Evaluating Hydraulic and Vegetative Effects on River Bank Erosion

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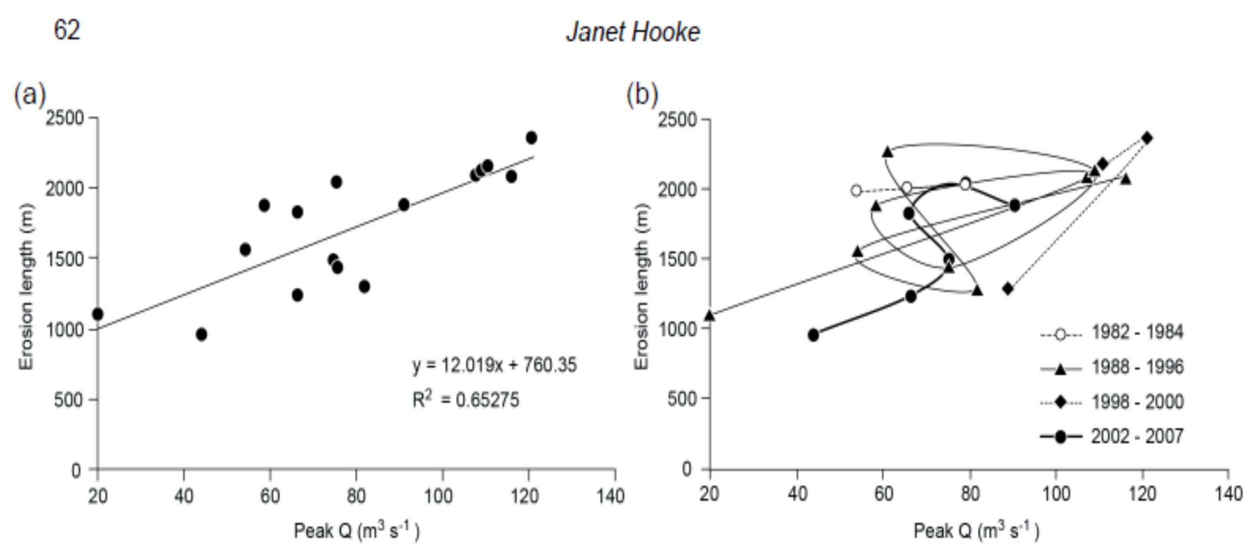
1. Abstract

River bank erosion and river migration are related processes. In meandering rivers, bank erosion often drives channel migration and floodplain formation. Bank erosion rates vary among rivers, but river size (e.g. width), power (related to velocity and discharge), shape (width/depth ratio and meander shape), and bank material strength (including plant roots) all affect bank erosion rates. The goal of this research is to monitor bank erosion rates on various time scales, and to measure the hydraulic and bank material parameters that influence bank erosion rates.



(Figure 1. Taken showing the relationship between erosion length and peak discharge. (Hooke 2012))

2. Hypotheses

1) The increase in annual peak discharge at the USGS gauge on Seneca Creek from the period 1938 to 2018 caused channel widening through bank erosion that is a simple function of the increase in annual peak discharge.

2) In the selected study reach, erosion is spatially variable; long-term erosion rates measured by dendrochronological and sequential air photo methods are expected to be highest on the outside of bends, but they are expected to be significantly reduced by bank vegetation and large woody debris.

3) Short-term erosion rates (measured quarterly or after large events) exhibit erosion lengths and widths that are highest on the outside of bends, that are correlated to event peak discharges, and are lower along reaches protected by woody debris and rooted bank vegetation.

$$B_e = \left\{ \left[a_1 C_s \left(\frac{W_b}{R_c} \right) \right]_{at\ L} - \left[a_2 \left(r_y \frac{r_d}{h_b} \right) + a_3 \left(LWD \frac{d_w}{D} \right) + a_4 (PI) + a_5 \left(d_c \frac{h_b}{D} \right) \right]_{at\ L + \text{Phase Lag}} \right\} a_6 V$$

Where Be = Bank Erosion Rate, Cs = bed sediment concentration, Wb = Bankfull channel width, Rc = Channel Radius of curvature, Ry = Fraction of bank covered by vegetation roots, Rd = vegetation root depth, Hb = bank height, LWD = fraction of bank covered by tree of large woody debris, Dw = Average height of large woody debris jams, D = hydraulic depth of channel, PI = Plastic Index, Dc = portion of bank sediment too coarse for incipient motion, V = mean channel velocity [L/T], L = distance along channel, and a1 and a6 are empirical coefficients and a2, a3, a4, and a5 are weighting factors.

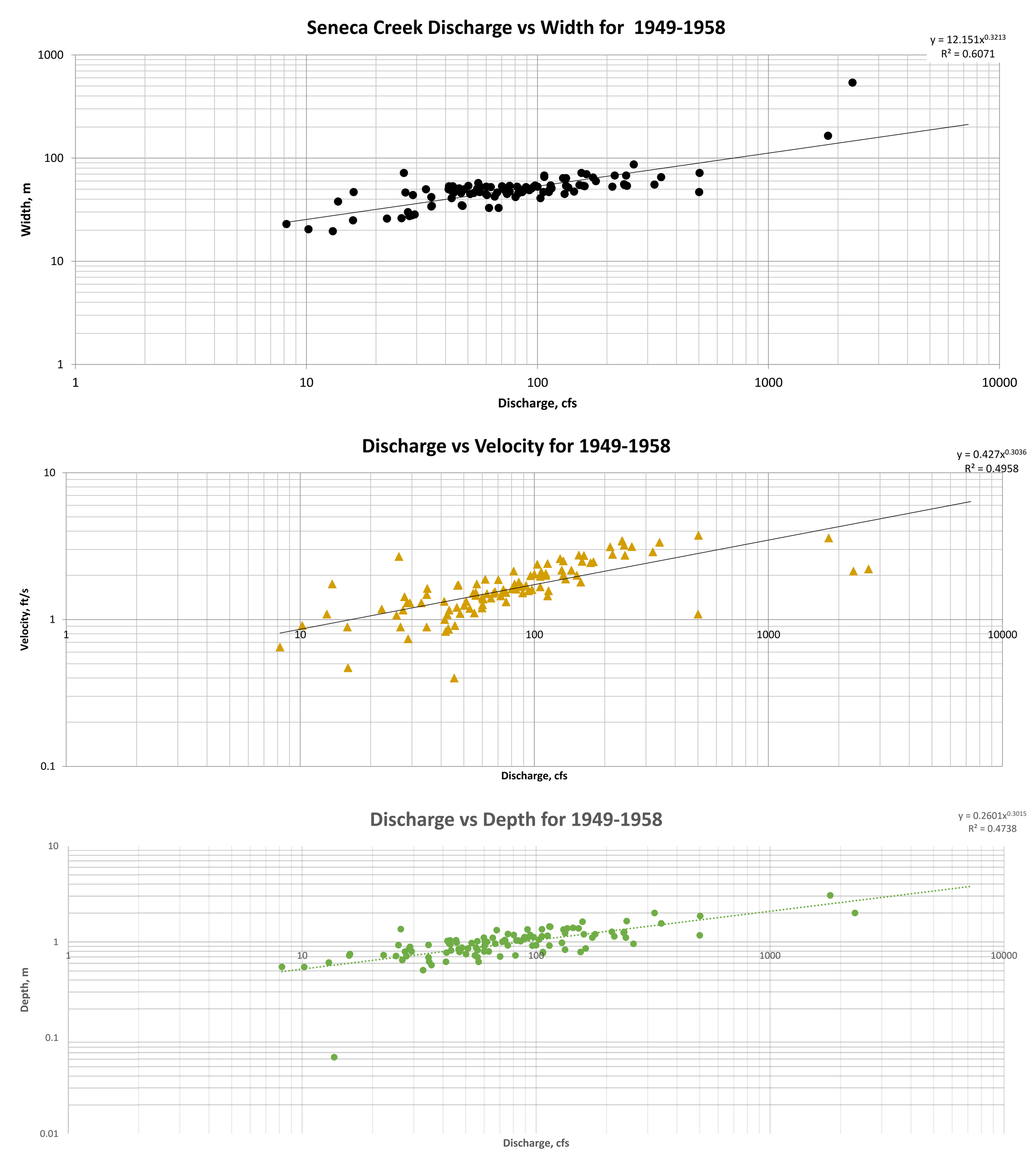
3. Site Selection

The study reach is a section of Seneca Creek near Dawsonville Maryland. The site was selected because of high rates of bank apparent bank erosion, location near a USGS gauging station, and an increase in annual maximum discharge.

(Figure 2. An air-photo of the study area displaying where specific sites for measurements are located. The superimposed yellow bar is 100 meters and the grey arrow is north direction.)

4a. Methods – Hydraulic Data

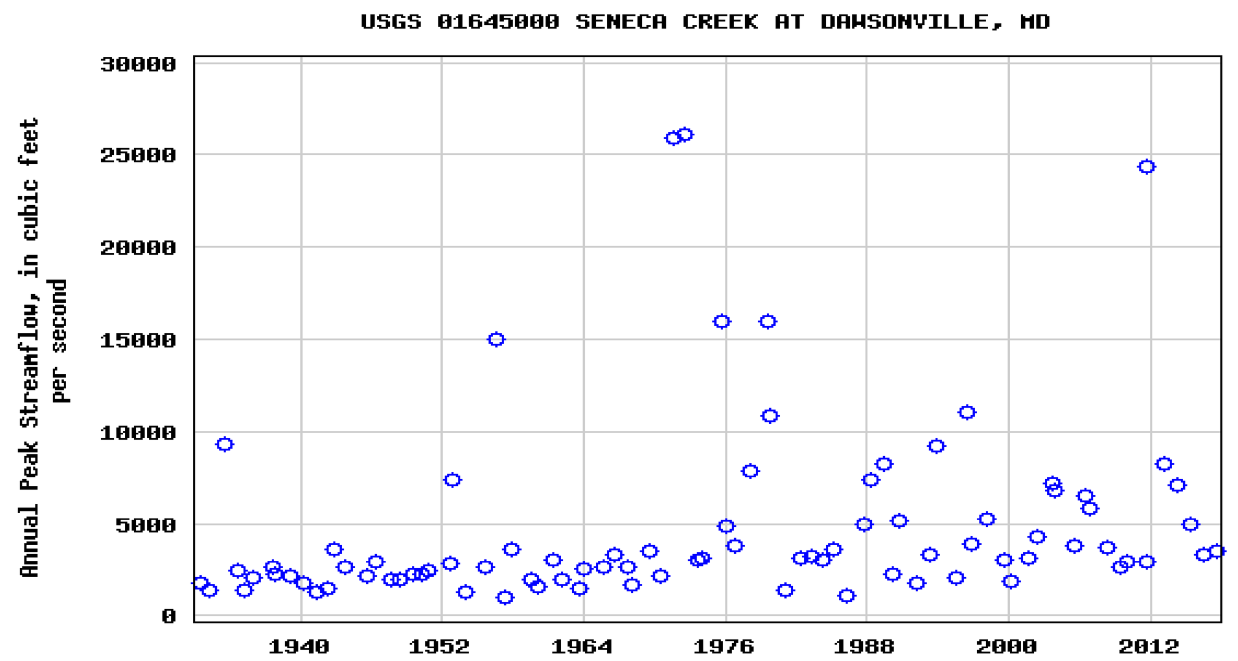
Hydraulic data, consisting of a) annual peak discharge, and b) measurements of river width and depth, velocity, and discharge has been acquired from the USGS. These data extend from 1930 to 2019. The data are divided into 10-year intervals and annual average peak discharge, and the At-a-station hydraulic geometry relationships are determined for each time interval.



(Figure 3. A set of graphs Displaying width, velocity and depth as a function of discharge.)

4. Methods – Hydraulic (Cntd)

Below are the data from 1930 to the present of annual peak discharges, showing an increasing trend in discharge.



4b. Methods – Collection of Spatially distributed Data

The first part of this study utilizes USGS hydraulic data. These data extend over a significant period of time, but only provide information about one cross section of the river. In this part of the study, spatial differences in bank erosion rates, and associated variations in channel morphology and bank characteristics will be evaluated. Selected reaches are shown in fig. 2. Table 1 includes the physical characteristics that measured from the 2008 and 2018 air photos to determine characteristics and erosion rates. will be measured at each of the study sites.

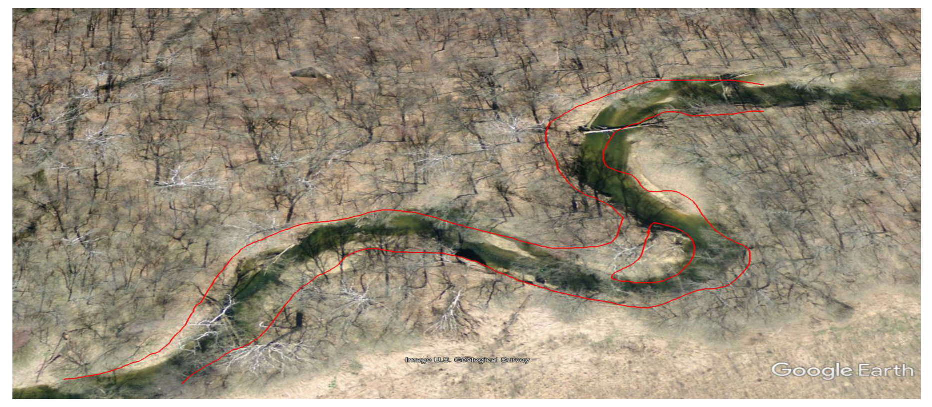


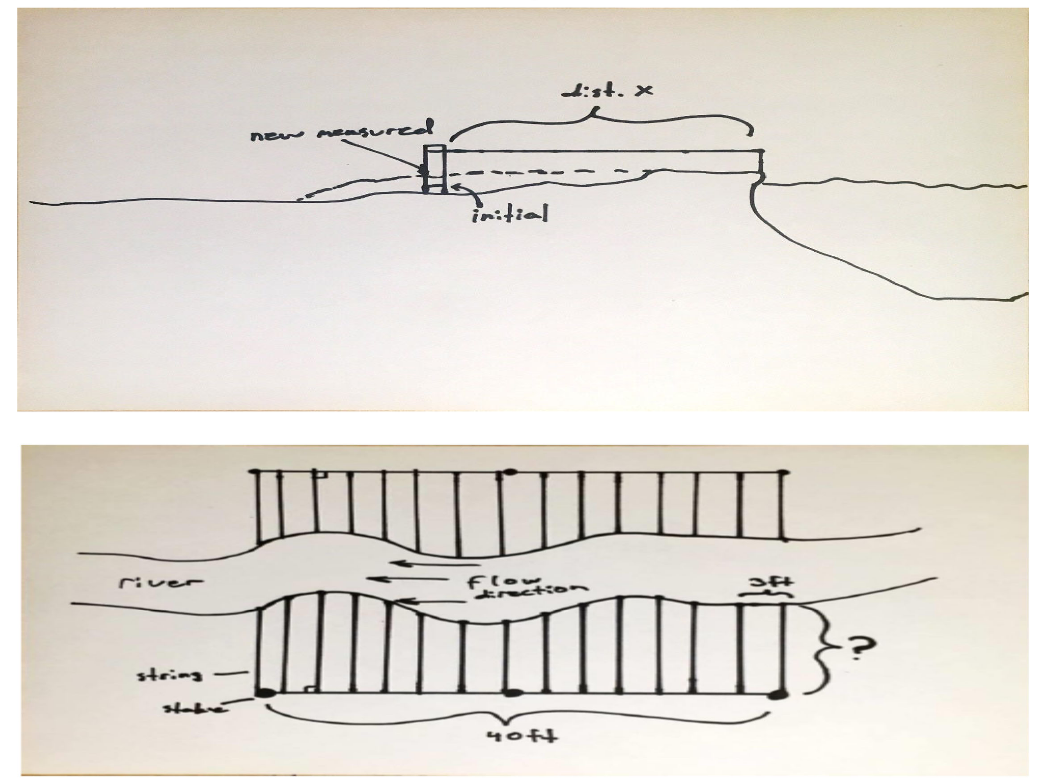
Figure 4. Migration rates determined from area change from air photos 2008 - 2018

Site Name	Length (m)	Ave Width, m*	Depth m	Rc, m	Rc/w	Rooting Depth, ft	Woody Debris Length, m	Migration Rate, m/yr
Site 1 bend	70	22.5	1.83	23.9	1.06	5	0	0.03
Site 2 Bend	143	13.2	1.8	28.5	2.15	2-3	0	0.93
Site 3 Straight	110	13.0	2.13	NA	NA	2-5	19.9	0.10
Site 4 Straight	52	14.7	2.13	NA	NA	3-4	3.26	0.30
Site 5 Bend	64	12.15	2.44	32.23	2.65	6	5.12	0.30
Site 6 Bend	113	16.2	2.44	36.61	2.26	3	5.29	0.05
Site 7 Bend	89	10.3	1.83	16.9	1.64	2-3	10.8	0.92 Cut-off
Site 8 Bend	109	18.5	1.83	31.66	1.71	2-3	7.23	0.20

Table 1. Physical measurements for each reach.

4c: Measurements of Short Term Changes

Below is a sketch of the short term measurement technique. Short term measurements will be repeated quarterly throughout the year.



(Figure 5. A diagram showing how bank erosion measurements will be made.)

Table 2. Initial bank erosion measurements at site 3 along with respective rooting depths. These data were measured multiple times and the error was found to be 0.83%

Measurement #	Distance to Bank, Ft	Rooting Depth, Ft
1	4” 10’	2” 3’
2	4” 9’	2” 5’
3	5” 2’	2” 7’
4	5” 1’	2” 6’
5	5” 6’	2” 6’
6	5” 10’	2” 8’
7	6” 2’	2” 9’
8	6” 0’	2” 10’
9	5” 11’	2” 9’
10	6” 2’	2” 9’
11	6” 4’	2” 9’
12	6” 1’	3” 3’
13	5” 9’	2” 8’
14	5” 3’	2” 7’
15	5” 4’	2” 6’
16	5” 4’	2” 5’
17	5” 3’	2” 4’
18	5” 0’	2” 3’
19	5” 1’	3” 0’
20	5” 9’	2” 7’

5. Error and Conclusion

The error in USGS discharge data is reported to be between 2%-5%, the air photo data will be repeated and the operator/resolution error will be determined. In summary these techniques will allow for analysis of channel changes and their association to hydraulic and geomorphic variables for 3 different time scales.