GROUND WATER (DYE) TRACING IN MURFREESBORO FOR PLANNING BEST MANAGEMENT PRACTICES FOR STORMWATER RUNOFF, PREDICTING SINKHOLE FLOODING PROBLEMS, AND TO AID IN CHEMICAL SPILL RESPONSE: RESULTS OF YEAR TWO OF THE INVESTIGATION

Prepared for:

The City of Murfreesboro

Water and Sewer Department

Prepared by:

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TABLE OF CONTENTS

	Page
Executive Summary	1
Introduction and Specific Aim	1
Study Area	2
Hydrogeologic Setting	9
Ground Water Tracing Methods	11
Ground Water Tracing Results	11
Summary and Conclusions	17
Recommendations	18
Acknowledgments	19
References	19
Appendices	21

LIST OF FIGURES

Figure 1. Ground water tracing results to York Spring.	4
Figure 2. Ground water tracing results to Garrison Spring.	5
Figure 3. Ground water tracing results to Foreign Car Cave stream.	6
Figure 4. Ground water tracing results for Bushman Spring, including Foreign Car Cave.	7
Figure 5. Ground water tracing results and new dye injection points for Black Fox Spring.	8
Figure 6. Stratigraphic column of the study area (adapted from Farmer and Hollyday, 1999).	10

LIST OF PHOTOGRAPHS

Photograph 1. York Spring.

Photograph 2. Jones Boulevard sinkhole.

Photograph 3. Dye injection into Hillmont Drive sinkhole.

Photograph 4. Measuring the discharge of Sinking Creek.

Photograph 5. Bushman Spring

Photograph 6. Dye injection into a sinking stream near Mt. Herman Church.

Photograph 7. Unnamed Cave near Crystal Court

LIST OF APPENDICES

Appendix A. Dye registration form submitted to the Tennessee Department of Environment and Conservation—UIC Program

Appendix B. Summary of laboratory results.

Appendix C. Material Safety Data Sheets for the dyes used for tracing.

GROUND WATER (DYE) TRACING IN MURFREESBORO FOR PLANNING BEST MANAGEMENT PRACTICES FOR STORMWATER RUNOFF, PREDICTING SINKHOLE FLOODING PROBLEMS, AND TO AID IN CHEMICAL SPILL RESPONSE: RESULTS OF YEAR 2 OF THE INVESTIGATION

EXECUTIVE SUMMARY

A total of 10 ground water (dye) traces were conducted during the investigation in which 5 showed positive results proving a hydrologic connection between the injection points and the monitored springs. Two traces were conducted to York Spring along the West Fork of the Stones River. No tracing had ever been conducted to this sizeable spring. The traces were helpful in determining the approximate location of a suspected sewer line leak or septic tank discharge that had tainted the water in a cave stream that was traced to the spring. Discharge measurements made along Sinking Creek documented a 15% loss which likely moves through the York Spring Drainage basin. Two other successful traces were conducted to Bushman Spring via a stream in Foreign Car Cave. One of the traces extends the length of the Bushman Spring drainage basin to nearly six miles making it one of the largest in the county. Finally, one successful trace was conducted from a newly formed sinkhole in "Little Ditch" to Garrison Spring. This trace provided important evidence on why a former trace failed and toward invalidating a questionable trace conducted during last year's investigation. Two of this year's failed traces were likely the result of the extraordinarily dry later winter and spring conditions. These unusual dry conditions made it a difficult year to conduct dye tracing.

At the end of the investigation, Josh Upham and Bruce Ross discovered two large springs along the upper reaches of the West Fork of the Stones River west of Barfield Crescent Park. No tracing has been conducted to these springs. They likely drain a large area west and northwest of the park. All of this suspected drainage area is within the Murfreesboro Urban Growth Boundary. Therefore, it is recommended that this work be continued in the next fiscal year to provide more information for the City with the area just described being the focus of the investigation. Also, the recharge area for Black Fox Spring still largely remains a mystery. If future funding is provided, a trace will be conducted during the summer months when Lytle Creek sinks to discover if it is a significant portion of the spring's discharge.

INTRODUCTION AND PURPOSE

Rutherford County is underlain by cavernous rock in which rain waters and contaminants rapidly enter the ground through sinkholes with little or no filtration. Murfreesboro has been experiencing unprecedented growth that has led to increasing amounts of storm water runoff that is often laden with chemicals applied to yards and fluids that leak from cars. In addition, the increased growth has resulted in more trucks carrying hazardous chemicals and gasoline that if spilled, would quickly disappear into a sinkhole without any prior knowledge as to which spring

the chemicals are going to emerge. This would result in killing of aquatic species in our surface streams and endangering our water supplies (Percy Priest Lake). Ground water tracing from sinkholes to springs using non-toxic dyes enables the delineation of surface watersheds that provide water to the subterranean streams that feed springs. Therefore, the primary purpose for conducting the ground water tracing was to determine the surface drainage basins of several springs that have elevated levels of *e-coli* to help ascertain potential sources of the contamination.

The secondary purpose for the ground water tracing was to aid in the development of best management practices for storm water runoff to lessen its impact on spring and surface water quality. These same results will enable rapid response to a hazardous waste or substance spills along highways or an underground storage tank leak. Most spilled or leaked contaminants are petroleum products that float on water. If it is known which spring is hydrologically connected to the spill site, the chemicals can be readily absorbed by floating absorption tubes set up around the spring orifice. Finally, the ground water tracing results will enable city personnel to determine the elevation difference between the sinkhole bottom and the spring to which it drains. If the bottom is close to the spring elevation, the water table simply rises quickly from the bottom of sinkholes during large storms. If there is approximately 25 feet of difference between a sinkhole bottom and spring, flooding can likely be prevented by the construction of drainage wells in sinkholes that do not drain quickly.

STUDY AREA

The study area is located largely within the Murfreesboro Urban Growth Boundary in the upper Stones River watershed. Figures 1 through 5 show the location of the springs involved in the study and the tracing results. Traces conducted for this study are shown in yellow and past traces are shown in red. York Spring (Figure 1) enters into the West Fork of the Stones River immediately upstream of where the river goes under the bridge on Thompson Lane. Garrison Spring is located in Garrison Creek near its confluence with “Little Ditch” which parallels the Lascassas Highway. This drainage then enters Bushman Creek where it crosses under the Lascassas Highway. Bushman Spring forms the head of Bushman Creek which flows into the

East Fork of the Stones River. A major subterranean branch of the Bushman Spring drainage occurs in Foreign Car Cave which is located next to the Honeywell factory on the south side of the John Bragg Highway. Two of the traces were detected in the cave stream. Black Fox Spring was monitored at the same time as Foreign Car Cave because it was uncertain to which of the springs the injected dyes would be detected. Two other traces were conducted in what is believed to be the Black Fox Spring drainage basin, but the dyes were never detected, likely due to lack of rainfall the month after the injections.

Figure 1. Ground water tracing results to York Spring

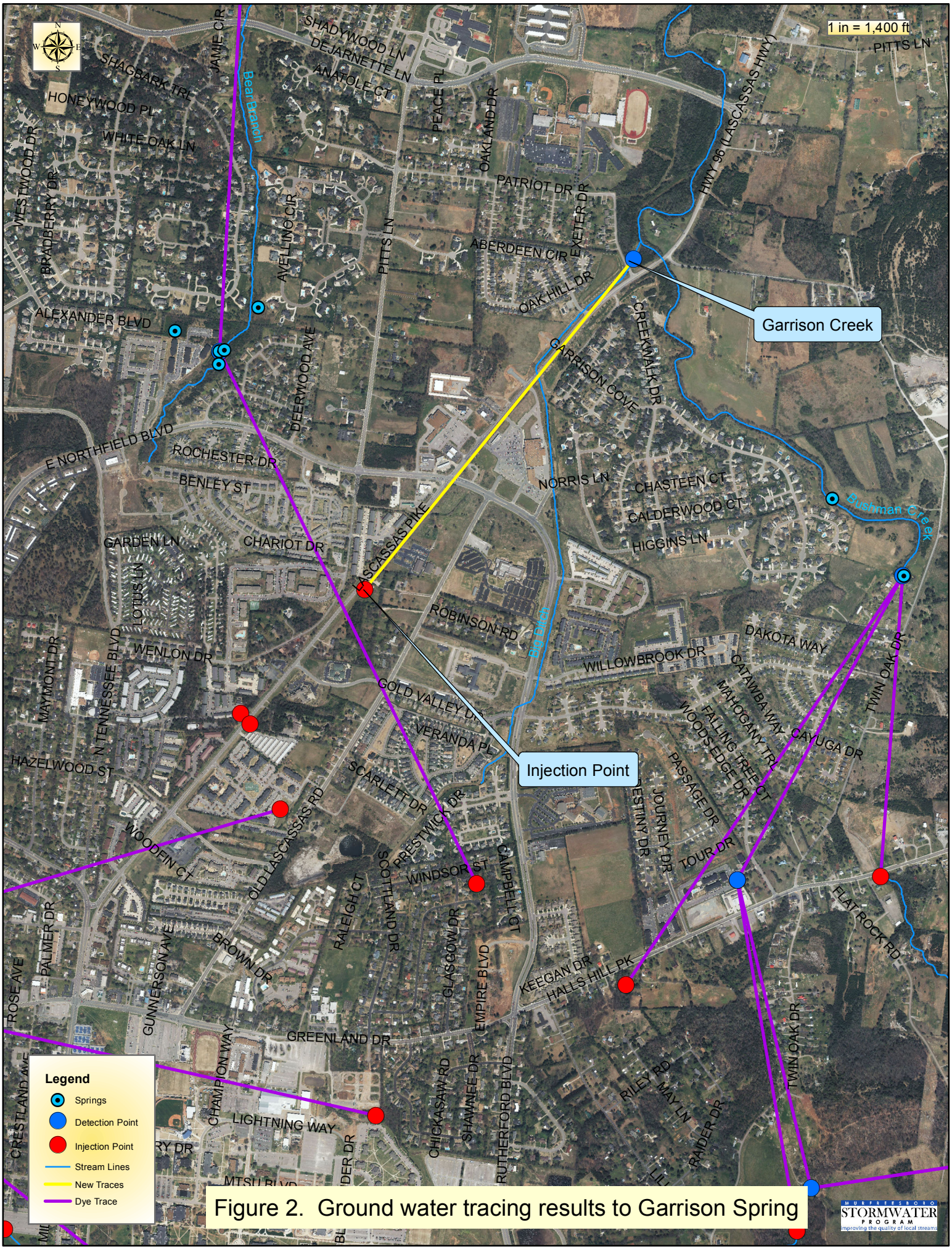


Figure 2. Ground water tracing results to Garrison Spring

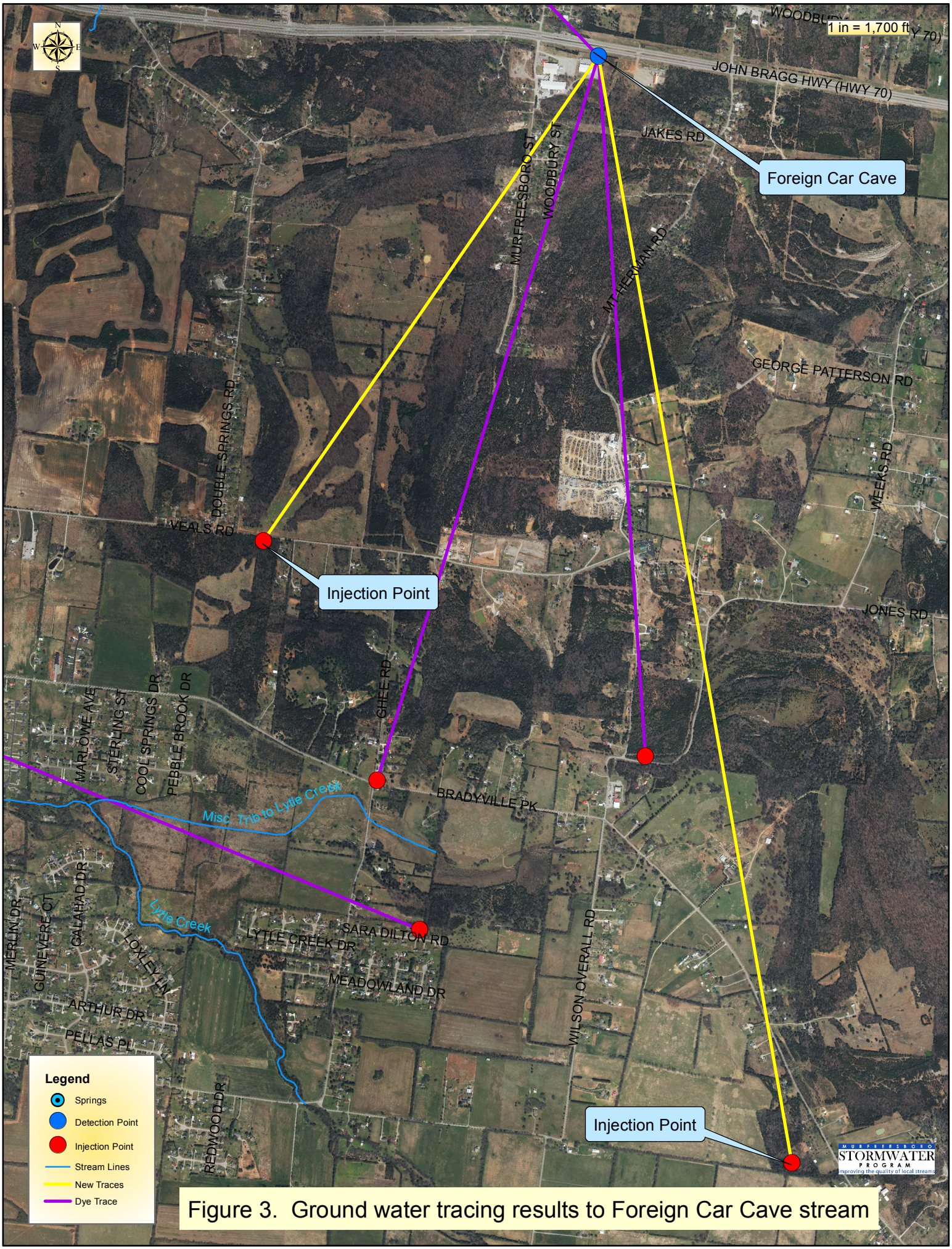


Figure 3. Ground water tracing results to Foreign Car Cave stream

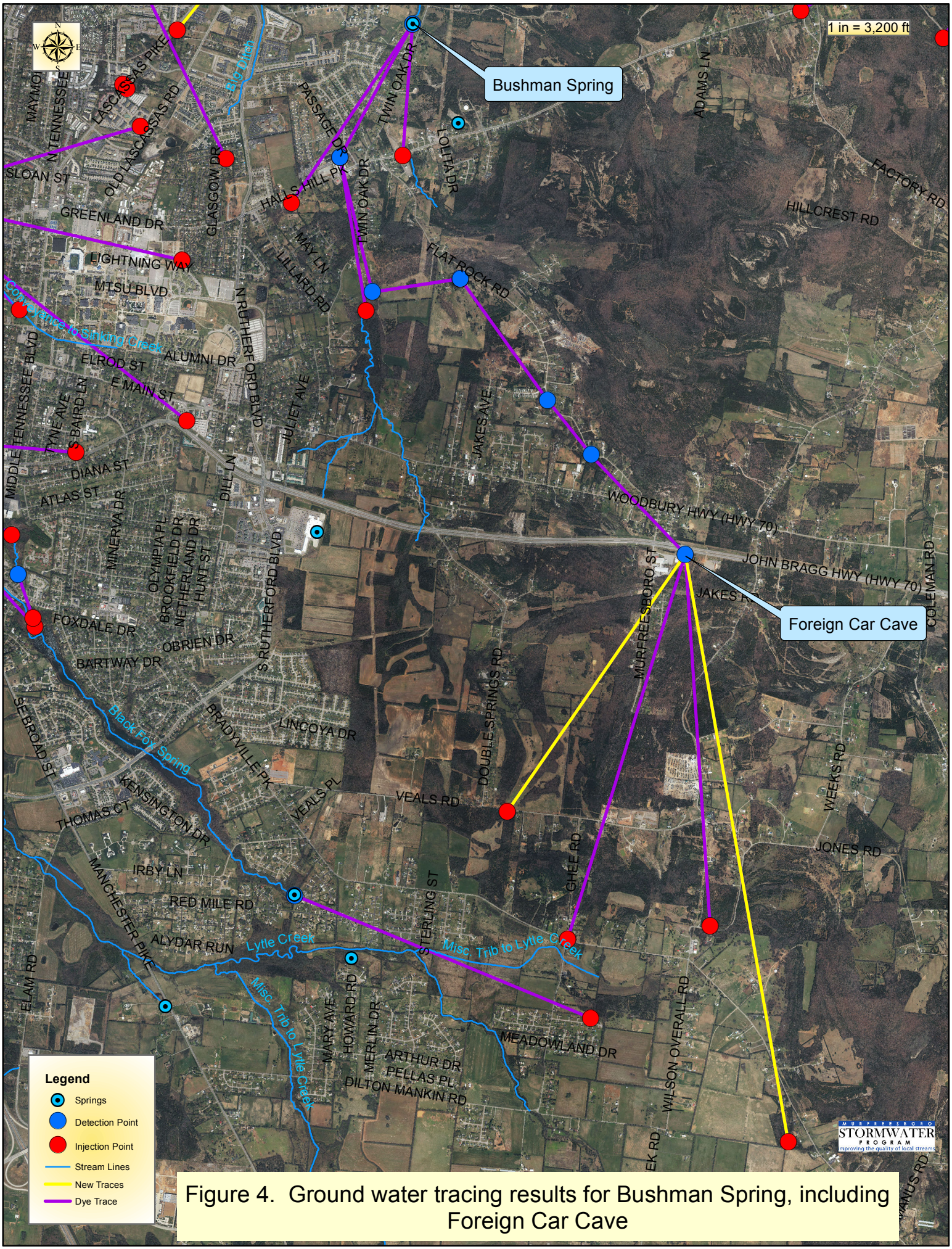


Figure 4. Ground water tracing results for Bushman Spring, including Foreign Car Cave

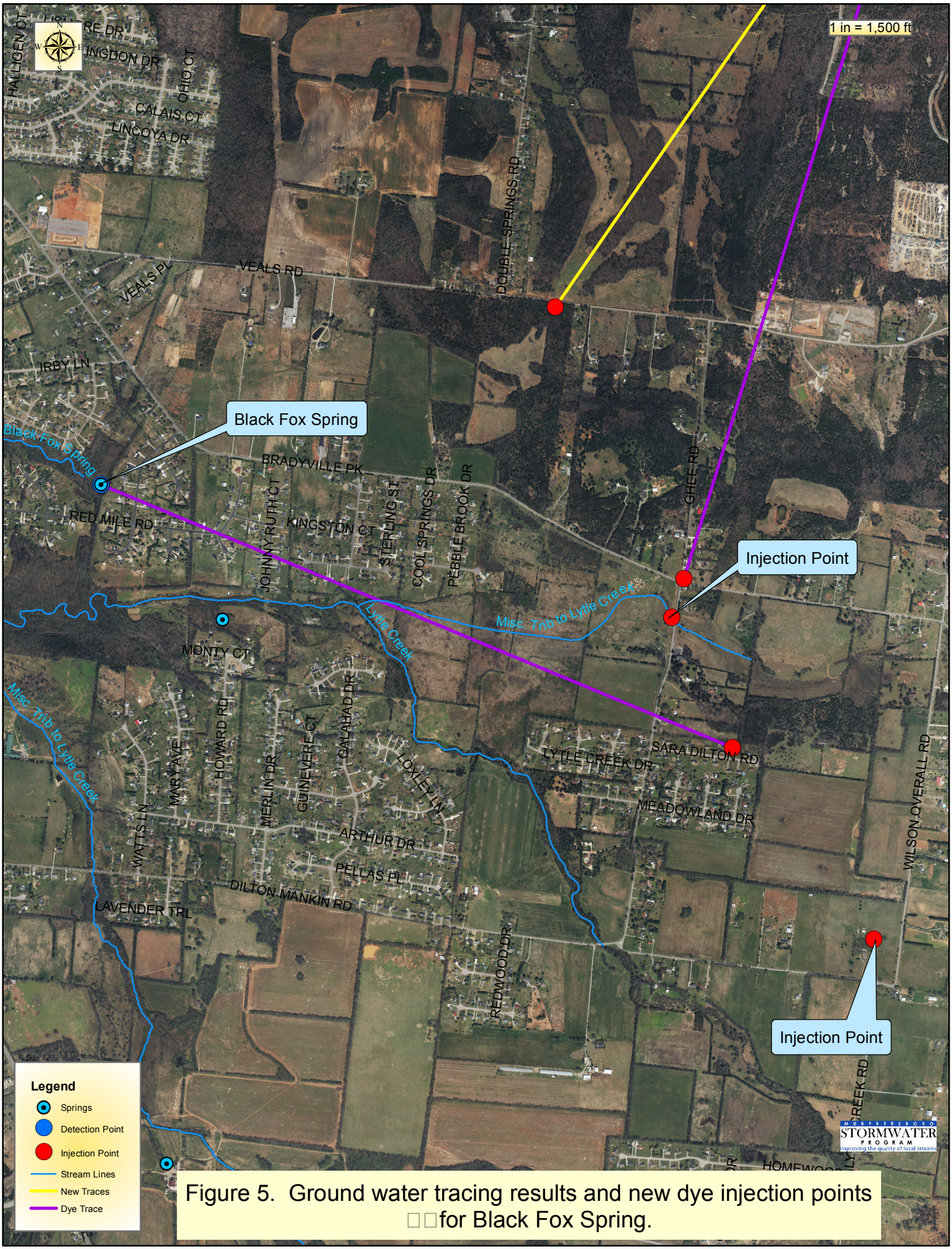


Figure 5. Ground water tracing results and new dye injection points for Black Fox Spring.

HYDROGEOLOGIC SETTING

Rutherford County is located in the Central Basin physiographic province, which is underlain by limestones of Ordovician age that have been gently upwarped to form the Nashville Dome. The first detailed geologic map of Rutherford County was made by Galloway in 1919. Detailed geology maps now exist for the entire County. The oldest rocks exposed in Rutherford County are those of the Murfreesboro Limestone Formation, which is approximately 400 feet thick. Above the Murfreesboro Limestone is the Pierce Formation (Figure 6), a shaly, thin-bedded limestone that confines water beneath it in the Murfreesboro Aquifer and perches water above it in the Ridley Limestone. The Ridley Limestone underlies most of the area of investigation, and it is the most karstic (cavernous) limestone in Rutherford County. Proprietary files of the Tennessee Cave Survey show that a majority of the 124 caves discovered and explored in Rutherford County occur in the Ridley Limestone aquifer. Snail Shell Cave near Rockvale is the largest with over nine miles of passage. All of the springs involved in this study are believed to emerge near the contact between the impermeable Pierce Formation and the overlying Ridley Limestone or the upper Ridley Limestone and the underlying Lower Ridley Confining Unit.

The first documented dye tracing in the Rutherford County occurred in the area of Snail Shell Cave as part of the State's proposal for the Superconducting Super Collider (Crawford, 1988). Crawford conducted two traces in the study area as part of his investigation. Since then, approximately 110 ground water traces have been conducted in the County by the author of this report. Five previously funded projects by the Rutherford County Planning Commission, two grants from the City of Murfreesboro, four MTSU Faculty Research Grants, and a grant from the Rutherford County Board of Education have enabled important discoveries to be made regarding ground water flow directions, causes for sinkhole flooding, and potential sources of spring water contamination. This research has resulted in a number of publications (Ogden and Scott, 1997; Ogden et.al., 1998; Ogden et.al., 1999; Ogden and Powell, 1999; Ogden, 2000; Ogden et.al., 2001; Ogden et.al., 2002, Ogden, et.al., 2003, James, et.al, 2004, Ogden, et.al., 2006, and James, et.al, 2006, Ogden et. al., 2012). Josh Upham, of Murfreesboro's Water and Sewer Department, has diligently updated the statewide GIS ground water tracing database he and the author created

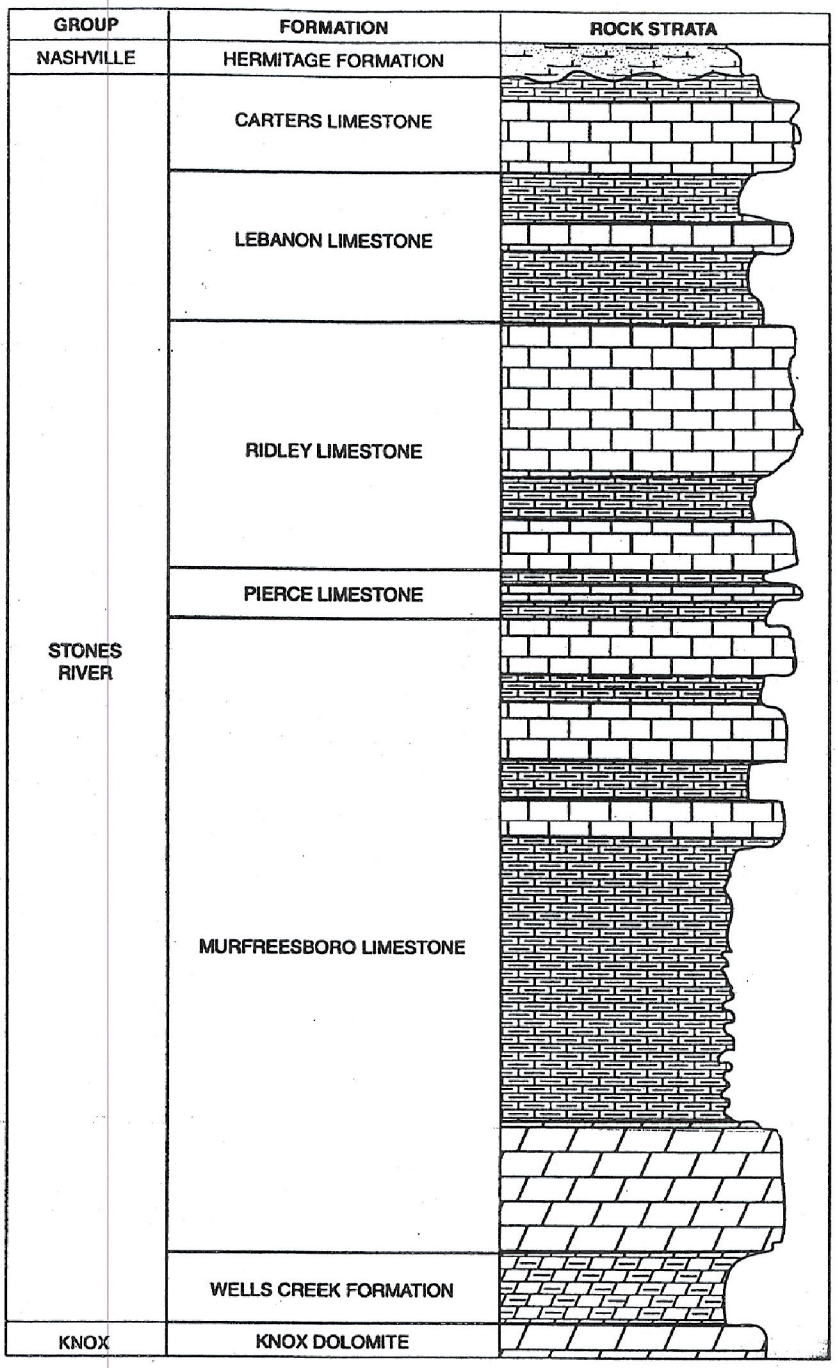


Figure 2. Stratigraphic column of the study area (from Farmer and Hollyday, 1999).

for TDEC-Ground Water Management Section in 2003. The author has conducted approximately 30 new traces in Rutherford County since 2003.

GROUND WATER TRACING METHODS

The ground water tracing was performed using three fluorescent dyes: sulphorhodamine B (SRB), eosine, and fluorescein. These tracing agents are non-toxic and routinely approved for use by various divisions of the Tennessee Department of Environment and Conservation. Prior to conducting the traces, the Tennessee Underground Injection Control Program was notified in writing as required for their dye tracing registration program (see Appendix A). The injected tracing agents were detected by using activated charcoal packets that absorb and concentrate the dye levels in the water. The charcoal packets, called "traps", were suspended in the waters expected to receive the dyes on a stiff wire connected to a concrete base. Prior to tracing, some of the traps were placed in the spring waters for approximately a week to test for background concentrations. The dyes are common coloring agents and frequently found as "contaminants" in the ground water. Once background levels were determined, new packets were set out immediately prior to injection. After injection of the tracing agents, the packets were changed at approximately seven day intervals and sent to the laboratory for analysis. Crawford Hydrology Lab, located at Western Kentucky University, was used to perform the analyses, which were done by a scanning spectrofluorophotometer.

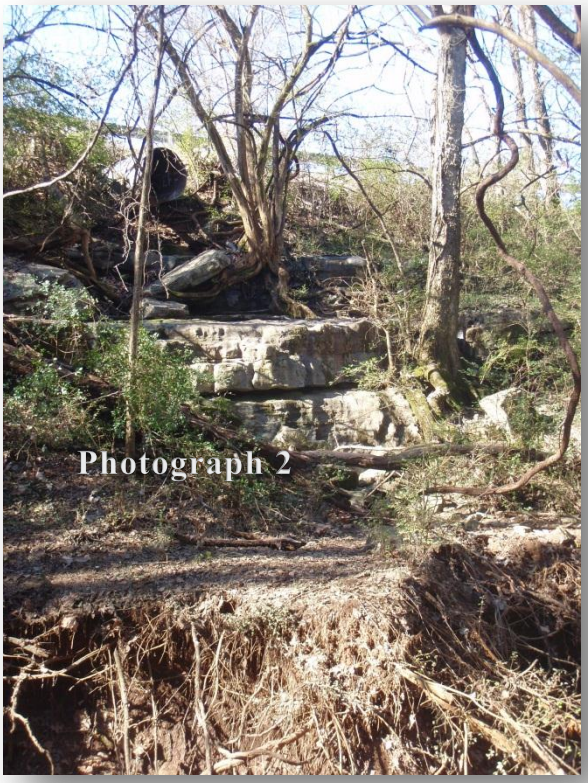
GROUND WATER TRACING RESULTS

A total of ten traces were conducted for this project of which five were successful. The following is a discussion of the results by spring basin. Past traces were conducted by the author to one of the springs. These are shown on the figures in red to provide a better overview of the springs' watersheds. Appendix B provides the results from the laboratory and Appendix C presents the Material Safety Data Sheets for the dyes utilized for tracing.

York Spring and the Sinking Creek Drainage Basin

A significant portion of the City in which no dye tracing had been conducted prior to this investigation lies west of Sinking Creek and north of Northfield Boulevard. Several deep sinkholes and two caves were known to exist between Jones Boulevard and Battleground Drive. These sinkholes and others in the area follow a northwest linear trend along the trough of a syncline. Prior tracing by the author has discovered that most of the springs in the county occur where a synclinal trough intersects one of the branches of the Stones River, generally at the contact between the lower Ridley Limestone and the impermeable Pierce Formation. A canoeing trip in January at the expected spring location found only a small spring which was called York Spring (Photograph 1). This was deemed too small to be the spring of interest. A large spring, called Battleground Spring, was discovered along Sinking Creek by Upham and Ross soon after the canoeing trip. In preparation for the first dye trace, a trip was made into an unnamed cave along Crystal Court. A large stream was discovered in the cave and appeared to contain a significant amount of raw sewage based on the smell and discoloration of the water. Since this indicated a broken sewer line or septic tank discharge an immediate trace was conducted to narrow down the source of contamination.

On January 25th, one pound of fluorescein dye was injected in the deep sinkhole along Jones Boulevard which contained a flowing stream at the time (Photograph 2). A dye detector packet was placed in the unnamed cave, Battleground Spring, and two locations in Sinking Creek near its confluence with the West Fork. The dye was detected in the cave, but nowhere else. Since the flowing stream in the Jones Boulevard sink did not have the appearance or smell of sewage, it was concluded that the source of contamination must occur between the injection point and the cave. Due to near drought conditions during the late winter and early spring, the West Fork of the Stones River had very low flow. Therefore, another canoeing trip was conducted in late March in hopes of finding a spring that may have been under water during the first float. With the river level down two to three feet, it was discovered that York Spring actually had significant flow discharging at several points along a bedding plane. Detectors were placed at the spring, and one pound of fluorescein dye was injected into a deep sink along Hillmont Drive (Photograph 3). This sinkhole is very close to the unnamed cave along Crystal Court and in a down-gradient direction of the cave. The dye was detected at York Spring a few days after injection.



Maney Spring is located on the property of the historic Oakland Mansion. The spring forms the beginning of Sinking Creek. The author has previously performed four traces to this spring. These four traces have made it possible to delineate with significant accuracy the entire watershed that provides recharge to the spring. This includes much of

the MTSU campus, Evergreen Cemetery by the former hospital, sinkholes near the Slick Pig restaurant, and the area just north of Greenland Drive and west of Old Lascassas Road. It has often puzzled the author how Sinking Creek gets its name since discussions with people living in the Murfreesboro area all their lives have never seen it sink. As part of this year's investigation, vintage 1938 stereo, aerial, black and white photographs were reviewed of the study area. The photographs clearly showed that Sinking Creek sank in its bed a few hundred yards upstream from where it crosses Sulphur Springs Road. Some of the streambed below the sinkpoint was totally vegetated indicating no significant downstream flow in many years. Even though it was abnormally dry during the spring of the present investigation, Sinking Stream did not sink. In an attempt to document some stream loss, discharge measurements where made with a flow meter at three locations above the 1938 sinkpoint (Photograph 4). The results showed a gradual loss of approximately 40 gpm or 15% of the creek's flow at the time. It is believed that this water moves through the bottom of Jones Boulevard Sink, then through the unnamed cave along Crystal Court,

Photograph 3

Photograph 4

and onward to York Spring. During higher flow conditions, the loss is likely much greater.

Garrison Spring

A sinkhole opened up in the bottom of the Little Ditch near the intersection of Rutherford Boulevard and the New Lascassas Road. During storm events, the sinkhole took nearly all the stormwater runoff along the New Lascassas Road. It was thought that this drainage would go to Bear Branch Spring located at the head of Bear Branch because of a former trace conducted to the spring from Scotland Acres Subdivision. Charcoal dye detectors were placed at the spring, as well as, in Little Ditch immediately below it confluence with Garrison Creek in which Garrison Spring occurs. Surprisingly, the dye was detected at Garrison Spring, not Bear Branch Spring.

These results now explain why a trace last year from a sinkhole located near the upper reaches of the Little Ditch failed. Garrison Spring had not yet been discovered and was therefore not monitored. Repeating that former failed trace would almost certainly lead to a positive result. Also, the results now put into question the dye trace conducted the previous year from a sinkhole in Scotland Acres subdivision. The lab results of this former trace to Bear Branch Spring and Lufkin Spring showed only 10 times background level of the dye which is the minimum necessary to call a trace positive. The author prefers to have dye levels 50 times or more above background before calling a trace positive. For this trace to have been positive, the dye would have had to move under the subterranean pathway of Garrison Spring which is very unlikely. Repeating this failed trace would almost certainly show a hydrologic connection to Garrison Spring.

Bushman Spring/Black Fox Spring

Bushman Springs forms the head of Bushman Creek (Figure 4 and Photograph 5) and is one of the largest springs in the County. Based on many previous dye traces by the author, the spring basin has a large drainage area including portions of Bradyville Pike in the vicinity of Mt. Herman Church, sinkholes and karst windows along Flat Rock Road,

subdivisions and businesses located along Halls Hill Pike east of Rutherford Blvd., and most of the area directly east of MTSU. The recharge area for Black Fox Spring has been somewhat of a mystery. The author has conducted only one trace to the spring. In an attempt to further delineate the spring's watershed, two pounds of fluorescein dye were injected on February 22nd into a sinking stream located about a 1000 feet down-gradient of the Rutherford County waste disposal center located on Bradyville Pike. Charcoal dye absorption packets were placed at Black Fox Spring and in the large stream in Foreign Car Cave. The dye was detected in the cave stream which had been previously traced to Bushman Spring. Then, on March 22nd, one pound of fluorescein dye was injected into a sinkhole located along Veals Road. This dye was also detected in the cave stream. In hopes of obtaining a positive trace to Black Fox Spring, one pound of sulphorhodamine B was placed in a sinking stream near the Dilton Crossroads on March 2nd. The sulphorhodamine B was never detected. Then, on March 22nd, two pounds of eosine were injected into a sinkhole located near the intersection of Wilson Overall Road and Lytle Creek Road. The dye was flushed with only 10 gallons of water carried to the sinkhole. It was hoped that the dye would be flushed into the subterranean drainage by the forecasted storm that night, but no significant amount of rain occurred. No other significant rainfall occurred during the next month and a half with is the likely reason for the trace to have been a failure. It is

Photograph 5

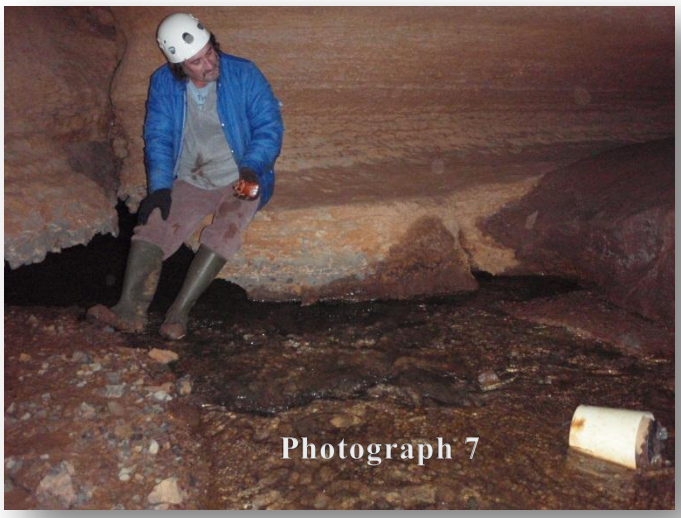
Photograph 6

believed that some of the discharge of Black Fox Spring is from Lytle Creek which sinks during the summer months. It is hoped that a dye trace can be performed at that point this summer to help solve the mystery of the recharge area of Black Fox Spring.

SUMMARY AND CONCLUSIONS

The purpose of this investigation was to delineate surface basins that provide recharge to some of the springs within Murfreesboro's Urban Growth Boundary to help locate potential sources of elevated levels of *e-coli* contamination in the springs. A total of ten ground water (dye) traces were conducted for this project although only five of the traces were successful. At least two of the five failures were likely due to the extraordinary dry late winter and spring conditions in which little to no stormwater entered the sinkholes after dye injection to carry the dyes to the springs.

The first area studied was north of Northfield Boulevard and west of Sinking Creek where no dye tracing had ever been conducted. Numerous deep sinkholes and caves occur in the area. Evidence of a broken sewer line or septic tank discharge was discovered in a cave stream along Crystal Court within this area of investigation.Two successful dye traces narrowed down the location of the source of contamination and showed that the tainted water emerges at York Spring along the West Fork of the Stones River. The dye traces showed that ground water in the area moves downdip and along a synclinal trough to York Spring which is located where the trough intersects the West Fork. Discharge measurements along portions of Sinking Creek


Photograph 7

documented stream loss that likely moves through the subterranean pathway of York Spring.

A dye trace along Bradyville Pike was initially expected to connect the injection point to Black Fox Spring but instead, was detected in a stream in Foreign Car Cave which was previously traced to Bushman Spring. The distance between the injection point and Bushman Spring is nearly six miles. Another successful trace to Foreign Car Cave was conducted from a sinkhole along Veals Road. Once again, the traces showed that ground water moves down the dip of a syncline and then along its trough to the spring. Finally, a successful trace was conducted from a newly formed sinkhole in the bottom of the Little Ditch which follows the New Lascass Highway. The trace was detected at Garrison Spring which is located along Garrison Creek which is a tributary of Little Ditch. The dye was expected to be detected at Bear Branch Spring. This traces now invalidates a questionable trace conducted last year from Scotland Acres to Bear Branch Spring.

The new tracing results provide the City with important information regarding the surface drainage basin of two newly discovered springs within the Urban Growth Boundary and significantly extends the size of the Bushman Spring basin to which many other traces had been conducted. There are still sizeable springs within the Urban Growth Boundary in which no dye tracing has been conducted and thus no knowledge exits of their recharge areas. Therefore, more work will be necessary to complete the mission of understanding the subterranean pathways beneath Murfreesboro.

RECOMMENDATIONS

The last two years of investigating ground water flowpaths in Murfreesboro have provided valuable insight to possible sources of ground water contamination within nearly ten different spring drainage basins. Near the conclusion of the present investigation, two large springs were discovered along the western side of the upper West Fork of the Stones River. These springs are believed to drain stormwaters that enter sinkholes in the Barfield Cresent Park area and regions to the southwest of the park. No

dye tracing has ever been performed to these two springs. The suspected drainage areas are all within the Murfreesboro Urban Growth Boundary. Other springs also occur in this area to which no dye traces have been conducted. Therefore, it is recommended that this research be continued for a third year with these springs being the focus of the investigation. In addition, a dye trace should be conducted during the summer where Lytle Creek sinks. If this trace positively connects Lytle Creek to Black Fox Spring, it would document a significant portion of the spring's watershed.

ACKNOWLEDGEMENTS

The author would like to thank Josh Upham and Bruce Ross for all their help in the field. Additional appreciation is given to Josh Upham for preparing most of the figures in the report and providing all of the photographs.

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APPENDIX A

Dye Tracing Registration Form submitted to the

Tennessee Department of Environment and Conservation-UIC Program

APPENDIX B

Summary of Laboratory Results

APPENDIX C

Material Safety Data Sheets for the Dyes used for Tracing

APPENDIX A

Dye Tracing Registration Form submitted to the

Tennessee Department of Environment and Conservation – UIC Program

Tennessee Department of Environment & Conservation
Dye Trace Registration

Owner/Operator of Facility Necessitating Trace:

Name: Murfreesboro Water + Sewer Dept., Attn: Robert Haley

Mailing Address: 220 NW Broad St., P.O. Box 1477

City, State, Zip Code: Murfreesboro, TN 37127

Phone: (615) 848-3200 County Rutherford

Person/Company Performing Trace:

Name: Albert E. Ogden

Mailing Address: 6478 Jones Lane,

City, State, Zip Code: Murfreesboro, TN 37127

Phone: (615) 907-0004

Property Owner at Injection Site:

Name: Varbis owners on private land

Mailing Address:

City, State, Zip Code:

Reason for Trace: to help determine sources of spring water contamination

If State or Federal Agency Oversight, Give Agency: none

Dyes to be Used with Approximate Amounts and Respective Injection Locations:

Fluorescein, eosine, and sulphorhodame B; approximately 1 pound of dye will be used at each injection site

CN-1112

RDA 2474

(continued on reverse)

Type Receptors or Visual: charcoal

Background Test: yes

Describe Injection Point(s) and Include Photocopy of Topographic Map with Locations Latitude and Longitude:

See attached maps
Coordinates are on an attached pages

Anticipated Injection Date: January 3rd until May 15th

Public Water Systems: List Surface Water Intakes, Wells or Springs within 2 Miles of the Injection Point(s):

Va Hospital Spring and Ayers Spring empty into Walter Hill Dam, but the City water intake is upstream. All other sites are greater than 2 miles from a water intake

Is the Area Served by a Public Water System? Yes

Estimate Percentage of Private Well/Spring Use Versus Public Water Use:

Everyone utilizes public water for drinking

Submitted by: Albert E. Ogden

Phone: (615) 907-0004

Date: 12/15/11

Mail or Fax the Completed Form to:

Tennessee Division of Water Supply
Ground Water Management Section
Attn: Scotty Sorrells
6th Floor, L & C Tower
401 Church Street
Nashville, Tennessee 37243-1549
Phone: (615) 532-0191; Fax: (615) 532-0503

There are currently no regulations requiring dye trace registration in Tennessee, unless there is the potential to impact a public water system. This registry is designed to avoid cross contamination and re-performing the same or similar trace. The dye tracing registry allows the Department to make informed responses to water pollution inquiries so that dye traces are not mistakenly identified as pollution to waters of the state.

APPENDIX B

Summary of Laboratory Results

CRAWFORD HYDROLOGY LAB * HOFFMAN ENVIRONMENTAL RESEARCH INSTITUTE

* Hydrogeologists, Geologists, Environmental Scientists * Karst Geophysical Subsurface Investigations

* Karst Groundwater Investigations * Fluorescent Dye Analysis

Western Kentucky University
Bowling Green, KY 42101
(270) 745-9224
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LABORATORY REPORT SHEET

FLUORIMETRIC ANALYSIS RESULTS

Murfreesboro 2012

Analysis requested by:

Albert Ogden

FLUORESCEIN	EOSINE	SULPHORHODAMINE B
Color Index: Acid Yellow 73	Color Index:	Color Index: Acid Red 52
Dye Receptor: Activated Charcoal	Dye Receptor: Activated Charcoal	Dye Receptor: Activated Charcoal
Analysis by: Spectrofluorophotometer	Analysis by: Spectrofluorophotometer	Analysis by: Spectrofluorophotometer

CHARCOAL SAMPLES

						FLUORESCEIN			EOSINE			SULPHORHODAMINE B			
						PQL in Eluent: 0.005 ppb			PQL in Eluent: 0.005 ppb			PQL in Eluent: 0.005 ppb			
						PQL in Water: 0.010 ppb			PQL in Water: 0.010 ppb			PQL in Water: 0.010 ppb			
						λ in Eluent: 516.0 nm			λ in Eluent: 540.0 nm			λ in Eluent: 577.0 nm			
						λ in Water: 510.2 nm			λ in Water: 534.4 nm			λ in Water: 582.2 nm			
Lab ID	Event	Date Collected	Feature Name	TIME	Peakfit	Results	Conc in ppb	Peak Center (nm)	Results	Conc in ppb	Peak Center (nm)	Results	Conc in ppb	Peak Center (nm)	Comments
EH-001-0	-	01/30/12	Garrison Spring	-		+?	45.242	511.6				ND			
EH-002-D	-	01/30/12	Crytal Ct. Cave	-		+?	2763.600	512.4				ND			DILUTED 1:100
EL-003-0	-	02/27/12	Black Fox Spring	-		B	0.034	508.0,POR				ND			
EL-003-1	-	03/08/12	Black Fox Spring	-		B	0.031	507.6,POR				ND			
EL-003-0	-	03/22/12	Black Fox Spring	-		B	0.062	508.6,POR	ND			ND			
EL-003-0	-	04/04/12	Black Fox Spring	-		B	0.044	507.8,POR	ND			ND			
EL-003-1	-	04/27/12	Black Fox Spring	-		B	0.056	508.4,POR	ND			ND			
EL-003-0	-	05/17/12	Black Fox Spring	-					ND			ND			
EL-004-0	-	02/28/12	Foreign Car Cave	-		B	0.035	508.4,POR				ND			
EH-004-1	-	03/07/12	Foreign Car Cave	-		+?	4.830	511.6				B	0.056	570.4,POR	
EL-004-0	-	03/20/12	Foreign Car Cave	-		B	0.401	510.8,POR	ND			ND			0.2NM OUT OF RANGE, EO SHOULDER PRESEN
EL-004-D	-	04/04/12	Foreign Car Cave	-		+++	299.500	512.0	ND			ND			DILUTED 1:100
EH-004-1	-	04/27/12	Foreign Car Cave	-		+++	40.265	511.6	ND			ND			
EL-005-0	-	03/07/12	Siegel Pit	-		B	0.032	507.8,POR				ND	0.019	NPI	
EL-006-0	-	03/08/12	Lytle Wetland	-		B	0.028	507.2,POR				ND			
EL-006-0	-	04/04/12	Lytle Wetland	-		B	0.056	508.0,POR	ND			ND			
EL-007-0	-	03/16/12	Old Fort Spring	-		B	0.093	508.6,POR	ND			ND	0.017	NPI	
EH-008-D	-	04/10/12	York Spring	-		+?	227.400	513.4	ND			ND			DILUTED 1:100

Comments:

DUP = Field Duplicate
B = Background
ND = No Detection
IB = Initial Background

NS = No Sample Recovered
GS = Grab Sample
NPI = No Peak Identified
POR = Peak Out of Range

NS = No Sample Recovered
GS = Grab Sample
NPI = No Peak Identified
POR = Peak Out of Range

Q = Lab Duplicate
+ = Positive
?+ = Questionable Positive, needs two hits in a row to equal +
Peakfit Utilized

ND Below Quantitation Limit
B Background
NS No Sample

\+ Positive
++ Very Positive
+++ Extremely Positive

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APPENDIX C

Material Safety Data Sheets for the Dyes used for Tracing

Material Safety Data Sheet
(FLUORESCEIN)
15174 URANINE C

CHEMCENTRAL/Dyes & Pigments
13395 Huron River Drive
Romulus, MI 48174

REVISION DATE: 12-6-00
CHEMTREC: 800-424-9300
EMERGENCY: 734-941-4800

SECTION I - IDENTIFICATION

TRADE NAME: ..... 15174 URANINE C
CHEMICAL NAME: ..... Acid Yellow 73 CAS# 6417-85-2
CHEMICAL FAMILY: ..... Xanthene

SECTION II - HAZARDOUS INGREDIENTS

HAZARDOUS INGREDIENT	PERCENT	CAS NUMBER	PEL
NONE as per 29CFR part 1910.1200 or Sara Title III			

HMIS HAZARD RATINGS (if applicable):
HEALTH: 1
FIRE 0
REACTIVITY 0

SECTION III - PHYSICAL DATA

APPEARANCE: ..... Orange powder, no characteristic odor.
BOILING POINT: ..... N/A
MELTING POINT: ..... N/A
FREEZING POINT: ..... N/A
VAPOR PRESSURE: ..... N/A
VAPOR DENSITY (AIR=1): ..... N/A
SPECIFIC GRAVITY: ..... Approximately 1
pH: ..... N/A
SOLUBILITY IN WATER: ..... Moderate
VOLATILITY: ..... N/A

SECTION IV - FIRE AND EXPLOSION DATA

FLASH POINT: ..... N/A
EXTINGUISHING MEDIA: ..... Water fog, CO_2, or Dry chemical.
FIRE FIGHT PROCEDURES: ... Fire fighters should be equipped with self contained breathing apparatus and turnout gear.
UNUSUAL FIRE HAZARD: ..... Adequate ventilation and clean up must be maintained to minimize dust accumulation. May form explosive dust/air mixture.

Material Safety Data Sheet
(FLUORESCEIN)
15174 URANINE C

SECTION V - REACTIVITY DATA

STABILITY: ..... Stable
CONDITIONS TO AVOID: ..... N/A
HAZARDOUS POLYMERIZATION: Does not occur
POLYMERIZATION TO AVOID: N/A
INCOMPATIBILITY: ..... Avoid contact with strong oxidizing agents
DECOMPOSITION: ..... Carbon monoxide,Carbon dioxide,and oxides of Nitrogen and Sulfur.

SECTION VI - HEALTH DATA

THRESHOLD LIMIT VALUE:.. Not Established
OVER EXPOSURE EFFECTS: Contact with eyes may result in severe irritation. Contact with skin may result in irritation. Ingestion may result in gastric disturbances. Inhalation of dust may irritate respiratory tract.

SECTION VII FIRST AID

FIRST AID PROCEDURES: Flush eyes with flowing water at least 15 minutes. If irritation develops, consult a physician. Wash affected skin areas thoroughly with soap and water. If irritation develops, consult a physician. Remove and launder contaminated clothing before reuse.

If swallowed, dilute with water and induce vomiting. Get immediate medical attention. If inhaled, move to fresh air. Aid in breathing, if necessary, and get medical attention.

NEVER GIVE FLUIDS OR INDUCE VOMITING IF PATIENT IS UNCONSCIOUS OR HAS CONVULSIONS.

SECTION VIII EMPLOYEE PROTECTION

RESPIRATORY PROTECTION: NIOSH/OSHA approved dust respirator as necessary.
PROTECTIVE GLOVES: ..... To prevent skin contact.
EYE PROTECTION: ..... Goggles.
ADDITIONAL MEASURES: ..... Eye wash fountains should be easily accessible.
HANDLING AND STORAGE:... Keep away from excessive heat and moisture. Keep containers closed.
VENTILATION: ..... Local exhaust to control dusts.

SECTION IX - SPILL AND DISPOSAL DATA

SPILL: ..... Spills should be contained and placed in suitable containers.
WASTE DISPOSAL: ..... Do not discharge into sewers or waterways. Dispose of in accordance with local regulations.

Material Safety Data Sheet
(FLUORESCEIN)
15174 URANINE C

SECTION X - TRANSPORTATION DATA

PROPER SHIPPING NAME: ..... Ink Material NMFC Item #101720
HAZARD CLASS AND LABEL: MFR LABEL ONLY
UN NUMBER: ..... N/A
REPORTABLE QUANTITY: ..... N/A

SECTION XI - ADDTIONAL INFORMATION

FOOT NOTES: This information is furnished without warranty, representation, or license of any kind, except that it is accurate to the best of CHEMCENTRAL Corporation's knowledge or obtained from sources believed by CHEMCENTRAL Corporation to be accurate.

The CHEMCENTRAL Corporation does not assume any legal responsibility for use or reliance upon same. Customers are encouraged to conduct their own tests. Before using any product, read its label.

MATERIAL SAFETY DATA SHEET

15189 Eosine OJ

(EOSINE)

SECTION I - IDENTIFICATION

MANUFACTURER/DISTRIBUTOR. CHEMCENTRAL/Dyes & Pigments Division
13395 Huron River Drive
Romulus, Michigan 48174
EMERGENCY PHONE NUMBER... (313) 941-4800
EFFECTIVE DATE..... 10/25/1996
REVISED DATE..... 10/25/1996
CHEMICAL NAME..... Acid Red 87 (Color Index name)
TRADE NAME..... 15189 Eosine OJ
CHEMICAL FAMILY..... Xanthene
CHEMICAL FORMULA..... 45380 (Color Index formula)

SECTION II - HAZARDOUS INGREDIENTS

HAZARDOUS COMPONENTS	HAZARDOUS %	TLV (Units)	PROD. CAS #
None as per part 29 CFR 1910.1200. This product supplied is in compliance with TSCA Reporting Requirements, SARA Title III. Not Listed.			

SECTION III - PHYSICAL DATA

BOILING Point(F)..... N/A
FREEZING POINT (F)..... N/A
VOLATILITY/VOL(%)..... N/A
MELTING POINT..... N/A
VAPOR PRESSURE (mm Hg)... N/A
VAPOR DENSITY (Air=1).... N/A
SOLUBILITY IN H20..... Moderate
APPEARANCE/ODOR..... Red powder, no characteristic odor
SPECIFIC GRAVITY (H20=1). Approximately 1
EVAPORATION RATE..... N/A
PH..... N/A

SECTION IV FIRE & EXPLOSION HAZARD DATA

FLASH POINT..... N/A
LOWER FLAME LIMIT..... N/A
HIGHER FLAME LIMIT..... N/A
EXTINGUISH MEDIA..... Water fog, CO_2, or Dry chemical.
FOR FIRE..... Fire fighters should be equipped with self contained breathing apparatus and turnout gear.

MATERIAL SAFETY DATA SHEET

15189 Eosine OJ

JNUSUAL FIRE HAZARD..... Adequate ventilation and clean up must be maintained to minimize dust accumulation. May form explosive dust/air mixture.

SECTION V - HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE.... Ingestion in rats, LD50=4,700 mg/kg

OVER EXPOSURE EFFECTS.... Contact with eyes may result in severe irritation. Contact with skin may result in irritation. Ingestion may result in gastric disturbances. Inhalation of dust may irritate respiratory tract.

FIRST AID PROCEDURES..... Flush eyes with flowing water at least 15 minutes. If irritation develops, consult a physician. Wash affected skin areas thoroughly with soap and water. If irritation develops, consult a physician. Remove and launder contaminated clothing before reuse. If swallowed, dilute with water and induce vomiting. Get immediate medical attention. If inhaled, move to fresh air. Aid in breathing, if necessary, and get medical attention.
NEVER GIVE FLUIDS OR INDUCE VOMITING IF PATIENT IS UNCONSCIOUS OR HAS CONVULSIONS.

SECTION VI - REACTIVITY DATA

CHEMICAL STABILITY..... Stable

CONDITIONS TO AVOID..... N/A

INCOMPATIBLE MATERIALS... Unknown

DECOMPOSITION PRODUCTS... Carbon monoxide,Carbon dioxide,and oxides of Nitrogen.

HAZARDOUS POLYMERIZATION. Does not occur

POLYMERIZATION AVOID..... N/A

SECTION VII - SPILL OR LEAK PROCEDURE

FOR SPILL ..... Spills should be contained and placed in suitable containers.

WASTE DISPOSAL METHOD.... Do not discharge into sewers or waterways. Dispose of in accordance with local regulations.

SECTION VIII - SPECIAL PROTECTION

RESPIRATORY PROTECTION... NIOSH/OSHA approved dust respirator as necessary.

VENTILATION..... Local exhaust to control dusts.

PROTECTIVE GLOVES..... To prevent skin contact.

EYE PROTECTION..... Goggles.

PROTECTIVE EQUIPMENT..... Eye wash fountains should be easily accessible.

MATERIAL SAFETY DATA SHEET

15189 Eosine OJ

HANDLING AND STORAGE..... Keep away from excessive heat and moisture. Keep containers closed.

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SECTION IX - SPECIAL PRECAUTIONS

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HAZARD CLASS..... N/A
DOT SHIPPING NAME..... Ink Material
NMFC Item #101720
REPORTABLE QUANTITY (RQ). N/A
UN NUMBER..... N/A
NA #..... N/A
DOT LABELS REQUIRED..... Mfg. Label Only
SPECIAL SHIPPING INSTRUCTIONS:
MANUFACTURER'S LABEL ONLY
PACKAGING SIZE..... Various

FOOT NOTES
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N/A = Not applicable

REFERENCES

Material Safety Data Sheet
(SULPHORHODAMINE B)
17152 Acid Rhodamine DW

CHEMCENTRAL/Dyes & Pigments
13395 Huron River Drive
Romulus, MI 48174

REVISION DATE: 10/17/01
CHEMTREC: 800-424-9300
EMERGENCY: 734-941-4800

SECTION I - IDENTIFICATION

TRADE NAME: ..... 17152 Acid Rhodamine DW
CHEMICAL NAME: ..... Acid Red 52 (Color Index Name) CAS # 3520-42-1
CHEMICAL FAMILY: ..... Xanthene

SECTION II - HAZARDOUS INGREDIENTS

HAZARDOUS INGREDIENT	PERCENT	CAS NUMBER	PEL
None as per 29CFR part 1910.1200 or Sara Title III			

HMIS HAZARD RATINGS (if applicable):
HEALTH: 2
FIRE 1
REACTIVITY 0

SECTION III - PHYSICAL DATA

APPEARANCE: ..... Black powder, mild odor.
BOILING POINT: ..... N/A
MELTING POINT: ..... N/A
FREEZING POINT: ..... N/A
VAPOR PRESSURE: ..... N/A
VAPOR DENSITY (AIR=1): ..... N/A
SPECIFIC GRAVITY: ..... Approximately 1
pH: ..... N/A
SOLUBILITY IN WATER: ..... Soluble
VOLATILITY: ..... N/A

SECTION IV - FIRE AND EXPLOSION DATA

FLASH POINT: ..... N/A
EXTINGUISHING MEDIA: ..... Water fog, CO_2, or Dry chemical.
FIRE FIGHT PROCEDURES: ... Fire fighters should be equipped with self contained breathing apparatus and turnout gear.
UNUSUAL FIRE HAZARD: ..... Adequate ventilation and clean up must be maintained to minimize dust accumulation. May form explosive dust/air mixture.

Material Safety Data Sheet

17152 Acid Rhodamine DW

SECTION X - TRANSPORTATION DATA

PROPER SHIPPING NAME: ..... INK MATERIAL
HAZARD CLASS AND LABEL: MFR LABEL ONLY
UN NUMBER: ..... N/A
REPORTABLE QUANTITY: ..... N/A

SECTION XI - ADDTIONAL INFORMATION

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N/A = Not Applicable