The impact of dams on nutrient flux in New England watersheds

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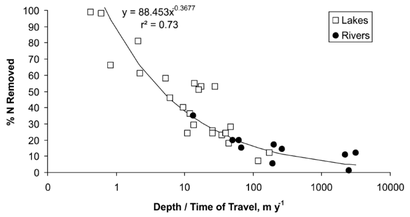
Dams and Nutrients

Attenuation of nitrogen by river networks is an important ecosystem service to mitigate eutrophication at vulnerable coastal estuaries downstream (Boyer et al. 2002). Dam reservoirs increase the residence time of water, effectively increasing the amount of nitrogen removed via denitrification as compared to a free-flowing river channel (Seitzenger et al. 2002). In addition, dams substantially change the flow regime of rivers, including the magnitude and duration of high and low flow events downstream of an impoundment (Magilligan et al. 2005).

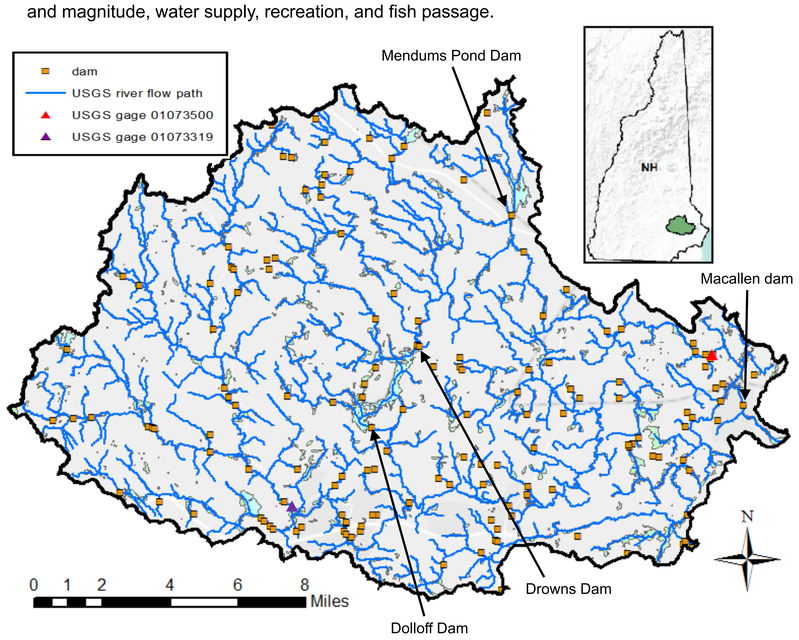
Drowns Dam, Nottingham, NH



Empirical relationship between fraction of nitrogen removed and the ratio of water depth to residence time from a meta-analysis of river and lake studies (Seitzenger et al. 2002).

Lamprey River watershed

The Lamprey River watershed contains many active dams ranging in height from 1 to 10 m, some of which are being considered for removal. The Lamprey is also the largest contributor of nitrogen from non-point sources to the Great Bay Estuary, which is experiencing increased algae blooms and decreased eel grass habitat in part due to elevated levels of nitrogen (NHDES 2012). Flooding in the Lamprey River has been problematic and is expected to increase in the future due to changes in land use and climate (Wake 2013). Excessively low flow can stress aquatic organisms, leading to NHDES piloting instream flow regulation in the Lamprey (NHDES 2015). Making decisions about managing and removing dams in the Lamprey River watershed requires weighing tradeoffs between nutrient fluxes, flow duration and magnitude, water supply, recreation, and fish passage.



Map plotted in ArcGIS 10.4 with USGS National Hydrography river flow lines and NHDES Dam Inventory.

Research Questions

- How do dams affect the frequency, duration, and magnitude of river flow downstream of a dam?
- How do different dam removal and management scenarios affect in-stream nutrient retention at a watershed scale?
- 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?

Methods

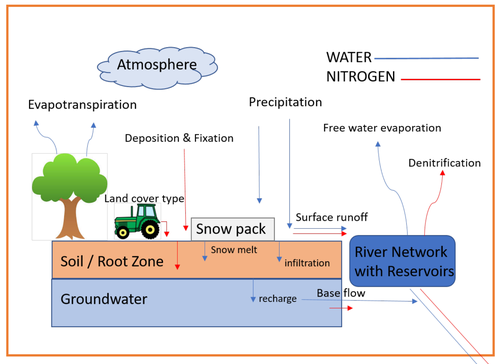
- Estimate nutrient retention at Pawtuckaway Lake from May 2017 to April 2018.
- Calibrate and validate the Water Balance Model (WBM) for the Lamprey River watershed for the years 2012 to 2016.
- Calibrate and validate WBM with observed historical data.
- Compare model output (daily discharge and total annual nitrogen flux) under various climate, land use, and dam management scenarios:

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

Dam Management Scenarios				
Dam Presence	Dam Operation			
	Current management	Flood Control	Water Supply	Recreation
Leave all existing dams				
Remove all dams				
Remove run of river dams				
Remove dams with reservoirs				
Upgrade existing dams				

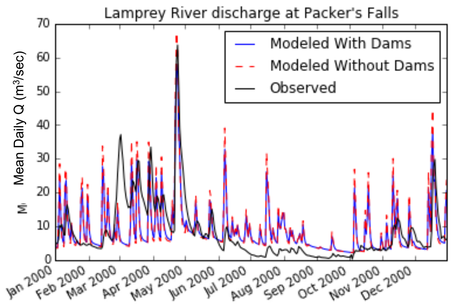
WBM

Model data inputs include: precipitation, air temperature, humidity, rooting depth, land cover type, impervious surface cover, leaf area index, soil water capacity, and reservoir locations and size.

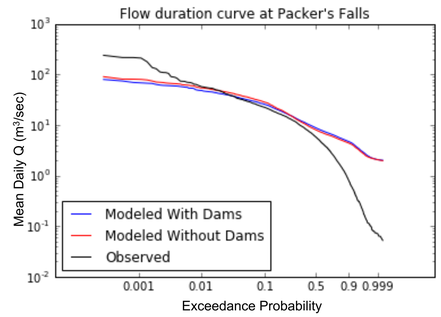


Example of flow paths in model grid cell for each time step

Preliminary Results



Hydrograph of modeled daily discharge with and without dams compared to observed discharge at USGS gage 01073500 for calendar year 2000. With current input data, the model is able to represent the magnitude and timing of most storm events, but fails to adequately represent seasonal changes in baseflow.



Flow duration curve for modeled daily discharge with and without dams compared to observed discharge at USGS gage 01073500 for calendar years 2000 to 2009. The model underpredicts discharge during high flow events and overpredicts discharge during low flow events. The model predicts that dam removal will slightly increase flood magnitude at Packer's Falls.

Future Work

- Finish constructing continuous record of nutrient flux at Pawtuckaway Lake.
- Finish WBM calibration for Lamprey River watershed and estimate discharge and in-stream nutrient flux for all scenarios.
- Compare WBM model output to other hydrologic and nutrient transport models.
- Run WBM model for other New England watersheds?

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