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Department of Biological and Agricultural Engineering

Can tidal marsh creation be used to reduce nitrogen loads reaching estuaries?

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and François Birgand (*presenter*)

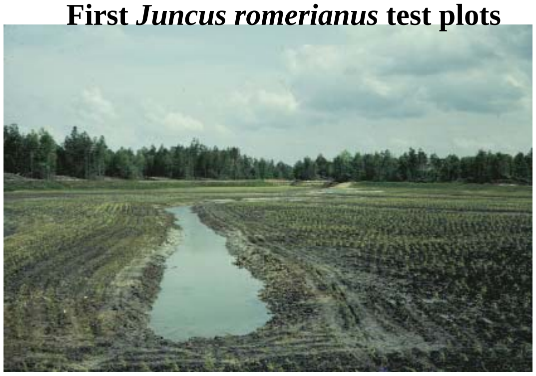
ASABE – Annual International Conference
Montréal, July 2014

Tidal Marsh Mitigation – P mining

“Reference”

8 ac site after grading - 1983
(1.2 ft upper to lower marsh)

40,000 greenhouse seedlings planted
(*S. cynosuroides, alterniflora* and *patens*)
First *Juncus romerianus* test plots



1984 – after two growing seasons

Maximizing ecosystem services

- Tidal stream and marsh restoration has progressed, but the practice is still developing
- Restoring or creating tidal marshes at current rate will never result in reclaiming all of the ecosystem services once provided
- We need to take full advantage of opportunities to maximizing these services (like **water quality**, C sequestration) in these areas without jeopardizing habitat services
- Case study - Tidal stream and marsh complex - North River Farms near Beaufort, NC

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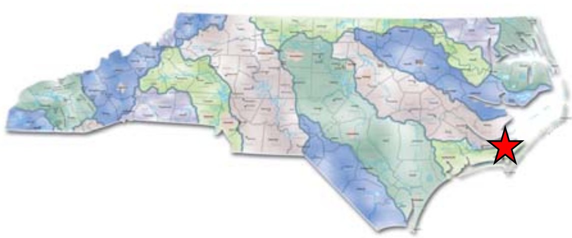

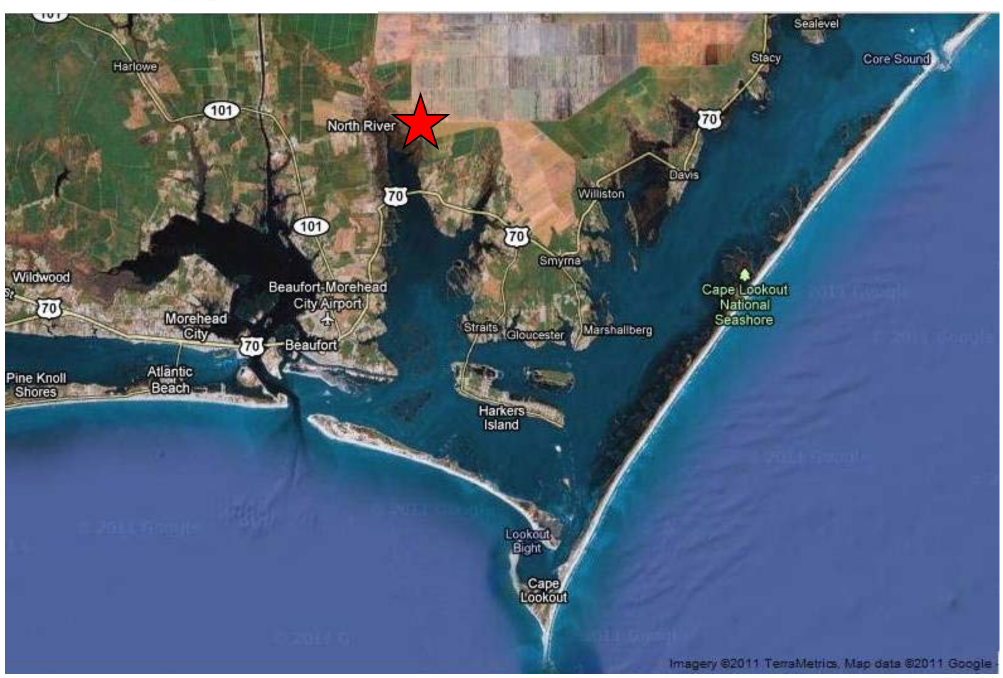

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Project Goals

- Demonstrate non-traditional design techniques for restoring wetlands to an agricultural landscape
- Create a stable tidal creek and marsh ecosystem that integrated into surrounding marsh
- **Reduce exports of agricultural pollutants to the North River estuary**
- **Conduct research studies to evaluate stability of the design and other ecosystem services provided**

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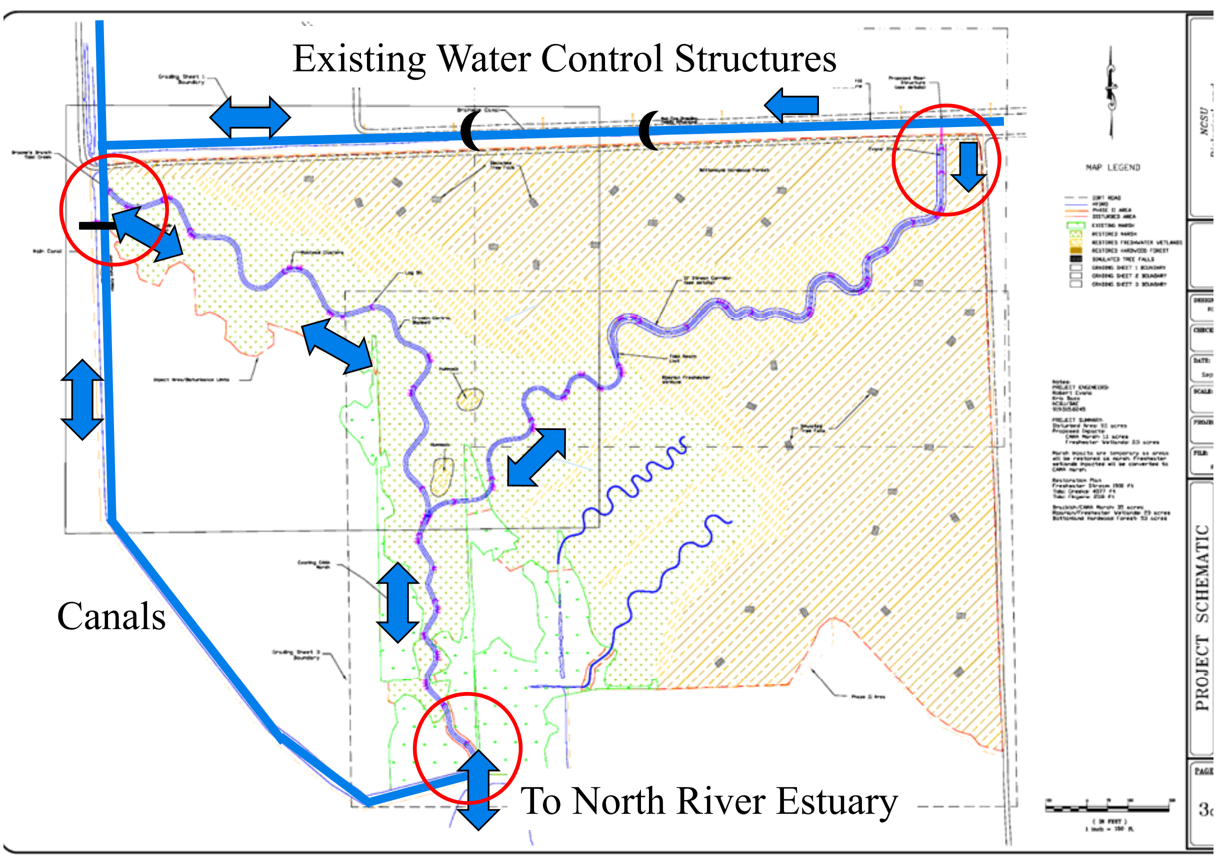
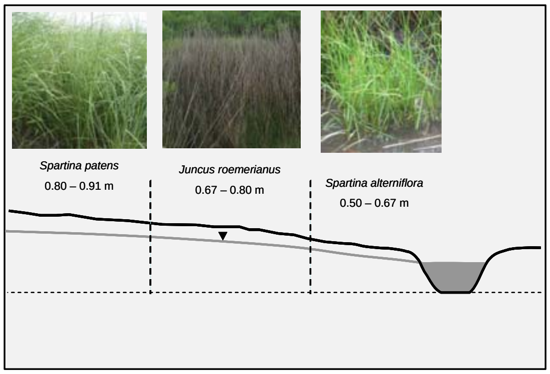


Construction - 2006

Phase II images – 110 acres (35 tidal marsh)

Tidal Marsh Planting plan (150,000 plants)



Earthwork

Diversion from canal to tidal creek

June 2009

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Research Question

- Are nutrients (NO_3-N) and sediment retained or released by a restored salt marsh?

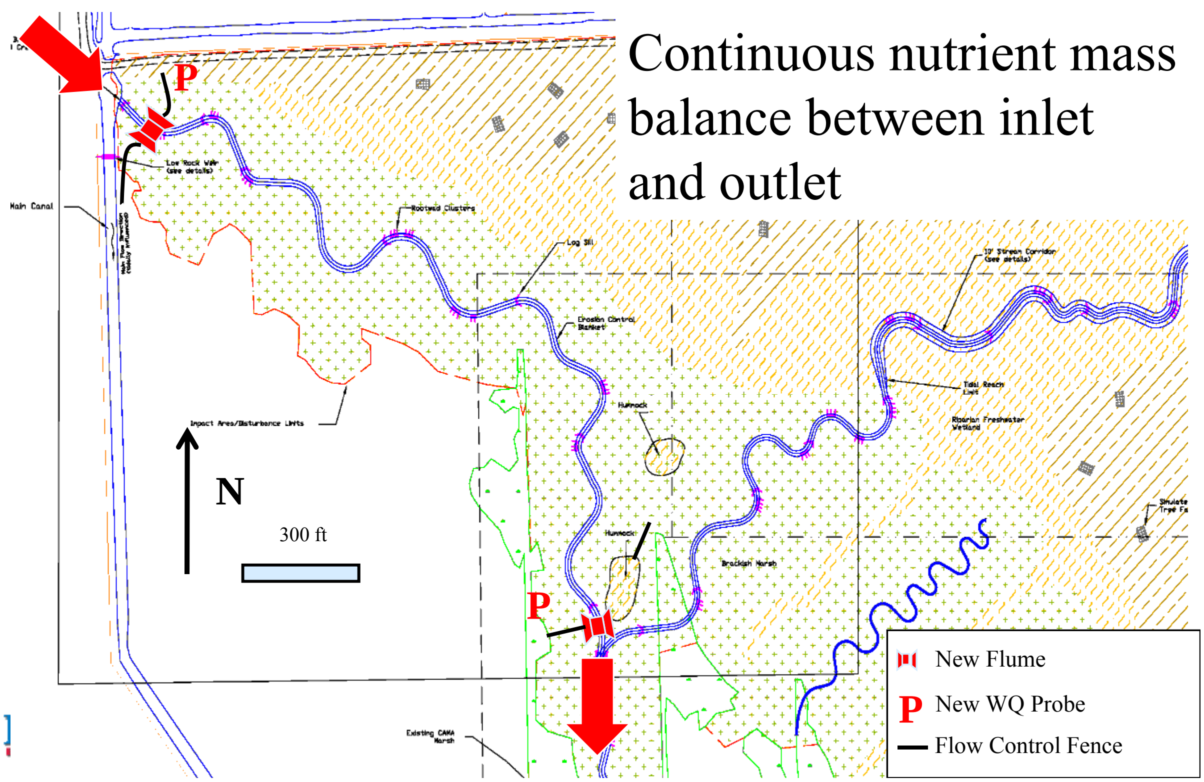
Advanced hydrology and water quality monitoring in the marsh

- <u>Primary Objective:</u>
  - Quantify the effects of in-stream and in-marsh processes on nutrients from ag land draining through the marsh (focus on NO_3-N)
    - At the tidal cycle, monthly, seasonally and yearly scales

Dr. Randall Etheridge
(previously PhD student)

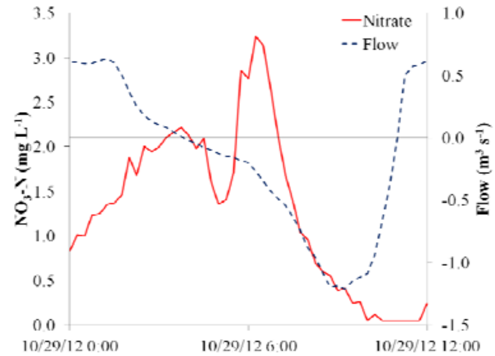
Methods

Continuous nutrient mass balance between inlet and outlet

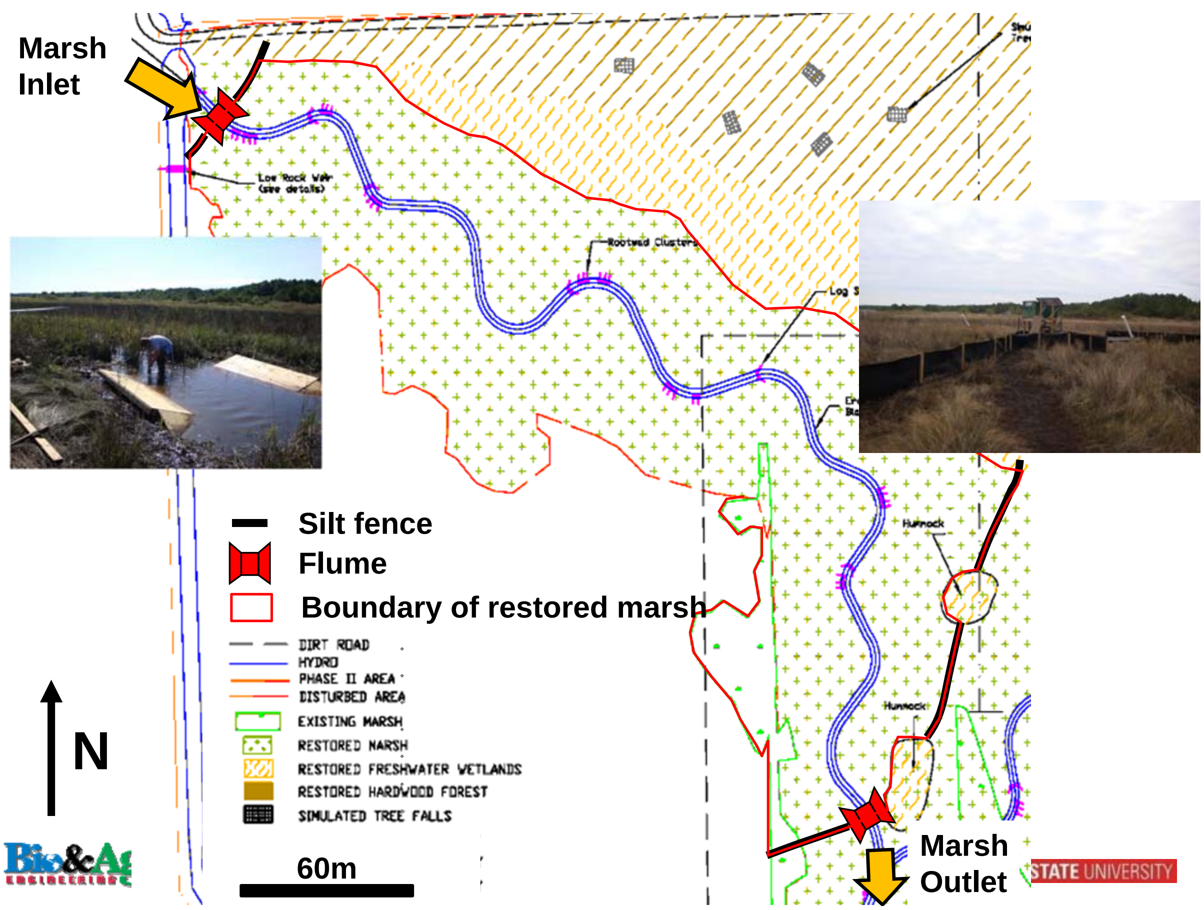


Mass Balance

$$M = k\sum_{i=1}^{i=t} q_i c_i \Delta t$$

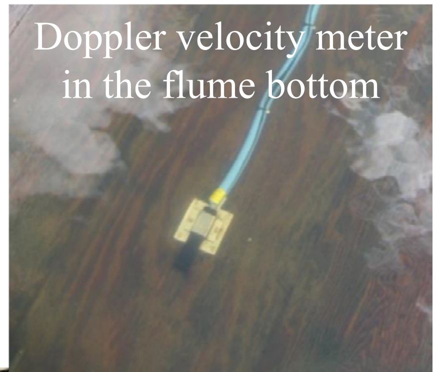


- M = total mass of N either exported or imported (kg)
- t = time (min)
- k = constant for converting units
- q_i = water flow at time i ($m^3\ s^{-1}$)
- c_i = concentration at time i ($mg\ L^{-1}$)



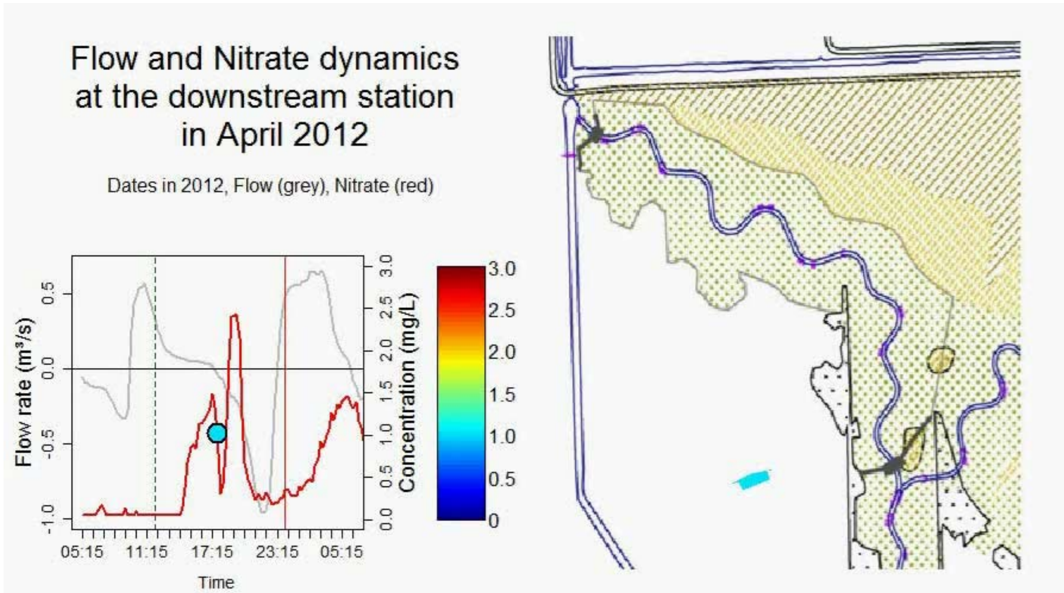
Flow Monitoring

- Doppler velocity meter records velocity and water depth in flume
- Velocity and water depth recorded every 15 minutes
- Use manual stream gauging to relate Doppler velocity to actual flow in the flume



Continuous Nitrate Monitoring

- Monitored using UV-visual spectrometer
- Absorption spectrum measured every 15 minutes
- Anti-fouling system



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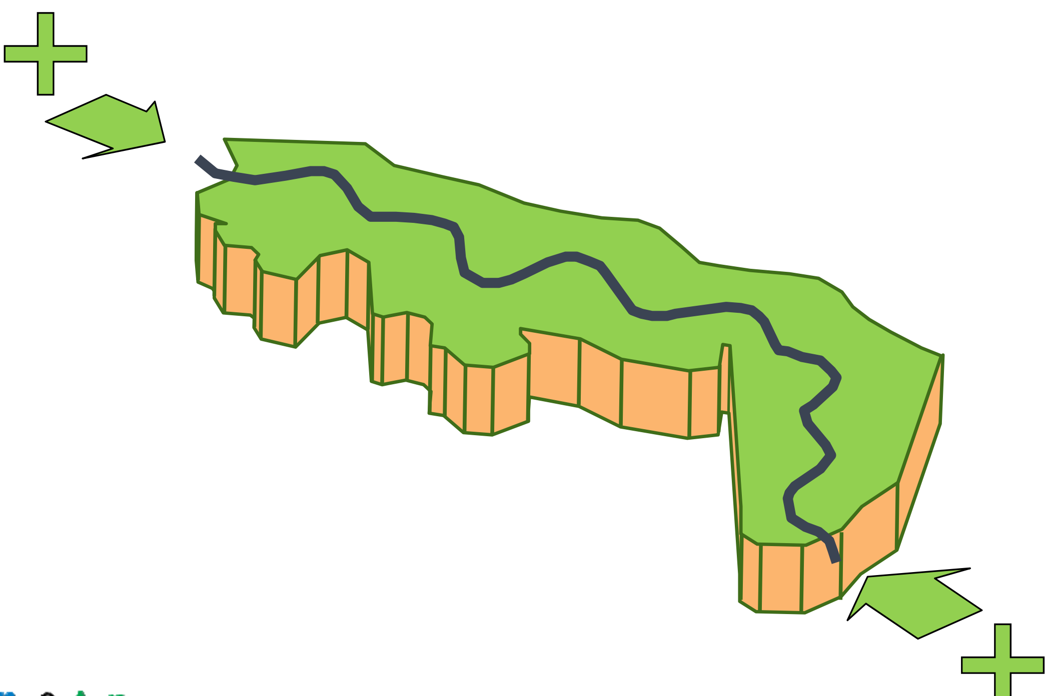
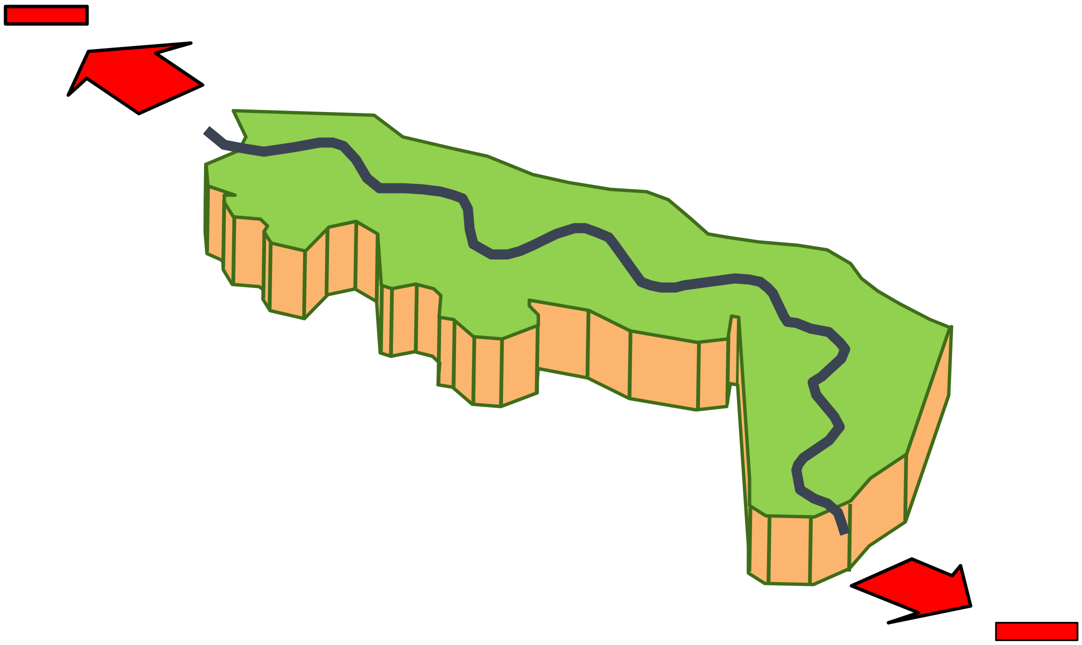
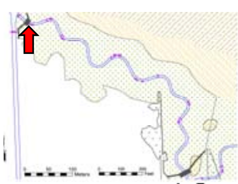
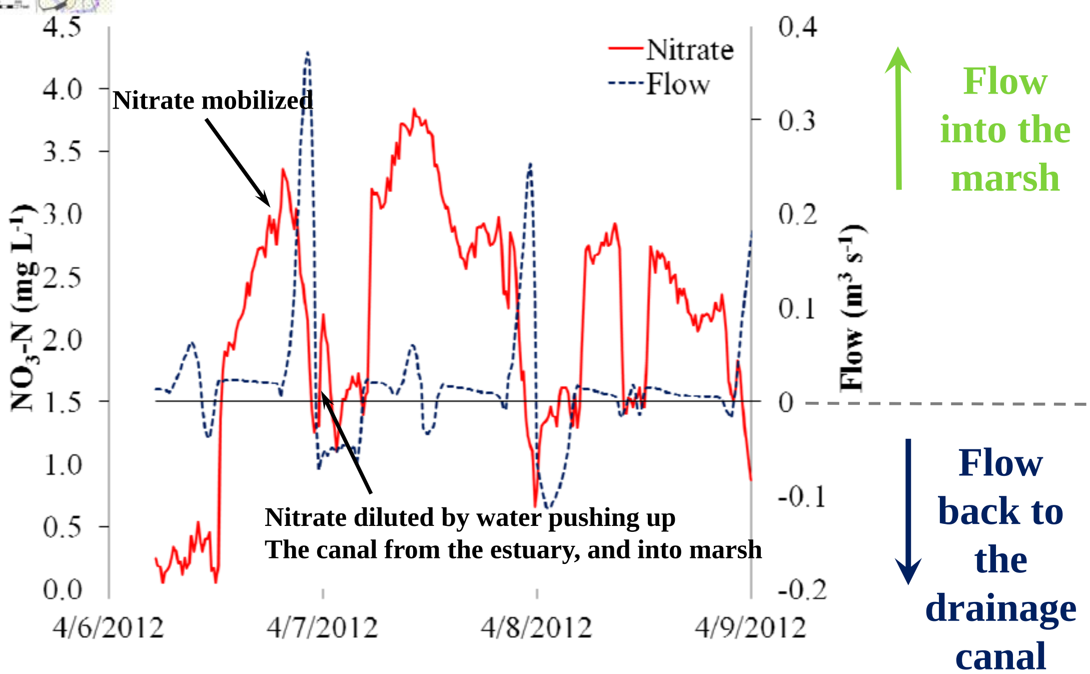


Positive Mass Balance = Retention
Negative Mass Balance = Release

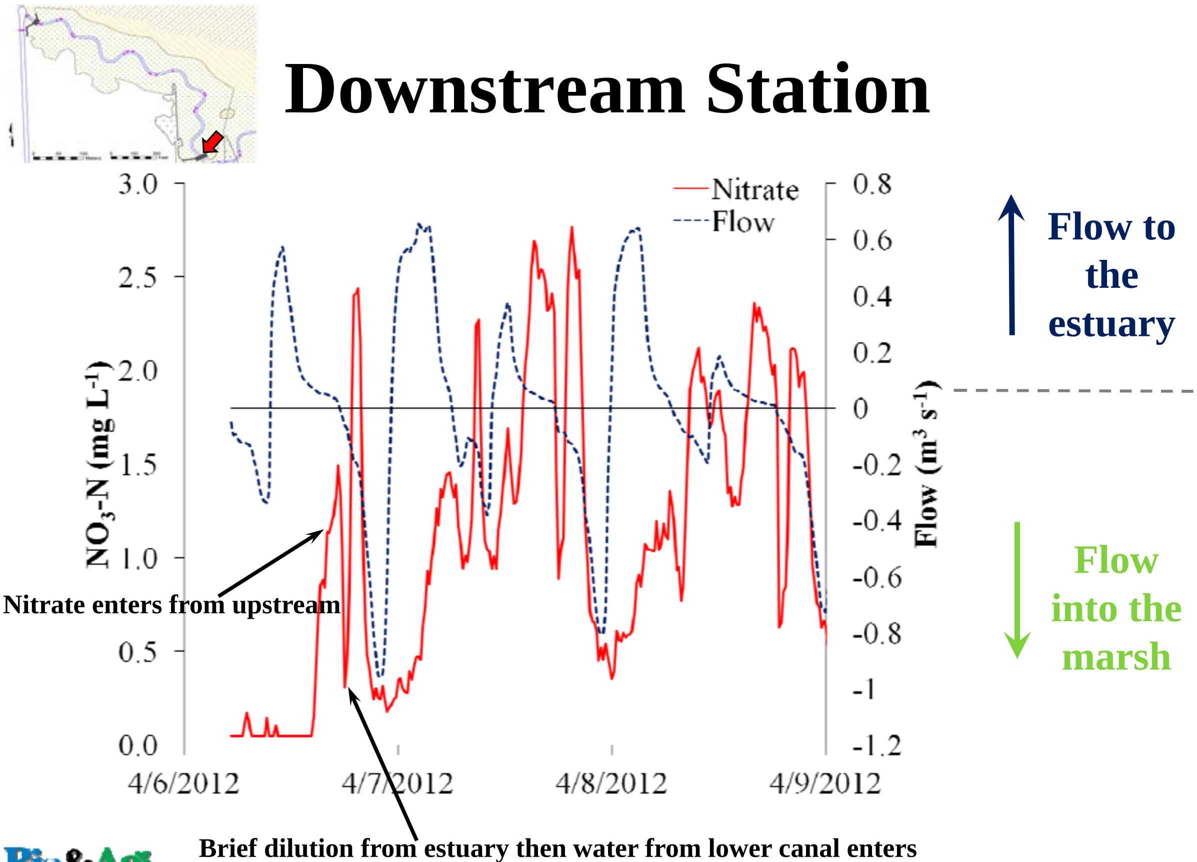




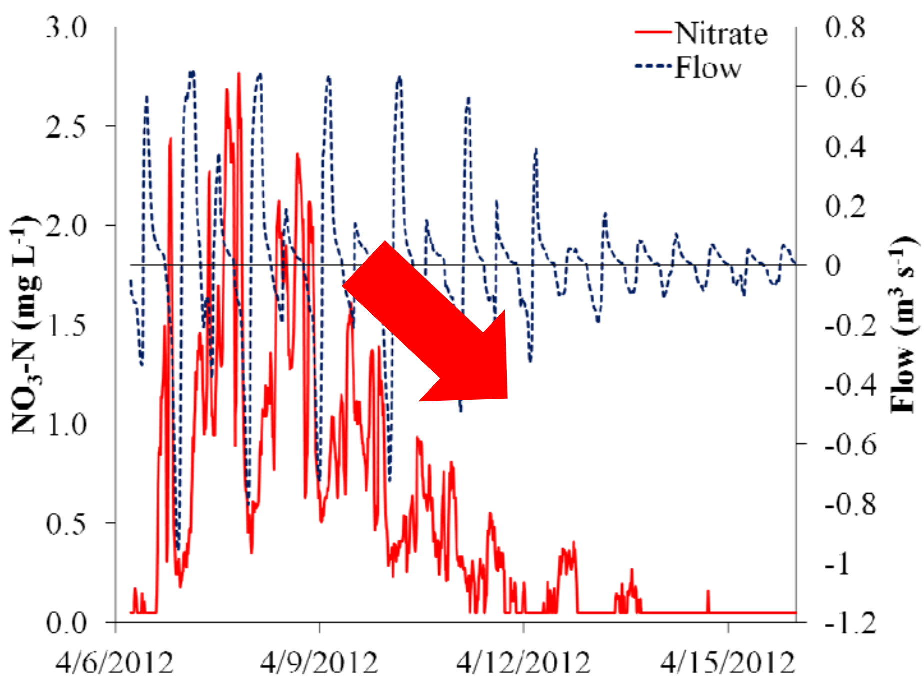
Upstream Station



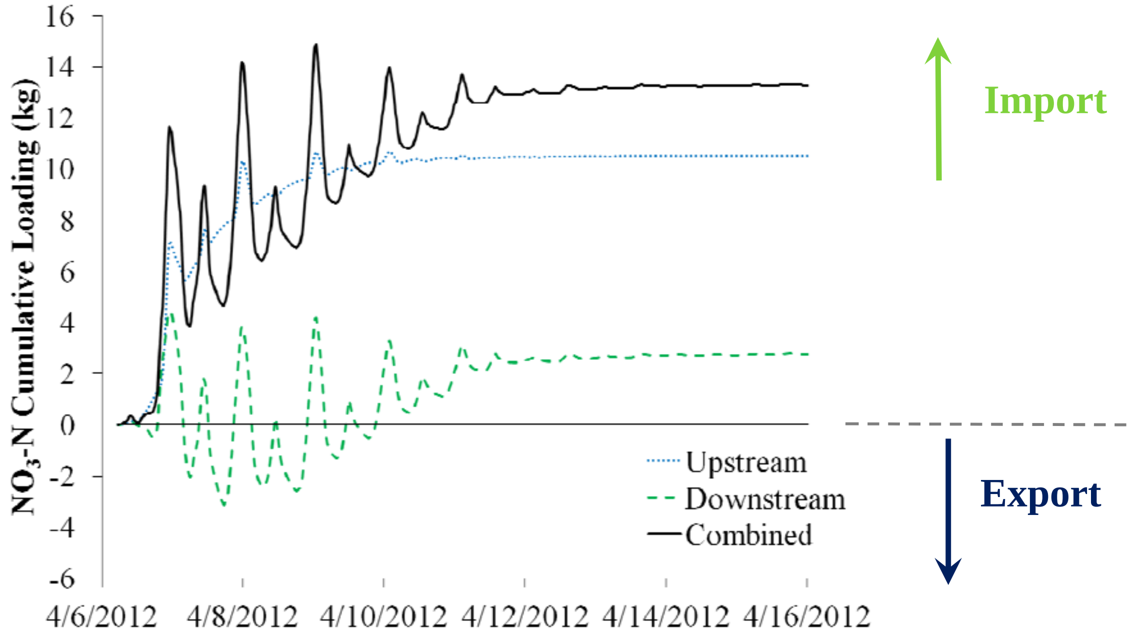
Downstream Station



Maximum nitrate concentrations decrease following the rainfall event



Nitrate



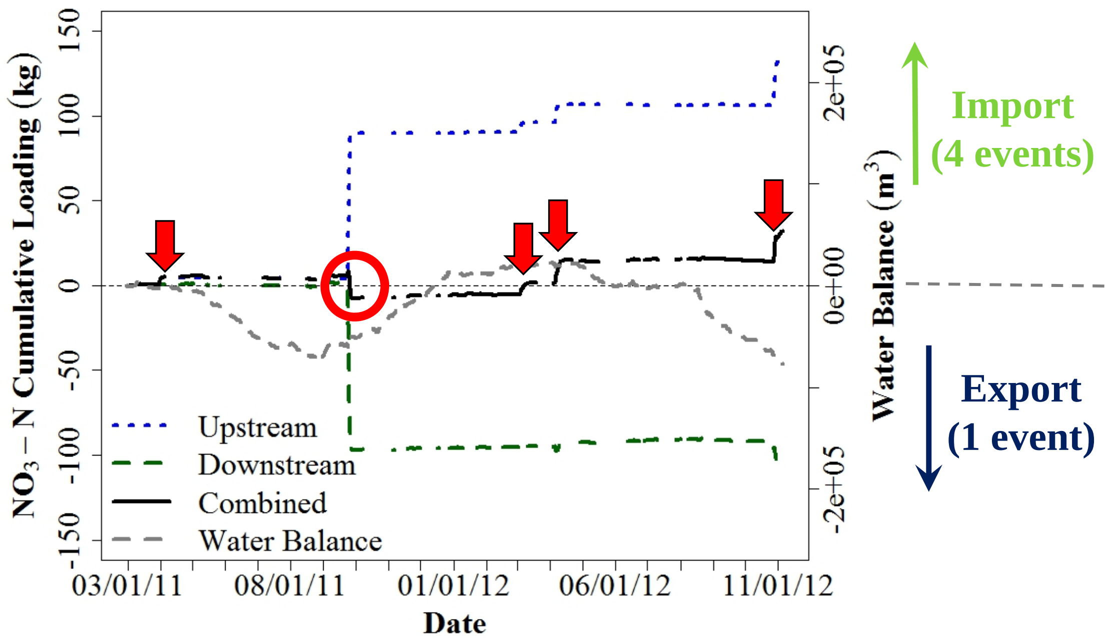
Mass Balance Summary:

Single storm event

Parameter	Input Mass (kg)	Output Mass (kg)	Mass Balance (kg)	Percent Retention
NO_3-N	**53**	**40**	**13**	**25%**
TKN	49	50	-1	-2%
DOC	562	561	1	0%
PO_4-P	2.11	2.13	-0.02	-1%
TP	4.4	4.4	0	0%
TSS	1700	1660	40	2%

Note – the use of the UV spectrometer was extended through extensive calibration techniques that related laboratory concentrations to absorbance spectra using Partial Least Squares Regression (PLSR)

Long term nitrate study



Mass Balance Summary

Entire study period (18 months)

Parameter	Input Mass (kg)	Output Mass (kg)	Mass Balance (kg)	Percent Retention
NO_3-N	**470**	**430**	**40**	**9%**
TKN	1,290	1,410	-120	-9%
TN	1,760	1,840	-80	-5%
DOC	18,000	19,400	-1,400	-8%
PO_4-P	57	59	-2	-4%
TP	117	125	-8	-7%
TSS	48,000	51,000	-3,000	-6%

Potential Factors

- NO_3-N concentration
- Temperature
- Residence Time
- Dissolved Oxygen
- Wetted Area

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Retention Model

$$R = k\rho_n A C_{t-1}$$

- R is the mass of NO_3-N retained (kg day^{-1})
- k is a constant for converting units
- ρ_n is the temperature adjusted mass transfer coefficient (m day^{-1})
- A is the wetted surface area of the marsh and stream (m^2)
- C_{t-1} is the NO_3-N concentration in the marsh during the previous time step (mg L^{-1})

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Retention Model

$$\frac{dm_s}{dt} = m_{UP} + m_{DN} - R$$

- m_s is the mass of NO_3-N stored in the system (kg)
- m_{up} is the mass of NO_3-N entering or leaving through the upstream station (kg)
- m_{dn} is the mass of NO_3-N entering or leaving through the upstream station (kg)

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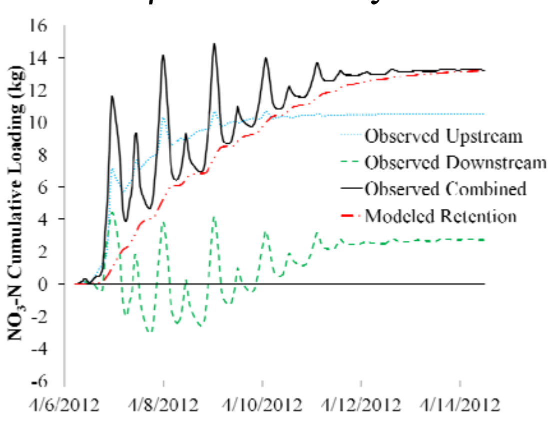
Model Performance

ρ = 0.28 m day^{-1}



- Literature ρ-values*: 0.01 – 1.2 m day^{-1}
- Calibrated ρ-values from this study: 0.18 – 0.31 m day^{-1}

*Literature ρ-values from Kadlec and Knight (1995), Birgand et al. (2007) and Kadlec (2012).

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Factors Impacting Percent Retention

- Flow and velocity at both stations
- Mass of NO_3-N input
- Duration of stage above bankfull

Significant at α=0.05

Conclusion

- The young restored tidal marsh appears to be a net nitrate sink
- Rainfall events drive nitrate delivery to the marsh – some retention, some export
- Residence time in the marsh, though longer than in the canal system, appear to limit nitrate treatment
- Restoring/creating marshes in strategic locations can reduce N losses to the estuary, but needs to be coupled with other land-use practices to make a significant impact
- What is the impact of the water balance observations (upwelling events?)

Questions?