Dye Trace Report on Campbell Valley Creek

Houston and Winona Counties, Minnesota
2012-2013

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Introduction

The karst lands of southeast Minnesota contain more than one hundred trout streams that receive perennial discharge from Paleozoic bedrock springs. Several of the Paleozoic bedrock units that provide discharge are karst aquifers. Field investigations into the flow characteristics of these formations have been conducted using fluorescent dyes to map groundwater springsheds and characterize groundwater flow velocities for use in water resource protection. Campbell Valley Creek is one of these designated trout streams. The creek is located roughly 64 kilometers (40 mi.) southeast of Rochester, Minnesota in southern Winona and northern Houston counties (Figure 1). Two dye traces were conducted to add to delineated springsheds of the region as part of the Environmental and Natural Resources Trust Fund (ENRTF) Springshed Mapping project.

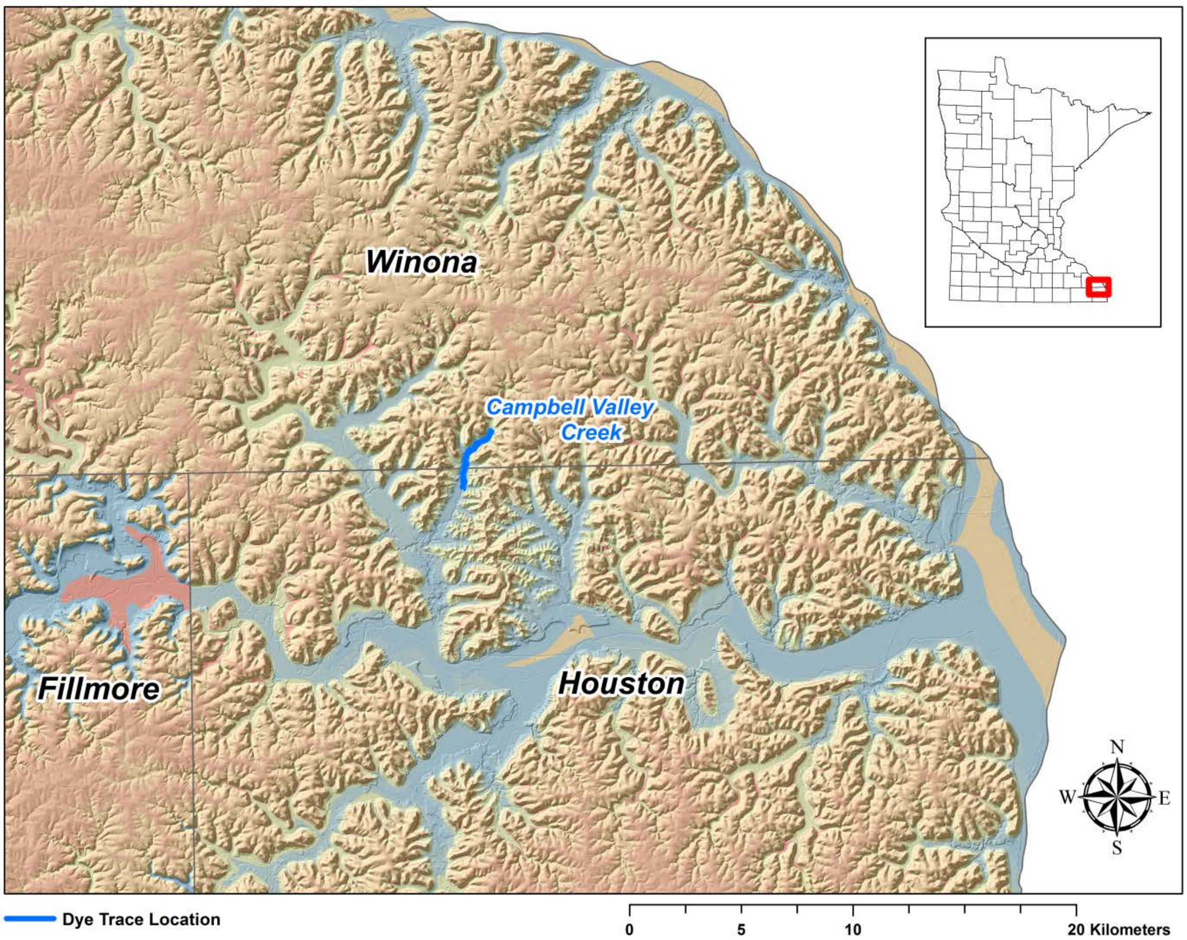

Figure 1. Regional geologic setting of Paleozoic rocks in southeast Minnesota and the location of the dye traces presented in this report. Ordovician units are depicted with brownish-orange hues. Lower Cambrian units are depicted with gray, blue, and light brown hues. Geologic map from Runkel et al., 2013.

In Houston and Winona counties, bedrock units from the Upper Cambrian through the Upper Ordovician are generally within 15 meters of the land surface and are capped by unconsolidated sediments such as loess, sand, and colluvium (Steenberg, 2014ab; Lusardi et al., 2014). The topography is dominated by a broad plateau of resistant dolostone of the Ordovician Prairie du Chien Group (OPDC). A geologic column for Houston County (Figure 2) shows lithostratigraphic and generalized hydrostratigraphic properties for each of the units (Steenberg, 2014a). Hydrostratigraphic attributes have been generalized into either aquifer or aquitard based on their relative permeability. Layers assigned as aquifers are permeable and easily transmit water through porous media, fractures or conduits. Layers assigned aquitard have lower permeability that vertically retards flow, effectively hydraulically separating aquifer layers. However, layers designated as aquitards may contain high permeability bedding plane fractures conductive enough to yield large quantities of water.

The Campbell Valley dye traces document surface water-groundwater interactions, and subterranean flow in hydrostratigraphic units of the Upper Cambrian.

The exact pathways underground cannot be identified or mapped. Thus, travel distances can only be minimum values, calculated from straight line point-to-point measurements.

Undoubtedly, actual underground travel pathways are more circuitous, so real travel distances are longer. The calculated groundwater velocities are therefore only lower limits on the actual flow velocities.

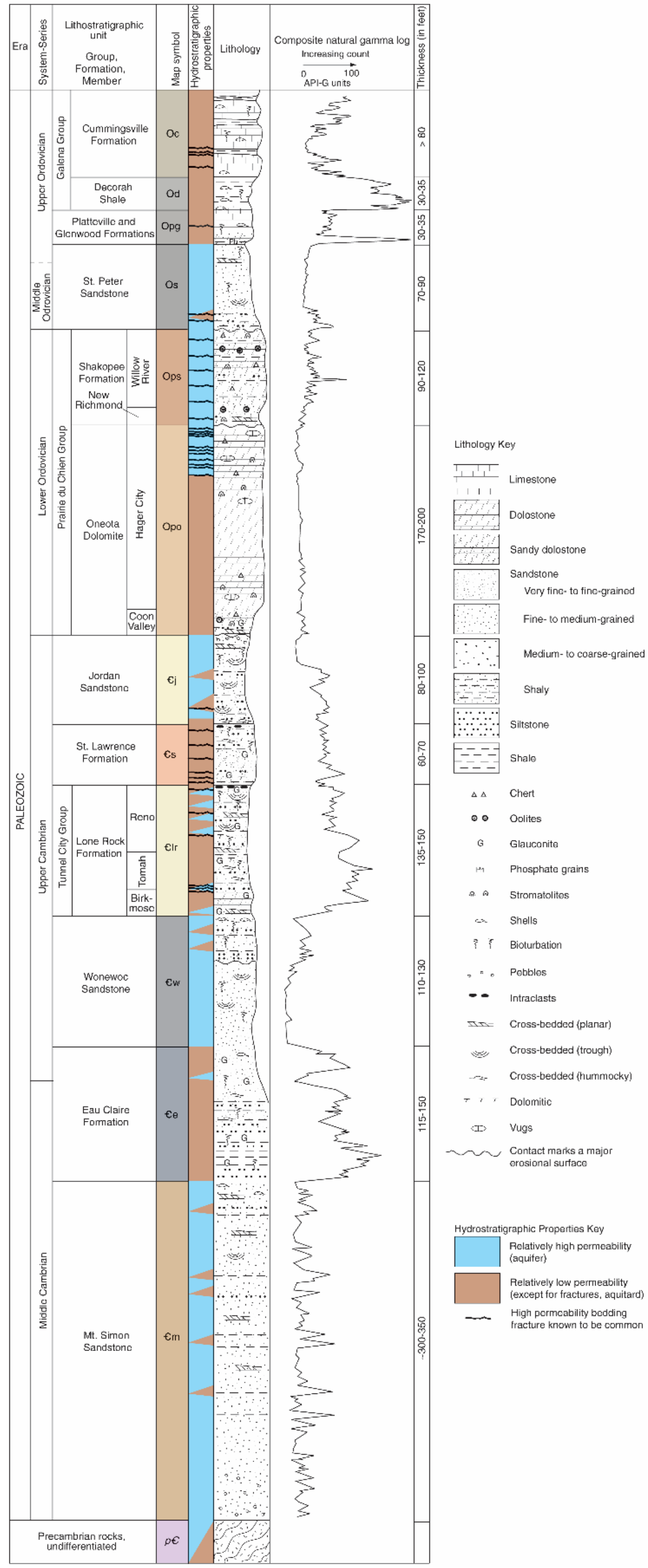

Figure 2. Geologic and hydrogeologic attributes of Paleozoic rocks in southeastern Minnesota. Modified from Steenberg, 2014a.

In the Campbell Valley, the stream starts at a small spring that emanates from the base of the Jordan sandstone. It immediately sinks into the top of the St. Lawrence Formation in stream sink 85B20 (85B20 is a shorthand version of the Karst Features Database (KFDB) ID number for that feature, the full ID number is MN85:B00020). Water resurges at two small perennial St. Lawrence springs, 85A325 and 85A345, which are labeled as Barnhart 1 and 2 after the property owner. These springs are roughly 2200 ft. downstream from the sinking point. Depending on moisture conditions, the stream at times also sinks into the Lone Rock Formation downstream from 85A325 and 85A345. The streamflow is augmented by four lower Lone Rock Formation springs, 85A138, 85A139, 85A140 and 85A141. 85A139 and 85A141 typically have the largest flows among these lower four springs and they also were sampled during these dye traces (Figure 3). Additional monitoring occurred at 85X36, which is at a road crossing over Campbell Valley Creek downstream of 85A139 and 85A141.

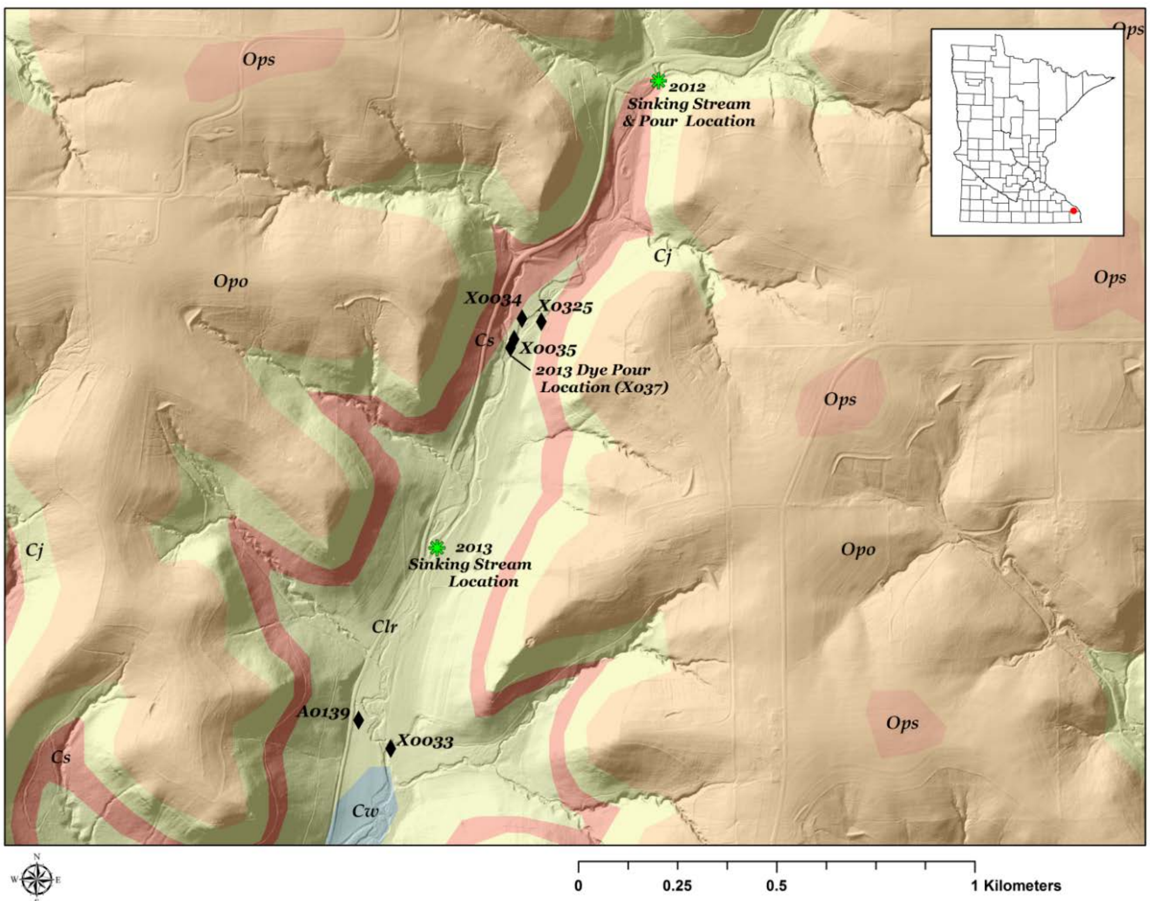

Figure 3. Campbell Valley passive sampling locations (black diamonds) and sinking stream locations (green asterisks). An additional monitoring location was located downstream of those shown in Figure 3, it's KFD number, coordinates, and detection results are available in the summary table (Table 1). The 2013 dye pour location (X037) is also shown with a black diamond. Geologic map from Runkel et al., 2013. See Figure 2 for definition of map symbols.

Methods

Dye tracing entails using fluorescent dyes to track groundwater flow directions and travel times. The dye is poured into a sinking stream or sinkhole; from there it flows through a conduit system until it re-emerges at a spring. Two separate dye traces were conducted in the Campbell Valley.

The first was initiated on 13 November 2012 when Uranine HS dye was poured into stream sink 85B20 which is stratigraphically at the top of the St. Lawrence Formation. Stream discharge at the time was estimated to be about 1-5 gallons per minute. The second trace was initiated on 7 March 2013 when Rhodamine WT dye was poured into the creek downstream of the Barnhart springs so it could flow downstream and sink into stream sink 85:B23, a Lone Rock Formation stream sink. Stream discharge at the time was estimated at 0.3–0.5 cubic feet per second (130-230 gallons per minute).

Dye trace sample packets were placed in selected springs along Campbell Valley Creek. Passive samplers, consisting of charcoal detectors, were used to detect the presence of dye in the water by adsorption onto the charcoal.

The detectors were returned to the University of Minnesota Earth Sciences Department Hydrochemistry Laboratory for analysis. There, the detectors were opened, the charcoal was removed, and the fluorescent materials were extracted, using an eluent solution of 70% isopropyl alcohol, 30% deionized water, and 10g/L NaOH. The eluent solution was analyzed using a Shimadzu RF5000U scanning spectrofluorophotometer to detect and record the emitted wavelengths and amplitudes (spectra) of fluorescent constituents in the water. All fluorescing components, including the dye as well as any naturally-occurring components (i.e., ‘background compounds’ in these waters which fluoresce), were quantified using PeakFit software as described in Alexander (2005). The dye used has a unique spectral signature, which is distinguished from the spectra of the background constituents.

Results and Discussion

Table 1 contains the dye input information, the location information for the sample sites, and the dye detection summary. Figure 4 shows linear connections between the dye input points and where dye resurging from springs was detected. The dye input points and receptor locations for both the 2012 and 2013 traces are shown in Figure 3.

Uranine dye from the 2012 trace was detected at levels high enough for positive identification and confirmation at all sampling sites. This result indicates that the dye emerged from the St. Lawrence Formation springs 85A325 and 85A345. The dye also emerged from the Lone Rock Formation springs 85A139 and 85A141. The dye was detected at the site named Barnhart #3 Downstream, which was in the creek downstream of springs 85A325 and 85A345. Similarly, it was detected at the Campbell Valley Creek bridge at County Road 13 (downstream of all of these springs).

Assuming a straight line distance from the stream sink (MN85:B0020) to springs 85A325 and 85A345, the minimum peak groundwater velocity is roughly 22 meters/day (71 ft./day), but could have been as fast as 84 meters/day (280 ft./day). Assuming a straight line distance from stream sink (MN85:B0020) to springs 85A139 and 85A141, the minimum peak groundwater velocity ranges between 55 and 210 meters/day (180 ft./day-700 ft./day). Despite being located within the lowermost Lone Rock Formation, these velocities are consistent with previous traces in the St. Lawrence and uppermost Lone Rock Formation (Green et al, 2012). Springs 85A139 and 85A141 both emanate from the lower Lone Rock Formation. This is the first trace to demonstrate that St. Lawrence stream sinks are connected to lower Lone Rock springs.

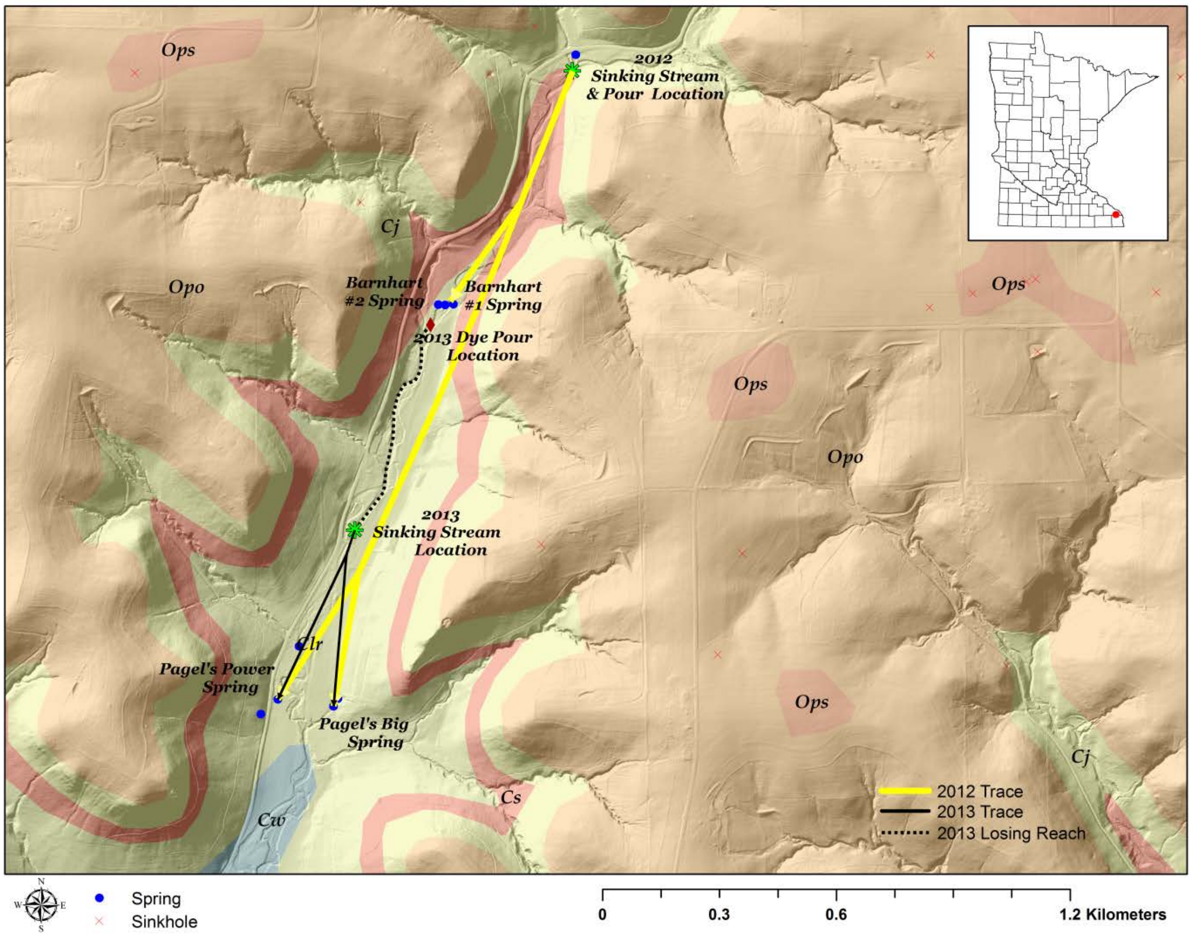

Figure 4. 2012-2013 Campbell Valley Creek site sampling locations and dye flow vectors. Dye flow vectors for the 2012 trace are shown in yellow. Dye flow vectors for the 2013 trace are shown in black. The stream reach between the 2013 dye pour location and the 2013 sinking stream location (green point) may have been a losing reach and is denoted with the dashed line. See Figure 2 for definition of map symbols. (Geologic map from Runkel et al., 2013.)

In the March, 2013 trace, Rhodamine WT dye was introduced into the creek at point 85X37. This site is upstream from the stratigraphically lower sinking stream reach, located within the Lone Rock Formation. Rhodamine WT dye was detected at levels high enough for positive quantification at springs 85A139 and 85A141; minimum peak groundwater velocity to these is roughly 33 meters/ day (110 ft./day), assuming a straight line distance from the sinking stream reach to the springs. The terminal sink on Campbell Valley Creek (represented as 85B23) is ephemeral in its location, but is roughly 1,800 feet (550 meters) downstream of where dye was introduced on March 7, 2013.

These traces demonstrate that water sinking into the St. Lawrence and Lone Rock formations is recharging the local groundwater system and discharging from springs. Figure 5 displays the traced connections and the Campbell Valley Surface Water Springshed (Green and Alexander, 2015). Water that runs off the surface watershed of the upper Campbell Valley contributes to the groundwater recharge in at least two discrete points at the stream sinks. Therefore, land use practices and other human activities in the Campbell Valley Surface Water Springshed can impact groundwater quality in the St. Lawrence and Lone Rock Formations.

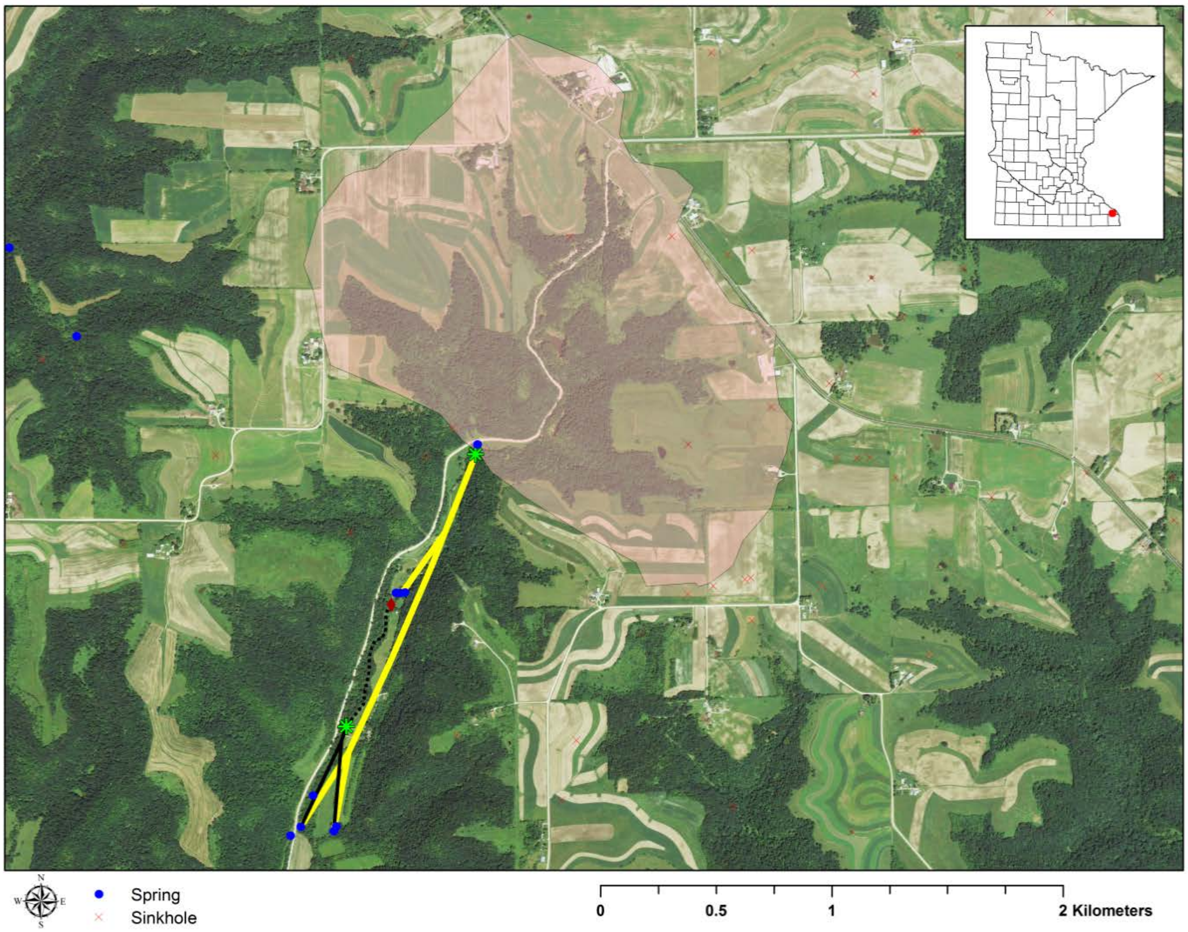

Figure 5. 2012-2013 Campbell Valley Creek site sampling locations, dye flow vectors, and the surface watershed that contributes water to this dynamic hydrologic system. The Campbell Valley Surface Water Springshed, is shown in translucent pink. The aerial image, taken in 2013, illustrates the land use practices of the upper watershed.

Acknowledgements

This trace could not have been possible without the cooperation of local landowners, specifically Jim Barnhart who gave us access to the stream sink and his springs, and Mike Pagel who gave us access to his property to monitor his springs.

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Table

Campbell Valley 2012-2013 Traces -- 13 Nov 2012 and 7 Mar 2013 (2 Traces)

Trace Input Location 1: Campbell Valley Stream Sink (MN85:B00020, 616,293 E / 4,859,365 N, NAD 83, Zone 15):
Poured 1166.15 grams Uranine HS (35 weight %) into a pool along the creek on 13 Nov 2012 at 12:02. Flow estimated at 5 gpm.

Trace Input Location 2: Campbell Valley Pour (MN85:X00037, 615,933 E / 4,858,709 N, NAD 83, Zone 15):
Poured 809.86 grams Rhodamine WT (17.7 weight %) into a riffle at head of pool, 50 ft. upstream of fence on 7 Mar 2013 at 18:40.

Field Personnel at Inputs and/or Sampling: Jeff Green, Kelsi Ustipak

Lab Personnel: Kelsi Ustipak, Betty J. Wheeler, Dr. E. Calvin Alexander, Jr.

Carbon (Bug) Analysis Results

Field Name	KFD #	Site Type	UTMs NAD 83, Zone 15		01 Nov to 13 Nov 2012	01 Nov to 13 Nov 2012	Dye Input 13 Nov 2012	13 Nov to 21 Nov 2012	21 Nov to 14 Dec 2012	14 Dec 2012 to 7 Jan 2013	7 Jan to 7 Mar 2013	Dye Input 7 Mar 2013	7 Mar to 23 Mar 2013	23 Mar to 13 Apr 2013	13 Apr to 30 Apr 2013	30 Apr to 7 Jun 2013
			Easting	Northing												
Pagel's Power Spring (aka, Yellow Commode Spring), (aka, Commode Spring) (aka, Power Spring)	MN85:A00139	spring	615,537	4,857,754		nd		nd	Uran (7.6 σ)	Uran (217 σ)	Uran (27 σ)		Uran (7.3 σ) RhWT (3.9 σ)	Uran (17 σ) RhWT (26 σ)	Uran (15 σ) RhWT (124 σ)	
Pagel's Big Spring Run (aka, Pagel Spring 1)	MN85:X00033 (associated with spring 85A141)	spring run	615,618	4,857,683				nd	Uran (332 σ)	Uran (278 σ) (diluted by 100x)	Uran (214 σ) (diluted by 10x)		Uran (285 σ) RhWT (4.8 σ)	Uran (75 σ) RhWT (5.3 σ)	Uran (193 σ) RhWT (15 σ)	Uran (188 σ) RhWT (11 σ)
Campbell Valley Creek Bridge at County Road 13	MN85:X00036	creek	615,250	4,857,099		nd		nd	Uran (180 σ)	Uran (395 σ)	Uran (181 σ)		Uran (81 σ) RhWT (4.9 σ)	Uran (96 σ) RhWT (10 σ)	Uran (93 σ) RhWT (32 σ)	
Barnhart #1 Spring Run	MN85:X00034	spring run	615,987	4,858,772	nd			nd	Uran (348 σ)	Uran (348 σ) (diluted by 10x)	Uran (213 σ) (diluted by 10x)		Uran (169 σ)		Uran (172 σ)	
Barnhart # 2 Spring (aka, Barnhart's Boil)	MN85:A00325	spring	615,957	4,858,771	nd				Uran (215 σ)	Uran (315 σ) (diluted by 10x)	Uran (176 σ)		Uran (204 σ)			
Barnhart #3 Downstream	MN85:X00035	creek	615,920	4,858,693				nd	Uran (81 σ)	Uran (236 σ)						

RhWT indicates Rhodamine WT dye detected
Uran indicates Uranine (fluorescein) dye detected

nd indicates no dye detected
(yellow cell) indicates no bug was received by the lab

Reference: Barry, John D., Green, Jeffrey A., and Steenberg, Julia R., 2015. "Conduit flow in the Cambrian Lone Rock formation, southeast Minnesota, U.S.A." Rochester, MN: *14th Sinkhole Conference,* NCKRI Symposium 5, Oct. 5-9, 2015.