DYE TRACING AND RECHARGE AREA DELINEATION FOR VARIED LAND MANAGEMENT PURPOSES IN THE SOUTHWEST ILLINOIS KARST

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Abstract

The Southwest Illinois Karst underlies a 410 km^2 sinkhole plain located a short distance southeast of St. Louis, Missouri. The Illinois Speleological Survey lists over 100 perennial and ephemeral springs in the sinkhole plain. The Ozark Underground Laboratory has delineated nine groundwater system recharge areas in some detail, has partially delineated two others, and plans work on three more. Dye tracings were done to characterize groundwater flow, identify lands which contribute water to the habitat of a federally-listed aquatic cave species (*Gammarus acherondytes*, the Illinois cave amphipod) and other important cave fauna, and to assess impacts to spring discharge from proposed quarry expansion. Over 100 dye introductions have been made, which were detected at 29 springs resulting in over 120 km^2 (~29% of the karst) shown to lie within the delineated recharge areas. These data are being used for recovery of the Illinois cave amphipod, to recognize special spill response needs, for permit applications for quarrying and subdivisions, and to disclose a flaw in a floodway model.

Key words: recharge area delineation, dye tracing, karst groundwater, southwestern Illinois

Introduction

The Southwest Illinois Karst lies within the Salem Plateau physiographic province (Willman *et al.* 1975) and within the Ozarks Ecoregion (Figure 1). Previous studies of the karst area and its groundwaters are provided by Frankie et al. (1997), IDNR (1998), Panno et al. (1994), and Stueber and Criss (2005).

The Illinois part of the Salem Plateau Karst includes three major areas that are intensely karstified. These are the Columbia, Waterloo and Renault subkarsts, respectively named for proximal towns (Figures 1 and 2, Titus 1976, Aley *et al.* 2000).

The general area is a sinkhole plain developed in Mississippian Period limestones of the Valmeyeran Series, covered on the east and south by insoluble, granular sedimentary rocks deposited during the Pennsylvanian Period. The rocks affecting the karst development are, from oldest to youngest, the Salem Limestone, the St. Louis Limestone, the Ste. Genevieve Limestone and the Aux Vases Sandstone. The karst area is bounded on the west and north by the Mississippi River floodplain alluvium, and is covered in many places by Pleistocene loess that is commonly 40 feet thick between sinkholes.

The area is undergoing rapid urbanization and has Illinois' longest caves, which have the highest

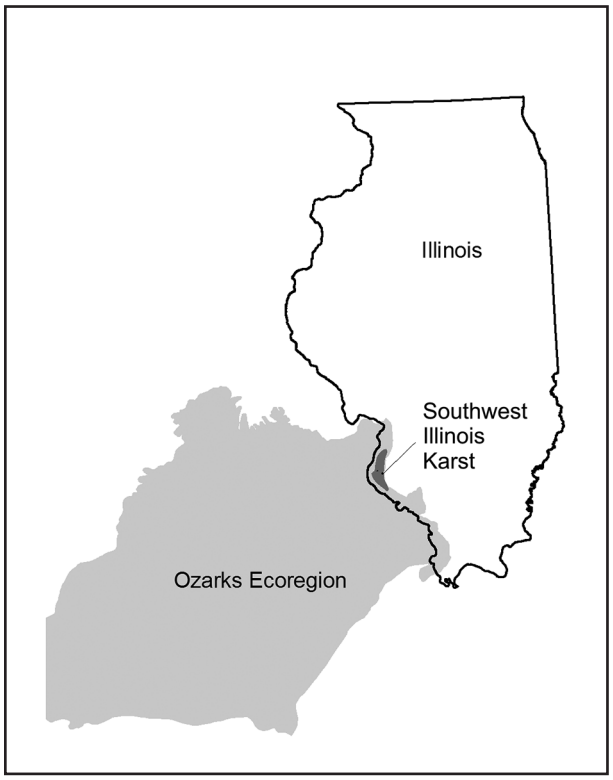

Figure 1 *Location map.*

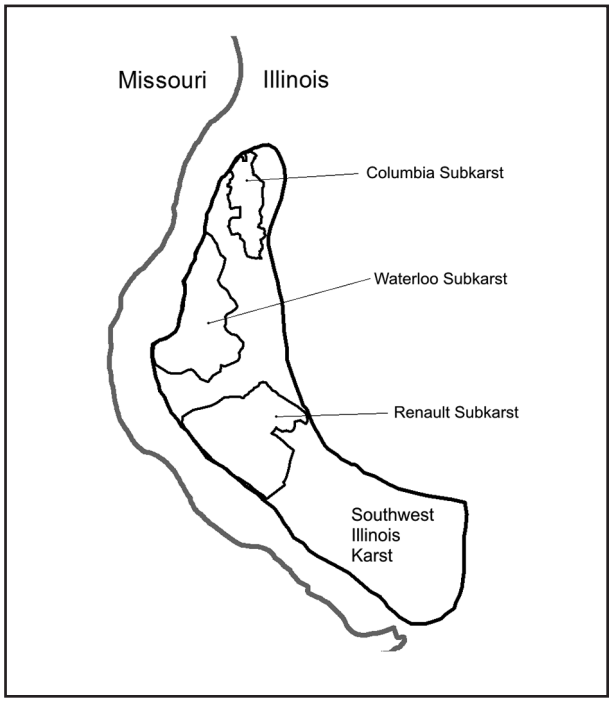

Figure 2 *The Salem Plateau in Illinois and its major subkarsts.*

number of globally-rare species found in the caves of the Ozarks Ecoregion (Lewis *et al.* 2003). Proposed changes in land use, the listing of the Illinois cave amphipod (ICA, *Gammarus acherondytes*) as federally listed as endangered, and proposed designation of cave-nature-preserve recharge areas as Class III groundwater have driven most of the dye tracing in the Southwest Illinois Karst.

Renault Subkarst Tracing

Thirty-six dye introductions demonstrating 42 flow paths have been made in the Renault Subkarst (Figure 3). Three dye introductions were made to determine if a proposed subdivision would impact the Fogelpole Cave groundwater system, which was known to provide habitat for the ICA. One introduction was made to help cavers determine if a newly discovered cave was part of the Fogelpole Cave system or if it flowed to Collier Spring, which drains a nominally separate cave system. The remaining 32 dye introductions delineate cave system recharge areas and areas that recharge state-managed lands, particularly the Armin Krueger Speleological Nature Preserve, the Illinois Caverns Natural Area and the Fogelpole Cave Nature Preserve. Each of these cave systems provide habitat for the ICA (see Aley *et al.* 2000).

Waterloo Subkarst Tracing

Thirty-one dye introductions demonstrating 34 groundwater flow paths have been made in the Waterloo Subkarst (Figure 4). Continuing work will delineate recharge areas for Frog Spring, Luhr Spring and Dual Spring, all of which are known to provide habitat for the ICA.

Eleven of the dye introductions were done to help characterize groundwater flow in the Southwest Illinois Karst (Aley and Aley 1998), and most proved to be relevant for subsequent recharge-area delineations. Two dye introductions were made to add detail to two of the characterization traces (Moss 1998). The remaining 18 dye introductions were made to help delineate the recharge areas of the Pautler Nature Preserve, Annbriar Spring and the Pautler Cave system, which currently has the highest number (16) of globally-rare species of any cave system in the Ozarks Ecoregion (Lewis *et al.* 2003). Both the Pautler Cave and Annbriar Spring groundwater systems provide habitat for the ICA, as do the Frog, Luhr and Dual Spring systems. The recharge area for the Pautler Nature Preserve was delineated in support of its designation as Class III groundwater. The recharge area delineations were

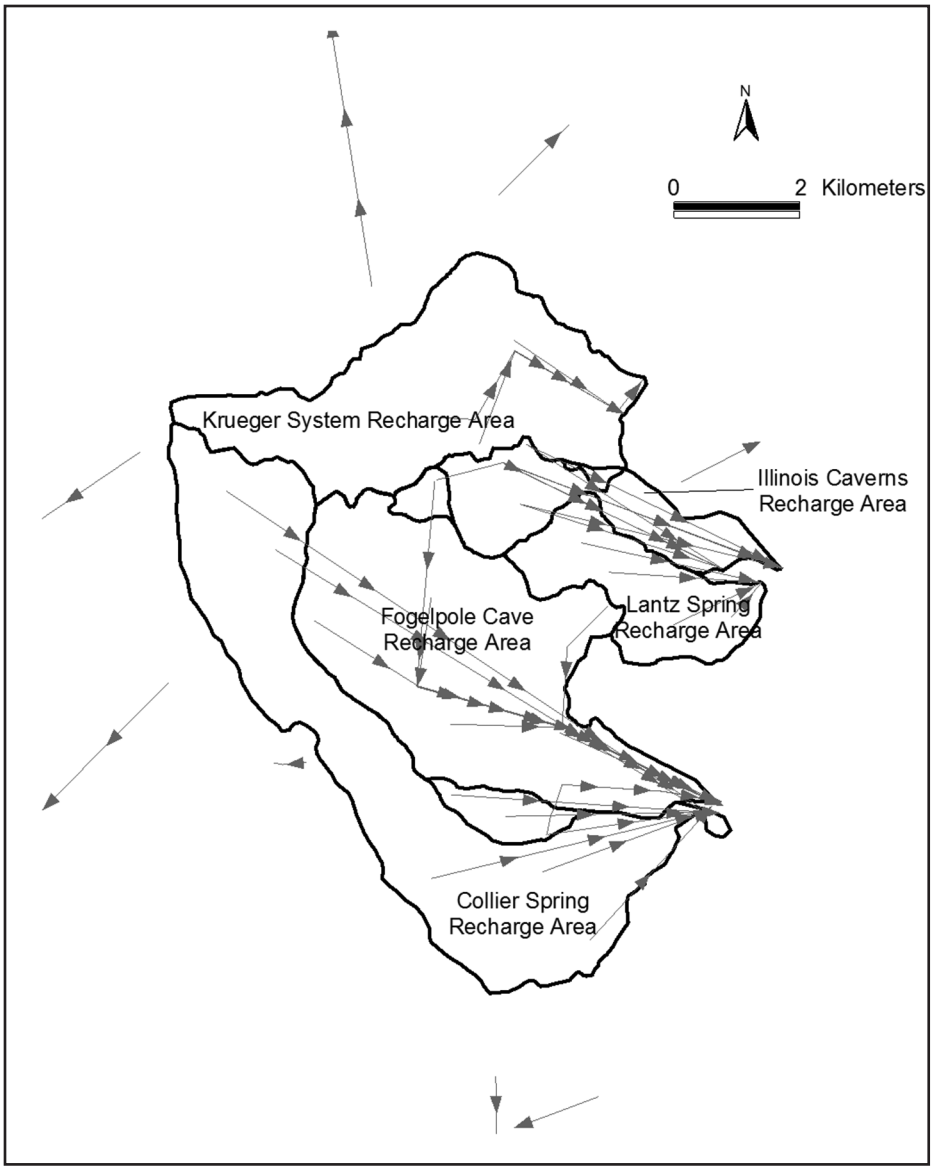

Figure 3 *Renault Subkarst: Recharge areas and dye traces.*

reported by Aley and Moss (2001).

Columbia Subkarst Tracing

Thirty-one dye introductions demonstrating 35 groundwater flow paths have been made in the Columbia Subkarst (Figure 5). Three dye introductions were made to provide necessary data to help resolve a sinkhole-flooding issue in Columbia, Illinois. All of these traces flowed to Ritter Spring (Aley *et al.* 2000). Two successful dye introductions were made to determine appropriate sampling locations for a closed landfill (Aley and Moss 2007), 19 dye introductions were made to delineate the Stemler Cave system recharge area (Aley *et al.* 2000) and seven dye introductions were made to delineate the Falling Springs recharge area (Moss and Aley 2002). The Stemler Cave recharge area was delineated as well as delineating the recharge area for the Stemler Cave Nature Preserve. The former was in support of the ICA and the latter was in support of Class III groundwater designation. The recharge area for Falling Springs was delineated as part of an assessment of potential impacts to the spring from a proposed quarry expansion.

One of these traces proved relevant in a lawsuit relating to a floodway issue. There was a question of whether or not modeling the topographic basin of Wilson Creek near Columbia, Illinois was appropriate. Trace 99-213 reported in Aley *et al.* (2000)

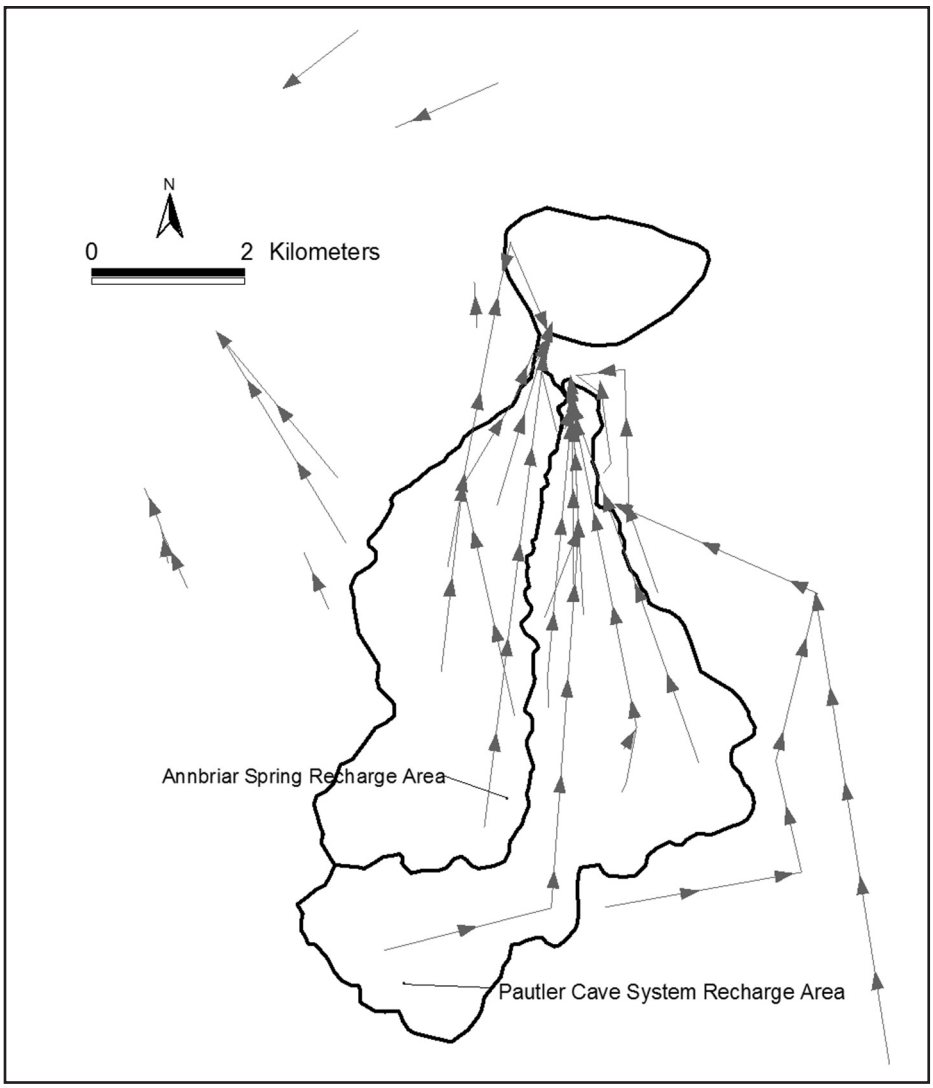

Figure 4 Waterloo Subkarst: Recharge areas and dye traces.

has shown that groundwater is derived from a zone extending at least 1.7 km outside the 9 km^2 topographic basin. Anecdotal reports showed much higher flood levels than the models predicted, and we were asked if we could explain the difference. There are six known springs at the head of Wilson Creek, one of which happened to have had a trace detected by us. It was clear that the topographic model did not successfully predict the amount of water discharged from Wilson Creek during the one-percent-probability flood.

Conclusion

Dye tracing is a versatile tool in the Southwest Illinois Karst, and bears on a number of questions, including:

- How does groundwater behave in the Southwest Illinois Karst?
- Which areas recharge cave systems providing habitat for the ICA?
- Which areas recharge nature preserves and natural areas?
- How would the proposed expansion of a quarry affect the discharge of proximal Falling Spring?
- Is there interbasin transfer of water, and how does that affect flood modeling?
- In which groundwater systems do particular caves lie?
- Where should water be sampled for potential landfill leachate?

The >100 groundwater traces completed in the Southwest Illinois Karst have helped answer these questions. The Southwest Illinois Karst has been

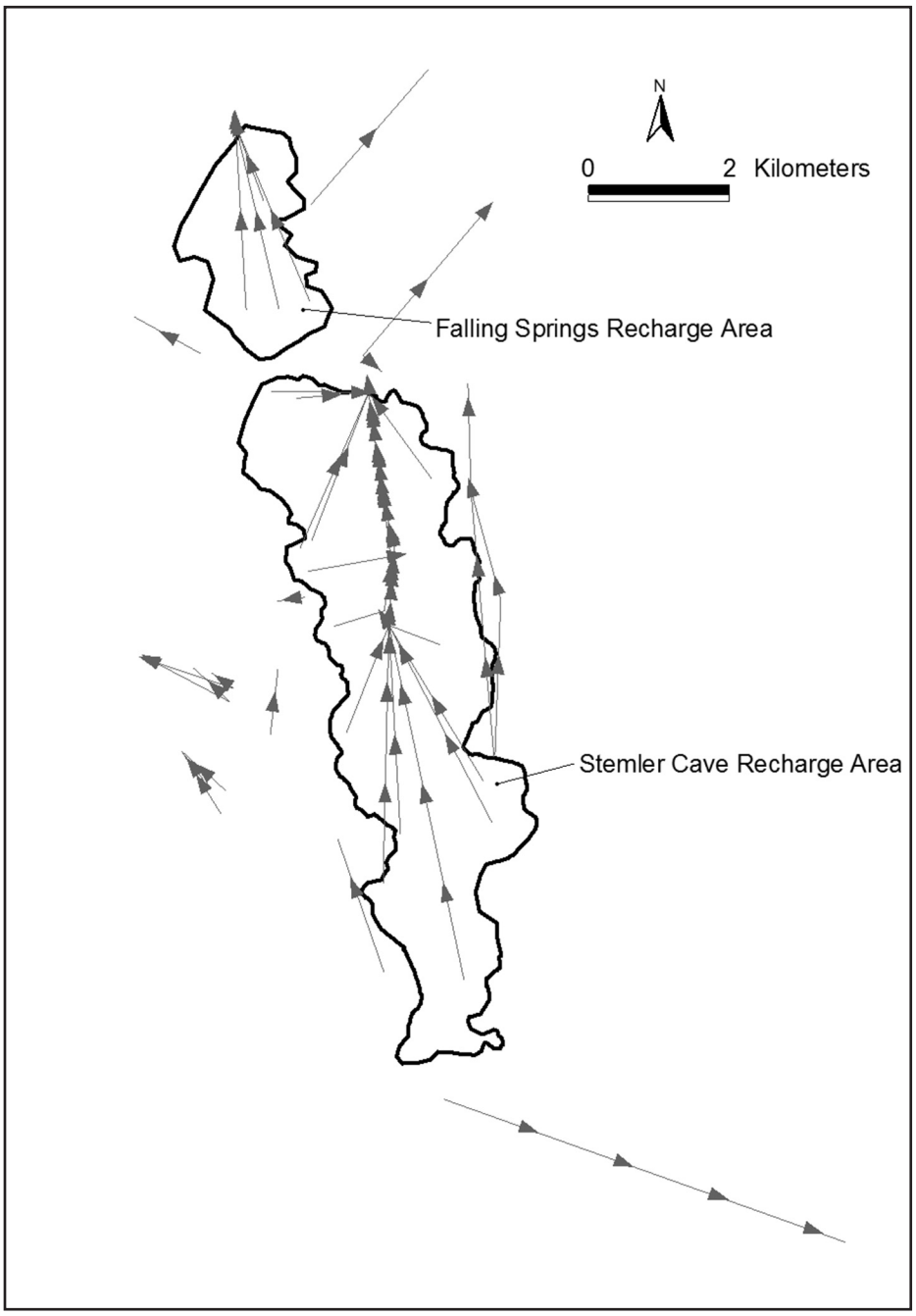

Figure 5 *Columbia Subkarst: Recharge areas and dye traces.*

shown to have very open conduit systems with large caves and high groundwater velocities. For each trace, we generally report the following:

- the amount and type of dye used,
- the elevation and location of the dye introduction point,
- the date and time of dye introduction,
- water flow conditions at the dye introduction point at the time of dye introduction,
- locations where dye was recovered,
- estimated velocities of groundwater flow paths,
- elevation change between introduction and recovery points,
- gradient of groundwater flow path, and
- a figure showing the trace.

The Illinois Speleological Survey is making the important data in these unpublished reports more accessible. The shape files of the traces and recharge

area delineations, as well as the text for most of the reports, are on a website maintained by the Illinois Speleological Survey (http://www.caves.org/iss). As in the floodway case, these data may prove to be useful for purposes other than those for which they were originally conducted.

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