Hydroperiod Effects on Annual Release Rates of N, P, and DOC in a Floodplain Wetland

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WSIS Biogeochemistry Objectives

Develop tools to support evaluation of specific proposals of water withdrawals or management.

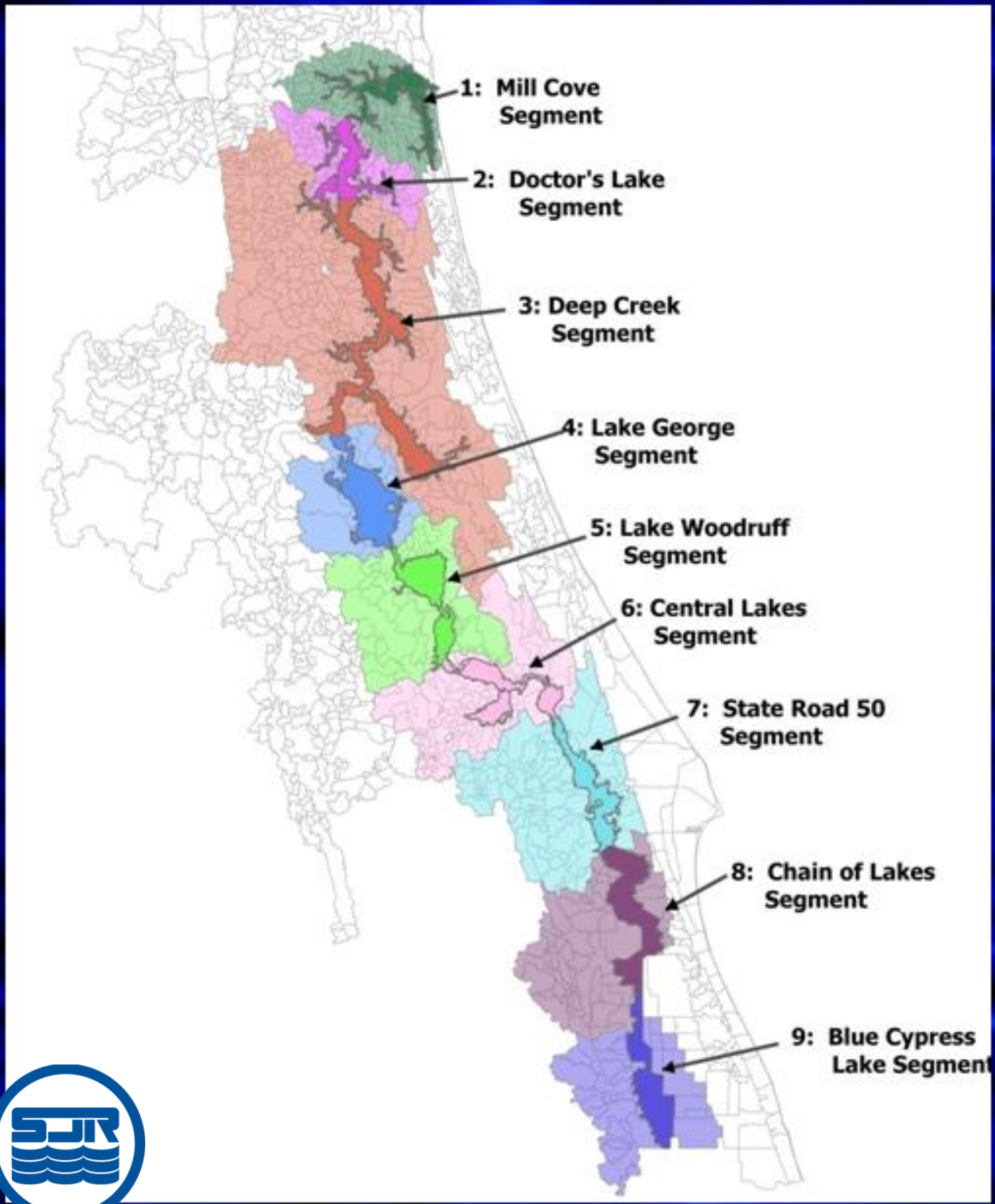
- Wetland Release Model – Mass released
- Reduction Model – Mass transferred
- Response Model – Effect on waterbody

Assess specific withdrawal scenarios.

Limiting Conditions

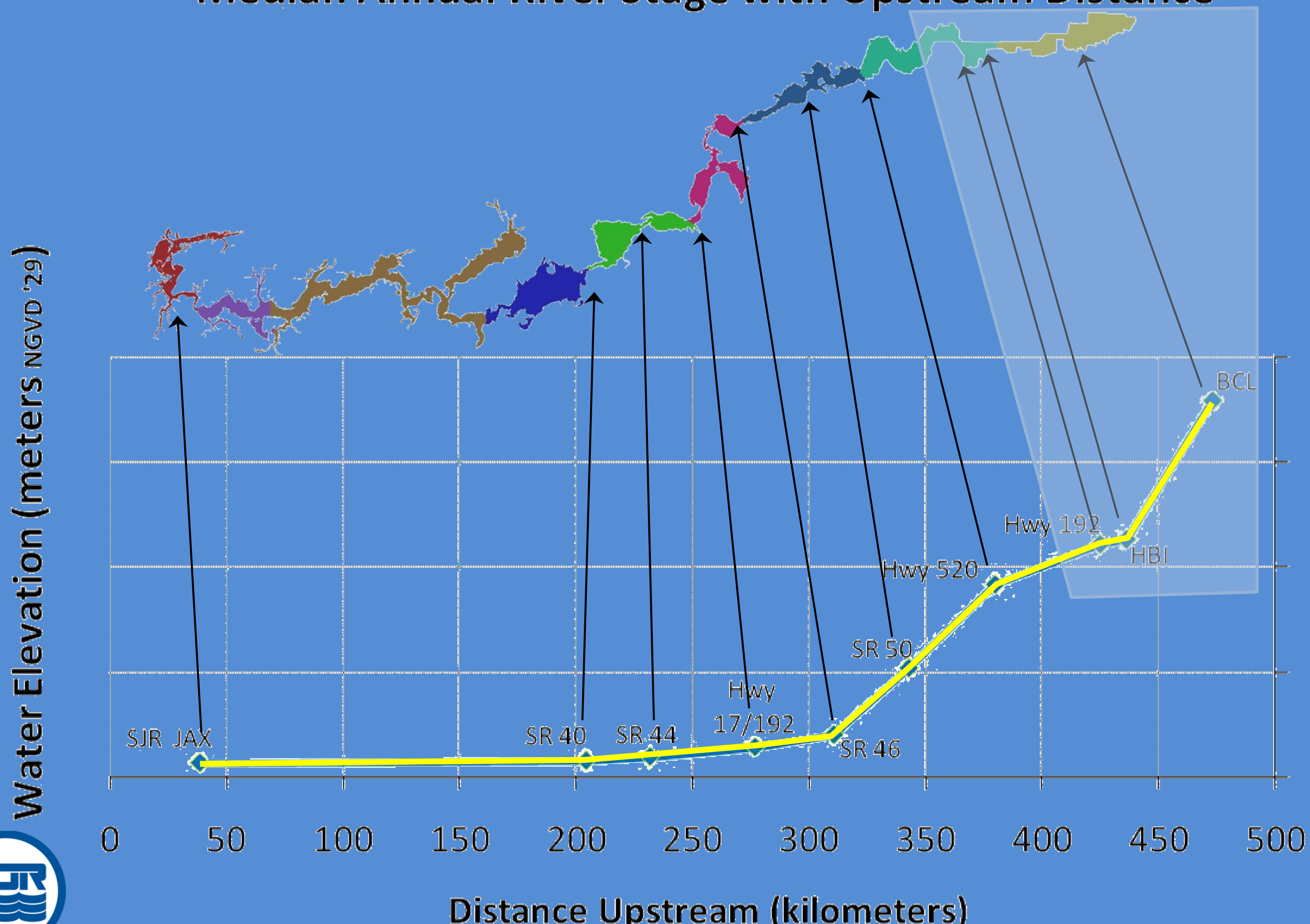
- Only predominately organic soils are considered.
- Only wetlands (soils) potentially affected by water withdrawals are considered.
- Only the effects of loading on the river are addressed.

St. Johns River - Main Stem

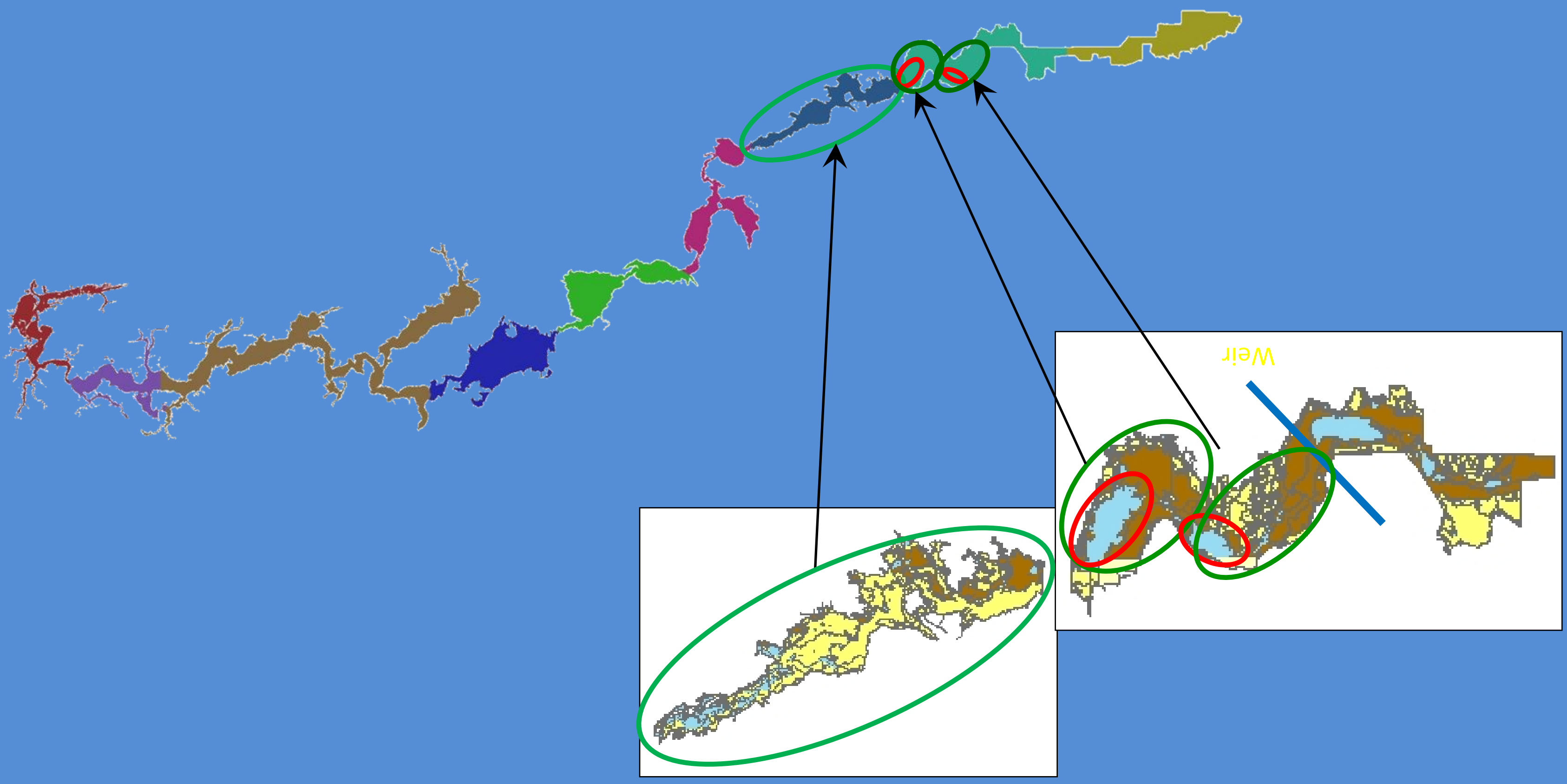


Ecologically similar Segments. River slope of <9 meters over 500 kilometers

Median Annual River Stage with Upstream Distance

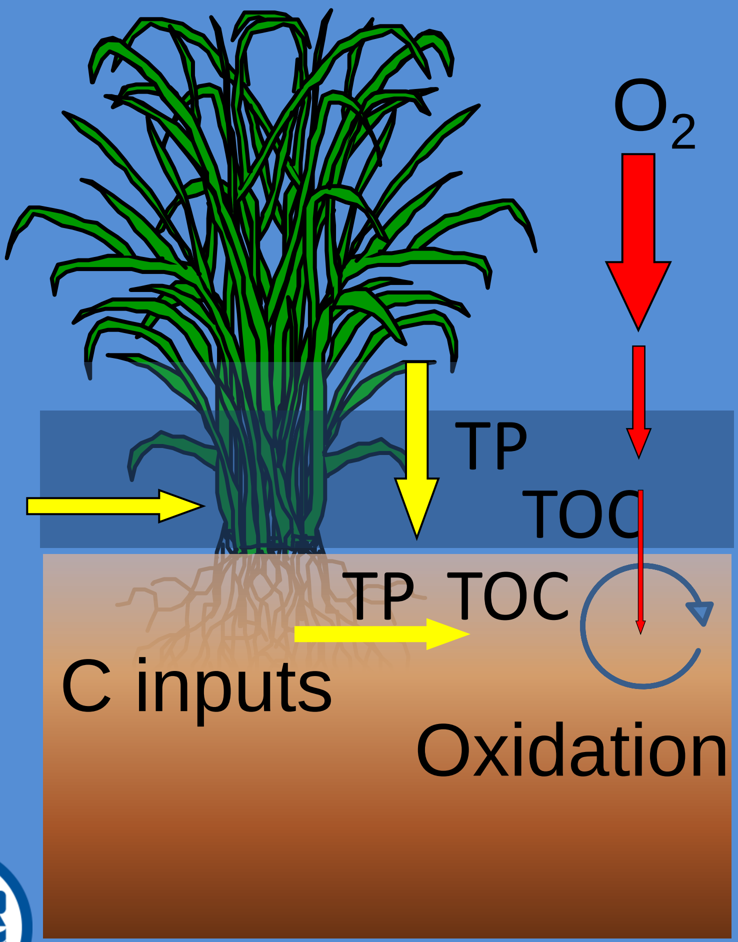


Lakes with Potential Affects from Withdrawals

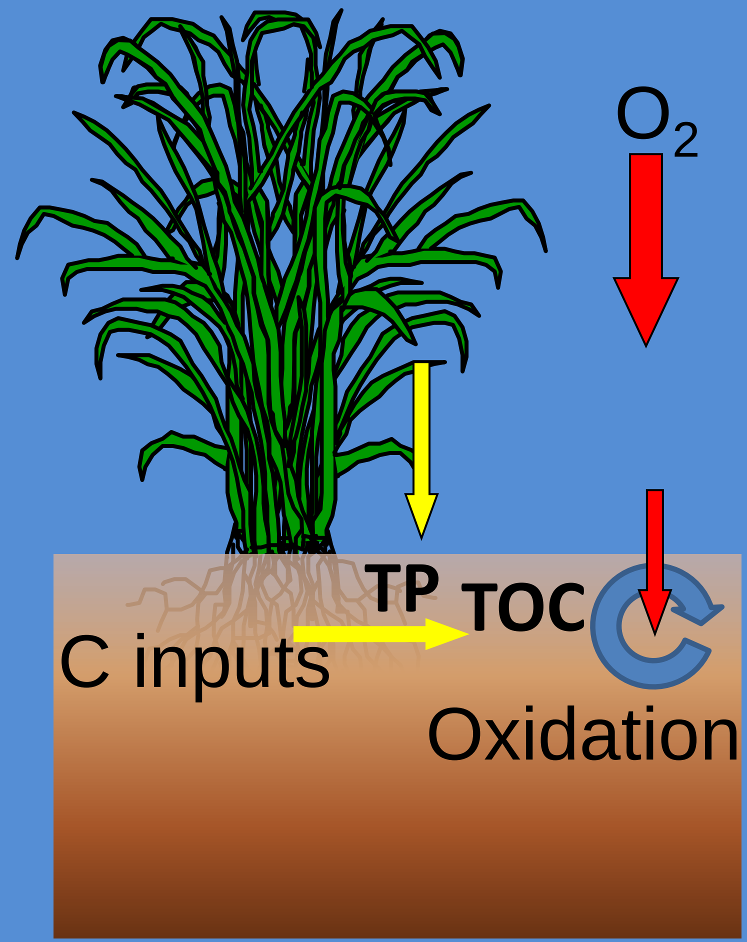


Biogeochemical Working Group Hypotheses

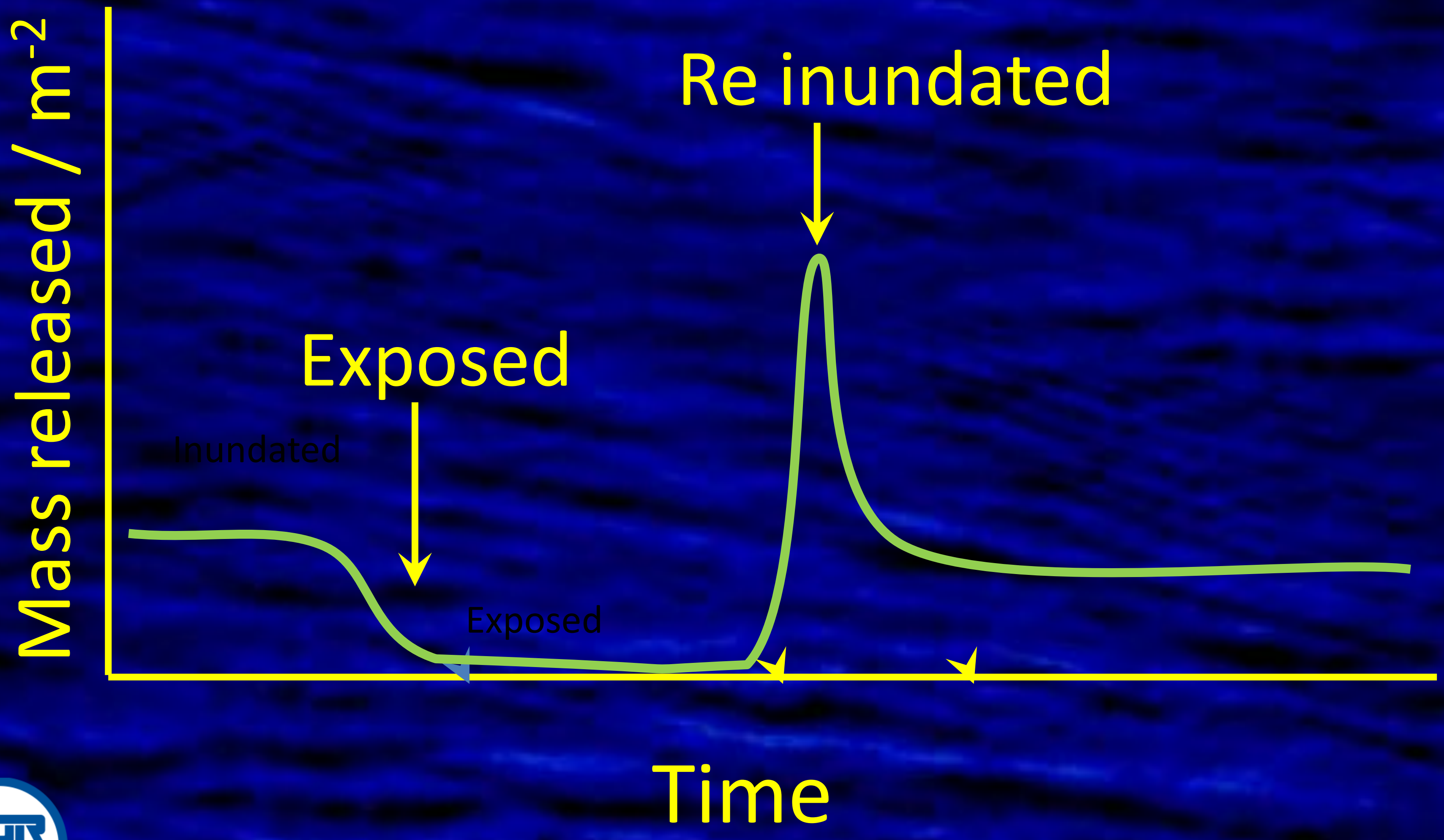
Inundated



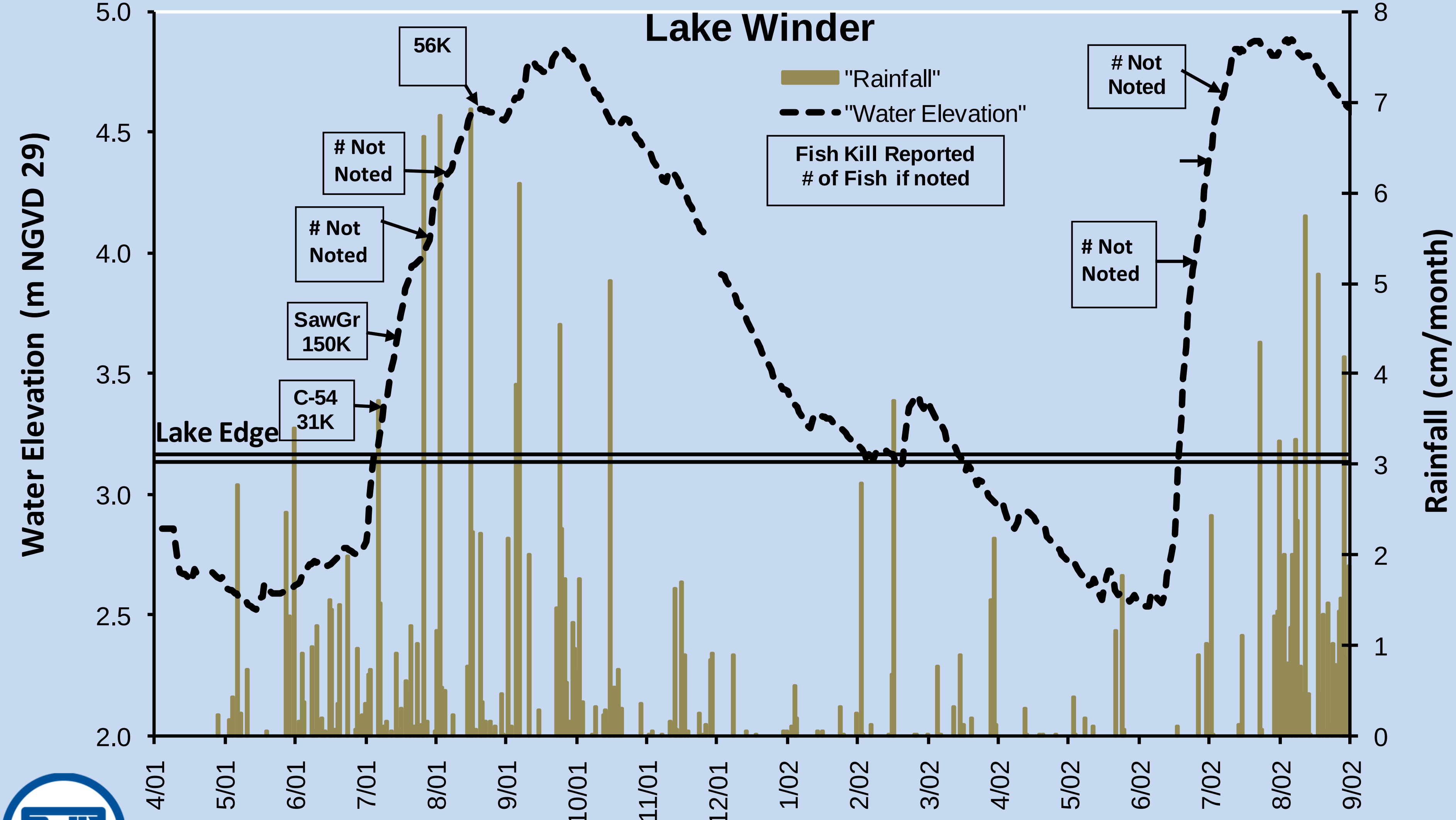
Exposed

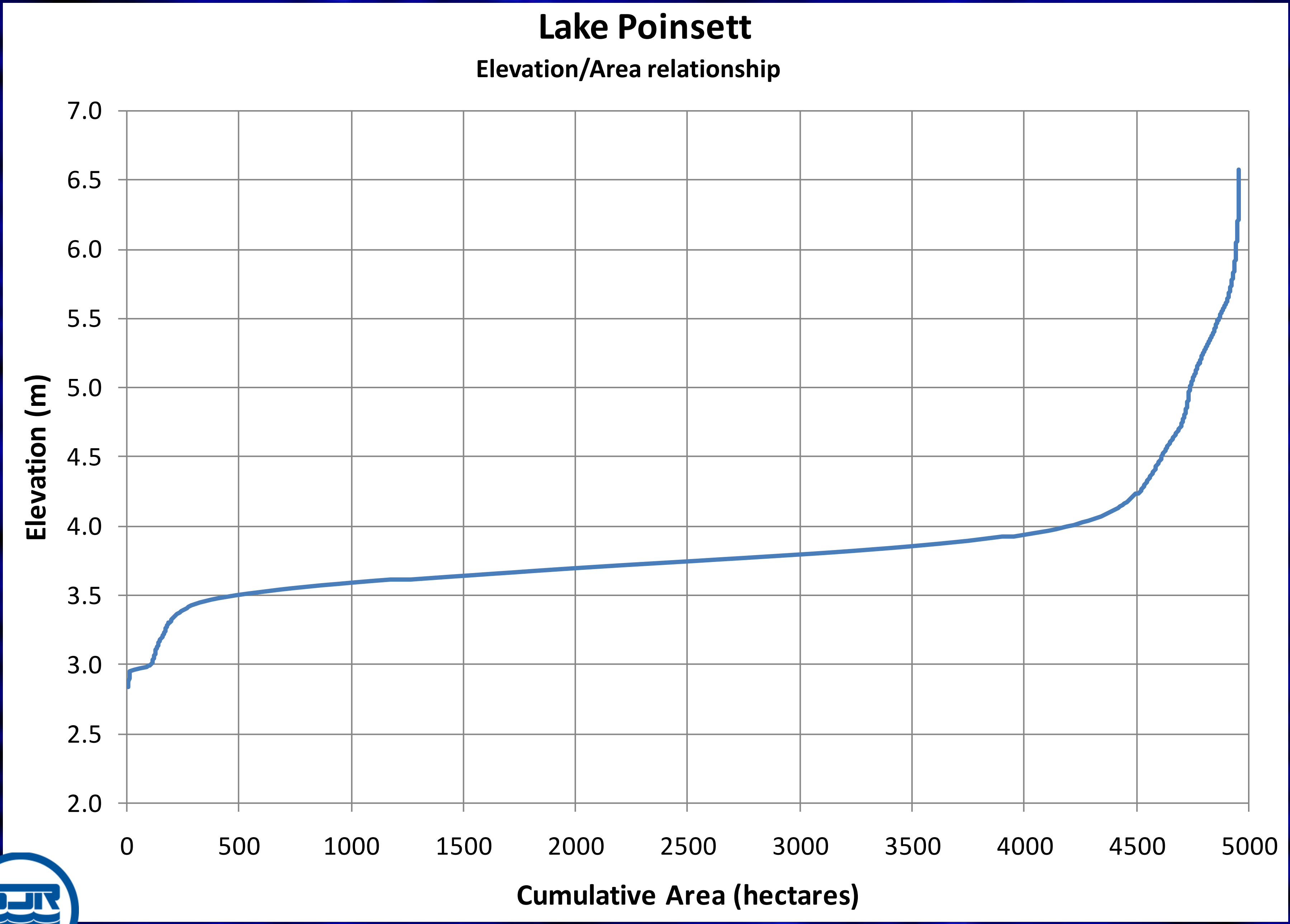


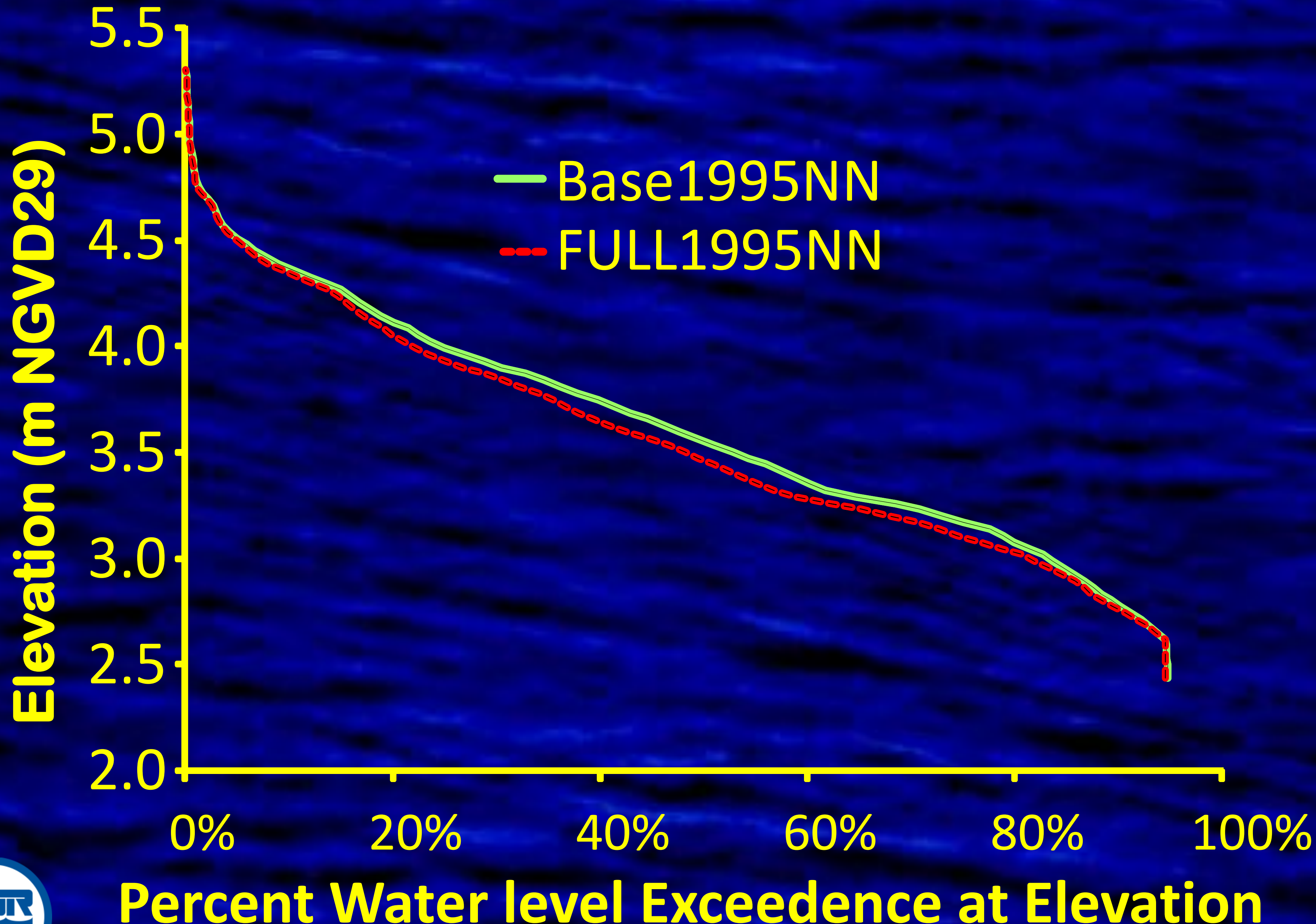
Effects of Hydroperiod on Release of Dissolved Products of Oxidation



Fish Kills Associated with Rain Events When River Stage is Above Wetland Surface




Lake Poinsett
Elevation/Area relationship
Elevation (m)
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Cumulative Area (hectares)



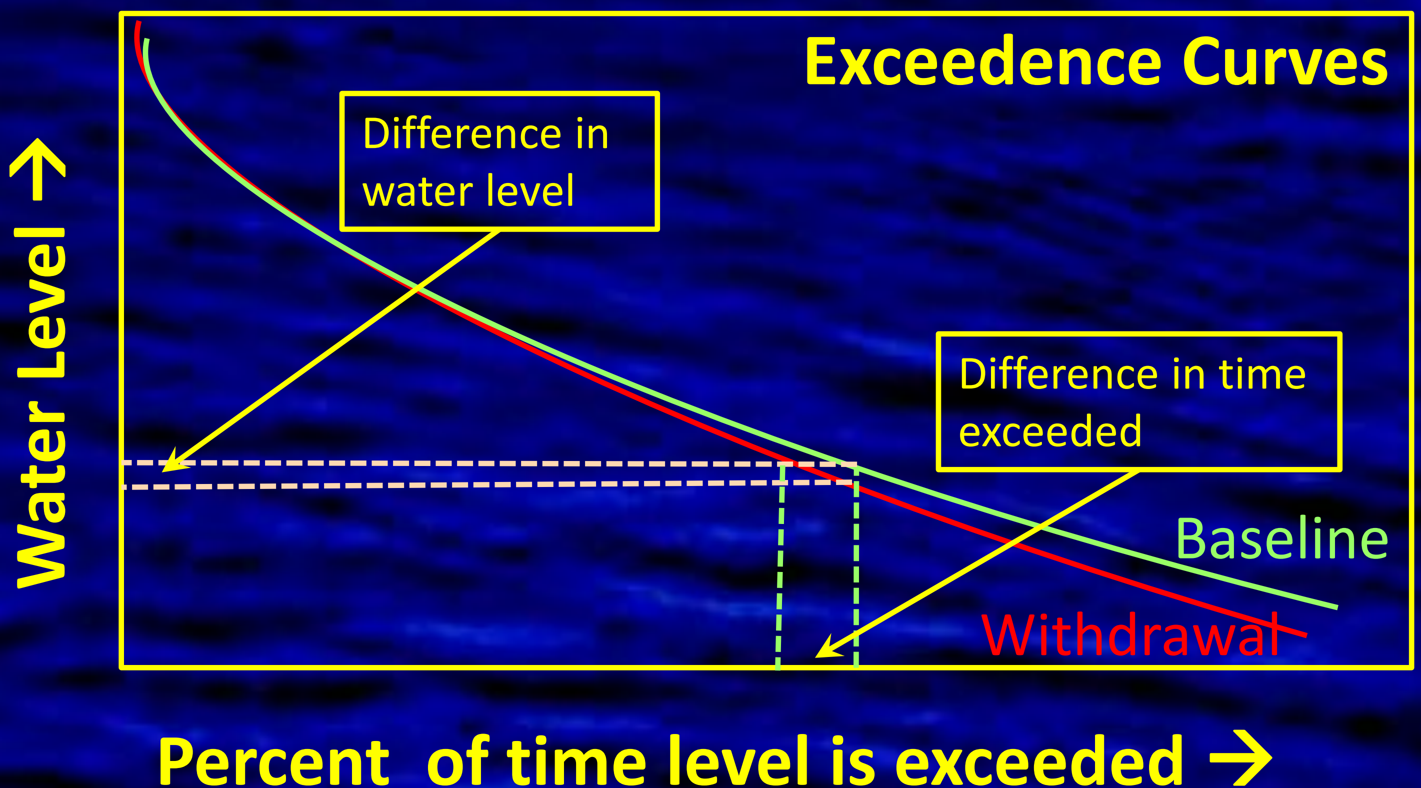
Base1995NN
FULL1995NN
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
Elevation (m NGVD29)
0%
20%
40%
60%
80%
100%
Percent Water level Exceedence at Elevation

Amplification through the chain of causation.

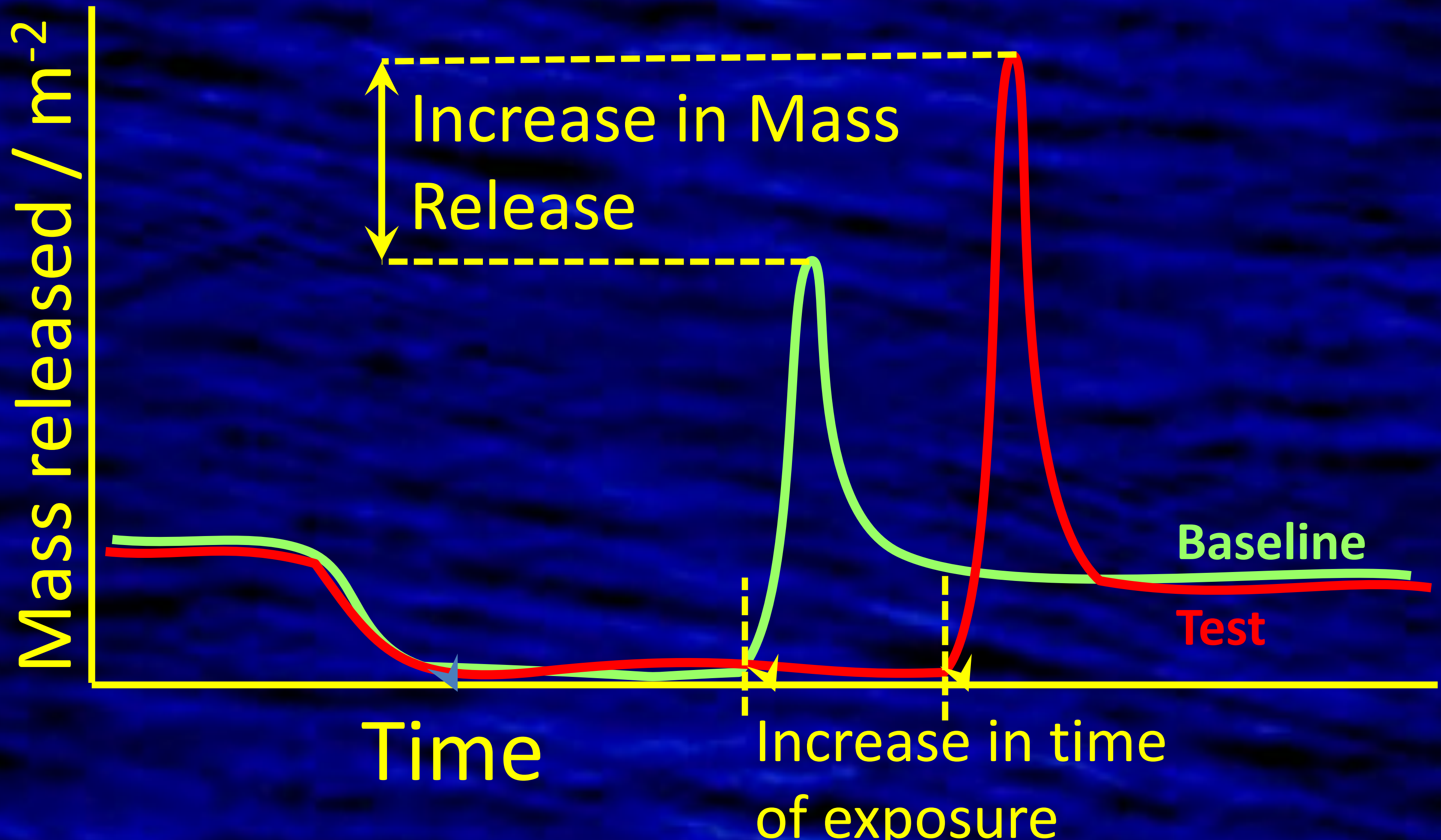
Minor change in water elevations (stage)

May result disproportionately increase in exposure period of organic soils

Resultant increase in loading may be greatly magnified effect acting over a broad expanse of wetland soils



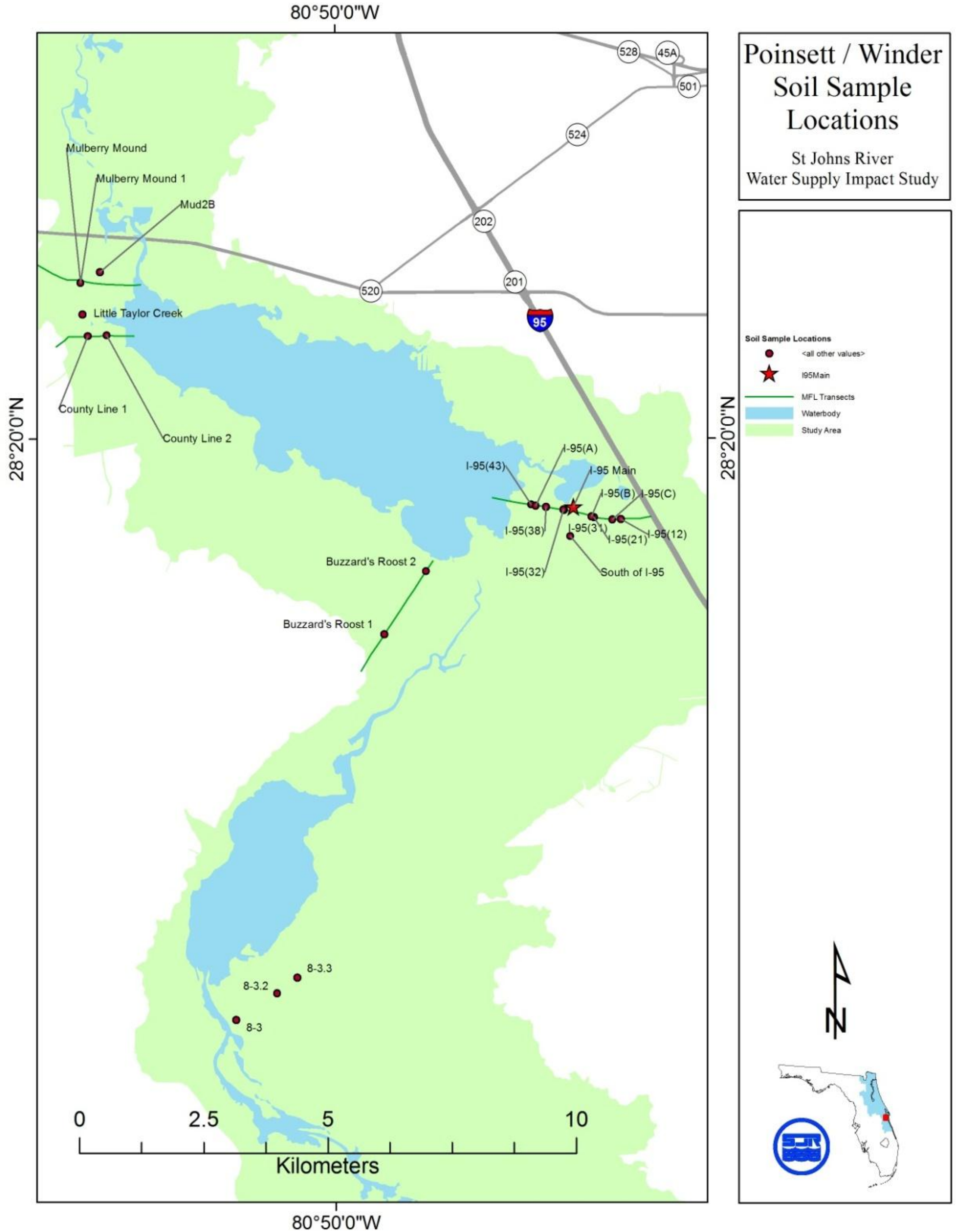
Effects of Hydroperiod on Release of Dissolved Products of Oxidation



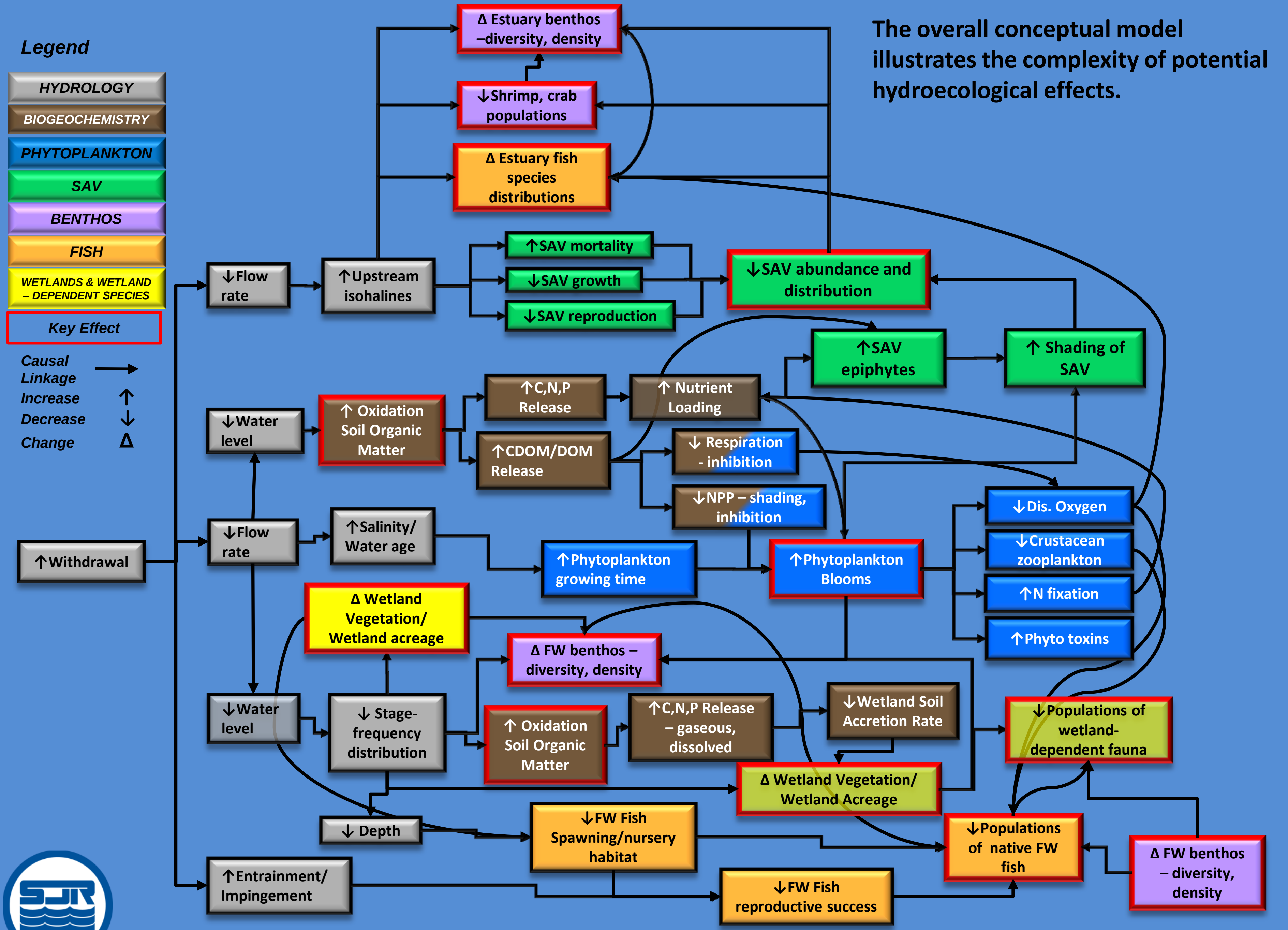
$$\text{Daily Release Rate (R)} = \frac{\text{Increase in Mass}}{\text{Increase in time of exposure}}$$

Soil Sample Locations

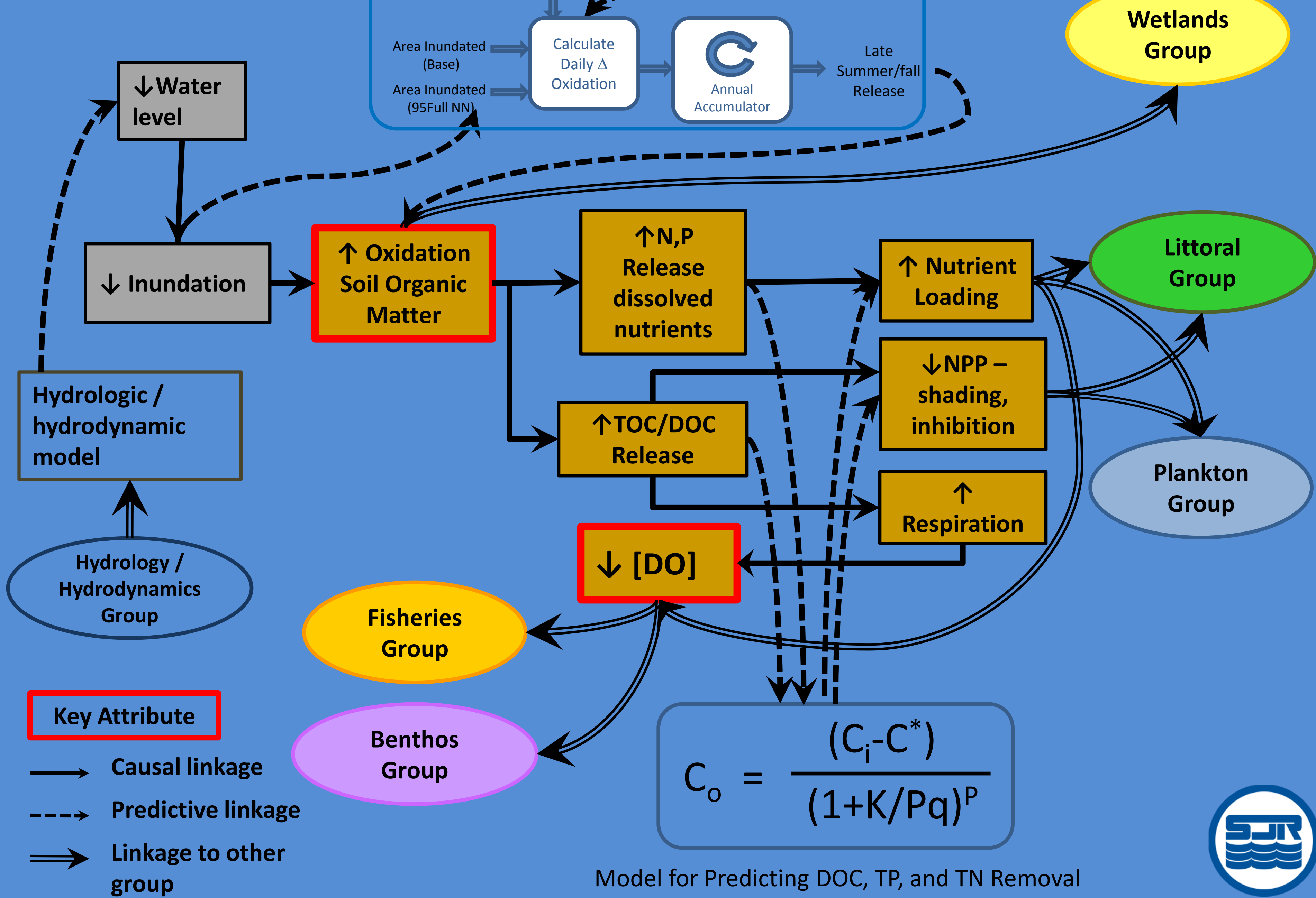
Lakes Winder & Poinsett



The overall conceptual model illustrates the complexity of potential hydroecological effects.



Conceptual model for Biogeochemistry



Release Model

⇩

Additional mass released/yr

⇩

Removal Model

⇩

Additional mass in Lake ⇨ Plankton & Littoral groups

⇩

Flow / Mass Balance

⇩

Additional concentration in Lake

⇩

Response model equation fit of Lake WQ

⇩

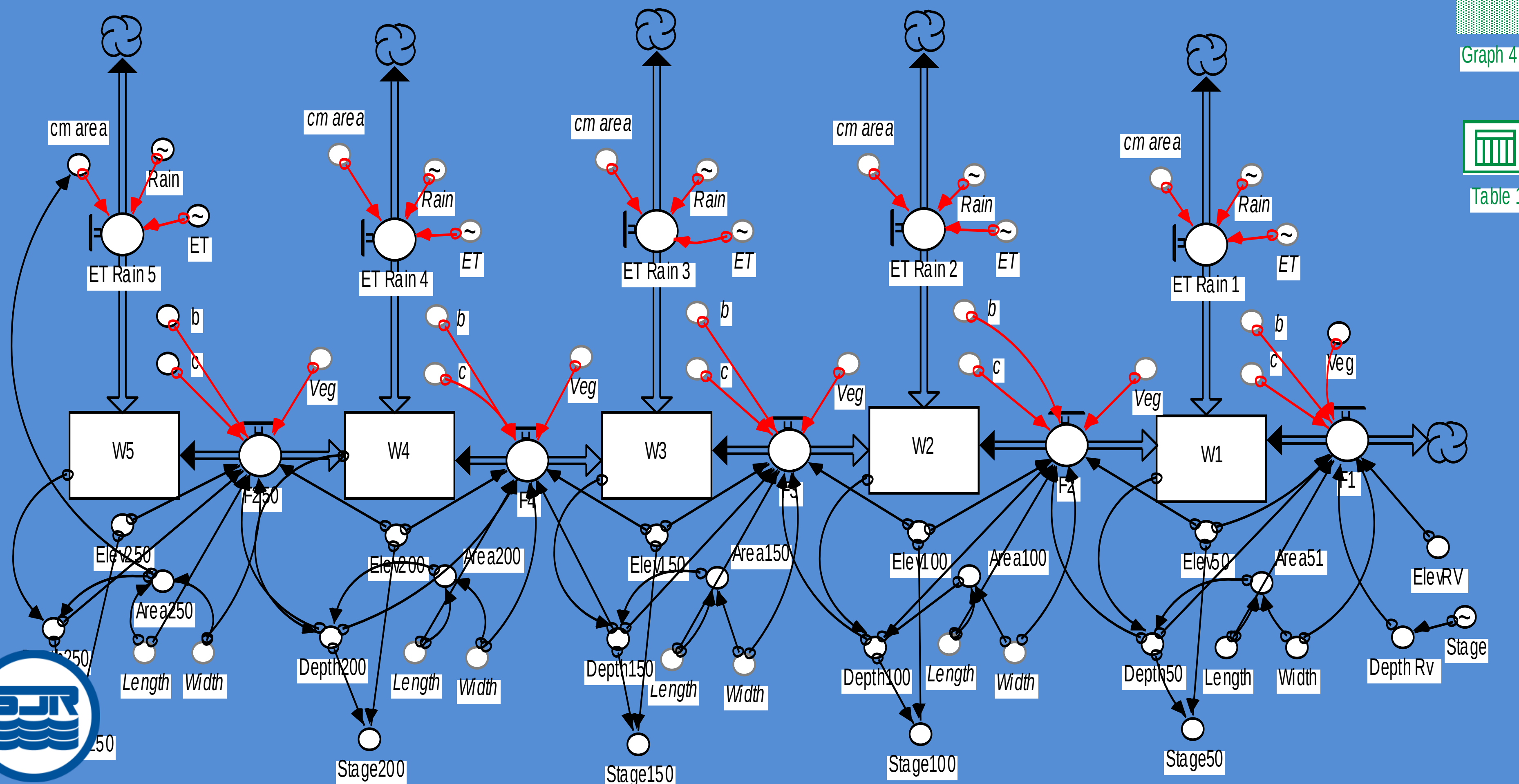
Decrease in DO in Lake ⇨ Fisheries & Benthos groups

STELLA© Wetland Hydrologic Model

Based on Kadlec & Wallace,2008, Generalized Friction Equations for Wetland Flow

$$\mathbf{u = a\,h^{(1\text{-}b)}\,S^{c}}$$

Velocity = cross-sectional area x Depth to the (1-b) power x -Slope to the (c) power



Wetland Release Model Input Values

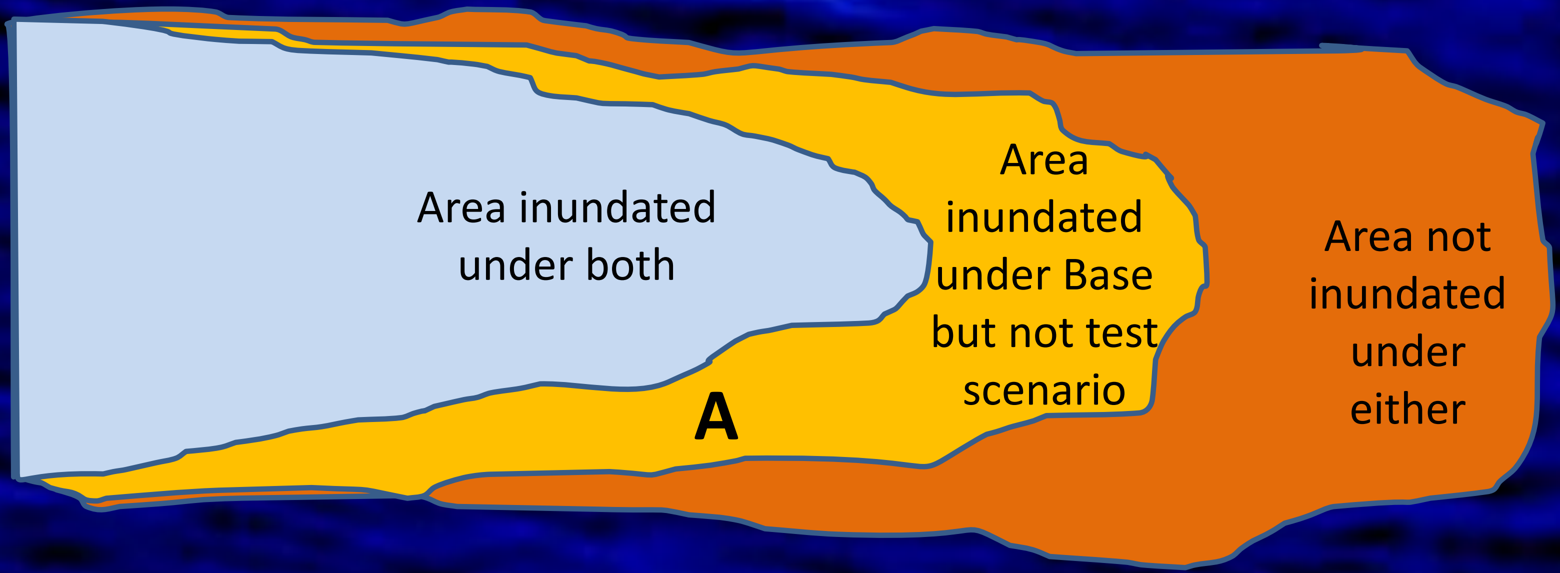
Variable	Study	Days of Exposure	N	Release per day of exposure
				mg m^{-2} d^{-1}
DOC	Field Cores	30	12	**18.7**
TKN	Diameter	61	30	**2.28**
TP	Diameter	61	30	**0.59**

Reduction Model Input Values

Constituent	1st Quartile	2nd Quartile	3rd Quartile
BOD/DOC	0.03	**2.72**	6.79
TKN	1.21	**3.69**	7.08
TP	-0.33	**5.80**	11.89

Note:
BOD/DOC = biochemical oxygen demand equated to dissolved organic carbon
TKN = total Kjeldahl nitrogen
TP = total phosphorus

Release Model calculates area of difference (A) for each day of the scenarios.



$$M = \sum_{1}^{365} (R \bullet A \bullet K)$$

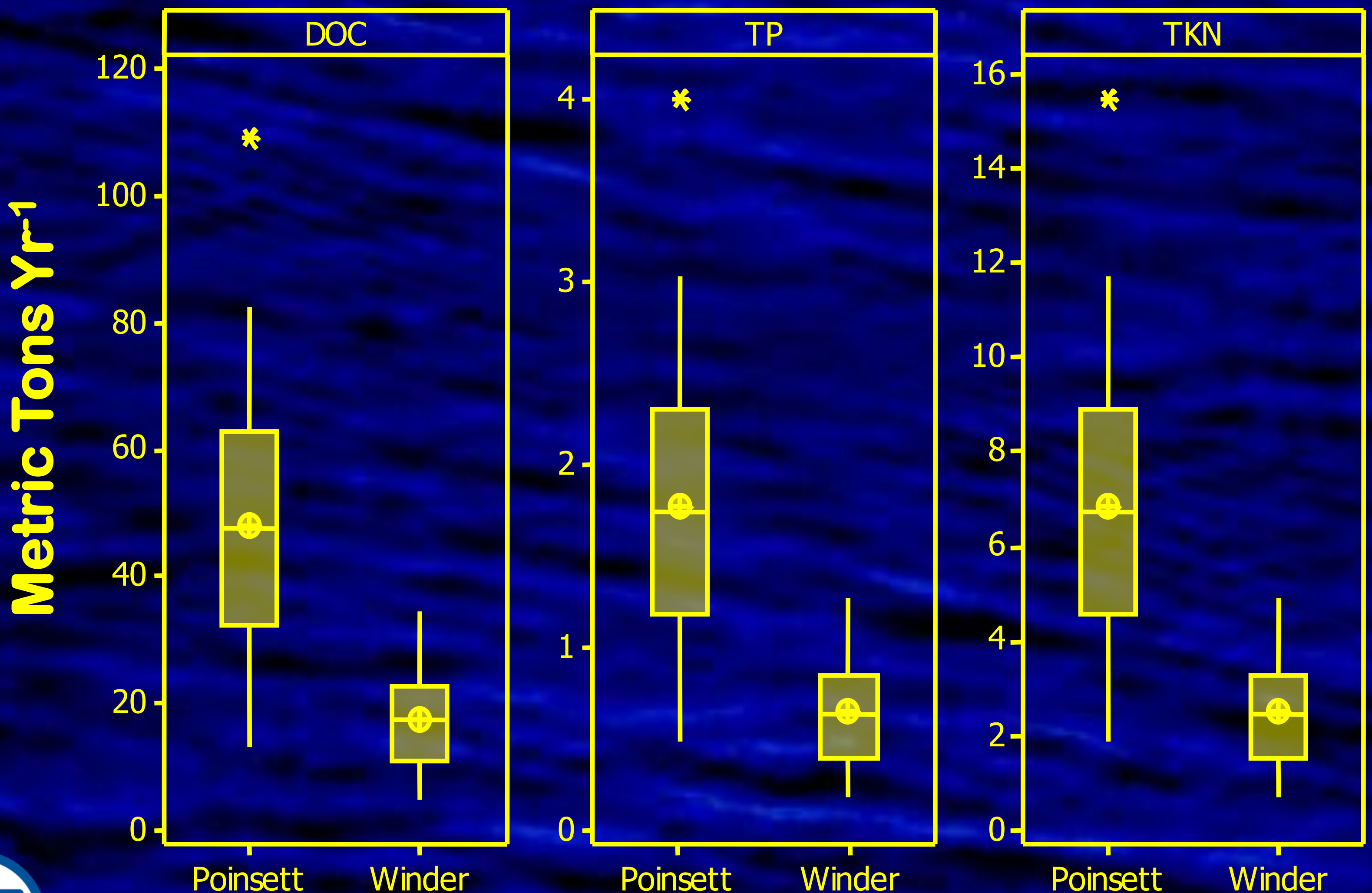
M = potential change in mass release (g)

R = areal daily increase in release when exposed ($g\ m^{-2}\ d^{-1}$)

A = additional area exposed ($m^2\ d^{-1}$)

K = temperature correction

Release Model Estimates



Reduction Model Calculations

$$L_r = M_i\left(\left(1 + \left(\frac{K}{P \times q}\right)\right)^{-p}\right)$$

L_r = Outflow load (g)

M_i = Inflow Mass (g)

K = Removal coefficient (m d^{-1})

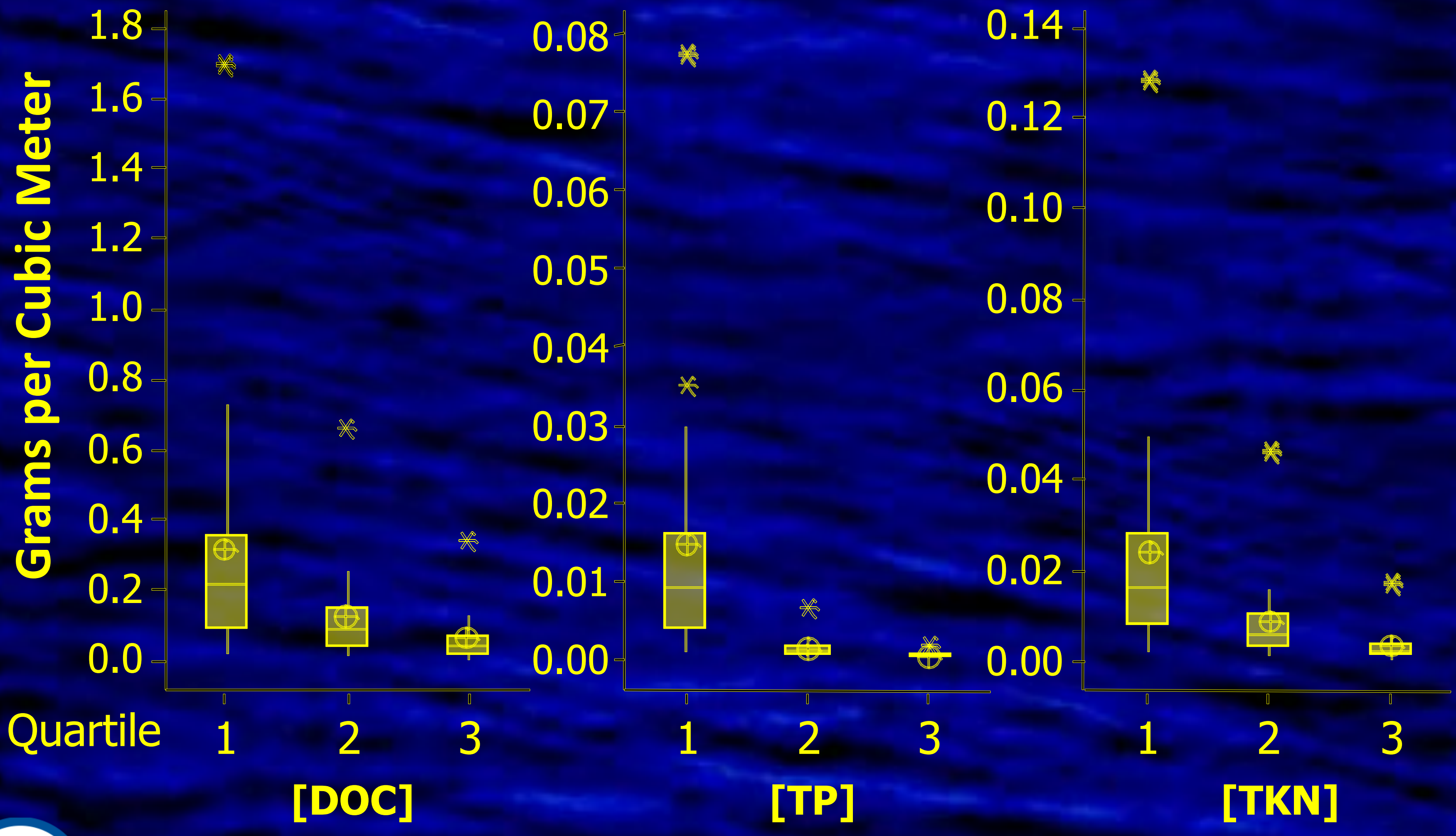
P = Number of tanks in series

corrects for variable flow path lengths and eddy diffusivity

q = Hydraulic loading (m d^{-1})

Derived from Tanks in Series Model, Kadlec and Wallace (2008)

Mass Balance Estimates: Combined Concentrations



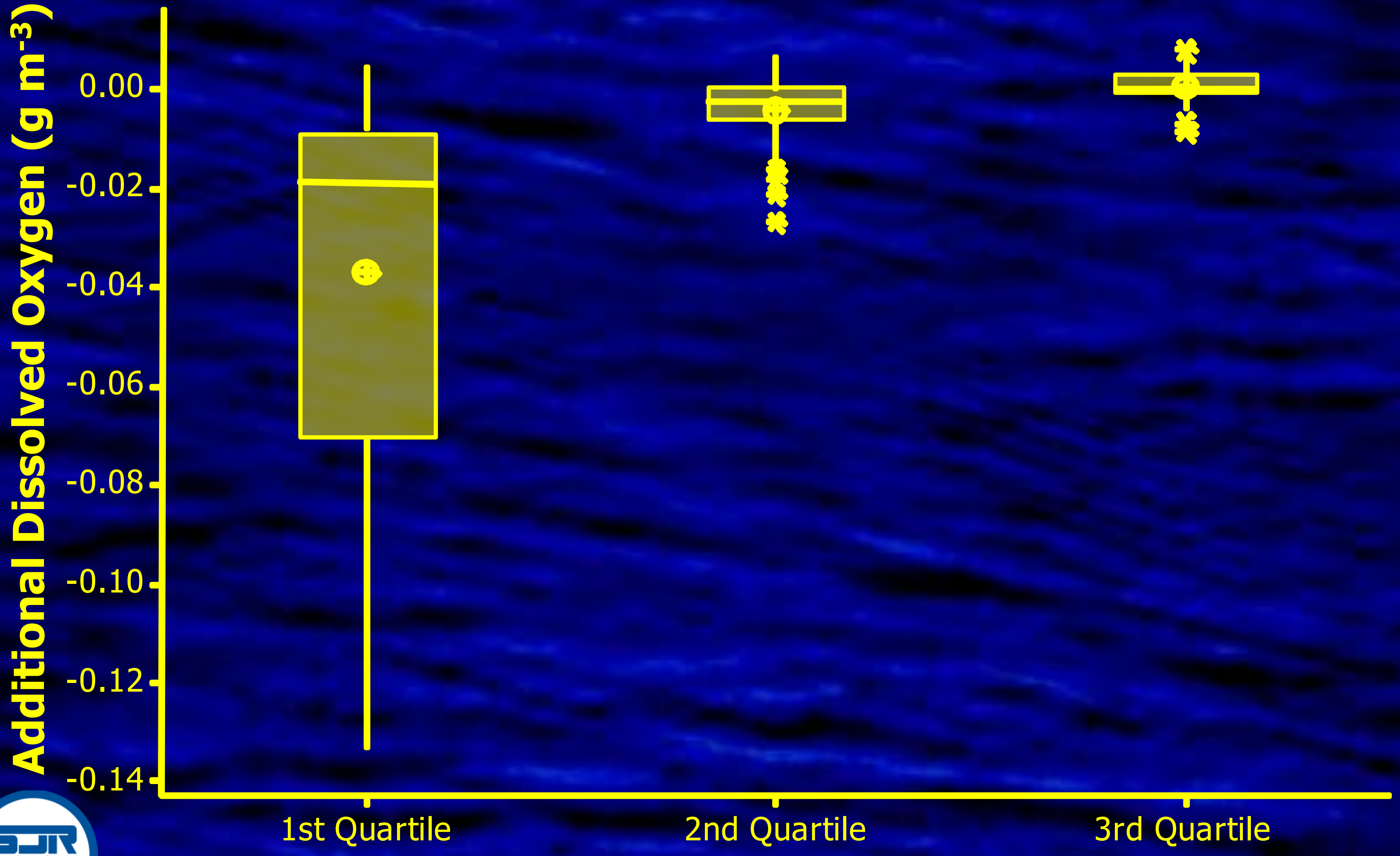
Response Model for Change in Dissolved Oxygen - Multiple Regression Model

The best model ($p<0.0001$; adjusted $r^2 = 0.415$) for predicting changes in [DO] in lake water from available information was a multiple regression:

$$\Delta [DO] = (-0.1014 \text{ mg L}^{-1} \text{ m}^{-1} \times \Delta \text{ water elevation}) + (-4.61097 \times \Delta [TP]) + (-0.07393 \times \Delta [TOC])$$

where water elevation is in meters above sea level NGVD29 and all concentrations are in mg L^{-1}. All parameters were significant at the $p < 0.05$ level.

Predicted Monthly Dissolved Oxygen Changes for Different Removal Rate Quartiles



Soil Organic Activity in Different Areas

Marsh Conservation Area (MCA)	n	Histosol Suborder	Bulk Density (g cm^{-3})	Loss on Ignition (%)	C:N Ratio (mass basis)	Soil Organic Matter (SOM) Activity*
Fort Drum MCA	12	Fibrists	0.06	95	17	Active
St. Johns MCA	36	Hemists	0.13	91	14	Slow
Blue Cypress MCA	**6**	**Fibrists**	**0.08**	**95**	**17**	**Active**
Three Forks MCA	6	Hemists	0.08	90	14	Slow
Lake Poinsett Wetlands	**6**	**Saprists**	**0.2**	**58**	**10**	**Passive**

Note:
*Soil organic matter activity is a measure of how quickly the organic matter fraction of soil will decompose, and is categorized as active, slow, or passive based on the C:N ratio.
n = Number of observations
C:N = Carbon to nitrogen ratio

Active SOM = C:N of 15 to 30, decomposition in 1 to 2 yrs
Slow SOM = C:N of 10 to 20, decomposition in 15 to 100 yrs
Passive SOM = C:N of 7 to 10, decomposition in 500 to 5,000 yrs

Brady & Weil, 2008

Results

- The refractory Lake Poinsett soils predicted less than a 0.05 mg L^{-1} decrease in DO.

- However, if we use the release rates from labile Blue Cypress Marsh soils, the median decrease would be 2.45 mg L^{-1}.

- Results are VERY soil (site) specific!

Conclusions

- The specific water withdrawal scenarios in this study were predicted to have only negligible ecological effects due to wetland biogeochemical dynamics.

- Modeling tools developed in this study are applicable to assist in assessing water withdrawals or management effects with when site specific information is available.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