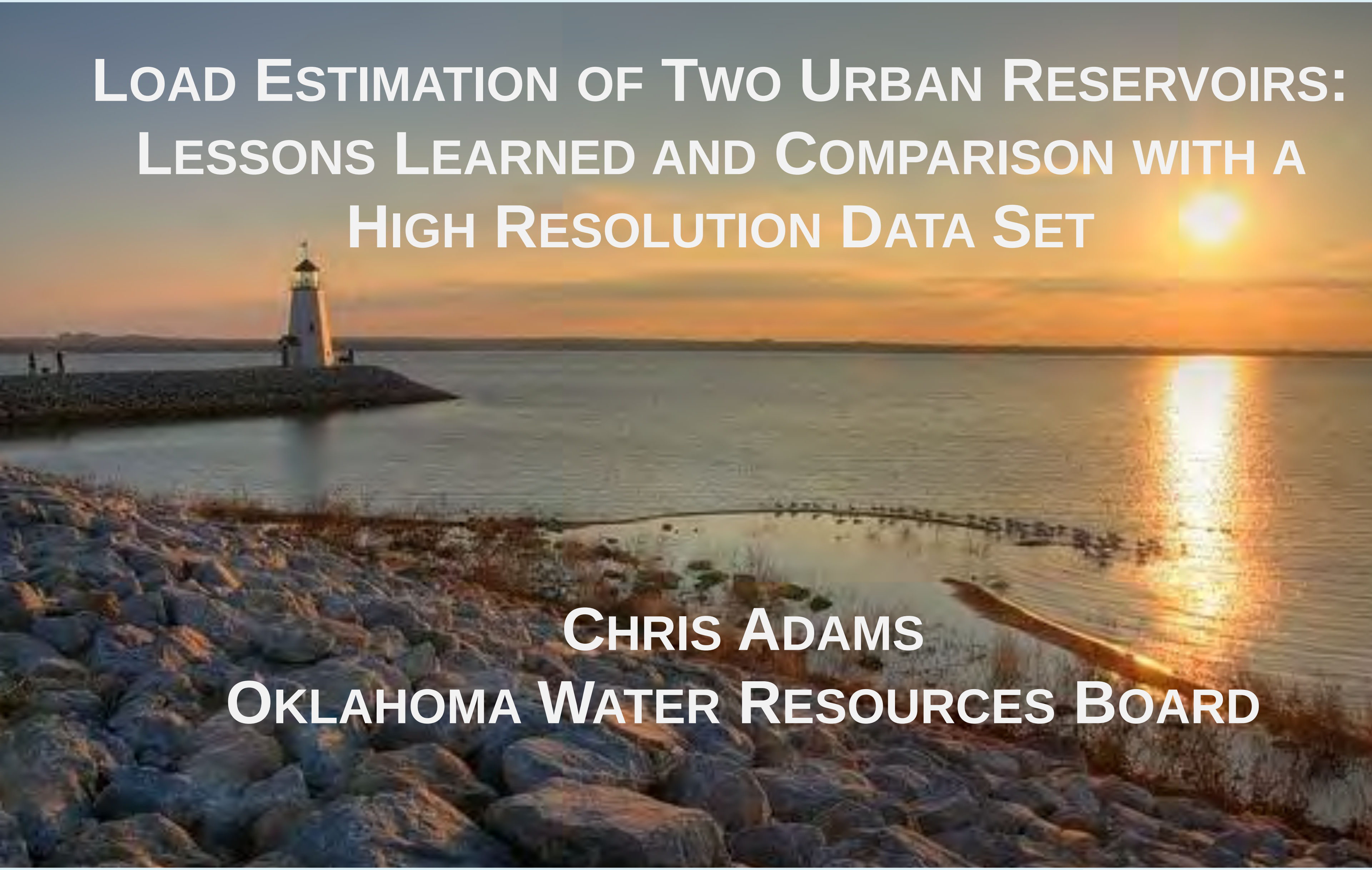


Load Estimation of Two Urban Reservoirs: Lessons Learned and Comparison with a High Resolution Data Set

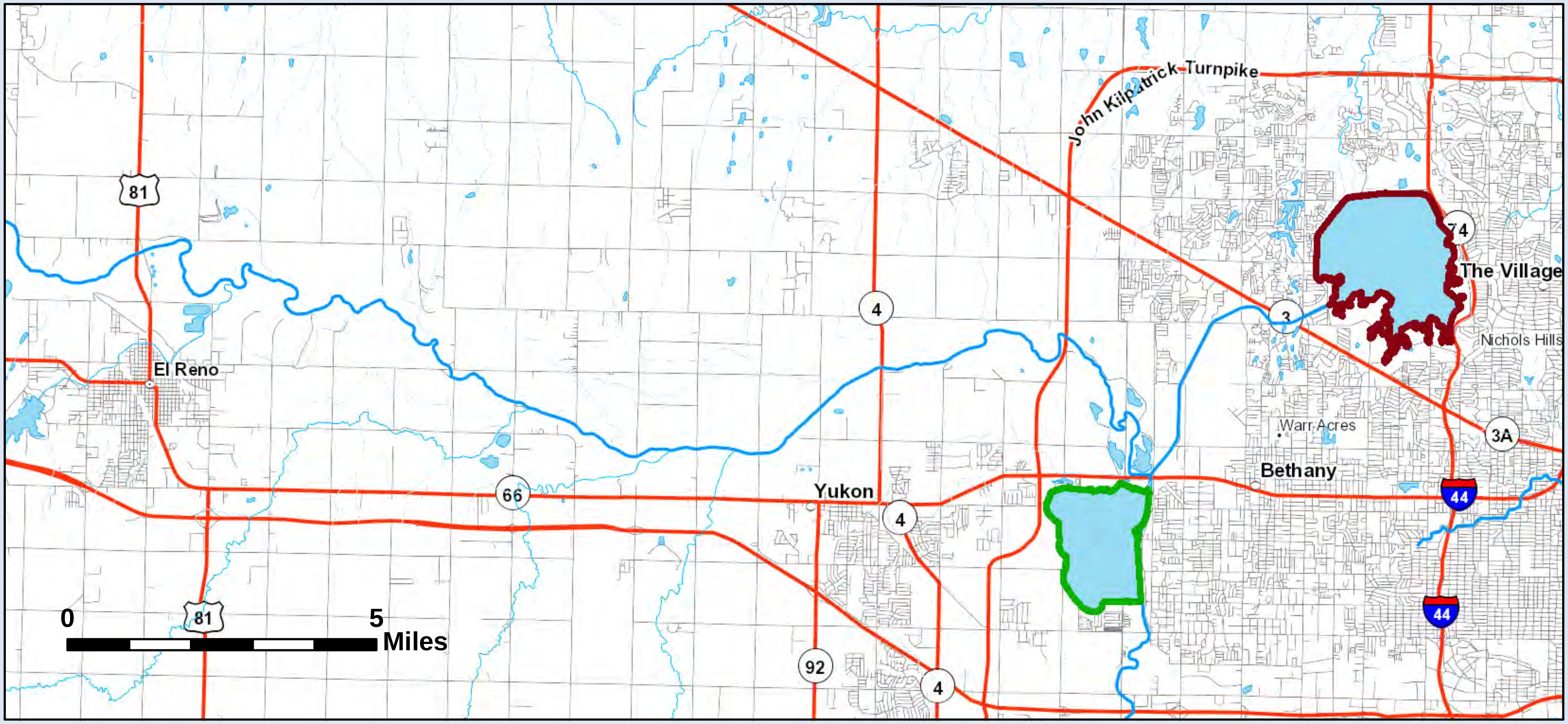
Chris Adams
Oklahoma Water Resources Board

CHRIS.ADAMS@OWRB.OK.GOV

State of Oklahoma
OWRB
WATER RESOURCES BOARD
the water agency

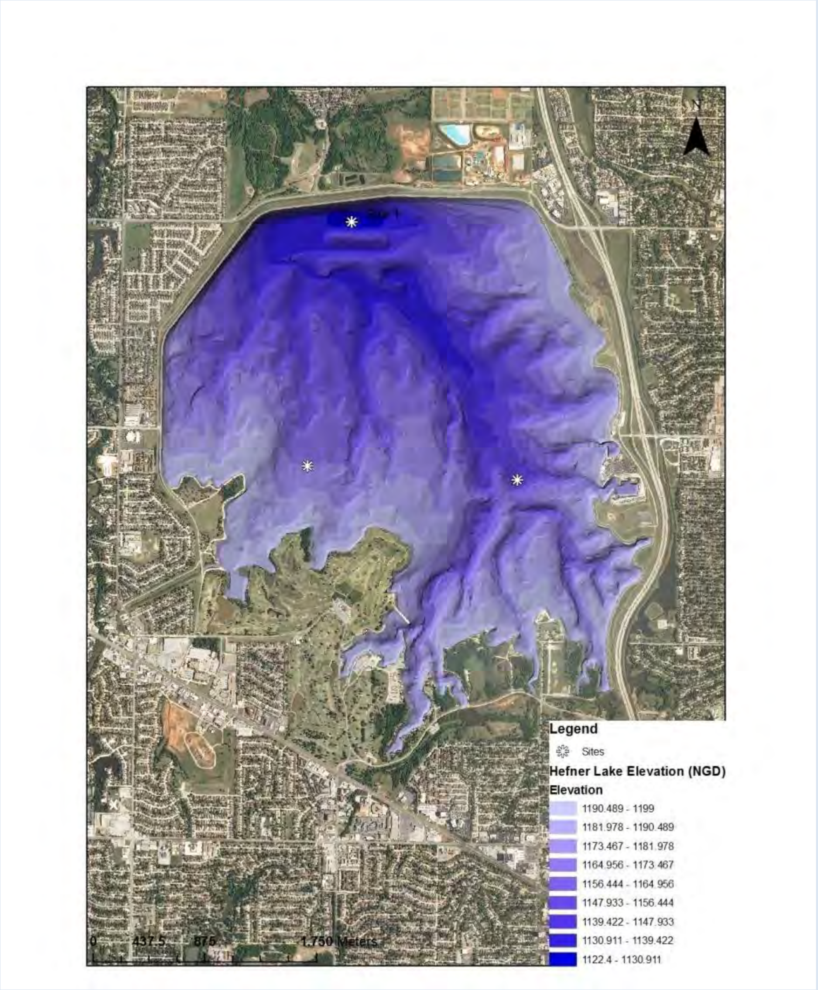
Overview

- Two OKC Urban Reservoirs
- External Load Estimates
- Internal Load Estimates
- Lake Modeling (BATHTUB)
- Feasibility of in-lake BMPs
- Continued Issues
- Comparison to a high resolution data set


John Kilpatrick Turnpike
81
4
74
The Village
3
Nichols Hills
El Reno
Warr Acres
3A
Bethany
Yukon
66
4
44
44
0
81
5
Miles
92
4

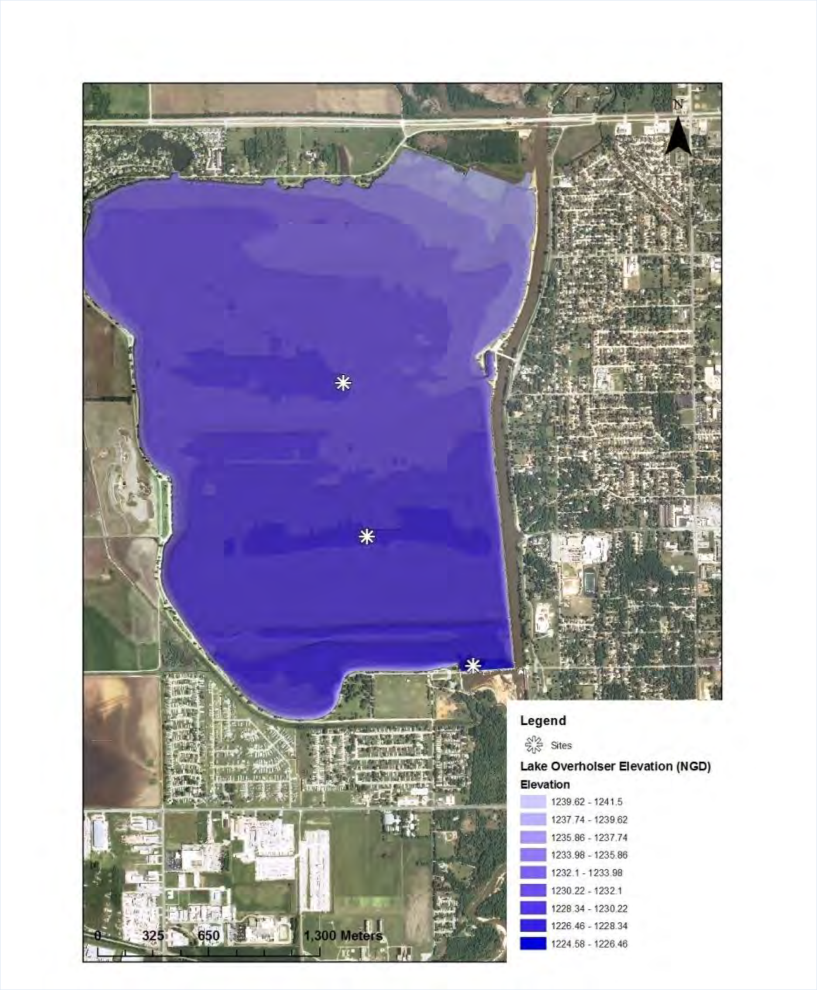
Lake Hefner

- Major Drinking Water Supply for OKC
- Terminal Urban Reservoir
- Surface Area = 10.11 km^2
- Mean Depth = 8.84 m
- Impaired for DO
- High TSI (Chl-a)



Lake Overholser

- Supplemental Drinking Water Supply for OKC
- Offset Urban Reservoir
- Surface Area = 6.44 km^2
- Mean Depth = 2.70 m
- Nutrient Limited Watershed
- Impaired for Turbidly

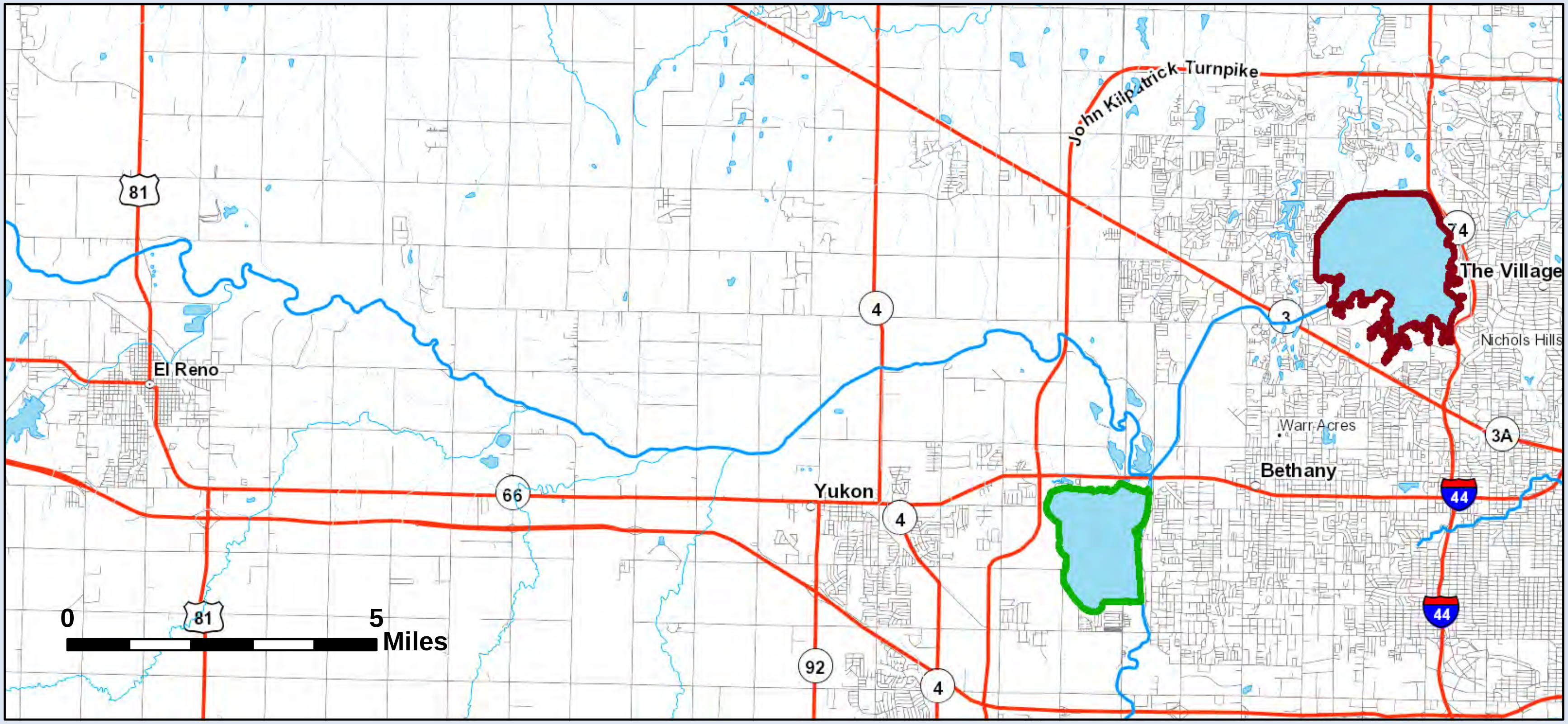


Initial Hypothesis

- Low to medium external P loading to both lakes
- High internal P loading
  - Hefner: Anoxic P release
  - Overholser: Wind induced sediment resuspension leading to P release

BATHTUB Model

- Simulates water quality conditions in lakes
- Works with limited inputs
  - Nutrient loads
  - Simple bathymetry (area, mean depth)
  - Water balance
- Choose from a selection of relationships
  - Mainly based on data from northern reservoirs/lakes
- Steady State Model– issues with changing nutrient limitations



John Kilpatrick Turnpike
81
74
The Village
4
3
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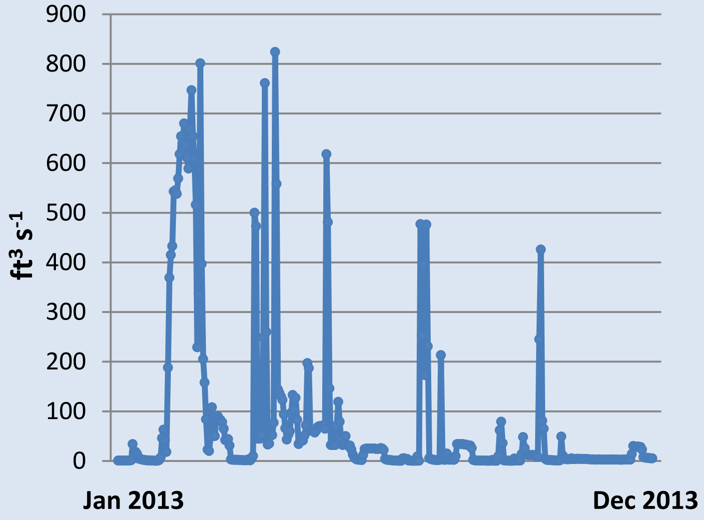
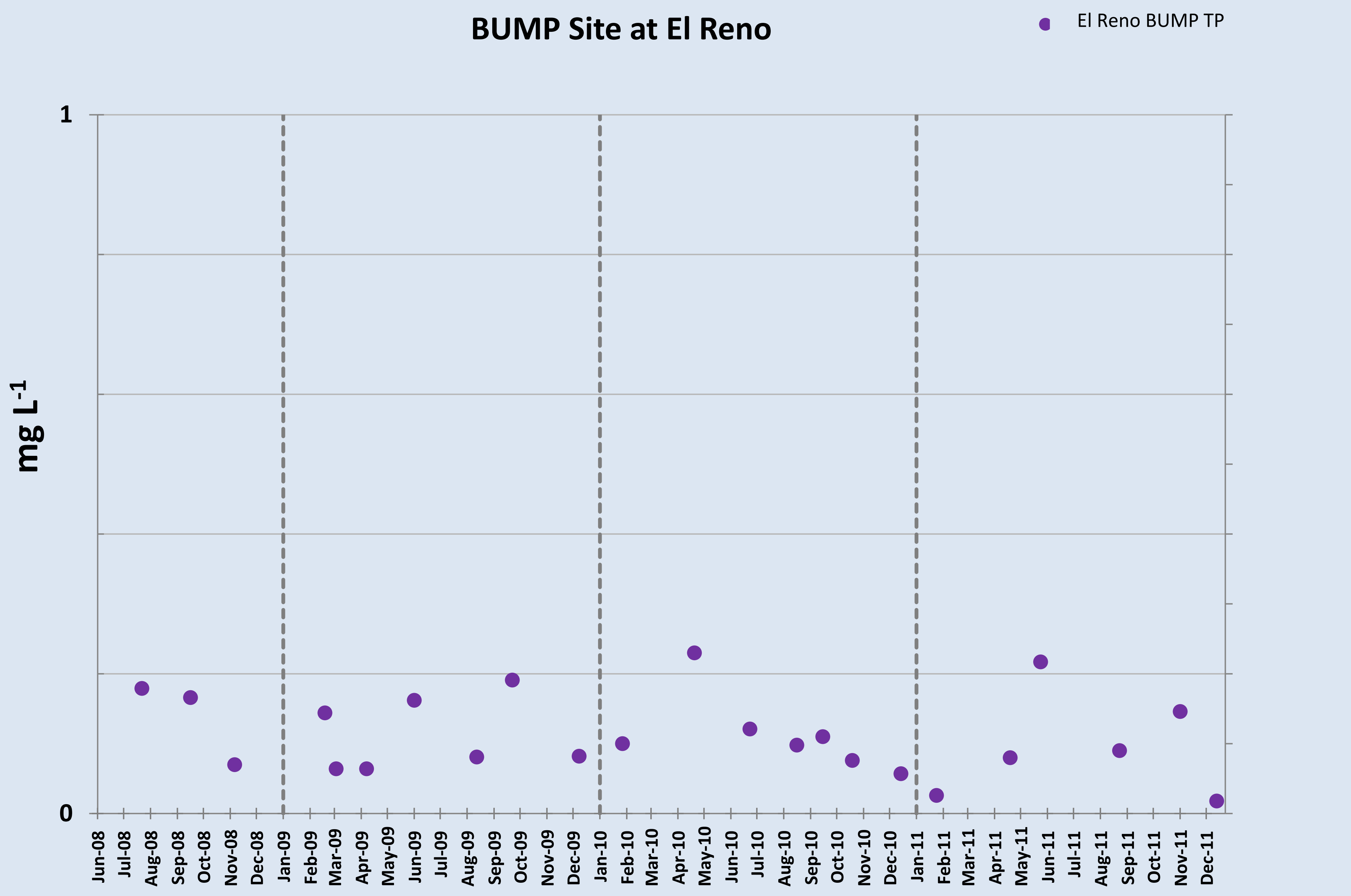
El Reno
Warr Acres
3A
Bethany
Yukon
66
4
44
44
0
81
5
Miles
92
4

External Load

- Available input data
  - Bluff Creek
    - Monitored in 2013
    - Had to use other data
  - BUMP data from El Reno
    - Designed to monitor WQ to maintain Beneficial Uses
    - 15 years
    - 8-12 samples per year
  - OCC North Canadian data
    - Designed to monitor changes in nutrient loads in response to catchment management BMPs
    - Canton Lake, El Reno, Yukon
    - 3-5 years
    - Weekly data
  - Atmospheric deposition
    - Little inland P data
    - may or may not be a major source
    - timing may be important




BUMP Site at El Reno
El Reno BUMP TP
mg L-1
1
0
Jun-08
Jul-08
Aug-08
Sep-08
Oct-08
Nov-08
Dec-08
Jan-09
Feb-09
Mar-09
Apr-09
May-09
Jun-09
Jul-09
Aug-09
Sep-09
Oct-09
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Feb-10
Mar-10
Apr-10
May-10
Jun-10
Jul-10
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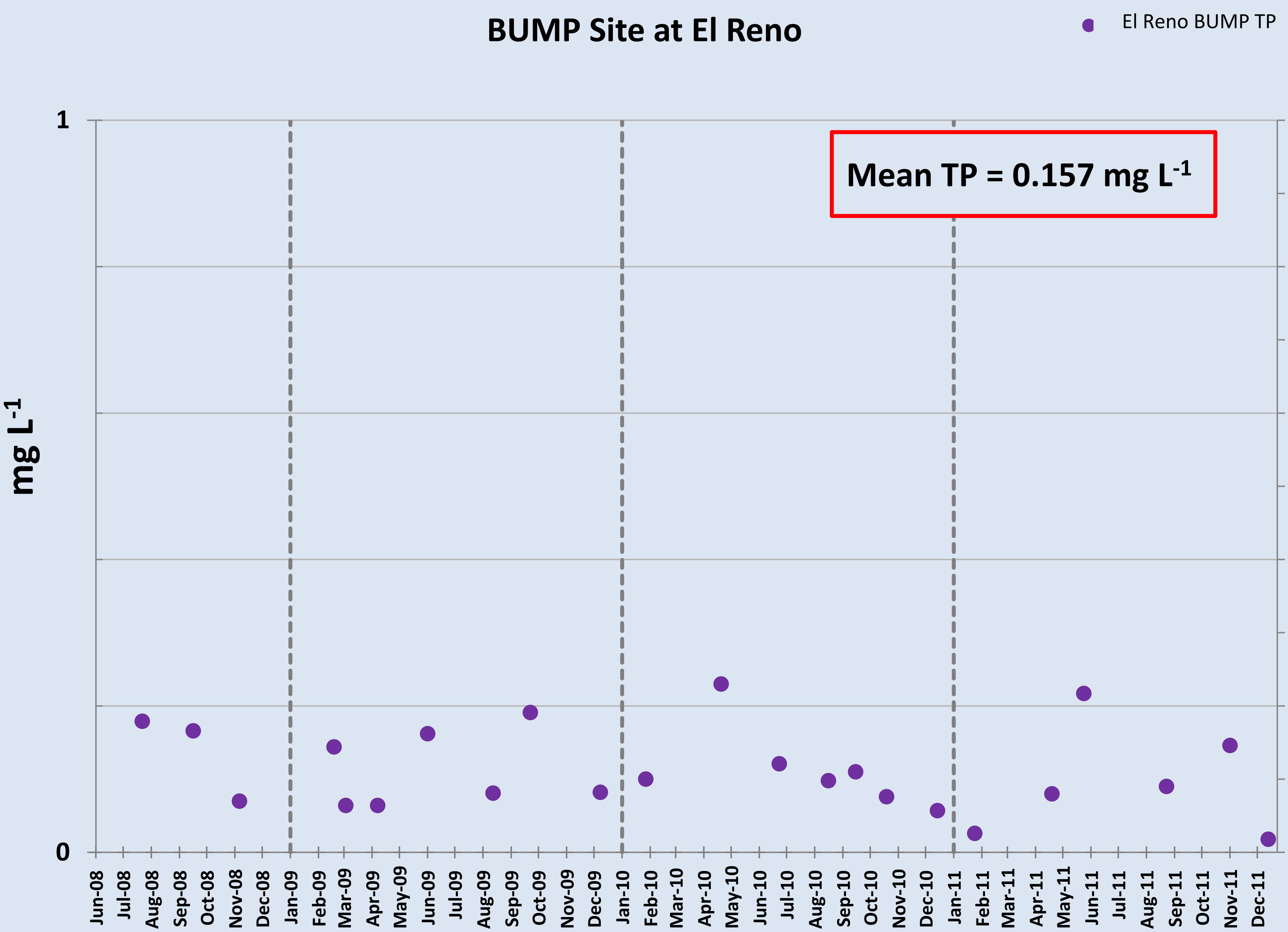

BUMP Site at El Reno
El Reno BUMP TP
Mean TP = 0.157 mg L-1
mg L-1
1
0
Jun-08
Jul-08
Aug-08
Sep-08
Oct-08
Nov-08
Dec-08
Jan-09
Feb-09
Mar-09
Apr-09
May-09
Jun-09
Jul-09
Aug-09
Sep-09
Oct-09
Nov-09
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Jan-10
Feb-10
Mar-10
Apr-10
May-10
Jun-10
Jul-10
Aug-10
Sep-10
Oct-10
Nov-10
Dec-10
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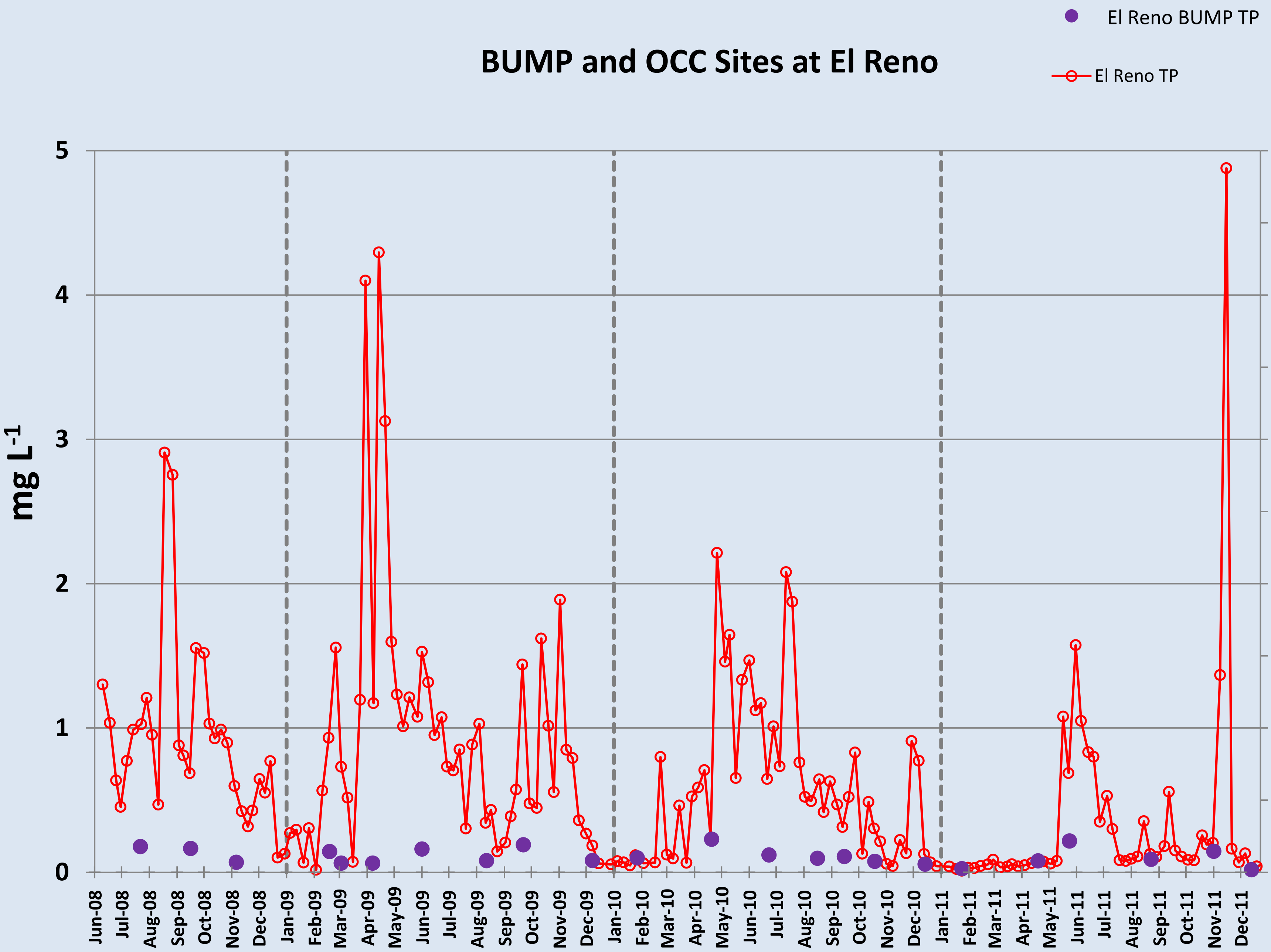
Oct-11
Nov-11
Dec-11


BUMP and OCC Sites at El Reno
El Reno BUMP TP
El Reno TP
mg L^{-1}
0
1
2
3
4
5
Jun-08
Jul-08
Aug-08
Sep-08
Oct-08
Nov-08
Dec-08
Jan-09
Feb-09
Mar-09
Apr-09
May-09
Jun-09
Jul-09
Aug-09
Sep-09
Oct-09
Nov-09
Dec-09
Jan-10
Feb-10
Mar-10
Apr-10
May-10
Jun-10
Jul-10
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Sep-10
Oct-10
Nov-10
Dec-10
Jan-11
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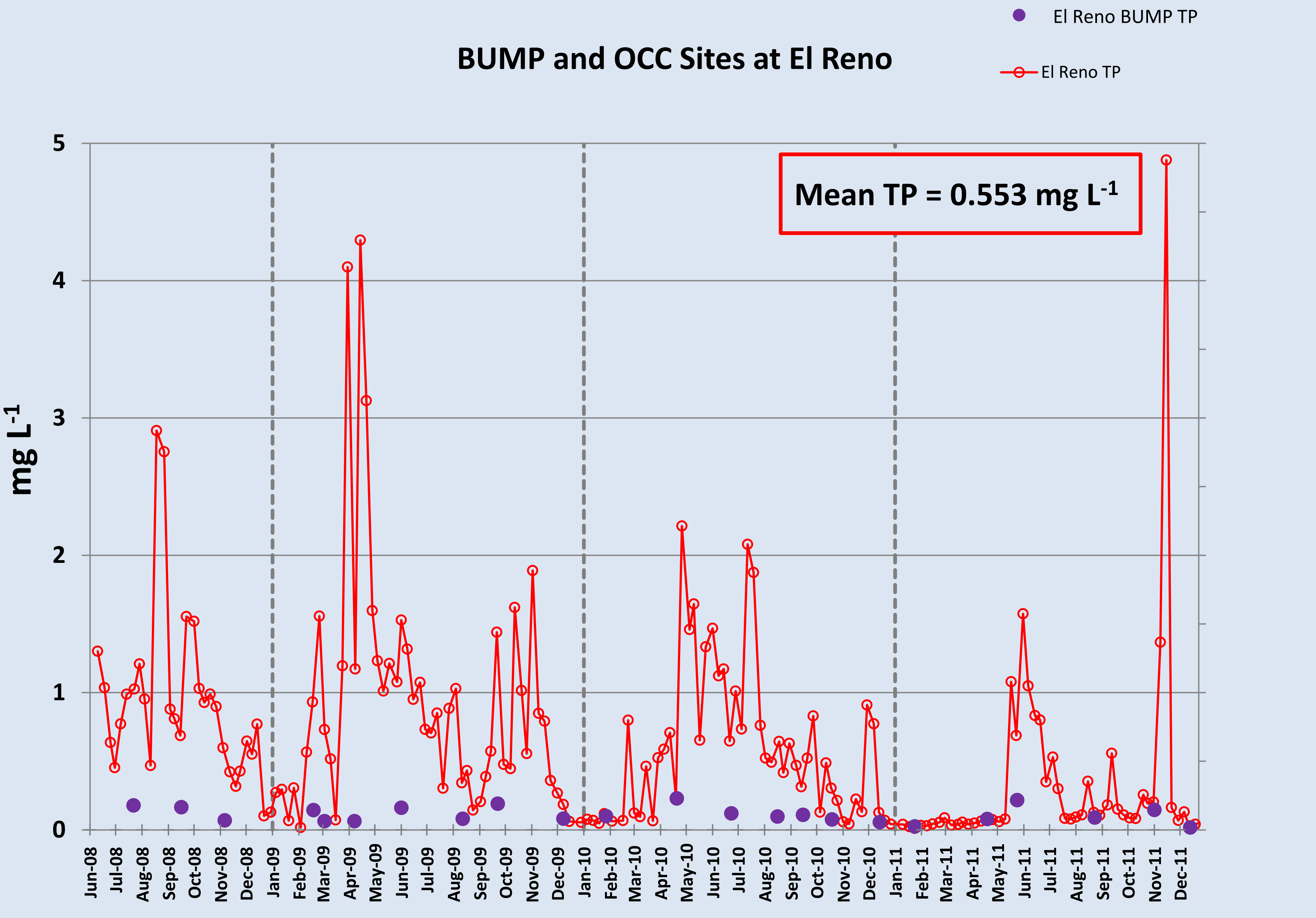
Oct-11
Nov-11
Dec-11



BUMP and OCC Sites at El Reno
El Reno BUMP TP
El Reno TP
Mean TP = 0.553 mg L-1
mg L-1
0
1
2
3
4
5
Jun-08
Jul-08
Aug-08
Sep-08
Oct-08
Nov-08
Dec-08
Jan-09
Feb-09
Mar-09
Apr-09
May-09
Jun-09
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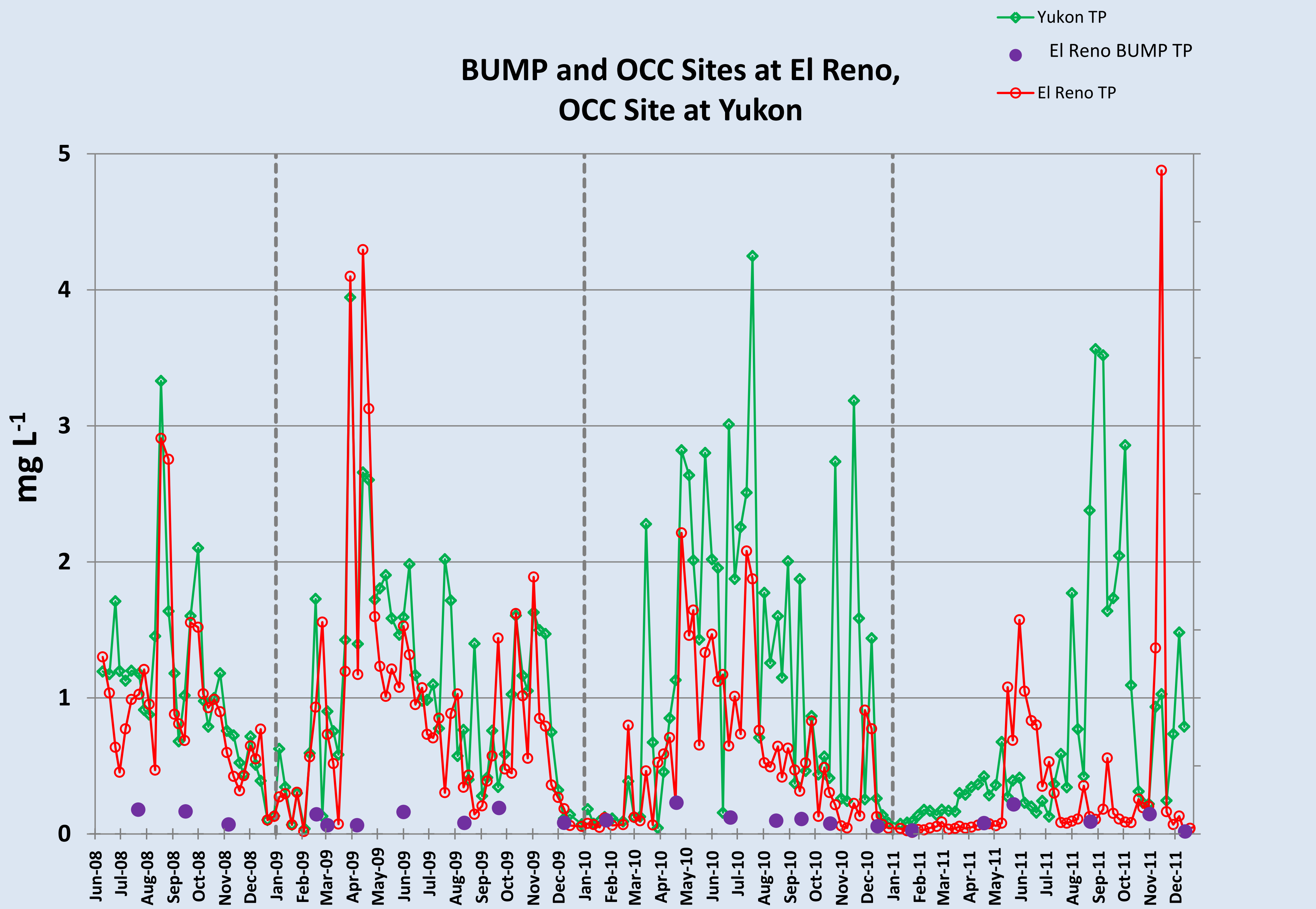

BUMP and OCC Sites at El Reno,
OCC Site at Yukon
Yukon TP
El Reno BUMP TP
El Reno TP
mg L-1
0
1
2
3
4
5
Jun-08
Jul-08
Aug-08
Sep-08
Oct-08
Nov-08
Dec-08
Jan-09
Feb-09
Mar-09
Apr-09
May-09
Jun-09
Jul-09
Aug-09
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Jul-10
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Oct-10
Nov-10
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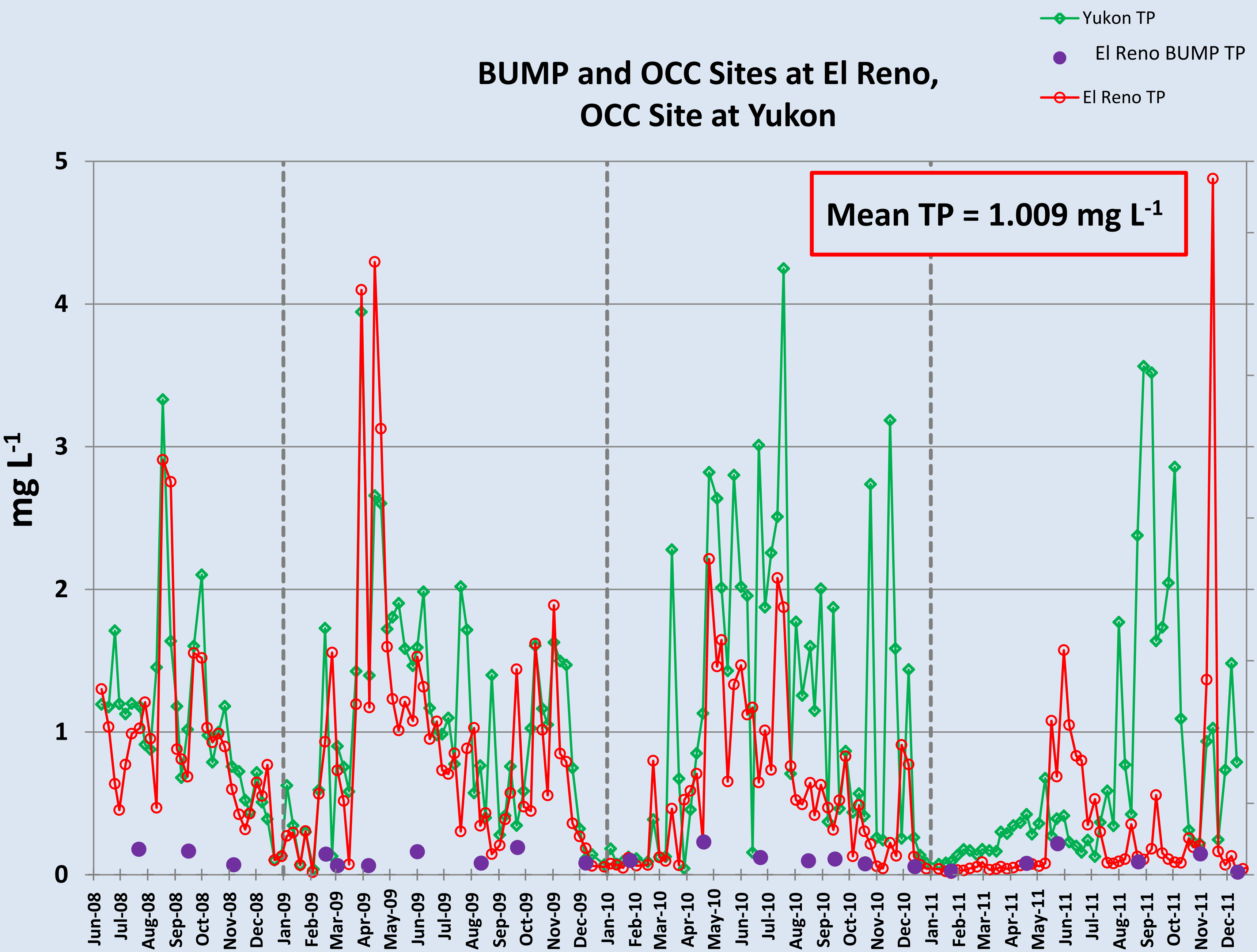
Oct-11
Nov-11
Dec-11


BUMP and OCC Sites at El Reno,
OCC Site at Yukon
Yukon TP
El Reno BUMP TP
El Reno TP
Mean TP = 1.009 mg L-1
mg L-1
0
1
2
3
4
5
Jun-08
Jul-08
Aug-08
Sep-08
Oct-08
Nov-08
Dec-08
Jan-09
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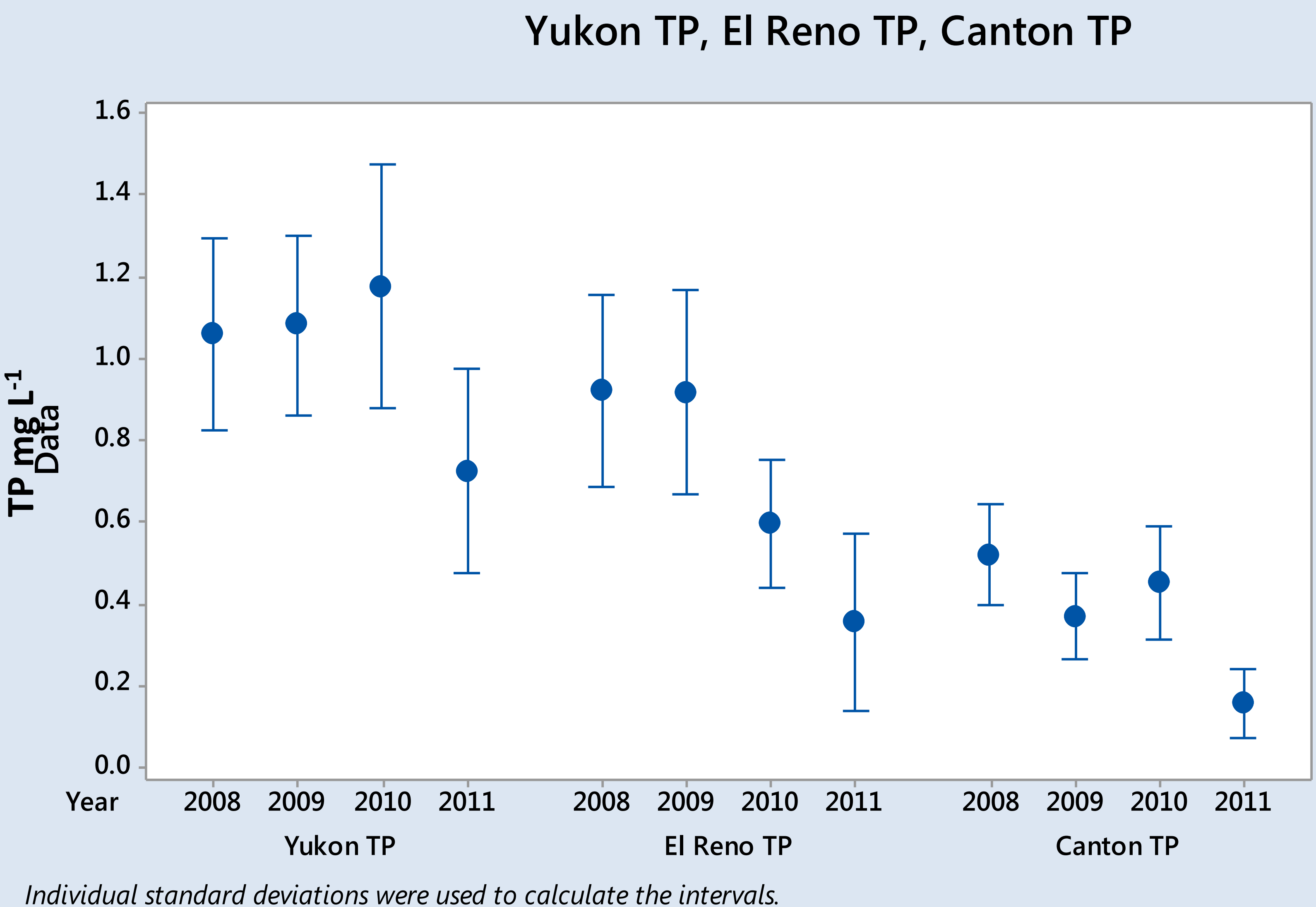
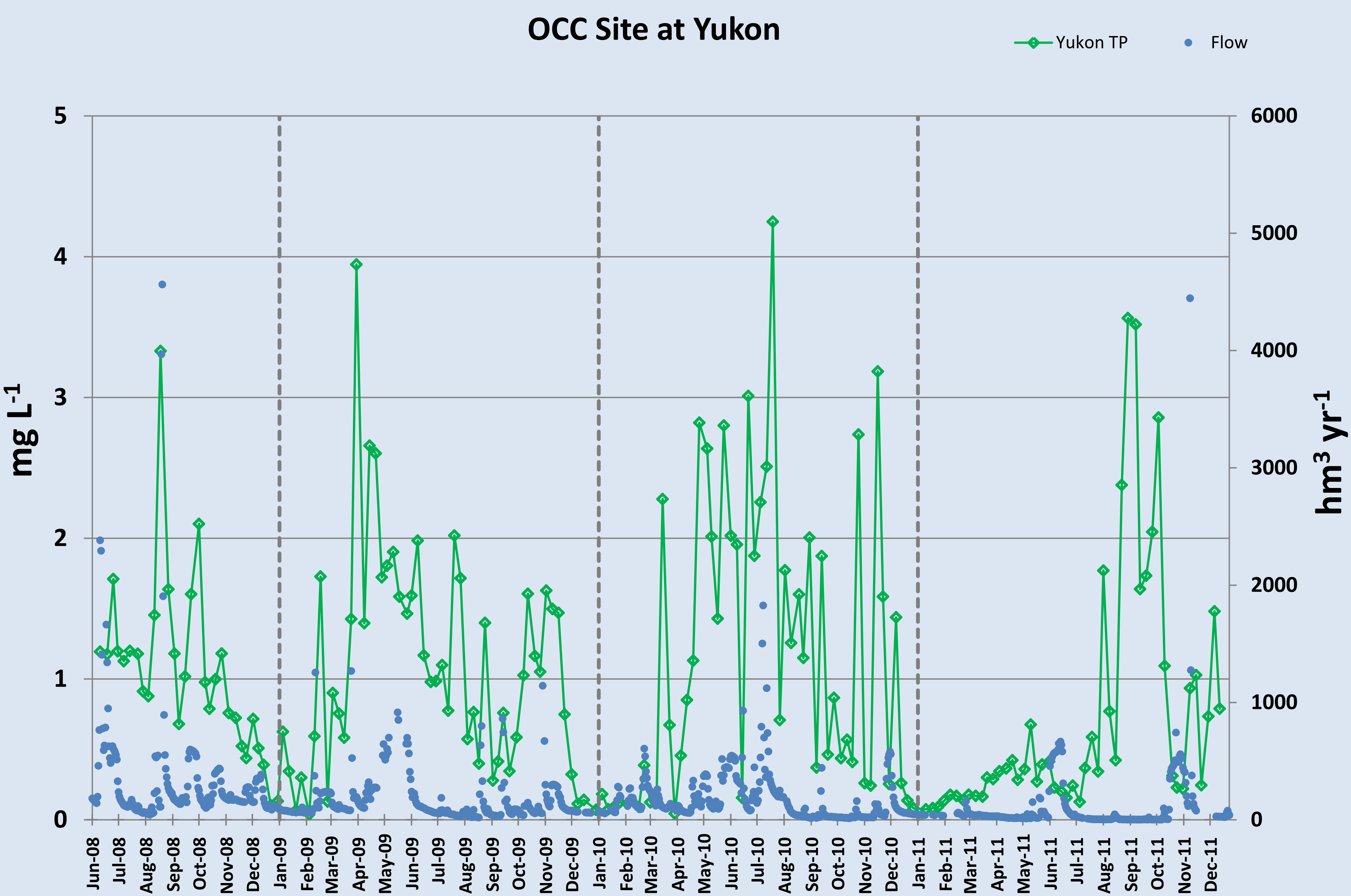
Oct-11
Nov-11
Dec-11


Yukon TP, El Reno TP, Canton TP
TP mg L-1
Data
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Year
2008
2009
2010
2011
2008
2009
2010
2011
2008
2009
2010
2011
Yukon TP
El Reno TP
Canton TP
Individual standard deviations were used to calculate the intervals.



OCC Site at Yukon
Yukon TP
Flow
mg L-1
hm3 yr-1
0
1
2
3
4
5
0
1000
2000
3000
4000
5000
6000
Jun-08
Jul-08
Aug-08
Sep-08
Oct-08
Nov-08
Dec-08
Jan-09
Feb-09
Mar-09
Apr-09
May-09
Jun-09
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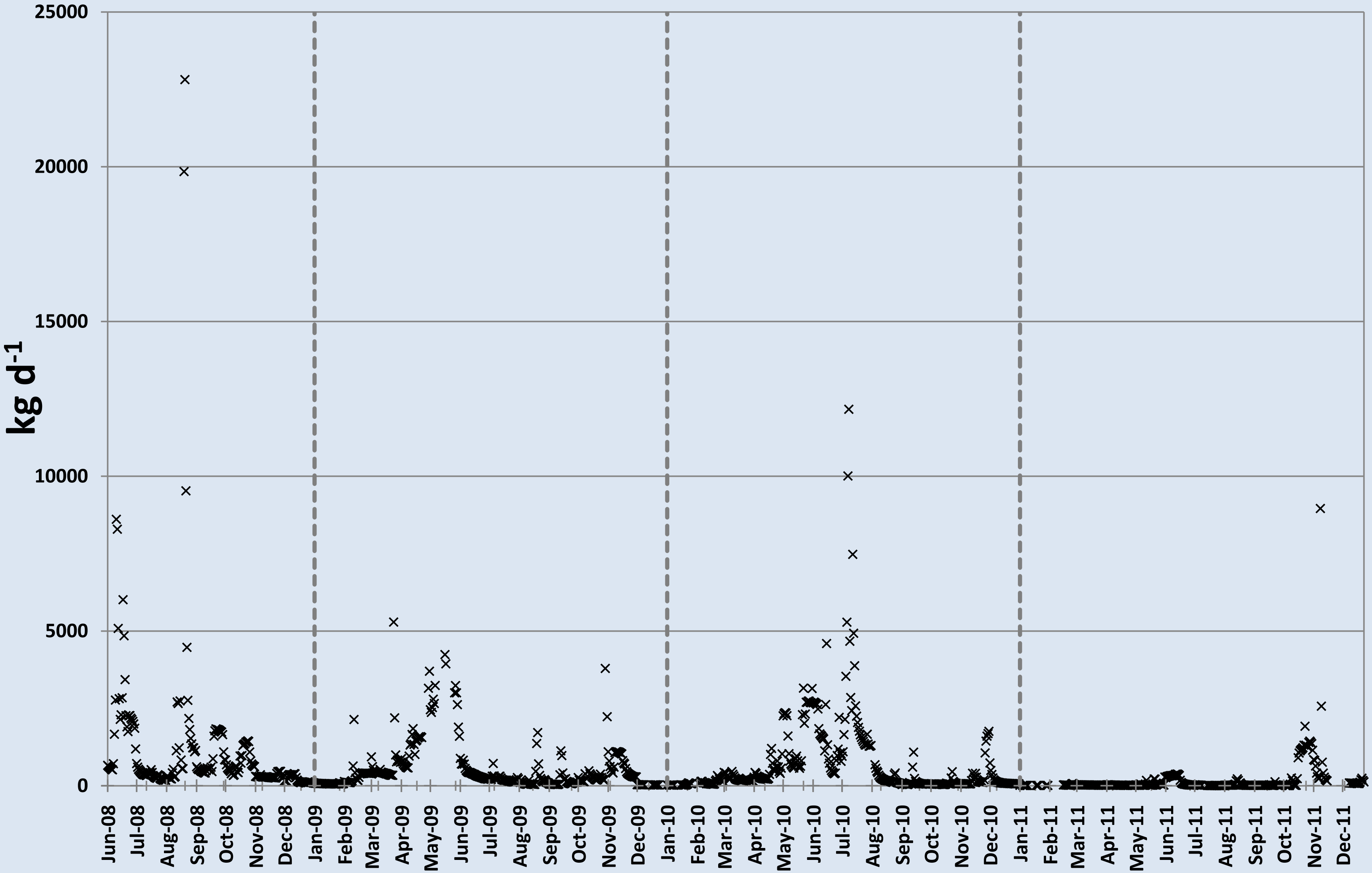
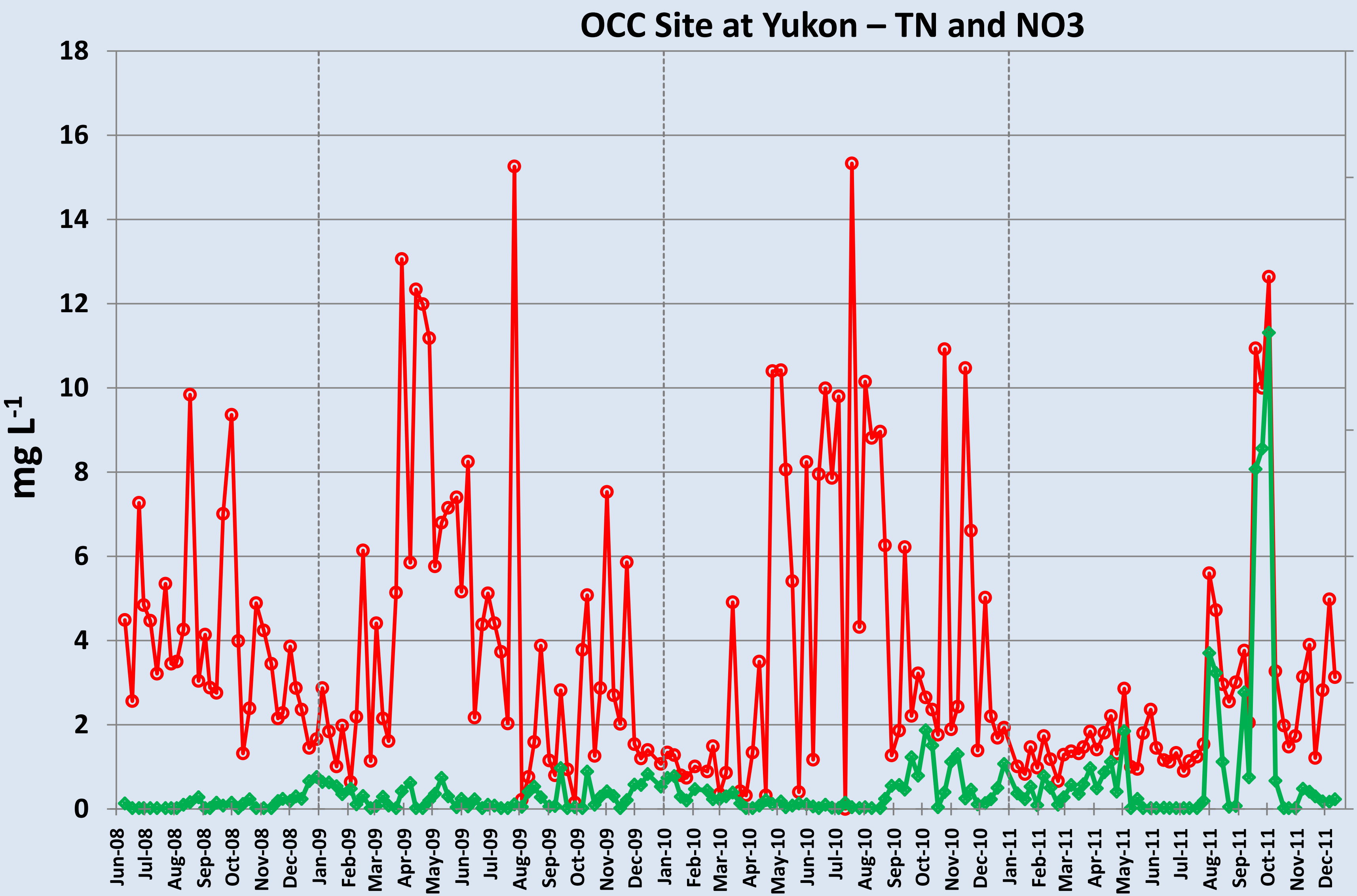
Nov-11
Dec-11

Yukon TP load




OCC Site at Yukon – TN and NO3
mg L-1
0
2
4
6
8
10
12
14
16
18
Jun-08
Jul-08
Aug-08
Sep-08
Oct-08
Nov-08
Dec-08
Jan-09
Feb-09
Mar-09
Apr-09
May-09
Jun-09
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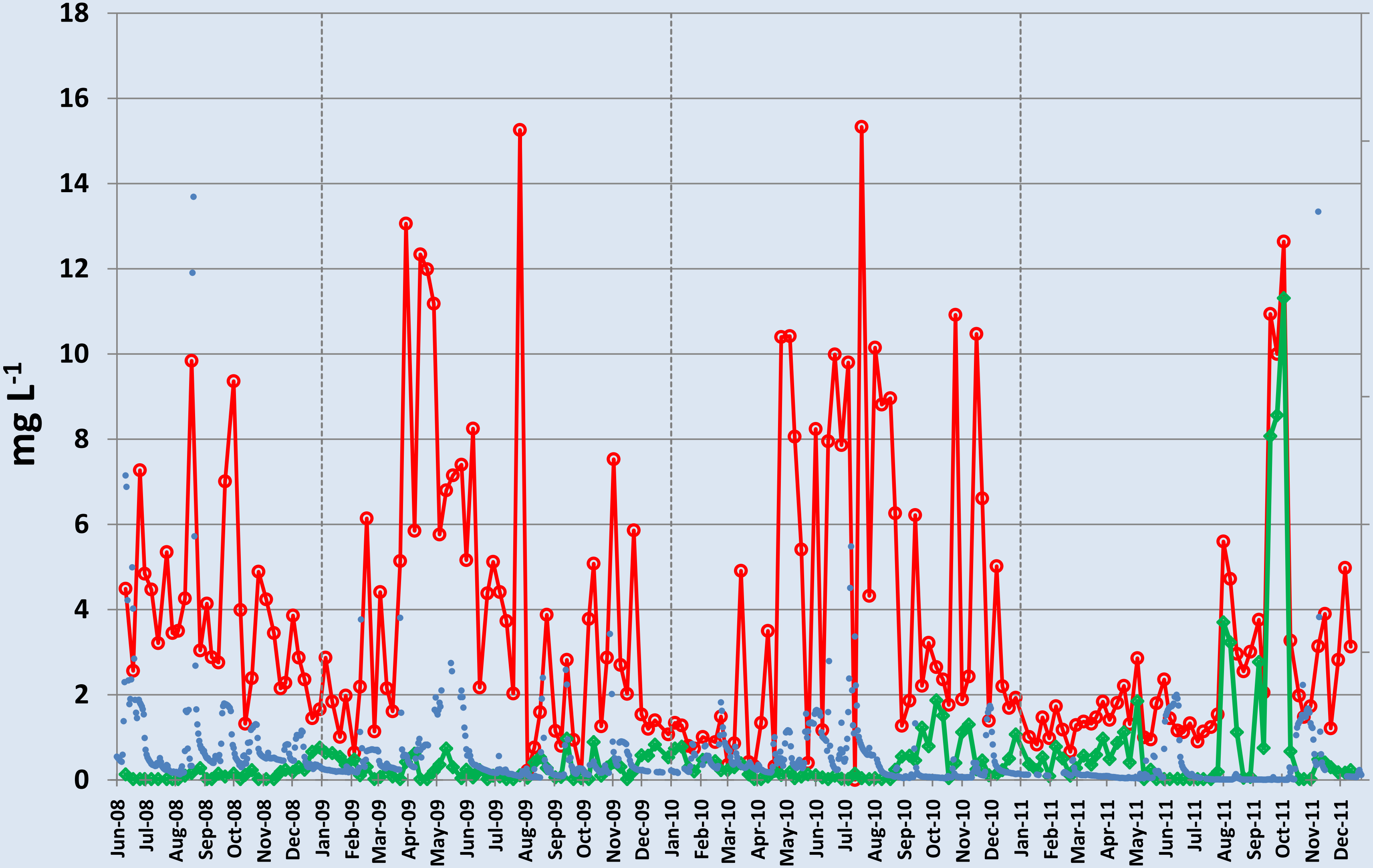
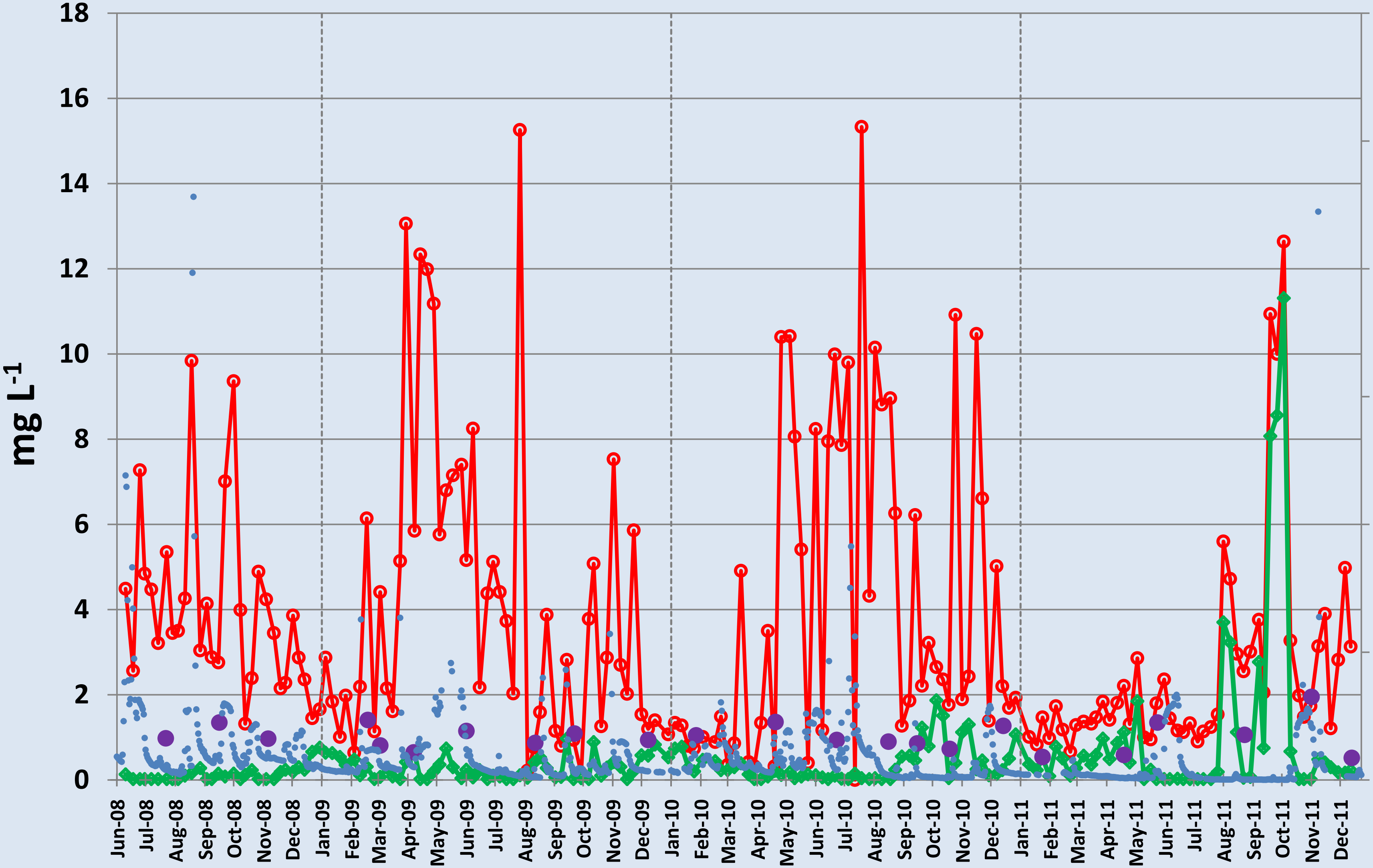
Nov-11
Dec-11

OCC Site at Yukon – TN and NO3



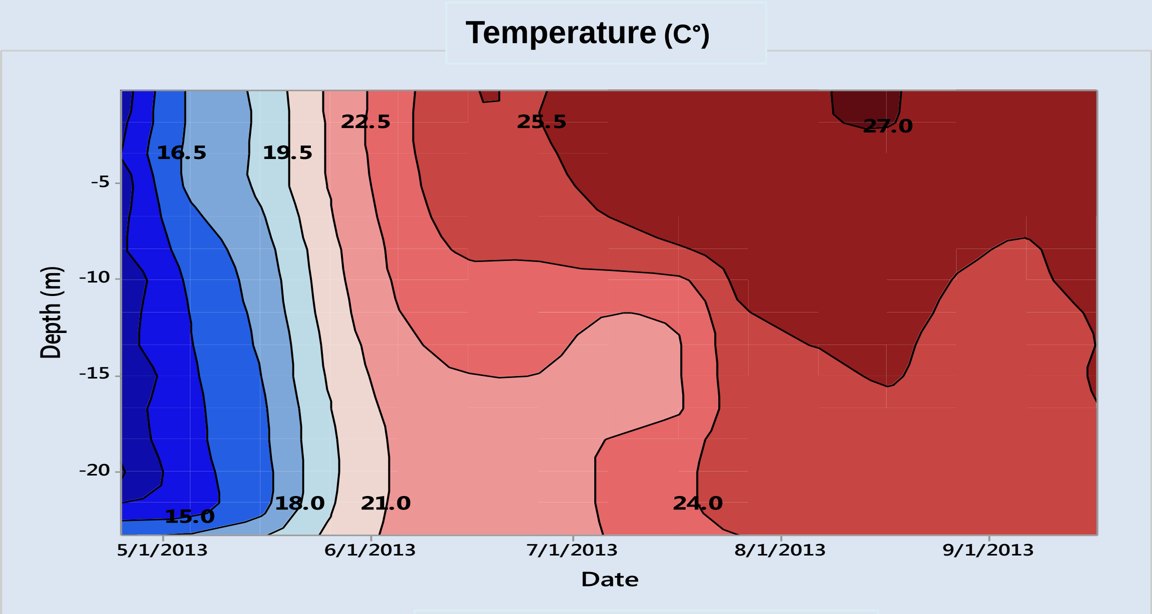
OCC Site at Yukon – TN and NO3

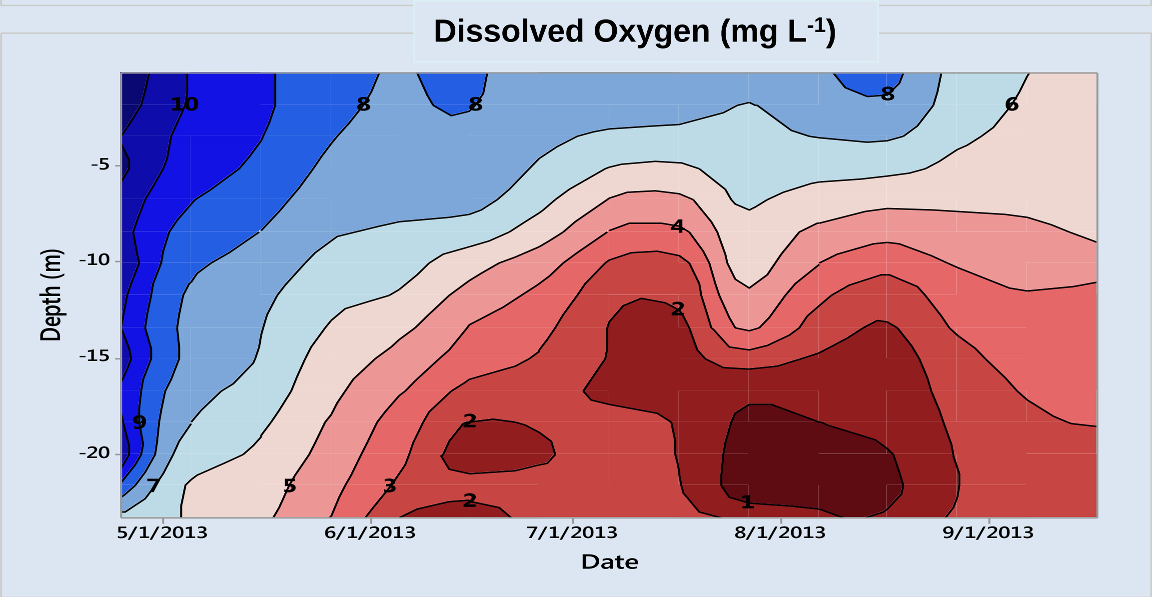


External Load Estimates to Lake Hefner Flux Model

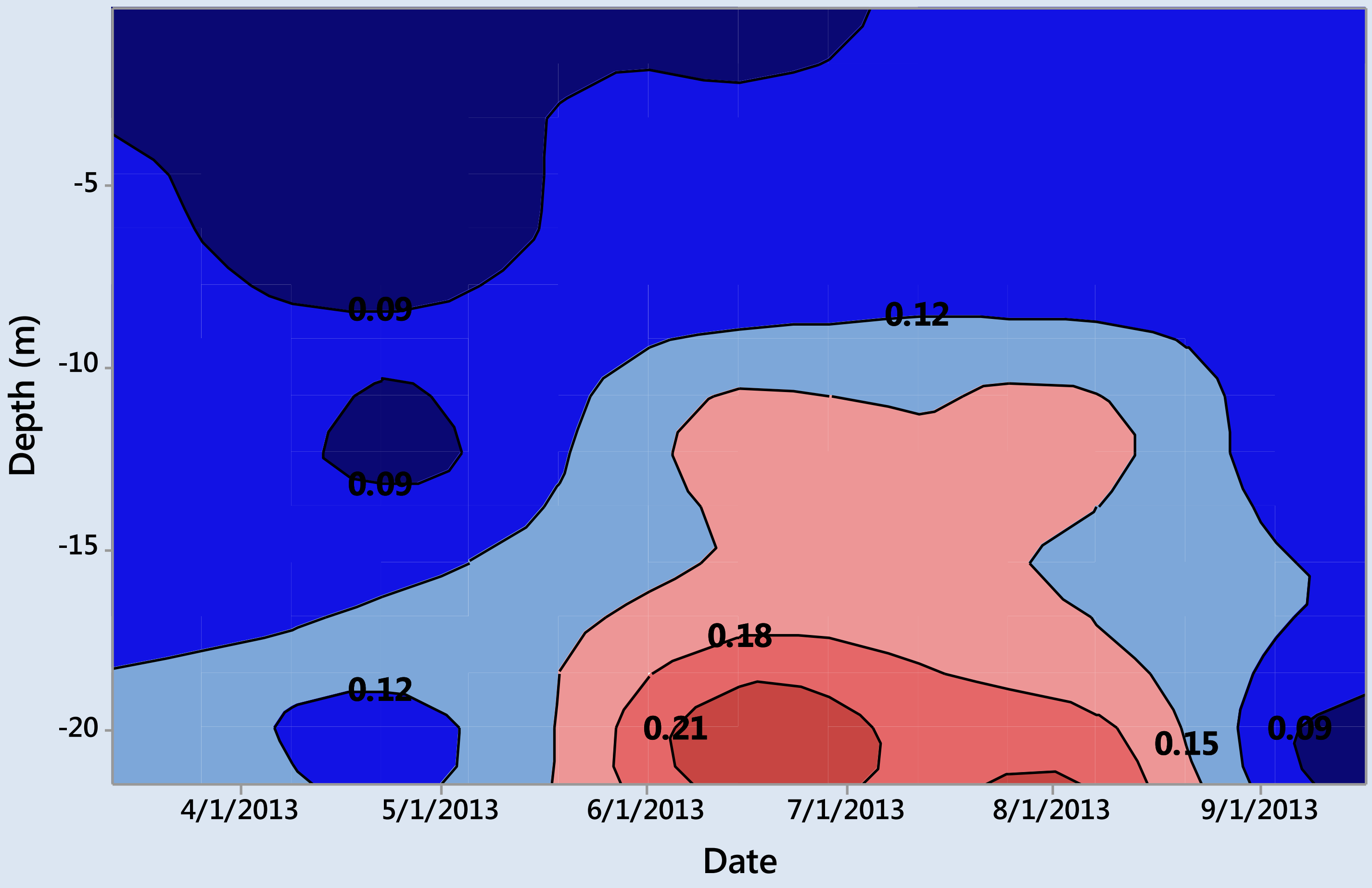
Parameter	Mean ($\mu g\ L^{-1}$)	Coefficient of Variation	Load ($kg\ yr^{-1}$)
Flow ($hm^3\ yr^{-1}$)	56.86	0.24	-
Total P	873	0.10	50633
Ortho-p	442	0.12	25621
Total N	3450	0.10	200263
Inorganic N	502	0.15	29134

Internal Loading



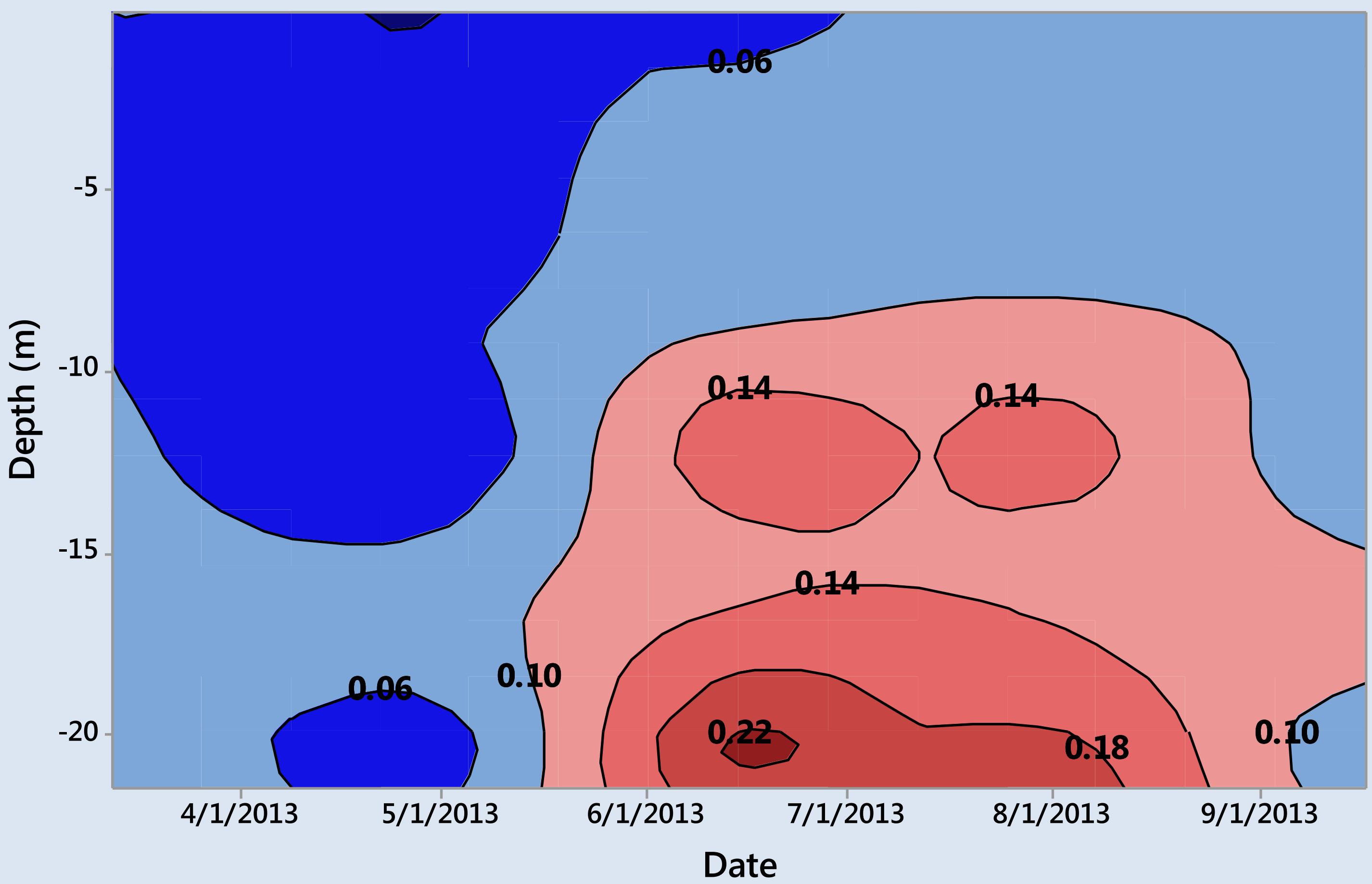


Hefner TP



0.09
0.09
0.12
0.12
0.18
0.21
0.15
0.09
-5
-10
-15
-20
Depth (m)
4/1/2013
5/1/2013
6/1/2013
7/1/2013
8/1/2013
9/1/2013
Date

Hefner Ortho-P



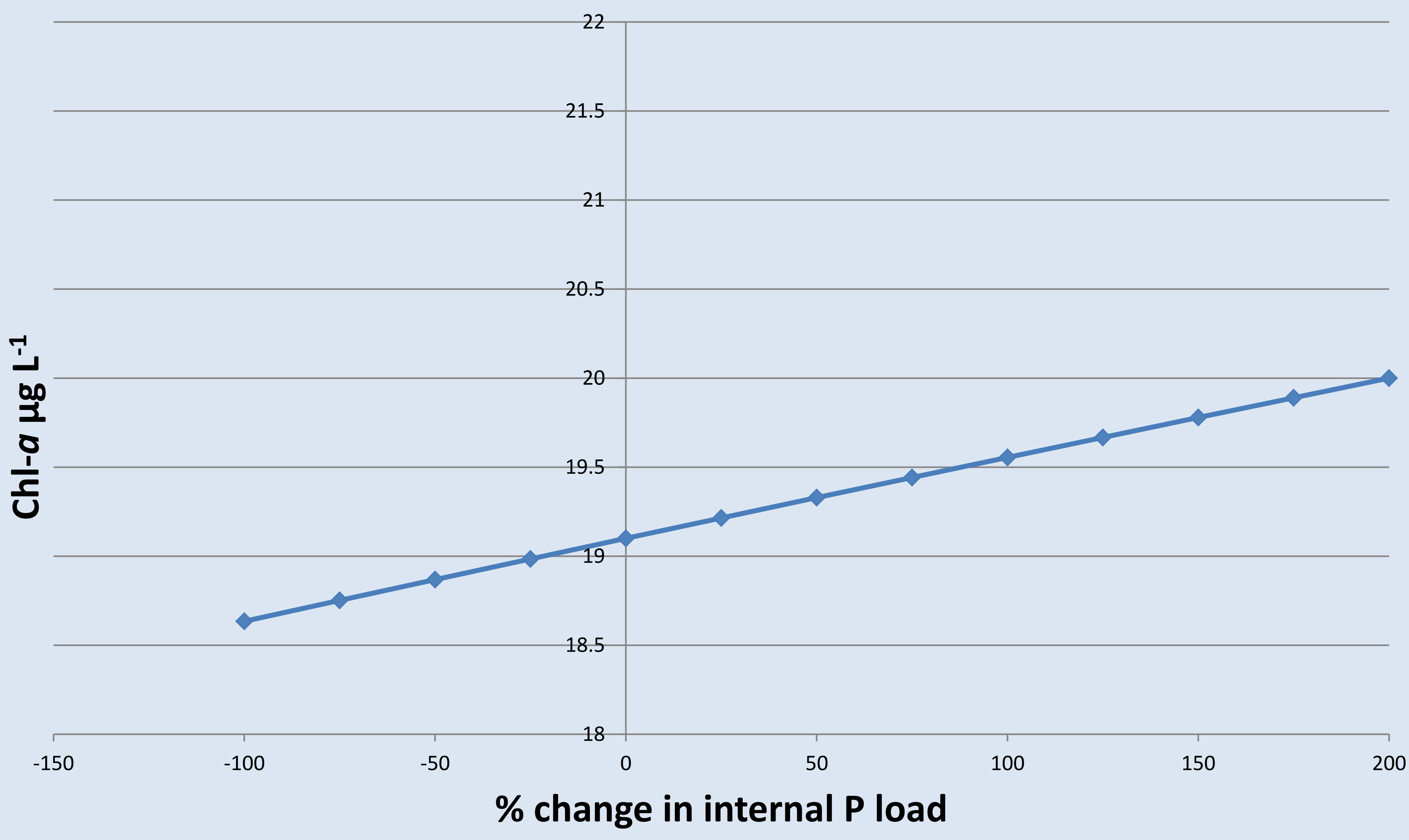
- Hefner Internal P load
  - Measure sediment P content (297-654 g kg^{-1})
  - Estimate P Release Rate (*RR = 3.66 mg* m^{-2} d^{-1})
  - Combine RR and spatial and temporal extent of anoxia

➔ Internal Load of 2437 kg yr^{-1}

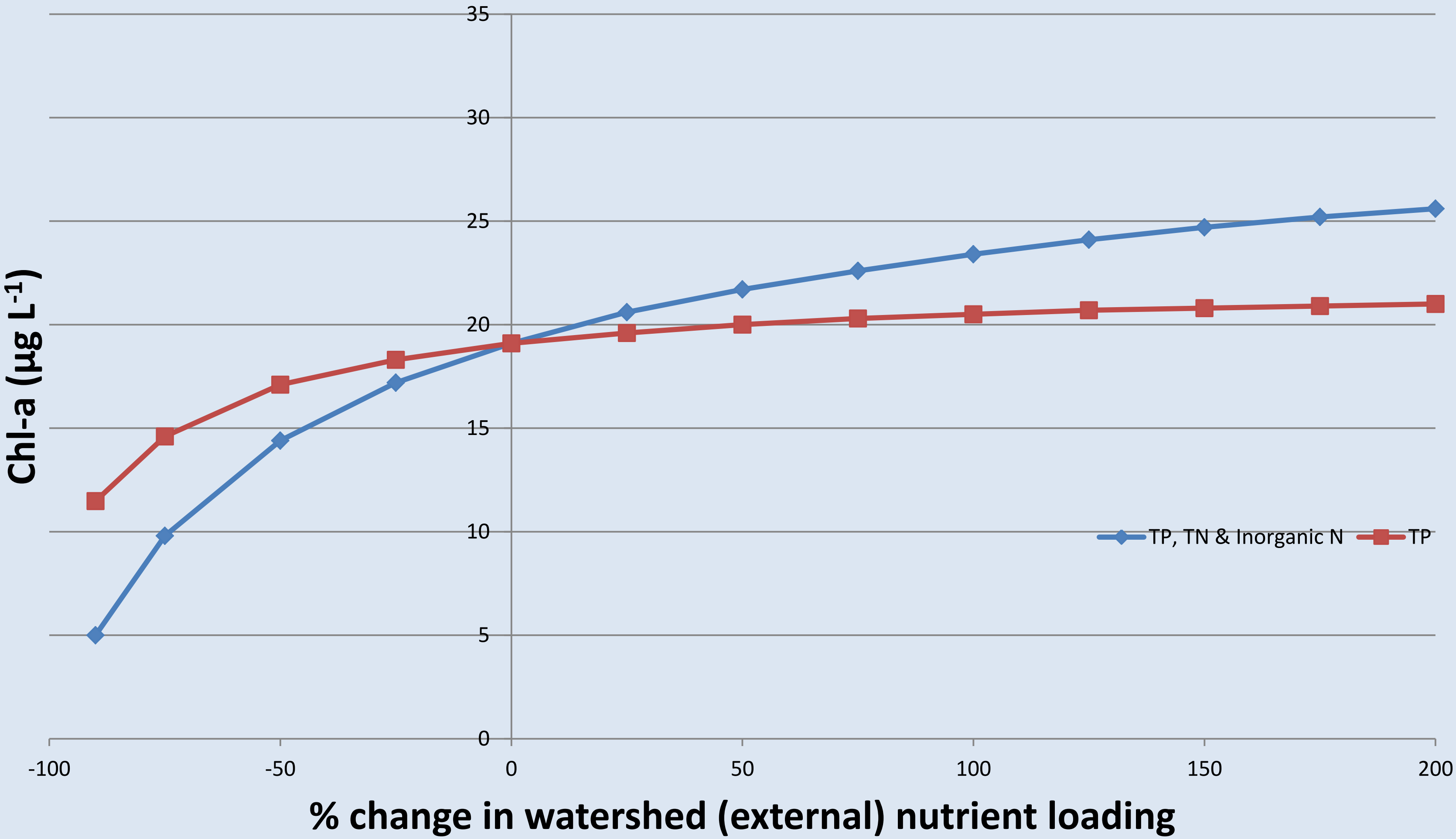
About 5%

Small but timing may be important

Hefner Δ Internal Load



Hefner Δ Internal Load



In-lake BMPs

Option	Benefit	Risk	Recommendation
Artificial circulation	Potential decreased internal P load and reduced hypolimnic anoxia while system operates	Potential increase in internal P loading and transport of nutrients to the epilimnion	No
Hypolimnetic oxygenation	Decreased internal P load and reduced hypolimnic anoxia while system operates	None	Not unless as part of a strategy that also targets external loads
Aluminum Sulfate Treatment	Decreased internal P load (estimated 1-7 years)	Potential risks to aquatic life	Not unless as part of a strategy that also targets external loads
Depth selective drinking water withdrawal	Direct reduction in P via removal of P rich waters & reduced chance of summer/autumn algal blooms. Minimal costs.	Possibility of destratification	Yes

Drinking Water Withdrawal

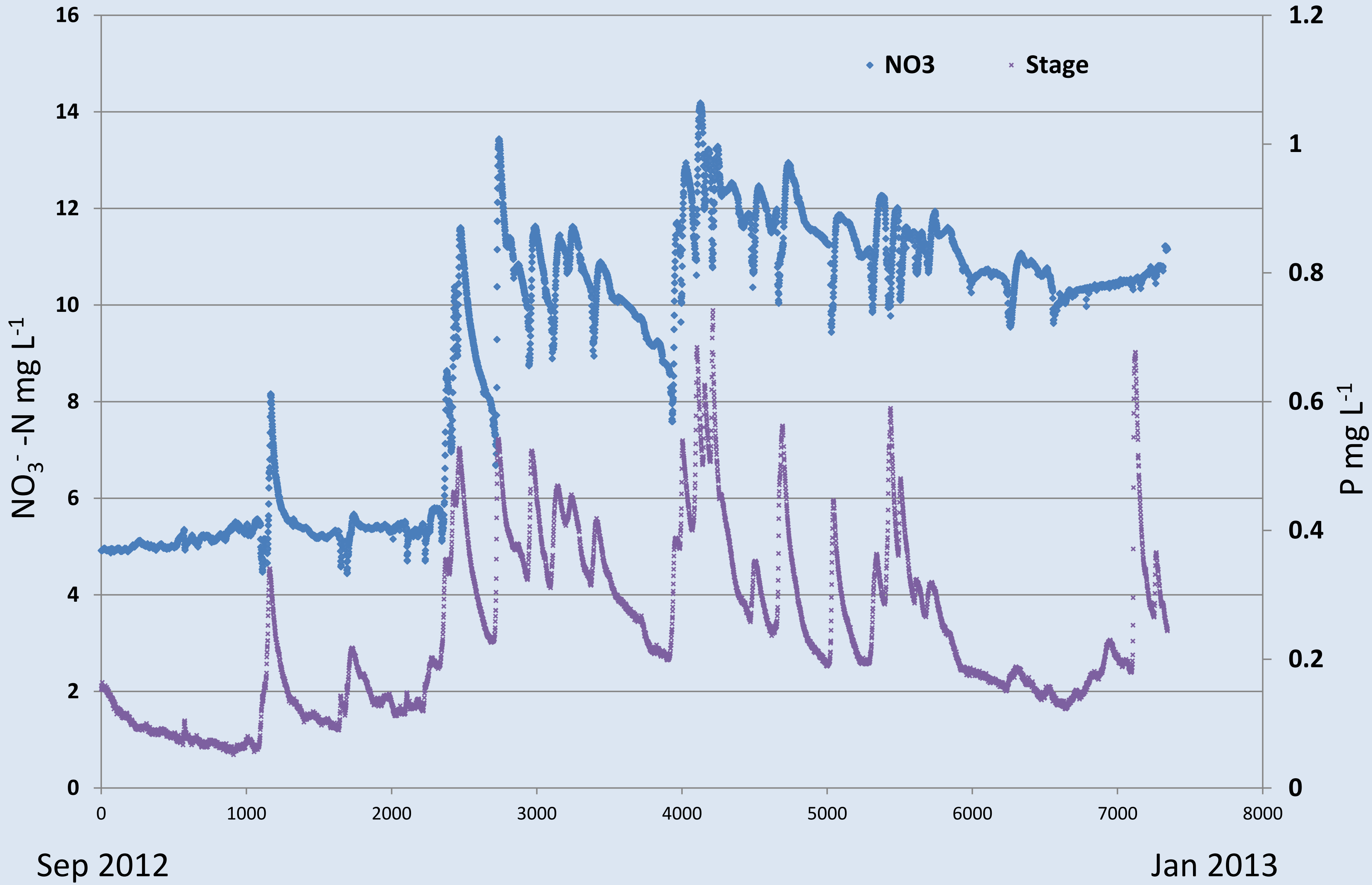
- Hypolimnetic TP concentrations as high as 393 µg L^{-1} (measured at 22 m depth, August 2013).

- April-September 2013 mean TP concentrations
  – At 12-22 m depths 172.7 µg L^{-1}
  – 20-22 m depths = 240.5 µg L^{-1}

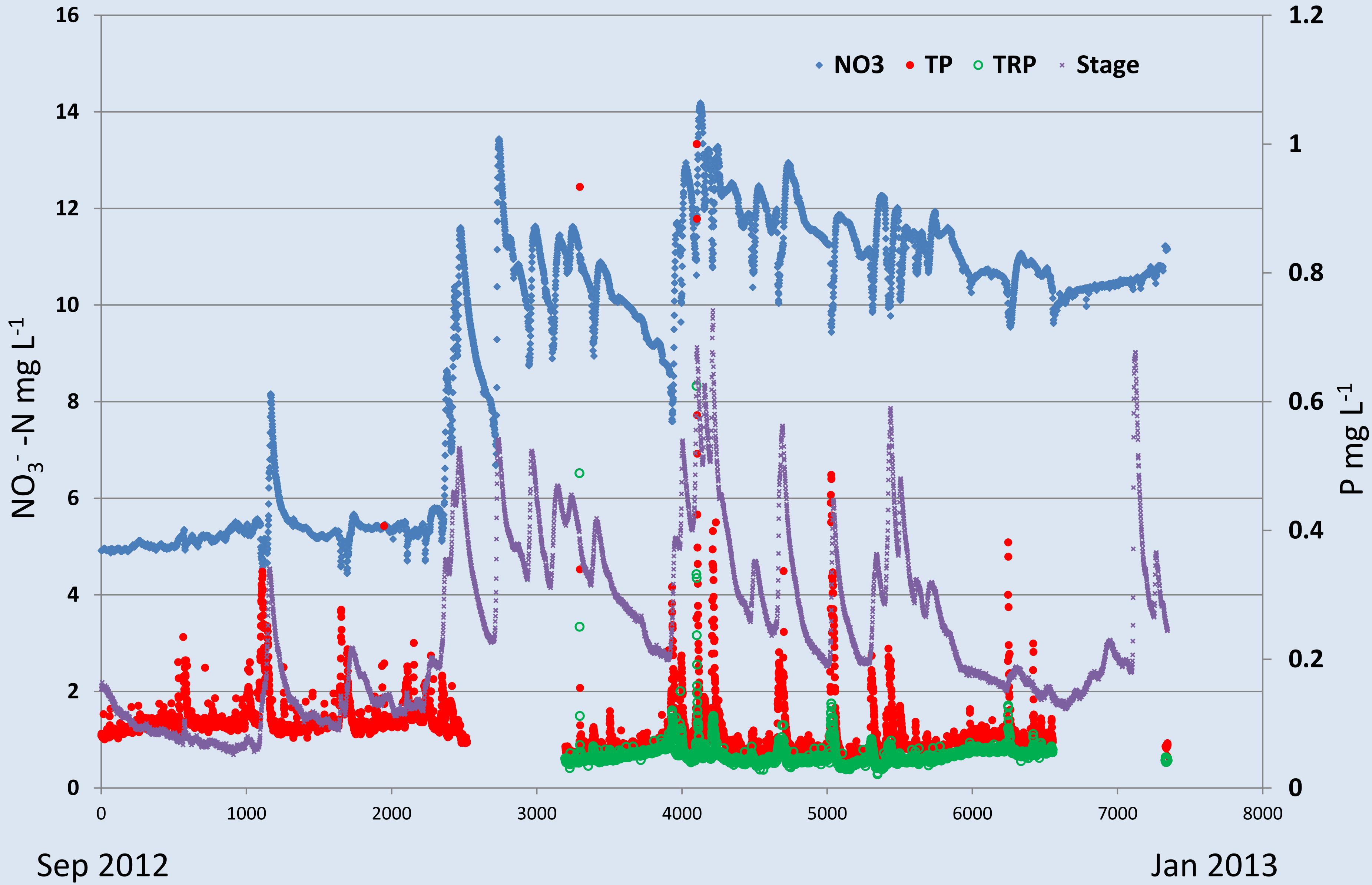
  – annual phosphorus removal via drinking water extraction could increase from 4281 kg yr^{-1} to either 7280 kg yr^{-1} (12-22 m) or 9459 kg yr^{-1} (20-22 m

Wensum, UK

- High Temporal Resolution
  - Weekly
  - Thirty Minute
- Data at various temporal Scales



NO3
Stage
16
14
12
10
8
6
4
2
0
1.2
1
0.8
0.6
0.4
0.2
0
NO_3^- -N mg L^{-1}
P mg L^{-1}
0
1000
2000
3000
4000
5000
6000
7000
8000
Sep 2012
Jan 2013



NO3
TP
TRP
Stage
16
14
12
10
8
6
4
2
0
1.2
1
0.8
0.6
0.4
0.2
0
0
1000
2000
3000
4000
5000
6000
7000
8000
NO_3^- -N mg L^{-1}
P mg L^{-1}
Sep 2012
Jan 2013

Summary

- Important to use the appropriate data sets
  - Often designed to capture different snapshots
- Model results suggest continued catchment management is needed to improve lake water quality
  - Non-point source work by OCC and partners
  - Urban
  - Point Source
- External loads appear to be decreasing
- Most relevant monitoring point discontinued
- Internal loads may become more important

Issues

- OCC data at Yukon is the best available data set for estimating loads to Hefner
- Discontinued since the purpose of that project was to monitor non-point source pollution higher up in the catchment
- Location is still a big issue….show the city inputs, point source dischargers
- Also, using flow to estimate missing nutrient records could be an issue…poor flow/concentration relationships
- Catchment likely more complicated
- Data allowing, use a more complicated model to try and catch some of the timing of inputs, high summer external loads, turnover, atmospheric deposition