Seasonal Variation and Land Use Effects on C-Q Behavior in the Shaver's Creek Watershed

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Abstract

In order to understand natural and man-made affects on an entire watershed, variables must be analyzed individually in order to control for them. Seasonal and land effects are two important baseline variables to control for, since they are fairly predictable and inter-related. This study seeks to provide some answers to two main questions: what affect does climate and land use have on Shaver's Creek watershed in central Pennsylvania? And how does the solute chemistry respond to these affects?

Introduction

In order to understand how ions move in a system, hydrologists use C-Q plots to graph concentration of ions (C) in solution versus stream discharge (Q). These relationships can be crucial in understanding weathering effects of a system versus input from a secondary source (human influence).

In general, concentrations of ions have a negative correlation in non-buffering instances and decrease with increasing discharge due to dilution. In buffered streams, the concentration remains constant or nearly constant with increasing discharge. Modeling these instances yields ideal slopes of negative one for dilution and zero for buffering, but in nature there is often a mixture of the two and slopes will fall somewhere between negative one and zero. In rare instances, there is a direct relationship between concentration and discharge and graphical representation of this relationship yields a positive slope. These instances are the opposite of what is expected in hydraulic systems and are often caused by secondary interactions between the stream and the surrounding lithology. These sites are particularly interesting because they pose an unique dilemma to the expected C-Q relationship (Godsey et al., 2009).

Sampling Sites

In order to gain a more complete understanding of the watershed, four distinct sites were chosen because of the lithology of the bedrock as well as the differing land cover.

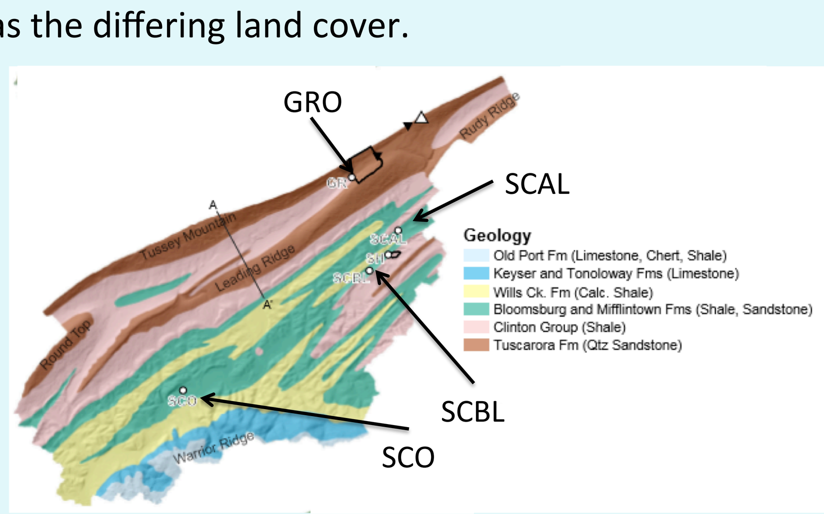

Figure 1: Lithology of Shaver's Creek (Dibiase 2015)

Fig 1: GRO lies on sandstone, SCAL and SCBL on mixed shale and sandstone, and SCO on shale.

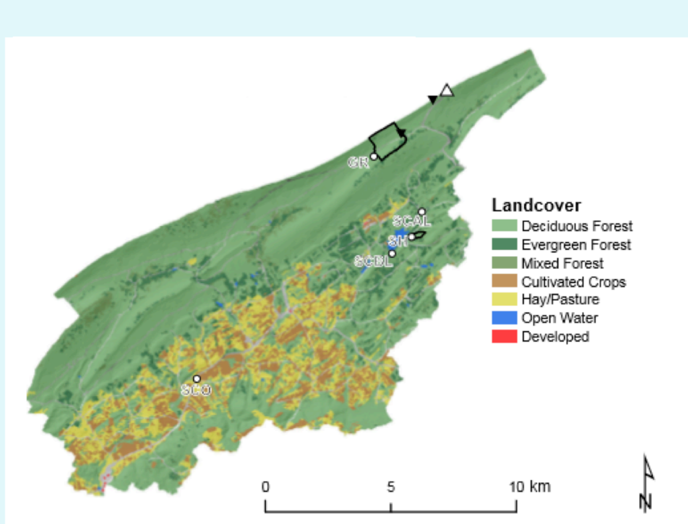

Figure 2: Land cover in Shaver's Creek Watershed (Dibiase 2015)

Fig 2: Garner Run and lake sites found on mixed forests. Outlet site in agricultural area. In 2014 Lake Perez was dry. Summer 2015 lake is full.

The four sites: Garner Run Outlet (GRO), Shaver's Creek Above the Lake (SCAL), Shaver's Creek Below the Lake (SCBL), Shaver's Creek Outlet (SCO).


GRO (above), SCBL (below) SCAL (above), SCO (below)


Methods

- Bulk samples collected and titrated within 24 hours of collection.
- Field data collected on YSI: pH, ORP, water temperature, pressure, DO, and conductivity.
- DOC samples collected in field. Filtered through 0.45 micron filters, acidified with 2N HCl, and analyzed on a Shimadzu TOC-Analyzer.
- Two samples for cation and anion analysis filtered from bulk sample in lab through 0.45 micron filters. Cation samples acidified with 2N HCl.
- Dionex ICS2500 used for anion analysis, Perkin-Elmer Optima 5300 used for cation analysis. Sontek Flow Tracker used for discharge measurements at lower three sites and flume used for Garner run discharge.


Pictured above(left): Auto titrator and lab pH probes used to calculate alkalinity in bulk samples. Picture above (right): RET and REU participants sample reach in Garner Run.

Seasonal Variation Results

If climate had no affect on alkalinity, each site would remain the same over the course of the whole year. However, figure 3 shows this is not the case. In general, the four sites increase in alkalinity during the summer and decrease in the winter. This trend is most likely due to precipitation. During high precipitation months (winter) the alkalinity decreases as water is diluted. During low precipitation months (summer) the alkalinity increases as water levels decrease.

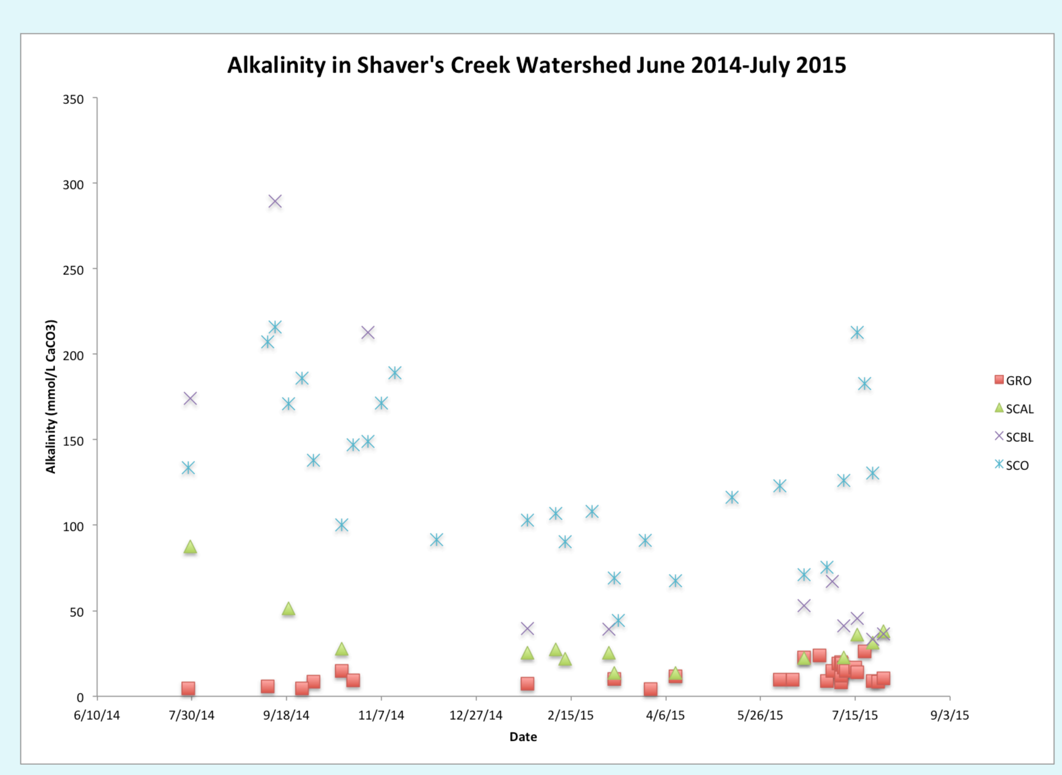

Figure 3: Alkalinity in Shaver's Creek Watershed June 2014-July 2015

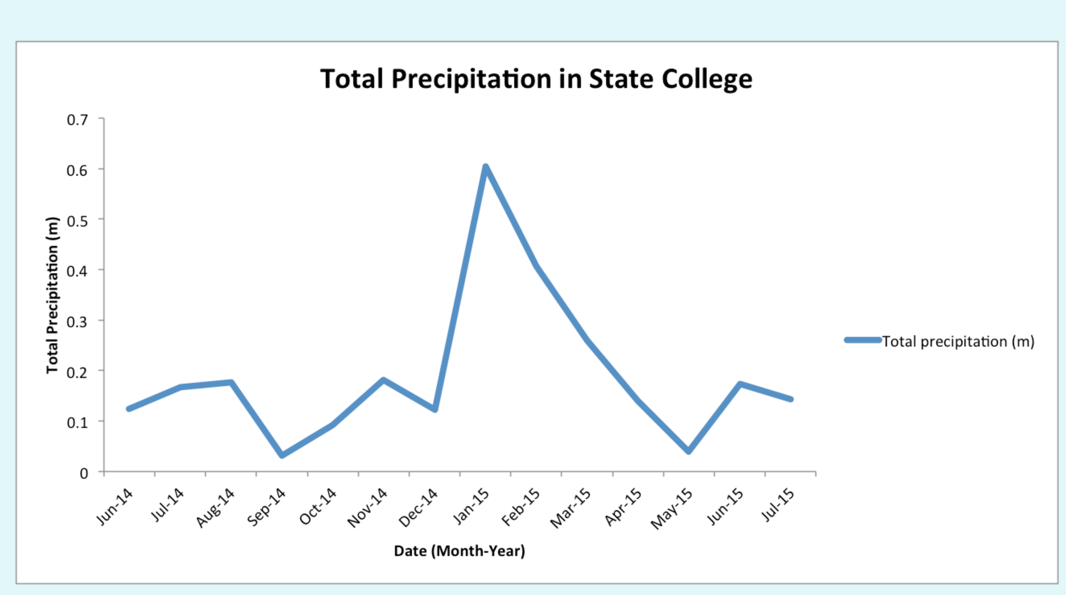

Figure 4: Total Precipitation in State College June 2014-July 2015

Additionally, if climate remained the same from year to year, the same peaks in alkalinity would be seen from season to season. Though this exact trend is not seen (Figure 4) a similar trend from season to season is observed. Precipitation in June 2015 was slightly higher than in 2014. This accounts for the slightly lower alkalinity in the summer 2015 sites than in the previous year. Additionally, Lake Perez was dry in 2014 due to dam repairs and re-filling, which caused a significantly lower flow at the below the lake site than usual and a significantly higher alkalinity reading than this summer.

Land Use Results

Garner Run is a first-order stream fed by groundwater consistently lower in calcium (Ca^{2+}) than surface water. The other three sites are fed by tributaries. This natural dilution of calcium ions at Garner Run could explain why it is half a log unit to a full log unit lower in concentration than at the other three sites.

As predicted, the lower three sites exhibit dilution of calcium with increasing discharge. Garner Run, however, exhibits the opposite pattern of enrichment with increasing discharge. Surface runoff could cause this trend: increased precipitation causes increased runoff that dissolves more ions from soil and surrounding bedrock. The ions are introduced to the stream during these events in large quantities and cause the trend seen at Garner Run. While this would not make sense in an area underlain by sandstone, we hypothesize there could be residual shale deposits in the area. The shallow groundwater over time could be expanding the hyporheic zone, causing an increase in cation exchange with subsurface clays. This exchanging could occur on rainfall event time-scales, which would explain the increase in calcium seen in Garner Run.

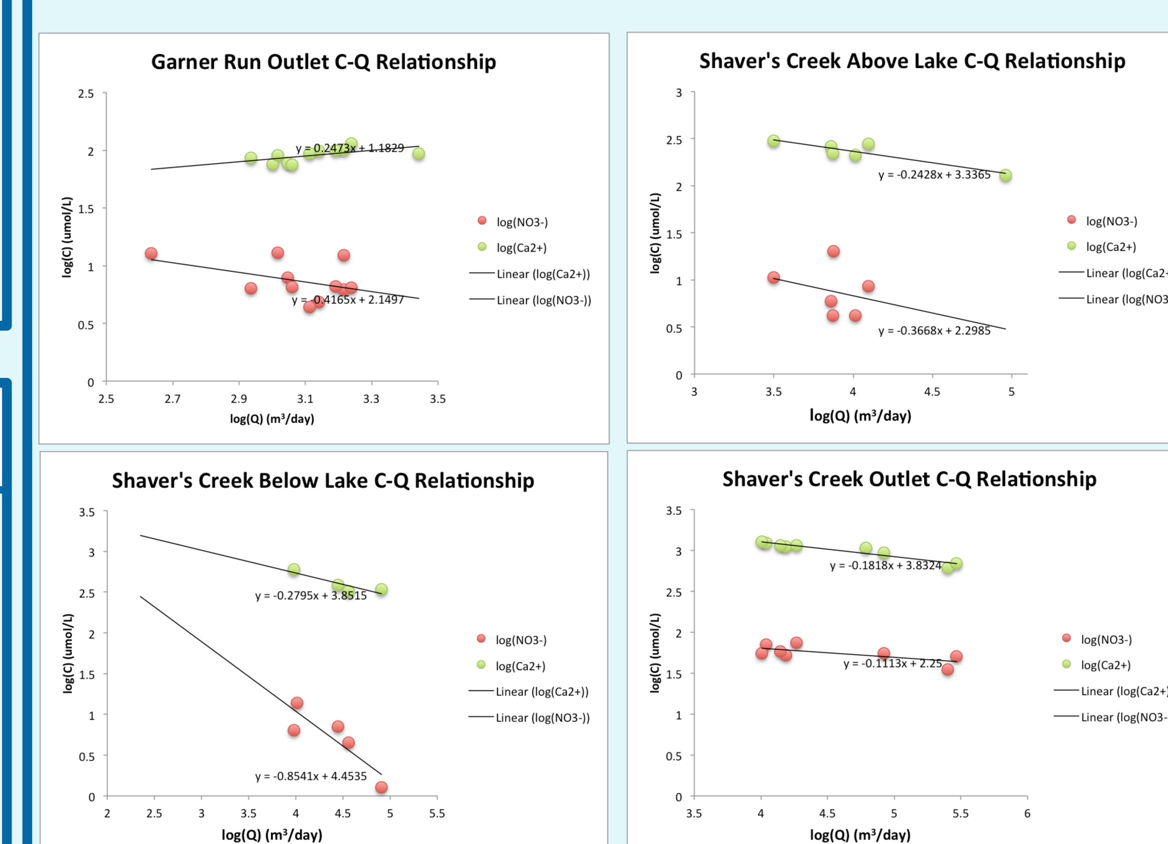

Figure 5: Shaver's Creek watershed C-Q plots by site

Throughout the watershed the concentration of nitrate (NO_3^-) follows the dilution trend and decreases with increasing discharge. However, the average concentration of nitrate is about half a log unit higher at the outlet than at the other sites, which remain, in general, around 10^1 umol/L. The upper three sites are in forested areas where nitrate ions are, predictably, from runoff and organic cycling in the area. At SCO the land use is predominately agriculture (corn) and pasture. Runoff from these farms carries fertilizer and cow manure into the stream which could be a cause of the elevated nitrate levels.

Conclusion

Understanding how climate and land use affect a watershed is an important first step in the ultimate goal of a complete understanding of Shaver's Creek watershed. The preliminary conclusions found in this poster show a direct relationship between alkalinity and precipitation and highlight areas in C-Q relationships that can be studies further. The next step is to continue to study the lithology of Garner Run and its interactions with the stream outlet.

Further study must include modeling in order to truly understand the complexities of the watershed. Future work must also include collecting more and more consistent data from all sites in order to understand how water moves through Shaver's Creek.

References

Godsey SE, Kirchner JW, Clow DW., (2009). Concentration-discharge relationships reflect chemostatic characteristics of US catchments. Hydrological processes (23, p. 1844 - 1864).
Lithology and Land use maps provided by Roman DiBiase 2015
Precipitation data provided by NOAA.

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