Konrad Hafen
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Term Project Status Report
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Modeling the surface storage potential of beaver dams in the Temple Fork Watershed

Introduction

Beaver are well-known ecosystem engineers that modify their environment to increase their chances of survival. They do this by building ponds that dam water, creating refuge and food storage for themselves. In so doing they alter chemical, biological, and hydrological processes. Previous work has even suggested that beaver ponds may increase the ability of a landscape to store water (Hood et al. 2008), and increase summer base flows (Nyssen et al. 2011). Understanding the extent to which beaver dams are capable of storing water on a landscape could be valuable as climate change scenarios predict a loss of water storage in mountain snowpack (Mote et al. 2005, Knowles et al. 2006, Stewart 2009). However, the magnitude to which beaver can provide water storage will vary spatially based on basin topography, geology, and hydrology, and to this point attempts to model beaver dam effects at scales meaningful to water management have been limited.

Freely available datasets providing national coverage of elevation, land cover, and geology provide the necessary data to develop such a model and allow the model to be developed within a geographic information system (GIS) thus providing spatially explicit model estimates. For this progress report I describe basic methods to develop and validate the described model.

Methods

The primary controls on the storage volume of a beaver dam are dam height, and the topography of the region that will be inundated by a dam of a given height. A simple model of pond storage may be constructed by assuming a beaver dam will inundate an area a certain distance upstream in a semicircular patter, and can be given by

$$V = 0.25\pi h d^2$$

where V is the volume stored by the pond, h is the height of the dam, and d is the distance the dam floods the stream in the upstream direction, which can be determined by

$$d = \frac{h}{s}$$

where s is the slope of the stream reach on which the dam is built (Figure 1).

As an alternative to slope, a digital elevation model (DEM) could be used to represent inundated topography and perhaps more accurately calculate pond volume. To accomplish this beaver dam height must be represented as an elevation (i.e., ground surface elevation + *h*). A search area in which to sample the DEM can be calculated using *d* (here I simply use *2d*), and a polygon can be generated (Figure 2). Within this polygon any cell of the DEM with a value less than the dam elevation is assumed to become inundated. Thus, a pond depth can be calculated by subtracting the value of the DEM cell from the elevation of the beaver dam (Figure 3).

Without accurate field data it will be difficult to validate the volumes of ponds produced from the model with actual pond volumes. However, pond areas can be easily calculated by identify and digitizing beaver ponds from aerial imagery. The location of the dams forming the ponds can be marked, and the dams can be modeled, areas of actual and modeled dams can be compared for validation. The major unknown is dam height. Several publications have recorded heights of beaver dams in various areas, most importantly Lokteff et al. (2013) report the height of every dam on both major streams (Temple Fork and Spawn Creek) in the Temple Fork watershed for the year 2012. I propose to use the mean dam height reported by Lokteff et al. (2013) for the model, and given enough time implement a Monte Carlo approach to account for stochasticity in dam height.

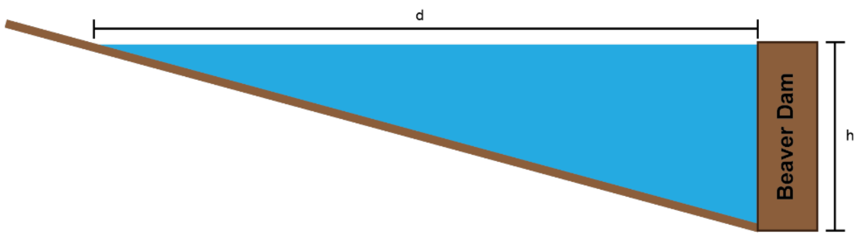

Figure 1. Cross section view of a beaver pond depicting the parameters necessary for a simple model of beaver pond storage capacity.

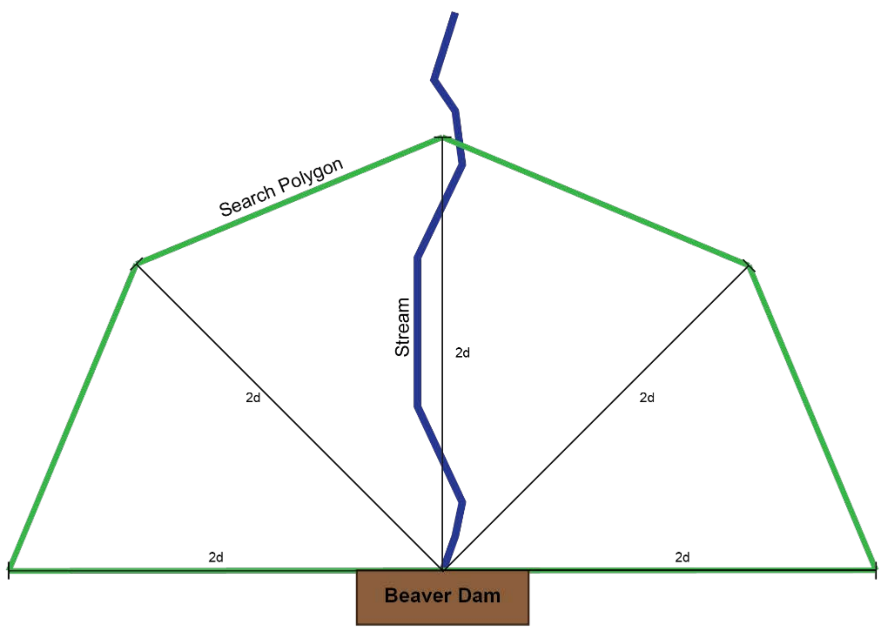

Figure 2. Planform view of the search polygon calculated from the parameters in Figure 1.

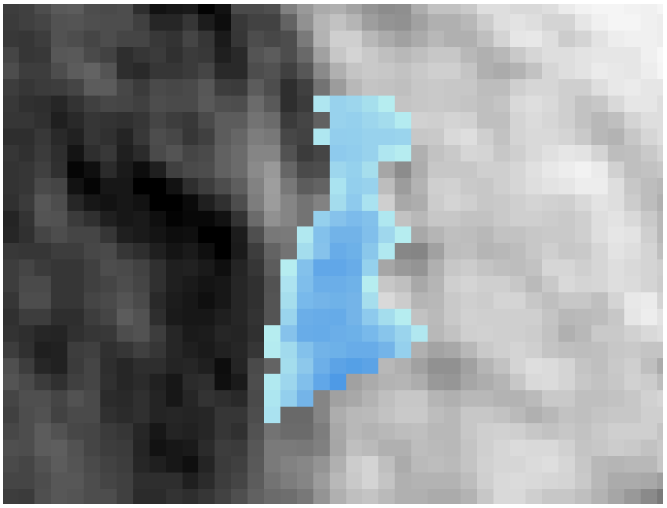

Figure 3. Example of a modeled beaver dam pond using a search polygon and DEM. Flow is from top to bottom. Darker blue represents greater water depth.

References

Hood, G. A., and S. E. Bayley. 2008. Beaver (*Castor canadensis*) mitigate the effects of climate on the area of open water in boreal wetlands in western Canada. Biological Conservation 141(2):556–567.

Knowles, N., M. D. Dettinger, and D. R. Cayan. 2006. Trends in snowfall versus rainfall in the western United States. Journal of Climate 19(18):4545–4559.

Lokteff, R. L., B. B. Roper, and J. M. Wheaton. 2013. Do beaver dams impede the movement of trout? Transactions of the American Fisheries Society 142:1114-1125.

Macfarlane, W. W., J. M. Wheaton, and M. L. Jensen. 2014. The Utah beaver restoration assessment tool: a decision support and planning tool. Ecogeomorphology and Topographic Analysis Laboratory, Utah State University, Prepared for Utah Division of Wildlife Resources. Available: http://etal.usu.edu/BRAT/

Mote, P. W., A. F. Hamlet, M. P. Clark, and D. P. Lettenmaier. 2005. Declining mountain snowpack in western North America.

Nyssen, J., J. Pontzeele, and P. Billi. Effect of beaver dams on the hydrology of small mountain streams: Example from the Chevral in the Ourthe Orientale basin, Ardennes, Belgium. Journal of Hydrology 402:92-102.

Stewart, I. T. 2009. Changes in snowpack and snowmelt runoff for key mountain regions. Hydrological Processes 23(1):78–94.