

# High Frequency Water Quality Data: Is this really necessary?

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# In Environmental Sciences we...

- ... want to tell the story of how the world functions
- ... make hypotheses
- ... we collect data *partial in space and in time*
- ... infer processes at play, quantify, extrapolate, model
- ... make conclusions on how the world functions and what we should do about it

# A little story

" ... ..Troy ... .. . ... .. hard; ... .. .  
... .. . ... .. unconscious ... .. , ... .. .  
face ... .. . ... .. bad ... .. ."

# A little story

" ... ..Troy ... .. . Marc ... .. . hard; ... .. .  
... .. . forehead. ... .. . unconscious ... ..  
floor, ... .. . face ... .. Marc ... .. . all ... .. .  
... bad ... .. . feared."

# A little story

"Marc ... .. ; ... missed ... ..  
... .. Troy ... .. smile ... ..  
... .. not ... .."

# A little story

"Marc ... .. catch. ... .. ball... ; ... missed ...  
... .. landed ... .. Troy ... .. unconscious ... ..  
... .. smile ... .. reassured ... .. was ... ..  
... not ... .. feared."

# A little story

"Marc and Troy were playing catch. Marc threw the ball hard; Troy missed it and it landed on his forehead. Troy was laying seemingly unconscious on the floor, but the smile on his face quickly reassured Marc that everything was all right and not as bad as he had feared."

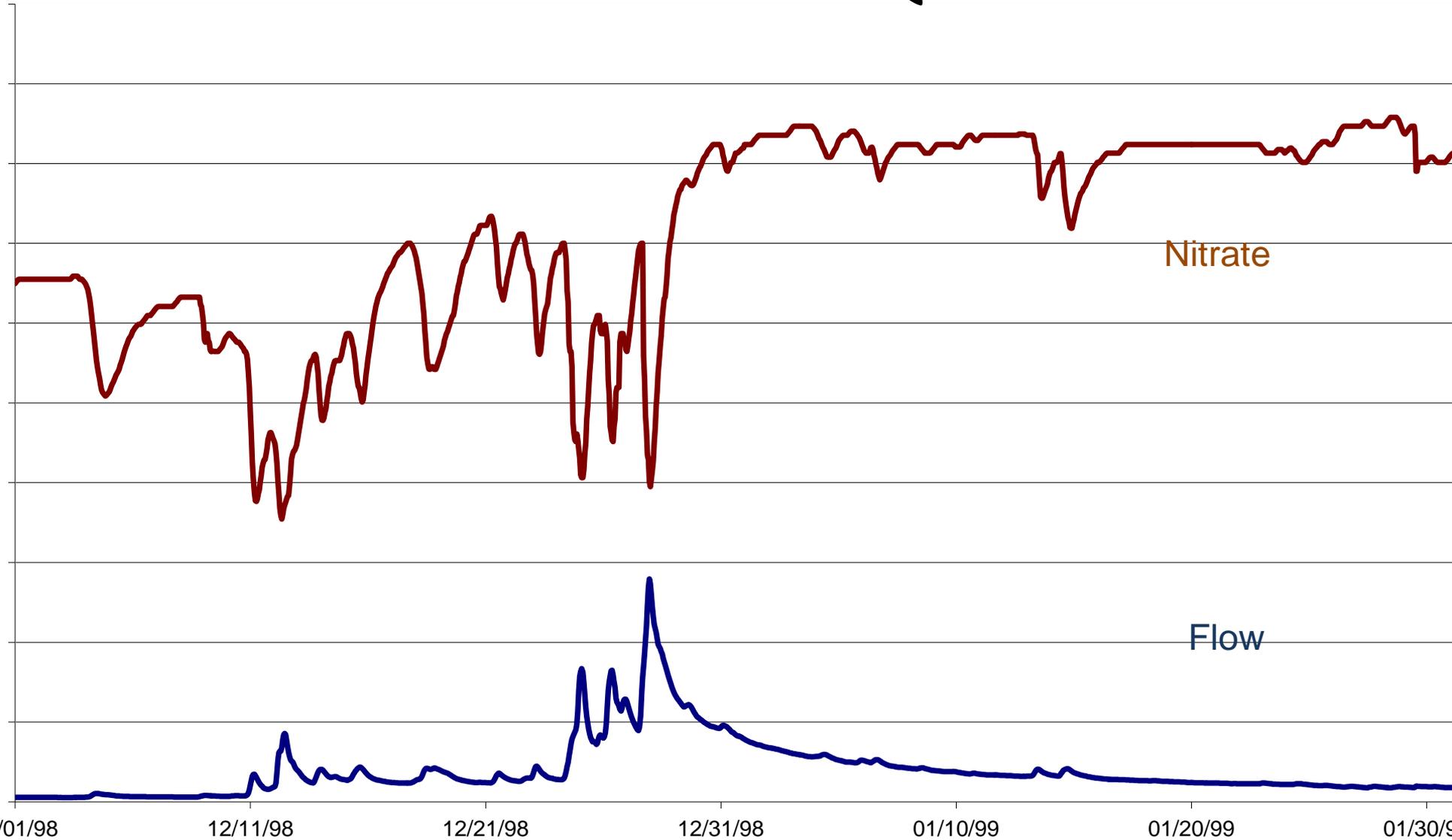
# Working with natural waters

- Flow, nutrient and pollutant loads intrinsically linked to rainfall pattern
- Rainfall is unpredictable
- There are no two same rainfall events
- Extrapolating from measurements made during a few rainfall events or throughout the year, regardless of rainfall is *RISKY*

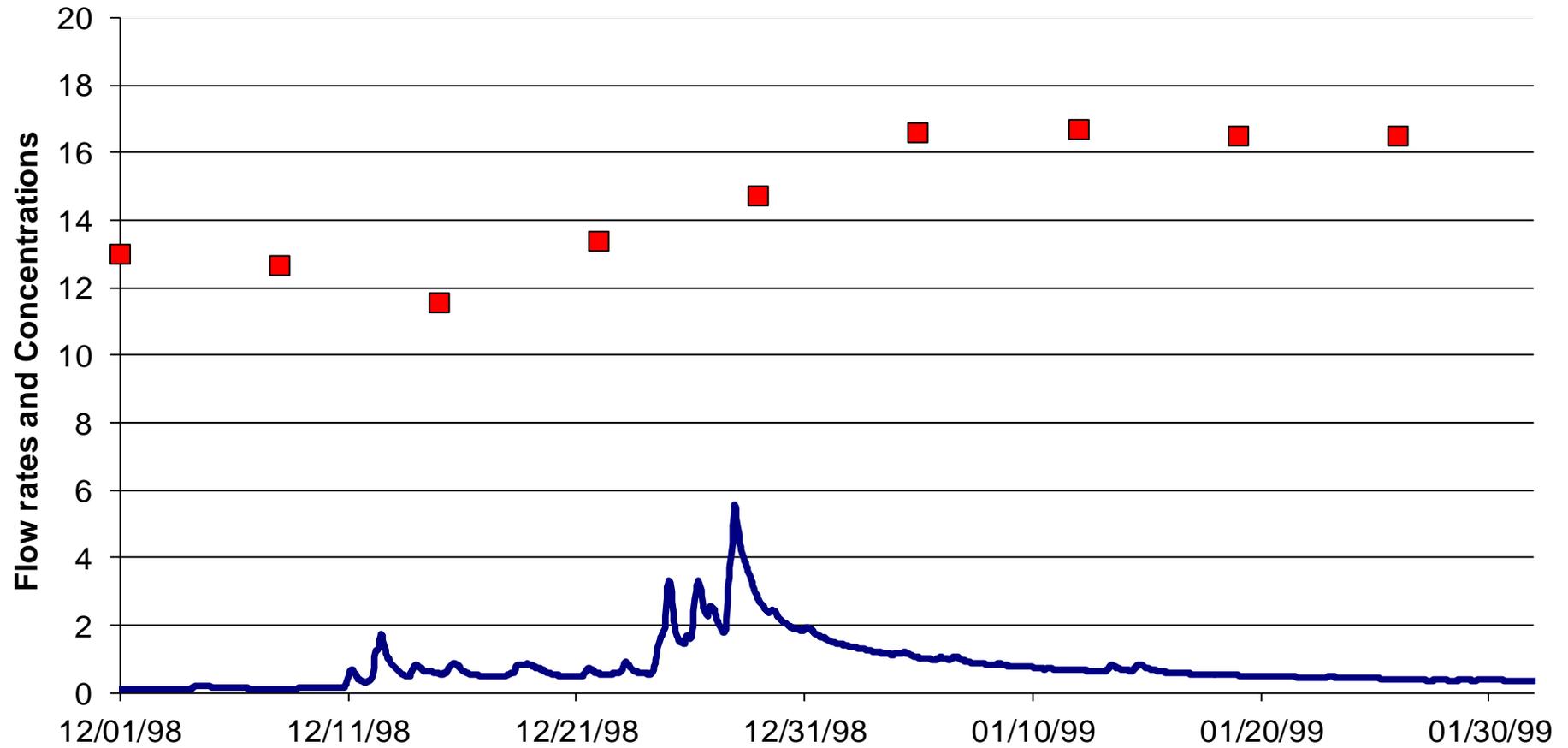
Two examples:

- upland watersheds
- tidal wetland

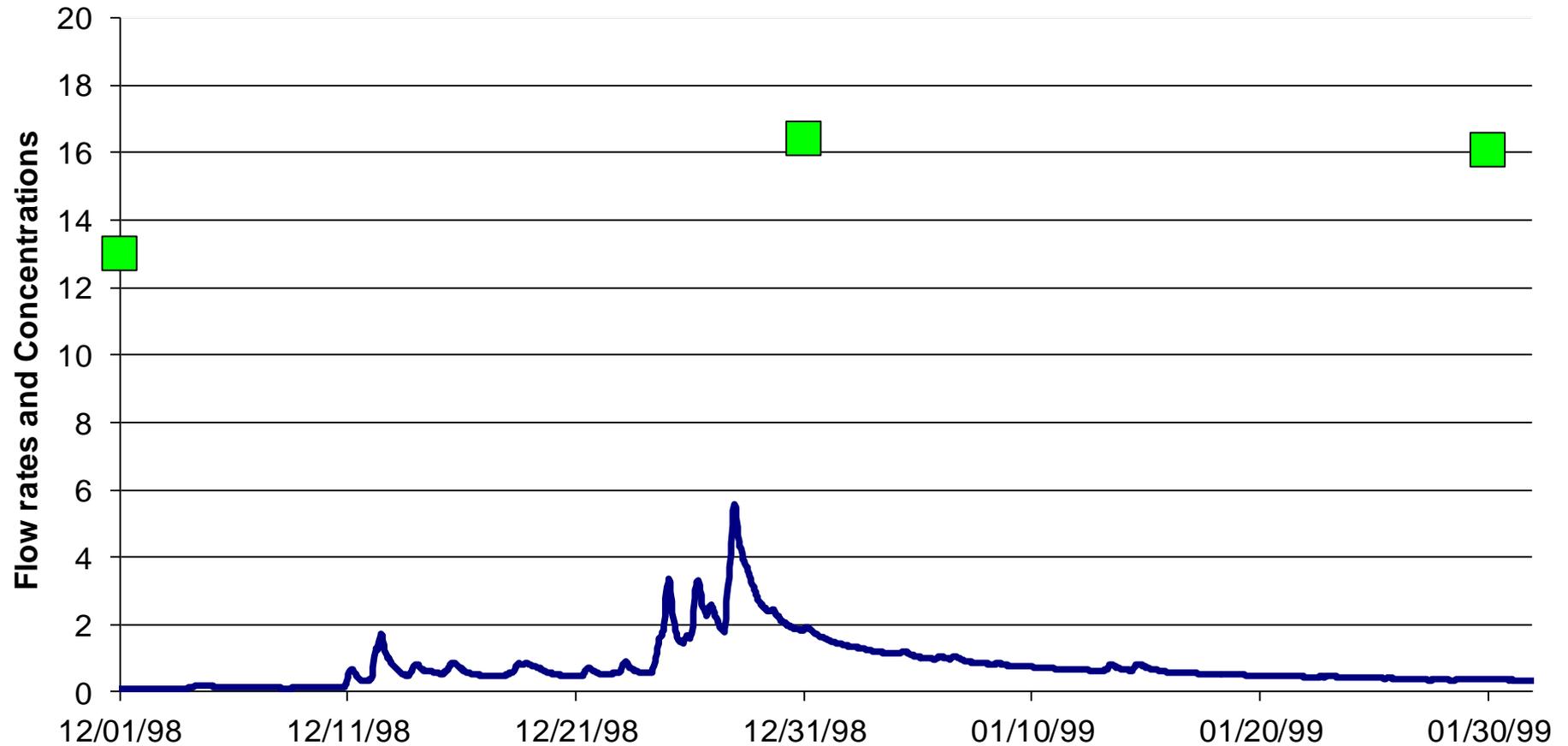
# Continuous WQ data



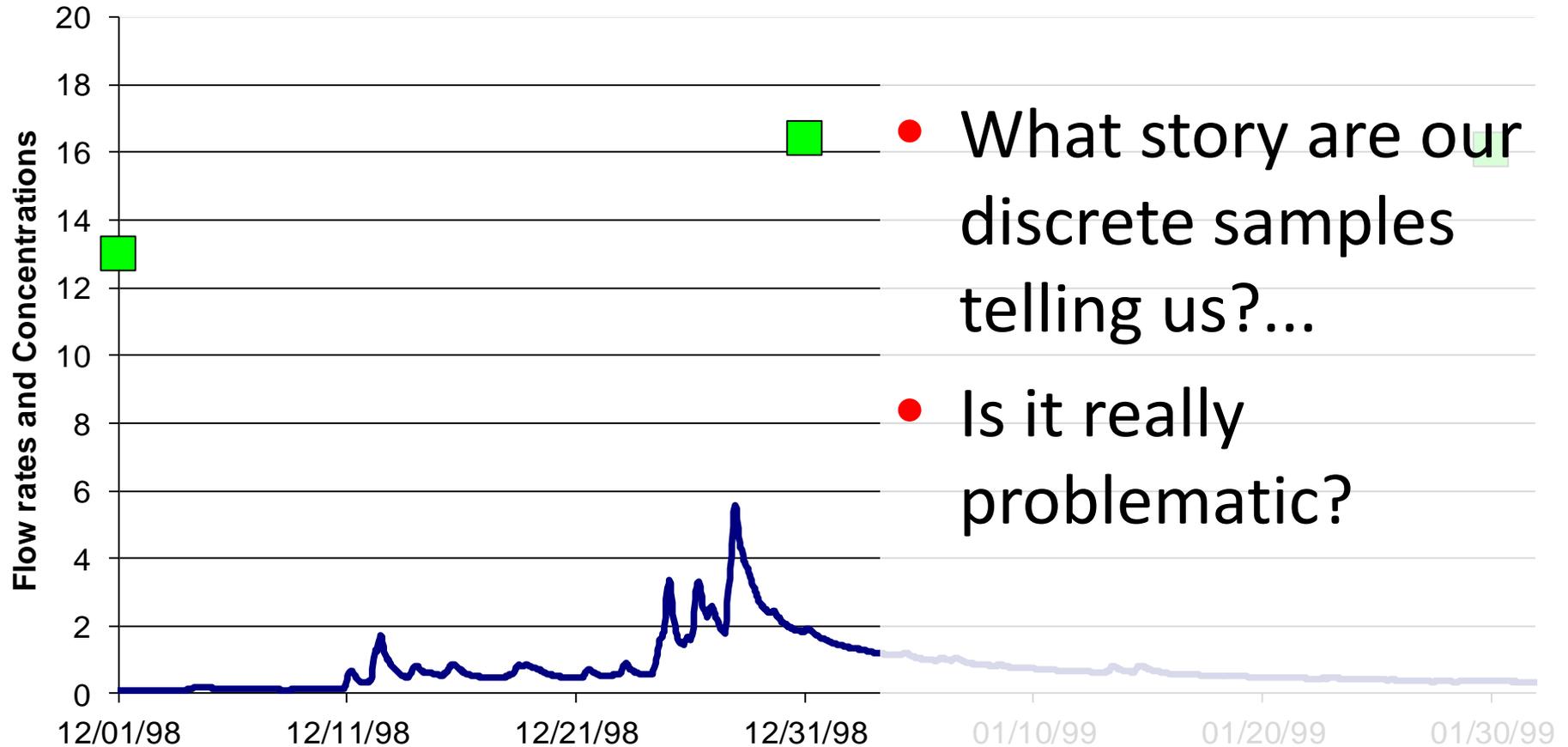
# Weekly samples...



# Monthly samples...



# So now what?

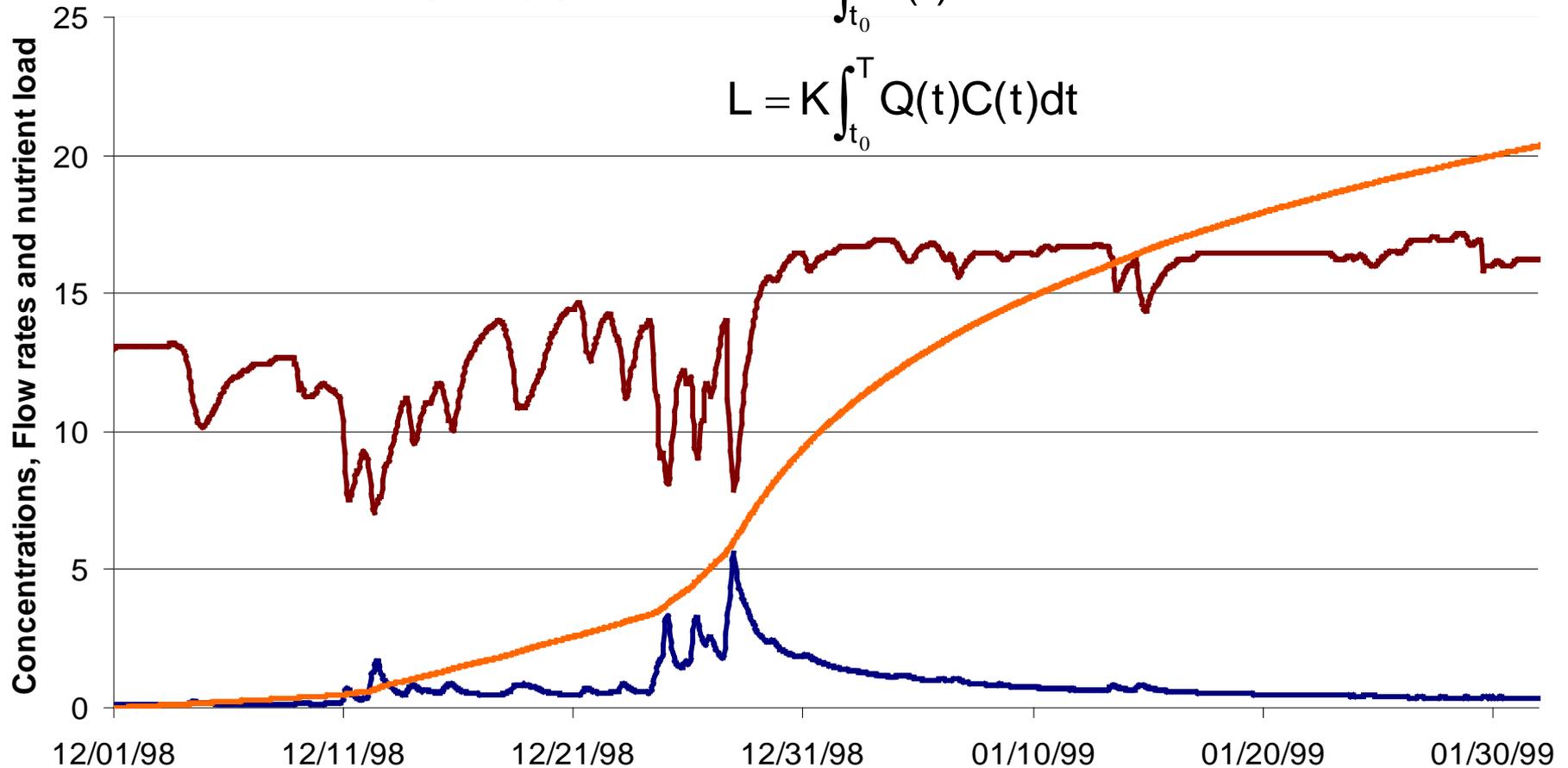


- What story are our discrete samples telling us?...
- Is it really problematic?

# Calculating nutrient annual loads

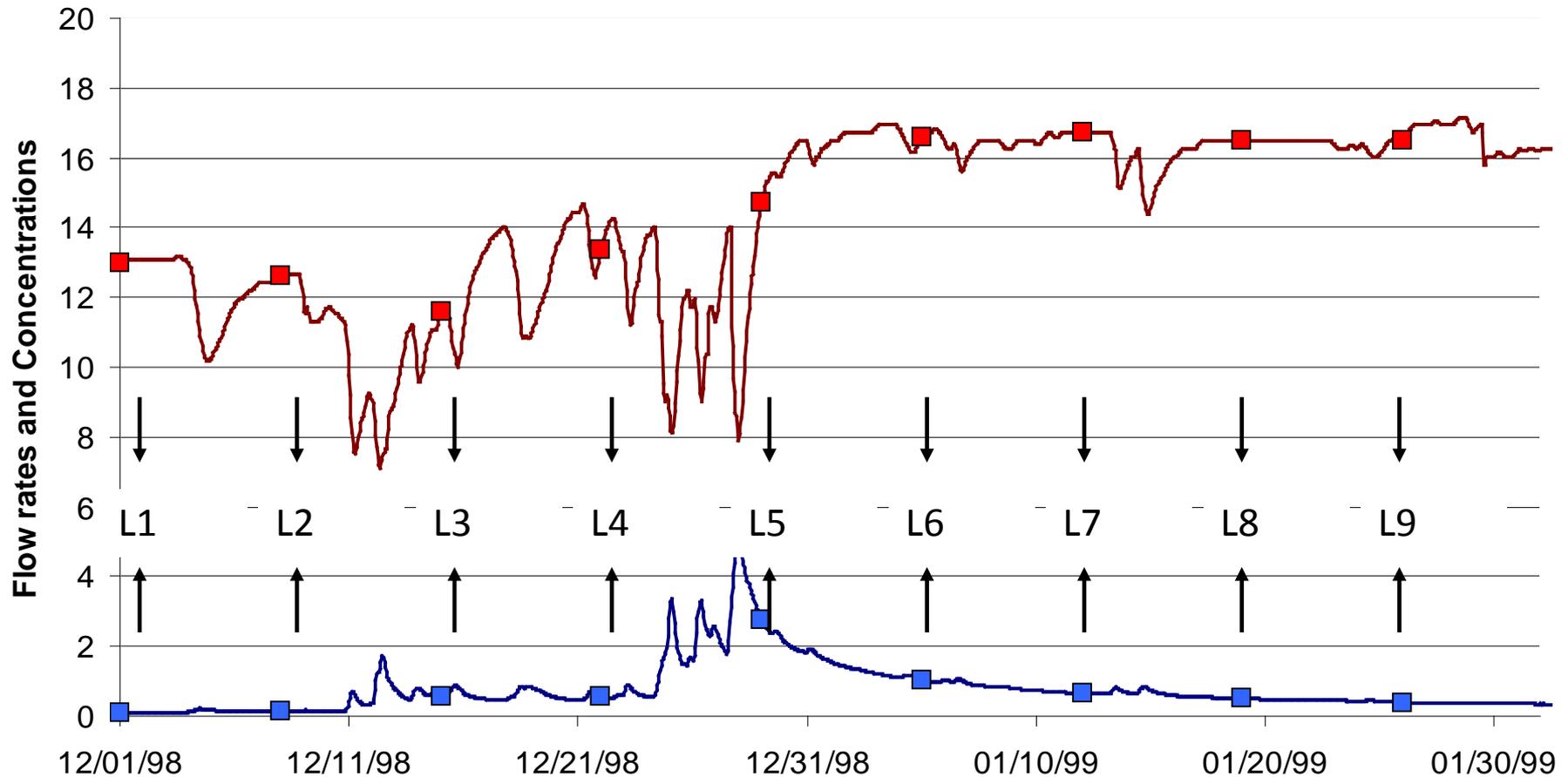
Definition :  $L = K \int_{t_0}^T L(t) dt$

$$L = K \int_{t_0}^T Q(t)C(t) dt$$



$$L = \sum_{i=1}^N \frac{C_{i+1}Q_{i+1} + C_iQ_i}{2} \delta t$$

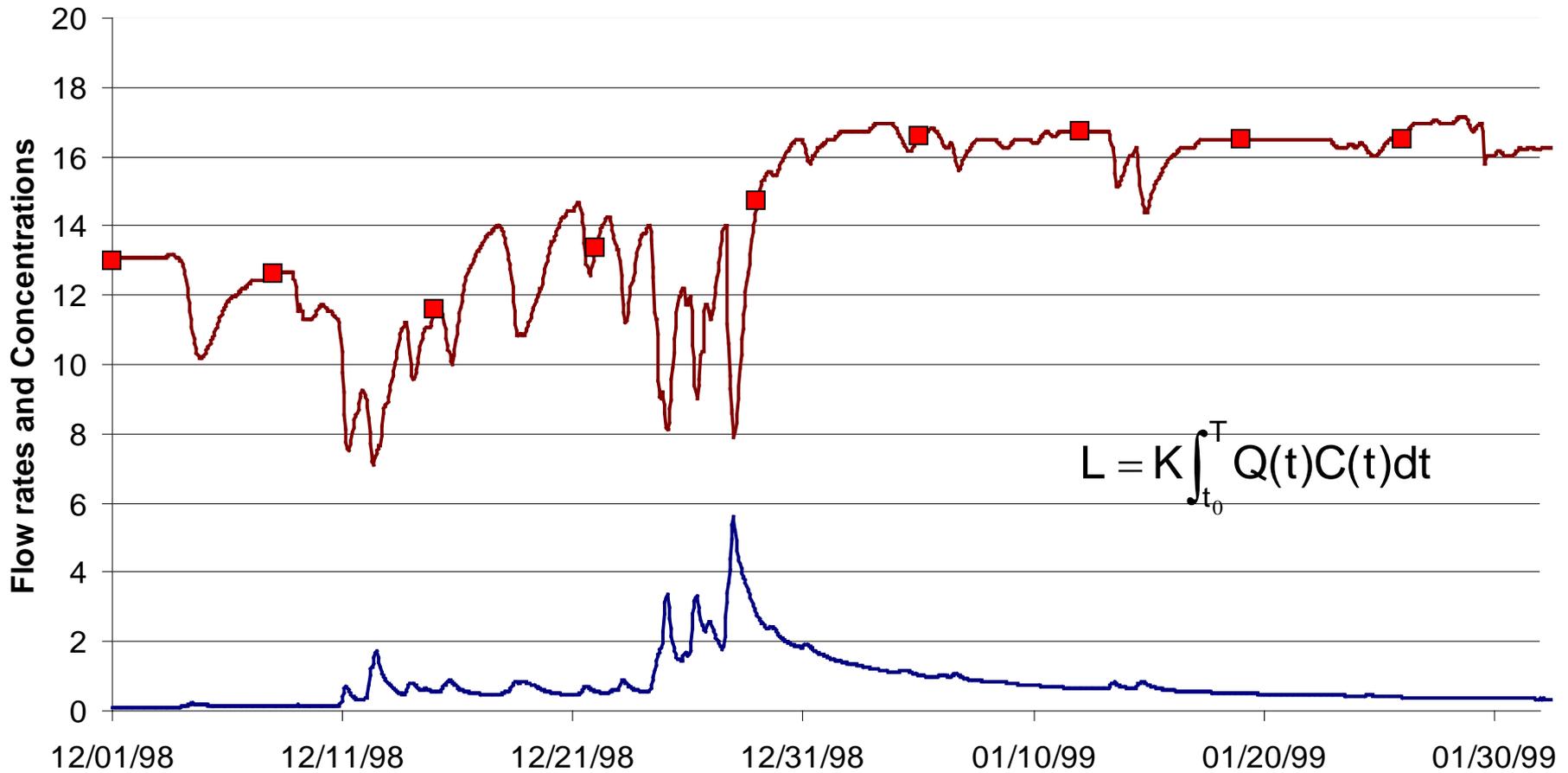
# Fluxes: « Averaging » methods



« Method 2 »

$$\hat{L} = K \sum_{i=1}^n \frac{C_i Q_i}{n} = K \sum_{i=1}^n \frac{L_i}{n}$$

# Fluxes: « Averaging » methods



« Method 5 »



$$\hat{L} = K\bar{Q} \frac{\sum_{i=1}^n C_i Q_i}{\sum_{i=1}^n Q_i}$$

F. Birgand

# 16 strategies and methods tested

$$1 \quad \hat{L} = K \left( \sum_{i=1}^n \frac{C_i}{n} \right) \left( \sum_{i=1}^n \frac{Q_i}{n} \right)$$

[Preston et al., 1989]

$$2 \quad \hat{L} = K \sum_{i=1}^n \frac{C_i Q_i}{n}$$

[Preston et al., 1989]

$$9 \quad \hat{L} = K \sum_{i \in n} C_i Q_i \left( 1 + \frac{\sum_{j \in N \setminus n} Q_j^2}{\sum_{i \in n} Q_i^2} \right)$$

[Cooper, 2005]

$$3 \quad \hat{L} = K \sum_{i=1}^n C_i \overline{Q_{i,j-1}}$$

[Meybeck et al., 1994]

$$4 \quad \hat{L} = K \overline{Q} \sum_{i=1}^n \frac{C_i}{n}$$

[Shih et al., 1992]

$$5 \quad \hat{L} = K \overline{Q} \frac{\sum_{i=1}^n C_i Q_i}{\sum_{i=1}^n Q_i}$$

[Littlewood, 1992]

$$8 \quad \hat{L} = K \overline{Q} \frac{\bar{l}}{\bar{q}} \frac{1 + \frac{1}{N} \frac{S_{lq}}{\bar{l}\bar{q}}}{1 + \frac{1}{N} \frac{S_{q^2}}{\bar{q}^2}} \quad \text{with} \quad \bar{l} = \sum_{i=1}^n C_i Q_i \quad \bar{q} = \sum_{i=1}^n Q_i$$

$$S_{lq} = \frac{1}{n-1} \sum_{i=1}^n ((Q_i - \bar{q})(C_i Q_i - \bar{l})) \quad \text{and} \quad S_{q^2} = \frac{1}{n-1} \sum_{i=1}^n (Q_i - \bar{q})^2$$

[Cohn, 1995]

# 16 strategies and methods tested

$$\hat{L} = K \sum_{k=1}^n C_k^{\text{int}} Q_k$$

[Moatar and Meybeck, 2004]

$$\hat{L} = K \sum_{k=1}^n C_k^{\text{ext}} Q_k \quad \ln(C_i) = a \ln(Q_i) + b$$

[Cohn et al., 1989]

[Ferguson, 1986]

$$\hat{L} = K \sum_{k=1}^n C_k^{\text{ext}} Q_k \times \exp\left(\frac{s^2}{2}\right) \quad \text{with} \quad s^2 = \frac{\sum_{i=1}^n (\ln(C_i) - (a \times \ln(Q_i) + b))^2}{n-2}$$

[Duan, 1983]

$$\hat{L} = K \sum_{k=1}^n C_k^{\text{ext}} Q_k \times \frac{\sum_{i=1}^n \exp(\ln(C_i) - (a \times \ln(Q_i) + b))}{n}$$

$$\hat{L} = K \sum_{k=1}^n C_k^{\text{ext}} Q_k \times g_m \left( \frac{m+1}{2m} \times (1-V) \times s^2 \right) \quad [\text{Cohn et al., 1989}]$$

$$\hat{L} = K \sum_{b \in B} L_b \quad [\text{Schleppi et al., 2006}]$$

$$L_b = \left( \frac{1}{180} \sum_{i=1}^{180} C_i \right) \times \sum_{i=1}^{180} Q_i$$

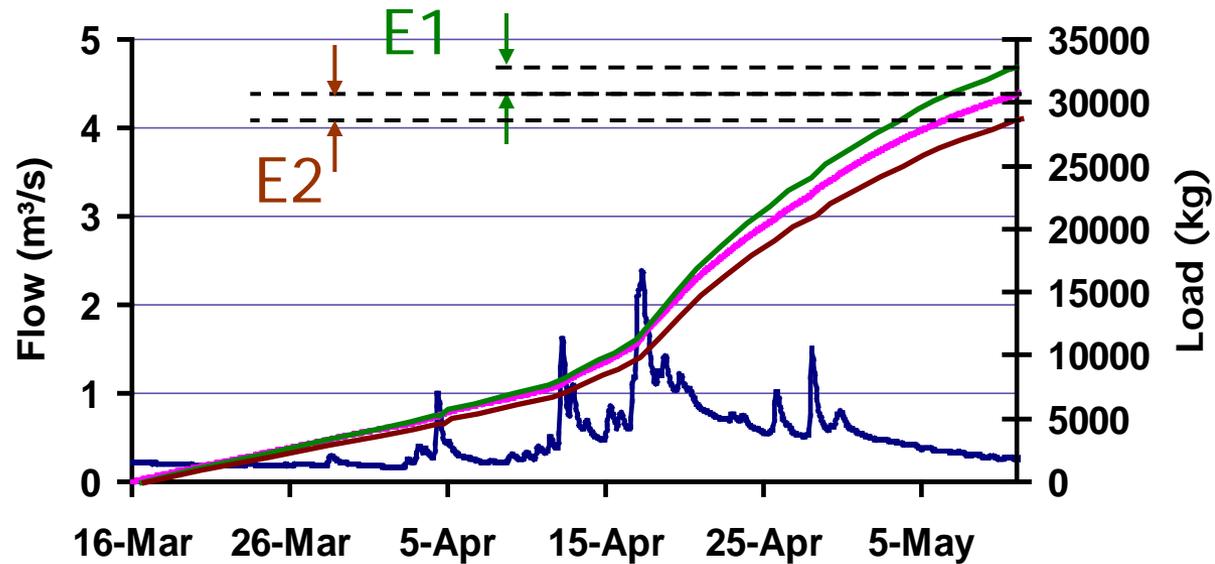
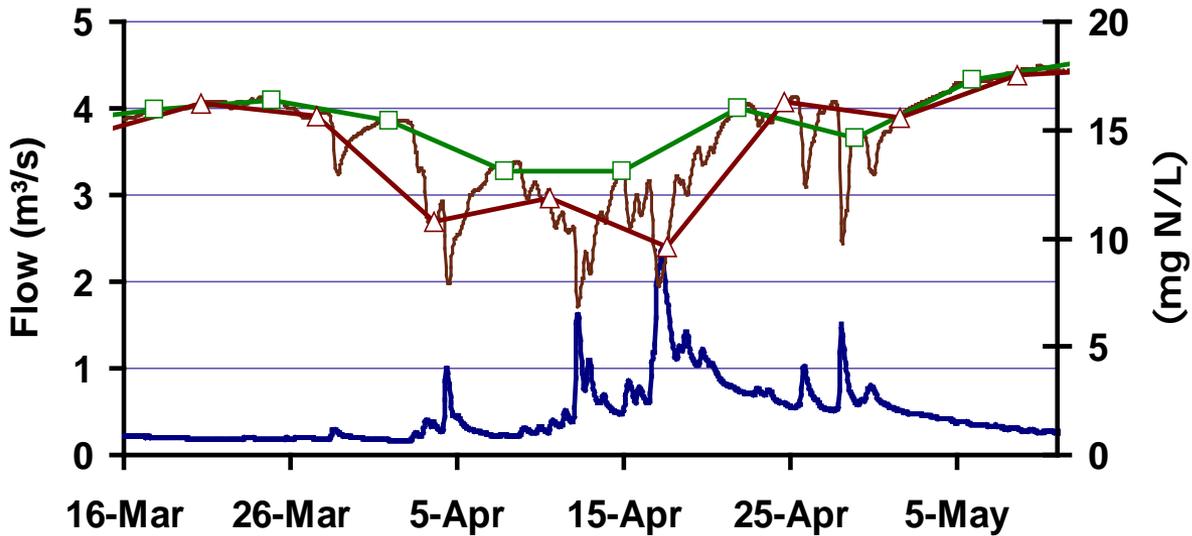
$$\hat{L} = \sum_{b \in B} L_b + \sum_{\text{int}=1}^P L_{\text{int}}$$

[Schleppi et al., 2006]

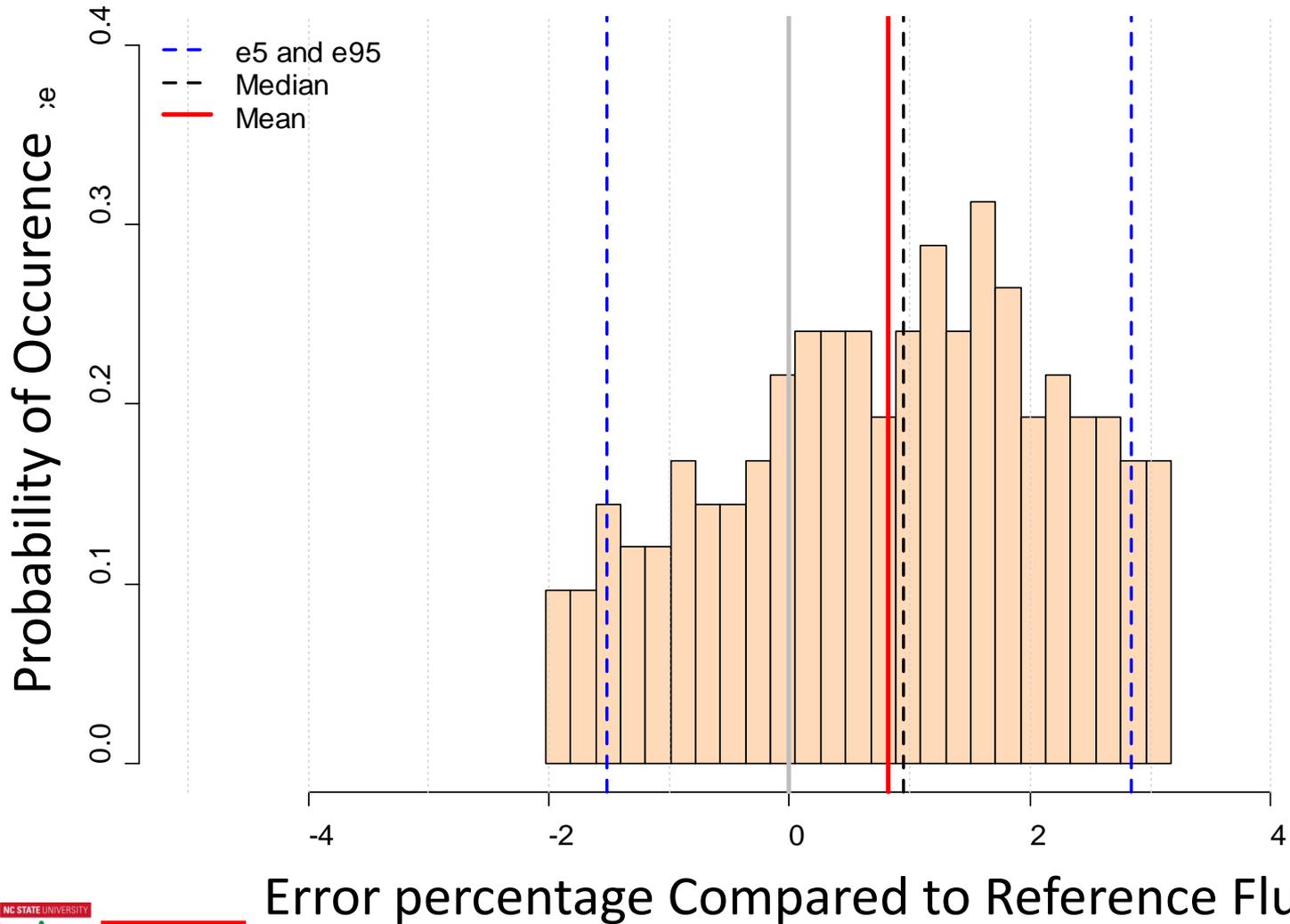
$$L_{\text{int}} = K' \times \sum_{k \in K} C_k^{\text{int}} Q_k$$

$$L_b = K \times \left( \frac{1}{n} \sum_{i=1}^n C_i \right) \times \sum_{i=1}^n Q_i$$

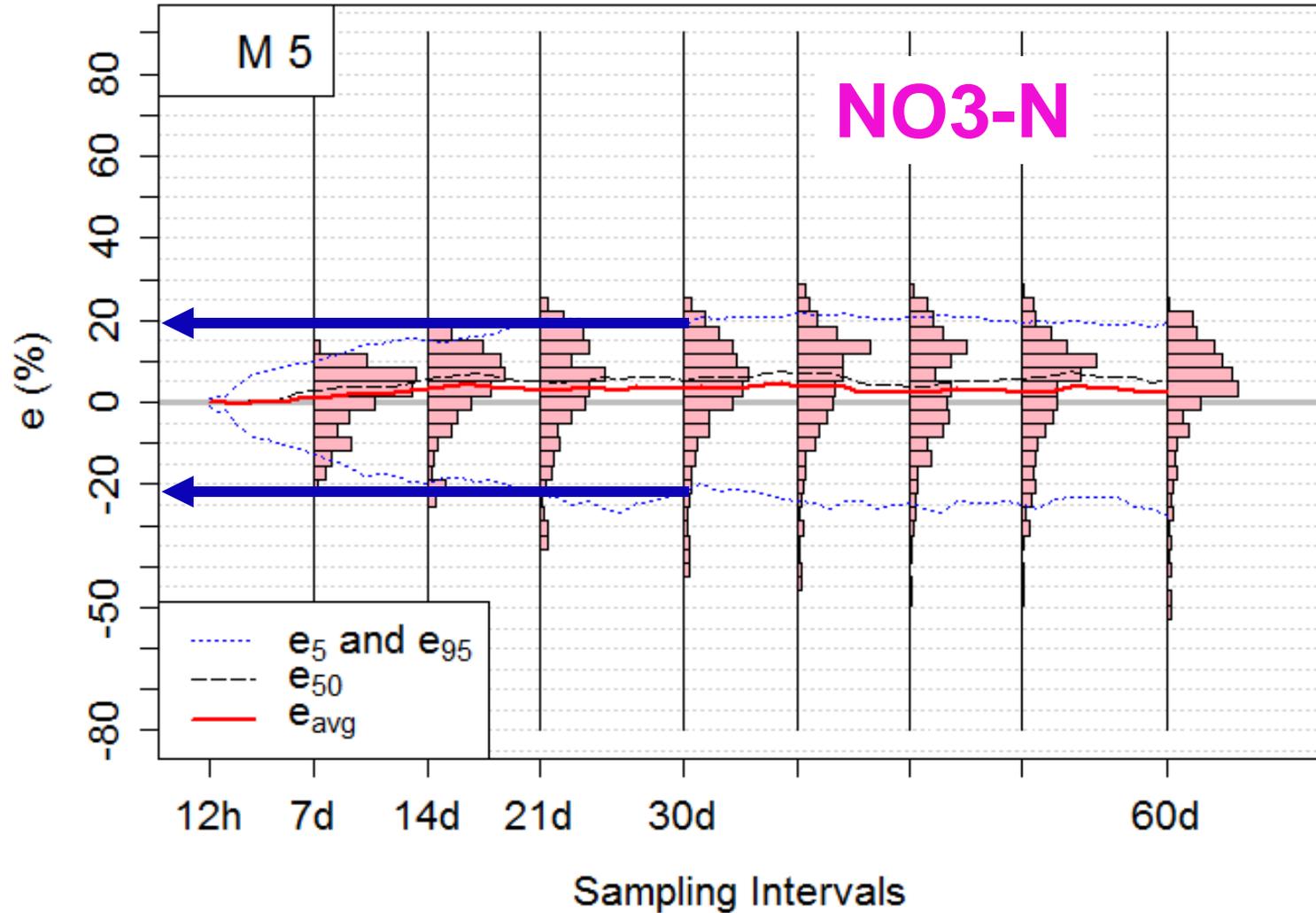
An infinite number of possible errors



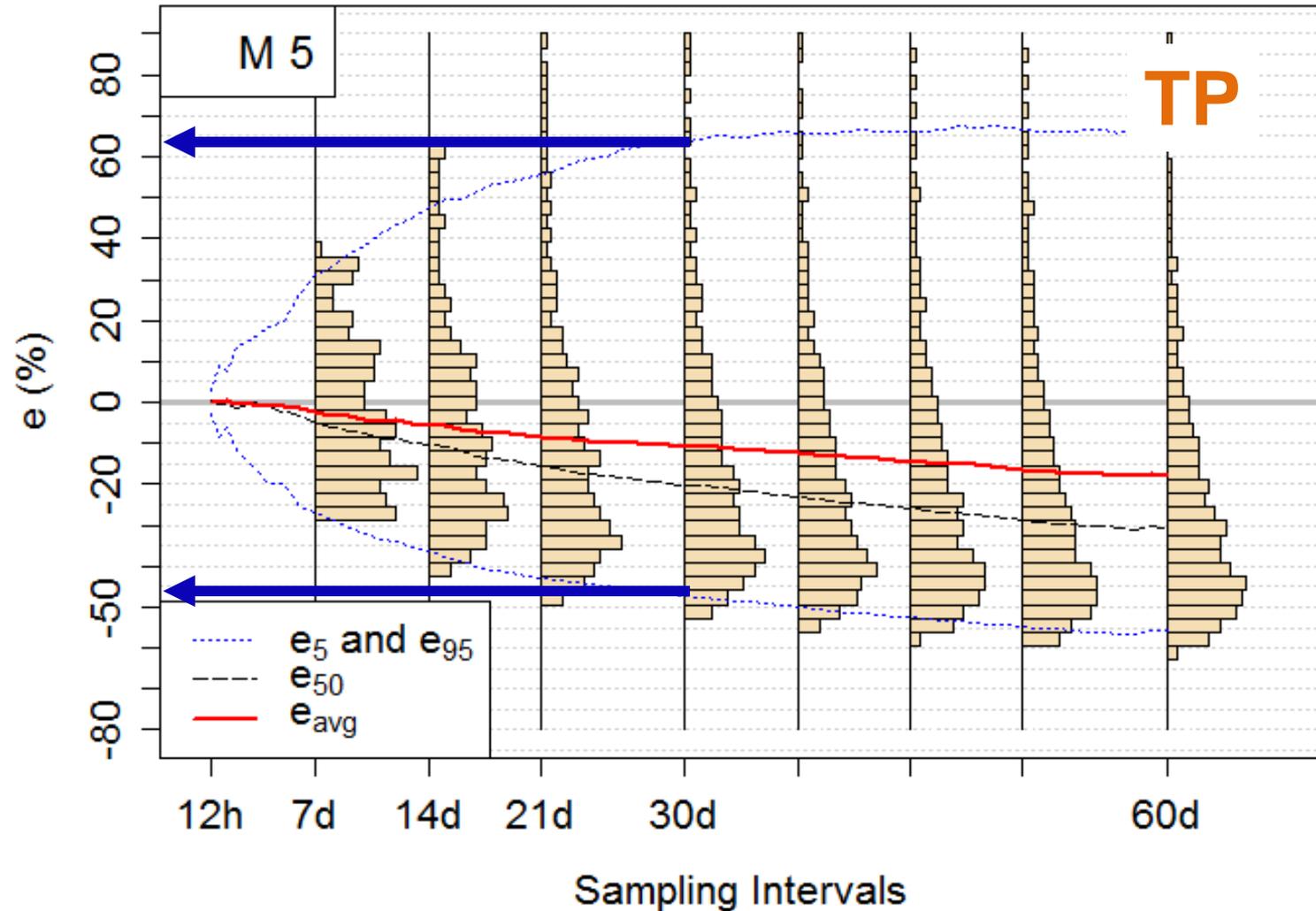
# Error Distributions



# Flow weighted average: least bad method



# Flow weighted average: least bad method

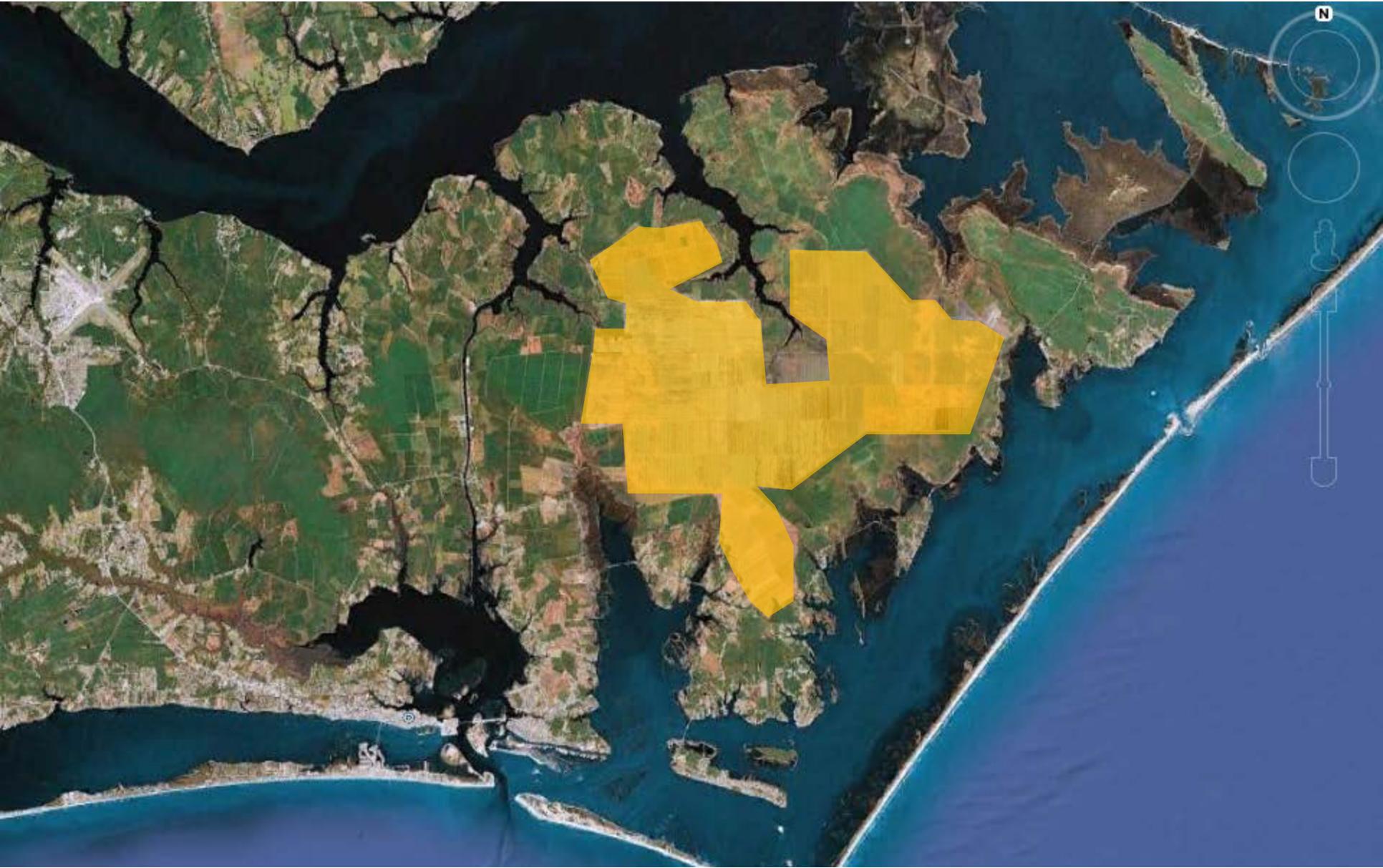


So there is no hope?

Yes, but hold on!

# Tidal wetland

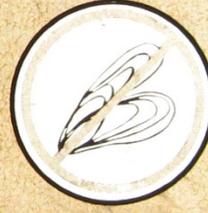




MORE THAN 100  
SHRIMP WITH CAST NETS

# CLOSED AREA

UNLAWFUL TO TAKE OYSTERS,  
CLAMS, OR MUSSELS.  
SHELLFISH MAY CAUSE  
SERIOUS ILLNESS IF EATEN.



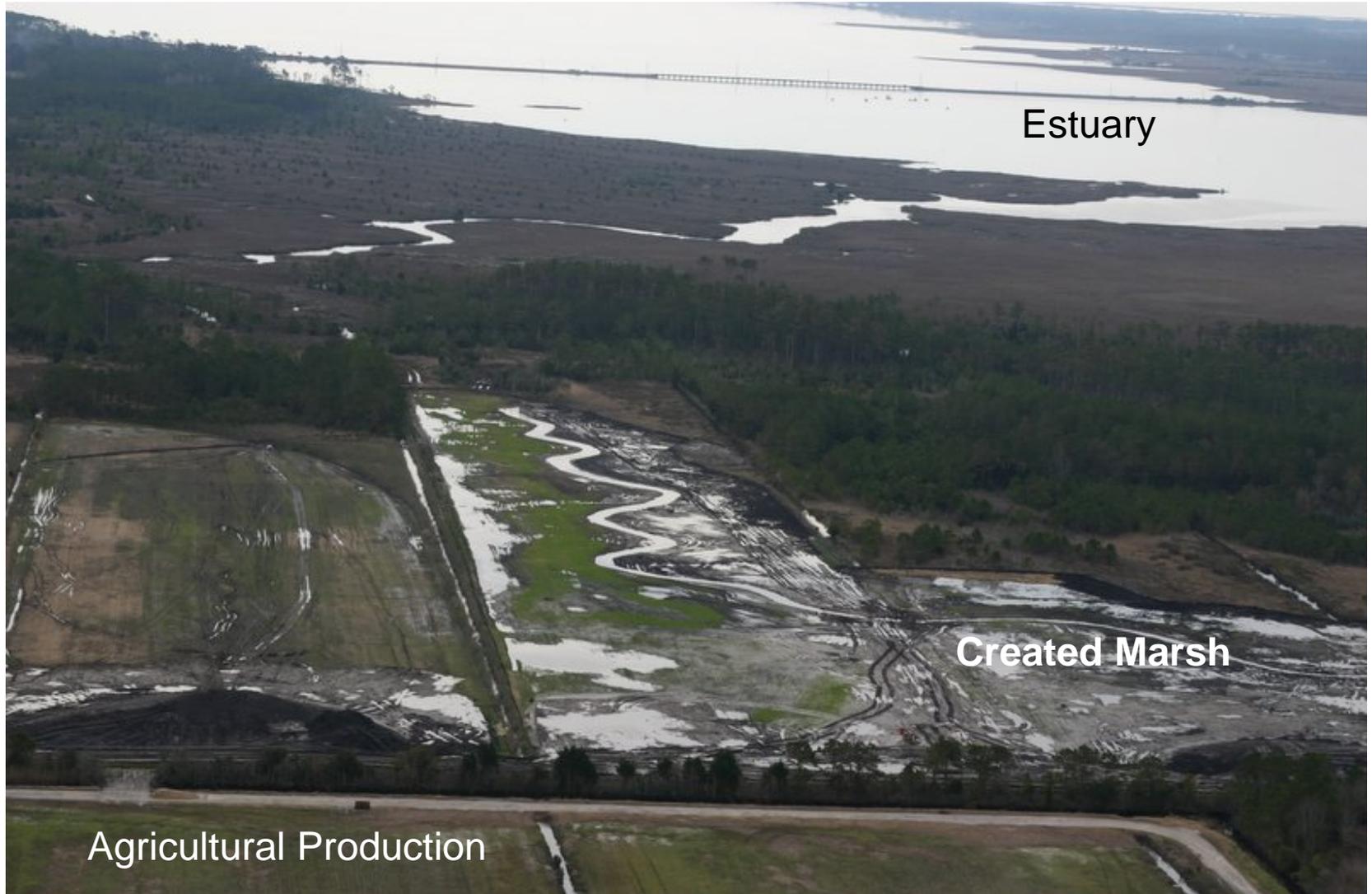
## NC MARINE FISHERIES



### NOTICE TO ALL FISHERMEN



It is unlawful to possess aboard a vessel or while engaged in fishing from the shore or a pier any species of finfish which is subject to a size or harvest restriction without having the head and tail attached. For more information call the Division at 1-800-682-2632 or visit the Division's web site <http://www.ncdmf.npt/>



Estuary

Created Marsh

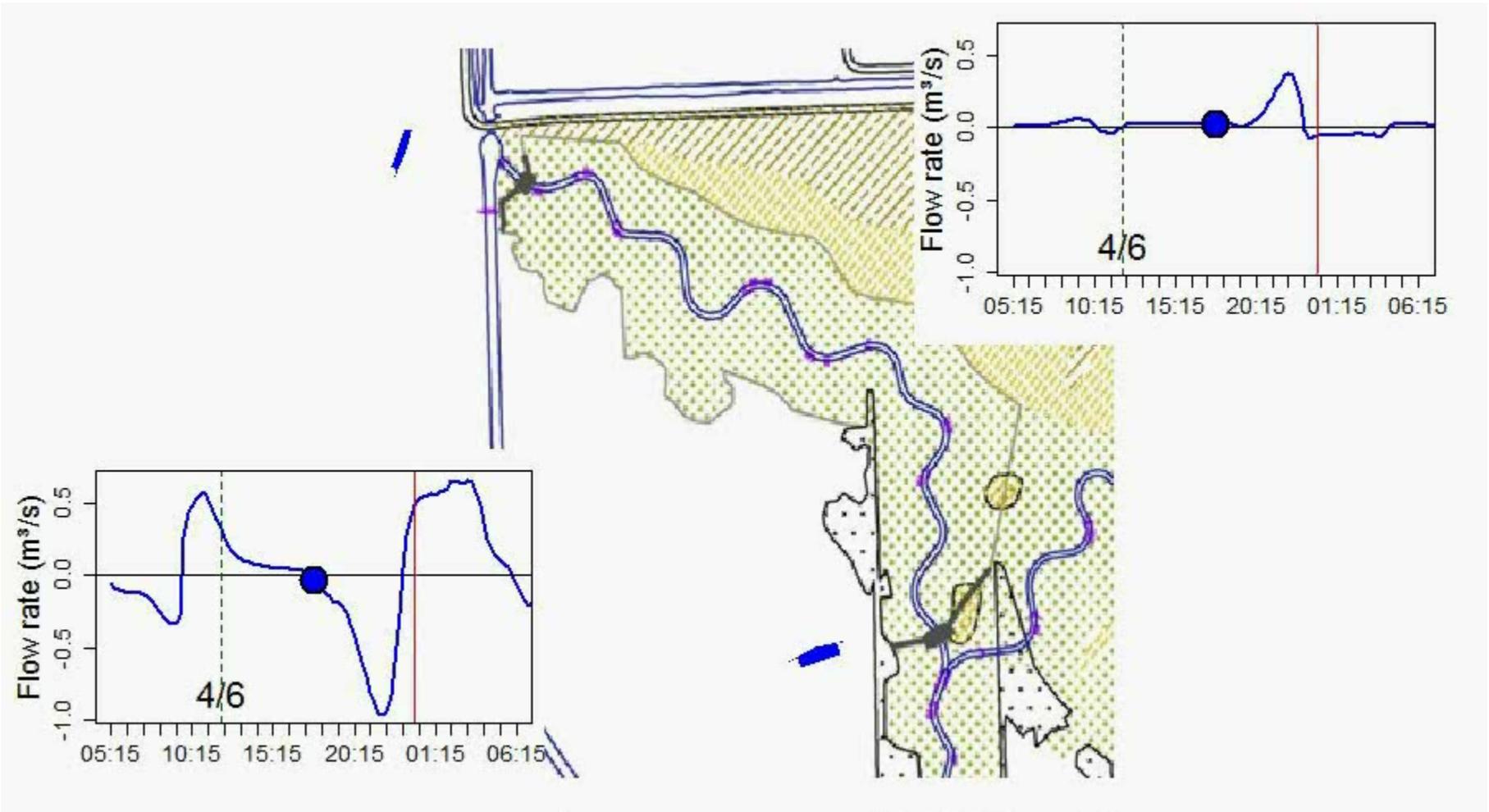
Agricultural Production

September 2007



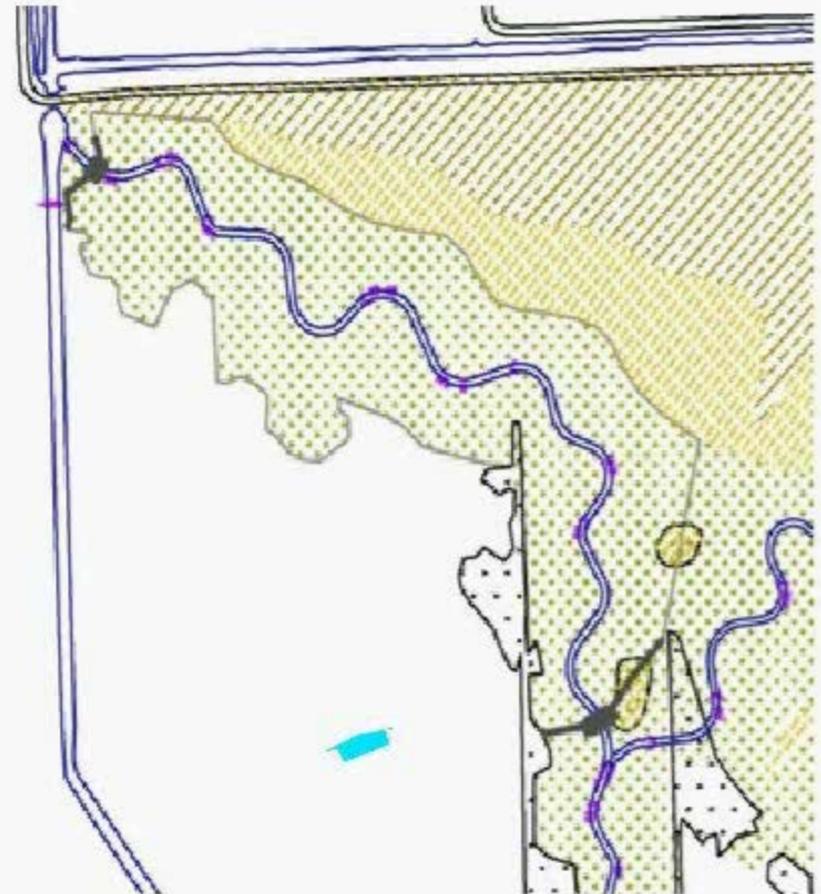
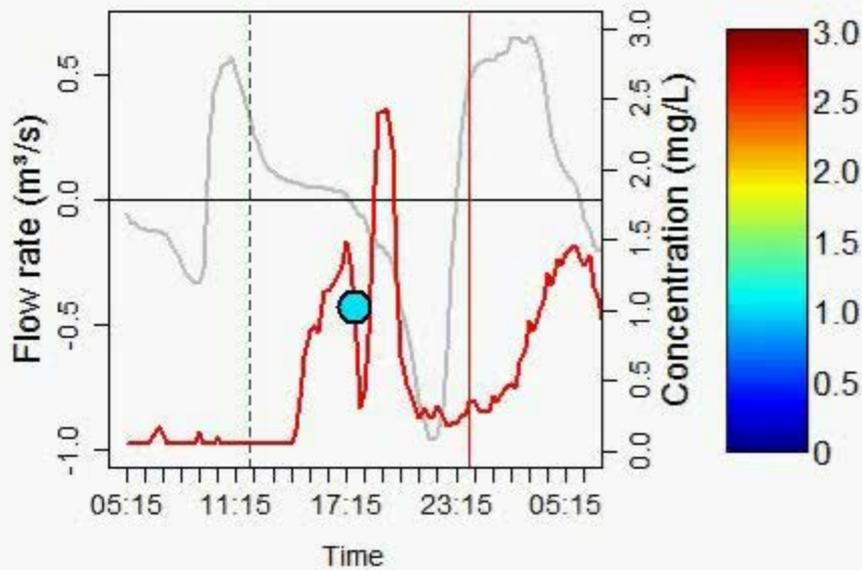
November 2012

# Flow dynamics

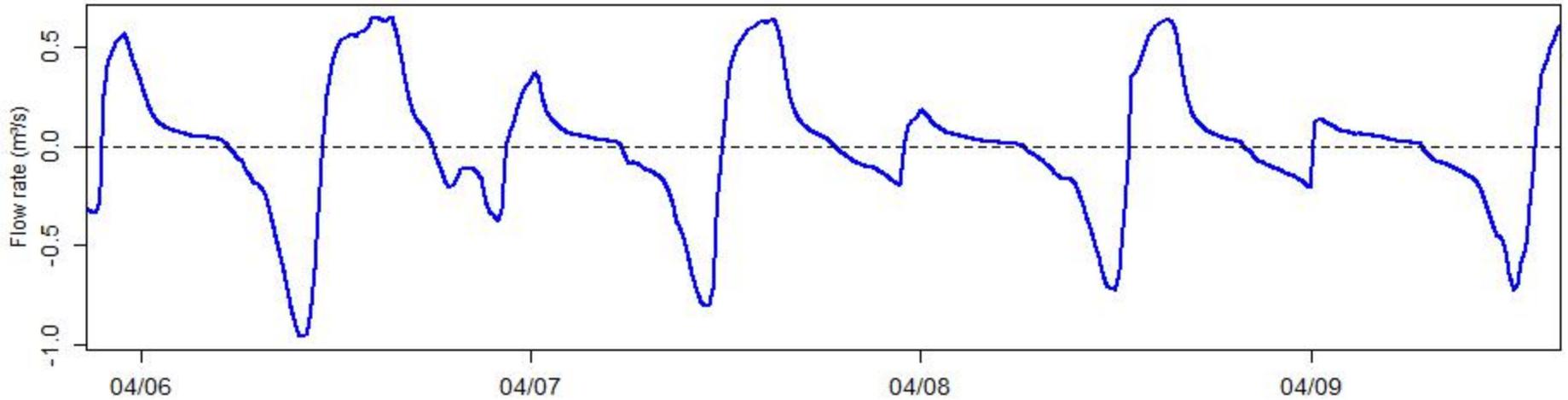


# Flow and Nitrate dynamics at the downstream station in April 2012

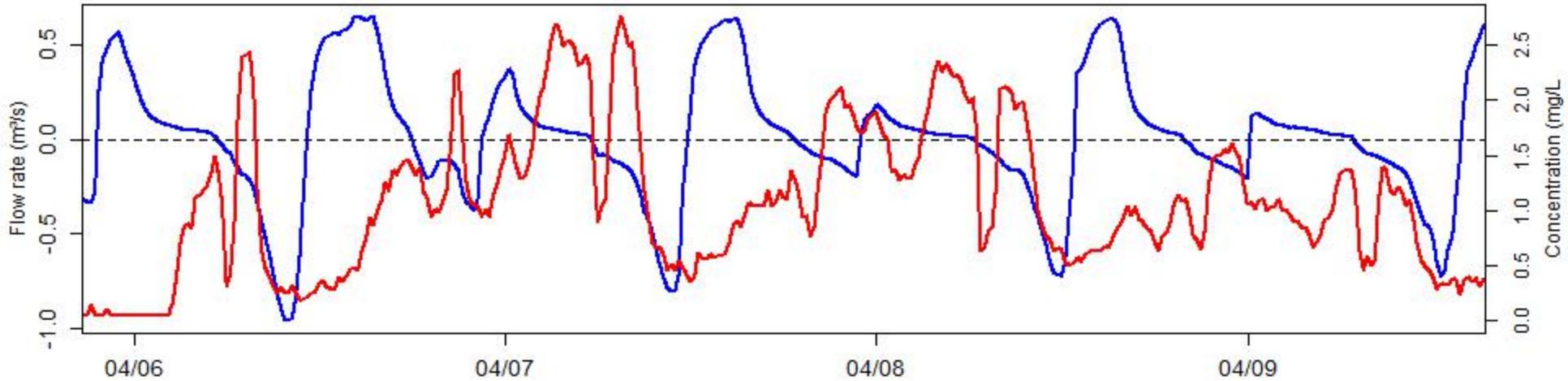
Dates in 2012, Flow (grey), Nitrate (red)



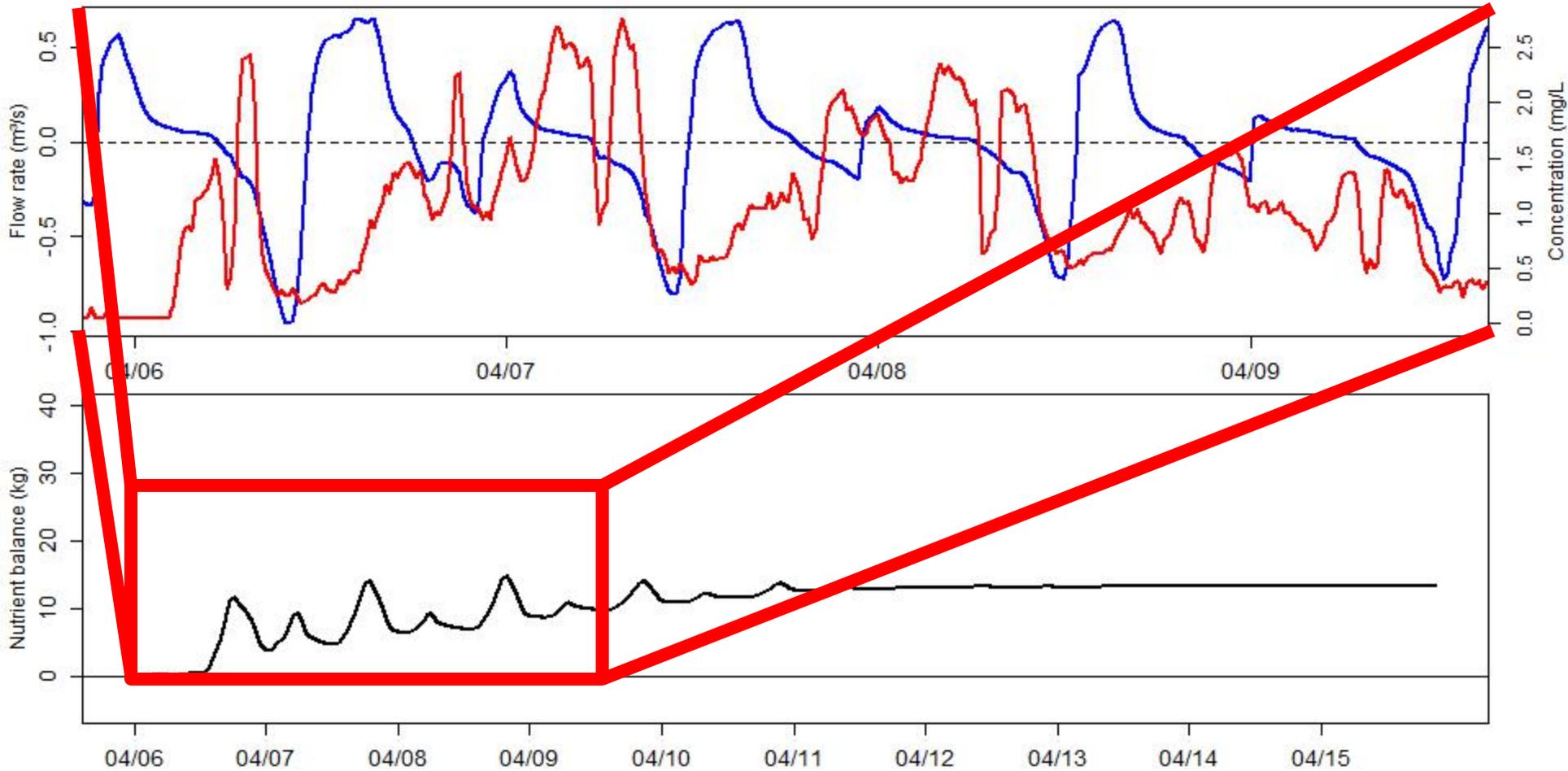
# Results



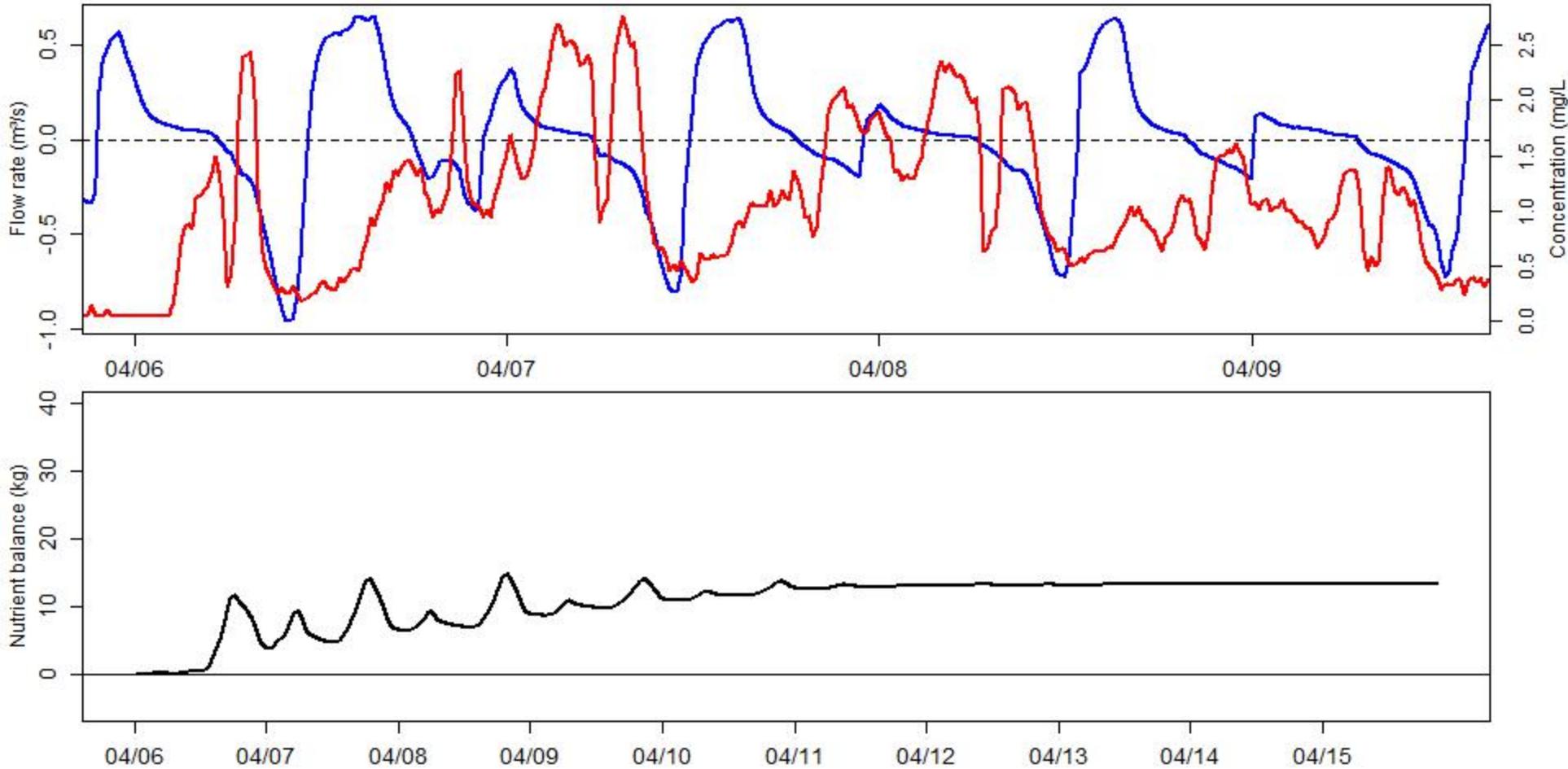
# Results



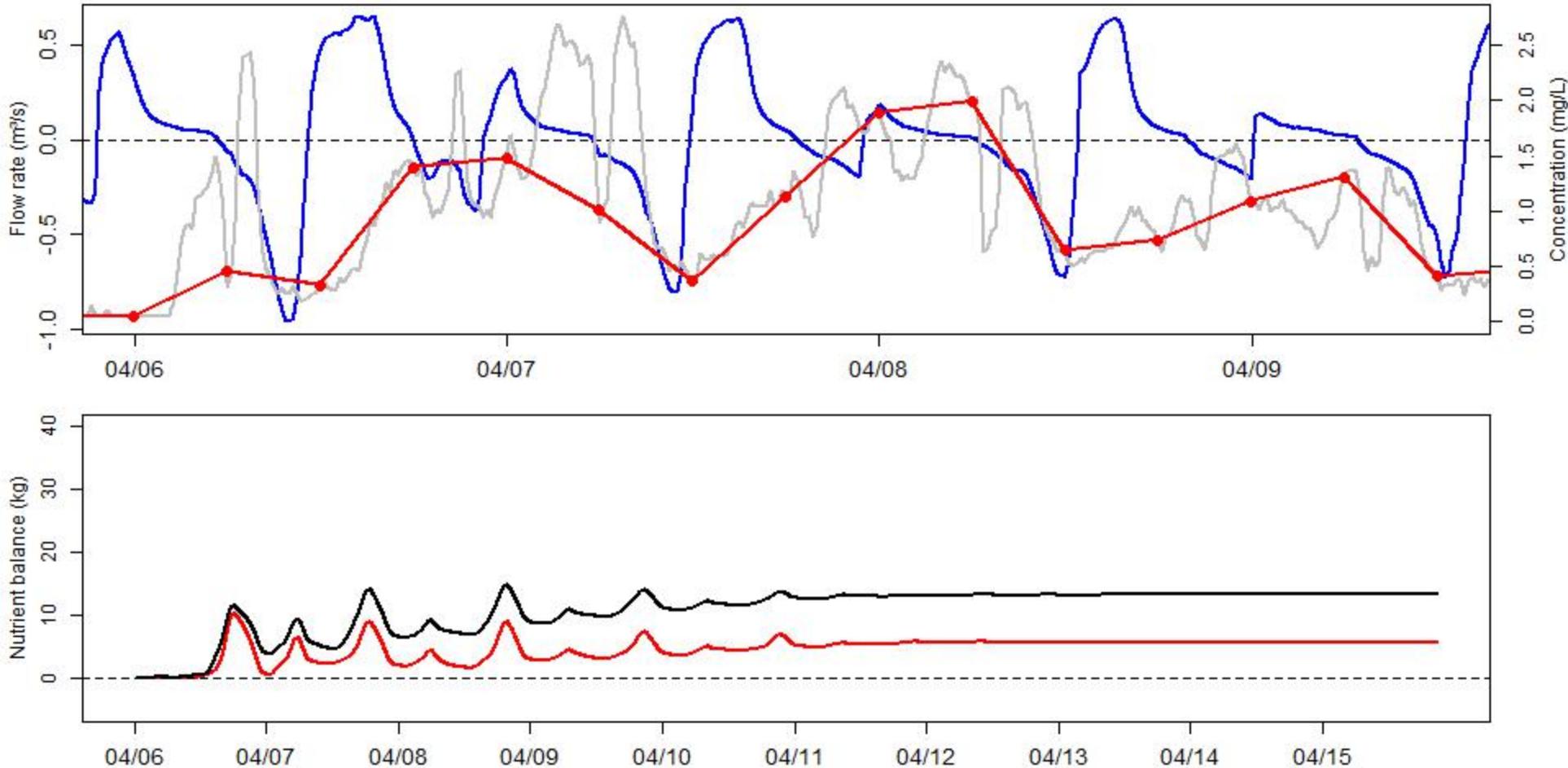
# Results



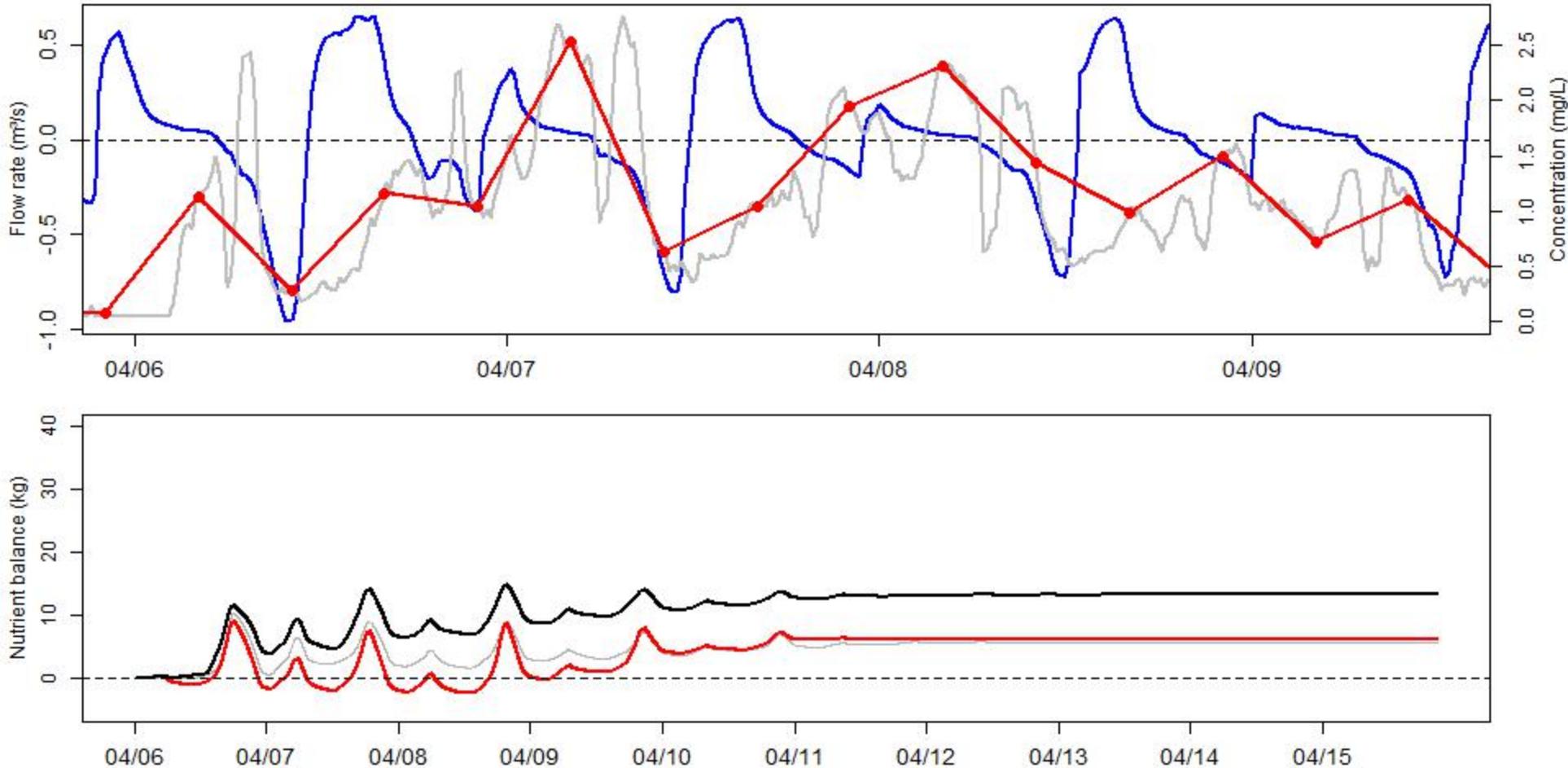
# What if we had sampled *every 6hrs* ?



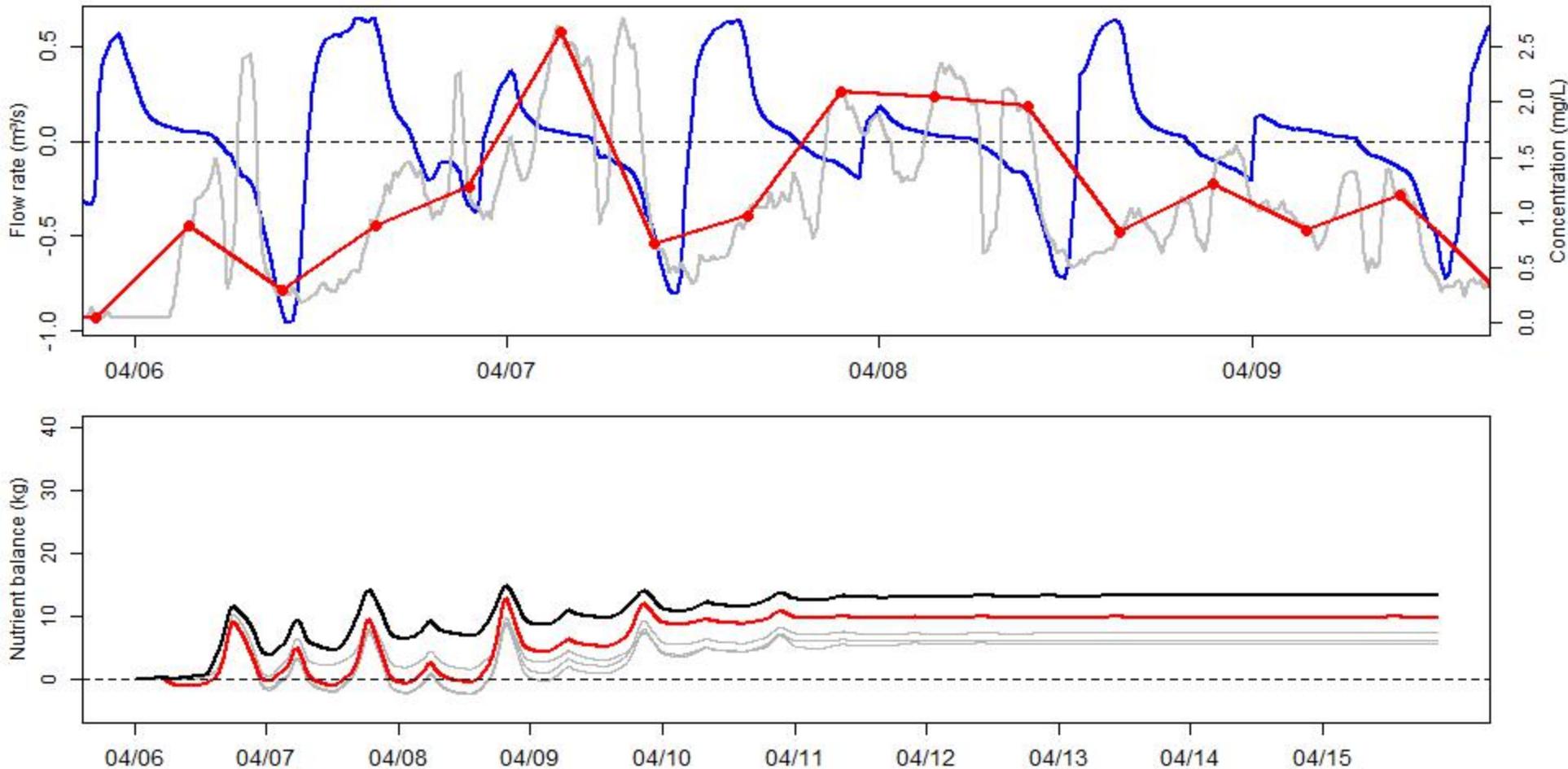
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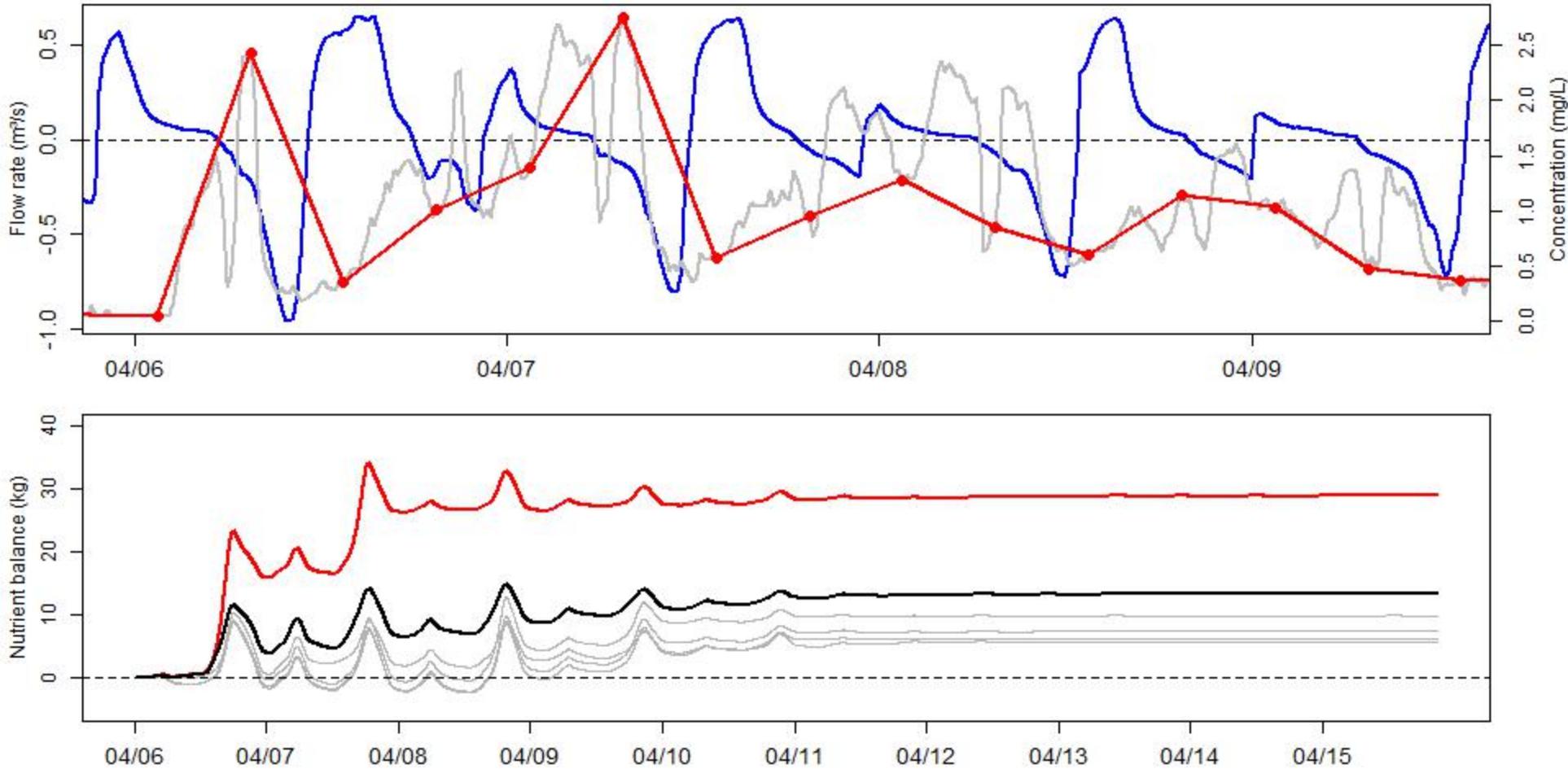
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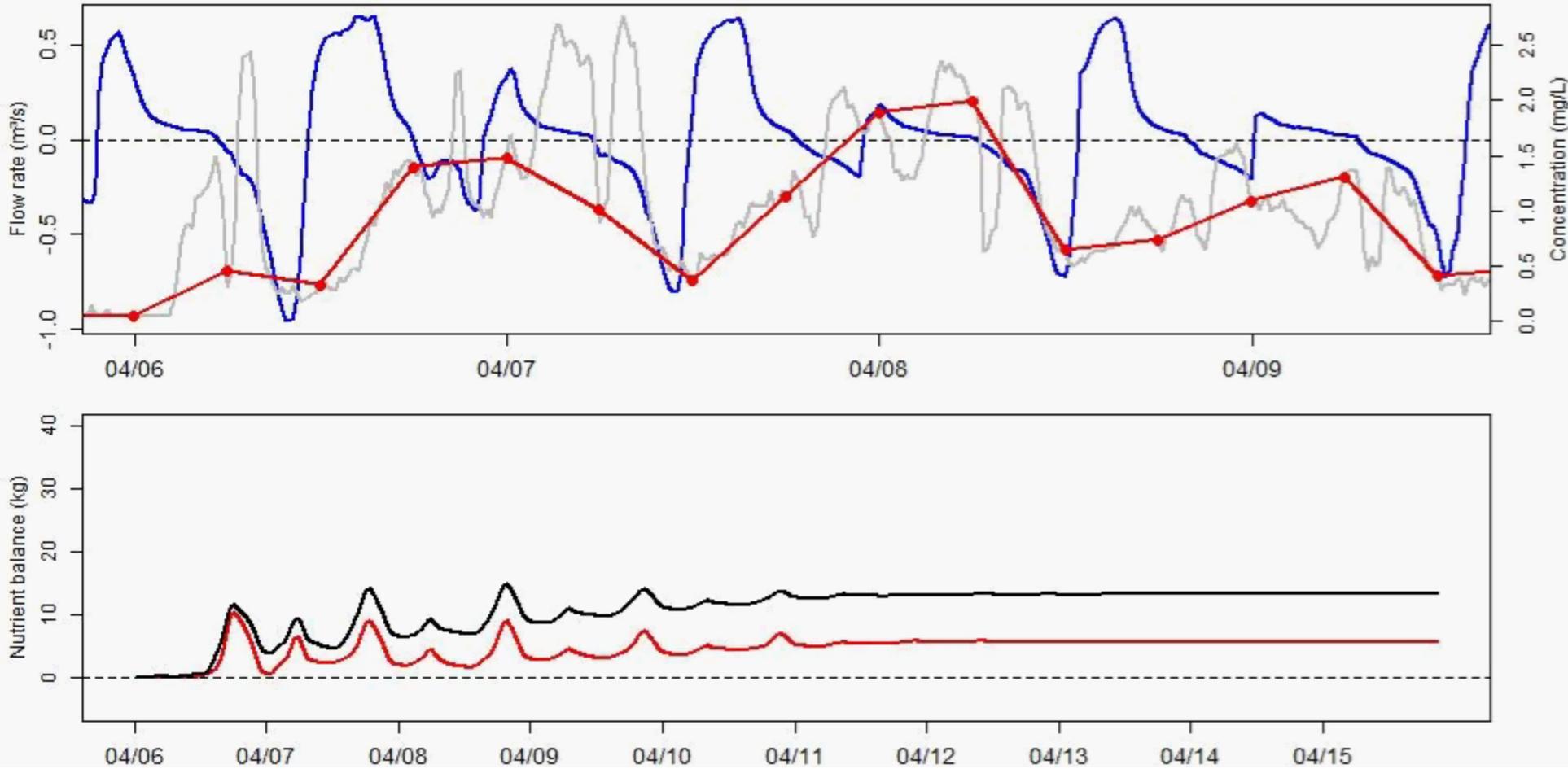
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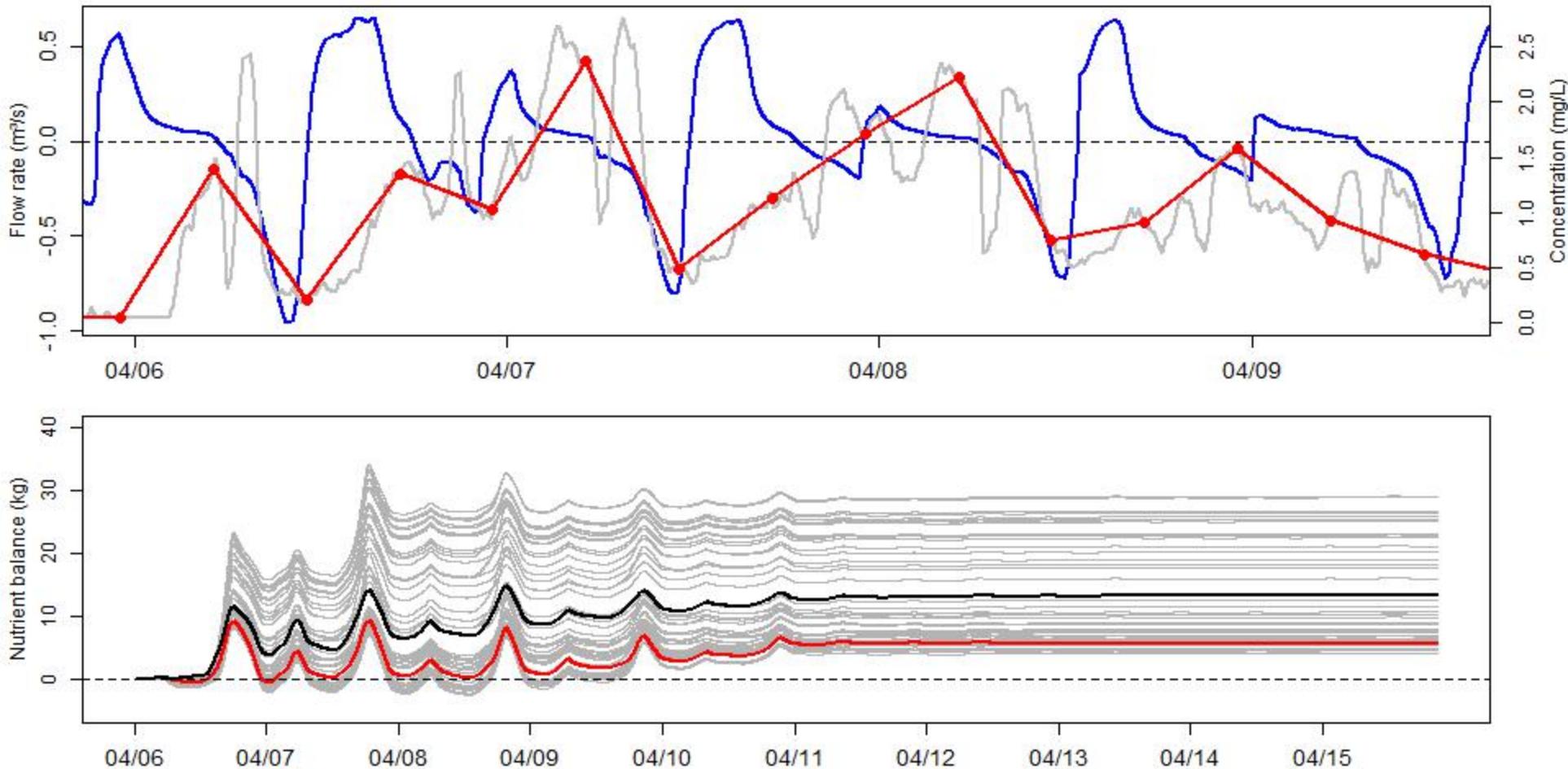
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# What if we had sampled every 6hrs ?

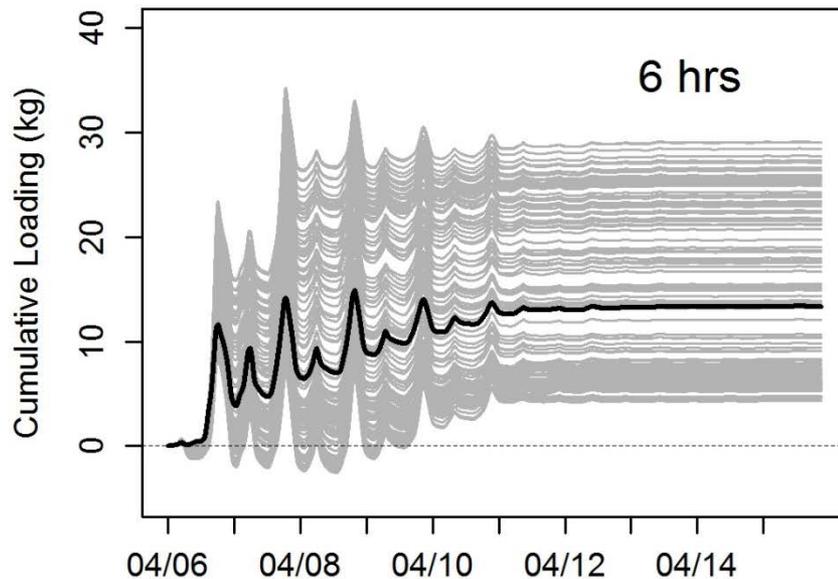


# What if we had sampled every 6hrs ?



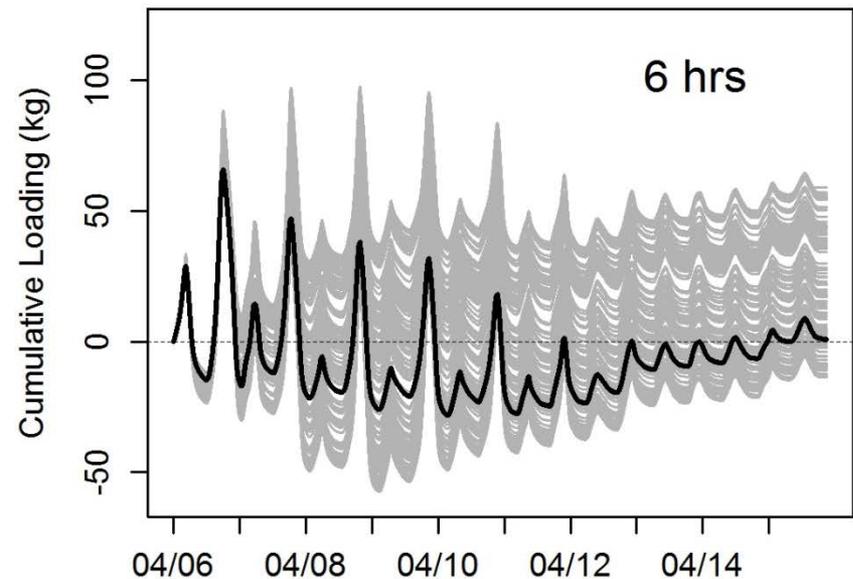
# What if we had sampled every 6hrs ?

**NO3**



Date in 2012

**DOC**



Date in 2012

*Etheridge et al., 2014, Ecol. Eng.*

# Sampling 'infrequently' would have changed our conclusions...

- Could have concluded wrongly on the nitrate dynamics in the marsh
- Would have possibly under- or overestimated by -70% to +130% the nitrate retention
- And never know about it...

# I believe that Infrequent data

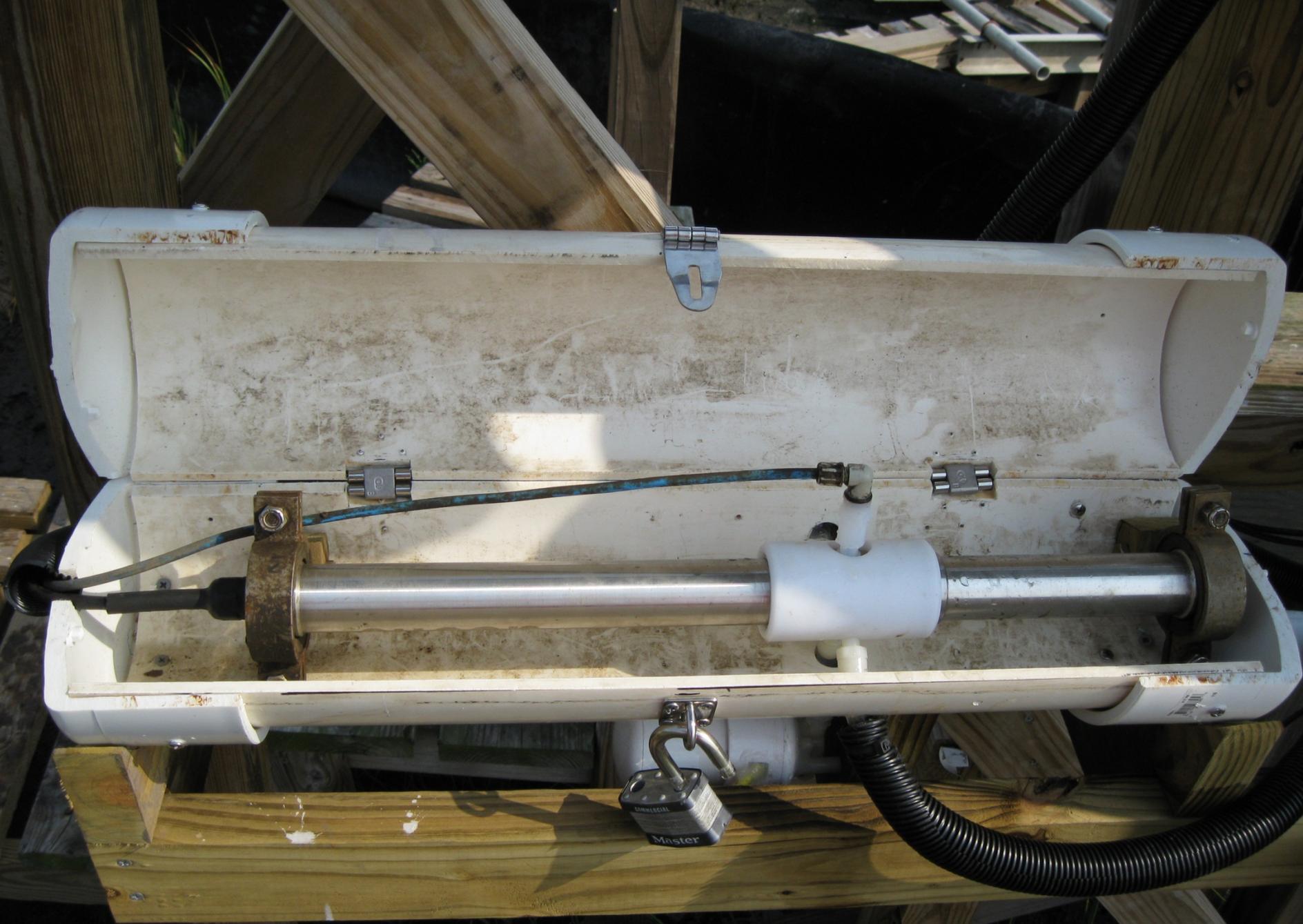
- Prevents from understanding processes at play
- Cannot catch the stochastic nature of hydrological processes
- Induces high risks of making the wrong assessment and uninformed decisions
- What about hope?

# We tried our chance

- Field UV-vis spectrophotometers

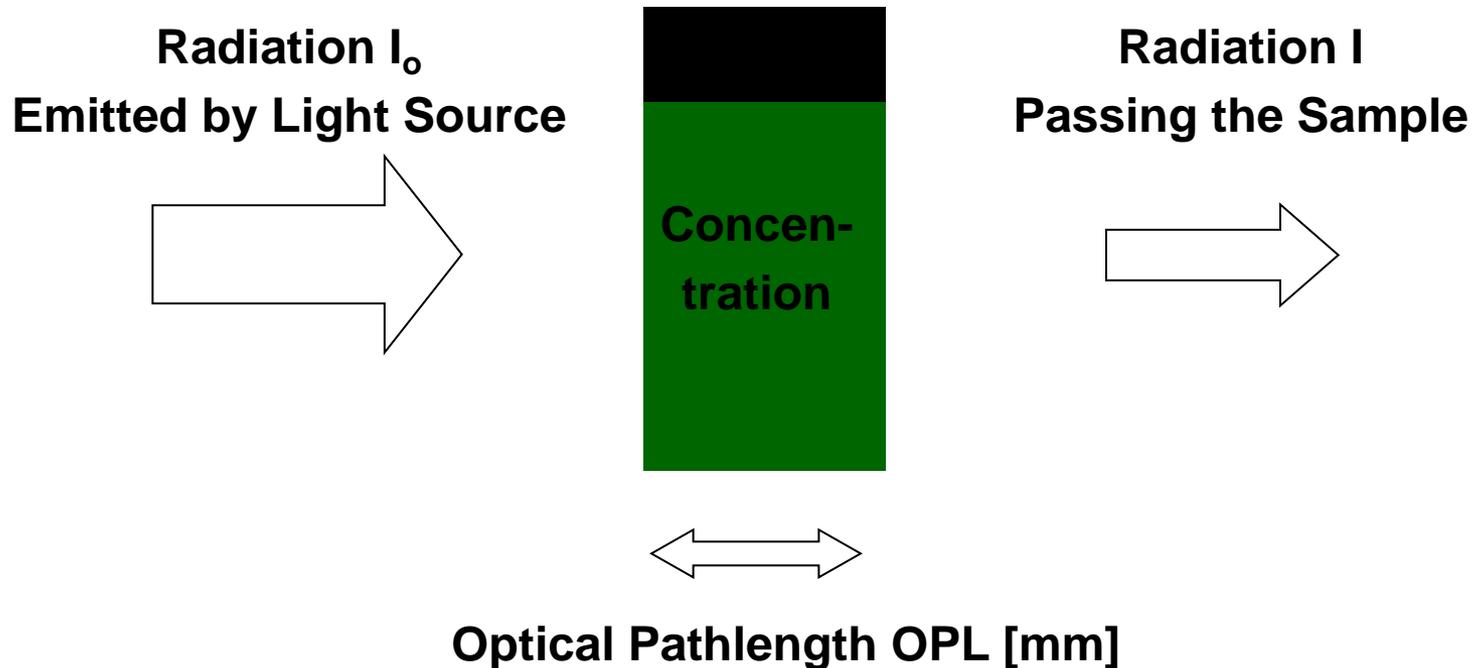


- Spectro::lyser from S::CAN, Austria

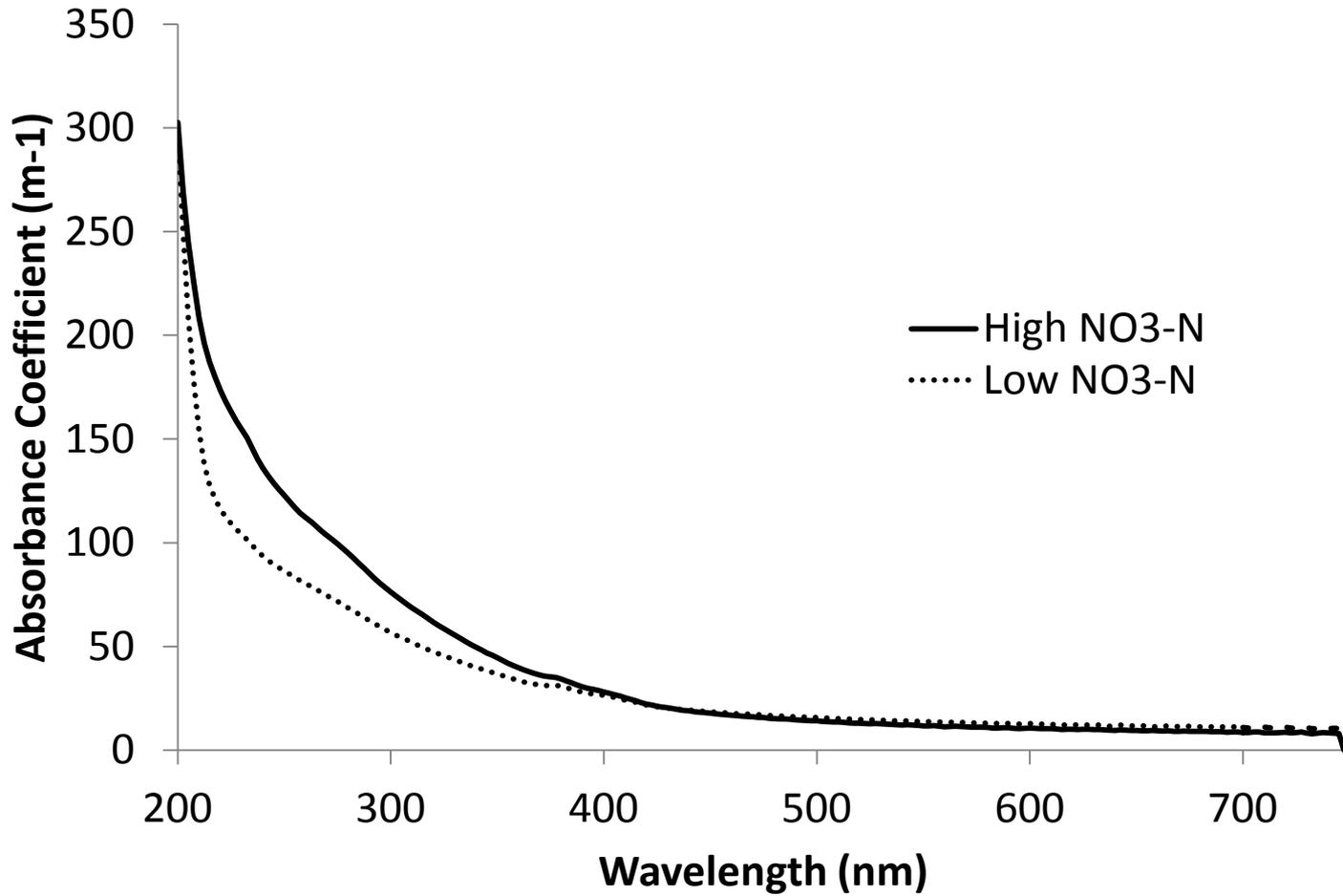


# The spectrometric process analyser

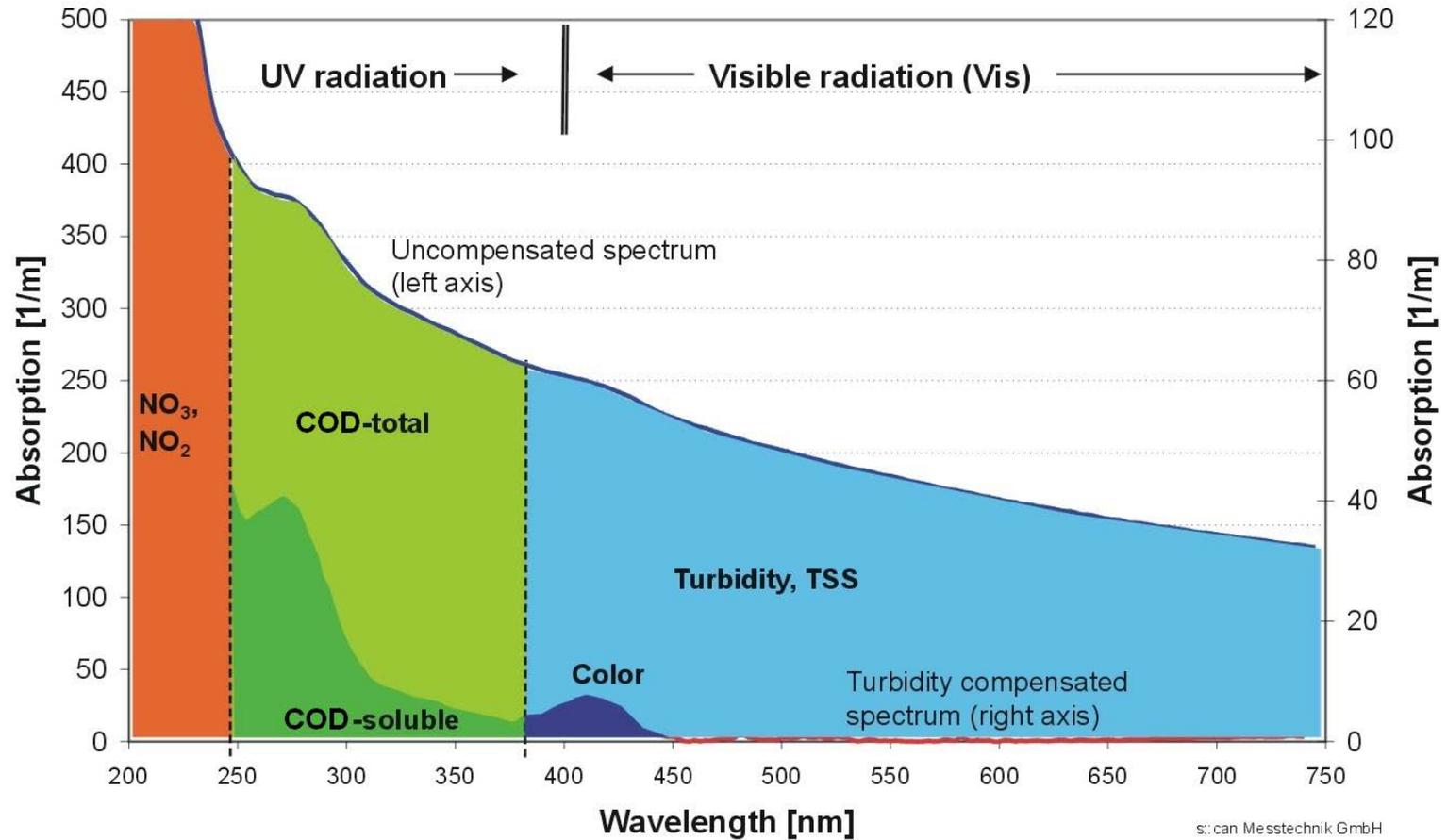
The measuring principle – Lambert Beer



# Absorption Spectra



# Absorption Spectra



s:can Messtechnik GmbH

# What parameter can we measure?

- Most manufacturers advertise for Nitrate
- Some add DOC and Turbidity
- Other parameters may be linked to turbidity (e.g. TP, PON) or to DOC (e.g. DON)
- Possibly covariability between light absorbance and other parameters?

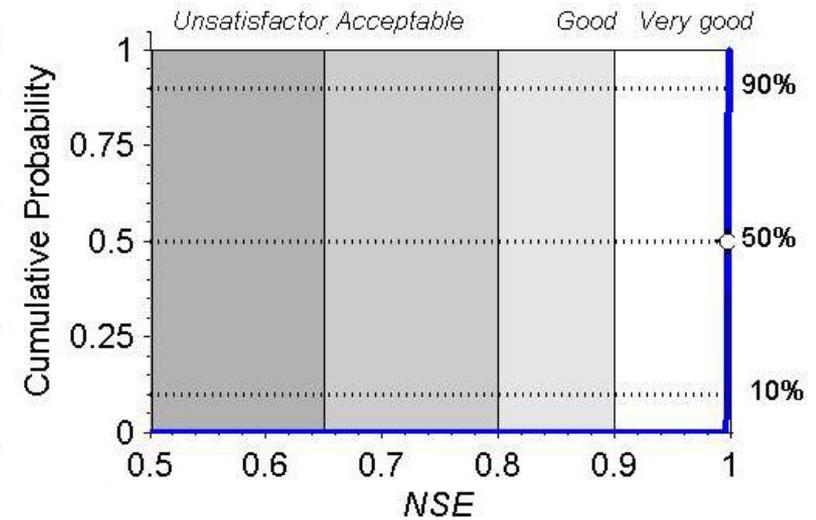
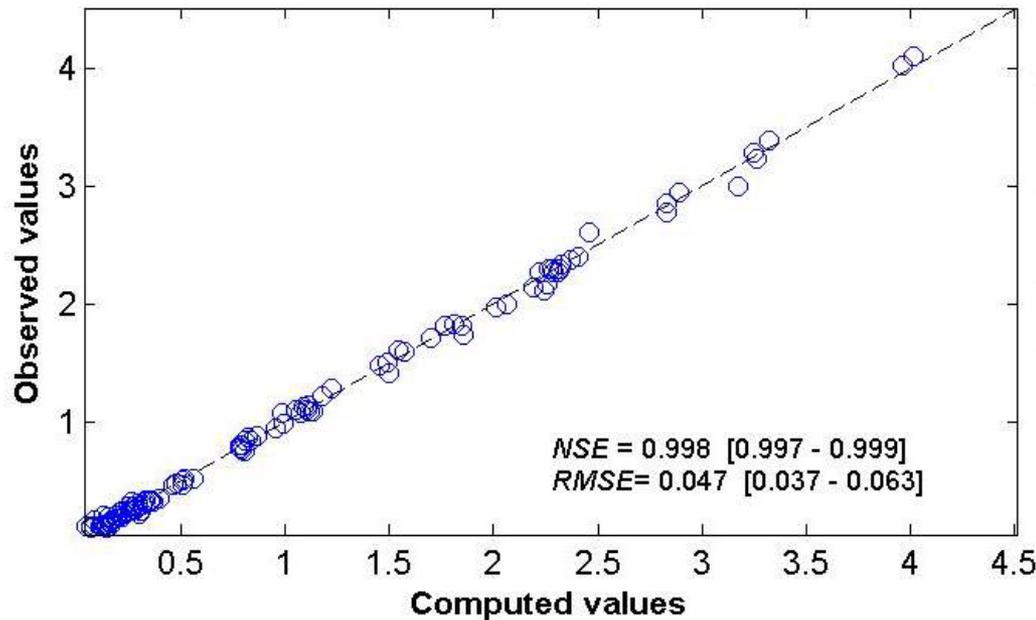
# Breaking the manufacturers code

- Manufacturers have created algorithms able to calculate reliable concentrations
- Relatively simple to require affordable computational capabilities
- Use chemometrics to create regressions between absorbance and concentrations
- Main tool: Partial Least Square Regression (PLSR)

# plsr

- Partial least squares regression correlates spectral data with chemical concentrations
- Reduces dimensions of system
- Allows selection of the number of dimensions to use in modeling the relationship between uv/vis spectral fingerprint and concentrations

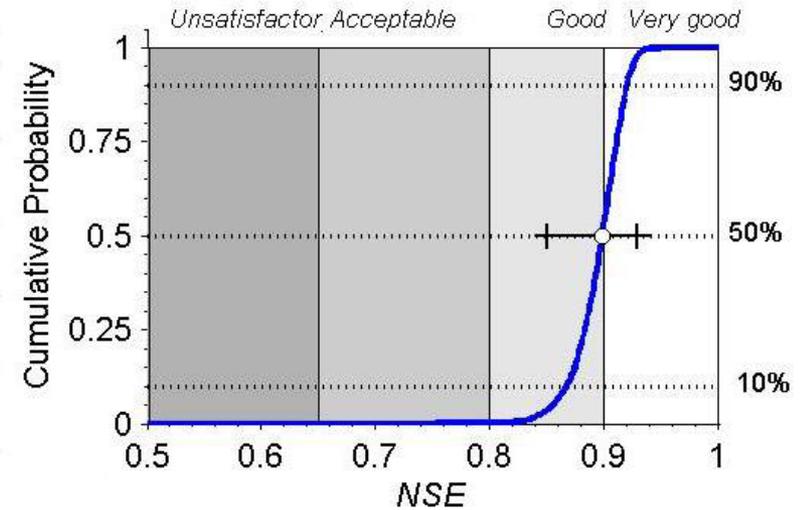
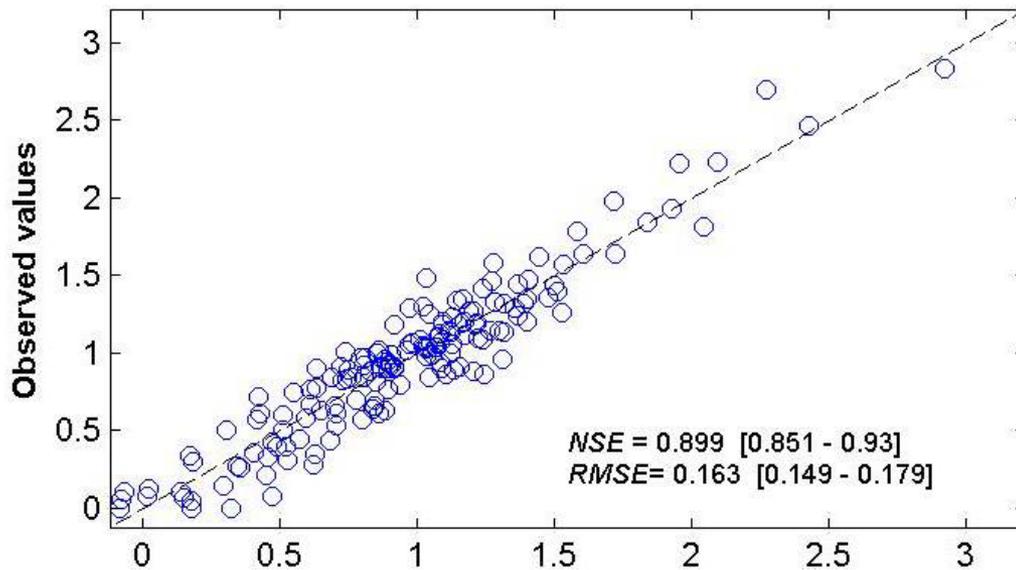
# Results for NO3 in our marsh



$p = 0$

(Graphs from Fiteval, Ritter and Muñoz-Carpena, 2013, JH)

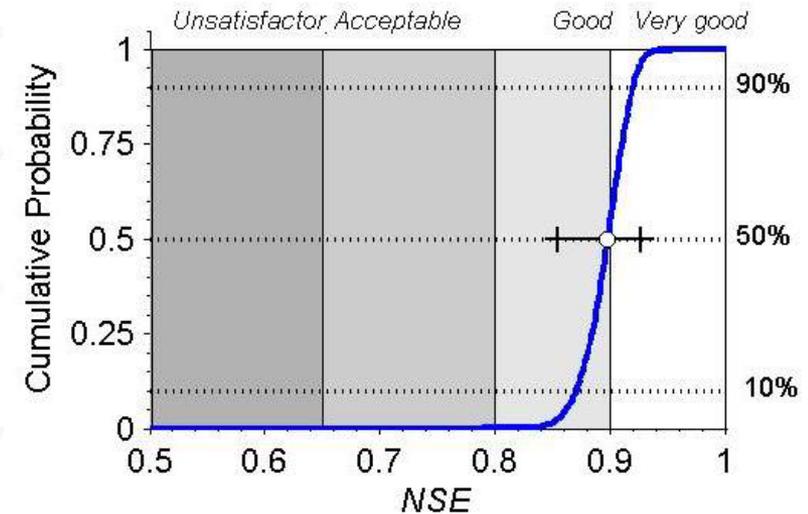
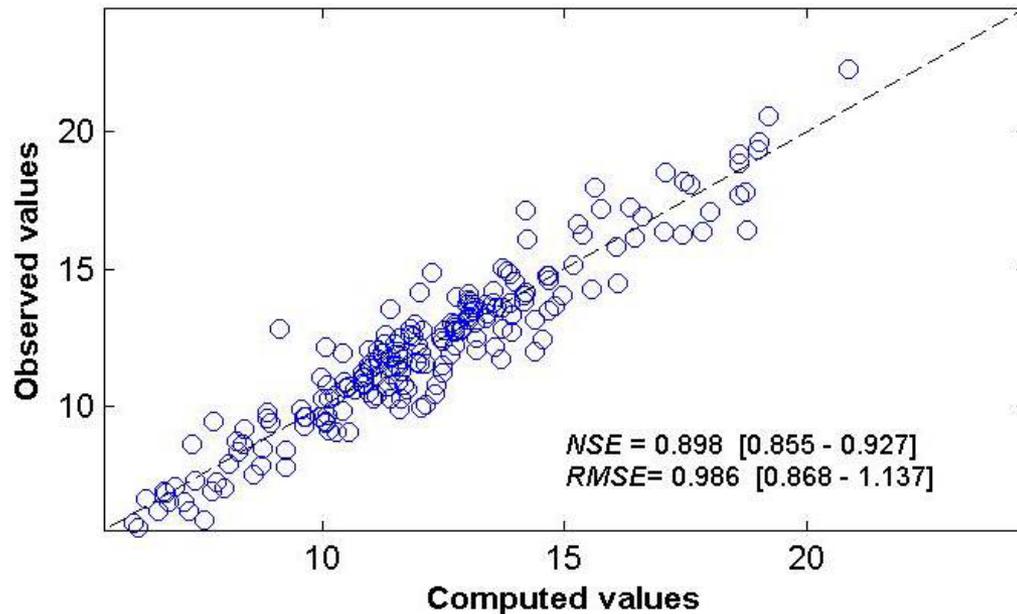
# Results for TKN in our marsh



$p = 0$

(Graphs from Fiteval, Ritter and Muñoz-Carpena, 2013, JH)

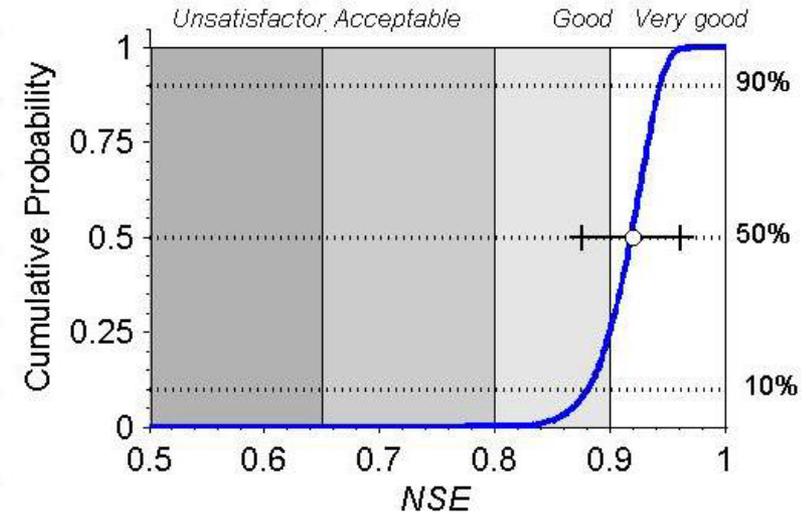
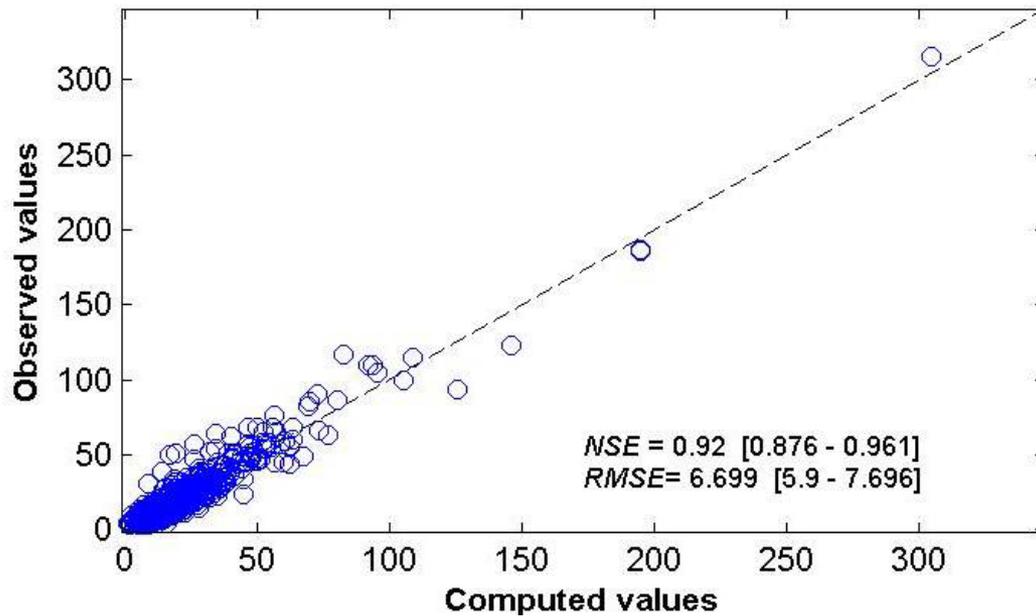
# Results for DOC in our marsh



*NB: FDOM did significantly improved regression*

(Graphs from Fiteval, Ritter and Muñoz-Carpena, 2013, JH)

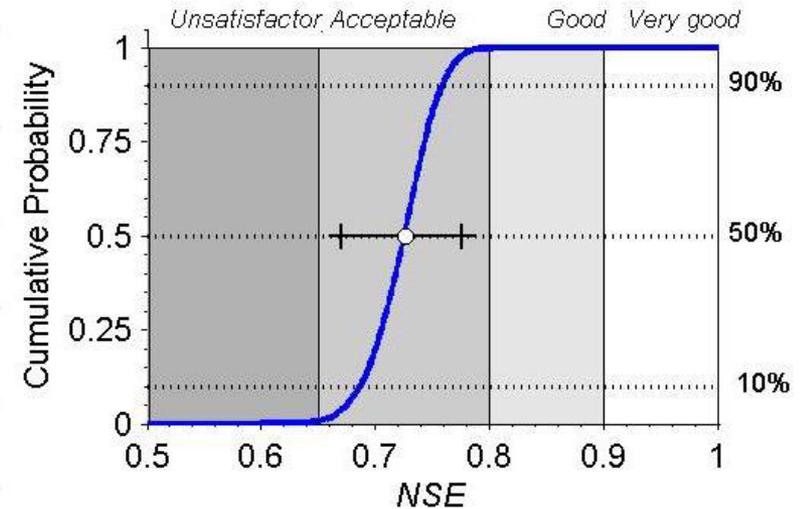
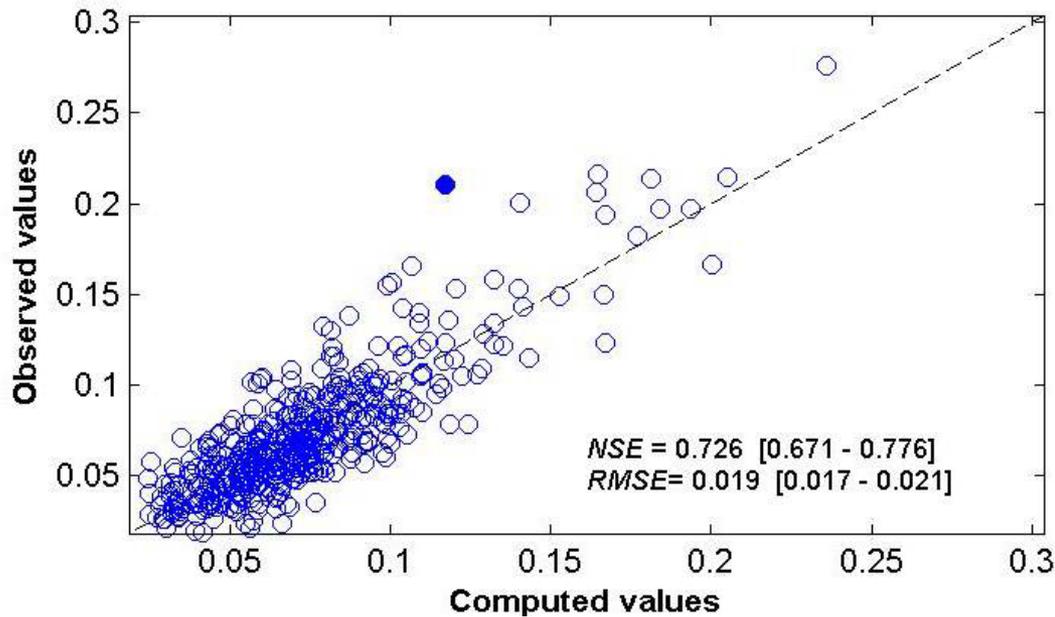
# Results for TSS in our marsh



$p = 0$

(Graphs from Fiteval, Ritter and Muñoz-Carpena, 2013, JH)

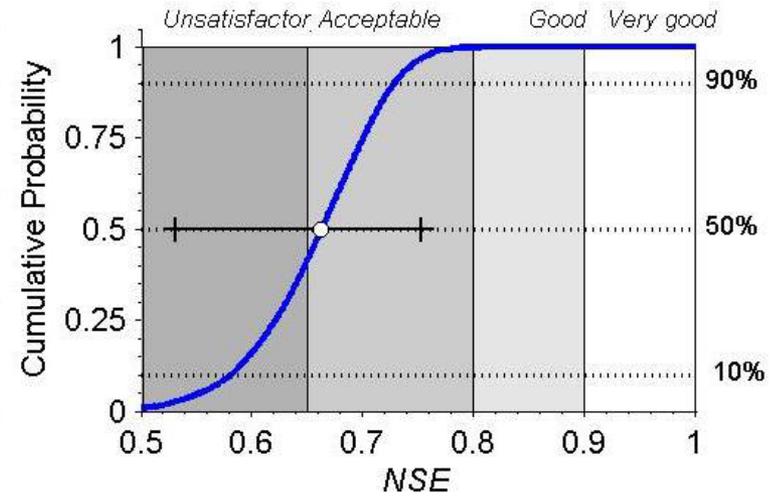
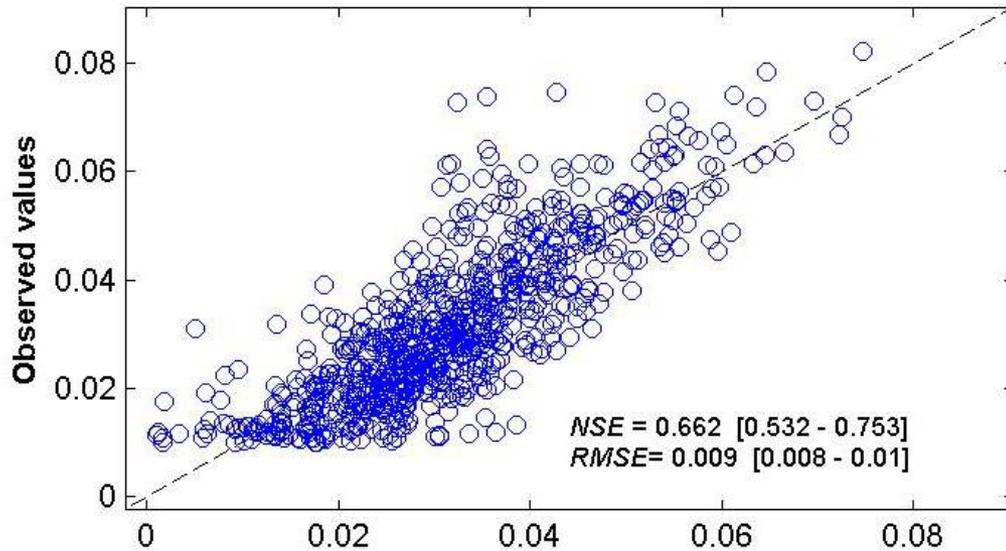
# Results for TP in our marsh



$$p = 0.006$$

(Graphs from Fiteval, Ritter and Muñoz-Carpena, 2013, JH)

# Results for PO4 in our marsh

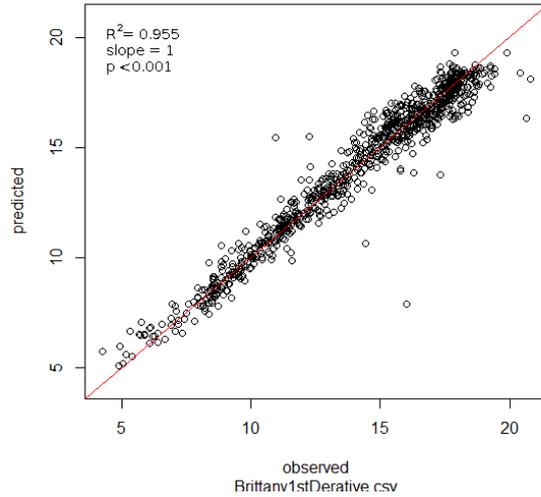


$$p = 0.41$$

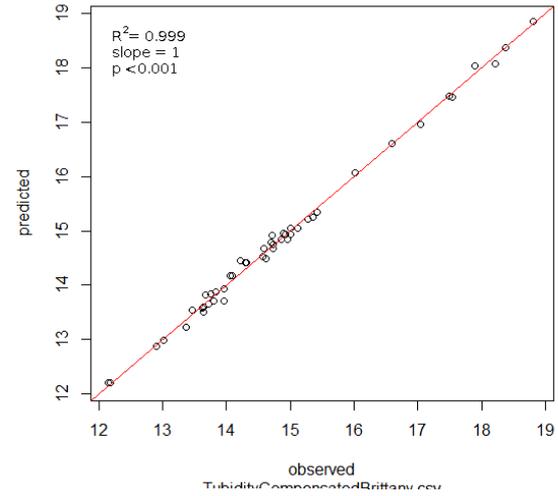
(Graphs from Fiteval, Ritter and Muñoz-Carpena, 2013, JH)

# Want more?

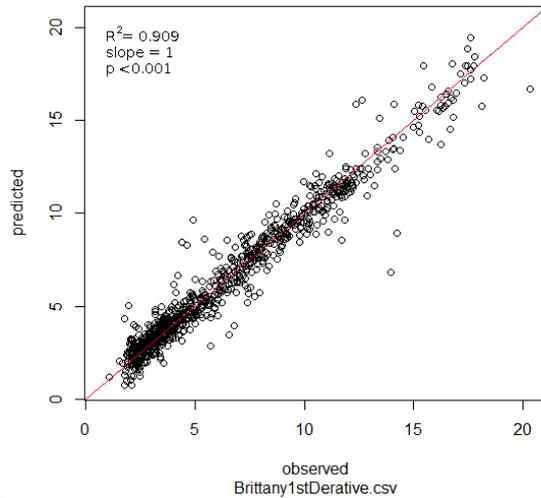
## NO3-N



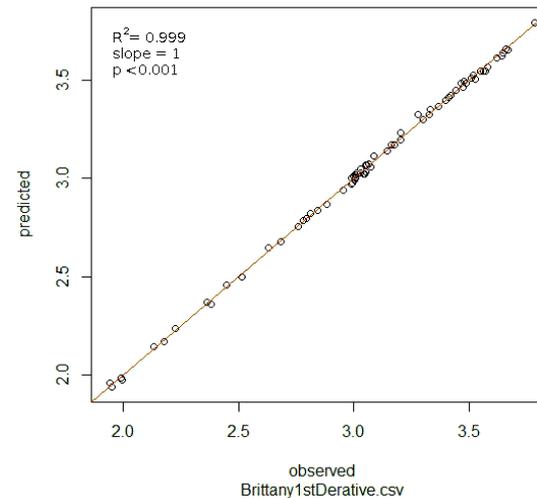
## TN



## DOC



## Silica



# WQ Rating curves

- We are essentially proposing to create water quality rating curves per station
- Need to quantify uncertainties
  - How many samples do we need per year?
  - Is it going to be cheaper/more expensive?

*Etheridge et al., 2014, LOM*

# Really necessary?

- Only mean to capture stochastic events intrinsically linked with hydrological processes
- Capture the effects of biogeochemical processes on water quality
- Key to improve/revise our models
- Key to improve our assessments and decisions

→ **My opinion: They are absolutely necessary!!**

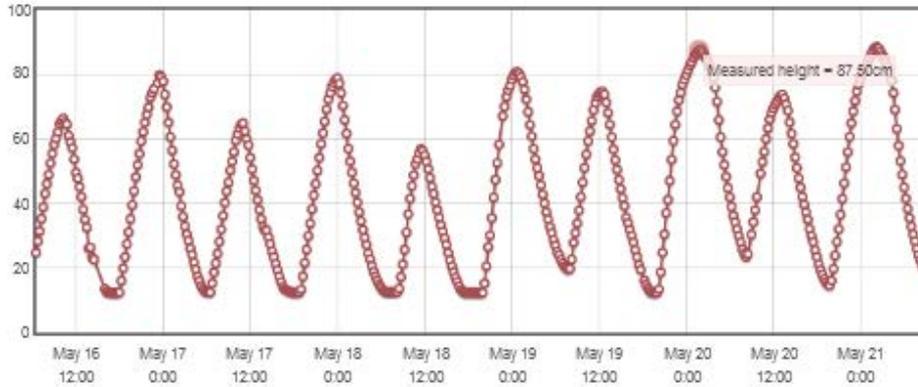
# Some uncomfortable questions...

- Should we keep monitoring stations with 2-6-12 samples per year?
- For what WQ parameter?
- Should we focus on several stations intensively instead?
- Is there a right compromise?
- Monitoring standards obsolete?...

# Just imagine...

- Cell phone apps ...
  - for each farmer to check on the WQ now and for the last days/months?
  - For each home owner to looks at the quality of the neighborhood creek?
- The more informed we are the better our decisions: better planning, must less wasting

Previous Next



# Hydrology for all!

[www.gaugecam.com](http://www.gaugecam.com)

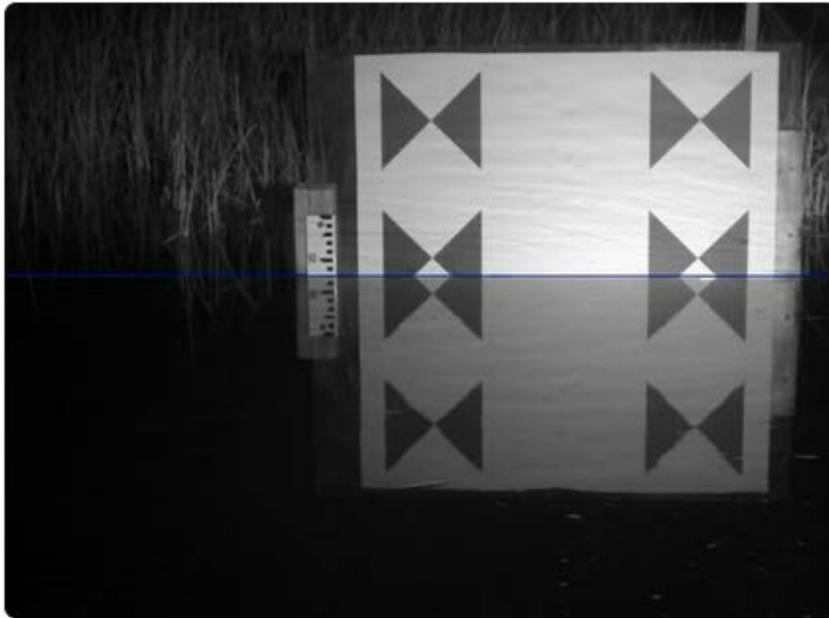
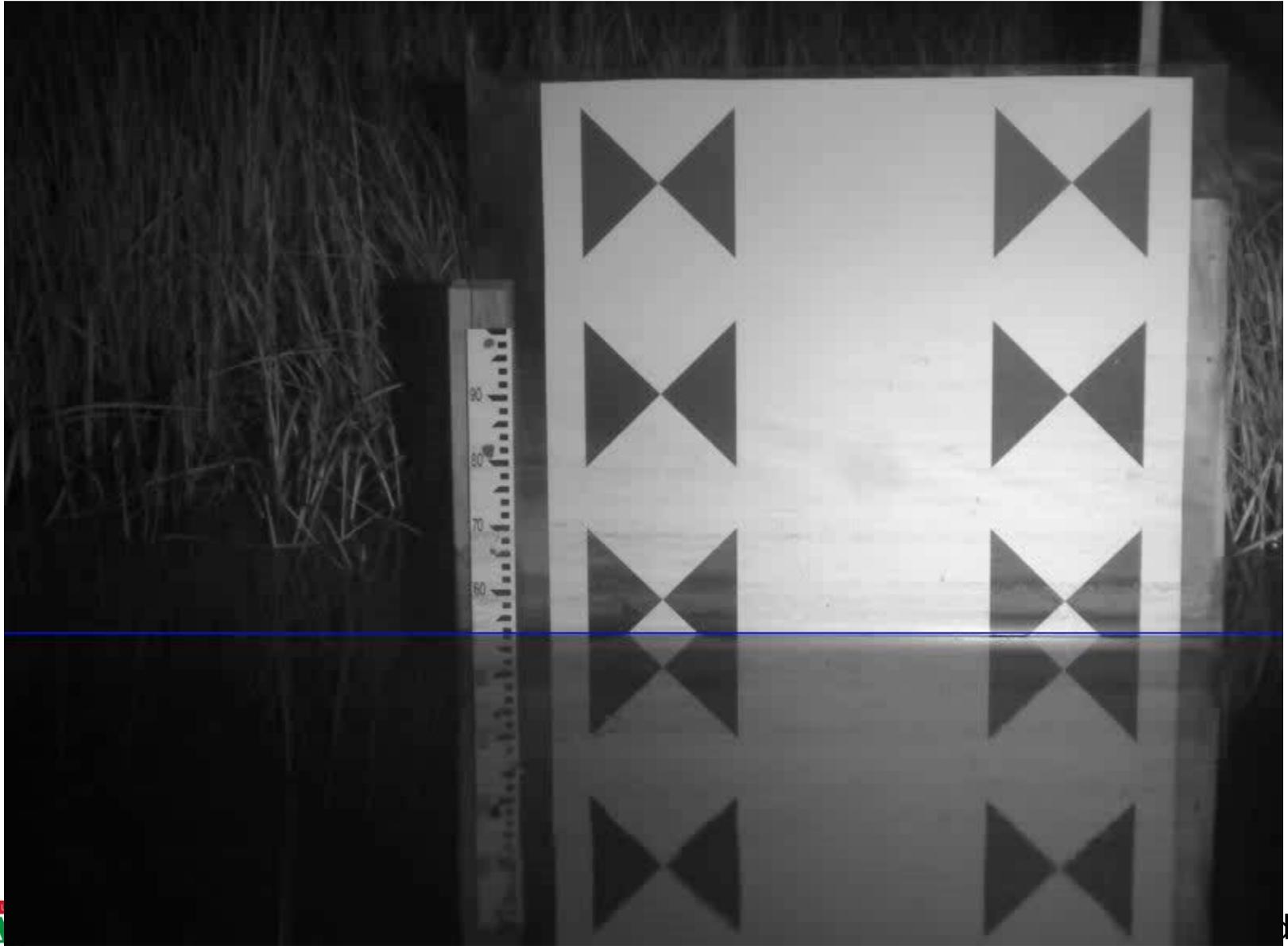


Image taken at: 22:45:00 GMT-0400 (Eastern Daylight Time) Sat May 19 2012  
Measured height: 87.50cm

# Videos: everyone can understand

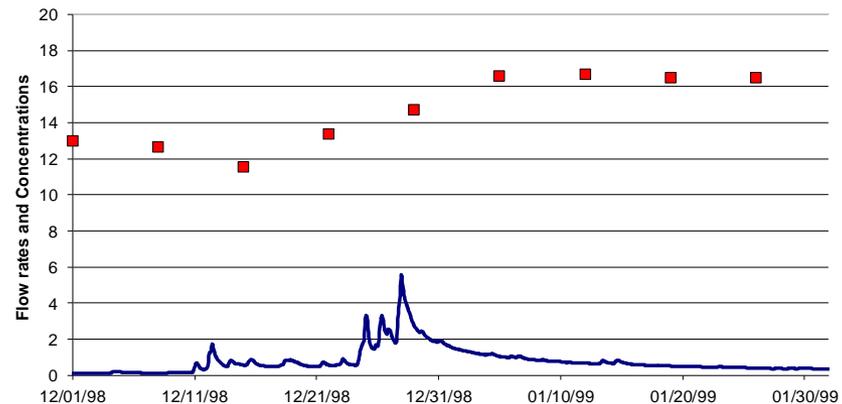


# The challenges...

- A lot more information that comes with...
  - ... A lot more work
  - ... A lot more money
- But I doubt we have the choice not to invest in these systems

# Partial stories halt progress...

" ... ..Troy ... .. . Marc ... .. hard; ... ..  
... .. forehead. ... .. unconscious ... ..  
floor, ... .. face ... .. Marc ... .. all ... ..  
... .. bad ... .. feared."





Thank you for your attention!

Questions?