Results of Tracing for Lanier and Hog Wallow Springs in the Balcones Canyonlands Preserve, Bull Creek
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Abstract

*Fluorescein and eosine dye traces were conducted in the Balcones Canyonlands Preserve Franklin Tract along Bull Creek to determine the source of water discharging from two springs (Hog Wallow and Lanier) adjacent to Tributary 7 and the main stem of Bull Creek, respectively. Both springs provide habitat for the threatened Jollyville Plateau Salamander (*Eurycea tonkawae*). The springs are located downstream of recharging stretches of the creeks where the surface water flow drops to zero then re-emerges at or adjacent to the spring. Dye was injected in these recharging stretches in both Tributary 7 and the main stem of Bull Creek on July 22nd and August 6th, 2014, respectively. Sites were monitored downstream, adjacent to and in the springs, as well as at a third spring, Pit Spring, located downstream of Lanier Spring and comprised of both bedrock channel and alluvial bank deposit spring outlets. Fluorescein dye was detected at Hog Wallow Spring within 9 hours of injection upstream and peaked at 28.6 ppb in the water collected at the spring. Dye from the Hog Wallow trace was also detected upstream of the confluence of Tributary 7 and the main stem of Bull Creek at Pit Spring. Eosine dye was detected within 11 hours of injection at Lanier Spring, and peaked at a water concentration of 8.38 ppb. These results, along with a previous dye trace in this area, indicate that there is both a shallow alluvial groundwater and upper Glen Rose bedrock groundwater source feeding Pit Spring. Due to the fast movement of water from the point of injection to both Hog Wallow and Lanier springs, along with the high concentrations of dye observed at both springs, the source of water to the springs providing salamander habitat is water that has been recently exposed to the surface. This has implications for management of surface water in this area due to recharging stream water reaching the springs within hours, allowing for very little time for natural filtration of contaminants.*

Introduction

There are multiple springs located in the Balcones Canyonlands Preserve (BCP) along Bull Creek (Fig. 1) that provide habitat for the threatened Jollyville Plateau Salamander (*Eurycea tonkawae*), but the source water for most of these springs is unknown. A likely source is surface water recharging the shallow groundwater system, which then re-emerges at the spring outlets as found by Johns (2014). In order to understand groundwater systems, especially in karst settings, dye tracing is often used to investigate groundwater flow routes and sources of resurfacing groundwater (Hauwert et al. 2004). Shallow groundwater movement in the BCP has been studied in multiple sections of Bull Creek using dye traces (Pit Spring trace, Four Points trace), but a greater understanding of the recharging water along and in the creek is needed. The purpose of this study is to further investigate groundwater flow direction and velocity in the subsurface surrounding Hog Wallow and Lanier Springs.

Prior to injection of dye at the two sites, flow in Bull Creek was low enough that there was no observable surface water flow from the point of injection to just upstream of Lanier Spring, but high enough that the spring discharge was measureable. Similar conditions were observed on Tributary 7 with respect to Hog Wallow Spring. Throughout the study period, flows discharging from both springs decreased to near zero until a large storm event on September 19th, 2014, caused increases in spring discharge and produced surface flow through the creek bed between injection and monitoring points. This storm event also created surface flow down the main channel of Bull Creek from Lanier to Pit Spring.

Hog Wallow Spring

Hog Wallow Spring discharges directly into Tributary 7 of Bull Creek upstream of the confluence with the main channel in the BCP (Fig. 2). As of July 2014, the spring was discharging approximately 76.4 gallons per minute (gpm) into Tributary 7 (Photo 1), which is a significant contribution to the overall stream flow. Approximately 600 feet upstream of Hog Wallow Spring, Tributary 7 stream flow drops to zero. At this point, water appears to be infiltrating into alluvial sediments in the creek bed (Photo 2). The water daylights again just upstream of Hog Wallow Spring, however the water at this site was pooled and stagnant for each visit in the study period.

Lanier Spring

Lanier Spring is adjacent to the main stem of Bull Creek downstream of the confluence with Tributary 8 (Fig. 2). Flow entering Bull Creek from the spring was measured at 38 gpm in July 2014 (Table 3). Bull Creek, approximately 800 feet upstream of Lanier Spring, disappears under the alluvium in the channel, similar to Tributary 7, and daylights further downstream adjacent to the spring. The area along Bull Creek where the surface flow decreases to zero consists of travertine/tufa dams that create a small grotto and pool

(Photo 4). Throughout the study period, the point of recharge to the alluvium migrated further upstream due to decreasing stream flow.

Pit Spring

Pit Spring is located in the main channel of Bull Creek downstream of Lanier Spring and just upstream of the confluence with Tributary 7. Pit Spring discharges a significant volume of water into Bull Creek. The spring emerges from solution-enlarged burrows and fractures in the upper Glen Rose bedrock stream channel as well as from alluvial deposits on the bank of the stream. A previous tracing study (Johns 2014) determined that the source of the water discharging from alluvial deposits at Pit Spring was a section of the creek further upstream where surface water flows under alluvial deposits in the creek bed. This water was moving through the alluvium at a velocity of approximately 2,560 ft/day (or 107 ft/hr). The flow coming out of the springs is thought to be due to the presence of a paleochannel adjacent to the modern stream channel that creates a preferential flowpath for the shallow groundwater. Adjacent to the alluvial bank, water discharges from fractures and openings in the Glen Rose limestone channel. The source of water discharging from fractures and conduits in the limestone bedrock at Pit Spring, however, was not determined in the previous study.

The exposed geology in the study area is composed of Glen Rose limestone bedrock overlain by alluvial deposits. Glen Rose limestone is typically considered a non-karstic formation with few solution conduits and slow groundwater movement relative to Edwards aquifer formations. Although there is relatively little elevation change in the study area, there is a Glen Rose outcrop just downstream of the injection point for the Hog Wallow Spring trace on Tributary 7.

Methods

All sites in this study are located in the BCP Franklin tract, which is managed by the City of Austin. Sites upstream, adjacent to, and downstream from Lanier and Hog Wallow Springs were monitored throughout the study. Sites downstream of Pit Spring in the main channel of Bull Creek were also monitored. There were two sites of dye injection upstream of Lanier and Hog Wallow Springs in the main stem of Bull Creek and Tributary 7, respectively (Fig. 2).

Sites were monitored using a combination of charcoal receptor packets and grab water samples. The charcoal receptors were fastened to roots or rocks in the stream channel and water samples were collected at the time of charcoal packet collection.

Throughout the period of study, there were 4 total storm events (Fig. 3). The first two rain events on June 12th and June 23rd occurred prior to tracer injection, and did not produce enough precipitation to increase Bull Creek discharge above 13 cfs, with a baseflow of approximately 4 cfs. The third rain event on July 17th produced enough rainfall to increase Bull Creek flows to 60 cfs and recharged the shallow groundwater system for favorable injection conditions. The main stem of Bull Creek continued to flow across the injection area until early August. The final rain event produced Bull Creek flows of over 300 cfs on September 19th, 2014. This storm reactivated dye that had settled or was absorbed to sediment and rocks in the creekbed, so collection of charcoal and water samples was extended for longer than initially planned. Flow measurements are taken from the USGS gaging station on Bull Creek downstream of the study area (http://waterdata.usgs.gov/nwis/uv?site_no=08154700).

Water and charcoal samples were analyzed for fluorescein, eosine, rhodamine WT and sulforhodamine B by the Ozark Underground Laboratory, Protem, Missouri (Aley, 1999).

Hog Wallow Spring Trace

For dye injection upstream of Hog Wallow Spring, 0.25 pounds of environmentally-safe fluorescein dye was mixed with one gallon of water and poured into flowing stream water approximately 350 feet upstream of where the surface water disappears and approximately 1,000 feet upstream of where the spring discharges into the tributary. A third of the dye mix was injected 3 times over a 12 hour period at 9:40, 13:15 and 18:50 on July 22nd to ensure that the dye concentrations at Hog Wallow Spring would not exceed a 24 hour average of 2 ppm for the safety of the salamanders in the spring (Smart 1984, Field et al. 1995). The straight-line distance from the last flowing water below the injection point to the spring is approximately 450 feet.

Monitoring at Hog Wallow Springs consisted of daily receptor collection for a week after injection, followed by weekly collection for 6 weeks after injection. Grab water samples were collected at each receptor changing. Grab water sample concentrations are reported in ppb, while charcoal fluorescein concentrations are reported as an average concentration per day. The charcoal concentrations are calculated by dividing the total concentration detected in the charcoal packet by the total days/hours of deployment.

Hog Wallow Monitoring sites include:

- Pooled water in Tributary 7 adjacent to Hog Wallow Spring (T7AH)
- Spring outlet on fence surrounding spring (HWS)
- Tributary 7 channel just downstream of where Hog Wallow Spring enters the tributary (T7DH)
- Tributary 7 further downstream of the spring but upstream of an abandoned stock pond (T7AT)
- Bull Creek downstream of Pit Spring (BDPS)
- Bull Creek downstream of confluence with Tributary 7 (BD)
- Bull Creek at the Preserve boundary fence. (BCPF)

Lanier Spring

Three eighths (0.375) of a pound of eosine dye was injected on August 6th, 2014, and split over three injection times (09:25, 12:00, and 20:00). The dye was poured into the main stem of Bull Creek upstream of the confluence with Tributary 8. The point of injection is approximately 500 feet upstream of a section of the creek covered in travertine deposits and dams (Photo 5). The injection area has flowing water through a narrow possibly channelized section of the stream where surface water disappears when it reaches the travertine deposits. Sites downstream of Lanier were monitored daily for 5 days after injection, followed by weekly monitoring visits for 6 weeks.

Lanier Monitoring sites include:

- Lanier Spring outlet (LNS)
- The main stem of Bull Creek adjacent to Lanier, but upstream of the springs confluence with the main stem (BDT8)
- Bull Creek approximately 180 feet downstream of Lanier Spring (BDLS)
- Bull Creek approximately 600 feet downstream of Lanier Spring, just downstream of a small natural weir (BWDL)
- One alluvial spring outlet on the bank of Bull Creek in the Pit Spring section of the creek (PSB1)
- Two channel outlets in the Pit Spring section of Bull Creek where water is discharging from bedrock (PSC2 and PSC3). PSC3 was added after PSC2 and PSB1 stopped flowing.

Stream discharge values for Lanier Spring, Bull Creek upstream of Lanier and Bull Creek downstream of Lanier can be found in Table 1.

Results and Discussion

Tracers were detected in several of the monitored sites within hours of injection. Dry conditions during early August led to flow decreasing to zero at a number of sites. Hog Wallow Spring was dry by August 12th, and the main stem of Bull Creek adjacent to Lanier Spring was dry by September 3rd. Lanier Spring, however, continued to have an estimated flow of 3–4 gpm throughout this period. The sites that did go dry during late August continued to stay dry until rains on September 17th, 2014, recharged the shallow groundwater. After the rains in September, all sites continued to have flowing water until the end of monitoring in mid-October.

The timing of peak water concentrations reported here is dependent on when sampling trips occurred. Because an autosampler was not employed to collect more frequent water samples, higher peak water concentrations could occur before or after the times that are reported.

Hog Wallow Spring Trace

Fluorescein dye was detected in charcoal packets and water samples at Hog Wallow Spring (HWS), Tributary 7 adjacent to Hog Wallow Spring (T7AH), Tributary 7 downstream of Hog Wallow Spring (T7DH) and Tributary 7 upstream of the stock tank (T7AT) within 9 hours after injection (Fig. 4). Site T7AT is further downstream of the spring than T7DH, but still upstream of the confluence with Bull Creek. Both water grab and charcoal samples showed a similar timing of peak concentrations that spike in concentrations within 24 hours of injection (Fig. 5). Assuming a straight-line distance from the injection point to Hog Wallow Spring, the approximate groundwater velocity is 70 ft/hr.

Dye was also detected in Bull Creek downstream of the confluence with Tributary 7 (BD) within 3 days of injection (Fig. 6). Estimated groundwater velocity to these sites is 55 to 82 ft/day (Table 2). Dye was also detected in samples that were retrieved from Pit Spring channel sites 7 days after injection. These sites are located over 2,200 feet away from the injection site and discharge from solution-enlarged features in the channel limestone bedrock (Photo 6). The time of arrival at the Pit Spring channel sites implies a minimum groundwater velocity of 13 ft/hr. Travel times, calculated velocities and peak concentrations are summarized in Table 2.

Peak charcoal dye concentrations were highest at Hog Wallow Spring (2,993 ppb/day), followed by Tributary 7 downstream of HWS but upstream of the stock tank (T7AT) (854 ppb/day). The lowest peak dye concentration on Tributary 7 was observed at site T7AH adjacent to Hog Wallow Spring (7.2 ppb/day). Peak fluorescein dye concentrations at Pit Spring were only 1.9 ppb/day (Fig. 7), while those further downstream on Bull Creek at sites BDPS, BD and BCPF were 4.92, 1.43 and 1.06 ppb/day, respectively (Table 2).

Sample collection at Hog Wallow Spring continued until October 16th, 2014. Although charcoal fluorescein concentrations dropped to zero prior to the large storm event on September 17th, low concentrations (up to 2.7 ppb/day) were seen again at the spring, along with sites adjacent to and downstream (Fig. 8).

The disappearance of water upstream of Hog Wallow Spring in an area of abundant alluvium, the spring location off the main creek channel, and the relatively fast arrival time of the tracer suggests that the surface water recharging upstream is migrating through porous and permeable alluvial fill of a former creek channel (i.e., a paleochannel) (Fig. 9). Observations of water present but not consistently flowing in the current creek channel and higher dye concentrations in the spring suggests that the water recharging upstream is preferentially flowing through the paleochannel rather than through the alluvial material of the present creek channel. Natural carbonate cementation of the channel alluvium may impact water migration as well.

According to previous tracing measurements (Johns 2014), Pit Spring has two different water sources. The source of water to the alluvial bank deposits was found by Johns (2014) to be re-emerging surface water from upstream, presumably following a paleochannel to the spring; however that study did not determine the source of water discharging from the bedrock outlets in the channel. The results from this study suggest that the water discharging from the channel bedrock is Tributary 7 surface water. Although dye was detected at both bank and channel outlets (PSB1 and PSC2, respectively), the tracer hit on the bank outlet is assumed to be due to a channel outlet just upstream of the charcoal packet. Water from Tributary 7 is most likely discharging to only the channel bedrock outlets, and then flowing downstream where it is detected by the bank outlet receptors. This water is moving into the upper part of the Glen Rose bedrock and presumably not deeper into the aquifer. Tributary 7 enters the main channel downstream of Pit Spring (Fig. 2); however Pit Spring is at a lower surface elevation (750 feet msl) than the injection point (784 feet msl) giving a 1.5% slope from the injection point to Pit Spring, suggesting that the water sourcing the bedrock outlets at Pit Spring is moving down gradient.

Flow measurements taken directly from Hog Wallow Spring on July 7th are greater than those taken further downstream near monitoring site T7AT (Table 1). These measurements could suggest a decrease in surface flow due to water being lost to the shallow bedrock groundwater system, which is probably the water carrying dye that reappears at the Pit Spring channel outlets.

Lanier Spring Trace

Eosine dye was detected at Lanier Spring within 11 hours of injection on the main stem of Bull Creek (Fig. 10). Downstream from the confluence of Lanier Spring and Bull Creek (BDLS) dye was detected 25 hours after injection, and within 49 hours further downstream (BWDL). Groundwater velocity to Lanier Spring is estimated to be approximately 79 ft/hr based on a straight-line distance from the point of recharge upstream (the injection point) to the spring itself (Table 3). Dye was not detected in the main channel of Bull Creek adjacent to Lanier Spring (BDT8) until almost 6 days after injection. Travel times, calculated velocities and peak concentrations are summarized in Table 3.

Peak charcoal dye concentrations for this trace were highest at the spring discharge point (496 ppb/day) and decreased further downstream to 138 and 8 ppb/day at sites BDLS and BWDL, respectively. The peak charcoal concentration in Bull Creek adjacent to Lanier Spring (BDT8), however, was only 0.5 ppb/day. No dye was detected at either channel or bank outlets at Pit Spring, which are located more than 4,000 feet downstream of the injection point, until after the September 17th rain event which carried surface flow directly to Pit Spring (Fig. 10).

After the September 17th rain event, concentrations of eosine in charcoal packets downstream of Lanier Springs increased from near zero to almost 6 ppb/day (Fig. 10) due to surface water carrying dye directly from the injection area to the downstream monitoring sites. Samples taken directly from the springs did not show a dye response to the rain event; however these samples stayed above eosine detection limits for the entire study period (Fig. 8).

The disappearance of water upstream of Lanier Spring in an area of abundant alluvium, the spring location off the main creek channel, and relatively fast arrival time of the tracer suggests that the surface water recharging upstream is migrating through porous and permeable alluvial fill of a former creek channel (a paleochannel) similar to Hog Wallow and the Pit Spring bank outlets (Fig. 9). Flow measurements showing greater volume of water flowing from the spring than the adjacent creek channel and consistently higher dye concentrations in the spring suggests that the water recharging upstream is preferentially flowing through the paleochannel rather than through the alluvial material of the present creek channel. Natural carbonate cementation of the channel alluvium may impact water migration as well.

Flow measurements taken in and around Lanier Spring on July 7th indicate that the spring contributes a majority of the flow to Bull Creek in this section. The spring has a flow (37 gpm) 4 times greater than that of the adjacent stream (9.2 gpm). Downstream of where Lanier enters the channel (BDLS), flow is even greater (51 gpm) suggesting additional inputs, most likely from recharging water upstream (Table 3).

Conclusions

Results of this study suggest that surface water is recharging a shallow groundwater system by moving through alluvial deposits surrounding Bull Creek and Tributary 7 to two springs (Lanier and Hog Wallow, respectively) at a velocity of approximately 70–80 ft/hr (Figures 11 and 12). Recharging surface water is preferentially migrating through paleochannels in the alluvium adjacent to the current creek channels. Both of these springs are habitat for the threatened Jollyville Plateau Salamander, and it is important to understand the groundwater source and flowpath to the spring in order to best protect the salamander. Water discharging from the springs has recently been exposed to the surface. The potential for surface contamination to these springs is therefore much higher than would be expected if the water feeding the springs originated from a longer groundwater flowpath that allows for greater filtration and attenuation of contaminants.

This study also suggests that the source of water discharging from fractures and solution enlarged conduits in the bedrock channel at Pit Spring is surface water from Tributary 7 of Bull Creek. Because the confluence of Tributary 7 with the main channel is downstream of Pit Spring, water must be traveling through the subsurface to reach the spring bedrock outlets. This implies that there is a shallow groundwater system in the bedrock itself. Although the channel outlets appear enlarged from dissolution of the limestone, the migration velocities of about 13 ft/hr are slower than those in nearby karst areas, suggesting that either the dissolution is only associated with the channel sites and not formation of a conduit system, or the groundwater gradient is very low. The appearance of fluorescein dye in Bull Creek upstream of the surface water confluence suggests that the groundwater flow is moving in a slightly different direction than surface water flow. Water that is recharging the shallow bedrock on Tributary 7 may enter Bull Creek by discharging in the channel at Pit Spring, while surface water from Tributary 7 will enter Bull Creek further downstream.

Recommendations

Groundwater tracing offers valuable information regarding flow paths and source water for springs that provide Jollyville Plateau Salamander (*Eurycea tonkawae*) habitat. While this study increases our understanding of the interaction between surface water and groundwater around two springs in the study area, creating a more general conceptual model of groundwater flow in this region will allow for better protection of water quality and threatened species. Understanding groundwater flow from Tributary 7 to Pit Spring, specifically, would be enhanced by a more rigorous study of stream gaging measurements. Because the results of this study suggest that the water discharging from springs that provide salamander habitat is water that has been recently exposed to the surface, it would be beneficial to trace additional springs that are near development and potential pollution sources.

References

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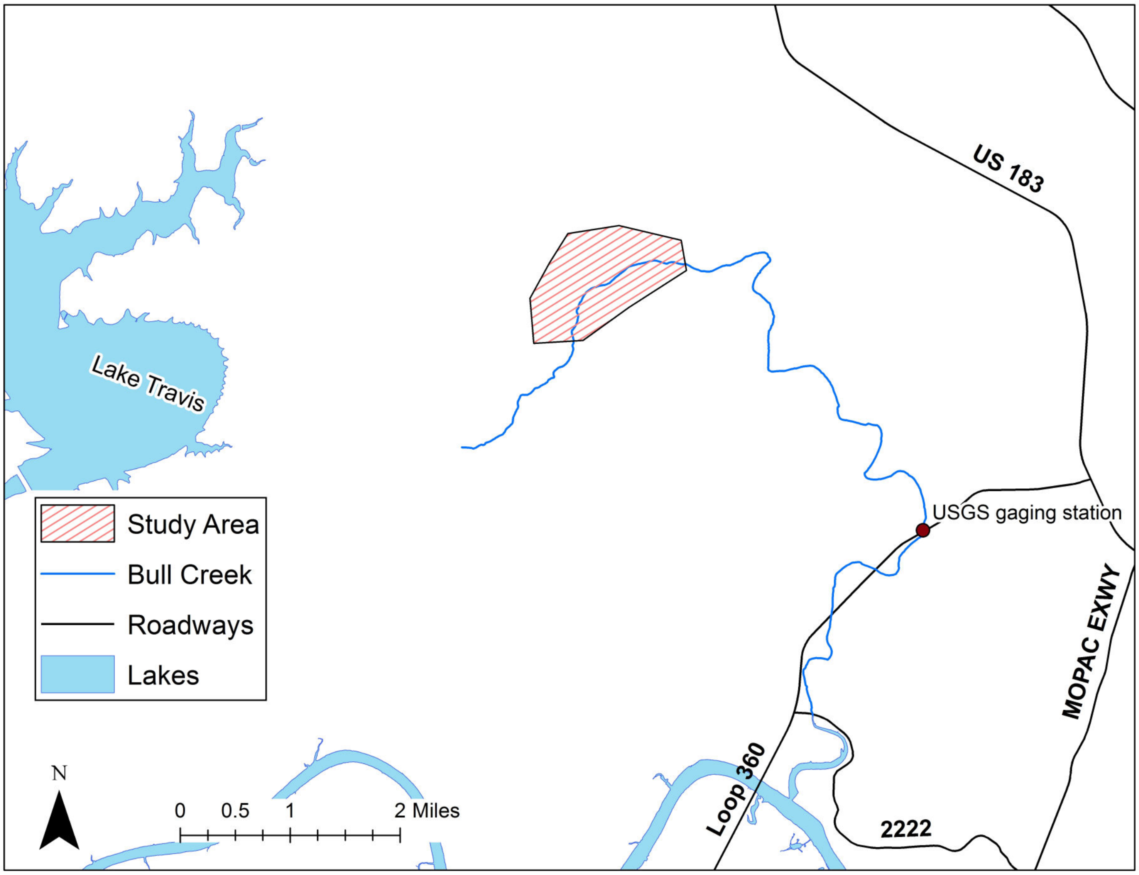

Figure 1. Map of the study area. Hatched lines indicate approximate study area containing the locations of the monitoring sites for both traces.

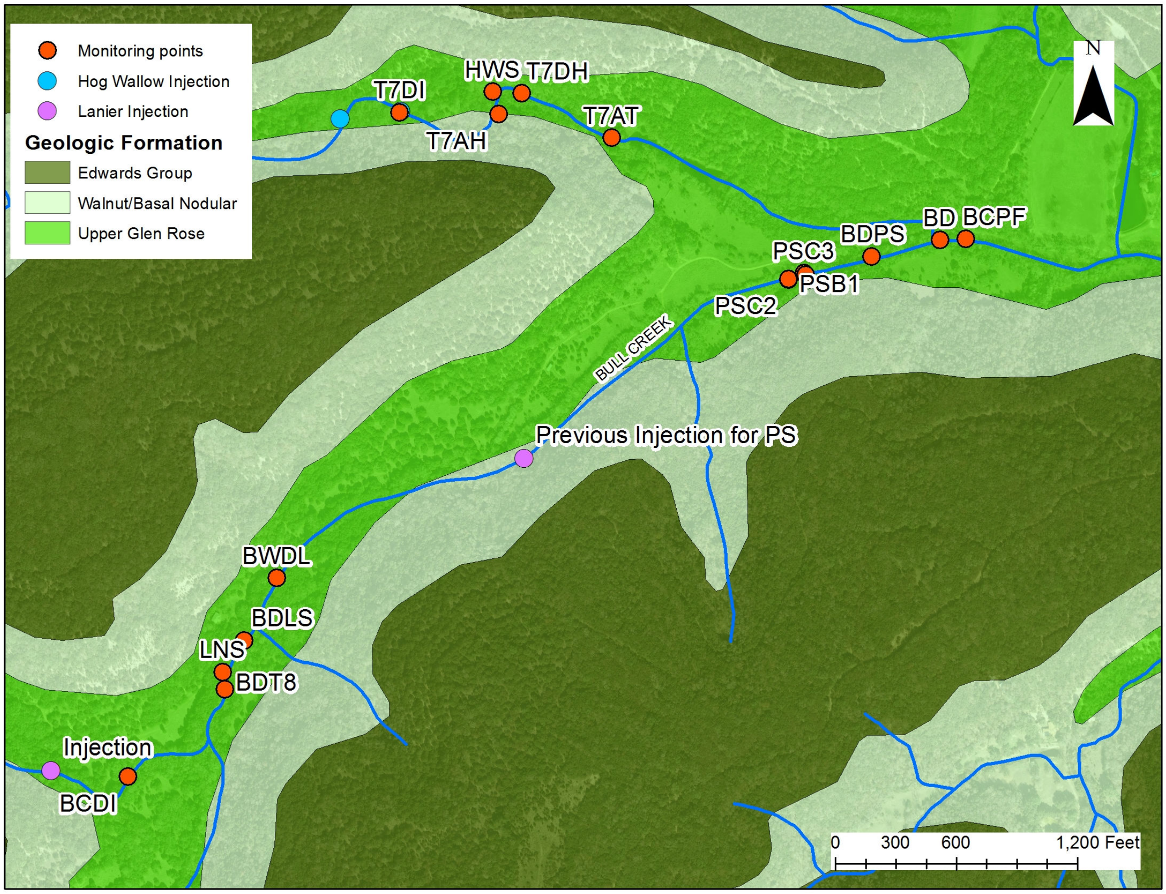

Figure 2. Geologic map of the study area and monitoring points for Hog Wallow Springs and Lanier Springs traces with tracer injection locations (and previous injection site for Pit Spring).

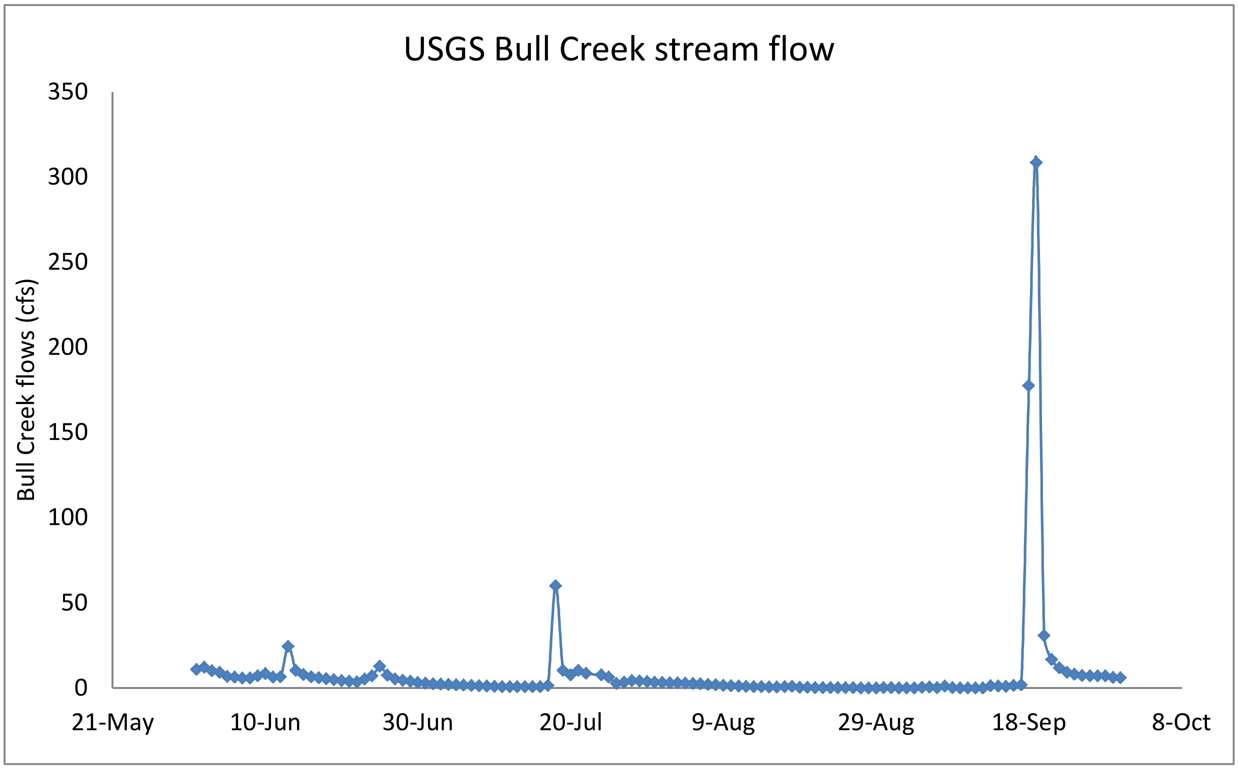

Figure 3. Average daily streamflow measurements from a USGS gaging station on Bull Creek at Loop 360 downstream of the study area during the 2014 study period.

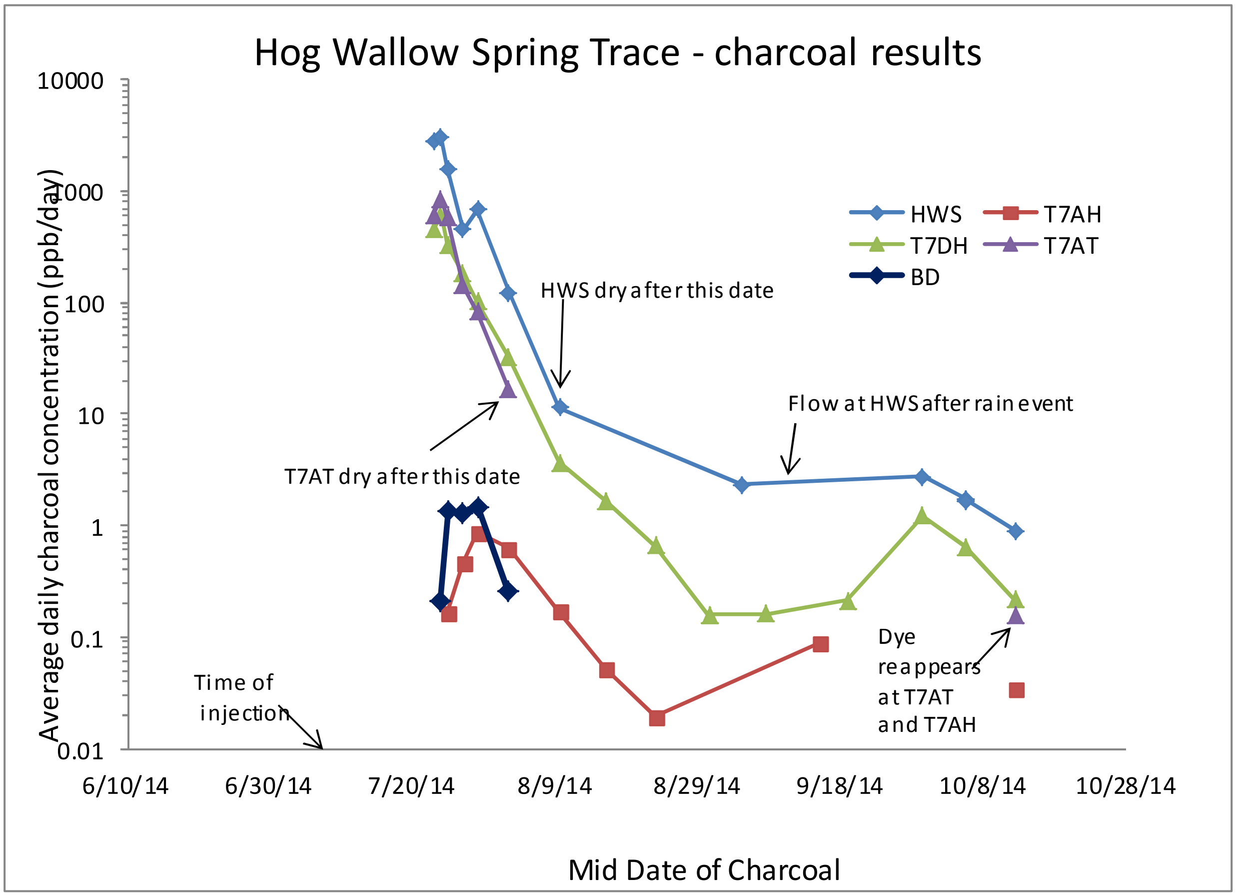

Figure 4. Average daily fluorescein concentrations from charcoal at Hog Wallow Springs and sites upstream and downstream of the spring.

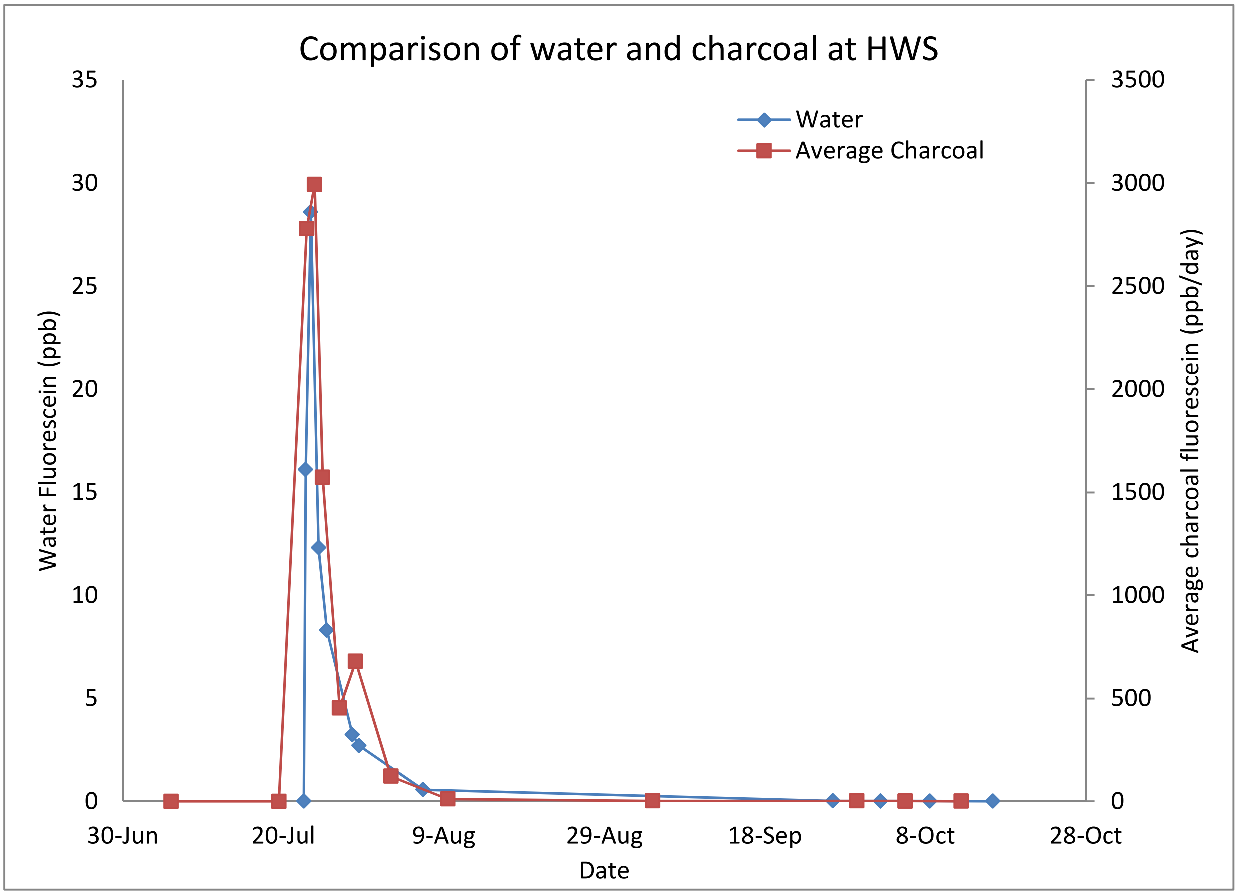

Figure 5. Comparison of charcoal and water dye concentrations at Hog Wallow Spring (HWS). Note the two y-axes show differences in scale of concentrations. The charcoal date is the mid-date between collection and deployment of the packet, while the water date is the date of collection.

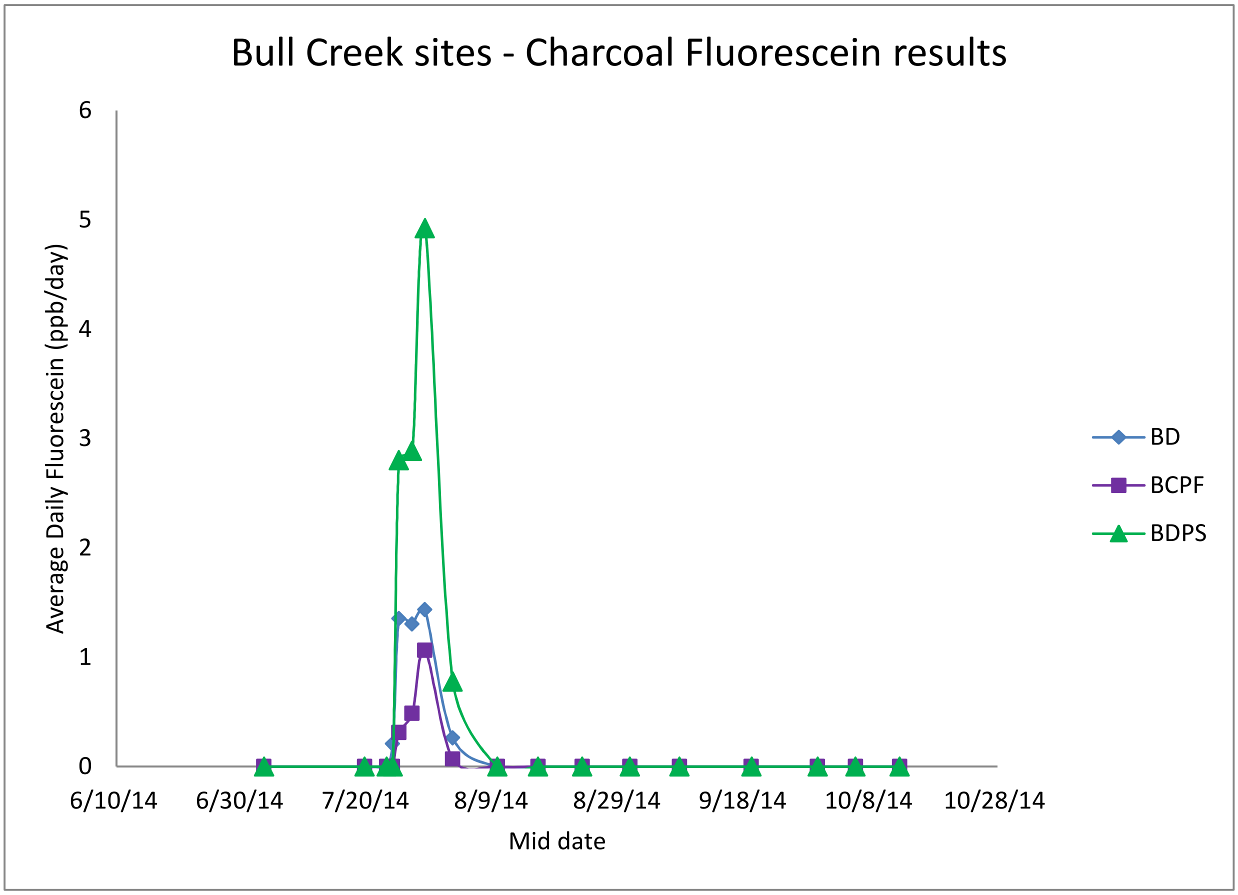

Figure 6. Average daily charcoal fluorescein concentrations at site on Bull Creek downstream (BD and BCPF) and just upstream (BDPS) of the confluence with Tributary 7.

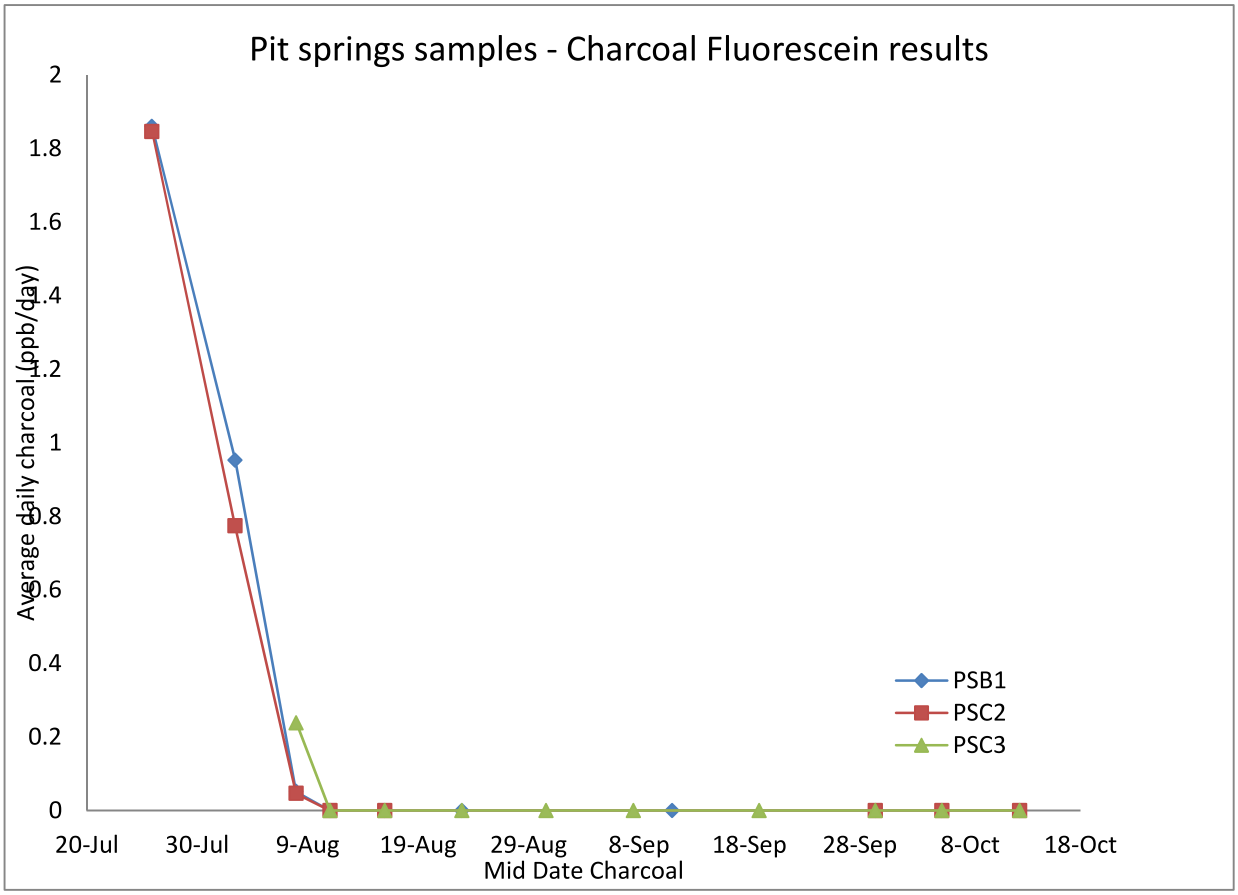

Figure 7. Average daily fluorescein concentrations at the three monitoring sites in Pit Spring channel and bank outlets. Fluorescein dye was only detected in samples collected during the first three collection trips after dye injection.

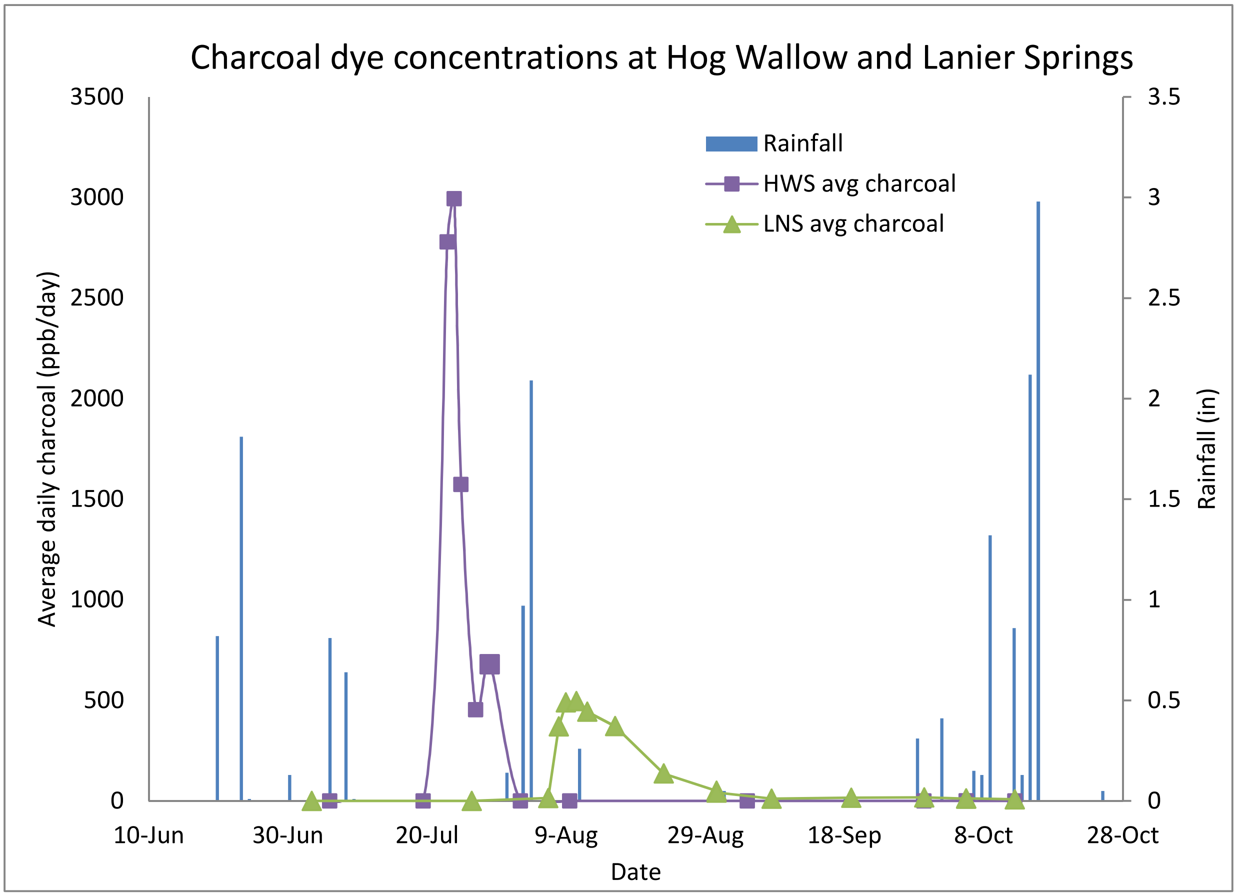

Figure 8. Dye concentrations at Hog Wallow and Lanier Springs following rainfall events. Dye was injected upstream of these sites after the rain events in July.

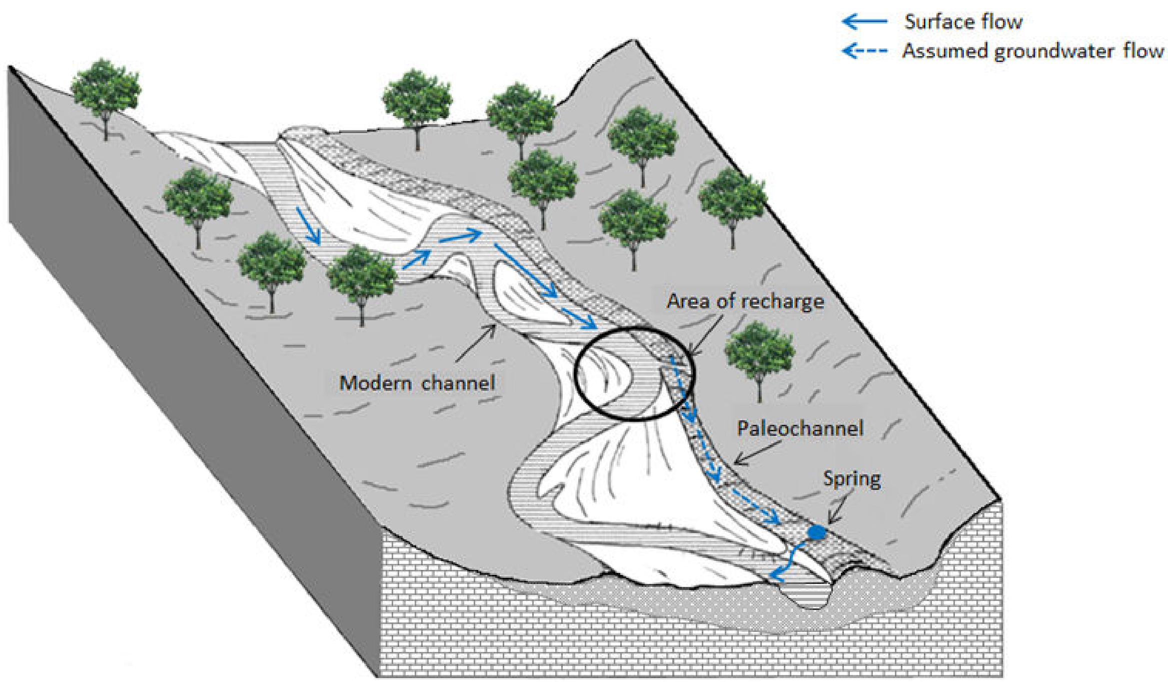

Figure 9. Schematic of estimated source water flowpaths for Hog Wallow and Lanier Spring. Surface flow disappears in the main channel under alluvial deposits, and follows a paleochannel to discharge at the spring outlet. The water discharging from the spring then reenters the current channel and continues as surface flow through the channel. Modified from Galloway (1981).

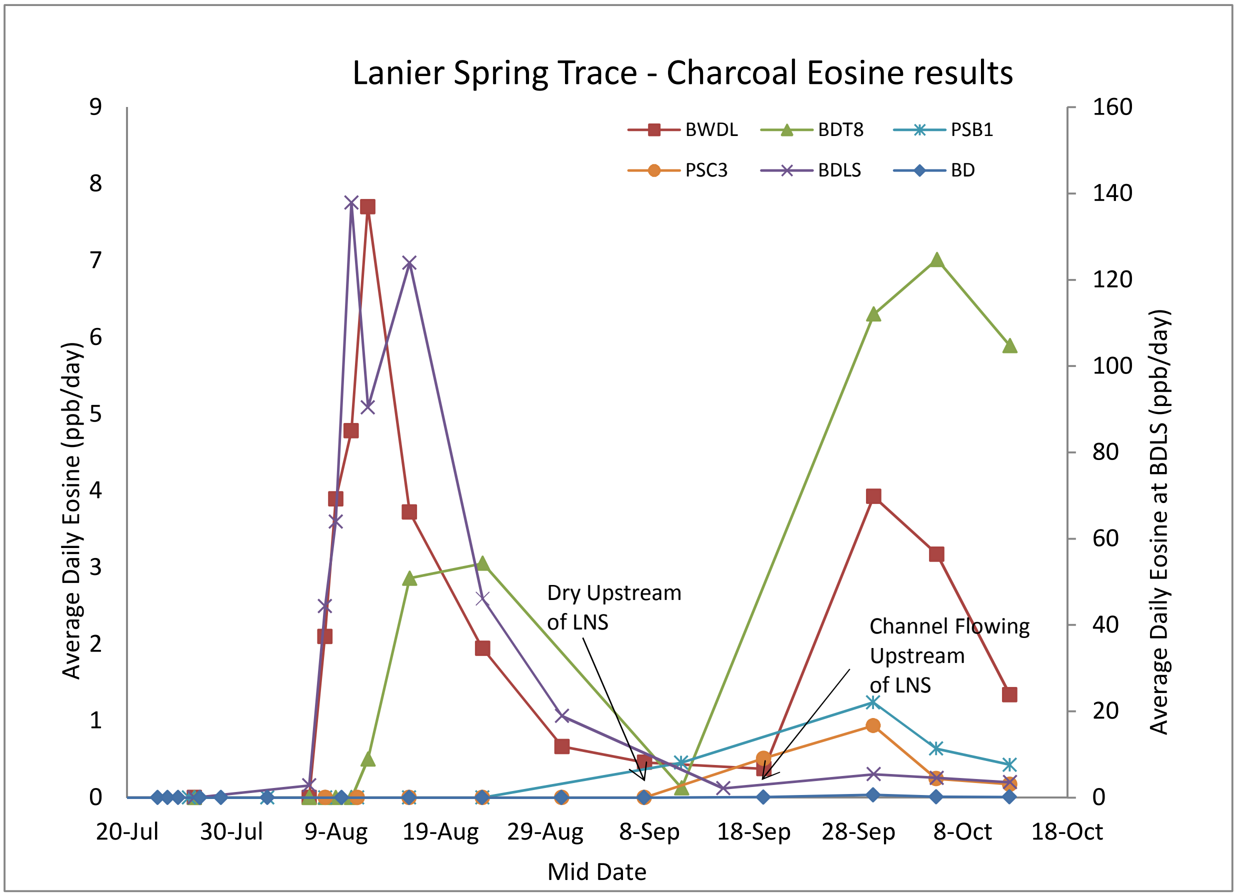

Figure 10. Average daily eosine concentrations at sites adjacent to and downstream of Lanier Springs.

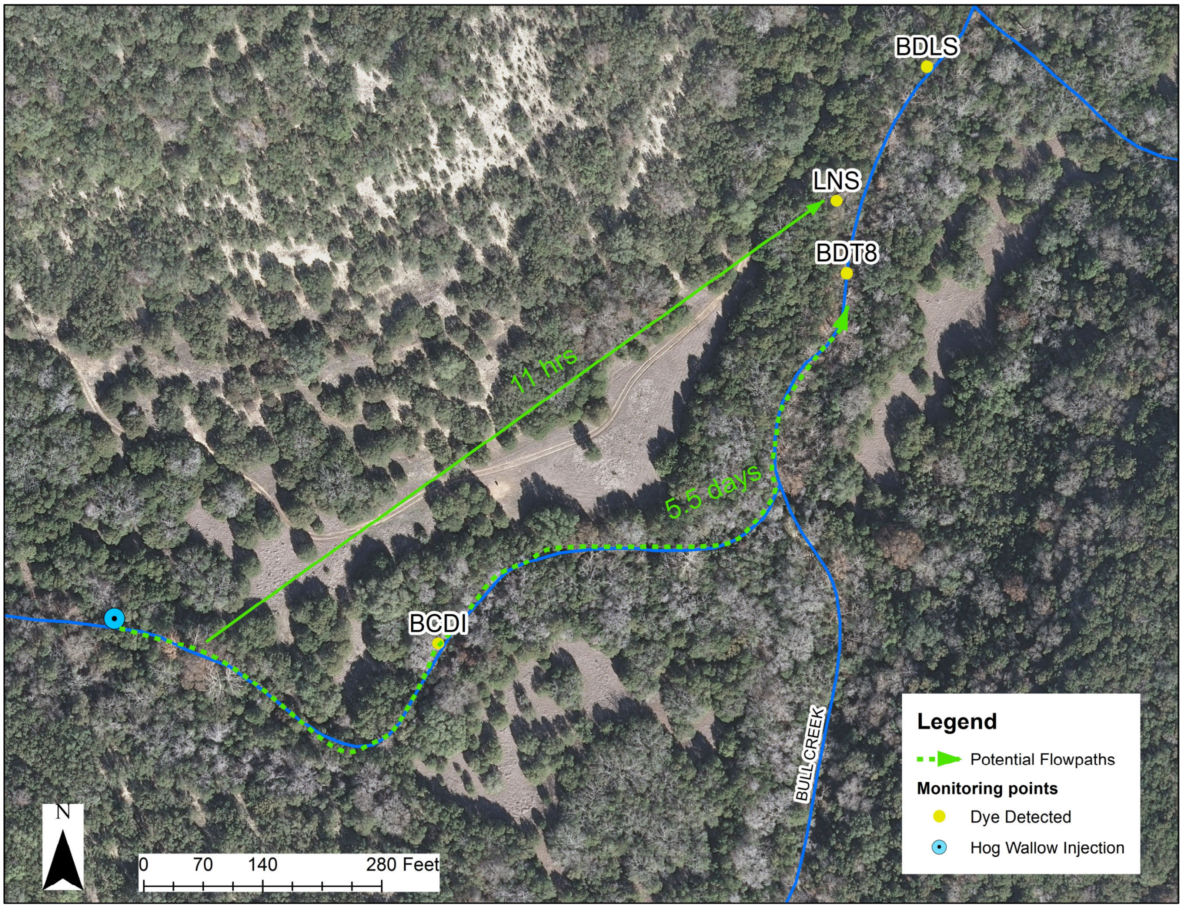

Figure 11. Time of tracer hit at Lanier Springs and BDT8 (Bull Creek adjacent to Lanier Springs) after injection upstream. Green arrows do not necessarily reflect exact flow paths.

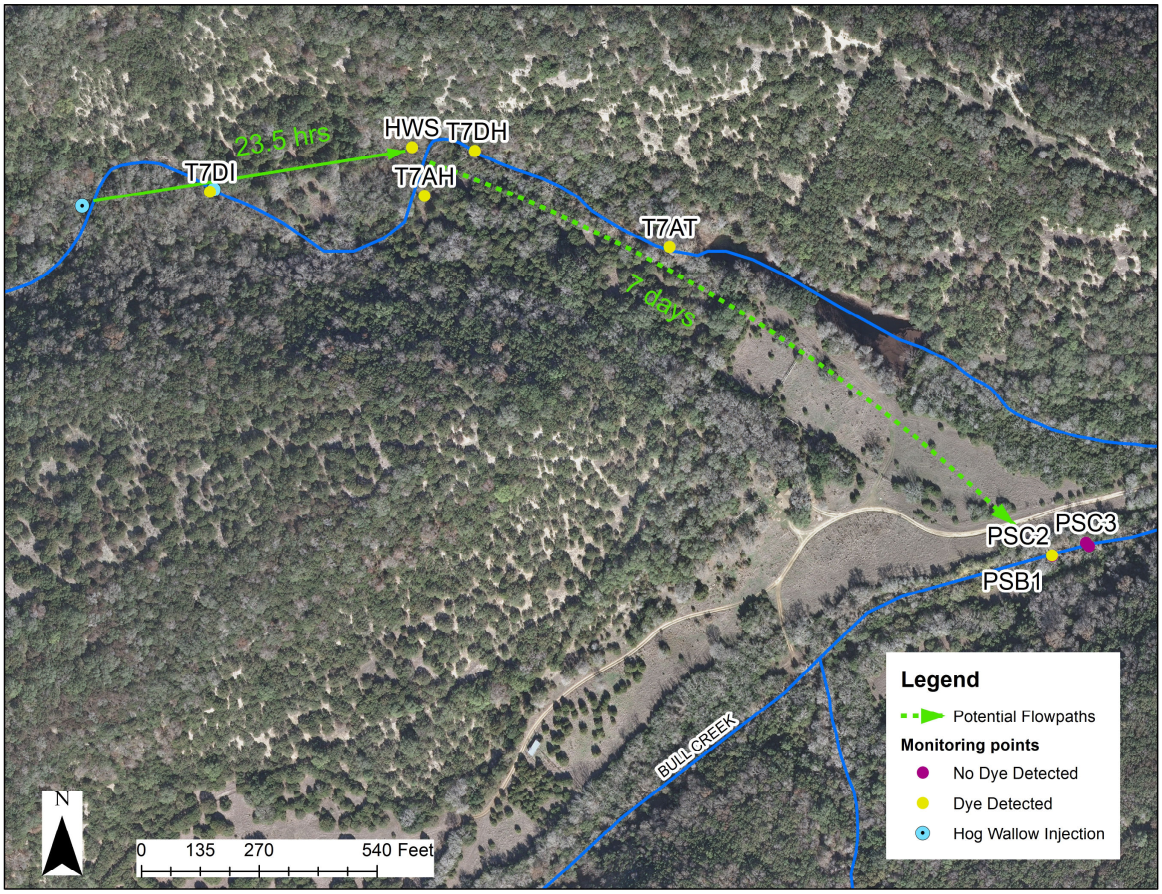

Figure 12. Time of tracer hit at Hog Wallow Springs, T7AT (tributary 7 further downstream of HWS) and PSC2 (Pit Spring channel outlet) after injection in tributary 7 upstream of where HWS discharges into the tributary. Green arrows do not necessarily reflect exact flow paths.

Photos

Photo 1: Inside the fence at Hog Wallow Spring. The fence was constructed to keep wild hogs out of the spring area.

Photo 2: Outcrop of the Glen Rose limestone formation downstream of Hog Wallow trace injection point. Green is visible fluorescein dye from the injection immediately upstream.

Photo 3. Lanier Spring. Site has been fenced to exclude hogs.

Photo 4. Bull Creek upstream of Lanier Springs where flow ceases due to water moving through alluvial deposits in creek bed.

Photo 5. Injection point of eosine dye for Lanier Springs trace.

Photo 6. Image of Pit Spring looking upstream. The left bank has alluvial outlets discharging water, while water is also coming out of fractures and openings in the Glen Rose bedrock channel.

Tables

Table 1. Flow measurements taken July 7th 2014

Site	flow (cfs)	gpm
Lanier Spring	0.0830	37.3
Bull Creek upstream of Lanier Spring	0.0205	9.2
Bull Creek Downstream of Lanier Spring	0.114	51.2
Hog Wallow Spring	0.170	76.4
Tributary 7 downstream of Hog Wallow Spring	0.107	47.9

Table 2. Summary of dye concentrations and arrival times for Hog Wallow Spring Trace

Site	Time of First Arrival (hrs)	Distance from injection point (ft)	Velocity based on first arrival (ft/hr)	Peak Charcoal Concentration (ppb/day)	Peak Water concentration (ppb)	Time of peak water (hrs)
T7AH	4	679	169.75	7.16	2.16	4.0
HWS	9	637	70.78	2993	28.6	23.5
T7DH	9	806	89.56	607	9.78	23.8
T7AT	9	1253	139.22	854	11	24.1
PSB1	168	2224	13.24	1.86	0.097	168.0
PSC2	168	2224	13.24	1.85	0.092	168.0
BDPS	48	2653	55.27	4.92	0.032	72.0
BD	36	2957	82.14	1.43	0.021	72.0
BCPF	36	3071	85.31	1.06	0.02	72.0

Table 3. Summary of dye concentrations and arrival times for Lanier Spring Trace

Site	Time of First Arrival (hrs)	Distance from injection point (ft)	Velocity based on first arrival (ft/hr)	Peak Charcoal Concentration (ppb/day)	Peak Water Concentration (ppb)	Time of peak water (hrs)
BDT8	136	830	6	0.5	0.13	313
LNS	11	874	79	496.1	8.38	74.5
BDLS	25	1058	42	137.9	3.18	121
BWDL	49	1387	28	7.7	0.69	121