Lower Boise River Phosphorus

AQUATOX Model Report

State of Idaho
Department of Environmental Quality

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DRAFT

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Model Calibration

Two Assessment Units (AUs) of the lower Boise River, Middleton to Indian Creek and Indian Creek to the mouth, are currently §303(d)-listed due to excess nutrients in the form of Total Phosphorus (TP). Idaho DEQ, in consultation with the Environmental Protection Agency (EPA) and the Lower Boise Watershed Council (LBWC), is currently developing a Total Maximum Daily Load (TMDL) for the river to address phosphorus-related impairments. During this process, Idaho DEQ and the LBWC have identified a numeric nuisance aquatic algae target for the §303(d)-listed AUs of the lower Boise River: mean benthic chlorophyll a biomass (periphyton or attached algae) of $\leq$ 150 mg/m^2.

Aquatic biological communities respond to altered physical and chemical surroundings, making it more practical to measure biotic integrity than to measure all of the physical and chemical factors that can determine ecosystem integrity. The AQUATOX model represents the combined environmental fate and effects of pollutants such as nutrients in aquatic ecosystems. For the lower Boise River (LBR) study, this model is used to simulate attached algae biomass, or periphyton, in relation to environmental factors, including nutrient enrichment.

Periphyton and other biotic responses to nutrients often depend on temporally- and spatially-varying site specific characteristics such as temperature, water chemistry, light availability, and other environmental factors. Because these complex interactions are also evident on the lower Boise River, Idaho DEQ is utilizing the AQUATOX model as a means to effectively and efficiently help identify the quantitative relationships among site-specific water quality and ecological response indicators, including attached algae, for the development of phosphorus allocations in the TMDL. The current modeling effort will account for these complex relationships, while the relationships between nutrients and periphyton will be a primary focus of this modeling effort.

This model calibration is used as a tool to evaluate phosphorus loadings and other environmental conditions that will help to achieve the target of mean benthic chlorophyll a biomass (periphyton or attached algae) of $\leq$ 150 mg/m^2.

Modeling goals attained through the model calibration include:

- Achieving positive correlations between monthly modeled periphyton simulations and measured data
- Simulating mean monthly and annual periphyton biomass that is reflective of measured and historical data
- Simulating periphyton community compositions that is reflective of observed data and conceptual understanding of the biotic community
- Simulating time-series periphyton within the range of measured and historical data

The final model calibration error and goodness-of-fit is evaluated and described using multiple lines of evidence, including the examination of:

- Daily absolute mean error (AME) of the model output for periphyton chlorophyll a (mg/m^2) relative to measured values

- 15-day rolling means absolute mean error (AME) of the model output for periphyton chlorophyll a (mg/m^2) relative to measured values
- R^2 correlations between monthly mean simulated, measured, and historical periphyton biomass data
- Differences in the periphyton monthly mean simulated biomass relative to measured and historical data were calculated

2014_0414_TGS						
Daily Absolute Mean Error (AME):						
Segment	*1*	*3*	*8*	*9*	*13*	**Overall**
August	0.5	0.6	156.0	54.5	39.2	**50.2**
October	53.7	22.8	27.0	21.2	55.2	**35.9**
March	3.2	179.8	22.7	71.0	79.4	**71.2**
Overall	**19.1**	**67.7**	**68.5**	**48.9**	**57.9**	**52.4**
15-Day Rolling Average Absolute Mean Error (AME):						
Segment	*1*	*3*	*8*	*9*	*13*	**Overall**
August	0.6	51.3	153.3	46.2	42.2	**58.7**
October	54.0	22.7	24.8	87.3	54.0	**48.5**
March	3.6	180.7	23.8	73.0	75.0	**71.2**
Overall	**19.4**	**84.9**	**67.3**	**68.8**	**57.0**	**59.5**
Periphyton biomass correlations (R^2):						
Segment	*1*	*3*	*8*	*9*	*13*	
measured	-0.0022	+0.07485	+0.1406	+0.1666	+0.144	
historical	+0.1569	+0.0227	+0.0093	+0.2129	+0.0706	
Mean relative difference monthly simulated periphyton biomass, and measured and historical data:						
Segment	*1*	*3*	*8*	*9*	*13*	**Overall**
measured	14	187	132	191	112	**637**
simulation	22	101	167	157	72	**519**
% difference	**57%**	**-46%**	**26%**	**-18%**	**-36%**	**-18%**
historical	10	53	78	284	158	**584**
simulation	19	59	100	149	94	**420**
% Difference	**94%**	**10%**	**28%**	**-48%**	**-41%**	**-28%**
Simulated periphyton ranges relative to measured and historical data:						
Segment	*1*	*3*	*8*	*9*	*13*	
January			underpredicts		underpredicts	
February		overpredicts	overpredicts	underpredicts		

March	in range	underpredicts	in range	in range	underpredicts	
April		in range	in range			
May		in range	in range			
June		in range	in range			
July		in range	in range			
August	in range	in range	overpredicts	in range	in range	
September	in range	in range				
October	overpredicts	in range	in range	in range	in range	
November	in range	in range	in range	in range	in range	
December		in range	in range			
**Model simulations were within range of measured and historical data during 28 of 37 (76%) month-segment combinations.*						

Model Scenarios for TMDL

The reduction scenario that resulted in the combination of necessary periphyton reductions, while also meeting reasonable assurance criteria for the TMDL is:

- Point sources at 0.10 mg/L TP May – September and 0.35 mg/L October – April
- Tributaries and groundwater at 0.07 mg/L TP year-round
- Stormwater wet weather loads at a 42% reduction from current conditions

The conclusions of this modeling study of the relationship between TP and periphyton are that:

- Phosphorus reductions must be accompanied by associated nitrogen and carbon reductions to be effective at reduction of total periphyton biomass
- Periphyton is a complex community of algal groups and organic detritus that will respond to nutrient reductions and changes in physical parameters in a species-specific way
- When the TP reductions are fully implemented, there will be episodes when the 30-day average periphyton biomass exceeds the 150 mg/m^2 target in localized regions of the river, but averaging biomass over the listed assessment units will meet the target
- Implementing TP reductions for both point and nonpoint sources will have an environmental benefit for reduction of excess algal growth throughout the lower Boise River
- Changes in riparian habitat and channel geometry that decrease the width-to-depth ratio of the river, thus increasing depth of the water column, are beneficial for reducing light to the substrate and as a result help reduce and control excess periphyton growth
- Increasing channel depth has a localized habitat benefit and cannot be translated downstream
- For the reduction scenario, the average TP concentration for May through September is 0.05 mg/L for AU 005_06b and 0.06 mg/L for AU 001_06, which meet the 0.07 mg/L target at the mouth of the Boise River with an allowance for a margin of safety.

AQUATOX is a valuable tool for modeling the periphyton groups that make up the total periphyton chlorophyll a (mg/m^2) biomass. It is highly recommended that this model continue to be used in watershed management applications and implementation of the phosphorus TMDL.

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1 Introduction

This report documents the AQUATOX model calibration and subsequent scenarios for use in the lower Boise River (LBR) total phosphorus (TP) total maximum daily load (TMDL). The purposes for using AQUATOX in developing the LBR TP TMDL are to do the following:

1. Estimate nutrient-periphyton relationships in the LBR as a tool to help develop appropriate TP load and wasteload allocations to meet the nuisance aquatic growth target established to fully support beneficial uses in the two §303(d)-listed assessment units (AUs):
   - Boise River–Middleton to Indian Creek (ID17050114SW005_06b)
   - Boise River–Indian Creek to mouth (ID17050114SW001_06)
2. Further inform results obtained in the United States Geological Survey (USGS) mass balance model and report (Etheridge 2013) that were derived primarily from the USGS synoptic sampling event in the LBR subwatershed during August 2012, October 2012, and March 2013

The AQUATOX model application uses existing data as direct model inputs to assist in model calibration and refinement. The model calibration required extensive input, review, and revision of the input data, parameters, coefficients, and assumptions to the model. This work was led by the Idaho Department of Environmental Quality (DEQ) with extensive consultation and cooperation from the Lower Boise Watershed Council (LBWC) modeling workgroup. In addition, DEQ contracted with the AQUATOX model developers—Jonathan Clough (Warren Pinnacle Consulting) and Richard Park (Eco Modeling)—to provide model calibration review and oversight and other technical assistance.

1.1 Background

The LBR subbasin is identified in the Idaho water quality standards as hydrologic unit code 17050114 with 36 AUs and several site-specific standards described in IDAPA 58.01.02.140.12. As described in the LBR TMDL (DEQ 1999), the subbasin drains approximately 1,290 square miles of rangeland, forests, agricultural lands, and urban areas into the Snake River at the confluence between the cities of Adrian and Nyssa, Oregon. The LBR is a 64-mile stretch of river that flows through Ada County, Canyon County, and the city of Boise, Idaho. The river flows in a northwesterly direction from Lucky Peak Dam to its confluence with the Snake River near Parma, Idaho. Major tributaries include Fifteenmile Creek, Mill Slough, Mason Creek, Indian Creek, Conway Gulch, and Dixie Drain (Figure 1).

Narrative criteria for excess nutrients are described in in the Idaho water quality standards as follows:

> Surface waters of the state shall be free from excess nutrients that can cause visible slime growths or other nuisance aquatic growths impairing designated beneficial uses. (IDAPA 58.01.02.200.06)

Additionally, in consultation with the LBWC, DEQ has identified a numeric nuisance aquatic growth target for the impaired AUs of the LBR: mean benthic (periphyton) chlorophyll *a* biomass $\leq$ 150 milligrams per square meter (mg/m^2). Based on results from the AQUATOX modeling effort, the target location, duration, and frequencies questions will be further refined and nutrient-periphyton relationships will be used to help develop TP allocations for the TMDL. In other words, due to the paucity of periphyton data in many parts of the year (e.g. spring, summer, and winter), the model will help to identify when/where potentially high periphyton biomass may be occurring and the relationship with nutrients and other environmental factors. This will also help to inform when and where the target should be applied, and the associated TP reductions needed to meet that target.

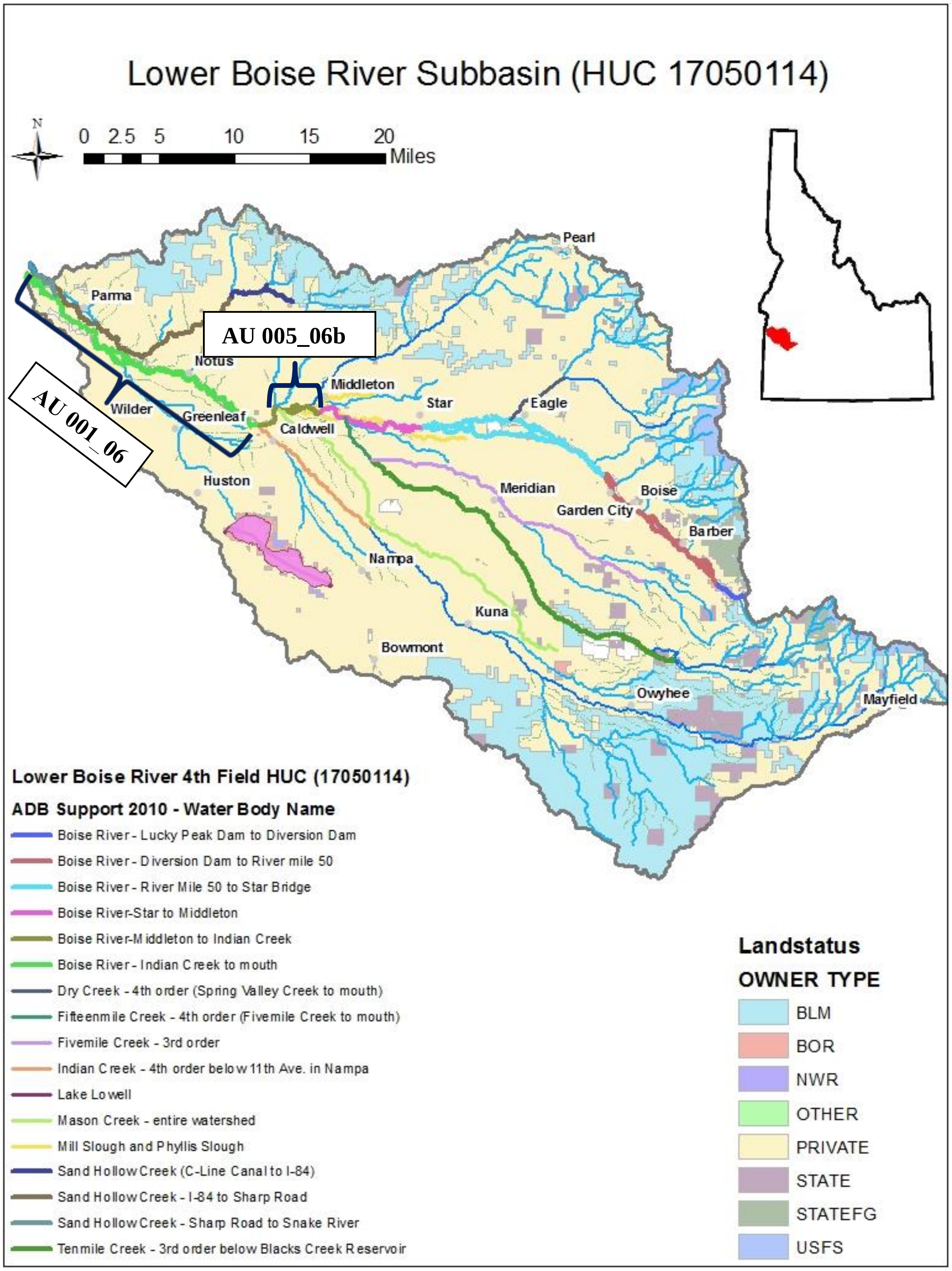


Figure 1. §303(d)-listed assessment units (AUs) of the lower Boise River that will be specifically addressed in the TMDL addendum with a numeric nuisance algae target (AUs begin with ID17050114).

The 2013 Water Environment Research Foundation (WERF) modeling guidance report speaks to the difficulty in developing nutrient targets:

> One of the highest-profile challenges facing states and the regulated community is the development of scientifically sound nutrient goals, such as TMDLs and site-specific numeric nutrient criteria. Goals must recognize that receiving water responses to nutrients depend on site specific characteristics (i.e., morphology, hydrology, turbidity, temperature, etc.), all of which vary in space and time. There is a need for practical, model-based approaches and guidance for deriving quantitative relationships between nutrient loads and site-specific water quality and ecological response indicators. (WERF 2013)

As such, QUAL2Kw and AQUATOX were considered two appropriate models for the analyses on the LBR. In consultation and coordination with the LBWC, technical advisory committee, and modeling workgroup, DEQ selected the AQUATOX model to help identify the nutrient-algae relationships in the LBR for several reasons:

1. AQUATOX is able to simulate the eutrophication variables of interest (such as dissolved oxygen (DO), pH, TP, and bottom-attached algal growth).
2. AQUATOX directly models scour and sloughing of periphyton due to environmental conditions, as well as the direct linkage between periphyton and phytoplankton (sestonic algae).
3. AQUATOX is a dynamic versus steady-state model.
4. DEQ can consult directly with the AQUATOX developers—Jonathan Clough (Warren Pinnacle Consulting, Inc.) and Richard Park (Eco Modeling)—to assist in model calibration and scenario development.
5. The AQUATOX model software was developed by the United States Environmental Protection Agency (EPA).
6. AQUATOX has been used and endorsed by LBWC members and consultants.
7. AQUATOX is lesser known and tested than QUAL2Kw but has been used for water quality assessments and regulation in various water bodies across the United States. For example, AQUATOX has been used to evaluate water quality and identify relationships among algae growth, nutrients, and other environmental factors for Cahaba River, phosphorus TMDL in Alabama, previously used to evaluate water quality objectives for the LBR (the modeling effort, however, did not result in the develop of a TMDL), and a number of other applications in the United States and abroad (Park et al. 2008).

Table 1 provides a comparison between the QUAL2Kw and AQUATOX models.

Table 1. QUAL2Kw and AQUATOX model comparison.

Model Simulation Capability	QUAL2Kw	AQUATOX
Attached Stream Algae	✓	✓
Substrate Limitation	✓	✓
Dynamic Hydraulics	✓	
Intracellular Nutrient Storage	✓	
Grazers		✓
Flow Stimulation Effects	✓	✓
Scour/Sloughing		✓
Multiple Algal Taxa		✓
Self-Shading		✓

Initially, to reduce the number of parameters and model uncertainty, grazers were not included in the LBR analysis. Additionally, during DEQ's visual assessment of the river in June and August 2013, there was little observed influence from grazers. DEQ acknowledges the existence of grazers in the river but recognized the importance of minimizing the number of model parameters to the extent practicable, given the limited data regarding their populations and grazing impacts in the LBR.

1.2 Model Segmentation

A 13-segment linked AQUATOX model setup was selected and evaluated for calibration (Figure 2-Figure 4). Pros and cons of more versus fewer model segments (e.g., model complexity, spatial scale analyses capabilities, and data sources) were evaluated and identified throughout the calibration process. Ultimately, the 13-segment linked option was selected, primarily for two reasons:

1. Although DEQ and the modeling workgroup considered calibrating the model with as few as 4 segments, the 13-segment version provided an appropriate localized spatial scale in which to evaluate periphyton and nutrient relationships and identify the potential impacts from point and nonpoint sources throughout the main stem LBR.
2. The 13-segment locations were refined to specifically correspond with the USGS sites used during the August 2012, October 2012, and March 2013 synoptic sampling in the LBR subwatershed (Figure 3 and Figure 4) (Etheridge 2013).

Through the model calibration, driving and similar variables that force the system to behave in certain ways (e.g., total suspended solids [TSS], pH, water temperature, DO, and water velocity) were modeled within the segment from which they were sampled. For example, data sampled at Veteran's Bridge (segment 3) were imported into segment 3 of the model.

Alternatively, observed nutrient, periphyton, and phytoplankton data collected at or near the downstream end of a segment were compared to model results for that upstream segment. For example, observed nutrient data sampled at Veteran's Bridge (bottom of segment 2, top of segment 3) were compared to model output from segment 2. However, all observed data that were not collected at or near an upstream segment break (i.e., they were collected well within a segment) were imported and compared to modeled data from within the segment where the data were collected.

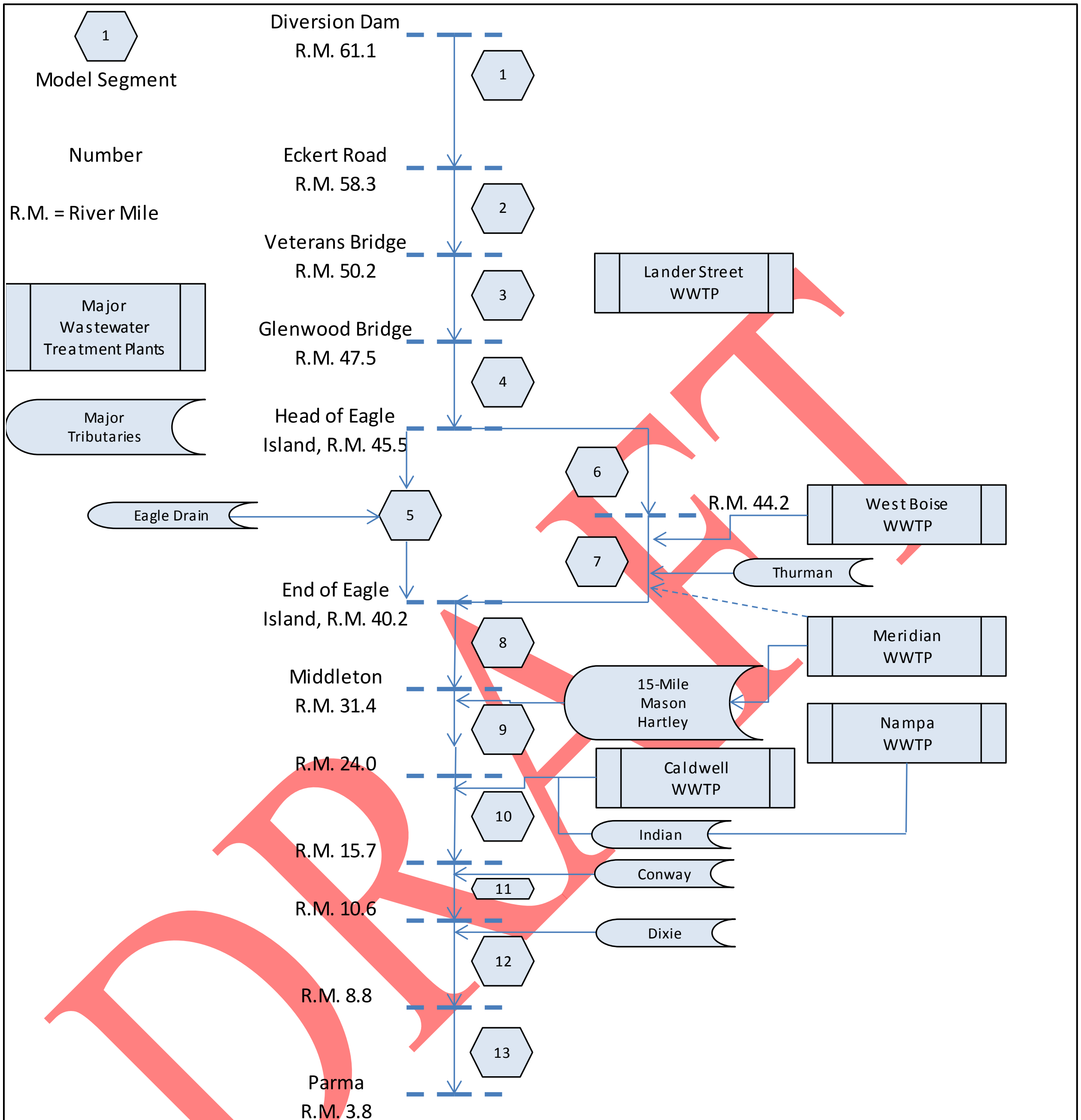


Figure 2. General model diagram of the 13-segment AQUATOX model calibration and scenarios used for the lower Boise River TP TMDL.

Segment	USGS River Mile	Location	Lat	Long	Site I.D.
1	***61.1***	Boise River at Diversion Dam	43.539617	-116.095037	USGS Site ID 13203510
	58.3	Ridenbaugh			
2	*58.3*	Eckert Road	43.565723	-116.132058	USGS Site ID 13203760
	57.5	Bubb			
	56.8	Meeves			
	56.4	Rossi Mill			
	56.1	United Water			
	55.9	Boise City Canal			
	52	Settlers			
	51.8	Fairview Acres			
	51.5	Boise City Parks			
	51.1	Thurman Mill			
	50.7	Boise Water Corp.			
	50.4	Farmers Union			
3	***50.17***	Boise River at Veteran's Parkway	43.63605833	-116.2411417	USGS Site ID 13205642
	50.01	Boise WWTP Lander			
	47.69	Riverside Village			
4	***47.5***	Boise River at Glenwood Bridge	43.66104167	-116.2796389	USGS Site ID 13206000
	46.01	New Dry Creek			
6	**45.51**	LOSS TO NORTH CHANNEL (Head of Eagle Island - channels split)	43.670434	-116.30753	GIS
	44.81	Lemp Ditch			
	44.5	Warm Springs Ditch			
7	**44.16**	Boise WWTP West Boise	43.672714	-116.331657	GIS
	43.5	Conway-Hamming			
	43.07	Aiken, Thomas			
	43.07	Mace-Catlin			
	42.85	Graham-Gilbert			
	42.8	South Channel			
	42.7	Wroten, Jon			
	42.4	Barber Pumps			
	42.02	Seven Suckers			
	41.89	Thurman Drain			
		IDFG Hatchery [S7]			
	41.78	Boise River abv Phyllis Diversion			
	41.41	Phyllis Canal			

Segment	USGS River Mile	Site - North Channel	Lat	Long	Site I.D.
5	**45.51**	Loss to N Channel	43.670434	-116.30753	GIS
	44	Ballentyne			
	42.8	Mace&Mace			
	42.8	Boise R N Channel			
	42.7	Eagle Drain @ Eagle			
	42.5	Dry Creek at Mouth			
	42.1	Hart-Davis			
	41.8	Boise River North Channel abv Middleton Canal			
	41.5	Middleton Irrigation Canal			
	41.4	Eagle Island Park			
	41.2	Little Pioneer			
	40.2	GAIN FROM N Chan			

Figure 3. The physical locations of AQUATOX segments 1 through 7, along with notable features such as the USGS sampling locations, major diversions, drains, tributaries, and wastewater treatment facilities throughout the length of the lower Boise River. River miles are identified according to the 2012 and 2013 USGS synoptic sampling locations (Etheridge 2013).

Segment	USGS River Mile	Location	Lat	Long	Site I.D.
8	**40.2**	GAIN FROM NORTH CHANNEL (Confluence of N. and S. Channels)	43.681375	-116.424625	GIS
	39.65	Boise River Below Eagle Island			
	36.63	Eureka #1 Return			
	36.4	Boise River NR Star			
	36.32	Canyon (County) Canal			
	36.27	Caldwell High Line			
	35.74	Otter Mitigation			
9	***31.43***	Boise River NR Middleton	43.68703889	-116.5867694	USGS Site ID 13210050
	30.31	Fifteen Mile Mouth (includes 5mile and Meridian WWTP + 10mile)			
	28.84	Boise River at Middleton Rd			
	27.93	AU ID17050114SW005_06b	43.69143	-116.626776	DEQ
	27.23	Mill Slough (includes Star WWTP)			
	27.1	Middleton WWTP			
		N. Midd. Drain [S9]			
		S. Midd. Drain [S9]			
	26.95	Willow Creek @ Middleton			
	25.57	Mason Slough			
	24.95	Mason Creek - USGS name			
	24.57	Riverside			
	24.43	Hartley (Combined)			
	24.03	Sebree			
	24.02	Campbell			
10	***23.98***	Boise River at HWY 20-26 Crossing	43.68898056	-116.6862333	USGS Site ID 13211000
	23.19	Shipley Pumps			
	23.09	Wagner Pumps			
	22.55	Caldwell WWTP			
	22.44	AU ID17050114SW001_06	43.677534	-116.705394	DEQ
	22.44	Indian Creek (includes Nampa)			
	21.43	Boise River Blw Caldwell WWTP			
	20.08	Simplot Pumps			
	20.08	Eureka No.2			
	20.08	Upper Center Point			
	20	McManus-Teater			
	19.07	Vale Pumps			
	18.06	Lower Center Point			
11	***15.66***	Boise River at Notus	43.720875	-116.7980028	USGS Site ID 13212500
	14.98	Bowman & Swisher			
	14.22	Conway Gulch @ Notus			
	13.33	Baxter Canal			
	12.33	Unnamed Drain Near Notus			
	11.09	Andrews Ditch			
	10.93	Unnamed Drain Near Dixie Drain			
12	10.6	Above Dixie Drain	43.732245	-116.889004	GIS
	10.53	Dixie Drain Near Wilder Measured			
	10	Mammon Pumps			
13	***8.77***	Boise River at HWY 95 Crossing	43.74721111	-116.9124611	USGS Site ID 13212900
	8.05	Hass Canal			
	7.47	Parma Canal			
	6.33	Island High Line			
	4.32	Crawforth Pumps			
	3.91	McConnel Island			
END	***3.8***	Parma	43.78150833	-116.9727944	USGS Site ID 13213000

Figure 4. The physical locations of AQUATOX segments 8 through 13, along with notable features such as the phosphorus-impaired Assessment Units (AU), USGS sampling locations, major diversions, drains, tributaries, and wastewater treatment facilities throughout the length of the lower Boise River. River miles are identified according to the 2012 and 2013 USGS synoptic sampling locations (Etheridge 2013).

1.3 Model Calibration Period

The model calibration period was selected as January 1, 2012, through April 22, 2013. This 16-month simulation period was selected, primarily, for the following reasons:

1. The model calibration allows for up to a 4-month model spin-up period, if necessary (January 1–April 22, 2012), while still leaving one full year (April 23, 2012–April 22, 2013) to model nutrient-periphyton relationships.
2. The model calibration period includes the May 1–September 30 target, identified in the Snake River-Hells Canyon TMDL and the October 1–April 30 nonirrigation season.
3. The model calibration period focuses on recent conditions and fully utilizes the data collected by the USGS during the August 2012, October 2012, and March 2013 synoptic sampling in the LBR subwatershed (Etheridge 2013).

2 Data Sources and Conditions

The ecosystem model in AQUATOX consists of multiple components requiring input data. *Driving variables*, such as water temperature, pH, and TSS serve to *drive* various model processes (e.g., force the system to behave in certain ways). Alternatively, *state variables* are simulated by the model and can be compared to modeled output. Whenever possible, dynamic or varying time-series data were entered as state and driving variables in the calibrated model.

2.1 Data Sources and Sample Locations

Each of the input model files is open to the public for review and analyses. The model calibration, import files, and other documentation are available from DEQ upon request:

1. AQUATOX Model
    a. 2014_0203_ATX_LBR_Linked_Existing Conditions_DDS.als

2. Import Files
    b. 2014_0124_ATX_LBR_Linked_EC_DDS.xls

3. Other data files used in model calibration:
    c. LBR_USGS_nutrient_sed_chla.xls
    d. USGS_Synoptic_Algae.xlsx
    e. 2013_1127 Copy of BOR parma_water_temp_interpolated.xls
    f. B River water temperatures.xlsx
    g. Dixie data request 090413.xlsx
    h. COB river and plant data_0513b.xlsx
    i. Caldwell WWTP flows 2012 to current.xlsx
    j. Eagle.FH.Water.Use.04.26.13.xls
    k. Middleton WWTP Data for LBR TMDL Modeling_2013_0712.xlsx
    l. LBRWQP 2013_0627.xlsx
    m. LBRWQP & NWIS River & Drains.xlsx
    n. Copy of Hydraulic Calcs BCN Edits 04-06.xlsx
    o. Light.xls
    p. Indian Creek Flows at Caldwell.xlsx
    q. 2013_0925_Site Data_dds.xlsx
    r. LBR Visual Assessment Summary.xlsx
    s. 2013_0904_ATX_LBR_Linked_EC_FlowSetup_HDR.xlsx
    t. 2013_1011_Depth Discharge calibration_JSC.xls
    u. 2013_1011_ATX_ZMean_Import_JSC.xls
    v. 2005-2007 Periphyton Community Composition.xls
    w. Boise River nr Middleton measurements_Idaho Power.xlsx
    x. Velocity data for LBR HUC.xlsx
    y. 2014_0131_ATX_TSS_Import_DDS.xls

The majority of information and physical, organic, and inorganic constituent data used in the model calibration were obtained under two broad categories (Table 2).

1. Previously collected field and laboratory data, including the following:
    - National Water Information System (NWIS) and other data collected by the USGS, and DEQ and LBWC-supported sampling conducted by the USGS, including three synoptic sampling events in the subwatershed in August and October 2012 and March 2013 (Etheridge 2013)
    - United States Bureau of Reclamation (USBR) AgriMet/HydroMet data
    - Idaho Department of Water Resources streamflow data

    - Point source discharge data collected by National Pollutant Discharge Elimination System (NPDES) permittees (Cities of Boise, Caldwell, and Middleton) using EPA-approved protocols (e.g., 40 CFR 136) and quality assurance procedures. (Note that Idaho is not a delegated state; therefore, the NPDES permits are issued by EPA and mandate EPA-approved sampling and analysis procedures.)
    - Data collected by the City of Boise at various locations along the LBR
    - Data collected by the Riverside Irrigation District at Indian Creek
2. Best professional judgment by DEQ personnel, modeling workgroup participants, and DEQ consultants Jonathan Clough and Richard Park, including the following:
    - Peer-reviewed scientific literature
    - Technical reports and draft or unpublished data
    - Best professional judgment based on field, modeling, and scientific expertise resulting in derived data

Numerous types of data were used during the modeling process, including, but not limited to, the following:

- Physical constituents—water volume (surface flow), ground water flow and concentration, slope and channel widths, dynamic mean depth, water velocity, riffle-run-pool characteristics, channel substrate, light, water temperature, wind, and shade
- Inorganic constituents—sediment, pH, nitrogen, phosphorus, oxygen, and carbon dioxide
- Organic constituents—algal groups (periphyton, phytoplankton) and detritus

Further documentation of data used in the AQUATOX model is available in the quality assurance project plan (DEQ 2014).

Table 2. Primary sampling locations where data were collected and used for the model calibration period from January 1, 2012, through April 22, 2013. A more-detailed list of water quality data used in the model calibration, by segment, is available in Appendix A.

Model Segment	River Mile[a]	USGS Sites and Point-Source Facilities	Parameters
1	61.1	13203510 BR Diversion Dam	Velocity, TSS, Nutrients, DO
2	58.3[b]	13203760 BR Eckert Road	Temp, pH, TSS, Peri, Phyto, Algae Communities
	55.0	BR Marden Bridge	Temp
3	50.17	13205642 BR Veteran's Parkway	Velocity, Temp, TSS, Nutrients, DO, Algae Communities
	50.01	Lander WWTF	Nutrients, DO, BOD,
4	47.5	13206000 BR Glenwood Bridge	Velocity, Temp, pH, TSS, Nutrients, DO, Peri, Phyto, Algae Communities
5	42.8	13206300 BR N Channel (Eagle)	Velocity, TSS, Nutrients, DO
	42.7	13206400 Eagle Drain	Nutrients, DO,
	41.8	13208600 BR N Channel Middleton	Velocity, Nutrients, DO,
7	44.16	West Boise WWTF	Nutrients, DO, BOD,
	42.8	13206305 BR S Channel	Velocity, Temp, pH, TSS, Nutrients, DO,
	41.89	13208750 Thurman Drain	Nutrients, DO
	41.78	13208800 BR Phyllis Diversion	Velocity, Nutrients, TSS
	41.7[b]	IDFG Eagle Island Fish Hatchery	Nutrients
8	36.4	13210000 BR Star Bridge	Velocity, TSS, Nutrients, DO,
9	31.43	13210050 BR Middleton	Velocity, Temp, pH, TSS, Nutrients, DO, Peri, Phyto, Algae Communities
	30.31	13210815 15 mile Creek	Nutrients, DO
	28.84	13210820 BR Middleton Road	Velocity
	27.23	132108247 Mill Slough	Nutrients, DO
	27.1	Middleton WWTF	Nutrients, DO, BOD
	26.95	13210835 Willow Creek	Nutrients, DO
	25.57	13210983 Mason Creek	Nutrients, DO
	24.43	13210988 Hartley Drain	Nutrients, DO
10	23.98	13211000 BR Hwy 20-26	Velocity, TSS, Nutrients, DO, Peri, Phyto, Algae Communities
	25.55	Caldwell WWTF	Nutrients, BOD, DO
	22.44	13211445 Indian Creek	Nutrients, DO
	21.43	13211600 BR Caldwell WWTF	Velocity, Nutrients, DO
11	15.66	13212500 BR Notus Bridge	Velocity, TSS, Nutrients, DO
	14.22	13212550 Conway Gulch	Nutrients, DO
12	10.53	13212890 Dixie Drain	Nutrients, BOD, DO
13	8.77	13212900 BR Hwy 95	Velocity, TSS, Nutrients, DO
	3.8	13213000 BR Parma	Velocity, Temp, pH, TSS, Nutrients, DO, Peri, Phyto, Algae Communities

Wastewater treatment facility (WWTF); total dissolved solids (TSS); dissolved oxygen (DO); biochemical oxygen demand (BOD)
a. River miles are identified according to the 2012 and 2013 USGS synoptic sampling locations (Etheridge 2013).
b. Estimate-Marden Bridge and IDFG Eagle Island Fish Hatchery not assigned river mile during USGS synoptic sampling 2012-13.

2.2 Physical Characteristics

Updated site data, including average temperature, temperature range, latitude, altitude, average light, annual light range, and baseline percent embeddedness are available, including references, are shown in Table 3 and available in the spreadsheet, “2013_0925_Site Data_dds.xlsx”.

Table 3. Site data for the LBR used in the AQUATOX model calibration.

Segment	1	2	3	4	5	6	7	8	9	10	11	12	13
Max length for reach (km)	4.506	13.084	4.297	3.203	8.546	2.173	6.373	14.114	11.99	13.39	8.143	2.945	7.998
Slope m/m <or blank>	0.0023	0.0024	0.002	0.0025	0.0013	0.0013	0.0023	0.0024	0.0015	0.0015	0.0015	0.0015	0.0015
Average temperature (°C)	5.47	5.47	7.99	8.61	8.61	9.27	9.27	9.27	9.6	9.6	9.6	9.6	9.6
Temperature range (°C)	14.08	14.08	18.04	18	18	17.73	17.73	17.73	21.2	21.2	21.2	21.2	21.2
Latitude	43.545	43.566	43.636	43.661	43.670	43.670	43.673	43.681	43.687	43.689	43.721	43.732	43.747
Altitude (m)	848	821	802	793	777	787	774	751	726	708	693	684	670
Average light (Langleys/day)	379	379	379	379	379	379	379	379	379	379	379	379	379
Annual light range (Langleys/day)	715	715	715	715	715	715	715	715	715	715	715	715	715
Mean evaporation (in./yr)	630	630	630	630	630	630	630	630	630	630	630	630	630
Baseline percent embeddedness (%)	51	18	8	5	17	4	21	18	15	17	17	18	18
Shade	0.05	0.1	0.15	0.15	0.15	0.15	0.15	0.1	0.05	0.05	0.05	0.05	0.05

Descriptions and data sources for Table 3.

Max length for reach (kilometers)	Model schematic Troy Smith
Slope m/m <or blank>	2013_0715_ATX_LBR_ModelInputGraphs_ExistingCondition_MK.xlsx
Average temperature (°C)	City of Boise Data
Temperature range (°C)	City of Boise Data
Latitude	Model schematic Troy Smith
Altitude (meters)	DEM 10 m DSharp
Average light (Langleys/day)	*http://www.usbr.gov/pn/agrimet/webarcread.html*
Annual light range (Langleys/day)	*http://www.usbr.gov/pn/agrimet/webarcread.html*, Initial conditions = 187 Ly/d
Mean evaporation (inches per year)	*http://www.wrcc.dri.edu/htmlfiles/westevap.final.html*
Baseline percent embeddedness (%)	DEQ 2013 visual assessment
Shade	Professional judgment (Troy Smith) based on Freshwater Trust data and Mark Shumar analyses

2.2.1 Initial Conditions

To begin the model calibration, initial conditions from the previous LBR AQUATOX exercise and report (CH2M Hill et al. 2008) were utilized as a starting point. The AQUATOX feature, "run model in spin-up mode" was then used to establish initial conditions for biota, nutrients, and suspended and bed sediments for the 2012 and 2013 current conditions (p. 41 AQUATOX User's Manual, Park and Clough 2012a). DEQ ran the spin-up mode from 1/1/2012 through 1/1/2013 and the values simulated on the last time-step of the simulation are automatically overwritten in the input file to be used as initial conditions.

The model calibration allowed for up to a 4-month model spin-up period, if necessary (January 1–April 22, 2012), while still leaving one full year (April 23, 2012–April 22, 2013) to model nutrient-periphyton relationships. However, using the spin-up mode eliminated the need for a full four month spin-up period. For the final model calibration, DEQ determined that only a 1-month model spin-up period was necessary and modeled simulations for use in the TMDL should begin on February 1, 2012. Further, during the calibration process, Jonathan Clough provided the following quote from the soon to be released EPA frequently asked questions document:

> Because stream retention times are generally short, the model is not sensitive to initial conditions in streams, except for the sediments (including toxicants within the sediments). If you are modeling a stream the initial conditions in the water column are immaterial because upstream loadings will replace them fairly rapidly anyway.

The initial conditions in the final model calibration differ according to segment, which enhances model performance over utilizing the same initial conditions for each segment (Table 4).[1] This table shows the initial conditions for segment 1 only, but these initial conditions vary in each segment for the current 2012-2013 model calibration, providing a more realistic starting point over utilizing the same default conditions for each segment.

[1] Additionally, DEQ found a heritage issue with the model, in that all of the same initial conditions—that should have been loaded only into model segments 1 through 13—were also loaded into all of the linked sources, including groundwater and point sources.

Table 4. State variable initial conditions used for AQUATOX model simulations in 2008 (CH2M Hill et al. 2008) and in the current January 2012–April 2013 model calibration.

State Variable Name	Initial Conditions in 2008 Model[1]	Initial Conditions in 2012–2013 Model[2]	Units
NH3 and NH4+	0	0.005601101	mg/L
NO3	0.06	0.059606372	mg/L
Tot. Sol. P	0.01	0.009251071	mg/L
CO2	0.5	0.750296454	mg/L
Oxygen	13	7.96433435	mg/L
TSS	5.15	3.021538781	mg/L
R detr sed	1	0.018598429	g/m^2
L detr sed	0.3	0.608978407	g/m^2
R detr diss	0.39130434	0.568666274	mg/L
L detr diss	1.56521739	0.379110849	mg/L
R detr part	0.04357826	0.063185142	mg/L
L detr part	0.17391304	0.042123428	mg/L
BuryRDetr	2	2	kg/m
BuryLDetr	1	1	kg/m
Peri Low-Nut Diatom	0.0024	1.3	g/m^2
Peri High-Nut Diatom	0.22	1.00E-05	g/m^2
Phyt High-Nut Diatom	0.02	1.00E-05	mg/L
Phyt Low-Nut Diatom	0.1	0.100119381	mg/L
Cladophora	0.0009	1.00E-05	g/m^2
Peri, Green	0.0015	0.0001	g/m^2
Phyto, Green	0.015	1.00E-05	mg/L
Phyt, Blue-Greens	0	0.001	g/m^2
Peri, Blue-Greens	0	1	g/m^2
Temperature	5	2.6	°C
Wind	1	1	m/s
Light	182	187	Ly/d
pH	7.4	7.2	pH

Notes: total dissolved solids (TSS) milligrams per liter (mg/L); grams per square meter (g/m^2); kilograms per cubic meter (kg/m^3); cubic meter (m^3); meters per second (m/s); Langleys per day (Ly/d)
[1]Initial conditions were the same for each model segment.
[2]Initial conditions for model segment 1. Initial conditions vary for each model segment 2 through 13.

Numerous specific data inputs were used to represent boundary and dynamic conditions in AQUATOX for the January 1, 2012–April 22, 2013 model calibration period. The entire set of inputs, boundary conditions, and observed data can be viewed via the calibrated model, import spreadsheet, and supporting data (see file list in section 2.1).

2.2.2 Morphometry

2.2.2.1 Water Volume

Volume is a state variable and can be computed in several ways depending on availability of data and the site dynamics. In the calibrated model, the daily volume values and flow rate calculations were developed by Michael Kasch (HDR, Inc.) and are available in the spreadsheet, “2013_0904_ATX_LBR_Linked_EC_FlowSetup_HDR.xlsx.”

Data sources for the water balance calculations were obtained from the following:

- National Water Information System: Web Interface, USGS Surface-Water Daily data for the Nation: *http://waterdata.usgs.gov/nwis/dv/?referred_module=sw*
- USBR Pacific Northwest Region/ HydroMet/AgriMet System Data Access: *http://www.usbr.gov/pn/hydromet/arcread.html*
- Idaho Department of Water Resources, Water Rights Accounting: *http://maps.idwr.idaho.gov/qWRAccounting/WRA_Select.aspx*

In the spreadsheet, water volume in each model segment and the flows into and out of the segment, are computed for each day. In the model, the volume is used for the initial condition, and the flows are included as inflows, withdrawals, or flow between segments. The inflows and outflows include withdrawals (56), tributaries (4), drains and sloughs (12), and point sources (5) with the total of each shown in parentheses. Four of the segments correspond with the location of a USGS gage. For these segments, the difference between the upstream flow and USGS record was included as the unaccounted flow (also generally assumed as ground water). The unaccounted flow was included in the same segment as the location of the gage except for the gage at Parma. The unaccounted flow based on the Parma gage was apportioned between the lowest four segments (10 through 13). The water balance spreadsheet includes over 160 columns of supporting flow calculations and direct inputs to the model. While the LBR is a complex flow system, the water balance was determined to provide a representation of the major inflows and withdrawals based on the available historical data. A simplified representation of the flow-balance structure is provided in Figure 5, while Figure 6 and 7 illustrate model simulated discharge versus measured flow at Glenwood and Parma during the model calibration period.

KEY TO THIS WORKSHEET
Observation Points or Streamflow Gaging Locations for references on Data Sources see README tab
Provisional Streamflow Data
Withdrawals
Sum of Withdrawals for Segment
Inputs / Drains
Calculated Flows due to lack of Gage Data
R.D Schmidt Winter Time Drain Flow Calculations
Segment Inflow or Outflow
Calculated Values, for equations see README tab
Estimated values shown in RED

							Segment 1 Upstream Inflow						Segment 1 Outflow
Data Source:			USGS	USBR	IDWR	IDWR	Calc'd	IDWR	IDWR	IDWR	Calc'd	Calc'd	Calc'd
			Boise River near Boise	LUC Lucky Peak Lake near Boise	Old Pen Canal 2995	New York Canal 3000	Segment 1 Inflow	Suprise Valley/ Micron 3527	Shake-speare Festival 3715	Riden-baugh Canal 3760	Total Withdrawal for Segment 1	Volume (ft3)	Segment 1 Outflow
Date	Year	Julian	13202000	QD	13202995	13203000	IN	13203527	13203715	13203760		2,650,954	OUT

Segment 2															
															Segment 2 Outflow
IDWR	IDWR	IDWR	IDWR	IDWR	IDWR	IDWR	IDWR	IDWR	IDWR	IDWR	IDWR	IDWR	Calc'd	Calc'd	Calc'd
Bubb Canal 4005	Herrick Well 4015	Meeves Canal 4020	Rossi Mill Canal 4060	River Run Canal 4070	Boise City Canal 4190	United Water 4200	Settler's Canal 5515	Davis Canal Fairview Acres 5517	Boise City Parks Canal 5613	Drainage District #3 5617	Thurman Mill Canal 5622	Farmers Union Canal 5640	Total Withdrawal for Segment 2	Volume (ft3)	Segment 2 Outflow
13204005	13204015	13204020	13204060	13204070	13204190	13204200	13205515	13205517	13205613	13205617	13205622	13205640		5,664,190	OUT

Segment 3									
COB								Segment 3 Outflow	
Plant Data	USGS	Calc'd	Calc'd	Calc'd	Calc'd	Calc'd	Calc'd	Calc'd	Calc'd
Lander Street WWTF	River @ Glenwood USGS	River @ Glenwood calculated	Glenwood Delta calc vs USGS %	Unaccounted (Ground-water)	(Ground-water) Input	(Ground-water) Withdrawal	(Ground-water) Withdrawal	Volume (ft3)	Segment 3 Outflow
Lander	13206000							1,857,050	OUT

Segment 4				
			Segment 4 Outflow	
IDWR	Calc'd	Calc'd	Calc'd	Calc'd
New Dry Creek Canal 6090	(Ground-water) Input	Total Withdrawal for Segment 4	Volume (ft3)	Segment 4 Outflow abv Eagle Island
13206090			1,280,415	OUT

Eagle Island Split Calculations		Segment 6					
						Segment 6 Outflow	
Calc'd	Calc'd	IDWR	IDWR	Calc'd	Calc'd	Calc'd	Calc'd
Eagle Island S. Channel split	Eagle Island N. Channel Split	Lemp 1&2 Canal 6205	Warm Springs Canal 6220	Total Withdrawal for Segment 6	(Ground-water) Input	Volume (ft3)	Segment 6 Outflow
South	North	13206205	13206220			1,179,730	OUT

Segment 7

IDWR	IDWR	IDWR	IDWR	USGS	Calc'd	Calc'd	Calc'd	Calc'd	Calc'd	IDWR	IDWR	COB Plant Data	IDWR		IDWR	Calc'd	Calc'd (Segment 7 Outflow)	Calc'd
Graham-Gilbert Canal 6260	Conway-Hamming Canal 6270	Thomas Aiken Canal 6290	Mace-Catlin Canal 6292	S. Channel @ Eagle Br 6305	S. Channel @ Eagle Br calculated	S. Channel Delta calc. vs USGS %	Unaccounted (Ground-water)	(Ground-water) Input	(Ground-water) Withdrawal	Barber Pumps 8738	Seven Suckers Canal 8740	West Boise WWTF	Thurman Drain 9450	IDFG Eagle Fish Hatchery	Phyliss Canal 9480	Total Withdrawal for Segment 7	Volume (ft3)	Segment 7 Outflow
13206260	13206270	13206290	13206292	13206305	calc.					13208738	13208740	WB WWTF	13209450		13209480		2,365,424	OUT

Segment 5

IDWR	IDWR	IDWR	IDWR	IDWR	IDWR	Calc'd	Calc'd	Calc'd	Calc'd (Segment 5 Outflow)	Calc'd
Ballentyne Canal 6265	Mace & Mace Canal 6295	Eagle Drain 6400	Hart Davis Canal 8450	Middleton Canal 8710	Little Pioneer Canal 9630	Total Withdrawal for Segment 5	Volume (ft3)	Pre Segment 5 Outflow Calc	(Ground-water) Input	Segment 5 Outflow
13206265	13206295	13206400	13208450	13208710	13209630		2,105,146			OUT

Segment 8

IDWR	IDWR	IDWR	Calc'd	Calc'd	Calc'd	Calc'd	Calc'd	Calc'd (Segment 8 Outflow)	Calc'd
Canyon County Canal 9990	Caldwell Highline Canal 10005	Middleton Gage from IDWR 10050	Middleton Gage Calculated	Middleton Delta calc. vs IDWR %	Unaccounted (Ground-water)	(Ground-water) Input	Total Withdrawal for Segment 8	Volume (ft3)	Segment 8 Outflow
13209990	13210005	13210050	calc.					5,445,703	OUT

Segment 9

		IDWR	IDWR	IDWR	IDWR	IDWR	IDWR	IDWR	IDWR	IDWR	IDWR	IDWR	Calc'd	Calc'd (Segment 9 Outflow)	Calc'd
Fifteenmile Creek Meridian WWTF	Middleton WWTF	Mill Slough N Middleton Drain 10824	Star Feeder 10826	Long Feeder 10828	Watts Check 10829	South Middleton Drain 10831	Willow Creek 10835	Mason Creek 10849	Mason Drain 10980	Riverside Canal 10984	West Hartley Gulch 10986	Hartley Drain 10988	(Ground-water) Input OTHERS	Volume (ft3)	Segment 9 Outflow
		13210824	13210826	13210828	13210829	13210831	13210835	13210849	13210980	13210984	13210986	13210988		8,754,878	OUT

Segment 10

									Segment 10 Outflow	
IDWR	IDWR	IDWR	IDWR	IDWR	IDWR		Calc'd	Calc'd	Calc'd	Calc'd
Sebree Canal 10992	Campbell Canal 10993	Siebenberg Canal 10994	Shipley Pumps 11001	Wagner Pumps 11003	Caldwell WWTF	Indian Creek (blw Riverside div) Nampa WWTF 11445	(Ground-water) Input	Total Withdrawal for Segment 10	Volume (ft3)	Segment 10 Outflow
13210992	13210993	13210994	13211001	13211003		13211445			2,875,304	

Segment 11

											Segment 11 Outflow	
IDWR	IDWR	IDWR	IDWR	IDWR	IDWR	IDWR	IDWR	Calc'd	Calc'd	Calc'd	Calc'd	Calc'd
Simplot Pumps 11603	Eureka #2 Canal 11725	Upper Center Point Canal 11735	McManus and Teater Canal 11745	Atwell Ditch 11747	Lower Center Point Canal 11825	Bowman and Swisher Canal 12548	Conway Gulch 12550	Total Withdrawal for Segment 11	Volume (ft3)	Pre Segment 11 Outflow	(Ground-water) Input	Segment 11 Outflow
13211603	13211725	13211735	13211745	13211747	13211825	13212548	13212550		6,617,482			

Segment 12

					Segment 12 Outflow	
IDWR	IDWR	IDWR	Calc'd	Calc'd	Calc'd	Calc'd
Baxter Canal 12645	Andrews Canal 12832	Dixie Slough 12890	(Ground-water) Input	Total Withdrawal for Segment 12	Volume (ft3)	Segment 12 Outflow
13212645	13212832	13212890			6,406,619	

Segment 13

													Segment 13 Outflow	
IDWR	IDWR	IDWR	IDWR	IDWR	IDWR	USGS	Calc'd	Calc'd	Calc'd	Calc'd	Calc'd	Calc'd	Calc'd	Calc'd
Mammon Pumps 12896	Haas Canal 12938	Parma Canal 12954	Island Highline Canal 12966	Crawforth Pumps 12992	McConnel Island Canal 12994	Boise River @ Parma USGS Flows 13000	Parma Gage Calculated	Parma Delta calc. vs USGS %	Unaccounted (Ground-water)	(Ground-water) Input	(Ground-water) Withdrawal	Total Withdrawal for Segment 12	Volume (ft3)	Segment 13 Outflow
13212896	13212938	13212954	13212966	13212992	13212994	13213000	calc.						7,515,775	

Figure 5. Simplified representation of the water flow balance structure used in the AQUATOX model. The entire flow balance spreadsheet is available from DEQ as "2013_0904_ATX_LBR_Linked_EC_FlowSetup_HDR.xlsx."

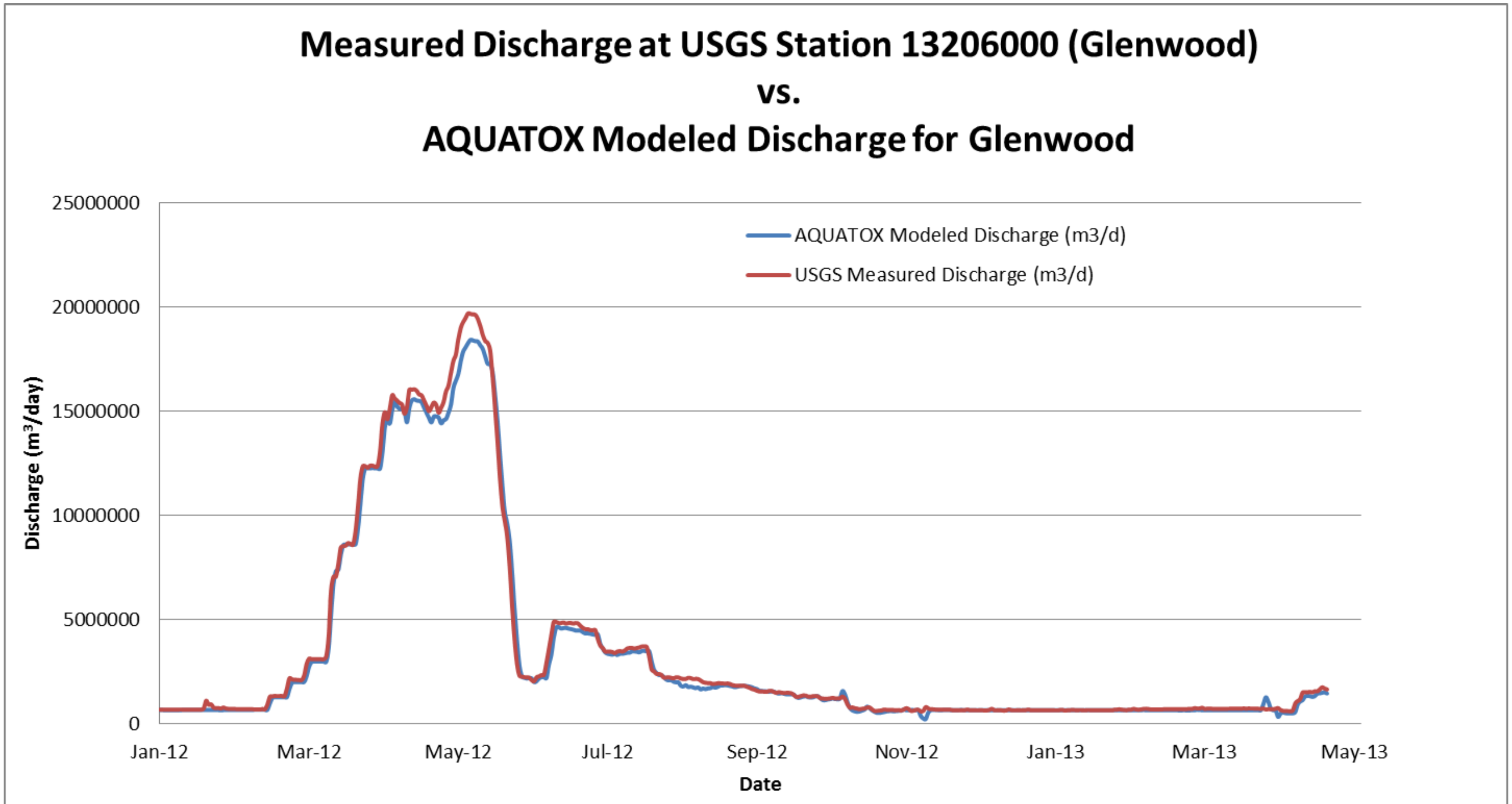


Figure 6. Model-simulated discharge versus measured discharge at Glenwood during the 2012–2013 model calibration period.

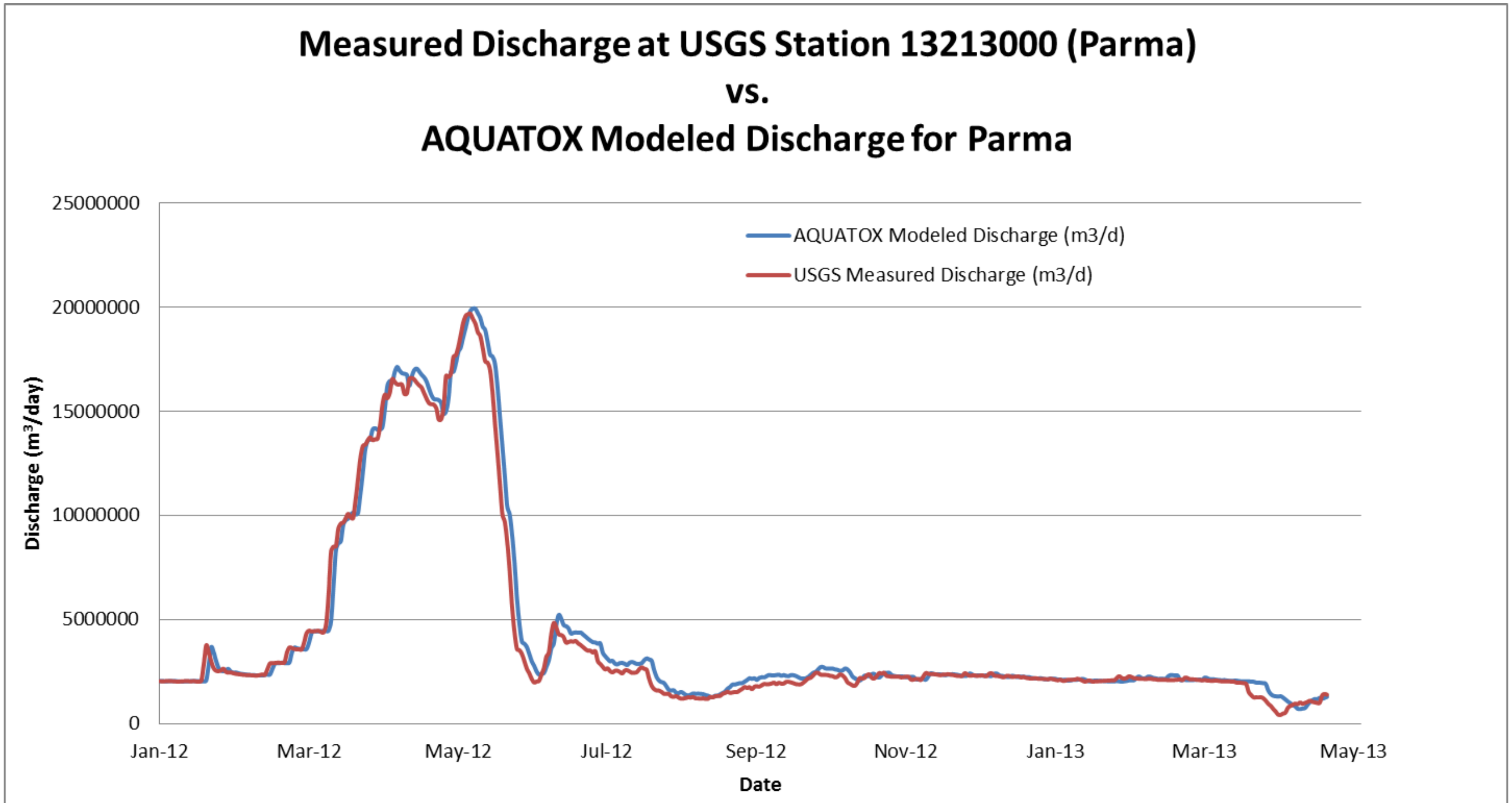


Figure 7. Model-simulated discharge versus measured discharge at Parma during the 2012–2013 model calibration period.

2.2.2.2 Ground Water

Ground Water Quantity

Ground water quantity in segments 10-13 were allocated according to Alex Etheridge's (USGS) best professional judgment and interpolation scenario based on the USGS synoptic survey and mass balance models (Etheridge 2013):

- March 6–April 15: use the USGS March synoptic percentages.
- April 15–August 23: interpolate from the March to August synoptic percentages.
- August 23–October 31: interpolate from the August to October synoptic percentages.
- October 31–March 6: interpolate from the October to March synoptic percentages.

AQUATOX Segment	August (%)	October (%)	March (%)
10	45	94	38
11	12	4	5
12	5	2	2
13	38	0	55

Ground Water Concentration

In segments 4-9, ground water total soluble phosphorus concentrations were assigned the values identified in the 2008 LBR Implementation Plan TP (DEQ 2008). Ground water values were based on data collected by USGS monitoring wells along the main stem of the LBR in 2001 (MacCoy 2004) as summarized in the LBR Implementation Plan TP (DEQ 2008).

- Segments 4–7 = 0.03 mg/L
- Segment 8 = 0.09 mg/L
- Segment 9 = 0.14 mg/L

In segments 10-13, ground water phosphorus concentrations were utilized results reported in Etheridge 2013, Table 7, and interpolated between synoptic events. The August phosphorus concentrations in ground water were derived from unmeasured phosphorus loads and unmeasured discharge (ground water gains) in August 2012. The October and March ground water concentrations were derived from average tributary phosphorus concentrations in October and March, since tributaries are thought to drain the shallow aquifer during nonirrigation season (Fox et al. 2002):

- August = 0.22 mg/L
- October = 0.16 mg/L
- March = 0.12 mg/L

2.2.2.3 Slope and Channel Widths

An extensive survey was conducted by the USGS in cooperation with the Federal Emergency Management Agency, to obtain stream channel cross-section data and document elevation reference marks for horizontal and vertical control (Hortness and Werner 1999). In 1997 and 1998, 238 cross sections and 108 elevation reference marks were measured on the Boise River between Barber Dam and the Ada/Canyon County boundary. These data were ultimately used to determine water surface elevations for the 10-, 50-, 100-, and 500-year floods and to define floodway limits. The USGS has made the data available at the following link: *http://id.water.usgs.gov/projects/BoiseWatershed/boiseriver/index.html* and available in the spreadsheet, "Copy of Hydraulic Calcs BCNB Edits 04-06.xls." The Manning's roughness coefficient values in this spreadsheet were literature values ranging from 0.043 to 0.03.

City of Boise staff used the data to calculate stream channel slope by measuring the horizontal and vertical distance between the lowest points of neighboring cross sections. The numbers for the many cross sections were averaged within general AQUATOX reaches. Stream widths were approximated using best professional judgment in segments that did not have data available. USGS stream gage data were used when available.

2.2.2.4 Dynamic Mean Depths ("Z mean")

Dynamic mean depths are calculated in the model from inputs provided. Dynamic mean depth is used in calculating:

- Light limitation for photosynthesis
- Biotic volumes for sloughing calculations
- Sedimentation of suspended particulate detritus to bottom sediments
- Oxygen reaeration

The model simulations require depth of water and flow rate in computing transport, scour, and deposition. Dynamic mean depth is calculated by the model according to Park and Clough 2012b, Equation 5:

$$Y = \frac{Q \cdot Manning}{\sqrt{Slope} \cdot Width}$$

where:

Y = dynamic mean depth (m)
Q = flow rate (m^3/sec)
Manning = Manning's roughness coefficient (s/$m^{1/3}$)
Slope = slope of channel (m/m)
Width = channel width (m)

AQUATOX normally uses an assumption of unchanging mean depth (i.e., mean over the site area). However, in the case of streams, the depth of the system can change considerably over time, which could result in a significantly different light climate for algae. For this reason, the option to import mean depth in meters was used.

For the calibrated model, Jonathan Clough (Warren Pinnacle Consulting, Inc.) used the dynamic volumes (see Volume 2.1.2.1) and calculated dynamic depths, which are available in the spreadsheet, "2013_1011_Depth Discharge calibration_JSC.xls."

From the output of this spreadsheet, Jonathan Clough created the following spreadsheet: "2013_1011_ATX_Zmean_Import_JSC.xls," which is directly imported into the model for the dynamic depth values for each segment. The depth discharge relationship was developed for

Diversion, Glenwood, Middleton, and Parma. As a result, the dynamic mean depths were then interpolated and assigned to the remaining segments, as follows:

- Diversion—Segments 1 and 2
- Glenwood— Segments 3 through 7
- Middleton—Segments 8 through 10
- Parma—Segments 11 through 13

2.2.2.5 Velocity

Velocity is calculated as a simple function of flow and cross-sectional area according to Park and Clough 2012b, Equation 14:

$$Velocity = \frac{AvgFlow}{XSecArea \cdot 86400} \cdot 100$$

where:

Velocity = (cm/s)
AvgFlow = average flow over reach (m^3/d)
XSecArea = cross-sectional area (m^2)
86400 = s/d
100 = cm/m

For calibration, model velocities were compared to observed velocities in each river segment, where available. Model accuracy was considered sufficient when model velocities were within 10–20 centimeters per second (cm/s) of observed velocities.

2.2.2.6 DEQ Visual Assessment Data

Riffle-Run-Pool

AQUATOX uses river habitat preferences in three categories: riffle, run, and pool. Calculations for photosynthesis and consumption are based on the preference of an organism for a specified habitat. To optimize model function and our conceptual understanding of these conditions in the LBR, DEQ personnel monitored the LBR to identify the correct ratios of riffle, run, and pool habitat for each model segment. The data collection occurred on June 20, 21, and August 9 and 12, 2013. The habitat types definitions were derived from the Beneficial Use Reconnaissance Program protocols (DEQ 2013) and the measured percentages of runs, riffles, and pools are presented in Table 5 and Figure 8.

Riffle—shallow water with a turbulent water surface; $\geq$ 50% of the stream width. The turbulence is caused by completely or partially submerged obstructions, often on the stream bottom. Cascades are one class of riffle characterized by swift current, exposed rocks and boulders, and considerable turbulence and consists of stepped drops over steep slopes. Riffles that are swift, relatively deep, and have considerable surface turbulence, sometimes represented by standing waves, are called rapids. Rapids at high flow may be confused with runs.

Run—uniform, nonturbulent flow. Runs are deeper than riffles with a faster current velocity than pools and (typically) glides; the stream bed can be flat beneath a run, and the water surface is seldom broken. Surface gradient tends to roughly parallel overall stream gradient, and substrate particle size can vary but tends to be coarser than in glides.

Pool—reduced water velocity, water deeper than the surrounding areas, and the bottom is often concave in shape forming a depression in the profile of the stream's thalweg that would retain water if there were no flow; $\geq$ 50% of the stream width. Pools usually occur at outside bends (e.g., lateral scour) and around large obstructions (e.g., plunge pool). Pocket water pools refer to groups of small pools often in areas of otherwise fast or turbulent flow, usually caused by eddies behind boulders or other obstructions. Eddies are also associated with backwater pools. Water impounded upstream from channel blockage, typically caused by a log jam or beaver dam, is classed as a dammed pool. Flats are actually wide shallow pools often confused with glides. Pools end where the stream bottom approaches the water surface, also known as the pool tail out.

Table 5. Percentages of run, riffle, and pool habitat for each AQUATOX model segment.

Segment	% Run	% Riffle	% Pool	
1	93.0	4.5	2.6	
2	72.6	26.5	0.9	
3	69.2	30.4	0.5	
4	65.5	34.5	0.0	
5	72.8	26.1	1.1	Segments 6 and 7 (South Channel) were averaged to estimate segment 5 (North Channel), which was not assessed
6	62.6	37.4	0.0	
7	75.1	23.6	1.3	
8	68.2	29.7	2.0	This represents total for segment 8 (part of 8 was assessed in June and part in August)
9	69.5	29.0	1.5	
10	80.4	19.1	0.5	
11	72.9	27.1	0.0	
12	75.4	24.6	0.0	
13	75.4	24.6	0.0	Segment 12 values were used to estimate segment 13, which was not assessed

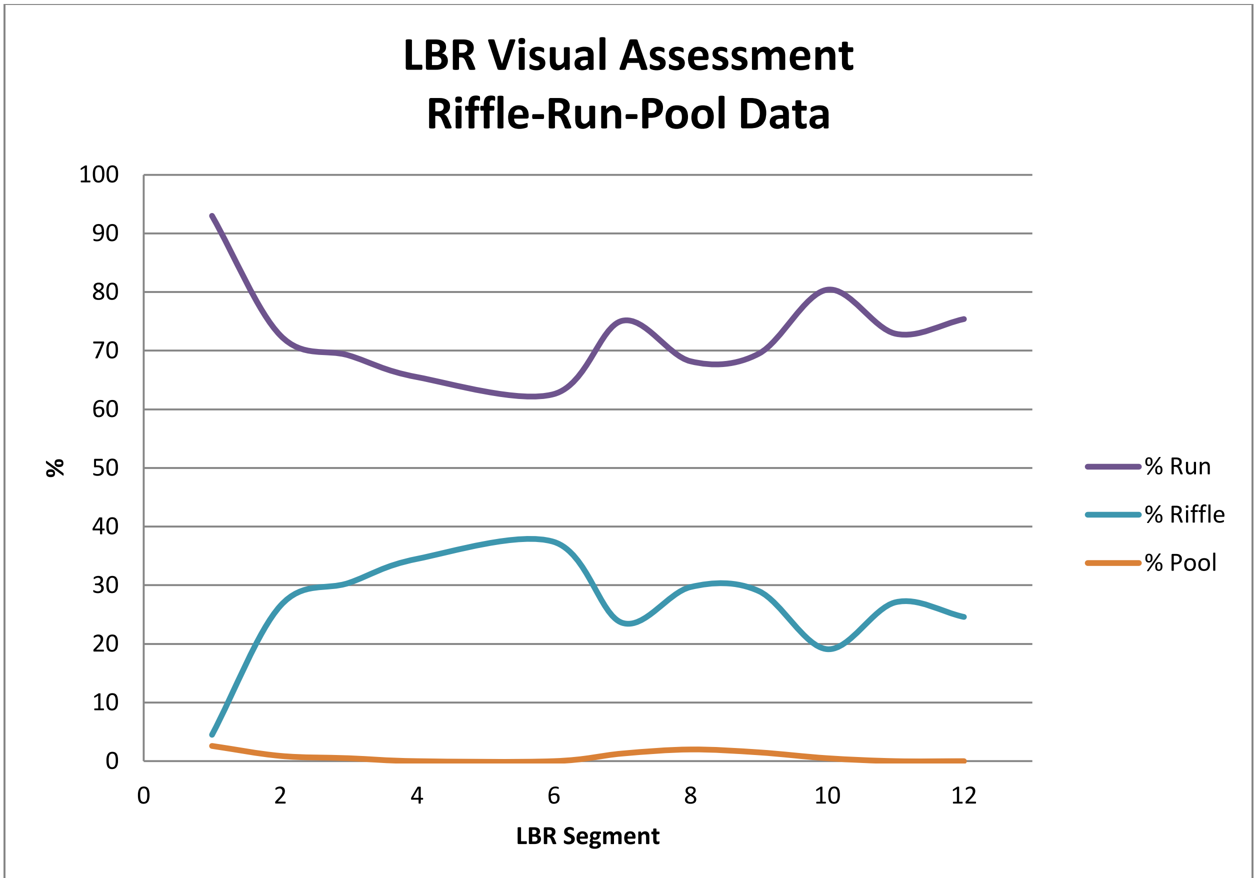


Figure 8. Percentages of run, riffle, and pool habitat for each AQUATOX model segment.

Water Depth, Water Clarity, Substrate, Periphyton, and Photo Documentation

During the same monitoring events in 2012 and 2013, DEQ also collected data on water depths, water visibility, substrate available, and periphyton coverage as indices for each AQUATOX segment (Table 6 and Figure 9).

Water Depth—Thalweg depth measurements were recorded using a 2-meter rod in riffles, runs, and pools throughout the survey.

Water Visibility—Water visibility was estimated as the visible distance into the water column from the surface by use of the 2-meter rod in riffles, runs, and pools throughout the survey.

Substrate and Periphyton—Channel bottom substrate available and periphyton abundance were visually estimated in riffles, runs, and pools throughout the survey: (1) from the boats in clearer segments, (2) using subsurface viewers in more turbid segments, and (3) physically picking up substrate in the most turbid segments. The substrate and periphyton estimates involved a two-tiered assessment:

- Estimate the percent substrate > 2 millimeter (mm) in the channel bottom (as suitable substrate for periphyton).
- Estimate the percent coverage by periphyton on substrate > 2 mm.

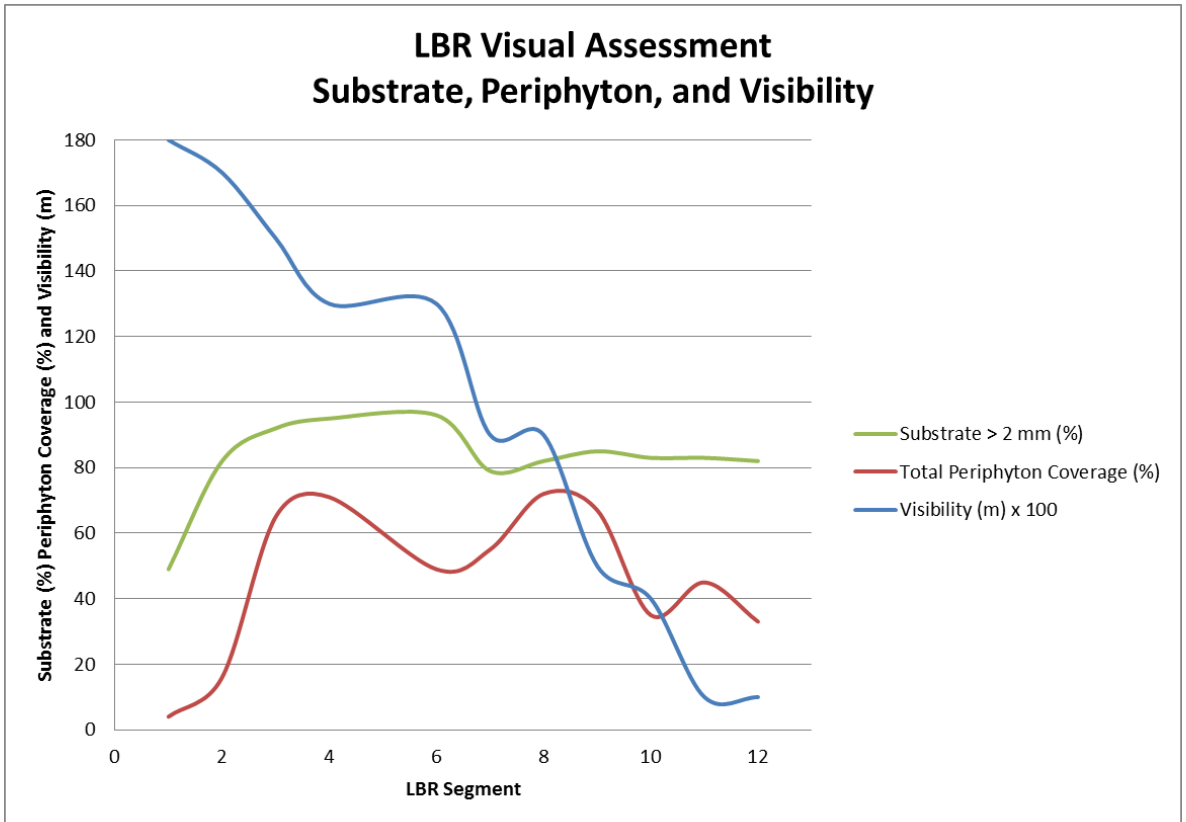
Photographs—Photos were taken along with Global Positioning System coordinates to identify every riffle and pool (the distances in between represent runs), different riparian shading, substrate types, and drains/diversions throughout the survey.

Measurements for stream depth and water clarity, and visual estimations of bottom substrate and periphyton coverage for each model segment are provided in Table 6.

Table 6. Periphyton visual assessment for each AQUATOX model segment on the LBR.

AQUATOX Segment	Visibility (meters)	Substrate > 2 mm (%)[a]	Periphyton Coverage on Substrate > 2 mm (%)[b]	Total Periphyton Coverage (%)[c]
1	1.8	49	9	4
2	1.7	82	20	16
3	1.5	92	71	65
4	1.3	95	75	71
5[d]	1.1	88	61	52
6	1.3	96	51	49
7	0.9	79	70	55
8	0.9	82	88	72
9	0.5	85	79	67
10	0.4	83	42	35
11	0.1	83	54	45
12	0.1	82	40	33
13[e]	0.1	82	40	33

a. Substrate > 2 millimeter (mm) in the channel bottom
b. Percent periphyton coverage only on substrate > 2 mm
c. Percent periphyton coverage on entire river bottom (Substrate x Periphyton Coverage)
d. Segment 5 was average of segments 6 and 7, because it was not assessed.
e. Segment 13 was assumed same as segment 12, because it was not assessed.



* Visibility measurements are multiplied by 100 on this figure for ease of representation on axis (e.g., a visibility of 1.8 meters is represented as 180 on the figure; a visibility of 0.1 meters is represented as 10 on the figure).

Figure 9. LBR visual assessment results for channel bottom substrate, periphyton coverage, and water visibility for each AQUATOX model segment.

2.2.3 Light

Light is important as a controlling factor for photosynthesis and photolysis. In the model input, USBR AgriMet weather data were utilized to provide dynamic, or daily varying, light data for each segment throughout the 2012–2013 model calibration period. These data are available in the spreadsheet, “Light.xlsx.”

2.2.4 Shade

The Freshwater Trust provided shade data that had been analyzed on the LBR for the City of Boise. Additionally, Mark Shumar (DEQ) provided his professional opinion for interpretation of the data and his experience on the LBR. Troy Smith (DEQ) through consultation with the modeling workgroup used best professional judgment to create a hybrid of the two, which resulted in the following shading percentages utilized in the model.

- Segment 1—5%
- Segment 2—10%
- Segment 3, 4, 5, 6, 7—15%
- Segment 8—10%
- Segment 9, 10, 11, 12,13—5%

2.2.5 Temperature

Temperature is a driving variable within AQUATOX. Virtually all processes are temperature-dependent, and it is an important controlling factor in the model, including biotic processes such as decomposition, photosynthesis, consumption, respiration, reproduction, and mortality.

The City of Boise collected and provided water temperature data at Marden, Veteran's, Glenwood, Eagle, and Middleton (Table 7). These data are available on the spreadsheet, "B River water temperatures.xls." The USGS collects water temperature data near Parma for USBR. USBR provided this water temperature data, which had not gone through a quality assurance/quality control process. DEQ reviewed the data and used an interpolation process to alleviate a few spurious data points. These data are available in the spreadsheet,"2013_1127 Copy of BOR Parma_water_temp_interpolated.xls."

For model calibration, observed temperature loadings were utilized because responses to short-term variations are of interest. Temperature is an important driving variable of the model simulation, and Section 3.3 describes how DEQ improved incomplete temperature datasets at Marden and Parma.

Table 7. Water temperature data sources for each AQUATOX segment. Data at Marden, Veteran's, Glenwood, Eagle, and Middleton were collected and provided by the City of Boise. Data at Parma were collected by USGS for USBR and provided by USBR.

AQUATOX Segment	Site	Dates
1	Marden	1/1/2012-7/25/2012; 12/3/2012–3/25/2013
2	Marden	1/1/2012-7/25/2012; 12/3/2012–3/25/2013
3	Veteran's	1/1/2012–4/1/2013
4	Glenwood	1/1/2012–4/1/2013
5	Eagle	1/1/2012–4/1/2013
6	Eagle	1/1/2012–4/1/2013
7	Eagle	1/1/2012–4/1/2013
8	Middleton	1/1/2012–3/13/2013
9	Middleton	1/1/2012–3/13/2013
10	Middleton	1/1/2012–3/13/2013
11	Parma	3/6/2012–4/22/2013
12	Parma	3/6/2012–4/22/2013
13	Parma	3/6/2012–4/22/2013

2.2.6 Wind

Wind is a driving variable that affects blue-green algal blooms and reaeration or oxygen exchange. However, wind is not an important driving variable for streams, so a constant rate of 1 meter per second is recommended (Park and Clough 2012a).

For model calibration, observed wind loading was set at a constant rate of 1 meter per second, the same value that had been used in the previous LBR AQUATOX exercise and report (CH2M Hill et al. 2008).

2.3 Inorganic Constituents

2.3.1 Sediment

TSS is a driving variable within AQUATOX. The user can provide loadings of TSS, and the AQUATOX will back-calculate suspended inorganic sediment concentrations by subtracting the simulated phytoplankton and suspended detritus concentrations. Due to sparse data during 2012-2013, historical monthly TSS averages were applied throughout the model calibration period. Historical mean monthly TSS values applied to the current model calibration are available on the import spreadsheet. The previous import spreadsheet, dated 2014_0103, still contains the sparse measured TSS and SSC data collected during the model simulation period for reference. DEQ recommends for best results to import the average TSS data for the best simulation accuracy.

2.3.2 pH

pH is a driving variable within AQUATOX. Dynamic, or varying, pH data were utilized when and where available to drive the model pH levels throughout the model calibration period. pH data were collected by USGS and the City of Boise and are available on the model import spreadsheet and “LBRWQP & NWIS River & Drains.xlsx.”

Model accuracy for pH was considered sufficient when modeled values were within 25% of the range of observed field data.

2.3.3 Nitrogen

In AQUATOX, two nitrogen compartments, *total ammonia* as N (NH_3, $_4$) and *nitrate* as N (NO_2 + NO_3), as N, are modeled. Nitrite occurs in very low concentrations and is rapidly transformed through nitrification and denitrification (Park and Clough 2012b); therefore, it is modeled with nitrate. Unionized ammonia (NH_3) is not modeled as a separate state variable but is estimated as a fraction of ammonia.

Dynamic, or varying, nitrogen data were utilized when and where available throughout the model calibration period. Nitrogen data were collected by USGS and the municipal wastewater treatment facilities (WWTFs). Data sources are available are available in:

- The model import spreadsheet
- LBR_USGS_nutrient_sed_chla.xlsx
- LBRWQP & NWIS River & Drains.xlsx
- Data provided by the municipal facilities

Model accuracy for nitrogen was considered sufficient when modeled concentrations/loads were within 25% of the range of observed field data.

2.3.4 Phosphorus

AQUATOX simulates *total soluble P* (identified as total soluble P and/or total P in the model) in the water column. TP is the sum of dissolved phosphate in the water column as well as phosphate associated with dissolved and suspended particulate organic matter and phytoplankton.

Dynamic, or varying, phosphorus data were used when and where available throughout the model calibration period. Phosphorus data were collected by USGS and the municipal WWTFs and are available in:

- The model import spreadsheet
- LBR_USGS_nutrient_sed_chla.xlsx
- LBRWQP & NWIS River & Drains.xlsx
- Data provided by the municipal facilities.

Model accuracy for phosphorus was considered sufficient when modeled concentrations/loads were within 25% of the range of observed field data.

2.3.5 Oxygen

DO is usually simulated as a daily average and does not account for diurnal fluctuations. It is a function of reaeration, photosynthesis, respiration, decomposition, and nitrification (Park and Clough 2012b, Equations 186 through 189).

Dynamic, or varying, DO data were utilized when and where available throughout the model calibration period. DO data were collected by USGS and the municipal WWTFs and are available on the model import spreadsheet, “LBR_USGS_nutrient_sed_chla.xlsx,” and “LBRWQP & NWIS River & Drains.xlsx,” and in data provided by the municipal facilities.

Model accuracy for DO was considered sufficient when modeled concentrations were within 2 mg/L of the range of the observed field data.

2.3.6 Carbon Dioxide

Carbon dioxide for the mainstem LBR was modeled under a constant loading scenario of 0.7 mg/L, the same values that had been used in the previous LBR AQUATOX model and report (CH2M Hill et al. 2008).

2.3.7 Nutrient Mass Balance

AQUATOX nutrient mass balance has been verified in linked-mode runs in the past to ensure that nutrient mass balance is maintained within an entire linked system. However, there were some code changes, and some of the accounting variables were not properly updated. When running with *tributary-input* loadings, these *tributary inputs* are not added to the total nutrient load (accounting variable) in kilograms. When this was fixed, mass balance was maintained as shown in Figure 10. In other words, mass balance was still being maintained by the model, but the accounting variables were not properly showing this (in some types of linked-mode runs only). After fixing these accounting variables that have no effects on results, other than the output of mass-balance metrics, the mass-balance check remained constant in all segments (J. Clough, pers. comm., 2013 and 2014).

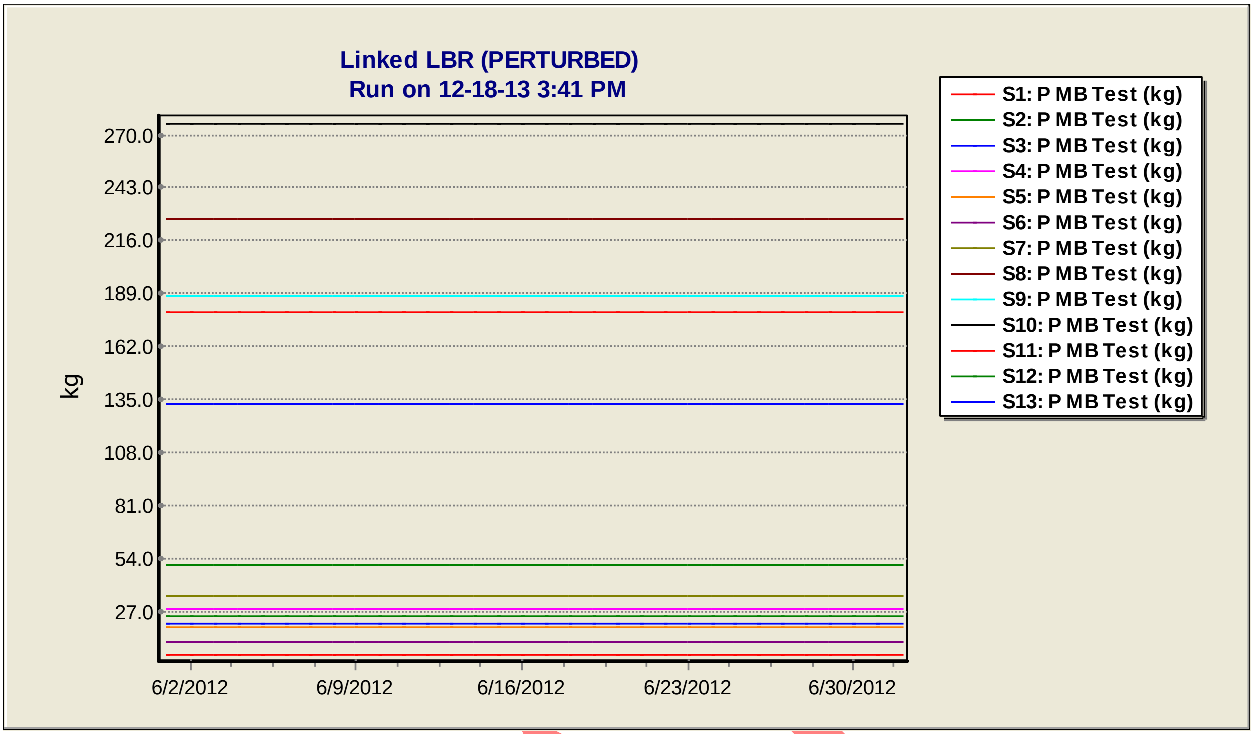


Figure 10. Mass-balance test for all segments, individually, show the P Mass Balance is maintained and working appropriately in the model. As identified in the AQUATOX technical documentation (Park and Clough 2012b), "Mass Balance Test = Total Mass + Loss – Load" and should stay constant.

2.4 Organic Constituents

Based on the best professional judgment and consultation with the modeling workgroup, the following decisions were made by DEQ for the model calibration:

- Animals and macrophytes were not included in model simulations in order to minimize model parameters and because necessary data were not available to accurate calibrate these parameters, although it is acknowledged they do occur in the LBR.
- Algal groups—an appropriate assemblage of algal groups in the model include:
  - Periphyton
    - Low-nutrient Diatoms
    - High-Nut Diatoms
    - Green algae
    - *Cladophora*, a specific genus of green algae
    - Cyanobacteria, or blue-green algae
  - Phytoplankton for each of these groups except for *Cladophora.*

Even though algal parameters are included in the model for phytoplankton, the model links the phytoplanktonic groups with the corresponding periphytic groups and the phytoplankton biomass in the model is mainly sloughed and scoured periphyton, also known as sestonic algae.

2.4.1 Algal Parameters

Parameters for the algal groups used in the final calibration are presented in Table 8. Section three provides additional detail about how the algal parameters in the final calibration differ from earlier model iterations (Tables 9 and 10), which parameters were most important for the final prediction of periphyton chlorophyll a (mg/m^2), and how model error and bias differs for each parameter set.

Table 8. Select algal parameters employed in the lower Boise River AQUATOX 2012-2013 model calibration.

Parameter	Topt	Tmax	Tresp	LightSat	Pmax	Lightex	P Half-sat	N Half-sat	C Half-sat	ExpMoCo	FCrit	%Slough
Periphyton												
Low-nutrient diatoms	15	39	2	64	0.77	0.03	0.006	0.07	0.054	0.01	0.005	99
High-nutrient diatoms	20	35	1.8	64	2.3	0.02	0.066	0.117	0.054	0.05	0.005	96
Peri Greens	20	42	2	110	1.08	0.22	0.05	0.1	0.054	0.01	0.007	90
Cladophora	15	25	2	135	1.08	0.22	0.0428	0.0586	0.054	0.05	0.008	25
Blue-greens	10.5	50	2.1	33	1.2	0.04	0.034	0.168	0.024	0.01	0.008	90
Phytoplankton												
Low-nutrient diatoms	15	39	2	64	0.77	0.03	0.006	0.07	0.054	0.01	NA	NA
High-nutrient diatoms	20	35	1.8	64	2.3	0.02	0.055	0.117	0.054	0.05	NA	NA
Phyto Greens	20	42	2	110	1.08	0.22	0.0428	0.1	0.054	0.01	NA	NA
Blue-greens	10.5	50	2	33	1.2	0.04	0.034	0.168	0.024	0.01	NA	NA

Notes:
Topt = optimal temperature (°C)
Tmax = maximum temperature (°C)
Tresp = temperature response slope
LightSat = saturating light (Ly/day)
Pmax = maximum photosynthetic rate (1/day)
Lightex = light extinction coefficient 1/m-g/m^3
P half-sat = phosphorus half-saturation constant (mg/L), Michaelis-Menten kinetics
N half-sat = nitrogen half-saturation constant (mg/L), Michaelis-Menten kinetics
C half-sat = inorganic carbon half-saturation constant (mg/L), Michaelis-Menten kinetics
ExpMoCo = exponential mortality coefficient (g/g-day)
Fcrit = critical force for periphyton scour (Newtons)
% Slough = percent periphyton lost in slough event (%)

Table 9. Select algal parameters employed in the AQUATOX default library.

Parameter	Topt	Tmax	Tresp	Light Sat	Pmax	Lightex	P Half-sat	N Half-sat	C Half-sat	Exp Mo Co	FCrit	% Slough
Periphyton												
Low-nutrient diatoms	20	39	2	64	0.65	0.03	0.006	0.07	0.054	0.01	0.001	90
High-nutrient diatoms	20	35	1.8	22.5	2.3	0.03	0.055	0.2	0.054	0.01	0.004	60
Peri Greens	25	42	2	70	1.7	0.03	0.1	0.8	0.054	0.01	0.004	90
Cladophora	15	25	2	270	1.08	0.14	0.04	0.1	0.054	0.05	0.002	25
Blue-greens	30	50	2	45	1.4	0.03	0.03	0.4	0.024	0.01	0.004	90
Phytoplankton												
Low-nutrient diatoms	26	39	2	56	1.4	0.14	0.001	0.0154	0.054	0.05	NA	NA
High-nutrient diatoms	20	35	1.8	18	1.87	0.14	0.055	0.117	0.054	0.05	NA	NA
Phyto Greens	25	42	2	54	3.6	0.144	0.05	0.006	0.054	0.04	NA	NA
Blue-greens	27	50	2	60	2.2	0.09	0.03	0.4	0.024	0.12	NA	NA

Notes:
Topt = optimal temperature (°C)
Tmax = maximum temperature (°C)
Tresp = temperature response slope
LightSat = saturating light (Ly/day)
Pmax = maximum photosynthetic rate (1/day)
Lightex = light extinction coefficient 1/m-g/m3
P half-sat = phosphorus half-saturation constant (mg/L), Michaelis-Menten kinetics
N half-sat = nitrogen half-saturation constant (mg/L), Michaelis-Menten kinetics
C half-sat = inorganic carbon half-saturation constant (mg/L), Michaelis-Menten kinetics
ExpMoCo = exponential mortality coefficient (g/g-day)
Fcrit = critical force for periphyton scour (Newtons)
% Slough = percent periphyton lost in slough event (%)

Table 10. Select algal parameters employed in the lower Boise River AQUATOX 2008 model calibration.

Parameter	Topt	Tmax	Tresp	Light Sat	Pmax	Lightex	P Half-sat	N Half-sat	C Half-sat	Exp Mo Co	FCrit	% Slough
Periphyton												
Low-nutrient diatoms	20	39	2	128	0.77	0.03	0.006	0.07	0.054	0.05	0.002	25
High-nutrient diatoms	20	35	1.8	45	2.06	0.03	0.2	0.117	0.054	0.05	0.002	25
Peri Greens	25	42	2	220	2.00	0.03	0.1	0.8	0.054	0.05	0.002	25
Cladophora	15	25	2	270	1.08	0.14	0.04	0.1	0.054	0.05	0.002	25
Blue-greens	30	50	2	148	1.40	0.03	0.03	0.4	0.024	0.05	0.002	25
Phytoplankton												
Low-nutrient diatoms	15	39	2	224	1.00	0.14	0.006	0.0154	0.054	0.05	NA	NA
High-nutrient diatoms	20	35	1.8	30	1.87	0.14	0.055	0.117	0.054	0.05	NA	NA
Phyto Greens	26	42	2	220	1.65	0.24	0.1	0.8	0.054	0.04	NA	NA
Blue-greens	30	50	2	148	2.20	0.15	0.03	0.4	0.024	0.12	NA	NA

Notes:
Topt = optimal temperature (°C)
Tmax = maximum temperature (°C)
Tresp = temperature response slope
LightSat = saturating light (Ly/day)
Pmax = maximum photosynthetic rate (1/day)
Lightex = light extinction coefficient 1/m-g/m3
P half-sat = phosphorus half-saturation constant (mg/L), Michaelis-Menten kinetics
N half-sat = nitrogen half-saturation constant (mg/L), Michaelis-Menten kinetics
C half-sat = inorganic carbon half-saturation constant (mg/L), Michaelis-Menten kinetics
ExpMoCo = exponential mortality coefficient (g/g-day)
Fcrit = critical force for periphyton scour (Newtons)
% Slough = percent periphyton lost in slough event (%)

2.4.2 Phytoplankton and Periphyton Chlorophyll *a*

AQUATOX converts *phytoplankton* biomass estimates into values for chlorophyll *a*, and uses a value of 45 micrograms (µg) C/µg chlorophyll *a* for cyanobacteria and a value of 28 for other phytoplankton. The results are presented as total chlorophyll *a* in micrograms per liter (Park and Clough 2012b, Equation 78).

Periphyton as chlorophyll *a* is computed as a conversion from the ash-free dry weight of periphyton. The conversion factor is based on the observed average ratio of chlorophyll *a* to ash-free dry weight (Park and Clough 2012b, Equation 79).

Phytoplankton periphyton data were utilized when and where available throughout the model calibration period, typically three data points collected from Eckert, Glenwood, Middleton, Highway 20-26, and Parma. These data were collected by USGS and are available in the model import spreadsheet and “USGS_Synoptic_Algae.xls” (Table 11).

Table 11. USGS periphyton and phytoplankton data collected on the lower Boise River during the model calibration period from January 1, 2012, through April 22, 2013 (Etheridge 2013).

Site ID	River Mile	Site Name	Periphyton Biomass (g/m^2)	Periphyton Chl-a (mg/m^2)	Phytoplankton Chl-a (µg/L)	Mean Water Depth (ft)	Mean Water Velocity (ft/s)	Light Extinction Coefficient
			Week of August 21, 2012					
13203760	58.1	BOISE RIVER AT ECKERT RD NR BOISE ID	3	3	1	1.04	1.47	0.09
13206000	47.5	BOISE RIVER AT GLENWOOD BRIDGE NR BOISE ID	47	147	3	0.72	1.37	0.04
13210050	31.4	BOISE RIVER NR MIDDLETON ID	10	40	6.4	0.43	2.26	0.07
13211000	24.0	BOISE RIVER AT HWY 20-26 XING NR CALDWELL ID	25	108	6.7	0.27	1.67	0.20
13213030	0.0	BOISE RIVER AT MOUTH NR PARMA ID	11	63	10.5	0.26	1.20	0.09
			Week of October 29, 2012					
13203760	58.1	BOISE RIVER AT ECKERT RD NR BOISE ID	3	4	ND	0.51	2.53	0.06
13206000	47.5	BOISE RIVER AT GLENWOOD BRIDGE NR BOISE ID	16	131	3.7	0.80	1.82	0.15
13210050	31.4	BOISE RIVER NR MIDDLETON ID	24	219	6.4	0.63	2.22	0.15
13211000	24.0	BOISE RIVER AT HWY 20-26 XING NR CALDWELL ID	25	255	5.6	0.57	2.57	0.14
13213030	0.0	BOISE RIVER AT MOUTH NR PARMA ID	32	181	9	0.67	2.48	0.10
			Week of March 4, 2013					
13203760	58.1	BOISE RIVER AT ECKERT RD NR BOISE ID	14	36	4.8	0.59	1.56	na
13206000	47.5	BOISE RIVER AT GLENWOOD BRIDGE NR BOISE ID	33	283	7.3	1.09	1.80	0.08
13210050	31.4	BOISE RIVER NR MIDDLETON ID	30	137	19.5	0.53	1.68	0.11
13211000	24.0	BOISE RIVER AT HWY 20-26 XING NR CALDWELL ID	23	211	17.5	0.46	1.87	0.13
13213030	0.0	BOISE RIVER AT MOUTH NR PARMA ID	16	92	36.2	0.58	2.39	0.13

2.4.2.1 Sloughing and Loss

AQUATOX technical documentation asserts that periphyton often exhibit a pattern of buildup and then a sharp decline in biomass due to sloughing (Park and Clough 2012b). Based on extensive experimental data from Walker Branch, Tennessee (Rosemond 1993), a complex sloughing formulation, extending the approach of Asaeda and Son (2000), was implemented. This function was better able to represent a wide range of conditions. Periphyton washout is calculated according to Park and Clough 2012b, Equation 72:

$$Washout_{periphyton} = Slough + Dislodge_{Peri,Tax}$$

where:

$Washout_{periphyton}$ = loss due to sloughing (g/m^3*d)
Slough = loss due to natural causes (g/m^3*d), see Equation 75
$Dislodge_{Peri, Tax}$ = loss due to toxicant-induced sloughing (g/m^3*d)

AQUATOX models natural sloughing as a function of senescence due to suboptimal conditions and the drag force of currents acting on exposed biomass, which increases drag as both biomass and velocity increase (Park and Clough 2012b, Equations 72-74).

In AQUATOX, suboptimal light, nutrients, and temperature cause senescence of cells that bind the periphyton and keep them attached to the substrate (Park and Clough 2012b). This effect is represented by a factor, *Suboptimal*, which is computed in modeling the effects of environmental conditions on photosynthesis. *Suboptimal* decreases the critical force necessary to cause sloughing. If the drag force exceeds the critical force for a given algal group modified by the *Suboptimal* factor and an adaptation factor, then sloughing occurs (Park and Clough 2012b, Equation 75). *Suboptimal* is calculated according to Park and Clough 2012b, Equation 76:

$$Suboptimal_{Org} = NutrLimit_{Org} \times LtLimit_{Org} \times TCorr_{Org} \times 20$$

If $Suboptimal_{Org} > 1$ then $Suboptimal_{Org} = 1$

where:

$Suboptimal_{Org}$ = factor for suboptimal nutrient, light, and temperature effect on senescence of given periphyton group (unitless)
$NutrLimit_{Org}$ = nutrient limitation for a given algal group (unitless) computed by AQUATOX
$LtLimit_{Org}$ = light limitation for a given algal group (unitless) computed by AQUATOX
$TCorr_{Org}$ = temperature limitation for a given algal group (unitless) computed by AQUATOX
20 = factor to desensitize construct

Through modeling periphyton at several sites, it was observed that sloughing appears to be triggered at greatly differing mean velocities (Park and Clough 2012b). The working hypothesis is that periphyton adapt to the ambient conditions of a particular channel. Therefore, a factor is included to adjust for the mean discharge of a given site compared to the reference site in

Tennessee. It is still necessary to calibrate *FCrit* for each site to account for intangible differences in channel and flow conditions, analogous to the calibration of shear stress by sediment modelers, but the range of calibration needed is reduced by the *Adaptation* factor (Park and Clough 2012b, Equation 77).

2.4.3 Detritus

In AQUATOX, the term *detritus* is used to include all nonliving organic material and associated decomposers (bacteria and fungi). The concentrations of detritus in the current model calibration are the result of several competing processes (Park and Clough 2012b, Equations 141 through 148) (Table 12). The initial conditions in the final model calibration differ according to segment, which enhances model performance over utilizing the same initial conditions for each segment. This table shows the initial conditions for segment 1 only, but these initial conditions vary in each segment for the current 2012-2013 model calibration, providing a more realistic starting point over utilizing the same default conditions for each segment.

Table 12. Initial detritus conditions for Segment 1 AQUATOX model simulations on the LBR.

Detritus Parameter	Initial Condition	Units	Modeled Loadings
Refractory sediment detritus	0.01859843	g/m^2 dry	0 - constant
Labile sediment detritus	0.6089784	g/m^2 dry	0 - constant
Suspended and dissolved detritus	0.2422097	mg/L dry	0 - constant
Buried refractory detritus	2	kg/m^3	NA
Buried labile detritus	1	kg/m^3	NA

Notes: grams per square meter (g/m^2); milligrams per liter (mg/L); kilograms per cubic meter (kg/m^3)

Through the course of several model iterations, the proportions of suspended and dissolved detritus that are labile/refractory and dissolved/particulate were refined from the initial default conditions.

3 Calibration of Model Simulation to Existing Data

3.1 Background

Aquatic biological communities respond to altered physical and chemical surroundings, making it more practical to measure biotic integrity than to measure all of the physical and chemical factors that can determine ecosystem integrity. Previous biological assessments of the LBR (Mullins 1999; MacCoy 2006) indicate declining trends in instream habitat quality and biotic integrity in a downstream direction.

The AQUATOX model represents the combined environmental fate and effects of pollutants such as nutrients in aquatic ecosystems. The model considers several trophic levels such as algae, submerged vegetation, invertebrates, and fish (Park et al. 2008, 2009; Park and Clough 2012a, 2012b). However, for purposes of the LBR study, this model's primary utility is in simulating attached algae, or periphyton.

Periphyton communities consist of diverse and variable populations of bacteria and algae that are attached to substrates in surface water. Algae are an important component of aquatic ecosystems since they are primary producers, providing food for aquatic invertebrates. Being primary producers, they are directly affected by physical and chemical factors. This makes them valuable indicators of water quality, as described in Barbour et al. (1999). Periphyton can be characterized by standard methods such as biomass and chlorophyll content.

Evaluating total periphyton biomass is a method to identify nutrient enrichment. Excessive periphyton growth can serve as an ecological indicator for high water temperatures or excess nutrient production. Excessive periphyton growth is defined as growth that is not normal for the system and that can cause negative local or downstream impacts on recreation, changes in nutrient cycling, biological and chemical oxygen demand, and benthic macroinvertebrate communities (Barbour et al. 1999).

Assemblages of periphyton populations are being used as indicators to measure the habitat function of the LBR in this study. Periphyton can respond to changes in temperature, water chemistry, light availability, nutrients, and other environmental factors. The current modeling effort will account for these complex relationships, while the relationships between nutrients and periphyton will be a primary focus of this modeling effort. In consultation with the LBWC, DEQ has identified a numeric nuisance aquatic growth target for periphytic chlorophyll *a* mean biomass to be less than or equal to 150 mg/m^2. This model will evaluate the TP loadings and other environmental conditions that will allow this target to be achieved.

3.2 Model Advantages and Limitations

Modeling has distinct advantages for stakeholders in the LBR watershed:

- Model advantages
  - Continuous simulation—modeling water quality parameters over any time period of concern saves money. Considerable resources go into establishing sampling plans and quality assurance project plans, collecting water quality data in the field, paying laboratory analytical costs, performing data quality assurance and data analysis, and funding project management and administrative positions necessary to maintain water quality data. Even after a thorough sampling project, the field data only represent water quality as a snapshot at the time of data collection. In comparison, labor and planning costs are much less for a modeling project and the model simulation is continuous, with a daily or hourly time step for the entire period of concern. Modeling is a relatively inexpensive way to more thoroughly describe the water quality of a stream.
  - Predict a future condition—modeling allows testing alternative management scenarios with its predictive capacity.

There are also limitations to this modeling effort:

- Model limitations
  - Managed watershed—the LBR is affected by urban, industrial, and agricultural land and water uses throughout its length. Land uses have altered the natural sinuosity and width/depth ratio of the river channel. Flood control, irrigation, and increased impervious surfaces—changing the rainfall/runoff response—have altered the natural hydrologic patterns. Decreased canopy cover and increased turbidity have changed the light availability and temperature patterns. Finally, agricultural return water, stormwater runoff, and wastewater treatment plant effluent contribute different chemical constituents than would occur without human influences.
  - Complex aquatic biota/nutrient/pollutant interactions—linking potential pollutants to biological impairments in surface water is a complex process. Growth and productivity of aquatic biota are affected by light and habitat availability, temperature, organic and inorganic constituents, and competition by other life forms. When human activities cause an imbalance in any of these factors, habitat quality may be impaired, and algal parameters identified in scientific literature for natural systems may not work accordingly in managed systems. Algal populations can become adapted to local conditions and exhibit different tolerances to changes in light, temperature, and nutrients than occur in natural habitats. As such, calibrating the algal simulation to existing data becomes more important than using algal parameters referenced in scientific literature.

Note on concerns of over-parameterization: AQUATOX as an ecological risk assessment model was chosen because the managed hydrology of the LBR and the associated aquatic biota/nutrient/pollutant relationships are so complex. Because multiple parameters can be altered for each algal group in the simulation, some stakeholders have expressed concerns that the model is too complex, or over-parameterized, to be useful. DEQ believes that as much as this model may be highly parameterized, less complex models would likely oversimplify the true complexity of system and biotic relationships. Therefore, although there is no perfect modeling tool, the complexity of the current AQUATOX model is appropriate given the complexity of the river management, biotic simulations, and the river habitats in the modeled reaches.

- Variability in measured data—the inherent variability of water chemistry is also a known model limitation. For example, several samples measuring TP were collected near Parma from 8/20/2012 through 8/24/2012 showing variable TP values. The concentration varied as much as 0.05 mg/L on the same day at the same location (Figure 11).

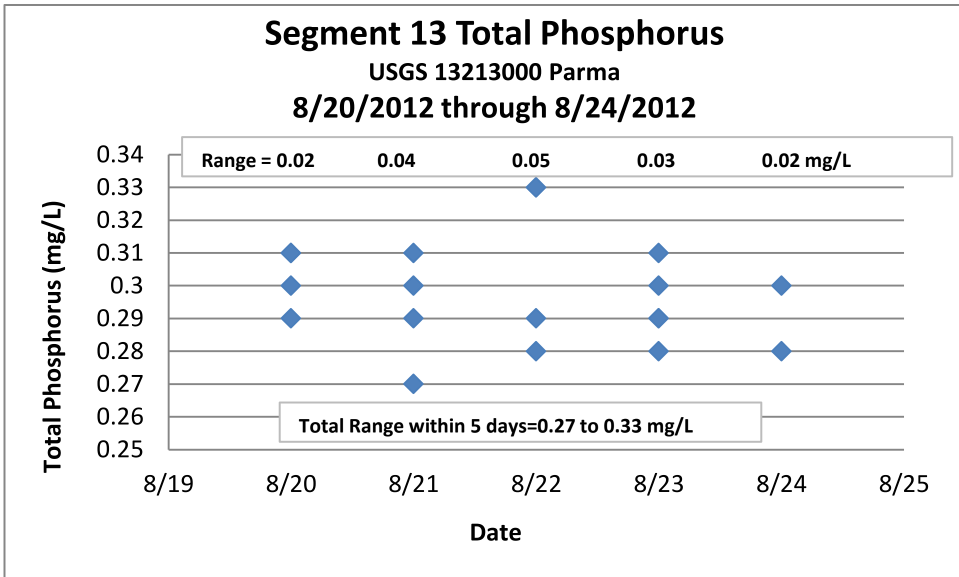


Figure 11. Water chemistry variability—example of total phosphorus concentrations ranging up to 0.05 mg/L on the same day at the same location.

- Variability in river chemistry—the upper reach of LBR in model segment 1 averages less than 0.01 mg/L TP, but the lowest reach in model segment 13 averages 0.29 mg/L TP during the modeled period from 1/1/2012 through 4/22/2013. Similar ranges of variation occur for total suspended sediment and nitrogen concentrations.
- Variability in river habitat—river habitat characteristics vary widely throughout the modeled reaches. The Boise River from Lucky Peak through Ann Morrison Park has consistently less periphyton covering the substrate than in lower reaches. Figure 12 shows the 2- to 8-inch cobbles in sandy substrate with less than 5% periphyton coverage in model segment 1. There was no virtually turbidity—visibility was over 2 meters.

Figure 12. Channel bottom characteristics and water clarity in model segment 1.

In contrast, Figure 13 shows periphyton covering 75% of the available substrate at a sample location at Friendship Bridge linking the Boise State University campus with Ann Morrison Park. Visibility was down to 1.3 meters in this portion of model segment 2.

Figure 13. Channel bottom characteristics in the lower portion of model segment 2.

In model segment 12, shown in Figure 14, visibility is 0.1 meters and 30% of the available habitat is covered with periphyton (not shown in photo).

Figure 14. Model segment 12 low water clarity.

This corresponds with previous biological assessments of the LBR (Mullins 1999; MacCoy 2006; Etheridge 2013) that indicate declining trends in instream habitat quality and biotic integrity in a downstream direction.

The AQUATOX model simulates 13 river segments, averaging the predictions over each model segment. DEQ believes that 13 model segments are sufficient to capture the variability in river habitats. However, water quality data are sampled at discrete points within the reach, and this creates variability between the field data and the reach-averaged model simulation.

The limitations of simulating a managed watershed with the inherent complexities of aquatic biota/nutrient/pollutant interactions and variable field data and river habitats all contribute to model uncertainty. Model uncertainty is addressed in the following sections, describing the accuracy of the simulation.

3.3 Model Calibration

Calibration is the adjustment of model parameters to create a better fit of simulated results to measured data. Accuracy goals for this model are to achieve simulated nutrient and chlorophyll values within 25% of the range of field data. Simulation accuracy will be described by absolute mean error (AME), which is calculated using the following:

$$AME = \frac{1}{n}\Sigma|xsim - xobs|$$

The AQUATOX model simulations are reported on different spatial and temporal scales than data measurements are collected. The temporal scale of the model is for a continuous simulation from January 1, 2012, through April 22, 2013; the temporal scale of field data collected during the model calibration period vary from almost daily data for temperature, to three samples for periphytic chlorophyll *a*. The spatial scale of this AQUATOX simulation is on a reach-wide average for each of the 13 segments, whereas the observed data within the Boise River channel are collected at specific locations as listed in section 1, Table 1. Where possible, gaps in field data were adjusted to give the model the most complete input datasets possible. To the extent certain data were developed from interpolation or averaging, temperature and light input were derived datasets.

Before beginning calibration, DEQ refined certain datasets that were missing data or were insufficient to describe the daily variation necessary to run the model.

Temperature—the temperature dataloggers at Marden Bridge—in model segment 2—were not operational between July 25 and December 3, which includes the portion of the year including the season of peak temperatures.

Temperature is a driving variable in AQUATOX. That is, it is not simulated, but the time series inputs are used to drive other variables in the study. Temperature data were collected by City of Boise for the study period:

- Marden Bridge—applied to model segments 1 and 2
- Veteran's Parkway Bridge—applied to model segment 3
- Glenwood—applied to model segment 4
- Eagle Road, south channel—applied to model segments 5, 6, and 7
- Middleton—applied to model segments 8, 9, and 10

The model linearly interpolates through missing data, but the simulated algal groups are sensitive to temperature, and it is important to more-accurately approximate temperature in these uppermost model segments. The missing data period fit well to a 5th-order polynomial curve, which showed maximum temperatures up to 15.9 °C in early September. This is realistic for the upstream segments since segment 3 temperatures at Veteran's Parkway Bridge—10.93 river miles downstream of the beginning of segment 1—reached the maximum of 17.7 °C in early September.

With these additional data points entered into the model for segments 1 and 2, the model is utilizing more realistic temperatures for this driving variable than with the linear interpolation and algal growth increased.

USGS data collected at Parma is used for segments 11, 12, and 13. Data were missing from January 1 through March 26, 2012. DEQ identified a typical January 1 low of 1.4 °C from the 7-day average of the January 2013 data and linearly interpolated to fill gaps in the missing data.

Light—the model had been displaying problematic light output, dropping to 20 Ly/d in the winter, which is not realistic.

Two things improved the light simulation. First, instead of using annual mean and range light loadings, dynamic daily varying data from the nearest AgriMet weather station was used to create an input file with 5-day moving average daily values. In addition, AQUATOX has a simplifying assumption for light that assumes ice cover forms when average water temperatures drop below 3 °C. This is assumption is not valid for the LBR because is too turbulent for a continuous ice cover to form that would limit light penetration to the substrate to that extent. Jonathan Clough programmed a new executable model version that does not factor in light decreases when stream temperature drops below 3 °C. This change improved the response of cold-water algae and cyanobacteria.

The light-limitation function in AQUATOX represents both limitation for suboptimal light intensity and photo-inhibition at high light intensities, and the AQUATOX Technical Documentation describes the function and related equations (Park and Clough 2012b).

Total Suspended Sediment—this is a driving variable, which means that the model does not simulate TSS, but it is used to drive other model simulations. The other driving variables are temperature and pH, and daily data was available for these two variables. However, TSS data for the model simulation period was sparse. DEQ considered various methods to establish TSS regressions with flow data, but none of these methods matched the sparse existing data. What finally improved model calibration was a dataset utilizing monthly TSS averages for all of the historical data. This TSS dataset is incorporated as part of the import spreadsheet to override the sparse measured data. The previous import spreadsheet, dated 2014_0103, still contains the sparse measured TSS and SSC data collected during the model simulation period for reference. DEQ recommends for best results to import the average TSS data for the best simulation accuracy.

3.3.1 Velocity

Water velocity affects periphyton sloughing, in that faster currents replenish nutrients and carry away senescent biomass. For calibration, model velocities were compared to observed velocities. AQUATOX calculates velocity from streamflow and dynamic mean depth input data. Velocity values can be further refined by editing Manning's roughness coefficient in AQUATOX site data. Model accuracy was considered sufficient when model velocities were within 10–20 cm/s of observed velocities. With the correct dynamic mean depths, simulated velocities were within desired accuracy, as shown in Figure 15 through Figure 23. No further velocity calibration was needed.

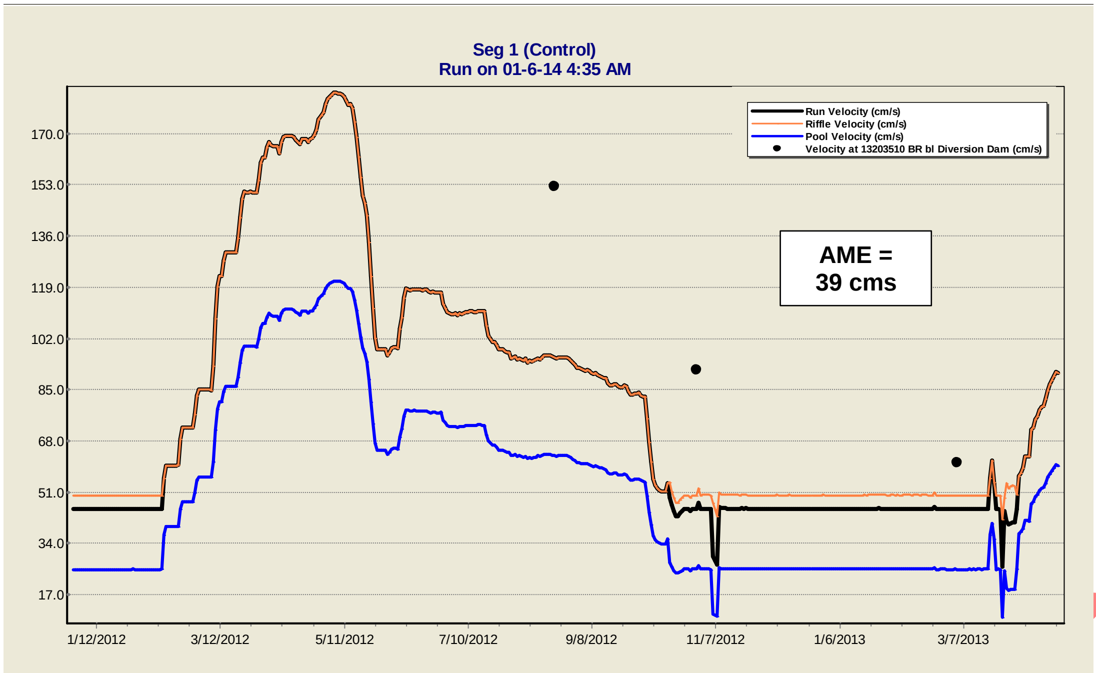


Figure 15. Segment 1 velocity simulation accuracy.

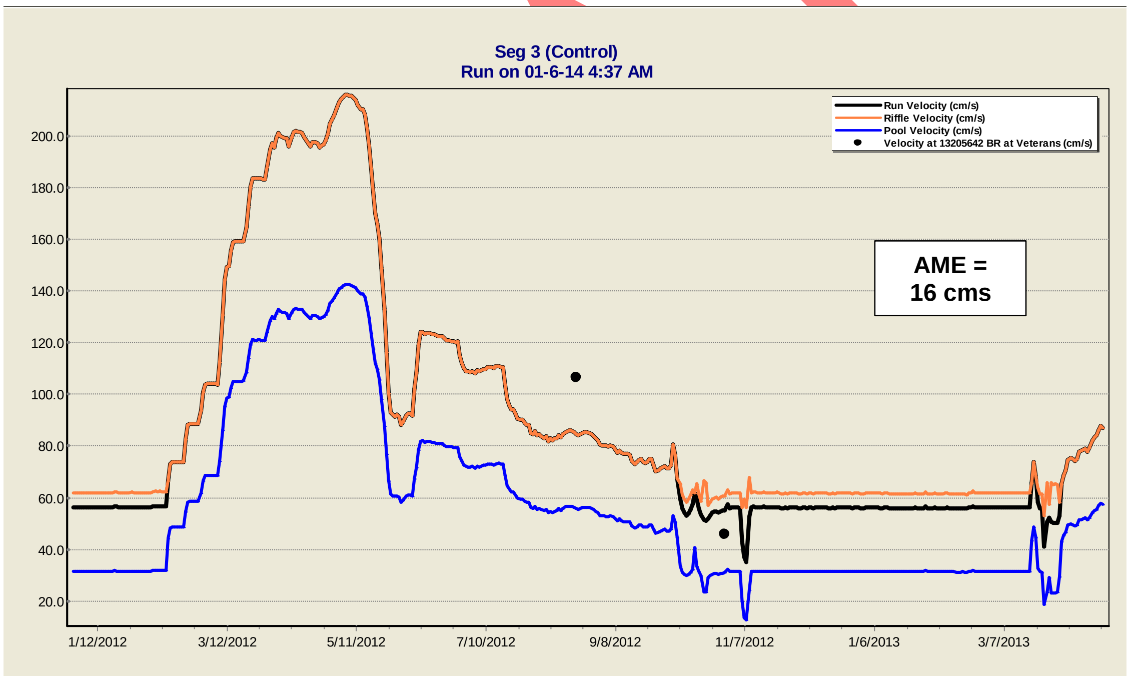


Figure 16. Segment 3 velocity simulation accuracy.

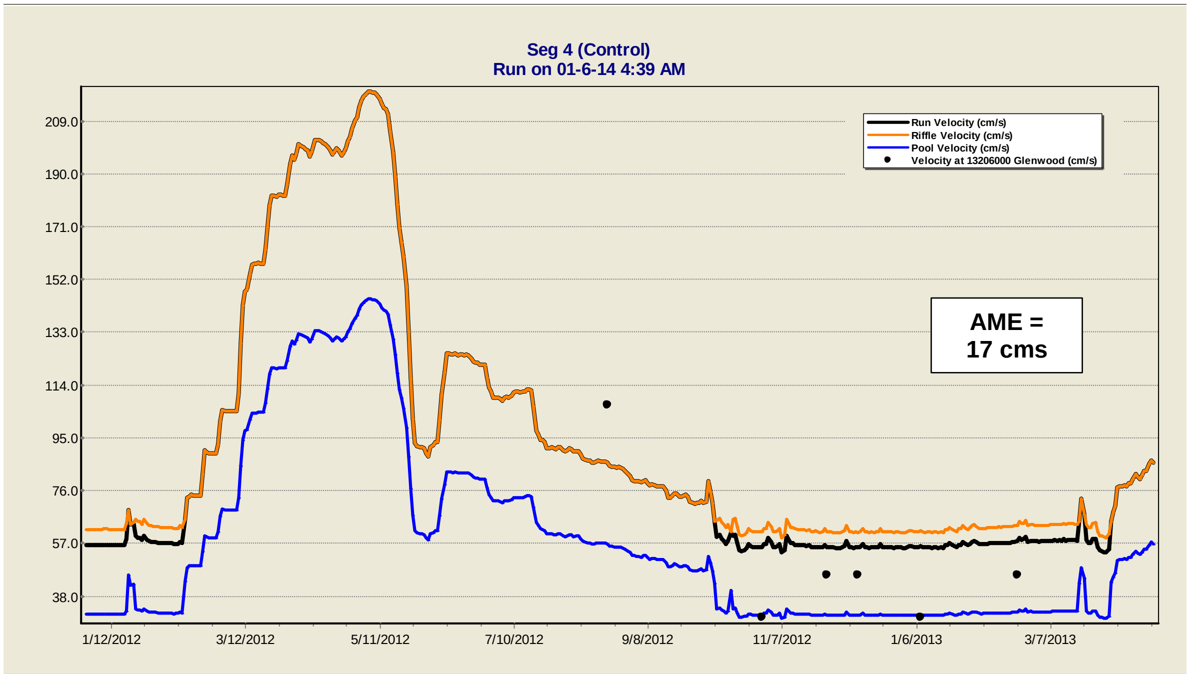


Figure 17. Segment 4 velocity simulation accuracy.

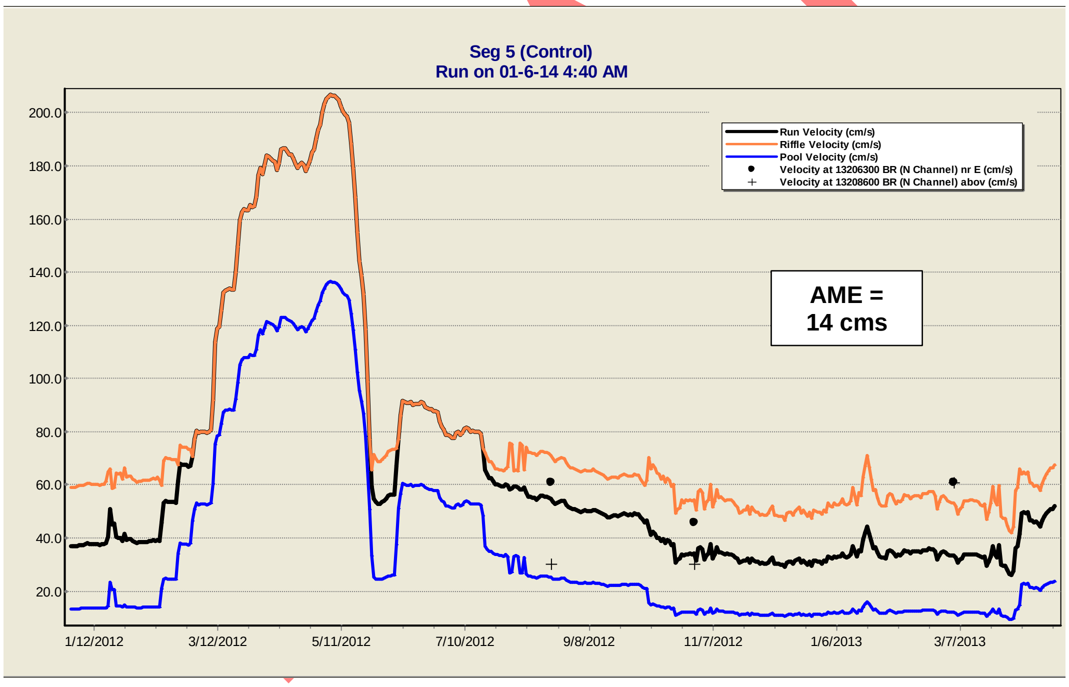


Figure 18. Segment 5 velocity simulation accuracy.

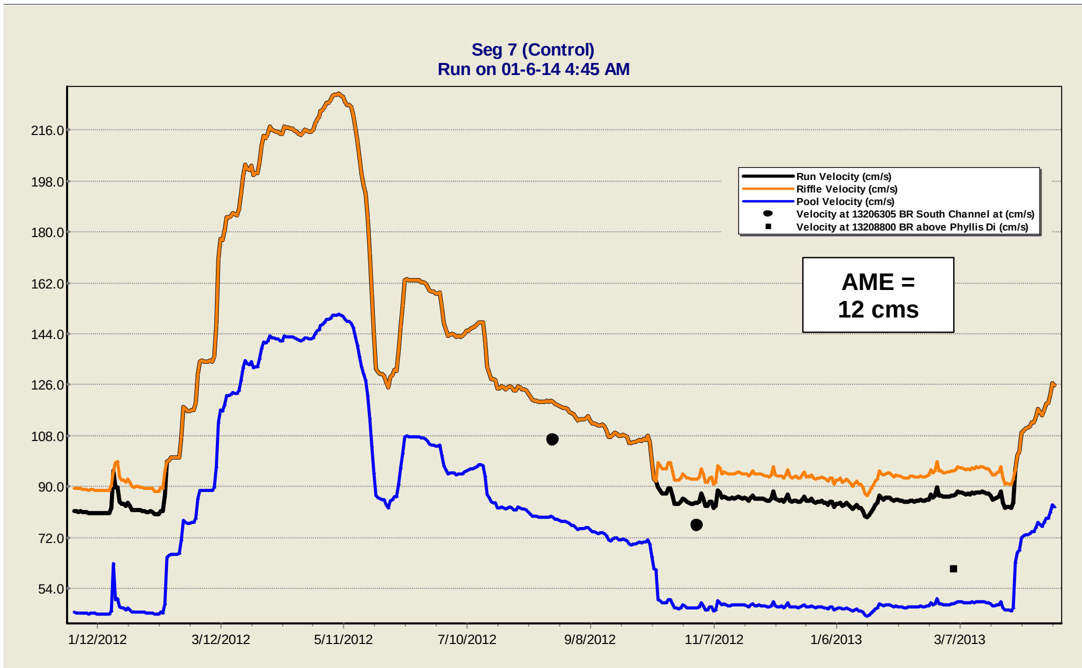


Figure 19. Segment 7 velocity simulation accuracy.

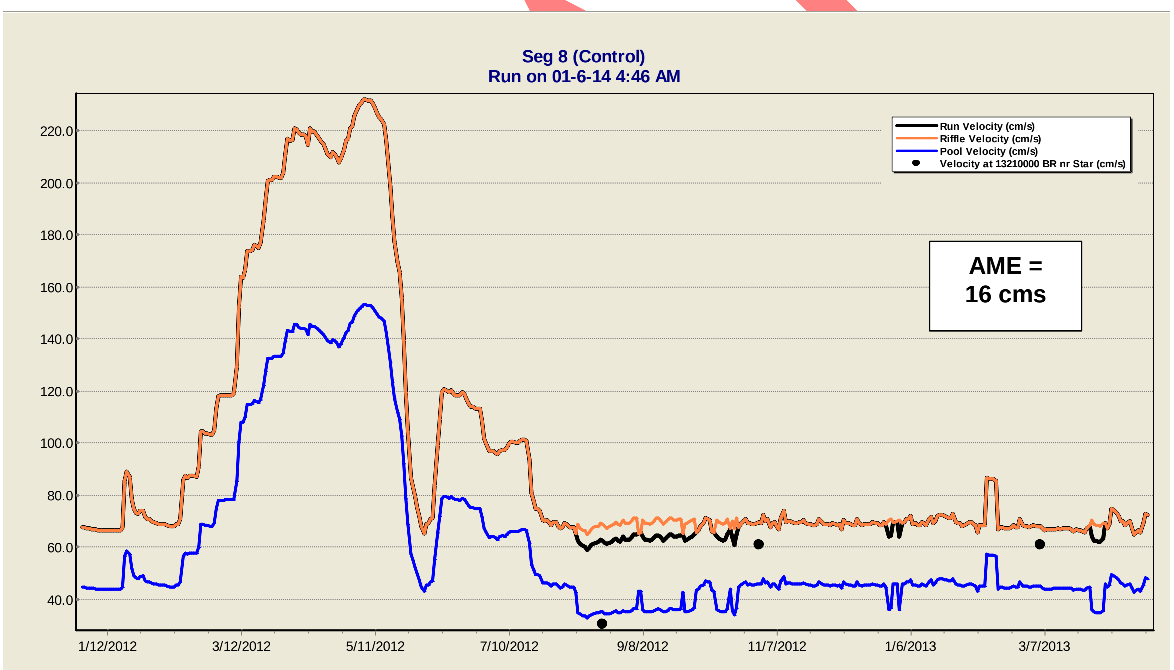


Figure 20. Segment 8 velocity simulation accuracy.

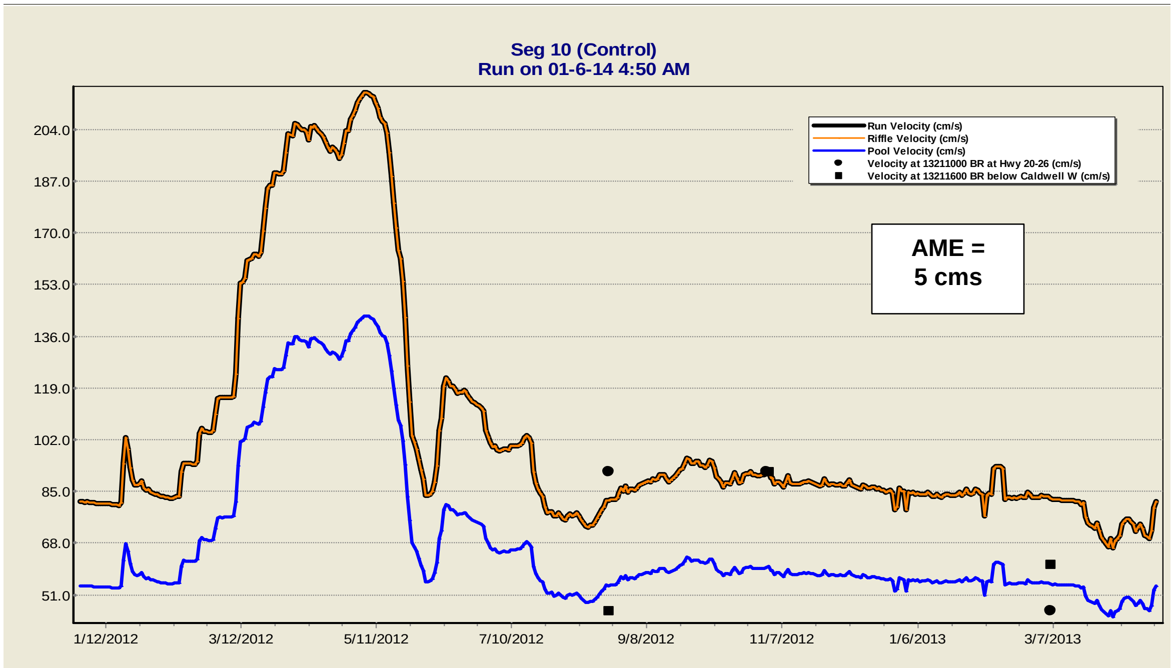


Figure 21. Segment 10 velocity simulation accuracy.

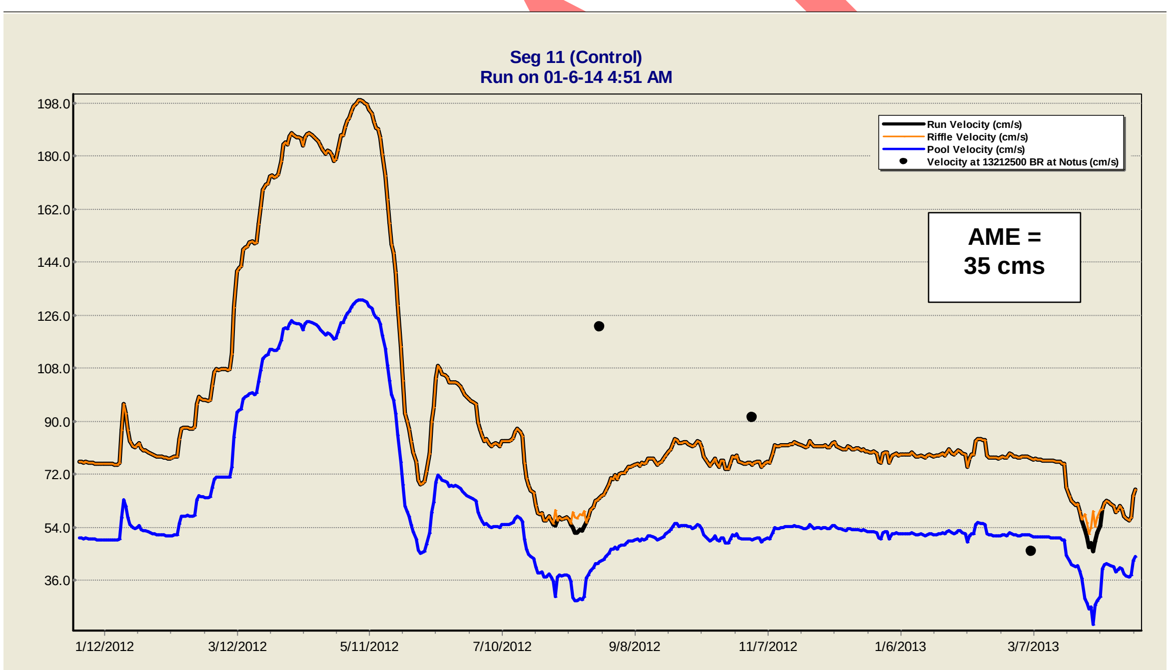


Figure 22. Segment 11 velocity simulation accuracy.

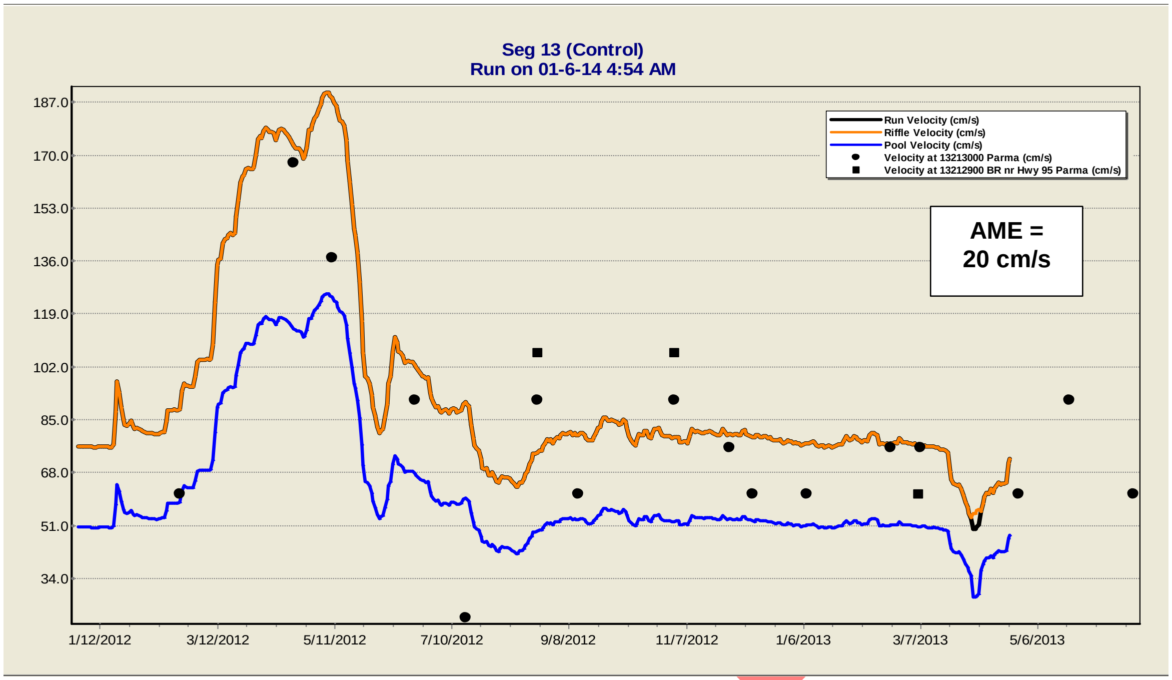


Figure 23. Segment 13 velocity simulation accuracy.

The average absolute mean error for all of the segments with velocity data is 19 cm/s. The goal was for the simulation to come within 10–20 cm/s of existing data, so the accuracy is within the desired range.

3.3.2 Nutrients

The boundary conditions were established by utilizing the constituent data for the river water column, and tributary and ground water inputs. DEQ performed iterative simulations using AQUATOX to identify the best initial load for nutrients and organic detritus. DEQ further optimized the simulations of nutrients and organic detritus by running the model in spin-up mode. This utility predicts the initial load by identifying the final predicted value of any given state variable and overwriting this value as the initial condition.

Whereas the 2008 LBR model used single set of default values for all of the segments and tributaries, this iterative process used for the current 2012-2013 model identified optimal initial conditions for each segment individually. Moving from the same initial load for each state variable to a load tailored for each segment resulted in better accuracy in the nutrient predictions.

Figure 24 through Figure 33 show the accuracy of simulation predictions for TP.

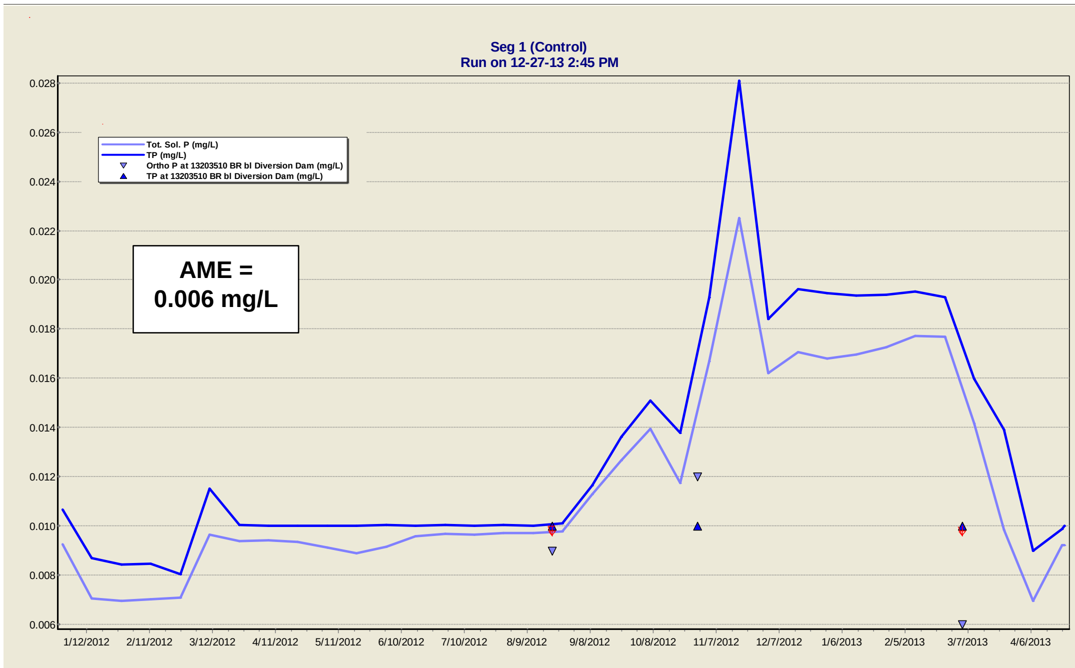


Figure 24. Segment 1 total phosphorus simulation accuracy (lines are modeled values; blue markers are observed data; red markers are nondetect observed data).

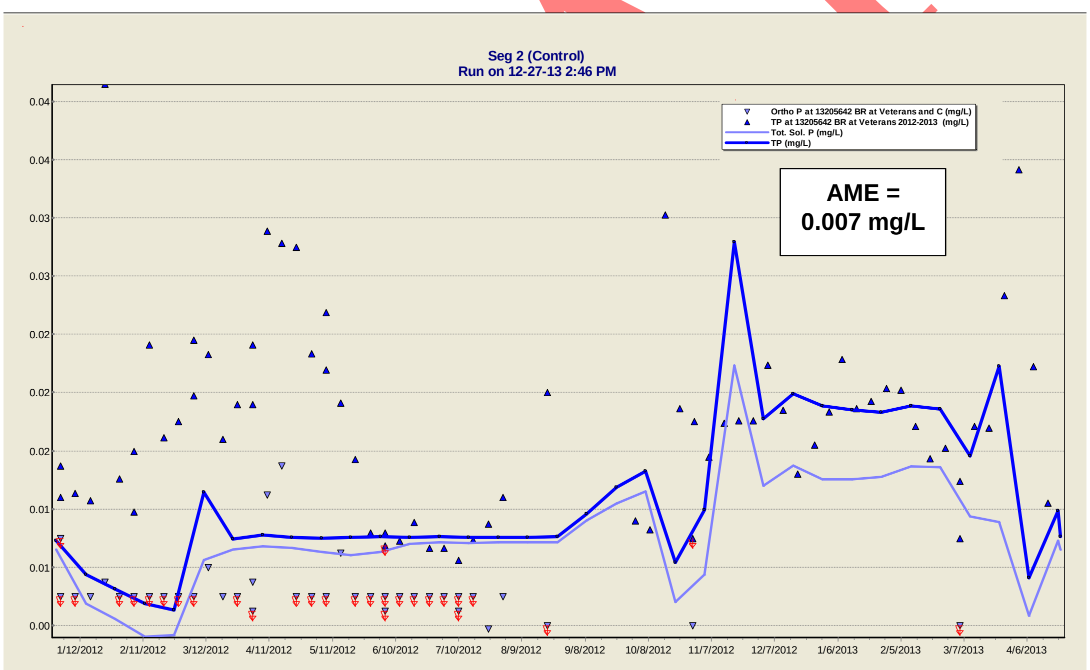


Figure 25. Segment 2 total phosphorus simulation accuracy (lines are modeled values; blue markers are observed data; red markers are nondetect observed data).

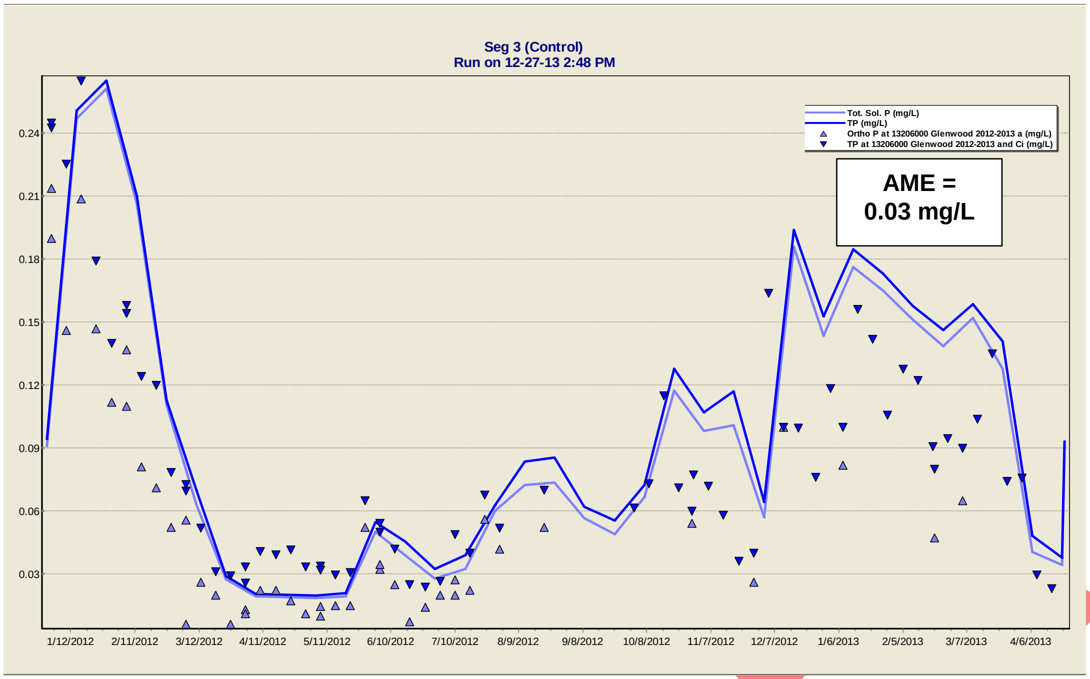


Figure 26. Segment 3 total phosphorus simulation accuracy (lines are modeled values; blue markers are observed data).

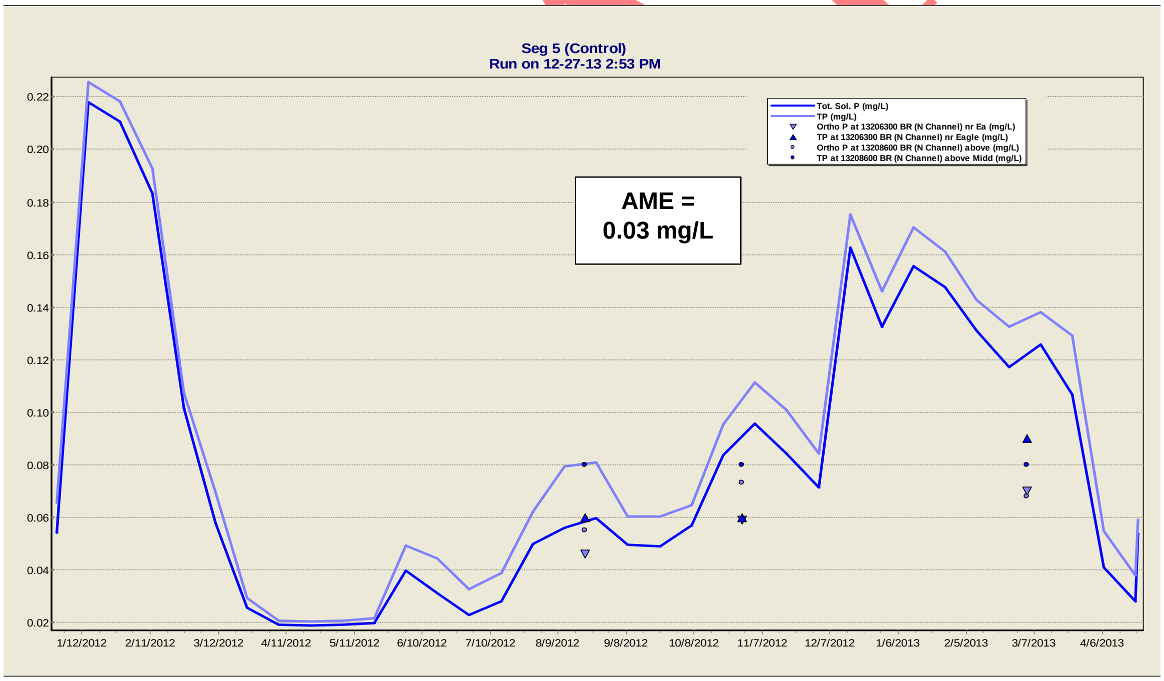


Figure 27. Segment 5 total phosphorus simulation accuracy (lines are modeled values; blue markers are observed data).

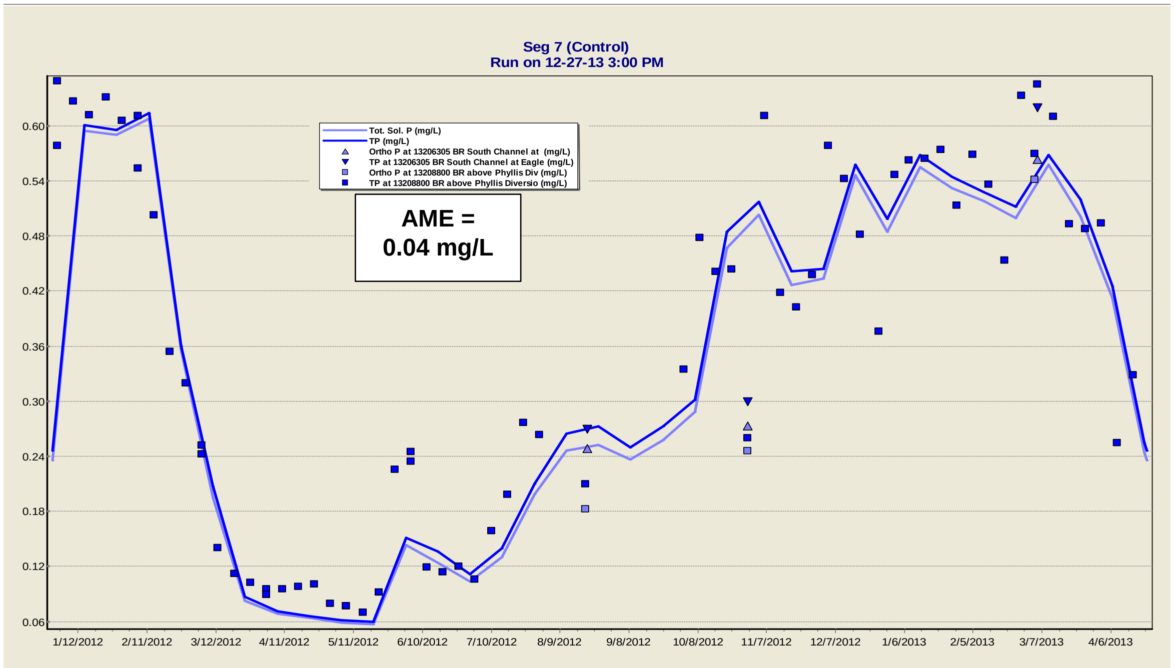


Figure 28. Segment 7 total phosphorus simulation accuracy (lines are modeled values; blue markers are observed data).

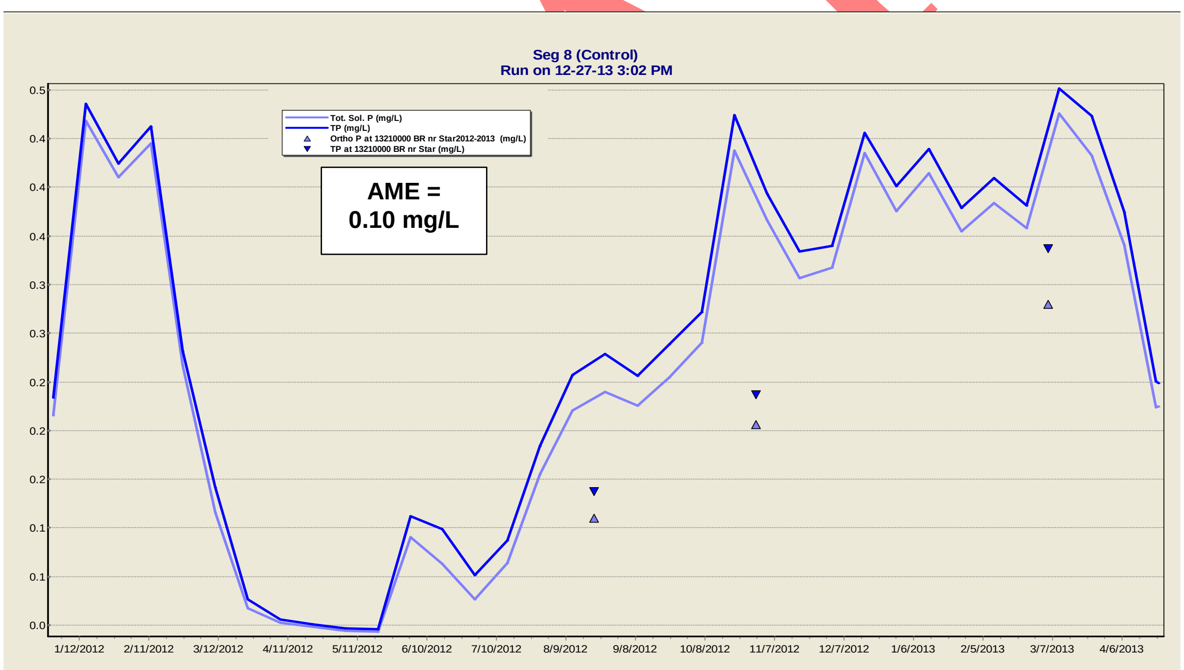


Figure 29. Segment 8 total phosphorus simulation accuracy (lines are modeled values; blue markers are observed data). The phosphorus simulation appears to overpredict existing data in model segment 8.

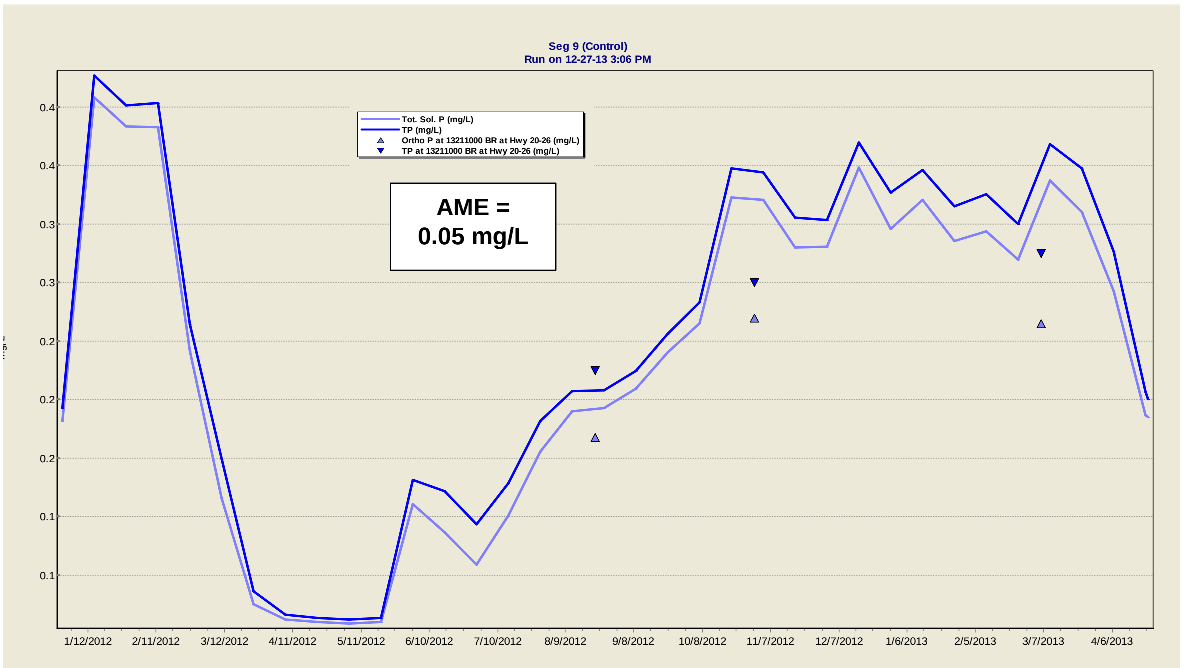


Figure 30. Segment 9 total phosphorus simulation accuracy (lines are modeled values; blue markers are observed data).

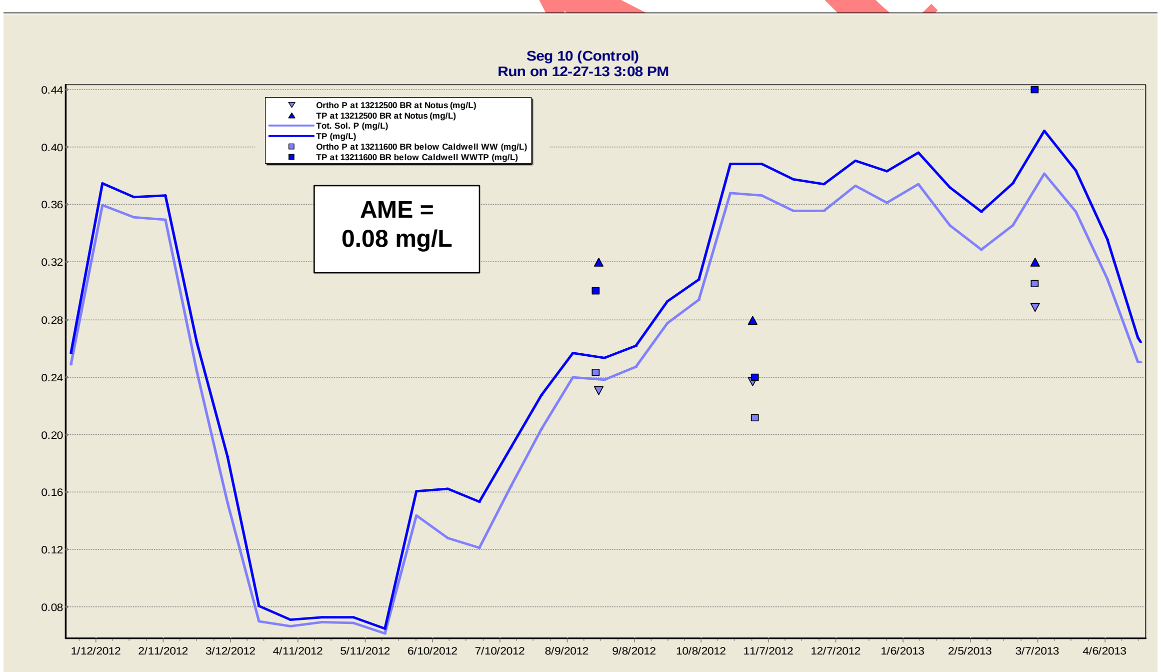


Figure 31. Segment 10 total phosphorus simulation accuracy (lines are modeled values; blue markers are observed data).

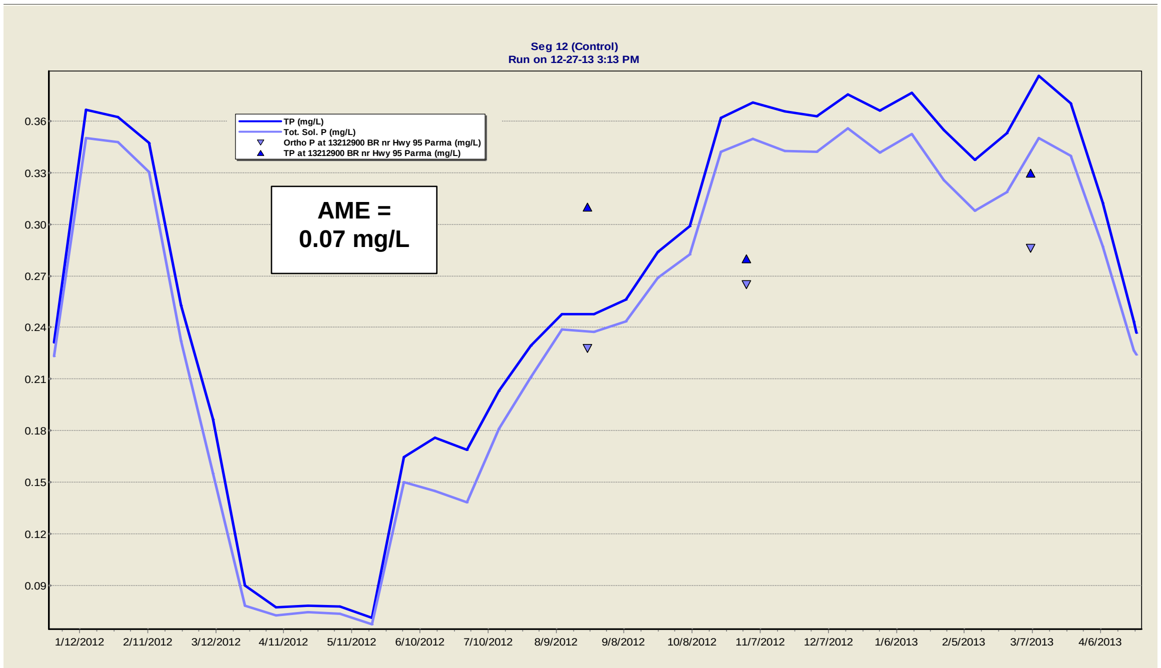


Figure 32. Segment 12 total phosphorus simulation accuracy (lines are modeled values; blue markers are observed data).

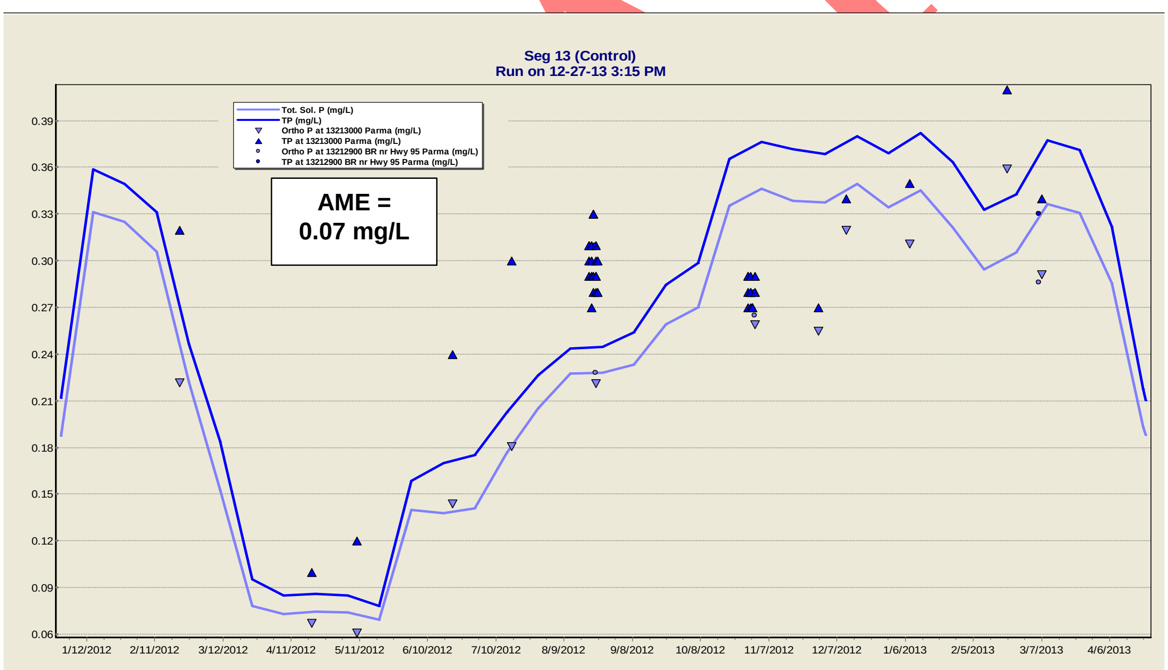


Figure 33. Segment 13 total phosphorus simulation accuracy (lines are modeled values; blue markers are observed data).

Because the variability of field data ranges up to 0.05 mg/L (Figure 11), the TP predictions appear very accurate. Simulations in model segments 1, 2, 3, 5, 7, and 9 all exhibit less than 0.05 mg/L absolute mean error, so these simulations are acceptably accurate; however, segment 8 appears to overpredict existing data by 0.10 mg/L.

The simulation accuracy goal is for the model predictions to fall within 25% of the range of field data. The field data range from 0.0085 mg/L to 0.65 mg/L TP. Twenty-five percent of this range of field data equals 0.16 mg/L. Since the total data variability and simulation error ranges from 0.006 mg/L to 0.10 mg/L, this model is accurately predicts TP concentrations.

In summary, this model predicts TP concentrations to within an average 0.05 mg/L over the entire LBR. For each model segment, this model simulates TP concentrations within the following values of the observed data:

- Segment 1—0.006 mg/L
- Segment 2—0.007 mg/L
- Segment 3—0.03 mg/L
- Segment 5—0.03 mg/L
- Segment 7—0.04 mg/L
- Segment 8—0.10 mg/L
- Segment 9—0.05 mg/L
- Segment 10—0.08 mg/L
- Segment 12—0.07 mg/L
- Segment 13—0.07 mg/L

These values contain both the field data variability and the simulation error.

3.3.3 Periphyton

The sum of biomass for the five periphytic algal groups—high- and low-nutrient diatoms, green algae, *Cladophora*, and blue-green algae—equals the total periphyton chlorophyll a (mg/m^2) biomass. Altering algal parameters was the most important action to achieve better fit of periphyton predictions to measured data.

Periphyton data collected during the model simulation period from 1/1/2012 through 4/22/2013 (Table 13) is sparse.

Table 13. USGS periphyton and phytoplankton data collected on the lower Boise River during the model calibration period from January 1, 2012, through April 22, 2013 (Etheridge 2013).

			Week of August 21, 2012					
			Periphyton Biomass	Periphyton Chl-a	Phytoplankton Chl-a	Mean Water Depth	Mean Water Velocity	Light Extinction Coefficient
Site ID	River Mile	Site Name	g/m^2	mg/m^2	µg/L	ft	ft/s	
13203760	58.1	BOISE RIVER AT ECKERT RD NR BOISE ID	3	3	1	1.04	1.47	0.09
13206000	47.5	BOISE RIVER AT GLENWOOD BRIDGE NR BOISE ID	47	147	3	0.72	1.37	0.04
13210050	31.4	BOISE RIVER NR MIDDLETON ID	10	40	6.4	0.43	2.26	0.07
13211000	24.0	BOISE RIVER AT HWY 20-26 XING NR CALDWELL ID	25	108	6.7	0.27	1.67	0.20
13213030	0.0	BOISE RIVER AT MOUTH NR PARMA ID	11	63	10.5	0.26	1.20	0.09
			Week of October 29, 2012					
			Periphyton Biomass	Periphyton Chl-a	Phytoplankton Chl-a	Mean Water Depth	Mean Water Velocity	Light Extinction Coefficient
Site ID	River Mile	Site Name	g/m^2	mg/m^2	µg/L	ft	ft/s	
13203760	58.1	BOISE RIVER AT ECKERT RD NR BOISE ID	3	4	ND	0.51	2.53	0.06
13206000	47.5	BOISE RIVER AT GLENWOOD BRIDGE NR BOISE ID	16	131	3.7	0.80	1.82	0.15
13210050	31.4	BOISE RIVER NR MIDDLETON ID	24	219	6.4	0.63	2.22	0.15
13211000	24.0	BOISE RIVER AT HWY 20-26 XING NR CALDWELL ID	25	255	5.6	0.57	2.57	0.14
13213030	0.0	BOISE RIVER AT MOUTH NR PARMA ID	32	181	9	0.67	2.48	0.10
			Week of March 4, 2013					
			Periphyton Biomass	Periphyton Chl-a	Phytoplankton Chl-a	Mean Water Depth	Mean Water Velocity	Light Extinction Coefficient
Site ID	River Mile	Site Name	g/m^2	mg/m^2	µg/L	ft	ft/s	
13203760	58.1	BOISE RIVER AT ECKERT RD NR BOISE ID	14	36	4.8	0.59	1.56	na
13206000	47.5	BOISE RIVER AT GLENWOOD BRIDGE NR BOISE ID	33	283	7.3	1.09	1.80	0.08
13210050	31.4	BOISE RIVER NR MIDDLETON ID	30	137	19.5	0.53	1.68	0.11
13211000	24.0	BOISE RIVER AT HWY 20-26 XING NR CALDWELL ID	23	211	17.5	0.46	1.87	0.13
13213030	0.0	BOISE RIVER AT MOUTH NR PARMA ID	16	92	36.2	0.58	2.39	0.13

Where possible, historical periphyton data (Table 14) were also used to inform the calibration process.

Table 14. Periphyton chlorophyll a biomass data collected by USGS on the lower Boise River between 1995 and 2013.

Station	Eckert (mg/m^2; samples)		Glenwood (mg/m^2; samples)		Middleton (mg/m^2; samples)		Caldwell (mg/m^2; samples)		Parma (mg/m^2; samples)	
January					289.0	1			188.0	1
February			4.2	3	7.8	3	337.0	1		
March	36.0	1	283.0	1	137.0	1	211.0	1	92.0	1
April			8.1	7	11.6	6				
May			4.6	2	6.4	2				
June			2.0	3	6.7	2				

July			4.9	2	11.5	2				
August	1.0	4	24.6	8	16.2	8	95.9	4	86.7	4
September	3.3	3	78.5	2						
October	8.7	23	136.4	27	235.2	17	420.2	13	135.1	13
November	19.8	12	274.2	5	282.6	16	272.9	15	219.0	10
December			5.2	4	13.2	4				

Notes: The numbers with white background represent the mean chlorophyll a biomass for all samples collected during that month; the numbers with grey background represent the total number of samples collected during that month.

Throughout the remainder of the model report the periphyton data that was collected within the simulation period is referred to as "measured" data and earlier periphyton data is referred to as "historical" data.

3.3.3.1 Community composition data used to calibrate algal groups

The periphyton community composition analysis in Rushforth 2007b reports organism presence—to genus or species level in most cases—in the Boise River for study dates in October 2005, September 2006, and March 2007. DEQ categorized these results into the 5 periphytic algal groupings used in the AQUATOX model. The Rushforth report categorized algae presence as:

- Rare—present in <10% of microscope fields
- Common—present in 10-20% of microscope fields
- Abundant—present in >20% of microscope fields

Figure 34 presents these findings grouped according to the AQUATOX model segments.

Periphyton community composition summarized from Rushforth 2007

Model segment	River Mile	Site	Lat	Long	
1	*61.1*	Diversion	43.54531	-116.099469	
	Blue-greens	*Cladophora*	*Greens*	*High-nutrient diatoms*	*Low-nutrient diatoms*
March	rare	rare	common	abundant	common
September	none	abundant	common	abundant	none
October	none	none	abundant	common	none
2	*58.3*	Eckert Road	43.56572	-116.132058	USGS Site ID 13203760
	Blue-greens	*Cladophora*	*Greens*	*High-nutrient diatoms*	*Low-nutrient diatoms*
March	common	rare	common	abundant	common
September	abundant	rare	rare	abundant	none
October	common	none	none	common	none
3	*50.17*	Veteran's Parkway	43.63606	-116.2411417	USGS Site ID 13205642
	Blue-greens	*Cladophora*	*Greens*	*High-nutrient diatoms*	*Low-nutrient diatoms*
March	common	none	rare	abundant	rare
September	none	abundant	none	abundant	rare
October	abundant	none	abundant	abundant	none
4	*47.5*	Glenwood	43.66104	-116.2796389	USGS Site ID 13206000
5	*45.51*	Loss to N Channel	43.67043	-116.30753	GIS
6	45.51	LOSS TO NORTH CHANNEL	43.67043	-116.30753	GIS
7	44.16	Boise WWTP West Boise	43.67271	-116.331657	GIS
8	40.2	GAIN FROM NORTH CHANNEL	43.68138	-116.424625	GIS
	Blue-greens	*Cladophora*	*Greens*	*High-nutrient diatoms*	*Low-nutrient diatoms*
March	none	common	rare	abundant	common
September	common	none	common	abundant	none
October	common	none	rare	abundant	none
9	*31.43*	Boise River NR Middleton	43.68704	-116.5867694	USGS Site ID 13210815
	Blue-greens	*Cladophora*	*Greens*	*High-nutrient diatoms*	*Low-nutrient diatoms*
March	common	rare	rare	abundant	common
September	rare	rare	rare	abundant	abundant
October	common	none	rare	abundant	none
10	*23.98*	Boise River at HWY 20-26	43.68898	-116.6862333	USGS Site ID 13211000
11	*15.66*	Boise River at Notus	43.72088	-116.7980028	USGS Site ID 13212500
12	*10.6*	Above Dixie Drain	43.73225	-116.889004	GIS
13	*8.77*	Boise River at HWY 95 Crossing	43.74721	-116.9124611	USGS Site ID 13212900
	Blue-greens	*Cladophora*	*Greens*	*High-nutrient diatoms*	*Low-nutrient diatoms*
March	rare	abundant	rare	abundant	none
September	none	common	common	abundant	common
October	abundant	none	rare	abundant	none
END	*3.8*	Parma	43.78151	-116.9727944	USGS Site ID 13213000

Figure 34. Summary of periphytic algal community compositions.

In AQUATOX, the periphyton chlorophyll a (mg/m^2) mirrors the sum of biomass for the five periphytic algal groups. To help calibrate the final periphyton predictions, DEQ created a visual display of the community composition by assigning values to algae presence:

- None = 0
- Rare = 1
- Common = 5
- Abundant = 8

Even though the Rushforth study did not provide the kind of biomass data that could be used as input to the model, the charts produced by this method (Figure 35) helped to identify relative abundance of the algal groups throughout the model segments in March, September, and October.

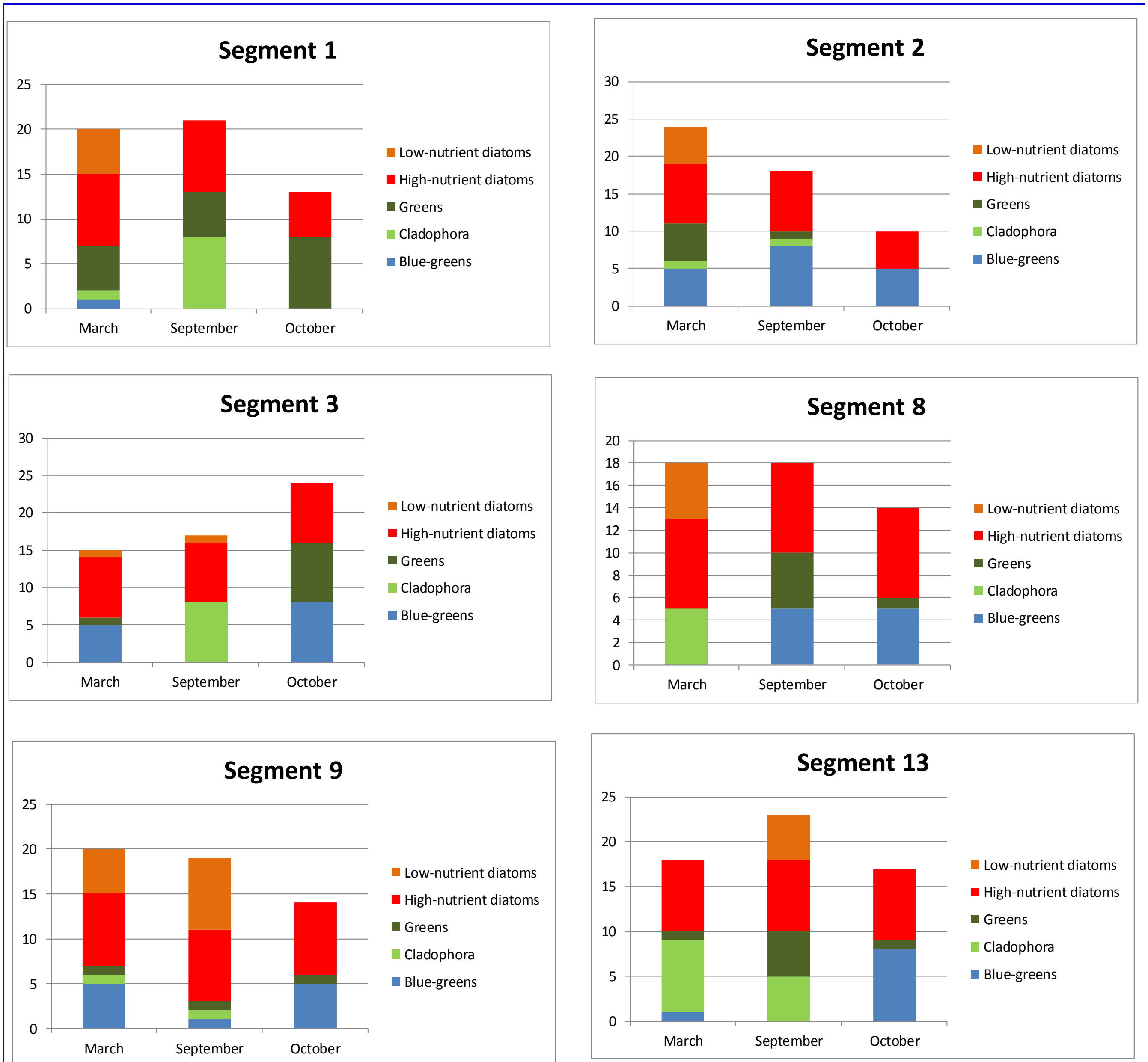


Figure 35. DEQ visual depiction of algal community composition in all sampled segments, based on previous analyses in the LBR (Rushforth 2007b).

In this manner, the final periphyton prediction has a better foundation in the algal community composition that has been shown to exist in the river. For an example of how this community composition chart was used in calibrating periphyton, Figure 36 shows a chart of the Segment 13 model prediction of periphyton chlorophyll a (mg/m^2) compared with the measured data at Parma during an earlier phase of the calibration.[2]

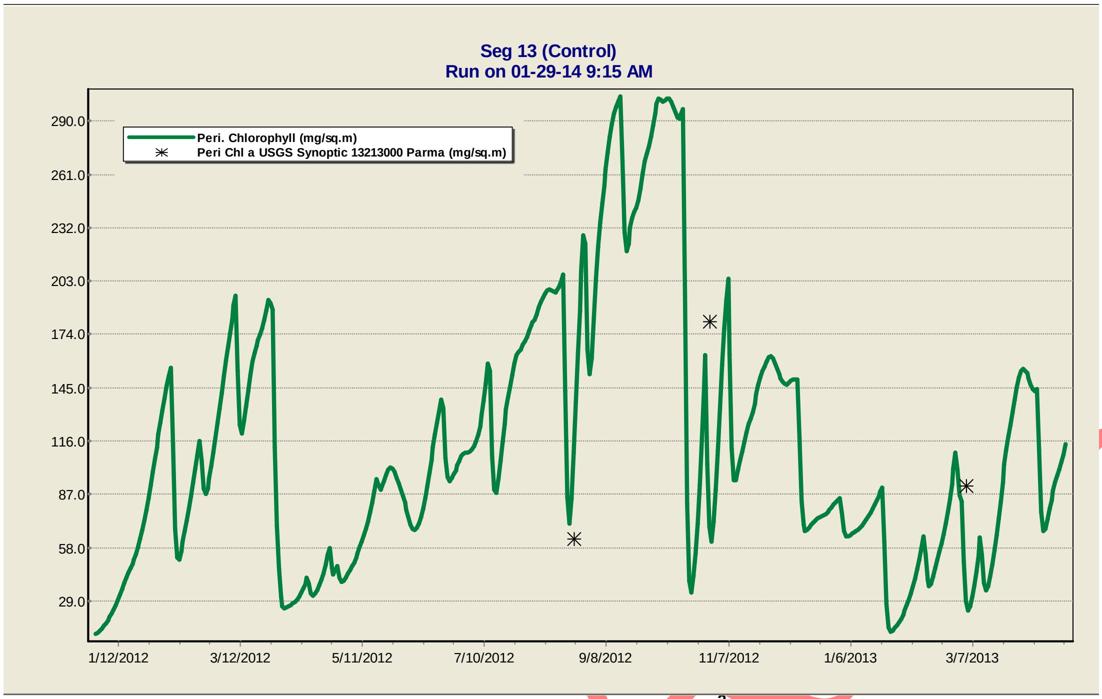


Figure 36. Model prediction of periphyton chlorophyll a (mg/m^2) during an earlier phase of the calibration process.

Figure 37 shows the model prediction of the biomass (g/m^2 dry) of each of the periphyton groups that combine to create the above periphyton chlorophyll prediction.

In comparing this output to the visual depiction of the algal community composition for Segment 13 (Figure 38), one can see that the model accurately predicts that high-nutrient diatoms as present throughout the year. However, the model accuracy is questionable due to the presence of low-nutrient diatoms throughout the year, because the Rushforth analyses only found them present in September samples. The Cladophora simulation appears correct in magnitude, but it should have appeared in March and September, as well as throughout the summer period, as shown in Figure 37. The green algae prediction appears very consistent with the Rushforth 2007 analyses, showing up mostly in the September samples. The blue-green algae prediction appears correct in magnitude, but it should probably only be seen in the fall months (e.g. October instead of March).

[2] Model iteration note: even though this earlier calibration appears to fit pretty well to the measured data and the community composition is acceptable, the overall calibration for this iteration was a poor fit because all of the other segments consistently under predicted current and historical data.

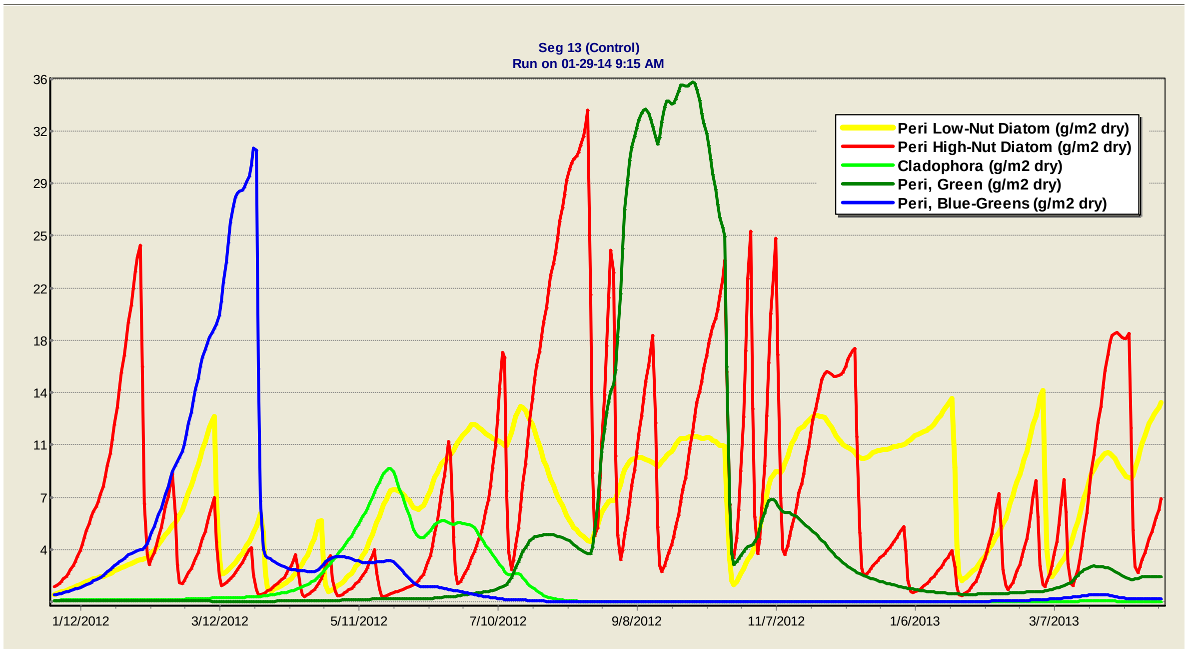


Figure 37. Prediction of periphytic algal groups (g/m^2 dry) during an earlier phase of the calibration process.

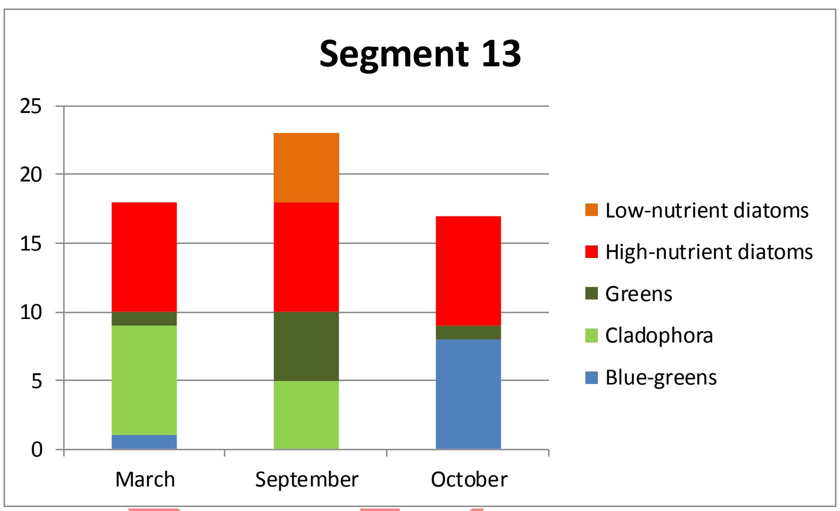


Figure 38. Visual depiction of algal community composition in Segment 13.

The next step in the calibration process is to adjust algal parameters—as informed by a sensitivity analysis—to help the model prediction align with community composition samples. The AQUATOX model has a function for running a sensitivity analysis, which ranks model input values in relation to their relative contributions to model output (p. 17-19 AQUATOX technical documentation) (Park and Clough 2012b). A summary of the sensitivity analysis of the lower Boise River model is provided in the next section, showing the variability of the periphyton chlorophyll (mg/m^2) predictions in response to changes in tested parameters.

In one sensitivity run, low-nutrient diatoms were affected by changes in sloughing—the percent periphyton lost in a slough event. Increasing the sloughing parameter resulted in a decrease for the overall periphyton chlorophyll prediction. Since the sloughing was set for 90% in the Figure 36 and Figure 37 model run, a new model run was made with the sloughing set for 97%. Low-nutrient diatoms are also affected by changes in the phosphorus half-saturation constant (mg/L—

Michaelis-Menten kinetics), where an increase in this parameter resulted in a decrease in periphyton. Since the P half-sat was set for 0.006 mg/L in the Figure 36 and Figure 37 model run, the new model run used 0.007 mg/L. The goal is to decrease the overall low-nutrient diatom prediction since sampling indicates they should only show up in relatively high abundance in or near fall months (e.g. September). The results of these two changes are shown in Figure 39

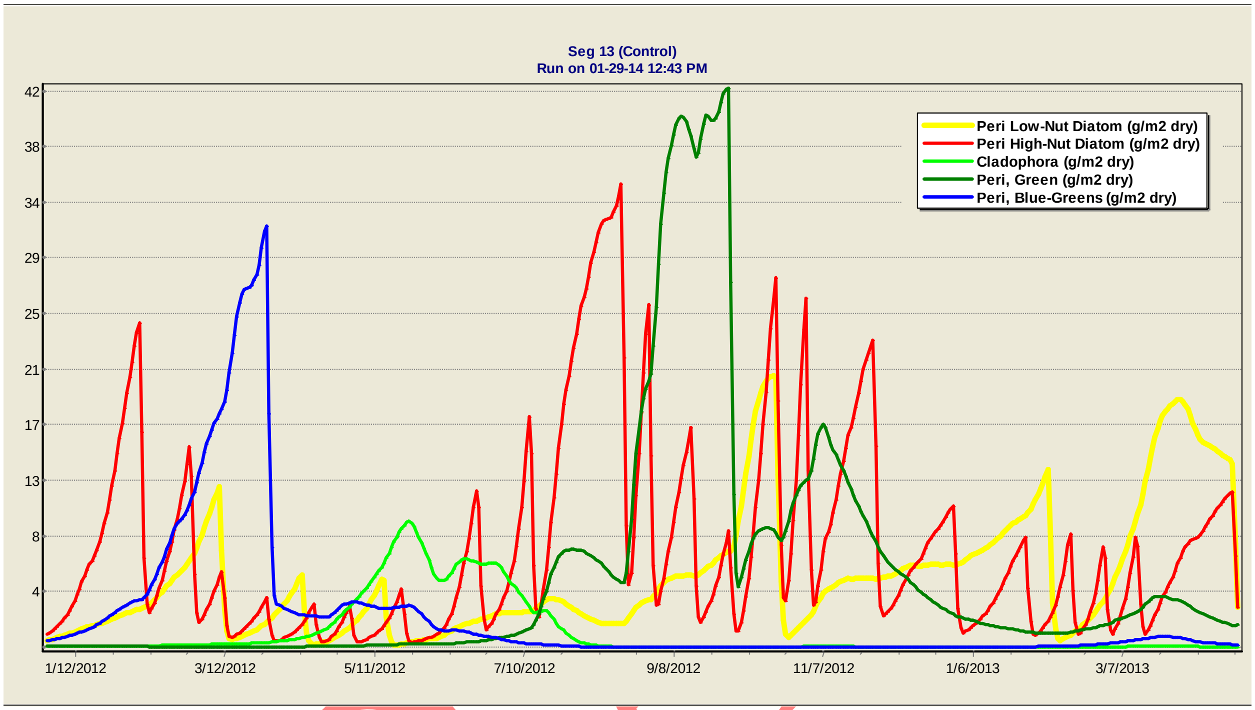


Figure 39. Prediction of periphytic algal groups (g/m^2 dry) after altering two parameters for low-nutrient diatoms.

This alteration in two parameters for low nutrient diatoms did reduce their appearance in May through September, but it allowed a greater proliferation of green algae in September, peaking out at 42 g/m^2 on September 29, whereas the previous iteration peaked at 36 g/m^2. Also, notice that the changes in two parameters for low nutrient diatoms also changed the high nutrient diatom simulation in March and April of 2013.

This specific example altering the phosphorus half-saturation constant and sloughing shows that certain algal groups are in competition for resources such as nutrients and habitat. Other resources include light and temperature. The algal parameters that are related to each resource include:

- Nutrients—phosphorus and nitrogen half-saturation constants
- Habitat—Critical force for periphyton scour; percent periphyton lost in slough event; percent riffle preference
- Temperature—optimal and maximum temperature, temperature response slope, exponential mortality coefficient
- Light—saturating light; maximum photosynthetic rate; light extinction

As described in section 2.4.2.1, AQUATOX calculates sloughing and loss through interactions of stream velocity, drag force, periphyton biomass, nutrient, light, and temperature limitations, along with channel adaptation as factors determining sloughing (Park and Clough 2012b). Figures 40-42 illustrate the potential complex relationships among periphyton sloughing in relation to biomass, water velocity, along with light, nutrient, temperature and velocity limitations.

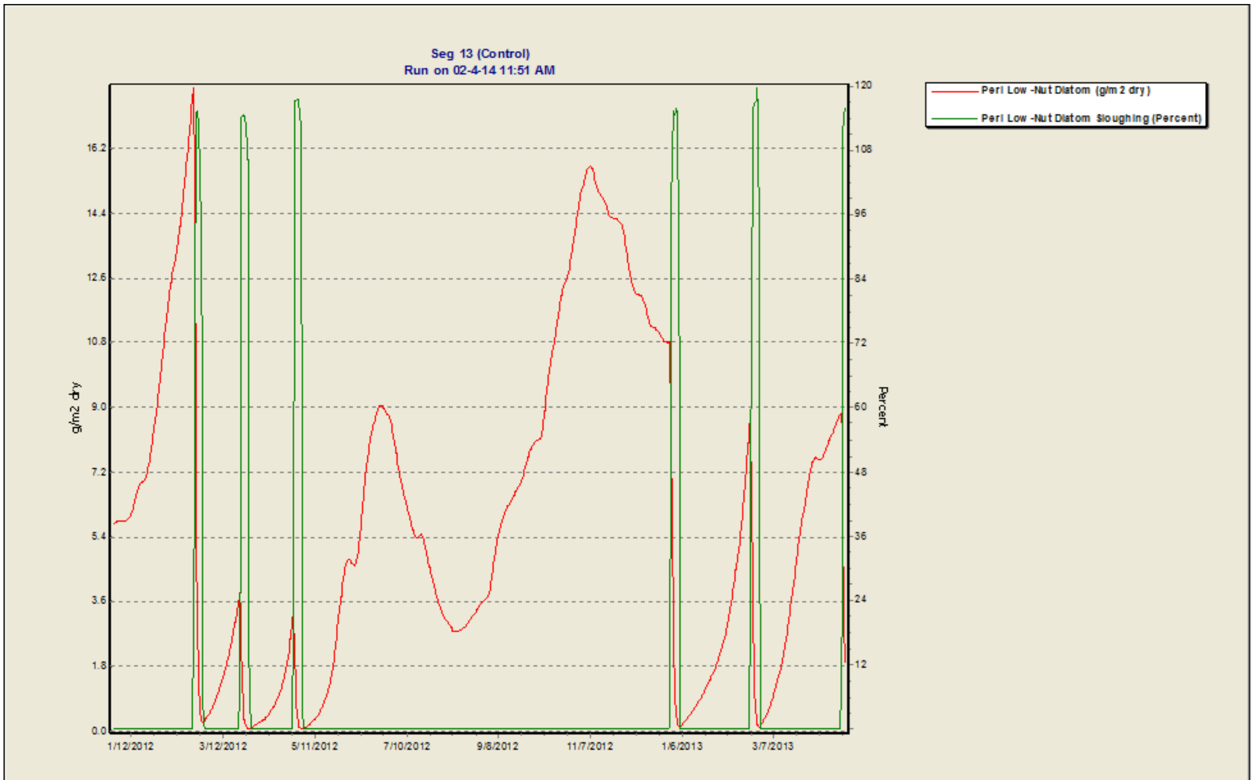


Figure 40. Example of periphyton low-nutrient diatom sloughing (%) relative to biomass (g/m^2 dry).

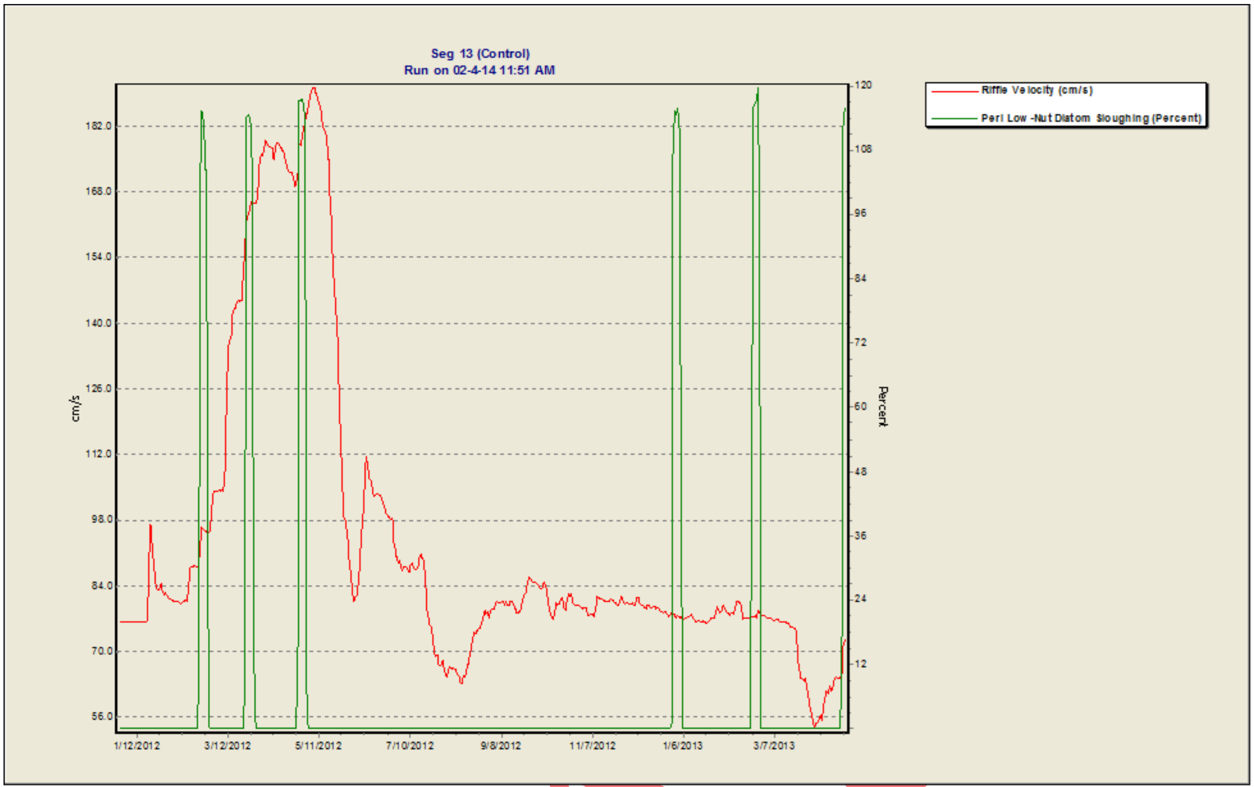


Figure 41. Example of periphyton low-nutrient diatom sloughing (%) relative to water velocity (cm/s).

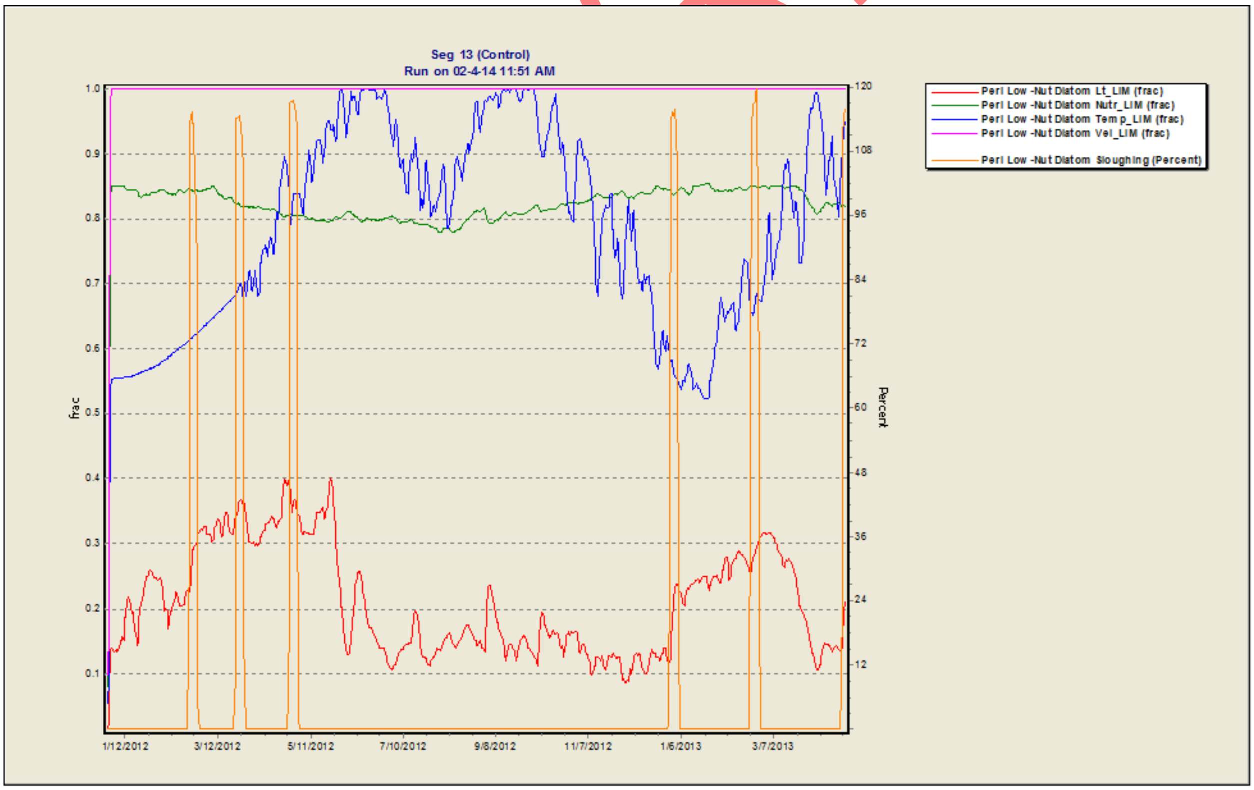


Figure 42. Example of periphyton low-nutrient diatom sloughing (%) relative to limitations (frac) from light, nutrients, temperature, and velocity.

As a result of sensitivity analyses, these parameter changes were the focus in iterative model runs to bring the simulated community composition more in line with historic field data.

3.3.3.2 Sensitivity Analysis

For each algal group, AQUATOX has 30 parameters that can be altered to refine the periphyton prediction for site-specific conditions. Some of these parameters, such as percent lipid content, do not have a wide range of variation in the literature and are not typically altered from the default. The parameters that exhibit a wide range of literature values based on physical and chemical conditions of the study site are those parameters most subject to calibration changes during model iterations.

Running AQUATOX in sensitivity mode allows an evaluation of input assumptions and how they relate to model output variability. “Sensitivity” refers to the relative importance of the input value to the model output. The AQUATOX sensitivity analysis allows the user to select parameters to be tested, the percent to vary these parameters, and the output variables upon which to track the effect of the tested parameters.

DEQ tested the sensitivity of the following algal parameters:

- Optimal temperature—Topt (deg C)
- Critical force for periphyton scour—fcrit (Newtons)
- Light Extinction Coefficient—Lightex (1/m-g/m^3)
- Percent periphyton lost in slough event—sloughing (%)
- Phosphorus half-saturation constant—Phalf-sat (mg/L), Michaelis-Menten kinetics
- Nitrogen half-saturation constant—Phalf-sat (mg/L), Michaelis-Menten kinetics
- Maximum photosynthetic rate—Pmax (1/day)

DEQ tracked the effect of altering these algal parameters on the following output variables:

- NH_3 and NH_4 (mg/L)
- NO_3 (mg/L)
- Total soluble phosphorus (mg/L)
- Total phosphorus (mg/L)
- Carbon dioxide (mg/L)
- Oxygen (mg/L)
- Total Suspended Sediment (mg/L)
- Phytoplankton chlorophyll a (ug/L)
- Periphyton chlorophyll a (mg/m^2)

The entire suite of output files is available from DEQ. The results of these sensitivity runs are summarized below. A plot showing the relative importance of each parameter to the selected algal group is followed by text describing the plot.

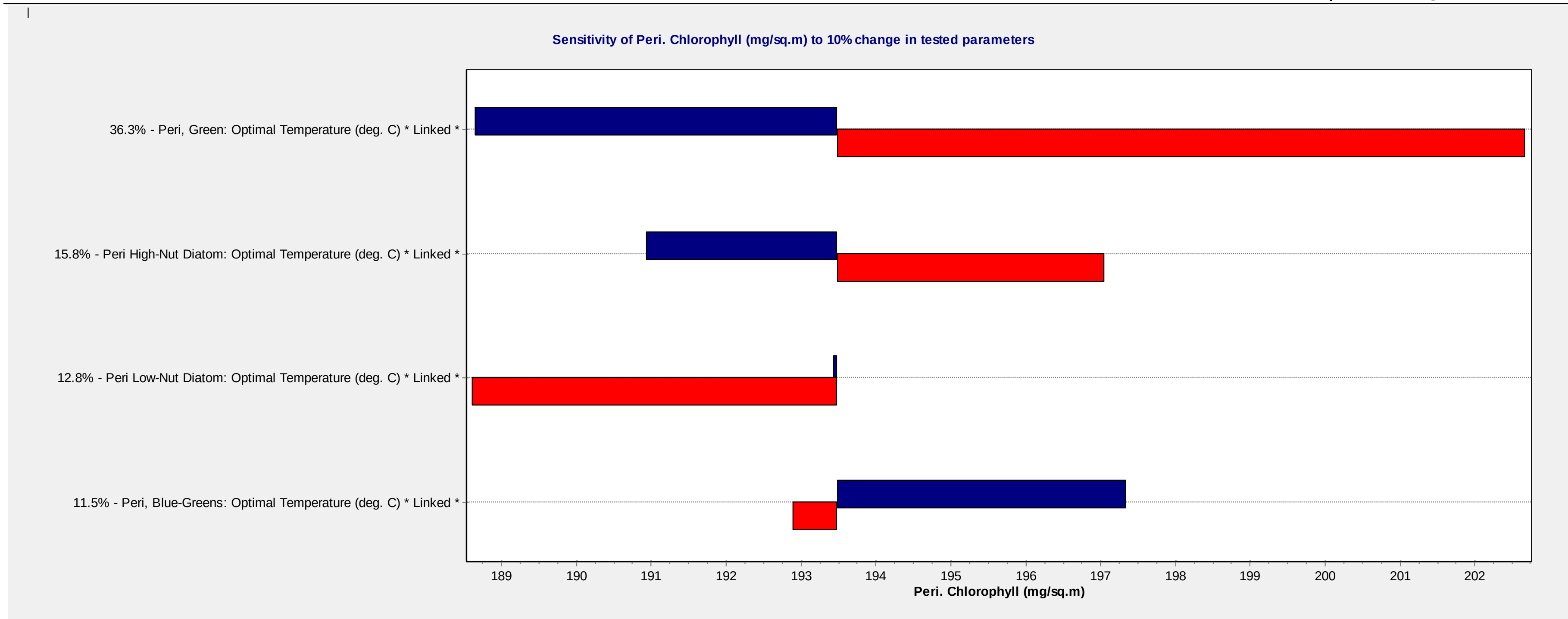


Figure 43. Optimal Temperature—Topt (deg C) effects on periphyton chlorophyll a.

Optimal Temperature--Topt (deg C)
Green periphyton
Increasing Topt by 10% resulted in an average output value of 188.65 as compared to the baseline result of 193.5
Decreasing Topt by 10% resulted in an average output value of 202.68 as compared to the baseline result of 193.5
High nutrient diatoms
Increasing Topt by 10% resulted in an average output value of 190.94 as compared to the baseline result of 193.5
Decreasing Topt by 10% resulted in an average output value of 197.06 as compared to the baseline result of 193.5
Low nutrient diatoms
Increasing Topt by 10% resulted in an average output value of 193.45 as compared to the baseline result of 193.5
Decreasing Topt by 10% resulted in an average output value of 188.61 as compared to the baseline result of 193.5
Blue-greens
Increasing Topt by 10% resulted in an average output value of 197.35 as compared to the baseline result of 193.5
Decreasing Topt by 10% resulted in an average output value of 192.9 as compared to the baseline result of 193.5
Cladophora
No results for Cladophora

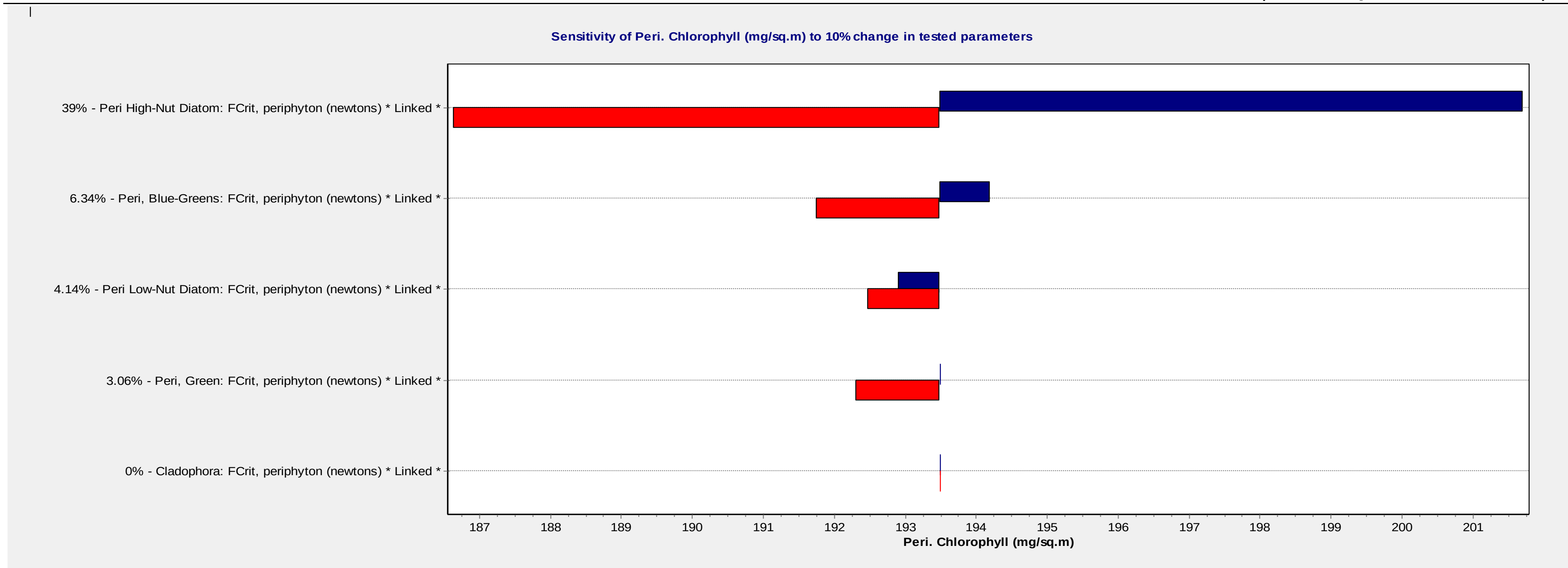


Figure 44. Critical Force for periphyton scour—fcrit (Newtons) effects on periphyton chlorophyll a.

Critical Force for periphyton scour--fcrit (Newtons)

High nutrient diatoms

Increasing fcrit by 10% resulted in an average output value of 201.71 as compared to the baseline result of 193.5

Decreasing fcrit by 10% resulted in an average output value of 186.64 as compared to the baseline result of 193.5

Blue-greens

Increasing fcrit by 10% resulted in an average output value of 194.2 as compared to the baseline result of 193.5

Decreasing fcrit by 10% resulted in an average output value of 191.75 as compared to the baseline result of 193.5

Low nutrient diatoms

Increasing fcrit by 10% resulted in an average output value of 192.91 as compared to the baseline result of 193.5

Decreasing fcrit by 10% resulted in an average output value of 192.48 as compared to the baseline result of 193.5

Green periphyton

Decreasing fcrit by 10% resulted in an average output value of 192.31 as compared to the baseline result of 193.5

No results for increasing fcrit for Green periphyton

Cladophora

No results for Cladophora

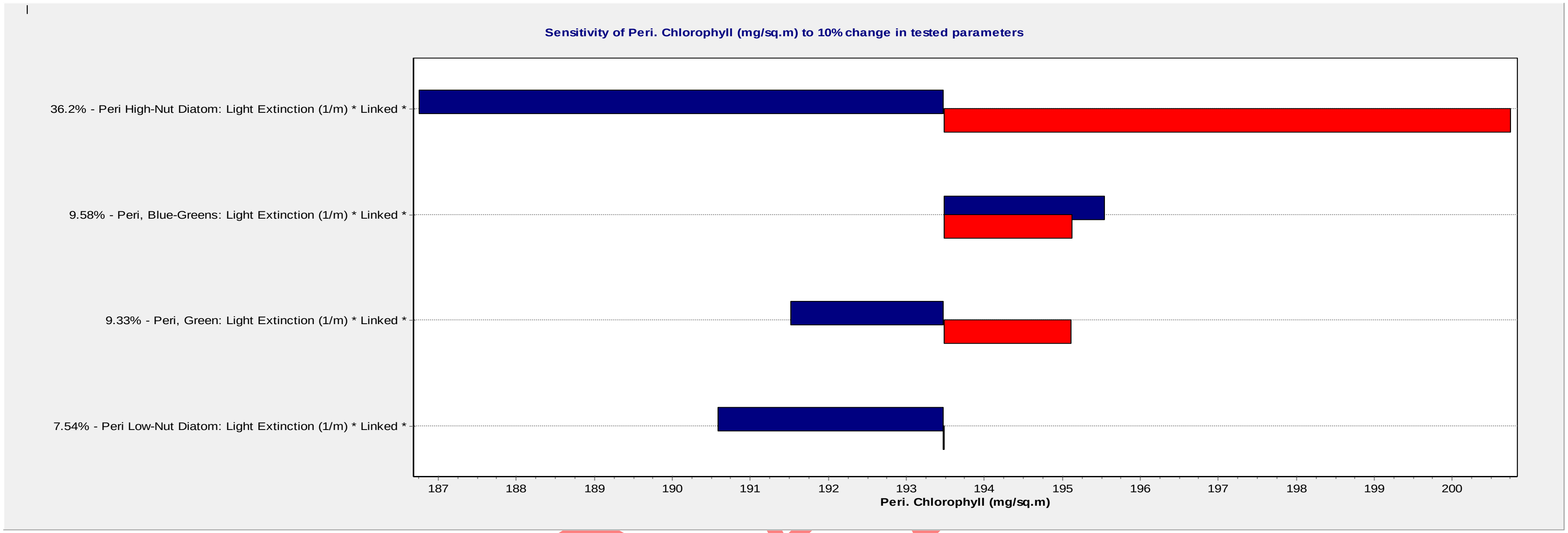


Figure 45. Light Extinction Coefficient—Lightex (1/m-g/m3) effects on periphyton chlorophyll a.

Light Extinction Coefficient--Lightex (1/m-g/m3)

High nutrient diatoms

Increasing Lightex by 10% resulted in an average output value of 186.76 as compared to the baseline result of 193.5

Decreasing Lightex by 10% resulted in an average output value of 200.77 as compared to the baseline result of 193.5

Blue-greens

Increasing Lightex by 10% resulted in an average output value of 195.57 as compared to the baseline result of 193.5

Decreasing Lightex by 10% resulted in an average output value of 195.14 as compared to the baseline result of 193.5

Green periphyton

Increasing Lightex by 10% resulted in an average output value of 191.53 as compared to the baseline result of 193.5

Decreasing Lightex by 10% resulted in an average output value of 195.14 as compared to the baseline result of 193.5

Low nutrient diatoms

Increasing Lightex by 10% resulted in an average output value of 190.6 as compared to the baseline result of 193.5

No results for decreasing Lightex for low nutrient diatoms

Cladophora

No results for Cladophora

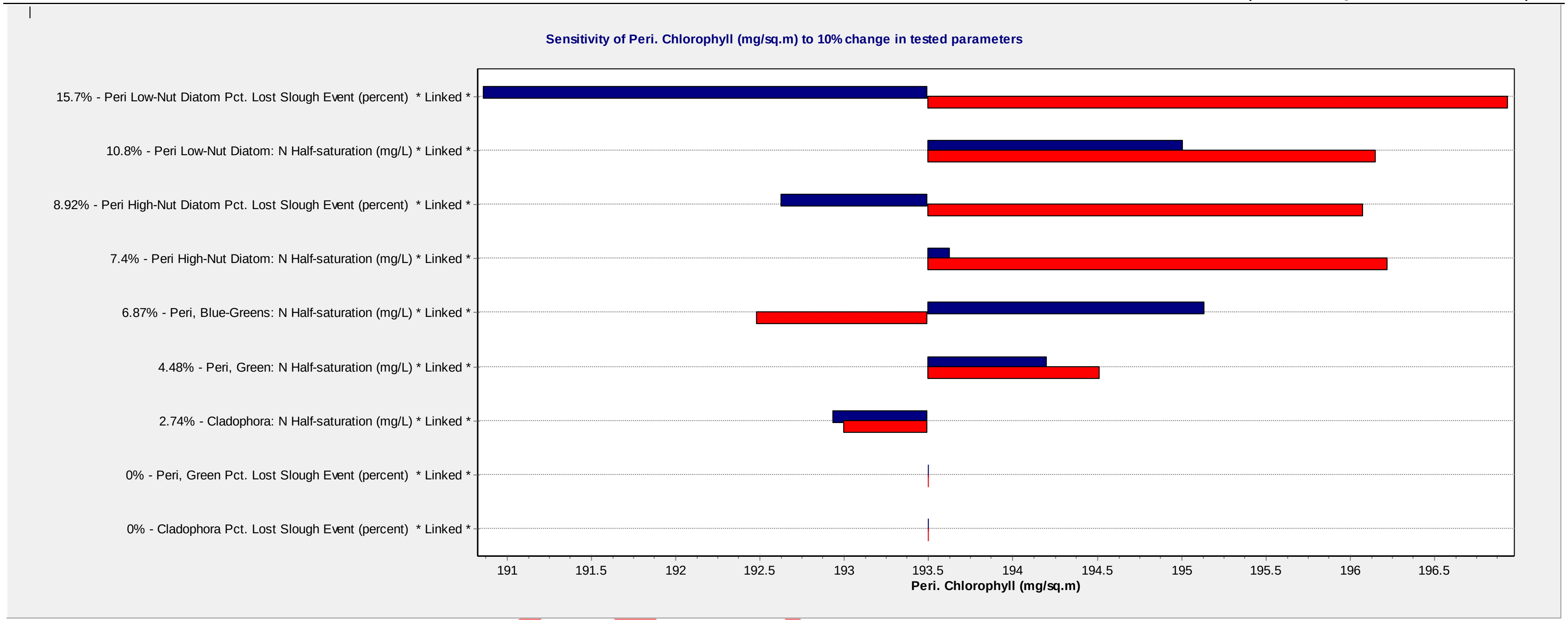


Figure 46. Percent periphyton lost in slough event—Sloughing (%), and Nitrogen half-saturation constant—N half-sat (mg/L), Michaelis-Menten kinetics effects on periphyton chlorophyll a.

Percent periphyton lost in slough event--sloughing (%)
Sloughing altered by 10%
Low nutrient diatoms
Increasing sloughing by 10% resulted in an average output value of 190.86 as compared to the baseline result of 193.5
Decreasing sloughing by 10% resulted in an average output value of 196.94 as compared to the baseline result of 193.5
High nutrient diatoms
Increasing sloughing by 10% resulted in an average output value of 192.63 as compared to the baseline result of 193.5
Decreasing sloughing by 10% resulted in an average output value of 196.08 as compared to the baseline result of 193.5

No results for blue-greens, greens, or Cladophora

Nitrogen half-saturation constant--N half-sat (mg/L), Michaelis-Menten kinetics

Low nutrient diatoms

Increasing N half-sat by 10% resulted in an average output value of 195.01 as compared to the baseline result of 193.5

Decreasing N half-sat by 10% resulted in an average output value of 196.16 as compared to the baseline result of 193.5

High nutrient diatoms

Increasing N half-sat by 10% resulted in an average output value of 193.63 as compared to the baseline result of 193.5

Decreasing N half-sat by 10% resulted in an average output value of 196.23 as compared to the baseline result of 193.5

Blue-greens

Increasing N half-sat by 10% resulted in an average output value of 195.14 as compared to the baseline result of 193.5

Decreasing N half-sat by 10% resulted in an average output value of 192.48 as compared to the baseline result of 193.5

Green periphyton

Increasing N half-sat by 10% resulted in an average output value of 194.21 as compared to the baseline result of 193.5

Decreasing N half-sat by 10% resulted in an average output value of 194.52 as compared to the baseline result of 193.5

Cladophora

Increasing N half-sat by 10% resulted in an average output value of 192.93 as compared to the baseline result of 193.5

Decreasing N half-sat by 10% resulted in an average output value of 193 as compared to the baseline result of 193.5

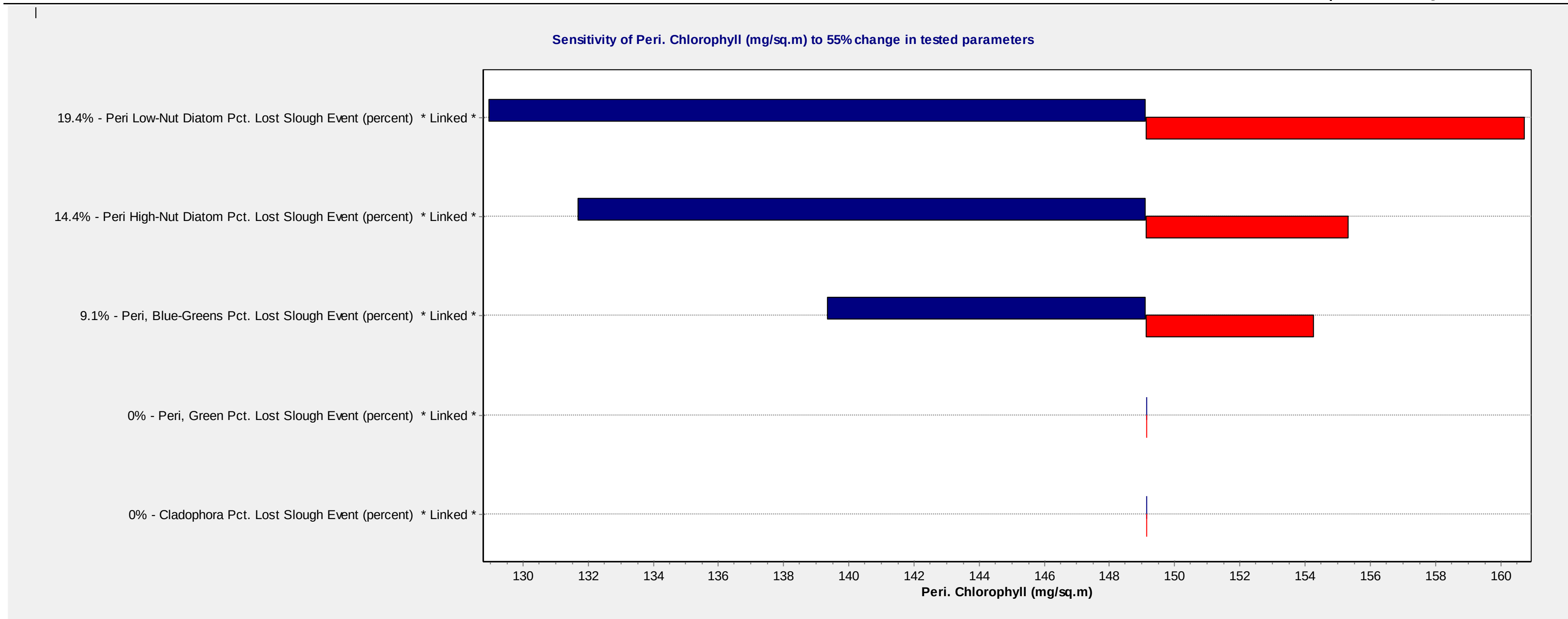


Figure 47. Percent periphyton lost in slough event—Sloughing (%), altering sloughing by the full range of variation, effects on periphyton chlorophyll a.

Percent periphyton lost in slough event--sloughing (%)

Altering sloughing by 55%--full range of variation in literature values

Low nutrient diatoms

Increasing sloughing by 55% resulted in an average output value of 128.97 as compared to the baseline result of 149.14

Decreasing sloughing by 55% resulted in an average output value of 160.77 as compared to the baseline result of 149.14

High nutrient diatoms

Increasing sloughing by 55% resulted in an average output value of 131.7 as compared to the baseline result of 149.14

Decreasing sloughing by 55% resulted in an average output value of 155.37 as compared to the baseline result of 149.14

Blue-greens

Increasing sloughing by 55% resulted in an average output value of 139.36 as compared to the baseline result of 149.14

Decreasing sloughing by 55% resulted in an average output value of 154.29 as compared to the baseline result of 149.14

No results for greens or Cladophora

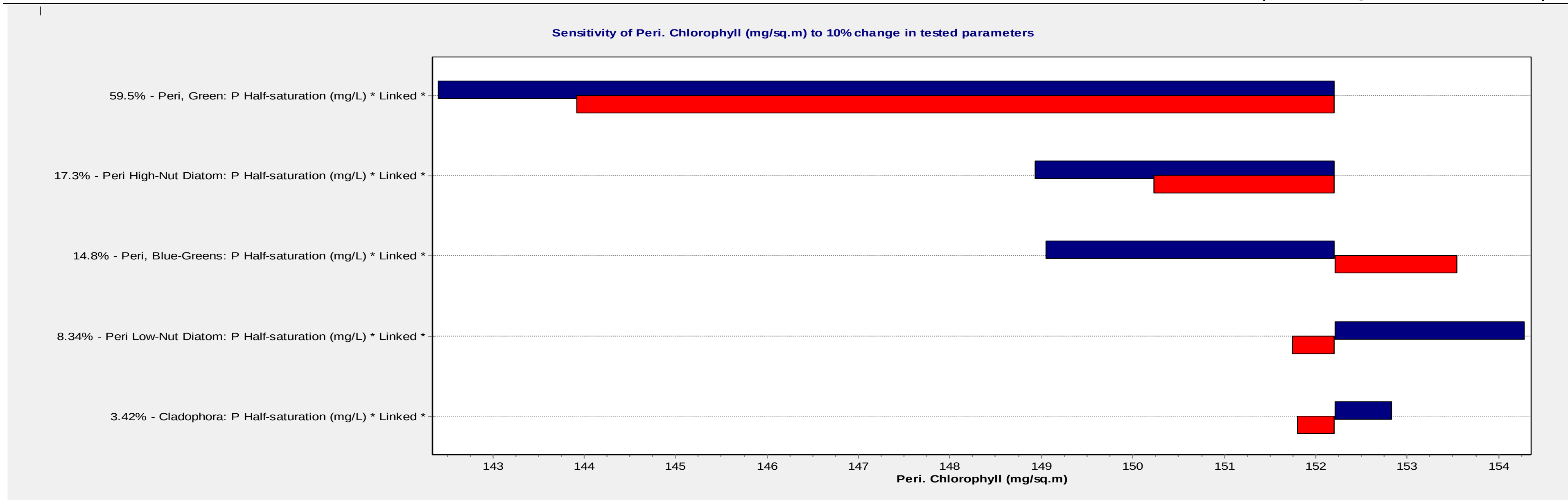


Figure 48. Phosphorus half-saturation constant—P half-sat (mg/L), Michaelis-Menten kinetics, effects on periphyton chlorophyll a.

Phosphorus half-saturation constant--P half-sat (mg/L), Michaelis-Menten kinetics

Green periphyton

Increasing P half-sat by 20% resulted in an average output value of 162.65 as compared to the baseline result of 171.13

Decreasing P half-sat by 20% resulted in an average output value of 175.86 as compared to the baseline result of 171.13

High nutrient diatoms

Increasing P half-sat by 20% resulted in an average output value of 173.09 as compared to the baseline result of 171.13

Decreasing P half-sat by 20% resulted in an average output value of 161.7 as compared to the baseline result of 171.13

Low nutrient diatoms

Increasing P half-sat by 20% resulted in an average output value of 163.88 as compared to the baseline result of 171.13

Decreasing P half-sat by 20% resulted in an average output value of 173.21 as compared to the baseline result of 171.13

Blue-greens

Increasing P half-sat by 20% resulted in an average output value of 173.77 as compared to the baseline result of 171.13

Decreasing P half-sat by 20% resulted in an average output value of 175.56 as compared to the baseline result of 171.13

Cladophora

Increasing P half-sat by 20% resulted in an average output value of 171.92 as compared to the baseline result of 171.13

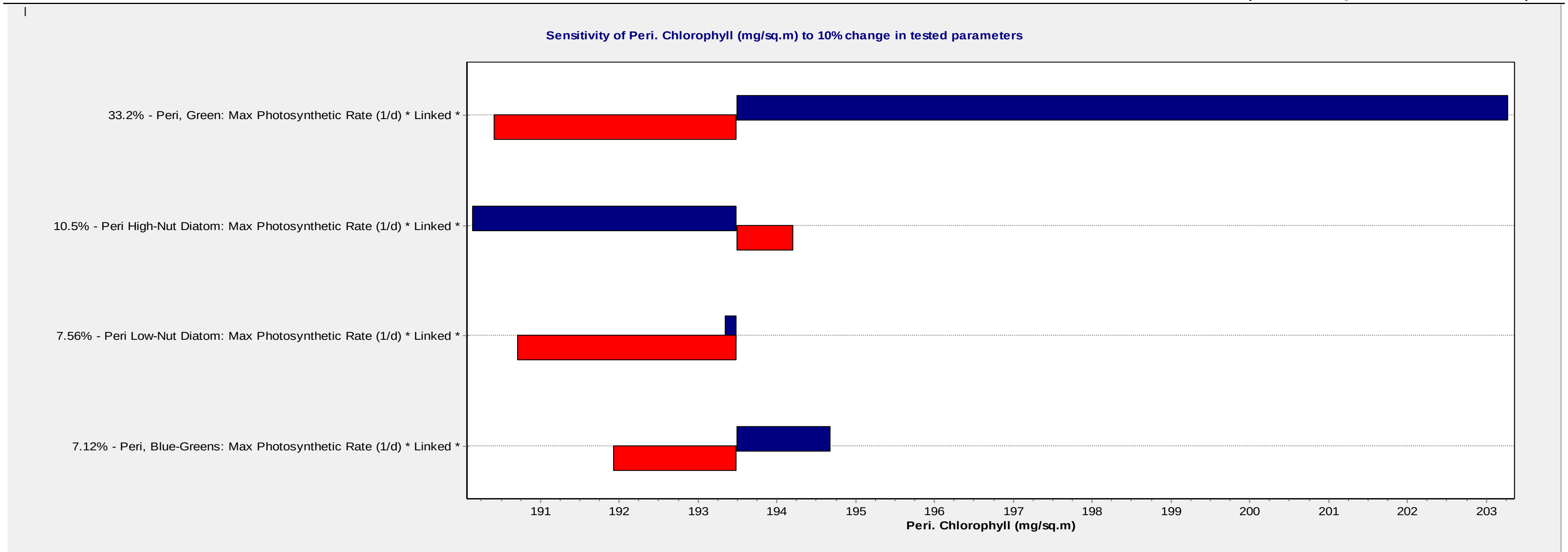


Figure 49. Maximum photosynthetic rate—Pmax (1/day)

Maximum photosynthetic rate--Pmax (1/day)

Green periphyton

Increasing Pmax by 10% resulted in an average output value of 203.29 as compared to the baseline result of 193.5

Decreasing Pmax by 10% resulted in an average output value of 190.43 as compared to the baseline result of 193.5

High nutrient diatoms

Increasing Pmax by 10% resulted in an average output value of 190.15 as compared to the baseline result of 193.5

Decreasing Pmax by 10% resulted in an average output value of 194.22 as compared to the baseline result of 193.5

Low nutrient diatoms

Increasing Pmax by 10% resulted in an average output value of 193.35 as compared to the baseline result of 193.5

Decreasing Pmax by 10% resulted in an average output value of 190.72 as compared to the baseline result of 193.5

Blue-greens

Increasing Pmax by 10% resulted in an average output value of 194.69 as compared to the baseline result of 193.5

Decreasing Pmax by 10% resulted in an average output value of 191.93 as compared to the baseline result of 193.5

Cladophora

No results for Cladophora

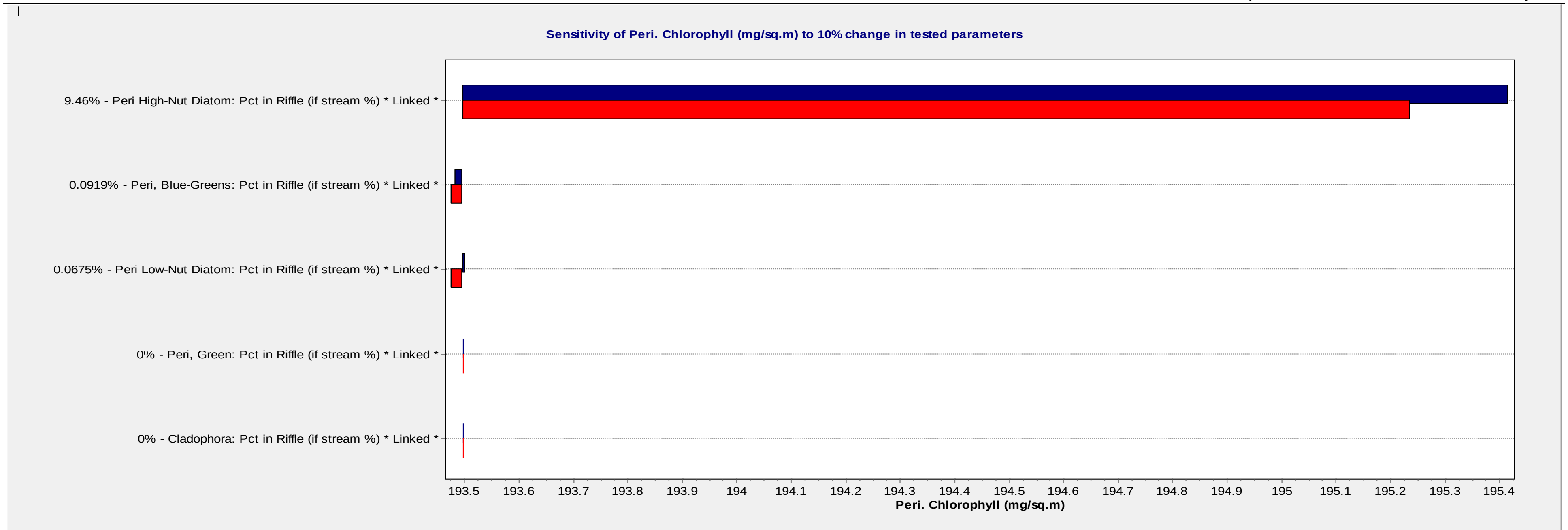


Figure 50. Preference of organism to riffle habitat—% Riffle effects on periphyton chlorophyll a.

Preference of organism to riffle habitat--% Riffle

High nutrient diatoms

Increasing % riffle by 10% resulted in an average output value of 195.42 as compared to the baseline result of 193.5

Decreasing % riffle by 10% resulted in an average output value of 195.24 as compared to the baseline result of 193.5

No real results for blue-greens, low nutrient diatoms, greens, or Cladophora

Note: the above results indicate:

- Optimal temperature has the greatest effect on green algae and secondarily on high-nutrient diatoms.
- Critical force and light extinction coefficient have the greatest effect on high-nutrient diatoms.
- Sloughing has the largest effect on low-nutrient diatoms and high-nutrient diatoms.
- N half-sat has very little effect on any of the algal groups.
- P half-sat has an effect on blue-green algae.
- Maximum photosynthetic rate has the greatest effect on green algae and a lesser effect on high-nutrient diatoms.
- Changes in the parameter for preference to riffle habitat had very little effect on any of the algal groups.

The above results show how changes in algal parameters for each group can alter the total periphyton chlorophyll a (mg/m^2) prediction. Another very interesting way to use the sensitivity function in AQUATOX is to identify how changes in the significant parameters for one group can affect other groups. This exemplifies the competition for resources among the algal groups. For instance, low-nutrient diatoms are very difficult to calibrate. They occupy a unique habitat, in that low phosphorus levels are ideal, so they proliferate more in the upper reaches of the model where total phosphorus averages 0.01 mg/L in segment 1 and 0.018mg/L in segment 2. The sensitivity analysis shows that a low phosphorus half-saturation constant appears to effect the low-nutrient diatom calibration far more than other parameters. When earlier model iterations showed unrealistic proliferation of low-nutrient diatoms and changes in the algal parameters for them were made, the calibration of remaining algal groups would then become imbalanced. The following plots show how changing parameters on one algal group can change the predictions of other algal groups, as well.

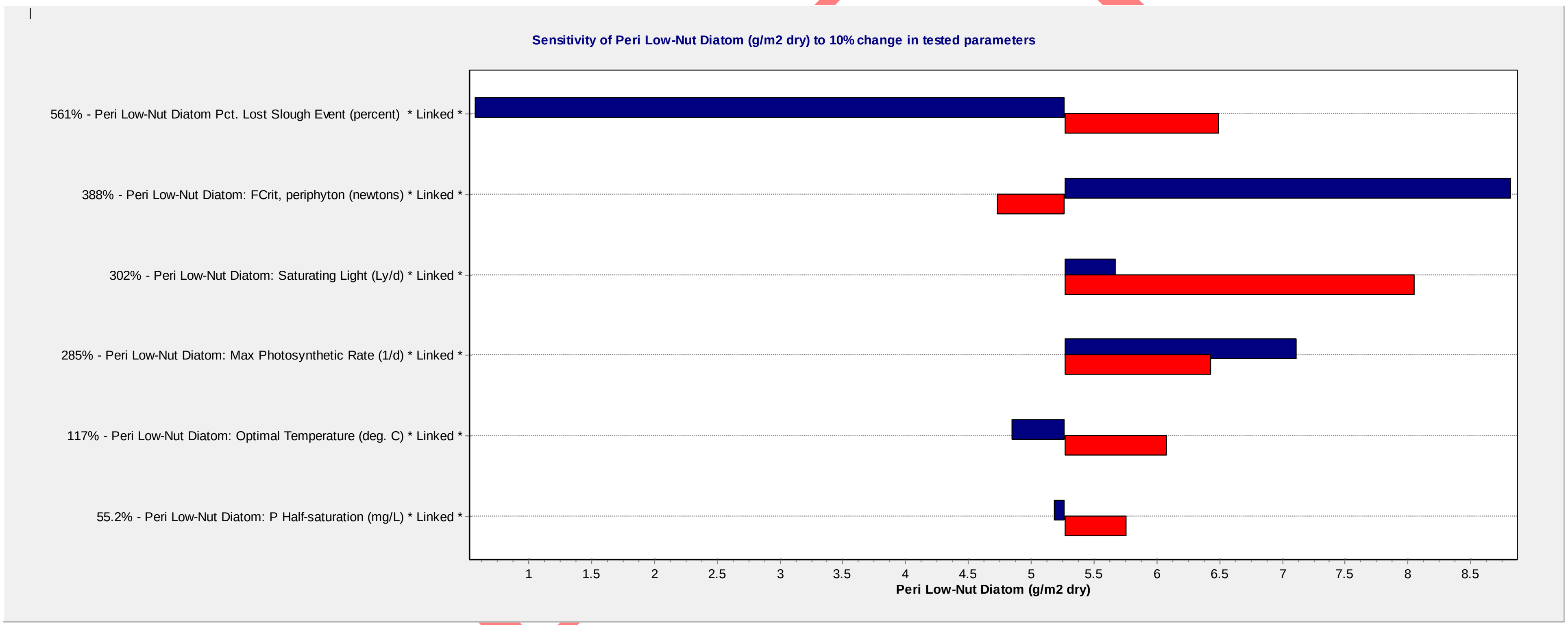


Figure 51. Changes in low-nutrient diatom sloughing and critical force affect low-nutrient diatom biomass.

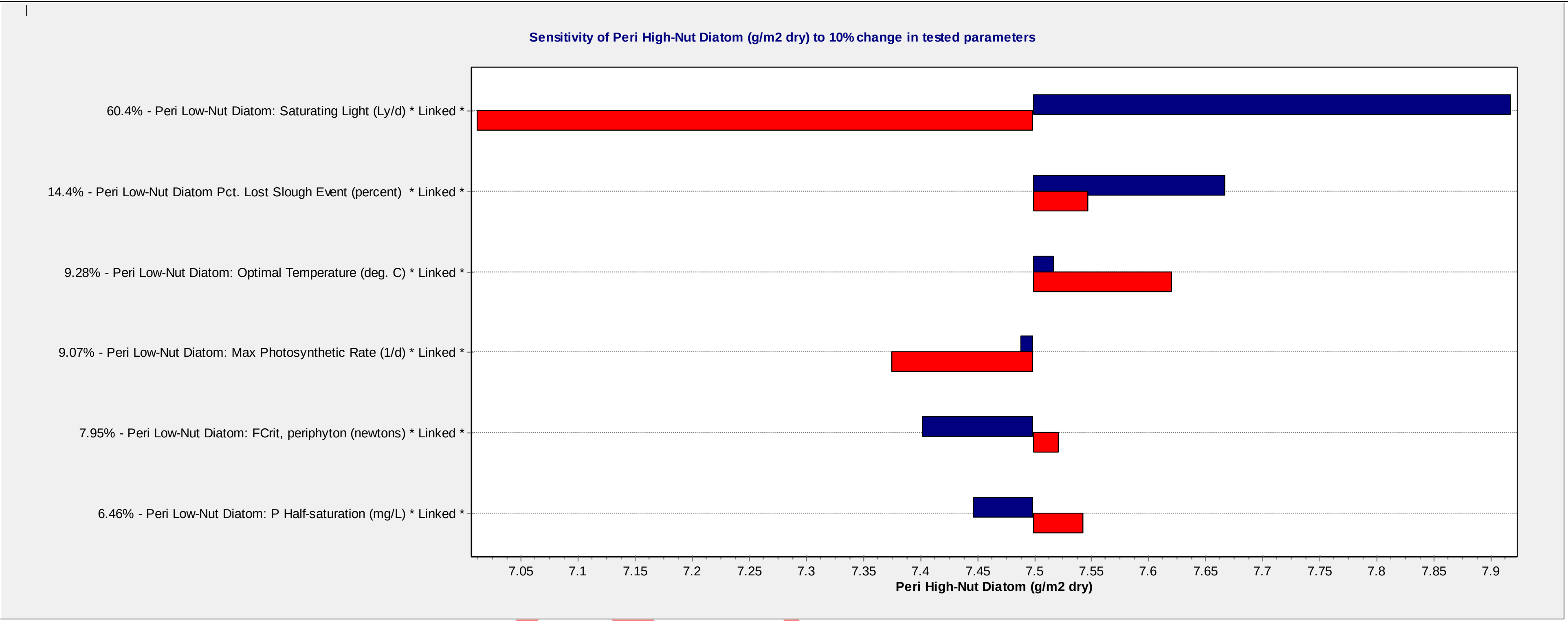


Figure 52. Changes to low-nutrient diatoms saturating light affect high-nutrient diatom biomass.

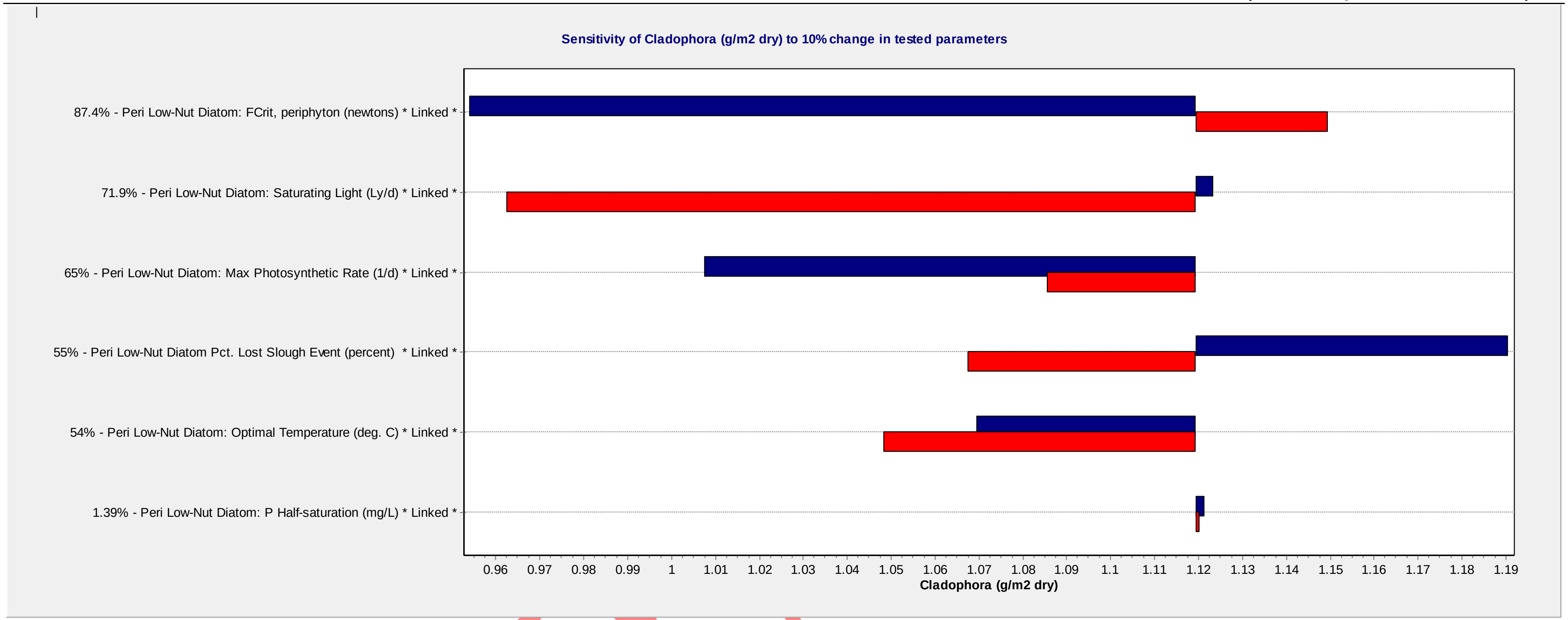


Figure 53. Changes to low-nutrient diatom critical force, saturating light, and sloughing affect Cladophora biomass.

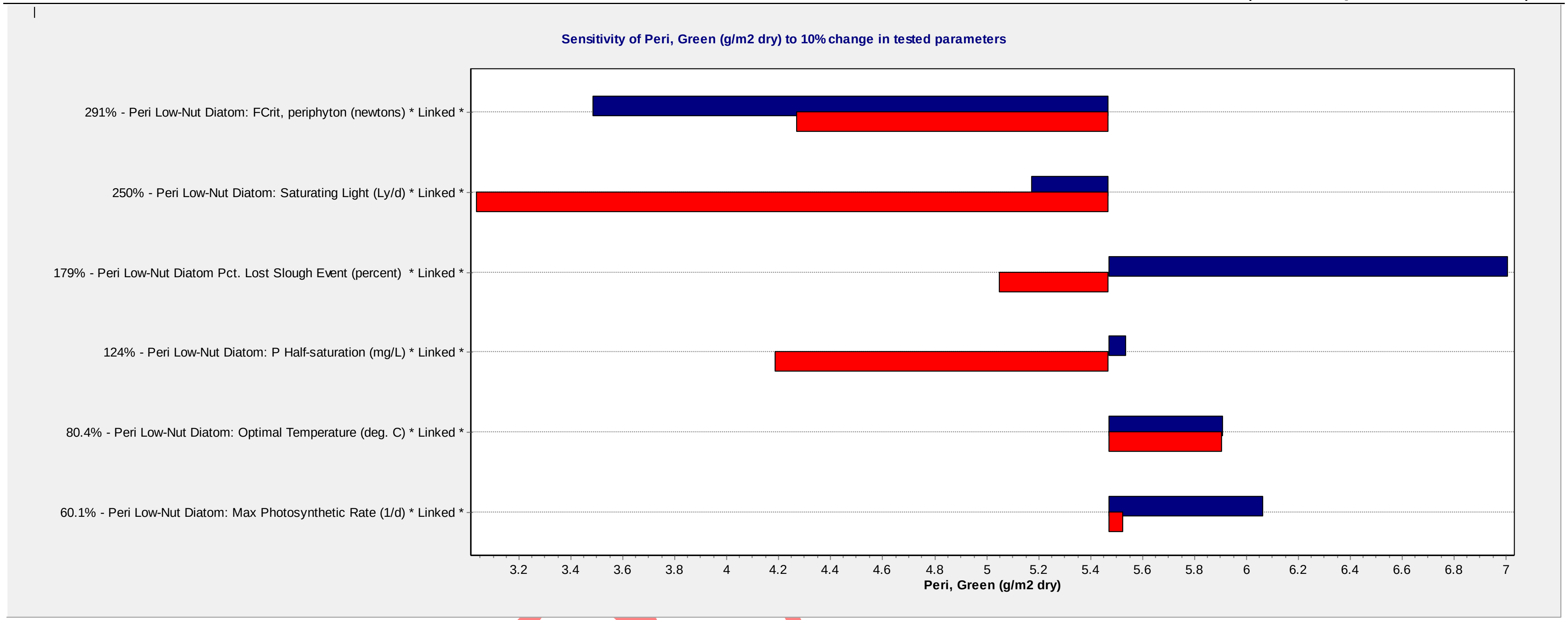


Figure 54. Changes to low-nutrient diatom sloughing affect green algae biomass.

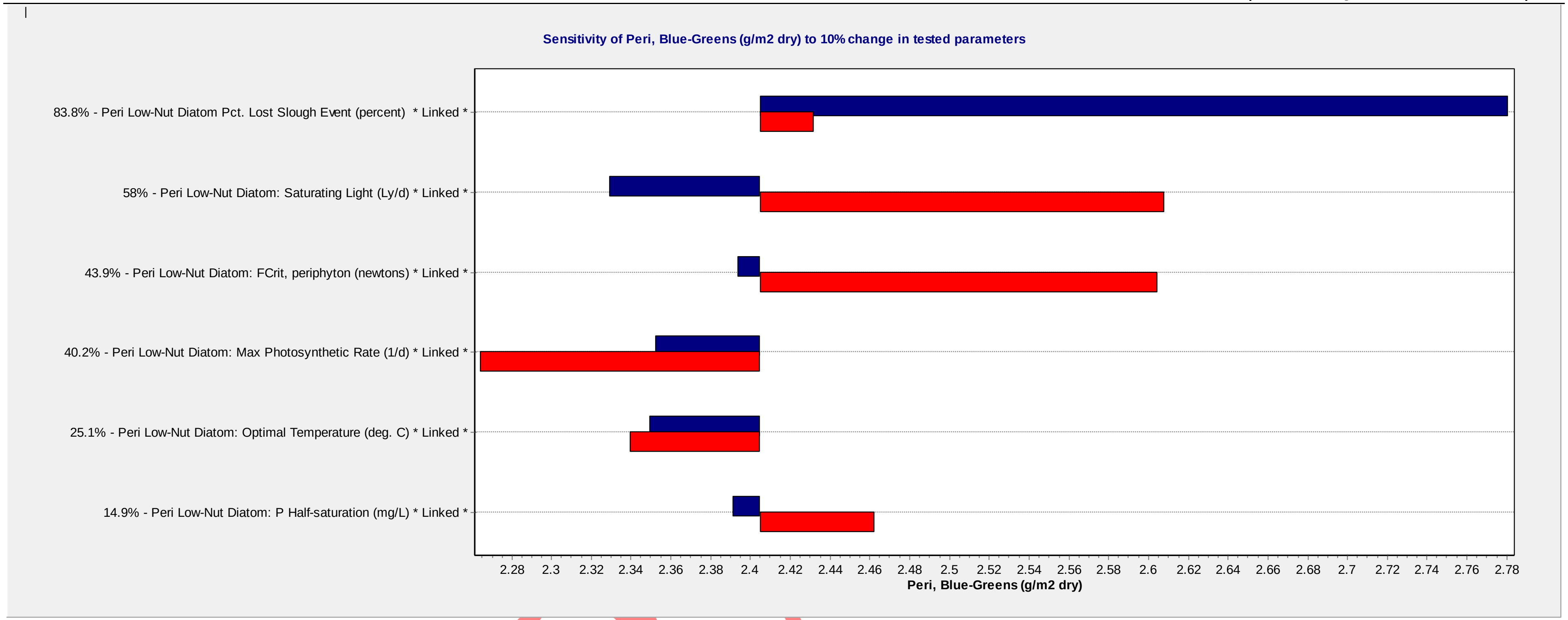


Figure 55. Changes to low-nutrient diatom saturating light affect blue-green algae biomass.

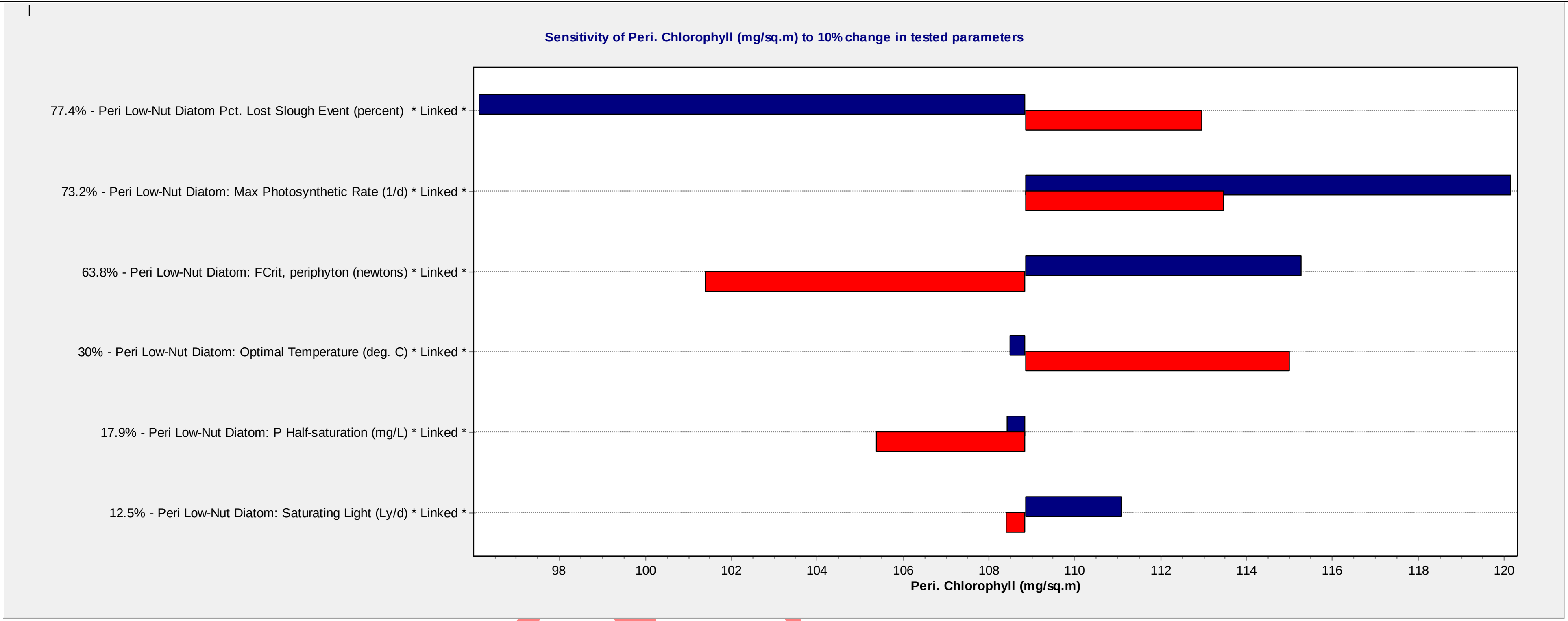


Figure 56. Changes to low-nutrient diatom sloughing and critical force affect periphyton chlorophyll a coverage.

Results from these sensitivity analyses illustrate how the algal groups interact and compete for resources. During the calibration process, these results were used to refine the AQUATOX predictions for each algal group to better reflect the periphyton community composition analysis reported in Rushforth 2007b.

3.3.3.3 Calibration Process

Altering algal parameters—as informed by the sensitivity analysis and historical community composition data—was the most important action to achieve a better calibration of modeled periphyton predictions to measured data. As described earlier in this report, DEQ altered some heritage issues in the model to improve model function:

- Where critical input datasets were incomplete, DEQ created derived datasets to improve accuracy
- The original AQUATOX executable model was programmed to form ice cover when surface water temperatures fell below 3ºC; upon DEQ's request, the model developers edited the source code to correct this
- Initial conditions were being loaded into every model source—including groundwater, hatcheries, and wastewater treatment facilities—that included incorrect constituents

Although DEQ made the final algal parameter selections, DEQ consulted with Richard Park (Eco Modeling), Chris Mebane (USGS), and other members of the modeling workgroup during the modeling process, and who provided assistance toward refining algal parameters where necessary to approach a better fit of the simulation to the existing data.

For the current 2012-2013 AQUATOX simulation, DEQ completed a sequence of model iterations while working with the modeling workgroup and the model developers. Once the model and datasets were optimized, DEQ ran AQUATOX with algal parameter sets from the earlier LBR studies to help understand how key algal parameters affect timing and biomass of the periphyton predictions. The following section provides these and other versions of the algal parameters, followed by plots of the resultant periphyton simulation compared with measured and historical periphyton data. As previously mentioned, "measured" refers to the periphyton data collected during the model simulation period, and "historical" refers to all of the other periphyton data.

<u>Comments on the calibration for the earlier 1999-2001 parameter set:</u>
The earliest algal parameter set applied to the LBR was completed based on an extensive calibration exercise for three rivers in Minnesota and published in Park, et al. 2009. A 1999-2001 AQUATOX simulation for LBR was based on this parameter set (CH2M Hill 2008). DEQ applied the 1999-2002 algal parameter set to the current 2012-2013 model calibration to evaluate the model differences. Applying 1991-2001 algal parameter set to current conditions, consistently underestimated periphyton biomass and high-nutrient diatoms were the predominant algal group that contributed to the simulation (Table 15; Figures 57-61).

Table 15. Select algal parameters employed in the lower Boise River AQUATOX 1999-2001 model calibration.

Algal Parameters in the lower Boise River 2008 AQUATOX model

Parameter	Topt	Tmax	Tresp	Light Sat	Pmax	Lightex	P Half-sat	N Half-sat	C Half-sat	Exp Mo Co	FCrit	% Slough
Periphyton												
Low-nutrient diatoms	20	39	2	128	0.77	0.03	0.006	0.07	0.054	0.05	0.002	25
High-nutrient diatoms	20	35	1.8	45	2.06	0.03	0.2	0.117	0.054	0.05	0.002	25
Peri Greens	25	42	2	220	2.00	0.03	0.1	0.8	0.054	0.05	0.002	25
Cladophora	15	25	2	270	1.08	0.14	0.04	0.1	0.054	0.05	0.002	25
Blue-greens	30	50	2	148	1.40	0.03	0.03	0.4	0.024	0.05	0.002	25
Phytoplankton												
Low-nutrient diatoms	15	39	2	224	1.00	0.14	0.006	0.0154	0.054	0.05	NA	NA
High-nutrient diatoms	20	35	1.8	30	1.87	0.14	0.055	0.117	0.054	0.05	NA	NA
Phyto Greens	26	42	2	220	1.65	0.24	0.1	0.8	0.054	0.04	NA	NA
Blue-greens	30	50	2	148	2.20	0.15	0.03	0.4	0.024	0.12	NA	NA

Notes:
Topt = optimal temperature (°C)
Tmax = maximum temperature (°C)
Tresp = temperature response slope
LightSat = saturating light (Ly/day)
Pmax = maximum photosynthetic rate (1/day)
Lightex = light extinction coefficient 1/m-g/m3
P half-sat = phosphorus half-saturation constant (mg/L), Michaelis-Menten kinetics
N half-sat = nitrogen half-saturation constant (mg/L), Michaelis-Menten kinetics
C half-sat = inorganic carbon half-saturation constant (mg/L), Michaelis-Menten kinetics
ExpMoCo = exponential mortality coefficient (g/g-day)
Fcrit = critical force for periphyton scour (Newtons)
% Slough = percent periphyton lost in slough event (%)

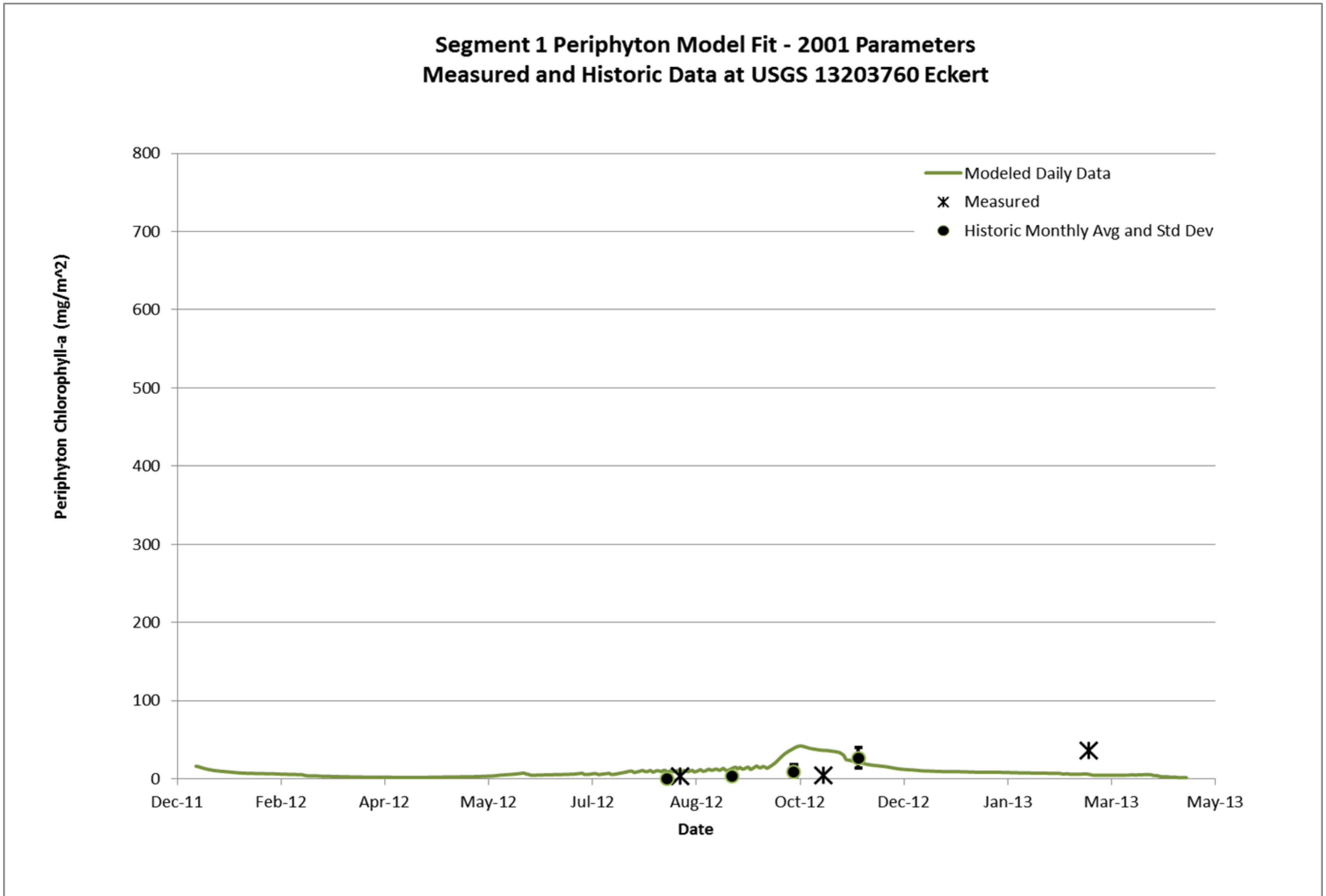


Figure 57. Model prediction of periphyton chlorophyll a (mg/m^2) at Eckert using the 1999-2001 algal parameters (CH2MHill et al. 2008).

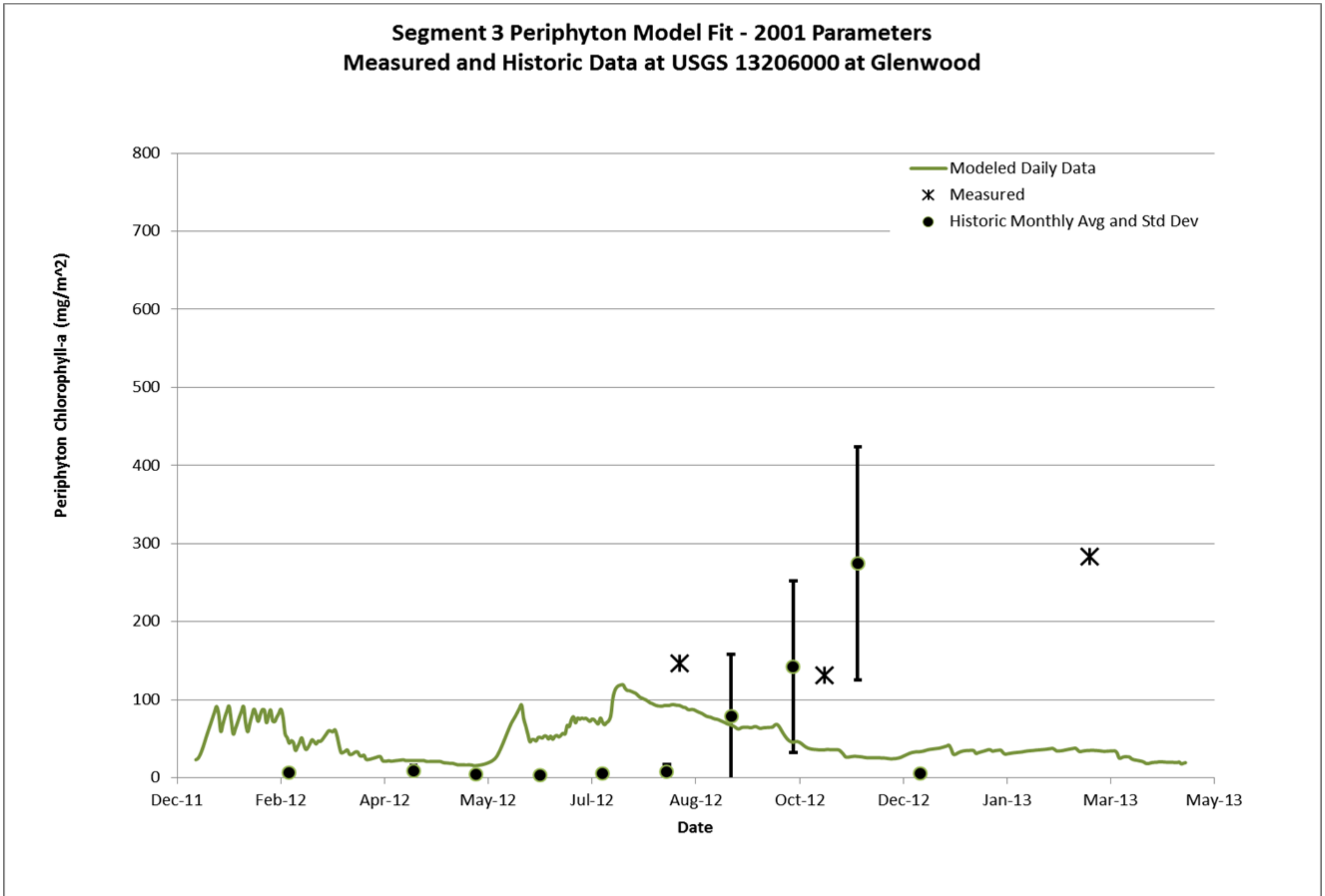


Figure 58. Model prediction of periphyton chlorophyll a (mg/m^2) at Glenwood using the 1999-2001 algal parameters (CH2MHill et al. 2008).

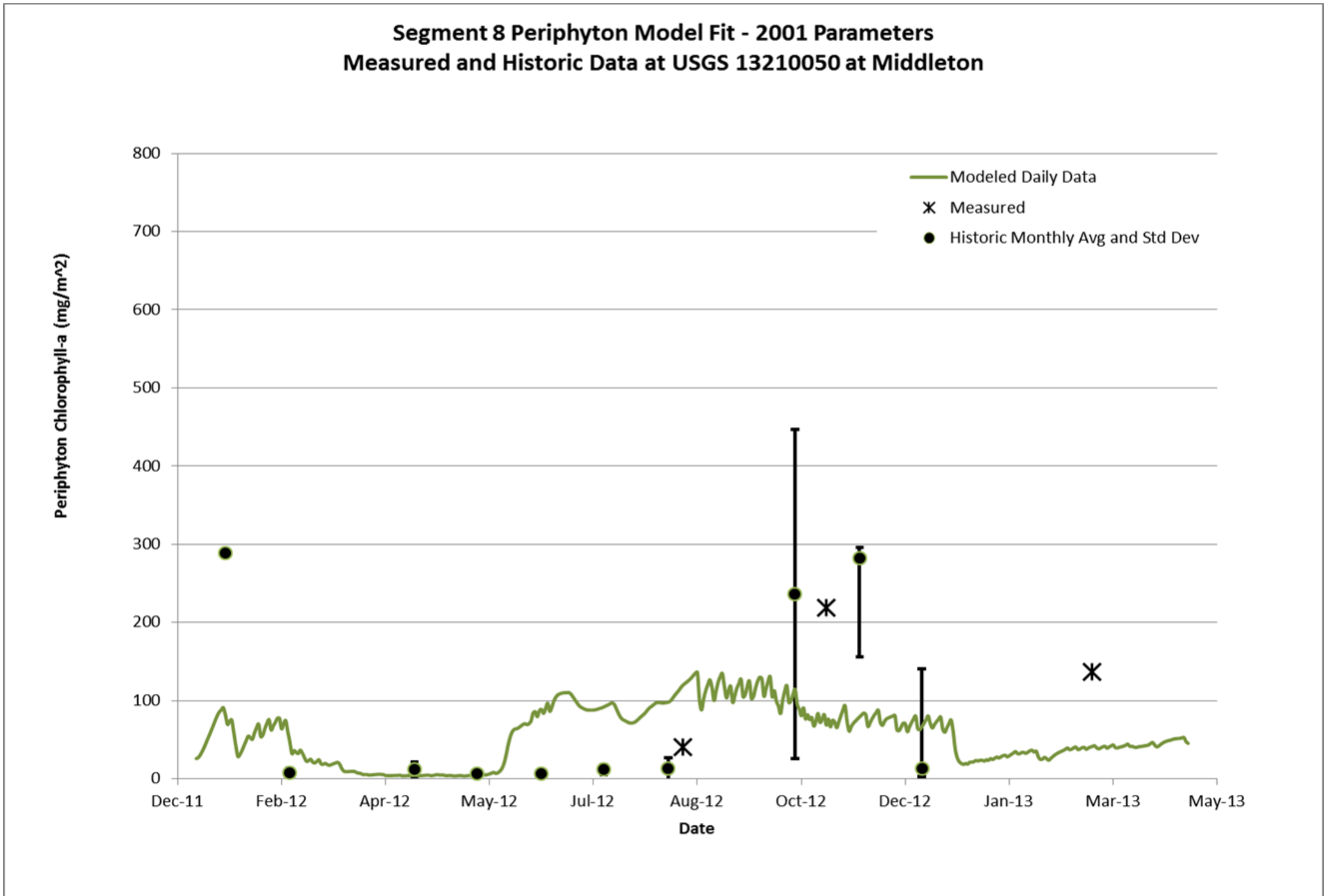


Figure 59. Model prediction of periphyton chlorophyll a (mg/m^2) at Middleton using the 1999-2001 algal parameters (CH2MHill et al. 2008).

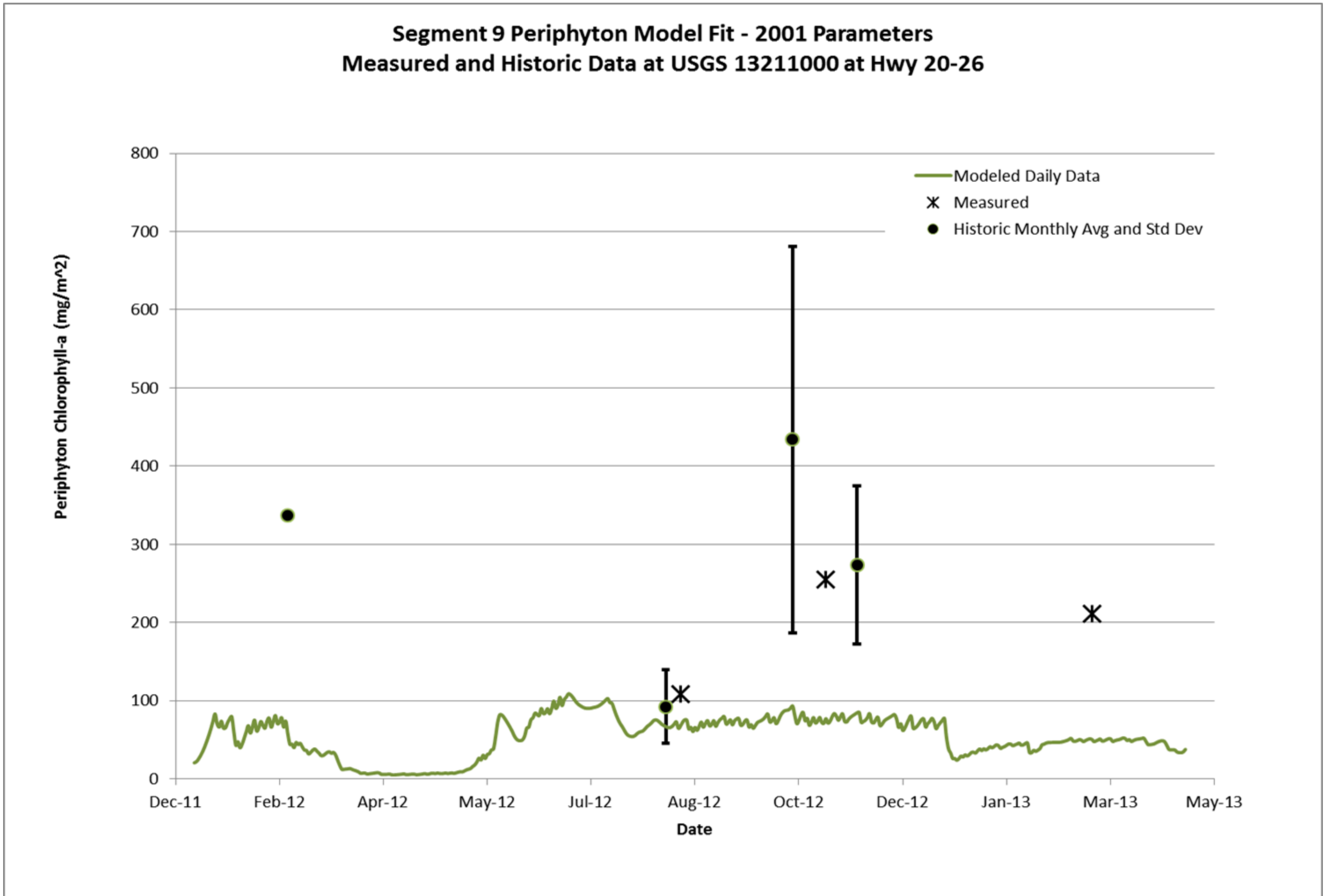


Figure 60. Model prediction of periphyton chlorophyll a (mg/m^2) at Caldwell using the 1999-2001 algal parameters (CH2MHill et al. 2008).

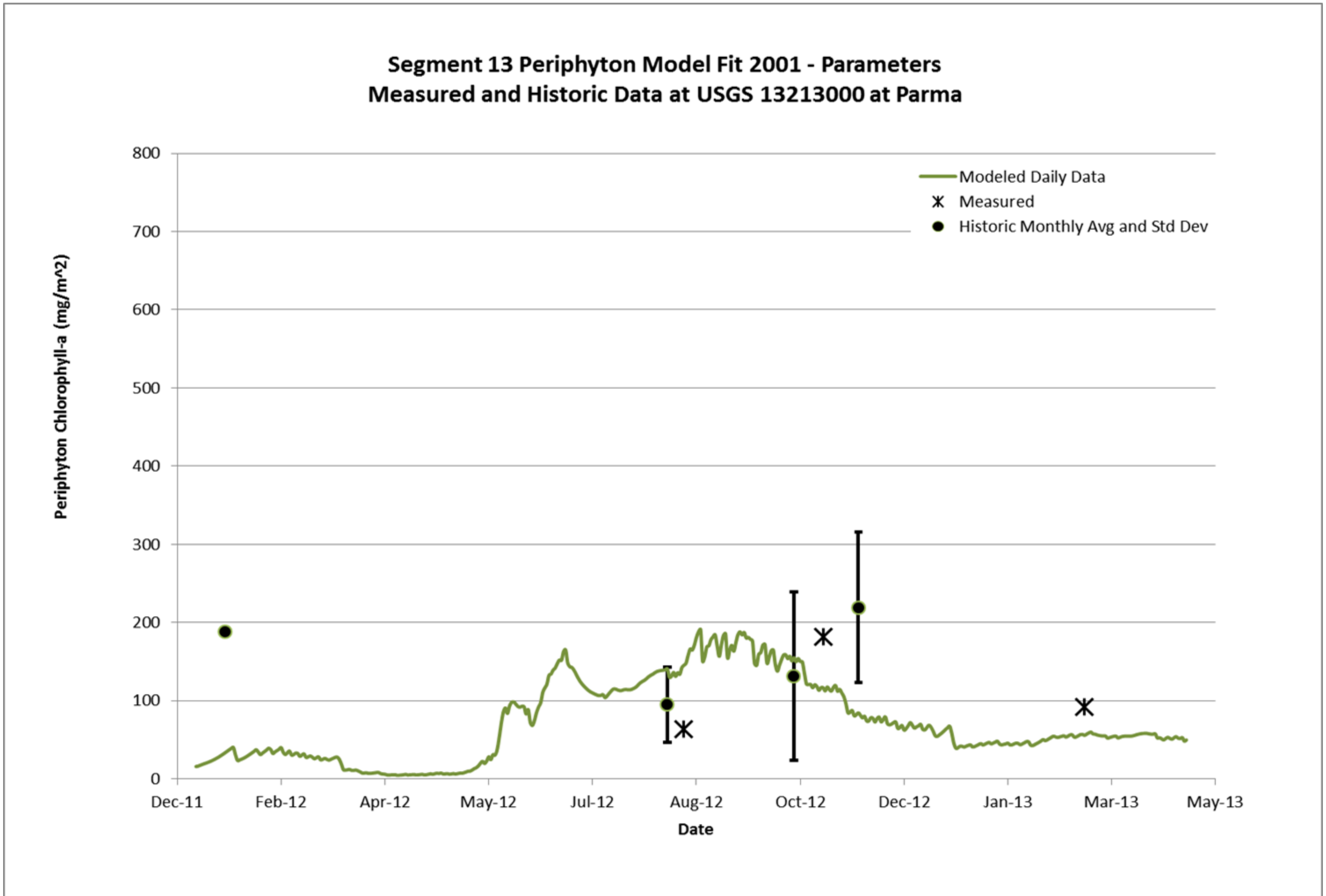


Figure 61. Model prediction of periphyton chlorophyll a (mg/m^2) at Parma using the 1999-2001 algal parameters (CH2MHill et al. 2008).

<u>Comments on the calibration for the earlier 2013_0925 parameter set:</u>

This DEQ parameter set raised concerns that "spikiness" of the periphyton predictions in the model calibration (Table 16; Figures 62-66) reflected unnatural sloughing patterns and did not allow biomass to match the high March value at Glenwood in segment 3. Since this version, DEQ has observed that diatoms typically show spiky growth pattern and that this simulation only reflected high-nutrient diatoms. Note that this calibration best matches the low growth through the summer period that is reflected in historical data.

Table 16. Select algal parameters employed in the lower Boise River AQUATOX 2013_0925 model calibration.

Algal Parameters in the lower Boise River AQUATOX model--2013_0925 Calibration												
Parameter	**Topt**	**Tmax**	**Tresp**	**Light Sat**	**Pmax**	**Lightex**	**P Half-sat**	**N Half-sat**	**C Half-sat**	**Exp Mo Co**	**FCrit**	**% Slough**
<u>Periphyton</u>												
Low-nutrient diatoms	20	39	2	64	0.77	0.03	0.006	0.07	0.054	0.05	0.002	25
High-nutrient diatoms	20	35	1.8	22.5	2.06	0.03	0.2	0.117	0.054	0.05	0.002	25
Peri Greens	25	42	2	110	2	0.03	0.1	0.8	0.054	0.05	0.002	25
Cladophora	15	25	2	270	1.08	0.14	0.04	0.1	0.054	0.05	0.002	25
Blue-greens	30	50	2	110	1.4	0.03	0.03	0.4	0.024	0.05	0.002	25
<u>Phytoplankton</u>												
Low-nutrient diatoms	15	39	2	224	1	0.14	0.006	0.0154	0.054	0.05	na	na
High-nutrient diatoms	20	35	1.8	45	1.87	0.14	0.055	0.117	0.054	0.05	na	na
Phyto Greens	26	42	2	220	1.65	0.24	0.01	0.8	0.054	0.04	na	na
Blue-greens	30	50	2	45	2.2	0.15	0.03	0.4	0.024	0.12	na	na

Topt = optimal temperature (deg C)
Tmax = maximum temperature (deg C)
Tresp = temperature response slope
LightSat = saturating light (Ly/day)
Pmax = maximum photosynthetic rate (1/day)
Lightex = light extinction coefficient 1/m-g/m3
P half-sat = phosphorus half-saturation constant (mg/L), Michaelis-Menten kinetics
N half-sat = nitrogen half-saturation constant (g/L), Michaelis-Menten kinetics
C half-sat = inorganic carbon half-saturation constant (mg/L). Michaelis-Menten kinetics
ExpMoCo = exponential mortality coefficient (g/g-day)
Fcrit = critical force for periphyton scour (Newtons)
%Slough = percent periphyton lost in slough event (%)

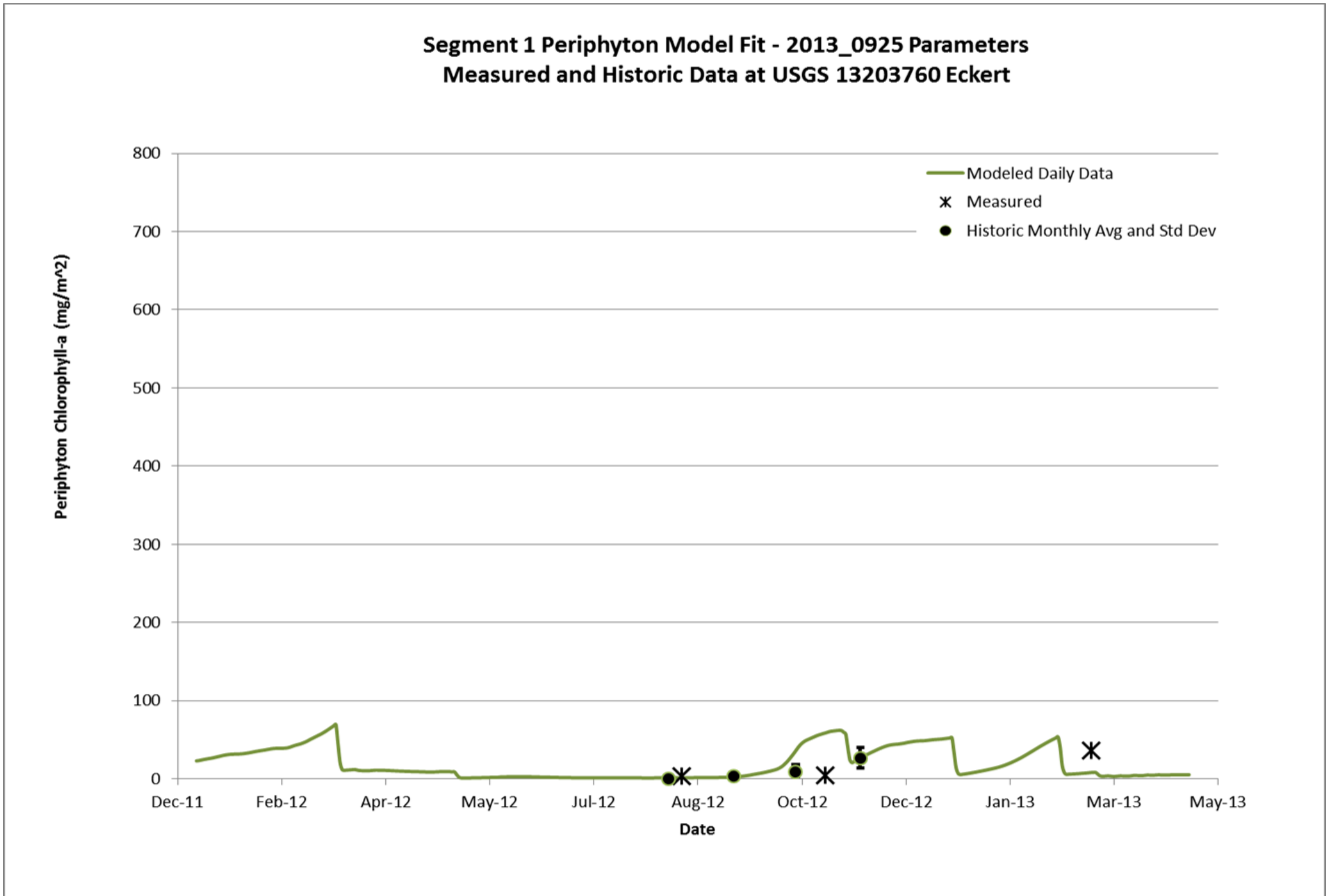


Figure 62. Model prediction of periphyton chlorophyll a (mg/m^2) at Eckert using the 2013_0925 algal parameters.

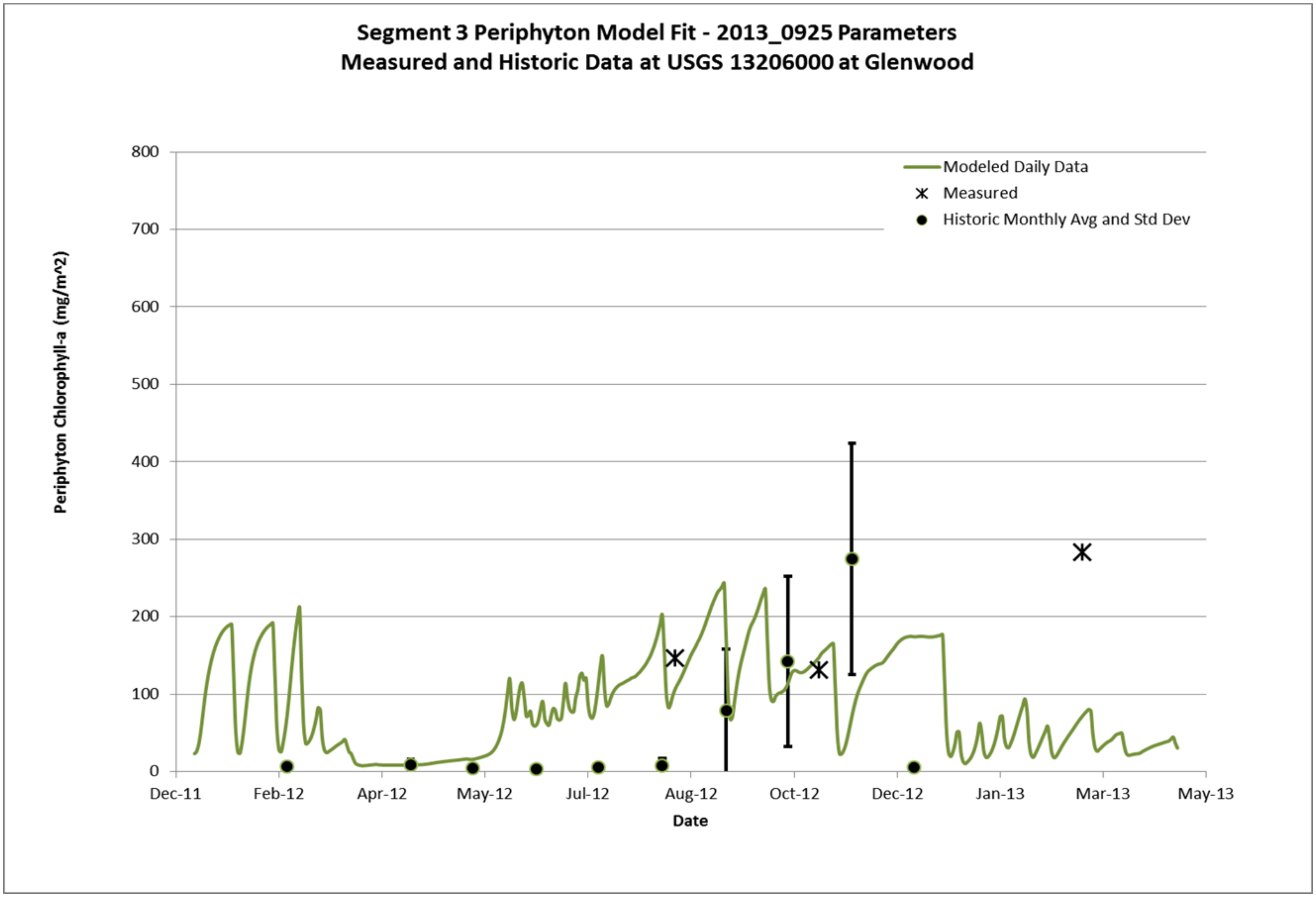


Figure 63. Model prediction of periphyton chlorophyll a (mg/m^2) at Glenwood using the 2013_0925 algal parameters.

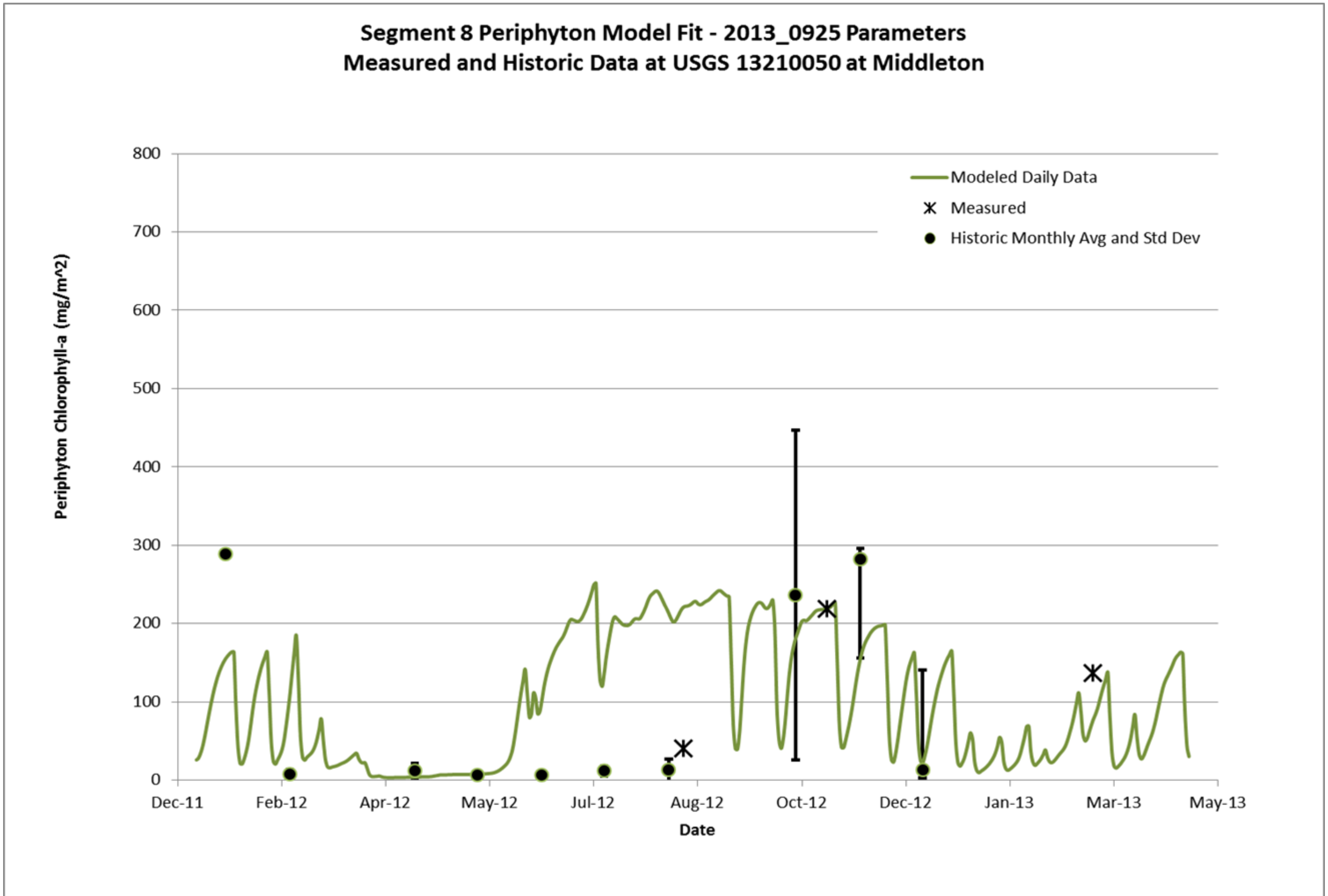


Figure 64. Model prediction of periphyton chlorophyll a (mg/m^2) at Middleton using the 2013_0925 algal parameters.

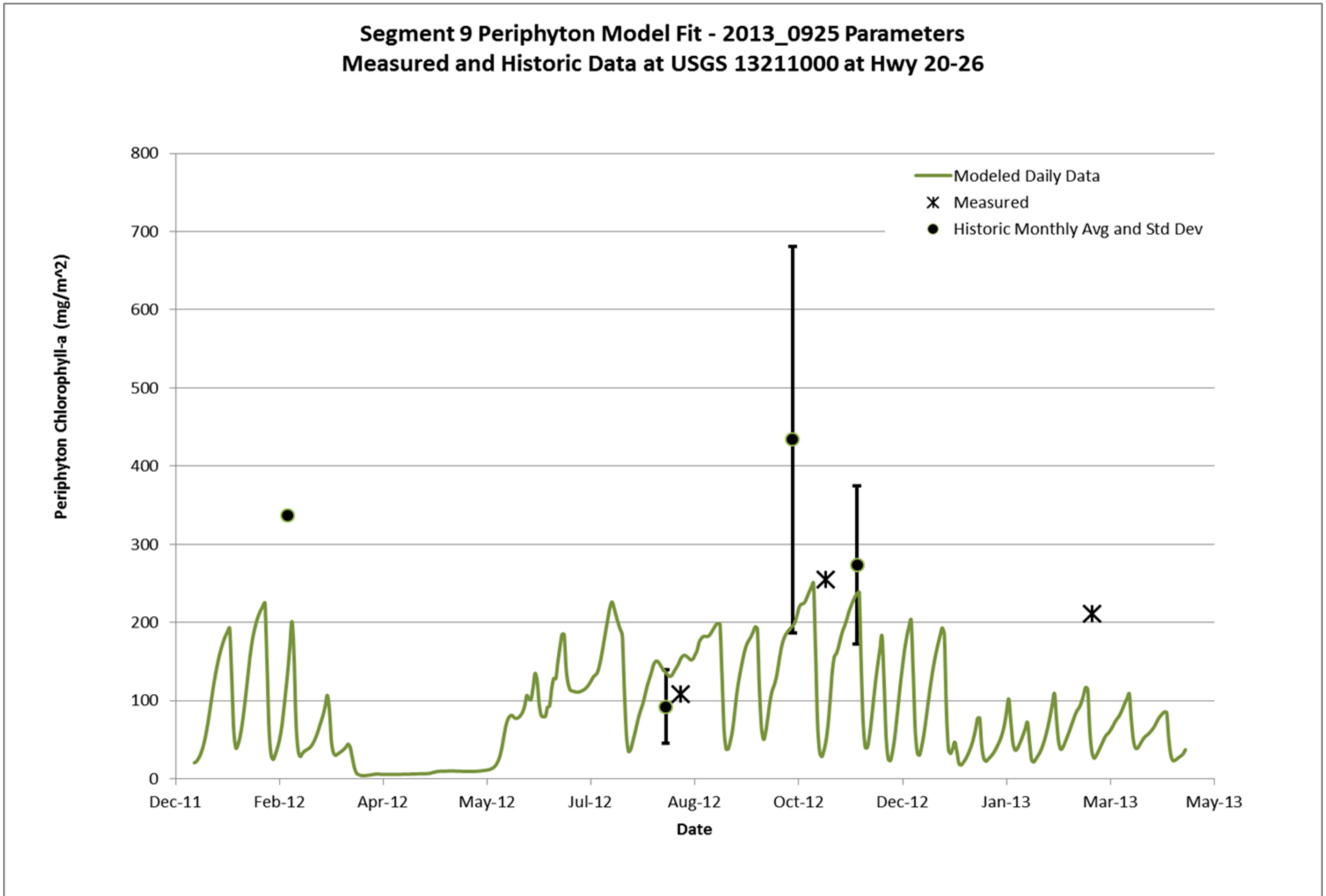


Figure 65. Model prediction of periphyton chlorophyll a (mg/m^2) at Caldwell using the 2013_0925 algal parameters.

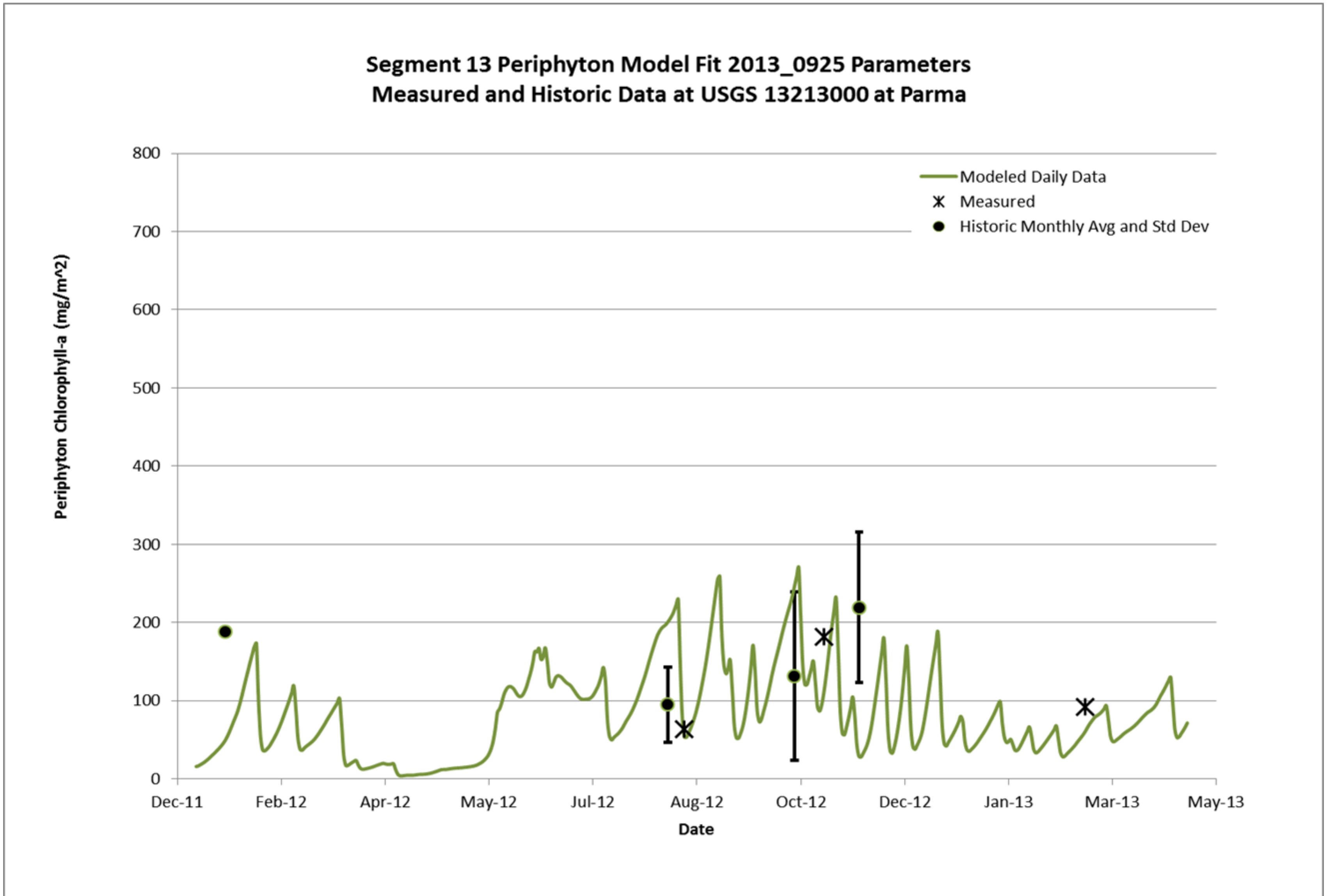


Figure 66. Model prediction of periphyton chlorophyll a (mg/m^2) at Parma using the 2013_0925 algal parameters.

Comments on the calibration for the 2013_1209 RAP parameter set:

This parameter set from Richard Park, a developer of the AQUATOX model and consultant to DEQ, was the first effort to reflect a community composition of all of the algal groups, not just high-nutrient diatoms (Table 17; Figures 67-71). Changing the parameters for blue-green algae to make it cold-tolerant was a significant improvement. One weakness of this calibration was over-prediction of periphyton throughout the summer season, especially August.

Table 17. Select algal parameters employed in the lower Boise River AQUATOX 2013_1209 RAP model calibration.

Algal Parameters in the lower Boise River AQUATOX model--2013_1209 RAP Calibration												
Parameter	Topt	Tmax	Tresp	Light Sat	Pmax	Lightex	P Half-sat	N Half-sat	C Half-sat	Exp Mo Co	FCrit	% Slough
Periphyton												
Low-nutrient diatoms	15	39	2	64	0.77	0.03	0.006	0.07	0.054	0.01	0.007	90
High-nutrient diatoms	20	35	1.8	64	2.3	0.03	0.055	0.117	0.054	0.05	0.009	25
Peri Greens	25	42	2	110	1.7	0.03	0.0093	0.1	0.054	0.01	0.007	90
Cladophora	15	25	2	270	1.08	0.22	0.01	0.0586	0.054	0.05	0.008	25
Blue-greens	10	50	2.1	33	1.2	0.03	0.006	0.168	0.024	0.01	0.008	90
Phytoplankton												
Low-nutrient diatoms	15	39	2	224	0.7	0.14	0.006	0.0154	0.054	0.05	na	na
High-nutrient diatoms	20	35	1.8	45	1.87	0.14	0.055	0.117	0.054	0.05	na	na
Phyto Greens	26	42	2	220	1.5	0.24	0.0093	0.1	0.054	0.04	na	na
Blue-greens	27	50	2	45	2.2	0.099	0.006	0.168	0.024	0.12	na	na

Topt = optimal temperature (deg C)
Tmax = maximum temperature (deg C)
Tresp = temperature response slope
LightSat = saturating light (Ly/day)
Pmax = maximum photosynthetic rate (1/day)
Lightex = light extinction coefficient 1/m-g/m3
P half-sat = phosphorus half-saturation constant (mg/L), Michaelis-Menten kinetics
N half-sat = nitrogen half-saturation constant (g/L), Michaelis-Menten kinetics
C half-sat = inorganic carbon half-saturation constant (mg/L). Michaelis-Menten kinetics
ExpMoCo = exponential mortality coefficient (g/g-day)
Fcrit = critical force for periphyton scour (Newtons)
%Slough = percent periphyton lost in slough event (%)

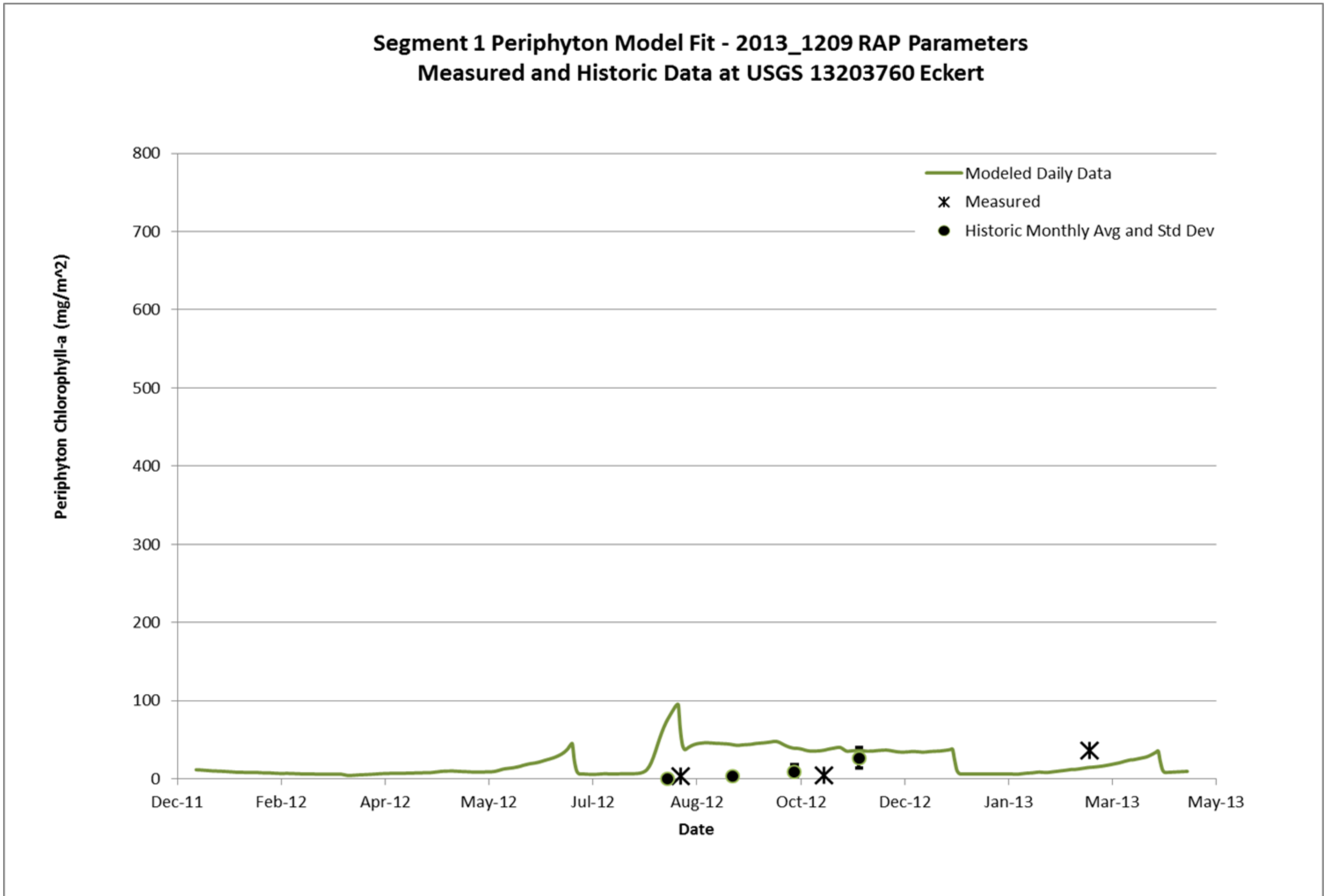


Figure 67. Model prediction of periphyton chlorophyll a (mg/m^2) at Eckert using the 2013_1209 RAP algal parameters.

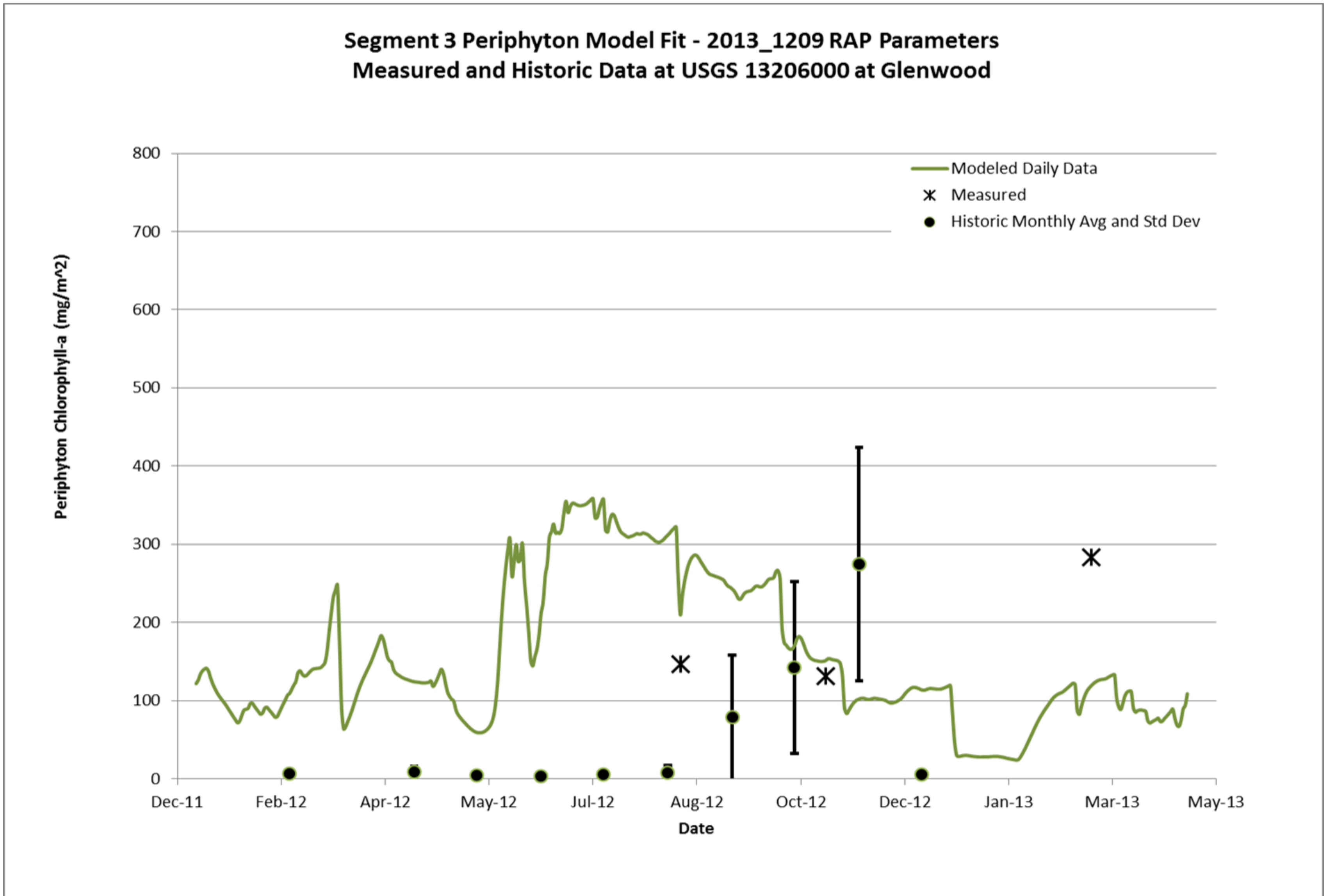


Figure 68. Model prediction of periphyton chlorophyll a (mg/m^2) at Glenwood using the 2013_1209 RAP algal parameters.

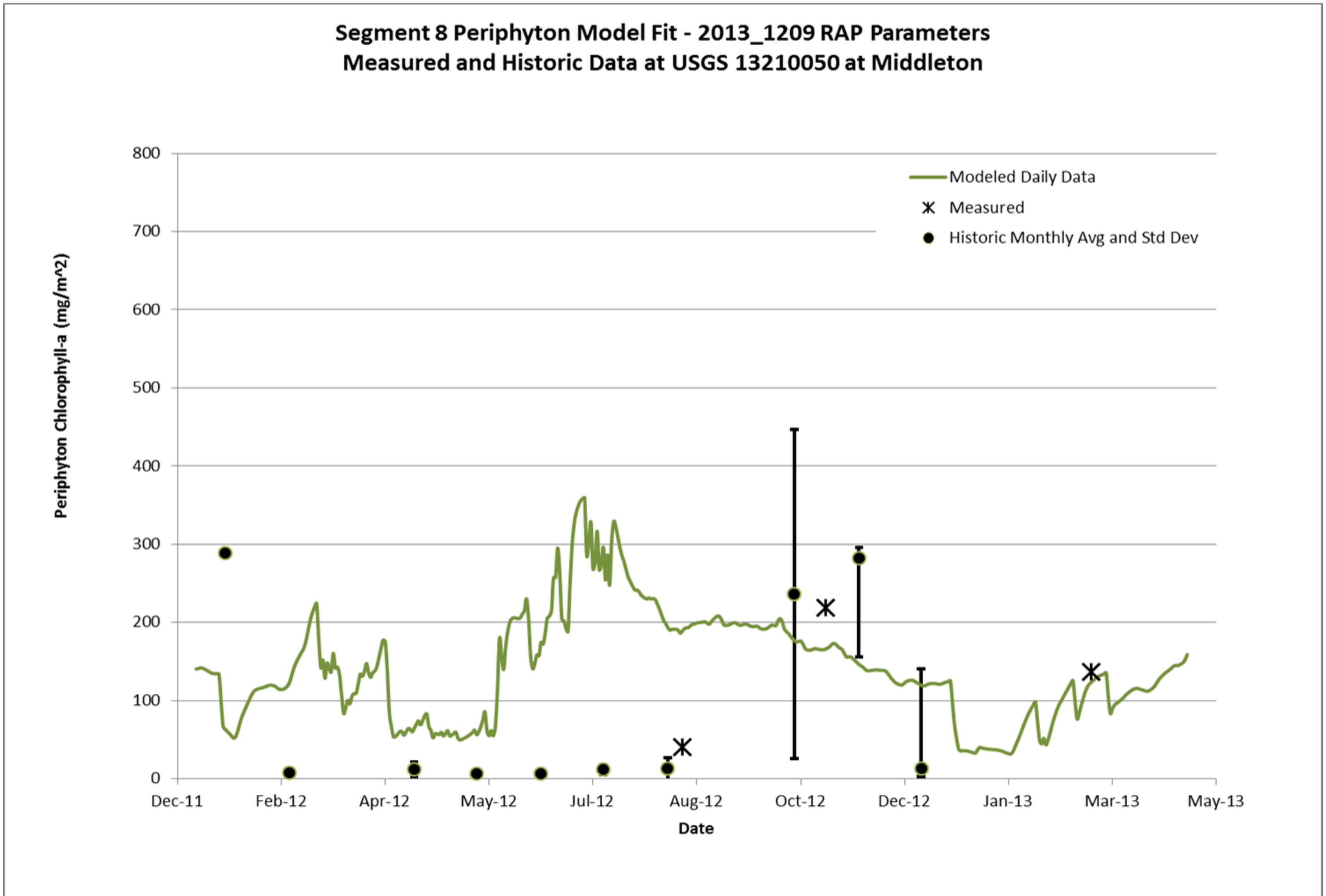


Figure 69. Model prediction of periphyton chlorophyll a (mg/m^2) at Middleton using the 2013_1209 RAP algal parameters.

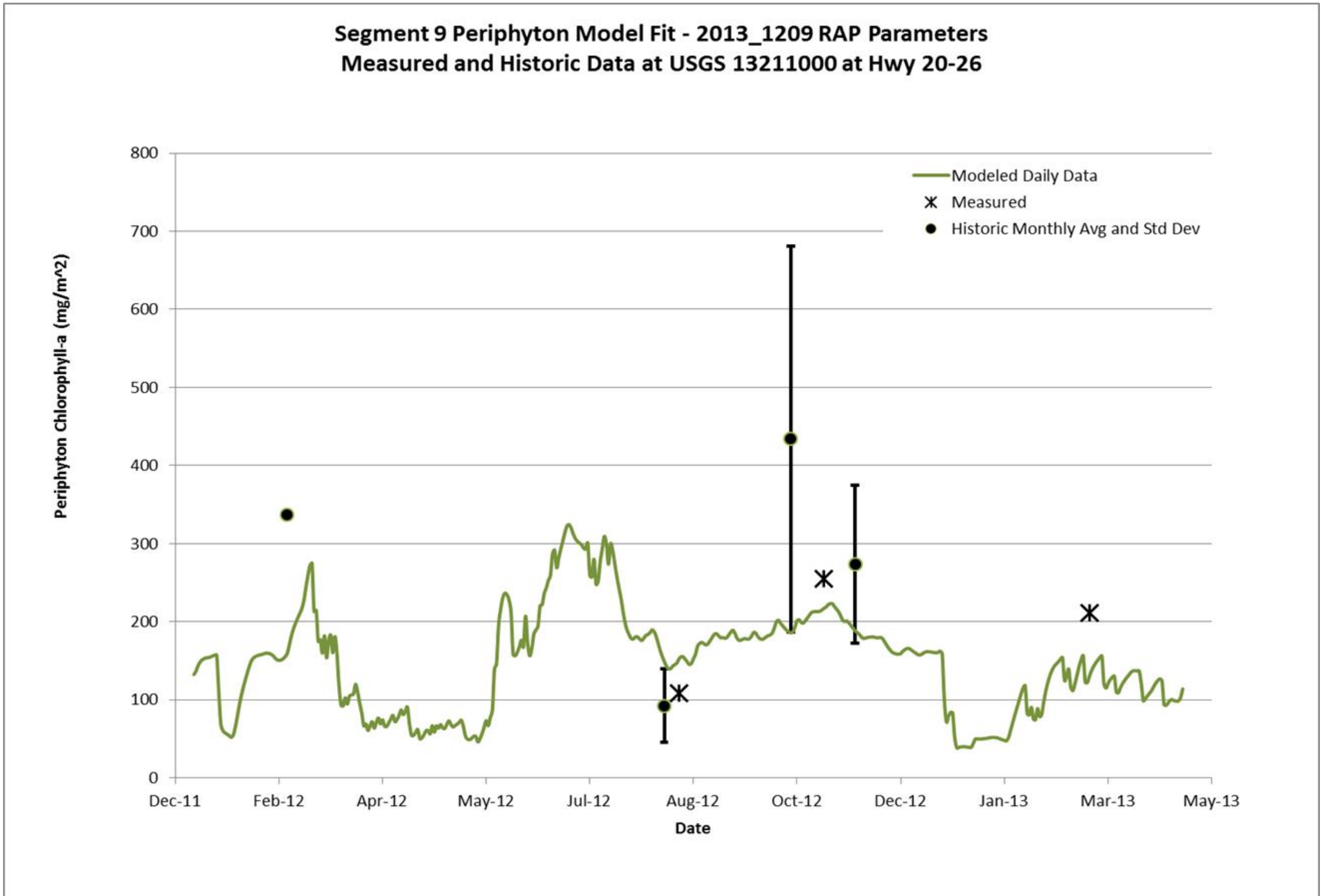


Figure 70. Model prediction of periphyton chlorophyll a (mg/m^2) at Caldwell using the 2013_1209 RAP algal parameters.

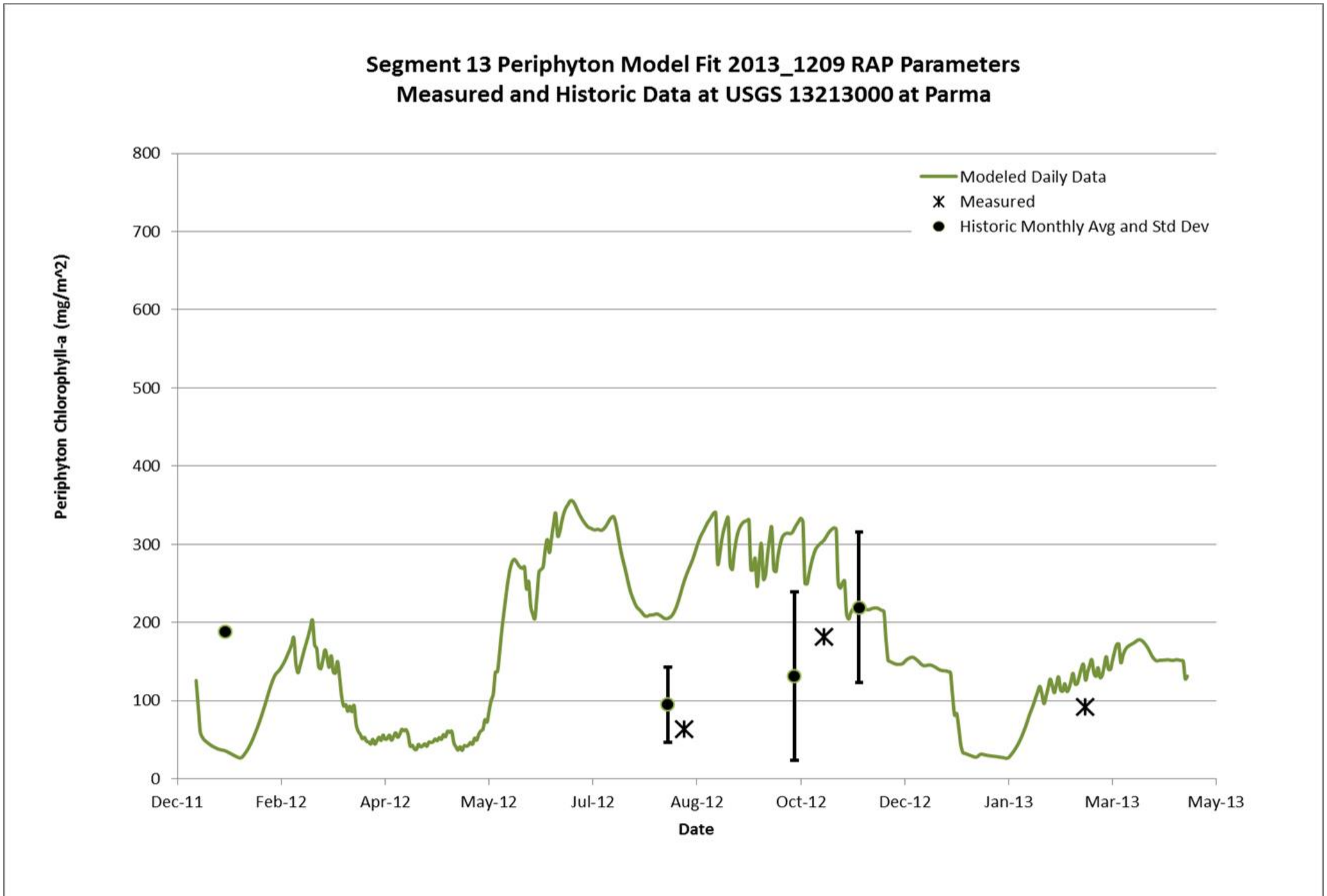


Figure 71. Model prediction of periphyton chlorophyll a (mg/m^2) at Parma using the 2013_1209 RAP algal parameters.

Comments on the calibration for the 2014_0103 parameter set:

This DEQ parameter set incorporated some P and N half-saturation constants suggested by Chris Mebane, USGS (2010) utilizing experimental research and data in Idaho streams (Table 18; Figures 72-76). This parameter set showed a good community composition, but resulted in consistent periphyton growth over predictions in summer, relative to historical and measured August data.

Table 18. Select algal parameters employed in the lower Boise River AQUATOX 2014_0103 model calibration.

Algal Parameters in the lower Boise River AQUATOX 2014_0103 calibration												
Parameter	Topt	Tmax	Tresp	Light Sat	Pmax	Lightex	P Half-sat	N Half-sat	C Half-sat	Exp Mo Co	FCrit	% Slough
Periphyton												
Low-nutrient diatoms	15	39	2	64	0.77	0.03	0.006	0.07	0.054	0.01	0.007	90
High-nutrient diatoms	20	35	1.8	64	2.3	0.03	0.055	0.117	0.054	0.01	0.009	25
Greens	25	42	2	110	1.7	0.03	0.0428	0.1	0.054	0.01	0.007	90
Cladophora	15	25	2	135	1.08	0.22	0.0428	0.0586	0.054	0.05	0.008	25
Blue-greens	10	50	2.1	33	1.2	0.03	0.034	0.168	0.024	0.01	0.008	90
Phytoplankton												
Low-nutrient diatoms	15	39	2	224	0.7	0.14	0.006	0.07	0.054	0.05	na	na
High-nutrient diatoms	20	35	1.8	45	1.87	0.14	0.055	0.117	0.054	0.05	na	na
Greens	26	42	2	220	1.5	0.24	0.0428	0.1	0.054	0.04	na	na
Blue-greens	27	50	2	60	2.2	0.099	0.034	0.168	0.024	0.12	na	na

Topt = optimal temperature (deg C)
Tmax = maximum temperature (deg C)
Tresp = temperature response slope
LightSat = saturating light (Ly/day)
Pmax = maximum photosynthetic rate (1/day)
Lightex = light extinction coefficient 1/m-g/m3
P half-sat = phosphorus half-saturation constant (mg/L), Michaelis-Menten kinetics
N half-sat = nitrogen half-saturation constant (g/L), Michaelis-Menten kinetics
C half-sat = inorganic carbon half-saturation constant (mg/L). Michaelis-Menten kinetics
ExpMoCo = exponential mortality coefficient (g/g-day)
Fcrit = critical force for periphyton scour (Newtons)
%Slough = percent periphyton lost in slough event (%)

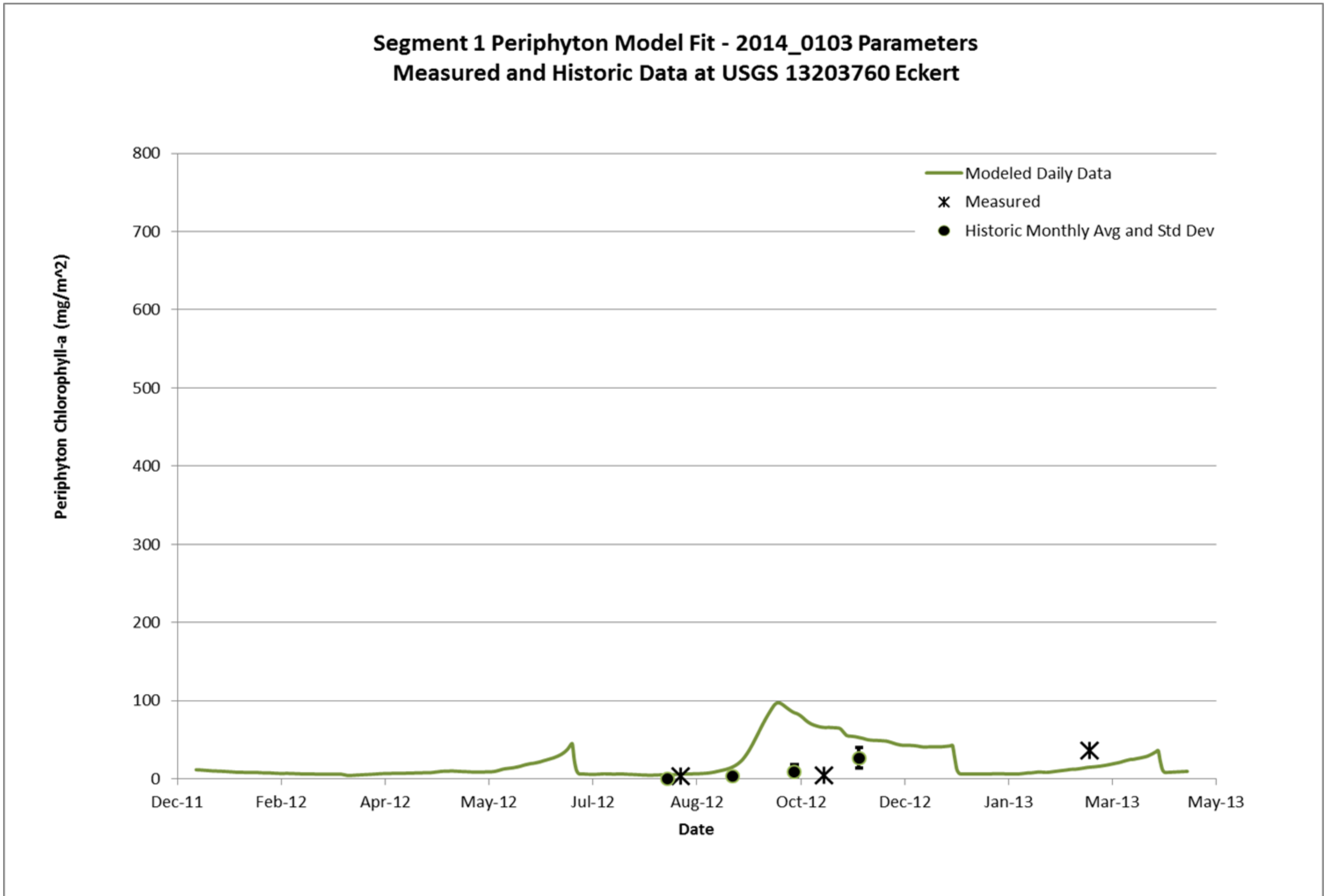


Figure 72. Model prediction of periphyton chlorophyll a (mg/m^2) at Eckert using the 2014_0103 algal parameters.

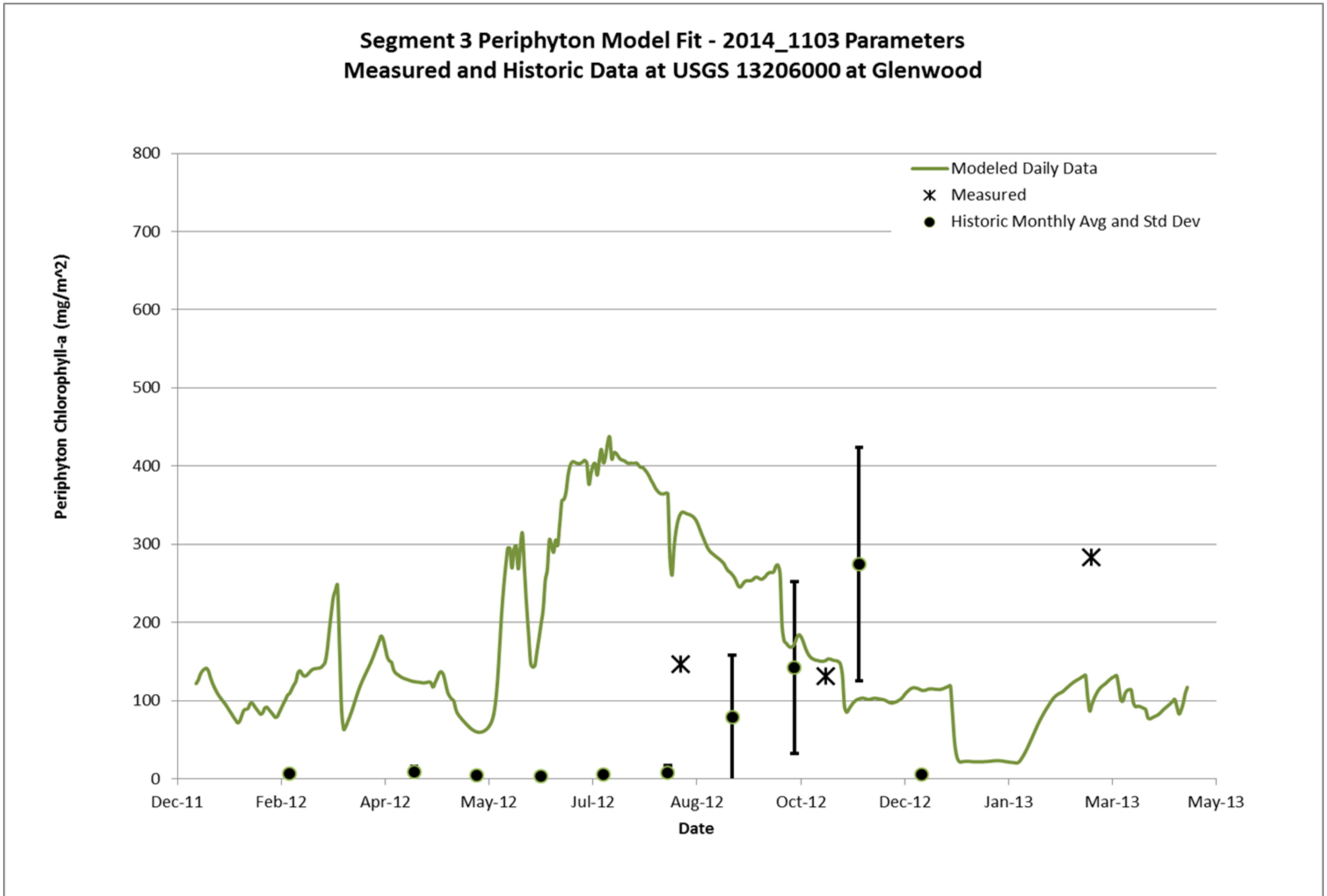


Figure 73. Model prediction of periphyton chlorophyll a (mg/m^2) at Glenwood using the 2014_0103 algal parameters.

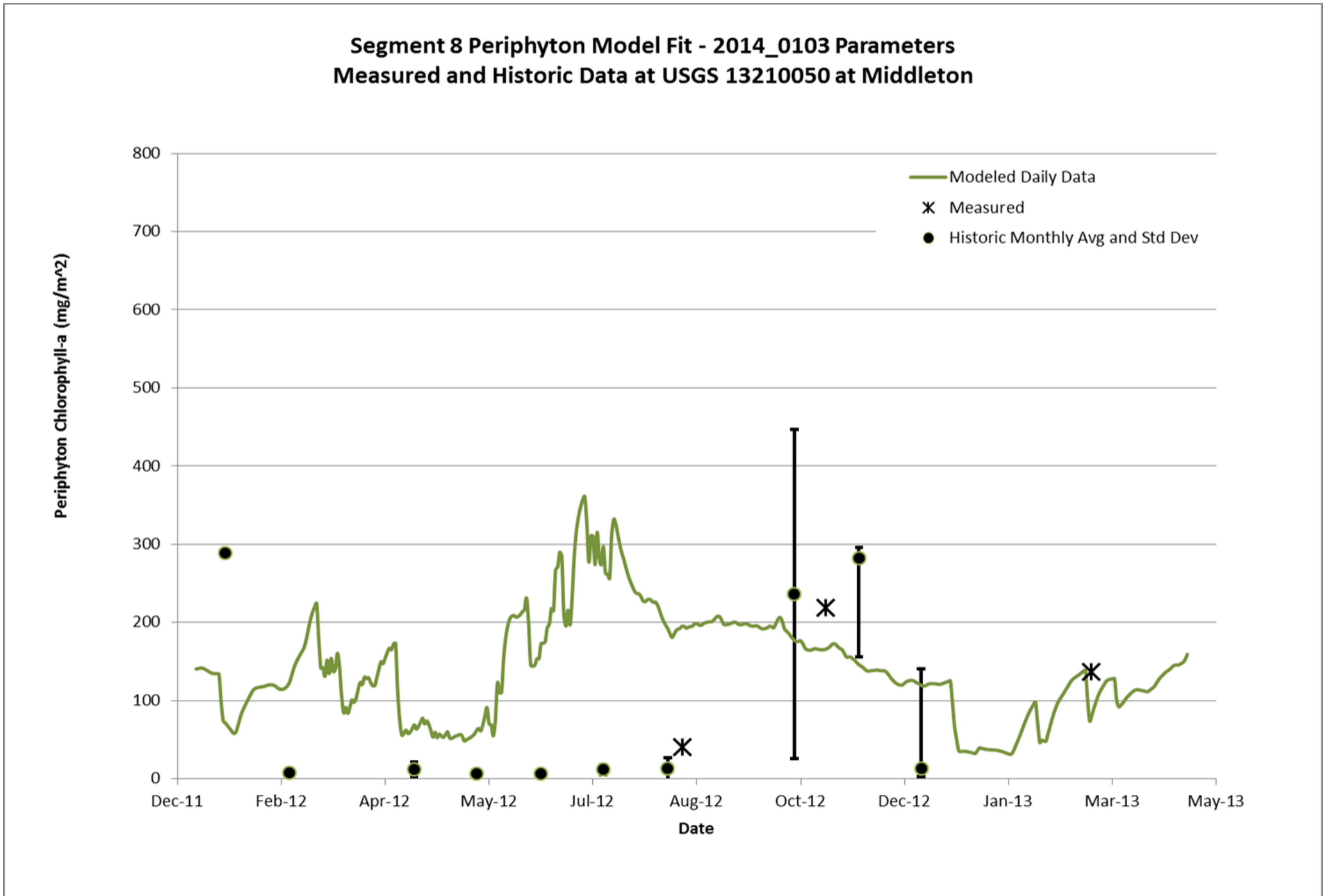


Figure 74. Model prediction of periphyton chlorophyll a (mg/m^2) at Middleton using the 2014_0103 algal parameters.

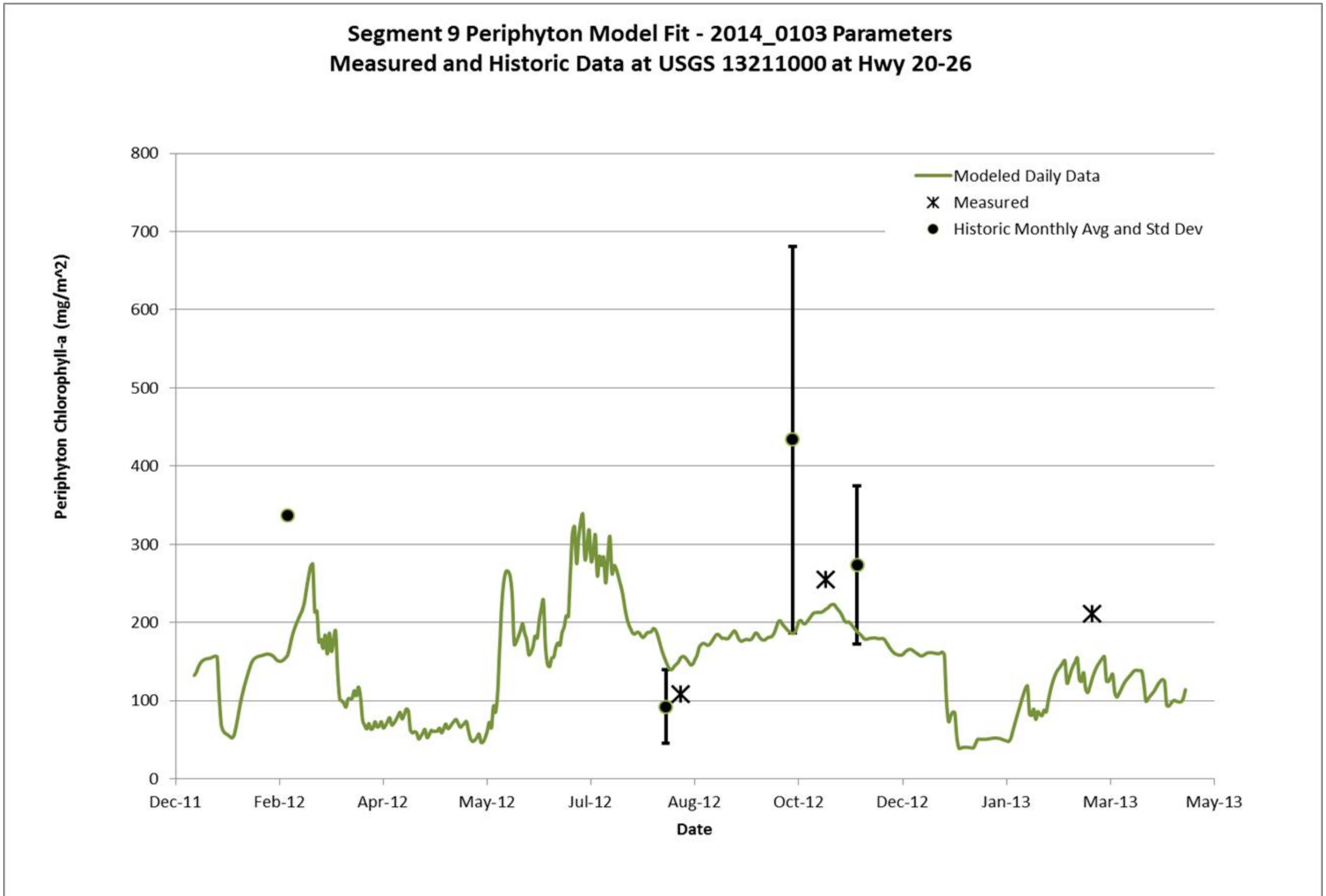


Figure 75. Model prediction of periphyton chlorophyll a (mg/m^2) at Caldwell using the 2014_0103 algal parameters.

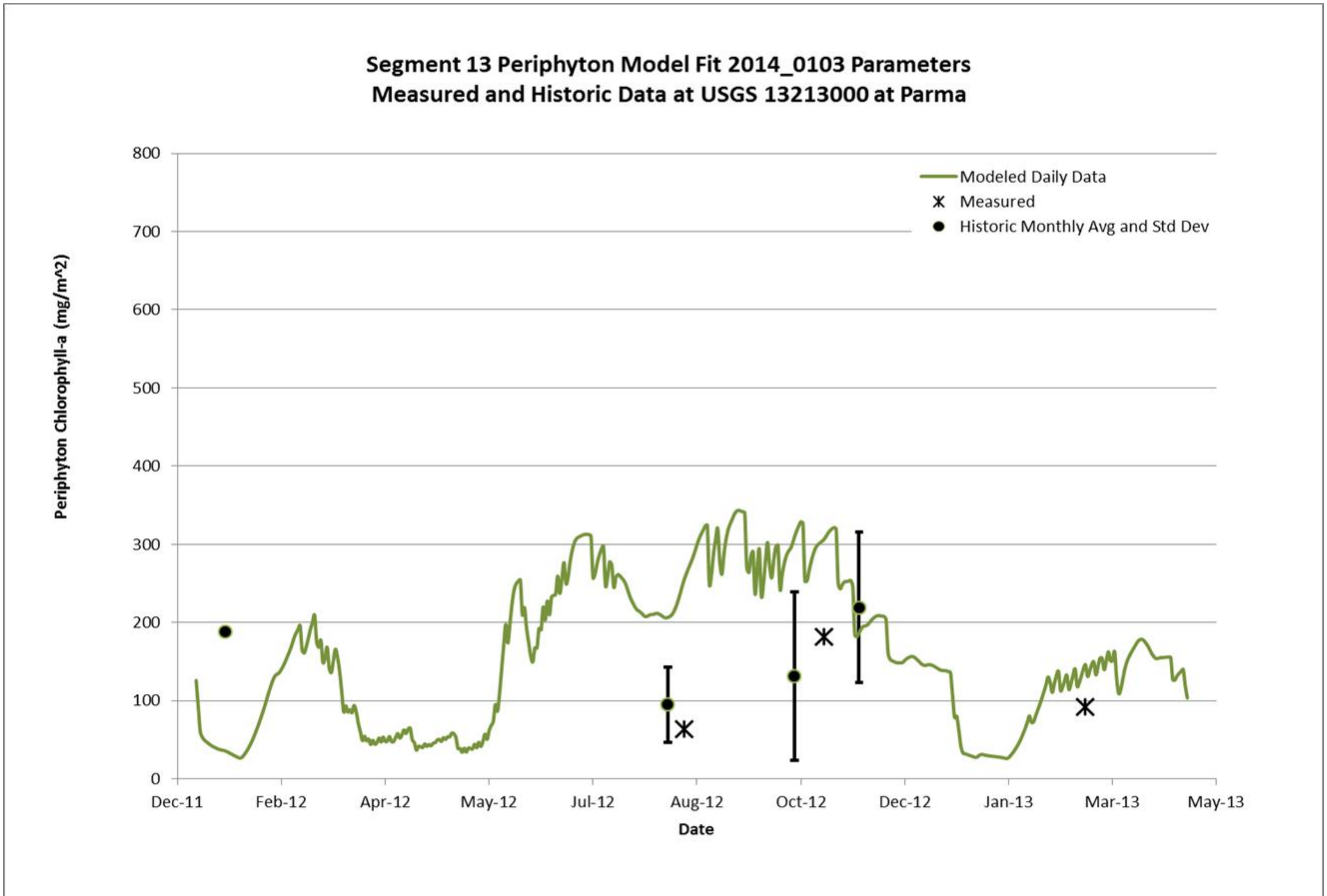


Figure 76. Model prediction of periphyton chlorophyll a (mg/m^2) at Parma using the 2014_0103 algal parameters.

3.3.3.4 Final Calibration

Goals for the final calibration include:

- To achieve positive correlations between simulated monthly averages and existing data
- Simulating an average biomass reflective of observed and historical data
- The simulation time-series lies within the range of observed and historical data
- Realistic community composition

The error for the final calibration is described using absolute mean error based on a 15-day rolling mean of the daily model output for periphyton chlorophyll a (mg/m^2).

DEQ emphasizes that some over- and under-predictions are quite likely and reasonable to some extent with all of the observed periphyton values. That is, the sampled data are believed to be accurate, but were taken at specific locations at specific times; whereas the model is predicting average periphyton values for each segment. Therefore, even under a *perfect* calibration, we would not expect the model to match the observed periphyton data perfectly. Similarly, given the sparse and wide variability in observed and historical periphyton data on the LBR, it is difficult to determine the extent to which the model is over- or under-predicting periphyton for each segment or specific sampling locations.

The following section provides:

- the algal parameters for the final calibration (Table 19)
- time series plots of the daily model output compared with measured data, all of the historical data, and the average and standard deviation of the historical data.
- Descriptive error statistics for the simulation

Table 19. Algal parameters in the lower Boise River AQUATOX 2014_0414 model calibration.

Parameter	Topt	Tmax	Tresp	LightSat	Pmax	Lightex	P Half-sat	N Half-sat	C Half-sat	ExpMoCo	FCrit	%Slough
Periphyton												
Low-nutrient diatoms	15	39	2	64	0.77	0.03	0.006	0.07	0.054	0.01	0.005	99
High-nutrient diatoms	20	35	1.8	64	2.3	0.02	0.066	0.117	0.054	0.05	0.005	96
Peri Greens	20	42	2	110	1.08	0.22	0.05	0.1	0.054	0.01	0.007	90
Cladophora	15	25	2	135	1.08	0.22	0.0428	0.0586	0.054	0.05	0.008	25
Blue-greens	10.5	50	2.1	33	1.2	0.04	0.034	0.168	0.024	0.01	0.008	90
Phytoplankton												
Low-nutrient diatoms	15	39	2	64	0.77	0.03	0.006	0.07	0.054	0.01	NA	NA
High-nutrient diatoms	20	35	1.8	64	2.3	0.02	0.055	0.117	0.054	0.05	NA	NA
Phyto Greens	20	42	2	110	1.08	0.22	0.0428	0.1	0.054	0.01	NA	NA
Blue-greens	10.5	50	2	33	1.2	0.04	0.034	0.168	0.024	0.01	NA	NA

(yellow)	**DDS 2014_0203**
(light green)	**Mebane, USGS**
(green)	**Mebane, plus calibration**

Notes:
Topt = optimal temperature (°C)
Tmax = maximum temperature (°C)
Tresp = temperature response slope
LightSat = saturating light (Ly/day)
Pmax = maximum photosynthetic rate (1/day)
Lightex = light extinction coefficient 1/m-g/m^3
P half-sat = phosphorus half-saturation constant (mg/L), Michaelis-Menten kinetics
N half-sat = nitrogen half-saturation constant (mg/L), Michaelis-Menten kinetics
C half-sat = inorganic carbon half-saturation constant (mg/L), Michaelis-Menten kinetics
ExpMoCo = exponential mortality coefficient (g/g-day)
Fcrit = critical force for periphyton scour (Newtons)
% Slough = percent periphyton lost in slough event (%)

This DEQ parameter set incorporated P half-sat values for green algae, including Cladophora, suggested by research on Idaho streams by Chris Mebane (USGS). The excerpt below is from an E-mail from dated 12/31/2013:

> "You might consider some of the following assumptions to fill in the blanks. Lee and others (2012) reported that periphyton in 8 streams in S. Idaho sampled seasonally throughout one year were dominated by blue-green algae, except for the most nutrient rich site which had roughly even split between blue-greens and diatoms. From this, one might assume that the undifferentiated periphyton growth in the ISU experiments consisted mostly of blue-greens and "low nutrient" diatoms. Because the default Km for P for high nutrient diatoms was higher than anything I estimated, you might just want to keep that. The highest Km estimate for N might be a reasonable guess for "high nutrient diatoms". I don't know how you estimate the relative abundances of "low-" and "high-nutrient diatoms" in the Boise River since I think you just had presence/absence data from Sam Rushforth.
>
> Since Cladophora is a green algae, absent better rationale, one might just assume that the *Selenastrum* estimate could be estimate a high range for Cladophora too. Neither of my N half sat estimates were very strong because the in situ data were strongly leveraged by one point, and for the ISU lab test, the Michalis-Menton model was a poor fit. Thus, because the defaults for N had higher half sat for blue greens (which are N fixers anyway, but that's a separate can of worms), one might use the higher N Km estimate for blue greens. All this assuming and guessing might lead to the following inputs for your modeling:

	P	N
Cladophora	0.043	0.27
Green algae	0.043	0.27
High-nutrient diatoms	0.055	0.57
Low-nutrient diatoms	0.034	0.27
Blue-green algae	0.034	0.57

> Lee, K.E., D.L. Lorenz, J.C. Petersen, and J.B. Greene. 2012. Seasonal patterns in nutrients, carbon, and algal responses in wadeable streams within three geographically distinct areas of the United States, 2007-08. U.S. Geological Survey, Reston, VA. Accessed from *http://pubs.usgs.gov/sir/2012/5086/* "

During attempts to incorporate these suggestions, DEQ found that using the above N half-sat constants made the nitrogen simulation incorrect and that some of the P half-sat constants resulted in excess biomass throughout the system. The final calibration (2014_0203) found that the suggested P half-sat constants were a good fit for *Cladophora*, but green algae needed a final adjustment to 0.05 mg/L.

The DEQ final parameter set for the calibration incorporates results from extensive model iterations supported by the sensitivity analyses presented above, where:

- Optimal temperature (Topt) has the greatest effect on green algae and secondarily on high-nutrient diatoms. Topt was important for seasonality of blue-green algal bloom. The 2013_1209 RAP calibration from Richard Park identified the best set of optimal temperatures, but DEQ calibrated a final adjustment on blue-greens.
- Changes in critical force and sloughing were required to control system-wide proliferation of low- and high-nutrient diatoms.
- N half-sat has very little effect on any of the algal groups.
- P half-sat was the most sensitive parameter for calibrating total biomass predictions.
- Maximum photosynthetic rate (Pmax) has the greatest effect on green algae and a lesser effect on high-nutrient diatoms. The 2013_1209 RAP calibration from Richard Park identified the best set of Pmax for this model calibration.

The next pages (Figures 77-81; Table 20) show time series plots of the daily model output compared with measured data, historical data, and the average and standard deviation of the historical data. Additionally, Figures 72-86 illustrate the modeled periphyton simulations as a 15-day rolling mean and the corresponding overall AME for each segment.

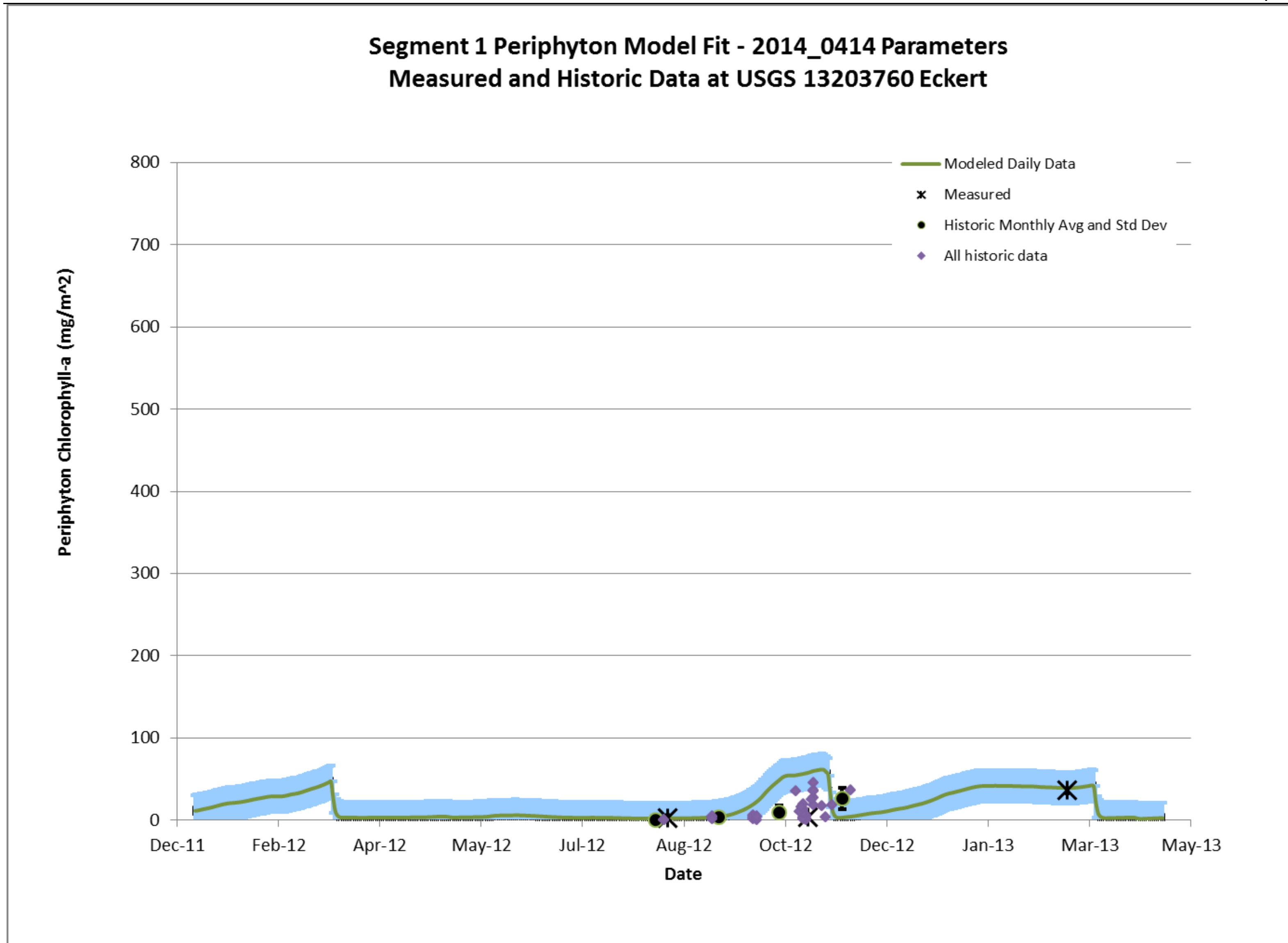


Figure 77. Daily model prediction of periphyton chlorophyll a (mg/m^2) at Eckert using the 2014_0414 algal parameters. The blue band represents the Segment 1 AME (19.1) for daily simulations relative to measured data, and applied to model calibration period.

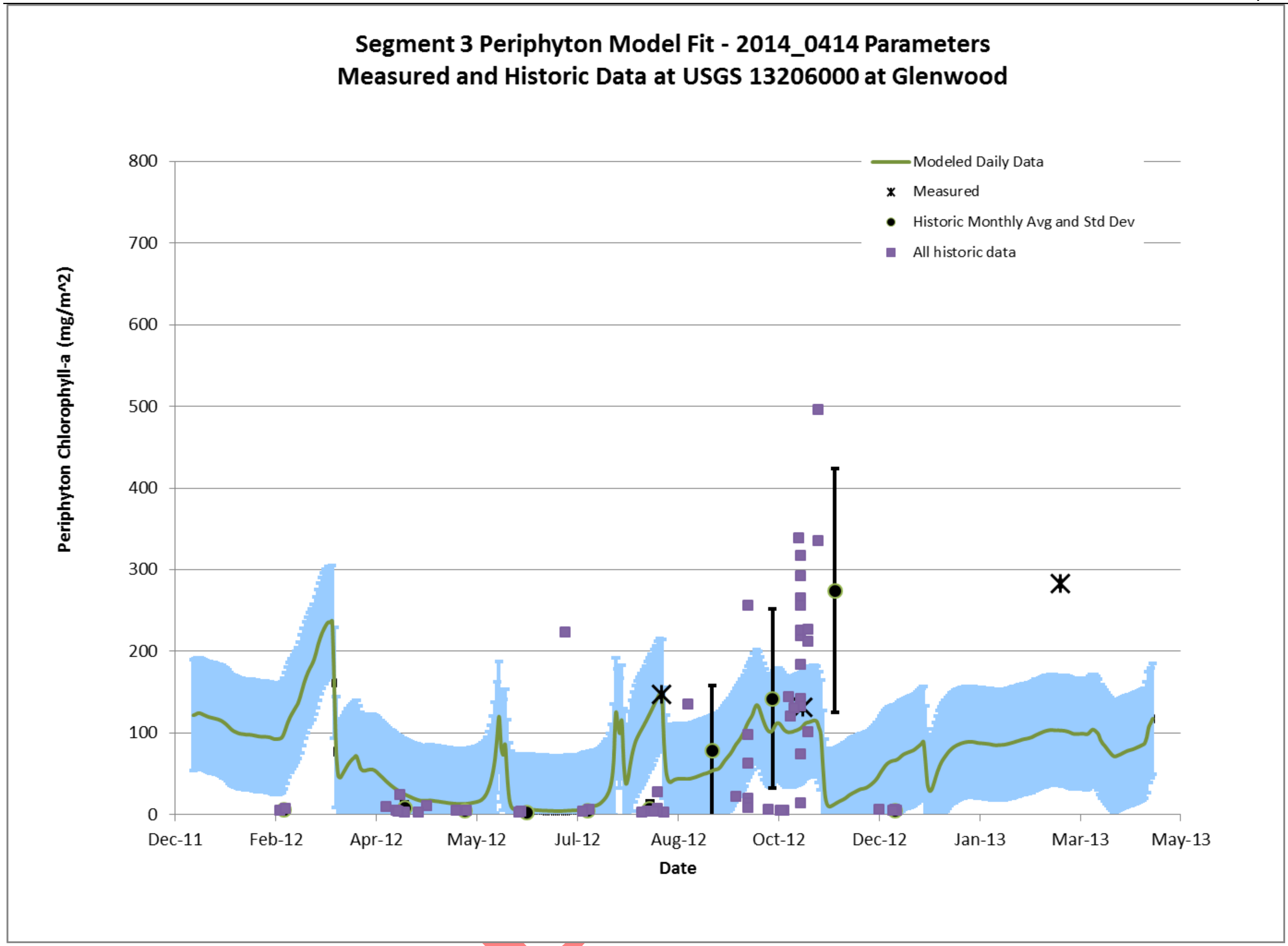


Figure 78. Daily model prediction of periphyton chlorophyll a (mg/m^2) at Glenwood using the 2014_0414 algal parameters. The blue band represents the Segment 3 AME (67.8) for daily simulations relative to measured data, and applied to model calibration period.

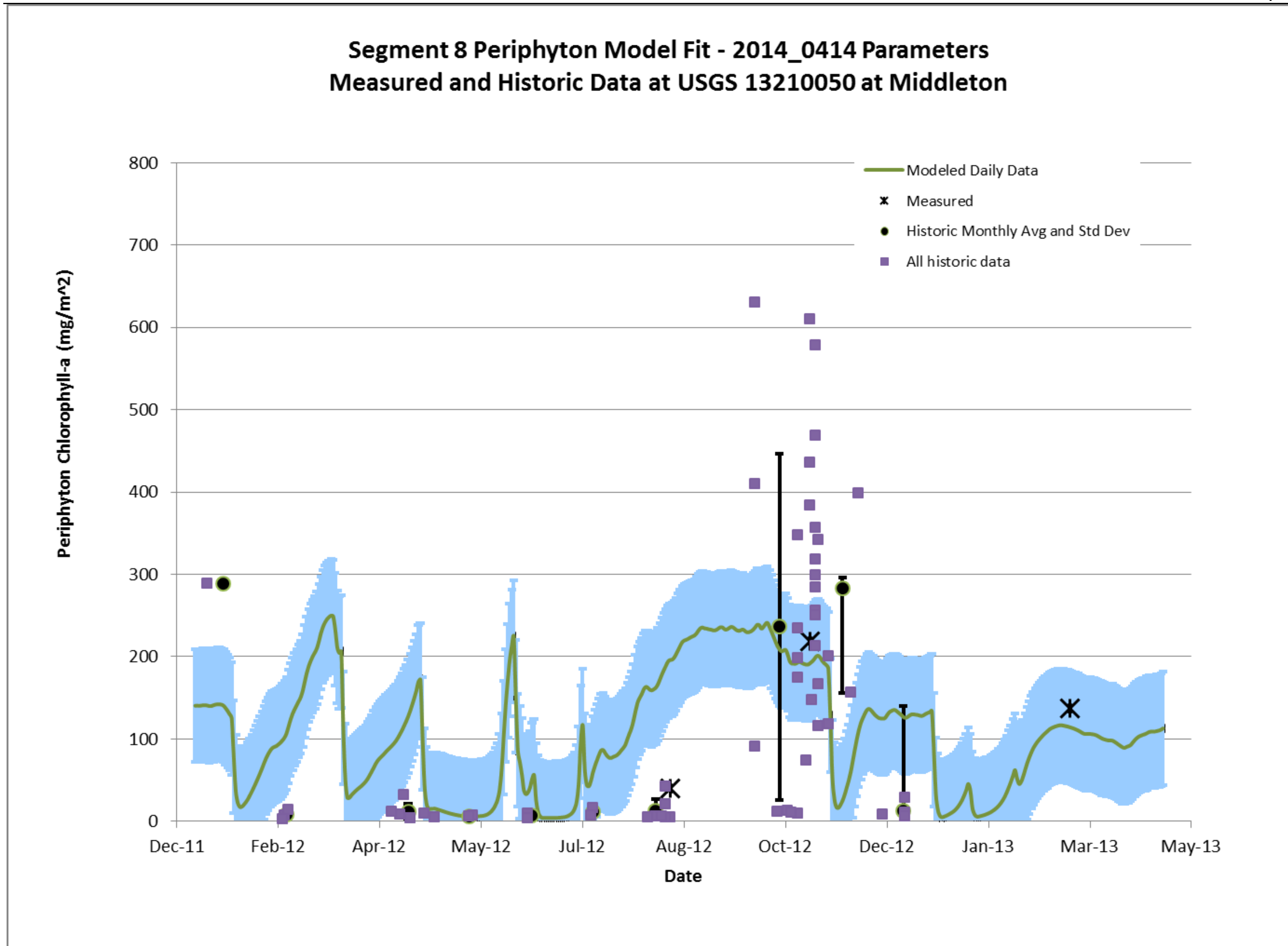


Figure 79. Daily model prediction of periphyton chlorophyll a (mg/m^2) at Middleton using the 2014_0414 algal parameters. The blue band represents the Segment 8 AME (68.5) for daily simulations relative to measured data, and applied to model calibration period.

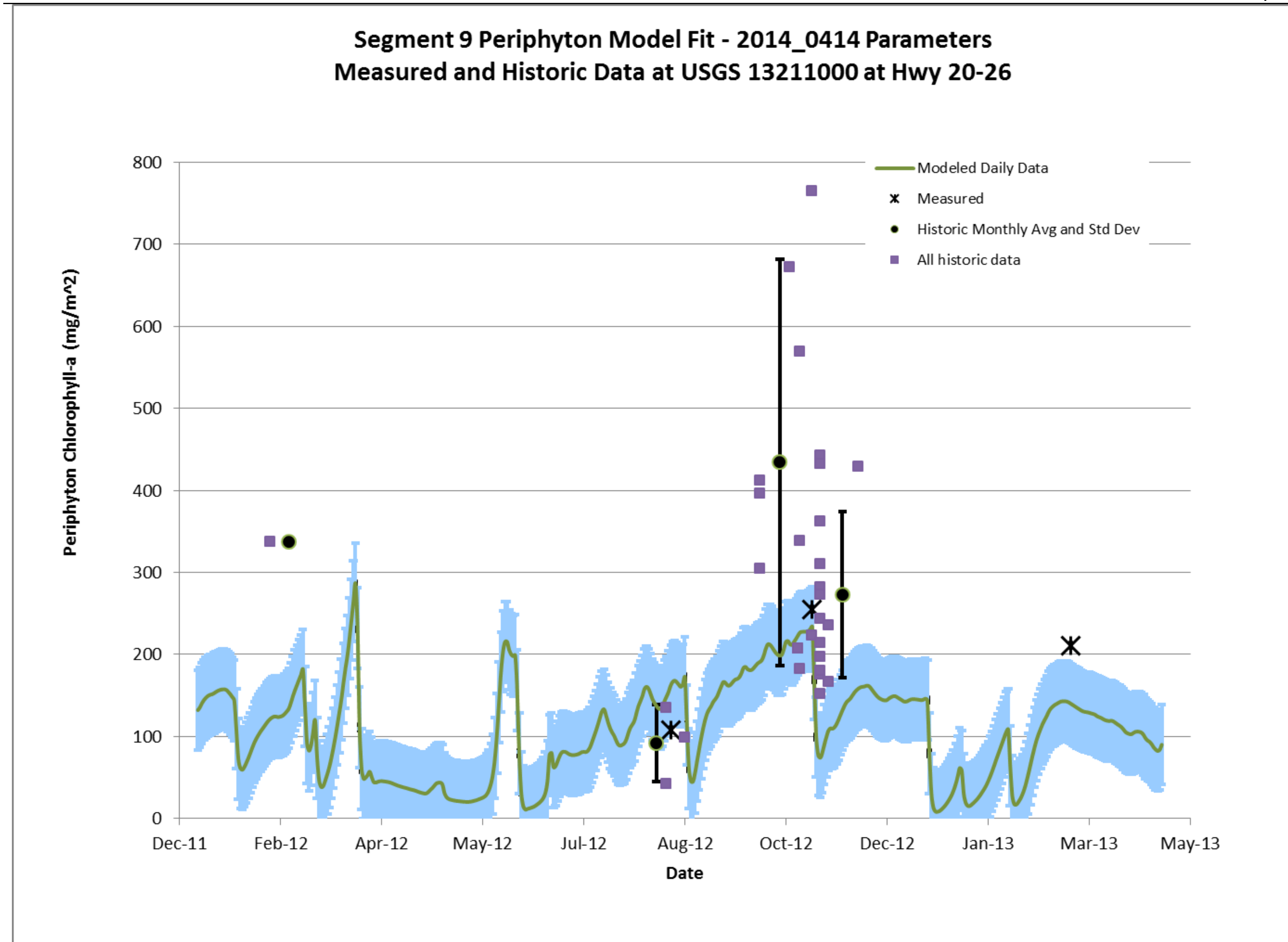


Figure 80. Daily model prediction of periphyton chlorophyll a (mg/m^2) at Caldwell using the 2014_0414 algal parameters. The blue band represents the Segment 9 AME (48.9) for daily simulations relative to measured data, and applied to model calibration period.

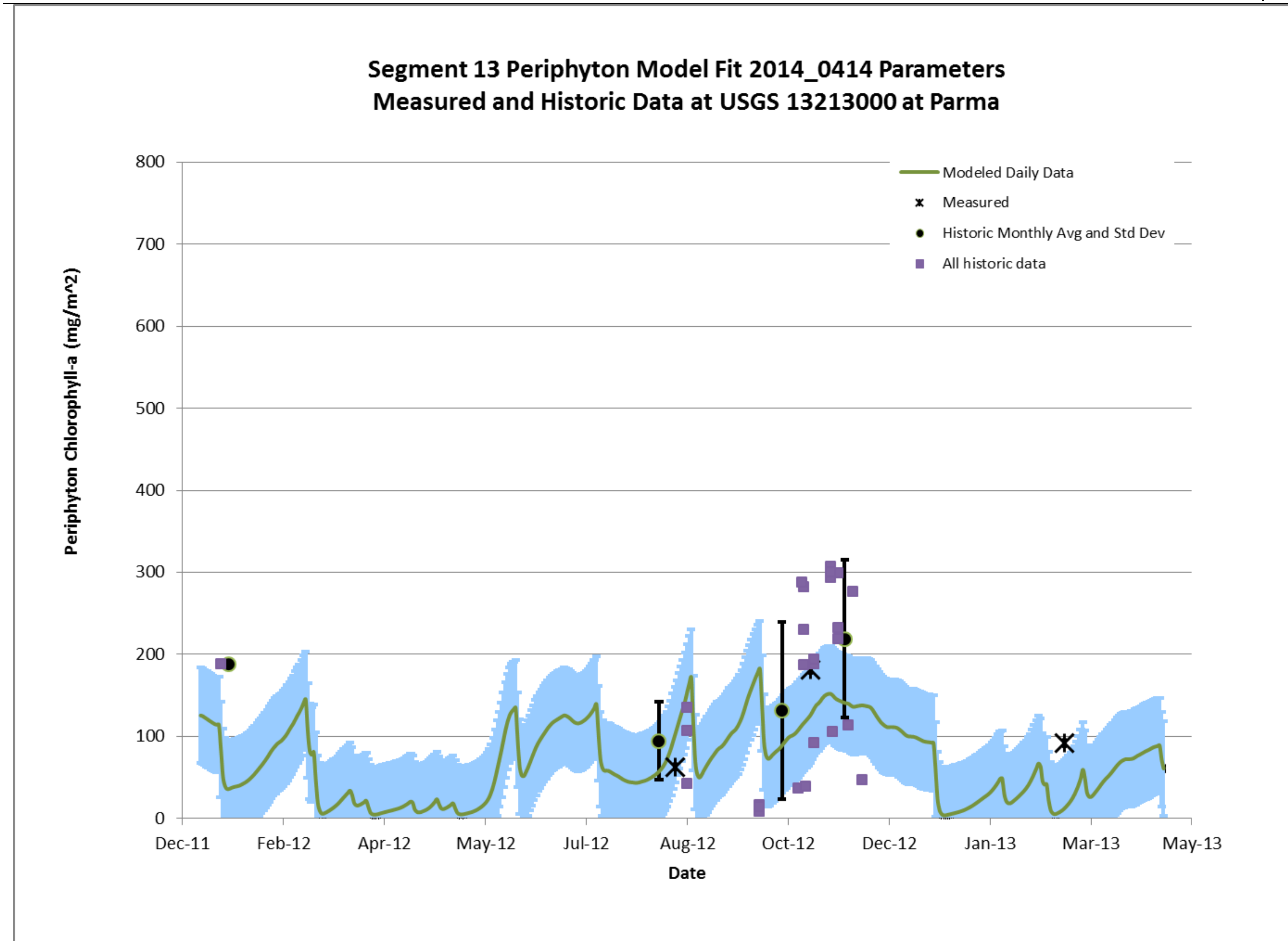


Figure 81. Daily model prediction of periphyton chlorophyll a (mg/m^2) at Parma using the 2014_0414 algal parameters. The blue band represents the Segment 13 AME (57.9) for daily simulations relative to measured data, and applied to model calibration period.

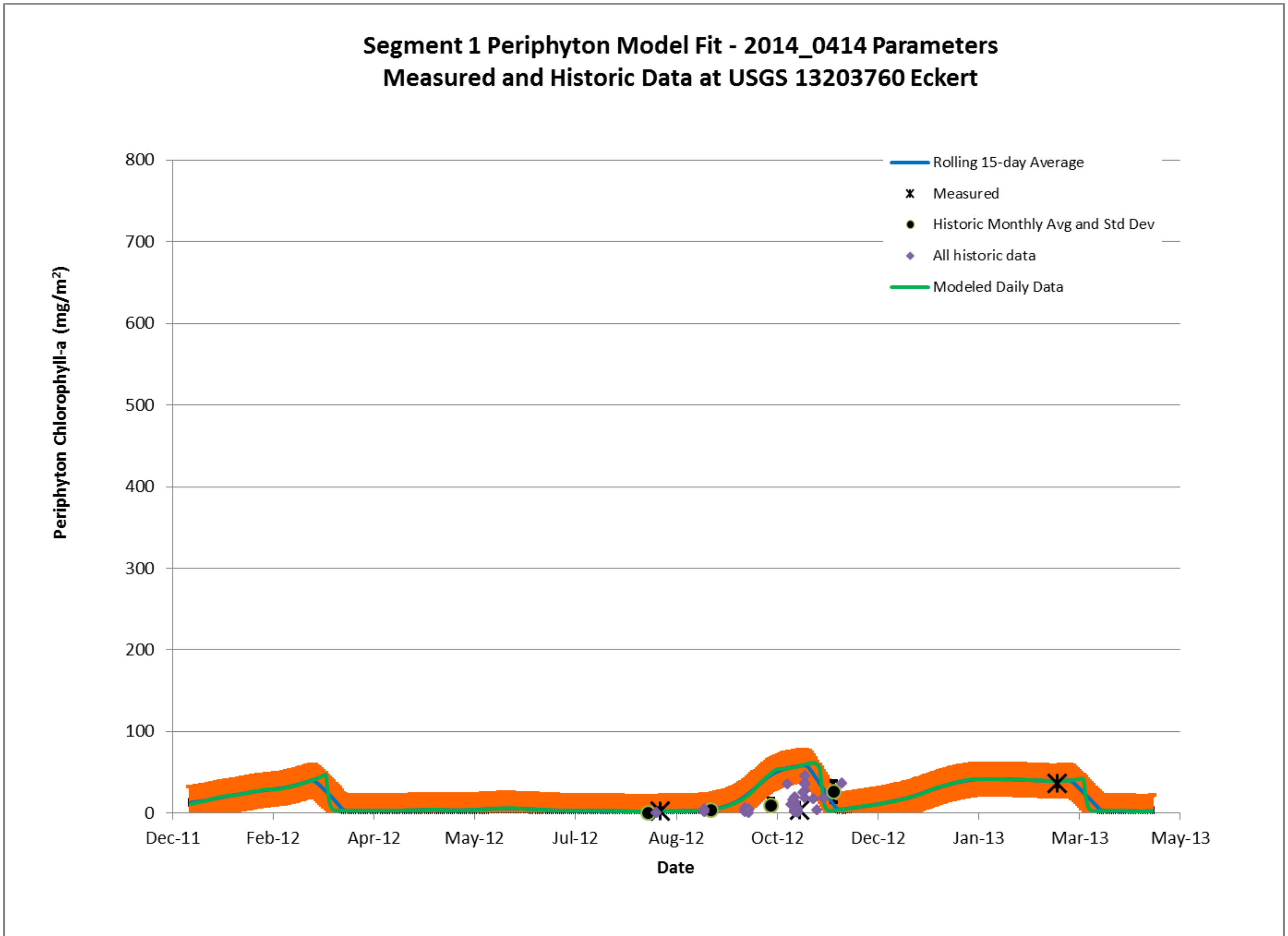


Figure 82. Modeled 15-day rolling mean vs. daily modeled periphyton chlorophyll a (mg/m^2) at Eckert using the 2014_0414 algal parameters. The orange band represents the Segment 1, 15-day rolling AME (19.4) for model simulations relative to measured data, and applied to model calibration period.

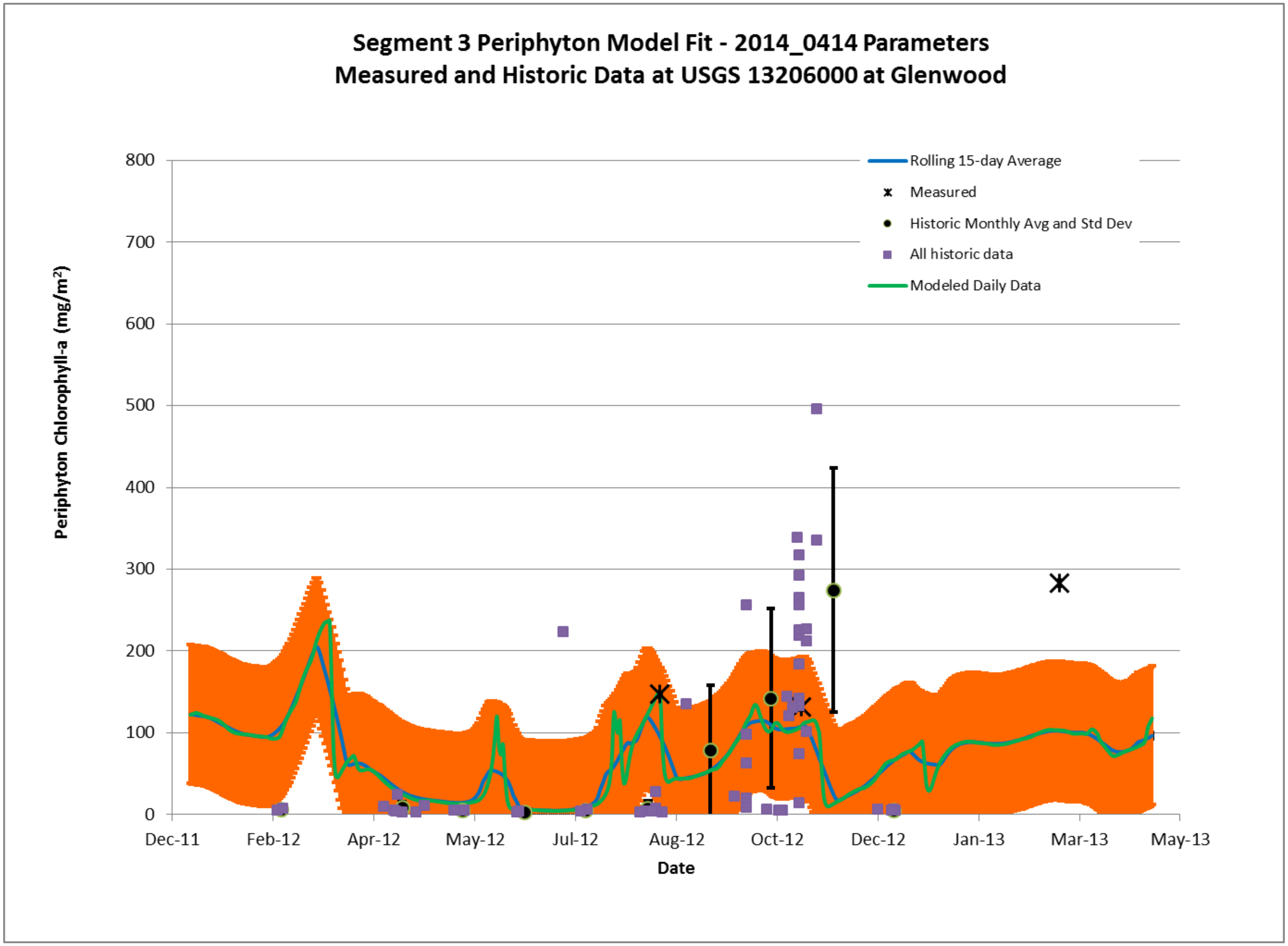


Figure 83. Modeled 15-day rolling mean vs. daily modeled periphyton chlorophyll a (mg/m^2) at Glenwood using the 2014_0414 algal parameters. The orange band represents the Segment 3, 15-day rolling AME (84.9) for model simulations relative to measured data, and applied to model calibration period.

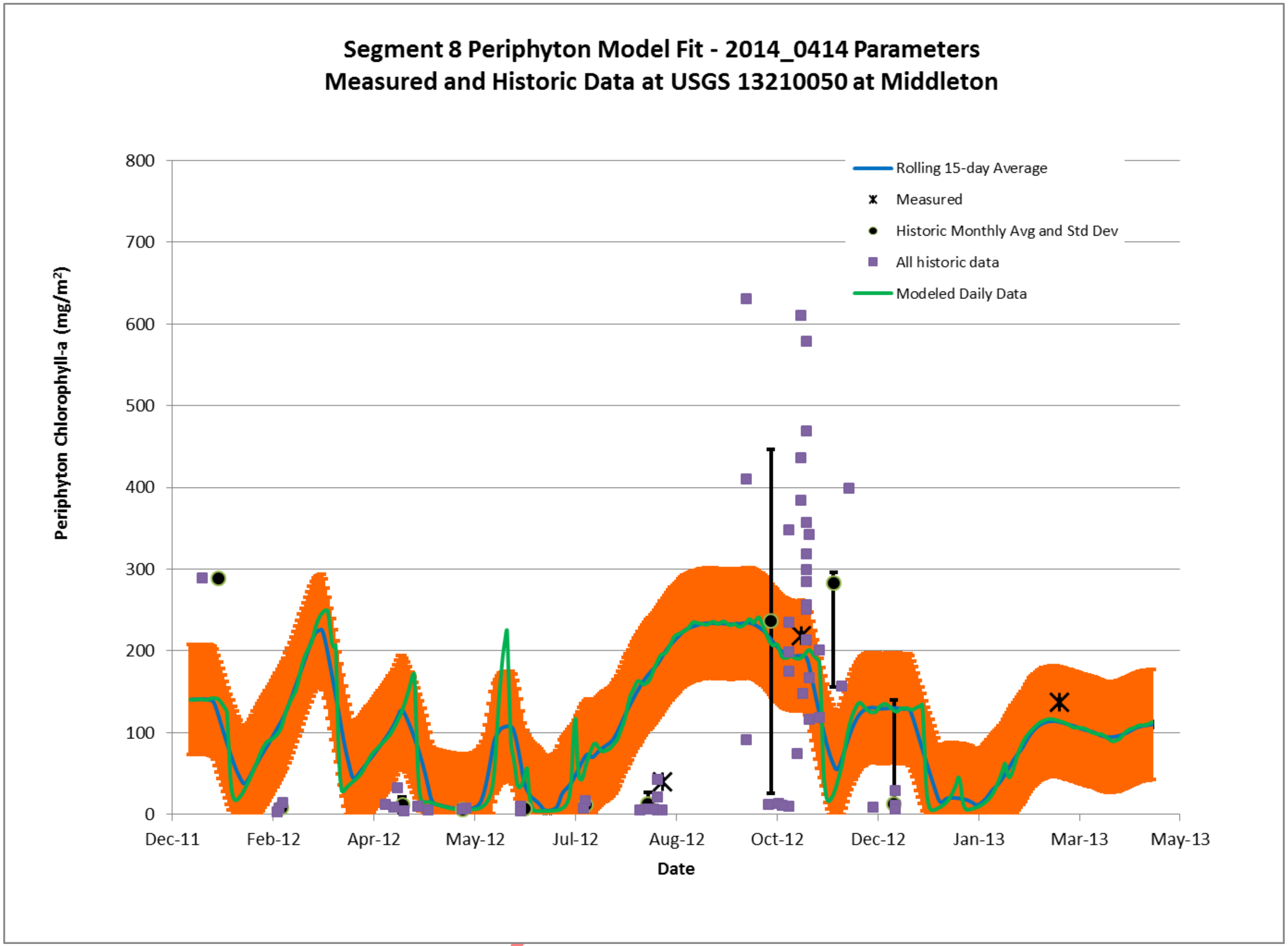


Figure 84. Modeled 15-day rolling mean vs. daily modeled periphyton chlorophyll a (mg/m^2) at Middleton using the 2014_0414 algal parameters. The orange band represents the Segment 8, 15-day rolling AME (67.3) for model simulations relative to measured data, and applied to model calibration period.

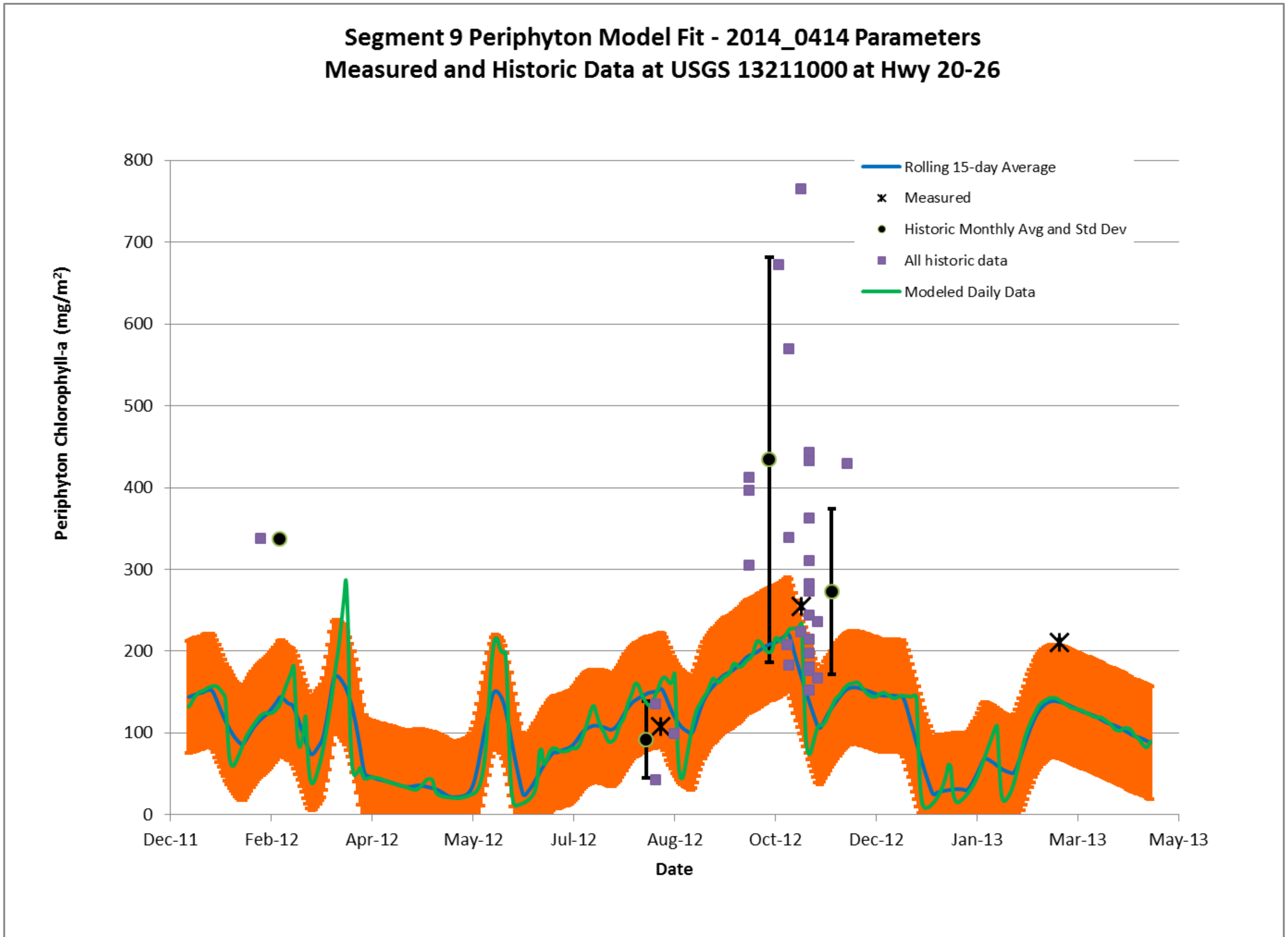


Figure 85. Modeled 15-day rolling mean vs. daily modeled periphyton chlorophyll a (mg/m²) at Caldwell using the 2014_0414 algal parameters. The orange band represents the Segment 9, 15-day rolling AME (68.8) for model simulations relative to measured data, and applied to model calibration period.

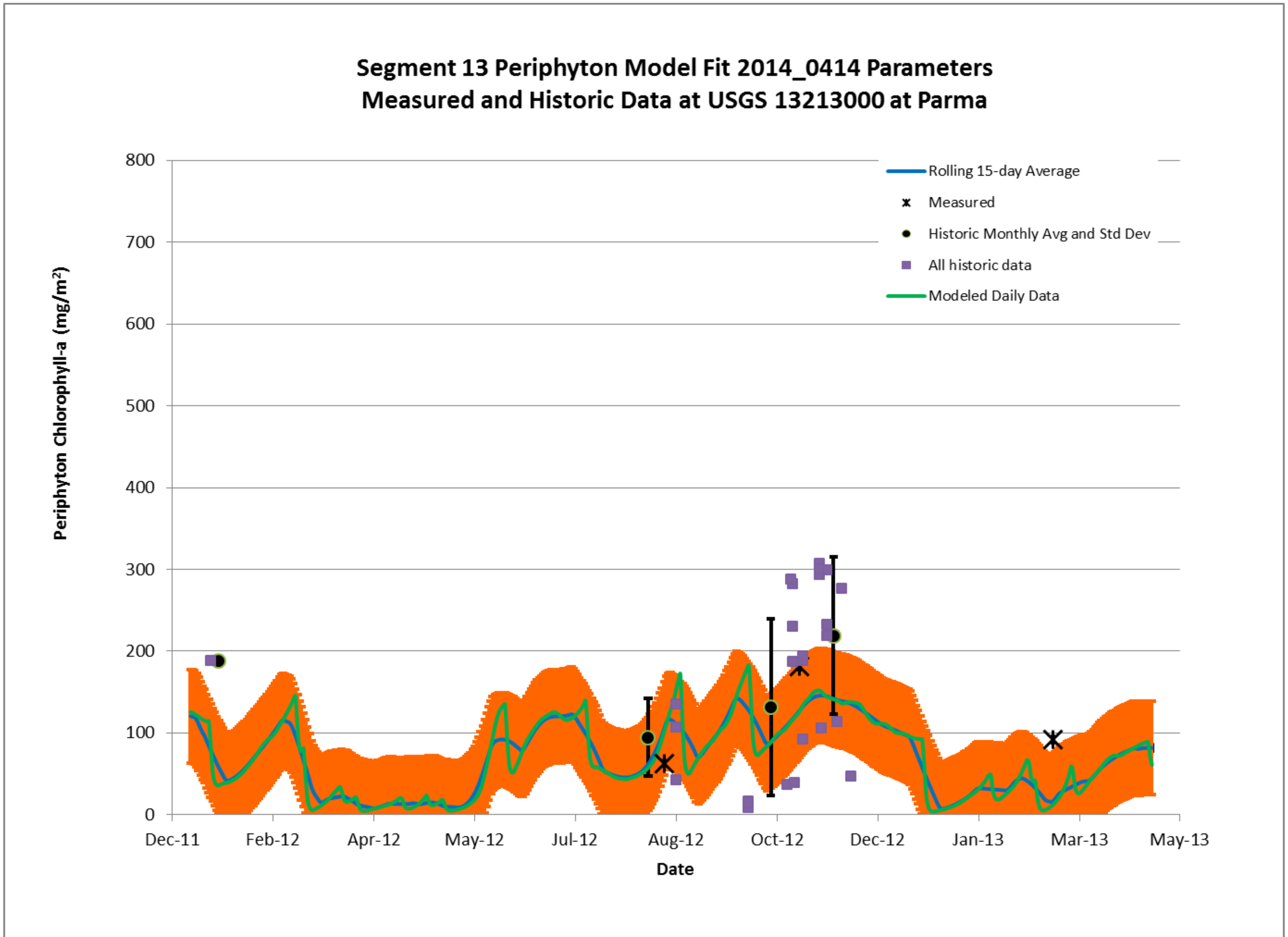


Figure 86. Modeled 15-day rolling mean vs. daily modeled periphyton chlorophyll a (mg/m^2) at Parma using the 2014_0414 algal parameters. The orange band represents the Segment 13, 15-day rolling AME (57.1) for model simulations relative to measured data, and applied to model calibration period.

Table 20. Periphyton simulations under the lower Boise River AQUATOX 2014_0203 model calibration.

2014_0414_TGS

Daily Absolute Mean Error (AME):

Segment	*1*	*3*	*8*	*9*	*13*	**Overall**
August	0.5	0.6	156.0	54.5	39.2	**50.2**
October	53.7	22.8	27.0	21.2	55.2	**35.9**
March	3.2	179.8	22.7	71.0	79.4	**71.2**
Overall	**19.1**	**67.7**	**68.5**	**48.9**	**57.9**	**52.4**

15-Day Rolling Average Absolute Mean Error (AME):

Segment	*1*	*3*	*8*	*9*	*13*	**Overall**
August	0.6	51.3	153.3	46.2	42.2	**58.7**
October	54.0	22.7	24.8	87.3	54.0	**48.5**
March	3.6	180.7	23.8	73.0	75.0	**71.2**
Overall	**19.4**	**84.9**	**67.3**	**68.8**	**57.1**	**59.5**

Periphyton biomass correlations (R^2):

Segment	*1*	*3*	*8*	*9*	*13*
measured	-0.0022	+0.07485	+0.1406	+0.1666	+0.144
historical	+0.1569	+0.0227	+0.0093	+0.2129	+0.0706

Mean relative difference monthly simulated periphyton biomass, and measured and historical data:

Segment	*1*	*3*	*8*	*9*	*13*	**Overall**
measured	14	187	132	191	112	**637**
simulation	22	101	167	157	72	**519**
% difference	**57%**	**-46%**	**26%**	**-18%**	**-36%**	**-18%**
historical	10	53	78	284	158	**584**
simulation	19	59	100	149	94	**420**
% Difference	**94%**	**10%**	**28%**	**-48%**	**-41%**	**-28%**

Simulated periphyton ranges relative to measured and historical data:

Segment	*1*	*3*	*8*	*9*	*13*
January			underpredicts		underpredicts
February		overpredicts	overpredicts	underpredicts	
March	in range	underpredicts	in range	in range	underpredicts
April		in range	in range		
May		in range	in range		
June		in range	in range		
July		in range	in range		
August	in range	in range	overpredicts	in range	in range

September	in range	in range			
October	overpredicts	in range	in range	in range	in range
November	in range	in range	in range	in range	in range
December		in range	in range		

**Model simulations were within range of measured and historical data during 28 of 37 (76%) month-segment combinations.*

Tables 20 and 21, Figures 77-86, and the section below, identify and describe the results of statistics and other analyses performed to help understand the strengths and limitations of the model predictions for periphyton. DEQ acknowledges that with limited measured data points for comparison, each individual statistic should be interpreted cautiously; however, when considered collectively, these analyses provide a clearer picture regarding how the model is functioning relative to previous model calibrations, and current measured and historical data.

<u>AME</u>

The AMEs for periphyton biomass were calculated for daily and 15-day rolling mean for simulation results relative to, and centered on, measured data. That is, daily model simulated periphyton was compared directly to the same day that measured field data was collected. The modeled rolling mean included simulation results 7 days before and 7 days after the corresponding measured data. For the final model calibration (2014_0414), the overall daily AME for all segment-season combinations with measured periphyton data is 52.4; the overall a5-day rolling mean AME for all segment-season combinations with measured periphyton data is 59.5. Both AME values are within the stated accuracy objective of 71 mg/m^2. By segment, daily AMEs range from 19.1 in segment 1 to 68.5 in segment 8; 15-day rolling AMEs range from 19.4 in segment 1 to 84.9 in segment 3. Additionally, by season, daily AMEs range from 35.9 to 71.2, while 15-day rolling AMEs range from 48.5 to 71.2.

In comparing the final model calibration (2014_0414) to previous calibration versions, the final calibration has the best (lowest) overall daily and 15-day rolling AME (Table 21). Although other calibration versions perform better in some segments, the final calibration results in the lowest AME for 21 of the 25 (84%) model-segment combinations.

Table 21. Daily and 15-day rolling absolute mean errors (AME) for the final (2014_0414) relative to measured data in previous model calibrations.

	Daily AME for Each Model Segment					
Model Version	**1**	**3**	**8**	**9**	**13**	**Overall AME**
2001 Parameters	22.9	132.6	108.5	126.4	61.0	**90.3**
2013_0925_DDS	28.1	89.8	80.1	142.8	37.5	**75.7**
2013_1209_RAP	38.0	82.2	71.7	54.3	116.2	**116.2**
2014_0103_DDS	28.6	133.4	88.3	56.2	117.9	**86.1**
2014_0414_TGS	19.1	67.7	68.5	48.9	57.9	**52.4**

	15-Day Rolling Mean AME for each Model Segment					
Model Version	**1**	**3**	**8**	**9**	**13**	**Overall AME**
2001 Parameters	23.3	133.1	106.7	127.1	62.7	**90.6**
2013_0925_DDS	28.1	86.8	83.7	105.2	42.7	**69.4**
2013_1209_RAP	38.2	108.5	74.8	50.2	116.2	**77.6**
2014_0103_DDS	29.0	123.0	75.8	52.0	117.9	**79.5**
2014_0414_TGS	19.4	96.2	66.3	68.3	57.5	**61.5**

R^2

R^2 correlations for periphyton biomass were also performed between monthly mean simulated, measured, and historical data. DEQ acknowledges that evaluating R^2 values for these analyses may be statistically valid and is, therefore, presenting them only as additional qualitative and quantitative measures to compare the model results to measured and historical data. The correlations between monthly simulations and historical data are positive for all segments, with R^2 values ranging from 0.0093 to 0.2129. Similarly, correlations between monthly simulations and measured data are positive for all segments, except segment 1, with R^2 values ranging from 0.0749 to 0.1667. The segment 1 negative correlation is -0.0022.

Monthly Biomass

Differences in the periphyton monthly mean simulated biomass relative to measured and historical data were calculated. Overall, monthly biomass simulations were 18% lower than measured data, and 28% lower when compared to historical data. For each model segment, model simulations ranged from over predicting measured data by up to 57% in segment 1 down to under predicting measured data by 46% in segment 3. Alternatively, model simulations ranged from over predicting historical data by 94% in segment 1 down to under predicting historical data by 48% in segment 9.

Overall Assessment

The data, tables, and figures illustrate the performance and fit of modeled periphyton biomass simulations relative to measured and historical data. Overall, the results indicate that rolling 15-day model simulations for periphyton biomass are within the DEQ pre-determined AME accuracy goal of 71 mg/m^2. The model simulations were positively correlated, albeit uncertain in some cases, with measured and historical data in all segments, except segment 1 for measured data. Differences between simulated monthly periphyton biomass, measured data, and historical data ranged by segment, but overall model simulations were 18 and 28% lower than measured and historical data, respectively. Finally, in comparing the daily and 15-day rolling mean model simulations to measured and historical data, the model simulations fall within range of the measured and historical data of 28 of 37 (76%) month-segment combinations. As with any model, additional data and further calibration could potentially improve the model fit. However, this version of the LBR AQUATOX model calibration has largely met the DEQ accuracy goals and model simulations frequently fall within the range of measured and historical data.

3.3.3.5 Uncertainty

Some notes on model uncertainty in the light of the unpredictability of periphyton populations:

- A lot of work went in to attempting to reflect the Rushforth (2007) community composition. However, those data are just a snapshot at three points in time and not a comprehensive study of community competition and succession.
- The plots shown in the sensitivity analysis were only for Segment 13. The results actually vary for each segment. This was another complicating factor in achieving a closer calibration: when the algal parameters and community composition were adjusted for better alignment in one segment, biotic and environmental factors in the model simulations would alter the alignment in other segments (often for worse).
- Conceptually, from historical data, it appears that the biomass slowly falls off through the winter, a limited spring bloom appears in March, biomass is very low through the summer months, and it gradually builds up through August and into the fall season. However, in both the measured and historical periphyton data on the LBR is too sparse, due to the many gaps in locations and months, to show a realistic and consistent pattern of biomass throughout the year.
- The complex seasonal hydrology and management of the LBR increases the difficulty of developing and verifying a conceptual framework for algal growth in the river, as well as verifying modeled relationships. However, in light of additional monitoring data needed to clearly quantify and qualify algal growth patterns in the LBR, this model-based approach that utilizes the plethora of site-specific environmental data to estimate relationships between site-specific environmental factors (including nutrients) and algae is likely among the most practical and defensible options.
- Through observations and reasoning, the low growth through the summer months is likely due to the higher water volume, velocity, and turbidity of the LBR. One limitation of the AQUATOX model is that it does not perform hydraulic simulations such as shear stress. However, AQUATOX does encapsulate the effects of stream velocity, drag force, periphyton biomass, nutrient, light, and temperature limitations, along with channel adaptation as factors determining sloughing (Park and Clough 2012b). Altering these algal parameters can help identify total biomass throughout the model simulation period, but does not reflect how stream forces can differ seasonally.

3.4 Conclusions and Recommendations

AQUATOX is an excellent choice to model the periphyton groups that make up the total periphyton chlorophyll a (mg/m^2) biomass. It simulates the competition for resources among the algal groups by estimating how changes in algal parameters affect other species as well as the total periphyton prediction.

Recommendations for future monitoring include:

- Further study to identify the actual community composition —it would be very enlightening to collect additional samples (temporally and spatially) through an entire water year in river segments 1, 3, 8, 9, and 13 to better encapsulate species competition and succession.
- Once better speciation and biomass are quantified and qualified, further sensitivity analyses could be performed with this AQUATOX calibration to more clearly identify species interactions and competition for resources.

- Collect an additional validation dataset of periphyton biomass that better characterizes seasonal differences among model segments 1, 3, 8, 9, and 13.

4 Model Scenarios for the TMDL

DEQ identified scenarios for modeling total phosphorus (TP) reductions through:

1. Resulting reductions of periphyton growth and biomass accrual in model segments 9-13 (the impaired AUs of the lower Boise River) commensurate with the mean benthic chlorophyll a target of 150 mg/m^2
2. Flow duration curve analyses with water quality targets for the range of flows that would result in meeting a May 1 – September 30 TP target of 0.07 mg/L at the mouth of the Boise River
3. USGS August 2012, October 2012, and March 2013 mass balance models (Etheridge 2013)
4. Consultation with the Lower Boise Watershed Council, the Technical Advisory Committee, the Model, Technical, and Policy Workgroup, and the model developers, Jonathan Clough and Dick Park
5. Iterative testing with the calibrated AQUATOX model

The reduction scenario that resulted in the combination of necessary periphyton reductions, while also meeting reasonable assurance criteria for the TMDL is:

- Point sources at 0.10 mg/L TP May – September and 0.35 mg/L October – April
- Tributaries and groundwater at 0.07 mg/L TP year-round
- Stormwater wet weather loads at a 42% reduction from current conditions

The predictive ability of the model tests the hypothesis that TP reductions will decrease excess algal growth and achieve the mean periphyton chlorophyll a concentration target of 150 mg/m^2.

4.1 Methods

Although phosphorus is often the limiting nutrient in western freshwater streams (Edmondson 1981), carbon, nitrogen, and physical parameters like lack of shade and antecedent water temperatures are also important factors in overall organic enrichment that leads to excess algal biomass (Mebane *et al* 2014; Maret, *et al* 2010). AQUATOX models living components—biota such as algae and cyanobacteria—as well as non-living organic materials, collectively termed “detritus”. Simulating reductions in all sources of organic enrichment is necessary when simulating total phosphorus reductions.

In addition, research has shown that water column nutrients contribute to a limited proportion of periphyton biomass, whereas physical parameters such as temperature, light, streamflow and depth account for the remaining biomass effects. However, these physical parameters are often more difficult to control, "leaving management of nutrient loading as the most likely method to control excessive algal biomass in streams" (Dodds *et al* 2002).

4.1.1 Phosphorus, Nitrogen, and Carbon Reductions

In order to more-accurately model phosphorus reduction scenarios, reductions in nitrogen and carbon must also be simulated. This is reasonable because watershed improvement projects that reduce phosphorus also control nitrogen. Nutrients adsorb to silt particles at an average ratio of 1.6 pounds per ton for phosphorus and 3.2 pounds per ton for nitrogen (Michigan DEQ 1999). Therefore, projects that reduce sediment loads also reduce nutrients in these proportions.

AQUATOX models total nitrogen and phosphorus as functions of the dissolved, bioavailable form of the nutrient as well as in the form which is bound up in detritus and plants. Refer to the phosphorus mass balance accounting on page 122 of "AQUATOX Release 3.1 Plus" technical documentation for further information.

For the phosphorus reduction scenario for the river segments, tributaries, and groundwater, the same ratio of TP reduction required to achieve the TP target was applied to any existing ammonia, nitrogen, biochemical oxygen demand, or chlorophyll data. The steps to build the import spreadsheet for simulating this reduction scenario included:

- Using the monthly average of historic water quality data at the same precision as historic data. This was necessary because of the uneven temporal scale of available water quality data. This allows more general application of the results. Non-detects in the historic data were treated as equal to the detection limit, which is a conservative assumption.
- Replacing any total soluble phosphorus data with total phosphorus. This allows the model to calculate stoichiometry on existing data rather than using literature values.
- Reducing monthly averages of ammonia, nitrogen, biochemical oxygen demand, and chlorophyll data according to the same ratio as required by bringing historic monthly average TP data to the TP target.

For model segments with a point source contributing effluent to a tributary, a weighted average TP concentration is calculated based on the seasonal design flow of the NPDES-permitted facilities. For tributaries including point sources, the nitrogen and carbon reductions are based on these weighted average TP concentrations.

For NPDES-permitted facilities with effluent flowing directly into the river, the same reductions of carbon and nitrogen cannot be expected based on target phosphorus reductions. DEQ surveyed facilities to determine estimated municipal wastewater treatment performance at various TP targets. Consensus among the facilities determined that Total 5-day biochemical oxygen demand (BOD) would average <5 mg/L, NO_3 as N would average from 5 to 30 mg/L, and NH_4 as N would average <1 mg/L (City of Boise 5-page memo dated 7/15/2014). In many instances, this represents more relative nitrogen and carbon in the effluent than would occur with a straight TP reduction ratio as calculated for the tributaries, river segments, and groundwater.

Appendix B provides the inputs for each model segment used in the reduction scenario with target TP for the NPDES-permitted facilities calculated based on seasonal design flow.

4.1.2 Total Suspended Sediment

For the TP reduction scenario, the total suspended sediment (TSS) data was represented as a 37% reduction. This reduction was used to approximate water quality conditions that could result from phosphorus-targeted BMPs, it was identified in the LBR sediment TMDL (DEQ 1999), and DEQ is currently developing a subsequent sediment TMDL for lower Boise River tributaries. Clearing suspended sediment out of the water column increases periphyton growth. Model results show that periphyton growth is limited by light availability and clearer water increases light available to substrate.

4.1.3 Detritus Reductions—Remineralization rates

In addition to modeling organic matter as carbonaceous biochemical oxygen demand (CBOD), AQUATOX also simulates organic matter as detritus, defined as all non-living organic material and associated decomposers (AQUATOX release 3.1 plus technical documentation page 141). Detritus exists in both dissolved and particulate components, as well as refractory proportions that are not readily decomposed and labile proportions that are more easily broken down into bioavailable nutrients. The life cycle processes of algae breaking down into detritus, and detritus breaking down into inorganic nutrients, then these nutrients being taken up again into new living organisms are guided in the model by remineralization rates. These rates will be different in a more nutrient-poor environment, like the target condition for LBR, than in a nutrient-rich environment.

Table 22 provides the remineralization rates used for the target condition. These rates are similar to a standard remineralization library included in the most recent technical documentation for “AQUATOX release 3.1 Plus”.

Table 22. Remineralization rates for the target condition.

Mesotrophic Remineralization		
Max. Degrdn. Rate, Labile	0.0159	g/g-d
Max. Degrdn. Rate, Refrac. (ColonizeMax)	0.007	g/g-d
Optimum Temperature	25	ºC
Maximum Temperature	65	ºC
Min. pH for Degradation	5	
Max. pH for Degradation	8.5	
Knitri, Max Rate of Nitrif.	0.02	1/day
Kdenitrification (max rate denitrification)	0.09	1/day
P to Organics, Labile	0.018	frac. dry
N to Organics, Labile	0.079	frac. dry
P to Organics, Refractory	0.0002	frac. dry
N to Organics, Refractory	0.002	frac. dry
P to Org., Dissolved Labile	0.0002	frac. dry
N to Org., Dissolved Labile	0.002	frac. dry
P to Org., Dissolved Refr.	0.0002	frac. dry
N to Org., Dissolved Refr.	0.002	frac. dry
O2: Biomass, Respiration, Decomposition	0.575	ratio

O2: N, Nitrification	4.57	ratio
Detrital Sed. Rate (Ksed)	0.15	m/d
Temperature of Obs. Ksed	20	ºC
Salinity of Obs. Ksed	0	‰
Wet to Dry, Susp. Labile	5	ratio
Wet to Dry, Susp. Refr.	5	ratio
Wet to Dry, Sed. Labile	5	ratio
Wet to Dry, Sed. Refr.	5	ratio
KD, Partition Coefficient, P to CaCO3	300	L/kg

These remineralization rates only apply where suspended and dissolved detritus is loaded to a segment of the model. For instance, organic matter for a wastewater treatment facility is represented by CBOD input to the model. However, mainstem river and tributary segments are represented by suspended and dissolved detrital loads. Therefore, these new remineralization rates apply only to the mainstem river and tributary segments.

Particulate and refractory detritus proportions also change in moving from a nutrient-rich to a nutrient-poor condition. To simulate the target scenario, the suspended and dissolved detritus is set to 10% particulate and 60% refractory, based on literature values for oligotrophic systems (AQUATOX Release 3.1 Plus technical documentation page 144) and the initial condition concentration for Model Segment 1.

4.2 Results

Through consultation with the Lower Boise Watershed Council, EPA and other interested parties, DEQ ultimately narrowed down the following TP reduction scenarios:

1. Existing Conditions (the calibrated model)
2. Scenario 1 + a 0.23 foot depth increase in model segment 10 (Hwy 20-26 Bridge to Notus Bridge)
3. ***Final Model Scenario*** – Point sources at 0.1 mg/L TP May – September and 0.35 mg/L TP October – April; tributaries and groundwater at 0.07 mg/L TP year-round; stormwater wet weather TP loads reduced by 42%
4. Scenario 2 + a 0.23 foot depth increase in model segment 10
5. Point sources, tributaries, and groundwater at 0.07 mg/L TP year-round; stormwater wet weather TP loads reduced by 42%
6. Scenario 3 +a 0.23 foot depth increase in model segment 10
7. Point sources at 0.05 mg/L TP year-round (approximate limits of technology); tributaries and groundwater at 0.07 mg/L TP year-round; stormwater wet weather TP loads reduced by 42%

Even though nutrient loading is easier to control, DEQ also investigated physical parameters that affect overall organic enrichment. Throughout testing of the scenarios, model segment

10 showed the most persistent exceedances, and increasing depth in this segment showed a benefit in reducing periphyton growth. The simulated depth increase represents a 5 meter (16 foot) narrowing of the channel that creates a 0.07 meter (0.23 foot) increase in depth through the 8.32 mile length of model segment 10.

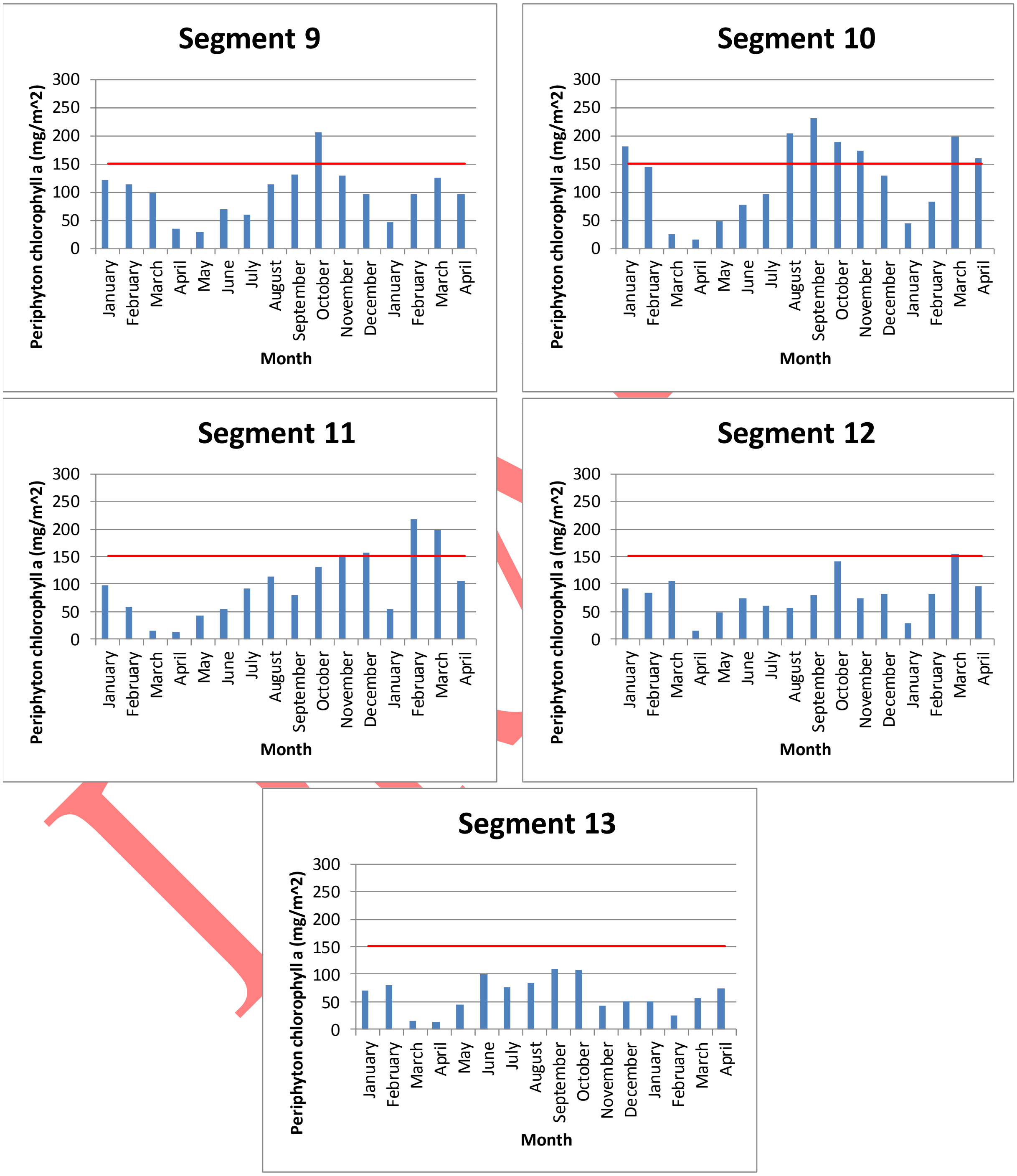


Figure 87. Scenario 1: Existing conditions with exceedances in model segments 9, 10, 11, and 12. Annual average periphyton 101 mg/m^2 for all 5 model segments.

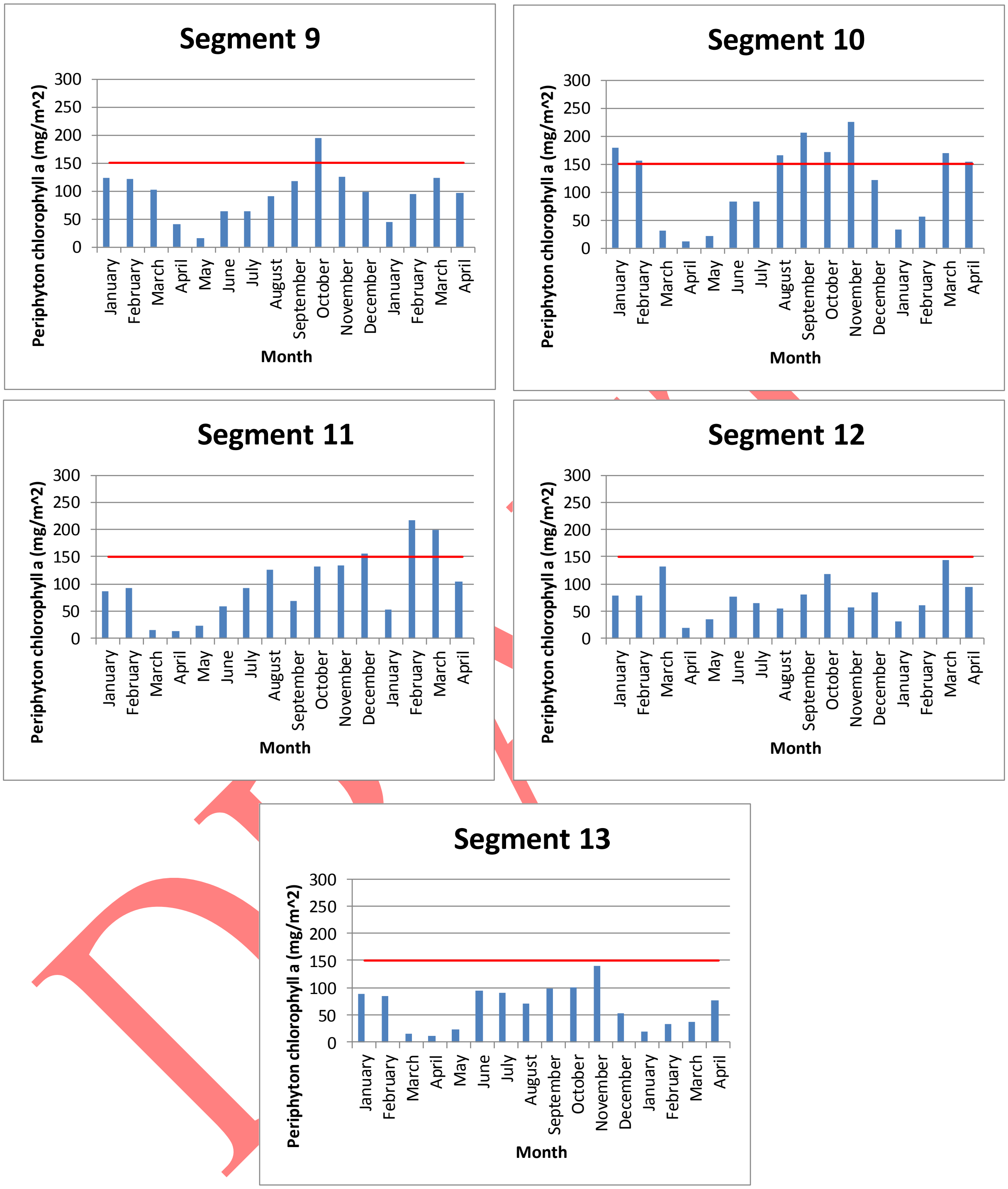


Figure 88. Scenario 2: Existing conditions added depth in Segment 10 with exceedances in segments 9, 10, and 11. Annual average periphyton 99 mg/m^2 for all 5 model segments.

In these model segments, the difference between existing conditions and adding a minor depth increase in segment 10 is that the periphyton chlorophyll a biomass decreases 2 mg/m^2 in these 5 modeled reach overall.

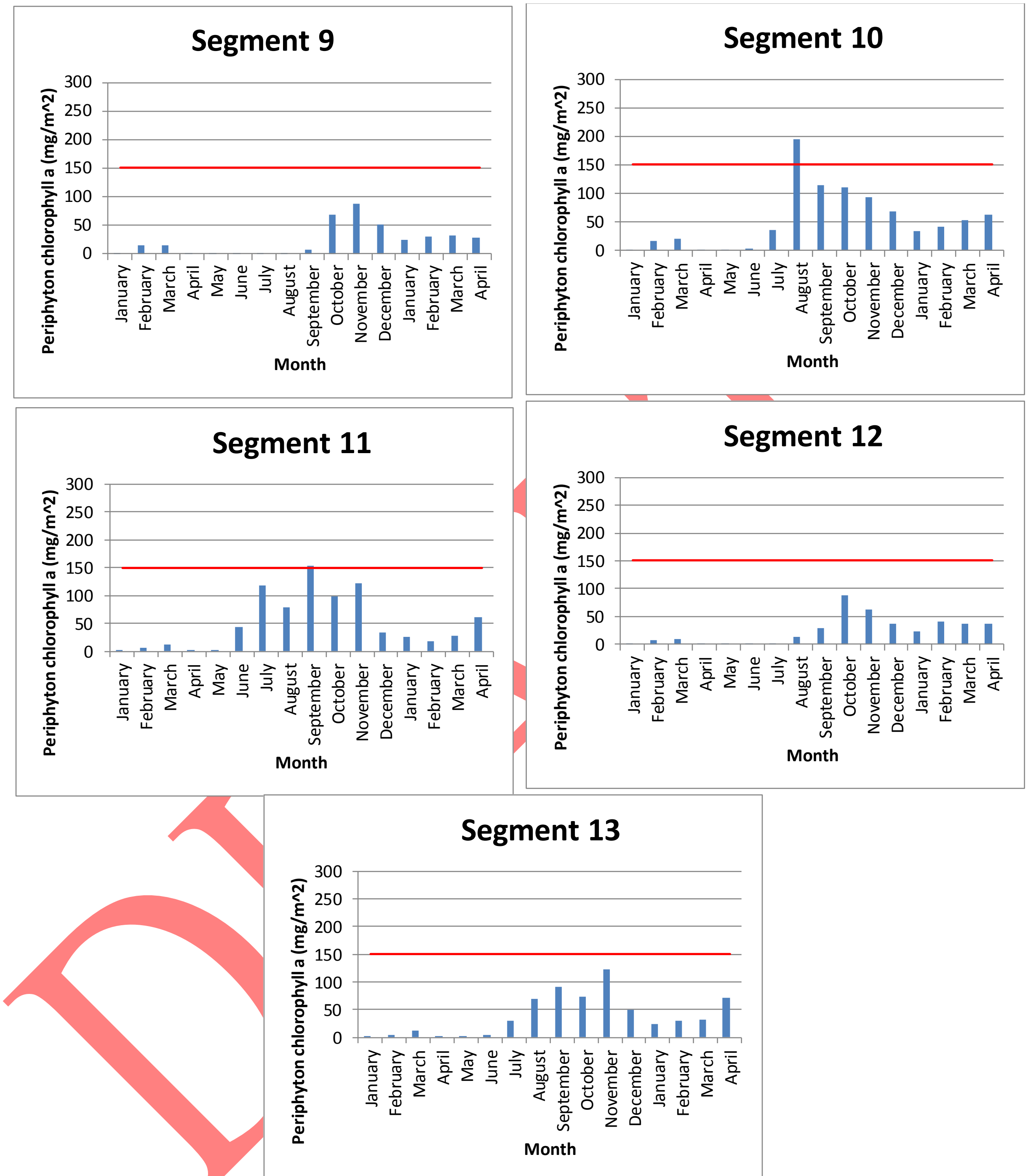


Figure 89. Scenario 3: Point source TP 0.1 mg/L summer and 0.35 mg/L winter; tributary and groundwater TP 0.07 mg/L—exceedances average 196 mg/m^2 in August in Segment 10 and 153 mg/m^2 in September in Segment 11. Annual average 47 mg/m^2 for all 5 model segments.

This reduction scenario still exhibits exceedances in segments 10 and 11, but shows a great reduction in overall periphyton growth. When the model output is examined, the remaining exceedances in these segments represent a shift in overall periphyton population toward emphasizing low-nutrient diatoms.

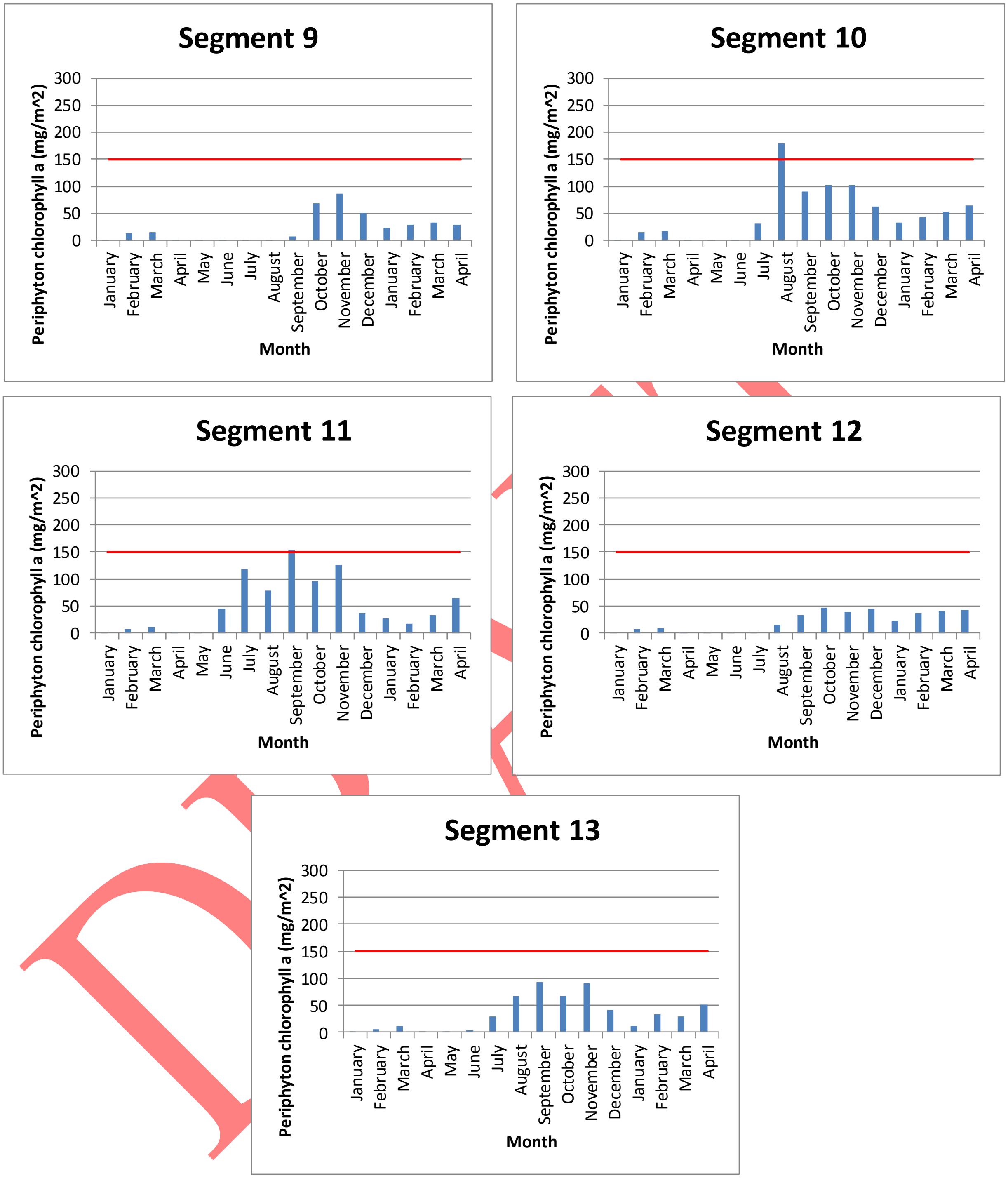


Figure 90. Scenario 4: Point source TP 0.1 mg/L summer and 0.35 mg/L winter; tributary and groundwater TP 0.07 mg/L with added depth in segment 10—exceedances average 180 mg/m^2 in August in Segment 10 and 155 mg/m^2 in September in Segment 11. Annual average 44 mg/m^2 for all 5 model segments.

Adding depth to model segment 10 makes an improvement to the August average periphyton chlorophyll a biomass from 196 mg/m^2 to 180 mg/m^2, a 9% reduction.

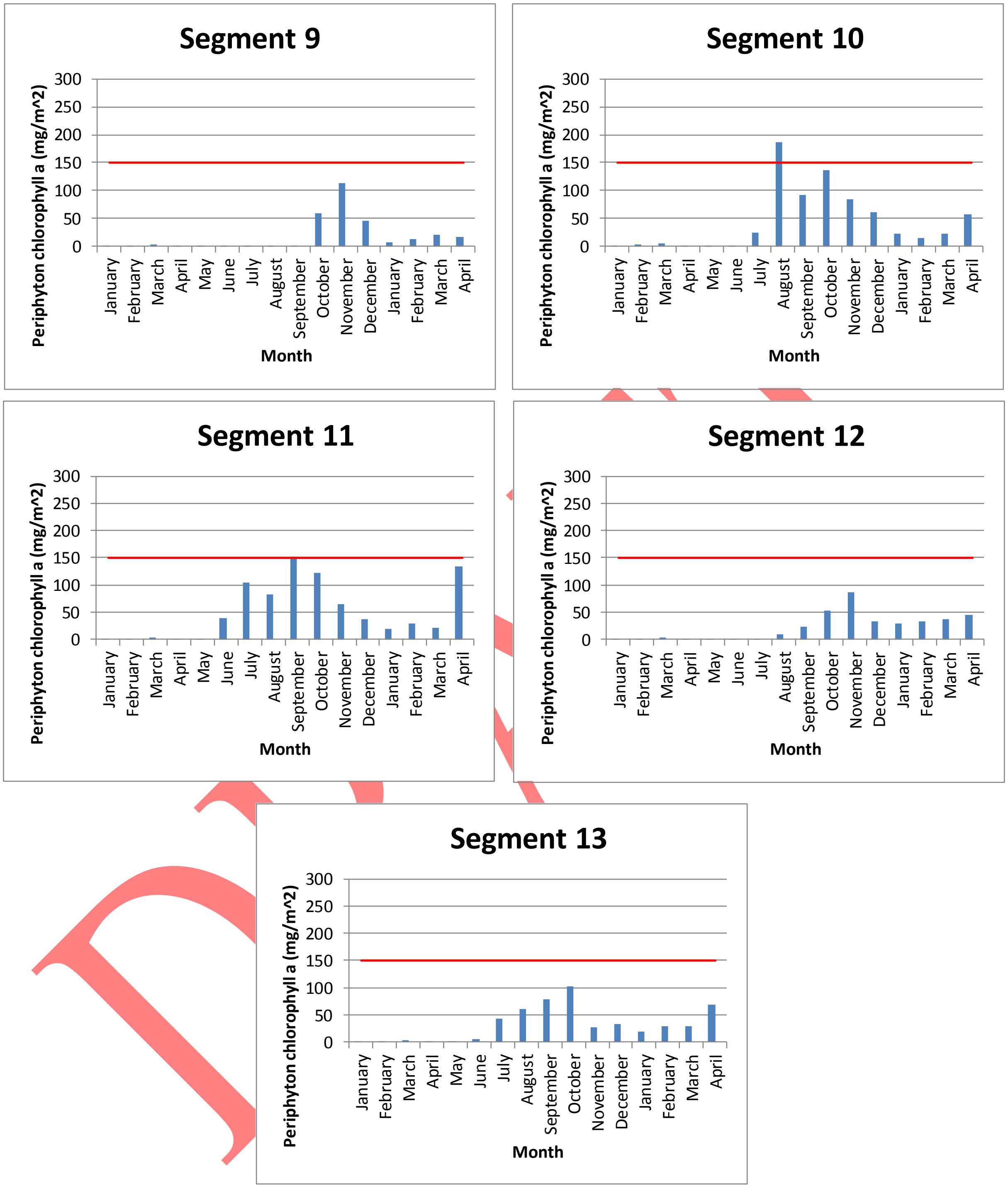


Figure 91. Scenario 5: TP 0.07 mg/L all point sources, tributaries, and groundwater year-round—exceedances average 185 mg/m^2 in August in Segment 10 and 153 mg/m^2 in September in Segment 11. Annual average 42 mg/m^2 for all 5 model segments.

Even if all sources are set at 0.07 mg/L TP, there are still some exceedances. This is because there is a shift toward the low-nutrient diatom population as available phosphorus decreases.

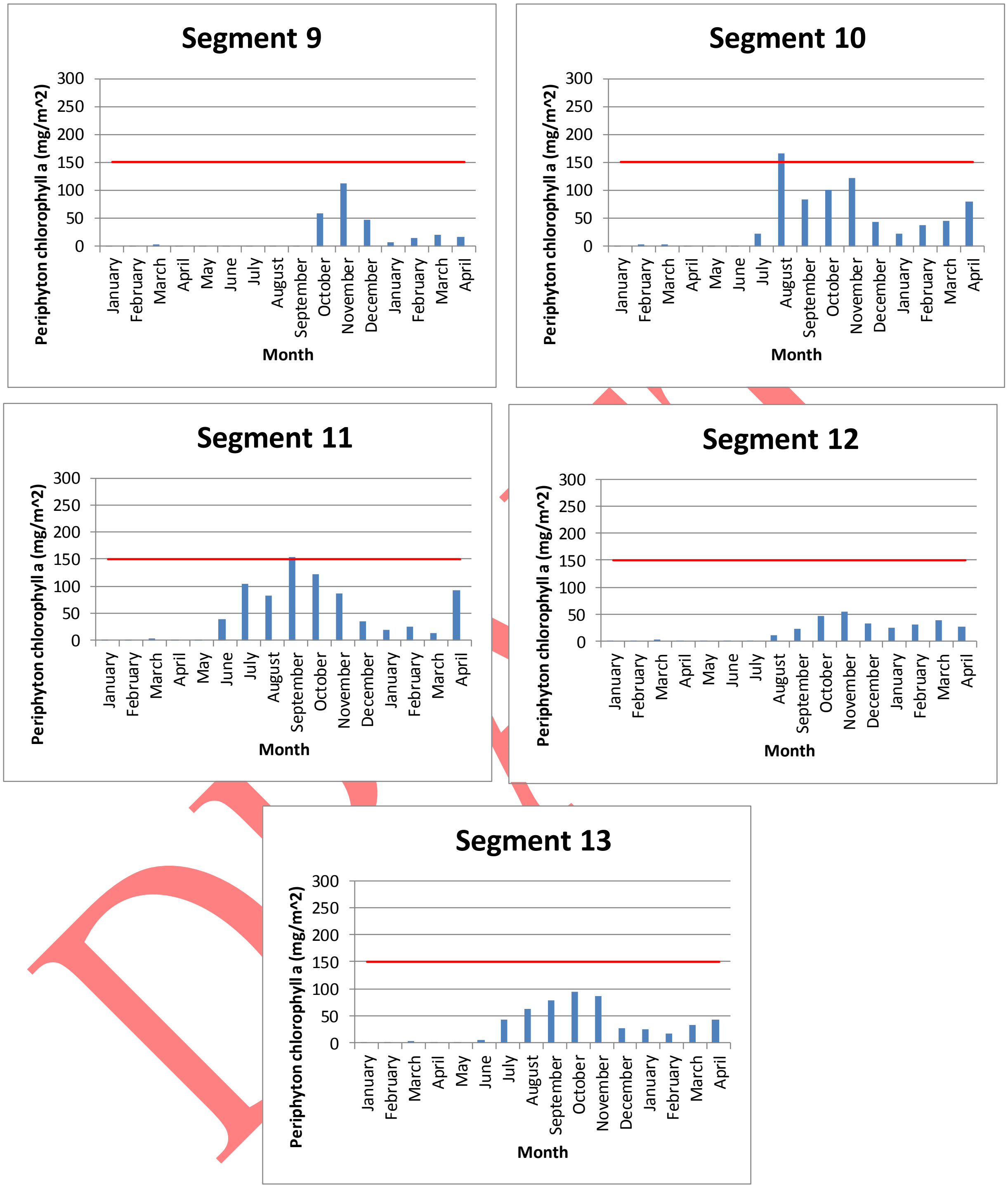


Figure 92. Scenario 6: TP 0.07 mg/L all point sources, tributaries, and groundwater year-round with added depth in Segment 10-- exceedances average 166 mg/m^2 in August in Segment 10 and 154 mg/m^2 in September in Segment 11. Annual average 42 mg/m^2 for all 5 model segments.

The localized habitat improvement reduces the August biomass in Segment 10 from 185 mg/m^2 to 166 mg/m^2, an 11% reduction.

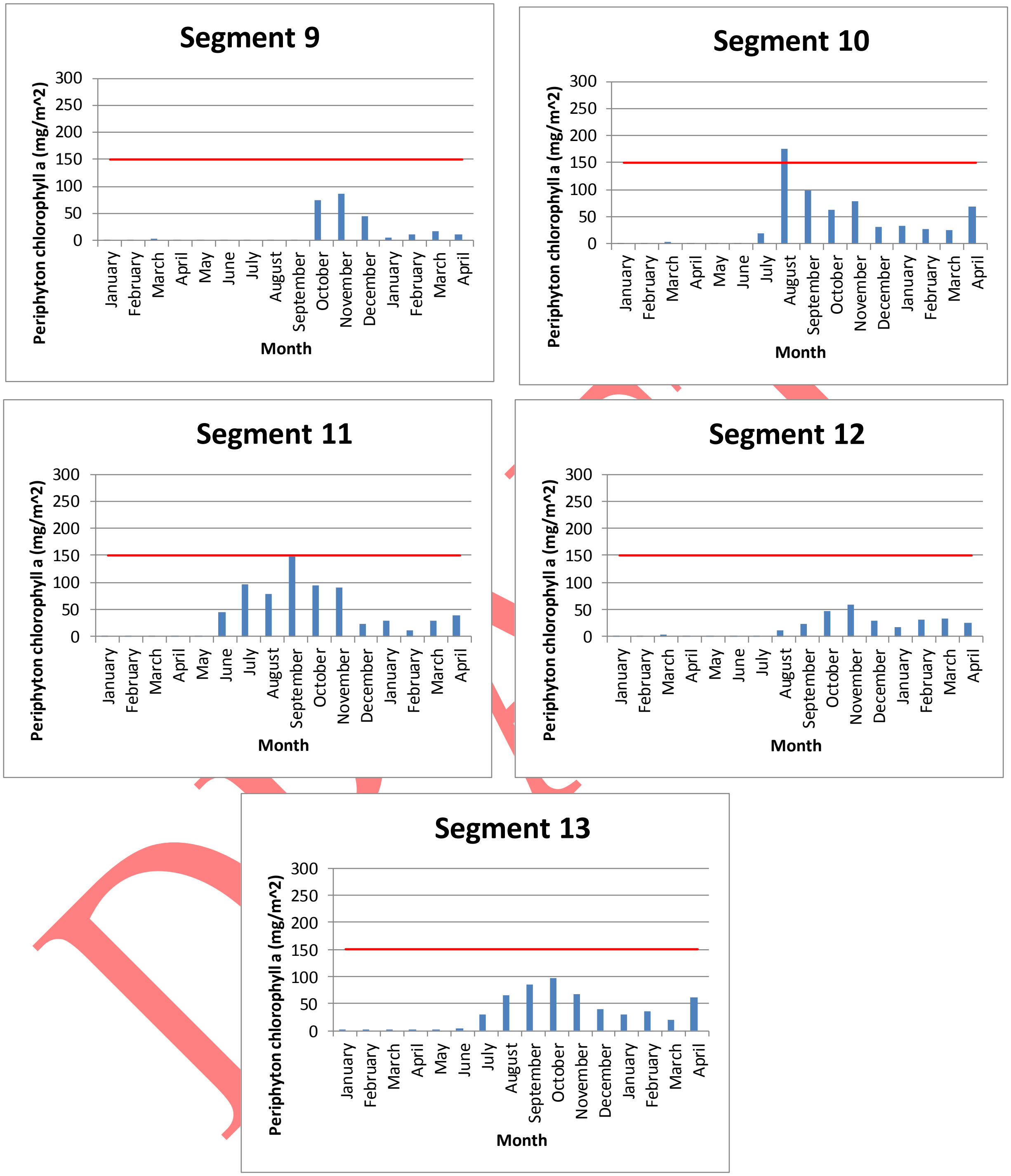


Figure 93. Scenario 7: TP 0.05 mg/L point sources and .07 mg/L tributaries and groundwater year-round--exceedances average 176 mg/m^2 in August in Segment 10. Annual average 31 mg/m^2 for all 5 model segments.

Even if the point sources are given a target at the extent of technological achievement at 0.05 mg/L TP, periphyton exceedances are still predicted for model segment 10. A summary of annual average periphyton chlorophyll a for all 7 scenarios, shown in Figure 94, shows a point of diminishing returns after the initial reduction scenario.

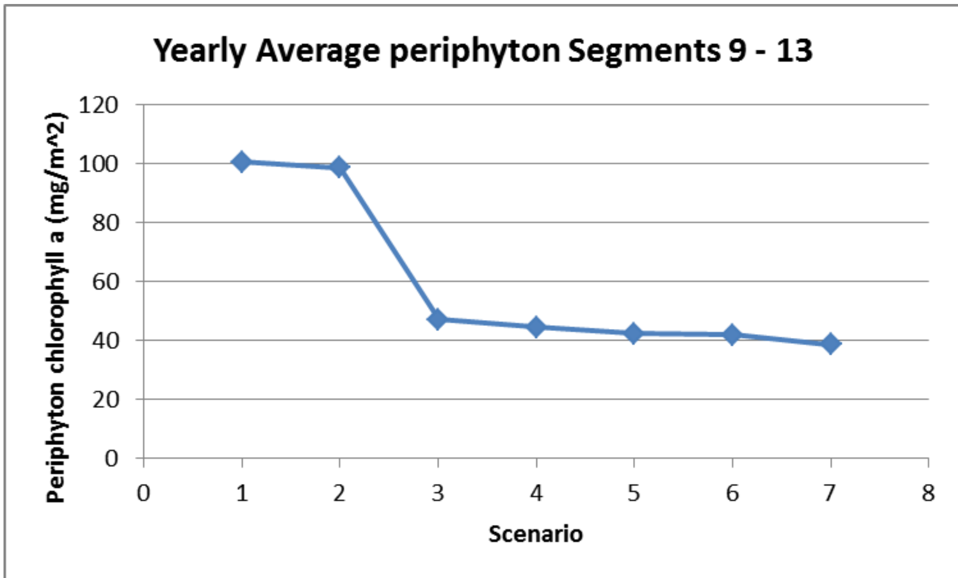


Figure 94. Summary of annual average periphyton for existing conditions in scenarios 1 and 2 and phosphorus reductions in scenarios 3 through 7.

The predicted annual average periphyton for Scenario 3, with point sources at TP 0.10 mg/L in the summer and 0.35 mg/L in the winter is 47 mg/m^2, and for Scenario 7, with point sources at the technological limit of phosphorus removal, it is 39 mg/m^2. This is a small net gain in environmental benefit for a large investment.

Results for the model scenarios described above are reported on a basis of model segments. If the results for the first reduction scenario—Scenario 3—are averaged for the listed assessment units, there are no exceedances of the periphyton target calculated on a monthly basis. The listed assessment units do not line up exactly with the model segments, but ID17050114SW005_06b, Boise River – Middleton to Indian Creek, equals a weighted average of model segments 9 and 10. ID17050114SW001_06, Boise River – Indian Creek to mouth, equals a weighted average of model segments 10 through 13 distributed in this manner:

- AU 005_6b is 5.49 miles (3.95 in Seg 9 - 71.9%; 1.54 in Seg 10 - 28.1%)
- AU 001_06 is 18.64 miles (6.78 in Seg 10 - 36.4%; All Seg 11 - 27.1%; All Seg 12 - 9.8%; All Seg 13 - 26.7%)

Figure 95 and Figure 96 show the predicted periphyton results for the indicated reduction scenario.

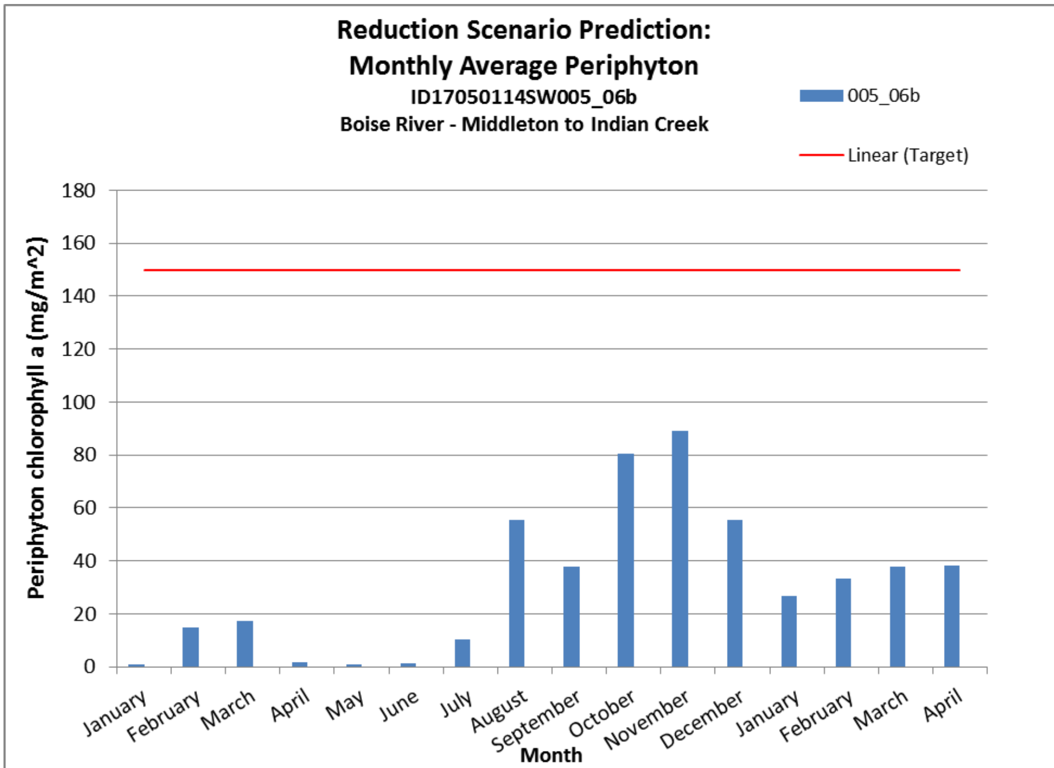


Figure 95. Predicted periphyton in ID17050114SW005_06b.

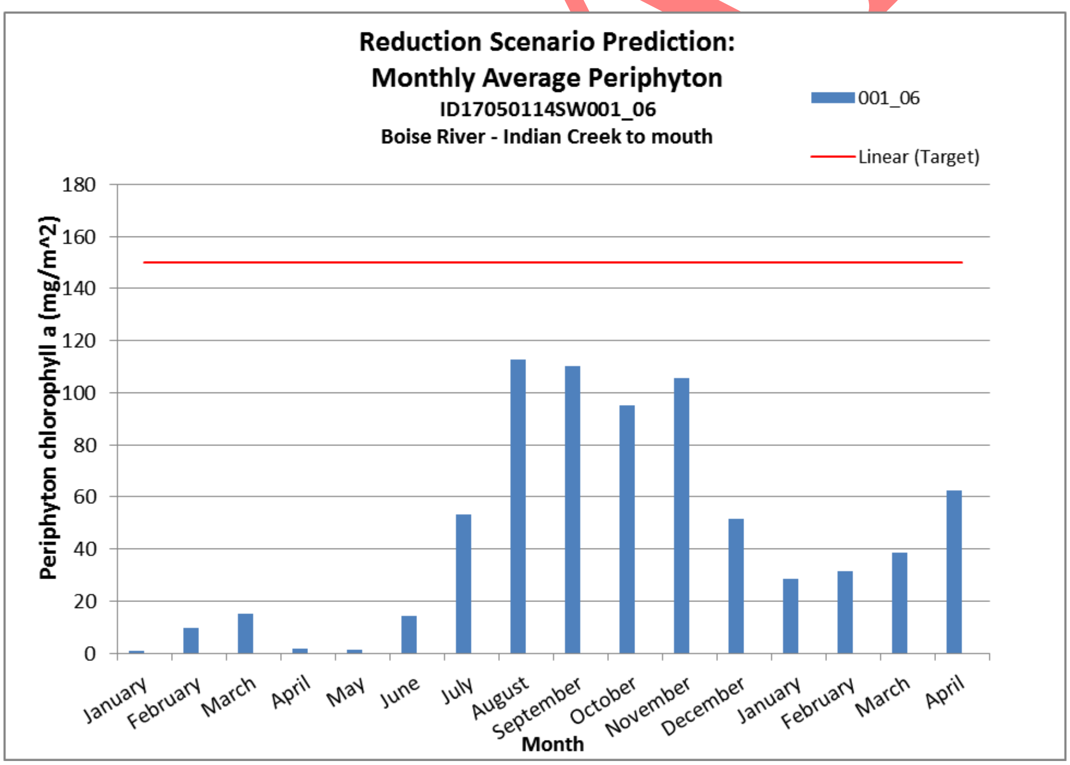


Figure 96. Predicted periphyton in ID17050114SW001_06.

Although there is no specific phosphorus target in the Boise River outside of the May-September timeframe, a TP target of 0.10 mg/L can be suggested to meet many beneficial uses. Model output for TP averaged for each month are shown in Figure 97 and Figure 98.

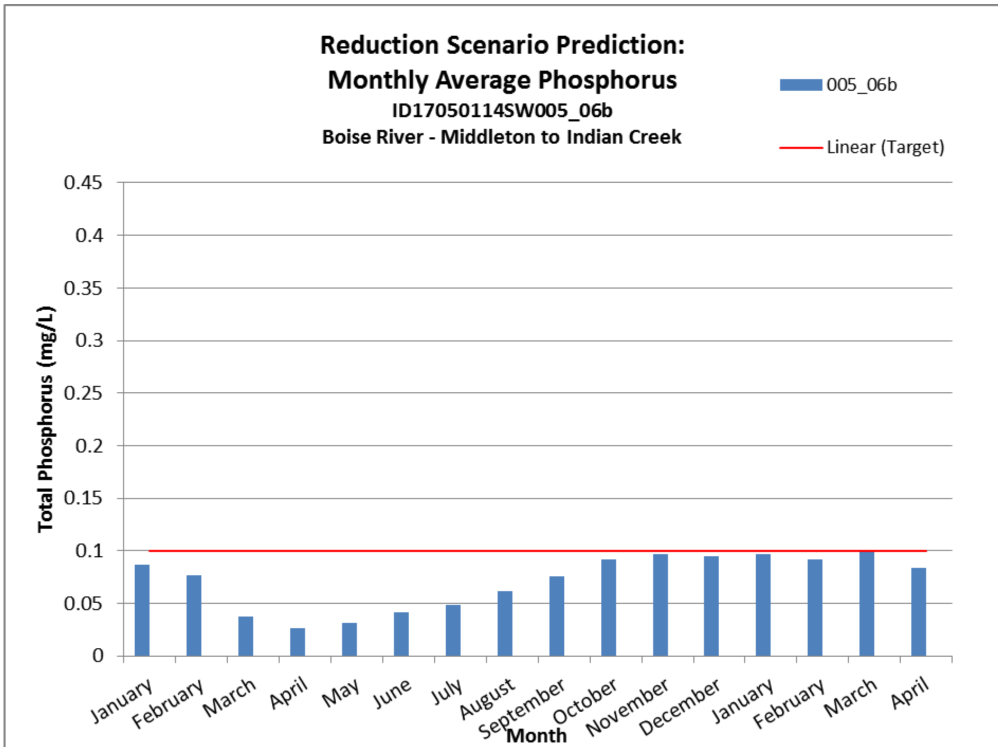


Figure 97. Predicted total phosphorus in ID17050114SW005_06b.

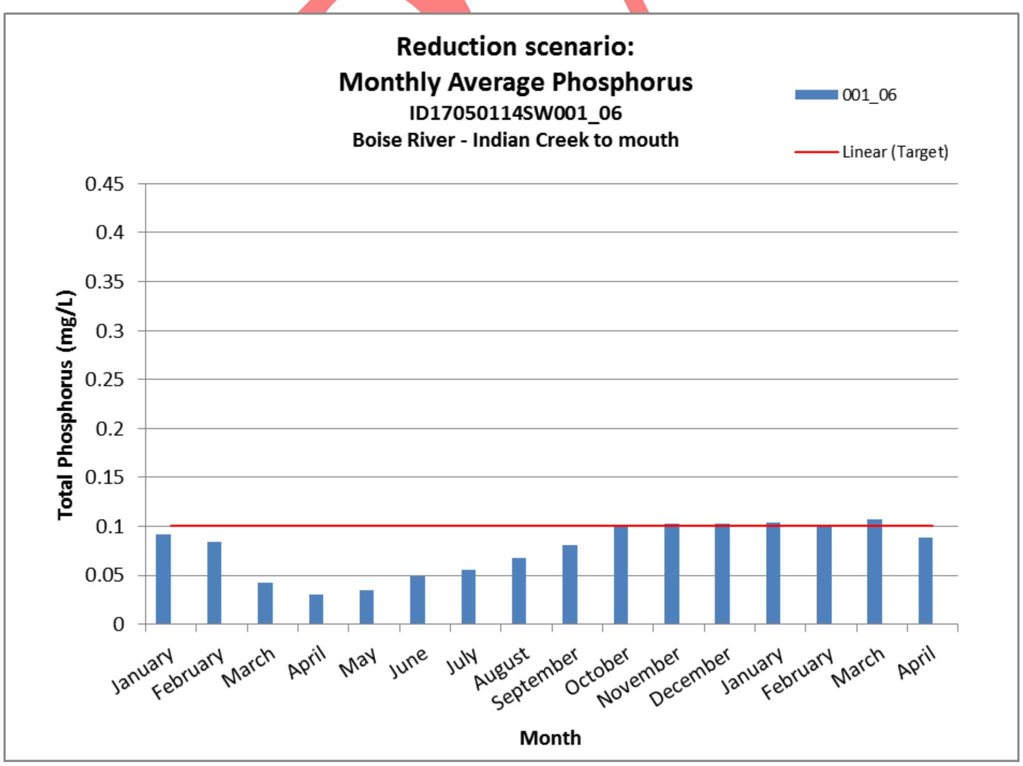


Figure 98. Predicted total phosphorus in ID17050114SW001_06.

In the above model results, the average TP concentration for May through September is 0.05 mg/L for AU 005_06b and 0.06 mg/L for AU 001_06. This allows for a margin of safety to meet the 0.07 mg/L target at the mouth of the Boise River. Existing conditions for the model period averaged according to assessment unit are provided in Figures 99 – 102 for comparison to the reduction scenario.

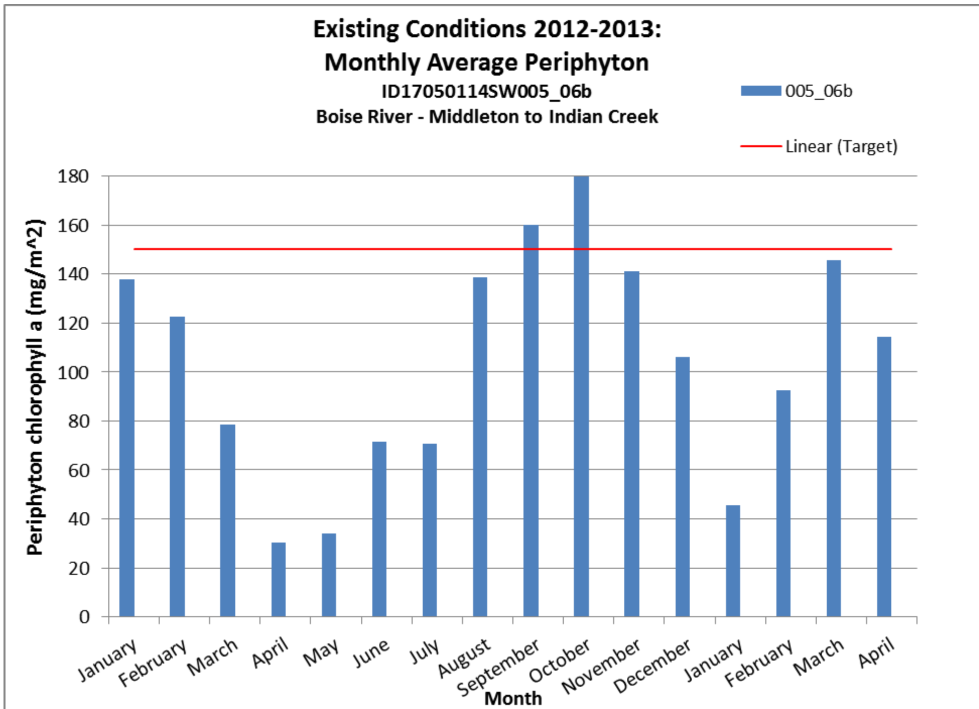


Figure 99. Existing conditions for periphyton for ID17050114SW005_06b.

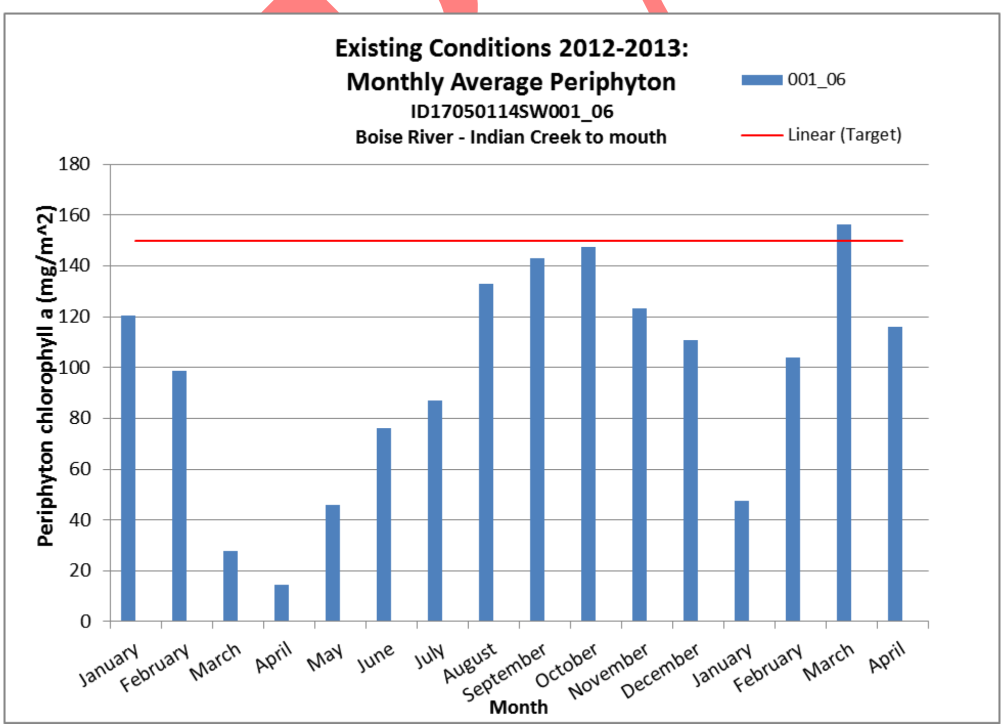


Figure 100. Existing conditions for periphyton for ID17050114SW001_06.

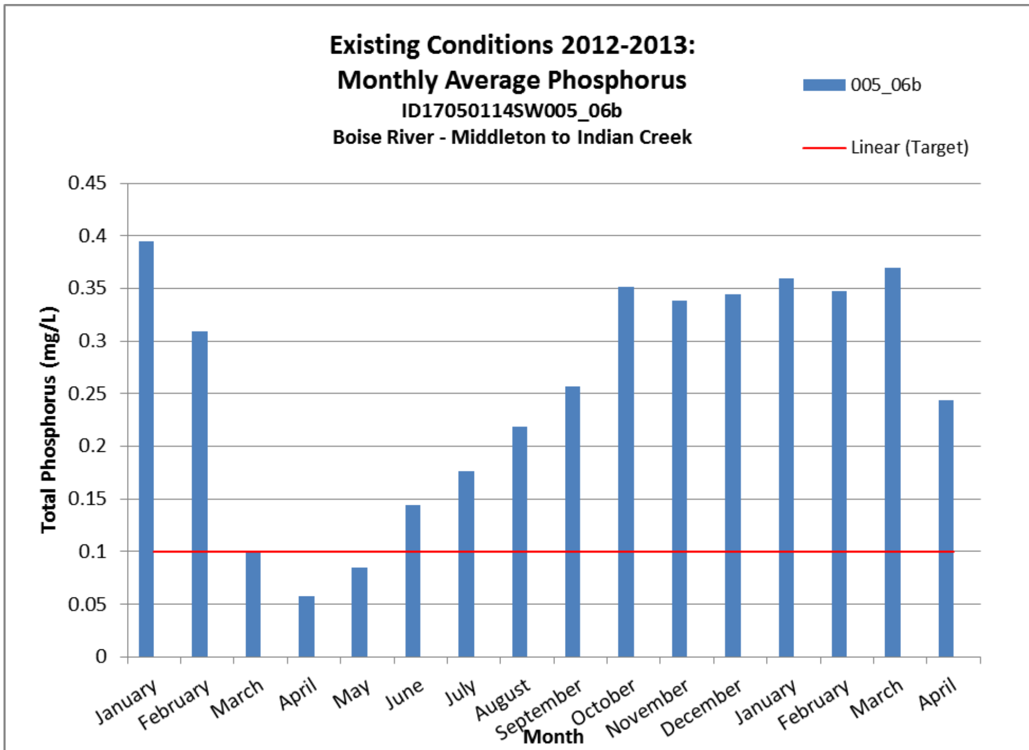


Figure 101. Existing conditions for total phosphorus for ID17050114SW005_06b.

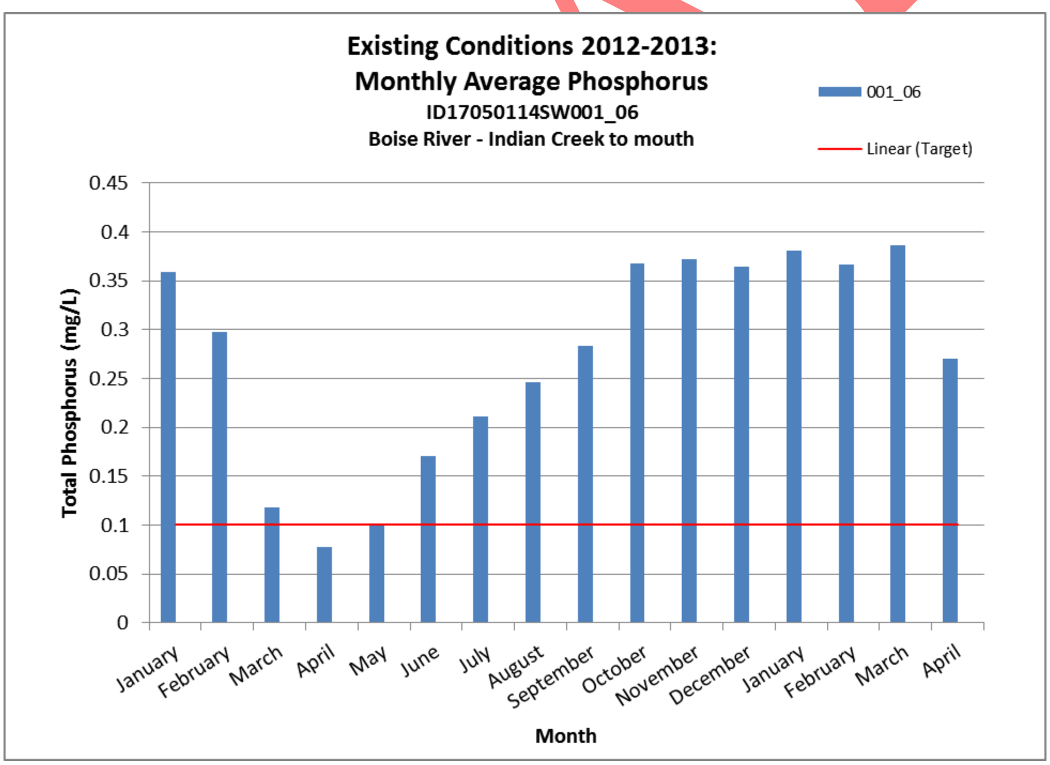


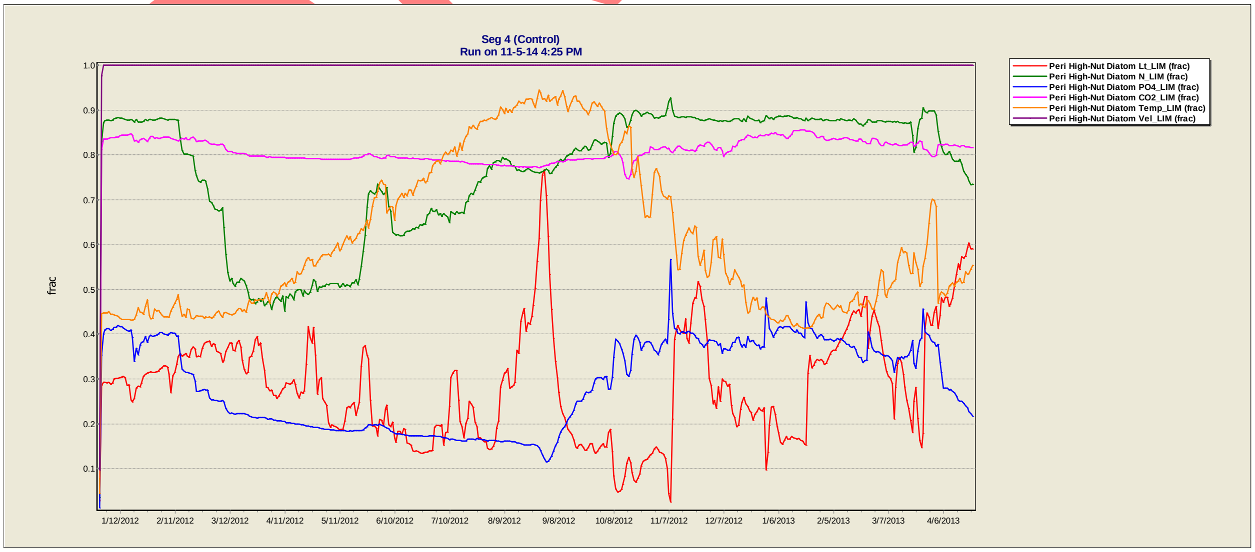
Figure 102. Existing conditions for total phosphorus for ID17050114SW001_06.

Examination of the difference between the existing and reduction scenarios for shows that a relatively large phosphorus reduction is necessary to result in a relatively smaller periphyton reduction. Existing phosphorus averages 0.28 mg/L annually for the two listed AUs, whereas the average annual total phosphorus for the reduction scenario equals 0.08 mg/L. This equals a 71% reduction in phosphorus year-round. Existing periphyton averages 101 mg/m^2 annually for the two listed AUs, whereas the annual average is 47 mg/m^2 for the reduction scenario. This equals a 53% reduction.

4.3 Discussion

Periphytic algal groups compete for resources such as substrate to occupy, nutrients for growth, and light for photosynthesis. Each of the periphyton groups in the model—high-nutrient diatoms, low-nutrient diatoms, green algae, *Cladophora*, and blue-green algae—have different adaptations. For instance, the blue-green algal species are more tolerant to cold water temperatures. High-nutrient diatoms prefer higher levels of phosphorus, but low-nutrient diatoms are adapted to lower levels of phosphorus. The predominant low-nutrient diatoms in the Boise River are in the genus *Fragilaria*, which are common in the upstream reaches from Diversion Dam through to Veteran's Parkway (Rushforth 2007b). This coincides with model segments 1, 2, and 3. High-nutrient diatoms, such as *Cyclotella*, are abundant throughout the entire river, and all model segments 1 through 13.

Limitations to periphyton growth occur when habitat becomes less available or nutrients become scarcer. Current conditions in the Boise River provide abundant nutrients that result in luxuriant overgrowth of periphyton to a perceived nuisance level. As nutrient input is reduced, there should be increased limitations on periphyton growth. The AQUATOX model can calculate habitat and nutrient limitations for each day and segment of the model simulation. Figure 103 shows an example of limitation calculations from one nutrient reduction scenario in the Glenwood river reach. The y-axis is fraction of limitation, with 1.0 being not at all limited by this factor and 0.1 being very limited by this factor. This nutrient reduction scenario shows how high-nutrient diatoms have become more limited for phosphorus—the blue line in the graphs—but low-nutrient diatoms are not at all limited by phosphorus. Note that for both algal groups, light—the red line near to the x-axis—is the most limiting factor.



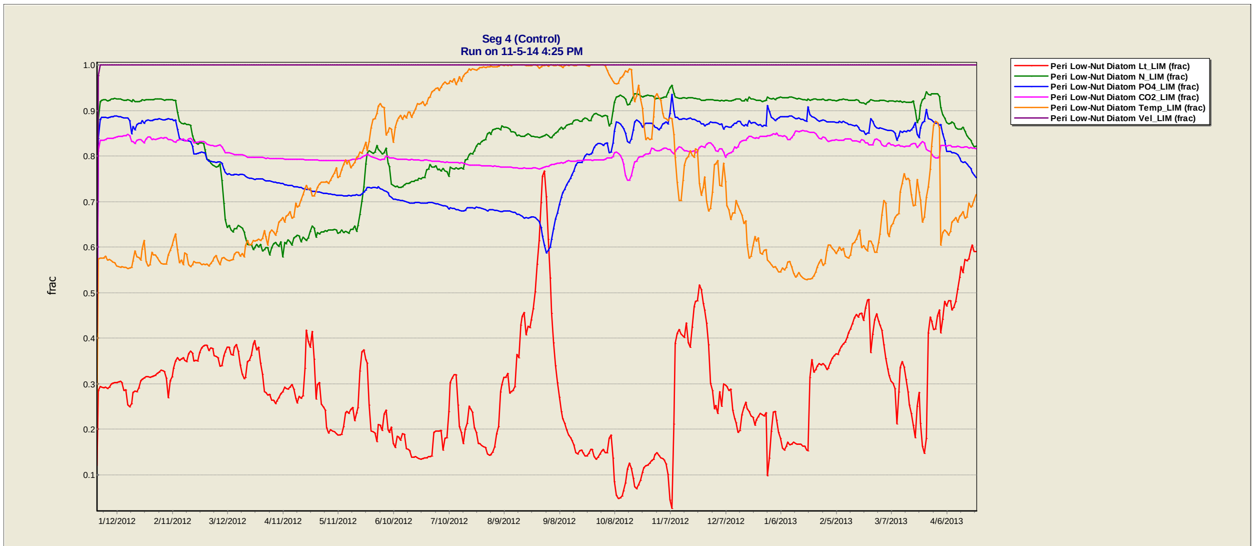


Figure 103. Nutrient, temperature, and light limitations for high- and low-nutrient diatoms in the nutrient reduction scenario.

From these nutrient limitation graphs, it is evident that there should be more low-nutrient than high-nutrient diatoms in this scenario, as is shown by Figure 104 showing the presence of the algal groups in this scenario. The yellow line represents low-nutrient diatoms, which are about 7 times more abundant than high-nutrient diatoms in this scenario.

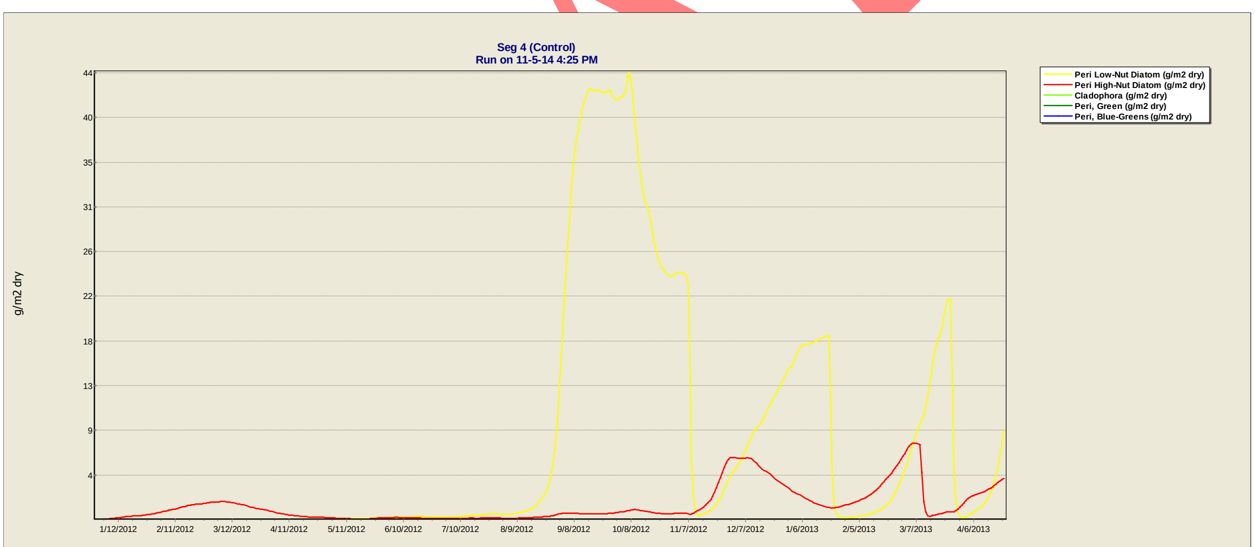


Figure 104. Presence of periphyton groups in the nutrient reduction scenario.

Low-nutrient diatoms can proliferate in conditions with lower phosphorus concentrations. In all of the modeled nutrient reduction scenarios described in the previous section, the low-nutrient diatoms cause the exceedances.

Throughout many iterations of model runs, it is always shown that light is the most limiting factor to periphyton growth. Therefore, it is not surprising that relatively minor habitat changes that affect light penetration to the substrate of the river have an impact on periphyton growth. As a minimal habitat change, DEQ simulated an increase in depth for Segment 10 (from Hwy 20-26 Bridge near Caldwell to the Notus Bridge), which is the model segment where the Caldwell

WWTP and Indian Creek enter the river. For a model simulation where the channel width is narrowed five meters, this increases the average depth for the model simulation period for this 8-mile reach a little less than three inches. With this minor increase in depth, the average annual periphyton chlorophyll load decreased from 55.3 mg/m^2 to 50.8 mg/m^2, an 8% decrease in periphyton. It should be noted that for every scenario, the benefit of increased depth is localized—that is, a depth increase benefits the local habitat but does not translate to a benefit downstream.

An artificially high width-to-depth ratio for freshwater streams is a known sign of impairment (Rosgen 1996). Common habitat improvement designs for restoring impaired streams include adding habitat complexity and decreasing the width-to-depth ratio of stream channels.

4.4 Conclusions and Recommendations

The conclusions of this modeling study of the relationship between TP and periphyton are that:

- Phosphorus reductions must be accompanied by associated nitrogen and carbon reductions to be effective at reduction of total periphyton biomass
- Periphyton is a complex community of algal groups and organic detritus that will respond to nutrient reductions and changes in physical parameters in a species-specific way
- When the TP reductions are fully implemented, there will be episodes when the 30-day average periphyton biomass exceeds the 150 mg/m^2 target in localized regions of the river, but averaging biomass over the listed assessment units will meet the target
- Implementing TP reductions for both point and nonpoint sources will have an environmental benefit for reduction of excess algal growth throughout the lower Boise River
- Changes in riparian habitat and channel geometry that decrease the width-to-depth ratio of the river, thus increasing depth of the water column, are beneficial for reducing light to the substrate and as a result help reduce and control excess periphyton growth
- Increasing channel depth has a localized habitat benefit and cannot be translated downstream
- For the reduction scenario, the average TP concentration for May through September is 0.05 mg/L for AU 005_06b and 0.06 mg/L for AU 001_06, which meet the 0.07 mg/L target at the mouth of the Boise River

AQUATOX is a valuable tool for modeling the periphyton groups that make up the total periphyton chlorophyll a (mg/m^2) biomass. It is highly recommended that this model continue to be used in watershed management applications and implementation of the phosphorus TMDL.

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Appendix A. Model Calibration Data and Figures

Water quality data used for the model calibration period from January 1, 2012, through April 22, 2013.

Model Segment or Source	Parameter and No. of Data Points Used in Model	Data Source
1	$NO_{2,3}$ = 3 $NH_{3,4}$ = 3 TP = 3 TSP = 3 O_2 = 3 pH = 3 Velocity = 3 Peri Chl a = 3 Phyto Chl a = 2	NWIS data at USGS Station 13203510 (Boise River below Diversion Dam)
	TSS = 16	Monthly historical mean values for NWIS data
	Water Temperature = 331	City of Boise data at Marden Bridge (320 measured and 11 interpolated data points)
2	$NH_{3,4}$ = 3 $NO_{2,3}$ = 3 TSP = 3 TP = 3 Velocity = 2	NWIS data at USGS Station 13205642 (Boise River at Veterans Memorial Parkway)

	BOD = 14 $NH_{3,4}$ = 37 $NO_{2,3}$ = 8 TSP = 35 TP = 66	City of Boise data at Veteran's Parkway Bridge
	pH = 3	NWIS data at USGS Station 13203510 (Boise River below Diversion Dam)[1]
	TSS = 16	Monthly historical mean values for NWIS data
	Water Temperature = 331	City of Boise data at Marden Bridge (320 measured and 11 interpolated data points)
3	O_2 = 31 Velocity = 2	NWIS data at USGS Station 13205642 (Boise River at Veterans Memorial Parkway)
	Peri Chl a = 3 Phyto Chl a = 3	NWIS data at USGS Station 13206000 (Boise River at Glenwood)
	$NH_{3,4}$ = 7 $NO_{2,3}$ = 7 TSP = 7 TP = 7	NWIS data at USGS Station 13206000 (Boise River at Glenwood)
	pH = 62 O_2 = 31 Water Temperature = 457	City of Boise data at Veteran's Parkway Bridge
	BOD = 14 $NH_{3,4}$ = 38 $NO_{2,3}$ = 37 TSP = 38 TP = 62	City of Boise Data at Glenwood Bridge
	TSS = 16	Monthly historical mean values for NWIS data

Lander WWTF	$NH_{3,4}$ = 113 $NO_{2,3}$ = 41 O_2 = 65 BOD = 147	City of Boise Data at Lander WWTF
	TP = 109	City of Boise Data at Lander WWTF (116 total data points before removing duplicate samples)
4	O_2 = 7 Velocity = 6 pH = 3	NWIS data at USGS Station 13206000 (Boise River at Glenwood)
	pH = 63	City of Boise and NWIS data at USGS Station 13206000 (Boise River at Glenwood)
	TSS = 16	Monthly historical mean values for NWIS data
	Water Temperature = 457 O_2 = 31	City of Boise Data at Glenwood Bridge
5	pH = 63	City of Boise and NWIS data at USGS Station 13206000 (Boise River at Glenwood)
	O_2 = 2 $NH_{3,4}$ = 3 $NO_{2,3}$ = 3 TSP = 3 TP = 3 Velocity = 3	NWIS data at USGS Station 13206300 (Boise River North Channel near Eagle)

	O_2 = 3 $NH_{3,4}$ = 3 $NO_{2,3}$ = 3 TSP = 3 TP = 3 Velocity = 3	NWIS data at USGS Station 13208600 (Boise River North Channel above Middleton Canal)
	TSS = 16	Monthly historical mean values for NWIS data
	Water Temperature = 457	City of Boise Data at Eagle Road
Eagle Drain	$NO_{2,3}$ = 11 $NH_{3,4}$ = 11 TSP = 11 O_2 = 11	NWIS data at USGS Station 13206400 (Eagle Drain)
6	pH = 63	City of Boise and NWIS data at USGS Station 13206000 (Boise River at Glenwood)[2]
	TSS = 16	Monthly historical mean values for NWIS data
	Water Temperature = 457	City of Boise Data at Eagle Road
	O_2 = 2 $NH_{3,4}$ = 3 $NO_{2,3}$ = 3 TSP = 3 TP = 3 Velocity = 2	NWIS data at USGS Station 13206305 (Boise River South Channel at Eagle)

	O_2 = 3 $NH_{3,4}$ = 3 $NO_{2,3}$ = 3 TSP = 3 TP = 3 Velocity = 3	NWIS data at USGS Station 13208300 (Boise River above Phyllis Diversion near Eagle)
	TSS = 16	Monthly historical mean values for NWIS data
	Water Temperature = 457 pH = 32 O_2 = 31 BOD = 7 TP = 65	City of Boise Data at Eagle Road[1]
West Boise WWTF	$NH_{3,4}$ = 133 $NO_{2,3}$ = 43 O_2 = 65 BOD = 146	City of Boise Data at West Boise WWTF
	TP = 70	City of Boise Data at West Boise WWTF (79 total data points before removing duplicate samples)
Thurman Drain	$NO_{2,3}$ = 3 $NH_{3,4}$ = 3 TSP = 3 O_2 = 3	NWIS data at USGS Station 13208750 (Thurman Drain at Mouth)
IDFG Eagle	$NO_{2,3}$ = 4 NH_4 = 4 TSP = 3	City of Boise Data at IDFG Eagle Fish Hatchery

8	pH = 7 $NH_{3,4}$ = 7 $NO_{2,3}$ = 7 TSP = 7 TP = 7 Peri Chl a = 3 Phyto Chla = 3	NWIS data at USGS Station 13210050 (Boise River near Middleton)
	O_2 = 2 $NH_{3,4}$ = 3 $NO_{2,3}$ = 3 TSP = 3 TP = 3 Velocity = 3	NWIS data at USGS Station 13210000 (Boise River near Star)
	TSS = 16	Monthly historical mean values for NWIS data
	Water Temperature = 417	City of Boise data at Middleton Bridge
9	pH = 7 O_2 = 6 Velocity = 8	NWIS data at USGS Station 13210050 (Boise River near Middleton)
	Velocity = 3	NWIS data at USGS Station 13210820 (Boise River at Middleton Road)
	O_2 = 3 $NH_{3,4}$ = 3 $NO_{2,3}$ = 3 TSP = 3 TP = 3 Peri Chl a = 3 Phyto Chl a = 3	NWIS data at USGS Station 13211000 (Boise River at Hwy 20-26 Xing near Caldwell)

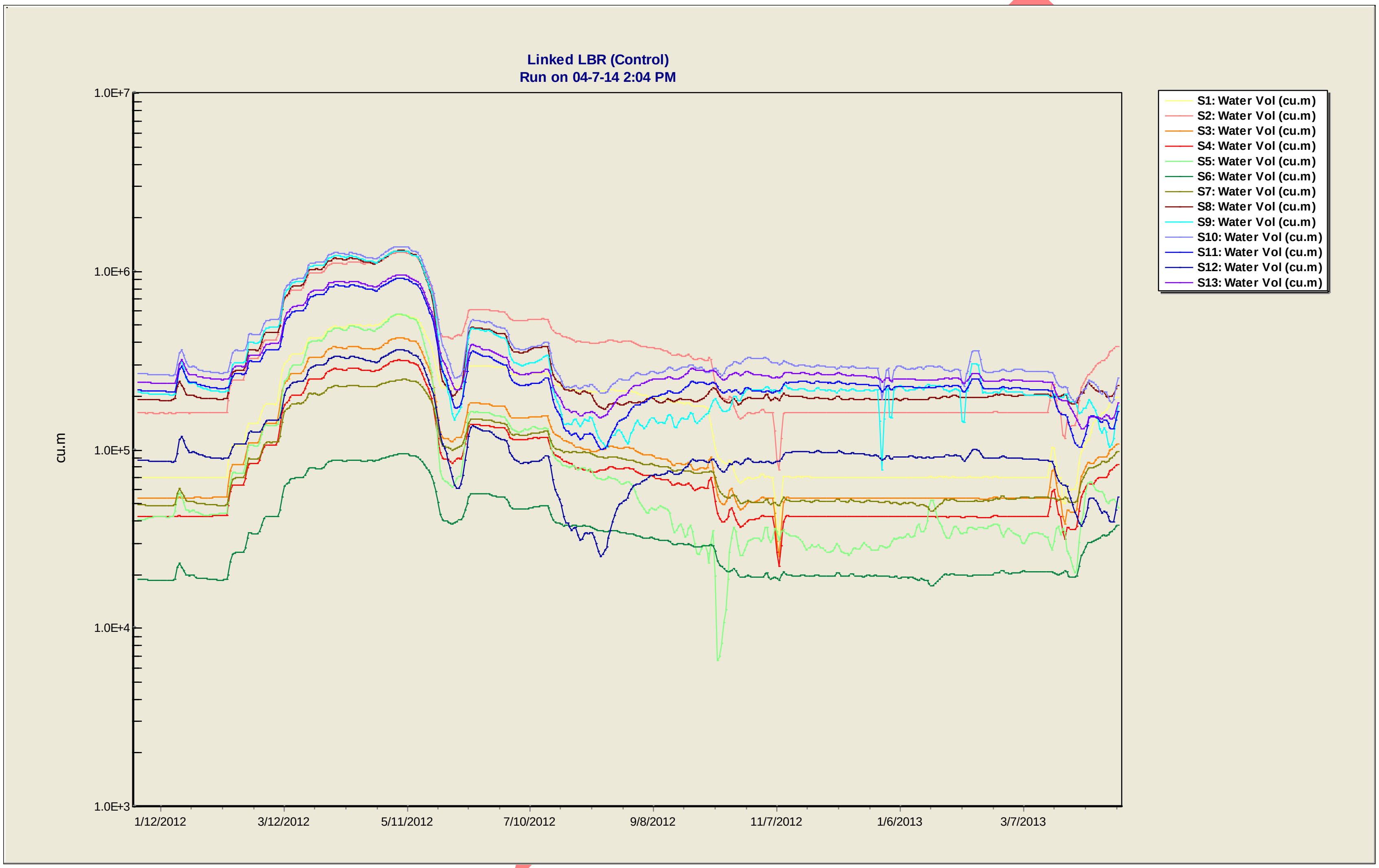
	TSS = 16	Monthly historical mean values for NWIS data
	Water Temperature = 417	City of Boise data at Middleton Bridge
Fifteenmile Creek	$NO_{2,3}$ = 3 $NH_{3,4}$ = 3 TSP = 3 O_2 = 3	NWIS data at USGS Station 13210815 (Fifteenmile Creek at Mouth)
Middleton WWTF	$NH_{3,4}$ = 16 TP = 1 O_2 = 457 BOD = 67	City of Middleton Data at Middleton WWTF
N. and S. Middleton Drains	$NO_{2,3}$ = 3 $NH_{3,4}$ = 3 TSP = 3 O_2 = 3	NWIS data at USGS Station 132108247 (Mill Slough Below Grade Ditch near Middleton)
Willow Creek	$NO_{2,3}$ = 3 $NH_{3,4}$ = 3 TSP = 3 O_2 = 3	NWIS data at USGS Station 13210835 (Willow Creek at Middleton)
Mason Creek	$NO_{2,3}$ = 6 $NH_{3,4}$ = 6 TSP = 6 O_2 = 6	NWIS data at USGS Station 13210983 (Mason Creek near Caldwell)
Hartley Drain	$NO_{2,3}$ = 3 $NH_{3,4}$ = 3 TSP = 3 O_2 = 3	NWIS data at USGS Station 13210988 (Hartley Drain near Caldwell)

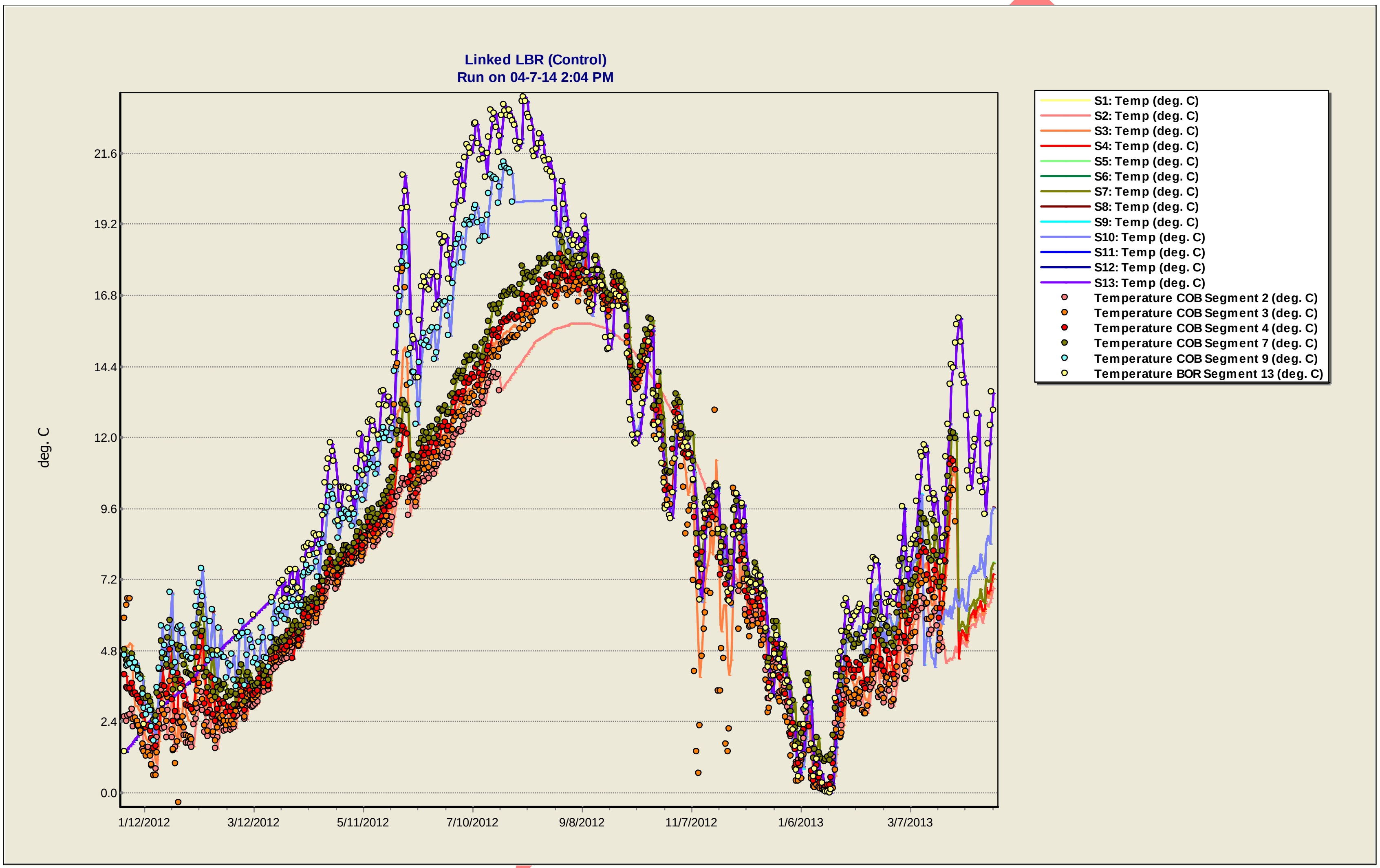
10	pH = 7	NWIS data at USGS Station 13210050 (Boise River near Middleton)
	Velocity = 3	NWIS data at USGS Station 13211000 (Boise River at Hwy 20-26 Xing near Caldwell)
	O_2 = 3 $NH_{3,4}$ = 3 $NO_{2,3}$ = 3 TSP = 3 TP = 3 Velocity = 3	NWIS data at USGS Station 13211600 (Boise River below WWTP near Caldwell)
	$NH_{3,4}$ = 3 $NO_{2,3}$ = 3 TSP = 3 TP = 3	NWIS data at USGS Station 13212500 (Boise River at Notus)
	TSS = 16	Monthly historical mean values for NWIS data
	Water Temperature = 417	City of Boise data at Middleton Bridge
Caldwell WWTF	$NH_{3,4}$ = 68 $NO_{2,3}$ = 67 TSP = 31 BOD = 135 O_2 = 45	City of Caldwell data at Caldwell WWTF
Indian Creek	$NO_{2,3}$ = 3 $NH_{3,4}$ = 3 TSP = 3 O_2 = 3	NWIS data at USGS Station 13211445 (Indian Creek at Mouth near Caldwell)
11	pH = 13	NWIS data at USGS Station 13213000 (Boise River near Parma)

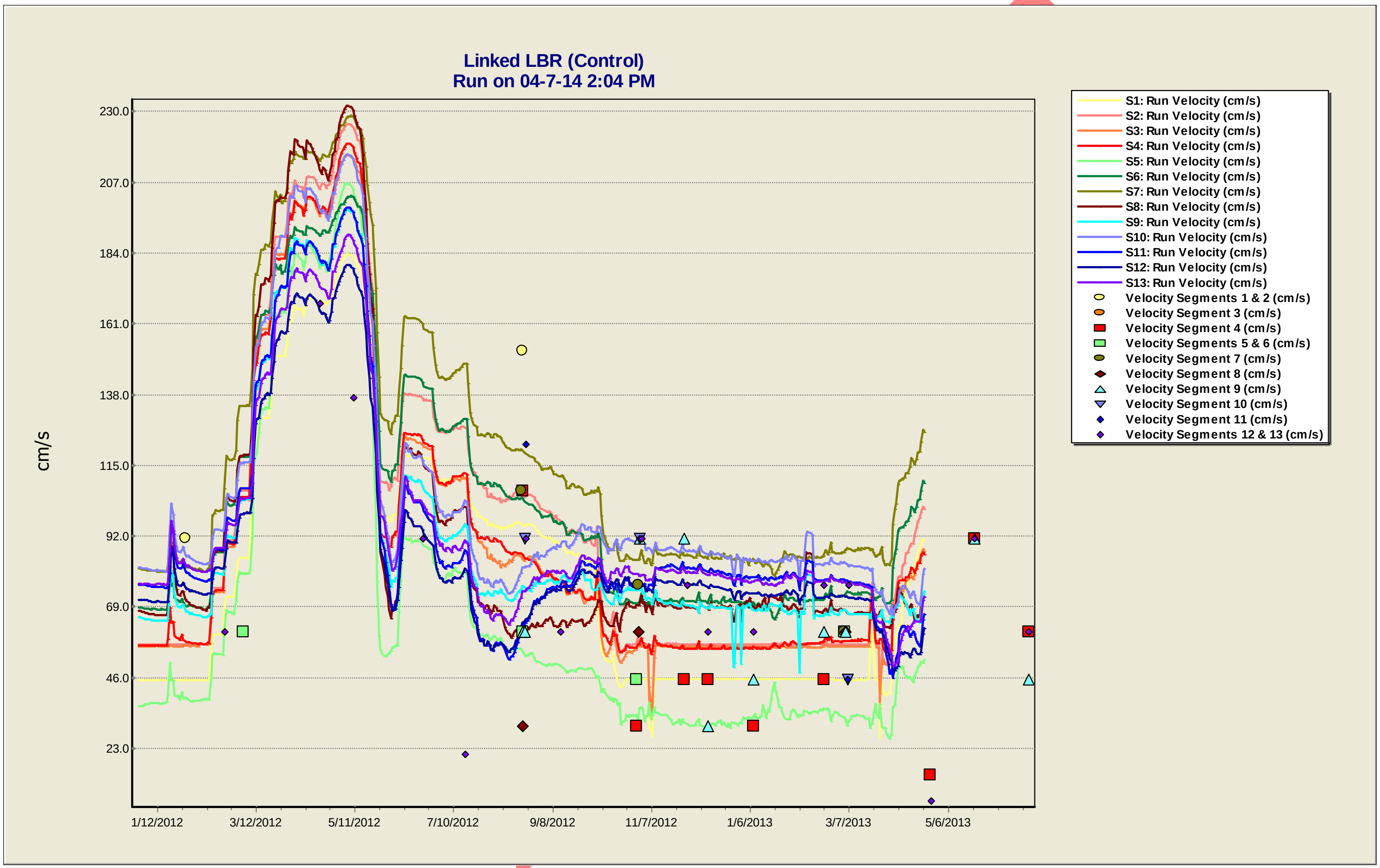
	O_2 = 3 Velocity = 3	NWIS data at USGS Station 13212500 (Boise River at Notus)
	TSS = 16	Monthly historical mean values for NWIS data
Conway Gulch	$NO_{2,3}$ = 3 $NH_{3,4}$ = 3 TSP = 3 O_2 = 3	NWIS data at USGS Station 13212550 (Conway Gulch at Notus)
12	pH = 13	NWIS data at USGS Station 13213000 (Boise River near Parma)
	$NH_{3,4}$ = 3 $NO_{2,3}$ = 3 TSP = 3 TP = 3	NWIS data at USGS Station 13212900 (Boise River at Hwy 95 Xing near Parma)
	TSS = 16	Monthly historical mean values for NWIS data
	Water Temperature = 402	USGS/USBR data near Parma (includes 9 interpolated data points)
Dixie Slough	$NO_{2,3}$ = 7 $NH_{3,4}$ = 7 TSP = 7	City of Boise (n = 4) and NWIS data (n = 3) at USGS Station 13212890 (Dixie Drain near Wilder)
	BOD = 4	City of Boise
	O_2 = 8	City of Boise (n = 5) and NWIS data (n = 3) at USGS Station 13212890 (Dixie Drain near Wilder)

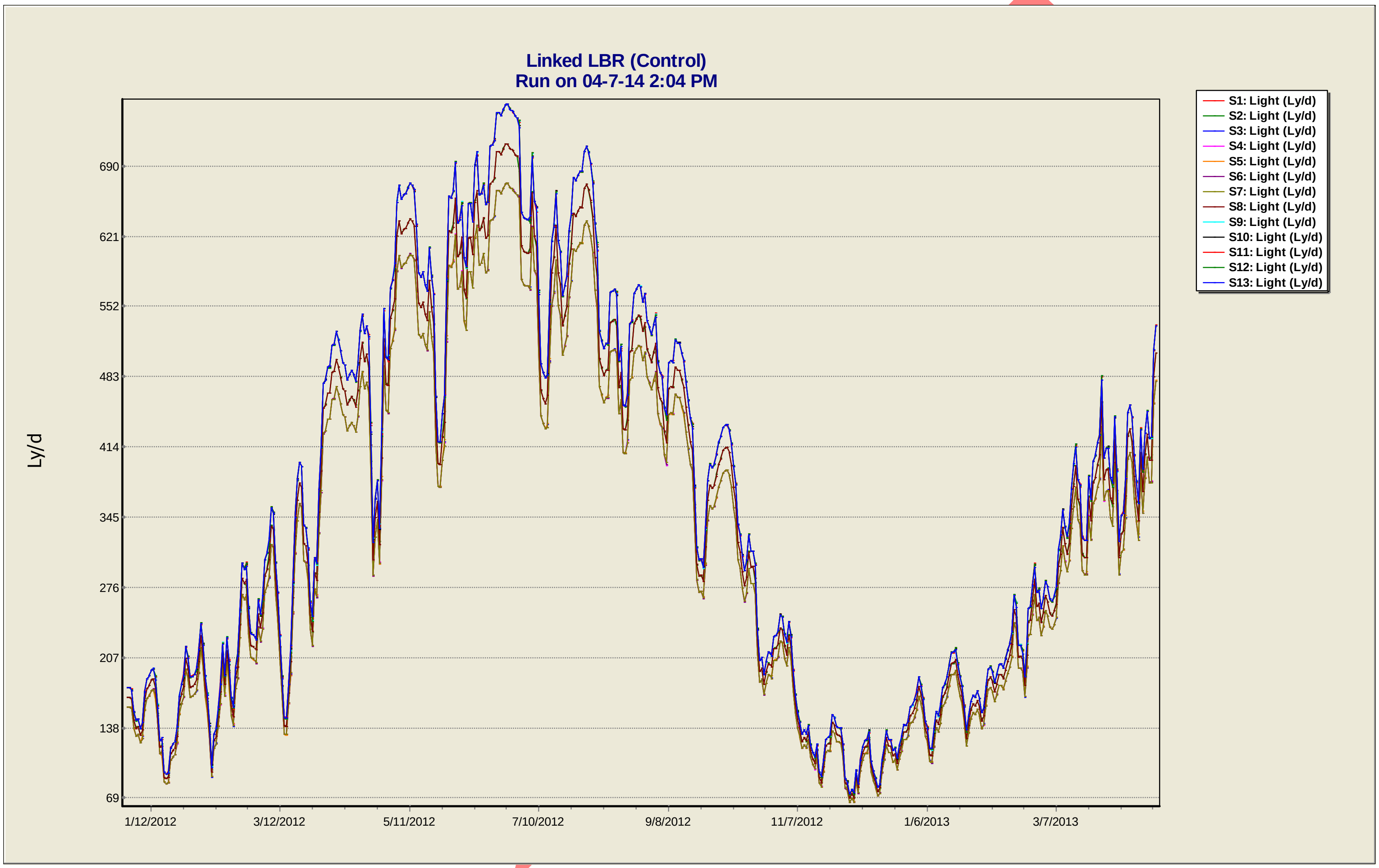
13	pH = 13 O_2 = 11 $NH_{3,4}$ = 12 $NO_{2,3}$ = 12 TSP = 12 TP = 43 Peri Chl a = 3 Phyto Chl a = 3 Velocity = 13	NWIS data at USGS Station 13213000 (Boise River near Parma)
	O_2 = 3 Velocity = 3	NWIS data at USGS Station 13212900 (Boise River at Hwy 95 Xing near Parma)
	TSS = 16	Monthly historical mean values for NWIS data
	Water Temperature = 402	USGS/USBR data near Parma (includes 9 interpolated data points)

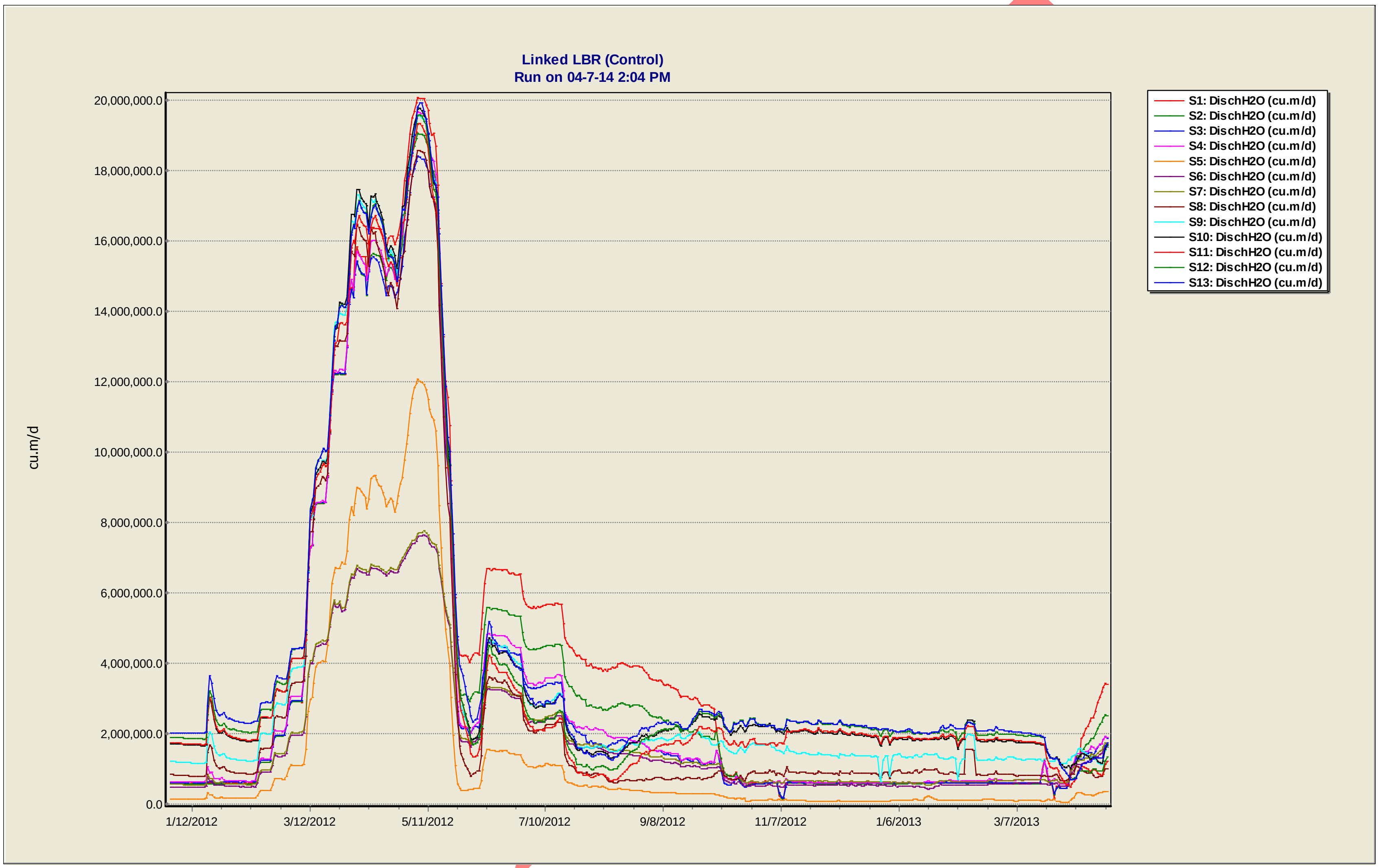
Model Calibration Figures – All Segments

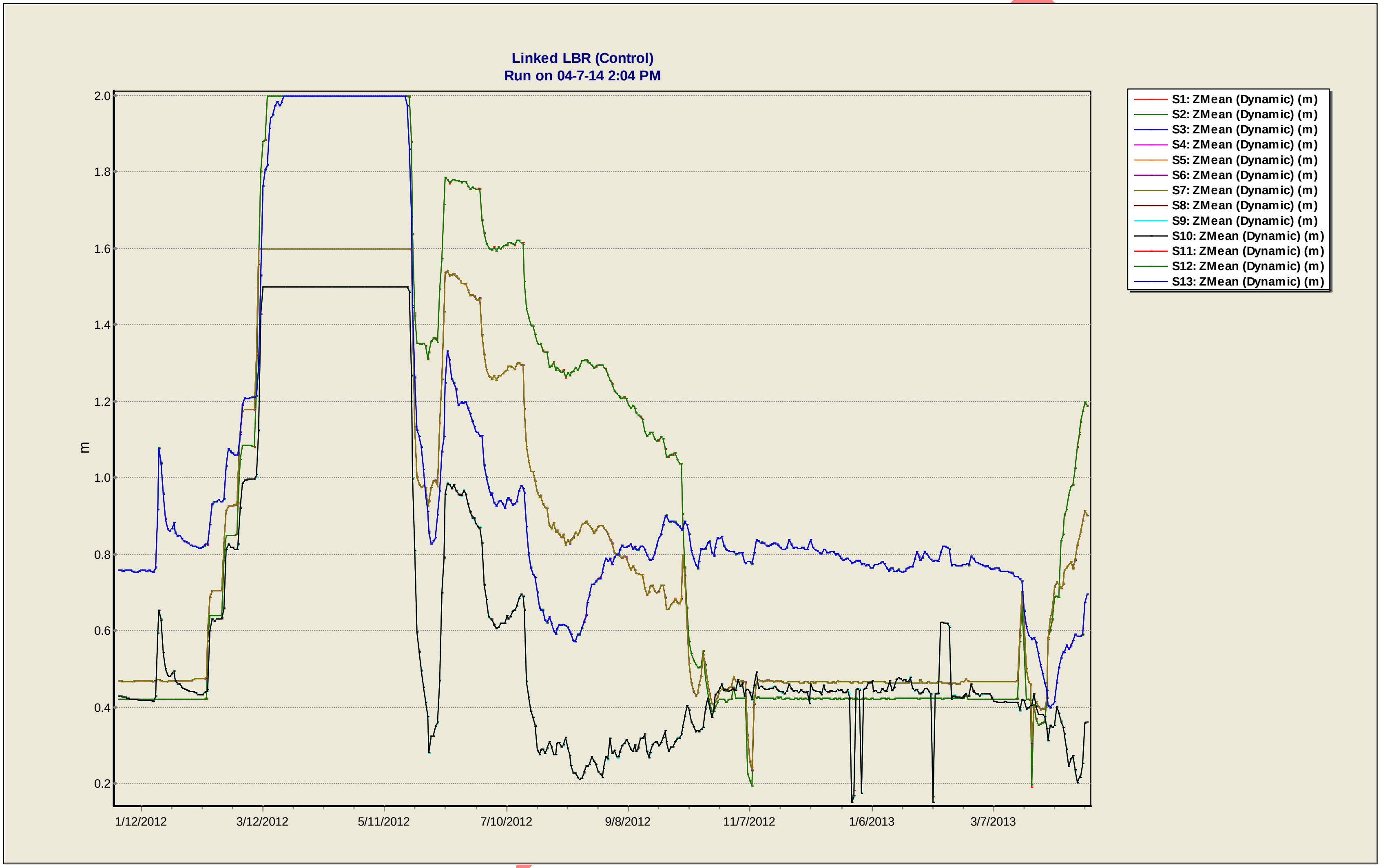

Linked LBR (Control)
Run on 04-7-14 2:04 PM
cu.m
1.0E+7
1.0E+6
1.0E+5
1.0E+4
1.0E+3
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
S1: Water Vol (cu.m)
S2: Water Vol (cu.m)
S3: Water Vol (cu.m)
S4: Water Vol (cu.m)
S5: Water Vol (cu.m)
S6: Water Vol (cu.m)
S7: Water Vol (cu.m)
S8: Water Vol (cu.m)
S9: Water Vol (cu.m)
S10: Water Vol (cu.m)
S11: Water Vol (cu.m)
S12: Water Vol (cu.m)
S13: Water Vol (cu.m)


Linked LBR (Control)
Run on 04-7-14 2:04 PM
deg. C
21.6
19.2
16.8
14.4
12.0
9.6
7.2
4.8
2.4
0.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
S1: Temp (deg. C)
S2: Temp (deg. C)
S3: Temp (deg. C)
S4: Temp (deg. C)
S5: Temp (deg. C)
S6: Temp (deg. C)
S7: Temp (deg. C)
S8: Temp (deg. C)
S9: Temp (deg. C)
S10: Temp (deg. C)
S11: Temp (deg. C)
S12: Temp (deg. C)
S13: Temp (deg. C)
Temperature COB Segment 2 (deg. C)
Temperature COB Segment 3 (deg. C)
Temperature COB Segment 4 (deg. C)
Temperature COB Segment 7 (deg. C)
Temperature COB Segment 9 (deg. C)
Temperature BOR Segment 13 (deg. C)

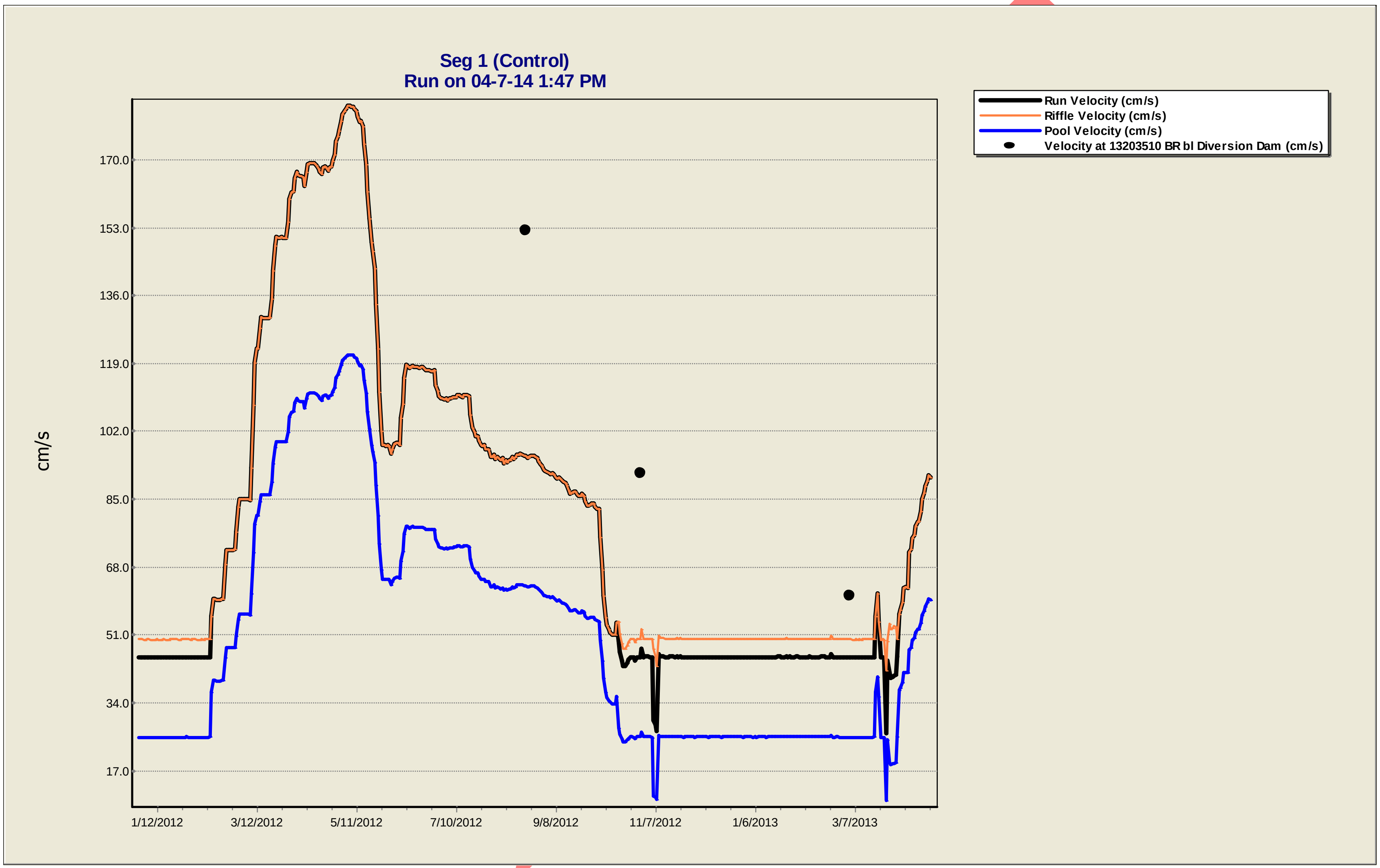

Linked LBR (Control)
Run on 04-7-14 2:04 PM
cm/s
230.0
207.0
184.0
161.0
138.0
115.0
92.0
69.0
46.0
23.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
5/6/2013
S1: Run Velocity (cm/s)
S2: Run Velocity (cm/s)
S3: Run Velocity (cm/s)
S4: Run Velocity (cm/s)
S5: Run Velocity (cm/s)
S6: Run Velocity (cm/s)
S7: Run Velocity (cm/s)
S8: Run Velocity (cm/s)
S9: Run Velocity (cm/s)
S10: Run Velocity (cm/s)
S11: Run Velocity (cm/s)
S12: Run Velocity (cm/s)
S13: Run Velocity (cm/s)
Velocity Segments 1 & 2 (cm/s)
Velocity Segment 3 (cm/s)
Velocity Segment 4 (cm/s)
Velocity Segments 5 & 6 (cm/s)
Velocity Segment 7 (cm/s)
Velocity Segment 8 (cm/s)
Velocity Segment 9 (cm/s)
Velocity Segment 10 (cm/s)
Velocity Segment 11 (cm/s)
Velocity Segments 12 & 13 (cm/s)


Linked LBR (Control)
Run on 04-7-14 2:04 PM
Ly/d
690
621
552
483
414
345
276
207
138
69
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
S1: Light (Ly/d)
S2: Light (Ly/d)
S3: Light (Ly/d)
S4: Light (Ly/d)
S5: Light (Ly/d)
S6: Light (Ly/d)
S7: Light (Ly/d)
S8: Light (Ly/d)
S9: Light (Ly/d)
S10: Light (Ly/d)
S11: Light (Ly/d)
S12: Light (Ly/d)
S13: Light (Ly/d)

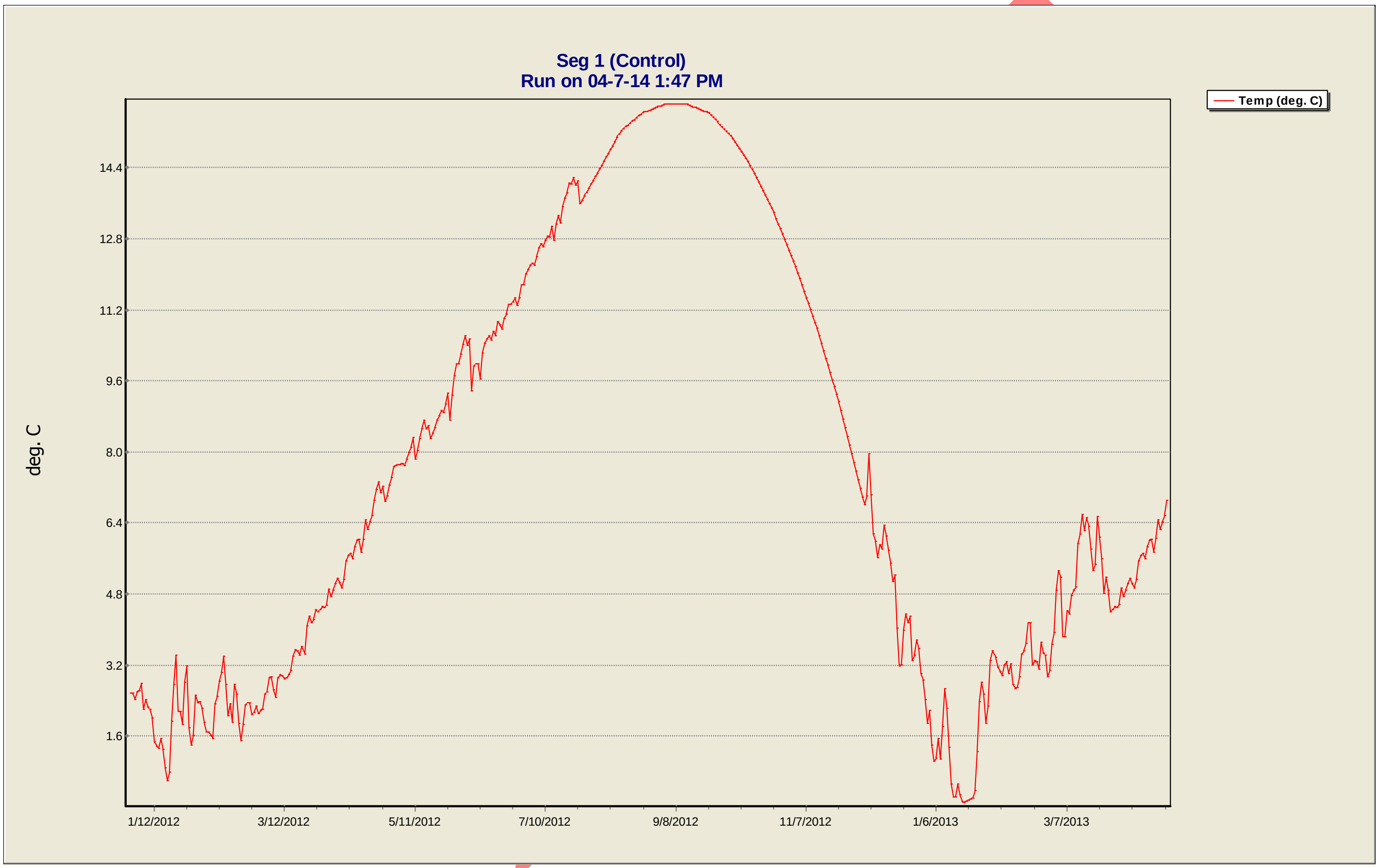

Linked LBR (Control)
Run on 04-7-14 2:04 PM
cu.m/d
20,000,000.0
18,000,000.0
16,000,000.0
14,000,000.0
12,000,000.0
10,000,000.0
8,000,000.0
6,000,000.0
4,000,000.0
2,000,000.0
0.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
S1: DischH2O (cu.m/d)
S2: DischH2O (cu.m/d)
S3: DischH2O (cu.m/d)
S4: DischH2O (cu.m/d)
S5: DischH2O (cu.m/d)
S6: DischH2O (cu.m/d)
S7: DischH2O (cu.m/d)
S8: DischH2O (cu.m/d)
S9: DischH2O (cu.m/d)
S10: DischH2O (cu.m/d)
S11: DischH2O (cu.m/d)
S12: DischH2O (cu.m/d)
S13: DischH2O (cu.m/d)

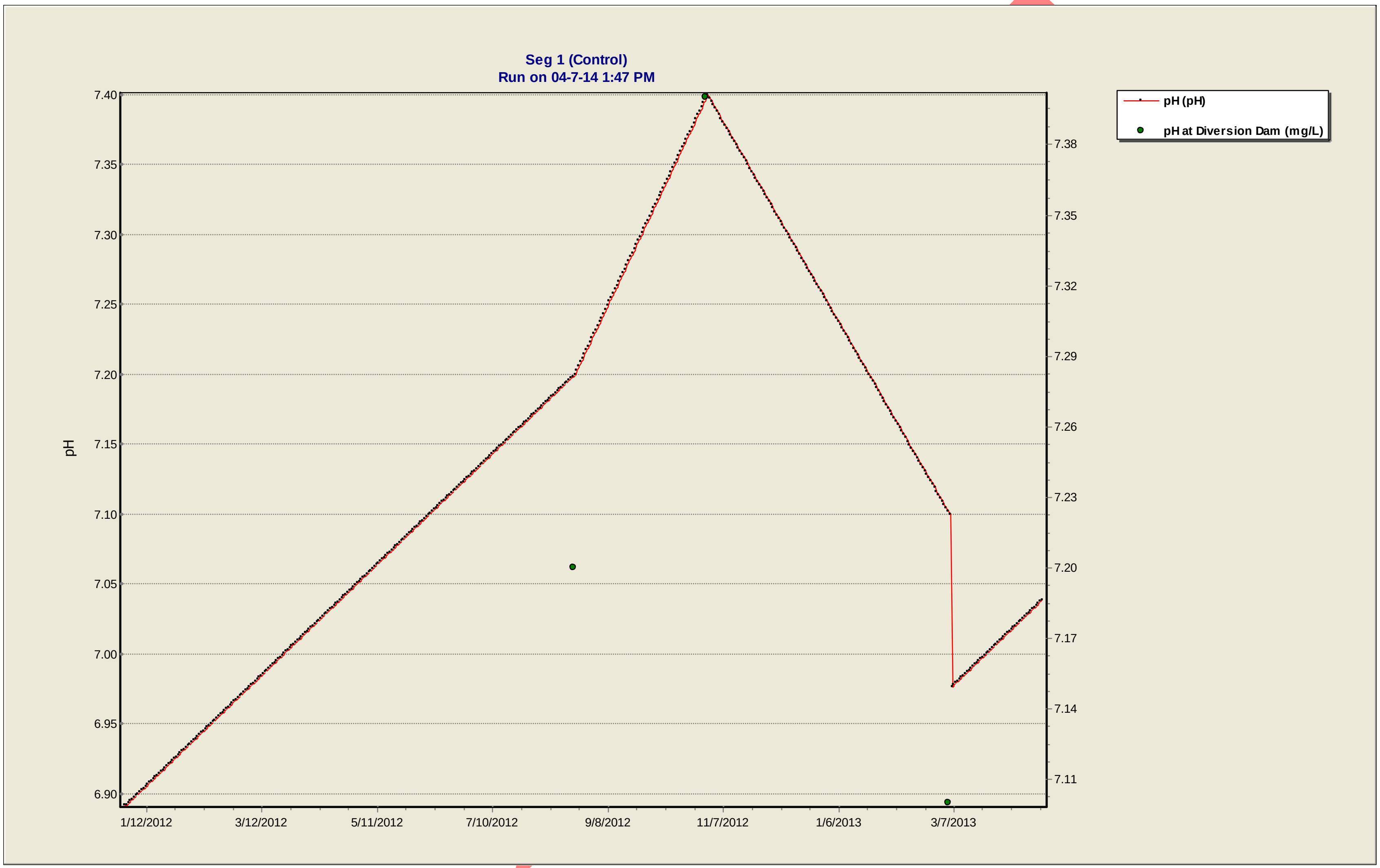

Linked LBR (Control)
Run on 04-7-14 2:04 PM
m
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
S1: ZMean (Dynamic) (m)
S2: ZMean (Dynamic) (m)
S3: ZMean (Dynamic) (m)
S4: ZMean (Dynamic) (m)
S5: ZMean (Dynamic) (m)
S6: ZMean (Dynamic) (m)
S7: ZMean (Dynamic) (m)
S8: ZMean (Dynamic) (m)
S9: ZMean (Dynamic) (m)
S10: ZMean (Dynamic) (m)
S11: ZMean (Dynamic) (m)
S12: ZMean (Dynamic) (m)
S13: ZMean (Dynamic) (m)

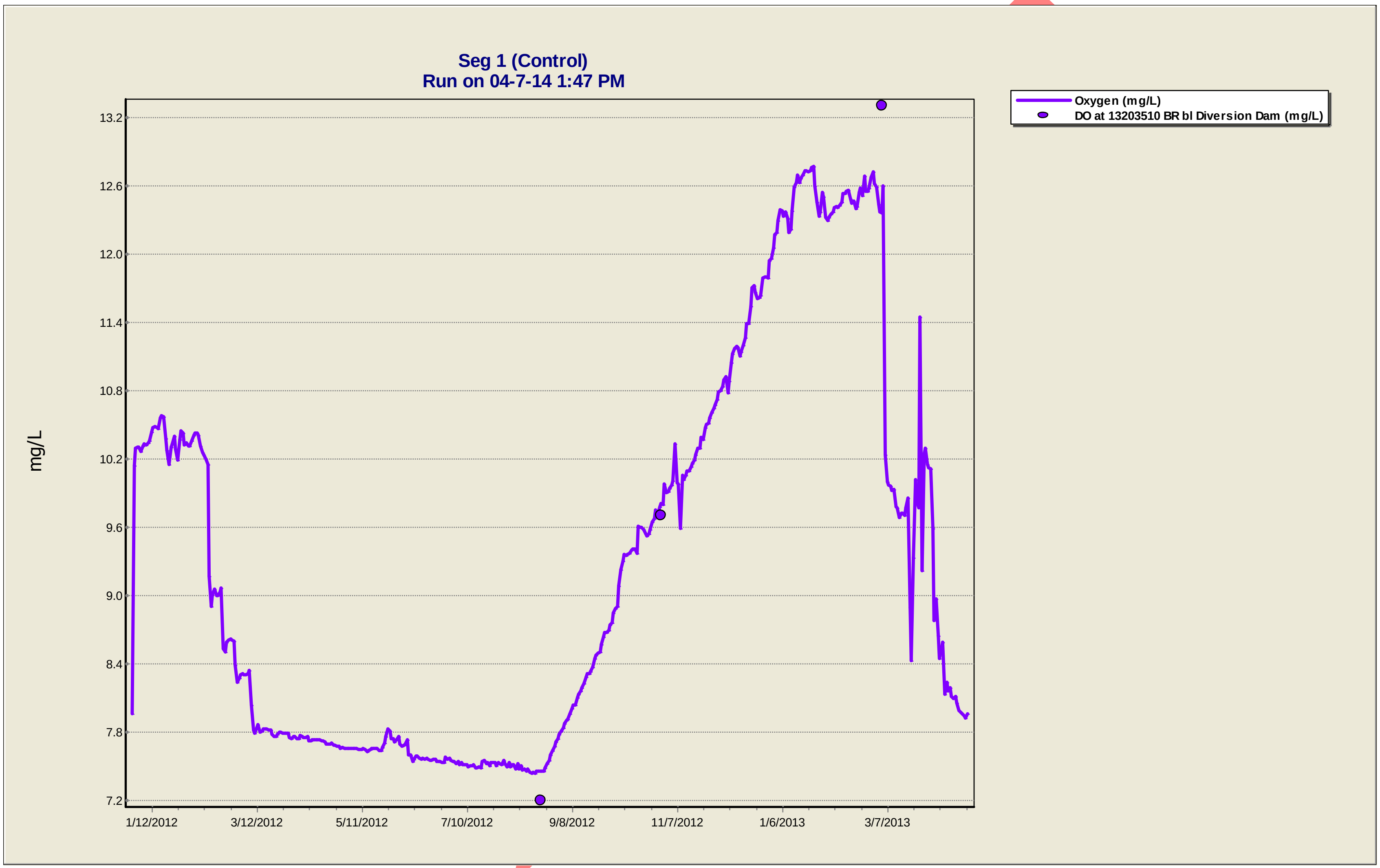
Select Model Results and Measured Data – Segment 1

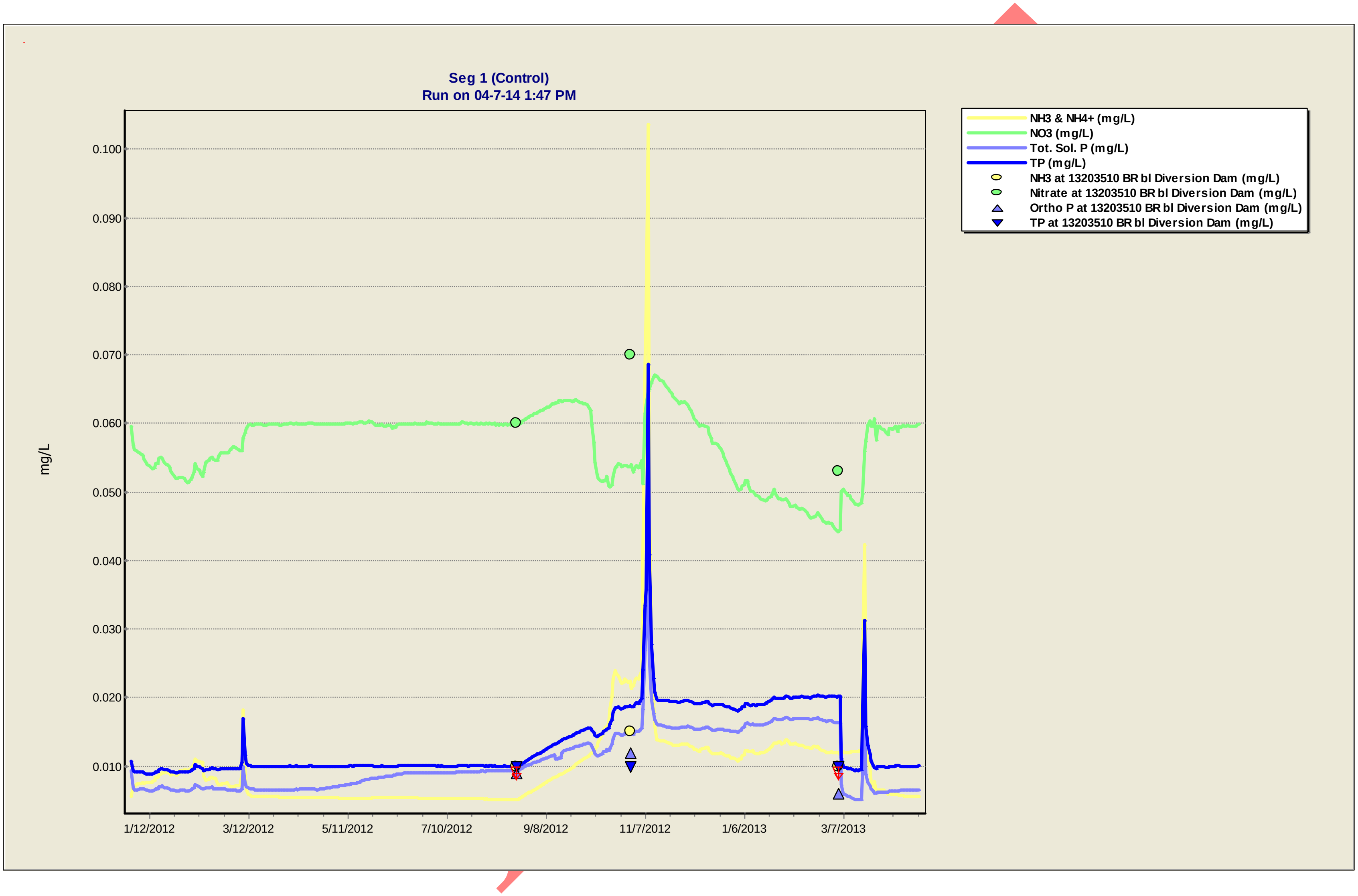


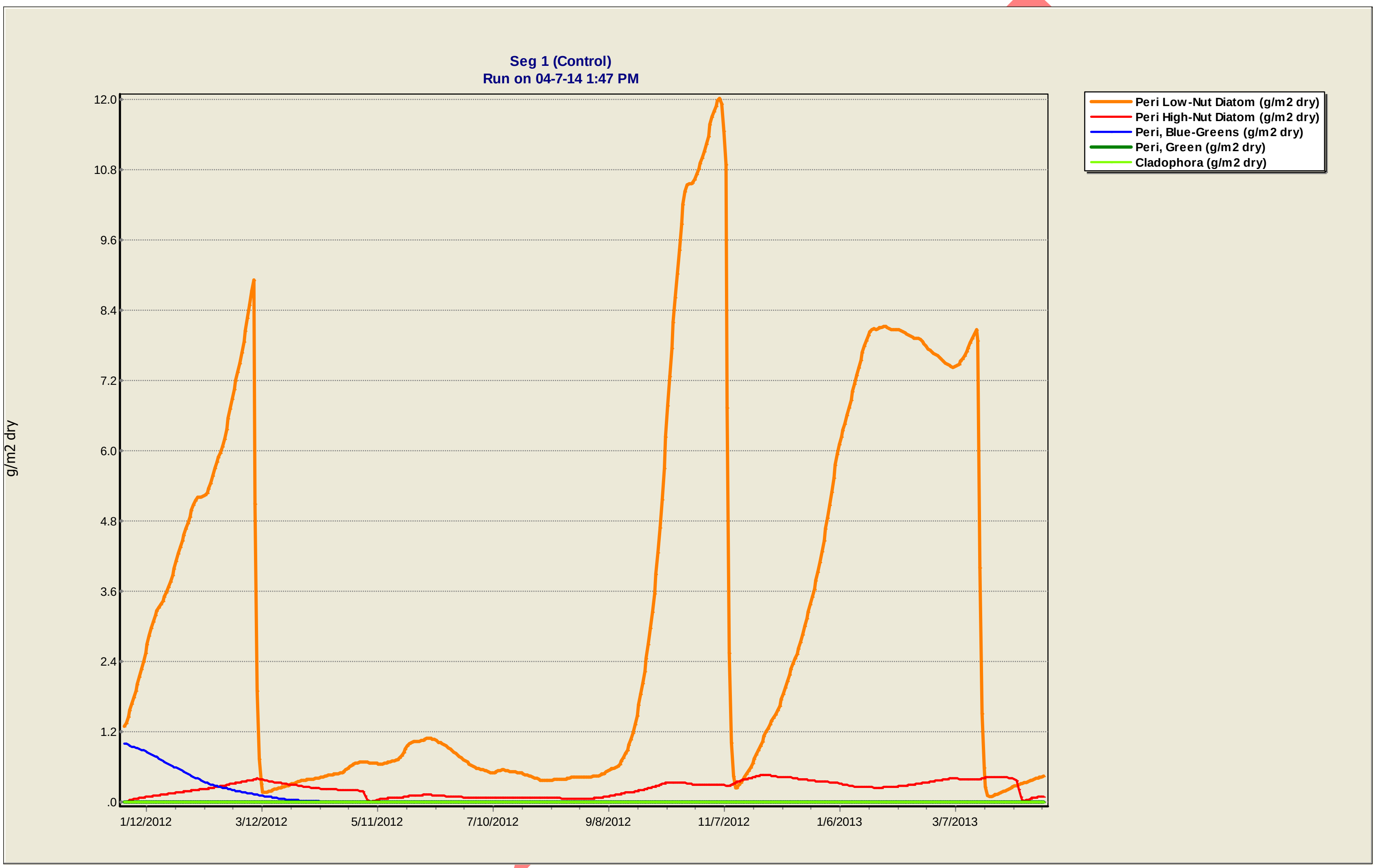
Seg 1 (Control)
Run on 04-7-14 1:47 PM
cm/s
170.0
153.0
136.0
119.0
102.0
85.0
68.0
51.0
34.0
17.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Run Velocity (cm/s)
Riffle Velocity (cm/s)
Pool Velocity (cm/s)
Velocity at 13203510 BR bl Diversion Dam (cm/s)

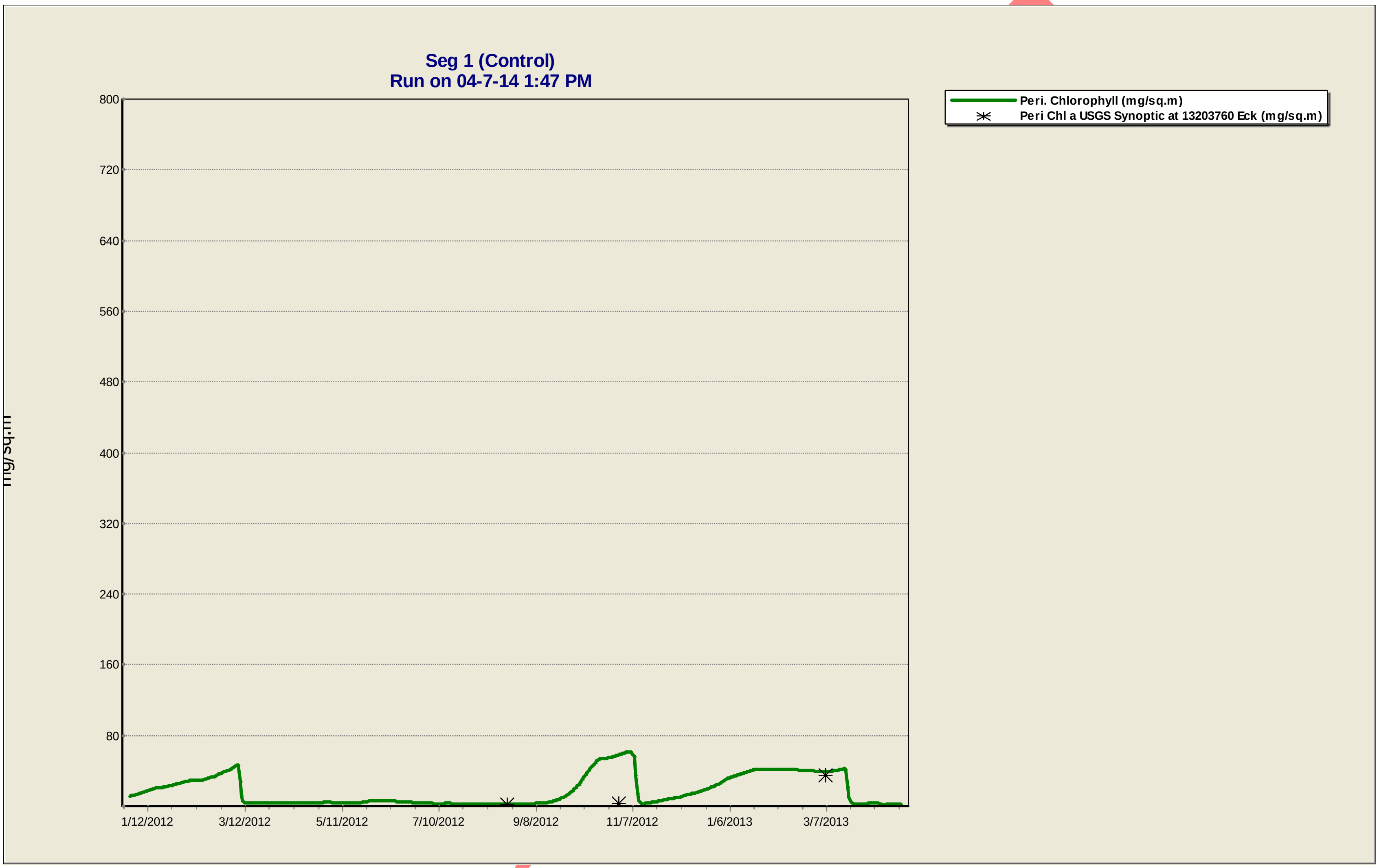

Seg 1 (Control)
Run on 04-7-14 1:47 PM
Temp (deg. C)
deg. C
14.4
12.8
11.2
9.6
8.0
6.4
4.8
3.2
1.6
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

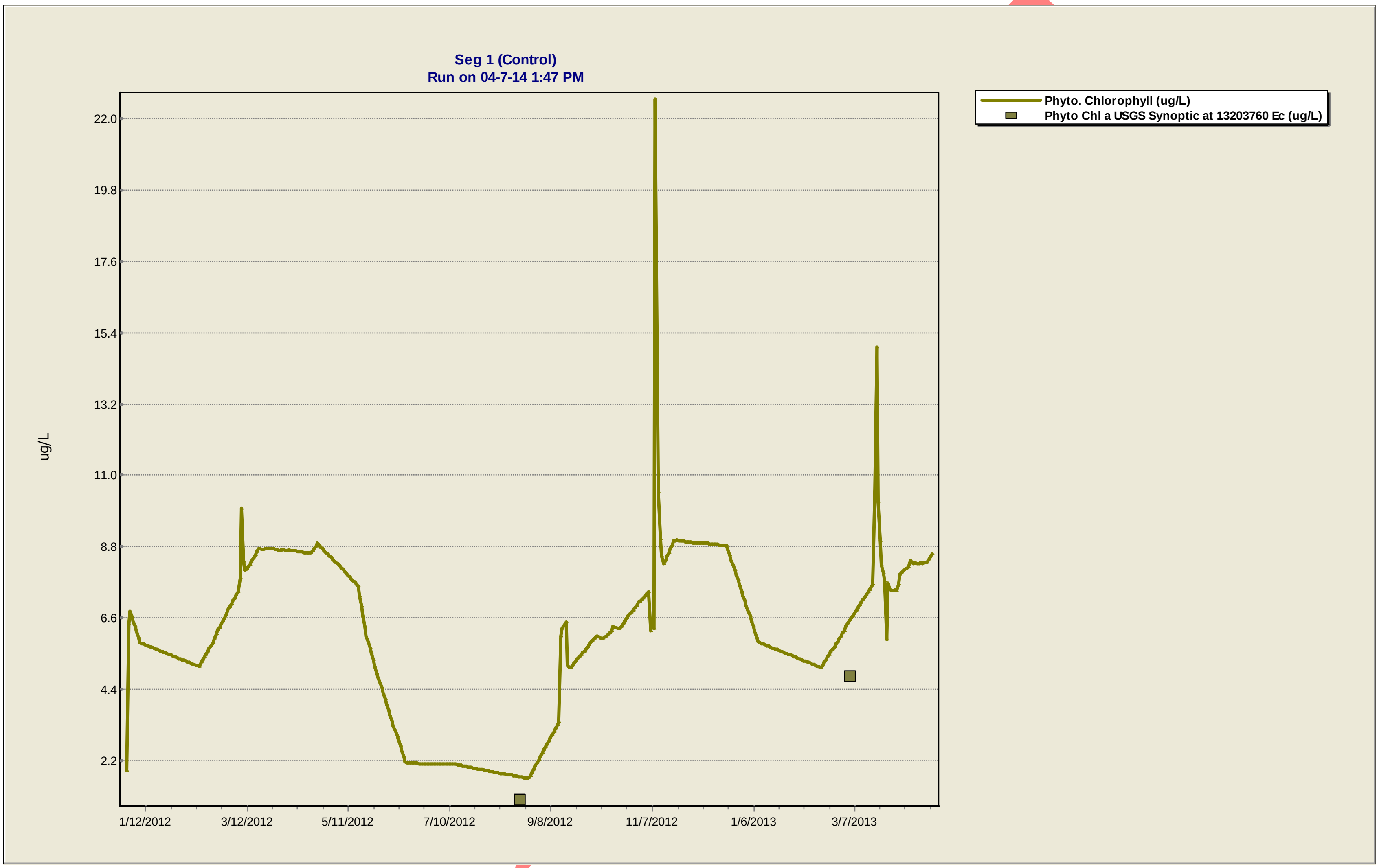

Seg 1 (Control)
Run on 04-7-14 1:47 PM
pH (pH)
pH at Diversion Dam (mg/L)
pH
7.40
7.35
7.30
7.25
7.20
7.15
7.10
7.05
7.00
6.95
6.90
7.38
7.35
7.32
7.29
7.26
7.23
7.20
7.17
7.14
7.11
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013


Seg 1 (Control)
Run on 04-7-14 1:47 PM
Oxygen (mg/L)
DO at 13203510 BR bl Diversion Dam (mg/L)
mg/L
13.2
12.6
12.0
11.4
10.8
10.2
9.6
9.0
8.4
7.8
7.2
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013


Seg 1 (Control)
Run on 04-7-14 1:47 PM
mg/L
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
NH3 & NH4+ (mg/L)
NO3 (mg/L)
Tot. Sol. P (mg/L)
TP (mg/L)
NH3 at 13203510 BR bl Diversion Dam (mg/L)
Nitrate at 13203510 BR bl Diversion Dam (mg/L)
Ortho P at 13203510 BR bl Diversion Dam (mg/L)
TP at 13203510 BR bl Diversion Dam (mg/L)

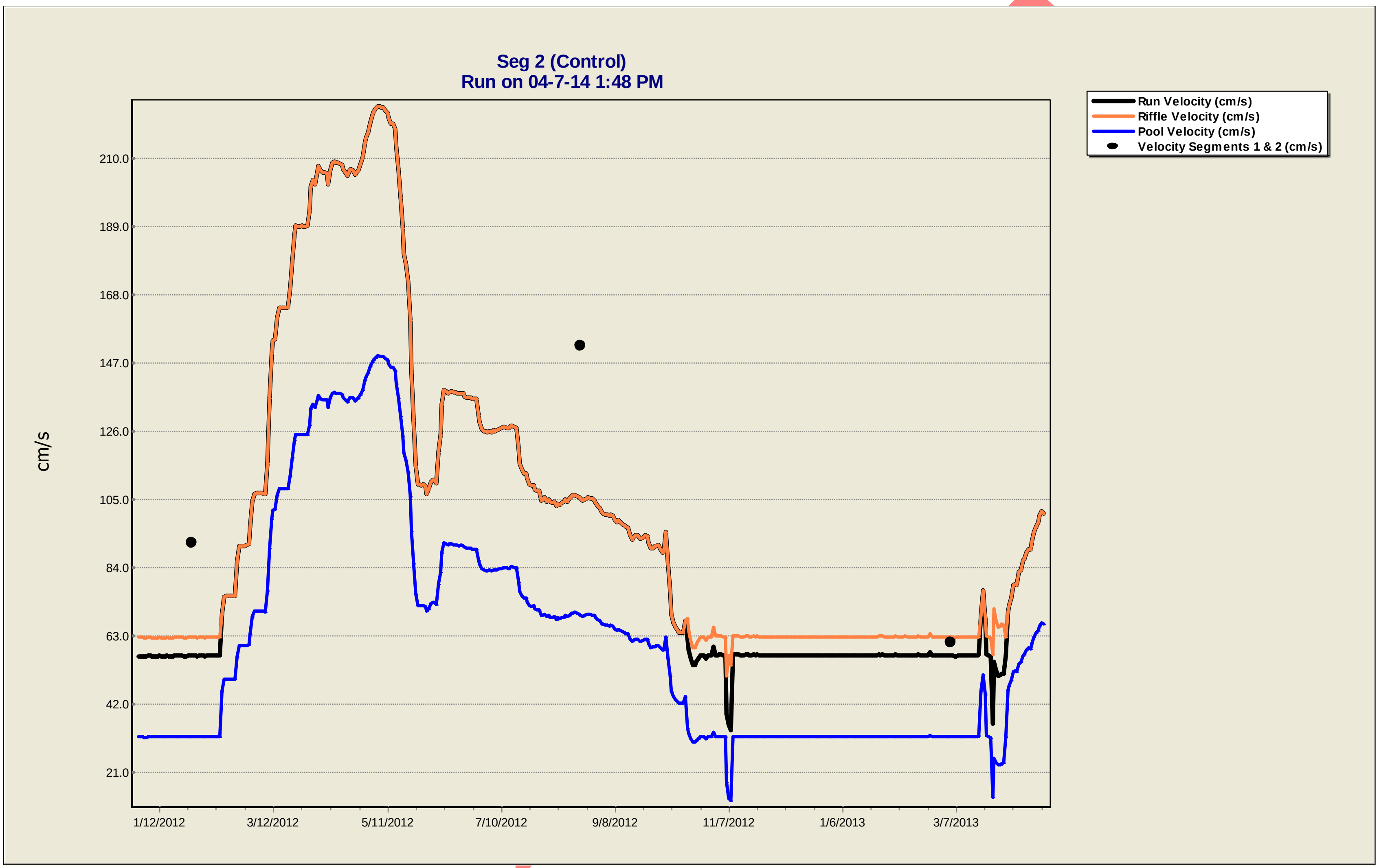

Seg 1 (Control)
Run on 04-7-14 1:47 PM
g/m2 dry
12.0
10.8
9.6
8.4
7.2
6.0
4.8
3.6
2.4
1.2
.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Peri Low-Nut Diatom (g/m2 dry)
Peri High-Nut Diatom (g/m2 dry)
Peri, Blue-Greens (g/m2 dry)
Peri, Green (g/m2 dry)
Cladophora (g/m2 dry)

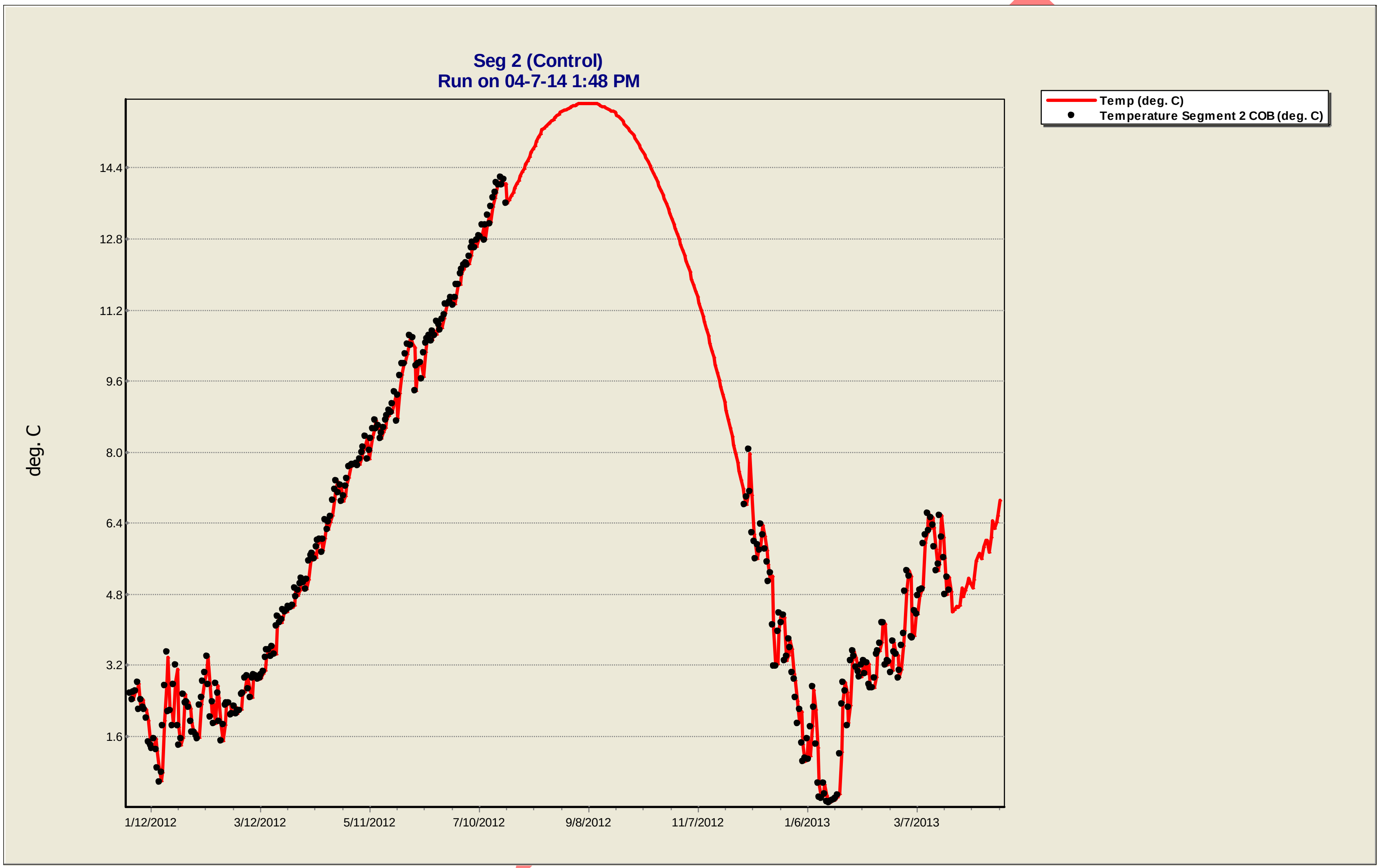

Seg 1 (Control)
Run on 04-7-14 1:47 PM
mg/sq.m
800
720
640
560
480
400
320
240
160
80
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Peri. Chlorophyll (mg/sq.m)
Peri Chl a USGS Synoptic at 13203760 Eck (mg/sq.m)

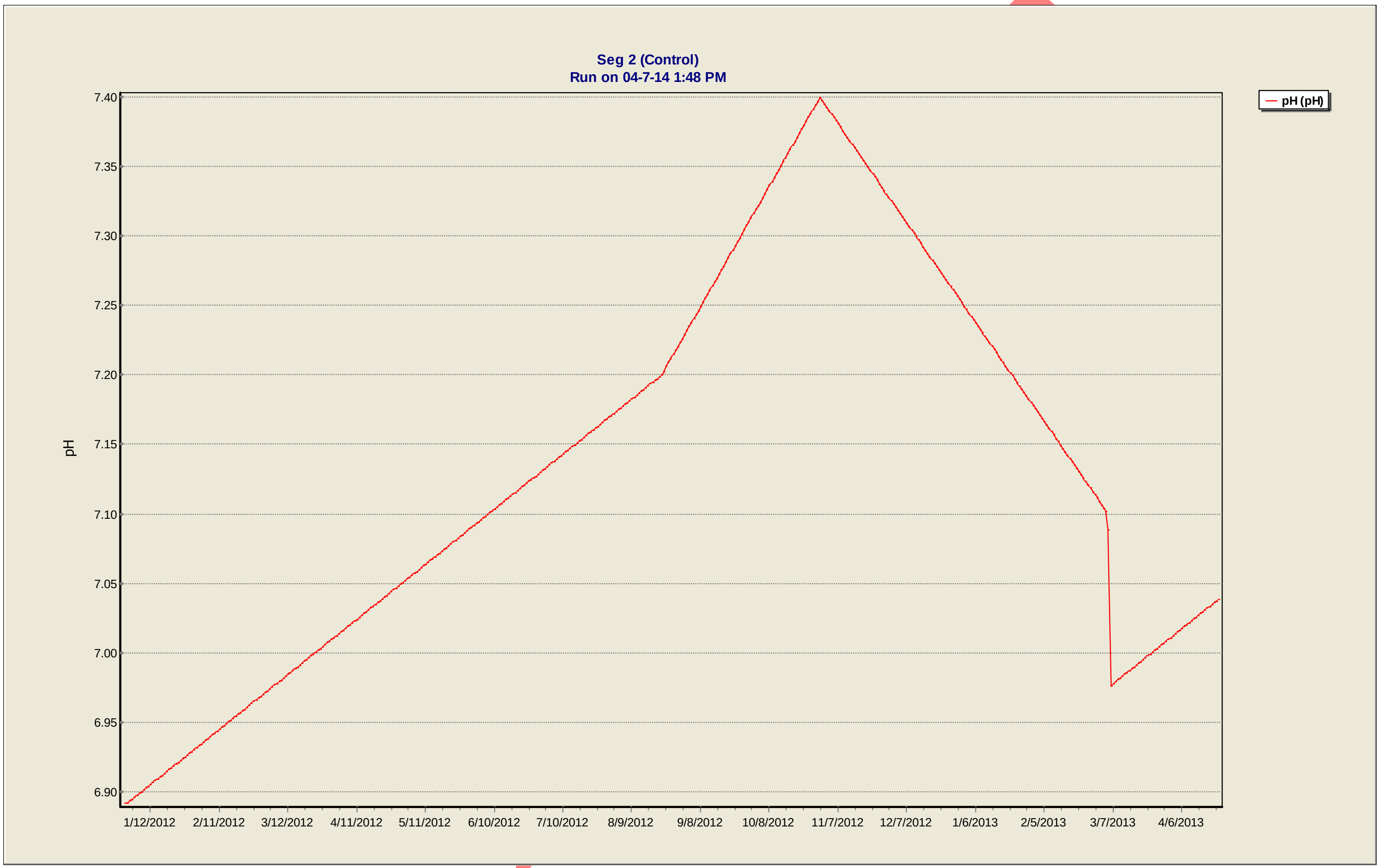


Seg 1 (Control)
Run on 04-7-14 1:47 PM
ug/L
22.0
19.8
17.6
15.4
13.2
11.0
8.8
6.6
4.4
2.2
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Phyto. Chlorophyll (ug/L)
Phyto Chl a USGS Synoptic at 13203760 Ec (ug/L)

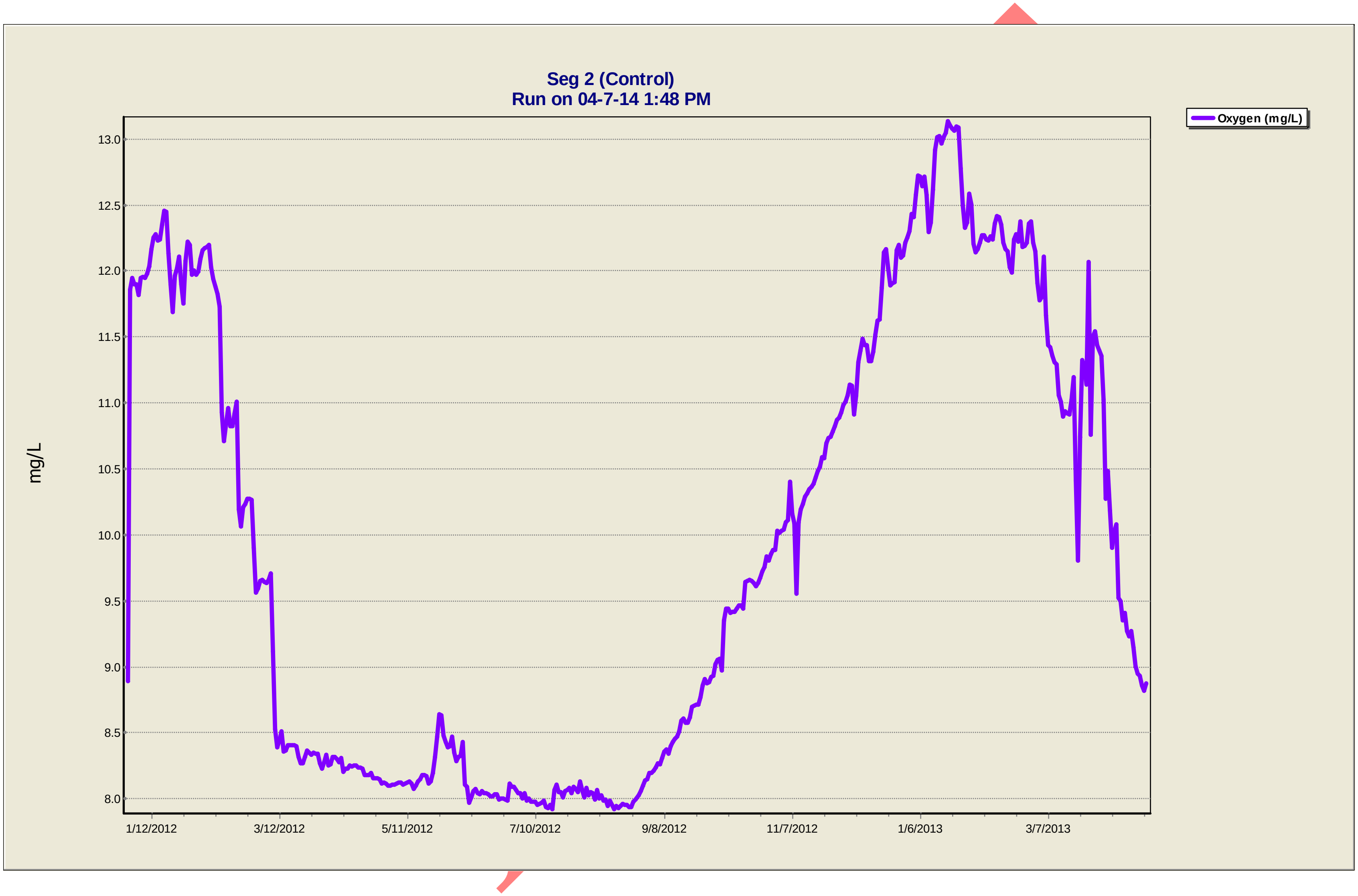
Select Model Results and Measured Data – Segment 2


Seg 2 (Control)
Run on 04-7-14 1:48 PM
Run Velocity (cm/s)
Riffle Velocity (cm/s)
Pool Velocity (cm/s)
Velocity Segments 1 & 2 (cm/s)
cm/s
210.0
189.0
168.0
147.0
126.0
105.0
84.0
63.0
42.0
21.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

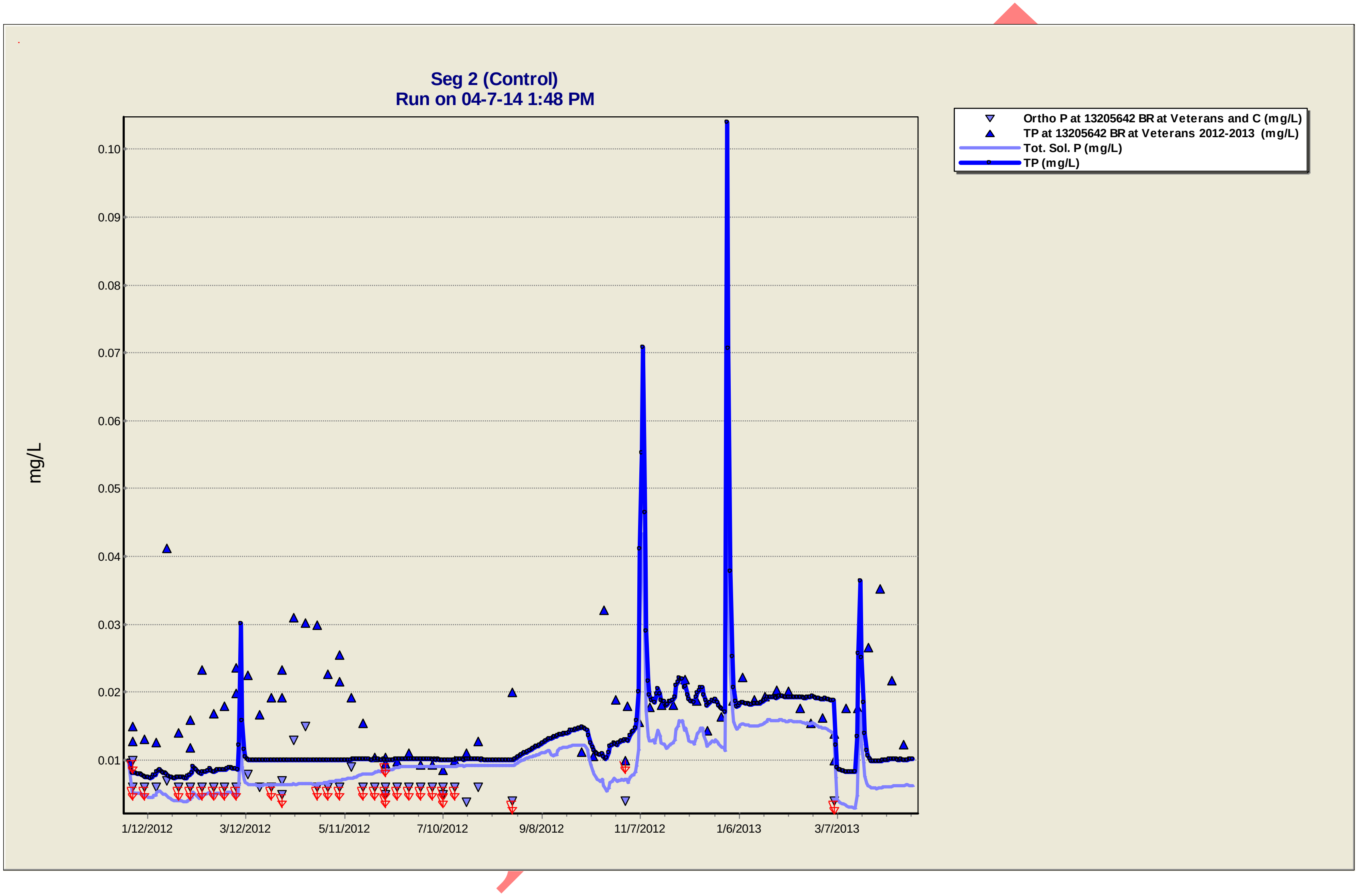

Seg 2 (Control)
Run on 04-7-14 1:48 PM
Temp (deg. C)
Temperature Segment 2 COB (deg. C)
deg. C
14.4
12.8
11.2
9.6
8.0
6.4
4.8
3.2
1.6
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

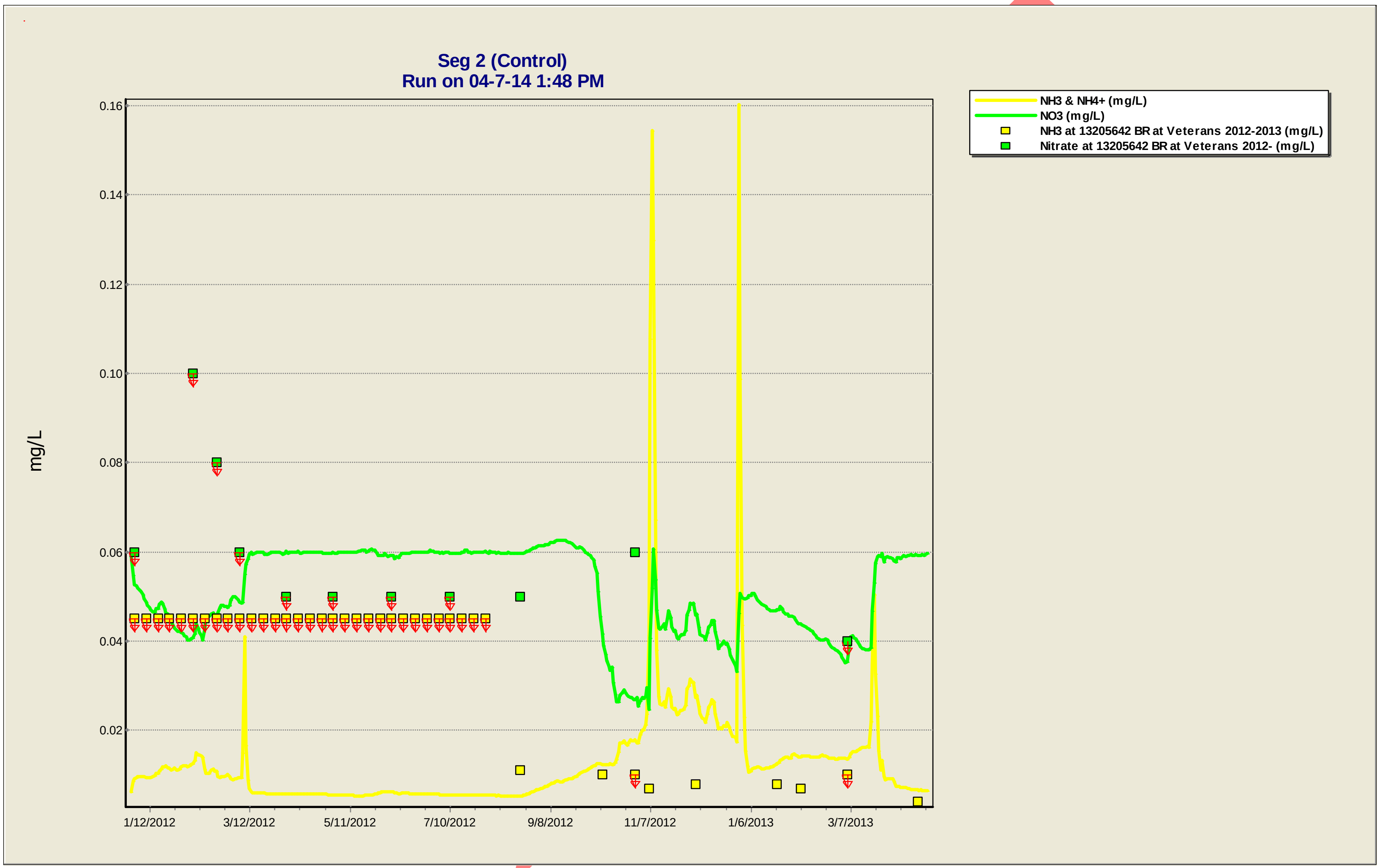


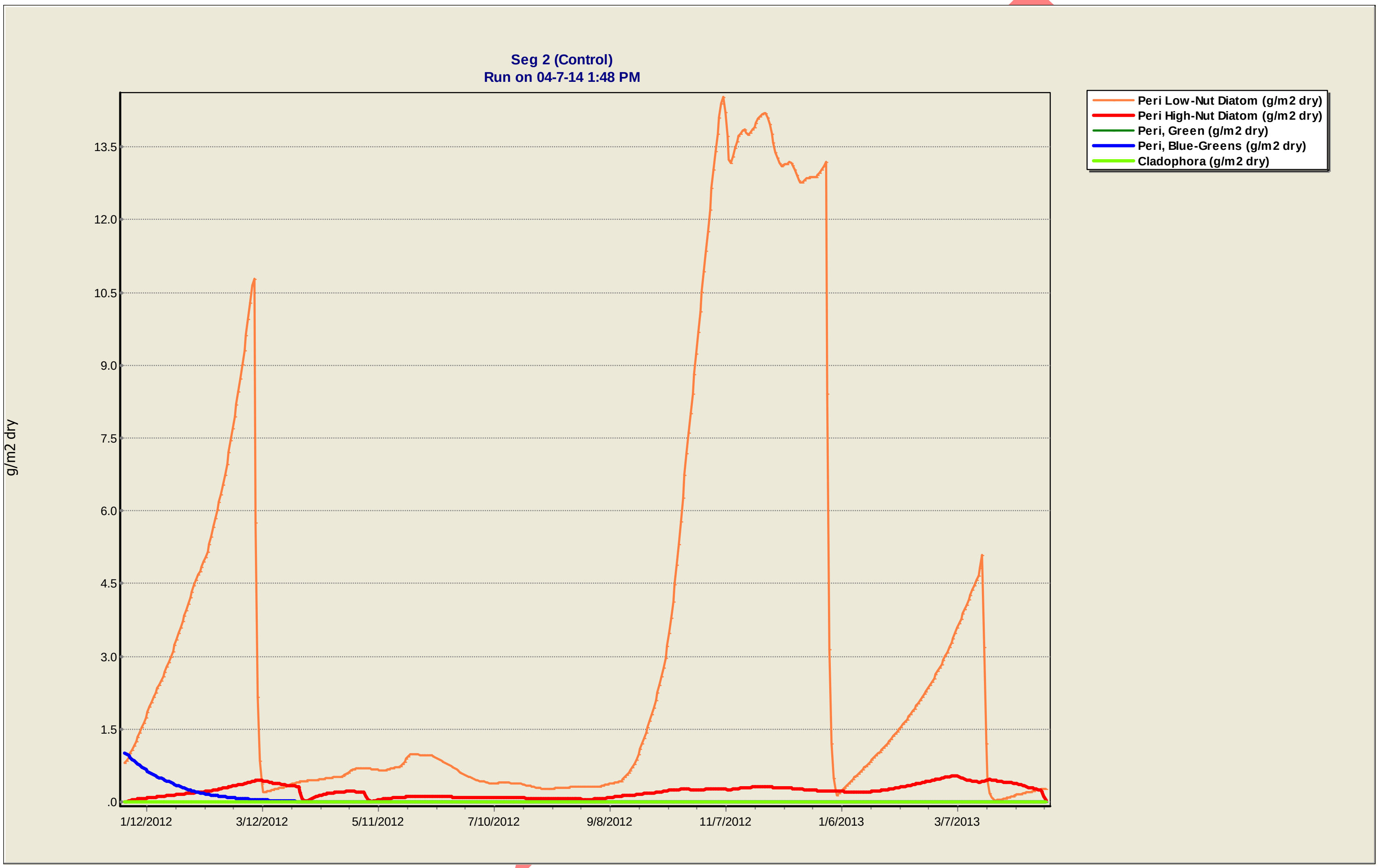
Seg 2 (Control)
Run on 04-7-14 1:48 PM
pH (pH)
pH
7.40
7.35
7.30
7.25
7.20
7.15
7.10
7.05
7.00
6.95
6.90
1/12/2012
2/11/2012
3/12/2012
4/11/2012
5/11/2012
6/10/2012
7/10/2012
8/9/2012
9/8/2012
10/8/2012
11/7/2012
12/7/2012
1/6/2013
2/5/2013
3/7/2013
4/6/2013

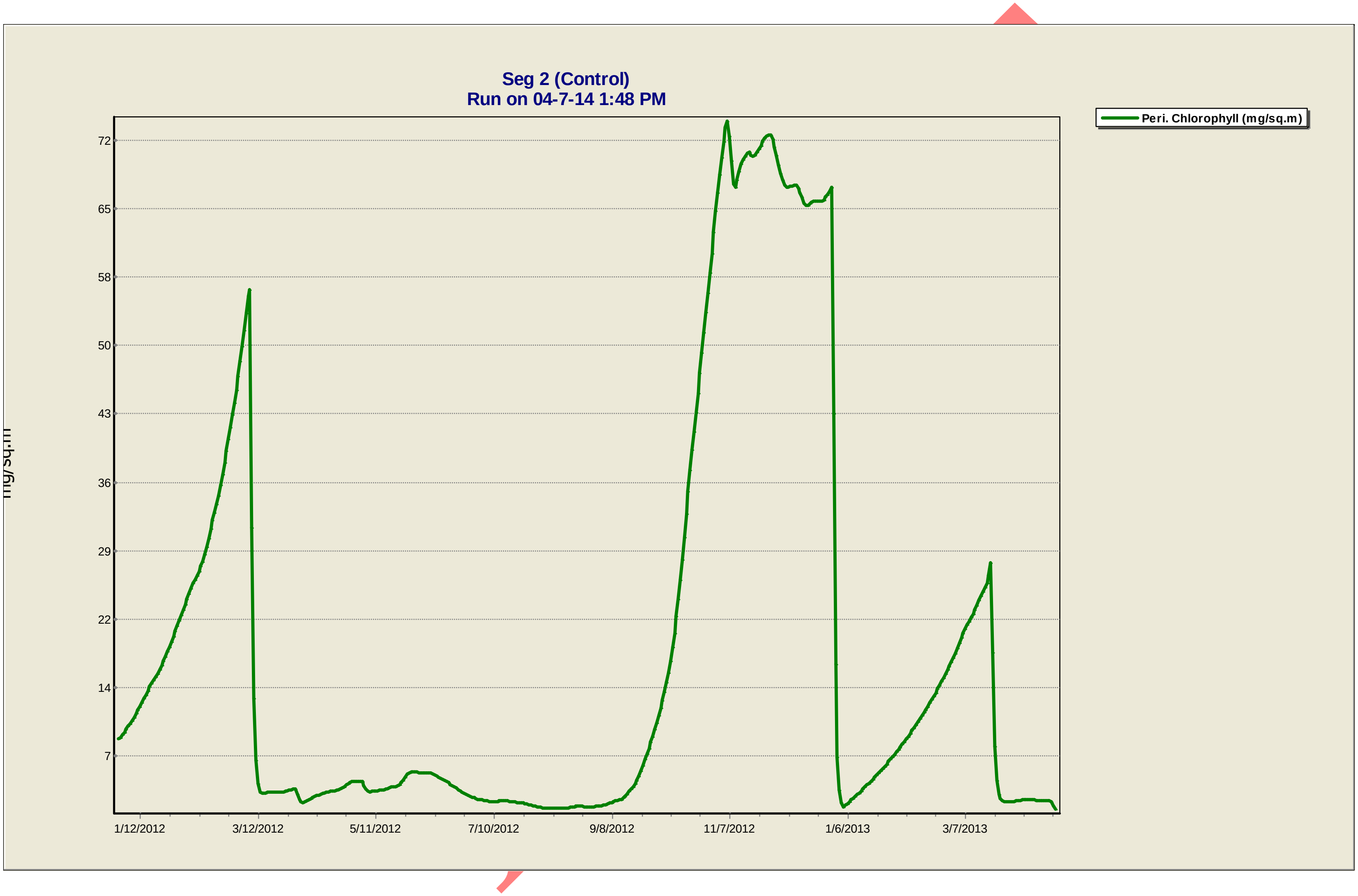


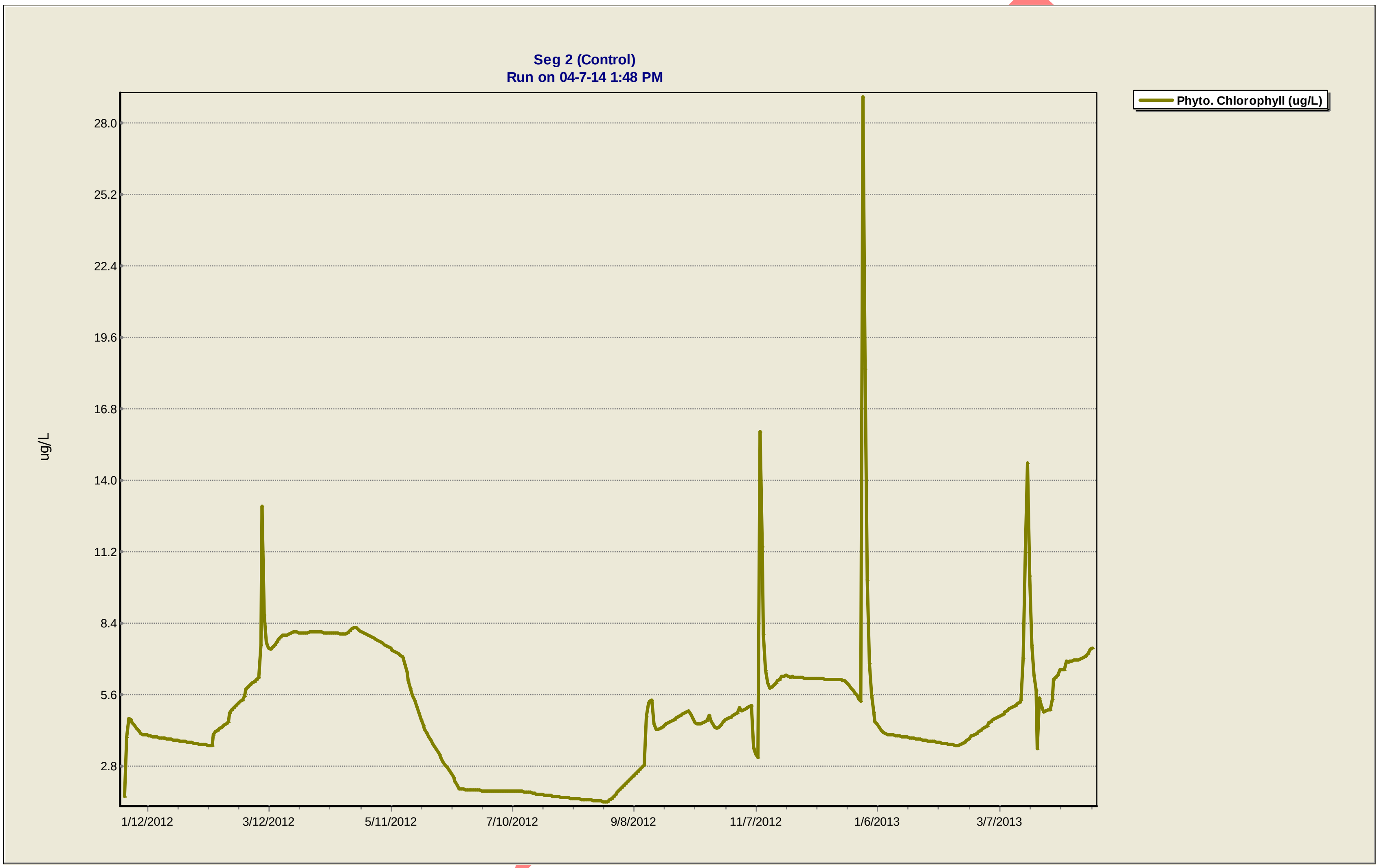
Seg 2 (Control)
Run on 04-7-14 1:48 PM
Oxygen (mg/L)
mg/L
13.0
12.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013


Seg 2 (Control)
Run on 04-7-14 1:48 PM
mg/L
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Ortho P at 13205642 BR at Veterans and C (mg/L)
TP at 13205642 BR at Veterans 2012-2013 (mg/L)
Tot. Sol. P (mg/L)
TP (mg/L)

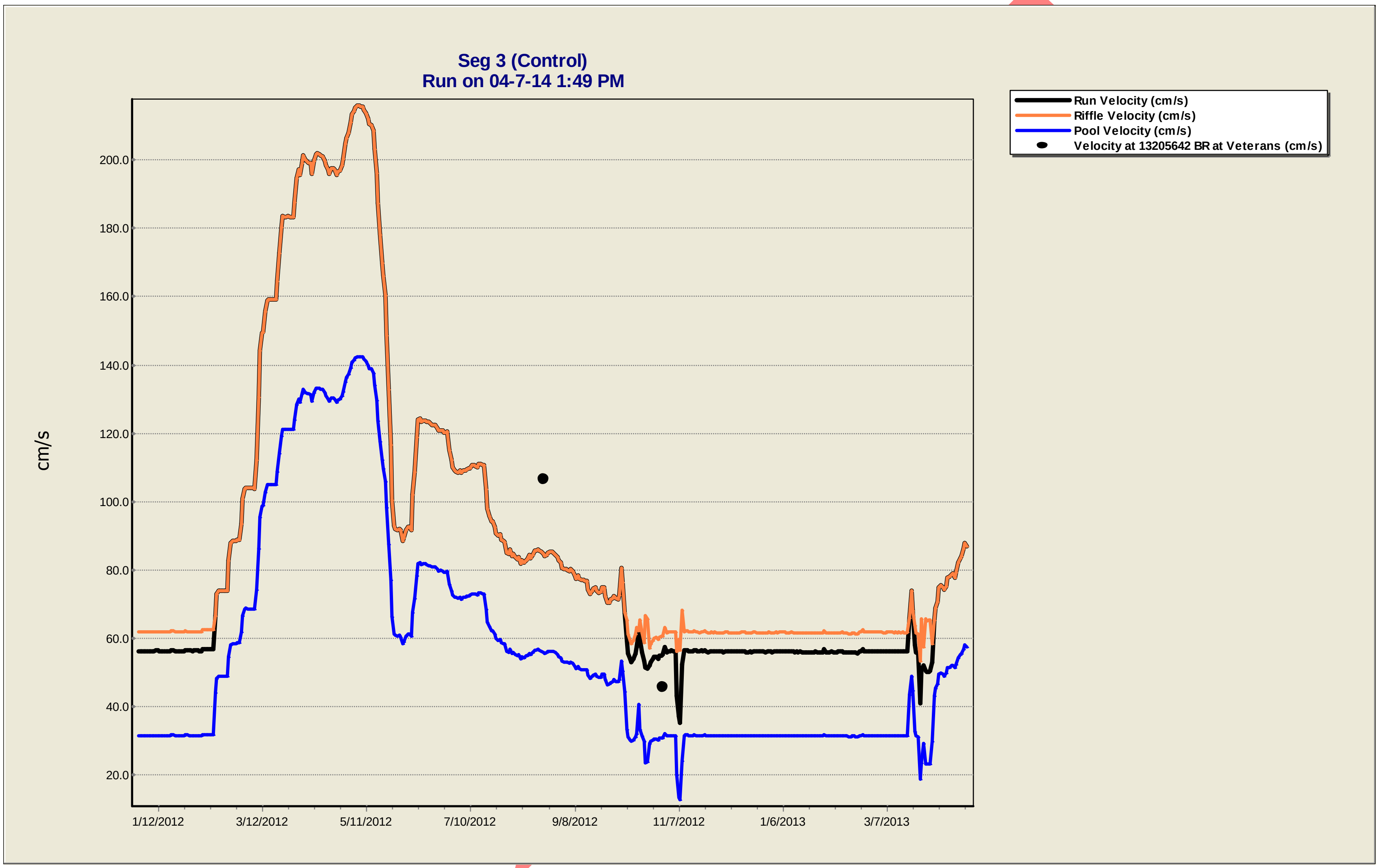

Seg 2 (Control)
Run on 04-7-14 1:48 PM
NH3 & NH4+ (mg/L)
NO3 (mg/L)
NH3 at 13205642 BR at Veterans 2012-2013 (mg/L)
Nitrate at 13205642 BR at Veterans 2012- (mg/L)
mg/L
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

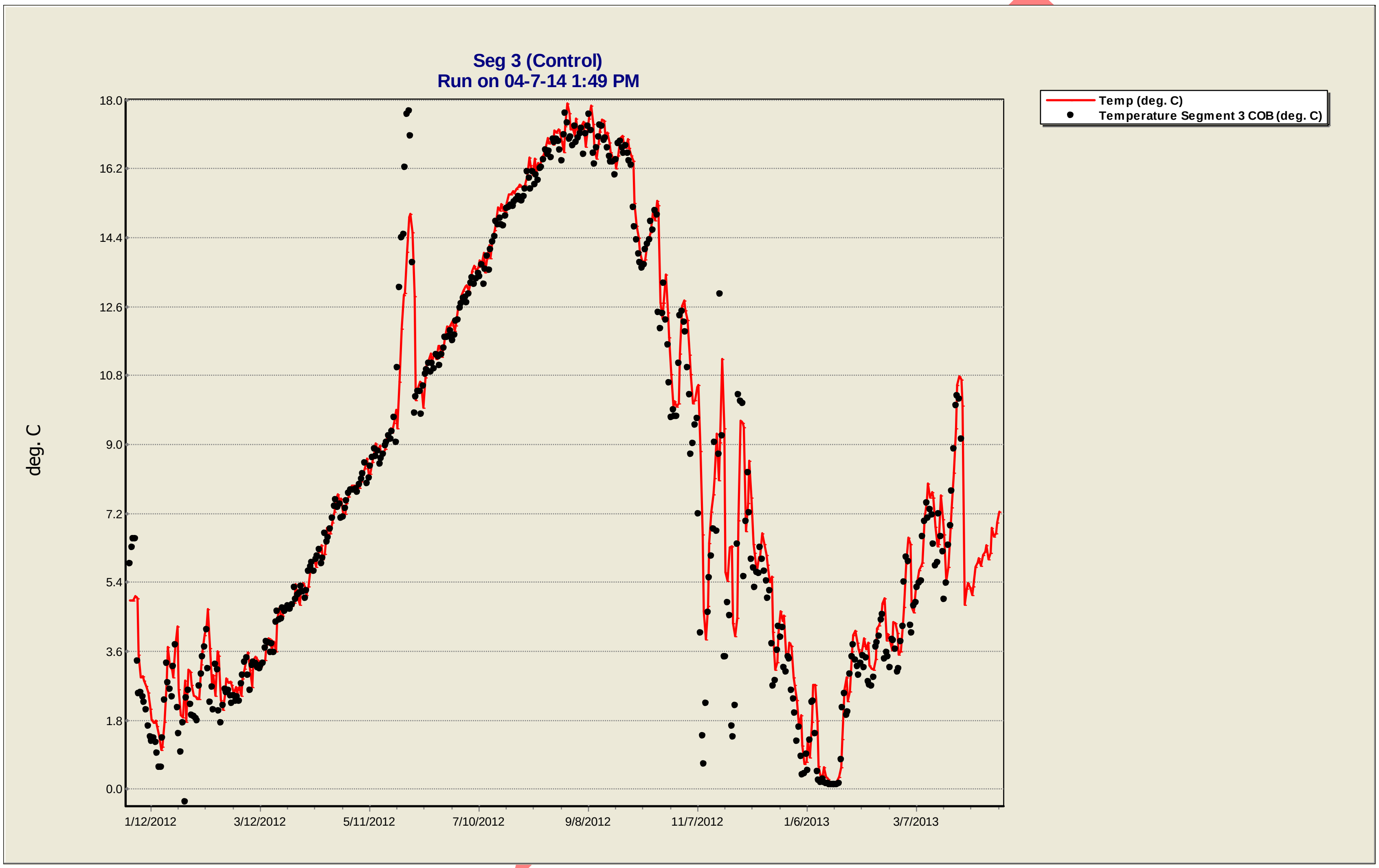

Seg 2 (Control)
Run on 04-7-14 1:48 PM
g/m2 dry
13.5
12.0
10.5
9.0
7.5
6.0
4.5
3.0
1.5
.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Peri Low-Nut Diatom (g/m2 dry)
Peri High-Nut Diatom (g/m2 dry)
Peri, Green (g/m2 dry)
Peri, Blue-Greens (g/m2 dry)
Cladophora (g/m2 dry)

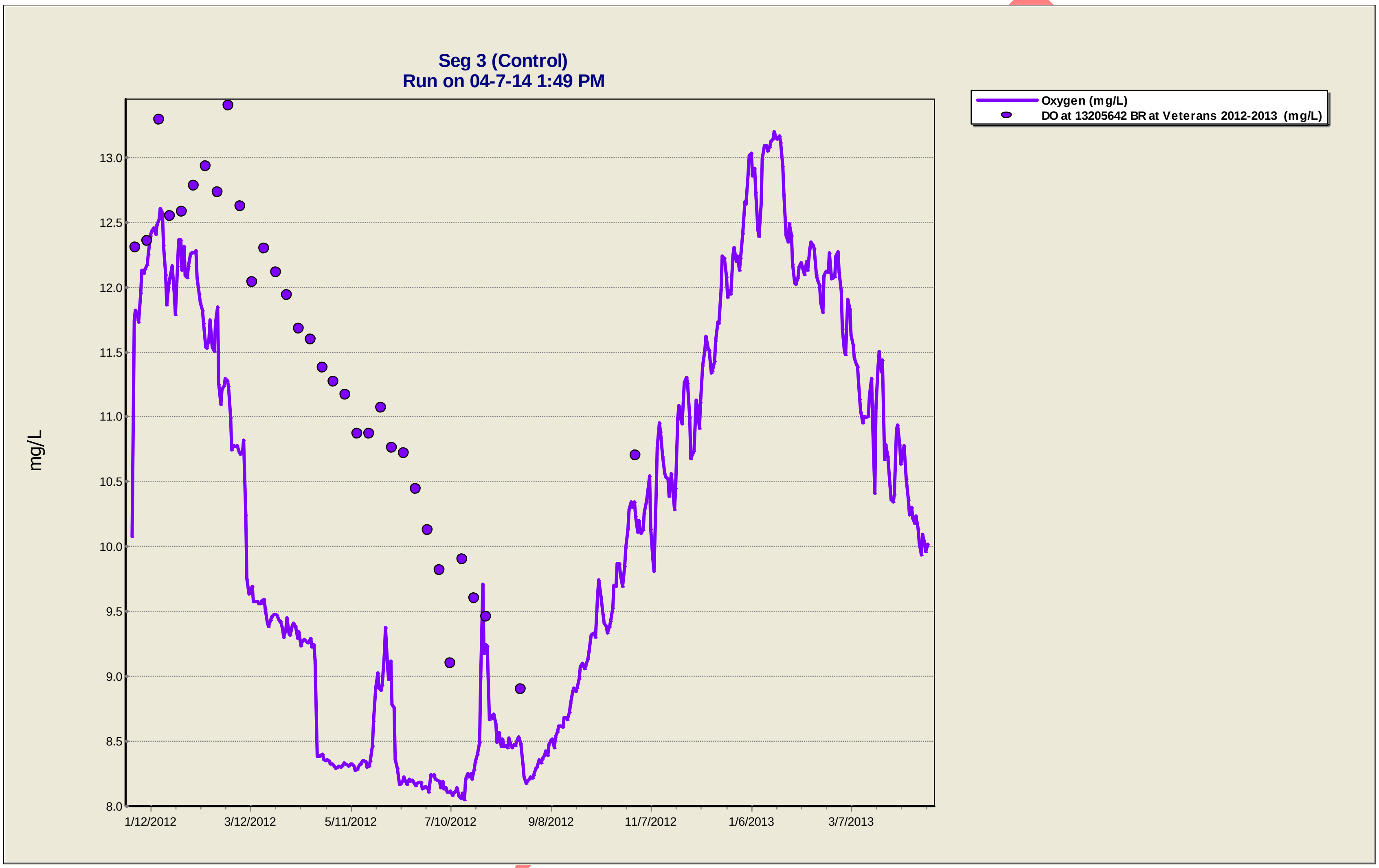

Seg 2 (Control)
Run on 04-7-14 1:48 PM
Peri. Chlorophyll (mg/sq.m)
mg/sq.m
72
65
58
50
43
36
29
22
14
7
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013


Seg 2 (Control)
Run on 04-7-14 1:48 PM
Phyto. Chlorophyll (ug/L)
ug/L
28.0
25.2
22.4
19.6
16.8
14.0
11.2
8.4
5.6
2.8
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

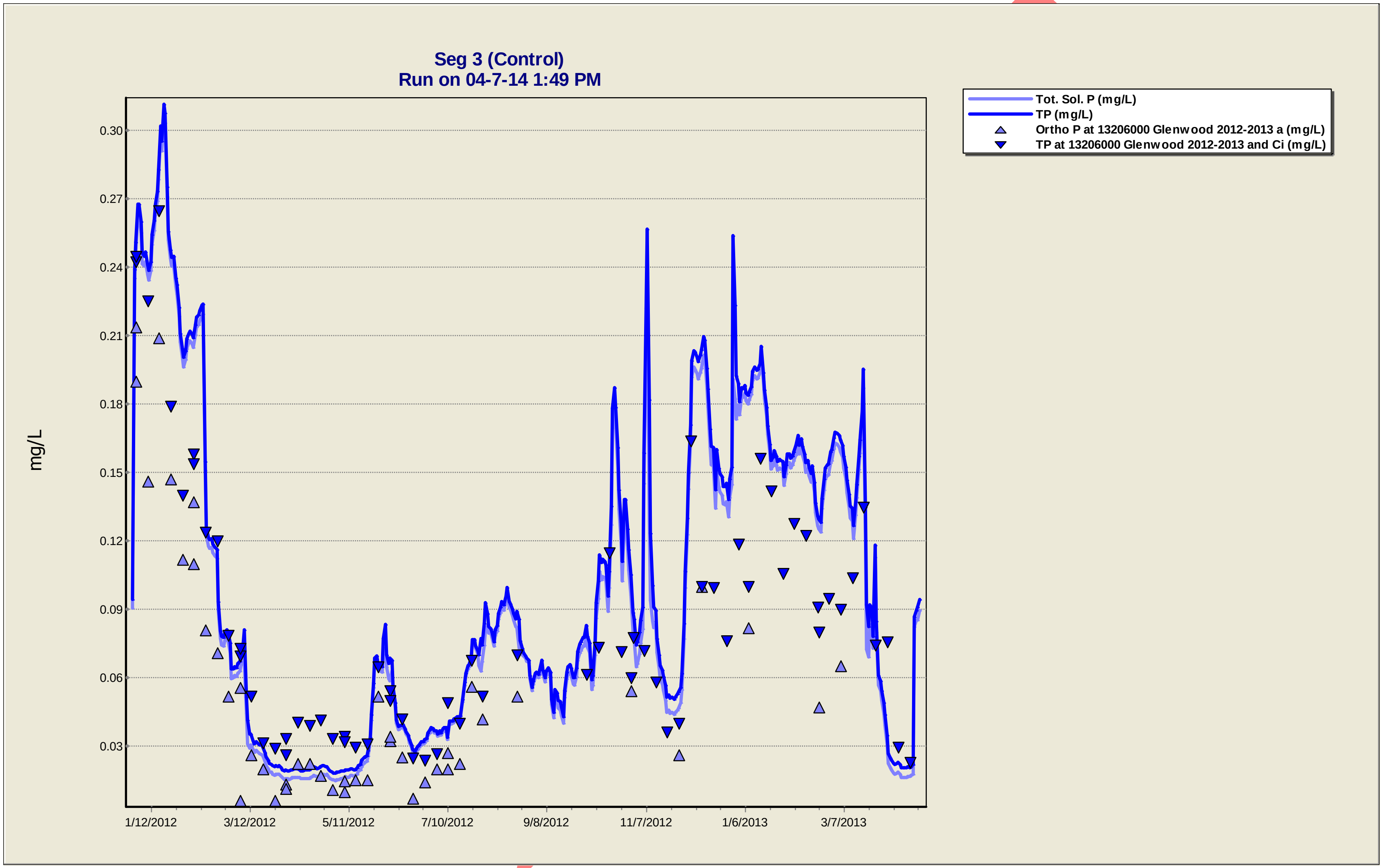
Select Model Results and Measured Data – Segment 3


Seg 3 (Control)
Run on 04-7-14 1:49 PM
Run Velocity (cm/s)
Riffle Velocity (cm/s)
Pool Velocity (cm/s)
Velocity at 13205642 BR at Veterans (cm/s)
cm/s
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

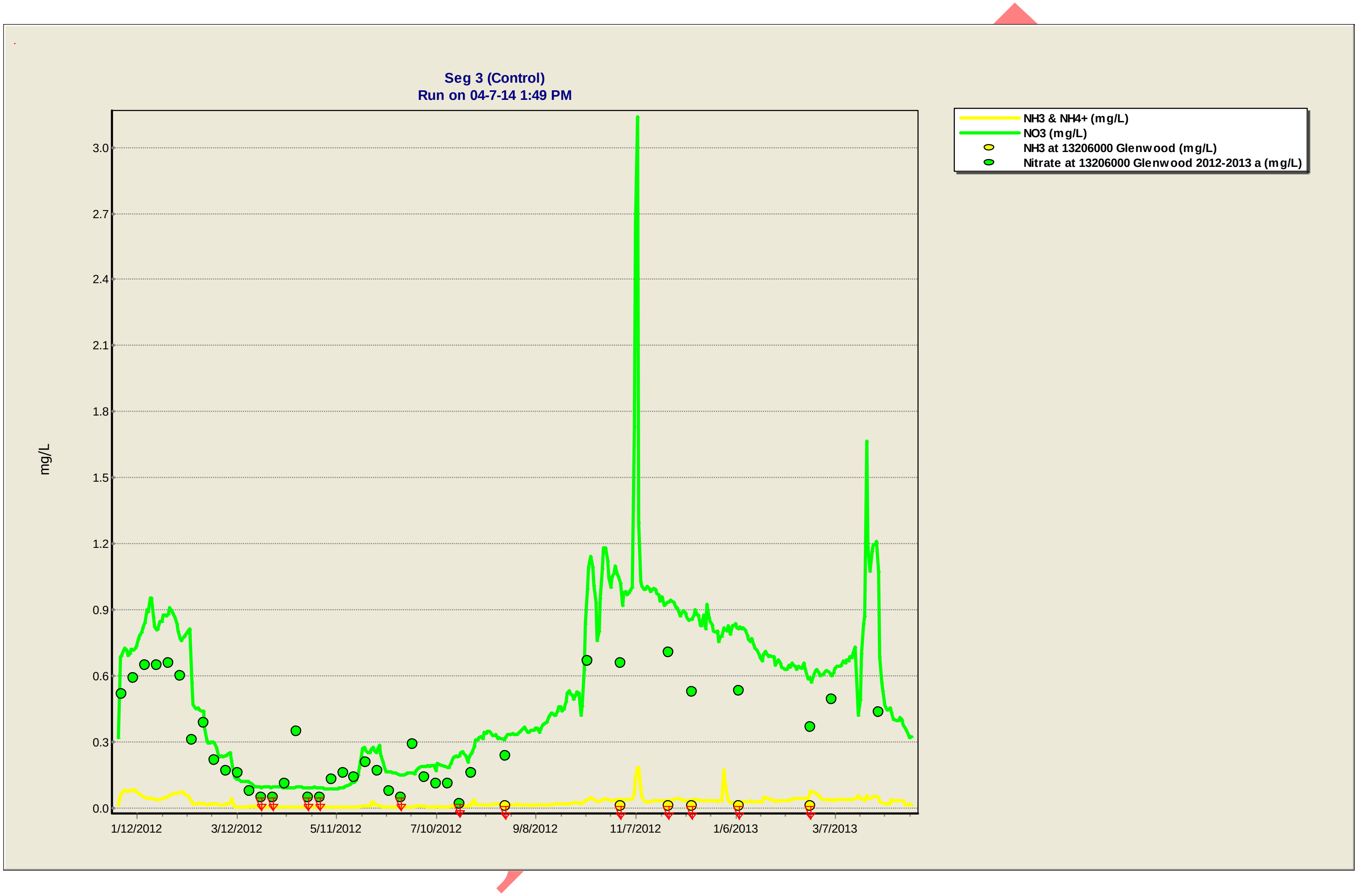

Seg 3 (Control)
Run on 04-7-14 1:49 PM
Temp (deg. C)
Temperature Segment 3 COB (deg. C)
deg. C
18.0
16.2
14.4
12.6
10.8
9.0
7.2
5.4
3.6
1.8
0.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

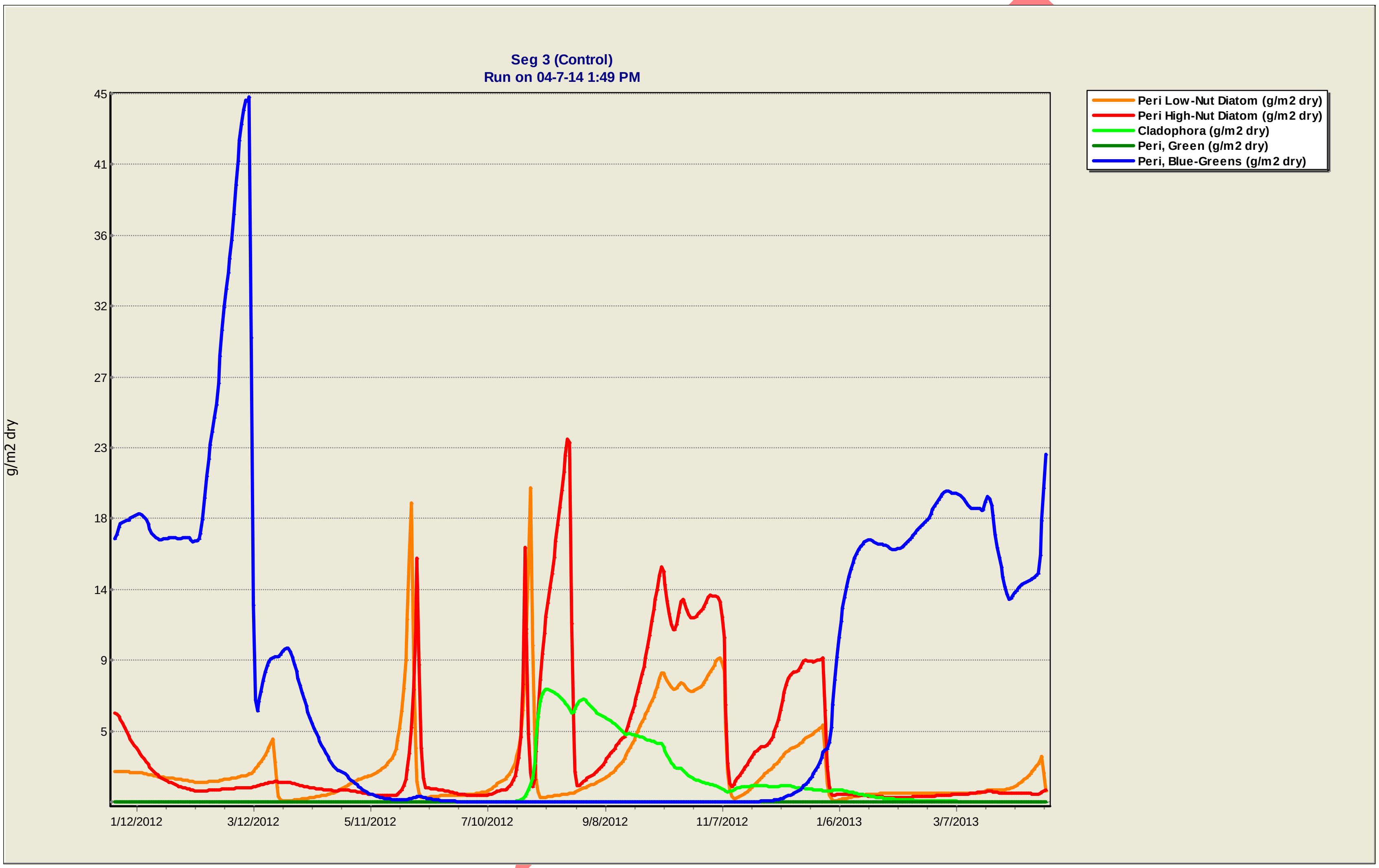


Seg 3 (Control)
Run on 04-7-14 1:49 PM
Oxygen (mg/L)
DO at 13205642 BR at Veterans 2012-2013 (mg/L)
mg/L
13.0
12.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

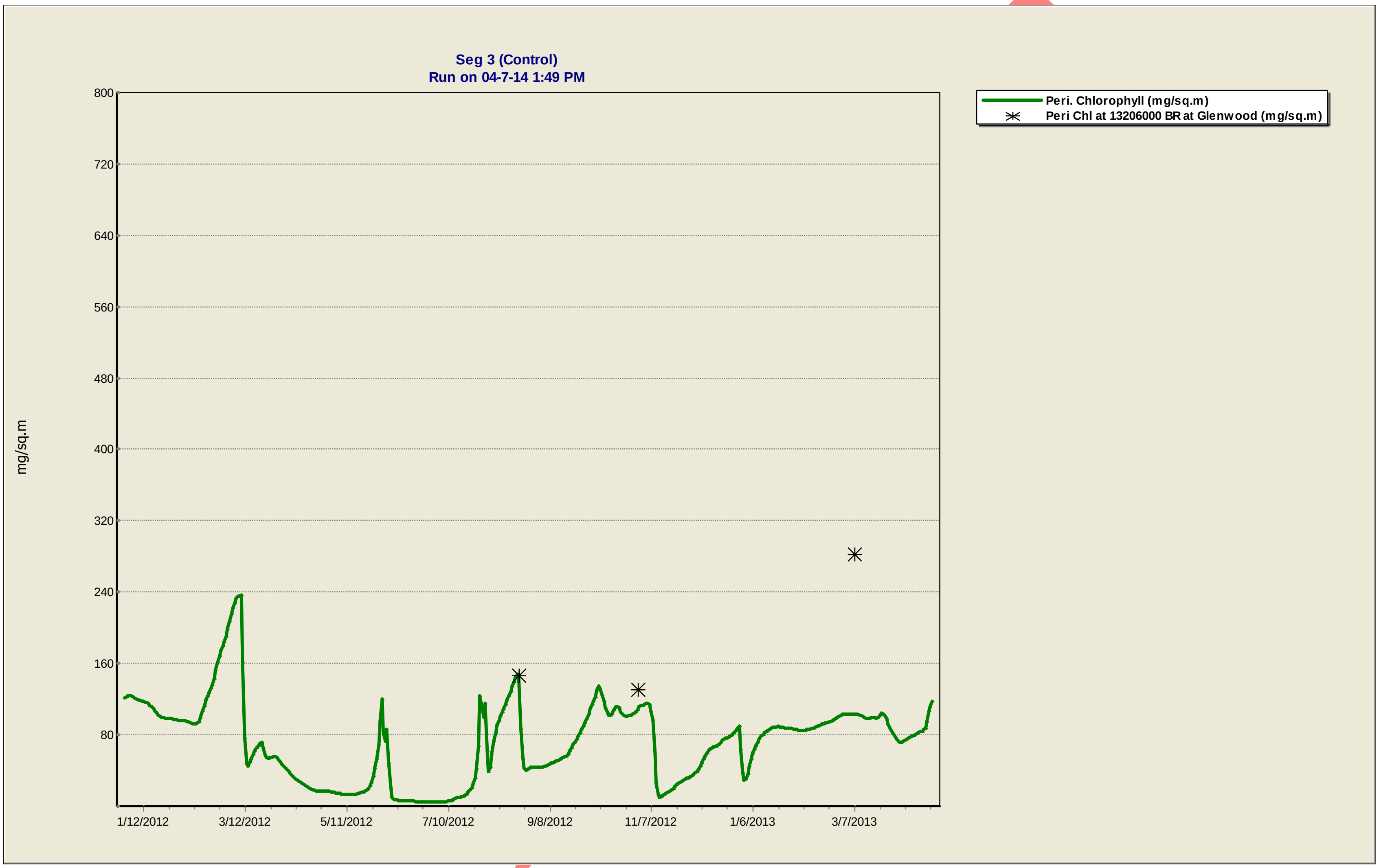


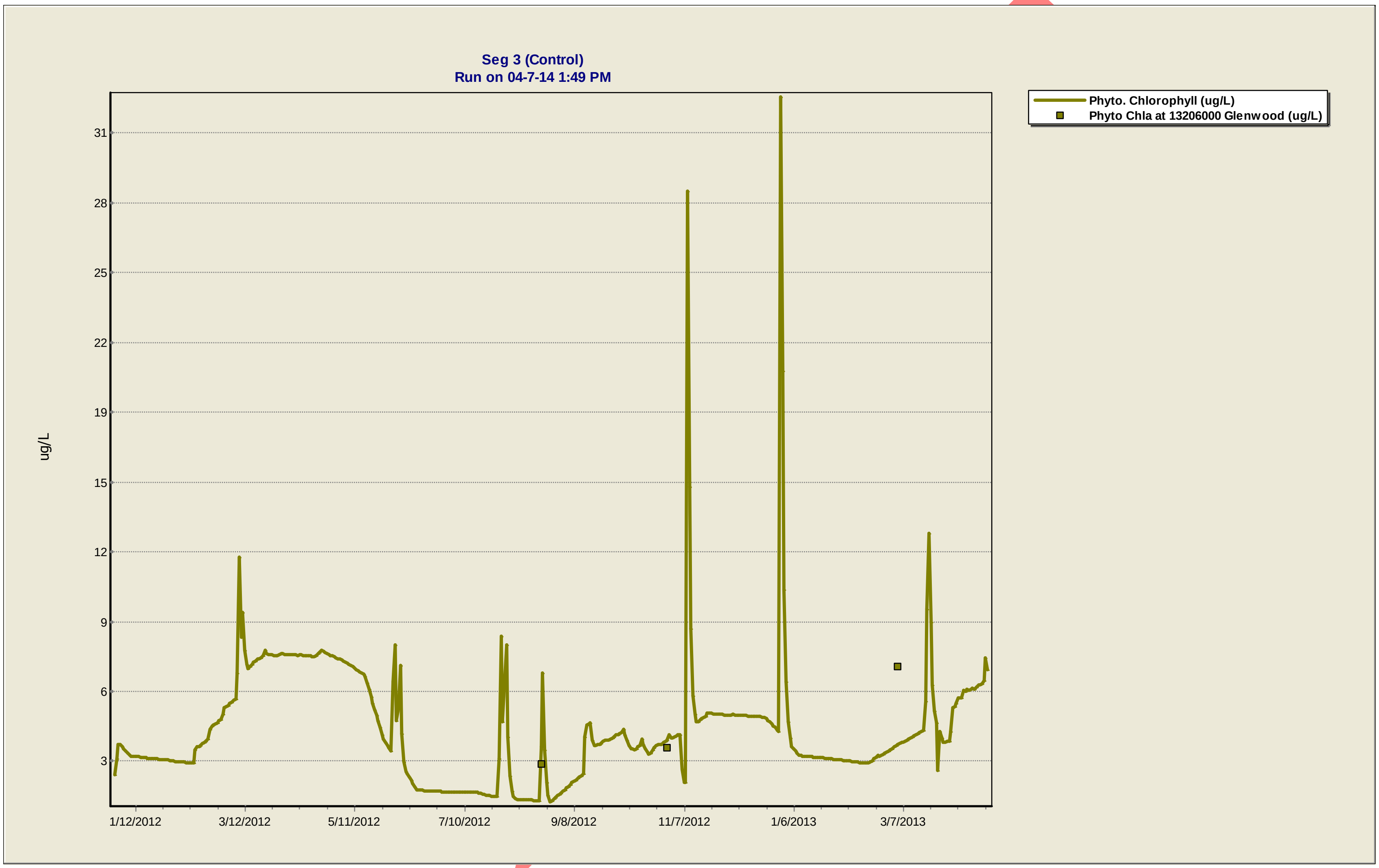
Seg 3 (Control)
Run on 04-7-14 1:49 PM
mg/L
0.30
0.27
0.24
0.21
0.18
0.15
0.12
0.09
0.06
0.03
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Tot. Sol. P (mg/L)
TP (mg/L)
Ortho P at 13206000 Glenwood 2012-2013 a (mg/L)
TP at 13206000 Glenwood 2012-2013 and Ci (mg/L)


Seg 3 (Control)
Run on 04-7-14 1:49 PM
mg/L
3.0
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
NH3 & NH4+ (mg/L)
NO3 (mg/L)
NH3 at 13206000 Glenwood (mg/L)
Nitrate at 13206000 Glenwood 2012-2013 a (mg/L)



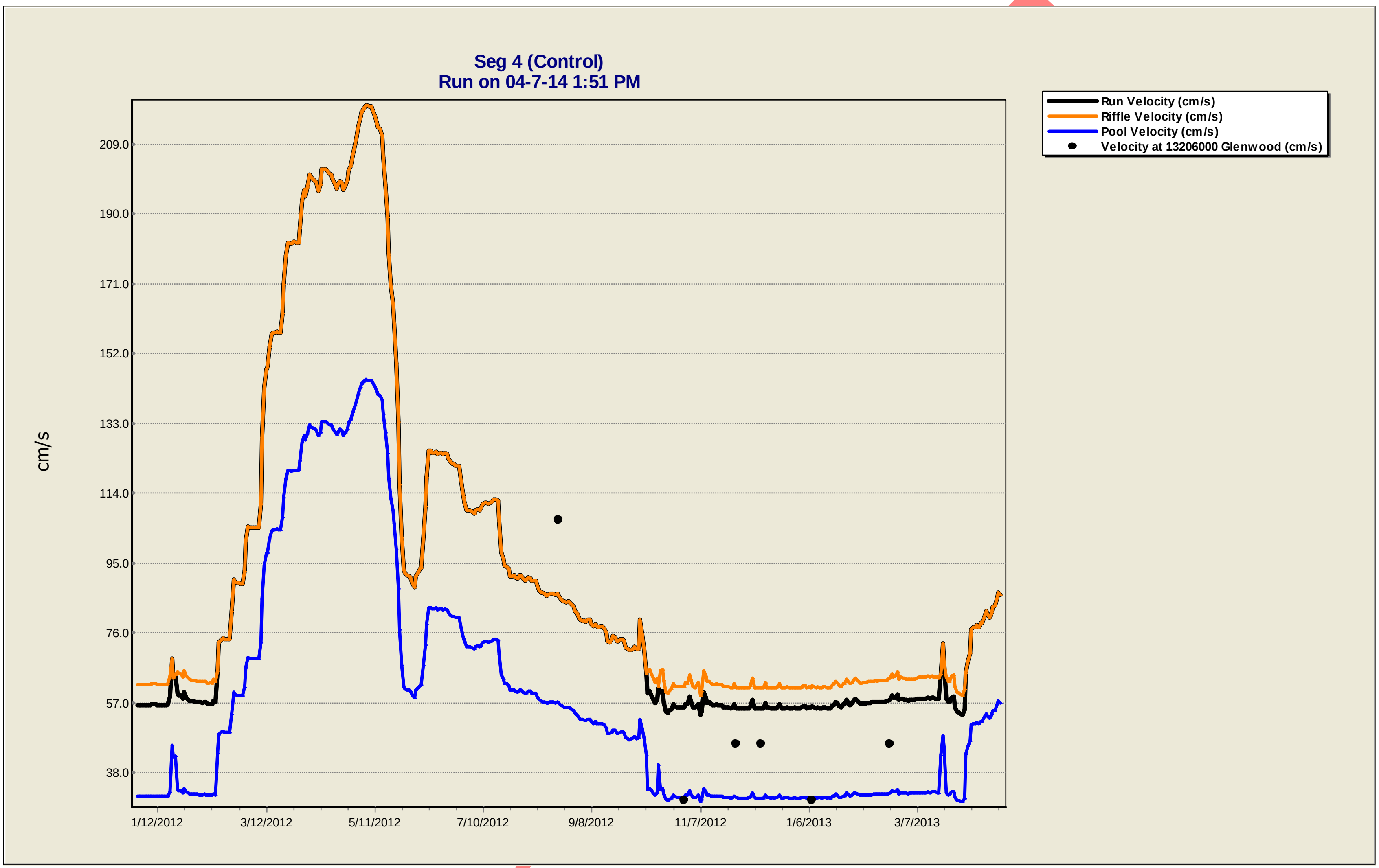
Seg 3 (Control)
Run on 04-7-14 1:49 PM
g/m2 dry
45
41
36
32
27
23
18
14
9
5
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Peri Low-Nut Diatom (g/m2 dry)
Peri High-Nut Diatom (g/m2 dry)
Cladophora (g/m2 dry)
Peri, Green (g/m2 dry)
Peri, Blue-Greens (g/m2 dry)

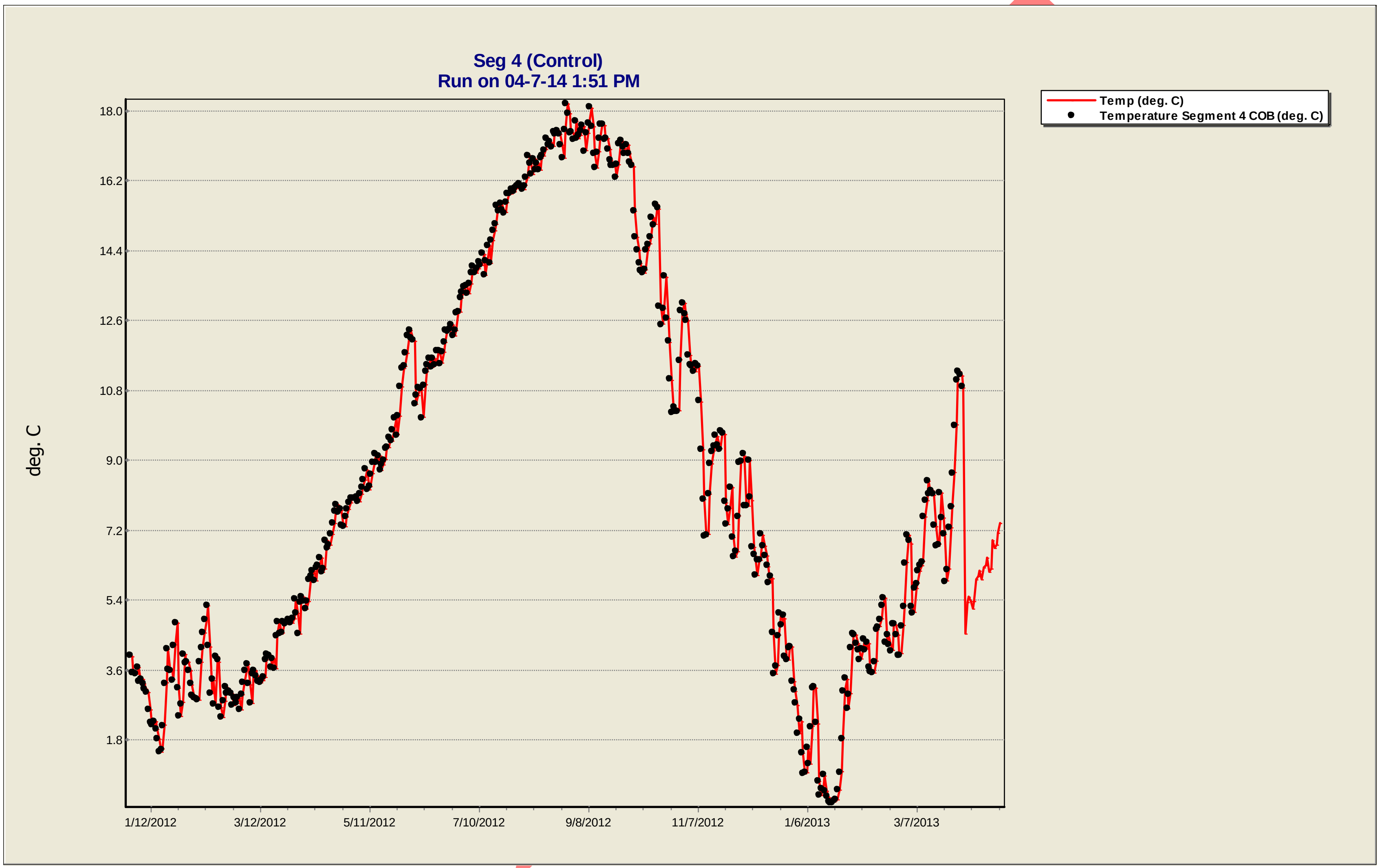

Seg 3 (Control)
Run on 04-7-14 1:49 PM
Peri. Chlorophyll (mg/sq.m)
Peri Chl at 13206000 BR at Glenwood (mg/sq.m)
mg/sq.m
800
720
640
560
480
400
320
240
160
80
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

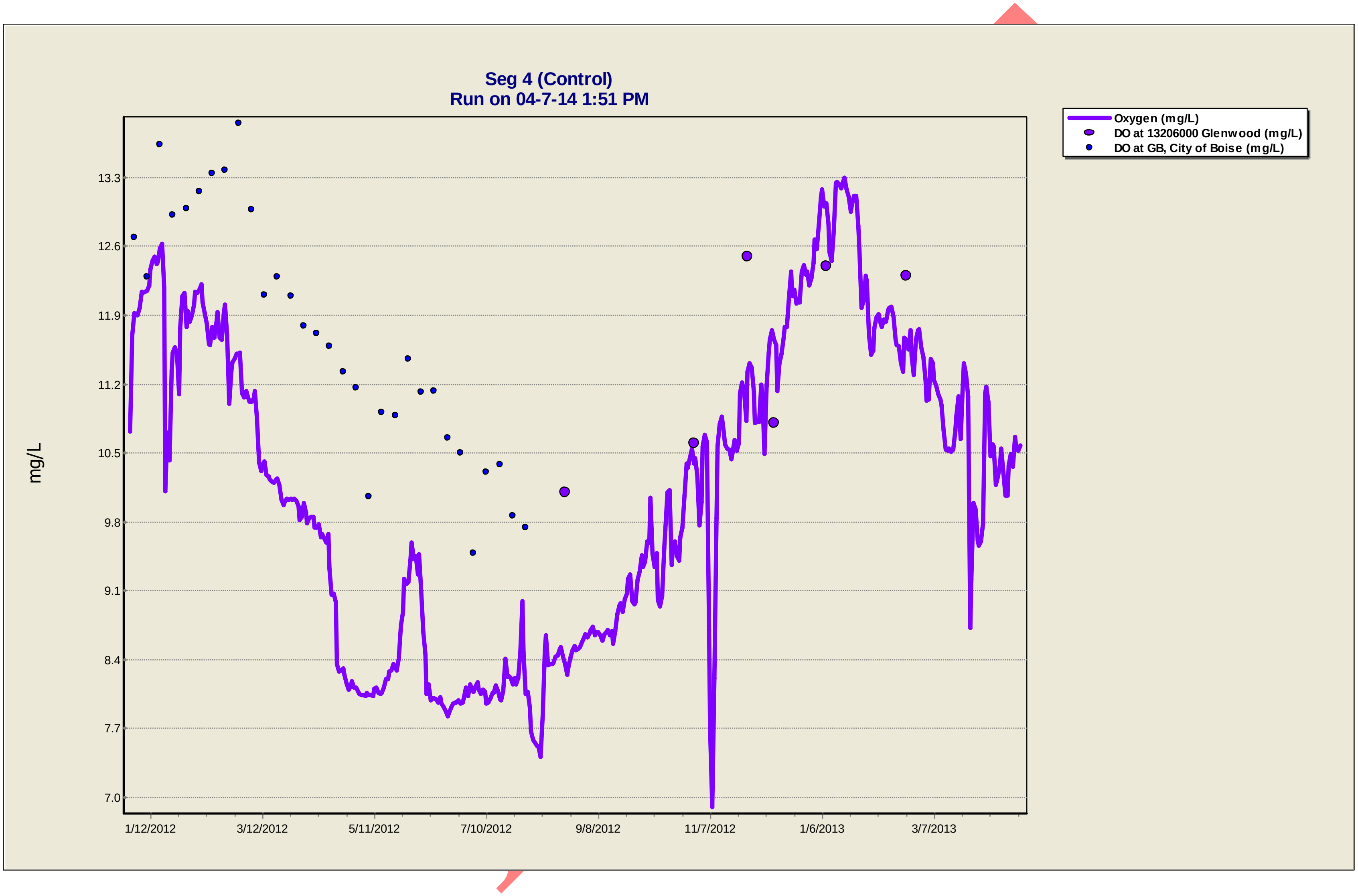


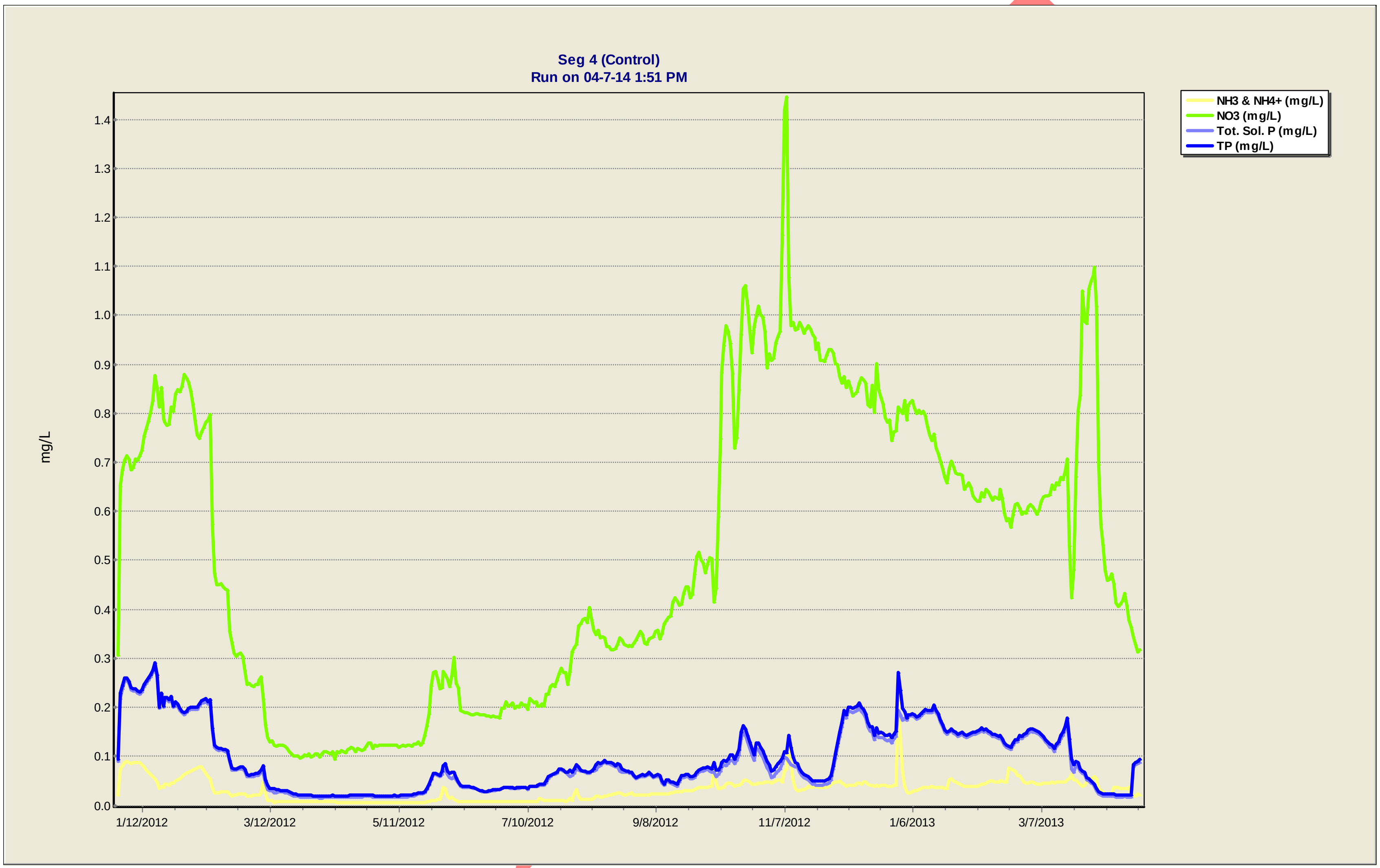
Seg 3 (Control)
Run on 04-7-14 1:49 PM
ug/L
31
28
25
22
19
15
12
9
6
3
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Phyto. Chlorophyll (ug/L)
Phyto Chla at 13206000 Glenwood (ug/L)

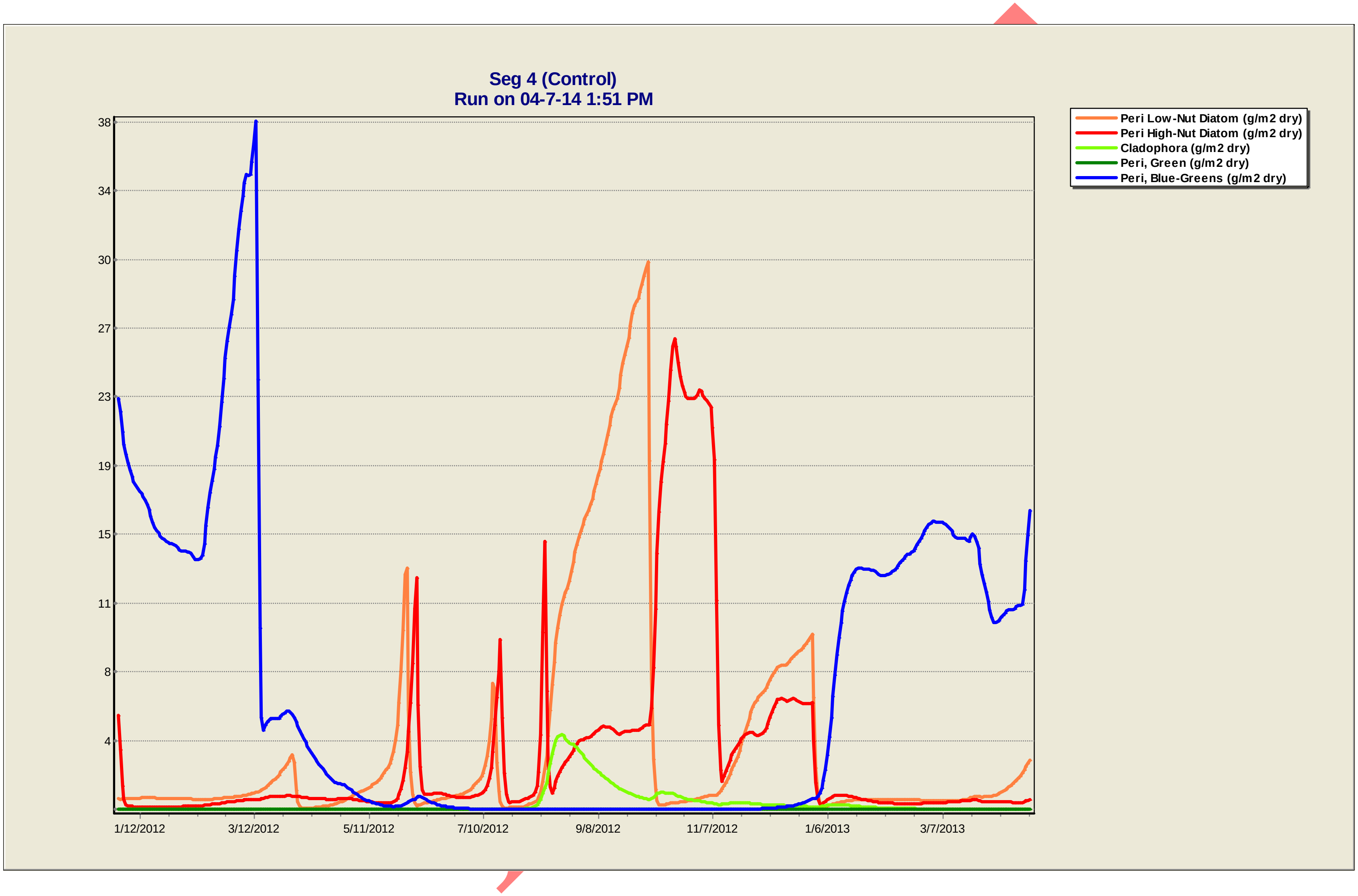
Select Model Results and Measured Data – Segment 4

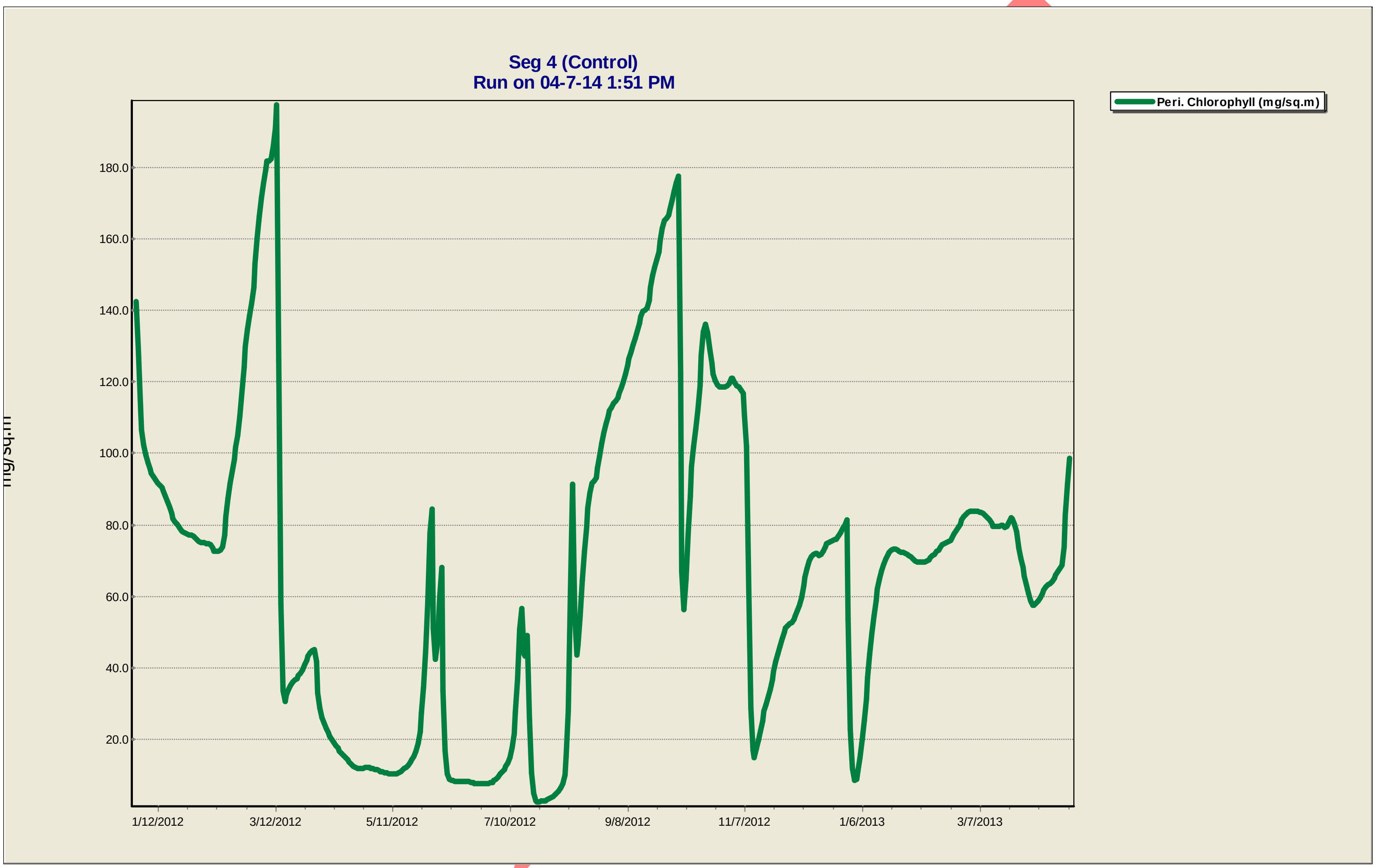

Seg 4 (Control)
Run on 04-7-14 1:51 PM
Run Velocity (cm/s)
Riffle Velocity (cm/s)
Pool Velocity (cm/s)
Velocity at 13206000 Glenwood (cm/s)
cm/s
209.0
190.0
171.0
152.0
133.0
114.0
95.0
76.0
57.0
38.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

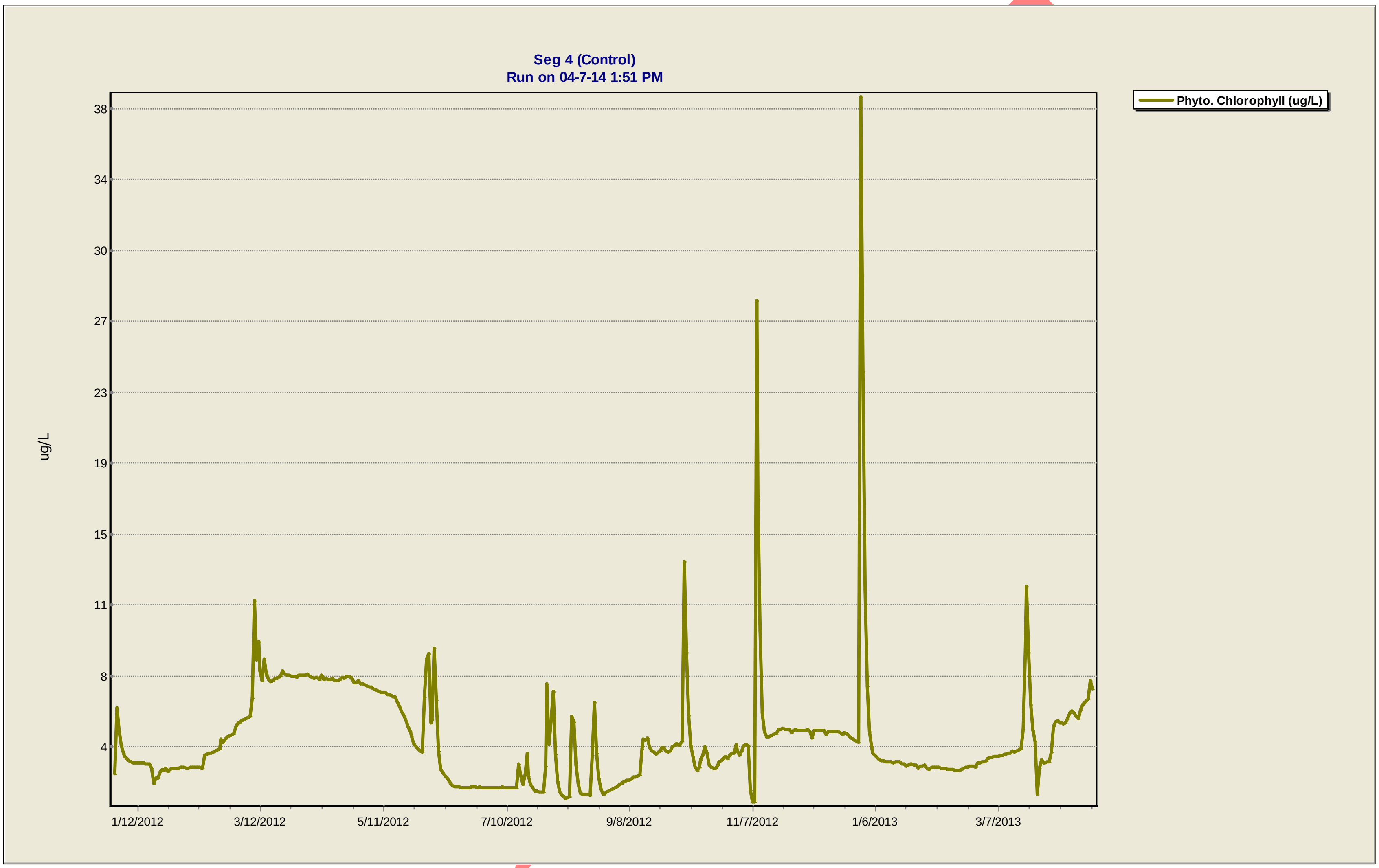

Seg 4 (Control)
Run on 04-7-14 1:51 PM
Temp (deg. C)
Temperature Segment 4 COB (deg. C)
deg. C
18.0
16.2
14.4
12.6
10.8
9.0
7.2
5.4
3.6
1.8
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013


Seg 4 (Control)
Run on 04-7-14 1:51 PM
Oxygen (mg/L)
DO at 13206000 Glenwood (mg/L)
DO at GB, City of Boise (mg/L)
mg/L
13.3
12.6
11.9
11.2
10.5
9.8
9.1
8.4
7.7
7.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013


Seg 4 (Control)
Run on 04-7-14 1:51 PM
mg/L
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
NH3 & NH4+ (mg/L)
NO3 (mg/L)
Tot. Sol. P (mg/L)
TP (mg/L)

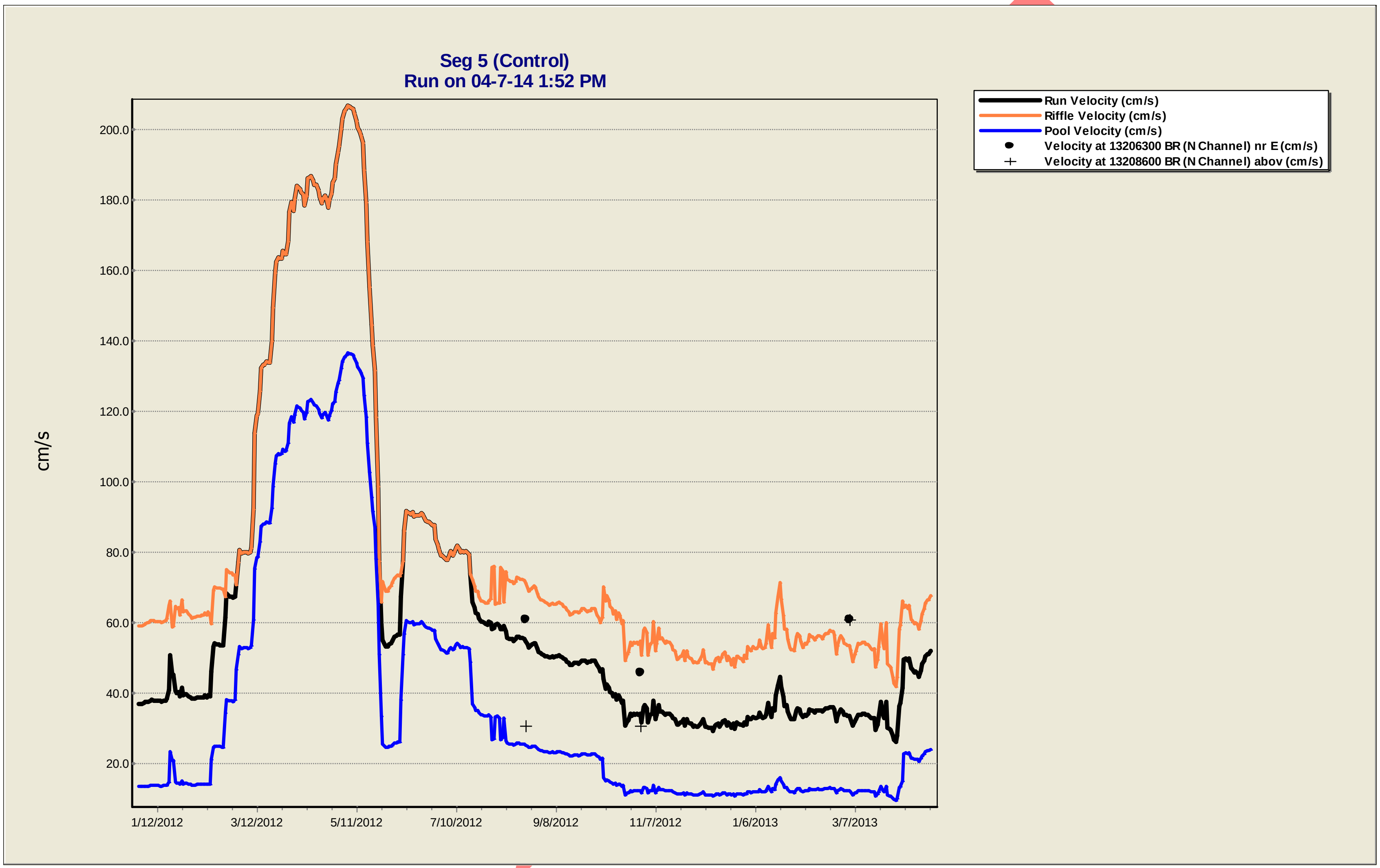

Seg 4 (Control)
Run on 04-7-14 1:51 PM
Peri Low-Nut Diatom (g/m2 dry)
Peri High-Nut Diatom (g/m2 dry)
Cladophora (g/m2 dry)
Peri, Green (g/m2 dry)
Peri, Blue-Greens (g/m2 dry)
38
34
30
27
23
19
15
11
8
4
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

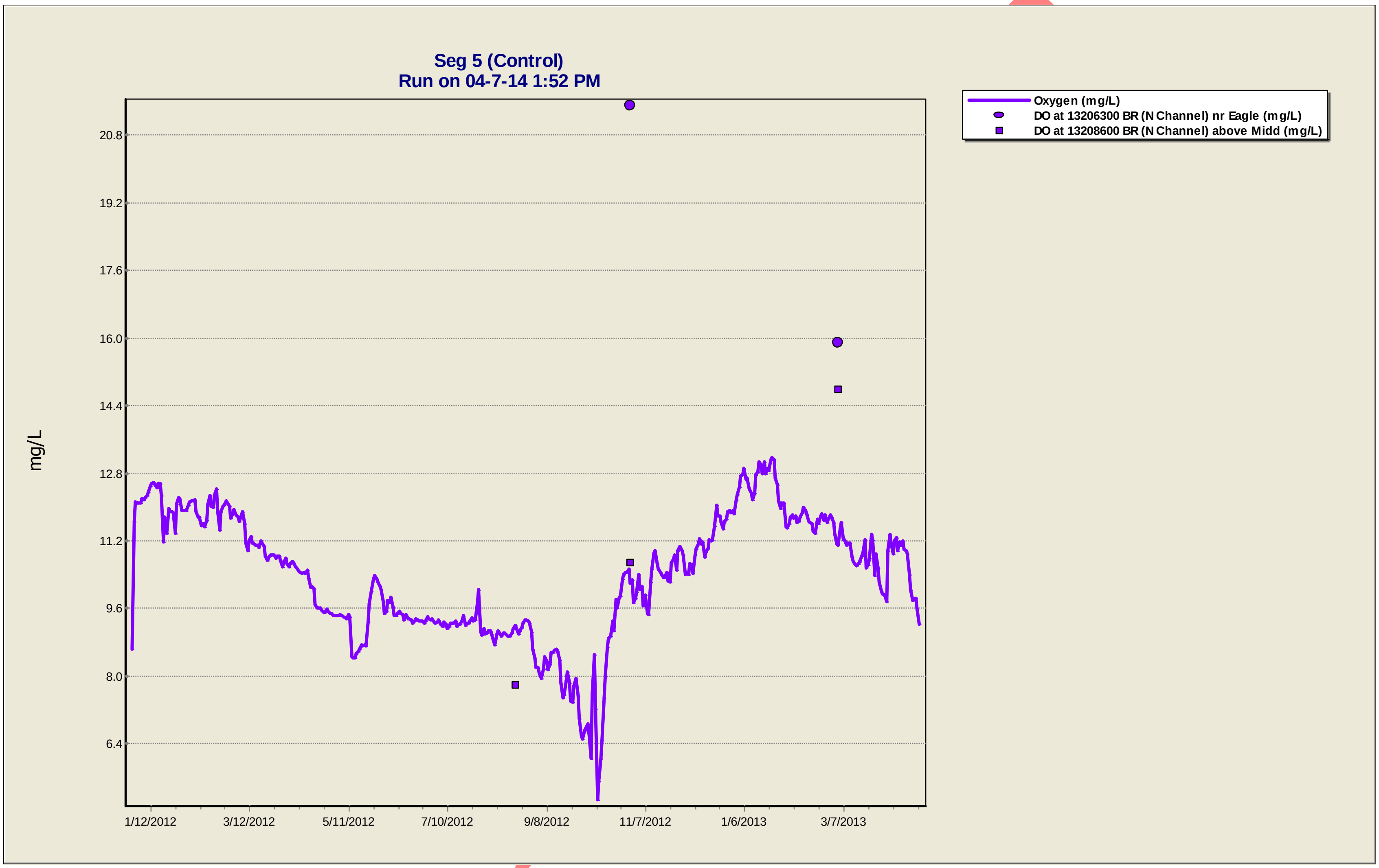

Seg 4 (Control)
Run on 04-7-14 1:51 PM
Peri. Chlorophyll (mg/sq.m)
mg/sq.m
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

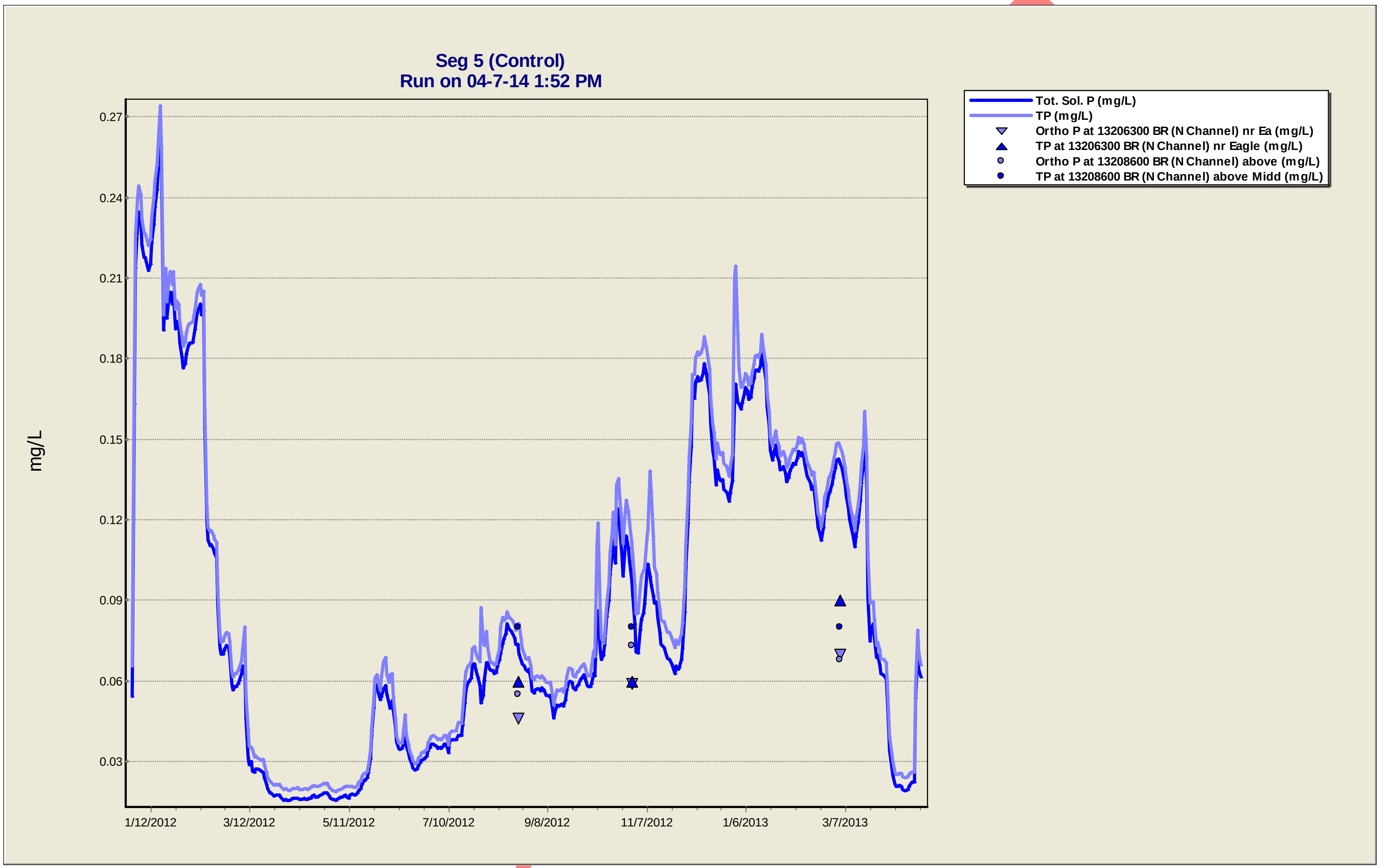


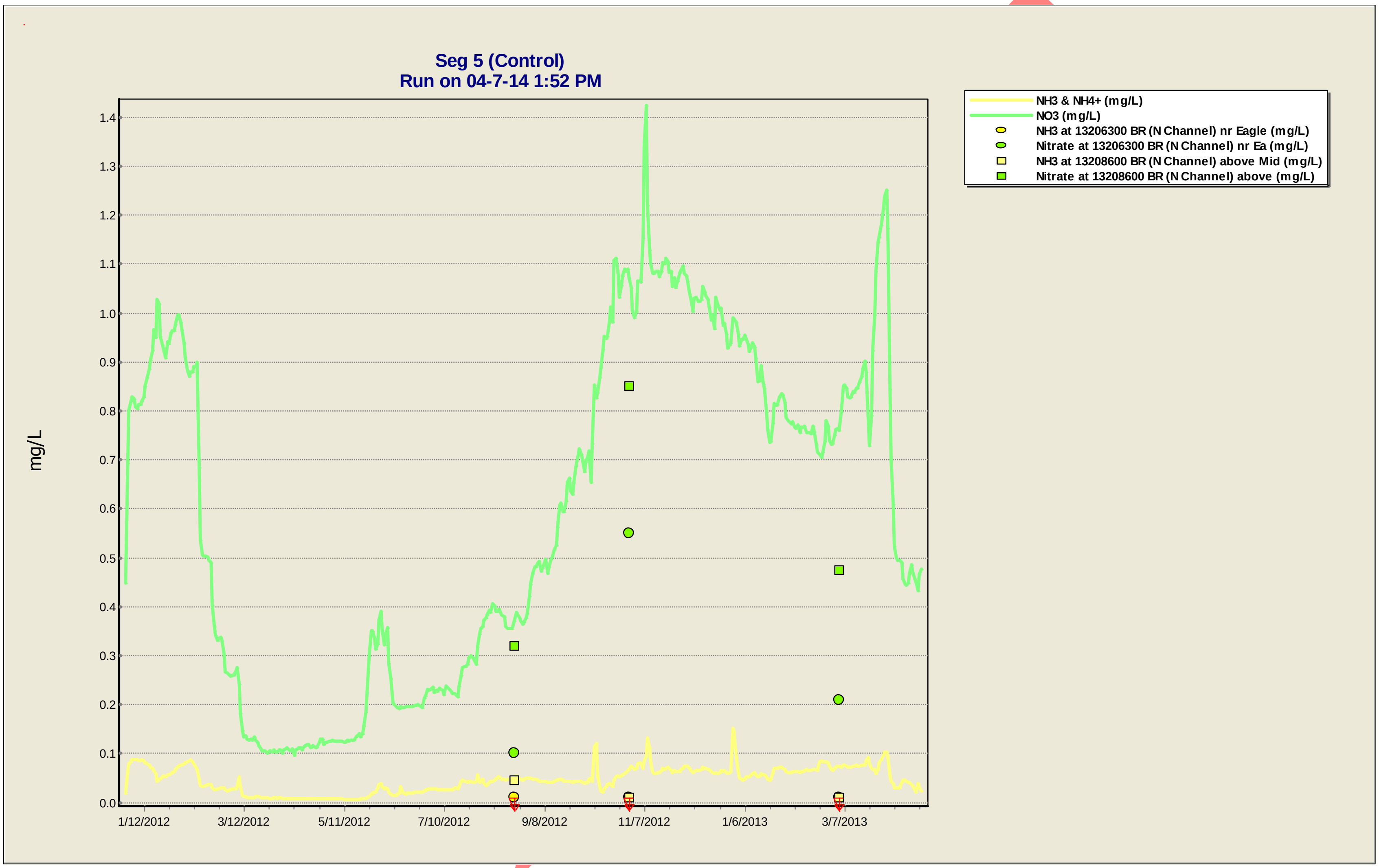
Seg 4 (Control)
Run on 04-7-14 1:51 PM
Phyto. Chlorophyll (ug/L)
ug/L
38
34
30
27
23
19
15
11
8
4
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

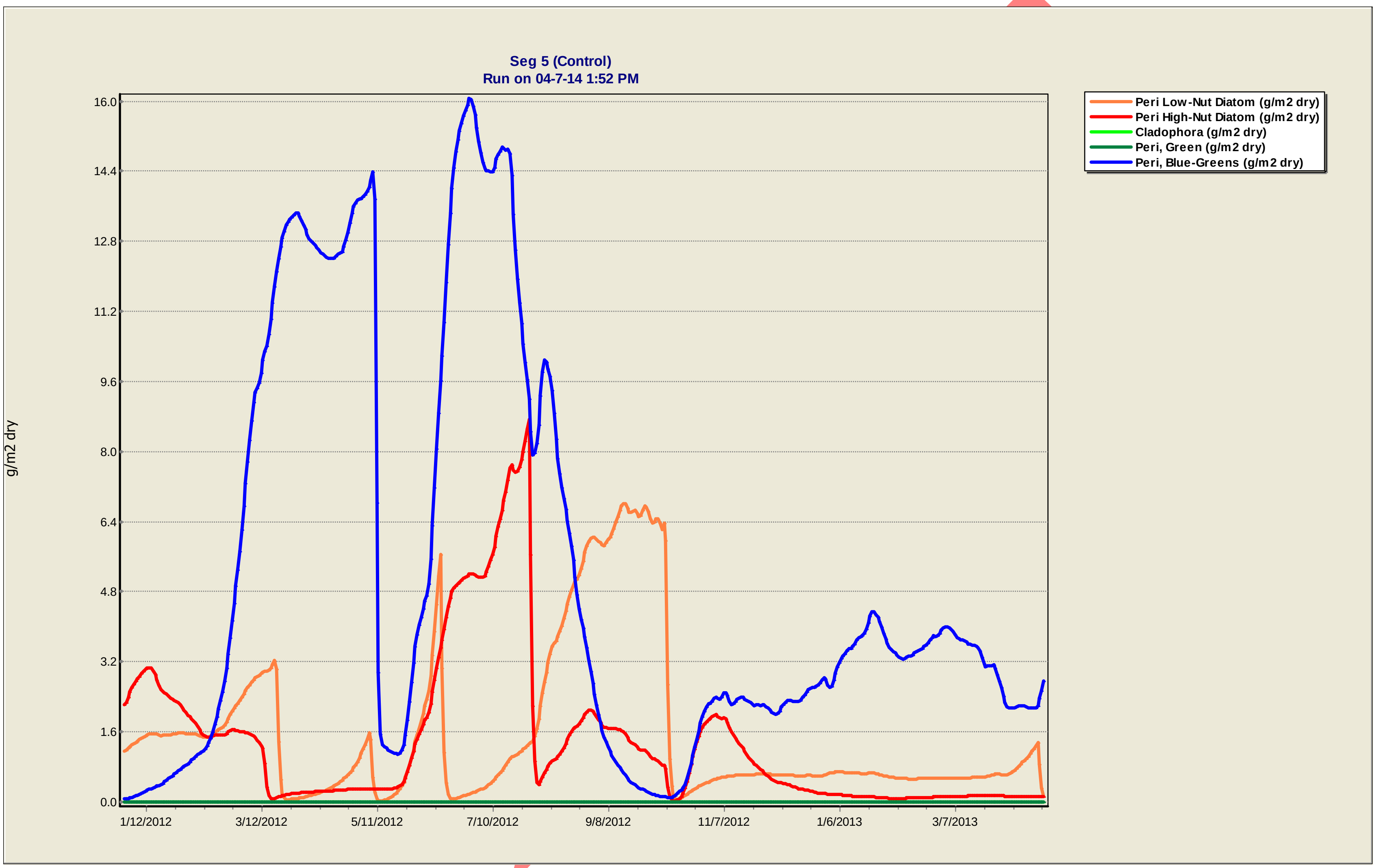
Select Model Results and Measured Data – Segment 5

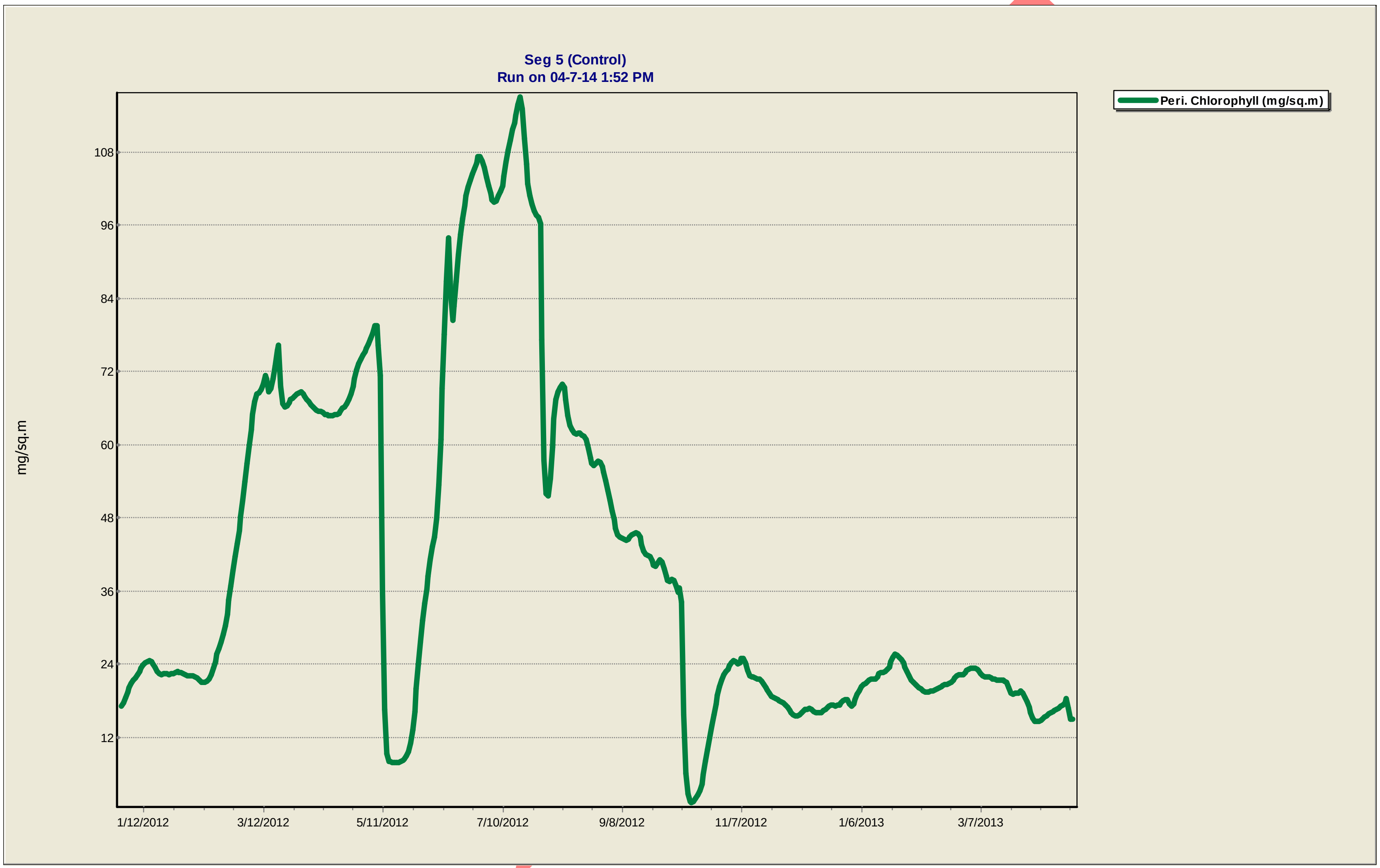

Seg 5 (Control)
Run on 04-7-14 1:52 PM
cm/s
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Run Velocity (cm/s)
Riffle Velocity (cm/s)
Pool Velocity (cm/s)
Velocity at 13206300 BR (N Channel) nr E (cm/s)
Velocity at 13208600 BR (N Channel) abov (cm/s)

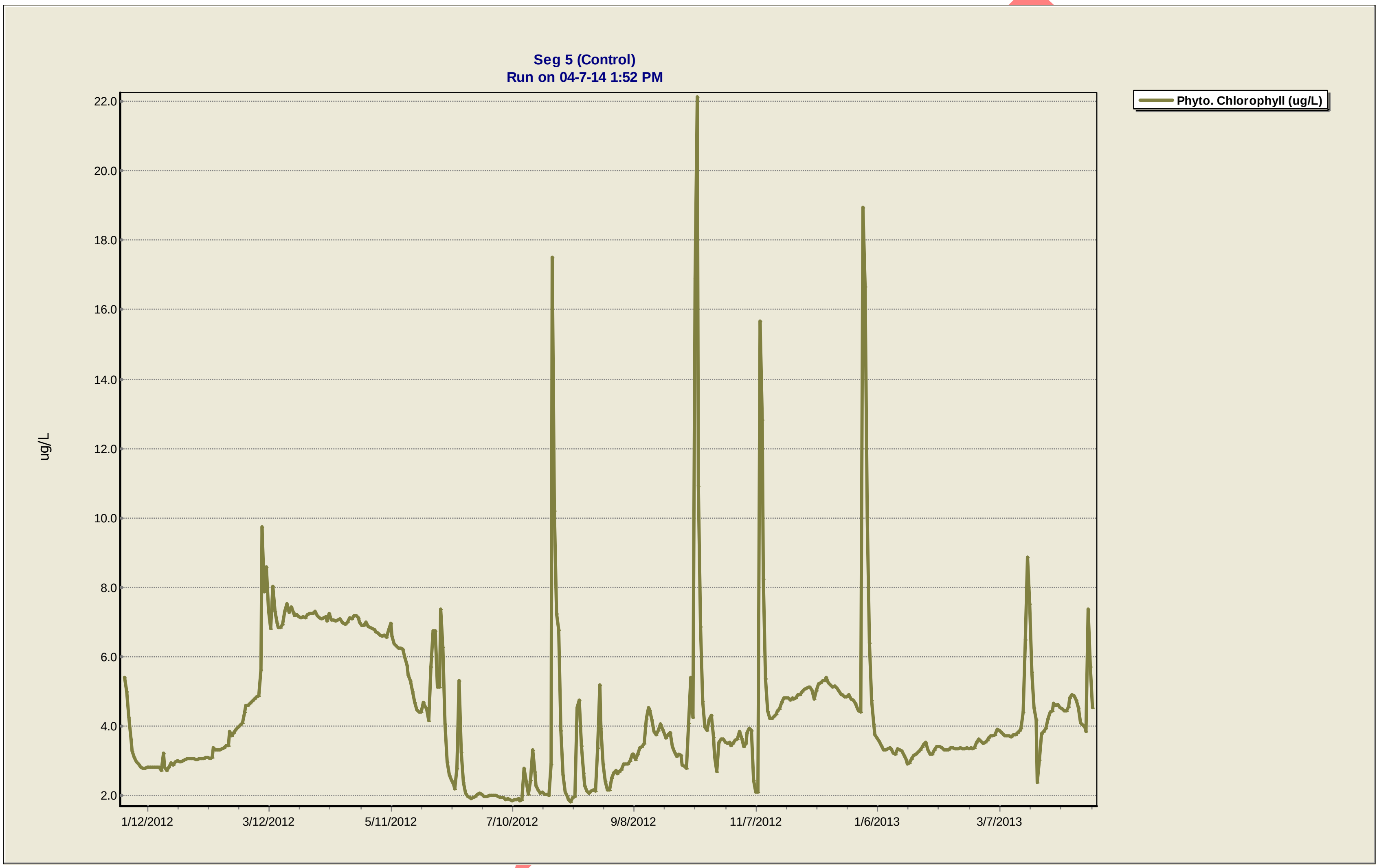

Seg 5 (Control)
Run on 04-7-14 1:52 PM
Oxygen (mg/L)
DO at 13206300 BR (N Channel) nr Eagle (mg/L)
DO at 13208600 BR (N Channel) above Midd (mg/L)
mg/L
20.8
19.2
17.6
16.0
14.4
12.8
11.2
9.6
8.0
6.4
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013


Seg 5 (Control)
Run on 04-7-14 1:52 PM
mg/L
0.27
0.24
0.21
0.18
0.15
0.12
0.09
0.06
0.03
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Tot. Sol. P (mg/L)
TP (mg/L)
Ortho P at 13206300 BR (N Channel) nr Ea (mg/L)
TP at 13206300 BR (N Channel) nr Eagle (mg/L)
Ortho P at 13208600 BR (N Channel) above (mg/L)
TP at 13208600 BR (N Channel) above Midd (mg/L)

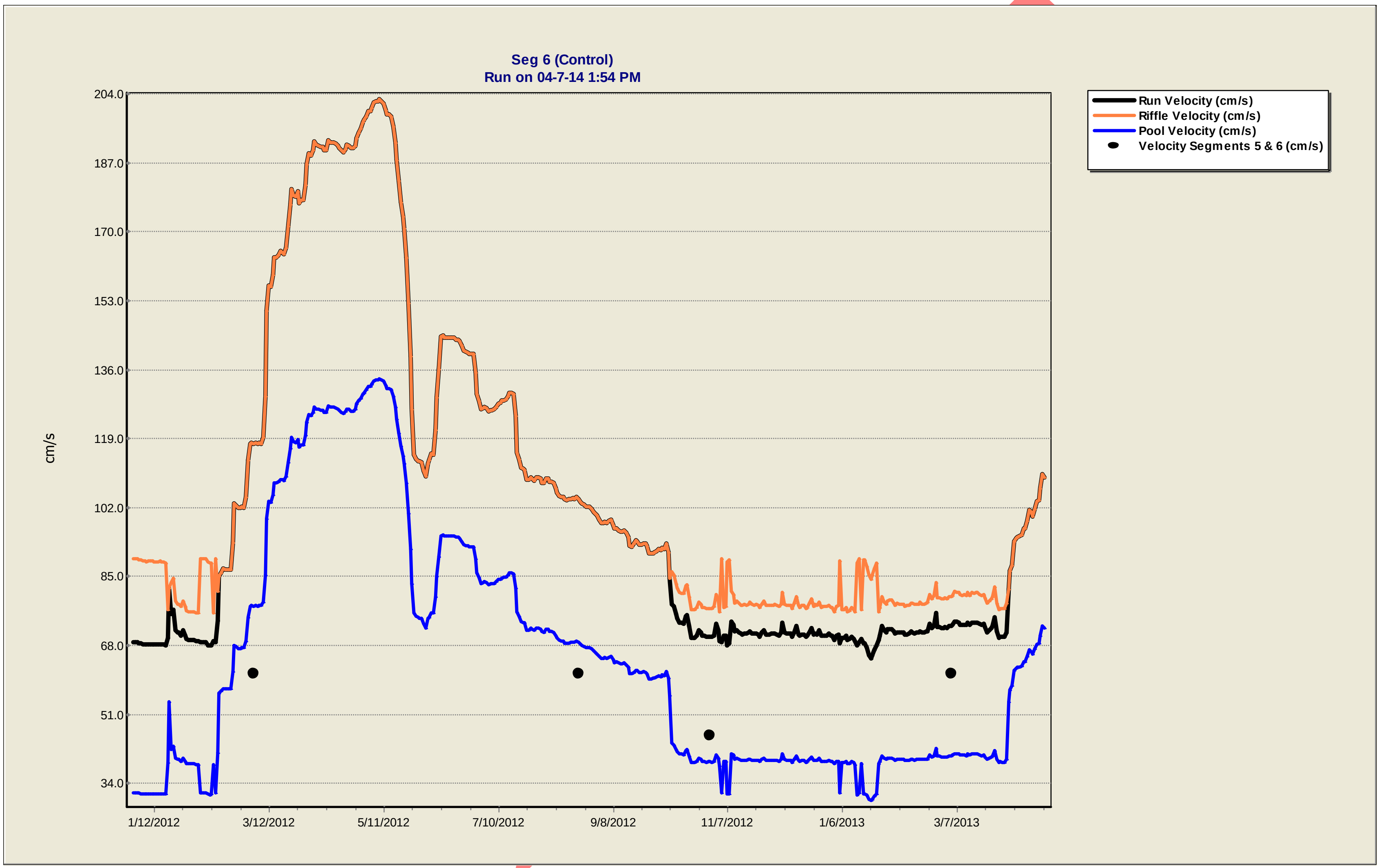

Seg 5 (Control)
Run on 04-7-14 1:52 PM
mg/L
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
NH3 & NH4+ (mg/L)
NO3 (mg/L)
NH3 at 13206300 BR (N Channel) nr Eagle (mg/L)
Nitrate at 13206300 BR (N Channel) nr Ea (mg/L)
NH3 at 13208600 BR (N Channel) above Mid (mg/L)
Nitrate at 13208600 BR (N Channel) above (mg/L)


Seg 5 (Control)
Run on 04-7-14 1:52 PM
16.0
14.4
12.8
11.2
9.6
8.0
6.4
4.8
3.2
1.6
0.0
g/m2 dry
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Peri Low-Nut Diatom (g/m2 dry)
Peri High-Nut Diatom (g/m2 dry)
Cladophora (g/m2 dry)
Peri, Green (g/m2 dry)
Peri, Blue-Greens (g/m2 dry)


Seg 5 (Control)
Run on 04-7-14 1:52 PM
Peri. Chlorophyll (mg/sq.m)
mg/sq.m
108
96
84
72
60
48
36
24
12
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

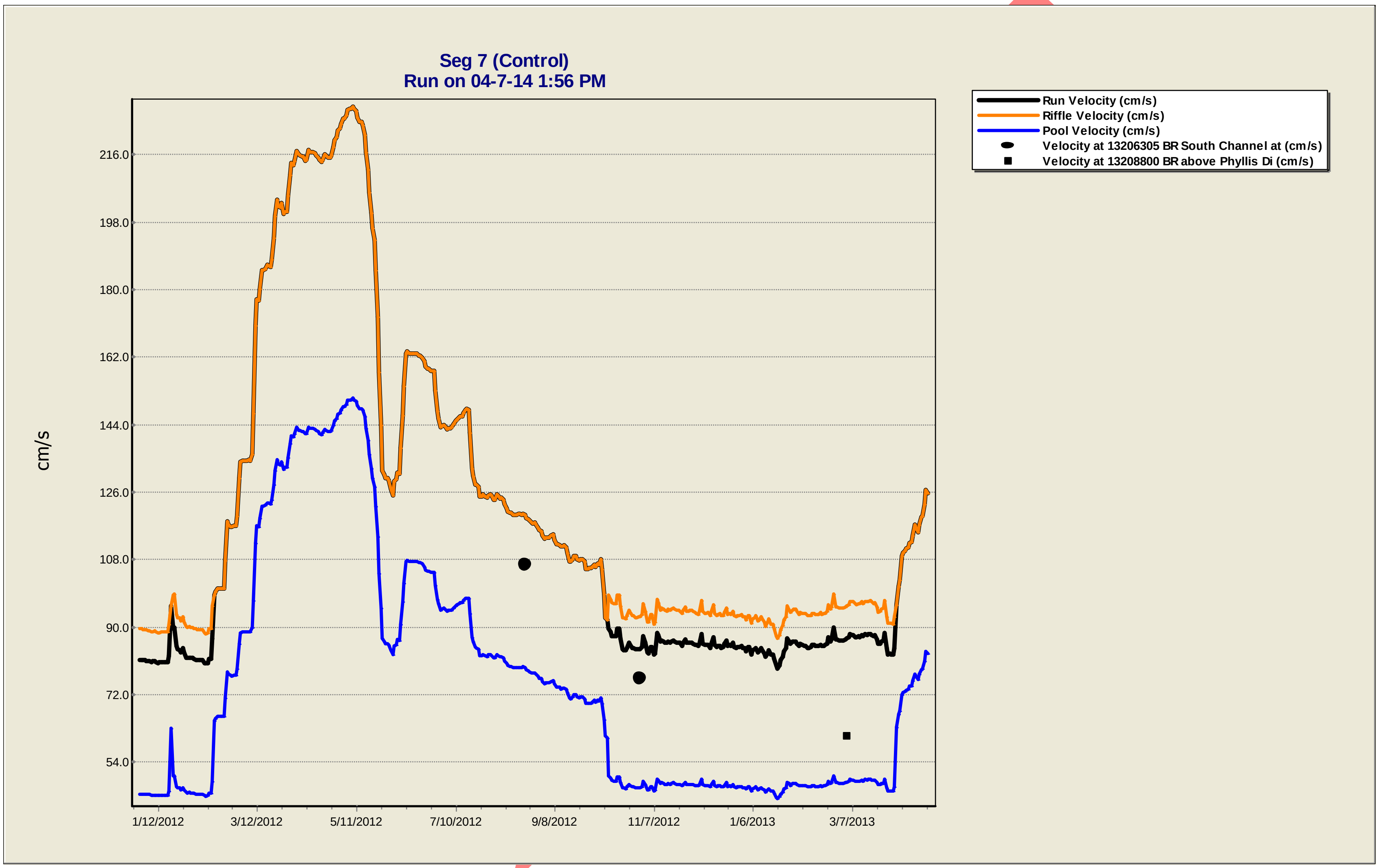

Seg 5 (Control)
Run on 04-7-14 1:52 PM
Phyto. Chlorophyll (ug/L)
ug/L
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

Select Model Results and Measured Data – Segment 6

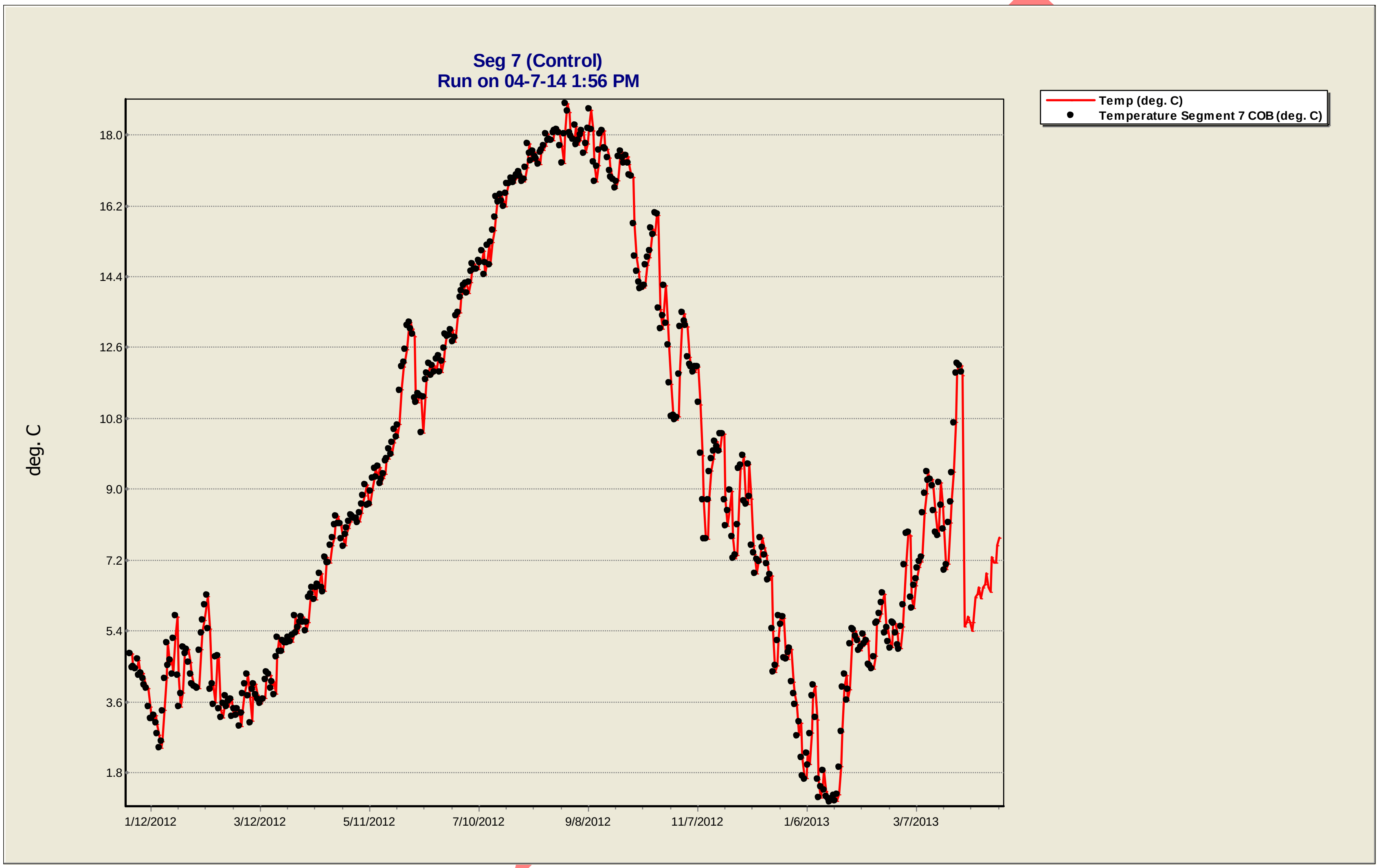


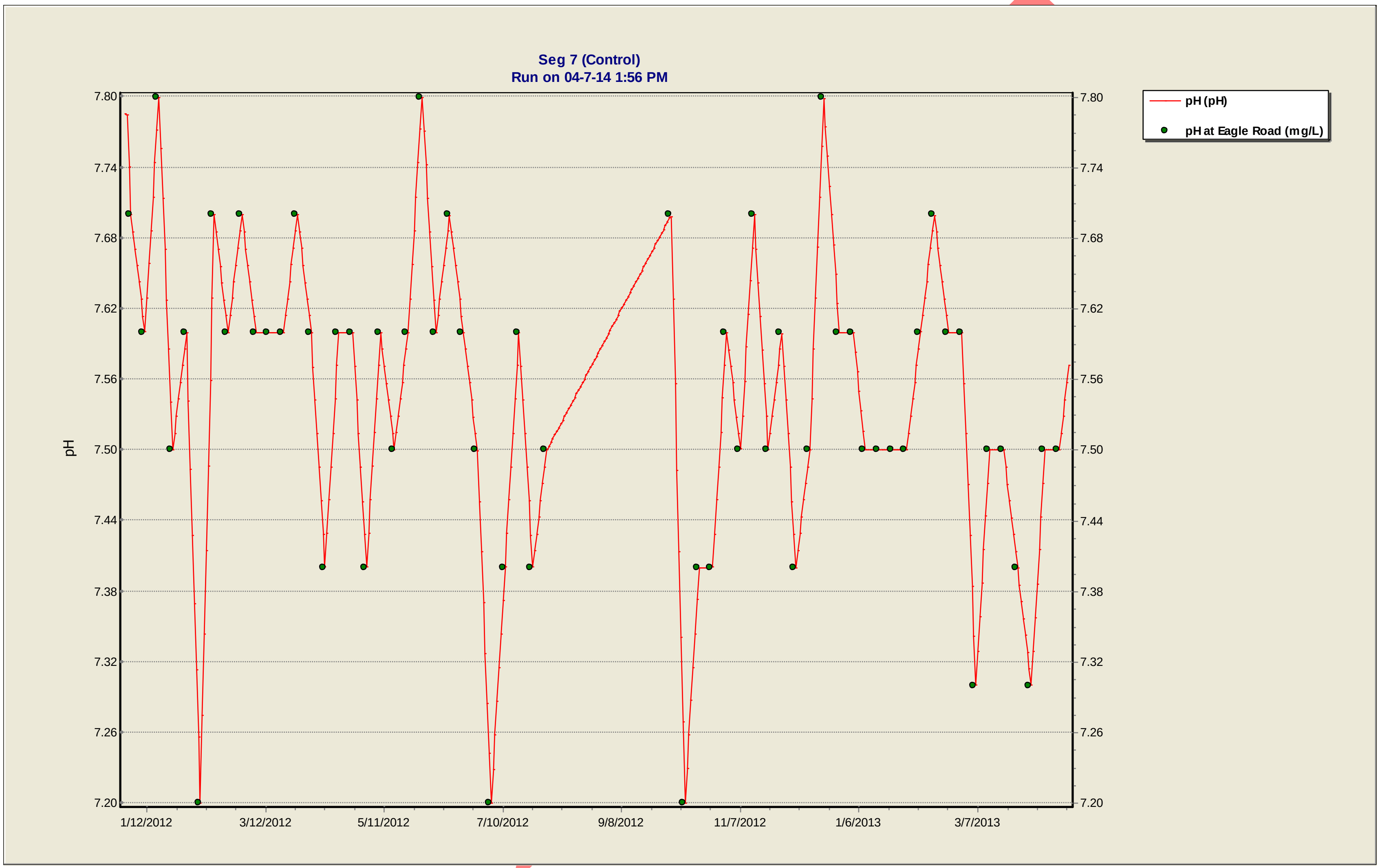
Seg 6 (Control)
Run on 04-7-14 1:54 PM
cm/s
204.0
187.0
170.0
153.0
136.0
119.0
102.0
85.0
68.0
51.0
34.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Run Velocity (cm/s)
Riffle Velocity (cm/s)
Pool Velocity (cm/s)
Velocity Segments 5 & 6 (cm/s)

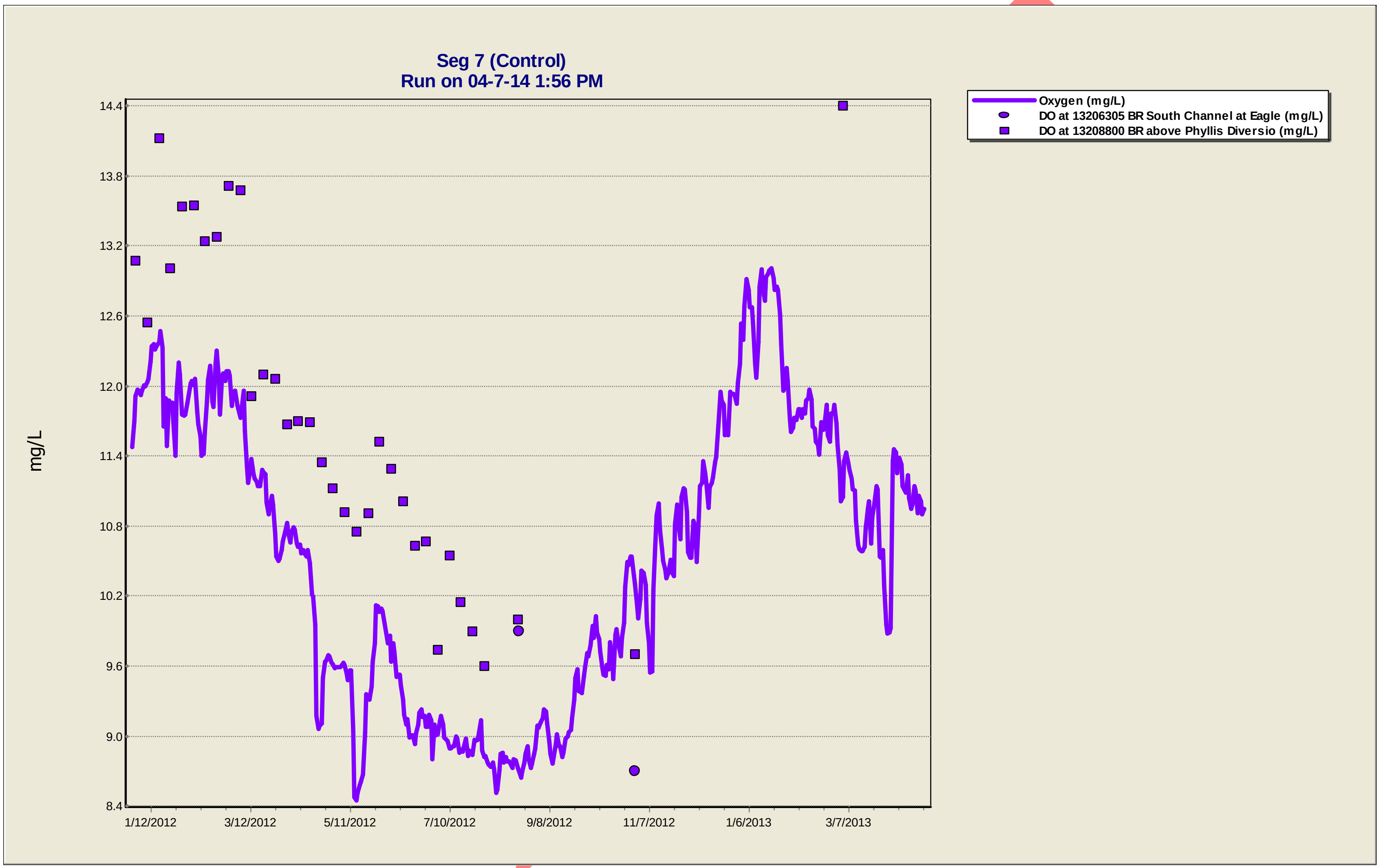
Select Model Results and Measured Data – Segment 7

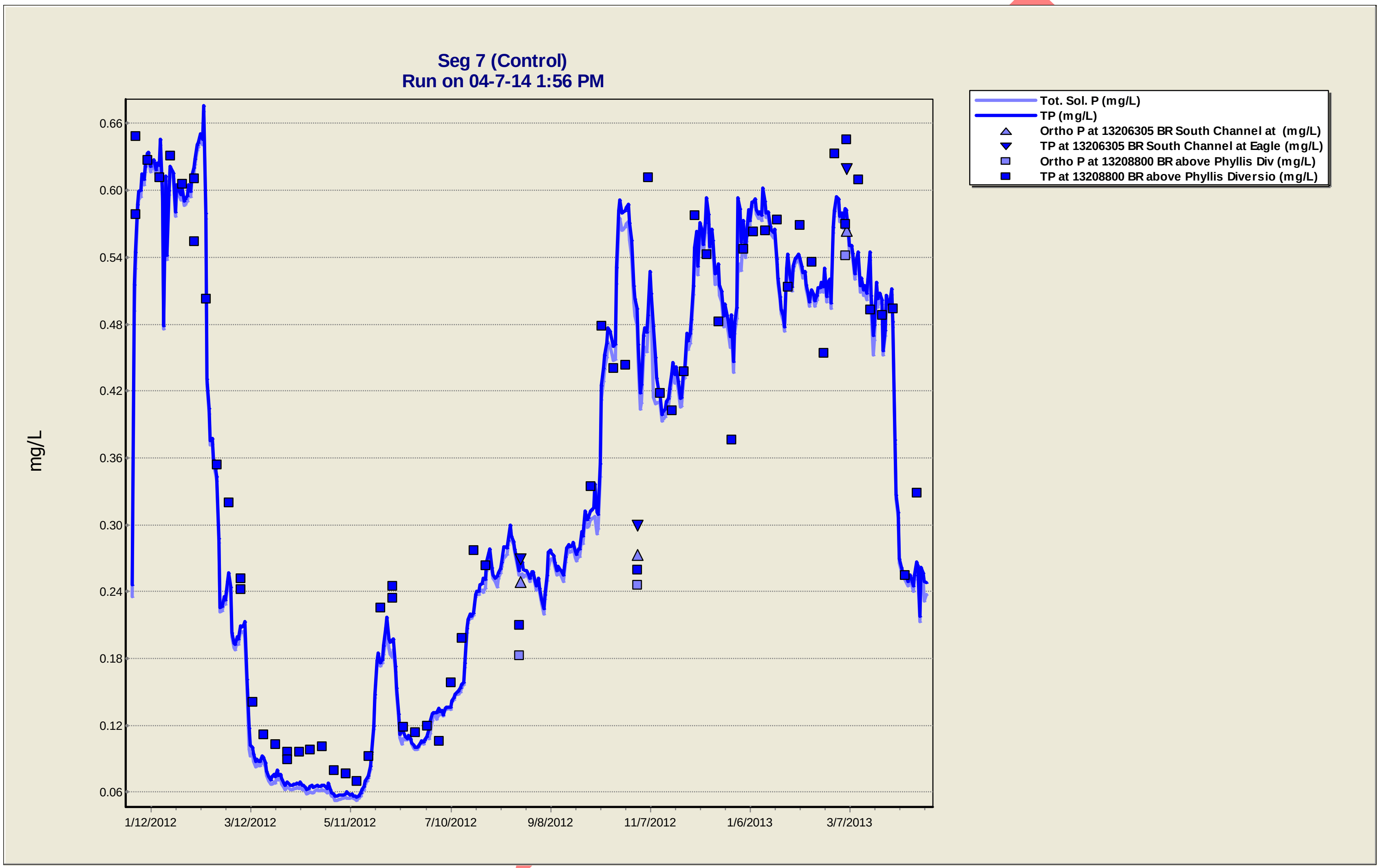


Seg 7 (Control)
Run on 04-7-14 1:56 PM
cm/s
216.0
198.0
180.0
162.0
144.0
126.0
108.0
90.0
72.0
54.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Run Velocity (cm/s)
Riffle Velocity (cm/s)
Pool Velocity (cm/s)
Velocity at 13206305 BR South Channel at (cm/s)
Velocity at 13208800 BR above Phyllis Di (cm/s)

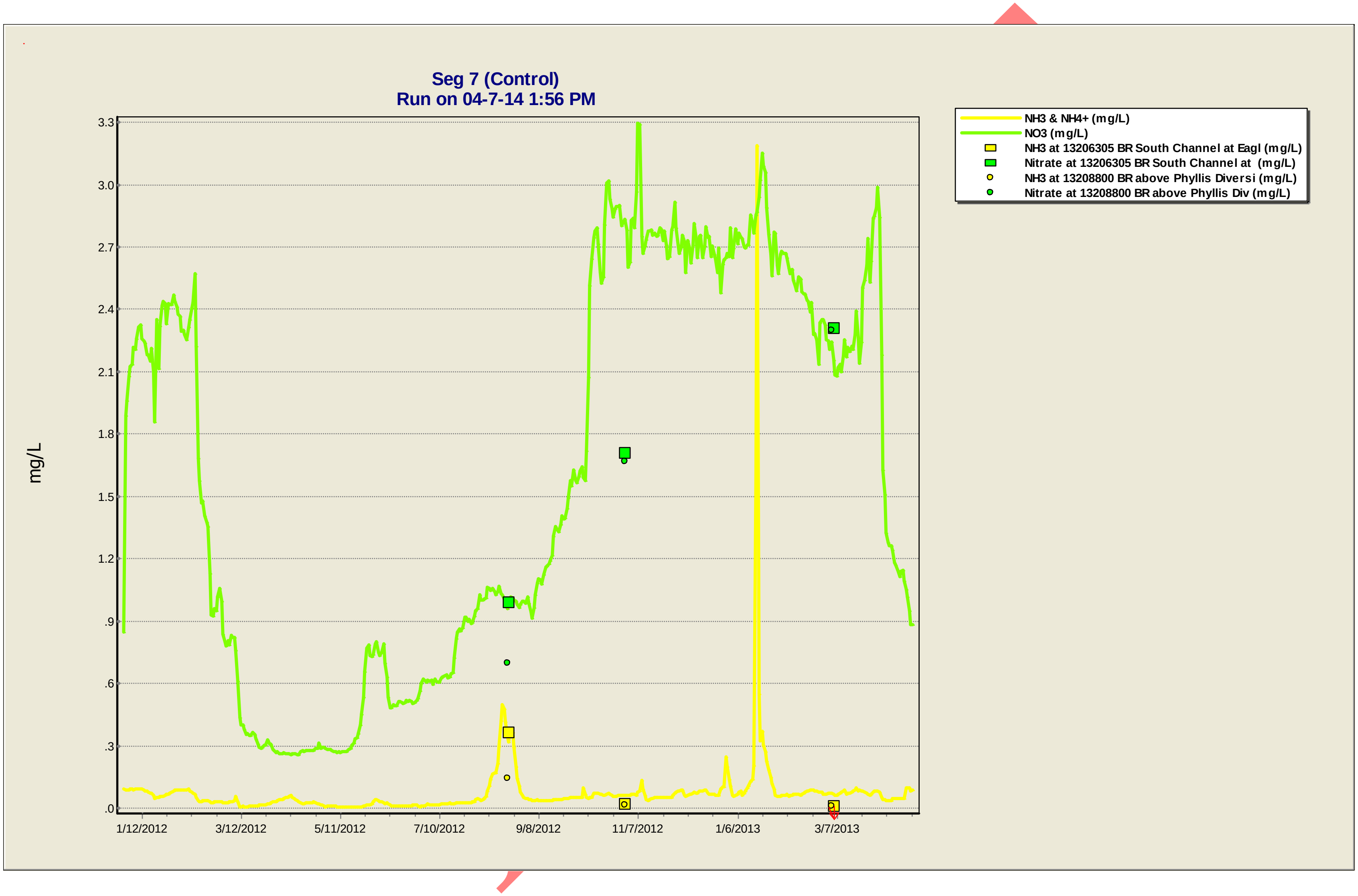

Seg 7 (Control)
Run on 04-7-14 1:56 PM
Temp (deg. C)
Temperature Segment 7 COB (deg. C)
deg. C
18.0
16.2
14.4
12.6
10.8
9.0
7.2
5.4
3.6
1.8
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013


Seg 7 (Control)
Run on 04-7-14 1:56 PM
pH
7.80
7.74
7.68
7.62
7.56
7.50
7.44
7.38
7.32
7.26
7.20
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
pH (pH)
pH at Eagle Road (mg/L)


Seg 7 (Control)
Run on 04-7-14 1:56 PM
mg/L
14.4
13.8
13.2
12.6
12.0
11.4
10.8
10.2
9.6
9.0
8.4
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Oxygen (mg/L)
DO at 13206305 BR South Channel at Eagle (mg/L)
DO at 13208800 BR above Phyllis Diversio (mg/L)

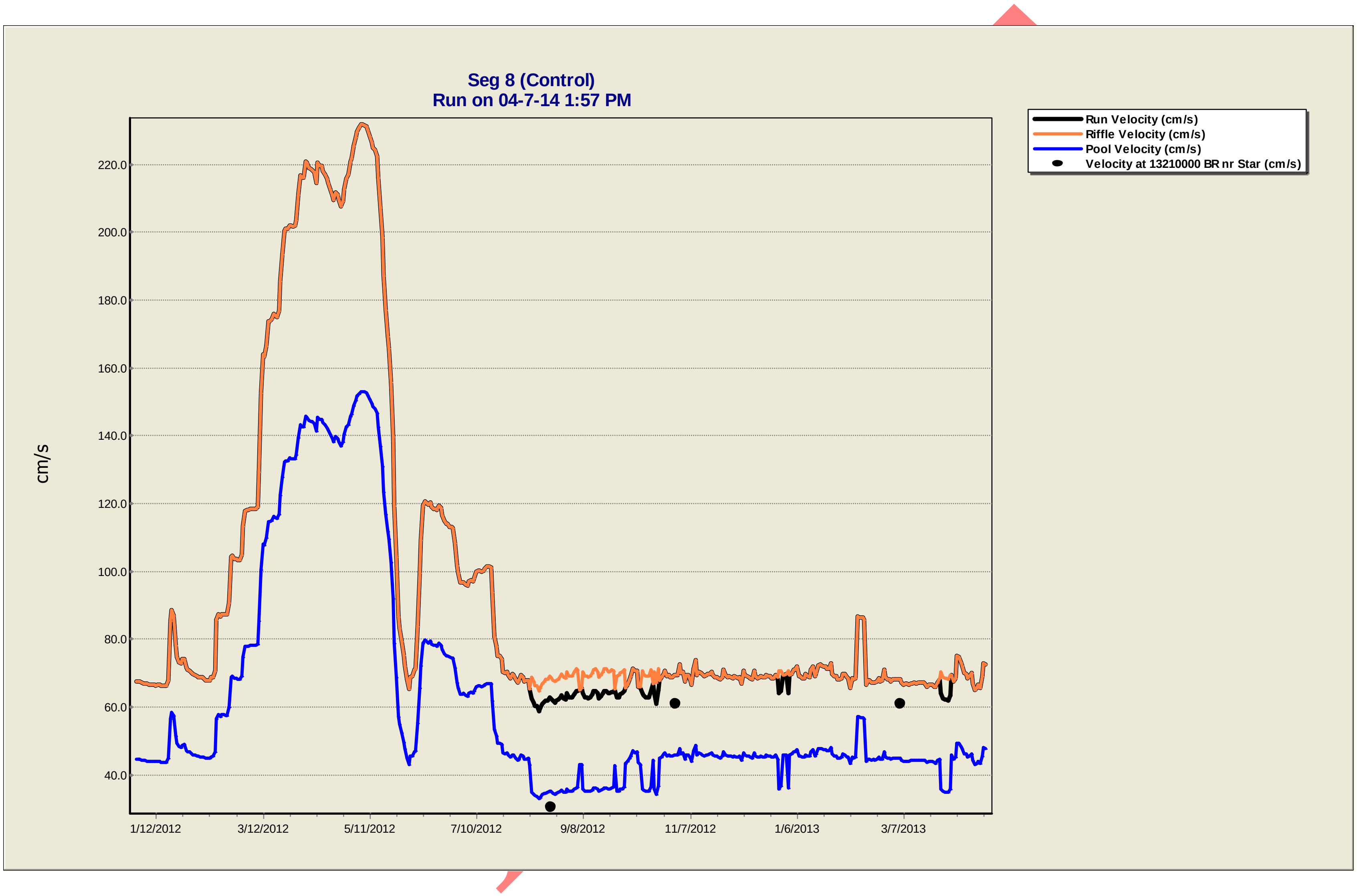


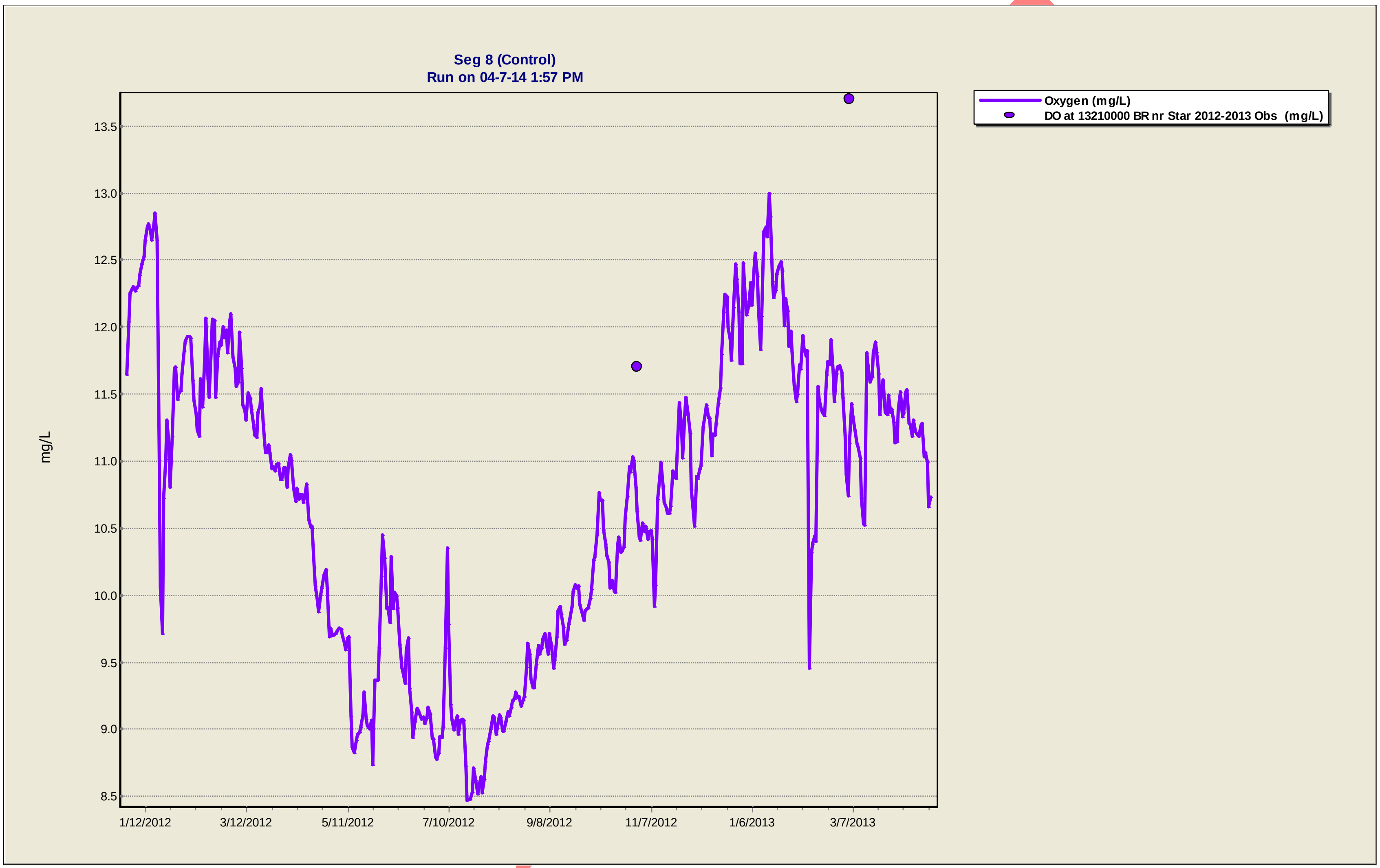
Seg 7 (Control)
Run on 04-7-14 1:56 PM
mg/L
0.66
0.60
0.54
0.48
0.42
0.36
0.30
0.24
0.18
0.12
0.06
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Tot. Sol. P (mg/L)
TP (mg/L)
Ortho P at 13206305 BR South Channel at (mg/L)
TP at 13206305 BR South Channel at Eagle (mg/L)
Ortho P at 13208800 BR above Phyllis Div (mg/L)
TP at 13208800 BR above Phyllis Diversio (mg/L)

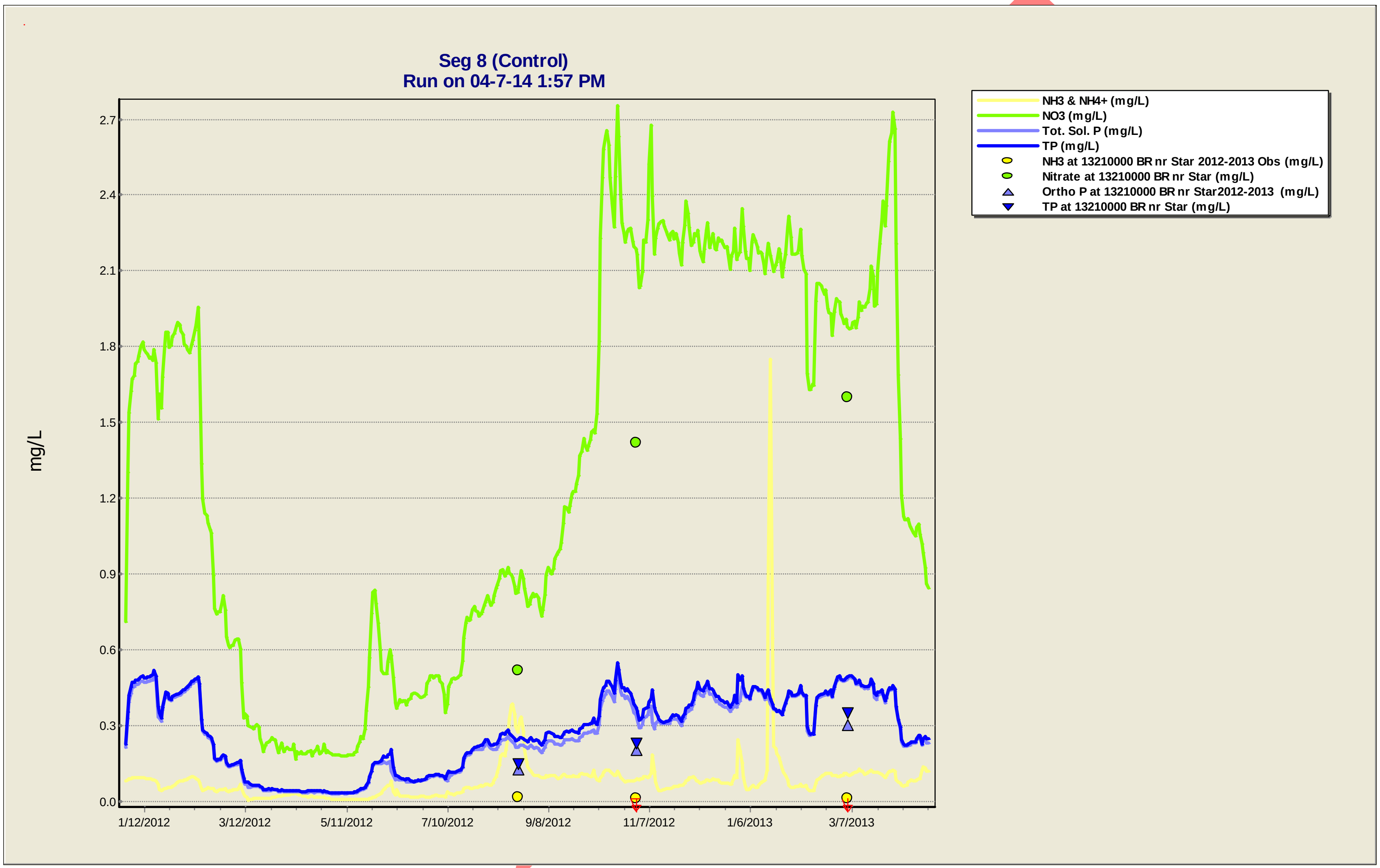


Seg 7 (Control)
Run on 04-7-14 1:56 PM
mg/L
3.3
3.0
2.7
2.4
2.1
1.8
1.5
1.2
.9
.6
.3
.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
NH3 & NH4+ (mg/L)
NO3 (mg/L)
NH3 at 13206305 BR South Channel at Eagl (mg/L)
Nitrate at 13206305 BR South Channel at (mg/L)
NH3 at 13208800 BR above Phyllis Diversi (mg/L)
Nitrate at 13208800 BR above Phyllis Div (mg/L)

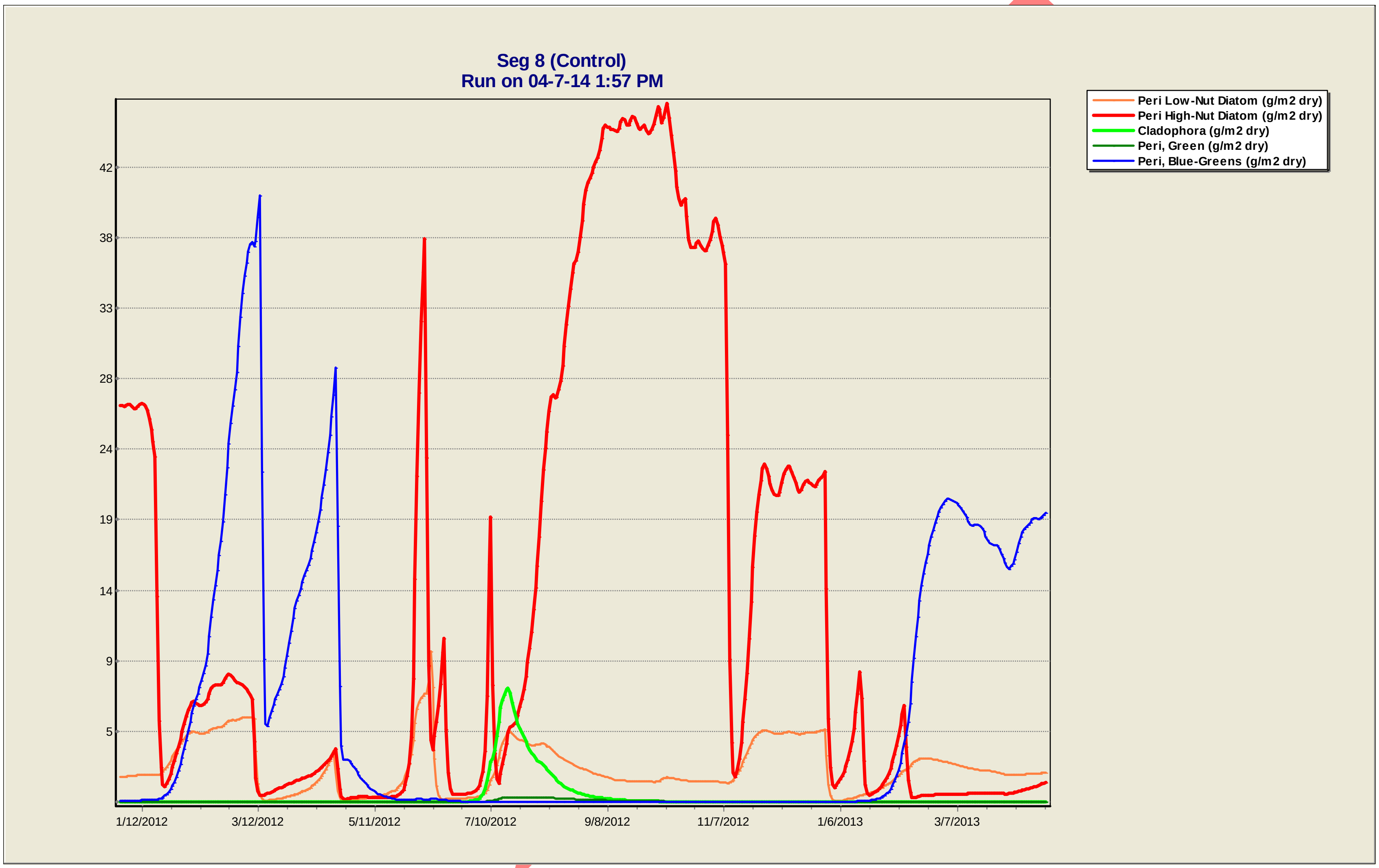
Select Model Results and Measured Data – Segment 8

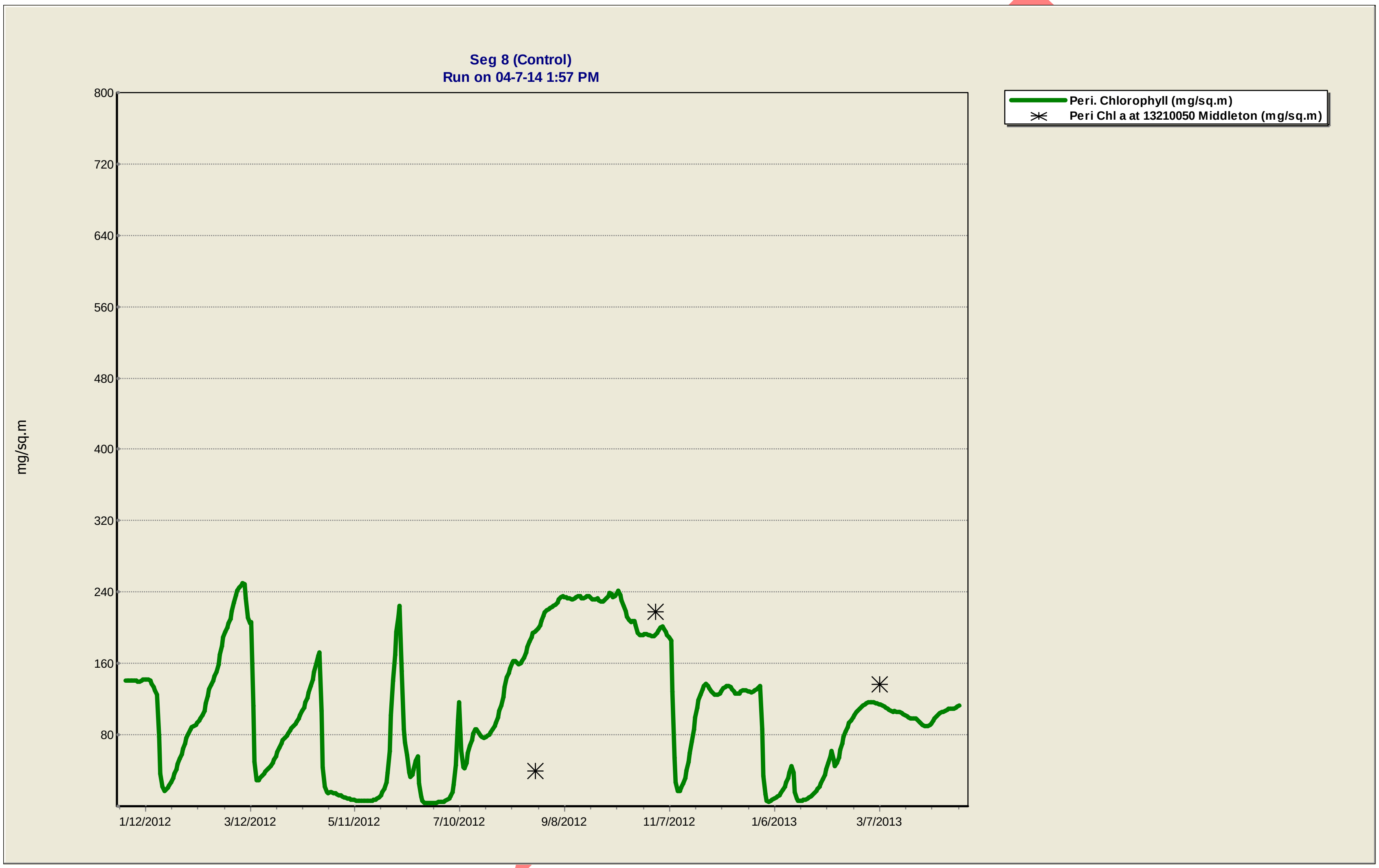

Seg 8 (Control)
Run on 04-7-14 1:57 PM
Run Velocity (cm/s)
Riffle Velocity (cm/s)
Pool Velocity (cm/s)
Velocity at 13210000 BR nr Star (cm/s)
cm/s
220.0
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

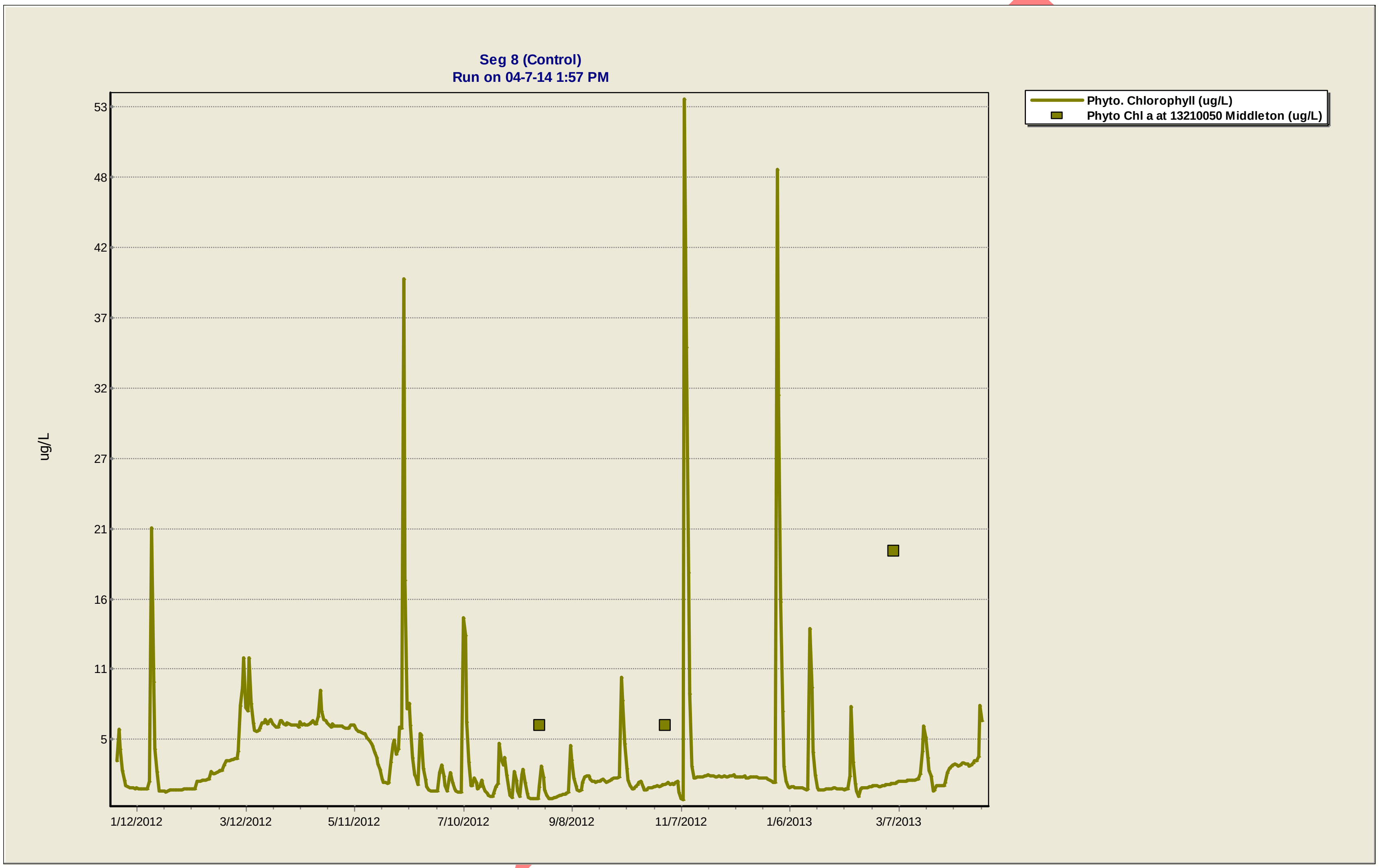

Seg 8 (Control)
Run on 04-7-14 1:57 PM
Oxygen (mg/L)
DO at 13210000 BR nr Star 2012-2013 Obs (mg/L)
mg/L
13.5
13.0
12.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013



Seg 8 (Control)
Run on 04-7-14 1:57 PM
mg/L
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
NH3 & NH4+ (mg/L)
NO3 (mg/L)
Tot. Sol. P (mg/L)
TP (mg/L)
NH3 at 13210000 BR nr Star 2012-2013 Obs (mg/L)
Nitrate at 13210000 BR nr Star (mg/L)
Ortho P at 13210000 BR nr Star2012-2013 (mg/L)
TP at 13210000 BR nr Star (mg/L)

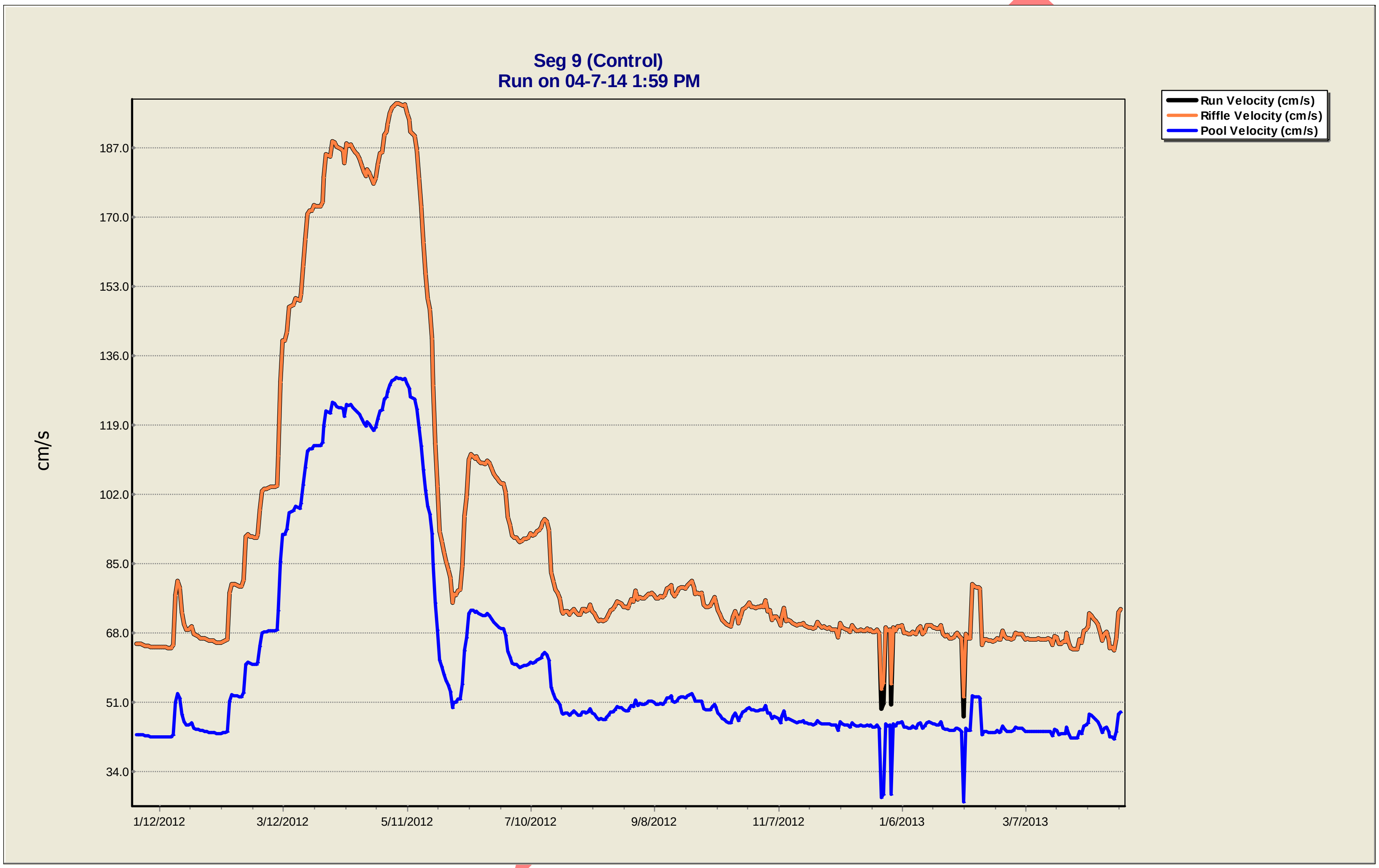

Seg 8 (Control)
Run on 04-7-14 1:57 PM
Peri Low-Nut Diatom (g/m2 dry)
Peri High-Nut Diatom (g/m2 dry)
Cladophora (g/m2 dry)
Peri, Green (g/m2 dry)
Peri, Blue-Greens (g/m2 dry)
42
38
33
28
24
19
14
9
5
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

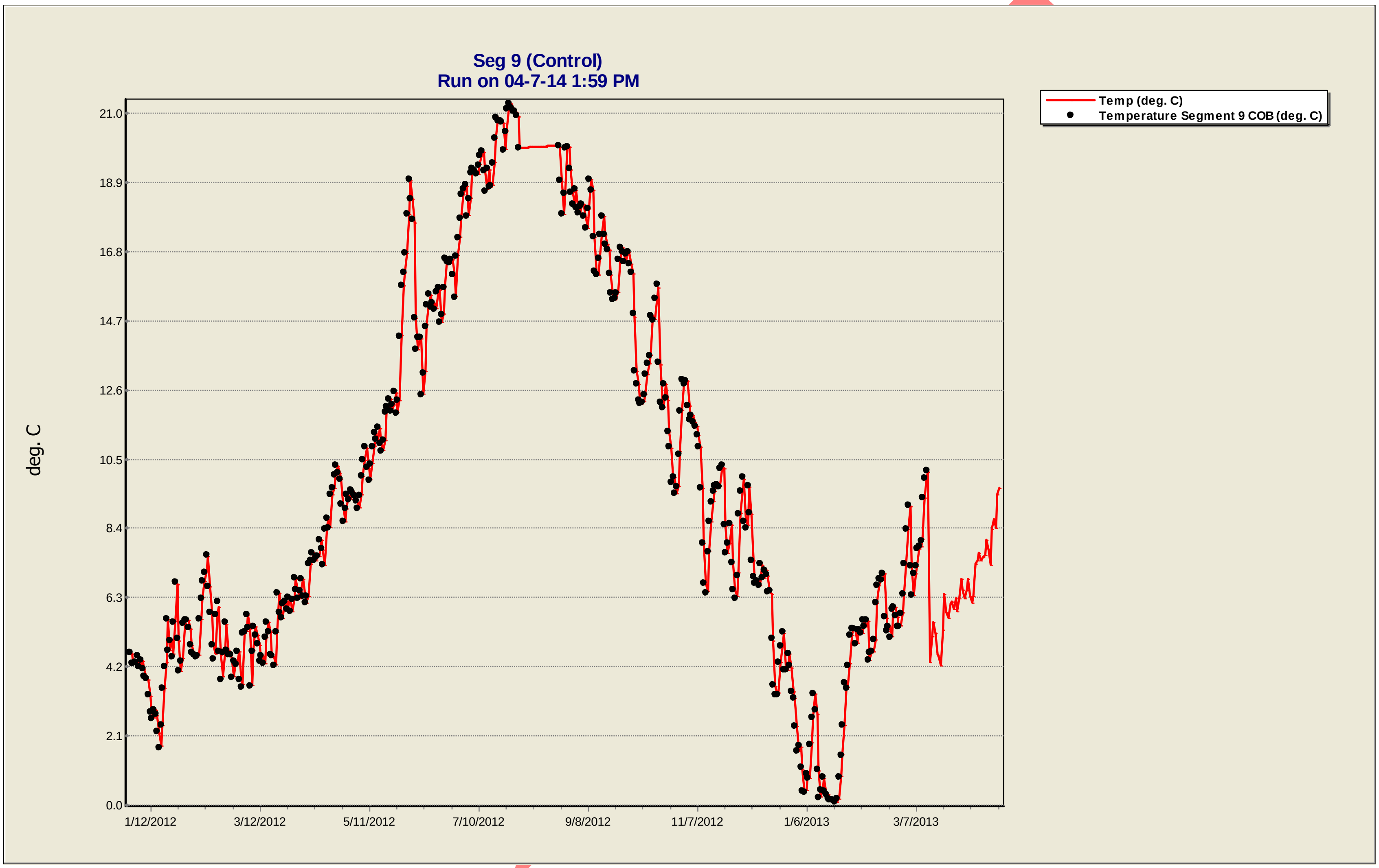

Seg 8 (Control)
Run on 04-7-14 1:57 PM
mg/sq.m
800
720
640
560
480
400
320
240
160
80
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Peri. Chlorophyll (mg/sq.m)
Peri Chl a at 13210050 Middleton (mg/sq.m)



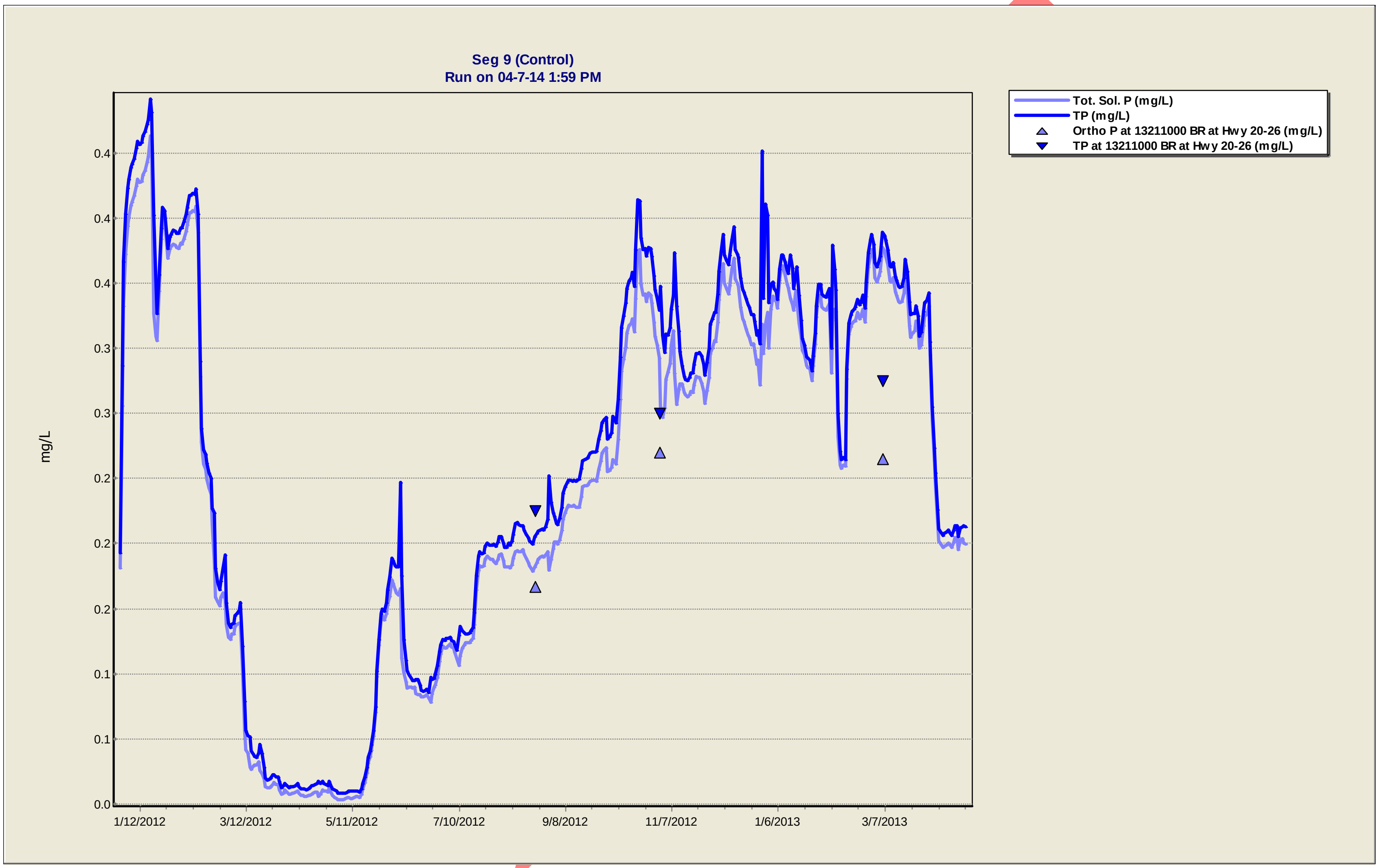
Seg 8 (Control)
Run on 04-7-14 1:57 PM
Phyto. Chlorophyll (ug/L)
Phyto Chl a at 13210050 Middleton (ug/L)
ug/L
53
48
42
37
32
27
21
16
11
5
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

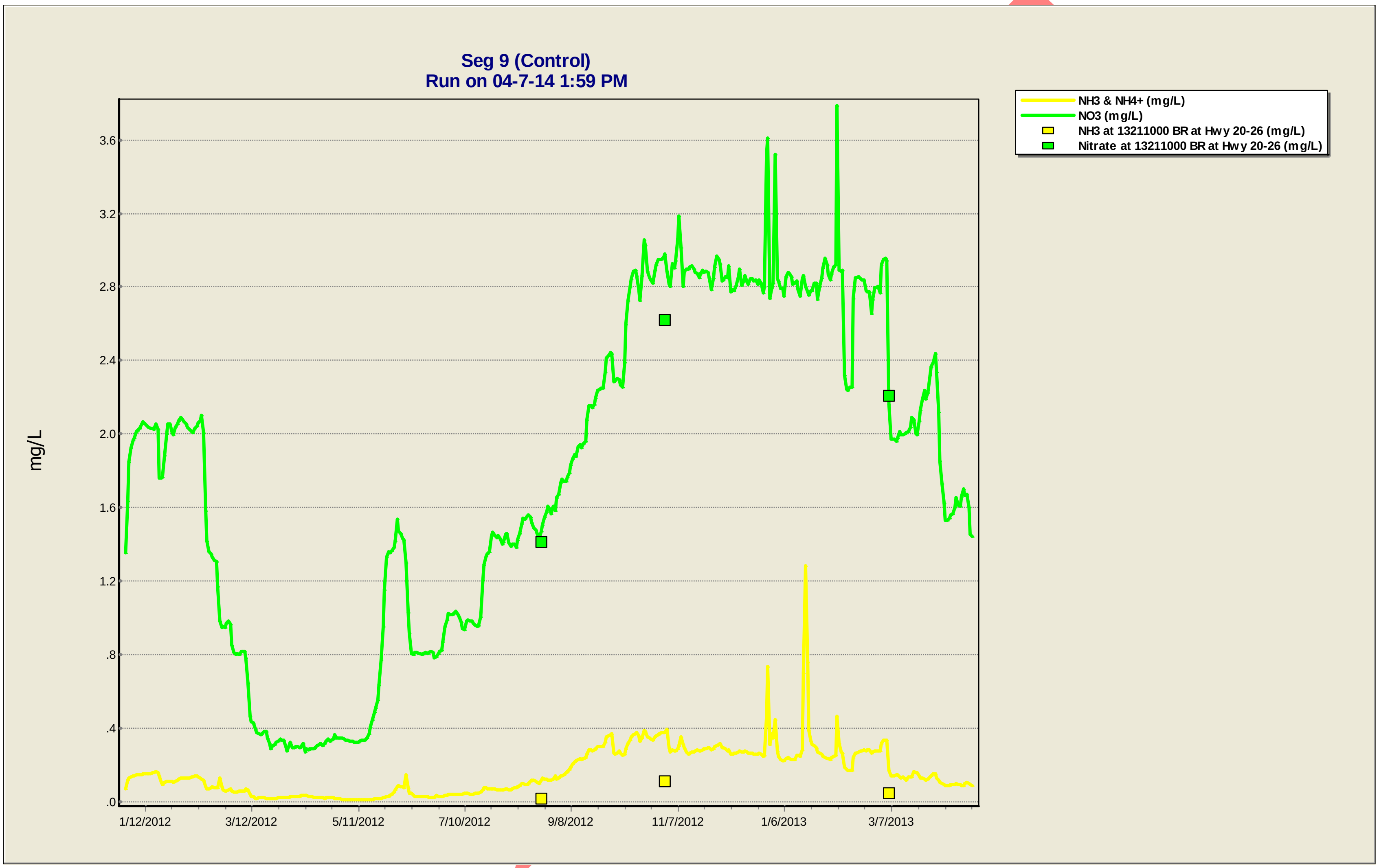
Select Model Results and Measured Data – Segment 9

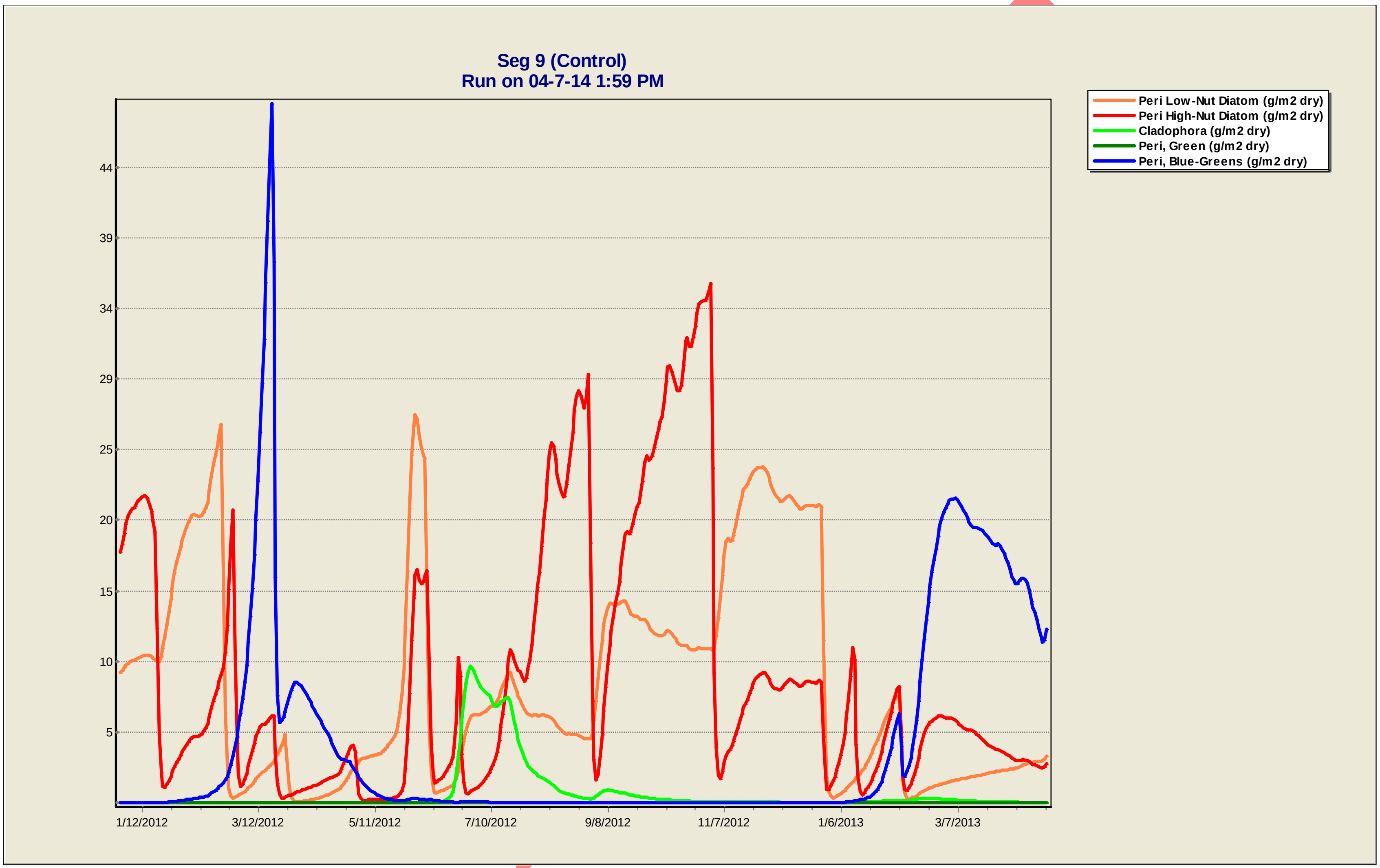

Seg 9 (Control)
Run on 04-7-14 1:59 PM
Run Velocity (cm/s)
Riffle Velocity (cm/s)
Pool Velocity (cm/s)
cm/s
187.0
170.0
153.0
136.0
119.0
102.0
85.0
68.0
51.0
34.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

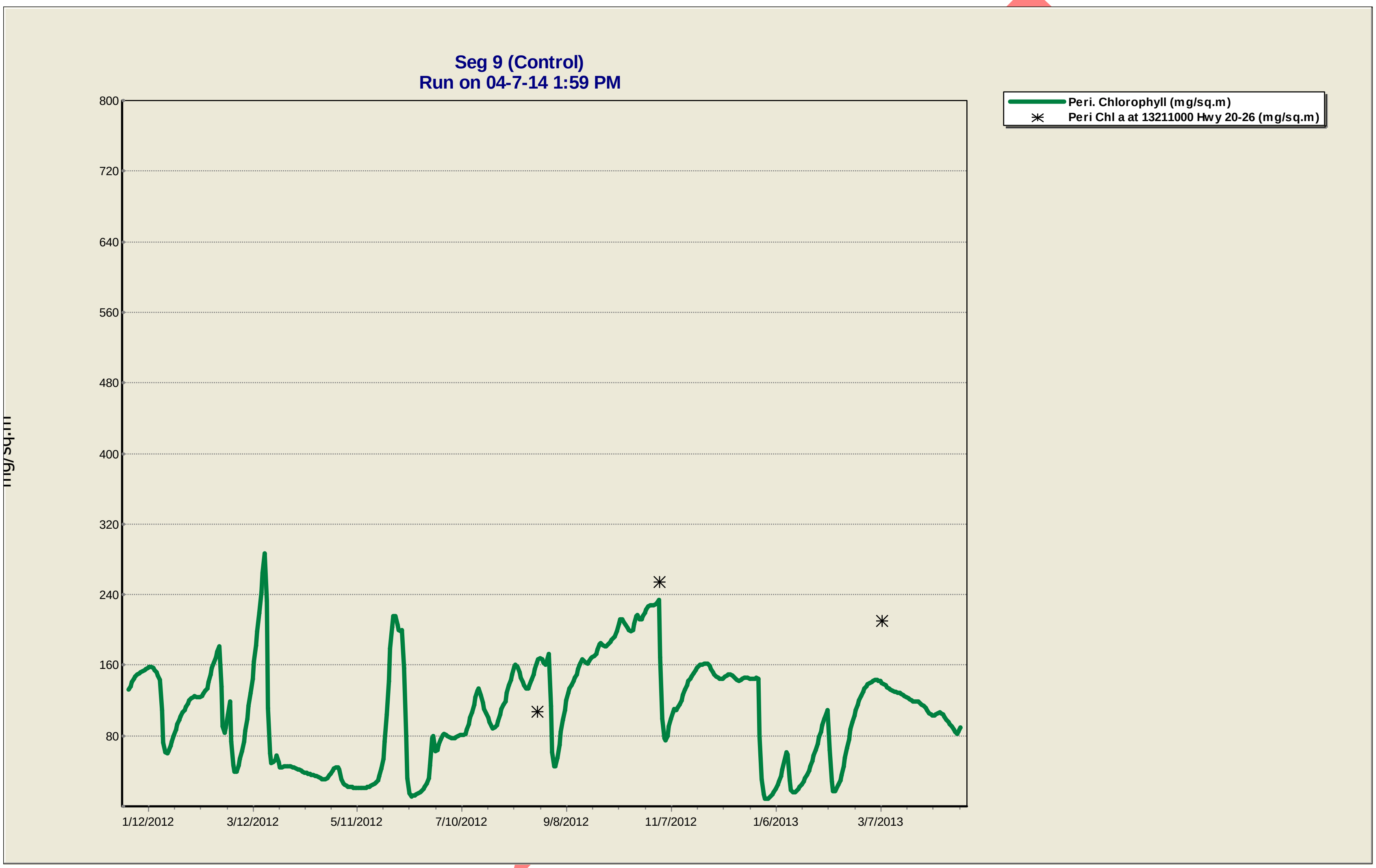

Seg 9 (Control)
Run on 04-7-14 1:59 PM
Temp (deg. C)
Temperature Segment 9 COB (deg. C)
deg. C
21.0
18.9
16.8
14.7
12.6
10.5
8.4
6.3
4.2
2.1
0.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

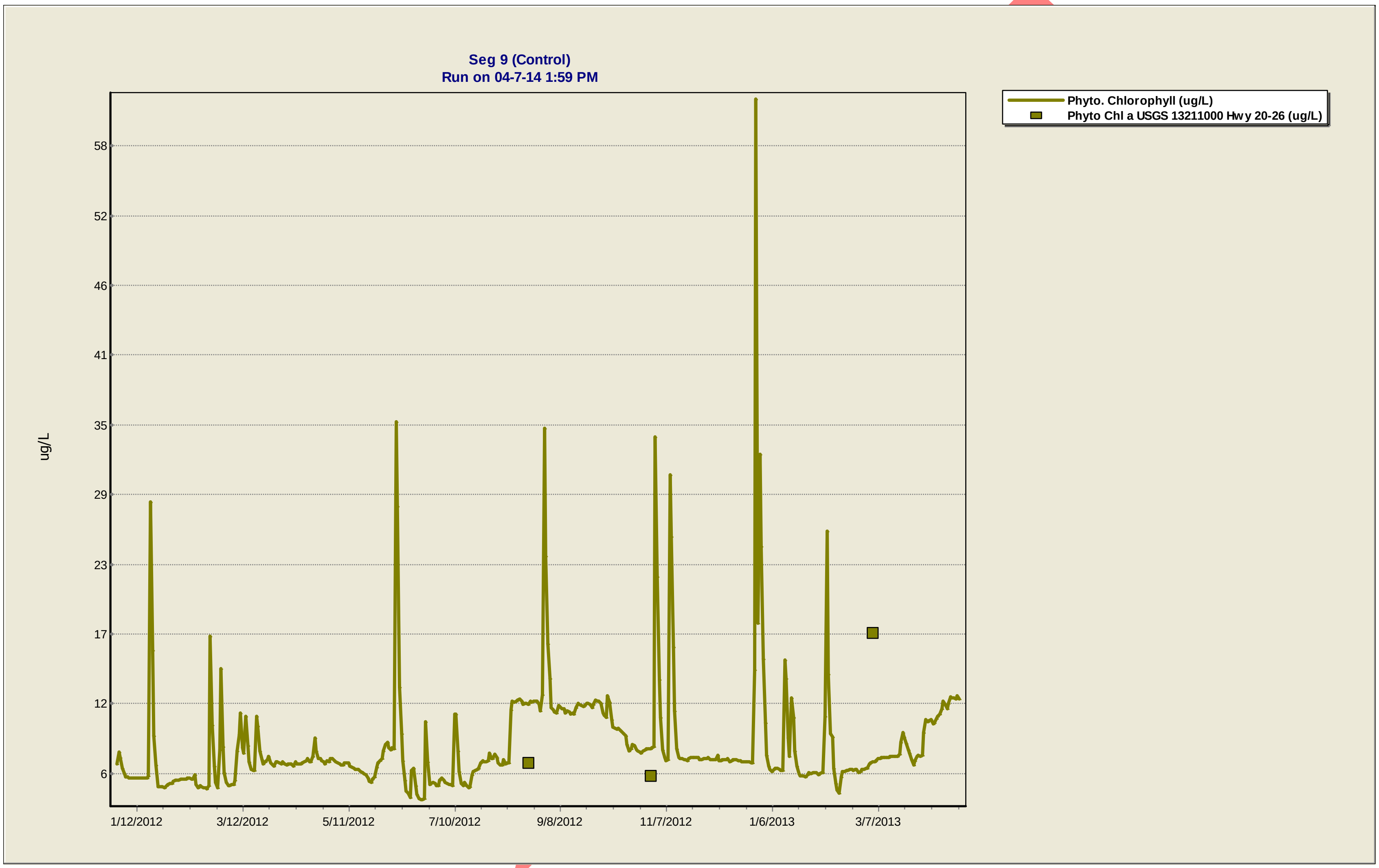

Seg 9 (Control)
Run on 04-7-14 1:59 PM
Oxygen (mg/L)
mg/L
12.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013


Seg 9 (Control)
Run on 04-7-14 1:59 PM
Tot. Sol. P (mg/L)
TP (mg/L)
Ortho P at 13211000 BR at Hwy 20-26 (mg/L)
TP at 13211000 BR at Hwy 20-26 (mg/L)
mg/L
0.4
0.4
0.4
0.3
0.3
0.2
0.2
0.2
0.1
0.1
0.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013


Seg 9 (Control)
Run on 04-7-14 1:59 PM
mg/L
3.6
3.2
2.8
2.4
2.0
1.6
1.2
.8
.4
.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
NH3 & NH4+ (mg/L)
NO3 (mg/L)
NH3 at 13211000 BR at Hwy 20-26 (mg/L)
Nitrate at 13211000 BR at Hwy 20-26 (mg/L)

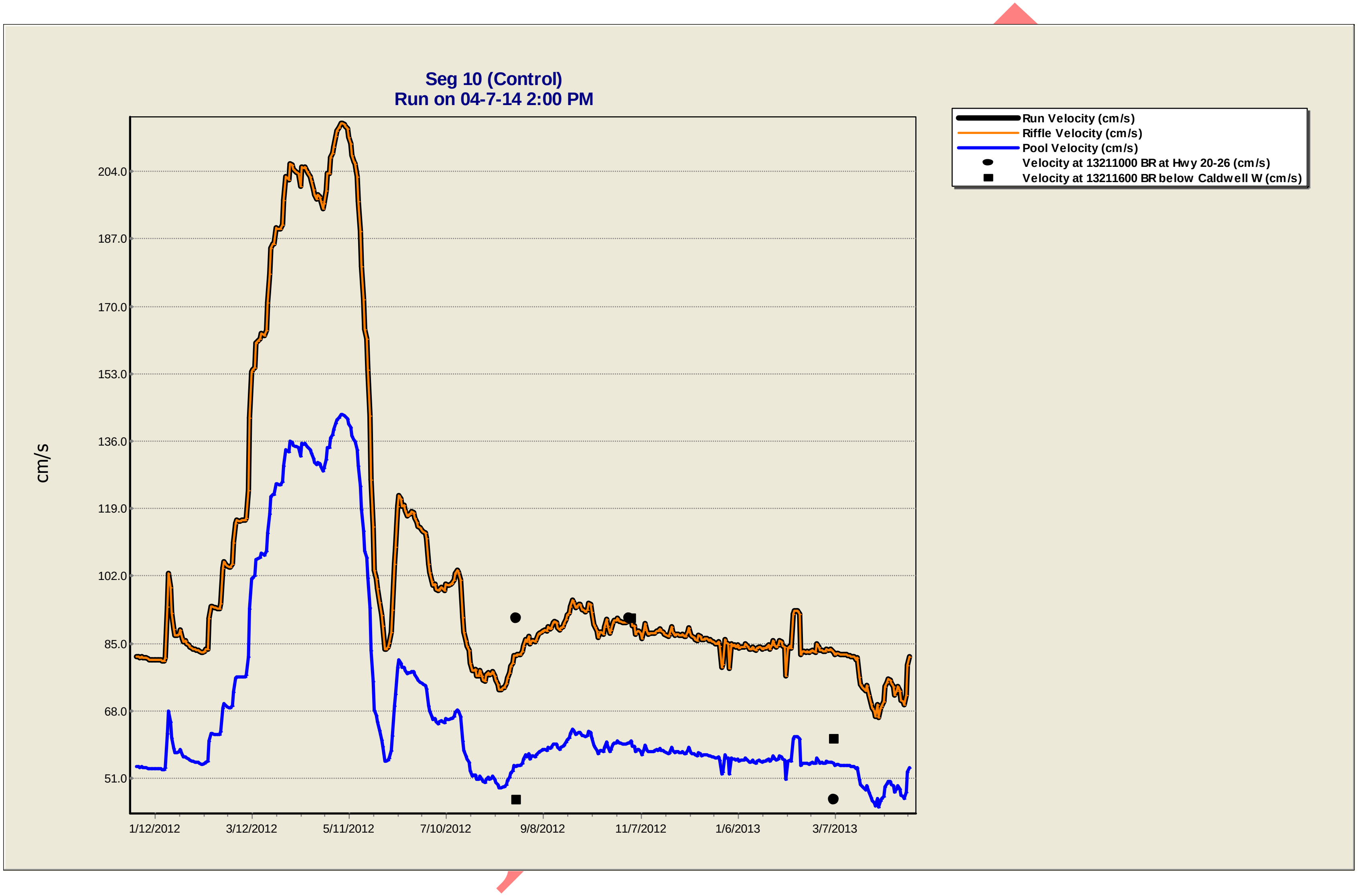

Seg 9 (Control)
Run on 04-7-14 1:59 PM
Peri Low-Nut Diatom (g/m2 dry)
Peri High-Nut Diatom (g/m2 dry)
Cladophora (g/m2 dry)
Peri, Green (g/m2 dry)
Peri, Blue-Greens (g/m2 dry)
44
39
34
29
25
20
15
10
5
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

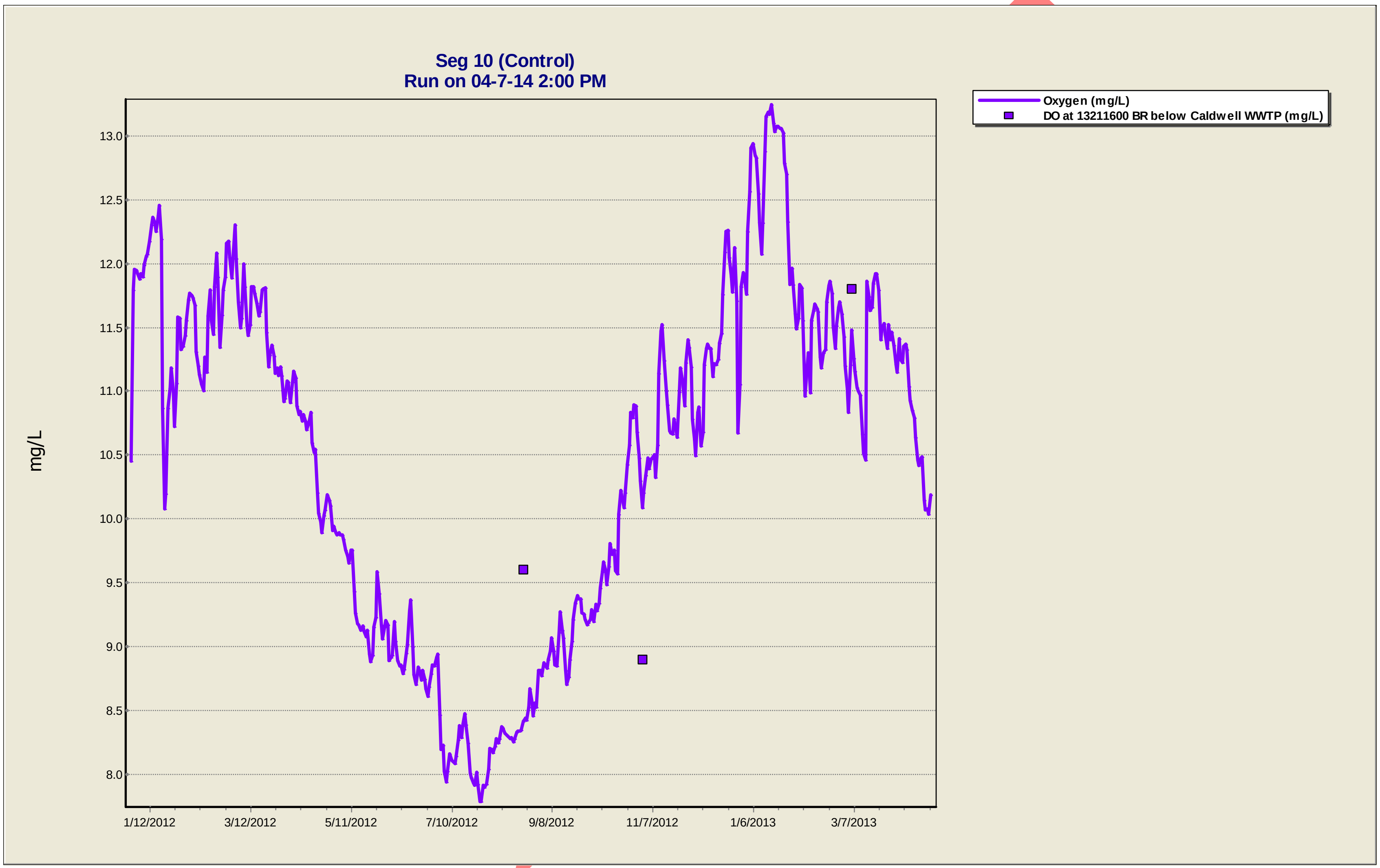

Seg 9 (Control)
Run on 04-7-14 1:59 PM
Peri. Chlorophyll (mg/sq.m)
Peri Chl a at 13211000 Hwy 20-26 (mg/sq.m)
mg/sq.m
800
720
640
560
480
400
320
240
160
80
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

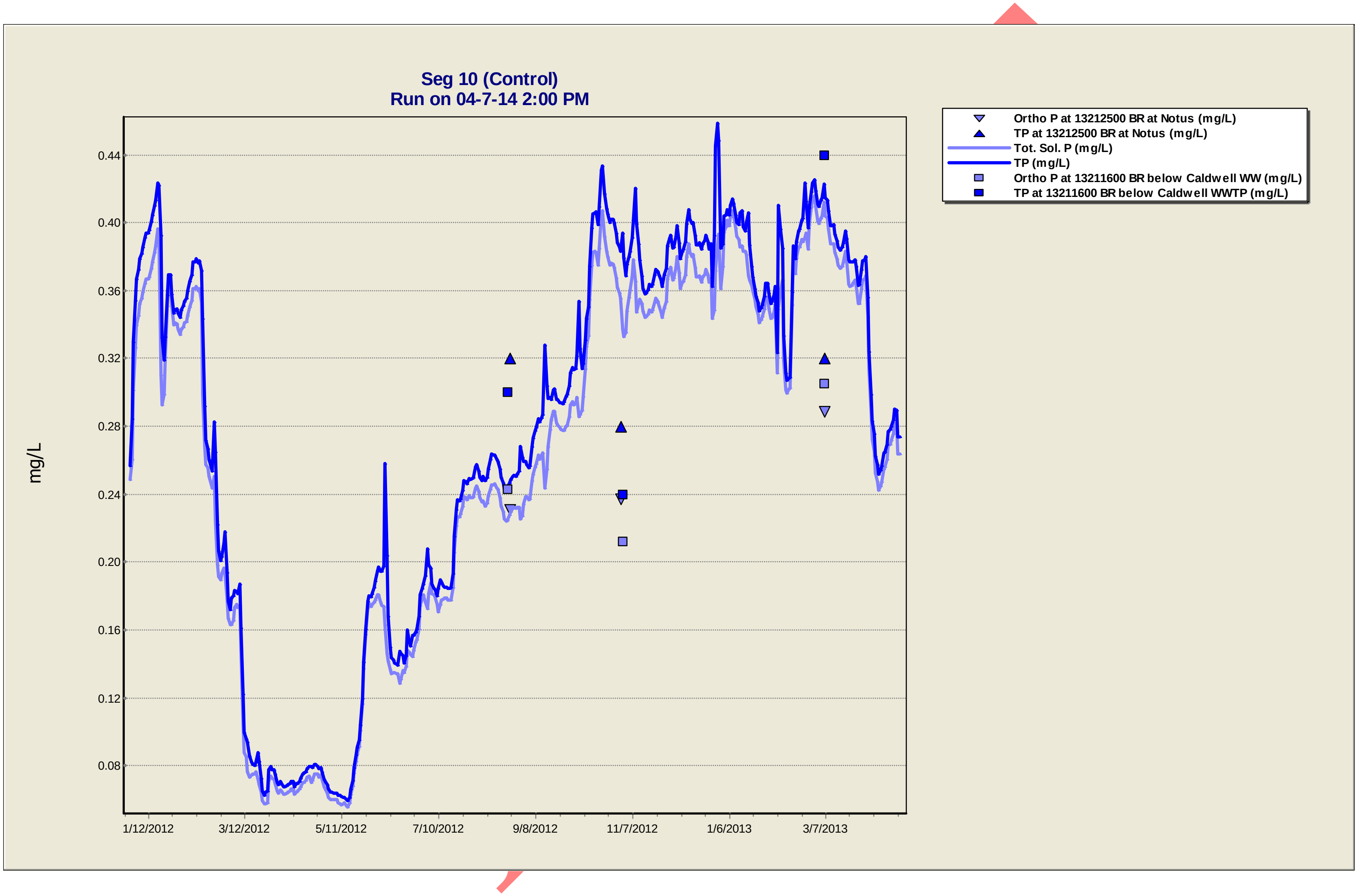


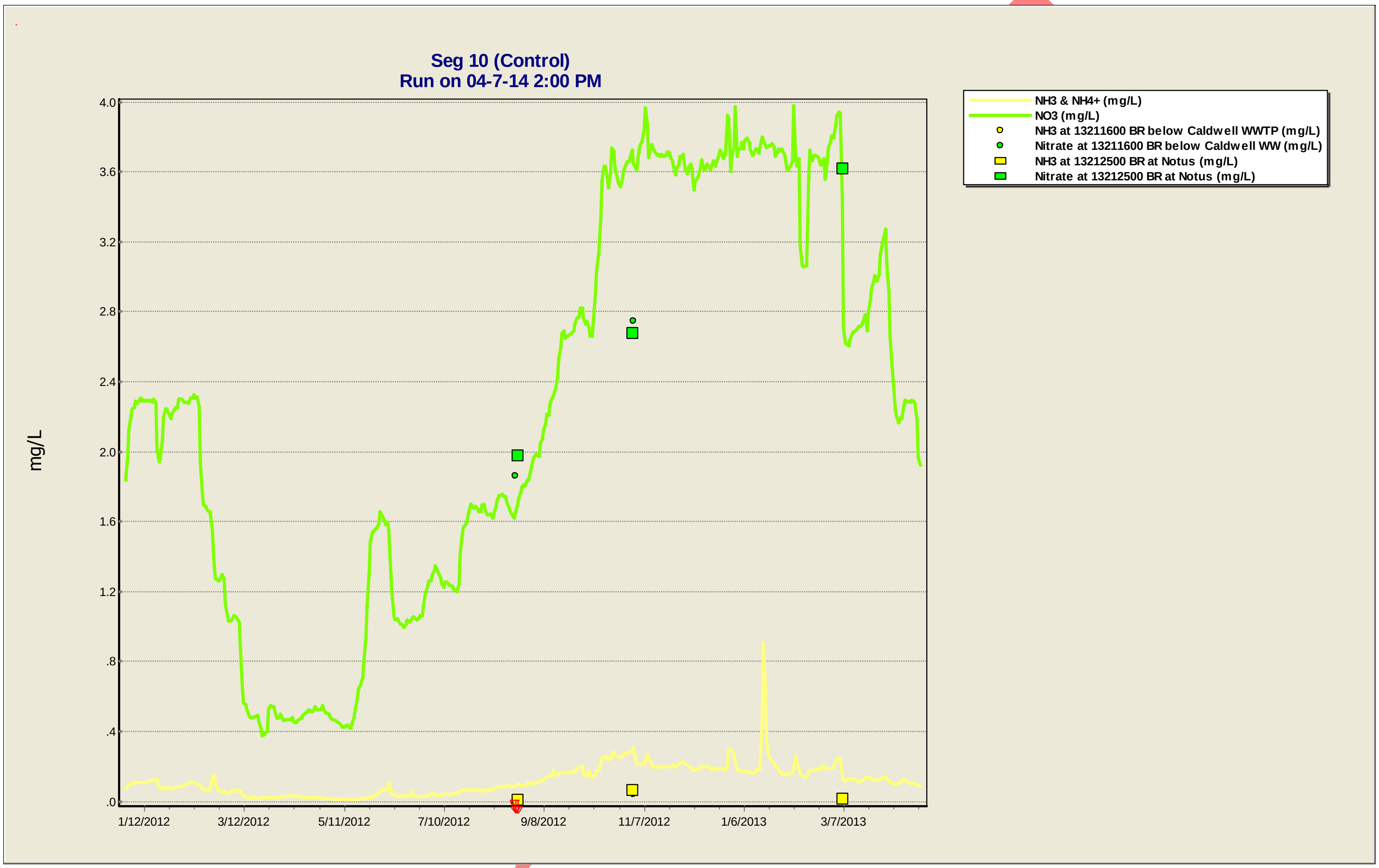
Seg 9 (Control)
Run on 04-7-14 1:59 PM
Phyto. Chlorophyll (ug/L)
Phyto Chl a USGS 13211000 Hwy 20-26 (ug/L)
ug/L
58
52
46
41
35
29
23
17
12
6
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

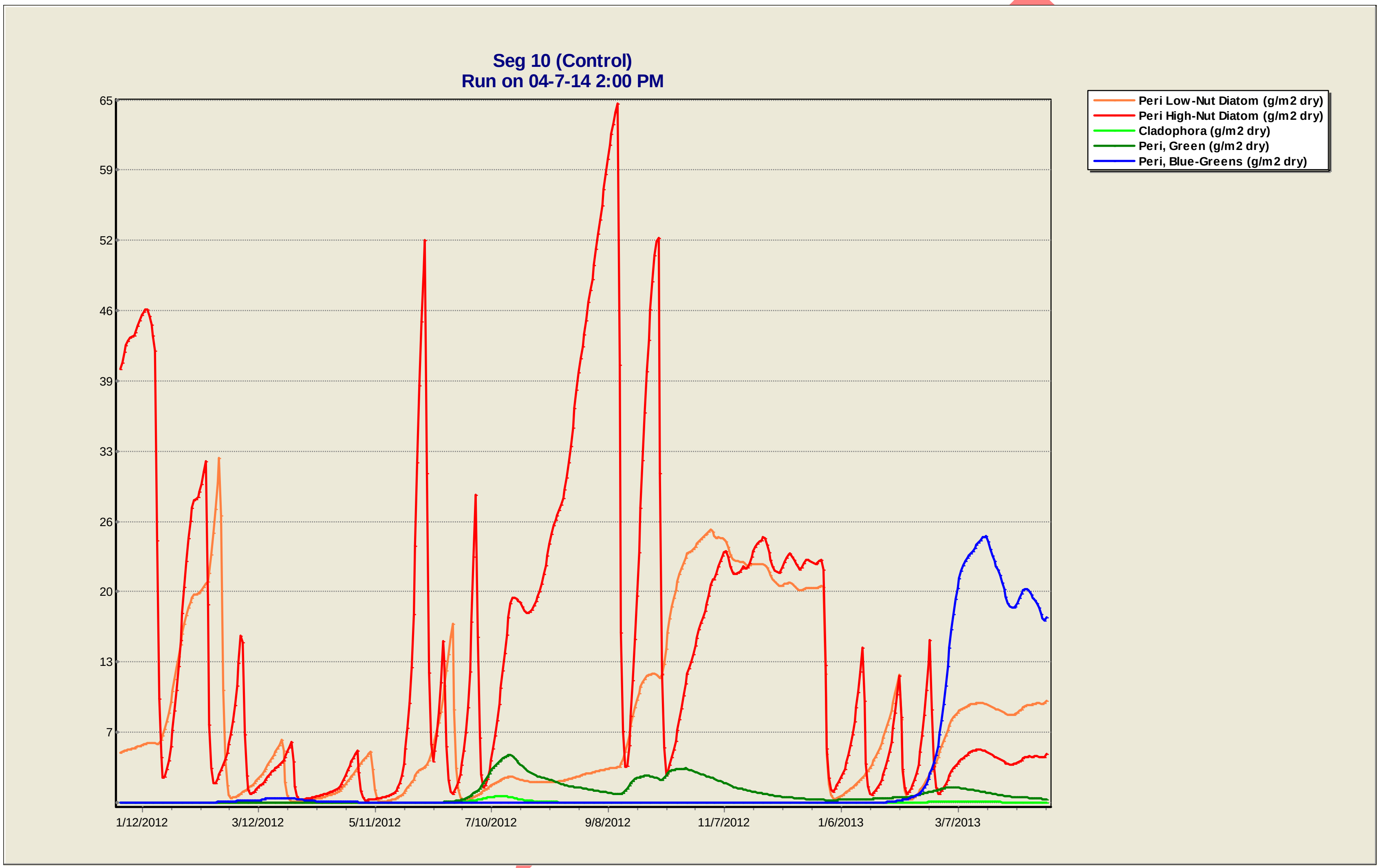
Select Model Results and Measured Data – Segment 10

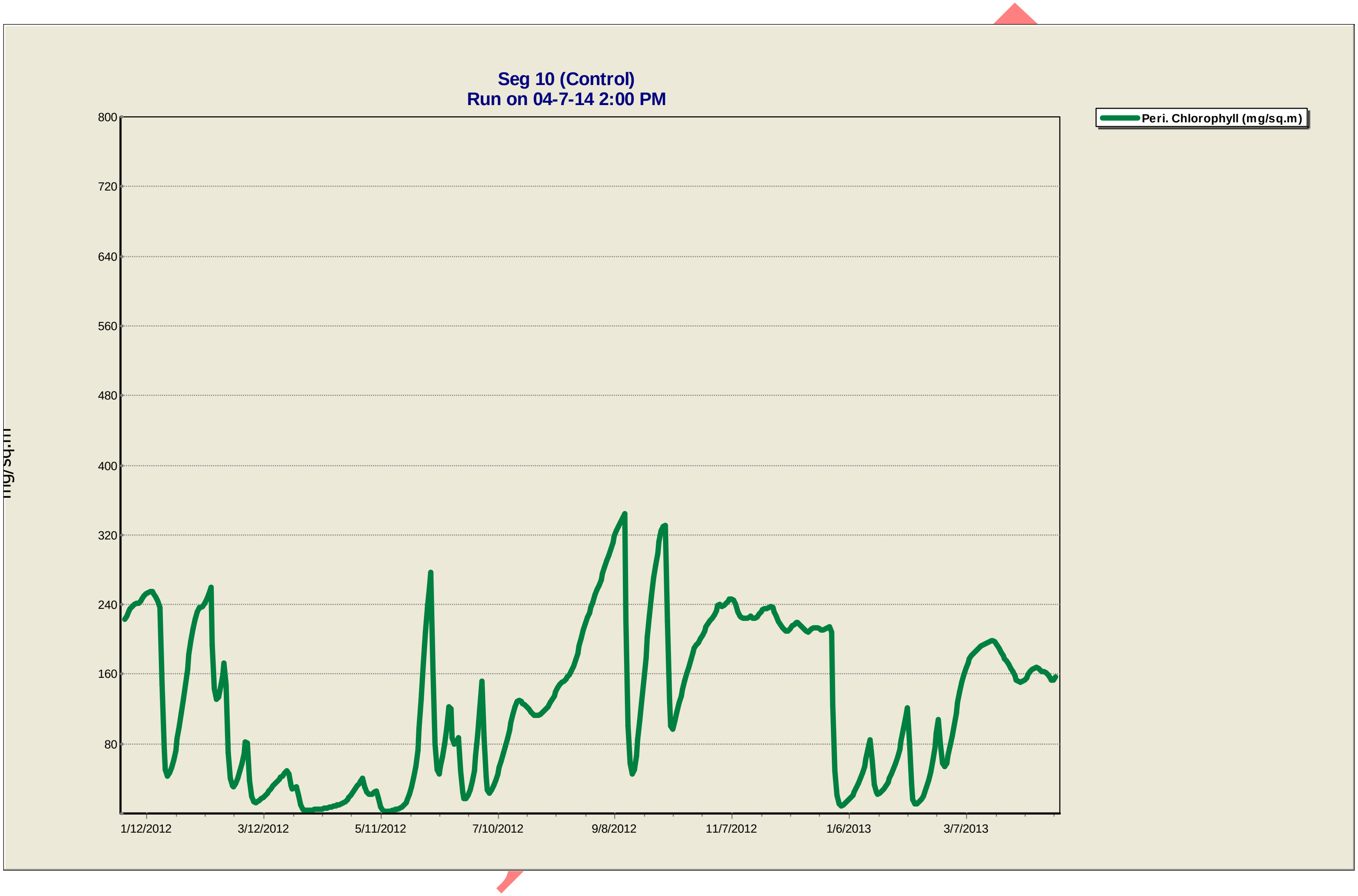

Seg 10 (Control)
Run on 04-7-14 2:00 PM
cm/s
204.0
187.0
170.0
153.0
136.0
119.0
102.0
85.0
68.0
51.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Run Velocity (cm/s)
Riffle Velocity (cm/s)
Pool Velocity (cm/s)
Velocity at 13211000 BR at Hwy 20-26 (cm/s)
Velocity at 13211600 BR below Caldwell W (cm/s)

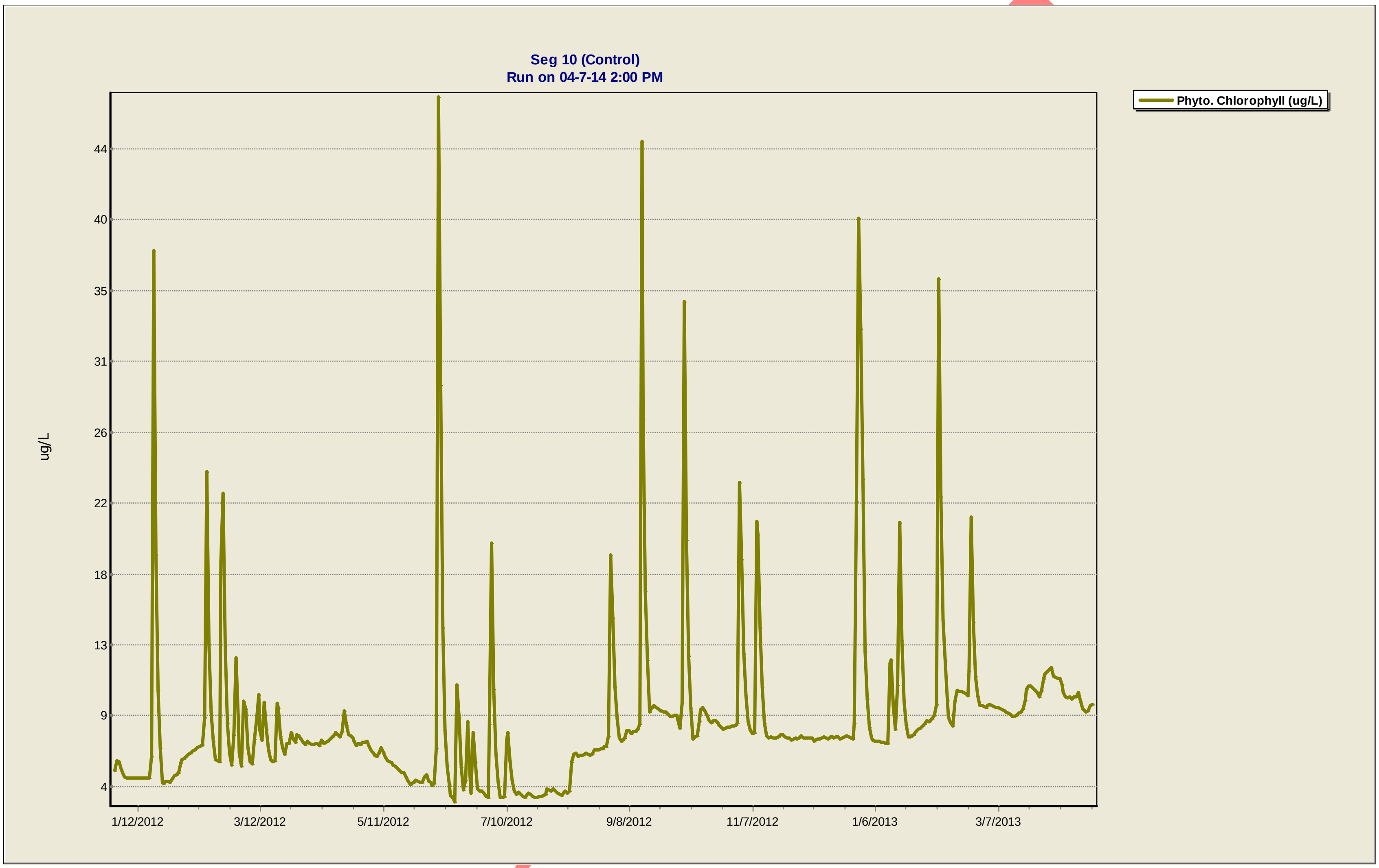

Seg 10 (Control)
Run on 04-7-14 2:00 PM
Oxygen (mg/L)
DO at 13211600 BR below Caldwell WWTP (mg/L)
mg/L
13.0
12.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013


Seg 10 (Control)
Run on 04-7-14 2:00 PM
mg/L
0.44
0.40
0.36
0.32
0.28
0.24
0.20
0.16
0.12
0.08
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Ortho P at 13212500 BR at Notus (mg/L)
TP at 13212500 BR at Notus (mg/L)
Tot. Sol. P (mg/L)
TP (mg/L)
Ortho P at 13211600 BR below Caldwell WW (mg/L)
TP at 13211600 BR below Caldwell WWTP (mg/L)

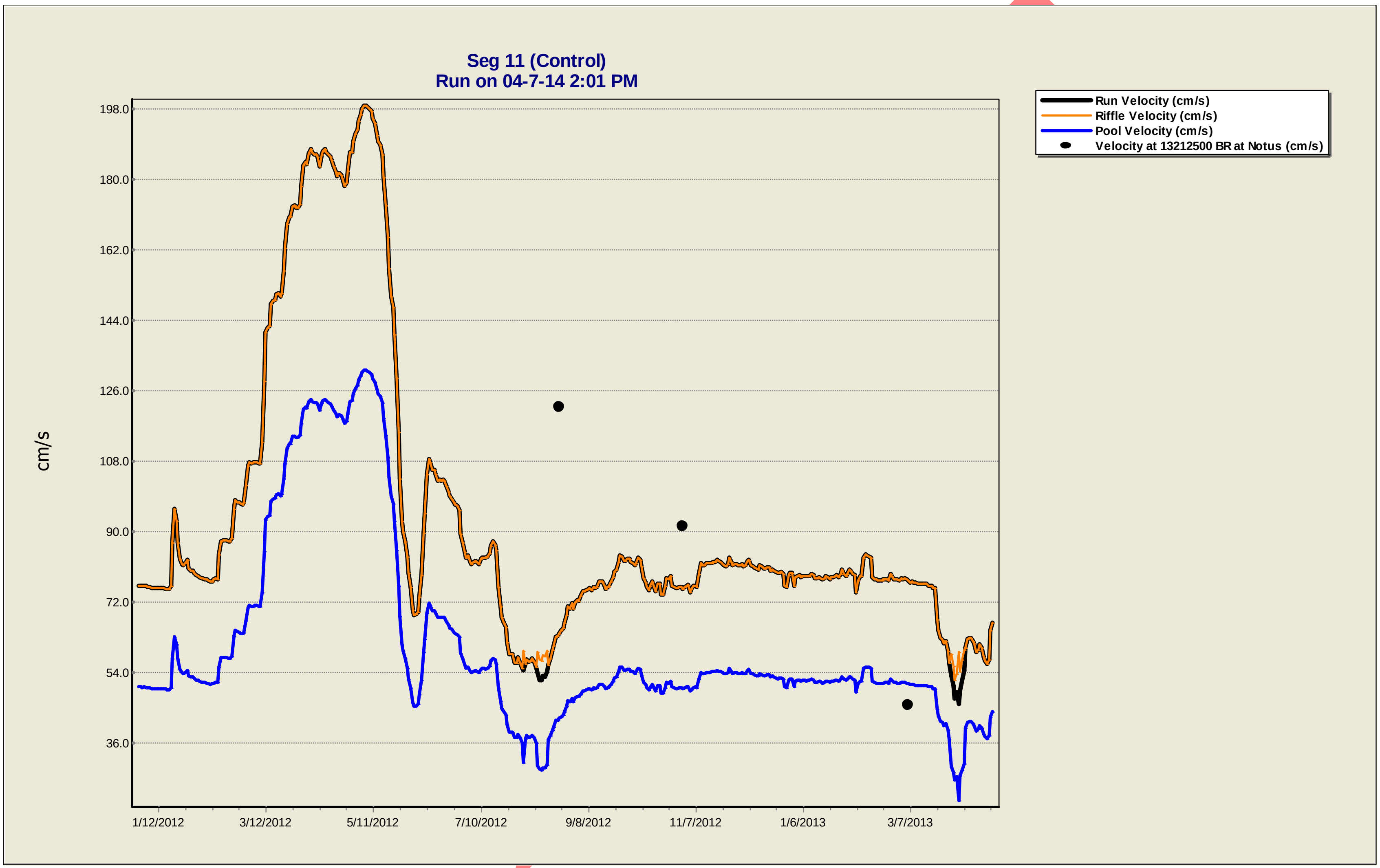

Seg 10 (Control)
Run on 04-7-14 2:00 PM
mg/L
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
.8
.4
.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
NH3 & NH4+ (mg/L)
NO3 (mg/L)
NH3 at 13211600 BR below Caldwell WWTP (mg/L)
Nitrate at 13211600 BR below Caldwell WW (mg/L)
NH3 at 13212500 BR at Notus (mg/L)
Nitrate at 13212500 BR at Notus (mg/L)

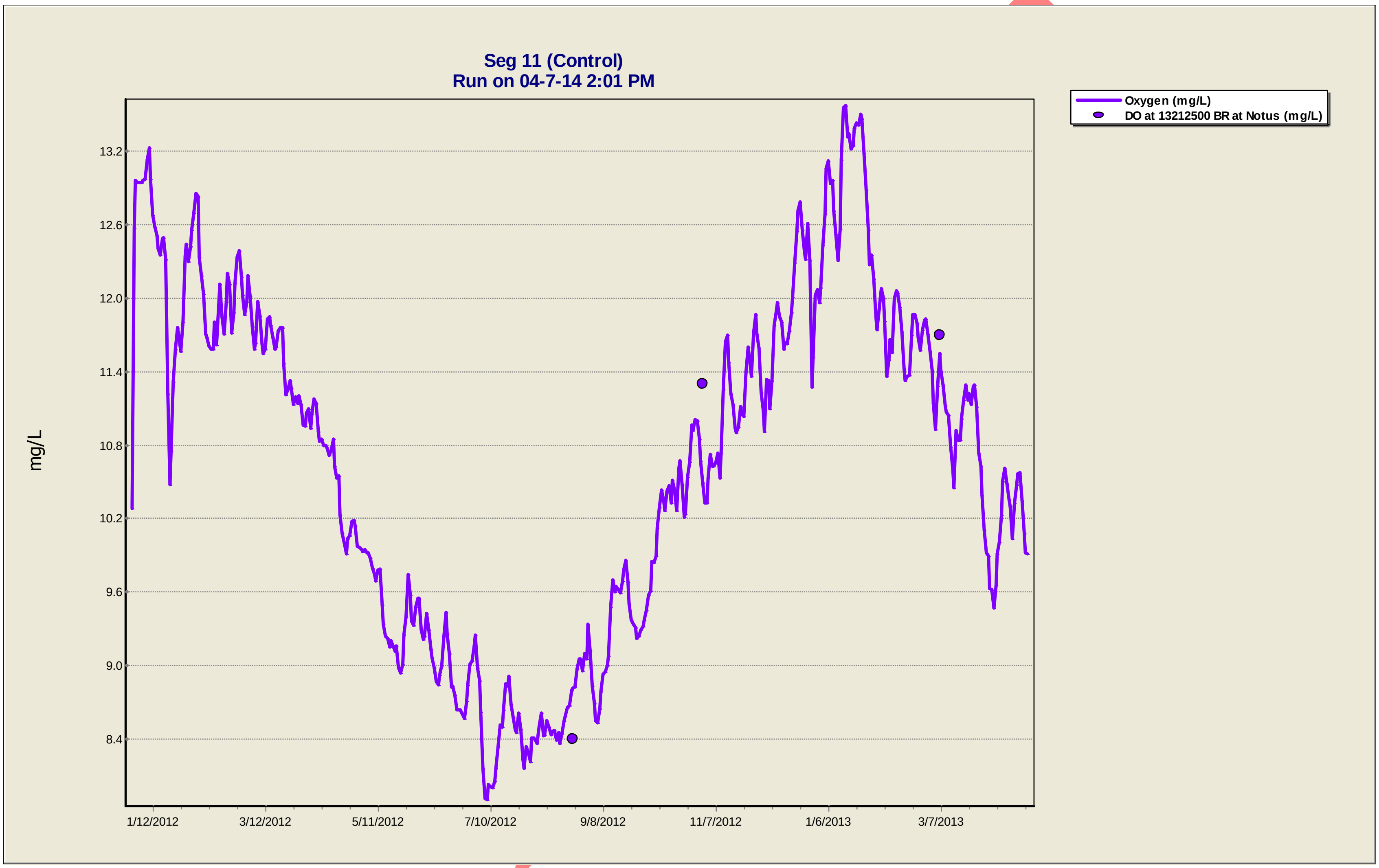

Seg 10 (Control)
Run on 04-7-14 2:00 PM
65
59
52
46
39
33
26
20
13
7
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Peri Low-Nut Diatom (g/m2 dry)
Peri High-Nut Diatom (g/m2 dry)
Cladophora (g/m2 dry)
Peri, Green (g/m2 dry)
Peri, Blue-Greens (g/m2 dry)


Seg 10 (Control)
Run on 04-7-14 2:00 PM
mg/sq.m
800
720
640
560
480
400
320
240
160
80
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Peri. Chlorophyll (mg/sq.m)

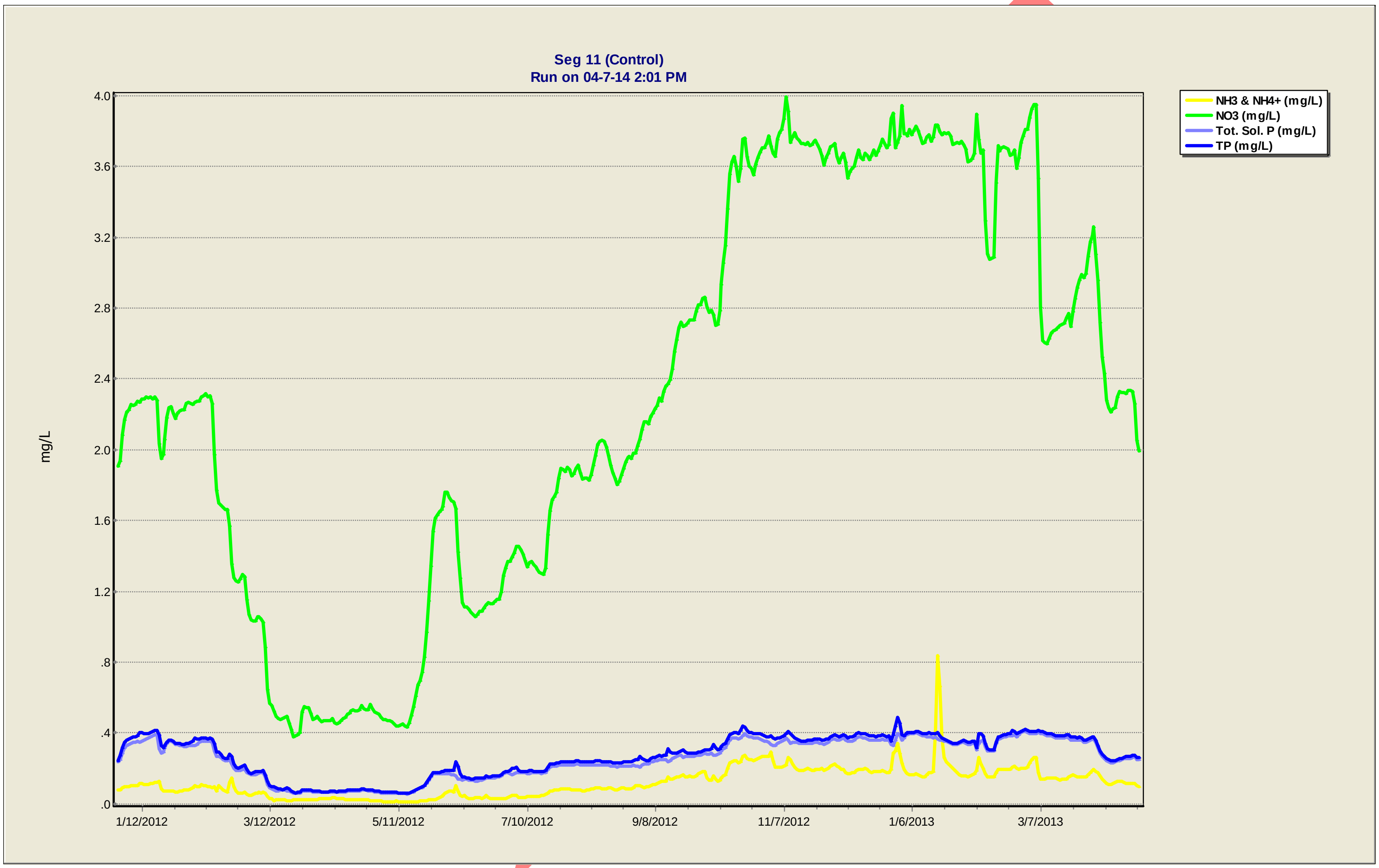

Seg 10 (Control)
Run on 04-7-14 2:00 PM
Phyto. Chlorophyll (ug/L)
ug/L
44
40
35
31
26
22
18
13
9
4
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

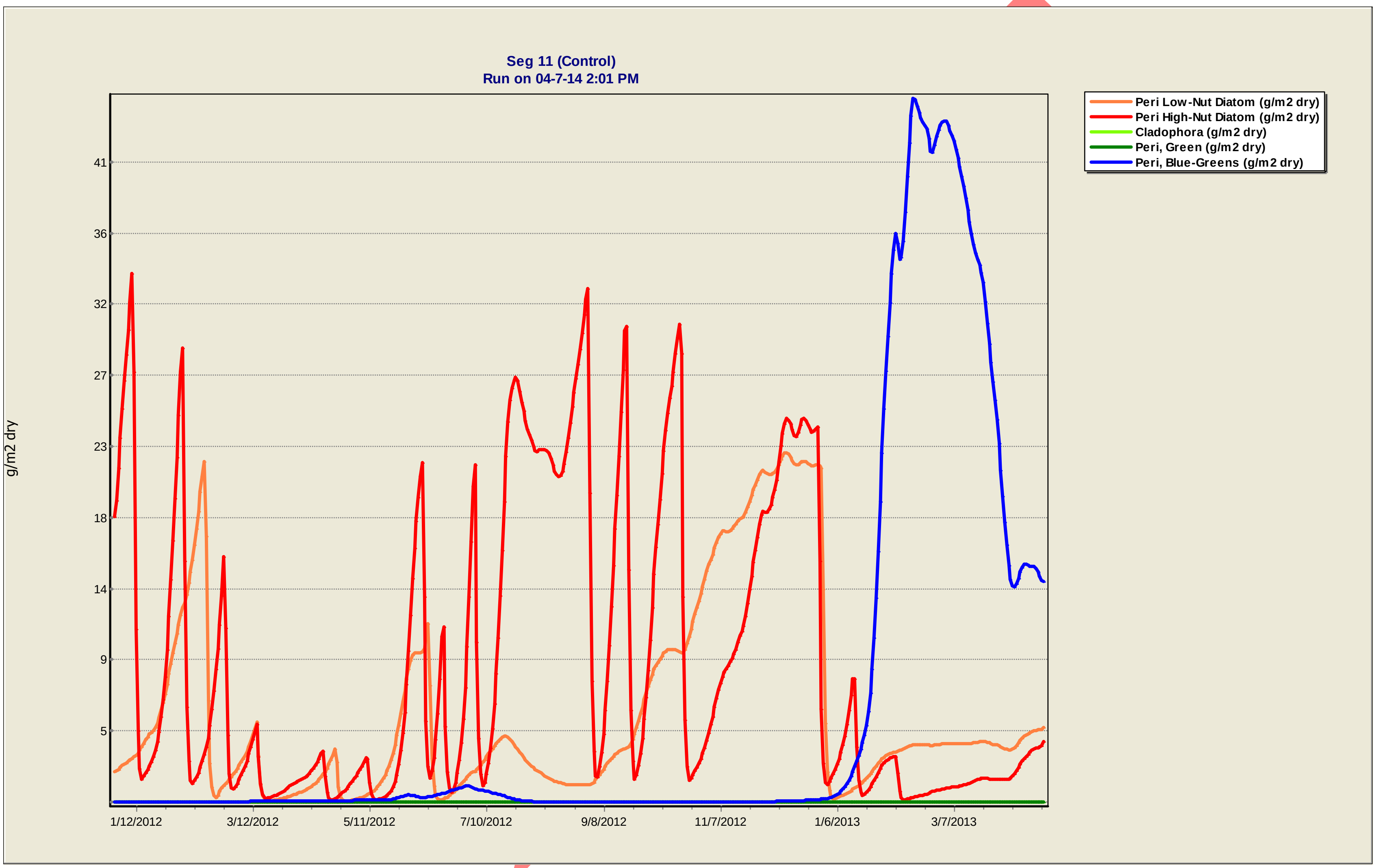
Select Model Results and Measured Data – Segment 11


Seg 11 (Control)
Run on 04-7-14 2:01 PM
Run Velocity (cm/s)
Riffle Velocity (cm/s)
Pool Velocity (cm/s)
Velocity at 13212500 BR at Notus (cm/s)
cm/s
198.0
180.0
162.0
144.0
126.0
108.0
90.0
72.0
54.0
36.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

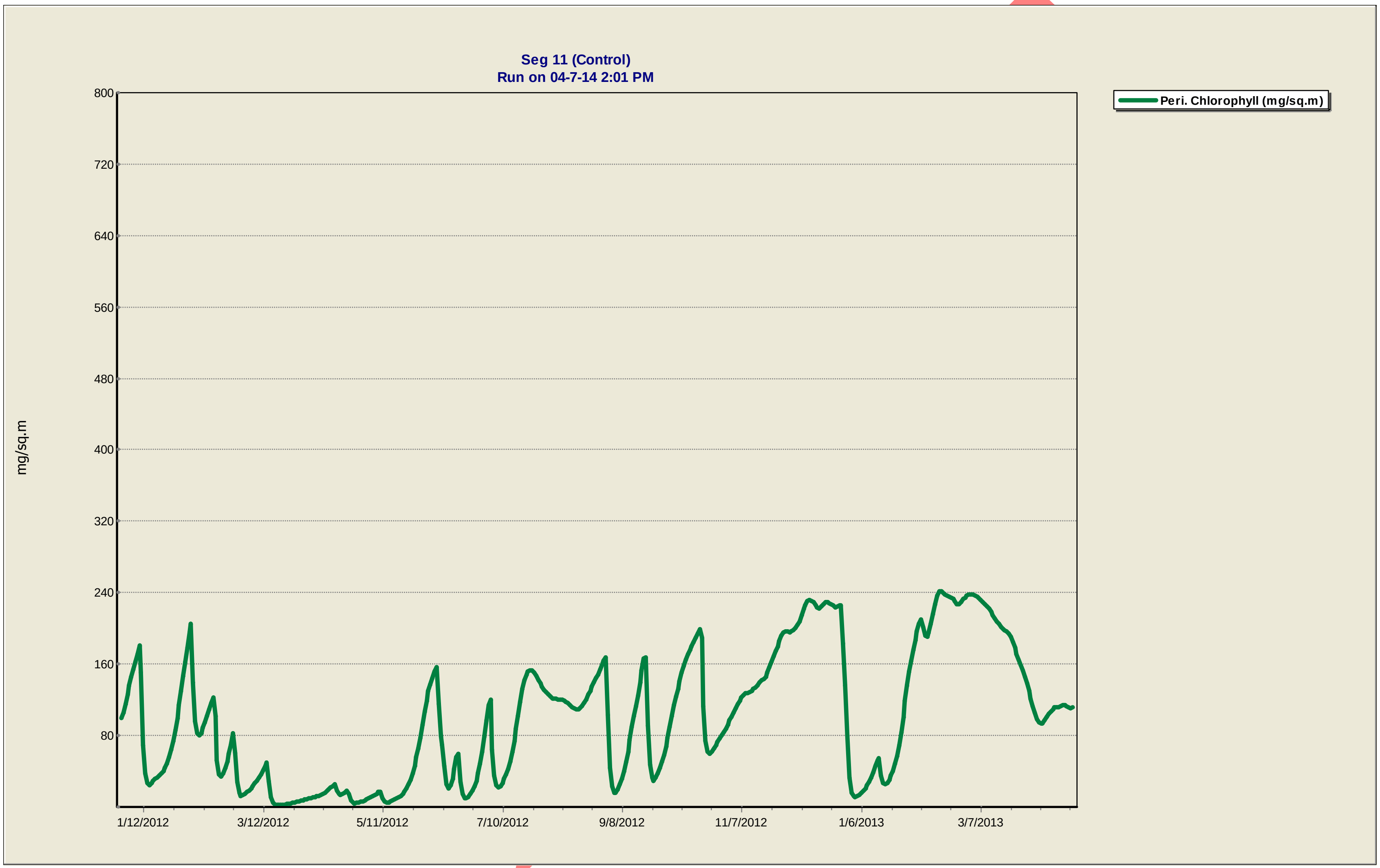


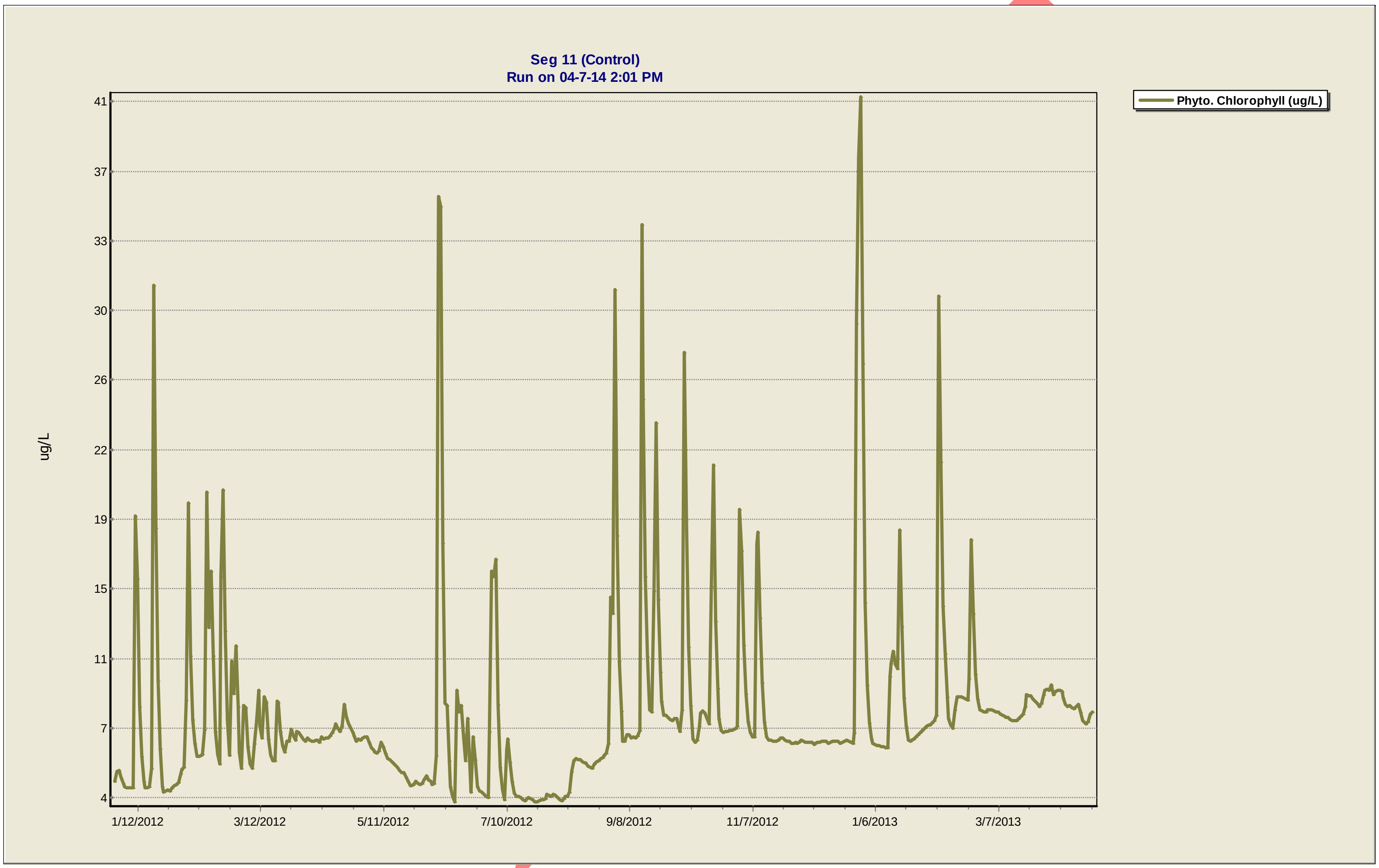
Seg 11 (Control)
Run on 04-7-14 2:01 PM
Oxygen (mg/L)
DO at 13212500 BR at Notus (mg/L)
mg/L
13.2
12.6
12.0
11.4
10.8
10.2
9.6
9.0
8.4
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013


Seg 11 (Control)
Run on 04-7-14 2:01 PM
NH3 & NH4+ (mg/L)
NO3 (mg/L)
Tot. Sol. P (mg/L)
TP (mg/L)
mg/L
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
.8
.4
.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

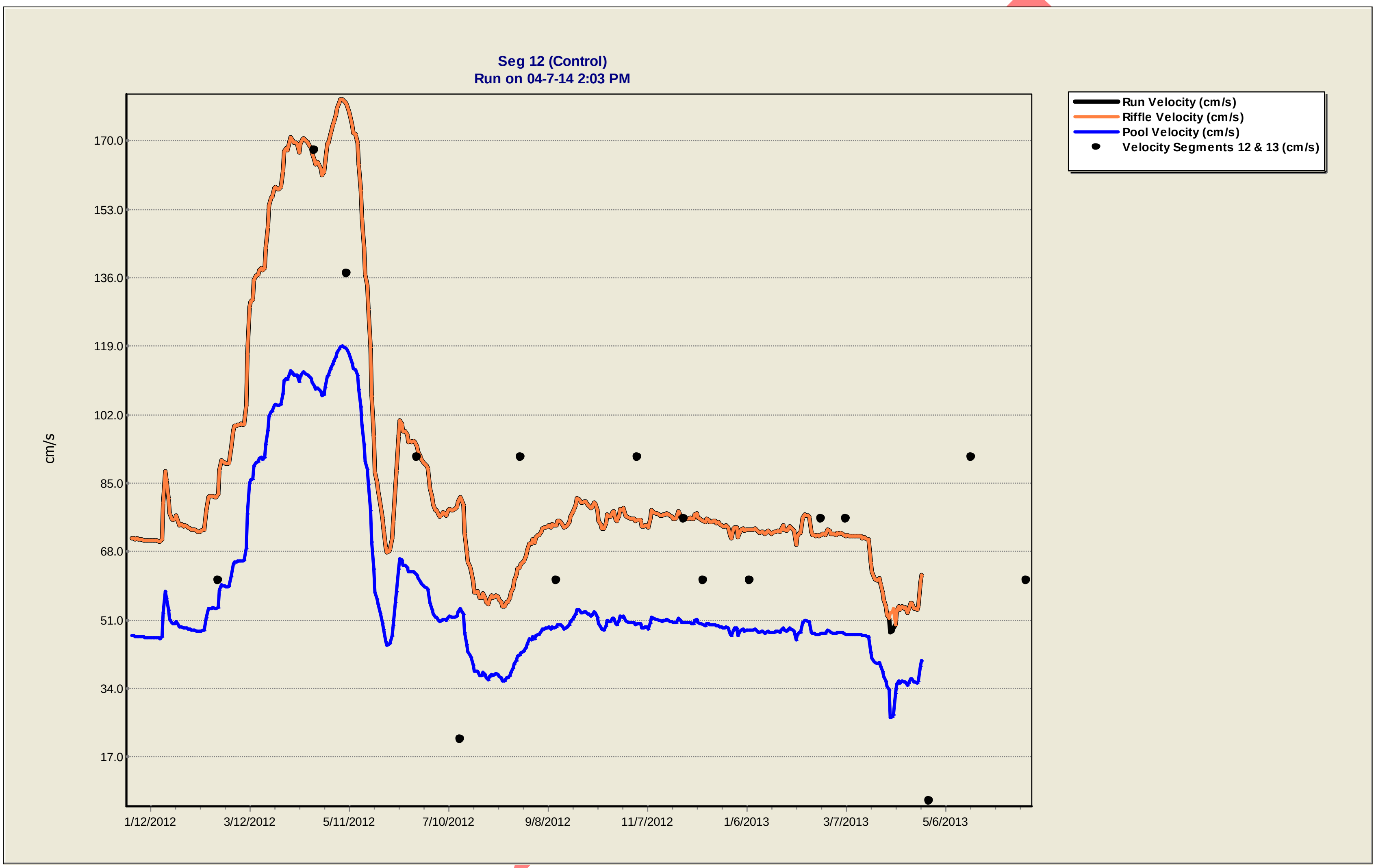


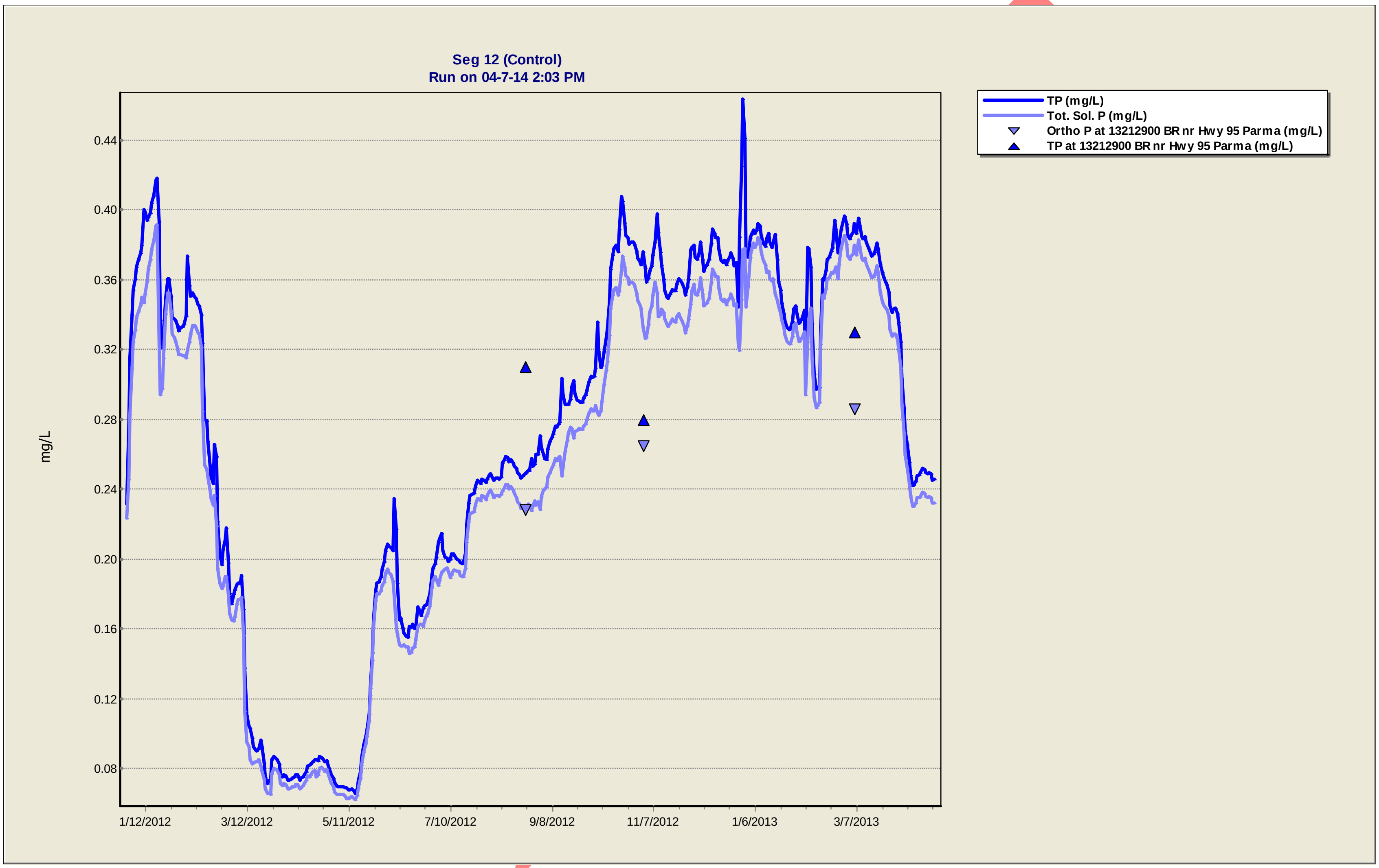
Seg 11 (Control)
Run on 04-7-14 2:01 PM
g/m2 dry
41
36
32
27
23
18
14
9
5
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Peri Low-Nut Diatom (g/m2 dry)
Peri High-Nut Diatom (g/m2 dry)
Cladophora (g/m2 dry)
Peri, Green (g/m2 dry)
Peri, Blue-Greens (g/m2 dry)

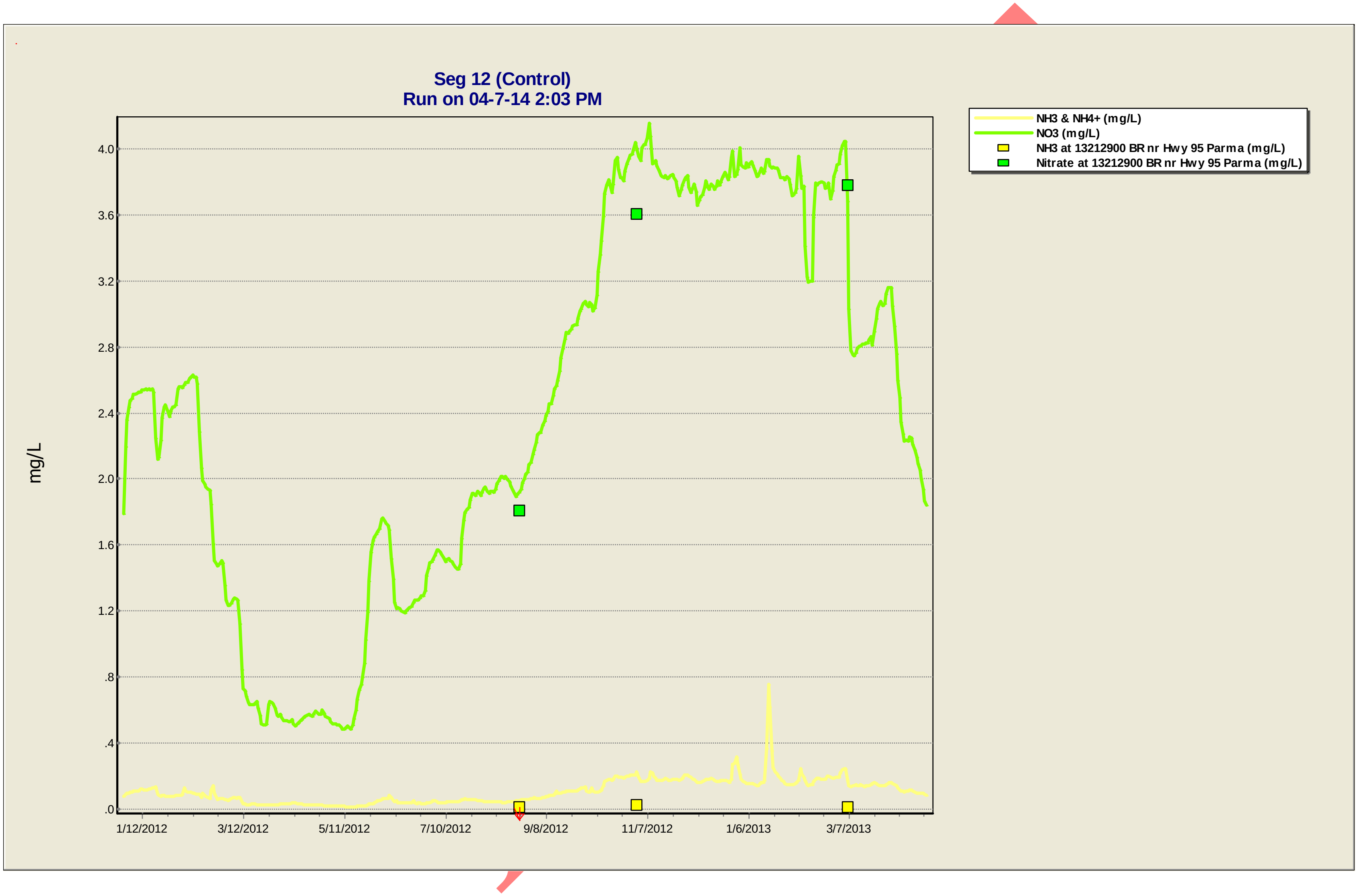

Seg 11 (Control)
Run on 04-7-14 2:01 PM
Peri. Chlorophyll (mg/sq.m)
mg/sq.m
800
720
640
560
480
400
320
240
160
80
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013


Seg 11 (Control)
Run on 04-7-14 2:01 PM
ug/L
41
37
33
30
26
22
19
15
11
7
4
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Phyto. Chlorophyll (ug/L)

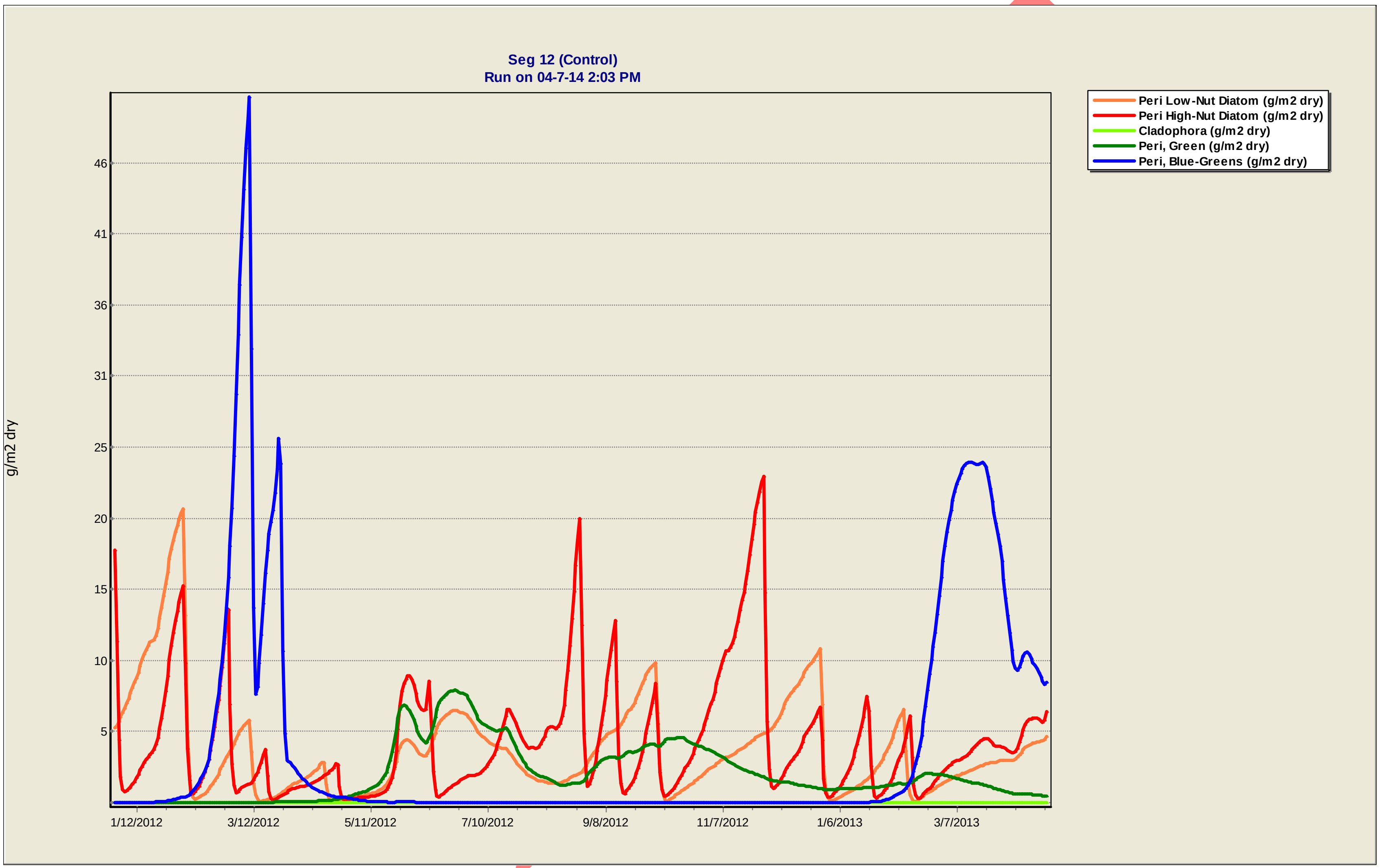
Select Model Results and Measured Data – Segment 12

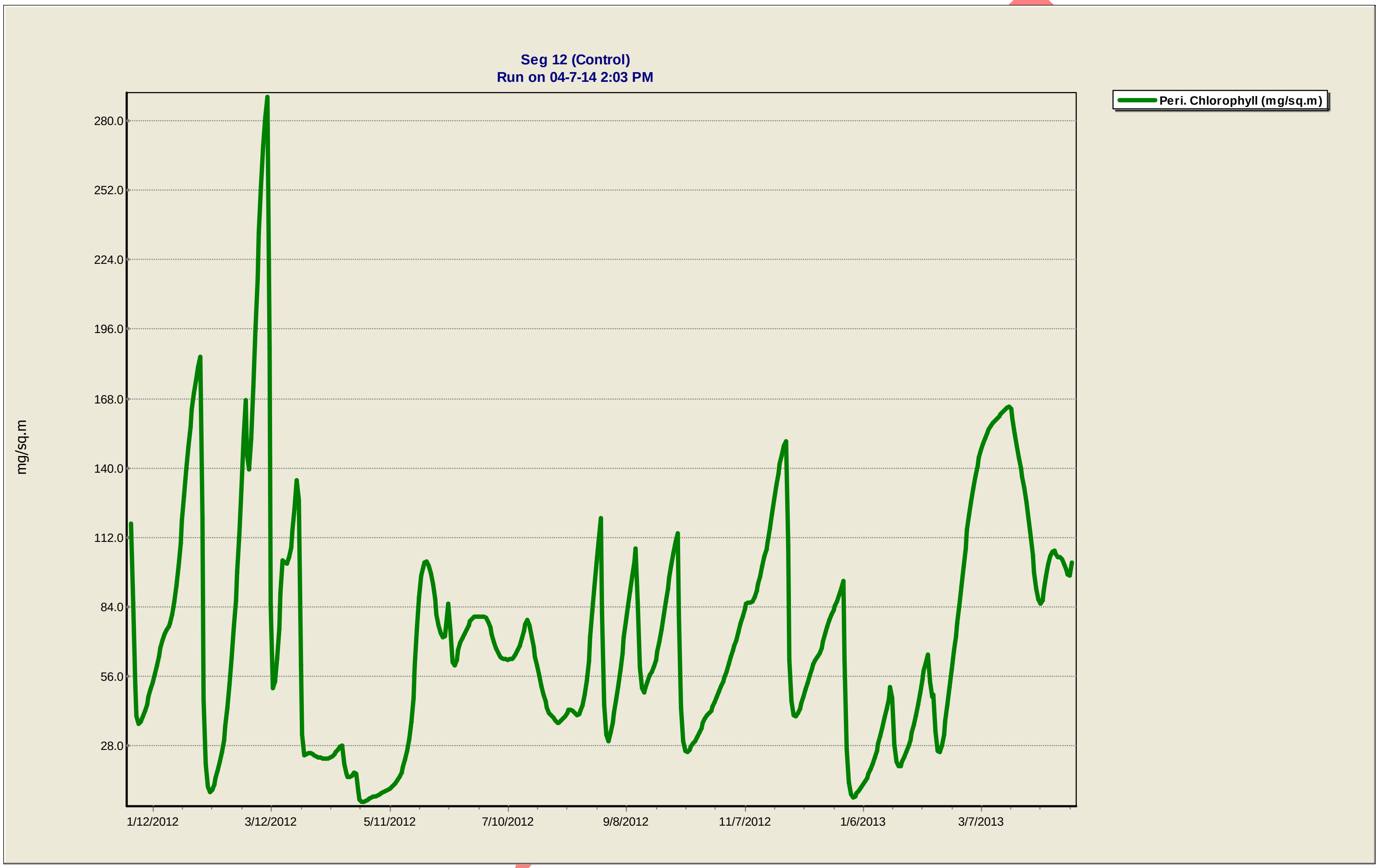

Seg 12 (Control)
Run on 04-7-14 2:03 PM
cm/s
170.0
153.0
136.0
119.0
102.0
85.0
68.0
51.0
34.0
17.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
5/6/2013
Run Velocity (cm/s)
Riffle Velocity (cm/s)
Pool Velocity (cm/s)
Velocity Segments 12 & 13 (cm/s)

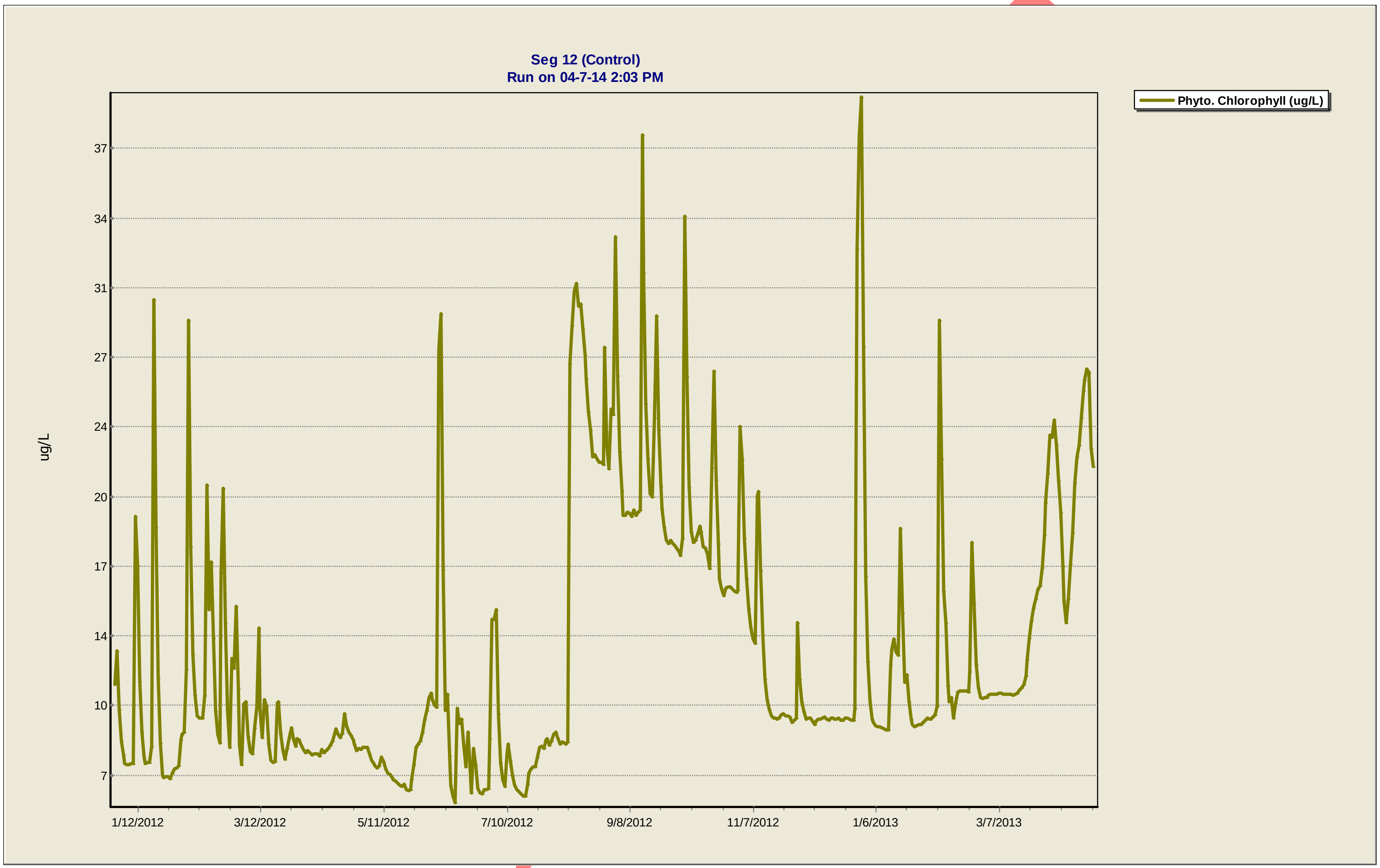

Seg 12 (Control)
Run on 04-7-14 2:03 PM
mg/L
0.44
0.40
0.36
0.32
0.28
0.24
0.20
0.16
0.12
0.08
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
TP (mg/L)
Tot. Sol. P (mg/L)
Ortho P at 13212900 BR nr Hwy 95 Parma (mg/L)
TP at 13212900 BR nr Hwy 95 Parma (mg/L)



Seg 12 (Control)
Run on 04-7-14 2:03 PM
mg/L
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
.8
.4
.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
NH3 & NH4+ (mg/L)
NO3 (mg/L)
NH3 at 13212900 BR nr Hwy 95 Parma (mg/L)
Nitrate at 13212900 BR nr Hwy 95 Parma (mg/L)

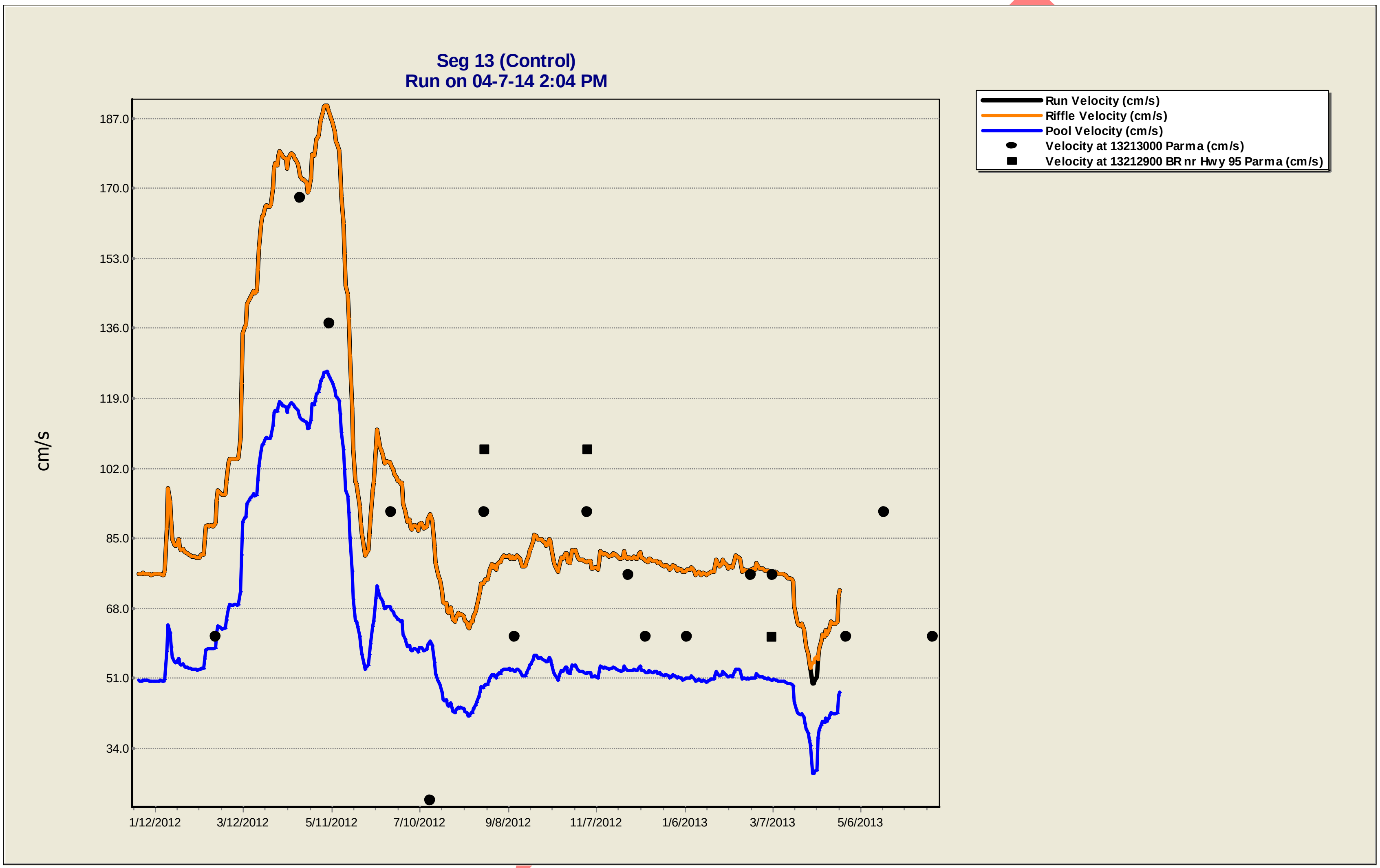

Seg 12 (Control)
Run on 04-7-14 2:03 PM
Peri Low-Nut Diatom (g/m2 dry)
Peri High-Nut Diatom (g/m2 dry)
Cladophora (g/m2 dry)
Peri, Green (g/m2 dry)
Peri, Blue-Greens (g/m2 dry)
g/m2 dry
46
41
36
31
25
20
15
10
5
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

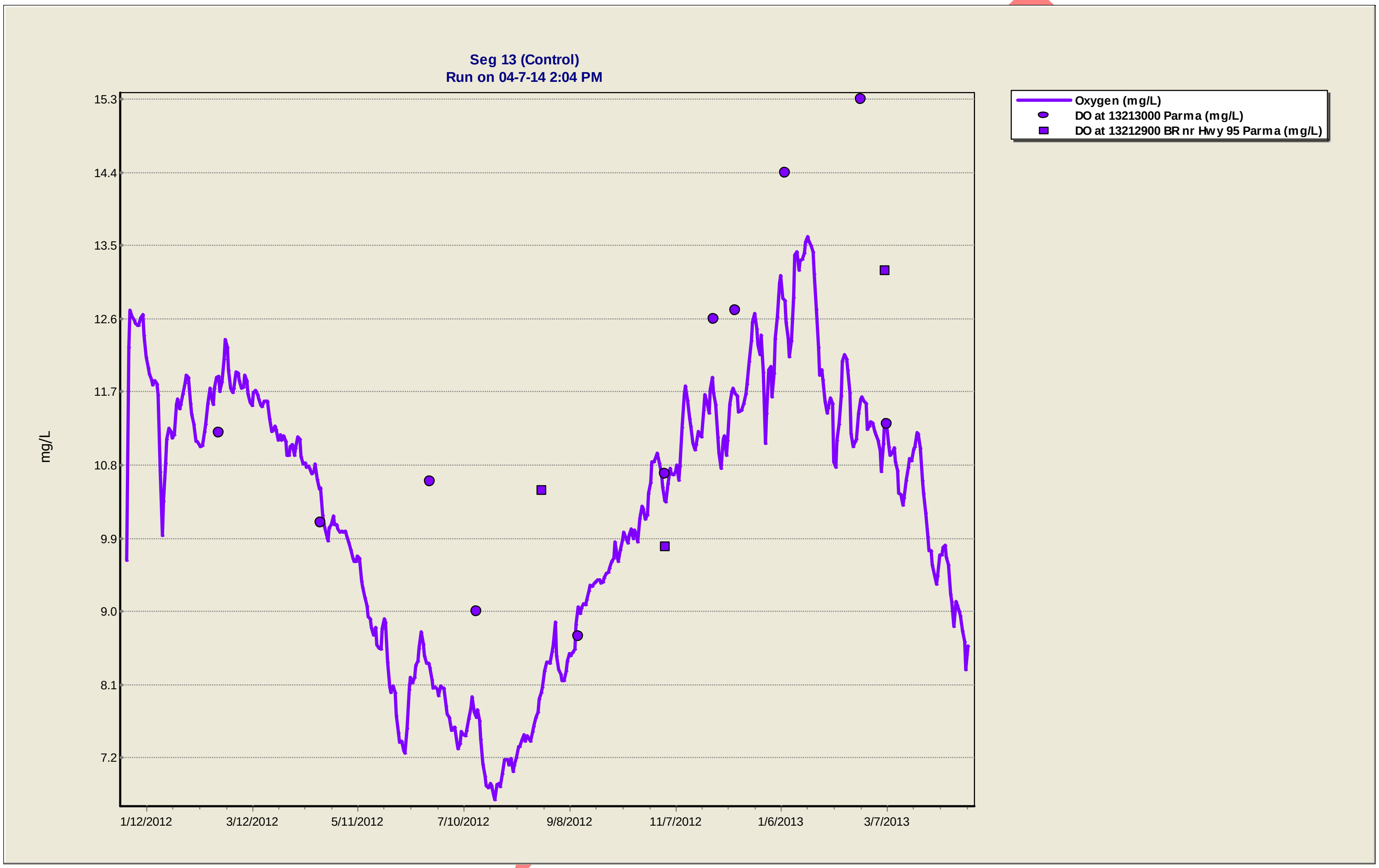

Seg 12 (Control)
Run on 04-7-14 2:03 PM
Peri. Chlorophyll (mg/sq.m)
mg/sq.m
280.0
252.0
224.0
196.0
168.0
140.0
112.0
84.0
56.0
28.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

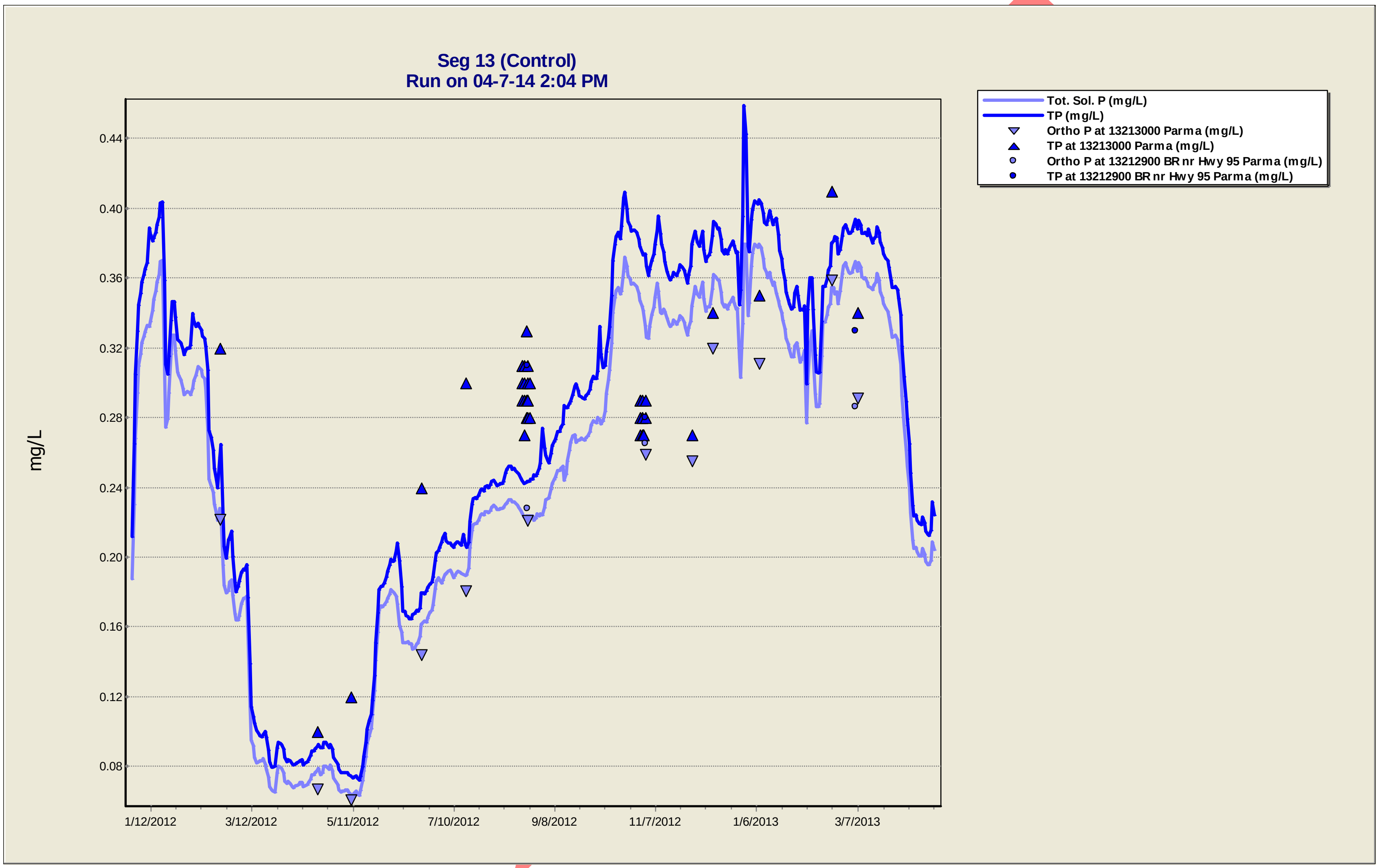


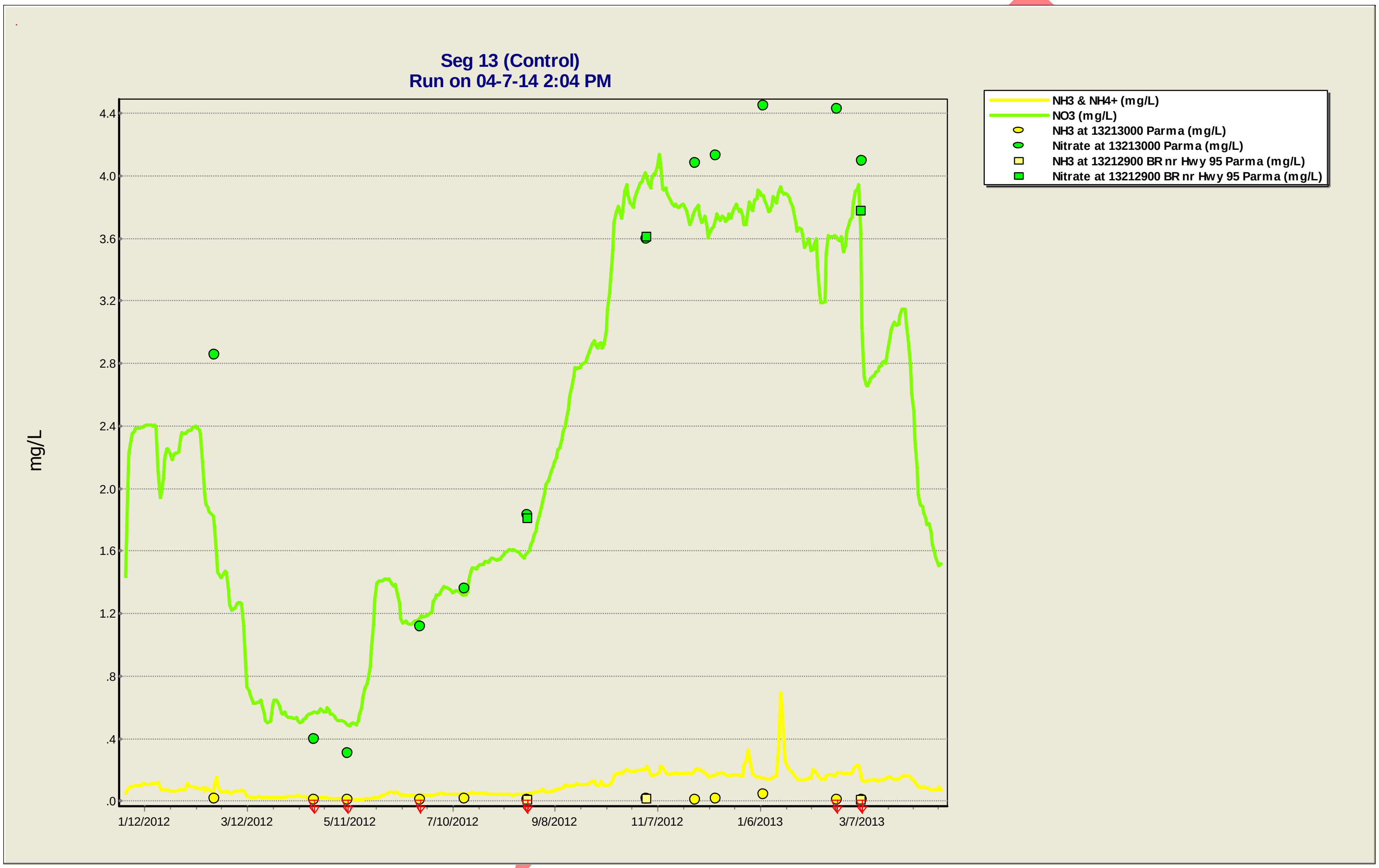
Seg 12 (Control)
Run on 04-7-14 2:03 PM
Phyto. Chlorophyll (ug/L)
ug/L
37
34
31
27
24
20
17
14
10
7
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

Select Model Results and Measured Data – Segment 13

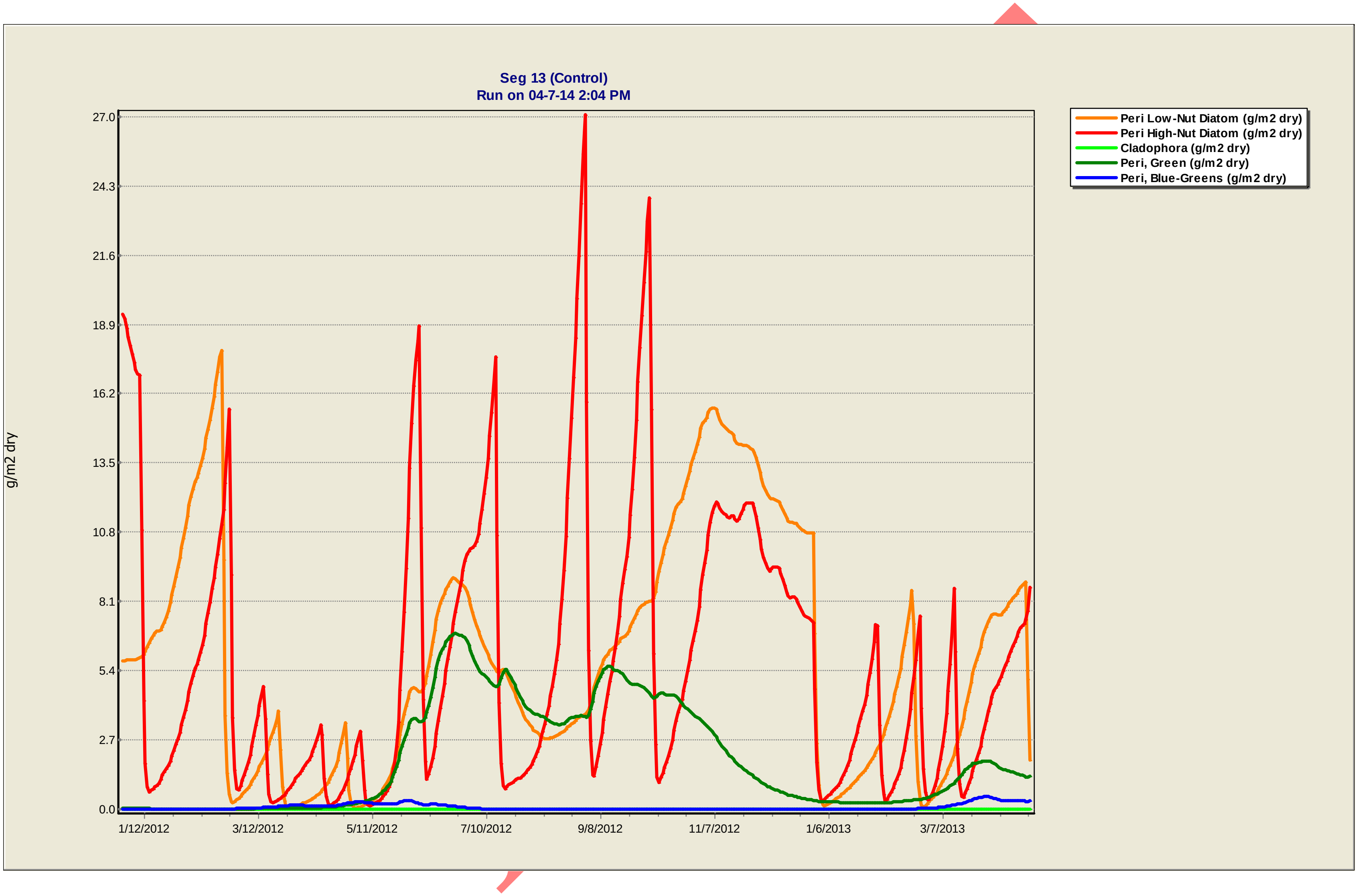

Seg 13 (Control)
Run on 04-7-14 2:04 PM
Run Velocity (cm/s)
Riffle Velocity (cm/s)
Pool Velocity (cm/s)
Velocity at 13213000 Parma (cm/s)
Velocity at 13212900 BR nr Hwy 95 Parma (cm/s)
cm/s
187.0
170.0
153.0
136.0
119.0
102.0
85.0
68.0
51.0
34.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
5/6/2013

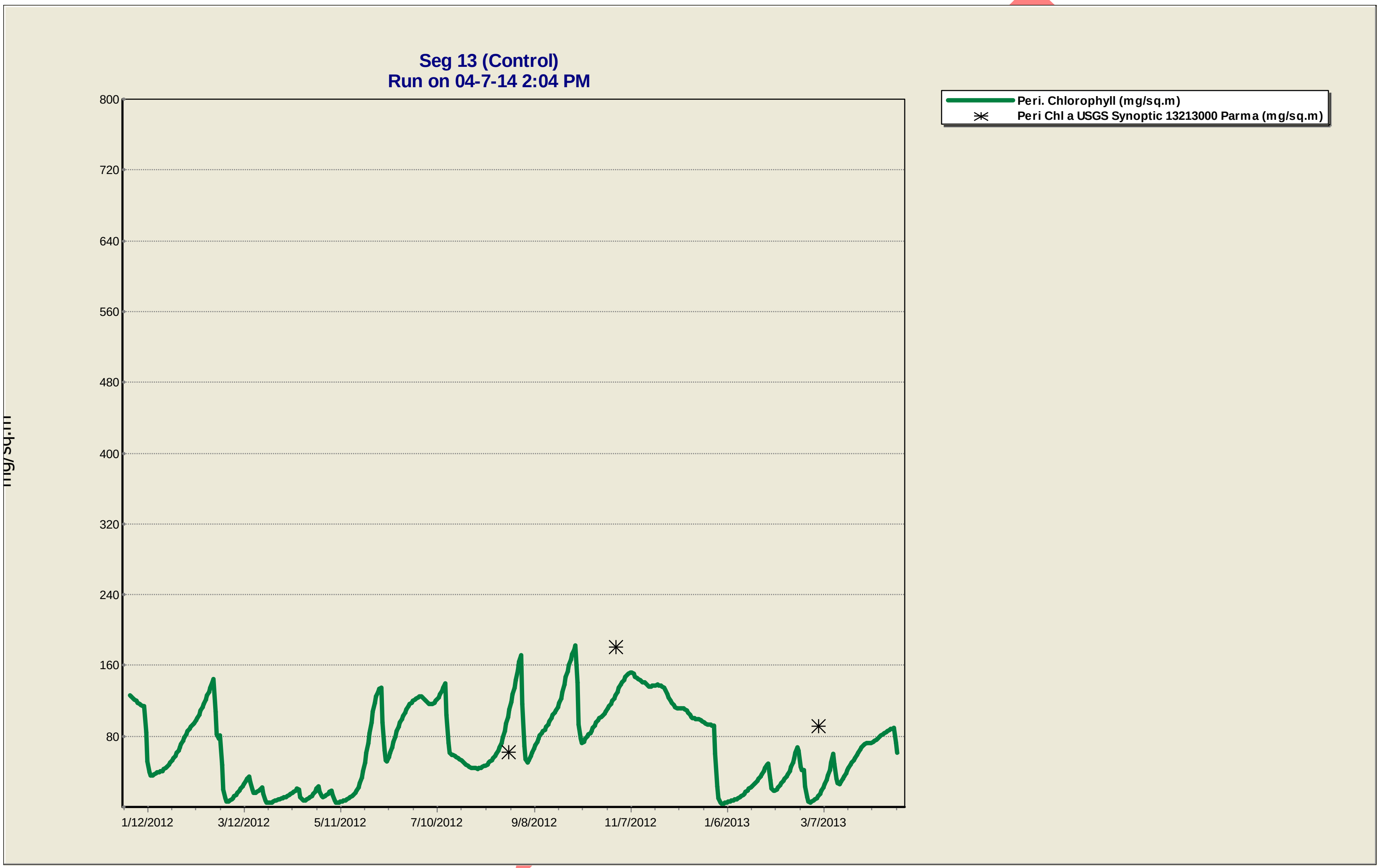

Seg 13 (Control)
Run on 04-7-14 2:04 PM
mg/L
15.3
14.4
13.5
12.6
11.7
10.8
9.9
9.0
8.1
7.2
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Oxygen (mg/L)
DO at 13213000 Parma (mg/L)
DO at 13212900 BR nr Hwy 95 Parma (mg/L)

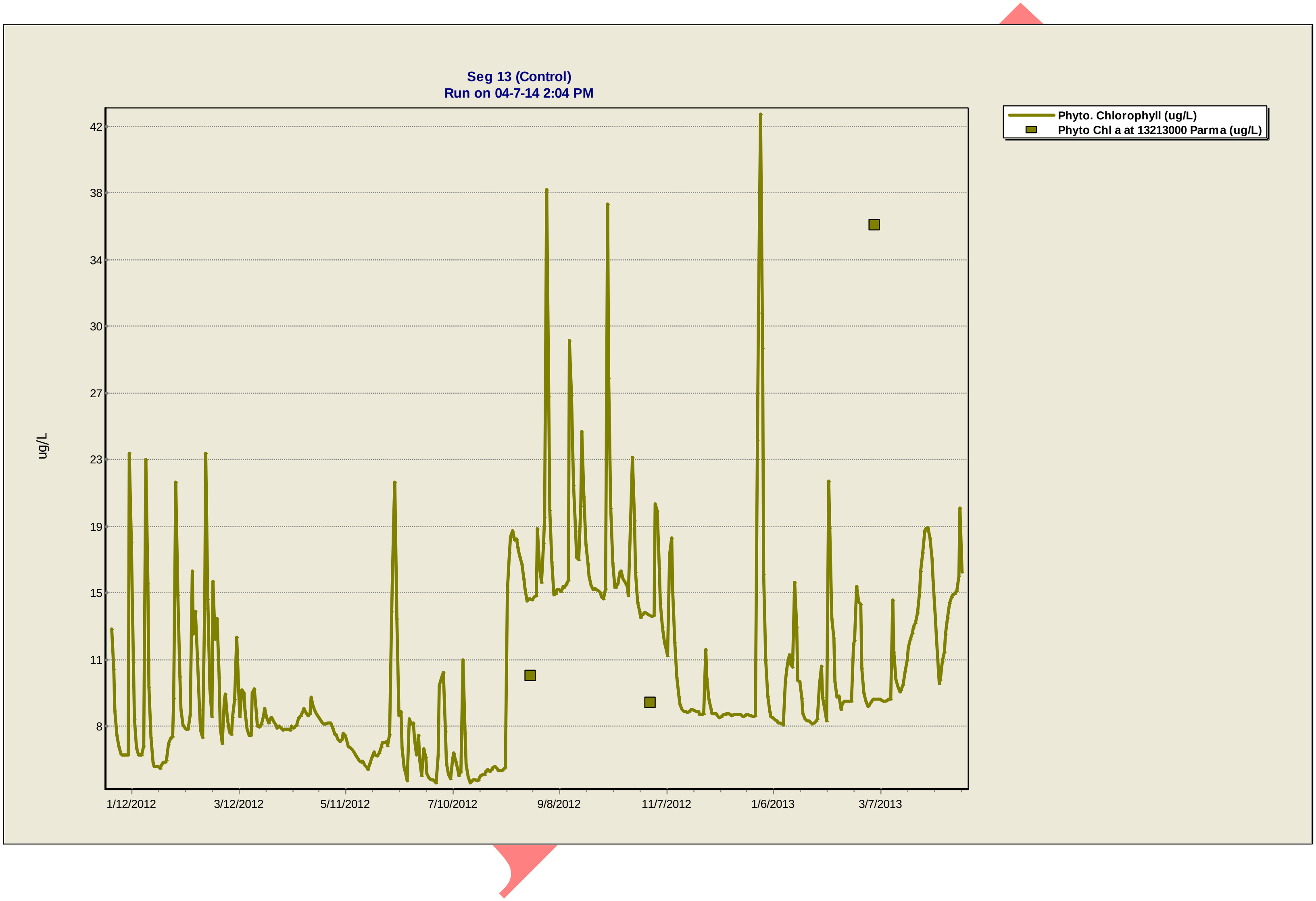

Seg 13 (Control)
Run on 04-7-14 2:04 PM
mg/L
0.44
0.40
0.36
0.32
0.28
0.24
0.20
0.16
0.12
0.08
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Tot. Sol. P (mg/L)
TP (mg/L)
Ortho P at 13213000 Parma (mg/L)
TP at 13213000 Parma (mg/L)
Ortho P at 13212900 BR nr Hwy 95 Parma (mg/L)
TP at 13212900 BR nr Hwy 95 Parma (mg/L)



Seg 13 (Control)
Run on 04-7-14 2:04 PM
mg/L
4.4
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
.8
.4
.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
NH3 & NH4+ (mg/L)
NO3 (mg/L)
NH3 at 13213000 Parma (mg/L)
Nitrate at 13213000 Parma (mg/L)
NH3 at 13212900 BR nr Hwy 95 Parma (mg/L)
Nitrate at 13212900 BR nr Hwy 95 Parma (mg/L)


Seg 13 (Control)
Run on 04-7-14 2:04 PM
g/m2 dry
27.0
24.3
21.6
18.9
16.2
13.5
10.8
8.1
5.4
2.7
0.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013
Peri Low-Nut Diatom (g/m2 dry)
Peri High-Nut Diatom (g/m2 dry)
Cladophora (g/m2 dry)
Peri, Green (g/m2 dry)
Peri, Blue-Greens (g/m2 dry)


Seg 13 (Control)
Run on 04-7-14 2:04 PM
Peri. Chlorophyll (mg/sq.m)
Peri Chl a USGS Synoptic 13213000 Parma (mg/sq.m)
mg/sq.m
800
720
640
560
480
400
320
240
160
80
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013


Seg 13 (Control)
Run on 04-7-14 2:04 PM
Phyto. Chlorophyll (ug/L)
Phyto Chl a at 13213000 Parma (ug/L)
ug/L
42
38
34
30
27
23
19
15
11
8
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

Appendix B. Reduction Scenario Input

Lander				
Dates	**Current ATOX Seasonal Flows (CMD)**	**Design Flows (CMD)**	**Target TP Conc. (mg/L)**	**ATOX Facility TP Conc. w/ Design Flow (mg/L)**
Oct - Apr 2012/2013	46118	56809	**0.35**	**0.43**
May - Sept 2012	48095	56809	**0.1**	**0.12**

Monthly average historic data (mg/L)					**Nutrient reductions (mg/L)**					
	NH4	NO3	TP	BOD		NH4	NO3	TP	TP reduction ratio	BOD
Jan	0.27	10.78	4.62	7.64	Jan	0.27	10.78	0.43	0.09	5.00
Feb	0.24	11.15	4.43	6.00	Feb	0.24	11.15	0.43	0.10	5.00
Mar	0.14	11.17	4.09	5.72	Mar	0.14	11.17	0.43	0.11	5.00
Apr	0.25	11.14	3.25	5.78	Apr	0.25	11.14	0.43	0.13	5.00
May	0.26	10.86	3.94	5.53	May	0.26	10.86	0.12	0.03	5.00
Jun	0.17	10.60	4.05	4.63	Jun	0.169	10.60	0.12	0.03	4.63
Jul	0.24	10.78	4.35	3.93	Jul	0.24	10.78	0.12	0.03	3.93
Aug	0.32	10.47	4.52	3.91	Aug	0.32	10.47	0.12	0.03	3.91
Sep	0.17	10.82	3.51	4.07	Sep	0.172	10.82	0.12	0.03	4.07
Oct	0.19	12.02	3.86	5.49	Oct	0.19	12.02	0.43	0.11	5.00
Nov	0.22	11.49	3.63	6.31	Nov	0.22	11.49	0.43	0.12	5.00
Dec	0.52	10.30	4.84	7.29	Dec	0.52	10.30	0.43	0.09	5.00
					Average TP reduction = 92.5%					

NH4 set by technology limitations rather than reduction ratio: Used existing monthly averages since they were <1

NO3 set by technology limitations to a range of 5 - 30. Used existing monthly averages since they were less than mean

BOD set by technology limitations to <5. Used existing monthly averages where <5, maxed at 5

West Boise

Dates	**Current ATOX Seasonal Flows (CMD)**	**Design Flows (CMD)**	**Target TP Conc. (mg/L)**	**ATOX Facility TP Conc. w/ Design Flow (mg/L)**
Oct - Apr 2012/2013	55560	90895	**0.35**	**0.57**
May - Sept 2012	60957	90895	**0.1**	**0.15**

Monthly average historic data (mg/L)					**Nutrient reductions (mg/L)**					
	NH4	NO3	TP	BOD		NH4	NO3	TP	TP reduction ratio	BOD
Jan	0.90	21.51	5.10	7.5	Jan	0.903	17.50	0.57	0.11	5.0
Feb	0.34	21.34	4.97	6.5	Feb	0.336	17.50	0.57	0.11	5.0
Mar	0.30	23.09	5.31	6.1	Mar	0.301	17.50	0.57	0.11	5.0
Apr	0.28	22.87	5.44	5.9	Apr	0.279	17.50	0.57	0.10	5.0
May	0.18	20.75	5.01	4.8	May	0.175	17.50	0.15	0.03	4.8
Jun	0.12	21.38	5.12	4.7	Jun	0.122	17.50	0.15	0.03	4.7
Jul	0.13	19.65	5.03	4.4	Jul	0.130	17.50	0.15	0.03	4.4
Aug	0.95	19.55	4.86	3.9	Aug	0.951	17.50	0.15	0.03	3.9
Sep	0.12	17.96	4.62	3.6	Sep	0.116	17.50	0.15	0.03	3.6
Oct	0.25	20.64	4.97	4.7	Oct	0.252	17.50	0.57	0.11	4.7
Nov	0.13	22.07	5.25	5.0	Nov	0.125	17.50	0.57	0.11	5.0
Dec	0.37	22.04	5.13	7.1	Dec	0.368	17.50	0.57	0.11	5.0
					Average TP reduction = 92.3%					

NH4 set by technology limitations rather than reduction ratio: Used existing monthly averages since they were <1

NO3 set by technology limitations to a range of 5 - 30. Used 17.5 as average.

BOD set by technology limitations to <5. Used existing monthly averages where <5, maxed at 5

Middleton				
Dates	**Current ATOX Seasonal Flows (CMD)**	**Design Flows (CMD)**	**Target TP Conc. (mg/L)**	**ATOX Facility TP Conc. w/ Design Flow (mg/L)**
Oct - Apr 2012/2013	1685	6931	**0.35**	**1.44**
May - Sept 2012	2347	6931	**0.1**	**0.30**

Monthly average historic data (mg/L)					**Nutrient reductions (mg/L)**					
	NH4	NO3	TP	BOD		NH4	NO3	TP	TP reduction ratio	BOD
Jan	31.28	0.11	5.38	32.0	Jan	1.00	0.109	1.44	0.27	5.00
Feb	30.85	0.06	5.12	27.5	Feb	1.00	0.064	1.44	0.28	5.00
Mar	32.03	0.06	5.01	39.8	Mar	1.00	0.064	1.44	0.29	5.00
Apr	33.75	0.40	5.41	44.7	Apr	1.00	0.404	1.44	0.27	5.00
May	21.26	0.17	3.71	24.7	May	1.00	0.173	0.30	0.08	5.00
Jun	18.89	0.07	3.40	15.5	Jun	1.00	0.071	0.30	0.09	5.00
Jul	15.58	0.12	3.30	14.0	Jul	1.00	0.121	0.30	0.09	5.00
Aug	5.99	4.66	3.07	12.2	Aug	1.00	4.659	0.30	0.10	5.00
Sep	5.86	5.96	3.05	14.0	Sep	1.00	5.962	0.30	0.10	5.00
Oct	8.83	5.27	3.37	17.8	Oct	1.00	5.269	1.44	0.43	5.00
Nov	19.63	3.49	3.99	23.8	Nov	1.00	3.488	1.44	0.36	5.00
Dec	27.24	0.10	4.49	28.1	Dec	1.00	0.096	1.44	0.32	5.00
					Average TP reduction = 77.8%					

NH4 set by technology limitations to 1 mg/L

NO3 set by technology limitations to a range of 5 - 30. Used existing monthly averages since they were < the mid-range

BOD set by technology limitations to 5.

Caldwell

Dates	Current ATOX Seasonal Flows (CMD)	Design Flows (CMD)	Target TP Conc. (mg/L)	ATOX Facility TP Conc. w/ Design Flow (mg/L)
Oct - Apr 2012/2013	21828	32192	**0.35**	**0.52**
May - Sept 2012	29908	32192	**0.1**	**0.11**

Monthly average historic data (mg/L)					**Nutrient reductions (mg/L)**					
	NH4	NO3	TP	BOD		NH4	NO3	TP	TP reduction ratio	BOD
Jan	0.04	17.43	0.64	10.9	Jan	0.040	17.43	0.52	0.8	5.0
Feb	0.44	10.25	0.88	8.5	Feb	0.439	10.25	0.52	0.6	5.0
Mar	0.26	16.36	1.07	7.7	Mar	0.263	16.36	0.52	0.5	5.0
Apr	0.73	11.64	1.10	4.8	Apr	0.729	11.64	0.52	0.5	4.8
May	1.18	6.83	0.94	3.9	May	1.180	6.83	0.11	0.1	3.9
Jun	0.44	6.72	1.25	3.3	Jun	0.436	6.72	0.11	0.1	3.3
Jul	0.85	6.42	1.86	4.4	Jul	0.845	6.42	0.11	0.1	4.4
Aug	0.94	6.48	1.23	3.2	Aug	0.941	6.48	0.11	0.1	3.2
Sep	0.66	9.47	1.60	3.9	Sep	0.664	9.47	0.11	0.1	3.9
Oct	2.44	10.69	0.31	3.6	Oct	2.443	10.69	0.52	1.7	3.6
Nov	0.04	21.90	0.65	6.8	Nov	0.040	21.90	0.52	0.8	5.0
Dec	1.08	15.42	0.64	7.0	Dec	1.078	15.42	0.52	0.8	5.0
					Average TP reduction = 49.5%					

NH4 set by technology limitations rather than reduction ratio: literature indicates <1. Used existing monthly averages where already <1 and set max at 1.

NO3 set by technology limitations to a range of 5 - 30. Used existing monthly averages since they were in that range.

BOD set by technology limitations to <5. Used existing monthly averages where <5, maxed at 5

Eagle Drain										
Monthly average historic data (mg/L)					**Nutrient reductions (mg/L)**					
	NH4	NO3	TP	BOD		NH4	NO3	TP	TP reduction ratio	BOD
Jan	0.04	2.14	0.16	2.1	Jan	0.02	0.9	0.07	0.4	0.9
Feb	0.04	1.98	0.13	1.3	Feb	0.02	1.1	0.07	0.5	0.7
Mar	0.03	1.99	0.11	1.4	Mar	0.02	1.3	0.07	0.6	0.9
Apr	0.02	0.71	0.09	2.4	Apr	0.01	0.6	0.07	0.8	1.9
May	0.01	0.87	0.09	1.6	May	0.01	0.7	0.07	0.8	1.2
Jun	0.01	0.74	0.06	1.3	Jun	0.01	0.7	0.06	1.0	1.3
Jul	0.01	0.78	0.07	1.2	Jul	0.01	0.8	0.07	1.0	1.2
Aug	0.01	0.66	0.09	1.1	Aug	0.01	0.5	0.07	0.8	0.8
Sep	0.01	0.81	0.10	0.7	Sep	0.01	0.6	0.07	0.7	0.5
Oct	0.04	1.58	0.16	0.5	Oct	0.02	0.7	0.07	0.4	0.2
Nov	0.11	3.84	0.16	1.1	Nov	0.05	1.6	0.07	0.4	0.5
Dec	0.16	6.22	0.19	1.6	Dec	0.06	2.3	0.07	0.4	0.6
					Average TP reduction = 34.3%					
TP target 0.07 mg/L. June left at 0.06 because monthly average already lower than target.										

Thurman Drain										
Monthly average historic data (mg/L)					Nutrient reductions (mg/L)					
	NH4	NO3	TP	BOD		NH4	NO3	TP	TP reduction ratio	BOD
Jan	0.04	3.80	0.17	1.2	Jan	0.02	1.6	0.07	0.4	0.5
Feb	0.04	3.29	0.18	1.0	Feb	0.02	1.3	0.07	0.4	0.4
Mar	0.02	3.00	0.10	1.2	Mar	0.01	2.2	0.07	0.7	0.9
Apr	0.03	1.43	0.11	2.4	Apr	0.02	0.9	0.07	0.6	1.5
May	0.05	1.47	0.13	1.9	May	0.03	0.8	0.07	0.5	1.0
Jun	0.03	1.62	0.10	1.1	Jun	0.02	1.1	0.07	0.7	0.8
Jul	0.05	1.75	0.13	1.1	Jul	0.03	1.0	0.07	0.6	0.6
Aug	0.02	1.31	0.09	1.9	Aug	0.02	1.1	0.07	0.8	1.5
Sep	0.02	1.94	0.10	1.1	Sep	0.02	1.4	0.07	0.7	0.8
Oct	0.04	3.28	0.13	0.5	Oct	0.02	1.8	0.07	0.5	0.3
Nov	0.06	3.79	0.15	0.7	Nov	0.03	1.8	0.07	0.5	0.3
Dec	0.03	4.08	0.15	0.9	Dec	0.01	2.0	0.07	0.5	0.4
TP target 0.07 mg/L.					Average TP reduction = 34.3%					

Fifteenmile Creek										
Monthly average historic data (mg/L)					**Nutrient reductions (mg/L)**					
	NH4	NO3	TP	BOD		NH4	NO3	TP	TP reduction ratio	BOD
Jan	0.18	3.44	0.43	2.8	Jan	0.06	1.2	0.146	0.3	1.0
Feb	0.03	4.64	0.30	1.0	Feb	0.01	2.3	0.146	0.5	0.5
Mar	0.79	6.50	0.35	1.8	Mar	0.33	2.7	0.146	0.4	0.8
Apr	0.34	1.76	0.56	3.7	Apr	0.09	0.5	0.146	0.3	1.0
May	0.05	1.36	0.23	1.8	May	0.02	0.4	0.074	0.3	0.6
Jun	0.06	1.89	0.36	2.2	Jun	0.01	0.4	0.074	0.2	0.4
Jul	0.07	2.04	0.35	2.0	Jul	0.01	0.4	0.074	0.2	0.4
Aug	0.05	2.23	0.33	1.8	Aug	0.01	0.5	0.074	0.2	0.4
Sep	0.02	2.00	0.22	1.5	Sep	0.01	0.7	0.074	0.3	0.5
Oct	1.37	5.18	0.50	0.5	Oct	0.40	1.5	0.146	0.3	0.1
Nov	0.02	4.73	0.57	1.1	Nov	0.005	1.2	0.146	0.3	0.3
Dec	0.02	5.16	0.74	1.7	Dec	0.004	1.0	0.146	0.2	0.3
					Average TP reduction = 34.3%					
TP target 0.07 mg/L for tributary. Meridian effluent to 15mile calculated under design flow.										

N. Middleton Drain (Mill Slough)											
Monthly average historic data (mg/L)					Nutrient reductions (mg/L)						
	NH4	NO3	TP	BOD		NH4	NO3	TP	TP reduction ratio	BOD
Jan	0.12	3.64	0.19	0.9	Jan	0.04	1.3	0.070	0.4	0.3
Feb	0.07	3.12	0.16	1.1	Feb	0.03	1.4	0.070	0.4	0.5
Mar	0.03	3.12	0.15	1.5	Mar	0.01	1.4	0.070	0.5	0.7
Apr	0.14	2.07	0.21	3.8	Apr	0.05	0.7	0.070	0.3	1.3
May	0.04	1.41	0.13	1.9	May	0.02	0.8	0.070	0.5	1.0
Jun	0.05	1.76	0.13	1.4	Jun	0.03	0.9	0.070	0.5	0.8
Jul	0.03	1.51	0.16	1.2	Jul	0.01	0.7	0.070	0.4	0.5
Aug	0.04	1.34	0.18	1.2	Aug	0.01	0.5	0.070	0.4	0.5
Sep	0.02	2.10	0.19	1.0	Sep	0.01	0.8	0.070	0.4	0.4
Oct	0.02	2.24	0.16	0.5	Oct	0.01	1.0	0.070	0.4	0.2
Nov	0.03	3.39	0.17	1.0	Nov	0.01	1.4	0.070	0.4	0.4
Dec	0.06	3.76	0.19	0.5	Dec	0.02	1.4	0.070	0.4	0.2
TP target 0.07 mg/L.					Average TP reduction = 57.5%					

S. Middleton Drain (Mill Slough)										
Monthly average historic data (mg/L)					Nutrient reductions (mg/L)					
	NH4	NO3	TP	BOD		NH4	NO3	TP	TP reduction ratio	BOD
Jan	0.04	2.14	0.16	2.1	Jan	0.02	0.9	0.07	0.4	0.9
Feb	0.04	1.98	0.13	1.3	Feb	0.02	1.1	0.07	0.5	0.7
Mar	0.03	1.99	0.11	1.4	Mar	0.02	1.3	0.07	0.6	0.9
Apr	0.02	0.71	0.09	2.4	Apr	0.01	0.6	0.07	0.8	1.9
May	0.01	0.87	0.09	1.6	May	0.01	0.7	0.07	0.8	1.2
Jun	0.01	0.74	0.06	1.3	Jun	0.01	0.7	0.06	1.0	1.3
Jul	0.01	0.78	0.07	1.2	Jul	0.01	0.8	0.07	1.0	1.2
Aug	0.01	0.66	0.09	1.1	Aug	0.01	0.5	0.07	0.8	0.8
Sep	0.01	0.81	0.10	0.7	Sep	0.01	0.6	0.07	0.7	0.5
Oct	0.04	1.58	0.16	0.5	Oct	0.02	0.7	0.07	0.4	0.2
Nov	0.11	3.84	0.16	1.1	Nov	0.05	1.6	0.07	0.4	0.5
Dec	0.16	6.22	0.19	1.6	Dec	0.06	2.3	0.07	0.4	0.6
					Average TP reduction = 34.3%					

TP target 0.07 mg/L for tributary. Star WWTF calculated under design flow.

Willow Creek

Monthly average historic data (mg/L)					Nutrient reductions (mg/L)					
	NH4	NO3	TP	BOD		NH4	NO3	TP	TP reduction ratio	BOD
Jan	0.04	2.64	0.38	1.4	Jan	0.007	0.5	0.07	0.2	0.3
Feb	0.03	0.50	0.51	1.8	Feb	0.004	0.1	0.07	0.1	0.2
Mar	0.04	0.81	0.18	0.9	Mar	0.016	0.3	0.07	0.4	0.4
Apr	0.03	0.72	0.16	2.8	Apr	0.013	0.3	0.07	0.4	1.2
May	0.03	0.56	0.14	1.3	May	0.016	0.3	0.07	0.5	0.7
Jun	0.05	0.75	0.19	1.1	Jun	0.018	0.3	0.07	0.4	0.4
Jul	0.04	1.04	0.23	1.3	Jul	0.011	0.3	0.07	0.3	0.4
Aug	0.03	0.67	0.19	1.2	Aug	0.012	0.2	0.07	0.4	0.4
Sep	0.02	0.45	0.15	1.3	Sep	0.010	0.2	0.07	0.5	0.6
Oct	0.02	1.92	0.19	1.1	Oct	0.006	0.7	0.07	0.4	0.4
Nov	0.02	2.22	0.28	2.0	Nov	0.005	0.6	0.07	0.3	0.5
Dec	0.02	2.78	0.30	0.7	Dec	0.005	0.6	0.07	0.2	0.2
TP target 0.07 mg/L.					Average TP reduction = 66.2%					

N. Middleton Drain (Mill Slough)										
Monthly average historic data (mg/L)					Nutrient reductions (mg/L)					
	NH4	NO3	TP	BOD		NH4	NO3	TP	TP reduction ratio	BOD
Jan	0.20	4.99	0.28	1.2	Jan	0.06	1.45	0.08	0.3	0.3
Feb	0.03	4.67	0.28	0.9	Feb	0.01	1.33	0.08	0.3	0.2
Mar	0.03	4.38	0.23	1.4	Mar	0.01	1.56	0.08	0.4	0.5
Apr	0.10	2.78	0.51	2.3	Apr	0.02	0.43	0.08	0.2	0.4
May	0.11	2.58	0.53	1.6	May	0.01	0.34	0.07	0.1	0.2
Jun	0.07	2.87	0.50	1.9	Jun	0.01	0.40	0.07	0.1	0.3
Jul	0.07	3.21	0.59	2.6	Jul	0.01	0.38	0.07	0.1	0.3
Aug	0.03	3.02	0.38	1.5	Aug	0.00	0.56	0.07	0.2	0.3
Sep	0.02	3.15	0.28	1.3	Sep	0.01	0.79	0.07	0.3	0.3
Oct	0.02	4.93	0.20	0.6	Oct	0.01	2.02	0.08	0.4	0.2
Nov	0.02	4.93	0.23	1.0	Nov	0.01	1.72	0.08	0.3	0.3
Dec	0.02	4.93	0.24	0.8	Dec	0.01	1.68	0.08	0.3	0.3
					Average TP reduction = 74.9%					

TP target 0.07 mg/L. Sorrento calculated under design flow.

East Hartley Drain										
Monthly average historic data (mg/L)					**Nutrient reductions (mg/L)**					
	NH4	NO3	TP	BOD		NH4	NO3	TP	TP reduction ratio	BOD
Jan	0.06	5.25	0.36	0.9	Jan	0.01	1.02	0.07	0.2	0.2
Feb	0.05	1.63	0.36	0.9	Feb	0.01	0.32	0.07	0.2	0.2
Mar	0.02	4.95	0.35	1.5	Mar	0.003	0.99	0.07	0.2	0.3
Apr	0.12	2.87	0.32	3.4	Apr	0.03	0.63	0.07	0.2	0.7
May	0.05	2.13	0.29	1.7	May	0.01	0.51	0.07	0.2	0.4
Jun	0.03	2.48	0.26	1.5	Jun	0.01	0.67	0.07	0.3	0.4
Jul	0.03	2.35	0.23	1.8	Jul	0.01	0.72	0.07	0.3	0.5
Aug	0.03	2.24	0.20	1.2	Aug	0.01	0.78	0.07	0.4	0.4
Sep	0.02	2.08	0.29	1.1	Sep	0.005	0.50	0.07	0.2	0.3
Oct	0.02	3.86	0.38	0.5	Oct	0.003	0.71	0.07	0.2	0.1
Nov	0.02	5.35	0.37	1.5	Nov	0.004	1.01	0.07	0.2	0.3
Dec	0.02	5.46	0.37	1.0	Dec	0.004	1.03	0.07	0.2	0.2
TP target 0.07 mg/L.					Average TP reduction = 76.9%					

Indian Creek										
Monthly average historic data (mg/L)					Nutrient reductions (mg/L)					
	NH4	NO3	TP	BOD		NH4	NO3	TP	TP reduction ratio	BOD
Jan	0.02	8.22	0.63	0.9	Jan	0.004	1.72	0.132	0.21	0.3
Feb	0.07	7.42	0.61	0.8	Feb	0.015	1.62	0.132	0.22	0.5
Mar	0.02	7.29	0.57	0.9	Mar	0.006	1.70	0.132	0.23	0.7
Apr	0.05	3.10	0.45	1.5	Apr	0.015	0.90	0.132	0.29	1.3
May	0.04	3.21	0.48	1.4	May	0.008	0.60	0.089	0.19	1.0
Jun	0.03	3.06	0.47	1.5	Jun	0.005	0.58	0.089	0.19	0.8
Jul	0.03	2.95	0.49	1.5	Jul	0.006	0.54	0.089	0.18	0.5
Aug	0.03	3.10	0.48	1.4	Aug	0.005	0.57	0.089	0.18	0.5
Sep	0.03	3.60	0.44	1.1	Sep	0.005	0.72	0.089	0.20	0.4
Oct	0.02	6.15	0.55	0.6	Oct	0.006	1.47	0.132	0.24	0.2
Nov	0.04	6.80	0.59	1.4	Nov	0.010	1.52	0.132	0.22	0.4
Dec	0.03	6.99	0.60	0.8	Dec	0.006	1.54	0.132	0.22	0.2
					Average TP reduction = 78.5%					
TP target 0.07 mg/L for tributary. IDFG Nampa, ConAgra, and Nampa calculated under design flow.										

Conway Gulch										
Monthly average historic data (mg/L)					Nutrient reductions (mg/L)					
	NH4	NO3	TP	BOD		NH4	NO3	TP	TP reduction ratio	BOD
Jan	0.02	5.93	0.19	0.9	Jan	0.008	2.25	0.072	0.4	0.3
Feb	0.02	5.39	0.18	0.5	Feb	0.008	2.16	0.072	0.4	0.2
Mar	0.02	5.73	0.16	1.0	Mar	0.007	2.58	0.072	0.5	0.5
Apr	0.03	3.38	0.33	1.8	Apr	0.007	0.74	0.072	0.2	0.4
May	0.04	3.17	0.33	1.3	May	0.009	0.68	0.070	0.2	0.3
Jun	0.03	2.71	0.32	0.9	Jun	0.006	0.59	0.070	0.2	0.2
Jul	0.03	3.03	0.74	1.3	Jul	0.003	0.29	0.070	0.1	0.1
Aug	0.03	3.56	0.45	1.6	Aug	0.005	0.55	0.070	0.2	0.2
Sep	0.02	2.92	0.15	1.4	Sep	0.009	1.33	0.070	0.5	0.6
Oct	0.02	6.27	0.19	0.5	Oct	0.006	2.44	0.072	0.4	0.2
Nov	0.02	5.56	0.19	0.6	Nov	0.008	2.11	0.072	0.4	0.2
Dec	0.02	5.48	0.15	0.5	Dec	0.010	2.63	0.072	0.5	0.2
					Average TP reduction = 68.0%					

TP target 0.07 mg/L. Notus contribution calculated on design flow of facility.

Dixie Drain

	Monthly average historic data (mg/L)					Nutrient reductions (mg/L)				
	NH4	NO3	TP	BOD		NH4	NO3	TP	TP reduction ratio	BOD
Jan	0.17	5.56	0.31	4.4	Jan	0.038	1.28	0.072	0.2	1.0
Feb	0.06	5.36	0.18	0.9	Feb	0.023	2.18	0.072	0.4	0.4
Mar	0.05	4.77	0.26	1.1	Mar	0.013	1.34	0.072	0.3	0.3
Apr	0.08	2.38	0.39	1.7	Apr	0.015	0.44	0.072	0.2	0.3
May	0.06	1.81	0.34	1.2	May	0.012	0.38	0.070	0.2	0.3
Jun	0.05	1.70	0.32	1.2	Jun	0.011	0.37	0.070	0.2	0.3
Jul	0.04	1.67	0.36	0.9	Jul	0.008	0.32	0.070	0.2	0.2
Aug	0.04	1.96	0.34	1.0	Aug	0.008	0.40	0.070	0.2	0.2
Sep	0.04	2.16	0.32	1.1	Sep	0.009	0.47	0.070	0.2	0.2
Oct	0.05	3.06	0.31	0.9	Oct	0.013	0.72	0.072	0.2	0.2
Nov	0.04	4.66	0.20	0.9	Nov	0.015	1.72	0.072	0.4	0.3
Dec	0.10	5.40	0.19	1.0	Dec	0.039	2.08	0.072	0.4	0.4
					Average TP reduction = 73.9%					

TP target 0.07 mg/L. Wilder and Greenleaf contributions calculated on design flow of facility.