ASSESSMENT OF POTENTIAL GROUNDWATER IMPACTS ON FALLING SPRINGS FROM A PROPOSED QUARRY EXPANSION ST. CLAIR COUNTY, ILLINOIS

FINAL REPORT

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A contract study for the Columbia Quarry Company
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2.0 INTRODUCTION

2.1 Background and Purpose

In 2000, the Ozark Underground Laboratory, Inc. (OUL) conducted a groundwater tracing study of an area of proposed quarry expansion at Columbia Quarry Company's Plant No. 9. The result of this investigation was that all of the proposed expansion area was found to recharge Falling Springs (Moss and Aley, 2000). Falling Springs is an Illinois Natural Area Inventory site and is protected through the Illinois Department of Natural Resources (IDNR) consultation process. Having demonstrated that the proposed expansion would impact the amount of water discharged from Falling Springs, Columbia Quarry asked OUL to assess the degree of impact to Falling Springs' discharge.

In this report, the name Falling Springs is used; the United States Geologic Survey topographic map uses the name Falling Spring. It is the experience of OUL that the former is the more common construction and more accurately represents the multiple outlets of the groundwater system under high flow conditions.

There are two possible impacts from quarrying. The first is reduction in recharge area. This causes a decrease in discharge directly proportional to the percent of the area removed from the recharge area of the spring. The other potential impact is diversion of flow from other parts of the Falling Springs Recharge Area by intersecting the conduits that carry water from relatively distant parts of the recharge area to Falling Springs. These two potential impacts must be assessed in very different ways.

In the Southwest Illinois Karst, the vast majority of water flows through conduits or caves. Dye tracing provides empirical data relating areas of recharge with discharge points. However, identifying the location of the conduits and determining the relative quantities of water transmitted through them is a very different task. These data must be obtained either through cave mapping or geophysical methods. OUL unsuccessfully searched for caves that might yield conduit location data relevant to the proposed expansion. In OUL's proposal (Aley and Moss, 2000), it was recommended that if cave mapping failed to produce the necessary data, then geophysical methods could be employed.

2.2 Study Area

The study area is within an area of intense karstification known as the Columbia karst (Aley et al., 2000) and is bounded by Prairie du Long Creek to the east and by the Mississippi River to the west. Prairie du Pont Creek bounds the study area on the north, and the Stemler Cave groundwater system lies to the southeast. Cement Hollow bounds the study area to the south. The study area is shown on Figure 1.

The area is underlain by St. Louis Limestone and covered with a relatively thick mantle of loess (wind-deposited silt). The study area is characterized by a relatively high density of sinkholes that permit rapid movement of surface water into the groundwater system. In contrast with other parts of the sinkhole plain, many of the sinkholes in the study area are plugged with fine-grained sediment and have seasonal or perennial ponds in them.

2.3 Acknowledgments

We greatly appreciate the landowners in the area who have been particularly helpful and trusting in allowing us to introduce dye and to sample for dye recovery on their property. In particular, we wish to thank John and Anne Cramer of Casper Stolle Quarry Company for allowing access to land owned by their company, including Falling Springs.

Steve Lewis (formerly of Columbia Quarry) and Gary Perrey of Columbia Quarry were also very helpful and we thank them.

Two people assisted in the study through investigating caves; they are Lea Claycomb and Rick Haley. Their help is greatly appreciated.

2.4 Expertise of the Authors

Philip Moss is registered as a Professional Geologist in Illinois (license number 196-000744) and is a Registered Geologist in Missouri. Mr. Moss has considerable experience with the karst region in which this investigation took place. The references section of this report list many of the investigations in which he was did the fieldwork and much of the data interpretation.

Thomas Aley is a Professional Hydrogeologist and is registered as a professional geologist in three states. He is the founder and owner of the Ozark Underground Laboratory. Mr. Aley has almost thirty years of full-time experience as a karst hydrogeologist and has conducted or supervised over 3,500 groundwater traces. Mr. Aley was the principal investigator of five groundwater studies in the region.

OUL has been in full-time operation since 1973. It deals primarily with land management issues in limestone regions, often using groundwater tracing to answer the needs of its clients. OUL works for both public and private clients worldwide to provide critical data on which to base informed decisions.

3.0 METHODS

3.1 Groundwater Tracing Methods

Groundwater tracing with fluorescent dyes is a very valuable investigative technique in karst aquifers (Aley, 2000). Fieldwork was conducted to identify locations where waters sink from the surface into the groundwater system. Reconnaissance was also done to locate springs, surface streams, and any other potentially relevant locations to be continuously sampled for the subsequent presence of the dye. Next, tracer dyes were selected and introduced into the sinking water. Sampling was conducted on a continuous basis until the end of the project.

3.2 Tracer Dye Nomenclature

Three fluorescent dyes were used in this groundwater tracing study. Fluorescein is C.I. Acid Yellow 73, Color Index Number 45350. Rhodamine WT is Acid Red 388; there is no assigned Color Index Number for this dye. Eosine (sometimes called eosin) is Acid Red 87, Color Index Number 45380. All three of the dyes used are harmless in the typical concentrations used in professionally directed groundwater tracing (Smart, 1984; Field et al., 1995). All three of these dyes are typically and routinely used for groundwater tracing studies, and the OUL has successfully used all three in numerous studies in the region and elsewhere (Aley and Moss, 2001; Aley et al., 2000).

3.3 Dye Introductions

The results of 13 dye introductions are included in this report and used for the recharge area delineations. Eight of these traces were initiated for this investigation. The remaining traces were conducted in previous investigations by OUL. The current traces are numbered sequentially with the first two digits indicating the year, the third digit represents the study area, and the last pair of digits indicates the serial number of the trace. For example, Trace 01-405 was initiated in 2001, it is located in the Falling Springs area, and is the fifth trace initiated for this study. Both sampling station numbers and trace numbers use the same scheme.

The "Results" section of this report contains the details of the individual dye introductions, including the locations and elevations of the dye introduction points.

3.4 Sampling Stations Used

The sampling stations are located on the Cahokia or Columbia 7.5-minute quadrangle maps. The locations of the sampling stations are shown on Figure 1. An index to dye sampling locations is presented in Table 1.

Table 1. Index to dye sampling stations.

Sta.	Station Name	Map	Location	El. (ft)
401	Falling Springs	Cahokia	SE ¼ SE ¼ Sec 15 T1N R10W	500
402	Sparrow Spring	Columbia	NW ¼ NW ¼ Sec 36 T1N R10W	495
403	WH Spring	Columbia	NW ¼ NW ¼ Sec 36 T1N R10W	520
404	Cement Hollow D/S of springs	Columbia	SW ¼ NW ¼ Sec 34 T1N R10W	520
405	Cement Hollow Cr. @ Rt. 3	Columbia	38^{0}29'06"N 90^{0}12'50"W	415
406	Sugarloaf Spring	Cahokia	NW ¼ SW ¼ Sec 27 T1N R10W	425
407	Mullins Cr. @ Mullins Cr. Rd.	Cahokia	SE ¼ NW ¼ Sec 13 T1N R10W	435
408	Prairie du Pont Cr. @ Imbs Sta. Rd.	Cahokia	NW ¼ SW ¼ Sec 19 T1N R9W	425
409	Prairie du Pont Cr. @ Mullins Cr. Rd.	Cahokia	NW ¼ NE ¼ Sec 19 T1N R10W	410
410	Young Spring	Cahokia	NE ¼ NE ¼ Sec 23 T1N R10W	485
411	Old Prairie du Pont Creek at levee road	Cahokia	SW ¼ SW ¼ Sec 11 T1N R10W	405

Some sampling stations are control stations that can identify the input of fluorescent compounds into the study area that are not derived from dye introductions made by OUL. Surface sampling stations are established to identify potential groundwater discharges from unsampled springs. The remaining sampling stations sample groundwater directly and provide detail on the groundwater flow paths.

3.5 Sampling and Analysis for Tracer Dyes

Sampling for tracer dyes placed primary reliance upon activated carbon samplers, and secondary reliance upon grab samples of water. All analysis was conducted using a Shimadzu RF5000U spectrofluorophotometer operated under a synchronous scan protocol. Details of the analytical approach are presented in OUL's procedures and criteria document that is included as Appendix C. A brief description is included in the Sections 3.4.1 and 3.4.2 for the reader's convenience.

3.5.1 Activated Carbon Samplers

All three of the dyes used (fluorescein, eosine, and rhodamine WT) can be adsorbed onto laboratory grade coconut shell charcoal samplers. The samplers were placed in the water to be sampled and typically were left for periods of about one to two weeks.

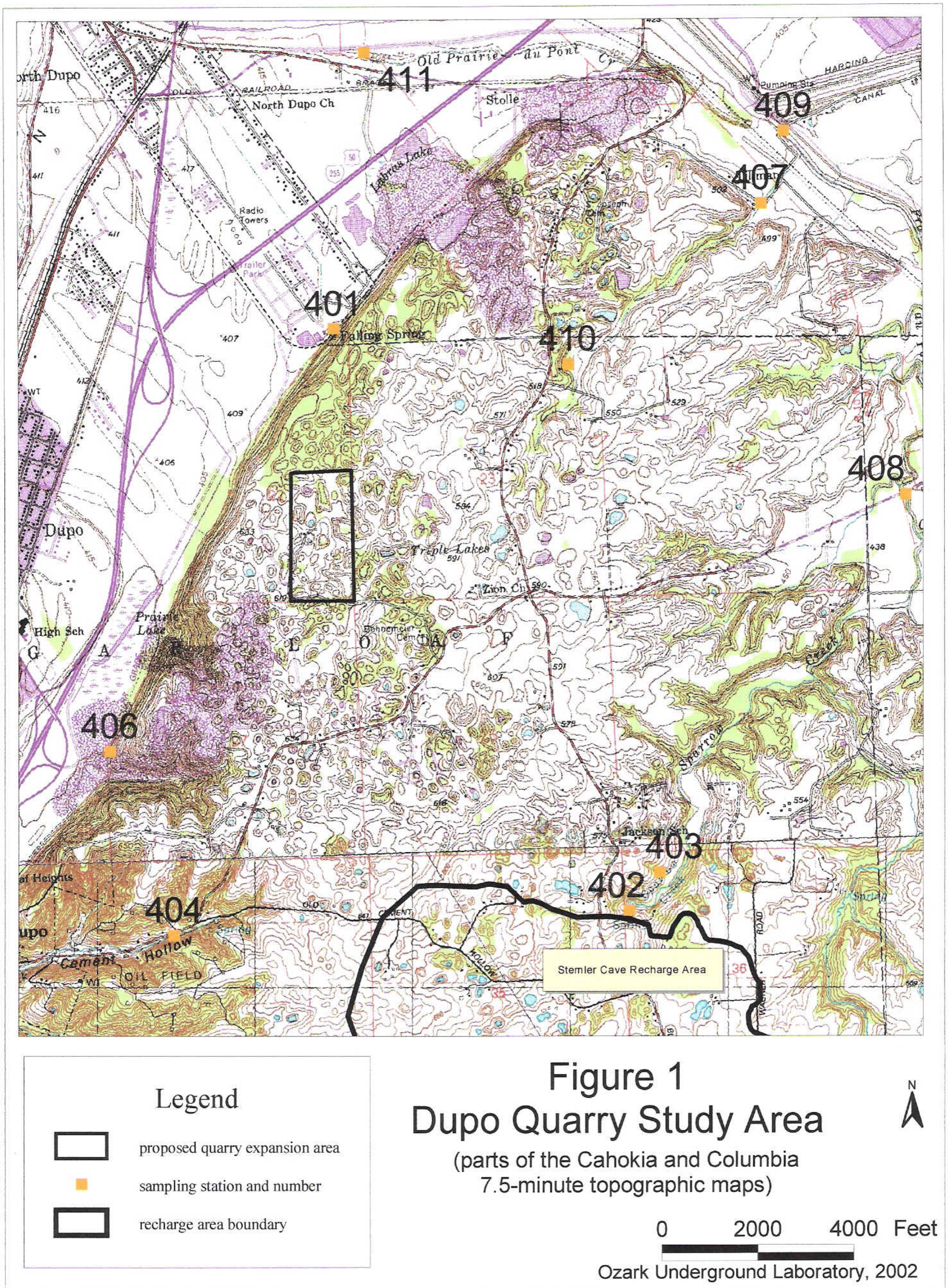


Figure 1
Dupo Quarry Study Area
(parts of the Cahokia and Columbia 7.5-minute topographic maps)

Ozark Underground Laboratory, 2002

The activated carbon samplers (simply called "samplers" or “packets” in the following discussions) are used as the primary sampling approach because they sample continuously and accumulate dyes. These samplers are ideal for determining whether a tracer dye has reached a sampling station. Two samplers were placed at each sampling station. This allows for the analysis of duplicate samples and provides a spare in case a sampler is lost or damaged.

Samplers placed at springs and surface streams were placed in flowing water, firmly anchored with wire, and weighted in place. Cords were sometimes run from the packets to trees along the banks so that samplers could be recovered even during relatively high flow events. Samplers were concealed to minimize disturbance or loss by people who might otherwise see them.

Samples collected in the field were immediately refrigerated and maintained under refrigeration until delivery to the laboratory. Upon arrival at OUL, samplers were immediately refrigerated at 4 degrees C. until analysis. All sampler placement, collection, and analysis work was conducted by OUL personnel, except for a few samples collected from Sugarloaf Spring by Gary Perrey of Columbia Quarry.

3.5.2 Water Samples

Water samples were analyzed during the study for background fluorescence, if dye were detected in the associated carbon sample, or if activated carbon samplers had been lost. Water collections were made in disposable 50 ml capped vials and kept refrigerated until analysis. Approximately 2.5 ml of the water sample was withdrawn with a disposable pipette and placed in a disposable cuvette. This sample was then subjected to analysis in OUL’s spectrofluorophotometer. All water samples were collected and analyzed by OUL personnel, except for a few samples collected from Sugarloaf Spring by Gary Perrey of Columbia Quarry. These samples provide data on the quantities of dyes present at the time of collection.

3.6 Cave Entrance Location and Cave Exploration

One of the tasks OUL undertook was to determine if conduits large enough for humans to traverse could be located. The purpose of this task was to locate the main conduit or conduits transmitting water from the distant parts of the recharge area to Falling Springs.

Several methods were used to locate cave entrances. They were:

- search the Illinois Speleological Survey's database of cave entrances,
- interviews with quarry operators, selected employees, and nearby landowners, and
- walk selected tracts of land to determine if human-sized openings were present.

If human-sized openings (caves) were found, then the cave would be explored to see if it reached a significant cave stream. If such a stream were found then the cave would be mapped to determine if it might be intersected by proposed quarrying.

4.0 RESULTS

4.1 Introduction

The contract estimated approximately six new dye traces would be initiated and that an estimated six sampling stations would be used for detecting dye. OUL made eight dye introductions specifically for this study and is including the results of five additional dye introductions in this report. Eleven sampling stations were established for this investigation. Dye was detected for all dye introductions, except for the Stolle Trace (Trace 01-405). Figure 11 shows the introduction points and the sampling stations used. This map also shows the diagrammatic path from the introduction point to the recovery point for each trace.

Five relevant dye traces were conducted by OUL prior to this study. Three were conducted under contract to The Columbia Quarry Company (Moss and Aley, 2000). Two traces were conducted under contract with the Illinois Nature Preserves Commission with funding from the US Fish and Wildlife Service and from the Illinois Department of Natural Resources' C2000 program (Aley et al., 2000). These previous traces are discussed in Section 4.2.

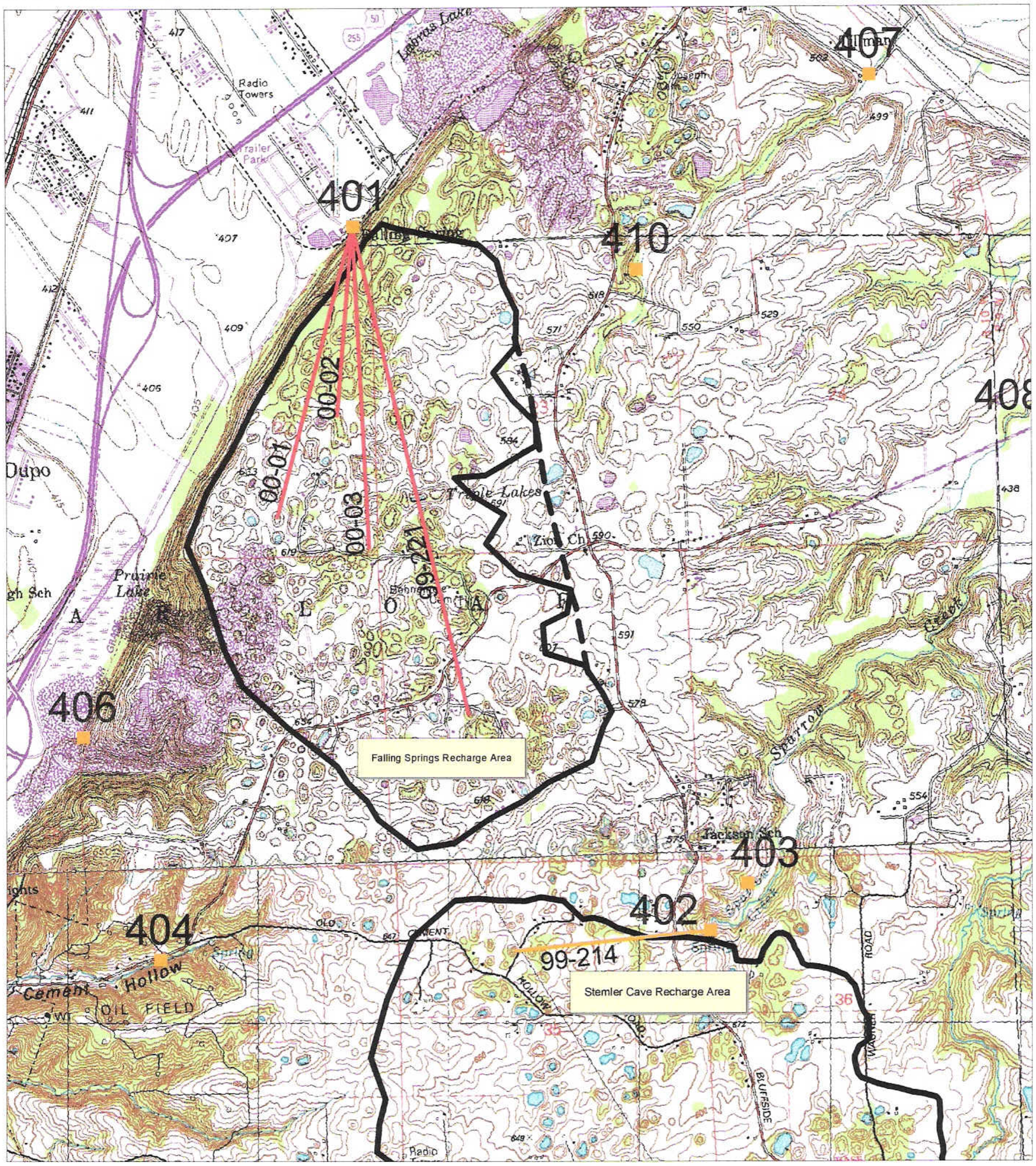
For each dye introduction the following information (where applicable) is included:

1) the amount and type of dye used,
2) the elevation and location of the dye introduction point,
3) the date and time of dye introduction,
4) flow conditions at the dye introduction point at the time of dye introduction,
5) locations where dye was detected,
6) elevation difference between introduction and recovery points,
7) groundwater flow path gradient,
8) relevance to the project,
9) a figure showing the trace and relevant portions of the recharge areas, and
10) any other information that appears relevant.

A figure is included in each discussion for the convenience of the reader. They are at the end of the narratives for each of the described traces. The reader does not have to refer to the recharge area delineation map to understand the geography of each trace. These figures include all the sampling stations that were used in this study. The lines representing the dye traces are shown as straight lines between the introduction point and each dye detection point. Figure 11 summarizes all the dye traces used for the Falling Springs Recharge Area delineation.

4.2 Previous Groundwater Tracing Results

Five previously conducted groundwater traces are included in this report because of their relevance. Traces 99-214 and 99-221 were done by OUL under contract to the Illinois Nature Preserves Commission (Aley et al., 2000). The three remaining traces (00-01, 00-02, and 00-03) were part of an initial investigation of the Dupo Quarry expansion property (Moss and Aley, 2000). Four of these traces were detected at Falling Springs and one was detected at Sparrow Spring. The previous traces are shown diagrammatically on Figure 2.



Legend

- sampling station and number
- recharge area boundary
- Falling Springs dye trace
- dye trace outside Falling Springs recharge area

Figure 2
Previous Groundwater Tracing
(parts of the Cahokia and Columbia 7.5-minute topographic maps)

N

0 2000 4000 Feet

Ozark Underground Laboratory, 2002

4.3 New Groundwater Tracing Results by Individual Traces

The dye tracing results initiated under contract with Columbia Quarry are discussed in the following sections. A figure is included at the end of each dye trace's discussion. The figure shows the individual dye trace discussed and associated recharge area boundaries. The recharge area boundaries are discussed in detail in Section 4.5. Figure 11 shows all dye traces.

Dye concentrations for each sampling station where dye was detected are tabulated in the discussion of the relevant trace. The concentrations are reported in parts per billion (ppb). The data are from activated carbon samplers unless otherwise noted. The following notes may be found in the tables: "ND" means no dye was detected; "SH" indicates a shoulder that has a peak fluorescence, but has not been calculated as dye; "dup" indicates a duplicate sample; and "NS" means that there was no sample collected for the time interval. Complete results are presented in Appendix A. Graphs of all analyzed samples are presented in Appendix B.

4.3.1 Trace 00-401: Hoock Trace

Potable water was used to introduce and flush dye for the Hoock Trace. At 1108 hours on November 1, 2000, the introduction of water began. One pound of eosine dye mixture containing approximately 75% dye and 25% diluent was introduced into a sinkhole at 1111 hours on November 1, 2000. A total of 2,500 gallons of water were discharged into the sinkhole and the dye introduction was completed at 1119 hours on November 1, 2000.

The elevation of the dye introduction point is approximately 550 feet above mean sea level (msl) and is in the SW ¼ SW ¼ of Section 26 T1N R10W. The dye was introduced using potable water hauled to the sinkhole by truck. The dye introduction point is shown on the Cahokia 7.5-minute quadrangle map. The purpose of the trace was to help define the southeastern boundary of the Falling Springs Recharge Area.

Data on the dye recovery locations for Trace 00-401 are listed below.

Station 403. WH Spring

Sampling Period	Peak Emission Wavelength (nm)	Eosine Dye Concentration (ppb)
2/26 to 3/5/01	ND	ND
3/5 to 3/22/01	533.6	0.739
3/22 to 4/24/01	534.8	1.37
4/24 to 5/24/01	538.0	SH
5/24 to 6/12/01	ND	ND

Station 408. Prairie du Pont Creek at Imbs Station Road

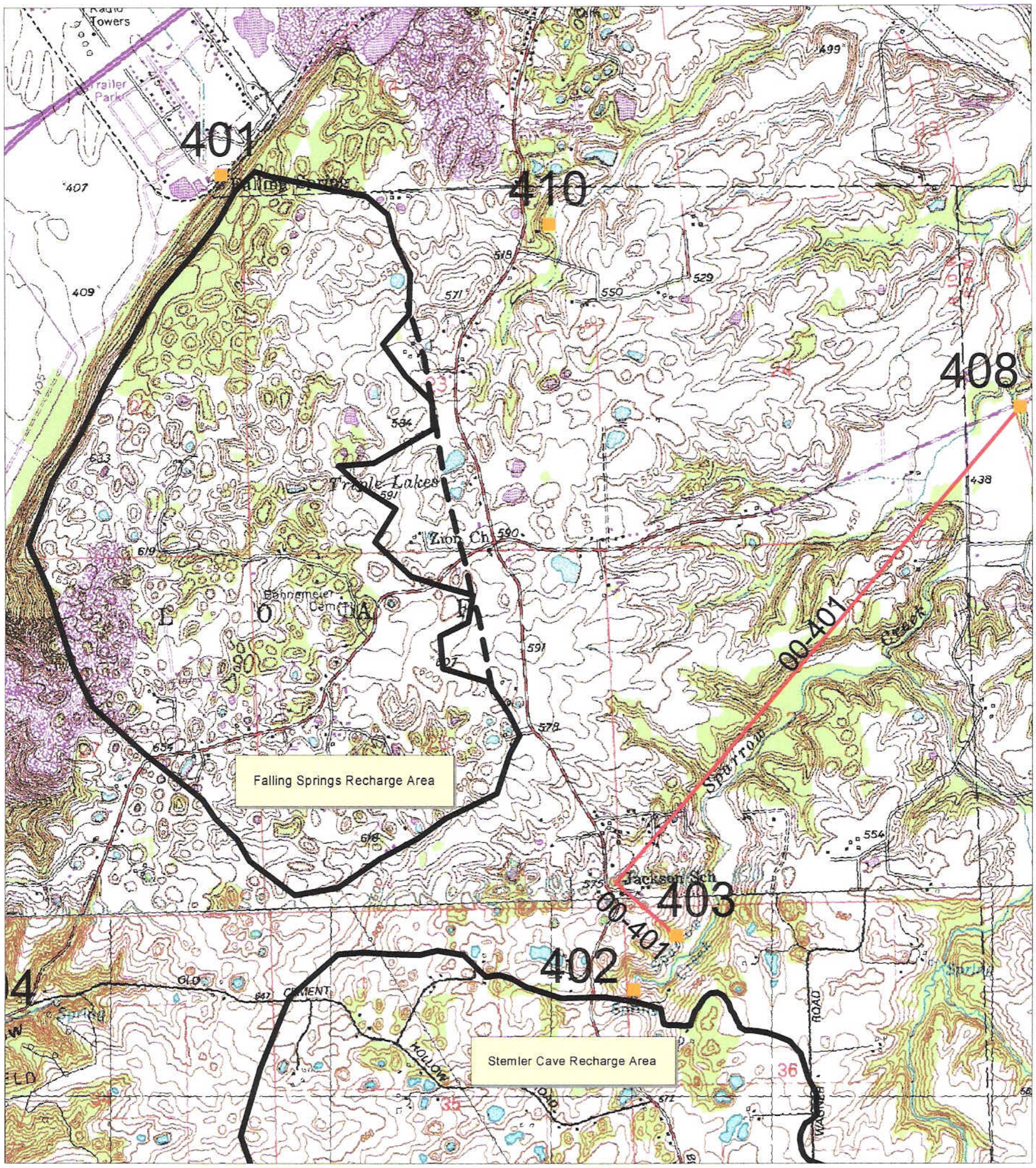
Sampling Period	Peak Emission Wavelength (nm)	Eosine Dye Concentration (ppb)
10/18 to 10/30/00	ND	ND
10/30 to 11/17/00	537.2	10.5
11/17/00 (water)	ND	ND
11/17 to 12/15/00	ND	ND
12/15/00 to 1/11/01	538.8	SH
1/11/01 (water)	ND	ND
1/11 to 2/26/01	ND	ND

Station 409. Prairie du Pont Creek at Mullins Creek Road

Sampling Period	Peak Emission Wavelength (nm)	Eosine Dye Concentration (ppb)
11/17 to 12/15/00	ND	ND
12/15/00 to 1/11/01	538.0	SH
1/11/01 (water)	ND	ND
1/11 to 2/2/01	537.3	22.1
2/2 to 2/26/01	NS	NS
2/26 to 3/5/01	ND	ND

Eosine dye from the Hoock Trace was detected at three sampling stations. The dye arrived at the sampling stations at appreciably different times. The dye detected at Station 408 and later at Station 409 (both on Prairie du Pont Creek) first arrived within 16 days of the dye introduction. The dye flowed through the groundwater system and was discharged at a spring on Prairie du Pont Creek upstream of the Imbs Station Road crossing. OUL has not searched for this spring. However, dye was also detected from this trace at WH Spring. This flow path did not yield detectable dye for approximately 140 days. This trace demonstrates that the Hoock sink does not contribute water to Falling Springs.

The straight-line distance to WH Spring is approximately 1200 feet; the elevation loss is approximately 30 feet, and the mean gradient is approximately 132 feet per mile. The groundwater velocity for this flow path (using the straight-line distance) is about 9 feet per day. Typical groundwater flow path velocities in the Southwestern Illinois Karst are in the range of 200 to 10,000 feet per day (Aley and Moss, 2001).



Legend

- sampling station and number
- recharge area boundary
- shared recharge area boundary
- dye trace

Figure 3
Trace 00-401: Hoock Trace
(parts of the Cahokia and Columbia
7.5-minute topographic maps)

N

0 2000 4000 Feet

Ozark Underground Laboratory, 2002

4.3.2 Trace 00-402: Hofstetter Trace

One-half pound of fluorescein dye mixture containing approximately 75% dye and 25% diluent was placed in a sinkhole as a dry set at 1453 hours on November 27, 2000. A dry set consists of dye being placed at or near the introduction point in such a manner as to provide for its introduction into the groundwater system when there is runoff. The elevation of the dye introduction point is approximately 535 feet msl and is in the NW ¼ SW ¼ of Section 23 T1N R10W. The dye introduction point is shown on the Cahokia 7.5-minute quadrangle map. The purpose of the trace was to help define the eastern boundary of the Falling Springs Recharge Area.

Data on the dye recovery location for Trace 00-402 are listed below.

Station 401. Falling Springs

Sampling Period	Peak Emission Wavelength (nm)	Fluorescein Dye Concentration (ppb)
11/17 to 11/28/00	ND	ND
11/28 to 12/15/00	513.7	806
12/15 to 12/29/00	513.6	614
12/29/00 to 1/11/01	512.3	13.0
1/11 to 1/15/01	512.2	19.7
1/11 to 1/15/01 (dup)	512.2	19.1
1/15 to 2/2/01	512.6	81.6
1/15 to 2/2/01 (dup)	512.6	77.1
2/2 to 2/6/01	512.6	46.8
2/6 to 2/26/01	512.7	64.8
2/6 to 2/26/01 (dup)	512.6	28.3
2/26 to 3/5/01	512.5	27.7
2/26 to 3/5/01 (dup)	512.6	25.1
3/5 to 3/22/01	512.2	15.9
3/5 to 3/22/01 (dup)	512.2	11.9
3/22 to 4/24/01	512.5	7.90
4/24 to 5/24/01	511.6	0.480
4/24 to 5/24/01 (dup)	511.6	2.15
5/24 to 6/12/01	511.2	1.81
5/24 to 6/12/01 (dup)	512.5	7.00
6/12 to 6/25/01	510.4	1.41
6/25 to 7/11/01	510.9	1.44
6/25 to 7/11/01 (dup)	ND	ND
7/11 to 8/1/01	ND	ND

Fluorescein dye from the Hofstetter Trace was detected at one sampling station, Falling Springs. This trace demonstrates that the Hofstetter sink lies within the recharge area of Falling Springs. The straight-line distance of the trace is approximately 3,680 feet and the elevation loss is approximately 35 feet. The mean gradient along this flow path is approximately 50 feet per mile.

The persistence of detectable dye at Falling Springs from this dye introduction is probably due to the trace being started as a dry set. The dye powder was placed on the ground and covered with leaves. Some of the dye probably entered the soil and was leached by several subsequent rains.

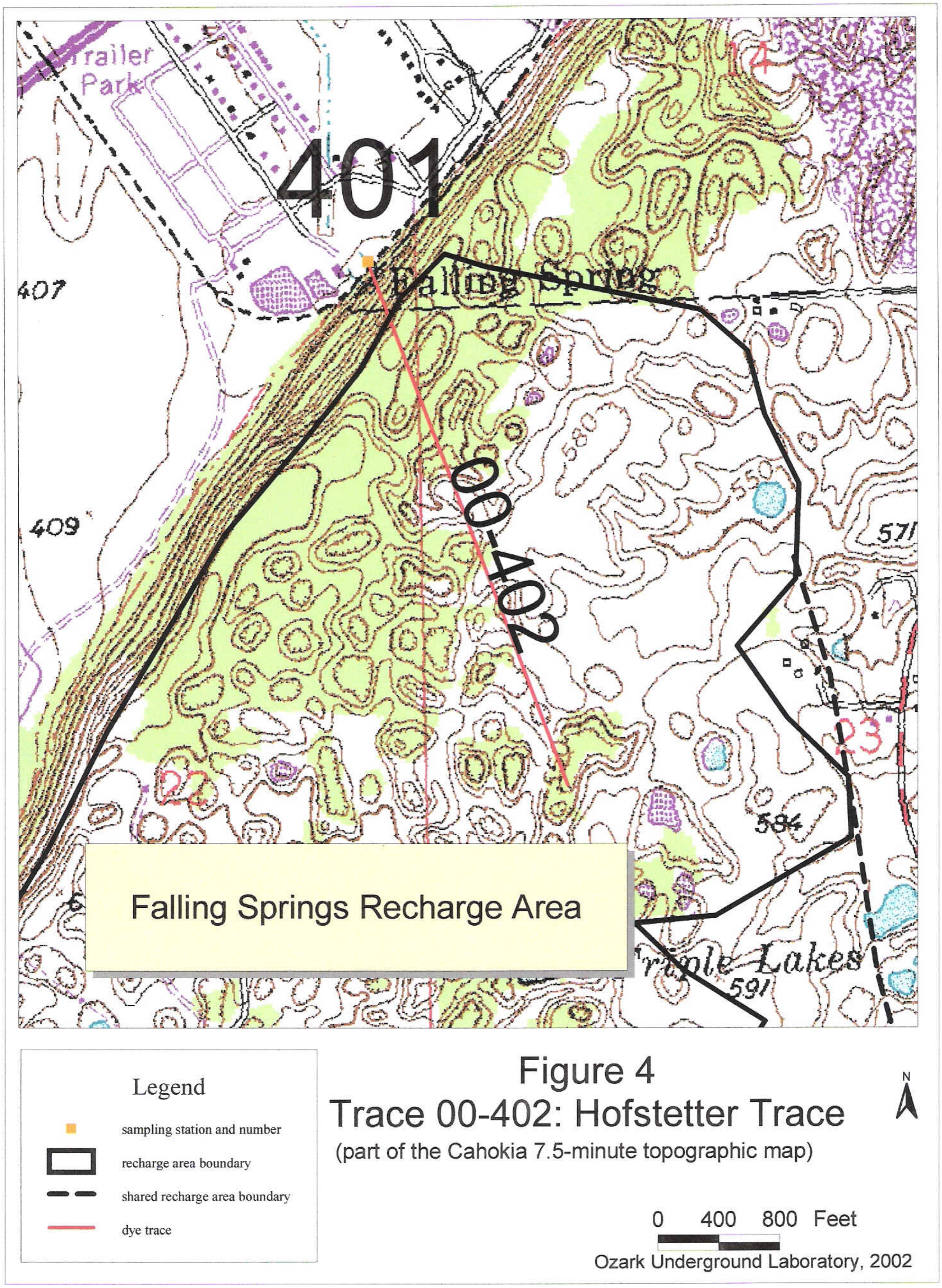


Figure 4
Trace 00-402: Hofstetter Trace
(part of the Cahokia 7.5-minute topographic map)

4.3.3 Trace 01-403: Mullins Creek Trace

One pound of eosine dye mixture containing approximately 75% dye and 25% diluent was introduced into the headwaters of Mullins Creek at 1423 hours on January 15, 2001. The elevation of the dye introduction point is approximately 550 feet msl and is in the NW ¼ SE ¼ Section 23 T1N R10W. The dye introduction point is shown on the Cahokia 7.5-minute quadrangle map. The purpose of the trace was to help define the eastern boundary of the Falling Springs Recharge Area by testing if Mullins Creek contributed water to Falling Springs.

Data on the dye recovery locations for Trace 01-403 are listed below.

Station 407. Mullins Creek at Mullins Creek Road

Sampling Period	Peak Emission Wavelength (nm)	Eosine Dye Concentration (ppb)
12/15/00 to 1/11/01	ND	ND
1/11 to 2/2/01	537.7	1,620
2/2 to 2/26/01	537.7	17.3
2/26 to 3/5/01	535.3	1.86
3/5 to 3/22/01	536.4	3.20
3/22 to 4/24/01	535.5	5.31
4/24 to 5/24/01	534.4	2.19
5/24 to 6/12/01	ND	ND

Station 409. Prairie du Pont Creek at Mullins Creek Road

Sampling Period	Peak Emission Wavelength (nm)	Eosine Dye Concentration (ppb)
11/17 to 12/15/01	ND	ND
12/15/00 to 1/11/01	538.0	SH
1/11 to 2/2/01	537.3	22.1
2/2 to 2/26/01	NS	
2/26 to 3/5/01	ND	ND

Eosine dye from the Mullins Creek was not detected at Falling Springs. It was detected at two sampling stations in the surface channel downstream of the dye introduction point. This trace demonstrates that Mullins Creek does not contribute water to Falling Springs and lies outside the Falling Springs Recharge Area.

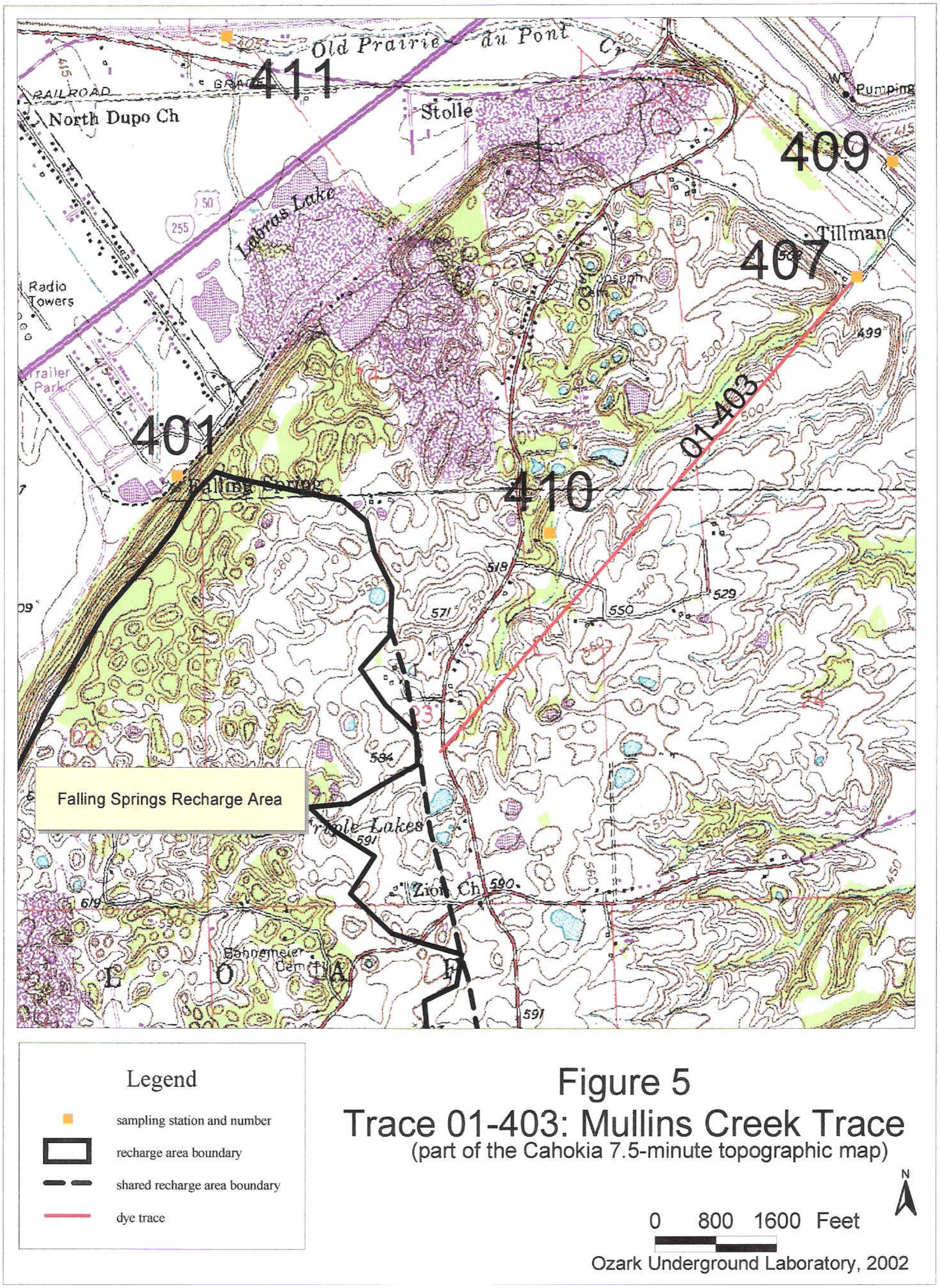


Figure 5
Trace 01-403: Mullins Creek Trace
(part of the Cahokia 7.5-minute topographic map)

4.3.4 Trace 01-404: Cement Hollow Trace

One pound of rhodamine WT dye mixture containing approximately 20% dye and 80% diluent was introduced into a sinkhole at 1214 hours on February 24, 2001. There was approximately 20 gallons per minute (gpm) of storm runoff entering the groundwater system at the time of dye introduction. The elevation of the dye introduction point is approximately 610 feet msl and is in the NW ¼ NW ¼ Section 35 T1N, R10W. The dye introduction point is shown on the Columbia 7.5-minute quadrangle map. The purpose of the trace was to help define the southeastern boundary of the Falling Springs Recharge Area.

Data on the dye recovery locations for Trace 01-404 are listed below.

Station 402. Sparrow Spring

Sampling Period	Peak Emission Wavelength (nm)	Rhodamine WT Dye Concentration (ppb)
1/11 to 2/2/01	ND	ND
2/2 to 2/26/01	563.2	SH
2/26 to 3/5/01	562.0	6.06
3/5 to 3/22/01	ND	ND

Station 408. Prairie du Pont Creek at Imbs Station Road

Sampling Period	Peak Emission Wavelength (nm)	Rhodamine WT Dye Concentration (ppb)
2/2 to 2/26/01	ND	ND
2/26 to 3/5/01	562.4	2.37
3/5 to 3/22/01	ND	ND

Station 409. Prairie du Pont Creek at Mullins Creek Road

Sampling Period	Peak Emission Wavelength (nm)	Rhodamine WT Dye Concentration (ppb)
2/2 to 2/26/01	ND	ND
2/26 to 3/5/01	563.6	2.01
3/5 to 3/22/01	ND	ND

Rhodamine WT dye from the Cement Hollow Trace was detected at three sampling stations; Sparrow Spring (Station 402), Prairie du Pont Creek at Imbs Stations Road (Station 408), and Prairie du Pont Creek at Mullins Creek Road (Station 409). Sparrow Spring is the discharge point for the Stemler Cave groundwater system (Aley et al., 2000). The Prairie du Pont sampling stations are downstream of Sparrow Spring and derived their dye detections from Sparrow Spring. This trace provided data that refined the recharge area boundary for the Stemler Cave groundwater system. This trace also demonstrates that its dye introduction point lies outside the Falling Springs Recharge Area. The straight-line distance of the trace is approximately 4,485 feet and the elevation loss is approximately 115 feet. The mean gradient along this flow path is approximately 135 feet per mile.

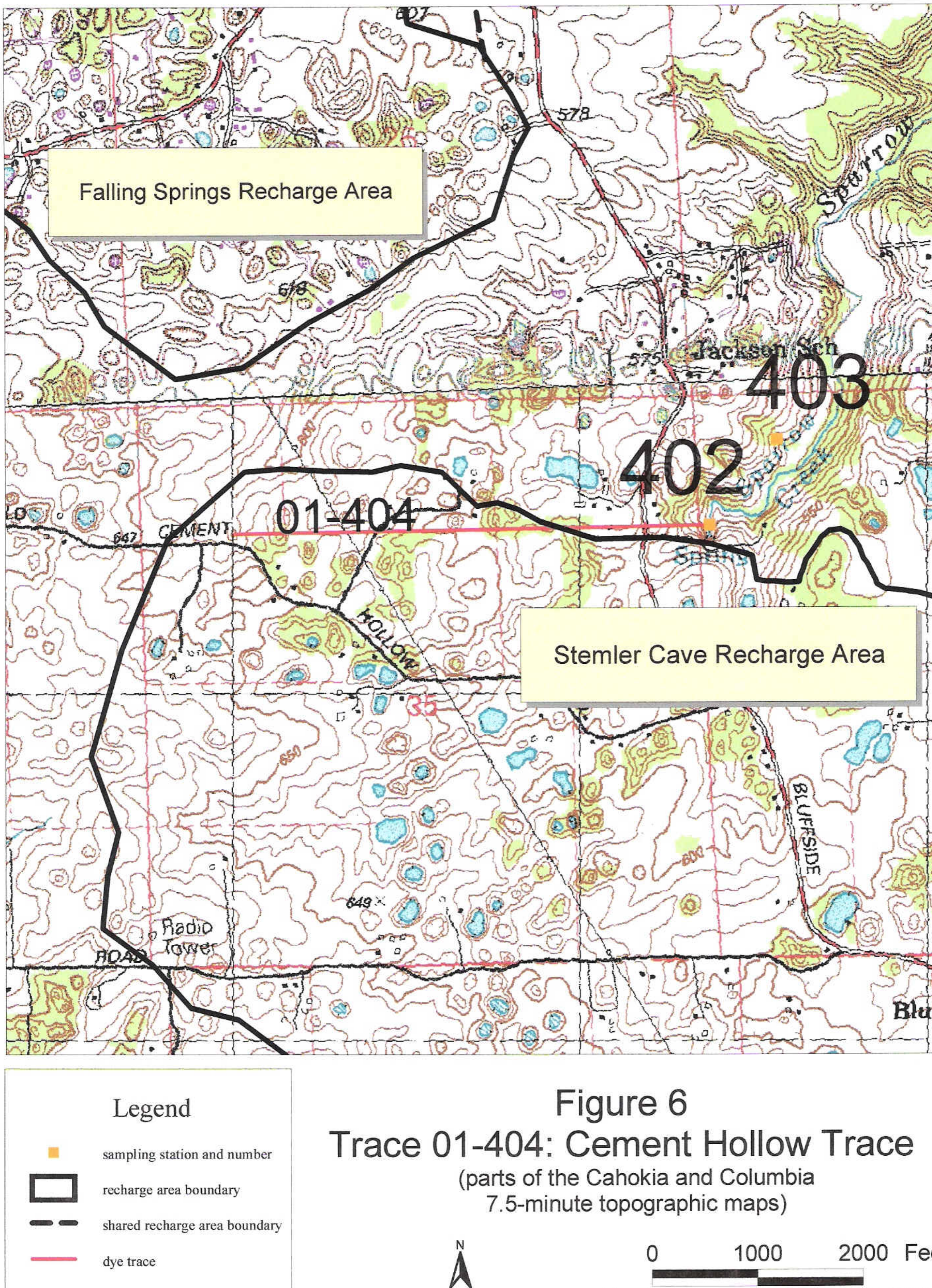


Figure 6
Trace 01-404: Cement Hollow Trace
(parts of the Cahokia and Columbia 7.5-minute topographic maps)

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4.3.5 Trace 01-405: Stolle Trace

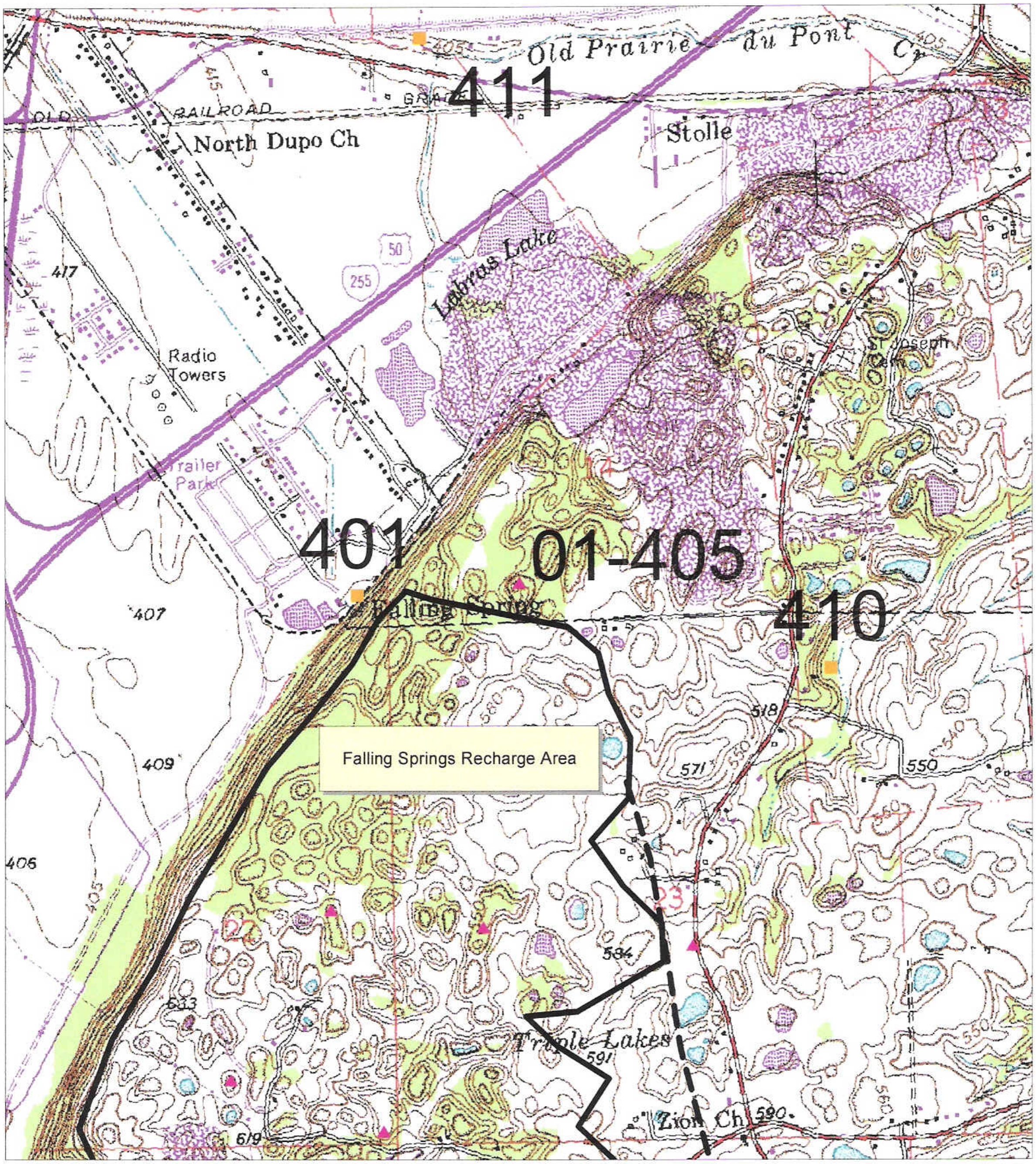
One-half pound of eosine dye mixture containing approximately 75% dye and 25% diluent was introduced into a cave pool in Casper Cave at 1055 hours on May 24, 2001. It was not clear whether or not there was flow through the pool at the time of dye introduction. The elevation of the dye introduction point is approximately 500 feet msl and is in the SW ¼ SW ¼ Section 14 T1N R10W. The dye introduction point is shown on the Cahokia 7.5-minute quadrangle map. The purpose of the trace was to help define the northern boundary of the Falling Springs Recharge Area.

No eosine dye was detected from the Stolle Trace. The dye introduction point is approximately 1,620 feet from Falling Springs. The cave was examined on November 16, 2001 for the presence of dye and no dye was observed. There was an intense storm event that produced approximately two inches of rain and significant runoff on October 24, 2001 (John Cramer, personal communication, 2001). It is clear that the dye was flushed into the groundwater system and did not flow to Falling Springs. This trace demonstrates that the Stolle sink does not lie in the Falling Springs Recharge Area.

Typical groundwater flow path velocities in the Southwestern Illinois Karst are in the range of 200 to 10,000 feet per day (Aley and Moss, 2001). Trace 00-401 demonstrated a flow path with a velocity of nine feet per day. For Trace 01-405, sampling continued for approximately six months after dye introduction. Had the dye flowed to Falling Springs at 200 feet per day, it would have arrived in about eight days. Sampling continued long enough to detect the dye from Trace 01-405, if it were to have flowed to Falling Springs.

Trace 01-403 also used eosine dye. Twice as much dye was used for Trace 01-403 as was used for Trace 01-405 and it was detected over 8,250 feet away from the dye introduction point for about four months.

It is most likely that the dye from Trace 01-405 flowed north towards Station 411 (Old Prairie du Pont Creek at levee road). However, that sampling station was not established until it became clear that the dye was unlikely to be detected at the other established sampling stations. Station 411 was established on September 10, 2001, over three months after the dye was introduced into Casper Cave. Another possibility is that the dye was in water used for dust control at Falling Springs Quarry. Eosine dye is not very noticeable to observers.



Legend

- sampling station and number
- recharge area boundary
- dye introduction point
- shared recharge area boundary

Figure 7
Trace 01-405: Stolle Trace
Dye Introduction Point
(part of the Cahokia 7.5-minute topographic map)

N

0 1000 2000 Feet

Ozark Underground Laboratory, 2002

4.3.6 Trace 01-406: Melvin Trace

On August 31, 2001, potable water was hauled to the Melvin sink to initiate the Melvin Trace. The introduction of water into the sinkhole began at 1434 hours. The rate of water introduction was approximately 250 gpm. One pound of rhodamine WT dye mixture containing approximately 20% dye and 80% diluent was introduced into the flowing water at 1437 hours. By 1444 hours, 2,500 gallons of water had been introduced into the sinkhole. There was no ponding of water in the sinkhole.

The elevation of the dye introduction point is approximately 635 feet msl and is in the SE ¼ SE ¼ Section 27 T1N R10W. The dye introduction point is shown on the Cahokia 7.5-minute quadrangle map. The purpose of the trace was to help define the southern boundary of the Falling Springs Recharge Area.

Data on the dye recovery location for Trace 01-406 are listed below.

Station 406. Sugarloaf Spring

Sampling Period	Peak Emission Wavelength (nm)	Rhodamine WT Dye Concentration (ppb)
7/11 to 8/15/01	ND	ND
8/15 to 9/10/01	562.6	10,000
9/10 to 9/25/01	564.6	3,250
9/25 to 10/1/01	563.9	666
10/1 to 10/12/01	564.5	381
10/12 to 10/22/01	564.5	227
10/22 to 10/30/01	564.5	171
10/30 to 11/8/01	564.4	203
11/8 to 11/16/01	564.1	157
11/16 to 11/27/01	564.1	61.5
11/16 to 11/27/01 (dup)	564.2	112
11/27 to 12/5/01	564.2	52.0
12/5 to 12/10/01	564.2	42.4

Dye from the Melvin Trace was detected at one sampling station, Sugarloaf Spring. Sugarloaf Spring is located on the Columbia Quarry Company's Dupo Plant. This groundwater trace demonstrates that the Melvin sink lies outside the Falling Springs Recharge Area and helps to define its southern boundary. The straight-line distance of the trace is approximately 3,490 feet and the elevation loss is approximately 210 feet. The mean gradient along this flow path is approximately 318 feet per mile.

Prior to this trace there was a question of whether the spring received any natural recharge or if it was being recharged by leaky water lines. The Melvin Trace demonstrates that Sugarloaf Spring does receive natural recharge. Section 4.4 provides additional information regarding the consideration of leaky water line recharge of Sugarloaf Spring.

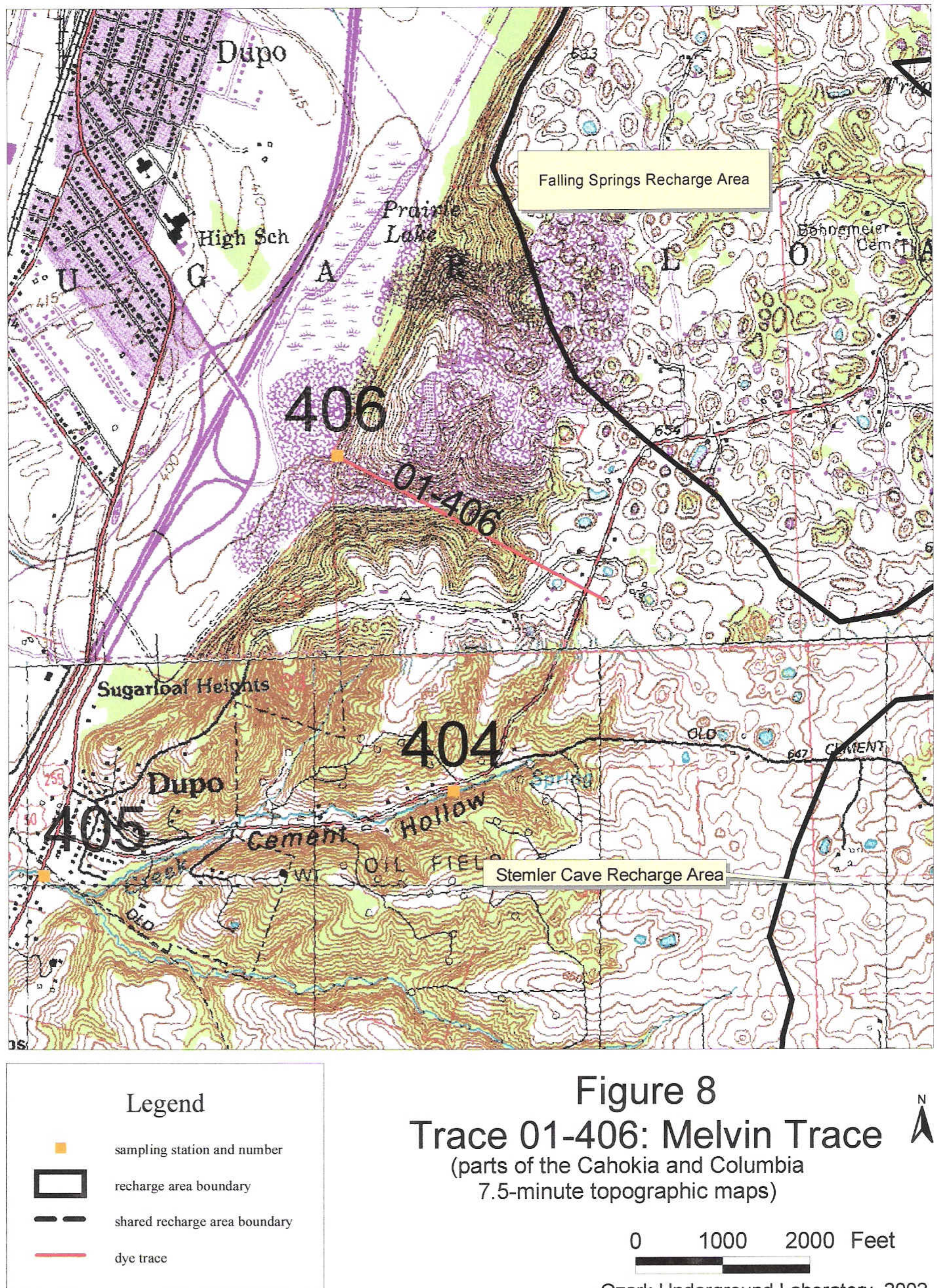


Figure 8
Trace 01-406: Melvin Trace
(parts of the Cahokia and Columbia
7.5-minute topographic maps)

Ozark Underground Laboratory, 2002

4.3.7 Trace 01-407: Haas Trace

One-half pound of fluorescein dye mixture containing approximately 75% dye and 25% diluent was introduced into a sinkhole on November 27, 2001 at 1230 hours. The flow was approximately one-half gpm at the time of dye introduction. The elevation of the dye introduction point is approximately 540 feet msl and is in the NE ¼ SW ¼ Section 26 T1N R10W. The dye introduction point is shown on the Cahokia 7.5-minute quadrangle map. The purpose of the trace was to help define the southern boundary of the Falling Springs Recharge Area.

Data on the dye recovery location for Trace 01-407 are listed below.

Station 401. Falling Springs

Sampling Period	**Peak Emission Wavelength (nm)**	**Fluorescein Dye Concentration (ppb)**
11/16 to 11/27/01	ND	ND
11/27 to 12/9/01	514.0	249
11/27 to 12/9/01 (dup)	514.8	379

Dye from the Haas Trace was detected at only one sampling station, Falling Springs. The Haas Trace demonstrates that its dye introduction point is within the Falling Springs Recharge Area. The straight-line distance of the trace is approximately 8,800 feet and the elevation loss is approximately 40 feet. The mean gradient along this flow path is approximately 24 feet per mile.

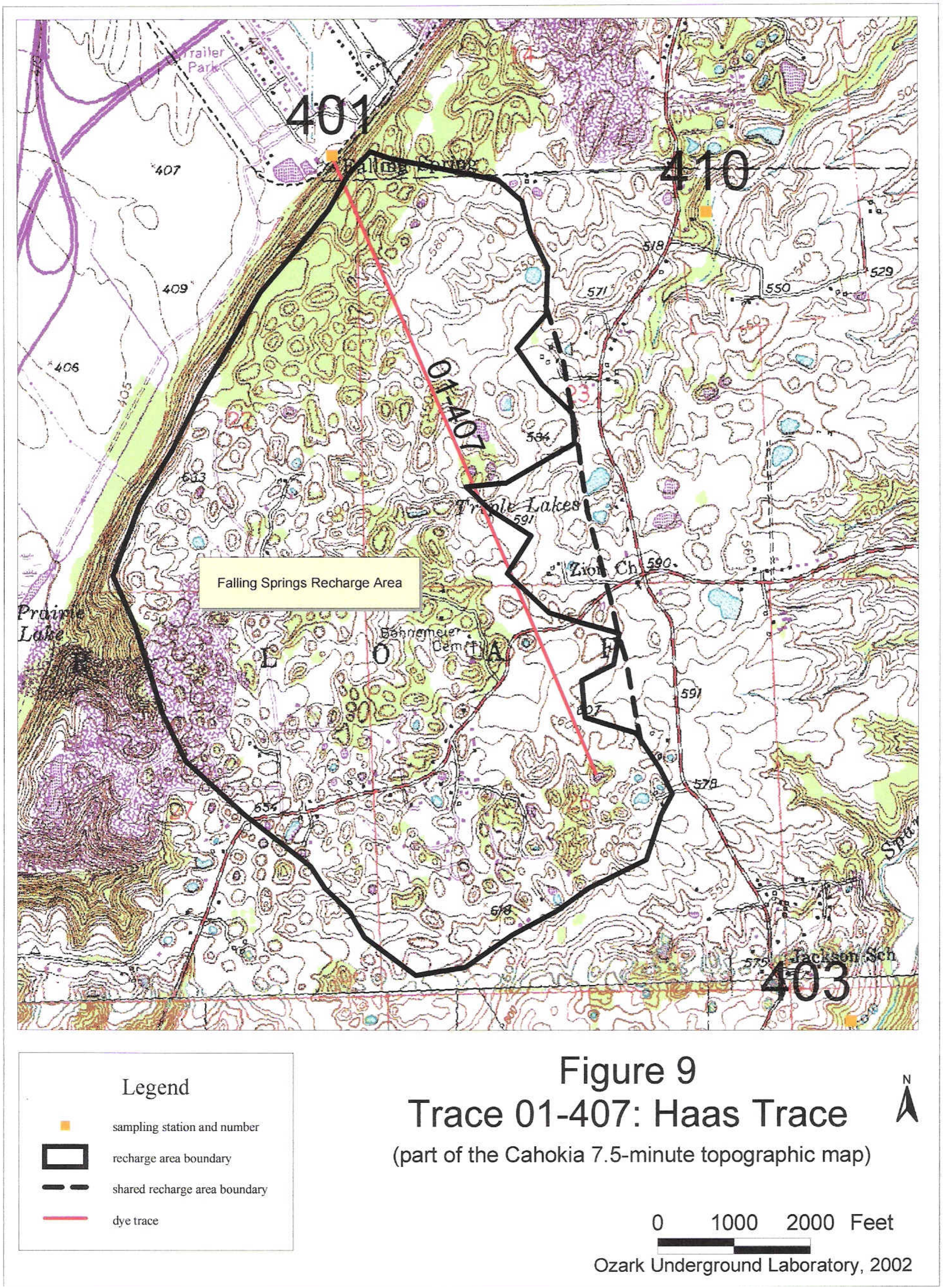


Figure 9
Trace 01-407: Haas Trace
(part of the Cahokia 7.5-minute topographic map)

4.3.8 Trace 01-408: Imbs Station Road Trace

On November 28, 2001, potable water was hauled to the Imbs Station Road sink to introduce and flush dye. The introduction of water began at 0946 hours; at 0950 hours one pound of rhodamine WT dye mixture containing approximately 20% dye and 80% diluent was introduced; the introduction of water was completed at 1015 hours. A total of 2,500 gallons of water was used to introduce and flush the dye.

The elevation of the dye introduction point is approximately 600 feet msl and is in the NE ¼ SE ¼ Section 27 T1N R10W. The dye introduction point is shown on the Cahokia 7.5-minute quadrangle map. The purpose of the trace was to help define the southern boundary of the Falling Springs Recharge Area.

Data on the dye recovery location for Trace 01-408 are listed below.

Station 401. Falling Springs

Sampling Period	**Peak Emission Wavelength (nm)**	**Rhodamine WT Dye Concentration (ppb)**
11/16 to 11/27/01	ND	ND
11/27 to 12/9/01	564.9	277
11/27 to 12/9/01 (dup)	563.6	211

Dye from the Imbs Station Road Trace was detected at only one sampling station, Falling Springs. The Imbs Station Road Trace demonstrates that its dye introduction point is within the Falling Springs Recharge Area. The straight-line distance of the trace is approximately 8,505 feet and the elevation loss is approximately 100 feet. The mean gradient along this flow path is approximately 62 feet per mile.

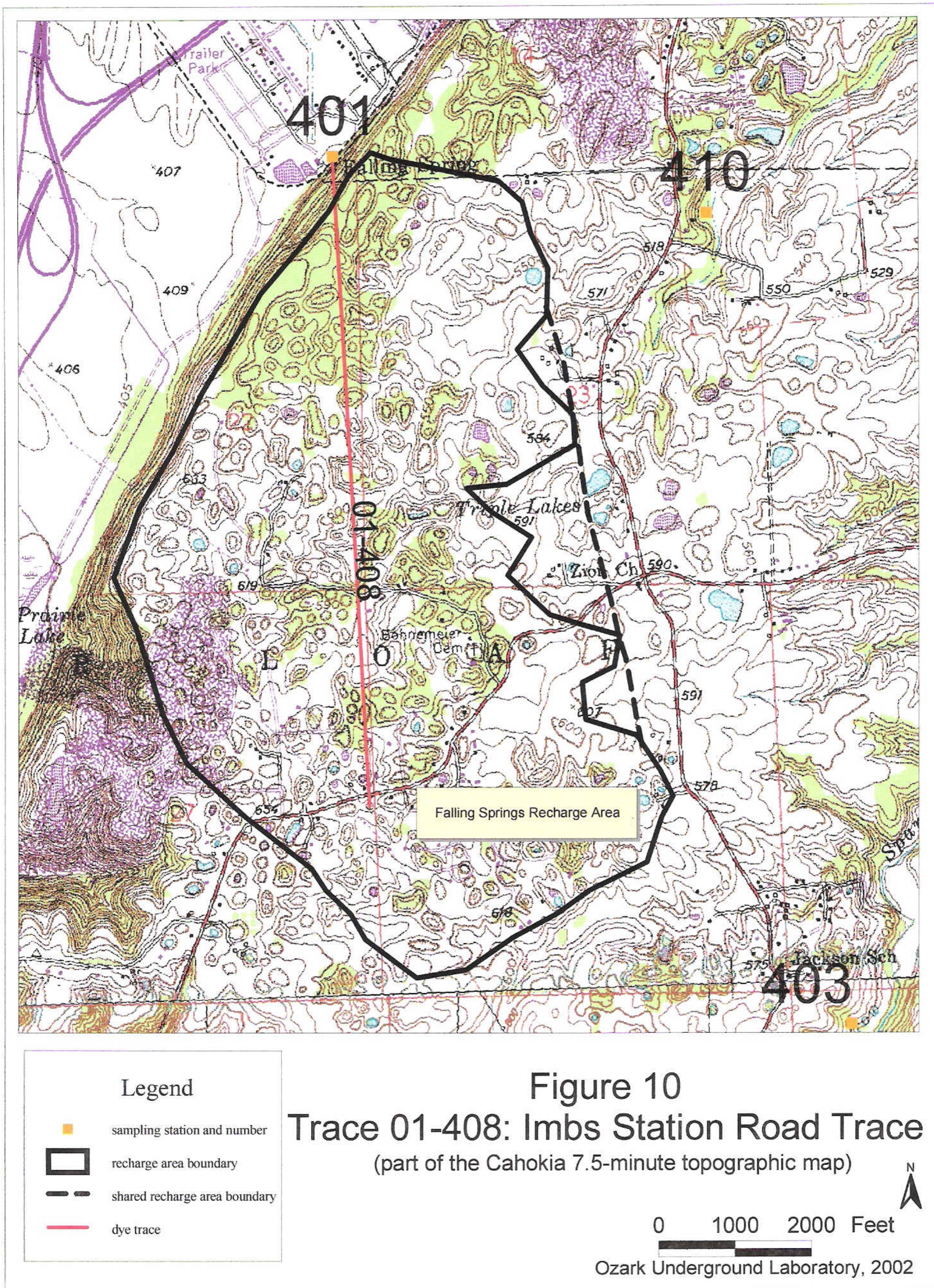


Figure 10
Trace 01-408: Imbs Station Road Trace
(part of the Cahokia 7.5-minute topographic map)

4.4 Specific Conductivity and Flow Measurements

Specific conductance is a measurement of the ability of water to conduct electricity. Water flowing through soluble rock units such as limestone tends to become saturated with calcium carbonate and to a lesser extent with other dissolved compounds. In a given geologic setting, surface waters tend to have lower specific conductivities than water flowing through the groundwater system.

During this study, one round of specific conductance measurements were made. The purpose of the measurements was to develop insight into the character of the waters sampled for dye. At the time of these measurements it was not clear that Sugarloaf Spring was a natural feature; no dye had been recovered from it. Sugarloaf Spring is located near a water tower and we considered the possibility that it was being recharged by leaks in the nearby drinking water system. All measurements were made with a Yellow Springs Instrument Company SCT meter which measures in micromhos/cm. These units are equivalent with microSiemens.

The specific conductance measurements along with Trace 01-406 (Melvin Trace) demonstrate that Sugarloaf Spring is a natural spring. There is a water tower and waterlines that are part of the city water system that are close to the spring. The possibility that the spring derived it entire flow from leaks was not supported by the data. The relatively high specific conductance of its water is almost certainly derived from its discharge through crushed limestone. Finely divided limestone has more surface area than large blocks of limestone and, as a result the water contacting it can become saturated with dissolved limestone more quickly.

Table 2. Specific Conductivity Data

STATION NUMBER	STATION NAME	DATE	TIME	Specific Conductivity (micromhos)
401	Falling Springs	11/17/00	1441	550
402	Sparrow Spring	11/17/00	1543	345
403	WH Spring	11/20/00	1320	540
404	Cement Hollow D/S of Spring	11/17/00	1601	505
405	Cement Hollow @ Rt. 3	11/17/00	1613	600
406	Sugarloaf Spring	11/17/00	1428	720
407	Mullins Cr. @ Mullins Cr. Rd.	11/17/00	1457	415
408	Prairie du Pont Cr. @ Imbs Sta. Rd.	11/17/00	1532	435
409	Prairie du Pont Cr. @ Mullins Cr. Rd.	11/17/00	1505	430
410	Young Spring	11/17/00	1521	405

NA	Plant #9 tap water	11/17/00	1419	445

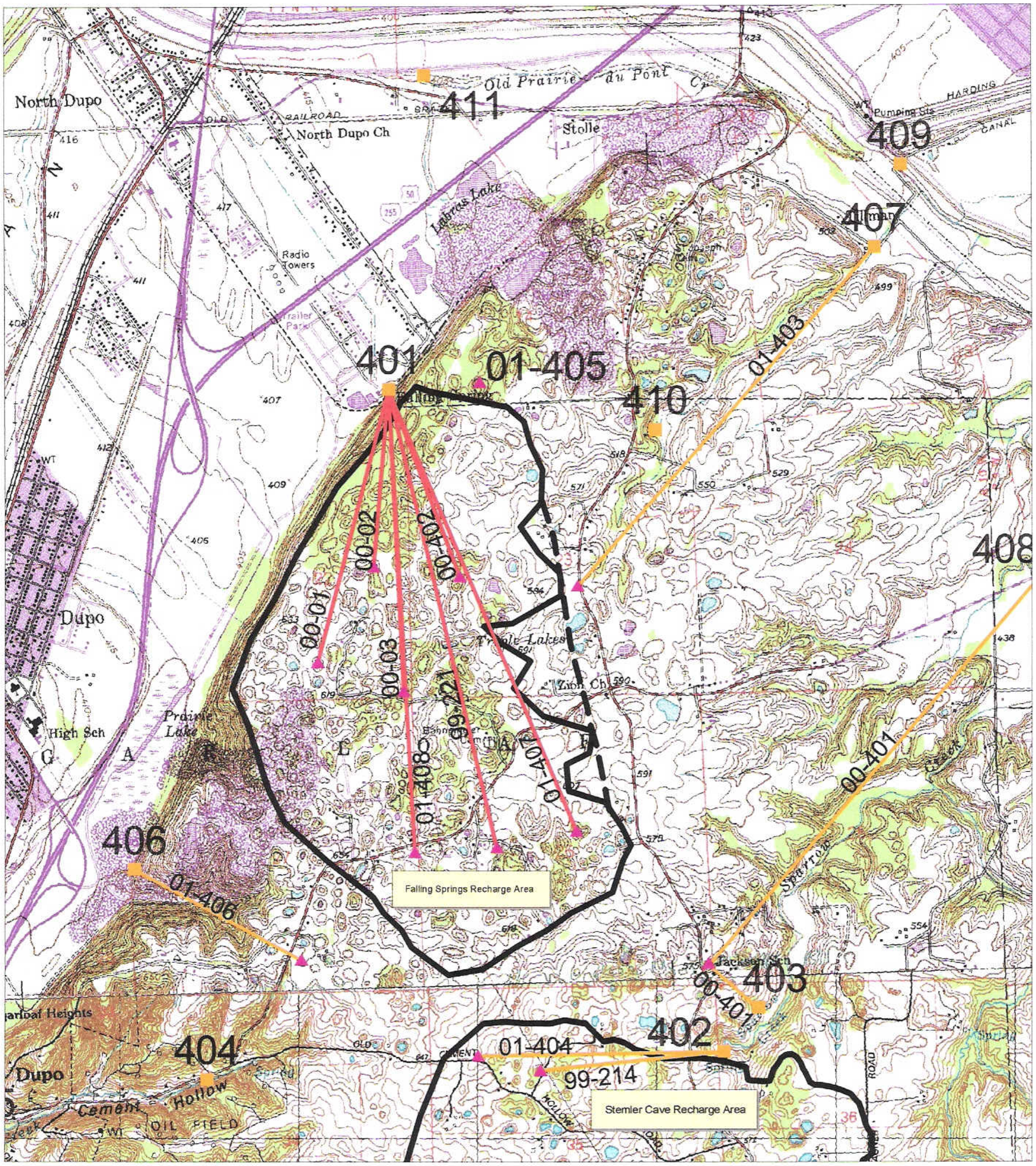
4.5 Recharge Area Delineation

The purpose of this recharge area delineation is to determine the location and size of the Falling Springs Recharge Area. Knowing the size of the recharge area allows for a calculation of the percent of the recharge area that will be removed by the proposed quarry expansion. As e use the term in this report, a recharge area for a spring is the surface land area that contributes water under some or all conditions to that particular spring.

The Falling Springs Recharge Area is shown on Figure 12. There are three distinct areas within the outer boundary. The outer boundary includes land that contributed water to Falling Springs prior to quarrying. There is an area in the southwest part of the Falling Springs Recharge Area whose surface has been lowered to an elevation below that of Falling Springs and no longer yields water to the spring. This part of the boundary cannot be tested directly, but results from interpolation from areas known to contribute water to Falling Springs or Sugarloaf Spring. While it is the interpretation by OUL that this land did contribute water to Falling Springs when its surface was higher in elevation that Falling Springs, its position on the margin of the recharge area is indicated by the lack of visible conduits exposed in the quarry wall and by a lack of discharge from the pit wall.

There is a dashed line shown running roughly north-south along the eastern edge of the Falling Springs Recharge Area map (Figure 12). The area between the solid line and the dashed line represents an area in which most or all surface runoff enters surface channels and does not contribute water to Falling Springs. However, precipitation that infiltrates the soil and bedrock does contribute to the flow of Falling Springs. The area between the dashed and solid lines comprises approximately 75 acres of shared recharge. Based on OUL experience and the local geologic setting, this land, on average, should contribute only about 50% as much water per acre as land recharging through sinkholes.

The pre-quarry recharge area for Falling Springs was approximately 1,200 acres (1.9 square miles). The current recharge area (accounting for recharge area that has already been removed) for Falling Springs is approximately 1140 acres (1.8 square miles). Figure 11 summarizes all the dye traces used for the Falling Springs Recharge Area delineation.



Legend

- sampling station and number
- recharge area boundary
- dye introduction point
- shared recharge area boundary
- Falling Springs dye trace
- dye trace outside Falling Springs recharge area

Figure 11
Falling Spring Pre-Quarry Recharge Area
showing All Dye Traces
(parts of the Cahokia and Columbia
7.5-minute topographic maps)

N

0 2000 4000 Feet

Ozark Underground Laboratory, 2002

4.6 Recharge Area Delineation Rationale

The recharge area delineation is based on results of the dye traces, the relative amounts of water discharged from relevant springs, and topographic features. The lines delineating the recharge area boundaries should generally be considered as a region having some width and some uncertainty as distinguished from a finite line. Areas near recharge area boundaries often recharge two or more springs.

Figure 12 shows the Falling Springs Recharge Area. Along the boundary are the letters A through H. The letters were placed on the figure to aid in the discussion of the rationale for the boundary location. The segment between A and B (Figure 12) is drawn to separate the sinkholes from the bluff line. The water yield on the west side of the boundary does not enter a karst groundwater system while the east side recharges Falling Springs.

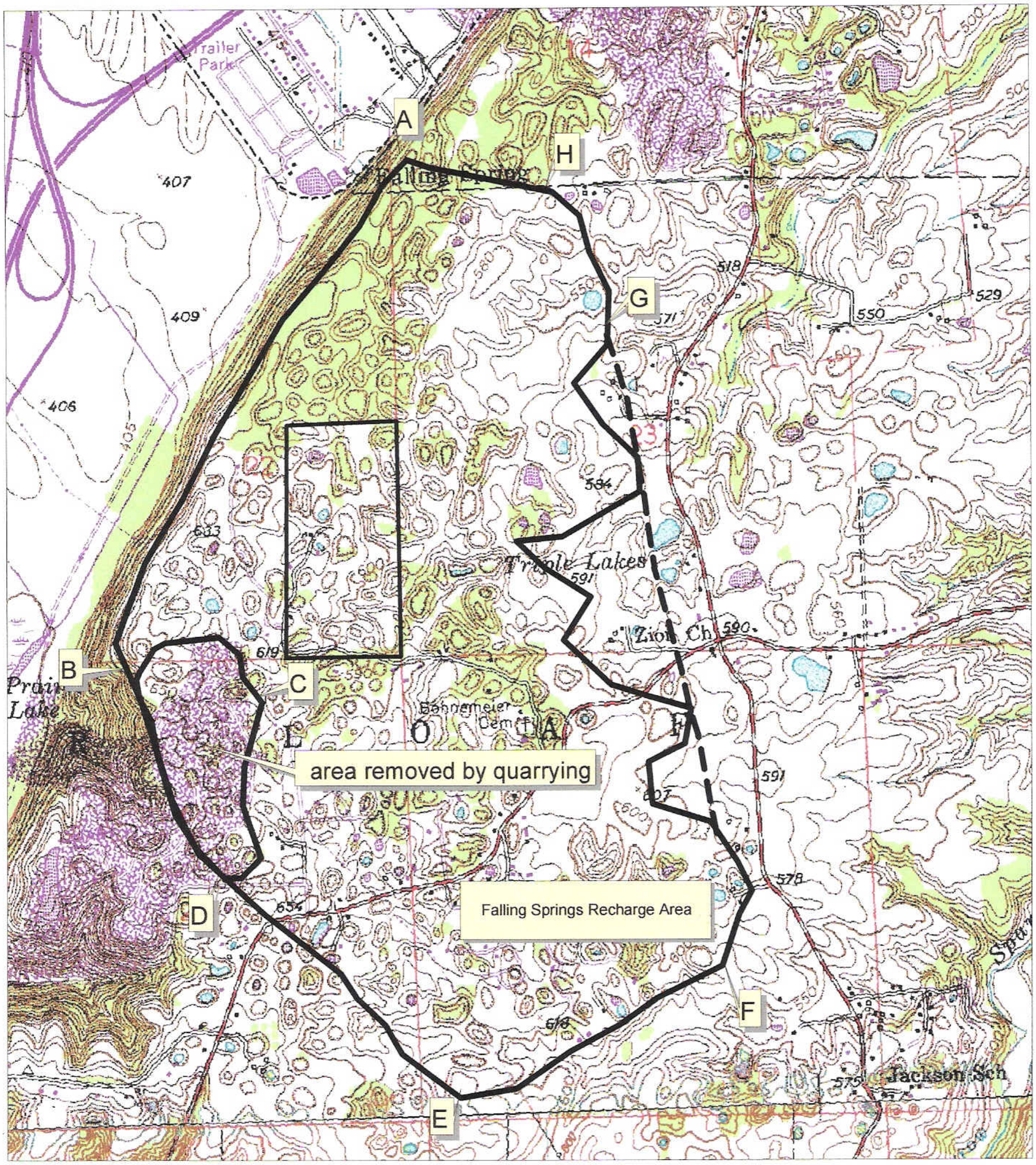
The segment between B and D (Figure 12) is the Falling Springs Recharge Area boundary prior to quarry operation. This boundary is inherently untestable, since the landscape has been irrevocably altered. However, the relatively large discharge from Sugarloaf Spring (Station 406 on Figure 11) makes it reasonable to assume that the boundary was about halfway between the dye introduction points for Traces 00-01 and 01-406.

The area contained within the polygon B-C-D-B (Figure 12) has been removed by quarrying. Its elevation is now lower than that of Falling Springs and no longer contributes water to Falling Springs.

The segment between D and E (Figure 12) is drawn about halfway between the dye introduction points for Traces 01-406 (detected at Sugarloaf Spring, Figure 11), 01-404 (detected at Sparrow Spring, Figure 11), and 01-408 (detected at Falling Springs, Figure 11).

The segment between E and F (Figure 12) is drawn approximately at the northern topographic boundary of a karst valley. A karst valley is shaped similarly to a normal valley, but has sinkholes draining it, providing rapid recharge to the groundwater system. OUL believes that the karst valley recharges the same set of springs that the Trace 00-401 sinkhole recharges (Figure 11). Based on Traces 99-221, 01-407, and 01-408, and our interpretation of the karst valley, OUL believes that the smaller sinkholes north of the boundary drain to Falling Springs, while the relatively large karst valley south of the boundary drains to springs along Sparrow Creek.

The region between F and G (Figure 12) has both a dashed line and a solid line drawn through it. The solid line divides the area that contributes all its water yield to Falling Springs from an area to the east which only contributes the deep infiltrating component of the precipitation falling on it. Most or all of the overland flow yielded by this area remains in surface channels and does not contribute water to Falling Springs. The area to the east of the dashed line does not contribute water to Falling Springs.



A - H: see Section 4.5

Legend
- proposed quarry expansion area
- recharge area boundary

Figure 12
Falling Springs Pre-Quarry and Current Recharge Area showing Proposed Expansion
(part of the Cahokia 7.5-minute topographic map)

0 1000 2000 Feet

N

Ozark Underground Laboratory, 2002

The segment between G and H (Figure 12) is drawn to separate land recharging Falling Springs from land recharging Young Spring (Station 410, Figure 11). No dye was detected at Young Spring, but it clearly must have a recharge area. Young Spring has a relatively small discharge, estimated to be about 10 gpm. It lies at the north edge of a karst valley that probably is the majority of its recharge area.

No increase in turbidity at Young Spring was noticed after rain events. Turbidity is the term for sediment suspended in water. Typically, springs in the Southwest Illinois Karst become extremely turbid following storm events. The loess-derived soils are highly erodable and any open sinkholes connected to karst conduits permit the transport of considerable sediment by runoff into the sinkholes. The lack of noticeable increase in turbidity indicates that Young Spring is not being recharged by the relatively open sinks that lie about 4,000 feet west of it. Closer to Young Spring, but still west of it, are some large, plugged sinkholes that are almost certainly recharging the spring. The Falling Springs Recharge Area boundary location was informed by these considerations.

There are no springs known to OUL between Falling Springs and the Casper Stolle quarry operations. There are no perennial springs in Falling Springs Quarry or even appreciable wet-weather springs (John Cramer, personal communication, 2001). The lack of alternate discharge points (springs) indicates that most of the land near the segment between H and A (Figure 12) must recharge Falling Springs. The area around the dye introduction point for Trace 01-405 (Figure 11) is shown outside the Falling Springs Recharge Area, since dye from Trace 01-405 was not detected at Falling Springs (Section 4.3.5).

4.7 Cave Entrance Location

Figure 13 shows the land examined for cave entrances. Some of the small areas marked were searched for cave entrances while locating potential dye introduction points. Some areas examined for caves lie outside the Falling Springs recharge area. The search for cave entrances was done during the recharge area delineation and land was examined when the opportunity presented. The shapes of areas examined were generally determined by land ownership. Every sinkhole on land owned by Columbia Quarry and Casper Stolle Quarry near Falling Springs was examined for humanly enterable openings. Rumors of caves were tracked down. Only land for which permission was obtained was searched. One sinkhole was excavated by Columbia Quarry with a trackhoe in order to try to make an entrance to the cave system which discharges at Falling Springs. This sinkhole was selected based on the relatively rapid groundwater velocity to Falling Springs demonstrated by Trace 00-02. Unfortunately, no enterable cave was found in the excavated sinkhole.

Five humanly enterable openings were located and explored, including two that are outlets of Falling Springs. None of the caves was extensive enough to yield relevant data on where major cave streams are located near Plant No.9. With the exception of one of the outlets of Falling Springs, none of the caves had significant streams in them. The relative infrequency of cave entrances in the parts of the Falling Springs Recharge Area searched suggests that cave entrances are probably infrequent throughout its recharge area. This is in contrast with the sinkhole areas in other parts of the Southwest Illinois Karst.

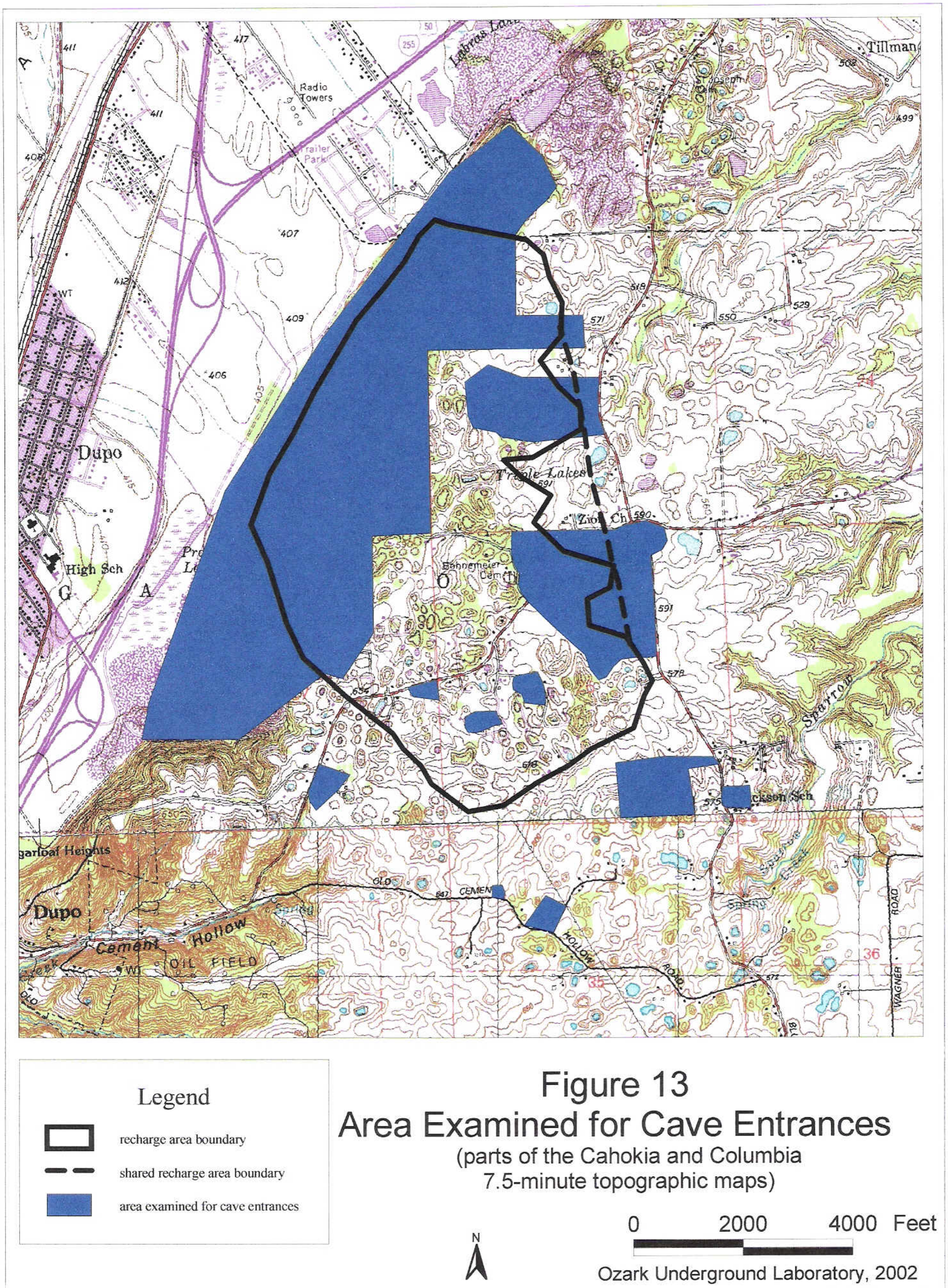


Figure 13
Area Examined for Cave Entrances
(parts of the Cahokia and Columbia 7.5-minute topographic maps)

5.0 SUMMARY AND CONCLUSIONS

OUL was contracted to help assess potential impacts on flow rates at Falling Springs by quarry expansion. These impacts could be from removal of recharge areas by quarrying or by intersecting conduits carrying flow from other parts of the recharge area.

The Falling Springs Recharge Area was delineated and found to be approximately 1,200 acres (1.9 square miles) before quarrying. The current recharge area (accounting for recharge area that has already been removed) for Falling Springs is approximately 1,140 acres (1.8 square miles). Within the recharge area, there is approximately 75 acres of shared recharge. OUL estimates that only about half of the water yielded by this area recharges Falling Springs. As a result, the 75 acres of shared recharge is roughly equivalent to 37 acres land that only contributes water to Falling Springs. This results in a normalized (using one hundred per cent recharge land equivalent) recharge area of 1,103 acres.

Approximately 72 acres of an 80-acre parcel are proposed for new quarrying; the remainder would be buffer. This means that the current flow of water at Falling Springs would be reduced by approximately 6.3% when all of the 72 acres is removed from the recharge area by quarrying. This figure does not reflect the impact on the flow rate at Falling Springs if quarrying intersects a karst conduit that carries water to the spring. Figure 14 shows the proposed expansion, the recharge area already removed by quarrying, and the lands owned by quarry companies in and near the Falling Springs Recharge Area.

Important findings from this investigation are:

1) The Falling Springs Recharge Area was approximately 1,200 acres (1.9 square miles) before quarrying.

2) The current size of the Falling Springs Recharge Area is approximately 1,140 acres (1.8 square miles). The difference is a result of previous quarry operation lowering the surface to elevations below that of the spring, thus removing it from the recharge area.

3) The 72 acres of the 80-acre parcel proposed for removal would reduce flow at Falling Springs by approximately 6.3% by removing that percent of the current recharge area.

4) No caves were found which yielded relevant data regarding the possible intersection of karst conduits carrying water to Falling Springs. A large area was examined for the presence of cave entrances and one sinkhole was excavated in an attempt to provide access to the cave system at an important location.

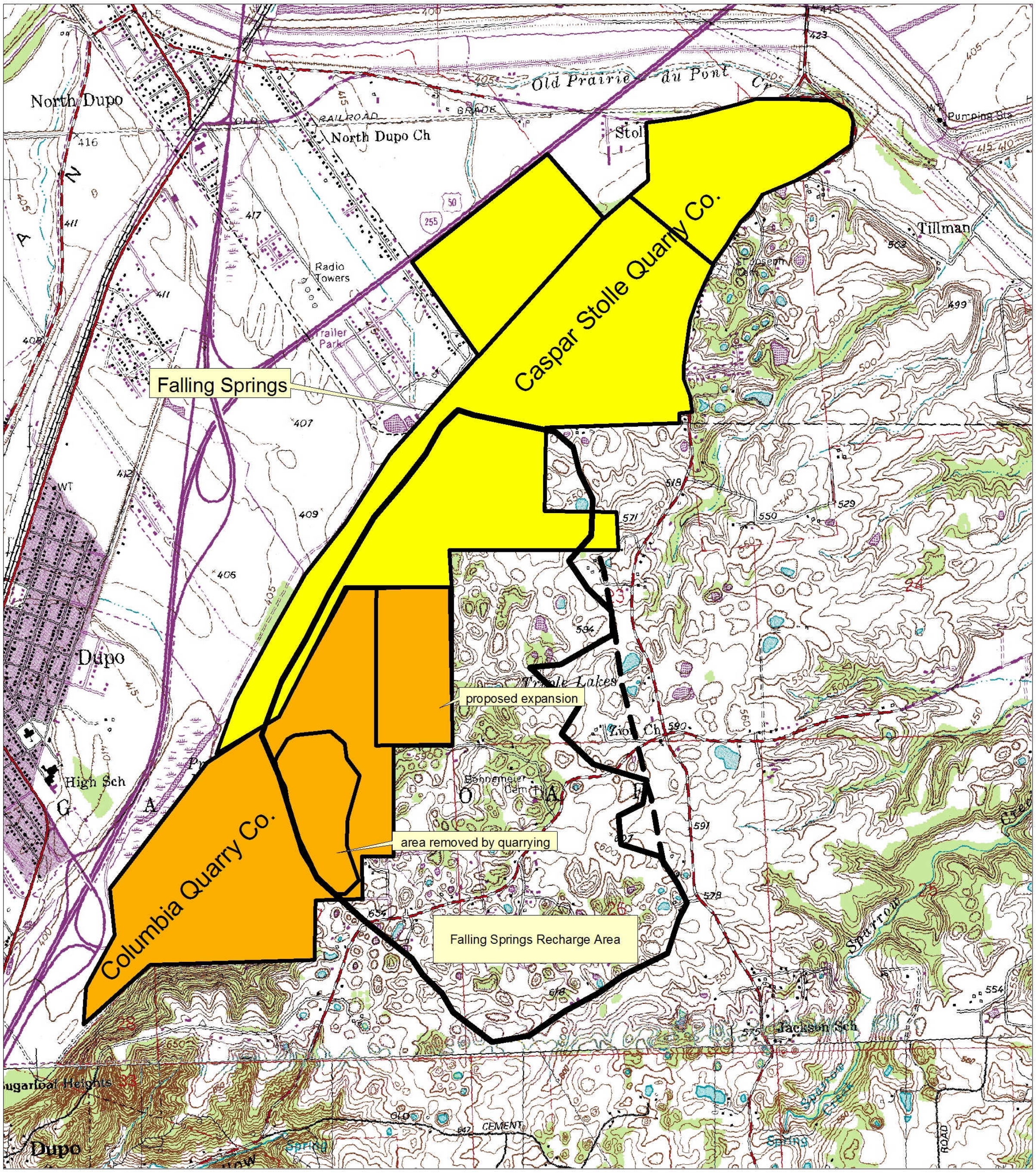


Figure 14
Falling Springs Recharge Area showing Quarry-Owned Lands
(parts of the Cahokia and Columbia 7.5-minute topographic maps)

Ozark Underground Laboratory, 2002

The possibility that suitable caves would not be found was recognized in OUL's proposal (Aley and Moss, 2000). Had the effort to find a suitable cave been successful, it would have been a much simpler task to answer the question of the conduit system's location. However, other methods exist to provide this information. It is OUL's recommendation that Task 3 of our proposal dated September 13, 2000 be implemented. Task 3 is Phase I geophysics, which will run geophysical lines near the south, east, and north boundaries of the proposed quarry expansion. This investigation would provide the necessary data to prevent intersection of karst conduits carrying significant quantities of water.

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