Evaluation of Channel Adjustments to Urbanization on the Paint Branch Stream System

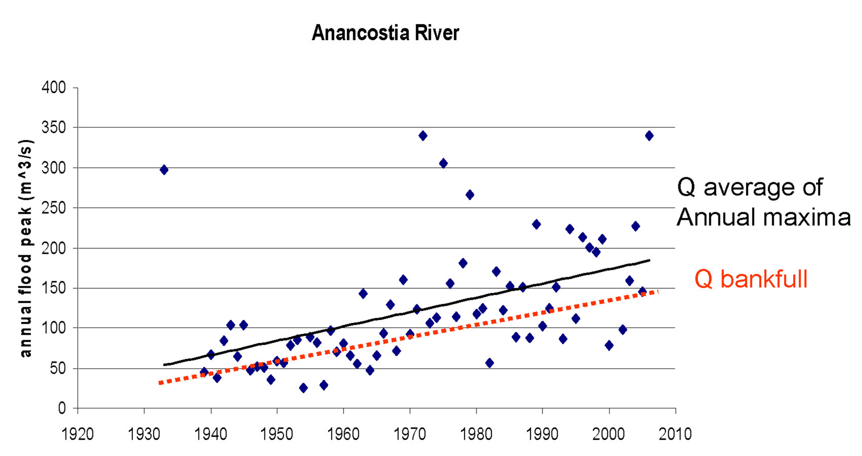
Krystle Behrns

Advisor: Dr. Karen L. Prestegaard

Introduction

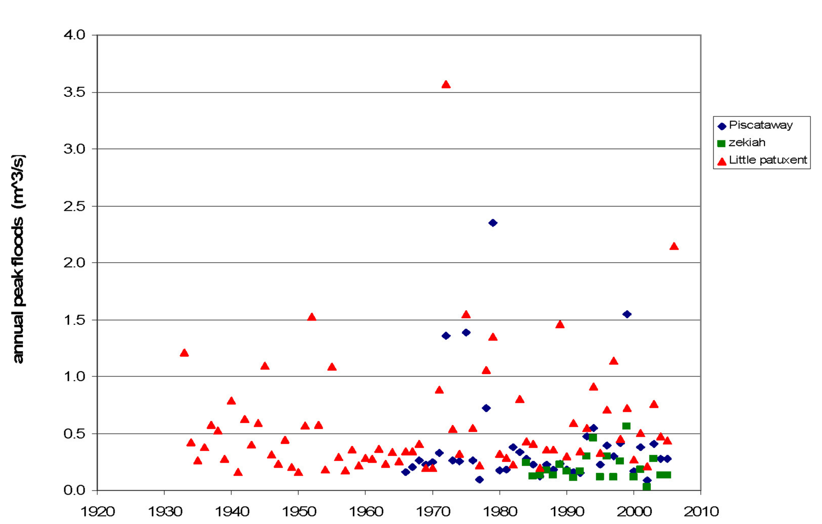
- Urbanization, which creates impervious surfaces, increases runoff and the magnitude of the bankfull flood.
  - Does the Anacostia River show an increase in flood discharges not observed in non-urban watersheds?
  - Does the increase in bankfull discharge cause the channels to enlarge to accommodate the flows?
- Previous work suggests channels adjust primarily by channel widening and it takes 15-30 years for channels to adjust to an increase in discharge (Hammer, 1972).
- Therefore, I hypothesize that most of the channel adjustment to urbanization occurred prior to 1996, and that channel changes between 1996 and the present are consistent with morphological changes expected for a quasi-equilibrium channel.

Trends in Discharge observed in the NE Branch, Anacostia River



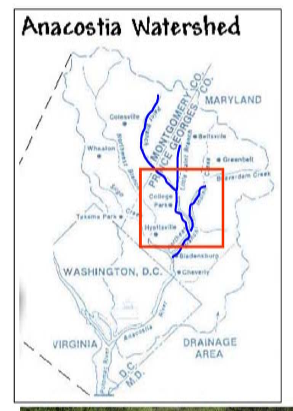
The trendline illustrates the change that has occurred in the annual maximum flood series. The mean annual maximum flood in 1933 was about 50 m^3/s and the mean increased to about 180 m^3/s in 2006. The mean annual flood is 1.35 times larger than the Q1.5 bankfull flood. Data from USGS (2007).

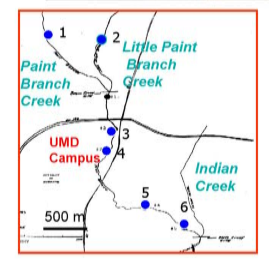
No trend in discharge at non-urban sites



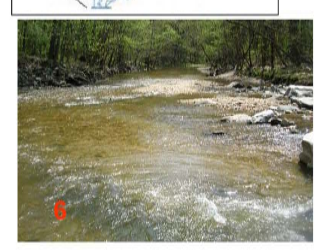
Annual flood data for three nearby low-urban reference streams within the Maryland Coastal Plain do not show systematic changes in discharge.

Study Site





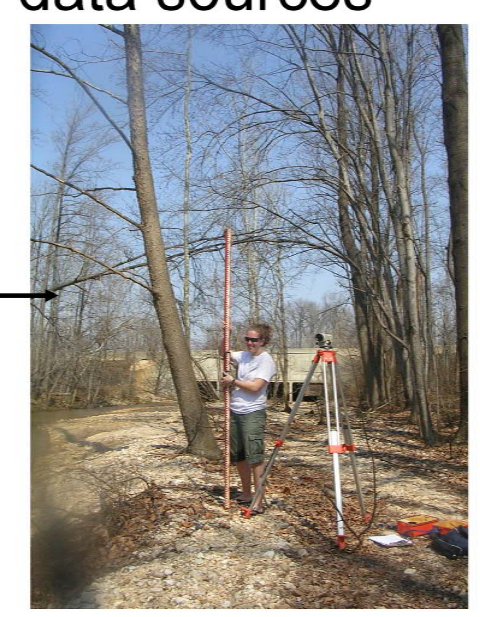
Note the major gravel bars in the downstream sites (3,5,6) versus the upstream sites (1,2).



Sites are listed in order (1-6) beginning upstream at Powdermill and ending at the airport.

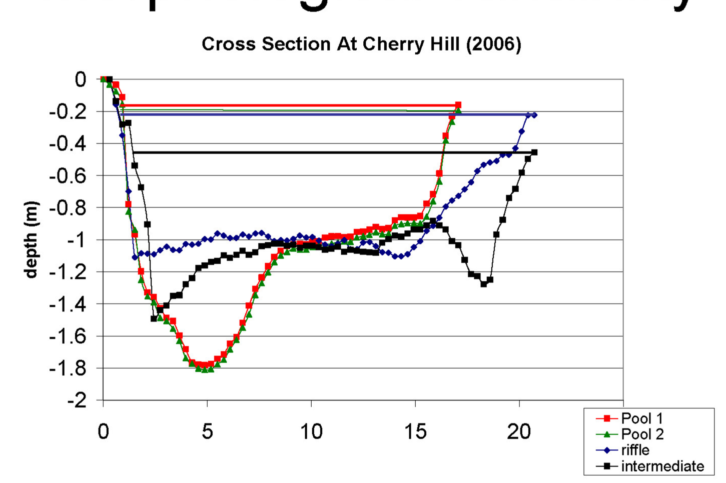
Methods and data sources

- Data sources
  - Non-urban reference streams (Prestegaard)
  - Patronik 1995 data and Prestegaard 1996 data
  - Re-survey of six sites from 1995/1996 along the Paint Branch Stream.
- Field methods & analysis
  - Survey a riffle, pool and intermediate cross section
  - Calculate width, depth, area for each, determine average
  - Define the with-in reach morphological variation as 2 standard deviations around mean.



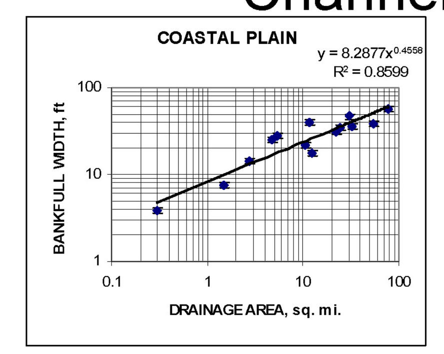
Field equipment: Stadia rod (2 meter) and surveyor's level

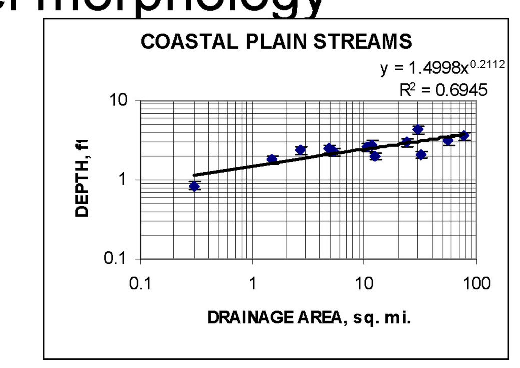
Morphological variability

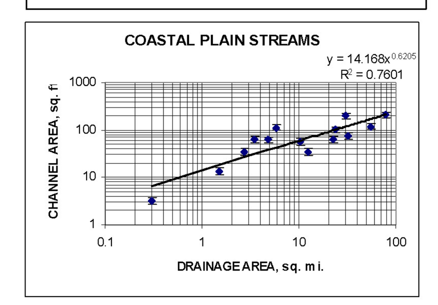


Measurement error was determined by re-survey of cross sections (see pool 1 & pool 2), which indicated 3.3% measurement error in cross sectional area. Measurement error is much smaller than within-reach morphological variation.

Determination of pre-urban Channel morphology

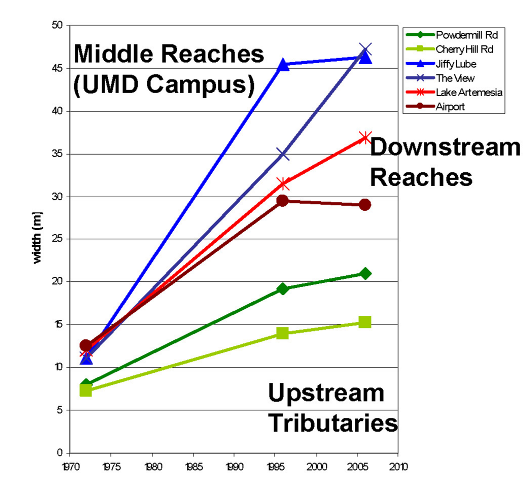






Pre-urban channel morphology for the Anacostia was estimated from channel morphology data for non-urban Reference Streams (Prestegaard et al., 2001)derived from reach-averaged data (10-12 cross sections per reach) for 14 reaches in the Western Coastal Plain of Maryland. Drainage basin area is used to estimate pre-urban channel width, depth, and cross sectional area.

Width Channel Change over time

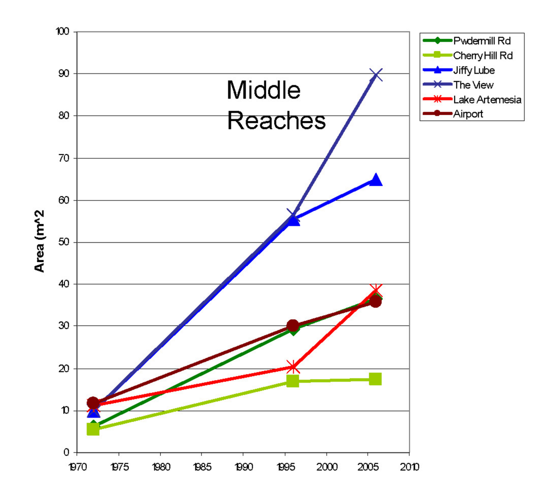


Upstream tributaries doubled their widths by 1995; post-1995 change is similar to morphological variation

Middle reach showed the largest increase in channel width; Jiffy lube site was stabilized on the left bank in 2005.

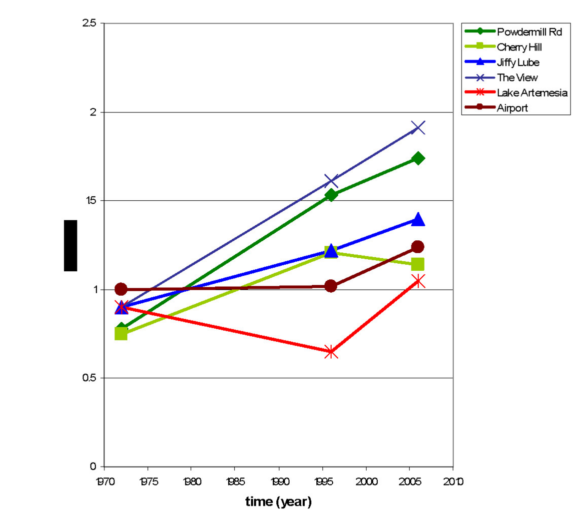
Downstream reaches showed significant widening prior to 1995. Airport site is stabilized with rip-rap.

Area Channel Change over time



- The area illustrates the overall change at each site.
- Most of the overall channel change was from the increase of widths at each site.
- The least amount of channel change was at the Cherry Hill site and the most overall change was located at the View (middle reaches).

Depth Channel Change over time



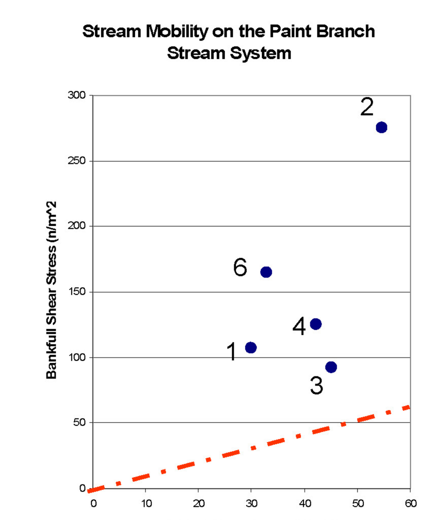
Every site experiences a significant amount of depth increase (except Cherry Hill)

Hammer suggest that stream channels enlarge primarily because of an increase in the width, not depth.

The increase in depth for the majority of the sites results in an increase in the change of fluid shear stress.

Therefore the sites that used to be threshold streams are now above threshold condition, which may not be consistent with a quasi-equilibrium stream.

Bed Sediment mobility



Bankfull shear stress was calculated for each cross section:

$T = \rho gRS$

Critical shear stress was calculated for the size of the bed sediment using a modified Shields' Criterion (0.045) for heterogeneous gravel beds.

T crit = (0.045)(rs-rw)gD84

D84 was calculated from the grain size distribution at each site and the gradient (S) was calculated from the field as the surface water gradient.

Red dotted line is for threshold channels. The reference channels were all within 20% of the threshold condition. The six measured sites are all above the threshold of motion. (Cherry Hill-1, Powdermill-2, Jiffy Lube-3, the View-4, the airport-6)

Conclusions

- Annual maximum flood series for the Anacostia shows a distinct increasing trend with time, which is not observed at 3 nearby comparison streams. This indicates that urbanization, not climate, is the likely cause for the increase in flood discharge in the NE branch of the Anacostia River.
- All of the sites showed large increases in channel width for the period 1938-1995. The amount of difference between 1996 and 2006 varied significantly among the sites. Channel depth also increased, which increases shear stress.
- Most of the stream channel morphology within the study reach indicated transformational change. The shear stress results indicate all of the sites are above the threshold of motion, which predicts high rates of sediment transport and deposition (e.g. gravel bar formation).