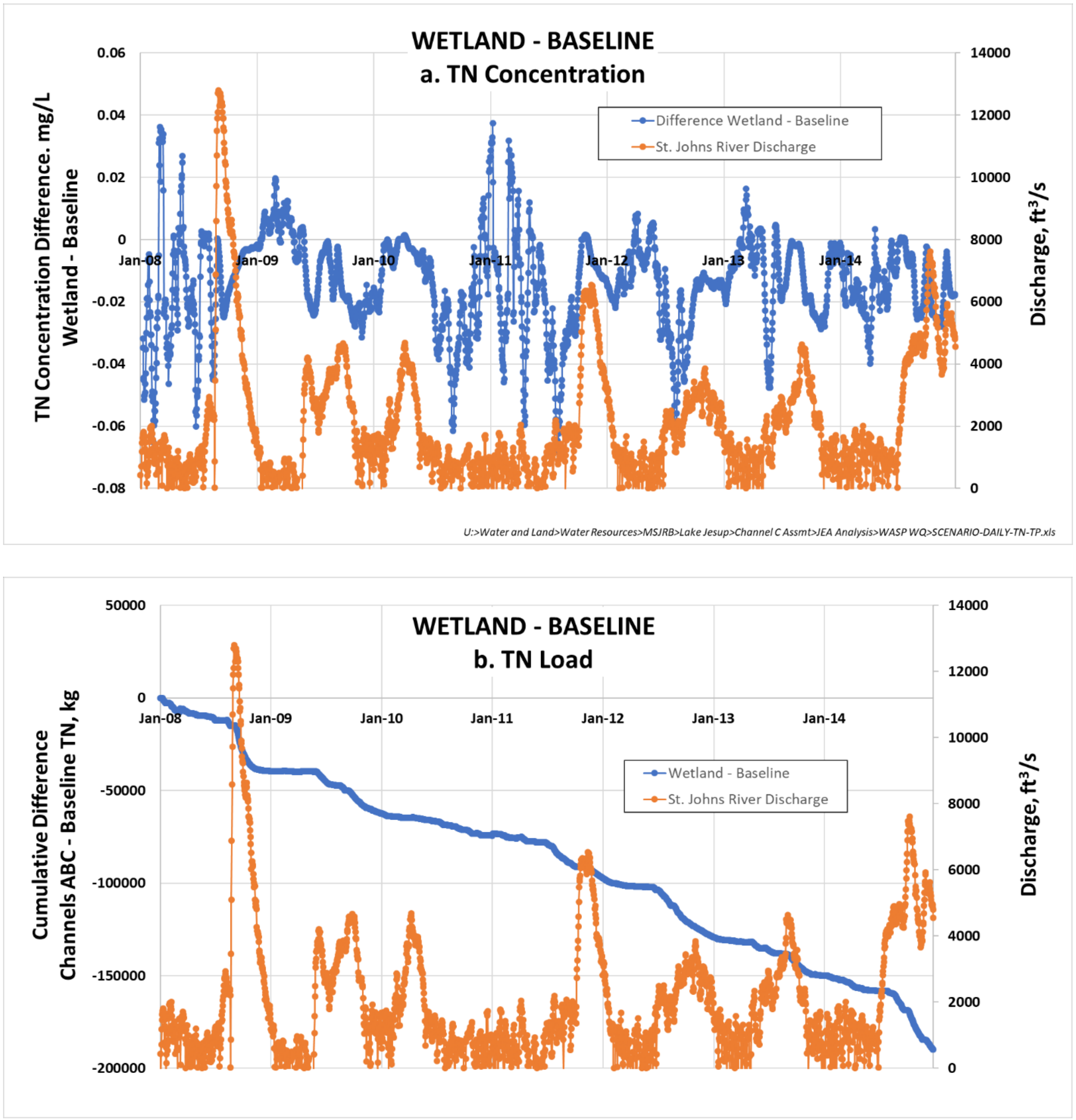


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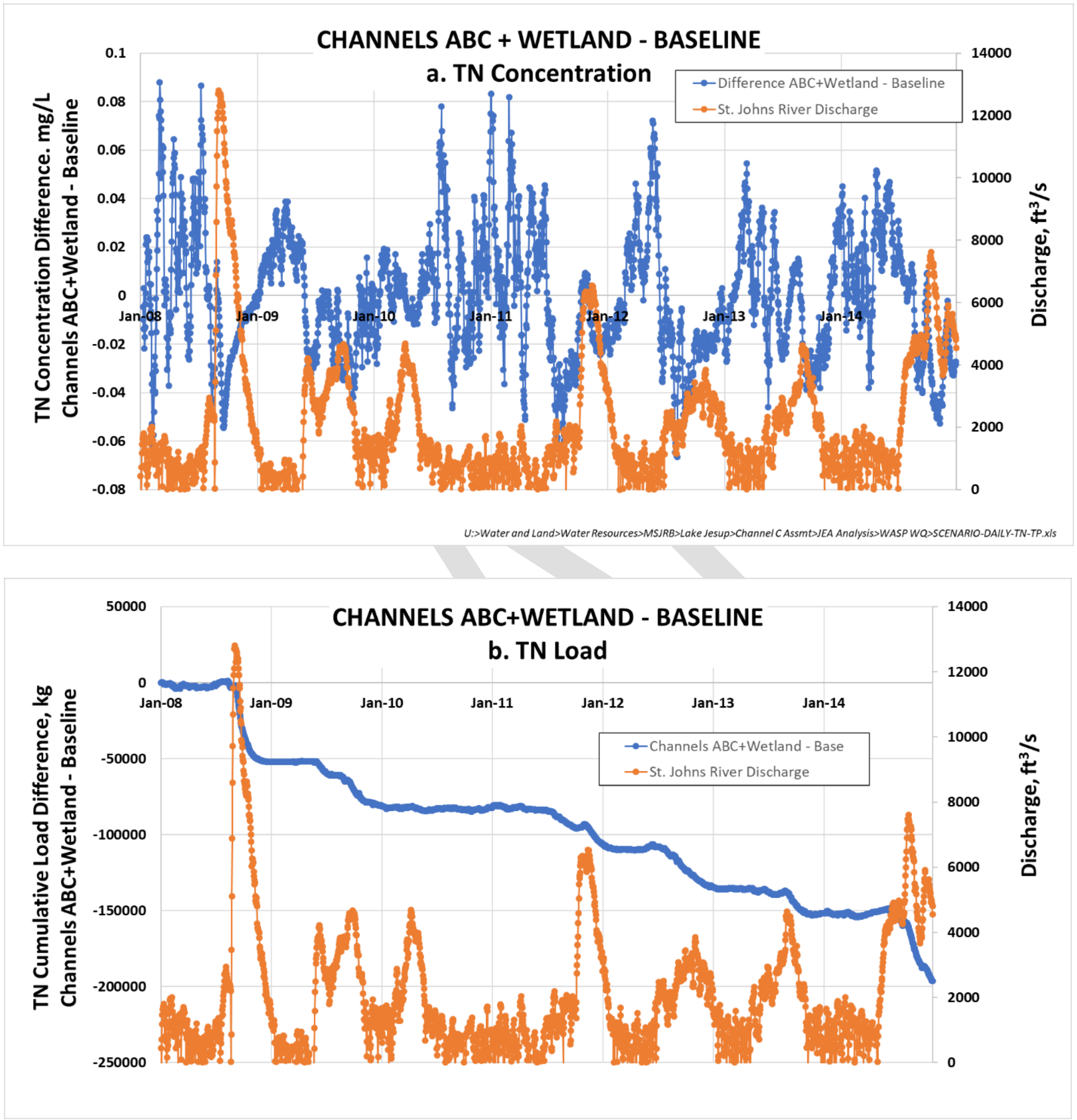
Figure 4. Channels A, B & C and Flow-Through Wetland Minus Baseline Scenario TN Concentration and Load Differences from the WASP Model Simulations, in Blue, and USGS Discharge Site #02234500 at the Outlet of Lake Monroe, in Orange 2008-14. a. TN Concentration Difference. b. TN Cumulative Load Difference.



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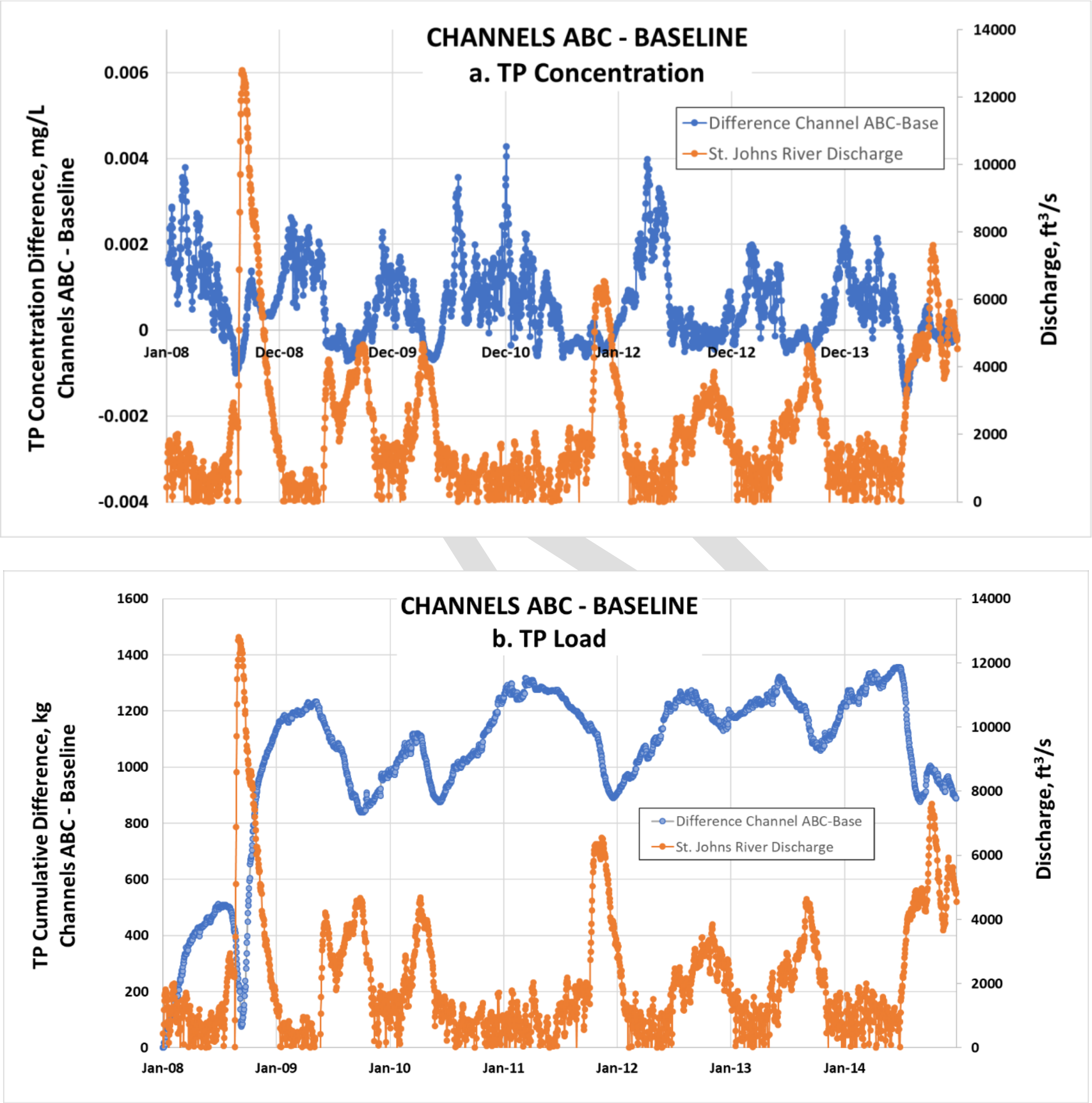
Phosphorus

The modeled average total phosphorus (TP) concentration exported downstream under the baseline condition is 0.101 mg/L. The estimated mean annual TP load exported downstream is 198 MT/yr. Long-term mean concentration differences in TP are negligible for all scenarios examined, with the maximum mean increase only 0.0006 mg/L between the channel ABC and baseline scenarios, and the maximum decrease only 0.0003 mg/L between the baseline and wetland scenarios. A similar negligible difference exists for the channel ABC scenario load, which increases the downstream mean TP load by 0.13 MT/yr. A 0.88 MT/yr TP load decrease is predicted for the wetland scenario.

While the overall mean concentration and load differences are small, the temporal pattern in scenario differences indicates intervals with potentially significant downstream load change. Under the channels ABC scenario, as was the case for TN, intervals of low discharge appear to coincide with intervals when the channels ABC scenario downstream TP concentration is greater than the baseline (i.e., positive differences) (Figure 5a). The largest increase in downstream load delivery occurs with Tropical Storm Fay, with the addition under the channel ABC scenario of approximately 0.9 MT of TP between September 2008 and February 2009 (although the initial flush of this event is predicted to reduce the TP load by approx. 0.4 MT). And while there is no net change in downstream load between June 2010 and December 2011, the first half of this interval is predicted to lead to a 0.43 MT increase in load, followed by a commensurate decrease. And in the first half of 2012, the channel ABC scenario increases the downstream TP load nearly one MT.

Figure 5. Channels A, B & C Minus Baseline Scenario TP Concentration and Load Differences from the WASP Model Simulations, in Blue, and USGS Discharge Site #02234500 at the Outlet of Lake Monroe, in Orange 2008-14. a. TP Concentration Difference. b. TP Cumulative Load Difference.



The concentration difference for the treatment wetland – baseline scenarios is mostly negative throughout the time series (i.e., wetland scenario downstream TP less that the baseline condition) (Figure 6a). Intermittent short duration pulses of the wetland scenario TP exceeding the baseline (i.e., positive values) occur in the simulation results, mostly in January and February and during low discharge, so translate to very low loads, at times of year when bloom potential would be expected to be minimal. The result of this concentration pattern is a mostly smooth decline in the cumulative TP load difference through the simulation (Figure 6b), with the steep load reduction associated with the high flow of Tropical Storm Fay accounting for roughly a quarter of the total reduction over the 7-year simulation duration. Overall, the flow-through wetland scenario simulation indicates an annual mean load reduction to Lake Monroe of 0.88 MT/yr.

Under the scenario that combines both the channels creation and treatment wetland, the mean downstream TP concentration is 0.101 mg/L, a negligible decrease of 0.0003 mg/L from the baseline condition mean. The time series of differences between these combined projects and the base case shows a slightly attenuated likeness to the channels-only scenario, in which downstream concentration is minimally increased over the base condition when discharge is low, with concentration reductions coinciding with higher discharge (Figure 7).

The channels plus wetland estimated mean annual TP load is 197.4 MT, or 0.68 MT per year less than the baseline condition. The time series pattern in cumulative load decline integrates the individual channels and wetland scenarios, and exhibits small increases in load delivery during intervals of low discharge, and larger declines in load delivery associated with high discharge. The largest decline is again associated with Tropical Storm Fay, with roughly one quarter of the overall decline associated with this event.

Figure 6. Flow-Through Wetland Minus Baseline Scenario TP Concentration and Load Differences from the WASP Model Simulations, in Blue, and USGS Discharge Site #02234500 at the Outlet of Lake Monroe, in Orange 2008-14. a. TP Concentration Difference. b. TP Cumulative Load Difference.

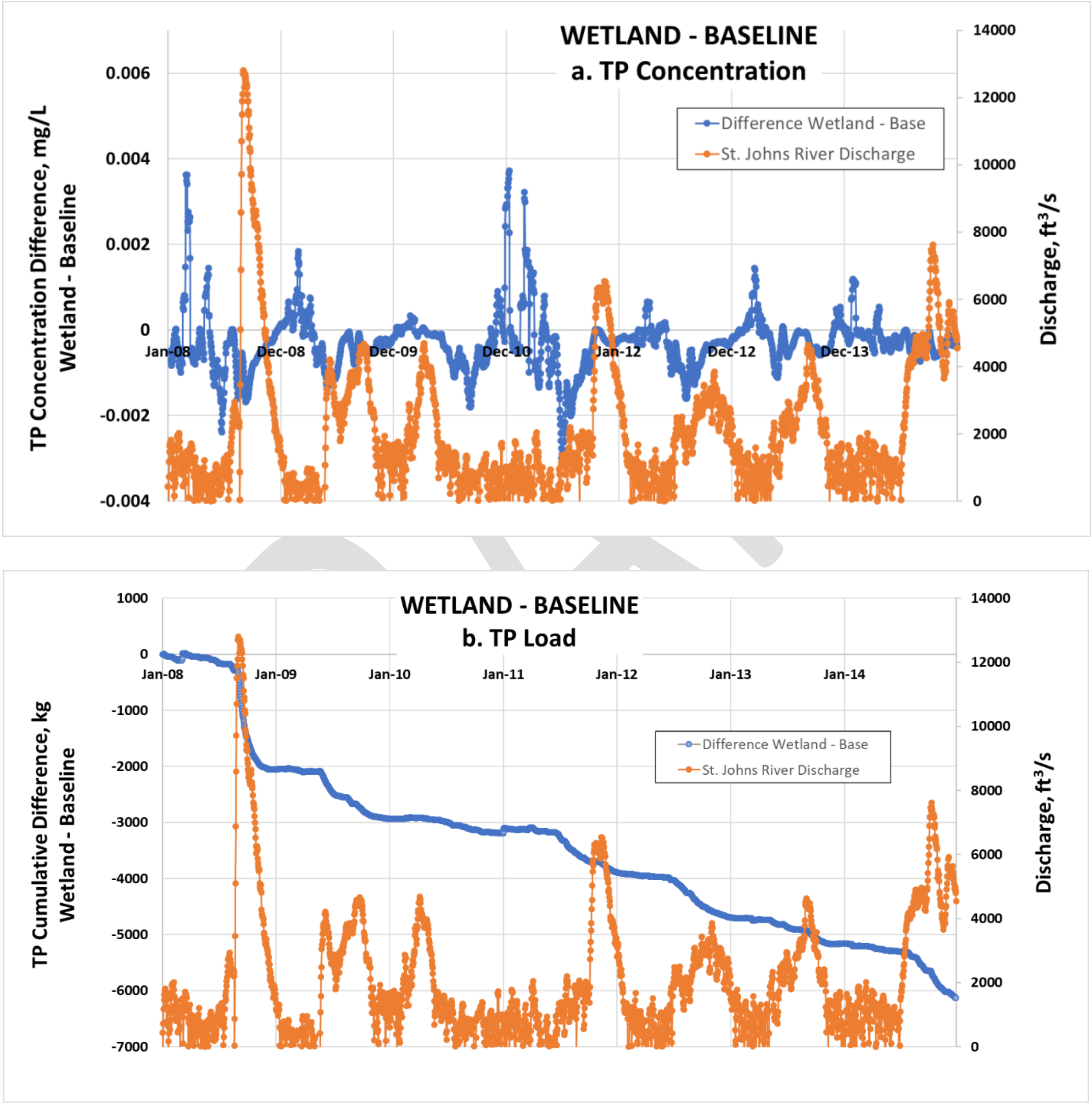
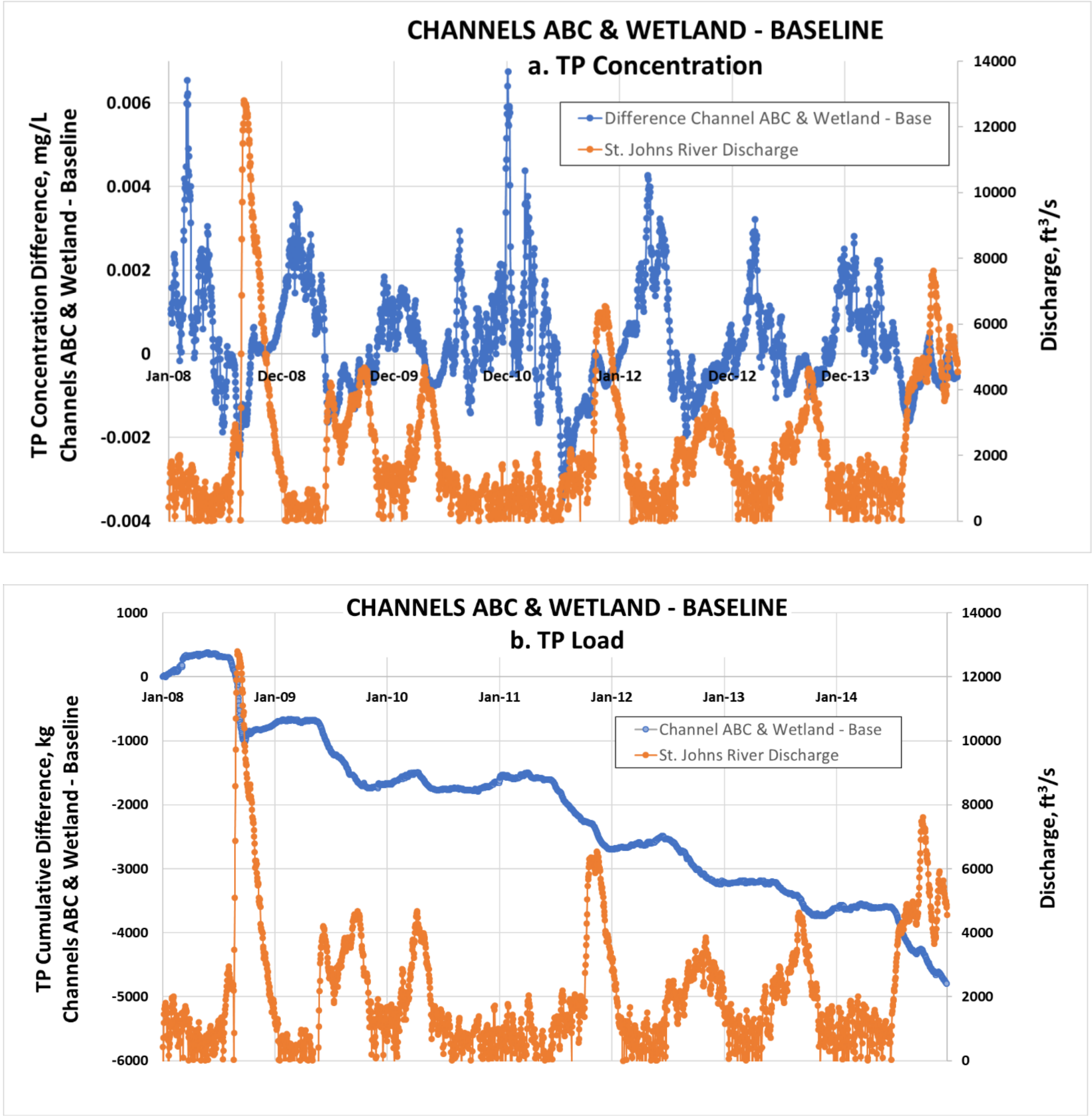


Figure 7. Combined Channels A, B and C and Flow-Through Wetland Minus Baseline Scenario TP Concentration and Load Differences from the WASP Model Simulations, in Blue, and USGS Discharge Site #02234500 at the Outlet of Lake Monroe, in Orange 2008-14. a. TP Concentration Difference. b. TP Cumulative Load Difference.



PROJECTS’ EFFECTS ON INTAKE WATER TO THE CAMERON WETLAND

This analysis addresses the degree to which the hydrodynamics generated by the proposed projects may reduce the effectiveness of the flow-through wetland project. This hypothetically could occur if the channel creation project delivered lower concentration St. Johns River water, intended for flushing the lake, to the inlet of the wetland. The overall effectiveness of the flow-through wetland could also be reduced if its cleaner effluent migrated from its outlet back to the inlet.

The maps of Figures 8, 9 and 10 show the annual average proportions of St. Johns River and/or flow-through wetland water throughout the lake under the channel ABC and wetland scenarios alone or combined. The fractions of St. Johns River or wetland effluent water are inferred in this simulation by setting these to an inflow dye concentration of 100 mg/L, with all other inflows set to zero. The shaded contours of the maps analogous to the proportion of inflow water under the given scenario.

The channel creation scenario map of Figure 8 displays the *difference* between the baseline condition (100 mg/L concentration SJR water entering through existing channels) and the channels ABC scenario (100 mg/L SJR water to directly entering the lake through channel A, B and C). For example, for one selected model cell near the outlet of the lake (i,j=141,41), under the baseline condition, the mean dye concentration is 37 mg/L, reflecting the normal mixing of the St. Johns and the lake near the outlet under which on average 37 percent of the water at this location originates from the river. Under the channel ABC scenario, the mean dye concentration for this same location is 86 mg/L, reflecting that this location, on average, would be composed 86 percent of St. Johns River Water. In Figure 8, this area is displayed in green, reflecting the fact that this area is roughly 50 mg/L greater than under the baseline condition.

Under the channel ABC scenario, St. Johns River water mixes with a small area of the lake in the vicinity of the outlet, though does not appear to mix appreciably into the body of the lake. The zones of mixing of St. Johns River water are distant from the flow-through wetland inlet, shown on the maps as a red dot. Scenario annual maps do not indicate any appreciable interannual variation in the degree of influence of St. Johns River water directed into the lake.

A much larger area of the lake appears to be influenced under the wetland scenario, though at somewhat lower proportions (Figure 9). It should be noted that as the wetland is nonexistent in the baseline condition, the difference shading of Figure 9 reflects the actual proportion of wetland effluent (i.e., baseline = zero). There is also noticeable interannual variation under the wetland scenario, with the area of influence in the relatively wet 2009 conditions limited to the north-west and central portion of the lake, while in the dry 2012 conditions, virtually the entire lake is comprised of at least 10 percent wetland effluent.

The scenario that combines the channels creation and flow-through wetland appears to create a zone in the neck and along the northwestern shore where river water and wetland effluent merge. Interannual variation in the extent of mixing is apparent, with the zone of at least 10 percent wetland and/or river water in 2012-13 reaching Bird Island, while in the relatively wetter 2009 conditions, the 10 percent contour ends appreciably north of this point.

Figure 8. Differences in the Proportions of St. Johns River Water in Lake Jesup Under the Channels A, B and C Creation Scenarios.   Red circle indicates location of wetland intake. Proportions expressed as annual averages in mg/L, with 100 mg/L = 100 percent St. Johns River Water.

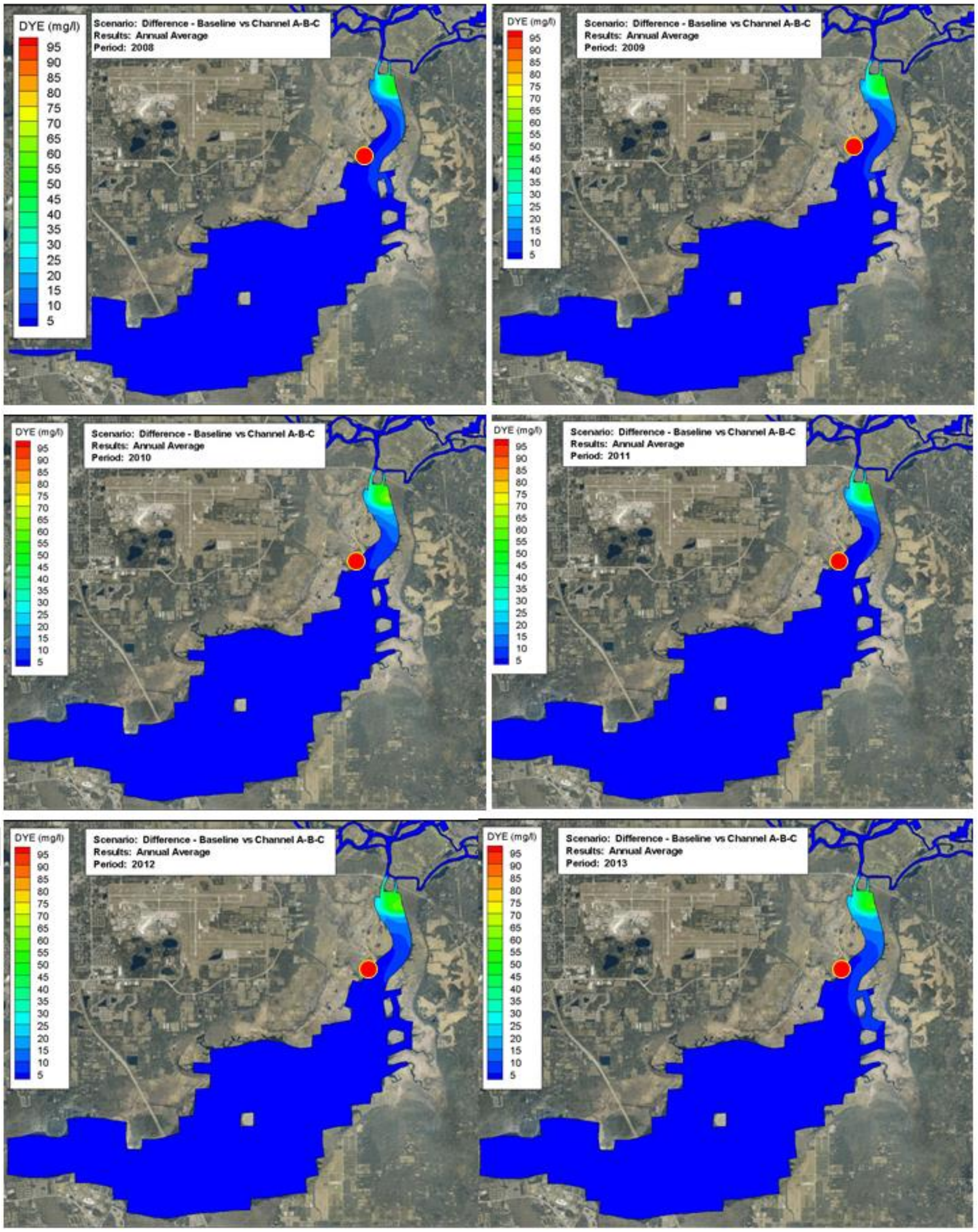


Figure 9. Differences in the Proportions of Flow-Through Wetland Water in Lake Jesup Under the Wetland Scenarios. Red circle indicates location of wetland intake. Proportions expressed as annual averages in mg/L, with 100 mg/L = 100 percent St. Johns River Water.

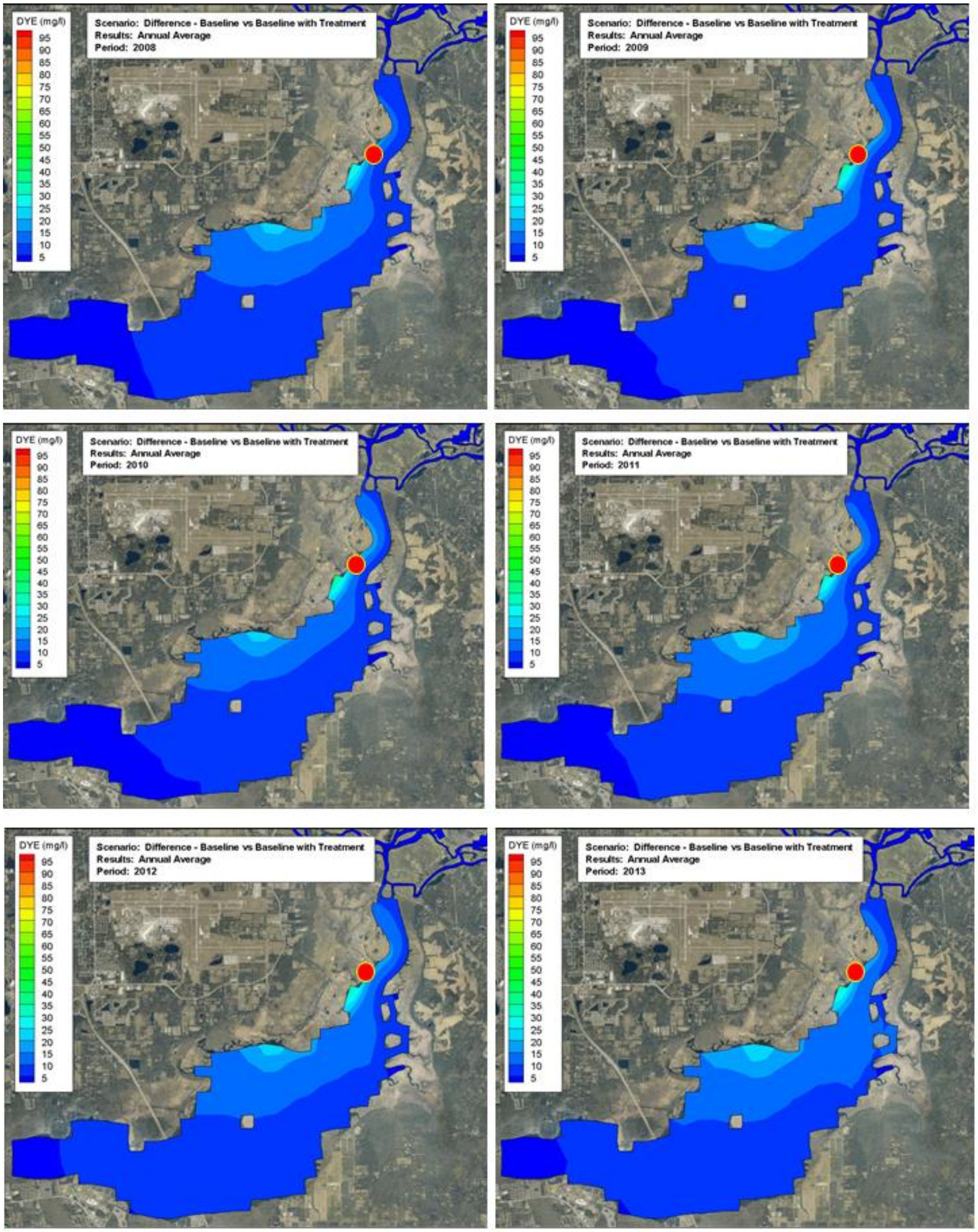
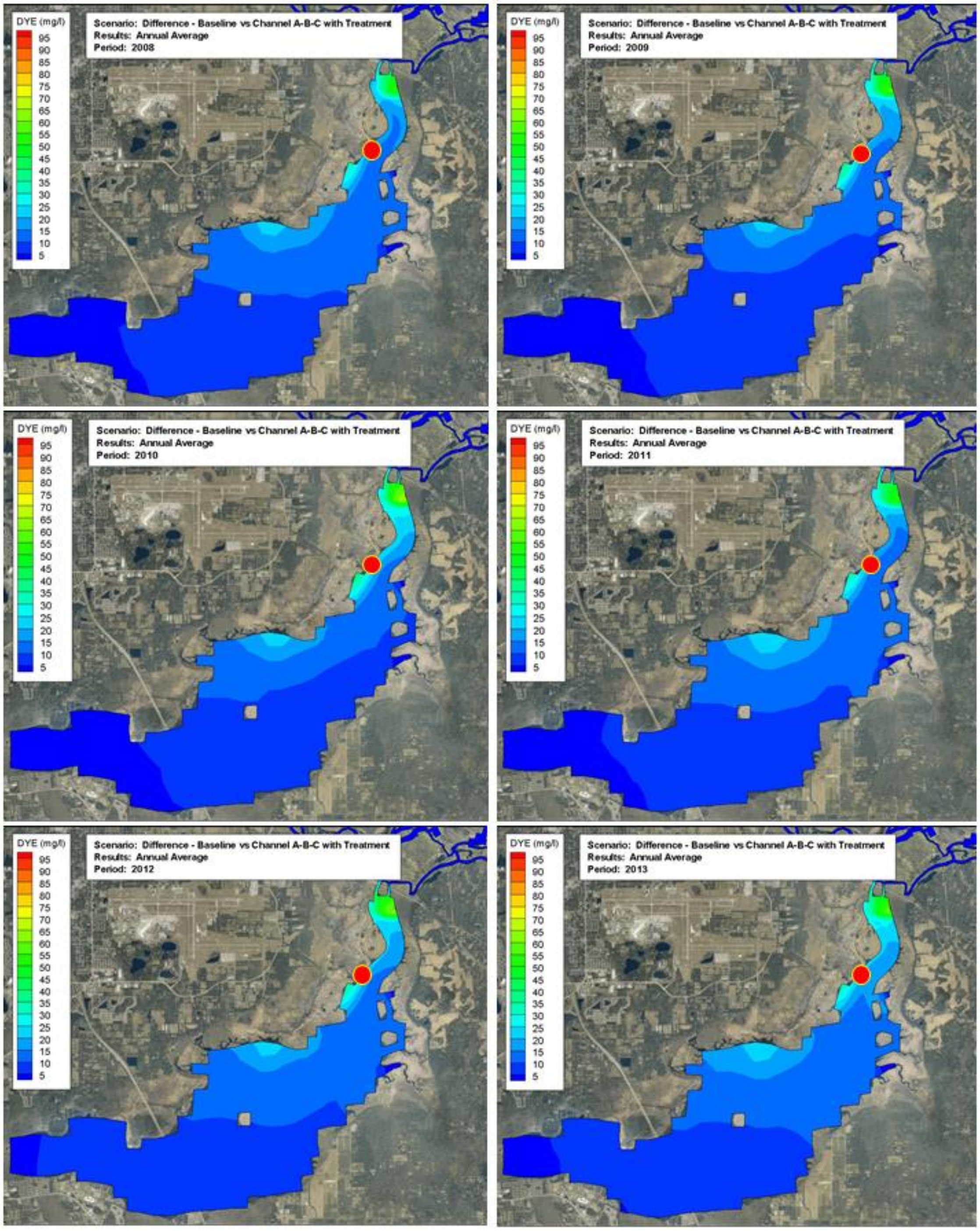
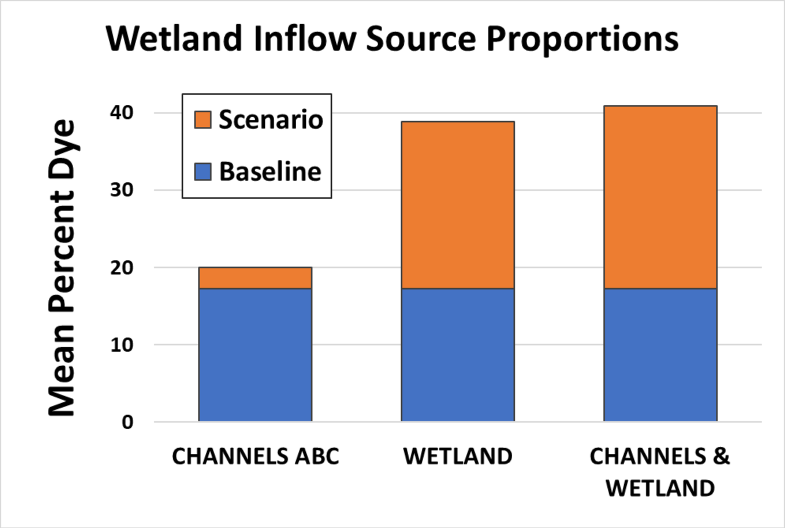


Figure 10. Differences in the Proportions of St. Johns River and Flow-Through Wetland Water in Lake Jesup Under the Combined Channels A, B and C and Wetland Scenarios. Red circle indicates location of wetland intake. Proportions expressed as annual averages in mg/L, with 100 mg/L = 100 percent St. Johns River Water.



The bar chart of Figure 11 compares the mean relative proportions of wetland and/or river water for the EFDC model cell adjacent to the flow-through wetland intake under the individual and combined scenarios. The overall average proportion of St. Johns River water in the vicinity of the wetland intake is under the baseline scenario is 17.2 percent. Under the channels ABC scenario, this increases by 2.8 percent. The flow-through wetland increases the proportion of “external” water, in this case water that originates from the outflow of the wetland, to 21.6 percent. The scenario with both both projects increases the amount of combined St. Johns and wetland-recycled water to 23.6 percent.

Figure 11. Overall Mean Percent of St. Johns River and/or Flow-Through Wetland Water for Modeled Scenarios at the Intake of the Flow-Through Wetland. Both the wetland and the channel creation scenarios combined increase the amount of



The degree of influence at the wetland intake determined by EFDC is simulated as a proportion of the two modeled external inflows, either the St. Johns River or the wetland effluent. When the relative influence for these two external inflows is expressed in terms of concentration, the differences narrow. Under the channel ABC scenario, the overall mean TN concentration at the wetland intake is reduced by 0.076 mg/L, or by 2.3 percent from the baseline, and the mean TP concentration is reduced by 0.002 mg/L, or 1.3 percent. Under the operating flow-through wetland scenario, the TN concentration intake concentration is reduced by 0.24 mg/L, or 7.3 percent, and the TP concentration is reduced by 0.007 mg/L, or 5.5 percent. With both projects enabled, the overall mean decrease in TN is 0.299 mg/L, or 9.2 percent, while the mean TP decrease is 0.009 mg/L, or 7.1 percent.

Table 1. Overall Mean Values for Simulated Water Quality Constituents at the Inlet to the Proposed Flow-Through Treatment Wetland for Lake Jesup Restoration Scenarios.

Location	**TN,** mg/L	**TP,** mg/L	**Chl a,** µg/L	**TSS,** mg/L	**Ke,** 1/m
SJR Abv. L. Jesup	1.554	0.093	8.8	5.4	1.35
Estimated Wetland Return Water	2.18	0.103	N/A	N/A	N/A
Wetland Intake, Baseline	3.260	0.126	89.2	15.5	3.51
Wetland Intake, Channels ABC	3.184	0.124	87.9	15.2	3.47
Wetland Intake, Wetland	3.019	0.119	76.0	12.8	2.98
Wetland Intake, Channels + Wetland	2.961	0.117	75.0	12.6	2.96

SAV HABITAT ASSESSMENT

The effect on potential SAV habitat from the channel creation and wetland projects' scenarios was assessed with output of the underwater light extinction coefficient, Ke, calculated from the light attenuating state variables in the WASP model. The simulated Ke values were used to calculate the mean depth corresponding to 9 and 14 percent of remaining surface light, based on literature values on the range in the minimum light level for growth of the primary rooted submersed plant of the St. Johns, *Vallisneria americana* (Dobberfuhl, 2007). Table 2 summarizes model predictions for vertical transparency depth and SAV potential for these two surface light levels.

Table 2. Areas (acres) with Mean Underwater Light Transmission Sufficient to Reach the Sediments and Potentially Support SAV, and Maximum Depths (meters) of Light Transmission, for Five Project Scenarios for Lake Jesup.

Light Level	Scenario	Baseline	A, B & C	A & C w/o B	Wetland Treatment	A, B & C + Wetland Treatment
9%	Suitable SAV Area	1,087	1,317	1,350	1,373	1,482
	Maximum Depth	0.90	1.40	1.40	1.19	1.49
14%	Suitable SAV Area	890	960	950	1,029	1,075
	Maximum Depth	0.90	1.20	1.10	1.00	1.20

Under the channels ABC scenario, the lake area that can potentially support SAV increases by 70 acres under the 14 percent of surface light depth, and by 230 acres for the 9 percent light level. Figures 12 and 13 show the areas added under this scenario are concentrated near the lake outlet. Because this zone is improved by the clearer St. Johns River Water, the increase in the maximum depth that can potentially support SAV is relatively large, increasing from 0.9 m to 1.2 for the 14 percent light level, and to 1.4 m for the 9 percent level (Table 2).

Under the flow-through wetland scenario, the lake area that can potentially support SAV increases by 139 acres under the 14 percent of surface light depth, and by 285 acres for the 9 percent light level. A large area of potential SAV expansion is created under the 14 percent light level (Figure 13) in the cove within which the flow-through wetland would discharge. Suitable areas also appear on the eastern shoreline opposite the wetland outflow. Under the 9 percent light level, the increased area appears as a thin band along much of the western shoreline (Figure 12).

With both projects in operation, the suitable SAV area increases by 186 acres for the 14 percent light level, and by 395 acres under the 9 percent light level. The effect on increased SAV area for the two projects together is not quite additive, as they appear to overlap in area affected at the lake outlet.

Figure 12. Areas of Transparency Depth for Lake Jesup Project Scenarios at the 9 Percent Light Level.

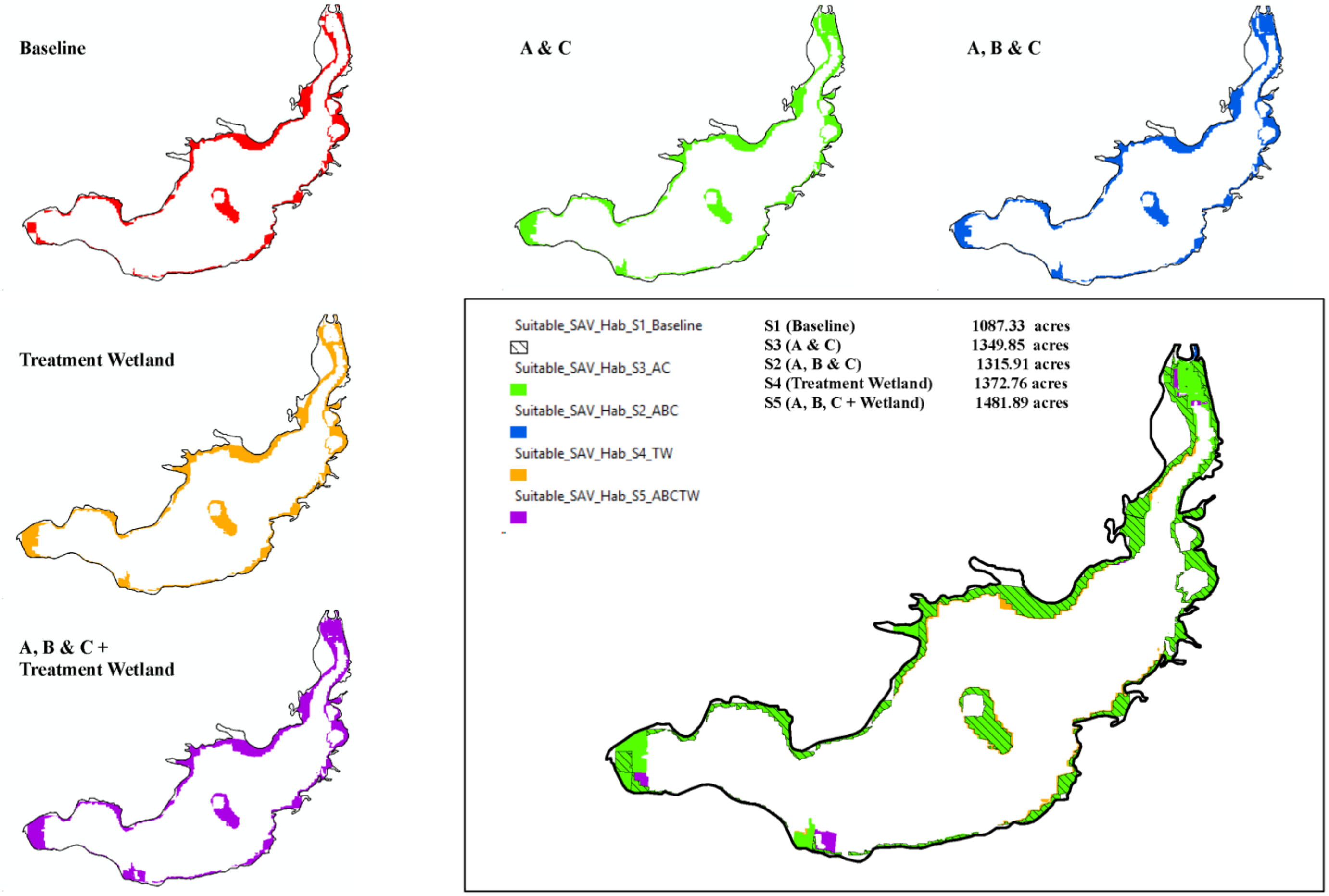
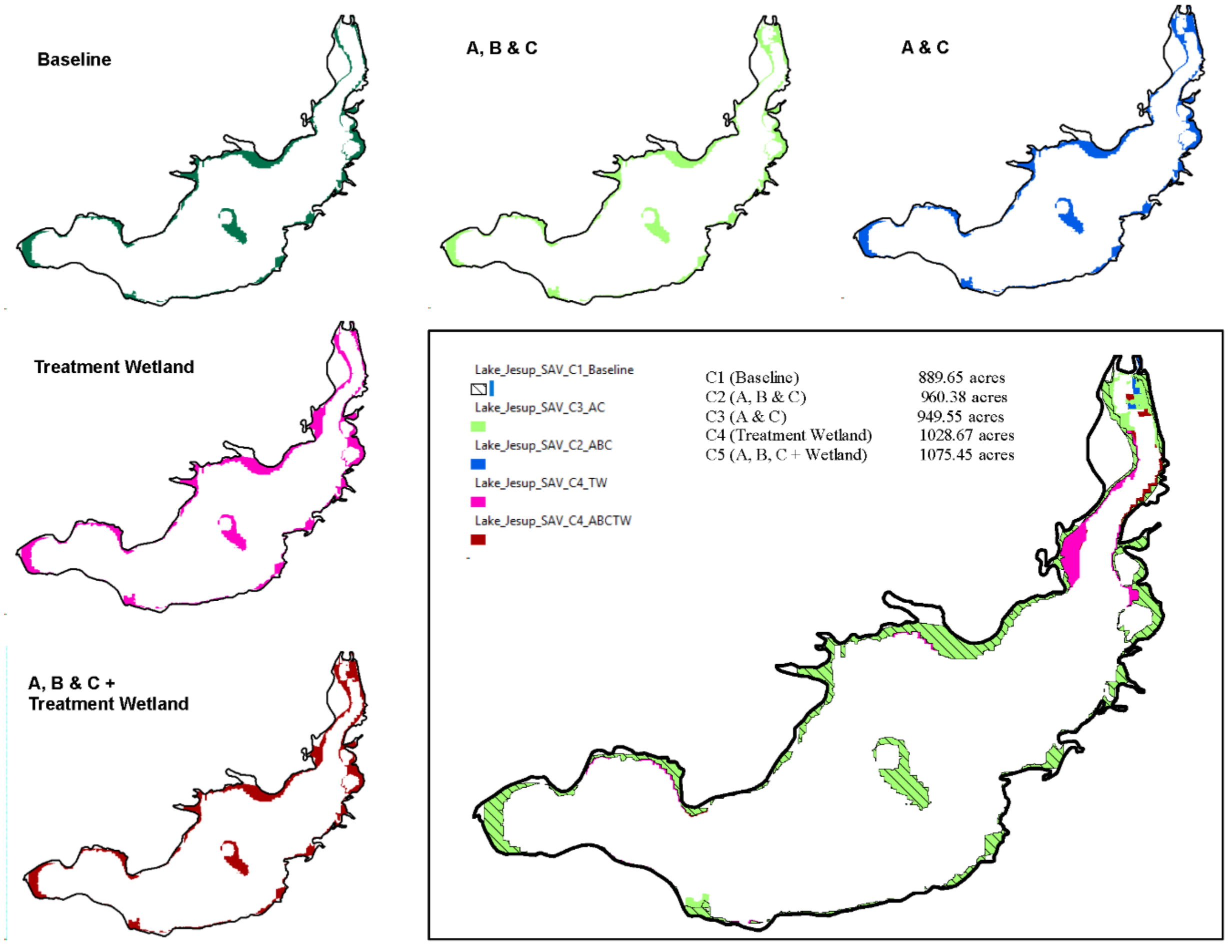


Figure 13. Areas of Transparency Depth for Lake Jesup Project Scenarios at the 14 Percent Light Level.



CONCLUSIONS AND RECOMMENDATIONS

The first phase of the channel C assessment focused on potentially beneficial effects on lake nutrient concentrations and reductions in algal biomass. Model results directed at this environmental element however indicated that only a small area of the lake would benefitt by the projects' improvements to lake circulation. Further reflection on the phase 1 results posed the following additional questions:

- **Could either of the projects increase downstream nutrient load to Lake Monroe?**
- **Could the channel C project reduce a proposed recirculating wetland efficiency?**
- **Could either of the projects improve littoral habitat for SAV?**

To answer these questions, the modeling tools developed in the first project phase were adapted to derive additional model parameters and output locations from redesigned simulations to provide data series that could potentially inform these points of interest.

DOWNSTREAM NUTRIENT LOAD

Based solely on the annual means, the channel creation project scenarios produce an overall decrease in TN loads of between 2.8 to 3.8 metric tons per year. However, closer inspection of the time series in load differences at finer time scales indicates that both channel scenarios may increase downstream TN load over long durations. This anomaly arises from the apparent interaction of discharge and concentration, whereby the channel scenarios produce concentrations lower than the baseline condition under higher flows, and higher concentrations than baseline under low flows. This negative interaction likely arises from higher TN supplied by N-fixing cyanobacteria during long residence time (the WASP model contains algorithms to simulate this phenomenon). The result is that most of the channel scenario load reduction occurs during short high-flow intervals, that occurred during TS Fay, and in the latter half of 2014 (Figure 2b). For most of the remainder of the simulation time series, the channel creation scenarios increase downstream TN load. Between June of 2010 through August 2014, the channel scenarios export roughly 25 to 30 addition metric tons of TN downstream, or xx annually.

The consequence of this increase in TN load is uncertain. Since the nuisance cyanobacteria community that flourishes in these lakes contains species capable of acquiring necessary nitrogen from atmospheric fixation, addition TN may not affect the overall algal biomass as much as TP. However, the addition of TN may also favor one of the most problematic cyanobacteria genera, the non-nitrogen-fixing *Microcystis*.

The flow-through wetland scenario indicates that this action will reduce downstream TN Load an average of 27 metric tons per year. The time series of simulation results (Figure 3b) indicates that the load decrease is relatively constant over the duration, with no intervals or flow conditions that suggest temporary increases in downstream TN load.

Because of the potential to increase algal productivity, the effect on downstream export of phosphorus is of greater concern than nitrogen. The modeled mean downstream TP load increase from the channel creation projects is 127 (A, B & C) and 102 (A, C, w/o B) kg/yr. Most of these mean load increases are driven by a large load increase associated with TS Fay. Annual TP load increases under these scenarios are smaller for the remainder of the simulations, though at times occur preceding spring and summer or during low flow, long residence time conditions, hence could promote downstream algal growth. In 2010, 2012 and 2014, the channel ABC scenario is predicted to modestly increase downstream TP load for durations of 3 to 6 months at a time, on the order of 0.1 to 0.3 MT. These loads represent between 0.5 to 1 percent of the total load for their durations, and while relatively small, they may require a mitigating project to offset these increases.

Under the flow-through wetland scenario simulation, annual mean downstream phosphorus load is reduced by 0.88 MT/yr. The load reduction is relatively constant over the simulation, and absent of short duration positive load export that could potentially promote algal productivity during favorable conditions.

A potential effect not accounted for in this modeling study is the propensity for phosphorus mobilization arising from marsh dehydration and rehydration cycles. During dehydration, marsh soil organic matter decomposes, converting phosphorus from organic to inorganic form. Upon the ensuing rehydration cycle, the shift in soil redox potential allows this inorganic phosphorus to be released into soil pore water and diffuse into draining marsh water. The creation of a channels in marshes facilitates the migration of this released phosphorus to lake surface waters. Some examination of this potential for marsh soil phosphorus mobilization should be included in future evaluations of this project.

FLOW TREATMENT WETLAND INFLOW EFFECTS

This analysis addresses the degree to which the hydrodynamics generated by the proposed projects may reduce the effectiveness of the flow-through wetland project. This hypothetically could occur if the channel creation project delivered lower concentration St. Johns River water, intended for flushing the lake, to the inlet of the wetland. The overall effectiveness of the flow-through wetland could also be reduced if its cleaner effluent migrated from the outlet back to the inlet.

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A much larger area of the lake appears to be influenced under the wetland scenario, though at a somewhat lower proportions (Figure 9). There is also noticeable interannual variation under the wetland scenario, with the area of influence in the relatively wet 2009 conditions limited to the north-west and central portion of the lake, while in the dry 2012 conditions, virtually the entire lake is comprised of at least 10 percent wetland effluent.

The scenario that combines the channels creation and flow-through wetland appears to create a zone in the neck and along the northwestern shore where river water and wetland effluent merge. Interannual variation in the extent of mixing is apparent, with the zone of at least 10 percent wetland and/or river water in 2012-13 reaching Bird Island, while in the relatively wetter 2009 conditions, the 10 percent contour ends appreciably north of this point.

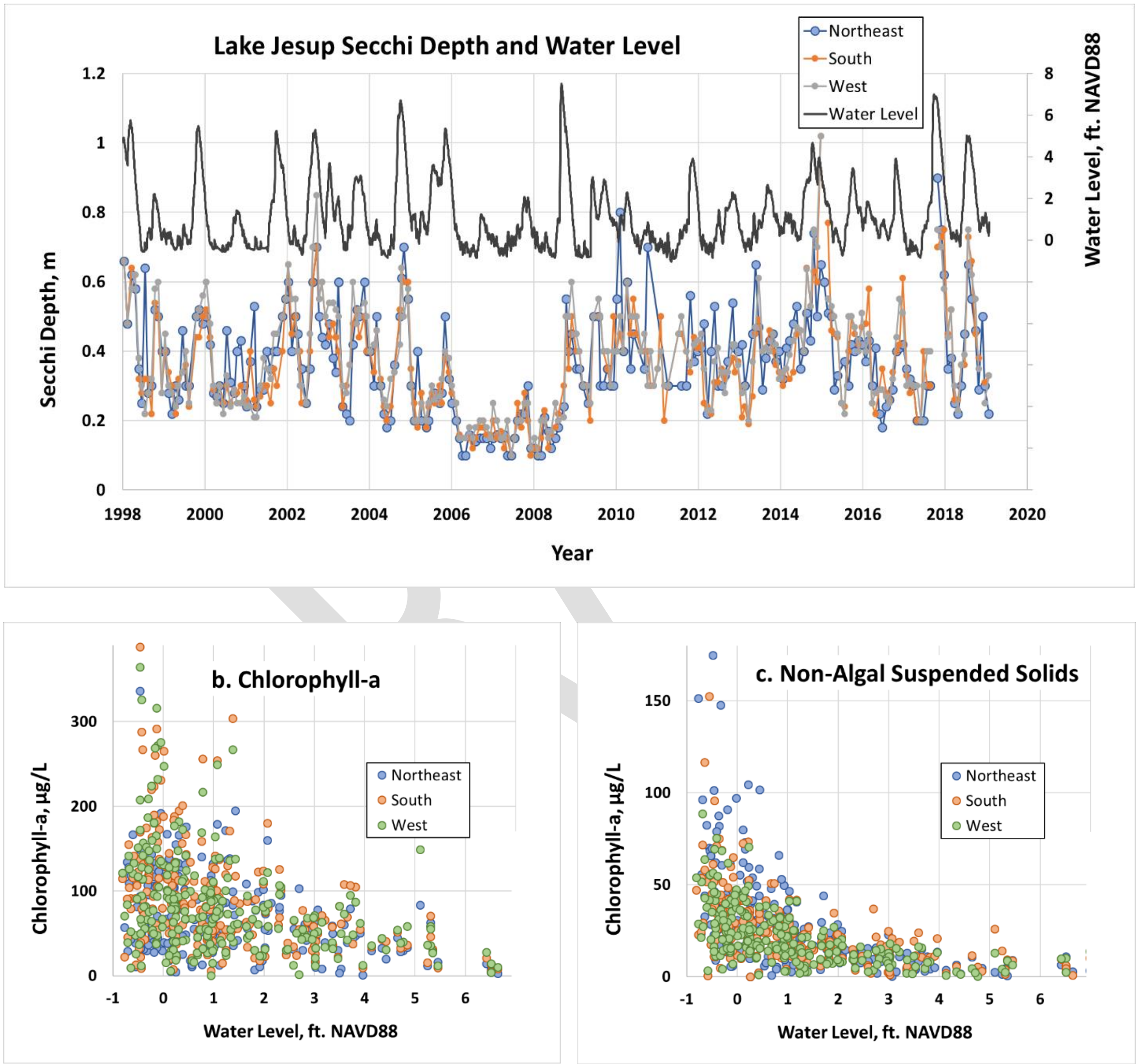
The overall average proportion of St. Johns River water in the vicinity of the wetland intake is under the baseline scenario is 17.2 percent, and increases by only 2.8 percent under the channels ABC scenario. The flow-through wetland increases the proportion of “external” water to 21.6 percent, with this external water being recirculated wetland outflow. The scenario that combines both projects increases the amount of St. Johns and wetland-recycled water to 23.6 percent.

When the relative influence for these two external inflows is expressed in terms of concentration, the differences narrow. Under the channel ABC scenario, the overall mean TN concentration at the wetland intake is reduced by 0.076 mg/L, or by 2.3 percent from the baseline, and the mean TP concentration is reduced by 0.002 mg/L, or 1.3 percent. Under the operating flow-through wetland scenario, the TN concentration intake concentration is reduced by 0.24 mg/L, or 7.3 percent, and the TP concentration is reduced by 0.007 mg/L, or 5.5 percent. With both projects enabled, the overall mean decrease in TN is 0.299 mg/L, or 9.2 percent, while the mean TP decrease is 0.009 mg/L, or 7.1 percent.

SAV HABITAT EXPANSION

Measurements of underwater light transmission in Lake Jesup are among the lowest of any lake in the SJRWMD, a condition that can limit the colonization of SAV. Figure 14(a) plots the Secchi depth measurements for the lake over time since the start of SJRWMD monitoring in 1998. Secchi depth has improved since the lowest point between 2006 – 2008, though the improvement is largely due to the absence of extended periods of low water level. Low water levels are strongly correlated with increased chlorophyll-a and suspended solids (Figure 14 b-c). It is well established that biological and chemical parameters, such as chlorophyll-a and suspended solids, directly alter light availability. Instances of SAV re-growth have been attributed to reductions in nutrient loading (Gurbiz and Kemp 2014; Dennison, et al 1993; Kahn, et al 1985), which directly affects algal productivity. When minimum growth requirements are met and SAV beds are established, there is a sort of ‘positive feedback’ loop that helps promote SAV, wherein SAV beds absorb wave energy, sink suspended particles, and thus improve overall water chemistry (Gurbiz and Kemp 2014). SAV also directly absorbs nutrients, leaving less available for epiphytic algae growth and algal blooms. This positive feedback loop acts as a buffer to the established SAV against disturbances.

Figure 14. Secchi Depth at the Three Water Quality Monitoring Stations in Lake Jesup, and Relationship Between Chlorophyll-a and Non-Algal Suspended Solids to Water Level. a. Time Series of Secchi depth and lake water level, 1998 – 2019. b. Relationship between Water Level and chlorophyll-a. c. Relationship between water level and non-algal suspended solids. Algal solids estimated as ((chl-a*50)/1000)*2.4.



WASP model results were applied to extrapolate the potential for SAV expansion, arising from water quality improvements that increase water column transparency and hence the depth of light transmission for photosynthesis by plants emerging from the sediments. Model results indicate that both projects will improve underwater light conditions, and hence may create additional area potentially suitable for SAV colonization. Because the outflow of the flow-through wetland is located on the gently sloping littoral shelf of the northwest shoreline, its operation impacts a greater amount of area is conducive for SAV colonization, and this is reflected in the model results. Under the 14 percent surface light level, the sufficiently illuminated area increases the total potentially suitable SAV area by 16 percent (139 acres) while at the 9 percent light level, total suitable area is increased by 26 percent (285 acres). Under the channel creation scenarios, SAV-suitable areas are increased by 7 – 8 percent (60 – 70 acres) under the 14 percent light level, and by 21 – 24 percent (230 – 260 acres) for the 9 percent light level. The increase in SAV-suitable area under the channel creation scenarios is located near the lake outlet, while the SAV area increase is distributed as a thin area around much of the lake. As littoral edge is a valuable habitat for forage and refugia, such a distribution may be more desirable than expansion in a concentrated area.

This estimate of improved light conditions should be considered tentative and indirect, as other conditions not assessed in the model would need to be met for SAV colonization, including substrate quality, wind and wave sheltering, and fluctuating water level. In short, while light is one of the dominant factors determining SAV growth, it should not be used as the sole predictor, as many other interdependent criteria such as water level, exert influence. Regular SAV surveys should be instituted for Lake Jesup to determine the baseline levels of coverage, the factors that promote expansion of grass beds, and to chart expansion of SAV as water quality improvement projects are implemented.

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