Updated: A Statistical Summary of Water Quality Differences between Barton Springs and Barton Creek: 2000-2017

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Introduction

A Capital Improvement Project is proposed to reconstruct inlets in the upstream dam at Barton Springs Pool (BSP) to allow creek water to flow into the pool under certain conditions. Adjustable gates would be installed to control inflows. The original inlets in the dam were plugged in the mid-1970's when the bypass culvert was constructed due to concerns of polluted stormwater runoff entering the pool through the then ungated openings. This report analyzes water quality data collected from BSP and Barton Creek upstream under baseflow conditions to evaluate water quality concerns and guide development of operational guidelines for gates in the upstream dam if the proposed project moves forward.

Data Collection

Baseflow data collected from Barton Creek (just above Barton Springs Pool) and Barton Springs from 2000 to 2017 were analyzed to determine whether there was a statistically significant difference in the chemical composition between the creek and the springs. To evaluate this without influence from seasonal effects or flow regimes, only data collected within the same week from the creek and from the springs were used. Paired data (see Appendix for paired data comparisons and raw data) were then compared using a paired t-test with a 5% false positive error rate.

Paired data from both grab samples and continuous sonde measurements were used to make these assessments. Grab samples for both sites have been collected since 2000 as part of the City of Austin's water quality monitoring. Continuous sonde measurements in Barton Springs have been collected by the USGS since 2000 and are reported as daily averages. Continuous data is used to pair with creek data when there were no grab samples from the springs. There are no continuous data for Barton Creek.

Figure 1: Map of sampling locations at Barton Creek and Barton Springs

Results

Table 1 below shows confidence intervals of the paired differences in physicochemical constituents sampled (i.e. DO, temperature, pH, and specific conductivity) between the creek and the spring. Confidence intervals of the paired differences serve as an indication of whether or not the samples are significantly different. If the 95% confidence interval (defined by lower and upper confidence limits, LCL and UCL, respectively) of the paired differences includes zero, then there is no significant difference between the two. Table 1 is partitioned into two parts by sample type (creek grab vs spring grab and creek grab vs spring continuous).

Table 1. Confidence intervals of the paired differences in physicochemical constituents between Barton Creek and Barton Springs.

	Continuous Data			Grab sample Data		
	LCL	UCL	N	LCL	UCL	N
Specific Conductivity (µS/cm)	-81.8	-33.8	11	-84.9	-41.5	24
Temperature (°C)	-2.9	4.5	12	-4.0	0.4	26
DO (mg/L)	0.8	2.3	12	1.4	3.3	17
pH (std. units)	0.5	0.8	11	0.6	1.0	20

The analyses indicate similar conclusions can be reached from the two data sets. High variation in temperature data restricted any inferences between the two sites for temperature. However, the analyses for the other three parameters showed statistically significant differences between the two sites. Specifically, they indicate that the creek specific conductivity was lower by about 30 to 80 µS/cm than that of the springs; whereas DO and pH in the creek was higher than the springs by about 1.0 to 3.0 mg/L and 0.5 to 1.0 standard units, respectively.

Among the parameters which did not have continuous data, *E. coli*, Nitrate/Nitrite, and Turbidity indicated statistically significant differences between the two sites (Table 2).

Table 2. Confidence intervals of the paired differences in chemical constituents between Barton Creek and Barton Springs.

	LCL	UCL
***E. coli* (mpn/100 mL)**	4.8	62.3
Nitrate/Nitrite (mg/L)	-0.8	-1.0
Turbidity (NTU)	-0.4	-2.2
Chlorophyll-a (µg/L)	-1.9	4.9

E. coli in the creek was 4.8 to 62.3 mpn/100 ml higher than the springs. Nitrate/Nitrite and turbidity in the creek, on the other hand, was 0.8 to 1.0 mg/L and 0.4 and 2.2 NTU lower than the springs. Chlorophyll-a showed no statistically significant paired difference. A majority of the measurements of ammonia, orthophosphorus, and phosphorus for both the creek and the springs were below detection limits, indicating some similarity between the two sites. A majority of measurements of total Kjeldahl nitrogen, and total suspended solids were either below detection limits or were rejected making any comparison impractical. For comparisons of chloride, sulfate, or volatile suspended solids, there were an insufficient number of paired samples to make a determination.

Although variation in creek temperature precludes a meaningful statistical comparison, there is seasonal temperature variation in the creek water. During the warm seasons, creek water temperature is as much as 8.3^{o} C (15^{o} F) warmer than the springs (85.5^{o} C in the creek versus 70.5^{o} C in the springs). During cooler months, the creek can be 9.2^{o} C (16.5^{o} F) cooler than the springs (51.3^{o} F in the creek versus 67.8^{o} F in the springs). These data will contribute to development of operational guidelines for the dam gates if installed.

Errata:
The sentence in the first paragraph in the Data Collection Section was revised from:
"To evaluate this without influence from seasonal effects or flow regimes, only data collected on the same day from the creek and from the springs were used. Paired data (see Appendix for paired data comparisons and raw data) were then compared using a paired t-test with a 5% false positive error rate."
to
"To evaluate this without influence from seasonal effects or flow regimes, only data collected within the same week from the creek and from the springs were used. Paired data (see Appendix for paired data comparisons and raw data) were then compared using a paired t-test with a 5% false positive error rate."

Note to Errata:
The original analysis of the data consisted of three scenarios: data from sampling of the creek and spring paired within a day of each other; paired within 3 days of each other; and paired within 7 days of each other. The results for conductivity, DO, and nitrate for all three scenarios were similar. However, results for E.Coli and turbidity showed no statistical significant increase for water sampled within 1 day of each other, whereas the results for E.Coli and turbidity showed a statistical significant increase for water sampled within 7 days of each other. Because there is less uncertainty in the 7 day pairings (due the larger time frame and more samples) and because this result showed a difference, the decision was made to go with this more conservative scenario. This was not reflected in the original sentence, which indicated a 1 day pairing. However, given that these two scenarios produce opposite results speaks to the ambiguity of the analysis from the data.

Addendum to the Errata:

Appendix 2 was also updated to reflect the correct sampling dates for Barton Springs. Previous versions used the sampling date for Barton Creek as an index in the Barton Springs table in order to identify the pairings. This has been corrected.

Appendix 1. Paired differences between Barton Creek and Barton Springs, including average, standard deviation, sample size (N), and lower and upper confidence limits for a paired t-test with a 5% false positive error rate. To compute the difference, measurements in the springs were subtracted from those of the creek.

Sample Date	Specific Conductivity (µS/cm)	Water Temperature (°C)	pH (std. units)	Dissolved Oxygen (mg/L)	Ammonia as N (mg/L)	Total Kjeldahl Nitrogen as N (mg/L)	Nitrate/ Nitrite as N (mg/L)	Ortho-Phosphorus as P (mg/L)
11/10/2000	28	-8.2						
12/4/2000	15	-6.7	0.81				-0.67	BDL
12/7/2000	17	-7.7	0.15					BDL
1/24/2001					BDL		-0.99	BDL
1/26/2001	-31.4	-5.16	0.78					
2/6/2001	-104	-7.3						
2/20/2001	-121.8	-4.02	1.12	0.02				
3/23/2001	-115.6	-4.51						
4/16/2001	36	3.4	0.76		BDL	BDL	-0.9043	BDL
4/25/2001	-119.3	1.23	1.21	4.6	0.01		-1.1	BDL
5/14/2001	-113	0.1						
1/14/2002	-45.4	-7.68	1.05	6.46	BDL		-1	BDL
2/13/2002	-55	-4.92	0.87	3.75	BDL		-0.71	BDL
7/31/2002		8.3						
10/31/2002		-2.77		2.37				
1/23/2003	-88	-8.49	1.26	4.81	BDL		-1.09	
1/27/2003	-77.9	-9.15	1.51	4.27	BDL		-1.04	BDL
2/19/2003	-81	-4.71	0.72	0.83				
4/2/2003	-95	-2.08	1.05	2.33	BDL	BDL	-0.98	BDL
4/20/2004	-10.6	0.17	0.94	2.76	BDL			
6/12/2007	-106.4	7.38	1.04	1.83	BDL		-0.82	BDL
8/1/2007	-90.3	5.07	0.92	1.12	BDL		-0.87	BDL
8/22/2007	-110.6	5.85	0.85	1.06				
7/14/2015	-118.3	7.06	0.18	1.38	BDL		-0.688	BDL
1/10/2017	-23.6	-4.21	0.31	1.32	BDL		-0.38	BDL
3/28/2017	-76	1.74	0.15	0.18	BDL		-0.928	BDL
5/2/2017	-29.7	-0.23	0.13	0.9				
Average	-63.20	-1.83	0.79	2.35			-0.87	
Std. Dev	51.6	5.4	0.4	1.8			0.2	
N	24	26	20	17			14	
LCL	-84.9	-4.0	0.6	1.4			-1.0	
UCL	-41.5	0.4	1.0	3.3			-0.8	

BDL = Below Detection Limits; R = Rejected Samples

Appendix 1 (Cont.)

Sample Date	Phosphorus As P (mg/L)	*E. coli* (MPN/ 100mL)	Chlorophyll-a (µg/L)	Total Suspended Solids (mg/L)	Volatile Suspended Solids (mg/L)	Turbidity (NTU)	Sulfate (mg/L)	Chloride (mg/L)
12/4/2000	BDL		BDL	R				
12/7/2000				R		-1.95		
1/24/2001	BDL		0.2	R		-2.44	14.1	8.4
1/26/2001								
2/6/2001								
2/20/2001								
3/23/2001				R				
4/16/2001	BDL		BDL	BDL				
4/25/2001	BDL		0.63					
5/14/2001				R				
1/14/2002	BDL		3.61	BDL		-2.94		
2/13/2002	BDL					-2.7		
7/31/2002								
10/31/2002								
1/23/2003	BDL		BDL	BDL		BDL		
1/27/2003	BDL		BDL	BDL	R	-2.15		
2/19/2003						-2.27		
4/2/2003	BDL		BDL	BDL		BDL		
4/20/2004		64		R		0.89		
6/12/2007		97		-0.6		0.94		
8/1/2007		17		-0.7		0.51		
8/22/2007								
12/16/2009		14						
1/14/2015		25.5						
4/15/2015		2.7						
7/9/2015								
7/14/2015		2.1		-0.72		R		
1/10/2017		-4.5		BDL				
3/28/2017		84.36		-1.6				
5/2/2017								
Average		33.57	1.48	-0.91		-1.35		
Std. Dev		38.2	1.9	0.5		1.6		
N		9	3	4		9		
LCL		4.8	-1.9	-1.6		-2.6		
UCL		62.3	4.9	-0.3		-0.1		

BDL = Below Detection Limits; R = Rejected Samples

Appendix 2. Raw data for Barton Creek, including average, standard deviation, sample size (N), and lower and upper confidence limits

Sample Date	Specific Conduct-ivity (µS/cm)	Water Temp-erature (°C)	pH (std. units)	Dissolved Oxygen (mg/L)	Ammonia as N (mg/L)	Total Kjeldahl Nitrogen as N (mg/L)	Nitrate/ Nitrite as N (mg/L)	Ortho phoshorus as P (mg/L)
11/10/2000	639	12.5						
12/4/2000	626	13	7.8	9.9		0.275	0.63	BDL
12/7/2000	628	12	7.14					0.02
1/24/2001							0.55	BDL
1/26/2001	549.6	13.34	8.07	11.14				
2/6/2001	545	12.5						
2/20/2001	522.6	15.44	7.93	9.32				
3/23/2001	540	15						
4/16/2001	572	24	8	6.9		0.198	0.2057	BDL
4/25/2001	459.3	21.95	8.1	11.85	0.03		0.21	BDL
5/14/2001	491	21						
1/14/2002	605.6	12.27	7.91	14.28			0.4	BDL
2/13/2002	590	15.3	7.8	11.4		0.1	0.62	BDL
7/31/2002	527	29.7	7.71	7.67			0.18	BDL
10/31/2002	582.4	18.53	7.97	8.7			0.19	BDL
1/23/2003	572	11.4	8	12			0.2	BDL
1/27/2003	580.1	10.75	8.32	11.73	0.03		0.27	BDL
2/19/2003	577	15.19	7.53	8.29				R
4/2/2003	554	18.4	7.9	9.5		0.11	0.28	BDL
4/20/2004	616.4	20.9	7.91	9.25	0.02			0.03
6/12/2007	565.6	28.68	7.96	8.21			0.18	BDL
8/1/2007	572.7	26.79	7.89	7.34			0.08	BDL
8/22/2007	543.4	27.63	7.78	7.29				
12/16/2009	663.7	11.66	7.77	10.28			0.55	BDL
1/14/2015	668.4	8.57	7.81	11.15		0.17	0.336	BDL
4/15/2015	663.5	20.9	7.66	7.4		0.145	0.324	BDL
7/9/2015	607.2	26.57	7.77	6.3				
7/14/2015	567.7	28.8	7.7	7.59		0.119	0.542	BDL
1/10/2017	613	16.6	7.32	7.73			1.02	BDL
3/28/2017	592	22.47	7.85	6.3	0.0248	0.208	0.262	BDL
5/2/2017	625	20.85	7.43	7.04				
Average	581.97	18.42	7.81	9.14				
Std. Dev	49.3	6.3	0.2	2.1				
N	30	30	26	25				
LCL	563.6	16.1	7.7	8.3				
UCL	600.4	20.8	7.9	10.0				

BDL = Below Detection Limits; R = Rejected Samples

Appendix 2 (cont.) Raw data for Barton Creek

Sample Date	Phosphorus As P (mg/L)	*E. coli* (MPN/ 100mL)	Chlorophyll-a (µg/L)	Total Suspended Solids (mg/L)	Volatile Suspended Solids (mg/L)	Turbidity (NTU)	Sulfate (mg/L)	Chloride (mg/L)
11/10/2000								
12/4/2000	BDL	56	BDL	BDL				
12/7/2000				0.1		1.05		
1/24/2001	R		0.92	R	BDL	0.56	55.2	37.4
1/26/2001								
2/6/2001								
2/20/2001								
3/23/2001								
4/16/2001	BDL	28	BDL	BDL				
4/25/2001	BDL		0.94	BDL	R	0.37	48.2	31.1
5/14/2001								
1/14/2002	R		4.11	R	R	0.46	48.8	30.2
2/13/2002	BDL	7		BDL		0.6		
7/31/2002	0.02		0.76	R	R	0.57	35.4	24.9
10/31/2002	BDL		BDL	BDL	BDL	0.44	47.4	28.2
1/23/2003	BDL	14	0.2	BDL		BDL		
1/27/2003	BDL		BDL	BDL	R	0.85	48.5	28.9
2/19/2003				R		0.73		
4/2/2003	BDL	21	BDL	BDL		BDL		
4/20/2004		72		R		0.89		
6/12/2007		110		1.7		2.54		
8/1/2007		72		1.5		2.31		
8/22/2007								
12/16/2009		21		R		0.41		
1/14/2015	BDL	27.5		BDL		R		
4/15/2015	BDL	20.1		BDL		0.8		
7/9/2015								
7/14/2015	BDL	23.3		1.4		R		
1/10/2017	0.0341	29.5		BDL		R		
3/28/2017	BDL	88.4		1		R		
5/2/2017								
Average	0.027	42.13	1.386	1.44		0.90	47.25	30.12
Std. Dev	0.0	31.7	1.6	0.6		0.7	6.5	4.2
N	2	14	2	5		14	6	6
LCL	0.019	24.0	-0.398	0.41		0.51	40.8	26.0
UCL	0.038	60.3	3.2	1.87		1.29	53.7	34.3

BDL = Below Detection Limits; R = Rejected Samples

Appendix 2 (cont.) Raw data for Barton Springs

Sample Date	Specific Conductivity (µS/cm)	Water Temperature (°C)	pH (std. units)	Dissolved Oxygen (mg/L)	Ammonia as N (mg/L)	Total Kjeldahl Nitrogen as N (mg/L)	Nitrate/ Nitrite as N (mg/L)	Ortho-phosphorus as P (mg/L)
11/15/2000	611	20.7	7.08		BDL	0.25	1.58	0.02
12/11/2000	611	19.7	6.99			R	1.3	0.02
1/24/2001	581	18.5	7.29		BDL	BDL	1.54	0.02
2/5/2001	649	19.8	7.12		BDL	0.28	1.4	0.02
2/21/2001	644.4	19.46	6.81	9.3	BDL	0.16	1.36	0.02
3/21/2001	655.6	19.51	6.94	8.26	BDL	0.44	1.3	0.02
4/16/2001	536	20.6	7.24		BDL	BDL	1.11	0.02
5/2/2001	578.6	20.72	6.89	7.25	0.02	R	1.31	0.02
5/16/2001	604	20.9	7.04		R	R	1.36	0.02
1/16/2002	651	19.95	6.86	7.82	BDL	R	1.4	0.02
2/12/2002	645	20.22	6.93	7.65	0.02	R	1.33	0.02
8/5/2002		21.4						
11/7/2002		21.3		6.33				
1/29/2003	660	19.89	6.74	7.19	0.02	R	1.29	
2/3/2003	658	19.9	6.81	7.46	BDL	R	1.31	0.02
2/26/2003	658	19.9	6.81	7.46				
4/9/2003	649	20.48	6.85	7.17	BDL	BDL	1.26	BDL
4/21/2004	627	20.73	6.97	6.49	R		1.06	
6/13/2007	672	21.3	6.92	6.38	BDL		1	0.007
8/8/2007	663	21.72	6.97	6.22	BDL		0.95	0.006
8/27/2007	654	21.78	6.93	6.23	R		0.94	0.005
12/21/2009								
1/20/2015								
4/21/2015								
7/16/2015								
7/21/2015	686	21.74	7.52	6.21	BDL		1.23	BDL
1/4/2017	636.6	20.81	7.01	6.41	BDL		1.4	BDL
3/22/2017	668	20.73	7.7	6.12	BDL		1.19	BDL
4/26/2017	654.7	21.08	7.3	6.14	BDL		1.19	BDL
Average	637.08	20.51	7.04	7.01			1.26	0.02
Std. Dev	35.4	0.8	0.2	0.9			0.2	0.01
N	23	25	23	18			22	15
LCL	621.9	20.2	6.9	6.6			1.2	
UCL	652.3	20.9	7.1	7.4			1.3	

BDL = Below Detection Limits; R = Rejected Samples

Appendix 2 (cont.) Raw data for Barton Springs

Sample Date	Phosphorus As P (mg/L)	*E. coli* (MPN/ 100mL)	Chlorophyll-a (µg/L)	Total Suspended Solids (mg/L)	Volatile Suspended Solids (mg/L)	Turbidity (NTU)	Sulfate (mg/L)	Chloride (mg/L)
11/15/2000	R			R		5		
12/11/2000	0.02		0.4	R		3		
1/24/2001	0.06		0.72	2.8		3	41.1	
2/5/2001	0.06		0.44	4		3		
2/21/2001	BDL		0.37	0.5		1.21		
3/21/2001	BDL		0.06	BDL				
4/16/2001	R		0.1	R		2	34.1	
5/2/2001	0.05		0.31	BDL				
5/16/2001	R		0.36	BDL		2		
1/16/2002	BDL		0.5	R		3.4		
2/12/2002	BDL		0.5	0.8		3.3	30.5	
8/5/2002								
11/7/2002								
1/29/2003	BDL		0.5	1.2	0.5	1.8		0.5
2/3/2003	BDL		0.5	BDL	0.5	3		0.5
2/26/2003						3		
4/9/2003	BDL		0.5	1.6	1.2	2.7		1.2
4/21/2004		8	0.5	R	1.6	0		1.6
6/13/2007		13	0.491	2.3	0.2	1.6	36.3	0.2
8/8/2007		55	0.468	2.2	0.1	1.8	32	0.1
8/27/2007			0.833	2.5	0.1	1.8		0.1
12/21/2009		7						
1/20/2015		2						
4/21/2015		17.4						
7/16/2015		18.8						
7/21/2015		21.2		2.12	1.06	3.7		1.06
1/4/2017		34		1	1			1
3/22/2017		4.04		2.6	1			1
4/26/2017		5.21		3.6	1		34	1
Average	0.05	16.88	0.44	2.09	0.75	2.52	34.67	0.75
Std. Dev	0.02	15.8	0.18	1.05	0.5	1.1	3.7	0.5
N	4	11	17	13	11	18	6	11
LCL	0.021	6.4	0.35	1.46	0.42	1.97	30.95	0.42
UCL	0.074	27.3	0.54	2.73	1.08	3.07	38.39	1.08

BDL = Below Detection Limits; R = Rejected Samples