TETRA TECH

MEMO

To:	Amie West, DEP
Cc:	James Albright, DEP Ansel Bubel, DEP Erin Rasnake, DEP
From:	Brian Watson, PE, PH, D.WRE, Tetra Tech Marcy Frick, REM, Tetra Tech Erin Lincoln, PH, Tetra Tech Jeremy Wyss HIT, Tetra Tech
Date:	November 17, 2017
Subject:	Caloosahatchee River Watershed Upper Model Modifications – Water Quality Calibration Results and Discussion

TABLE OF CONTENTS

1.0 INTRODUCTION

Tetra Tech was contracted by the Florida Department of Environmental Protection (DEP) to address DEP and stakeholder issues regarding the setup and calibration of the 2009 and 2014 versions of the Caloosahatchee River and Estuary Hydrological Simulation Program – FORTRAN (HSPF) and Environmental Fluid Dynamics Code (EFDC) models. These models will be used to develop total maximum daily loads (TMDLs) for impaired freshwater bodies within the Caloosahatchee River Watershed and to refine the Caloosahatchee tidal estuary TMDL that DEP adopted in 2009. Tetra Tech worked with DEP and the stakeholders to refine and calibrate the HSPF and EFDC models, and the final modeling report (*Hydrology and Water Quality Modeling Report for the Caloosahatchee River and Estuary, Florida*, Tetra Tech 2017) and model files (2017 HSPF Model) were provided to DEP in May 2017.

DEP has been using the 2017 HSPF Model to determine the appropriate TMDLs for the impaired freshwater bodies in the watershed. These waterbodies include waterbody identification (WBID) numbers 3237C (Lake Hicpochee), 3237E (C-19 Canal), 3237D (Ninemile Canal), and 3246 (S-4 Basin). These waterbodies are located in the upper portion of the Caloosahatchee River Watershed. When making impairment assessments, DEP uses all applicable data collected within in a WBID. The 2017 HSPF Model was calibrated to select locations in the Caloosahatchee River Watershed, and those locations were primarily limited to Impaired Waters Rule (IWR) stations with long periods of historic sampling data. The selected calibration stations represented the conditions of the stream from which they were collected; however, that particular stream may not be representative of all streams within a WBID. The HSPF model was calibrated with the assumption that acceptable calibrations at selected calibration locations produced acceptable model results in other non-calibration streams. When DEP used the HSPF model to set TMDLs, some of the model streams within a WBID showed the verified impairment while others did not, making it difficult to determine the appropriate TMDL targets for each of the impaired WBIDs.

To better assess the impaired waterbodies, DEP asked Tetra Tech to reassess the 2017 HSPF Model calibration in the upper portion of the Caloosahatchee River Watershed (**Figure 1**), specifically for the impaired WBIDs (Lake Hicpochee, C-19 Canal, Ninemile Canal, and S-4 Basin) and work to improve the calibration where necessary. This document discusses the modifications made to the 2017 HSPF Model to improve the calibration in the upper portion of the Caloosahatchee River Watershed, referred to as the Upper Watershed Model, and presents the updated model results.

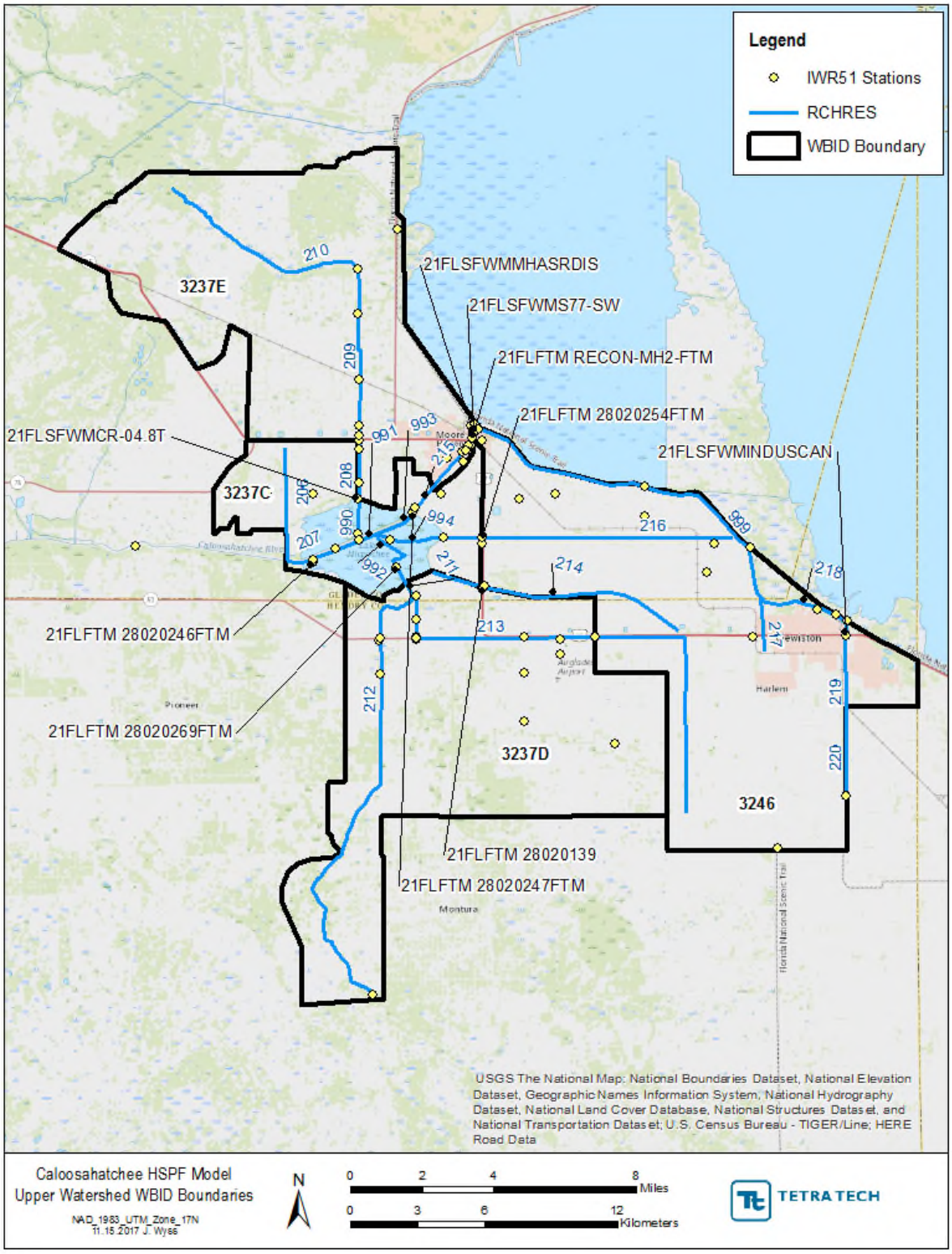

Figure 1: Upper Portion of the Caloosahatchee River Watershed WBID Boundaries

2.0 CALIBRATION ASSESSMENT AND REFINEMENT

This section discusses the 2017 HSPF Model calibration refinement in the Upper Watershed Model, the simulated model response compared to all applicable monitoring data within a WBID, and the parameter refinements made to improve the model calibration. While all reach segments and its associated data were evaluated and used for the model refinement, figures and statistics are only provided at representative reach locations in each WBID. All of the data in each WBID were used in the representative figures and statistics.

2.1 C-19 CANAL (WBID 3237E)

The C-19 Canal WBID is currently impaired for dissolved oxygen (DO), total nitrogen (TN), and macrophytes. In the 2017 HSPF Model, RCHRES 208 was used as the calibration location and was compared to measured data from station 21FLSFWMCR-04.8T located on the C-19 Canal. The WBID contains three HSPF model reaches (RCHRES): 208, 209, and 210. The WBID includes a small portion of the main stem Caloosahatchee River downstream of S-77, and monitoring stations located on that section of the main stem are used in the C-19 Canal WBID impairment assessments. For the Upper Watershed Model evaluation and update, all stations in the WBID, including those in the main stem, were used for assessment.

The mouth of RCHRES 208 is located at the boundary of the C-19 Canal WBID and the Lake Hicpochee WBID. For DO and DO saturation (DOSAT) (Figures B-247 through B-250 in Tetra Tech 2017), the 2017 HSPF Model calibration was acceptable. However, when the RCHRES 208 results were compared to all available measured data for WBID 3237E (**Figure 2** and **Table 1**), the DO model simulation trended higher than the observed data. All three RCHRES assigned to the C-19 Canal WBID had a similar simulated DO response. The DO monitoring data from station 21FLSFWMCR-04.8T, which was used for the 2017 HSPF Model calibration, are not representative of all of the monitoring data from the C-19 Canal WBID. To improve the C-19 Canal WBID DO calibration in the Upper Watershed Model, the lake flag (LKFG) was turned off (value changed from 1 to 0), which changed the HSPF model reaeration calculations from lake/wind reaeration to stream reaeration. **Figure 3** shows the Upper Watershed Model refined DO calibration time series for RCHRES 208 compared to all data collected in the WBID. Turning off the LKFG parameter resulted in less reaeration and better model performance when compared to all data collected in the WBID. DO statistics improved to Very Good with annual and median errors of approximately 13% (**Table 2**).

For TN and total phosphorus (TP) (Figures B-243 through B-246 in Tetra Tech 2017), the 2017 HSPF Model calibration overestimated TN during the winter and spring, slightly underestimated TN during summer and fall, and underestimated TP. When comparing the RCHRES 208 model results to all available measured data from the C-19 Canal WBID, there was still a high simulation for TN during the summer and fall (**Figure 4** and **Table 1**), but the TP simulation was more in range with the observed data (**Figure 6** and **Table 1**). All three RCHRES assigned to the C-19 Canal WBID had a similar simulated response for TN and TP. To improve the C-19 Canal WBID TN and TP calibrations in the Upper Watershed Model, investigation into the cause of the simulated TN trend of high and low concentrations revealed that the high concentrations were controlled by organic matter concentrations in the groundwater and that low

concentrations were controlled by the instream organic matter settling rate. Specific parameter modifications focused on reducing organic matter, nitrate + nitrite (NOx), and ammonia (NH_4) concentrations in interflow and groundwater from the upland, and reducing the instream organic matter settling rate. **Figure 5**Error! Reference source not found. shows the Upper Watershed Model refined TN calibration for RCHRES 208 compared to all data collected in the WBID. Reducing organic matter, NOx, and NH_4 concentrations in interflow and groundwater and reducing the instream organic matter settling rate brought the simulation more in range with the observed data. **Figure 7** shows the Upper Watershed Model refined TP calibration for RCHRES 208 compared to all data collected in the WBID. TN average and median statistics were Very Good for both the 2017 HSPF Model and Upper Watershed Model, but the visual calibration was improved in the Upper Watershed Model. Due to the adjustments in organic matter, the TP simulation was lowered slightly, reducing the median annual average by 1.5%, which changed the rating from Very Good to Good (**Table 2**).

Table 1: 2017 HSPF Model Summary of Annual Concentration Comparisons for DOSAT, TN, and TP for RCH208

Parameter	Average Annual % Error	Average Annual % Error Rating	Median Annual % Error	Median Annual % Error Rating
DOSAT	43.9%	Good	47.3%	Fair
TN	20.0%	Very Good	22.3%	Very Good
TP	-19.1%	Very Good	-29.2%	Very Good

Table 2: Upper Watershed Model Revised Summary of Annual Concentration Comparisons for DOSAT, TN, and TP for RCH208

Parameter	Average Annual % Error	Average Annual % Error Rating	Median Annual % Error	Median Annual % Error Rating
DOSAT	13.4%	Very Good	13.2%	Very Good
TN	17.8%	Very Good	21.0%	Very Good
TP	-20.6%	Very Good	-30.7%	Good

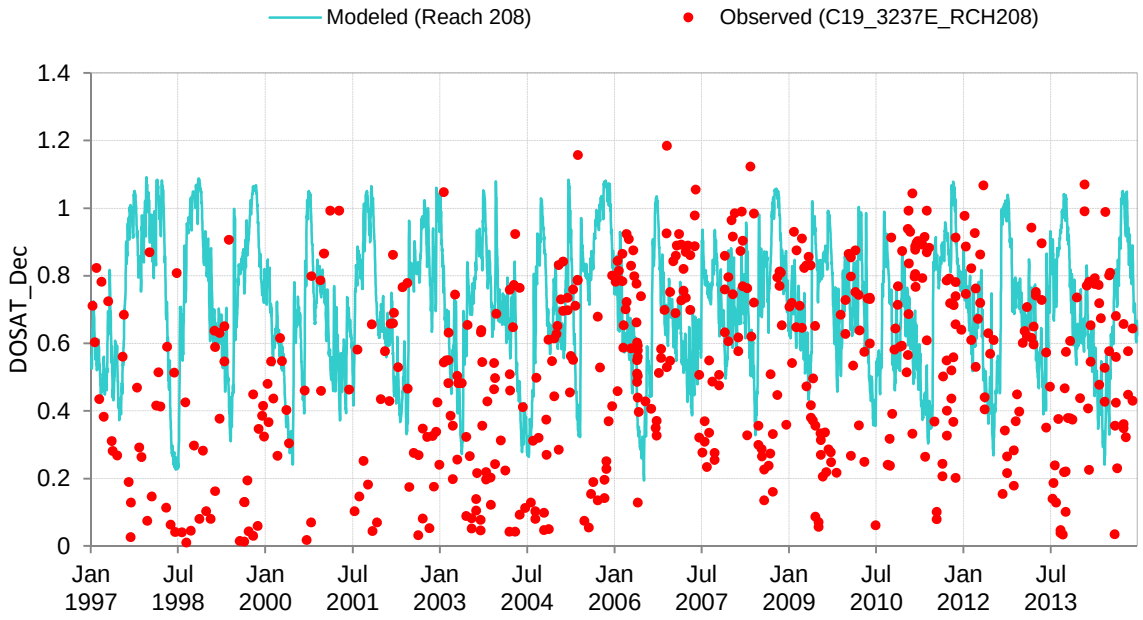

Figure 2: Original DOSAT Calibration for RCH208 Compared to All Measured Data

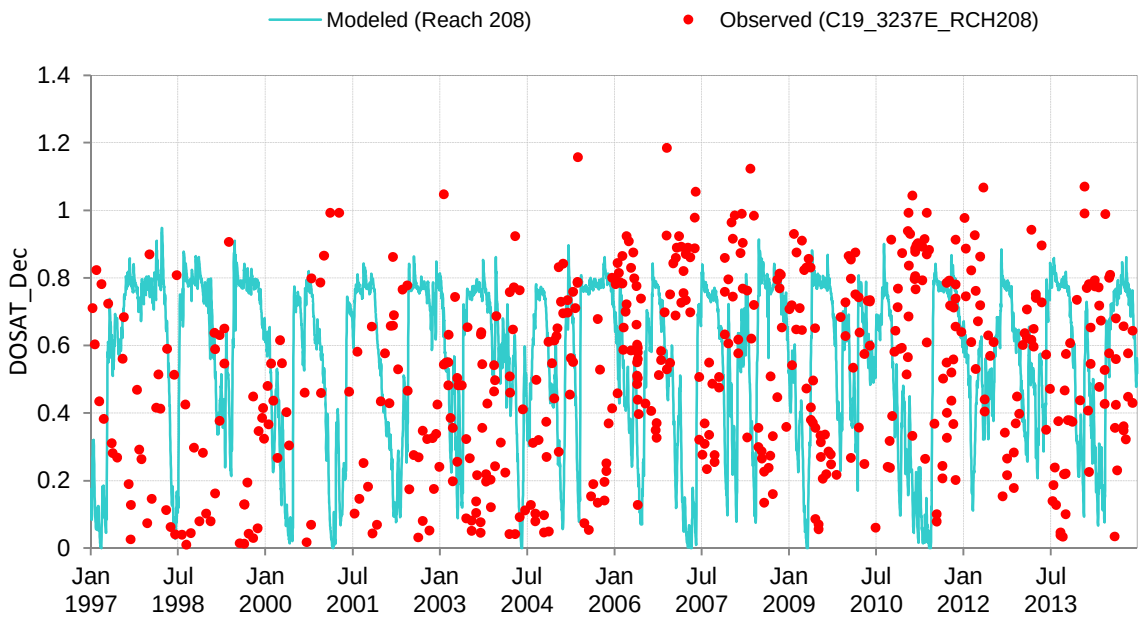

Figure 3: Revised DOSAT Calibration for RCH208 Compared to All Measured Data

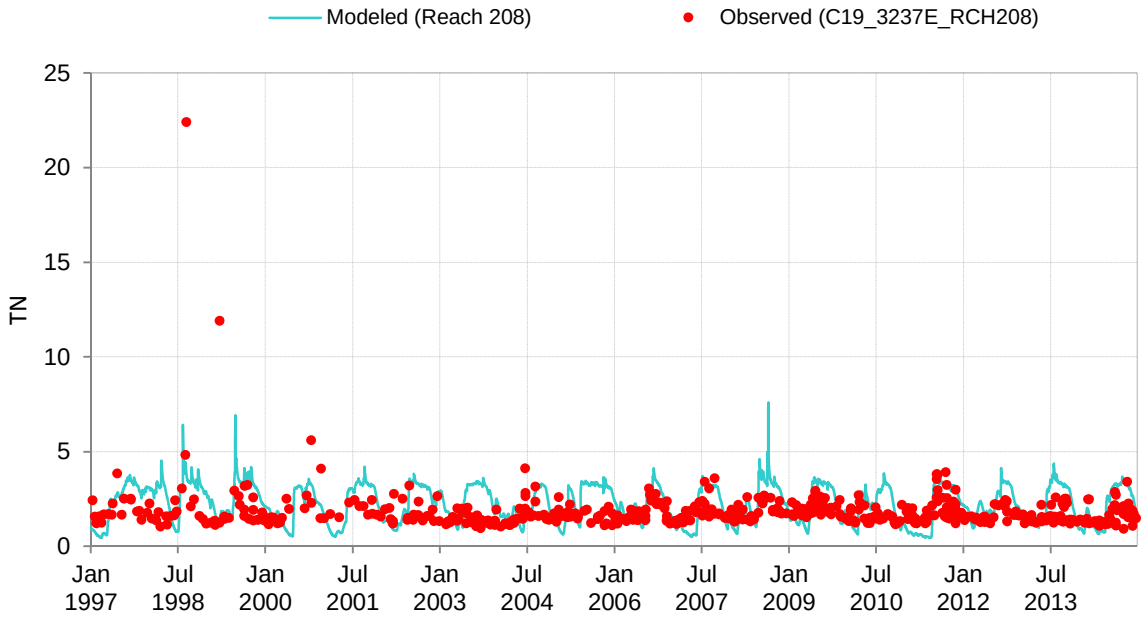

Figure 4: Original TN Calibration for RCH208 Compared to All Measured Data

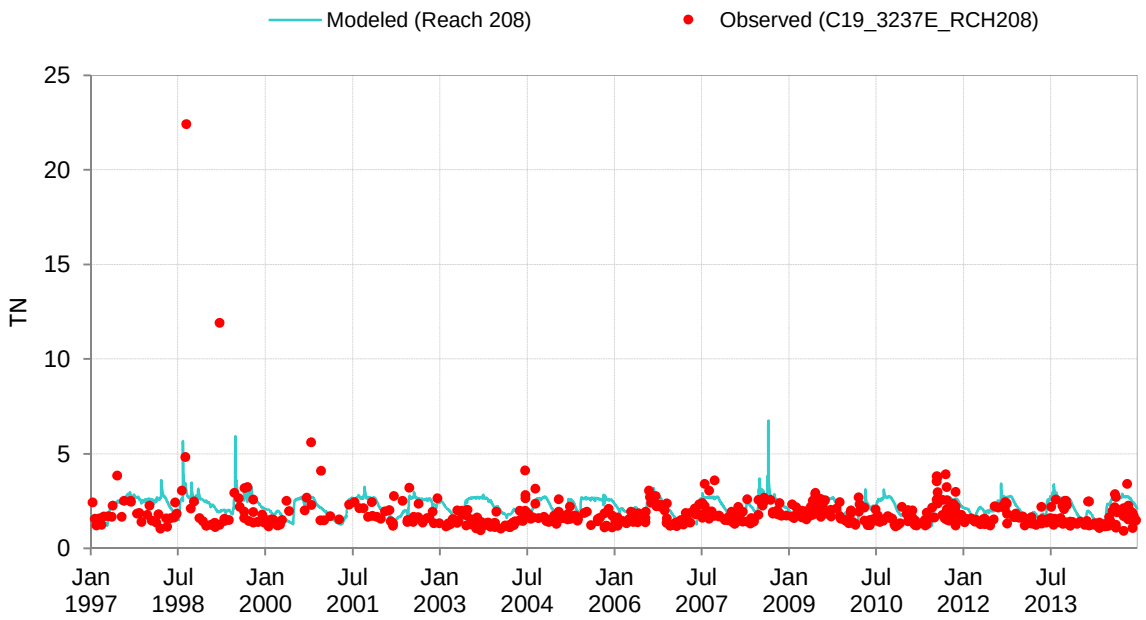

Figure 5: Revised TN Calibration for RCH208 Compared to All Measured Data

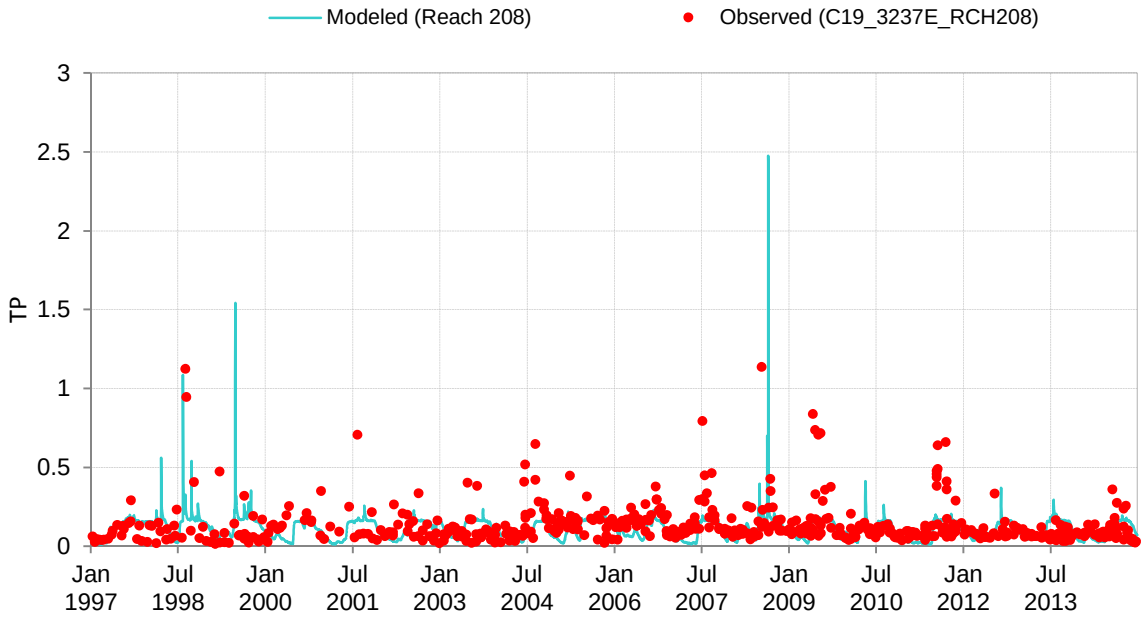

Figure 6: Original TP Calibration for RCH208 Compared to All Measured Data

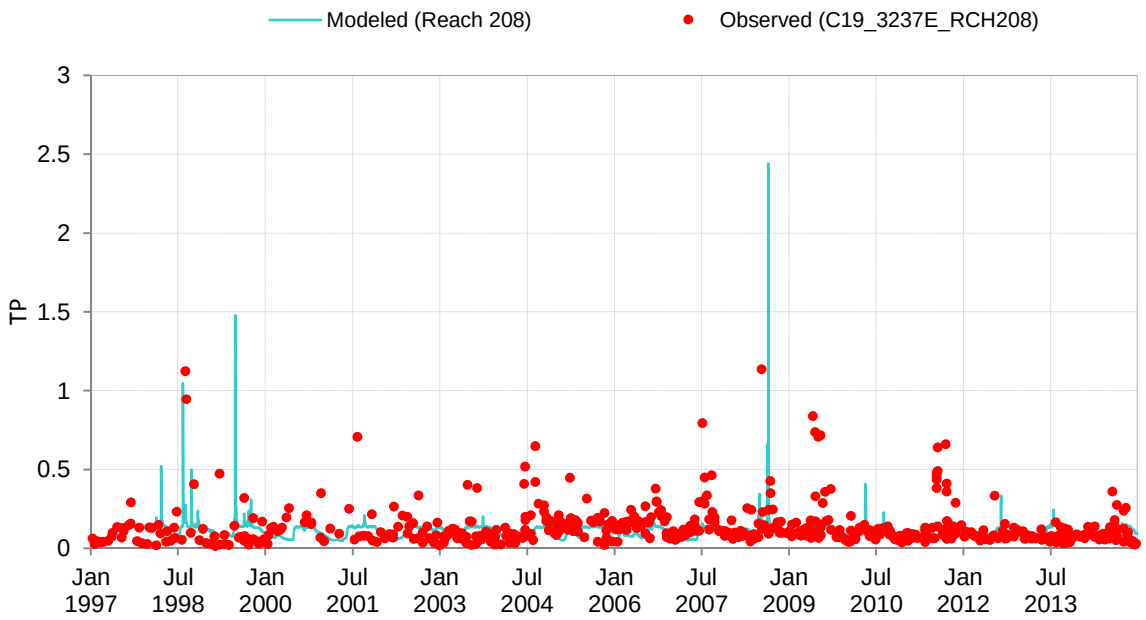

Figure 7: Revised TP Calibration for RCH208 Compared to All Measured Data

2.2 NINEMILE CANAL (WBID 3237D)

The Ninemile Canal WBID contains three HSPF model RCHRES (211, 212, and 213). RCHRES 213 originates in the S-4 Basin and flows through the Ninemile Canal Basin. The WBID is currently impaired for DO and macrophytes. In the 2017 HSPF Model, none of the RCHRES assigned to the Ninemile Canal WBID were used for calibration or validation. Tetra Tech used RCHRES 214 (Ninemile Canal), which is located along the S-4/Ninemile Canal WIBID boundary, and compared it with measured data from station 21FLFTM 28020139, which is assigned to the Ninemile Canal WBID in the IWR database. DEP's assignments of RCHRES to WBIDS has RCHRES 214 assigned to the S-4 Basin.

In the 2017 HSPF Model, RCHRES 212 and 213 used a weir type function-table (F-TABLE) with the LKFG parameter turned on and RCHRES 211 used a non-weir type F-Table with the LKFG parameter turned off. Compared to the measured DO data, RCHRES 211 (no weir) (**Figure 8** and **Table 3**) had a poor simulation while RCHRES 212 (weir) had a more reasonable simulation, but still overestimated the measured DO concentrations. To improve the Ninemile Canal WBID DO calibration in the Upper Watershed Model, a weir F-TABLE was added to RCHRES 211 to better represent the ponding that occurred in the reach. In addition, the LKFG parameter was turned off for all three RCHRES to change the reaeration calculations from lake/wind reaeration to stream reaeration. **Figure 9** shows the Upper Watershed Model refined DO calibration time series for RCHRES 211 compared to all data collected in the WBID. Supplying a weir and turning off the LKFG parameter resulted in less reaeration, an increased response to benthic oxygen demand, and therefore better model performance when compared to all data collected in the WBID. DO statistics improved from Poor to Good and Very Good (**Table 4**).

For TN and TP, all three RCHRES showed a reasonable fit between their simulation and the TN and TP monitoring data in the WBID in the 2017 HSPF Model. RCHRES 211 was used as the representative reach for the TN and TP simulation for the WBID. When comparing RCHRES 211 model results to all available measured data from the Ninemile Canal WBID, there was a reasonable fit for TN (**Figure 10** and **Table 3**) and a reasonable fit for TP (**Figure 12** and **Table 3**). The S-4 Basin/Industrial Canal routing influences RCHRES 213 and 211, and when comparing their TN and TP simulation to all available WBID monitoring data, it appeared that these RCHRES may have been experiencing dilution due to that routing. To improve the Ninemile Canal WBID TN and TP calibration in the Upper Watershed Model, Tetra Tech investigated the cause of the simulated trend of high and low nutrient concentrations and determined that the S-4 Basin/Industrial Canal routing was not diluting the nutrient concentrations, but that the issue was caused by too much organic matter settling within the reaches. Specific parameter modifications focused on reducing organic matter, NOx, and NH_4 concentrations in interflow and groundwater, and reducing the instream organic matter settling rate. **Figure 11** shows the Upper Watershed Model refined TN calibration for RCHRES 211 compared to all data collected in the WBID. Reducing organic matter, NOx, and NH_4 concentrations in interflow and groundwater and reducing the instream organic matter settling rate brought the simulation more in range with the observed data. **Figure 13** shows the Upper Watershed Model refined TP calibration for RCHRES 211 compared to all data collected in the WBID. TN statistics were Very Good in both the 2017 HSPF Model and Upper Watershed Model, but in the Upper Watershed Model the percent error was reduced by approximately 5% and the visual calibration was improved. However, due to the changes in the organic matter parameterization and simulation, the TP percent error increased, but the statistics were still rated Very Good (**Table 4**).

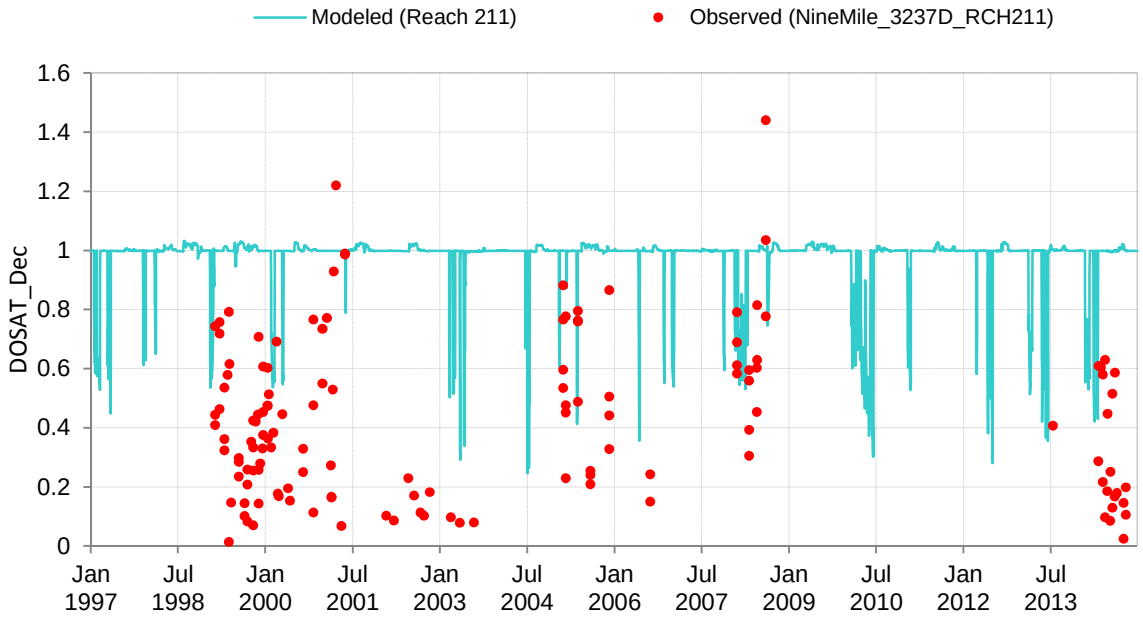

Figure 8: Original DOSAT Calibration for RCH211 Compared to All Measured Data

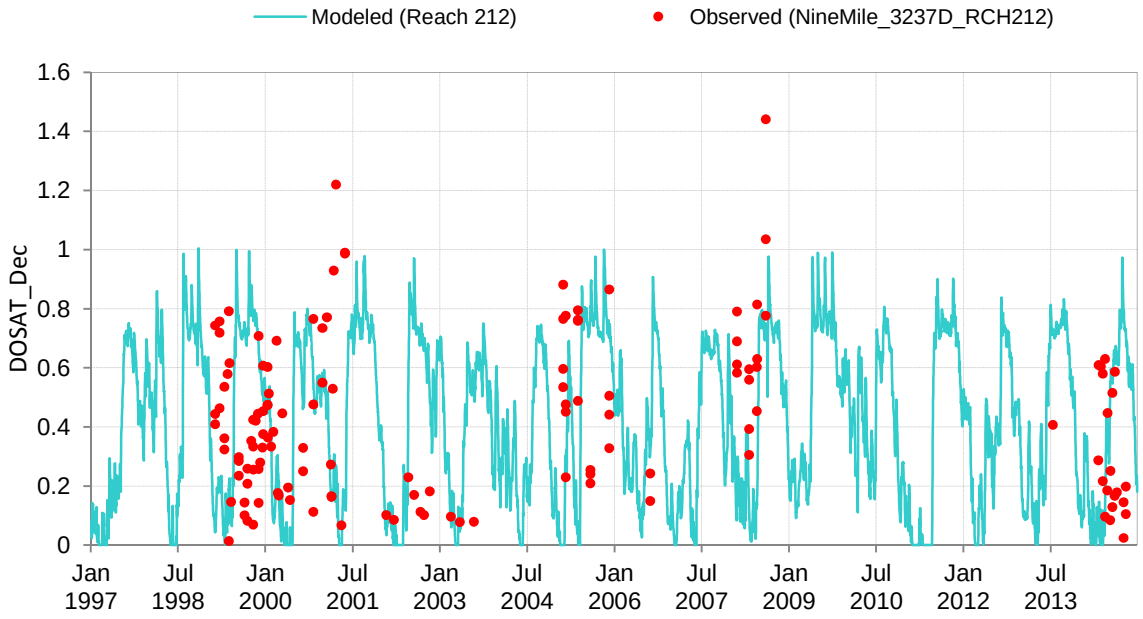

Figure 9: Revised DOSAT Calibration for RCH211 Compared to All Measured Data

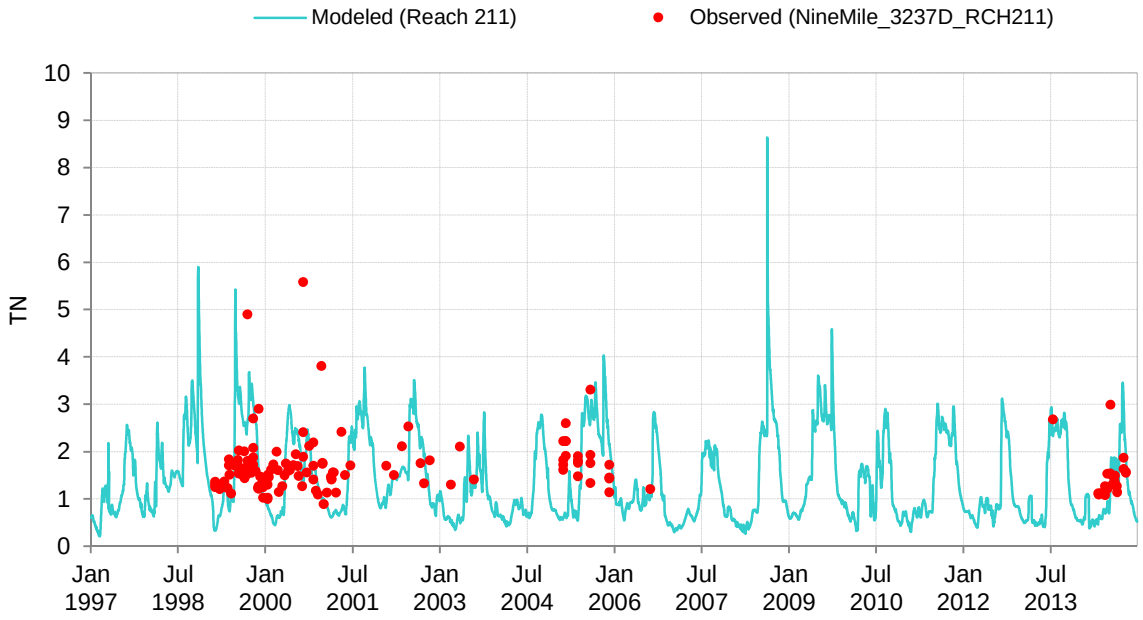

Figure 10: Original TN Calibration for RCH211 Compared to All Measured Data

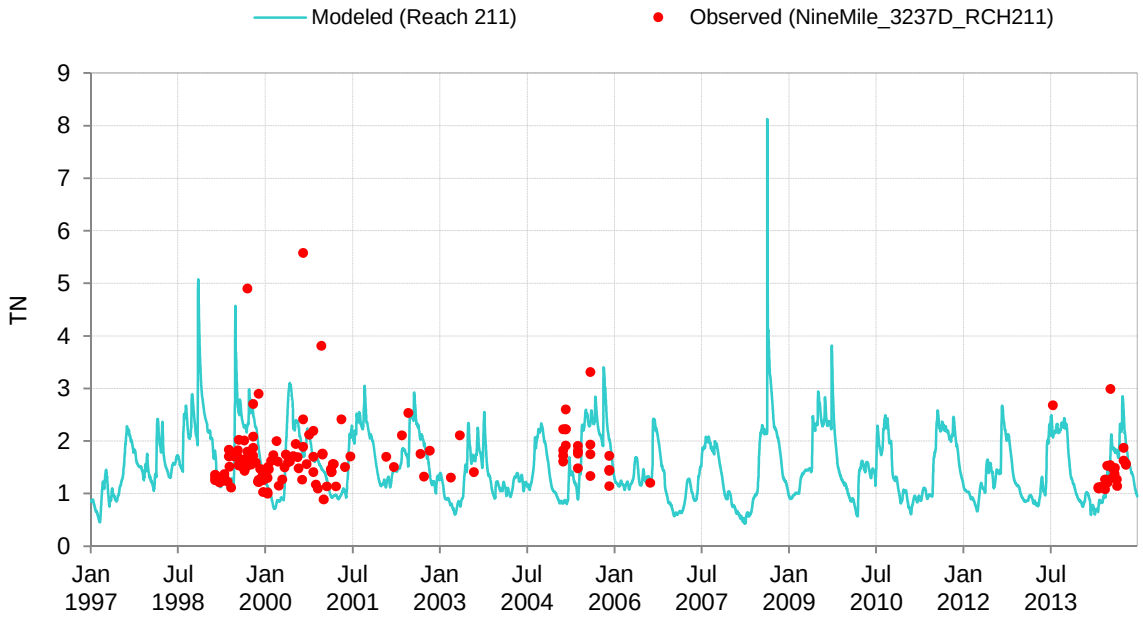

Figure 11: Revised TN Calibration for RCH211 Compared to All Measured Data

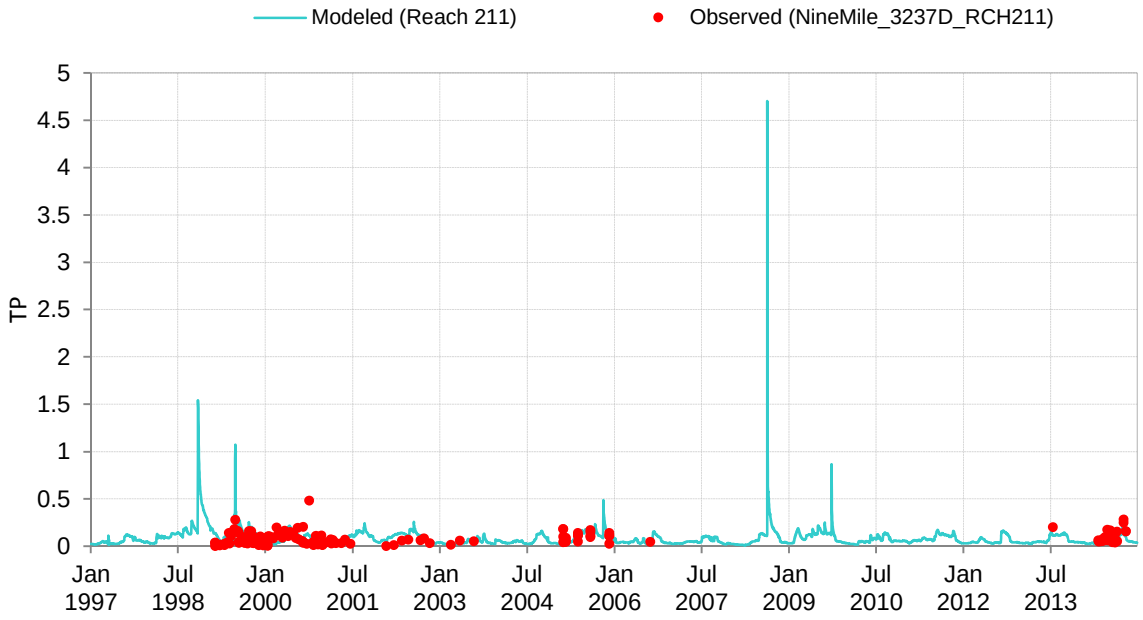

Figure 12: Original TP Calibration for RCH211 Compared to All Measured Data

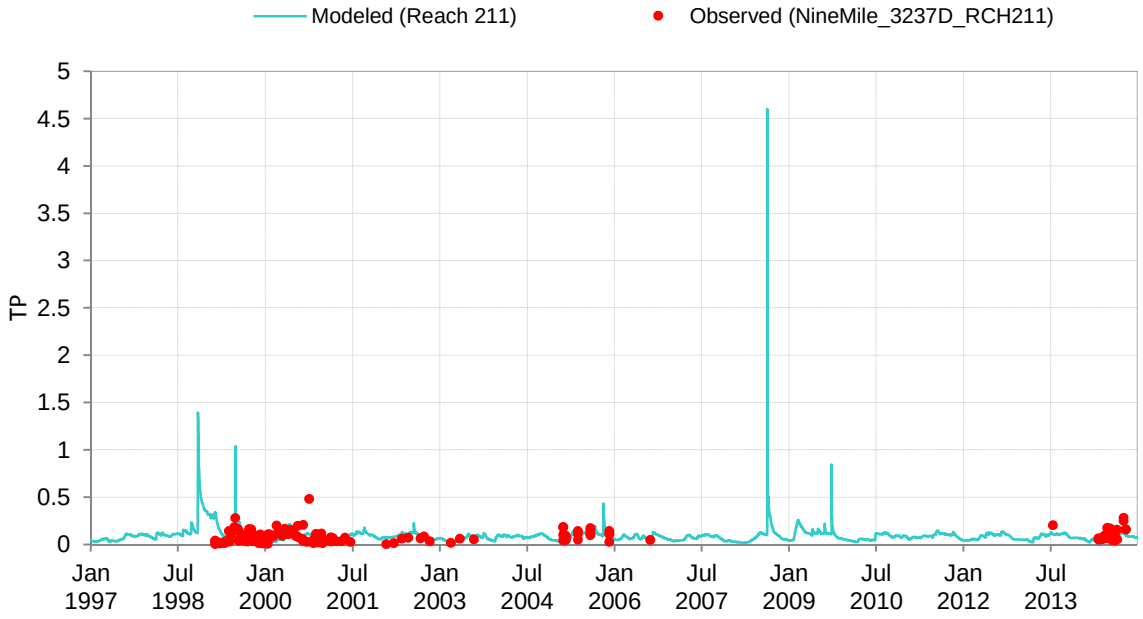

Figure 13: Revised TP Calibration for RCH211 Compared to All Measured Data

Table 3: 2017 HSPF Model Summary of Annual Concentration Comparisons for DOSAT, TN, and TP for RCH211

Parameter	Average Annual % Error	Average Annual % Error Rating	Median Annual % Error	Median Annual % Error Rating
DOSAT	158.7%	Poor	150.3%	Poor
TN	-19.4%	Very Good	-15.9%	Very Good
TP	-2.6%	Very Good	10.1%	Very Good

Table 4: Upper Watershed Model Revised Summary of Annual Concentration Comparisons for DOSAT, TN, and TP for RCH211

Parameter	Average Annual % Error	Average Annual % Error Rating	Median Annual % Error	Median Annual % Error Rating
DOSAT	38.7%	Good	28.2%	Very Good
TN	-11.3%	Very Good	-10.4%	Very Good
TP	10.5%	Very Good	26.4%	Very Good

2.3 S-4 BASIN (WBID 3246)

The S-4 Basin WBID contains seven HSPF model RCHRES (214, 216, 217, 218, 219, 220, and 999). RCHRES 217 is located within the S-4 Basin; however, this RCHRES is not included by DEP in the model impairment assessments. The WBID is currently impaired for DO, TN, chlorophyll-a, and macrophytes. In the 2017 HSPF Model, RCHRES 216 was used as the calibration location and was compared to measured data from station 21FLFTM 28020254FTM. RCHRES 219 was used as a validation location and was compared to measure data from station 21FLSFWMINDUSCAN.

In the 2017 HSPF Model, all RCHRES in the S-4 Basin used a weir type F-TABLE with the LKFG parameter turned on. For DO and DOSAT (Figures B-291 through B-294 in Tetra Tech 2017), the calibration showed a poor fit and the simulation trended high compared to measured data. When comparing RCHRES 216 to all data collected within the WBID, the simulated response showed a better fit and the simulation trended low (**Figure 14** and **Table 5**). The DO monitoring data from station 21FLFTM 28020254FTM do not appear to be representative of all of the monitoring data from the S-4 Basin WBID. To improve the S-4 Basin WBID DO calibration in the Upper Watershed Model, the LKFG parameter was turned off and benthic oxygen demand (BENOD) was recalibrated to provide improved model fit. **Figure 15** and **Table 6** show the Upper Watershed Model refined DO calibration for RCHRES 216 compared to all data collected in the WBID. Turning off the LKFG parameter and recalibrating BENOD improved model performance when compared to all data collected in the WBID. DO statistics were Very Good for both models, but the Upper Watershed Model had a reduction in percent error and the visual calibration was slightly improved (**Table 6**).

For TN and TP (Figures B-285 through B-288 in Tetra Tech 2017), the 2017 HSPF Model calibration had a poor fit and was simulated low compared to the measured data for TN, but showed a good fit for TP. When comparing RCHRES 216 to all data from the S-4 Basin WBID, it also showed the simulation was low for TN (**Figure 16** and **Table 5**) but a good fit for TP (**Figure 18** and **Table 5**). To improve the S-4 Basin WBID TN and TP calibration in the Upper Watershed Model, Tetra Tech determined that the peaks in the modeled TN were caused by organic matter concentrations in the groundwater, but that the overall low concentrations were controlled by the instream organic matter settling rate. Additionally, the S-4 Basin/Industrial Canal routing was not routed to RCHRES 217, contributing to the model underestimation. Specific parameter modifications focused on reducing organic matter, NOx, and NH_4 concentrations in interflow and groundwater, reducing the instream organic matter settling rate, and revising the S-4 Basin/Industrial Canal routing so that some of the water is released into RCHRES 217, which greatly improved the model representation of RCHRES 217. **Figure 17** shows the Upper Watershed Model refined TN calibration for RCHRES 216 compared to all data collected in the WBID. Reducing organic matter, NOx, and NH_4 concentrations in interflow and groundwater, and reducing the instream organic matter settling rate brought the simulation more in range with the observed data. **Figure 19** shows the Upper Watershed Model refined TP calibration for RCHRES 216 compared to all data collected in the WBID. TN statistics were improved from Fair to Very Good, and TP statistics remained in the Good to Very Good range (**Table 6**).

During the detailed assessment of all RCHRES in the S-4 Basin WBID, Tetra Tech identified some occurrences of numerical instability in RCHRES 999 and 218. This numerical instability occurred on days when the RCHRES became dry. When a RCHRES goes dry, the HSPF model turns off the nutrient, DO, and sediment simulations and publishes a value of -1.0E+30 in the output for the associated constituents,

and the statistical summaries become biased due to the low values. Statistics were therefore not reported for the 2017 HSPF Model in **Table 10**, **Table 11**, and **Table 12**. To fix these instabilities, additional surface area and volume were added to the F-TABLES to allow the RCHRES to store additional water. RCHRES 218 had numerical instability a total of 70 days during the 6,573 days simulation period, and RCHRES 999 had numerical instability a total of 12 days during the simulation period.

Table 5: 2017 HSPF Model Summary of Annual Concentration Comparisons for DOSAT, TN, and TP for RCH216

Parameter	Average Annual % Error	Average Annual % Error Rating	Median Annual % Error	Median Annual % Error Rating
DOSAT	-28.7%	Very Good	-27.1%	Very Good
TN	-49.8%	Fair	-51.1%	Fair
TP	7.8%	Very Good	-45.0%	Good

Table 6: Upper Watershed Model Revised Summary of Annual Concentration Comparisons for DOSAT, TN, and TP for RCH216

Parameter	Average Annual % Error	Average Annual % Error Rating	Median Annual % Error	Median Annual % Error Rating
DOSAT	-8.4%	Very Good	-7.2%	Very Good
TN	-24.5%	Very Good	-29.1%	Very Good
TP	-19.1%	Very Good	-32.7%	Good

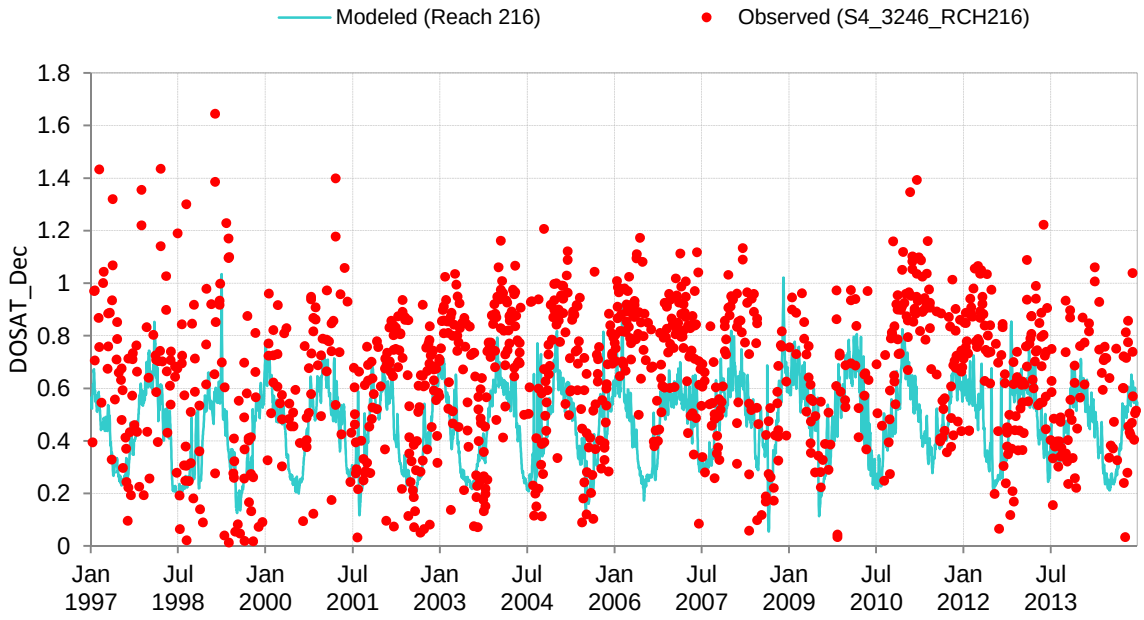

Figure 14: Original DOSAT Calibration for RCH216 Compared to All Measured Data

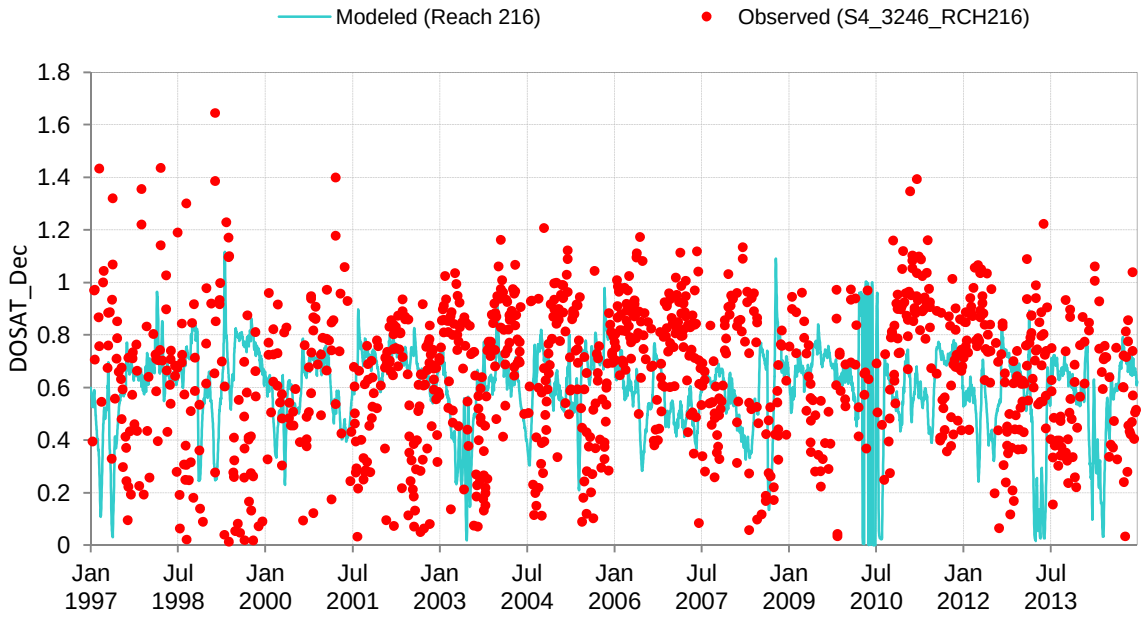

Figure 15: Revised DOSAT Calibration for RCH216 Compared to All Measured Data

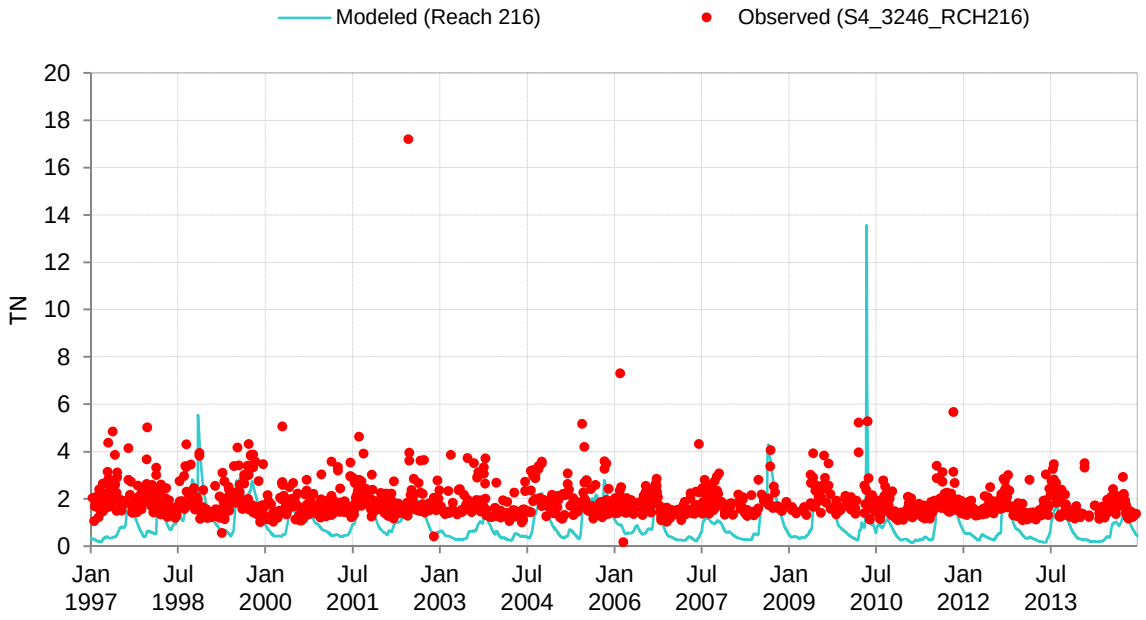

Figure 16: Original TN Calibration for RCH216 Compared to All Measured Data

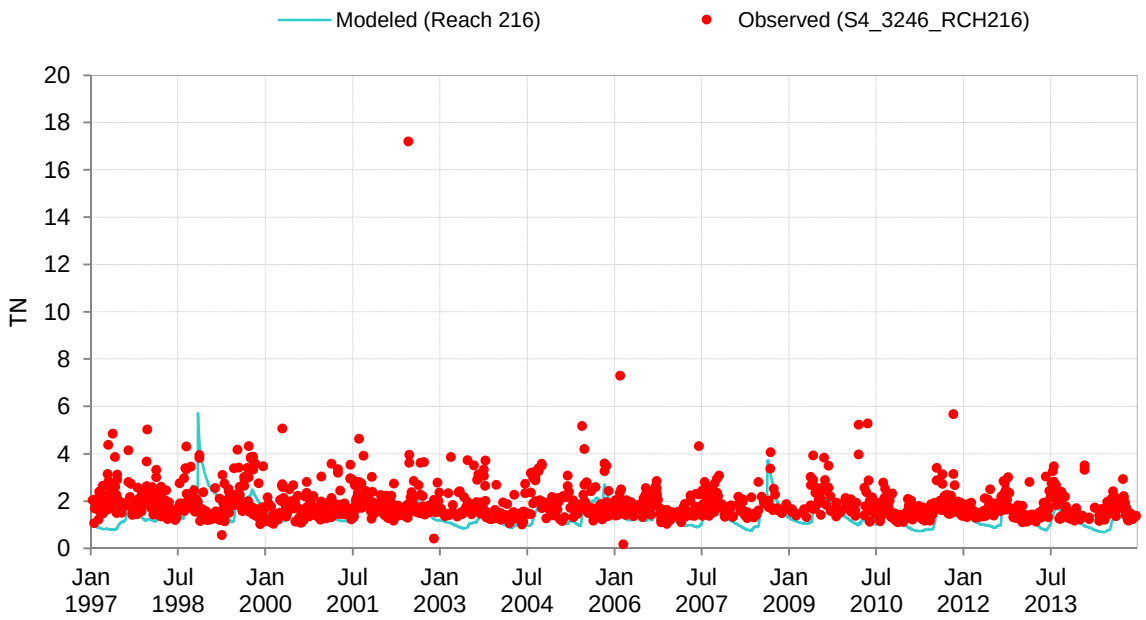

Figure 17: Revised TN Calibration for RCH216 Compared to All Measured Data

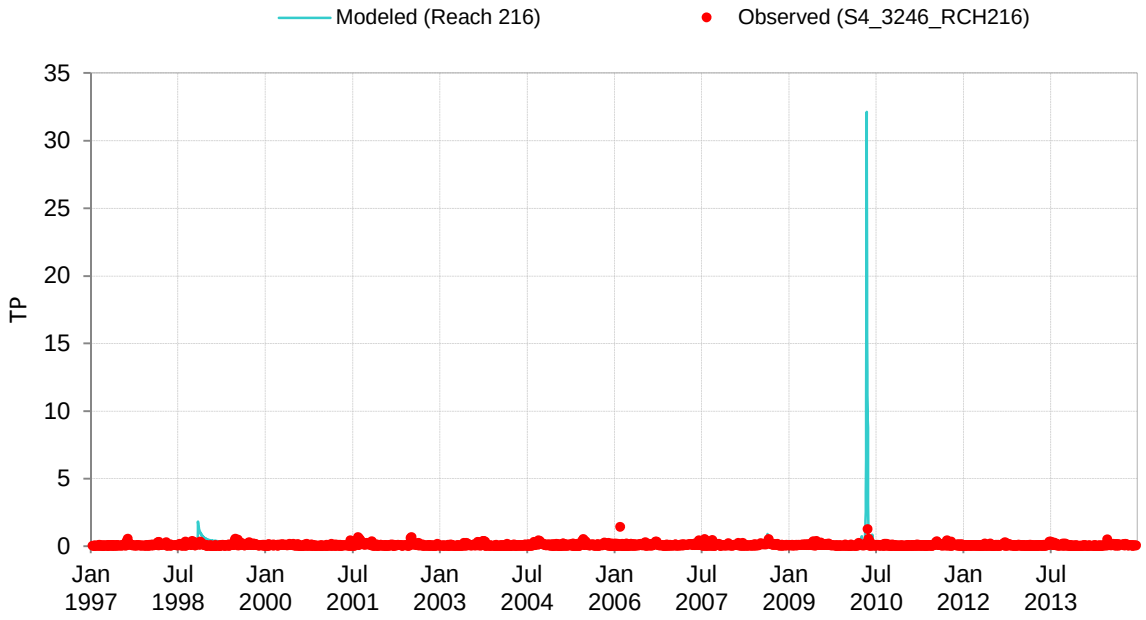

Figure 18: Original TP Calibration for RCH216 Compared to All Measured Data

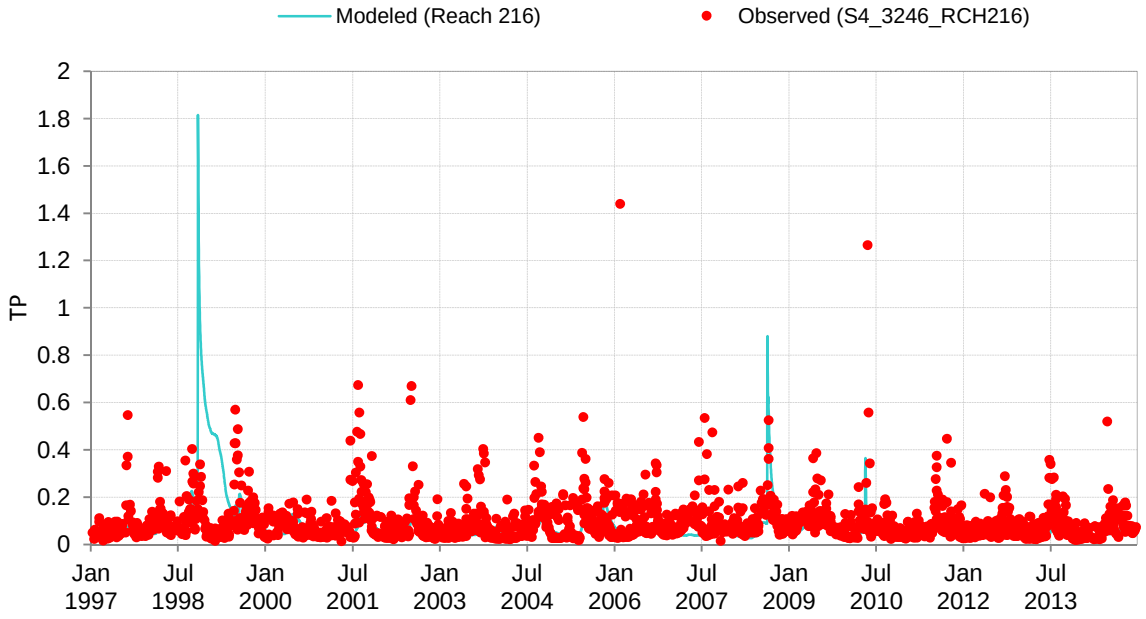

Figure 19: Revised TP Calibration for RCH216 Compared to All Measured Data

2.4 LAKE HICPOCHEE (WBID 3237C)

The Lake Hicpochee WBID contains eight HSPF model RCHRES (206, 207, 215, 990, 991, 992, 993, and 994). RCHRES 215 originates below S-77 and is the headwaters of the Caloosahatchee River. Many of the water quality sampling stations within RCHRES 215 are within the C-19 Canal WBID; however, RCHRES 215 is predominately located within the Lake Hicpochee WBID. The WBID is currently impaired for DO. In the 2017 HSPF Model, RCHRES 991 was used as a calibration location and was compared to measured data from station 21FLFTM 28020269FTM. RCHRES 207 (compared to observed data from station 21FLFTM 28020246FTM), RCHRES 215 (compared to observed data from stations 21FLFTM 28020247FTM, 21FLFTM RECON-MH2-FTM, 21FLFTM RECON-MH-FTM, 21FLSFWMMHASRDIS, 21FLSFWMS77, and 21FLSFWMS77-SW), and RCHRES 990 (compared to observed data from station 21FLFTM 28020248FTM) were used for model validation.

RCHRES 991 is located in the middle of the Lake Hicpochee WBID in the main stem of the Caloosahatchee River. For DO and DOSAT (Figures B-315 through B-318 in Tetra Tech 2017), the calibration appeared reasonable. When comparing RCHRES 991 to all data collected within the WBID, the simulated response also produced a very good fit (**Figure 20** and **Table 7**). The DO monitoring data from station 21FLFTM 28020269FTM appear to be representative of all of the monitoring data from the Lake Hicpochee WBID. Unlike the C-19 Canal and Ninemile Canal WBIDs, not all RCHRES within the Lake Hicpochee WBID had similar simulated responses. This was due to some RCHRES having weir type F-TABLES and the LKFG parameter active (RCHRES 991 **Figure 20**), while other RCHRES did not have weir type F-TABLES and the LKFG parameter inactive (RCHRES 992 **Figure 22**). To improve the Lake Hicpochee WBID DO calibration, the model modifications focused on bringing synergy between the model setup for all RCHRES in the Lake Hicpochee WBID. The specific modifications included providing weir type F-TABLES for all RCHRES that did not already have one in the model (i.e. 206, 215, 990, 992, and 994) and turning the LKFG parameter on for all RCHRES in the WBID. The LKFG parameters was used for these reaches because they were located in the lake or may be experience water ponding within the reaches when the lake level is high. **Figure 21** shows the Upper Watershed Model refined DO calibration time series for RCHRES 991 compared to all data collected in the WBID and **Figure 23** shows the Upper Watershed Model refined DO calibration time series for RCHRES 992 compared to all data collected in the WBID. RCHRES 991 (**Table 8**) shows little change to the setup and parameter modifications, but RCHRES 992 shows meaningful improvement to the DO simulation.

For TN and TP (Figures B-309 through B-312 in Tetra Tech 2017), the 2017 HSPF Model calibration had a very good fit for TN but over simulated TP. When comparing RCHRES 991 to all data from the Lake Hicpochee WBID, it also showed a good fit for TN (**Figure 24** and **Table 7**) and an over simulation of TP (**Figure 26** and **Table 7**). Similar to DO, not all RCHRES within the WBID had similar simulated responses. This is due the fact that the WBID includes some RCHRES representing the main stem Caloosahatchee River, which is dominated by the Lake Okeechobee boundary, and some RCHRES representing small tributary streams, which are controlled by the upstream WBIDs that are contributing to them. To improve the Lake Hicpochee WBID TN and TP calibration, the model modifications focused on improving the model fit of TN and TP in the upstream WBIDs as previously discussed in **Section 2.1** for the C-19 Canal WBID, **Section 2.2** for the Ninemile Canal WBID, and **Section 2.3** for the S-4 Basin WBID. The Lake Okeechobee boundary was created with observed data and was not adjusted for the recalibration effort. **Figure 25** shows the Upper Watershed Model refined TN calibration time series for

RCHRES 991 compared to all data collected in the WBID, and **Figure 27** shows the Upper Watershed Model refined TP calibration time series for RCHRES 991 compared to all data collected in the WBID. RCHRES 991 (**Table 8**) shows little change to the setup and parameter modifications for TN and TP because the simulation is controlled by the unmodified Lake Okeechobee boundary time series.

During the detailed assessment of all RCHRES in the Lake Hicpochee WBID, Tetra Tech identified some occurrences of numerical instability in RCHRES 994, 993, and 990. This numerical instability occurred on days when the RCHRES became dry. When a RCHRES goes dry, the HSPF model turns off the nutrient, DO, and sediment simulations and publishes a value of -1.0E+30 in the output for the associated constituents, and the statistical summaries become biased due to the low values. Statistics were therefore not reported for the 2017 HSPF Model in **Table 10**, **Table 11**, and **Table 12**. To fix these instabilities, additional surface area and volume were added to the F-TABLES to allow the RCHRES to store additional water.

Table 7: 2017 HSPF Model Summary of Annual Concentration Comparisons for DOSAT, TN, and TP for RCH991

Parameter	Average Annual % Error	Average Annual % Error Rating	Median Annual % Error	Median Annual % Error Rating
DOSAT	6.8%	Very Good	9.1%	Very Good
TN	-5.0%	Very Good	2.6%	Very Good
TP	91.0%	Poor	164.7%	Poor

Table 8: Upper Watershed Model Revised Summary of Annual Concentration Comparisons for DOSAT, TN, and TP for RCH991

Parameter	Average Annual % Error	Average Annual % Error Rating	Median Annual % Error	Median Annual % Error Rating
DOSAT	-8.0%	Very Good	-1.5%	Very Good
TN	-2.0%	Very Good	6.7%	Very Good
TP	87.5%	Poor	162.5%	Poor

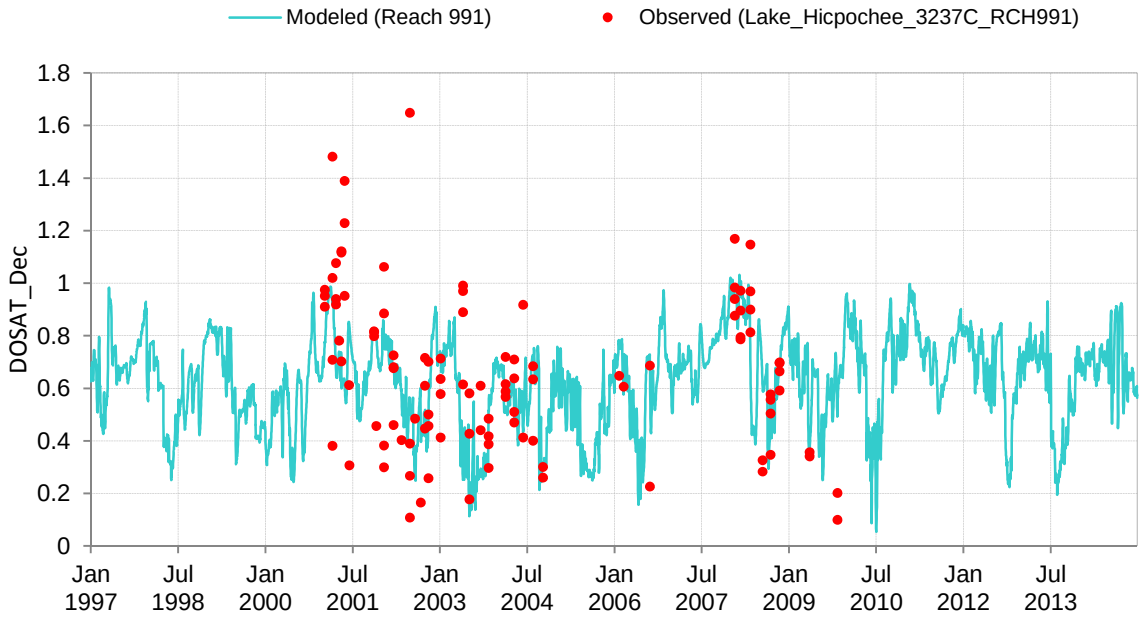

Figure 20: Original DOSAT Calibration for RCH991 Compared to All Measured Data

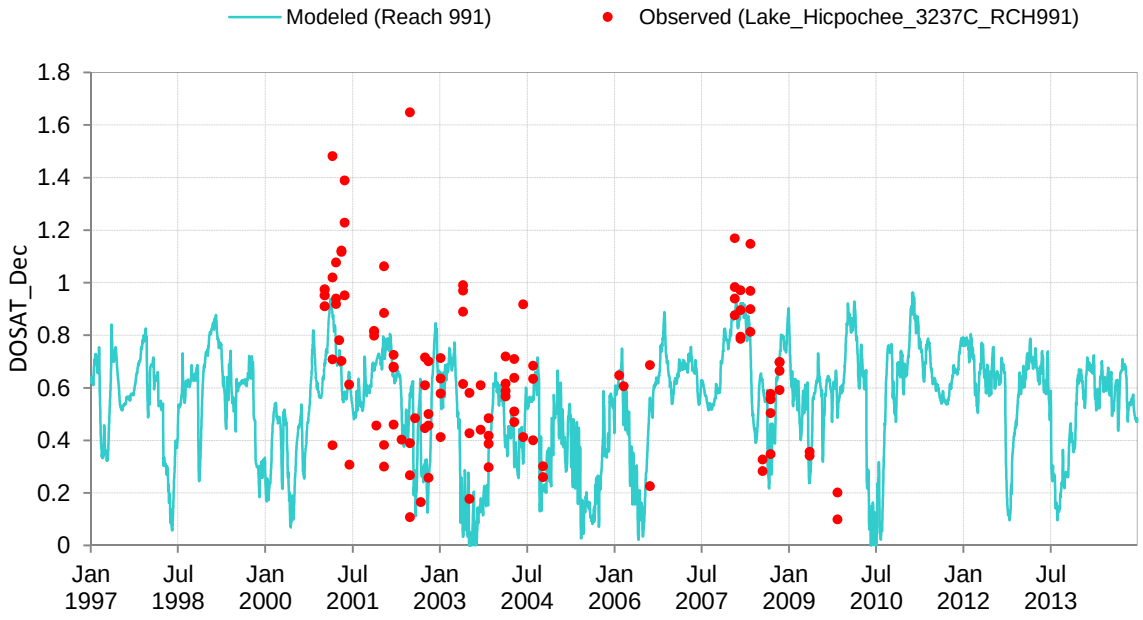

Figure 21: Revised DOSAT Calibration for RCH991 Compared to All Measured Data

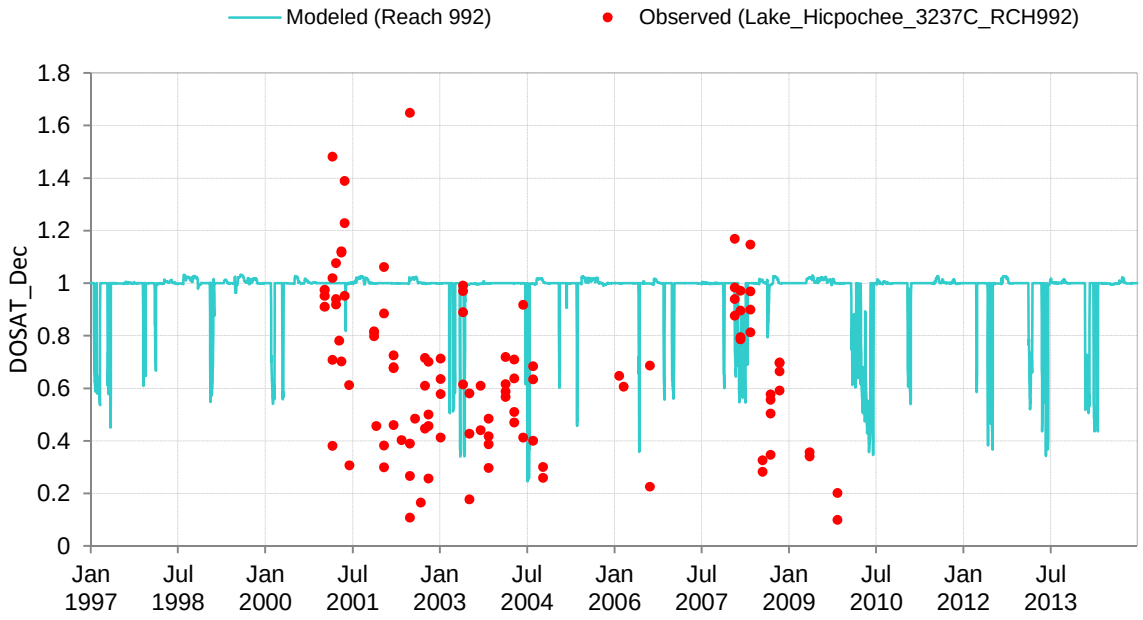

Figure 22: Original DOSAT Calibration for RCH992 Compared to All Measured Data

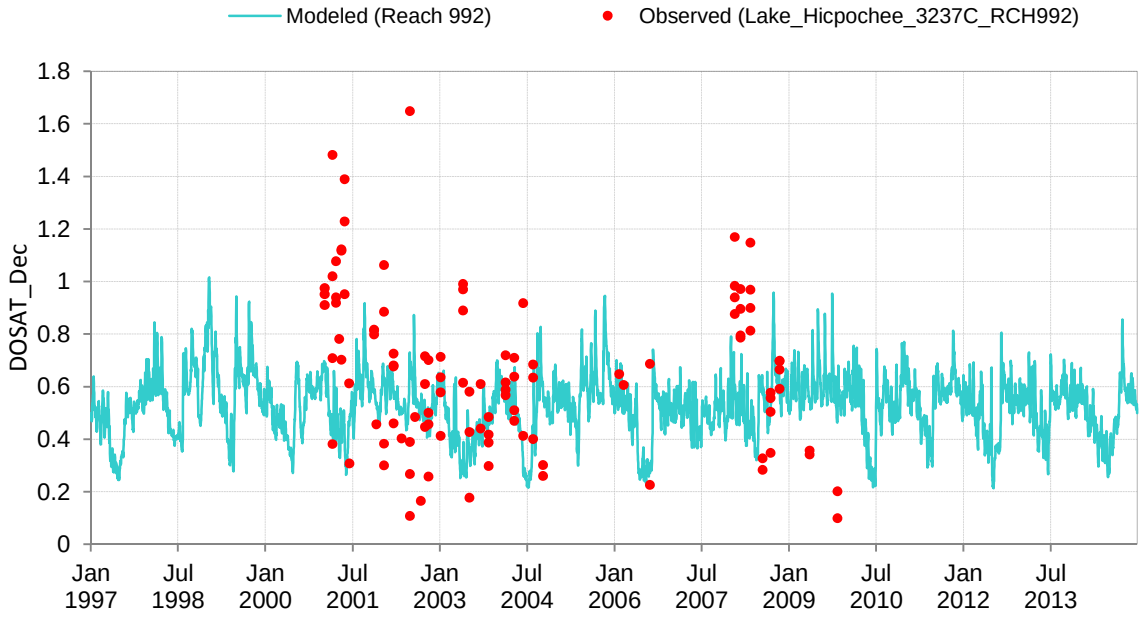

Figure 23: Revised DOSAT Calibration for RCH992 Compared to All Measured Data

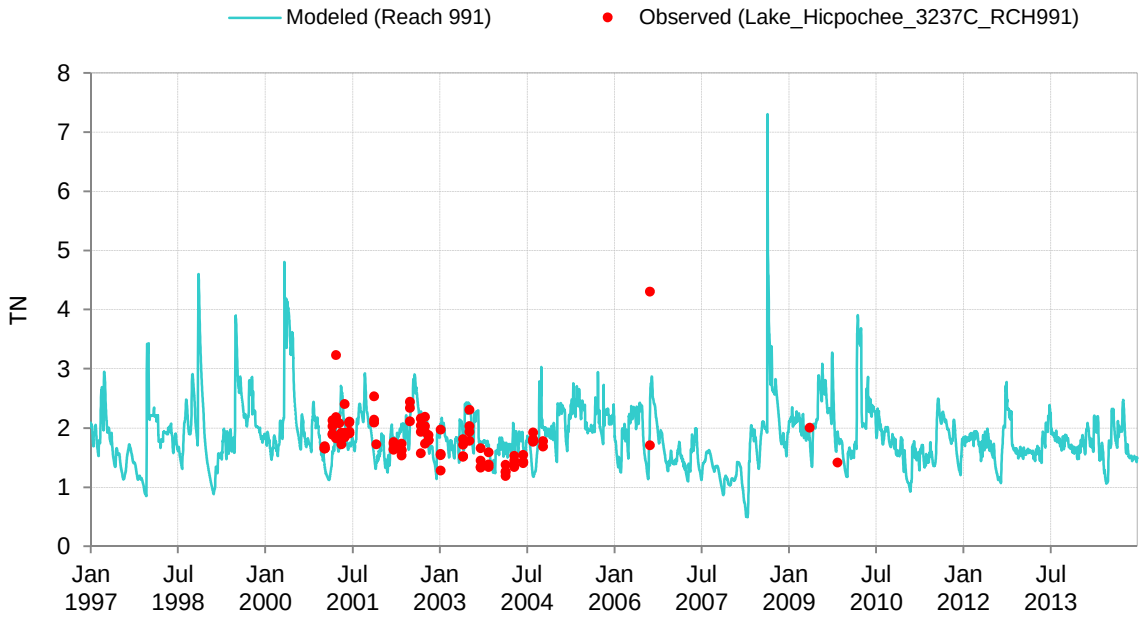

Figure 24: Original TN Calibration for RCH991 Compared to All Measured Data

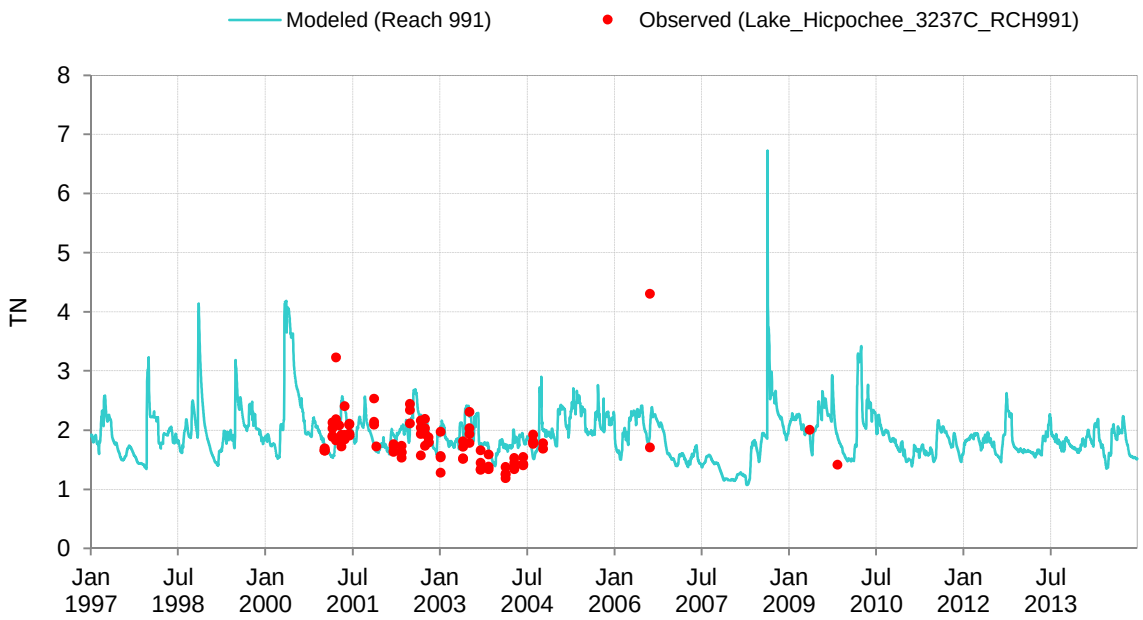

Figure 25: Revised TN Calibration for RCH991 Compared to All Measured Data

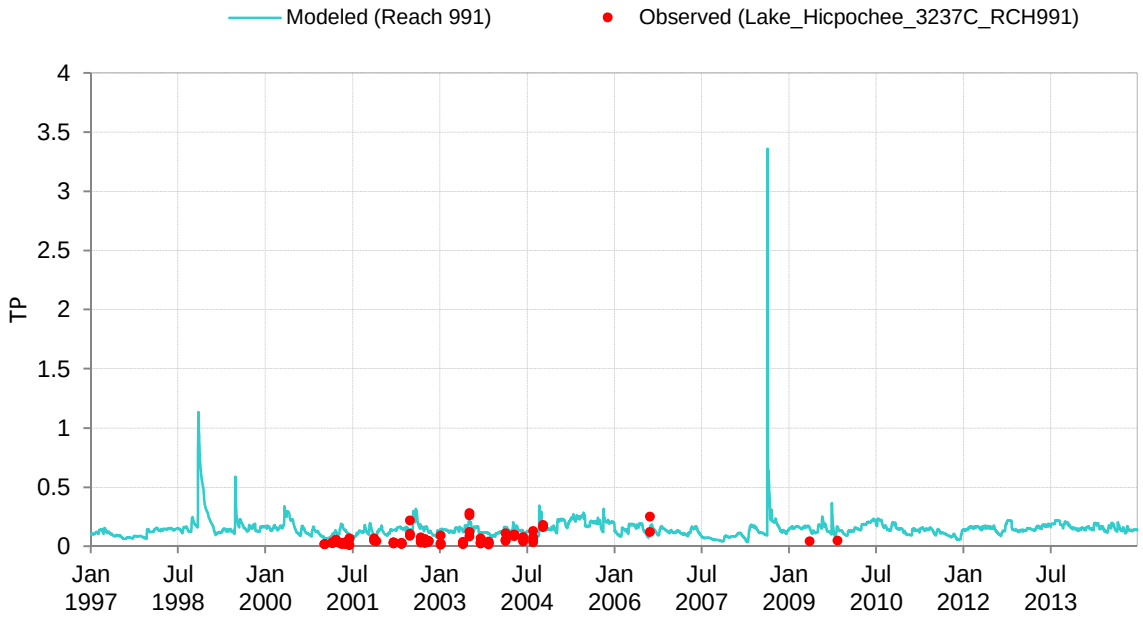

Figure 26: Original TP Calibration for RCH991 Compared to All Measured Data

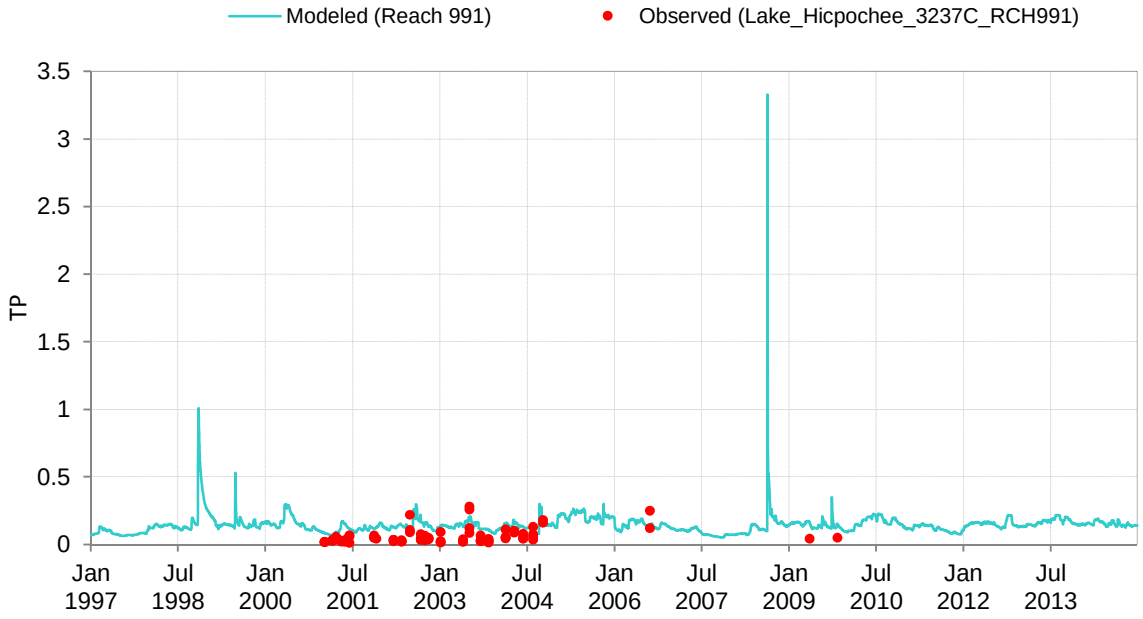

Figure 27: Revised TP Calibration for RCH991 Compared to All Measured Data

3.0 SUMMARY OF MODEL MODIFICATIONS

The following sections contain a bulleted summary of the steps that were taken by Tetra Tech to refine the Upper Watershed Model calibration, and a bulleted summary of the results of the model updates.

3.1 MODEL AND PARAMETER MODIFICATIONS

- The Lake Hicpochee, C-19, Ninemile, and S-4 Basin WBIDs were subset from the 2017 HSPF Model. Before any modifications were made, Tetra Tech confirmed that the subset model produced results identical to the 2017 HSPF Model for this area. The subset model included:
  - RCHRES 205 through 220, 888, 990, 991, 992, 993, 994, and 999.
  - Hydrologic response units (HRUs) 261 through 316.
  - Updated PLTGENS to provide output for each RCHRES.
- Created new workbooks to compare simulated and observed data for subset model.
  - All RCHRES were assigned to a WBID based on DEP assignments.
  - All monitoring data within a WBID were compiled into a single dataset.
  - All RCHRES within a WBID were compared to the same observed dataset.
- Revised Industrial Canal to interior S-4 Basin routing.
  - RCHRES 219 previously routed to RCHRES 220 and RCHRES 213. Revised RCHRES 219 routed to RCHRES 220 and RCHRES 217.
- Revised interflow and groundwater monthly DO concentrations.
  - Calculated DOSAT based on the monthly average temperature at La Belle, Florida and assumed interflow was 75% of the saturated value and groundwater was 50% of the saturated value.
  - LaBelle, Florida was selected because it is located near the center of the Caloosahatchee River Watershed and is representative of the entire model domain area. The parameter modifications made in the Upper Watershed Model could therefore be adopted for the whole watershed if additional model refinements are mode in the future.
- Revised interflow and groundwater NOx, NH_4, organic matter, and orthophosphate concentrations.
  - An informal sensitivity analysis indicated that interflow and groundwater nutrient concentrations caused the simulation to be higher than observed instream measurements for TN and TP. Reducing these concentrations allowed for the simulation to provide a better fit to the observed data.
- Revised LKFG so that only RCHRES assigned to the Lake Hicpochee WBID were simulated as lakes (**Table 9**).

Table 9: Upper Watershed Model Modifications

RCHRES	Original Lake Flag	Revised Lake Flag
205	1	1
206	0	1
207	1	1

RCHRES	Original Lake Flag	Revised Lake Flag
208	1	0
209	1	0
210	1	0
211	0	0
212	1	0
213	1	0
214	1	0
215	0	1
216	1	0
217	1	0
218	1	0
219	1	0
220	1	0
888	0	0
990	0	1
991	1	1
992	0	1
993	1	1
994	0	1
999	1	0

- Modified the following F-TABLES
  - RCHRES 206 – incorporated a weir to improve DO simulation.
  - RCHRES 211 – incorporated a weir to improve DO simulation.
  - RCHRES 215 – incorporated a weir to improve DO simulation.
  - RCHRES 218 – added area and volume to remove numerical instability.
  - RCHRES 990 – incorporated a weir to improve DO simulation (the weir also removed numerical instability).
  - RCHRES 992 – incorporated a weir to improve DO simulation.
  - RCHRES 993 – added area and volume to remove numerical instability.
  - RCHRES 994 – incorporated a weir to improve DO simulation (the weir also removed numerical instability).
  - RCHRES 999 – added area and volume to remove numerical instability.
- Modified silt and clay critical shear stress for scour (TAUCS) and critical shear stress for deposition (TAUCD) based on revised simulation of critical shear stress (TAU) due to modified F-TABLES. These modifications ensure the sediment simulation remained similar to the 2017 HSPF Model.
- Reduced settling rate of refractory organic matter (REFSET) for all RCHRES.
- Reduced settling rate of biochemical oxygen demand (KODSET) for all RCHRES.
- Reduced decay rate of biochemical oxygen demand (KBOD20) for all RCHRES.
- Modified benthic oxygen demand (BENOD) in the S-4 Basin.
- Reduced nitrification rate of NH_4 (KTAM20) and nitrification rate of nitrite (KNO220) for all RCHRES.
- Increased the non-refractory fraction of algae biomass (NONREF) for all RCHRES.

3.2 MODEL RESPONSE TO MODIFICATIONS

Table 10: 2017 HSPF Model and Upper Watershed Model Summary of Annual Concentration Comparisons for DOSAT for All RCHRES for All Data within a WBID

WBID	RCHRES	2017 HSPF Model Average Annual % Error	2017 HSPF Model Median Annual % Error	Upper Watershed Model Average Annual % Error	Upper Watershed Model Median Annual % Error
C-19	210	55.5%	59.0%	16.2%	19.5%
C-19	209	44.8%	48.8%	18.0%	19.0%
C-19	208	43.9%	47.3%	13.4%	13.2%
Ninemile	213	39.3%	35.3%	12.8%	5.9%
Ninemile	212	48.6%	42.9%	12.5%	3.0%
Ninemile	211	158.7%	150.3%	38.7%	28.2%
S-4	999	N/A	N/A	-22.1%	-19.2%
S-4	220	-19.8%	-15.9%	-33.3%	-31.7%
S-4	219	-7.3%	-3.1%	-34.3%	-33.0%
S-4	218	N/A	N/A	-31.9%	-31.3%
S-4	217	-31.2%	-29.5%	-8.9%	-9.6%
S-4	216	-28.7%	-27.1%	-8.4%	7.2%
S-4	214	-21.5%	-17.4%	13.0%	17.2%
Lake H.	994	N/A	N/A	-5.8%	-1.5%
Lake H.	993	N/A	N/A	0.3%	7.6%
Lake H.	992	65.3%	74.8%	-10.0%	-6.0%
Lake H.	991	6.8%	9.1%	-8.0%	-1.5%
Lake H.	990	N/A	N/A	1.0%	6.1%
Lake H.	215	54.2%	63.5%	26.5%	36.6%
Lake H.	207	-7.8%	-4.7%	-10.0%	-5.7%
Lake H.	206	773.8%	89.2%	-12.5%	-8.2%

Table 11: 2017 HSPF Model and Upper Watershed Model Summary of Annual Concentration Comparisons for TN for All RCHRES for All Data within a WBID

WBID	RCHRES	2017 HSPF Model Average Annual % Error	2017 HSPF Model Median Annual % Error	Upper Watershed Model Average Annual % Error	Upper Watershed Model Median Annual % Error
C-19	210	26.6%	27.2%	18.9%	21.5%
C-19	209	18.7%	21.3%	15.7%	18.9%
C-19	208	20.0%	22.3%	17.8%	21.0%
Ninemile	213	-31.2%	-28.1%	-26.1%	-23.5%
Ninemile	212	12.4%	16.4%	1.5%	3.6%
Ninemile	211	-19.4%	-15.9%	-11.3%	-10.4%
S-4	999	N/A	N/A	-26.5%	-24.3%
S-4	220	-26.6%	-27.4%	-4.7%	-4.0%
S-4	219	-21.9%	-25.9%	-8.7%	-13.7%

WBID	RCHRES	2017 HSPF Model Average Annual % Error	2017 HSPF Model Median Annual % Error	Upper Watershed Model Average Annual % Error	Upper Watershed Model Median Annual % Error
S-4	218	N/A	N/A	-29.2%	-35.7%
S-4	217	-70.2%	-74.9%	-17.8%	-21.3%
S-4	216	-49.8%	-51.1%	-24.5%	-29.1%
S-4	214	-40.8%	-41.7%	-28.6%	-31.3%
Lake H.	994	N/A	N/A	-30.9%	-28.2%
Lake H.	993	N/A	N/A	0.2%	7.3%
Lake H.	992	-31.6%	-25.6%	-28.5%	-24.6%
Lake H.	991	-5.0%	2.6%	-2.0%	6.7%
Lake H.	990	N/A	N/A	8.4%	17.4%
Lake H.	215	-7.0%	10.0%	-3.7%	5.0%
Lake H.	207	-9.9%	-5.3%	-5.6%	2.0%
Lake H.	206	46.9%	60.8%	6.4%	14.7%

Table 12: 2017 HSPF Model and Upper Watershed Model Summary of Annual Concentration Comparisons for TN for All RCHRES for All Data within a WBID

WBID	RCHRES	2017 HSPF Model Average Annual % Error	2017 HSPF Model Median Annual % Error	Upper Watershed Model Average Annual % Error	Upper Watershed Model Median Annual % Error
C-19	210	-7.8%	-21.0%	-13.0%	-25.0%
C-19	209	-20.1%	-30.5%	-22.3%	-31.5%
C-19	208	-19.1%	-29.2%	-20.6%	-30.7%
Ninemile	213	4.4%	18.1%	1.9%	13.1%
Ninemile	212	-6.1%	14.1%	-12.3%	7.2%
Ninemile	211	-2.6%	10.1%	10.5%	26.4%
S-4	999	N/A	N/A	5.4%	5.4%
S-4	220	4.8%	7.1%	24.7%	31.8%
S-4	219	41.4%	43.2%	54.1%	54.6%
S-4	218	N/A	N/A	16.0%	3.3%
S-4	217	43.3%	17.2%	31.1%	23.8%
S-4	216	7.8%	-45.0%	-19.1%	-32.7%
S-4	214	-19.2%	-32.0%	-13.1%	-19.3%
Lake H.	994	N/A	N/A	-6.4%	-2.5%
Lake H.	993	N/A	N/A	102.9%	182.8%
Lake H.	992	3.0%	22.7%	4.8%	21.4%
Lake H.	991	91.0%	164.7%	87.5%	162.5%
Lake H.	990	N/A	N/A	25.9%	67.4%
Lake H.	215	96.2%	159.8%	98.6%	173.3%
Lake H.	207	121.9%	145.4%	78.6%	145.5%
Lake H.	206	67.5%	124.5%	25.9%	64.9%