Integration of Water Tracing and Structural Geology for the Delineation of Springsheds

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ABSTRACT

Fountain, Fillmore Co., Minnesota, a small town self-identifed as “The Sinkhole Capitol of the U.S.A.,” is located on a large sinkhole plain in the Upper Ordovician Galena Group. Recent mapping of the structural setting in the Fountain area provides new constraints for the interpretations of flow paths in springsheds defined by three decades of dye traces (Runkel, 2012, private communication). The strata of the Galena Group are deformed into a low-angle, assymetric syncline that is plunging northwest. The Fountain East dye traces, initiated in May 2012, were designed to further refine springshed boundaries on the northern edge of the sinkhole plain and to delineate source areas for cold-water springs that feed Minnesota designated trout streams in the area, particularly Rice Creek. Two major springsheds were previously mapped in the Fountain East area: the Fountain Springshed, which drains northwest and forms the headwaters for Rice Creek; and the Mahoney Springshed that drains southeast to form the headwaters for Mahoney Creek. The newest tracing efforts begin to document a new springshed to the northeast of Fountain feeding Klomp’s Spring and ultimately Rice Creek. The integration of dye trace data, structural contours, and ArcGIS imagery contextualizes the regional subsurface flow and further provides evidence for the delineation of the Fountain, Mahoney and Klomp Springsheds. Knowledge of the structural setting of the Fountain East trace area is a significant step in answering broader questions regarding the hydrogeologic behavior of the Galena Group karst system and its role in the productivity of designated trout streams.

INTRODUCTION

Dye traces are designed to track subsurface water flow directions and travel times from the point where dye is introduced to a karst conduit system to the point where it reemerges from a spring, seep or well. In the Fountain sinkhole plain, sinkholes in the carbonate Prosser Formation drain surface water that rapidly discharges at springs in the bottom of the shaly-carbonate Cummingsville Formation or top of the Decorah Shale (see Cross Section). Three decades of dye tracing in this area have identified three springsheds in total. The Fountain Springshed is a springshed from which water discharges to four springs collectively known as the Fountain Big Springs Complex (A37, A44, A45, A51)*, forming the headwaters to Rice Creek - a Minnesota designated trout stream. Water in the Mahoney springshed discharges at Finseth Spring (A144), which forms the headwaters for Mahoney Creek. A third, unnamed springshed, feeds Nelson Spring (A235) - a tributary to Mahoney Creek. Sinkholes in the Fountain East 2012 trace were chosen due to their proximity to the boundary of the Fountain Springshed, to further delineate the boundaries of springsheds in the area.

** The spring and sinkhole numbers in this poster are abbreviated versions of those features numbers in the Minnesota Karst Features Data Base. The prefix A designates a spring or seep. The prefix D designates a sinkhole. See Reference List of Sites box to the right.*

METHODS

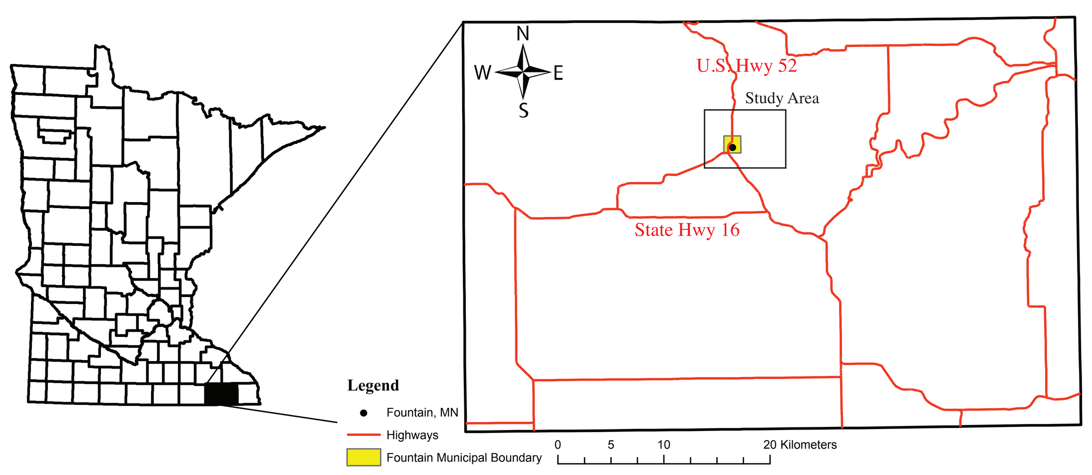
Dye was poured into three sinkholes on 21 May 2012: eosin into Klomp Sinkhole, Rhodamine WT into D4373, and uranine C (a.k.a. fluorescein) into D1075. Passive charcoal detectors were placed at springs (A37, A44, A45, A51, A123, A124, A144), exchanged at regular intervals and returned to the University of Minnesota Department of Earth Sciences. Charcoal was extracted with an eluent, which was then qualitatively analyzed using a Shimadzu RF5000U Scanning Spectrofluorophotometer. The resultant spectra curves were fitted using PeakFit v.4.0 software. The results of historic dye traces near Fountain, MN were compiled and summarized for this poster. Preliminary data on structural geology was provided by geologists at the Minnesota Geological Survey (Runkel and Steenberg, private communication, 2012) based on well logs, natural gamma logs, and outcrop observation from Fillmore County. A final map was created in ESRI ArcMap10 and edited with Adobe Illustrator CS5.

RESULTS

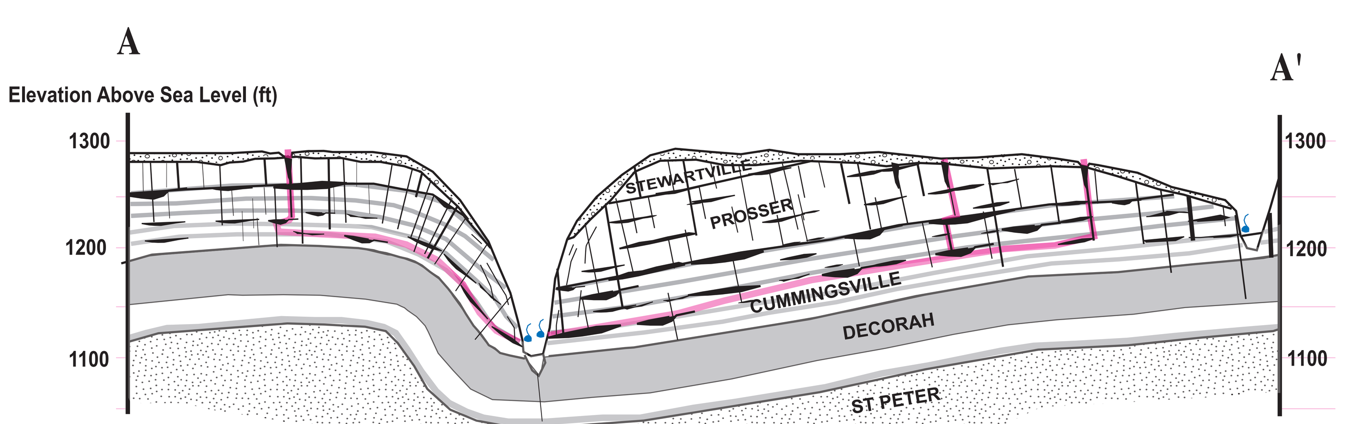
Eosin dye from Klomp Sinkhole emerged in A123. Rhodamine WT dye from D4373 emerged in A37 of the Fountain Big Springs Complex. Uranine C (a.k.a. fluorescein) dye emerged from D1075 in springs A45 and A51 of the Fountain Big Springs Complex.

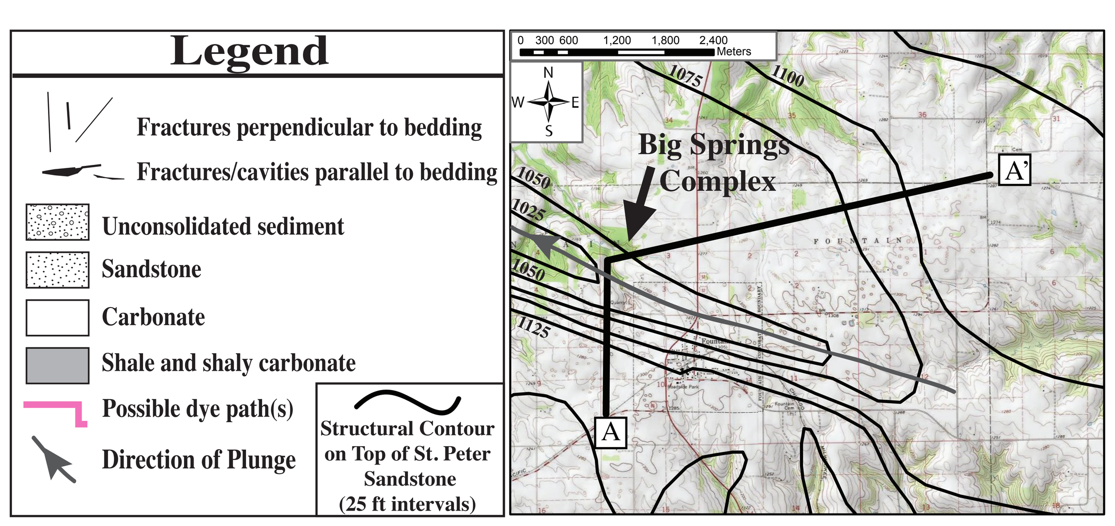
Reference List of Sites

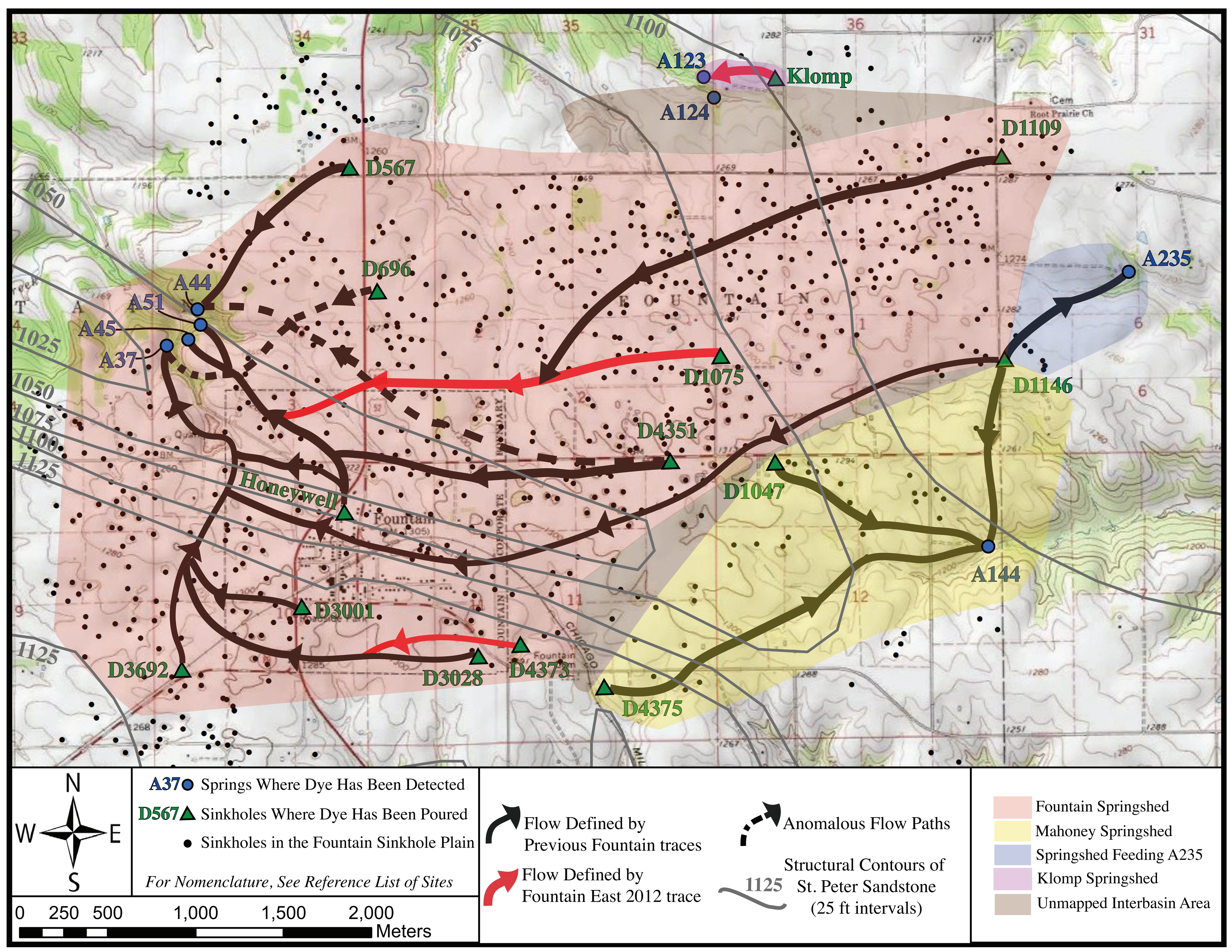
Short #	KFDB #	Common Name
A37	MN23A0037	Fountain Big Spring
A44	MN23A0044	Little Falls Spring
A45	MN23A0045	Little Quarry Spring
A51	MN23A0051	Quarry Spring
A123	MN23A0123	Klomp's Ram (North) Spring
A124	MN23A0124	Klomp's South Spring
A144	MN23A0144	Finseth Spring
N/A	N/A	Honeywell
N/A	**N/A**	**Klomp Sinkhole**
D567	MN23D0567	Bushman Sinkhole
D696	MN23D0696	Kramer Sinkhole
D1047	MN23D1047	Doc Johnson Sinkhole
D1075	**MN23D1075**	**Mulvihill Sinkhole**
D1109	MN23D1109	Root Prairie Sinkhole
D1146	MN23D1146	Roadpit Sinkhole
D3001	MN23D3001	Picnic Sinkhole
D3028	MN23D3028	Root River Trail Extension Sinkhole
D3696	MN23D3696	8 Mile Sinkhole
D4351	MN23D4351	Co Rd 11 (Mahoney) Sinkhole
D4373	**MN23D4373**	**Reinhardt Sinkhole**
D4375	MN23D4375	Parking Lot Sinkholehole

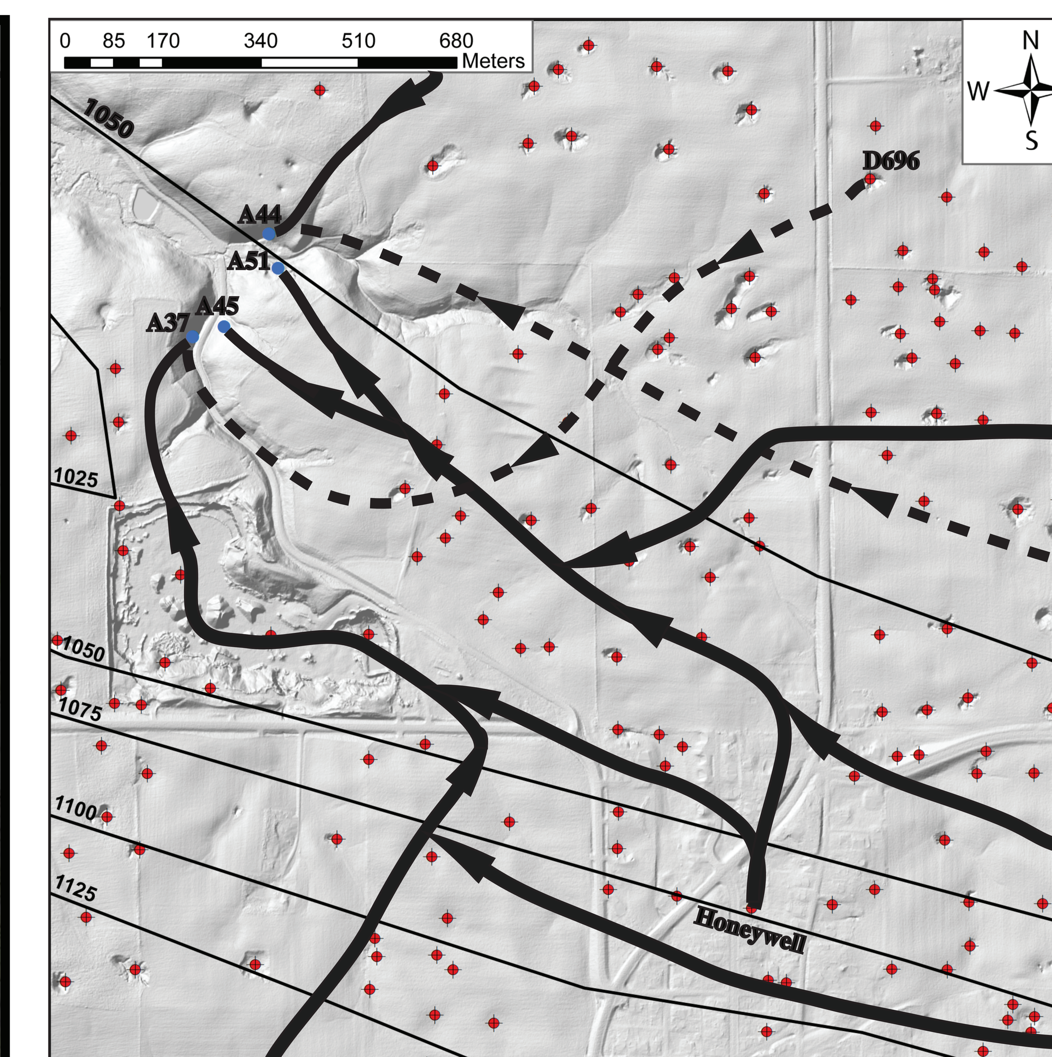


Cross-Section Through Fountain Big Springs Complex









Above: LiDAR based map that focuses on the region surrounding the Fountain Big Springs Complex. Flow paths are in black, arrowed lines. Flow paths that are anomalous due to their criss-crossing nature are dashed. Sinkholes are imaged as red dots with cross-hairs - note their abundance and the fact that sinkholes do not always coincide with depressions in the landscape and visa-versa.

Left: The final map for this project includes a topographic map overlain with KFDB locations of sinkholes and springs. Structural contours provide context to the bedrock geology. Flow paths are illustrated in 2-D to show potential flow directions of dye from sinkholes to springs. Shaded areas indicate approximate springshed boundaries in the Fountain sinkhole plain.

DISCUSSION

The Fountain East 2012 trace defines a new, small springshed on the northern edge of the Fountain sinkhole plain, known as Klomp Springshed. Springs A123 and A124 are ~20 meters apart, however the flow from Klomp Sinkhole does not contribute to A124, indicating that a separate conduit system feeds each spring. The gentle dip of bedding (<<1°) likely has partial control over this springshed, as A123 is down-dip to Klomp Sinkhole.

D1075 contributes flow to springs A45 and A51. This result adds data to refine the eastern edge of the Fountain Springshed. Previous traces show that sinkholes D1109, D4351, and Honeywell also connect to conduits that feed both springs. There appears to be a division of flow at A45 and A51, such that one spring may act as overflow to the other. However, the three-dimensional geometry of this conduit system remains uncertain as our mapping efforts only comprise a two-dimensional view of the problem. The flow paths for sinkholes feeding A45 and A51 follow the dip of bedding from East to West, indicating that the structural control of groundwater flow here is subtle.

D4373 connects to a conduit that feeds A37. In the past, sinkholes D3692, D3028, and D3001 have exclusively fed A37. Each of these springs occurs on the southern edge of the Fountain sinkhole plain, where a locally pronounced dip in bedding (~3°) due to an assymetric syncline exerts an obvious control on the direction of groundwater flow.

CONCLUSION

The results of the Fountain East 2012 trace contributed additional data to refine springshed boundaries in the Fountain sinkhole plain. Future dye trace efforts in this sinkhole plain can seek to further define the Fountain and Mahoney Springsheds, and to define the new springsheds feeding springs A123, A124 and A235 on the north and northwest edges of the currently mapped springsheds. The integration of historic dye trace data and structural contours provides clear evidence that the local dip of bedrock geology can be a significant control on groundwater flow. This is especially true in the southwest portion of the sinkhole plain, where the steep side of the syncline heavily influences the direction of flow toward the Fountain Big Springs Complex.

Examining other springsheds in southeast Minnesota in the context of structural geology will lead to more accurate and precise understanding of the groundwater flow and thereby improve our ability to predict potential pathways of contamination to trout streams due to localized pollution. However, to gain a truly accurate picture of groundwater flow, a three-dimensional understanding of the conduit system is necessary.

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A37, Fountain Big Spring - a solution enlarged cavity in Cummingsville Formation is where the spring emerges.
Photo by Kelsi R. Ustipak

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