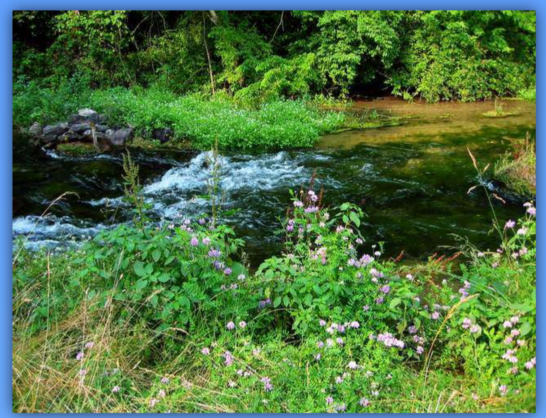
Determination of source waters and flow paths to limestone springs in Cumberland County, Pennsylvania with fluorescent dye tracing



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INTRODUCTION

Pennsylvania spring creeks are rich in ecological, recreational, consumptive, and historical value, and are derived from karst (limestone) groundwater flows that are poorly understood, and subjected to rapid infiltration of agricultural ,industrial, and other anthropogenic contaminants. Big Spring and other spring creeks discharge from the carbonate aquifer of the Cumberland Valley, with similarly uncertain contributing areas and flowpaths that can occur from outside topographical watershed divides. Larger spring creeks of the region include Big Spring, Green Spring and Bullshead Branch, Mt. Rock, and Cool Spring (Newville water supply) associated with Big Spring. Based on demonstrated conduit flow from outside the surface watershed of Big Spring (Brookhart 2007), it is clear that agricultural runoff, insufficient sewage or septic treatment, trucking infrastructure, limestone quarrying, and other industry can rapidly degrade quality of the springs and the groundwater that feeds them. Once true contributing areas are determined, water quality can be protected by managing points of rapidly infiltrating surface runoff (e.g. sinkhole collapses) to minimize influx of nutrients and contaminants. The only accurate and definitive method for such determination in limestone geology (karst) is to conduct a hydrologic trace test with fluorescent dyes (Käss 1998), as groundwater flow in karst occurs through unpredictable, or unmapped features such as fractures, caves, or bedding planes, often inconsistent with surface topography (Otz et al. 2003).

The objective of this study is to investigate source areas for spring creek systems.
Field reconnaissance has revealed several points of interest for hydrologic dye deployment. These locations include sink hole locations at Ott, Cramer, and Smith Rds. and a sinking reach of Burd Run (Middle Spring Watershed) near Cleversburg.

Past dye trace results have proven a connection between the Cramer Rd. location and Big Spring (Figure 6) and between the Yellow Breeches Creek in Walnut Bottom and Huntsdale hatchery springs. We are seeking to further delineate contributing areas on the premise that groundwater flow is occurring along geologic strike of the valley's carbonate rock formations.

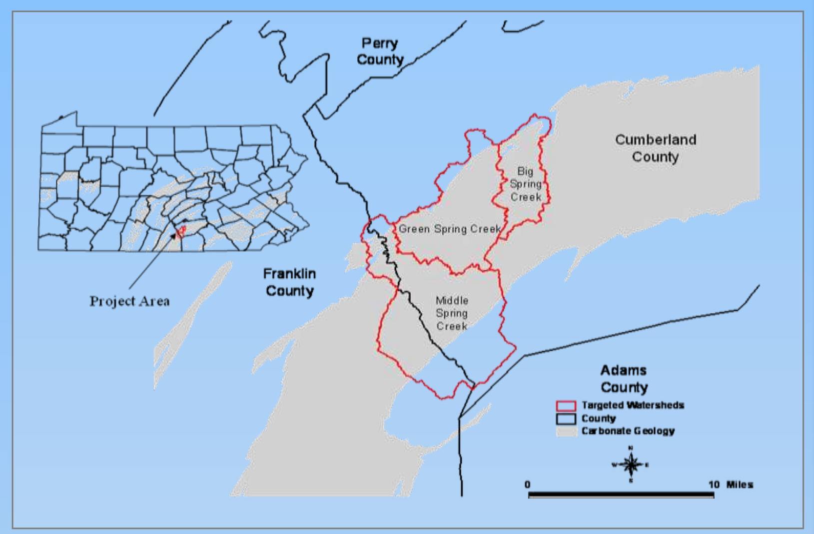

Figure 1 –surface watersheds in Western Cumberland County, Pennsylvania. For Big Spring, surface watershed area only explains a small percentage of discharge (10-20% Map – C. McGarrell, PAFBC)

METHODS

We used the fluorescent tracers uranine (URA), and sodium naphthionate (NAP). These tracers have been proven non-ecotoxic for freshwater invertebrates and vertebrates, and non-genotoxic for vertebrates (Behrens et al. 2001). Release occurred following public notification of the surrounding communities in the evening of March 26, 2009. We took water samples via an autosampler or grab sampling, keeping samples cold and dark until analysis. Charcoal receptor bags were also deployed and interchanged weekly at sample springs. Samples were analyzed by a Perkin-Elmer LS-3B Fluorescence Spectrometer with excitation/emission of 491/512 nm for URA in water, 491/517 nm for URA in eluted charcoal, and 320/420 nm for NAP in water. Potential positives were further analyzed to determine peak emission wavelength (Figure 2). In a related study, we are also characterizing complete background fluorescence of infiltrating runoff and sample springs, to determine quantities of specific dyes to use, and to detect organic freight (e.g. animal and human waste and possibly industrial hydrocarbons) of carbonate waters.

Sampling springs included west and east sources of Big Spring, Cool Spring (municipal supply of Newville, PA associated with Big Spring Creek), Green Spring, Bullshead Branch of Green Spring, and Mt. Rock Spring (Figure 6). Additionally, contributing springs of Burd Run in Shippensburg and Yellow Breeches Creek below Walnut Bottom were sampled.

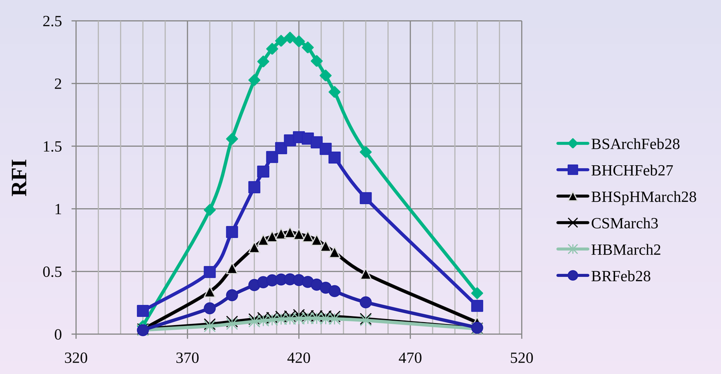

Figure 2 – Peak fluorescence analysis for positive or potentially positive dye detection (e.g. NAP emission at 420 nm)

RESULTS

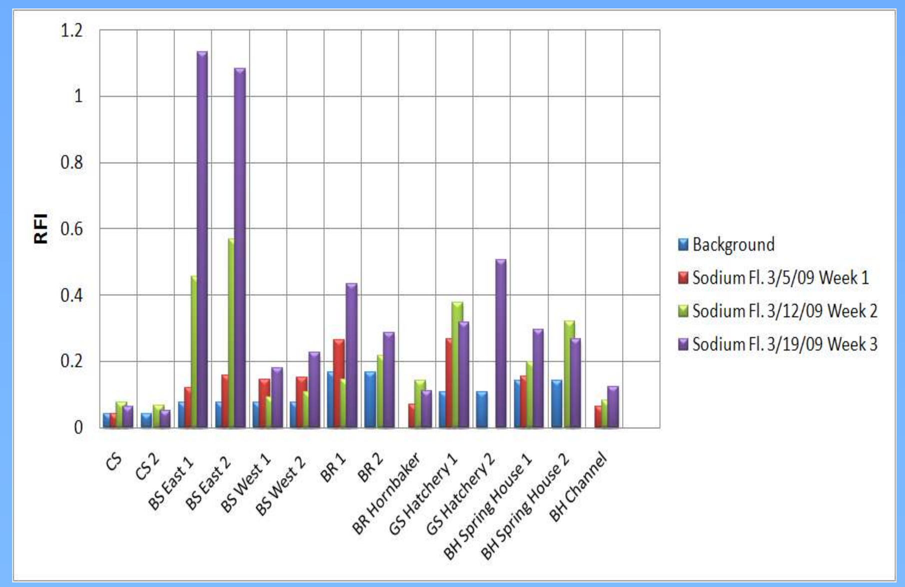

Figure 3 – Detection of uranine (sodium fluorescein) on charcoal receptors in the east source spring of Big Spring Creek. RFI – relative fluorescence intensity in eluted charcoal samples. Breakthrough occurred within 2 weeks of release into Thompson Creek (Middle Spring surface watershed).

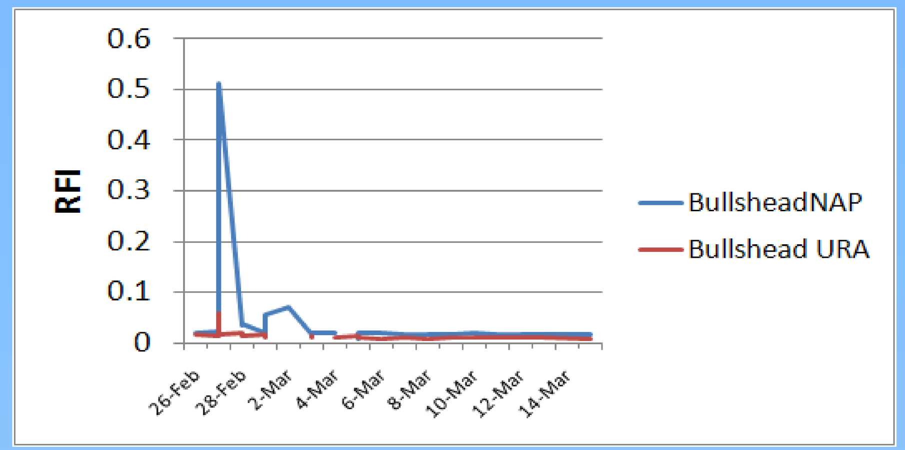

Figure 4– NAP breakthrough in Bullshead Branch within 1 Day of release from Ott Road sinking stream (Bullshead/Green Spring surface watershed).

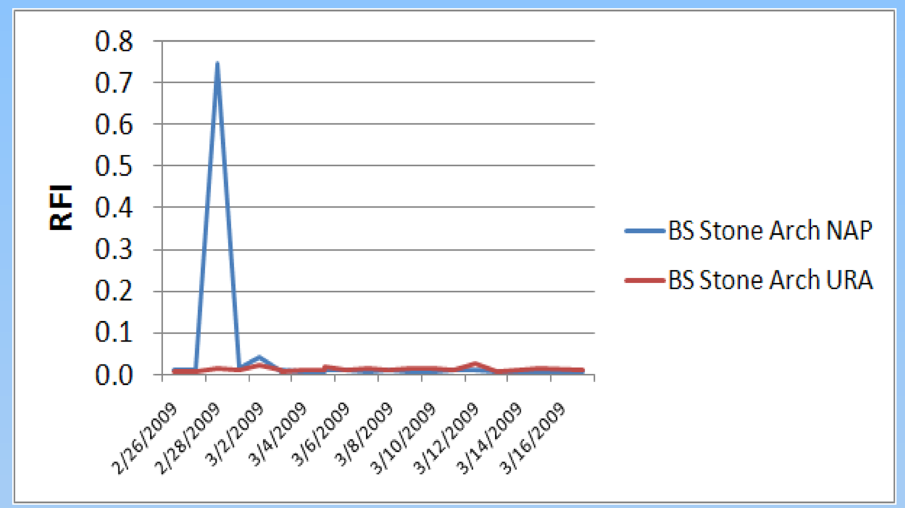

Figure 5– NAP breakthrough in lower Big Spring Creek within 2 days of release from Ott Road sinking stream (Bullshead/Green Spring surface watershed). NAP breakthrough was not detected upstream of this sample reach.

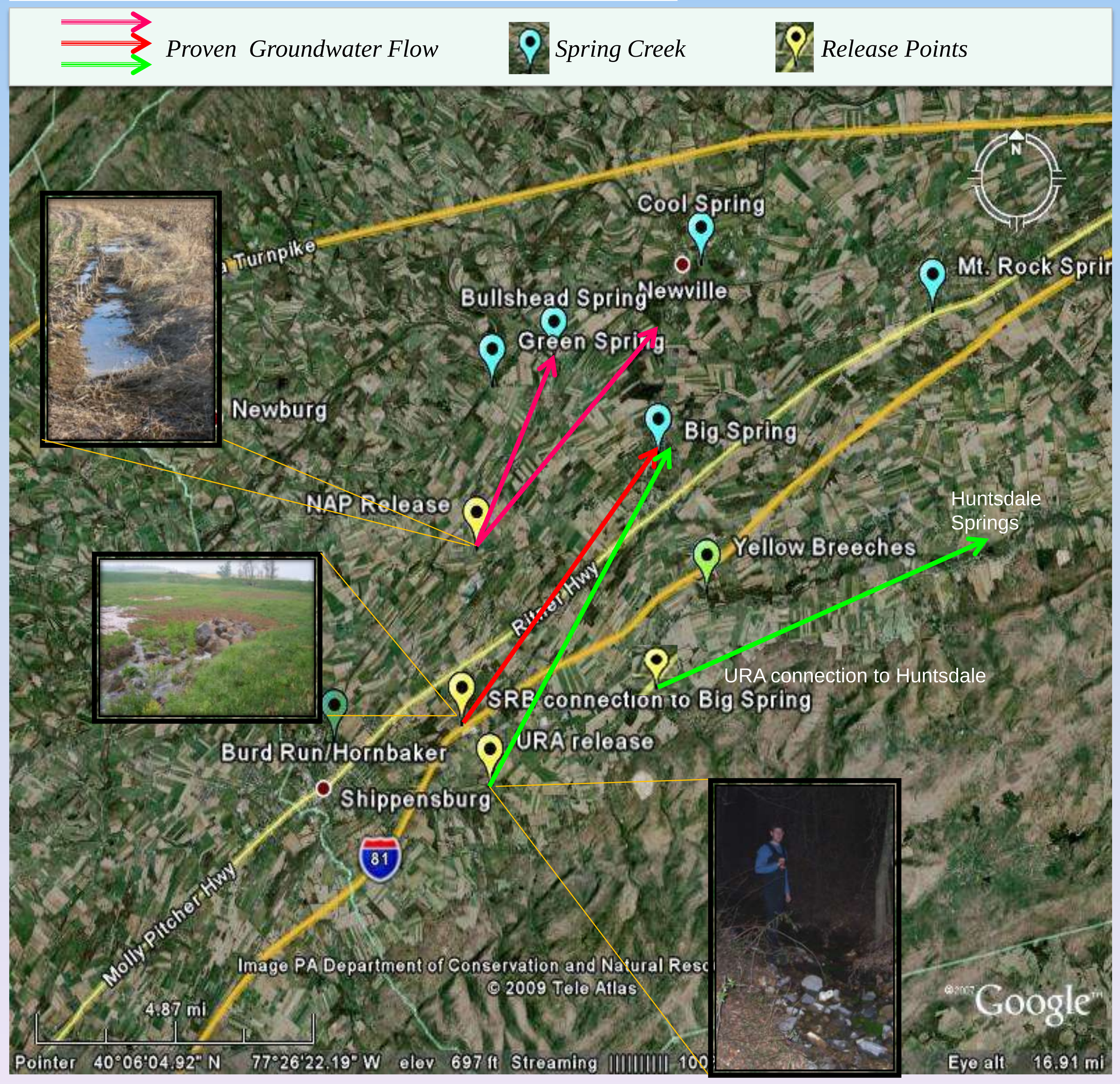

Figure 6 – Study springs, dye release locations, and proven connections in Western Cumberland County ***URA release*** *- Thompson Creek near Cleversburg.* ***NAP release*** *is a sinking stream draining ag and possibly quarry runoff.* ***SRB connection to Big Spring and URA to Huntsdale*** *from Brookhart (2007).*

Conclusions

Big Spring source springs are fed by largely separate parallel subterranean flow systems that originate in other surface topographical basins (Middle Spring and Green Spring Basins) and follow geological strike more than mapped groundwater contours (Figure 6, 7). Meaningful source area protection of limestone spring tributaries and downstream surface waters must take into account such regional flow patterns and protection of critical recharge zones (karst features such as sinkhole collapses and sinking streams). This is particularly so for karst features associated with intensive land use in the valley center that rapidly contribute nutrients, sediment, and other contaminants to spring creeks via conduit flow.

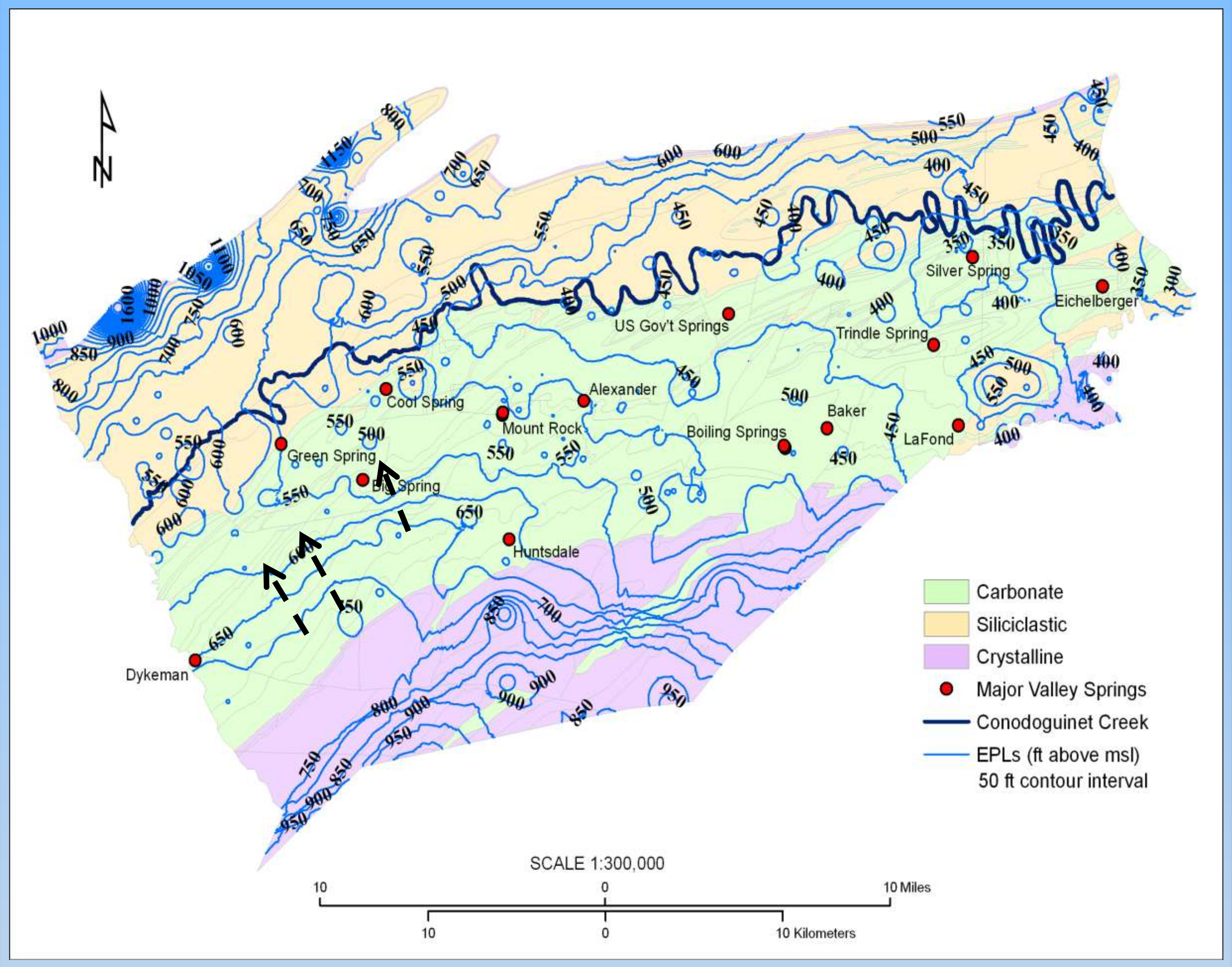

Figure 7 - Groundwater contours with potential groundwater flow perpendicular to contours in western Cumberland County (dashed arrows). Contrast with proven flow paths in Figure 6. GIS data from Pennsylvania Geological Survey 2001, 2008

ACKNOWLEDGMENTS

This research was funded by a Shippensburg University Undergraduate Research grant to D. Miller and M. Kalambo, a Center for Land Use Grant to T. M. Hurd, and by Big Spring Watershed Association. We also thank Hugh Lewis for help sampling, and private landowners and Southampton Township for assistance in accessing release and sampling points.

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