Using Stream Power to Estimate Impounded Sediment Volume and Dominant Grain Size at Dams in New England

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Problem: Dams and Impounded Sediment

Impounded sediment compromises dam functionality by reducing the storage volume of the reservoir (3). The release of large volumes of sediment can harm downstream ecological health and infrastructure, hence erodible sediment may need to be stabilized or removed prior to dam removal (Figure 1; 3). Fine-grained sediment can be especially challenging because it is easily eroded and is more likely to be contaminated (3). For these reasons, it is important to understand sediment volume and grain-size distribution at a dammed impoundment.

Figure 1. (A) The sediment-filled impoundment of the Briggsville Dam on the Hoosic River in Clarksburg, MA, during removal in 2011. Photo from Buzzards Bay Coalition. (B) Riprap-stabilized banks at the former dam site.

Stream Power and Dams

Total stream power TSP is the energy applied by flowing water to a river's bed and banks. TSP is directly proportional to the specific weight of water γ, river discharge Q and slope S (1, 5). This energy is responsible for sediment transport. Specific stream power SSP is TSP per unit river width b (2). Sediment is deposited in reaches where the stream power is less than upstream, and eroded from reaches where the stream power increases relative to upstream (1, 2, 5). Dams decrease stream power by pooling water, and decreasing river velocity, resulting in sedimentation (Figure 2; 6).

$$TSP = \gamma QS$$

$$SSP = \frac{\gamma QS}{b}$$

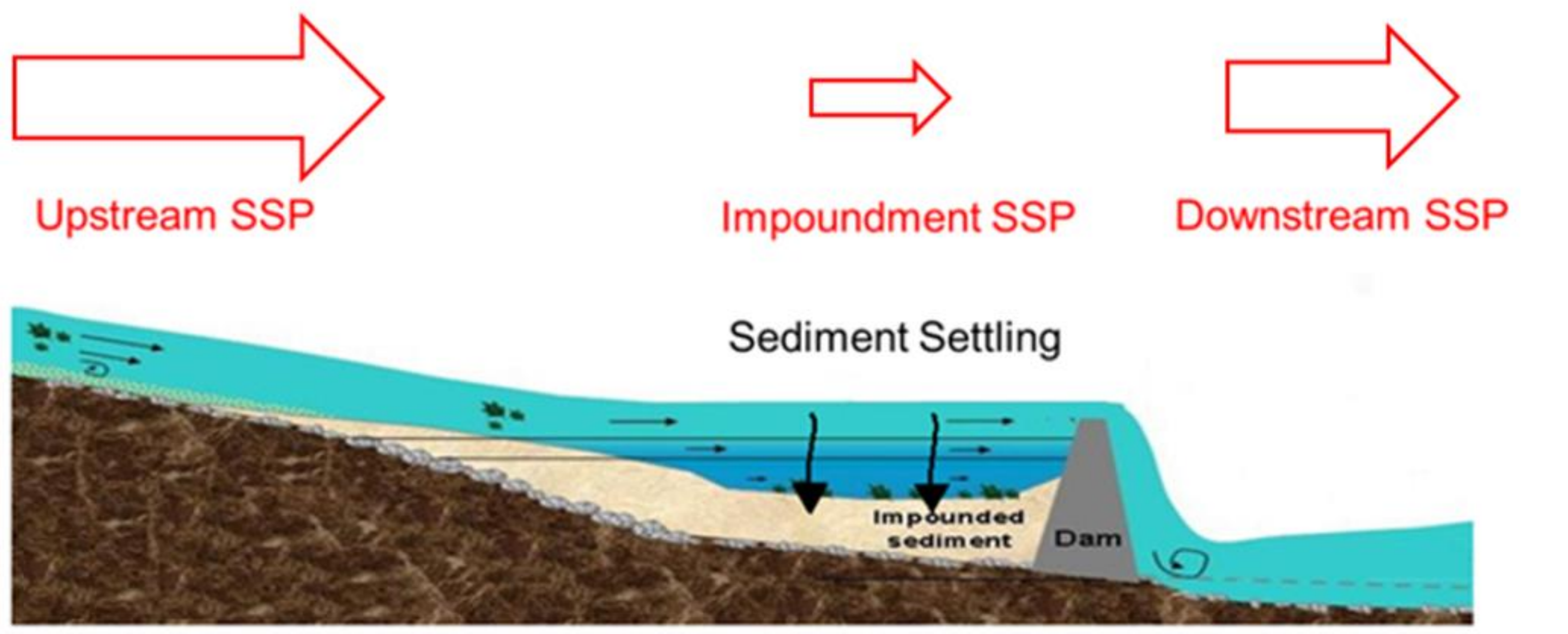

Figure 2. Dammed river reach showing that stream power reduction results in sedimentation.

Research Questions

1. Can data on stream power and dam size parameters be used to predict the volume and dominant grain size of impounded sediment?
2. What is the relationship between remotely sensed estimates of stream power and field-measured stream power?
3. Can remotely sensed estimates of impounded sediment characteristics complement other dam datasets to analyze dam removal tradeoffs?

Methods Overview

Data will be collected for a minimum of 20 study dams in New England from dam removal feasibility reports, environmental impact reports, journal articles, GIS analysis and fieldwork (Figure 3, Table 1). Regression analysis will be used to relate stream power and dam size to impounded sediment volume and dominant grain size (2; 8).

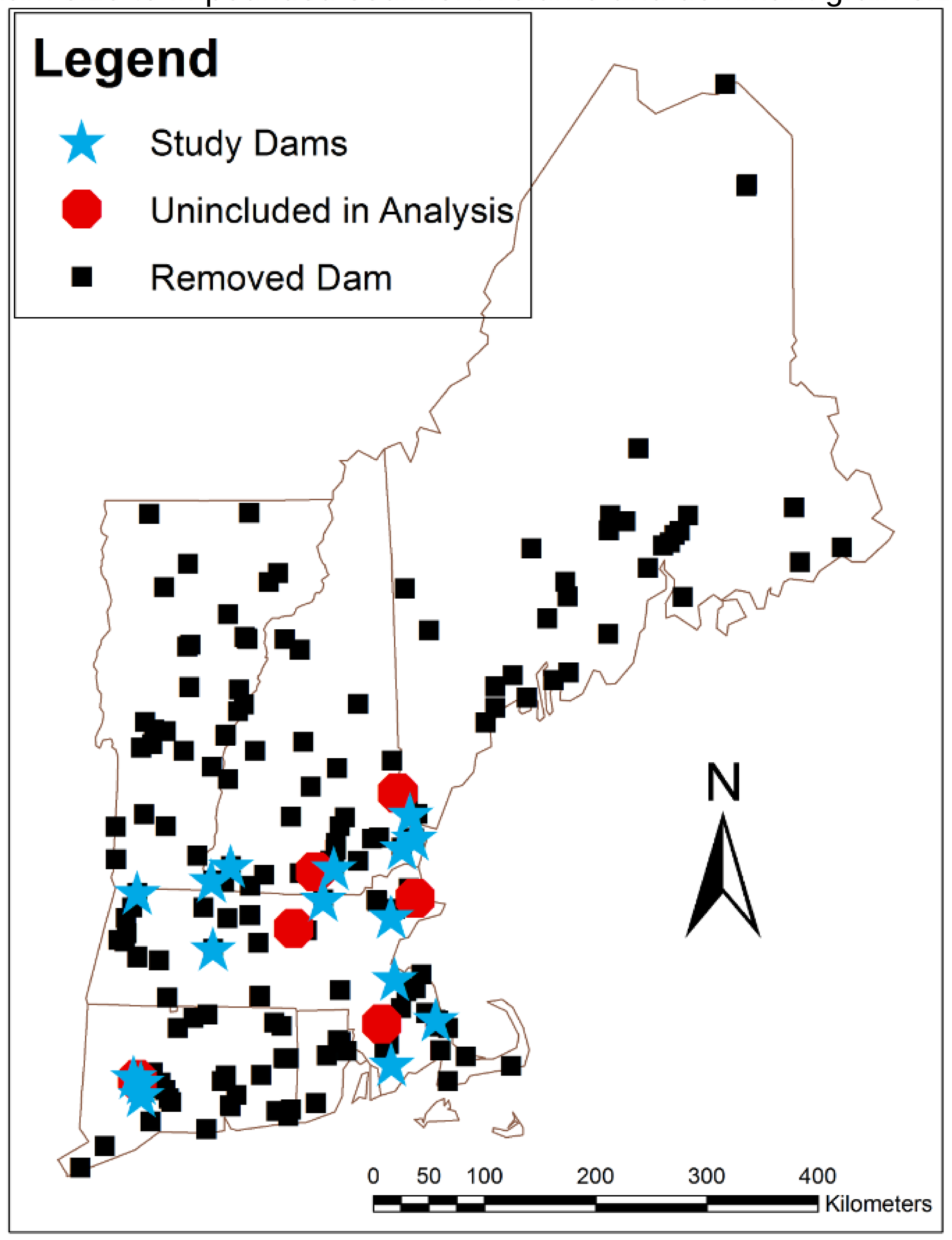

Figure 3. Map showing 16 confirmed study dams, and the 7 dams that have been excluded from analysis. Also shown are 186 New England dams that have been removed. Removed dams represent potential study sites. Removed dam data from American Rivers.

Metric	Parameters	Published Reports (Field Measured)	Fieldwork (Field Measured)	River Gauges (Field Measured)	GIS Analysis (Remote Sensing)	Hydraulic Geometry (Remote Sensing)
Impounded Sediment	Impounded Sediment Volume	✓				
	Impounded Sediment Grain Size	✓				
Dam Size	Impoundment Surface Area	✓			✓	
	Dam Height	✓				
Stream Power	2-Year Flood Discharge	✓		✓	✓	✓
	2-Year Flood Water Surface Slope	✓			✓	
	Average Upstream Bankfull Width	✓	✓		✓	

Table 1. Table showing data needed for thesis work with check marks showing expected data sources.

Study Implications

It is hoped that the remote assessment tools developed in this thesis will enable the estimation of impounded sediment volume and grain size at the watershed or state level (3). These tools could be used with existing datasets to examine trade-offs such as those between impounded sediment management, aquatic organism passage, and hydropower.

Remotely Sensed Stream Power

River flowlines overlain atop digital elevation models (DEMs) will be used to create longitudinal river profiles for 5 to 10 km upstream of study dams (2). Longitudinal profiles will be smoothed and the river slope calculated for 500-m-long sub-reaches (Figure 4; 2). Stream power upstream of a dam will be approximated as the average stream power of the upstream sub-reaches (2).

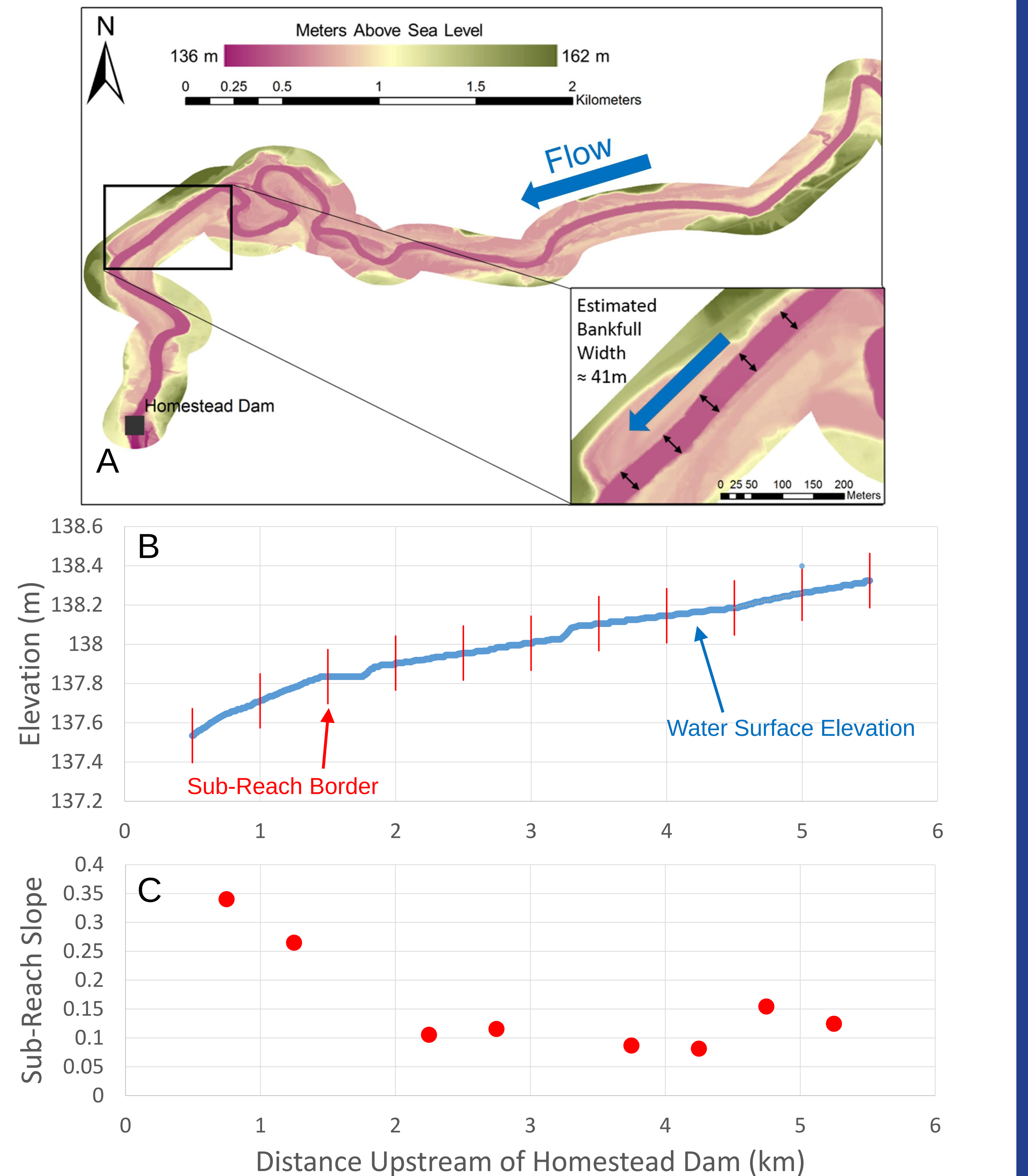

Figure 4. (A) LiDAR-derived digital elevation model showing the Ashuelot River upstream of the Homestead Dam. (B) Longitudinal profile of river elevation from 0.5 to 5.5 km upstream of Homestead Dam. (C) Slope of the best fit lines through the sub-reaches. LiDAR from GRANIT database.

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References

1. Bagnold, R. A. (1966). An approach to the sediment transport problem from general physics. US government printing office.
2. Bizzi, S., & Lerner, D. N. (2015). The use of stream power as an indicator of channel sensitivity to erosion and deposition processes. River Research and Applications, 31(1), 16-27.
3. Edwardson, K. Milone & MacBroom, Inc. (2016). Guidance for Assessing and Managing Sediment Behind Dams/Barriers (Rep.). NH: NHDES.
4. Ferguson, R. I. (1986). Hydraulics and hydraulic geometry. Progress in Physical Geography, 10(1), 1-31.
5. Gartner, J. (2016). Stream Power: Origins, Geomorphic Applications, and GIS Procedures (Thesis). Retrieved from https://scholarworks.umass.edu/cgi/viewcontent.cgi?article=1000&context=water_publications
6. GRANIT LiDAR Distribution Site. (New Hampshire GIS Database). (2018). GRANIT. http://lidar.unh.edu/map/#
7. Rivers, American (2017): American Rivers Dam Removal Database.
8. Verstraeten, G., & Poesen, J. (2000). Estimating trap efficiency of small reservoirs and ponds: methods and implications for the assessment of sediment yield. Progress in Physical Geography, 24(2), 219-251.