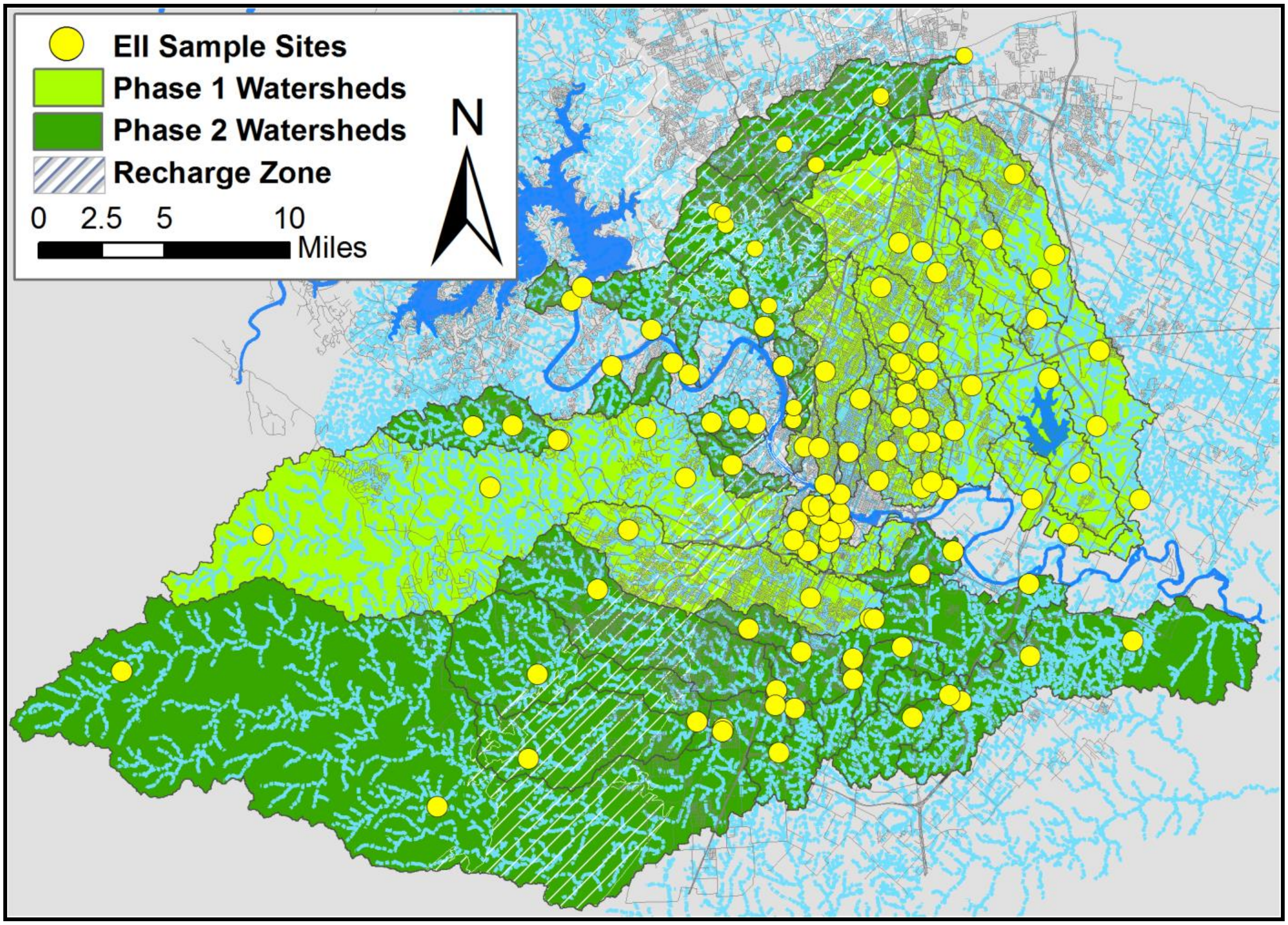
Environmental Integrity Index
Phase I & II (2013-2014) Watershed Summary Report



Short Report SR-15-08 July 2015
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City of Austin, Watershed Protection Department

On the cover: EII sampled watersheds color-coded by the respective phase (2013 Phase 1, 2014 Phase 2). Sample site locations are indicated within each watershed. Recharge zone, area lakes and major roadways are also included. Additional information regarding data and EII scores can be found in the watershed summary sections of this report.

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EII Phase I & II (2013-2014) Watershed Report

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Environmental Integrity Index (EII) Phase I & II data collected during 2013 and 2014 are presented and evaluated within the context of historical EII data. 118 sites located within 50 watersheds throughout the greater Austin area were sampled to assess environmental conditions. This data is primarily used for prioritizing subwatersheds for Capital Improvement Projects, regulations and/or other programs through the Citywide Watershed Protection Department masterplan. The values are also used in the WPD Business Plan as performance measures for water quality maintenance. The baseline information accumulated through the EII provides a large, comprehensive and quality assured dataset unique to our region which can be utilized for identifying and tracking both anthropogenic and climatic changes to our aquatic resources.

Introduction

The Environmental Integrity Index (EII) is a comprehensive biological, chemical and physical monitoring tool that was developed and tested in the urban watersheds in 1994 and 1995 and initiated citywide in 1996. By 2000, water quality sampling frequency became a quarterly event and the biological and habitat surveys were completed once per year. Fifty City of Austin planning watersheds with approximately 150 individual sites were grouped into three phases and sampled on a three-year rotating basis with approximately 50 sites sampled per year. Phase 1 primarily included the urban watersheds sampled historically under the Water Watchdog volunteer program while Phase 2 and Phase 3 included primarily suburban and developing watersheds (Figure 1 and Table 1). Phase 1 watersheds were sampled in 2000, 2003 and 2006, Phase 2 watersheds were sampled in 2001, 2004 and2007 and Phase 3 watersheds were sampled in 2002, 2005 and 2008.

In 2009, following the completion of three full cycles of the three-phase rotation (2000-2008), the watersheds were regrouped into two phases for sampling on a two-year rotating schedule (Figure 2 and Table 2). This regrouping was designed to increase frequency of site visits which would improve the resolution of temporal trend evaluation, and facilitated meeting the frequency requirements of the Texas Commission on Environmental Quality (TCEQ) for potential evaluation in the Clean Rivers Program. To balance time and resources, sites that did not exhibit adequate baseflow, or were determined to be redundant were dropped. The current (2013-14) two-phase cycle involves the monitoring of 118 sites within 50 watersheds.

This report presents data collected for the EII monitoring program in 2013 and 2014 and covers the associated water quality, habitat, and biological data. Data and scores from the previous EII sampling events are included for comparison within the tables and figures of the watershed summary sections of the report.

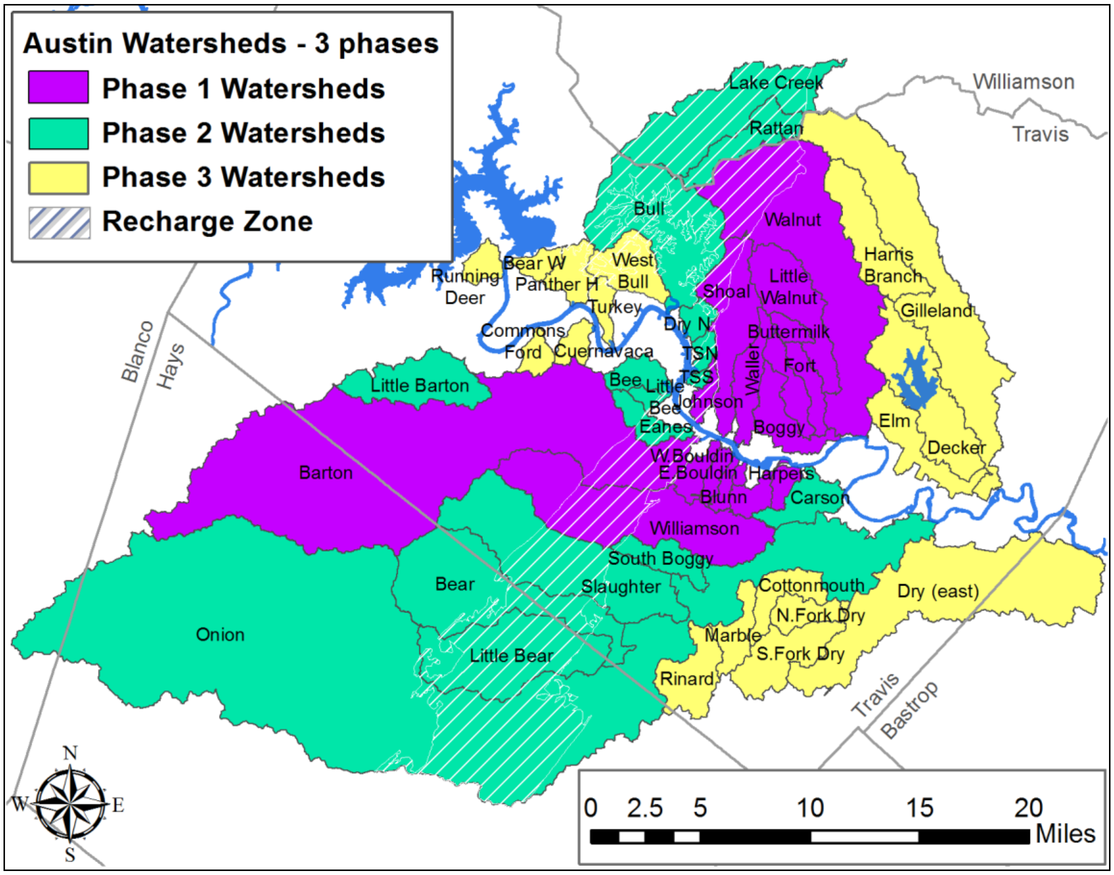

Figure 1. Historic three-phase rotation of watersheds sampled from 1999 through 2008

Table 1. EII Watersheds grouped by the historic 3-phase rotation of 1999-2008

Phase I 2000, 2003, 2006	Phase II 2001, 2004, 2007	Phase IIII 2002, 2005, 2008
Barton Creek	Bear Creek	Cottonmouth
Blunn Creek	Bee Creek	Decker Creek
Boggy Creek	Bull Creek	Dry Creek
Buttermilk Creek	Carson Creek	Elm Creek
Country Club Creek	Dry Creek	Gilleland Creek
East Bouldin Creek	Eanes Creek	Harris Branch
Fort Branch	Huck's Slough	Lake Austin (6 tributaries)
Harpers Branch	Lake Creek	Marble Creek
Johnson Creek	Little Barton Creek	North Fork Dry Creek
Little Walnut Creek	Little Bear Creek	Rinard Creek
Shoal Creek	Little Bee Creek	South Fork Dry Creek
Tannehill Branch	Onion Creek	
Waller Creek	Rattan Creek	
Walnut Creek	Slaughter Creek	
West Bouldin Creek	South Boggy Creek	
Williamson Creek	Taylor Slough (North)	
	Taylor Slough (South)	

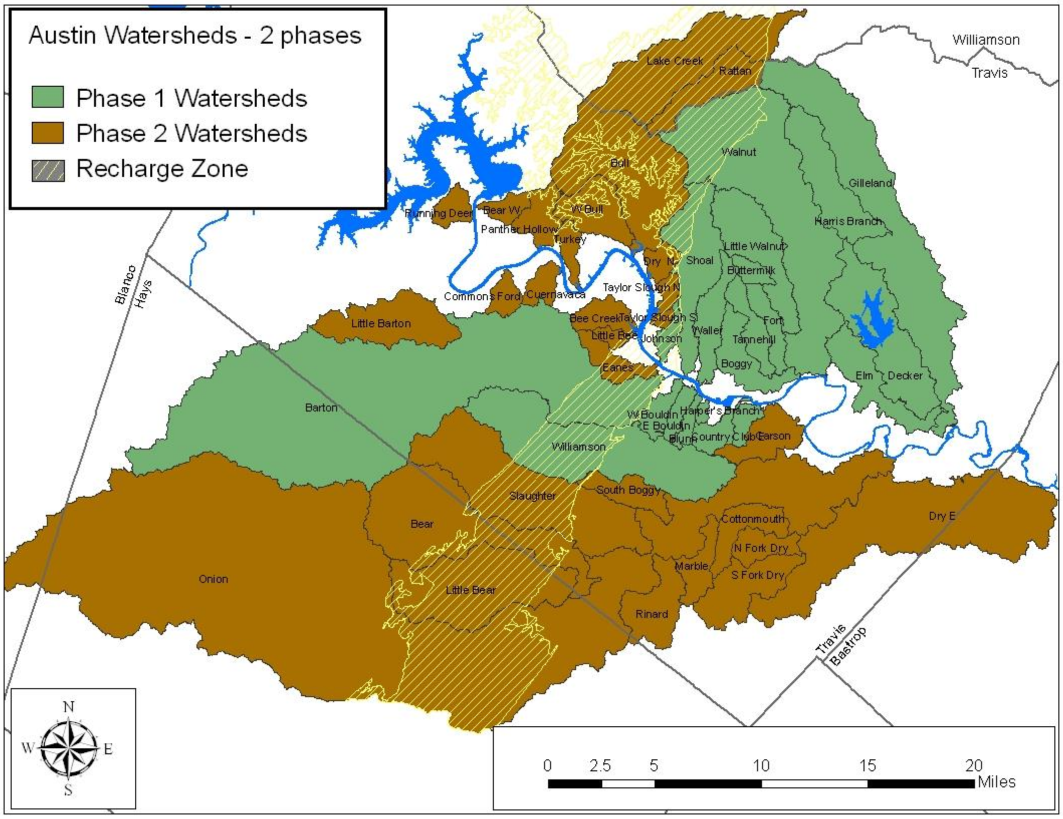

Figure 2. Current two-phase rotation of watersheds sampled from in 2009 through 2014

Table 2. EII Watersheds grouped by the 2-phase rotation of 2009-2014

Phase I – 2009, 2011,2013	Phase II – 2010, 2012, 2014
Barton Creek	Bear Creek
Blunn Creek	Bee Creek
Boggy (north) Creek	Bull Creek
Buttermilk Creek	Carson Creek
Country Club Creek	Cottonmouth Creek
Decker Creek	Dry Creek East
East Bouldin Creek	Dry (north) Creek
Elm Creek	Eanes Creek
Fort Branch	Lake Austin (6 tributaries)
Gilleland Creek	Lake Creek
Harpers Branch	Little Barton Creek
Harris Branch	Little Bear Creek
Johnson Creek	Little Bee Creek
Little Walnut Creek	Marble Creek
Shoal Creek	North Fork Dry
Tannehill Branch	Onion Creek
Waller Creek	Rattan Creek
Walnut Creek	Rinard
West Bouldin Creek	Slaughter Creek
Williamson Creek	South Boggy Creek
	South Fork Dry
	Taylor Slough (North)
	Taylor Slough (South)
	West Bull

Methods

Data was collected adhering to the Water Resource Evaluation Standard Operating Procedures Manual (SR-04-04) The collection of quarterly water quality sample at any given site is carried out during baseflow conditions (non-stormflow). During all sampling events (both quarterly and annual) physico-chemical measurements are collected with a multiprobe (Hach Hydrolab or Quanta Datasonde). These in-situ field measurements include:

- Dissolved Oxygen (mg/L)
- Specific Conductivity (µS/cm)
- pH (Standard Units)
- Water Temperature (^{o}C)

Quarterly water samples are collected and submitted to the LCRA Environmental Laboratory and analyzed for:

- Ammonia as N (mg/L)
- Nitrate as N (mg/L)
- Total Kjeldahl N (mg/L)
- Orthophosphorus as P (mg/L)
- Total Suspended Solids (mg/L)
- *Escherichia coli* bacteria (MPN/100ml) (for Barton, Bull, Onion and Walnut sites only)

Quarterly water samples that are analyzed at the COA laboratory were analyzed for:

- Turbidity (NTU)
- *Escherichia coli* bacteria (MPN/100ml) (for sites that will not be submitted for CRP/TMDL program)

Annual biological samples and physical stream assessments are conducted in the late Spring /early Summer. Benthic macroinvertebrates and diatoms are collected primarily from riffles during baseflow, but may be collected from intermittent pools if flow was absent. The annual assessment includes:

- Benthic macroinvertebrate and diatom surveys
- Stream and reach stability assessment
- Non-contact recreational assessment
- Habitat assessment
- Flow measurement, canopy density, and bank full measurement
- Photographs
- Sediment sample (collected from watershed mouth sites only and submitted to DHL Analytical)

Data from all sampling events (quarterly water quality events and one biological event) for a given year are analyzed, in part, through the use of seven sub-index categories. The average of the sub-indexes is an "overall watershed score" that is normalized relative to the other watersheds for that year. Detailed description of the calculation methods are provided in the EII Methodology Report (SR-02-12). The seven EII reporting categories are:

- Aquatic Life Use Score (an average of the Benthic Macroinvertebrate and Diatom sub-index scores)
- Water Quality Score
- Contact Recreation Score
- Non-Contact Recreation Score
- Sediment Quality Score
- Physical Integrity Score
- Overall Watershed Score

EII monitoring site locations were selected to represent stream reaches within each watershed. Reach boundaries were determined based on patterns in geomorphology, hydrology and land use. This provides the ability to evaluate trends over time, while providing the flexibility to move site locations if necessary. During the 2013-2014 Phase I & II sampling periods there were a total of 118 water quality sites in 50 watersheds. The monitoring schedule and flow status for these sample events are presented in Tables 3 and 4.

Table 3. 2013 EII Phase I Monitoring Schedule*

Watershed	Site #	Site Name	2013				
			Jan	Apr	May-Jun	Jun	Sep
			WQ	WQ	Bio	WQ	WQ
Barton	44	BAR @ Stark	B	B	B	B	B
Barton	46	BAR @ Shield	B	B	B	B	n
Barton	48	BAR @ Hwy71 ds LBA	B	B	B	B	B
Barton	49	BAR @ Ogletree	B	B	B	B	B
Barton	51	BAR @ Lost Ck	B	B	B	B	B
Barton	879	BAR btwn dams us BSP	n	n	B	B	B
Blunn	362	BLU @ Long Bow	B	B	B	B	B
Blunn	364	BLU us Stacy Pool	B	B	B	B	B
Blunn	180	BLU @ Riverside Dr	B	B	B	B	B
Boggy	2754	BOG @ Manor Rd	B	B	B	B	B
Boggy	837	BOG @ Nile Rd	B	B	B	B	B
Boggy	493	BOG @ Delwau	B	B	B	B	n
Buttermilk	3861	BMK @ VCC	B	B	B	B	B
Buttermilk	782	BMK @ Providence	n	n	n	n	n
Buttermilk	851	BMK @ LWA	B	B	B	B	B
Country Club East	1475	CCE @ ACC	n	n	n	n	n
Country Club West	850	CCW @ E Oltorf	B	B	B	n	B
Country Club West	849	CCW @ Crosssing Plc	B	n	n	n	n
Decker Creek	1196	DKR @ Lindell	B	B	B	n	B
Decker Creek	1974	DKR @ Gilbert	B	B	B	B	B
East Bouldin	121	EBO @ Alpine	B	n	n	n	n
East Bouldin	119	EBO @ Elizabeth	B	B	B	B	B
East Bouldin	5401	EBO @ Christopher	B	B	B	n	B
Elm	1204	ELM @ FM 973	n	n	n	n	n
Elm	3614	ELM @ Austins Colony	n	n	n	n	n
Fort Branch	126	FOR @ Glencrest	B	B	B	B	n
Fort Branch	125	FOR us Manor	n	n	n	n	n
Fort Branch	898	FOR @ Single Shot	n	n	n	n	n
Fort Branch	5400	FOR @ Tura Ln	n	n	n	n	n
Gilleland	1193	GIL @ S Railroad	B	B	B	B	B
Gilleland	1914	GIL @ Cameron	B	B	B	B	B
Gilleland	1194	W GIL @ Cameron	B	B	n	n	n
Gilleland	1191	GIL @ West Parsons	B	B	B	B	B
Gilleland	1192	GIL @ FM973	B	B	B	B	B
Gilleland	886	GIL @ FM969	B	B	B	B	B
Harper's Branch	844	HRP @ Woodland	B	B	B	B	B
Harris	1199	HRS @ Crystal Bend	B	B	B	B	B
Harris	1201	HRS @ Boyce	B	B	B	B	B
Johnson Creek	897	JOH @ Woodmont	B	n	n	n	n
Little Walnut	838	LWA @ Golden Meadow	B	B	B	B	n
Little Walnut	3860	LWA @ Georgian	B	B	B	B	B
Little Walnut	3857	LWA @ Cameron	B	B	B	B	B
Little Walnut	634	LWA @ US183	B	B	B	B	B
Shoal	118	SHL @ Crosscreek	B	B	B	B	B
Shoal	117	SHL @ Shl Edge Ct	B	B	B	B	B
Shoal	116	SHL @ 24th	B	B	B	B	B
Shoal	122	SHL us 1st	B	B	B	B	B
Tannehill	3858	TAN @ Berkman	B	B	B	B	B
Tannehill	843	TAN @ Lovell	B	B	B	B	B
Tannehill	1476	TAN @ Desirable	B	B	B	B	n
Waller	780	WLR @ 51st	B	B	n	n	B
Waller	624	WLR @ 23rd	B	B	B	B	B
Waller	38	WLR ds Cesar Chavez	B	B	B	B	B
Walnut	463	WLS @ Metro Pk	B	B	B	B	B
Walnut	895	WLN ds Metric	B	B	B	B	B
Walnut	464	WLN ds IH35	B	B	B	B	B
Walnut	502	WLN @ Old Manor	B	B	B	B	B
Walnut	503	WLN us Freescale	B	B	B	n	n
West Bouldin	3856	WBO @ Cardinal	B	B	B	n	n
West Bouldin	3854	WBO @ Oltorf	B	B	B	B	B
West Bouldin	5399	WBO @ Treadwell	B	B	B	n	B
Williamson	490	WMS @ Hwy71	B	B	B	n	n
Williamson	491	WMS @ IH35	B	B	B	n	B
Williamson	223	WMS @ Mckinney Falls	B	B	B	B	B

* B = baseflow n = no flow S = storm flow **dark blue** = Water samples were collected light blue = Water samples were not collected

Table 4. 2014 EII Phase II Monitoring Schedule*

Watershed	Site #	Site Name	2014 Jan WQ	2014 Apr WQ	2014 May-Jun Bio	2014 Jul WQ	2014 Sep WQ
Bear	4112	BER @ Bear Creek Pass	B	B	B	B	B
Bear	1087	BER @ Twin Creeks	B	B	B	B	n
Bee	1104	BEE @ 360	B	B	B	B	B
Bee	322	BEE @ Roadrunner	B	B	B	B	n
Bee	319	BEE @ LKA	B	B	B	B	n
Bull	151	BUL Trib 6 @ BUL	B	B	B	B	B
Bull	1164	BUL Trib 5 ds Hanks	B	B	B	B	B
Bull	349	BUL us Trib 7	B	B	B	B	B
Bull	920	BUL @ St Edwards us Dam	B	B	B	B	B
Bull	350	BUL @ LOOP360	B	B	B	B	B
Carson	1096	CAR @ Hoecke	B	B	B	B	B
Carson	1094	CAR @ Shady Spgs	B	B	B	B	B
Cottonmouth	1206	CTM @ D G Collins	B	B	B	B	n
Dry Creek South	1211	SFD @ Pearce	B	B	B	B	B
Dry Creek South	1210	SFD @ Wolf	B	B	n	B	n
Dry North	1108	DRN @ Mt Bonnel Rd	B	B	B	B	B
Eanes	1106	EAN @ Camp Craft	B	B	n	B	n
L.A.Bear West	1224	BRW @ Fritz Hughes	B	B	B	B	B
L.A.Commons Ford	1048	CMF in CF Metro Pk	B	B	B	B	n
L.A.Cuernevaca	1222	CRN @ River Hills	B	B	B	B	n
L.A.Panther Hollow	1223	PAN @ Big View	B	B	n	B	n
L.A.Running Deer	316	RDR @ Running Deer Trl	B	B	B	B	n
L.A.Turkey Cr	1221	TRK @ City Pk	B	B	n	B	n
Lake Creek	1100	LKC ds Meadowheath	B	B	B	B	B
Lake Creek	3978	LKC @ Shadowbrook	B	B	B	B	n
Lake Creek	1098	LKC @ Sugar Berry	B	B	B	B	n
Little Barton	1115	LBA @ Hamilton Pool	B	B	n	B	n
Little Barton	1114	LBA @ Great Divide	B	B	n	B	n
Little Barton	77	LBA @ BAR	B	B	B	B	B
Little Bear	3374	LBR @ Ashmun	n	n	B	n	n
Little Bear	1101	LBR @ BER	B	B	B	B	n
Marble	232	MAR @ Thaxton	B	B	n	B	n
Marble	231	MAR @ Wm Cannon	B	B	B	B	B
North Fork Dry	1217	NFD @ FM 812	B	B	n	n	n
Onion	4595	ONI @ Hudson	B	B	B	B	B
Onion	612	ONI nr Driftwood	B	B	B	B	B
Onion	236	ONI @ Twin Cks	B	B	B	B	B
Onion	241	ONI us Footbridge	B	B	B	B	B
Onion	255	ONI @ Mckinney Lower Falls	B	B	B	B	B
Onion	1366	ONI @ SAR	B	B	B	B	B
Rattan	1009	RAT us Parmer	n	n	n	n	n
Rattan	1097	RAT @ Shadowbrook	n	n	n	n	n
Rinard	5398	RIN ds SH 45	B	n	n	n	n
Rinard	233	RIN @ Bradshaw	B	B	B	B	B
Slaughter	623	SLA @ FM 1826	B	B	B	B	n
Slaughter	1082	SLA @ Pine Vly	B	B	B	B	B
South Fork Dry	1215	SFD @ US183	B	B	n	B	n
South Fork Dry	1216	SFD @ FM 812	B	B	B	B	n
Taylor Slough (N)	3969	TYN @ Mayfield Pk	B	B	B	B	n
Taylor Slough (S)	318	TYS @ Reed Pk	B	B	B	B	B
West Bull	148	WBL @ Bell Mt	B	B	B	B	n
West Bull	343	WBL us BUL	B	B	B	B	n

* B = baseflow   n = no flow   S = storm flow   dark blue = Water samples were collected   light blue = Water samples were not collected

Results

As described in the Methods section, data is normalized and scored by sub-index categories in order to rate the environmental integrity of each watershed or sub-watershed. The scores of the seven sub-index categories are averaged to provide an overall EII total watershed score. The total score can vary from year to year based on anthropogenic influences such as development and acute water quality issues, but is also affected by climatic influences (such as drought or flooding), minor changes in methods and other variables. Figure 3 lists each watershed from the lowest to the highest historic (2000-2012) average total score shown in blue, in comparison to the current (2013-2014) total score shown in red.

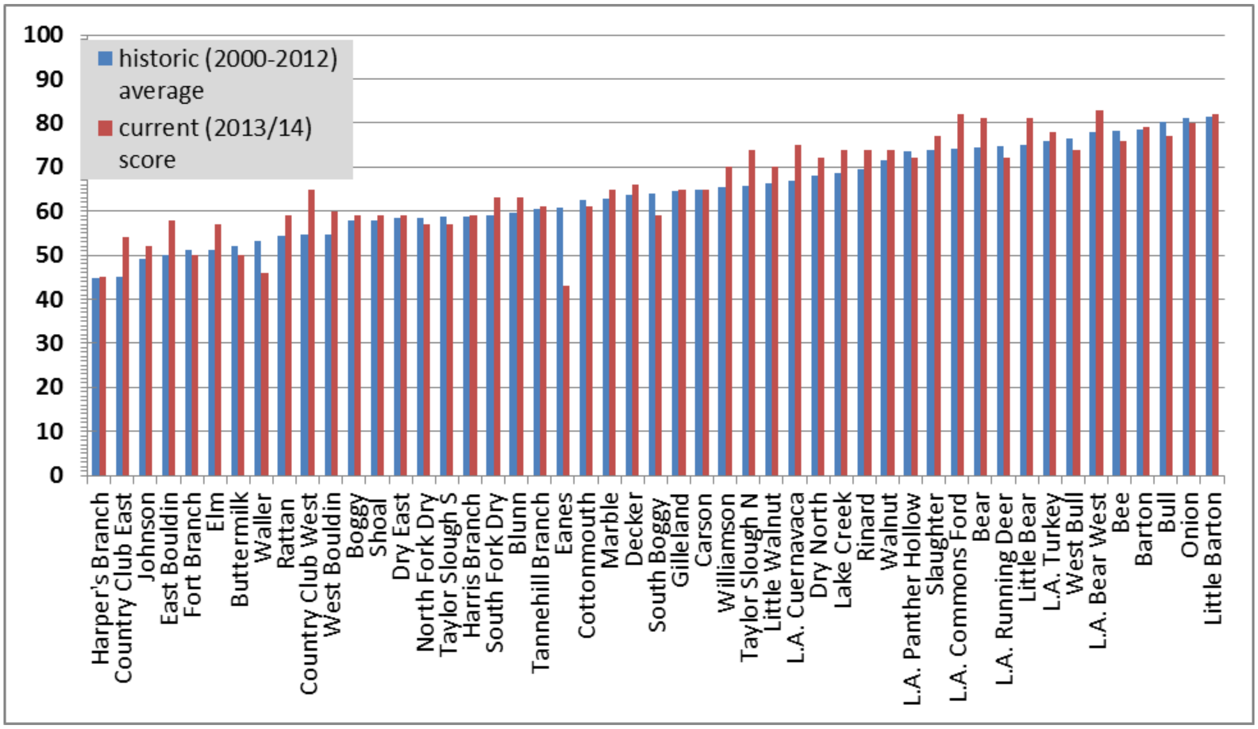

Figure 3. Overall EII total watershed scores. Watersheds are listed in ascending order of their corresponding historic (2000-2012) average total score. The current (2013-2014) total score indicates that most watershed scores were generally similar to average score.

Of the 49 scoring watersheds (Figure 3), 35 had the same or better score than the respective historic average. On average, scores for all watersheds were within two points of their historic average, with a standard deviation of five points. The largest difference in scores was for Eanes watershed, which was lower than the historic average by 18 points. This drop is primarily due to a combination of increasing bacteria concentrations and a lack of baseflow which limited both biological and sediment sampling. The current scores for both Country Club East and West increased considerably (9 and 10 points respectively) compared to their historic average, but had few water samples collected due to little or no baseflow. Factors that contribute to differences between current and historic scores at individual sites can be further evaluated within the Watershed Summary sections of this report.

Water chemistry data for each watershed for the 2013-2014 sample events are presented as box and whisker plots in Figures 4a – 4i. The dashed horizontal line on each graph indicates the historic EII average value. The whiskers indicate the minimum/maximum values and the boxes indicate the interquartile range. The median and mean of each data set are shown within the boxes as stars and horizontal lines respectively. The graphs indicate the general range of these data among watersheds and allows for easy comparison and identification of outliers. A more detailed evaluation of spatial and temporal trends at sites within a given watershed can be found in the watershed summary sections of this report.

pH
Across all watersheds for 2013 and 2014, pH values (Figure 4a) were within expected range. Austin surface water to the west of the Balcones Escarpment is frequently slightly basic due to the dominance of calcium carbonate in limestone bedrock and spring water; however, this is less frequently the case in the eastern tributaries. Values across all watersheds tend to be slightly acidic since rainwater runoff is slightly acidic (due to carbonic acid) and leaf litter decay can contribute to acidity (due to tannic acid).

Conductivity
For most watersheds, conductivity (Figure 4b) was also within the expected range; however, there were a few instances of both acute and chronically high values. Streams that are influenced by treated effluent (like Gilleland Creek) often have elevated conductivity throughout the year. Episodic pollutant loads such as wastewater spills or salt water pool discharge may cause spikes in conductivity as well.

Dissolved Oxygen
Aquatic life such as fish, salamanders, zooplankton, and benthic macroinvertebrates rely on dissolved oxygen (DO) in the water. Several factors can affect the concentration of DO including temperature, physical mixing and demand from organisms that produce and/or consume it. While plants, phytoplankton and periphyton can contribute large amounts of DO in the water, bacterial communities that thrive in nutrient-rich environments and decaying organic matter can cause the level of oxygen to plummet. As one might expect, the concentration of DO in Austin's surface waters (Figure 4c) is highly variable throughout the day, week or season based on changes in temperature, plant/algal growth and nutrients. It is important for surface waters to maintain more than 4 mg/L for sustaining fish populations. High spikes (i.e. >12 mg/L) may indicate an over-productive algae or plant community caused by excess nutrients. These spikes in DO during the day are frequently coupled with plummeting concentrations overnight as the bacterial community consumes it.

Nutrients (Orthophosphorus, Ammonia, and Nitrate/Nitrite)
Nutrients in surface water are an important component for aquatic ecosystems, but excess nutrient load (called eutrophication) can create several serious problems for aquatic life. Elevated phosphorus (Figure 4d) and nitrate (Figure 4f) concentrations are commonly associated with algal blooms which can result in dissolved oxygen spikes/troughs, fish kills, bad odors, and other associated water quality related problems. Ammonia (Figure 4e) in surface water converts readily to nitrate, so it is important to monitor both ammonia and nitrate. One of the more common sources for these nutrients in urban environments is wastewater from both treated effluent and raw sewage (via spills, leaks, etc). Accordingly, the streams that exhibit higher concentrations of these nutrients are typically known to either be driven in part by treated wastewater effluent or have aging infrastructure in which spills and overflows are common. Gilleland Creek, Harris Branch, and Lake Creek are examples of streams with treated effluent while Waller, Shoal, and East/West Bouldin are examples of watersheds with aging wastewater infrastructure and/or other human and animal fecal inputs. Another source in suburban areas may be agriculture-related inputs (e.g. fertilizers and manure) which may be the reason for elevated nutrients in southeastern watersheds such as Marble and South Fork Dry.

Sediment (Total Suspended Solids and Turbidity)
Sediment is one of the most common pollutants in water. Although it is naturally occurring, sediment levels can be elevated from accelerated and unnatural erosion from active and historic development practices. Nutrients and other pollutants can be released from eroded soil and the fine silty particles degrade the habitat for aquatic life. Murky, turbid water block sunlight for aquatic vegetation and can harm sensitive tissues such as fish and invertebrate gills and eggs. TSS (Figure 4g) and Turbidity (Figure 4h) concentrations were similar to previous years. Generally, the watersheds of the Blackland Prairie ecoregion (east of IH35) had higher TSS and Turbidity than the watersheds of the Central Texas Plateau ecoregion (west of IH35). Additionally, nearby active construction can also be a source of suspended sediments and high turbidity.

Bacteria (*Escherichia coli*)
E. coli is used as the primary indicator of instream pathogens. Contributions to *E. coli* contamination include direct and indirect sources from humans and animals. Generally, the 2013-2014 *E. coli* concentrations in Austin streams (Figure 4i) were higher than the previous EII cycle and have inspired new protocols for response and investigation of sites with elevated concentrations (e.g. *E. coli* Bacteria Source Isolation Sampling SR-15-07).

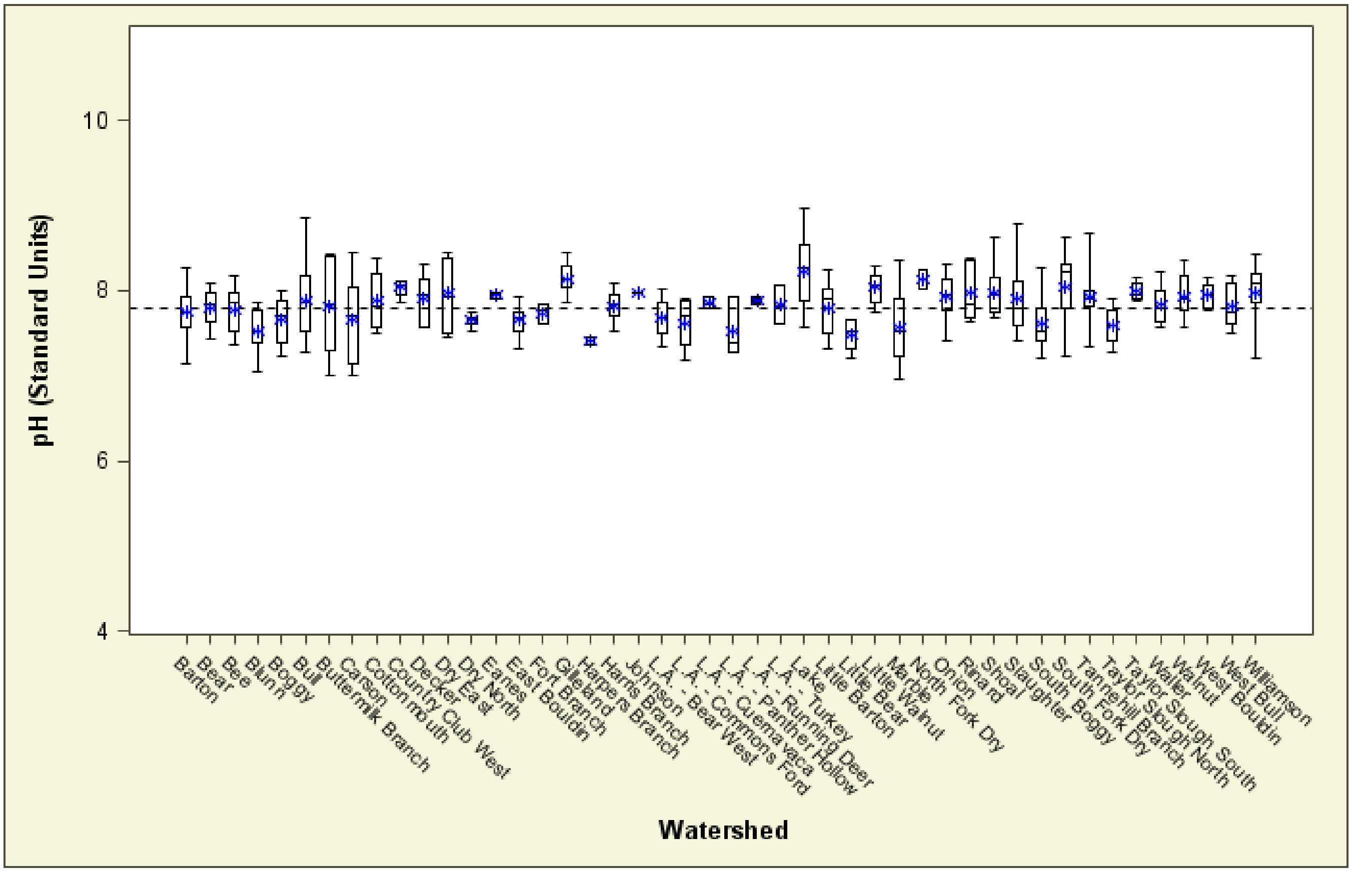

Figure 4a. pH data from quarterly samples collected from 2013 and 2014 for all watersheds

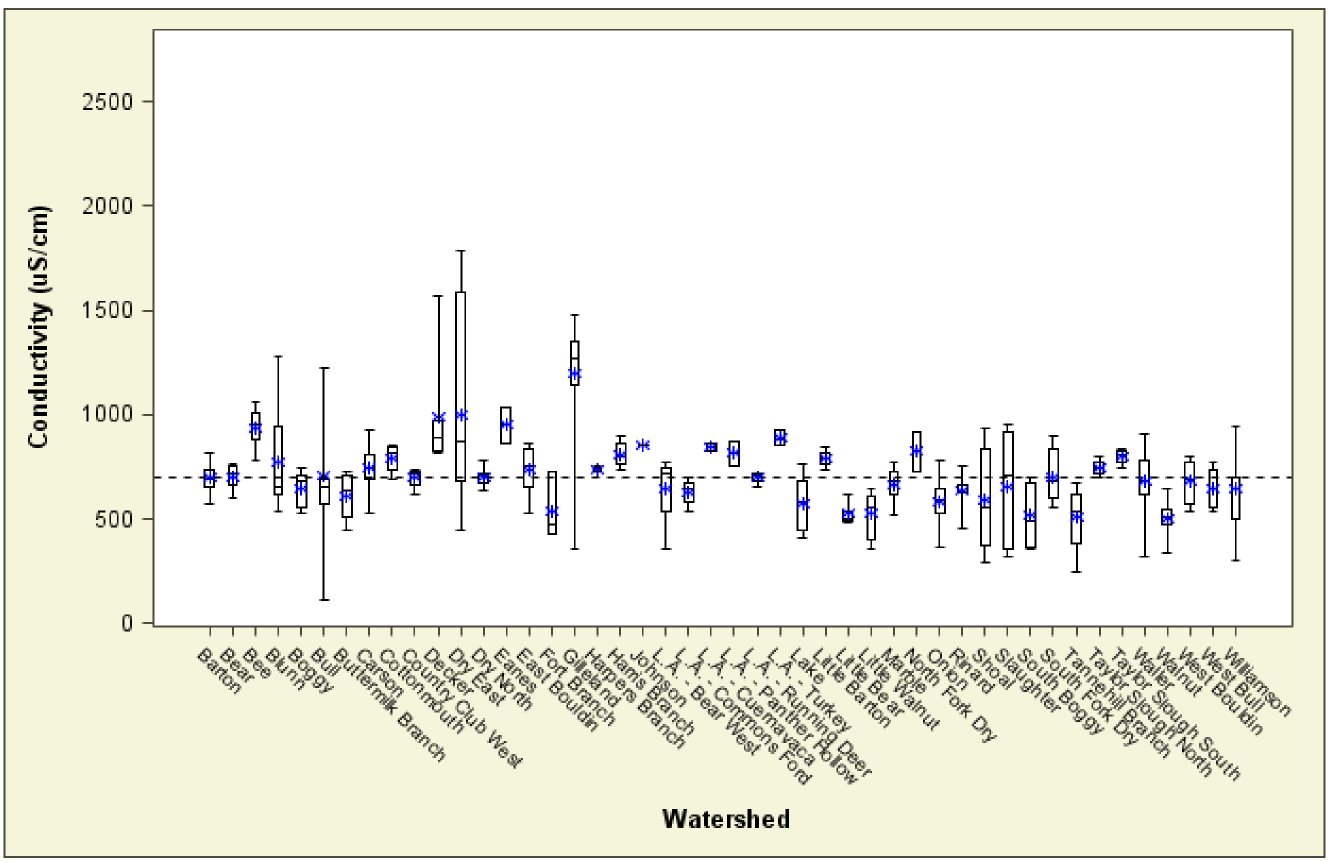

Figure 4b. Conductivity data from quarterly samples collected from 2013 and 2014 for all watersheds

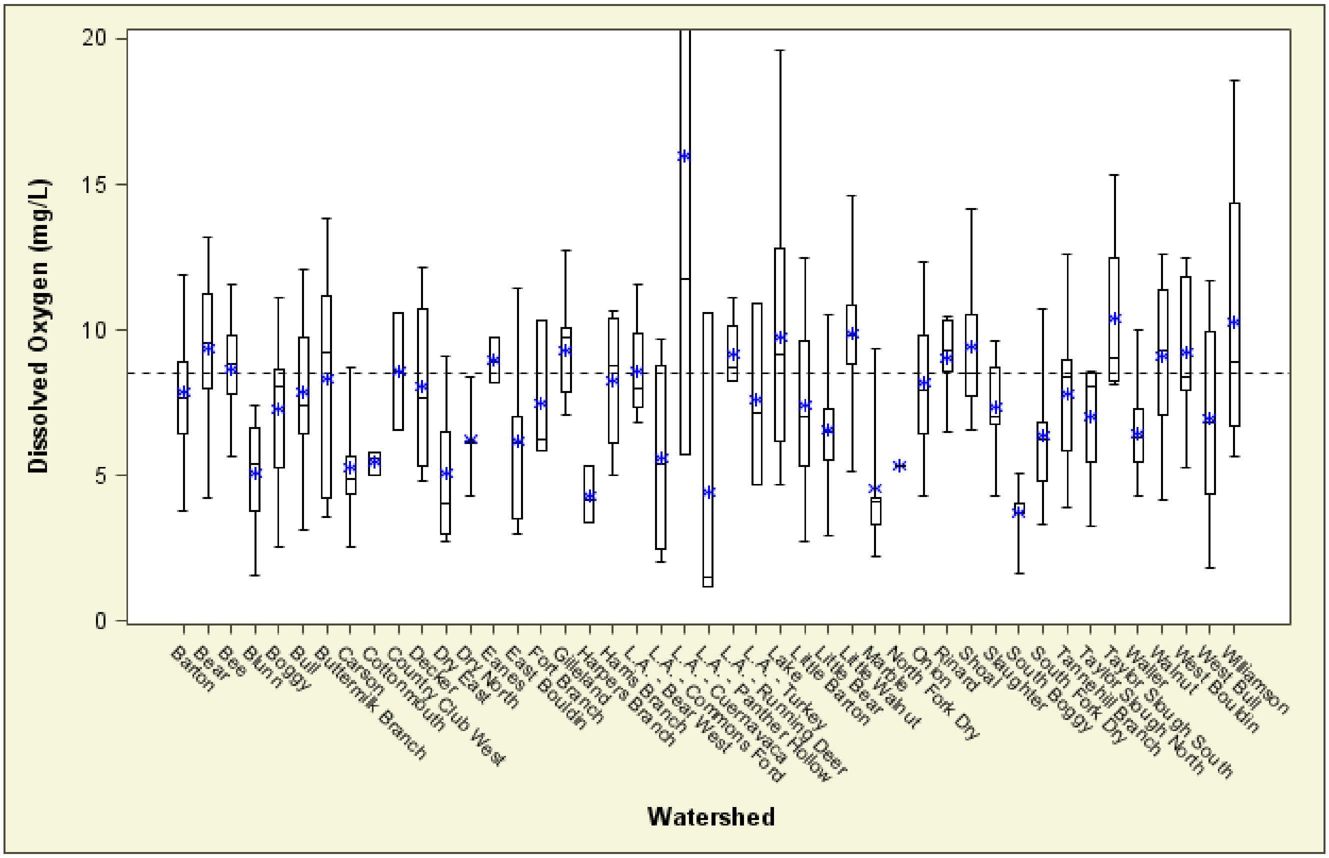

Figure 4c. Dissolved oxygen data from quarterly samples collected from 2013 and 2014 for all watersheds

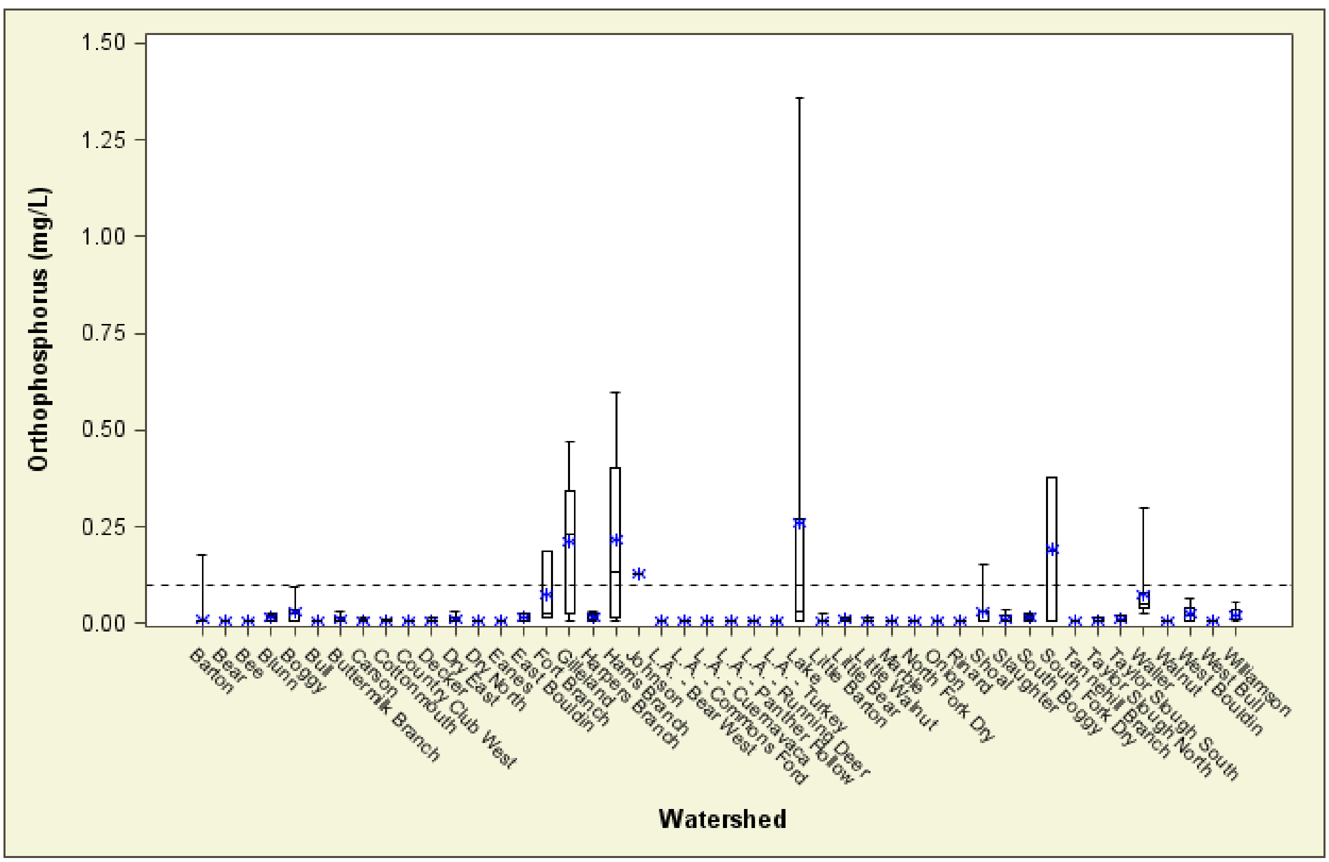

Figure 4d. Orthophosphorus data from quarterly samples collected from 2013 and 2014 for all watersheds

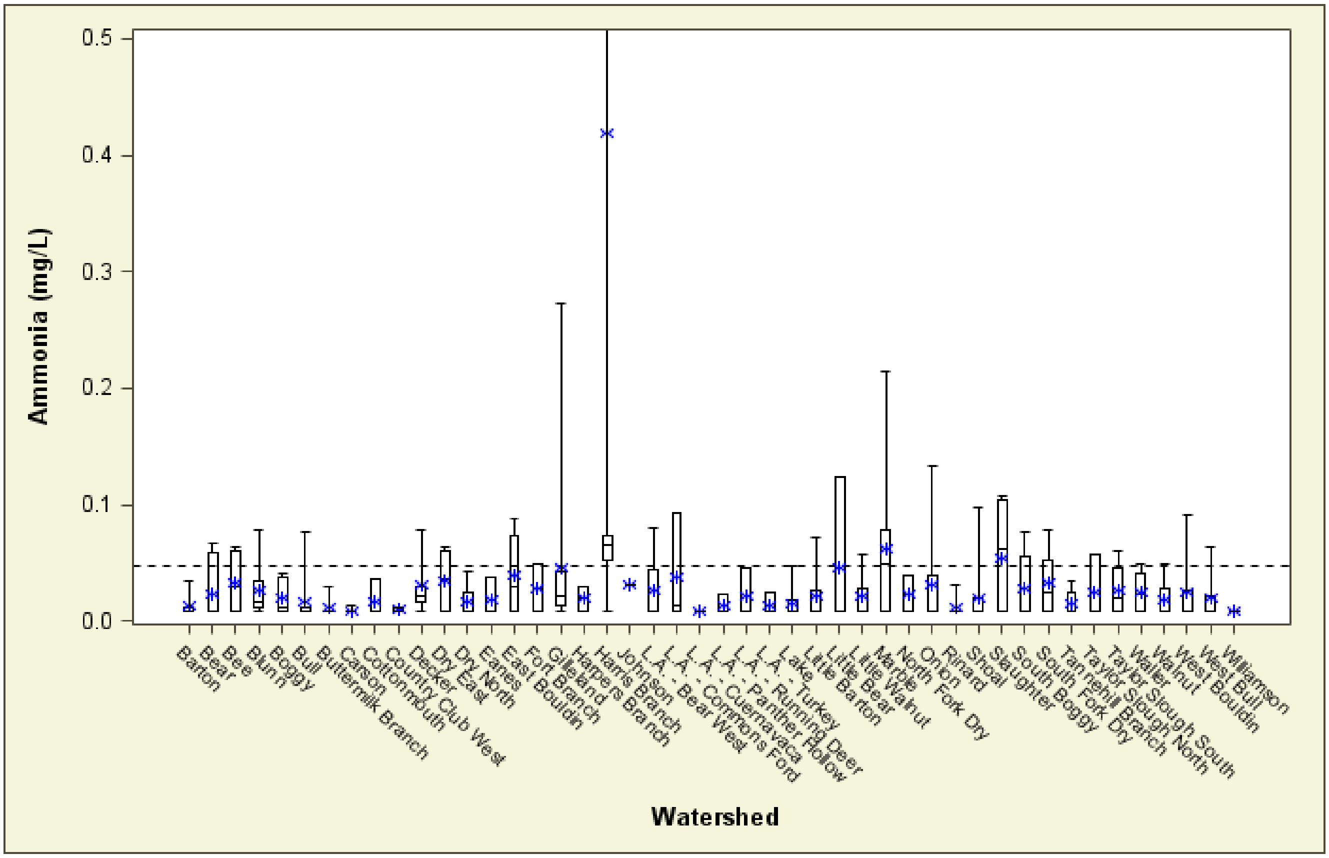

Figure 4e. Ammonia data from quarterly samples collected from 2013 and 2014 for all watersheds

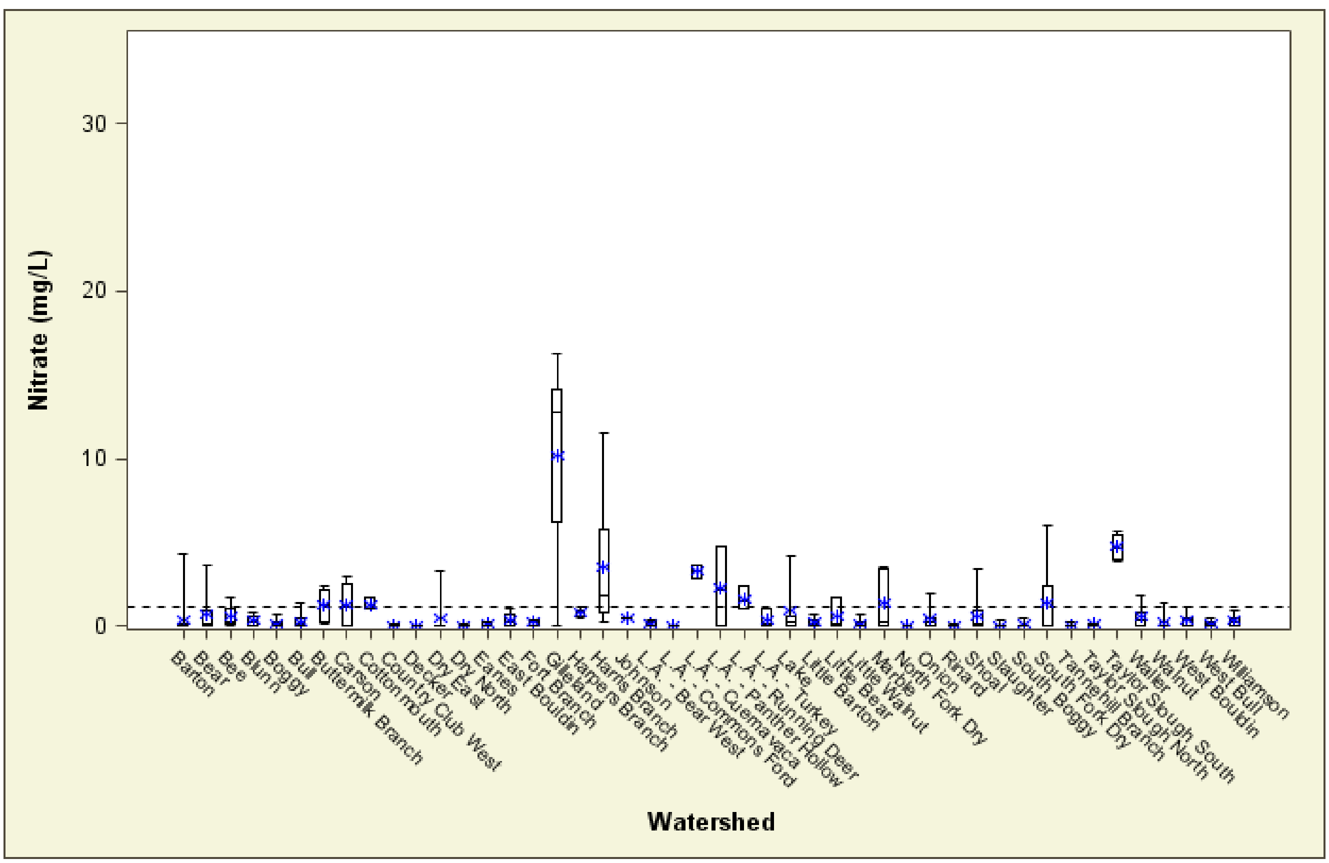

Figure 4f. Nitrate data from quarterly samples collected from 2013 and 2014 for all watersheds

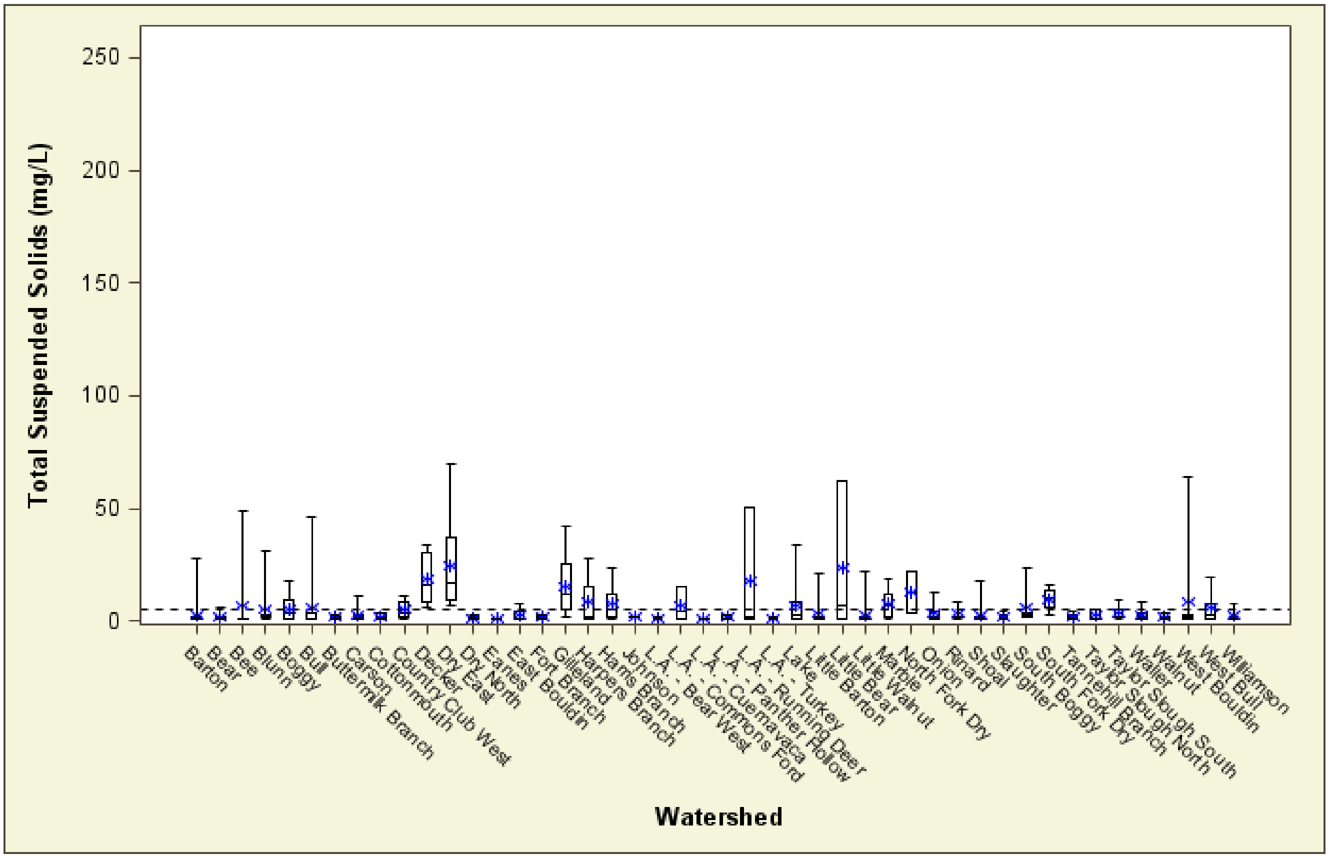

Figure 4g. TSS data from quarterly samples collected from 2013 and 2014 for all watersheds

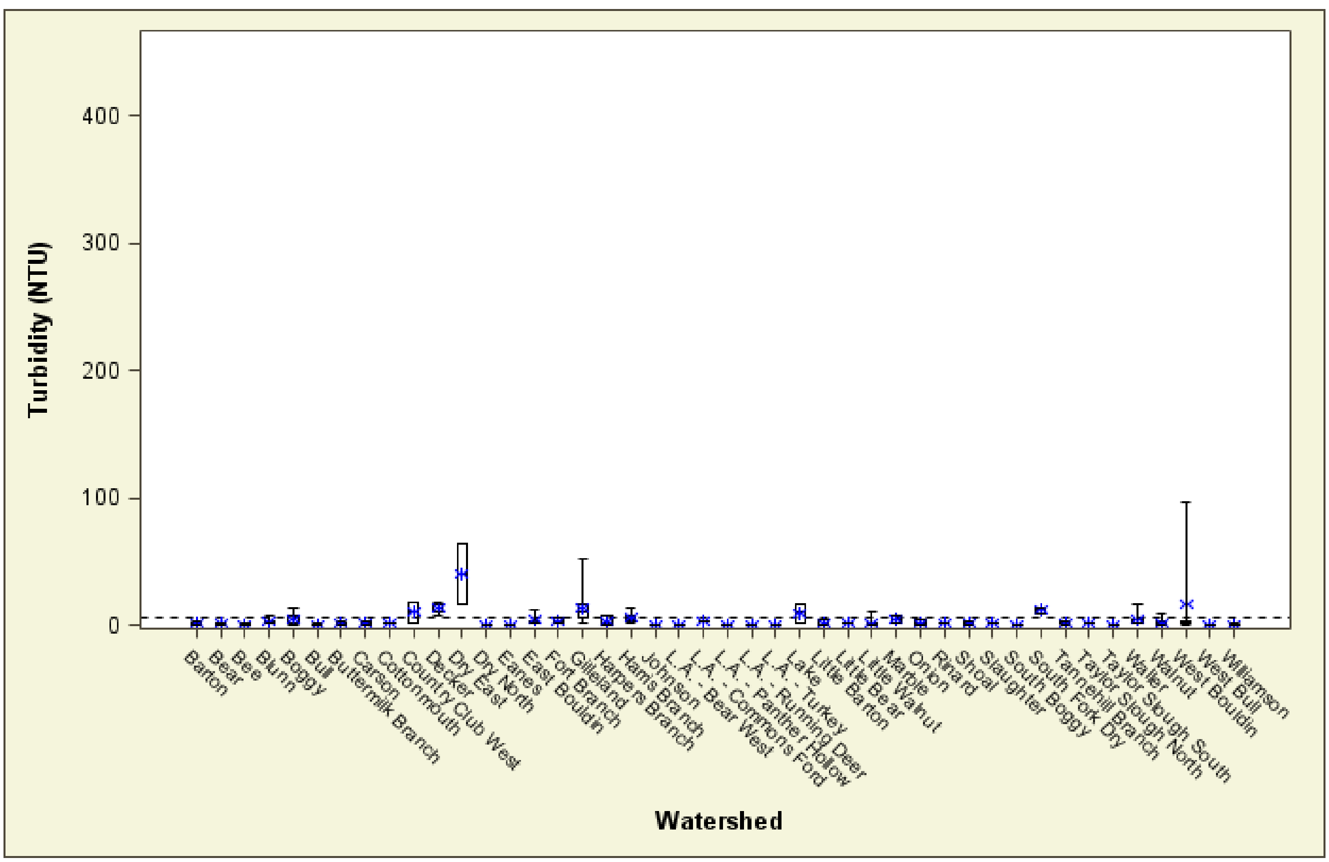

Figure 4h. Turbidity data from quarterly samples collected from 2013 and 2014 for all watersheds

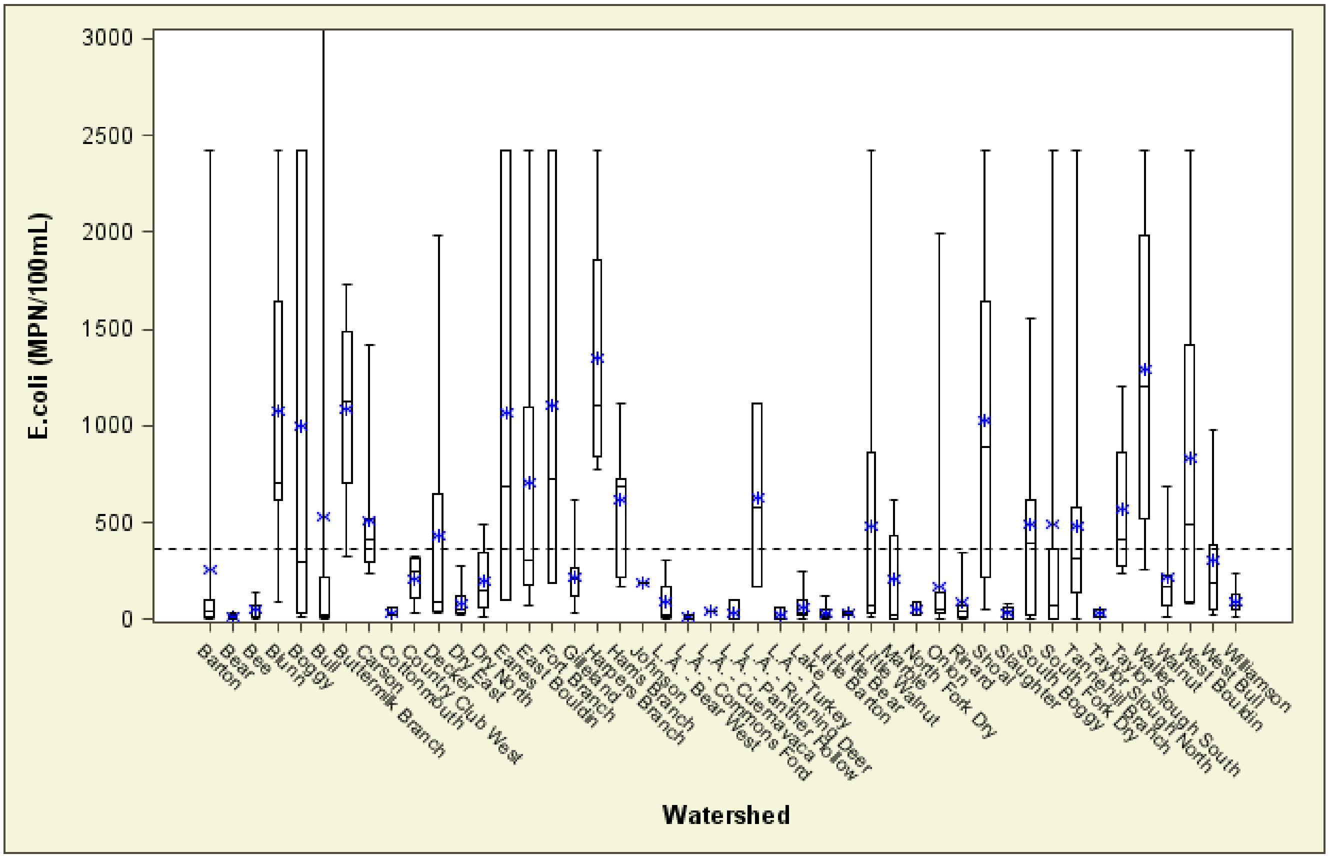

Figure 4i. ***E. coli*** **data from quarterly samples collected from 2013 and 2014 for all watersheds**

Benthic macroinvertebrate and diatom data are assessed using univariate metric scores such as diversity, community structure, functional feeding groups, indicator groups and the pollution tolerance of taxa present at each site. This biological data is most easily reviewed spatially using the current total score of a watershed compared to other watersheds total scores and temporally using the context of its historic average score (Figures 5 and 6). Sample sites that were dry at the time of sampling are not scored, and therefore a watershed may not have a current score if all sites within the watershed were dry.

In both diatom and benthic macroinvertebrate data sets, the aquatic life scores are generally higher in watersheds that are suburban and/or less intensely developed indicating a correlation between historic development practices and stream integrity. Additionally, aquatic life scores are typically higher in larger watersheds due to more reliable baseflow.

The benthic macroinvertebrate current sub-index score shows that most (38 of 47) sampled watersheds scored as high as or higher than their historic average score (Fig 5). Five of the nine watersheds that scored lower than their historic average scored significantly (more than 10 points) lower. Interestingly, most of the watersheds that scored lower are located in the southeast part of Travis County, but the cause of this spatial pattern is unclear.

Similarly, the current diatom sub-index score shows that most (37 of 44) sampled watersheds scored as high as or higher than their historic average score as well (Fig 6). Although many watersheds scored significantly higher (more than 10 points) than their historic average, only one watershed (Rattan) scored lower.

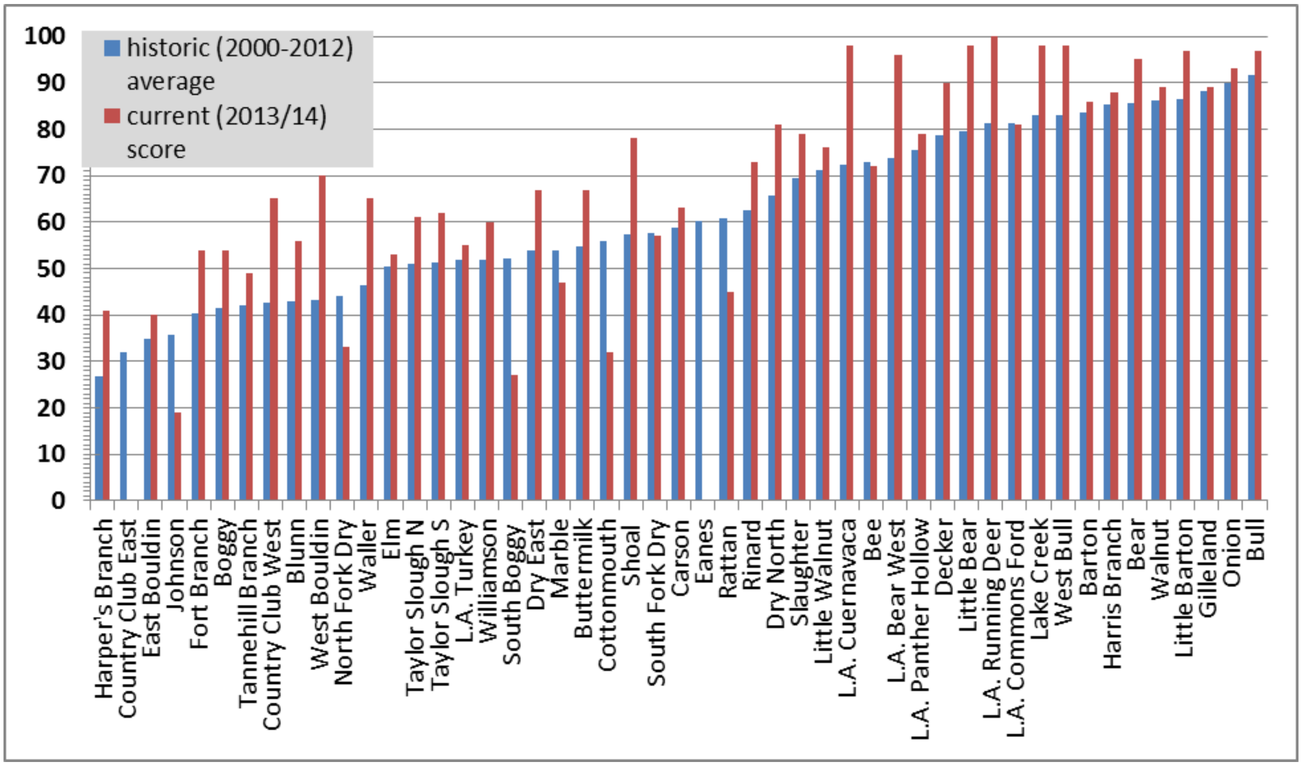

Figure 5. Benthic macroinvertebrate sub-index score for EII watersheds. Watersheds are listed in ascending order of their corresponding historic (2000-2012) average score. A lack of a current score is an indication that the site was dry and no sample was collected.

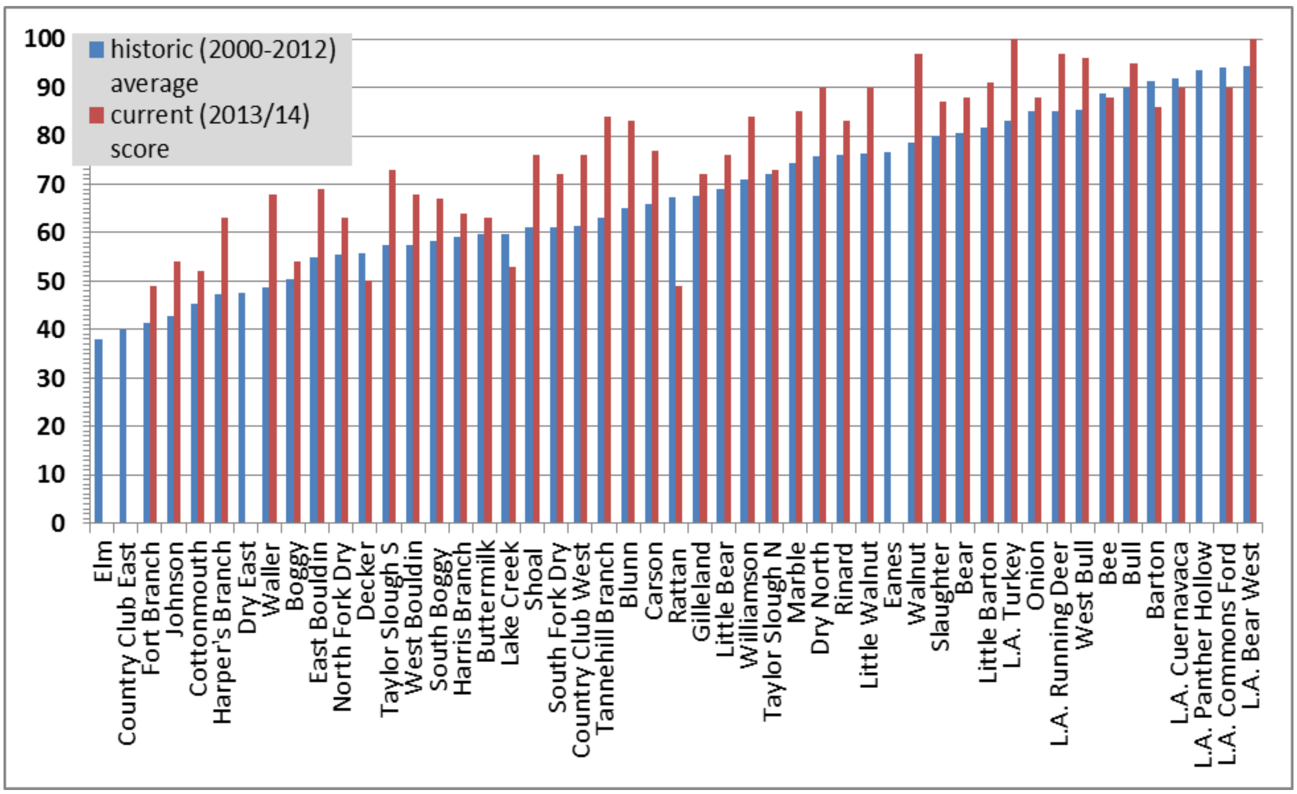

Figure 6. Diatom sub-index score for EII watersheds. Watersheds are listed in ascending order of their corresponding historic (2000-2012) average score. A lack of a current score is an indication that the site was dry and no sample was collected.

Recommendations

Although individual samples at any given site may include a parameter which may be outside the normal range, the following recommendations are based primarily on water quality considerations that are chronic in nature or are of a sufficiently elevated concentration that they warrant additional or continued attention. Bacteria (*E. coli*) and nutrient concentrations continue to be one of the most salient water quality problems impacting Austin-area surface waters. In response to this issue, a special investigation methodology was developed in 2014 (SR-15-07) to identify sources of *E.coli* contamination. Watersheds that are not specifically included below do not have any recommendations for action at this time based on the most recent data.

Bee Creek: Conductivity is typically higher in the middle and downstream reaches of the watershed. A spike in conductivity was observed in 2012 during drought conditions in the upstream reach of Bee Creek and was attributed to a salt-water pool discharging in the creek outside of the City jurisdiction. The 2014 data indicated higher-than-normal conductivity throughout the watershed but not as high as the levels observed in 2012. Conductivity in the middle and upstream reaches will be scrutinized in the 2016 sampling year.

Blunn Creek: *E.coli* concentrations have been chronically high since 2006, especially in the middle reach. Blunn was one of seven creeks selected in 2014 for comprehensive bacteria investigation (BSI, SR-14-17). A broken wastewater line was found and repaired in the headwater reach, upstream of Woodward Street, however other anthropogenic non-point sources occur in the upper watershed that apparently continue to be a source of fecal pollution. Preliminary 2015 data indicate a significant reduction in *E.coli* concentration, however education/outreach or other strategies may be prudent to mitigate potential direct human inputs in the upper watershed. A remaining issue is elevated conductivity in the downstream reach (BLU1) that is likely due to chronic discharges from Big Stacy Pool (during maintenance). Strategies to resolve this problem are currently being explored by both PARD Aquatics and WPD Spill Response staff.

Boggy Creek (north): *E.coli* concentrations (especially in the upper reach) have been chronically high for the last decade. Boggy was investigated in the BSI study and sources were speculated to be diffuse and widespread, including direct human input, leaking infrastructure and animal sources within stormwater pipes. Education/outreach or some other method of mitigating direct human inputs is warranted at this location. Investigation is ongoing.

Buttermilk: *E.coli* concentrations have been historically higher than the EII average. Buttermilk was also investigated in the BSI study and sources were speculated to be diffuse and widespread, including direct human input and unknown sources within stormwater systems. Investigation is ongoing with a recommendation for continued monitoring of the box culvert under IH35 near site 10439. Education/outreach or some other method of mitigating direct human inputs is warranted at this location.

East Bouldin: *E.coli* concentrations in the middle reach (EBO 2) have been chronically high over the past decade. Ammonia concentrations are also high across all reaches of this watershed, but other nutrients (OrthoP and Nitrate) are within expected range. East Bouldin was investigated in the BSI study and sources were speculated to be leaking wastewater infrastructure of old residential neighborhoods. Difficulty in finding these leaks complicate resolution, however investigation is ongoing. The BSI also recommended development and implementation of an outreach and/or incentive program for property owners to audit their private wastewater connections for leaks.

Fort Branch: Baseflow in Fort Branch has been unreliable for the period of record, limiting the amount of water quality data available. However in the available data, the upper watershed (FOR4) indicates elevated *E.coli* concentrations. Ammonia and orthophosphate were both generally higher than average as well. This reach was investigated in the BSI study and sources were speculated to be both leaking infrastructure and direct human inputs. Investigation by televising wastewater lines is ongoing with recommendations to sample *E.coli* at site 10451 during baseflow following a scour event to determine if there is chronic input from leaking infrastructure .

Gilleland Creek: Water quality scores in Gilleland Creek have been historically poor throughout the EII sampling program, largely due to the significant contribution of permitted wastewater effluent. Conductivity, nitrates and orthophosphate are consistently high (attributed to the effluent) with trends decreasing from upstream to downstream. Improvements to this wastewater system to reduce nutrient loading would benefit the aquatic integrity of Gilleland Creek.

Harris Branch: Similar to Gilleland, the water quality scores in Harris Branch have been historically poor throughout the EII sampling program, largely due to the significant contribution of treated effluent. All nutrients evaluated (ammonia, nitrate and orthoP) under the EII program are typically high throughout the watershed. Unlike Gilleland, *E.coli* is also chronically elevated, especially in the upper watershed. This is likely due to episodic wastewater spills from point sources (manhole overflows, lift stations and package plants, etc). Some of these issues may be resolved as some of the problematic wastewater facilities are in the process of being retrofitted or taken offline.

Harpers Branch: This small watershed has chronically elevated *E.coli* concentrations. Similar to other urban watersheds, sources include leaking wastewater infrastructure, direct anthropogenic and animal inputs, as well as unknown sources within stormwater systems.

Lake Creek: Trends of increasing nutrients, conductivity and pH have been observed since the beginning of the EII program. The upstream reach (LKC 3) has chronically elevated nutrients with occasionally very high orthophosphate concentrations. These issues are largely due to treated wastewater effluent in addition to episodic spills. Improvements to this wastewater system to reduce nutrient loading would benefit the aquatic integrity of Lake Creek.

Little Walnut: The most upstream reach (LWA 4) exhibits chronically high *E.coli* and was therefore included in the BSI study to identify sources *of E.coli* contamination. The source of elevated bacteria concentrations was traced back to the uppermost headwater which is fed largely by a labyrinth of stormwater culverts sprawling under both residential and commercial areas. The bacteria results from these culverts were inconsistent over time and warrant additional investigation. Currently, it is speculated that urban wildlife may contribute to the inconsistent bacteria load within these culverts and continued monitoring at sites 10528 and 10529 is recommended.

Shoal: *E.coli* concentrations have historically been elevated throughout Shoal Creek likely due to aging wastewater infrastructure. Many sewer lines within and adjacent to the creek have been removed, but several remain. This watershed has a large residential component that was built in the early 1900's with low integrity wastewater lines such as Orangeburg pipe. As these lines get replaced and there are other incremental improvements to the wastewater infrastructure that services this watershed, the total bacteria load should decrease.

Tannehill Branch: *E.coli* concentration is historically chronically high in the headwater reach, with decreasing concentrations in downstream reaches. This trend is apparent in 2006, 2009 and 2013 but appears to be increasing in magnitude over time. If this trend persists in 2015, additional scrutiny of this upstream reach is warranted.

Taylor Slough South: In response to historically elevated *E.coli* concentrations, this watershed is included in a TCEQ Total Maximum Daily Load program and Implementation Plan. Range in concentration has been variable from year to year and appears to be trending lower, but will continue to receive scrutiny.

West Bull Creek: Although not consistently high, some *E.coli* concentrations at the downstream reach (WBL 1) are unexpectedly higher than average and may warrant a longitudinal survey to identify the source based on results and in conjunction with the 2016 EII sample year.

West Bouldin Creek: The middle reach (WBO2) has chronically elevated *E.coli* concentrations with occasionally high ammonia, similar to East Bouldin Creek. Based on similar landuse and development history, considerations and recommendations for this watershed are the same as East Bouldin.

Waller Creek: Ammonia, orthophosphate and *E.coli* concentrations are elevated throughout the watershed. The headwaters (WLR3) were investigated in the BSI study and sources were speculated to be from unknown sources in stormwater systems and direct human inputs. Additional bacteria sampling is recommended at sites 10446, 10530, 10441 and 10601 including strontium and nitrogen isotope analysis at sites 10530 and 10441.

References

COA-ERM. 2004. Water Resource Evaluation Standard Operating Procedures Manual. City of Austin, Watershed Protection Department, Environmental Resource Management, SR-04-04.

COA-ERM. 2012. Environmental Integrity Index Methodology. City of Austin, Watershed Protection Department, Environmental Resource Management, SR-02-12.

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Watershed Summaries

Current and historic EII total watershed scores, total reach scores, and the respective index scores are presented in tables and line graphs of the watershed summaries. The total watershed score is an average of the scores for six categories: Water Quality, Sediment, Contact Recreation, Non-contact Recreation, Physical Integrity, and Aquatic Life. These indices are described in detail in the EII methodology report (SR-02-12). They are:

> **Water Quality** – Concentrations of bacteria, total suspended solids, total dissolved solids, nitrate-nitrite as N, orthophosphorus, ammonia as N, and conductivity as evaluated to a reference condition determined from a QCURVE table pinning back to 2004.
>
> **Sediment** – Analysis of sediment is conducted at one site (the most downstream) and includes metals, PAHs, PCBs, organochlorine pesticides, and grain size.
>
> **Contact Recreation** – The suitability of a waterbody for swimming and wading is evaluated using *Escherichia coli* concentrations, which is used as an indicator of pathogenic bacteria.
>
> **Non-contact Recreation** – The aesthetic condition of a site is evaluated based on litter, odor, clarity and percent algae cover.
>
> **Physical Integrity** – The physical habitat is evaluated with standard stream integrity assessments that include parameters such as instream cover, epifaunal substrate, embeddedness, velocity and depth regimes, channel alteration, sediment deposition, riffle frequency, channel flow status, and vegetative protection.
>
> **Aquatic Life** – Metric analysis of benthic macroinvertebrate samples and diatom samples are averaged to form a single aquatic life score. Metrics include the community structure, diversity and tolerance.

The watershed summaries in the following sections present a review of each watershed listed in alphabetical order. Each watershed section is seventeen pages in length and includes:

- 1 page summary sheet
- 2 maps (a land use map and an aerial photograph)
- 2 pages with water quality data and summary statistics for 2013/2014
- 5 data summary graphs (box and whisker graph)
- 1 score summary graph (line graphs)
- 4 pages summarizing biological data for 2013/2014
- 2 pages of site photographs

Details of each section are described below:

Summary sheet – This sheet includes a brief list of watershed facts that describe the physical and development characteristics of the watershed. An overview map is located at the top right-hand corner of the page which shows the corresponding Phase watersheds relative to the featured watershed. The flow regime table for all sites in the watershed shows the current and historic flow presence as well as sample collection. The last table of the summary sheet shows EII total score and sub-index scores for each sample reach from downstream to upstream grouped by year. The most downstream sample reach is the "first" reach (ex BEE1) and the reaches proceeding upstream will have consecutively increasing numbers (ex BEE2, BEE3, etc). The score table is color coded to enable visual navigation.

Land use and aerial photograph maps – The land use map shows both current and historical sampling sites within the featured watershed. Property parcels are color coded to reflect land use designations as determined by COA GIS data (2006 with updates). Dark bold outlines indicate the watershed boundaries, and the interior sub-watershed reach boundaries. The aerial photograph map uses 2011 aerial photography (winter "leaf-off") with both current and historical sampling sites, in addition to other development related features within the watershed.

Water Quality Data – The fourth and fifth pages present the complete data set for water chemistry. Site means and watershed means are provided to help reduce influence of seasonal or episodic variation. Values which exceed one standard deviation above the average for the respective year have been highlighted in orange.

Data summary graphs – The five pages following the water quality data present the water quality parameter in box-and-whisker graphs by reach and by year (Figure 7) to facilitate evaluation of both temporal and spatial trends. The most downstream site is the first reach (i.e. BER1), and increase in number toward the headwaters. Reach data for a given year is presented left to right, downstream to upstream (i.e. mouth to headwater) in order to facilitate the evaluation of spatial trends within the watershed. Reach data are clustered by sample year from historical to current (left to right). A thin dashed line through each graph indicates the median value for each parameter for all cumulative historic EII data to provide context for what may be above or below "average".

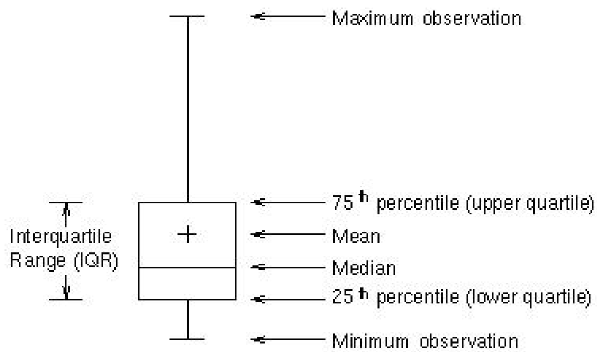

Figure 7. Legend for box-and-whisker plots

Summary line graphs – EII sub-index and total scores for each reach over the past decade are presented as line graphs. Smaller watersheds with only a single reach will appear as a single set of points, while larger watersheds with multiple reaches will appear as multiple line graphs which can be evaluated for spatial trends within the watershed from upstream to downstream (left to right). Lines are shown in grayscale with the most recent scores in black and oldest in light grey to help visual review of temporal trends over the past 20 years. Most watersheds summaries include line graphs for Total, Water Quality, Aquatic Life, Physical Integrity, Contact Recreation and Non-Contact Recreation scores. However, the Lake Austin Tributaries just present the Total scores for each of the six Lake Austin tributaries.

Benthic Macroinvertebrates and Diatoms

The results of biological samples are presented in the tables following the summary graphs. Biological sampling enables a more holistic perspective of water quality than water chemistry sampling. The diversity, structure and tolerance of the biological community can provide insight to the antecedent conditions of water quality over months and even years rather than a discrete point in time. Benthic macroinvertebrates were collected with three composite surber samples (within flowing streams) or timed kick nets (within the remaining pools of non-flowing streams). All individuals were identified to the lowest practical taxon and enumerated. Diatoms were scraped from the periphyton of stable flat rocks within the wetted width of the channel. A small portion of the homogenized sample was identified by a diatomist as a surrogate for the identification of the millions of individuals that might be in one sample. A brief description of each metric parameter is provided below the taxa table.

Site photographs – Photographs for each site were selected from previous site visits based on their ability to represent the characteristics of the site. The photo title indicates the site number, transect number, perspective (upstream/downstream or upriffle/downriffle) and date. For example, a photo title of 44_t03-us-09_17_2008 indicates that the photo was taken at site number 44 at transect 3, viewing upstream on Sep 17, 2008.

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