Hydrology and aqueous geochemistry of Baker Woodlands, Lancaster, Pennsylvania

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INTRODUCTION

The Baker Woodlands Environmental Research Site in Lancaster, Pennsylvania is comprised of 60 acres of forest, fields, streams and wetlands. The site is underlain by the Conestoga Formation, a deformed clay-bearing Cambrian limestone. The local soils and sediments consist primarily of clay, left behind as the limestone bedrock weathers. This clay was mined and fired by a brick factory located on the site between 1920 and 1980. The clay pits were used as landfills from the early 1950's until the early 1960s (de Wet et al., 1999).

The Baker Woodlands is one of the few urban wooded areas remaining in Lancaster County. The hydrology and water chemistry of the site is important in gaining an understanding of how land use and planning in an urban area impacts the surrounding earth systems.

The streams and wetlands in the site flow into the adjacent Little Conestoga Creek. The Little Conestoga Creek is a tributary of the Conestoga River, which is in turn a tributary of the Susquehanna River, the largest freshwater contributor to the upper Chesapeake Bay. A knowledge and understanding of the characteristics of the Susquehanna River are vital to maintaining water quality and ecosystem health (Lindsey et al., 1998). The goal of the study was, therefore, to describe the hydrology and aqueous geochemistry of the site, a small portion of the larger Susquehanna River Watershed.

METHODS

Hydrology. The original objective was to determine the hydrologic budget of the Baker Woodlands. Hydrologic monitoring equipment and a data logger were installed to collect and record data. This equipment had previously been installed in 1998 by Franklin and Marshall College student Kevin Keller as part of his senior thesis. However, much of this equipment was subsequently vandalized and remained unusable until June 1999. Therefore, much of our initial work consisted of re-installing vandalized equipment and installing new equipment. To prevent future acts of vandalism, enclosures were constructed for unprotected equipment.

To measure the surface discharge, two weirs were installed. A previously installed weir in the channel flowing from the wetland into the Little Conestoga Creek was too small to handle the discharge during periods of heavy rain and floods. It was removed and re-installed in the stream that feeds the wetland. A larger weir was then designed and installed in the channel. Staff gauges were secured upstream from each weir to measure water level. Using this data and the known proportions of the weir, discharge can be calculated (Sanders, 1998).

To determine the discharge of the Little Conestoga Creek, a cross section of the creek and floodplain was drawn using data obtained with a Topcon AT-G2 auto level. An MJP Geopacks Flometer 1 was used to measure the flow velocity at half meter intervals. Discharge was then calculated using the velocity data and cross-section dimensions.

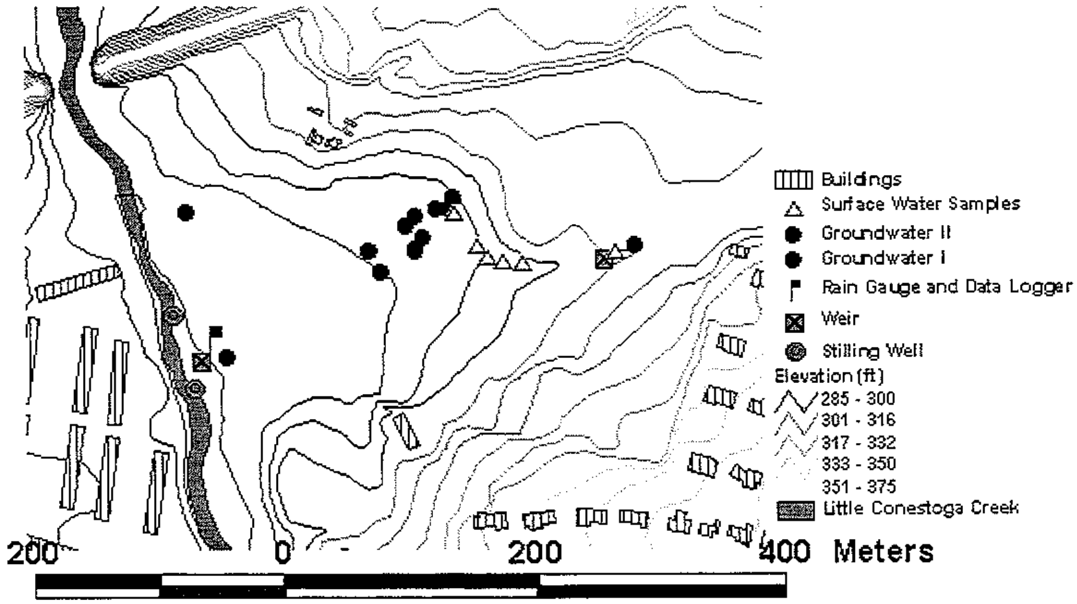

Figure 1: Portion of Baker Woodlands site showing locations of samples taken and equipment installed.

A Druck PDCR 1230-8389 pressure transducer, connected to a Campbell CR10 data logger, was installed in the downstream stilling well along the Little Conestoga Creek (Figure 1). This stilling well is directly below the point at which the channel from the wetland meets the Creek. The other stilling well, currently unusable, is upstream from that point. The object of placing the wells upstream and downstream from the channel is to measure the effects of the site drainage on the creek. A Texas Electronics TE525 tipping bucket rain gauge and a groundwater well were also installed on the site and connected to the datalogger. Data from the datalogger is downloaded and viewed in a computer spreadsheet.

Aqueous geochemistry. The surface water and groundwater at the site were analyzed for major cations, nutrients, and alkalinity in order to correlate these values with local geology and land use. Nine surface water samples were taken: six from the stream flowing into the wetland, and three from points on the Little Conestoga Creek: above, at, and below the outlet from the wetlands. These samples are labeled PKW-2000 through PKW-2008; PKW-2006 though PKW-2008 being samples from the Little Conestoga Creek. Twelve groundwater samples, labeled PKGW-2000 through PKGW-2010, were taken from holes left at sediment core sampling sites PKC-1500 through PKC-1510 (excluding PKGW-2008/PKC-1508). Groundwater samples PKGW-2011 and PKGW-2012 were taken from holes drilled with a hand auger. Temperature, pH, and total dissolved solids values were taken in the field.

Samples were analyzed for Ca^{2+}, Na^{+}, and K^{+} using an Atomic Absorption Spectrometer. An average of three emission readings was taken for each sample . Mg^{2+} concentration was analyzed using an Inductively Coupled Plasma Atomic Emission Spectrometer (ICP) . Other metals detected by the ICP were present in concentrations too low to yield accurate results.

Nitrate and phosphate concentrations were determined by using the reagents NitraVer and PhosVer with a Spectronic 20D spectrophotometer. The alkalinity of each sample, interpreted as mg/L of $CaCO_3$, was determined by acidifying the samples with sulfuric acid, and then back-titrating with NaOH past the endpoint of pH 8.2, using a pH meter as an indicator. The volume of NaOH used to reach the equivalence point for each sample was determined using a Gran Function plot. This was converted to the acidity of the sample, or mg/L of $CaCO_3$ that would be needed to neutralize the acid in the sample. The negative value of each acidity value gave the alkalinity of the samples.

RESULTS

Hydrology. Equipment necessary to collect data for the calculation of the hydrologic budget is installed and functioning. The lack of adequate rainfall during the month of study at the site however, limited the amount of data collected. A topographic cross-section of the Little Conestoga Creek was produced at the downstream stilling well. Precipitation data was collected for two weeks using the data logger. Groundwater levels were also monitored, although data was not collected.

Aqueous Geochemistry. Nitrate analysis yielded values ranging from a groundwater average of 2.3 ppm to an average of 5.0 ppm in the Little Conestoga Creek. The average surface water nitrate value for the site was 4.2 ppm. All of these values are below the drinking water standard of 10 ppm (Loper, 1998). The results of the phosphate analysis suggested that the Spectronic 20D used was not precise enough to read the very low (0 - 0.2 ppm) concentrations probably present.

General increasing or decreasing trends are suggested by the surface water major cation results (Fig. 2). Ca^{2+} concentration tends to decrease from east to west towards the Little Conestoga Creek. Mg^{2+}, K^{+}, and Na^{+} concentrations however, increase with proximity to the Creek. Calcium is the dominant cation, with milliequivalent concentrations 3 to 7 times more than magnesium. Of particular interest is the alkalinity as $CaCO_3$, determined by titration. When compared to Ca^{2+} concentrations in milliequivalents, it can be seen that the cation/anion ratio is greater than 1. Conversely, Mg^{2+} concentrations result in a cation/anion ratio of less than 1.

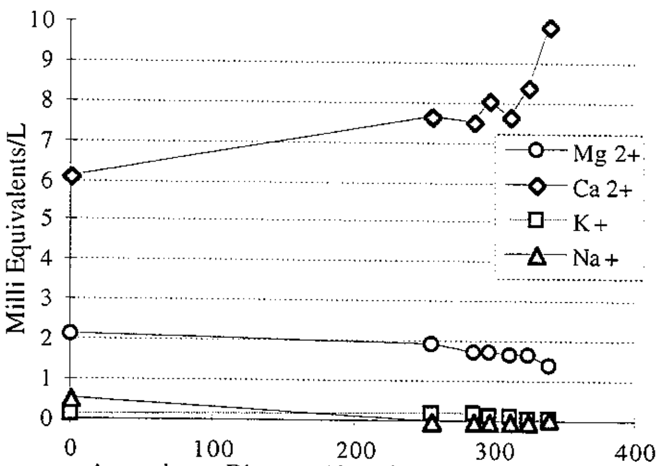

Figure 2. Cation concentrations in surface water.

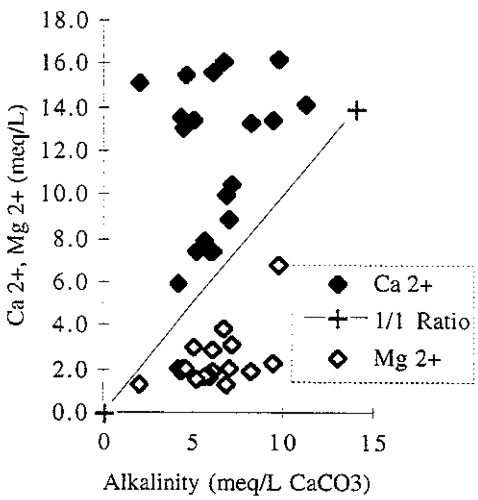

Figure 3. Ca^{2+} and Mg^{2+} versus alkalinity as $CaCO_3$. This data suggest a Ca^{2+}/CO_3^{2-} ratio greater than 1 and a Mg^{2+}/CO_3^{2-} ratio less than 1.

DISCUSSION

Hydrology. At the completion of the 1999 Keck summer project, too little data was collected from the hydrology equipment to warrant analysis. Future research will be conducted with the equipment installed and data collected during this project. This research will entail data collection, the production of hydrographs for the stream, channel, and creek, an analysis of baseflow recession and other discharge patterns, and finding a correlation with rainfall. Evapotranspiration values can be obtained from weather stations in the area. With precipitation, stream discharge, and evapotranspiration data, an approximate groundwater flow value can eventually be determined.

Aqueous Geochemistry. Since the bedrock at the site is predominately limestone, the elevated calcium and magnesium concentrations are of particular interest. Ca^{2+} concentration in all of the samples was greater than their respective alkalinity values (Fig. 3). A Ca^{2+} concentration equal to the alkalinity would indicate that all of the calcium had come from the dissolution of the calcium carbonate bedrock. However, since there is a higher concentration of Ca^{2+} ions in the water than alkalinity levels as indicated by $CaCO_3$, some of this calcium must have come from a source other than the limestone bedrock. While the site lies on Conestoga Limestone, it is also adjacent to the dolomitic Ledger Formation and the shale-rich Kinzers Formation. The shale of the Kinzers Formation may be contributing some of the calcium at the site although most is probably sourced from the underlying Conestoga Formation. While not as concentrated as the calcium levels, the magnesium found in the water is still considerable, and may come in part from the dolomite of the Ledger Formation.

The landfill also may contribute to the Ca^{2+} and Mg^{2+} concentration levels. When the landfill was abandoned, it was covered with a layer of crushed and compacted dolomite and limestone varying between 10 cm and 1 m in thickness. The Pennsylvania Keck 1999 geophysics group analyzed the contents of the landfill using X-ray fluorescence methods and found magnesium concentrations in the crushed layer of about 9 wt.%. Correspondingly, the magnesium concentrations in the stream increase as the stream runs along the length of the landfill and peak at the beginning of the wetland area. Magnesium levels in the wetland groundwater between the stream and the creek then decrease towards the Little Conestoga Creek, away from the landfill. In addition, using the XRF we detected about 40 to 60 wt. % calcium in samples taken from the crushed layer of the landfill.

Sodium and potassium are present in very small concentrations (Fig. 2). The clay that overlies the limestone may contribute some of the sodium and potassium, but monovalent elements such as sodium and potassium tend to adhere to negativity-charged clay particles, and therefore do not dissolve in the water, the concentrations of these two cations in the water should be low. Trace amounts of sodium and potassium may also be coming from other nearby formations, such as the Kinzers Formation. Unfortunately, thin sections or detailed petrologic analyses of these units were not available, so their composition and elemental contribution cannot be determined exactly.

Nitrate concentration is highest in the Little Conestoga Creek, as expected. The Creek's watershed includes many farms which create nitrate runoff from fertilizers (Loper, 1998). Along the stream, the nitrate concentration is highest near the east side of the site, which is bordered by Franklin and Marshall College's sports fields. Nitrate may enter the stream here as fertilizer runoff from the sports fields. The decrease in concentration with distance from the sports fields may be due to a combination of the consumption of nitrates by plants in and around the stream and a dilution effect from groundwater entering the stream.

CONCLUSIONS

Hydrologic budget conclusions are difficult to draw, because the monitoring equipment has not been collecting data long enough for a meaningful evaluation. More data will be collected and analyzed during future research by the Department of Geosciences at Franklin and Marshall College.

Concentrations of the species analyzed for are not dangerously high in any samples. High concentrations of calcium and magnesium may be present because of the limestone, dolomite, and shale bedrock at or near the site. The crushed limestone and dolomite on the surface of the landfill may also cause high calcium and magnesium concentrations. Sodium and potassium are present only in very low concentrations. Nitrate concentrations reflect the land use characteristics of the Little Conestoga Creek watershed. Phosphate concentrations were too low to accurately determine with the equipment available. Future studies may analyze for other major anions such as sulfate and chloride, and install groundwater wells to determine the shape and behavior of the water table.

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