

# Ordovician Karst of Southeast Minnesota Field Trip Guidebook

**6 October 2015 Field Trip - 14th Sinkhole Conference  
Rochester, Minnesota, U.S.A.**

**Calvin Alexander & Jeff Green, Leaders  
Tony Runkel & John Barry, Co-Leaders**



**Fountain Big Spring**



## Sinkhole Conference Field Trip Outline and Timeline

- 7:30 Leave Civic Center – both buses together
- 7:45 **Stop 1**, Paragon Chateau 14 Theater, St. Peter Sandstone Formation; 30 min.
- 8:15 Leave Stop 1
- 8:30 **Stop 2 (Rolling)**, Golden Hills road cut, Platteville, Decorah and Cummingsville Formations.
- 8:45 **Stop 3**, Orion Township Dye Traces/CAFOs; 30 min.
- 9:15 Leave Stop 3
- 9:45 **Stop 4**, Lower Shakopee Formation, Prairie du Chien Group road cut south of Chatfield at Middle Branch Root River; 30 min.
- 10:15 Leave Stop 3

### Buses separate

**Bus 1 (low stair climbing)** turns hard right on Co. 8 at the northwest corner of Fountain and then right on Keeper Road to Fountain Big Spring. This group will be led by Jeff Green and Tony Runkel.

- 10:30 **Stop 5**, Fountain Big Spring Group; 30 min.
- 11:00 Leave Stop 5
- 11:15 **Stop 6**, Root River Trail Sinkhole Kiosk; 30 min.
- 11:45 Leave Stop 6
- 12:15 **Stop 8**, Mystery Cave Visitor's Center; 2 hr. and 15 min.  
Split into two groups. One group eats box lunch while other group tours cave & vice versa.
- 14:30 Leave Stop 8

**Bus 2 (lots of stair climbing)** turns left on Co. 8 at the south edge of Fountain and goes to the Fountain sinkhole kiosk parking lot. This group will be led by Calvin Alexander and John Barry.

- 10:30 **Stop 6**, Root River Trail Sinkhole Kiosk; 30 min.
- 11:00 Leave Stop 6.
- 11:15 **Stop 5**, Fountain Big Spring Group; 30 min.
- 11:45 Leave Stop 5
- 12:15 **Stop 7**, Niagara Cave; 2 hr. and 15 min.  
Split into two groups. One group eats box lunch while other group tours cave & vice versa.
- 14:30 Leave Stop 7

## Buses rejoin

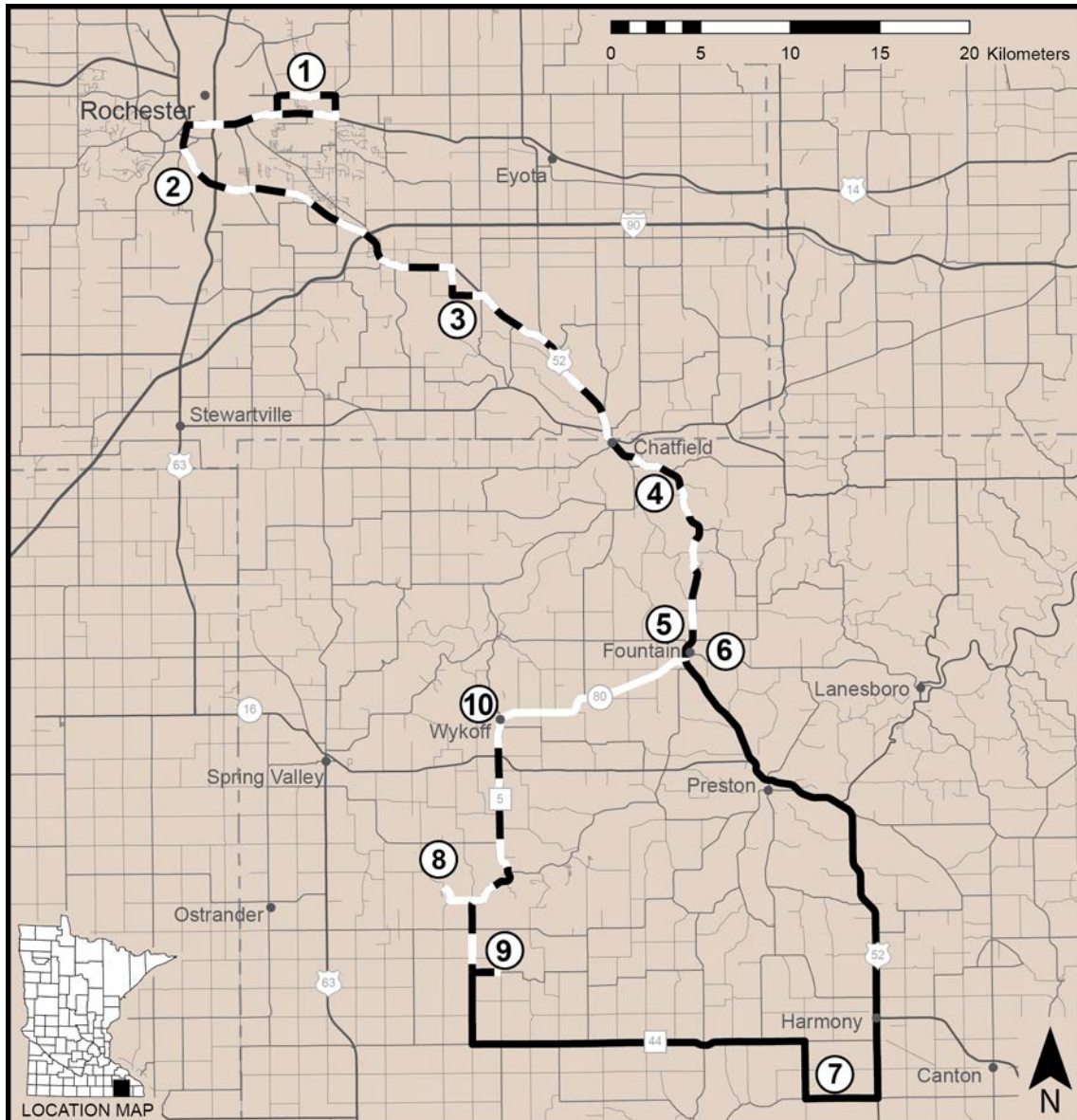
14:45 **Stop 9**, Cherry Grove Blind Valley SNA/Goliath's Cave; 1 hour

15:45 Leave Stop 9.

16:00 **Stop 10**, Wykoff Storm Water Treatment System, 30 min.

16:30 Leave Stop 10

17:30 Rochester Civic Center, End of field trip.



**Figure 1. Field trip route**

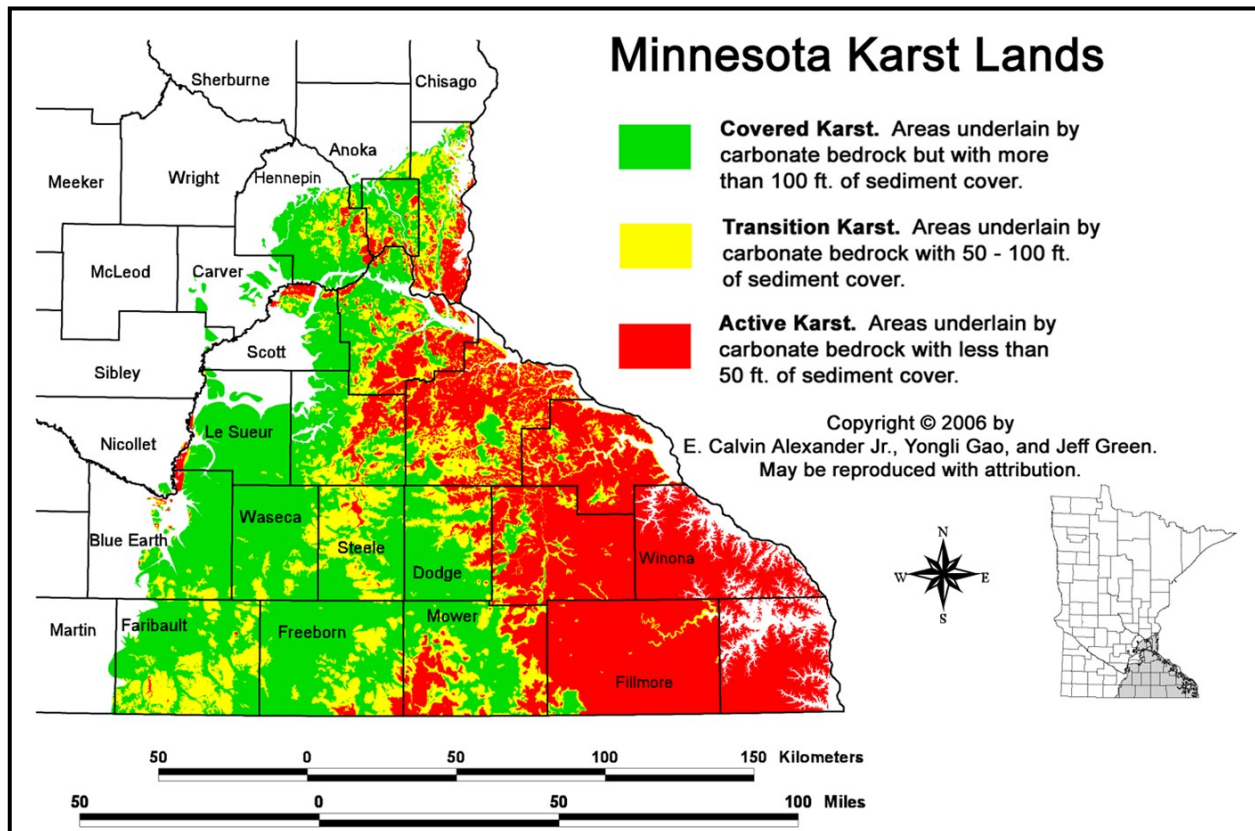
## Introduction

This field trip is designed to acquaint you with the Paleozoic bedrock aquifers of southeastern Minnesota. A major portion of Minnesota's population lives on top of those aquifers and depends on them for their domestic, agricultural and industrial water supplies. These aquifers provide the base flow for the rivers and streams in the area. Society's ability to manage this critical groundwater resource becomes ever more important as population grows and water usage steadily increases.

One major challenge is that these Paleozoic aquifers are dual-or triple-porosity fractured and karst aquifers. The movement of water in these aquifers is not adequately described by isotropic, homogeneous porous media mechanics. Unfortunately, those mechanics are built into the scientific and public culture of ground-water management. Darcy's equations seem inextricably imbedded in ground-water management efforts at every level.

This field trip will focus on the heterogeneities in the routes that water uses as it moves from recharge areas to discharge areas through the Paleozoic aquifers. We will look at a variety of conduits, pipes, high transmissivity zones and other ground-water flow paths. We will see porosity that ranges from the resolution of our vision to voids that houses could be built in.





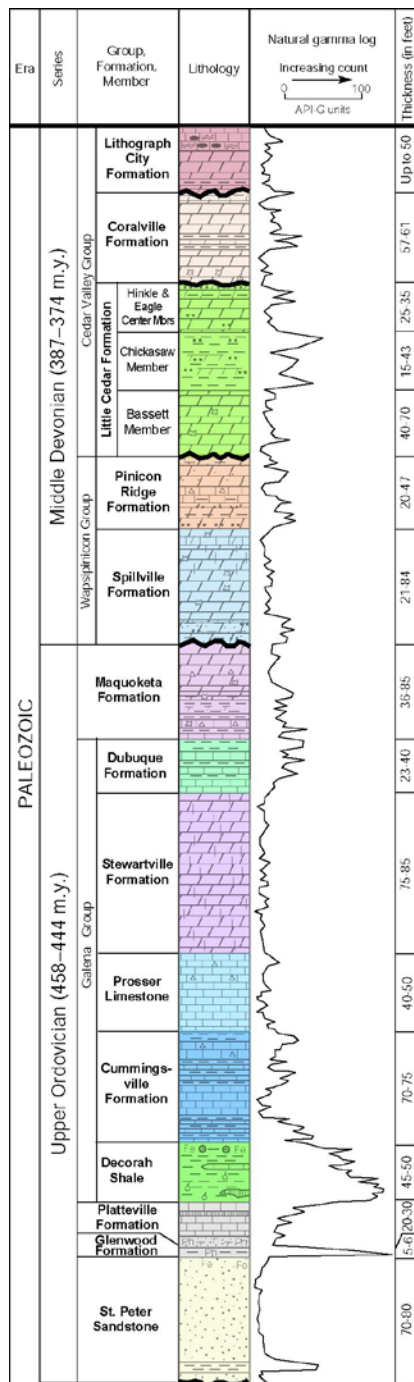
**Figure 2. Minnesota Karst Lands Map**

The colored portions of this map are underlain by carbonate bedrock. In the green and yellow areas there is >100 feet and 50 to 100 feet of glacial cover. Almost all of the surface karst features are in the < 50 feet of cover, red areas.

**Figure 2** is a cross between the bedrock geology and depth to bedrock maps in southeast Minnesota. In the red areas, active karst occurs where the cover over the bedrock is less than about 50 feet thick. The images on the next two pages show the bed rock lithostratigraphy in more detail.

**Figure 3** is a conventional stratigraphic column for the Paleozoic bedrock of southeast Minnesota. The vertical scale is proportional to the thickness of the individual rock units. Unconformities are shown but represent gaps in deposition and or erosional removal of previously deposited rocks.

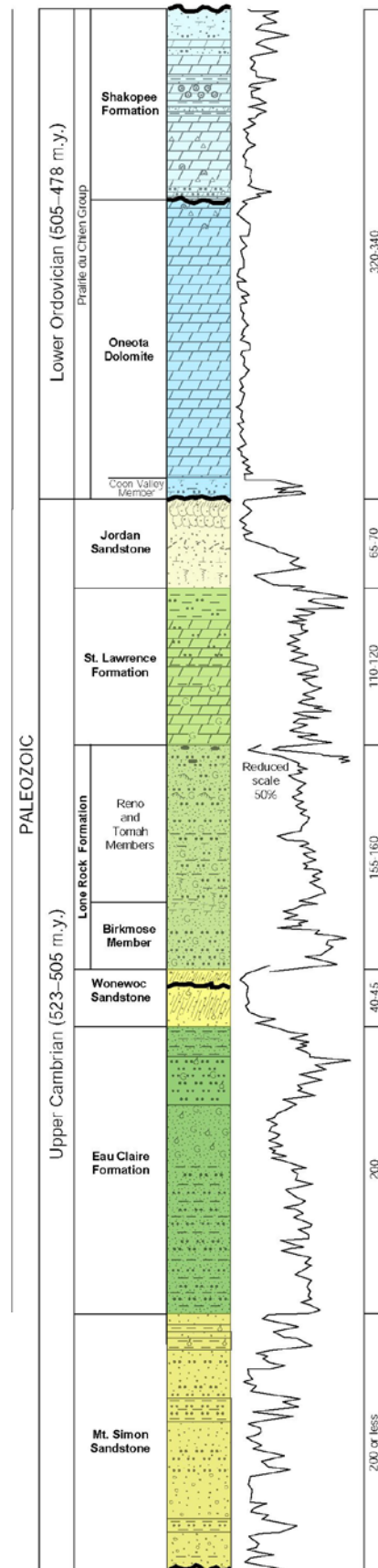
**Figure 4** is the same information plotted on a chronostratigraphic column where the vertical scale is linear time. This figure illustrates that the unconformities represent large gaps during which karst processes were operating. Many of the karst features we will see today may be traced back to syndepositional features. Many of the karst features may be very old.



Continued above right

**Figure 3. Paleozoic lithostratigraphic column of SE Minnesota bedrock**

The vertical scale is linear unit thickness. Unconformities accented in black (Alexander et al., 2013).





## Stop 1

### St. Peter Sandstone and Glenwood Shale

*Parking lot, Paragon Chateau 14 Theater, 37th St. and US 63*

*in Rochester, Olmsted Co., Minnesota*

*44 ° 03' 33.82" N; 92° 26 ' 58.93" W*

*1039 ft. elevation*

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The St. Peter Sandstone is fine- to medium-grained, friable, quartzose sandstone, which is typically about 100 feet thick in Olmsted County. Some exposures are silica cemented but much of the Formation is so friable that it can be dug with a shovel or by hand. Freshly exposed surfaces of the St. Peter are typically bright white to light gray and often display bright yellow to red to purple Liesegang banding near its top. Newly exposed surfaces develop a hardened gray to black surface within a year or two. The St. Peter is widely exposed in both natural and artificial faces. The basal contact with the underlying Shakopee is rarely exposed (an erosional unconformity and interstratal karst surface).

The St. Peter should be close to an ideal porous medium. However, as you look at this face note the large, systematic, open, near vertical joints that are exposed. We will pass several exposures of St. Pete in road cuts on this trip. Watch for the big open joints. They are always there. The St. Peter is at least a dual porosity aquifer.

In addition, this face has exposed a large filled crevice in the St. Peter. This cryptic feature is not well understood. The fill does not appear to contain any glacial materials and so is probably pre-Pleistocene. Note the complex smaller joints near the edges of the fill. Is this a filled feature formed by collapse into the underlying Prairie du Chien? Engineering boreholes in the Rochester area have encountered a significant number of open voids in the St. Peter. The foundations of several of the buildings in Rochester had to be modified and upgraded when such voids were found. There are several small caves known in the St. Peter in Minnesota and sinkholes have been mapped where the St. Peter is first bedrock.



**Figure 5. Cut face of the St. Peter Sandstone at the Paragon Chateau 14 Theater parking lot Rochester, Minnesota. Both systematic joints and a large filled fracture are visible.**



In October 2005 a stormwater retention pond in a new housing development in Woodbury, Minnesota was filled for the first time by a heavy rain fall. Within a few days about a dozen sinkholes developed in the sides and bottom of the pond and drained 60 acre-feet of water into the underlying St. Peter and Prairie du Chien aquifers. The largest sinkhole developed on top of a feature that probably resembled the filled crevice visible at this stop.



**Figure 6. Catastrophic collapse sinkholes in the St. Peter Sandstone**

These drained a storm water retention pond in the Dancing Waters development, Woodbury, Minnesota in the southern Twin Cities metropolitan area



**Figure 7. Close up photo of the largest sinkhole that drained the Dancing Waters storm water retention pond**

There is a thin delta of recent sediments over an 18 inch clay liner, over a varying wedge of glacial deposits over the St. Peter Sandstone.

## **Stop 2 (Rolling)**

*Golden Hill Cut – Western Face*

*Road cut on US 52 between the Zumbro River and US 63 in southwestern Rochester*

*Rochester, Olmsted Co., Minnesota*

*43° 59' 18" N; 92° 28' 47" W*

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The Golden Hill Road Cut on US 52 has long been a favorite stop with geologists and hydrogeologists. The road cut was expanded to the west in 2003 and 2004 as part of a Minnesota Department of Transportation project to widen and rebuild US 52 through Rochester. This new excavation work exposed a beautiful section from the top of the St. Peter Sandstone through the Glenwood Formation, the Platteville Formation, the Decorah Shale, and the bottom section of the Cummingsville Formation of the Galena Group. In addition to excellent fossil hunting in the exposed Decorah Shale, the road cut exhibits several well-exposed hydrogeologically significant features. As noted above, however, we may not be able to stop.

Numerous solutionally enlarged joints cut the Platteville Formation, which is exposed as a vertical face. Secondary calcite flowstone is visible on several of the exposed joint faces along with iron staining showing where groundwater has moved through the bedrock.

The Decorah Shale is exposed as a cut slope for stability and to help control land slips. Water is normally visible in the roadside ditch accumulating from flow in and at the top of the Decorah. Note that the Decorah Shale has a distinctly rusty orange “oxidized” tint in the northern 100 meters of the exposure while the rest of the Decorah Shale is a gray/green “reduced” color.

The alternating bands of carbonate and shale are clearly exposed in the vertical Cummingsville wall at the top of the road cut. There is considerably more topography on the eroded top of the Cummingsville than there is on the overlying land surface. In addition to numerous joints, several small conduits intersect the cut face. Some of these are currently actively carrying water. Others of them are currently dry. This difference is most obvious in the winter when large accumulations of ice form on the cliff faces where the groundwater emerges into the subfreezing air.

The movement of water through the Cummingsville Formation is neither homogeneous nor isotropic.





**Figure 8. West Side of Golden Hill Road Cut, looking north**  
March 2005, photo by Terry Lee.



**Figure 9. West side of Golden Hill Road cut, looking west**  
March 2005, photo by Terry Lee.



## **Stop 3**

*Schoenfelder Farms Blue Ridge CAFO  
Section 5, Orion Township, Olmsted Co. MN  
43° 55' 30.24" N, 92° 17' 18.71" W  
1273 ft. elevation*

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Schoenfelder Farms owns a large cattle feedlot operation (Blue Ridge) centrally located in the Orion sinkhole plain. The feedlot was initially permitted by the MPCA in 1991. The Schoenfelders' have been researching solutions to update the site and meet current pollution control laws. According to federal feedlot laws, the facility must comply with a "zero runoff" status and therefore must eliminate or collect all water leaving the feedlot. Many proposals have been presented by Schoenfelder Farms and their private engineers to the MPCA, but challenges have set back construction for three seasons. In attempts to find a suitable site for a large manure storage structure, many locations have been evaluated at Blue Ridge.

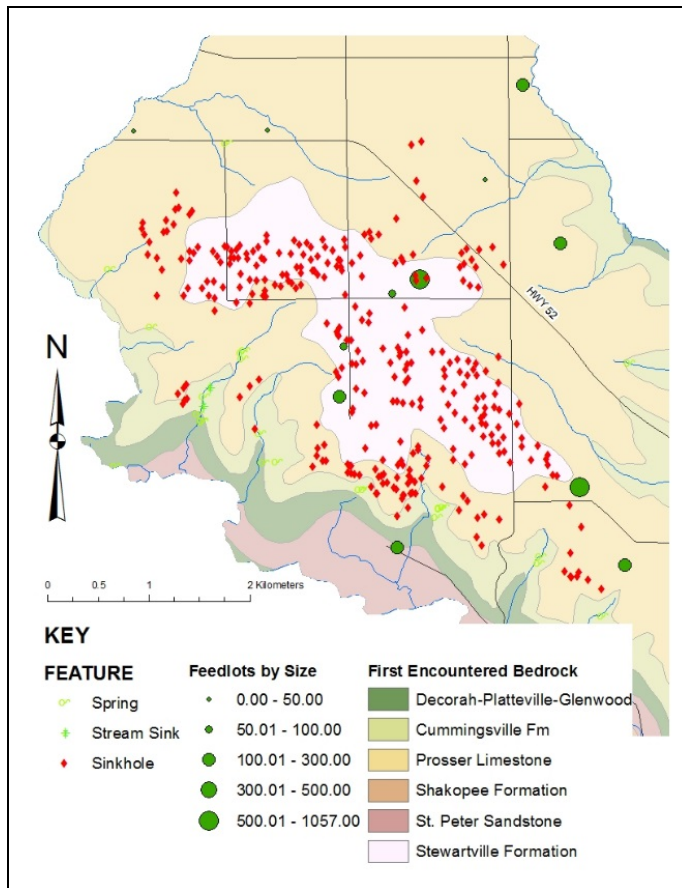
Three primary challenges exist for locating the proposed storage area. Minnesota feedlot rules require the following.

1. Due to the proximity of sinkholes within the plain, a liquid manure storage area (LMSA) cannot be constructed on most of the Schoenfelder property. According to Minnesota Feedlot rules LMSAs must not be located within 91 meters (300 feet) to any sinkhole. (Minn. R. 7020.2005 Subp. 1.)
2. The total size of the LMSA may not be larger than 950,000 liters (250,000 gallons) when four or more sinkholes exist within 305 meters (1,000 feet.) The required volume for the facility is significantly more than 960,000 liters, and many sites would not allow for the 22 million liter (6 million gallon) or larger structure. (Minn. R. 7020.2100 Subp. 2. A.)
3. Minnesota feedlot rules require a minimum vertical separation to bedrock of 3 meters (10 feet) when the site has a capacity of 1,000 or more animal units (1 slaughter steer is equal to 1 animal unit). Most of the sinkhole plain has soil cover of less than 1.5 meters. (Minn. R. 7020.2100 Subp. 2. B. [3])

Since the feedlot is located at the northern edge of the plain, the only potentially suitable location is 1000 feet north in an open field. One small corner of the Schoenfelder property appears to allow for separation to sinkholes and vertical separation to bedrock. In the fall of 2014, test pits were dug with an excavator to determine separation to bedrock.

As of March, 2015 research is continuing to find a solution that meets Minnesota Feedlot Rules and is a viable option for the Schoenfelders'. Additional geophysics exploration may include Electrical Resistivity Imaging in the spring of 2015.

This stop and surrounding issues will be discussed by Larsen (2015) during the Conference.



**Figure 10. A map of the Orion Sinkhole Plain (Larsen, 2015)**



**Figure 11. A pail of foaming water collected from the contaminated well**  
Photo by Steven Schmidt, 2013

## Stop 4

*Shakopee Formation, Prairie du Chien Group  
Road cut on US 52 just north of the Middle Branch of Root River,  
Chatfield Township, Fillmore Co., Minnesota*

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Stop 4 is stratigraphically the lowest stop on this field trip—near the middle of the Ordovician Prairie du Chien Group. The top of the New Richmond Sandstone is just above river level. It was exposed during construction of this road cut and bridge but was subsequently covered. The vertical road cuts are in the Willow River Member, Shakopee Formation, and Prairie du Chien Group. The thin to medium-bedded dolomite of the Shakopee Formation contains thin interbeds of quartzose sandstone and shale. There is a karst erosional unconformity between the Shakopee and lower Oneota Formation. The paleo epikarst developed on this contact is proving to be a significant horizontal high transmissivity zone in Prairie du Chien.

The most obvious solution features in these road cuts are the large solutionally enlarged vertical joints that are filled with rusty brown sediments. The spacing of these systematic joints is similar to those observed in the St. Peter outcrops. There is a lot evidence for bioherms and complex, small-scale deformation in these outcrops. Many of the Prairie du Chien outcrops show evidence of solution brecciation and many contain drusy quartz and sulfide minerals from low grade hydrothermal solutions.

The Prairie du Chien is one of the most heavily used aquifers throughout southeastern Minnesota. Downhole flow logging by the Minnesota Geological Survey has shown that most of the water movement in the aquifer typically takes place along thin “high transmissivity” zones.

The Prairie du Chien is also commonly quarried for road aggregate. The massive bed of carbonate that makes up the bottom of this outcrop is one of the most valuable beds in the entire Prairie du Chien section. This bed, when quarried and crushed yields the highest quality gravel for highway construction.



**Figure 12. Lower Shakopee Formation road cut**

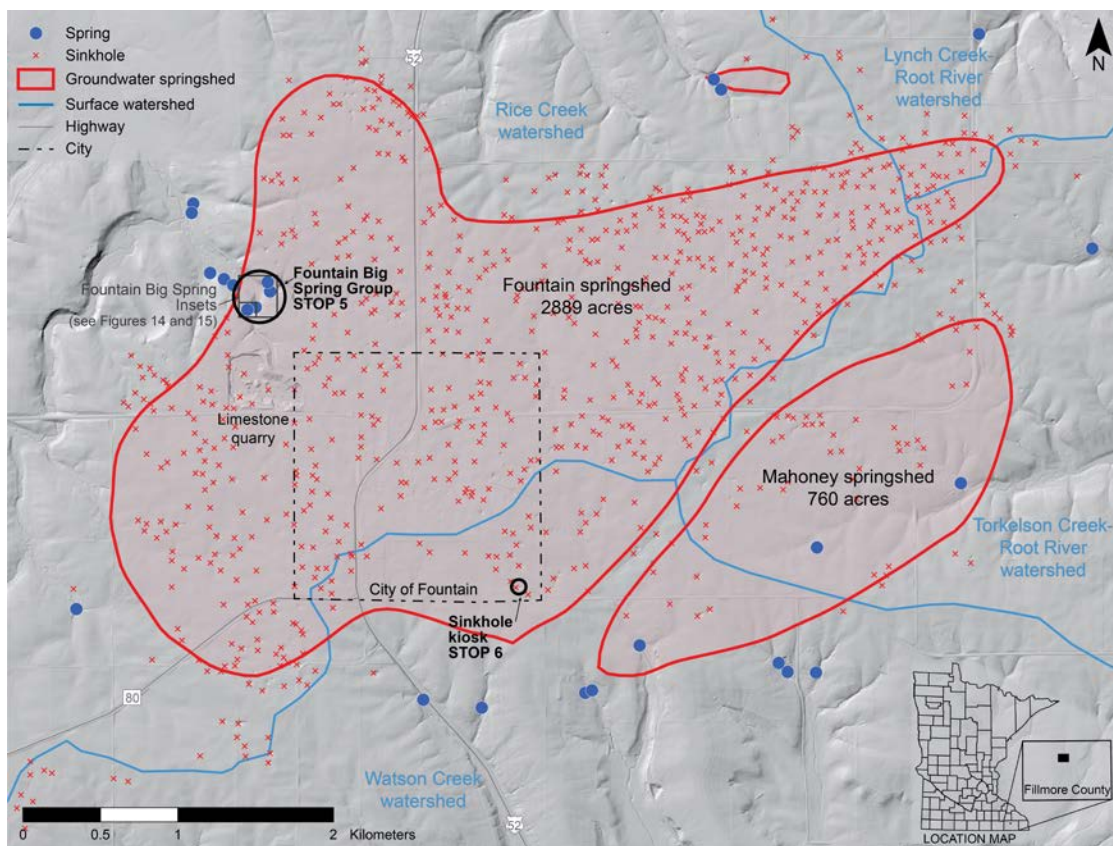
Both major solutionally enlarged vertical joints and a solutionally enlarged subhorizontal features. Note also the thin soil cover over the bedrock but no sinkholes or other surface karst features.



## Stop 5

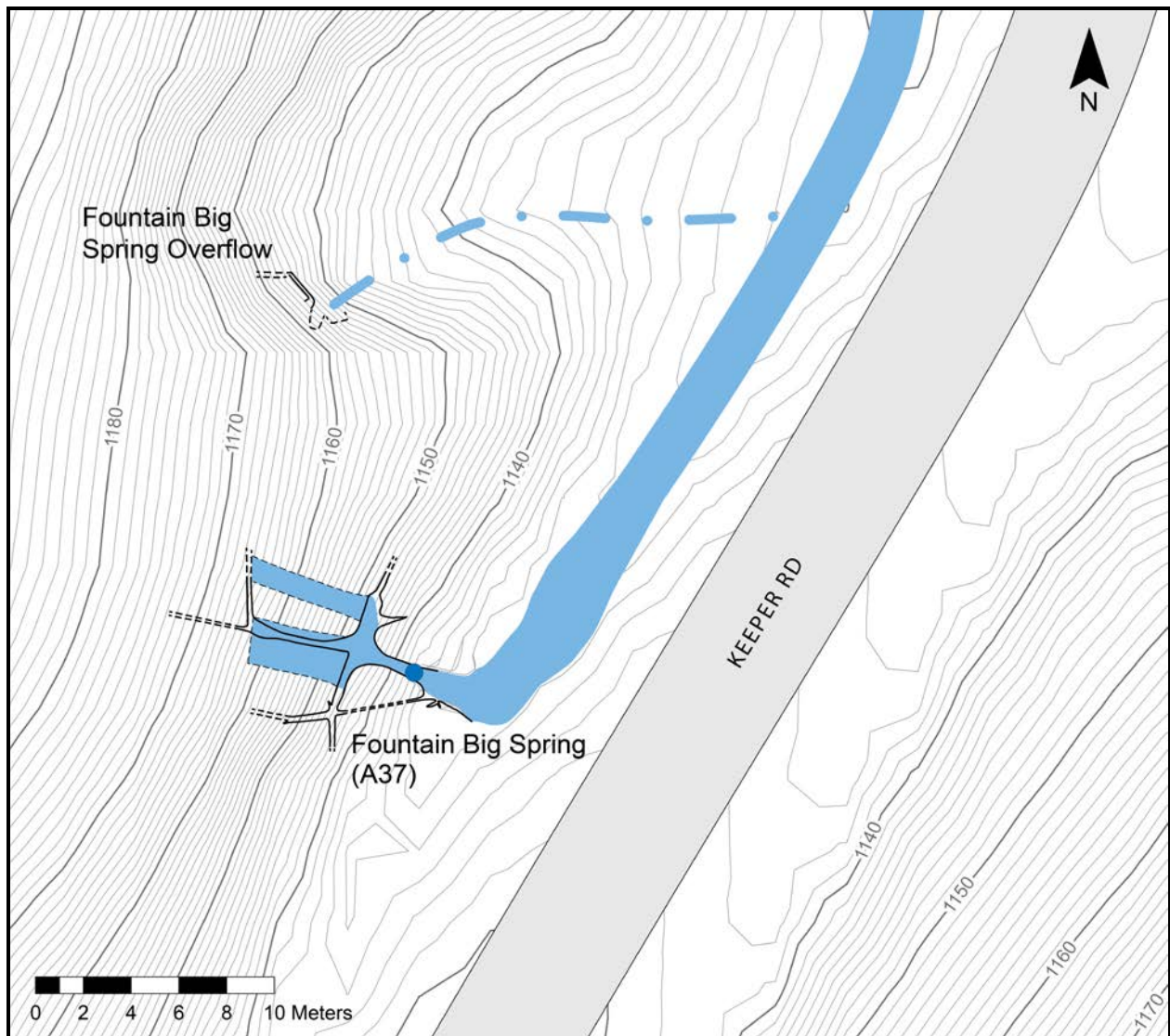
*Fountain Big Springs, MN23:A0037*  
*Cummingsville Formation, Galena Group*  
*Fountain Township, Fillmore Co., Minnesota*

As you drive up onto the upper Galena Group north of the town of Fountain, MN, you enter a sinkhole plain geomorphic unit. Red “x”s are superimposed on the LiDAR image in Figure 13 of the Fountain area marking many, but not all, of the sinkholes. These sinkholes quickly route any surface runoff into the underlying karst aquifer. The light blue dots mark many, but again not all, of the springs where the groundwater returns to the surface. The dozens of dye traces that have defined the three springsheds shown in Figure 13 have been omitted for clarity.



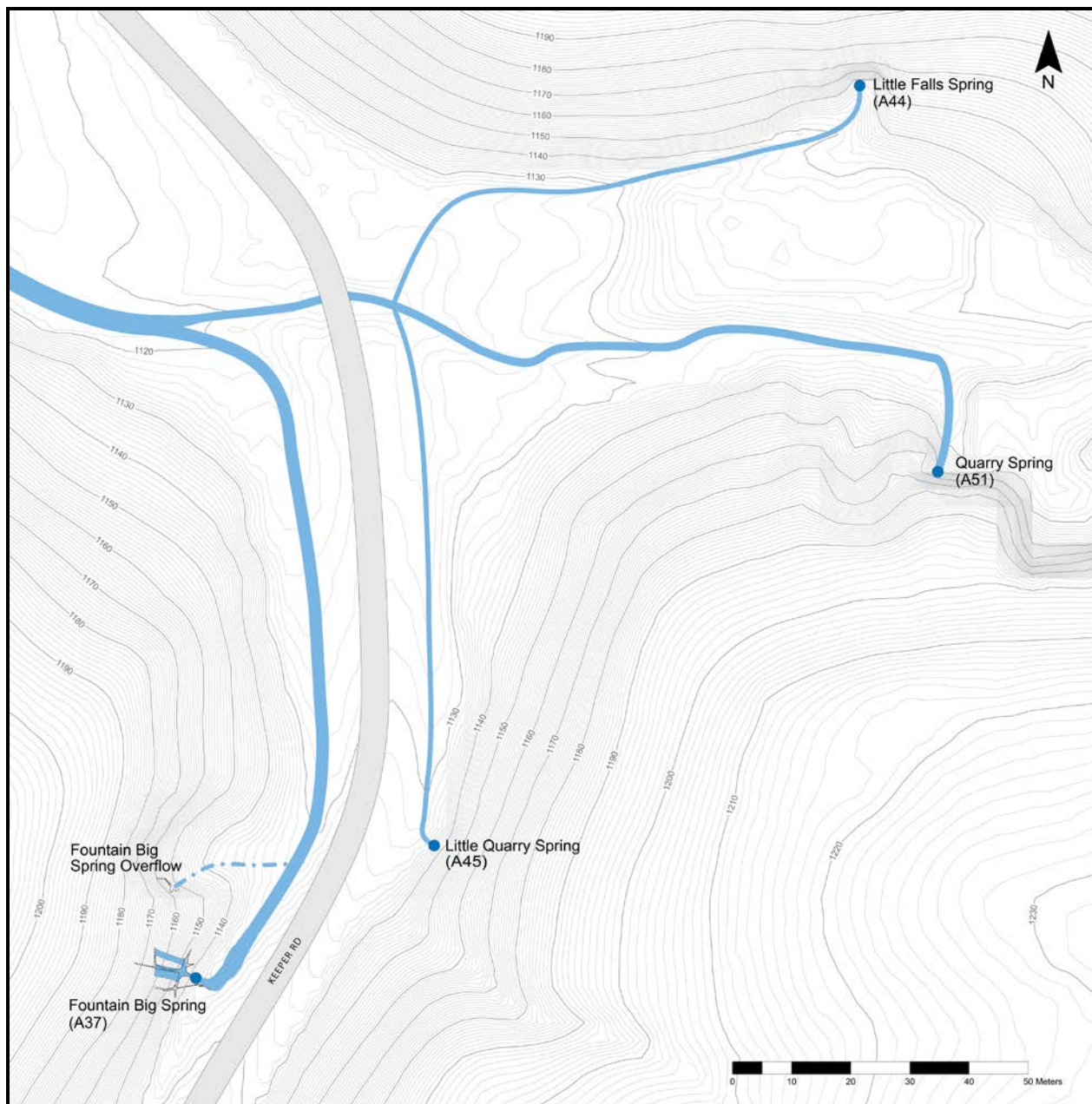
**Figure 13. Fountain Sinkhole Plain. Stops 5 and 6.**

Stop 5 is at the major spring complex that drains much of the area. Many of the sinkholes in and around Fountain drain to the spring complex at Stop 5, with a time-scale of hours. A map of the largest of these springs, Fountain Big Spring – MN23:A00037, is shown as Figure 14 detailing the current and former outlet points of Fountain Big Spring’s orifices which highlights the fact that springs move. There are several “Big Springs” scattered around SE Minnesota, hence the unique identification number assigned to each specific spring and other karst feature.



**Figure 14. Fountain Big Spring, MN23:A00037, Diagram by Holly Johnson, Minnesota DNR**





**Figure 15. Fountain Spring Group, Diagram by Holly Johnson, Minnesota DNR**

These four springs are the head of Rice Creek.

One of the conduits feeding the Fountain Spring Group can be accessed, via open crevices, at least four places in the quarry just south of the springs. The conduit is oval in cross-section about 4 feet high and about 10 feet wide. It has smooth, sinuous walls. Stand up spaces develop when the conduit crosses one of the major systematic joints cuts.

Figure 15 shows the four distinct but interacting springs emerging within a few hundred feet of each other near Stop 5. All four springs emerge near the base of the Cummingsville Formation in the Galena Group just above the Decorah Shale. These are typical conduit springs. Their flow often increases by an order of magnitude within a couple of hours after a rainfall and the springs become very sediment laden.

Springs can become plugged by colluvium or debris or the spring can develop a new lower elevation outlet, either naturally or through human intervention. Fountain Big Spring has moved in the not too distant past. The previous outlet is a few feet down the valley and is now acting as a high flow overflow spring. That this was the main spring outlet for a long period is evident from the size of the notch or “steep head” that was eroded into the valley wall by the old, higher spring outlet. Construction of the road down the ravine may have caused the new opening of the spring to form.

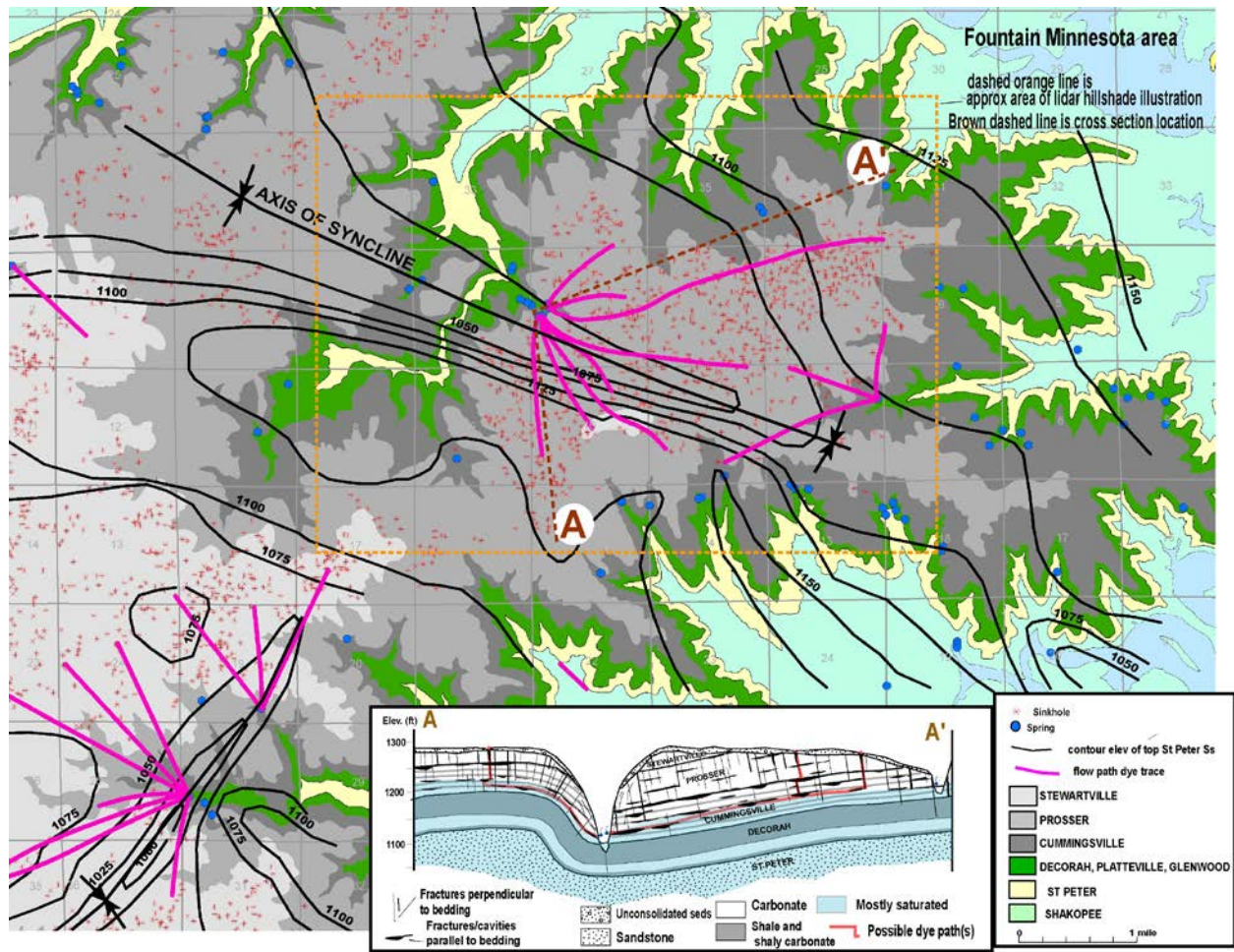
Little Quarry Spring, MN23:A00045, emerges from a joint/bedding plane intersection across the road from Fountain Big Spring. Under some flow conditions water entering sinkholes in Fountain emerges from the springs on both sides of the road. Under other conditions it emerges from one or the other depending on where it sinks. Stage dependent changes in the flow systems feeding karst springs are common.

Quarry Spring, MN23:A00051, emerges around the point of the ridge east of Little Quarry Spring in an old limestone quarry. Little Falls Spring, MN23:A0044, emerges on the south side of the ridge north of Quarry and Little Quarry spring. The spring runs from all four springs converge at the culvert just north of Fountain Big Springs to form the headwaters of Rice Creek, which flows north and then northeast to the Middle Branch of the Root River, downstream from Stop 5.

Dye traces from many of the sinkholes in the Fountain Sinkhole Plain have defined two major subsurface springsheds that drain the Fountain Sinkhole Plain. Most of the sinkholes drain to the four springs at Stop 5. The subsurface drainage cuts across several first order surface drainage basins. A smaller set of the sinkholes in the southeastern corner of the Sinkhole Plain drain to a spring that is the headwaters of Mahoney Creek which flows east to the Middle Branch of the Root River. The question of why so much of the groundwater drains to the four springs at Stop 5 is beginning to be understood as the result of detailed structural contour mapping on the area bedrock by the Minnesota Geological Survey (Tony Runkel, written communication, 2012; see also Runkel and others, 2013). These four springs drain from the axis of an asymmetric syncline that is plunging to the northwest.

Figure 16 below is a preliminary version of Tony Runkel’s work showing the relationship between the bedrock geology, the sinkholes, dye traces, springs, and the synform. In the lower left you can see a couple of other nearby springsheds near the community of Wykoff. We are actively conducting additional dye traces and stratigraphic field work to refine this map.





**Figure 16. Structural contour map of central Fillmore County**

This shows structural control of spring locations (Runkel, written communications, 2012)

## Stop 6

*DNR Sinkhole Kiosk, Fountain.*

*From Root River Trail parking lot on south side of Co. 8  
in southeast edge of Fountain proceed 0.4 miles along the trail to Kiosk.*

*43° 44' 08.97" N; 92° 07' 35.95" W*

*1295 ft. elevation*

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At this stop, we will walk on the Root River State Trail (which is built on an abandoned railroad right-of-way) to a sinkhole where the Minnesota Department of Natural Resources–Parks and Trails Division installed a karst educational display. The display is designed to educate trail users about karst land & water resources. The first bedrock here is Prosser Formation limestone of the middle Ordovician Galena Group. Unconsolidated material depth over the bedrock is less than 15 meters. This area is representative of the high-density sinkhole plains that occur on broad ridge tops underlain by the Prosser limestone or Stewartville limestone of the Galena in southeastern Minnesota and northeastern Iowa. The density of the sinkholes can be seen on the 2009 LiDAR imagery. This is the northern end of a broad arc of Galena that runs from southeast Minnesota through Iowa into Wisconsin and Illinois.

As part of the display design, a dye trace was conducted from this sinkhole. Liquid fluorescein (206 gm.) was poured into the sinkhole's swallow hole and was flushed with 4500 liters of water from a fire truck. The dye was detected at the Fountain Big Spring which lies to the northwest. Breakthrough flow velocity was 1-2 miles/day. The area around Fountain is in the groundwater springshed which feeds the Fountain Big Spring and three other smaller springs that are associated with it.

## Stop 7

### *Niagara Cave*

*2.5 miles south of Harmony on Minnesota 139, 2.3 miles west on Fillmore Co. 30*

*Harmony Township, Fillmore Co., Minnesota*

*43° 30' 50.16" N; 92° 03' 18.06" W*

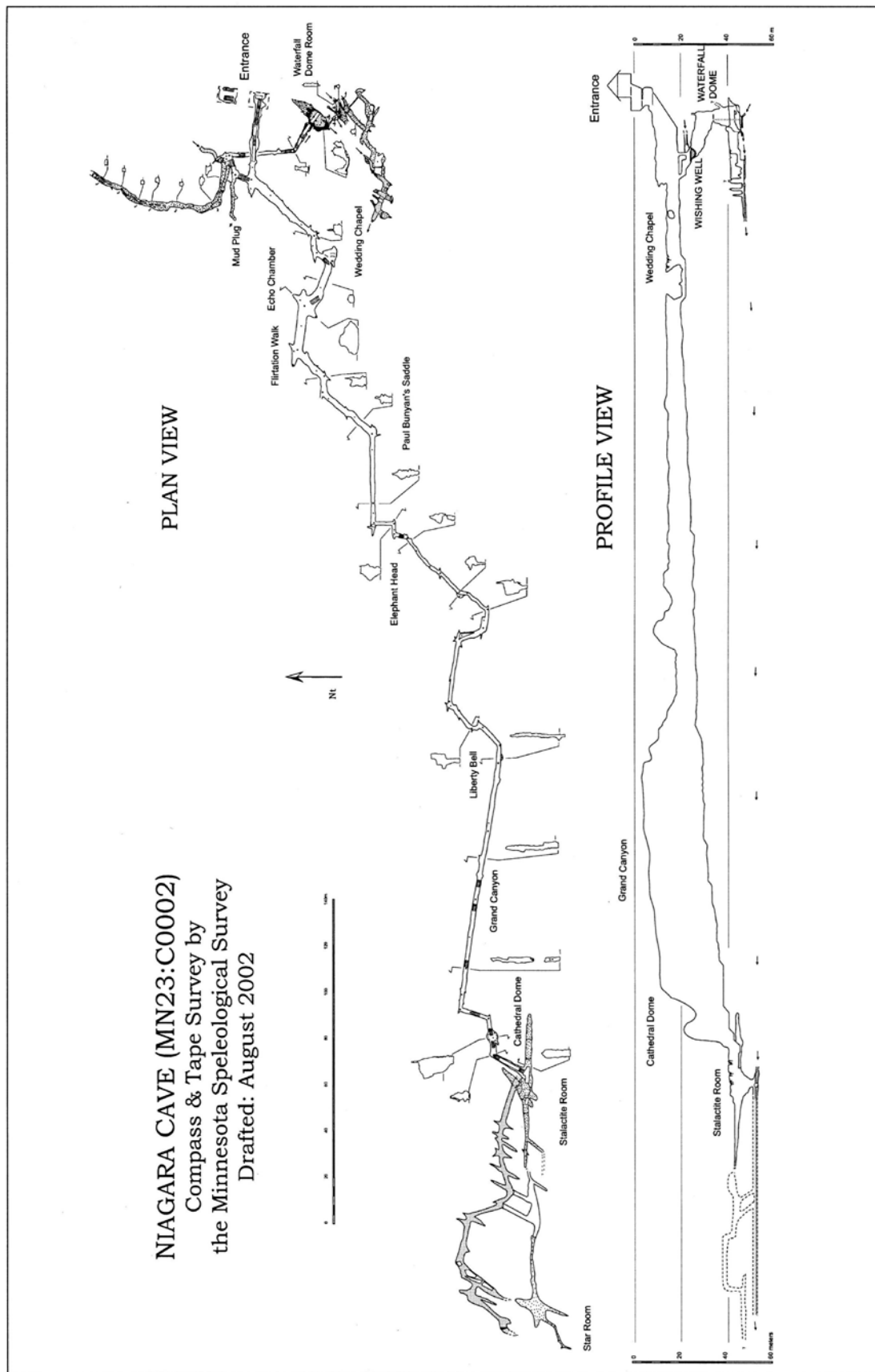
*1265 ft. elevation*

<http://www.niagaracave.com>

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Niagara Cave will be one of the lunch stops on the field trip. The group will split into two groups. One group will tour the cave while the other eats lunch. Then the two groups will reverse. Our hosts, the Bishop Family, will be happy to sell you a wide variety of interesting, geologically oriented souvenirs from their gift shop.

Figure 17 is the map of Niagara Cave. Niagara Cave is an unusual upper Mississippi Valley cave. Most of the large caves in the southeast Minnesota/northeast Iowa karst are maze caves developed near the Galena/Dubuque contact (Mystery Cave, for example) or dendritic stream conduit caves developed near the bottom of the Galena in the Cummingsville Formation (Cold Water Cave, Tyson's Spring Cave, etc.) Niagara's entrance is a sinkhole through the Dubuque Formation. The cave cuts down through the Stewartville Formation in several dome pits and vadose canyons to a stream passage in the Prosser Formation.



**Figure 17. Niagara Cave Map**



Dye tracing has shown that the cave stream returns to the surface in Hawkeye Spring on the edge of the Upper Iowa River. Niagara Cave contains the best, most accessible example of a cave stream, active vadose canyon, and waterfall of any cave in the area.

The landscape we have been driving across south of Rochester consists of an ancient, erosion surface that cuts across the Paleozoic stratigraphy. That ancient erosion surface probably dates back to at least Cretaceous time. It has been glaciated several times during the Pleistocene. It was not covered by ice during the Wisconsin Glacial, but did receive an agriculturally significant layer of loess at the end of the Wisconsin. That flat surface is being dissected by modern streams (the Cannon, Zumbro and Root Rivers) which drain eastward to the Mississippi River. The landscape consists of flat topped interfluvies (which are in intensive row-crop agriculture) cut by steep sided recent valleys. Many of the springs emerge from near the bottoms of the steep valley sides and drain to the base flow rivers.

The water tables under the interiors of the interfluvies are often shallow and low gradient. Many of the base level springs emerge, at a significantly lower level, from low gradient stream caves which can extend for miles back into the interfluvies. Niagara Cave shows how the groundwater moves from the high flat water tables to the low flat water tables. The ground water moves in high gradient conduits and waterfalls between the two parts of the groundwater system.

A fascinating system of up-gradient stream piracy via dome pits is evident in Niagara Cave.

## Stop 8

*Mystery Cave I Visitor Center*

*Forestville/Mystery Cave State Park*

*Forestville Township, Fillmore Co., Minnesota*

*43° 37' 02.25" N; 92° 18' 42.58" W*

*1243 ft. elevation*

[http://www.dnr.state.mn.us/state\\_parks/forestville\\_mystery\\_cave/index.html](http://www.dnr.state.mn.us/state_parks/forestville_mystery_cave/index.html)

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Mystery Cave is an over 12 mile long maze cave developed in the Dubuque and Stewartville formations and is the longest mapped cave in Minnesota. The goal of this stop is to see the Mystery I Park and visit the Visitors Center. It was operated as a private commercial cave from 1947 to 1984, and then the cave was purchased in 1984 by the State of Minnesota and made part of the pre-existing Forestville State Park. Guided tours are conducted in Mystery I along lighted, handicap-accessible paths by Department of Natural Resources staff cave guides. These tours leave from the Mystery Cave Visitor Center.

A plan view map of Mystery Cave is shown in Figure 18. The strong joint control on the cave's development is evident in the preferred directions of the cave passages. Mystery Cave is divided into three parts, Mystery I, II, and III, based on the history of the discovery of the sections of the cave. Mystery Cave contains several types of passages.

Solutionally enlarged joints in the Stewartville Formation are typically straight, narrow passages, several 10s of feet high and often with a solution tube at the contact with the overlying Dubuque Formation. The straight crevices with tubes at their tops form a characteristic "key hole" cross section. Differential weathering of trace fossils in the Stewartville produce characteristic "knobbles" on the surface on the sides of the crevices. The resulting passages are called "Stewartville Crevices" and range from just wide enough to get one's body through to not quite wide enough to get one's body through.

A second major passage type are "big Dubuque passages", which are rectangular shape passages formed by ceiling collapse of the Dubuque layers into lower solution voids. These passages are often 10 to 30 feet wide with flat ceiling and straight walls.

A third significant passage type is large, solutionally sculpted passages in the Stewartville. These are only present in Mystery II as the east part of 5th Avenue and its continuation down the Garden of the Gods at the east end of the known cave.

A fourth type of passage is the currently active stream passages in the Stewartville that make up the lower levels of the cave.

The cave currently functions as a meander cut-off for a series of entrenched bedrock meanders on the South Branch of the Root River (cave cross section, Figure 19). The South Branch sinks into the cave, flows underground through the lower level passages of the cave, and then re-emerges in the Rise of the South Branch at Seven, Crayfish, and Saxifrage Springs. During all but flood flows a several mile long stretch of the River is completely dry. The South Branch is a

low-grade warm water fishery above its sinks. It becomes a high-grade trout fishery downstream from the springs. Fishing for anything is lousy in the dry stretch.

Air-filled passages in Mystery I extend under the Root River. The river is perched about 20 feet above the local water table. The sinking points move around the riverbed. A sinking point is an ephemeral feature. As water flows into the sinking point, any limbs, leaves, or other trash floating in the river get sucked into the sink and plug it. Conversely, floods scour the bottom and sides of the channel and open new connections to the underlying conduit system. Depending on flow conditions the terminal sink moves up and down the River.

The Underground Rivers of Mystery Cave map summarizes what is currently known from tracing experiments about the various flow connections between the sink points, through the accessible stream passages in the cave, to the springs. Sink points near the top of the meander cut-off feed both the Rise of the Root River springs and the two large springs that form the head of Forestville Creek several miles to the north east. Note that the river passages in the cave run entirely in joint segments, but the overall trend of the underground stream is from the sink points to the springs, and the overall trend does not follow the preferred joint direction.

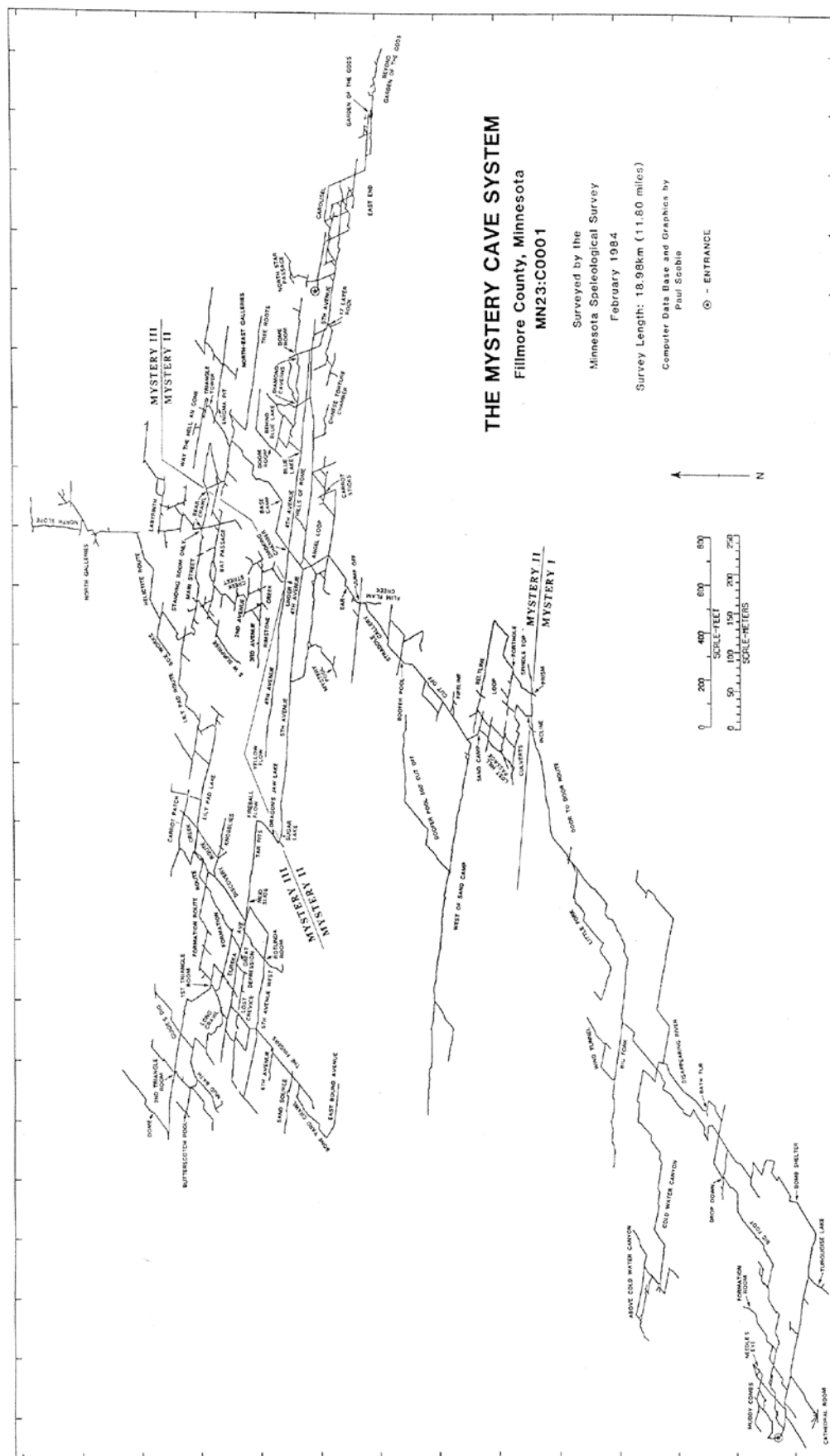
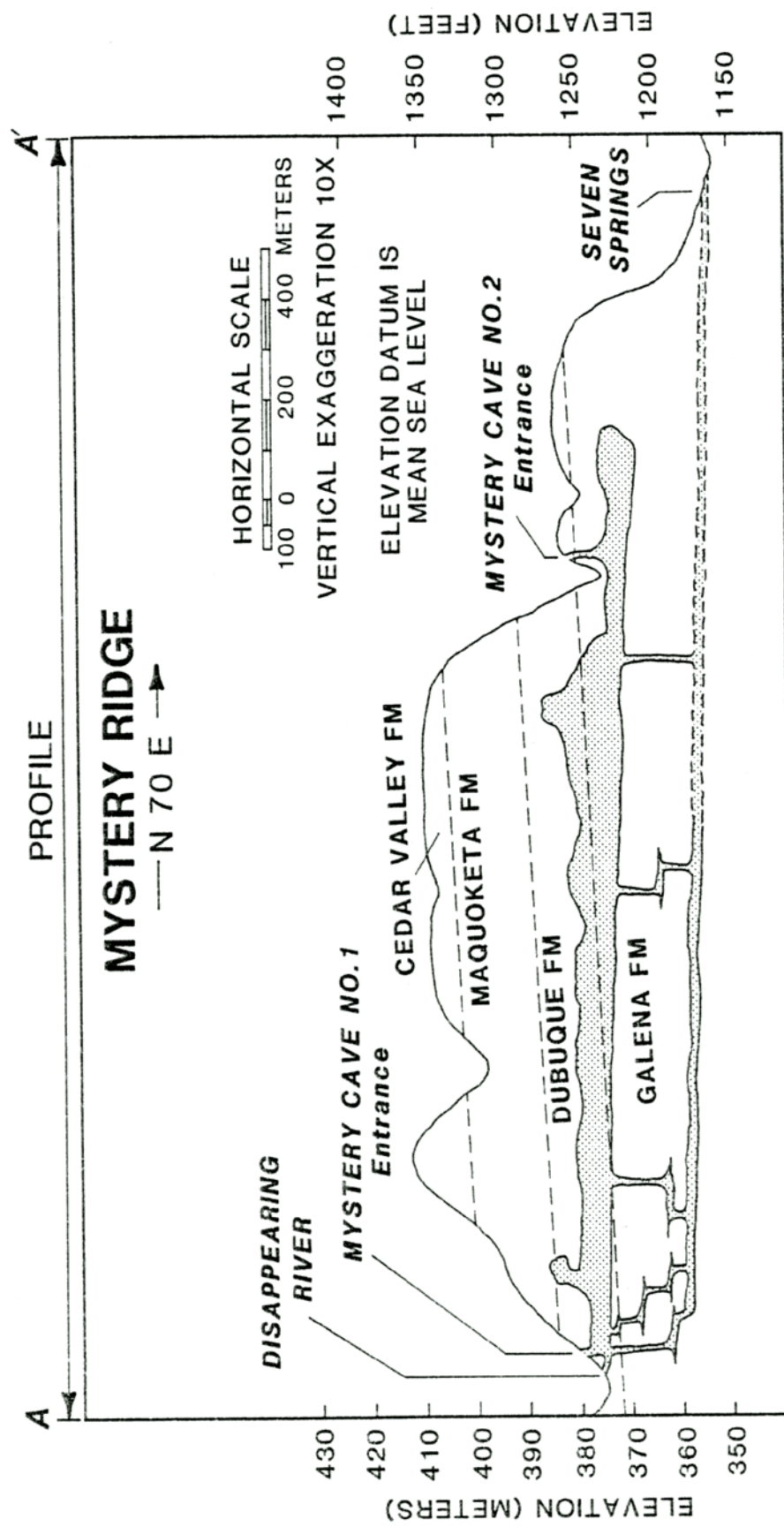


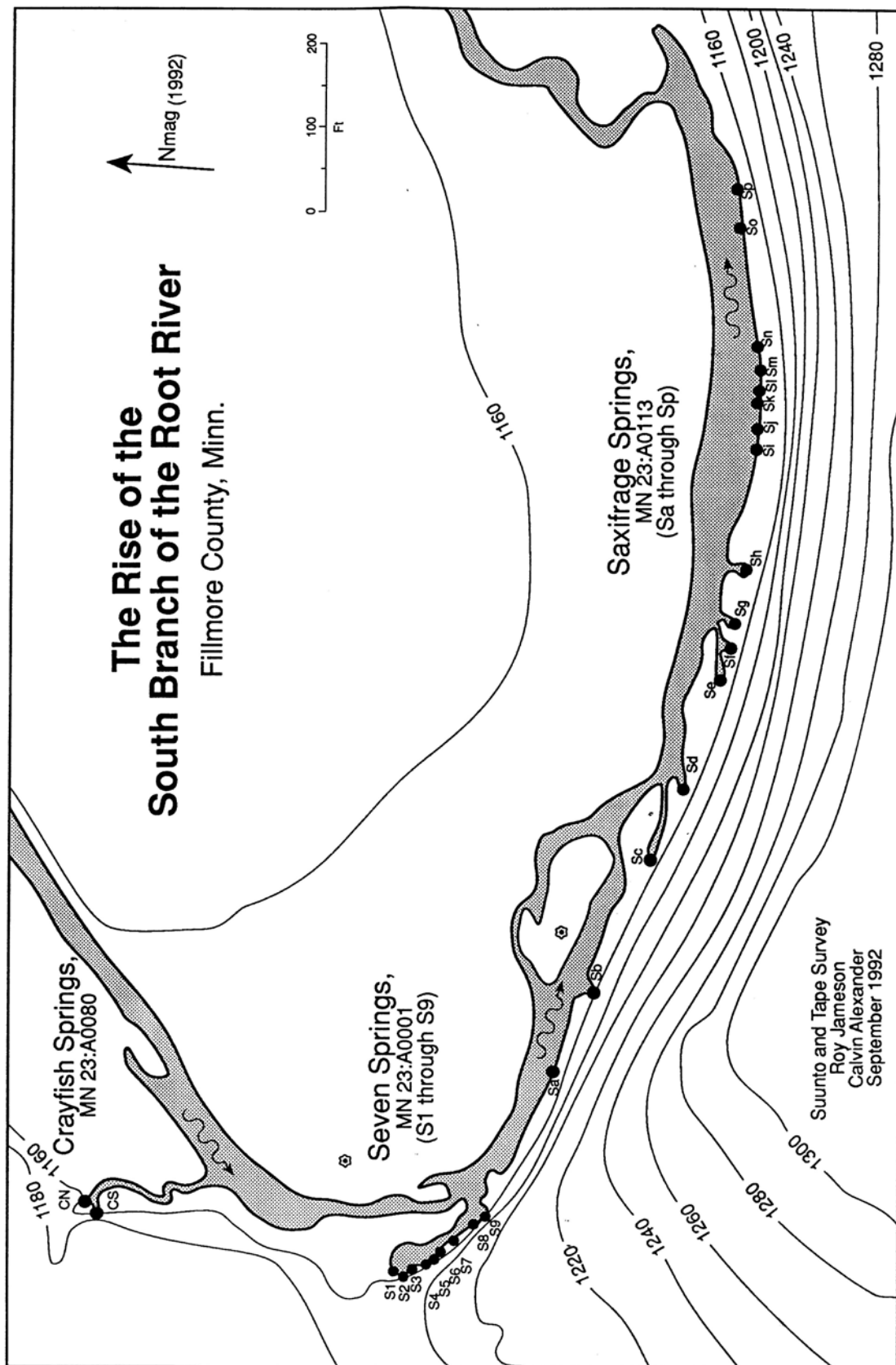
Figure 18. 1984 Minnesota Speleological Survey Map of Mystery Cave





**Figure 19. Simplified cross section of Mystery Cave to Seven Springs**  
Fig. 3, Milske et al., 1983.





**Figure 21. The resurgence of the South Branch of the Root River**  
Located at Seven, Crayfish and Saxifrage Springs.

## Stop 9

*Cherry Grove Blind Valley Scientific & Natural Area/  
Goliath's Cave.*

*43° 34' 54.88" N; 92° 15' 51.07" W*

*1290 ft. elevation*

*<http://www.dnr.state.mn.us/snas/detail.html?id=sna02022>*

*<http://www.cavepreserve.com/goliath.html>*

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The Cherry Grove Blind Valley Scientific and Natural Area (CGBV SNA) is a 40 acre parcel owned by the Minnesota Department of Natural Resources (DNR) and is part of the state Scientific and Natural Areas program. The CGBV SNA is an excellent example of a blind valley in the Galena Group karst. It was purchased in order to preserve and protect the surface and subsurface karst features. Dye tracing from the blind valley demonstrated that the water sinking there flowed through a large conduit (Goliath's Cave) to the Canfield Big Spring. This is the headwater spring of Canfield Creek, a state-designated trout stream. The former owners of the property had submitted an application to Fillmore County to convert the property into a limestone quarry. The county preferred that the property be purchased by the state to provide for its permanent protection. The property was purchased by the DNR in 1999.

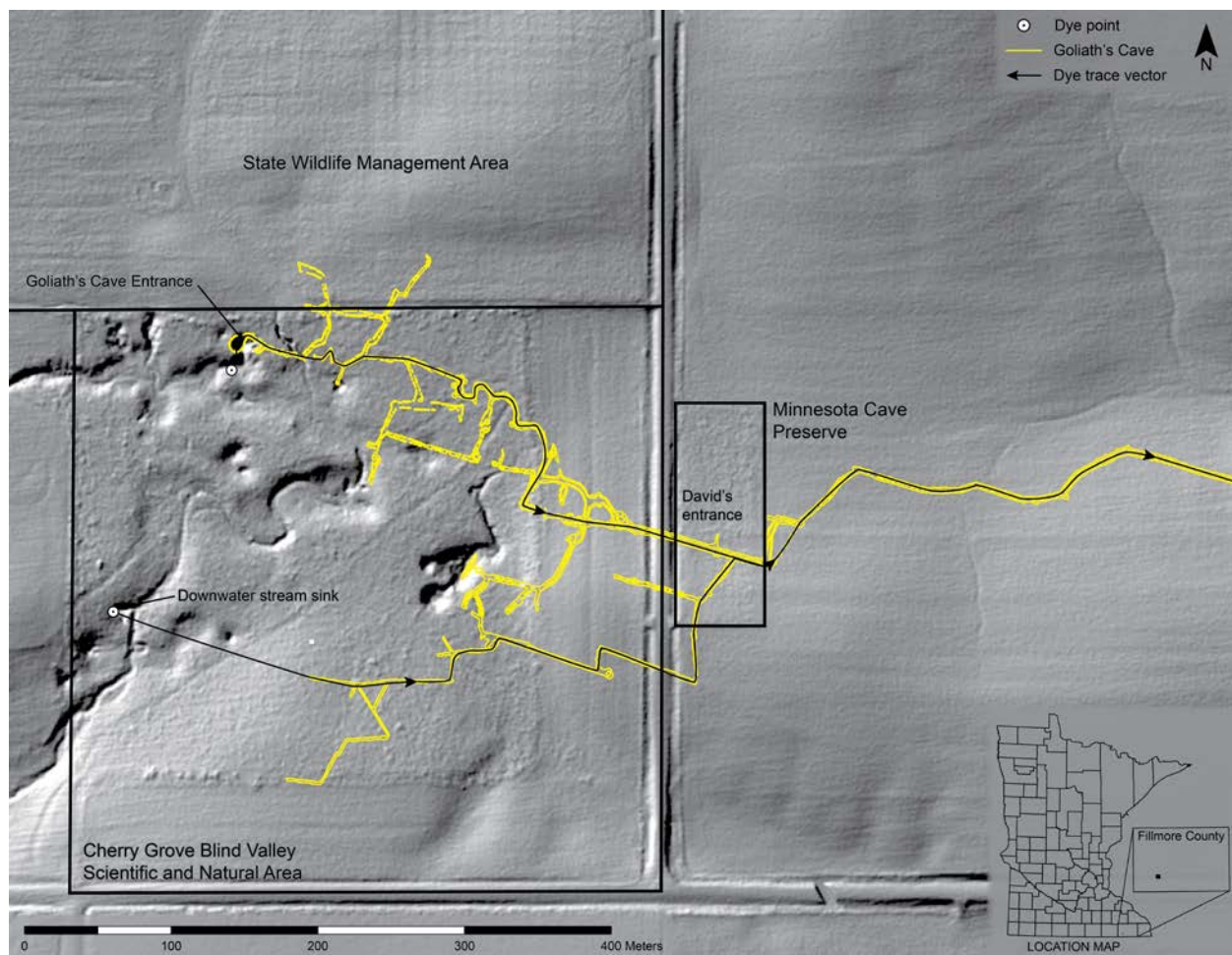
The Minnesota caving community had been aware of what was then called Jesse's Grove since 1950s. The area was named for Jesse McCracken, an early settler in the area who had lived her entire life adjacent to the property. The cavers knew that the woods contained numerous sinkholes, several sinking streams, and at least three caves. One small cave was dry. One cave was a stream sink that led to tight, partially water filled passages. The third cave had an entrance crawl that was often sumped or clogged with debris washed from the large sinkhole/ephemeral stream sink entrance. Cavers found that beyond the dangerous entrance crawl was a maze of walking passages in the Dubuque Formation. At the east side of the maze section of the cave a small and wet passage led to walking passage in the top of the Stewartville Formation. That passage extended for half a mile to the east before dropping down into a major flooded conduit. The cavers named this entire cave system Goliath's Cave after a large column found at the end of the entrance crawl.

The SNA program gated the small dry cave and the entrance to Goliath's Cave; access to the cave is only allowed for research, survey and management purposes. However, most of the cave is east of the CGBV SNA property. John Ackerman purchased a few acres of land immediately east of the CGBV SNA and the underground rights to the entire 80 acres east of the SNA and made the property part of his Minnesota Cave Preserve. He drilled a 30-inch diameter entrance shaft (named David's Entrance) into the main stream passage and opened his section of the cave to exploration and scientific study. The "interactions" between the SNA program and John Ackerman were not friendly and have been chronicled in the book *Opening Goliath*, by Cary J. Griffith (2009). Ongoing hydrogeological studies have focused on the Cave Preserve part of Goliath's Cave due in large part to the safe, rapid access to the bulk of the cave via David's Entrance. The work reported by Alexander and others (2015) at this meeting was only possible

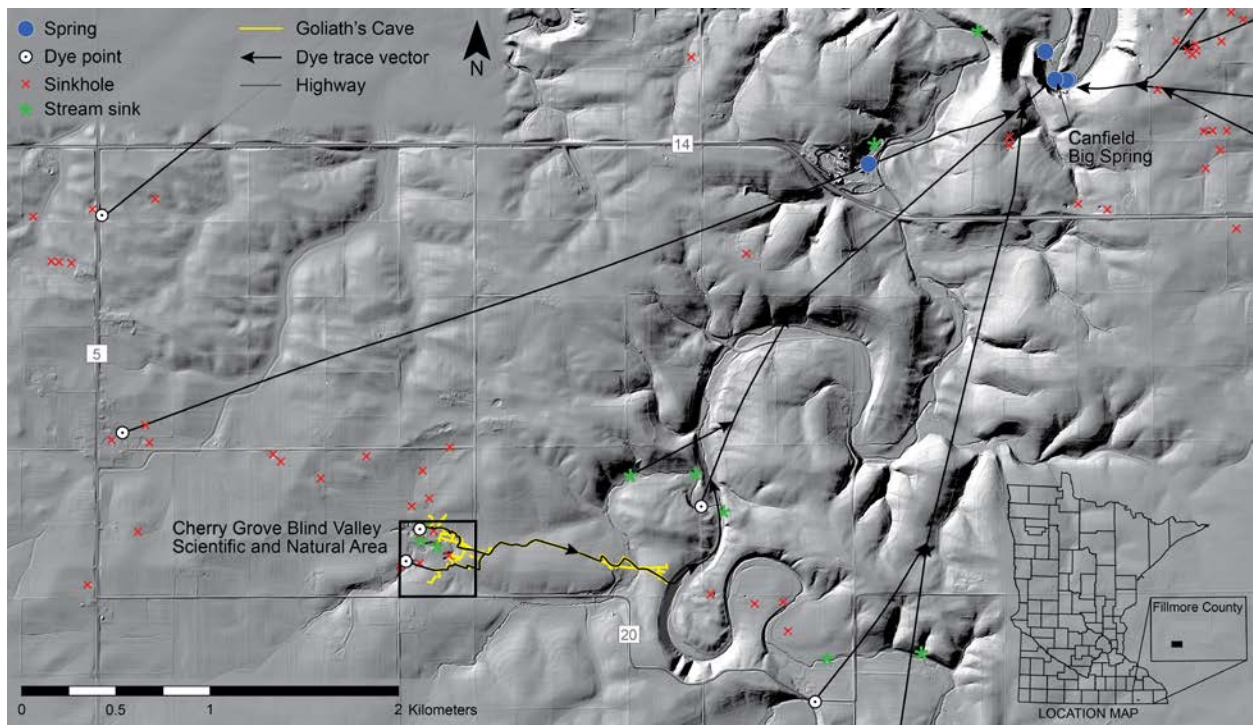


because of the availability of David's Entrance. Goliath's Cave appears to contain both old hypogenetic passages connected and enlarged by new epigenetic speleogenesis.

This field trip stop will focus on the surface features of the CGBV SNA. Depending on the weather conditions, we will visit one or more sinking streams, several sinkholes, the natural entrance (Goliath's Sinkhole) and one of several agricultural tile drain outlets that empty into the blind valley. This stop will involve about half a mile of walking through the woods of the blind valley. Figures 22 and 23 show the relationships between Goliath's Cave and the surface karst features in the CGBV SNA. Note that there are no surface karst features over the Minnesota Cave Preserve sections of Goliath's Cave. If a few people are interested, a visit to the Cave Preserve section of Goliath's can be arranged during or immediately after the Sinkhole Conference.



**Figure 22. Cherry Grove Blind Valley Scientific and Natural Area and the adjacent Minnesota Cave Preserve**



**Figure 23. Flow system**

From Cherry Grove Blind Valley Scientific and Natural Area, the Minnesota Cave Preserve and Goliath's Cave to Canfield Big Spring at the south edge of Forestville/Mystery Cave State Park.

## Stop 10

*City of Wykoff Storm Water System*

*Wykoff, junction of State 80 with County 5, Fillmore County, MN*

*43° 42' 28.09" N; 92° 16' 05.72" W*

*1322 ft. elevation*

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The City of Wykoff (pop. approx. 800) is located in western Fillmore County. It is in an area underlain by Stewartville Formation (fine-grained dolomitic limestone and dolostone) and Dubuque Formation (fine-grained limestone with thin shale beds) bedrock of the middle Ordovician Galena Group. Unconsolidated material depth over the bedrock is less than 15 meters. Wykoff lies on a sinkhole plain; surface runoff in this landscape typically flows into sinkholes. Historically, the city used sinkholes as dumping points for its storm water. Four sinkholes had been modified to receive storm water, one of which was covered up and was only found during a road and storm sewer upgrade. Both street surface runoff and storm sewer flow were routed into these sinkholes. The buried sinkhole was in the center of the city; the other three were at its west, east, and south boundaries.

During 1992 to 1994, a County Geologic Atlas was produced by the Minnesota Department of Natural Resources (DNR)–Division of Waters and the Minnesota Geological Survey (MGS). The MGS mapped & characterized the geology and the DNR mapped and characterized the hydrogeology. As part of that project, the DNR and the University of Minnesota Geology & Geophysics Department staff performed multiple dye traces to produce a springshed map. One of the dye traces was from a sinkhole developed above the Dubuque Formation subcrop on the west edge of the city. This sinkhole had a storm water grate over it and had been modified to serve as a storm water receptor. The dye traveled rapidly west (over two miles in 24 hours) underground to a spring on Mahoods Creek, emanating from Galena Group strata that approximate the contact between the Cummingsville and Prosser Formations. Mahoods Creek is an important coldwater tributary to Spring Valley Creek, a state designated trout stream.

In the late 1990's, the City began to move forward with the idea of upgrading their water, sewer, and storm water systems. In order to demonstrate the importance of modifying the storm water system and make a case for state and federal grants, the Fillmore County local water planning coordinator funded two more dye traces from the storm water sinkholes on the east and south borders of the city. DNR Waters and the University of Minnesota Geology & Geophysics Department staff performed these traces, which also went to Mahoods Creek. This work underscored the importance of modifying the cities' storm water system.

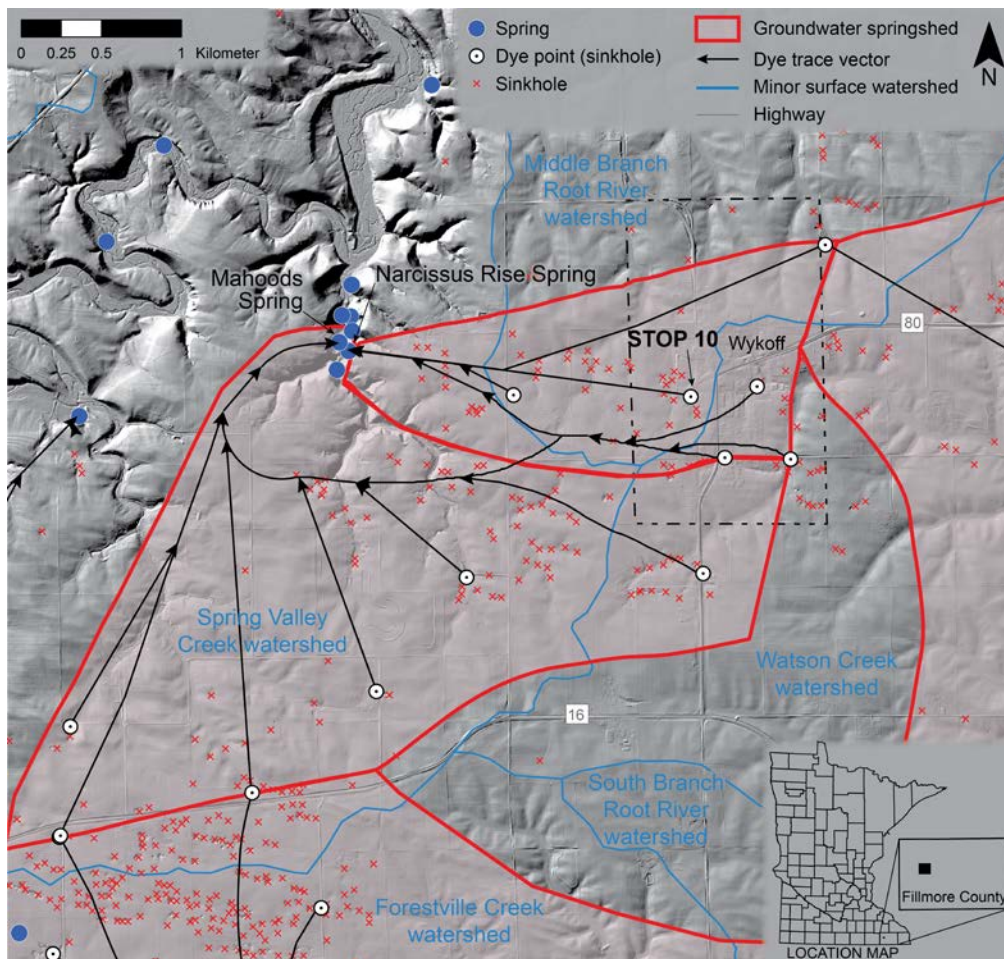
The city was denied a federal grant for a total upgrade of all of its street and storm sewer systems. City funds were available to reconstruct the storm sewer system and upgrade the streets in the west part of the town. This reconstruction was engineered so that only local surface flow was routed into the sinkhole on the south edge of town. The buried sinkhole also had storm water diverted from it. This left the storm water sinkholes on the east and west sides of town. To remediate the east side sinkhole, the Fillmore County Soil and Water Conservation District received funds from the Minnesota Board of Soil and Water Resources. The sinkhole was



excavated and then sealed with concrete and rock. The storm water now flows across the sinkhole down a grass waterway.

For the west side sinkhole, a variety of options were explored. When it appeared that there was no way to divert flow from it, the plan was to install a peat filter to treat the storm water. That idea was discarded after reviewing the literature about peat filters and discussing the long-term maintenance required with city staff. The city's engineering firm, WHKS, was able to design the storm water system to reroute the storm water away from this sinkhole into a swale that flows out to the west of the city. Since the sinkhole still received overland flow, some treatment was necessary. The sinkhole was excavated down to the opening in the bedrock. A perforated pipe wrapped with filter cloth was positioned over the bedrock opening with large diameter rock placed around it. The excavation was then backfilled with smaller diameter rock and pea gravel. The pipe was in place to allow water that flowed to the sinkhole to be routed into the bedrock opening after it passed through the rock filter and filter cloth.

The project cost approximately \$20,000. Half of that cost was born by the city, the other half came from a Department of Natural Resources Conservation Partners Grant. The DNR was interested in this site due to the impact on the groundwater system and on water quality in Mahoods Creek.



**Figure 24. City of Wykoff and mapped springsheds**



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