Toward understanding the impact of dams on floods, droughts, and nutrient flux on the Lamprey River watershed

By David Simon

M.S. Hydrology Candidate

dws1005@wildcats.unh.edu

University of New Hampshire

NSF

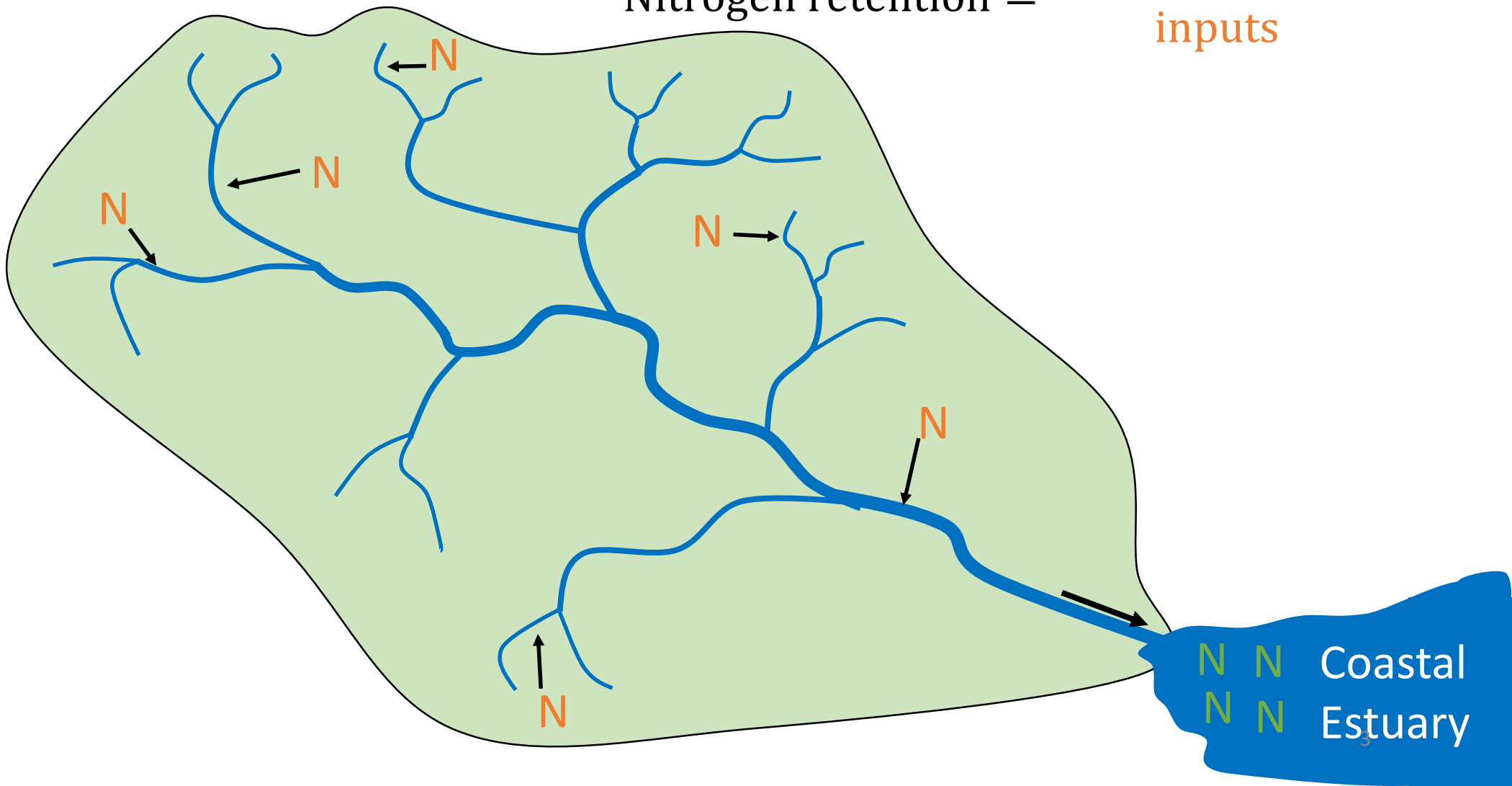
NEST New England SusTainability Consortium

Acknowledgements

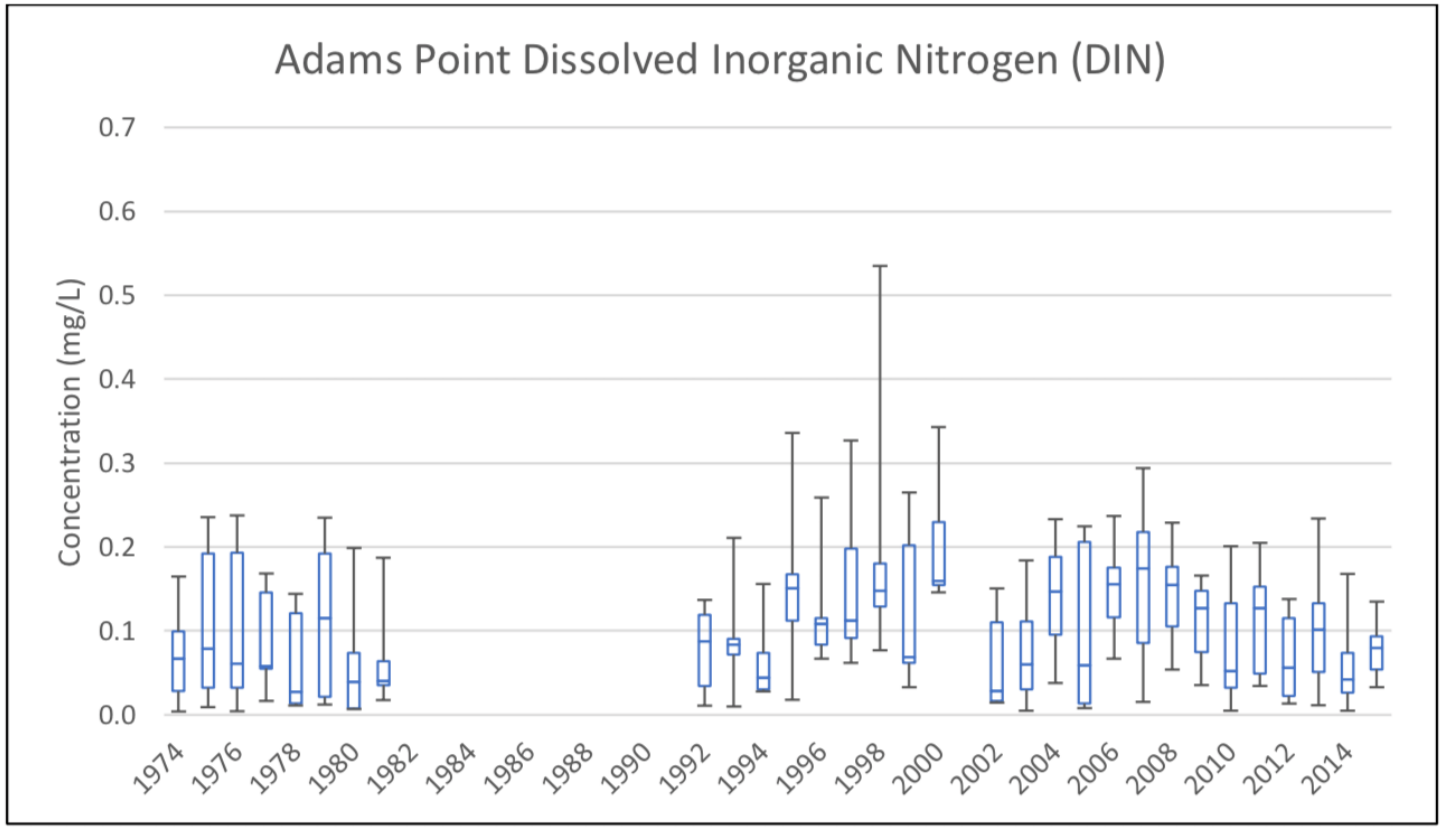
- Water Systems Analysis Group: Shan Zuidema, Danielle Grogan, Alex Prusevich, and Wil Wollheim
- The McDowell Group
- Wayne Ives of NHDES
- Colleagues from the Future of Dams Team

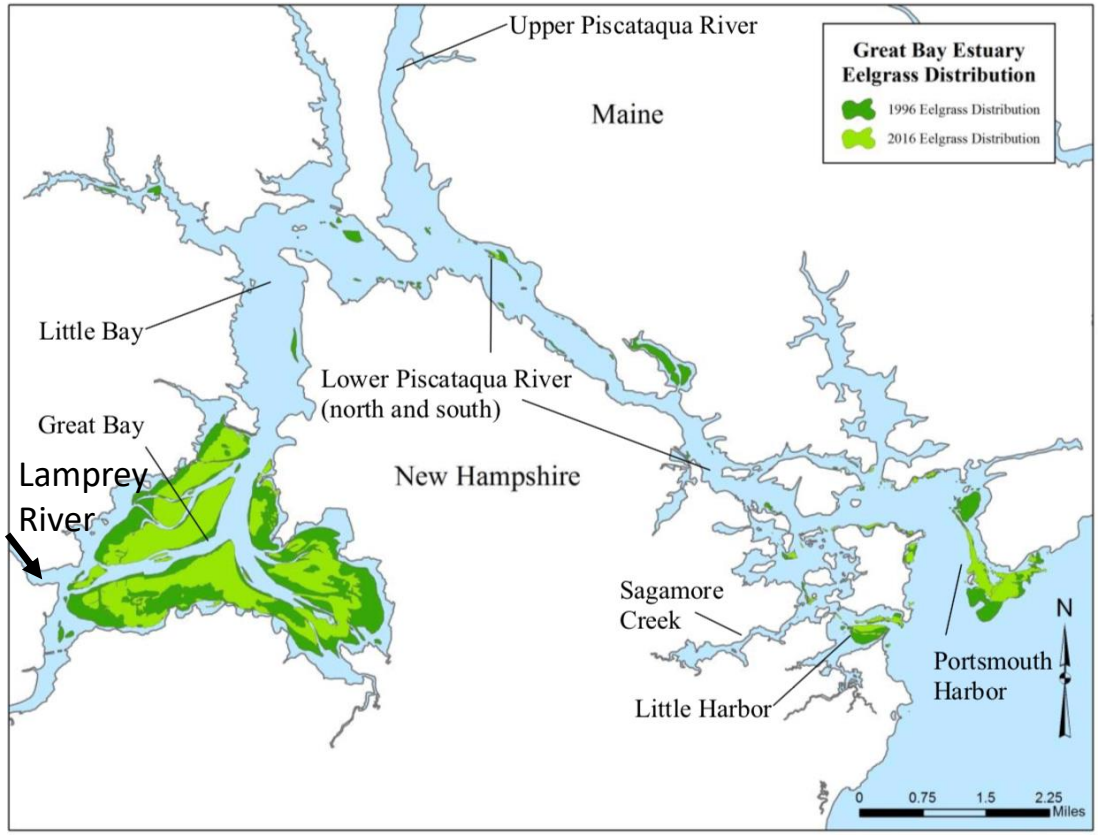
River network scale nitrogen retention

$$\text{Nitrogen retention} = \frac{\text{inputs} - \text{outputs}}{\text{inputs}}$$



Motivation



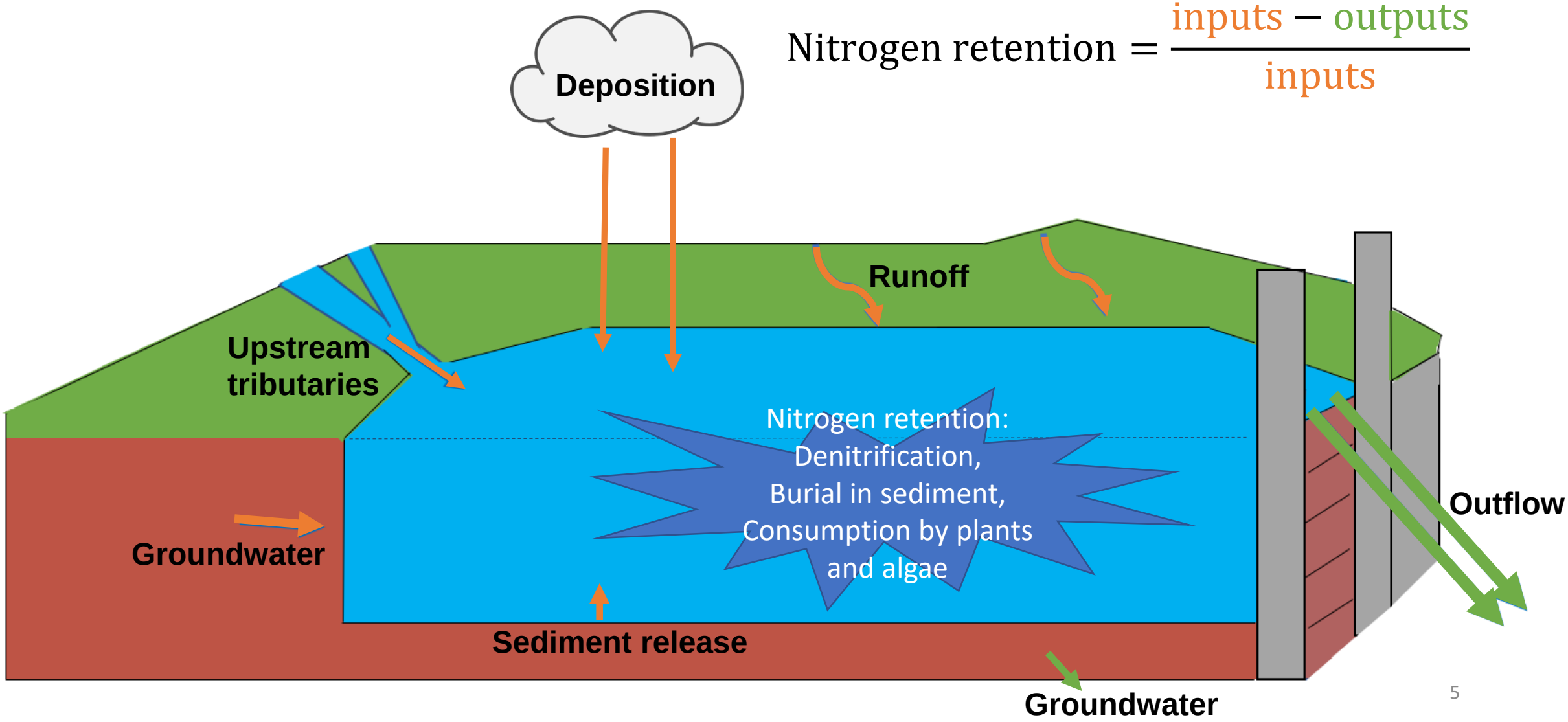


DIN = ammonium (NH_4^+) + nitrite (NO_2^-) + nitrate (NO_3^-)

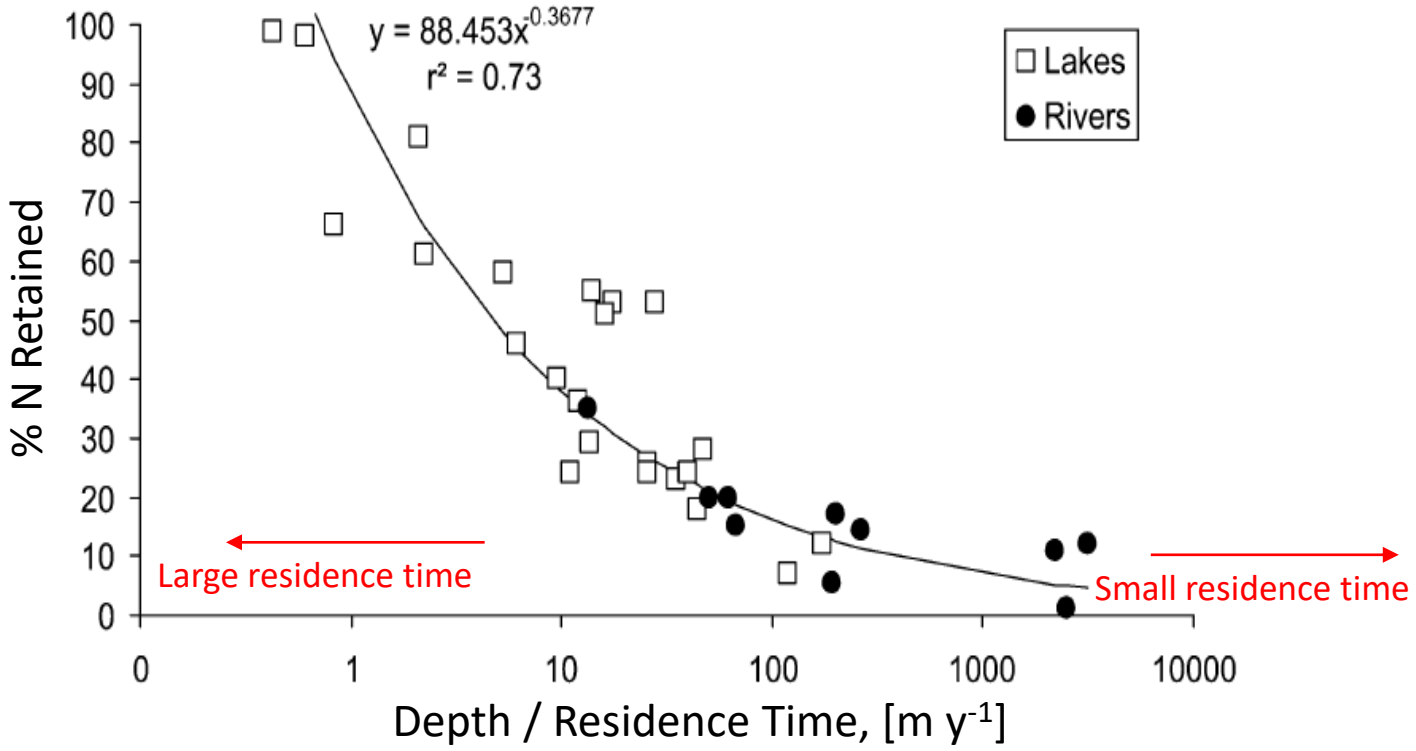
Figures modified from PREP State of our Estuaries 2018.

Nitrogen retention pathways

$$\text{Nitrogen retention} = \frac{\text{inputs} - \text{outputs}}{\text{inputs}}$$



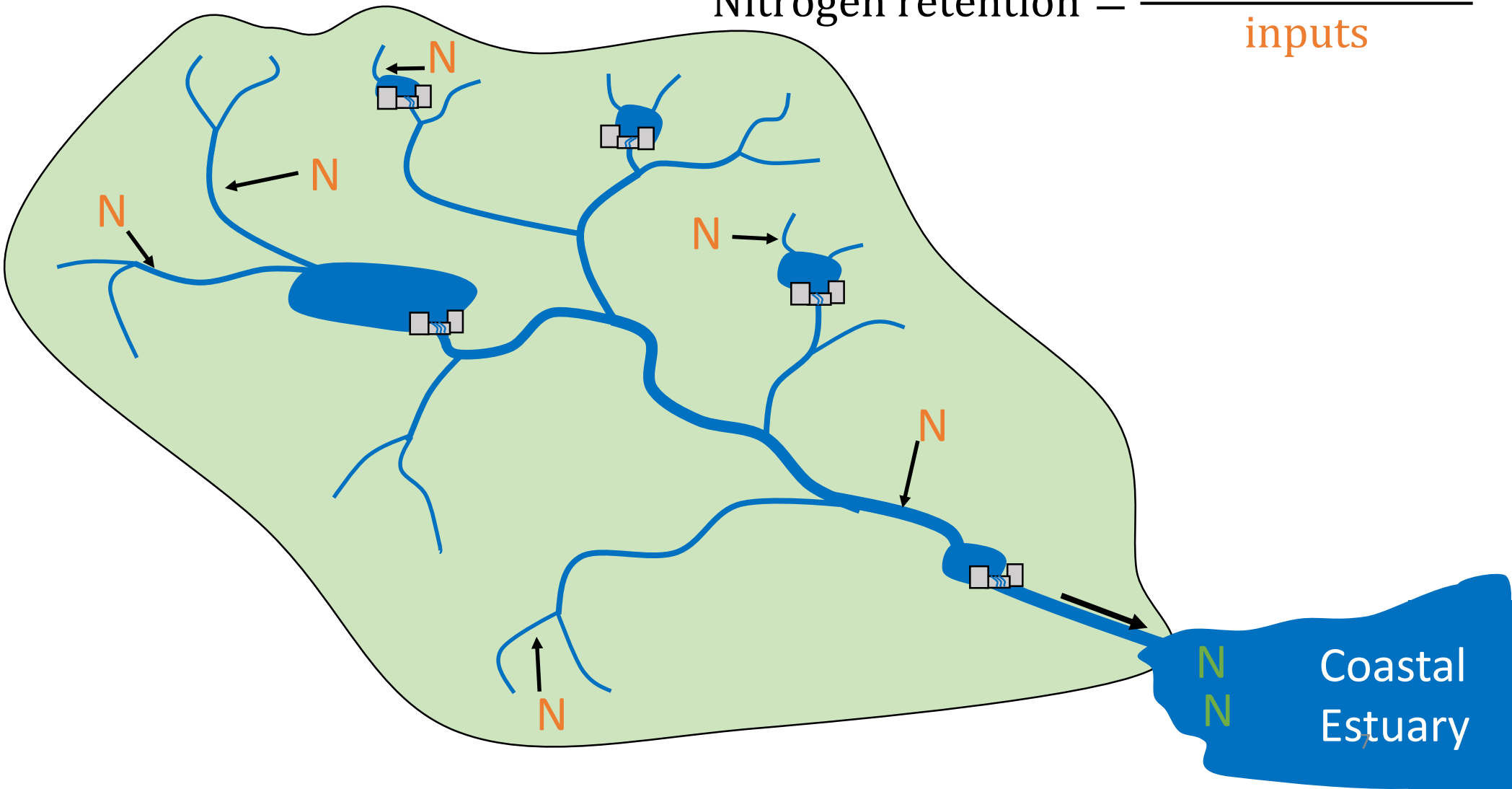
Residence time effects on nitrogen retention



Observed relationship between the fraction of nitrogen retained and the ratio of water depth to residence time from an analysis of river, lake, and reservoir studies (Modified from Seitzinger et al. 2002).

River network scale nitrogen retention with dams

$$\text{Nitrogen retention} = \frac{\text{inputs} - \text{outputs}}{\text{inputs}}$$



Research questions

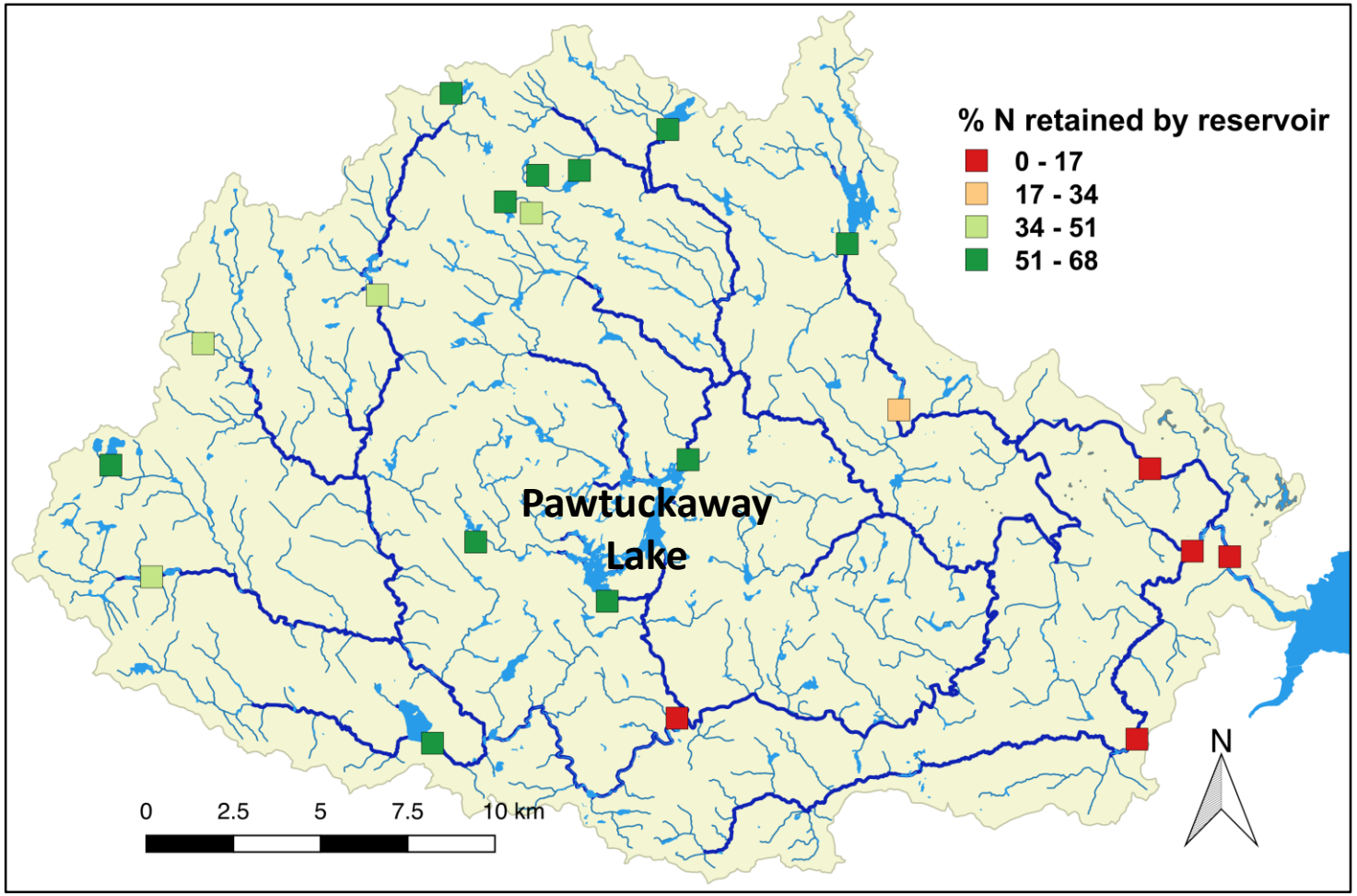
1. Can we predict nutrient retention at a managed reservoir in New Hampshire?

2. How do different dam management scenarios affect in-stream nutrient retention at a watershed scale?

3. How do dams affect the frequency, duration, and magnitude of high- and low-flow events downstream of a network of dams?

4. How can dams be utilized to help mitigate changes in hydrology and increases in nutrient loading as a result of future climate and land use change?

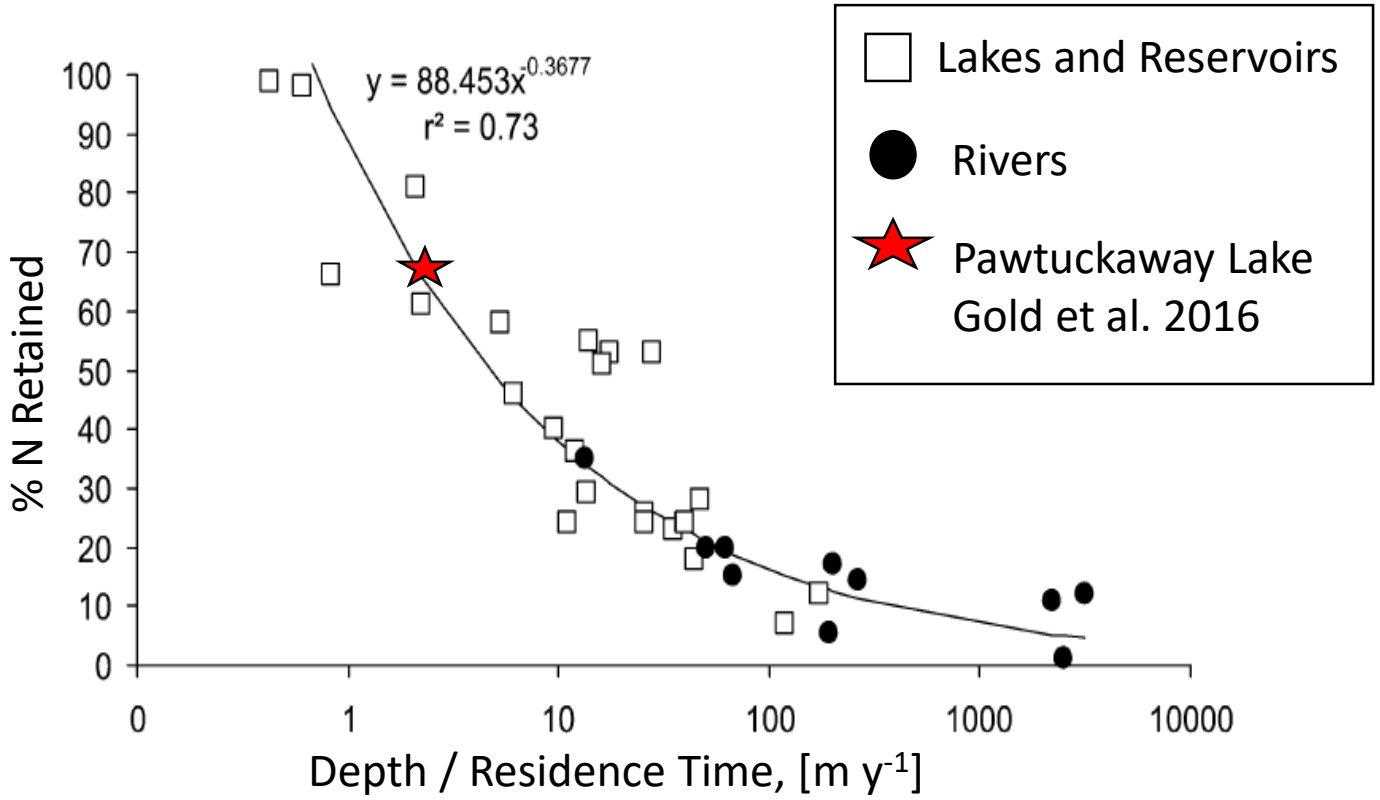
Estimated reservoir nitrogen retention in the Lamprey River watershed



Estimates from Gold et al. 2016

Pawtuckaway Lake

- Largest reservoir in the Lamprey River watershed.
- Wealth of water quality data.
- High potential for nitrogen retention (63.5%) from Gold et al. 2016 estimates



Observed relationship between the fraction of nitrogen retained and the ratio of water depth to residence time from an analysis of river, lake, and reservoir studies (Modified from Seitzinger et al. 2002).

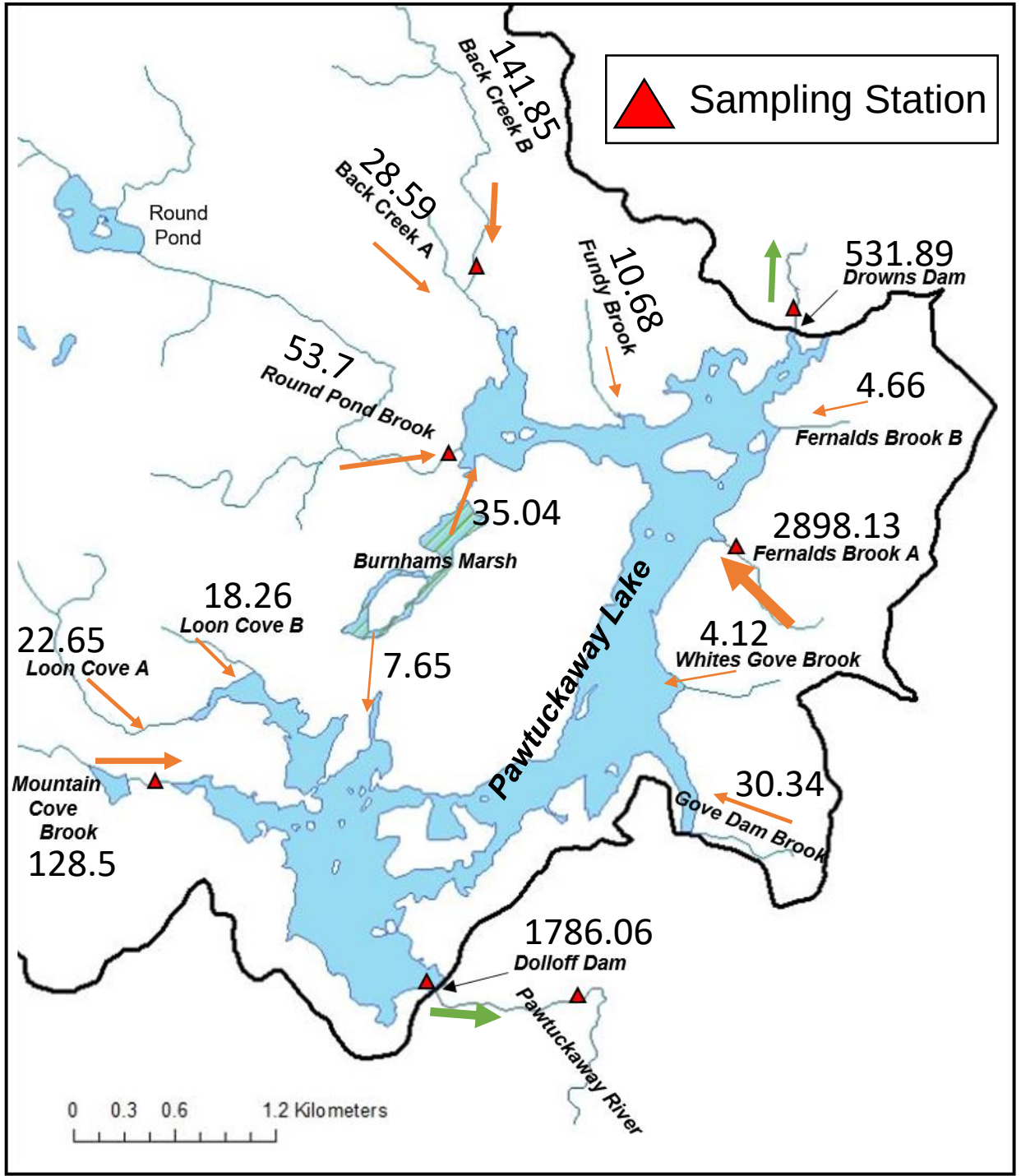
Field Work

Flux = concentration x discharge

Measuring discharge downstream of Dolloff Dam.

Filtering a water sample taken above Dolloff Dam.

Measuring water height (stage) above pressure logger at downstream of Drowns Dam.



$$\text{Nitrogen retention} = \frac{\text{inputs} - \text{outputs}}{\text{inputs}}$$

1992 NHDES Results

Flux measurements [kg NO_3^-] for water year 1992 from NHDES Pawtuckaway Lake Diagnostic and Feasibility Study, 1995.

Pawtuckaway NO_3^- Retention = 0.315

2017-2018 Results

Sampling for:
-ammonium (NH_4^+)
-nitrite (NO_2^-) plus nitrate (NO_3^-)
-total dissolved nitrogen (TDN)
-total phosphorus (TP)

Continuous record of discharge.

Research questions

1. Can we predict nutrient retention at a managed reservoir in New Hampshire?

2. How do dams affect the frequency, duration, and magnitude of high- and low-flow events downstream of a network of dams?

3. How do different dam management scenarios affect in-stream nutrient retention at a watershed scale?

4. How can dams be utilized to help mitigate changes in hydrology and increases in nutrient loading as a result of future climate and land use change?

Dams' effects on hydrology

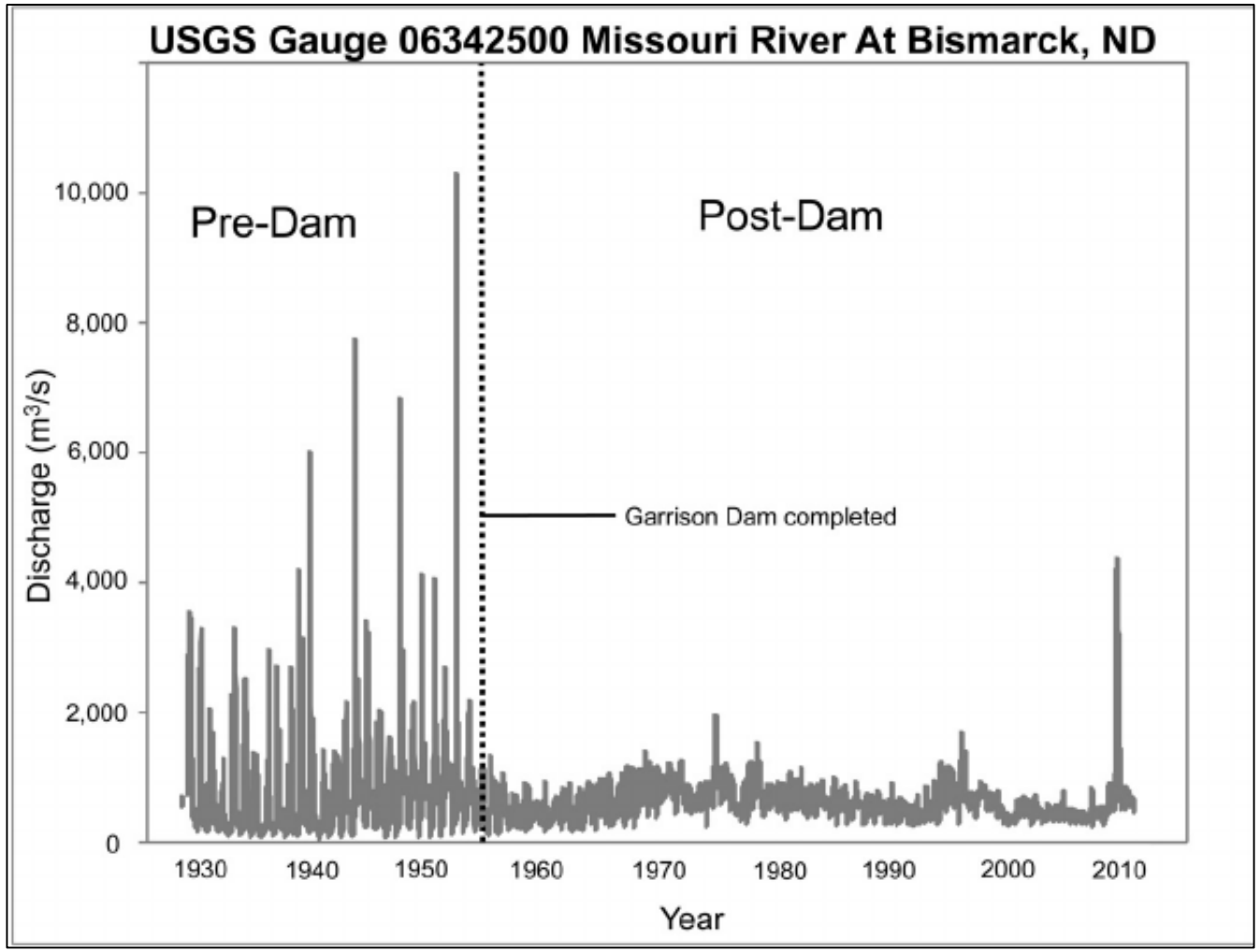
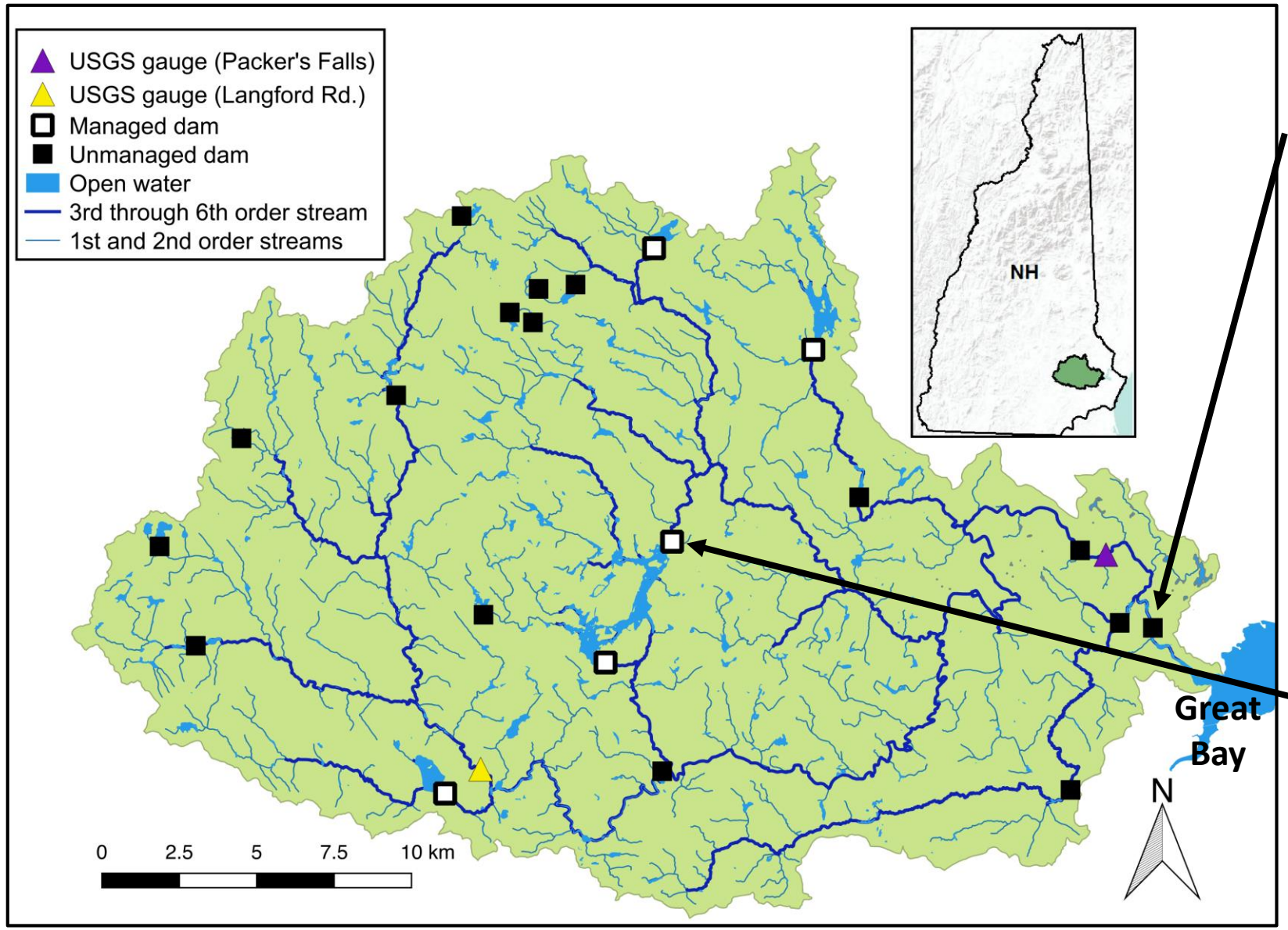


Figure from Skalak et al. 2013

Lamprey River Watershed

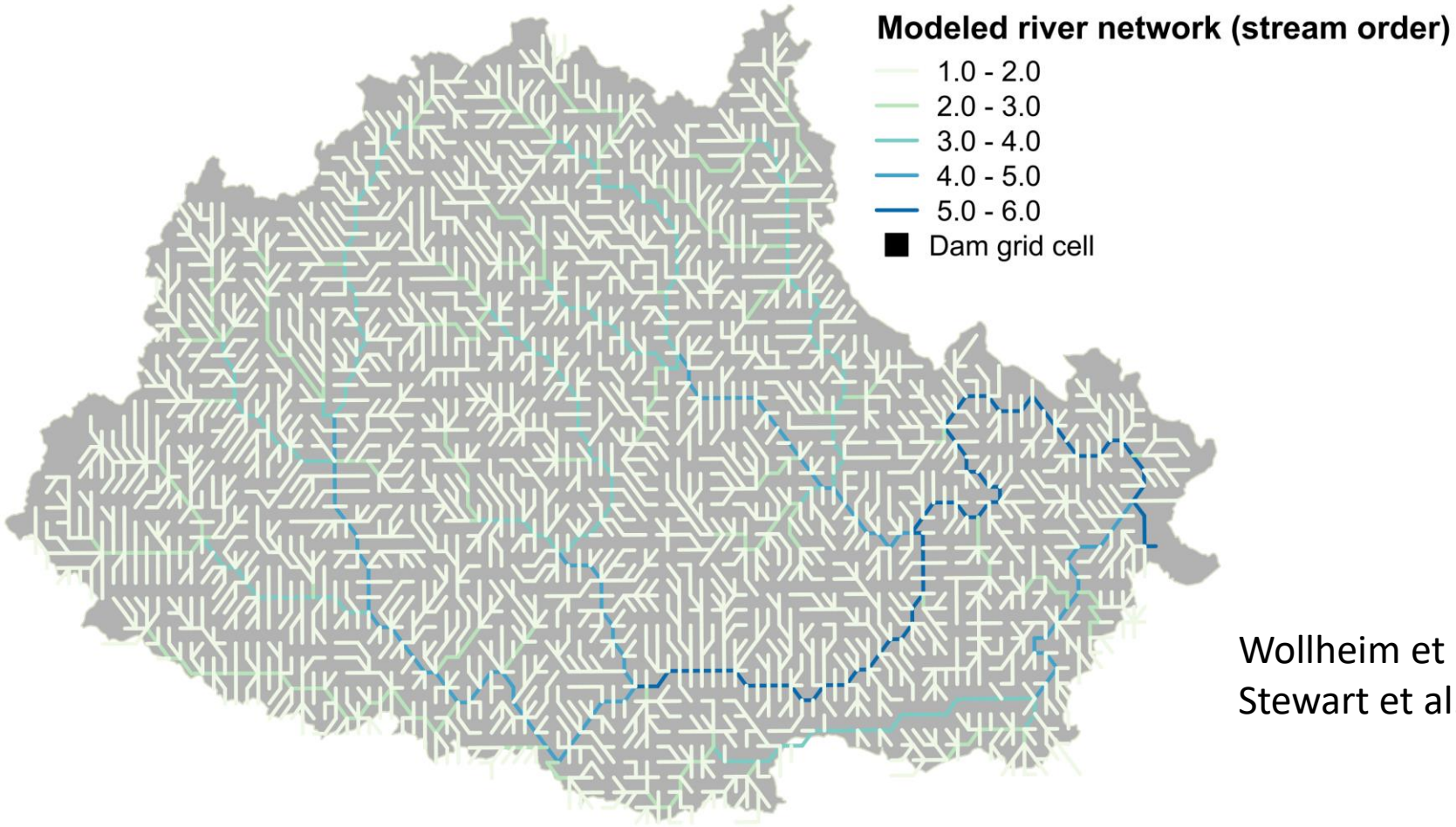


Macallen Dam, Newmarket, NH

Drowns Dam, Nottingham, NH

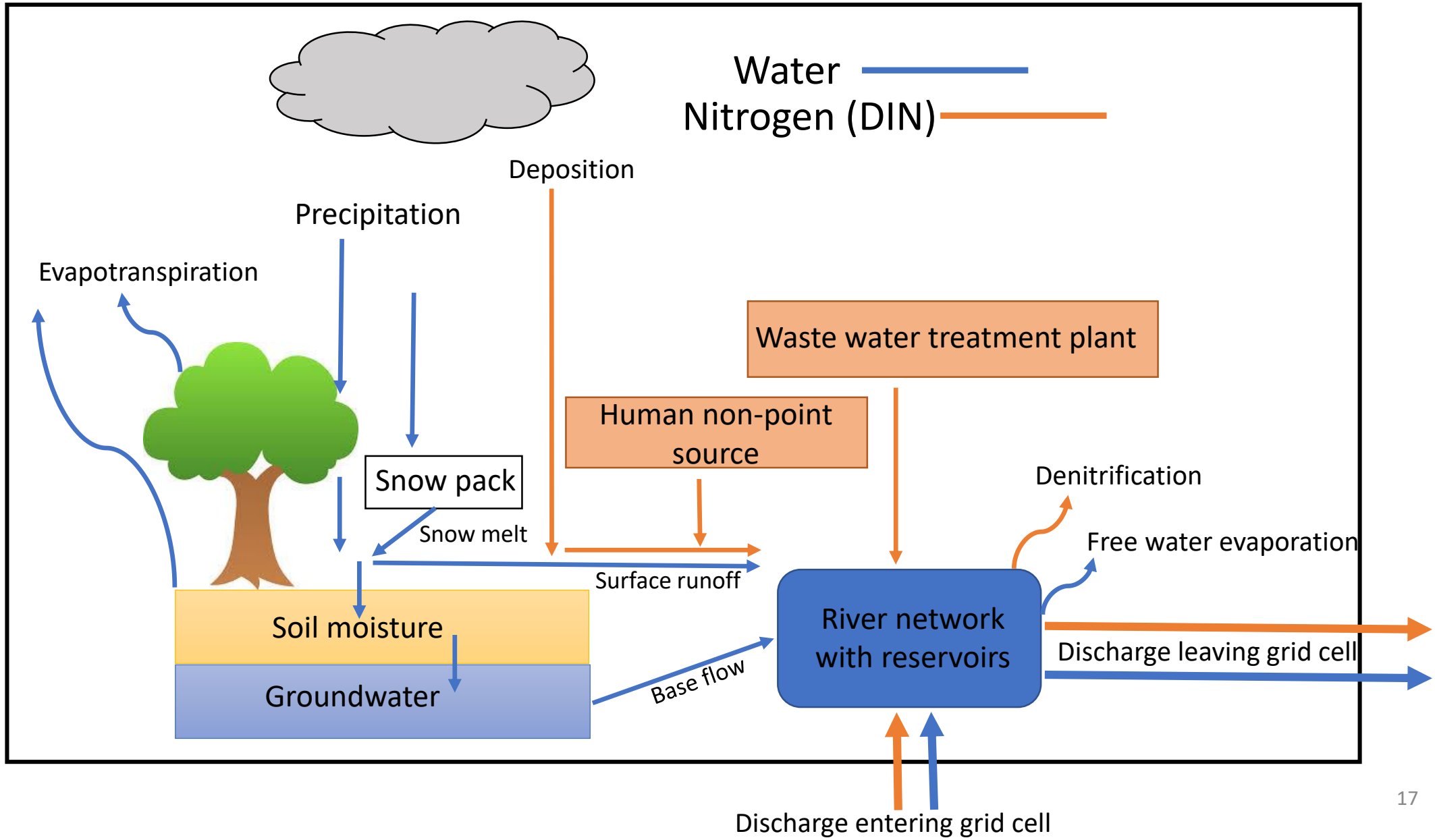
WBM: The Water Balance Model

Lamprey River watershed

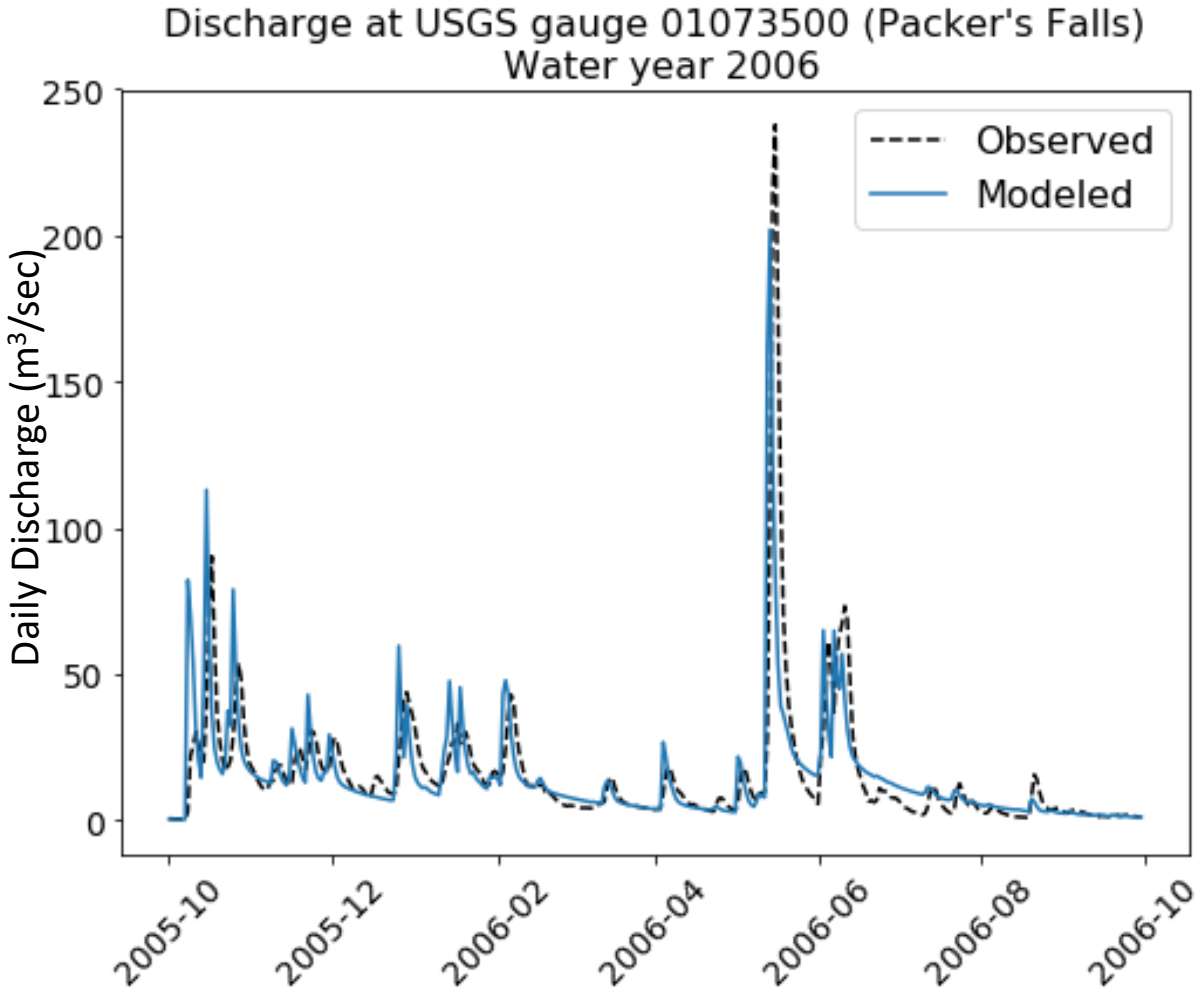


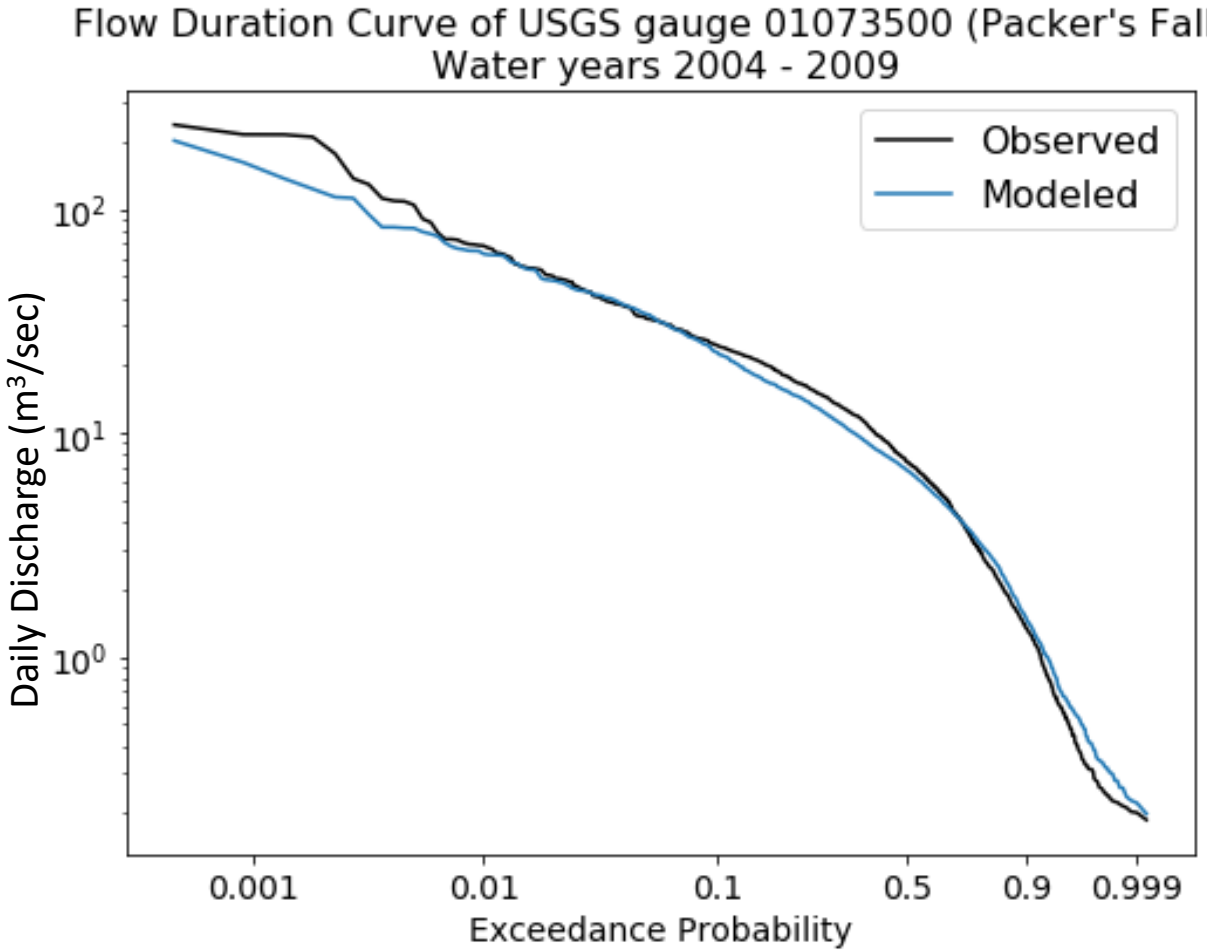
Wollheim et al. 2008
Stewart et al. 2011

WBM Grid Cell

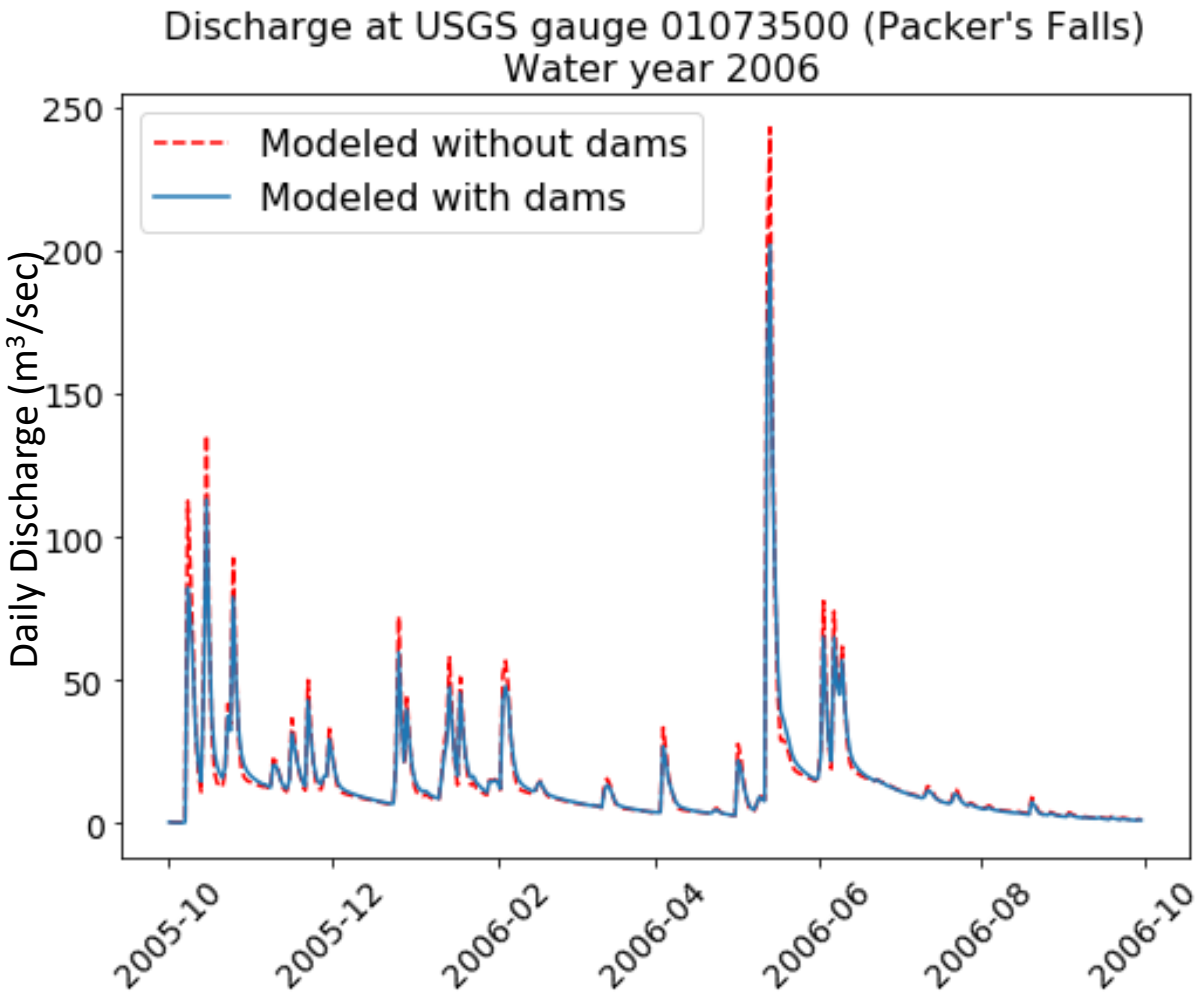


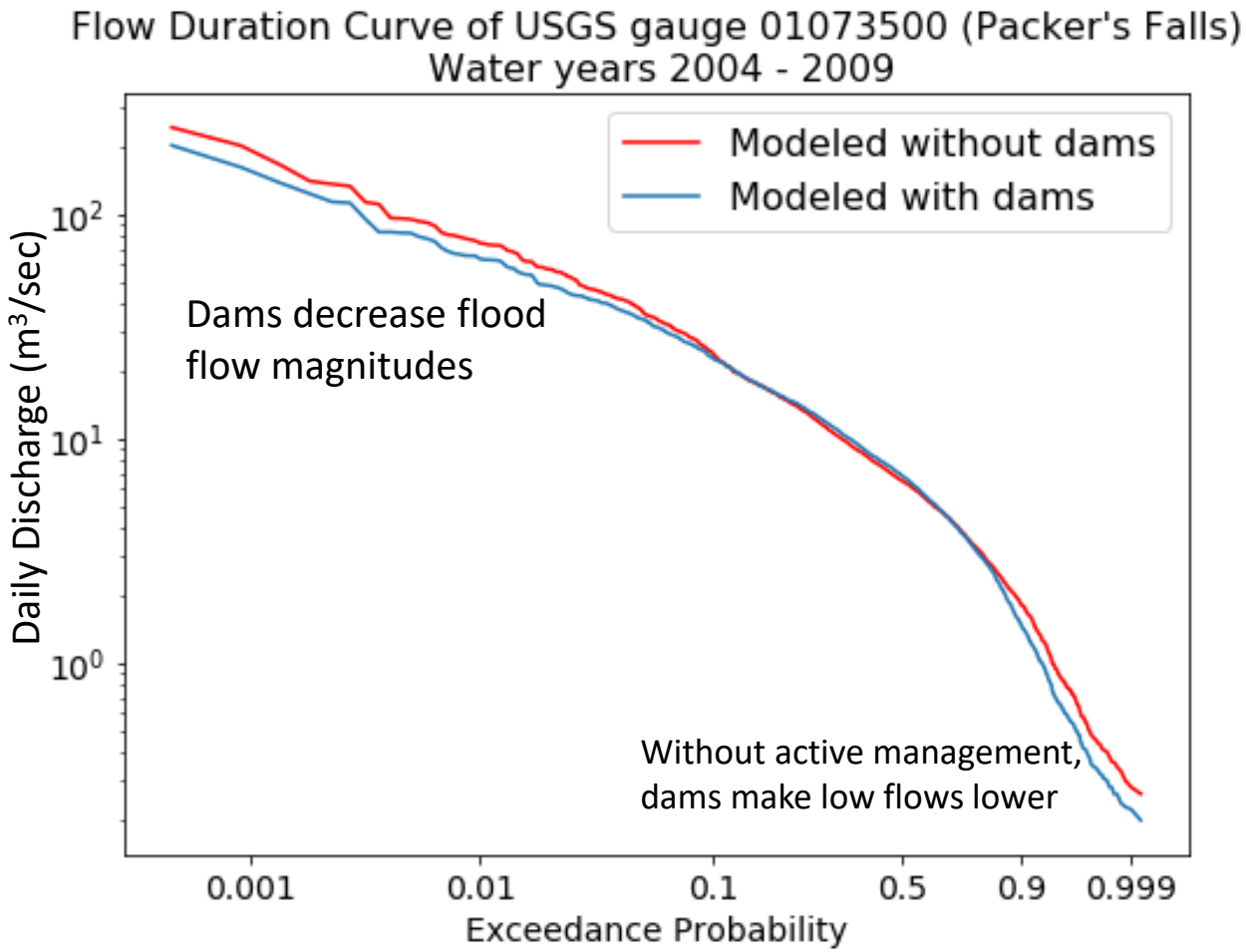
Lamprey discharge: observed and modeled





Lamprey discharge: with and without dams





Research questions

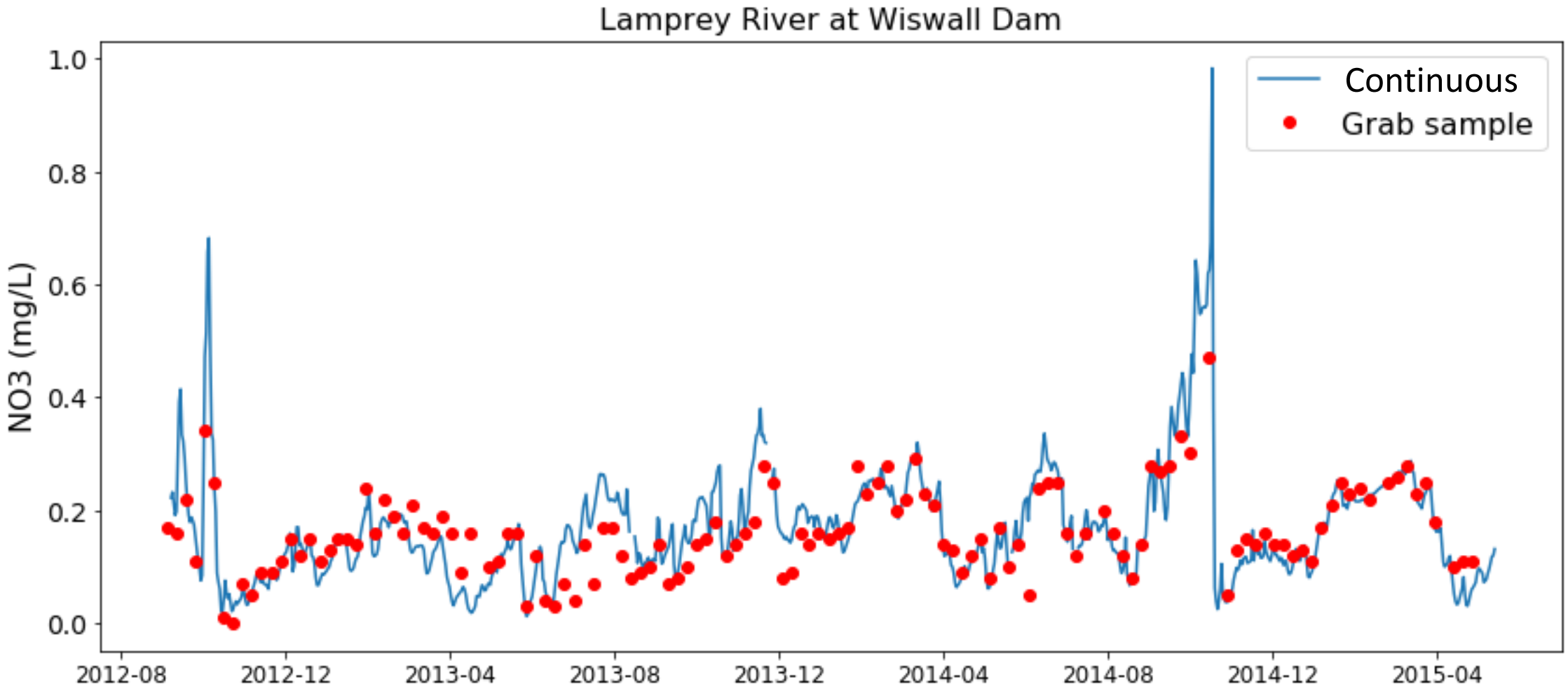
1. Can we predict nutrient retention at a managed reservoir in New Hampshire?

2. How do dams affect the frequency, duration, and magnitude of high- and low-flow events downstream of a network of dams?

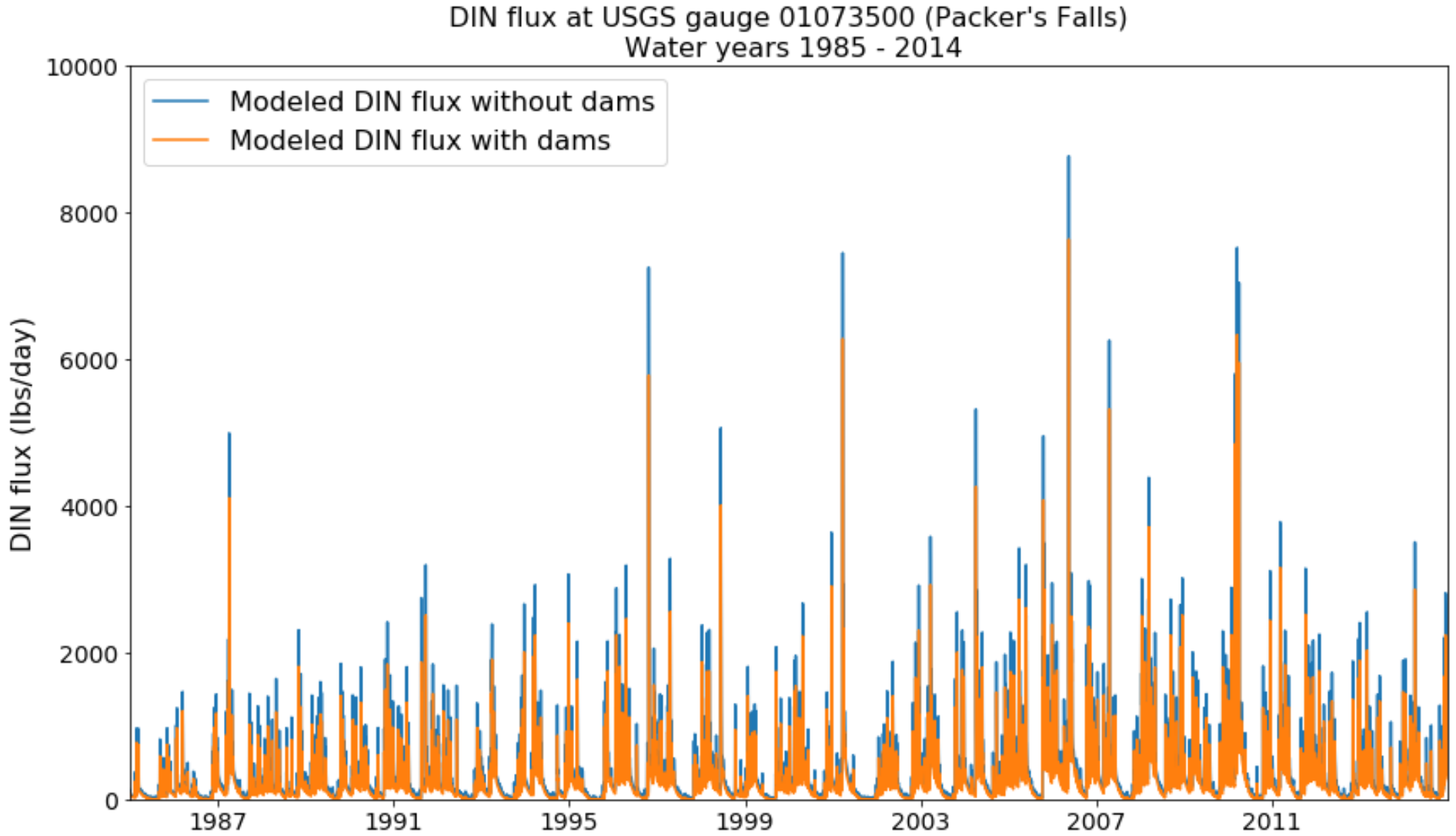
3. How do different dam management scenarios affect in-stream nutrient retention at a watershed scale?

4. How can dams be utilized to help mitigate changes in hydrology and increases in nutrient loading as a result of future climate and land use change?

Lamprey DIN concentration and mass flux



Lamprey DIN flux: with and without dams



Research questions

1. Can we predict nutrient retention at a managed reservoir in New Hampshire?

2. How do dams affect the frequency, duration, and magnitude of high- and low-flow events downstream of a network of dams?

3. How do different dam management scenarios affect in-stream nutrient retention at a watershed scale?

4. How can dams be utilized to help mitigate changes in hydrology and increases in nutrient loading as a result of future climate and land use change?

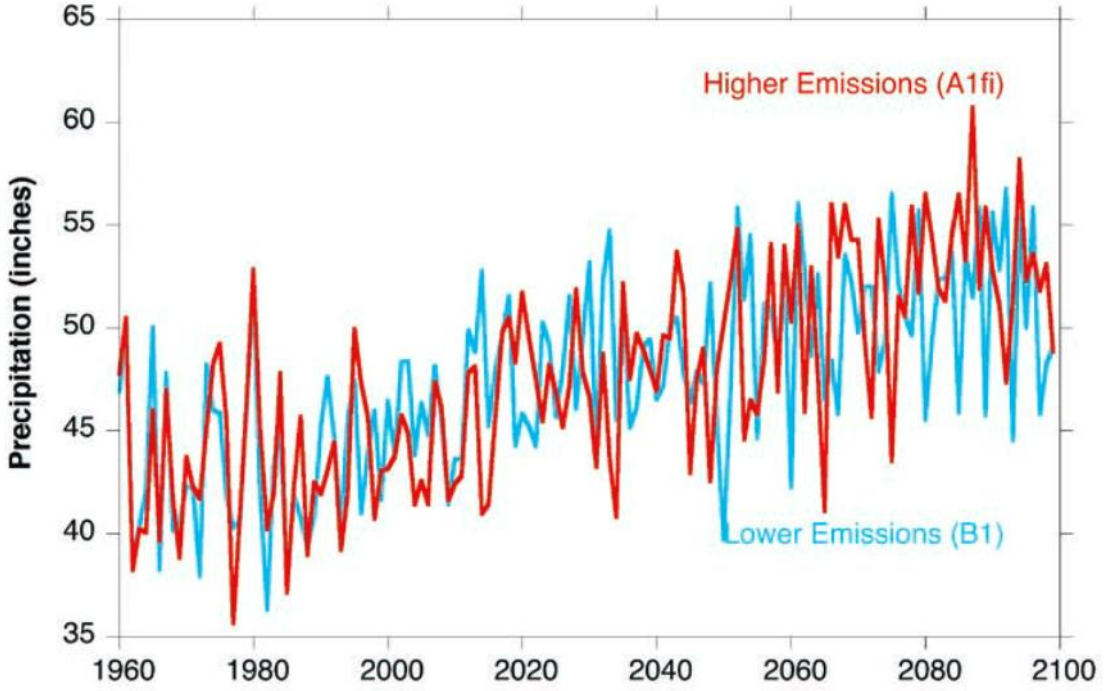
Modeling scenarios

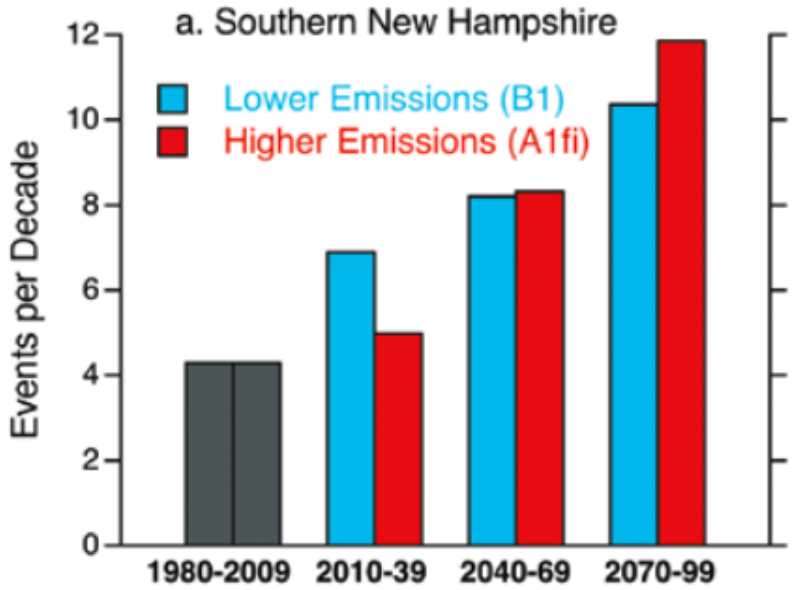
Climate and Land Use Scenarios		
	Current Climate	Future Climate
Future Land Use		
Current Land Use		

Dam Management Scenarios				
Dam Presence	Dam Operation			
	Current management	Flood Control	Water Supply	Recreation
Leave all existing dams	Scenario 1			
Remove all dams	Scenario 2			
Remove managed dams				
Remove unmanaged dams				
Upgrade existing dams				

Scenarios: Climate

- Contemporary (years 1985 – 2014)
- Future (years 2070 - 2099)



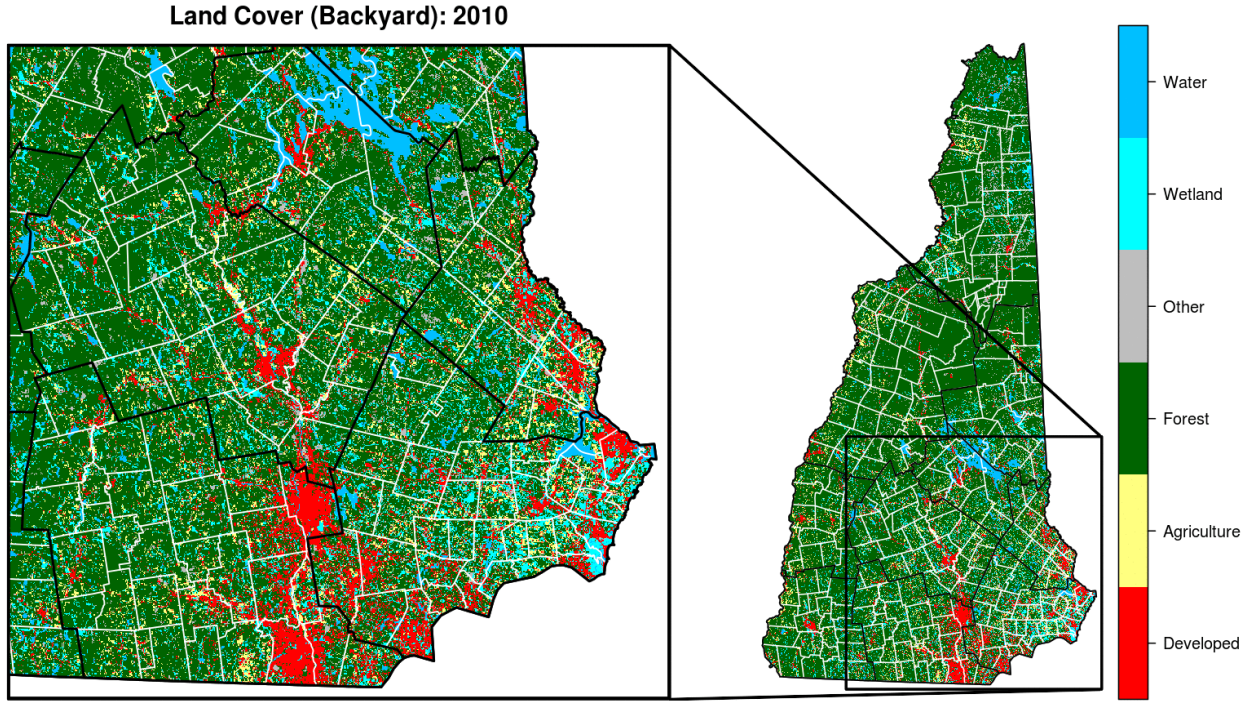


Average number of precipitation events per decade with more than 4 inches of rain in 48 hours. (Historic data shown in grey)

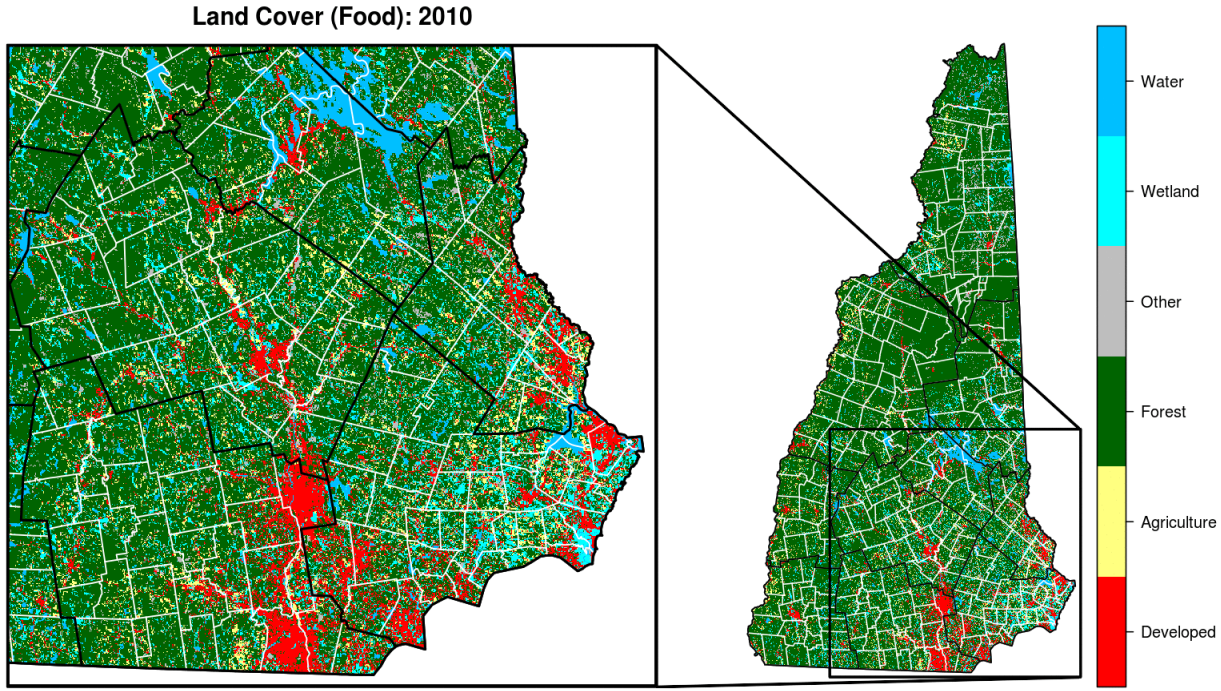
Figures taken from Climate Change in Southern New Hampshire 2014.

Scenarios: Land Use

Backyard Amenities Scenario



Community Amenities-Food Scenario

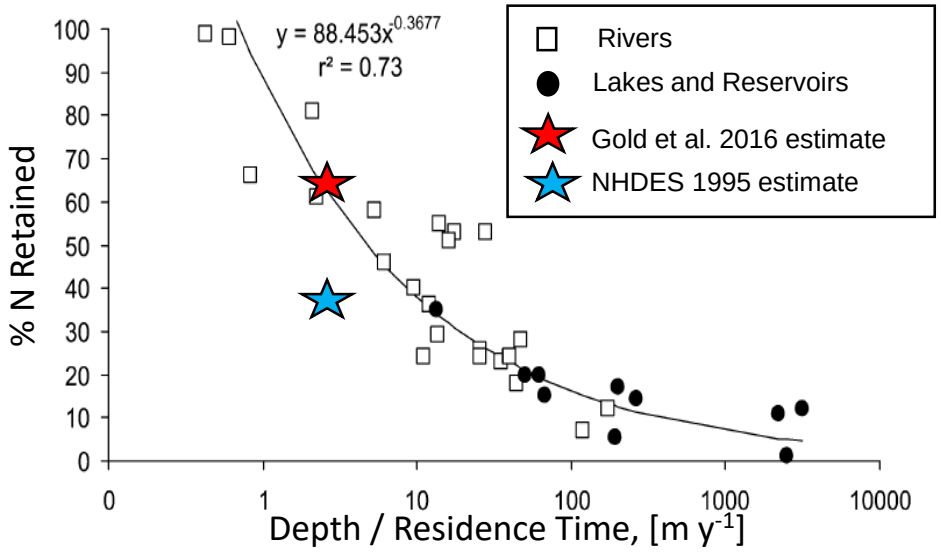


Figures taken from Alternative Land Cover Scenarios for New Hampshire,
NH EPSCoR Ecosystems and Society

Summary

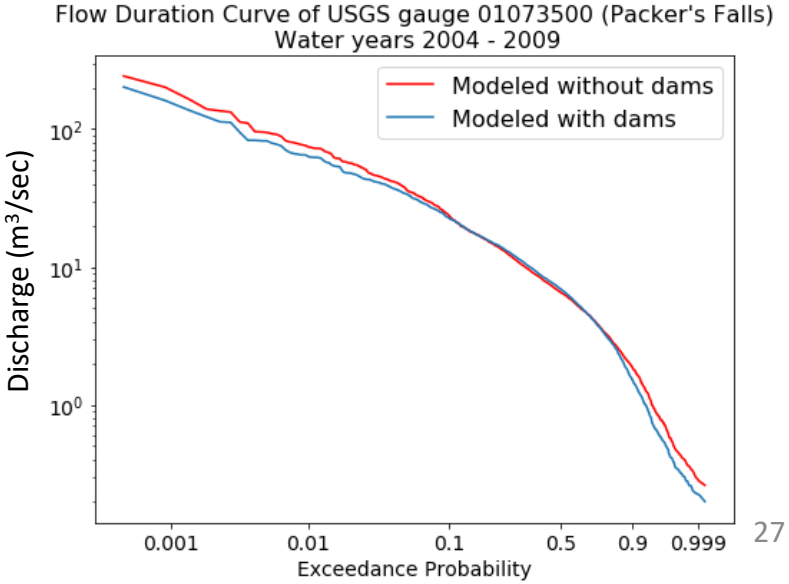
1. Can we predict nutrient retention at a managed reservoir in New Hampshire?

Compare estimated fraction of nitrogen retained at Pawtuckaway Lake obtained from field measurements to estimates from previous studies and empirical relationships.



2. How do dams affect the frequency, duration, and magnitude of high- and low-flow events downstream of a dam?

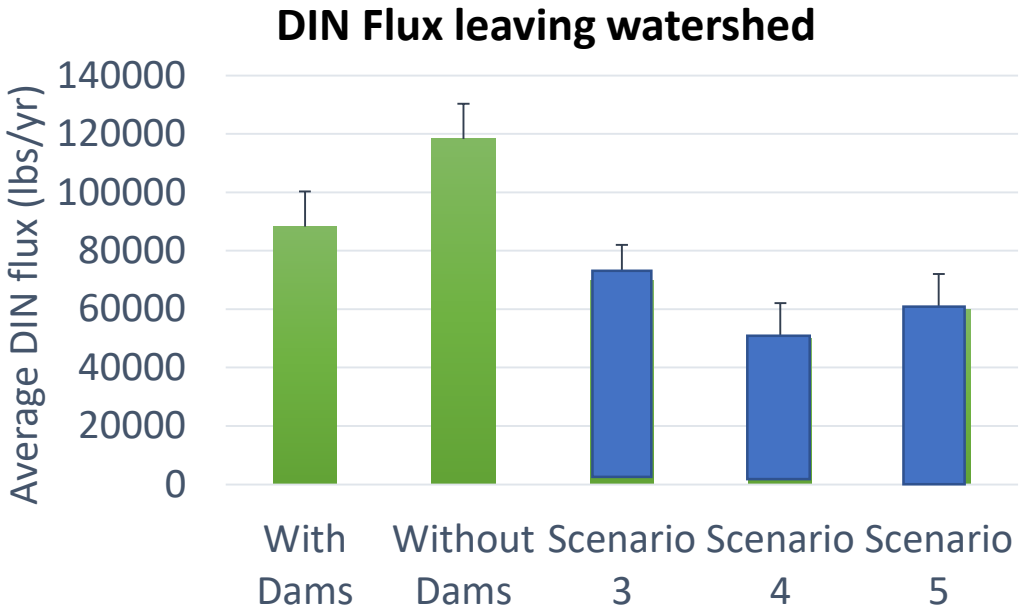
Compare flow duration curves for different dam management scenarios downstream of a single dam and at the watershed outlet for a network of dams.



Summary

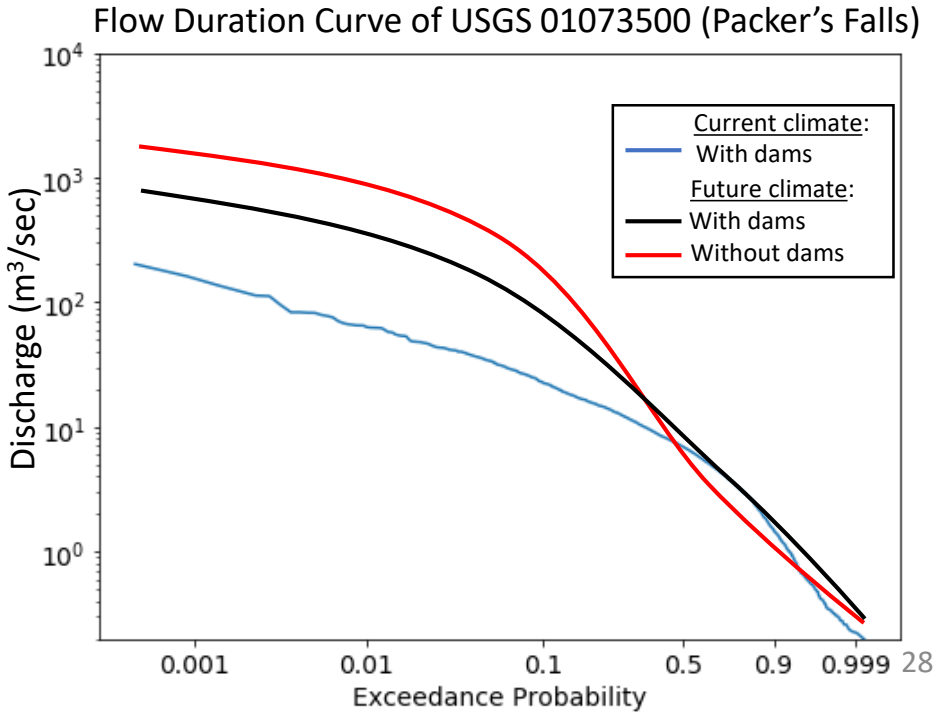
3. How do different dam management scenarios affect in-stream nutrient retention at a watershed scale?

Compare modeled average annual DIN flux leaving the watershed for each dam management scenario.

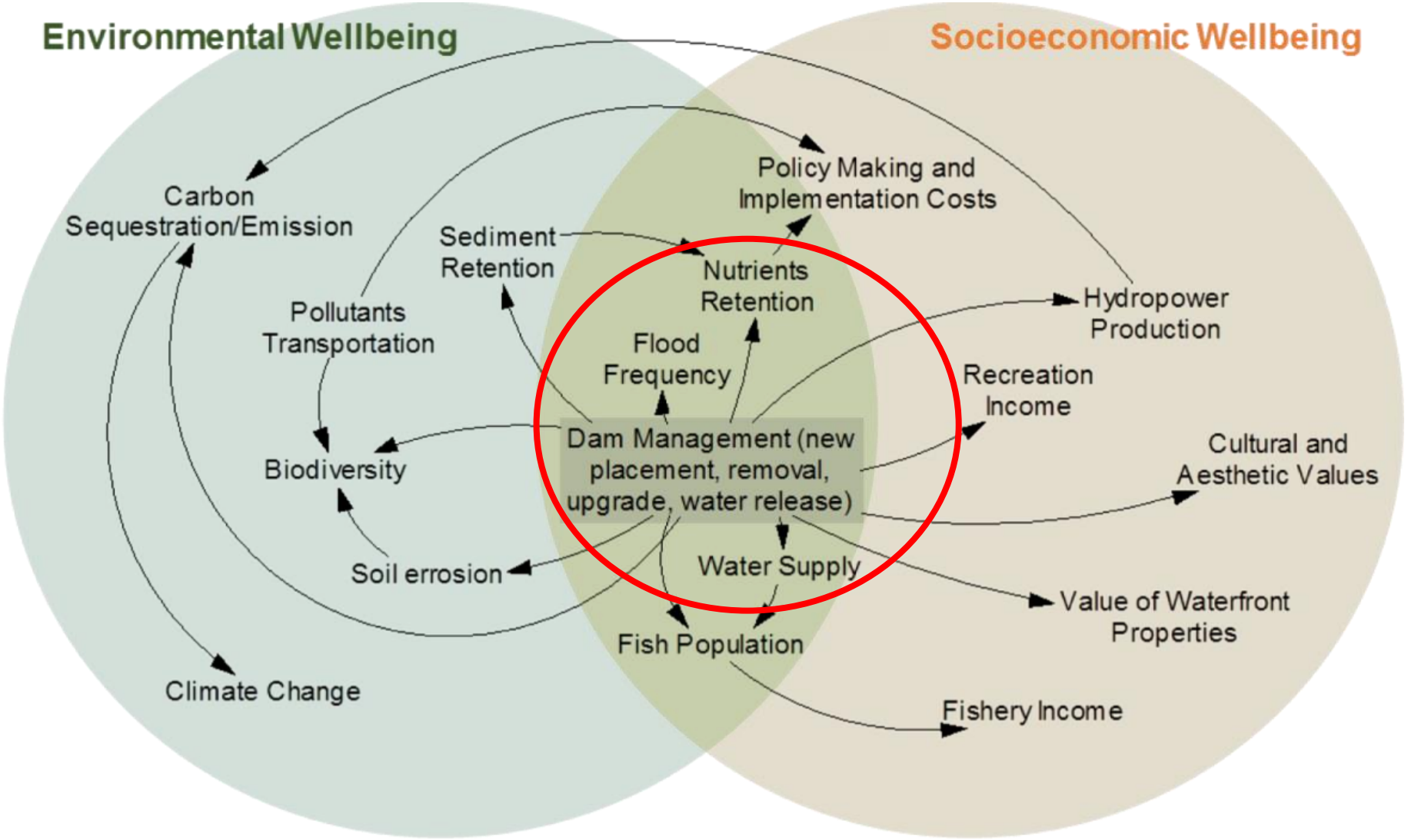


4. How can dams be used to help mitigate changes in hydrology and increases in nutrient loading as a result of future climate and land use change?

Compare flow duration curves and average annual DIN flux for future climate and land use scenarios.



Decision factors in dam management



Weiwei Mo and Cuihong Song, University of New Hampshire.


Thank You
David Simon
dws1005@wildcats.unh.edu