Appendix H. Total Phosphorus Loading Capacity of Petenwell and Castle Rock Flowages

Section 1. Jensen Lake Model

1.1 Introduction

Estimating the loads of total phosphorus (TP) that will allow Petenwell and Castle Rock Flowages to meet their water quality criteria is a primary goal of the Wisconsin River TMDL. The CE-QUAL-W2 model was selected for this task because it is a two-dimensional model (vertical and longitudinal) and preliminary analyses indicated significant changes in TP through the reservoirs. However, the CE-QUAL-W2 model developed by LTI has several shortcomings, leading DNR to revisit this component of the TMDL modeling. Compared with monitoring data, the CE-QUAL-W2 model:

1. Under-predicted TP at seven of the eight reservoir stations,
2. Under-predicted variability in chlorophyll *a* at all eight reservoir stations,
3. Poorly simulated the seasonal pattern of TP in the reservoirs, particularly missing the peak in mid-summer,
4. Poorly simulated seasonal patterns in the relative abundance of algal groups.

DNR first attempted to re-calibrate the CE-QUAL-W2 model to address these issues. While the DNR calibration improved several aspects of model fit (see Section 2 of this appendix for details), TP was still under-predicted, particularly in Petenwell. Also, while current chlorophyll patterns were more accurately simulated by the DNR calibration, there was almost no response in chlorophyll when TP reductions of up to 65% were simulated. This counterintuitive result is probably related to algal nutrient limitation parameters, but extensive exploration of these parameters did not produce both a reasonable fit to current conditions and the expected reduction in chlorophyll with TP reductions. One option at this stage would have been to use the TP predictions from the CE-QUAL-W2 model, but predict chlorophyll response with one of the many existing empirical TP:Chl models (e.g., Jones and Bachmann 1976; McCauley et al. 1989; Filstrup et al. 2014). However, the fact that the primary water quality variable, summer TP, was substantially under-predicted in all iterations of the CE-QUAL-W2 model led us to explore alternative approaches.

1.2 Methods

An empirical mass-balance model (Jensen et al. 2006) was evaluated as an alternative to the mechanistic CE-QUAL-W2 model for simulating P dynamics in the reservoirs. The Jensen model is relatively simple in comparison with CE-QUAL-W2. It uses daily inflows of water and P and reservoir water temperature as inputs. The change in P concentration in the reservoir is modeled as a difference between input and output, the sedimentation of P is deducted, and the release of P from the sediment is added. Sedimentation and release rates are calibrated parameters that may be temperature dependent. The pool of P in the sediment is tracked over the simulation period, so if external P loads are reduced, there will be a lag in water column P response as the sediment P moves toward a new equilibrium with the reduced inputs.

We developed separate Jensen models for Petenwell Reservoir, the main body of Castle Rock Reservoir, and the Yellow River arm of Castle Rock Reservoir. We considered developing a single segmented model with segments centered on the eight main monitoring stations across the two reservoirs, but decided against this approach for two reasons. First, a substantial number of discrete TP measurements appear to not be representative samples of their respective reservoir segments. For example, the TP sample at Petenwell station 10031170 on 7/11/13 was 527 µg/L, but the next highest concentration at any Petenwell station on that date or dates two weeks before and after was 155 µg/L. This is an extreme example, but there are several other cases with a similar pattern of isolated high TP concentrations with no obvious relationship to upstream or downstream measurements. These anomalies could be caused by localized sediment P release, but if these high concentrations were really representative of the entire reservoir segment, they would likely manifest in higher concentrations at downstream stations in subsequent samples. A more likely explanation is that TP is not uniformly mixed laterally and concentrations > ~160 µg/L are local "hot spots". We therefore decided to use the median TP concentration across all stations in each reservoir on each sample date as representative of the entire reservoir. The median values follow a much smoother pattern than any of the individual stations and this approach allows each reservoir to be treated as a single unit. The second reason for developing separate models is so that measured TP loads could be used as the inflow to Castle Rock rather than the predicted outflow of Petenwell, which eliminates the potential for compounded errors. One factor that complicates this approach is that station 10031174 in Castle Rock integrates both the main body and Yellow River arm inputs. However, the pattern in median TP using all three main body stations in Castle Rock is very well predicted using only the inflow to the main body (i.e., not Yellow River arm inputs), which is not surprising considering that the Yellow River arm contributes only 15% of the total TP load to Castle Rock.

For each model, daily hydrologic inputs were primarily derived from USGS gages, with small ungauged areas estimated by applying drainage area ratios to gaged flows. As with the DNR CE-QUAL-W2 calibration, daily TP inputs were estimated by linearly interpolating measured concentrations and then multiplying by measured flows. The same gage associations were used as by LTI for both flow and water quality (Appendix M, Tables 3.1 and 3.2). Daily water temperatures were calculated from the CE-QUAL-W2 model output as the mean of all segments encompassing the monitoring stations for each water body. Reservoir volumes were taken from CE-QUAL-W2 model geometry, which is based on Fishing Hot Spots bathymetric maps (Table 1). Reservoir surface areas were taken from WDNR 1:24,000-scale water body polygons. Mean depth is volume divided by surface area.

The coefficients for sedimentation and release of TP calibrated by Jensen and colleagues for a set of Danish lakes did a reasonable job of simulating the TP dynamics in Petenwell and Castle Rock Flowages, but in general produced lags in reservoir response that were too long. Therefore, we calibrated a new set of sedimentation and release coefficients and initial sediment P concentration for each model (Table 1). All parameters for each model were calibrated simultaneously using the generalized reduced gradient method with Solver in Microsoft Excel with the objective of minimizing the RMSE of predictions. In preliminary model calibrations for Petenwell, the initial sediment P concentration was low (5.5 g/m^2) relative to the lakes studied by Jensen and colleagues, but increased to 7.5 g/m^2 over the four year simulation, which is consistent with the net retention observed in the TP mass balance. The implication of this pattern is that the current sediment P concentration would have accumulated in ~11 years, which seems unlikely given that long-term monitoring on the Wisconsin River at Biron indicates that TP loading to Petenwell has been at or slightly above current levels since at least 1977. A more likely explanation is that some of the deposited P in these reservoirs is buried and no longer exchangeable with the water column. Because the long-term monitoring suggests that P inputs are at approximately steady state, we assumed that the current calibrated sediment release is proportional to current loading, and that a given reduction in loading would result in the same proportional reduction in sediment release once a new equilibrium is reached. The disadvantage of this approach is that it does not allow the lag time of reservoir response to load reduction to be assessed.

Table 1. Jensen model parameters

Parameter	Petenwell	Castle Rock (Main Body)	Castle Rock (Yellow R. Arm)
Volume (m^3)	4.98×10^8	1.43×10^8	1.63×10^7
Area (m^2)	9.38×10^7	4.03×10^7	8.02×10^6
Depth (m)	5.31	3.56	2.03
Sedimentation rate, bS (m d^{-1})	0.2903	0.1705	0.0871
Temperature dependence of bS, tS	0.0244	-0.041	0
Sediment release rate, bF (g m^{-2} d^{-1})	0.0252	0.0115	0.0047
Temperature dependence of bF, tF	0.0939	0	0.0752

1.3 Results

The Jensen model significantly improved the model fit relative to the CE-QUAL-W2 model and essentially eliminated prediction bias (Table 2). The Jensen model also replicates very well the seasonal pattern of TP concentrations in all three water bodies (Figures 2-4). The good fit of the Jensen model to measured data indicates that the seasonal dynamics of TP in these reservoirs are largely driven by input TP loads and temperature-mediated sedimentation and release. Both of the primary model coefficients – sedimentation rate and sediment release rate – follow the same rank order among water bodies: Petenwell is highest, followed by the main body and then the Yellow River arm of Castle Rock. The rank order of sedimentation rate follows the order of residence time and the rank order of sediment release rate follows the order of measured P release rates from sediment core incubations (Appendix E).

The Jensen models for each water body were used to estimate current (2010-13) summer mean TP concentrations, and to estimate the external TP load reductions that would meet TP criteria (40 µg/L) (Table 3). The load reductions for Petenwell and the Yellow River arm of Castle Rock are similar at 63% and 60%. Because Petenwell Reservoir retains 25% of its inflow TP load, the main body of Castle Rock Reservoir will be below its TP criterion if Petenwell attains its criterion.

Table 2. Fit of model predictions to measured total phosphorus concentrations (RMSE: root mean squared error)

		RMSE (µg/L)		Bias (%)	
Water Body	Period	Jensen	CE-QUAL-W2	Jensen	CE-QUAL-W2
Petenwell	Apr-Sep	14	35	0	-18
	Jun-Sep	14	37	0	-20
Castle Rock Main Body	Apr-Sep	11	20	+1	-7
	Jun-Sep	12	21	-1	-13
Castle Rock Yellow R. Arm	Apr-Sep	19	43	+2	-28
	Jun-Sep	18	49	+1	-34

Table 3. Summary of current loading and loading capacity for total phosphorus in Petenwell and Castle Rock Flowages.

	Current Conditions (2010-13)				
Water Body	Inflow TP load (t/yr)	Outflow TP load (t/yr)	TP Retention	Summer TP conc (µg/L)	Inflow TP load (t/yr) to meet TP Criteria (40 µg/L)
Petenwell Reservoir	428	319	25%	109	158 (-63%)
Castle Rock Reservoir (Main Body)	329	346	11%	79	167 (-49%)
Castle Rock Reservoir (Yellow River Arm)	59			101	23 (-60%)

1.4 Discussion

This section discusses four potential concerns with using the Jensen model to model TP dynamics and estimate TP loading capacity in Petenwell and Castle Rock Flowages.

1. **Dissolved oxygen** – Both monitoring data and the CE-QUAL-W2 model indicate that anoxia periodically develops near the bottom of both reservoirs, primarily in July. The Jensen model does not explicitly simulate oxygen, but the authors note that

"…temperature integrates most of the seasonal mechanisms responsible for the phosphorus release in eutrophic relatively iron-rich lakes." Presumably, the incidence of anoxia will decrease as P loads decrease, which may lead to lower net release rates for a given sediment P concentration. As with Jensen, the CE-QUAL-W2 model predicts a linear response of reservoir P to load reduction (Figure 5), so neither tool is capable of characterizing this theoretical non-linearity. This conservative assumption may be offset by the assumption of prompt reductions in sediment P, which may in fact have a lagged response.

2. **Stratification –** The bottom anoxia described above is made possible by thermal stratification, which limits re-oxygenation of bottom waters by mixing. Stratification can also result in vertically non-uniform TP concentrations. The Jensen model considers the reservoir as a single mixed compartment. However, because the model coefficients are calibrated to surface concentrations, the modeled reservoir concentrations should be considered surface concentrations, not volume-weighted averages. This also means that modeled reservoir concentrations cannot necessarily be used as estimates of outflow concentrations.

3. **Advective transport –** The shapes and high flow-through volumes of both reservoirs means that TP is transported advectively (with directional water movement). This should result in significant lags in reservoir TP response to input loads, which could limit the applicability of a single-compartment model. In particular, one would expect to see the Jensen model predictions respond more quickly to changes in P inputs than the sample data. This does not appear to be the case – in fact, the Jensen model predictions appear to lag behind the observations in both reservoirs. In late summer, measured P concentrations in both reservoirs decrease more quickly than the Jensen model predicts (Figures 2, 3). One possible cause for this pattern is that advective transport in these reservoirs takes place predominantly in the main channel, which has a lower volume than the overall reservoir volume used in the Jensen model. Another possibility is that algal growth decreases as a result of decreased solar radiation in late summer, which leads to higher P sedimentation than would be predicted by water temperature alone.

4. **Other factors limiting algal growth** – While the CE-QUAL-W2 model simulates a wide variety of water quality parameters and algal groups in reservoirs, the Jensen model only simulates TP. Therefore, a separate model is needed to predict chlorophyll response to TP reductions. This approach does not allow evaluation of other factors that can limit algal growth (e.g., nitrogen, light, grazing). However, as described above, there was almost no response in chlorophyll when TP reductions of up to 65% were simulated with CE-QUAL-W2, which calls into question the utility of either the LTI or DNR calibrations. The lack of algal response to TP reductions is probably related to the low algal half-saturation for phosphorus limited growth (AHSP = 3 µg/L) that is the default in CE-QUAL-W2, and which fit well in calibrating to current conditions in both reservoirs. The model algorithms used by CE-QUAL-W2 to represent algal communities (and thereby chlorophyll) are gross simplifications of actual processes, and large uncertainties in the predictions are inherent (Sullivan et al. 2011). Therefore, it is our opinion that an alternative, empirical approach for predicting chlorophyll response to TP is preferable. This approach is described in Appendix C.

Section 2. Revised CE-QUAL-W2 Model Calibration

DNR revised the CE-QUAL-W2 model calibration conducted by LTI (Appendix M) to address the following issues:

1. **Boundary conditions:** Changes in boundary nutrient concentrations and organic nutrient forms described below had relatively minor impacts on simulated conditions in the reservoirs, but were retained in the final DNR calibration because they were believed to be more accurate than the assumptions in the LTI calibration.
    a. Nutrient concentrations: The Fluxmaster estimates of phosphorus (P) and nitrogen (N) used as boundary conditions in the LTI calibration appear to be biased during several periods, as evidenced by serial autocorrelation in residuals. The consequence of boundary condition bias in the reservoirs is likely to be most significant for the mainstem Wisconsin River station (723259) because it delivers the majority of nutrients. To address this issue, the DNR calibration uses interpolated concentrations from the sample values at this station only for all P and N parameters. Other tributary boundary conditions were not modified from the LTI calibration.
    b. Labile vs. refractory organic nutrients: The sources of organic P and N are allochthonous (primarily terrestrial plant origin), which tends to break down more slowly (refractory) and authochthonous (primarily algae), which tends to break down more quickly (labile). Seasonal patterns in both terrestrial and aquatic primary production should create seasonal patterns in the fraction of labile and refractory organic nutrients. These fractions were not directly measured, so in the DNR calibration, it was assumed that they followed a sinusoidal pattern with a maximum of 100% labile organic nutrients on August 1 and a maximum of 100% refractory organic nutrients on February 1. In addition, the fraction of particulate organic nutrients was increased to 50% because this form decays to inorganic forms faster, which could help increase simulated algal growth rates to better match observed growth rates.
2. **Nitrogen cycling:** Seasonal patterns in the concentrations of inorganic forms of nitrogen (NH4 and NOx) were not accurately simulated in the LTI calibration, which could have contributed to the relatively poor simulation of algal succession and seasonal chlorophyll patterns. Two nitrogen cycling parameters were changed in the DNR calibration, which together with changes to algal parameters described below, improved the simulation of algal dynamics.
    a. Sediment release rate of ammonium, as a fraction of SOD (NH4R) was decreased from 0.005 to 0.001.
    b. The decay of nitrate by denitrification (NO3DK) was increased from 0.1 to 0.2.
3. **Algal parameters:** Algal succession and seasonal chlorophyll patterns were not simulated accurately in the LTI calibration. In particular, the algae monitoring showed that diatoms were the dominant algal group in the inflow to Petenwell, but that they quickly diminished in abundance in the reservoirs, particularly in mid-summer. Monitoring also showed that blue-green algae had dramatic blooms at most reservoir

stations during July and August. The blue-green blooms also coincide with the highest chlorophyll levels in the reservoirs. In contrast to these observed patterns, the LTI calibration shows diatoms remaining the dominant taxon throughout the reservoirs, and no distinct pattern in chlorophyll between May and early October. Several algal parameters were changed in the DNR calibration in an attempt to better simulate the observed algal succession and seasonal chlorophyll patterns (Table 4). Blue-green algae were made to grow (AG), die (AM) and settle (AS) faster, with all of these processes only occurring at warmer temperatures (AT1 and AT2), and to be capable of nitrogen limitation (AHSN). The temperature range for diatom growth was decreased (AT1 and AT2), and the settling rate for other algae was increased. For all algal taxa, the fraction of algal biomass that is converted to particulate organic matter when algae die (APOM) was increased to increase organic matter mineralization and nutrient cycling. Light extinction by algae (EXA) was changed to values that were empirically derived by Sullivan et al. (2011) for the Klamath River in Oregon.

Table 4. Changes in algal parameters from LTI calibration to DNR calibration.

	ALG1 (Blue-greens)		ALG2 (Diatoms)		ALG3 (Other)	
PARAMETER	LTI	DNR	LTI	DNR	LTI	DNR
AG	1.5	3				
AM	0.08	0.1				
AS	0	0.3			0.2	0.3
AHSN	0	0.014				
AT1	10	18	10	5		
AT2	25	28	15	10		
APOM	0.8	0.98	0.8	0.95	0.8	0.95
EXA	0.2	0.088	0.2	0.542	0.2	0.17

Summary statistics of TP and Chl in Petenwell and Castle Rock Flowages are in Figure 1. Plots of the major water quality parameters in Petenwell and Castle Rock Flowages simulated by the LTI and DNR calibrations are at the end of this appendix.

Compared with the LTI calibration, the DNR calibration increases the accuracy of the following patterns:

1. Timing of depletion of inorganic N (NH4 + NOx) in Petenwell Reservoir in late summer
2. Peak in PO4 in mid-summer, particularly in Petenwell Reservoir
3. Peaks in TP and CHLA in late summer at all reservoir stations in most years
4. Seasonal patterns in relative abundance of algal groups

Compared with the LTI calibration, the DNR calibration decreases the accuracy of the following patterns:

1. Increase in TKN in mid-summer
2. PO4 in fall, particularly in Castle Rock Reservoir

References

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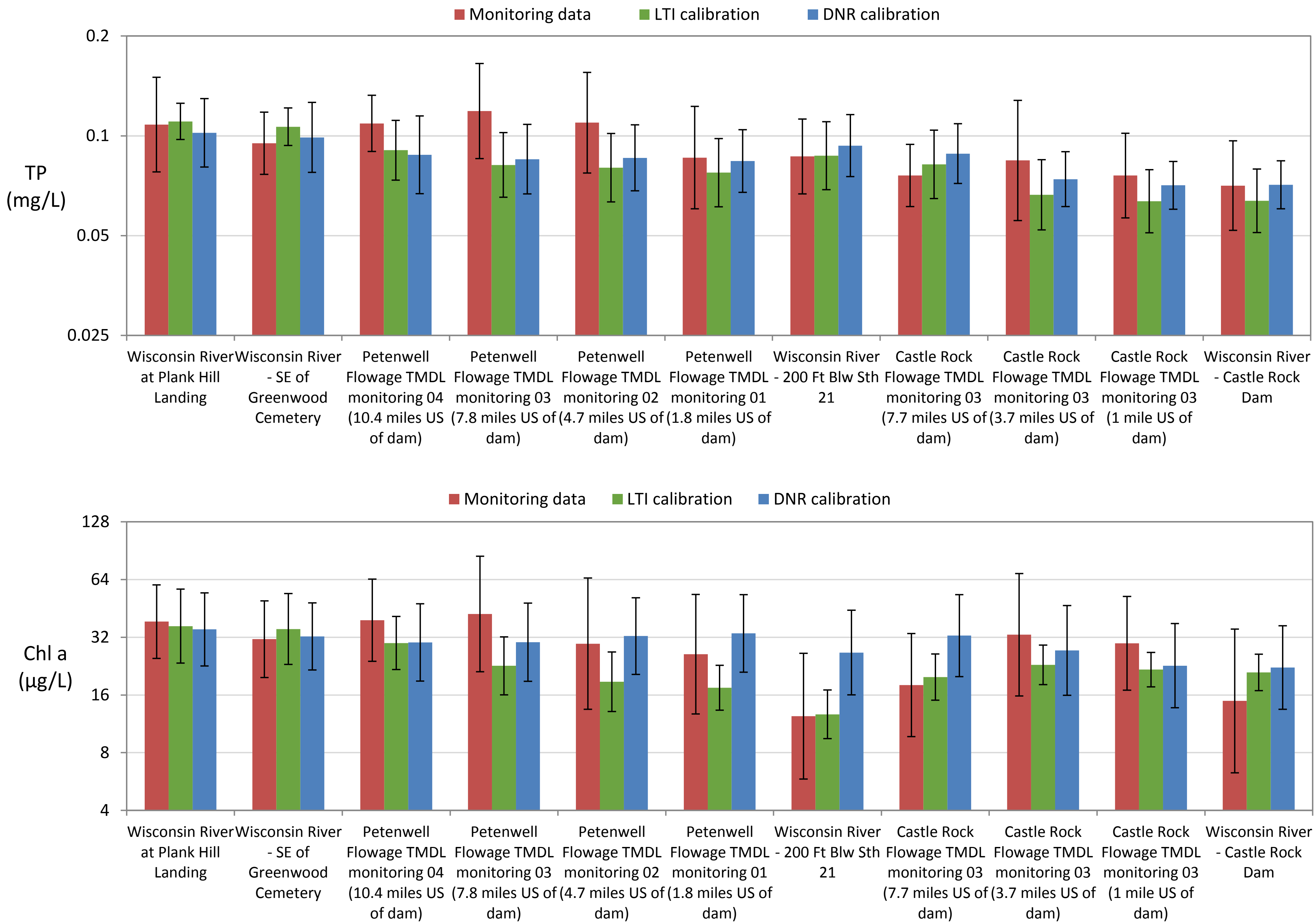


Figure 1. Summary statistics of TP and Chl in Petenwell and Castle Rock Flowages. Bars are geometric means; error bars are 1 standard deviation.

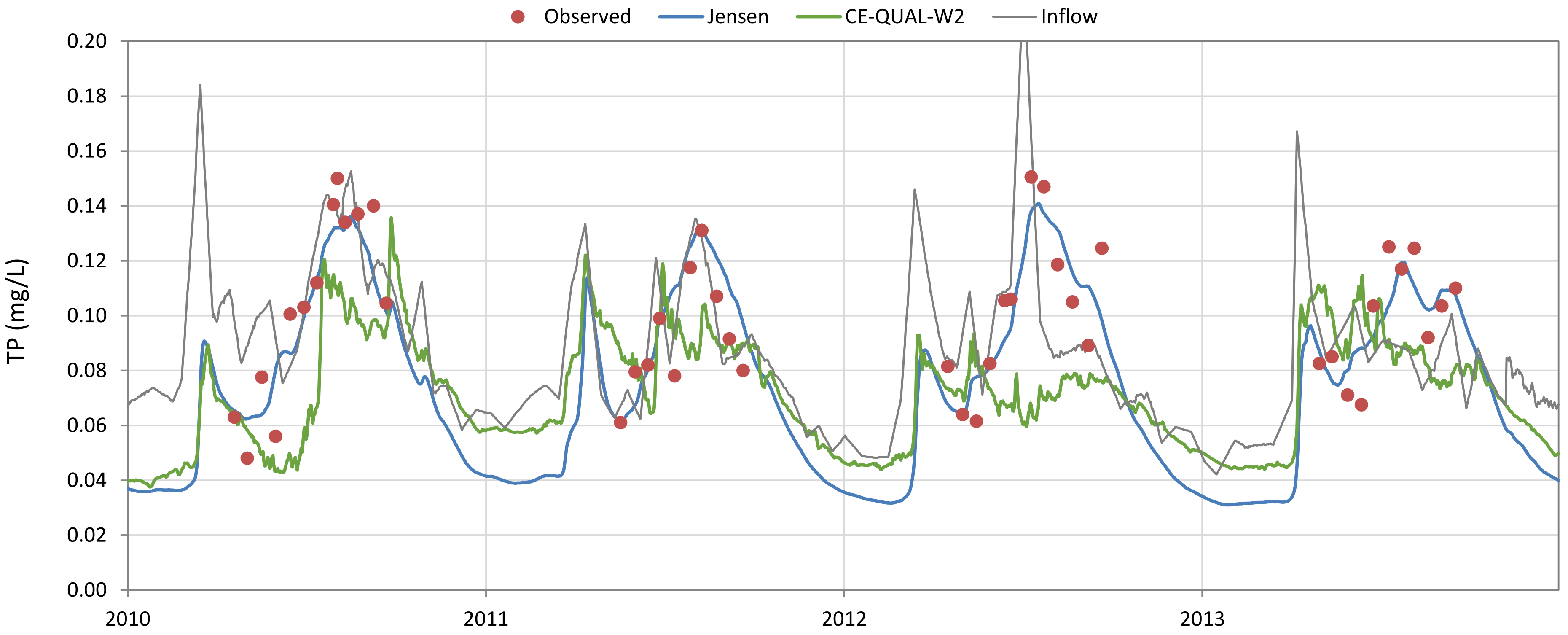


Figure 2. Plot of daily total phosphorus (TP) concentrations in Petenwell Reservoir. Observed values are the median of the four monitoring stations (SWIMS station ID 10031168, 10031169, 10031170, and 10031171). Inflow concentration is the flow-weighted average of all inflows. CE-QUAL-W2 line is the median of the top layer of model segments 9-20.

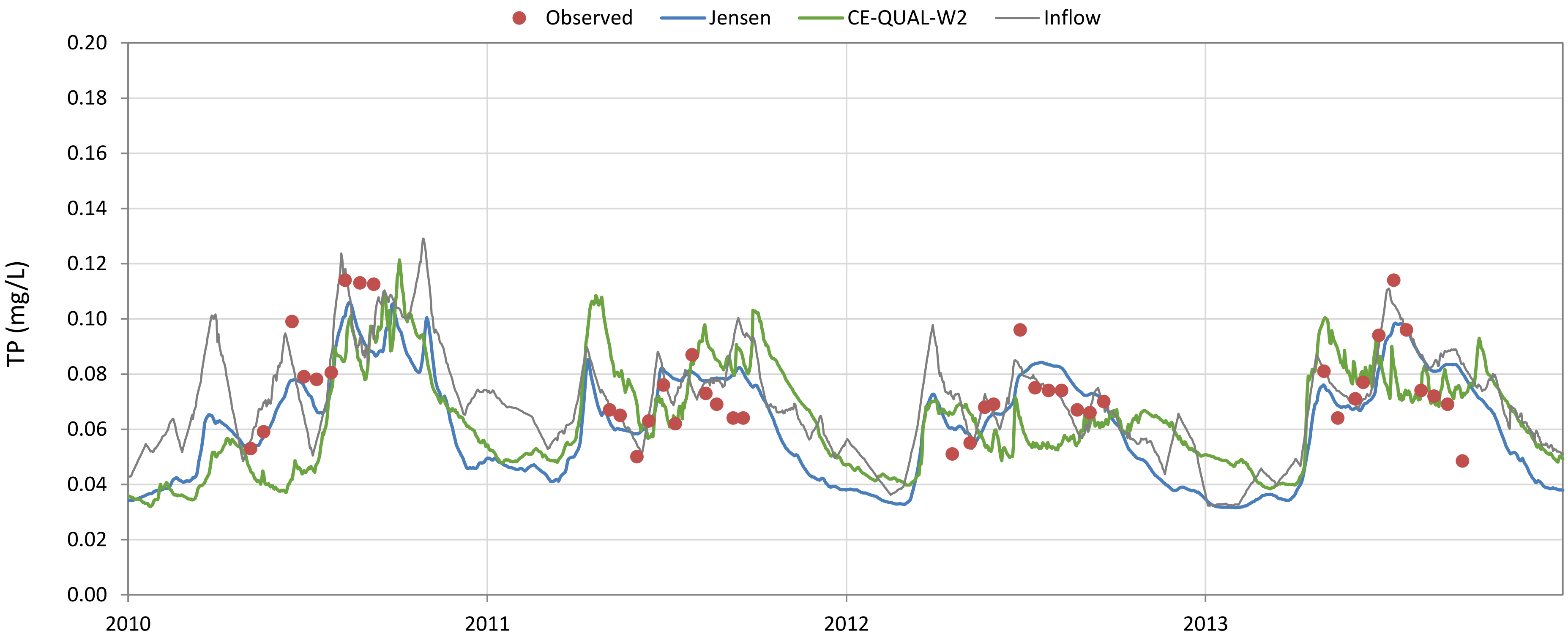


Figure 3. Plot of daily total phosphorus (TP) concentrations in the main body of Castle Rock Reservoir. Observed values are the median of the three monitoring stations (SWIMS station ID 10031172, 10031173, and 10031174). Inflow concentration is the flow-weighted average of all inflows. CE-QUAL-W2 line is the median of the top layer of model segments 41-50.

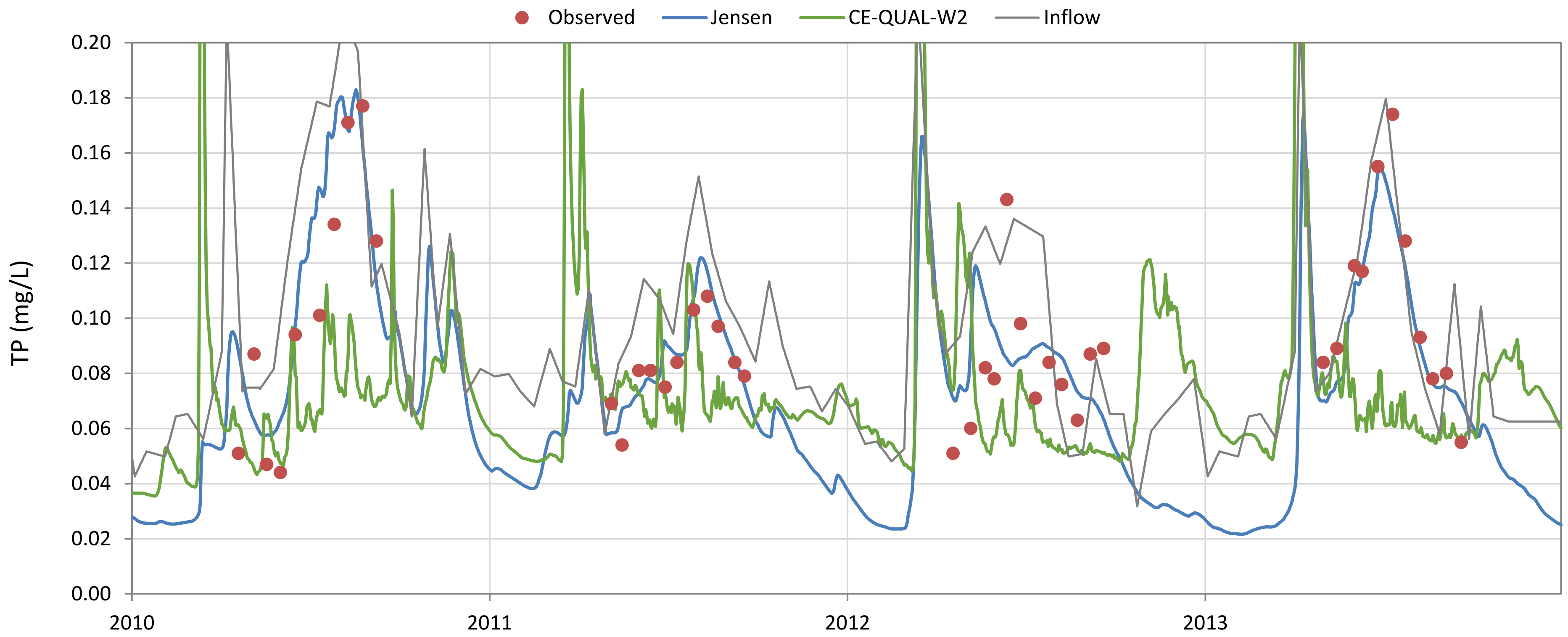


Figure 4. Plot of daily total phosphorus (TP) concentrations in the Yellow River arm of Castle Rock Reservoir. Observed values are from SWIMS station ID 10031175. Inflow concentration is the flow-weighted average of all inflows. CE-QUAL-W2 line is the top layer of model segment 57.

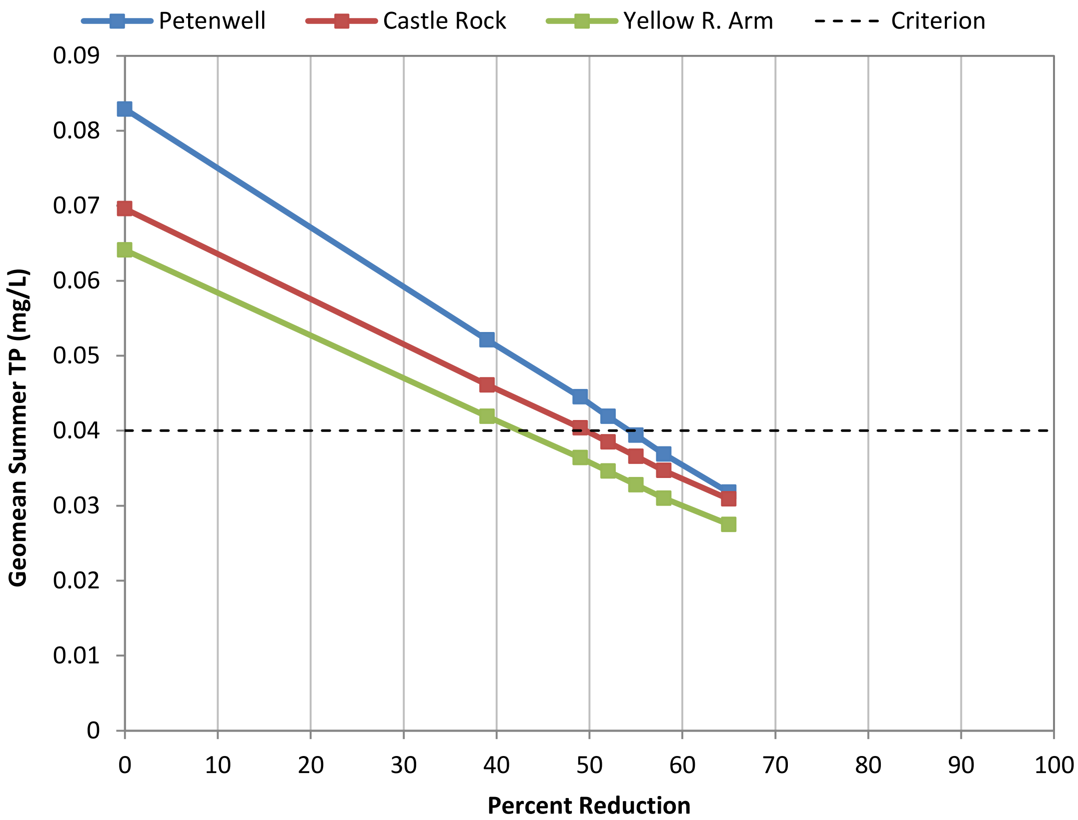
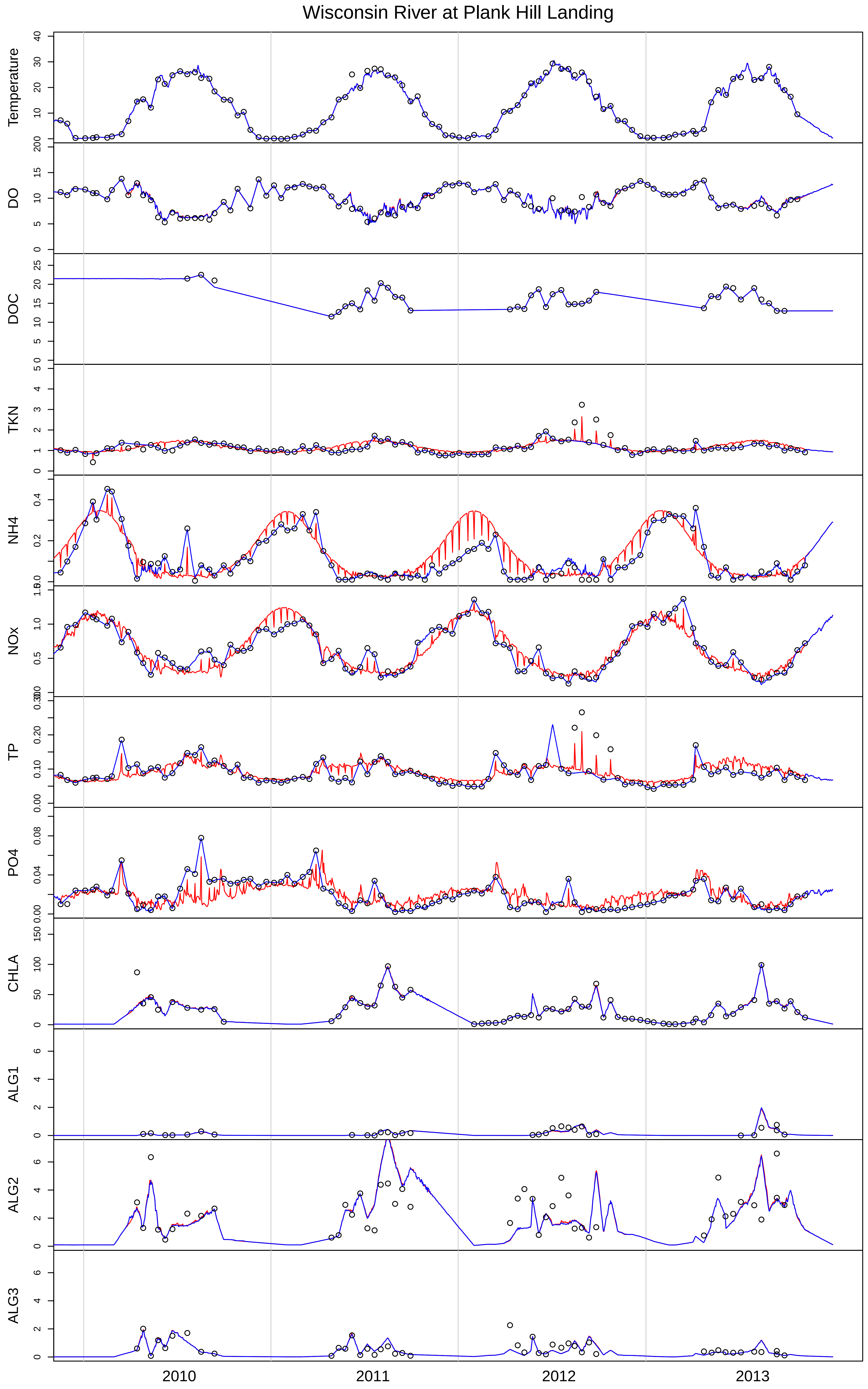
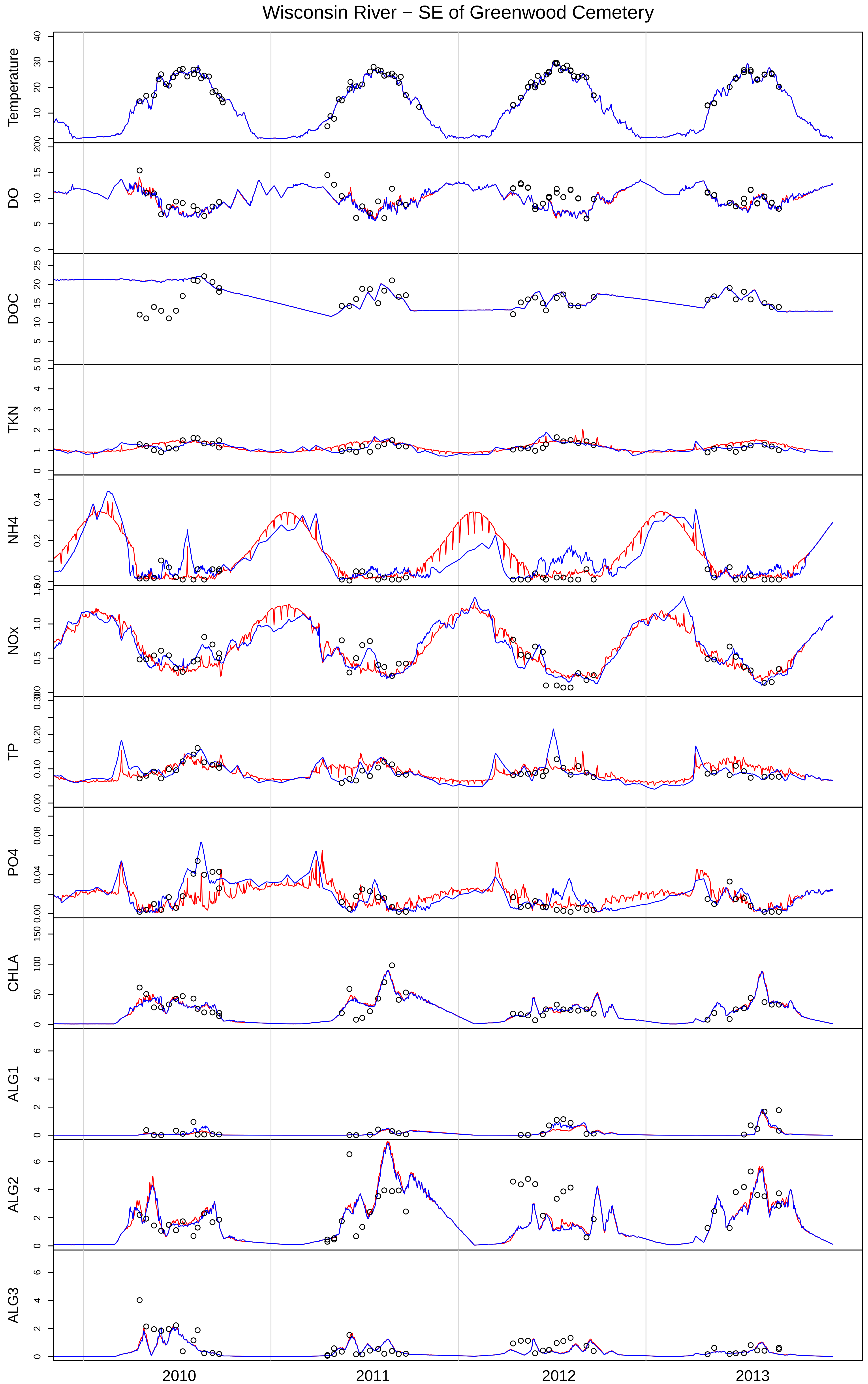


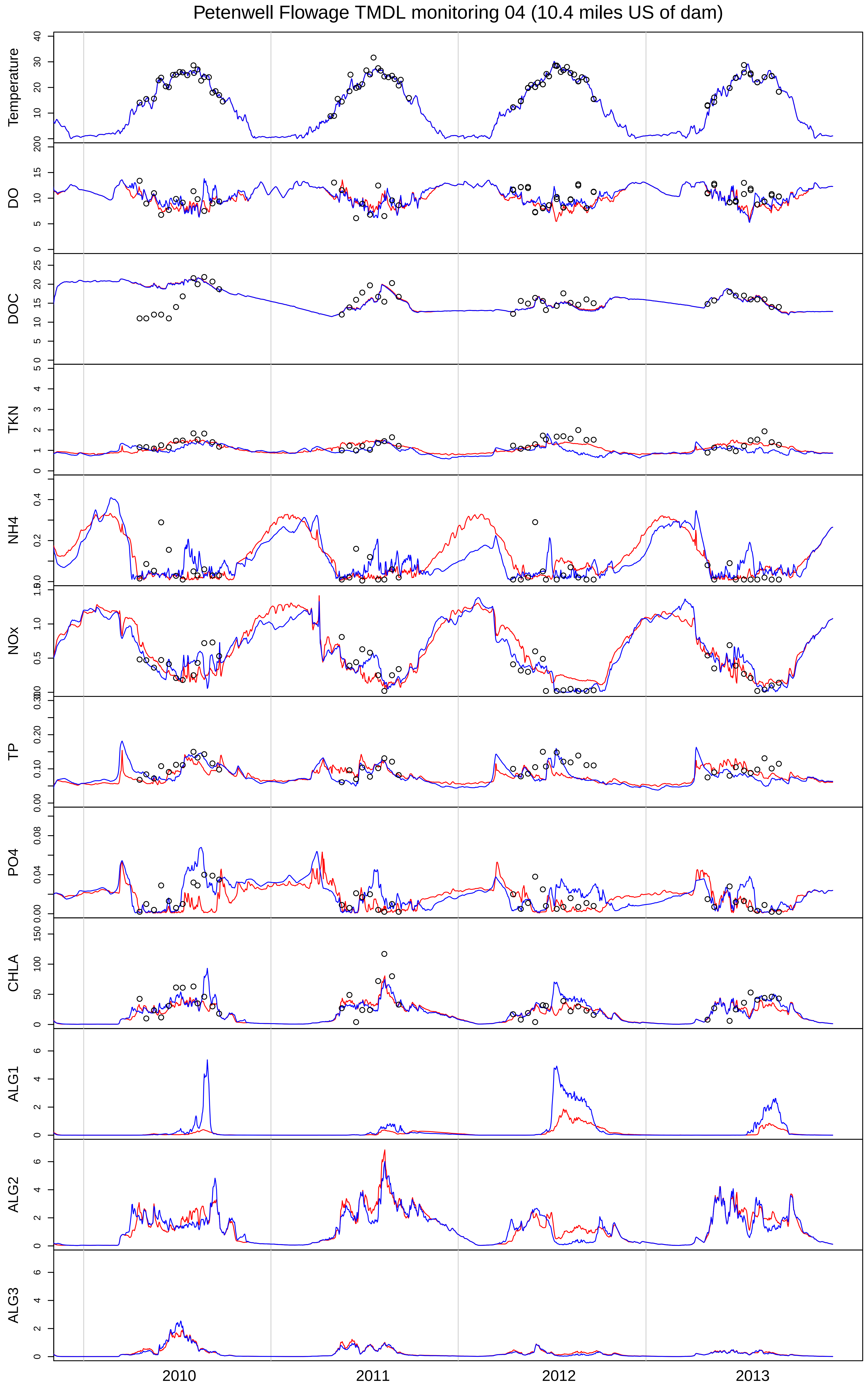
Figure 5. Linear response of reservoir geometric mean summer TP to the range of load reductions as simulated by CE-QUAL-W2 model.

Plots following this page are water quality simulations by CE-QUAL-W2 models for Petenwell and Castle Rock Flowages; red lines are LTI calibration, blue lines are DNR calibration, black circles are measured values.


Wisconsin River at Plank Hill Landing
Temperature
DO
DOC
TKN
NH4
NOx
TP
PO4
CHLA
ALG1
ALG2
ALG3
2010
2011
2012
2013

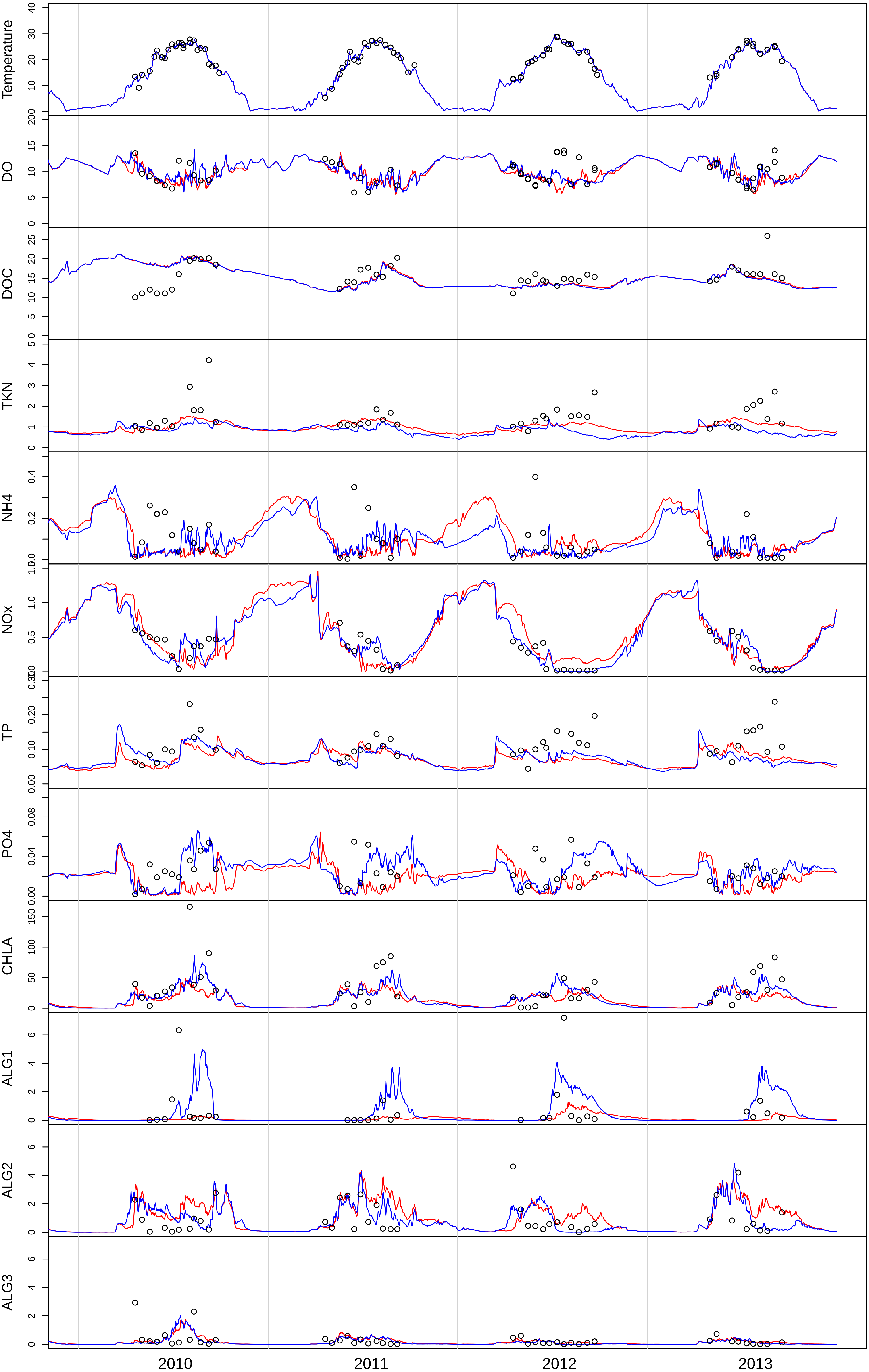


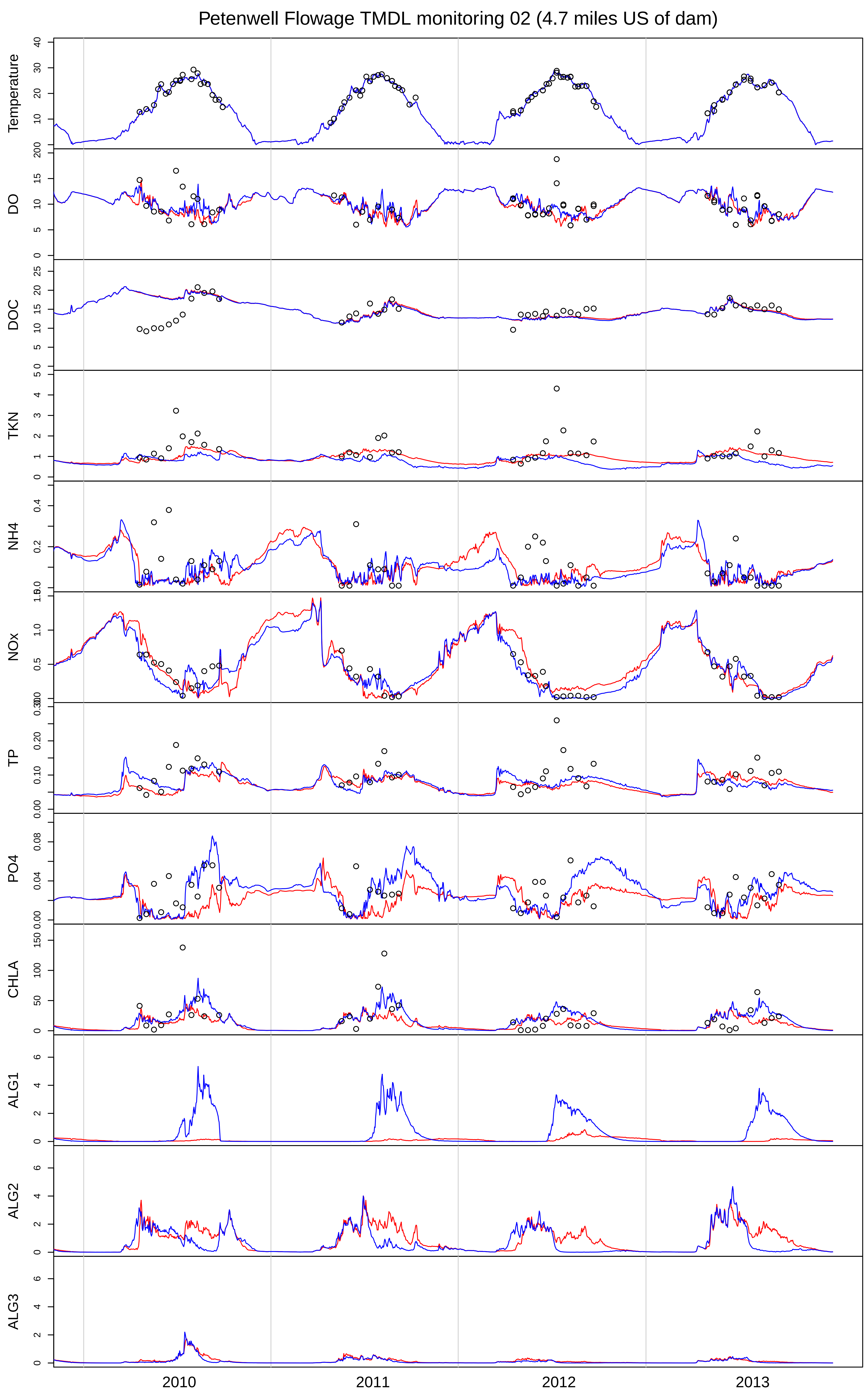
Wisconsin River − SE of Greenwood Cemetery
Temperature
DO
DOC
TKN
NH4
NOx
TP
PO4
CHLA
ALG1
ALG2
ALG3
2010
2011
2012
2013



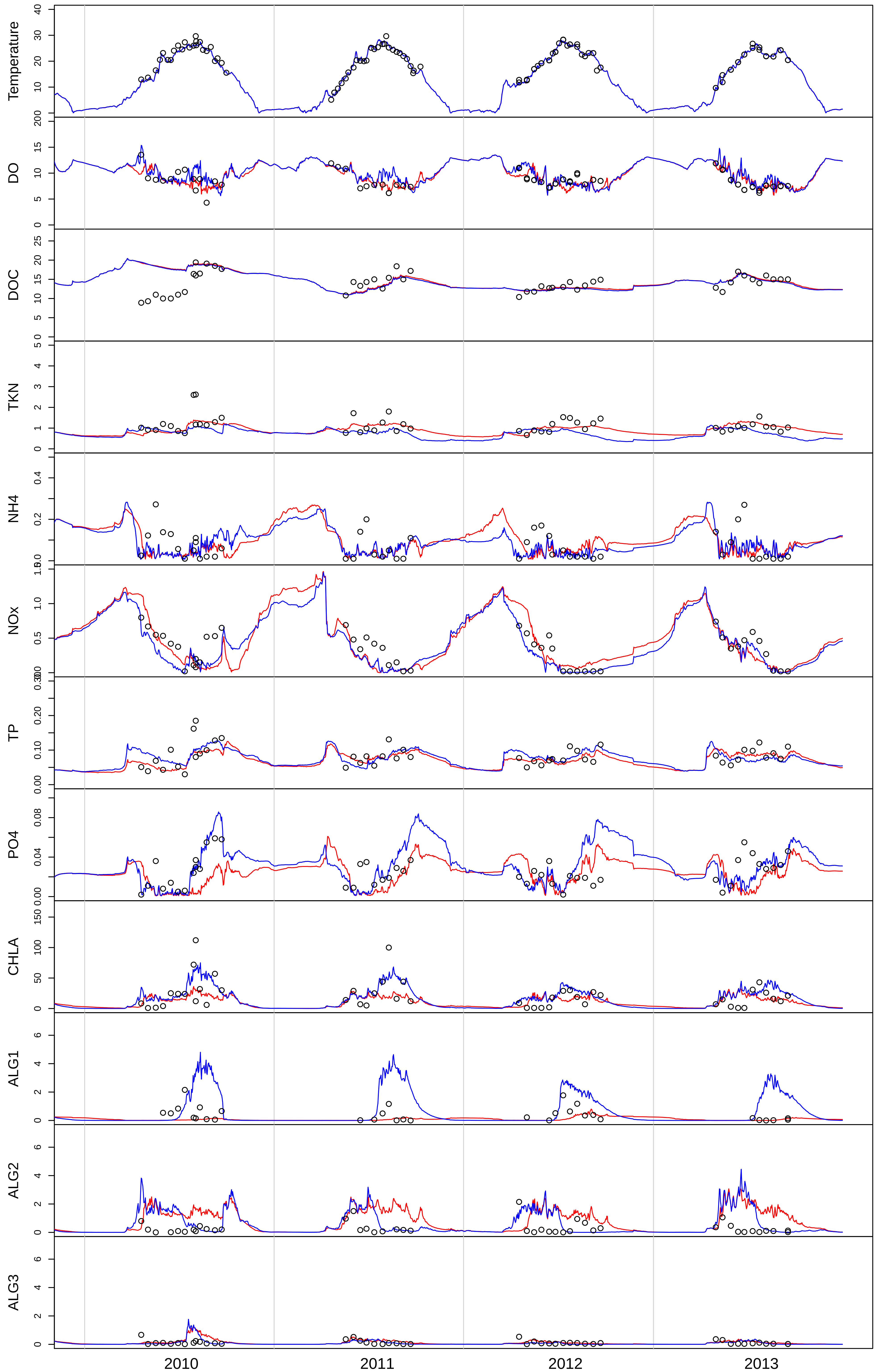
Petenwell Flowage TMDL monitoring 04 (10.4 miles US of dam)
Temperature
DO
DOC
TKN
NH4
NOx
TP
PO4
CHLA
ALG1
ALG2
ALG3
2010
2011
2012
2013

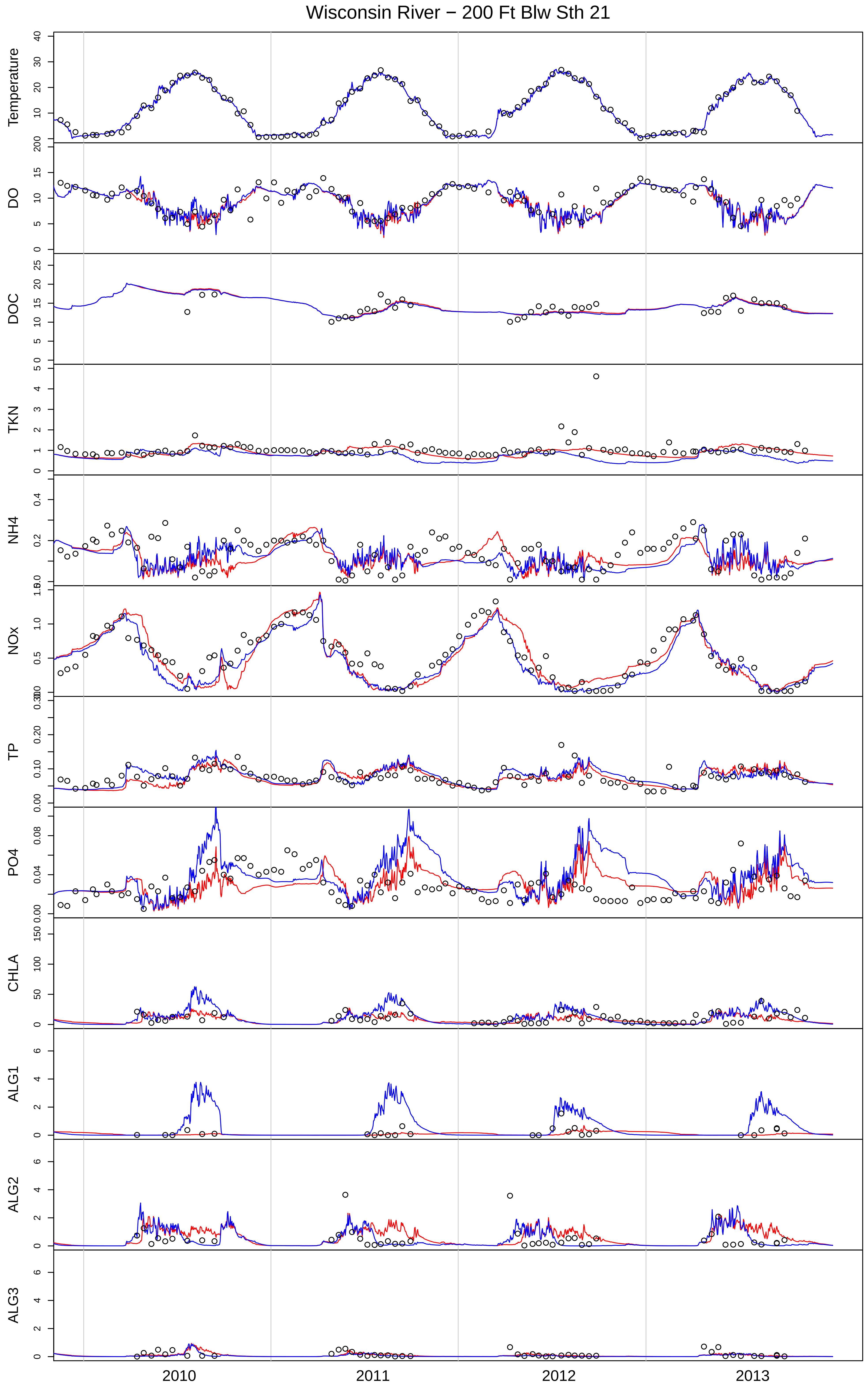
Petenwell Flowage TMDL monitoring 03 (7.8 miles US of dam)




Petenwell Flowage TMDL monitoring 02 (4.7 miles US of dam)
Temperature
DO
DOC
TKN
NH4
NOx
TP
PO4
CHLA
ALG1
ALG2
ALG3
2010
2011
2012
2013

Petenwell Flowage TMDL monitoring 01 (1.8 miles US of dam)




Wisconsin River − 200 Ft Blw Sth 21
Temperature
DO
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NH4
NOx
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PO4
CHLA
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2010
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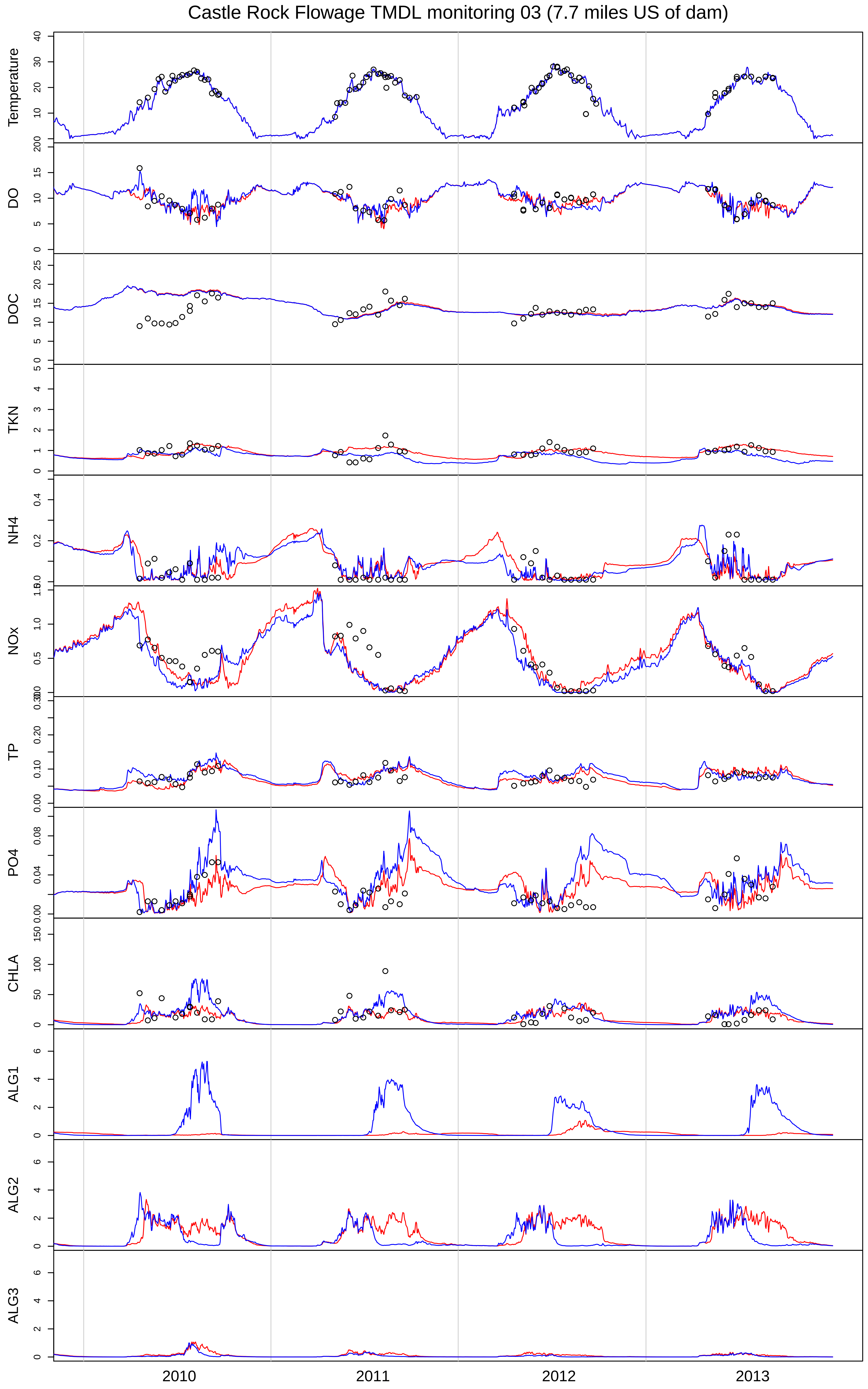

Castle Rock Flowage TMDL monitoring 03 (7.7 miles US of dam)
Temperature
DO
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NH4
NOx
TP
PO4
CHLA
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ALG2
ALG3
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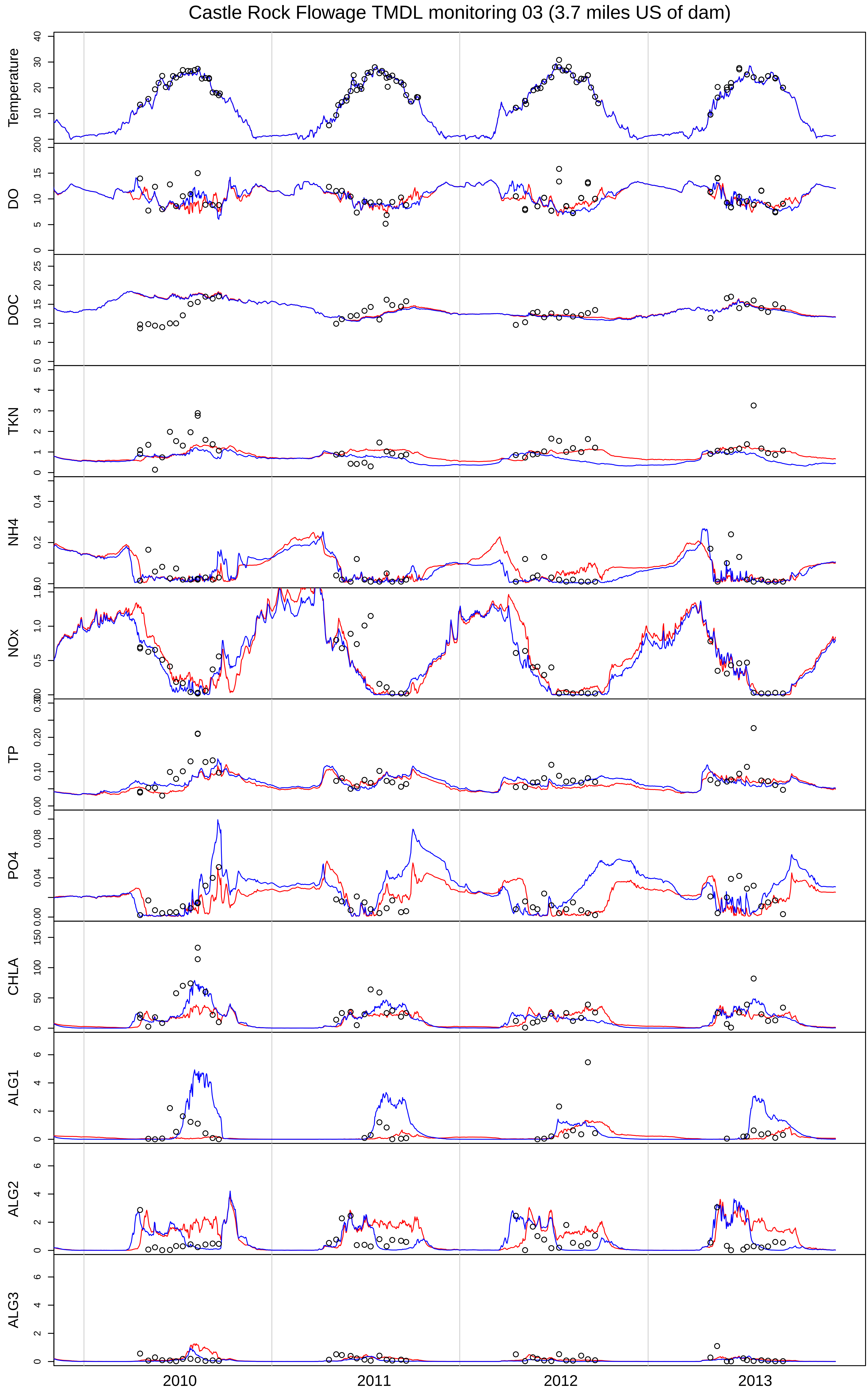
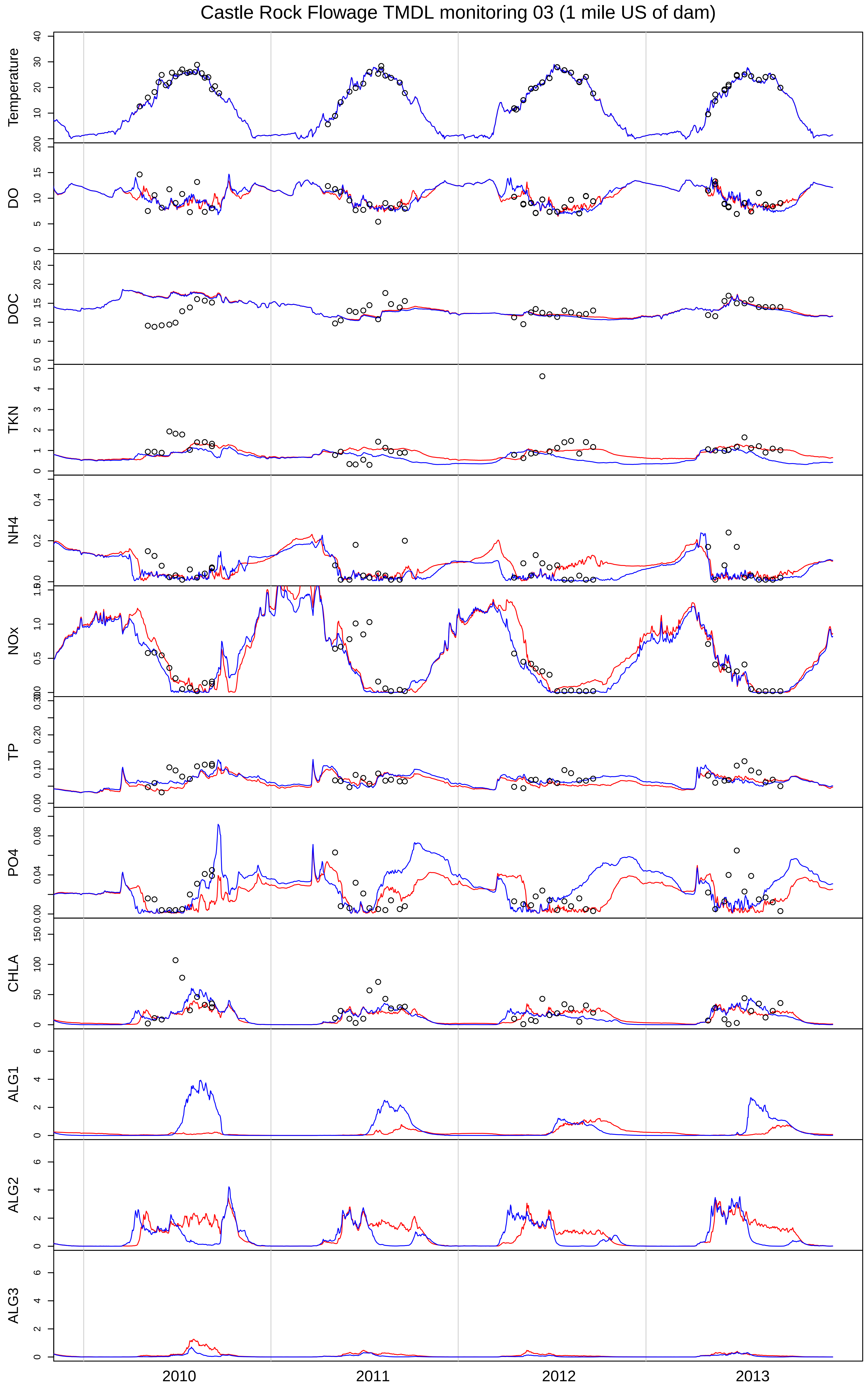


Castle Rock Flowage TMDL monitoring 03 (3.7 miles US of dam)
Temperature
DO
DOC
TKN
NH4
NOx
TP
PO4
CHLA
ALG1
ALG2
ALG3
2010
2011
2012
2013


Castle Rock Flowage TMDL monitoring 03 (1 mile US of dam)
Temperature
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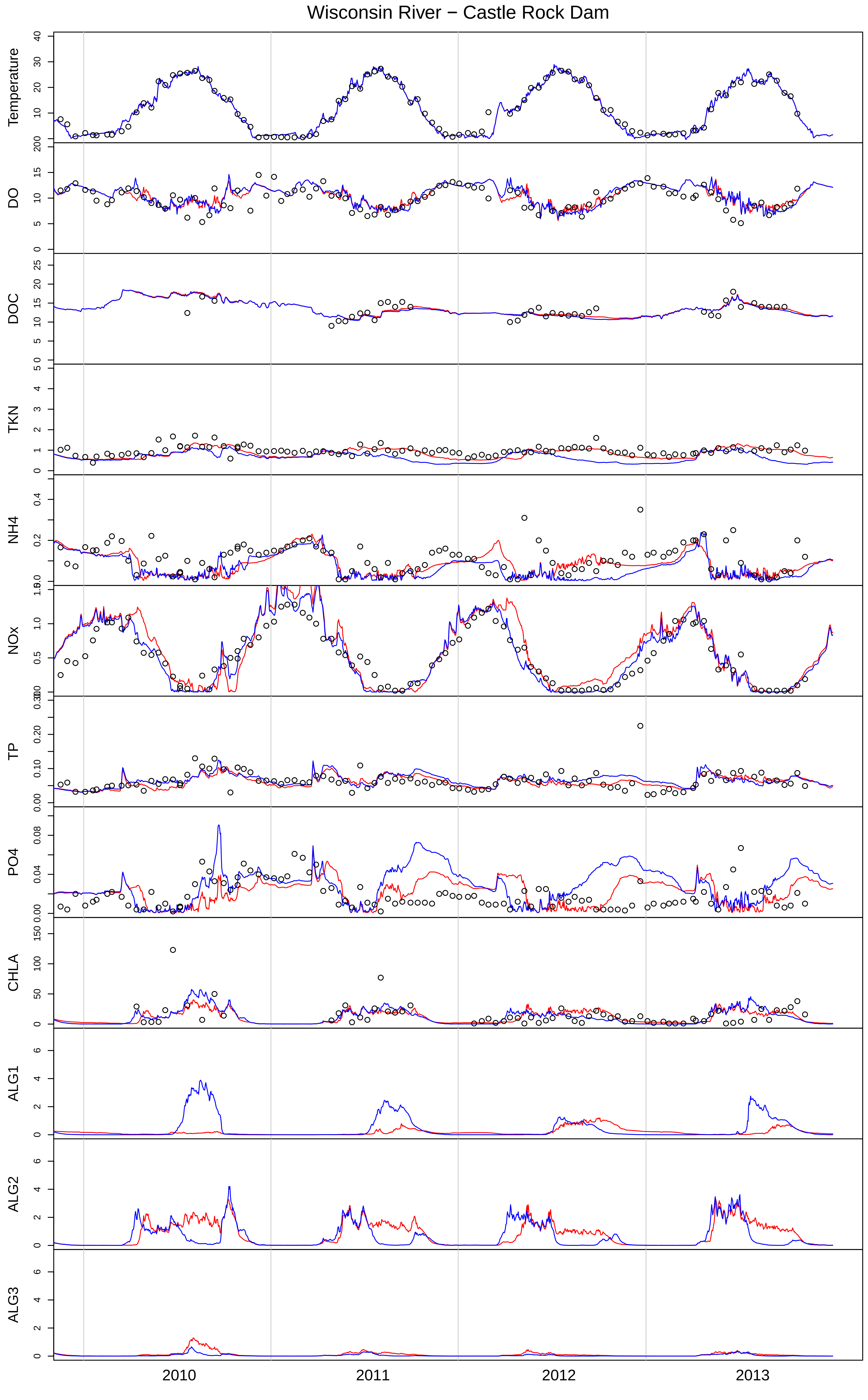
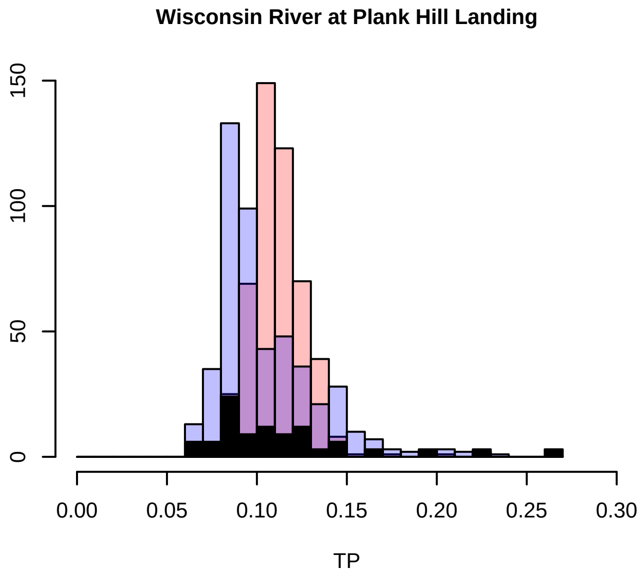
DOC
TKN
NH4
NOx
TP
PO4
CHLA
ALG1
ALG2
ALG3
2010
2011
2012
2013


Wisconsin River − Castle Rock Dam
Temperature
DO
DOC
TKN
NH4
NOx
TP
PO4
CHLA
ALG1
ALG2
ALG3
2010
2011
2012
2013

Plots following this page are histograms of simulated total phosphorus (TP) and chlorophyll a (CHLA) by CE-QUAL-W2 models for Petenwell and Castle Rock Flowages; red bars are LTI calibration, blue bars are DNR calibration, purple bars are areas of overlap between red and blue, black bars are measured values.


Wisconsin River at Plank Hill Landing
0
50
100
150
0.00
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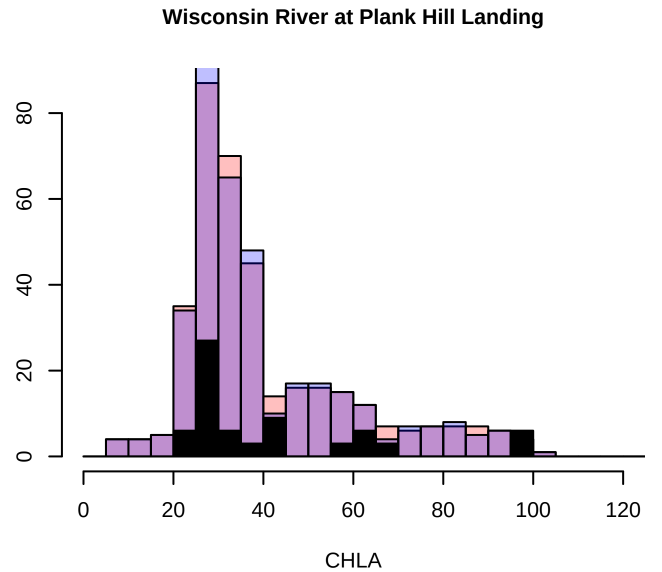
0.25
0.30
TP


Wisconsin River at Plank Hill Landing
0
20
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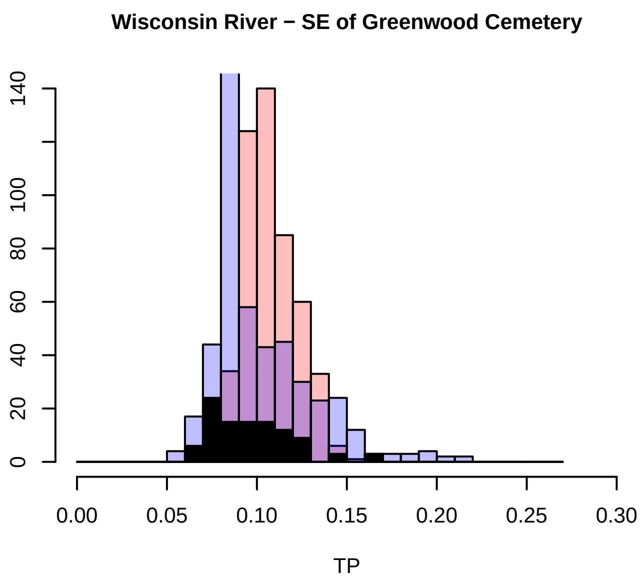
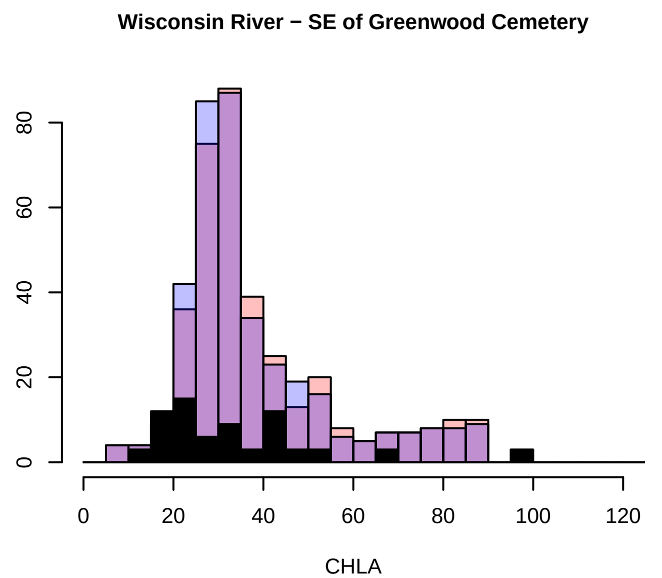
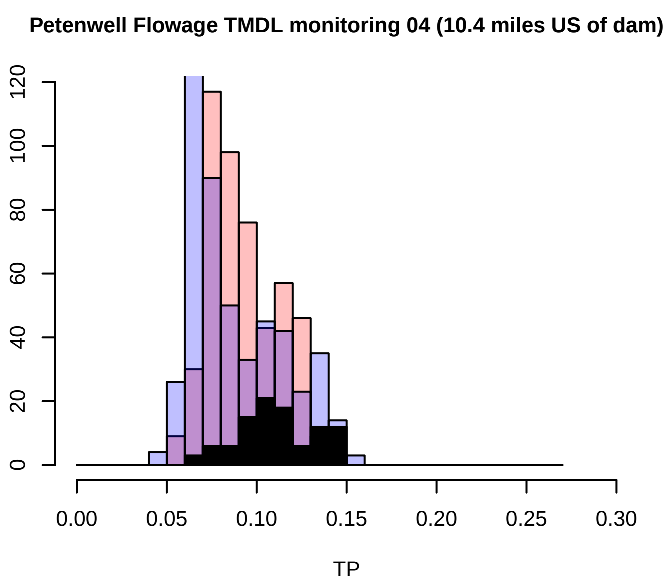
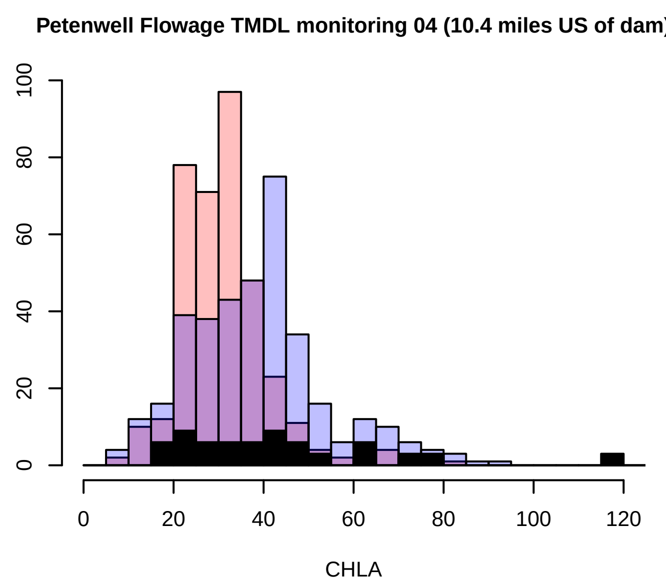
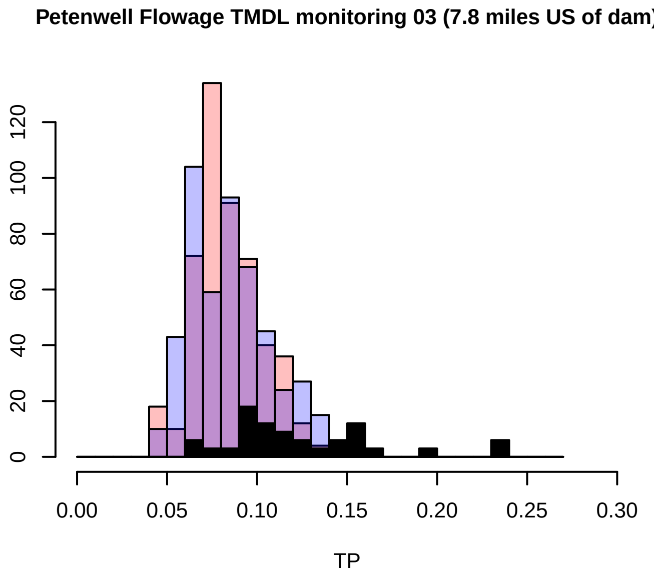
60
80
0
20
40
60
80
100
120
CHLA

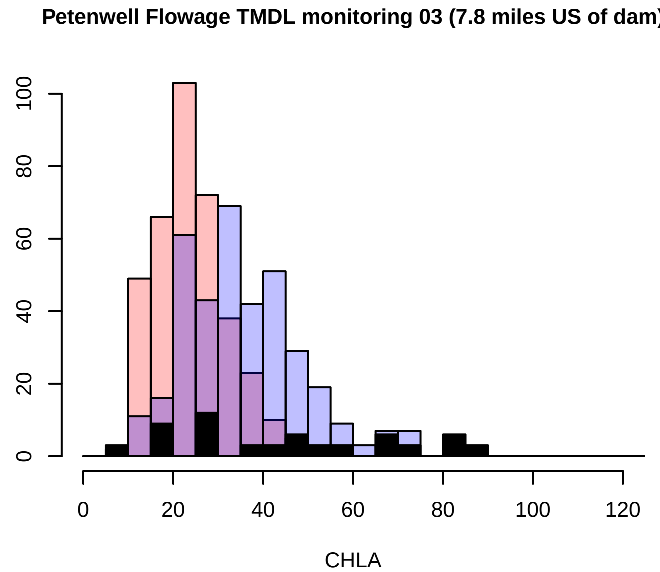

Wisconsin River − SE of Greenwood Cemetery
0
20
40
60
80
100
140
0.00
0.05
0.10
0.15
0.20
0.25
0.30
TP

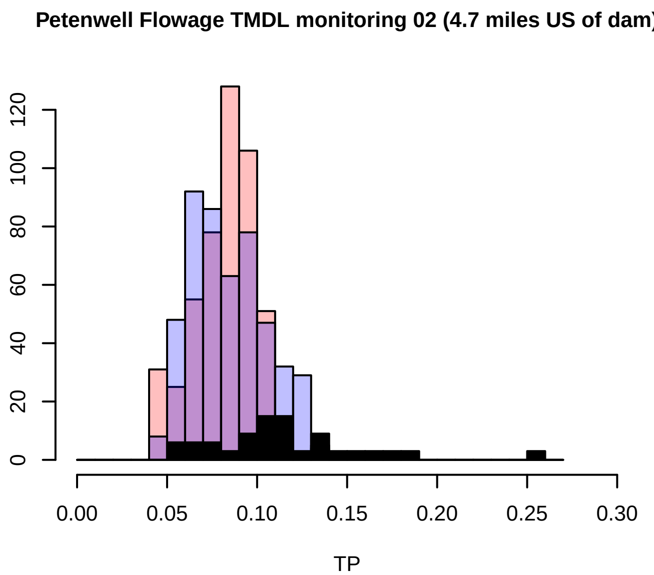

Wisconsin River − SE of Greenwood Cemetery
0
20
40
60
80
0
20
40
60
80
100
120
CHLA

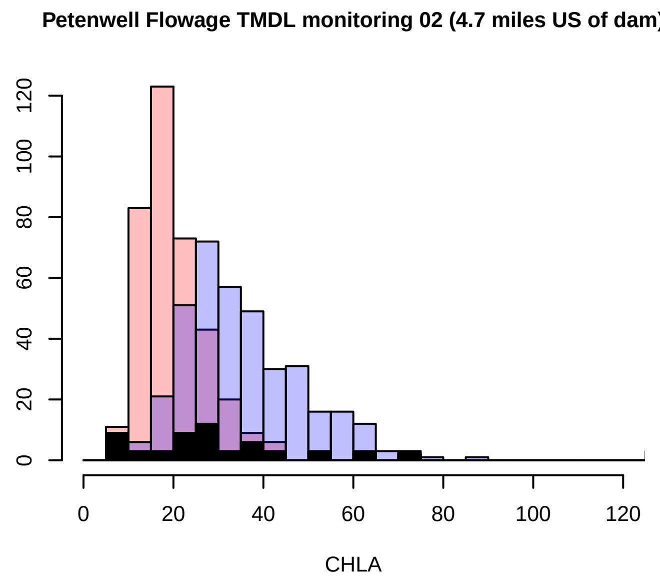

Petenwell Flowage TMDL monitoring 04 (10.4 miles US of dam)
0
20
40
60
80
100
120
0.00
0.05
0.10
0.15
0.20
0.25
0.30
TP

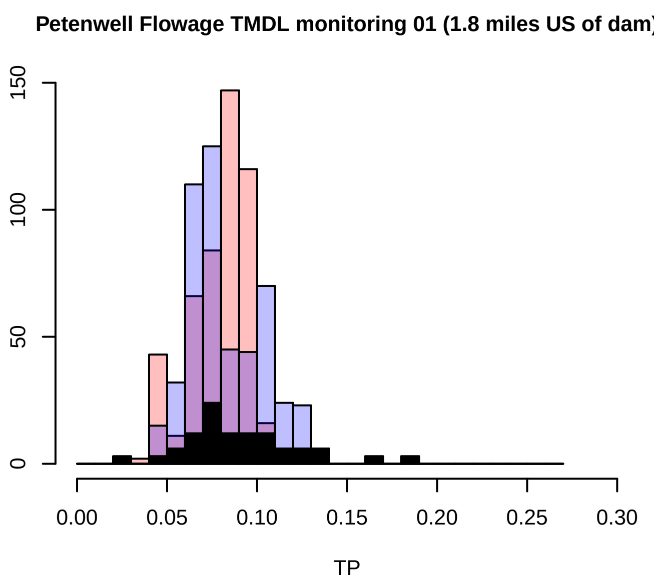

Petenwell Flowage TMDL monitoring 04 (10.4 miles US of dam)
0
20
40
60
80
100
0
20
40
60
80
100
120
CHLA

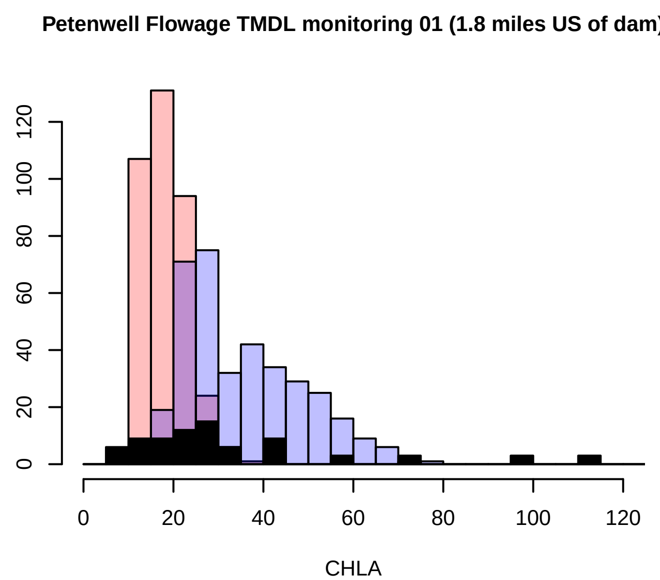

Petenwell Flowage TMDL monitoring 03 (7.8 miles US of dam)
0
20
40
60
80
100
120
0.00
0.05
0.10
0.15
0.20
0.25
0.30
TP

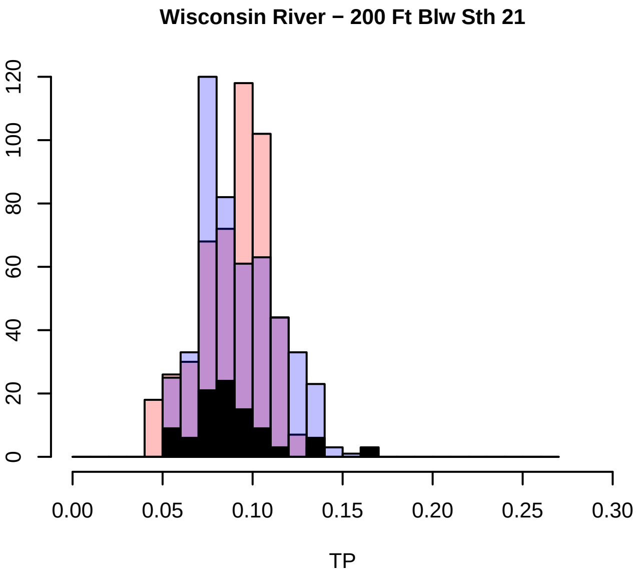

Petenwell Flowage TMDL monitoring 03 (7.8 miles US of dam)
0
20
40
60
80
100
0
20
40
60
80
100
120
CHLA

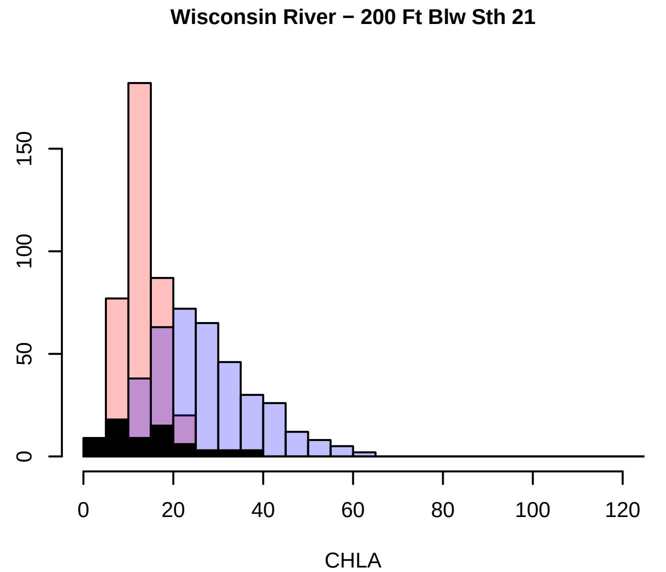

Petenwell Flowage TMDL monitoring 02 (4.7 miles US of dam)
0
20
40
60
80
100
120
0.00
0.05
0.10
0.15
0.20
0.25
0.30
TP

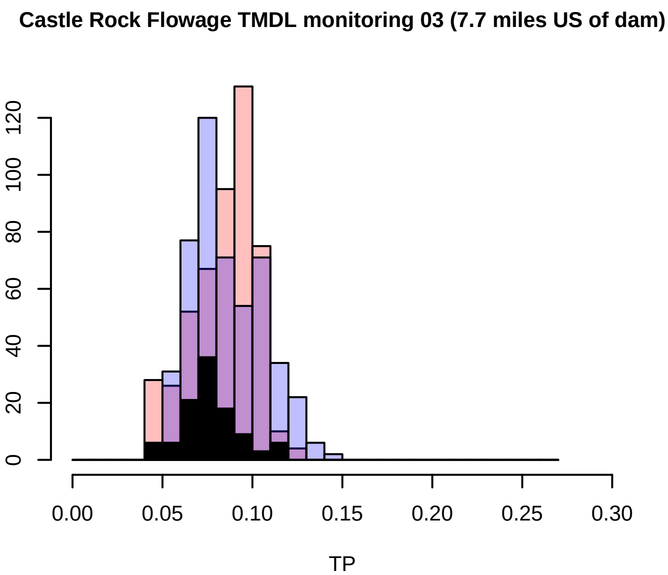

Petenwell Flowage TMDL monitoring 02 (4.7 miles US of dam)
0
20
40
60
80
100
120
0
20
40
60
80
100
120
CHLA

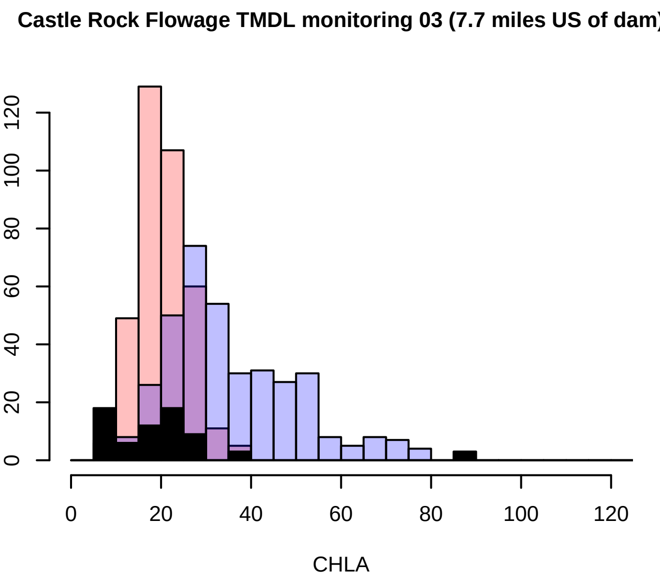

Petenwell Flowage TMDL monitoring 01 (1.8 miles US of dam)
0
50
100
150
0.00
0.05
0.10
0.15
0.20
0.25
0.30
TP

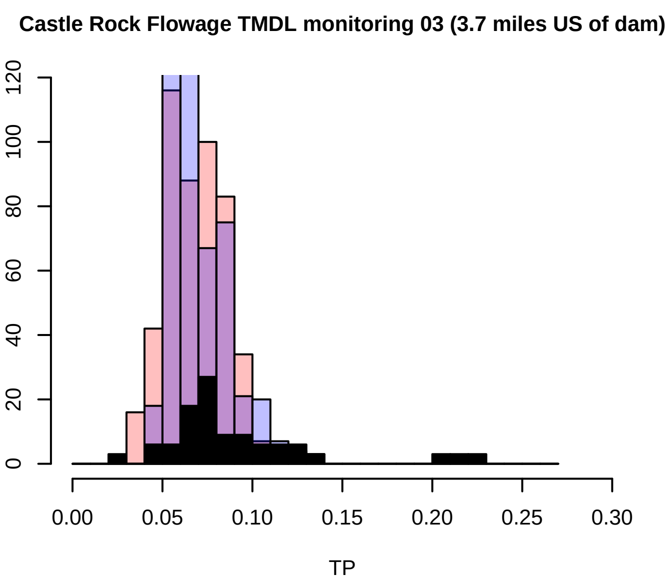

Petenwell Flowage TMDL monitoring 01 (1.8 miles US of dam)
0
20
40
60
80
100
120
0
20
40
60
80
100
120
CHLA

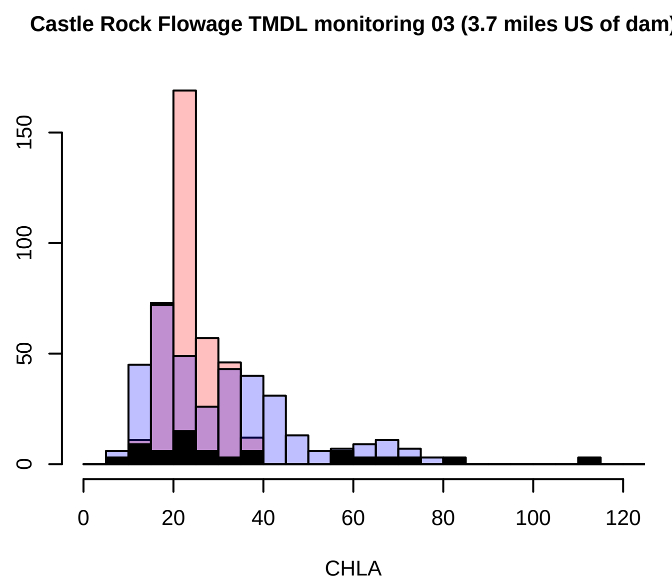

Wisconsin River − 200 Ft Blw Sth 21
0 20 40 60 80 100 120
0.00 0.05 0.10 0.15 0.20 0.25 0.30
TP


Wisconsin River − 200 Ft Blw Sth 21
0 50 100 150
0 20 40 60 80 100 120
CHLA

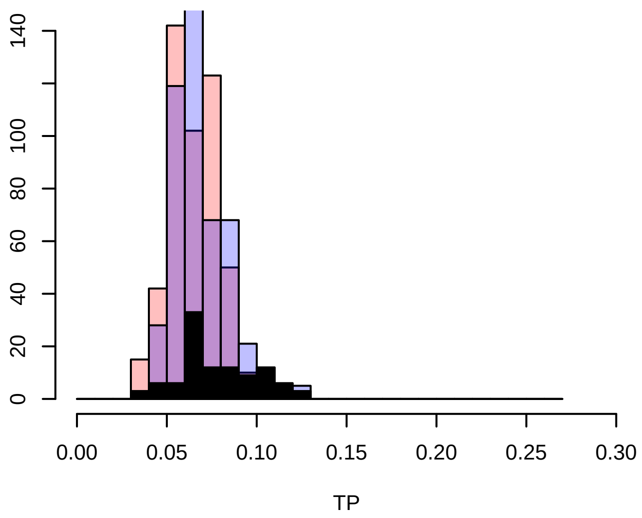

Castle Rock Flowage TMDL monitoring 03 (7.7 miles US of dam)
0 20 40 60 80 100 120
0.00 0.05 0.10 0.15 0.20 0.25 0.30
TP


Castle Rock Flowage TMDL monitoring 03 (7.7 miles US of dam)
0 20 40 60 80 100 120
0 20 40 60 80 100 120
CHLA

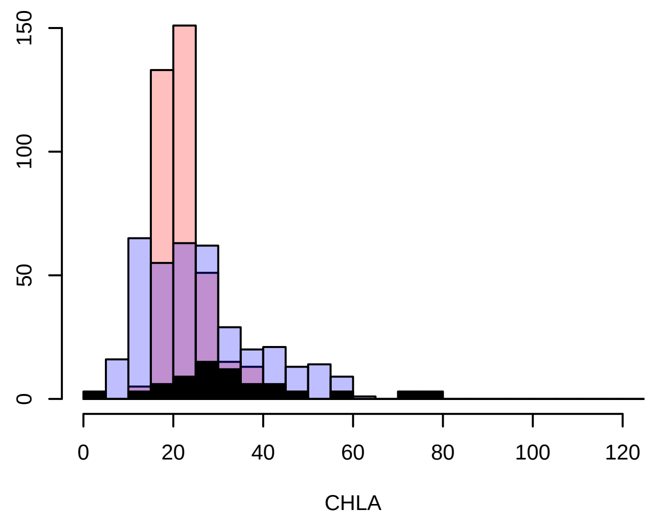

Castle Rock Flowage TMDL monitoring 03 (3.7 miles US of dam)
0 20 40 60 80 100 120
0.00 0.05 0.10 0.15 0.20 0.25 0.30
TP


Castle Rock Flowage TMDL monitoring 03 (3.7 miles US of dam)
0 50 100 150
0 20 40 60 80 100 120
CHLA

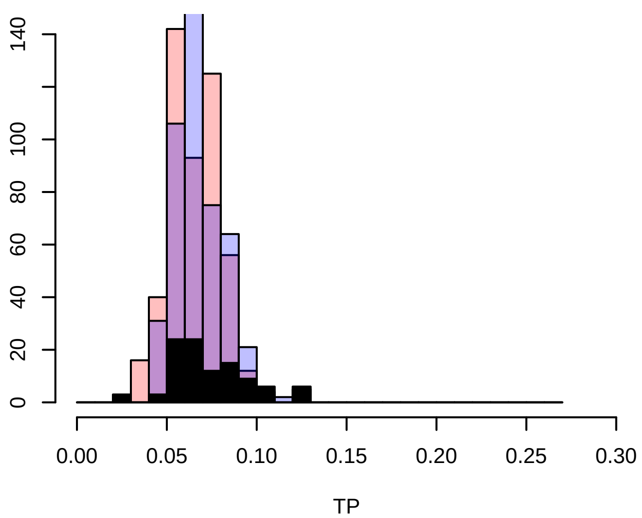
Castle Rock Flowage TMDL monitoring 03 (1 mile US of dam)



Castle Rock Flowage TMDL monitoring 03 (1 mile US of dam)



Wisconsin River − Castle Rock Dam



Wisconsin River − Castle Rock Dam