January 23, 2014

AQUATOX Model Calibration for the LBR TP TMDL

Troy Smith and Darcy Sharp

Primary Model Uses for the TMDL

AQUATOX

- Estimate nutrient-periphyton relationships
- Tool for TP allocations to meet the periphyton target of 150 mg/m^2

USGS Mass Balance

- Estimate current TP loads
- Tool for TP allocations to meet the May-Sept target of 0.07 mg/L

AQUATOX Modeling Consultation

Core Group

- Ben Cope – EPA
- Bill Stewart – EPA
- Kate Harris – Boise
- Robbin Finch – Boise
- Tom Dupuis – HDR
- Michael Kasch – HDR
- Matt Gregg – Brown and Caldwell
- Jack Harrison - HyQual
- Lee Van de Bogart – Caldwell

Consultants

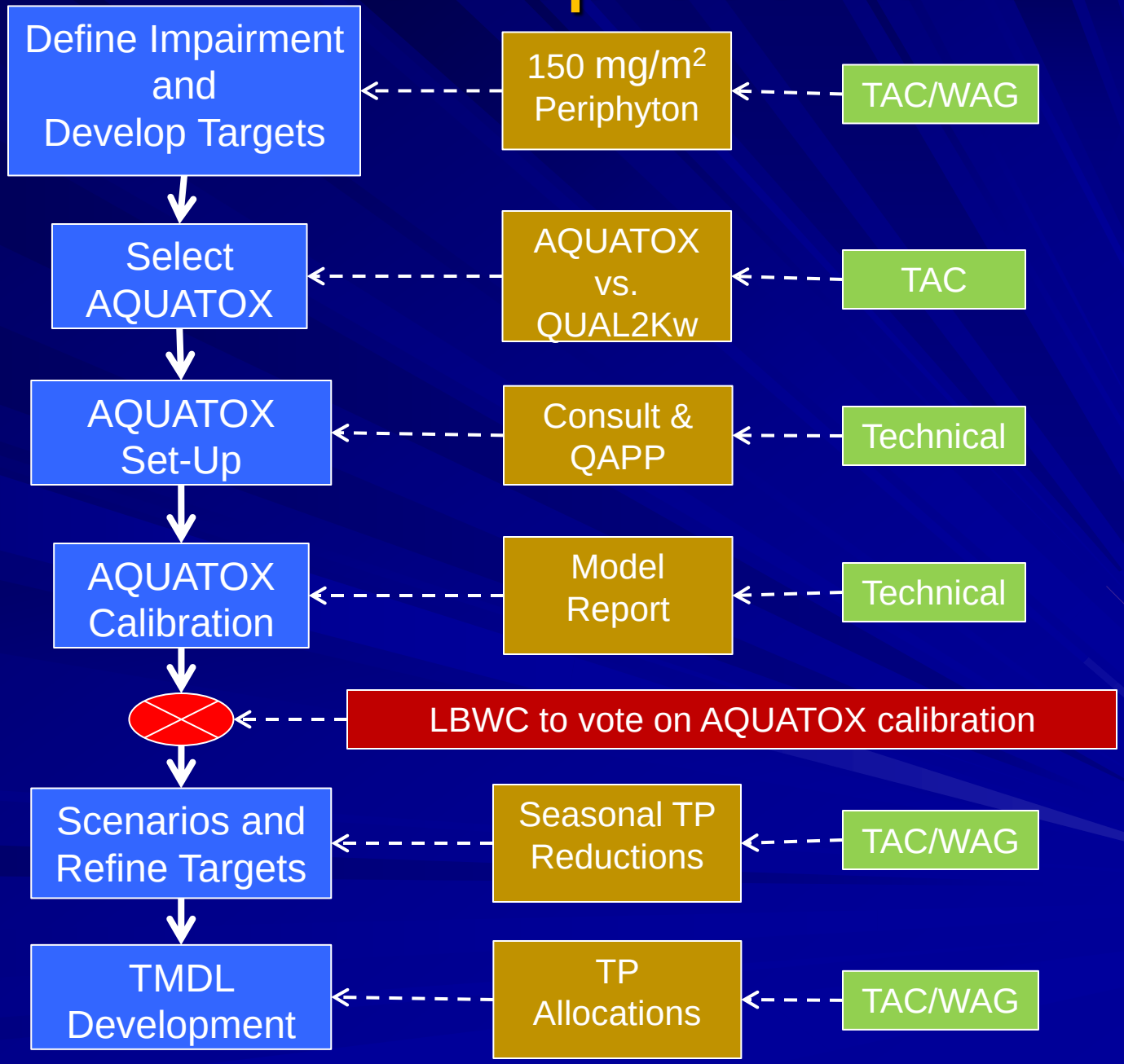
- Jonathan Clough – Warren Pinnacle Consulting
- Dick Park – Eco Modeling

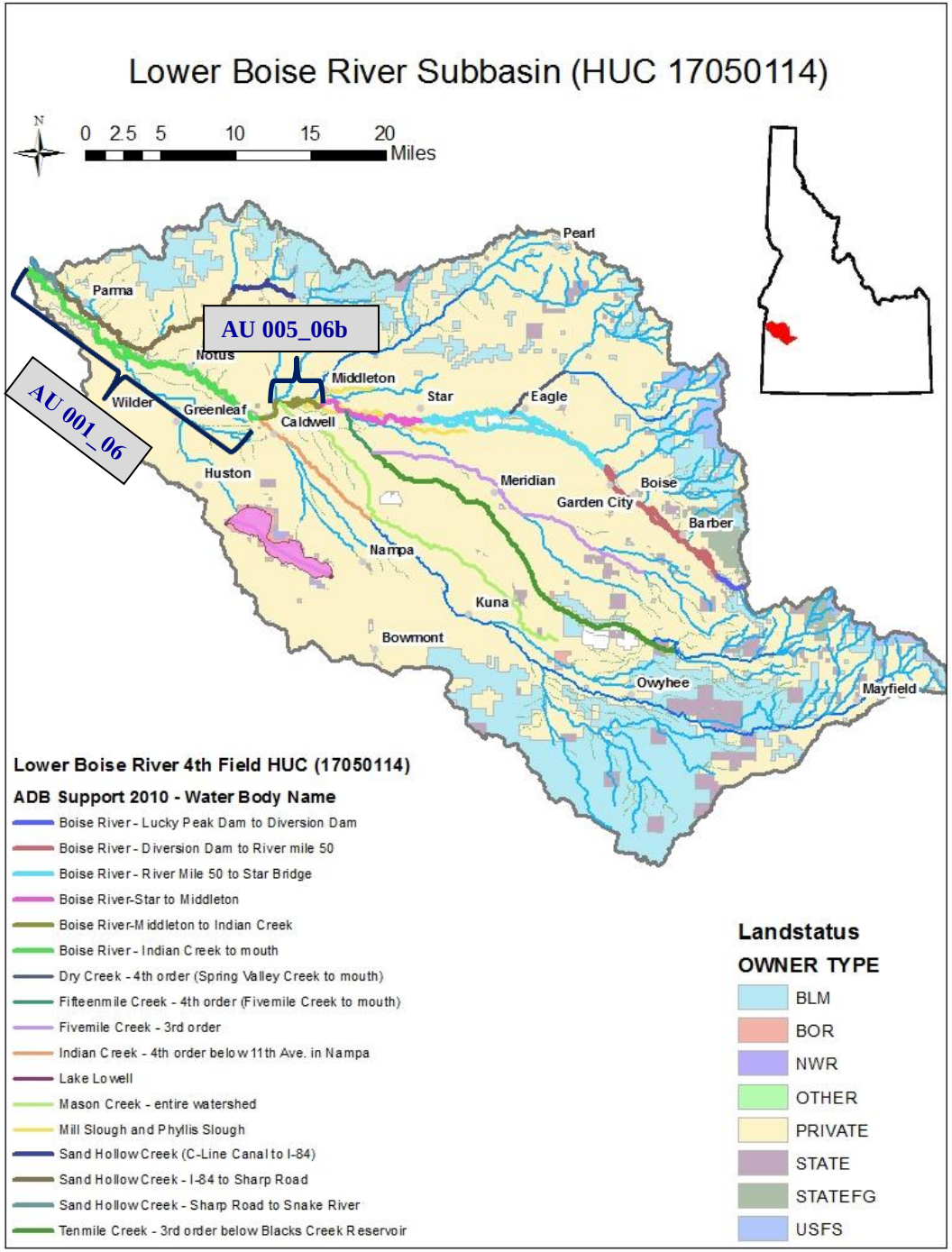
Additional Assistance

- Alex Etheridge, Dorene MacCoy, Chris Mebane – USGS
- Clifton Bell – Brown and Caldwell

- 4 Meetings – Model Selection
- 28 Model Work Meetings

Simplified Process Representation

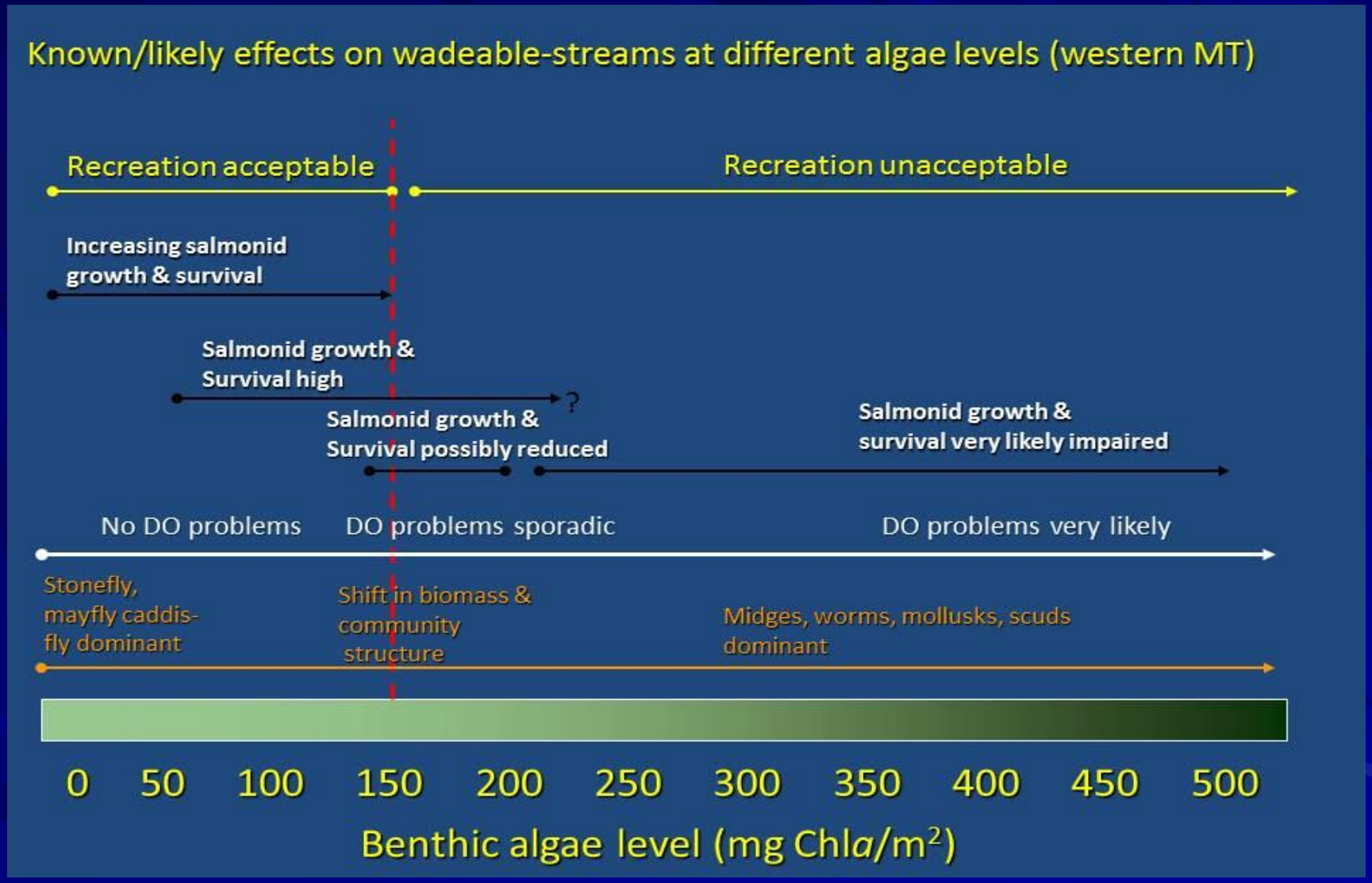



Lower Boise River Subbasin (HUC 17050114)
N
0 2.5 5 10 15 20
Miles
Pearl
Parma
AU 005_06b
Notus
Middleton
Star
Eagle
AU 001_06
Wilder
Greenleaf
Caldwell
Huston
Meridian
Boise
Garden City
Barber
Nampa
Kuna
Bowmont
Owyhee
Mayfield
Lower Boise River 4th Field HUC (17050114)
ADB Support 2010 - Water Body Name
Boise River - Lucky Peak Dam to Diversion Dam
Boise River - Diversion Dam to River mile 50
Boise River - River Mile 50 to Star Bridge
Boise River-Star to Middleton
Boise River-Middleton to Indian Creek
Boise River - Indian Creek to mouth
Dry Creek - 4th order (Spring Valley Creek to mouth)
Fifteenmile Creek - 4th order (Fivemile Creek to mouth)
Fivemile Creek - 3rd order
Indian Creek - 4th order below 11th Ave. in Nampa
Lake Lowell
Mason Creek - entire watershed
Mill Slough and Phyllis Slough
Sand Hollow Creek (C-Line Canal to I-84)
Sand Hollow Creek - I-84 to Sharp Road
Sand Hollow Creek - Sharp Road to Snake River
Tenmile Creek - 3rd order below Blacks Creek Reservoir
Landstatus
OWNER TYPE
BLM
BOR
NWR
OTHER
PRIVATE
STATE
STATEFG
USFS

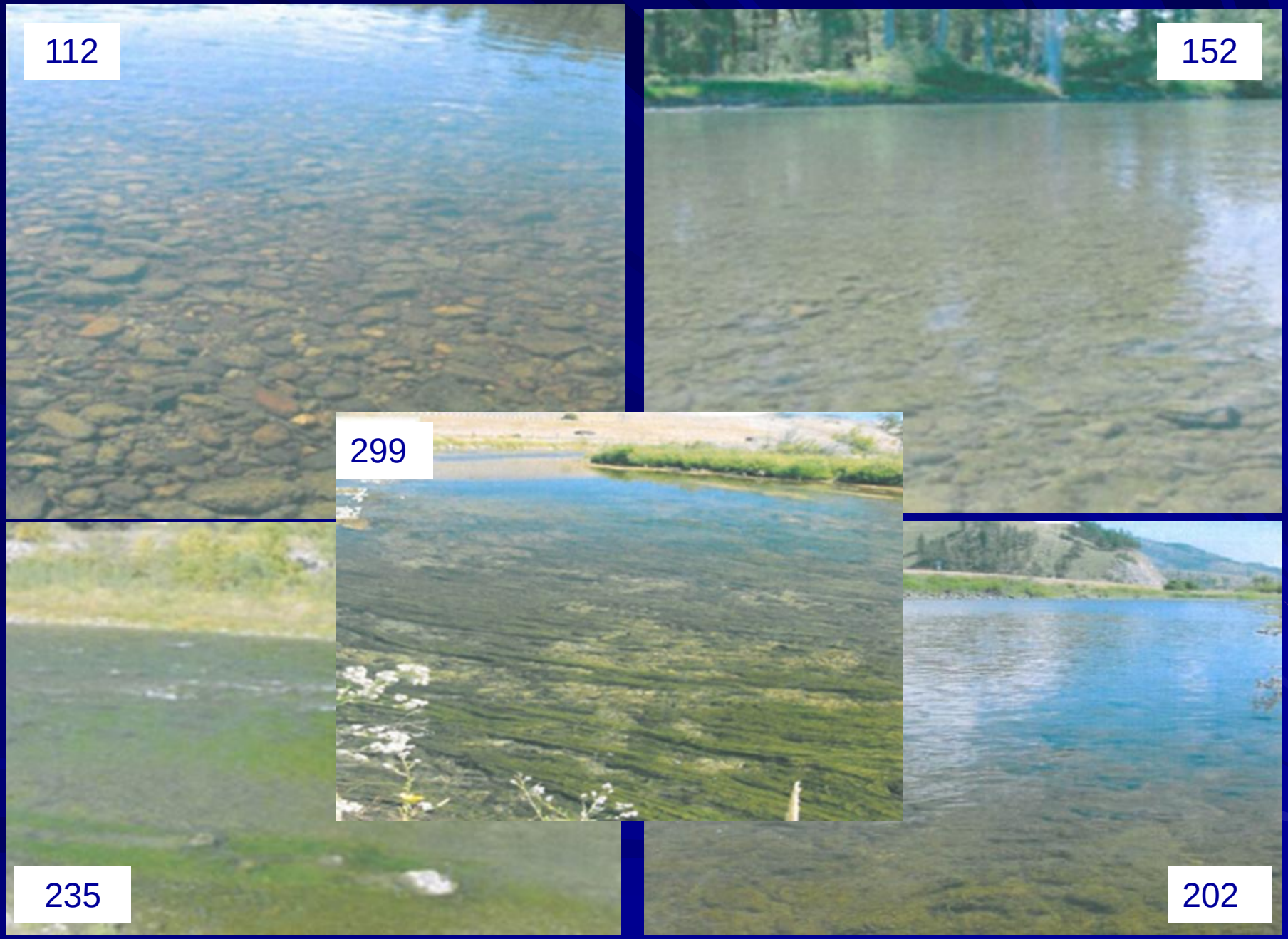
Target Development and Objectives

- LBWC supported a mean benthic chlorophyll-a biomass target of $\leq$ 150 mg/m^2
  - Impaired mainstem AUs of the Lower Boise River
  - Need to refine appropriate locations, durations, frequencies
- Translate nutrient-periphyton relationships into numeric nutrient WLAs/LAs
  - Identify conditions that achieve benthic chl a target and support beneficial uses

Beneficial Use Implications

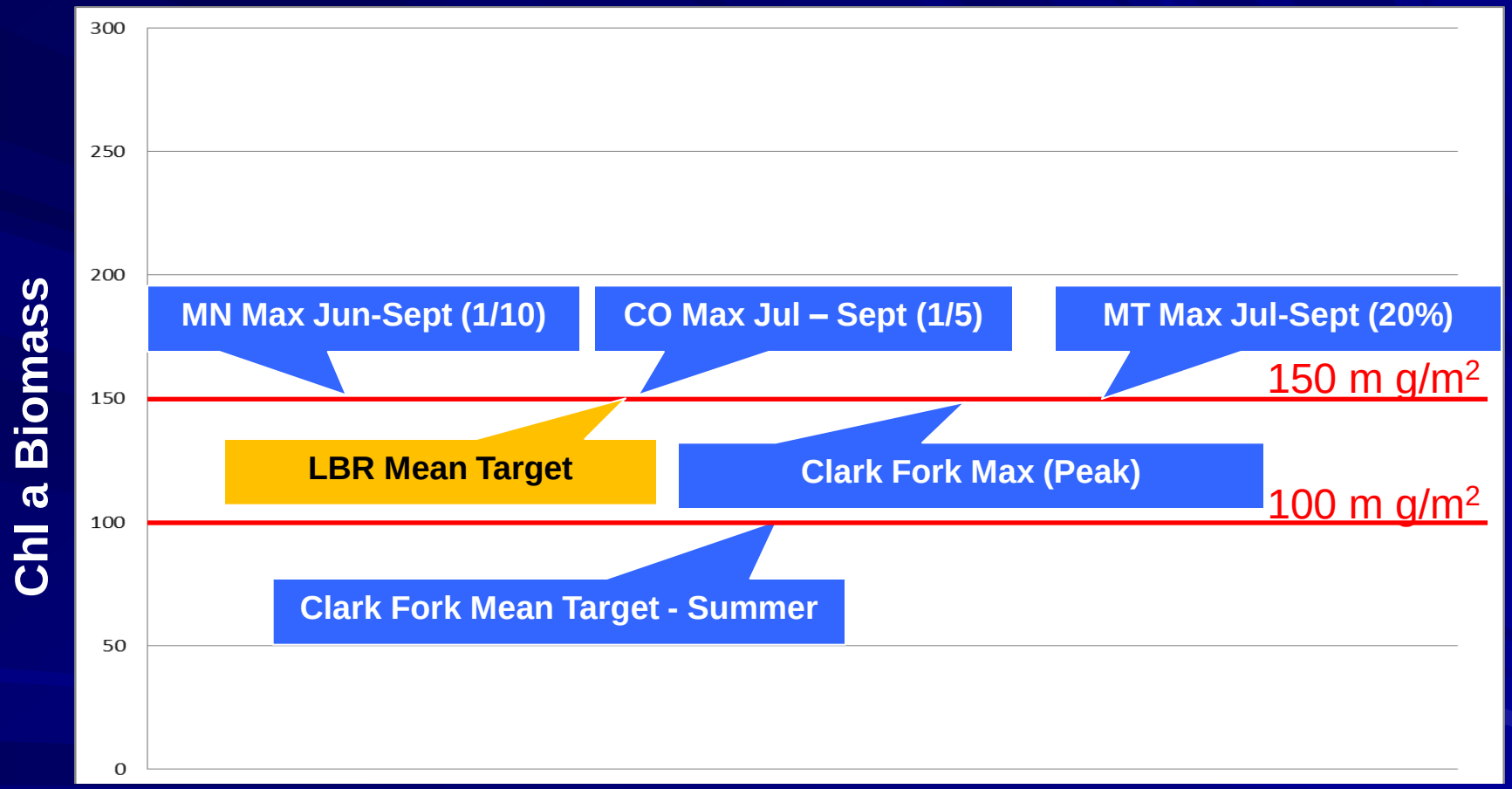


Source: *Overview of Montana's Draft Numeric Nutrient Criteria and their Implementation*. Suplee, M. July 26, 2013. Board of Environmental Review Meeting.

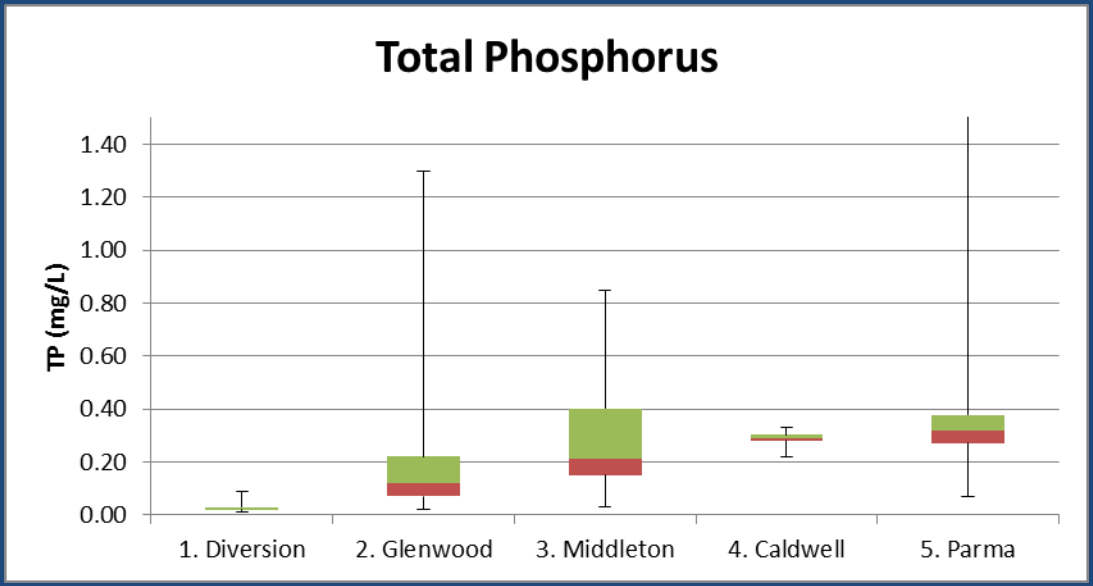


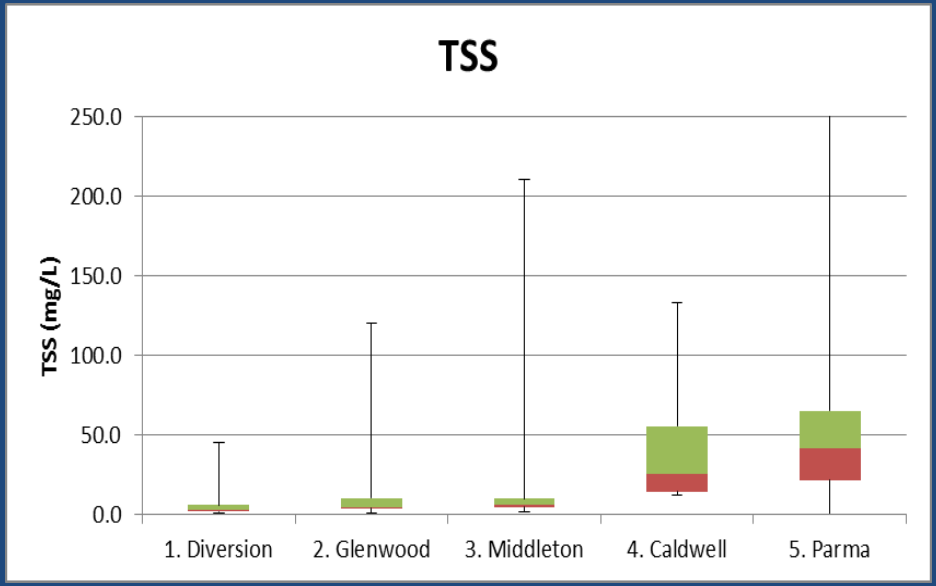
Source: 2009. Suplee et al. *How green is too green? Public opinion of what constitutes undesirable algae levels in streams*. JAWRA 45(1):123 – 140.

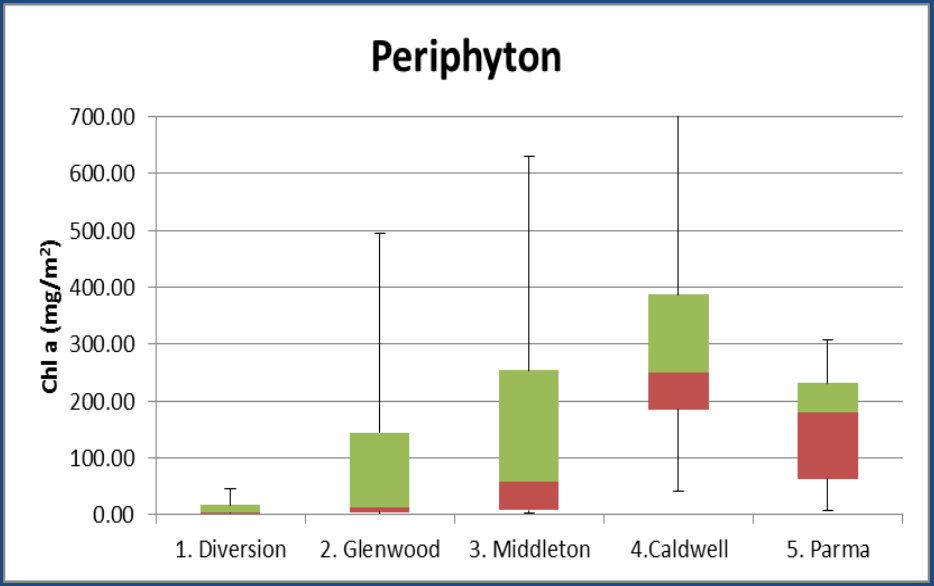
LBR vs. Other Waters



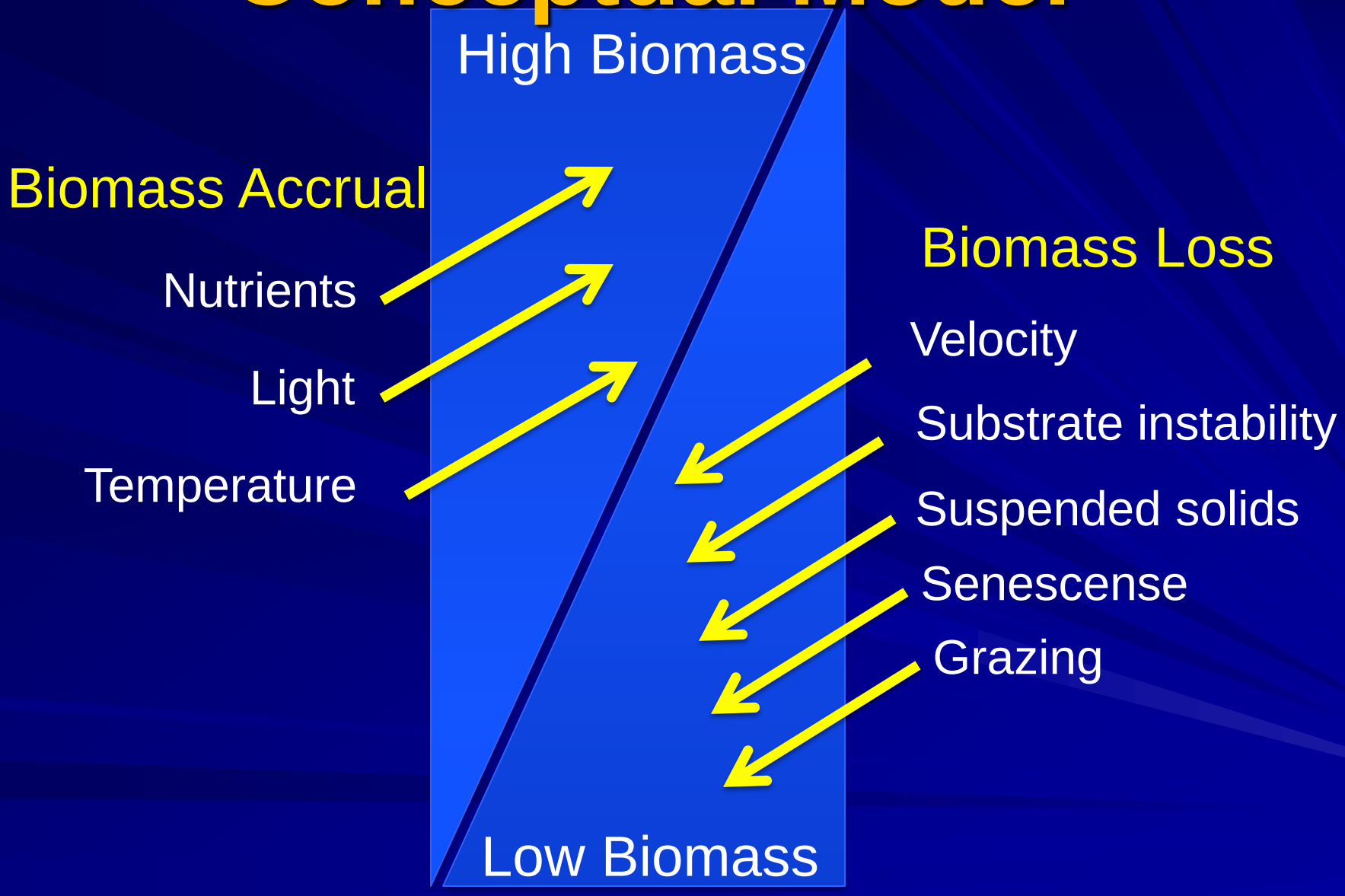
Lower Boise River Conditions







Conceptual Model



Modified from Biggs 1996

**Figure modified from Kate Harris slide 2013 (City of Boise).

Two Primary WQ Models Considered

Simulation Capability	Model Code	
	QUAL2K	AQUATOX
Attached stream algae	√	√
Substrate limitation	√	√
Dynamic hydraulics		√
Intracellular nutrient storage	√	
Grazers		√
Flow stimulation effects		√
Scour/sloughing		√
Multiple algal taxa		√
Self-shading		√

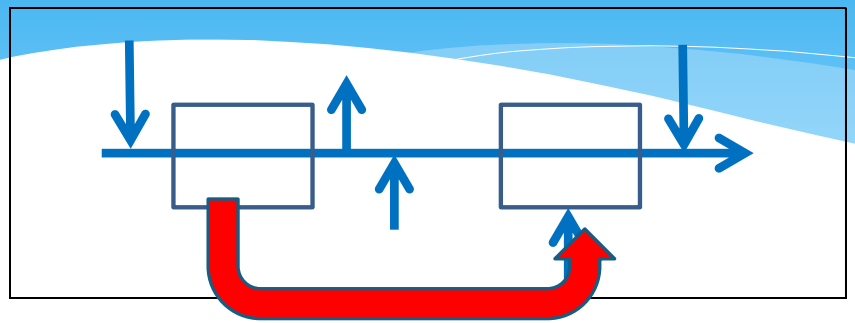
**Figure modified from Clifton Bell presentation 7/9/2013 (Brown and Caldwell).

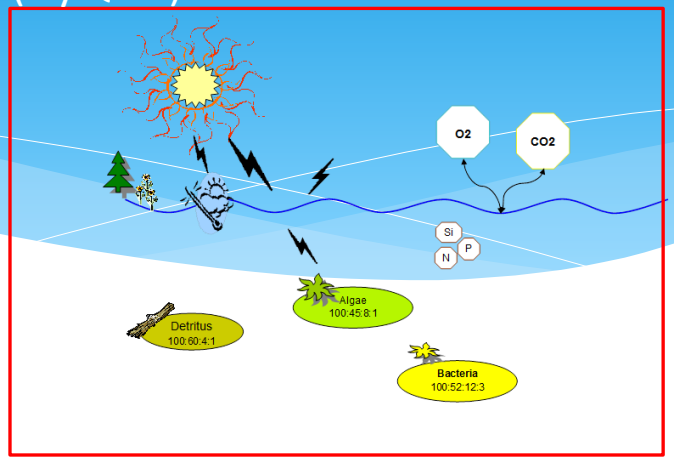
AQUATOX Model Selection

- Parameters of interest (scour and loss)
  - Directly links periphyton and phytoplankton (sestonic algae)
- Developed with support from the EPA
- Previously used and endorsed by LBWC
- Direct consultation with AQUATOX developers
  - Jonathan Clough (Warren Pinnacle Consulting, Inc.)
  - Richard Park (Eco Modeling)

AQUATOX: Periphyton Biomass Model

**Slide courtesy of Jack Harrison (HyQual).



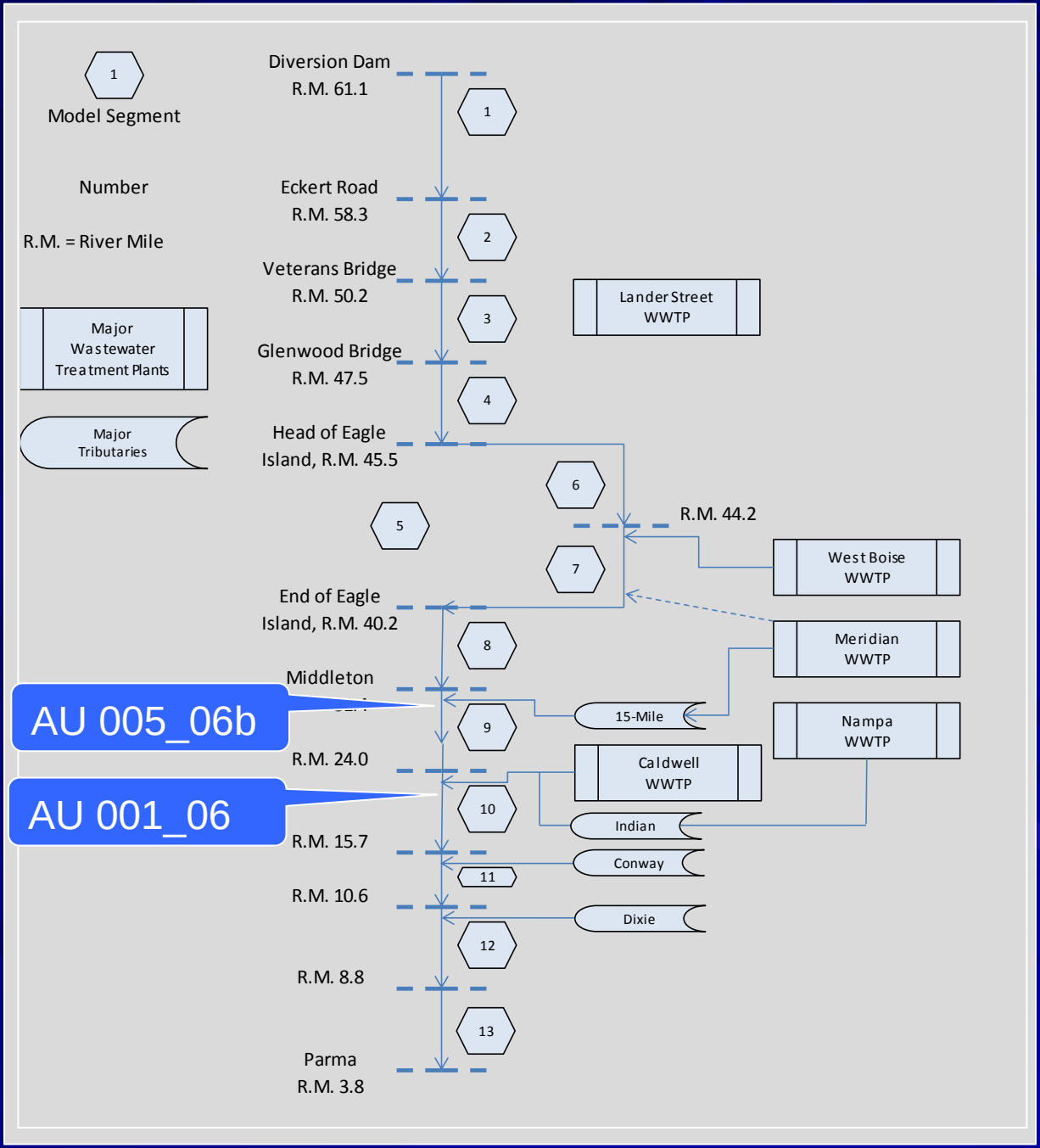


$$\frac{dBiomass_{Peri}}{dt} = Loading + Photosynthesis - Respiration - Excretion - Mortality - Predation + Sed_{Peri}$$

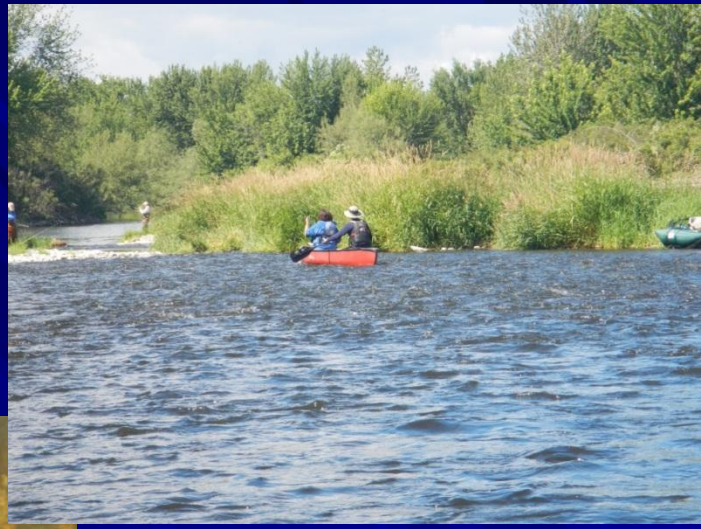
AQUATOX

- Richard A. Park, Eco Modeling, Diamondhead MS
dickpark@CableOne.net
- Jonathan S. Clough, Warren Pinnacle Consulting, Warren VT
jclough@warrenpinnacle.com
- Marjorie Coombs Wellman, Office of Water, US EPA, Washington DC
wellman.marjorie@epamail.epa.gov

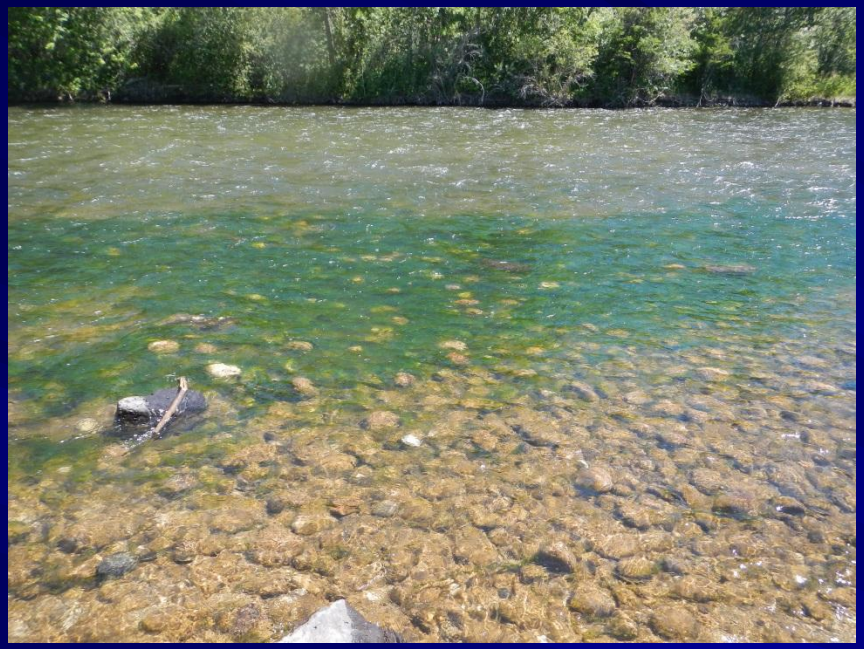
AQUATOX Model Set-Up

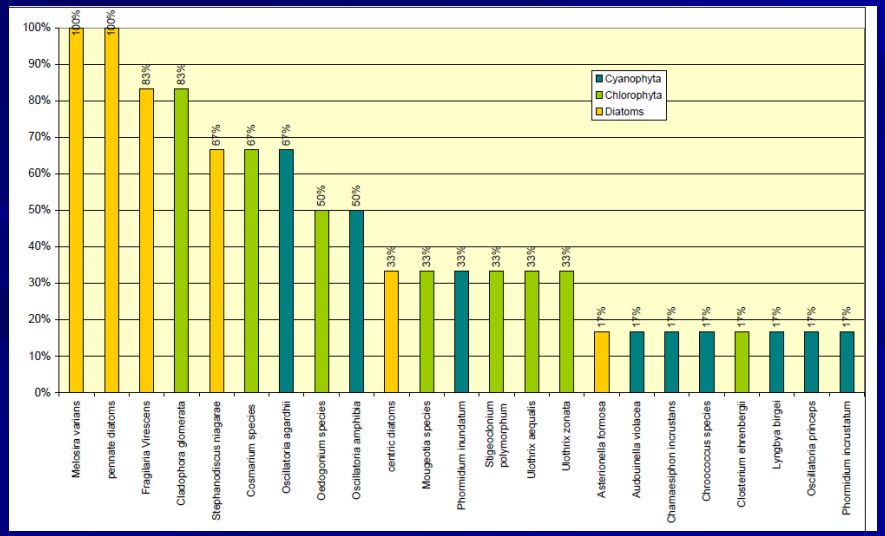


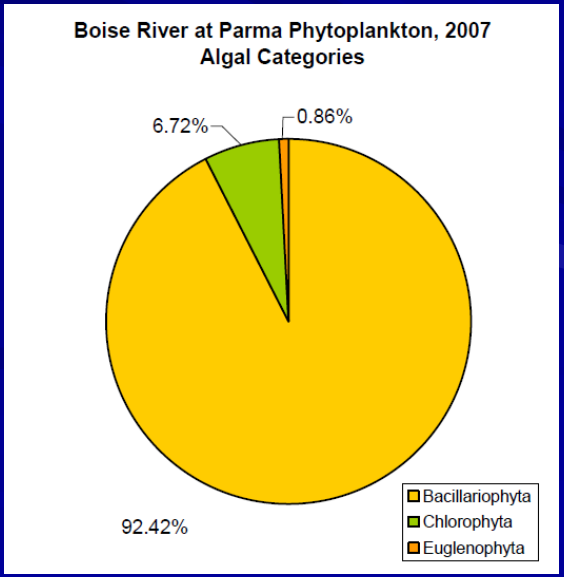
Segment	RM	USGS Sites and Point-Sources	Parameters
1	61.1	13203510 BR Diversion Dam	Velocity, TSS, Nutrients, DO
2	58.3[2]	13203760 BR Eckert Road	Temp, pH, TSS, Peri, Phyto, Algae Communities
	55.0	BR Marden Bridge	Temp
3	50.17	13205642 BR Veteran's Parkway	Velocity, Temp, TSS, Nutrients, DO, Algae 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[2]	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



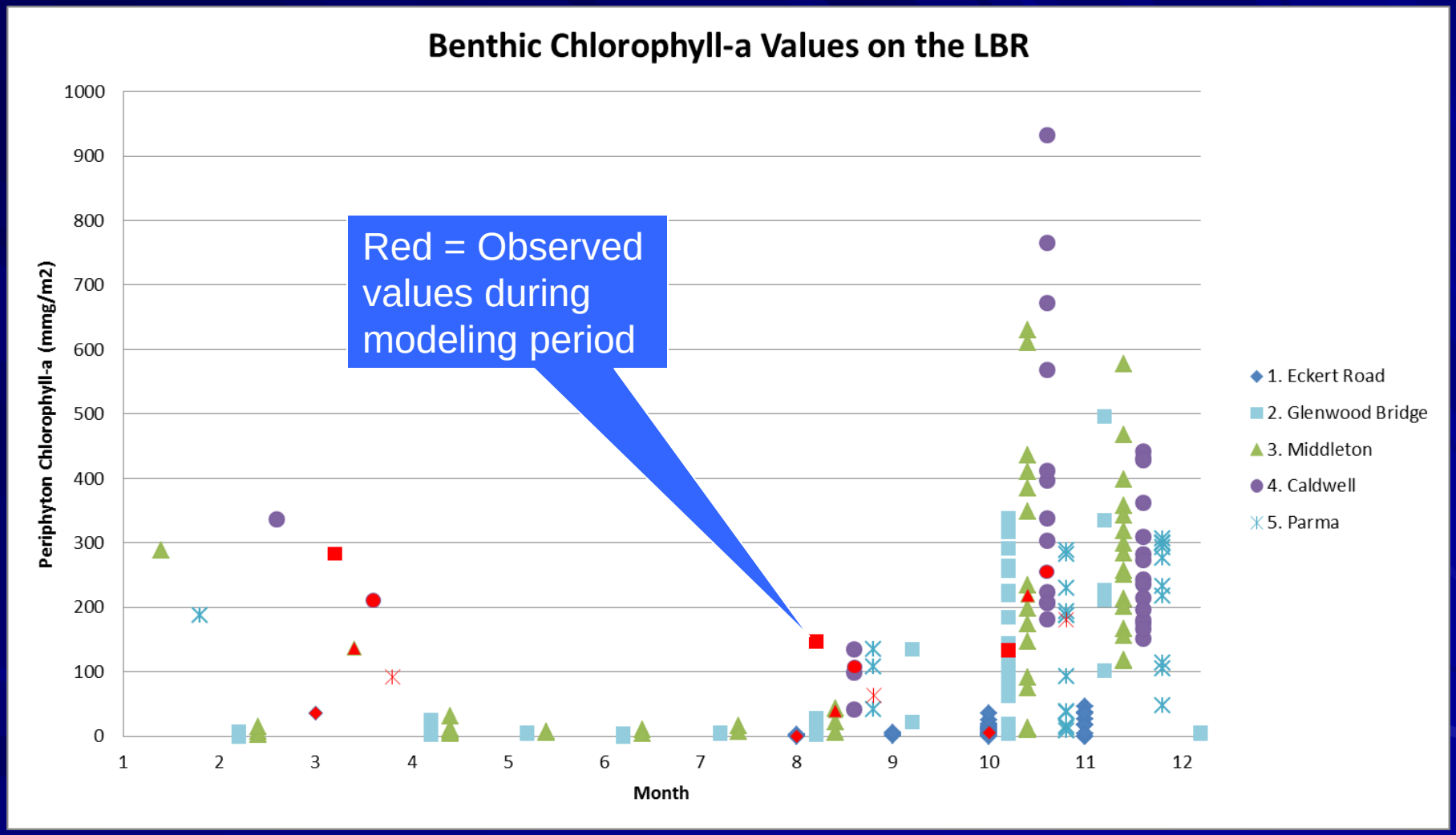
Algae Speciation

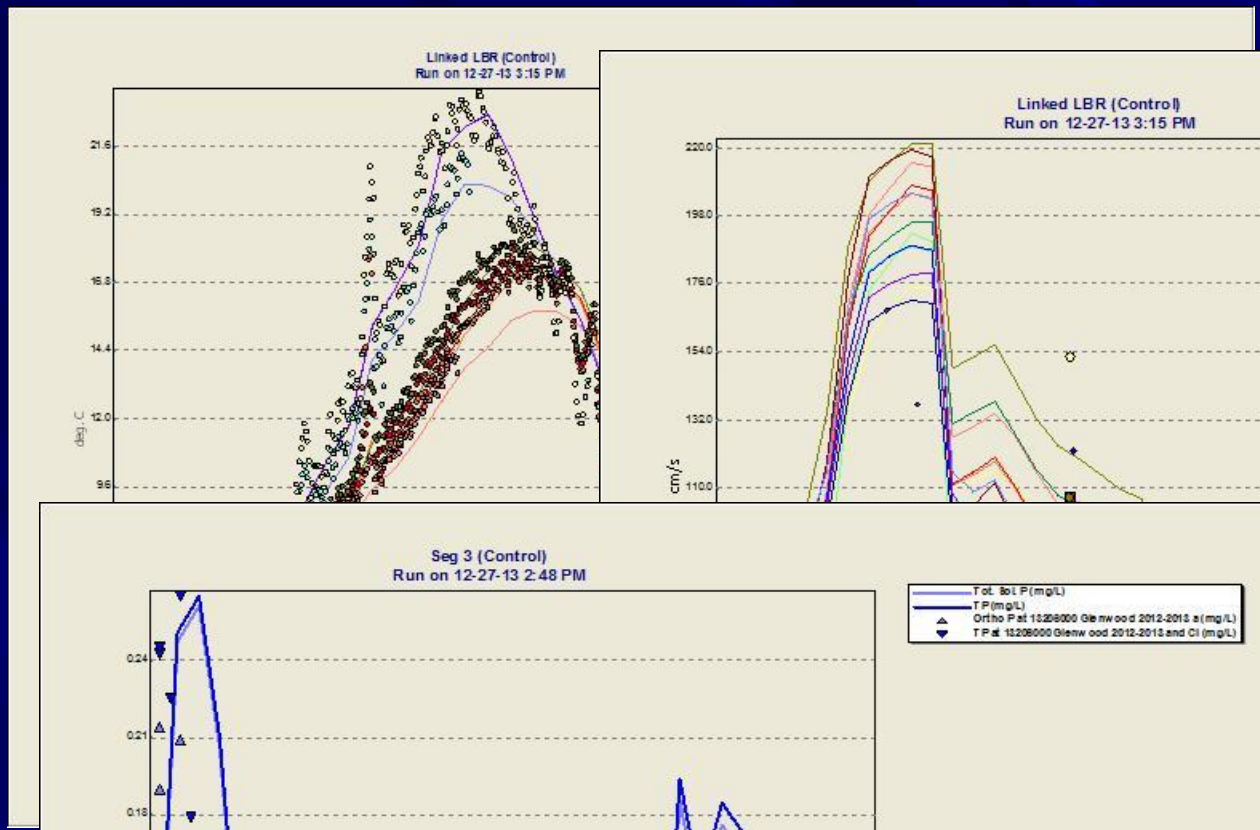




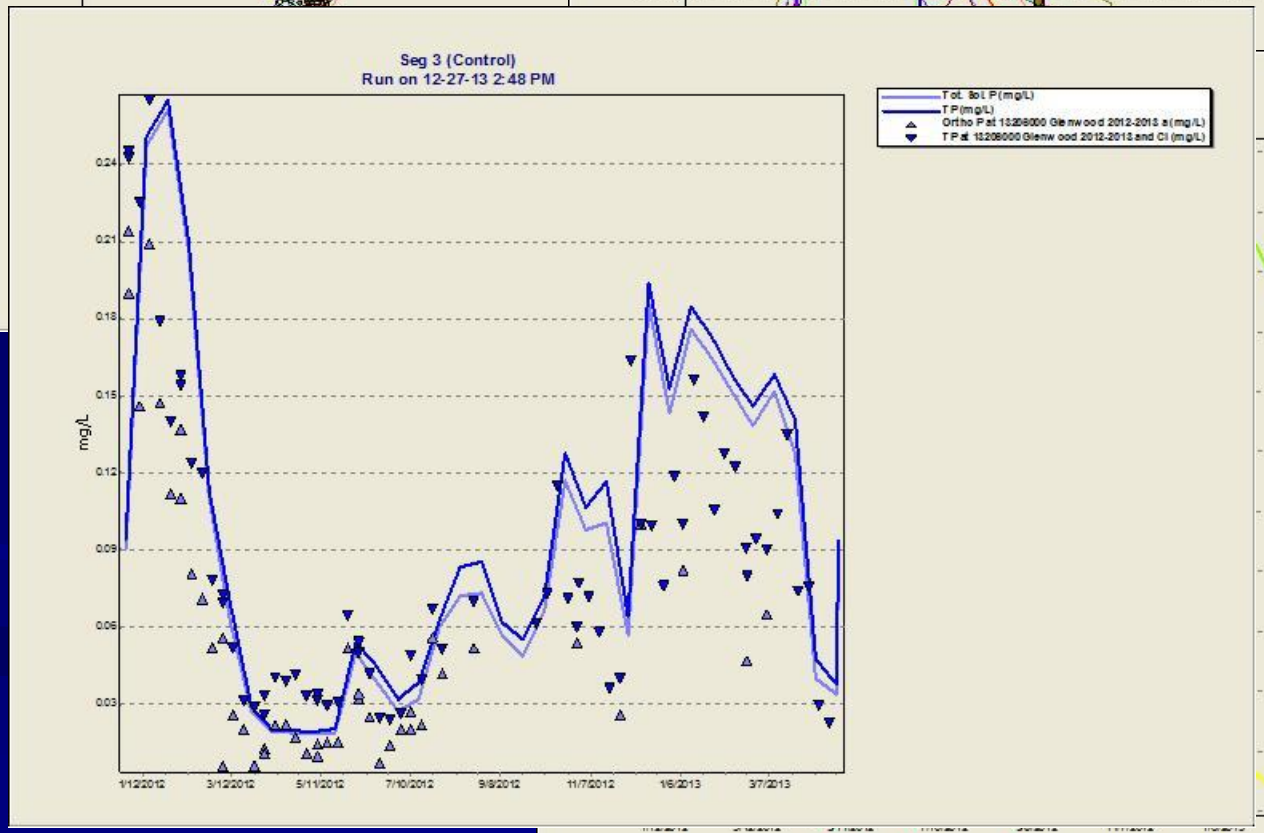


Observed vs. Historical Values

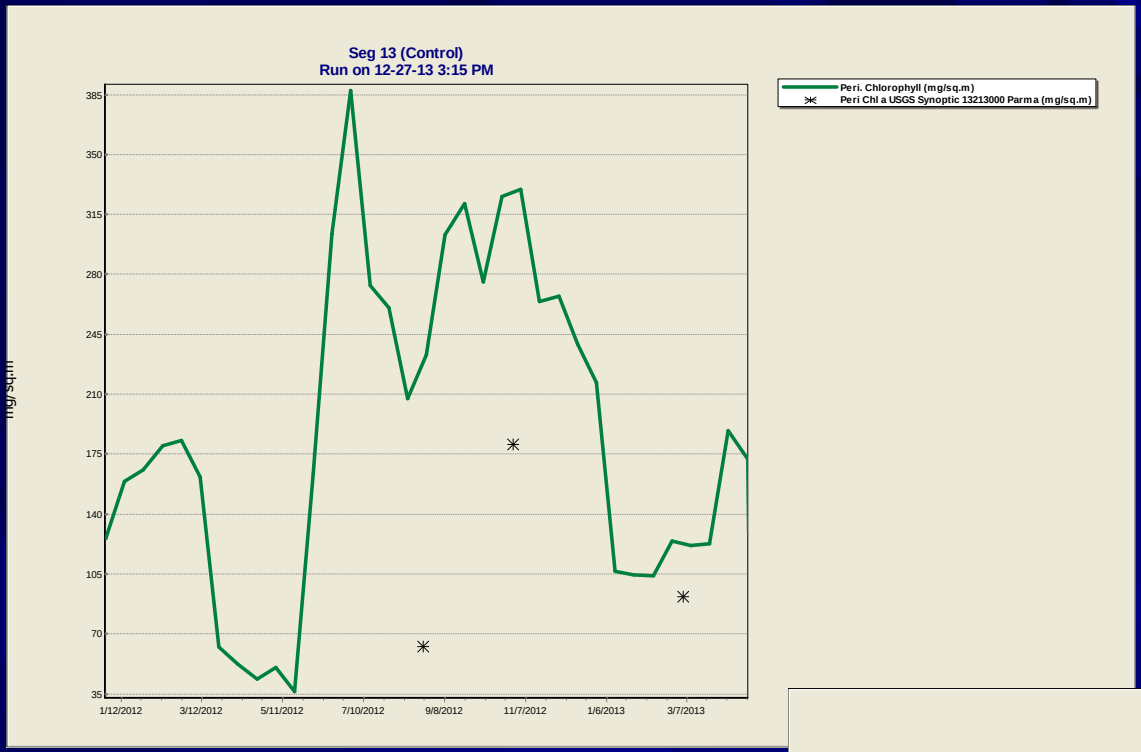


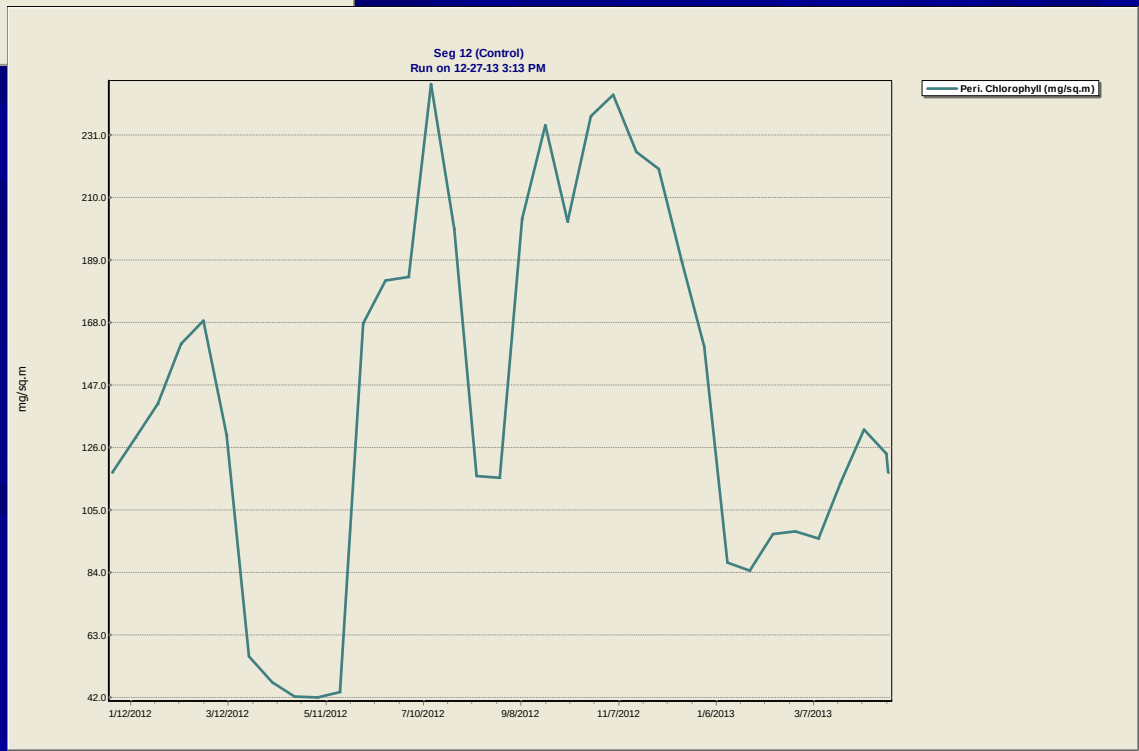

Linked LBR (Control)
Run on 12-27-13 3:15 PM
deg. C

Linked LBR (Control)
Run on 12-27-13 3:15 PM
cm/s
B1: Run Velocity (cm/s)
B2: Run Velocity (cm/s)
B3: Run Velocity (cm/s)
B4: Run Velocity (cm/s)
B5: Run Velocity (cm/s)
B6: Run Velocity (cm/s)
B7: Run Velocity (cm/s)
B8: Run Velocity (cm/s)
B9: Run Velocity (cm/s)
B10: Run Velocity (cm/s)
B11: Run Velocity (cm/s)
B12: Run Velocity (cm/s)
B13: Run Velocity (cm/s)
Velocity Segments 1 & 2(cm/s)
Velocity Segment 3(cm/s)
Velocity Segment 4(cm/s)
Velocity Segments 6 & 8(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)


Seg 3 (Control)
Run on 12-27-13 2:48 PM
mg/L
Tot. Sol P(mg/L)
TP(mg/L)
Ortho P at 13208000 Glenwood 2012-2013 a(mg/L)
TP at 13208000 Glenwood 2012-2013 and Cl (mg/L)
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/9/2012
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)
3/7/2013


Seg 13 (Control)
Run on 12-27-13 3:15 PM
Peri. Chlorophyll (mg/sq.m)
Peri Chl a USGS Synoptic 13213000 Parma (mg/sq.m)
mg/sq.m
385
350
315
280
245
210
175
140
105
70
35
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 12-27-13 3:13 PM
Peri. Chlorophyll (mg/sq.m)
mg/sq.m
231.0
210.0
189.0
168.0
147.0
126.0
105.0
84.0
63.0
42.0
1/12/2012
3/12/2012
5/11/2012
7/10/2012
9/8/2012
11/7/2012
1/6/2013
3/7/2013

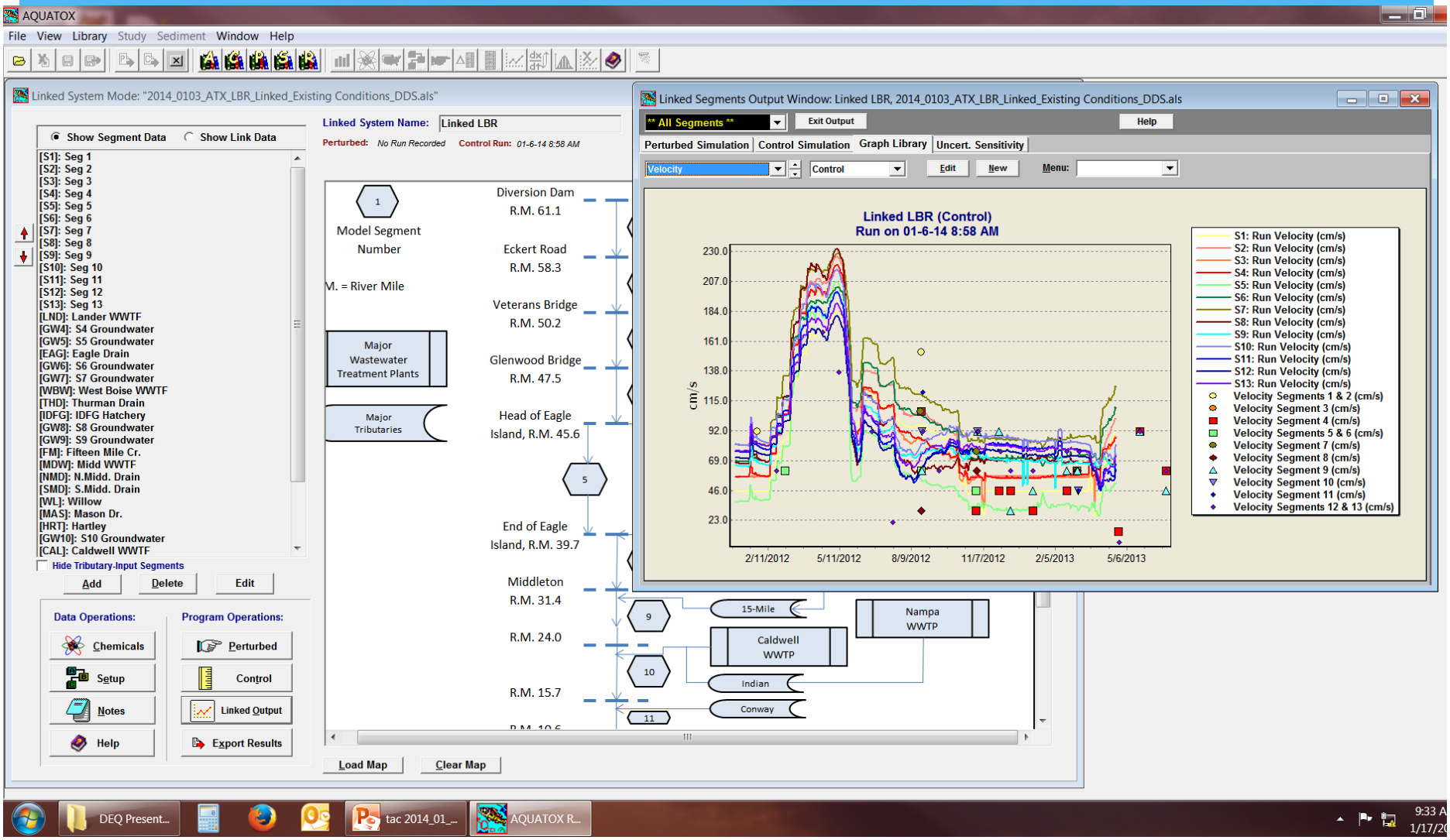
AQUATOX Modeling for LBR TP TMDL

- Why modeling?
  - "…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."

***2013. WERF. Modeling Guidance for Developing Site-Specific Nutrient Goals.*

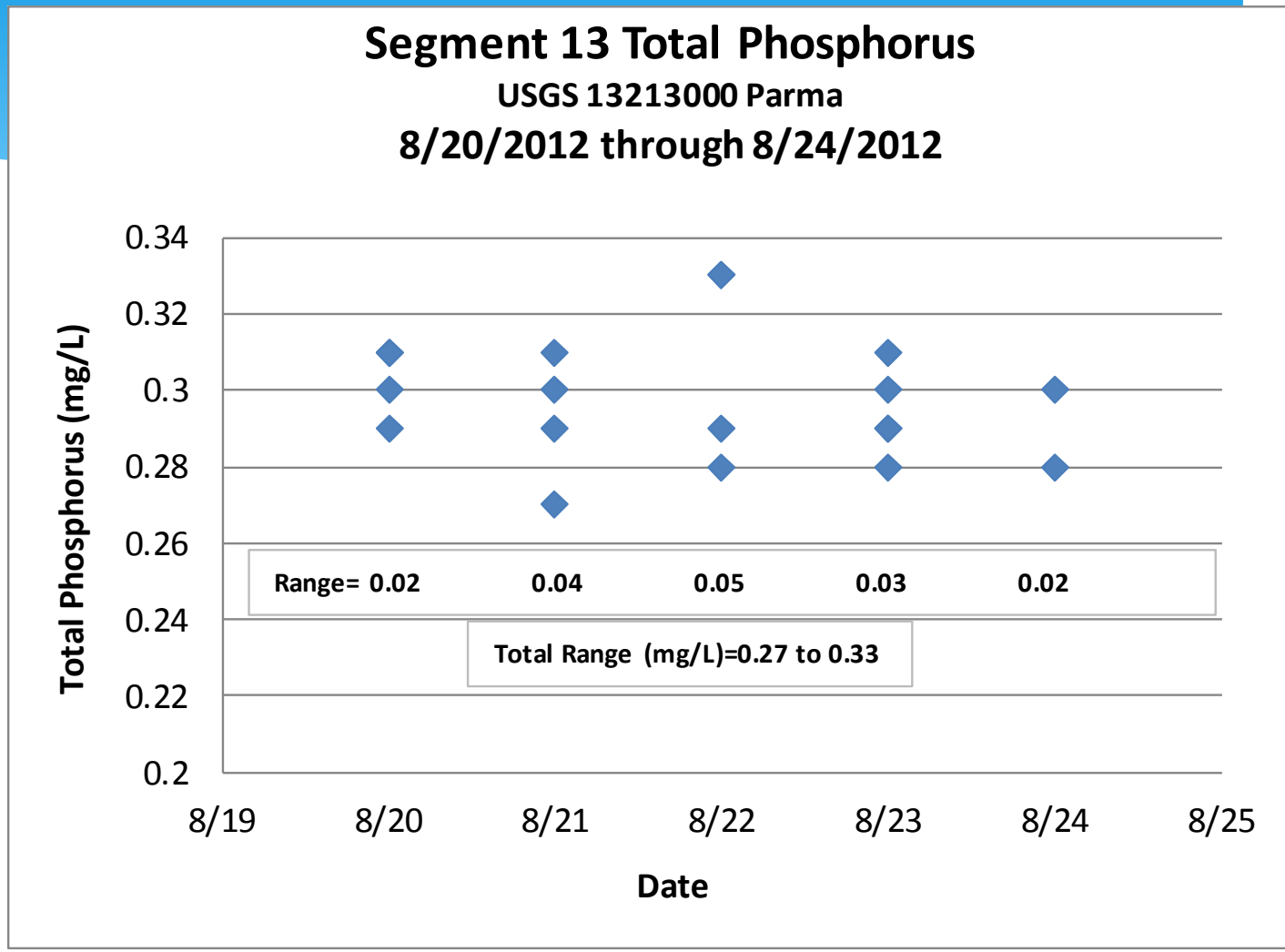
AQUATOX MODEL DEVELOPMENT

How good is the model?



Variability in Phosphorus Data at Parma

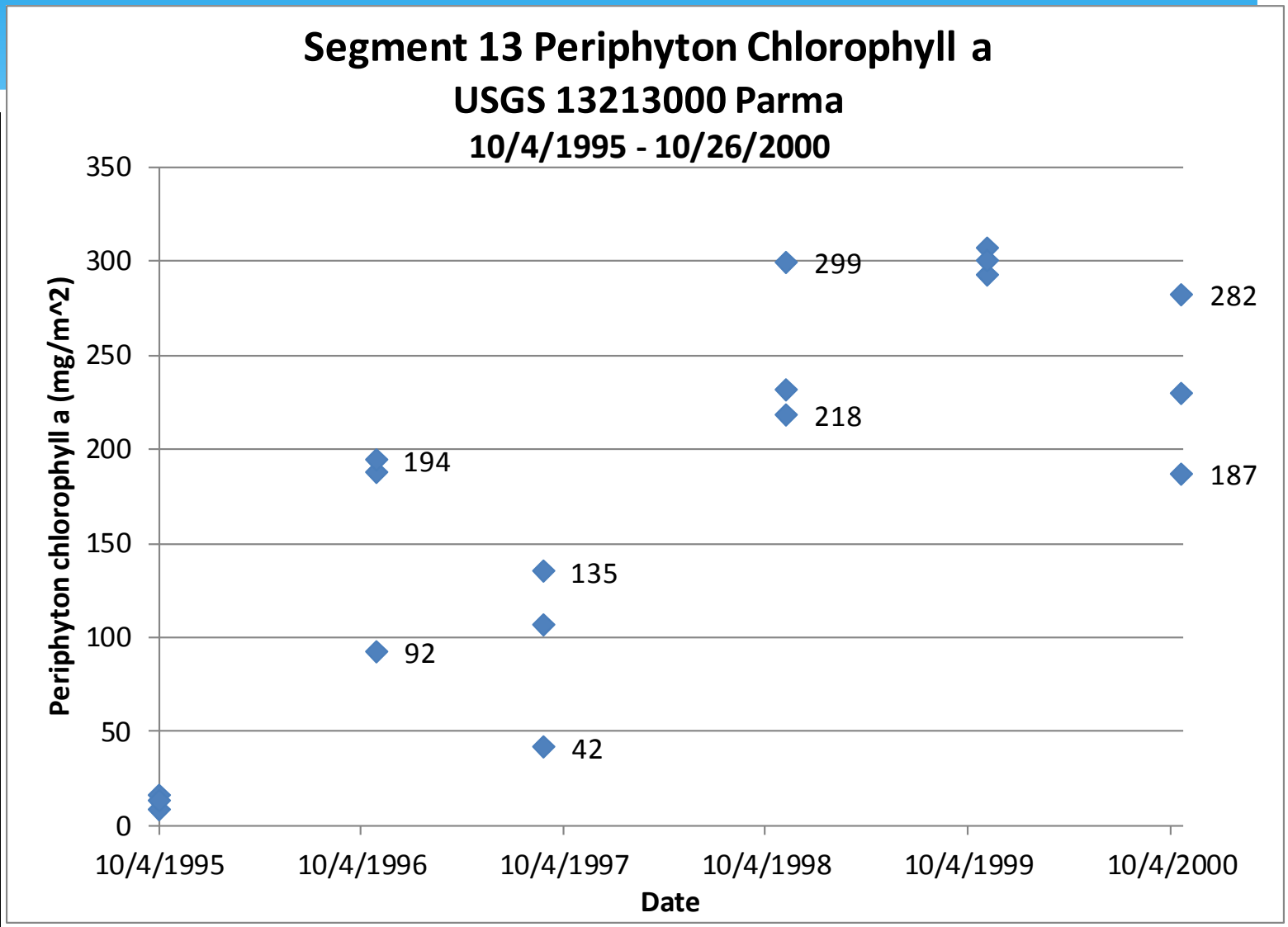
08/20/12	0.31	0.02
08/20/12	0.3	
08/20/12	0.31	
08/20/12	0.29	
08/21/12	0.27	0.04
08/21/12	0.29	
08/21/12	0.3	
08/21/12	0.31	
08/22/12	0.28	0.05
08/22/12	0.33	
08/22/12	0.29	
08/22/12	0.33	
08/23/12	0.29	0.03
08/23/12	0.29	
08/23/12	0.3	
08/23/12	0.31	
08/23/12	0.28	
08/24/12	0.28	0.02
08/24/12	0.3	



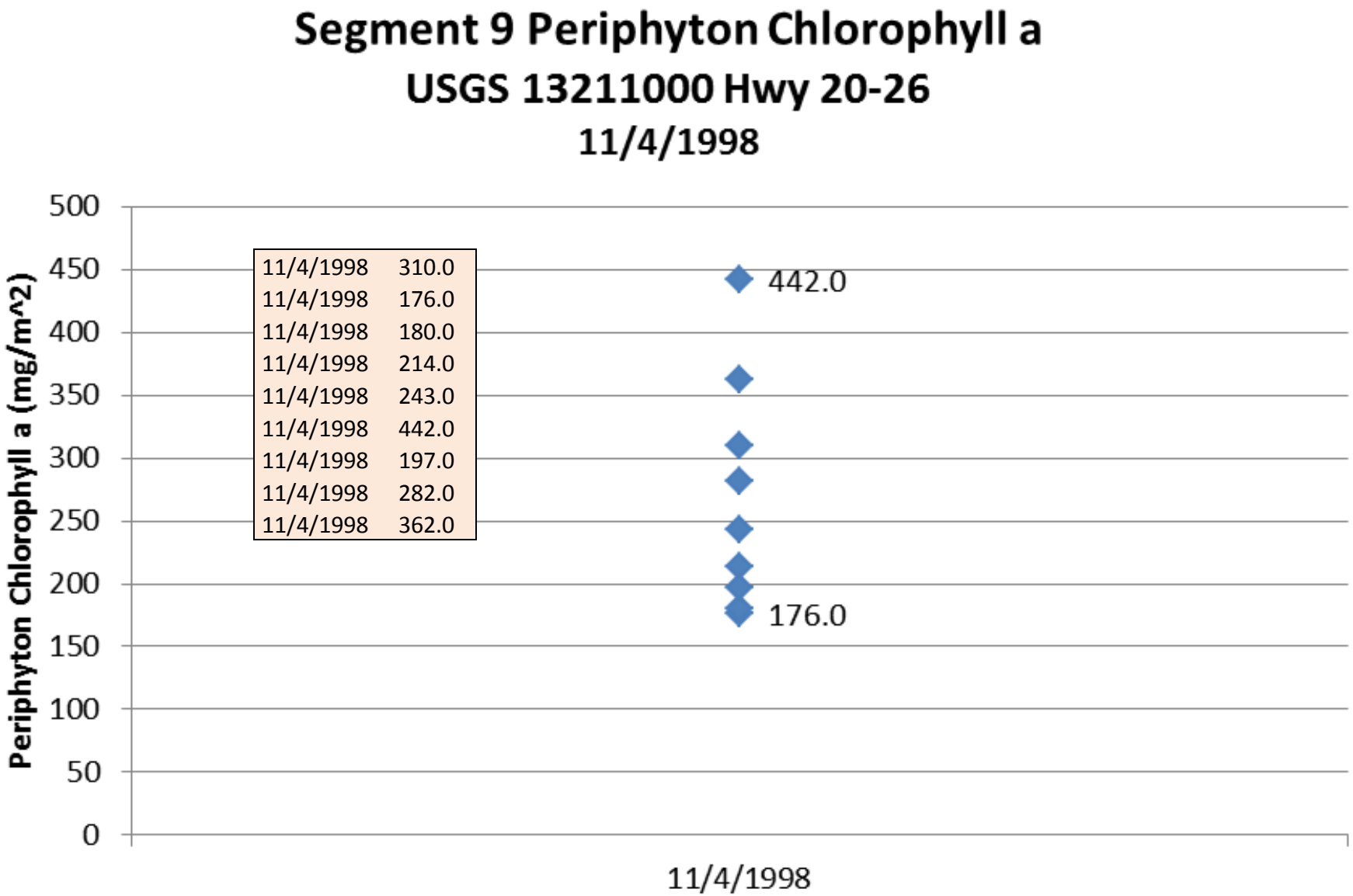
Range of 0.05 mg/L range sampled in the same location at the same time.

Variability in Historic Periphyton Data at Parma

Date	Value
10/4/1995	16
10/4/1995	8
10/4/1995	14
10/31/1996	188
10/31/1996	92
10/31/1996	194
8/29/1997	135
8/29/1997	42
8/29/1997	107
11/12/1998	218
11/12/1998	232
11/12/1998	299
11/8/1999	307
11/8/1999	293
11/8/1999	300
10/26/2000	230
10/26/2000	282
10/26/2000	187

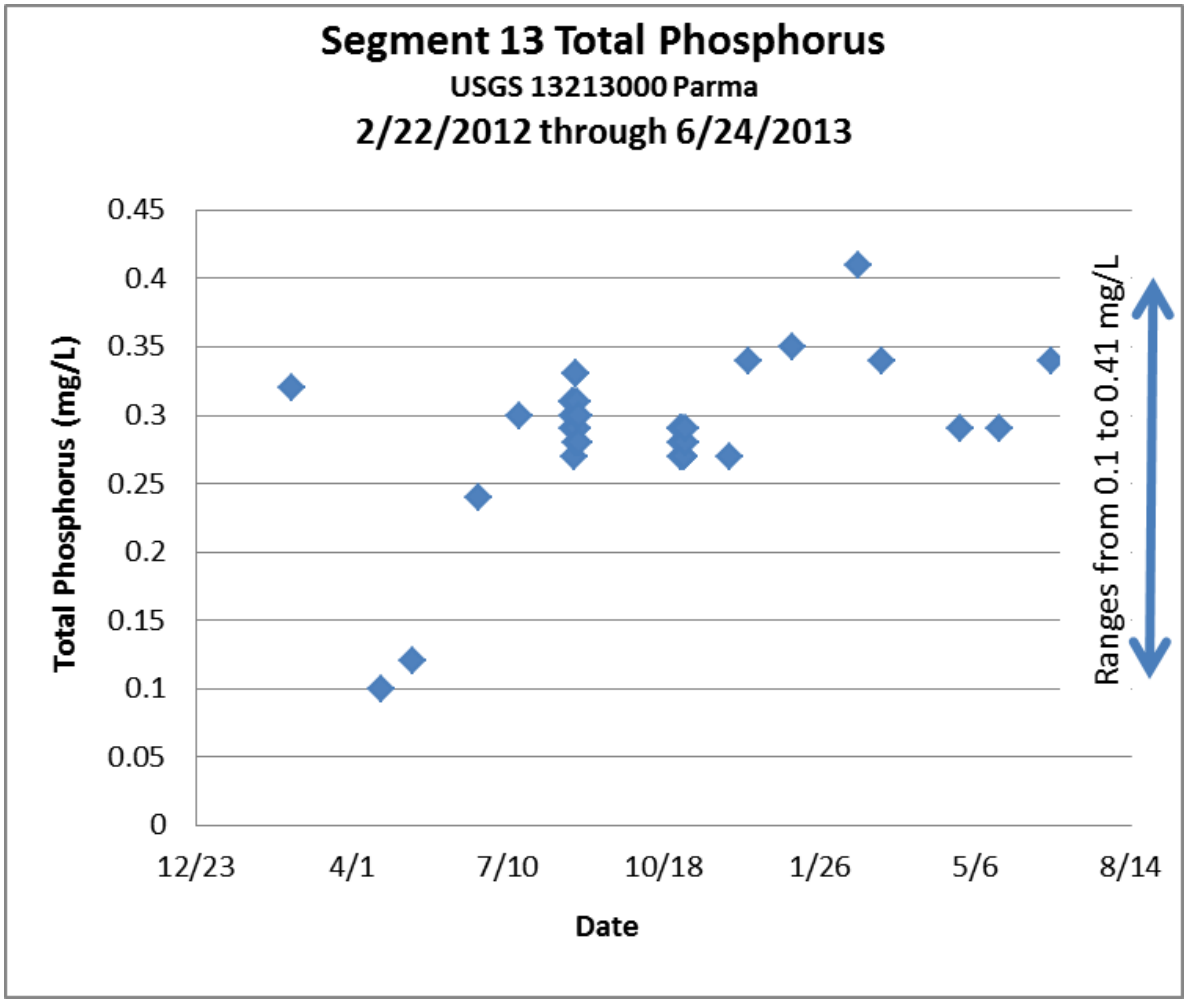


Variability in Historic Periphyton Data at Caldwell



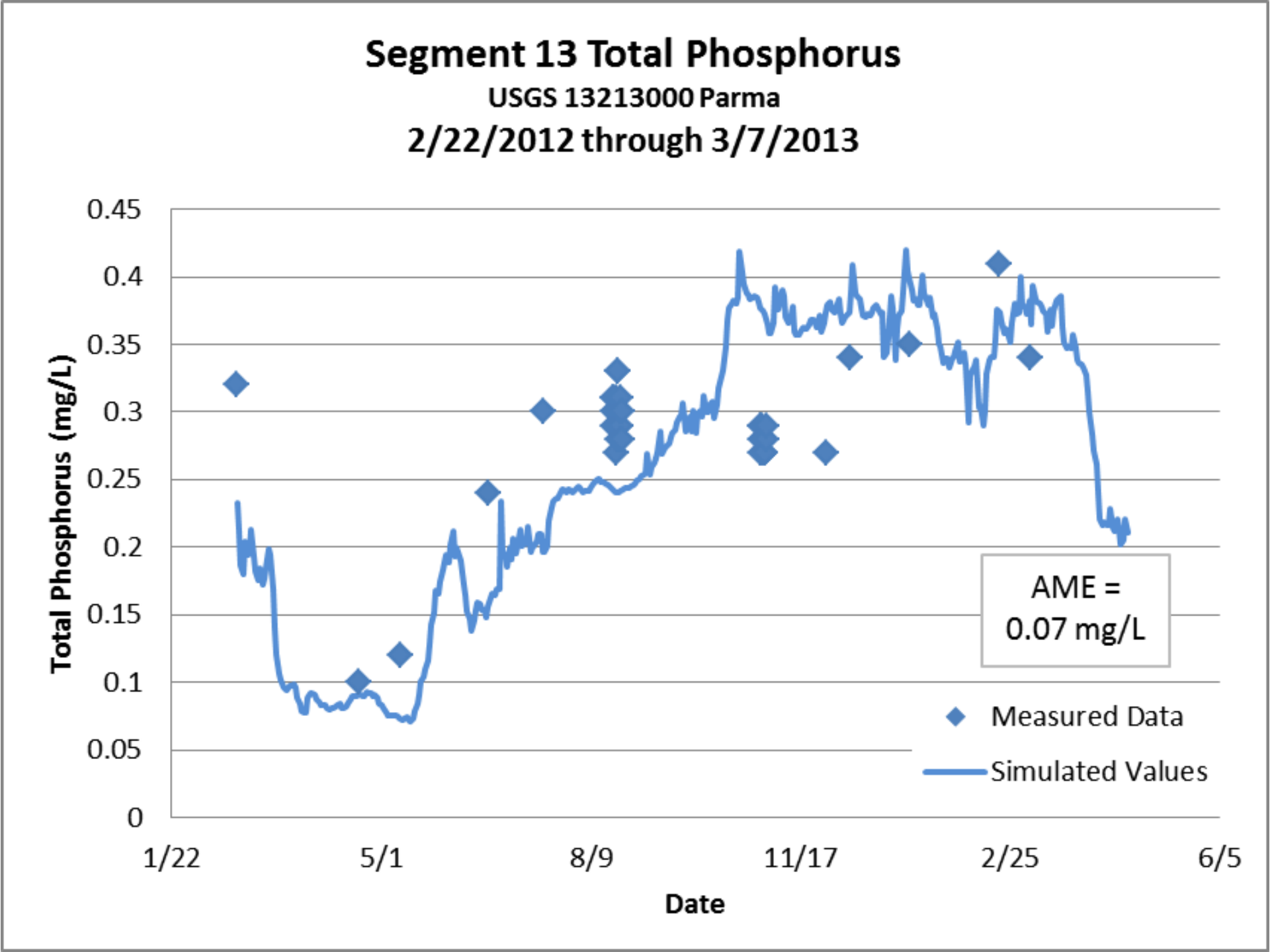
Accuracy Goal:

Nutrient and algal concentrations within 25% of the range of the field data



25% of this range = 0.10 mg/L

Accuracy Goal +/- 0.10 mg/L


Segment 13 Total Phosphorus
USGS 13213000 Parma
2/22/2012 through 3/7/2013
Total Phosphorus (mg/L)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1/22
5/1
8/9
11/17
2/25
6/5
Date
AME = 0.07 mg/L
Measured Data
Simulated Values

Simulation Accuracy

Absolute Mean Error (AME)

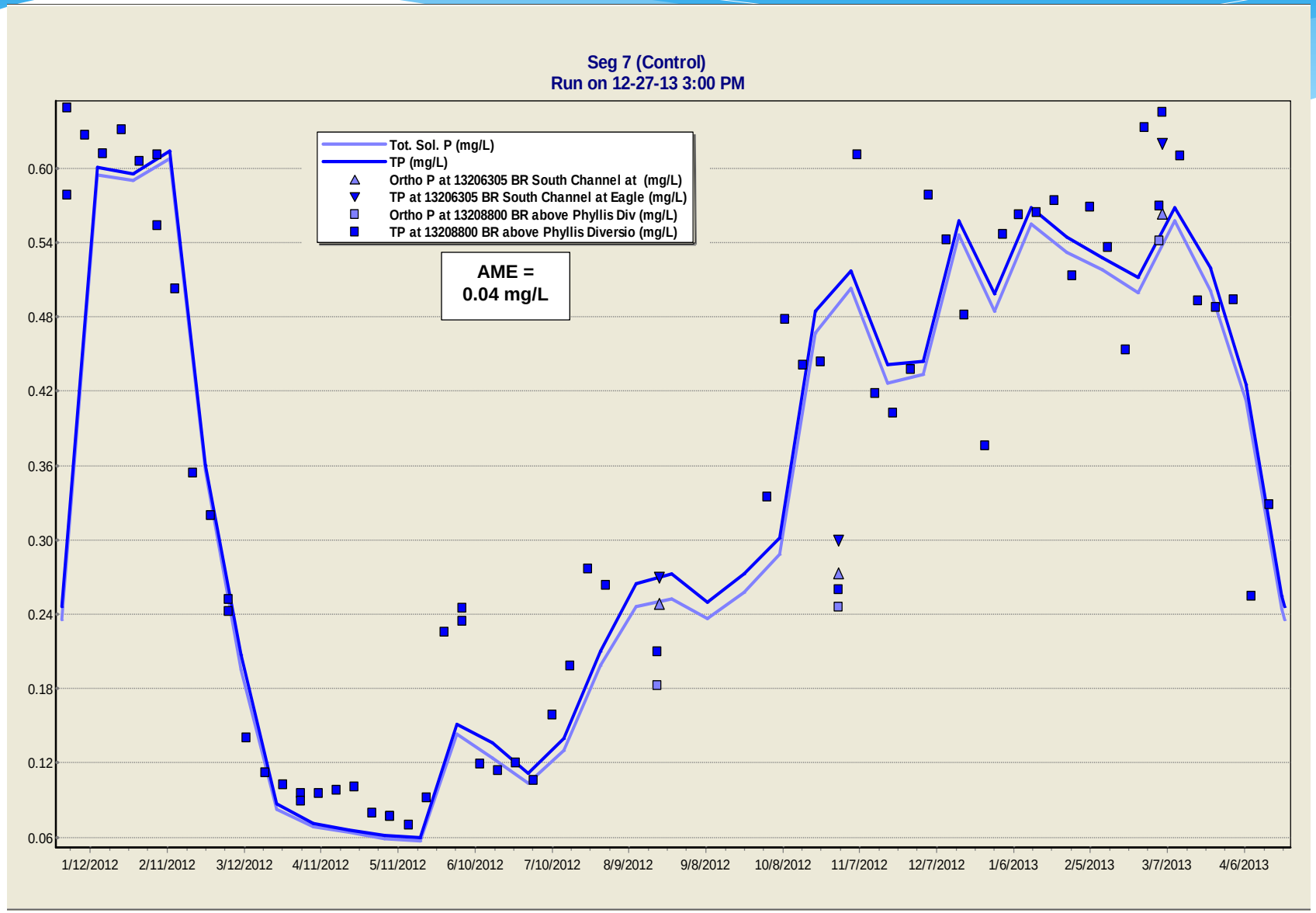
$$AME = \frac{\Sigma|x_{sim} - x_{obs}|}{n}$$

Segment 13			
Date	Modeled	Measured	Absolute difference
2/22/2012	0.23	0.32	0.09
4/20/2012	0.09	0.10	0.01
5/10/2012	0.07	0.12	0.05
6/21/2012	0.16	0.24	0.08
7/17/2012	0.20	0.30	0.10
8/20/2012	0.24	0.30	0.06
8/21/2012	0.24	0.29	0.05
8/22/2012	0.24	0.31	0.07
8/23/2012	0.24	0.29	0.05
8/24/2012	0.24	0.29	0.05
10/29/2012	0.38	0.28	0.09
10/30/2012	0.37	0.28	0.09
10/31/2012	0.37	0.27	0.10
11/1/2012	0.37	0.29	0.08
11/29/2012	0.37	0.27	0.10
12/11/2012	0.39	0.34	0.05
1/8/2013	0.40	0.35	0.05
2/20/2013	0.37	0.41	0.04
3/7/2013	0.36	0.34	0.02
Average absolute difference =			0.07

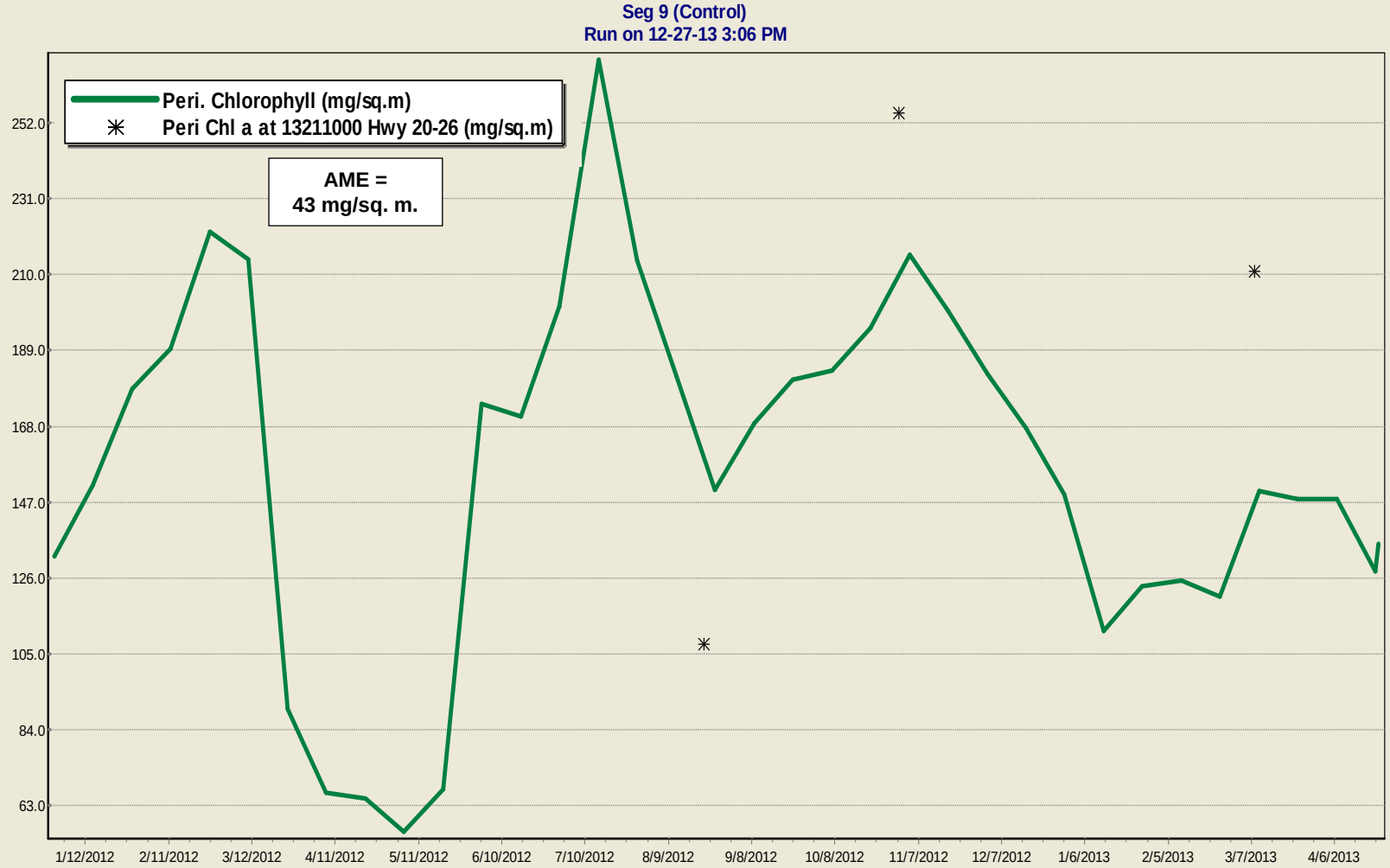
Phosphorus Accuracy Goal

* Phosphorus data ranges from 0.0085 to .6454
* 25% of the range of the field data is 0.16 mg/L
* Overall accuracy goal for phosphorus = 0.16 mg/L AME

Overall phosphorus calibration was within 0.05 mg/L of observed data



Periphyton accuracy goal = 70 mg/sq. m
Accuracy achieved = 71 mg/sq. m



Reviews & Comments

- Comments received from:
  - Brown and Caldwell
  - Dick Park and Jonathan Clough
  - EPA
  - HDR
  - HyQual
  - USGS
- Contents:
  - Model/calibration documentation
  - Over/underpredictions
  - Goodness of fit
  - Choice of parameterization
  - Model sensitivity…

Continued Consultation

- Jan ~27 – DEQ to release AQUATOX model calibration & report
- Feb 18 – Model workgroup to identify calibration strengths, limitations, etc.
- Feb ~~27~~ 26 – TAC to discuss and develop recommendations for LBWC

LBWC Vote

- March 13, DEQ to ask LBWC to vote on current AQUATOX model calibration
  - For use in developing scenarios and TP allocations in the TMDL

Refine Target and Allocations

- Refine target duration, location, frequency
- Other adjustments
  - Parma TP load $\leq$ 0.07 mg/L, May – Sept
  - Reduce TSS (37%)?
  - Tiered and critical low flows?

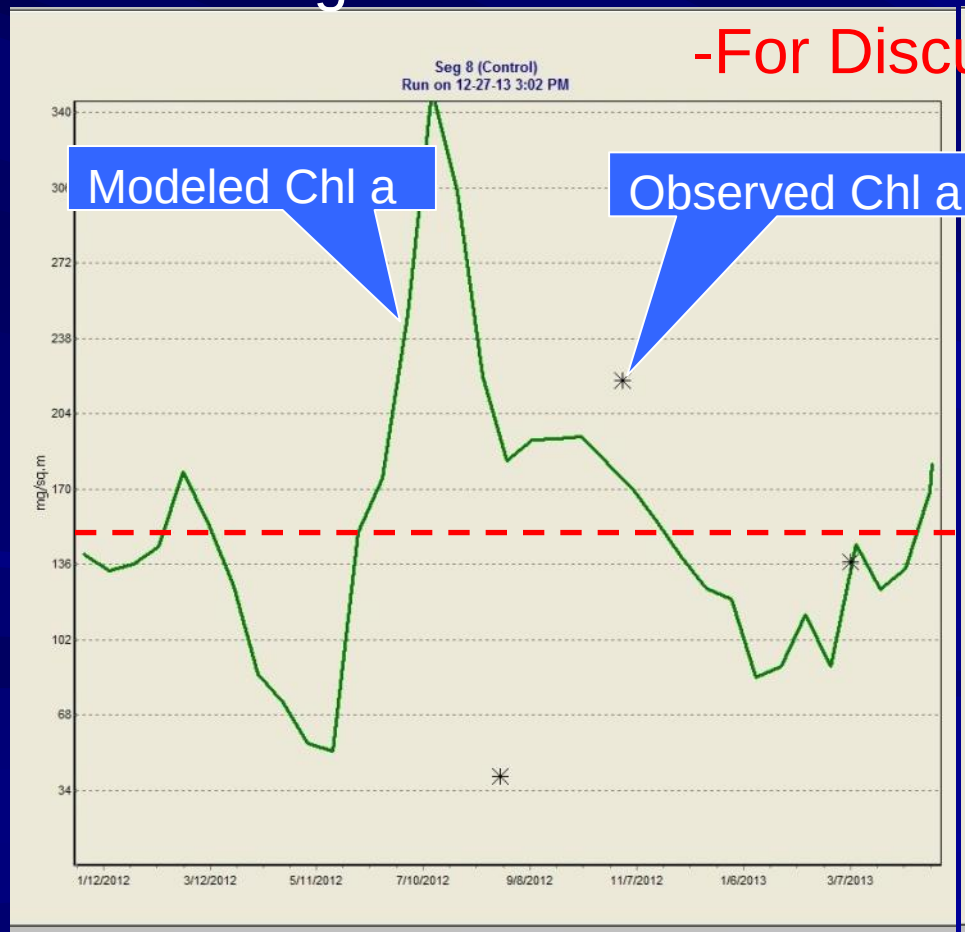
Modeling Periphyton Response

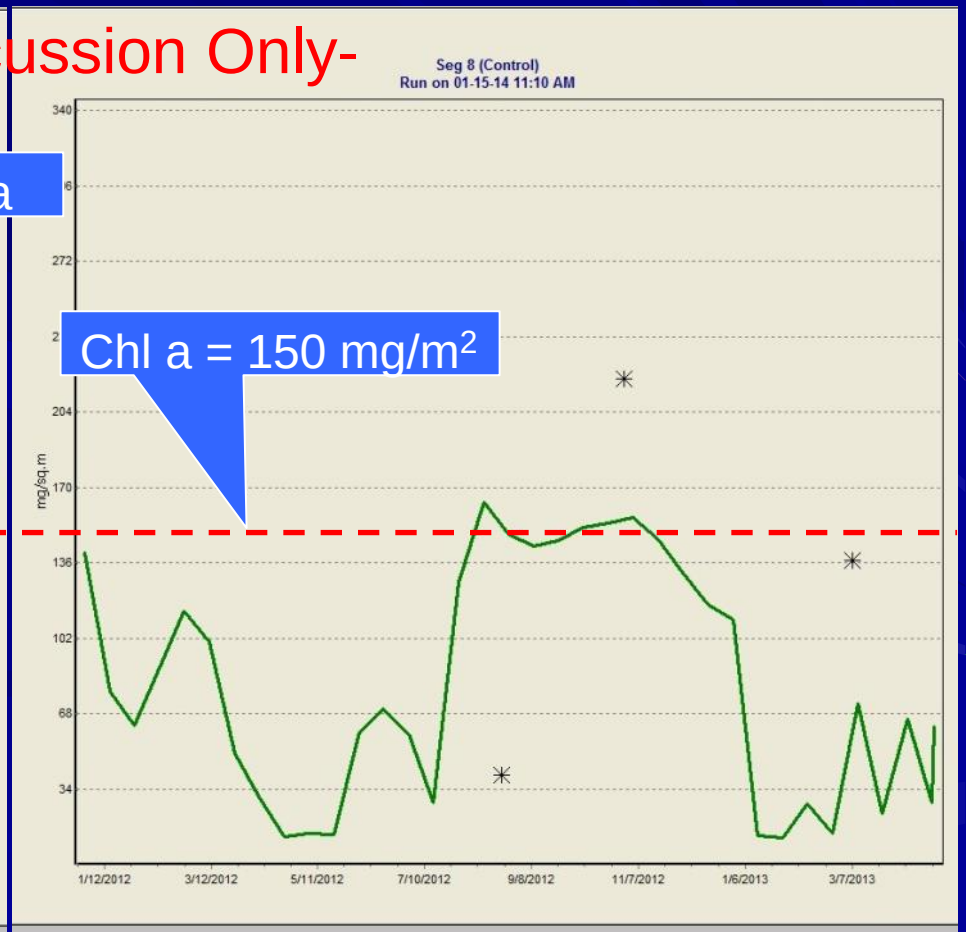
EXAMPLE -

-For Discussion Only-

Existing

< TP





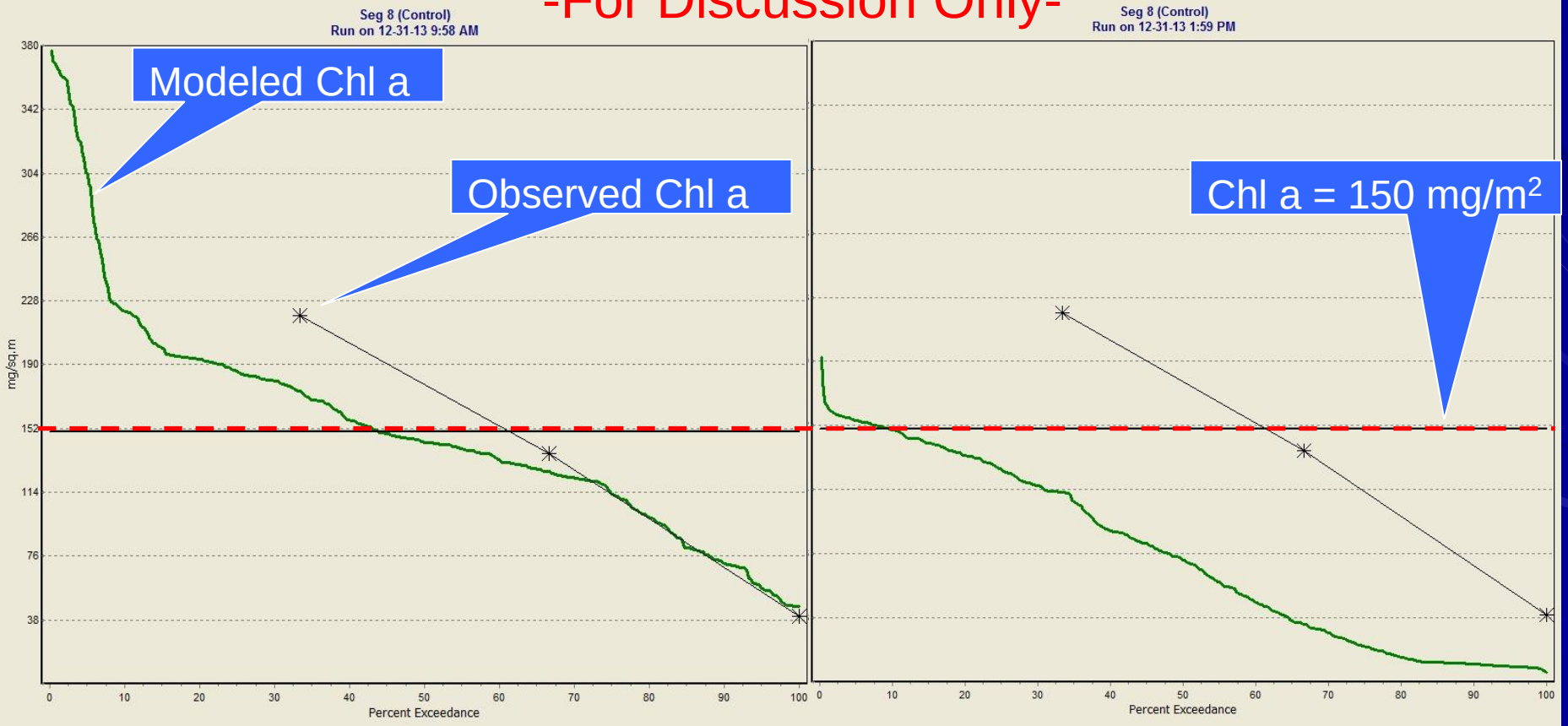
Modeling Periphyton Response

EXAMPLE -

Existing

< TP

-For Discussion Only-



Next Steps

- ~Jan 27– DEQ to provide “final” model calibration and model report
- TAC members – Provide DEQ comments on the model calibration and model report
  - Model workgroup meeting Feb 18
- Feb ~~27~~ 26 TAC meeting – Discussion & recommendations for acceptance of model calibration

Contact Information

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