

Investigation of Laura Spring in the Raven Run Watershed, Fayette County, Kentucky

By

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Purpose of Study

This study was undertaken to delineate the recharge area of a spring used as a household supply. The spring is called Laura Spring by the owner, Mr. Richard Levine, 5675 Kiddville Lane, Lexington, and is designated 9000-1949 in the Division of Water's groundwater data base.

Geologic Setting

Laura Spring, and the other springs and dye injection points involved in the study, are located on Raven Run Creek and its tributaries in Fayette County, Kentucky (Figure 1). This is an area of deeply dissected drainage adjacent to the Kentucky River in the Inner Bluegrass karst region. Raven Run Creek and tributaries are entrenched in a gorge 300 feet below the surrounding peneplain.

The upland surface is underlain by the Grier and Curdsville members of the Lexington Limestone. The Raven Run gorge is developed in the High Bridge Group of limestones and dolomites. The springs are located just above and below the contact between the Oregon dolomite and the Camp Nelson limestone and dolomite. Stress relief fracturing along the margins of the stream gorges is believed to have a significant role in local patterns of groundwater movement.

Water Quality Analysis

Laura Spring is used for domestic purposes by the Levine family including bathing and dishwashing, although drinking water is obtained in bottled form. The spring has been modified by construction of a small 5 by 3 feet covered concrete reservoir; water is pumped uphill through a buried water line.

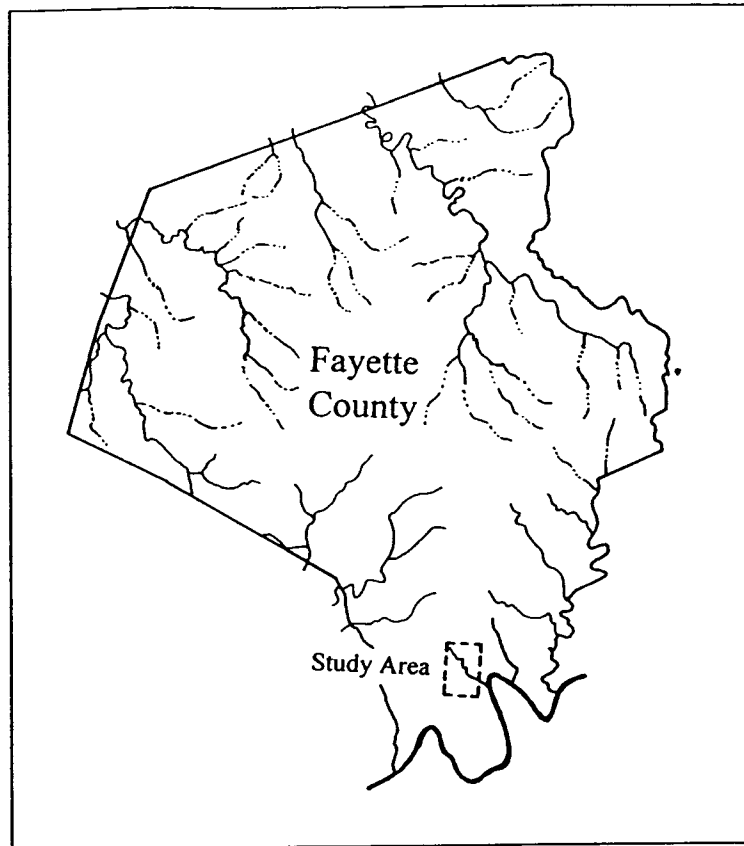


Figure 1: Location of Raven Run Study Area

At the request of Mr. Levine, grab samples of the spring water were collected on 17 March 1998 for analysis of multiple parameters including fecal coliform bacteria, dissolved metals, pesticides, and nutrients. Coliform samples were collected both at the spring source and at the kitchen tap. All other parameters were sampled from the source only.

Laboratory analysis reported a fecal coliform count of 40 and 35 colonies per 100 ml from the source and the kitchen tap, respectively. This suggested potential contamination of the groundwater aquifer supplying Laura Spring. All other parameters were within acceptable ranges for drinking water quality (See Appendix 1 for analytical reports).

Methodology

Based on the results of the surface investigations described below, two separate dye injections were conducted at an interval of four weeks, using two discrete injection points and a different dye for each trace. Fluorescein dye was used in the first trace, and Rhodamine WT for the second. Table 1 provides a characterization of all receptor sites used in both traces; see Figure 4 for locations.

The land surface above Laura Spring was investigated for possible injection sites. The point chosen for injection was an enlarged fissure or "grike" located about 300 feet

from the Levine residence on the Martin property, on the uphill slope away from Laura spring. The grike is about ten feet long, one foot wide, and at least six feet deep. The owner has in the past made efforts to fill the grike with loose rock placed at one end, but continued erosion has kept the feature open beneath the rock fill. Soil erosion is aligned with the grike; it is not forming a depression but instead collapsing along the length. This feature is located near a cluster of trees and a utility pole almost directly in line with the power lines that cross through the property. Martin reports a filled-in pond above this. Also above this grike, to the northwest, is a

STUDY ID#	KENTUCKY SPRING ID#	NAME	DESCRIPTION	EST. FLOW (CFS)
1	9000-2455	Cave Spring	Perennial spring discharges at edge and slightly above surface stream, upper tributary to Raven Run. Receptor placed 2 feet from spring in direct flow.	1.5 (high) .5 (low)
2	N/A	Waterfall Spring	Intermittent spring discharges from beneath talus on slope about 40 feet above surface stream, upper tributary to Raven Run. Dropped from study due to cessation of flow at time of trace.	0.1 (high) 0.0 (low)
3	9000-2457	Deadfall Spring	Seasonal spring discharges from beneath talus on slope about 40 feet above surface stream, upper tributary to Raven Run. Receptor placed on ledge just above surface stream. During period of trace, flow had reduced to trickle barely sufficient for purpose.	0.05 (high) 0.01 (low)
4	N/A	N/A	Surface stream, upper tributary to Raven Run. About 100 feet above junction with Raven Run.	6.0 (high) 1.0 (low)
5	9000-1949	Laura Spring	Perennial spring on Raven Run, used as domestic water source, discharge point modified by enclosure. Receptor placed to receive overflow from spring box.	0.5 (high) 0.3 (low)
6	9000-2458	Undercut Spring	Perennial spring on Raven Run about 150 feet downstream from Laura Spring. Discharge from bedding plane in undercut slightly above level of surface stream.	0.3 (high) 0.2 (low)
7	N/A	N/A	Surface stream. Raven Run just above major series of cataracts and before junction with another surface tributary but about 50 feet downstream from a three foot high waterfall. Placed in chute between large flat rock and stream bank.	12.0 (high) 2.5 (low)
8	N/A	N/A	Surface stream, lower tributary to Raven Run. Above cataracts, about 100 feet above junction with Raven Run, next to leaning tree.	6.0 (high) 1.5 (low)
9	9000-2459	Powerline Spring	Seasonal spring discharges from hillside above upper tributary to Raven Run; named for powerlines directly overhead. Receptor placed in flow across ledge above stream.	0.05 (high) 0.01 (low)
10	N/A	N/A	Surface stream, tributary to tributary of Raven Run. Beneath 2-foot waterfall located about 50 feet back from junction.	1.5 (high) 0.2 (low)
11	9000-2456	Martin Cave Spring	Seasonal overflow spring, flow discharges from beneath talus pile below low cave opening. Spring channel splits into three forks that merge with surface stream; receptor placed in middle fork just above junction with surface stream.	??? (high) 0.05 (low)

Table 1: Characteristics of Receptor Sites

shallow grassy swale that ends in two or more tiny swallets. No evidence can be seen of water flow into either the grike or into the swallets. To the south is a series of small dry sinks with no visible inflow.

The gorge of Raven Run and the tributary streams surrounding the planned injection point were surveyed for springs on 8 May 1998 following a period of moderate to heavy rains. Numerous springs were observed discharging from just above the level of the surface streams or from points on the slope 30 to 50 feet above the stream. Many of the springs were later determined to be seasonal or intermittent, ceasing flow during drier weather conditions. Laura Spring (#5) and Undercut Spring (#6) on Raven Run and Cave Spring (#1) on the upper tributary were the most significant, perennial springs located for the study. Activated charcoal dye receptors were placed at five springs and at three surface stream locations at this time to establish background conditions prior to the actual trace. Subsequently, Waterfall Spring (#2) was eliminated from the study for lack of flow and Powerline Spring (#9) and an additional surface stream location (#10) were added.

Fluorescein dye, 2 ounces in solution, was injected into the upland grike on 12 May 1998. Prior to injection, approximately 10 gallons of water were directed into the grike through a water hose. After injection, the dye was flushed with approximately 360 additional gallons of water, at a rate of approximately 2 gpm for 180 minutes. Receptors were retrieved and replaced on May 19 and retrieved and not replaced on May 29.

Investigation of the tributary above Cave Spring during base flow conditions revealed that nearly the entire flow of the tributary

stream discharges from Cave Spring. The surface stream bed above Cave Spring was dry except for a trickle that represented discharge from Martin Cave Spring (#11) located about 75 feet upstream from Cave Spring. The relative position of Martin Cave Spring suggested an overflow route for the flow to Cave Spring (note that Cave Spring is a misnomer as there is no cave opening at this spring; Martin Cave Spring, however, has a low opening about three feet high and eight feet wide). Discharge at Martin Cave Spring is from beneath a talus pile at the entrance. The surface stream bed upstream from Martin Cave Spring, during base flow conditions, remains dry for approximately 500 feet until flow is again encountered. The flow in the surface stream sinks into fractures in the limestone bedrock of the stream bed; no open swallet was observed.

On 8 June 1998, dye receptors were placed at Cave Spring and at Martin Cave Spring and 0.5 cup of a 20% solution of Rhodamine WT was added to the flow of the tributary stream about ten feet above where the stream sinks into bedrock fractures. Receptors were retrieved on 15 June 1998 and not replaced.

For each trace, dye was eluted from collected receptors using so-called "Smart" solution, consisting of 5:3:2 ratio of 1-propanol, deionized water, and ammonium hydroxide. The elutant was evaluated with a Shimadzu spectrofluorophotometer to determine the magnitude of spectral peaks for Fluorescein and Rhodamine, if present.

Results

The receptors collected prior to introduction of Fluorescein on 12 May 1998 showed no sign of any background dye that might interfere with the trace, except for Waterfall Tributary where a slight possible background was evident. Following dye injection into the grike, receptors collected on 19 May 1998 indicated extremely positive results for Deadfall Spring (#3); very positive for Powerline Spring (#9) and surface stream water in the upper tributary of Raven Run (#4); and positive for Laura Spring (#5), Undercut Spring (#6) and the waters of Raven Run (#7). Fluorescein was not detected in the waters of the lower tributary of Raven Run (#8, #10), nor at Cave Spring (#1). Similar results followed examination of the receptors collected on 29 May 1998, although the positives were ambiguous for Laura Spring and the waters of Raven Run. These results are summarized in Table 2, and selected plots from the Shimadzu are shown in Figure 2.

ID#	NAME	5/8	5/19	5/29
1	Cave Spring	-	-	-
3	Deadfall Spring	-	+++	++
4	Upper Tributary	-	++	+
5	Laura Spring	-	+	?
6	Undercut Spring	-	+	+
7	Raven Run	-	+	?
8	Lower Tributary	-	-	-
9	Powerline Spring	-	++	+
10	Waterfall Tributary	B	B	B

Table 2: Summary of Results of Fluorescein Trace

Receptors collected on 15 June 1998 after injection of Rhodamine dye into the upper tributary where it sinks into bedrock fractures gave extremely positive results for Cave Spring (#1) and very positive for Martin Cave Spring (#11). Although receptors were not placed at any other sites for this trace, unexpected visual evidence of a strong positive to Laura Spring was provided by Mr. Levine who reported pink water in his bathroom following dye injection. Results are summarized in Table 3, and selected Shimadzu plots are shown in Figure 3 (following page).

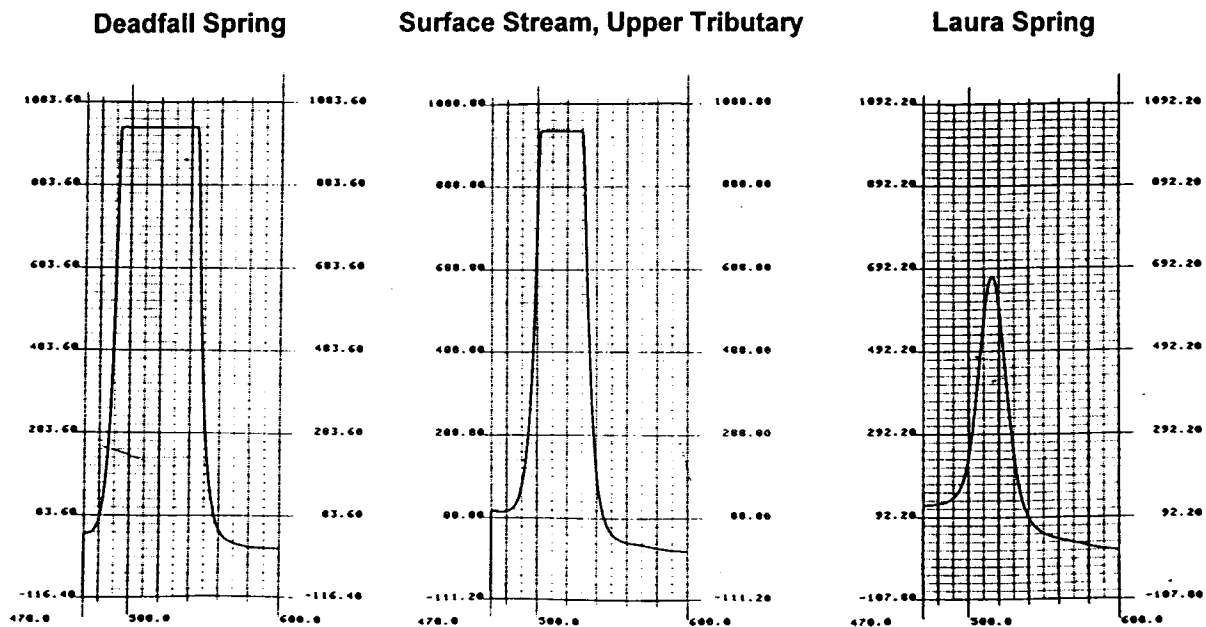


Figure 2: Graphs of Spectral Peaks from Fluorescein Trace
 Note: Truncated spikes shown for Deadfall Spring and the Upper Tributary result from use of the high-sensitivity setting on the Shimadzu.

ID#	NAME	6/15
1	Cave Spring	+++
11	Martin Cave Spring	++
5	Laura Spring	+++ Visual

Table 3: Summary of Results of Rhodamine Trace

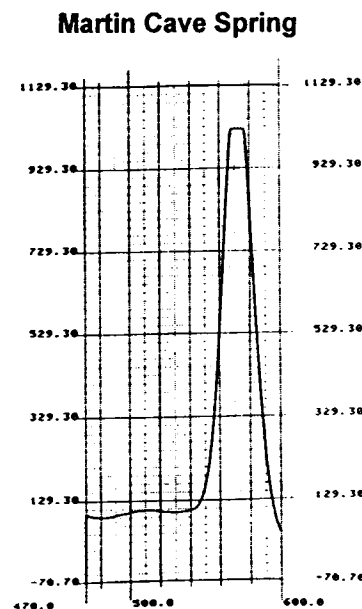
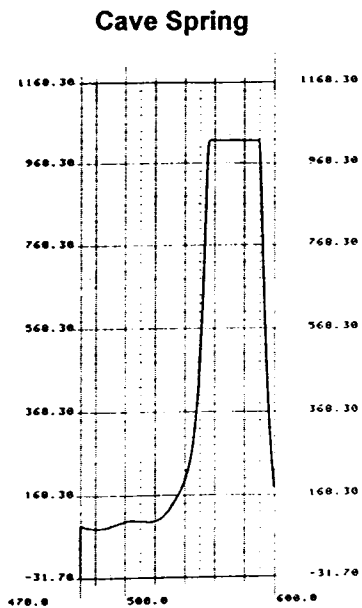


Figure 3: Graphs of Spectral Peaks from Rhodamine Trace

Note: Truncated spikes shown result from use of the high-sensitivity setting on the Shimadzu

Interpretation of Results

The Fluorescein trace resulted in detection of dye at numerous sites over an arc of about 90 degrees from the injection point. These results led to the initial conclusion that groundwater movement from the uplands to the gorge of Raven Run and its tributary in the vicinity of the Levine property tends to follow a widespread pattern of dispersal from multiple points along an arc, rather than simple linear flow. The second trace, using Rhodamine, was intended only to confirm a predicted link between Cave Spring and the point further up the tributary where flow sinks into fractures. The Rhodamine trace was not expected to reveal additional insights about flow pathways from upland to gorge. Critical information was nevertheless provided in a wholly unexpected manner. The property owner's visual confirmation of Rhodamine in Laura Spring revises conclusions drawn from the results of the Fluorescein injection.

The presence of Rhodamine dye in Laura Spring indicates that leakage must be occurring through the bed of the tributary stream at some unknown location. Surface water is therefore likely to be a significant component of the flow from Laura Spring. In light of this revelation, the upland groundwater dispersal hypothesis based upon the Fluorescein trace must be revised. It now appears likely that the positive trace for Fluorescein to Laura Spring does not indicate a direct connection to the upland grike, but also represents leakage of surface flow into the stream bed. The mild positive for Fluorescein at Laura Spring probably results from dye discharged from Deadfall and Powerline springs into the tributary that leaked through the stream bed and was then transported to Laura Spring. This indicates bed leakage for both traces occurred between Powerline Spring and Laura Spring.

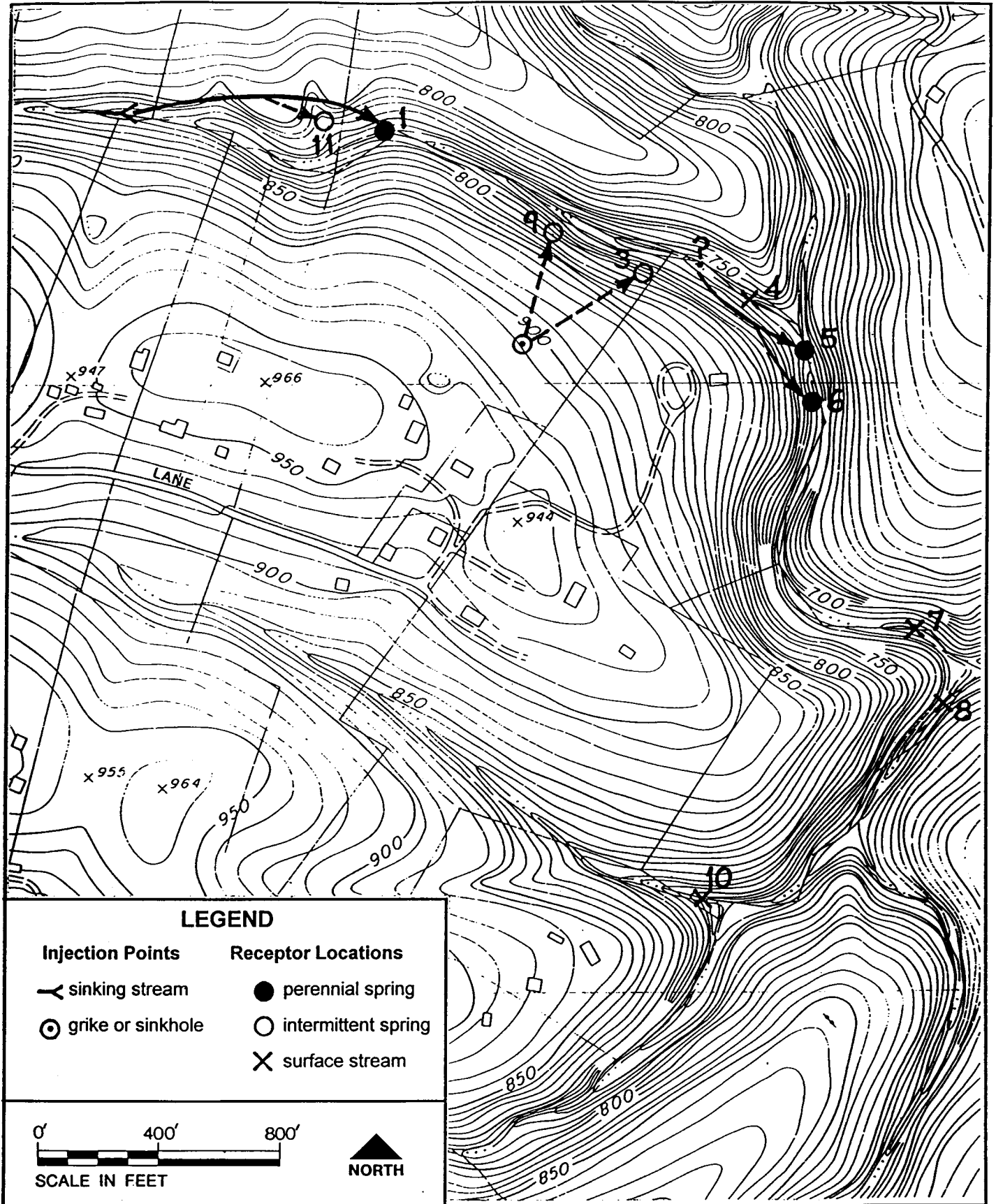


Figure 4: Map of Raven Run study area showing injection points, dye receptor locations, and positive traces obtained during moderate flow conditions.

Figure 4 shows the final interpretation of the results of the two dye traces. Strong positives for Fluorescein at Powerline (#9) and Deadfall (#3) springs indicate a direct (more or less) pathway from the upland grike. Strong positives for Rhodamine at Martin Cave Spring (#11) and Cave Spring (#1) indicate that Cave Spring is a resurgence for the sinking stream further up the tributary valley and that Martin Cave Spring is a higher-level overflow route. Fluorescein recovery from Laura (#5) and Undercut (#6) springs downstream from Powerline and Deadfall springs, when combined with the visual Rhodamine dye confirmation from Laura Spring, indicate that the discharge from Laura and Undercut Springs is partly or entirely derived from diversion of surface water flowing in the upper tributary stream. Because Fluorescein dye was recovered, this points to an area of leakage between Powerline Spring and Laura Spring.

An important procedural conclusion to be drawn from this study is that the unexpected is always possible and more receptor sites are better than few. The Rhodamine trace was originally considered to be incidental to

the primary investigation, merely to confirm the predicted source of Cave Spring's flow from the upstream diversion of surface flow, so no receptors were placed below Cave Spring. Deeper reflection on this situation prior to the Rhodamine trace might have anticipated the probability that bed leakage may occur in more than one location and hence more than one spring may be affected. If Mr. Levine, who was not aware that a Rhodamine trace was intended, had not been curious as to why water in his house pumped from Laura Spring had a faint pink tinge, interpretation of groundwater dispersal from upland to gorge would have been based solely on the Fluorescein results. Thus the assumption of a straight-line connection between the upland and Laura Spring would be completely erroneous. This account should serve as an object lesson to anyone undertaking to trace groundwater flow in karst.

I would like to acknowledge the assistance of Joseph A. Ray, Division of Water, in the planning and evaluation of this study. Assistance with collection of water samples was provided by Peter T. Goodman.