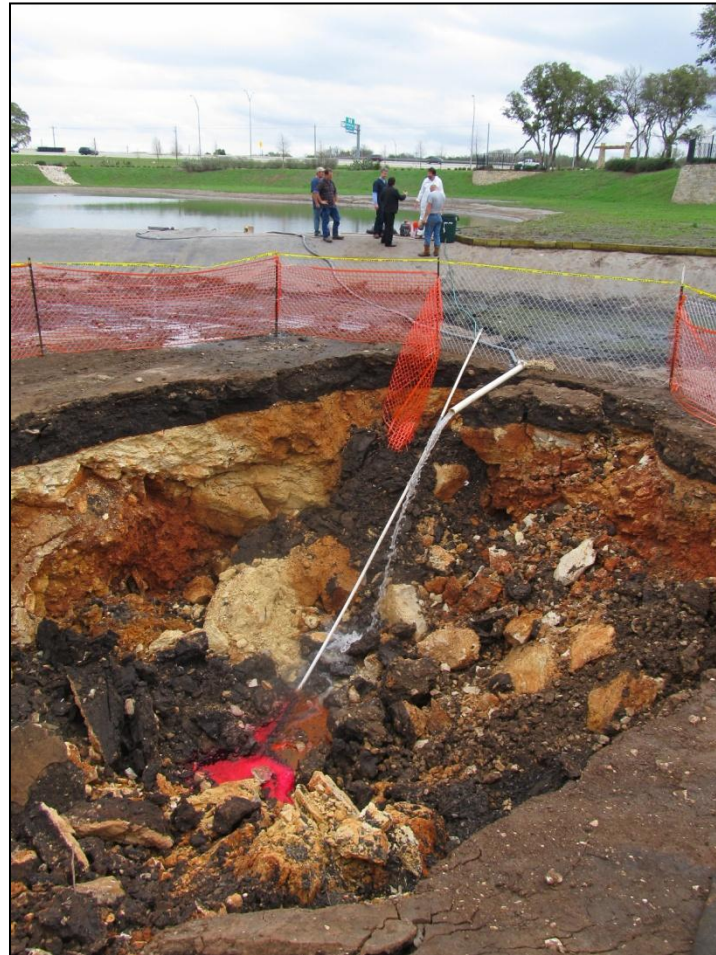




**Barton Springs
Edwards Aquifer**
CONSERVATION DISTRICT

Dye Tracing Results from the Arbor Trails Sinkhole, Barton Springs Segment of the Edwards Aquifer, Austin, Texas



BSEACD Report of Investigations 2013-0501

May 2013

Barton Springs/Edwards Aquifer Conservation District

1124 Regal Row

Austin, Texas

Disclaimer

All of the information provided in this report is believed to be accurate and reliable; however, the Barton Springs/Edwards Aquifer Conservation District and the report's authors assume no liability for any errors or for the use of the information provided.

Cover. Phloxine B dye injection at Arbor Trails sinkhole. Dye was injected on February 3, 2012 at about 13:00. A mass of 16.27 lbs (7,382g) was mixed with water and then gravity injected via a hose using storm water from an adjacent pond. (see Figure 7).

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ABSTRACT

On January 24, 2012, a 4.5 inch rainfall filled a Storm Water Retention Pond (SWRP) located in the recharge zone of the Barton Springs segment of the Edwards Aquifer with about 10 feet of stormwater. Subsequently, a cover-collapse sinkhole developed within the floor of the SWRP, measuring about 30 ft in diameter and 12 ft deep. About 7 million gallons of stormwater drained into the aquifer through this opening.

To determine the path, velocity, and destination of stormwater entering the sinkhole, a dye trace was conducted. Phloxine B was injected into the sinkhole on February 3, 2012. The dye was detected at one well and arrived at Barton Springs in less than 4 days, corresponding to a minimum velocity of 1.3 mi/day. The successful dye trace confirmed conclusions of previously published reports by demonstrating that the sinkhole is well integrated into the aquifer system, and that groundwater in the study area is within the Sunset Valley Groundwater Basin. Phloxine B proved to be a very good, conservative tracer through the collapsed terra rosa material of the sinkhole.

INTRODUCTION

Sudden cover-collapse sinkhole (doline) development is uncommon in the karstic Cretaceous-age Edwards limestone of central Texas. On January 24, 2012, a 4.5 in rainfall filled a Storm Water Retention Pond (SWRP), located in the recharge zone of the Barton Springs segment of the Edwards Aquifer, with about 10 ft of stormwater. Subsequently, a sinkhole developed within the floor of the SWRP, measuring about 30 ft in diameter and 12 ft deep. About 7 million gallons of stormwater drained into the aquifer through this opening. The sinkhole is located on a commercial development property called Arbor Trails, and hereafter is referred to as the Arbor Trails Sinkhole (ATS). The property is located southwest of the intersection of William Cannon Dr. and MoPac (Loop 1) within the recharge zone of the Barton Springs segment of the Edwards Aquifer (**Figure 1**).

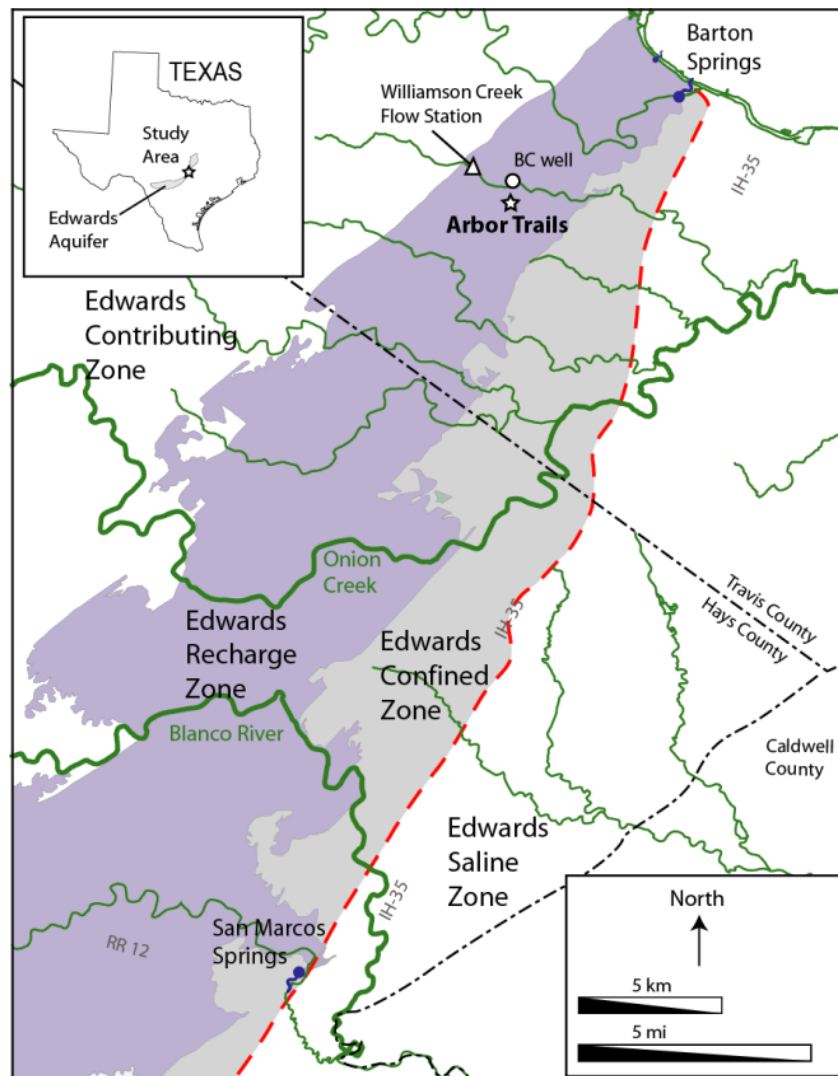


Figure 1. Location map of the study area. Indicated are the Brush Country well (BC well) and a USGS stream gage station on Williamson Creek.

The ATS is located near a groundwater basin divide (Cold Springs and Sunset Valley basins) defined by previous studies and dye tracing by Hauwert et al., 2004 (**Figure 2**). The purpose of the dye trace is to understand whether water that entered the ATS flowed north to Cold Springs, or northeast to Barton Springs. Understanding groundwater flow in the area is important as it contains relatively dense urban development with large highways and roads that could be potential sources of contaminants. Understanding the flow routes can help agencies notify existing groundwater users and to know which spring would be impacted in the event of a spill. Barton Springs is a major recreational destination for

the City of Austin and is habitat for the endangered Barton Springs salamander. The ATS provided an opportunity to trace groundwater flow and better delineate and define groundwater flow in the area.

The dye trace study was conducted by the Barton Springs/Edwards Aquifer Conservation District (District) and the City of Austin (CoA). District staff injected 16.3 lbs of Phloxine B dye into the ATS on February 3, 2012. The dye was detected at one well and Barton Springs within a few days. Results of the trace indicate rapid groundwater flow from the injection site to Barton Springs and confirms that the area is part of the Sunset Valley Groundwater basin as previously defined by Hauwert et al., 2004.

This report documents the dye trace study conducted at this feature. The reader is referred to Hunt et al., 2013, to learn more about the ATS and its mitigation.

Previous Work

Previous groundwater dye tracing studies that established major flow paths and also groundwater basins within the aquifer were published by Hauwert et al., 2004. The ATS is located near a groundwater divide between the Cold Springs and Sunset Valley basins. Whirlpool Cave is located 0.5 miles southwest of the ATS. In 1999 5 lbs of Eosine dye were traced from Whirlpool Cave to Upper and Main Barton Springs in 3-4 days. In 1997 10 lbs of Rhodamine WT (RWT) were injected into a monitor well located in the middle of Williamson Creek (BC well, **Figure 2**), which is located 0.5 miles north of the ATS. Dye arrived from the BC well at Cold Springs in less than 8 days (Hauwert et al., 2004). These two features, along with other traces and data, helped define the groundwater basins known as the Cold Springs and Sunset Valley Groundwater Basins (**Figure 2**).

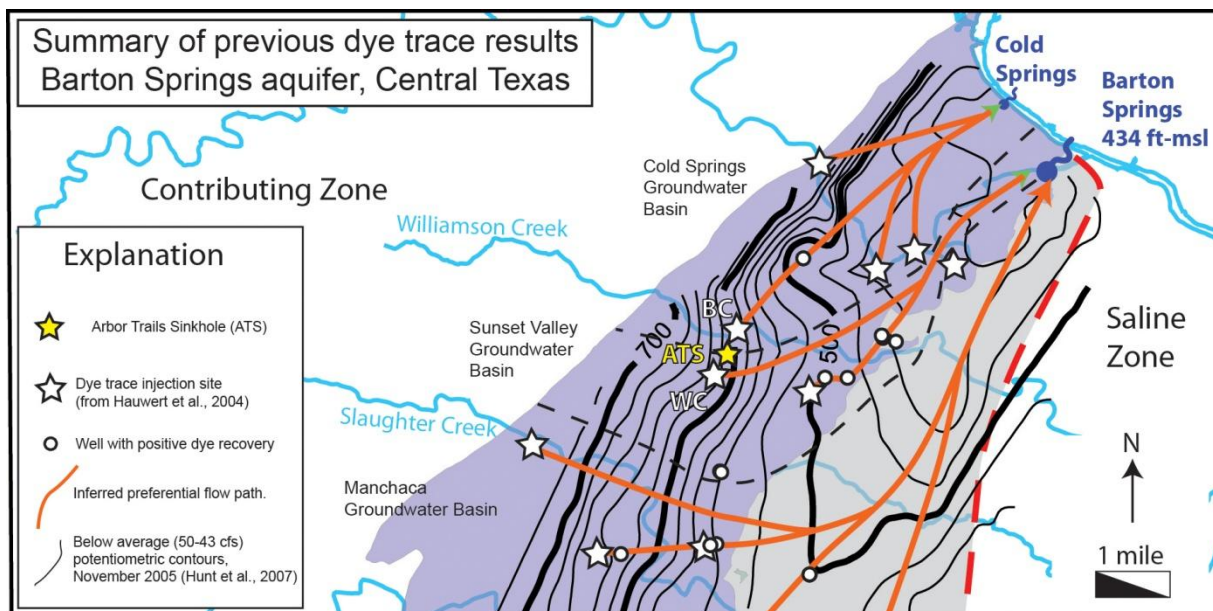


Figure 2. Summary of previous dye tracing in the area and the delineation of groundwater basins. Note the Arbor Trails Sinkhole is located very close to the estimated groundwater divide between the Cold Springs and Sunset Valley basins. WC is whirlpool cave and BC is Brush Country Well.

Setting

The ATS is located within the recharge zone of the Barton Springs segment of the Edwards Aquifer (Figures 1 and 2). The 72-acre property was developed in accordance with City of Austin's Land Development Code and the State of Texas requirements (Chapter 213 Edwards Rules). Review of topographic contours from the City of Austin 2-ft contour maps dated 1981 prior to MoPac (Loop 1) reveals a very shallow and large (6 acre) depression centered on the SWRP (Figure 3). The contours are present but more subtle on the 10-ft contour USGS quadrangle map of the area. The area appears well drained with no ponded water features evident in the aerial photos, and hardwood trees are present. However, the subdued nature of the feature and the subsequent disturbance from the highway that bisected the eastern portion of the depression made detection of the feature in the field difficult.

As part of the site engineering studies, geotechnical cores and borings were conducted throughout the site. In the preliminary geotechnical studies, 6-m (20-ft) deep cores were collected near the ATS (B-8 and B-9; **Figure 3**). The core holes and borings extended to the same depth as the final SWRP excavation depth. Both cores returned rock quality designation (RQD) of very poor to incompetent rock. Both cores indicated lost fluids within the first 10 feet and solution channels and small voids (HBC/Terracon, 2005), consistent with epikarst.

The location of the SWRP for the Arbor Trails development is shown in **Figure 4**. The purpose of the SWRP is to capture storm runoff from impervious areas (buildings and parking lots) and then irrigate vegetative areas throughout the property with the stormwater. The SWRP consists of two water quality controls: a geomembrane-lined wet pond, inset within a compacted clay-lined retention pond. The wet pond has a forebay and main permanent pool area that are separated by a berm. The wet pond was constructed for aesthetics within the retention basin. The retention pond has its capture volume above the permanent pool elevation for the wet pond. The capture volume for the retention pond extends up 6 ft onto the slope areas of the basin. The retention pond is the actual permitted water-quality control structure for the surrounding shopping center. During a rain event, stormwater captured by the retention basin is held and then used to irrigate vegetated areas throughout the property within 72 hours.

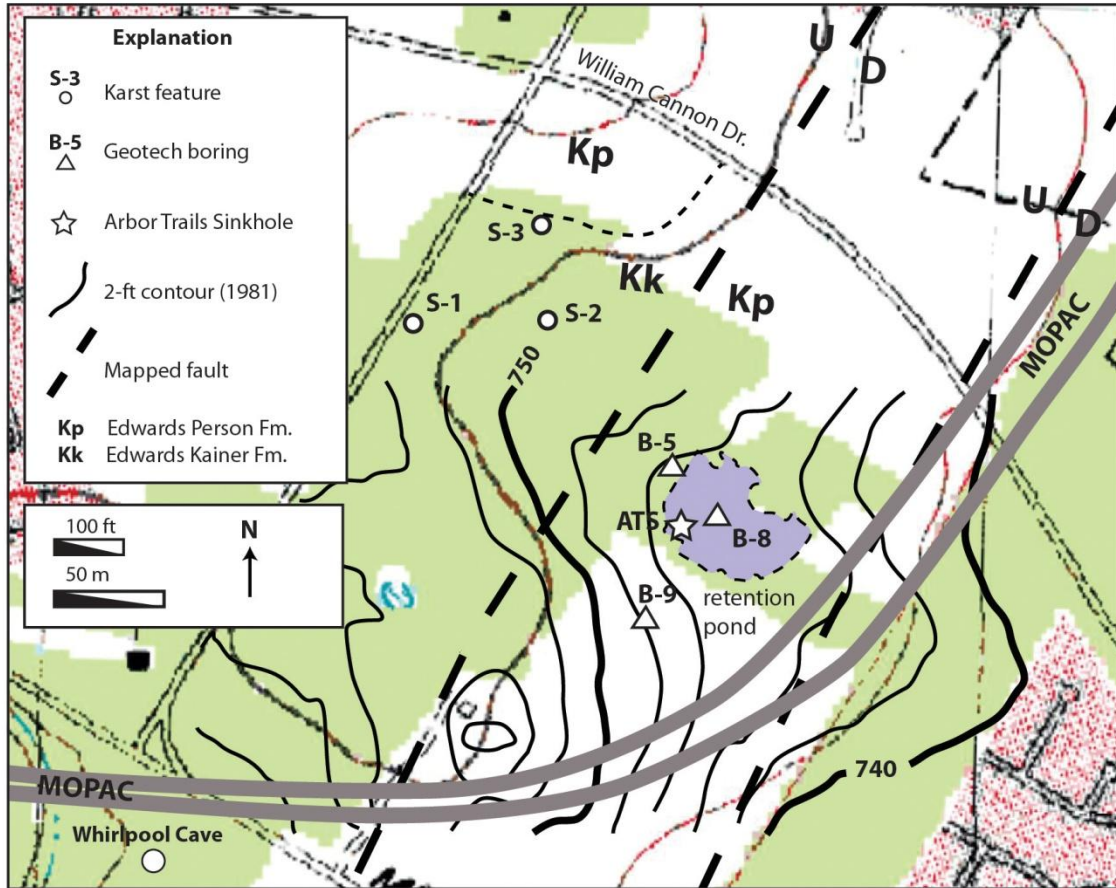


Figure 3. Predevelopment topographic map. Basemap is USGS Oak Hill Quadrangle (10-ft contours in brown). Geologic information from HBC/Terracon (2004) and likely sourced from Small et al., 1996. Black lines are City of Austin 2-ft topographic contours dated 1981, prior to major highway construction (MoPac). Contours create a depression centered around the SWRP, shown as dashed lines.



Figure 4. Detailed site map with key elements of the stormwater retention pond (SWRP), sinkhole location, and 2012 geophysics and boreholes.

Hydrologic Conditions and Sinkhole Collapse

Prior to collapse of the ATS, central Texas had been experiencing a severe drought. Beginning in late January, rainfall and subsequent recharge brought the aquifer out of drought conditions. **Figure 5** illustrates the rainfall, runoff, and response of wells and springs to the recharge. On January 24, 2012 a 4.5 in rainfall event occurred in the area of the Arbor Trails development filling, the SWRP with about 10 ft of water. On January 25, 2012, maintenance crews noticed the pond was draining into a developing sinkhole (**Figure 6a**). The size of the sinkhole was about 30 ft in diameter and 12 ft deep. About 7 million gallons of storm water drained into the aquifer through this opening. It is possible the drought and desiccation of the clay liner in the pond contributed to the compromise of the SWRP and development of the sinkhole.

A significant increase in turbidity at Barton Springs is associated with the late January rainfall (and March rainfall; **Figure 5**). These types of increases are relatively common in this karst system. District staff observed the runoff and recharge into swallets (Brodie Cave) within nearby tributaries of Slaughter

Creek from the same rainfall event that triggered the collapse of the ATS. It was noted that the stormwater entering those features was very turbid. Accordingly, the jump in turbidity cannot be solely attributed to the failure of the SWRP.

After the collapse, the sinkhole was further characterized by ACI Consulting (Austin, TX) through excavation, surface geophysics, and borehole drilling. These studies are discussed in Hunt et al. (2013). The ATS was excavated to a total depth of 21 feet. Most of the geologic material in the sinkhole consisted of friable, highly altered (weathered) clayey limestone and terra rosa, an iron-rich clay soil. Very little competent bedrock was encountered in the excavations. Solution fractures in the ATS were observed to have a NNE strike. Steep (~30 degree) west-dipping limestone beds in the ATS and along strike behind the northern retaining wall, were observed (**Figure 6**). The highly altered, fractured, and dipping nature of the rocks along strike supports the presence of the inferred mapped fault zones (**Figure 3**).

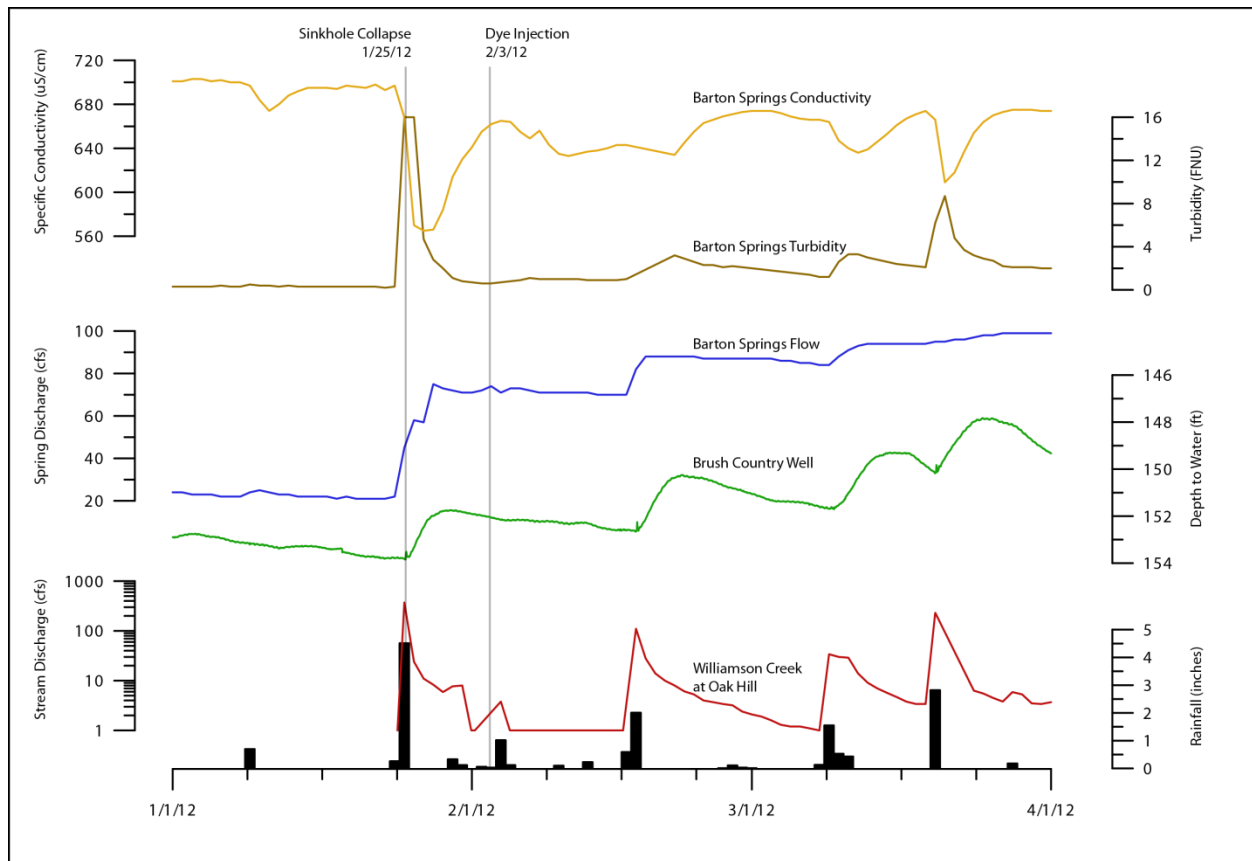


Figure 5: Hydrograph showing rainfall, streamflow, and Barton Springs flow with conductivity and turbidity. Time of sinkhole collapse and dye injection indicated.

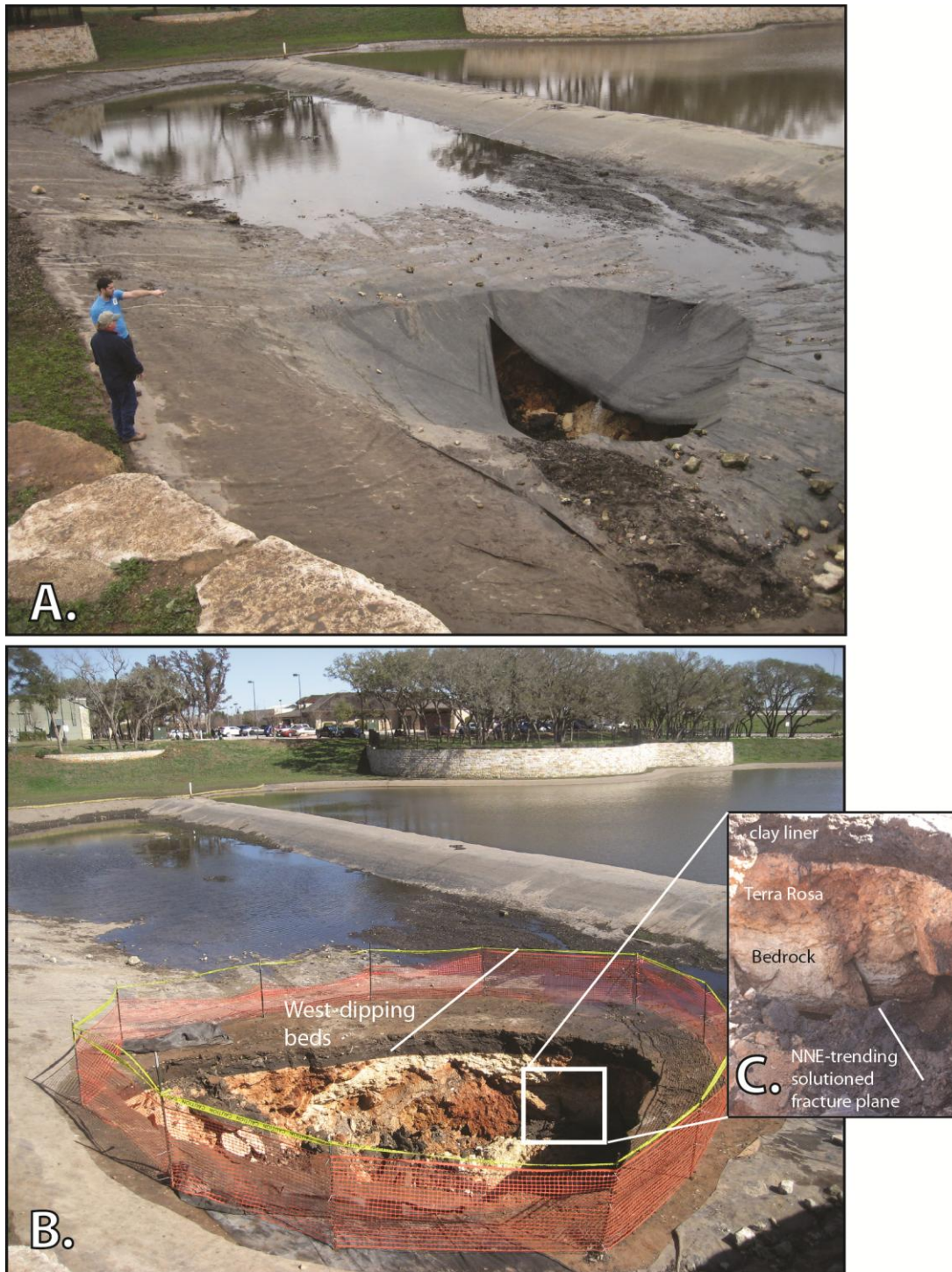


Figure 6. Photographs of sinkhole, all photos facing north. A) photo taken the day the sinkhole was observed (credit Heather Beatty, TCEQ). B) Photo taken two days after collapse and prior to excavation. Note the limestone beds are dipping to the west. C) Photo showing solutioned fracture in bedrock overlain by terra rosa and clay liner.

DYE TRACING METHODS

Groundwater dye tracing involves the introduction of non-toxic, organic dyes into the subsurface via injection points, such as caves, sinkholes, and wells, and analyzing charcoal receptors and water samples taken from discharge points, such as wells and springs. Alexander and Quinlan (1992) and Alley (1999) discuss the methodology of groundwater tracing with dyes.

Groundwater Tracers (Phloxine B)

Phloxine B dye used in this study was selected because it is nontoxic, inexpensive, widely tested and used, and easily detected by its fluorescence. The dye has been evaluated to be suitable for this and other studies due to its physical characteristics, safety for drinking water supplies, and aquatic habitats, and low background concentrations (Smart, 1984; Field et al., 1995).

Phloxine B has been used extensively in the San Antonio segment of the Edwards Aquifer (Johnson et al., 2012), but it has not been used in the Barton Springs segment. **Table 1** lists the molecular weight and emission wavelength of Phloxine B. The amount that was injected was consistent with previous injections (Hauwert et al., 2004) for the given location, distance, and hydrologic conditions. In addition, few public water supply systems are located along the expected flow paths, so that visible concentrations were less of a concern.

Table 1. Chemical Characteristics of Dyes

| Common Name | Color Index Generic Name | Molecular Weight | CAS Number | Emission Wavelength (nm) |
|-------------|-----------------------------|---------------------|------------|-----------------------------|
| Phloxine B | Acid Red 92 | 829.63 | 18472-87-2 | 541 |

from Johnson et al., (2012)

Injection

A mass of 16.3 lbs (7,382 grams) of Phloxine B Dye was injected on February 3, 2012, at about 13:00. The dye was in powder form and was mixed with water at the ATS site. The dye solution was mixed with water from the adjacent storm water pond and gravity injected into the sinkhole with a hose and PVC pipe that was placed in the bottom of the sinkhole where the dye solution infiltrated. About 5,000 gallons of water was pumped from the adjacent storm water pond to flush the dye into the feature (**Figure 7**).



Figure 7. Phloxine B dye injection at the Arbor Trails Sinkhole. Dye was injected on February 3, 2012, at about 13:00. A mass of 16.27 lbs (7,382g) was mixed with water and then gravity injected via a hose using storm water from an adjacent pond.

Sampling

Samples were collected by the District and CoA during the course of this study. Staff who injected the dye were not involved in sample collection. Sampling supplies were provided by the respective labs, and sampling procedures outlined by Ozark Underground Labs (OUL) were followed (Aley, 1999; Hauwert et al., 2004). Field control samples were carried by staff collecting samples.

Spring sampling locations were monitored by the City of Austin and included Barton Springs (Main, Eliza, Upper, and Old Mill spring outlets) and Cold Springs (**Figure 2**). From 2/3/12 to 3/5/12 ten wells were monitored by the BSEACD weekly for the presence or absence of dyes in groundwater using charcoal samples (**Table 3**). No background charcoal samples were in place prior to injection.

Barton Springs sites were monitored from 2/2/12 to 3/13/12 with charcoal receptors. No background receptors were in place prior to injection. However, grab samples taken on 2/2/12 were non-detect for Phloxine B. After injection of the dye, charcoal receptors were collected approximately daily beginning 2/7/12. Grab samples were taken when receptors were changed. In addition, water samples were taken from an ISCO 3700 Automatic Compact Sampler at 4- to 8-hour intervals at Upper Barton Springs from 2/7/12 to 2/25/12. Charcoal and grab samples from Cold Springs were collected weekly between 2/3/12 and 3/13/12. No background receptors were in place at Cold Springs prior to injection, but water samples collected on 2/3/12 were non-detect for Phloxine B.

Laboratories

Receptors and grab samples from springs were analyzed at the Edwards Aquifer Authority (EAA), and replicate samples were analyzed at OUL in Missouri. Detection limits are provided in **Table 2**. Below is a brief narrative of each laboratory's methods.

Table 2. Reported Detection Limits for Phloxine B

| | Water Detection Limit (ug/L or ppb) | Charcoal Detection Limit (ug/L or ppb) |
|-----|--|---|
| EAA | 0.044 | 0.044 |
| OUL | 0.004 | 0.004 |

Edwards Aquifer Authority

For analyses at the EAA, dye was extracted from charcoal receptors prior to analysis by eluting the charcoal (desorbing the dye) for one hour in a solution containing 95% of a 70% solution of 2-propanol in water and 5% sodium hydroxide. Phloxine B in vials and eluents from charcoal were analyzed in the laboratory with a Perkin Elmer LS-50B Luminescence Spectrometer using synchronous scan and right-angle sampling geometry. The scan spanned 401 to 650 nm at 0.5-nm intervals (covering Eosine, Uranine, and Phloxine B), with a difference between excitation and emission wavelengths ($\Delta\lambda$) of 15 nm and emission and excitation slits set at 6 nm (see Narrative **Appendix 1**).

Results of the analysis are recorded in intensity units and converted to concentrations by comparison with known standards. Three standards were prepared for each of the three dyes detected in the tracer tests. Dye solutions were prepared on the basis of mass and diluted with deionized water filtered

through a 0.2-micron filter to produce dye concentrations in the range that were expected in the water samples (see Narrative **Appendix 1**).

Detection limits for each dye were calculated from background fluorescence of naturally occurring fluorophores and instrument noise, following the method of Alexander (2005). The method defines limits of detection (LOD) and quantitation (LOQ) as three and ten times the fit standard error of background fluorescence, respectively. Water samples were selected that contained dyes at concentrations just above background fluorescence to calculate LOD and LOQ, and fit standard error was calculated using peak-fitting software (see Narrative **Appendix 1**).

Ozark Underground Labs

OUL does not routinely analyze for Phloxine B dye. However, the lab did the analyses and followed procedures established for the analyses of other dyes (such as Pyranine). OUL elutes charcoal in a mixture of 5% aqua ammonia and 95% isopropyl alcohol solution and sufficient potassium hydroxide flakes to saturate the solution for most dyes. 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. Fifteen ml of the eluting solution is poured over washed charcoal in a disposable sample beaker. The sample beaker is capped, allowed to stand for 60 minutes, and then the liquid is carefully poured off the charcoal into a new disposable beaker which has been appropriately labeled with the laboratory identification number (Aley, 2008).

OUL analyzes water and eluent samples on one of two Shimadzu spectrofluorometers: model RF-5000U or RF-5301. The RF-5301 is the primary instrument used; the RF-5000U is primarily used as a back-up instrument except for tracing studies which were begun using this instrument. Approximately 3 ml of the eluent is withdrawn from the sample container using a disposable polyethylene pipette, placed in a transparent, disposable rectangular polystyrene cuvette designed for fluorometric analysis, and then inserted into the RF-5000U or the RF-5301. Positive detections will have peak emission wavelengths in the range from about 573 to 578 nm.

A sample of the dye was shipped to OUL. To calculate detection limits OUL normally uses a sizeable collection of data. However, this data set did not exist for Phloxine B. However, the fluorescence peaks for Phloxine B are about 4 times larger per ppb of dye concentration than are the peaks for Pyranine. The detection limit in elutants is 0.015 ppb for Pyranine, so the estimated detection limit for Phloxine B is about 25% of that or 0.004 ppb. (Tom Alley, personal communication, 8/20/12).

Quality Control

Field control samples were carried by staff collecting samples. Eight field control samples were analyzed by the EAA and were non-detect for Phloxine B.

Split samples were taken from each site and sent for analyses to the EAA and OUL labs. Laboratory quality control procedures included dye standards, duplicate and replicate samples, distilled water blanks, and rinsate samples described in Johnson et al. (2012).

RESULTS

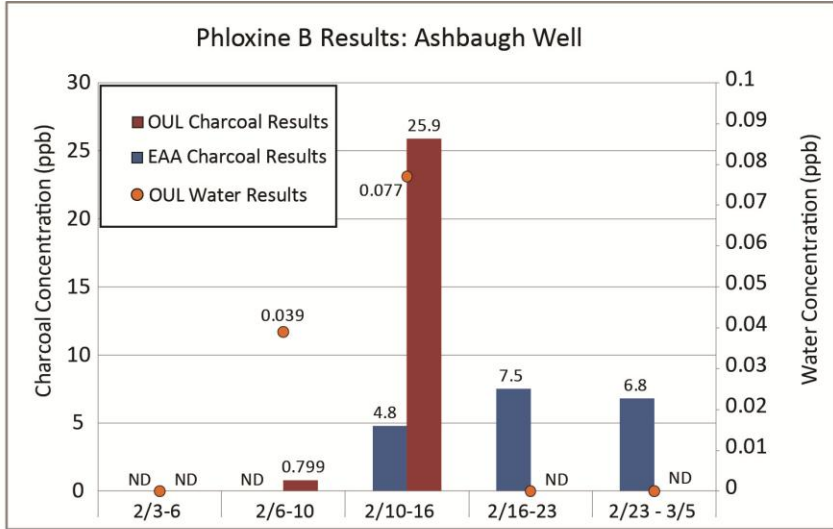
Lab results from the EAA and OUL are presented in **Appendix 1 and 2**, respectively. Results of the dye trace are summarized in **Table 3**. Breakthrough curves for three sites are shown in **Figures 8**. Interpreted flow paths are presented in **Figure 9**.

Table 3: Sites monitored and results

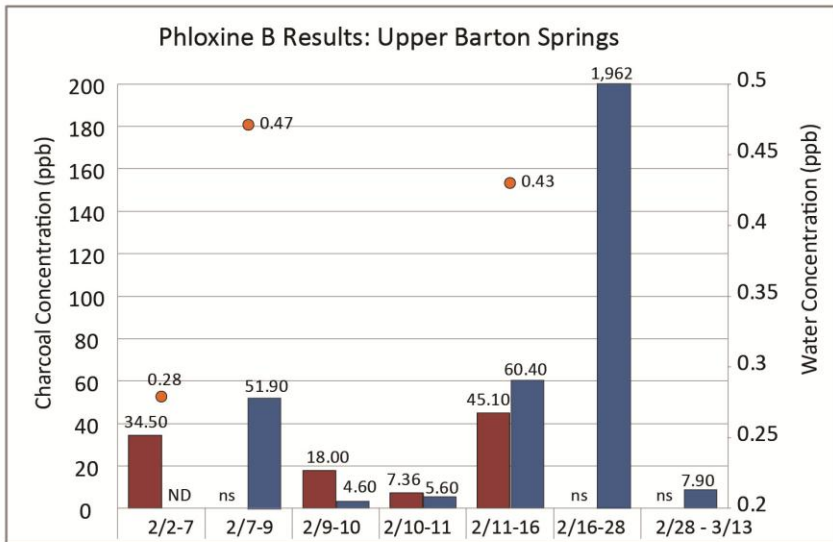
| Site ID | Site Name | Type | Ddlat | Ddlong | Linear Distance from Injection (miles) | First Dye Arrival (days) | Pumping Well | Comment |
|--------------------|--------------|---------------------------------|-----------|------------|--|--------------------------|--------------|-----------------------------------|
| Positive | | | | | | | | |
| 183A | Upper Barton | Spring | 30.263563 | -97.774216 | 4.9 | < 4 | n/a | OUL 2/2-2/7; both labs after 2/7 |
| 42914B | Main Barton | Spring | 30.263683 | -97.770821 | 5.1 | < 4 | n/a | Both labs 2/2-2/7 and after |
| 5850207 | Ashbaugh | Domestic (Irrigation only) Well | 30.217596 | -97.822845 | 1.0 | < 7 | yes | OUL 2/6-2/10; both labs 2/10-2/16 |
| Tentative | | | | | | | | |
| 42921B | Eliza | Spring | 30.264278 | -97.770172 | 5.1 | < 8 T | n/a | possible EAA detection 2/9-2/11 |
| 5850230 | Picard | Domestic Well | 30.226685 | -97.809219 | 1.9 | < 7 T | yes | possible EAA detection 2/6-2/10 |
| 58501GR | Randalls | Monitor Well | 30.223333 | -97.835281 | 0.4 | < 3 T | no | possible EAA detection 2/3-2/6 |
| 58502B | 6200 Brodie | Domestic Well | 30.221865 | -97.826498 | 0.8 | < 3 T | yes | possible EAA detection 2/3-2/6 |
| Non-Detects | | | | | | | | |
| 42916C | Cold Spring | Spring | 30.279593 | -97.780434 | 5.4 | ND | n/a | |
| 58502SC | Schaffer | Abandoned well | 30.221682 | -97.828135 | 0.7 | ND | no | |
| 42922B | Old Mill | Spring | 30.26354 | -97.768066 | 5.2 | ND | n/a | |
| 5850235 | Holiday Inn | Monitor Well | 30.234873 | -97.814096 | 1.8 | ND | no | |
| 5850212 | Sunset MW | Monitor Well | 30.225475 | -97.806183 | 2.0 | ND | no | |
| 5850222 | Besse | Domestic Well | 30.217216 | -97.818794 | 1.3 | ND | yes | |
| 58502JR | Jenkins | Domestic Well | 30.217044 | -97.817631 | 1.4 | ND | yes | |
| 5850128 | Whirlpool | Monitor Well | 30.215555 | -97.847221 | 0.5 | ND | no | |

ND = Non-detect; T = tentative

A)



B)



C)

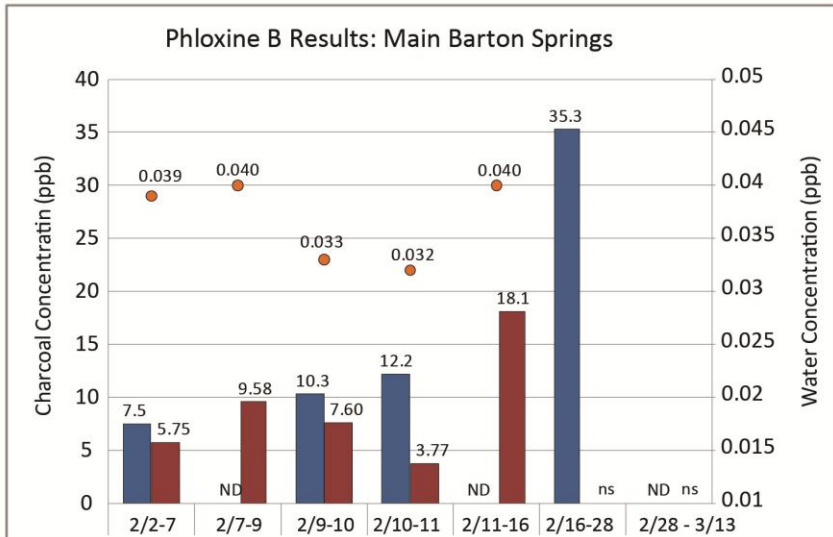


Figure 8. Phloxine B breakthrough graphs from the study. Both labs repeatedly detected Phloxine B at these three sites in charcoal samples. Additionally OUL detected dye in water samples from the three sites. A) Ashbaugh well, the only well monitoring site with both labs returning positive results; B) Upper Barton Springs contained the highest concentrations of dye from both labs; and C) Main Barton Springs consistently had positive results from both labs. Note that “ND” indicates a non-detect and “ns” indicates no sample.

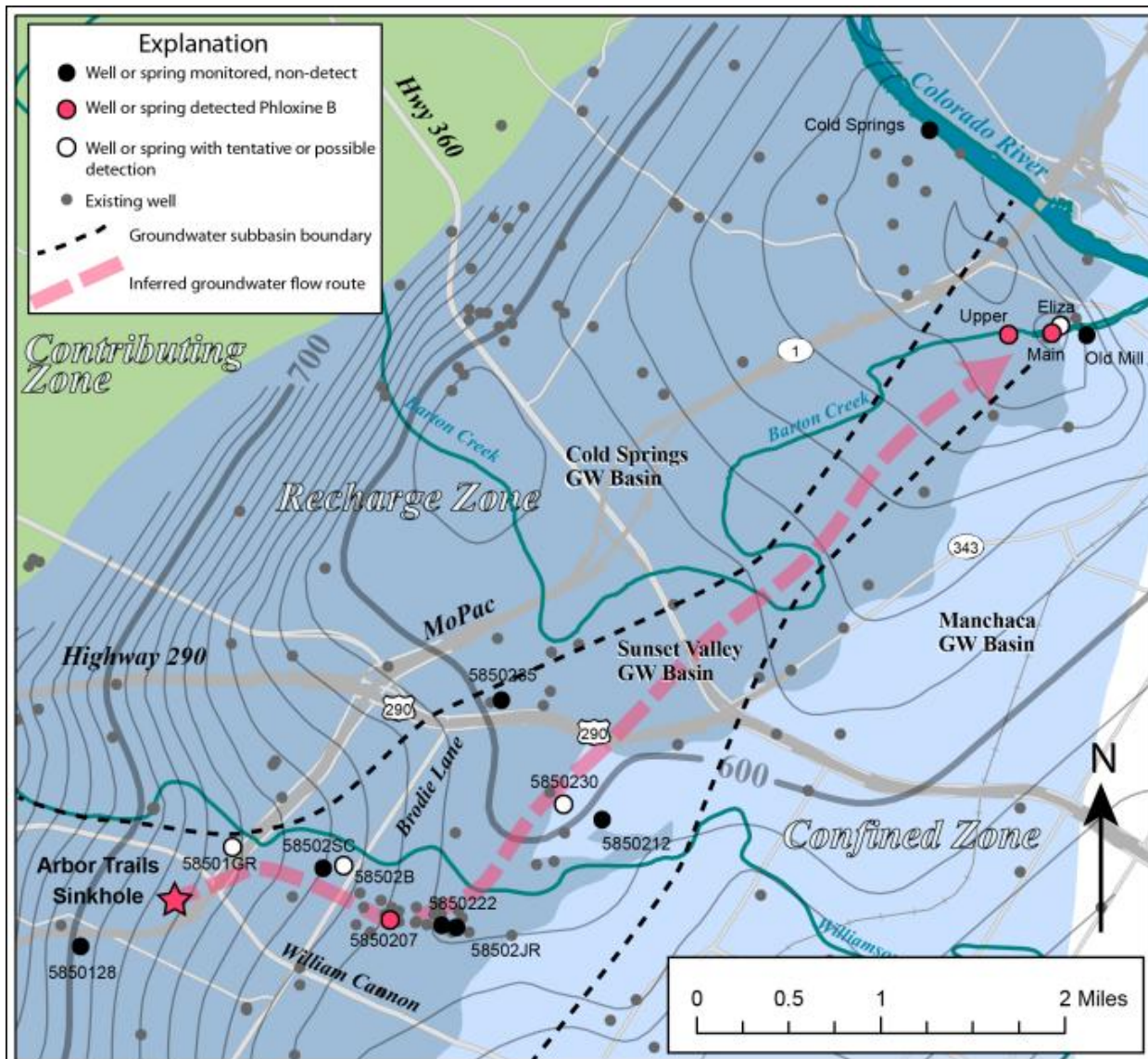


Figure 9. Map of results from the Arbor Trails Sinkhole dye trace. Pink circles indicate positive detections (very high confidence, both labs) of Phloxine B. White circles are wells with tentative detections (single detections from EAA lab), and solid black circles are locations with non-detects (both labs). Dashed pink line represents estimated flow route and is coincident with the “Sunset Valley Flow Route” defined by Hauwert et al., 2004. Small gray circles are existing water-supply wells. Light gray potentiometric lines are from February 2002 high flow conditions.

DISCUSSION

Although no background charcoal samples were in place prior to injection, grab samples analyzed the day before, and the day of, the injection were non-detect. In addition, Phloxine B has never been utilized as a fluorescent dye in the Barton Springs segment of the Edwards Aquifer. Accordingly, background concentrations were not a major concern for this study.

The first arrival of the Phloxine B dye was not well defined by sampling at Barton Springs. Charcoal receptors were placed at Upper and Main springs from 2/3-2/7, and both had a positive dye detection. Although we report a 4 day minimum travel time, OUL labs interpreted the first arrival at Barton Springs within 2 days (Tom Alley, personal communication).

Duplicate samples from the EAA and OUL were generally in agreement. Both labs repeatedly detected Phloxine B at the Ashbaugh well, Upper Barton Springs, and Main Barton Springs. However, there were detections reported by OUL that were not reported by the EAA. This is particularly true for water samples. The lower detection limit for the OUL lab (one order of magnitude lower) offers one explanation of the differences in results.

However, the EAA lab indicated dye at four additional sites not reported by OUL, but only from one sample at each site. Both labs re-evaluated their respective samples and did not change their reported results (**Appendix 3**). For the purposes of this study, those sites are listed as tentative detections (**Table 3**).

CONCLUSIONS

- Results of this study were similar to other dye trace studies in this area by Hauwert et al., 2004.
- Rapid travel time (1.3 mi/day at a minimum) was documented from the ATS to Barton Springs.
- Groundwater flow from the William Cannon and MoPac area was within the Sunset Valley Groundwater Basin as delineated by Hauwert et al., 2004.
- Subtle karst features near fault zones, expressed as closed surface depressions, can be very well integrated into the conduit flow system.
- Phloxine B was a very good conservative tracer through the collapsed terra rosa material in the ATS.

ACKNOWLEDGMENTS

This study would not have been possible without the full support of the property owner of the Arbor Trails retail development, Mr. Greg Christopher, President of Christopher Commercial Inc. (CCI). We would also thank the CCI executive team of Vice President and General Counsel Dan Myrick, Construction and Maintenance Manager Dan Manchiela, and SWRP project manager Chuck Meehan.

We would like to extend our thanks to the Edwards Aquifer Authority (EAA) and especially Geary Schindel for his support of the dye tracing portion of this study. The EAA provided Phloxine B dye and also performed the majority of the dye trace analyses.

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Appendices

Appendix 1: Dye Trace Results EAA

Appendix 2: Dye Trace Results OUL

Appendix 3: Correspondence on confirmation of results

Appendices 1: Dye Trace Results EAA

Arbor Trails Sinkhole Results

Narrative

Edwards Aquifer Authority (EAA) analyzed 201 samples submitted by Barton Springs Edwards Aquifer Conservation District (BSEACD) from the Arbor Trails Sinkhole project. Although vials from autosamplers and grab samples required no preparation before analysis, dye must be extracted from charcoal receptors prior to analysis by eluting the charcoal (desorbing the dye) for one hour in a solution containing 95% of a 70% solution of 2-propanol in water and 5% sodium hydroxide. The eluent was then decanted into a labeled glass vial and stored in darkness until analyzed.

Uranine, Phloxine B, and Eosin in vials and eluents from charcoal were analyzed in the laboratory with a Perkin Elmer LS-50B Luminescence Spectrometer using synchronous scan and right-angle sampling geometry. The scan spanned 401 to 650 nm at 0.5-nm intervals, with a difference between excitation and emission wavelengths ($\Delta\lambda$) of 15 nm and emission and excitation slits set at 6 nm.

Dye Standards

Results of the analysis are recorded in intensity units and converted to concentrations by comparison with known standards. Three standards were prepared for each of the three dyes detected in the tracer tests. Dye solutions were prepared on the basis of mass and diluted with deionized water filtered through a 0.2-micron filter to produce dye concentrations in the range that was expected in the water samples. To convert intensity to concentration, a power regression was calculated between intensity units and standard concentrations. For example, Figure 1 shows power regression of Uranine concentrations versus amplitude.

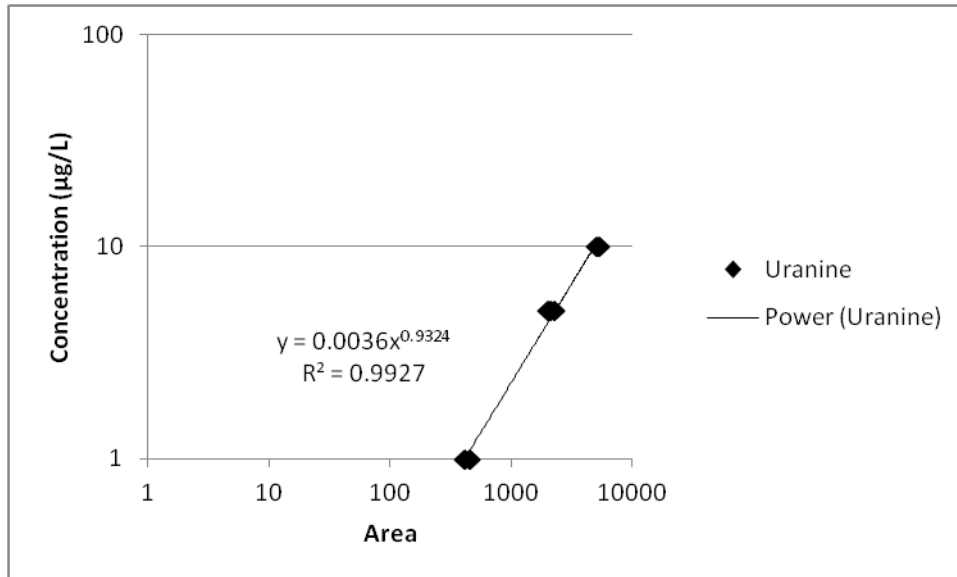


Figure 1. Power Regression for Uranine

Detection Limits

Detection and quantitation limits for each dye were calculated from background fluorescence of naturally occurring fluorophores and instrument noise, following the method of Alexander (2005). The method defines limits of detection (LOD) and quantitation (LOQ) as three and 10 times the fit standard error of background fluorescence, respectively. Water samples were selected that contained dyes at concentrations just above background fluorescence to calculate LOD and LOQ, and fit standard error was calculated using peak-fitting software. For example, Figure 2 shows original intensities, separated dye peaks, and calculated LODs and LOQs for each dye. Using regression equations yields the limits of detection and quantitation for each dye in Table 1.

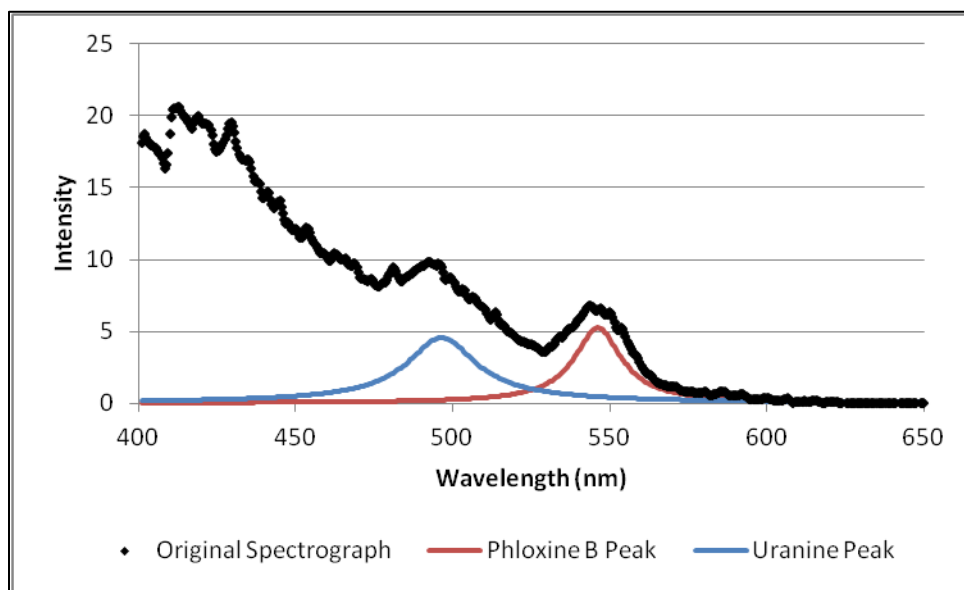


Figure 2. Example of Peak Used for LOD

Table 1. Limits of Detection and Quantitation for the Dyes

| Dye | Sample | Fit Standard Error | Limit of Detection ($\mu\text{g/L}$) | Limit of Quantitation ($\mu\text{g/L}$) |
|-----------------------|---|--------------------|--|---|
| Uranine (charcoal) | Upper Barton 2/11/2012 1:05:00 PM | 0.54 | 0.0061 | 0.020 |
| Eosin (charcoal) | 42916B 2/16/2012 2:14:00 PM | 0.77 | 0.068 | 0.23 |
| Phloxine B (charcoal) | Upper Barton 2/11/2012 1:05:00 PM | 0.54 | 0.044 | 0.15 |
| Phloxine B (water) | Upper Barton 2/19/2012 9:00:00 AM | 0.54 | 0.044 | 0.15 |

Control Samples

One control sample (February 1, 2012; sample 100) of charcoal contained detectable concentrations of Uranine and Phloxine B because it was processed differently than the other charcoal samples. A contaminated pipettor was used to transfer eluent into a vial for analysis to avoid introducing suspended particles of charcoal into the vial. The normal procedure is to pour eluent from the desorption cup into a vial. When the analyst observed dye in the results, he prepared a new sample from the remaining charcoal and poured eluent into a vial for analysis. The second sample contained no detectable dyes. Consequently, none of the sample results were compromised.

References

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Results for Arbor Trails Sinkhole

| Sample No. | Sample | Site Name | Sample Name | Set Date | Collected | Center | Height | FWHM | Peak Area | Dye | Concentration (µg/L) |
|------------|----------|-------------|-------------|--------------------|--------------------|--------|--------|------|-----------|------------|----------------------|
| 154 | Water | 6200 Brodie | 58-50-2 | | 2/3/2012 2:10 PM | | | | | | ND |
| 160 | Water | 6200 Brodie | 58-50-2 | | 2/6/2012 1:02 PM | | | | | | ND |
| 194 | Charcoal | 6200 Brodie | 58-50-2 | 2/3/2012 2:10 PM | 2/6/2012 1:02 PM | 493.2 | 9.1 | 31.4 | 310 | Uranine | 0.76 |
| 194 | Charcoal | 6200 Brodie | 58-50-2 | 2/3/2012 2:10 PM | 2/6/2012 1:02 PM | 555.1 | 0.88 | 27.9 | 38.7 | Phloxine B | 1.4 |
| 204 | Water | 6200 Brodie | 58-50-2 | | 2/7/2012 | | | | | | ND |
| 164 | Water | 6200 Brodie | 58-50-2 | | 2/10/2012 2:55 PM | | | | | | ND |
| 114 | Charcoal | 6200 Brodie | 58-50-2 | 2/10/2012 2:55 PM | 2/10/2012 2:55 PM | | | | | | ND |
| 124 | Charcoal | 6200 Brodie | 58-50-2 | 2/16/2012 11:55 AM | 2/16/2012 11:55 AM | | | | | | ND |
| 170 | Water | 6200 Brodie | 58-50-2 | | 2/16/2012 11:55 AM | | | | | | ND |
| 123 | Charcoal | 6200 Brodie | 58-50-2 | 2/10/2012 2:45 PM | 2/16/2012 12:05 PM | | | | | | ND |
| 198 | Charcoal | 6200 Brodie | 58-50-2 | 2/16/2012 11:55 AM | 2/23/2012 1:45 PM | | | | | | ND |
| 214 | Charcoal | 6200 Brodie | 58-50-2 | 2/23/2012 1:45 PM | 3/5/2012 1:30 PM | | | | | | ND |
| 203 | Water | Ashbaugh | 58-50-207 | | 2/23/2012 1:35 PM | | | | | | ND |
| 213 | Water | Ashbaugh | 58-50-207 | | 3/5/2012 1:10 PM | | | | | | ND |
| 155 | Water | Ashbaugh | 58-50-207 | | 2/3/2012 2:17 PM | | | | | | ND |
| 107 | Charcoal | Ashbaugh | 58-50-207 | 2/6/2012 12:53 PM | 2/6/2012 12:53 PM | | | | | | ND |
| 159 | Water | Ashbaugh | 58-50-207 | | 2/6/2012 12:53 PM | | | | | | ND |
| 163 | Water | Ashbaugh | 58-50-207 | | 2/10/2012 2:30 PM | | | | | | ND |
| 113 | Charcoal | Ashbaugh | 58-50-207 | 2/10/2012 2:30 PM | 2/10/2012 2:30 PM | 546.2 | 4.9 | 21.7 | 126 | Phloxine B | 4.8 |
| 169 | Water | Ashbaugh | 58-50-207 | | 2/16/2012 11:35 AM | | | | | | ND |
| 122 | Charcoal | Ashbaugh | 58-50-207 | 2/16/2012 11:35 AM | 2/16/2012 11:35 AM | 546.5 | 6.3 | 21.5 | 191 | Phloxine B | 7.5 |
| 122 | Charcoal | Ashbaugh | 58-50-207 | 2/16/2012 11:35 AM | 2/16/2012 11:35 AM | 496.4 | 5.6 | 45.0 | 268 | Uranine | 0.67 |
| 197 | Charcoal | Ashbaugh | 58-50-207 | 2/16/2012 11:35 AM | 2/23/2012 1:35 PM | | | | | | ND |
| 212 | Charcoal | Ashbaugh | 58-50-207 | 2/23/2012 1:35 PM | 3/5/2012 1:10 PM | 546.5 | 5.4 | 22.8 | 174 | Phloxine B | 6.8 |
| 212 | Charcoal | Ashbaugh | 58-50-207 | 2/23/2012 1:35 PM | 3/5/2012 1:10 PM | 546.7 | 5.7 | 20.9 | 177 | Phloxine B | 6.9 |
| 152 | Water | Besse | 58-50-222 | | 2/3/2012 1:09 PM | | | | | | ND |
| 158 | Water | Besse | 58-50-222 | | 2/6/2012 12:44 PM | | | | | | ND |
| 202 | Water | Besse | 58-50-222 | | 2/10/2012 | | | | | | ND |
| 211 | Water | Besse | 58-50-222 | | 2/10/2012 | | | | | | ND |
| 162 | Water | Besse | 58-50-222 | | 2/10/2012 2:25 PM | | | | | | ND |
| 112 | Charcoal | Besse | 58-50-222 | 2/10/2012 2:25 PM | 2/10/2012 2:25 PM | | | | | | ND |
| 168 | Water | Besse | 58-50-222 | | 2/16/2012 11:30 AM | | | | | | ND |
| 121 | Charcoal | Besse | 58-50-222 | 2/16/2012 11:30 AM | 2/16/2012 11:30 AM | | | | | | ND |
| 196 | Charcoal | Besse | 58-50-222 | 2/16/2012 11:30 AM | 2/23/2012 12:55 PM | | | | | | ND |
| 210 | Charcoal | Besse | 58-50-222 | 2/23/2012 12:55 PM | 3/5/2012 1 PM | | | | | | ND |
| 286 | Water | Cold Spring | 42916 | | 2/3/2012 5:30 PM | | | | | | ND |
| 192 | Water | Cold Spring | 42916 | | 2/10/2012 3:45 PM | | | | | | ND |

| Sample No. | Sample | Site Name | Sample Name | Set Date | Collected | Center | Height | FWHM | Peak Area | Dye | Concentration (µg/L) |
|------------|----------|-------------|-------------|-------------------|--------------------|--------|--------|------|-----------|------------|----------------------|
| 142 | Charcoal | Cold Spring | 42916C | 2/3/2012 5:35 PM | 2/10/2012 3:50 PM | 523.7 | 185 | 20.1 | 4085 | Eosin | 46.1 |
| 193 | Water | Cold Spring | 42916 | | 2/16/2012 2:12 PM | | | | | | ND |
| 129 | Charcoal | Cold Spring | 42916B | 2/10/2012 3:47 PM | 2/16/2012 2:14 PM | 523.8 | 206 | 19.9 | 4512 | Eosin | 50.2 |
| 281 | Charcoal | Cold Spring | 42916 | 2/16/2012 2:12 PM | 3/13/2012 1:25 PM | | | | | | ND |
| 276 | Water | Cold Spring | 42916 | | 3/13/2012 1:35 PM | | | | | | ND |
| 219 | Charcoal | Control | Control | 3/5/2012 | 3/5/2012 | | | | | | ND |
| 100 | Charcoal | Control | Control | 2/1/2012 5 PM | 2/1/2012 5 PM | | | | | | ND |
| 100 | Charcoal | Control | Control | 2/1/2012 5 PM | 2/1/2012 5 PM | 549.1 | 0.98 | 23.7 | 33.5 | Phloxine B | 1.2 |
| 100 | Charcoal | Control | Control | 2/1/2012 5 PM | 2/1/2012 5 PM | 492.1 | 9.6 | 30.7 | 324 | Uranine | 0.79 |
| 102 | Charcoal | Control | Control | 2/3/2012 | 2/3/2012 | | | | | | ND |
| 101 | Charcoal | Control | Control | 2/3/2012 | 2/3/2012 | | | | | | ND |
| 110 | Charcoal | Control | Control | 2/6/2012 | 2/6/2012 | | | | | | ND |
| 120 | Charcoal | Control | Control | 2/10/2012 | 2/10/2012 | | | | | | ND |
| 127 | Charcoal | Control | Control | 2/16/2012 | 2/16/2012 | | | | | | ND |
| 128 | Charcoal | Control | Control | 2/16/2012 | 2/16/2012 | | | | | | ND |
| 287 | Water | Eliza | 42921 | | 2/2/2012 1:45 PM | | | | | | ND |
| 139 | Charcoal | Eliza | 42921A | 2/2/2012 1:45 PM | 2/7/2012 4:45 PM | | | | | | ND |
| 185 | Water | Eliza | 42921 | | 2/7/2012 4:50 PM | | | | | | ND |
| 144 | Charcoal | Eliza | 42921A | 2/7/2012 4:45 PM | 2/9/2012 2:15 PM | | | | | | ND |
| 190 | Water | Eliza | 42921 | | 2/9/2012 2:20 PM | | | | | | ND |
| 173 | Water | Eliza | 42921 | | 2/10/2012 4:40 PM | | | | | | ND |
| 148 | Charcoal | Eliza | 42921B | 2/9/2012 2:17 PM | 2/10/2012 4:42 PM | | | | | | ND |
| 131 | Charcoal | Eliza | 42921A | 2/10/2012 4:40 PM | 2/11/2012 9:45 AM | | | | | | ND |
| 176 | Water | Eliza | 42921 | | 2/11/2012 9:45 AM | | | | | | ND |
| 149 | Charcoal | Eliza | 42921C | 2/9/2012 2:20 PM | 2/11/2012 9:50 AM | 548.1 | 5.0 | 18.9 | 101 | Phloxine B | 3.9 |
| 181 | Water | Eliza | 42921 | | 2/16/2012 3:15 PM | | | | | | ND |
| 134 | Charcoal | Eliza | 42921A | 2/11/2012 9:45 AM | 2/16/2012 3:15 PM | | | | | | ND |
| 270 | Water | Eliza | 42921 | | 2/28/2012 3:20 PM | | | | | | ND |
| 275 | Charcoal | Eliza | 42921 | 2/16/2012 3:17 PM | 2/28/2012 3:22 PM | | | | | | ND |
| 278 | Water | Eliza | 42921 | | 3/13/2012 2:10 PM | | | | | | ND |
| 283 | Charcoal | Eliza | 42921 | 2/28/2012 3:20 PM | 3/13/2012 2:10 PM | | | | | | ND |
| 106 | Charcoal | Holiday Inn | 58-50-235 | 2/3/2012 1:57 PM | 2/6/2012 1:57 PM | | | | | | ND |
| 117 | Charcoal | Holiday Inn | 58-50-235 | 2/6/2012 1:57 PM | 2/16/2012 12:50 PM | | | | | | ND |
| 153 | Water | Jenkins | 58-50-2JR | | 2/3/2012 1:15 PM | | | | | | ND |
| 104 | Charcoal | Jenkins | 58-50-2JR | 2/6/2012 12:37 PM | 2/6/2012 12:37 PM | | | | | | ND |
| 104 | Charcoal | Jenkins | 58-50-2JR | 2/6/2012 12:37 PM | 2/6/2012 12:37 PM | | | | | | ND |
| 157 | Water | Jenkins | 58-50-2JR | | 2/6/2012 12:37 PM | | | | | | ND |
| 201 | Water | Jenkins | 58-50-2JR | | 2/7/2012 | | | | | | ND |
| 207 | Water | Jenkins | 58-50-2JR | | 2/10/2012 | | | | | | ND |

| Sample No. | Sample | Site Name | Sample Name | Set Date | Collected | Center | Height | FWHM | Peak Area | Dye | Concentration (µg/L) |
|------------|----------|-------------|-------------|--------------------|--------------------|--------|--------|------|-----------|------------|----------------------|
| 166 | Water | Jenkins | 58-50-2JR | | 2/10/2012 2:10 PM | | | | | | ND |
| 111 | Charcoal | Jenkins | 58-50-2JR | 2/6/2012 12:37 PM | 2/12/2012 2:10 PM | | | | | | ND |
| 126 | Charcoal | Jenkins | 58-50-2JR | 2/16/2012 11:20 AM | 2/16/2012 11:20 AM | | | | | | ND |
| 167 | Water | Jenkins | 58-50-2JR | | 2/16/2012 11:20 AM | | | | | | ND |
| 195 | Charcoal | Jenkins | 58-50-2JR | 2/16/2012 11:20 AM | 2/23/2012 12:35 PM | | | | | | ND |
| 206 | Charcoal | Jenkins | 58-50-2JR | 2/23/2012 12:35 PM | 3/5/2012 12:50 PM | | | | | | ND |
| 145 | Charcoal | Main Barton | 42914A | 2/7/2012 5 PM | 2/9/2010 2:35 PM | | | | | | ND |
| 188 | Water | Main Barton | 42914 | | 2/9/2010 2:35 PM | | | | | | ND |
| 288 | Water | Main Barton | 42914 | | 2/2/2012 2 PM | | | | | | ND |
| 140 | Charcoal | Main Barton | 42914A | 2/2/2012 2 PM | 2/7/2012 5 PM | 547.3 | 9.9 | 22.1 | 191 | Phloxine B | 7.5 |
| 186 | Water | Main Barton | 42914 | | 2/7/2012 5 PM | | | | | | ND |
| 174 | Water | Main Barton | 42914 | | 2/10/2012 4:55 PM | | | | | | ND |
| 150 | Charcoal | Main Barton | 42914B | 2/9/2012 2:37 PM | 2/10/2012 4:57 PM | 547.7 | 11.9 | 18.9 | 260 | Phloxine B | 10.3 |
| 179 | Water | Main Barton | 42914 | | 2/11/2012 2:05 PM | | | | | | ND |
| 132 | Charcoal | Main Barton | 42914A | 2/10/2012 4:55 PM | 2/11/2012 2:05 PM | 548.1 | 14.8 | 19.4 | 308 | Phloxine B | 12.2 |
| 182 | Water | Main Barton | 42914 | | 2/16/2012 3:30 PM | | | | | | ND |
| 137 | Charcoal | Main Barton | 42914A | 2/11/2012 2:05 PM | 2/16/2012 3:30 PM | | | | | | ND |
| 269 | Water | Main Barton | 42914 | | 2/28/2012 3:35 PM | | | | | | ND |
| 273 | Charcoal | Main Barton | 42914 | 2/16/2012 3:32 PM | 2/28/2012 3:37 PM | 547.7 | 39.3 | 19.4 | 858 | Phloxine B | 35.3 |
| 277 | Water | Main Barton | 42914 | | 3/13/2012 2:30 PM | | | | | | ND |
| 285 | Charcoal | Main Barton | 42914 | 2/28/2012 3:35 PM | 3/13/2012 2:30 PM | | | | | | ND |
| 290 | Water | Old Mill | 42922 | | 2/2/2012 2:30 PM | | | | | | ND |
| 141 | Charcoal | Old Mill | 42922B | 2/2/2012 2:32 PM | 2/7/2012 5:27 PM | | | | | | ND |
| 187 | Water | Old Mill | 42922 | | 2/7/2012 5:30 PM | | | | | | ND |
| 146 | Charcoal | Old Mill | 42922A | 2/7/2012 5:25 PM | 2/9/2012 3 PM | | | | | | ND |
| 191 | Water | Old Mill | 42922 | | 2/9/2012 3 PM | | | | | | ND |
| 151 | Charcoal | Old Mill | 42922A | 2/9/2012 3 PM | 2/10/2012 5:15 PM | | | | | | ND |
| 175 | Water | Old Mill | 42922 | | 2/10/2012 5:15 PM | | | | | | ND |
| 133 | Charcoal | Old Mill | 42922A | 2/10/2012 5:15 PM | 2/11/2012 1:30 PM | | | | | | ND |
| 178 | Water | Old Mill | 42922 | | 2/11/2012 1:30 PM | | | | | | ND |
| 183 | Water | Old Mill | 42922 | | 2/16/2012 3:50 PM | | | | | | ND |
| 136 | Charcoal | Old Mill | 42922B | 2/11/2012 1:32 PM | 2/16/2012 3:52 PM | | | | | | ND |
| 271 | Water | Old Mill | 42922 | | 2/28/2012 4 PM | | | | | | ND |
| 272 | Charcoal | Old Mill | 42922 | 2/16/2012 3:52 PM | 2/28/2012 4:02 PM | | | | | | ND |
| 272 | Charcoal | Old Mill | 42922 | 2/16/2012 3:52 PM | 2/28/2012 4:02 PM | | | | | | ND |
| 280 | Water | Old Mill | 42922 | | 3/13/2012 3:15 PM | | | | | | ND |
| 284 | Charcoal | Old Mill | 42922 | 2/28/2012 4 PM | 3/13/2012 3:15 PM | | | | | | ND |
| 218 | Water | Picard | 58-50-230 | | 3/5/2012 2:10 PM | | | | | | ND |
| 156 | Water | Picard | 58-50-230 | | 2/3/2012 4:34 PM | | | | | | ND |

| Sample No. | Sample | Site Name | Sample Name | Set Date | Collected | Center | Height | FWHM | Peak Area | Dye | Concentration (µg/L) |
|------------|----------|--------------|-------------|--------------------|--------------------|--------|--------|------|-----------|------------|----------------------|
| 161 | Water | Picard | 58-50-230 | | 2/6/2012 1:16 PM | | | | | | ND |
| 161 | Water | Picard | 58-50-230 | | 2/6/2012 1:16 PM | | | | | | ND |
| 109 | Charcoal | Picard | 58-50-230 | 2/6/2012 1:16 PM | 2/6/2012 1:16 PM | 554.1 | 0.79 | 47.2 | 40.9 | Phloxine B | 1.5 |
| 205 | Water | Picard | 58-50-230 | | 2/9/2012 | | | | | | ND |
| 165 | Water | Picard | 58-50-230 | | 2/10/2012 3:05 PM | | | | | | ND |
| 165 | Water | Picard | 58-50-230 | | 2/10/2012 3:05 PM | | | | | | ND |
| 115 | Charcoal | Picard | 58-50-230 | 2/10/2012 3:05 PM | 2/10/2012 3:05 PM | | | | | | ND |
| 125 | Charcoal | Picard | 58-50-230 | 2/16/2012 12:20 PM | 2/16/2012 12:20 PM | | | | | | ND |
| 171 | Water | Picard | 58-50-230 | | 2/16/2012 12:20 PM | | | | | | ND |
| 200 | Charcoal | Picard | 58-50-230 | 2/16/2012 12:20 PM | 2/23/2012 2:20 PM | | | | | | ND |
| 217 | Charcoal | Picard | 58-50-230 | 2/23/2012 2:20 PM | 3/5/2012 2:10 PM | | | | | | ND |
| 103 | Charcoal | Randalls | 58-50-1GR | 2/3/2012 10:50 AM | 2/6/2012 2:14 PM | 553.7 | 1.6 | 33.0 | 94.0 | Phloxine B | 3.6 |
| 103 | Charcoal | Randalls | 58-50-1GR | 2/3/2012 10:50 AM | 2/6/2012 2:14 PM | 493.2 | 13.8 | 34.8 | 542 | Uranine | 1.3 |
| 118 | Charcoal | Randalls | 58-50-1GR | 2/6/2012 2:14 PM | 2/16/2012 1:05 PM | | | | | | ND |
| 208 | Charcoal | Randalls | 58-50-1GR | 2/16/2012 1:05 PM | 3/5/2012 11:45 AM | | | | | | ND |
| 215 | Water | Schaffer | 58-50-2 | | 2/9/2012 | | | | | | ND |
| 199 | Charcoal | Schaffer | 58-50-2 | 2/16/2012 12:05 PM | 2/23/2012 2 PM | | | | | | ND |
| 216 | Charcoal | Schaffer | 58-50-2 | 2/23/2012 2 PM | 3/5/2012 1:40 PM | | | | | | ND |
| 105 | Charcoal | Sunset MW | 58-50-212 | 2/3/2012 1:40 PM | 2/6/2012 1:34 PM | | | | | | ND |
| 116 | Charcoal | Sunset MW | 58-50-212 | 2/6/2012 1:34 PM | 2/16/2012 12:35 PM | | | | | | ND |
| 289 | Water | Upper Barton | 183 | | 2/2/2012 1:30 PM | | | | | | ND |
| 220 | Water | Upper Barton | 183 | | 2/7/2012 9 AM | | | | | | ND |
| 138 | Charcoal | Upper Barton | 183A | 2/2/2012 1:20 PM | 2/7/2012 4:20 PM | | | | | | ND |
| 184 | Water | Upper Barton | 183 | | 2/7/2012 4:20 PM | | | | | | ND |
| 221 | Water | Upper Barton | 183 | | 2/7/2012 5 PM | | | | | | ND |
| 222 | Water | Upper Barton | 183 | | 2/8/2012 1 AM | | | | | | ND |
| 223 | Water | Upper Barton | 183 | | 2/8/2012 5 PM | | | | | | ND |
| 224 | Water | Upper Barton | 183 | | 2/9/2012 1 AM | | | | | | ND |
| 225 | Water | Upper Barton | 183 | | 2/9/2012 9 AM | | | | | | ND |
| 143 | Charcoal | Upper Barton | 183A | 2/7/2012 4:20 PM | 2/9/2012 2 PM | 547.5 | 57.4 | 19.5 | 1246 | Phloxine B | 51.9 |
| 189 | Water | Upper Barton | 183 | | 2/9/2012 2 PM | | | | | | ND |
| 226 | Water | Upper Barton | 183 | | 2/9/2012 5 PM | | | | | | ND |
| 227 | Water | Upper Barton | 183 | | 2/10/2012 1 AM | | | | | | ND |
| 228 | Water | Upper Barton | 183 | | 2/10/2012 9 AM | | | | | | ND |
| 147 | Charcoal | Upper Barton | 183A | 2/9/2012 2 PM | 2/10/2012 4:25 PM | 545.0 | 4.6 | 18.9 | 104 | Phloxine B | 4.0 |
| 147 | Charcoal | Upper Barton | 183A | 2/9/2012 2 PM | 2/10/2012 4:25 PM | 545.9 | 5.6 | 19.6 | 119 | Phloxine B | 4.6 |
| 172 | Water | Upper Barton | 183 | | 2/10/2012 4:25 PM | | | | | | ND |
| 229 | Water | Upper Barton | 183 | | 2/10/2012 5 PM | | | | | | ND |
| 229 | Water | Upper Barton | 183 | | 2/10/2012 5 PM | | | | | | ND |

| Sample No. | Sample | Site Name | Sample Name | Set Date | Collected | Center | Height | FWHM | Peak Area | Dye | Concentration (µg/L) |
|------------|----------|--------------|-------------|-------------------|-------------------|--------|--------|------|-----------|------------|----------------------|
| 230 | Water | Upper Barton | 183 | | 2/11/2012 1 AM | | | | | | ND |
| 231 | Water | Upper Barton | 183 | | 2/11/2012 9 AM | | | | | | ND |
| 130 | Charcoal | Upper Barton | 183A | 2/10/2012 4:25 PM | 2/11/2012 1:05 PM | 547.3 | 4.7 | 17.7 | 46.8 | Phloxine B | 1.8 |
| 177 | Water | Upper Barton | 183 | | 2/11/2012 1:05 PM | | | | | | ND |
| 130 | Charcoal | Upper Barton | 183A | 2/10/2012 4:25 PM | 2/11/2012 1:05 PM | 546.5 | 5.5 | 20.6 | 145 | Phloxine B | 5.6 |
| 130 | Charcoal | Upper Barton | 183A | 2/10/2012 4:25 PM | 2/11/2012 1:05 PM | 495.8 | 6.6 | 45.6 | 386 | Uranine | 0.93 |
| 232 | Water | Upper Barton | 183 | | 2/11/2012 5 PM | | | | | | ND |
| 233 | Water | Upper Barton | 183 | | 2/12/2012 1 AM | | | | | | ND |
| 234 | Water | Upper Barton | 183 | | 2/12/2012 9 AM | | | | | | ND |
| 235 | Water | Upper Barton | 183 | | 2/12/2012 5 PM | | | | | | ND |
| 236 | Water | Upper Barton | 183 | | 2/13/2012 1 AM | | | | | | ND |
| 237 | Water | Upper Barton | 183 | | 2/13/2012 9 AM | | | | | | ND |
| 238 | Water | Upper Barton | 183 | | 2/13/2012 5 PM | | | | | | ND |
| 239 | Water | Upper Barton | 183 | | 2/14/2012 1 AM | | | | | | ND |
| 240 | Water | Upper Barton | 183 | | 2/14/2012 9 AM | | | | | | ND |
| 241 | Water | Upper Barton | 183 | | 2/14/2012 5 PM | | | | | | ND |
| 242 | Water | Upper Barton | 183 | | 2/15/2012 1 AM | | | | | | ND |
| 243 | Water | Upper Barton | 183 | | 2/15/2012 9 AM | | | | | | ND |
| 180 | Water | Upper Barton | 183 | | 2/16/2012 2:55 PM | | | | | | ND |
| 135 | Charcoal | Upper Barton | 183A | 2/11/2012 1:05 PM | 2/16/2012 2:55 PM | 547.5 | 65.6 | 19.6 | 1444 | Phloxine B | 60.4 |
| 244 | Water | Upper Barton | 183 | | 2/17/2012 5 PM | | | | | | ND |
| 245 | Water | Upper Barton | 183 | | 2/18/2012 1 AM | | | | | | ND |
| 246 | Water | Upper Barton | 183 | | 2/18/2012 9 AM | | | | | | ND |
| 247 | Water | Upper Barton | 183 | | 2/18/2012 5 PM | 533.0 | 1.8 | 32.5 | 92.3 | Phloxine B | 3.5 |
| 247 | Water | Upper Barton | 183 | | 2/18/2012 5 PM | 533.7 | 1.6 | 32.8 | 74.7 | Phloxine B | 2.8 |
| 248 | Water | Upper Barton | 183 | | 2/19/2012 1 AM | 536.3 | 5.2 | 20.4 | 125 | Phloxine B | 4.8 |
| 249 | Water | Upper Barton | 183 | | 2/19/2012 9 AM | 535.8 | 2.5 | 20.9 | 85.3 | Phloxine B | 3.3 |
| 250 | Water | Upper Barton | 183 | | 2/19/2012 5 PM | 535.2 | 2.1 | 21.8 | 59.7 | Phloxine B | 2.3 |
| 251 | Water | Upper Barton | 183 | | 2/20/2012 1 AM | 535.0 | 2.5 | 25.4 | 96.0 | Phloxine B | 3.7 |
| 252 | Water | Upper Barton | 183 | | 2/20/2012 9 AM | 535.3 | 2.2 | -1 | 95.4 | Phloxine B | 3.7 |
| 253 | Water | Upper Barton | 183 | | 2/20/2012 5 PM | 535.8 | 2.8 | 26.4 | 204 | Phloxine B | 8.0 |
| 254 | Water | Upper Barton | 183 | | 2/21/2012 1 AM | 535.5 | 2.9 | 21.0 | 90.8 | Phloxine B | 3.5 |
| 255 | Water | Upper Barton | 183 | | 2/21/2012 9 AM | 532.8 | 2.3 | 32.3 | 94.7 | Phloxine B | 3.6 |
| 256 | Water | Upper Barton | 183 | | 2/21/2012 5 PM | 534.5 | 2.0 | -1 | 87.4 | Phloxine B | 3.3 |
| 257 | Water | Upper Barton | 183 | | 2/22/2012 1 AM | 535.9 | 2.7 | 21.6 | 80.6 | Phloxine B | 3.1 |
| 258 | Water | Upper Barton | 183 | | 2/22/2012 9 AM | | | | | | ND |
| 259 | Water | Upper Barton | 183 | | 2/22/2012 5 PM | 536.1 | 2.3 | 24.0 | 92.9 | Phloxine B | 3.6 |
| 260 | Water | Upper Barton | 183 | | 2/23/2012 1 AM | 538.5 | 1.8 | 17.4 | 36.4 | Phloxine B | 1.4 |
| 261 | Water | Upper Barton | 183 | | 2/23/2012 9 AM | 534.8 | 2.1 | 26.2 | 82.8 | Phloxine B | 3.2 |

| Sample No. | Sample | Site Name | Sample Name | Set Date | Collected | Center | Height | FWHM | Peak Area | Dye | Concentration (µg/L) |
|------------|----------|--------------|-------------|-------------------|-------------------|--------|--------|------|-----------|------------|----------------------|
| 262 | Water | Upper Barton | 183 | | 2/23/2012 5 PM | 535.0 | 2.5 | 33.0 | 222 | Phloxine B | 8.7 |
| 263 | Water | Upper Barton | 183 | | 2/24/2012 1 AM | | | | | | ND |
| 264 | Water | Upper Barton | 183 | | 2/24/2012 9 AM | 536.6 | 1.7 | 23.3 | 4.3 | Phloxine B | 0.15J |
| 265 | Water | Upper Barton | 183 | | 2/24/2012 5 PM | 533.4 | 1.6 | 32.1 | 1.3 | Phloxine B | 0.043J |
| 266 | Water | Upper Barton | 183 | | 2/25/2012 1 AM | 535.1 | 1.9 | 24.8 | 88.6 | Phloxine B | 3.4 |
| 267 | Water | Upper Barton | 183 | | 2/25/2012 9 AM | 534.8 | 2.0 | 27.1 | 85.1 | Phloxine B | 3.2 |
| 268 | Water | Upper Barton | 183 | | 2/28/2012 2:45 PM | | | | | | ND |
| 274 | Charcoal | Upper Barton | 183 | 2/16/2012 2:17 PM | 2/28/2012 2:50 PM | 548.5 | 1708 | 20.0 | 42,000 | Phloxine B | 1962 |
| 279 | Water | Upper Barton | 183 | | 3/13/2012 2:55 PM | | | | | | ND |
| 282 | Charcoal | Upper Barton | 183 | 2/28/2012 2:45 PM | 3/13/2012 2:55 PM | 546.4 | 11.3 | 18.1 | 201 | Phloxine B | 7.9 |
| 282 | Water | Upper Barton | 183 | | 3/13/2012 2:55 PM | 546.5 | 11.3 | 17.6 | 313 | Phloxine B | 12.5 |
| 119 | Charcoal | Whirlpool | 58-50-128 | 2/6/2012 2:45 PM | 2/16/2012 1:20 PM | | | | | | ND |
| 209 | Charcoal | Whirlpool | 58-50-128 | 2/16/2012 1:20 PM | 3/5/2012 12:20 PM | | | | | | ND |

ND indicates not detected at the following limits of detection:

- Uranine (charcoal) 0.0061 µg/L
- Eosin (charcoal) 0.068 µg/L
- Phloxine B (charcoal) 0.044 µg/L
- Phloxine B (water) 0.044 µg/L

J indicates detection between limit of detection and limit of quantitation.

FWHM indicates full width at half maximum.

Appendices 2: Dye Trace Results OUL

Certificate of Analysis

Date of certificate: March 8, 2012

Client: BSEACD

Project name: Arbor Trails Sinkhole, Austin, TX

Project contacts: Brian Smith (brians@bseacd.org)
Brian Hunt (Brianh@bseacd.org)

Mailing address: 1124 RegalRow
Austin, Texas 78748

Samples collected by: BSEACD/COA

Date samples shipped: February 22, 2012

Date samples rec'd at OUL: February 24, 2012

Date analyzed by OUL: March 1, 2 and 5, 2012

Included with certificate of analysis: Table of results and copies of sample collection data sheets

Results for charcoal samplers analyzed for the presence of pyranine and phloxine B dyes.

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

| OUL Number | Station Name | Date/Time Placed | Date/Time Collected | Pyranine Results | | Phloxine B Results | | |
|------------|-----------------------------------|------------------|---------------------|------------------|-----------|--------------------|-----------|--|
| | | | | Peak nm | Conc. ppb | Peak nm | Conc. ppb | |
| V5656P | 58-50-2 6200 Brodie | 2/3/2012 1410 | 2/6/2012 1302 | ND | | ND | | |
| V5657P | 58-50-2 6200 Brodie | 2/6/2012 1302 | 2/10/2012 1455 | ND | | ND | | |
| V5658P | 58-50-2 6200 Brodie | 2/10/2012 1455 | 2/16/2012 1155 | ND | | ND | | |
| V5659P | 58-50-207 Ashbaugh | 2/3/2012 1417 | 2/6/2012 1253 | ND | | ND | | |
| V5660P | Laboratory control charcoal blank | | | | | | | |
| V5661P | 58-50-207 Ashbaugh | 2/6/2012 1253 | 2/10/2012 1430 | ND | | 573.6 ** | 0.799 | |
| V5662P | 58-50-207 Ashbaugh | 2/10/2012 1430 | 2/16/2012 1135 | ND | | 575.9 | 25.9 | |
| V5663P | 58-50-222 Besse | 2/3/2012 1309 | 2/6/2012 1244 | ND | | ND | | |
| V5664P | 58-50-222 Besse | 2/6/2012 1244 | 2/10/2012 1425 | ND | | ND | | |
| V5665P | 58-50-222 Besse | 2/10/2012 1425 | 2/16/2012 1130 | ND | | ND | | |
| V5666P | 42916A Cold Spring | 2/10/2012 1545 | 2/16/2012 1412 | ND | | ND | | |
| V5667P | 42916A Cold Spring | 2/3/2012 1730 | 2/10/2012 1545 | ND | | ND | | |
| V5668P | 42921B Eliza | 2/11/2012 0947 | 2/16/2012 1517 | 501.6 ** | 29.4 | ND | | |
| V5669P | 58-50-235 Holiday Inn | 2/3/2012 1357 | 2/6/2012 1357 | ND | | ND | | |
| V5670P | 58-50-235 Holiday Inn | 2/6/2012 1357 | 2/16/2012 1250 | ND | | ND | | |
| V5671P | 58-50-2JR Jenkins | 2/3/2012 1315 | 2/6/2012 1237 | ND | | ND | | |
| V5672P | 58-50-2JR Jenkins | 2/6/2012 1237 | 2/12/2012 1410 | ND | | ND | | |
| V5673P | 58-50-2JR Jenkins | 2/10/2012 1410 | 2/16/2012 1120 | ND | | ND | | |
| V5674P | 42914B Main Barton | 2/10/2012 1657 | 2/11/2012 1407 | 502.4 | 8.39 | 576.6 | 3.77 | |
| V5675P | 42914B Main Barton | 2/11/2012 1407 | 2/16/2012 1532 | 500.6 ** | 31.9 | 576.0 | 18.1 | |
| V5676P | 42914B Main Barton | 2/2/2012 1402 | 2/7/2012 1702 | ND | | 573.4 ** | 5.75 | |
| V5677P | 42914B Main Barton | 2/7/2012 1702 | 2/9/2012 1437 | ND | | 575.6 | 9.58 | |
| V5678P | 42914B Main Barton | 2/9/2012 1435 | 2/10/2012 1655 | ND | | 575.6 | 7.60 | |
| V5679P | 42922B Old Mill | 2/10/2012 1717 | 2/11/2012 1332 | 499.6 ** | 3.98 | ND | | |
| V5680P | Laboratory control charcoal blank | | | | | | | |
| V5681P | 42922A Old Mill | 2/11/2012 1330 | 2/16/2012 1550 | 501.8 ** | 20.0 | ND | | |
| V5682P | 42922A Old Mill | 2/2/2012 1430 | 2/7/2012 1725 | ND | | ND | | |
| V5683P | 42922B Old Mill | 2/7/2012 1727 | 2/9/2012 1502 | ND | | ND | | |
| V5684P | 42922C Old Mill | 2/7/2012 1730 | 2/16/2012 1555 | 499.2 ** | 14.7 | ND | | |

| OUL Number | Station Name | Date/Time Placed | Date/Time Collected | Pyranine Results | | Phloxine B Results | |
|------------|-----------------------------------|------------------|---------------------|------------------|-----------|--------------------|-----------|
| | | | | Peak nm | Conc. ppb | Peak nm | Conc. ppb |
| V5685P | 42922B Old Mill | 2/9/2012 1502 | 2/10/2012 1717 | ND | | ND | |
| V5686P | 58-50-230 Picard | 2/3/2012 1634 | 2/6/2012 1316 | ND | | ND | |
| V5687P | 58-50-230 Picard | 2/6/2012 1316 | 2/10/2012 1505 | ND | | ND | |
| V5688P | 58-50-230 Picard | 2/10/2012 1505 | 2/16/2012 1220 | ND | | ND | |
| V5689P | 58-50-1GR Randalls | 2/3/2012 1050 | 2/6/2012 1414 | ND | | ND | |
| V5690P | 58-50-1GR Randalls | 2/6/2012 1414 | 2/16/2012 1305 | ND | | ND | |
| V5691P | 58-50-2 Schaffer | 2/3/2012 1542 | 2/10/2012 1445 | ND | | ND | |
| V5692P | 58-50-2 Schaffer | 2/10/2012 1445 | 2/16/2012 1205 | ND | | ND | |
| V5693P | 58-50-212 Sunset MW | 2/3/2012 1340 | 2/6/2012 1334 | ND | | ND | |
| V5694P | 58-50-212 Sunset MW | 2/6/2012 1334 | 2/16/2012 1235 | ND | | ND | |
| V5695P | 183B Upper Barton | 2/10/2012 1627 | 2/11/2012 1307 | ND | | 576.4 | 7.36 |
| V5696P | 183B Upper Barton | 2/11/2012 1307 | 2/16/2012 1457 | ND | | 576.0 | 45.1 |
| V5697P | 183B Upper Barton | 2/2/2012 1322 | 2/7/2012 1622 | ND | | 576.4 | 34.5 |
| V5698P | 183C Upper Barton | 2/7/2012 1625 | 2/16/2012 1500 | ND | | 576.0 | 637 |
| V5699P | 183B Upper Barton | 2/9/2012 1402 | 2/10/2012 1627 | ND | | 576.0 | 18.0 |
| V5700P | Laboratory control charcoal blank | | | | | | |
| V5701P | 58-50-128 Whirlpool | 2/3/2012 1442 | 2/6/2012 1445 | ND | | ND | |
| V5702P | 58-50-128 Whirlpool | 2/6/2012 1445 | 2/16/2012 1320 | ND | | ND | |

Note: Dye concentrations are based upon standards used at the OUL. The standard concentrations are based upon the as sold weight of the dye that the OUL uses. If the client is not using OUL dyes, the client should provide the OUL with a sample of the dye to compare to the OUL dyes.

Footnotes:

ND = No dye detected

** = 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.

Thomas J. Aley, PHG and RG



Project: Arbor Trails Sinkhole, Austin Texas Week No: 1-3 Samples Collected By: BSEACD/COA
 Samples Shipped By: Brian Hunt, BSEACD Samples Received By: C. Aley / ouc
 Date Samples Shipped: 2/22/2012 Date & Time Samples Received: 2/24/12 13:15
 Bill to: BSEACD, 1124 Regal Row, Austin Texas 78748 Send Results to: Brianh@bseacd.org (same mailing address as billing)
 Analyze for: Phloxine B and Pyranine for all samples; see BSEACD comments for additional

| OUL use only | | Please indicate stations where dye was visible in the field for field technician use - use black ink only | | | | OUL use only | | BSEACD Comments | |
|--------------|------------|---|--------------|--------------------|-----------------------|-----------------|--------------|-------------------|--|
| # Char rec'd | LAB NUMBER | STATION NUMBER 1-4 Numbers | STATION NAME | PLACED Date & Time | COLLECTED Date & Time | # Water / Rec'd | Analyze/Hold | Additional Dye | |
| 1 | V5656 | 58-50-2 | 6200 Brodie | 2/3/2012 14:10 | 2/6/12 13:02 | ⊗ | A | | |
| 1 | V5657 | 58-50-2 | 6200 Brodie | 2/6/12 13:02 | 2/10/12 14:55 | | A | | |
| 1 | V5658 | 58-50-2 | 6200 Brodie | 2/10/12 14:55 | 2/16/12 11:55 | | A | | |
| 1 | V5659 | 58-50-207 | Ashbaugh | 2/3/2012 14:17 | 2/6/12 12:53 | | A | | |
| 1 | V5660 | 58-50-207 | Ashbaugh | 2/6/12 12:53 | 2/10/12 14:30 | | A | | |
| 1 | V5661 | 58-50-207 | Ashbaugh | 2/10/12 14:30 | 2/16/12 11:35 | | A | | |
| 1 | V5662 | 58-50-222 | Besse | 2/3/2012 13:09 | 2/6/12 12:44 | | A | | |
| 1 | V5663 | 58-50-222 | Besse | 2/6/12 12:44 | 2/10/12 14:25 | | A | | |
| 1 | V5664 | 58-50-222 | Besse | 2/10/12 14:25 | 2/16/12 11:30 | | A | | |
| 1 | V5665 | 42916A | Cold Spring | 2/10/12 15:45 | 2/16/12 14:12 | | A | | |
| 1 | V5666 | 42916A | Cold Spring | 2/3/12 17:30 | 2/10/12 15:45 | | A | Eos, FI, RWT, SRB | |
| 1 | V5667 | 42921B | Eliza | 2/11/12 9:47 | 2/16/12 15:17 | | A | | |
| 1 | V5668 | 58-50-235 | Holiday Inn | 2/3/2012 13:57 | 2/6/12 13:57 | | A | | |
| 1 | V5669 | 58-50-235 | Holiday Inn | 2/6/12 13:57 | 2/16/12 12:50 | | A | | |
| 1 | V5670 | 58-50-2JR | Jenkins | 2/3/2012 13:15 | 2/6/12 12:37 | | A | | |
| 1 | V5671 | 58-50-2JR | Jenkins | 2/6/12 12:37 | 2/12/12 14:10 | | A | | |
| 1 | V5672 | 58-50-2JR | Jenkins | 2/10/12 14:10 | 2/16/12 11:20 | | A | | |
| 1 | V5673 | 42914B | Main Barton | 2/10/12 16:57 | 2/11/12 1407 | | A | | |
| 1 | V5674 | 42914B | Main Barton | 2/11/12 1407 | 2/16/12 1532 | | A | | |
| 1 | V5675 | 42914B | Main Barton | 2/2/12 1402 | 2/7/12 1702 | | A | Eos, FI, RWT, SRB | |
| 1 | V5676 | 42914B | Main Barton | 2/7/12 1702 | 2/9/12 1437 | | A | Eos, FI, RWT, SRB | |

This sheet filled out by OUL staff? Yes No
 Charts for samples on this page proofed by OUL: ES
 OUL Project No. 1151 Date Analyzed: 3/19/12 Analyzed By: EGA & WE / ouc
 V5660 - OUL Charcoal blank.
 *Water listed on separate COC. V660L
 Analyzed 3/2/12 by WE / ouc
 graphs proofed by RS

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: Arbor Trails Sinkhole, Austin Texas Week No: 1-3 Samples Collected By: BSEACD/COA

Samples Shipped By: Brian Hunt, BSEACD Date & Time Samples Received: 2/24/12 1315 Samples Received By: C. Oley/ou

Date Samples Shipped: 2/22/2012 Send Results to: Brianh@bseacd.org (same mailing address as billing)

Analyze for: Phloxine B and Pyramine for all samples; see BSEACD comments for additional

| OUL use only | | Please indicate stations where dye was visible in the field for field technician use - use black ink only | | | | OUL use only | | BSEACD Comments | |
|--------------|------------|---|--------------|--------------------|-----------------------|----------------|--------------|-------------------|--|
| # Char rec'd | LAB NUMBER | STATION NUMBER 1-4 Numbers | STATION NAME | PLACED Date & Time | COLLECTED Date & Time | # Water /Rec'd | Analyze/Hold | Additional Dye | |
| 1 | V5678 | 42914A | Main Barton | 2/9/10 1435 | 2/10/12 1655 | ⊗ | A | | |
| 1 | V5679 | 42922B | Old Mill | 2/10/12 17:17 | 2/11/12 1332 | | A | | |
| 1 | V5681 | 42922A | Old Mill | 2/11/12 1330 | 2/16/12 1550 | | A | | |
| 1 | V5682 | 42922A | Old Mill | 2/2/12 1430 | 2/7/12 1725 | | A | | |
| 1 | V5683 | 42922B | Old Mill | 2/7/12 1727 | 2/9/12 1502 | | A | Eos, Fl, RWT, SRB | |
| 1 | V5684 | 42922C | Old Mill | 2/7/12 1730 | 2/16/12 1555 | | A | Eos, Fl, RWT, SRB | |
| 1 | V5685 | 42922B | Old Mill | 2/9/12 1502 | 2/10/12 1717 | | A | | |
| 1 | V5686 | 58-50-230 | Picard | 2/3/2012 16:34 | 2/6/12 13:16 | | A | | |
| 1 | V5687 | 58-50-230 | Picard | 2/6/12 13:16 | 2/10/12 15:05 | | A | | |
| 1 | V5688 | 58-50-230 | Picard | 2/10/12 15:05 | 2/16/12 12:20 | | A | | |
| 1 | V5689 | 58-50-1GR | Randalls | 2/3/2012 10:50 | 2/6/12 14:14 | | A | | |
| 1 | V5690 | 58-50-1GR | Randalls | 2/6/12 14:14 | 2/16/12 13:05 | | A | | |
| 1 | V5691 | 58-50-2 | Schaffer | 2/3/2012 15:42 | 2/10/12 14:45 | | A | | |
| 1 | V5692 | 58-50-2 | Schaffer | 2/10/12 14:45 | 2/16/12 12:05 | | A | | |
| 1 | V5693 | 58-50-212 | Sunset MW | 2/3/2012 13:40 | 2/6/12 13:34 | | A | | |
| 1 | V5694 | 58-50-212 | Sunset MW | 2/6/12 13:34 | 2/16/12 12:35 | | A | | |
| 1 | V5695 | 183B | Upper Barton | 2/10/12 16:27 | 2/11/12 1307 | | A | | |
| 1 | V5696 | 183B | Upper Barton | 2/11/12 1307 | 2/16/12 1457 | | A | | |
| 1 | V5697 | 183B | Upper Barton | 2/2/12 1322 | 2/7/12 1622 | | A | | |
| 1 | V5698 | 183C | Upper Barton | 2/7/12 1625 | 2/16/12 1500 | | A | | |
| 1 | V5699 | 183B | Upper Barton | 2/9/12 1402 | 2/10/12 1627 | | A | | |

analyzed 3-2-12

analyzed 3-5-12

V5680-OUL Charcoal blank. V5700-OUL Charcoal blank.

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

OUL Project No. 1157 Date Analyzed: 3/1, 2, 15/2012 Analyzed By: MR/ou

⊗ Water listed on separate COC - L6/ou

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: Arbor Trails Sinkhole, Austin Texas
 Week No: 1 - 3
 Samples Collected By: BSEACD/COA
 Samples Shipped By: Brian Hunt, BSEACD
 Samples Received By: C. Aley / oul
 Date Samples Shipped: 2/22/2012 Date & Time Samples Received: 2/24/12 1315
 Bill to: BSEACD, 1124 Regal Row, Austin Texas 78748 Send Results to: Brianh@bseacd.org (same mailing address as billing)

Analyze for: Phloxine B and Pyranine for all samples; see BSEACD comments for additional

| OUL use only | | Please indicate stations where dye was visible in the field for field technician use - use black ink only | | | | OUL use only | BSEACD Comments | |
|--------------|------------|---|--------------|--------------------|-----------------------|-----------------|-----------------|----------------|
| # Char rec'd | LAB NUMBER | STATION NUMBER 1-4 Numbers | STATION NAME | PLACED Date & Time | COLLECTED Date & Time | # Water / Rec'd | Analyze/Hold | Additional Dye |
| 1 | V5701 | 58-50-128 | Whirlpool | 2/3/2012 14:42 | 2/6/12 14:45 | ⊗ | A | |
| 1 | V5702 | 58-50-128 | Whirlpool | 2/6/12 14:45 | 2/16/12 13:20 | ↓ | A | |
| 0 | H | 58-50-2 | 6200 Brodie | 2/3/2012 14:10 | | | H | |
| 0 | H | 58-50-2 | 6200 Brodie | 2/6/12 13:02 | | | H | |
| 0 | H | 58-50-2 | 6200 Brodie | 2/10/12 14:55 | | | H | |
| 0 | H | 58-50-2 | 6200 Brodie | 2/16/12 11:55 | | | H | |
| 0 | H | 58-50-207 | Ashbaugh | 2/3/2012 14:17 | | | H | |
| 0 | H | 58-50-207 | Ashbaugh | 2/6/12 12:53 | | | H | |
| 0 | H | 58-50-207 | Ashbaugh | 2/10/12 14:30 | | | H | |
| 0 | H | 58-50-207 | Ashbaugh | 2/16/12 11:35 | | | H | |
| 0 | H | 58-50-222 | Besse | 2/3/2012 13:09 | | | H | |
| 0 | H | 58-50-222 | Besse | 2/6/12 12:44 | | | H | |
| 0 | H | 58-50-222 | Besse | 2/10/12 14:25 | | | H | |
| 0 | H | 58-50-222 | Besse | 2/16/12 11:30 | | | H | |
| 1 | H | 42916C | Cold Spring | 2/10/12 15:50 | 2/16/12 1417 | ⊗ | H | |
| 1 | H | 42916B | Cold Spring | 2/3/12 1732 | 2/10/12 1547 | ⊗ | H | |
| 0 | H | 42916 | Cold Spring | 2/10/12 1545 | | | H | |
| 0 | H | 42916 | Cold Spring | 2/16/12 1412 | | | H | |
| 1 | H | 42921B | Eliza | 2/10/12 16:42 | 2/11/12 0947 | ⊗ | H | |
| 1 | H | 42921B | Eliza | 2/2/12 1347 | 2/7/12 1647 | ↓ | H | |
| 1 | H | 42921B | Eliza | 2/7/12 1647 | 2/9/12 1417 | ↓ | H | |

⊗ Water listed on separate OOL. LG-fall

This sheet filled out by OUL staff? Yes / No Charts for samples on this page proofed by OUL: RS
 OUL Project No. 1151 Date Analyzed: 3/5/12 Analyzed By: MS/oul

Project: Arbor Trails Sinkhole, Austin Texas Week No: 1 - 3 Samples Collected By: BSEACD/COA
 Samples Shipped By: Brian Hunt, BSEACD Samples Received By: C. Okeyfou
 Date Samples Shipped: 2/22/2012 Date & Time Samples Received: 2/24/12 1315
 Bill to: BSEACD, 1124 Regal Row, Austin Texas 78748 Send Results to: Brianh@bseacd.org (same mailing address as billing)

Analyze for: Phloxine B and Pyramine for all samples; see BSEACD comments for additional

| OUL use only | | Please indicate stations where dye was visible in the field for field technician use - use black ink only | | | | BSEACD Comments | | |
|--------------|------------|---|--------------|--------------------|-----------------------|-----------------------------|--------------|----------------|
| # Char rec'd | LAB NUMBER | STATION NUMBER 1-4 Numbers | STATION NAME | PLACED Date & Time | COLLECTED Date & Time | OUL use only # Water /Rec'd | Analyze/Hold | Additional Dye |
| 1 | H | 42921A | Eliza | 2/9/12 1415 | 2/10/12 1640 | 3 | H | |
| 1 | H | 42921C | Eliza | 2/9/12 1420 | 2/16/12 1520 | 1 | H | |
| 0 | H | 42921 | Eliza | 2/10/12 1640 | | 1 | H | |
| 0 | H | 42921 | Eliza | 2/11/12 0945 | | 1 | H | |
| 0 | H | 42921 | Eliza | 2/16/12 1515 | | 1 | H | |
| 0 | H | 42921 | Eliza | 2/17/12 1650 | | 1 | H | |
| 0 | H | 42921 | Eliza | 2/9/12 1420 | | 1 | H | |
| 0 | H | 58-50-2JR | Jenkins | 2/3/2012 13:15 | | 1 | H | |
| 0 | H | 58-50-2JR | Jenkins | 2/6/12 12:37 | | 1 | H | |
| 0 | H | 58-50-2JR | Jenkins | 2/10/12 14:10 | | 1 | H | |
| 0 | H | 58-50-2JR | Jenkins | 2/16/12 11:20 | | 1 | H | |
| 1 | H | 42914C | Main Barton | 2/2/12 1405 | 2/7/12 1705 | 3 | H | |
| 0 | H | 42914 | Main Barton | 2/10/12 1655 | | 1 | H | |
| 0 | H | 42914 | Main Barton | 2/11/12 1405 | | 1 | H | |
| 0 | H | 42914 | Main Barton | 2/16/12 1530 | | 1 | H | |
| 0 | H | 42914 | Main Barton | 2/17/12 1700 | | 1 | H | |
| 0 | H | 42914 | Main Barton | 2/9/10 1435 | | 1 | H | |
| 0 | H | 42922 | Old Mill | 2/10/12 1715 | | 1 | H | |
| 0 | H | 42922 | Old Mill | 2/11/12 1330 | | 1 | H | |
| 0 | H | 42922 | Old Mill | 2/16/12 1550 | | 1 | H | |
| 0 | H | 42922 | Old Mill | 2/17/12 1730 | | 1 | H | |

This sheet filled out by OUL staff? Yes (No) Charts for samples on this page proofed by OUL: PS
 OUL Project No. _____ Date Analyzed: _____ Analyzed By: _____
 *Water listed on Separate COC. 16604

Project: Arbor Trails Sinkhole, Austin Texas Week No: 1-3 Samples Collected By: BSEACD/COA
 Samples Shipped By: Brian Hunt, BSEACD Samples Received By: C. Aley/ou
 Date Samples Shipped: 2/22/2012 Date & Time Samples Received: 2/24/12 1315
 Bill to: BSEACD, 1124 Regal Row, Austin Texas 78748 Send Results to: Brianh@bseacd.org (same mailing address as billing)
 Analyze for: Phloxine B and Pyranine for all samples; see BSEACD comments for additional

| OUL use only | | Please indicate stations where dye was visible in the field for field technician use - use black ink only | | | | OUL use only | | BSEACD Comments | |
|--------------|------------|---|--------------|--------------------|-----------------------|----------------|--------------|-----------------|--|
| # Char rec'd | LAB NUMBER | STATION NUMBER 1-4 Numbers | STATION NAME | PLACED Date & Time | COLLECTED Date & Time | # Water /Rec'd | Analyze/Hold | Additional Dye | |
| 0 | H | 42922 | Old Mill | 2/9/12 1500 | | | H | | |
| 0 | H | 58-50-230 | Picard | 2/3/2012 16:34 | | | H | | |
| 0 | H | 58-50-230 | Picard | 2/6/12 13:16 | | | H | | |
| 0 | H | 58-50-230 | Picard | 2/10/12 15:05 | | | H | | |
| 0 | H | 58-50-230 | Picard | 2/16/12 12:20 | | | H | | |
| 1 | H | 183C | Upper Barton | 2/2/12 1325 | 2/7/12 1625 | 0 | H | | |
| 1 | H | 183B | Upper Barton | 2/7/12 1622 | 2/9/12 1402 | 0 | H | | |
| 0 | H | 183 | Upper Barton | 2/10/12 1625 | | | H | | |
| 0 | H | 183 | Upper Barton | 2/11/12 1305 | | | H | | |
| 0 | H | 183 | Upper Barton | 2/16/12 1455 | | | H | | |
| 0 | H | 183 | Upper Barton | 2/7/12 1620 | | | H | | |
| 0 | H | 183 | Upper Barton | 2/9/12 1400 | | | H | | |

⊕ Water listed on separate COC - LG-fout

This sheet filled out by OUL staff? Yes (No) Charts for samples on this page proofed by OUL: RS
 OUL Project No. _____ Date Analyzed: _____ Analyzed By: _____



Certificate of Analysis

Date of certificate: March 8, 2012
Client: BSEACD
Project name: Arbor Trails Sinkhole, Austin, TX
Project contacts: Brian Smith (brians@bseacd.org)
 Brian Hunt (brianh@bseacd.org)
Mailing address: 1124 Regal Row
 Austin, Texas 78748

Samples collected by: BSEACD/COA
Date samples shipped: February 22, 2012
Date samples rec'd at OUL: February 24, 2012
Date analyzed by OUL: March 1 and 2, 2012
COA includes: Table of results, copies of sample collection data sheets

Results for water samples analyzed for the presence of fluorescein, eosine, rhodamine WT (RWT) and sulforhodamine B (SRB) dyes.

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

| OUL Number | Station Number and Name | Date/Time Placed | Date/Time Collected | Fluorescein Results | | Eosine Results | | RWT Results | | SRB Results | |
|------------|-------------------------|------------------|---------------------|---------------------|-----------|----------------|-----------|-------------|-----------|-------------|-----------|
| | | | | Peak nm | Conc. ppb | Peak nm | Conc. ppb | Peak nm | Conc. ppb | Peak nm | Conc. ppb |
| V5667 | 42916A Cold Spring | 2/3/12 1730 | 2/10/12 1545 | ND | | 542.3 | 47.3 | ND | | ND | |
| V5676 | 42914B Main Barton | 2/2/12 1402 | 2/7/12 1702 | ND | | 544.6 * | 0.661 | ND | | ND | |
| V5677 | 42914B Main Barton | 2/7/12 1702 | 2/9/12 1437 | ND | | ND | | ND | | ND | |
| V5682 | 42922A Old Mill | 2/2/12 1430 | 2/7/12 1725 | ND | | 543.6 | 0.399 | ND | | ND | |
| V5683 | 42922B Old Mill | 2/7/12 1727 | 2/9/12 1502 | ND | | ND | | ND | | ND | |

Note: Dye concentrations are based upon standards used at the OUL. The standard concentrations are based upon the as sold weight of the dye that the OUL uses. If the client is not using OUL dyes, the client should provide the OUL with a sample of the dye to compare to the OUL dyes.

Footnotes:

ND = No dye detected

* = A fluorescence peak is present that does not meet all the criteria for a positive dye result. However, it has been calculated as though it was the tracer dye.

Thomas J. Aley, PHG and RG

Project: Arbor Trails Sinkhole, Austin Texas Week No: 1-3 Samples Collected By: BSEACD/COA
 Samples Shipped By: Brian Hunt, BSEACD Date & Time Samples Received: 2/24/12 13:15 Samples Received By: C. Aley / OUL
 Date Samples Shipped: 2/22/2012 Date & Time Samples Received: 2/24/12 13:15
 Bill to: BSEACD, 1124 Regal Row, Austin Texas 78748 Send Results to: Brianh@bseacd.org (same mailing address as billing)

Analyze for: Phloxine B and Pyranine for all samples; see BSEACD comments for additional

| OUL use only | | Please indicate stations where dye was visible in the field for field technician use - use black ink only | | | | OUL use only | | BSEACD Comments | |
|--------------|------------|---|--------------|--------------------|-----------------------|----------------|--------------|-------------------|---|
| # Char rec'd | LAB NUMBER | STATION NUMBER 1-4 Numbers | STATION NAME | PLACED Date & Time | COLLECTED Date & Time | # Water /Rec'd | Analyze/Hold | Additional Dye | |
| 1 | V5656 | 58-50-2 | 6200 Brodie | 2/3/2012 14:10 | 2/6/12 13:02 | ⊗ | A | | A |
| 1 | V5657 | 58-50-2 | 6200 Brodie | 2/6/12 13:02 | 2/10/12 14:55 | | A | | A |
| 1 | V5658 | 58-50-2 | 6200 Brodie | 2/10/12 14:55 | 2/16/12 11:55 | | A | | A |
| 1 | V5659 | 58-50-207 | Ashbaugh | 2/3/2012 14:17 | 2/6/12 12:53 | | A | | A |
| 1 | V5660 | 58-50-207 | Ashbaugh | 2/6/12 12:53 | 2/10/12 14:30 | | A | | A |
| 1 | V5661 | 58-50-207 | Ashbaugh | 2/10/12 14:30 | 2/16/12 11:35 | | A | | A |
| 1 | V5662 | 58-50-222 | Besse | 2/3/2012 13:09 | 2/6/12 12:44 | | A | | A |
| 1 | V5663 | 58-50-222 | Besse | 2/6/12 12:44 | 2/10/12 14:25 | | A | | A |
| 1 | V5664 | 58-50-222 | Besse | 2/10/12 14:25 | 2/16/12 11:30 | | A | | A |
| 1 | V5665 | 42916A | Cold Spring | 2/10/12 15:45 | 2/16/12 14:12 | | A | | A |
| 1 | V5666 | 42916A | Cold Spring | 2/3/12 17:30 | 2/10/12 15:45 | | A | Eos, FI, RWT, SRB | |
| 1 | V5667 | 42921B | Eliza | 2/11/12 9:47 | 2/16/12 15:17 | | A | | |
| 1 | V5668 | 58-50-235 | Holiday Inn | 2/3/2012 13:57 | 2/6/12 13:57 | | A | | |
| 1 | V5669 | 58-50-235 | Holiday Inn | 2/6/12 13:57 | 2/16/12 12:50 | | A | | |
| 1 | V5670 | 58-50-2JR | Jenkins | 2/3/2012 13:15 | 2/6/12 12:37 | | A | | |
| 1 | V5671 | 58-50-2JR | Jenkins | 2/6/12 12:37 | 2/12/12 14:10 | | A | | |
| 1 | V5672 | 58-50-2JR | Jenkins | 2/10/12 14:10 | 2/16/12 11:20 | | A | | |
| 1 | V5673 | 42914B | Main Barton | 2/10/12 16:57 | 2/11/12 14:07 | | A | | |
| 1 | V5674 | 42914B | Main Barton | 2/11/12 14:07 | 2/16/12 15:32 | | A | | |
| 1 | V5675 | 42914B | Main Barton | 2/2/12 14:02 | 2/7/12 17:02 | | A | Eos, FI, RWT, SRB | |
| 1 | V5676 | 42914B | Main Barton | 2/7/12 17:02 | 2/9/12 14:37 | | A | Eos, FI, RWT, SRB | |

This sheet filled out by OUL staff? Yes No
 Charts for samples on this page proofed by OUL: ES
 OUL Project No. 1151 Date Analyzed: 3/1/12 Analyzed By: ES & MR / OUL
V5660 - OUL Charcoal blank.
 *Water listed on separate COC. Below
 Analyzed 3/2/12 by MR / OUL
 graphs proofed by RS

Project: Arbor Trails Sinkhole, Austin Texas Week No: 1-3 Samples Collected By: BSEACD/COA
 Samples Shipped By: Brian Hunt, BSEACD Date & Time Samples Received: 2/24/12 1315 Samples Received By: C. Oley/ou
 Date Samples Shipped: 2/22/2012 Send Results to: Brianh@bseacd.org (same mailing address as billing)

Analyze for: Phloxine B and Pyranine for all samples; see BSEACD comments for additional

| OUL use only | | Please indicate stations where dye was visible in the field for field technician use - use black ink only | | | | OUL use only | | BSEACD Comments | |
|--------------|------------|---|--------------|--------------------|-----------------------|----------------|--------------|-------------------|--|
| # Char rec'd | LAB NUMBER | STATION NUMBER 1-4 Numbers | STATION NAME | PLACED Date & Time | COLLECTED Date & Time | # Water /Rec'd | Analyze/Hold | Additional Dye | |
| | V5678 | 42914A | Main Barton | 2/9/10 1435 | 2/10/12 1655 | | A | | |
| | V5679 | 42922B | Old Mill | 2/10/12 17:17 | 2/11/12 1332 | | A | | |
| | V5681 | 42922A | Old Mill | 2/11/12 1330 | 2/16/12 1550 | | A | | |
| | V5682 | 42922A | Old Mill | 2/12/12 1430 | 2/17/12 1725 | | A | | |
| | V5683 | 42922B | Old Mill | 2/17/12 1727 | 2/19/12 1502 | | A | Eos, FI, RWT, SRB | |
| | V5684 | 42922C | Old Mill | 2/17/12 1730 | 2/16/12 1555 | | A | Eos, FI, RWT, SRB | |
| | V5685 | 42922B | Old Mill | 2/19/12 1502 | 2/10/12 1717 | | A | | |
| | V5686 | 58-50-230 | Picard | 2/3/2012 16:34 | 2/6/12 13:16 | | A | | |
| | V5687 | 58-50-230 | Picard | 2/6/12 13:16 | 2/10/12 15:05 | | A | | |
| | V5688 | 58-50-230 | Picard | 2/10/12 15:05 | 2/16/12 12:20 | | A | | |
| | V5689 | 58-50-1GR | Randalls | 2/3/2012 10:50 | 2/6/12 14:14 | | A | | |
| | V5690 | 58-50-1GR | Randalls | 2/6/12 14:14 | 2/16/12 13:05 | | A | | |
| | V5691 | 58-50-2 | Schaffer | 2/3/2012 15:42 | 2/10/12 14:45 | | A | | |
| | V5692 | 58-50-2 | Schaffer | 2/10/12 14:45 | 2/16/12 12:05 | | A | | |
| | V5693 | 58-50-212 | Sunset MW | 2/3/2012 13:40 | 2/6/12 13:34 | | A | | |
| | V5694 | 58-50-212 | Sunset MW | 2/6/12 13:34 | 2/16/12 12:35 | | A | | |
| | V5695 | 183B | Upper Barton | 2/10/12 16:27 | 2/11/12 1307 | | A | | |
| | V5696 | 183B | Upper Barton | 2/11/12 1307 | 2/16/12 1457 | | A | | |
| | V5697 | 183B | Upper Barton | 2/2/12 1322 | 2/7/12 1622 | | A | | |
| | V5698 | 183C | Upper Barton | 2/7/12 1625 | 2/16/12 1500 | | A | | |
| | V5699 | 183B | Upper Barton | 2/9/12 1402 | 2/10/12 1627 | | A | | |

Analyzed 3-2-12

Analyzed 3-5-12

This sheet filled out by OUL staff? Yes No
 OUL Project No. 115/ Date Analyzed: 3/1, 2, 15/2012 Analyzed By: MR/ou
 V5680-OUL Charcoal blank. V5700-OUL Charcoal blank.
 Water listed on separate COC. L6/bou

Project: Arbor, Frails Sinkhole, Austin, Texas Week No: 1-3 Samples Collected By: BSEACD/COA
 Samples Shipped By: Brian Hunt, BSEACD Date Samples Received: 2/24/12 1315 Samples Received By: C. Aley / oul
 Date Samples Shipped: 2/22/2012 Date & Time Samples Received: 2/24/12 1315
 Bill to: BSEACD, 1124 Regal Row, Austin, Texas 78748 Send Results to: Brianh@bseacd.org (same mailing address as billing)
 Analyze for: Phloxine B and Pyranine for all samples; see BSEACD comments for additional

| OUL use only | | Please indicate stations where dye was visible in the field for field technician use - use black ink only | | | | OUL use only | | BSEACD Comments | |
|--------------|------------|---|--------------|--------------------|-----------------------|-----------------|--------------|-----------------|--|
| # Char rec'd | LAB NUMBER | STATION NUMBER 1-4 Numbers | STATION NAME | PLACED Date & Time | COLLECTED Date & Time | # Water / Rec'd | Analyze/Hold | Additional Dye | |
| 1 | V5701 | 58-50-128 | Whirlpool | 2/3/2012 14:42 | 2/6/12 14:45 | ⊕ | A | | |
| 1 | V5702 | 58-50-128 | Whirlpool | 2/6/12 14:45 | 2/16/12 13:20 | ↓ | A | | |
| 0 | H | 58-50-2 | 6200 Brodie | 2/3/2012 14:10 | | | H | | |
| 0 | H | 58-50-2 | 6200 Brodie | 2/5/12 13:02 | | | H | | |
| 0 | H | 58-50-2 | 6200 Brodie | 2/10/12 14:55 | | | H | | |
| 0 | H | 58-50-2 | 6200 Brodie | 2/16/12 11:55 | | | H | | |
| 0 | H | 58-50-207 | Ashbaugh | 2/3/2012 14:17 | | | H | | |
| 0 | H | 58-50-207 | Ashbaugh | 2/6/12 12:53 | | | H | | |
| 0 | H | 58-50-207 | Ashbaugh | 2/10/12 14:30 | | | H | | |
| 0 | H | 58-50-207 | Ashbaugh | 2/16/12 11:35 | | | H | | |
| 0 | H | 58-50-222 | Besse | 2/3/2012 13:09 | | | H | | |
| 0 | H | 58-50-222 | Besse | 2/6/12 12:44 | | | H | | |
| 0 | H | 58-50-222 | Besse | 2/10/12 14:25 | | | H | | |
| 0 | H | 58-50-222 | Besse | 2/16/12 11:30 | | | H | | |
| 1 | H | 42916C | Cold Spring | 2/10/12 15:50 | 2/16/12 1417 | ⊗ | H | | |
| 1 | H | 42916B | Cold Spring | 2/3/12 1732 | 2/10/12 1547 | ⊗ | H | | |
| 0 | H | 42916 | Cold Spring | 2/10/12 1545 | | | H | | |
| 0 | H | 42916 | Cold Spring | 2/16/12 1412 | | | H | | |
| 1 | H | 42921B | Eliza | 2/10/12 16:42 | 2/11/12 0947 | ⊗ | H | | |
| 1 | H | 42921B | Eliza | 2/2/12 1347 | 2/7/12 1647 | ↓ | H | | |
| 1 | H | 42921B | Eliza | 2/7/12 1647 | 2/9/12 1417 | ↓ | H | | |

⊕ Water listed on separate COC. L6-fall

This sheet filled out by OUL staff? Yes / No PS Charts for samples on this page proofed by OUL: MS/oul
 OUL Project No. 1151 Date Analyzed: 2/5/12 Analyzed By: MS/oul

Project: Arbor Trails Sinkhole, Austin, Texas Week No: 1-3 Samples Collected By: BSEACD/COA
 Samples Shipped By: Brian Hunt, BSEACD Samples Received By: C. Aley/OW
 Date Samples Shipped: 2/22/2012 Date & Time Samples Received: 2/24/12 1315
 Bill to: BSEACD, 1124 Regal Row, Austin Texas 78748 Send Results to: Brianh@bseacd.org (same mailing address as billing)

Analyze for: Phloxine B and Pyranine for all samples; see BSEACD comments for additional

| OUL use only | | Please indicate stations where dye was visible in the field for field technician use - use black ink only | | | | OUL use only | | BSEACD Comments | |
|--------------|------------|---|--------------|--------------------|-----------------------|----------------|--------------|-----------------|--|
| # Char rec'd | LAB NUMBER | STATION NUMBER 1-4 Numbers | STATION NAME | PLACED Date & Time | COLLECTED Date & Time | # Water /Rec'd | Analyze/Hold | Additional Dye | |
| 1 | H | 42921A | Eliza | 2/9/12 1415 | 2/10/12 1640 | 3 | H | | |
| 1 | H | 42921C | Eliza | 2/9/12 1420 | 2/16/12 1520 | ↓ | H | | |
| 0 | H | 42921 | Eliza | 2/10/12 1640 | | | H | | |
| 0 | H | 42921 | Eliza | 2/11/12 0945 | | | H | | |
| 0 | H | 42921 | Eliza | 2/16/12 1515 | | | H | | |
| 0 | H | 42921 | Eliza | 2/7/12 1650 | | | H | | |
| 0 | H | 42921 | Eliza | 2/9/12 1420 | | | H | | |
| 0 | H | 58-50-2JR | Jenkins | 2/3/2012 13:15 | | | H | | |
| 0 | H | 58-50-2JR | Jenkins | 2/6/12 12:37 | | | H | | |
| 0 | H | 58-50-2JR | Jenkins | 2/10/12 14:10 | | | H | | |
| 0 | H | 58-50-2JR | Jenkins | 2/16/12 11:20 | | | H | | |
| 1 | H | 42914C | Main Barton | 2/2/12 1405 | 2/7/12 1705 | 3 | H | | |
| 0 | H | 42914 | Main Barton | 2/10/12 1655 | | | H | | |
| 0 | H | 42914 | Main Barton | 2/11/12 1405 | | | H | | |
| 0 | H | 42914 | Main Barton | 2/16/12 1530 | | | H | | |
| 0 | H | 42914 | Main Barton | 2/7/12 1700 | | | H | | |
| 0 | H | 42914 | Main Barton | 2/9/10 1435 | | | H | | |
| 0 | H | 42922 | Old Mill | 2/10/12 1715 | | | H | | |
| 0 | H | 42922 | Old Mill | 2/11/12 1330 | | | H | | |
| 0 | H | 42922 | Old Mill | 2/16/12 1550 | | | H | | |
| 0 | H | 42922 | Old Mill | 2/7/12 1730 | | | H | | |

This sheet filled out by OUL staff? Yes (No) Charts for samples on this page proofed by OUL: PS
 OUL Project No. _____ Date Analyzed: _____ Analyzed By: _____
 *Water listed on Separate COC. 16/01/12
 4 of 5 OW

Project: Arbor Trails Sinkhole, Austin Texas Week No: 1-3 Samples Collected By: BSEACD/COA

Samples Shipped By: Brian Hunt, BSEACD Samples Received By: C. Aley/OW

Date Samples Shipped: 2/22/2012 Date & Time Samples Received: 2/24/12 1315

Bill to: BSEACD, 1124 Regal Row, Austin Texas 78748 Send Results to: Brianh@bseacd.org (same mailing address as billing)

Analyze for: Phloxine B and Pyranine for all samples; see BSEACD comments for additional

| OUL use only | | Please indicate stations where dye was visible in the field for field technician use - use black ink only | | | | OUL use only | | BSEACD Comments | |
|--------------|------------|---|--------------|--------------------|-----------------------|---------------|--------------|-----------------|--|
| # Char rec'd | LAB NUMBER | STATION NUMBER 1-4 Numbers | STATION NAME | PLACED Date & Time | COLLECTED Date & Time | # Water/Rec'd | Analyze/Hold | Additional Dye | |
| 0 | H | 42922 | Old Mill | 2/9/12 1500 | | 1 | H | | |
| 0 | H | 58-50-230 | Picard | 2/3/2012 16:34 | | 1 | H | | |
| 0 | H | 58-50-230 | Picard | 2/6/12 13:16 | | 1 | H | | |
| 0 | H | 58-50-230 | Picard | 2/10/12 15:05 | | 1 | H | | |
| 0 | H | 58-50-230 | Picard | 2/16/12 12:20 | | 1 | H | | |
| 1 | H | 183C | Upper Barton | 2/2/12 1325 | 2/7/12 1625 | 0 | H | | |
| 1 | H | 183B | Upper Barton | 2/7/12 1622 | 2/9/12 1402 | 0 | H | | |
| 0 | H | 183 | Upper Barton | 2/10/12 1625 | | 1 | H | | |
| 0 | H | 183 | Upper Barton | 2/11/12 1305 | | 1 | H | | |
| 0 | H | 183 | Upper Barton | 2/16/12 1455 | | 1 | H | | |
| 0 | H | 183 | Upper Barton | 2/7/12 1620 | | 1 | H | | |
| 0 | H | 183 | Upper Barton | 2/9/12 1400 | | 1 | H | | |

⊕ Water listed on separate COC - CG form

This sheet filled out by OUL staff? Yes (No) Charts for samples on this page proofed by OUL: RS
 OUL Project No. _____ Date Analyzed: _____ Analyzed By: _____



Certificate of Analysis

Date of certificate: March 19, 2012
Client: BSEACD
Project name: Arbor Trails Sinkhole, Austin, TX
Project contacts: Brian Smith (brians@bseacd.org)
 Brian Hunt (brianh@bseacd.org)
Mailing address: 1124 Regal Row
 Austin, Texas 78748

Samples collected by: BSEACD/COA
Date samples shipped: February 22, 2012
Date samples rec'd at OUL: February 24, 2012 and archived
Date of analysis request: March 14, 2012
Date analyzed by OUL: March 16 and 19, 2012
COA includes: Table of results, copies of sample collection data sheets

Results for charcoal and water samples analyzed for the presence of pyranine and phloxine B dyes.

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

| OUL Number | Station Number and Name | Medium | Date/Time Placed | Date/Time Collected | Pyranine Results | | Phloxine B Results | |
|------------|--------------------------------|----------|------------------|---------------------|------------------------|-----------|--------------------|-----------|
| | | | | | Peak nm | Conc. ppb | Peak nm | Conc. ppb |
| V6108P | 42921B Eliza | charcoal | 2/10/12 1642 | 2/11/12 0947 | 501.8 | 11.7 | ND | |
| V6109P | 42921B Eliza | charcoal | 2/2/12 1347 | 2/7/12 1647 | ND | | ND | |
| V6110P | 42921B Eliza | charcoal | 2/7/12 1647 | 2/9/12 1417 | ND | | ND | |
| V6111P | 42921A Eliza | charcoal | 2/9/12 1415 | 2/10/12 1640 | ND | | ND | |
| V6112P | 42921C Eliza | charcoal | 2/9/12 1420 | 2/16/12 1520 | 500.4 ** | 15.4 | ND | |
| V6113 | 58-50-207 Ashbaugh | water | | 2/6/12 1253 | Analysis not requested | | ND | |
| V6114 | 58-50-207 Ashbaugh | water | | 2/10/12 1430 | Analysis not requested | | 554.2 | 0.039 |
| V6115 | 58-50-207 Ashbaugh | water | | 2/16/12 1135 | Analysis not requested | | 554.8 | 0.077 |
| V6116 | 42921 Eliza | water | | 2/10/12 1640 | Analysis not requested | | ND | |
| V6117 | 42921 Eliza | water | | 2/11/12 0945 | Analysis not requested | | ND | |
| V6118 | 42921 Eliza | water | | 2/16/12 1515 | Analysis not requested | | ND | |
| V6119 | 42921 Eliza | water | | 2/7/12 1650 | Analysis not requested | | ND | |
| V6120 | Laboratory control water blank | | | | | | | |
| V6121 | 42921 Eliza | water | | 2/9/12 1420 | Analysis not requested | | ND | |
| V6122 | 42914 Main Barton | water | | 2/10/12 1655 | Analysis not requested | | 554.4 | 0.033 |
| V6123 | 42914 Main Barton | water | | 2/11/12 1405 | Analysis not requested | | 553.2 | 0.032 |

| OUL Number | Station Number and Name | Medium | Date/Time Placed | Date/Time Collected | Pyramine Results | | Phloxine B Results | |
|------------|-------------------------|--------|------------------|---------------------|------------------------|-----------|--------------------|-----------|
| | | | | | Peak nm | Conc. ppb | Peak nm | Conc. ppb |
| V6124 | 42914 Main Barton | water | | 2/16/12 1530 | Analysis not requested | 552.6 | 0.040 | |
| V6125 | 42914 Main Barton | water | | 2/7/12 1700 | Analysis not requested | 555.4 | 0.039 | |
| V6126 | 42914 Main Barton | water | | 2/9/12 1435 | Analysis not requested | 555.6 | 0.040 | |
| V6127 | 183 Upper Barton | water | | 2/9/12 1625 | Analysis not requested | 554.8 | 0.471 | |
| V6128 | 183 Upper Barton | water | | 2/11/12 1305 | Analysis not requested | 554.8 | 0.430 | |
| V6129 | 183 Upper Barton | water | | 2/16/12 1455 | Analysis not requested | 554.8 | 0.628 | |
| V6130 | 183 Upper Barton | water | | 2/7/12 1620 | Analysis not requested | 555.0 | 0.279 | |
| V6131 | 183 Upper Barton | water | | 2/9/12 1400 | Analysis not requested | 555.2 | 0.390 | |

Note: Dye concentrations are based upon standards used at the OUL. The standard concentrations are based upon the as sold weight of the dye that the OUL uses. If the client is not using OUL dyes, the client should provide the OUL with a sample of the dye to compare to the OUL dyes.

Footnotes:

ND = No dye detected

** = 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.

Thomas J. Aley, PHG and RG



Project: Arbor Trails Sinkhole, Austin Texas Week No: 1-3 Samples Collected By: BSEACD/COA
 Samples Shipped By: Brian Hunt, BSEACD *Rec'd 2/24/12, analysis report samples received*
 Date Samples Shipped: 2/22/2012 Date & Time Samples Received: 3/14/12 @ 8:00 Samples Received By: *Robert J. Scott / OUL*
 Bill to: BSEACD, 1124 Regal Row, Austin Texas 78748 Send Results to: Brianh@bseacd.org (same mailing address as billing)

| OUL use only | | Please indicate stations where dye was visible in the field for field technician use - use black ink only | | | | OUL use only | | BSEACD Comments | |
|--------------|-------------------|---|--------------|--------------------|-----------------------|----------------|--------------|-----------------|--|
| # Char rec'd | LAB NUMBER | STATION NUMBER 1-4 Numbers | STATION NAME | PLACED Date & Time | COLLECTED Date & Time | # Water /Rec'd | Analyze/Hold | Additional Dye | |
| 0 | 010001 | 58-50-207 | Ashbaugh | 2/16/12 12:53 | | 1 | A | | |
| 0 | 010002 | 58-50-207 | Ashbaugh | 2/10/12 14:30 | | 1 | A | | |
| 0 | 010003 | 58-50-207 | Ashbaugh | 2/16/12 11:35 | | 1 | A | | |
| 1 | V6108 | 429218 | Eliza | 2/10/12 16:42 | 2/11/12 0947 | 0 | A | Pyranine | |
| 1 | V6109 | 429218 | Eliza | 2/2/12 1347 | 2/7/12 1647 | 0 | A | Pyranine | |
| 1 | V6110 | 429218 | Eliza | 2/7/12 1647 | 2/9/12 1417 | 0 | A | Pyranine | |
| 1 | V6111 | 42921A | Eliza | 2/9/12 1415 | 2/10/12 1640 | 0 | A | Pyranine | |
| 1 | V6112 | 42921C | Eliza | 2/9/12 1420 | 2/16/12 1520 | 0 | A | Pyranine | |
| 0 | 010004 | 42921 | Eliza | 2/10/12 1640 | | 1 | A | | |
| 0 | 010005 | 42921 | Eliza | 2/11/12 0945 | | 1 | A | | |
| 0 | 010006 | 42921 | Eliza | 2/16/12 1515 | | 1 | A | | |
| 0 | 010007 | 42921 | Eliza | 2/7/12 1650 | | 1 | A | | |
| 0 | 010008 | 42921 | Eliza | 2/9/12 1420 | | 1 | A | | |
| 0 | 010009 | 42914 | Main Barton | 2/10/12 1655 | | 1 | A | | |
| 0 | 010010 | 42914 | Main Barton | 2/11/12 1405 | | 1 | A | | |
| 0 | 010011 | 42914 | Main Barton | 2/16/12 1530 | | 1 | A | | |
| 0 | 010012 | 42914 | Main Barton | 2/7/12 1700 | | 1 | A | | |
| 0 | 010013 | 42914 | Main Barton | 2/9/10 1435 | | 1 | A | | |
| 0 | 010014 | 183 | Upper Barton | 2/10/12 1625 | | 1 | A | | |
| 0 | 010015 | 183 | Upper Barton | 2/11/12 1305 | | 1 | A | | |
| 0 | 010016 | 183 | Upper Barton | 2/16/12 1455 | | 1 | A | | |

This sheet filled out by OUL staff? Yes (No) Charts for samples on this page proofed by OUL: *CL - Pyranine and Phloxine B*
 OUL Project No. 1151 Date Analyzed: 3-16-12 Analyzed By: *me/oul*

Project: Arbor Trails Sinkhole, Austin Texas Week No: 1-3 Samples Collected By: BSEACD/COA
 Samples Shipped By: Brian Hunt, BSEACD *rec'd 2/24/12, analyzing request from* Samples Received By: *Roberta Sutt / OUL*
 Date Samples Shipped: 2/22/2012 Date & Time Samples Received: 3/14/12 @ 8:00
 Bill to: BSEACD, 1124 Regal Row, Austin Texas 78748 Send Results to: Brianh@bseacd.org (same mailing address as billing)

| OUL use only | | Please indicate stations where dye was visible in the field for field technician use - use black ink only | | | | | OUL use only | | BSEACD Comments | |
|--------------|------------------|---|--------------|--------------------|-----------------------|----------------|--------------|----------------|-----------------|--|
| # Char rec'd | LAB NUMBER | STATION NUMBER | STATION NAME | PLACED Date & Time | COLLECTED Date & Time | # Water /Rec'd | Analyze/Hold | Additional Dye | | |
| 0 | V6113 | 58-50-207 | Ashbaugh | 2/6/12 12:53 | | 1 | A | | | |
| 0 | V6114 | 58-50-207 | Ashbaugh | 2/10/12 14:30 | | 1 | A | | | |
| 0 | V6115 | 58-50-207 | Ashbaugh | 2/16/12 11:35 | | 1 | A | | | |
| 1 | V6116 | 42921B | Eliza | 2/10/12 16:42 | 2/11/12 0947 | 0 | A | Pyranine | | |
| 1 | V6117 | 42921B | Eliza | 2/2/12 1347 | 2/7/12 1647 | 0 | A | Pyranine | | |
| 1 | V6118 | 42921B | Eliza | 2/7/12 1647 | 2/9/12 1417 | 0 | A | Pyranine | | |
| 1 | V6119 | 42921A | Eliza | 2/9/12 1415 | 2/10/12 1640 | 0 | A | Pyranine | | |
| 1 | V6120 | 42921C | Eliza | 2/9/12 1420 | 2/16/12 1520 | 0 | A | Pyranine | | |
| 0 | V6116 | 42921 | Eliza | 2/10/12 1640 | | 1 | A | | | |
| 0 | V6117 | 42921 | Eliza | 2/11/12 0945 | | 1 | A | | | |
| 0 | V6118 | 42921 | Eliza | 2/16/12 1515 | | 1 | A | | | |
| 0 | V6119 | 42921 | Eliza | 2/7/12 1650 | | 1 | A | | | |
| 0 | V6121 | 42921 | Eliza | 2/9/12 1420 | | 1 | A | | | |
| 0 | V6122 | 42914 | Main Barton | 2/10/12 1655 | | 1 | A | | | |
| 0 | V6123 | 42914 | Main Barton | 2/11/12 1405 | | 1 | A | | | |
| 0 | V6124 | 42914 | Main Barton | 2/16/12 1530 | | 1 | A | | | |
| 0 | V6125 | 42914 | Main Barton | 2/7/12 1700 | | 1 | A | | | |
| 0 | V6126 | 42914 | Main Barton | 2/9/10 1435 | | 1 | A | | | |
| 0 | V6127 | 183 | Upper Barton | 2/10/12 1625 | | 1 | A | | | |
| 0 | V6128 | 183 | Upper Barton | 2/11/12 1305 | | 1 | A | | | |
| 0 | V6129 | 183 | Upper Barton | 2/16/12 1455 | | 1 | A | | | |

V6120 - OUL Water blank.

This sheet filled out by OUL staff? Yes (No) Charts for samples on this page proofed by OUL: *Curly Phloxine B*
 OUL Project No. 1151 Date Analyzed: 3/18/12 Analyzed By: *MR Fowl*

Project: Arbor Trails Sinkhole, Austin Texas Week No: 1-3 Samples Collected By: BSEACD/COA
 Samples Shipped By: Brian Hunt, BSEACD Date & Time Samples Received: 3/14/12 @ 800 Samples Received By: Rebecca Scott/OU
 Date Samples Shipped: 2/22/2012 Date & Time Samples Received: 3/14/12 @ 800
 Bill to: BSEACD, 1124 Regal Row, Austin Texas 78748 Send Results to: Brianh@bseacd.org (same mailing address as billing)
 Analyze for: Phloxine B and Pyranine where indicated

| OUL use only | | Please indicate stations where dye was visible in the field for field technician use - use black ink only | | | | OUL use only | | BSEACD Comments | |
|--------------|------------|---|--------------|--------------------|-----------------------|----------------|--------------|-----------------|--|
| # Char rec'd | LAB NUMBER | STATION NUMBER 1-4 Numbers | STATION NAME | PLACED Date & Time | COLLECTED Date & Time | # Water /Rec'd | Analyze/Hold | Additional Dye | |
| 0 | V6130 | 183 | Upper Barton | 2/7/12 1620 | | 1 | A | | |
| 0 | V6131 | 183 | Upper Barton | 2/9/12 1400 | | 1 | A | | |

This sheet filled out by OUL staff? Yes No Charts for samples on this page proofed by OUL: Clay/phloxine B
 OUL Project No. 1157 Date Analyzed: 3-19-12 Analyzed By: ARLOW
 2 of 2 OUL

Appendix 3: Correspondence on confirmation of results

Brian Hunt

From: Julie Stearman [jstearman@ozarkundergroundlab.com] on behalf of taley@ozarkundergroundlab.com
Sent: Tuesday, May 15, 2012 9:52 AM
To: Brian Hunt
Subject: RE: Confirmation of Results

Hi Brian:

At your request I re-examined the analysis graphs for the following three samples. I also had our lab do a re-analyzed of the three samples. The re-analysis showed the following:

V5656P. This is Station 6. 58-50-2 6200 Brodie. This was a charcoal sampler elutant. There is a fluorescence peak in this sample at 521.2 nm. The results confirmed the initial analysis.

V5687P. This is Station 11. 58-50-230 Picard. This was a charcoal sampler elutant. There were no fluorescence peaks in this sample. The results confirmed the initial analysis.

V5689P. This is Station 12. 58-50-1GR Randalls. This was a charcoal sampler elutant. There was a fluorescence peak in this sample at 519.3 nm. The results confirmed the initial analysis.

Under the protocol we are using for phloxine dye positive detections will have peak emission wavelengths in the range from about 573 to 578 nm. The fluorescence peaks at Stations 6 and 12 were far outside of this range. The peaks were also well outside the range for pyranine dye.

Based upon both our initial and our re-analysis results there was no detectable phloxine dye or pyranine dye in any of these three samples.

Best regards,

Tom Aley

From: Brian Hunt [<mailto:brianh@bseacd.org>]
Sent: Thursday, May 10, 2012 5:46 PM
To: Julie Stearman
Cc: Brian Hunt
Subject: RE: Invoice

Hi Julie,

For our recent study we had some duplicate charcoal and water samples analyzed by the Edwards Aquifer Authority. For the most part there is good agreement in the all results, but there are three samples that I wonder if you could look at your analyses to reconfirm the results. These include three different wells where your results indicate a non-detect, while the EAA indicates a detection of Phloxine B. They only detected the dye once in each of these wells corresponding to the samples I listed below.

The samples are: V5656P, V5687P, and V5689P.

Thank you!

Cheers, Brian

*Brian B. Hunt
Senior Hydrogeologist
Barton Springs/Edwards Aquifer Conservation District
1124 Regal Row
Austin, Texas 78748
(512) 282-8441 office
(512) 282-7016 fax
brianh@bseacd.org*

Here's all the legal stuff:

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From: Julie Stearman [<mailto:jstearman@ozarkundergroundlab.com>]
Sent: Tuesday, March 20, 2012 10:56 AM
To: Brian Hunt
Subject: Invoice

Hello Brian, Please see the attached invoice; let me know if you have any questions.

Thank you,
Julie Stearman

Brian Hunt

From: Steven Johnson [sjohnson@edwardsaquifer.org]
Sent: Friday, May 11, 2012 3:37 PM
To: Brian Hunt
Subject: RE: dye trace results

Brian, the yellow line is the combination of the two peaks in the sample that are shown in red. The green line is the original spectrograph. The peaks around 500 are Uranine as in 194 and 103 or background optical properties of water as in 109 and 115.

Steve Johnson

Hydrogeologist Supervisor-Aquifer Science Team

Edwards Aquifer Authority

1615 N. St. Mary's Street
San Antonio, TX 78215
210/222-2204

<mailto:sjohnson@edwardsaquifer.org>



From: Brian Hunt [mailto:brianh@bseacd.org]
Sent: Friday, May 11, 2012 3:04 PM
To: Steven Johnson
Subject: RE: dye trace results

Steve, the yellow line is the sample and the two red lines are for the standard and blank?

Thanks again!

b

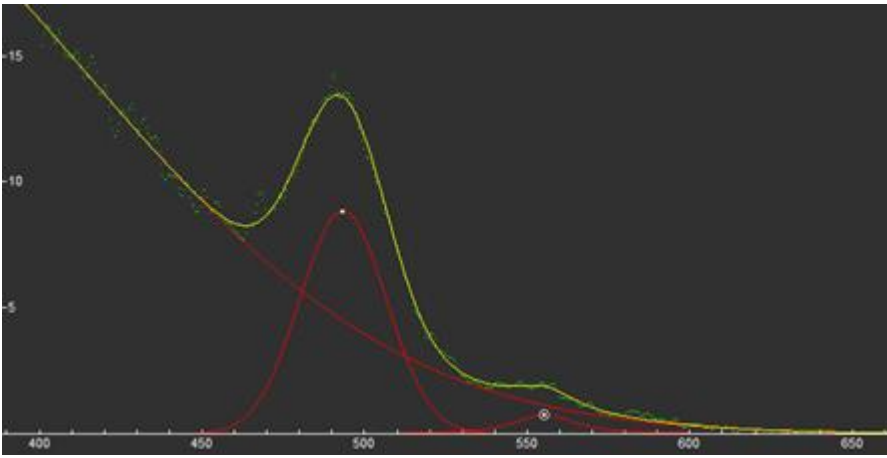
Brian B. Hunt
Senior Hydrogeologist
Barton Springs/Edwards Aquifer Conservation District
1124 Regal Row
Austin, Texas 78748
(512) 282-8441 office
(512) 282-7016 fax
brianh@bseacd.org

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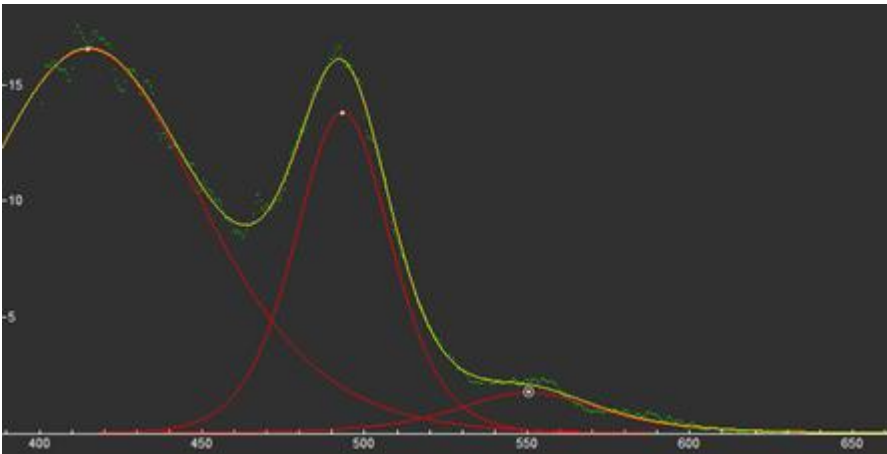
From: Steven Johnson [<mailto:sjohnson@edwardsaquifer.org>]
Sent: Friday, May 11, 2012 10:08 AM
To: Brian Hunt
Subject: RE: dye trace results

Brian, here are the three sample results:

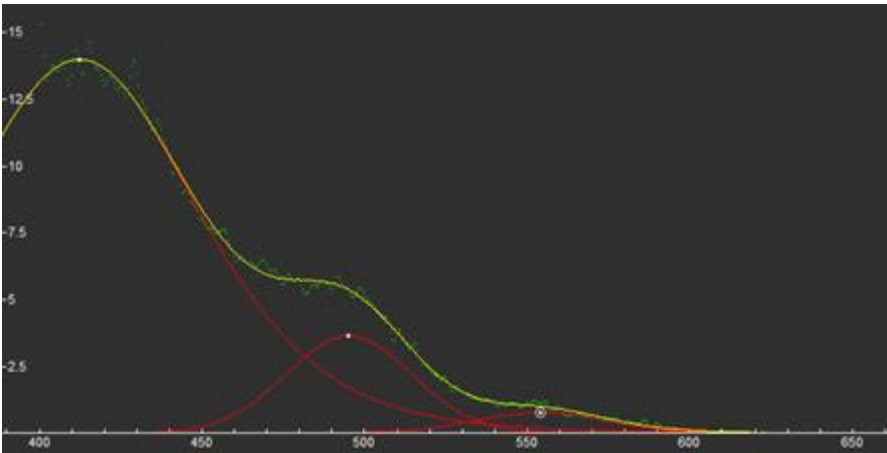


sample #194 (6200 Brodie, charcoal 2/3-2/6)

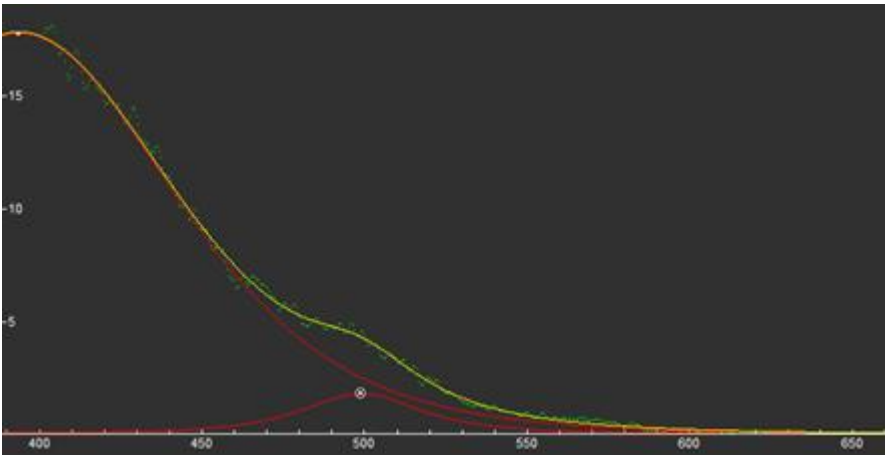
Phloxine B shows up around 550 nm. In this case, it's a very low concentration, but I think it's there.



#103 (Randalls, charcoal 2/3-2/6) Same results as above



#109 (Picard, charcoal 2/6-2/10) This one has the lowest concentration. Phloxine B is more easily recognized than Uranine and Eosin because it appears where the background interference is low. I have the dates as 2/3-2/6/10.



For comparison, here's sample #115 from Picard with no detectable Phloxine B so you can see the contrast in the 550 nm area.

I would call the other samples tentative detections at least because they were in only one sample from the site and because the peak shape is somewhat subjective.

Steve Johnson

Hydrogeologist Supervisor-Aquifer Science Team

Edwards Aquifer Authority

1615 N. St. Mary's Street
 San Antonio, TX 78215
 210/222-2204

<mailto:sjohnson@edwardsaquifer.org>



From: Brian Hunt [<mailto:brianh@bseacd.org>]

Sent: Thursday, May 10, 2012 5:59 PM

To: Steven Johnson

Cc: Brian Smith

Subject: dye trace results

Hi Steve,

We some of the dye trace samples to OUL labs as duplicates. For the most part there is good agreement in the results where they overlap. However, there are 3 sites that you all detect Phloxine B and OUL did not. I wanted to see if perhaps you wouldn't mind looking at the results of those 3 sites again—if possible.

The three samples include: EAA sample #194 (6200 Brodie, charcoal 2/3-2/6); #103 (Randalls, charcoal 2/3-2/6); and #109 (Picard, charcoal 2/6-2/10).

I suspect those sites would have been on the flow path, and since they were only detected once, and by only 1 lab, I am trying to confirm or deny. I've asked OUL to review those three samples too.

Thanks!
 Cheers,
 Brian