DO PAIRED WATERSHED STUDIES WORK?

Smith, Katrina and Nichols, Kyle K., Department of Geosciences, Skidmore College, Saratoga Springs, NY 12866

SKIDMORE
C O L L E G E

Abstract

The ability to quantify change in a watershed depends on understanding the basin's baseline behavior. If baseline information is not available, many studies rely on basins in close proximity to approximate the initial conditions. In some cases, it is assumed that basin hydrology is similar if two basins are nearby and they have similar areas. However, basin hydrology depends not only on basin size, but also on bedrock and surficial geology, land use, hypsometry, and precipitation distribution.

In order to test the baseline hydrology of proximal basins, we measured discharge from September to November, 2003 (n=15) in the East Branch Kayaderosseras Creek, (EBK) and Sturdevant Creek, Saratoga County, New York. We divided the EBK into two sub-basins (5 and 16 km^2) and Sturdevant Creek into three sub-basins (3, 7, and 20 km^2). Both basins have a similar bedrock geology, land use pattern, and hypsometry. Three recording tipping bucket rain gauges, placed at different elevations in the basins, have a high correlation (r^2 > 0.9, trendline slopes close to 1.0) suggesting a weak orographic effect and no small-scale (< 5 km^2) precipitation events during the collection period. The main difference between the two basins is the surficial geology and their associated infiltration capacities. The surficial geology of each basin (based on the Hudson-Mohawk Surficial Geology Quad, 1:250,000), is a patchwork of bedrock, till, and kame moraine (and some swamp in Sturdevant Creek basin). The area of kame moraine in EBK is ~2x larger than in Sturdevant Creek.

In general, discharge increases at larger sub-basin sizes. However, the EBK increases in discharge at a lower rate than Sturdevant Creek in 12 of the 15 data sets. Such lower increase in discharge (EBK) is most likely due to a higher percentage of "kame moraine" and the associated slower release of groundwater to the creek. In 11 of the 15 data sets, the EBK had higher discharges at small basin areas (<3 km^2) while Sturdevant Creek had higher discharges at larger basin areas (>16 km^2). Similar discharges from 3 to 16 km^2 suggest the range where the paired watershed method is effective for the EBK and Sturdevant basins. Overall, our results show that the paired watershed is strongly dependent on basin geology in addition to basin area.

What is a paired watershed study?

- Compare a "control" watershed to an "altered" watershed in order to quantify the magnitude of change of a certain variable of interest
- Change can be due to different human alterations such as: change in water and sediment discharge due to logging, change in nutrient loading due to agricultural and grazing practices, and change in hydrology and water quality due to land use and land management practices
- Fundamental assumption states that the "altered" watershed had similar baseline behavior as the "control" watershed
- Watershed variables include: area, bedrock and surficial geology, climate, land use, relief, and hypsometry

Study Area

- East Branch Kayaderosseras Creek (EBK) and Sturdevant Creek in Upstate New York are located less that 10 km apart and have similar climates
- EBK is divided into two sub-basins (K1 = 5 km^2, K2 = 16 km^2) and Sturdevant Creek is divided into 3 sub-basins (S1 = 3 km^2, 23 = 7 km^2, S3 = 20 km^2)
- Both basins head in bedrock on the uplifted side of the McGregor fault, cross the fault, and then flow across glacial deposits (Figure 1)
- Both basins are dominated by metamorphic rocks (Table 1)
- EBK has a two fold higher portion of "Kame moraine" than Sturdevant Creek (Table 2)

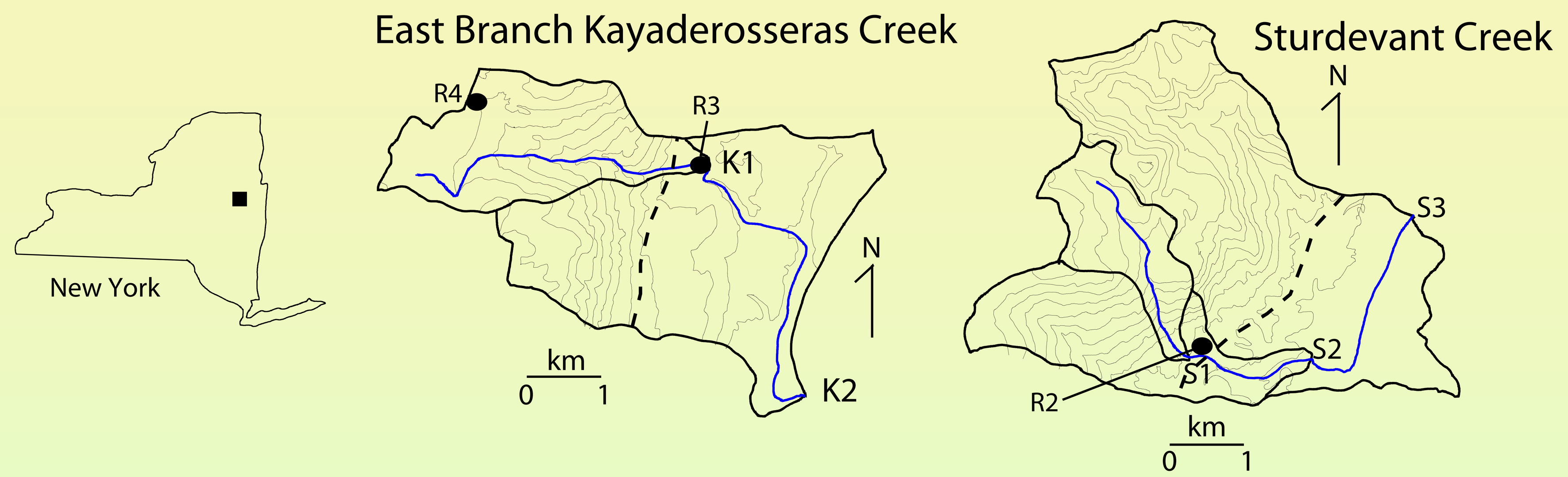

Figure 1. Topographic maps of EBK and Sturdevant Creek basins. Thick black lines represent basin outlines for K1, K2, S1, S2, and S3. Thin black lines are contour lines at 100 ft. intervals. Dashed lines represent approximate location of McGregor Fault. Blue lines represent creeks. Rain gauges (R2, R3, and R4) are represented by black dots.

Table 1: Bedrock Geology*

Sturdevant (20 km^2)	
Metasedimentary rock and related migmatite	70%
Granitic, quartz syenitic gneisses	30%
Kayaderosseras (16 km^2)	
Metasedimentary rock and related migmatite	53%
Pottsdam sandstone, quartzite, quartz schist	46%
Beekmantown limestone and dolostone	1%

*based on 1:250,000 Hudson-Mohawk Surficial Geologic Map

Table 2: Surficial Geology*

Sturdevant (20 km^2)	
Kame moraine	36%
Bedrock	32%
Till	20%
Swamp peat and muck	12%
Kayaderosseras (16 km^2)	
Kame moraine	65%
Bedrock	22%
Till	13%

*based on 1:250,000 Hudson-Mohawk Surficial Geologic Map

Table 3: Land Use*

Sturdevant	
S1 sub-basin (*2.8 km^2*)	1 residences
S2 sub-basin (*7.3 km^2*)	18 residences
S3 sub-basin (*20 km^2*)	60 residences
Kayaderosseras	
K1 sub-basin (*5.1 km^2*)	13 residences
K2 sub-basin (*16 km^2*)	74 residences

*based on 2001 aerial photos

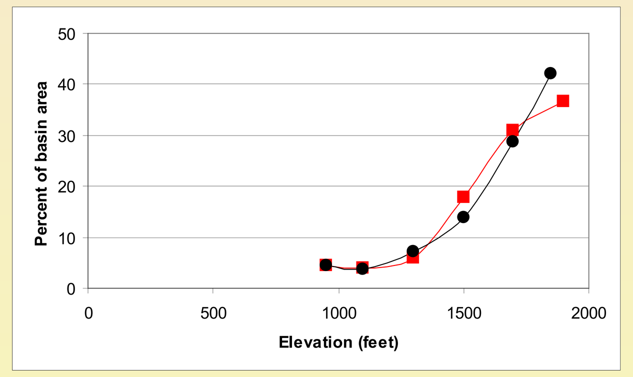

Figure 2a.

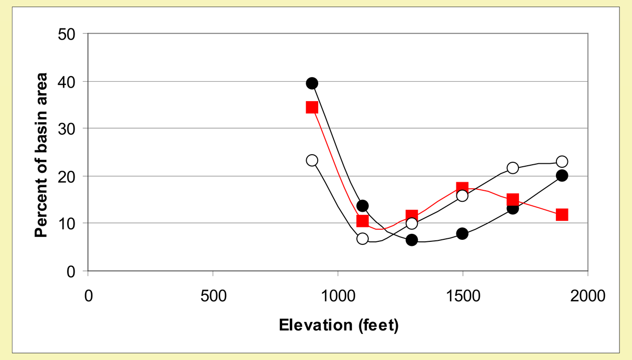

Figure 2b.

Figure 2. Basin hypsometry of the EBK and Sturdevant paired watersheds. Majority of basin area in S1 (black circles) and K1 (red boxes) is above 1500 ft (a), and most of the basin area in K2 (red boxes), S2 (open circles), and S3 (black circles) is below 1300 ft (b).

Methods

- Locate similar basins in close proximity to one another and of similar size
- Determined basin sizes, hypsometry, and geologic makeup
- Measured stream discharges (Marsh McBirney 2000 FloMate) at K1, K2, S1, S2, and S3 stream cross sections to determine discharge
- Determine land use by conducting a first order count of residences using recent aerial photos
- Place tipping bucket rain gauges within each basin to collect precipitation data

Results

- *Hypsometry:* Both basins lie in areas with similar topography (Figure 2)
- *Rain data:* All the rain gauges collected uniform data of storm events (Figure 3)
- *Bedrock geology:* Both basins are composed primarily of matasedimentary rock (Table 1)
- *Surficial geology:* Higher percentage of Kame moraine in the EBK basin leads to higher infiltration and swamp in Sturdevant lowers infiltration
- *Land use:* Both basins have similar development (Table 3)
- *Discharge:* In 12 out of 15 days, the discharge increases faster in Sturdevant Creek than in EBK (Figure 4a)
  - During two days, the discharge increased faster in EBK than in Sturdevant Creek (Figure 4b)
  - During 12 sampling periods the discharge trendlines intersected between 3 km^2 and 16 km^2
  - The average increase in discharge (trendlines) for Sturdevant Creek (0.099 +/- 0.023) is statistically higher than the increase in discharge of EBK (0.074 +/- 0.018) (t = 2.145, df = 14, P=0.05)

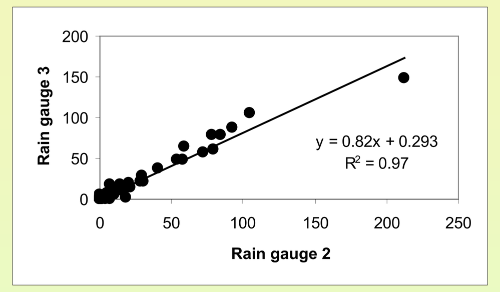

Figure 3a.

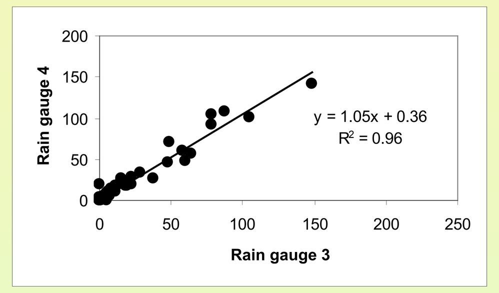

Figure 3b.

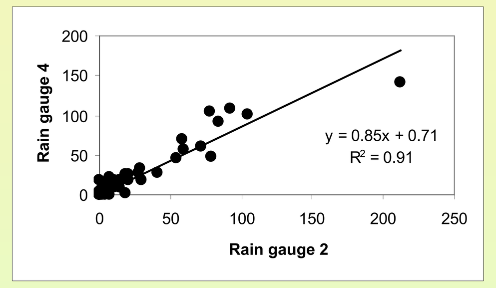

Figure 3c.

Figure 3. Comparison of precipitation recordings from rain gauges. (a) Rain gauge 3 (near K1) plotted against Rain gauge 2 (near S1). (b) Rain gauge 4 (top of the EBK basin) plotted against Rain gauge 3. (c) Rain gauge 4 plotted against Rain gauge 2. High correlation between data and slopes close to 1 suggest uniform precipitation.

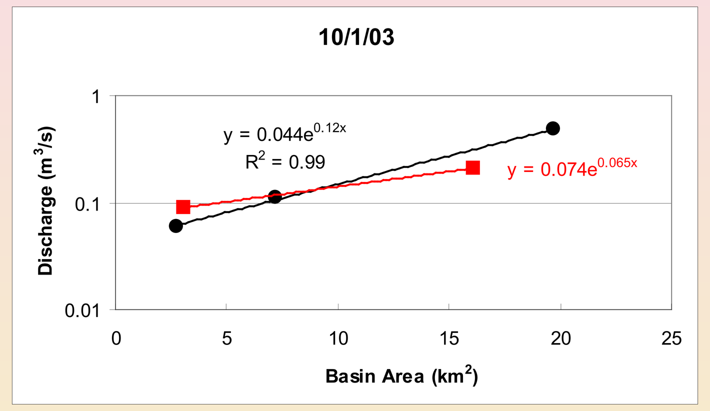

Figure 4a.

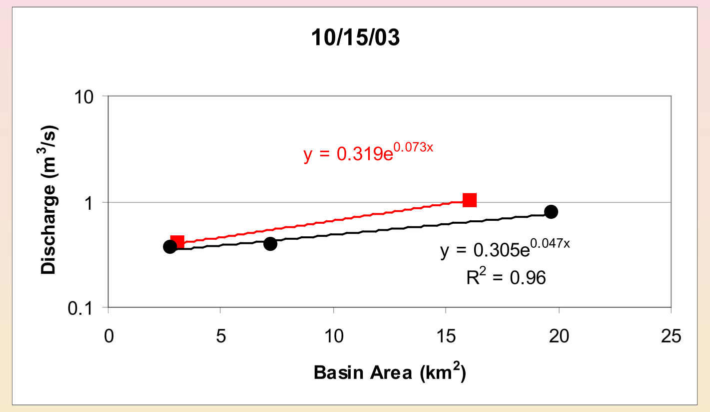

Figure 4c.

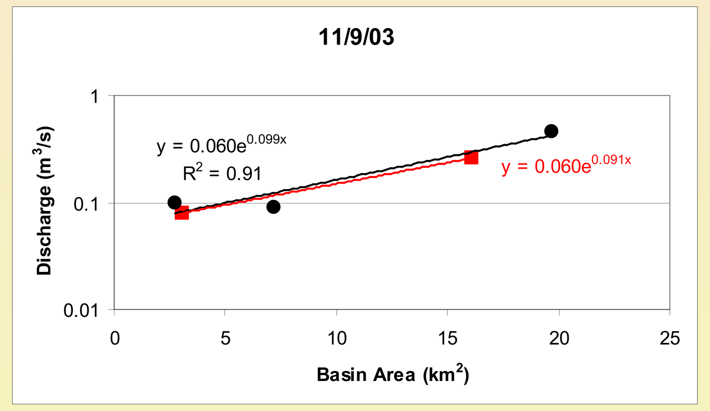

Figure 4c.

Figure 4. Discharge data for EBK (red boxes) and Sturdevant Creek (black squares) on three different days in October, 2003. (a) Discharge trendlines intersect; Sturdevant Creek discharge increases faster than EBK discharge. (b) EBK discharge increases faster than Sturdevant Creek discharge. (c) Similar discharge increases for both basins.

Depth & velocity measurements taken at S2

Discussion

- The EBK basin has smaller discharges in larger areas (>16 km^2)
  - This is due to the high percentage of Kame moraine which has a high infiltration rate
  - Sturdevant Creek also has a swampy area with low infiltration
- Sturdevant basin has smaller discharges in smaller areas (<3 km^2)
- Intersections of EBK and Sturdevant discharge trend lines show that the basins behave in a similar way for basins that are 3 km^2 to 16 km^2
- For large basins there is a greater possibility of geological differences between basins

Conclusions

- Both basins have similar discharges for basins ranging from 3 km^2 to 16 km^2
- The paired watershed method is accurate for the EBK and Sturdevant basins up to 16 km^2
- Surficial sediments, in addition to basin size, are important in the surface hydrology of the EBK and Sturdevant basins greater than 16 km^2

Suggestions for Future Research

- Comparing more than two basins would better test paired watershed study viability
- More data spanning different seasons would give a broader perspective of surface hydrology
- In general, future paired watershed studies should consider geology, land use, and hypsometry in addition to basin size when designating watersheds