Lower Bull Creek District Park Contact Recreation Use Assessment Update, January 2011

January 2011; SR-11-07

City of Austin Watershed Protection Department
Austin/Travis County Health and Human Services Department

Abstract

Previous studies (COA 2008) found fecal indicator bacteria concentrations were elevated above human contact recreation standards in Bull Creek District Park, a popular swimming and dog off-leash area in northwest Austin, and noted that park usage and most probably the dog off-leash use was the likely source of the fecal contamination. A public education campaign was initiated to improve collection of dog waste, but was unsuccessful at reducing bacteria levels below human health standards. A riparian restoration project was conducted in the park and dogs are currently allowed on-leash only. Bacteria levels have improved at the former off-leash area during the on-leash only period, particularly following a large flood event, and now are below the recreation standard.

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Introduction

In August 2007, a sanitary sewage overflow occurred in the Bull Creek Watershed between West Rim Cove and Spicewood Springs Road, upstream of Lower Bull Creek District Park in Austin, Texas. The 48 acre park, including approximately 3 miles of hiking trails, is a popular location for swimming and wading and previously included a dog off-leash area near Lakewood Drive. The Austin/Travis County Health and Human Services Department (ATCHHSD) received complaints of gastrointestinal illness among people who swam at Bull Creek District Park. An epidemiologic investigation concluded that contact with water at Bull Creek was the common exposure between all persons that became ill. A multi-departmental task force investigated the elevated levels of *E. coli* indicator bacteria in Bull Creek from August 2007 to December 2007. These events and associated monitoring data thru December 2007 are documented in a previous report produced by the multi-departmental City of Austin task force (COA 2008). The primary conclusions and recommendations of the previous analysis (COA 2008) were:

- *E. coli* indicator bacteria at the Lakewood Drive monitoring site exceeded the State of Texas contact recreation standard.
- *E. coli* levels were higher at the Lakewood Drive monitoring site near the designated dog off-leash area than the Loop 360 monitoring site although both sites were downstream of the sewage spill.
- *E. coli* levels were higher on weekends than weekdays, suggesting that usage of the park was correlated to higher indicator bacteria.
- There was no corroborating evidence of on-going leaking wastewater infrastructure that would cause the elevated levels of *E. coli* bacteria
- The most likely cause of the fecal contamination at the Lakewood Drive monitoring site was the dog off-leash use.
- A public education campaign should be implemented in an attempt to reduce the bacteria levels in Bull Creek while maintaining all uses of the park.

This report chronicles the events and monitoring data since the previous analysis. As recommended in the previous City of Austin report (COA 2007), a public education campaign was initiated and indicator bacteria monitoring was extended thru December 2010. The public education campaign did not reduce the bacteria levels in the park, and a physical restoration project was conducted at the former off-leash area by the Watershed Protection Department. As part of the on-going scientific evaluation of the hypothesis that park use was correlated to elevated bacteria levels, *E. coli* was monitored while the park was closed for six months during the restoration construction. Following restoration work, a limited-use period with dogs allowed in the park on-leash only was instituted for 6 months with on-going bacteria monitoring. During the 6-month on-leash only period, a tropical storm caused significant flooding and geomorphic alteration of Bull Creek near the Lakewood Drive monitoring location. Significant temporal milestones since the previous analyses discussed in this report are:

- Mar 2008: A public "Scoop the Poop" education campaign was initiated
- Jun 2008: The citizen volunteer BCDOG group was formed
- Dec 2009: The park was closed to conduct a physical restoration project.
- Jun 2010: The park was opened for on-leash only use
- Sep 2010: Tropical Storm Hermine caused extensive flooding in the watershed

Indicator bacteria are selected on the basis of ease of measurement, persistence in the environment, and correlation to sources of pathogenic organisms (APHA 1995). Currently, *Escherichia coli* are the preferred indicator bacteria (TCEQ 2008). Although the type of *E. coli*

used in water testing may not directly cause illness, *E. coli* bacteria originate in the intestinal track of warm-blooded organisms including humans, dogs and birds and the presence of *E. coli* in natural waters is considered an indicator of the potential presence of pathogenic microorganisms. The Texas Commission on Environmental Quality (TCEQ) assesses contact recreation safety for humans using *E. coli* (TCEQ 2008). The contact recreation criteria for *E. coli* currently used by TCEQ is a long-term geometric mean of 126 colonies/100 mL (30 TAC 307), roughly equivalent to an increased risk of illness from water contact for 8 swimmers out of 1,000. The single sample limit of 394 mpn/dL is no longer used by TCEQ following recent standards revisions in 2010.

Methods

E. coli bacteria samples were collected at 4 monitoring locations (Figure 1, Table 1) by the Austin/Travis County Health and Human Services Department (ATCHHSD) and the Watershed Protection Department (WPD). ATCHHSD collected samples at the Lakewood Drive and Loop 360 locations generally on Monday and Wednesday mornings. WPD collected samples at all four monitoring locations on Sunday afternoons. The Lakewood site represents the direct effects of the dog off-leash area and high-intensity recreational use. The Loop 360 is not within the designated boundaries of the off-leash area, but does experience high-intensity recreational use. The Spicewood Springs monitoring location captures any impacts from the upstream portion of the mainstem of Bull Creek including several horse farms, while the Tributary 2 captures the more high-density residential and commercial land uses along the eastern boundary of the Bull Creek watershed.

Samples were collected every other week in sterile 125 mL sample containers, preserved on ice during processing, and *E. coli* counts were measured by Standard Method 9223b at either the Walnut Creek Wastewater Treatment Plant laboratory or at the WPD in-house lab. Additionally, WPD staff counted the number of people and dogs present during weekend site visits.

Table 1. Primary monitoring locations with short names used in this report, listed in downstream to upstream order.

Site #	Site Name	Short Name	Latitude	Longitude
4189	Bull Creek 375ft Upstream of Lakewood Drive	Lakewood	30.36626	-97.78572
350	Bull Creek @ Loop 360 First Crossing	Loop 360	30.37167	-97.78493
3456	Bull Creek Tributary 2 @ Bull Creek	Trib 2	30.38244	-97.77014
4472	Bull Creek @ Spicewood Springs Crossing 1	Spicewood	30.39034	-97.77500

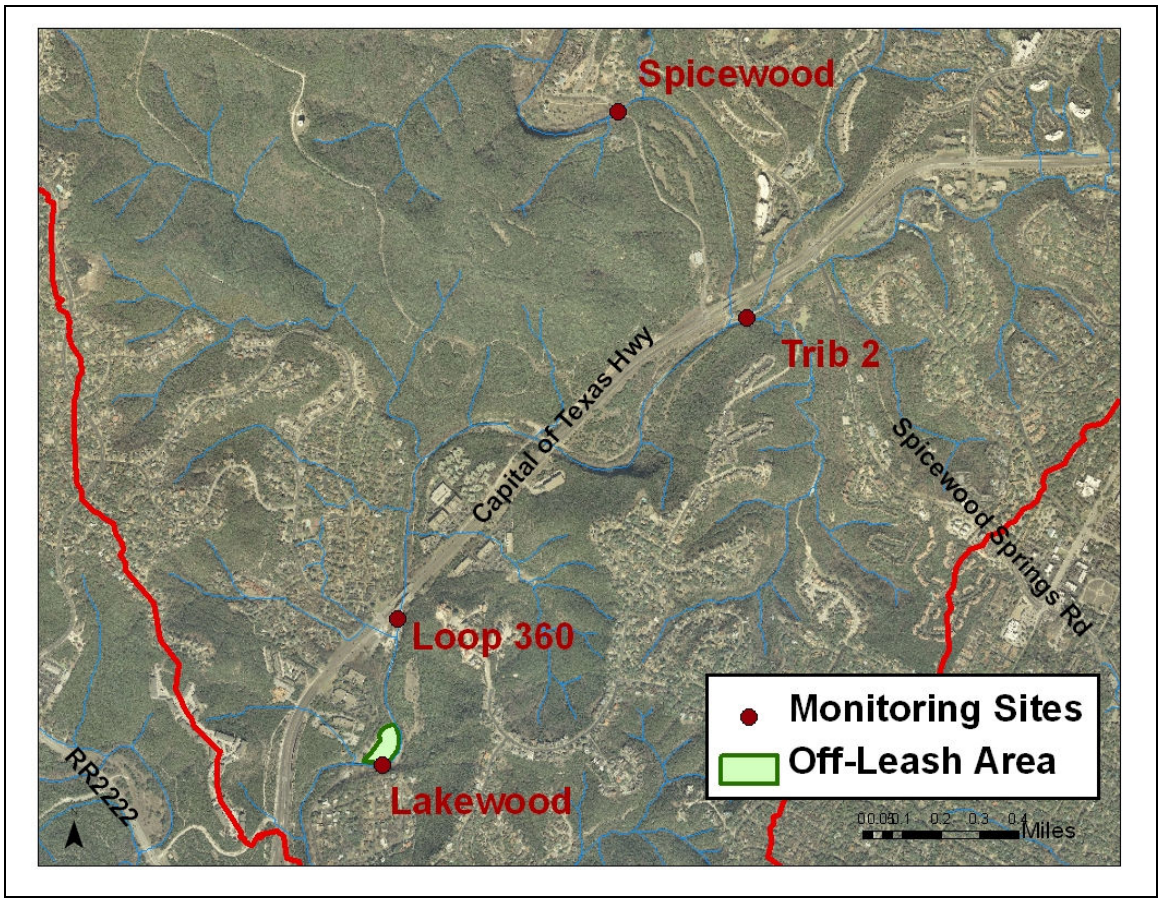

Figure 1. Primary monitoring locations.

Contact recreation fecal impairments are assessed generally following TCEQ guidance (TCEQ 2008) using a geometric mean of data collected when the creek is flowing above the 7Q2 compared to the standard of 126 mpn/dL. Data collected when Bull Creek flows as measured by the USGS Gauge 08154700 at Loop 360 were less than 0.1 ft^3/s were excluded following TCEQ guidance. Geometric means above the standard indicate fecal contamination resulting in potentially unsafe human water contact conditions. Multiple samples collected on the same day were averaged before any other analysis. The deviation from standard TCEQ guidance is the time period of assessment. While TCEQ assesses contact recreation safety over a 5-year period, the time frame of this study required a shorter evaluation period.

Exploratory library-independent genetic microbial source tracking methods were evaluated by the University of Texas at Austin (Bae and Kirsits 2010) against dog fecal samples and for ambient water samples collected by WPD in late August 2010. DNA was directly extracted with the MP Biomedicals FastDNA Spin Kit for Soil. The 20 L ambient water samples were processed thru a hollow fiber ultrafilter on the same day they were collected. DNA was analyzed by quantitative polymerase chain reaction (qPCR) with seven human-associated and four host-specific *Bacteroidales* assays. Positive signals from testing of water samples using these markers may indicate the contribution of fecal bacteria from that source.

Bacteria concentrations in sediment were assessed independently and are documented in a separate report (Wagner and Scoggins 2010). Although the conclusions are repeated in this report, please refer to the full report for more detailed methodology.

Results

Site Means Versus TCEQ Standard

Site geometric means were calculated by time period for each site with sufficient data (at least 7 measurement dates) and compared to the TCEQ contact recreation standard (Figure 2). The time periods are defined by relevant management actions (Table 2). The historic geometric mean *E. coli* at the Loop 360 site based on 17 measurements from 2003 to 2007 is 70 mpn/dL. Monitoring at Trib 2 and Spicewood was not initiated until late in the post-education period, and the Trib 2 site was frequently dry.

Table 2. Time periods based on relevant management actions

Name	Start	End	Basis
Historic	2003	Jul 2007	All historic routine *E. coli* monitoring data collected prior to the sewage spill
PostSpill	Aug 2007	Feb 2008	Data collected after the Bull sewage spill but before any management action in the park
PostEducation	Mar 2008	Aug 2009	Data collected after the start of the public education campaign
PreClosure	Sep 2009	Nov 2009	Data collected after the return of flow to Bull Creek in the summer of 2009 and prior to the closure of the park
Closure	Dec 2009	May 2010	Data collected when the former off-leash area was closed for physical restoration
OnLeash	June 2010	Dec 2010	Data collected after restoration when the park was opened with dogs allowed on-leash only

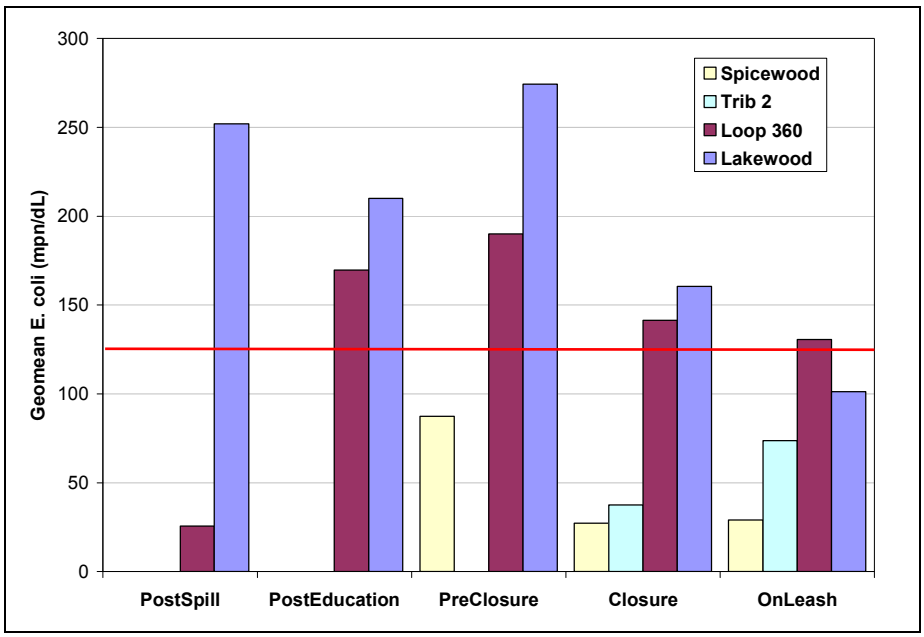

Figure 2. Site geometric mean *E. coli* by time period for sites and periods with at least 7 measurement dates. Sites in upstream to downstream order, left to right. Monitoring at Trib 2

and Spicewood began late in the post-education period and the Trib 2 site was frequently dry. The red line represents the Texas contact recreation standard (126 mpn/dL).

Bacteria levels increased at the Loop 360 site following the onset of public education and remained elevated throughout the remainder of the study until Tropical Storm Hermine in September 2010 (Figure 3). The historic *E. coli* geometric mean at Loop 360 is 70 mpn/dL (n=17, 2003-2007). Bacteria levels began to decrease at the Lakewood Drive monitoring site during the closure period, and fell below the standard during the on-leash period for the first time since sampling was initiated in August 2007. The Trib 2 site flows less frequently than mainstem Bull Creek, and the upstream sites maintain lower bacteria levels than sites in the park.

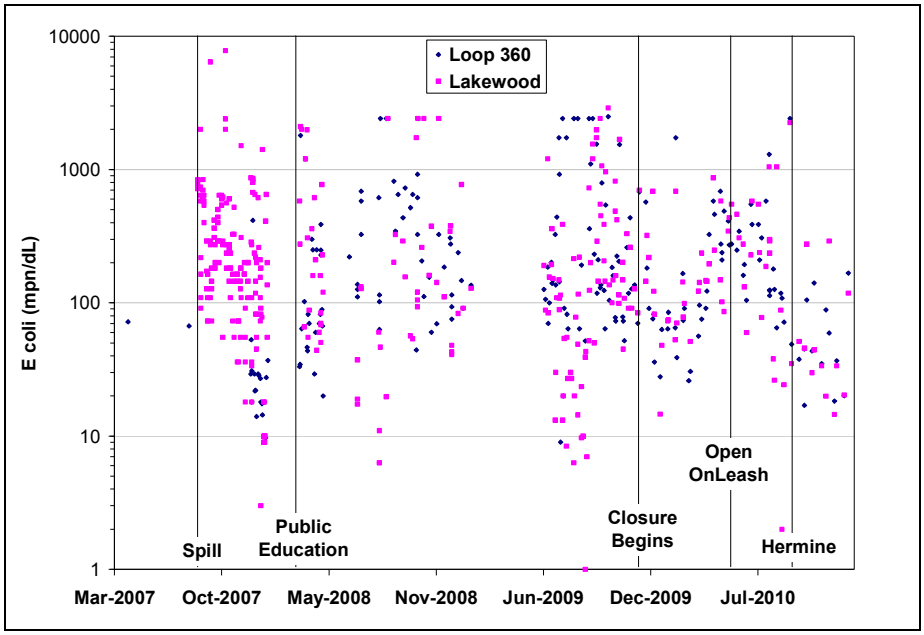

Figure 3. *E. coli* at the Lakewood and Loop 360 monitoring locations over time from 2007 to 2010 with vertical bars marking significant events in time.

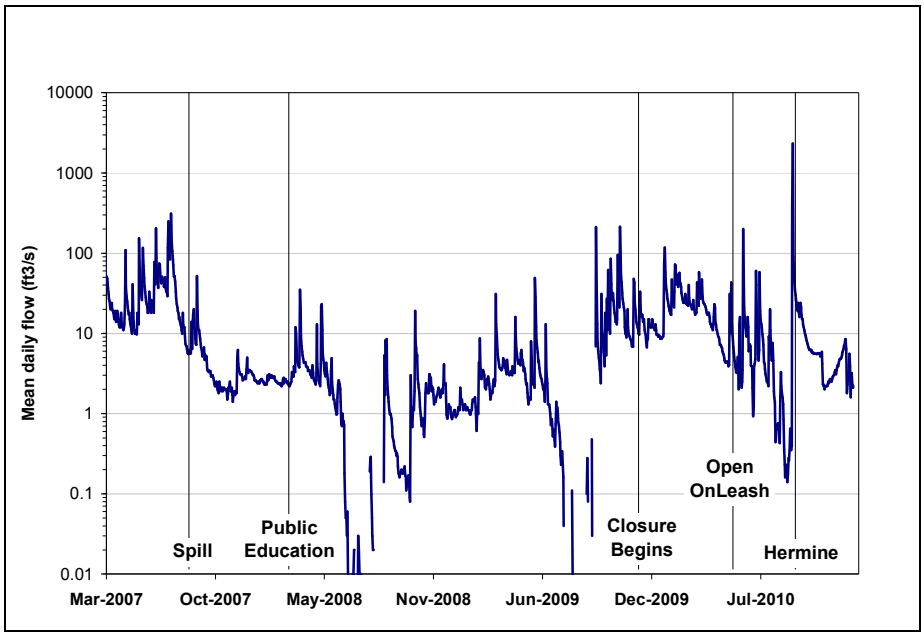

Figure 4. Mean daily flow in Bull Creek from the USGS gauge at Loop 360 (08154700).

Public Education Campaign

A public education campaign was initiated in March 2008 in an attempt to inform the public of the potential for fecal contamination of Bull Creek from uncollected dog waste. A press conference was held in the park that was well covered by local media, signage was posted in the park (Figure 5), and outreach was directed to individual park users. *E. coli* monitoring results were regularly posted in a kiosk at the park along with contact recreation warning signs. Public opinion surveys were conducted before and after the education campaign. There was a 31% increase in the number of respondents who believed that uncollected dog waste was a potential water quality problem, and 60% of respondents claimed to pick up dog waste more frequently than before the education campaign.

Figure 5. Example of educational signage posted in Bull Creek District Park.

Bull Creek Dog Off-Leash Group

The Bull Creek Dog Off-Leash Group (BCDOG) became active in June 2009 and began work doing outreach and additional maintenance within Bull Creek District Park. Following the unsuccessful results of the public education campaign to reduce bacteria levels in Bull Creek, COA staff decided to postpone additional actions including potentially prohibiting dogs in the park or removing the off-leash use to see if the volunteer group could affect a positive change. While the BCDOG volunteers made improvements to the appearance of the park and reduced the amount of visible dog waste on the ground, bacteria levels continued to remain above the contact recreation standard. For this reason, COA staff decided to temporarily close the park for 6 months to conduct a physical restoration project while continuing to monitor bacteria levels in an attempt to test the hypothesis that park use was correlated to elevated bacteria.

Riparian Restoration Project

The restoration project was a collaborative effort between the Watershed Protection Department (WPD), the Parks and Recreation Department (PARD), and the non-profit organization American YouthWorks (AYW). It was designed, managed and funded by the WPD Stormwater Treatment and Stream Restoration Section. The majority of the construction work was completed under contract by the American YouthWorks, with support by PARD and WPD field crews. The restoration project was initiated to enhance the pollution reduction efforts of the public education campaign and the volunteer activity to pick up dog waste. The primary goal of the restoration project was to create a functional riparian landscape that acts as a water quality filter for runoff, reduce continued erosion and reverse the effects of soil compaction in the Critical Water Quality Zone near the swimming areas. These functions were restored to the site by enhancing the soil and vegetation, installing terraces and rain gardens to capture and treat runoff, and by limiting pedestrian foot traffic to specific pathways (Figure 6). The soil in the upland grassy area was amended with compost and reseeded with native grasses thereby increasing the density and the

diversity of vegetative cover and reducing runoff to the creek. On the slopes, coir logs and cedar log terracing were used to slow down stormwater runoff and allow it to infiltrate. Between the log terraces, WPD broke up the extremely compacted soil, installed soil retention blanket, and planted seed, sod and rooted plants. Large limestone boulders were placed near the bend in the creek to retain soil and provide a seat wall for park visitors. Together, the boulders, log terraces, vegetative barriers and onsite signage encourage park visitors to stay on the trails and help maintain the long-term success of the restored landscape. While most of these efforts were focused on improving vegetative coverage on the surface they are also providing considerably better growing conditions for the existing grove of majestic Live Oak trees onsite. PARD installed a permanent underground irrigation system which helped to establish the recently planted vegetation and will allow it thrive in the future. The project had an estimated cost of $137,500 and was successfully completed on-time and under budget. Monitoring of the restoration project indicated that the goals of the restoration project were achieved, although re-opening of the park to recreational use did produce limited damage to some of the restored vegetation near the "horseshoe" waterfall area.

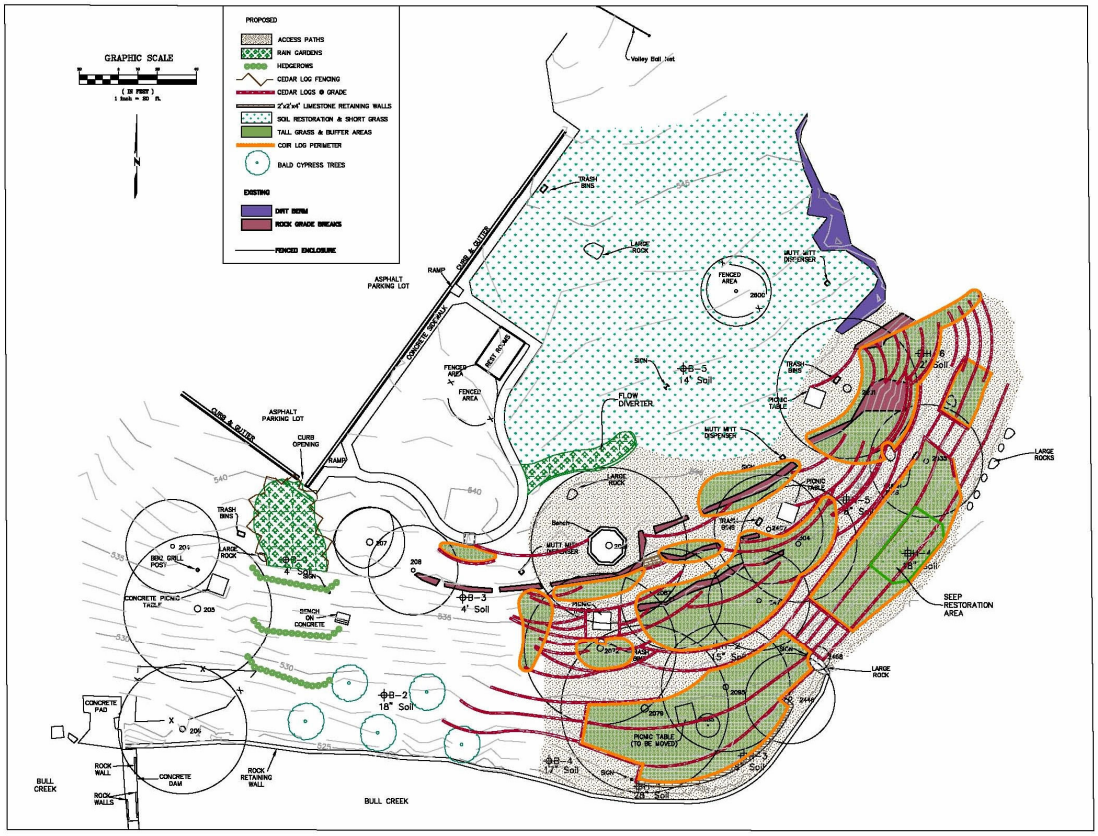

Figure 6. Schematic diagram of the riparian restoration project.

Tropical Storm Hermine

Several months after the completion of the restoration project Tropical Storm Hermine brought 12" of rain to the area on September 7 and 8, 2010. Although this rainfall total is over a 100-year event the overall distribution was such that the flows near the park can be characterized between a 10-year event and a 50-year event. Hermine caused extensive flooding in Bull Creek and deposited several inches of sand and gravel in some areas of the restoration project. Since the

park is in a floodplain, the flooding and deposition is a natural occurrence and was not unexpected. In the long term this deposited material will be beneficial to the riparian landscape. However, in the short term WPD is proceeding to re-establish the limited areas of vegetation that were impacted which may extend the time required for full establishment of the new vegetation. Although the damage to the overall project was considered minimal, the landscape near the limestone block wall will require additional time to heal. As for the creek itself, the former "horseshoe" waterfall area was completely filled in by sediments (Figure 7).

Figure 7. Area near the "horseshoe" waterfall looking upstream: Before restoration (Top left), after restoration (top right), after Tropical Storm Hermine (lower left); Area upstream of waterfall soon after restoration showing successful revegetation (lower right)

Unfortunately Tropical Storm Hermine caused considerable damage to the mitigation areas related to the new Lakewood Drive low water crossing project, with trees and a parking lot removed by floodwaters on the south side of the creek. The flood either scoured or buried older sediment deposits near the Lakewood Drive monitoring site. This impact to the sediment was related to an overall reduction in the E. coli levels as shown in figure 8.

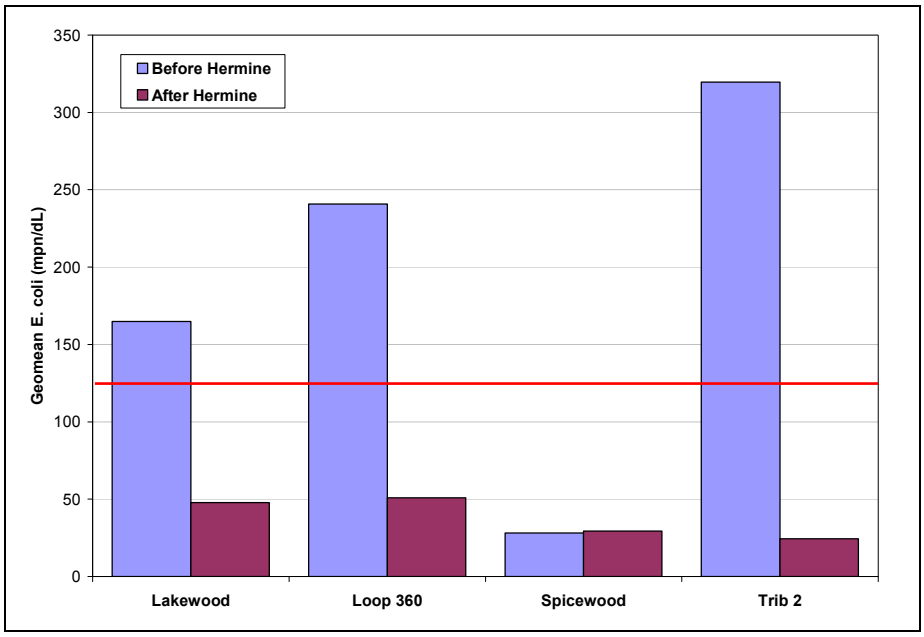

Figure 8. *E. coli* geometric means before (left, blue bar) and after Hermine (right, red bar), during the on-leash only period June 2010 to December 2010.

Genetic Microbial Source Tracking

Exploratory analysis using genetic library-independent microbial source tracking was attempted by the University of Texas at Austin for dog fecal samples and ambient water samples collected in late August 2010. Full validation of the qPCR assays is still underway as part of other COA source water investigations to characterize the source of local waters by chemical and biological profiles. The qPCR assays employed seven human-associated and four host-specific assays including dogs for *Bacteriodales* bacteria (Bae and Kirsits 2010). The BacCow-UCD marker is associated with cows, the BacCan-UCD is associated with dogs, the BacUni-UCD is the universal total *Bacteriodales* marker and the BacHum-UCD is associated with humans. The amplified *Bacteroidales* DNA from dog fecal samples showed weak cross-reactivity with the HF183 and BuniF2 human-associated markers, indicated by the lack of positive detection (ND) in all dog fecal samples except for one Buni-F2 detection. However, only 10 of the 19 dog fecal samples showed a positive signal with the dog-associated BacCan-UCD marker (Table 3). Thus, there appears to be a low false positive detection rate of dog fecal samples using the human markers although there is low confidence in the ability of the dog-associated markers to detect dog fecal contamination.

Table 3. Number of dog fecal samples showing positive signals by qPCR assays (Bae and Kirsits 2010).

Sampling Area	#	Human-associated markers							Host-specific markers			
		HF-183	Bsteri -F1	Buni -F2	Bfragi -F1	Pcopri-F1	Bvulg -F1	Bthetal -F2	BacUni -UCD	BacHum -UCD	BacCow -UCD (cow)	BacCan-UCD (dog)
Pease Park	2	ND	2	ND	1	2	2	2	2	2	2	2
Auditorium Shores	5	ND	4	ND	ND	5	3	1	5	3	1	4
Bull District park	2	ND	2	ND	2	2	2	1	1	2	1	1
Red Bud Isle Park	4	ND	5	1	3	4	4	4	3	4	2	2
Norwood Dog Park	6	ND	5	ND	3	6	6	2	5	3	2	2
Sum	*19*	*0*	*18*	*1*	*9*	*19*	*17*	*10*	*18*	*11*	*8*	*10*

ND indicates non-detection

The ambient water samples collected at the Loop 360 and Lakewood monitoring sites from late August 2010 were processed and compared to the genetic markers. For the two human-associated markers that showed weak cross-reactivity with the dog fecal samples, HF183 and BuniF2, there was no detection of human-associated *Bacteroidales* genomic DNA at either site and a positive detection of dog-associated *Bacteroidales* genomic DNA at the Loop 360 site (Table 4). Analysis of ambient samples suggest that the fecal bacteria may be of non-human origin.

Table 4. Average Ct values measured by qPCR assays in the water samples

Sample Name	Human-associated markers							Host-specific markers			
	HF 183	Bsteri F1	Buni F2	BfragiF 1	Pcopri F1	Bvulg F1	Bthetal F2	BacUni-UCD	BacHum -UCD	BacCow -UCD	BacCan-UCD
Loop 360	ND	ND	ND	27.15	26.12	ND	ND	ND	ND	ND	34.15[b]
Lakewood	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

[a] ND indicates non-detection
[b] one positive out of duplicates in undiluted and 1:10 dilution

Bacteria in Sediment Study
WPD conducted a study on the bacteria levels associated with instream sediments from Bull Creek from April to December 2008 (Wagner and Scoggins 2010). *E. coli* bacteria were effectively isolated from instream sediments and compared to the ambient samples from the overlying water column. The study concluded that sediments may be a source of *E. coli* through resuspension Point or non-point loading sources could contaminate sediments with fecal bacteria that are released when humans or dogs agitate the stream sediments during recreation. However, there was a lack of spatial or temporal consistency in the sediment bacteria concentrations that would explain the results of the routine water column bacteria monitoring.

Fecal Loading from Birds
The University of Texas at Austin (UT) was commissioned by the Texas Department of Transportation (TXDOT) to study the impacts of birds nesting under bridges on fecal bacteria levels in underlying streams (Sejkora et al 2010). Bird and bat colonies inhabiting bridges over streams are known sources of fecal contamination. The UT study included monitoring on Bull Creek within the park from February 2009 to June 2010 relative to migratory cliff swallow

(*Petrochelidon pyrrhonota*) nesting underneath Loop 360 at Spicewood Springs Road. Fecal loading from cliff swallows is likely to peak in April from the time eggs are laid until fledging when the young birds are capable of leaving the nest. The UT study concluded that while birds are contributing fecal bacteria to Bull Creek especially during the 20-day period between hatching and fledging, the birds did not increase fecal bacteria above the current contact recreation standard (126 mpn/dL).

Correlations with Flow and Rainfall

In general there is little significant correlation between *E. coli* and mean daily stream flow measured by the USGS gauge at Loop 360 (08154700) as assessed by Kendall's tau-B correlation analysis (Table 5, Figure 9). *E. coli* at Lakewood was positively correlated with flow during the post-spill, post-education and on-leash monitoring periods. E. coli values at the Loop 360 site were inversely related to flow during the post-education period.

Table 5. Results of Kendall's tau-B correlation of *E. coli* with mean daily stream flow. Green shaded cells show significant correlation ($\alpha<0.05$).

Period	Site	N	Tau-b	Pr>tau
Historic	Loop 360	17	-0.14	0.43
PostSpill	Lakewood Dr	158	0.17	0.01
PostSpill	Loop 360	20	0.32	0.06
PostEducation	Lakewood Dr	110	0.37	0.01
PostEducation	Loop 360	96	-0.21	0.01
PostEducation	Spicewood	10	0.12	0.66
PostEducation	Trib 2	4	-0.33	0.47
PreClosure	Lakewood Dr	33	-0.01	0.92
PreClosure	Loop 360	27	0.13	0.36
PreClosure	Spicewood	7	0.14	0.65
PreClosure	Trib 2	2	.	.
Closure	Lakewood Dr	33	-0.09	0.43
Closure	Loop 360	35	-0.21	0.09
Closure	Spicewood	12	-0.21	0.33
Closure	Trib 2	12	0.19	0.37
OnLeash	Lakewood Dr	35	0.27	0.03
OnLeash	Loop 360	36	0.13	0.27
OnLeash	Spicewood	17	0.31	0.08
OnLeash	Trib 2	16	0.11	0.56

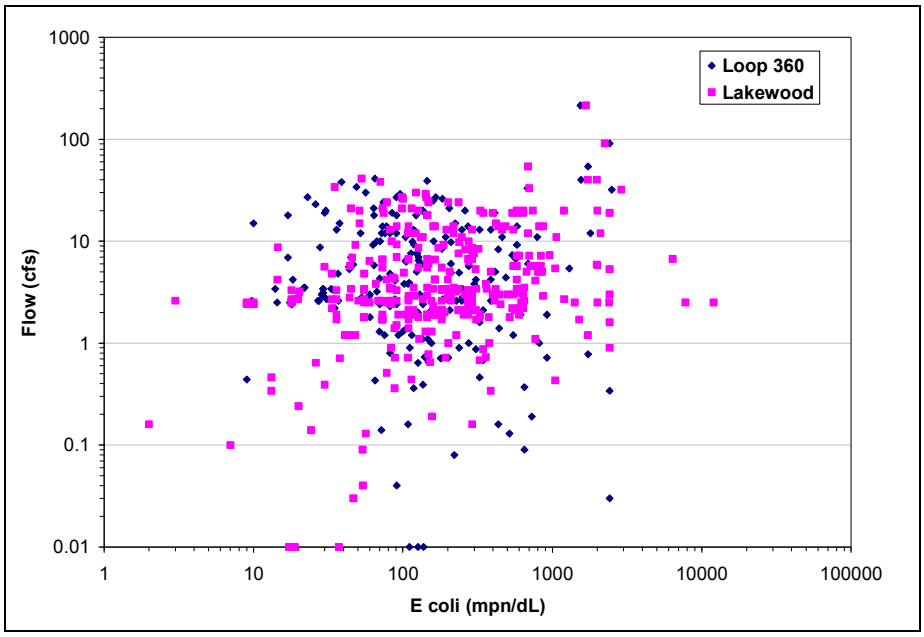

Figure 9. E. coli (mpn/dL) versus mean daily stream flow (ft3/s) for the Lakewood and Loop 360 sites using all data.

Correlation between E. coli and antecedent rainfall was assessed by Kendall's tau-b correlation test using the number of days since measurable rainfall and rainfall total in the 72 hours prior to sampling as measured by the National Weather Service gauge at Camp Mabry (Table 6). In general, E. coli levels were inversely related to number of days since rainfall and positively related to rainfall totals within the past 72 hours at the Lakewood and Loop 360 monitoring locations. There was no correlation with rainfall during the closure period, although the rainfall totals and number of rainfall days from December to May 2010 were consistent with averages from the same groups of months averaged since 2000 suggesting that there was nothing unusual about the climatic patterns during the closure period.

Table 6. Results of Kendall's tau-B correlation of *E. coli* with number of days since rainfall and total rainfall in the 72 hours prior to sampling. Green shaded cells show significant correlation ($\alpha<0.05$).

			Days Since Rain		Rain in Last 72h	
Period	Site	N	Tau-b	Pr>=|Tau|	Tau-b	Pr>=|Tau|
Historic	Loop 360	17	-0.36	0.05	0.42	0.03
PostSpill	Lakewood	158	-0.19	0.01	0.26	0.01
PostSpill	Loop 360	20	-0.12	0.46	0.21	0.25
PostEducation	Lakewood	110	-0.15	0.03	0.15	0.04
PostEducation	Loop 360	96	-0.15	0.04	0.17	0.03
PostEducation	Spicewood	10	0.11	0.65	-0.18	0.50
PostEducation	Trib 2	4	.	.	.	.
PreClosure	Lakewood	33	-0.05	0.72	0.26	0.05
PreClosure	Loop 360	27	-0.29	0.04	0.43	0.01
PreClosure	Spicewood	7	-0.1	0.75	0.07	0.85
PreClosure	Trib 2	2	.	.	.	.
Closure	Lakewood	33	0.05	0.71	0.14	0.27
Closure	Loop 360	35	-0.13	0.29	0.16	0.19
Closure	Spicewood	12	0.05	0.83	-0.17	0.48
Closure	Trib 2	12	0.03	0.88	-0.24	0.31
OnLeash	Lakewood	35	-0.32	0.01	0.23	0.09
OnLeash	Loop 360	36	-0.38	0.01	0.33	0.01
OnLeash	Spicewood	17	-0.24	0.18	-0.19	0.35
OnLeash	Trib 2	16	-0.08	0.68	-0.03	0.89

Correlations with Air Temperature and Month

Water temperature is not measured continuously, but air temperature is a good surrogate for water temperature and may be related to the likelihood of park use. National Weather Service Austin average air temperature measurements were compared to *E. coli* measurements on the same day by Kendall's tau-b correlation analysis. In general, E. coli measures are directly related to air temperature values (Table 7), although there was a significant inverse relationship to temperature at the Lakewood site during the post-education period.

There is no clear pattern in average monthly *E. coli* geometric means at the Lakewood or Loop 360 sites (Figure 10). January yielded the lowest overall monthly geometric means at both sites. The Lakewood site may yield higher geometric mean *E. coli* during the spring and summer months although the Loop 360 site may yield higher summer geometric mean *E. coli* values.

Table 7. Results of Kendall's tau-B correlation of *E. coli* with average air temperature. Green shaded cells show significant correlation (α<0.05).

Period	Site	N	Temperature	
			Tau-b	Pr>=|Tau|
Historic	Loop 360	17	0.16	0.36
PostSpill	Lakewood	158	0.33	0.01
PostSpill	Loop 360	20	0.21	0.23
PostEducation	Lakewood	110	-0.30	0.01
PostEducation	Loop 360	96	0.13	0.06
PostEducation	Spicewood	10	-0.09	0.71
PostEducation	Trib 2	4	.	.
PreClosure	Lakewood	33	0.33	0.01
PreClosure	Loop 360	27	0.21	0.12
PreClosure	Spicewood	7	0.61	0.05
PreClosure	Trib 2	2	.	.
Closure	Lakewood	33	0.27	0.03
Closure	Loop 360	35	0.35	0.01
Closure	Spicewood	12	0.41	0.06
Closure	Trib 2	12	0.03	0.89
OnLeash	Lakewood	35	0.21	0.09
OnLeash	Loop 360	36	0.39	0.01
OnLeash	Spicewood	17	0.09	0.59
OnLeash	Trib 2	16	0.57	0.01
All data	Lakewood	370	0.03	0.34
All data	Loop 360	231	0.29	0.01
All data	Spicewood	46	0.01	0.92
All data	Trib 2	34	0.52	0.01

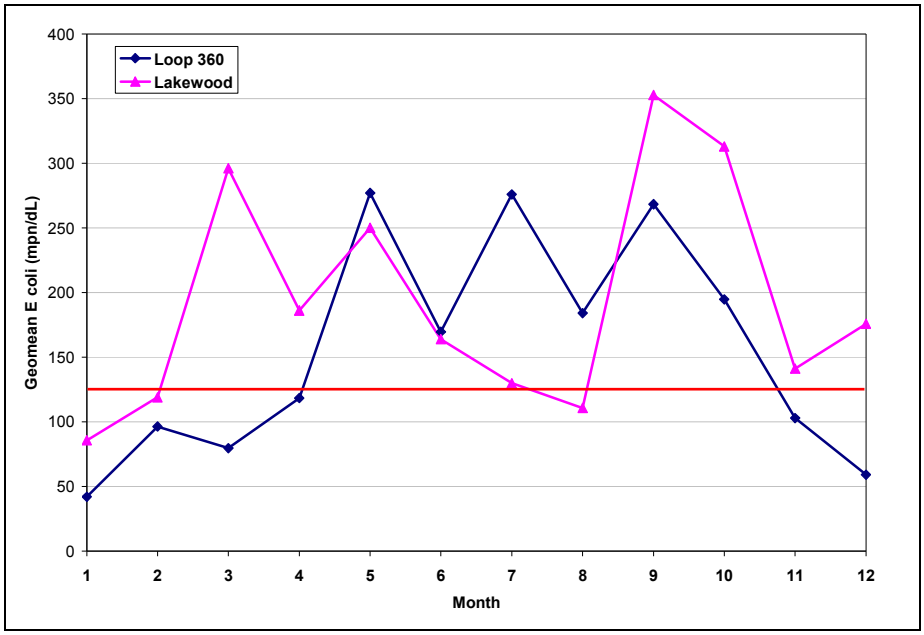

Figure 10. Monthly geometric mean *E. coli* for all data. The red line represents the Texas contact recreation standard of 126 mpn/dL.

Load Duration Curves

Load duration curves are recognized tools for non-point or point-source determination in Total Maximum Daily Load assessments (EPA 2007). Load duration curves characterize water quality under different flow regimes to visualize the frequency and magnitude of standard exceedances. Impairments observed under low flow regimes typically indicate point source impacts while impairments observed under high flow regimes typically indicate non-point source impacts. Load duration curves were calculated for the Lakewood (Figure 11) and Loop 360 (Figure 12) sites by following EPA methodology using the mean daily flows from the USGS flow gauge at Loop 360 (08154700) without including a margin of safety in the contact recreation standard as the curves are not being used for actual TMDL apportionment.

Exceedances of the standard occurred across the range of flow regimes at the Lakewood site, suggesting a combination of point and non-point source impacts. There are clear differences in the post-spill periods before education began between the Loop 360 and Lakewood sites, with few exceedances at Loop 360 but consistent exceedances at Lakewood. The post-spill, pre-education time period was consistent with historical monitoring at Loop 360. The reduction in bacteria levels during the on-leash period occurred primarily after the flooding of Tropical Storm Hermine (Figure 13).

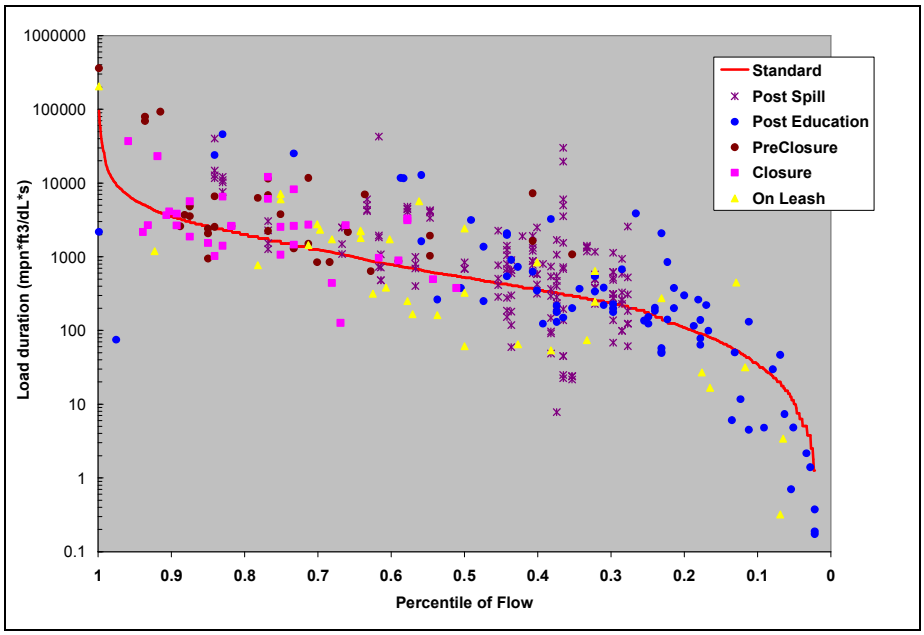

Figure 11. Load duration curve for the Lakewood site by time period calculated using mean daily flows from the USGS gauge at Loop 360 (08154700). The horizontal axis represents the percentile of flow, with the largest recorded flow values at the left of the graph. The red line represents the Texas contact recreation standard, and values above the line exceed the standard.

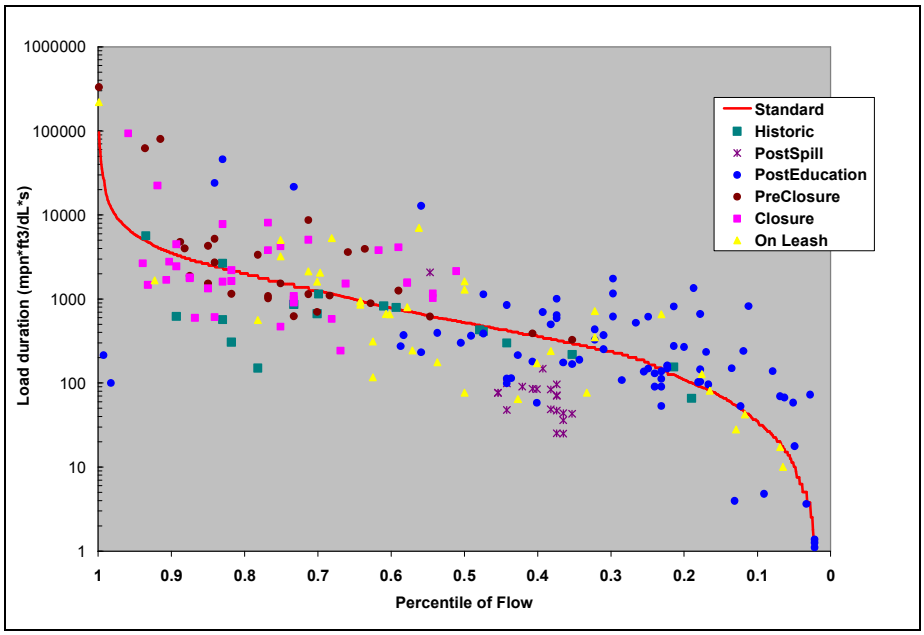

Figure 12. Load duration curve for the Loop 360 site by period using mean daily flows from the USGS gauge at Loop 360 (08154700). The horizontal axis represents the percentile of flow, with the largest recorded flow values at the left of the graph. The red line represents the Texas contact recreation standard, and values above the line exceed the standard.

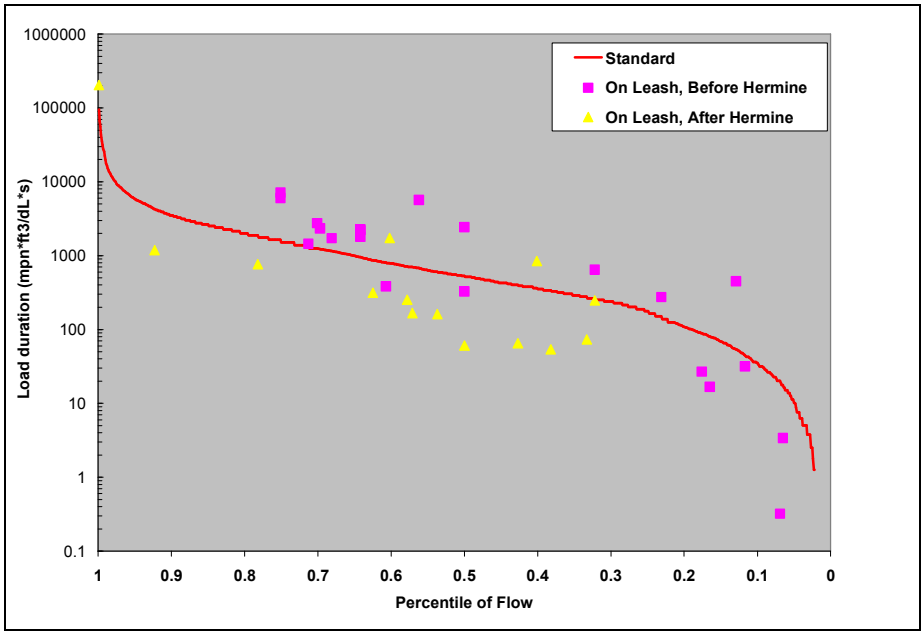

Figure 13. Load duration curve for the Lakewood site during the on-leash period with data separated before and after Tropical Storm Hermine. The horizontal axis represents the percentile of flow, with the largest recorded flow values at the left of the graph. The red line represents the Texas contact recreation standard, and values above the line exceed the standard.

Park Usage

The number of dogs (Figure 14) and people (Figure 15) present are counted instantaneously by WPD staff during weekend sampling events at the Loop 360 and Lakewood sites, typically performed in the early afternoon hours on a Sunday. There is no statistically significant

correlation with time by Kendall's tau-B analysis for the number of people or number of dogs present at the Loop 360 site for the period of record. There is a negative correlation of the number of dogs present (tau-B= -0.32, n=48, Pr>tau=0.0019) at the Lakewood site over time for the period of record, but no significant correlation with time in number of people present at the Lakewood site.

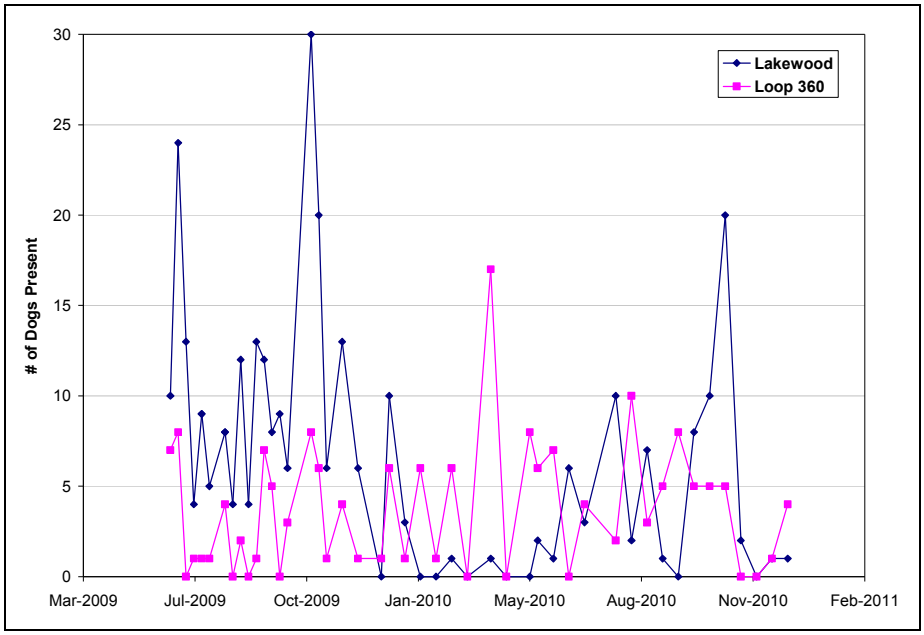

Figure 14. Number of dogs present at weekend sampling events.

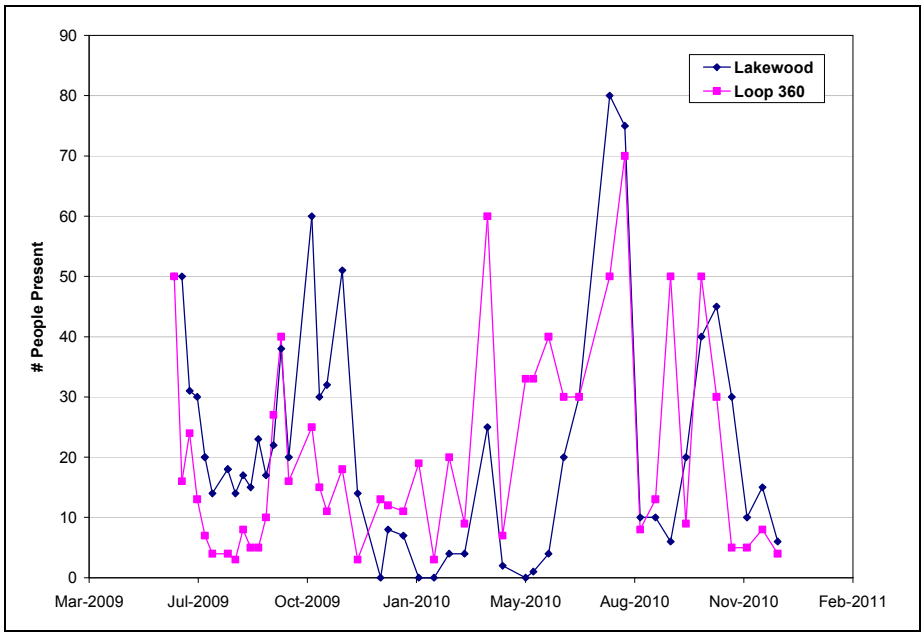

Figure 15. Number of people present at weekend sampling events.

The Lakewood site maintained significantly higher number of people and dogs than the Loop 360 site on average (Table 8) for the post-education and pre-closure period by Wilcoxon signed-rank test (Table 9). The Loop 360 site maintained significantly higher numbers of dogs than the Lakewood site during the closure period, and there is no significant difference in number of dogs

(Pr>|S|=0.51) between sites during the on-leash period. Site differences in number of people present follow observed patterns with # of dogs. Number of people present may be increasing at the Loop 360 site over time.

Table 8. Number of observations, mean and standard deviation for number of people and dogs present by site and period.

Parameter	Period	SiteNickName	# Obs	Mean	Stdev
DOGS AT SITE	PostEducation	Lakewood Drive	14	9.6	5.3
		Loop 360	12	2.7	3.0
	PreClosure	Lakewood Drive	8	12.3	8.6
		Loop 360	8	3.5	2.8
	Closure	Lakewood Drive	12	1.5	2.8
		Loop 360	12	4.9	4.9
	OnLeash	Lakewood Drive	14	5.1	5.6
		Loop 360	14	3.7	3.0
PEOPLE AT SITE	PostEducation	Lakewood Drive	14	24.1	12.2
		Loop 360	12	12.4	13.3
	PreClosure	Lakewood Drive	8	33.4	15.8
		Loop 360	8	19.4	11.2
	Closure	Lakewood Drive	12	4.6	7.0
		Loop 360	12	21.7	16.7
	OnLeash	Lakewood Drive	14	28.4	24.2
		Loop 360	14	25.9	21.8

Table 9. Wilcoxon signed-rank test results for number of people and number of dogs present. Pr>|S| values less than 0.05 indicate significant differences between sites.

		Site Means		
Period	Parameter	Lakewood	Loop 360	Pr>|S|
PostEducation	Dogs	9.6	2.7	0.0005
PreClosure	Dogs	12.3	3.5	0.0078
Closure	Dogs	1.5	4.9	0.0449
OnLeash	Dogs	5.1	3.7	0.5073
PostEducation	People	24.1	12.4	0.0010
PreClosure	People	33.4	19.4	0.0547
Closure	People	4.6	21.7	0.0005
OnLeash	People	28.4	25.9	0.3311

Nutrients from Bull Creek Study

WPD routinely monitors the water quality of the Bull Creek Watershed from a chemical perspective, and recently published a report summarizing that monitoring data (Duncan et al 2010). Ammonia, conductivity, aquatic vegetation coverage and dissolved oxygen values at the Loop 360 site were not significantly different from other upstream monitoring locations across the Bull Creek Watershed. The lack of substantially elevated ammonia, increased algae coverage, increase in conductivity or depressed dissolved oxygen do not support the hypothesis that on-going wastewater leakage is responsible for elevated indicator bacteria levels within the park. The Bull Creek Study (Duncan et al 2010) describes a recent increasing *E. coli* over time at the Loop 360 site, but does not describe any temporal trends in nutrient concentrations.

Weekend/Weekday

Previous analyses (COA 2008) noted a strong increase in *E. coli* concentrations on weekend days relative to weekdays, suggesting that park usage which is generally higher on weekends is correlated to indicator bacteria. The increased E. coli geometric mean on weekend pattern was maintained at the Lakewood site until the park was closed in December 2009 for restoration (Figure 16), although the difference in mean *E. coli* on weekends was only significant by the non-parametric Wilcoxon rank-sum test in the post-spill and post-education periods. A similar pattern of higher *E. coli* on weekends was never observed at the Loop 360 site (Figure 17). There is no significant difference by Wilcoxon rank-sum test between weekend and weekday *E. coli* at Loop 360 in any time period.

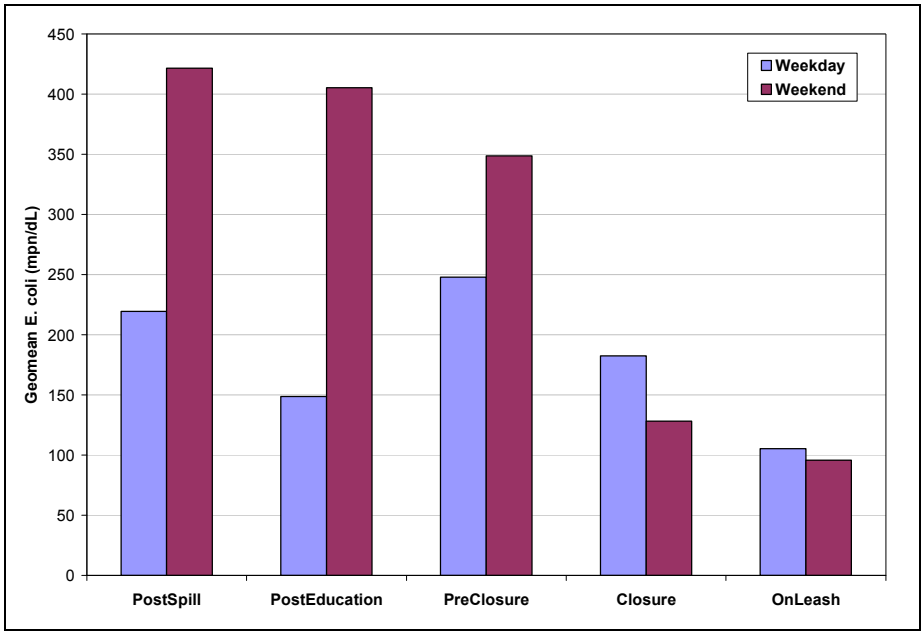

Figure 16. Geometric mean *E. coli* on weekdays (blue, left) and weekends (red, right) at the Lakewood site.

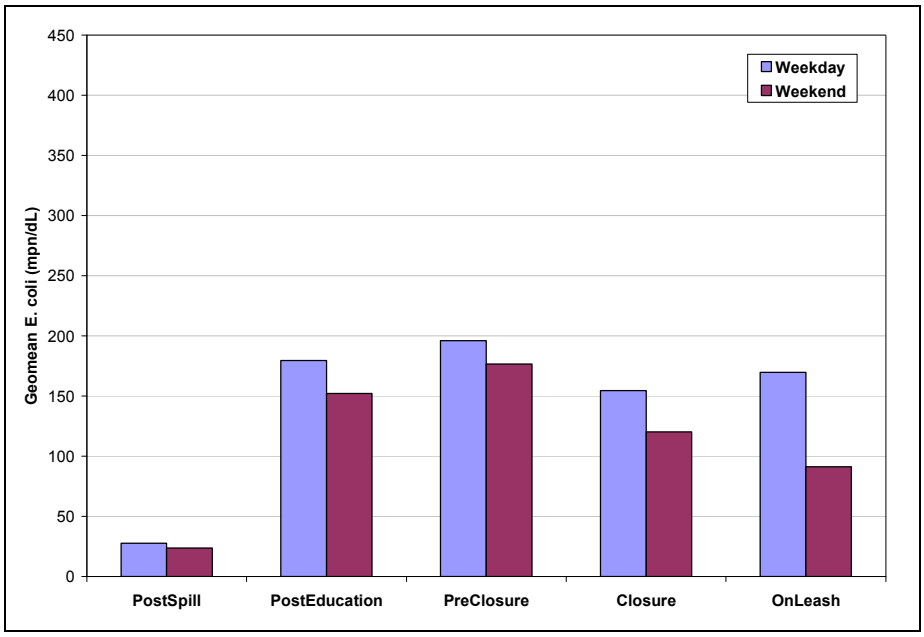

Figure 17. Geometric mean *E. coli* on weekdays (blue, left) and weekends (red, right) at the Loop 360 site.

Conclusions

The goal for safe human water contact relative to fecal contamination is to consistently keep *E. coli.* indicator bacteria levels below the Texas contact recreation standard of 126 mpn/dL when calculated as a geometric average. Indicator bacteria monitoring was conducted in Bull Creek District Park at multiple locations over time under varying park use management strategies.

Average *E. coli* bacteria levels at the Lakewood site, where the former dog off-leash area was located, dropped below the maximum State of Texas contact recreation standard during the time period when dogs were allowed in the park on-leash only, although the decrease in this period primarily occurred following Tropical Storm Hermine. *E. coli* levels increased above the contact recreation standard at the Loop 360 site following the public education campaign initiated in March 2008 and remain above the contact recreation standard. The source of fecal contamination appears to be localized within Bull Creek District Park.

The public education campaign conducted in March 2008 did yield a measured improvement in public opinion but did not successfully lower bacteria levels below the Texas contact recreation standard. Volunteer efforts initiated in June 2008 did not successfully lower bacteria levels below the contact recreation standard. A physical restoration project was conducted in Bull Creek District Park near the Lakewood site while the park was closed from December 2009 to May 2010. The project was successfully completed on time and under budget, but did not lower bacteria levels below the contact recreation standard.

Genetic microbial source tracking conducted to date indicates that the fecal contamination is not of human origin, although additional validation of the method is required. Birds may be contributing fecal loads to Bull Creek particularly in April but are not responsible for increasing bacteria above contact recreation standards. Based on patterns in water chemistry, there is no evidence of on-going wastewater contamination of Bull Creek in the park. Contaminated sediments may be a reservoir for fecal bacteria although there is no spatial or temporal trend that would consistently explain the observed bacteria levels in water.

Based on load duration curves, there appears to be a mix of point and non-point sources of fecal contamination to Bull Creek. Usage by people may be increasing over time at the Loop 360 site while number of dogs present may be decreasing over time at the Lakewood site. Weekend *E. coli* concentrations remain significantly higher than weekdays at the Lakewood site thru the post-education period, suggesting a continued relationship between water column *E. coli* and park use. There was no difference in weekend and weekday bacteria levels at Loop 360.

Discussion and Recommendations

Until more specific and validated analytical methods become reasonably available, there will not be a determination that the fecal contamination is exclusively or primarily from dogs with a high degree of confidence. All indications suggest that the contamination is not from on-going leaking wastewater infrastructure, and genetic bacteria source testing conducted to date suggest the fecal contamination is of non-human origin. Most likely, there is a mix of fecal sources operating within Bull Creek District including non-point source fecal contributions from upstream areas, dog waste in the park and human usage that are interacting with instream sediments. Sediments may be acting as a reservoir for fecal bacteria that are re-suspended in the water column during recreation activities.

Genetic bacteria testing methods and applications are still in development, even on a national scale. Although genetic methods are appealing in similar situations where conflicting uses are in question, it is likely that the full application of these methods to the fecal source identification within Bull Creek could be several years away.

The increase observed at the Loop 360 site following the public education campaign may have been the result of overall increased usage of the park or creating a pattern of avoidance of the Lakewood area by some park users because of the increased signage there resulting in a transfer of use to Loop 360. The lack of an observed weekend/weekday pattern at the Loop 360 site may be a function of the geomorphology of that location, as that reach is more of a bedrock run with generally less sediment accumulation than the Lakewood site.

Remediation of fecal contamination where contact recreation is not supported is extremely challenging, as there are frequently uncontrollable sources like wildlife and a high degree of variability in bacteria measurements. Remediation efforts must control all known or probable fecal contamination sources to the maximum extent practical. Control of known fecal sources is the reasoning behind EPA policy recommendations (EPA 2001) and Texas Parks and Wildlife Department regulations (TPWD Code 59.134e) that restrict dogs from areas near human swimming locations.

It is likely that the combination of public education, volunteer activity, reduction in usage during the closure period, and physical restoration of the riparian areas reduced the fecal load to sediments in Bull Creek. Previously contaminated sediments were likely scoured away or buried by flooding from Tropical Storm Hermine. It is critical to maintain the reduction in fecal loadings to prevent sediments from becoming re-contaminated. If sediments become sufficiently re-contaminated by re-introduction of a fecal source, it is likely that contact recreation will not be supported even if that source is removed until another rare, large flooding event like Hermine occurs.

There is a range of signage posted within Bull Creek District Park currently, including both regularly updated postings of bacteria counts, swimming advisories, and educational signage on

the water quality impacts from uncollected dog waste. This signage should be revisited, consolidated and updated once the future management of the park has been determined.

The ultimate management decision for Bull Creek District Park rests with the Austin Parks and Recreation Department, and must take into consideration the protection of human health. There are a range of potential options available relative to Bull Creek water quality, including:

- Prohibit swimming in Bull Creek: A prohibition on swimming would not address a known potential human health concern and thus is inconsistent with the practices of the City of Austin and may pose inherent legal liability concerns as suggested by Law Department staff. This is also the removal of a popular park use and reduction in the resource value of Bull Creek inconsistent with the mission of the Watershed Protection Department which seeks to improve water quality.
- Prohibit dogs from Bull Creek District Park: Removal of dogs from Bull Creek would be easier to enforce than current "Scoop the Poop" regulations, although enforcement is limited by the available resources of the Austin Police Department. The removal of dogs would be a removal of a popular park use and may require a new City ordinance. Although the prohibition of dogs would most likely reduce fecal loading to Bull Creek relative to continued off-leash use, the prohibition may not be necessary now that contact recreation is supported.
- Evaluate a provisional return to off-leash use or allow off-leash only on weekdays: A provisional off-leash evaluation period with continued monitoring to verify that indicator bacteria levels do not increase is a logical approach. However, this strategy risks the re-contamination of sediments particularly if there is insufficient sustained volunteer engagement to assist the resource-limited Parks and Recreation Department with the maintenance of the park. A return to off-leash use may negatively impact restored areas, which may require some additional protection via fencing or additional maintenance until all vegetation is fully established. Weekday-only dog off-leash use has been suggested, and may be a solution to help reduce park uses but still inherently risks re-contaminating stream sediments. If sediments become re-contaminated, no management action is likely to reduce bacteria levels below contact recreation standards until a rare, large flood event like Hermine occurs.
- Create a smaller, fenced area for off-leash use at Bull Creek District Park: A smaller fenced area for off-leash use within lower Bull Creek District Park may help segregate some park uses and may keep intense dog activities further from the creek. Increased distance from the creek with healthy riparian buffers may reduce fecal contamination of Bull Creek during runoff events. Users within a fenced area may be more likely to collect dog waste because of the confines of the smaller area. Engineering controls could also be added to improve stormwater treatment. Dogs may still be a non-point source of fecal loading to the creek, and enforcement would be required to insure off-leash use is restricted to the fenced area only. Significant funding would need to be provided for the construction of this fenced area.
- Continue dog on-leash only use with continued educational outreach on the collection of pet waste: Dogs being allowed on-leash only maintains all current uses, although in a reduced capacity for dog-related uses. Although there is the same risk that sediments may be re-contaminated over time, the risk is likely lower with on-leash only use relative to off-leash use.
- Additional monitoring: Additional monitoring has the benefit of continuing to provide information that can increase understanding of the potential fecal sources, but additional monitoring in the near term as the sole management measure is only recommended if the

park remains on-leash only for dogs to fully evaluate the potential impacts of this management strategy for a longer period of time after Tropical Storm Hermine. Additional monitoring should be continued at Bull Creek District Park, regardless of the selected management strategy, although a lower frequency may be appropriate, to insure contact recreation use remains supported.

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