DO PAIRED WATERSHED STUDIES WORK?

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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 climates. 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 (15 and 16 km²) and Sturdevant Creek into five sub-basins (3, 7, and 20 km²). 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 > 0.9; 6.9 median slopes close to 1) suggesting a weak orographic effect and no small-scale (<10 km²) precipitation events close to 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 Mohawk Surficial Geologic Quadrangle, 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 lower release of groundwater to the creek. In 11 of the 15 data sets, the EBK had higher discharges at smaller basin areas (<3 km²) while Sturdevant Creek had higher discharges at larger basin areas (>10 km²). Similar discharges from 3 to 16 km² 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 assumptions stated above “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 than 10 km apart and have similar climates
- EBK is divided into two sub-basins (K1 = 5 km², K2 = 16 km²) and Sturdevant Creek is divided into 3 sub-basins (S1 = 3 km², S2 = 5.1 km², S3 = 7.3 km²)
- Both basins head in bedrock on the upfip 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)

Table 1: Bedrock Geology*

<table>
<thead>
<tr>
<th>Bedrock Geology</th>
<th>EBK</th>
<th>Sturdevant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metasedimentary rock and related migmatisite</td>
<td>70%</td>
<td>30%</td>
</tr>
<tr>
<td>Granite, quartz syenitic gneisses</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Kame moraine</td>
<td>53%</td>
<td>46%</td>
</tr>
<tr>
<td>Pottsdam sandstone, quartzite, schist</td>
<td>46%</td>
<td>5%</td>
</tr>
<tr>
<td>Backmanstown limestone and dolostone</td>
<td>1%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 2: Surficial Geology

<table>
<thead>
<tr>
<th>Surficial Geology</th>
<th>EBK</th>
<th>Sturdevant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kame moraine</td>
<td>36%</td>
<td>65%</td>
</tr>
<tr>
<td>Bedrock</td>
<td>20%</td>
<td>15%</td>
</tr>
<tr>
<td>Swamp peat and mud</td>
<td>12%</td>
<td>0%</td>
</tr>
<tr>
<td>Kame moraine</td>
<td>18%</td>
<td>15%</td>
</tr>
</tbody>
</table>

Figure 1. Topographic maps of EBK and Sturdevant Creek basins. Thick black lines represent basline 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 (K1, K2, and R) are represented by black dots.

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, and most of the basin area in K2 (red dots), S2 (open circles), and S3 (black circles) is below 1300 ft (b).

Table 3: Land Use*

<table>
<thead>
<tr>
<th>Land Use</th>
<th>EBK</th>
<th>Sturdevant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-basin 1-5 km²</td>
<td>1 residence</td>
<td>1 residence</td>
</tr>
<tr>
<td>Sub-basin 6-15 km²</td>
<td>1 residence</td>
<td>2 residences</td>
</tr>
<tr>
<td>Sub-basin 16 km²</td>
<td>1 residence</td>
<td>2 residences</td>
</tr>
</tbody>
</table>

Results

- Locates 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 in 15 data sets
- Determined 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

Methods

- Hydrology: All basins lie in areas with similar topography (Figure 2) and similar land use (Figure 3a).
- Rain data: All the rain gauges collected uniform data for storm events (Table 3). The bedrock geology of both basins is dominated by metamorphic rocks (Table 1).
- Surficial geology: Higher percentage of kame moraine in the EBK basin leads to higher infiltration and lower stream flows (Figure 4a).
- Land use: Both basins have similar development (Table 3).
- Discharge: 12 out of 15 days, the discharge increases faster in Sturdevant Creek than in EBK (Figure 4a).

Discussion

- EBK basin has smaller discharges in larger areas (>16 km²).
- EBK basin has higher infiltration rate compared to Sturdevant Creek basin.
- Sturdevant Creek has smaller discharges in smaller areas (<3 km²).
- Intercross sections of EBK and Sturdevant Creek show that the basins behave in a similar way for basins that are 3 km² to 16 km².
- For larger basins there is a greater possibility of geologic differences between basins.

Conclusions

- Both basins have similar discharges for basins ranging from 3 km² to 16 km².
- The paired watershed method is accurate for the EBK and Sturdevant basins up to 16 km².
- Surficial sediments, in addition to basin size, are important in the surface hydrology of the EBK and Sturdevant basins greater than 16 km².

Suggestions for Future Research

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

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