Barton Springs Edwards Aquifer CONSERVATION DISTRICT

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# Dye Trace at Raccoon Cave near Jacob's Well Spring, Hays County, Texas

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## Abstract

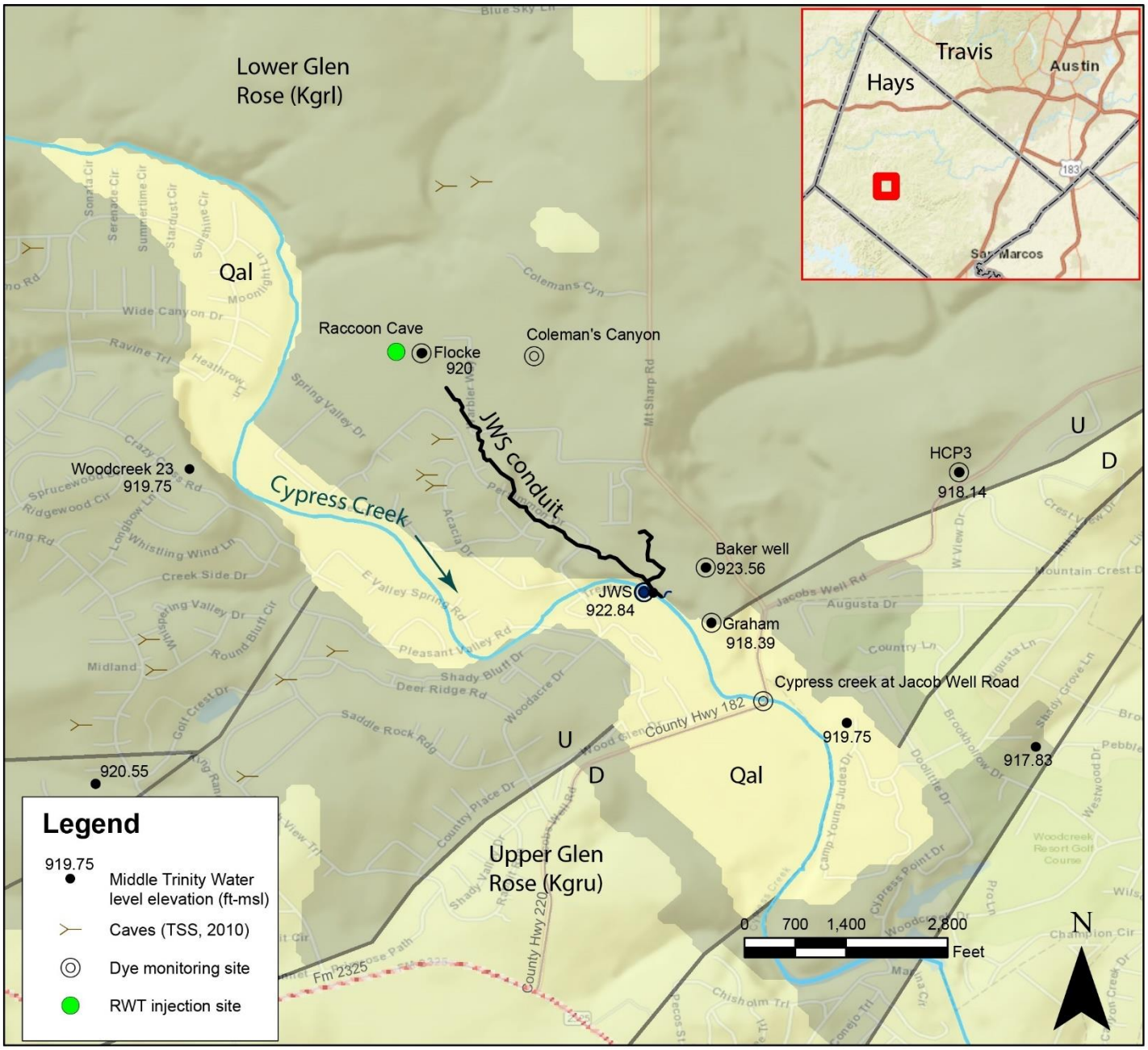
A consortium of agencies and scientists planned and executed a dye-trace test in the vicinity of Jacob's Well Spring (JWS) in late March – early April 2018. The goal of the trace was to evaluate the hydrogeologic connection of Racoon Cave, a karst feature developed within the Lower Glen Rose formation, with JWS and area wells. The purpose of this memo is to document this tracer test and provide insight for future dye-trace studies in the Cypress Creek watershed.

Five pounds of the fluorescent dye Rhodamine WT (RWT) was injected and flushed with water into Raccoon Cave on March 27, 2018. Monitoring sites included five area wells, locations downstream of JWS along Cypress Creek, and JWS (**Figure 1**). Jacob's Well was monitored with an automatic sampler, an in situ field fluorimeter, and daily charcoal samples. Area wells and Cypress Creek downstream from JWS were monitored on a weekly basis with charcoal samples. All dye monitoring continued through May 2018.

Results from the dye trace are equivocal. No water samples had dye detections, and RWT was interpreted for charcoal samples from two wells (Baker, Flocke) and Cypress Creek downstream of JWS. These detections occurred within the first week of sampling after injection. However, the results were very low concentrations and one of the well samples had a background detection. No detections occurred on samples after 6/4/18. The field fluorimeter in JWS indicated that a very low concentration of RWT may have flowed out of JWS within one day of the injection.

Hydrologic data collected by the USGS and the field fluorimeter (instrument also collects water temperature, turbidity, and specific conductance data) provide the strongest case for the direct connection of the karst features to JWS. Both instruments measured increases in turbidity and decreases in temperature and conductivity within hours of rain events. Thus, local recharge to JWS within karst features, such as Raccoon Cave, in the Cypress watershed is likely occurring.

We recommend a repeat of the dye trace occur at Racoon Cave with a larger dye mass. In addition, placement of charcoal receptors at JWS should be at a minimum of one week to allow the accumulation of dye. Background analyses will be important to any future study.




Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community, Sources: Esri, DeLorme, USGS, NPS, Sources: Esri, USGS, NOAA

***Figure 1.*** *Location and geologic map of study area. Groundwater flow occurs from NW to SE in the area along the conduit to JWS. Cave map from David Moore. Head elevations shown have some uncertainty within a few feet.*

# Methods

Dye tracing is a long-established, safe, and scientifically sound approach to characterize surface and groundwater interactions. Non-toxic fluorescent dyes are introduced into the groundwater system via recharge features, such as caves, sinkholes, and fractures, or into recharge zones of an aquifer. Water samples or absorbent charcoal packets are collected routinely at downgradient wells and springs and analyzed for the presence of the injected dyes (Aley, 2002). In situ instruments also measure the fluorescence of specific wavelengths that a particular dye emits, allowing for rapid, instantaneous quantification of dye concentrations in water.

Rhodamine WT was selected for the trace and purchased from Ozark Underground Labs (OUL) in liquid one-pound bottles. Initial estimations of the preferred mass using the Worthington Equation (#2) (Worthington and Smart, 2003) indicated visible amounts would be detected with about 0.5 lbs of dye. However, it is assumed the pathway from the injection point to JWS is likely more circuitous than the equation accounts, thus five pounds of RWT was applied.

Sampling protocols for this trace are detailed in Hauwert et al. (2004). All samples were stored in a light-proof box to avoid photodecomposition of dye. Vials and charcoal receptors were handled using standard chain-of-custody protocols.

Samples were analyzed at the Edwards Aquifer Authority (EAA) tracer test laboratory using its Perkin Elmer LS-50B Luminescence Spectrometer. Lab protocols are described in Johnson et al., 2012. Detection limits were not evaluated for RWT at the EAA, but are likely on the order of 0.1 ug/L (parts per billion, ppb). Some initial screening of water samples was done at the BSEACD with a Perkin Elmer LS-50B Luminescence Spectrometer.

The in situ field fluorimeter manufactured by Eureka (Manta2) was deployed into JWS and secured to a bolt about 20 deep within the well. The instrument measured temperature, conductivity, turbidity, and fluorescence from RWT, fluorescein, and eosine. The minimum detection limit for the Manta2 fluorimeter (Cyclops 7F) is reported to be 0.01 ug/L (ppb) (http://www.turnerdesigns.com/t2/doc/brochures/S-0209.pdf).

## Summary of Tasks:

Photographs of some of the tasks are provided in Appendices.

- Sunday March 25th staged bladder tanks and filled at the injection site.
- Monday March 26th hoses were installed from the bladder tanks and tested- a flow of about 1-2,000 gallons was injected into feature. Installed background charcoal packets at wells and JWS.
- Tuesday March 27th Install fluorimeter into JWS at 11 am (10-minute recording frequency). Installed ISCO autosampler at JWS. Began flow of pre-injection water into the cave of about 10,000 gallons. Exchanged charcoal receptors for background.
    - Injected 5 lbs of RWT at 12:30 by pouring into water stream at bottom of cave.
    - Injected about 10,000 gallons of "flush" water until about 4pm.

***Table 1.*** *Monitor Sites and sample schedule*

| | Site Name | Type site | Monitoring Type | Personnel | Frequency |
|---|---|---|---|---|---|
| 1 | Jacob's Well Spring (JWS) | Spring | 1. receptor + grab<br>2. Auto water samples;<br>3. Fluorimeter | BSEACD<br>EAA; Greg Tatum* | Hourly to daily receptors and water samples;<br>Fluorimeter: 10 minutes<br>3/27/18 to 3/30/18 |
| 2 | Cypress Creek at JW road (aka Jacob's Well Road LWX) | Creek downstream of JWS along low water crossing | receptor + grab | BSEACD | weekly |
| 3 | Flocke well (Raccoon Site) | Domestic well | receptor + grab | BSEACD | Weekly receptors; periodic grabs |
| 4 | Baker well (aka WVWA) | Domestic well | receptor + grab | BSEACD | weekly |
| 5 | Graham well (Reagan Gammon) | Domestic/HTGCD monitor well | receptor + grab | HTGCD | weekly |
| 7 | HCP3 well | monitor | receptor | HTGCD | weekly |

*All charcoal receptors to have a duplicate (A and B) and water sample. *Diver installed fluorimeter.*

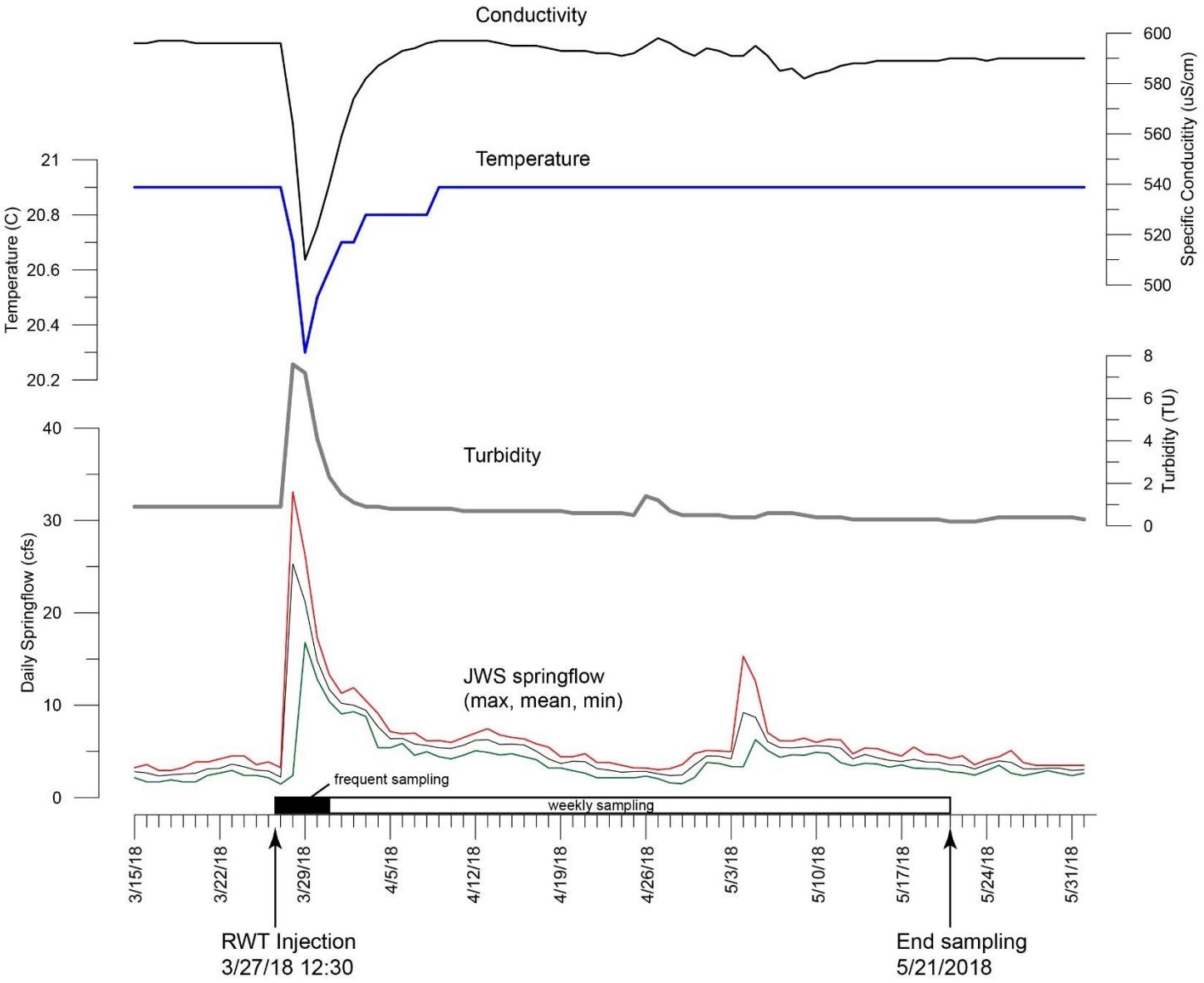



***Figure 2.*** *Hydrograph of USGS daily data from Jacob's Well Spring (USGS 08170990) annotated with injection and sampling notes. Rainfall occurred in the evening of 3/27/18 (after injection) and local recharge is apparent on the hydrograph resulting in increased springflow and turbidity, and decreased temperature and conductivity.*

## Results

All samples were catalogued by District staff (**Appendices Table A-1**) and provided to the EAA for analysis. **Tables 2 and 3** are a subset of the results provided by the EAA. Note that only charcoal had interpretations as positive detections of RWT. These results contained positive detections, and all other samples not included in **Tables 2 and 3** were non-detect for dyes and are listed in the appendices.

**Figure 3** presents the Manta 2 field fluorimeter results from 3/27/18 through 3/30/18. The instrument reports a concentration in parts per billion (ppb). The instrument reported a background concentration over 5.2 ppb prior to dye injection, so 5.2 ppb was shifted downward to reflect true background concentrations and normalize the data. This shift was performed since the instrument was not fully calibrated for RWT concentration precision, but provides a relative measure of dye intensity, and clearly shows an increase in RWT concentration in a feasible time period following the dye injection.

The BSEACD used its Perkin Elmer LS-50B Luminescence Spectrometer for qualitative screening of water samples indicating the simple presence or absence of a certain fluorescence level. A split of water samples was taken from the autosampler for the first 2 days and screened for dye. No dye was detected in those samples (**Appendices**).

***Table 2.*** *Charcoal Sample Results (A and B indicate duplicates); ND indicates non-detection.*

| *Site Name* | *Placed Date* | *Collected Date* | *Result (intensity)* | *Result (wavelength)* | *Comment* |
|---|---|---|---|---|---|
| *JWS* | 3/23/2018 | 3/27/2018 | ND | ND | |
| *Flocke A* | 3/26/2018 | 3/27/2018 | ND | ND | |
| *Flocke B* | 3/26/2018 | 3/27/2018 | ND | ND | |
| *Graham A* | 3/26/2018 | 3/27/2018 | ND | ND | |
| *Graham B* | 3/26/2018 | 3/27/2018 | ND | ND | |
| *HCP3* | 3/26/2018 | 3/27/2018 | ND | ND | |
| *Jacobs Well Rd LWX A* | 3/26/2018 | 3/27/2018 | ND | ND | |
| *Jacobs Well Rd LWX B* | 3/26/2018 | 3/27/2018 | ND | ND | |
| ***WVWA A*** | **3/26/2018** | **3/27/2018** | **12*** | **548** | **background** |
| ***WVWA B*** | **3/26/2018** | **3/27/2018** | **13*** | **548** | **background** |
| *Lanahan A* | 3/26/2018 | 3/27/2018 | ND | ND | |
| *Lanahan B* | 3/26/2018 | 3/27/2018 | ND | ND | |
| *JWS* | 3/27/2018 | 3/28/2018 | ND | ND | |
| ***Flocke A*** | **3/27/2018** | **4/4/2018** | **18** | **523** | **Positive for RWT** |
| ***Flocke B*** | **3/27/2018** | **4/4/2018** | **18** | **523** | **Positive for RWT** |
| *Graham A* | 3/27/2018 | 4/4/2018 | ND | ND | |
| *Graham B* | 3/27/2018 | 4/4/2018 | ND | ND | |
| *HCP3* | 3/27/2018 | 4/4/2018 | ND | ND | |
| ***Jacobs Well Rd LWX A*** | **3/27/2018** | **4/4/2018** | **17** | **558** | **Positive for RWT** |
| ***Jacobs Well Rd LWX B*** | **3/27/2018** | **4/4/2018** | **17** | **558** | **Positive for RWT** |
| ***WVWA A*** | **3/27/2018** | **4/4/2018** | **84** | **548** | **Positive for RWT** |
| ***WVWA B*** | **3/27/2018** | **4/4/2018** | **82** | **549** | **Positive for RWT** |
| *Lanahan A* | 3/27/2018 | 4/4/2018 | ND | ND | |
| *Lanahan B* | 3/27/2018 | 4/4/2018 | ND | ND | |
| *Control* | 4/4/2018 | 4/4/2018 | ND | ND | |
| *JWS* | 3/28/2018 | 4/6/2018 | ND | ND | |

***Table 3.*** *Autosampler water results. ND indicates non-detection.*

| *Site Name* | *Collected Date* | *Time* | *Analysis* |
|---|---|---|---|
| *JWS* | 3/27/2018 | 14:00 | ND |
| *JWS* | 3/27/2018 | 17:00 | ND |
| *JWS* | 3/27/2018 | 20:00 | ND |
| *JWS* | 3/27/2018 | 23:00 | ND |
| *JWS* | 3/28/2018 | 2:00 | ND |
| *JWS* | 3/28/2018 | 5:00 | ND |
| *JWS* | 3/28/2018 | 8:00 | ND |
| *JWS* | 3/28/2018 | 11:00 | ND |
| *JWS* | 3/28/2018 | 17:00 | ND |
| *JWS* | 3/28/2018 | 20:00 | ND |
| *JWS* | 3/28/2018 | 23:00 | ND |
| *JWS* | 3/29/2018 | 2:00 | ND |
| *JWS* | 3/29/2018 | 5:00 | ND |
| *JWS* | 3/29/2018 | 8:00 | ND |
| *JWS* | 3/29/2018 | 11:00 | ND |
| *JWS* | 3/29/2018 | 14:00 | ND |
| *JWS* | 3/29/2018 | 17:00 | ND |
| *JWS* | 3/29/2018 | 20:00 | ND |
| *JWS* | 3/29/2018 | 23:00 | ND |
| *JWS* | 3/30/2018 | 2:00 | ND |
| *JWS* | 3/30/2018 | 5:00 | ND |
| *JWS* | 3/30/2018 | 8:00 | ND |
| *JWS* | 3/30/2018 | 11:00 | ND |

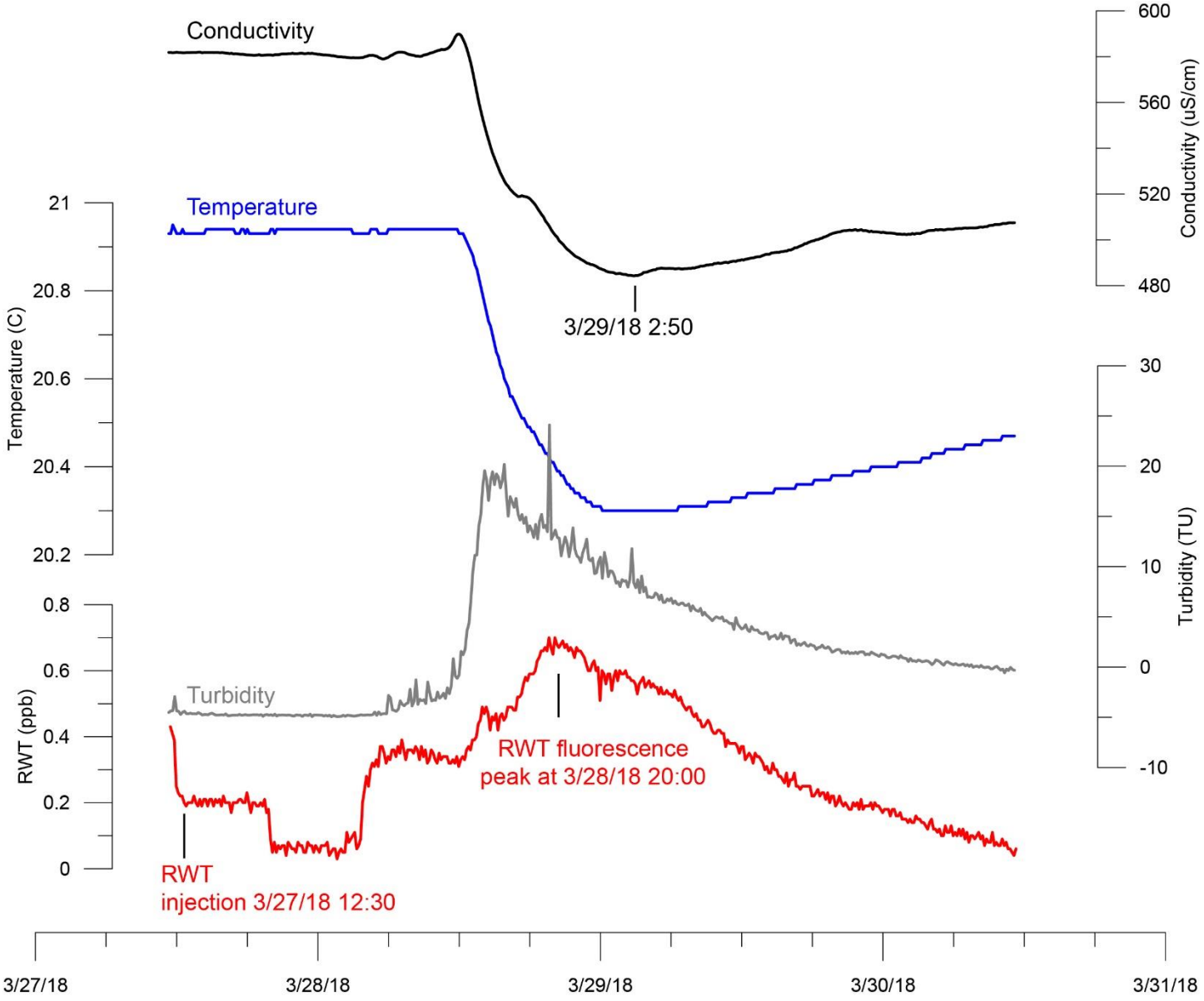



***Figure 3.*** *Hydrograph from the Manta2 field fluorimeter. Data frequency is 10 minutes. Field parameters responded similarly to the USGS daily data in Figure 2. Note the relative peak of RWT about 1 day after injection.*

## Discussion

The purpose of this tracer test was to establish a hydrogeologiclogic connection between karst features in the Lower Glen Rose and JWS in the Cypress watershed. Raccoon Cave was selected because of logistical access and its location near the terminus of the JWS conduit system (**Figure 1**).

The dye tracing results are equivocal due to low RWT concentrations on a few charcoal samples and potential background presence of the RWT dye. The short deployment of the charcoal packets at JWS may not have allowed the accumulation of the low levels of dye concentration in the water below grab detection limits. However, the charcoal samples deployed over a longer period of time downstream of JWS may have allowed the charcoal receptors to absorb enough of the fluorescence to be detectible. The in situ field fluorimeter suggests a peak of RWT about 1 day after injection of the dye. However, this is only a relative increase and at very low concentrations.

After the injection of the dye, a significant rainstorm occurred and affected the hydrologic parameters at JWS (**Figures 2 and 3**). The hydrologic data collected presents a compelling argument for local recharge with increases in springflow and turbidity coupled with decreases in temperature and conductivity. The quick response of those parameters is likely due to recharge occurring in the Lower Glen Rose within the Cypress Creek watershed.

## Conclusion

Initial dye tracing results are equivocal. However, the hydrologic response to rain and the limited dye detections suggests a hydrogeologic connection is possible from the area around Raccoon Cave to JWS. We recommend a repeat of the dye trace at Racoon Cave with a larger dye mass, and more extensive monitoring of additional wells in the area. In addition, placement of charcoal receptors at JWS should be at a minimum of 1 week to allow the accumulation of dye. Background analyses will be important to any future study.

## Acknowledgements

This study would not have been possible without the full cooperation of Steve Flocke who owns Raccoon Cave and allowed the use of his well and pool for injection water. We also extend our thanks to Reagan Gammon who allowed monitoring of her well (Graham well).

The BSEACD co-coordinated the study with the Edwards Aquifer Authority (EAA). The BSEACD hired Zara Environmental to help arrange access and logistics at the injection site. Marcus Gary (EAA), and Anastacio Moncada (EAA) helped stage equipment at the well. The EAA provided injection bladders and hoses, Manta2 fluorimeter, autosampler, and sample supplies. Anastacio Moncada (EAA) performed the sample analyses. Sampling was done by Justin Camp (BSEACD) with assistance from Jeff Watson (HTGCD). Sampling, access to JWS, and logistical support was provided by the WVWA (David Baker, Ashely Waymouth and Doug Norman). Hays County Parks Department supported access for the study. Diver Greg Tatum installed and retrieved the Manta2 fluorimeter in JWS.

## References

Aley, T., 2002, Groundwater Tracing Handbook, Ozark Underground Laboratory, Protem, Missouri, 35 p.

Hauwert, N. M., Johns, D. A., Sansom, J. W., Aley, T. J., 2004, Groundwater Tracing of the Barton Springs Edwards Aquifer, southern Travis and northern Hays Counties, Texas: Barton Springs/Edwards Aquifer Conservation District and the City of Austin Watershed Protection and Development Review Department, 100 p. and appendices.

Johnson, S., Schindel, G., Veni, G., Hauwert, N., Hunt, B., Smith, B.A., and Gary, M., 2012, Tracing Groundwater Flowpaths in the Vicinity of San Marcos Springs, Texas: Edwards Aquifer Authority, San Antonio, Texas, August 2012, 139 p.

Wierman, D.A., A.S. Broun, and B.B. Hunt (Eds), 2010, Hydrogeologic Atlas of the Hill Country Trinity Aquifer, Blanco, Hays, and Travis Counties, Central Texas: Prepared by the Hays-Trinity , Barton/Springs Edwards Aquifer, and Blanco Pedernales Groundwater Conservation Districts, July 2010, 17 plates+DVD.

Worthington, S.R.H. and Smart, C., 2003, Empirical Determination of Tracer Mass for sink to spring tests in Karst. American Society of Civil Engineers, Geotechnical Special Publications no. 122, p. 287-295.

## Appendices

Bladder tanks for injecting water into Raccoon Cave. Each tank holds 5,000 gallons when full.

Entrance to Raccoon Cave showing injection hose going down to base of the cave. Brian Smith for scale.


Brian Cowan holding the 5 lbs of RWT dye prior to injection.

Photo looking down to base of shaft within Raccoon Cave showing the hose and injection of dye into the water flowing out of the hose.

View of RWT dye as it is poured into the bottom of Raccoon Cave. Photo by Zara Environmental.

View of Jacob's Well Spring with the installation of the fluorimeter instrument by a diver (Greg Tatum). Also visible are the automatic sampler and tubing.

**Table A-1. Sample log**

| Sate Name | Sample Type | Date Installed | Date removed | Positive Result | Sampler | Notes 1 | Notes 2 |
|---|---|---|---|---|---|---|---|
| JWS | Charcoal | 3/23/18 10:15 | 3/27/18 10:15 | | WVWA | background | In spring |
| Flocke | Water | 3/26/18 9:45 | | | BSEACD | background | |
| Flocke A | Charcoal | 3/26/18 9:45 | 3/27/18 12:30 | | BSEACD | background | good, hose running |
| Flocke B | Charcoal | 3/26/18 9:47 | 3/27/18 12:32 | | BSEACD | background | good, hose running |
| Graham | Water | 3/26/18 10:20 | | | BSEACD | background | |
| Graham A | Charcoal | 3/26/18 10:20 | 3/27/18 11:45 | | BSEACD | background | good, hose running |
| Graham B | Charcoal | 3/26/18 10:22 | 3/27/18 11:47 | | BSEACD | background | good, hose running |
| HCP3 | Charcoal | 3/26/18 10:40 | 3/27/18 13:15 | | BSEACD | background | good, attached |
| Jacobs Well Rd LWX | Water | 3/26/18 10:50 | | | BSEACD | background | |
| Jacobs Well Rd LWX A | Charcoal | 3/26/18 10:50 | 3/27/18 13:30 | | BSEACD | background | good, in flow |
| Jacobs Well Rd LWX B | Charcoal | 3/26/18 10:52 | 3/27/18 13:32 | | BSEACD | background | good, in flow |
| WVWA | Water | 3/26/18 12:50 | | | BSEACD | background | |
| WVWA A | Charcoal | 3/26/18 12:50 | 3/27/18 11:30 | 12@548 | BSEACD | background | good, hose running |
| WVWA B | Charcoal | 3/26/18 12:52 | 3/27/18 11:32 | 13@548 | BSEACD | background | good, hose running |
| Lanahan A | Charcoal | 3/26/18 13:20 | 3/27/18 11:55 | | BSEACD | background | good, hose running |
| Lanahan B | Charcoal | 3/26/18 13:22 | 3/27/18 11:57 | | BSEACD | background | good, hose running |
| JWS | Charcoal | 3/27/18 10:15 | 3/28/18 10:00 | | WVWA | | In spring |
| JWS | Water | 3/27/18 10:15 | | | WVWA | surface grab | |
| WVWA | Water | 3/27/18 11:30 | | | BSEACD | surface grab | |
| WVWA A | Charcoal | 3/27/18 11:30 | 4/4/18 12:05 | 84@548 | BSEACD | Round 1 | good, hose running |
| WVWA B | Charcoal | 3/27/18 11:32 | 4/4/18 12:07 | 82@549 | BSEACD | Round 1 | good, hose running |
| Graham A | Charcoal | 3/27/18 11:45 | 4/4/18 12:30 | | BSEACD | Round 1 | good, hose running |
| Graham B | Charcoal | 3/27/18 11:47 | 4/4/18 12:32 | | BSEACD | Round 1 | good, hose running |
| Lanahan | Water | 3/27/18 11:55 | | | BSEACD | Bakground | |
| Lanahan A | Charcoal | 3/27/18 11:55 | 4/4/18 12:55 | | BSEACD | Round 1 | hose not running, but wet. Monitoring discontinued |
| Lanahan B | Charcoal | 3/27/18 11:57 | 4/4/18 12:57 | | BSEACD | Round 1 | hose not running, but wet. Monitoring discontinued |
| JWS B1 | Water | 3/27/18 12:00 | | | BSEACD | Autosampler 1 | |
| Flocke A | Charcoal | 3/27/18 12:30 | 4/4/18 11:15 | 18@523 | BSEACD | Round 1 | good, hose running |
| Flocke B | Charcoal | 3/27/18 12:32 | 4/4/18 11:17 | 18@523 | BSEACD | Round 1 | good, hose running |
| JWS B2 | Water | 3/27/18 13:00 | | | BSEACD | Autosampler 1 | |
| HCP3 | Charcoal | 3/27/18 13:15 | 4/4/18 10:45 | | BSEACD | Round 1 | wet, on probe. Monitoring discontinued |

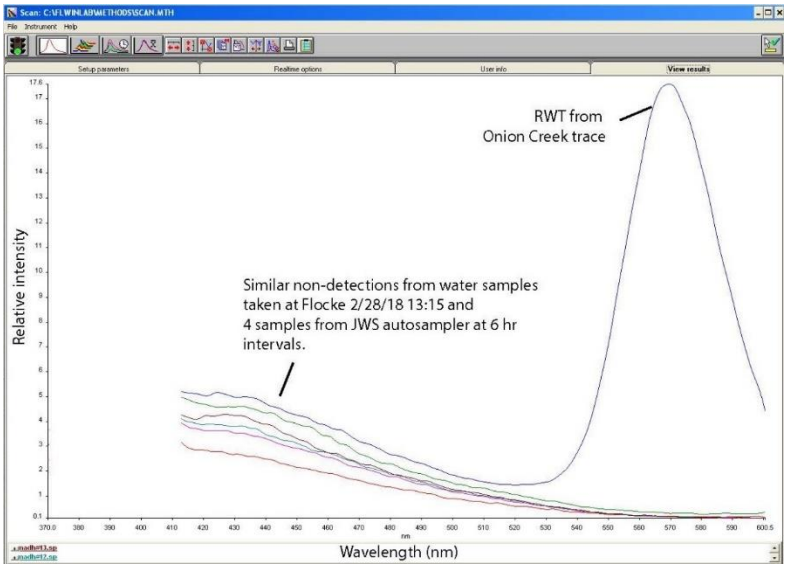
| Sate Name | Sample Type | Date Installed | Date removed | Positive Result | Sampler | Notes 1 | Notes 2 |
|---|---|---|---|---|---|---|---|
| Jacobs Well Rd LWX A | Charcoal | 3/27/18 13:30 | 4/4/18 11:00 | 17@558 | BSEACD | Round 1 | good, in flow |
| JWS | Water | 3/27/18 13:30 | | | WVWA | surface grab | |
| Jacobs Well Rd LWX B | Charcoal | 3/27/18 13:32 | 4/4/18 11:02 | 17@558 | BSEACD | Round 1 | good, in flow |
| JWS B3 | Water | 3/27/18 14:00 | | | BSEACD | Autosampler 1 | |
| JWS | Water | 3/27/18 14:30 | | | WVWA | surface grab | |
| JWS B4 | Water | 3/27/18 15:00 | | | BSEACD | Autosampler 1 | |
| JWS | Water | 3/27/18 15:30 | | | WVWA | surface grab | |
| JWS B5 | Water | 3/27/18 16:00 | | | BSEACD | Autosampler 1 | |
| JWS | Water | 3/27/18 16:30 | | | WVWA | surface grab | |
| JWS B6 | Water | 3/27/18 17:00 | | | BSEACD | Autosampler 1 | |
| JWS | Water | 3/27/18 17:30 | | | WVWA | surface grab | |
| JWS B7 | Water | 3/27/18 18:00 | | | BSEACD | Autosampler 1 | |
| JWS B8 | Water | 3/27/18 19:00 | | | BSEACD | Autosampler 1 | |
| JWS B9 | Water | 3/27/18 20:00 | | | BSEACD | Autosampler 1 | |
| JWS B10 | Water | 3/27/18 21:00 | | | BSEACD | Autosampler 1 | |
| JWS B11 | Water | 3/27/18 22:00 | | | BSEACD | Autosampler 1 | |
| JWS B12 | Water | 3/27/18 23:00 | | | BSEACD | Autosampler 1 | |
| JWS | Water | 3/28/18 8:00 | | | WVWA | surface grab | |
| JWS | Water | 3/28/18 9:00 | | | WVWA | surface grab | |
| JWS | Charcoal | 3/28/18 10:00 | 4/6/18 13:30 | | BSEACD | In spring | |
| JWS | Water | 3/28/18 10:00 | | | WVWA | surface grab | |
| JWS | Water | 3/28/18 11:00 | | | WVWA | surface grab | |
| JWS | Water | 3/28/18 12:00 | | | WVWA | surface grab | |
| JWS | Water | 3/28/18 13:00 | | | WVWA | surface grab | |
| Flocke | Water | 3/28/18 13:15 | | | BSEACD | surface grab | |
| JWS | Water | 3/28/18 14:00 | | | WVWA | surface grab | |
| WVWA | Water | 3/28/18 14:40 | | | BSEACD | surface grab | |
| JWS | Water | 3/28/18 15:00 | | | WVWA | surface grab | |
| JWS B1 | Water | 3/28/18 15:00 | | | BSEACD | Autosampler 2 | |
| JWS | Water | 3/28/18 16:00 | | | WVWA | surface grab | |
| JWS B2 | Water | 3/28/18 16:00 | | | BSEACD | Autosampler 2 | |
| JWS | Water | 3/28/18 17:00 | | | WVWA | surface grab | |

| Sate Name | Sample Type | Date Installed | Date removed | Positive Result | Sampler | Notes 1 | Notes 2 |
|---|---|---|---|---|---|---|---|
| JWS B3 | Water | 3/28/18 17:00 | | | BSEACD | Autosampler 2 | |
| JWS | Water | 3/28/18 18:00 | | | WVWA | surface grab | |
| JWS B4 | Water | 3/28/18 18:00 | | | BSEACD | Autosampler 2 | |
| JWS B5 | Water | 3/28/18 19:00 | | | BSEACD | Autosampler 2 | |
| JWS B6 | Water | 3/28/18 20:00 | | | BSEACD | Autosampler 2 | |
| JWS B7 | Water | 3/28/18 21:00 | | | BSEACD | Autosampler 2 | |
| JWS B8 | Water | 3/28/18 22:00 | | | BSEACD | Autosampler 2 | |
| JWS B9 | Water | 3/28/18 23:00 | | | BSEACD | Autosampler 2 | |
| JWS B13 | Water | 3/29/18 0:00 | | | BSEACD | Autosampler 1 | |
| JWS B14 | Water | 3/29/18 1:00 | | | BSEACD | Autosampler 1 | |
| JWS B15 | Water | 3/29/18 2:00 | | | BSEACD | Autosampler 1 | |
| JWS B16 | Water | 3/29/18 3:00 | | | BSEACD | Autosampler 1 | |
| JWS B17 | Water | 3/29/18 4:00 | | | BSEACD | Autosampler 1 | |
| JWS B18 | Water | 3/29/18 5:00 | | | BSEACD | Autosampler 1 | |
| JWS B19 | Water | 3/29/18 6:00 | | | BSEACD | Autosampler 1 | |
| JWS B20 | Water | 3/29/18 7:00 | | | BSEACD | Autosampler 1 | |
| JWS | Water | 3/29/18 8:00 | | | WVWA | surface grab | |
| JWS B21 | Water | 3/29/18 8:00 | | | BSEACD | Autosampler 1 | |
| JWS B22 | Water | 3/29/18 9:00 | | | BSEACD | Autosampler 1 | |
| JWS B23 | Water | 3/29/18 10:00 | | | BSEACD | Autosampler 1 | |
| JWS B24 | Water | 3/29/18 11:00 | | | BSEACD | Autosampler 1 | |
| JWS | Water | 3/29/18 12:00 | | | WVWA | surface grab | |
| Flocke | Water | 3/29/18 13:45 | | | BSEACD | surface grab | |
| WVWA | Water | 3/29/18 14:45 | | | BSEACD | surface grab | |
| JWS B1 | Water | 3/29/18 15:00 | | | BSEACD | Autosampler 3 | |
| JWS | Water | 3/29/18 16:00 | | | WVWA | surface grab | |
| JWS B2 | Water | 3/29/18 16:00 | | | BSEACD | Autosampler 3 | |
| JWS B3 | Water | 3/29/18 17:00 | | | BSEACD | Autosampler 3 | |
| JWS B4 | Water | 3/29/18 18:00 | | | BSEACD | Autosampler 3 | |
| JWS B5 | Water | 3/29/18 19:00 | | | BSEACD | Autosampler 3 | |
| JWS B6 | Water | 3/29/18 20:00 | | | BSEACD | Autosampler 3 | |
| JWS B7 | Water | 3/29/18 21:00 | | | BSEACD | Autosampler 3 | |

| Sate Name | Sample Type | Date Installed | Date removed | Positive Result | Sampler | Notes 1 | Notes 2 |
|---|---|---|---|---|---|---|---|
| JWS B8 | Water | 3/29/18 22:00 | | | BSEACD | Autosampler 3 | |
| JWS B9 | Water | 3/29/18 23:00 | | | BSEACD | Autosampler 3 | |
| JWS B10 | Water | 3/30/18 0:00 | | | BSEACD | Autosampler 2 | |
| JWS B11 | Water | 3/30/18 1:00 | | | BSEACD | Autosampler 2 | |
| JWS B12 | Water | 3/30/18 2:00 | | | BSEACD | Autosampler 2 | |
| JWS B13 | Water | 3/30/18 3:00 | | | BSEACD | Autosampler 2 | |
| JWS B14 | Water | 3/30/18 4:00 | | | BSEACD | Autosampler 2 | |
| JWS B15 | Water | 3/30/18 5:00 | | | BSEACD | Autosampler 2 | |
| JWS B16 | Water | 3/30/18 6:00 | | | BSEACD | Autosampler 2 | |
| JWS B17 | Water | 3/30/18 7:00 | | | BSEACD | Autosampler 2 | |
| JWS | Water | 3/30/18 8:00 | | | WVWA | surface grab | |
| JWS B18 | Water | 3/30/18 8:00 | | | BSEACD | Autosampler 2 | |
| JWS B19 | Water | 3/30/18 9:00 | | | BSEACD | Autosampler 2 | |
| JWS B20 | Water | 3/30/18 10:00 | | | BSEACD | Autosampler 2 | |
| JWS B21 | Water | 3/30/18 11:00 | | | BSEACD | Autosampler 2 | |
| WVWA | Water | 3/30/18 11:30 | | | BSEACD | surface grab | |
| Flocke | Water | 3/30/18 11:50 | | | BSEACD | surface grab | |
| JWS B22 | Water | 3/30/18 12:00 | | | BSEACD | Autosampler 2 | |
| JWS B23 | Water | 3/30/18 13:00 | | | BSEACD | Autosampler 2 | |
| JWS B24 | Water | 3/30/18 14:00 | | | BSEACD | Autosampler 2 | |
| JWS | Water | 3/30/18 17:00 | | | WVWA | surface grab | |
| JWS B10 | Water | 3/31/18 0:00 | | | BSEACD | Autosampler 3 | |
| JWS B11 | Water | 3/31/18 1:00 | | | BSEACD | Autosampler 3 | |
| JWS B12 | Water | 3/31/18 2:00 | | | BSEACD | Autosampler 3 | |
| JWS B13 | Water | 3/31/18 3:00 | | | BSEACD | Autosampler 3 | |
| JWS B14 | Water | 3/31/18 4:00 | | | BSEACD | Autosampler 3 | |
| JWS B15 | Water | 3/31/18 5:00 | | | BSEACD | Autosampler 3 | |
| JWS B16 | Water | 3/31/18 6:00 | | | BSEACD | Autosampler 3 | |
| JWS B17 | Water | 3/31/18 7:00 | | | BSEACD | Autosampler 3 | |
| JWS B18 | Water | 3/31/18 8:00 | | | BSEACD | Autosampler 3 | |
| JWS B19 | Water | 3/31/18 9:00 | | | BSEACD | Autosampler 3 | |
| JWS B20 | Water | 3/31/18 10:00 | | | BSEACD | Autosampler 3 | |

| Sate Name | Sample Type | Date Installed | Date removed | Positive Result | Sampler | Notes 1 | Notes 2 |
|---|---|---|---|---|---|---|---|
| JWS B21 | Water | 3/31/18 11:00 | | | BSEACD | Autosampler 3 | |
| Control | Charcoal | 4/4/18 10:00 | 4/4/18 14:00 | | BSEACD | Round 1 | |
| Jacobs Well Rd LWX | Water | 4/4/18 11:00 | | | BSEACD | surface grab | |
| Jacobs Well Rd LWX A | Charcoal | 4/4/18 11:00 | 4/20/18 12:15 | | BSEACD | Round 2 | good, in flow |
| Jacobs Well Rd LWX B | Charcoal | 4/4/18 11:02 | 4/20/18 12:17 | | BSEACD | Round 2 | good, in flow |
| Flocke | Water | 4/4/18 11:15 | | | BSEACD | surface grab | |
| Flocke A | Charcoal | 4/4/18 11:15 | 4/20/18 11:50 | | BSEACD | Round 2 | Hardly running, turned up pressure in hose |
| Flocke B | Charcoal | 4/4/18 11:17 | 4/20/18 11:52 | | BSEACD | Round 2 | Hardly running, turned up pressure in hose |
| WVWA | Water | 4/4/18 12:05 | | | BSEACD | surface grab | |
| WVWA A | Charcoal | 4/4/18 12:05 | 4/20/18 11:30 | | BSEACD | Round 2 | good, hose running |
| WVWA B | Charcoal | 4/4/18 12:07 | 4/20/18 11:32 | | BSEACD | Round 2 | good, hose running |
| Graham | Water | 4/4/18 12:30 | | | BSEACD | surface grab | |
| Graham A | Charcoal | 4/4/18 12:30 | 4/20/18 12:05 | | BSEACD | Round 2 | good, hose running |
| Graham B | Charcoal | 4/4/18 12:32 | 4/20/18 12:07 | | BSEACD | Round 2 | good, hose running |
| JWS | Water | 4/4/18 13:15 | | | BSEACD | surface grab | |
| JWS | Water | 4/6/18 13:30 | | | BSEACD | surface grab | |
| JWS A | Charcoal | 4/6/18 13:30 | 4/20/18 11:00 | | BSEACD | Round 2 | In spring |
| JWS B | Charcoal | 4/6/18 13:32 | 4/20/18 11:02 | | BSEACD | Round 2 | In spring |
| Control | Charcoal | 4/20/18 10:00 | 4/20/18 14:00 | | BSEACD | Round 2 | |
| JWS | Water | 4/20/18 11:00 | | | BSEACD | surface grab | |
| JWS A | Charcoal | 4/20/18 11:00 | 5/4/18 13:15 | | BSEACD | Round 3 | In spring |
| JWS B | Charcoal | 4/20/18 11:02 | 5/4/18 13:17 | | BSEACD | Round 3 | In spring |
| WVWA | Water | 4/20/18 11:30 | | | BSEACD | surface grab | |
| WVWA A | Charcoal | 4/20/18 11:30 | 5/4/18 12:55 | | BSEACD | Round 3 | good, hose running |
| WVWA B | Charcoal | 4/20/18 11:32 | 5/4/18 12:57 | | BSEACD | Round 3 | good, hose running |
| Flocke | Water | 4/20/18 11:50 | | | BSEACD | surface grab | |
| Flocke A | Charcoal | 4/20/18 11:50 | 5/4/18 13:30 | | BSEACD | Round 3 | Hardly running, turned up pressure in hose |
| Flocke B | Charcoal | 4/20/18 11:52 | 5/4/18 13:32 | | BSEACD | Round 3 | Hardly running, turned up pressure in hose |
| Graham | Water | 4/20/18 12:05 | | | BSEACD | surface grab | |
| Graham A | Charcoal | 4/20/18 12:05 | 5/4/18 13:50 | | BSEACD | Round 3 | good, hose running |
| Graham B | Charcoal | 4/20/18 12:07 | 5/4/18 13:52 | | BSEACD | Round 3 | good, hose running |
| Jacobs Well Rd LWX | Water | 4/20/18 12:15 | | | BSEACD | surface grab | |

| Sate Name | Sample Type | Date Installed | Date removed | Positive Result | Sampler | Notes 1 | Notes 2 |
|---|---|---|---|---|---|---|---|
| Jacobs Well Rd LWX A | Charcoal | 4/20/18 12:15 | 5/4/18 14:05 | | BSEACD | Round 3 | good, in flow |
| Jacobs Well Rd LWX B | Charcoal | 4/20/18 12:17 | 5/4/18 14:07 | | BSEACD | Round 3 | good, in flow |
| Control | Charcoal | 5/4/18 12:00 | 5/4/18 16:30 | | BSEACD | Round 3 | |
| WVWA | Water | 5/4/18 12:55 | | | BSEACD | surface grab | |
| JWS | Water | 5/4/18 13:15 | | | BSEACD | surface grab | |
| JWS A | Charcoal | 5/4/18 13:15 | 5/21/18 14:25 | | BSEACD | Round 4 | In spring |
| JWS B | Charcoal | 5/4/18 13:17 | 5/21/18 14:25 | | BSEACD | Round 4 | In spring |
| Flocke | Water | 5/4/18 13:30 | | | BSEACD | surface grab | |
| Graham | Water | 5/4/18 13:50 | | | BSEACD | surface grab | |
| Jacobs Well Rd LWX | Water | 5/4/18 14:05 | | | BSEACD | surface grab | |
| Jacobs Well Rd LWX A | Charcoal | 5/4/18 14:05 | 5/21/18 14:35 | | BSEACD | Round 4 | good, in flow |
| Jacobs Well Rd LWX B | Charcoal | 5/4/18 14:07 | 5/21/18 14:35 | | BSEACD | Round 4 | good, in flow |
| JWS | Water | 5/21/18 14:25 | | | BSEACD | surface grab | |
| Jacobs Well Rd LWX | Water | 5/21/18 14:35 | | | BSEACD | surface grab | |




***Results from screening of water samples from JWS using the District's spectrofluorimeter. Note the flat lines are analyses from JWS and do not show a peak in the RWT range. For comparison, a positive detection of RWT is shown from another dye trace along Onion Creek.***