Surface/Groundwater Interactions and Sediment Characteristics of Headwater Streams in the Piedmont of North Carolina

by

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Abstract

Despite their size, the health of headwater streams has enormous implications in terms of water quality and general downstream health for larger river systems. The ecological micro-niches provided by headwater systems foster biodiversity and help process pollutants and excess nutrient loads. More research is needed to understand the dynamics of surface and subsurface hydrologic interactions and how they vary based on extremely localized geomorphic influences. There is still much to learn regarding how groundwater and surface water interact because the processes that control these interactions change greatly over space and time. This study quantifies the degree of surface and groundwater interaction in three streams in the Piedmont region of the Carolinas. The streams in this study may serve as reference reaches for stream restoration projects in the southeast, as very few anthropogenic factors are thought to be influencing the three study streams.

Field work conducted in 2009 in 13 watersheds on 307 ha of relatively undisturbed land in the Piedmont region of North Carolina showed indications of downstream sediment coarsening in 10 of 13 streams. Large woody debris jams were found to contribute to accumulations of poorly sorted sediment that had low D_{50} values relative to overall mean D_{50} values for the stream

as a whole. Additional work in 2010 – 2011 focused heavily on three specific 1st order streams that, after thorough geomorphic characterization, were determined to be representative of typical environments found on the property.

In order to quantify specific surface/groundwater interaction points and to standardize data collection, repeat measurement areas were established at 25 meter intervals in each of the three intensively studied streams. Eighteen rounds of temperature and specific conductance measurements were collected along these 25 m intervals at each creek from July of 2009 – April of 2011. Temperature and specific conductance measurements repeatedly showed evidence for groundwater upwelling in specific areas of two creeks. The third creek, located in a different lithology, showed no evidence for distinct groundwater upwelling zones, instead showing a pattern of more gradual and diffuse contributions of groundwater to baseflow. Where bed substrate allowed, piezometers were installed at 25 m increments on each of the three creeks and five separate rounds of head gradient measurements were collected from autumn 2010 to spring 2011. Vertical head gradients showed repeated upwelling trends that corresponded with where specific conductance and temperature perturbations were observed in two of the creeks.

Sediment depth measurements were performed at 25 m increments prior to the installation of piezometers, and D_{50} values were calculated for sediments at each piezometer. Negative correlations were found for sediment depth versus vertical hydraulic gradient ($p = 0.05$) and for sediment depth versus D_{50} ($p = 0.001$). Longitudinal profile surveying of each creek allowed for a comparison of D_{50} versus streambed slope, for which a positive correlation was found ($p = 0.028$). Water chemistry samples taken at repeat 25 m sampling points were found to have elevated Ca^{2+} concentrations at probable areas of groundwater upwelling. Stream water had elevated nitrate concentrations upstream of debris jams. In several instances nitrate diminished by as much as 50% immediately below large woody debris jams and NH_4^+ concentrations tended to be highest where nitrate was low.

Overall, the results of this research provide information on the factors that influence surface and groundwater interaction and the degree to which they vary based on surface changes in geomorphology. Large woody debris jams were found to be most influential in creating surface/sub-surface exchange processes. The results highlight the need for stream restoration projects to include debris jams and coarse woody material in restored headwater systems. Increased interaction between surface and groundwater systems will result in natural filtration and bioremediation processes, which will be beneficial for downstream water quality and the millions of people and animals that depend on clean drinking water.