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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.

- <u>Sunday March 25th staged bladder tanks and filled at the injection site.</u>
- <u>Monday March 26th</u> 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.
- <u>Tuesday March 27th</u> 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.

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

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	
НСР3	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	
НСР3	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 2. Charcoal Sample Results (A and B indicate duplicates); ND indicates non-detection.

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

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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	Date	Date	Positive	Sampler	Notes 1	Notes 2
	Туре	Installed	removed	Result			
	Charcoal	3/23/18	3/27/18		WVWA	background	In spring
JWS		10:15	10:15				
Flocke	Water	3/26/18				background	
		9:45			BSEACD	l	
Flocke A	Charcoal	3/26/18	3/27/18		BSEACD	background	good, hose running
	Charcoal	9:45	12:30			background	good hose running
Flocke B	Charcoar	9.47	3/27/10		DSEACD	Dackground	good, nose running
	Water	3/26/18	12.52			background	
Graham	water	10:20			BSEACD	BuckBround	
	Charcoal	3/26/18	3/27/18		BSEACD	background	good, hose running
Graham A		10:20	11:45			_	
	Charcoal	3/26/18	3/27/18		BSEACD	background	good, hose running
Graham B		10:22	11:47				
	Charcoal	3/26/18	3/27/18		BSEACD	background	
НСР3		10:40	13:15				good, attached
lacobe Wall Rd LW/V	Water	3/26/18				background	
	Charcoal	2/26/19	2/27/10		BSEACD	background	
Jacobs Well Rd I WX A	Charcoar	3/20/18 10·50	13.30		DJEACD	Dackground	good in flow
Jacobs Well Ra LWAA	Charcoal	3/26/18	3/27/18		BSEACD	background	
Jacobs Well Rd LWX B	end cour	10:52	13:32		202/102	SuchBround	good, in flow
	Water	3/26/18				background	
WVWA		12:50			BSEACD	_	
	Charcoal	3/26/18	3/27/18	12@548	BSEACD	background	good, hose running
WVWA A		12:50	11:30				
	Charcoal	3/26/18	3/27/18	13@548	BSEACD	background	good, hose running
WVWA B		12:52	11:32		0.054.00	l	
Lonobon A	Charcoal	3/26/18	3/2//18		BSEACD	background	good, hose running
	Charcoal	3/26/18	3/27/18		BSEACD	background	good bose running
Lanahan B	Charcoar	13:22	11:57		DJLACD	background	good, nose running
	Charcoal	3/27/18	3/28/18		WVWA		In spring
JWS		10:15	10:00				
	Water	3/27/18					
JWS		10:15			WVWA	surface grab	
	Water	3/27/18					
WVWA		11:30			BSEACD	surface grab	
	Charcoal	3/27/18	4/4/18	84@548	BSEACD	Round 1	good, hose running
WWWAA	Charcoal	2/27/19	12:05	92@E40	DSEACD	Bound 1	good boso running
	Charcoar	5/2//10 11·32	4/4/10	82@549	DJEACD	Kounu 1	good, nose running
	Charcoal	3/27/18	4/4/18		BSEACD	Round 1	good, hose running
Graham A	end cour	11:45	12:30		2027.02		2000, 1000 ramma
	Charcoal	3/27/18	4/4/18		BSEACD	Round 1	good, hose running
Graham B		11:47	12:32				
	Water	3/27/18					
Lanahan		11:55			BSEACD	Bakground	
	Charcoal	3/27/18	4/4/18		BSEACD	Round 1	
Lanahan A	Characal	11:55	12:55			Davied 1	hose not running, but wet. Monitoring discontinued
Lanahan R	Charcoal	3/2//18	4/4/18		BSEACD	Round 1	base not running but wat Manitaring discontinued
	Water	3/27/18	12.57				nose not running, but wet. Monitoring discontinued
JWS B1	Water	12:00			BSEACD	Autosampler 1	
Flocke A	Charcoal	3/27/18	4/4/18	18@523	BSEACD	Round 1	good, hose running
		12:30	11:15	_			
	Charcoal	3/27/18	4/4/18	18@523	BSEACD	Round 1	good, hose running
Flocke B		12:32	11:17		_		
	Water	3/27/18					
JWS B2		13:00	41.1.5		BSEACD	Autosampler 1	
	Charcoal	3/27/18	4/4/18		BSEACD	Round 1	wet, on probe. Monitoring discontinued
TCP3	1	13:15	10:45				

Index Index Wate 32.03 10.00 10.00 854.00 Andreg and inflow Normal 10.00	Sate Name	Sample	Date	Date	Positive	Sampler	Notes 1	Notes 2
Index weight w		Туре	Installed	removed	Result			
incode Wint with a state of the st		Charcoal	3/27/18	4/4/18	17@558	BSEACD	Round 1	
MAS VIZTAB VIZTAB VIXTA VIXTA Surface grad Macha Wall ML LUXAB 12/37.8 4/4/18 12/55.8 55.4.0 Rourel 1 pod1 flow MAS BA VIXTB 12/07.8 VIXTB SES.0.0 Autoample 1 MAS BA VIXTB 12/07.18 VIXTB Ses.0.0 Autoample 1 MAS BA VIXTB 12/37.18 VIXTB Ses.0.0 Autoample 1 MAS BA 15.00 12/37.18 VIXTB Ses.0.0 Autoample 1 MAS BA 12/37.18 VIXTB Ses.0.0 Autoample 1 Autoample 1 MAS BA 12/37.18 VIXTB Ses.0.0 Autoample 1 Autoample 1 MAS BA 12/37.18 VIXTB Ses.0.0 Autoample 1 Autoample 1 MAS BA 12/37.18 VIXTB Ses.0.0 Autoample 1 Autoample 1 MAS BA 12/37.18 VIXTB Ses.0.0 Autoample 1 Autoample 1 MAS BA 12/37.18 VIXTB Ses.0.0 A	Jacobs Well Rd LWX A		13:30	11:00				good, in flow
JNS Charcod J330 4/4/18 170/58 65/AC Round good, in flow Jacobs Weil Rd LWX 8 Water 3/32 1102 F Round Round good, in flow JMS 80 Water 3/27/18 1102 SEACO Round Round good, in flow JMS 80 Water 3/27/18 1102 SEACO Autosampler 1 Good, in flow JMS 80 Water 3/27/18 IC SEACO Autosampler 1 Good, in flow JMS 80 Water 3/27/18 IC SEACO Autosampler 1 Good, in flow JMS 80 Water 3/27/18 IC SEACO Autosampler 1 Good, in flow JMS 80 Water 3/27/18 IC SEACO Autosampler 1 Good, in flow JMS 80 Water 3/27/18 IC SEACO Autosampler 1 Good, in flow JMS 80 Water 3/27/18 IC SEACO Autosampler 1 Good, in flow JMS		Water	3/27/18					
Jacobs Weilind LWork 12/17/18 14/18 179/58 6554.00 Round 1 pood, in flow JMS 83 Wate 12/17/18 IC Actionampler 1 Incommentationamentatinamentatinamentationamentationamentationamentatinamentationamentat	JWS		13:30			WVWA	surface grab	
Jacoby Weil Rd UKV8 Water 13.32 (2) 13.2 11.02 (2) 1		Charcoal	3/27/18	4/4/18	17@558	BSEACD	Round 1	
MNS B3 Math JAU J3 JAU J3 JAU J3 JAU J3 JAU J3 JAU J3	Jacobs Well Rd LWX B	14/-1	13:32	11:02				good, in flow
Jay SaWater1200100100010001000MSWater127/18NVMAsurface grabJMS B4Water3/27/18StrACDAutosampler1JMS B4Water3/27/18StrACDAutosampler1JMS B53/27/18StrACDAutosampler1JMS B63/27/18StrACDAutosampler1JMS B63/27/18StrACDAutosampler1JMS B63/27/18StrACDAutosampler1JMS B63/27/18StrACDAutosampler1JMS B73/27/18StrACDAutosampler1JMS B7Water3/27/18StrACDAutosampler1JMS B1Water3/27/18StrACDAutosampler1JMS B11Water3/27/18StrACDAutosampler1JMS B11Water3/27/18StrACDAutosampler1JMS B11Water3/27/18StrACDAutosampler1JMS B11Water3/27/18JMS B		Water	3/2//18				Autocomplay 1	
MN 	1002 83	Wator	2/27/19	-		BSEACD	Autosampier 1	
JNS B4 JNS B4Water3/27/18 3/27/18Autosampler 1JNS B4 JNS B5Water3/27/18 3/27/18WAWASurface grabJNS B5Water3/27/18 10:30WAWASurface grabJNS B5Water3/27/18 3/27/18WAWASurface grabJNS B6Water3/27/18 3/27/18WAWASurface grabJNS B6Water3/27/18 3/27/18WAWASurface grabJNS B7Water3/27/18 3/27/18WAWASurface grabJNS B7Water3/27/18 3/27/18WAWASurface grabJNS B8Water3/27/18 3/27/18BSEACDAutosampler 1JNS B1Water3/27/18 3/27/18BSEACDAutosampler 1JNS B11Water3/27/18 3/27/18BSEACDAutosampler 1JNS B11Water3/27/18 3/27/18BSEACDAutosampler 1JNS B11Water3/27/18 3/27/18BSEACDAutosampler 1JNS B12Water3/27/18 3/27/18BSEACDAutosampler 1JNS B11Water3/27/18 3/27/18BSEACDAutosampler 1JNS B12Water3/27/18 3/28/18WAWASurface grabJNS B12Water3/28/18 3/28/18WAWASurface grabJNSCharcoll 3/28/18 10:00WAWASurface grabJNSWater3/28/18 10:00WAWASurface grabJNSWater3/28/18 10:00WAWASurface grabJNSWa	11/1/5	Water	14.30				surface grab	
JNS BAWater15:00Image: Signal sector	5005	Water	3/27/18				Surface grab	
MySMvere 15.301.5.30Mvere 15.301.5.3	JWS B4		15:00			BSEACD	Autosampler 1	
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Water 3/28/18 WWater 3/28/18 JWS 14:00 WVWA surface grab WVWA 14:40 BSEACD surface grab WVWA 14:40 BSEACD surface grab JWS 3/28/18 WWWA surface grab JWS 15:00 WVWA surface grab JWS B1 15:00 WVWA surface grab JWS B1 3/28/18 BSEACD Autosampler 2 JWS 16:00 WVWA surface grab JWS B2 16:00 BSEACD Autosampler 2 JWS B2 3/28/18 BSEACD BSEACD JWS B2 16:00 BSEACD Autosampler 2 JWS 17:00 WVWA surface grab	Flocke		13:15			BSEACD	surface grab	
JWSIdealIdealWVWASurface grabWVWA3/28/18IdealBSEACDSurface grabWVWA14:40BSEACDSurface grabJWS15:00WVWASurface grabJWS B115:00WVWASurface grabJWS B115:00BSEACDAutosampler 2JWS B115:00MWWASurface grabJWS B115:00MWWASurface grabJWS B116:00MWWASurface grabJWS B23/28/18MWWASurface grabJWS B216:00MWWASurface grabJWS B216:00BSEACDAutosampler 2JWS B216:00MWWASurface grabJWS B217:00MWWASurface grab		Water	3/28/18				-	
Water3/28/18Mater3/28/18WVWA14:40BSEACDsurface grabJWS3/28/18MaterMVWAJWS B115:00WVWAsurface grabJWS B115:00BSEACDAutosampler 2JWS B115:00BSEACDAutosampler 2JWS B116:00WWAsurface grabJWS B216:00WWAsurface grabJWS B216:00BSEACDAutosampler 2JWS B217:00MSWASurface grab	JWS		14:00			WVWA	surface grab	
WVWA14:40BSEACDsurface grabJWS3/28/18Water3/28/18JWS B115:00WVWAsurface grabJWS B115:00BSEACDAutosampler 2JWS B115:00Water3/28/18JWS B13/28/18WaterBSEACDJWS B116:00WVWAsurface grabJWS B23/28/18MaterBSEACDJWS B216:00BSEACDAutosampler 2JWS B217:00Water17:00JWS B217:00WWWASurface grab		Water	3/28/18					
Water 3/28/18 15:00 WWater 3/28/18 15:00 WWWA surface grab JWS B1 3/28/18 15:00 BSEACD Autosampler 2 JWS B1 3/28/18 16:00 WWWA surface grab JWS B2 3/28/18 16:00 WWWA surface grab JWS B2 3/28/18 16:00 BSEACD Autosampler 2 JWS B2 3/28/18 16:00 BSEACD Autosampler 2 JWS B2 3/28/18 16:00 BSEACD Autosampler 2 JWS B2 16:00 BSEACD Autosampler 2 JWS B2 16:00 BSEACD Autosampler 2 JWS B2 17:00 WWWA surface grab	WVWA		14:40			BSEACD	surface grab	
JWS 15:00 WVWA surface grab JWS B1 3/28/18 15:00 BSEACD Autosampler 2 JWS B1 3/28/18 16:00 WVWA surface grab JWS B2 3/28/18 16:00 WVWA surface grab JWS B2 3/28/18 16:00 WVWA surface grab JWS B2 3/28/18 16:00 BSEACD Autosampler 2 JWS B2 3/28/18 16:00 BSEACD Autosampler 2 JWS B2 16:00 BSEACD Autosampler 2 JWS B2 16:00 BSEACD Autosampler 2 JWS B2 16:00 BSEACD Autosampler 2 JWS B2 17:00 WWWA surface grab		Water	3/28/18					
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JWS B1 IS:00 IS:00 ISEACD Autosampler 2 JWS B2 3/28/18 MWWA Surface grab JWS B2 3/28/18 MWWA Surface grab JWS B2 3/28/18 BEEACD Autosampler 2 JWS B2 3/28/18 BEEACD Autosampler 2 JWS B2 16:00 BEEACD Autosampler 2 JWS B2 17:00 WWWA Surface grab		Water	3/28/18			DCEACD	Automatica	
Water 3/26/18 WVWA surface grab JWS 16:00 WVWA surface grab JWS B2 3/28/18 BSEACD Autosampler 2 JWS 3/28/18 BSEACD Autosampler 2 JWS 17:00 WVWA surface grab	14A2 RT	Water.	15:00			BSEACD	Autosampier 2	
Water 3/28/18 BSEACD Autosampler 2 JWS B2 Water 3/28/18 Water Water JWS 16:00 BSEACD Autosampler 2	IWS	water	5/20/18 16:00			\\/\/\A	surface grab	
JWS B2 Mater 3/28/18 BSEACD Autosampler 2 JWS 3/28/18 Wurder Wurder<	3003	Water	3/28/18			** * **/A	Surruce grav	
Water 3/28/18 WVWA surface grab	JWS B2		16:00			BSEACD	Autosampler 2	
JWS 17:00 WVWA surface grab	-	Water	3/28/18			1		
	JWS		17:00			WVWA	surface grab	

Sate Name	Sample	Date	Date	Positive	Sampler	Notes 1	Notes 2
	Туре	Installed	removed	Result			
	Water	3/28/18					
JWS B3		17:00			BSEACD	Autosampler 2	
	Water	3/28/18					
JWS		18:00			WVWA	surface grab	
	Water	3/28/18				Autocomplar 2	
JVV3 D4	Water	3/28/18			DJEACD	Autosampier 2	
IWS B5	water	19:00			BSEACD	Autosampler 2	
	Water	3/28/18					
JWS B6		20:00			BSEACD	Autosampler 2	
	Water	3/28/18					
JWS B7		21:00			BSEACD	Autosampler 2	
	Water	3/28/18					
JWS B8	14/-1	22:00			BSEACD	Autosampler 2	
	water	3/28/18			REACD	Autocomplor 2	
3003 83	Water	3/29/18			BJLACD	Autosampier 2	
JWS B13	water	0:00			BSEACD	Autosampler 1	
	Water	3/29/18					
JWS B14		1:00			BSEACD	Autosampler 1	
	Water	3/29/18					
JWS B15		2:00			BSEACD	Autosampler 1	
	Water	3/29/18					
JWS B16	\M/ator	3:00			BSEACD	Autosampler 1	
IW/S B17	water	3/29/18			BSEACD	Autosampler 1	
5005 017	Water	3/29/18			DOLACD	Autosumpier 1	
JWS B18		5:00			BSEACD	Autosampler 1	
	Water	3/29/18					
JWS B19		6:00			BSEACD	Autosampler 1	
	Water	3/29/18					
JWS B20	\A/atax	7:00			BSEACD	Autosampler 1	
1W/S	water	3/29/18			\\/\/\A/A	surface grab	
5005	Water	3/29/18				Surface Brub	
JWS B21		8:00			BSEACD	Autosampler 1	
	Water	3/29/18					
JWS B22		9:00			BSEACD	Autosampler 1	
NA/C 822	Water	3/29/18			DEFACD	A. 1	
JWS B23	\A/atar	10:00			BSEACD	Autosampier 1	
JWS B24	water	11:00			BSEACD	Autosampler 1	
	Water	3/29/18					
JWS		12:00			WVWA	surface grab	
	Water	3/29/18					
Flocke		13:45			BSEACD	surface grab	
	Water	3/29/18				ourface grab	
VV V VVA	Water	3/29/18			BSEACD	Surface grab	
JWS B1	water	15:00			BSEACD	Autosampler 3	
	Water	3/29/18					
JWS		16:00			WVWA	surface grab	
	Water	3/29/18					
JWS B2		16:00			BSEACD	Autosampler 3	
	Water	3/29/18				Autocomplar 2	
20 201	Water	3/29/18			DJEACD	Autosampier 3	
JWS B4	water	18:00			BSEACD	Autosampler 3	
-	Water	3/29/18					
JWS B5		19:00			BSEACD	Autosampler 3	
	Water	3/29/18					
JWS B6		20:00			BSEACD	Autosampler 3	
	Water	3/29/18				Autocomplex 2	
1442 R1		21:00			RSEACD	Autosampler 3	

Sate Name	Sample	Date	Date	Positive	Sampler	Notes 1	Notes 2
	Туре	Installed	removed	Result			
NA/6 DO	Water	3/29/18			DEFACD	A	
JWS B8	Wator	22:00			BSEACD	Autosampler 3	
IWS B9	water	3/29/18 23·00			BSEACD	Autosampler 3	
1110 05	Water	3/30/18			DOLITOD	/ acosumplet s	
JWS B10		0:00			BSEACD	Autosampler 2	
	Water	3/30/18					
JWS B11		1:00			BSEACD	Autosampler 2	
NA/C D12	Water	3/30/18				Autoreur 100 2	
JWS B12	Water	2:00			BSEACD	Autosampier 2	
JWS B13	water	3:00			BSEACD	Autosampler 2	
	Water	3/30/18				•	
JWS B14		4:00			BSEACD	Autosampler 2	
	Water	3/30/18					
JWS B15	\A/atau	5:00			BSEACD	Autosampler 2	
IWS B16	water	5/30/18 6·00			BSEACD	Autosampler 2	
	Water	3/30/18			502,105		
JWS B17		7:00			BSEACD	Autosampler 2	
	Water	3/30/18					
JWS		8:00		-	WVWA	surface grab	
	water	3/30/18			BSEACD	Autosampler 2	
3005 010	Water	3/30/18			DJLACD	Autosumpler 2	
JWS B19		9:00			BSEACD	Autosampler 2	
	Water	3/30/18					
JWS B20		10:00			BSEACD	Autosampler 2	
	Water	3/30/18			RSEACD	Autocomplor 2	
3003 021	Water	3/30/18			DJLACD	Autosampier 2	
WVWA		11:30			BSEACD	surface grab	
	Water	3/30/18					
Flocke	\A/atau	11:50			BSEACD	surface grab	
IWS B22	water	3/30/18 12:00			BSEACD	Autosampler 2	
	Water	3/30/18			502,105		
JWS B23		13:00			BSEACD	Autosampler 2	
	Water	3/30/18					
JWS B24	Matar	14:00			BSEACD	Autosampler 2	
IWS	water	3/30/18			WVWA	surface grab	
	Water	3/31/18					
JWS B10		0:00			BSEACD	Autosampler 3	
	Water	3/31/18					
JWS B11	\M/ator	1:00			BSEACD	Autosampler 3	
IWS B12	water	2:00			BSFACD	Autosampler 3	
	Water	3/31/18					
JWS B13		3:00			BSEACD	Autosampler 3	
	Water	3/31/18					
JWS B14	Wator	4:00			BSEACD	Autosampler 3	
JWS B15	water	5:00			BSEACD	Autosampler 3	
	Water	3/31/18					
JWS B16		6:00			BSEACD	Autosampler 3	
	Water	3/31/18			DCEACO	Auto	
1M2 RT1	Water	7:00			BSEACD	Autosampler 3	
JWS B18	water	8:00			BSEACD	Autosampler 3	
	Water	3/31/18			-		
JWS B19		9:00			BSEACD	Autosampler 3	
INVC 020	Water	3/31/18			DCEACD	A	
14A2 R50		10:00			BSEACD	Autosampler 3	

Sate Name	Sample	Date	Date	Positive	Sampler	Notes 1	Notes 2
	Туре	Installed	removed	Result			
	Water	3/31/18					
JWS B21		11:00			BSEACD	Autosampler 3	
Control	Charcoal	4/4/18	4/4/18		REACD	Round 1	
Control	Water	4/4/18	14.00		DJEACD		
Jacobs Well Rd LWX	water	11:00			BSEACD	surface grab	
	Charcoal	4/4/18	4/20/18		BSEACD		
Jacobs Well Rd LWX A		11:00	12:15			Round 2	good, in flow
	Charcoal	4/4/18	4/20/18		BSEACD		
Jacobs Well Rd LWX B		11:02	12:17			Round 2	good, in flow
Flocke	water	4/4/18			BSEACD	surface grab	
Flocke A	Charcoal	4/4/18	4/20/18		BSEACD	Surface grab	
	enarcour	11:15	11:50		502.105	Round 2	Hardly running, turned up pressure in hose
	Charcoal	4/4/18	4/20/18		BSEACD		
Flocke B		11:17	11:52			Round 2	Hardly running, turned up pressure in hose
	Water	4/4/18			DOFACD	f	
WVWA	Charcoal	12:05	1/20/19		BSEACD	surface grab	good boso rupping
WVWA A	Charcoar	4/4/10	4/20/18		DJEACD	Round 2	
	Charcoal	4/4/18	4/20/18		BSEACD		good, hose running
WVWA B		12:07	11:32			Round 2	
	Water	4/4/18					
Graham		12:30			BSEACD	surface grab	
Crohom A	Charcoal	4/4/18	4/20/18		BSEACD	Dound 2	good, hose running
Granam A	Charcoal	12:30	12:05		BSEACD	Round 2	good hose rupping
Graham B	Charcoar	12:32	12:07		DJLACD	Round 2	
	Water	4/4/18					
JWS		13:15			BSEACD	surface grab	
	Water	4/6/18					
JWS		13:30			BSEACD	surface grab	
1\N/S A	Charcoal	4/6/18	4/20/18		BSEACD	Round 2	in spring
500570	Charcoal	4/6/18	4/20/18		DOLINOD	Nound 2	In spring
JWS B		13:32	11:02		BSEACD	Round 2	
	Charcoal	4/20/18	4/20/18				
Control	14/-1	10:00	14:00		BSEACD	Round 2	
1\\/S	water	4/20/18			BSEACD	surface grab	
5115	Charcoal	4/20/18	5/4/18		DOLINOD	Surface Bras	In spring
JWS A		11:00	13:15		BSEACD	Round 3	
	Charcoal	4/20/18	5/4/18				In spring
JWS B		11:02	13:17		BSEACD	Round 3	
	Water	4/20/18			RSEACD	surface grab	
VVVVA	Charcoal	4/20/18	5/4/18		BJLACD	Surface grab	good hose running
WVWA A	enarcour	11:30	12:55		BSEACD	Round 3	Booghiese raining
	Charcoal	4/20/18	5/4/18				good, hose running
WVWA B		11:32	12:57		BSEACD	Round 3	
Flocke	Water	4/20/18			DOFACD	f	
Elocko A	Charcoal	11:50	5/1/18		BSEACD	surface grab	
TIOCKE A	Charcoar	4/20/18	13:30		BSEACD	Round 3	Hardly running, turned up pressure in hose
	Charcoal	4/20/18	5/4/18				
Flocke B		11:52	13:32		BSEACD	Round 3	Hardly running, turned up pressure in hose
	Water	4/20/18					
Graham	Charrie	12:05	F/4/40		BSEACD	surface grab	
Graham A	Charcoal	4/20/18	5/4/18 13·50		BSEACD	Bound 3	good, nose running
Stanant A	Charcoal	4/20/18	5/4/18		DJLACD		good, hose running
Graham B	0.10.0001	12:07	13:52		BSEACD	Round 3	
	Water	4/20/18					
Jacobs Well Rd LWX		12:15			BSEACD	surface grab	

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