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Total Phosphorus Mass Balance Model – Lower Boise River, Ada and Canyon Counties, Idaho

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U.S. Department of the Interior
U.S. Geological Survey

Thank you

- IDEQ – Cooperator
- Rex Barrie & Liz Cresto - IDWR
  - Diversion Flows
- Kate Harris - City of Boise
  - WWTP sampling

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Objectives

- Determine gaining and losing reaches between Veteran's Parkway and Parma

- Evaluate sources of phosphorus in the Boise River

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Agenda

- Study Area & Sites
- Study Approach
- Sample Results
- Model Results
  - Approach
  - Assumptions / Limitations
  - Results
  - Scenarios
  - Observations
- Periphyton Discussion

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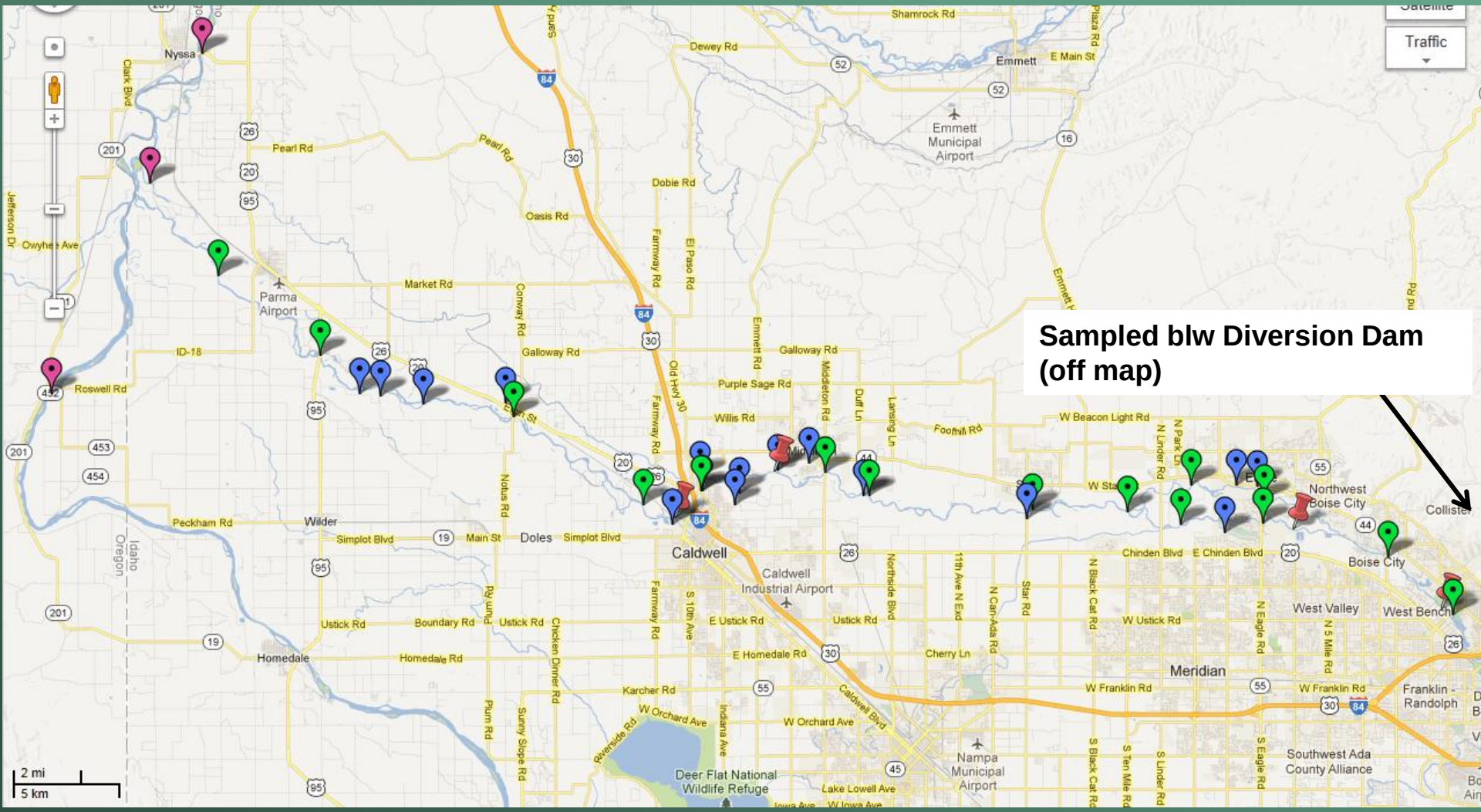
Study Reach: Veteran's to Parma



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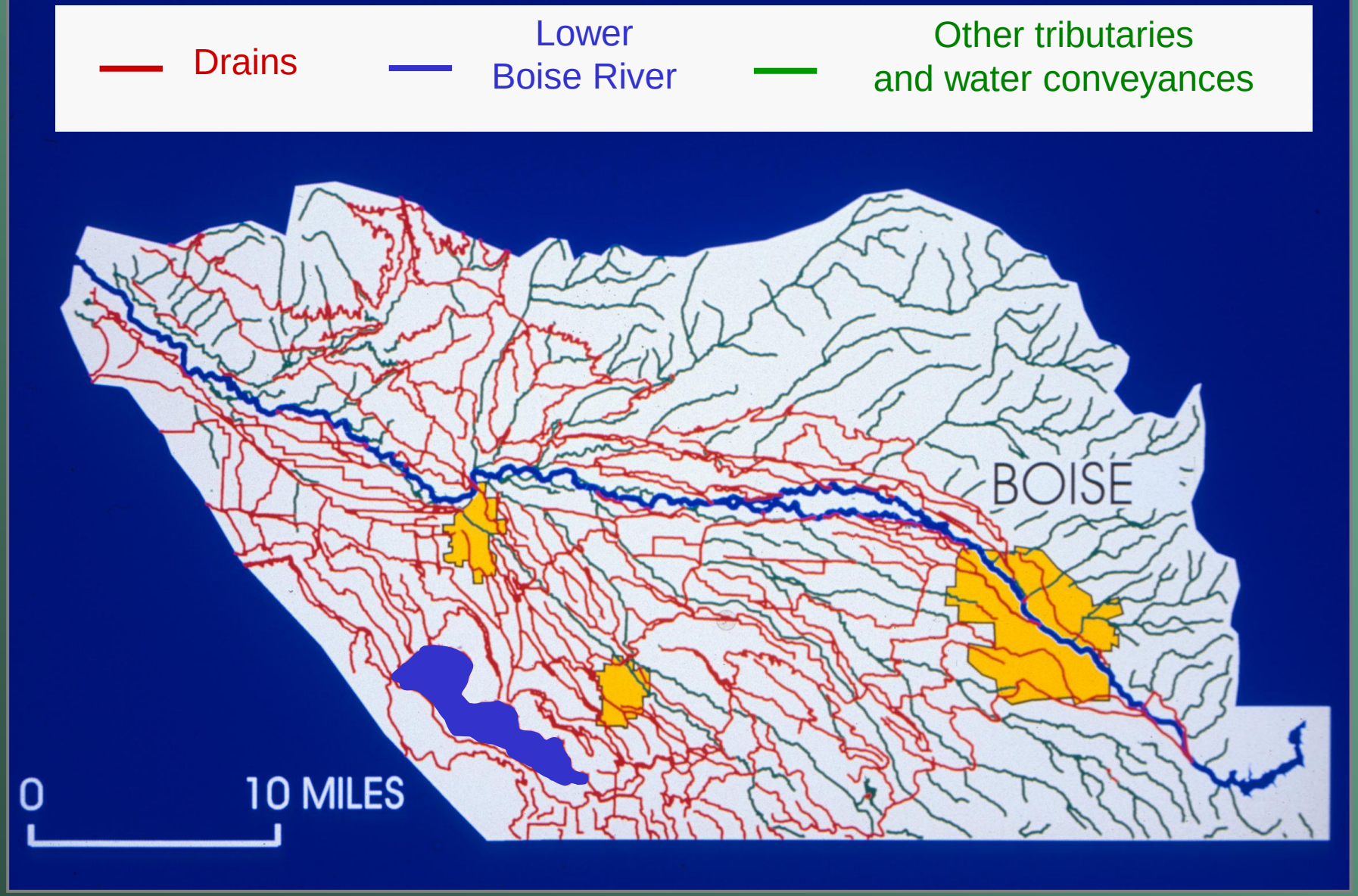

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Plumbing

USGS Approach

- Sample returns & above / blw
- Sample WWTPs
- Measure flow at sample locations
- Diversion Q from IDWR
- Sample shallow wells and piezometers

- Report
  - Peer reviewed draft to DEQ 6/13
  - Published 12/13

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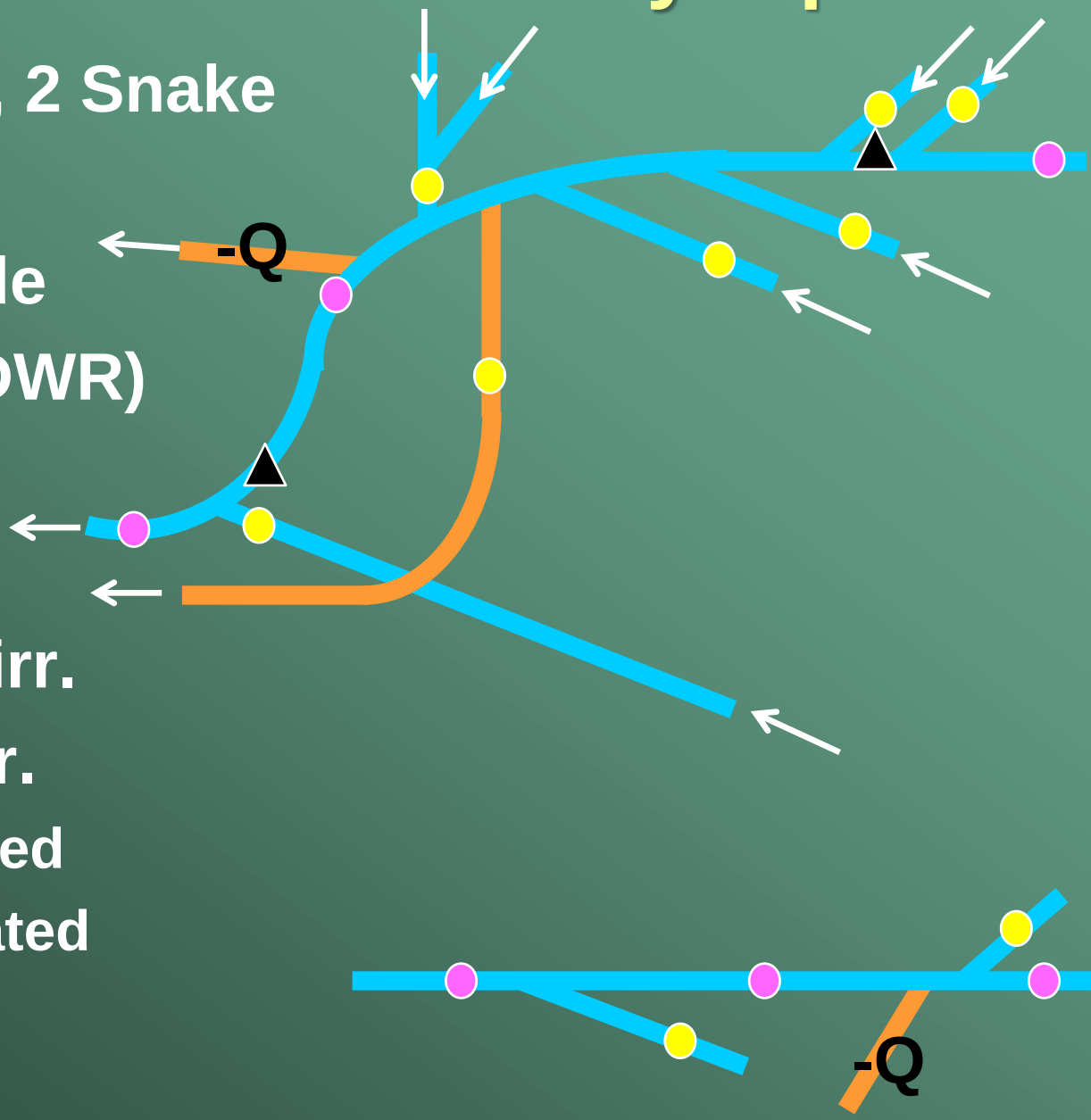
August 20 and October 29 Synoptics

- 14 BR, 2 N.Chan, 2 Snake
- 7 Point Sources
- 15 tribs, Riverside
- 49 Diversions (IDWR)



- August - during irr.
- October - post irr.
  - Indian Crk diverted
  - Dixie Drain elevated

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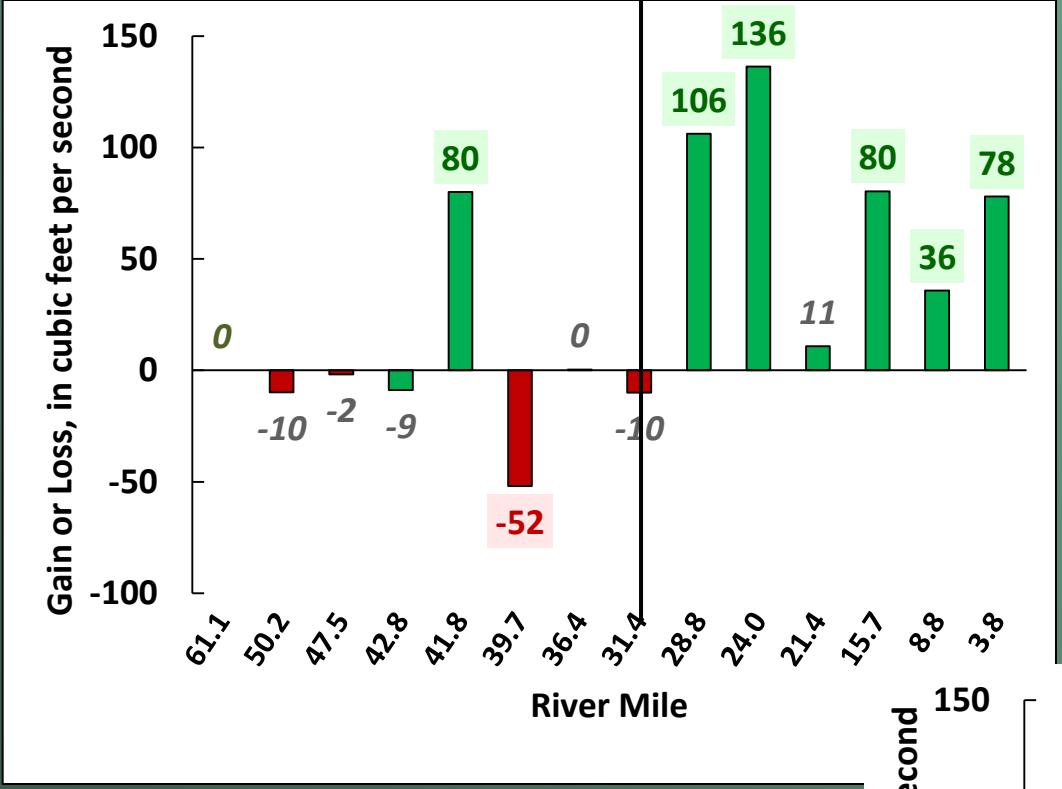
Groundwater Gains & Losses

August



October

Average Q Uncertainty
7.4% main-stem
3.4% tributaries
10% diversions

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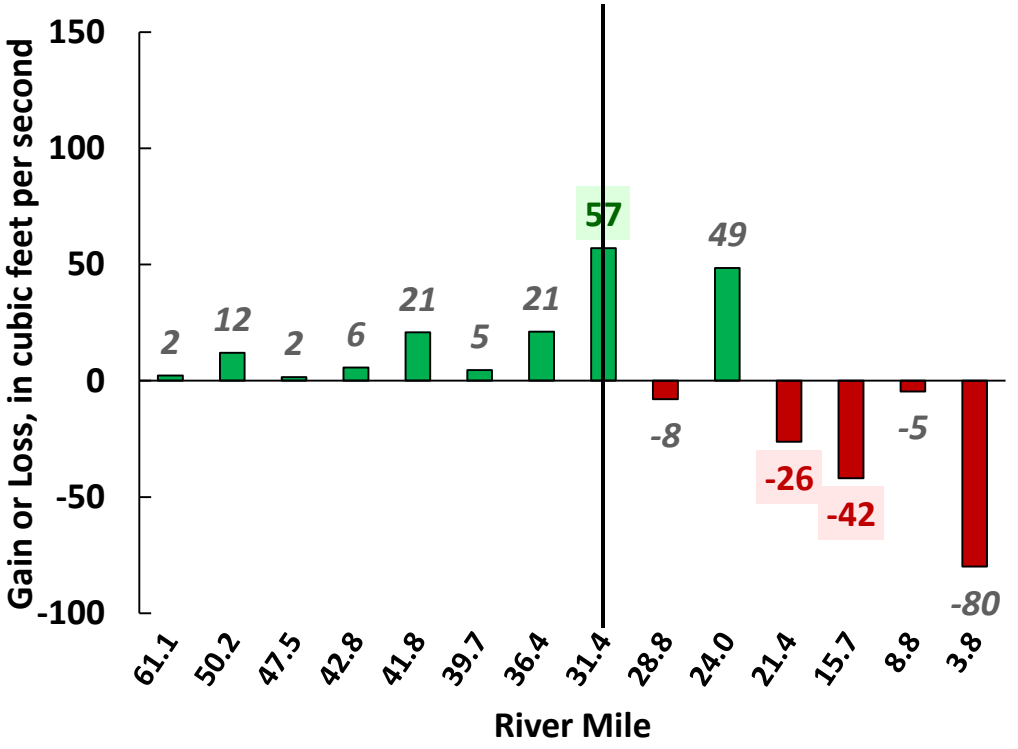
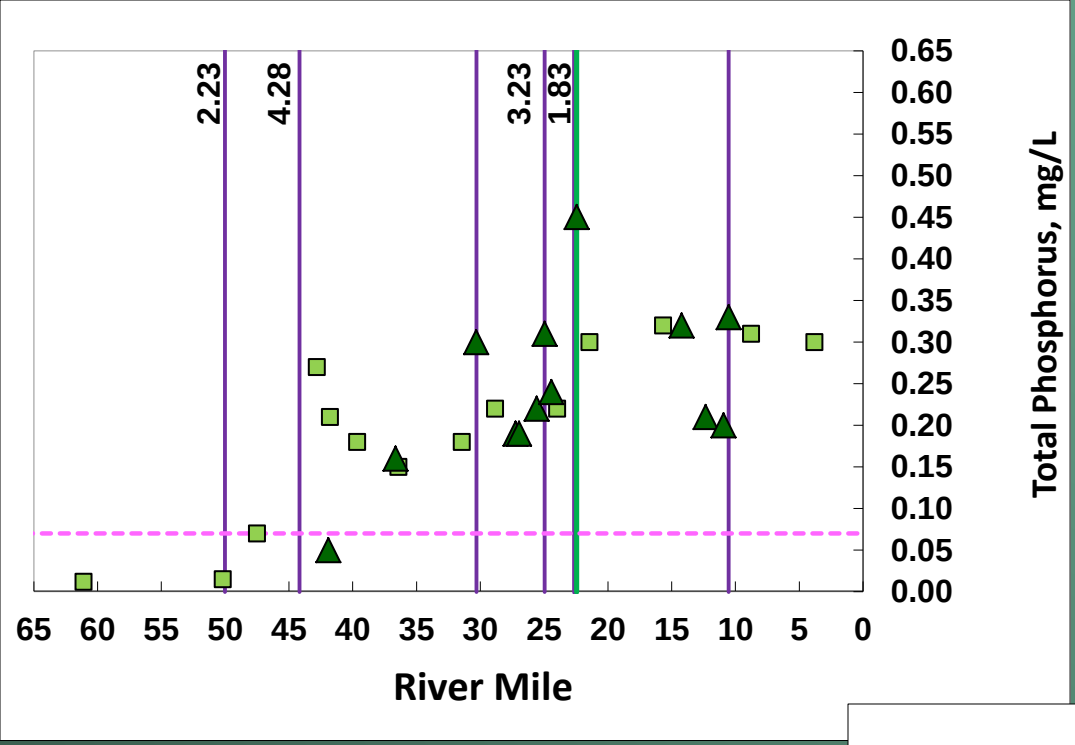
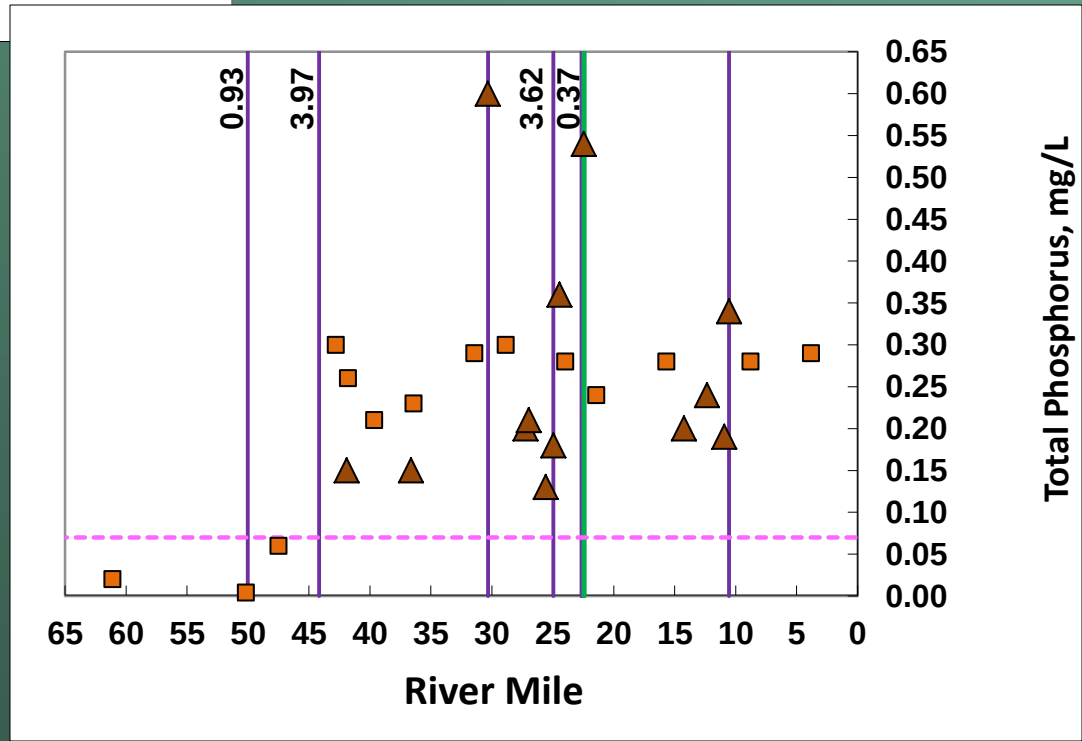


Sample Results

August



October



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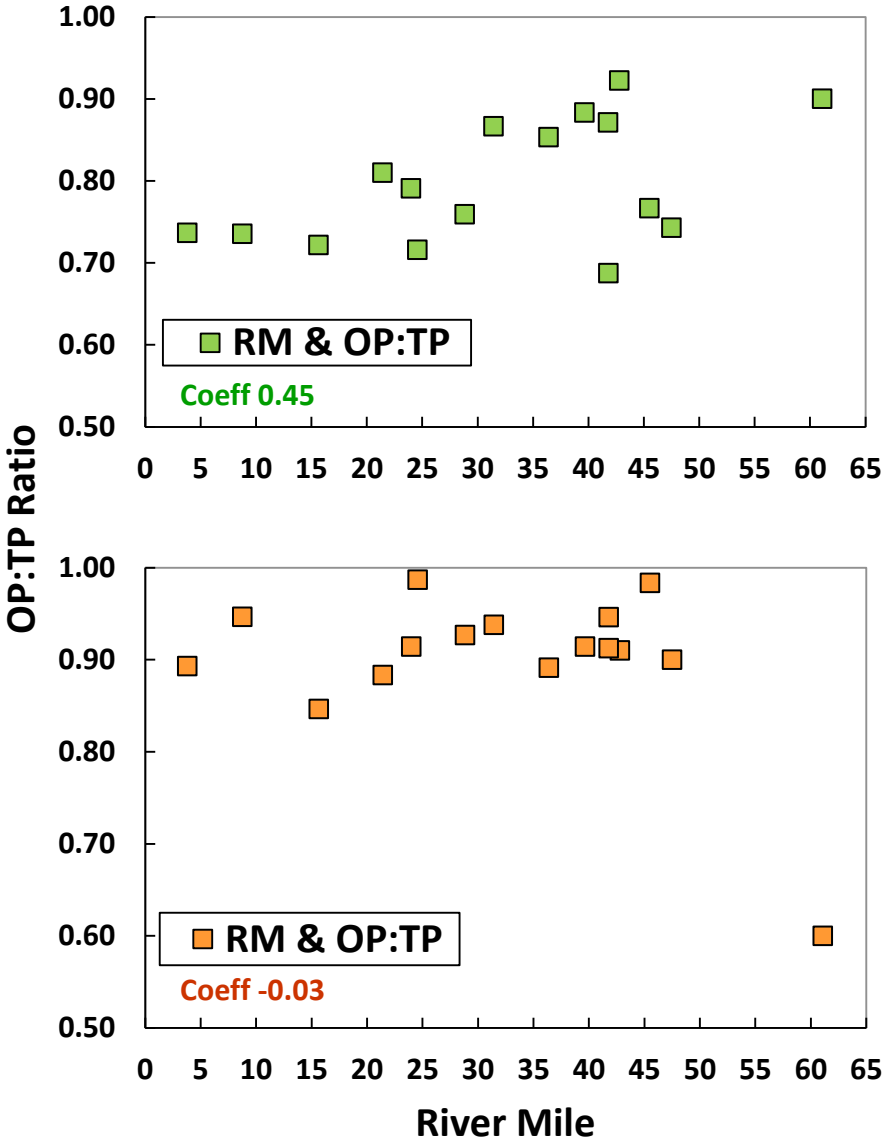
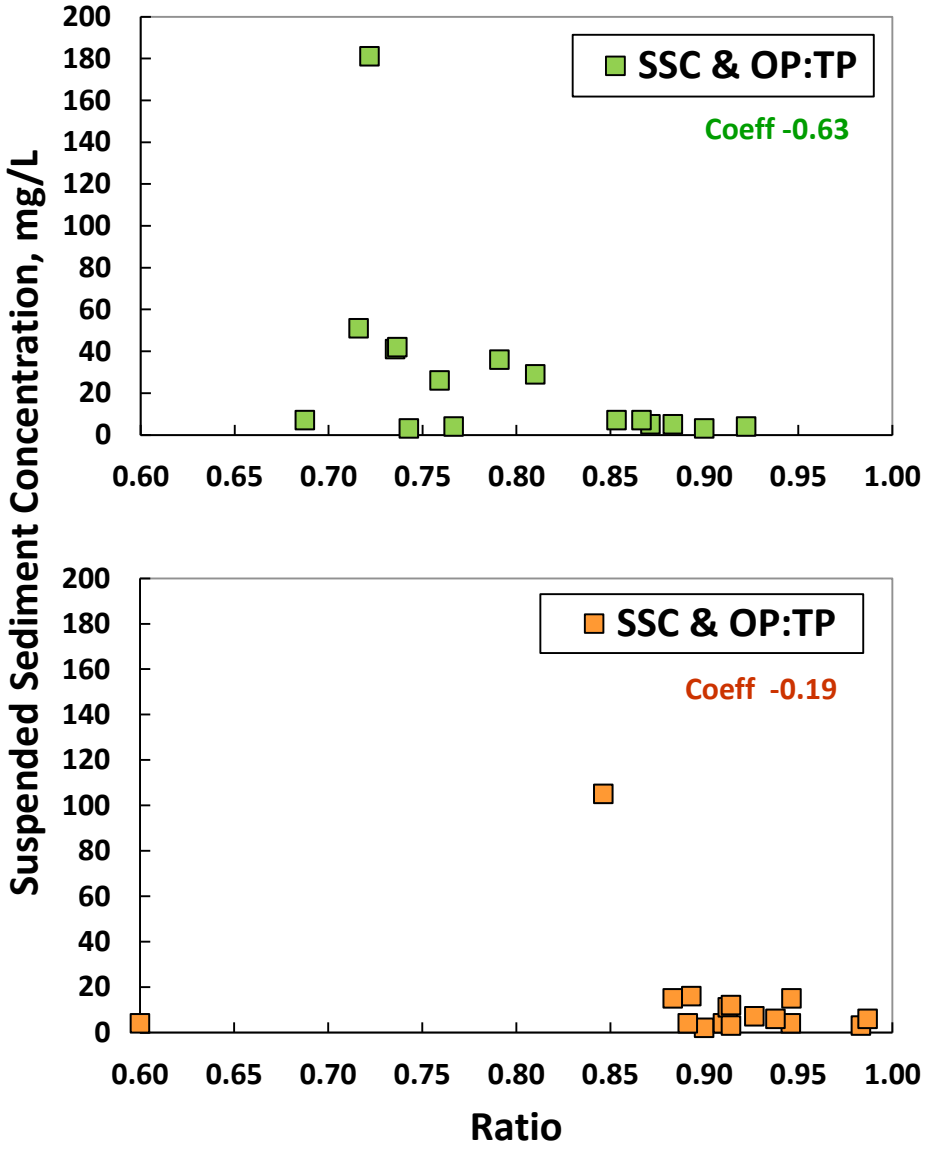
Particulate Phosphorus

August





October

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Results Summary

- Two unnamed drains sampled below Notus
- August
  - GW gains & losses < Q uncertainty Veterans – Middleton
  - Significant GW gains Middleton – Parma
  - Significant correlations
- October
  - GW gains & losses < Q uncertainty Star - Middleton, Caldwell - Notus
  - GW gain Veterans – Caldwell, loss blw Caldwell to Parma
  - Insignificant correlations

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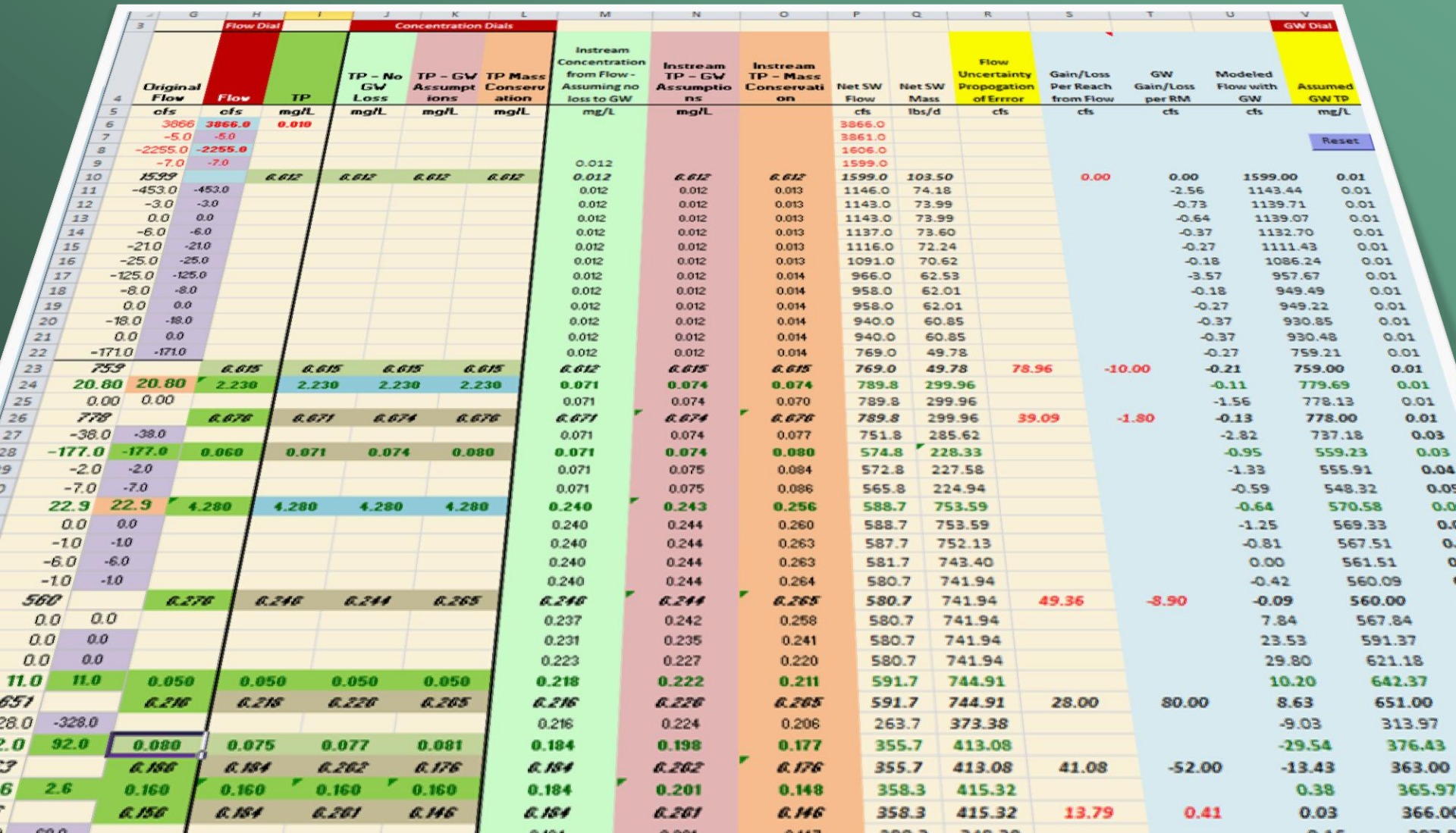
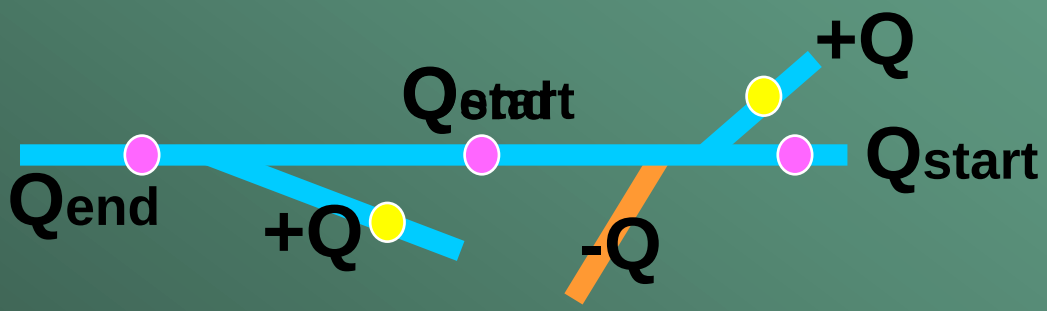
Model Results



Original Flow	Flow	TP	TP – No GW Loss	TP – GW Assumptions	TP Mass Conservation	Instream Concentration from Flow - Assuming no loss to GW	Instream TP – GW Assumptions	Instream TP – Mass Conservation	Net SW Flow	Net SW Mass	Flow Uncertainty Propogation of Errror	Gain/Loss Per Reach from Flow	GW Gain/Loss per RM	Modeled Flow with GW	Assumed GW TP
cfs	cfs	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		cfs	lbs/d	cfs	cfs	cfs	cfs	mg/L
3866	3866.0	0.010							3866.0						
-5.0	-5.0								3861.0						Reset
-2255.0	-2255.0								1606.0						
-7.0	-7.0					0.012			1599.0						
1599		0.012	0.012	0.012	0.012	0.012	0.012	0.012	1599.0	103.50		0.00	0.00	1599.00	0.01
-453.0	-453.0					0.012	0.012	0.013	1146.0	74.18			-2.56	1143.44	0.01
-3.0	-3.0					0.012	0.012	0.013	1143.0	73.99			-0.73	1139.71	0.01
0.0	0.0					0.012	0.012	0.013	1143.0	73.99			-0.64	1139.07	0.01
-6.0	-6.0					0.012	0.012	0.013	1137.0	73.60			-0.37	1132.70	0.01
-21.0	-21.0					0.012	0.012	0.013	1116.0	72.24			-0.27	1111.43	0.01
-25.0	-25.0					0.012	0.012	0.013	1091.0	70.62			-0.18	1086.24	0.01
-125.0	-125.0					0.012	0.012	0.014	966.0	62.53			-3.57	957.67	0.01
-8.0	-8.0					0.012	0.012	0.014	958.0	62.01			-0.18	949.49	0.01
0.0	0.0					0.012	0.012	0.014	958.0	62.01			-0.27	949.22	0.01
-18.0	-18.0					0.012	0.012	0.014	940.0	60.85			-0.37	930.85	0.01
0.0	0.0					0.012	0.012	0.014	940.0	60.85			-0.37	930.48	0.01
-171.0	-171.0					0.012	0.012	0.014	769.0	49.78			-0.27	759.21	0.01
759		0.015	0.015	0.015	0.015	0.012	0.015	0.015	769.0	49.78	78.96	-10.00	-0.21	759.00	0.01
20.80	20.80	2.230	2.230	2.230	2.230	0.071	0.074	0.074	789.8	299.96			-0.11	779.69	0.01
0.00	0.00					0.071	0.074	0.070	789.8	299.96			-1.56	778.13	0.01
778		0.076	0.071	0.074	0.076	0.071	0.074	0.076	789.8	299.96	39.09	-1.80	-0.13	778.00	0.01
-38.0	-38.0					0.071	0.074	0.077	751.8	285.62			-2.82	737.18	0.03
-177.0	-177.0	0.060	0.071	0.074	0.080	0.071	0.074	0.080	574.8	228.33			-0.95	559.23	0.03
-2.0	-2.0					0.071	0.075	0.084	572.8	227.58			-1.33	555.91	0.04
-7.0	-7.0					0.071	0.075	0.086	565.8	224.94			-0.59	548.32	0.05
22.9	22.9	4.280	4.280	4.280	4.280	0.240	0.243	0.256	588.7	753.59			-0.64	570.58	0.0
0.0	0.0					0.240	0.244	0.260	588.7	753.59			-1.25	569.33	0.0
-1.0	-1.0					0.240	0.244	0.263	587.7	752.13			-0.81	567.51	0.
-6.0	-6.0					0.240	0.244	0.263	581.7	743.40			0.00	561.51	0
-1.0	-1.0					0.240	0.244	0.264	580.7	741.94			-0.42	560.09	
560		0.276	0.246	0.244	0.265	0.246	0.244	0.265	580.7	741.94	49.36	-8.90	-0.09	560.00	
0.0	0.0					0.237	0.242	0.258	580.7	741.94			7.84	567.84	
0.0	0.0					0.231	0.235	0.241	580.7	741.94			23.53	591.37	
0.0	0.0					0.223	0.227	0.220	580.7	741.94			29.80	621.18	
11.0	11.0	0.050	0.050	0.050	0.050	0.218	0.222	0.211	591.7	744.91			10.20	642.37	
651		0.216	0.218	0.226	0.265	0.216	0.226	0.265	591.7	744.91	28.00	80.00	8.63	651.00	
28.0	-328.0					0.216	0.224	0.206	263.7	373.38			-9.03	313.97	
2.0	92.0	0.080	0.075	0.077	0.081	0.184	0.198	0.177	355.7	413.08			-29.54	376.43	
3		0.166	0.184	0.262	0.176	0.184	0.262	0.176	355.7	413.08	41.08	-52.00	-13.43	363.00	
6	2.6	0.160	0.160	0.160	0.160	0.184	0.201	0.148	358.3	415.32			0.38	365.97	
		0.156	0.184	0.261	0.146	0.184	0.261	0.146	358.3	415.32	13.79	0.41	0.03	366.00	

Modeling Approach

- Step 1 - GW flow from flow balance



$$\Delta Q = Q_{end} - (Q_{start} + Q_{in} - Q_{out})$$

$$\frac{\Delta Q}{L} = \frac{Q_{gw}}{L}$$

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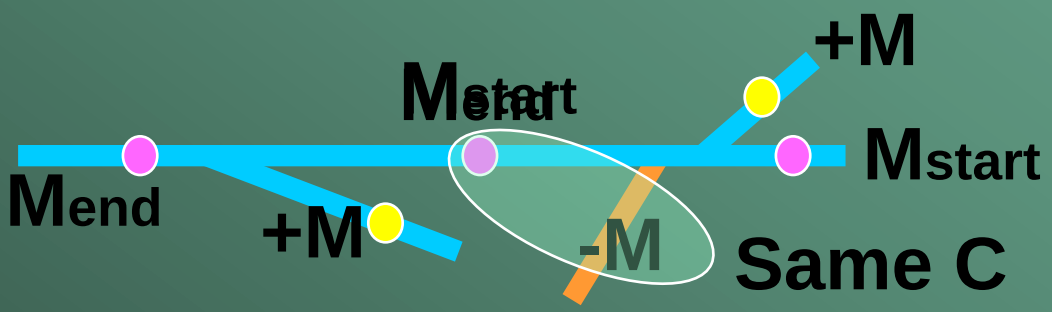
Calibrated Mass Balance Model

- Use measured mass
- No assumptions on GW TP



$$M = Q * C * F$$

$$\Delta M = M_{end} - (M_{start} + M_{in} - M_{out})$$

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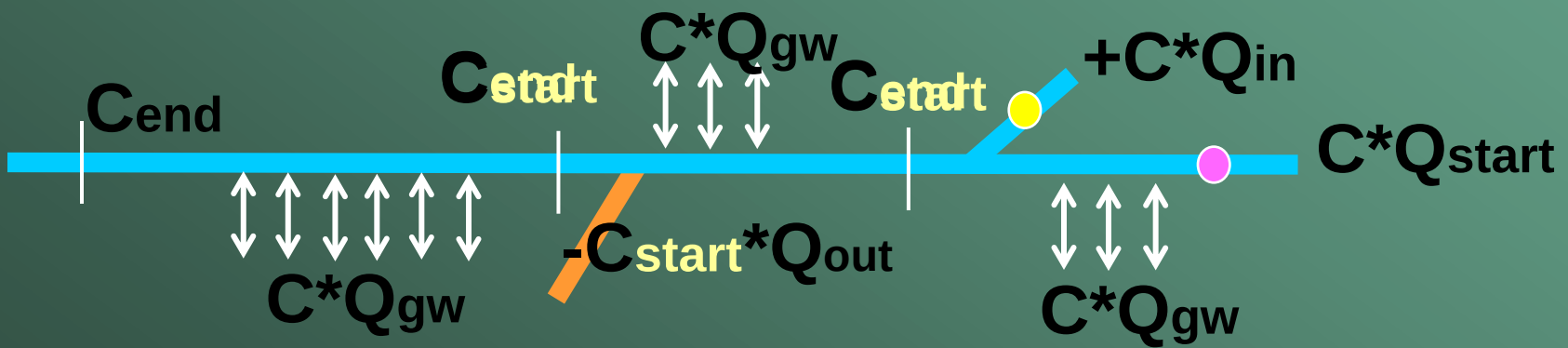
$$\frac{\Delta M}{L}$$

Uncalibrated Mass Balance Model

- Estimate GW concentrations
  - Account for gained & lost mass with GW exchange



$$\frac{((C_{start}*Q_{start})-(C_{start}*Q_{out})+(C_{in}*Q_{in})+/-(C_{gw}*Q_{gw}))}{Q_{end}} = C_{end}$$

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Flow

Two Models

1. Calibrated - Conservation of Mass Model
2. Uncalibrated – GW concentration assumptions

- 3 GW Concentration Scenarios
  1. Back-calc C_{GW} except $\Delta Q < Q$ uncertainty
  2. TP = 0.25 mg/L in gaining reaches
  3. TP = trib base flow

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Assumptions & Limitations

- Steady state
  - No biogeochemical processes
  - Snap-shot for specified dates
- Groundwater
- Plumbing
  - Returns – no account for diverted load
- Storm events

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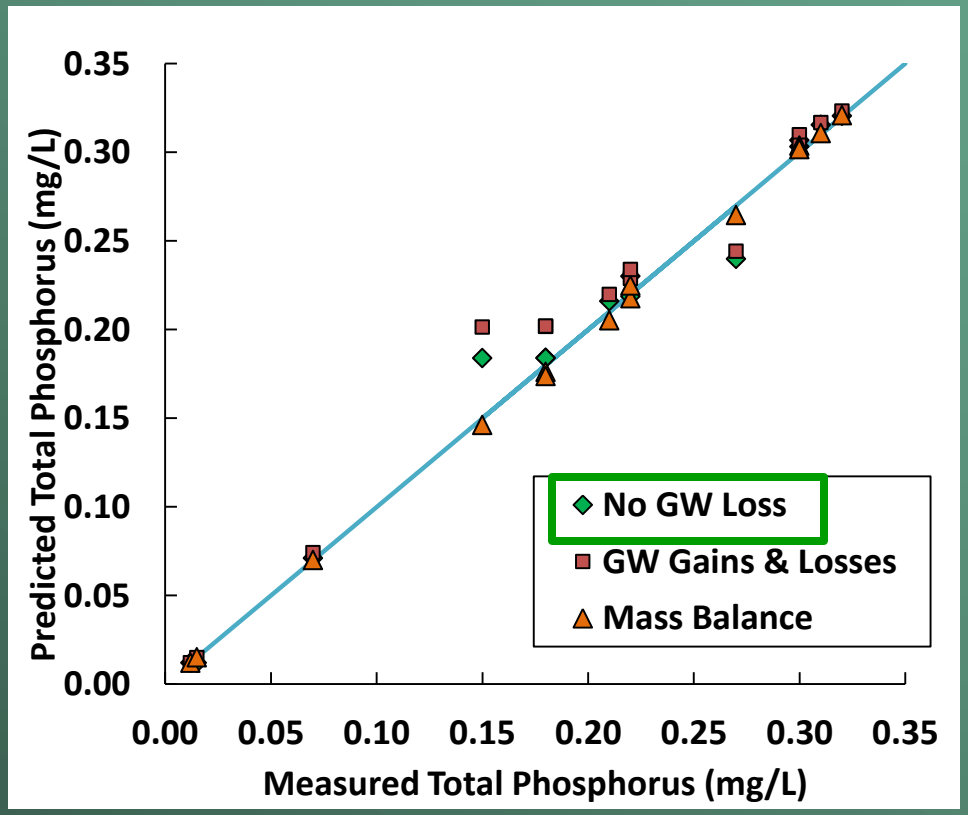
August Results

- 14 main-stem samples
  - 97% R^2 uncalibrated model
    - Best Fit GW = back-calculated TP



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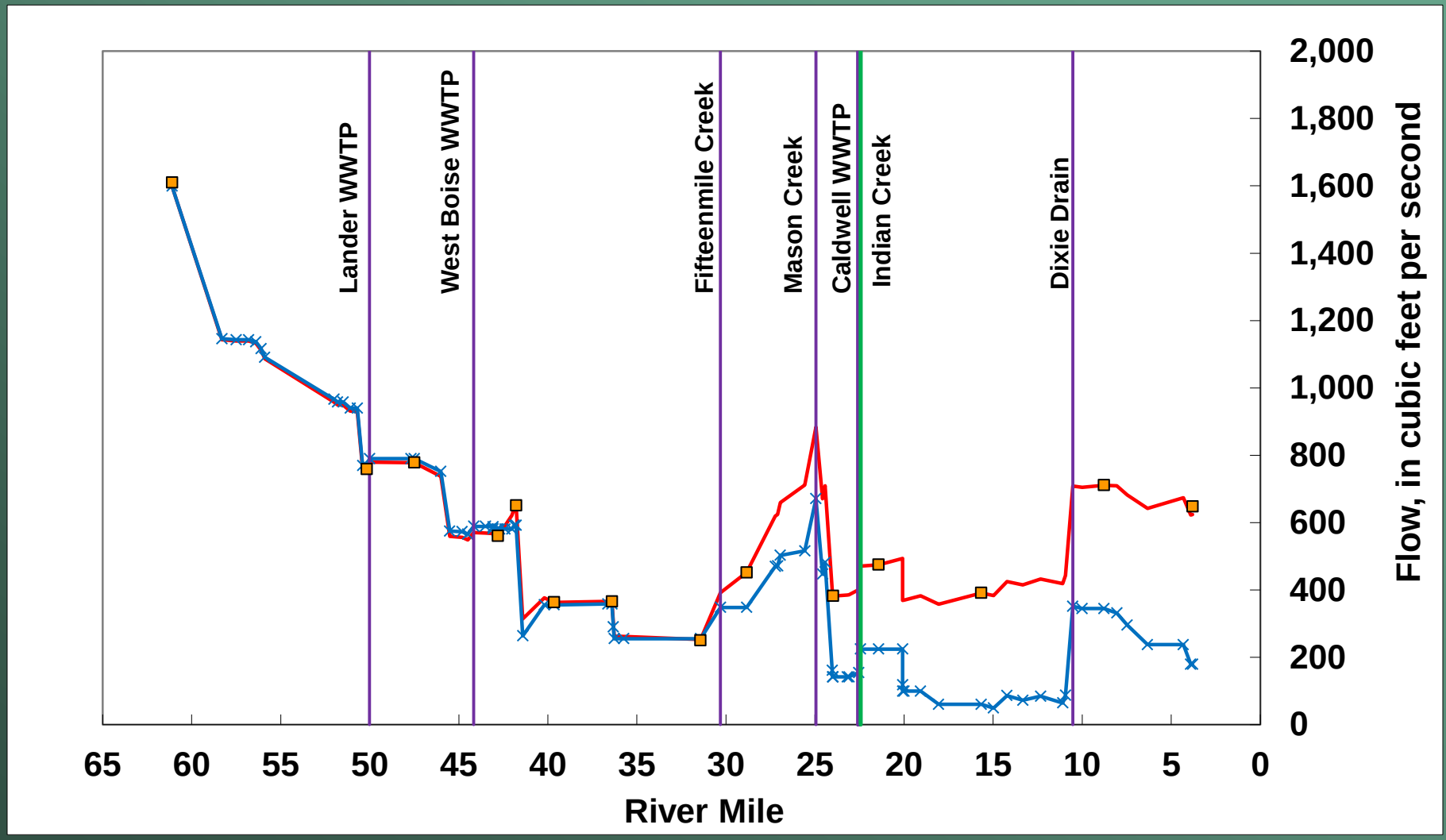
Flow Calibration Plot - August



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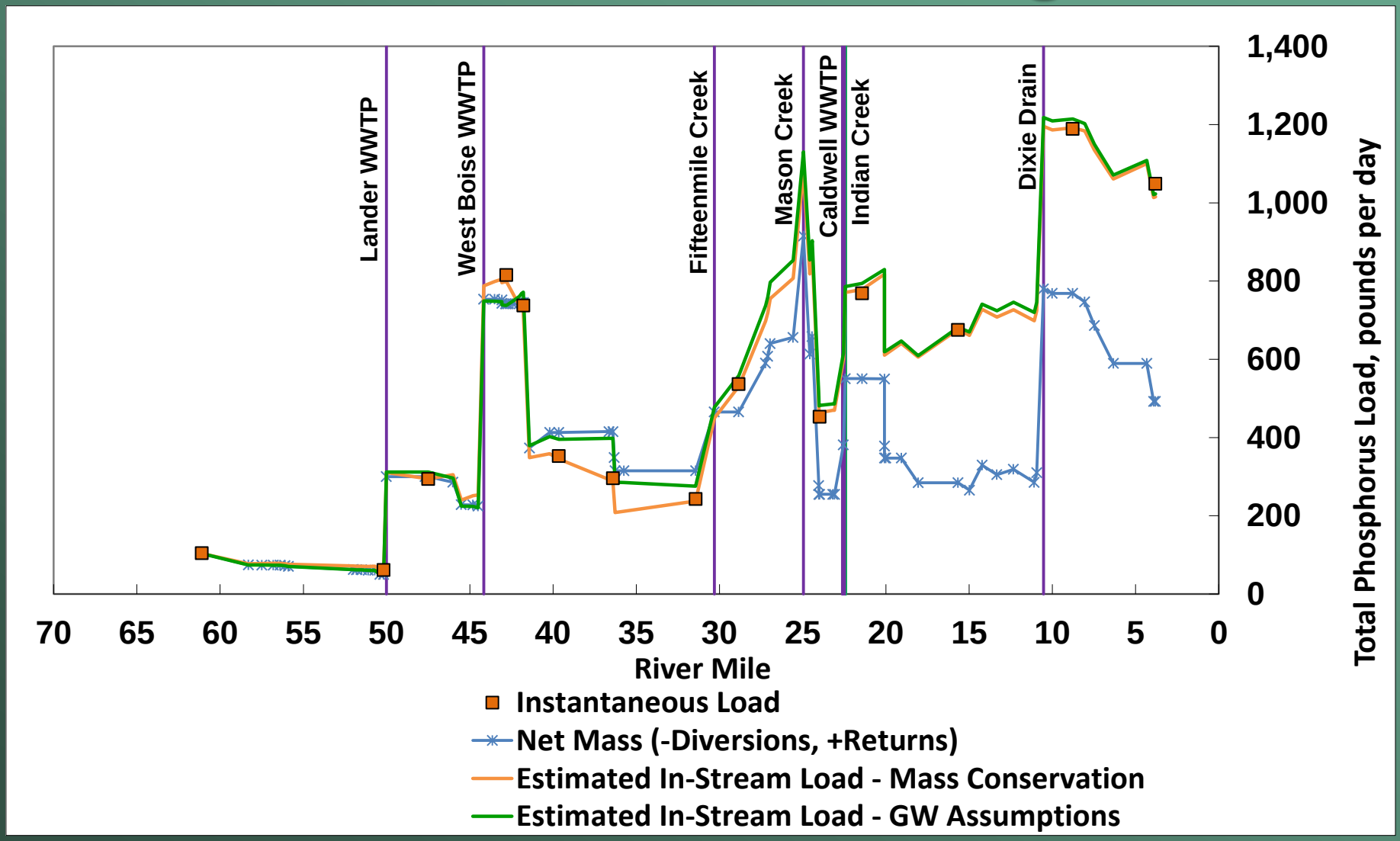
TP Load Calibration Plot - Aug



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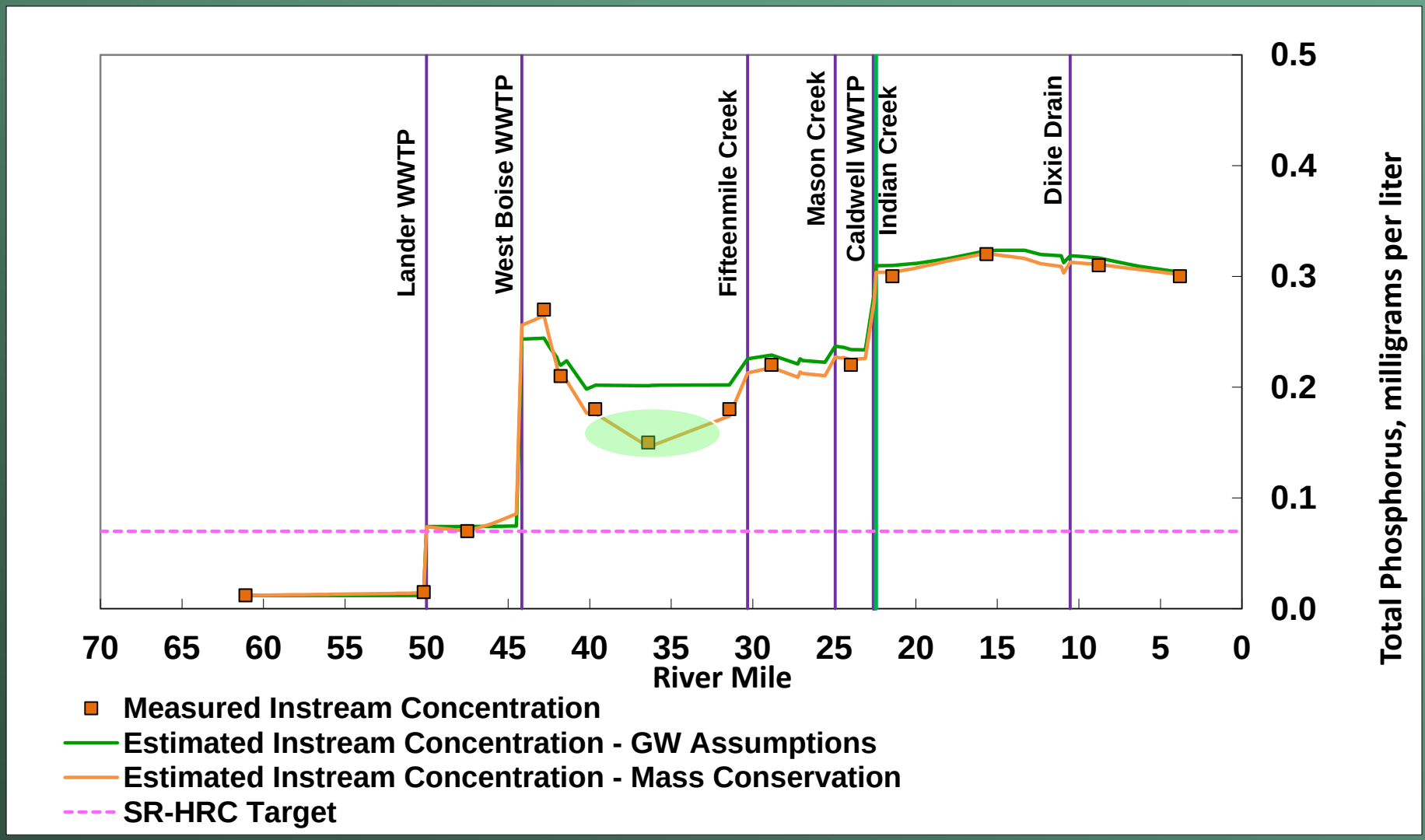
TP Concentration Calibration Plot - Aug



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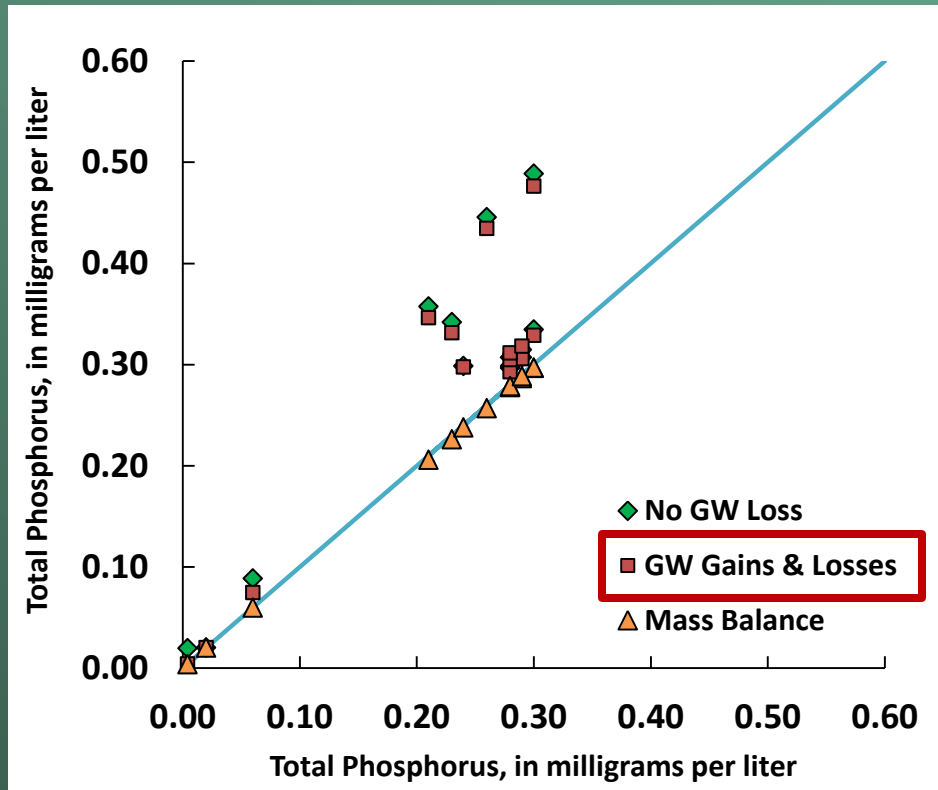
October Results

- 14 mainstem samples
  - 0.83 – 0.80 R^2 for uncalibrated models
    - Best fit GW = trib TP
    - Best model includes GW Losses



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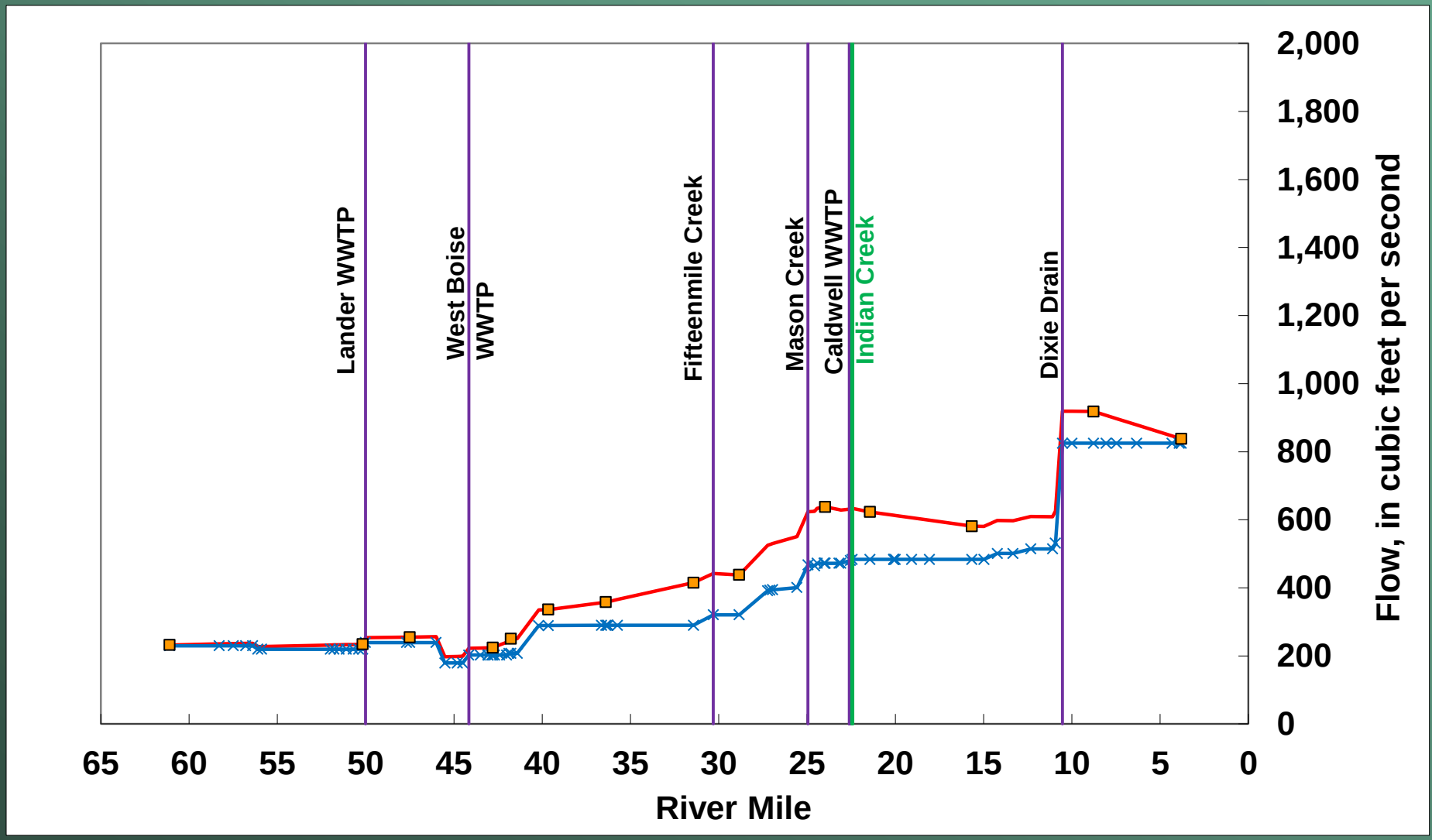
Flow Calibration Plot - October



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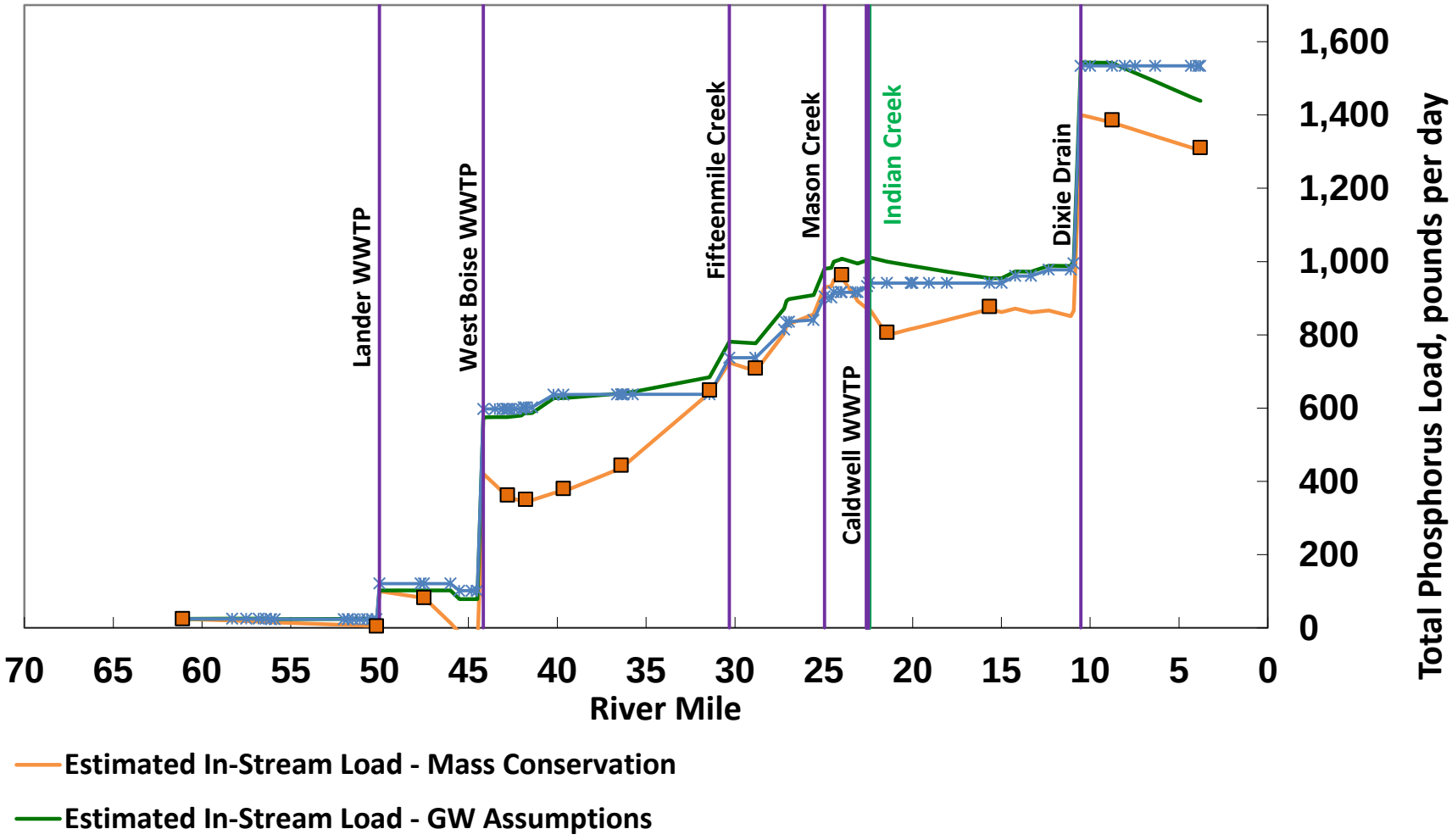
TP Load Calibration Plot - October



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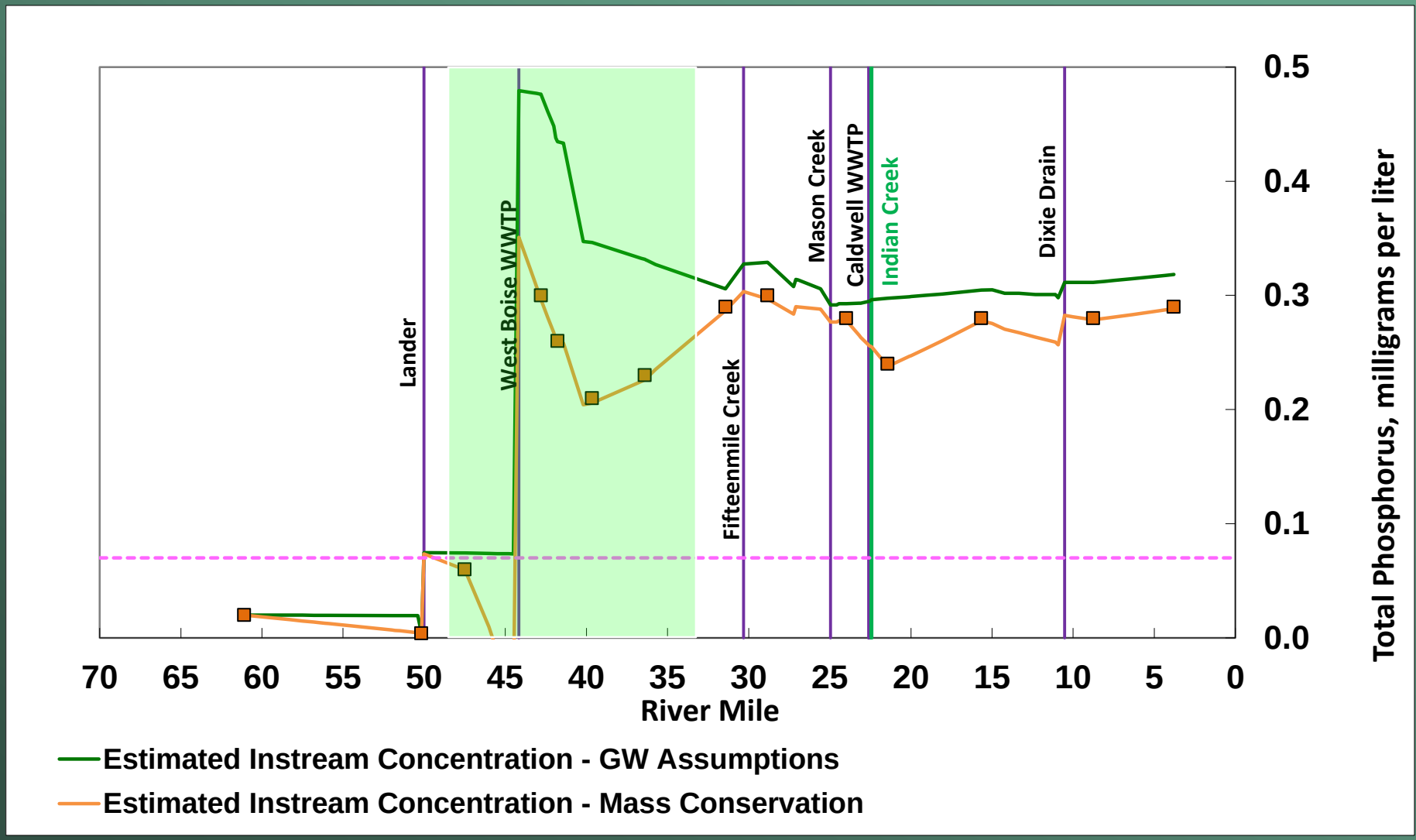
TP Concentration Calibration Plot - Oct



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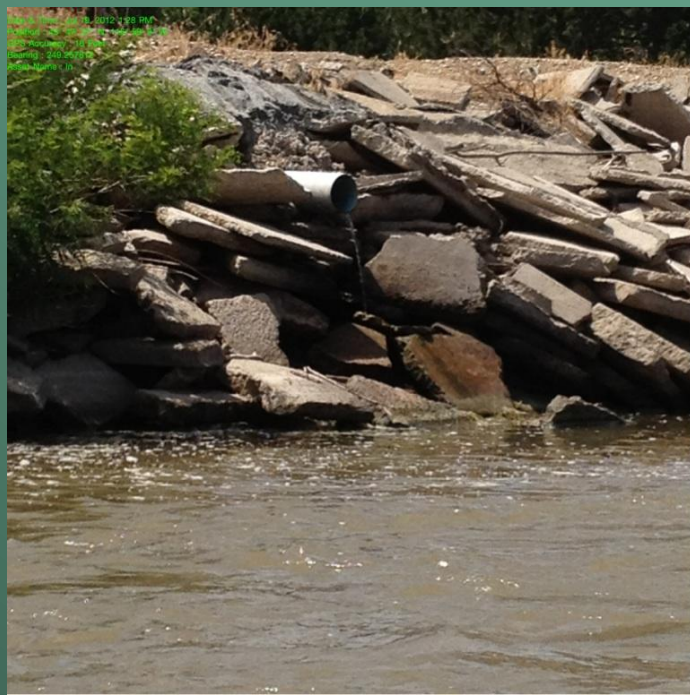
Modeling Scenarios

1. Reduce Point Sources
2. Reduce Nonpoint Sources
3. Reduce Point & Nonpoint Sources



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Scenario 1 – Reduce Point Sources

- All WWTPs = 0.10 mg/L
  - Lander, West Boise, Middleton, Caldwell
- Indian, 15mile, Dixie = 0.10 mg/L
- GW = back-calc TP
- No account for ΔTP in diversions

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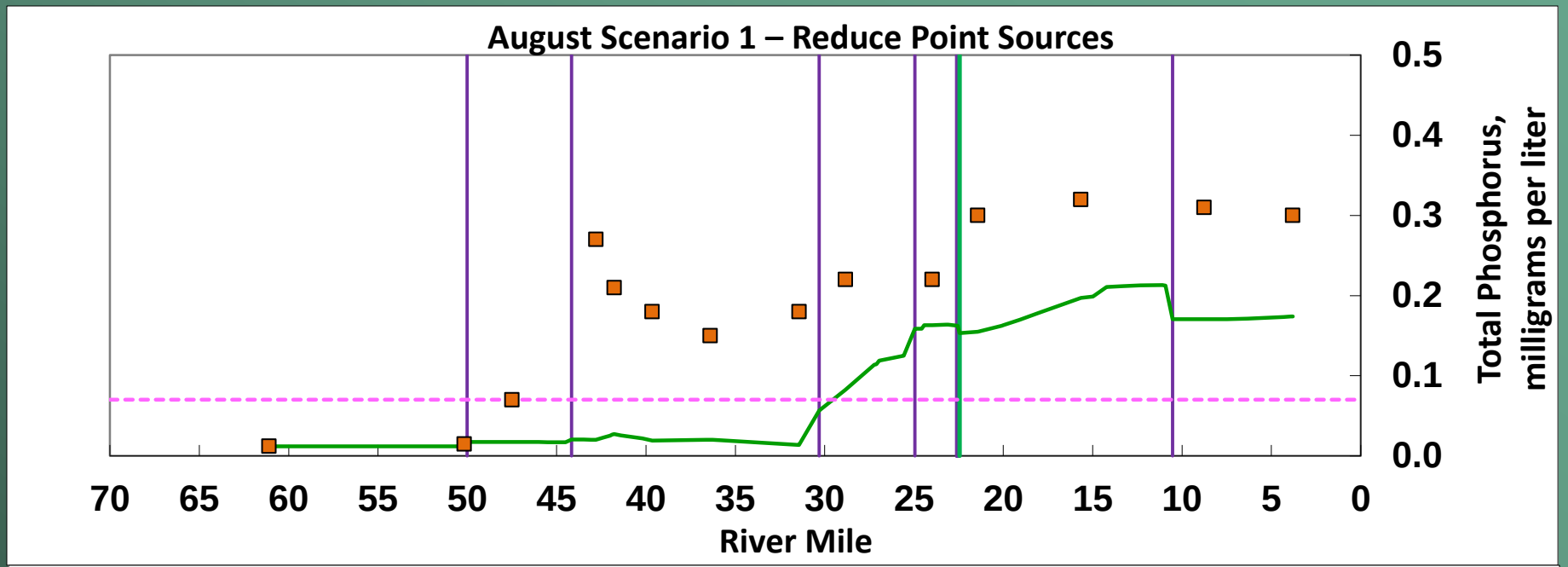

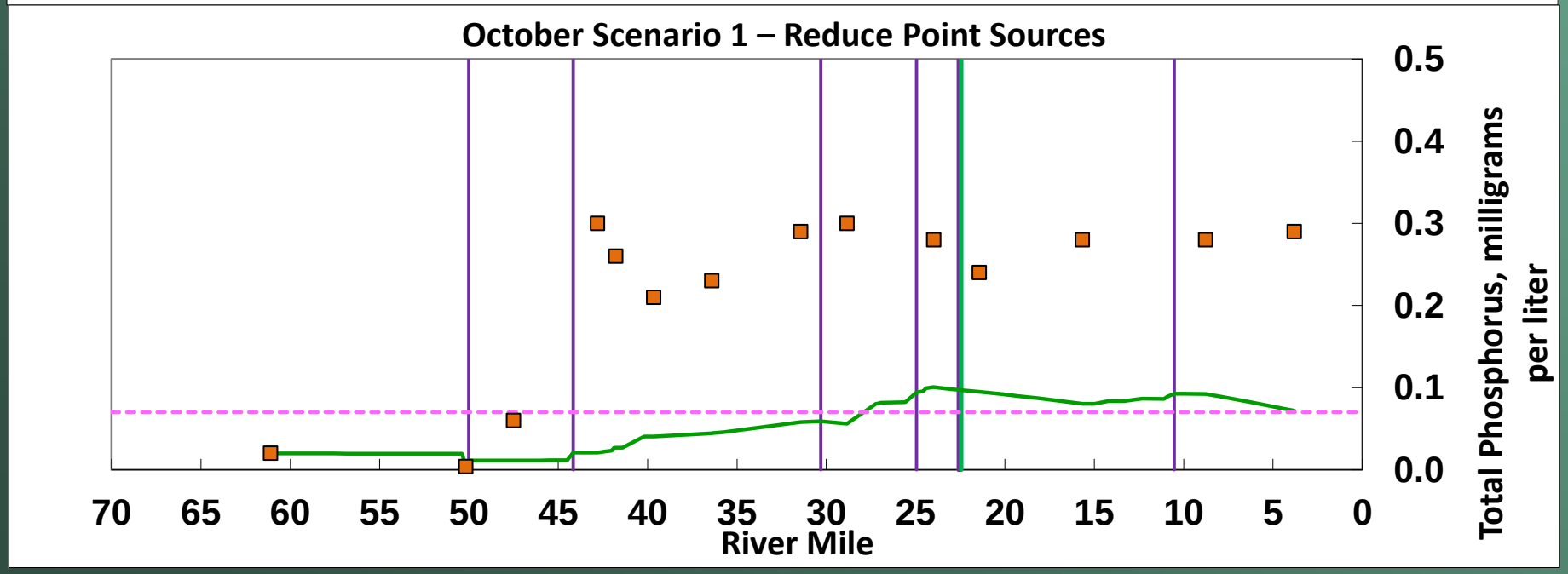

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Results: Reduce Point Sources

August

- 0.17 mg/L at mouth
  - 43% load reduction
- Riverside = 0.16 mg/L
- Nyssa = 0.07 mg/L

October

- 0.07 mg/L at mouth
  - 76% load reduction
- Riverside = 0.10 mg/L
- Nyssa = 0.04 mg/L

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Scenario 2– Reduce Nonpoint Sources

- Major tribs = 0.10 mg/L
  - Mason Crk & Slough, Hartley, Conway, Willow, Mill, 2 Unnamed drains, Dixie
- GW = 0.10 mg/L
- Indian & 15mile unchanged

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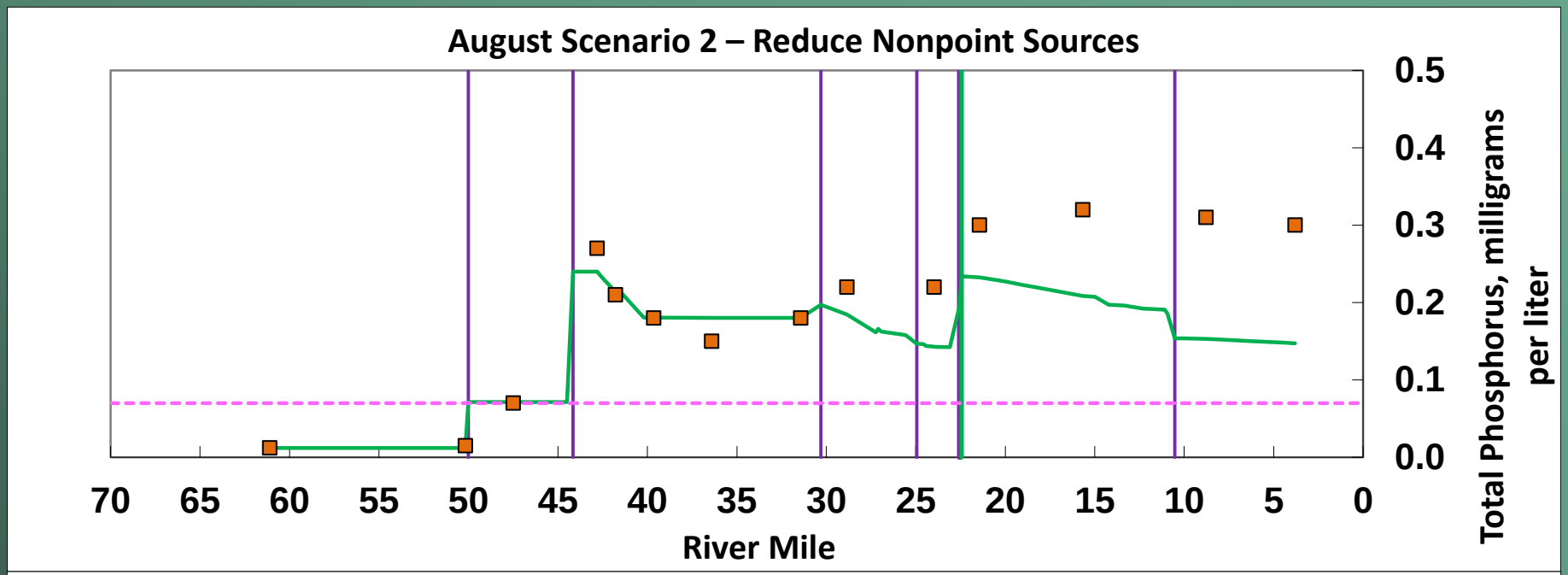

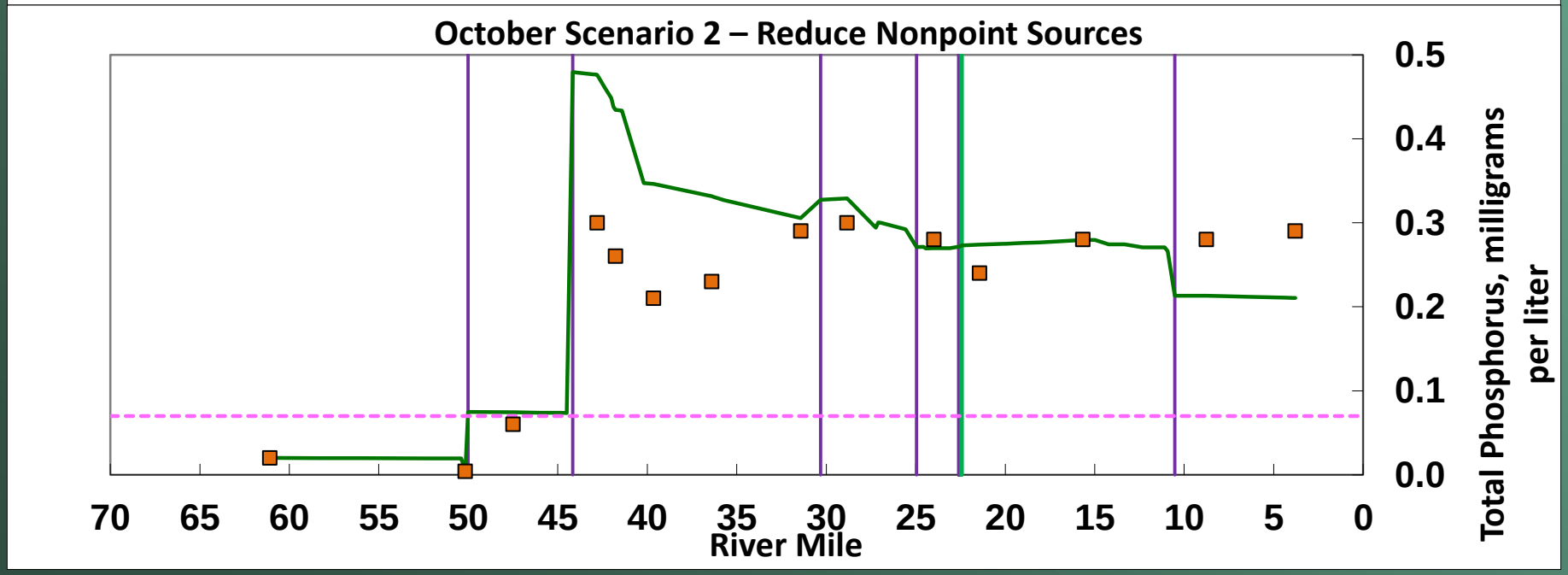

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Results: Reduce Nonpoint Sources

August

- 0.15 mg/L at mouth
  - 50% load reduction
- Riverside = 0.15 mg/L
- Nyssa = 0.07 mg/L

October

- 0.21 mg/L at mouth
  - 28% load reduction
- Riverside = 0.26 mg/L
- Nyssa = 0.05 mg/L

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Scenario 3 – Reduce Point & Nonpoint Sources

- All WWTPs = 0.10 mg/L
  - Lander, West Boise, Middleton, Caldwell
- All major tribs = 0.10 mg/L
  - Mason Crk & Slough, Hartley, Conway, 15mile, Willow, Mill, 2 Unnamed drains
- Indian Q = 0, Dixie = 0.07 mg/L
- GW = 0.10 mg/L

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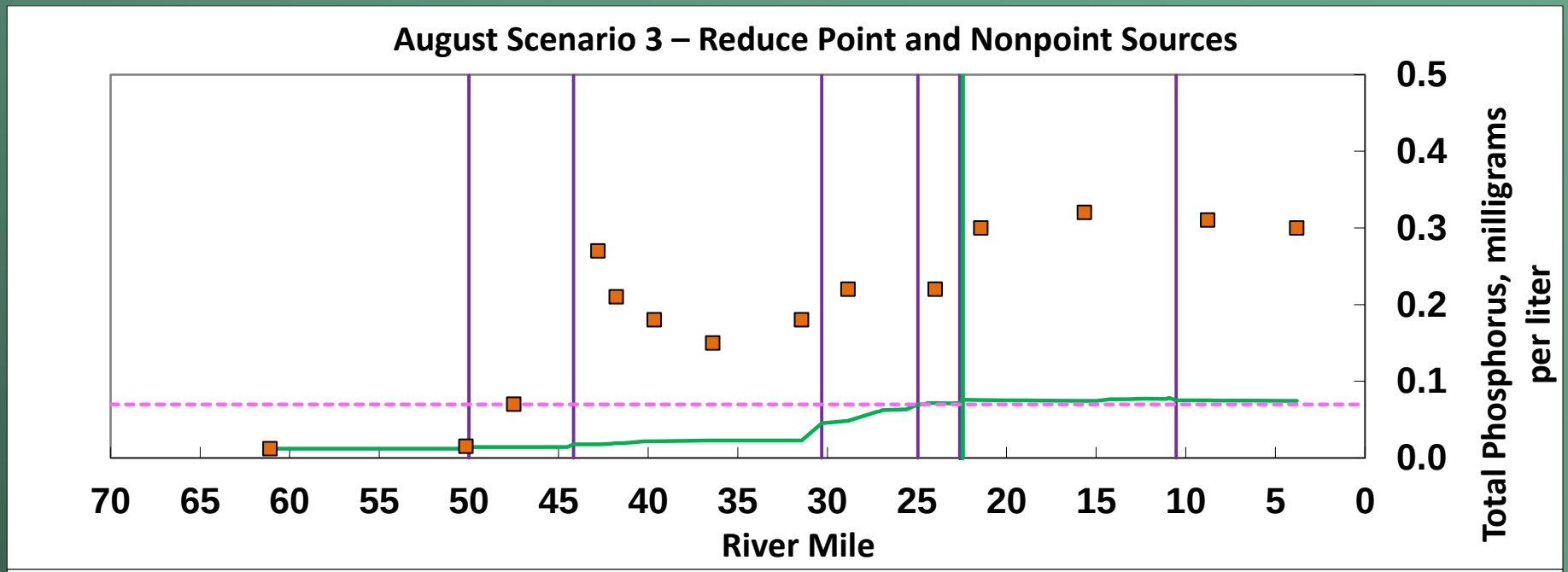

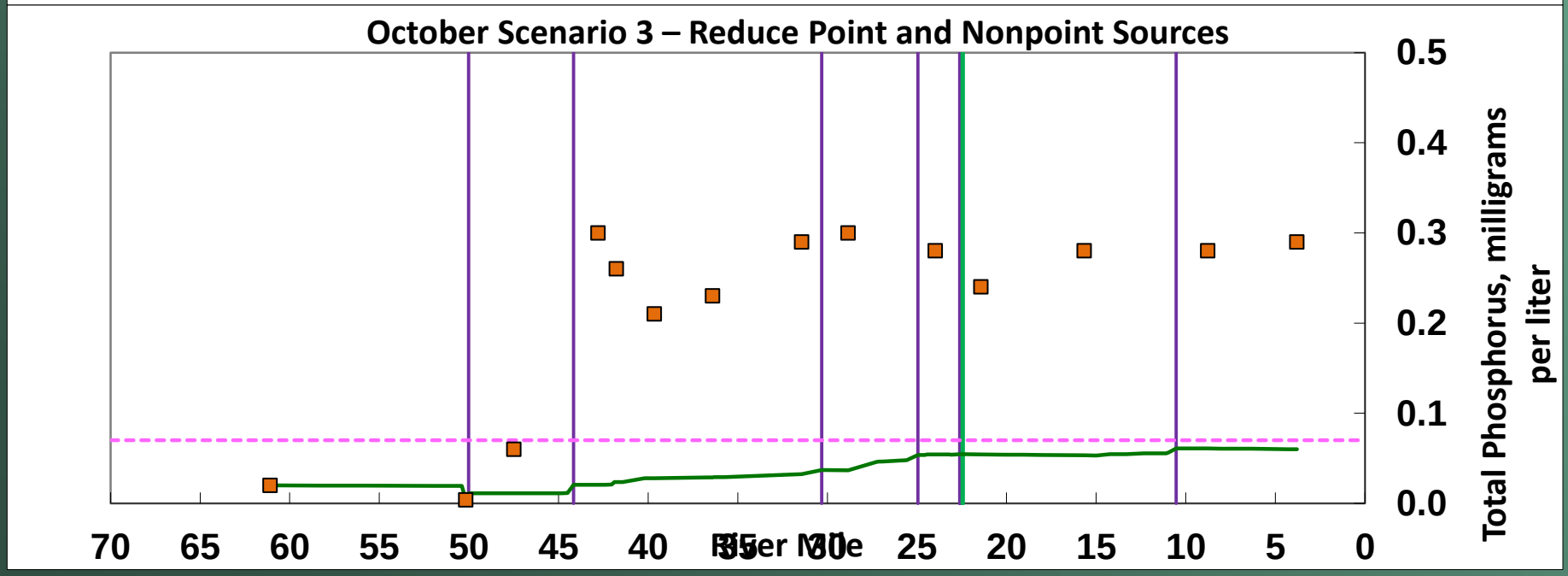

Provisional – Subject to Peer Review

Results: Reduce Point & Nonpoint Sources

August

- 0.07 mg/L at mouth
  - 76% load reduction
- Riverside = 0.07 mg/L
- Nyssa = 0.06 mg/L

October

- 0.06 mg/L at mouth
  - 79% load reduction
- Riverside = 0.05 mg/L
- Nyssa = 0.03 mg/L

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Modeling Results Summary

- Both models – useful to evaluate BMP scenarios during specific season
- Both point and non-point sources impact TP in August
- Point sources more significant in late October
- More unexplained loss of mass in October

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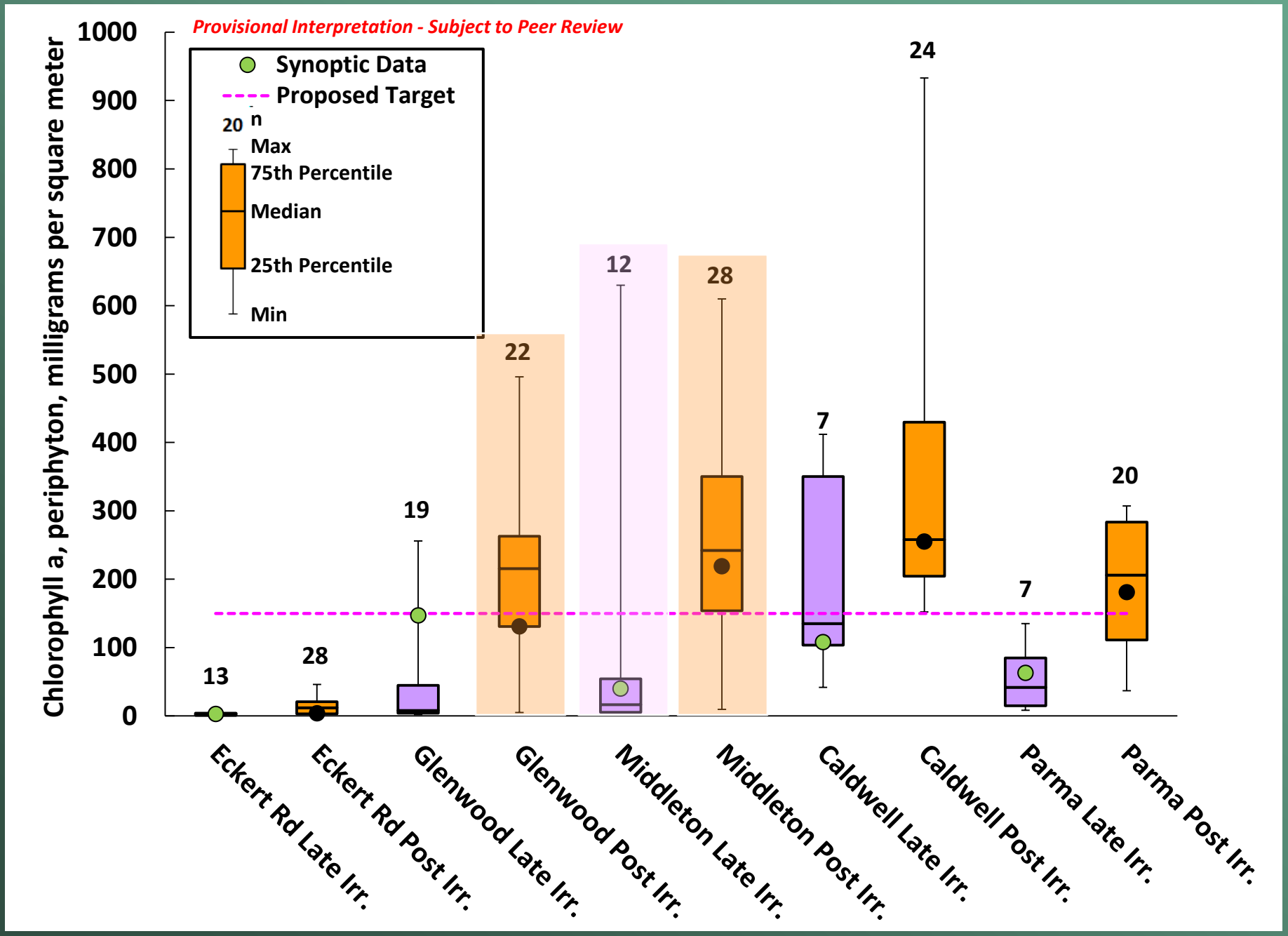
What about Periphyton?


Provisional Interpretation - Subject to Peer Review
Synoptic Data
Proposed Target
n
Max
75th Percentile
Median
25th Percentile
Min
Chlorophyll a, periphyton, milligrams per square meter
1000
900
800
700
600
500
400
300
200
100
0
13
28
19
22
12
28
7
24
7
20
Eckert Rd Late Irr.
Eckert Rd Post Irr.
Glenwood Late Irr.
Glenwood Post Irr.
Middleton Late Irr.
Middleton Post Irr.
Caldwell Late Irr.
Caldwell Post Irr.
Parma Late Irr.
Parma Post Irr.

Considerations

- BMP implementation & WQ changes
  - Nitrogen
  - Suspended sediment
  - Uptake – P vs Periphyton
  - DO implications

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Questions?