Ozark UNDERGROUND LABORATORY 1572 Aley Lane • Protem, MO 65733 • (417) 785-4289 • fax (417) 785-4290 • contact@ozarkundergroundlab.com

# Groundwater Tracing and Recharge Area Delineation Summary Report

# Cave Springs Cave
# Cave Springs, Arkansas

## FINAL REPORT

July 2015

**Ozark Underground Laboratory, Inc.**
Shiloh L. Beeman, RG., Senior Hydrogeologist
and Thomas Aley, PHG and PG, President

Summary report prepared in partnership with The Nature Conservancy, Crafton Tull Associates, and Wright Water Engineers for the Cave Springs Area Karst Resource Conservation Study performed on behalf of the Northwest Arkansas Regional Planning Commission.

# Executive Summary

Cave Springs Cave is located in the northwest Arkansas community of Cave Springs, near the intersection of Arkansas Highways 264 and 112 in southern Benton County. Cave Springs Cave provides habitat for the largest known population of Ozark Cavefish (*Amblyopsis rosae*), a federally listed threatened species. In addition to providing habitat for federally protected species, water quality in the cave is an indicator of regional water quality in the shallow aquifer.

The data presented in this summary report is part of the larger Cave Springs Area Karst Conservation Study. This study is being performed to gather and analyze data for the area, develop protective and appropriate land development practices, and implement these practices in the recharge area for Cave Springs Cave in order to protect the unique karst resources of the area while allowing for future growth and development of the area.

Existing geologic, hydrologic, biologic, and land use practices have been compiled and analyzed as part of the Cave Springs karst study. This report summarizes the groundwater tracing investigations and recharge area delineation for Cave Springs Cave derived from both historical data and additional investigations in 2014. Prior to 1991, there were a number of private wells in the area where water levels could be measured. Although most wells are no longer available, the groundwater tracing results and the historical groundwater potentiometric contour map have provided an adequate and reasonable delineation of the recharge area for Cave Springs Cave.

Aley (1978a and b) divided the Cave Springs recharge area into two segments: the Direct Recharge Area and the Indirect Recharge Area. The current study focused substantial attention on the credibility and utility of this division.

The Direct Recharge Area comprises 8.9 square miles and provides most of the recharge water for Cave Springs. The northeastern boundary of the Direct Recharge Area lies roughly parallel to, and west of, Interstate 49.

The Indirect Recharge Area comprises 10.6 square miles and lies to the northeast of the Direct Recharge Area. Groundwater tracing has shown that very little of the water from sinking streams in this area reaches Cave Springs. However, the groundwater potentiometric contour map indicates that there is some groundwater movement from the Indirect Recharge Area into the Direct Recharge Area and ultimately to Cave Springs. Given this information, the OUL has concluded that the division of the Cave Springs recharge area into Direct and Indirect Recharge Areas is both technically reasonable and of practical value.

The total recharge area for Cave Springs is therefore 19.5 square miles; this is the sum of the Direct and Indirect Recharge Areas. Interstate 49 lies entirely within the Indirect Recharge

Area. The Cave Springs recharge area encompasses lands that are included in the municipalities of Cave Springs, Rogers, Lowell, and Springdale.

Based on contoured water level elevations from prior to 1991, a trough in the groundwater potentiometric surface is located from Cave Springs to the east. This trough is located roughly parallel to Highway 264. The presence of this trough is supported by groundwater tracing data. This groundwater trough represents a preferential pathway whereby contaminants can enter the Cave Springs groundwater system.

In addition to identifying a more precise groundwater recharge area for Cave Springs, four additional springs were identified as having hydrologic interactions with Cave Springs: Reed Spring, Shores Spring, Wallis Spring, and South Spring. Based upon the identified hydrologic interactions with Cave Springs, the proximity of the springs to Cave Springs, and the locations of known Ozark Cavefish habitat, Reed Spring, Shores Spring and Wallis Spring have been identified as being presumptive habitat for the Ozark Cavefish. Therefore, the area between the identified Cave Springs recharge area and these springs was identified as presumptive habitat for the Ozark Cavefish. Insufficient data exist to indicate that South Spring provides presumptive habitat for Ozark Cavefish.

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# LIST OF ACRONYMS

| | |
|---|---|
| AHTD | Arkansas Highway and Transportation Department |
| Br | Branch |
| BTEX | benzene, toluene, ethylbenzene, and xylenes |
| cfs | cubic feet per second (1 cfs approximately equals 450 gpm) |
| Cr | Creek |
| CTA | Crafton Tull Associates |
| d/s | downstream |
| ft | feet |
| gpm | gallons per minute (450 gpm approximately equals 1 cfs) |
| hr | hour |
| in. | inches |
| IRWP | Illinois River Watershed Partnership |
| L or l | liter |
| lb | pound |
| mg/L | milligrams per liter |
| msl | mean sea level |
| MW | monitoring well |
| ND | not detected |
| NE | northeast |
| nm | nanometers |
| NW | northwest |
| NWARPC | Northwest Arkansas Regional Planning Commission |
| NWS | National Weather Service |
| OUL | Ozark Underground Laboratory, Inc. |
| PCE | perchloroethane |
| ppb | parts per billion |
| ppm | parts per million |
| Rd | Road |
| RWT | rhodamine WT |
| S | South |
| Spr | Spring |
| St | Street |
| SVGC | Shadow Valley Golf Course |
| TCE | trichloroethane |
| TNC | The Nature Conservancy |
| Trib | Tributary |
| u/s | upstream |
| USGS | United States Geologic Survey |
| WWE | Wright Water Engineers |

# 1 INTRODUCTION

The groundwater tracing study described in this report was conducted as part of the Cave Springs Area Karst Resource Conservation Study performed on behalf of the Northwest Arkansas Regional Planning Commission (NWARPC) with funding from the Arkansas Highway and Transportation Department (AHTD). The work described in this report was performed by the Ozark Underground Laboratory, Inc. (OUL) in collaboration The Nature Conservancy (TNC), Crafton Tull Associates (CTA), and Wright Water Engineers (WWE).

## 1.1 Purpose and Scope of Study

The purpose of the groundwater tracing study was to develop the necessary data to support the overall goals of the Cave Springs Area Karst Resource Conservation Study. The following tasks were outlined as necessary to develop this data:

- Refine the recharge area for Cave Springs Cave and hydrologically associated springs; and
- Collect data to verify the implication of the previously identified Direct and Indirect subdivisions of the Cave Springs Cave recharge area.

Other tasks were identified following a comprehensive review of available literature relating to the hydrology, water quality, and biology of Cave Springs Cave, as well as cave and karst conservation and management. These studies are summarized as part of the larger karst conservation study in an annotated bibliography (Aley and Slay 2015) and a literature review summary report (Aley et al. 2015).

The results of the groundwater tracing study described in this report have been used in conjunction with data compiled and analyzed in other tasks of the karst conservation study to create a more precisely defined recharge area delineation for Cave Springs Cave. This recharge area delineation is a key component of the karst conservation study. An assessment of the relative vulnerability of these lands is performed in a subsequent report in order to guide the successive karst conservation study objectives. These objectives, supported by the data gathered, compiled, and analyzed in this study, will allow for future land use planning and continued development of the Cave Springs area while protecting water quality and important cave fauna in Cave Springs Cave.

## 1.2 Site Background

Cave Springs Cave is located in the northwest Arkansas community of Cave Springs, near the intersection of Arkansas Highways 264 and 112 in southern Benton County (Figure 1). Much of the accessible cave passages contain a perennial cave stream that discharges from the mouth of the cave. Known cave passages are located beneath lands owned by the Arkansas Natural Heritage Commission. The spring flows into a small lake called Partners Lake (formerly known as Lake Keith). This lake and surrounding lands are being developed into a watershed sanctuary and educational center by the Illinois River Watershed Partnership (IRWP).

Cave Springs Cave provides habitat for the largest known population of Ozark Cavefish (*Amblyopsis rosae*). This small cave-adapted fish is federally listed as a threatened species. The cave also provides habitat for several species of bats. The Gray Bat, a federally listed endangered species, uses the cave as a maternity site. In addition to providing habitat for federally protected species, water quality in the cave is an indicator of regional water quality in the shallow aquifer.

Much of the Cave Springs Cave recharge area was initially developed for agricultural use. In the last decade, an increasing amount of the agricultural lands has been converted into suburban development. This continued development has lead to concerns about groundwater quality and the future well-being of Cave Springs Cave and its associated cave fauna. Planning for future growth, including highway construction and improvements, while protecting the unique karst resources of the area has led to the current karst conservation study.

## 1.3 Geologic Setting

A vast number of literature references document the geologic setting of the Cave Springs study area. Aley and Slay (2015) and Aley et al. (2015) summarize the available technical literature. The following sections provide an overview of information relating to the geologic setting that is most relevant to the dye tracing study detailed in this report.

### 1.3.1 Geology

Geologic mapping of the study area shows that the entire recharge area for Cave Springs is underlain by the Boone Formation of Mississippian age (Glick 1970 and 1972). No faults or other structural features are shown on the geologic maps. The Boone Formation consists primarily of limestone and chert with the chert content varying both vertically and laterally. The beds are all relatively flat-lying.

Lineaments and fracture traces in limestone terrains are interpreted as representing linear fractures or often fracture systems along which there has been preferential solution of the bedrock. Fracture traces are expressed for lateral distances of less than one mile; lineaments are expressed for distances of one mile or more. Lineaments and fracture traces are identified from aerial photographs and are expressed based on topography. In karst areas the linear features routinely include relatively straight valley alignments and lines of sinkholes. Aley et al. (2015) summarized available information from studies that included fracture traces and lineaments in the Cave Springs area. Figure 2 illustrates major lineaments in the Cave Springs study area.

In some areas of northwest Arkansas, lineaments are oriented along faults such as the Bella Vista Fault. These faults can dramatically influence groundwater movement (Aley and

Aley 2014). However, faults are very limited in northwest Arkansas and none are known to exist in the Cave Springs study area. Most lineaments and fracture traces in northwest Arkansas are associated with fracture zones along which there has been little or no detectable movement of one side relative to the other.

Karst development of the carbonate bedrock in the area is well known. Springs and caves are well documented on the USGS topographic map, as well as in the literature and in the local nomenclature (i.e., Cave Springs, Spring Creek, etc.). Aley et al. (2015) summarizes the technical literature related to the karst development of the area.

### 1.3.2 Topography and Drainage

The study area largely consists of lands located east of Cave Springs Cave. Osage Creek provides an approximate study area boundary on the north and west; Spring Creek is an approximate boundary on the south, and US Highway 71 is an approximate boundary on the east. The study area consists of relatively flat-lying uplands to the east that become dissected by valleys tributary to Osage Creek and Spring Creek. Large, flat bottomed valleys occur along Osage Creek and Spring Creek. The topography of the study area is shown in Figure 2.

Most of the upland tributaries are losing streams that do not maintain perennial flow. Flow is often found downstream of one or more springs, and this flow is often re-introduced to the groundwater system through losing stream segments. Even the larger streams (Osage Creek and Spring Creek) exhibit losing stream segments (Moix et al. 2003). Area streams exhibit large and temporary surges in flow due to storm water runoff.

### 1.3.3 Soils

Based upon the Benton County soil survey (Phillips and Harper 1977), the following three major soil associations are present within the study area.

- The Clarksville-Nixa-Noark Association. This soil association in Benton County is comprised of 42% Clarksville soils, 33% Nixa soils, and 12% Noark soils. The remaining 13% is comprised of Britwater, Elsah, Secesh, Waben, Tonti, and Captina soils.
- The Tonti-Nixa-Captina. This soil association in Benton County is comprised of 33% Tonti soils, 25% Nixa soils, and 17% Captina soils. The remaining 25% is comprised of Cherokee, Clarksville, Elsah, Noark, Peridge, and Secesh soils.
- The Captina-Peridge Association. Described as: "Moderately well drained and well drained, nearly level to gently sloping deep loams soils on broad upland divides, " this soil association in Benton County is comprised of 60% Captina soils and 30% Peridge soils. The remaining 10% of these soils is comprised of Cherokee, Johnsburg, Newtonia, and Tonti soils.

Soil series within these soil associations have distinctly different properties related to their ability to remove contaminants and protect underlying karst groundwater systems. Data on some important hydrogeological characteristics of the major soil series found in the Cave Springs study area are summarized in Table 1. Soils in the study area are illustrated in Figure 3.

**Table 1. Major Soil Series and Hydrogeologically Important Characteristics.** Data from Phillips and Harper (1977).

| Soil Series | Depth to Bedrock (in) | Depth Below Surface (in) | Percent less than 3 inches passing #4 sieve | Permeability (in/hr) |
|---|---|---|---|---|
| Captina | >42 | 0-7 | 100 | 0.6-2.0 |
| | | 7-21 | 95-100 | 0.6-2.0 |
| | | 21-30 | 80-100 | 0.06-0.2 |
| | | 30-48 | 50-90 | 0.06-0.2 |
| Nixa | 40-60 | 0-17 | 40-70 | 0.6-2.0 |
| | | 17-30 | 40-70 | <0.06 |
| | | 30-50 | 15-45 | 0.06-0.2 |
| Noark | >60 | 0-10 | 20-50 | 0.6-2.0 |
| | | 10-17 | 20-50 | 0.6-2.0 |
| | | 17-30 | 20-50 | 0.6-2.0 |
| | | 30-72 | 10-40 | 0.6-2.0 |
| Peridge | >60 | 0-9 | 95-100 | 0.6-2.0 |
| | | 9-42 | 95-100 | 0.6-2.0 |
| | | 42-54 | 60-80 | 0.6-2.0 |
| | | 54-74 | 60-80 | 0.6-2.0 |
| Tonti | 40-60 | 0-6 | 70-80 | 0.6-2.0 |
| | | 6-19 | 60-85 | 0.6-2.0 |
| | | 19-29 | 50-70 | 0.06-0.2 |
| | | 29-42 | 35-55 | 0.06-2.0 |

## 1.4 Previous Groundwater Tracing Studies

During the data compilation phase of the Cave Springs karst conservation study, eight studies were identified that provided information relating to the boundaries of the Cave Springs recharge area. Relevant information from these studies is summarized in the annotated bibliography (Aley and Slay 2015) and the summary of existing knowledge for the area (Aley et al. 2015). The following studies included dye tracing to Cave Springs Cave:

- Highway 71 relocation study conducted in 1978 (Aley 1978a and Aley 1978b), and
- Airport corridor study conducted in 2000-2001 (Aley and Moss 2001).

Table 2 summarizes details of the traces from these studies that were performed in the Cave Springs study area. Groundwater traces from previous studies are illustrated in Figure 4. Additional details are provided in the following sections.

**Table 2. Dye Traces from Previous Studies.** From Aley (1978a), Aley (1978b) and Aley and Moss (2001).

| Trace No. | Dye Introduction Location | Coordinates | Dye Mixture Type & Quantity | Detection Locations |
|---|---|---|---|---|
| 78-02 | South Border Section 33 Trace (Tributary to Cross Creek) | N36.26973 W94.18149 | 2 lb fluorescein | Cave Springs |
| 78-04 | North Border Section 28 Trace (Tributary to Osage Creek) | N36.28791 W94.18651 | 2 lb fluorescein | Cave Springs |
| 78-06 | Southwest Quarter Section 10 Trace (Puppy Creek) | N36.24176 W94.16525 | 2 lb fluorescein | Puppy Creek upstream of Spring Creek |
| 78-07 | Puppy Creek North of Highway 264 Trace | N36.25573 W94.14560 | 2 lb fluorescein | Puppy Creek upstream of Spring Creek |
| 78-08 | Blossom Way Trace | N36.29169 W94.17176 | 3 lb fluorescein | South Spring, Cave Springs |
| 00-01 | Puppy Creek Trace | N36.24738 W94.15508 | 3 lb eosine | Puppy Creek upstream of Spring Creek |
| 00-02 | Wellington Subdivision Trace (Tributary to Osage Creek) | N36.25622 W94.22210 | 2 lbs sulfo-rhodamine B | Bond Spring |
| 00-03 | Cross Creek Trace | N36.25303 W94.18623 | 2 lb fluorescein | Cave Springs, Reed Spring |
| 00-04 | Reynolds Trace (Tributary to Cross Creek) | N36.24844 W94.18636 | 3 lb eosine | Cave Springs, Reed Spring |
| 00-05 | Powell Trace (Tributary to Cross Creek) | N36.24141 W94.18530 | 5 lb rhodamine WT | No Recovery |
| 01-08 | Sharp Trace (Tributary to Puppy Creek) | N36.23206 W94.19498 | 3 lb fluorescein | Puppy Creek upstream of Spring Creek |

### 1.4.1 1978 Groundwater Tracing Study

Groundwater tracing in the Cave Springs Cave recharge area was performed in 1978 as part of the Highway 71 relocation study for the highway corridor from Fayetteville north to McKisic Creek. The work was detailed in an initial report issued in May 1978 (Aley 1978a) and a supplemental report issued in August of the same year (Aley 1978b).

Aley (1978a) details two groundwater traces (Traces 78-02 and 78-04) that yielded dye to Cave Springs Cave. Aley (1978b) summarizes three other traces relevant to the delineation of the Cave Springs recharge area. Two of these traces (Traces 78-06 and 78-07) were introduced in Puppy Creek, which is tributary to Spring Creek southeast of Cave Springs. Although these traces did not yield dye to Cave Springs, they help define the recharge area boundary in this area. A third trace (Trace 78-08) was introduced in Blossom Way Creek, a large tributary to Osage Creek. Dye from this trace was detected at Cave Springs and South Spring, located in Blossom Way Creek at New Hope Road.

Aley (1978a) estimated the size of the recharge area for Cave Springs as part of the study for AHTD. The size of the recharge area was based upon an estimated mean annual flow rate of the spring of 4.5 cfs and an assumption that about 2.3 square miles of recharge area was needed for each 1 cfs of mean annual flow. Based upon these values, the estimated size of the Cave Springs recharge area was 10.35 square miles. This estimate did not account for the recharge area being shared with other springs. It is now known that some of the recharge area is shared with South, Reed, Shores, and Wallis Springs.

Aley (1978b) performed a groundwater trace from the channel of Blossom Way Creek (Trace 78-08) that yielded dye to South Spring and a small amount to Cave Springs. This tracing was part of expanded work for the AHTD. Based upon this trace, much of the topographic basin for Blossom Way Creek was identified as an "Indirect Recharge Area" for Cave Springs. The "Direct Recharge Area" is that area where, when water enters the groundwater system, most or all of it discharges from Cave Springs. The Indirect Recharge Area is land where little of the water that enters the groundwater system discharges from Cave Spring, but where the land is topographically tributary to the areas that have been traced to Cave Springs (Trace 78-08). The boundary of the Direct Recharge area for Cave Springs as delineated by Aley (1978b) lies a short distance west of the present location for Interstate 49 (formerly I-540 and before that US 71). This highway location was chosen based in substantial part on the tracing work by Aley (1978a and 1978b). That highway corridor was chosen to minimize highway impacts on Cave Springs.

### 1.4.2 2000-2001 Groundwater Tracing Study

Aley and Moss (2001) conducted a series of groundwater traces along and near the southern margin of the Cave Springs recharge area in conjunction with six potential corridors for an airport connector highway that would extend from Interstate 49 to the Northwest Arkansas Regional Airport. Six traces from this study are relevant to the delineation of the Cave Springs recharge area (Traces 00-01 through 00-05 and Trace 01-08).

The results of the study showed that some areas contribute water to both Cave Springs and Reed Spring, and that the combined recharge area for the two springs was about 19.10 square miles. Because of the hydrological linkage between Cave Springs and Reed Spring, Reed Spring must be viewed as presumptive habitat for the Ozark Cavefish. The combined recharge area included the Indirect Recharge Area for Cave Springs. The study also showed that the two more-northern corridors for the airport connector highway had the potential to adversely impact Cave Springs/Reed Spring, but that the three more-southern corridors were outside of the recharge area for Cave Springs and Reed Spring.

# 2 METHODOLOGY

Groundwater tracing using fluorescent dyes is the most appropriate method for delineating the recharge areas of karst springs and caves (Aley and Aley 1991). Whenever possible, additional hydrogeologic information is also used. Field reconnaissance was conducted to identify locations where waters sink from the surface into the groundwater system and where springs and streams were accessible for sampling. Next, a selected tracer dye was introduced into the most appropriate waters. Springs, surface streams, and other potentially relevant locations were continuously sampled for the subsequent presence of the dyes. By careful selection of dye introduction locations, and by conducting multiple traces, the area that contributes waters to a particular cave or spring can be delineated. This section provides an overview of the dye introduction, sampling, and laboratory procedures used during the groundwater tracing study.

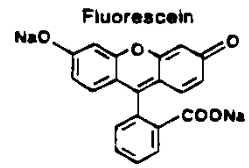
## 2.1 Dye Introductions

Four different dyes were used for thirteen separate dye introductions during the current groundwater tracing study. These dyes were fluorescein, eosine, rhodamine WT, and pyranine. All four of these dyes are environmentally safe and pose no risk to humans, livestock, or to aquatic life in the concentrations used in professionally directed groundwater tracing work (Smart 1984, Field et al. 1995). Table 3 illustrates the chemical structures of these dyes and summarizes some of their more important properties.

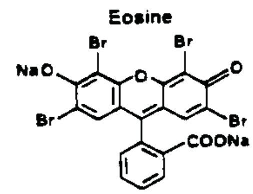
These dyes are among the most detectable of the commonly used fluorescent tracer dyes. They can be adsorbed onto activated carbon samplers for cumulative sampling and can also be detected in water samples.

**Table 3. Properties of Tracer Dyes Used in This Study.**

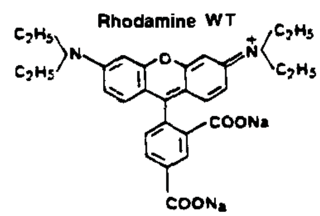
**Fluorescein Dye**
- Also known as Acid Yellow 73
- Color Index Constitution Number 45350
- Brilliant fluorescent yellow-green dye
- Most commonly used fluorescent tracer dye
- Most highly detectable dye
- Powdered dye, 75% dye equivalent, 25% diluent



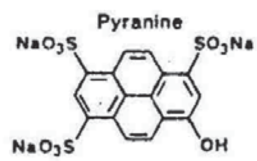

**Eosine Dye**
- Also known as Acid Red 87
- Color Index Constitution Number 45380
- Greenish to peach-colored dye
  (dependent on concentration)
- Powdered dye, 75% dye equivalent, 25% diluent




**Rhodamine WT Dye**
- Also known as Acid Red 388
- Color Index Constitution Number not assigned
- Reddish orange-colored dye
- Less resistant to adsorption onto aquifer materials
  than fluorescein and eosine




**Pyranine Dye**
- Also known as Solvent Green 7
- Color Index Constitution Number 59040
- Green-colored dye
- Emission fluorescence wavelength varies with pH




The results of the dye introductions performed as part of this study were used for characterizing flow paths and identifying discharge points. Each dye introduction was made specifically for this investigation. The traces are numbered sequentially with the first two digits indicating the year and the last pair of digits indicating the serial number of the trace. The dye introduction locations and the amount and type of dye used are summarized in Table 4. The dye introduction locations are shown in Figure 5.

**Table 4. 2014 Dye Introduction Locations.**

| Trace No. | Dye Introduction Location | Coordinates | Dye Mixture Type & Quantity | Dye Introduction Date & Time |
|---|---|---|---|---|
| 14-01 | Upper Osage Creek | N36.33405 W94.16190 | 2 lb Fluorescein | 5-14-2014 2050 |
| 14-02 | Osage Creek Near Cross Church | N36.31237 W94.19402 | 6 lb Rhodamine WT | 5-14-2014 2110 |
| 14-03 | Lower Pinnacle Valley | N36.29934 W94.21194 | 3 lb Eosine | 5-14-2014 2130 |
| 14-04 | South Blossom Tributary at Dixieland Road | N36.27200 W94.14636 | 4 lb Rhodamine WT | 6-05-2014 1830 |
| 14-05 | North Blossom Tributary at Dixieland Road | N36.29477 W94.14487 | 4 lb Eosine | 6-05-2014 1905 |
| 14-06 | Upper Pinnacle Valley (Southgate and Sloan Rd) | N36.29184 W94.20435 | 1 lb Fluorescein | 6-05-2014 1950 |
| 14-07 | South Blossom Tributary at Pleasant Grove Road | N36.28406 W94.16502 | 3 lb Eosine | 7-10-2014 1415 |
| 14-08 | Mt. Hebron Road Storm Water Basin | N36.26315 W94.19489 | 2 lb Fluorescein | 7-30-2014 2100 |
| 14-09 | South Blossom Tributary at Pleasant Grove Road | N36.28406 W94.16502 | 3 lb Eosine | 7-30-2014 2130 |
| 14-10 | Otter Creek Subdivision | N36.26305 W94.22189 | 1 lb Pyranine | 8-08-2014 1230 |
| 14-11 | Cross Creek at Highway 264 | N36.25915 W94.19398 | 4 lb Rhodamine WT | 8-08-2014 1320 |
| 14-12 | Hyde Park Subdivision | N36.27513 W94.21878 | 2 lb Eosine | 9-12-2014 0915 |
| 14-13 | Biltmore Subdivision | N36.27294 W94.20821 | 3 lb Rhodamine WT | 9-12-2014 1020 |

## 2.2 Sampling for Tracer Dyes

This section describes the types of tracer dye sampling performed during this study. All samples were collected and analyzed by staff of the OUL in Protem, Missouri.

### 2.2.1 Types of Samples

Three kinds of fluorescent tracer dye samples were collected during the project: activated carbon samplers, grab water samples, and composite water samples.

Primary reliance was placed upon the activated carbon samplers, also called charcoal samplers or charcoal packets. The activated carbon samplers consisted of fiberglass screen wire packets filled with 4.25 grams of laboratory-grade activated coconut shell carbon. These samplers adsorb, retain, and concentrate the tracer dyes. When eluted in the laboratory, samples routinely yield dye concentrations one to two or more orders of magnitude greater than the mean dye concentrations in the water. Activated carbon samplers are continuous and accumulating samplers.

Grab samples of water provide dye concentrations at a particular point in time. Water samples are routinely collected in 50-milliliter plastic sampling vials at all sampling stations where practical and are archived upon receipt at the lab. The water samples were analyzed for the following reasons:

- Dyes were detected in the associated activated carbon sampler,
- An activated carbon sampler was lost or was not retrievable,
- Fluorescence peaks in the associated carbon sampler suggested that the water sample should be analyzed, or
- The data would be otherwise useful for the study.

Composite water samples were collected at Cave Springs Cave with an ISCO automatic pump sampler. Eight hourly subsamples were collected into each composite water sample. Three composite water samples were collected each day for continuous monitoring of the spring. Composite water samples were collected to create a better understanding of groundwater travel times and to provide insight on how potential contaminants would move through the groundwater system.

All sample collection procedures followed the protocols found in OUL's Procedures and Criteria document (Aley and Kirkland 2011) in Appendix A.

### 2.2.2 Sampling Locations

Forty-eight (48) sampling locations were established for the dye tracing study. Sampling locations consisted of springs and stream locations. Table 5 summarizes the sampling station locations. Figure 5 illustrates the locations of the sampling stations.

**Table 5. Sampling Stations for the Cave Springs Recharge Area Delineation Study.**

| Station No. | Station Name | Coordinates | Approx. Elevation (feet msl) |
|---|---|---|---|
| 101 | Cave Spring | N36.26127 W94.22725 | 1150 |
| 102 | Cave Spring - North Pipe | N36.26136 W94.22746 | 1140 |
| 103 | Cave Spring - NW Culvert | N36.26143 W94.22732 | 1140 |
| 104 | Cave Spring - NE Culvert | N36.26133 W94.22735 | 1140 |
| 105 | Cave Spring - South Pipes | N36.26128 W94.22739 | 1140 |
| 106 | Cave Spring - South Valve | N36.26121 W94.22749 | 1140 |
| 107 | Boat Ramp Spring - East | N36.26161 W94.23077 | 1135 |
| 108 | Boat Ramp Spring - Center | N36.26155 W94.23076 | 1135 |
| 109 | Boat Ramp Spring - West | N36.26155 W94.23085 | 1135 |

| Station No. | Station Name | Coordinates | Approx. Elevation (feet msl) |
|---|---|---|---|
| 110 | Unnamed Tributary at 112 | N36.26524 W94.23177 | 1140 |
| 111 | Shores Spring | N36.26722 W94.23388 | 1130 |
| 112 | Wallis Spring | N36.27852 W94.22935 | 1150 |
| 113 | Osage Creek upstream of SVGC Spring Branch | N36.28334 W94.22710 | 1135 |
| 114 | Shadow Valley Golf Course (SVGC) Spring Branch | N36.28339 W94.22747 | 1135 |
| 115 | Osage Creek at Rainbow Road | N36.30638 W94.20757 | 1180 |
| 116 | Osage Creek d/s Cross Church | N36.31364 W94.19254 | 1190 |
| 117 | Village Pond Outfall | N36.31436 W94.19265 | 1195 |
| 118 | Osage Creek u/s Blossom Way | N36.31646 W94.18667 | 1200 |
| 119 | Osage West Spring | N36.31545 W94.18421 | 1210 |
| 120 | Osage Spring | N36.31525 W94.18267 | 1210 |
| 121 | Osage Spring - Culvert 1 | N36.31521 W94.18253 | 1210 |
| 122 | Osage Spring - Culvert 2 | N36.31497 W94.18225 | 1210 |
| 123 | Osage Spring - Culvert 3 | N36.31493 W94.18219 | 1210 |
| 124 | Blossom Way downstream of South Spring | N36.31495 W94.18272 | 1210 |
| 125 | Blossom Way upstream of South Spring | N36.31256 W94.18089 | 1215 |
| 126 | North Spring | N36.31950 W94.18204 | 1210 |
| 127 | Osage Creek upstream of North Spring | N36.32021 W94.17957 | 1215 |
| 128 | Spring Creek upstream of 112 | N36.24385 W94.23866 | 1100 |
| 129 | Johnson Spring 1 | N36.23973 W94.23233 | 1125 |
| 130 | Johnson Spring 2 | N36.23977 W94.23071 | 1125 |
| 131 | Johnson Spring 3 | N36.23980 W94.23023 | 1125 |
| 132 | Spring Creek at Wagon Wheel Road | N36.24067 W94.22579 | 1110 |
| 133 | Reed Spring Branch at Wagon Wheel Road | N36.24088 W94.22559 | 1112 |
| 134 | Reed Spring | N36.24217 W94.21809 | 1140 |
| 135 | Cross Creek upstream of Wagon Wheel Road | N36.24011 W94.21191 | 1140 |
| 136 | Cross Creek upstream of Brown Road | N36.24362 W94.20522 | 1158 |
| 137 | Spring Creek at 56th Street | N36.22407 W94.19215 | 1148 |
| 138 | Puppy Creek upstream of Spring Creek | N36.22430 W94.19193 | 1148 |
| 139 | Puppy Creek at Puppy Creek Road | N36.23422 W94.17506 | 1195 |
| 140 | Puppy Creek at Goad Springs Road | N36.24735 W94.15502 | 1240 |
| 141 | Goad Springs Branch | N36.24705 W94.15504 | 1240 |
| 142 | Puppy Creek at 6th Street | N36.25088 W94.14978 | 1165 |
| 143 | Pinnacle Valley Tributary | N36.29927 W94.21171 | 1180 |
| 144 | Unnamed Tributary at Bright Road | N36.26300 W94.22449 | 1170 |
| 145 | Unnamed Tributary at Pleasant Grove Road | N36.28383 W94.16489 | 1275 |
| 146 | Blossom Way at S 28th Place | N36.29296 W94.16585 | 1260 |
| 147 | Blossom Tributary upstream of Bellview Road | N36.29077 W94.17163 | 1250 |
| 148 | Sands Road Tributary | N36.27160 W94.23098 | 1150 |

Notes: 1. Coordinates are referenced NAD83.
2. Elevations are approximate in feet above mean sea level.

***Stations 101 through 106*** Station 101 was established in the spring flow at the mouth of Cave Springs Cave. At the time the study began, at least five other discharge locations were observed near the mouth of the cave. These locations were associated with piping and culverts from the historical trout farming operations at the site. Stations 102 through 106 were established in these other flow outlets for control purposes. As the study progressed, Stations 102 through 106 were eliminated as site improvements associated with the IRWP renovation of the cave entrance area either made them inaccessible or caused them to cease flowing.

***Stations 107 through 109*** At the beginning of the study, Partners Lake had been drained for site improvements. During this time, a spring with three small discharge locations was observed west of the boat ramp on the south side of the lake. Sampling stations 107 through 109 were established in the flows from this spring. These sampling stations were eliminated when the lake improvements were completed, and the lake was refilled.

***Stations 110 and 144*** Stations 110 and 144 were established in the unnamed tributary to Osage Creek located immediately north of Cave Springs Cave. This tributary runs through the Otter Creek subdivision located northeast and east of the cave.

***Stations 111 and 112*** Station 111 was established at Shores Spring. This spring, identified on the USGS topographic map, is located on the Shores family farm north of Cave Springs and west of Arkansas Highway 112 (southwest of the intersection of Highway 112 and Shores Road). Similarly, Station 112 was established at Wallis Spring. This spring, also identified on the USGS topographic map, is located on the Wallis family farm. This location is north of Shores Spring and southwest of the intersection of Wallis Road and Arkansas Highway 112. Permission was obtained from property owners for sampling these springs. These sampling stations were important for determining if Cave Springs shares a portion of its recharge area with these nearby springs.

***Stations 113, 115, 116*** Stations 113, 115, and 116 were established in Osage Creek as control stations to characterize dye concentrations in Osage Creek.

***Stations 114 and 117*** Station 114 and 117 were established in spring branches on the northwest side of Osage Creek. Several springs are located east of Arkansas Highway 112 along the edge of the Shadow Valley Golf Course. Station 114 was established in this spring branch upstream of its confluence with Osage Creek. Station 117 was located in the discharge of the small lake at the office/commercial area known as “Village on the Creeks.” This lake was historically associated with trout farm operations and has apparently inundated West Spring (Aley 1978a and 1978b).

***Stations 118 and 127*** Stations 118 and 127 were established in Osage Creek upstream of Blossom Way Creek. Station 118 is just upstream of Blossom Way Creek, while Station 127 is upstream of North Spring. These stations are control stations for several of the dye introductions in the upper Osage Creek/Blossom Way Creek topographic basins.

***Stations 119 through 123*** Osage Spring is located in an area that has been changed dramatically in recent years by commercial construction. Water from the spring is impounded in a pond that appears to drain through as many as five culverts into the channelized flow of Blossom

Way Creek. All five of these culverts were sampled as part of the sampling program to ensure that no potential flow pathway was overlooked.

***Stations 124 and 125*** South Spring is the location where groundwater flow discharges in Blossom Way Creek. Surface flow in Blossom Way Creek downstream of South Spring was continuous throughout the study period. Surface flow upstream of South Spring was only present following rainfall events that produced significant runoff. Flow from South Spring discharges over a short distance in the channel of Blossom Way Creek upstream of the New Hope Road bridge and downstream of the bridge at Rife Medical Lane. At times during the study period, this area was impacted by beaver activity. Station 124 was established immediately downstream of the New Hope Road bridge and upstream from Osage Spring. Station 125 was established as a control station upstream of South Spring since the spring rises in the channel of Blossom Way Creek.

***Station 126*** North Spring is located in the channel of Osage Creek upstream of Blossom Way Creek. North Spring is the location where groundwater discharges to Osage Creek under most flow conditions. Continuous surface flow in Osage Creek downstream of North Spring occurred throughout the study period. Surface flow upstream of North Spring was only present following rainfall events that produced significant runoff. North Spring contributes water to Osage Creek between Stations 127 and 118.

***Stations 128, 132, and 137*** These three sampling stations were established as control stations in Spring Creek. Station 128 was located upstream of Arkansas Highway 112. Station 132 was located upstream of Wagon Wheel Road and upstream of the spring branch that flows from Reed Spring. Station 137 was located at 56th Street in Springdale. This location is upstream of Puppy Creek.

***Stations 129 through 131*** Stations 129 through 131 were established at Johnson Spring. This spring is located south of Spring Creek and not far upstream of the confluence of Spring Creek and Osage Creek. As the historical tracing data were compiled, additional tracing on the southern boundary of the Cave Springs recharge area was determined to be unnecessary and these stations were eliminated.

***Stations 133 and 134*** Station 134 was established at Reed Spring. This spring, previously shown to share part of its recharge area with Cave Springs, was a critical sampling station. Reed Spring is located on private property and was sampled with property owner permission. Station 133 was established about a mile southwest of Reed Spring where the spring branch that flows from Reed Spring crosses Wagon Wheel Road. The purpose of this sampling station was to evaluate whether or not other springs contributed flow to this spring branch downstream of Reed Spring.

***Stations 135 and 136*** These two stations were established in lower Cross Creek at public road crossings downstream of small springs located on private property. Cross Creek is tributary to Spring Creek upstream of Reed Spring. Historical traces by the OUL have shown that parts of the upper Cross Creek topographic basin contribute water to both Reed Spring and Cave Springs.

***Stations 138 through 142*** Stations 138 through 142 were established in Puppy Creek. Puppy Creek is tributary to Spring Creek upstream of Cross Creek. At least three springs exist in Puppy Creek. A large quarry (Sharps Quarry) is also present in the Puppy Creek watershed. Although no dye introductions were performed in the Puppy Creek topographic basin, sampling was performed to determine if dye introductions in the upper Blossom Way Creek topographic basin contributed flow to any of the springs in Puppy Creek.

***Station 143*** Station 143 was established in the unnamed tributary to Osage Creek that flows through the Pinnacle gated community. This tributary was called Pinnacle Valley Tributary. The sampling station was located on the upstream side of Rainbow Road near the Rogers wastewater treatment plant.

***Station 145 through 147*** These stations were established in the upper portions of Blossom Way Creek as control stations for Traces 14-04, 14-05, 14-07, and 14-09. Flow was intermittent during the study at all of these locations.

***Station 148*** Station 148 was established in an unnamed tributary to Osage Creek located between Wallis Road and Shores Road. This station was established upstream of Arkansas Highway 112 as a control station for Traces 14-12 and 14-13, which were introduced farther upstream in this tributary.

### 2.2.3 Sampling Events

Background sampling was performed to detect and quantify the presence of tracer dyes or fluorescent compounds with characteristics similar to tracer dyes at any of the sampling stations. Background sampling was performed with charcoal samplers and water samples. Background sampling occurred from May 1 to May 15, 2014. Three weekly background sampling events occurred at all sampling stations established at the beginning of the study and for which access permission had been obtained. As the study progressed, additional locations were added as needed. Locations that were added later were not included in the initial background study; whenever possible, background samples were collected prior to dye introductions in those areas.

Sampling for tracer dyes was performed following dye introductions. The sampling intervals were approximately one to two weeks long at most stations. Sampling events following dye introductions occurred from May 21, 2014 to October 20, 2014.

### 2.2.4 Sample Collection Procedures

**Activated Carbon Samplers and Grab Water Samples** Activated carbon samplers placed at springs and along surface streams were placed in flowing water or in locations anticipated to have flowing water during storm events. Samplers were firmly anchored with plastic tie wire and weighted in place. Cords were sometimes run from the packets to trees along the banks or other stationery objects so that samplers could be recovered even during relatively high flow events. Samplers were concealed to minimize disturbance or loss to people who might otherwise see them. A minimum of two samplers were placed at each surface water sampling station. Placement of multiple samplers allows for the analysis of duplicate samples if needed and provides a spare in case a sampler is lost or damaged.

When carbon samplers were collected, new samplers were placed. Collected samplers were placed in sterile plastic bags. The bags were labeled on the outside with the station name and the date and time of collection. Grab water samples were also collected at the same time as the activated carbon samplers.

Samples collected in the field were maintained under refrigeration until delivery to the laboratory. Upon arrival at OUL, samplers were refrigerated until analysis. All sampler placement, collection, and analysis work was conducted by OUL personnel and conformed to the protocol in Appendix A (Aley and Kirkland 2011).

**Composite Water Samples** Composite water samples were collected with an ISCO automatic pump sampler. The automatic pump sampler was installed within the locked gate near the cave entrance. The ISCO sampler was programmed to collect one subsample per hour. Eight hourly samples were composited into one sample container, so that three composite samples were collected during each 24 hour period. The automatic sampler unit was serviced once per week. In an effort to conserve project funds, composite water samples were often placed on hold pending analysis of activated carbon samples at Cave Springs. Composite water samples were analyzed if dye was detected in activated carbon samplers.

**Specific Conductance Measurements** Specific conductance is a measurement of the ability of water to conduct electricity. Water flowing through soluble rock units such as limestone dissolves calcium carbonate and, to a lesser extent, other compounds. In karst settings surface waters tend to have lower specific conductivity values than waters flowing through the groundwater system.

During this study a number of specific conductance measurements were made of waters at sampling stations. The purpose of the measurements was to assess the similarities of waters being sampled. All measurements were made with a YSI Model 330 conductivity meter, which measures in micromhos/centimeter (µmhos/cm). These units are equivalent to microSiemens.

## 2.3 Laboratory Analysis

Laboratory analysis was performed at the OUL in Protem, Missouri. Activated carbon samples were rinsed under a relatively strong jet of water and eluted in a standard eluting solution. Water samples were pH adjusted to raise the pH of the water to 9.5 or higher. Elutant and pH-adjusted water samples were analyzed on a Shimadzu RF-5301 spectrofluorophotometer under a synchronous scanning protocol. All dye concentrations were based on the as-sold mixtures of the dyes.

Low concentrations of fluorescent compounds similar to tracer dyes can be found in urban areas. Background sampling prior to the introduction of tracer dyes is routinely performed to characterize background fluorescence and to identify the existence of any tracer dyes that may be present.

The OUL has established normal emission fluorescence wavelength ranges for the dyes used in this project (fluorescein, eosine, rhodamine WT, and pyranine). The normal acceptable range equals mean values plus and minus two standard deviations (see Table 6). These values are derived from actual groundwater tracing studies conducted by the OUL.

The detection limits are based upon concentrations of dye necessary to produce emission fluorescence peaks where the signal to noise ratio is 3. The detection limits are realistic for most field studies since they are based upon results from actual field samples rather than being based upon values from spiked samples in a matrix of reagent water or the elutants from unused activated carbon samplers. In some cases detection limits may be smaller than reported if the water being sampled has very little fluorescent material in it. In some cases detection limits may be greater than reported; this most commonly occurs if the sample is turbid due to suspended material or a coloring agent such as tannic compounds. Turbid samples are typically allowed to settle, centrifuged, or, if these steps are not effective, diluted prior to analysis.

**Table 6. Spectrofluorophotometer Normal Emission Wavelength Ranges and Detection Limits** for Fluorescein, Eosine, Rhodamine WT and Pyranine Dyes in Water and Elutant samples (Aley and Kirkland 2011).

| **Dye and Matrix** | **Normal Acceptable Emission Wavelength Range** nanometers (nm) | **Detection Limit** (ppb) |
|---|---|---|
| Eosine in Elutant | 540.0 to 545.8 | 0.050 |
| Eosine in Water | 532.8 to 537.3 | 0.015 |
| Fluorescein in Elutant | 514.5 to 519.6 | 0.025 |
| Fluorescein in Water | 506.8 to 510.6 | 0.002 |
| Rhodamine WT in Elutant | 565.2 to 571.8 | 0.170 |
| Rhodamine WT in Water | 572.4 to 577.7 | 0.015 |
| Pyranine in Elutant | 502.2 to 508.2 | 0.015 |
| Pyranine in Water | 497.5 to 503.2 | 0.010 |

Note: Detection limits are based upon the as-sold weight of the dye mixtures used by the OUL.

Normal emission wavelength ranges and detection limits for the dyes reported in this study when analyzed on the OUL's RF-5301 spectrofluorophotometer are shown in Table 6. Detailed procedures and criteria used during the tracer study are found in the OUL's Procedures and Criteria Document found in Appendix A (Aley and Kirkland 2011).

The following four criteria are used by the OUL as normal criteria for determining positive dye recoveries in elutants from activated carbon samplers:

**Elutant Criterion 1.** At least one fluorescence peak must be present at the station in the normal range for the dye for samples analyzed by the RF-5301.

**Elutant Criterion 2.** The dye concentration associated with the fluorescence peak must be at least 3 times the detection limit.

**Elutant Criterion 3.** The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

**Elutant Criterion 4.** The shape of the fluorescence peak must be typical of the dye for which the analysis is run. Much background fluorescence yields low, broad, and asymmetrical fluorescence peaks rather than the more narrow and symmetrical fluorescence peaks typical of fluorescent tracer dyes. In addition, there must be no other factors that suggest that the fluorescence peak may not be the dye from the groundwater tracing work.

The following three criteria are used by the OUL as normal criteria for determining positive dye recoveries in water samples.

**Water Criterion 1.** The associated charcoal samplers for the station should contain a positive dye detection in accordance with the elutant criteria listed above. This criterion may be waived if no charcoal sampler exists.

**Water Criterion 2.** No factors must exist that suggest that the fluorescence peak may not be fluorescent dye from the groundwater tracing work in question. The fluorescence peak should generally be in the typical range listed in the Procedures and Criteria document.

**Water Criterion 3.** The dye concentration associated with the fluorescence peak must be at least three times the detection limit.

**Water Criterion 4.** The dye concentration must be at least 10 times greater than any other concentration reflective of background at the station in question.

## 2.4 Precipitation and Flow Rate Data

Precipitation data for the study period were obtained from the National Weather Service cooperating station at the Northwest Arkansas Regional Airport near Highfill, Arkansas. This station is located approximately four miles west of Cave Springs Cave. Rainfall measurements are also reported at additional stations by network of volunteers through the Community Collaborative Rain, Hail, and Snow (CoCoRaHS) network. Where available in closer proximity to the dye introduction locations, these rainfall amounts are shown in the text.

As part of this study, the OUL attempted to install a weir downstream of the cave in hopes of providing more accurate flow rate measurements. Major leakage around and beneath the old flume area downstream of the dam defeated these efforts. During the course of the study, a series of staff gauge measurements were made at an existing staff gauge in the pool at the mouth of the cave. These staff gauge measurements were converted to flow rates based on an equation in Graening and Brown (2003):

$$\text{Stage (in meters)} \times 35.79\ \text{m}^2/\text{min} - 110 = \text{flow rate in m}^3/\text{min}$$

This flow rate can be converted to cfs by multiplying by 0.59. In addition, the OUL measured flow at the outlet of Partners Lake on October 20, 2014.

# 3 STUDY RESULTS

This section summarizes findings from the site visits and dye tracing work performed from April through October 2014. Results are summarized under the following headings:

1) Study Area Description and Field Reconnaissance;
2) Precipitation and Flow Rate Measurements;
3) Groundwater Tracing; and
4) Water Quality Samples and Specific Conductance Measurements.

## 3.1 Study Area Description and Field Reconnaissance

The study area largely consists of lands located east of Cave Springs Cave and bounded by Osage Creek to the north and west and Spring Creek to the south. Large, flat floored valleys exist along Osage Creek and Spring Creek and are largely the result of karst development of the bedrock subsurface. Limestone bedrock can be observed in outcrops and along some stream channels.

Most of the tributary valleys were dry during most of the study period. Sustained surface flow is often found downstream of one or more small springs, and this flow is often re-introduced to the groundwater system through losing stream segments. Streams exhibit large and temporary surges in response to rainfall runoff events.

Land use in much of the Cave Springs Cave recharge area was initially agricultural. In the last decade, an increasing amount of the agricultural land has been converted into suburban development. Most of this development consists of residential subdivisions of varying size, as well as churches and schools. These areas of development are interspersed with agricultural lands.

## 3.2 Precipitation and Flow Rate Measurements

Precipitation data for the four months prior to the study (January through April 2014) as well as the six month study period (May through October 2014) are provided in Table 7. Relatively low flow conditions existed in the study area during the initial field reconnaissance in April 2014. Flow rates decreased over the study period with a few storm events providing significant increases in flow until the last month of the study. The study area was 7.03 inches (49%) below normal for the four months preceding the dye tracing study. Below normal rainfall persisted throughout the summer and into the fall, with the exception of June and October. The study area was 6.31 inches of rainfall (26%) below normal for the five months when dyes were introduced (May through September 2014). By the end of September, the study area was 13.34

inches (35%) below normal for the calendar year. Even with the lower than normal rainfall conditions, a successful groundwater tracing program was conducted.

**Table 7. Precipitation Data from the Northwest Arkansas Regional Airport.** (NWS 2014). Units in inches.

| Date | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | T | 0.09 | 0.00 | M | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 | 0.00 |
| 2 | T | 0.16 | 0.50 | 0.00 | 0.00 | 0.83 | 0.00 | 0.02 | 2.43 | 1.01 |
| 3 | 0.00 | 0.00 | 0.04 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | T |
| 4 | T | 0.20 | 0.00 | 0.00 | 0.00 | T | 0.00 | 0.00 | 0.00 | 0.00 |
| 5 | 0.23 | T | 0.00 | 0.00 | 0.00 | 0.22 | 0.00 | 0.00 | 0.00 | 0.01 |
| 6 | 0.00 | T | 0.00 | 0.17 | 0.00 | 0.07 | 0.00 | 0.49 | 0.10 | 0.00 |
| 7 | 0.00 | 0.00 | 0.00 | 0.34 | 0.00 | 0.07 | 0.00 | T | 0.00 | 0.00 |
| 8 | 0.14 | 0.00 | 0.05 | 0.05 | 1.27 | 0.36 | 0.00 | 1.13 | 0.00 | 0.27 |
| 9 | 0.01 | 0.00 | 0.00 | 0.00 | 0.02 | 0.03 | 0.00 | 0.01 | 0.00 | 0.15 |
| 10 | 0.97 | 0.00 | 0.00 | 0.00 | 0.00 | 0.69 | 0.27 | 0.00 | 0.04 | 3.15 |
| 11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | T | 0.24 |
| 12 | 0.00 | 0.00 | T | 0.00 | 1.22 | T | 0.00 | 0.00 | 0.11 | 0.01 |
| 13 | 0.00 | 0.00 | 0.00 | 0.39 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 2.36 |
| 14 | T | T | 0.00 | T | 0.53 | 0.00 | 0.00 | 0.00 | 0.00 | T |
| 15 | 0.00 | 0.00 | 0.76 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.09 | 0.00 |
| 16 | 0.00 | 0.00 | 1.25 | 0.00 | 0.05 | 0.00 | T | 0.01 | T | 0.00 |
| 17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.19 | 0.00 | 0.57 | 0.00 |
| 18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.56 | 0.00 |
| 19 | 0.00 | 0.00 | T | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 |
| 20 | 0.00 | 0.00 | 0.00 | T | 0.00 | 0.01 | 0.00 | T | 0.00 | 0.24 |
| 21 | 0.00 | 0.00 | 0.00 | 0.28 | 0.00 | 0.00 | 0.00 | 0.00 | 0.19 | 0.00 |
| 22 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | T | 0.00 | 0.00 | 0.00 | 0.00 |
| 23 | 0.00 | 0.00 | T | 0.00 | T | 1.72 | 0.05 | 0.00 | 0.00 | 0.22 |
| 24 | 0.00 | 0.00 | 0.00 | 0.10 | 0.45 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 25 | 0.00 | T | 0.00 | 0.05 | 0.04 | 1.46 | 0.00 | 0.00 | 0.00 | 0.00 |
| 26 | 0.00 | T | 0.07 | T | M | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 27 | 0.00 | 0.00 | 0.00 | 0.27 | M | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 28 | T | 0.03 | 0.13 | T | 0.01 | 0.53 | 0.00 | 0.00 | 0.00 | 0.23 |
| 29 | 0.00 | -- | 0.00 | 0.00 | T | 0.01 | 0.00 | T | 0.00 | 0.00 |
| 30 | 0.00 | -- | 0.00 | 0.00 | 0.01 | 0.00 | 1.08 | 0.04 | 0.00 | 0.00 |
| 31 | 0.00 | -- | 0.01 | -- | 0.05 | -- | 0.11 | 0.00 | -- | 0.00 |
| Totals | 1.35 | 0.48 | 2.85 | 1.98 | 3.71 | 6.60 | 1.70 | 1.70 | 4.42 | 7.89 |
| Normal | 2.54 | 2.61 | 4.10 | 4.44 | 7.68 | 5.11 | 3.42 | 3.45 | 4.78 | 4.14 |
| Departure | -1.19 | -2.13 | -1.25 | -2.46 | -3.97 | 1.49 | -1.72 | -1.75 | -0.36 | 3.75 |

| | |
|---|---|
| Total Precipitation Received (inches) | 32.68 |
| Total Normal Precipitation (inches) | 42.27 |
| Total Departure from Normal (inches) | -9.59 |

Notes: T = Trace
Data from 4/1/2014 and 5/12-17/2014 is reported from Fayetteville - Drake Field since data were reported as "Missing" at NWARA.

Flow rate data from Cave Springs can be an important part of evaluating the size of the recharge area. Some historical flow data from Cave Springs exists, as summarized in Aley et al. (2015). However, the accuracy of the flow rate data for Cave Springs is poor for a number of reasons. These reasons include the following:

- For many years a trout farm existed at Cave Springs. There were multiple buried water lines leading from inside the cave to various raceways. As a result, during the early phase of work under this project flowing water could be seen at multiple points downgradient of the cave. While most of this water was probably derived from the cave, it is possible that there are multiple springs at Cave Springs. The former pipes leading from the cave have now been capped or otherwise sealed to the extent feasible.
- There is significant leakage that bypasses the old concrete dam at the mouth of the cave. This leakage cannot be readily reduced without a significant construction effort, and that effort could adversely impact cavefish (sometimes found in the pool behind the dam) and other cave fauna.
- Some small springs or leakage points that have long been inundated by Partners Lake are also present. They were visible when the lake was drained as a part of the renovation of the area, but the lake has now been refilled and the springs are again inundated.

The result of these conditions is that past flow rate measurements likely under-estimate the rate of water flow from the cave. The percent of under-estimation is unknown, but the percent is undoubtedly greatest during low flow conditions.

The OUL attempted to install a weir downstream of the cave to provide more accurate flow rate measurements. Major leakage around and beneath the old flume area defeated these efforts.

Graening and Brown (2003) made calculations of flow rates discharging from the mouth of Cave Springs Cave on 59 dates during the period November 1997 to December 1999. The measurements were based on a staff gage located at the mouth of the cave. The mean flow rate was 3.54 cfs; flow rates ranged from 0.60 to 11.79 cfs. The maximum flow rate reported in available data was 15.3 cfs on July 1, 1999 (Graening and Brown 1999).

A staff gauge remains at the mouth of the cave. Staff gauge measurements were made throughout this study and were converted to flow rates as described in Section 2.4. These data are presented in Table 8.

**Table 8. Staff Gauge and Flow Rate Measurements.** Based upon equation in Graening and Brown (2003).

| Date | Staff Gauge Measurement (feet) | Flow Rate (cfs) |
|---|---|---|
| 5/15/2014 | 11.38 | 8.32 |
| 5/21/2014 | 11.20 | 7.17 |
| 5/23/2014 | 11.18 | 7.04 |
| 5/28/2014 | 11.18 | 7.04 |
| 6/04/2014 | 11.24 | 7.42 |
| 6/12/2014 | 11.20 | 7.17 |
| 6/19/2014 | 11.19 | 7.10 |
| 6/29/2014 | 11.40 | 8.45 |
| 7/08/2014 | 11.18 | 7.04 |
| 7/16/2014 | 11.13 | 6.72 |
| 7/23/2014 | 11.10 | 6.53 |
| 7/31/2014 | 11.15 | 6.85 |
| 8/06/2014 | 11.09 | 6.46 |
| 8/12/2014 | 11.08 | 6.40 |
| 8/15/2014 | 11.10 | 6.53 |
| 8/21/2014 | 10.98 | 5.76 |
| 9/04/2014 | 11.08 | 6.40 |
| 9/10/2014 | 10.90 | 5.24 |
| 9/23/2014 | 10.88 | 5.11 |
| 10/3/2014 | 10.98 | 5.76 |
| 10/13/2014 | 11.56 | 9.48 |
| 10/20/2014 | 11.18 | 7.08 |

The lowest staff gauge measurement was 10.88 on 9/23/2014 (5.76 cfs), and the highest staff gauge measurement was 11.56 feet (9.48 cfs) on 10/13/2014. The mean staff gauge measurement over the study period (5/15/2014 to 10/20/2014) was 11.15 (6.87 cfs).

On October 20, 2014, the flow discharging from Partners Lake was measured with a pygmy current meter. This measurement is an approximation of the flow from Cave Springs. Flow on this date was estimated to be near average flows observed during the study period due to recent rainfall, although lower flows were observed during much of the study period. The flow was measured in the flume on the west side of Arkansas Highway 112. The measured flow rate was 5.28 cfs. The measurement was characterized as "poor," which indicates an estimated error rate of plus or minus 8% or more. Based on the USGS rating table found in Brown et al. (1998), the flow rate at the mouth of the cave should have been 4.28 cfs at that time. The flow rates shown in Table 8 may be inaccurately high, possibly because the control point has shifted since the rating table was developed. Alternatively, there may be leakage out of Partners Lake.

## 3.3 Groundwater Tracing

Thirteen dye introductions were made during this study to provide more detailed information about the Cave Springs recharge area. The results of these traces are described in this section.

The comprehensive analytical results are included in tabular form in Appendix B. Smaller tables within the text include dye analysis results for sampling stations where dyes from groundwater traces conducted as part of this investigation were detected. Dye concentrations are reported in parts per billion (ppb). Within the tables, the following abbreviations are routinely encountered: "ND" means that no dye was detected and "nm" is an abbreviation for nanometers.

Charcoal samplers are continuous and accumulating samplers left in place for a period of time (often one to two weeks). The "total" concentration is the amount of dye accumulated during the entire sampling period. Since sampling periods often vary due to field conditions, weather, and scheduling, a mean concentration-per-day has also been calculated. This average daily concentration is the total concentration divided by the number of days the sampler was left in place. This calculated mean concentration-per-day value provides more easily comparable concentration data from the charcoal samplers. A grab sample of water was collected when the activated carbon samplers were collected. The corresponding water sample concentration is provided for the collection date of each charcoal sampler.

### 3.3.1 Trace 14-01: Upper Osage Creek Trace

Two pounds of fluorescein dye mixture containing approximately 75% dye equivalent and 25% diluent was introduced in the upper reach of Osage Creek downstream of Arkansas Highway 12/Business 71/Walnut Street in Rogers on May 14, 2014 at 2050 hours. This segment of Osage Creek is a losing stream and is dry under most conditions. However, at the time of the dye introduction, there was approximately 1 cfs of flow in the creek resulting from storm water runoff from earlier in the day. The Rogers area experienced approximately 1.8 inches of precipitation around the time of the dye introduction on May 14-15, 2014 (CoCoRaHS 2014). The dye introduction point is located at coordinates N36.33405 W94.16190 at an elevation of approximately 1255 ft msl.

The purpose of this trace was to determine if flow from the upper reaches of Osage Creek contributed water to Cave Springs. If a hydrologic connection were determined to exist, the results of this trace, together with Trace 14-02, introduced downstream of the Osage Spring complex, would provide information regarding the interaction of surface and subsurface flow paths in the Cave Springs recharge area.

The following springs and spring branches were sampled for this trace:

- Stations 101 to 109 Cave Springs and associated sampling stations;
- Station 111 Shores Spring;

- Station 112 Wallis Spring;
- Station 114 Shadow Valley Golf Course Spring Branch;
- Station 117 Village Pond Outfall;
- Stations 119 to 123 Osage Spring and associated sampling stations;
- Station 124 South Spring; and
- Station 125 North Spring.

Sampling stations established in Osage Creek downstream of the dye introduction point were monitored following the Trace 14-01 dye introduction as control stations (listed from upstream to downstream):

- Station 127 Osage Creek upstream of North Spring;
- Station 118 Osage Creek upstream of Blossom Way;
- Station 116 Osage Creek downstream of Cross Church;
- Station 115 Osage Creek at Rainbow Road; and
- Station 113 Osage Creek upstream of Shadow Valley Golf Course.

Fluorescein dye from Trace 14-01 was detected in samples from the following springs: North Spring, South Spring, and four of the five sampling station associated with Osage Spring (Stations 119, 120, 121 and 122). Data from all sampling stations are provided in Appendix B. Tables that follow summarize the results from activated carbon samplers and water samples from North Spring, South Spring, and Osage Spring (Station 120).

Osage Spring is located in an area that has been changed dramatically in recent years by commercial construction. Water from the spring is impounded in a pond that appears to drain through as many as five culverts under the newer commercial area into the channelized flow of Blossom Way Creek. All five of these culverts were sampled as part of the sampling program to ensure that no potential flow pathway was overlooked. These stations include:

- Station 119 Osage West Spring;
- Station 120 Osage Spring;
- Station 121 Osage Spring – Culvert 1;
- Station 122 Osage Spring – Culvert 2; and
- Station 123 Osage Spring – Culvert 3.

Samples collected from four of these springs (Stations 119-122) contained fluorescein dye from Trace 14-01. Based upon the results of this trace, the culvert where Station 123 (Osage Spring – Culvert 3) was established is not hydrologically connected to Osage Spring or any other spring with a hydrologic connection to upper Osage Creek. The results from Station 120 (Osage Spring) are summarized below as a representative sampling station for the Osage Spring complex.

**Station 120. Osage Spring.**

| Sampling Period | Peak Emission Wavelength in Activated Carbon (nm) | Fluorescein Concentration | | |
|---|---|---|---|---|
| | | Total in Activated Carbon (ppb) | Mean Concentration per Day (ppb/day) | Corresponding Water Sample (ppb) |
| 04/23/14 to 05/01/14 | -- | ND | -- | ND |
| 05/01/14 to 05/07/14 | -- | ND | -- | ND |
| 05/14/14 | Fluorescein Dye Introduction | | | |
| 05/07/14 to 05/15/14 | 515.3 | 1.32 | 0.171 | ND |
| 05/15/14 to 05/21/14 | 515.3 | 37.8 | 6.19 | 0.035 |
| 05/21/14 to 05/28/14 | 515.4 | 6.13 | 0.876 | 0.013 |
| 05/28/14 to 06/04/14 | 515.6 | 3.97 | 0.551 | 0.006 |
| 06/04/14 to 06/12/14 | 515.4 | 1.26 | 0.158 | ND |
| 06/12/14 to 06/19/14 | 515.8 | 0.476 | 0.069 | ND |
| 06/19/14 to 06/30/14 | 516.9 | 0.458 | 0.043 | ND |
| 06/30/14 to 07/16/14 | 515.8 | 0.316 | 0.019 | ND |
| 07/16/14 to 07/23/14 | 513.6 ** | 0.191 | 0.029 | ND |
| 07/23/14 to 07/31/14 | 515.8 | 0.167 | 0.020 | ND |
| 07/31/14 to 08/27/14 | -- | ND | -- | -- |
| 08/27/14 to 09/11/14 | -- | ND | -- | -- |
| 09/11/14 to 09/23/14 | -- | ND | -- | -- |

Notes: ND = Not detected
** Does not meet all criteria for a positive dye detection, but calculated as tracer dye.

Station 126 was established to sample flow from North Spring. This spring is located in the channel of Osage Creek upstream of Blossom Way Creek. North Spring is the location where flow surfaces in Osage Creek under most flow conditions. Surface flow in Osage Creek downstream of North Spring in the study area was constant throughout the study period. Surface flow upstream of North Spring was only present following rainfall events that produced significant runoff. At the time of the Trace 14-01 dye introduction, continuous surface flow existed from the dye introduction location to North Spring. This surface flow of dye potentially added to the fluorescein concentration during the first sampling period following the dye introduction.

**Station 126. North Spring.**

| Sampling Period | Peak Emission Wavelength in Activated Carbon (nm) | Fluorescein Concentration | | |
|---|---|---|---|---|
| | | Total in Activated Carbon (ppb) | Mean Concentration per Day (ppb/day) | Corresponding Water Sample (ppb) |
| 05/08/14 to 05/14/14 | -- | ND | -- | ND |
| 05/14/14 | Fluorescein Dye Introduction | | | |
| 05/14/14 to 05/21/14 | 515.9 | 981 | 139 | 0.038 |
| 05/21/14 to 05/28/14 | 515.2 | 6.29 | 0.900 | 0.012 |
| 05/28/14 to 06/04/14 | 515.4 | 3.06 | 0.431 | 0.007 (1) |
| 06/04/14 to 06/12/14 | 515.0 | 1.75 | 0.218 | ND |
| 06/12/14 to 06/19/14 | 515.8 | 0.358 | 0.052 | -- |
| 06/19/14 to 06/30/14 | 514.6 | 0.384 | 0.036 | -- |
| 06/30/14 to 07/17/14 | 515.2 | 0.355 | 0.021 | -- |
| 07/17/14 to 07/31/14 | -- | ND | | -- |
| 07/31/14 to 08/15/14 | -- | ND | -- | -- |
| 08/15/14 to 08/27/14 | -- | ND | -- | -- |

Notes: ND = Not detected
(1) Water sample result did not meet all criteria for a positive dye detection, but it was calculated as tracer dye because there is a detection in the corresponding activated carbon sample.

South Spring is the location where flow surfaces in Blossom Way under most flow conditions. Surface flow in Blossom Way downstream of South Spring was constant throughout the study period. Surface flow upstream of South Spring was only present following rainfall events that produced significant runoff. Flow from South Spring surfaces over a short distance in the channel of Blossom Way upstream of the New Hope Road bridge and downstream of the bridge at Rife Medical Lane. At times during the study period this area was impacted by beaver activity. For these reasons the sampling station for South Spring (Station 124) was established downstream of the beaver dam and was named "Blossom Way downstream of South Spring." The sampling results from Station 124 following the Trace 14-01 dye introduction are summarized below.

**Station 124. Blossom Way Downstream of South Spring**

| Sampling Period | Peak Emission Wavelength in Activated Carbon (nm) | Fluorescein Concentration | | |
|---|---|---|---|---|
| | | Total in Activated Carbon (ppb) | Mean Concentration per Day (ppb/day) | Corresponding Water Sample (ppb) |
| 04/23/14 to 05/01/14 | -- | ND | -- | ND |
| 05/01/14 to 05/07/14 | -- | ND | -- | ND |
| 05/14/14 | Fluorescein Dye Introduction | | | |
| 05/07/14 to 05/15/14 | 515.8 | 1.38 | 0.179 | 1.00 |
| 05/15/14 to 05/21/14 | 515.4 | 140 | 22.9 | ND |
| 05/21/14 to 05/28/14 | 515.0 | 1.94 | 0.277 | ND |
| 05/28/14 to 06/04/14 | 515.4 | 0.894 | 0.124 | ND |
| 06/04/14 to 06/12/14 | -- | ND | -- | ND |
| 06/12/14 to 06/19/14 | -- | ND | -- | ND |
| 06/19/14 to 06/30/14 | -- | ND | -- | ND |
| 06/30/14 to 07/16/14 | -- | ND | -- | ND |
| 07/16/14 to 07/23/14 | -- | ND | -- | ND |
| 07/23/14 to 07/31/14 | -- | ND | -- | ND |
| 07/31/14 to 08/27/14 | -- | ND | -- | ND |
| 08/27/14 to 09/11/14 | -- | ND | -- | ND |
| 9/11/14 to 9/17/14 | -- | ND | -- | ND |
| 09/17/14 to 09/23/14 | -- | ND | -- | ND |
| 09/23/14 to 09/29/14 | -- | ND | -- | ND |

Notes: ND = Not detected

The dye was introduced at dusk. Visible dye was present in Osage Creek the following morning at Interstate 49. As expected, fluorescein dye was detected in all surface water sampling stations in Osage Creek following the dye introduction (Stations 127, 118, 116, 115, and 113). The data from these stations are detailed in Appendix B. Activated carbon sampler results from these sampling stations are summarized in the following table. The sampling period is listed by week number following the Trace 14-01 dye introduction. The stations are listed from upstream to downstream.

North Spring contributes water to Osage Creek between Stations 127 and Stations 118. Flow from Osage Spring and South Spring enters Osage Creek at the confluence of Blossom Way, which is located between Stations 118 and 116. Even with these contributing flows, dye concentrations during a given sampling period generally decreased with increasing distance from the dye introduction location. Additionally, dye concentrations generally decreased with time at each sampling station.

**Trace 14-01: Activated Carbon Sample Results from Osage Creek Sampling Stations.** Fluorescein concentrations provided are the total concentration in the activated carbon samples divided by the number of days the sampler was in place (ppb/day).

| **Sampling Period** denoted by week number following the dye introduction | Upstream>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>Downstream | | | | |
|---|---|---|---|---|---|
| | **Station 127** Osage Creek u/s North Spring(1) (ppb/day) | **Station 118** Osage Creek u/s Blossom Way (ppb/day) | **Station 116** Osage Creek d/s Cross Church (ppb/day) | **Station 115** Osage Creek at Rainbow Road (ppb/day) | **Station 113** Osage Creek u/s Shadow Valley Golf Course (ppb/day) |
| 5/14/2014 | Fluorescein Dye Introduction | | | | |
| Week 1 | 189 | NS | 0.590(2) | 11.4 | 1.61 |
| Week 2 | 0.432 | 1.59 | 0.658 | 0.287 | ND |
| Week 3 | 0.063** | 0.237 | 0.116 | 0.068 | ND |
| Week 4 | NS | 0.086 | 0.049 | 0.071 | (3) |
| Week 5 | ND | 0.023 | ND | 0.026 | (3) |
| Week 6 | ND | 0.034 | ND | 0.021 | ND |
| Week 7 | ND | ND | ND | ND | ND |
| Week 8 | NS | ND | ND | ND | ND |

Notes: ND = not detected
NS = no sample
** Does not meet all criteria for a positive dye detection, but calculated as tracer dye
u/s indicates upstream and d/s indicates downstream
(1) Flow at this station was intermittent during the sampling period.
(2) Activated carbon sampler was washed out of the stream during part of the sampling period.
(3) Fluorescein dye was detected in this sample but is attributable to a subsequent dye introduction.

Diagrammatic tracing flow paths are illustrated in Figure 6. Dye from Trace 14-01 was not detected in Cave Springs, Shores Spring, or Wallis Spring. The results of this trace demonstrate that flow sinking from Osage Creek does not contribute flow to the groundwater system associated with Cave Springs. Trace 14-01 further shows that the losing stream segment of Osage Creek upstream of Blossom Way contributes flow to Osage Spring, North Spring and South Spring.

### 3.3.2 Trace 14-02: Osage Creek near Cross Church Trace

Six pounds of rhodamine WT dye mixture containing approximately 20% dye equivalent and 80% diluent was introduced in Osage Creek downstream of Cross Church in Rogers on May

14, 2014 at 2110 hours. This location is downstream of Interstate 49 and the confluence of Blossom Way Creek with Osage Creek. It is also downstream of Osage Spring, North Spring, and South Spring. Although perennial flow is present in Osage Creek in this location, this dye introduction occurred upstream of a losing stream segment of Osage Creek identified in a USGS study (Moix et al. 2003). At the time of the dye introduction approximately 8 cfs of flow was present in the creek. The Rogers area experienced approximately 1.8 inches of precipitation on May 14-15, 2014 (CoCoRaHS 2014). The dye introduction point is located at coordinates N36.31237 W94.19402 at an elevation of approximately 1185 ft msl.

The purpose of this trace was to determine if flow downstream of Osage Spring and Blossom Way Creek contributes water to the Cave Springs groundwater system. If a hydrologic connection were determined to exist, the results of this trace together with Trace 14-01 introduced upstream of Blossom Way would provide additional information regarding the interaction of surface and subsurface flow paths in the Cave Springs recharge area.

The following springs and spring branches were sampled following the dye introduction:

- Stations 101 to 109 Cave Springs and associated sampling stations;
- Station 111 Shores Spring;
- Station 112 Wallis Spring; and
- Station 114 Shadow Valley Golf Course Spring Branch.

Sampling stations established in Osage Creek downstream of the dye introduction point were also monitored following the Trace 14-02 dye introduction for control purposes (listed from upstream to downstream):

- Station 115 Osage Creek at Rainbow Road; and
- Station 113 Osage Creek upstream of Shadow Valley Golf Course.

Rhodamine WT dye was not detected in any of the sampling stations established at springs in the study area. Dye from Trace 14-02 was detected in sampling stations downstream of the dye introduction point on Osage Creek. Activated carbon sampler results from these sampling stations are summarized in the table below. The sampling period is listed by week number following the Trace 14-02 dye introduction. The stations are listed from upstream to downstream. Data from all sampling stations are provided in Appendix B.

**Trace 14-02: Activated Carbon Sample Results from Osage Creek Sampling Stations.** Rhodamine WT concentrations provided are the total concentration in the activated carbon samples divided by the number of days the sampler was in place (ppb/day).

| **Sampling Period** denoted by week number following the dye introduction | Upstream>>>>>>>>>>>>>>>>>>>>>>>>>>>Downstream | |
|---|---|---|
| | **Station 115** Osage Creek at Rainbow Road (ppb/day) | **Station 113** Osage Creek u/s Shadow Valley Golf Course (ppb/day) |
| 5/14/2014 | Rhodamine WT Dye Introduction | |
| Week 1 | 271 | 64.7 |
| Week 2 | 3.38 | ND |
| Week 3 | 1.29 | ND |
| Week 4 | 0.786 | ND |
| Week 5 | 0.350 | ND |
| Week 6 | 0.213 | ND |
| Week 7 | ND | ND |
| Week 8 | ND | ND |

Notes: ND = not detected
u/s indicates upstream

Diagrammatic tracer flow paths are illustrated in Figure 7. Dye from Trace 14-02 was not detected in Cave Springs, Shores Spring, or Wallis Spring. The results of this trace demonstrate that flow sinking from Osage Creek downstream of Blossom Way does not contribute flow to the groundwater system associated with Cave Springs.

### 3.3.3 Trace 14-03: Lower Pinnacle Valley Trace

Three pounds of eosine dye mixture containing approximately 75% dye equivalent and 25% diluent was introduced in the lower part of the tributary valley to Osage Creek called Pinnacle Valley in this study. The dye introduction occurred on May 14, 2014 at 2015 hours. The dye introduction point was located downstream of Rainbow Road near the Rogers wastewater treatment facility. Intermittent flow was observed in this tributary during the study period. At the time of the dye introduction, approximately 50 gpm of flow was present in the tributary. The Rogers area received approximately 1.8 inches of precipitation on May 14-15, 2014. The dye introduction is located at coordinates N36.29934 W94.21194 at an elevation of approximately 1180 ft msl.

The purpose of this trace was to determine if flow from this tributary valley contributes water to the Cave Springs groundwater system.

The following springs and spring branches were sampled in conjunction with this trace:

- Stations 101 to 109 Cave Springs and associated sampling stations;
- Station 111 Shores Spring;
- Station 112 Wallis Spring; and
- Station 114 Shadow Valley Golf Course Spring Branch.

The following sampling station on Osage Creek downstream of the dye introduction point was also monitored:

- Station 113 Osage Creek upstream of Shadow Valley Golf Course.

Eosine dye from Trace 14-03 was not detected in any of the sampling stations established at springs in the study area. Dye from Trace 14-03 was only detected at: Station 113 (Osage Creek upstream of Shadow Valley Golf Course). This sampling station is located downstream of the dye introduction point and was in continuous surface flow during the study. Data from all sampling stations are provided in Appendix B.

Diagrammatic tracer flow paths are illustrated in Figure 7. Dye from Trace 14-03 was not detected in Cave Springs, Shores Spring, or Wallis Spring. The results of this trace demonstrate that flow sinking from the lower portion of Pinnacle Valley does not contribute flow to Cave Springs.

### 3.3.4 Trace 14-04: South Blossom Tributary at Dixieland Road Trace

Four pounds of rhodamine WT dye mixture containing approximately 20% dye equivalent and 80% diluent was introduced in the upper part of a southern tributary to Blossom Way Creek on June 5, 2014 at 1830 hours. The dye introduction point was located downstream of Dixieland Road near the Fastlane recreation area. Dye was introduced into pools of water in the channel. No flow was present at the time of the dye introduction. Although more rain was forecasted, only approximately 0.2 inches of precipitation fell in the Rogers area near the time of the dye introduction (CoCoRaHS 2014). The dye introduction was located at coordinates N36.27200 W94.14636 with an elevation of 1298 ft msl.

One purpose of this trace was to determine if flow from the headwaters of Blossom Way Creek contributes water to Puppy Creek. Another purpose was to better understand the flow of water into and through the Cave Springs groundwater system, which would provide additional information regarding the Cave Springs Direct-Indirect Recharge Area division.

The following springs and spring branches were sampled following the dye introduction:

- Stations 101 to 109 Cave Springs and associated sampling stations;
- Station 111 Shores Spring;
- Station 112 Wallis Spring;

- Stations 119 to 123 Osage Spring and associated sampling stations;
- Station 124 South Spring;
- Station 125 North Spring; and
- Station 134 Reed Spring.

The following sampling stations in Blossom Way Creek downstream of the dye introduction point were also monitored:
- Station 145 Unnamed Tributary at Pleasant Grove Road; and
- Station 125 Blossom Way upstream of South Spring.

No dye was recovered from this dye introduction in either Puppy Creek, Cave Springs, or farther downstream in Blossom Way. These results indicate there is not a significant amount of flow that sinks in the uppermost part of the Blossom Way. Trace 14-07 was introduced a little farther downstream in this tributary to replicate this trace in an area that experiences greater flows from storm water runoff.

### 3.3.5 Trace 14-05: North Blossom Tributary at Dixieland Road Trace

Four pounds of eosine dye mixture containing approximately 75% dye equivalent and 25% diluent was introduced in the upper part of a northern tributary to Blossom Way Creek on June 5, 2014 at 1905 hours. The dye introduction point was located south of the parking area for the Razorback Trail and 200 feet west (downstream) of Dixieland Road. Dye was introduced into a flow of approximately 75 gpm. Although more rain was forecasted, only approximately 0.2 inches of precipitation fell in the area around the time of the dye introduction (CoCoRaHS 2014). The dye introduction was located at coordinates N36.29477 W94.14487 at an elevation of 1290 ft msl.

Flow the next morning (June 6) was approximately double (150 gpm) what it was during the dye introduction approximately 12 hours earlier. Observations of flow rates at downstream locations indicated this tributary to Blossom Way was losing water to the groundwater system. All flow (dyed water) was observed to be completely lost to the groundwater flow system by the Interstate 49 interchange.

One purpose of this trace was to create a better understanding of the Cave Springs Direct-Indirect Recharge Area division. Another purpose was to understand whether or not this area contributes water to Puppy Creek, Cave Spring, Osage Creek or South Spring.

The following springs and spring branches were sampled following the dye introduction:
- Stations 101 to 109 Cave Springs and associated sampling stations;
- Station 111 Shores Spring;
- Station 112 Wallis Spring;
- Stations 119 to 123 Osage Spring and associated sampling stations;
- Station 124 South Spring;
- Station 125 North Spring; and

- Station 134 Reed Spring.

The following sampling stations in Blossom Way downstream of the dye introduction point were also monitored:

- Station 146 Blossom Way at S. 28th Place; and
- Station 125 Blossom Way upstream of South Spring.

The only spring station where eosine from Trace 14-05 was detected was South Spring. Dye from Trace 14-05 was also detected in surface stream sampling stations downstream of the dye introduction point. Stations 146 and 125 only received intermittent flow in Blossom Way. All sampling stations downstream of South Spring (Stations 125, 116, and 115) exhibited continuous surface flow following the dye introduction.

Activated carbon sampler results from these sampling stations are summarized in the following table. The sampling period is listed by week number following the Trace 14-05 dye introduction. The stations are listed from upstream to downstream. Data from all sampling stations are provided in Appendix B.

**Trace 14-05: Activated Carbon Sampler Results from Blossom Way and Osage Creek Sampling Stations.** Eosine concentrations provided are the total concentration in the activated carbon samples divided by the number of days the sampler was in place (ppb/day).

| **Sampling Period** denoted by week number following the dye introduction | Upstream>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>Downstream | | | | |
|---|---|---|---|---|---|
| | **Station 146** Blossom Way at S 28th Place (ppb/day) | **Station 125** Blossom Way u/s South Spring(1) (ppb/day) | **Station 124** Blossom Way d/s South Spring (ppb/day) | **Station 116** Osage Creek d/s Cross Church (ppb/day) | **Station 115** Osage Creek at Rainbow Road (ppb/day) |
| 06/05/2014 | Eosine Dye Introduction | | | | |
| Week 1 | NS | 0.303** | 1.32 | 1.17 | 0.515** |
| Week 2 | 7.28 | 0.108** | 1.06 | 0.806 | 0.397** |
| Week 3 | 1.87 | 0.201 | 0.426 | 0.276 | 0.145** |

Notes: NS = No sample
u/s indicates upstream and d/s indicates downstream
** Does not meet all criteria for a positive dye detection, but calculated as tracer dye.
(1) Flow at this station was intermittent during the sampling periods.

Diagrammatic tracer flow paths are illustrated in Figure 6. Dye from Trace 14-05 was not detected in Osage Spring, Cave Springs, Shores Spring, Wallis Spring or any of the sampling stations in Puppy Creek. The results of this trace indicate flow sinking from the north and central portions of the Blossom Way headwaters contribute water to South Spring under the flow conditions tested. Based upon the results of this trace, the upper reaches of Blossom Way do not directly contribute water to Cave Springs and thus the Indirect Recharge Area designation for this area is appropriate.

### 3.3.6 Trace 14-06: Upper Pinnacle Valley (Southgate and Sloan) Trace

One pound of fluorescein dye mixture containing approximately 75% dye equivalent and 25% diluent was introduced in the upper portion of the Pinnacle Valley tributary to Osage Creek in Rogers on June 5, 2014 at 1950 hours. This location is downstream of the intersection of Southgate and Sloan Road. At the time of the dye introduction approximately 2 gpm was flowing in the stream. Although it was raining at the time of the dye introduction, only approximately 0.2 inches of precipitation fell in the Rogers area near the time of the dye introduction (CoCoRaHS 2014). The dye introduction was located at coordinates N36.29184 W94.20435 with an elevation of 1230 ft msl.

The purpose of this trace was to determine if flow in the upper portion of this Pinnacle Valley tributary contributes water to the Cave Springs groundwater system and to determine if there was a hydrologic connection to Cave Springs and/or Shores and Wallis Springs.

The following springs and spring branches were sampled in conjunction following the dye introduction:

- Stations 101 to 109 Cave Springs and associated sampling stations;
- Station 111 Shores Spring;
- Station 112 Wallis Spring; and
- Station 114 Shadow Valley Golf Course Spring Branch.

Sampling stations established in Pinnacle Valley tributary and Osage Creek downstream of the dye introduction point were also monitored following the Trace 14-06 dye introduction (listed from upstream to downstream):

- Station 143 Pinnacle Valley Tributary; and
- Station 113 Osage Creek upstream of Shadow Valley Golf Course.

Fluorescein dye from this trace was not detected in any of the sampling stations established at springs in the study area. Dye from Trace 14-06 was detected in surface water sampling stations downstream of the dye introduction point. Activated carbon sampler results from these sampling stations are summarized in the following table. The sampling period is listed by week number following the Trace 14-06 dye introduction. The stations are listed from upstream to downstream. Data from all sampling stations are provided in Appendix B.

**Trace 14-06: Activated Carbon Sample Results from Pinnacle Valley and Osage Creek Sampling Stations.** Fluorescein concentrations provided are the total concentration in the activated carbon samples divided by the number of days the sampler was in place (ppb/day).

| **Sampling Period** denoted by week number following the dye introduction | Upstream>>>>>>>>>>>>>>>>>>>>>>>>>>>>Downstream | |
|---|---|---|
| | **Station 143** Pinnacle Valley Tributary (ppb/day) | **Station 113** Osage Creek u/s Shadow Valley Golf Course (ppb/day) |
| 06/05/2014 | Fluorescein Dye Introduction | |
| Week 1 | 0.655 | 0.186 |
| Week 2 | 0.243 | 0.115 |
| Week 3 | 0.025 | ND |

Notes: ND = not detected
u/s indicates upstream

Diagrammatic tracer flow paths are illustrated in Figure 7. Dye from Trace 14-06 was not detected in Cave Springs, Shores Spring, or Wallis Spring. The results of this trace demonstrate that this location in the Pinnacle Valley tributary is not in the Cave Springs recharge area.

### 3.3.7 Traces 14-07 & 09: South Blossom Way Tributary at Pleasant Grove Road Trace

Trace 14-07 was introduced in the southern Blossom Way tributary downstream of Pleasant Grove Road on July 10, 2014 at 1415 hours. Approximately 50 gpm of flow was present at the time of dye introduction. It was derived from storm water runoff. Additional precipitation was forecasted for later that afternoon. However the storm passed mainly to the south of the study area and only 0.27 inch of precipitation was received that day. Dye from this trace was flushed into the subsurface, but not enough flow accompanied the dye introduction to completely flush the dye into the groundwater system.

This trace was repeated as Trace 14-09 on July 31, 2014 at 2130 hours when more rainfall was received. At the time of the Trace 14-09 dye introduction the flow in the location was 0.75 cfs. Approximately 1.47 inches of precipitation fell in the Rogers area around the time of the second dye introduction (CoCoRaHS 2014).

Three pounds of eosine dye mixture containing approximately 75% dye equivalent and 25% diluent was introduced during each of the dye introductions. The dye introductions were located at coordinates N36.28406 W94.16502 with an elevation of 1275 ft msl.

One purpose of this trace was to create a better understanding of the Cave Springs Direct-Indirect Recharge Area division. Another purpose was to understand whether or not this area contributes water directly to Cave Springs, Osage Spring, North Spring, South Spring or Puppy Creek.

The following springs and spring branches were sampled following the dye introduction:

- Station 101 Cave Springs;
- Station 111 Shores Spring;
- Station 112 Wallis Spring;
- Stations 119 to 123 Osage Spring and associated sampling stations;
- Station 124 South Spring;
- Station 126 North Spring; and
- Station 134 Reed Spring.

The following sampling stations in Blossom Way and Osage Creek downstream of the dye introduction point were also monitored (listed from upstream to downstream):

- Station 147 Blossom Tributary at Bellview Road;
- Station 125 Blossom Way upstream of South Spring;
- Station 116 Osage Creek downstream of Cross Church; and
- Station 115 Osage Creek at Rainbow Road.

The only spring station where eosine from Traces 14-07 and 14-09 was detected was South Spring. Dye from these traces was also detected in sampling stations downstream of the dye introduction point. Stations 146 and 125 only received intermittent flow in Blossom Way that resulted from precipitation events that generated a significant amount of storm water runoff. These events did not occur very frequently over the study period. All sampling stations downstream of South Spring (Stations 125, 116, and 115) exhibited continuous surface flow following the dye introduction.

Activated carbon sampler results from these sampling stations are summarized in the following table. The sampling periods listed by week number following the Trace 14-07 dye introduction. The stations are listed from upstream to downstream. The data from Station 124 (Blossom Way downstream of South Spring) are not as consistent as desired due to problems with beaver activity in the area (moving, hiding, and flooding samplers) during the sampling periods following the dye introductions. All data from all sampling stations are provided in Appendix B.

**Traces 14-07 and 14-09: Activated Carbon Sampler Results from Blossom Way and Osage Creek Sampling Stations.** Eosine concentrations provided are the total concentration in the activated carbon samples divided by the number of days the sampler was in place (ppb/day).

| | Upstream>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>Downstream | | | | |
|---|---|---|---|---|---|
| **Sampling Period** denoted by week number following the dye introduction | **Station 147** Blossom Tributary u/s Bellview Rd(1) (ppb/day) | **Station 125** Blossom Way u/s South Spring(1) (ppb/day) | **Station 124** Blossom Way d/s South Spring (ppb/day) | **Station 116** Osage Creek d/s Cross Church (ppb/day) | **Station 115** Osage Creek at Rainbow Road (ppb/day) |
| 07/10/2014 | Trace 14-07 Eosine Dye Introduction | | | | |
| Week 1 | NS | NS | 0.770(2) | 1.09(2) | 0.370** |
| Week 2 | NS | NS | 0.738(2) | NS | NS |
| 7/31/14 | Trace 14-09 Eosine Dye Introduction | | | | |
| Week 3 | 242 | ND | 0.140(2) | 1.04(2) | 0.455** |
| Week 4 | NS | NS | NS | NS | NS |
| Week 5 | ND | ND | NS | 5.33 | 2.09 |
| Week 6 | NS | NS | NS | NS | NS |
| Week 7 | ND | ND | 2.19 | 1.14 | 0.329 |
| Week 8 | 1.42 | NS | NS | NS | NS |
| Week 9 | NS | 0.072** | 0.248 | NS | 0.327 |
| Week 10 | NS | ND | 0.058 | NS | 0.385 |
| Week 11 | NS | ND | 0.254 | NS | 0.149 |
| Week 12 | NS | ND | 0.284 | NS | 0.565 |

Notes: NS = No sample
u/s indicates upstream and d/s indicates downstream
(1) Flow at this station was intermittent during the sampling period.
(2) Dye at this station may also be attributable to Trace 14-05.
** Not all the criteria were met for a positive dye detection, but was calculated as tracer dye.

Flow enters South Spring enters Blossom Way between Stations 125 and 124. Flow from Osage Spring entered Blossom Way between Stations 124 and 116. Flow from Blossom Way enters Osage Creek upstream of Station 116. Due to the infrequent flows upstream of South Spring, there is not a consistent data set immediately downstream of the dye introduction point. Problems with beaver activity in the area of Station 124 also created a data gap. However, reviewing the dataset as a whole and understanding the intermittent flows in the upper reaches of Blossom Way, the groundwater discharge point for these traces is South Spring.

Diagrammatic tracer flow paths are illustrated in Figure 6. Dye from Traces 14-07 and 14-09 was not detected in Osage Spring, North Spring, Cave Springs, Shores Spring, or Wallis Spring. Based upon the results of this trace, the upper reaches of Blossom Way do not contribute water to Cave Springs under the flow conditions tested and thus the Indirect Recharge Area designation for this area is appropriate.

### 3.3.8 Trace 14-08: Mt. Hebron Road Storm Water Basin Trace

Two pounds of fluorescein dye mixture containing approximately 75% dye equivalent and 25% diluent was introduced into storm water runoff entering the storm water retention basin on the east side of Mt. Hebron Road north of Arkansas Highway 264 on July 31, 2014 at 2100 hours. This location is south of the Janie Darr Elementary School and is within the Cross Creek topographic basin. At the time of the dye introduction approximately 75 gpm of flow was entering the storm water basin from storm water flow on the east side of Mt. Hebron Road. Approximately 1.19 inches of precipitation fell in the area associated with the storm event that flushed the dye during the dye introduction (NWS 2014). The dye introduction was located at coordinates N36.26315 W94.19489 at an elevation of approximately 1230 ft msl.

It was anticipated that this dye introduction would result in dye detections at Cave Springs. However, the purpose of this trace was to determine if dye would also be detected at Reed Spring, Shores Spring and Wallis Spring in order to determine if hydrologic interactions exist with these nearby springs. Another purpose of this trace was to characterize the functioning of a storm water basin within the Cave Springs recharge area.

The following springs were sampled in conjunction with the dye introduction for Trace 14-08:

- Station 101 Cave Springs;
- Station 111 Shores Spring;
- Station 112 Wallis Spring; and
- Station 134 Reed Spring.

The sampling stations established in Cross Creek downstream of the dye introduction point were also monitored following the Trace 14-08 dye introduction. These stations were established to monitoring springs on private property located downstream of the dye introduction point and to also determine if dye resurfaced in the Cross Creek down gradient of the dye introduction location (stations listed from upstream to downstream):

- Station 136 Cross Creek upstream of Brown Road; and
- Station 135 Cross Creek upstream of Wagon Wheel Road.

Fluorescein dye was detected in samples collected from the following springs: Cave Springs and Reed Spring. Tables that follow summarize the results from activated carbon samplers and water samples from Cave Springs and Reed Spring. Duplicate charcoal samplers were analyzed for both Cave Springs and Reed Springs. Replicate water samples were also analyzed periodically. The mean concentrations are provided in the table below. Data from all samples collected are provided in Appendix B.

**Station 101. Cave Springs** When available, duplicate activated carbon samples were analyzed for this station. Replicate samples were also analyzed periodically. Mean concentrations are provided in this table.

| Sampling Period | Peak Emission Wavelength in Activated Carbon (nm) | Fluorescein Concentration | | |
|---|---|---|---|---|
| | | Total in Activated Carbon (ppb) | Mean Concentration per Day (ppb/day) | Corresponding Water Sample (ppb) |
| 07/16/14 to 07/23/14 | -- | ND | -- | ND |
| 07/23/14 to 07/31/14 | -- | ND | -- | ND |
| 07/30/14 | Fluorescein Dye Introduction | | | |
| 07/31/14 to 08/06/14 | 516.1 | 904 | 151 | 0.534 |
| 08/06/14 to 08/12/14 | 515.3 | 52.3 | 9.00 | 0.286 |
| 08/12/14 to 08/15/14 | 515.4 | 120 | 37.2 | 0.019 |
| 08/15/14 to 08/21/14 | 515.2 | 6.18 | 1.01 | 0.007 (1) |
| 08/21/14 to 08/26/14 | 515.4 | 1.53 | 0.325 | 0.008 (1) |
| 08/26/14 to 09/04/14 | 515.3 | 0.53 | 0.059 | 0.096 |
| 09/04/14 to 09/10/14 | 515.6 | 2.22 | 0.349 | 0.007 (1) |
| 09/10/14 to 09/17/14 | 515.5 ** | 0.170 | 0.026 | ND |
| 09/17/14 to 09/23/14 | 515.5 | 0.470 | 0.079 | 0.013 |
| 09/23/14 to 09/29/14 | 515.4 | 0.186 | 0.031 | ND |
| 09/29/14 to 10/03/14 | -- | ND | -- | ND |
| 10/03/14 to 10/13/14 | 515.4 | 3.99 | 0.402 | 0.025 |
| 10/13/14 to 10/20/14 | 515.8 | 9.16 | 1.31 | 0.020 |

Notes: ND = Not detected
** Does not meet all criteria for a positive dye detection, but calculated as tracer dye.
(1) Flow at the station was intermittent during the sampling period.

The highest concentration of fluorescein in activated carbon samplers occurred during the first sampling period following the dye introduction. Smaller peaks of fluorescein concentrations occurred when rainfall runoff events occurred that provided subsequent flushes of water into the groundwater system.

Additional information can be obtained by reviewing the composite water samples collected by the ISCO automatic pump sampler. The following table summarizes the composite water samples results at Cave Springs during the first week following the Trace 14-08 dye introduction. Additional composite water results from this trace are included in Appendix B.

**Composite Water Sample Results at Station 101 Cave Spring** for the first week following the Trace 14-08 dye introduction.

| Composite Water Sampling Period | | Peak Emission Wavelength in Composite Water (nm) | Fluorescein Concentration (ppb) |
|---|---|---|---|
| Beginning | Ending | | |
| 7/31/2014 at 2100 hours | | Fluorescein dye introduction | |
| 7/31/14 2100 | 8/1/14 0400 | 507.8 | 0.012 |
| 8/1/14 0500 | 8/1/14 1200 | 507.7 | 0.708 |
| 8/1/14 1300 | 8/1/14 2000 | 507.7 | 1.02 |
| 8/1/14 2100 | 8/2/14 0400 | 507.7 | 0.655 |
| 8/2/14 0500 | 8/2/14 1200 | 507.7 | 0.410 |
| 8/2/14 1300 | 8/2/14 2000 | 507.8 | 0.302 |
| 8/2/14 2100 | 8/3/14 0400 | 507.7 | 0.540 |
| 8/3/14 0500 | 8/3/14 1200 | 507.6 | 1.45 |
| 8/3/14 1300 | 8/3/14 2000 | 507.5 | 2.56 |
| 8/3/14 2100 | 8/4/14 0400 | 507.7 | 2.76 |
| 8/4/14 0500 | 8/4/14 1200 | 507.6 | 2.72 |
| 8/4/14 1300 | 8/4/14 2000 | 507.7 | 2.05 |
| 8/4/14 2100 | 8/5/14 0400 | 507.4 | 1.74 |
| 8/5/14 0500 | 8/5/14 1200 | 507.7 | 1.42 |
| 8/5/14 1300 | 8/5/14 2000 | 507.7 | 1.06 |
| 8/5/14 2100 | 8/6/14 0400 | 507.9 | 0.707 |
| 8/6/14 0500 | 8/6/14 1200 | 507.6 | 0.500 |
| 8/6/14 1300 | 8/6/14 2000 | 507.7 | 0.124 |
| 8/6/14 2100 | 8/7/14 0400 | 508.1 | 0.231 |
| 8/7/14 0500 | 8/7/14 1200 | 507.9 | 0.164 |
| 8/7/14 1300 | 8/7/14 2000 | 507.9 | 0.118 |

The first arrival of the fluorescein dye from Trace 14-08 occurred in the composite sample collected from 7/31/14 at 2100 to 8/01/14 at 0400 at a concentration of 0.012 ppb. This first arrival time was less than 28 hours after the dye introduction. The straight line travel distance from the dye introduction point to Cave Spring is approximately 9,700 feet, indicating a flow rate of greater than 346 feet per hour.

In addition to Cave Springs, a small amount of fluorescein dye from Trace 14-08 was detected at Station 134 (Reed Spring). The following table summarizes the fluorescein results from this station following the Trace 14-08 dye introduction.

**Station 134. Reed Spring** Fluorescein values based on the mean of original and duplicate activated carbon samples.

| Sampling Period | Peak Emission Wavelength in Activated Carbon (nm) | Fluorescein Concentration | | |
|---|---|---|---|---|
| | | Total in Activated Carbon (ppb) | Mean Concentration per Day (ppb/day) | Corresponding Water Sample (ppb) |
| 07/16/14 to 07/23/14 | -- | ND | -- | -- |
| 07/23/14 to 07/31/14 | -- | ND | -- | -- |
| 07/30/14 | Fluorescein Dye Introduction | | | |
| 07/31/14 to 08/06/14 | 512.6 ** | 0.132 | 0.023 | ND |
| 08/06/14 to 08/12/14 | -- | ND | -- | ND |
| 08/12/14 to 08/15/14 | -- | ND | -- | ND |
| 08/15/14 to 08/21/14 | -- | ND | -- | ND |
| 08/21/14 to 08/26/14 | -- | ND | -- | ND |
| 08/26/14 to 09/04/14 | -- | ND | -- | ND |
| 09/04/14 to 09/11/14 | -- | ND | -- | ND |
| 09/11/14 to 09/17/14 | -- | ND | -- | ND |
| 09/17/14 to 09/23/14 | -- | ND | -- | ND |
| 09/23/14 to 09/29/14 | -- | ND | -- | ND |
| 09/29/14 to 10/03/14 | -- | ND | -- | ND |
| 10/03/14 to 10/13/14 | -- | ND | -- | ND |
| 10/13/14 to 10/20/14 | -- | ND | -- | ND |

Notes: ND = Not detected
** Does not meet all criteria for a positive dye detection, but calculated as tracer dye.

The staff gage at Cave Springs was read approximately once per week. Using the equation for that gage we calculate the flow rates of the spring on the dates of observation. Flow rates on dates between the staff gage measurements were estimated proportionally between the observed rates. Composite water samples were collected at Cave Springs during Trace 14-08. Mean daily fluorescein dye concentrations were calculated based on the analysis of these samples.

1 cfs = 86,400 cubic ft./day X 62.4 pounds per cubic ft. = 5.39 million pounds per day per cfs (or 0.00539 billion pounds per day per cfs). The mean daily weight of water discharging from Cave Springs was calculated by multiplying the flow rate in cfs by 0.00539 billion pounds. This value was then multiplied by the mean daily fluorescein dye concentration to calculate the total mass of dye discharging per day from Cave Springs. Using this approach, and totaling the daily values, we calculated that during the period from August 1 through October 20, 2015, a total of 0.3007 pounds of fluorescein dye discharged from Cave Springs. Two pounds of

fluorescein was introduced at the dye introduction point so we detected 15.0% of the dye introduced. A very small amount of dye from this dye introduction discharged at Reed Spring; the amount was <0.2% of the dye introduced.

The distribution of fluorescein discharged at Cave Springs, based on the 15.0% dye recovery, was as follows:

- 29.4% of all dye detected at Cave Springs from this trace discharged on August 4, 2014. This was the date of peak dye discharge.
- 76.9% of all dye detected at Cave Springs discharged during the period August 1 to August 5, 2014.
- 95.4% of all dye detected at Cave Springs discharged during the period August 1 through August 21, 2014.
- During the last month of sampling (September 21 through October 20, 2014) only 3.9% of all dye detected discharged from Cave Springs.

Many soluble contaminants will behave similarly to the tracer dye. Depending upon the contaminant, storm water detention basins and underlying soils and residuum will prevent a large portion of these contaminants from reaching Cave Springs. Storm water detention basins constructed in accordance with BMPs appropriate for karst areas will perform better than the basin used for Trace 14-08. Even so, contaminants introduced into the karst groundwater system in the Direct recharge area for Cave Springs will enter as relatively short duration pulses and be transported to Cave Springs. As shown by the tracing results, smaller concentration pulses of water soluble contaminants will enter the groundwater system with subsequent storms that yield water to retention basins.

Diagrammatic tracer flow paths are illustrated in Figure 8. Based upon the results of this trace, almost all of the storm water that infiltrates from this storm water detention basin discharges at Cave Springs. A small amount of the groundwater recharge from this storm water detention basin also contributes flow to Reed Spring. Dye from Trace 14-08 was not detected in Shores Spring, Wallis Spring, or in samples from the stations established downstream in Cross Creek.

### 3.3.9 Trace 14-10: Otter Creek Subdivision Trace

One pound of pyranine dye mixture containing approximately 77% dye equivalent and 23% diluent was introduced in the unnamed tributary to Osage Creek at S. Gleneagle Drive in the town of Cave Springs on August 8, 2014 at 1230 hours. The dye introduction point was in the Otter Creek Subdivision near a wastewater lift station. This tributary, presumably known as "Otter Creek" based upon the name of the subdivision, flows immediately north of Cave Springs Cave. The dye introduction was flushed with approximately 3,900 gallons of water hauled from the spring branch downstream of the mouth of Cave Springs Cave. No flow was present in the channel prior to the addition of flush water, which entered the subsurface a short distance downstream of the dye introduction point. Approximately 1.13 inches of precipitation fell in the area on the day of the dye introduction (NWS 2014). The dye introduction is located at coordinates N36.26305 W94.22189 at an elevation of approximately 1180 ft msl. The purpose of this trace was to determine travel times from this location to the Cave Springs Cave.

Sampling stations established at the following springs were sampled in conjunction with Trace 14-10:

- Station 101 Cave Springs;
- Station 111 Shores Spring; and
- Station 112 Wallis Spring.

The following sampling stations downstream of the dye introduction point were also monitored (listed upstream to downstream):

- Station 144 Unnamed Tributary at Bright Road; and
- Station 110 Unnamed Tributary at 112.

This dye introduction was performed during a dry period in early August. Two truckloads of hauled water from Cave Springs were used to initiate the trace. The lack of detections of the dye in Cave Springs Cave or other sampling stations downstream suggests that the dye was detained in the epikarst without adequate water to flush it into the groundwater system. It was later determined that the results of Trace 14-08 (Mt Hebron Road Storm Water Basin Trace) provided adequate travel time information to the cave. Therefore, this trace was not replicated.

### 3.3.10 Trace 14-11: Cross Creek at Highway 264 Trace

Four pounds of rhodamine WT dye mixture containing approximately 20% dye equivalent and 80% diluent was introduced into Cross Creek at Arkansas Highway 264/W. Monroe Avenue on August 8, 2014 at 1320. This location is east of Mt. Hebron Road within the corporate boundary of Lowell. At the time of the dye introduction there was no flow in Cross Creek. Approximately 3,900 gallons of hauled water was used to flush the dye into the groundwater system. This water was hauled by truck from downstream of Cave Springs Cave. Approximately 1.13 inches of precipitation fell in the area on the day of the dye introduction (NWS 2014). The dye introduction was located at coordinates N36.25948 W94.19398 at an elevation of approximately 1220 ft msl.

This trace was designed to determine groundwater interactions between Cave Springs, Reed Spring, Shores Spring and Wallis Spring from this area.

The following springs were sampled for Trace 14-11:

- Station 101 Cave Springs;
- Station 111 Shores Spring;
- Station 112 Wallis Spring; and
- Station 134 Reed Spring.

The sampling stations in Cross Creek downstream of the dye introduction point were also monitored following the Trace 14-11 dye introduction. These stations monitored springs on private property located downstream of the dye introduction point and were also designed to determine if dye resurfaced in the Cross Creek down gradient of the dye introduction location:

- Station 136 Cross Creek upstream of Brown Road; and
- Station 135 Cross Creek upstream of Wagon Wheel Road.

Surface water stations downstream of Reed Spring were also monitored following the Trace 14-11 dye introduction, including the following:

- Station 133 Reed Spring Branch at Wagon Wheel Road;
- Station 132 Spring Creek upstream of Wagon Wheel Road; and
- Station 128 Spring Creek upstream of 112.

Rhodamine WT dye was detected in samples collected from both Cave Springs and Reed Spring. Tables that follow summarize the results from activated carbon samplers and water samples from these locations. Duplicate charcoal samplers were analyzed for both Cave Springs and Reed Springs and mean concentrations are shown in the table. Replicate water samples were also analyzed periodically. Data from all samples collected are provided in Appendix B.

**Station 101. Cave Springs** When available, duplicate activated carbon samples were analyzed for this station. Replicate samples were also analyzed periodically. Mean concentrations are provided in this table.

| Sampling Period | Peak Emission Wavelength in Activated Carbon (nm) | Rhodamine WT Concentration | | |
|---|---|---|---|---|
| | | Total in Activated Carbon (ppb) | Mean Concentration per Day (ppb/day) | Corresponding Water Sample (ppb) |
| 07/23/14 to 07/31/14 | -- | ND | -- | ND |
| 07/31/14 to 08/06/14 | -- | ND | -- | ND |
| 08/08/14 | Rhodamine WT Dye Introduction | | | |
| 08/06/14 to 08/12/14 | 567.4 | 2.93 | 0.504 | ND |
| 08/12/14 to 08/15/14 | -- | ND | -- | ND |
| 08/15/14 to 08/21/14 | -- | ND | -- | ND |
| 08/21/14 to 08/26/14 | -- | ND | -- | ND |
| 08/26/14 to 09/04/14 | -- | ND | -- | ND |
| 09/04/14 to 09/10/14 | -- | ND | -- | ND |
| 09/10/14 to 09/17/14 | -- | ND | -- | ND |
| 09/17/14 to 09/23/14 | -- | ND | -- | ND |
| 09/23/14 to 09/29/14 | -- | ND | -- | ND |
| 09/29/14 to 10/03/14 | -- | ND | -- | ND |

Notes: ND = Not detected

Rhodamine WT dye from Trace 14-11 was also detected at Station 134 (Reed Spring). The following table summarizes the rhodamine WT results from this station for Trace 14-11.

**Station 134. Reed Spring** When available, duplicate activated carbon samples were analyzed for this station. Replicate samples were also analyzed periodically. Values are mean concentrations.

| **Sampling Period** | **Peak Emission Wavelength in Activated Carbon** (nm) | **Rhodamine WT Concentration** | | |
|---|---|---|---|---|
| | | **Total in Activated Carbon** (ppb) | **Mean Concentration per Day** (ppb/day) | **Corresponding Water Sample** (ppb) |
| 07/23/14 to 07/31/14 | -- | ND | -- | -- |
| 07/31/14 to 08/06/14 | -- | ND | -- | -- |
| 08/08/14 | Rhodamine WT Dye Introduction | | | |
| 08/06/14 to 08/12/14 | 567.0 | 5,560 | 949 | 11.0 |
| 08/12/14 to 08/15/14 | 568.5 | 1,890 | 598 | 0.993 |
| 08/15/14 to 08/21/14 | 568.3 | 522 | 85.8 | 0.059 |
| 08/21/14 to 08/26/14 | 567.7 | 106 | 20.8 | ND |
| 08/26/14 to 09/04/14 | 567.9 | 116 | 13.2 | 0.643 |
| 09/04/14 to 09/11/14 | 567.0 | 197 | 28.7 | ND |
| 09/11/14 to 09/17/14 | 567.6 | 23.1 | 3.85 | ND |
| 09/17/14 to 09/23/14 | 567.2 | 77.6 | 11.9 | ND |
| 09/23/14 to 09/29/14 | 563.9 | 28.1 | 4.61 | ND |
| 09/29/14 to 10/03/14 | 567.6 | 11.7 | 2.90 | ND |
| 10/03/14 to 10/13/14 | 566.4 | 45.1 | 4.56 | ND |
| 10/13/14 to 10/20/14 | 566.7 | 45.6 | 6.50 | ND |

Notes: ND = Not detected

Diagrammatic tracer flow paths are illustrated in Figure 8. Based upon the results of this trace, groundwater flow in this area of Cross Creek contributes water to both Reed Spring and Cave Springs. Dye from Trace 14-11 was not detected in Shores Spring, Wallis Spring, or in samples from the stations established downstream in Cross Creek (Stations 135 and 136). The results of this trace and Trace 14-08 provide information on the approximate division of groundwater flow between Cave Springs and Reed Spring under the flow conditions tested.

Mass balance calculations for the recovery of dye from Trace 14-11 at Reed Spring were made. Based on activated carbon sampler data 64% of the rhodamine WT detected at Reed Spring discharged during the period between the date of dye introduction (August 8, 2014) and August 12. A total of 97.3% of all dye detected in carbon samplers discharged from Reed Spring during the period August 8 to September 11. The estimated mean flow rate of Reed Spring during the period August 8 to September 11, 2014 was 100 gpm and the mean measured rhodamine WT dye concentration in water samples for this period was 2.54 ppb. Using these values, the estimated weight of rhodamine WT discharging from Reed Spring during this period was 0.110 pounds; this was 2.7% of the four pounds of rhodamine WT introduced for this trace.

The amount of rhodamine WT from this trace in water samples at Cave Springs was below the detection limit of 0.015 ppb.

### 3.3.11 Trace 14-12: Hyde Park Subdivision Trace

Two pounds of eosine dye mixture containing approximately 75% dye equivalent and 25% diluent was introduced into a storm water drainage structure in the Hyde Park Subdivision on September 12, 2014 at 0915. This drainage structure discharges flow into the unnamed tributary to Osage Creek that flows between Shores Road and Sands Road. No flow was present in the tributary at the time of the dye introduction. The dye introduction was flushed with 20,000 gallons of water (flow volume metered) from a Cave Springs fire hydrant at the corner of Wembly Park and Chancery Lane. Approximately 0.11 inch of precipitation fell in the area on the day of the dye introduction (NWS 2014). The dye introduction coordinates N36.27513 are W94.21878 at an elevation of approximately 1220 ft msl.

The purpose of this trace was to help define the Cave Springs recharge area boundary in this area and evaluate groundwater interactions between Cave Springs, Shores Spring and Wallis Spring.

The following springs were sampled in conjunction with Trace 14-11:

- Station 101 Cave Springs;
- Station 111 Shores Spring; and
- Station 112 Wallis Spring.

One sampling station was established in the unnamed tributary where the dye was introduced for control purposes:

- Station 148 Sands Road Tributary.

Eosine dye was detected in samples collected from both Wallis Spring and Shores Spring. Dye from this trace was not detected at Cave Springs. Tables that follow summarize the results from activated carbon samplers and water samples from Shores Spring and Wallis Spring. Data from all samples collected are provided in Appendix B.

**Station 111. Shores Spring.**

| Sampling Period | Peak Emission Wavelength in Activated Carbon (nm) | Eosine Concentration | | |
|---|---|---|---|---|
| | | Total in Activated Carbon (ppb) | Mean Concentration per Day (ppb/day) | Corresponding Water Sample (ppb) |
| 08/27/14 to 09/04/14 | -- | ND | -- | ND |
| 09/04/14 to 09/11/14 | -- | ND | -- | ND |
| 09/12/14 | Eosine Dye Introduction | | | |
| 09/11/14 to 09/17/14 | 541.7 | 1,320 | 221 | 2.06 |
| 09/17/14 to 09/23/14 | 541.3 | 154 | 25.4 | 0.511 |
| 09/23/14 to 09/29/14 | 541.6 | 23.2 | 3.85 | 0.299 |
| 09/29/14 to 10/03/14 | 541.5 | 11.1 | 2.69 | 0.804 |
| 10/03/14 to 10/13/14 | 541.6 | 30.7 | 3.12 | 0.247 |
| 10/13/14 to 10/20/14 | 541.7 | 37.6 | 5.32 | 0.148 |

Notes: ND = Not detected

**Station 112. Wallis Spring.**

| Sampling Period | Peak Emission Wavelength in Activated Carbon (nm) | Eosine Concentration | | |
|---|---|---|---|---|
| | | Total in Activated Carbon (ppb) | Mean Concentration per Day (ppb/day) | Corresponding Water Sample (ppb) |
| 08/27/14 to 09/04/14 | -- | ND | -- | ND |
| 09/04/14 to 09/11/14 | -- | ND | -- | ND |
| 09/12/14 | Eosine Dye Introduction | | | |
| 09/11/14 to 09/17/14 | 541.7 | 1,250 | 210 | 9.47 |
| 09/17/14 to 09/23/14 | 541.7 | 999 | 165 | 2.54 |
| 09/23/14 to 09/29/14 | 541.9 | 638 | 107 | 1.09 |
| 09/29/14 to 10/03/14 | 541.5 | 175 | 41.4 | 0.757 |
| 10/03/14 to 10/13/14 | 541.4 | 179 | 18.2 | 0.580 |
| 10/13/14 to 10/20/14 | 541.5 | 84.4 | 11.9 | 0.193 |

Notes: ND = Not detected

Eosine dye from Trace 14-12 was detected at both Shores Spring and Wallis Spring. The peak concentration per day of dye arrived at both springs during the first sampling period following the dye introduction (samplers collected on 9/17/2014). Overall, samples collected from Wallis Spring had higher concentrations of dye than Shores Spring. Wallis Spring is located closer to the dye introduction point and also had a higher observed flow rate than Shores Spring. Eosine dye from Trace 14-12 was not detected at Cave Springs.

Diagrammatic tracer flow paths are illustrated in Figure 8. The results of this trace along with Trace 14-13 help define the recharge area boundary in this area as well as provide valuable information regarding hydrologic connections between Cave Springs, Shores Spring, and Wallis Spring.

Mass balance calculations for the recovery of dye from Trace 14-12 at Shores and Wallis Springs were made. Based on activated carbon sampler data 84% of the eosine detected at Shores Spring and 38% of the eosine detected at Wallis Spring discharged during the period between the date of dye introduction (September 12, 2014) and September 17. A total of 97.6% of all dye detected in carbon samplers discharged from Shores Spring during the period September 12 to October 13, 2015; the comparable value for Wallis Spring for this period was 97.5%. The estimated mean flow rate of Shores Spring during the period September 17 to October 13, 2015 was 50 gpm; the comparable value for Wallis Spring for this period was 90 gpm. The mean measured eosine dye concentration in water samples for this period was 0.678 ppb at Shores Spring and 2.44 ppb at Wallis Spring. Using these values, the estimated weight of eosine discharged during the period September 12 through October 13, 2015 was 0.015 pounds at Shores Spring and 0.100 pounds at Wallis Spring. The total from the two springs was 5.75% of the two pounds of eosine dye introduced for Trace 14-12. Eosine dye was still detectable in water samples at both springs when sampling ended so this percentage would have increased slightly if sampling had continued until dye was no longer detectable in water samples from either of these springs.

### 3.3.12 Trace 14-13: Biltmore Subdivision Trace

Three pounds of rhodamine WT dye mixture containing approximately 20% dye equivalent and 80% diluent was introduced into an unnamed tributary to Osage Creek at Rainbow Road on September 12, 2014 at 1020. This tributary is located south of the Biltmore Subdivision and flows through the Hyde Park Subdivision downstream of the dye introduction location. No flow was present in the tributary at the time of the dye introduction. The dye introduction was flushed with 20,000 gallons of water (flow volume metered) from a Cave Springs fire hydrant located south of the intersection of Rainbow Road and Addison Avenue in the Biltmore Subdivision. Approximately 0.11 inch of precipitation fell in the study area on the day of the dye introduction (NWS 2014). The dye introduction point is located at coordinates N36.27294 W94.20821 at an elevation of approximately 1245 ft msl.

The purposes of this trace were to help define the Cave Springs recharge area boundary in this area and determine if groundwater interactions exist between Cave Springs, Shores Spring and Wallis Spring.

The following springs were sampled in conjunction with Trace 14-11:

- Station 101 Cave Springs;
- Station 111 Shores Spring; and
- Station 112 Wallis Spring.

One sampling station (Station 148 Sands Road Tributary) was established in the unnamed tributary where the dye was introduced.

Rhodamine WT dye was detected in samples collected at Cave Springs. No rhodamine WT dye was detected in Shores Spring. The following table summarizes results from activated carbon samplers and water samples from Cave Springs. Duplicate charcoal samplers were analyzed for Cave Springs. Replicate water samples were also analyzed periodically. The mean concentrations are provided in the table below. Data from all samples collected are provided in Appendix B.

**Station 101. Cave Springs** When available, duplicate activated carbon samples were analyzed for this station. Replicate samples were also analyzed periodically. Mean concentrations are shown in this table.

| Sampling Period | Peak Emission Wavelength in Activated Carbon (nm) | Rhodamine WT Concentration | | |
|---|---|---|---|---|
| | | Total in Activated Carbon (ppb) | Mean Concentration per Day (ppb/day) | Corresponding Water Sample (ppb) |
| 08/26/14 to 09/04/14 | -- | ND | -- | ND |
| 09/04/14 to 09/10/14 | -- | ND | -- | ND |
| 09/12/14 | Rhodamine WT Dye Introduction | | | |
| 09/10/14 to 09/17/14 | -- | ND | -- | ND |
| 09/17/14 to 09/23/14 | -- | ND | -- | ND |
| 09/23/14 to 09/29/14 | -- | ND | -- | ND |
| 09/29/14 to 10/03/14 | -- | ND | -- | ND |
| 10/03/14 to 10/13/14 | 565.2 | 2.57 | 0.259 | ND |
| 10/13/14 to 10/20/14 | 565.4 | 2.07 | 0.294 | ND |

Notes: ND = Not detected
** Does not meet all criteria for a positive dye detection, but calculated as tracer dye.

Rhodamine WT dye from this trace was first detected at Cave Springs three to four weeks after the dye introduction. This detection followed a large rainfall event (6.18 inches of precipitation over six days from 10/8 to 10/13/2014) (NWS 2014). Dye from this trace was not detected at Shores Spring or Wallis Spring.

Diagrammatic tracer flow paths are illustrated in Figure 8. Based upon the results of this trace, groundwater flow in this area contributes to Cave Springs. The results of this trace and Trace 14-12 help refine the recharge area boundary in this area north of Cave Springs.

## 3.4 Specific Conductance Measurements and Water Quality Samples

In a karst area, specific conductance is an indirect measurement of the amount of rock in solution. Specific conductance was measured at springs in the study area during nine sampling events. The range of values and mean values are summarized in Table 9.

**Table 9 Summary of Specific Conductance Measurements in Study Area Springs** (April – October 2014).

| **Spring Name** (Station Number) | **Specific Conductance** (µmhos/cm) | |
|---|---|---|
| | **Range** | **Mean** |
| Cave Spring (Station 101) | 328 - 379 | 355.1 |
| Shores Spring (Station 111) | 322 – 390 | 367.6 |
| Wallis Spring (Station 112) | 329 – 393 | 374.7 |
| Osage Spring (Station 120) | 323 – 356 | 340.0 |
| South Spring (Station 124) | 305 – 368 | 345.6 |
| North Spring (Station 126) | 177 – 331 | 374.3 |
| Reed Spring (Station 134) | 355 – 404 | 383.7 |

Specific conductance measurements are very similar at Cave Spring, Shores Spring and Wallis Spring. Values are also similar at Osage Spring and South Spring. Values are slightly higher at Reed Spring. The similarity of these values suggests these springs receive water from similar sources.

North Spring and South Spring discharge within the stream channels of Osage Creek and Blossom Way Creek, respectively. These creeks only have flow following precipitation events that generated storm water runoff. When the creeks were flowing upstream of North and South Springs, the measured specific conductance values at these springs were lower than when no flow was present in the streams.

Water quality samples were collected on the same day (October 20, 2014) at Cave Spring, Reed Spring, Shores Spring and Wallis Spring. These samples were collected as part of the Cave Springs Area Karst Resource Conservation Study to address an observed data gap. The detailed water quality reports and a discussion of the data are included in Appendix C. The results are summarized in Table 10.

**Table 10 Summary of Water Quality Sample Results.** Samples collected 10/20/2014 and analyzed by National Testing Laboratories, Ypsilanti, Michigan (Beeman and Aley 2014). Organic analytes (both trihalomethanes and volatiles) were also analyzed in each sample. No detected analytes were reported in these categories.

| Analyte | Units | Cave Spring | Reed Spring | Shores Spring | Wallis Spring | Detection Limit |
|---|---|---|---|---|---|---|
| **Microbiologicals** | | | | | | |
| Total Coliform & E. coli | -- | *present* | *present* | *present* | *present* | -- |
| **Inorganic Analytes - Metals** | | | | | | |
| Calcium | mg/L | 62.9 | 73.8 | 72.4 | 75.1 | 2.0 |
| Magnesium | mg/L | 2.20 | 2.28 | 1.98 | 2.06 | 0.10 |
| Potassium | mg/L | 2.3 | 2.4 | 2.1 | 2.0 | 1.0 |
| Silica | mg/L | 9.5 | 11.0 | 11.6 | 11.9 | 0.1 |
| Sodium | mg/L | 5 | 5 | 4 | 5 | 1 |
| *Other inorganic analytes (metals) that were analyzed with no detections in any of the samples: aluminum, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, silver, and zinc.* | | | | | | |
| **Physical Factors** | | | | | | |
| Alkalinity (as total $CaCO_3$) | mg/L | 140 | 150 | 160 | 160 | 20 |
| Hardness | mg/L | 170 | 190 | 190 | 200 | 10 |
| pH | pH units | 6.8 | 6.6 | 6.6 | 6.7 | -- |
| Total Dissolved Solids | mg/L | 170 | 200 | 200 | 200 | 20 |
| **Inorganic Analytes - Other** | | | | | | |
| Chloride | mg/L | 5.2 | 5.8 | 5.0 | ND | 5.0 |
| Fluoride | mg/L | ND | ND | ND | ND | 0.5 |
| Nitrate as N | mg/L | 4.0 | 6.4 | 4.6 | 4.0 | 0.5 |
| Nitrite as N | mg/L | ND | ND | ND | ND | 0.5 |
| Ortho Phosphate | mg/L | ND | ND | ND | ND | 2.0 |
| Sulfate | mg/L | ND | ND | ND | ND | 5.0 |

The following observations are made of this suite of water quality data:

- All four samples contained E. coli and total coliform bacteria.
- No significant metals were detected in any of the samples.
- No organic analytes were detected, including gasoline constituents (such as BTEX) or common organic solvents (such as TCE and PCE).

For each of the four springs sampled, the values for each of the water quality analytes were very similar to each other. This similarity in water quality parameters suggests the springs discharge groundwater from an integrated flow system. The data indicate the springs have similar and likely partially shared recharge areas.

# 4 RECHARGE AREA DELINEATION

A number of historical studies have provided estimates of the recharge area of Cave Springs Cave. These studies are summarized in Aley and Slay (2015) and discussed in relation to each other in Aley et al. (2015). The groundwater recharge area delineation resulting from this study has been identified based upon data from all known sources available, including the following:

- Groundwater tracing data from two previous studies (Aley 1978a, 1978b; Aley and Moss 2001);
- Identified habitat for the Ozark cavefish;
- Groundwater tracing data and specific conductance data in this report;
- Potentiometric contour map of groundwater elevations; and
- Recent water quality data.

Figure 9 illustrates all groundwater traces performed in the Cave Springs study area. The recharge area boundary is largely based on groundwater tracing data (both current and historical studies). In karst areas, groundwater divides often change based upon flow conditions. Groundwater traces conducted in this study were performed under unseasonably low flow conditions. Traces from some areas did not result in dye detections in Cave Springs during the current study, but there were dye tracing results from some of the same areas from previous studies conducted under higher flow conditions. The identified recharge area is based on the most reasonable interpretation of the entire set of data.

The recharge area boundary is defined by topography in many areas. Many of the upland areas are drained by losing streams. Under some, if not all, flow conditions runoff from these areas can enter the groundwater system through these losing stream segments. This makes the topographic boundaries appropriate for defining the recharge area. In other areas, such as the northwest portion of the recharge area, the boundary is influenced by land development features. These features, including subdivision boundaries and roads, alter the natural flow of water over the land surface and therefore affect how surface water runoff is allowed to infiltrate into the groundwater system. In areas with significant development, these features were considered along with the topography.

## 4.1 Western and Northern Portions of the Recharge Area Boundary

The USGS conducted a seepage run study of Osage Creek (Moix et al. 2003). In such studies the flow rates of a stream and its tributaries are measured at numerous points on the same day or on two consecutive days. Seepage runs are typically conducted in summer or early fall when flow rates are relatively low. The study by Moix et al. (2003), conducted on July 24, 2001, identified several segments of Osage Creek where the flow at an upstream station was larger than at the next downstream station, thus suggesting possible water loss into the groundwater system. Four of these potential "losing stream segments" were at elevations higher than Cave Springs, and it was therefore possible that one or more of them contributed flow to Cave Springs. The OUL conducted Traces 14-01, 14-02, and 14-03 to determine which segments of Osage Creek, if any, contributed water to Cave Springs. These traces demonstrated that Osage Creek does not contribute any detectable amounts of water to Cave Springs.

After Osage Creek was determined to be outside of the Cave Springs recharge area, Traces 14-06, 14-12, and 14-13 were designed to identify the western and northwestern border of the Cave Springs recharge area. No dye from Trace 14-06 was detected at Cave Springs. Rhodamine WT dye from Trace 14-13 was detected at Cave Springs and at no other sampling station. Eosine dye from Trace 14-12 was introduced into the same losing stream as Trace 14-13, but about 2,800 feet downstream. Eosine was not detected at Cave Springs, but was detected at both Wallis and Shores Springs. Both of these springs are in the Osage Creek valley on the opposite side of Arkansas Highway 112 from the dye introduction point for Trace 14-12. Based on these results, the dye introduction points for Traces 14-06 and 14-12 are shown as outside of the Cave Springs recharge area. The boundary for the Cave Springs recharge area is located approximately midway between the dye introduction points for Traces 14-12 and 14-13.

Since the losing stream at the dye introduction point for Trace 14-12 receives water from areas within the Cave Springs recharge area, the OUL has concluded that both Wallis and Shores Springs share portions of their recharge areas with Cave Springs.

## 4.2 Southern Portions of the Recharge Area Boundary

The recharge area delineations and site characterizations have focused substantial attention on the southern border of the Cave Springs recharge area and on hydrologic interactions and recharge areas shared between Cave Springs and Reed Spring.

Figure 10 is the potentiometric map of the Cave Springs recharge area included in Aley et al. (2015). A potentiometric map is a contour map of the top of the groundwater surface (or "water table"). Two sets of contour lines are shown in Figure 10; both were based on the same data but different computer programs were used to develop the contour lines. Both programs showed the presence of a distinct trough in the potentiometric surface (i.e., the top surface of the water table).

The trough, called the "Cave Springs Groundwater Trough," extends from Cave Springs eastward. The axis of the trough is located roughly parallel to Arkansas Highway 264 and 1,000 to 2,500 feet north of this highway. Figure 10 shows the land area where groundwater flow is appreciably influenced by the trough. This interpretation is based upon potentiometric contours and the results from five groundwater traces where the dye introduction points provided a north-south transect across the trough. A brief discussion of the five groundwater traces that provide a transect across the Cave Springs Groundwater Trough is provided in the following paragraphs.

Trace 78-02 was the most northern of the traces. Dye for this trace was introduced about 400 feet north of the northern boundary of the delineated groundwater trough. Reed Spring was not sampled during this trace since its potential relevance was unknown in 1978. A substantial amount of dye from this trace was detected in carbon samplers at Cave Springs (Aley 1978a). Dye first arrived at Cave Springs about 7 days after dye introduction and the peak concentration of dye at that spring occurred 7 to 9 days after dye introduction. The flow of water at the dye introduction point was about 10 gpm, but local reports indicated that appreciably larger surface flow rates could enter the groundwater system in this area.

Trace 14-08 was the Mt. Hebron Road Storm Water Basin Trace. Dye for this trace was introduced into a flow of about 75 gpm entering and sinking within the stormwater basin. This dye introduction point is on or very near, the axis of the Cave Springs Groundwater Trough. Most of the dye from this trace was detected at Cave Springs, but a small amount was detected at Reed Spring. Dye from this trace first arrived at Cave Springs within 28 hours of the time of dye introduction. The straight-line travel distance to Cave Springs was 9,700 feet. This was the most rapid groundwater movement demonstrated by any of the traces conducted during the current study.

Trace 14-11 was the Cross Creek at Highway 264 Trace. This dye introduction was made about 1400 feet south of the introduction point for Trace 14-08. Dye for this trace was introduced into the channel of Cross Creek. There was no natural flow in the creek at that time so the dye was flushed into the groundwater system with 3,900 gallons of water delivered by tank truck. The majority of the dye from this trace was detected at Reed Spring, but a small amount was detected at Cave Springs. This was the inverse of the distribution of the different dyes observed with Trace 14-08.

Traces 00-03 and 00-04 both yielded tracer dye to both Reed Spring and Cave Spring, but the majority of the dye discharged from Reed Spring. The dye introduction point for Trace 00-03 is about 2,200 feet south of the introduction point for Trace 14-11 and the introduction point for Trace 00-04 is about 1,400 feet south of the introduction point for Trace 00-03. The north-south distance where dye introductions have shown that water flows to both Cave Springs and Reed Spring is thus at least 5,000 feet.

The Cave Springs Groundwater Trough indicates a zone of higher than average permeability which suggests a zone of solutional openings hydrologically integrated into a groundwater flow system. This preferential flow zone conveys water westward to Cave Springs with some water also discharging from Reed Spring. This setting provides especially favorable habitat for Ozark Cavefish and associated groundwater fauna. In addition, such a zone is likely to be overlain by numerous discrete recharge zones including those into which the tracer dyes were introduced.

The Cave Springs Groundwater Trough is a very important feature of the Cave Springs Cave recharge area. Lands overlying this trough have a high potential for introducing contaminants into the Cave Springs Cave groundwater system. In many cases, water quality in both Cave Springs and Reed Spring would be impacted.

## 4.3 Direct and Indirect Recharge Areas

Aley (1978a and b) divided the Cave Springs recharge area into two segments: the Direct Recharge Area and the Indirect Recharge Area. The current study focused substantial attention on the credibility and utility of this division.

The Direct Recharge Area comprises 8.9 square miles and provides most of the recharge water for Cave Springs. The northeastern boundary of the Direct Recharge Area lies roughly parallel to, and west of, Interstate 49.

The Indirect Recharge Area comprises 10.6 square miles and lies to the northeast of the Direct Recharge Area. Groundwater tracing has shown that very little of the water from sinking streams in this area reaches Cave Springs. However, the groundwater potentiometric contour map indicates that there is some groundwater movement from the Indirect Recharge Area into the Direct Recharge Area and ultimately to Cave Springs. Given this information, the OUL has concluded that the division of the Cave Springs recharge area into Direct and Indirect Recharge Areas is both technically reasonable and of practical value.

The total recharge area for Cave Springs is 19.5 square miles; this is the sum of the Direct and Indirect Recharge Areas. Interstate 49 lies entirely within the Indirect Recharge Area. The Cave Springs recharge area encompasses lands that are included in the municipalities of Cave Springs, Rogers, Lowell, and Springdale.

During the groundwater tracing study described in this summary report, Traces 14-04, 14-05, 14-07, and 14-09 were designed to further examine the credibility and utility of the boundary between the Direct and Indirect Recharge Areas. The following paragraphs summarize the results of these traces, as well as historical traces in this area.

- Dye for Trace 14-04 was introduced into a stream channel that receives storm water runoff from a large parking lot. The dye introduction point was on the east side of I-49. There was no visible flow in the stream channel at the time of dye introduction so the dye was introduced into a pool in the channel. Substantial rainfall was predicted for the period after dye introduction, but very little arrived. No dye from this introduction was subsequently detected.

- Dye for Trace 14-05 was introduced on June 5, 2014 into one of the main branches of Blossom Way Creek at a point approximately 5,600 feet east of I-49. Dye from this introduction flowed on the surface until about the point where the stream was crossed by the north bound lanes of I-49. Downstream of that point surface flow in the channel decreased in multiple areas until the point where Blossom Way Creek was again crossed by I-49 and where the stream channel was dry on the day following the dye introduction. Dye from Trace 14-05 was detected at South Spring but not at Cave Springs.

- Dye for Trace 78-08 was introduced on May 26, 1978 at or near the point where surface flow ended in Blossom Way Creek on June 6, 2014. The 1978 dye introduction yielded a small amount of dye at Cave Springs but the majority of the dye at South Spring. Differences in groundwater conditions likely explain the finding that Trace 78-08 yielded dye to Cave Springs but that Trace 14-05 did not.

- Dyes for Traces 14-07 and 14-09 were introduced into a major branch of Blossom Way Creek on the west side of I-49 and near the boundary between the Direct and Indirect Recharge Areas. Dye from these traces was detected at South Spring; no dye was detected at Cave Springs.

The potentiometric map of groundwater elevations (Figure 10) indicates groundwater flow from the Indirect Recharge Area into the Direct Recharge Area along an appreciable portion of the boundary between the two areas. Combining this information with dye tracing results the OUL concludes the following:

- the location shown for the boundary between the Indirect and Direct Recharge Areas for Cave Springs is reasonable;
- no portion of I-49 lies in the Direct Recharge Area for Cave Springs; and
- the Indirect Recharge Area for Cave Springs contributes a relatively small amount of water to Cave Springs.

## 4.4 Hydrologic Interactions between Cave Springs and Other Springs

It is common for springs in the Ozarks to share recharge areas with other springs. Springs with shared recharge areas may help explain how Ozark Cavefish became distributed in multiple caves and springs. Based upon the results presented in this report, four springs have been identified as having hydrologic interactions with Cave Springs: Reed Spring, Shores Spring, Wallis Spring, and South Spring.

Reed Spring is located south of Cave Springs in the Spring Creek valley. This spring flows from the valley floor near the valley wall along Wagon Wheel Road. Groundwater traces 14-08 and 14-11 from the current study, as well as traces from earlier studies, have documented the shared recharge area between Cave Springs and Reed Spring.

Shores Spring and Wallis Spring are located north of Cave Springs on the west side of Arkansas Highway 112. These springs flow from the valley floor on the east side of Osage Creek. Traces 14-12 and 14-13 were designed, in part, to evaluate hydrologic connections between these two springs and Cave Springs. These dye introduction points were located 2,800 feet apart in the same valley. Although Trace 14-12 went only to Shores Spring and Wallis Spring, and Trace 14-13 went only to Cave Springs under the low flow conditions tested, it is extremely likely that if repeated under higher flow conditions, both of these traces would result in tracer dye detections at all three springs. In addition to groundwater tracing data, the water quality and specific conductance measurements suggest the springs would have at least partial shared recharge areas. Furthermore, Mule Hole Sink, located near Wallis Road and Arkansas Highway 112, is a known habitat site for the Ozark Cavefish. This location is topographically cross-gradient to Cave Springs and not within the delineated recharge area for Cave Springs. The combination of these factors suggest hydrologic interactions between Cave Springs, Shores Spring, and Wallis Spring.

The presence of hydrologic interactions between Cave Springs and Reed Spring, Shores Spring and Wallis Spring and the relative locations of the four springs indicate the existence of presumptive habitat for the Ozark Cavefish that is beyond the delineated recharge area for Cave Springs. The presence of cavefish in Mule Hole Sink about 1,200 feet east of Wallis Spring and about 4,000 feet west of the boundary of the Cave Springs recharge area supports this conclusion. Presumptive habitat is based on hydrologic interactions between a site known to provide habitat for an aquatic groundwater species and nearby areas, caves or springs. Much of the underground habitat for groundwater species is inaccessible to people to identify the full habitat range. Therefore, presumptive habitat designations are made when appropriate hydrologic interactions are identified.

Although some hydrologic interactions have been demonstrated to exist between South Spring and Cave Spring, insufficient data exist to indicate that South Spring provides presumptive habitat for the Ozark Cavefish.

# 5 SUMMARY AND CONCLUSIONS

A groundwater tracing study was conducted to refine the recharge area for Cave Springs Cave, a biologically significant cave and namesake for the northwest Arkansas community in Benton County, Arkansas. The study described in this report was performed as part of the larger Cave Springs Area Karst Resource Conservation Study.

## 5.1 Groundwater Tracing Summary

Thirteen groundwater traces were performed as part of this study, as summarized in the following bullets:

- **Trace 14-01: Upper Osage Creek Trace.** Two pounds of fluorescein dye mixture was introduced into the upper reach of Osage Creek at Business US 71/Arkansas Highway 12/W. Walnut Street in Rogers. Dye from this trace was detected in Osage Spring, North Spring, and South Spring. Dye was not detected at Cave Springs.

- **Trace 14-02: Osage Creek Near Cross Church Trace.** Six pounds of rhodamine WT dye mixture was introduced into Osage Creek near Cross Church. This location is downstream of the confluence of Blossom Way and upstream of a segment of Osage Creek that has been documented to lose flow to the groundwater system. Dye from this trace was not detected at Cave Springs. The results of this trace, along with Trace 14-01, indicate Osage Creek does not contribute flow to the Cave Springs groundwater system.

- **Trace 14-03: Lower Pinnacle Valley Trace.** Three pounds of eosine dye mixture was introduced into an unnamed tributary to Osage Creek identified as "Pinnacle Valley". This valley drains a large residential area, including a gated community and some of the Pinnacle Hills commercial area located west of Interstate 49. Dye from this trace was not detected in Cave Springs, Shores Spring, or Wallis Spring. The results of this trace indicate flow from the lower portion of this tributary valley does not contribute flow to the Cave Springs groundwater system.

- **Trace 14-04: South Blossom Tributary at Dixieland Road Trace.** Four pounds of rhodamine WT dye mixture was introduced into the headwaters area of a southern tributary to Blossom Way creek. No dye was recovered from this trace due to a lack of adequate rainfall to flush the dye into the groundwater system. The trace was later repeated farther downstream in the tributary valley (Trace 14-07).

- **Trace 14-05: North Blossom Way Tributary at Dixieland Road Trace**. Four pounds of eosine dye mixture was introduced into the upper reach of the northern tributary to Blossom Way Creek. Dye from this trace was detected in South Spring, but not in Osage Spring or Cave Springs.

- **Trace 14-06: Upper Pinnacle Valley (Southgate and Sloan) Trace.** One pound of fluorescein dye was introduced into an upper tributary to Pinnacle Valley near the intersection of Southgate and Sloan. Dye from this trace was detected in the control station farther down in the valley. Dye was not detected at Cave Springs, Shores Spring, or Wallis Spring indicating this area does not contribute water to the Cave Springs groundwater system.

- **Trace 14-07: South Blossom Tributary at Pleasant Grove Road Trace.** Three pounds of eosine dye mixture was introduced into the southern tributary to Blossom Way near Pleasant Grove Road. This dye introduction was made downgradient of the same tributary as Trace 14-04. Dye from this trace was not immediately recovered due to lack of sufficient rainfall to flush the dye into the groundwater system. The trace was repeated as Trace 14-09.

- **Trace 14-08: Mt. Hebron Road Storm Water Basin Trace.** Two pounds of fluorescein dye mixture was introduced into a storm water retention basin along Mt. Hebron Road north of Arkansas Highway 264. This location is within the Cross Creek topographic basin. Dye from this trace was detected in Cave Springs within approximately 28 hours. A small amount of dye from this trace was also detected at Reed Spring, further indicating Cave Springs and Reed Spring have shared recharge areas.

- **Trace 14-09: South Blossom Tributary at Pleasant Grove Road Trace** (Repeat). Three pounds of eosine dye mixture was introduced into the southern tributary to Blossom Way near Pleasant Grove Road. This trace was a repeat of Trace 14-07 with a larger storm event to flush the dye into the groundwater system. Dye from this trace was detected at South Spring.

- **Trace 14-10: Otter Creek Subdivision Trace.** One pound of pyranine dye mixture was introduced into the unnamed tributary in the Otter Creek subdivision. Dye from this trace was introduced with approximately 3,900 gallons of hauled water. It appears that not enough water was used to flush the dye into the groundwater system under the dry conditions at the time of the dye introduction. This dye was not detected in any of the sampling stations.

- **Trace 14-11: Cross Creek at Highway 264 Trace.** Four pounds of rhodamine WT dye mixture was introduced into Cross Creek at Highway 264. This location is east of Mt. Hebron Road. The results of this trace indicate much of the flow from this area contributes flow to Reed Spring under the flow conditions tested. A small amount of dye from this trace was also detected in Cave Springs.

- **Trace 14-12: Hyde Park Subdivision Trace.** Two pounds of eosine dye mixture was introduced into a storm water drainage culvert in the Hyde Park subdivision. This structure discharges flow to the unnamed tributary to Osage Creek between Wallis Spring and Shores Spring. The dye was flushed with 20,000 gallons of water from a nearby fire hydrant. Dye from this trace was detected at Shores Spring and Wallis Spring, but not at Cave Springs.

- **Trace 14-13: Biltmore Subdivision Trace.** Three pounds of rhodamine WT dye mixture was introduced into an unnamed tributary to Osage Creek between Wallis and Shores Springs near the southern boundary of the Biltmore Subdivision. This location is upgradient of Trace 14-12 and in the same tributary valley. Dye from this trace was detected at Cave Springs.

## 5.2 Conclusions

1. A reasonable recharge area delineation has been made for Cave Springs Cave based upon the results of the current groundwater tracing study as well as data in available literature sources. The total recharge area for Cave Springs is 19.5 square miles.

2. The Cave Springs recharge area is appropriately divided into a Direct Recharge Area 8.9 square miles where groundwater discharges through Cave Springs. The Indirect Recharge Area 10.6 square miles contributes a lesser amount of groundwater to Cave Springs.

3. The Cave Springs recharge area encompasses lands that are included in the municipalities of Cave Springs, Rogers, Lowell, and Springdale.

4. All of Interstate 49 within The Cave Springs Recharge Area is located within the Indirect Recharge Area.

5. Based on contoured water level elevations from before 1991, a trough in the groundwater potentiometric surface is located from Cave Springs and extends to the east. The presence of the Cave Springs Groundwater Trough is supported by groundwater tracing data. The land area overlying this trough is 1.8 square miles.

6. Four springs have hydrologic interactions with Cave Springs under at least some flow conditions: Reed Spring, Shores Spring, Wallis Spring, and South Spring.

7. Flow rate measurements at Cave Springs based on staff gauge measurements during the study period ranged from 5.11 cfs to 9.48 cfs.

8. Water quality samples analyzed for 83 parameters were collected from Cave Springs, Shores Spring, Wallis Spring, and Reed Spring on October 20, 2014. The results of these samples were similar, suggesting similar or partially shared recharge areas. The results indicated good water quality.

9. Reed Spring, Shores Spring and Wallis Spring provide presumptive habitat for the Ozark Cavefish based upon hydrologic interactions with Cave Springs, the proximity of the springs to Cave Springs, and the locations of known Ozark Cavefish habitat.

10. Insufficient data exist to suggest that South Spring provides presumptive habitat for the Ozark Cavefish.

# 6 REFERENCES

Aley, Thomas. 1978a. Impacts of the proposed relocation of U.S. Highway 71 from Fayetteville north to McKisic Creek upon groundwater resources and cave fauna. May 26, 1978. Ozark Underground Laboratory contract study for Arkansas Highway and Transportation Dept. 61 p. *Included in Final Environmental Impact Statement Job 1445, Highway 71 Relocation in Washington and Benton Counties, Arkansas.*

Aley, Thomas. 1978b. Supplemental investigations: Impacts of the proposed relocation of U.S. Highway 71 from Fayetteville North to McKisic Creek upon groundwater resources and cave fauna. August 2, 1978. Ozark Underground Laboratory contract study for Arkansas Highway and Transportation Dept. 18 p. *Included in Final Environmental Impact Statement Job 1445, Highway 71 Relocation in Washington and Benton Counties, Arkansas.*

Aley, Tom and Cathy Aley. 1991. Delineation and hazard area mapping of areas contributing water to significant caves. IN: Proceedings of the Eighth National Cave Management Symposium, pp. 116-122.

Aley, Tom and Cathy Aley. 2014. Recharge area delineation and vulnerability mapping for Civil War Cave, Centerton Spring, and Centerton Fish Hatchery Spring, Benton County, Arkansas. Ozark Underground Laboratory contract report to The Nature Conservancy. 94 p.

Aley, Thomas and Philip Moss. 2001. Northwest Arkansas Regional Airport access corridor groundwater tracing investigations. Final Report. Ozark Underground Laboratory contract study for Barnard Dunkelberg, Inc., 46 p. + appendix materials.

Aley, Thomas, Catherine Aley, and Michael Slay. 2015. Summary of existing knowledge about hydrology, cave biology, and cave conservation methods applicable to Cave Springs Cave, Benton County, Arkansas: Final report. Contract report compiled as part of the Cave Springs Area Karst Resource Conservation Study for the Northwest Arkansas Regional Planning Commission. 88 p.

Aley, Thomas and Michael Slay. 2015. Annotated bibliography of relevant hydrologic, biologic, and land management information related to Cave Springs Cave, Benton County, Arkansas: Final report. Contract report compiled as part of the Cave Springs Area Karst Resource Conservation Study for the Northwest Arkansas Regional Planning Commission. 65 p.

Aley, Thomas and Shiloh Kirkland. 2011. Procedures and criteria for the analysis of fluorescent dyes in water and charcoal samplers: fluorescein, eosine, rhodamine WT, and sulforhodamine B dyes. Ozark Underground Laboratory, Inc., September 1, 2012. 19 p.

Brown, Arthur V.; G. O. Graening, and P. Vendrell. 1998. Monitoring cavefish populations and environmental quality in Cave Springs Cave, Arkansas. Publication MSC-214. Arkansas Water Resources Center, Univ. of Arkansas, Fayetteville, AR, 32 p.

CoCoRaHS. 2014. Community Collaborative Rain, Hail and Snow Network daily precipitation data for Stations AR-BT-20 (Rogers 2.1 SE) and AR-BT-35 (Rogers 3.4 NE). www.cocorahs.org.

Field, Malcolm S, R.G. Wilhelm, J.F. Quinlan, and T.J. Aley. 1995. An assessment of the potential adverse properties of fluorescent tracer dyes used for groundwater tracing. *Environmental Monitoring and Assessment*, Vol.38, pp. 75-96. Kluwar Academic Publishers.

Glick, E.E. 1970. Geologic map of the Rogers, Arkansas 7.5 minute topographic map. U.S. Geological Survey. Map marked “Master Copy”. Map from Arkansas Geological Commission. 1 p.

Glick, E.E. 1972. Geologic map of the Bentonville South, Arkansas 7.5 minute topographic map. U.S. Geological Survey. Map marked “Master Copy”. Map from Arkansas Geological Commission. 1 p.

Graening, Gary O. and Arthur V. Brown. 1999. Cavefish population status and environmental quality in Cave Springs Cave, Arkansas. A report for Arkansas Natural Heritage Commission. Publ. No 276, Arkansas Water Resources Center, Univ. of Arkansas, Fayetteville, AR, 38 p.

Graening, Gary O. and Arthur V. Brown. 2003. Ecosystem dynamics and pollution effects in an Ozark cave system. Jour. of the Amer. Water Resources Association. December 2003. pp. 1497-1507.

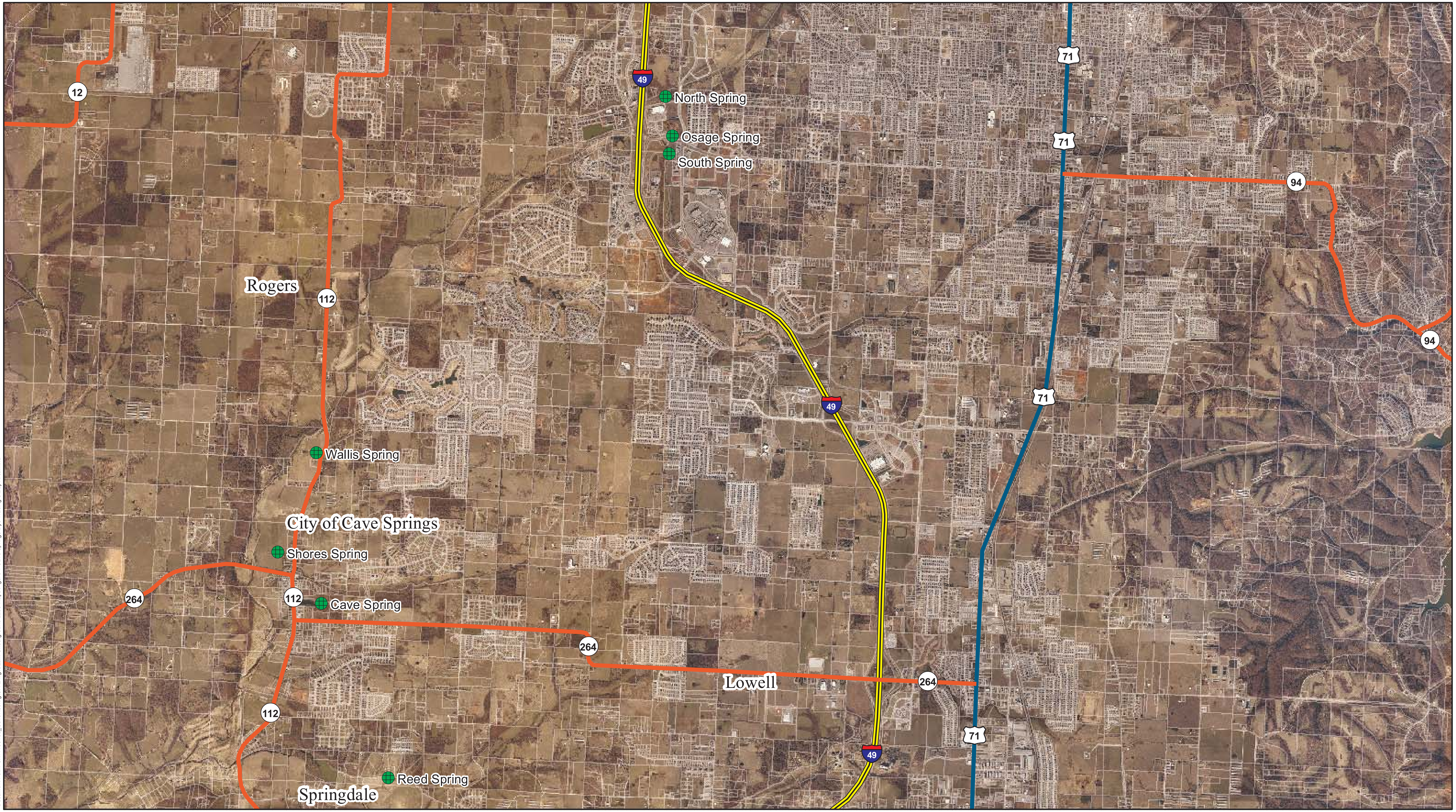
Moix, Matthew W.; C. Shane Barks; and Jaysson E. Funkhouser. 2003. Water quality and streamflow gains and losses of Osage and Prairie Creeks, Benton County, Arkansas, July 2001. U.S. Geological Survey, Water-Resources Investigations Report 03-4187. 29 p.

NWS. 2014. National Weather Service precipitation data from the Northwest Regional Airport (XNA) near Highfill, Arkansas.

Smart, P.L. 1984. A review of the toxicity of twelve fluorescent dyes used for water tracing. National Speleological Society Bulletin, Vol. 46, pp. 21-33.

Williams, R. 1991. Water quality and groundwater recharge for the Cave Springs complex and associated streams near Cave Spring. MS thesis, Univ. of Arkansas, Fayetteville, AR, 134 p.

# FIGURES

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WWE WRIGHT WATER ENGINEERS, INC.

Ozark UNDERGROUND LABORATORY

Cave Springs Dye Tracing Study Area
Figure 1

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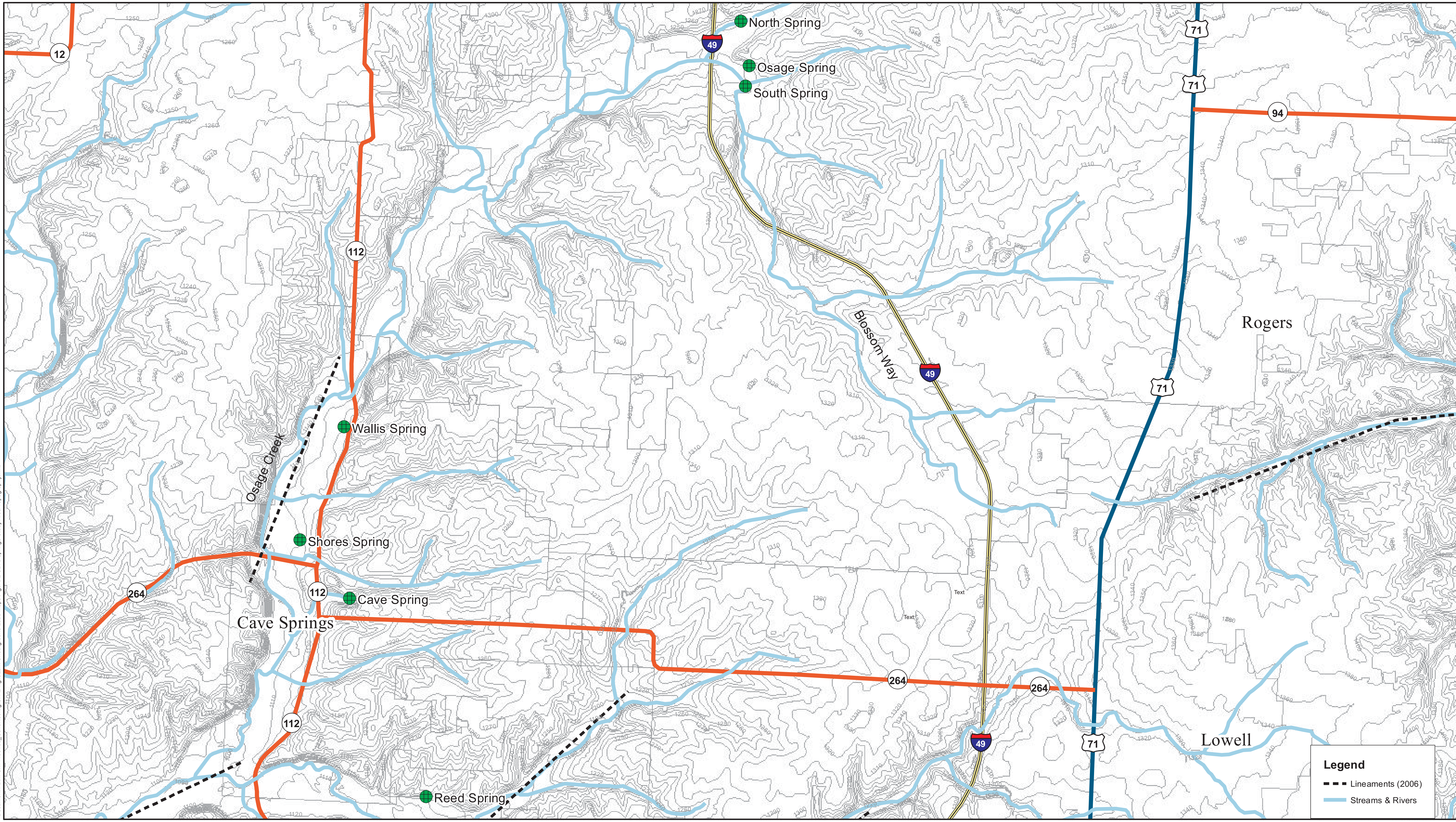


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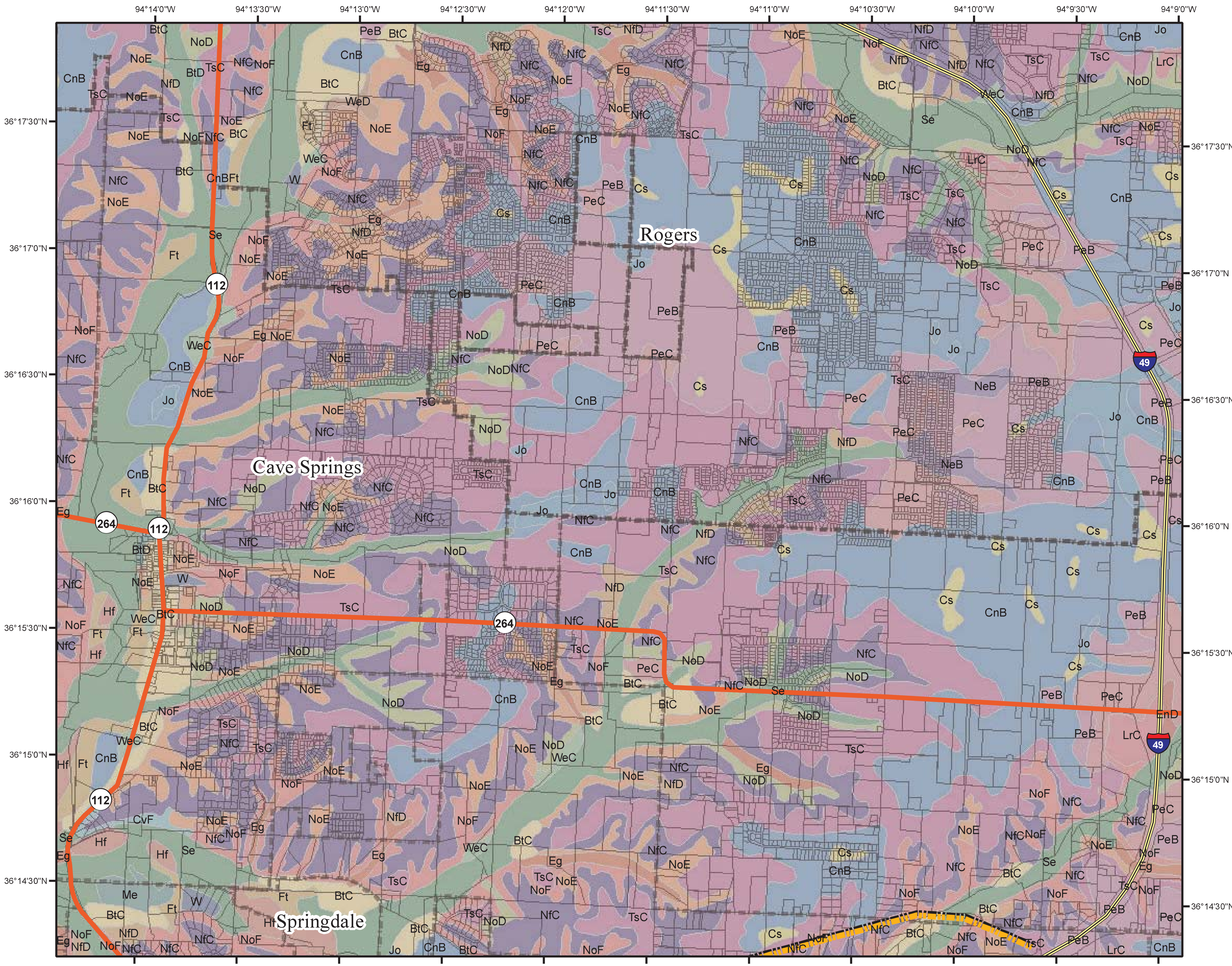
# Cave Springs Study Area Topography
## Figure 2

N

0 2,200 4,400
Feet

Map Revised: 1/7/2015 1:16:16 PM
Document Path: G:\14103100_CaveRechrg\CIVIL\Dwg\Ozark Underground Labs Maps\Figure 2 Cave Springs Study Area Topography.mxd




**Soil Type**

- CnB - Captina silt loam, 1 to 3 percent slopes
- JaB - Jay silt loam, 1 to 3 percent slopes
- NeB - Newtonia silt loam, 1 to 3 percent slopes
- PeB - Peridge silt loam, 1 to 3 percent slopes
- Ft - Fatima silt loam, occasionally flooded
- Hf - Healing silt loam, occasionally flooded
- Me - Mayes silty clay loam
- Se - Secesh gravelly silt loam, occasionally flooded
- BtC - Britwater gravelly silt loam, 3 to 8 percent slopes
- CeC - Cane loam, 3 to 8 percent slopes
- LrC - Linker fine sandy loam, 3 to 8 percent slopes
- NfC - Nixa very gravelly silt loam, 3 to 8 percent slopes
- NfD - Nixa very gravelly silt loam, 8 to 12 percent slopes
- PeC - Peridge silt loam, 3 to 8 percent slopes
- TsC - Tonti gravelly silt loam, 3 to 8 percent slopes
- Eg - Elsah soils, occasionally and frequently flooded
- Cs - Cherokee silt loam
- Jo - Johnsburg silt loam
- BtD - Britwater gravelly silt loam, 8 to 12 percent slopes
- EnD - Enders very gravelly loam, 3 to 12 percent slopes
- NoD - Noark very gravelly silt loam, 8 to 12 percent slopes
- WeC - Waben very gravelly silt loam, 3 to 8 percent slopes
- WeD - Waben very gravelly silt loam, 8 to 12 percent slopes
- NoE - Noark very gravelly silt loam, 12 to 20 percent slopes
- NoF - Noark very gravelly silt loam, 20 to 45 percent slopes
- CvF - Clarksville extremely gravelly silt loam, 12 to 50 percent slopes
- W - Water

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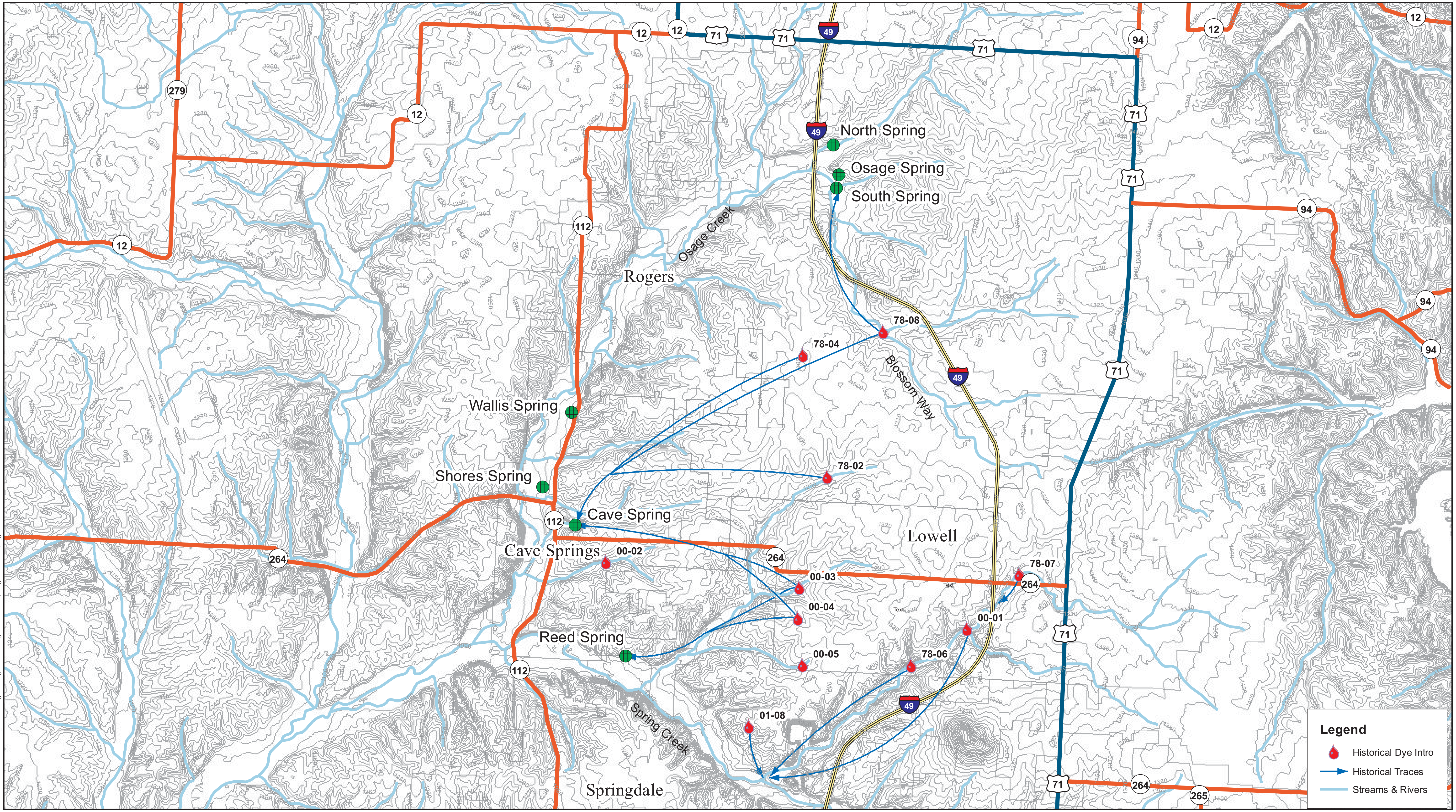
# Cave Springs Area Soils Map
## Figure 3

N

0 2,000 4,000
Feet

Map Revised: 12/19/2014 9:29:10 AM
Document Path: G:\14103100_CaveRechrg\CIV\Dwg\Ozark Underground Labs Maps\Figure 3 Cave Springs Area Soils.mxd

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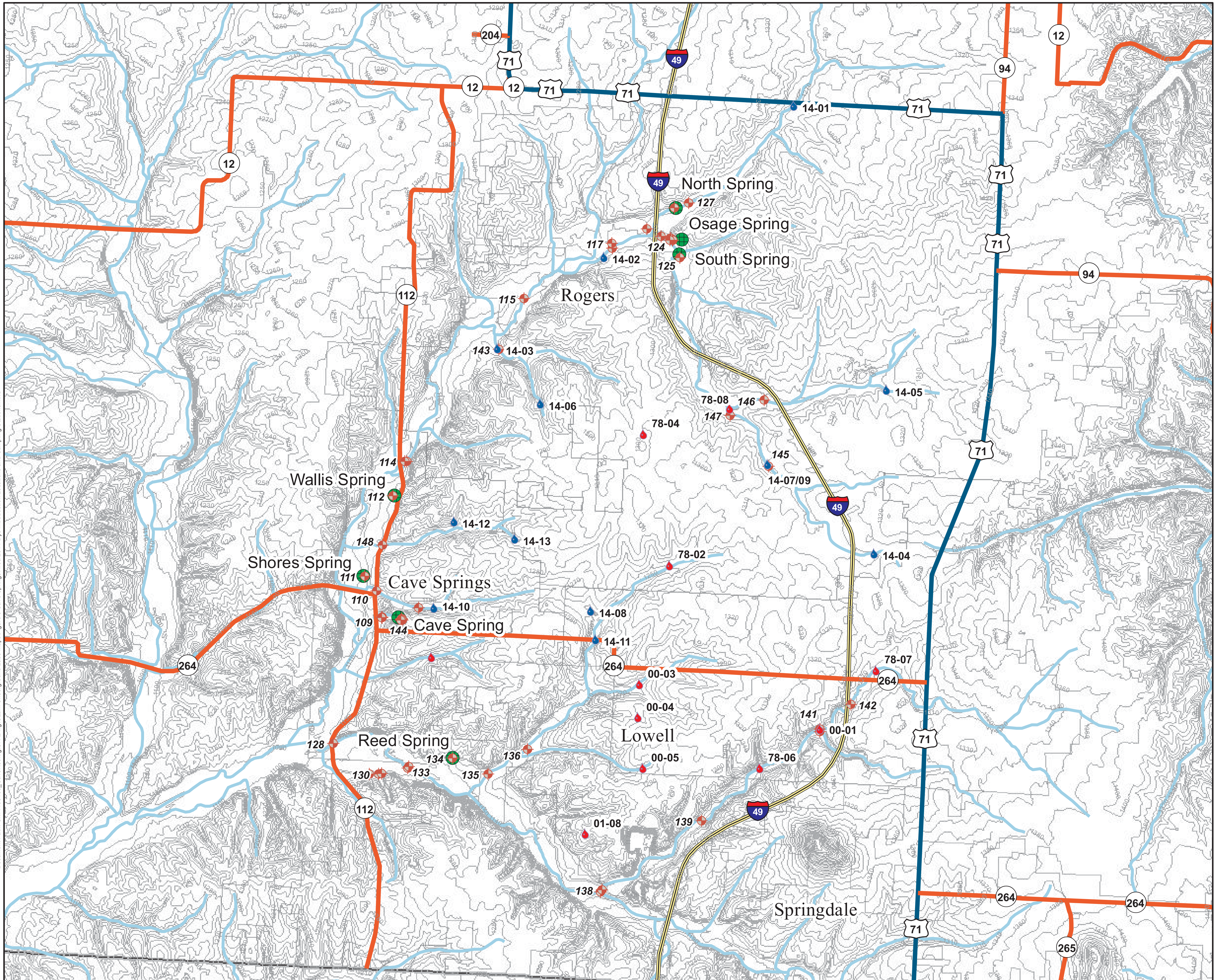
# Cave Springs Area Historical Groundwater Traces
## Figure 4

N

0 4,500 9,000

Feet

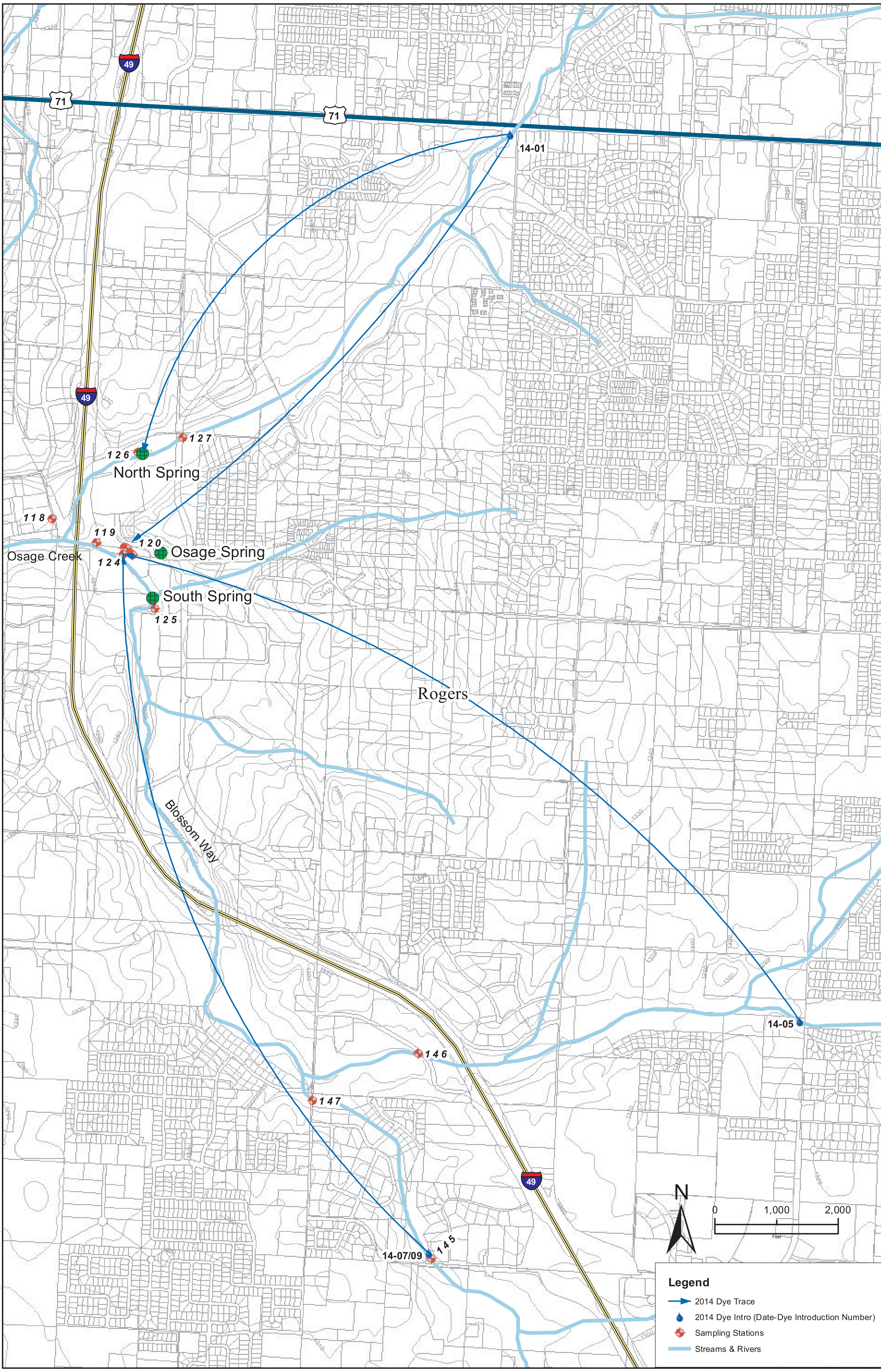



# Cave Springs Area 2014 Dye Introduction Locations and Sampling Stations Figure 5

**Legend**

- Historical Dye Intro (Date-Dye Introduction Number)
- 2014 Dye Intro (Date-Dye Introduction Number)
- Sampling Stations
- Streams & Rivers

Map Revised: 1/7/2015 12:46:01 PM
Document Path: G:\14103100_CaveRechrg\CIV\Dwg\Ozark Underground Labs Maps\Figure 5 Cave Springs Area 2014 Dye Introduction Locations and Sampling Stations.mxd




Map Revised: 1/12/2015 2:01:30 PM
Document Path: G:\14103100_CaveRechrg\CIV\Dwg\Ozark Underground Labs Maps\Figure 6 Cave Springs Area 2014 Dye Tracing Results Map 1.mxd

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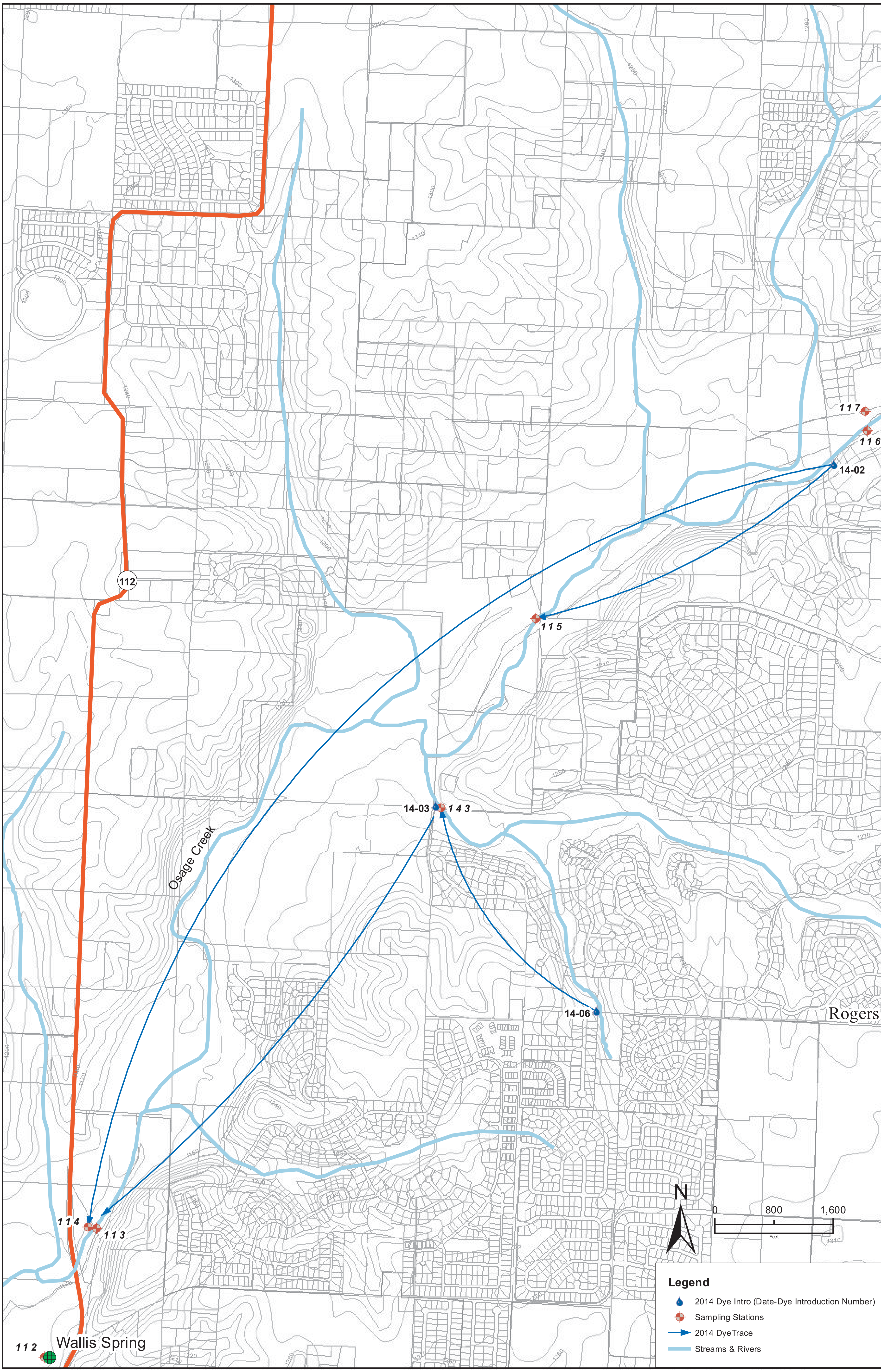
# Cave Springs Area 2014 Dye Tracing Results
## Map 1
## Figure 6




Map Revised: 1/12/2015 2:26:30 PM
Document Path: G:\14103100_CaveRechrg\CIV\Dwg\Ozark Underground Labs Maps\Figure 7 Cave Springs Area 2014 Dye Tracing Results Map 2.mxd

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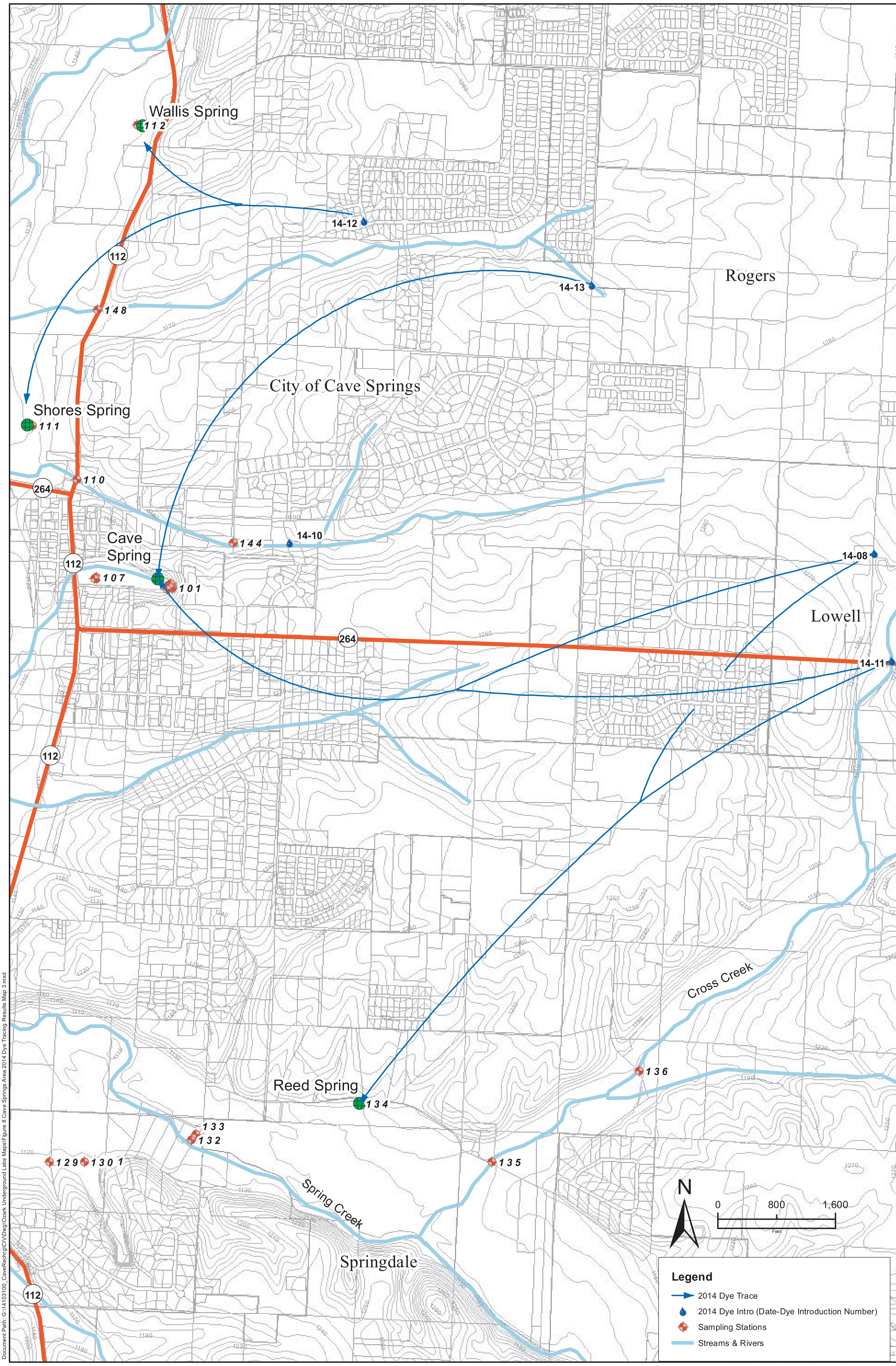
# Cave Springs Area 2014 Dye Tracing Results
## Map 2
## Figure 7

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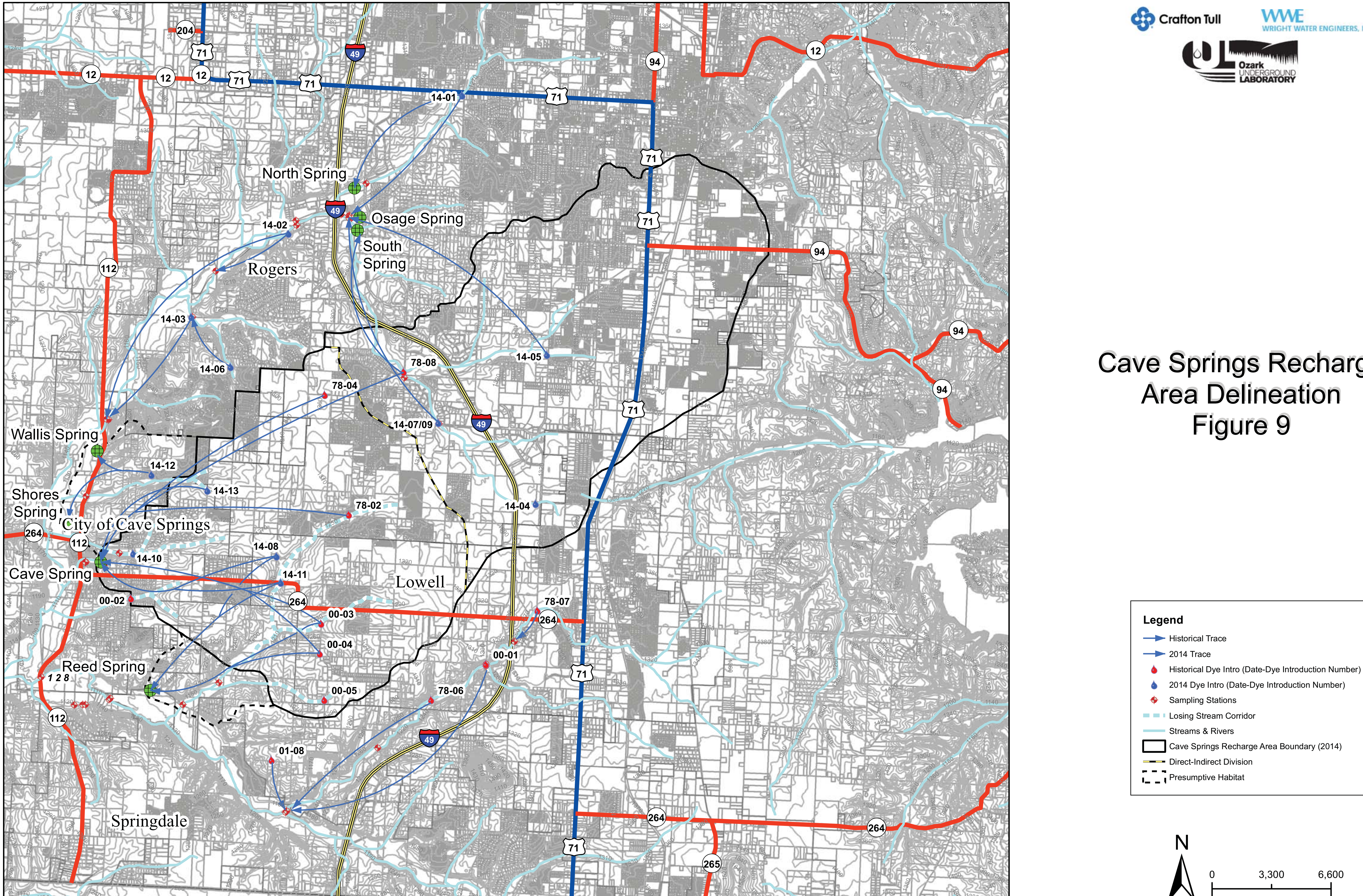
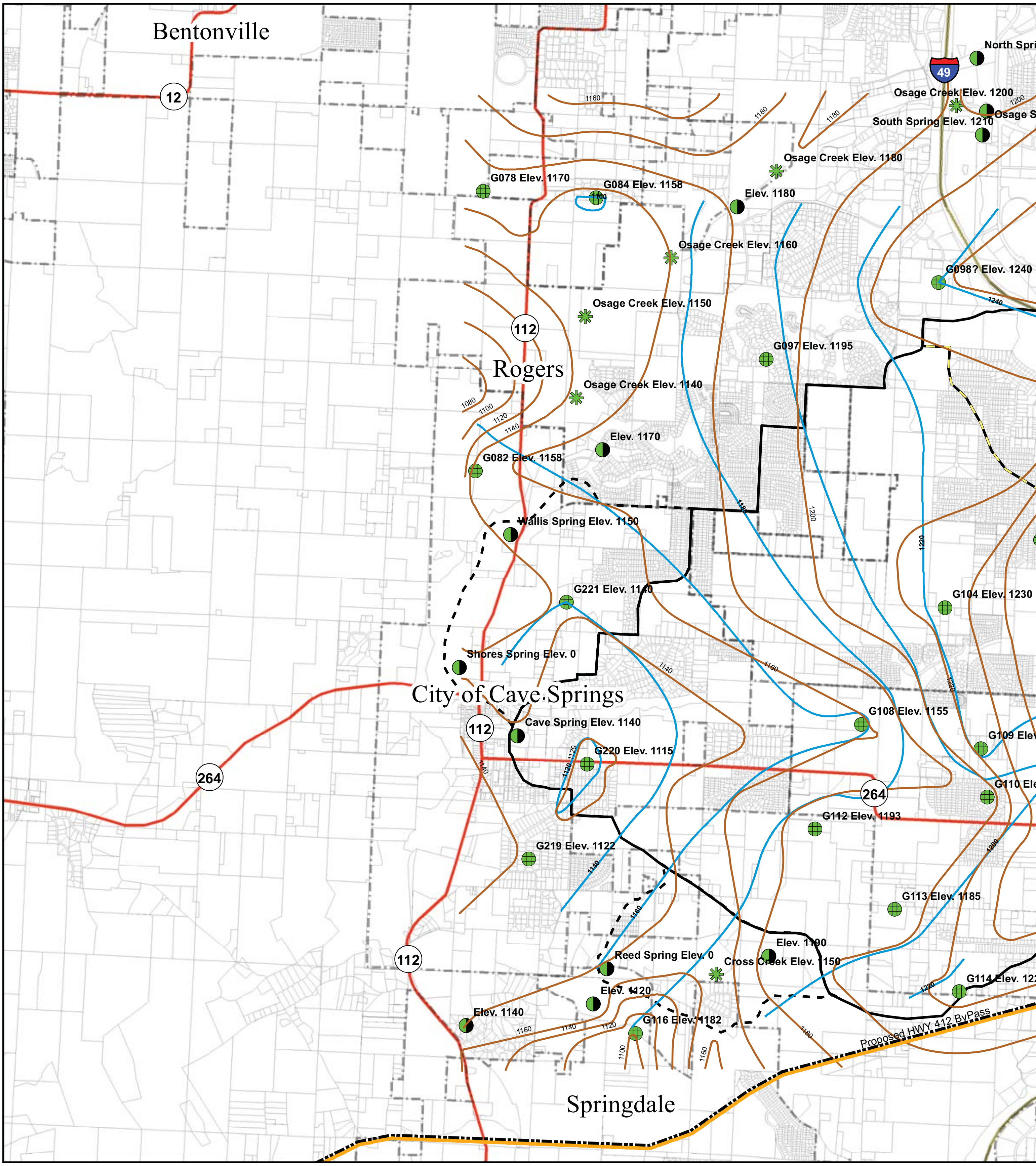
# Cave Springs Area 2014 Dye Tracing Results
## Map 3
## Figure 8




# Cave Springs Recharge Area Delineation Figure 9

Map Revised: 7/23/2015 2:06:37 PM
Document Path: G:\14103100_CaveRechrg\CIV\Dwg\Ozark Underground Labs Maps\Figure 9 Cave Springs Recharge Area Delineation.mxd

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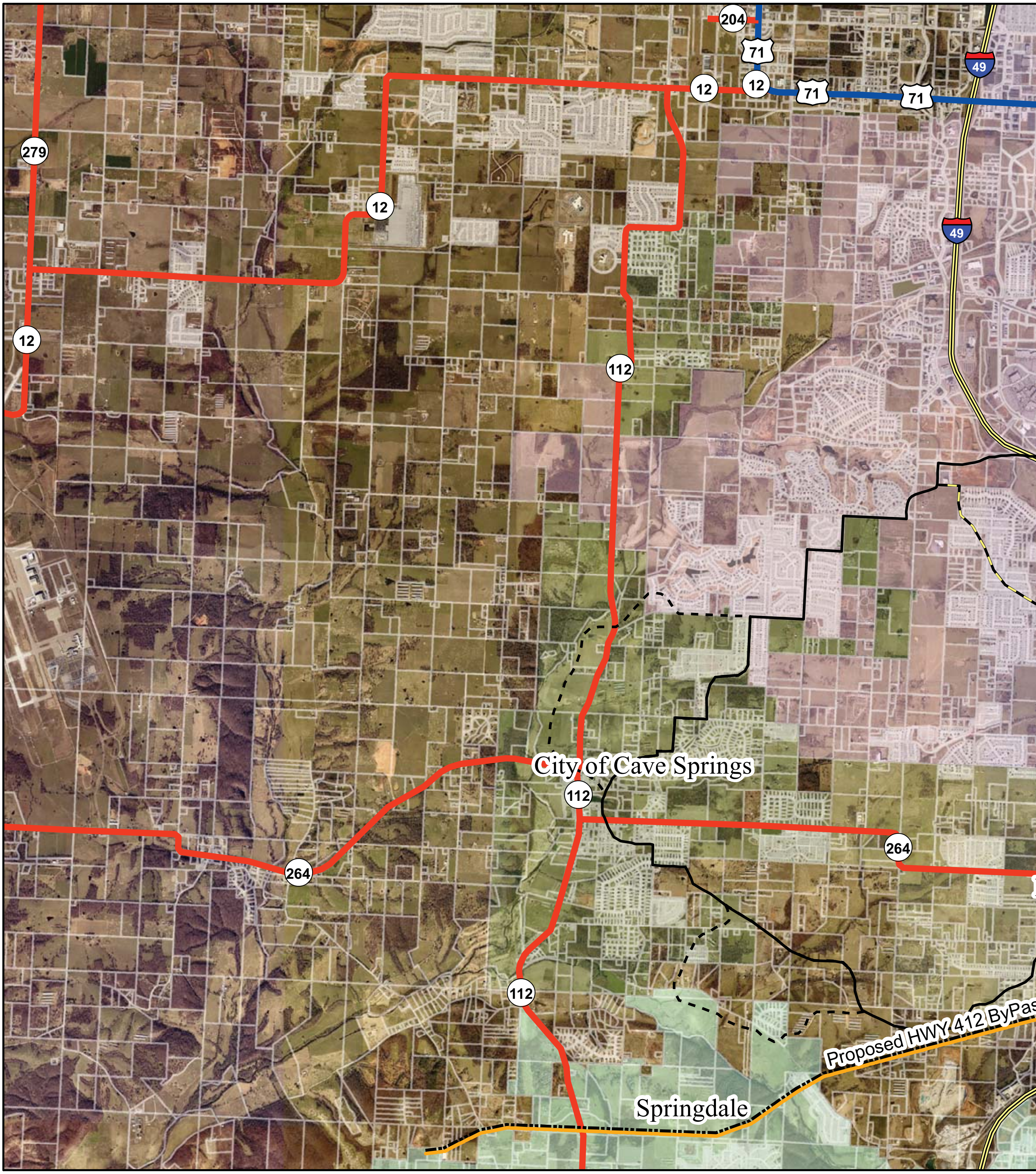
# Cave Springs Area Po

# Fig

Map Revised: 7/23/2015 2:07:53 PM

Document Path: G:\14103100_CaveRechrg\CIV\Dwg\Ozark Underground Labs Maps\Figure 10 Cave Springs Area Potentiometric contour map.mxd




Map Revised: 7/23/2015 2:04:10 PM
Document Path: G:\14103100_CaveRechrg\CIVDwg\Ozark Underground Labs Maps\Figure 11 Cave Springs Recharge Area - Rogers, Lowell, Cave Springs and Springdale.mxd

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Cave Springs

Rogers, Lowell, Cave

Fig

# APPENDIX A

Ozark Underground Laboratory's
Procedures and Criteria Document

Ozark UNDERGROUND LABORATORY 1572 Aley Lane • Protem, MO 65733 • (417) 785-4289 • fax (417) 785-4290 • contact@ozarkundergroundlab.com

# PROCEDURES AND CRITERIA ANALYSIS OF FLUORESCENT DYES IN WATER AND CHARCOAL SAMPLERS:

## FLUORESCEIN, EOSINE, RHODAMINE WT, AND SULFORHODAMINE B DYES

Revision Date:
**September 1, 2011**

**Thomas Aley, PHG, PG**
President

and

**Shiloh L. Kirkland, PG**
Sr. Hydrogeologist

**Ozark Underground Laboratory, Inc.**
1572 Aley Lane
Protem, Missouri 65733
417-785-4289
contact@ozarkundergroundlab.com

## INTRODUCTION

This document describes standard procedures and criteria currently in use at the Ozark Underground Laboratory (OUL) as of the date shown on the title page. Some samples may be subjected to different procedures and criteria because of unique conditions; such non-standard procedures and criteria are identified in reports for those samples. Standard procedures and criteria change as knowledge and experience increases and as equipment is improved or up-graded. The OUL maintains a summary of changes in standard procedures and criteria.

## TRACER DYES AND SAMPLE TYPES

### Dye Nomenclature

Dye manufacturers and retailers use a myriad of names for the dyes. This causes confusion among dye users and report readers. The primary dyes used at the OUL and described in this document are included in Table 1 below.

**Table 1.** Primary OUL Dye Nomenclature.

| OUL Common Name | Color Index Number | Color Index Name | Other Names |
|---|---|---|---|
| Fluorescein | 45350 | Acid Yellow 73 | uranine, uranine C, sodium fluorescein, fluorescein LT and fluorescent yellow/green |
| Eosine | 45380 | Acid Red 87 | eosin, eosine OJ, and D&C Red 22 |
| Rhodamine WT | None assigned | Acid Red 388 | fluorescent red (but not the same as rhodamine B) |
| Sulforhodamine B | 45100 | Acid Red 52 | pontacyl brilliant pink B, lissamine red 4B, and fluoro brilliant pink |

The OUL routinely provides dye for tracing projects. Dyes purchased for groundwater tracing are always mixtures that contain both dye and an associated diluent. Diluents enable the manufacturer to standardize the dye mixture so that there are minimal differences among batches. Additionally, diluents are often designed to make it easier to dissolve the dye mixture in water, or to produce a product which meets a particular market need (groundwater tracing is only a tiny fraction of the dye market). The percent of dye in “as-sold” dye mixtures often varies dramatically among manufacturers and retailers, and retailers are sometimes incorrect about the percent of dye in their products. The OUL subjects all of its dyes to strict quality control (QC) testing. Table 2 summarizes the as-sold dye mixtures used by the OUL.

**Table 2.** As-Sold Dye Mixtures at the OUL.

| OUL Common Name | Form | Dye Equivalent |
|---|---|---|
| Fluorescein | Powder | 75% dye equivalent, 25% diluent |
| Eosine | Powder | 75% dye equivalent, 25% diluent |
| Rhodamine WT | Liquid | 20% dye equivalent, 80% diluent |
| Sulforhodamine B | Powder | 75% dye equivalent, 25% diluent |

Analytical results are based on the as-sold weights of the dyes provided by the OUL. The use of dyes from other sources is discouraged due to the wide variability of dye equivalents within the market. However, if alternate source dyes are used, a sample should be provided to the OUL for quality control and to determine if a correction factor is necessary for the analytical results.

### Types of Samples

Typical samples that are collected for fluorescent tracer dye analysis include charcoal samplers (also called activated carbon or charcoal packets) and water samples.

The charcoal samplers are packets of fiberglass screening partially filled with 4.25 grams of activated coconut charcoal. The charcoal used by the OUL is Calgon 207C coconut shell carbon, 6 to 12 mesh, or equivalent. The most commonly used charcoal samplers are about 4 inches long by 2 inches wide. A cigar-shaped sampler is made for use in very small diameter wells (such as 1-inch diameter piezometers); this is a special order item and should be specifically requested in advance when needed. All of the samplers are closed by heat sealing.

In specialized projects, soil samples have been collected from soil cores and analyzed for fluorescent tracer dyes. Project-specific procedures have been developed for projects such as these. For additional information, please contact the OUL.

## FIELD PROCEDURES

Field procedures included in this section are intended as guidance, and not firm requirements. Placement of samplers and other field procedures require adjustment to field conditions. Personnel at the OUL are available to provide additional assistance for implementation of field procedures specific to specialized field conditions.

### Placement of Samplers

Charcoal samplers are placed so as to be exposed to as much water as possible. Water should flow through the packet. In springs and streams they are typically attached to a rock or other anchor in a riffle area. Attachment of the packets often uses plastic tie wires. In swifter water galvanized wire (such as electric fence wire) is often used. Other types of anchoring wire can be used. Electrical wire with plastic insulation is also good. Packets are attached so that they extend outward from the anchor rather than laying flat against it. Two or more separately anchored packets are typically used for sampling springs and streams. The placement of multiple packets is recommended in order to minimize the chance of loss during the sampling period. The use of fewer packets is discouraged except when the spring or stream is so small that there is not appropriate space for placing multiple packets.

When pumping wells are being sampled, the samplers are typically placed in sample holders made of plastic pipe fittings. Brass hose fittings can be at the end of the sample holders so that the sample holders can be installed on outside hose bibs and water which has run through the samplers can be directed to waste through a connected garden hose. The samplers can be unscrewed in the middle so that charcoal packets can be changed. The middle portions of the samplers consist of 1.5 inch diameter pipe and pipe fitting.

Charcoal packets can be lowered into monitoring wells for sampling purposes. In general, if the well is screened, samplers should be placed approximately in the middle of the screened interval. Due to the typically lower volume of water that flows through a well, only one charcoal sampler should be used per well. However, multiple packets can be placed in a single well at depths to test different depth horizons when desirable. A weight should be added near the charcoal packet to ensure that it will not float. The weight should be of such a nature that it will not affect water quality. One common approach is to anchor the packets with a white or uncolored plastic cable tie to the top of a dedicated weighted disposable bailer. We typically run nylon cord from the top of the well to the charcoal packet and its weight. ***Do not use colored cord*** since some of them are colored with fluorescent dyes. Nylon fishing line should not be used since it can be readily cut by a sharp projection in the well.

In some cases, especially with small diameter wells and appreciable well depths, the weighted disposable bailers sink very slowly or may even fail to sink because of friction and floating of the anchoring cord. In such cases a weight may be added to the top of the disposable bailer. Stainless steel weights are ideal, but are not needed in all cases. All weights should be cleaned prior to use; the cleaning approach should comply with decontamination procedures in use at the project site.

### Optional Preparation of Charcoal Samplers

Charcoal packets routinely contain some fine powder that washes off rapidly when they are placed in water. While not usually necessary, the following optional preparation step is suggested if the fine charcoal powder is problematic.

Charcoal packets can be triple rinsed with distilled, demineralized, or reagent water known to be free of tracer dyes. This rinsing is typically done by soaking. With this approach, approximately 25 packets are placed in one gallon of water and soaked for at least 10 minutes. The packets are then removed from the water and excess water is shaken off the packets. The packets are then placed in a second gallon of water and again soaked for at least 10 minutes. After this soaking they are removed from the water and excess water is shaken off the packets. The packets are then placed in a third gallon of water and the procedure is again repeated. Rinsed packets are placed in plastic bags and are placed at sampling stations within three days. Packets can also be rinsed in jets of water for about one minute; this requires more water and is typically difficult to do in the field with water known to be free of tracer dyes.

## Collection and Replacement of Samplers

Samplers are routinely collected and replaced at each of the sampling stations. The frequency of sampler collection and replacement is determined by the nature of the study. Collections at one week intervals are common, but shorter or longer collection frequencies are acceptable and sometimes more appropriate. Shorter sampling frequencies are often used in the early phases of a study to better characterize time of travel. As an illustration, we often collect and change charcoal packets 1, 2, 4, and 7 days after dye injection. Subsequent sampling is then weekly.

The sampling interval in wells at hazardous wastes sites should generally be no longer than about a week. Contaminants in the water can sometimes use up sorption sites on the charcoal that would otherwise adsorb the dye. This is especially important if the dye might pass in a relatively short duration pulse.

Where convenient, the collected samplers should be briefly rinsed in the water being sampled to remove dirt and accumulated organic material. This is not necessary with well samples. The packets are shaken to remove excess water. Next, the packet (or packets) are placed in a plastic bag (Whirl-Pak® bags are ideal). The bag is labeled on the outside with a black permanent type felt marker pen, such as a Sharpie®. ***Use only pens that have black ink***; colored inks may contain fluorescent dyes. The notations include station name or number and the date and time of collection. Labels must not be inserted inside the sample bags.

Collected samplers are kept in the dark to minimize algal growth on the charcoal prior to analysis work. New charcoal samplers are routinely placed when used charcoal packets are collected. The last set of samplers placed at a stream or spring is commonly not collected.

## Water Samples

Water samples are often collected. They should be collected in either glass or plastic; the OUL routinely uses 50 milliliter (mL) research-grade polypropylene copolymer Perfector Scientific vials (Catalog Number 2650) for such water samples. No more than 30 mL of water is required for analysis. The sides of the vials should be labeled with the project name, sample ID, sample date and time with a black permanent felt tip pen. ***Do not label the lid only***. The vials should be placed in the dark and refrigerated immediately after collection, and maintained under refrigeration until shipment. The OUL supplies vials for the collection of water samples.

## Sample Shipment

When water or charcoal samplers are collected for shipment to the OUL they should be shipped promptly. We prefer (and in some studies require) that samples be refrigerated with frozen re-usable ice packs upon collection and that they be shipped refrigerated with frozen ice packs by overnight express. ***Do not ship samplers packed in wet ice*** since this can create a potential for cross contamination when the ice melts. Our experience indicates that it is not essential for samplers to be maintained under refrigeration; yet maintaining them under refrigeration clearly minimizes some potential problems. A product known as "green ice" should not be used for maintaining the samples in a refrigerated condition since this product contains a dye which could contaminate samples if the "green ice" container were to break or leak.

We receive good overnight and second day air service from both UPS and FedEx. The U.S. Postal Service does not typically provide next day service to us. DHL does not provide overnight service to us. FedEx is recommended for international shipments. The OUL does not receive Saturday delivery.

Each shipment of charcoal samplers or water samples ***must be accompanied by a sample custody document***. The OUL provides a sheet (which bears the title "Samples for Fluorescence Analysis") that can be used if desired. These sheets can be augmented by a client's chain-of-custody forms or any other relevant documentation. OUL's custody document works well for charcoal samplers because it allows for both the placement date and time as well as the collection date and time. Many other standard chain-of-custody documents do not allow for these types of samples. Attachment 1 includes a copy of OUL's Sample Collection Data Sheet.

Please write legibly on the custody documents and ***use black ink***. Check the accuracy of the sample sheet against the samples prior to shipment to identify and correct errors that may delay the analysis of your samples following receipt at the laboratory.

### Supplies Provided by the OUL

The OUL provides supplies for the collection of fluorescent tracer dyes. Supplies provided upon request are charcoal packets, Whirl-Pak® bags (to contain the charcoal packets after collection for shipment to the laboratory), and water vials. These supplies are subjected to strict QA/QC procedures to ensure the materials are free of any potential tracer dye contaminants. The charge for these materials is included in the cost of sample analysis. Upon request, coolers and re-freezable ice packs are also provided for return shipment of samples.

The OUL also has tracer dyes available for purchase. These dyes are subject to strict QA/QC testing. All analytical work is based upon the OUL as-sold weight of the dyes.

## LABORATORY PROCEDURES

The following procedures are followed upon receipt of samples at the laboratory.

### Receipt of Samples

Samplers shipped to the OUL are logged in and refrigerated upon receipt. Prior to cleaning and analysis, samplers are assigned a laboratory identification number.

It sometimes occurs that there are discrepancies between the sample collection data sheet and the actual samples received. When this occurs, a "Discrepancy Sheet" form is completed and sent to the shipper of the sample for resolution. The purpose of the form is to help resolve discrepancies, even when they may be minor. Many discrepancies arise from illegible custody documents. ***Please write legibly*** on the custody documents and ***use black ink***. Check the accuracy of the sample sheet against the samples prior to shipment to identify and correct errors that may delay the analysis of your samples following receipt at the laboratory.

**Cleaning of Charcoal Samplers**

Samplers are cleaned by spraying them with jets of clean water from a laboratory well in a carbonate aquifer. OUL uses non-chlorinated water for the cleansing to minimize dye deterioration. We do not wash samplers in public water supplies. Effective cleansing cannot generally be accomplished simply by washing in a conventional laboratory sink even if the sink is equipped with a spray unit.

The duration of packet washing depends upon the condition of the sampler. Very clean samplers may require less than a minute of washing; dirtier samplers may require several minutes of washing.

**Elution of the Charcoal**

There are various eluting solutions that can be used for the recovery of tracer dyes. The solutions typically include an alcohol, water, and a strong basic solution such as aqueous ammonia and /or potassium hydroxide.

The standard elution solution used at the OUL is a mixture of 5% aqua ammonia and 95% isopropyl alcohol solution and sufficient potassium hydroxide pellets to saturate the solution. The isopropyl alcohol solution is 70% alcohol and 30% water. The aqua ammonia solution is 29% ammonia. The potassium hydroxide is added until a super-saturated layer is visible in the bottom of the container. This super-saturated layer is not used for elution. Preparation of eluting solutions uses dedicated glassware which is never used in contact with dyes or dye solutions.

The eluting solution will elute fluorescein, eosine, rhodamine WT, and sulforhodamine B dyes. It is also suitable for separating fluorescein peaks from peaks of some naturally present materials found in may be found in samplers.

Fifteen mL of the eluting solution is poured over the washed charcoal in a disposable sample beaker. The sample beaker is capped. The sample is allowed to stand for 60 minutes. After this time, the liquid is carefully poured off the charcoal into a new disposable beaker which has been appropriately labeled with the laboratory identification number. A few grains of charcoal may inadvertently pass into the second beaker; no attempt is made to remove these from the second sample beaker. After the pouring, a small amount of the elutant will remain in the initial sample beaker. After the transfer of the elutant to the second sample beaker, the contents of the first sample beaker (the eluted charcoal) are discarded. Samples are kept refrigerated until analyzed.

**pH Adjustment of Water Samples**

The fluorescence intensity of several of the commonly used fluorescent tracer dyes is pH dependent. The pH of samples analyzed for fluorescein, eosine, and pyranine dyes are adjust to a target pH of greater than 9.5 in order to obtain maximum fluorescence intensities.

Adjustment of pH is achieved by placing samples in a high ammonia atmosphere for at least two hours in order to increase the pH of the sample. Reagent water standards are placed in the same atmosphere as the samples. If dye concentrations in a sample are off-scale and require dilution for quantification of the dye concentration, the diluting water used is OUL reagent water that has been pH adjusted in a high ammonia atmosphere. Samples that are only analyzed for rhodamine WT or sulforhodamine B are not required to be pH adjusted.

**Analysis on the Shimadzu RF-5301**

The OUL uses a Shimadzu spectrofluorophotometer model RF-5301. This instrument is capable of synchronous scanning. The OUL also owns a Shimadzu RF-540 spectrofluorometers that is occasionally used for special purposes.

A sample of the elutant or water is withdrawn from the sample container using a disposable polyethylene pipette. Approximately 3 mL of the sample is then placed in disposable rectangular polystyrene cuvette. The cuvette has a maximum capacity of 3.5 mL. The cuvette is designed for fluorometric analysis; all four sides and the bottom are clear. The acceptable spectral range of these cuvettes is 340 to 800 nm. The pipettes and cuvettes are discarded after one use.

The cuvette is then placed in the RF-5301. This instrument is controlled by a programmable computer and operated by proprietary software developed for dye tracing applications.

Our instruments are operated and maintained in accordance with the manufacturer's recommendations. On-site installation of our first instrument and a training session on its use was provided by the instrument supplier. Repairs are made by a Shimadzu-authorized repairman.

Our typical analysis of an elutant sample where fluorescein, eosine, rhodamine WT, or sulforhodamine B dyes may be present includes synchronous scanning of excitation and emission spectra with a 17 nm separation between excitation and emission wavelengths. For these dyes, the excitation scan is from 443 to 613 nm; the emission scan is from 460 to 630 nm. The emission fluorescence from the scan is plotted on a graph. The typical scan speed setting is “fast” on the RF-5301. The typical sensitivity setting used is "high."

**Table 3.** Excitation and emission slit width settings routinely used for dye analysis.

| **Parameter** | **Excitation Slit (nm)** | **Emission Slit (nm)** |
|---|---|---|
| ES, FL, RWT, and SRB in elutant | 3 | 1.5 |
| ES, FL, RWT, and SRB in water | 5 | 3 |

Note: ES = Eosine. FL = Fluorescein. RWT = Rhodamine WT. SRB = Sulforhodamine B.

The instrument produces a plot of the synchronous scan for each sample; the plot shows emission fluorescence only. The synchronous scans are subjected to computer peak picks using proprietary software; peaks are picked to the nearest 0.1 nm. Instrument operators have the ability to manually adjust peaks as necessary based upon computer-picked peaks and experience. All samples run on the RF-5301 are stored electronically with sample information. All samples analyzed are recorded in a bound journal.

## Quantification

We calculate the magnitude of fluorescence peaks for fluorescein, eosine, rhodamine WT, and sulforhodamine B dyes in both elutant and water samples. Dye quantities are expressed in microgram per liter (parts per billion; ppb). The dye concentrations are calculated by separating fluorescence peaks due to dyes from background fluorescence on the charts, and then calculating the area within the fluorescence peak. This area is proportional to areas obtained from standard solutions.

We run dye concentration standards each day the RF-5301 is used. Six standards are used; the standard or standards appropriate for the analysis work being conducted are selected. All standards are based upon the as-sold weights of the dyes. The standards are as follows:

1) 10 ppb fluorescein and 100 ppb rhodamine WT in well water from the Jefferson City-Cotter Formation
2) 10 ppb eosine in well water from the Jefferson City-Cotter Formation
3) 100 ppb sulforhodamine B in well water from the Jefferson City-Cotter Formation.
4) 10 ppb fluorescein and 100 ppb rhodamine WT in elutant.
5) 10 ppb eosine in elutant.
6) 100 ppb sulforhodamine B in elutant.

## Preparation of Standards

Dye standards are prepared as follows:

<u>Step 1.</u> A small sample of the as-sold dye is placed in a pre-weighed sample vial and the vial is again weighed to determine the weight of the dye. We attempt to use a sample weighing between 1 and 5 grams. This sample is then diluted with well water to make a 1% dye solution by weight (based upon the as-sold weight of the dye). The resulting dye solution is allowed to sit for at least four hours to ensure that all dye is fully dissolved.

<u>Step 2.</u> One part of each dye solution from Step 1 is placed in a mixing container with 99 parts of well water. Separate mixtures are made for fluorescein, rhodamine WT, eosine, and sulforhodamine B. The resulting solutions contain 100 mg/L dye (100 parts per million dye mixture). The typical prepared volume of this mixture is appropriate for the sample bottles being used; we commonly prepare about 50 mL of the Step 2 solutions. The dye solution from Step 1 that is used in making the Step 2 solution is withdrawn with a digital Finnpipette which is capable of measuring volumes between 0.200 and 1.000 mL at intervals of 0.005 mL. The calibration certificate with this instrument indicates that the accuracy (in percent) is as follows:

At 0.200 mL, 0.90%

At 0.300 mL, 0.28%

At 1.000 mL, 0.30%

The Step 2 solution is called the long term standard. OUL experience indicates that Step 2 solutions, if kept refrigerated, will not deteriorate appreciably over periods of less than a year. Furthermore, these Step 2 solutions may last substantially longer than one year.

Step 3. A series of intermediate-term dye solutions are made. Approximately 45 mL. of each intermediate-term dye solution is made. All volume measurements of less than 5 mL are made with a digital Finnpipette. (see description in Step 2). All other volume measurements are made with Rheinland Kohn Geprufte Sicherheit 50 mL capacity pump dispenser which will pump within plus or minus 1% of the set value. The following solutions are made; all concentrations are based on the as-sold weight of the dyes:

1) 1 ppm fluorescein dye and 10 ppm rhodamine WT dye.
2) 1 ppm eosine.
3) 10 ppm sulforhodamine B dye.

Step 4. A series of six short-term dye standards are made from solutions in Step 3. These standards were identified earlier in this section. In the experience of the OUL these standards have a useful shelf life in excess of one week. However, in practice, Step 4 elutant standards are made weekly, and Step 4 water standards are made daily.

**Dilution of Samples**

Samples with peaks that have arbitrary fluorescence unit values of 500 or more are diluted a hundred fold to ensure accurate quantification.

Some water samples have high turbidity or color which interferes with accurate detection and measurement of dye concentrations. It is often possible to dilute these samples and then measure the dye concentration in the diluted sample.

The typical dilutions are either 10 fold (1:10) or 100 fold (1:100). A 1:10 dilution involves combining one part of the test sample with 9 parts of water (if the sample is water) or elutant (if the sample is elutant). A 1:100 dilution involves combining one part of the test sample is combined with 99 parts of water or elutant, based upon the sample media. Typically, 0.300 mL of the test solution is combined with 29.700 mL of water (or elutant as appropriate) to yield a new test solution.

All volume measurements of less than 5 mL are made with a digital Finnpipette. All other volume measurements are made with Rheinland Kohn Geprufte Sicherheit 50 mL capacity pump dispenser which will pump within plus or minus 1% of the set value.

The water used for dilution is from a carbonate aquifer. All dilution water is pH adjusted to greater than pH 9.5 by holding it in open containers in a high ammonia concentration chamber. This adjustment takes a minimum of two hours.

**Quality Control**

Laboratory blanks are run for every sample where the last two digits of the laboratory numbers are 00, 20, 40, 60, or 80. A charcoal packet is placed in a pumping well sampler and at least 25 gallons of unchlorinated water is passed through the sampler at a rate of about 2.5 gallons per minute. The sampler is then subjected to the same analytical protocol as all other samplers.

System functioning tests of the analytical instruments are conducted in accordance with the manufacturer's recommendations. Spiked samples are also analyzed when appropriate for quality control purposes.

All materials used in sampling and analysis work are routinely analyzed for the presence of any compounds that might create fluorescence peaks in or near the acceptable wavelength ranges for any of the tracer dyes. This testing includes approximately 1% of materials used.

Project specific QA/QC samples may include sample replicates and sample duplicates. A replicate sample is when a single sample is analyzed twice. A sample duplicate is where two samples are collected in a single location and both are analyzed. Sample replicates and duplicates are run for QA/QC purposes upon request of the client. These results are reported in the Certificate of Analysis.

**Reports**

Sample analysis results are typically reported in a Certificate of Analysis. However, specialized reports are provided in accordance with the needs of the client. Certificates of Analysis typically provide a listing of station number, sample ID, and dye concentrations if detected. Standard data format includes deliverables in MS Excel and Adobe Acrobat (.pdf) format. Hard copy of the data package, and copies of the analytical charts are available upon request.

Work at the OUL is directed by Mr. Thomas Aley. Mr. Aley has 45 years of professional experience in hydrology and hydrogeology. He is certified as a Professional Hydrogeologist (Certificate #11576) by the American Institute of Hydrology and licenced as a Professional Geologist in Missouri, Arkansas, Kentucky, and Alabama. Additional details regarding laboratory qualifications are available upon request.

**Waste Disposal**

All laboratory wastes are disposed of according to applicable state and federal regulations. Waste elutant and water samples are collected in 15 gallon poly drums and disposed with a certified waste disposal facilityas non-hazardous waste.

In special cases, wastes for a particular project may be segregated and returned to the client upon completion of the project. These projects may have samples that contain contaminants that the client must account for all materials generated and disposed. These situations are managed on a case-by-case basis.

## CRITERIA FOR DETERMINATION OF POSITIVE DYE RECOVERIES

**Normal Emission Ranges and Detection Limits**

The OUL has established normal emission fluorescence wavelength ranges for each of the four dyes described in this document. The normal acceptable range equals mean values plus and minus two standard deviations. These values are derived from actual groundwater tracing studies conducted by the OUL.

The detection limits are based upon concentrations of dye necessary to produce emission fluorescence peaks where the signal to noise ratio is 3. The detection limits are realistic for most field studies since they are based upon results from actual field samples rather than being based upon values from spiked samples in a matrix of reagent water or the elutants from unused activated carbon samplers. In some cases detection limits may be smaller than reported if the water being sampled has very little fluorescent material in it. In some cases detection limits may be greater than reported; this most commonly occurs if the sample is turbid due to suspended material or a coloring agent such as tannic compounds. Turbid samples are typically allowed to settle, centrifuged, or, if these steps are not effective, diluted prior to analysis.

Table 4 provides normal emission wavelength ranges and detection limits for the four dyes when analyzed on the OUL's RF-5301.

**Table 4**. RF-5301 Spectrofluorophotometer. Normal emission wavelength ranges and detection limits for fluorescein, eosine, rhodamine WT, and sulforhodamine B dyes in water and elutant samples.

| Fluorescent Dye | Normal Acceptable Emission Wavelength Range (nm) | | Detection Limit (ppb) | |
|---|---|---|---|---|
| | Elutant | Water | Elutant | Water |
| Eosine | 540.0 to 545.8 | 532.8 to 537.3 | 0.050 | 0.015 |
| Fluorescein | 514.5 to 519.6 | 506.8 to 510.6 | 0.025 | 0.002 |
| Rhodamine WT | 565.2 to 571.8 | 572.4 to 577.7 | 0.170 | 0.015 |
| Sulforhodamine B | 576.4 to 583.2 | 580.8 to 584.4 | 0.080 | 0.008 |

Note: Detection limits are based upon the as-sold weight of the dye mixtures normally used by the OUL.
Fluorescein and eosine detection limits in water are based on samples pH adjusted to greater than 9.5.

It is important to note that the normal acceptable emission wavelength ranges are subject to change based on instrument maintenance, a change in instrumentation, or slight changes in dye formulation. Significant changes in normal acceptable emission wavelength ranges will be updated in this document as they occur.

## Fluorescence Background

Due to the nature of fluorescence analysis, it is important to identify and characterize any potential background fluorescence at dye introduction and monitoring locations prior to the introduction of any tracer dyes.

There is generally little or no detectable fluorescence background in or near the general range of eosine, rhodamine WT, and sulforhodamine B dyes encountered in most groundwater tracing studies. There is often some fluorescence background in or near the range of fluorescein dye present at some of the stations used in groundwater tracing studies.

## Criteria for Determining Dye Recoveries

The following sections identify normal criteria used by the OUL for determining dye recoveries. The primary instrument in use is a Shimadzu RF-5301.

## EOSINE

### Normal Criteria Used by the OUL for Determining Eosine Dye Recoveries in Elutants from Charcoal Samplers

**Criterion 1.** There must be at least one fluorescence peak in the range of 540.0 to 545.8 nm in the sample.

**Criterion 2.** The dye concentration associated with the fluorescence peak must be at least 3 times the detection limit. The eosine detection limit in elutant samples is 0.050 ppb, thus this dye concentration limit equals 0.150 ppb.

**Criterion 3.** The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

**Criterion 4.** The shape of the fluorescence peak must be typical of eosine. Much background fluorescence yields low, broad, and asymmetrical fluorescence peaks rather than the more narrow and symmetrical fluorescence peaks typical of eosine. In addition, there must be no other factors which suggest that the fluorescence peak may not be eosine dye from our groundwater tracing work.

### Normal Criteria Used by the OUL for Determining Eosine Dye Recoveries in Water Samples

**Criterion 1.** In most cases, the associated charcoal samplers for the station should also contain eosine dye in accordance with the criteria listed above. This criterion may be waived if no charcoal sampler exists.

**Criterion 2.** There must be no factors which suggest that the fluorescence peak may not be eosine dye from our groundwater tracing work. The fluorescence peak should generally be in the range of 532.8 to 537.3 nm.

**Criterion 3.** The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our eosine detection limit in water samples is 0.015 ppb, thus this dye concentration limit equals 0.045 ppb.

**Criterion 4.** The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

## FLUORESCEIN

### Normal Criteria Used by the OUL for Determining Fluorescein Dye Recoveries in Elutants from Charcoal Samplers

**Criterion 1.** There must be at least one fluorescence peak in the range of 514.5 to 519.6 nm in the sample.

**Criterion 2.** The dye concentration associated with the fluorescence peak must be at least 3 times the detection limit. The fluorescein detection limit in elutant samples is 0.025 ppb, thus this dye concentration limit equals 0.075 ppb.

**Criterion 3.** The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

**Criterion 4.** The shape of the fluorescence peak must be typical of fluorescein. Much background fluorescence yields low, broad, and asymmetrical fluorescence peaks rather than the more narrow and symmetrical fluorescence peaks typical of fluorescein. In addition, there must be no other factors which suggest that the fluorescence peak may not be fluorescein dye from our groundwater tracing work.

### Normal Criteria Used by the OUL for Determining Fluorescein Dye Recoveries in Water Samples

**Criterion 1.** In most cases, the associated charcoal samplers for the station should also contain fluorescein dye in accordance with the criteria listed above. This criterion may be waived if no charcoal sampler exists.

**Criterion 2.** There must be no factors which suggest that the fluorescence peak may not be fluorescein dye from our groundwater tracing work. The fluorescence peak should generally be in the range of 506.8 to 510.6 nm.

**Criterion 3.** The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our fluorescein detection limit in water samples is 0.002 ppb, thus this dye concentration limit equals 0.006 ppb.

**Criterion 4.** The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

## RHODAMINE WT

### Normal Criteria Used by the OUL for Determining Rhodamine WT Dye Recoveries in Elutants from Charcoal Samplers

**Criterion 1.** There must be at least one fluorescence peak in the sample in the range of 565.2 to 571.8 nm.

**Criterion 2.** The dye concentration associated with the rhodamine WT peak must be at least 3 times the detection limit. The detection limit in elutant samples is 0.170 ppb, thus this dye concentration limit equals 0.510 ppb.

**Criterion 3.** The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

**Criterion 4.** The shape of the fluorescence peak must be typical of rhodamine WT. In addition, there must be no other factors which suggest that the fluorescence peak may not be dye from the groundwater tracing work under investigation.

### Normal Criteria Used by the OUL for Determining Rhodamine WT Dye Recoveries in Water Samples

**Criterion 1.** In most cases, the associated charcoal samplers for the station should also contain rhodamine WT dye in accordance with the criteria listed above. These criteria may be waived if no charcoal sampler exists.

**Criterion 2.** There must be no factors which suggest that the fluorescence peak may not be rhodamine WT dye from the tracing work under investigation. The fluorescence peak should generally be in the range of 572.4 to 577.7 nm.

**Criterion 3.** The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our rhodamine WT detection limit in water samples is 0.015 ppb, thus this dye concentration limit is 0.045 ppb.

**Criterion 4.** The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

## SULFORHODAMINE B

### Normal Criteria Used by the OUL for Determining Sulforhodamine B Dye Recoveries in Elutants from Charcoal Samplers

**Criterion 1.** There must be at least one fluorescence peak in the sample in the range of 576.4 to 583.2 nm.

**Criterion 2.** The dye concentration associated with the sulforhodamine B peak must be at least 3 times the detection limit. The detection limit in elutant samples is 0.080 ppb, thus this dye concentration limit equals 0.240 ppb.

**Criterion 3.** The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

**Criterion 4.** The shape of the fluorescence peak must be typical of sulforhodamine B. In addition, there must be no other factors which suggest that the fluorescence peak may not be dye from the groundwater tracing work under investigation.

### Normal Criteria Used by the OUL for Determining Sulforhodamine B dye Recoveries in Water Samples

**Criterion 1.** In most cases, the associated charcoal samplers for the station should also contain sulforhodamine B dye in accordance with the criteria listed earlier. This criterion may be waived if no charcoal sampler exists.

**Criterion 2.** There must be no factors which suggest that the fluorescence peak may not be sulforhodamine B dye from the tracing work under investigation. The fluorescence peak should generally be in the range of 580.8 to 584.4 nm.

**Criterion 3.** The dye concentration associated with the fluorescence peak must be at least three times the detection limit. The detection limit in water is 0.008 ppb, thus this dye concentration limit equals 0.024 ppb.

**Criterion 4.** The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

**Standard Footnotes**

Sometimes not all the criteria are met for a straight forward determination of tracer dye in a sample. For these reasons, the emission graph is scrutinized carefully by the analytical technician and again during the QA/QC process. Sometimes the emission graphs require interpretation as to whether or not a fluorescence peak represents the tracer dye or not. Background samples from each of the sampling stations aid in the interpretation of the emission fluorescence graphs. When the results do not meet all the criteria for a positive dye detection, often the fluorescence peak is quantified and flagged with a footnote to the result as not meeting all the criteria for a positive dye detection. Standard footnotes are as follows:

Single asterisk (*): A fluorescence peak is present that does not meet all the criteria for a positive dye recovery. However, it has been calculated as though it were the tracer dye.

Double asterisk (**): A fluorescence peak is present that does not meet all the criteria for this dye. However, it has been calculated as a positive dye recovery.

Other footnotes specific to the fluorescence signature are sometimes also used. These footnotes are often developed for a specific project.

The quantification of fluorescence peaks that do not meet all the criteria for a positive dye detection can be important for interpretation of the dataset as a whole.

**ATTACHMENT 1**
**Sample Collection Data Sheet**

# OZARK UNDERGROUND LABORATORY, INC.

1572 Aley Lane Protem, MO 65733 (417) 785-4289 fax (417) 785-4290 email: contact@ozarkundergroundlab.com

## SAMPLE COLLECTION DATA SHEET for FLUORESCENCE ANALYSIS

**Project** ______________________________ **Week No:** ___ **Samples Collected By:** ______________________________

**Samples Shipped By:** ______________________________ **Samples Received By:** ______________________________

**Date Samples Shipped:** ___________ **Date Samples Received:** ___________ **Time Samples Received:** ___________ **Return Cooler? Yes** ☐ **No** ☐

**Bill to:** ______________________________ **Send Results to:** ______________________________

**Analyze for:** ☐ **Fluorescein** ☐ **Eosine** ☐ **Rhodamine WT** ☐ **Other** ______________ **Ship cooler to:** ___

| *OUL use only* | | ***Please indicate stations where dye was visible in the field*** *for field technician use - use black ink only* | | | | | | *OUL use only* |
|---|---|---|---|---|---|---|---|---|
| # CHAR REC'D | LAB NUMBER | STATION NUMBER 1-4 Numbers | STATION NAME | PLACED | | COLLECTED | | # WATER REC'D |
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**COMMENTS** ______________________________________________________________

______________________________________________________________

**This sheet filled out by OUL staff? Yes** ☐ **No** ☐ **Charts for samples on this page proofed by OUL:** ______________________________

**OUL Project No.** _______ **Date Analyzed:** ________________ **Analyzed By:** ______________________________

Ozark UNDERGROUND LABORATORY 1572 Aley Lane • Protem, MO 65733 • (417) 785-4289 • fax (417) 785-4290 • contact@ozarkundergroundlab.com

# PROCEDURES AND CRITERIA
# FOR THE ANALYSIS OF PYRANINE DYE

**An Addendum to:**

**PROCEDURES AND CRITERIA
ANALYSIS OF FLUORESCENT DYES
IN WATER AND CHARCOAL SAMPLERS:**

**FLUORESCEIN, EOSINE, RHODAMINE WT,
AND SULFORHODAMINE B DYES**

Revision Date:
**September 1, 2011**

**Thomas Aley, PHG, PG**
President
and
**Shiloh L. Kirkland, PG**
Sr. Hydrogeologist

**Ozark Underground Laboratory, Inc.**
1572 Aley Lane
Protem, Missouri 65733
417-785-4289

## INTRODUCTION

This addendum is to be used in conjunction with the Ozark Underground Laboratory's (OUL) document entitled "Procedures and Criteria Analysis of Fluorescent Dyes in Water and Charcoal Samplers: Fluorescein, Eosine, Rhodamine WT, and Sulforhodamine B." This document covers information for pyranine dye.

Pyranine is not as commonly used by the OUL as the other four dyes. The necessity of employing a different analysis protocol, plus other factors which can limit the utility of pyranine, make this dye generally less useful than the other more commonly used dyes (fluorescein, eosine, rhodamine WT, and sulforhodamine B).

## DYE NOMENCLATURE AND SAMPLE TYPES

The following tables summarize the common dye nomenclature for pyranine dye and the as-sold mixture at the OUL.

**Table 1.** Primary OUL Dye Nomenclature.

| OUL Common Name | Color Index Number | Color Index Name | Other Names |
|---|---|---|---|
| Pyranine | 59040 | Solvent Green 7 | D&C Green 8 |

**Table 2.** Pyranine As-Sold Dye Mixture at the OUL.

| OUL Common Name | Form | Dye Equivalent |
|---|---|---|
| Pyranine | Powder | 77% dye equivalent |

Pyranine dye can be adsorbed onto charcoal samplers, which can be eluted in the laboratory and analyzed for pyranine dye. Pyranine dye also can be analyzed in water samples.

## FIELD PROCEDURES

Field procedures for the sampling of pyranine dye are summarized in OUL's Procedures and Criteria document for Fluorescein, Eosine, Rhodamine WT and Sulforhodamine B. Since pyranine can also be adsorbed onto charcoal samplers and analyzed in water samples, the field procedures for sample collection are the same.

## LABORATORY PROCEDURES

### Sample Preparation

Laboratory procedures for the preparation of pyranine dye samples are the same as for fluorescein and eosine. The same elutant mixture is used to elute charcoal samplers for pyranine analysis. The pH of the water samples is also adjusted to above 9.5 using the same procedure as described for fluorescein and eosine.

**Preparation of Standards**

The preparation of standards for pyranine dye is similar to the other four fluorescent dyes. However, these standards are only run on days when pyranine analysis is planned.

The Step 3 standard for pyranine consists of a solution containing 1 ppm pyranine dye, based upon the as-sold weight of the dye. The Step 4 standards for pyranine consist of the following:

1) 10 ppb pyranine in well water from the Jefferson City-Cotter Formation.
2) 10 ppb pyranine in elutant.

**Sample Analysis**

The largest difference between the analysis of pyranine dye and the standard protocol for fluorescein, eosine, rhodamine WT and sulforhodamine B is the synchronous scanning protocol on the Shimadzu RF-5301. The typical analysis of elutant and water samples where pyranine dye may be present includes a synchronous scanning of excitation and emission spectra with a 35 nm separation between excitation and emission wavelengths. For this dye, the excitation scan is from 360 to 600 nm; the emission scan is from 395 to 635 nm. The emission fluorescence from the scan is plotted on a graph. The typical scan speed setting is “fast” on the RF-5301. The typical sensitivity setting is "high." Excitation and emission slit width settings are summarized in Table 3.

**Table 3.** Excitation and emission slit width settings routinely used for pyranine dye analysis.

| **Parameter** | **Excitation Slit (nm)** | **Emission Slit (nm)** |
|---|---|---|
| Pyranine in Elutant | 5 | 3 |
| Pyranine in Water | 5 | 3 |

The normal emission wavelength ranges and detection limits for pyranine dye in water and elutant are summarized in Table 4.

**Table 4.** RF-5301 Spectrofluorophotometer. Normal emission wavelength ranges and detection limits for pyranine dye in water and elutant samples.

| Dye and Matrix | Normal Acceptable Emission Wavelength Range (nm) | Detection Limit (ppb) |
|---|---|---|
| Pyranine in Elutant | 502.2 to 508.2 | 0.015 |
| Pyranine in Water | 497.5 to 503.5 | 0.010 |

Note: Detection limits are based upon the as-sold weight of the dye mixtures normally used by the OUL.
Pyranine detection limits in water are based on samples pH adjusted to greater than 9.5.

The protocols for the analysis of pyranine dye are substantially different than those for the other dyes. As a result, there is less potential interference between pyranine and fluorescein than might otherwise be indicated by the emission wavelength values shown in Table 4.

## Criteria for Determination of Dye Recoveries

The following normal criteria are used by the OUL for determining dye recoveries in water and elutant samples.

The analysis protocol for pyranine dye is different than the protocol for the other four dyes discussed in the parent document. If the other dyes are present in a sample analyzed for pyranine dye their emission fluorescence peaks (if any) will be appreciably different than the values presented above. Because of this, there is very little analytical interference between fluorescein and pyranine dyes when both are present in a sample.

## PYRANINE

### Normal Criteria Used by the OUL for Determining Pyranine Dye Recoveries in Elutants from Charcoal Samplers

**Criterion 1.** There must be at least one fluorescence peak at the sample in question in the range of 502.2 to 508.2 nm.

**Criterion 2.** The dye concentration associated with the pyranine dye peak must be at least 3 times the detection limit. The detection limit in elutant samples is 0.015 ppb, thus this dye concentration limit equals 0.045 ppb.

**Criterion 3.** The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

**Criterion 4.** The shape of the fluorescence peak must be typical of pyranine dye. In addition, there must be no other factors which suggest that the fluorescence peak may not be dye from the groundwater tracing work under investigation.

### Normal Criteria Used by the OUL for Determining Pyranine Dye Recoveries in Water Samples

**Criterion 1.** In most cases, the associated charcoal samplers for the station should also contain pyranine dye in accordance with the criteria listed earlier. This criterion may be waived if no charcoal sampler exists.

**Criterion 2.** There must be no factors which suggest that the fluorescence peak may not be pyranine dye from the tracing work under investigation. The fluorescence peak should generally be in the range of 497.5 to 503.5 nm.

**Criterion 3.** The dye concentration associated with the fluorescence peak must be at least three times the detection limit. The detection limit in water is 0.010 ppb, thus this dye concentration limit equals 0.030 ppb.

**Criterion 4.** The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

# APPENDIX B

Groundwater Tracing Analytical Results

**Table 1. Results for charcoal samplers analyzed for the presence of fluorescein, eosine and rhodamine WT (RWT) dyes.**
Peak wavelengths are reported in nanometers (nm); dye concentrations are reported in parts per billion (ppb).

| OUL | Station | Station Name | Date/Time | Date/Time | Fluorescein | | | | Eosine | | | | RWT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Number | | Placed | Collected | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. |
| **X5834** | **101** | **Cave Spring** | **4/23/14 1800** | **5/1/14 1145** | **ND** | | | | **ND** | | | | **ND** | | | |
| X5924 | 101 | Cave Spring | 5/1/14 1145 | 5/7/14 1530 | ND | | | | ND | | | | ND | | | |
| X5924D | 101 | Cave Spring | 5/1/14 1145 | 5/7/14 1530 | ND | | | | ND | | | | ND | | | |
| X6293 | 101 | Cave Spring | 5/7/14 1530 | 5/14/14 1625 | ND | | | | ND | | | | ND | | | |
| X6293D | 101 | Cave Spring | 5/7/14 1530 | 5/14/14 1625 | ND | | | | ND | | | | ND | | | |
| | 101 | Cave Spring | 5/14/14 1625 | 5/15/14 1100 | water sample only | | | | | | | | | | | |
| X6315 | 101 | Cave Spring | 5/15/14 1100 | 5/21/14 1200 | ND | | | | ND | | | | ND | | | |
| X6315D | 101 | Cave Spring | 5/15/14 1100 | 5/21/14 1200 | ND | | | | ND | | | | ND | | | |
| X6352 | 101 | Cave Spring | 5/21/14 1200 | 5/23/14 1145 | ND | | | | ND | | | | ND | | | |
| X6352D | 101 | Cave Spring | 5/21/14 1200 | 5/23/14 1145 | ND | | | | ND | | | | ND | | | |
| X6544 | 101 | Cave Spring | 5/23/14 1145 | 5/28/14 1025 | ND | | | | ND | | | | ND | | | |
| X6544D | 101 | Cave Spring | 5/23/14 1145 | 5/28/14 1025 | ND | | | | ND | | | | ND | | | |
| X6718 | 101 | Cave Spring | 5/28/14 1025 | 6/4/14 1240 | ND | | | | ND | | | | ND | | | |
| X6718D | 101 | Cave Spring | 5/28/14 1025 | 6/4/14 1240 | ND | | | | ND | | | | ND | | | |
| X6982 | 101 | Cave Spring | 6/4/14 1240 | 6/12/14 1210 | ND | | | | ND | | | | ND | | | |
| X6982D | 101 | Cave Spring | 6/4/14 1240 | 6/12/14 1210 | ND | | | | ND | | | | ND | | | |
| X7430 | 101 | Cave Spring | 6/12/14 1210 | 6/19/14 0915 | ND | | | | ND | | | | ND | | | |
| X7430D | 101 | Cave Spring | 6/12/14 1210 | 6/19/14 0915 | ND | | | | ND | | | | ND | | | |
| X7595 | 101 | Cave Spring | 6/19/14 0915 | 6/29/14 1935 | ND | | | | ND | | | | ND | | | |
| X7595D | 101 | Cave Spring | 6/19/14 0915 | 6/29/14 1935 | ND | | | | ND | | | | ND | | | |
| X7966 | 101 | Cave Spring | 6/29/14 1935 | 7/8/14 1430 | ND | | | | ND | | | | ND | | | |
| X8163 | 101 | Cave Spring | 7/8/14 1430 | 7/16/14 1240 | ND | | | | ND | | | | ND | | | |
| X8163D | 101 | Cave Spring | 7/8/14 1430 | 7/16/14 1240 | ND | | | | ND | | | | ND | | | |
| X8405 | 101 | Cave Spring | 7/16/14 1240 | 7/23/14 1300 | ND | | | | ND | | | | ND | | | |
| X8405D | 101 | Cave Spring | 7/16/14 1240 | 7/23/14 1300 | ND | | | | ND | | | | ND | | | |
| X8770 | 101 | Cave Spring | 7/23/14 1300 | 7/31/14 1315 | ND | | | | ND | | | | ND | | | |
| X8770D | 101 | Cave Spring | 7/23/14 1300 | 7/31/14 1315 | ND | | | | ND | | | | ND | | | |
| X8937 | 101 | Cave Spring | 7/31/14 1315 | 8/6/14 1330 | 516.1 | 828 | 138 | 14-08 | ND | | | | ND | | | |
| X8937D | 101 | Cave Spring | 7/31/14 1315 | 8/6/14 1330 | 516.1 | 980 | 163 | 14-08 | ND | | | | ND | | | |
| X9348 | 101 | Cave Spring | 8/6/14 1330 | 8/12/14 0900 | 515.3 | 47.3 | 8.15 | 14-08 | ND | | | | 567.6 | 2.47 | 0.424 | 14-11 |
| X9348D | 101 | Cave Spring | 8/6/14 1330 | 8/12/14 0900 | 515.2 | 57.2 | 9.84 | 14-08 | ND | | | | 567.2 | 3.38 | 0.583 | 14-11 |
| X9316 | 101 | Cave Spring | 8/12/14 0900 | 8/15/14 1415 | 515.3 | 135 | 41.9 | 14-08 | ND | | | | ND | | | |
| X9316D | 101 | Cave Spring | 8/12/14 0900 | 8/15/14 1415 | 515.4 | 104 | 32.4 | 14-08 | ND | | | | ND | | | |
| X9509 | 101 | Cave Spring | 8/15/14 1415 | 8/21/14 1627 | 515.2 | 6.18 | 1.01 | 14-08 | ND | | | | ND | | | |
| X9772 | 101 | Cave Spring | 8/21/14 1627 | 8/26/14 0930 | 515.4 | 1.53 | 0.325 | 14-08 | ND | | | | ND | | | |
| X9987 | 101 | Cave Spring | 8/26/14 0930 | 9/4/14 1030 | 515.0 | 0.562 | 0.062 | 14-08 | ND | | | | ND | | | |
| X9987D | 101 | Cave Spring | 8/26/14 0930 | 9/4/14 1030 | 514.6 | 0.505 | 0.056 | 14-08 | ND | | | | ND | | | |

| OUL Number | Station Number | Station Name | Date/Time Placed | Date/Time Collected | Fluorescein Peak | Fluorescein Conc. | Fluorescein Conc./day | Fluorescein Trace No. | Eosine Peak | Eosine Conc. | Eosine Conc./day | Eosine Trace No. | RWT Peak | RWT Conc. | RWT Conc./day | RWT Trace No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Y0241 | 101 | Cave Spring | 9/4/14 1030 | 9/10/14 1910 | 515.8 | 2.52 | 0.397 | 14-08 | ND | | | | ND | | | |
| Y0241D | 101 | Cave Spring | 9/4/14 1030 | 9/10/14 1910 | 515.4 | 1.91 | 0.300 | 14-08 | ND | | | | ND | | | |
| Y0448 | 101 | Cave Spring | 9/10/14 1910 | 9/17/14 1200 | 515.2 ** | 0.172 | 0.026 | 14-08 | ND | | | | ND | | | |
| Y0448D | 101 | Cave Spring | 9/10/14 1910 | 9/17/14 1200 | 514.7 ** | 0.168 | 0.025 | 14-08 | ND | | | | ND | | | |
| Y0558 | 101 | Cave Spring | 9/17/14 1200 | 9/23/14 1145 | 515.4 | 0.557 | 0.093 | 14-08 | ND | | | | ND | | | |
| Y0558D | 101 | Cave Spring | 9/17/14 1200 | 9/23/14 1145 | 514.6 | 0.383 | 0.064 | 14-08 | ND | | | | ND | | | |
| Y0751 | 101 | Cave Spring | 9/23/14 1145 | 9/29/14 1230 | 515.4 | 0.184 | 0.031 | 14-08 | ND | | | | ND | | | |
| Y0751D | 101 | Cave Spring | 9/23/14 1145 | 9/29/14 1230 | 515.4 | 0.187 | 0.031 | 14-08 | ND | | | | ND | | | |
| Y1150 | 101 | Cave Spring | 9/29/14 1230 | 10/3/14 1545 | ND | | | | ND | | | | ND | | | |
| Y1150D | 101 | Cave Spring | 9/29/14 1230 | 10/3/14 1545 | ND | | | | ND | | | | ND | | | |
| Y1098 | 101 | Cave Spring | 10/3/14 1545 | 10/13/14 1330 | 515.4 | 3.99 | 0.402 | 14-08 | ND | | | | 565.2 | 2.57 | 0.259 | 14-13 |
| Y1437 | 101 | Cave Spring | 10/13/14 1330 | 10/20/14 1345 | 515.8 | 9.35 | 1.33 | 14-08 | ND | | | | 565.6 | 1.99 | 0.283 | 14-13 |
| Y1437D | 101 | Cave Spring | 10/13/14 1330 | 10/20/14 1345 | 515.8 | 8.96 | 1.28 | 14-08 | ND | | | | 565.2 | 2.14 | 0.305 | 14-13 |
| **X5835** | **102** | **Cave Spr - North Pipe** | **4/23/14 1700** | **5/1/14 1150** | **ND** | | | | **ND** | | | | **ND** | | | |
| X5925 | 102 | Cave Spr - North Pipe | 5/1/14 1150 | 5/7/14 1535 | ND | | | | ND | | | | ND | | | |
| X6295 | 102 | Cave Spr - North Pipe | 5/7/14 1535 | 5/14/14 1030 | ND | | | | ND | | | | ND | | | |
| X6316 | 102 | Cave Spr - North Pipe | 5/14/14 1030 | 5/21/14 1210 | ND | | | | ND | | | | ND | | | |
| X6545 | 102 | Cave Spr - North Pipe | 5/21/14 1210 | 5/28/14 1010 | ND | | | | ND | | | | ND | | | |
| X6719 | 102 | Cave Spr - North Pipe | 5/28/14 1010 | 6/4/14 1130 | ND | | | | ND | | | | ND | | | |
| X6983 | 102 | Cave Spr - North Pipe | 6/4/14 1130 | 6/12/14 1155 | ND | | | | ND | | | | ND | | | |
| X7431 | 102 | Cave Spr - North Pipe | 6/12/14 1155 | 6/19/14 0920 | ND | | | | ND | | | | ND | | | |
| X7596 | 102 | Cave Spr - North Pipe | 6/19/14 0920 | 6/29/14 1910 | ND | | | | ND | | | | ND | | | |
| X8164 | 102 | Cave Spr - North Pipe | 6/29/14 1910 | 7/16/14 1245 | ND | | | | ND | | | | ND | | | |
| **X5836** | **103** | **Cave Spr - NW Culvert** | **4/23/14 1710** | **5/1/14 1200** | **ND** | | | | **ND** | | | | **ND** | | | |
| X5926 | 103 | Cave Spr - NW Culvert | 5/1/14 1200 | 5/7/14 1540 | ND | | | | ND | | | | ND | | | |
| X6296 | 103 | Cave Spr - NW Culvert | 5/7/14 1540 | 5/14/14 1040 | ND | | | | ND | | | | ND | | | |
| X6317 | 103 | Cave Spr - NW Culvert | 5/14/14 1040 | 5/21/14 1215 | ND | | | | ND | | | | ND | | | |
| X6546 | 103 | Cave Spr - NW Culvert | 5/21/14 1215 | 5/28/14 1015 | ND | | | | ND | | | | ND | | | |
| X6721 | 103 | Cave Spr - NW Culvert | 5/28/14 1015 | 6/4/14 1140 | ND | | | | ND | | | | ND | | | |
| X6984 | 103 | Cave Spr - NW Culvert | 6/4/14 1140 | 6/12/14 1200 | ND | | | | ND | | | | ND | | | |
| X7432 | 103 | Cave Spr - NW Culvert | 6/12/14 1200 | 6/19/14 0925 | ND | | | | ND | | | | ND | | | |
| X7597 | 103 | Cave Spr - NW Culvert | 6/19/14 0925 | 6/29/14 1915 | ND | | | | ND | | | | ND | | | |
| X8165 | 103 | Cave Spr - NW Culvert | 6/29/14 1915 | 7/16/14 1250 | ND | | | | ND | | | | ND | | | |
| **X5837** | **104** | **Cave Spr - NE Culvert** | **4/23/14 1720** | **5/1/14 1205** | **ND** | | | | **ND** | | | | **ND** | | | |
| X5927 | 104 | Cave Spr - NE Culvert | 5/1/14 1205 | 5/7/14 1545 | ND | | | | ND | | | | ND | | | |
| X6297 | 104 | Cave Spr - NE Culvert | 5/7/14 1545 | 5/14/14 1045 | ND | | | | ND | | | | ND | | | |
| X6318 | 104 | Cave Spr - NE Culvert | 5/14/14 1045 | 5/21/14 1220 | ND | | | | ND | | | | ND | | | |
| X6547 | 104 | Cave Spr - NE Culvert | 5/21/14 1220 | 5/28/14 1020 | ND | | | | ND | | | | ND | | | |

| OUL | Station | Station Name | Date/Time | Date/Time | Fluorescein | | | | Eosine | | | | RWT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Number | | Placed | Collected | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. |
| X6722 | 104 | Cave Spr - NE Culvert | 5/28/14 1020 | 6/4/14 1145 | ND | | | | ND | | | | ND | | | |
| X6985 | 104 | Cave Spr - NE Culvert | 6/4/14 1145 | 6/12/14 1205 | ND | | | | ND | | | | ND | | | |
| X7433 | 104 | Cave Spr - NE Culvert | 6/12/14 1205 | 6/19/14 0930 | ND | | | | ND | | | | ND | | | |
| X7598 | 104 | Cave Spr - NE Culvert | 6/19/14 0930 | 6/29/14 1920 | ND | | | | ND | | | | ND | | | |
| X8166 | 104 | Cave Spr - NE Culvert | 6/29/14 1920 | 7/16/14 1255 | ND | | | | ND | | | | ND | | | |
| **X5838** | **105** | **Cave Spr - South Pipes** | **4/23/14 1730** | **5/1/14 1210** | **ND** | | | | **ND** | | | | **ND** | | | |
| X5928 | 105 | Cave Spr - South Pipes | 5/1/14 1210 | 5/7/14 1550 | ND | | | | ND | | | | ND | | | |
| X6298 | 105 | Cave Spr - South Pipes | 5/7/14 1550 | 5/14/14 1800 | ND | | | | ND | | | | ND | | | |
| X6319 | 105 | Cave Spr - South Pipes | 5/14/14 1800 | 5/21/14 1230 | ND | | | | ND | | | | ND | | | |
| X6548 | 105 | Cave Spr - South Pipes | 5/21/14 1230 | 5/28/14 1035 | ND | | | | ND | | | | ND | | | |
| X6723 | 105 | Cave Spr - South Pipes | 5/28/14 1035 | 6/4/14 1245 | ND | | | | ND | | | | ND | | | |
| X6986 | 105 | Cave Spr - South Pipes | 6/4/14 1245 | 6/12/14 1150 | ND | | | | ND | | | | ND | | | |
| X7434 | 105 | Cave Spr - South Pipes | 6/12/14 1150 | 6/19/14 1315 | ND | | | | ND | | | | ND | | | |
| X7599 | 105 | Cave Spr - South Pipes | 6/19/14 1315 | 6/29/14 1925 | ND | | | | ND | | | | ND | | | |
| X8167 | 105 | Cave Spr - South Pipes | 6/29/14 1925 | 7/16/14 1300 | ND | | | | ND | | | | ND | | | |
| **X5839** | **106** | **Cave Spr - South Valve** | **4/23/14 1740** | **5/1/14 1215** | **ND** | | | | **ND** | | | | **ND** | | | |
| X5929 | 106 | Cave Spr - South Valve | 5/1/14 1215 | 5/7/14 1555 | ND | | | | ND | | | | ND | | | |
| X6299 | 106 | Cave Spr - South Valve | 5/7/14 1555 | 5/14/14 1810 | ND | | | | ND | | | | ND | | | |
| X6321 | 106 | Cave Spr - South Valve | 5/14/14 1810 | 5/21/14 1235 | ND | | | | ND | | | | ND | | | |
| X6549 | 106 | Cave Spr - South Valve | 5/21/14 1235 | 5/28/14 1040 | ND | | | | ND | | | | ND | | | |
| X6724 | 106 | Cave Spr - South Valve | 5/28/14 1040 | 6/4/14 1250 | ND | | | | ND | | | | ND | | | |
| **X5930** | **107** | **Boat Ramp Spring - east** | **5/1/14 1225** | **5/7/14 1115** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6322 | 107 | Boat Ramp Spring - east | 5/7/14 1115 | 5/21/14 1310 | ND | | | | ND | | | | ND | | | |
| X6550 | 107 | Boat Ramp Spring - east | 5/21/14 1310 | 5/28/14 1135 | ND | | | | ND | | | | ND | | | |
| X6987 | 107 | Boat Ramp Spring - east | 5/28/14 1135 | 6/12/14 1120 | ND | | | | ND | | | | ND | | | |
| X7601 | 107 | Boat Ramp Spring - east | 6/12/14 1120 | 6/29/14 2030 | ND | | | | ND | | | | ND | | | |
| X8168 | 107 | Boat Ramp Spring - east | 6/29/14 2030 | 7/16/14 1325 | ND | | | | ND | | | | ND | | | |
| **X5931** | **108** | **Boat Ramp Spring - center** | **5/1/14 1230** | **5/7/14 1120** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6323 | 108 | Boat Ramp Spring - center | 5/7/14 1120 | 5/21/14 1315 | ND | | | | ND | | | | ND | | | |
| X6551 | 108 | Boat Ramp Spring - center | 5/21/14 1315 | 5/28/14 1140 | ND | | | | ND | | | | ND | | | |
| X6988 | 108 | Boat Ramp Spring - center | 5/28/14 1140 | 6/12/14 1125 | ND | | | | ND | | | | ND | | | |
| X7602 | 108 | Boat Ramp Spring - center | 6/12/14 1125 | 6/29/14 2035 | ND | | | | ND | | | | ND | | | |
| X8169 | 108 | Boat Ramp Spring - center | 6/29/14 2035 | 7/16/14 1330 | ND | | | | ND | | | | ND | | | |
| **X5932** | **109** | **Boat Ramp Spring - west** | **5/1/14 1235** | **5/7/14 1125** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6324 | 109 | Boat Ramp Spring - west | 5/7/14 1125 | 5/21/14 1320 | ND | | | | ND | | | | ND | | | |
| X6552 | 109 | Boat Ramp Spring - west | 5/21/14 1320 | 5/28/14 1145 | ND | | | | ND | | | | ND | | | |
| X6989 | 109 | Boat Ramp Spring - west | 5/28/14 1145 | 6/12/14 1130 | ND | | | | ND | | | | ND | | | |
| X7603 | 109 | Boat Ramp Spring - west | 6/12/14 1130 | 6/29/14 2040 | ND | | | | ND | | | | ND | | | |

## Cave Springs Area Karst Resource Conservation Study

| OUL Number | Station Number | Station Name | Date/Time Placed | Date/Time Collected | Fluorescein Peak | Fluorescein Conc. | Fluorescein Conc./day | Fluorescein Trace No. | Eosine Peak | Eosine Conc. | Eosine Conc./day | Eosine Trace No. | RWT Peak | RWT Conc. | RWT Conc./day | RWT Trace No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **X5933** | **110** | **Unnamed Trib at 112** | **5/1/14 1435** | **5/8/14 0845** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6325 | 110 | Unnamed Trib at 112 | 5/8/14 0845 | 5/21/14 1825 | ND | | | | ND | | | | ND | | | |
| X6553 | 110 | Unnamed Trib at 112 | 5/21/14 1825 | 5/28/14 1210 | ND | | | | ND | | | | ND | | | |
| X6725 | 110 | Unnamed Trib at 112 | 5/28/14 1210 | 6/4/14 1110 | ND | | | | ND | | | | ND | | | |
| X6990 | 110 | Unnamed Trib at 112 | 6/4/14 1110 | 6/12/14 1705 | ND | | | | ND | | | | ND | | | |
| X7435 | 110 | Unnamed Trib at 112 | 6/12/14 1705 | 6/19/14 1035 | ND | | | | ND | | | | ND | | | |
| X8170 | 110 | Unnamed Trib at 112 | 6/19/14 1035 | 7/16/14 1345 | ND | | | | ND | | | | ND | | | |
| X8771 | 110 | Unnamed Trib at 112 | 7/16/14 1345 | 7/31/14 1200 | ND | | | | ND | | | | ND | | | |
| X9349 | 110 | Unnamed Trib at 112 | 7/31/14 1200 | 8/12/14 0950 | ND | | | | ND | | | | ND | | | |
| X9317 | 110 | Unnamed Trib at 112 | 8/12/14 0950 | 8/15/14 0940 | ND | | | | ND | | | | ND | | | |
| X9774 | 110 | Unnamed Trib at 112 | 8/15/14 0940 | 8/27/14 1030 | ND | | | | ND | | | | ND | | | |
| X9988 | 110 | Unnamed Trib at 112 | 8/27/14 1030 | 9/4/14 1245 | ND | | | | ND | | | | ND | | | |
| Y0449 | 110 | Unnamed Trib at 112 | 9/4/14 1245 | 9/17/14 1130 | ND | | | | ND | | | | ND | | | |
| Y0559 | 110 | Unnamed Trib at 112 | 9/17/14 1130 | 9/23/14 1300 | ND | | | | ND | | | | ND | | | |
| Y0752 | 110 | Unnamed Trib at 112 | 9/23/14 1300 | 9/29/14 1340 | ND | | | | ND | | | | ND | | | |
| Y1099 | 110 | Unnamed Trib at 112 | 9/29/14 1340 | 10/13/14 1315 | ND | | | | ND | | | | ND | | | |
| **X5934** | **111** | **Shores Spring** | **5/1/14 1500** | **5/8/14 0855** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6301 | 111 | Shores Spring | 5/8/14 0855 | 5/14/14 1845 | ND | | | | ND | | | | ND | | | |
| X6326 | 111 | Shores Spring | 5/14/14 1845 | 5/21/14 1815 | ND | | | | ND | | | | ND | | | |
| X6554 | 111 | Shores Spring | 5/21/14 1815 | 5/28/14 1220 | ND | | | | ND | | | | ND | | | |
| X6726 | 111 | Shores Spring | 5/28/14 1220 | 6/4/14 1100 | ND | | | | ND | | | | ND | | | |
| X6991 | 111 | Shores Spring | 6/4/14 1100 | 6/12/14 1655 | ND | | | | ND | | | | ND | | | |
| X7436 | 111 | Shores Spring | 6/12/14 1655 | 6/19/14 1050 | ND | | | | ND | | | | ND | | | |
| X7604 | 111 | Shores Spring | 6/19/14 1050 | 6/30/14 1420 | ND | | | | ND | | | | ND | | | |
| X7967 | 111 | Shores Spring | 6/30/14 1420 | 7/8/14 1450 | ND | | | | ND | | | | ND | | | |
| X8171 | 111 | Shores Spring | 7/8/14 1450 | 7/16/14 1400 | ND | | | | ND | | | | ND | | | |
| X8406 | 111 | Shores Spring | 7/16/14 1400 | 7/23/14 1310 | ND | | | | ND | | | | ND | | | |
| X8772 | 111 | Shores Spring | 7/23/14 1310 | 7/31/14 1150 | ND | | | | ND | | | | ND | | | |
| X8938 | 111 | Shores Spring | 7/31/14 1150 | 8/6/14 1400 | ND | | | | ND | | | | ND | | | |
| X9350 | 111 | Shores Spring | 8/6/14 1400 | 8/12/14 1010 | ND | | | | ND | | | | ND | | | |
| X9318 | 111 | Shores Spring | 8/12/14 1010 | 8/15/14 0950 | ND | | | | ND | | | | ND | | | |
| X9510 | 111 | Shores Spring | 8/15/14 0950 | 8/21/14 1655 | ND | | | | ND | | | | ND | | | |
| X9775 | 111 | Shores Spring | 8/21/14 1655 | 8/27/14 1020 | ND | | | | ND | | | | ND | | | |
| X9989 | 111 | Shores Spring | 8/27/14 1020 | 9/4/14 1255 | ND | | | | ND | | | | ND | | | |
| Y0242 | 111 | Shores Spring | 9/4/14 1255 | 9/11/14 1210 | ND | | | | ND | | | | ND | | | |
| Y0450 | 111 | Shores Spring | 9/11/14 1210 | 9/17/14 1120 | ND | | | | 541.7 | 1,320 | 221 | 14-12 | ND | | | |
| Y0561 | 111 | Shores Spring | 9/17/14 1120 | 9/23/14 1310 | ND | | | | 541.3 | 154 | 25.4 | 14-12 | ND | | | |
| Y0753 | 111 | Shores Spring | 9/23/14 1310 | 9/29/14 1350 | ND | | | | 541.6 | 23.2 | 3.85 | 14-12 | ND | | | |

| OUL | Station | Station Name | Date/Time | Date/Time | Fluorescein | | | | Eosine | | | | RWT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Number | | Placed | Collected | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. |
| Y1151 | 111 | Shores Spring | 9/29/14 1350 | 10/3/14 1725 | ND | | | | 541.5 | 11.1 | 2.69 | 14-12 | ND | | | |
| Y1101 | 111 | Shores Spring | 10/3/14 1725 | 10/13/14 1300 | ND | | | | 541.6 | 30.7 | 3.12 | 14-12 | ND | | | |
| Y1438 | 111 | Shores Spring | 10/13/14 1300 | 10/20/14 1450 | ND | | | | 541.7 | 37.6 | 5.32 | 14-12 | ND | | | |
| **X5935** | **112** | **Wallis Spring** | **5/1/14 1815** | **5/8/14 0910** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6302 | 112 | Wallis Spring | 5/8/14 0910 | 5/14/14 1825 | ND | | | | ND | | | | ND | | | |
| X6327 | 112 | Wallis Spring | 5/14/14 1825 | 5/21/14 1800 | ND | | | | ND | | | | ND | | | |
| X6555 | 112 | Wallis Spring | 5/21/14 1800 | 5/28/14 1230 | ND | | | | ND | | | | ND | | | |
| X6727 | 112 | Wallis Spring | 5/28/14 1230 | 6/4/14 1050 | ND | | | | ND | | | | ND | | | |
| X6992 | 112 | Wallis Spring | 6/4/14 1050 | 6/12/14 1645 | ND | | | | ND | | | | ND | | | |
| X7437 | 112 | Wallis Spring | 6/12/14 1645 | 6/19/14 1100 | ND | | | | ND | | | | ND | | | |
| X7605 | 112 | Wallis Spring | 6/19/14 1100 | 6/30/14 1445 | ND | | | | ND | | | | ND | | | |
| X7968 | 112 | Wallis Spring | 6/30/14 1445 | 7/8/14 1510 | ND | | | | ND | | | | ND | | | |
| X8172 | 112 | Wallis Spring | 7/8/14 1510 | 7/16/14 1415 | ND | | | | ND | | | | ND | | | |
| X8407 | 112 | Wallis Spring | 7/16/14 1415 | 7/23/14 1330 | ND | | | | ND | | | | ND | | | |
| X8773 | 112 | Wallis Spring | 7/23/14 1330 | 7/31/14 1125 | ND | | | | ND | | | | ND | | | |
| X8939 | 112 | Wallis Spring | 7/31/14 1125 | 8/6/14 1420 | ND | | | | ND | | | | ND | | | |
| X9351 | 112 | Wallis Spring | 8/6/14 1420 | 8/12/14 1020 | ND | | | | ND | | | | ND | | | |
| X9319 | 112 | Wallis Spring | 8/12/14 1020 | 8/15/14 1000 | ND | | | | ND | | | | ND | | | |
| X9511 | 112 | Wallis Spring | 8/15/14 1000 | 8/21/14 1708 | ND | | | | ND | | | | ND | | | |
| X9776 | 112 | Wallis Spring | 8/21/14 1708 | 8/27/14 1015 | ND | | | | ND | | | | ND | | | |
| X9990 | 112 | Wallis Spring | 8/27/14 1015 | 9/4/14 1305 | ND | | | | ND | | | | ND | | | |
| Y0243 | 112 | Wallis Spring | 9/4/14 1305 | 9/11/14 1220 | ND | | | | ND | | | | ND | | | |
| Y0451 | 112 | Wallis Spring | 9/11/14 1220 | 9/17/14 1110 | ND | | | | 541.7 | 1,250 | 210 | 14-12 | ND | | | |
| Y0562 | 112 | Wallis Spring | 9/17/14 1110 | 9/23/14 1215 | ND | | | | 541.7 | 999 | 165 | 14-12 | ND | | | |
| Y0754 | 112 | Wallis Spring | 9/23/14 1215 | 9/29/14 1150 | ND | | | | 541.9 | 638 | 107 | 14-12 | ND | | | |
| Y1152 | 112 | Wallis Spring | 9/29/14 1150 | 10/3/14 1715 | ND | | | | 541.5 | 175 | 41.4 | 14-12 | ND | | | |
| Y1102 | 112 | Wallis Spring | 10/3/14 1715 | 10/13/14 1240 | ND | | | | 541.4 | 179 | 18.2 | 14-12 | ND | | | |
| Y1439 | 112 | Wallis Spring | 10/13/14 1240 | 10/20/14 1515 | ND | | | | 541.5 | 84.4 | 11.9 | 14-12 | ND | | | |
| **X5841** | **113** | **Osage Cr u/s SVGC Spr Br** | **4/23/14 1815** | **5/1/14 1540** | **ND** | | | | **ND** | | | | **ND** | | | |
| X5936 | 113 | Osage Cr u/s SVGC Spr Br | 5/1/14 1540 | 5/8/14 0925 | ND | | | | ND | | | | ND | | | |
| X6303 | 113 | Osage Cr u/s SVGC Spr Br | 5/8/14 0925 | 5/14/14 1900 | ND | | | | ND | | | | ND | | | |
| X6328 | 113 | Osage Cr u/s SVGC Spr Br | 5/14/14 1900 | 5/21/14 1750 | 515.0 | 11.2 | 1.61 | 14-01 | 541.8 | 172 | 24.7 | 14-03 | 568.4 | 449 | 64.7 | 14-02 |
| X6556 | 113 | Osage Cr u/s SVGC Spr Br | 5/21/14 1750 | 5/28/14 1240 | ND | | | | ND | | | | ND | | | |
| X6728 | 113 | Osage Cr u/s SVGC Spr Br | 5/28/14 1240 | 6/4/14 1030 | ND | | | | ND | | | | ND | | | |
| X6993 | 113 | Osage Cr u/s SVGC Spr Br | 6/4/14 1030 | 6/12/14 1615 | 519.4 | 1.53 | 0.186 | 14-06 | ND | | | | ND | | | |
| X7438 | 113 | Osage Cr u/s SVGC Spr Br | 6/12/14 1615 | 6/19/14 1130 | 518.4 | 0.779 | 0.115 | 14-06 | ND | | | | ND | | | |
| X7606 | 113 | Osage Cr u/s SVGC Spr Br | 6/19/14 1130 | 6/30/14 1500 | ND | | | | ND | | | | ND | | | |
| X8173 | 113 | Osage Cr u/s SVGC Spr Br | 6/30/14 1500 | 7/16/14 1430 | ND | | | | ND | | | | ND | | | |

| OUL | Station | Station Name | Date/Time | Date/Time | Fluorescein | | | | Eosine | | | | RWT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Number | | Placed | Collected | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. |
| X8774 | 113 | Osage Cr u/s SVGC Spr Br | 7/16/14 1430 | 7/31/14 1105 | ND | | | | ND | | | | ND | | | |
| X9321 | 113 | Osage Cr u/s SVGC Spr Br | 7/31/14 1105 | 8/15/14 1010 | ND | | | | 541.7 | 6.19 | 0.412 | 14-09 | ND | | | |
| X9777 | 113 | Osage Cr u/s SVGC Spr Br | 8/15/14 1010 | 8/27/14 0955 | ND | | | | ND | | | | ND | | | |
| **X5937** | **114** | **SVGC Spring Branch** | **5/1/14 1530** | **5/8/14 0930** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6304 | 114 | SVGC Spring Branch | 5/8/14 0930 | 5/14/14 1915 | ND | | | | ND | | | | ND | | | |
| X6329 | 114 | SVGC Spring Branch | 5/14/14 1915 | 5/21/14 1745 | ND | | | | ND | | | | ND | | | |
| X6557 | 114 | SVGC Spring Branch | 5/21/14 1745 | 5/28/14 1250 | ND | | | | ND | | | | ND | | | |
| X6729 | 114 | SVGC Spring Branch | 5/28/14 1250 | 6/4/14 1040 | ND | | | | ND | | | | ND | | | |
| X6994 | 114 | SVGC Spring Branch | 6/4/14 1040 | 6/12/14 1620 | ND | | | | ND | | | | ND | | | |
| X7439 | 114 | SVGC Spring Branch | 6/12/14 1620 | 6/19/14 1135 | ND | | | | ND | | | | ND | | | |
| X7607 | 114 | SVGC Spring Branch | 6/19/14 1135 | 6/30/14 1510 | ND | | | | ND | | | | ND | | | |
| X8174 | 114 | SVGC Spring Branch | 6/30/14 1510 | 7/16/14 1440 | ND | | | | ND | | | | ND | | | |
| X8775 | 114 | SVGC Spring Branch | 7/16/14 1440 | 7/31/14 1115 | ND | | | | ND | | | | ND | | | |
| X9322 | 114 | SVGC Spring Branch | 7/31/14 1115 | 8/15/14 1020 | ND | | | | ND | | | | ND | | | |
| X9778 | 114 | SVGC Spring Branch | 8/15/14 1020 | 8/27/14 1005 | ND | | | | ND | | | | ND | | | |
| **X6305** | **115** | **Osage Cr at Rainbow Rd** | **5/8/14 1000** | **5/14/14 1930** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6330 | 115 | Osage Cr at Rainbow Rd | 5/14/14 1930 | 5/21/14 1645 | 516.0 | 78.6 | 11.4 | 14-01 | ND | | | | 567.6 | 1,870 | 271 | 14-02 |
| X6558 | 115 | Osage Cr at Rainbow Rd | 5/21/14 1645 | 5/28/14 1310 | 515.5 | 1.97 | 0.287 | 14-01 | ND | | | | 569.4 | 23.2 | 3.38 | 14-02 |
| X6730 | 115 | Osage Cr at Rainbow Rd | 5/28/14 1310 | 6/4/14 1005 | 515.0 | 0.464 | 0.068 | 14-01 | ND | | | | 568.6 | 8.89 | 1.29 | 14-02 |
| X6995 | 115 | Osage Cr at Rainbow Rd | 6/4/14 1005 | 6/12/14 1750 | 516.4 | 0.589 | 0.071 | 14-01 | 541.6 ** | 4.28 | 0.515 | 14-05 | 570.0 | 6.54 | 0.786 | 14-02 |
| X7441 | 115 | Osage Cr at Rainbow Rd | 6/12/14 1750 | 6/19/14 1550 | 516.2 | 0.182 | 0.026 | 14-01 | 541.0 ** | 2.75 | 0.397 | 14-05 | 568.0 | 2.42 | 0.350 | 14-02 |
| X7608 | 115 | Osage Cr at Rainbow Rd | 6/19/14 1550 | 6/30/14 1535 | 515.8 | 0.230 | 0.021 | 14-01 | 541.6 ** | 1.59 | 0.145 | 14-05 | 569.0 | 2.34 | 0.213 | 14-02 |
| X8175 | 115 | Osage Cr at Rainbow Rd | 6/30/14 1535 | 7/16/14 1510 | ND | | | | 541.7 ** | 5.92 | 0.370 | 14-05 & 07 | ND | | | |
| X8776 | 115 | Osage Cr at Rainbow Rd | 7/16/14 1510 | 7/31/14 1040 | ND | | | | 541.4 ** | 6.73 | 0.455 | 14-05 & 07 | ND | | | |
| X9323 | 115 | Osage Cr at Rainbow Rd | 7/31/14 1040 | 8/15/14 1040 | ND | | | | 541.6 | 31.3 | 2.09 | 14-07 & 09 | ND | | | |
| X9779 | 115 | Osage Cr at Rainbow Rd | 8/15/14 1040 | 8/27/14 0935 | ND | | | | 541.4 | 3.94 | 0.329 | 14-07 & 09 | ND | | | |
| Y0244 | 115 | Osage Cr at Rainbow Rd | 8/27/14 0935 | 9/10/14 1940 | ND | | | | 541.2 | 4.71 | 0.327 | 14-07 & 09 | ND | | | |
| Y0452 | 115 | Osage Cr at Rainbow Rd | 9/10/14 1940 | 9/17/14 1030 | ND | | | | 542.2 | 2.55 | 0.385 | 14-07 & 09 | ND | | | |
| Y0563 | 115 | Osage Cr at Rainbow Rd | 9/17/14 1030 | 9/23/14 1240 | ND | | | | 541.8 | 0.905 | 0.149 | 14-07 & 09 | ND | | | |
| Y0755 | 115 | Osage Cr at Rainbow Rd | 9/23/14 1240 | 9/29/14 1130 | ND | | | | 541.2 | 3.36 | 0.565 | 14-07 & 09 | ND | | | |
| **X5842** | **116** | **Osage Cr d/s Cross Church** | **4/23/14 1500** | **5/1/14 1615** | **ND** | | | | **ND** | | | | **ND** | | | |
| X5938 | 116 | Osage Cr d/s Cross Church | 5/1/14 1615 | 5/8/14 1035 | ND | | | | ND | | | | ND | | | |
| X6331 | 116 | Osage Cr d/s Cross Church | 5/8/14 1035 | 5/21/14 1655 | 516.1 | 7.85 | 0.590 | 14-01 | ND | | | | ND | | | |
| X6559 | 116 | Osage Cr d/s Cross Church | 5/21/14 1655 | 5/28/14 1325 | 515.8 | 4.51 | 0.658 | 14-01 | ND | | | | ND | | | |
| X6731 | 116 | Osage Cr d/s Cross Church | 5/28/14 1325 | 6/4/14 2025 | 515.8 | 0.843 | 0.116 | 14-01 | ND | | | | ND | | | |
| X6996 | 116 | Osage Cr d/s Cross Church | 6/4/14 2025 | 6/12/14 1815 | 515.4 | 0.387 | 0.049 | 14-01 | 541.4 | 9.25 | 1.17 | 14-05 | ND | | | |
| X7442 | 116 | Osage Cr d/s Cross Church | 6/12/14 1815 | 6/19/14 1620 | ND | | | | 541.6 | 5.57 | 0.806 | 14-05 | ND | | | |
| X7609 | 116 | Osage Cr d/s Cross Church | 6/19/14 1620 | 6/30/14 0930 | ND | | | | 541.8 | 2.95 | 0.276 | 14-05 | ND | | | |

Cave Springs Area Karst Resource Conservation Study

| OUL Number | Station Number | Station Name | Date/Time Placed | Date/Time Collected | Fluorescein Peak | Fluorescein Conc. | Fluorescein Conc./day | Fluorescein Trace No. | Eosine Peak | Eosine Conc. | Eosine Conc./day | Eosine Trace No. | RWT Peak | RWT Conc. | RWT Conc./day | RWT Trace No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| X8176 | 116 | Osage Cr d/s Cross Church | 6/30/14 0930 | 7/17/14 0910 | ND | | | | 541.5 | 18.5 | 1.09 | 14-05 & 07 | ND | | | |
| X8777 | 116 | Osage Cr d/s Cross Church | 7/17/14 0910 | 7/31/14 0955 | ND | | | | 541.6 | 14.6 | 1.04 | 14-05 & 07 | ND | | | |
| X9324 | 116 | Osage Cr d/s Cross Church | 7/31/14 0955 | 8/15/14 1100 | ND | | | | 541.6 | 80.0 | 5.33 | 14-07 & 09 | ND | | | |
| X9781 | 116 | Osage Cr d/s Cross Church | 8/15/14 1100 | 8/27/14 0915 | ND | | | | 541.7 | 13.5 | 1.14 | 14-07 & 09 | ND | | | |
| **X5939** | **117** | **Village Pond Outfall** | **5/1/14 1620** | **5/8/14 1030** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6332 | 117 | Village Pond Outfall | 5/8/14 1030 | 5/21/14 1635 | ND | | | | ND | | | | ND | | | |
| X6561 | 117 | Village Pond Outfall | 5/21/14 1635 | 5/28/14 1340 | ND | | | | ND | | | | ND | | | |
| X6732 | 117 | Village Pond Outfall | 5/28/14 1340 | 6/4/14 2030 | ND | | | | ND | | | | ND | | | |
| X6997 | 117 | Village Pond Outfall | 6/4/14 2030 | 6/12/14 1820 | ND | | | | ND | | | | ND | | | |
| X7443 | 117 | Village Pond Outfall | 6/12/14 1820 | 6/19/14 1630 | ND | | | | ND | | | | ND | | | |
| X7610 | 117 | Village Pond Outfall | 6/19/14 1630 | 6/30/14 0940 | ND | | | | ND | | | | ND | | | |
| X8177 | 117 | Village Pond Outfall | 6/30/14 0940 | 7/17/14 0920 | ND | | | | ND | | | | ND | | | |
| X8778 | 117 | Village Pond Outfall | 7/17/14 0920 | 7/31/14 1010 | ND | | | | ND | | | | ND | | | |
| X9325 | 117 | Village Pond Outfall | 7/31/14 1010 | 8/15/14 1110 | ND | | | | ND | | | | ND | | | |
| X9782 | 117 | Village Pond Outfall | 8/15/14 1110 | 8/27/14 0920 | ND | | | | ND | | | | ND | | | |
| **X5941** | **118** | **Osage Cr u/s Blossom Way** | **5/1/14 1630** | **5/7/14 2015** | **ND** | | | | **ND** | | | | **ND** | | | |
| | 118 | Osage Cr u/s Blossom Way | 5/7/14 2015 | 5/21/14 1625 | water sample only | | | | | | | | | | | |
| X6562 | 118 | Osage Cr u/s Blossom Way | 5/21/14 1625 | 5/28/14 1550 | 515.4 | 11.1 | 1.59 | 14-01 | ND | | | | ND | | | |
| X6733 | 118 | Osage Cr u/s Blossom Way | 5/28/14 1550 | 6/4/14 2010 | 515.8 | 1.70 | 0.237 | 14-01 | ND | | | | ND | | | |
| X6998 | 118 | Osage Cr u/s Blossom Way | 6/4/14 2010 | 6/12/14 1840 | 515.6 | 0.683 | 0.086 | 14-01 | ND | | | | ND | | | |
| X7444 | 118 | Osage Cr u/s Blossom Way | 6/12/14 1840 | 6/19/14 1645 | 516.2 | 0.159 | 0.023 | 14-01 | ND | | | | ND | | | |
| X7611 | 118 | Osage Cr u/s Blossom Way | 6/19/14 1645 | 6/30/14 0700 | 514.8 | 0.361 | 0.034 | 14-01 | ND | | | | ND | | | |
| X8178 | 118 | Osage Cr u/s Blossom Way | 6/30/14 0700 | 7/17/14 0815 | ND | | | | ND | | | | ND | | | |
| X8779 | 118 | Osage Cr u/s Blossom Way | 7/17/14 0815 | 7/31/14 1455 | ND | | | | ND | | | | ND | | | |
| X9326 | 118 | Osage Cr u/s Blossom Way | 7/31/14 1455 | 8/15/14 1125 | ND | | | | ND | | | | ND | | | |
| X9783 | 118 | Osage Cr u/s Blossom Way | 8/15/14 1125 | 8/27/14 0905 | ND | | | | ND | | | | ND | | | |
| **X5942** | **119** | **Osage West Spring** | **5/1/14 1645** | **5/7/14 2005** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6333 | 119 | Osage West Spring | 5/7/14 2005 | 5/21/14 1530 | 515.5 | 172 | 12.5 | 14-01 | ND | | | | ND | | | |
| X6563 | 119 | Osage West Spring | 5/21/14 1530 | 5/28/14 1515 | 515.4 | 74.7 | 10.7 | 14-01 | ND | | | | ND | | | |
| X6734 | 119 | Osage West Spring | 5/28/14 1515 | 6/4/14 2000 | 515.8 | 5.39 | 0.749 | 14-01 | ND | | | | ND | | | |
| X6999 | 119 | Osage West Spring | 6/4/14 2000 | 6/12/14 1910 | 515.8 | 1.48 | 0.185 | 14-01 | ND | | | | ND | | | |
| X7612 | 119 | Osage West Spring | 6/12/14 1910 | 6/30/14 0800 | 514.6 | 0.923 | 0.053 | 14-01 | ND | | | | ND | | | |
| X8179 | 119 | Osage West Spring | 6/30/14 0800 | 7/17/14 0825 | 514.8 | 0.299 | 0.018 | 14-01 | ND | | | | ND | | | |
| X9784 | 119 | Osage West Spring | 7/17/14 0825 | 8/27/14 0755 | 513.2 ** | 0.153 | 0.004 | 14-01 | ND | | | | ND | | | |
| **X5843** | **120** | **Osage Spring** | **4/23/14 1300** | **5/1/14 1700** | **ND** | | | | **ND** | | | | **ND** | | | |
| X5943 | 120 | Osage Spring | 5/1/14 1700 | 5/7/14 1910 | ND | | | | ND | | | | ND | | | |
| X6306 | 120 | Osage Spring | 5/7/14 1910 | 5/15/14 1220 | 515.3 | 1.32 | 0.171 | 14-01 | ND | | | | ND | | | |
| X6334 | 120 | Osage Spring | 5/15/14 1220 | 5/21/14 1455 | 515.3 | 37.8 | 6.19 | 14-01 | ND | | | | ND | | | |

| OUL | Station | Station Name | Date/Time | Date/Time | Fluorescein | | | | Eosine | | | | RWT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Number | | Placed | Collected | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. |
| X6564 | 120 | Osage Spring | 5/21/14 1455 | 5/28/14 1455 | 515.4 | 6.13 | 0.876 | 14-01 | ND | | | | ND | | | |
| X6735 | 120 | Osage Spring | 5/28/14 1455 | 6/4/14 1940 | 515.6 | 3.97 | 0.551 | 14-01 | ND | | | | ND | | | |
| X7001 | 120 | Osage Spring | 6/4/14 1940 | 6/12/14 1940 | 515.4 | 1.26 | 0.158 | 14-01 | ND | | | | ND | | | |
| X7445 | 120 | Osage Spring | 6/12/14 1940 | 6/19/14 1815 | 515.8 | 0.476 | 0.069 | 14-01 | ND | | | | ND | | | |
| X7613 | 120 | Osage Spring | 6/19/14 1815 | 6/30/14 0825 | 516.9 | 0.458 | 0.043 | 14-01 | ND | | | | ND | | | |
| X8181 | 120 | Osage Spring | 6/30/14 0825 | 7/16/14 1935 | 515.8 | 0.316 | 0.019 | 14-01 | ND | | | | ND | | | |
| X8408 | 120 | Osage Spring | 7/16/14 1935 | 7/23/14 1030 | 513.6 ** | 0.191 | 0.029 | 14-01 | ND | | | | ND | | | |
| X8781 | 120 | Osage Spring | 7/23/14 1030 | 7/31/14 1600 | 515.8 | 0.167 | 0.020 | 14-01 | ND | | | | ND | | | |
| X9785 | 120 | Osage Spring | 7/31/14 1600 | 8/27/14 0825 | ND | | | | ND | | | | ND | | | |
| Y0245 | 120 | Osage Spring | 8/27/14 0825 | 9/11/14 1350 | ND | | | | ND | | | | ND | | | |
| Y0564 | 120 | Osage Spring | 9/11/14 1350 | 9/23/14 1550 | ND | | | | ND | | | | ND | | | |
| **X5844** | **121** | **Osage Spr - Culvert 1** | **4/23/14 1320** | **5/1/14 1705** | **ND** | | | | **ND** | | | | **ND** | | | |
| X5944 | 121 | Osage Spr - Culvert 1 | 5/1/14 1705 | 5/7/14 1915 | ND | | | | ND | | | | ND | | | |
| X6307 | 121 | Osage Spr - Culvert 1 | 5/7/14 1915 | 5/15/14 1215 | 514.6 | 0.530 | 0.069 | 14-01 | ND | | | | ND | | | |
| X6335 | 121 | Osage Spr - Culvert 1 | 5/15/14 1215 | 5/21/14 1450 | 515.2 | 29.1 | 4.76 | 14-01 | ND | | | | ND | | | |
| X6565 | 121 | Osage Spr - Culvert 1 | 5/21/14 1450 | 5/28/14 1450 | 515.6 | 5.33 | 0.762 | 14-01 | ND | | | | ND | | | |
| X6736 | 121 | Osage Spr - Culvert 1 | 5/28/14 1450 | 6/4/14 1930 | 515.2 | 3.26 | 0.454 | 14-01 | ND | | | | ND | | | |
| X7002 | 121 | Osage Spr - Culvert 1 | 6/4/14 1930 | 6/12/14 1935 | 515.2 | 1.18 | 0.148 | 14-01 | ND | | | | ND | | | |
| X7446 | 121 | Osage Spr - Culvert 1 | 6/12/14 1935 | 6/19/14 1810 | 515.6 | 0.443 | 0.064 | 14-01 | ND | | | | ND | | | |
| X7614 | 121 | Osage Spr - Culvert 1 | 6/19/14 1810 | 6/30/14 0820 | 515.8 | 0.814 | 0.077 | 14-01 | ND | | | | ND | | | |
| X8182 | 121 | Osage Spr - Culvert 1 | 6/30/14 0820 | 7/16/14 1930 | 516.4 | 0.456 | 0.028 | 14-01 | ND | | | | ND | | | |
| X8409 | 121 | Osage Spr - Culvert 1 | 7/16/14 1930 | 7/23/14 1025 | 514.8 | 0.171 | 0.026 | 14-01 | ND | | | | ND | | | |
| | 121 | Osage Spr - Culvert 1 | 7/23/14 1025 | 7/31/14 1555 | wso | | | | | | | | | | | |
| X9786 | 121 | Osage Spr - Culvert 1 | 7/31/14 1555 | 8/27/14 0820 | 514.6 | 0.130 | 0.005 | 14-01 | ND | | | | ND | | | |
| Y0246 | 121 | Osage Spr - Culvert 1 | 8/27/14 0820 | 9/11/14 1345 | ND | | | | ND | | | | ND | | | |
| Y0565 | 121 | Osage Spr - Culvert 1 | 9/11/14 1345 | 9/23/14 1545 | ND | | | | ND | | | | ND | | | |
| **X5845** | **122** | **Osage Spr - Culvert 2** | **4/23/14 1350** | **5/1/14 1710** | **ND** | | | | **ND** | | | | **ND** | | | |
| X5945 | 122 | Osage Spr - Culvert 2 | 5/1/14 1710 | 5/7/14 1925 | ND | | | | ND | | | | ND | | | |
| X6308 | 122 | Osage Spr - Culvert 2 | 5/7/14 1925 | 5/15/14 1205 | 514.8 | 0.445 | 0.058 | 14-01 | ND | | | | ND | | | |
| X6336 | 122 | Osage Spr - Culvert 2 | 5/15/14 1205 | 5/21/14 1445 | 515.5 | 21.5 | 3.52 | 14-01 | ND | | | | ND | | | |
| X6566 | 122 | Osage Spr - Culvert 2 | 5/21/14 1445 | 5/28/14 1445 | 514.6 | 1.49 | 0.213 | 14-01 | ND | | | | ND | | | |
| X6737 | 122 | Osage Spr - Culvert 2 | 5/28/14 1445 | 6/4/14 1920 | 514.8 | 0.646 | 0.090 | 14-01 | ND | | | | ND | | | |
| X7003 | 122 | Osage Spr - Culvert 2 | 6/4/14 1920 | 6/12/14 1930 | 514.8 | 0.804 | 0.100 | 14-01 | ND | | | | ND | | | |
| X7447 | 122 | Osage Spr - Culvert 2 | 6/12/14 1930 | 6/19/14 1805 | 514.6 | 0.516 | 0.074 | 14-01 | ND | | | | ND | | | |
| X7615 | 122 | Osage Spr - Culvert 2 | 6/19/14 1805 | 6/30/14 0815 | 515.0 | 0.682 | 0.064 | 14-01 | ND | | | | ND | | | |
| X8183 | 122 | Osage Spr - Culvert 2 | 6/30/14 0815 | 7/16/14 1925 | 516.8 | 0.741 | 0.045 | 14-01 | ND | | | | ND | | | |
| **X5846** | **123** | **Osage Spr - Culvert 3** | **4/23/14 1400** | **5/1/14 1715** | **ND** | | | | **ND** | | | | **ND** | | | |
| X5946 | 123 | Osage Spr - Culvert 3 | 5/1/14 1715 | 5/7/14 1935 | ND | | | | ND | | | | ND | | | |

| OUL | Station | Station Name | Date/Time | Date/Time | Fluorescein | | | | Eosine | | | | RWT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Number | | Placed | Collected | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. |
| X6309 | 123 | Osage Spr - Culvert 3 | 5/7/14 1935 | 5/15/14 1155 | ND | | | | ND | | | | ND | | | |
| X6337 | 123 | Osage Spr - Culvert 3 | 5/15/14 1155 | 5/21/14 1440 | ND | | | | ND | | | | ND | | | |
| X6567 | 123 | Osage Spr - Culvert 3 | 5/21/14 1440 | 5/28/14 1440 | ND | | | | ND | | | | ND | | | |
| X6738 | 123 | Osage Spr - Culvert 3 | 5/28/14 1440 | 6/4/14 1910 | ND | | | | ND | | | | ND | | | |
| X7004 | 123 | Osage Spr - Culvert 3 | 6/4/14 1910 | 6/12/14 1925 | ND | | | | ND | | | | ND | | | |
| X7448 | 123 | Osage Spr - Culvert 3 | 6/12/14 1925 | 6/19/14 1800 | ND | | | | ND | | | | ND | | | |
| X7616 | 123 | Osage Spr - Culvert 3 | 6/19/14 1800 | 6/30/14 0810 | ND | | | | ND | | | | ND | | | |
| X8184 | 123 | Osage Spr - Culvert 3 | 6/30/14 0810 | 7/16/14 1920 | ND | | | | ND | | | | ND | | | |
| X8410 | 123 | Osage Spr - Culvert 3 | 7/16/14 1920 | 7/23/14 1015 | ND | | | | ND | | | | ND | | | |
| X8782 | 123 | Osage Spr - Culvert 3 | 7/23/14 1015 | 7/31/14 1545 | ND | | | | ND | | | | ND | | | |
| **X5847** | **124** | **Blossom Way d/s South Spr** | **4/23/14 1340** | **5/1/14 1720** | **ND** | | | | **ND** | | | | **ND** | | | |
| X5947 | 124 | Blossom Way d/s South Spr | 5/1/14 1720 | 5/7/14 1920 | ND | | | | ND | | | | ND | | | |
| X6310 | 124 | Blossom Way d/s South Spr | 5/7/14 1920 | 5/15/14 1230 | 515.8 | 1.38 | 0.179 | 14-01 | ND | | | | ND | | | |
| X6338 | 124 | Blossom Way d/s South Spr | 5/15/14 1230 | 5/21/14 1500 | 515.4 | 140 | 22.9 | 14-01 | ND | | | | ND | | | |
| X6568 | 124 | Blossom Way d/s South Spr | 5/21/14 1500 | 5/28/14 1500 | 515.0 | 1.94 | 0.277 | 14-01 | ND | | | | ND | | | |
| X6739 | 124 | Blossom Way d/s South Spr | 5/28/14 1500 | 6/4/14 1950 | 515.4 | 0.894 | 0.124 | 14-01 | ND | | | | ND | | | |
| X7005 | 124 | Blossom Way d/s South Spr | 6/4/14 1950 | 6/12/14 1945 | ND | | | | 541.6 | 10.5 | 1.32 | 14-05 | ND | | | |
| X7449 | 124 | Blossom Way d/s South Spr | 6/12/14 1945 | 6/19/14 1825 | ND | | | | 541.5 | 7.33 | 1.06 | 14-05 | ND | | | |
| X7617 | 124 | Blossom Way d/s South Spr | 6/19/14 1825 | 6/30/14 0830 | ND | | | | 541.4 | 4.52 | 0.426 | 14-05 | ND | | | |
| X8185 | 124 | Blossom Way d/s South Spr | 6/30/14 0830 | 7/16/14 1945 | ND | | | | 541.7 | 12.7 | 0.770 | 14-05 & 07 | ND | | | |
| X8411 | 124 | Blossom Way d/s South Spr | 7/16/14 1945 | 7/23/14 1035 | ND | | | | 541.4 | 4.89 | 0.738 | 14-05 & 07 | ND | | | |
| X8783 | 124 | Blossom Way d/s South Spr | 7/23/14 1035 | 7/31/14 1605 | ND | | | | 541.6 | 1.15 | 0.140 | 14-05 & 07 | ND | | | |
| X9787 | 124 | Blossom Way d/s South Spr | 7/31/14 1605 | 8/27/14 0830 | ND | | | | 541.6 | 58.5 | 2.19 | 14-07 & 09 | ND | | | |
| Y0247 | 124 | Blossom Way d/s South Spr | 8/27/14 0830 | 9/11/14 1410 | ND | | | | 541.8 | 3.77 | 0.248 | 14-07 & 09 | ND | | | |
| Y0453 | 124 | Blossom Way d/s South Spr | 9/11/14 1410 | 9/17/14 1425 | ND | | | | 541.8 | 0.348 | 0.058 | 14-07 & 09 | ND | | | |
| Y0566 | 124 | Blossom Way d/s South Spr | 9/17/14 1425 | 9/23/14 1600 | ND | | | | 542.6 | 1.54 | 0.254 | 14-07 & 09 | ND | | | |
| Y0756 | 124 | Blossom Way d/s South Spr | 9/23/14 1600 | 9/29/14 1520 | ND | | | | 541.6 | 1.70 | 0.284 | 14-07 & 09 | ND | | | |
| **X6311** | **125** | **Blossom Way u/s South Spr** | **5/7/14 1930** | **5/15/14 1245** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6339 | 125 | Blossom Way u/s South Spr | 5/15/14 1245 | 5/21/14 1420 | ND | | | | ND | | | | ND | | | |
| X6569 | 125 | Blossom Way u/s South Spr | 5/21/14 1420 | 5/28/14 1420 | ND | | | | ND | | | | ND | | | |
| X6741 | 125 | Blossom Way u/s South Spr | 5/28/14 1420 | 6/4/14 1545 | ND | | | | ND | | | | ND | | | |
| X7006 | 125 | Blossom Way u/s South Spr | 6/4/14 1545 | 6/12/14 2015 | ND | | | | 542.2 ** | 2.48 | 0.303 | 14-05 | ND | | | |
| X7450 | 125 | Blossom Way u/s South Spr | 6/12/14 2015 | 6/19/14 1730 | ND | | | | 541.2 ** | 0.746 | 0.108 | 14-05 | ND | | | |
| X7618 | 125 | Blossom Way u/s South Spr | 6/19/14 1730 | 6/30/14 0715 | ND | | | | 541.6 | 2.13 | 0.201 | 14-05 | ND | | | |
| X8186 | 125 | Blossom Way u/s South Spr | 6/30/14 0715 | 7/16/14 1900 | ND | | | | 542.0 | 1.16 | 0.070 | 14-05 | ND | | | |
| X8784 | 125 | Blossom Way u/s South Spr | 7/16/14 1900 | 7/31/14 1505 | ND | | | | ND | | | | ND | | | |
| X9327 | 125 | Blossom Way u/s South Spr | 7/31/14 1505 | 8/15/14 1200 | ND | | | | ND | | | | ND | | | |
| X9788 | 125 | Blossom Way u/s South Spr | 8/15/14 1200 | 8/27/14 0850 | ND | | | | ND | | | | ND | | | |

Cave Springs Area Karst Resource Conservation Study

| OUL | Station | Station Name | Date/Time | Date/Time | Fluorescein | | | | Eosine | | | | RWT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Number | | Placed | Collected | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. |
| Y0248 | 125 | Blossom Way u/s South Spr | 8/27/14 0850 | 9/11/14 1320 | ND | | | | 541.8 ** | 1.09 | 0.072 | 14-07 & 09 | ND | | | |
| Y0454 | 125 | Blossom Way u/s South Spr | 9/11/14 1320 | 9/17/14 1335 | ND | | | | ND | | | | ND | | | |
| Y0567 | 125 | Blossom Way u/s South Spr | 9/17/14 1335 | 9/23/14 1530 | ND | | | | ND | | | | ND | | | |
| Y0757 | 125 | Blossom Way u/s South Spr | 9/23/14 1530 | 9/29/14 1500 | ND | | | | ND | | | | ND | | | |
| **X6312** | **126** | **North Spring** | **5/8/14 1115** | **5/14/14 1405** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6341 | 126 | North Spring | 5/14/14 1405 | 5/21/14 1550 | 515.9 | 981 | 139 | 14-01 | ND | | | | ND | | | |
| X6570 | 126 | North Spring | 5/21/14 1550 | 5/28/14 1540 | 515.2 | 6.29 | 0.900 | 14-01 | ND | | | | ND | | | |
| X6742 | 126 | North Spring | 5/28/14 1540 | 6/4/14 1825 | 515.4 | 3.06 | 0.431 | 14-01 | ND | | | | ND | | | |
| X7007 | 126 | North Spring | 6/4/14 1825 | 6/12/14 1855 | 515.0 | 1.75 | 0.218 | 14-01 | ND | | | | ND | | | |
| X7451 | 126 | North Spring | 6/12/14 1855 | 6/19/14 1715 | 515.8 | 0.358 | 0.052 | 14-01 | ND | | | | ND | | | |
| X7619 | 126 | North Spring | 6/19/14 1715 | 6/30/14 0730 | 514.6 | 0.384 | 0.036 | 14-01 | ND | | | | ND | | | |
| X8187 | 126 | North Spring | 6/30/14 0730 | 7/17/14 0850 | 515.2 | 0.355 | 0.021 | 14-01 | ND | | | | ND | | | |
| X8785 | 126 | North Spring | 7/17/14 0850 | 7/31/14 1530 | ND | | | | ND | | | | ND | | | |
| X9328 | 126 | North Spring | 7/31/14 1530 | 8/15/14 1230 | ND | | | | ND | | | | ND | | | |
| X9789 | 126 | North Spring | 8/15/14 1230 | 8/27/14 0740 | ND | | | | ND | | | | ND | | | |
| **X6313** | **127** | **Osage Cr u/s North Spring** | **5/8/14 1100** | **5/14/14 1345** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6342 | 127 | Osage Cr u/s North Spring | 5/14/14 1345 | 5/21/14 1600 | 516.0 | 1,340 | 189 | 14-01 | ND | | | | ND | | | |
| X6571 | 127 | Osage Cr u/s North Spring | 5/21/14 1600 | 5/28/14 1530 | 515.2 | 3.01 | 0.432 | 14-01 | ND | | | | ND | | | |
| X6743 | 127 | Osage Cr u/s North Spring | 5/28/14 1530 | 6/4/14 1815 | 514.8 ** | 0.450 | 0.063 | 14-01 | ND | | | | ND | | | |
| X7452 | 127 | Osage Cr u/s North Spring | 6/4/14 1815 | 6/19/14 1700 | ND | | | | ND | | | | ND | | | |
| X7621 | 127 | Osage Cr u/s North Spring | 6/19/14 1700 | 6/30/14 0740 | ND | | | | ND | | | | ND | | | |
| X8188 | 127 | Osage Cr u/s North Spring | 6/30/14 0740 | 7/17/14 0840 | ND | | | | ND | | | | ND | | | |
| X8786 | 127 | Osage Cr u/s North Spring | 7/17/14 0840 | 7/31/14 1520 | ND | | | | ND | | | | ND | | | |
| X9329 | 127 | Osage Cr u/s North Spring | 7/31/14 1520 | 8/15/14 1220 | ND | | | | ND | | | | ND | | | |
| X9790 | 127 | Osage Cr u/s North Spring | 8/15/14 1220 | 8/27/14 0730 | ND | | | | ND | | | | ND | | | |
| **X5948** | **128** | **Spring Creek u/s 112** | **5/1/14 1415** | **5/7/14 1135** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6343 | 128 | Spring Creek u/s 112 | 5/7/14 1135 | 5/21/14 1845 | ND | | | | ND | | | | ND | | | |
| X6572 | 128 | Spring Creek u/s 112 | 5/21/14 1845 | 5/28/14 1835 | ND | | | | ND | | | | ND | | | |
| X6744 | 128 | Spring Creek u/s 112 | 5/28/14 1835 | 6/4/14 1335 | ND | | | | ND | | | | ND | | | |
| X7008 | 128 | Spring Creek u/s 112 | 6/4/14 1335 | 6/12/14 1110 | ND | | | | ND | | | | ND | | | |
| X7453 | 128 | Spring Creek u/s 112 | 6/12/14 1110 | 6/19/14 0945 | ND | | | | ND | | | | ND | | | |
| X7622 | 128 | Spring Creek u/s 112 | 6/19/14 0945 | 6/30/14 1310 | ND | | | | ND | | | | ND | | | |
| X8189 | 128 | Spring Creek u/s 112 | 6/30/14 1310 | 7/17/14 1015 | ND | | | | ND | | | | ND | | | |
| | 128 | Spring Creek u/s 112 | 7/17/14 1015 | 7/31/14 1940 | water sample only | | | | | | | | | | | |
| | 128 | Spring Creek u/s 112 | 7/31/14 1940 | 8/6/14 1445 | water sample only | | | | | | | | | | | |
| X9352 | 128 | Spring Creek u/s 112 | 8/6/14 1445 | 8/12/14 1110 | ND | | | | ND | | | | 570.8 | 18.3 | 3.13 | 14-11 |
| X9330 | 128 | Spring Creek u/s 112 | 8/12/14 1110 | 8/15/14 1515 | ND | | | | ND | | | | 568.8 | 30.4 | 9.59 | 14-11 |
| X9791 | 128 | Spring Creek u/s 112 | 8/15/14 1515 | 8/27/14 1100 | ND | | | | ND | | | | ND | | | |

Cave Springs Area Karst Resource Conservation Study

| OUL | Station | Station Name | Date/Time | Date/Time | Fluorescein | | | | Eosine | | | | RWT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Number | | Placed | Collected | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. |
| **X5949** | **129** | **Johnson Spring 1** | **5/1/14 1400** | **5/7/14 1150** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6344 | 129 | Johnson Spring 1 | 5/7/14 1150 | 5/21/14 1855 | ND | | | | ND | | | | ND | | | |
| X6745 | 129 | Johnson Spring 1 | 5/21/14 1855 | 6/4/14 1345 | ND | | | | ND | | | | ND | | | |
| X7009 | 129 | Johnson Spring 1 | 6/4/14 1345 | 6/12/14 1100 | ND | | | | ND | | | | ND | | | |
| X7454 | 129 | Johnson Spring 1 | 6/12/14 1100 | 6/19/14 1005 | ND | | | | ND | | | | ND | | | |
| **X6746** | **130** | **Johnson Spring 2** | **5/21/14 1900** | **6/4/14 1350** | **ND** | | | | **ND** | | | | **ND** | | | |
| X7010 | 130 | Johnson Spring 2 | 6/4/14 1350 | 6/12/14 1055 | ND | | | | ND | | | | ND | | | |
| X7455 | 130 | Johnson Spring 2 | 6/12/14 1055 | 6/19/14 1010 | ND | | | | ND | | | | ND | | | |
| **X5950** | **131** | **Johnson Spring 3** | **5/1/14 1350** | **5/7/14 1200** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6345 | 131 | Johnson Spring 3 | 5/7/14 1200 | 5/21/14 1905 | ND | | | | ND | | | | ND | | | |
| X6747 | 131 | Johnson Spring 3 | 5/21/14 1905 | 6/4/14 1355 | ND | | | | ND | | | | ND | | | |
| X7011 | 131 | Johnson Spring 3 | 6/4/14 1355 | 6/12/14 1050 | ND | | | | ND | | | | ND | | | |
| X7456 | 131 | Johnson Spring 3 | 6/12/14 1050 | 6/19/14 1015 | ND | | | | ND | | | | ND | | | |
| **X6346** | **132** | **Spring Cr at Wagon Wheel Rd** | **5/7/14 1210** | **5/21/14 1925** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6573 | 132 | Spring Cr at Wagon Wheel Rd | 5/21/14 1925 | 5/28/14 1815 | ND | | | | ND | | | | ND | | | |
| X6748 | 132 | Spring Cr at Wagon Wheel Rd | 5/28/14 1815 | 6/4/14 1405 | ND | | | | ND | | | | ND | | | |
| X7012 | 132 | Spring Cr at Wagon Wheel Rd | 6/4/14 1405 | 6/12/14 1040 | ND | | | | ND | | | | ND | | | |
| X7623 | 132 | Spring Cr at Wagon Wheel Rd | 6/12/14 1040 | 6/30/14 1300 | ND | | | | ND | | | | ND | | | |
| X8190 | 132 | Spring Cr at Wagon Wheel Rd | 6/30/14 1300 | 7/16/14 1805 | ND | | | | ND | | | | ND | | | |
| X8787 | 132 | Spring Cr at Wagon Wheel Rd | 7/16/14 1805 | 7/31/14 1930 | ND | | | | ND | | | | ND | | | |
| X8941 | 132 | Spring Cr at Wagon Wheel Rd | 7/31/14 1930 | 8/6/14 1500 | ND | | | | ND | | | | ND | | | |
| X9353 | 132 | Spring Cr at Wagon Wheel Rd | 8/6/14 1500 | 8/12/14 1120 | ND | | | | ND | | | | ND | | | |
| X9331 | 132 | Spring Cr at Wagon Wheel Rd | 8/12/14 1120 | 8/15/14 1525 | ND | | | | ND | | | | 570.6 | 8.46 | 2.67 | 14-11 |
| X9792 | 132 | Spring Cr at Wagon Wheel Rd | 8/15/14 1525 | 8/26/14 2010 | ND | | | | ND | | | | ND | | | |
| **X6347** | **133** | **Reed Spr Br at Wagon Wheel Rd** | **5/7/14 1215** | **5/21/14 1935** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6574 | 133 | Reed Spr Br at Wagon Wheel Rd | 5/21/14 1935 | 5/28/14 1805 | ND | | | | ND | | | | ND | | | |
| X6749 | 133 | Reed Spr Br at Wagon Wheel Rd | 5/28/14 1805 | 6/4/14 1410 | ND | | | | ND | | | | ND | | | |
| X7013 | 133 | Reed Spr Br at Wagon Wheel Rd | 6/4/14 1410 | 6/12/14 1035 | ND | | | | ND | | | | ND | | | |
| X7457 | 133 | Reed Spr Br at Wagon Wheel Rd | 6/12/14 1035 | 6/19/14 1505 | ND | | | | ND | | | | ND | | | |
| X7624 | 133 | Reed Spr Br at Wagon Wheel Rd | 6/19/14 1505 | 6/30/14 1255 | ND | | | | ND | | | | ND | | | |
| X8191 | 133 | Reed Spr Br at Wagon Wheel Rd | 6/30/14 1255 | 7/16/14 1755 | ND | | | | ND | | | | ND | | | |
| X8788 | 133 | Reed Spr Br at Wagon Wheel Rd | 7/16/14 1755 | 7/31/14 1920 | ND | | | | ND | | | | ND | | | |
| X8942 | 133 | Reed Spr Br at Wagon Wheel Rd | 7/31/14 1920 | 8/6/14 1510 | ND | | | | ND | | | | ND | | | |
| X9332 | 133 | Reed Spr Br at Wagon Wheel Rd | 8/6/14 1510 | 8/15/14 1530 | ND | | | | ND | | | | 568.3 | 497 | 33.6 | 14-11 |
| X9793 | 133 | Reed Spr Br at Wagon Wheel Rd | 8/15/14 1530 | 8/26/14 2020 | ND | | | | ND | | | | 568.2 | 105 | 9.34 | 14-11 |
| **X5951** | **134** | **Reed Spring** | **5/1/14 1330** | **5/7/14 1225** | **ND** | | | | **ND** | | | | **ND** | | | |
| X5951D | 134 | Reed Spring | 5/1/14 1330 | 5/7/14 1225 | ND | | | | ND | | | | ND | | | |
| X6348 | 134 | Reed Spring | 5/7/14 1225 | 5/21/14 1945 | ND | | | | ND | | | | ND | | | |

| OUL Number | Station Number | Station Name | Date/Time Placed | Date/Time Collected | Fluorescein Peak | Fluorescein Conc. | Fluorescein Conc./day | Fluorescein Trace No. | Eosine Peak | Eosine Conc. | Eosine Conc./day | Eosine Trace No. | RWT Peak | RWT Conc. | RWT Conc./day | RWT Trace No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| X6348D | 134 | Reed Spring | 5/7/14 1225 | 5/21/14 1945 | ND | | | | ND | | | | ND | | | |
| X6575 | 134 | Reed Spring | 5/21/14 1945 | 5/28/14 1755 | ND | | | | ND | | | | ND | | | |
| X6575D | 134 | Reed Spring | 5/21/14 1945 | 5/28/14 1755 | ND | | | | ND | | | | ND | | | |
| X6750 | 134 | Reed Spring | 5/28/14 1755 | 6/4/14 1425 | ND | | | | ND | | | | ND | | | |
| X6750D | 134 | Reed Spring | 5/28/14 1755 | 6/4/14 1425 | ND | | | | ND | | | | ND | | | |
| X7014 | 134 | Reed Spring | 6/4/14 1425 | 6/12/14 1025 | ND | | | | ND | | | | ND | | | |
| X7014D | 134 | Reed Spring | 6/4/14 1425 | 6/12/14 1025 | ND | | | | ND | | | | ND | | | |
| X7458 | 134 | Reed Spring | 6/12/14 1025 | 6/19/14 1455 | ND | | | | ND | | | | ND | | | |
| X7458D | 134 | Reed Spring | 6/12/14 1025 | 6/19/14 1455 | ND | | | | ND | | | | ND | | | |
| X7625 | 134 | Reed Spring | 6/19/14 1455 | 6/30/14 1245 | ND | | | | ND | | | | ND | | | |
| X7625D | 134 | Reed Spring | 6/19/14 1455 | 6/30/14 1245 | ND | | | | ND | | | | ND | | | |
| X7969 | 134 | Reed Spring | 6/30/14 1245 | 7/8/14 1600 | ND | | | | ND | | | | ND | | | |
| Y1441 | 134 | Reed Spring | 7/8/14 1600 | 7/16/14 1745 | ND | | | | ND | | | | ND | | | |
| Y1441D | 134 | Reed Spring | 7/8/14 1600 | 7/16/14 1745 | ND | | | | ND | | | | ND | | | |
| X8412 | 134 | Reed Spring | 7/16/14 1745 | 7/23/14 1230 | ND | | | | ND | | | | ND | | | |
| X8412D | 134 | Reed Spring | 7/16/14 1745 | 7/23/14 1230 | ND | | | | ND | | | | ND | | | |
| X8789 | 134 | Reed Spring | 7/23/14 1230 | 7/31/14 1910 | ND | | | | ND | | | | ND | | | |
| X8789D | 134 | Reed Spring | 7/23/14 1230 | 7/31/14 1910 | ND | | | | ND | | | | ND | | | |
| X8943 | 134 | Reed Spring | 7/31/14 1910 | 8/6/14 1520 | 512.6 ** | 0.110 | 0.019 | 14-08 | ND | | | | ND | | | |
| X8943D | 134 | Reed Spring | 7/31/14 1910 | 8/6/14 1520 | 512.4 ** | 0.154 | 0.026 | 14-08 | ND | | | | ND | | | |
| X9354 | 134 | Reed Spring | 8/6/14 1520 | 8/12/14 1200 | ND | | | | ND | | | | 567.0 | 5,550 | 947 | 14-11 |
| X9354D | 134 | Reed Spring | 8/6/14 1520 | 8/12/14 1200 | ND | | | | ND | | | | 567.0 | 5,570 | 950 | 14-11 |
| X9333 | 134 | Reed Spring | 8/12/14 1200 | 8/15/14 1545 | ND | | | | ND | | | | 568.5 | 2,040 | 645 | 14-11 |
| X9333D | 134 | Reed Spring | 8/12/14 1200 | 8/15/14 1545 | ND | | | | ND | | | | 568.5 | 1,740 | 551 | 14-11 |
| X9512 | 134 | Reed Spring | 8/15/14 1545 | 8/21/14 1740 | ND | | | | ND | | | | 568.2 | 462 | 76.0 | 14-11 |
| X9512D | 134 | Reed Spring | 8/15/14 1545 | 8/21/14 1740 | ND | | | | ND | | | | 568.4 | 581 | 95.5 | 14-11 |
| X9794 | 134 | Reed Spring | 8/21/14 1740 | 8/26/14 2000 | ND | | | | ND | | | | 567.6 | 104 | 20.5 | 14-11 |
| X9794D | 134 | Reed Spring | 8/21/14 1740 | 8/26/14 2000 | ND | | | | ND | | | | 567.8 | 107 | 21.0 | 14-11 |
| X9991 | 134 | Reed Spring | 8/26/14 2000 | 9/4/14 1530 | ND | | | | ND | | | | 567.6 | 115 | 13.1 | 14-11 |
| X9991D | 134 | Reed Spring | 8/26/14 2000 | 9/4/14 1530 | ND | | | | ND | | | | 568.2 | 117 | 13.3 | 14-11 |
| Y0249 | 134 | Reed Spring | 9/4/14 1530 | 9/11/14 1250 | ND | | | | ND | | | | 567.0 | 269 | 39.1 | 14-11 |
| Y0249D | 134 | Reed Spring | 9/4/14 1530 | 9/11/14 1250 | ND | | | | ND | | | | 567.0 | 125 | 18.2 | 14-11 |
| Y0455 | 134 | Reed Spring | 9/11/14 1250 | 9/17/14 1235 | ND | | | | ND | | | | 567.4 | 16.8 | 2.80 | 14-11 |
| Y0455D | 134 | Reed Spring | 9/11/14 1250 | 9/17/14 1235 | ND | | | | ND | | | | 567.8 | 29.3 | 4.89 | 14-11 |
| Y0568 | 134 | Reed Spring | 9/17/14 1235 | 9/23/14 1350 | ND | | | | ND | | | | 567.2 | 80.3 | 13.3 | 14-11 |
| Y0568D | 134 | Reed Spring | 9/17/14 1235 | 9/23/14 1350 | ND | | | | ND | | | | 567.2 | 62.8 | 10.4 | 14-11 |
| Y0758 | 134 | Reed Spring | 9/23/14 1350 | 9/29/14 1610 | ND | | | | ND | | | | 566.0 | 34.8 | 5.70 | 14-11 |
| Y0758D | 134 | Reed Spring | 9/23/14 1350 | 9/29/14 1610 | ND | | | | ND | | | | 565.8 | 21.4 | 3.51 | 14-11 |

| OUL | Station | Station Name | Date/Time | Date/Time | Fluorescein | | | | Eosine | | | | RWT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Number | | Placed | Collected | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. |
| Y1153 | 134 | Reed Spring | 9/29/14 1610 | 10/3/14 1700 | ND | | | | ND | | | | 567.4 | 11.7 | 2.90 | 14-11 |
| Y1153D | 134 | Reed Spring | 9/29/14 1610 | 10/3/14 1700 | ND | | | | ND | | | | 566.8 | 11.6 | 2.89 | 14-11 |
| Y1103 | 134 | Reed Spring | 10/3/14 1700 | 10/13/14 1410 | ND | | | | ND | | | | 566.4 | 43.3 | 4.38 | 14-11 |
| Y1103D | 134 | Reed Spring | 10/3/14 1700 | 10/13/14 1410 | ND | | | | ND | | | | 566.4 | 46.9 | 4.74 | 14-11 |
| Y1442 | 134 | Reed Spring | 10/13/14 1410 | 10/20/14 1430 | ND | | | | ND | | | | 566.8 | 45.9 | 6.55 | 14-11 |
| Y1442D | 134 | Reed Spring | 10/13/14 1410 | 10/20/14 1430 | ND | | | | ND | | | | 565.6 | 45.2 | 6.44 | 14-11 |
| **X5952** | **135** | **Cross Cr u/s Wagon Wheel Rd** | **5/1/14 1320** | **5/7/14 1235** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6349 | 135 | Cross Cr u/s Wagon Wheel Rd | 5/7/14 1235 | 5/21/14 1955 | ND | | | | ND | | | | ND | | | |
| X6576 | 135 | Cross Cr u/s Wagon Wheel Rd | 5/21/14 1955 | 5/28/14 1745 | ND | | | | ND | | | | ND | | | |
| X6751 | 135 | Cross Cr u/s Wagon Wheel Rd | 5/28/14 1745 | 6/4/14 1435 | ND | | | | ND | | | | ND | | | |
| X7015 | 135 | Cross Cr u/s Wagon Wheel Rd | 6/4/14 1435 | 6/12/14 1015 | ND | | | | ND | | | | ND | | | |
| X7459 | 135 | Cross Cr u/s Wagon Wheel Rd | 6/12/14 1015 | 6/19/14 1445 | ND | | | | ND | | | | ND | | | |
| X7626 | 135 | Cross Cr u/s Wagon Wheel Rd | 6/19/14 1445 | 6/30/14 1235 | ND | | | | ND | | | | ND | | | |
| X8192 | 135 | Cross Cr u/s Wagon Wheel Rd | 6/30/14 1235 | 7/16/14 1730 | ND | | | | ND | | | | ND | | | |
| X8413 | 135 | Cross Cr u/s Wagon Wheel Rd | 7/16/14 1730 | 7/23/14 1215 | ND | | | | ND | | | | ND | | | |
| X8790 | 135 | Cross Cr u/s Wagon Wheel Rd | 7/23/14 1215 | 7/31/14 1855 | ND | | | | ND | | | | ND | | | |
| X8944 | 135 | Cross Cr u/s Wagon Wheel Rd | 7/31/14 1855 | 8/6/14 1540 | ND | | | | ND | | | | ND | | | |
| X9355 | 135 | Cross Cr u/s Wagon Wheel Rd | 8/6/14 1540 | 8/12/14 1140 | ND | | | | ND | | | | ND | | | |
| X9334 | 135 | Cross Cr u/s Wagon Wheel Rd | 8/12/14 1140 | 8/15/14 1550 | ND | | | | ND | | | | ND | | | |
| X9513 | 135 | Cross Cr u/s Wagon Wheel Rd | 8/15/14 1550 | 8/21/14 1730 | ND | | | | ND | | | | ND | | | |
| X9795 | 135 | Cross Cr u/s Wagon Wheel Rd | 8/21/14 1730 | 8/26/14 1950 | ND | | | | ND | | | | ND | | | |
| X9992 | 135 | Cross Cr u/s Wagon Wheel Rd | 8/26/14 1950 | 9/4/14 1520 | ND | | | | ND | | | | ND | | | |
| Y0250 | 135 | Cross Cr u/s Wagon Wheel Rd | 9/4/14 1520 | 9/11/14 1245 | ND | | | | ND | | | | ND | | | |
| Y0456 | 135 | Cross Cr u/s Wagon Wheel Rd | 9/11/14 1245 | 9/17/14 1225 | ND | | | | ND | | | | ND | | | |
| Y0569 | 135 | Cross Cr u/s Wagon Wheel Rd | 9/17/14 1225 | 9/23/14 1340 | ND | | | | ND | | | | ND | | | |
| Y0759 | 135 | Cross Cr u/s Wagon Wheel Rd | 9/23/14 1340 | 9/29/14 1600 | ND | | | | ND | | | | ND | | | |
| **X5953** | **136** | **Cross Cr u/s Brown Rd** | **5/1/14 1310** | **5/7/14 1245** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6350 | 136 | Cross Cr u/s Brown Rd | 5/7/14 1245 | 5/21/14 2000 | ND | | | | ND | | | | ND | | | |
| X6577 | 136 | Cross Cr u/s Brown Rd | 5/21/14 2000 | 5/28/14 1735 | ND | | | | ND | | | | ND | | | |
| X6752 | 136 | Cross Cr u/s Brown Rd | 5/28/14 1735 | 6/4/14 1440 | ND | | | | ND | | | | ND | | | |
| X7016 | 136 | Cross Cr u/s Brown Rd | 6/4/14 1440 | 6/12/14 1005 | ND | | | | ND | | | | ND | | | |
| X7461 | 136 | Cross Cr u/s Brown Rd | 6/12/14 1005 | 6/19/14 1440 | ND | | | | ND | | | | ND | | | |
| X7627 | 136 | Cross Cr u/s Brown Rd | 6/19/14 1440 | 6/30/14 1230 | ND | | | | ND | | | | ND | | | |
| X8193 | 136 | Cross Cr u/s Brown Rd | 6/30/14 1230 | 7/16/14 1725 | ND | | | | ND | | | | ND | | | |
| X8414 | 136 | Cross Cr u/s Brown Rd | 7/16/14 1725 | 7/23/14 1200 | ND | | | | ND | | | | ND | | | |
| X8791 | 136 | Cross Cr u/s Brown Rd | 7/23/14 1200 | 7/31/14 1845 | ND | | | | ND | | | | ND | | | |
| X8945 | 136 | Cross Cr u/s Brown Rd | 7/31/14 1845 | 8/6/14 1550 | ND | | | | ND | | | | ND | | | |
| X9356 | 136 | Cross Cr u/s Brown Rd | 8/6/14 1550 | 8/12/14 1130 | ND | | | | ND | | | | ND | | | |

Cave Springs Area Karst Resource Conservation Study

| OUL Number | Station Number | Station Name | Date/Time Placed | Date/Time Collected | Fluorescein Peak | Fluorescein Conc. | Fluorescein Conc./day | Fluorescein Trace No. | Eosine Peak | Eosine Conc. | Eosine Conc./day | Eosine Trace No. | RWT Peak | RWT Conc. | RWT Conc./day | RWT Trace No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| X9335 | 136 | Cross Cr u/s Brown Rd | 8/12/14 1130 | 8/15/14 1600 | ND | | | | ND | | | | ND | | | |
| X9514 | 136 | Cross Cr u/s Brown Rd | 8/15/14 1600 | 8/21/14 1720 | ND | | | | ND | | | | ND | | | |
| X9796 | 136 | Cross Cr u/s Brown Rd | 8/21/14 1720 | 8/26/14 1945 | ND | | | | ND | | | | ND | | | |
| X9993 | 136 | Cross Cr u/s Brown Rd | 8/26/14 1945 | 9/4/14 1510 | ND | | | | ND | | | | ND | | | |
| Y0251 | 136 | Cross Cr u/s Brown Rd | 9/4/14 1510 | 9/11/14 1240 | ND | | | | ND | | | | ND | | | |
| Y0457 | 136 | Cross Cr u/s Brown Rd | 9/11/14 1240 | 9/17/14 1215 | ND | | | | ND | | | | ND | | | |
| Y0570 | 136 | Cross Cr u/s Brown Rd | 9/17/14 1215 | 9/23/14 1330 | ND | | | | ND | | | | ND | | | |
| Y0761 | 136 | Cross Cr u/s Brown Rd | 9/23/14 1330 | 9/29/14 1550 | ND | | | | ND | | | | ND | | | |
| Y1104 | 136 | Cross Cr u/s Brown Rd | 9/29/14 1550 | 10/13/14 1345 | ND | | | | ND | | | | ND | | | |
| **X6578** | **137** | **Spring Cr at 56th St** | **5/7/14 1320** | **5/28/14 1715** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6753 | 137 | Spring Cr at 56th St | 5/28/14 1715 | 6/4/14 1735 | ND | | | | ND | | | | ND | | | |
| X7017 | 137 | Spring Cr at 56th St | 6/4/14 1735 | 6/12/14 0940 | ND | | | | ND | | | | ND | | | |
| X7462 | 137 | Spring Cr at 56th St | 6/12/14 0940 | 6/19/14 1430 | ND | | | | ND | | | | ND | | | |
| X7628 | 137 | Spring Cr at 56th St | 6/19/14 1430 | 6/30/14 1220 | ND | | | | ND | | | | ND | | | |
| X8194 | 137 | Spring Cr at 56th St | 6/30/14 1220 | 7/16/14 1705 | ND | | | | ND | | | | ND | | | |
| X8792 | 137 | Spring Cr at 56th St | 7/16/14 1705 | 7/31/14 1840 | ND | | | | ND | | | | ND | | | |
| X9336 | 137 | Spring Cr at 56th St | 7/31/14 1840 | 8/15/14 1610 | ND | | | | ND | | | | ND | | | |
| X9797 | 137 | Spring Cr at 56th St | 8/15/14 1610 | 8/26/14 1935 | ND | | | | ND | | | | ND | | | |
| **X6579** | **138** | **Puppy Cr u/s Spring Cr** | **5/7/14 1330** | **5/28/14 1720** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6754 | 138 | Puppy Cr u/s Spring Cr | 5/28/14 1720 | 6/4/14 1745 | ND | | | | ND | | | | ND | | | |
| X7018 | 138 | Puppy Cr u/s Spring Cr | 6/4/14 1745 | 6/12/14 0950 | ND | | | | ND | | | | ND | | | |
| X7463 | 138 | Puppy Cr u/s Spring Cr | 6/12/14 0950 | 6/19/14 1420 | ND | | | | ND | | | | ND | | | |
| X7629 | 138 | Puppy Cr u/s Spring Cr | 6/19/14 1420 | 6/30/14 1215 | ND | | | | ND | | | | ND | | | |
| X8195 | 138 | Puppy Cr u/s Spring Cr | 6/30/14 1215 | 7/16/14 1715 | ND | | | | ND | | | | ND | | | |
| X8793 | 138 | Puppy Cr u/s Spring Cr | 7/16/14 1715 | 7/31/14 1835 | ND | | | | ND | | | | ND | | | |
| X9337 | 138 | Puppy Cr u/s Spring Cr | 7/31/14 1835 | 8/15/14 1620 | ND | | | | ND | | | | ND | | | |
| X9798 | 138 | Puppy Cr u/s Spring Cr | 8/15/14 1620 | 8/26/14 1730 | ND | | | | ND | | | | ND | | | |
| **X6581** | **139** | **Puppy Cr at Puppy Cr Rd** | **5/7/14 1400** | **5/28/14 1705** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6755 | 139 | Puppy Cr at Puppy Cr Rd | 5/28/14 1705 | 6/4/14 1725 | ND | | | | ND | | | | ND | | | |
| X7019 | 139 | Puppy Cr at Puppy Cr Rd | 6/4/14 1725 | 6/12/14 0930 | ND | | | | ND | | | | ND | | | |
| X7464 | 139 | Puppy Cr at Puppy Cr Rd | 6/12/14 0930 | 6/19/14 1410 | ND | | | | ND | | | | ND | | | |
| X7630 | 139 | Puppy Cr at Puppy Cr Rd | 6/19/14 1410 | 6/30/14 1200 | ND | | | | ND | | | | ND | | | |
| X8196 | 139 | Puppy Cr at Puppy Cr Rd | 6/30/14 1200 | 7/16/14 1655 | ND | | | | ND | | | | ND | | | |
| X8794 | 139 | Puppy Cr at Puppy Cr Rd | 7/16/14 1655 | 7/31/14 1825 | ND | | | | ND | | | | ND | | | |
| X9338 | 139 | Puppy Cr at Puppy Cr Rd | 7/31/14 1825 | 8/15/14 1630 | ND | | | | ND | | | | ND | | | |
| X9799 | 139 | Puppy Cr at Puppy Cr Rd | 8/15/14 1630 | 8/26/14 1920 | ND | | | | ND | | | | ND | | | |
| **X6582** | **140** | **Puppy Cr at Goad Springs Rd** | **5/7/14 1415** | **5/28/14 1645** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6756 | 140 | Puppy Cr at Goad Spring Rd | 5/28/14 1645 | 6/4/14 1715 | ND | | | | ND | | | | ND | | | |

| OUL | Station | Station Name | Date/Time | Date/Time | Fluorescein | | | | Eosine | | | | RWT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Number | | Placed | Collected | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. |
| X7021 | 140 | Puppy Cr at Goad Spring Rd | 6/4/14 1715 | 6/12/14 0920 | ND | | | | ND | | | | ND | | | |
| X7465 | 140 | Puppy Cr at Goad Spring Rd | 6/12/14 0920 | 6/19/14 1350 | ND | | | | ND | | | | ND | | | |
| X7631 | 140 | Puppy Cr at Goad Spring Rd | 6/19/14 1350 | 6/30/14 1150 | ND | | | | ND | | | | ND | | | |
| X8197 | 140 | Puppy Cr at Goad Spring Rd | 6/30/14 1150 | 7/16/14 1645 | ND | | | | ND | | | | ND | | | |
| X8415 | 140 | Puppy Cr at Goad Spring Rd | 7/16/14 1645 | 7/23/14 1140 | ND | | | | ND | | | | ND | | | |
| X8795 | 140 | Puppy Cr at Goad Spring Rd | 7/23/14 1140 | 7/31/14 1630 | ND | | | | ND | | | | ND | | | |
| X9339 | 140 | Puppy Cr at Goad Spring Rd | 7/31/14 1630 | 8/15/14 1640 | ND | | | | ND | | | | ND | | | |
| X9801 | 140 | Puppy Cr at Goad Spring Rd | 8/15/14 1640 | 8/26/14 1910 | ND | | | | ND | | | | ND | | | |
| **X6583** | **141** | **Goad Springs Br** | **5/7/14 1500** | **5/28/14 1655** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6757 | 141 | Goad Springs Br | 5/28/14 1655 | 6/4/14 1705 | ND | | | | ND | | | | ND | | | |
| X7022 | 141 | Goad Springs Br | 6/4/14 1705 | 6/12/14 0910 | ND | | | | ND | | | | ND | | | |
| X7466 | 141 | Goad Springs Br | 6/12/14 0910 | 6/19/14 1400 | ND | | | | ND | | | | ND | | | |
| X7632 | 141 | Goad Springs Br | 6/19/14 1400 | 6/30/14 1140 | ND | | | | ND | | | | ND | | | |
| X8198 | 141 | Goad Springs Br | 6/30/14 1140 | 7/16/14 1635 | ND | | | | ND | | | | ND | | | |
| X8416 | 141 | Goad Springs Br | 7/16/14 1635 | 7/23/14 1130 | ND | | | | ND | | | | ND | | | |
| X8796 | 141 | Goad Springs Br | 7/23/14 1130 | 7/31/14 1640 | ND | | | | ND | | | | ND | | | |
| X9341 | 141 | Goad Springs Br | 7/31/14 1640 | 8/15/14 1650 | ND | | | | ND | | | | ND | | | |
| X9802 | 141 | Goad Springs Br | 8/15/14 1650 | 8/26/14 1900 | ND | | | | ND | | | | ND | | | |
| **X6584** | **142** | **Puppy Cr at 6th St** | **5/7/14 1435** | **5/28/14 1615** | **ND** | | | | ND | | | | **ND** | | | |
| X6758 | 142 | Puppy Cr at 6th St | 5/28/14 1615 | 6/4/14 1650 | ND | | | | ND | | | | ND | | | |
| X7023 | 142 | Puppy Cr at 6th St | 6/4/14 1650 | 6/12/14 0845 | ND | | | | ND | | | | ND | | | |
| X7633 | 142 | Puppy Cr at 6th St | 6/12/14 0845 | 6/30/14 1100 | ND | | | | ND | | | | ND | | | |
| X8199 | 142 | Puppy Cr at 6th St | 6/30/14 1100 | 7/16/14 1620 | ND | | | | ND | | | | ND | | | |
| X8417 | 142 | Puppy Cr at 6th St | 7/16/14 1620 | 7/23/14 1115 | ND | | | | ND | | | | ND | | | |
| X9342 | 142 | Puppy Cr at 6th St | 7/23/14 1115 | 8/15/14 1700 | ND | | | | ND | | | | ND | | | |
| X9803 | 142 | Puppy Cr at 6th St | 8/15/14 1700 | 8/26/14 1845 | ND | | | | ND | | | | ND | | | |
| **X6314** | **143** | **Pinnale Valley Trib** | **5/8/14 0950** | **5/14/14 1920** | **ND** | | | | **ND** | | | | **ND** | | | |
| X6351 | 143 | Pinnale Valley Trib | 5/14/14 1920 | 5/21/14 1725 | ND | | | | ND | | | | ND | | | |
| X6585 | 143 | Pinnale Valley Trib | 5/21/14 1725 | 5/28/14 1300 | ND | | | | ND | | | | ND | | | |
| X6759 | 143 | Pinnale Valley Trib | 5/28/14 1300 | 6/4/14 1015 | ND | | | | ND | | | | ND | | | |
| X7024 | 143 | Pinnale Valley Trib | 6/4/14 1015 | 6/12/14 1735 | 515.4 | 5.44 | 0.655 | 14-06 | ND | | | | ND | | | |
| X7467 | 143 | Pinnale Valley Trib | 6/12/14 1735 | 6/19/14 1540 | 516.0 | 1.68 | 0.243 | 14-06 | ND | | | | ND | | | |
| X7634 | 143 | Pinnale Valley Trib | 6/19/14 1540 | 6/30/14 1525 | 516.4 | 0.273 | 0.025 | 14-06 | ND | | | | ND | | | |
| | 143 | Pinnale Valley Trib | 6/30/14 1525 | 7/16/14 1455 | wso | | | | | | | | | | | |
| | 143 | Pinnale Valley Trib | 7/16/14 1455 | 7/31/14 1050 | wso | | | | | | | | | | | |
| | 143 | Pinnale Valley Trib | 7/31/14 1050 | 8/12/14 1040 | ns | | | | | | | | | | | |
| X9343 | 143 | Pinnale Valley Trib | 8/12/14 1040 | 8/15/14 1025 | ND | | | | ND | | | | ND | | | |
| X9804 | 143 | Pinnale Valley Trib | 8/15/14 1025 | 8/27/14 0945 | ND | | | | ND | | | | ND | | | |
| X9994 | 143 | Pinnale Valley Trib | 8/27/14 0945 | 9/4/14 1315 | ND | | | | ND | | | | ND | | | |

| OUL Number | Station Number | Station Name | Date/Time Placed | Date/Time Collected | Fluorescein Peak | Fluorescein Conc. | Fluorescein Conc./day | Fluorescein Trace No. | Eosine Peak | Eosine Conc. | Eosine Conc./day | Eosine Trace No. | RWT Peak | RWT Conc. | RWT Conc./day | RWT Trace No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Y0252 | 143 | Pinnale Valley Trib | 9/4/14 1315 | 9/10/14 1930 | ND | | | | ND | | | | ND | | | |
| Y0458 | 143 | Pinnale Valley Trib | 9/10/14 1930 | 9/17/14 1045 | ND | | | | ND | | | | ND | | | |
| | 143 | Pinnale Valley Trib | 9/17/14 1045 | 9/23/14 1230 | water sample only | | | | | | | | | | | |
| Y0762 | 143 | Pinnale Valley Trib | 9/23/14 1230 | 9/29/14 1140 | ND | | | | ND | | | | ND | | | |
| **X7468** | **144** | **Unnamed Trib at Bright Rd** | **6/4/14 1300** | **6/19/14 1025** | **ND** | | | | **ND** | | | | **ND** | | | |
| X8201 | 144 | Unnamed Trib at Bright Rd | 6/19/14 1025 | 7/16/14 1345 | ND | | | | ND | | | | ND | | | |
| X8797 | 144 | Unnamed Trib at Bright Rd | 7/16/14 1345 | 7/31/14 1330 | ND | | | | ND | | | | ND | | | |
| X9357 | 144 | Unnamed Trib at Bright Rd | 7/31/14 1330 | 8/12/14 1055 | ND | | | | ND | | | | ND | | | |
| X9344 | 144 | Unnamed Trib at Bright Rd | 8/12/14 1055 | 8/15/14 0930 | ND | | | | ND | | | | ND | | | |
| X9805 | 144 | Unnamed Trib at Bright Rd | 8/15/14 0930 | 8/27/14 1045 | ND | | | | ND | | | | ND | | | |
| X9995 | 144 | Unnamed Trib at Bright Rd | 8/27/14 1045 | 9/4/14 1230 | ND | | | | ND | | | | ND | | | |
| Y0253 | 144 | Unnamed Trib at Bright Rd | 9/4/14 1230 | 9/10/14 1845 | ND | | | | ND | | | | ND | | | |
| Y0459 | 144 | Unnamed Trib at Bright Rd | 9/10/14 1845 | 9/17/14 1140 | ND | | | | ND | | | | ND | | | |
| Y0571 | 144 | Unnamed Trib at Bright Rd | 9/17/14 1140 | 9/23/14 1145 | ND | | | | ND | | | | ND | | | |
| Y0763 | 144 | Unnamed Trib at Bright Rd | 9/23/14 1145 | 9/29/14 1210 | ND | | | | ND | | | | ND | | | |
| Y1105 | 144 | Unnamed Trib at Bright Rd | 9/29/14 1210 | 10/13/14 1215 | ND | | | | ND | | | | ND | | | |
| **X7635** | **145** | **Unnamed Trib at Pleasant Grove Rd** | **6/12/14 1520** | **6/21/14 0845** | **ND** | | | | **ND** | | | | **ND** | | | |
| X7637 | 145 | Unnamed Trib at Pleasant Grove Rd | 6/21/14 0845 | 6/30/14 1025 | ND | | | | ND | | | | ND | | | |
| X8202 | 145 | Unnamed Trib at Pleasant Grove Rd | 6/30/14 1025 | 7/16/14 1545 | ND | | | | ND | | | | ND | | | |
| X8798 | 145 | Unnamed Trib at Pleasant Grove Rd | 7/16/14 1545 | 7/31/14 1410 | ND | | | | ND | | | | ND | | | |
| X9345 | 145 | Unnamed Trib at Pleasant Grove Rd | 7/31/14 1410 | 8/15/14 1330 | ND | | | | ND | | | | ND | | | |
| X9806 | 145 | Unnamed Trib at Pleasant Grove Rd | 8/15/14 1330 | 8/27/14 1145 | ND | | | | ND | | | | ND | | | |
| X9996 | 145 | Unnamed Trib at Pleasant Grove Rd | 8/27/14 1145 | 9/4/14 1350 | ND | | | | ND | | | | ND | | | |
| **X7636** | **146** | **Blossom Way at S 28th Place** | **6/12/14 1545** | **6/21/14 0830** | **ND** | | | | **541.0** | **63.3** | **7.28** | **14-05** | **ND** | | | |
| X7638 | 146 | Blossom Way at S 28th Place | 6/21/14 0830 | 6/30/14 1010 | ND | | | | 541.4 | 16.9 | 1.87 | 14-05 | ND | | | |
| X8203 | 146 | Blossom Way at S 28th Place | 6/30/14 1010 | 7/16/14 1525 | ND | | | | 541.3 | 17.1 | 0.675 | 14-05 | ND | | | |
| X8418 | 146 | Blossom Way at S 28th Place | 7/16/14 1525 | 7/23/14 1345 | ND | | | | 543.0 | 0.425 | 0.061 | 14-05 | ND | | | |
| X8799 | 146 | Blossom Way at S 28th Place | 7/23/14 1345 | 7/31/14 1400 | ND | | | | 540.6 | 0.848 | 0.106 | 14-05 | ND | | | |
| X9346 | 146 | Blossom Way at S 28th Place | 7/31/14 1400 | 8/15/14 1350 | ND | | | | 541.6 | 4.39 | 0.293 | 14-05 | ND | | | |
| X9807 | 146 | Blossom Way at S 28th Place | 8/15/14 1350 | 8/27/14 1110 | ND | | | | 543.2 | 0.216 | 0.018 | 14-05 | ND | | | |
| X9997 | 146 | Blossom Way at S 28th Place | 8/27/14 1110 | 9/4/14 1335 | ND | | | | 542.4 | 1.24 | 0.153 | 14-05 | ND | | | |
| **X8801** | **147** | **Blossom Trib at Bellview Rd** | **7/16/14 1535** | **7/31/14 1350** | **ND** | | | | **541.8** | **3,610** | **242** | **14-07 & 09** | **ND** | | | |
| X9347 | 147 | Blossom Trib at Bellview Rd | 7/31/14 1350 | 8/15/14 1340 | ND | | | | ND | | | | ND | | | |
| X9808 | 147 | Blossom Trib at Bellview Rd | 8/15/14 1340 | 8/27/14 1130 | ND | | | | ND | | | | ND | | | |
| X9998 | 147 | Blossom Trib at Bellview Rd | 8/27/14 1130 | 9/4/14 1325 | ND | | | | 541.6 | 11.5 | 1.42 | 14-07 & 09 | ND | | | |
| **Y0461** | **148** | **Sands Road Trib** | **9/12/14 0830** | **9/17/14 1110** | **ND** | | | | **ND** | | | | **ND** | | | |
| Y0572 | 148 | Sands Road Trib | 9/17/14 1110 | 9/23/14 1200 | ND | | | | ND | | | | ND | | | |
| Y0764 | 148 | Sands Road Trib | 9/23/14 1200 | 9/29/14 1200 | ND | | | | ND | | | | ND | | | |

| OUL Number | Station Number | Station Name | Date/Time Placed | Date/Time Collected | Fluorescein | | | | Eosine | | | | RWT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. | Peak | Conc. | Conc./day | Trace No. |
| Y1106 | 148 | Sands Road Trib | 9/29/14 1200 | 10/13/14 1225 | ND | | | | 543.2 | 0.763 | 0.055 | 14-12 | 568.2 | 4.43 | 0.316 | 14-13 |

**Table 2. Results for charcoal samplers analyzed for the presence of pyranine dye.**

Peak wavelengths are reported in nanometers (nm); dye concentrations are reported in parts per billion (ppb).

| OUL Number | Station Number | Station Name | Date/Time Placed | Date/Time Collected | Pyranine | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Peak | Conc. | Conc./day | Trace No. |
| **X7595** | **101** | **Cave Spring** | **6/19/14 0915** | **6/29/14 1935** | **ND** | | | |
| X7595 Dup | 101 | Cave Spring | 6/19/14 0915 | 6/29/14 1935 | ND | | | |
| X7966 | 101 | Cave Spring | 6/29/14 1935 | 7/8/14 1430 | ND | | | |
| X8770 | 101 | Cave Spring | 7/23/14 1300 | 7/31/14 1315 | ND | | | |
| X8770 Dup | 101 | Cave Spring | 7/23/14 1300 | 7/31/14 1315 | ND | | | |
| X8937 | 101 | Cave Spring | 7/31/14 1315 | 8/6/14 1330 | ND | | | |
| X8937 Dup | 101 | Cave Spring | 7/31/14 1315 | 8/6/14 1330 | ND | | | |
| X9348 | 101 | Cave Spring | 8/6/14 1330 | 8/12/14 0900 | ND | | | |
| X9348 Dup | 101 | Cave Spring | 8/6/14 1330 | 8/12/14 0900 | ND | | | |
| X9316 | 101 | Cave Spring | 8/12/14 0900 | 8/15/14 1415 | ND | | | |
| X9316 Dup | 101 | Cave Spring | 8/12/14 0900 | 8/15/14 1415 | ND | | | |
| X9509 | 101 | Cave Spring | 8/15/14 1415 | 8/21/14 1627 | ND | | | |
| X9772 | 101 | Cave Spring | 8/21/14 1627 | 8/26/14 0930 | ND | | | |
| X9773 | 101 | Cave Spring | 8/15/14 1415 | 8/27/14 1230 | ND | | | |
| X9987 | 101 | Cave Spring | 8/26/14 0930 | 9/4/14 1030 | ND | | | |
| Y0241 | 101 | Cave Spring | 9/4/14 1030 | 9/10/14 1910 | ND | | | |
| Y0448 | 101 | Cave Spring | 9/10/14 1910 | 9/17/14 1200 | ND | | | |
| Y0558 | 101 | Cave Spring | 9/17/14 1200 | 9/23/14 1145 | ND | | | |
| Y0751 | 101 | Cave Spring | 9/23/14 1145 | 9/29/14 1230 | ND | | | |
| Y1150 | 101 | Cave Spring | 9/29/14 1230 | 10/3/14 1545 | ND | | | |
| Y1098 | 101 | Cave Spring | 10/3/14 1545 | 10/13/14 1330 | ND | | | |
| Y1437 | 101 | Cave Spring | 10/13/14 1330 | 10/20/14 1345 | ND | | | |
| **X9349** | **110** | **Unnamed Trib at 112** | **7/31/14 1200** | **8/12/14 0950** | **ND** | | | |
| X9317 | 110 | Unnamed Trib at 112 | 8/12/14 0950 | 8/15/14 0940 | ND | | | |

Cave Springs Area Karst Resource Conservation Study

| OUL Number | Station Number | Station Name | Date/Time Placed | Date/Time Collected | Pyranine | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Peak | Conc. | Conc./day | Trace No. |
| X9774 | 110 | Unnamed Trib at 112 | 8/15/14 0940 | 8/27/14 1030 | ND | | | |
| X9988 | 110 | Unnamed Trib at 112 | 8/27/14 1030 | 9/4/14 1245 | ND | | | |
| Y0449 | 110 | Unnamed Trib at 112 | 9/4/14 1245 | 9/17/14 1130 | ND | | | |
| Y0559 | 110 | Unnamed Trib at 112 | 9/17/14 1130 | 9/23/14 1300 | ND | | | |
| Y0752 | 110 | Unnamed Trib at 112 | 9/23/14 1300 | 9/29/14 1340 | ND | | | |
| Y1099 | 110 | Unnamed Trib at 112 | 9/29/14 1340 | 10/13/14 1315 | ND | | | |
| **X7604** | **111** | **Shores Spring** | **6/19/14 1050** | **6/30/14 1420** | **ND** | | | |
| X7967 | 111 | Shores Spring | 6/30/14 1420 | 7/8/14 1450 | ND | | | |
| X8938 | 111 | Shores Spring | 7/31/14 1150 | 8/6/14 1400 | ND | | | |
| X9350 | 111 | Shores Spring | 8/6/14 1400 | 8/12/14 1010 | ND | | | |
| X9318 | 111 | Shores Spring | 8/12/14 1010 | 8/15/14 0950 | ND | | | |
| X9510 | 111 | Shores Spring | 8/15/14 0950 | 8/21/14 1655 | ND | | | |
| X9775 | 111 | Shores Spring | 8/21/14 1655 | 8/27/14 1020 | ND | | | |
| X9989 | 111 | Shores Spring | 8/27/14 1020 | 9/4/14 1255 | ND | | | |
| Y0242 | 111 | Shores Spring | 9/4/14 1255 | 9/11/14 1210 | ND | | | |
| Y0450 | 111 | Shores Spring | 9/11/14 1210 | 9/17/14 1120 | ND | | | |
| Y0561 | 111 | Shores Spring | 9/17/14 1120 | 9/23/14 1310 | ND | | | |
| Y0753 | 111 | Shores Spring | 9/23/14 1310 | 9/29/14 1350 | ND | | | |
| Y1151 | 111 | Shores Spring | 9/29/14 1350 | 10/3/14 1725 | ND | | | |
| Y1101 | 111 | Shores Spring | 10/3/14 1715 | 10/13/14 1300 | ND | | | |
| Y1438 | 111 | Shores Spring | 10/13/14 1300 | 10/20/14 1450 | ND | | | |
| **X7605** | **112** | **Wallis Spring** | **6/19/14 1100** | **6/30/14 1445** | **ND** | | | |
| X7968 | 112 | Wallis Spring | 6/30/14 1445 | 7/8/14 1510 | ND | | | |
| X8939 | 112 | Wallis Spring | 7/31/14 1125 | 8/6/14 1420 | ND | | | |
| X9351 | 112 | Wallis Spring | 8/6/14 1420 | 8/12/14 1020 | ND | | | |
| X9319 | 112 | Wallis Spring | 8/12/14 1020 | 8/15/14 1000 | ND | | | |

Cave Springs Area Karst Resource Conservation Study

| OUL Number | Station Number | Station Name | Date/Time Placed | Date/Time Collected | Pyranine | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Peak | Conc. | Conc./day | Trace No. |
| X9511 | 112 | Wallis Spring | 8/15/14 1000 | 8/21/14 1708 | ND | | | |
| X9776 | 112 | Wallis Spring | 8/21/14 1708 | 8/27/14 1015 | ND | | | |
| X9990 | 112 | Wallis Spring | 8/27/14 1015 | 9/4/14 1305 | ND | | | |
| Y0243 | 112 | Wallis Spring | 9/4/14 1305 | 9/11/14 1220 | ND | | | |
| Y0451 | 112 | Wallis Spring | 9/11/14 1220 | 9/17/14 1110 | ND | | | |
| Y0562 | 112 | Wallis Spring | 9/17/14 1110 | 9/23/14 1215 | ND | | | |
| Y0754 | 112 | Wallis Spring | 9/23/14 1215 | 9/29/14 1150 | ND | | | |
| Y1152 | 112 | Wallis Spring | 9/29/14 1150 | 10/3/14 1715 | ND | | | |
| Y1102 | 112 | Wallis Spring | 10/3/14 1725 | 10/13/14 1240 | ND | | | |
| Y1439 | 112 | Wallis Spring | 10/13/14 1240 | 10/20/14 1515 | ND | | | |
| **X9332** | **133** | **Reed Spr Br at Wagon Wheel Rd** | **7/31/14 1920** | **8/15/14 1530** | **ND** | | | |
| X9793 | 133 | Reed Spr Br at Wagon Wheel Rd | 8/15/14 1530 | 8/26/14 2020 | ND | | | |
| **X7625** | **134** | **Reed Spring** | **6/19/14 1455** | **6/30/14 1245** | **ND** | | | |
| X7625 Dup | 134 | Reed Spring | 6/19/14 1455 | 6/30/14 1245 | ND | | | |
| X7969 | 134 | Reed Spring | 6/30/14 1245 | 7/8/14 1600 | ND | | | |
| X8789 | 134 | Reed Spring | 7/23/14 1230 | 7/31/14 1910 | ND | | | |
| X8789 Dup | 134 | Reed Spring | 7/23/14 1230 | 7/31/14 1910 | ND | | | |
| X8943 | 134 | Reed Spring | 7/31/14 1910 | 8/6/14 1520 | ND | | | |
| X8943 Dup | 134 | Reed Spring | 7/31/14 1910 | 8/6/14 1520 | ND | | | |
| X9354 | 134 | Reed Spring | 8/6/14 1520 | 8/12/14 1200 | ND | | | |
| X9354 Dup | 134 | Reed Spring | 8/6/14 1520 | 8/12/14 1200 | ND | | | |
| X9333 | 134 | Reed Spring | 8/12/14 1200 | 8/15/14 1545 | ND | | | |
| X9333 Dup | 134 | Reed Spring | 8/12/14 1200 | 8/15/14 1545 | ND | | | |
| X9512 | 134 | Reed Spring | 8/15/14 1545 | 8/21/14 1740 | ND | | | |
| X9794 | 134 | Reed Spring | 8/21/14 1740 | 8/26/14 2000 | ND | | | |
| X9991 | 134 | Reed Spring | 8/26/14 2000 | 9/4/14 1530 | ND | | | |

**Cave Springs Area Karst Resource Conservation Study**

| OUL Number | Station Number | Station Name | Date/Time Placed | Date/Time Collected | Pyranine | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Peak | Conc. | Conc./day | Trace No. |
| Y0249 | 134 | Reed Spring | 9/4/14 1530 | 9/11/14 1250 | ND | | | |
| Y0455 | 134 | Reed Spring | 9/11/14 1250 | 9/17/14 1235 | ND | | | |
| Y0568 | 134 | Reed Spring | 9/17/14 1235 | 9/23/14 1350 | ND | | | |
| Y0758 | 134 | Reed Spring | 9/23/14 1350 | 9/29/14 1610 | ND | | | |
| Y1153 | 134 | Reed Spring | 9/29/14 1610 | 10/3/14 1700 | ND | | | |
| Y1103 | 134 | Reed Spring | 10/3/14 1700 | 10/13/14 1410 | ND | | | |
| Y1442 | 134 | Reed Spring | 10/13/14 1410 | 10/20/14 1430 | ND | | | |
| **X9343** | **143** | **Pinnale Valley Trib** | **8/12/14 1040** | **8/15/14 1025** | **ND** | | | |
| X9804 | 143 | Pinnale Valley Trib | 8/15/14 1025 | 8/27/14 0945 | ND | | | |
| **X9357** | **144** | **Unnamed Trib at Bright Rd** | **7/31/14 1330** | **8/12/14 1055** | **ND** | | | |
| Y0571 | 144 | Unnamed Trib at Bright Rd | 9/17/14 1140 | 9/23/14 1145 | ND | | | |
| Y0763 | 144 | Unnamed Trib at Bright Rd | 9/23/14 1145 | 9/29/14 1210 | ND | | | |
| Y1105 | 144 | Unnamed Trib at Bright Rd | 9/29/14 1210 | 10/13/14 1215 | ND | | | |

**Table 3. Results for water samples analyzed for the presence of fluorescein, eosine and rhodamine WT (RWT) dyes.**

Peak wavelengths are reported in nanometers (nm); dye concentrations are reported in parts per billion (ppb).

| OUL | Station | Station Name | Date/Time | Fluorescein | | | Eosine | | | RWT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Number | | Collected | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. |
| **X5725** | **101** | **Cave Spring** | **4/23/14 1800** | **ND** | | | **ND** | | | **ND** | | |
| X6476 | 101 | Cave Spring | 5/15/14 1100 | ND | | | ND | | | ND | | |
| X9144 | 101 | Cave Spring | 8/6/14 1330 | 507.5 | 0.534 | 14-08 | ND | | | ND | | |
| X9144R | 101 | Cave Spring | 8/6/14 1330 | 507.6 | 0.534 | 14-08 | ND | | | ND | | |
| X9673 | 101 | Cave Spring | 8/12/14 0900 | 507.9 | 0.286 | 14-08 | ND | | | ND | | |
| X9659 | 101 | Cave Spring | 8/15/14 1415 | 507.2 | 0.019 | 14-08 | ND | | | ND | | |
| X9856 | 101 | Cave Spring | 8/21/14 1627 | 507.6 (1) | 0.007 | 14-08 | ND | | | ND | | |
| X9898 | 101 | Cave Spring | 8/26/14 0930 | 510.0 (1) | 0.008 | 14-08 | ND | | | ND | | |
| X9999 | 101 | Cave Spring | 9/4/14 1030 | 507.7 | 0.097 | 14-08 | ND | | | ND | | |
| X9999R | 101 | Cave Spring | 9/4/14 1030 | 507.9 | 0.095 | 14-08 | ND | | | ND | | |
| Y0254 | 101 | Cave Spring | 9/10/14 1910 | 509.0 (1) | 0.005 | 14-08 | ND | | | ND | | |
| Y0254R | 101 | Cave Spring | 9/10/14 1910 | 507.4 (1) | 0.008 | 14-08 | ND | | | ND | | |
| Y0462 | 101 | Cave Spring | 9/17/14 1200 | ND | | | ND | | | ND | | |
| Y0656 | 101 | Cave Spring | 9/23/14 1145 | 507.8 | 0.013 | 14-08 | ND | | | ND | | |
| Y0865 | 101 | Cave Spring | 9/29/14 1230 | ND | | | ND | | | ND | | |
| Y1342 | 101 | Cave Spring | 10/3/14 1545 | ND | | | ND | | | ND | | |
| Y1177 | 101 | Cave Spring | 10/13/14 1330 | 508.0 | 0.025 | 14-08 | ND | | | ND | | |
| Y1443 | 101 | Cave Spring | 10/20/14 1345 | 508.6 | 0.020 | 14-08 | ND | | | ND | | |
| **X5954** | **102** | **Cave Spr - North Pipe** | **5/7/14 1535** | **ND** | | | **ND** | | | **ND** | | |
| **X5955** | **106** | **Cave Spr - South Valve** | **5/7/14 1555** | **ND** | | | **ND** | | | **ND** | | |
| **X5870** | **107** | **Boat Ramp Spring - east** | **5/1/14 1225** | **ND** | | | **ND** | | | **ND** | | |
| **X5871** | **108** | **Boat Ramp Spring - center** | **5/1/14 1230** | **ND** | | | **ND** | | | **ND** | | |
| **X5872** | **109** | **Boat Ramp Spring - west** | **5/1/14 1235** | **ND** | | | **ND** | | | **ND** | | |
| X5956 | 109 | Boat Ramp Spring - west | 5/7/14 1125 | ND | | | ND | | | ND | | |
| X8392 | 109 | Boat Ramp Spring - west | 7/16/14 1330 | ND | | | ND | | | ND | | |
| **X5873** | **110** | **Unnamed Trib at 112** | **5/1/14 1435** | **ND** | | | **ND** | | | **ND** | | |
| X6413 | 110 | Unnamed Trib at 112 | 5/21/14 1825 | ND | | | ND | | | ND | | |
| X8393 | 110 | Unnamed Trib at 112 | 7/16/14 1345 | ND | | | ND | | | ND | | |
| X9071 | 110 | Unnamed Trib at 112 | 7/31/14 1200 | ND | | | ND | | | ND | | |
| X9674 | 110 | Unnamed Trib at 112 | 8/12/14 0950 | ND | | | ND | | | ND | | |

| OUL Number | Station Number | Station Name | Date/Time Collected | Fluorescein | | | Eosine | | | RWT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. |
| X9661 | 110 | Unnamed Trib at 112 | 8/15/14 0940 | ND | | | ND | | | ND | | |
| **X5874** | **111** | **Shores Spring** | **5/1/14 1500** | **ND** | | | **ND** | | | **ND** | | |
| X9675 | 111 | Shores Spring | 8/12/14 1010 | ND | | | ND | | | ND | | |
| X9662 | 111 | Shores Spring | 8/15/14 0950 | ND | | | ND | | | ND | | |
| Y0463 | 111 | Shores Spring | 9/17/14 1120 | ND | | | 534.4 | 2.06 | 14-12 | ND | | |
| Y0657 | 111 | Shores Spring | 9/23/14 1310 | ND | | | 534.4 | 0.511 | 14-12 | ND | | |
| Y0866 | 111 | Shores Spring | 9/29/14 1350 | ND | | | 535.0 | 0.299 | 14-12 | ND | | |
| Y1343 | 111 | Shores Spring | 10/3/14 1725 | ND | | | 534.5 | 0.804 | 14-12 | ND | | |
| Y1179 | 111 | Shores Spring | 10/13/14 1300 | ND | | | 535.2 | 0.247 | 14-12 | ND | | |
| Y1444 | 111 | Shores Spring | 10/20/14 1450 | ND | | | 535.0 | 0.148 | 14-12 | ND | | |
| **X5875** | **112** | **Wallis Spring** | **5/1/14 1815** | **ND** | | | **ND** | | | **ND** | | |
| X5957 | 112 | Wallis Spring | 5/8/14 0910 | ND | | | ND | | | ND | | |
| X9676 | 112 | Wallis Spring | 8/12/14 1020 | ND | | | ND | | | ND | | |
| X9663 | 112 | Wallis Spring | 8/15/14 1000 | ND | | | ND | | | ND | | |
| Y0464 | 112 | Wallis Spring | 9/17/14 1110 | ND | | | 534.8 | 9.47 | 14-12 | ND | | |
| Y0658 | 112 | Wallis Spring | 9/23/14 1215 | ND | | | 534.8 | 2.54 | 14-12 | ND | | |
| Y0867 | 112 | Wallis Spring | 9/29/14 1150 | ND | | | 534.8 | 1.09 | 14-12 | ND | | |
| Y1344 | 112 | Wallis Spring | 10/3/14 1715 | ND | | | 534.7 | 0.757 | 14-12 | ND | | |
| Y1181 | 112 | Wallis Spring | 10/13/14 1240 | ND | | | 535.0 | 0.580 | 14-12 | ND | | |
| Y1445 | 112 | Wallis Spring | 10/20/14 1515 | ND | | | 534.6 | 0.193 | 14-12 | ND | | |
| **X5726** | **113** | **Osage Creek u/s SVGC Spr Br** | **4/23/14 1815** | **ND** | | | **ND** | | | **ND** | | |
| X5876 | 113 | Osage Creek u/s SVGC Spr Br | 5/1/14 1540 | ND | | | ND | | | ND | | |
| X5958 | 113 | Osage Creek u/s SVGC Spr Br | 5/8/14 0925 | ND | | | ND | | | ND | | |
| X6477 | 113 | Osage Creek u/s SVGC Spr Br | 5/14/14 1900 | ND | | | ND | | | ND | | |
| X6414 | 113 | Osage Creek u/s SVGC Spr Br | 5/21/14 1750 | ND | | | ND | | | ND | | |
| X6636 | 113 | Osage Creek u/s SVGC Spr Br | 5/28/14 1240 | ND | | | ND | | | ND | | |
| X6891 | 113 | Osage Creek u/s SVGC Spr Br | 6/4/14 1030 | ND | | | ND | | | ND | | |
| X7138 | 113 | Osage Creek u/s SVGC Spr Br | 6/12/14 1615 | ND | | | ND | | | ND | | |
| X7539 | 113 | Osage Creek u/s SVGC Spr Br | 6/19/14 1130 | 510.0 (1) | 0.004 | 14-06 | ND | | | ND | | |
| **X5877** | **114** | **SVGC Spring Branch** | **5/1/14 1530** | **ND** | | | **ND** | | | **ND** | | |
| X5959 | 114 | SVGC Spring Branch | 5/8/14 0930 | ND | | | ND | | | ND | | |
| X6637 | 114 | SVGC Spring Branch | 5/28/14 1250 | ND | | | ND | | | ND | | |

| OUL Number | Station Number | Station Name | Date/Time Collected | Fluorescein | | | Eosine | | | RWT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. |
| X6892 | 114 | SVGC Spring Branch | 6/4/14 1040 | ND | | | ND | | | ND | | |
| X9072 | 114 | SVGC Spring Branch | 7/31/14 1115 | ND | | | ND | | | ND | | |
| **X5961** | **115** | **Osage Cr at Rainbow Rd** | **5/8/14 1000** | **ND** | | | **ND** | | | **ND** | | |
| X6415 | 115 | Osage Cr at Rainbow Rd | 5/21/14 1645 | ND | | | ND | | | 574.4 | 0.117 | 14-02 |
| X6638 | 115 | Osage Cr at Rainbow Rd | 5/28/14 1310 | ND | | | ND | | | ND | | |
| X6893 | 115 | Osage Cr at Rainbow Rd | 6/4/14 1005 | ND | | | ND | | | ND | | |
| X7139 | 115 | Osage Cr at Rainbow Rd | 6/12/14 1750 | ND | | | ND | | | ND | | |
| X7541 | 115 | Osage Cr at Rainbow Rd | 6/19/14 1550 | ND | | | ND | | | ND | | |
| X8394 | 115 | Osage Cr at Rainbow Rd | 7/16/14 1510 | ND | | | ND | | | ND | | |
| X9073 | 115 | Osage Cr at Rainbow Rd | 7/31/14 1040 | ND | | | ND | | | ND | | |
| X9664 | 115 | Osage Cr at Rainbow Rd | 8/15/14 1040 | ND | | | 536.4 | 0.062 | 14-07 & 09 | ND | | |
| X9903 | 115 | Osage Cr at Rainbow Rd | 8/27/14 0935 | ND | | | ND | | | ND | | |
| Y0505 | 115 | Osage Cr at Rainbow Rd | 9/10/14 1940 | ND | | | ND | | | ND | | |
| Y0617 | 115 | Osage Cr at Rainbow Rd | 9/17/14 1030 | ND | | | ND | | | ND | | |
| Y0659 | 115 | Osage Cr at Rainbow Rd | 9/23/14 1240 | ND | | | ND | | | ND | | |
| Y0868 | 115 | Osage Cr at Rainbow Rd | 9/29/14 1130 | ND | | | **ND** | | | ND | | |
| **X5727** | **116** | **Osage Cr d/s Cross Church** | **4/23/14 1500** | **ND** | | | ND | | | **ND** | | |
| X6416 | 116 | Osage Cr d/s Cross Church | 5/21/14 1655 | 510.2 (1) | 0.007 | 14-01 | ND | | | ND | | |
| X6639 | 116 | Osage Cr d/s Cross Church | 5/28/14 1325 | ND | | | ND | | | ND | | |
| X6894 | 116 | Osage Cr d/s Cross Church | 6/4/14 2025 | ND | | | | | | ND | | |
| X7141 | 116 | Osage Cr d/s Cross Church | 6/12/14 1815 | ND | | | 534.2 | 0.047 | 14-05 | ND | | |
| X7542 | 116 | Osage Cr d/s Cross Church | 6/19/14 1620 | ND | | | ND | | | ND | | |
| X7689 | 116 | Osage Cr d/s Cross Church | 6/30/14 0930 | ND | | | | | | ND | | |
| X8395 | 116 | Osage Cr d/s Cross Church | 7/17/14 0910 | ND | | | 533.8 | 0.087 | 14-05 | ND | | |
| X9074 | 116 | Osage Cr d/s Cross Church | 7/31/14 0955 | ND | | | | | | ND | | |
| X9665 | 116 | Osage Cr d/s Cross Church | 8/15/14 1100 | ND | | | 535.2 | 0.061 | 14-07 & 09 | ND | | |
| X9904 | 116 | Osage Cr d/s Cross Church | 8/27/14 0915 | ND | | | ND | | | ND | | |
| **X6641** | **117** | **Village Pond Outfall** | **5/28/14 1340** | **ND** | | | **ND** | | | **ND** | | |
| X6895 | 117 | Village Pond Outfall | 6/4/14 2030 | ND | | | ND | | | ND | | |
| X9075 | 117 | Village Pond Outfall | 7/31/14 1010 | ND | | | ND | | | ND | | |
| **X5878** | **118** | **Osage Cr u/s Blossom Way** | **5/1/14 1635** | **ND** | | | **ND** | | | **ND** | | |
| X5962 | 118 | Osage Cr u/s Blossom Way | 5/7/14 2015 | ND | | | ND | | | ND | | |

| OUL Number | Station Number | Station Name | Date/Time Collected | Fluorescein | | | Eosine | | | RWT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. |
| X6417 | 118 | Osage Cr u/s Blossom Way | 5/21/14 1625 | 507.2 | 0.025 | 14-01 | ND | | | ND | | |
| X6642 | 118 | Osage Cr u/s Blossom Way | 5/28/14 1550 | 507.2 (1) | 0.006 | 14-01 | ND | | | ND | | |
| X6896 | 118 | Osage Cr u/s Blossom Way | 6/4/14 2010 | 506.8 (1) | 0.007 | 14-01 | ND | | | ND | | |
| X7142 | 118 | Osage Cr u/s Blossom Way | 6/12/14 1840 | ND | | | ND | | | ND | | |
| X7543 | 118 | Osage Cr u/s Blossom Way | 6/19/14 1645 | ND | | | ND | | | ND | | |
| **X5879** | **119** | **Osage West Spring** | **5/1/14 1645** | **ND** | | | **ND** | | | **ND** | | |
| X6418 | 119 | Osage West Spring | 5/21/14 1530 | 507.7 | 0.330 | 14-01 | ND | | | ND | | |
| X6643 | 119 | Osage West Spring | 5/28/14 1515 | 506.8 | 0.026 | 14-01 | ND | | | ND | | |
| X6897 | 119 | Osage West Spring | 6/4/14 2000 | 504.4 (1) | 0.013 | 14-01 | ND | | | ND | | |
| X7143 | 119 | Osage West Spring | 6/12/14 1910 | ND | | | ND | | | ND | | |
| X7690 | 119 | Osage West Spring | 6/30/14 0800 | ND | | | ND | | | ND | | |
| X8396 | 119 | Osage West Spring | 7/17/14 0825 | ND | | | ND | | | ND | | |
| **X5729** | **120** | **Osage Spring** | **4/23/14 1300** | **ND** | | | **ND** | | | **ND** | | |
| X5881 | 120 | Osage Spring | 5/1/14 1700 | ND | | | ND | | | ND | | |
| X5963 | 120 | Osage Spring | 5/7/14 1910 | ND | | | ND | | | ND | | |
| X6478 | 120 | Osage Spring | 5/15/14 1220 | ND | | | ND | | | ND | | |
| X6419 | 120 | Osage Spring | 5/21/14 1455 | 507.0 | 0.035 | 14-01 | ND | | | ND | | |
| X6644 | 120 | Osage Spring | 5/28/14 1455 | 507.8 | 0.013 | 14-01 | ND | | | ND | | |
| X6898 | 120 | Osage Spring | 6/4/14 1940 | 508.2 | 0.006 | 14-01 | ND | | | ND | | |
| X7144 | 120 | Osage Spring | 6/12/14 1940 | ND | | | ND | | | ND | | |
| X7544 | 120 | Osage Spring | 6/19/14 1815 | ND | | | ND | | | ND | | |
| X7691 | 120 | Osage Spring | 6/30/14 0825 | ND | | | ND | | | ND | | |
| X8397 | 120 | Osage Spring | 7/16/14 1935 | ND | | | ND | | | ND | | |
| X8508 | 120 | Osage Spring | 7/23/14 1030 | ND | | | ND | | | ND | | |
| X9076 | 120 | Osage Spring | 7/31/14 1600 | ND | | | ND | | | ND | | |
| **X5730** | **121** | **Osage Spr-Culvert 1** | **4/23/14 1320** | **ND** | | | **ND** | | | **ND** | | |
| X5964 | 121 | Osage Spr - Culvert 1 | 5/7/14 1915 | ND | | | ND | | | ND | | |
| X6479 | 121 | Osage Spr - Culvert 1 | 5/15/14 1215 | ND | | | ND | | | ND | | |
| X6421 | 121 | Osage Spr - Culvert 1 | 5/21/14 1450 | 507.8 | 0.035 | 14-01 | ND | | | ND | | |
| X6645 | 121 | Osage Spr - Culvert 1 | 5/28/14 1450 | 508.0 | 0.013 | 14-01 | ND | | | ND | | |
| X6899 | 121 | Osage Spr - Culvert 1 | 6/4/14 1930 | 504.4 (1) | 0.007 | 14-01 | ND | | | ND | | |
| X7145 | 121 | Osage Spr - Culvert 1 | 6/12/14 1935 | ND | | | ND | | | ND | | |

| OUL Number | Station Number | Station Name | Date/Time Collected | Fluorescein | | | Eosine | | | RWT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. |
| X7545 | 121 | Osage Spr - Culvert 1 | 6/19/14 1810 | ND | | | ND | | | ND | | |
| X7692 | 121 | Osage Spr - Culvert 1 | 6/30/14 0820 | ND | | | ND | | | ND | | |
| X8398 | 121 | Osage Spr - Culvert 1 | 7/16/14 1930 | ND | | | ND | | | ND | | |
| X8509 | 121 | Osage Spr - Culvert 1 | 7/23/14 1025 | ND | | | ND | | | ND | | |
| X9077 | 121 | Osage Spr - Culvert 1 | 7/31/14 1555 | ND | | | ND | | | ND | | |
| **X5731** | **122** | **Osage Spr-Culvert 2** | **4/23/14 1350** | **ND** | | | **ND** | | | **ND** | | |
| X5965 | 122 | Osage Spr - Culvert 2 | 5/7/14 1925 | ND | | | ND | | | ND | | |
| X6481 | 122 | Osage Spr - Culvert 2 | 5/15/14 1205 | ND | | | ND | | | ND | | |
| X6422 | 122 | Osage Spr - Culvert 2 | 5/21/14 1445 | 507.2 | 0.013 | 14-01 | ND | | | ND | | |
| X6646 | 122 | Osage Spr - Culvert 2 | 5/28/14 1445 | 508.4 | 0.010 | 14-01 | ND | | | ND | | |
| X6901 | 122 | Osage Spr - Culvert 2 | 6/4/14 1920 | ND | | | ND | | | ND | | |
| X7146 | 122 | Osage Spr - Culvert 2 | 6/12/14 1930 | ND | | | ND | | | ND | | |
| X7546 | 122 | Osage Spr - Culvert 2 | 6/19/14 1805 | ND | | | ND | | | ND | | |
| X7693 | 122 | Osage Spr - Culvert 2 | 6/30/14 0815 | ND | | | ND | | | ND | | |
| X8399 | 122 | Osage Spr - Culvert 2 | 7/16/14 1925 | ND | | | ND | | | ND | | |
| X9078 | 122 | Osage Spr - Culvert 2 | 7/31/14 1550 | ND | | | ND | | | ND | | |
| **X5732** | **123** | **Osage Spr-Culvert 3** | **4/23/14 1400** | **ND** | | | **ND** | | | **ND** | | |
| X5882 | 123 | Osage Spr - Culvert 3 | 5/1/14 1715 | ND | | | ND | | | ND | | |
| X5966 | 123 | Osage Spr - Culvert 3 | 5/7/14 1935 | ND | | | ND | | | ND | | |
| X6482 | 123 | Osage Spr - Culvert 3 | 5/15/14 1155 | ND | | | ND | | | ND | | |
| X6423 | 123 | Osage Spr - Culvert 3 | 5/21/14 1440 | ND | | | ND | | | ND | | |
| X6647 | 123 | Osage Spr - Culvert 3 | 5/28/14 1440 | ND | | | ND | | | ND | | |
| X7147 | 123 | Osage Spr - Culvert 3 | 6/12/14 1925 | ND | | | ND | | | ND | | |
| **X5728** | **124** | **Blossom Way d/s South Spr** | **4/23/14 1340** | **ND** | | | **ND** | | | **ND** | | |
| X5883 | 124 | Blossom Way d/s South Spr | 5/1/14 1720 | ND | | | ND | | | ND | | |
| X6483 | 124 | Blossom Way d/s South Spr | 5/15/14 1230 | 508.2 | 1.00 | 14-01 | ND | | | ND | | |
| X6424 | 124 | Blossom Way d/s South Spr | 5/21/14 1500 | ND | | | ND | | | ND | | |
| X6648 | 124 | Blossom Way d/s South Spr | 5/28/14 1500 | ND | | | ND | | | ND | | |
| X6902 | 124 | Blossom Way d/s South Spr | 6/4/14 1950 | ND | | | | | | ND | | |
| X7148 | 124 | Blossom Way d/s South Spr | 6/12/14 1945 | ND | | | 534.0 | 0.058 | 14-05 | ND | | |
| X7547 | 124 | Blossom Way d/s South Spr | 6/19/14 1825 | ND | | | ND | | | ND | | |
| X7694 | 124 | Blossom Way d/s South Spr | 6/30/14 0830 | ND | | | ND | | | ND | | |

| OUL Number | Station Number | Station Name | Date/Time Collected | Fluorescein | | | Eosine | | | RWT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. |
| X8401 | 124 | Blossom Way d/s South Spr | 7/16/14 1945 | ND | | | 537.4 (1) | 0.052 | 14-05 | ND | | |
| X8510 | 124 | Blossom Way d/s South Spr | 7/23/14 1035 | ND | | | ND | | | ND | | |
| X9079 | 124 | Blossom Way d/s South Spr | 7/31/14 1605 | ND | | | 534.3 | 3.48 | 14-05 | ND | | |
| X9905 | 124 | Blossom Way d/s South Spr | 8/27/14 0830 | ND | | | ND | | | ND | | |
| Y0506 | 124 | Blossom Way d/s South Spr | 9/11/14 1410 | ND | | | ND | | | ND | | |
| Y0618 | 124 | Blossom Way d/s South Spr | 9/17/14 1425 | ND | | | ND | | | ND | | |
| Y0661 | 124 | Blossom Way d/s South Spr | 9/23/14 1600 | ND | | | ND | | | ND | | |
| Y0869 | 124 | Blossom Way d/s South Spr | 9/29/14 1520 | ND | | | ND | | | ND | | |
| **X6484** | **125** | **Blossom Way u/s South Spr** | **5/15/14 1245** | **ND** | | | **ND** | | | **ND** | | |
| X6649 | 125 | Blossom Way u/s South Spr | 5/28/14 1420 | ND | | | ND | | | ND | | |
| X6903 | 125 | Blossom Way u/s South Spr | 6/4/14 1545 | ND | | | ND | | | ND | | |
| X7149 | 125 | Blossom Way u/s South Spr | 6/12/14 2015 | ND | | | ND | | | ND | | |
| X7548 | 125 | Blossom Way u/s South Spr | 6/19/14 1730 | ND | | | ND | | | ND | | |
| X7695 | 125 | Blossom Way u/s South Spr | 6/30/14 0715 | ND | | | ND | | | ND | | |
| X9081 | 125 | Blossom Way u/s South Spr | 7/31/14 1505 | ND | | | ND | | | ND | | |
| X9666 | 125 | Blossom Way u/s South Spr | 8/15/14 1200 | ND | | | ND | | | ND | | |
| Y0507 | 125 | Blossom Way u/s South Spr | 9/11/14 1320 | ND | | | ND | | | ND | | |
| **X5967** | **126** | **North Spring** | **5/8/14 1115** | **ND** | | | **ND** | | | **ND** | | |
| X6425 | 126 | North Spring | 5/21/14 1550 | 507.2 | 0.038 | 14-01 | ND | | | ND | | |
| X6650 | 126 | North Spring | 5/28/14 1540 | 509.2 | 0.012 | 14-01 | ND | | | ND | | |
| X6904 | 126 | North Spring | 6/4/14 1825 | 508.6 (1) | 0.007 | 14-01 | ND | | | ND | | |
| X7150 | 126 | North Spring | 6/12/14 1855 | ND | | | ND | | | ND | | |
| **X5884** | **128** | **Spring Creek u/s 112** | **5/1/14 1415** | **ND** | | | **ND** | | | **ND** | | |
| X5968 | 128 | Spring Creek u/s 112 | 5/7/14 1135 | ND | | | ND | | | ND | | |
| X9082 | 128 | Spring Creek u/s 112 | 7/31/14 1940 | ND | | | ND | | | ND | | |
| X9658 | 128 | Spring Creek u/s 112 | 8/6/14 1445 | ND | | | ND | | | ND | | |
| X9677 | 128 | Spring Creek u/s 112 | 8/12/14 1110 | ND | | | ND | | | 572.6 | 0.346 | 14-11 |
| X9667 | 128 | Spring Creek u/s 112 | 8/15/14 1515 | ND | | | ND | | | 571.6 (1) | 0.098 | 14-11 |
| **X5885** | **129** | **Johnson Spring 1** | **5/1/14 1400** | **ND** | | | **ND** | | | **ND** | | |
| X5969 | 129 | Johnson Spring 1 | 5/7/14 1150 | ND | | | ND | | | ND | | |
| **X5970** | **130** | **Johnson Spring 2** | **5/7/14 1155** | **ND** | | | **ND** | | | **ND** | | |
| X6426 | 130 | Johnson Spring 2 | 5/21/14 1900 | ND | | | ND | | | ND | | |

Cave Springs Area Karst Resource Conservation Study

| OUL Number | Station Number | Station Name | Date/Time Collected | Fluorescein | | | Eosine | | | RWT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. |
| **X5886** | **131** | **Johnson Spring 3** | **5/1/14 1350** | **ND** | | | **ND** | | | **ND** | | |
| X6905 | 131 | Johnson Spring 3 | 6/4/14 1355 | ND | | | ND | | | ND | | |
| **X5971** | **132** | **Spring Cr at Wagon Wheel Rd** | **5/7/14 1210** | **ND** | | | **ND** | | | **ND** | | |
| X7151 | 132 | Spring Cr at Wagon Wheel Rd | 6/12/14 1040 | ND | | | ND | | | ND | | |
| X9668 | 132 | Spring Cr at Wagon Wheel Rd | 8/15/14 1525 | ND | | | ND | | | 577.6 (1) | 0.097 | 14-11 |
| **X5972** | **133** | **Reed Spr Br at Wagon Wheel Rd** | **5/7/14 1215** | **ND** | | | **ND** | | | **ND** | | |
| X6906 | 133 | Reed Spr Br at Wagon Wheel Rd | 6/4/14 1410 | ND | | | ND | | | ND | | |
| X9669 | 133 | Reed Spr Br at Wagon Wheel Rd | 8/15/14 1530 | ND | | | ND | | | 573.6 | 2.60 | 14-11 |
| X9906 | 133 | Reed Spr Br at Wagon Wheel Rd | 8/26/14 2020 | ND | | | ND | | | 574.6 | 0.237 | 14-11 |
| **X5887** | **134** | **Reed Spring** | **5/1/14 1330** | **ND** | | | **ND** | | | **ND** | | |
| Y1446 | 134 | Reed Spring | 7/16/14 1745 | ND | | | ND | | | ND | | |
| X9145 | 134 | Reed Spring | 8/6/14 1520 | ND | | | ND | | | ND | | |
| X9145R | 134 | Reed Spring | 8/6/14 1520 | ND | | | ND | | | ND | | |
| X9678 | 134 | Reed Spring | 8/12/14 1200 | ND | | | ND | | | 573.8 | 11.0 | 14-11 |
| X9670 | 134 | Reed Spring | 8/15/14 1545 | ND | | | ND | | | 574.2 | 0.993 | 14-11 |
| X9859 | 134 | Reed Spring | 8/21/14 1740 | ND | | | ND | | | 575.4 | 0.050 | 14-11 |
| X9859R | 134 | Reed Spring | 8/21/14 1740 | ND | | | ND | | | 574.6 | 0.067 | 14-11 |
| X9907 | 134 | Reed Spring | 8/26/14 2000 | ND | | | ND | | | ND | | |
| X9907R | 134 | Reed Spring | 8/26/14 2000 | ND | | | ND | | | ND | | |
| Y0004 | 134 | Reed Spring | 9/4/14 1530 | ND | | | ND | | | 573.0 | 0.643 | 14-11 |
| Y0257 | 134 | Reed Spring | 9/11/14 1250 | ND | | | ND | | | ND | | |
| Y0465 | 134 | Reed Spring | 9/17/14 1235 | ND | | | ND | | | ND | | |
| Y0662 | 134 | Reed Spring | 9/23/14 1350 | ND | | | ND | | | ND | | |
| Y0662R | 134 | Reed Spring | 9/23/14 1350 | ND | | | ND | | | ND | | |
| Y0870 | 134 | Reed Spring | 9/29/14 1610 | ND | | | ND | | | ND | | |
| Y1345 | 134 | Reed Spring | 10/3/14 1700 | ND | | | ND | | | ND | | |
| Y1182 | 134 | Reed Spring | 10/13/14 1410 | ND | | | ND | | | ND | | |
| Y1447 | 134 | Reed Spring | 10/20/14 1430 | ND | | | ND | | | ND | | |
| Y1447R | 134 | Reed Spring | 10/20/14 1430 | ND | | | ND | | | ND | | |
| **X5888** | **135** | **Cross Cr u/s Wagon Wheel Rd** | **5/1/14 1320** | **ND** | | | **ND** | | | **ND** | | |
| X5973 | 135 | Cross Cr u/s Wagon Wheel Rd | 5/7/14 1235 | ND | | | ND | | | ND | | |
| X6907 | 135 | Cross Cr u/s Wagon Wheel Rd | 6/4/14 1435 | ND | | | ND | | | ND | | |

| OUL Number | Station Number | Station Name | Date/Time Collected | Fluorescein | | | Eosine | | | RWT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. |
| X7152 | 135 | Cross Cr u/s Wagon Wheel Rd | 6/12/14 1015 | ND | | | ND | | | ND | | |
| Y1183 | 135 | Cross Cr u/s Wagon Wheel Rd | 10/13/14 1355 | ND | | | ND | | | ND | | |
| **X5889** | **136** | **Cross Cr u/s Brown Rd** | **5/1/14 1310** | **ND** | | | **ND** | | | **ND** | | |
| X5974 | 136 | Cross Cr u/s Brown Rd | 5/7/14 1245 | ND | | | ND | | | ND | | |
| X6908 | 136 | Cross Cr u/s Brown Rd | 6/4/14 1440 | ND | | | ND | | | ND | | |
| **X5975** | **137** | **Spring Cr at 56th St** | **5/7/14 1320** | **ND** | | | **ND** | | | **ND** | | |
| X7153 | 137 | Spring Cr at 56th St | 6/12/14 0940 | ND | | | ND | | | ND | | |
| **X5976** | **138** | **Puppy Cr u/s Spring Cr** | **5/7/14 1330** | **ND** | | | **ND** | | | **ND** | | |
| X6909 | 138 | Puppy Cr u/s Spring Cr | 6/4/14 1745 | ND | | | ND | | | ND | | |
| X7154 | 138 | Puppy Cr u/s Spring Cr | 6/12/14 0950 | ND | | | ND | | | ND | | |
| **X9083** | **139** | **Puppy Cr at Puppy Cr Rd** | **7/31/14 1825** | **ND** | | | **ND** | | | **ND** | | |
| **X5977** | **140** | **Puppy Cr at Goad Springs Rd** | **5/7/14 1415** | **ND** | | | **ND** | | | **ND** | | |
| X6910 | 140 | Puppy Cr at Goad Spring Rd | 6/4/14 1715 | ND | | | ND | | | ND | | |
| X7155 | 140 | Puppy Cr at Goad Spring Rd | 6/12/14 0920 | ND | | | ND | | | ND | | |
| **X5978** | **141** | **Goad Springs Br** | **5/7/14 1500** | **ND** | | | **ND** | | | **ND** | | |
| **X5979** | **142** | **Puppy Cr at 6th St** | **5/7/14 1435** | **ND** | | | **ND** | | | **ND** | | |
| X6651 | 142 | Puppy Cr at 6th St | 5/28/14 1615 | ND | | | ND | | | ND | | |
| X6911 | 142 | Puppy Cr at 6th St | 6/4/14 1650 | ND | | | ND | | | ND | | |
| **X5981** | **143** | **Pinnale Valley Trib** | **5/8/14 0950** | **ND** | | | **ND** | | | **ND** | | |
| X6485 | 143 | Pinnale Valley Trib | 5/14/14 1920 | ND | | | ND | | | ND | | |
| X6652 | 143 | Pinnale Valley Trib | 5/28/14 1300 | ND | | | ND | | | ND | | |
| X6912 | 143 | Pinnale Valley Trib | 6/4/14 1015 | ND | | | ND | | | ND | | |
| X7156 | 143 | Pinnale Valley Trib | 6/12/14 1735 | 508.0 | 0.064 | 14-06 | ND | | | ND | | |
| X7549 | 143 | Pinnale Valley Trib | 6/19/14 1540 | 509.6 | 0.043 | 14-06 | ND | | | ND | | |
| X8402 | 143 | Pinnale Valley Trib | 7/16/14 1455 | ND | | | ND | | | ND | | |
| X9084 | 143 | Pinnale Valley Trib | 7/31/14 1050 | ND | | | ND | | | ND | | |
| X9679 | 143 | Pinnale Valley Trib | 8/12/14 1040 | ND | | | ND | | | ND | | |
| X9671 | 143 | Pinnale Valley Trib | 8/15/14 1025 | ND | | | ND | | | ND | | |
| **X7157** | **146** | **Blossom Way at S 28th Place** | **6/12/14 1545** | **ND** | | | **534.0** | **0.644** | **14-05** | **ND** | | |
| X7696 | 146 | Blossom Way at S 28th Place | 6/21/14 0830 | ND | | | 534.0 | 0.398 | 14-05 | ND | | |
| X7697 | 146 | Blossom Way at S 28th Place | 6/30/14 1010 | ND | | | 534.2 | 0.342 | 14-05 | ND | | |
| X7697R | 146 | Blossom Way at S 28th Place | 6/30/14 1010 | ND | | | 534.2 | 0.369 | 14-05 | ND | | |

Cave Springs Area Karst Resource Conservation Study

| OUL Number | Station Number | Station Name | Date/Time Collected | Fluorescein | | | Eosine | | | RWT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. |
| X8403 | 146 | Blossom Way at S 28th Place | 7/16/14 1525 | ND | | | ND | | | ND | | |
| X8511 | 146 | Blossom Way at S 28th Place | 7/23/14 1345 | ND | | | ND | | | ND | | |
| X9085 | 146 | Blossom Way at S 28th Place | 7/31/14 1400 | ND | | | 534.4 | 0.056 | 14-05 | ND | | |
| X9672 | 146 | Blossom Way at S 28th Place | 8/15/14 1350 | ND | | | ND | | | ND | | |
| Y0162 | 146 | Blossom Way at S 28th Place | 9/4/14 1335 | ND | | | ND | | | ND | | |

**Cave Springs Area Karst Resource Conservation Study**

**Table 4. Results for water samples analyzed for the presence of pyranine dye.**

Peak wavelengths are reported in nanometers (nm); dye concentrations are reported in parts per billion (ppb).

| OUL Number | Station Number | Station Name | Date/Time Collected | Pyranine | | |
|---|---|---|---|---|---|---|
| | | | | Peak (nm) | Conc. (ppb) | Trace No. |
| **X9144** | **101** | **Cave Spring** | **8/6/14 1330** | **ND** | | |
| X9144R | 101 | Cave Spring | 8/6/14 1330 | ND | | |
| X9673 | 101 | Cave Spring | 8/12/14 0900 | ND | | |
| X9659 | 101 | Cave Spring | 8/15/14 1415 | ND | | |
| X9856 | 101 | Cave Spring | 8/21/14 1627 | ND | | |
| X9898 | 101 | Cave Spring | 8/26/14 0930 | ND | | |
| X9999 | 101 | Cave Spring | 9/4/14 1030 | ND | | |
| Y0254 | 101 | Cave Spring | 9/10/14 1910 | ND | | |
| Y0462 | 101 | Cave Spring | 9/17/14 1200 | ND | | |
| Y0656 | 101 | Cave Spring | 9/23/14 1145 | ND | | |
| Y0865 | 101 | Cave Spring | 9/29/14 1230 | ND | | |
| Y1342 | 101 | Cave Spring | 10/3/14 1545 | ND | | |
| Y1177 | 101 | Cave Spring | 10/13/14 1330 | ND | | |
| Y1443 | 101 | Cave Spring | 10/20/14 1345 | ND | | |
| **X9674** | **110** | **Unnamed Trib at 112** | **8/12/14 0950** | **ND** | | |
| X9661 | 110 | Unnamed Trib at 112 | 8/15/14 0940 | ND | | |
| X9899 | 110 | Unnamed Trib at 112 | 8/27/14 1030 | ND | | |
| Y0001 | 110 | Unnamed Trib at 112 | 9/4/14 1245 | ND | | |
| Y1178 | 110 | Unnamed Trib at 112 | 10/13/14 1315 | ND | | |
| **X9506** | **111** | **Shores Spring** | 8/6/14 1400 | **ND** | | |
| X9675 | 111 | Shores Spring | 8/12/14 1010 | ND | | |
| X9662 | 111 | Shores Spring | 8/15/14 0950 | ND | | |
| X9857 | 111 | Shores Spring | 8/21/14 1655 | ND | | |
| X9901 | 111 | Shores Spring | 8/27/14 1020 | ND | | |
| Y0002 | 111 | Shores Spring | 9/4/14 1255 | ND | | |
| Y0255 | 111 | Shores Spring | 9/11/14 1210 | ND | | |
| Y0463 | 111 | Shores Spring | 9/17/14 1120 | ND | | |
| Y0657 | 111 | Shores Spring | 9/23/14 1310 | ND | | |
| Y0866 | 111 | Shores Spring | 9/29/14 1350 | ND | | |
| Y1343 | 111 | Shores Spring | 10/3/14 1725 | ND | | |
| Y1179 | 111 | Shores Spring | 10/13/14 1300 | ND | | |
| Y1444 | 111 | Shores Spring | 10/20/14 1450 | ND | | |
| **X9507** | **112** | **Wallis Spring** | 8/6/14 1420 | **ND** | | |
| X9676 | 112 | Wallis Spring | 8/12/14 1020 | ND | | |
| X9663 | 112 | Wallis Spring | 8/15/14 1000 | ND | | |

| OUL Number | Station Number | Station Name | Date/Time Collected | Pyranine | | |
|---|---|---|---|---|---|---|
| | | | | Peak (nm) | Conc. (ppb) | Trace No. |
| X9858 | 112 | Wallis Spring | 8/21/14 1708 | ND | | |
| X9902 | 112 | Wallis Spring | 8/27/14 1015 | ND | | |
| Y0003 | 112 | Wallis Spring | 9/4/14 1305 | ND | | |
| Y0256 | 112 | Wallis Spring | 9/11/14 1220 | ND | | |
| Y0464 | 112 | Wallis Spring | 9/17/14 1110 | ND | | |
| Y0658 | 112 | Wallis Spring | 9/23/14 1215 | ND | | |
| Y0867 | 112 | Wallis Spring | 9/29/14 1150 | ND | | |
| Y1344 | 112 | Wallis Spring | 10/3/14 1715 | ND | | |
| Y1181 | 112 | Wallis Spring | 10/13/14 1240 | ND | | |
| Y1445 | 112 | Wallis Spring | 10/20/14 1515 | ND | | |
| **X9669** | **133** | **Reed Spr Br at Wagon Wheel Rd** | **8/15/14 1530** | **ND** | | |
| X9906 | 133 | Reed Spr Br at Wagon Wheel Rd | 8/26/14 2020 | ND | | |
| **X9145** | **134** | **Reed Spring** | **8/6/14 1520** | **ND** | | |
| X9145 Rep | 134 | Reed Spring | 8/6/14 1520 | ND | | |
| X9678 | 134 | Reed Spring | 8/12/14 1200 | ND | | |
| X9670 | 134 | Reed Spring | 8/15/14 1545 | ND | | |
| X9859 | 134 | Reed Spring | 8/21/14 1740 | ND | | |
| X9907 | 134 | Reed Spring | 8/26/14 2000 | ND | | |
| Y0004 | 134 | Reed Spring | 9/4/14 1530 | ND | | |
| Y0257 | 134 | Reed Spring | 9/11/14 1250 | ND | | |
| Y0465 | 134 | Reed Spring | 9/17/14 1235 | ND | | |
| Y0662 | 134 | Reed Spring | 9/23/14 1350 | ND | | |
| Y0870 | 134 | Reed Spring | 9/29/14 1610 | ND | | |
| Y1345 | 134 | Reed Spring | 10/3/14 1700 | ND | | |
| Y1182 | 134 | Reed Spring | 10/13/14 1410 | ND | | |
| Y1447 | 134 | Reed Spring | 10/20/14 1430 | ND | | |
| **X9679** | **143** | **Pinnale Valle Trib** | **8/12/14 1040** | **ND** | | |
| X9671 | 143 | Pinnale Valle Trib | 8/15/14 1025 | ND | | |
| X9916 | 143 | Pinnale Valle Trib | 8/27/14 0945 | ND | | |

**Table 5. Results for composite water samples analyzed for the presence of fluorescein, eosine and rhodamine WT (RWT) dyes.**

Peak wavelengths are reported in nanometers (nm); dye concentrations are reported in parts per billion (ppb).

| OUL | Station | Station Name | Date/Time | Date/Time | Fluorescein | | | Eosine | | | RWT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Number | | Started | Ended | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. |
| X5982 | 100 | Cave Springs | 5/7/14 1035 | 5/7/14 1735 | ND | | | ND | | | ND | | |
| X5983 | 100 | Cave Springs | 5/7/14 1835 | 5/8/14 0135 | ND | | | ND | | | ND | | |
| X6486 | 100 | Cave Springs | 5/8/14 0235 | 5/8/14 0935 | ND | | | ND | | | ND | | |
| X6487 | 100 | Cave Springs | 5/8/14 1035 | 5/8/14 1735 | ND | | | ND | | | ND | | |
| X6488 | 100 | Cave Springs | 5/8/14 1835 | 5/9/14 0135 | ND | | | ND | | | ND | | |
| X6488R | 100 | Cave Springs | 5/8/14 1835 | 5/9/14 0135 | ND | | | ND | | | ND | | |
| X6489 | 100 | Cave Springs | 5/9/14 0235 | 5/9/14 0935 | ND | | | ND | | | ND | | |
| | 100 | Cave Springs | 5/9/14 0935 | 5/14/14 1035 | Water from the Cave Springs continuous sampler was not analyzed for this period. | | | | | | | | |
| X6490 | 100 | Cave Springs | 5/14/14 1035 | 5/14/14 1735 | ND | | | ND | | | ND | | |
| X6427 | 100 | Cave Springs | 5/14/14 1735 | 5/15/14 0035 | ND | | | ND | | | ND | | |
| X6428 | 100 | Cave Springs | 5/15/14 0135 | 5/15/14 0835 | ND | | | ND | | | ND | | |
| X6429 | 100 | Cave Springs | 5/15/14 0935 | 5/15/14 1635 | ND | | | ND | | | ND | | |
| | 100 | Cave Springs | 5/15/14 1635 | 5/21/14 1550 | Water from the Cave Springs continuous sampler was not analyzed for this period. | | | | | | | | |
| X6430 | 100 | Cave Springs | 5/21/14 1550 | 5/21/14 1950 | ND | | | ND | | | ND | | |
| X6353 | 100 | Cave Springs | 5/21/14 2050 | 5/22/14 0350 | ND | | | ND | | | ND | | |
| X6354 | 100 | Cave Springs | 5/22/14 0450 | 5/22/14 1150 | ND | | | ND | | | ND | | |
| X6355 | 100 | Cave Springs | 5/22/14 1250 | 5/22/14 1950 | ND | | | ND | | | ND | | |
| X6355R | 100 | Cave Springs | 5/22/14 1250 | 5/22/14 1950 | ND | | | ND | | | ND | | |
| X6356 | 100 | Cave Springs | 5/22/14 2050 | 5/23/14 0350 | ND | | | ND | | | ND | | |
| X6357 | 100 | Cave Springs | 5/23/14 0450 | 5/23/14 1150 | ND | | | ND | | | ND | | |
| X6586 | 100 | Cave Springs | 5/23/14 1250 | 5/23/14 1950 | ND | | | ND | | | ND | | |
| X6587 | 100 | Cave Springs | 5/23/14 2050 | 5/24/14 0350 | ND | | | ND | | | ND | | |
| X6588 | 100 | Cave Springs | 5/24/14 0450 | 5/24/14 1150 | ND | | | ND | | | ND | | |
| X6589 | 100 | Cave Springs | 5/24/14 1250 | 5/24/14 1950 | ND | | | ND | | | ND | | |
| X6590 | 100 | Cave Springs | 5/24/14 2050 | 5/25/14 0350 | ND | | | ND | | | ND | | |
| X6591 | 100 | Cave Springs | 5/25/14 0450 | 5/25/14 1150 | ND | | | ND | | | ND | | |
| X6592 | 100 | Cave Springs | 5/25/14 1250 | 5/25/14 1950 | ND | | | ND | | | ND | | |
| X6592R | 100 | Cave Springs | 5/25/14 1250 | 5/25/14 1950 | ND | | | ND | | | ND | | |
| X6593 | 100 | Cave Springs | 5/25/14 2050 | 5/26/14 0350 | ND | | | ND | | | ND | | |
| X6594 | 100 | Cave Springs | 5/26/14 0450 | 5/26/14 1150 | ND | | | ND | | | ND | | |
| X6595 | 100 | Cave Springs | 5/26/14 1250 | 5/26/14 1950 | ND | | | ND | | | ND | | |

| OUL Number | Station Number | Station Name | Date/Time Started | Date/Time Ended | Fluorescein | | | Eosine | | | RWT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. |
| X6596 | 100 | Cave Springs | 5/26/14 2050 | 5/27/14 0350 | ND | | | ND | | | ND | | |
| X6597 | 100 | Cave Springs | 5/27/14 0450 | 5/27/14 1150 | ND | | | ND | | | ND | | |
| X6598 | 100 | Cave Springs | 5/27/14 1250 | 5/27/14 1950 | ND | | | ND | | | ND | | |
| X6599 | 100 | Cave Springs | 5/27/14 2050 | 5/28/14 0350 | ND | | | ND | | | ND | | |
| X6601 | 100 | Cave Springs | 5/28/14 0450 | 5/28/14 0950 | ND | | | ND | | | ND | | |
| X6869 | 100 | Cave Springs | 5/28/14 1250 | 5/28/14 1950 | ND | | | ND | | | ND | | |
| X6869R | 100 | Cave Springs | 5/28/14 1250 | 5/28/14 1950 | ND | | | ND | | | ND | | |
| X6870 | 100 | Cave Springs | 5/28/14 2050 | 5/29/14 0350 | ND | | | ND | | | ND | | |
| X6871 | 100 | Cave Springs | 5/29/14 0450 | 5/29/14 1150 | ND | | | ND | | | ND | | |
| X6872 | 100 | Cave Springs | 5/29/14 1250 | 5/29/14 1950 | ND | | | ND | | | ND | | |
| X6873 | 100 | Cave Springs | 5/29/14 2050 | 5/30/14 0350 | ND | | | ND | | | ND | | |
| X6874 | 100 | Cave Springs | 5/30/14 0450 | 5/30/14 1150 | ND | | | ND | | | ND | | |
| X6875 | 100 | Cave Springs | 5/30/14 1250 | 5/30/14 1950 | ND | | | ND | | | ND | | |
| X6876 | 100 | Cave Springs | 5/30/14 2050 | 5/31/14 0350 | ND | | | ND | | | ND | | |
| X6877 | 100 | Cave Springs | 5/31/14 0450 | 5/31/14 1150 | ND | | | ND | | | ND | | |
| X6878 | 100 | Cave Springs | 5/31/14 1250 | 5/31/14 1950 | ND | | | ND | | | ND | | |
| X6879 | 100 | Cave Springs | 5/31/14 2050 | 6/1/14 0350 | ND | | | ND | | | ND | | |
| X6881 | 100 | Cave Springs | 6/1/14 0450 | 6/1/14 1150 | ND | | | ND | | | ND | | |
| X6882 | 100 | Cave Springs | 6/1/14 1250 | 6/1/14 1950 | ND | | | ND | | | ND | | |
| X6883 | 100 | Cave Springs | 6/1/14 2050 | 6/2/14 0350 | ND | | | ND | | | ND | | |
| X6884 | 100 | Cave Springs | 6/2/14 0450 | 6/2/14 1150 | ND | | | ND | | | ND | | |
| X6885 | 100 | Cave Springs | 6/2/14 1250 | 6/2/14 1950 | ND | | | ND | | | ND | | |
| X6886 | 100 | Cave Springs | 6/2/14 2050 | 6/3/14 0350 | ND | | | ND | | | ND | | |
| X6887 | 100 | Cave Springs | 6/3/14 0450 | 6/3/14 1150 | ND | | | ND | | | ND | | |
| X6888 | 100 | Cave Springs | 6/3/14 1250 | 6/3/14 1950 | ND | | | ND | | | ND | | |
| X6889 | 100 | Cave Springs | 6/3/14 2050 | 6/4/14 0350 | ND | | | ND | | | ND | | |
| X6890 | 100 | Cave Springs | 6/4/14 0450 | 6/4/14 1150 | ND | | | ND | | | ND | | |
| X6890R | 100 | Cave Springs | 6/4/14 0450 | 6/4/14 1150 | ND | | | ND | | | ND | | |
| X7025 | 100 | Cave Springs | 6/4/14 1300 | 6/4/14 2000 | ND | | | ND | | | ND | | |
| X7026 | 100 | Cave Springs | 6/4/14 2100 | 6/5/14 0400 | ND | | | ND | | | ND | | |
| X7027 | 100 | Cave Springs | 6/5/14 0500 | 6/5/14 1200 | ND | | | ND | | | ND | | |
| X7028 | 100 | Cave Springs | 6/5/14 1300 | 6/5/14 2000 | ND | | | ND | | | ND | | |
| X7029 | 100 | Cave Springs | 6/5/14 2100 | 6/6/14 0400 | ND | | | ND | | | ND | | |

Cave Springs Area Karst Resource Conservation Study

| OUL Number | Station Number | Station Name | Date/Time Started | Date/Time Ended | Fluorescein | | | Eosine | | | RWT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. |
| X7030 | 100 | Cave Springs | 6/6/14 0500 | 6/6/14 1200 | ND | | | ND | | | ND | | |
| X7031 | 100 | Cave Springs | 6/6/14 1300 | 6/6/14 2000 | ND | | | ND | | | ND | | |
| X7032 | 100 | Cave Springs | 6/6/14 2100 | 6/7/14 0400 | ND | | | ND | | | ND | | |
| X7033 | 100 | Cave Springs | 6/7/14 0500 | 6/7/14 1200 | ND | | | ND | | | ND | | |
| X7034 | 100 | Cave Springs | 6/7/14 1300 | 6/7/14 2000 | ND | | | ND | | | ND | | |
| X7035 | 100 | Cave Springs | 6/7/14 2100 | 6/8/14 0400 | ND | | | ND | | | ND | | |
| X7036 | 100 | Cave Springs | 6/8/14 0500 | 6/8/14 1200 | ND | | | ND | | | ND | | |
| X7037 | 100 | Cave Springs | 6/8/14 1300 | 6/8/14 2000 | ND | | | ND | | | ND | | |
| X7038 | 100 | Cave Springs | 6/8/14 2100 | 6/9/14 0400 | ND | | | ND | | | ND | | |
| X7039 | 100 | Cave Springs | 6/9/14 0500 | 6/9/14 1200 | ND | | | ND | | | ND | | |
| X7039R | 100 | Cave Springs | 6/9/14 0500 | 6/9/14 1200 | ND | | | ND | | | ND | | |
| X7041 | 100 | Cave Springs | 6/9/14 1300 | 6/9/14 2000 | ND | | | ND | | | ND | | |
| X7042 | 100 | Cave Springs | 6/9/14 2100 | 6/10/14 0400 | ND | | | ND | | | ND | | |
| X7043 | 100 | Cave Springs | 6/10/14 0500 | 6/10/14 1200 | ND | | | ND | | | ND | | |
| X7044 | 100 | Cave Springs | 6/10/14 1300 | 6/10/14 2000 | ND | | | ND | | | ND | | |
| X7045 | 100 | Cave Springs | 6/10/14 2100 | 6/11/14 0400 | ND | | | ND | | | ND | | |
| X7046 | 100 | Cave Springs | 6/11/14 0500 | 6/11/14 1200 | ND | | | ND | | | ND | | |
| X7047 | 100 | Cave Springs | 6/11/14 1300 | 6/11/14 2000 | ND | | | ND | | | ND | | |
| X7048 | 100 | Cave Springs | 6/11/14 2100 | 6/12/14 0400 | ND | | | ND | | | ND | | |
| X7049 | 100 | Cave Springs | 6/12/14 0500 | 6/12/14 1200 | ND | | | ND | | | ND | | |
| X7049R | 100 | Cave Springs | 6/12/14 0500 | 6/12/14 1200 | ND | | | ND | | | ND | | |
| | 100 | Cave Springs | 6/12/14 1200 | 7/31/14 1300 | Water from the Cave Springs continuous sampler was not analyzed for this period. | | | | | | | | |
| X9146 | 100 | Cave Springs | 7/31/14 1300 | 7/31/14 2000 | ND | | | ND | | | ND | | |
| X9147 | 100 | Cave Springs | 7/31/14 2100 | 8/1/14 0400 | 507.8 | 0.012 | 14-08 | ND | | | ND | | |
| X9148 | 100 | Cave Springs | 8/1/14 0500 | 8/1/14 1200 | 507.7 | 0.708 | 14-08 | ND | | | ND | | |
| X9149 | 100 | Cave Springs | 8/1/14 1300 | 8/1/14 2000 | 507.7 | 1.02 | 14-08 | ND | | | ND | | |
| X9150 | 100 | Cave Springs | 8/1/14 2100 | 8/2/14 0400 | 507.7 | 0.655 | 14-08 | ND | | | ND | | |
| X9151 | 100 | Cave Springs | 8/2/14 0500 | 8/2/14 1200 | 507.7 | 0.410 | 14-08 | ND | | | ND | | |
| X9152 | 100 | Cave Springs | 8/2/14 1300 | 8/2/14 2000 | 507.8 | 0.302 | 14-08 | ND | | | ND | | |
| X9153 | 100 | Cave Springs | 8/2/14 2100 | 8/3/14 0400 | 507.7 | 0.540 | 14-08 | ND | | | ND | | |
| X9154 | 100 | Cave Springs | 8/3/14 0500 | 8/3/14 1200 | 507.6 | 1.45 | 14-08 | ND | | | ND | | |
| X9155 | 100 | Cave Springs | 8/3/14 1300 | 8/3/14 2000 | 507.5 | 2.56 | 14-08 | ND | | | ND | | |
| X9156 | 100 | Cave Springs | 8/3/14 2100 | 8/4/14 0400 | 507.7 | 2.76 | 14-08 | ND | | | ND | | |

Cave Springs Area Karst Resource Conservation Study

| OUL Number | Station Number | Station Name | Date/Time Started | Date/Time Ended | Fluorescein | | | Eosine | | | RWT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. |
| X9157 | 100 | Cave Springs | 8/4/14 0500 | 8/4/14 1200 | 507.6 | 2.72 | 14-08 | ND | | | ND | | |
| X9158 | 100 | Cave Springs | 8/4/14 1300 | 8/4/14 2000 | 507.7 | 2.05 | 14-08 | ND | | | ND | | |
| X9159 | 100 | Cave Springs | 8/4/14 2100 | 8/5/14 0400 | 507.4 | 1.74 | 14-08 | ND | | | ND | | |
| X9161 | 100 | Cave Springs | 8/5/14 0500 | 8/5/14 1200 | 507.7 | 1.42 | 14-08 | ND | | | ND | | |
| X9162 | 100 | Cave Springs | 8/5/14 1300 | 8/5/14 2000 | 507.7 | 1.06 | 14-08 | ND | | | ND | | |
| X9163 | 100 | Cave Springs | 8/5/14 2100 | 8/6/14 0400 | 507.9 | 0.707 | 14-08 | ND | | | ND | | |
| X9164 | 100 | Cave Springs | 8/6/14 0500 | 8/6/14 1200 | 507.6 | 0.500 | 14-08 | ND | | | ND | | |
| X9165 | 100 | Cave Springs | 8/6/14 1300 | 8/6/14 2000 | 507.7 | 0.124 | 14-08 | ND | | | ND | | |
| X9367 | 100 | Cave Springs | 8/6/14 2100 | 8/7/14 0400 | 508.1 | 0.231 | 14-08 | ND | | | ND | | |
| X9368 | 100 | Cave Springs | 8/7/14 0500 | 8/7/14 1200 | 507.9 | 0.164 | 14-08 | ND | | | ND | | |
| X9369 | 100 | Cave Springs | 8/7/14 1300 | 8/7/14 2000 | 507.9 | 0.118 | 14-08 | ND | | | ND | | |
| X9370 | 100 | Cave Springs | 8/7/14 2100 | 8/8/14 0400 | 508.0 | 0.090 | 14-08 | ND | | | ND | | |
| X9371 | 100 | Cave Springs | 8/8/14 0500 | 8/8/14 0800 | 507.8 | 0.079 | 14-08 | ND | | | ND | | |
| X9372 | 100 | Cave Springs | 8/8/14 0830 | 8/8/14 1200 | 508.6 | 0.055 | 14-08 | ND | | | ND | | |
| X9373 | 100 | Cave Springs | 8/8/14 1230 | 8/8/14 1600 | 511.8 ** | 0.045 | 14-08 | ND | | | ND | | |
| X9373R | 100 | Cave Springs | 8/8/14 1230 | 8/8/14 1600 | 511.6 ** | 0.042 | 14-08 | ND | | | ND | | |
| X9374 | 100 | Cave Springs | 8/8/14 1630 | 8/8/14 2000 | 508.6 | 0.087 | 14-08 | ND | | | ND | | |
| X9375 | 100 | Cave Springs | 8/8/14 2030 | 8/9/14 0000 | 508.0 | 0.121 | 14-08 | ND | | | ND | | |
| X9376 | 100 | Cave Springs | 8/9/14 0030 | 8/9/14 0400 | 506.8 | 0.136 | 14-08 | ND | | | ND | | |
| X9377 | 100 | Cave Springs | 8/9/14 0430 | 8/9/14 0800 | 508.1 | 0.115 | 14-08 | ND | | | ND | | |
| X9378 | 100 | Cave Springs | 8/9/14 0830 | 8/9/14 1200 | 508.2 | 0.089 | 14-08 | ND | | | ND | | |
| X9379 | 100 | Cave Springs | 8/9/14 1230 | 8/9/14 1600 | 508.2 | 0.077 | 14-08 | ND | | | ND | | |
| X9381 | 100 | Cave Springs | 8/9/14 1630 | 8/9/14 2000 | 508.6 | 0.073 | 14-08 | ND | | | ND | | |
| X9382 | 100 | Cave Springs | 8/9/14 2030 | 8/10/14 0000 | 508.0 | 0.070 | 14-08 | ND | | | ND | | |
| X9383 | 100 | Cave Springs | 8/10/14 0030 | 8/10/14 0400 | 507.9 | 0.057 | 14-08 | ND | | | ND | | |
| X9384 | 100 | Cave Springs | 8/10/14 0430 | 8/10/14 0800 | 507.9 | 0.055 | 14-08 | ND | | | ND | | |
| X9385 | 100 | Cave Springs | 8/10/14 0830 | 8/10/14 1200 | 507.4 | 0.044 | 14-08 | ND | | | ND | | |
| X9386 | 100 | Cave Springs | 8/10/14 1230 | 8/10/14 1600 | 508.2 | 0.041 | 14-08 | ND | | | ND | | |
| X9387 | 100 | Cave Springs | 8/10/14 1630 | 8/10/14 2000 | 508.0 | 0.042 | 14-08 | ND | | | ND | | |
| X9388 | 100 | Cave Springs | 8/10/14 2030 | 8/11/14 0000 | 508.2 | 0.050 | 14-08 | ND | | | ND | | |
| X9389 | 100 | Cave Springs | 8/11/14 0030 | 8/11/14 0400 | 508.4 | 0.112 | 14-08 | ND | | | ND | | |
| X9389R | 100 | Cave Springs | 8/11/14 0030 | 8/11/14 0400 | 508.2 | 0.111 | 14-08 | ND | | | ND | | |
| X9390 | 100 | Cave Springs | 8/11/14 0430 | 8/11/14 0800 | 508.5 | 0.181 | 14-08 | ND | | | ND | | |

Cave Springs Area Karst Resource Conservation Study

| OUL Number | Station Number | Station Name | Date/Time Started | Date/Time Ended | Fluorescein | | | Eosine | | | RWT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. |
| X9391 | 100 | Cave Springs | 8/11/14 0830 | 8/11/14 1200 | 508.1 | 0.213 | 14-08 | ND | | | ND | | |
| X9392 | 100 | Cave Springs | 8/11/14 1230 | 8/11/14 1600 | 508.1 | 0.234 | 14-08 | ND | | | ND | | |
| X9393 | 100 | Cave Springs | 8/11/14 1630 | 8/11/14 2000 | 508.1 | 0.311 | 14-08 | ND | | | ND | | |
| X9394 | 100 | Cave Springs | 8/11/14 2030 | 8/12/14 0000 | 507.8 | 0.325 | 14-08 | ND | | | ND | | |
| X9395 | 100 | Cave Springs | 8/12/14 0030 | 8/12/14 0400 | 508.2 | 0.293 | 14-08 | ND | | | ND | | |
| X9396 | 100 | Cave Springs | 8/12/14 0430 | 8/12/14 0800 | 508.3 | 0.279 | 14-08 | ND | | | ND | | |
| X9358 | 100 | Cave Springs | 8/12/14 0830 | 8/12/14 1200 | 509.2 | 0.185 | 14-08 | ND | | | ND | | |
| X9359 | 100 | Cave Springs | 8/12/14 1230 | 8/12/14 1600 | 507.7 | 0.211 | 14-08 | ND | | | ND | | |
| X9361 | 100 | Cave Springs | 8/12/14 1630 | 8/12/14 2000 | 508.2 | 0.168 | 14-08 | ND | | | ND | | |
| X9362 | 100 | Cave Springs | 8/12/14 2030 | 8/13/14 0000 | 508.3 | 0.185 | 14-08 | ND | | | ND | | |
| X9363 | 100 | Cave Springs | 8/13/14 0030 | 8/13/14 0400 | 507.7 | 0.169 | 14-08 | ND | | | ND | | |
| X9364 | 100 | Cave Springs | 8/13/14 0430 | 8/13/14 0800 | 508.1 | 0.177 | 14-08 | ND | | | ND | | |
| X9365 | 100 | Cave Springs | 8/13/14 0830 | 8/13/14 1200 | 508.0 | 0.127 | 14-08 | ND | | | ND | | |
| X9366 | 100 | Cave Springs | 8/15/14 0900 | 8/15/14 1200 | 507.2 | 0.027 | 14-08 | ND | | | ND | | |
| X9515 | 100 | Cave Springs | 8/15/14 1300 | 8/15/14 2000 | 507.8 | 0.016 | 14-08 | ND | | | ND | | |
| X9516 | 100 | Cave Springs | 8/15/14 2100 | 8/16/14 0400 | 507.8 | 0.019 | 14-08 | ND | | | ND | | |
| X9517 | 100 | Cave Springs | 8/16/14 0500 | 8/16/14 1200 | 507.2 | 0.017 | 14-08 | ND | | | ND | | |
| X9518 | 100 | Cave Springs | 8/16/14 1300 | 8/16/14 2000 | 506.8 | 0.015 | 14-08 | ND | | | ND | | |
| X9519 | 100 | Cave Springs | 8/16/14 2100 | 8/17/14 0400 | 508.3 | 0.013 | 14-08 | ND | | | ND | | |
| X9521 | 100 | Cave Springs | 8/17/14 0500 | 8/17/14 1200 | 507.6 | 0.014 | 14-08 | ND | | | ND | | |
| X9522 | 100 | Cave Springs | 8/17/14 1300 | 8/17/14 2000 | 508.2 | 0.011 | 14-08 | ND | | | ND | | |
| X9523 | 100 | Cave Springs | 8/17/14 2100 | 8/18/14 0400 | 508.4 | 0.010 | 14-08 | ND | | | ND | | |
| X9524 | 100 | Cave Springs | 8/18/14 0500 | 8/18/14 1200 | 507.8 ** | 0.008 | 14-08 | ND | | | ND | | |
| X9525 | 100 | Cave Springs | 8/18/14 1300 | 8/18/14 2000 | ND | | | ND | | | ND | | |
| X9526 | 100 | Cave Springs | 8/18/14 2100 | 8/19/14 0400 | 504.8 ** | 0.006 | 14-08 | ND | | | ND | | |
| X9526R | 100 | Cave Springs | 8/18/14 2100 | 8/19/14 0400 | 506.8 ** | 0.009 | 14-08 | ND | | | ND | | |
| X9527 | 100 | Cave Springs | 8/19/14 0500 | 8/19/14 1200 | 508.2 ** | 0.007 | 14-08 | ND | | | ND | | |
| X9528 | 100 | Cave Springs | 8/19/14 1300 | 8/19/14 2000 | 506.8 ** | 0.007 | 14-08 | ND | | | ND | | |
| X9529 | 100 | Cave Springs | 8/19/14 2100 | 8/20/14 0400 | ND | | | ND | | | ND | | |
| X9530 | 100 | Cave Springs | 8/20/14 0500 | 8/20/14 1200 | ND | | | ND | | | ND | | |
| X9531 | 100 | Cave Springs | 8/20/14 1300 | 8/20/14 2000 | 507.2 ** | 0.006 | 14-08 | ND | | | ND | | |
| X9532 | 100 | Cave Springs | 8/20/14 2100 | 8/21/14 0400 | 508.4 ** | 0.007 | 14-08 | ND | | | ND | | |
| X9533 | 100 | Cave Springs | 8/21/14 0500 | 8/21/14 1200 | 507.6 ** | 0.005 | 14-08 | ND | | | ND | | |

| OUL Number | Station Number | Station Name | Date/Time Started | Date/Time Ended | Fluorescein | | | Eosine | | | RWT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. |
| X9534 | 100 | Cave Springs | 8/21/14 1300 | 8/21/14 2000 | ND | | | ND | | | ND | | |
| X9809 | 100 | Cave Springs | 8/21/14 2100 | 8/22/14 0400 | ND | | | ND | | | ND | | |
| X9810 | 100 | Cave Springs | 8/22/14 0500 | 8/22/14 1200 | ND | | | ND | | | ND | | |
| X9811 | 100 | Cave Springs | 8/22/14 1300 | 8/22/14 2000 | ND | | | ND | | | ND | | |
| X9812 | 100 | Cave Springs | 8/22/14 2100 | 8/23/14 0400 | ND | | | ND | | | ND | | |
| X9813 | 100 | Cave Springs | 8/23/14 0500 | 8/23/14 1200 | ND | | | ND | | | ND | | |
| X9814 | 100 | Cave Springs | 8/23/14 1300 | 8/23/14 2000 | ND | | | ND | | | ND | | |
| X9815 | 100 | Cave Springs | 8/23/14 2100 | 8/24/14 0400 | ND | | | ND | | | ND | | |
| X9815R | 100 | Cave Springs | 8/23/14 2100 | 8/24/14 0400 | ND | | | ND | | | ND | | |
| X9816 | 100 | Cave Springs | 8/24/14 0500 | 8/24/14 1200 | ND | | | ND | | | ND | | |
| X9817 | 100 | Cave Springs | 8/24/14 1300 | 8/24/14 2000 | ND | | | ND | | | ND | | |
| X9818 | 100 | Cave Springs | 8/24/14 2100 | 8/25/14 0400 | ND | | | ND | | | ND | | |
| X9819 | 100 | Cave Springs | 8/25/14 0500 | 8/25/14 1200 | ND | | | ND | | | ND | | |
| X9821 | 100 | Cave Springs | 8/25/14 1300 | 8/25/14 2000 | ND | | | ND | | | ND | | |
| X9822 | 100 | Cave Springs | 8/25/14 2100 | 8/26/14 0400 | ND | | | ND | | | ND | | |
| X9823 | 100 | Cave Springs | 8/26/14 0500 | 8/26/14 1200 | ND | | | ND | | | ND | | |
| X9824 | 100 | Cave Springs | 8/26/14 1300 | 8/26/14 2000 | 506.8 ** | 0.013 | 14-08 | ND | | | ND | | |
| X9825 | 100 | Cave Springs | 8/26/14 2100 | 8/27/14 0400 | ND | | | ND | | | ND | | |
| X9826 | 100 | Cave Springs | 8/27/14 0500 | 8/27/14 1200 | ND | | | ND | | | ND | | |
| Y0005 | 100 | Cave Springs | 8/27/14 1300 | 8/27/14 2000 | ND | | | ND | | | ND | | |
| Y0006 | 100 | Cave Springs | 8/27/14 2100 | 8/28/14 0400 | ND | | | ND | | | ND | | |
| Y0007 | 100 | Cave Springs | 8/28/14 0500 | 8/28/14 1200 | ND | | | ND | | | ND | | |
| Y0008 | 100 | Cave Springs | 8/28/14 1300 | 8/28/14 2000 | ND | | | ND | | | ND | | |
| Y0009 | 100 | Cave Springs | 8/28/14 2100 | 8/29/14 0400 | ND | | | ND | | | ND | | |
| Y0010 | 100 | Cave Springs | 8/29/14 0500 | 8/29/14 1200 | ND | | | ND | | | ND | | |
| Y0011 | 100 | Cave Springs | 8/29/14 1300 | 8/29/14 2000 | ND | | | ND | | | ND | | |
| Y0012 | 100 | Cave Springs | 8/29/14 2100 | 8/30/14 0400 | ND | | | ND | | | ND | | |
| Y0013 | 100 | Cave Springs | 8/30/14 0500 | 8/30/14 1200 | ND | | | ND | | | ND | | |
| Y0014 | 100 | Cave Springs | 8/30/14 1300 | 8/30/14 2000 | ND | | | ND | | | ND | | |
| Y0015 | 100 | Cave Springs | 8/30/14 2100 | 8/31/14 0400 | ND | | | ND | | | ND | | |
| Y0016 | 100 | Cave Springs | 8/31/14 0500 | 8/31/14 1200 | ND | | | ND | | | ND | | |
| Y0017 | 100 | Cave Springs | 8/31/14 1300 | 8/31/14 2000 | ND | | | ND | | | ND | | |
| Y0017R | 100 | Cave Springs | 8/31/14 1300 | 8/31/14 2000 | ND | | | ND | | | ND | | |

Cave Springs Area Karst Resource Conservation Study

| OUL Number | Station Number | Station Name | Date/Time Started | Date/Time Ended | Fluorescein | | | Eosine | | | RWT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. |
| Y0018 | 100 | Cave Springs | 8/31/14 2100 | 9/1/14 0400 | ND | | | ND | | | ND | | |
| Y0019 | 100 | Cave Springs | 9/1/14 0500 | 9/1/14 1200 | ND | | | ND | | | ND | | |
| Y0021 | 100 | Cave Springs | 9/1/14 1300 | 9/1/14 2000 | ND | | | ND | | | ND | | |
| Y0022 | 100 | Cave Springs | 9/1/14 2100 | 9/2/14 0400 | ND | | | ND | | | ND | | |
| Y0023 | 100 | Cave Springs | 9/2/14 0500 | 9/2/14 1200 | ND | | | ND | | | ND | | |
| Y0024 | 100 | Cave Springs | 9/2/14 1300 | 9/2/14 2000 | ND | | | ND | | | ND | | |
| Y0025 | 100 | Cave Springs | 9/2/14 2100 | 9/3/14 0400 | ND | | | ND | | | ND | | |
| Y0026 | 100 | Cave Springs | 9/3/14 0500 | 9/3/14 1200 | ND | | | ND | | | ND | | |
| Y0027 | 100 | Cave Springs | 9/3/14 1300 | 9/3/14 2000 | ND | | | ND | | | ND | | |
| Y0028 | 100 | Cave Springs | 9/3/14 2100 | 9/4/14 0400 | 509.2 | 0.014 | 14-08 | ND | | | ND | | |
| Y0029 | 100 | Cave Springs | 9/4/14 0500 | 9/4/14 1200 | 507.9 | 0.068 | 14-08 | ND | | | ND | | |
| | 100 | Cave Springs | 9/4/14 1200 | 9/10/14 2100 | Water from the Cave Springs continuous sampler was not analyzed for this period. | | | | | | | | |
| Y0258 | 100 | Cave Springs | 9/10/14 2100 | 9/11/14 0400 | ND | | | ND | | | ND | | |
| Y0259 | 100 | Cave Springs | 9/11/14 0500 | 9/11/14 1200 | 507.4 ** | 0.007 | 14-08 | ND | | | ND | | |
| Y0261 | 100 | Cave Springs | 9/11/14 1300 | 9/11/14 2000 | ND | | | ND | | | ND | | |
| Y0262 | 100 | Cave Springs | 9/11/14 2100 | 9/12/14 0400 | ND | | | ND | | | ND | | |
| Y0263 | 100 | Cave Springs | 9/12/14 0500 | 9/12/14 1200 | ND | | | ND | | | ND | | |
| Y0466 | 100 | Cave Springs | 9/12/14 1300 | 9/12/14 2000 | ND | | | ND | | | ND | | |
| Y0467 | 100 | Cave Springs | 9/12/14 2100 | 9/13/14 0400 | ND | | | ND | | | ND | | |
| Y0468 | 100 | Cave Springs | 9/13/14 0500 | 9/13/14 1200 | ND | | | ND | | | ND | | |
| | 100 | Cave Springs | 9/13/14 1200 | 9/17/14 1300 | Water from the Cave Springs continuous sampler was not analyzed for this period. | | | | | | | | |
| Y0573 | 100 | Cave Springs | 9/17/14 1300 | 9/17/14 2000 | ND | | | ND | | | ND | | |
| Y0574 | 100 | Cave Springs | 9/17/14 2100 | 9/18/14 0400 | ND | | | ND | | | ND | | |
| Y0575 | 100 | Cave Springs | 9/18/14 0500 | 9/18/14 1200 | ND | | | ND | | | ND | | |
| Y0576 | 100 | Cave Springs | 9/18/14 1300 | 9/18/14 2000 | ND | | | ND | | | ND | | |
| Y0577 | 100 | Cave Springs | 9/18/14 2100 | 9/19/14 0400 | ND | | | ND | | | ND | | |
| Y0578 | 100 | Cave Springs | 9/19/14 0500 | 9/19/14 1200 | ND | | | ND | | | ND | | |
| Y0579 | 100 | Cave Springs | 9/19/14 1300 | 9/19/14 2000 | 507.8 | 0.008 | 14-08 | ND | | | ND | | |
| Y0581 | 100 | Cave Springs | 9/19/14 2100 | 9/20/14 0400 | 508.2 | 0.016 | 14-08 | ND | | | ND | | |
| Y0582 | 100 | Cave Springs | 9/20/14 0500 | 9/20/14 1200 | 507.6 | 0.029 | 14-08 | ND | | | ND | | |
| Y0583 | 100 | Cave Springs | 9/20/14 1300 | 9/20/14 2000 | 507.6 | 0.033 | 14-08 | ND | | | ND | | |
| Y0584 | 100 | Cave Springs | 9/20/14 2100 | 9/21/14 0400 | 507.4 | 0.024 | 14-08 | ND | | | ND | | |
| Y0585 | 100 | Cave Springs | 9/21/14 0500 | 9/21/14 1200 | 507.0 | 0.016 | 14-08 | ND | | | ND | | |

Cave Springs Area Karst Resource Conservation Study

| OUL Number | Station Number | Station Name | Date/Time Started | Date/Time Ended | Fluorescein | | | Eosine | | | RWT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. |
| Y0585R | 100 | Cave Springs | 9/21/14 0500 | 9/21/14 1200 | 508.4 | 0.016 | 14-08 | ND | | | ND | | |
| Y0586 | 100 | Cave Springs | 9/21/14 1300 | 9/21/14 2000 | 507.6 | 0.009 | 14-08 | ND | | | ND | | |
| Y0587 | 100 | Cave Springs | 9/21/14 2100 | 9/22/14 0400 | 507.8 ** | 0.007 | 14-08 | ND | | | ND | | |
| Y0588 | 100 | Cave Springs | 9/22/14 0500 | 9/22/14 1200 | 506.4 ** | 0.006 | 14-08 | ND | | | ND | | |
| Y0589 | 100 | Cave Springs | 9/23/14 0500 | 9/23/14 1200 | 507.4 | 0.012 | 14-08 | ND | | | ND | | |
| Y0765 | 100 | Cave Springs | 9/23/14 1300 | 9/23/14 2000 | 509.8 | 0.009 | 14-08 | ND | | | ND | | |
| Y0766 | 100 | Cave Springs | 9/23/14 2100 | 9/24/14 0400 | 508.4 ** | 0.005 | 14-08 | ND | | | ND | | |
| Y0767 | 100 | Cave Springs | 9/24/14 0500 | 9/24/14 1200 | 507.8 ** | 0.006 | 14-08 | ND | | | ND | | |
| Y0768 | 100 | Cave Springs | 9/24/14 1300 | 9/24/14 2000 | 509.2 ** | 0.008 | 14-08 | ND | | | ND | | |
| Y0769 | 100 | Cave Springs | 9/24/14 2100 | 9/25/14 0400 | 508.0 ** | 0.007 | 14-08 | ND | | | ND | | |
| Y0770 | 100 | Cave Springs | 9/25/14 0500 | 9/25/14 1200 | 510.4 ** | 0.007 | 14-08 | ND | | | ND | | |
| Y0771 | 100 | Cave Springs | 9/25/14 1300 | 9/25/14 2000 | 509.8 ** | 0.007 | 14-08 | ND | | | ND | | |
| Y0772 | 100 | Cave Springs | 9/25/14 2100 | 9/26/14 0400 | 509.8 ** | 0.005 | 14-08 | ND | | | ND | | |
| Y0773 | 100 | Cave Springs | 9/26/14 0500 | 9/26/14 1200 | 508.0 ** | 0.006 | 14-08 | ND | | | ND | | |
| Y0774 | 100 | Cave Springs | 9/26/14 1300 | 9/26/14 2000 | 509.4 ** | 0.006 | 14-08 | ND | | | ND | | |
| Y0775 | 100 | Cave Springs | 9/26/14 2100 | 9/27/14 0400 | 508.2 ** | 0.006 | 14-08 | ND | | | ND | | |
| Y0776 | 100 | Cave Springs | 9/27/14 0500 | 9/27/14 1200 | 507.0 ** | 0.006 | 14-08 | ND | | | ND | | |
| Y0777 | 100 | Cave Springs | 9/27/14 1300 | 9/27/14 2000 | 508.4 ** | 0.005 | 14-08 | ND | | | ND | | |
| Y0778 | 100 | Cave Springs | 9/27/14 2100 | 9/28/14 0400 | ND | | | ND | | | ND | | |
| Y0779 | 100 | Cave Springs | 9/28/14 0500 | 9/28/14 1200 | ND | | | ND | | | ND | | |
| Y0781 | 100 | Cave Springs | 9/28/14 1300 | 9/28/14 2000 | ND | | | ND | | | ND | | |
| Y0782 | 100 | Cave Springs | 9/28/14 2100 | 9/29/14 0400 | ND | | | ND | | | ND | | |
| Y0783 | 100 | Cave Springs | 9/29/14 0500 | 9/29/14 1200 | ND | | | ND | | | ND | | |
| Y1154 | 100 | Cave Springs | 9/29/14 1300 | 9/29/14 2000 | ND | | | ND | | | ND | | |
| Y1155 | 100 | Cave Springs | 9/29/14 2100 | 9/30/14 0400 | ND | | | ND | | | ND | | |
| Y1156 | 100 | Cave Springs | 9/30/14 0500 | 9/30/14 1200 | ND | | | ND | | | ND | | |
| Y1157 | 100 | Cave Springs | 9/30/14 1300 | 9/30/14 2000 | ND | | | ND | | | ND | | |
| Y1158 | 100 | Cave Springs | 9/30/14 2100 | 10/1/14 0400 | ND | | | ND | | | ND | | |
| Y1159 | 100 | Cave Springs | 10/1/14 0500 | 10/1/14 1200 | ND | | | ND | | | ND | | |
| Y1161 | 100 | Cave Springs | 10/1/14 1300 | 10/1/14 2000 | ND | | | ND | | | ND | | |
| Y1162 | 100 | Cave Springs | 10/1/14 2100 | 10/2/14 0400 | ND | | | ND | | | ND | | |
| Y1162R | 100 | Cave Springs | 10/1/14 2100 | 10/2/14 0400 | ND | | | ND | | | ND | | |
| Y1163 | 100 | Cave Springs | 10/2/14 0500 | 10/2/14 1200 | ND | | | ND | | | ND | | |

| OUL Number | Station Number | Station Name | Date/Time Started | Date/Time Ended | Fluorescein | | | Eosine | | | RWT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. |
| Y1164 | 100 | Cave Springs | 10/2/14 1300 | 10/2/14 2000 | ND | | | ND | | | ND | | |
| Y1165 | 100 | Cave Springs | 10/2/14 2100 | 10/3/14 0400 | ND | | | ND | | | ND | | |
| Y1166 | 100 | Cave Springs | 10/3/14 0500 | 10/3/14 1200 | ND | | | ND | | | ND | | |
| Y1167 | 100 | Cave Springs | 10/3/14 1300 | 10/3/14 2000 | ND | | | ND | | | ND | | |
| Y1107 | 100 | Cave Springs | 10/3/14 2100 | 10/4/14 0400 | ND | | | ND | | | ND | | |
| Y1108 | 100 | Cave Springs | 10/4/14 0500 | 10/4/14 1200 | ND | | | ND | | | ND | | |
| Y1109 | 100 | Cave Springs | 10/4/14 1300 | 10/4/14 2000 | ND | | | ND | | | ND | | |
| Y1110 | 100 | Cave Springs | 10/4/14 2100 | 10/5/14 0400 | ND | | | ND | | | ND | | |
| Y1111 | 100 | Cave Springs | 10/5/14 0500 | 10/5/14 1200 | ND | | | ND | | | ND | | |
| Y1112 | 100 | Cave Springs | 10/5/14 1300 | 10/5/14 2000 | ND | | | ND | | | ND | | |
| Y1113 | 100 | Cave Springs | 10/5/14 2100 | 10/6/14 0400 | ND | | | ND | | | ND | | |
| Y1113R | 100 | Cave Springs | 10/5/14 2100 | 10/6/14 0400 | ND | | | ND | | | ND | | |
| Y1114 | 100 | Cave Springs | 10/6/14 0500 | 10/6/14 1200 | ND | | | ND | | | ND | | |
| Y1115 | 100 | Cave Springs | 10/6/14 1300 | 10/6/14 2000 | ND | | | ND | | | ND | | |
| Y1116 | 100 | Cave Springs | 10/6/14 2100 | 10/7/14 0400 | ND | | | ND | | | ND | | |
| Y1117 | 100 | Cave Springs | 10/7/14 0500 | 10/7/14 1200 | ND | | | ND | | | ND | | |
| Y1118 | 100 | Cave Springs | 10/7/14 1300 | 10/7/14 2000 | ND | | | ND | | | ND | | |
| Y1119 | 100 | Cave Springs | 10/7/14 2100 | 10/8/14 0400 | ND | | | ND | | | ND | | |
| Y1121 | 100 | Cave Springs | 10/8/14 0500 | 10/8/14 1200 | ND | | | ND | | | ND | | |
| Y1122 | 100 | Cave Springs | 10/8/14 1300 | 10/8/14 2000 | ND | | | ND | | | ND | | |
| Y1123 | 100 | Cave Springs | 10/8/14 2100 | 10/9/14 0400 | ND | | | ND | | | ND | | |
| Y1124 | 100 | Cave Springs | 10/9/14 0500 | 10/9/14 1200 | ND | | | ND | | | ND | | |
| Y1125 | 100 | Cave Springs | 10/9/14 1300 | 10/9/14 2000 | ND | | | ND | | | ND | | |
| Y1126 | 100 | Cave Springs | 10/9/14 2100 | 10/10/14 0400 | ND | | | ND | | | ND | | |
| Y1127 | 100 | Cave Springs | 10/10/14 0500 | 10/10/14 1200 | ND | | | ND | | | ND | | |
| Y1128 | 100 | Cave Springs | 10/10/14 1300 | 10/10/14 2000 | ND | | | ND | | | ND | | |
| Y1129 | 100 | Cave Springs | 10/10/14 2100 | 10/11/14 0400 | ND | | | ND | | | ND | | |
| Y1130 | 100 | Cave Springs | 10/11/14 0500 | 10/11/14 1200 | 508.2 | 0.030 | 14-08 | ND | | | ND | | |
| Y1131 | 100 | Cave Springs | 10/11/14 1300 | 10/11/14 2000 | 508.0 | 0.032 | 14-08 | ND | | | ND | | |
| Y1448 | 100 | Cave Springs | 10/13/14 1300 | 10/13/14 2000 | 509.4 | 0.027 | 14-08 | ND | | | ND | | |
| Y1449 | 100 | Cave Springs | 10/13/14 2100 | 10/14/14 0400 | 511.2 ** | 0.017 | 14-08 | ND | | | ND | | |
| Y1450 | 100 | Cave Springs | 10/14/14 0500 | 10/14/14 1200 | 514.0 ** | 0.021 | 14-08 | ND | | | ND | | |
| Y1451 | 100 | Cave Springs | 10/14/14 1300 | 10/14/14 2000 | 513.2 ** | 0.020 | 14-08 | ND | | | ND | | |

Cave Springs Area Karst Resource Conservation Study

| OUL Number | Station Number | Station Name | Date/Time Started | Date/Time Ended | Fluorescein | | | Eosine | | | RWT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. | Peak (nm) | Conc. (ppb) | Trace No. |
| Y1452 | 100 | Cave Springs | 10/14/14 2100 | 10/15/14 0400 | 511.2 ** | 0.018 | 14-08 | ND | | | ND | | |
| Y1453 | 100 | Cave Springs | 10/15/14 0500 | 10/15/14 1200 | 510.2 | 0.021 | 14-08 | ND | | | ND | | |
| Y1454 | 100 | Cave Springs | 10/15/14 1300 | 10/15/14 2000 | 510.2 | 0.021 | 14-08 | ND | | | ND | | |
| Y1455 | 100 | Cave Springs | 10/15/14 2100 | 10/16/14 0400 | 510.2 | 0.023 | 14-08 | ND | | | ND | | |
| Y1456 | 100 | Cave Springs | 10/16/14 0500 | 10/16/14 1200 | 510.2 | 0.020 | 14-08 | ND | | | ND | | |
| Y1457 | 100 | Cave Springs | 10/16/14 1300 | 10/16/14 2000 | 509.0 | 0.019 | 14-08 | ND | | | ND | | |
| Y1458 | 100 | Cave Springs | 10/16/14 2100 | 10/17/14 0400 | 510.4 | 0.019 | 14-08 | ND | | | ND | | |
| Y1459 | 100 | Cave Springs | 10/17/14 0500 | 10/17/14 1200 | 507.2 | 0.018 | 14-08 | ND | | | ND | | |
| Y1461 | 100 | Cave Springs | 10/17/14 1300 | 10/17/14 2000 | 508.4 | 0.018 | 14-08 | ND | | | ND | | |
| Y1462 | 100 | Cave Springs | 10/17/14 2100 | 10/18/14 0400 | 508.4 | 0.019 | 14-08 | ND | | | ND | | |
| Y1463 | 100 | Cave Springs | 10/18/14 0500 | 10/18/14 1200 | 507.0 | 0.019 | 14-08 | ND | | | ND | | |
| Y1464 | 100 | Cave Springs | 10/18/14 1300 | 10/18/14 2000 | 509.4 | 0.020 | 14-08 | ND | | | ND | | |
| Y1465 | 100 | Cave Springs | 10/18/14 2100 | 10/19/14 0400 | 508.8 | 0.020 | 14-08 | ND | | | ND | | |
| Y1466 | 100 | Cave Springs | 10/19/14 0500 | 10/19/14 1200 | 507.8 | 0.019 | 14-08 | ND | | | ND | | |
| Y1467 | 100 | Cave Springs | 10/19/14 1300 | 10/19/14 2000 | 508.2 | 0.017 | 14-08 | ND | | | ND | | |
| Y1468 | 100 | Cave Springs | 10/19/14 2100 | 10/20/14 0400 | 508.2 | 0.019 | 14-08 | ND | | | ND | | |
| Y1469 | 100 | Cave Springs | 10/20/14 0500 | 10/20/14 1200 | 507.6 | 0.018 | 14-08 | ND | | | ND | | |

Cave Springs Area Karst Resource Conservation Study

**Table 6. Results for composite water samples analyzed for the presence of pyranine dye.**

Peak wavelengths are reported in nanometers (nm); dye concentrations are reported in parts per billion (ppb).

| OUL Number | Station Number | Station Name | Date/Time Started | Date/Time Ended | Pyranine | | |
|---|---|---|---|---|---|---|---|
| | | | | | Peak (nm) | Conc. (ppb) | Trace No. |
| X9146 | 100 | Cave Springs | 7/31/14 1300 | 7/31/14 2000 | ND | | |
| X9147 | 100 | Cave Springs | 7/31/14 2100 | 8/1/14 0400 | ND | | |
| X9148 | 100 | Cave Springs | 8/1/14 0500 | 8/1/14 1200 | ND | | |
| X9149 | 100 | Cave Springs | 8/1/14 1300 | 8/1/14 2000 | ND | | |
| X9150 | 100 | Cave Springs | 8/1/14 2100 | 8/2/14 0400 | ND | | |
| X9151 | 100 | Cave Springs | 8/2/14 0500 | 8/2/14 1200 | ND | | |
| X9152 | 100 | Cave Springs | 8/2/14 1300 | 8/2/14 2000 | ND | | |
| X9153 | 100 | Cave Springs | 8/2/14 2100 | 8/3/14 0400 | ND | | |
| X9154 | 100 | Cave Springs | 8/3/14 0500 | 8/3/14 1200 | ND | | |
| X9155 | 100 | Cave Springs | 8/3/14 1300 | 8/3/14 2000 | ND | | |
| X9156 | 100 | Cave Springs | 8/3/14 2100 | 8/4/14 0400 | ND | | |
| X9157 | 100 | Cave Springs | 8/4/14 0500 | 8/4/14 1200 | ND | | |
| X9158 | 100 | Cave Springs | 8/4/14 1300 | 8/4/14 2000 | ND | | |
| X9159 | 100 | Cave Springs | 8/4/14 2100 | 8/5/14 0400 | ND | | |
| X9161 | 100 | Cave Springs | 8/5/14 0500 | 8/5/14 1200 | ND | | |
| X9162 | 100 | Cave Springs | 8/5/14 1300 | 8/5/14 2000 | ND | | |
| X9163 | 100 | Cave Springs | 8/5/14 2100 | 8/6/14 0400 | ND | | |
| X9164 | 100 | Cave Springs | 8/6/14 0500 | 8/6/14 1200 | ND | | |
| X9165 | 100 | Cave Springs | 8/6/14 1300 | 8/6/14 2000 | ND | | |
| X9367 | 100 | Cave Springs | 8/6/14 2100 | 8/7/14 0400 | ND | | |
| X9368 | 100 | Cave Springs | 8/7/14 0500 | 8/7/14 1200 | ND | | |
| X9369 | 100 | Cave Springs | 8/7/14 1300 | 8/7/14 2000 | ND | | |
| X9370 | 100 | Cave Springs | 8/7/14 2100 | 8/8/14 0400 | ND | | |
| X9371 | 100 | Cave Springs | 8/8/14 0500 | 8/8/14 0800 | ND | | |
| X9372 | 100 | Cave Springs | 8/8/14 0830 | 8/8/14 1200 | ND | | |
| X9373 | 100 | Cave Springs | 8/8/14 1230 | 8/8/14 1600 | ND | | |
| X9373 Rep | 100 | Cave Springs | 8/8/14 1230 | 8/8/14 1600 | ND | | |
| X9374 | 100 | Cave Springs | 8/8/14 1630 | 8/8/14 2000 | ND | | |
| X9375 | 100 | Cave Springs | 8/8/14 2030 | 8/9/14 0000 | ND | | |
| X9376 | 100 | Cave Springs | 8/9/14 0030 | 8/9/14 0400 | ND | | |
| X9377 | 100 | Cave Springs | 8/9/14 0430 | 8/9/14 0800 | ND | | |
| X9378 | 100 | Cave Springs | 8/9/14 0830 | 8/9/14 1200 | ND | | |
| X9379 | 100 | Cave Springs | 8/9/14 1230 | 8/9/14 1600 | ND | | |
| X9381 | 100 | Cave Springs | 8/9/14 1630 | 8/9/14 2000 | ND | | |

Cave Springs Area Karst Resource Conservation Study

| OUL Number | Station Number | Station Name | Date/Time Started | Date/Time Ended | Pyranine | | |
|---|---|---|---|---|---|---|---|
| | | | | | Peak (nm) | Conc. (ppb) | Trace No. |
| X9382 | 100 | Cave Springs | 8/9/14 2030 | 8/10/14 0000 | ND | | |
| X9383 | 100 | Cave Springs | 8/10/14 0030 | 8/10/14 0400 | ND | | |
| X9384 | 100 | Cave Springs | 8/10/14 0430 | 8/10/14 0800 | ND | | |
| X9385 | 100 | Cave Springs | 8/10/14 0830 | 8/10/14 1200 | ND | | |
| X9386 | 100 | Cave Springs | 8/10/14 1230 | 8/10/14 1600 | ND | | |
| X9387 | 100 | Cave Springs | 8/10/14 1630 | 8/10/14 2000 | ND | | |
| X9388 | 100 | Cave Springs | 8/10/14 2030 | 8/11/14 0000 | ND | | |
| X9389 | 100 | Cave Springs | 8/11/14 0030 | 8/11/14 0400 | ND | | |
| X9389 Rep | 100 | Cave Springs | 8/11/14 0030 | 8/11/14 0400 | ND | | |
| X9390 | 100 | Cave Springs | 8/11/14 0430 | 8/11/14 0800 | ND | | |
| X9391 | 100 | Cave Springs | 8/11/14 0830 | 8/11/14 1200 | ND | | |
| X9392 | 100 | Cave Springs | 8/11/14 1230 | 8/11/14 1600 | ND | | |
| X9393 | 100 | Cave Springs | 8/11/14 1630 | 8/11/14 2000 | ND | | |
| X9394 | 100 | Cave Springs | 8/11/14 2030 | 8/12/14 0000 | ND | | |
| X9395 | 100 | Cave Springs | 8/12/14 0030 | 8/12/14 0400 | ND | | |
| X9396 | 100 | Cave Springs | 8/12/14 0430 | 8/12/14 0800 | ND | | |
| X9358 | 100 | Cave Springs | 8/12/14 0830 | 8/12/14 1200 | ND | | |
| X9359 | 100 | Cave Springs | 8/12/14 1230 | 8/12/14 1600 | ND | | |
| X9361 | 100 | Cave Springs | 8/12/14 1630 | 8/12/14 2000 | ND | | |
| X9362 | 100 | Cave Springs | 8/12/14 2030 | 8/13/14 0000 | ND | | |
| X9363 | 100 | Cave Springs | 8/13/14 0030 | 8/13/14 0400 | ND | | |
| X9364 | 100 | Cave Springs | 8/13/14 0430 | 8/13/14 0800 | ND | | |
| X9365 | 100 | Cave Springs | 8/13/14 0830 | 8/13/14 1200 | ND | | |
| X9366 | 100 | Cave Springs | 8/15/14 0900 | 8/15/14 1200 | ND | | |
| X9515 | 100 | Cave Springs | 8/15/14 1300 | 8/15/14 2000 | ND | | |
| X9516 | 100 | Cave Springs | 8/15/14 2100 | 8/16/14 0400 | ND | | |
| X9517 | 100 | Cave Springs | 8/16/14 0500 | 8/16/14 1200 | ND | | |
| X9518 | 100 | Cave Springs | 8/16/14 1300 | 8/16/14 2000 | ND | | |
| X9519 | 100 | Cave Springs | 8/16/14 2100 | 8/17/14 0400 | ND | | |
| X9521 | 100 | Cave Springs | 8/17/14 0500 | 8/17/14 1200 | ND | | |
| X9522 | 100 | Cave Springs | 8/17/14 1300 | 8/17/14 2000 | ND | | |
| X9523 | 100 | Cave Springs | 8/17/14 2100 | 8/18/14 0400 | ND | | |
| X9524 | 100 | Cave Springs | 8/18/14 0500 | 8/18/14 1200 | ND | | |
| X9525 | 100 | Cave Springs | 8/18/14 1300 | 8/18/14 2000 | ND | | |
| X9526 | 100 | Cave Springs | 8/18/14 2100 | 8/19/14 0400 | ND | | |
| X9527 | 100 | Cave Springs | 8/19/14 0500 | 8/19/14 1200 | ND | | |

Cave Springs Area Karst Resource Conservation Study

| OUL Number | Station Number | Station Name | Date/Time Started | Date/Time Ended | Pyranine | | |
|---|---|---|---|---|---|---|---|
| | | | | | Peak (nm) | Conc. (ppb) | Trace No. |
| X9528 | 100 | Cave Springs | 8/19/14 1300 | 8/19/14 2000 | ND | | |
| X9529 | 100 | Cave Springs | 8/19/14 2100 | 8/20/14 0400 | ND | | |
| X9530 | 100 | Cave Springs | 8/20/14 0500 | 8/20/14 1200 | ND | | |
| X9531 | 100 | Cave Springs | 8/20/14 1300 | 8/20/14 2000 | ND | | |
| X9532 | 100 | Cave Springs | 8/20/14 2100 | 8/21/14 0400 | ND | | |
| X9533 | 100 | Cave Springs | 8/21/14 0500 | 8/21/14 1200 | ND | | |
| X9534 | 100 | Cave Springs | 8/21/14 1300 | 8/21/14 2000 | ND | | |
| X9809 | 100 | Cave Springs | 8/21/14 2100 | 8/22/14 0400 | ND | | |
| X9810 | 100 | Cave Springs | 8/22/14 0500 | 8/22/14 1200 | ND | | |
| X9811 | 100 | Cave Springs | 8/22/14 1300 | 8/22/14 2000 | ND | | |
| X9812 | 100 | Cave Springs | 8/22/14 2100 | 8/23/14 0400 | ND | | |
| X9813 | 100 | Cave Springs | 8/23/14 0500 | 8/23/14 1200 | ND | | |
| X9814 | 100 | Cave Springs | 8/23/14 1300 | 8/23/14 2000 | ND | | |
| X9815 | 100 | Cave Springs | 8/23/14 2100 | 8/24/14 0400 | ND | | |
| X9816 | 100 | Cave Springs | 8/24/14 0500 | 8/24/14 1200 | ND | | |
| X9817 | 100 | Cave Springs | 8/24/14 1300 | 8/24/14 2000 | ND | | |
| X9818 | 100 | Cave Springs | 8/24/14 2100 | 8/25/14 0400 | ND | | |
| X9819 | 100 | Cave Springs | 8/25/14 0500 | 8/25/14 1200 | ND | | |
| X9821 | 100 | Cave Springs | 8/25/14 1300 | 8/25/14 2000 | ND | | |
| X9822 | 100 | Cave Springs | 8/25/14 2100 | 8/26/14 0400 | ND | | |
| X9823 | 100 | Cave Springs | 8/26/14 0500 | 8/26/14 1200 | ND | | |
| X9824 | 100 | Cave Springs | 8/26/14 1300 | 8/26/14 2000 | ND | | |
| X9825 | 100 | Cave Springs | 8/26/14 2100 | 8/27/14 0400 | ND | | |
| X9826 | 100 | Cave Springs | 8/27/14 0500 | 8/27/14 1200 | ND | | |
| Y0005 | 100 | Cave Springs | 8/27/14 1300 | 8/27/14 2000 | ND | | |
| Y0006 | 100 | Cave Springs | 8/27/14 2100 | 8/28/14 0400 | ND | | |
| Y0007 | 100 | Cave Springs | 8/28/14 0500 | 8/28/14 1200 | ND | | |
| Y0008 | 100 | Cave Springs | 8/28/14 1300 | 8/28/14 2000 | ND | | |
| Y0009 | 100 | Cave Springs | 8/28/14 2100 | 8/29/14 0400 | ND | | |
| Y0010 | 100 | Cave Springs | 8/29/14 0500 | 8/29/14 1200 | ND | | |
| Y0011 | 100 | Cave Springs | 8/29/14 1300 | 8/29/14 2000 | ND | | |
| Y0012 | 100 | Cave Springs | 8/29/14 2100 | 8/30/14 0400 | ND | | |
| Y0013 | 100 | Cave Springs | 8/30/14 0500 | 8/30/14 1200 | ND | | |
| Y0014 | 100 | Cave Springs | 8/30/14 1300 | 8/30/14 2000 | ND | | |
| Y0015 | 100 | Cave Springs | 8/30/14 2100 | 8/31/14 0400 | ND | | |
| Y0016 | 100 | Cave Springs | 8/31/14 0500 | 8/31/14 1200 | ND | | |
| Y0017 | 100 | Cave Springs | 8/31/14 1300 | 8/31/14 2000 | ND | | |

**Cave Springs Area Karst Resource Conservation Study**

| OUL Number | Station Number | Station Name | Date/Time Started | Date/Time Ended | Pyranine | | |
|---|---|---|---|---|---|---|---|
| | | | | | Peak (nm) | Conc. (ppb) | Trace No. |
| Y0018 | 100 | Cave Springs | 8/31/14 2100 | 9/1/14 0400 | ND | | |
| Y0019 | 100 | Cave Springs | 9/1/14 0500 | 9/1/14 1200 | ND | | |
| Y0021 | 100 | Cave Springs | 9/1/14 1300 | 9/1/14 2000 | ND | | |
| Y0022 | 100 | Cave Springs | 9/1/14 2100 | 9/2/14 0400 | ND | | |
| Y0023 | 100 | Cave Springs | 9/2/14 0500 | 9/2/14 1200 | ND | | |
| Y0024 | 100 | Cave Springs | 9/2/14 1300 | 9/2/14 2000 | ND | | |
| Y0025 | 100 | Cave Springs | 9/2/14 2100 | 9/3/14 0400 | ND | | |
| Y0026 | 100 | Cave Springs | 9/3/14 0500 | 9/3/14 1200 | ND | | |
| Y0027 | 100 | Cave Springs | 9/3/14 1300 | 9/3/14 2000 | ND | | |
| Y0028 | 100 | Cave Springs | 9/3/14 2100 | 9/4/14 0400 | ND | | |
| Y0029 | 100 | Cave Springs | 9/4/14 0500 | 9/4/14 1200 | ND | | |
| Y0258 | 100 | Cave Springs | 9/10/14 2100 | 9/11/14 0400 | ND | | |
| Y0259 | 100 | Cave Springs | 9/11/14 0500 | 9/11/14 1200 | ND | | |
| Y0261 | 100 | Cave Springs | 9/11/14 1300 | 9/11/14 2000 | ND | | |
| Y0262 | 100 | Cave Springs | 9/11/14 2100 | 9/12/14 0400 | ND | | |
| Y0263 | 100 | Cave Springs | 9/12/14 0500 | 9/12/14 1200 | ND | | |
| Y0466 | 100 | Cave Springs | 9/12/14 1300 | 9/12/14 2000 | ND | | |
| Y0467 | 100 | Cave Springs | 9/12/14 2100 | 9/13/14 0400 | ND | | |
| Y0468 | 100 | Cave Springs | 9/13/14 0500 | 9/13/14 1200 | ND | | |

**Footnotes:**

ND = No dye detected

** = A fluorescence peak is present that does not meet all the criteria for this dye. This is because either the peak is out of the normally acceptable wavelength range for this dye, and/or the shape of the fluorescence peak is irregular, and/or the concentration is not ten times the background concentration. However, based on all available data, it is the Ozark Underground Laboratory's conclusion that this is a positive dye result.

(1) = A fluorescence peak is present that does not meet all the criteria for this dye. However, it has been calculated as a positive dye result because dye was present in the corresponding charcoal sampler.

ns = A sample was not collected for this sampling period.

wso = A water sample only was collected for this sampling period.

# APPENDIX C

Water Quality Analytical Results

# Informational Water Quality Report

## Watercheck

National Testing Laboratories, Ltd.
Quality Water Analysis

6571 Wilson Mills Rd
Cleveland, Ohio 44143
1-800-458-3330

| Client: |
| --- |
| |

| Ordered By: |
| --- |
| Beeman, Shiloh<br>PO Box 2852<br>Springfield, MO 65801<br>ATTN: Shiloh Beeman |

Sample Number: 849197

| | |
| --- | --- |
| Location: | Cave Spring |
| Type of Water: | Other |
| Collection Date and Time: | 10/20/2014 14:00 |
| Received Date and Time: | 10/21/2014 10:10 |
| Date Completed: | 10/30/2014 |

Spring Water

### Definition and Legend

This informational water quality report compares the actual test result to national standards as defined in the EPA's Primary and Secondary Drinking Water Regulations.

***Primary Standards:*** Are expressed as the maximum contaminant level (MCL) which is the highest level of contaminant that is allowed in drinking water. MCLs are enforceable standards.

***Secondary standards:*** Are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor,or color) in drinking water. Individual states may choose to adopt them as enforceable standards.

***Action levels:*** Are defined in treatment techniques which are required processes intended to reduce the level of a contaminant in drinking water.

**mg/L (ppm):** Unless otherwise indicated, results and standards are expressed as an amount in milligrams per liter or parts per million.

**Minimum Detection Level (MDL):** The lowest level that the laboratory can detect a contaminant.

ND: The contaminant was not detected above the minimum detection level.

NA: The contaminant was not analyzed.

✓ The contaminant was not detected in the sample above the minimum detection level.

● The contaminant was detected at or above the minimum detection level, but not above the referenced standard.

▲ The contaminant was detected above the standard, which is not an EPA enforceable MCL.

✚ The contaminant was detected above the EPA enforceable MCL.

✖ These results may be invalid.

| Status | Contaminant | Results | Units | National Standards | | Min. Detection Level |
|---|---|---|---|---|---|---|
| | | | Microbiologicals | | | |
| | Total Coliform by P/A | Total coliform bacteria and E. coli bacteria were both present in this sample. | | | | |
| | | | Inorganic Analytes - Metals | | | |
| | Aluminum | ND | mg/L | 0.2 | EPA Secondary | 0.1 |
| | Arsenic | ND | mg/L | 0.010 | EPA Primary | 0.005 |
| | Barium | ND | mg/L | 2 | EPA Primary | 0.30 |
| | Cadmium | ND | mg/L | 0.005 | EPA Primary | 0.002 |
| | Calcium | 62.9 | mg/L | -- | | 2.0 |
| | Chromium | ND | mg/L | 0.1 | EPA Primary | 0.010 |
| | Copper | ND | mg/L | 1.3 | EPA Action Level | 0.004 |
| | Iron | 0.021 | mg/L | 0.3 | EPA Secondary | 0.020 |
| | Lead | ND | mg/L | 0.015 | EPA Action Level | 0.002 |
| | Magnesium | 2.20 | mg/L | -- | | 0.10 |
| | Manganese | ND | mg/L | 0.05 | EPA Secondary | 0.004 |
| | Mercury | ND | mg/L | 0.002 | EPA Primary | 0.001 |
| | Nickel | ND | mg/L | -- | | 0.020 |
| | Potassium | 2.3 | mg/L | -- | | 1.0 |
| | Selenium | ND | mg/L | 0.05 | EPA Primary | 0.020 |
| | Silica | 9.5 | mg/L | -- | | 0.1 |
| | Silver | ND | mg/L | 0.100 | EPA Secondary | 0.002 |
| | Sodium | 5 | mg/L | -- | | 1 |
| | Zinc | ND | mg/L | 5 | EPA Secondary | 0.004 |
| | | | Physical Factors | | | |
| | Alkalinity (Total as CaCO3) | 140 | mg/L | -- | | 20 |
| | Hardness | 170 | mg/L | 100 | NTL Internal | 10 |
| | pH | 6.8 | pH Units | 6.5 to 8.5 | EPA Secondary | |
| | Total Dissolved Solids | 170 | mg/L | 500 | EPA Secondary | 20 |
| | Turbidity | 0.4 | NTU | 1.0 | EPA Action Level | 0.1 |

| Status | Contaminant | Results | Units | National Standards | | Min. Detection Level |
|---|---|---|---|---|---|---|
| | **Inorganic Analytes - Other** | | | | | |
| ● | Chloride | 5.2 | mg/L | 250 | EPA Secondary | 5.0 |
| ✓ | Fluoride | ND | mg/L | 4.0 | EPA Primary | 0.5 |
| ● | Nitrate as N | 4.0 | mg/L | 10 | EPA Primary | 0.5 |
| ✓ | Nitrite as N | ND | mg/L | 1 | EPA Primary | 0.5 |
| ✓ | Ortho Phosphate | ND | mg/L | -- | | 2.0 |
| ✓ | Sulfate | ND | mg/L | 250 | EPA Secondary | 5.0 |
| | **Organic Analytes - Trihalomethanes** | | | | | |
| ✓ | Bromodichloromethane | ND | mg/L | -- | | 0.002 |
| ✓ | Bromoform | ND | mg/L | -- | | 0.004 |
| ✓ | Chloroform | ND | mg/L | -- | | 0.002 |
| ✓ | Dibromochloromethane | ND | mg/L | -- | | 0.004 |
| ✓ | Total THMs | ND | mg/L | 0.080 | EPA Primary | 0.002 |
| | **Organic Analytes - Volatiles** | | | | | |
| ✓ | 1,1,1,2-Tetrachloroethane | ND | mg/L | -- | | 0.002 |
| ✓ | 1,1,1-Trichloroethane | ND | mg/L | 0.2 | EPA Primary | 0.001 |
| ✓ | 1,1,2,2-Tetrachloroethane | ND | mg/L | -- | | 0.002 |
| ✓ | 1,1,2-Trichloroethane | ND | mg/L | 0.005 | EPA Primary | 0.002 |
| ✓ | 1,1-Dichloroethane | ND | mg/L | -- | | 0.002 |
| ✓ | 1,1-Dichloroethene | ND | mg/L | 0.007 | EPA Primary | 0.001 |
| ✓ | 1,1-Dichloropropene | ND | mg/L | -- | | 0.002 |
| ✓ | 1,2,3-Trichlorobenzene | ND | mg/L | -- | | 0.002 |
| ✓ | 1,2,3-Trichloropropane | ND | mg/L | -- | | 0.002 |
| ✓ | 1,2,4-Trichlorobenzene | ND | mg/L | 0.07 | EPA Primary | 0.002 |
| ✓ | 1,2-Dichlorobenzene | ND | mg/L | 0.6 | EPA Primary | 0.001 |
| ✓ | 1,2-Dichloroethane | ND | mg/L | 0.005 | EPA Primary | 0.001 |
| ✓ | 1,2-Dichloropropane | ND | mg/L | 0.005 | EPA Primary | 0.002 |
| ✓ | 1,3-Dichlorobenzene | ND | mg/L | -- | | 0.001 |

| Status | Contaminant | Results | Units | National Standards | | Min. Detection Level |
|---|---|---|---|---|---|---|
| ✓ | 1,3-Dichloropropane | ND | mg/L | -- | | 0.002 |
| ✓ | 1,4-Dichlorobenzene | ND | mg/L | 0.075 | EPA Primary | 0.001 |
| ✓ | 2,2-Dichloropropane | ND | mg/L | -- | | 0.002 |
| ✓ | 2-Chlorotoluene | ND | mg/L | -- | | 0.001 |
| ✓ | 4-Chlorotoluene | ND | mg/L | -- | | 0.001 |
| ✓ | Acetone | ND | mg/L | -- | | 0.01 |
| ✓ | Benzene | ND | mg/L | 0.005 | EPA Primary | 0.001 |
| ✓ | Bromobenzene | ND | mg/L | -- | | 0.002 |
| ✓ | Bromomethane | ND | mg/L | -- | | 0.002 |
| ✓ | Carbon Tetrachloride | ND | mg/L | 0.005 | EPA Primary | 0.001 |
| ✓ | Chlorobenzene | ND | mg/L | 0.1 | EPA Primary | 0.001 |
| ✓ | Chloroethane | ND | mg/L | -- | | 0.002 |
| ✓ | Chloromethane | ND | mg/L | -- | | 0.002 |
| ✓ | cis-1,2-Dichloroethene | ND | mg/L | 0.07 | EPA Primary | 0.002 |
| ✓ | cis-1,3-Dichloropropene | ND | mg/L | -- | | 0.002 |
| ✓ | DBCP | ND | mg/L | -- | | 0.001 |
| ✓ | Dibromomethane | ND | mg/L | -- | | 0.002 |
| ✓ | Dichlorodifluoromethane | ND | mg/L | -- | | 0.002 |
| ✓ | Dichloromethane | ND | mg/L | 0.005 | EPA Primary | 0.002 |
| ✓ | EDB | ND | mg/L | -- | | 0.001 |
| ✓ | Ethylbenzene | ND | mg/L | 0.7 | EPA Primary | 0.001 |
| ✓ | Methyl Tert Butyl Ether | ND | mg/L | -- | | 0.004 |
| ✓ | Methyl-Ethyl Ketone | ND | mg/L | -- | | 0.01 |
| ✓ | Styrene | ND | mg/L | 0.1 | EPA Primary | 0.001 |
| ✓ | Tetrachloroethene | ND | mg/L | 0.005 | EPA Primary | 0.002 |
| ✓ | Tetrahydrofuran | ND | mg/L | -- | | 0.01 |
| ✓ | Toluene | ND | mg/L | 1 | EPA Primary | 0.001 |
| ✓ | trans-1,2-Dichloroethene | ND | mg/L | 0.1 | EPA Primary | 0.002 |

| Status | Contaminant | Results | Units | National Standards | | Min. Detection Level |
|---|---|---|---|---|---|---|
| ✓ | trans-1,3-Dichloropropene | ND | mg/L | -- | | 0.002 |
| ✓ | Trichloroethene | ND | mg/L | 0.005 | EPA Primary | 0.001 |
| ✓ | Trichlorofluoromethane | ND | mg/L | -- | | 0.002 |
| ✓ | Vinyl Chloride | ND | mg/L | 0.002 | EPA Primary | 0.001 |
| ✓ | Xylenes (Total) | ND | mg/L | 10 | EPA Primary | 0.001 |

*We certify that the analyses performed for this report are accurate, and that the laboratory tests were conducted by methods approved by the U.S. Environmental Protection Agency or variations of these EPA methods.*

*These test results are intended to be used for informational purposes only and may not be used for regulatory compliance.*

*National Testing Laboratories, Ltd.*

NATIONAL TESTING LABORATORIES, LTD

# Informational Water Quality Report

## Watercheck

| *Client:* |
|---|
| |

| *Ordered By:* |
|---|
| Beeman, Shiloh<br>PO Box 2852<br>Springfield, MO 65801<br>ATTN: Shiloh Beeman |

National Testing Laboratories, Ltd.
Quality Water Analysis

6571 Wilson Mills Rd
Cleveland, Ohio 44143
1-800-458-3330

**Sample Number:** 849198

| | |
|---|---|
| Location: | Reed Spring |
| Type of Water: | Other |
| Collection Date and Time: | 10/20/2014 14:30 |
| Received Date and Time: | 10/21/2014 10:10 |
| Date Completed: | 10/30/2014 |

Spring

### Definition and Legend

This informational water quality report compares the actual test result to national standards as defined in the EPA's Primary and Secondary Drinking Water Regulations.

***Primary Standards:*** Are expressed as the maximum contaminant level (MCL) which is the highest level of contaminant that is allowed in drinking water. MCLs are enforceable standards.

***Secondary standards:*** Are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor,or color) in drinking water. Individual states may choose to adopt them as enforceable standards.

***Action levels:*** Are defined in treatment techniques which are required processes intended to reduce the level of a contaminant in drinking water.

**mg/L (ppm):** Unless otherwise indicated, results and standards are expressed as an amount in milligrams per liter or parts per million.

**Minimum Detection Level (MDL):** The lowest level that the laboratory can detect a contaminant.

**ND:** The contaminant was not detected above the minimum detection level.

**NA:** The contaminant was not analyzed.

✔ The contaminant was not detected in the sample above the minimum detection level.

● The contaminant was detected at or above the minimum detection level, but not above the referenced standard.

▲ The contaminant was detected above the standard, which is not an EPA enforceable MCL.

✚ The contaminant was detected above the EPA enforceable MCL.

✖ These results may be invalid.

| Status | Contaminant | Results | Units | National Standards | | Min. Detection Level |
|---|---|---|---|---|---|---|
| | | | Microbiologicals | | | |
| ✚ | Total Coliform by P/A | Total coliform bacteria and E. coli bacteria were both present in this sample. | | | | |
| | | | Inorganic Analytes - Metals | | | |
| ✓ | Aluminum | ND | mg/L | 0.2 | EPA Secondary | 0.1 |
| ✓ | Arsenic | ND | mg/L | 0.010 | EPA Primary | 0.005 |
| ✓ | Barium | ND | mg/L | 2 | EPA Primary | 0.30 |
| ✓ | Cadmium | ND | mg/L | 0.005 | EPA Primary | 0.002 |
| ● | Calcium | 73.8 | mg/L | -- | | 2.0 |
| ✓ | Chromium | ND | mg/L | 0.1 | EPA Primary | 0.010 |
| ✓ | Copper | ND | mg/L | 1.3 | EPA Action Level | 0.004 |
| ✓ | Iron | ND | mg/L | 0.3 | EPA Secondary | 0.020 |
| ✓ | Lead | ND | mg/L | 0.015 | EPA Action Level | 0.002 |
| ● | Magnesium | 2.28 | mg/L | -- | | 0.10 |
| ✓ | Manganese | ND | mg/L | 0.05 | EPA Secondary | 0.004 |
| ✓ | Mercury | ND | mg/L | 0.002 | EPA Primary | 0.001 |
| ✓ | Nickel | ND | mg/L | -- | | 0.020 |
| ● | Potassium | 2.4 | mg/L | -- | | 1.0 |
| ✓ | Selenium | ND | mg/L | 0.05 | EPA Primary | 0.020 |
| ● | Silica | 11.0 | mg/L | -- | | 0.1 |
| ✓ | Silver | ND | mg/L | 0.100 | EPA Secondary | 0.002 |
| ● | Sodium | 5 | mg/L | -- | | 1 |
| ✓ | Zinc | ND | mg/L | 5 | EPA Secondary | 0.004 |
| | | | Physical Factors | | | |
| ● | Alkalinity (Total as CaCO3) | 150 | mg/L | -- | | 20 |
| ▲ | Hardness | 190 | mg/L | 100 | NTL Internal | 10 |
| ✓ | pH | 6.6 | pH Units | 6.5 to 8.5 | EPA Secondary | |
| ● | Total Dissolved Solids | 200 | mg/L | 500 | EPA Secondary | 20 |
| ● | Turbidity | 0.3 | NTU | 1.0 | EPA Action Level | 0.1 |

| Status | Contaminant | Results | Units | National Standards | | Min. Detection Level |
|---|---|---|---|---|---|---|
| | **Inorganic Analytes - Other** | | | | | |
| ● | Chloride | 5.8 | mg/L | 250 | EPA Secondary | 5.0 |
| ✓ | Fluoride | ND | mg/L | 4.0 | EPA Primary | 0.5 |
| ● | Nitrate as N | 6.4 | mg/L | 10 | EPA Primary | 0.5 |
| ✓ | Nitrite as N | ND | mg/L | 1 | EPA Primary | 0.5 |
| ✓ | Ortho Phosphate | ND | mg/L | -- | | 2.0 |
| ✓ | Sulfate | ND | mg/L | 250 | EPA Secondary | 5.0 |
| | **Organic Analytes - Trihalomethanes** | | | | | |
| ✓ | Bromodichloromethane | ND | mg/L | -- | | 0.002 |
| ✓ | Bromoform | ND | mg/L | -- | | 0.004 |
| ✓ | Chloroform | ND | mg/L | -- | | 0.002 |
| ✓ | Dibromochloromethane | ND | mg/L | -- | | 0.004 |
| ✓ | Total THMs | ND | mg/L | 0.080 | EPA Primary | 0.002 |
| | **Organic Analytes - Volatiles** | | | | | |
| ✓ | 1,1,1,2-Tetrachloroethane | ND | mg/L | -- | | 0.002 |
| ✓ | 1,1,1-Trichloroethane | ND | mg/L | 0.2 | EPA Primary | 0.001 |
| ✓ | 1,1,2,2-Tetrachloroethane | ND | mg/L | -- | | 0.002 |
| ✓ | 1,1,2-Trichloroethane | ND | mg/L | 0.005 | EPA Primary | 0.002 |
| ✓ | 1,1-Dichloroethane | ND | mg/L | -- | | 0.002 |
| ✓ | 1,1-Dichloroethene | ND | mg/L | 0.007 | EPA Primary | 0.001 |
| ✓ | 1,1-Dichloropropene | ND | mg/L | -- | | 0.002 |
| ✓ | 1,2,3-Trichlorobenzene | ND | mg/L | -- | | 0.002 |
| ✓ | 1,2,3-Trichloropropane | ND | mg/L | -- | | 0.002 |
| ✓ | 1,2,4-Trichlorobenzene | ND | mg/L | 0.07 | EPA Primary | 0.002 |
| ✓ | 1,2-Dichlorobenzene | ND | mg/L | 0.6 | EPA Primary | 0.001 |
| ✓ | 1,2-Dichloroethane | ND | mg/L | 0.005 | EPA Primary | 0.001 |
| ✓ | 1,2-Dichloropropane | ND | mg/L | 0.005 | EPA Primary | 0.002 |
| ✓ | 1,3-Dichlorobenzene | ND | mg/L | -- | | 0.001 |

| Status | Contaminant | Results | Units | National Standards | | Min. Detection Level |
|---|---|---|---|---|---|---|
| ✓ | 1,3-Dichloropropane | ND | mg/L | -- | | 0.002 |
| ✓ | 1,4-Dichlorobenzene | ND | mg/L | 0.075 | EPA Primary | 0.001 |
| ✓ | 2,2-Dichloropropane | ND | mg/L | -- | | 0.002 |
| ✓ | 2-Chlorotoluene | ND | mg/L | -- | | 0.001 |
| ✓ | 4-Chlorotoluene | ND | mg/L | -- | | 0.001 |
| ✓ | Acetone | ND | mg/L | -- | | 0.01 |
| ✓ | Benzene | ND | mg/L | 0.005 | EPA Primary | 0.001 |
| ✓ | Bromobenzene | ND | mg/L | -- | | 0.002 |
| ✓ | Bromomethane | ND | mg/L | -- | | 0.002 |
| ✓ | Carbon Tetrachloride | ND | mg/L | 0.005 | EPA Primary | 0.001 |
| ✓ | Chlorobenzene | ND | mg/L | 0.1 | EPA Primary | 0.001 |
| ✓ | Chloroethane | ND | mg/L | -- | | 0.002 |
| ✓ | Chloromethane | ND | mg/L | -- | | 0.002 |
| ✓ | cis-1,2-Dichloroethene | ND | mg/L | 0.07 | EPA Primary | 0.002 |
| ✓ | cis-1,3-Dichloropropene | ND | mg/L | -- | | 0.002 |
| ✓ | DBCP | ND | mg/L | -- | | 0.001 |
| ✓ | Dibromomethane | ND | mg/L | -- | | 0.002 |
| ✓ | Dichlorodifluoromethane | ND | mg/L | -- | | 0.002 |
| ✓ | Dichloromethane | ND | mg/L | 0.005 | EPA Primary | 0.002 |
| ✓ | EDB | ND | mg/L | -- | | 0.001 |
| ✓ | Ethylbenzene | ND | mg/L | 0.7 | EPA Primary | 0.001 |
| ✓ | Methyl Tert Butyl Ether | ND | mg/L | -- | | 0.004 |
| ✓ | Methyl-Ethyl Ketone | ND | mg/L | -- | | 0.01 |
| ✓ | Styrene | ND | mg/L | 0.1 | EPA Primary | 0.001 |
| ✓ | Tetrachloroethene | ND | mg/L | 0.005 | EPA Primary | 0.002 |
| ✓ | Tetrahydrofuran | ND | mg/L | -- | | 0.01 |
| ✓ | Toluene | ND | mg/L | 1 | EPA Primary | 0.001 |
| ✓ | trans-1,2-Dichloroethene | ND | mg/L | 0.1 | EPA Primary | 0.002 |

| Status | Contaminant | Results | Units | National Standards | | Min. Detection Level |
|---|---|---|---|---|---|---|
| ✓ | trans-1,3-Dichloropropene | ND | mg/L | -- | | 0.002 |
| ✓ | Trichloroethene | ND | mg/L | 0.005 | EPA Primary | 0.001 |
| ✓ | Trichlorofluoromethane | ND | mg/L | -- | | 0.002 |
| ✓ | Vinyl Chloride | ND | mg/L | 0.002 | EPA Primary | 0.001 |
| ✓ | Xylenes (Total) | ND | mg/L | 10 | EPA Primary | 0.001 |

*We certify that the analyses performed for this report are accurate, and that the laboratory tests were conducted by methods approved by the U.S. Environmental Protection Agency or variations of these EPA methods.*

*These test results are intended to be used for informational purposes only and may not be used for regulatory compliance.*

*National Testing Laboratories, Ltd.*

NATIONAL TESTING LABORATORIES, LTD

# Informational Water Quality Report

## Watercheck

| *Client:* |
|---|
| |

| *Ordered By:* |
|---|
| Beeman, Shiloh<br>PO Box 2852<br>Springfield, MO 65801<br>ATTN: Shiloh Beeman |

National Testing Laboratories, Ltd.
Quality Water Analysis

6571 Wilson Mills Rd
Cleveland, Ohio 44143
1-800-458-3330

Sample Number: 849196

| | |
|---|---|
| Location: | Shores Spring |
| Type of Water: | Other |
| Collection Date and Time: | 10/20/2014 14:50 |
| Received Date and Time: | 10/21/2014 10:10 |
| Date Completed: | 10/30/2014 |

Spring

### Definition and Legend

This informational water quality report compares the actual test result to national standards as defined in the EPA's Primary and Secondary Drinking Water Regulations.

***Primary Standards:*** Are expressed as the maximum contaminant level (MCL) which is the highest level of contaminant that is allowed in drinking water. MCLs are enforceable standards.

***Secondary standards:*** Are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor,or color) in drinking water. Individual states may choose to adopt them as enforceable standards.

***Action levels:*** Are defined in treatment techniques which are required processes intended to reduce the level of a contaminant in drinking water.

**mg/L (ppm):** Unless otherwise indicated, results and standards are expressed as an amount in milligrams per liter or parts per million.

**Minimum Detection Level (MDL):** The lowest level that the laboratory can detect a contaminant.

ND: The contaminant was not detected above the minimum detection level.

NA: The contaminant was not analyzed.

✓ The contaminant was not detected in the sample above the minimum detection level.

● The contaminant was detected at or above the minimum detection level, but not above the referenced standard.

▲ The contaminant was detected above the standard, which is not an EPA enforceable MCL.

✚ The contaminant was detected above the EPA enforceable MCL.

✖ These results may be invalid.

| Status | Contaminant | Results | Units | National Standards | | Min. Detection Level |
|---|---|---|---|---|---|---|
| | **Microbiologicals** | | | | | |
| | Total Coliform by P/A | Total coliform bacteria and E. coli bacteria were both present in this sample. | | | | |
| | **Inorganic Analytes - Metals** | | | | | |
| | Aluminum | ND | mg/L | 0.2 | EPA Secondary | 0.1 |
| | Arsenic | ND | mg/L | 0.010 | EPA Primary | 0.005 |
| | Barium | ND | mg/L | 2 | EPA Primary | 0.30 |
| | Cadmium | ND | mg/L | 0.005 | EPA Primary | 0.002 |
| | Calcium | 72.4 | mg/L | -- | | 2.0 |
| | Chromium | ND | mg/L | 0.1 | EPA Primary | 0.010 |
| | Copper | ND | mg/L | 1.3 | EPA Action Level | 0.004 |
| | Iron | ND | mg/L | 0.3 | EPA Secondary | 0.020 |
| | Lead | ND | mg/L | 0.015 | EPA Action Level | 0.002 |
| | Magnesium | 1.98 | mg/L | -- | | 0.10 |
| | Manganese | ND | mg/L | 0.05 | EPA Secondary | 0.004 |
| | Mercury | ND | mg/L | 0.002 | EPA Primary | 0.001 |
| | Nickel | ND | mg/L | -- | | 0.020 |
| | Potassium | 2.1 | mg/L | -- | | 1.0 |
| | Selenium | ND | mg/L | 0.05 | EPA Primary | 0.020 |
| | Silica | 11.6 | mg/L | -- | | 0.1 |
| | Silver | ND | mg/L | 0.100 | EPA Secondary | 0.002 |
| | Sodium | 4 | mg/L | -- | | 1 |
| | Zinc | ND | mg/L | 5 | EPA Secondary | 0.004 |
| | **Physical Factors** | | | | | |
| | Alkalinity (Total as CaCO3) | 160 | mg/L | -- | | 20 |
| | Hardness | 190 | mg/L | 100 | NTL Internal | 10 |
| | pH | 6.6 | pH Units | 6.5 to 8.5 | EPA Secondary | |
| | Total Dissolved Solids | 200 | mg/L | 500 | EPA Secondary | 20 |
| | Turbidity | 0.2 | NTU | 1.0 | EPA Action Level | 0.1 |

| Status | Contaminant | Results | Units | National Standards | | Min. Detection Level |
|---|---|---|---|---|---|---|
| | | | Inorganic Analytes - Other | | | |
| ● | Chloride | 5.0 | mg/L | 250 | EPA Secondary | 5.0 |
| ✓ | Fluoride | ND | mg/L | 4.0 | EPA Primary | 0.5 |
| ● | Nitrate as N | 4.6 | mg/L | 10 | EPA Primary | 0.5 |
| ✓ | Nitrite as N | ND | mg/L | 1 | EPA Primary | 0.5 |
| ✓ | Ortho Phosphate | ND | mg/L | -- | | 2.0 |
| ✓ | Sulfate | ND | mg/L | 250 | EPA Secondary | 5.0 |
| | | | Organic Analytes - Trihalomethanes | | | |
| ✓ | Bromodichloromethane | ND | mg/L | -- | | 0.002 |
| ✓ | Bromoform | ND | mg/L | -- | | 0.004 |
| ✓ | Chloroform | ND | mg/L | -- | | 0.002 |
| ✓ | Dibromochloromethane | ND | mg/L | -- | | 0.004 |
| ✓ | Total THMs | ND | mg/L | 0.080 | EPA Primary | 0.002 |
| | | | Organic Analytes - Volatiles | | | |
| ✓ | 1,1,1,2-Tetrachloroethane | ND | mg/L | -- | | 0.002 |
| ✓ | 1,1,1-Trichloroethane | ND | mg/L | 0.2 | EPA Primary | 0.001 |
| ✓ | 1,1,2,2-Tetrachloroethane | ND | mg/L | -- | | 0.002 |
| ✓ | 1,1,2-Trichloroethane | ND | mg/L | 0.005 | EPA Primary | 0.002 |
| ✓ | 1,1-Dichloroethane | ND | mg/L | -- | | 0.002 |
| ✓ | 1,1-Dichloroethene | ND | mg/L | 0.007 | EPA Primary | 0.001 |
| ✓ | 1,1-Dichloropropene | ND | mg/L | -- | | 0.002 |
| ✓ | 1,2,3-Trichlorobenzene | ND | mg/L | -- | | 0.002 |
| ✓ | 1,2,3-Trichloropropane | ND | mg/L | -- | | 0.002 |
| ✓ | 1,2,4-Trichlorobenzene | ND | mg/L | 0.07 | EPA Primary | 0.002 |
| ✓ | 1,2-Dichlorobenzene | ND | mg/L | 0.6 | EPA Primary | 0.001 |
| ✓ | 1,2-Dichloroethane | ND | mg/L | 0.005 | EPA Primary | 0.001 |
| ✓ | 1,2-Dichloropropane | ND | mg/L | 0.005 | EPA Primary | 0.002 |
| ✓ | 1,3-Dichlorobenzene | ND | mg/L | -- | | 0.001 |

| Status | Contaminant | Results | Units | National Standards | | Min. Detection Level |
|---|---|---|---|---|---|---|
| ✓ | 1,3-Dichloropropane | ND | mg/L | -- | | 0.002 |
| ✓ | 1,4-Dichlorobenzene | ND | mg/L | 0.075 | EPA Primary | 0.001 |
| ✓ | 2,2-Dichloropropane | ND | mg/L | -- | | 0.002 |
| ✓ | 2-Chlorotoluene | ND | mg/L | -- | | 0.001 |
| ✓ | 4-Chlorotoluene | ND | mg/L | -- | | 0.001 |
| ✓ | Acetone | ND | mg/L | -- | | 0.01 |
| ✓ | Benzene | ND | mg/L | 0.005 | EPA Primary | 0.001 |
| ✓ | Bromobenzene | ND | mg/L | -- | | 0.002 |
| ✓ | Bromomethane | ND | mg/L | -- | | 0.002 |
| ✓ | Carbon Tetrachloride | ND | mg/L | 0.005 | EPA Primary | 0.001 |
| ✓ | Chlorobenzene | ND | mg/L | 0.1 | EPA Primary | 0.001 |
| ✓ | Chloroethane | ND | mg/L | -- | | 0.002 |
| ✓ | Chloromethane | ND | mg/L | -- | | 0.002 |
| ✓ | cis-1,2-Dichloroethene | ND | mg/L | 0.07 | EPA Primary | 0.002 |
| ✓ | cis-1,3-Dichloropropene | ND | mg/L | -- | | 0.002 |
| ✓ | DBCP | ND | mg/L | -- | | 0.001 |
| ✓ | Dibromomethane | ND | mg/L | -- | | 0.002 |
| ✓ | Dichlorodifluoromethane | ND | mg/L | -- | | 0.002 |
| ✓ | Dichloromethane | ND | mg/L | 0.005 | EPA Primary | 0.002 |
| ✓ | EDB | ND | mg/L | -- | | 0.001 |
| ✓ | Ethylbenzene | ND | mg/L | 0.7 | EPA Primary | 0.001 |
| ✓ | Methyl Tert Butyl Ether | ND | mg/L | -- | | 0.004 |
| ✓ | Methyl-Ethyl Ketone | ND | mg/L | -- | | 0.01 |
| ✓ | Styrene | ND | mg/L | 0.1 | EPA Primary | 0.001 |
| ✓ | Tetrachloroethene | ND | mg/L | 0.005 | EPA Primary | 0.002 |
| ✓ | Tetrahydrofuran | ND | mg/L | -- | | 0.01 |
| ✓ | Toluene | ND | mg/L | 1 | EPA Primary | 0.001 |
| ✓ | trans-1,2-Dichloroethene | ND | mg/L | 0.1 | EPA Primary | 0.002 |

| Status | Contaminant | Results | Units | National Standards | | Min. Detection Level |
|---|---|---|---|---|---|---|
| ✓ | trans-1,3-Dichloropropene | ND | mg/L | -- | | 0.002 |
| ✓ | Trichloroethene | ND | mg/L | 0.005 | EPA Primary | 0.001 |
| ✓ | Trichlorofluoromethane | ND | mg/L | -- | | 0.002 |
| ✓ | Vinyl Chloride | ND | mg/L | 0.002 | EPA Primary | 0.001 |
| ✓ | Xylenes (Total) | ND | mg/L | 10 | EPA Primary | 0.001 |

*We certify that the analyses performed for this report are accurate, and that the laboratory tests were conducted by methods approved by the U.S. Environmental Protection Agency or variations of these EPA methods.*

*These test results are intended to be used for informational purposes only and may not be used for regulatory compliance.*

*National Testing Laboratories, Ltd.*

NATIONAL TESTING LABORATORIES, LTD

# Informational Water Quality Report

## Watercheck

| *Client:* |
|---|
| |

| *Ordered By:* |
|---|
| Beeman, Shiloh<br>PO Box 2852<br>Springfield, MO 65801<br>ATTN: Shiloh Beeman |

National Testing Laboratories, Ltd.
Quality Water Analysis

6571 Wilson Mills Rd
Cleveland, Ohio 44143
1-800-458-3330

Sample Number: 849199

| | |
|---|---|
| Location: | Wallis Spring |
| Type of Water: | Other |
| Collection Date and Time: | 10/20/2014 15:15 |
| Received Date and Time: | 10/21/2014 10:10 |
| Date Completed: | 10/30/2014 |

Spring

### Definition and Legend

This informational water quality report compares the actual test result to national standards as defined in the EPA's Primary and Secondary Drinking Water Regulations.

| | |
|---|---|
| ***Primary Standards:*** | Are expressed as the maximum contaminant level (MCL) which is the highest level of contaminant that is allowed in drinking water. MCLs are enforceable standards. |
| ***Secondary standards:*** | Are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor,or color) in drinking water. Individual states may choose to adopt them as enforceable standards. |
| ***Action levels:*** | Are defined in treatment techniques which are required processes intended to reduce the level of a contaminant in drinking water. |
| **mg/L (ppm):** | Unless otherwise indicated, results and standards are expressed as an amount in milligrams per liter or parts per million. |
| **Minimum Detection Level (MDL):** | The lowest level that the laboratory can detect a contaminant. |
| ND: | The contaminant was not detected above the minimum detection level. |
| NA: | The contaminant was not analyzed. |

✓ The contaminant was not detected in the sample above the minimum detection level.

● The contaminant was detected at or above the minimum detection level, but not above the referenced standard.

▲ The contaminant was detected above the standard, which is not an EPA enforceable MCL.

✚ The contaminant was detected above the EPA enforceable MCL.

✖ These results may be invalid.

| Status | Contaminant | Results | Units | National Standards | | Min. Detection Level |
|---|---|---|---|---|---|---|
| | **Microbiologicals** | | | | | |
| | Total Coliform by P/A | Total coliform bacteria and E. coli bacteria were both present in this sample. | | | | |
| | **Inorganic Analytes - Metals** | | | | | |
| | Aluminum | ND | mg/L | 0.2 | EPA Secondary | 0.1 |
| | Arsenic | ND | mg/L | 0.010 | EPA Primary | 0.005 |
| | Barium | ND | mg/L | 2 | EPA Primary | 0.30 |
| | Cadmium | ND | mg/L | 0.005 | EPA Primary | 0.002 |
| | Calcium | 75.1 | mg/L | -- | | 2.0 |
| | Chromium | ND | mg/L | 0.1 | EPA Primary | 0.010 |
| | Copper | ND | mg/L | 1.3 | EPA Action Level | 0.004 |
| | Iron | ND | mg/L | 0.3 | EPA Secondary | 0.020 |
| | Lead | ND | mg/L | 0.015 | EPA Action Level | 0.002 |
| | Magnesium | 2.06 | mg/L | -- | | 0.10 |
| | Manganese | ND | mg/L | 0.05 | EPA Secondary | 0.004 |
| | Mercury | ND | mg/L | 0.002 | EPA Primary | 0.001 |
| | Nickel | ND | mg/L | -- | | 0.020 |
| | Potassium | 2.0 | mg/L | -- | | 1.0 |
| | Selenium | ND | mg/L | 0.05 | EPA Primary | 0.020 |
| | Silica | 11.9 | mg/L | -- | | 0.1 |
| | Silver | ND | mg/L | 0.100 | EPA Secondary | 0.002 |
| | Sodium | 5 | mg/L | -- | | 1 |
| | Zinc | ND | mg/L | 5 | EPA Secondary | 0.004 |
| | **Physical Factors** | | | | | |
| | Alkalinity (Total as CaCO3) | 160 | mg/L | -- | | 20 |
| | Hardness | 200 | mg/L | 100 | NTL Internal | 10 |
| | pH | 6.7 | pH Units | 6.5 to 8.5 | EPA Secondary | |
| | Total Dissolved Solids | 200 | mg/L | 500 | EPA Secondary | 20 |
| | Turbidity | 0.2 | NTU | 1.0 | EPA Action Level | 0.1 |

| Status | Contaminant | Results | Units | National Standards | | Min. Detection Level |
|---|---|---|---|---|---|---|
| | **Inorganic Analytes - Other** | | | | | |
| ✓ | Chloride | ND | mg/L | 250 | EPA Secondary | 5.0 |
| ✓ | Fluoride | ND | mg/L | 4.0 | EPA Primary | 0.5 |
| ● | Nitrate as N | 4.0 | mg/L | 10 | EPA Primary | 0.5 |
| ✓ | Nitrite as N | ND | mg/L | 1 | EPA Primary | 0.5 |
| ✓ | Ortho Phosphate | ND | mg/L | -- | | 2.0 |
| ✓ | Sulfate | ND | mg/L | 250 | EPA Secondary | 5.0 |
| | **Organic Analytes - Trihalomethanes** | | | | | |
| ✓ | Bromodichloromethane | ND | mg/L | -- | | 0.002 |
| ✓ | Bromoform | ND | mg/L | -- | | 0.004 |
| ✓ | Chloroform | ND | mg/L | -- | | 0.002 |
| ✓ | Dibromochloromethane | ND | mg/L | -- | | 0.004 |
| ✓ | Total THMs | ND | mg/L | 0.080 | EPA Primary | 0.002 |
| | **Organic Analytes - Volatiles** | | | | | |
| ✓ | 1,1,1,2-Tetrachloroethane | ND | mg/L | -- | | 0.002 |
| ✓ | 1,1,1-Trichloroethane | ND | mg/L | 0.2 | EPA Primary | 0.001 |
| ✓ | 1,1,2,2-Tetrachloroethane | ND | mg/L | -- | | 0.002 |
| ✓ | 1,1,2-Trichloroethane | ND | mg/L | 0.005 | EPA Primary | 0.002 |
| ✓ | 1,1-Dichloroethane | ND | mg/L | -- | | 0.002 |
| ✓ | 1,1-Dichloroethene | ND | mg/L | 0.007 | EPA Primary | 0.001 |
| ✓ | 1,1-Dichloropropene | ND | mg/L | -- | | 0.002 |
| ✓ | 1,2,3-Trichlorobenzene | ND | mg/L | -- | | 0.002 |
| ✓ | 1,2,3-Trichloropropane | ND | mg/L | -- | | 0.002 |
| ✓ | 1,2,4-Trichlorobenzene | ND | mg/L | 0.07 | EPA Primary | 0.002 |
| ✓ | 1,2-Dichlorobenzene | ND | mg/L | 0.6 | EPA Primary | 0.001 |
| ✓ | 1,2-Dichloroethane | ND | mg/L | 0.005 | EPA Primary | 0.001 |
| ✓ | 1,2-Dichloropropane | ND | mg/L | 0.005 | EPA Primary | 0.002 |
| ✓ | 1,3-Dichlorobenzene | ND | mg/L | -- | | 0.001 |

| Status | Contaminant | Results | Units | National Standards | | Min. Detection Level |
|---|---|---|---|---|---|---|
| ✓ | 1,3-Dichloropropane | ND | mg/L | -- | | 0.002 |
| ✓ | 1,4-Dichlorobenzene | ND | mg/L | 0.075 | EPA Primary | 0.001 |
| ✓ | 2,2-Dichloropropane | ND | mg/L | -- | | 0.002 |
| ✓ | 2-Chlorotoluene | ND | mg/L | -- | | 0.001 |
| ✓ | 4-Chlorotoluene | ND | mg/L | -- | | 0.001 |
| ✓ | Acetone | ND | mg/L | -- | | 0.01 |
| ✓ | Benzene | ND | mg/L | 0.005 | EPA Primary | 0.001 |
| ✓ | Bromobenzene | ND | mg/L | -- | | 0.002 |
| ✓ | Bromomethane | ND | mg/L | -- | | 0.002 |
| ✓ | Carbon Tetrachloride | ND | mg/L | 0.005 | EPA Primary | 0.001 |
| ✓ | Chlorobenzene | ND | mg/L | 0.1 | EPA Primary | 0.001 |
| ✓ | Chloroethane | ND | mg/L | -- | | 0.002 |
| ✓ | Chloromethane | ND | mg/L | -- | | 0.002 |
| ✓ | cis-1,2-Dichloroethene | ND | mg/L | 0.07 | EPA Primary | 0.002 |
| ✓ | cis-1,3-Dichloropropene | ND | mg/L | -- | | 0.002 |
| ✓ | DBCP | ND | mg/L | -- | | 0.001 |
| ✓ | Dibromomethane | ND | mg/L | -- | | 0.002 |
| ✓ | Dichlorodifluoromethane | ND | mg/L | -- | | 0.002 |
| ✓ | Dichloromethane | ND | mg/L | 0.005 | EPA Primary | 0.002 |
| ✓ | EDB | ND | mg/L | -- | | 0.001 |
| ✓ | Ethylbenzene | ND | mg/L | 0.7 | EPA Primary | 0.001 |
| ✓ | Methyl Tert Butyl Ether | ND | mg/L | -- | | 0.004 |
| ✓ | Methyl-Ethyl Ketone | ND | mg/L | -- | | 0.01 |
| ✓ | Styrene | ND | mg/L | 0.1 | EPA Primary | 0.001 |
| ✓ | Tetrachloroethene | ND | mg/L | 0.005 | EPA Primary | 0.002 |
| ✓ | Tetrahydrofuran | ND | mg/L | -- | | 0.01 |
| ✓ | Toluene | ND | mg/L | 1 | EPA Primary | 0.001 |
| ✓ | trans-1,2-Dichloroethene | ND | mg/L | 0.1 | EPA Primary | 0.002 |

| Status | Contaminant | Results | Units | National Standards | | Min. Detection Level |
|---|---|---|---|---|---|---|
| ✓ | trans-1,3-Dichloropropene | ND | mg/L | -- | | 0.002 |
| ✓ | Trichloroethene | ND | mg/L | 0.005 | EPA Primary | 0.001 |
| ✓ | Trichlorofluoromethane | ND | mg/L | -- | | 0.002 |
| ✓ | Vinyl Chloride | ND | mg/L | 0.002 | EPA Primary | 0.001 |
| ✓ | Xylenes (Total) | ND | mg/L | 10 | EPA Primary | 0.001 |

*We certify that the analyses performed for this report are accurate, and that the laboratory tests were conducted by methods approved by the U.S. Environmental Protection Agency or variations of these EPA methods.*

*These test results are intended to be used for informational purposes only and may not be used for regulatory compliance.*

*National Testing Laboratories, Ltd.*

NATIONAL TESTING LABORATORIES, LTD