Eutrophication Modeling in a Large Texas Reservoir

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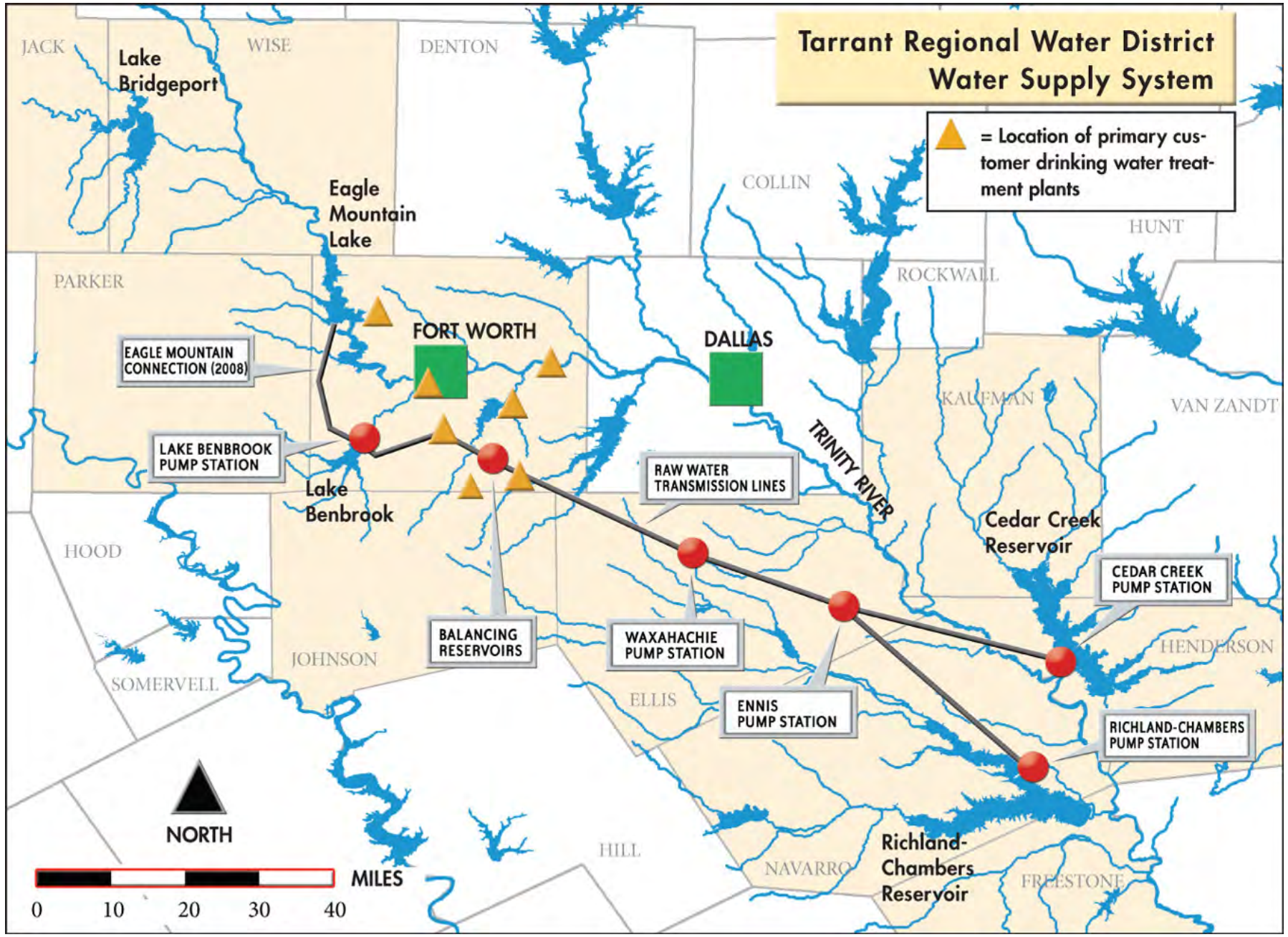
Tarrant Regional Water District

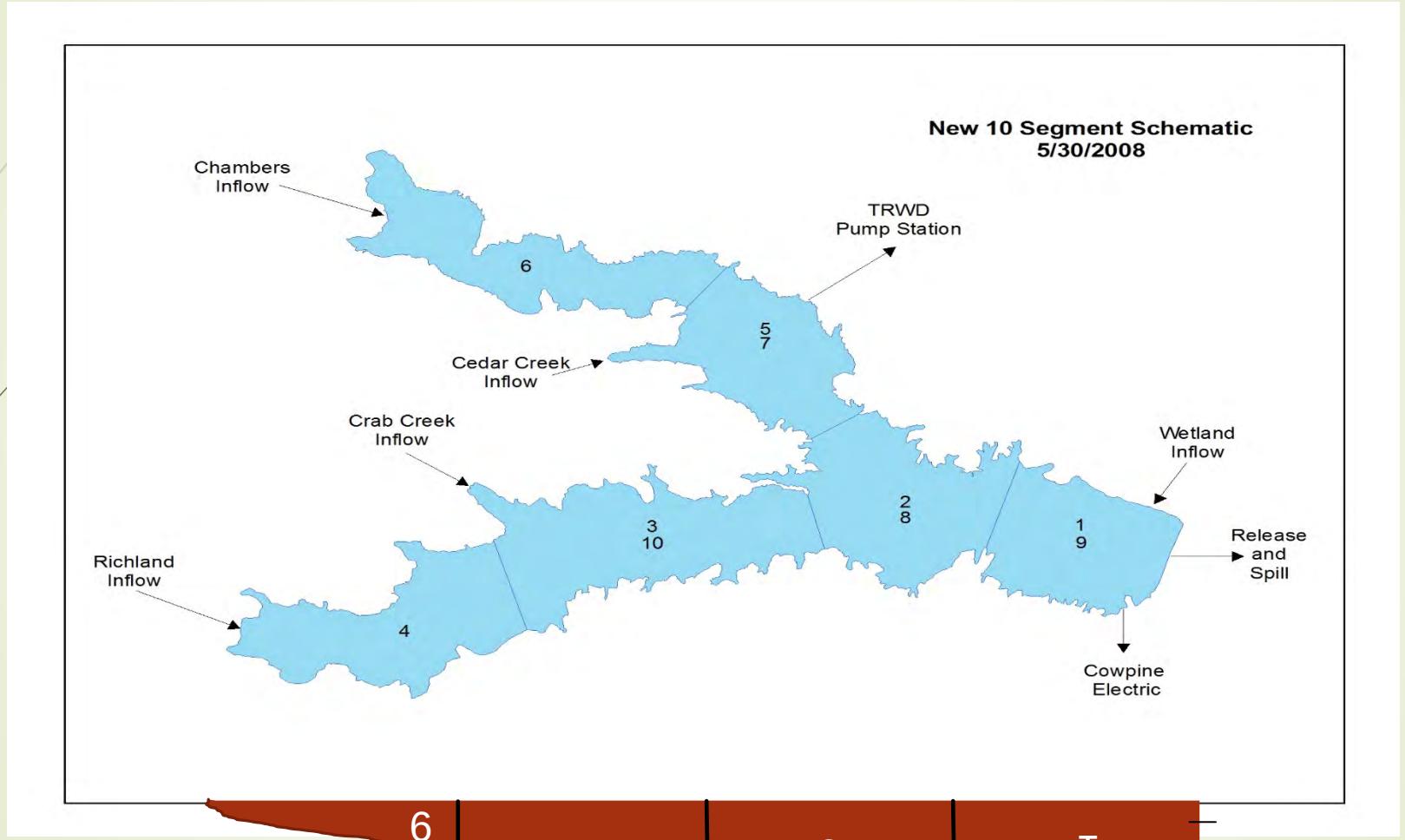
March 2018

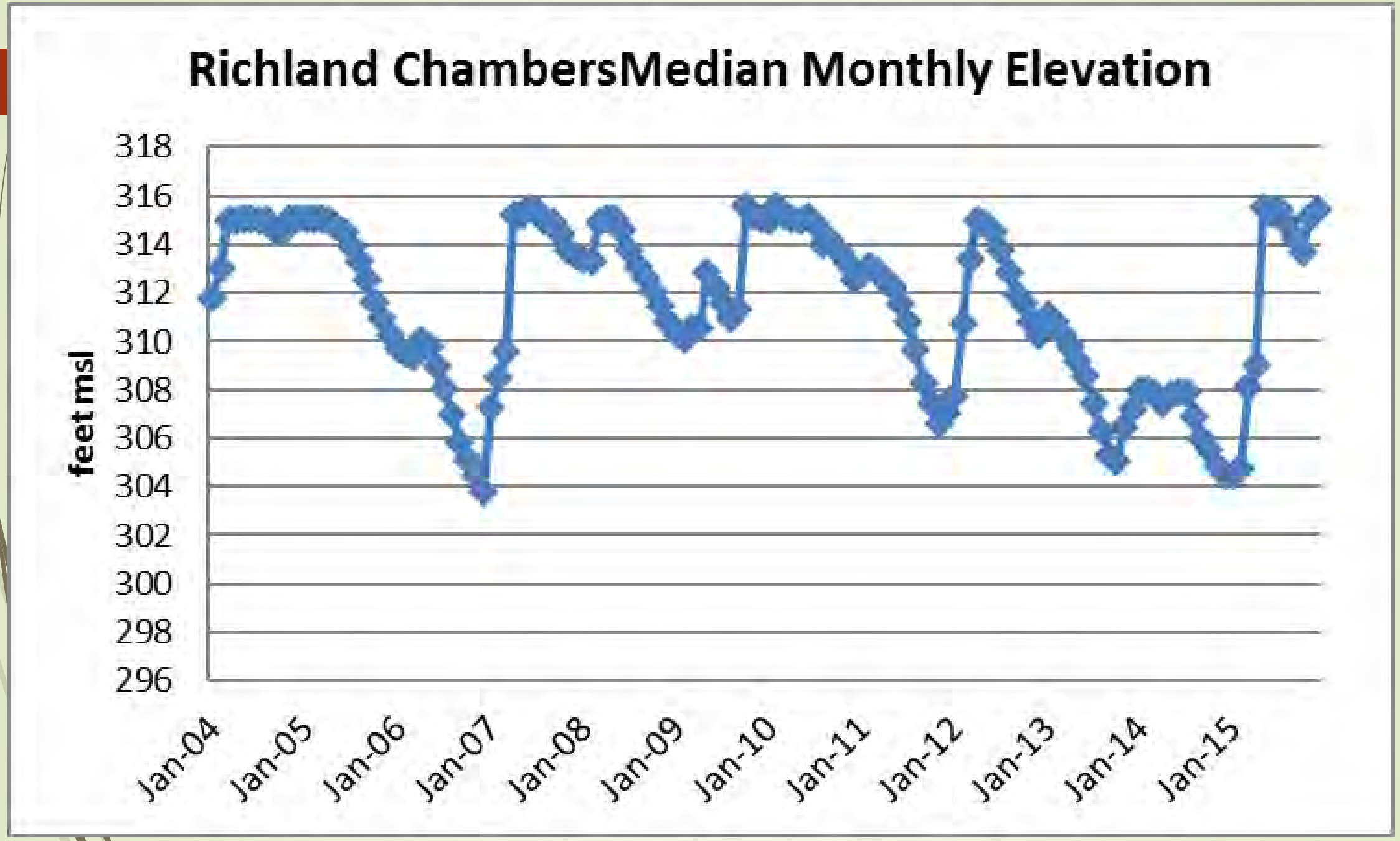

Tarrant Regional Water District
Water Supply System
= Location of primary customer drinking water treatment plants
JACK
WISE
DENTON
COLLIN
HUNT
ROCKWALL
PARKER
KAUFMAN
VAN ZANDT
HOOD
JOHNSON
SOMERVELL
ELLIS
HILL
NAVARRO
FREESTONE
HENDERSON
Lake Bridgeport
Eagle Mountain Lake
FORT WORTH
DALLAS
EAGLE MOUNTAIN CONNECTION (2008)
LAKE BENBROOK PUMP STATION
Lake Benbrook
RAW WATER TRANSMISSION LINES
TRINITY RIVER
Cedar Creek Reservoir
CEDAR CREEK PUMP STATION
BALANCING RESERVOIRS
WAXAHACHIE PUMP STATION
ENNIS PUMP STATION
RICHLAND-CHAMBERS PUMP STATION
Richland-Chambers Reservoir
NORTH
MILES
0
10
20
30
40

WASP8

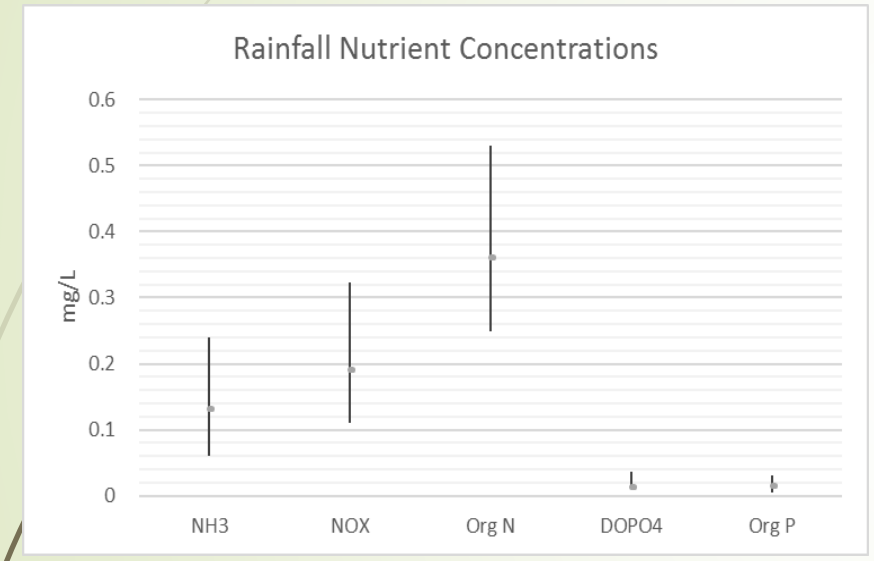
- EPA supported mass balance model
- Can be used with hydrodynamic models, ours is descriptive monthly
- Has routines for oxygen, nitrogen, phosphorus and phytoplankton
- Upgraded to include temperature, light and solids
- Our application
  - 12 year run (2004-2015)
  - 10 segment model
  - Monthly flow input
  - Daily water quality loading

Richland-Chambers 10-Seg WASP8 Model

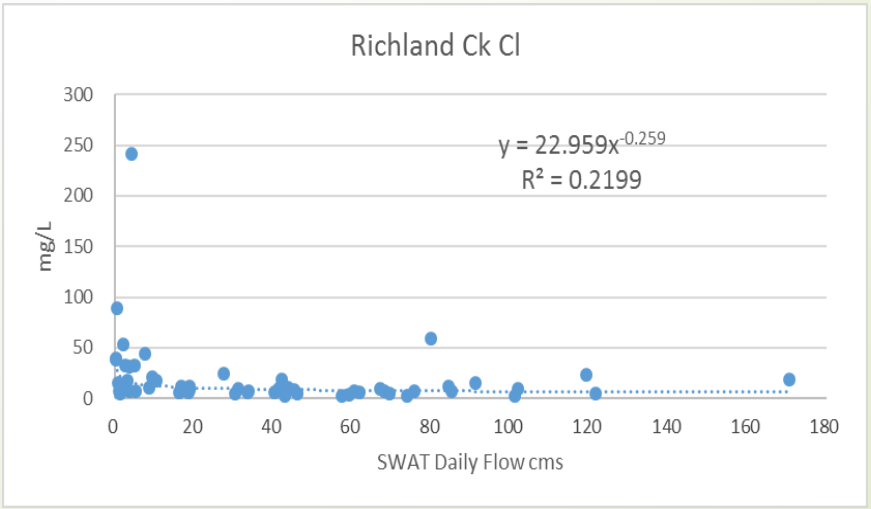



Richland ChambersMedian Monthly Elevation
feet msl
318
316
314
312
310
308
306
304
302
300
298
296
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15

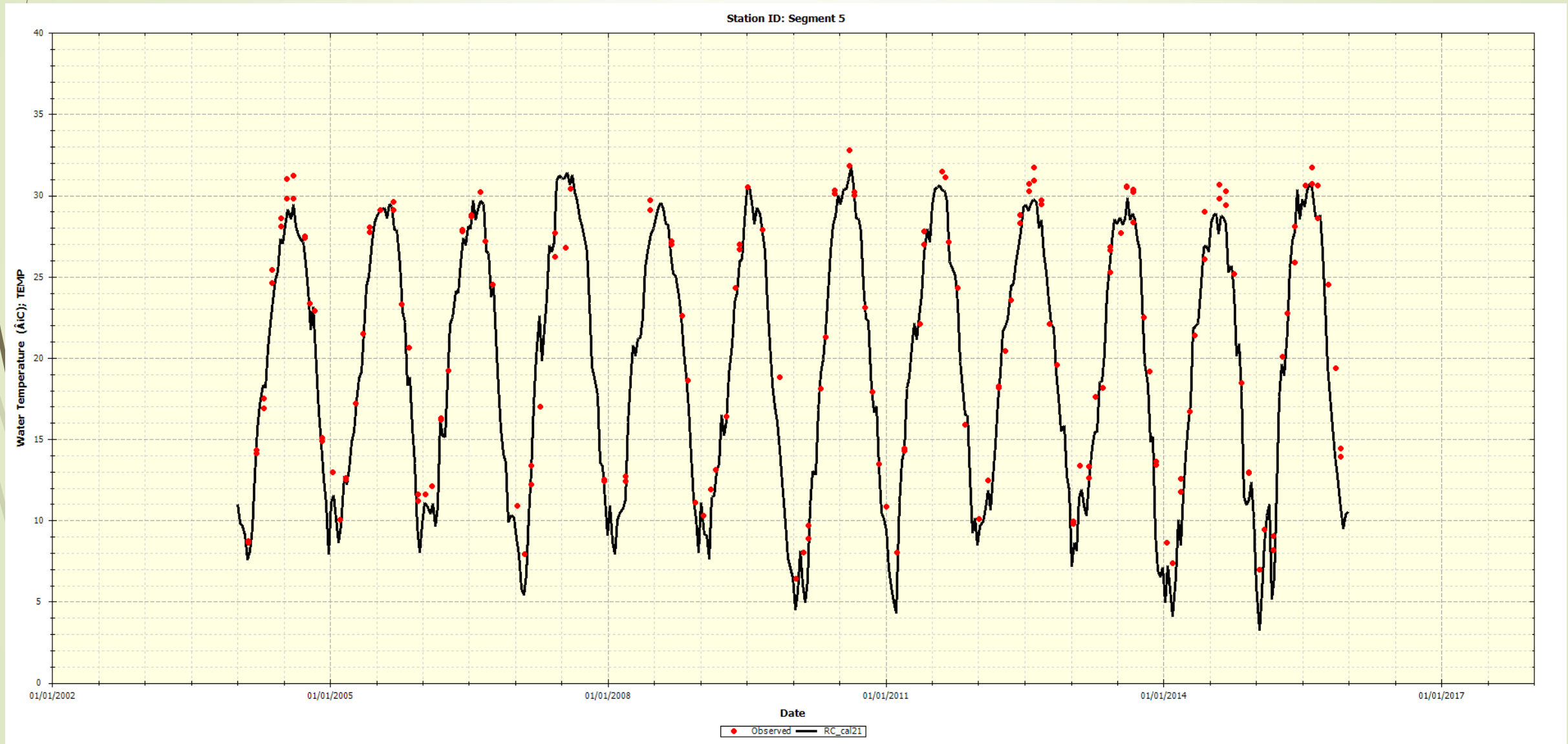
Loads come from watershed, rainfall, wetland and sediment



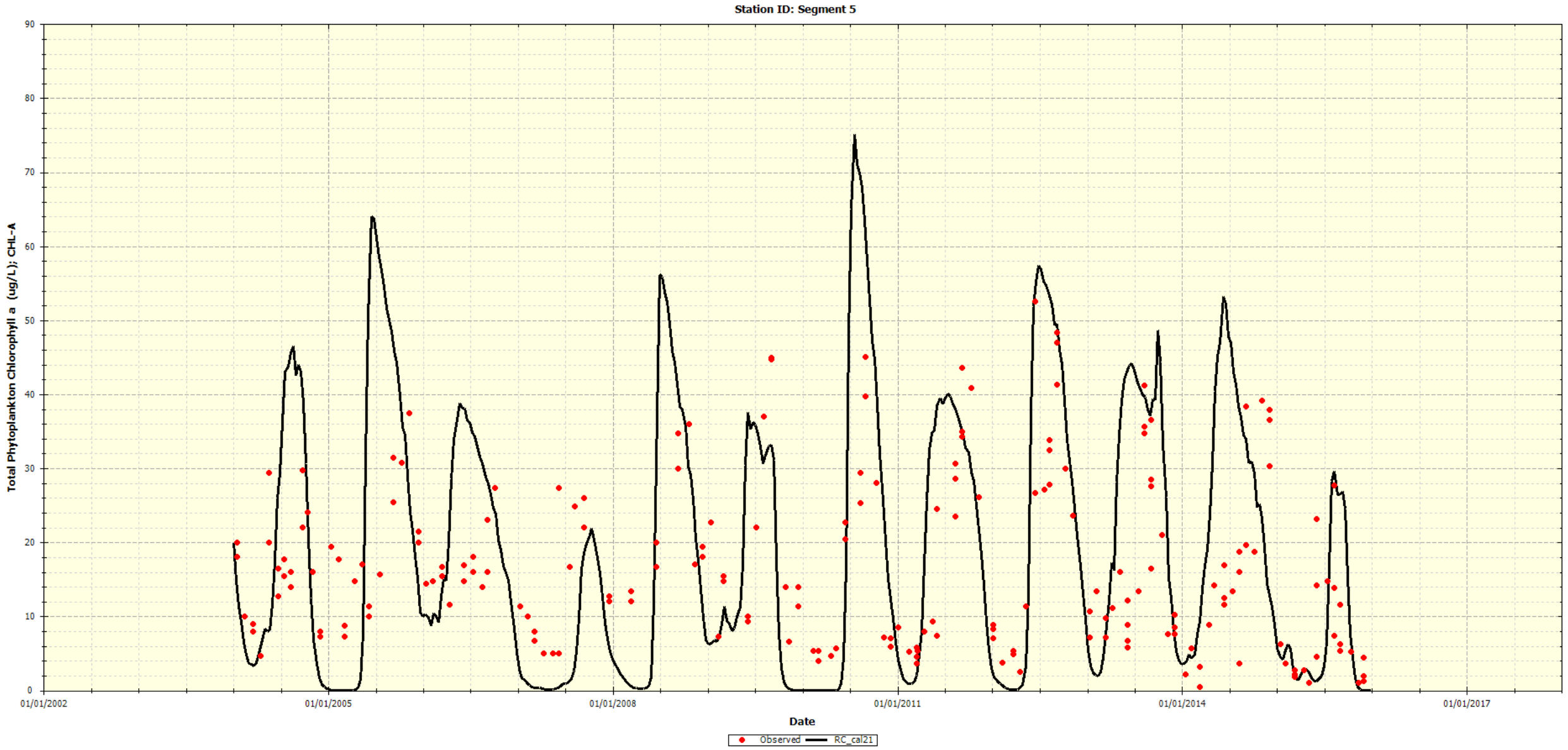
SWAT



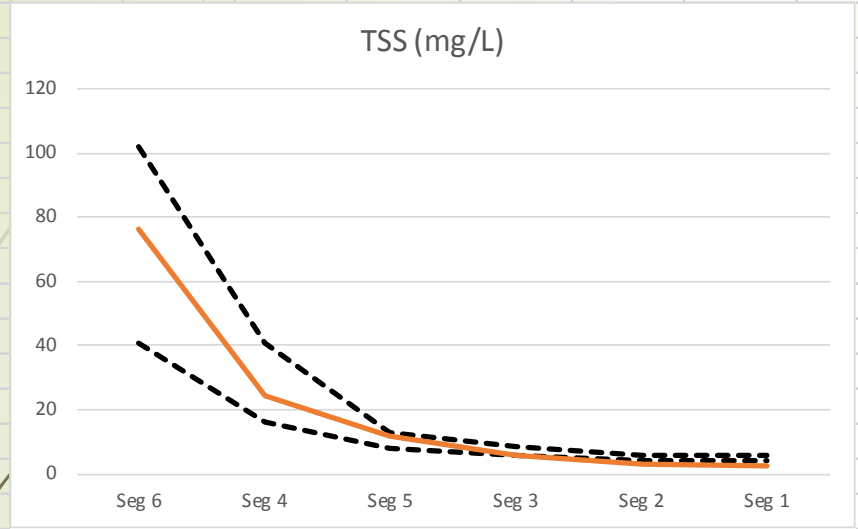
Temperature and Heat Transfer .....

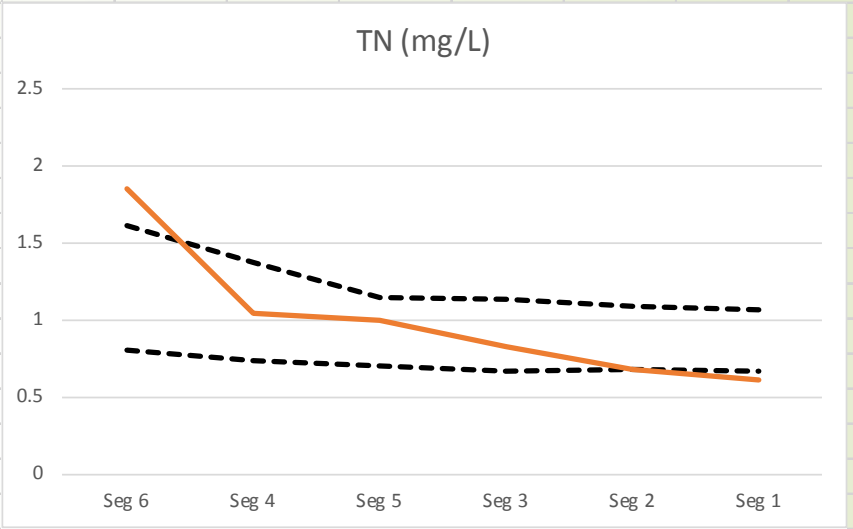


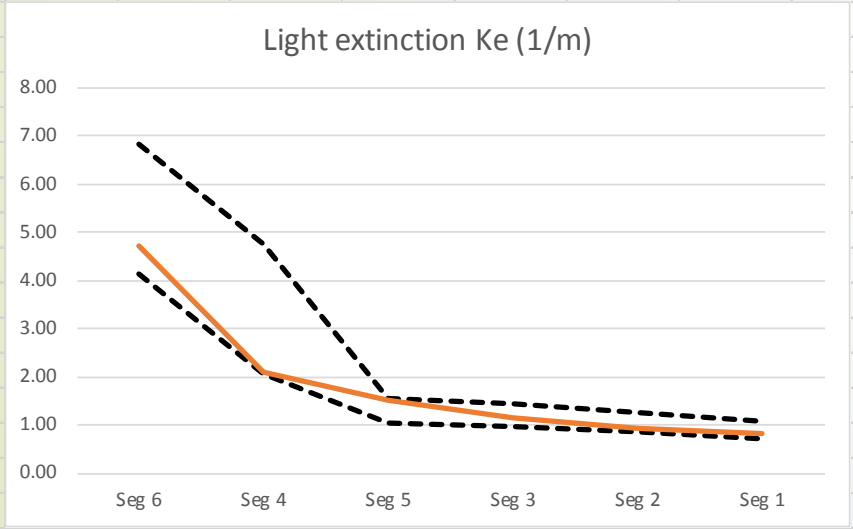
More Chl'a'....

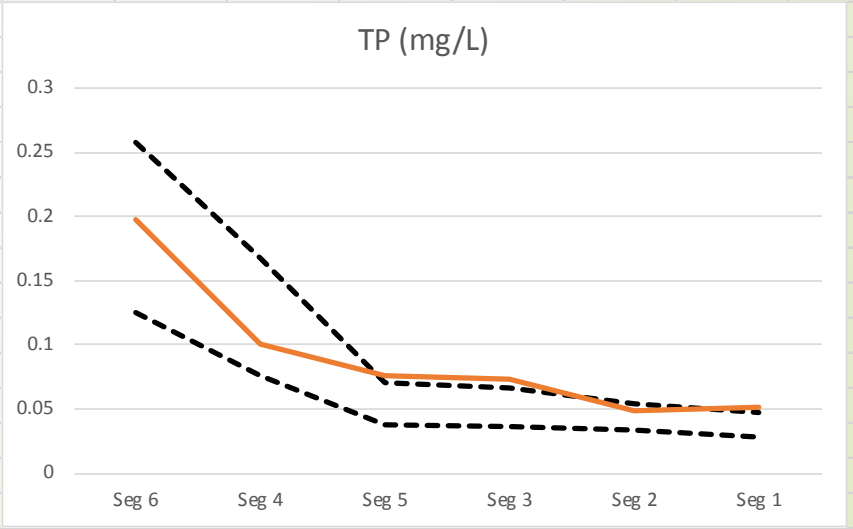

Station ID: Segment 5
Total Phytoplankton Chlorophyll a (ug/L); CHL-A
90
80
70
60
50
40
30
20
10
0
01/01/2002
01/01/2005
01/01/2008
01/01/2011
01/01/2014
01/01/2017
Date
Observed
RC_cal21

Capture General tendencies rather than absolute concentrations









Statistics help support Intuition….

TP	Seg 1	Seg 2	Seg 3	Seg 5
Sample size	92	96	59	215
Observed	0.037	0.041	0.047	0.052
Predicted	0.060	0.050	0.078	0.075
RPD	52.5%	47.3%	53.9%	46.1%
Correlation	**0.2802**	**0.3439**	**0.4387**	**0.2367**

TN	Seg 1	Seg 2	Seg 3	Seg 5
Sample size	92	94	60	215
Observed	0.820	0.805	0.892	0.902
Predicted	0.651	0.769	0.877	0.938
RPD	42.4%	39.5%	37.2%	41.7%
Correlation	-0.0507	0.0837	0.1933	**0.1873**

Ke	Seg 1	Seg 2	Seg 3	Seg 5
Sample size	51	53	52	52
Observed	0.935	1.044	1.152	1.293
Predicted	0.824	0.945	1.161	1.651
RPD	53.3%	54.2%	55.9%	34.5%
Correlation	**0.3293**	**-0.3985**	**-0.3872**	0.0237

Chl'a'	Seg 1	Seg 2	Seg 3	Seg 5
Sample size	92	96	60	214
Observed	12.500	15.500	16.200	14.100
Predicted	22.107	20.221	23.084	14.837
RPD	59.8%	55.3%	66.1%	71.2%
Correlation	**0.2899**	**0.4025**	**0.4654**	**0.1631**

WASP was used *to conduct 3 types of tests:*

1.Sensitivity of modeled loads

2.Reduction scenarios

3.Assimilation Capacity

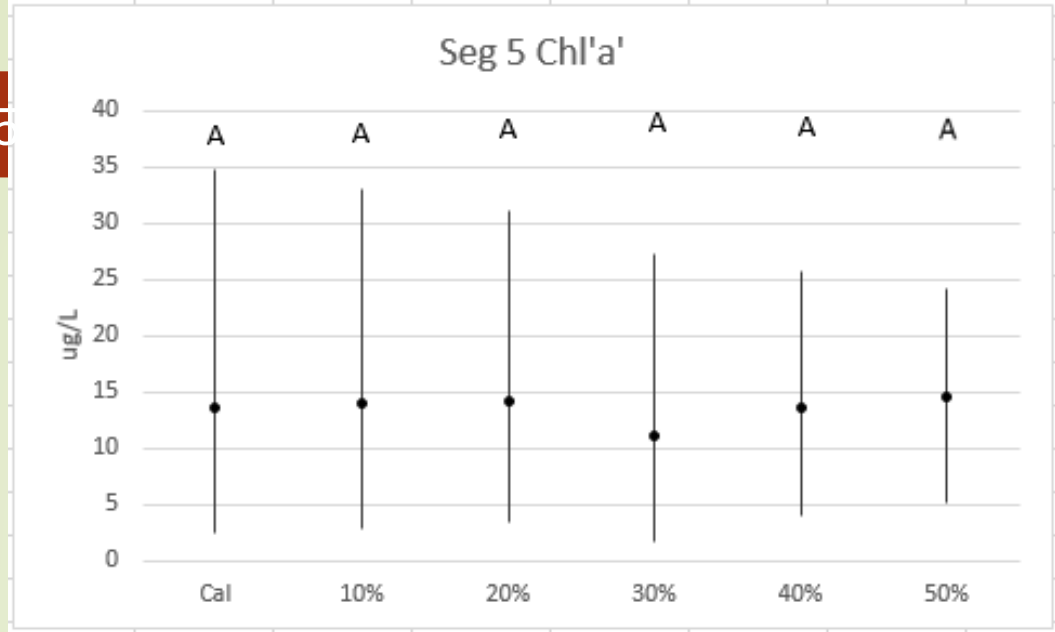
Sensitivity Analysis

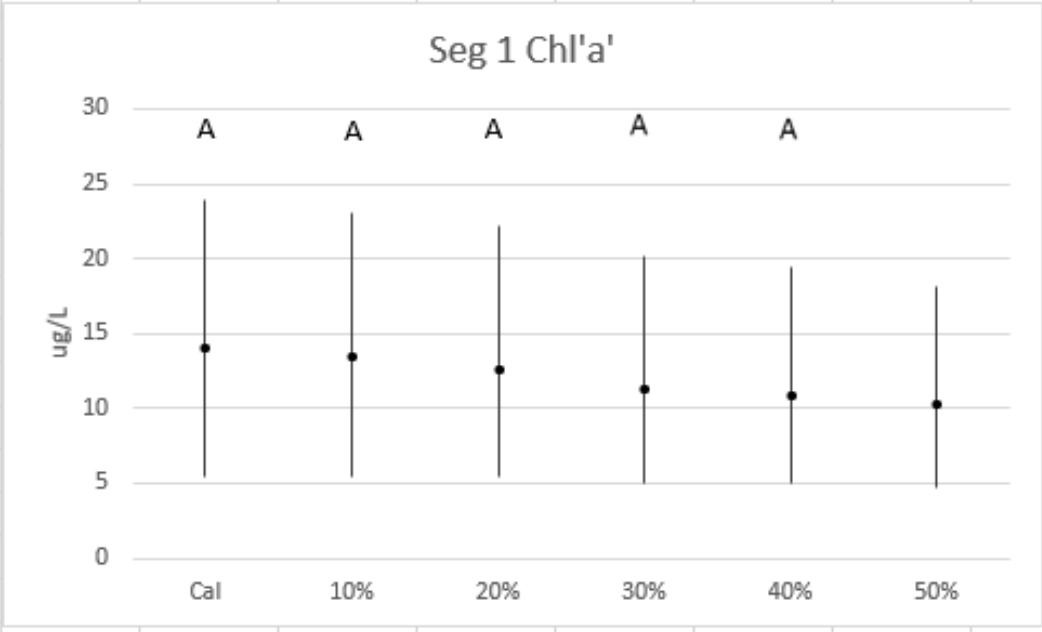
- Watershed
- Atmosphere
- Sediment Flux
- Wetland diversion project

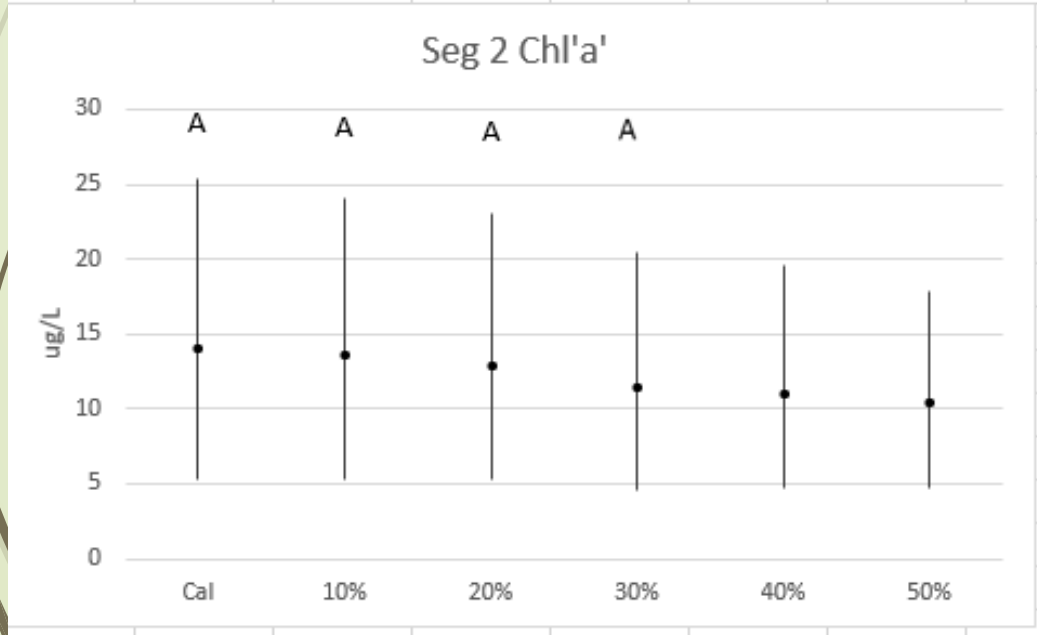
What loading function drives this reservoir?

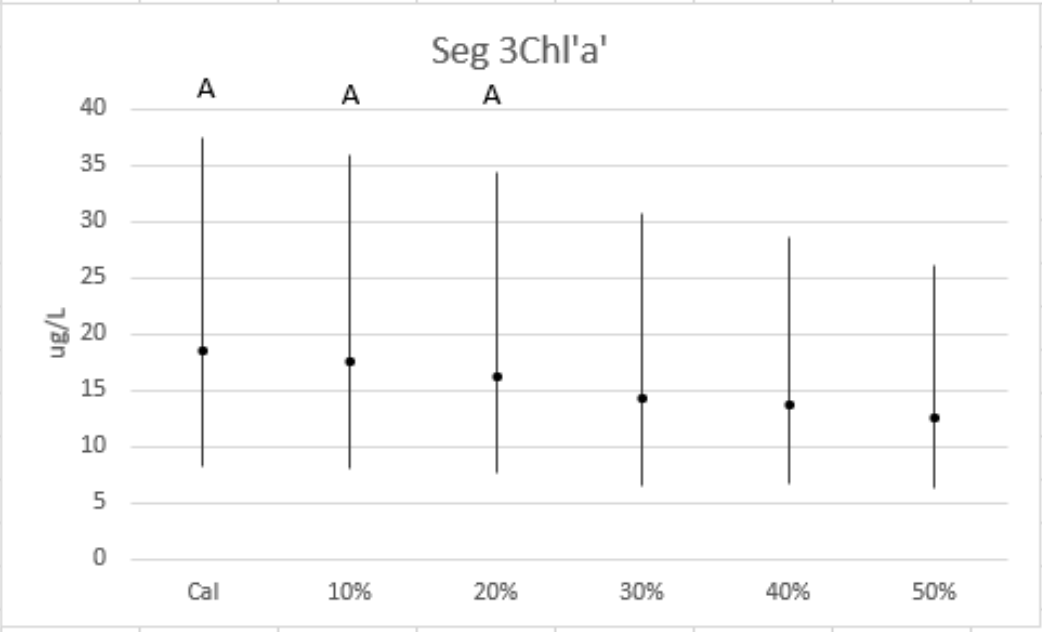
Reduction Scenarios

Systematic reduction in nutrients and solids in increments of 10% to determine at what % reduction will the Chl'a' be statistically less than that of the calibration model.


Seg 5 Chl'a'
ug/L
0
5
10
15
20
25
30
35
40
A
A
A
A
A
A
Cal
10%
20%
30%
40%
50%


Seg 1 Chl'a'
ug/L
0
5
10
15
20
25
30
A
A
A
A
A
Cal
10%
20%
30%
40%
50%

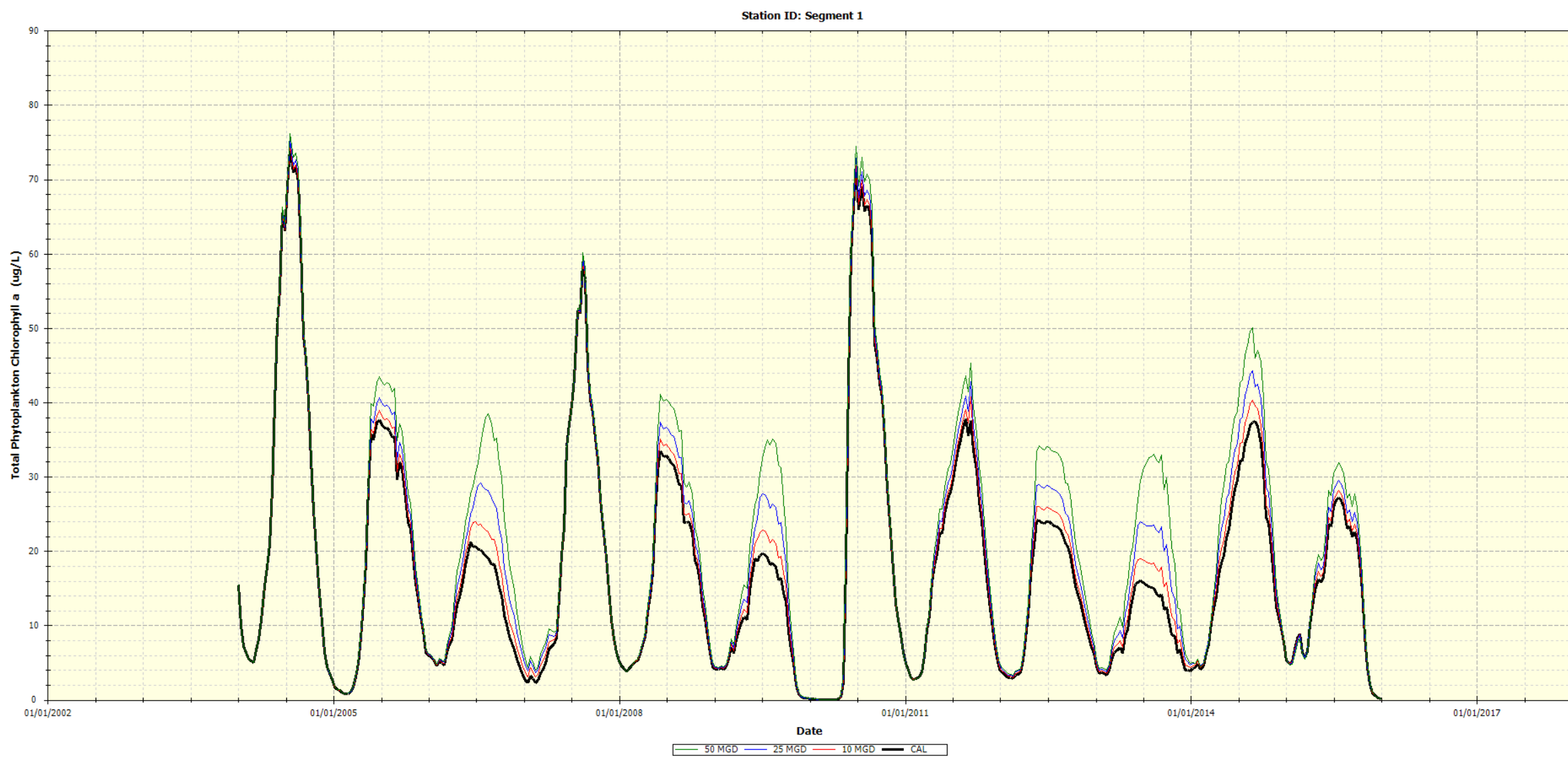

Seg 2 Chl'a'
ug/L
0
5
10
15
20
25
30
A
A
A
A
Cal
10%
20%
30%
40%
50%


Seg 3Chl'a'
ug/L
0
5
10
15
20
25
30
35
40
A
A
A
Cal
10%
20%
30%
40%
50%

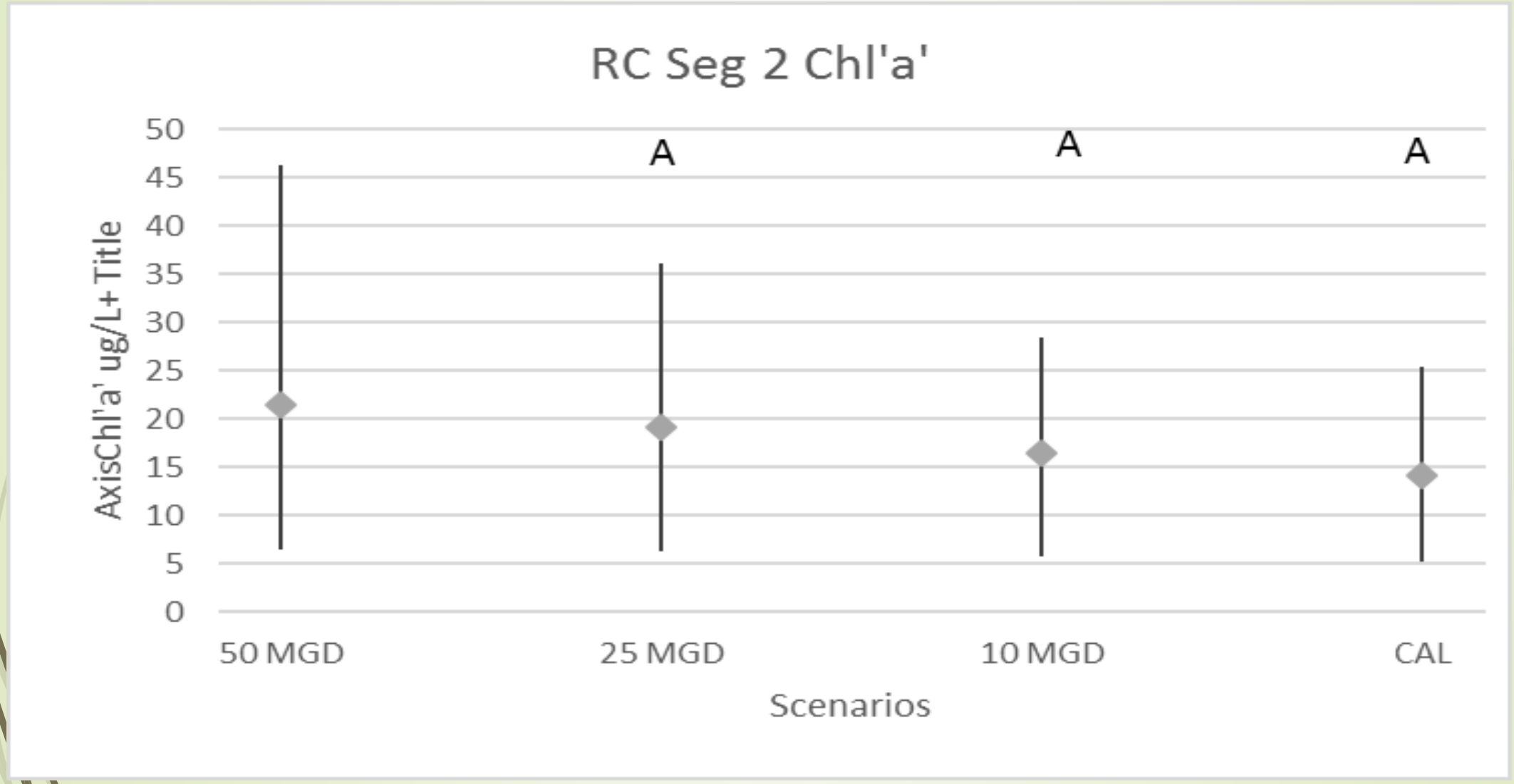
Assimilation Capacity

Nutrient	Concentration	10 MGD	25 MGD	50 MGD
	mg/L	kg/day	kg/day	kg/day
NH4	1	37.9	94.6	189.3
NOX	1.55	58.7	146.7	293.3
Org N	1	37.9	94.6	189.3
OPO4	0.39	14.8	36.9	73.8
Org P	0.1	3.8	9.5	18.9

Wastewater loading increases the Chl'a' peaks



Median Chl’a’ change

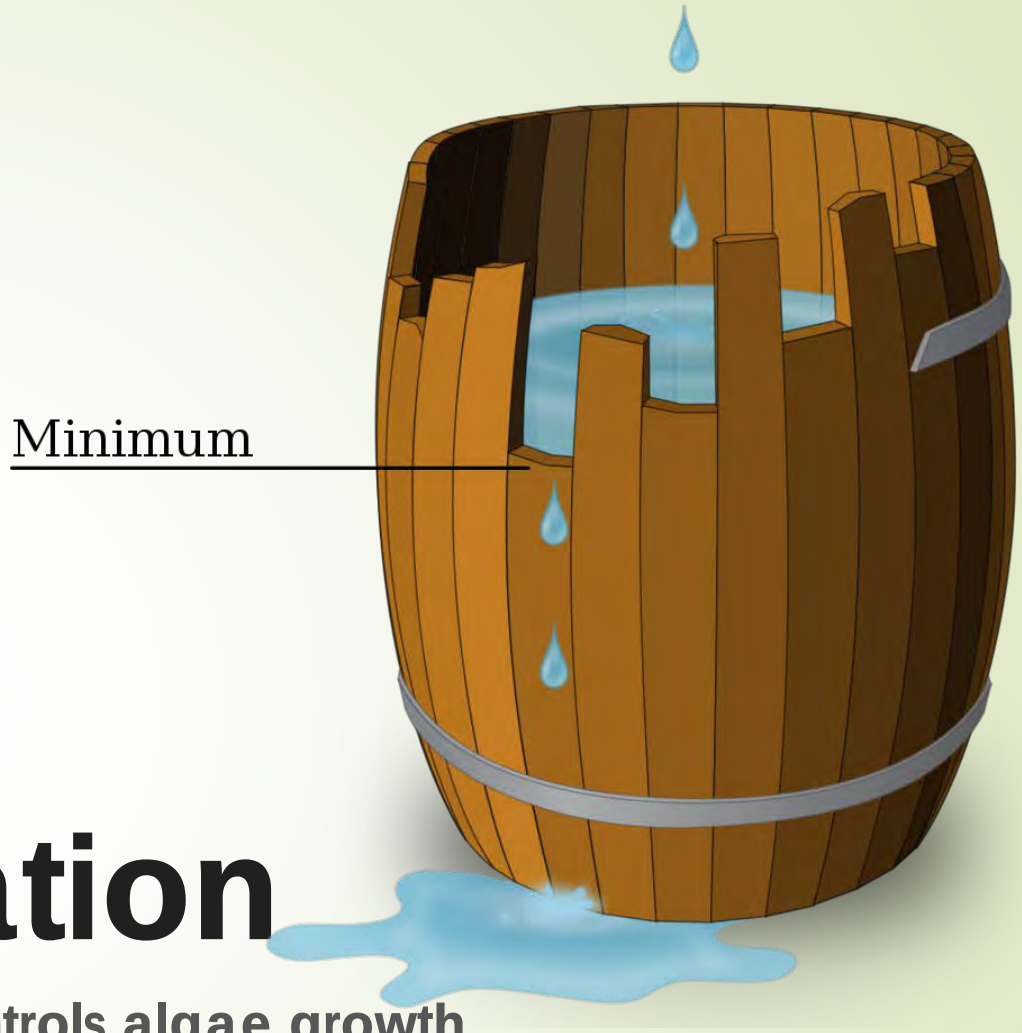


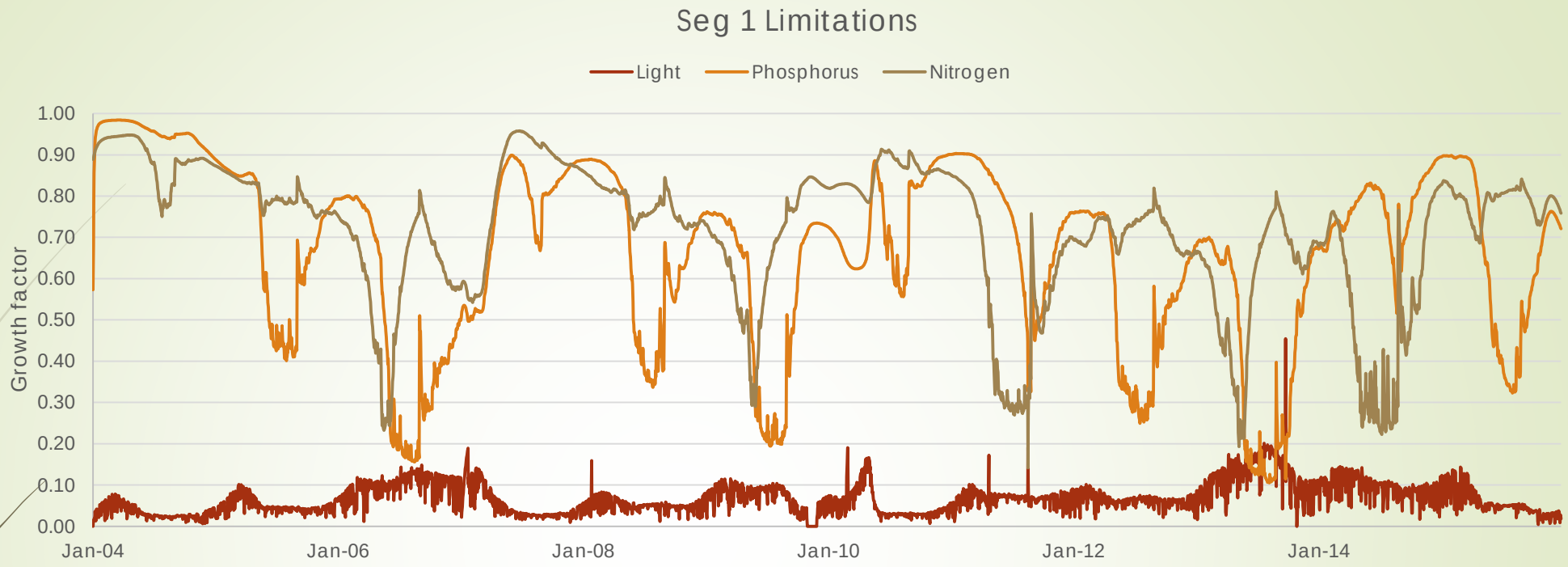
Conclusions

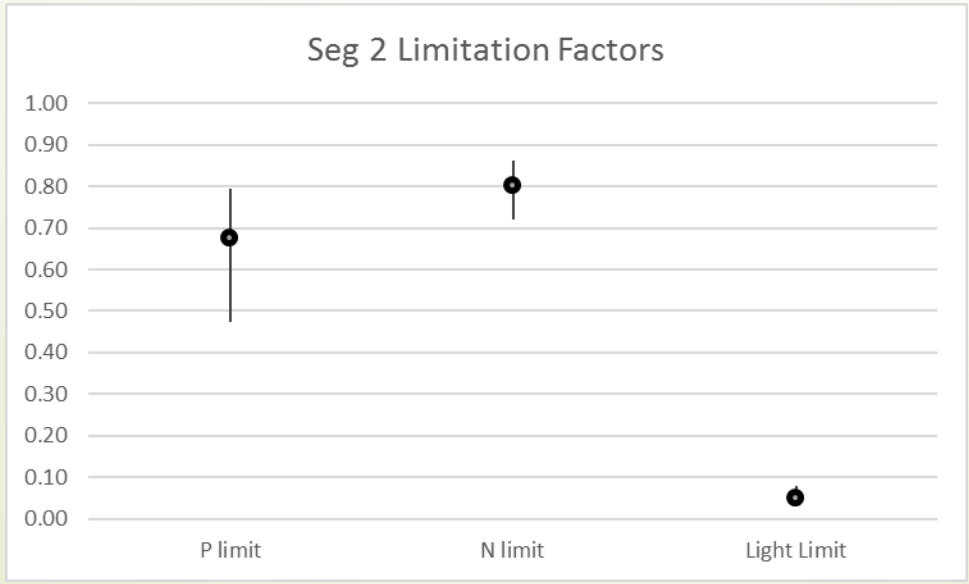
- Water quality in large reservoirs is difficult to change
- Why?

Chl’a’ Limitation

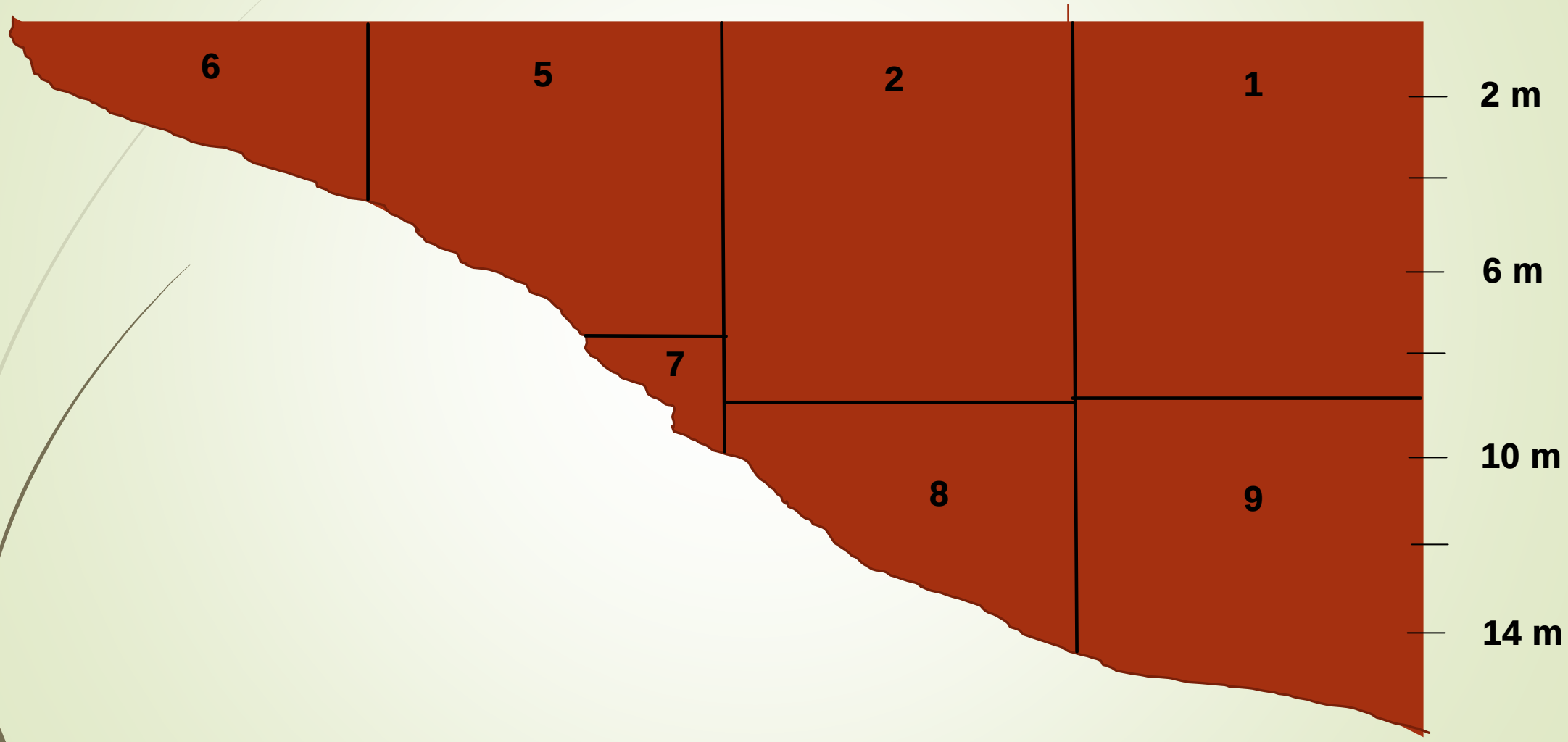
Leibig’s Law of the Minimum controls algae growth



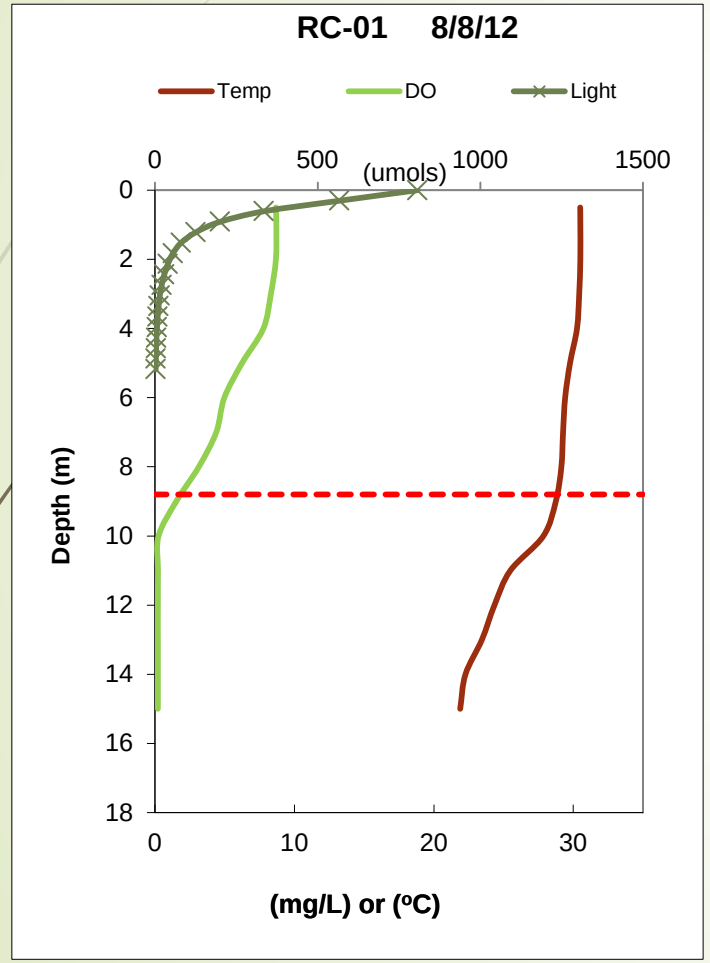

Seg 1 Limitations
Light
Phosphorus
Nitrogen
Growth factor
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14

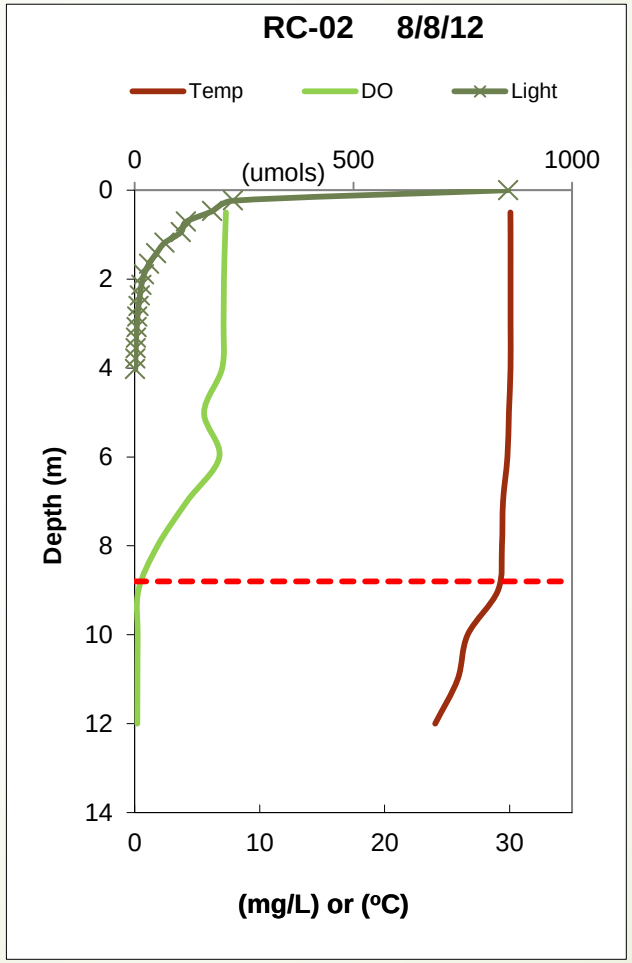

Seg 2 Limitation Factors
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
P limit
N limit
Light Limit

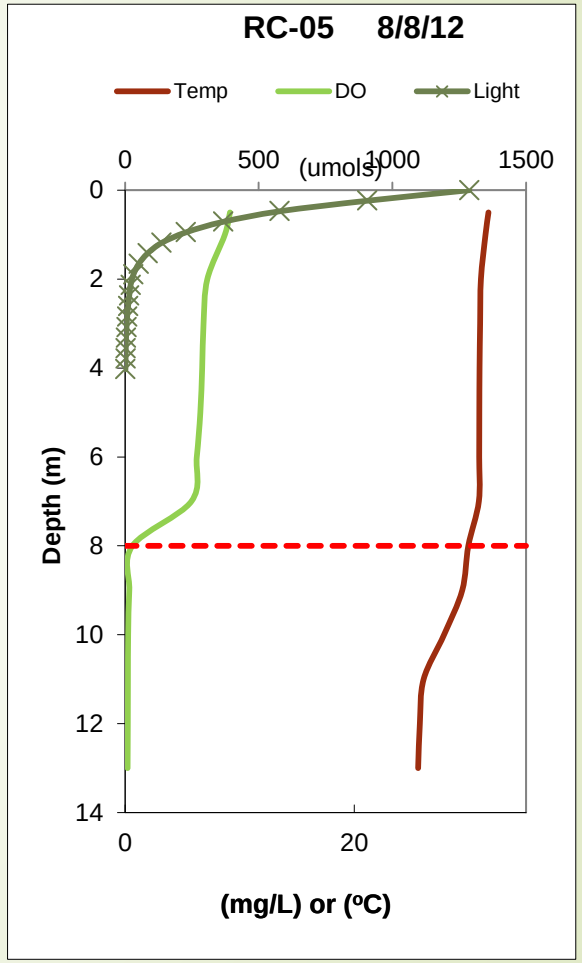
Cross Section of Chambers Arm of RC Reservoir



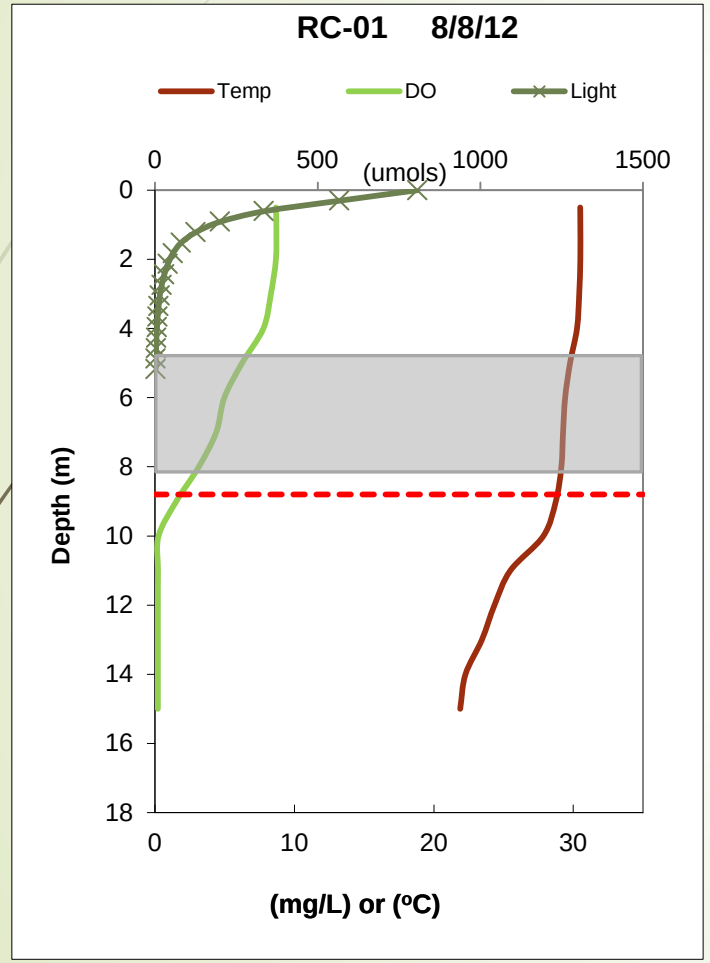
RC Vertical Profiles

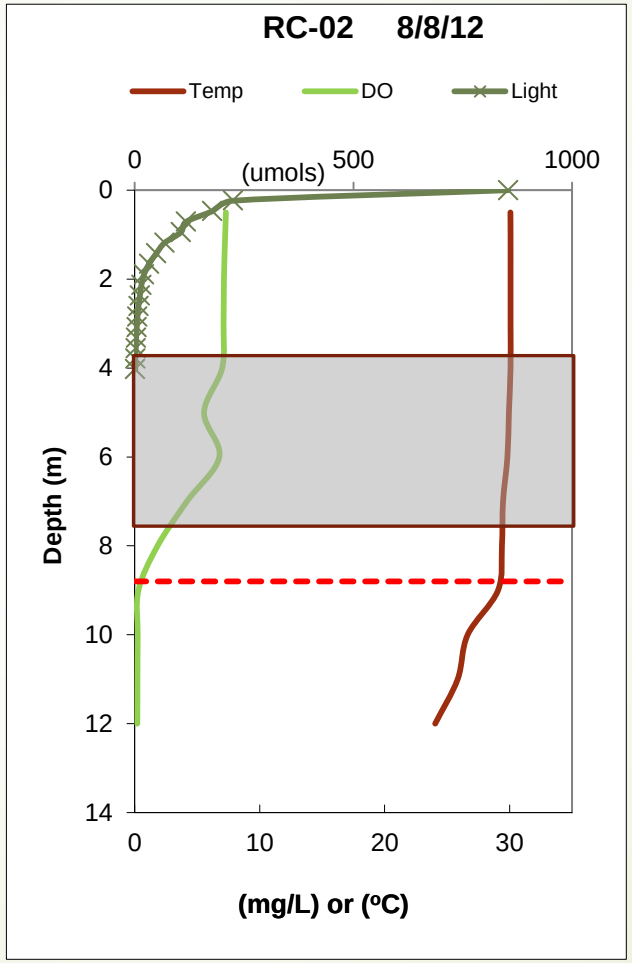


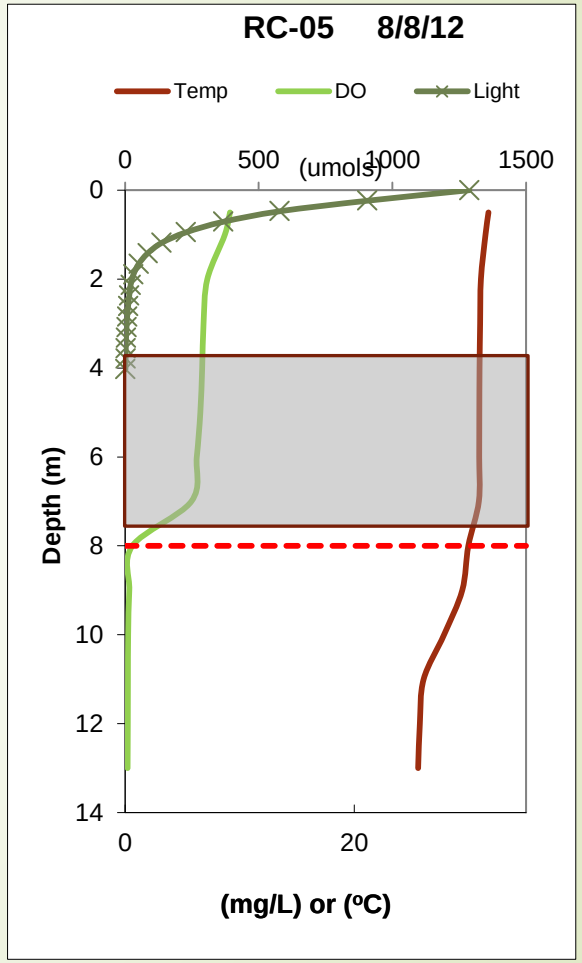




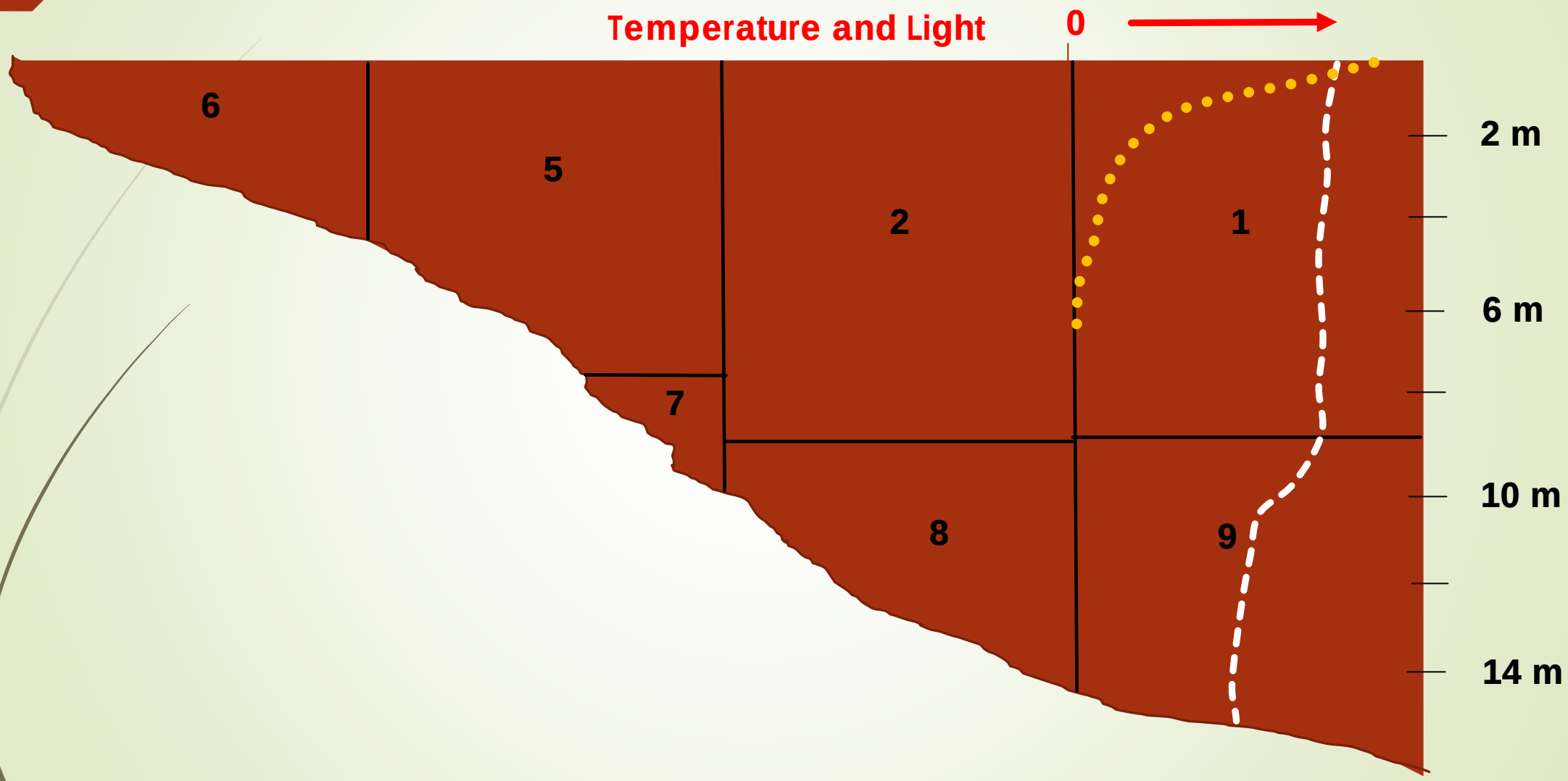
RC Vertical Profiles







Cross Section of Chambers Arm of RC Reservoir



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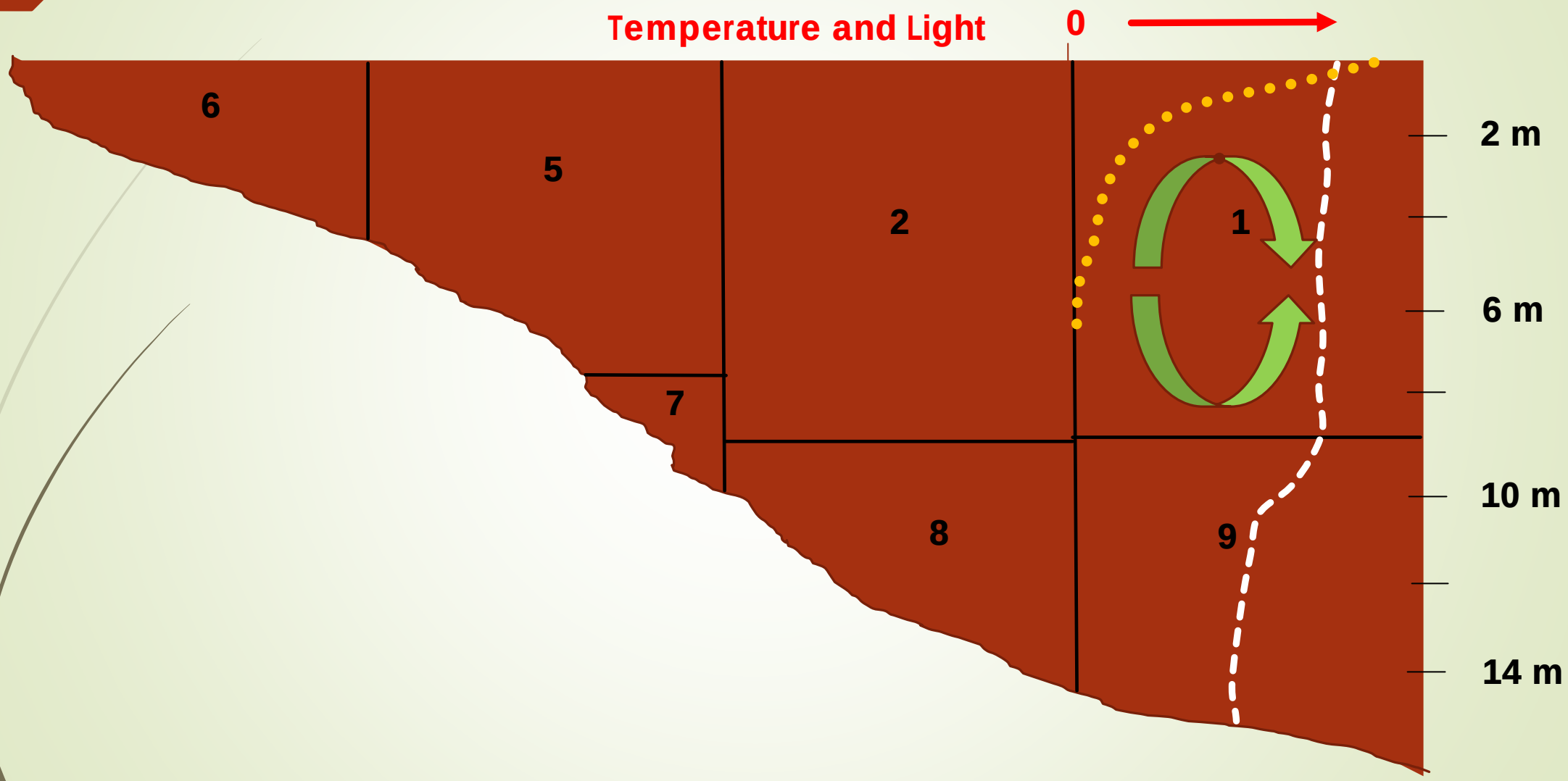

Chl’a’ Light Limitation

- Rapid Light extinction not necessarily a result of highly turbid water (although there are some fine clays that remain in suspension) as much as it is a result of deep mixing.

Future work

- Inclusion of a second or third algae group (diatom, bluegreens)
- Additional work with NOX, seasonality
- Greater understanding of the depth of mixing for algae
- Development of a true hydrodynamic model (EFDC) to improve scenario testing