Joe Pool Lake

Water Quality Report, 2017 - 2021

Trinity River Authority of Texas
Technical Services & Basin Planning

Grand Prairie Texas

Midlothian DFW's Southern Star

Cedar Hill

Duncanville City of Champions

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Contents

Joe Pool Lake Water Quality Report, 2017-2021

Executive Summary

The Trinity River Authority of Texas, in association with the cities of Cedar Hill, Duncanville, Grand Prairie and Midlothian, conducts routine water-quality sampling on Joe Pool Lake and its tributaries. The goal of this program is to assess, monitor, and protect the reservoir and its myriad uses, including water supply, recreation, and the support of fish and other aquatic life.

Annually, the Authority produces a summary of data collected the previous year. These reports focus on impairments, specific hydrologic events, and a review of the data collected that year. Every fifth year, the program calls for a comprehensive report with more in-depth analyses that includes the review of hydrologic data, water quality sampling data, trend analysis, and load duration curves. This report is the second of the five-year reports which focuses on data collected between 2017 and 2021. Data collected prior to 2013 are considered historical and are evaluated when appropriate, primarily to examine long-term trends or when that data can inform the current analysis.

During this 5-year data summary, no additional segments in the watershed were listed on the TCEQ 2018, 2020, or 2022 Integrated Report. The non-support listing for bacteria in Walnut Creek in the 2016 Integrated Report is currently shown as a concern in the 2022 Integrated Report. However, occasional instances of exceedances of stream standards were observed and previously-noted increasing trends for Chlorophyll-*a* seem to continue. Several decreasing trends for nutrients were observed, but those are more likely due to the hydrology of the last five years than actual decreases in these parameters. Tributary sites B3 Soap Creek, B4 Walnut Creek, and B5 Bowman Branch currently have *E. coli* geometric means above the existing standard of 126 MPN/100 mL for the period of 2017-2021. Once there is sufficient data for TCEQ to assess these streams, they will likely be categorized as having concerns or impairments on the next Integrated Report. Bacteria issues are common for these types of tributaries in the Dallas/Fort Worth Metropolitan Area.

Load duration curve analysis suggest that most of the nutrient and *E. coli* loadings to the reservoir come during runoff events, though there are some point sources that provide a constant flow of nutrients and *E. coli* to Joe Pool Lake. It is important to note that no *E. coli* exceedances were observed within the lake. However, since 2013, there have been two single giardia cysts found at the active intake site, one in 2015 and one in 2021, and no cryptosporidia oocysts have been found. While the numbers for giardia are not alarming, it does indicate that these parameters should continue to be watched as the watershed develops. For the nutrients, loadings appear to be closely correlated to runoff. This is an important observation and speaks to the ability of storm events to change water quality within the main body of the reservoir over a short period of time. This conclusion is supported by flow duration curves, which suggest tributaries convey the vast majority of their flow during rain events. Accordingly, the reservoir appears to fill with pulses that provide a load, which is then assimilated during periods of low inflow.

The data did not show any trends or high concentrations of dissolved metals, pesticides, or other potentially toxic substances in either the water column or sediments. There were, however, two episodes of high geosmin (not a concern to human health, but a nuisance, taste and odor inducing compound) in the spring of 2017 and again in the spring of 2020.

Introduction

Joe Pool Lake is a 7,740-acre water supply reservoir located primarily in Dallas County in the southern part of the Dallas-Fort Worth Metroplex (DFW). The reservoir has a watershed of 222 square miles and a freshwater storage capacity (at normal pool elevation) of 142,900 acre-feet with a firm yield of 15,610 acre-feet per year. TRA entered into a contract with the USACE for the development and operation of Joe Pool Lake and acquired water rights for the yield from the Texas Commission on Environmental Quality (TCEQ). TRA then entered into separate agreements with the cities of Cedar Hill, Duncanville, Grand Prairie, and the Midlothian to make the water supply available to them.

As part of that partnership, TRA began sampling the reservoir and tributaries in 1992 in order to assure the continued suitability of the reservoir as a source of potable water. Annually, a water quality report summarizing the results of the previous year's monitoring efforts has been produced. In 2012, a comprehensive review of the monitoring program was undertaken and major changes were made. As part of that effort, fifteen-years of water quality data (1997-2012) were compiled and analyzed. The dataset included a total of 33,214 records from 25 sites covering 150 water quality parameters, which were measured at 78 depths ranging from the surface to 80 feet. In addition to changes to the actual monitoring program, a five-year reporting cycle was established. This cycle calls for summary reports in years one through four and a comprehensive report in year five. The first five-year report of the new cycle focused on the activities and findings of Joe Pool Lake Water Quality Program during the four-year period of 2013-2016. This report is the second of the five-year reports which covers the data collected between 2017 and 2021, but analyses and conclusions are presented within the context of the larger, historical data set when appropriate.

For brevity, water quality parameters are referred to throughout this document by abbreviations, acronyms, and common industry nomenclature.

Water Quality Monitoring Activities, 2017-2021

In 2017, in partnership with the cities of Duncanville, Grand Prairie, Midlothian, and Mansfield, the Authority applied for grant funding to create a Watershed Protection Plan (WPP) to improve and protect the water quality in Joe Pool Lake. Part of that process involved an intensive data collection effort, over and above the previous sampling schedule. At the end of that project, the Joe Pool Lake sampling plan was adapted and some of the analytical costs for the stream sites were transferred to the TRA's Clean Rivers Program while the lake and intake sites remain funded by the Joe Pool Lake Customer Cities. Additionally, with the removal of the marina near intake site #2, sampling was discontinued for total organic carbon and volatile organic compounds.

Since January 1, 2017, TRA staff have conducted field monitoring quarterly at three lake sites (A1-A3), five tributary sites (B1-B5) and two intakes (I1-I2) (Figure 1). During the past five years, 20 separate sampling trips were made at 10 sites to sample 148 unique parameters, resulting in more than 5,000 individual data points. Resultant data were computerized, quality assured and entered into a water quality database for storage and further analysis. Appendix B displays the field monitoring schedules and parameters sampled.

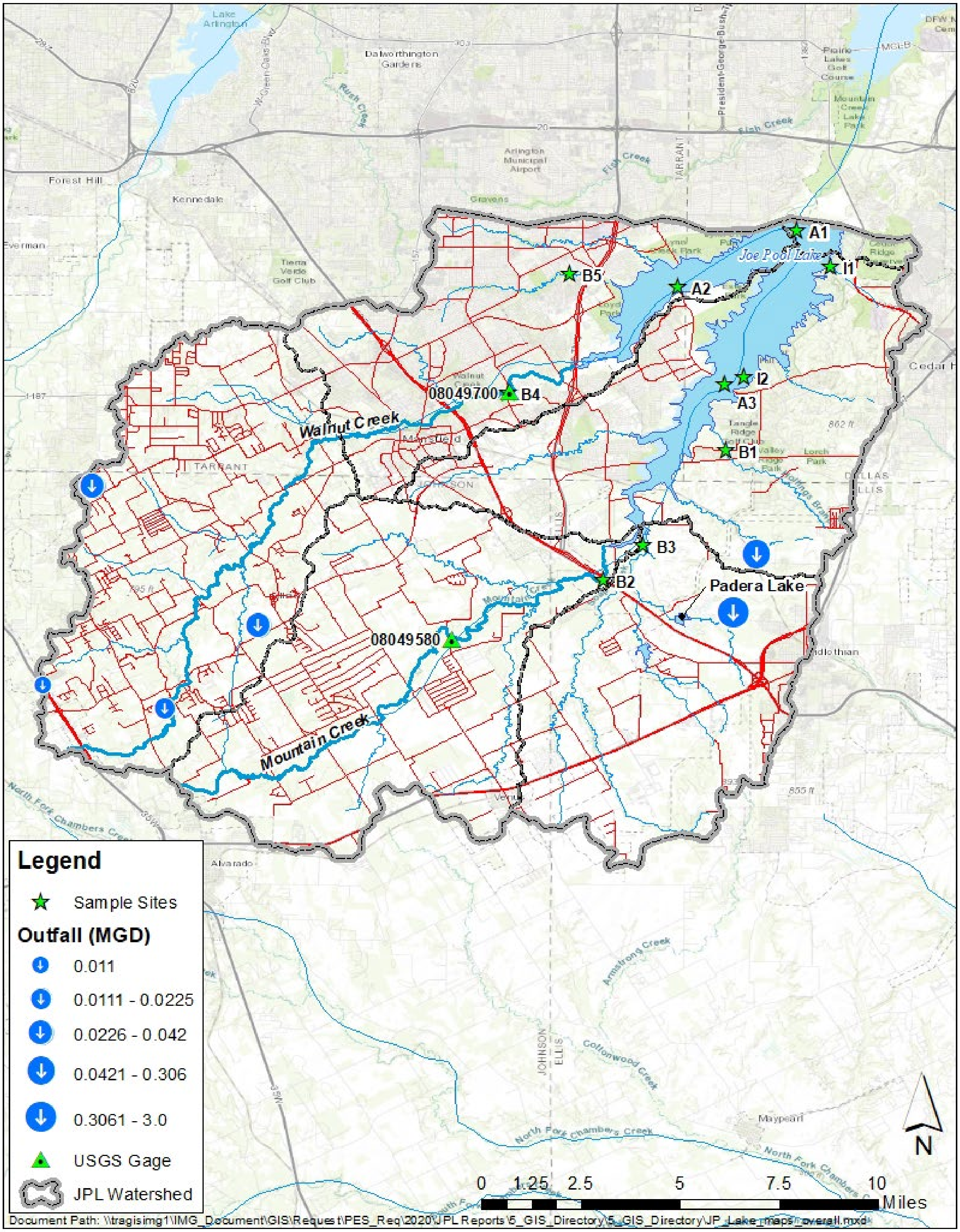


Figure 1. Map showing Joe Pool Lake and its watershed, monitoring sites, USGS gages, and outfalls.

Joe Pool Lake Basin Hydrology

2017-2021 Overview

Unlike the previous 5-year summary report (2013-2016), which saw years of both extreme drought and extreme flooding, the hydrology for 2017-2021 was, overall, fairly normal when compared to long-term averages. The annual summary of rainfall and inflow data for 2017-2021 showed that 2017 was very dry, 2018 was very wet, and 2019-2021 were very close to normal (Figure 2 and Figure 3), indicating a somewhat average hydrology for the reporting period. The average rainfall measured at Joe Pool Lake for 2017-2021 was 3.69 inches above the 1990-2021 regional normal for the DFW area, but almost matched the 40.4-inch annual average measured at Joe Pool Lake since 1991 (Table 1). Joe Pool Lake was below conservation pool approximately 62% and above conservation pool 38% of the time (Figure 4), which is consistent with the long-term average of 60% and 40%. The top of the flood pool for Joe Pool Lake is 536 ft and for this reporting period, the elevation never exceeded 535 ft, only rising above 530 ft twice, once in the fall of 2018 during a particularly strong storm event and again in the spring of 2019 (Figure 5).

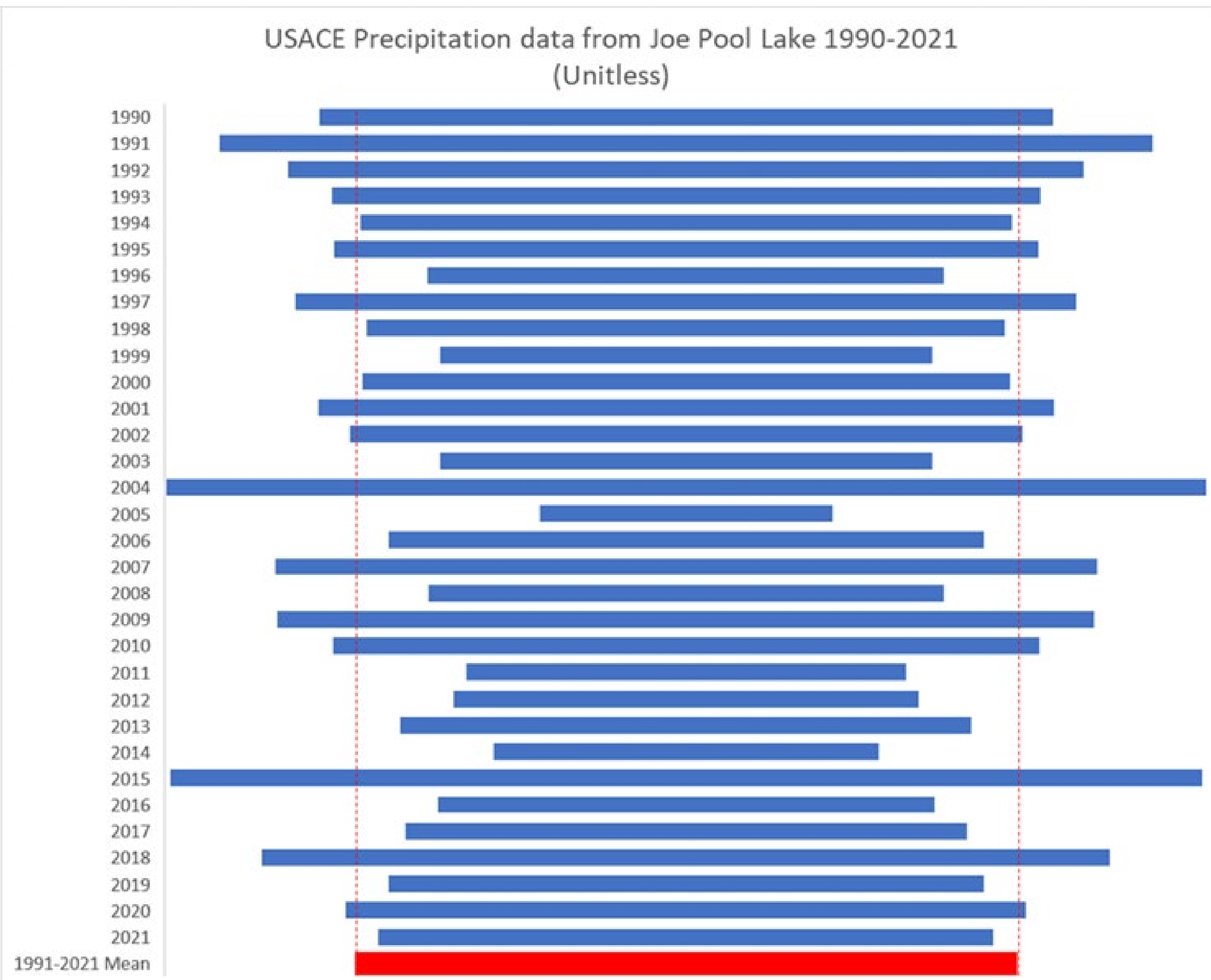


Figure 2. Funnel Chart showing precipitation at Joel Pool Lake from 1990-2021.

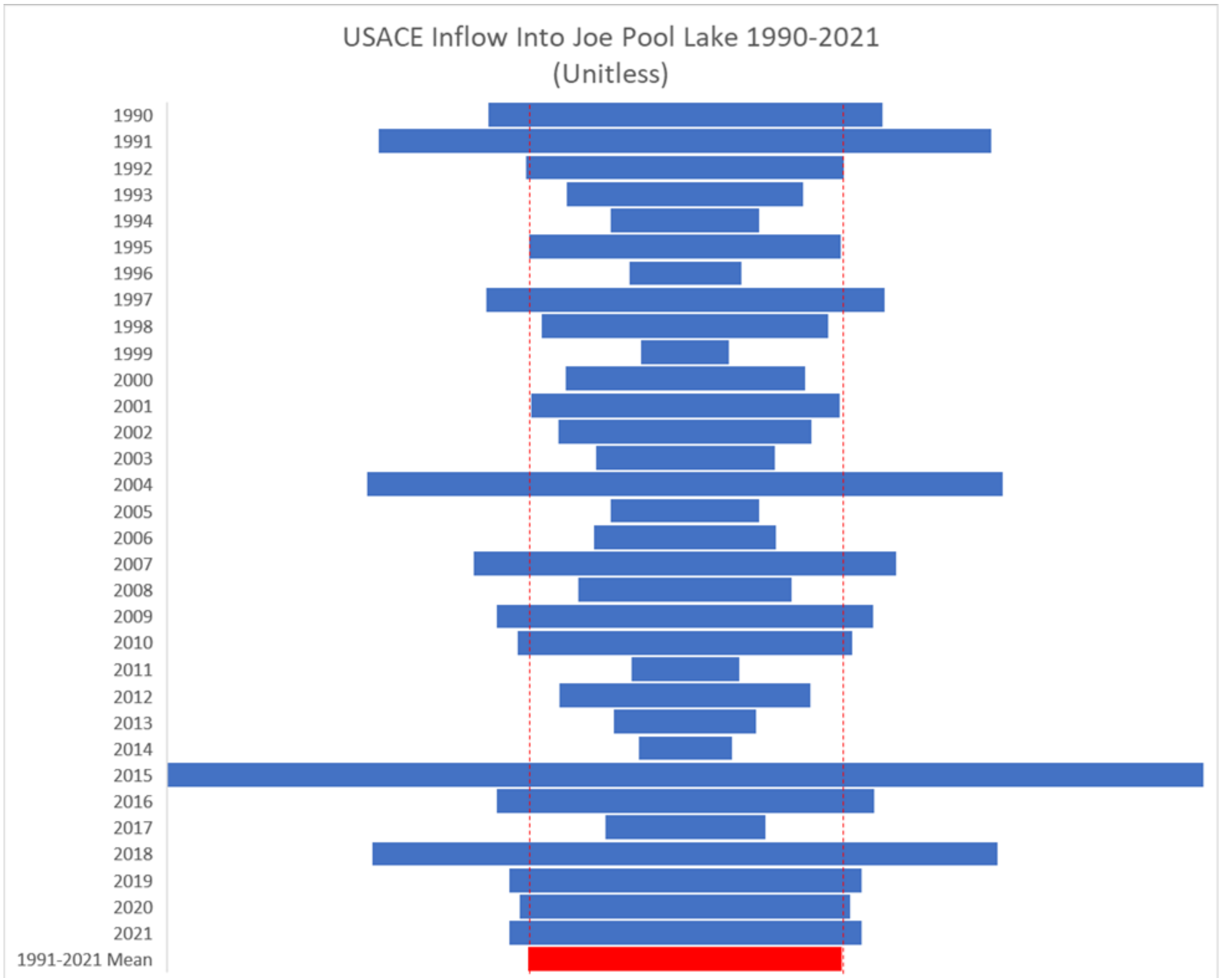


Figure 3. Funnel chart showing inflow for Joel Pool Lake from 1990-2021.

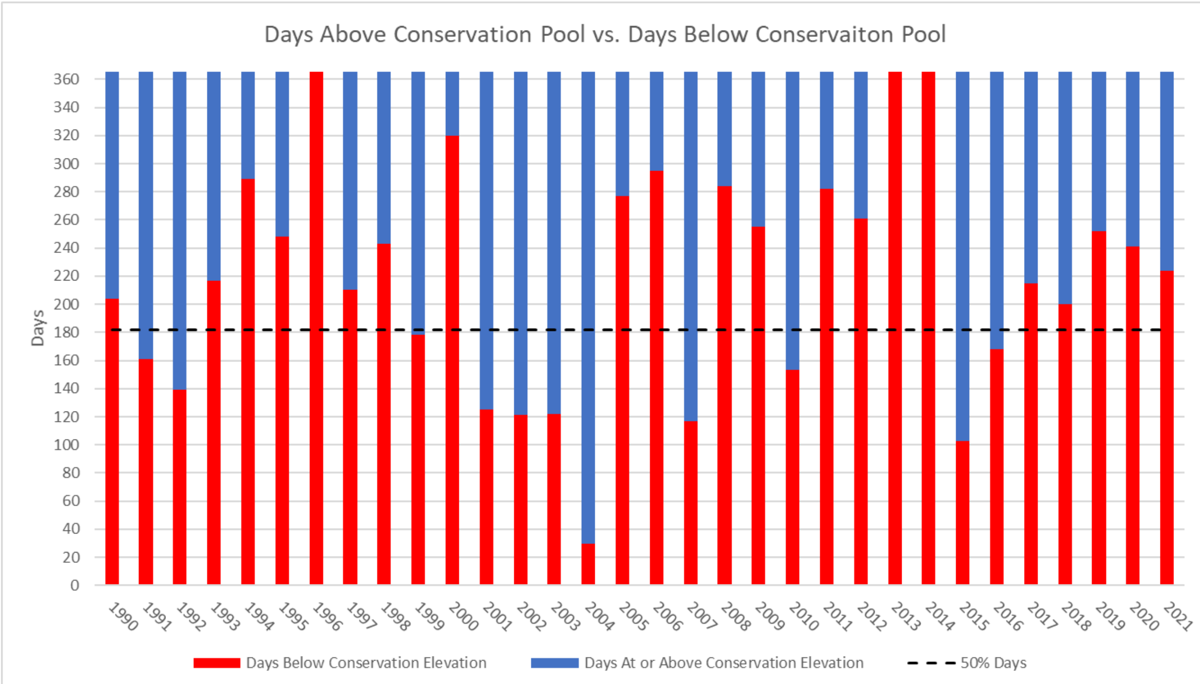


Figure 4. Comparison of days above to days below conservation pool (522 ft) at Joe Pool Lake between 1990 and 2021.

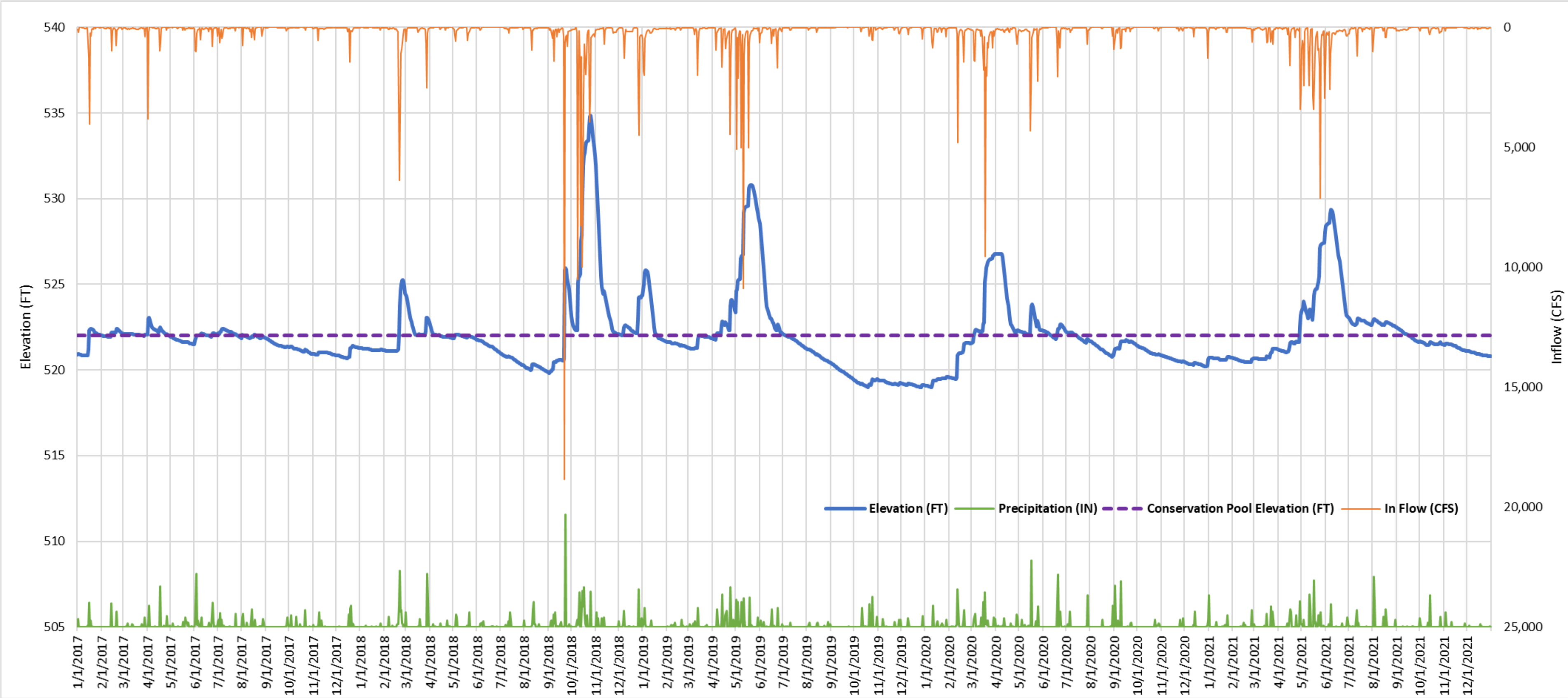


Figure 5. Joe Pool Lake elevation, inflow and precipitation between 2017-2021 (Note: Precipitation is shown for display only and is not related to either Y-axis scale)

Table 1. Table showing precipitation, inflow, and days above and below conservation pool for Joe Pool Lake.

Year	Precipitation (Inches) DFW Normal 37.01 inches	Inflow (AF)	Days Below Conservation Elevation	Days at or Above Conservation Elevation
1990	45.2	80,105	204	161
1991	57.4	124,525	161	204
1992	49.0	64,568	139	227
1993	43.7	48,241	217	148
1994	40.2	30,206	289	76
1995	43.4	63,386	248	117
1996	31.9	22,930	366	0
1997	48.1	80,925	210	155
1998	39.4	58,217	243	122
1999	30.4	18,109	178	187
2000	39.9	48,771	320	46
2001	45.3	62,802	125	240
2002	41.5	51,635	121	244
2003	30.4	36,524	122	243
2004	64.0	128,956	30	336
2005	18.2	30,374	277	88
2006	36.7	37,109	295	70
2007	50.6	85,949	117	248
2008	31.9	43,419	284	82
2009	50.3	76,618	255	110
2010	43.5	68,156	153	212
2011	27.1	22,071	282	83
2012	28.7	51,123	261	105
2013	35.2	29,026	365	0
2014	23.9	19,112	365	0
2015	63.5	210,239	103	262
2016	30.6	76,722	168	198
2017	34.7	32,571	215	150
2018	52.2	126,982	200	165
2019	36.7	71,680	252	113
2020	41.9	67,249	241	125
2021	37.9	71,580	224	141
Average	**40.4**	**63,746**	**220**	**146**

Flow Duration Curves

Flow duration curves (FDC) were created to better understand the hydrologic characteristics of Joe Pool Lake's ungaged tributaries by calculating the flow exceedance frequency based on the drainage area approach (DAR)[1]. The average daily streamflow records between 1/1/1992 and 12/31/2021 from the USGS gage at Mountain Creek near Venus (USGS gage 08049580) and the USGS gage at Walnut Creek at Mansfield (USGS gage 08049700) were used to create average daily flow values for each subbasin that were scaled based on each site's contributing drainage area. For site B1, which is not in either of the gaged watersheds, the DARs were averaged. The flow contribution from TRA's Mountain Creek Regional wastewater treatment plant (MCRWS) was added to the DAR calculated flows at B3 based on average daily discharge data and adjusted for assumed seasonally varying channel losses (0.8 for winter, 0.5 for spring and fall, and 0.2 for summer). Contribution of other wastewater treatment plants are minimal and were disregarded.

The Nash-Sutcliffe E Values (ENS) (Nash and Sutcliffe, 1970) were used as an indicator of the accuracy of each site's DAR calculated flow. An efficiency value of 1 (ENS=1) indicates that the model predicted flow data perfectly match the measured data. Generally, ENS > 0.5 indicates satisfactory validation (Moriasi et al. 2007). As can be seen in Table 2, only B2 and B3 meet the acceptance value of >0.5. This low performance is predictable given the limited number of gaged streams and empirical streamflow measurements at the sites. FDCs were developed for all sites, but are not presently being used in a quantitative evaluation of the watershed. They do, however, provide a generalized, but important, picture of the hydrologic characteristics from the five tributaries.

Table 2 Nash-Sutcliffe E Values at Tributary Sites for the Simulation Period 2013-2021

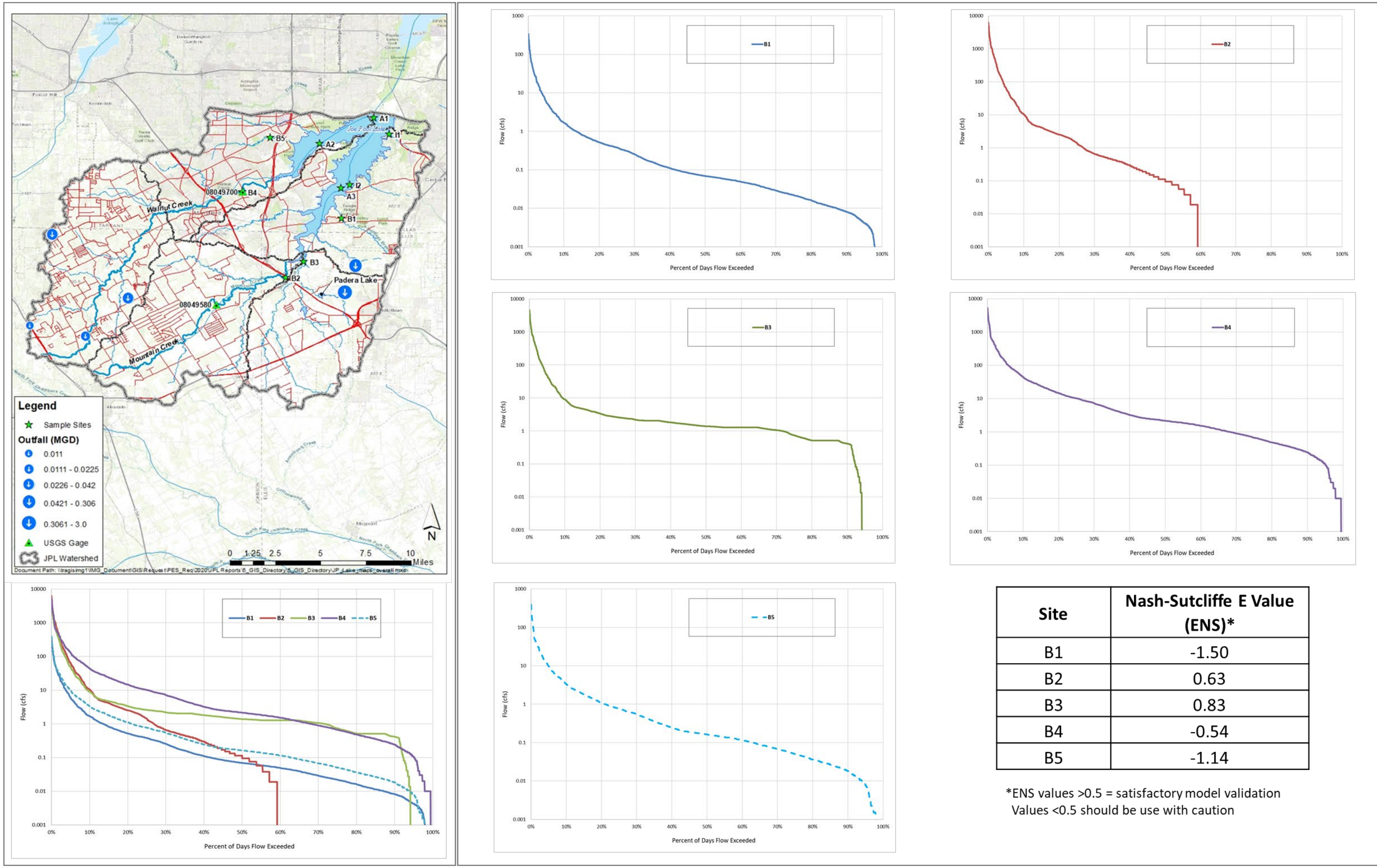
Site	**Nash-Sutcliffe E Value (ENS)**	
	2013-2016	2013-2021
B1	-0.034	-1.50
B2	0.722	0.63
B3	0.371	0.83
B4	-1.441	-0.54
B5	-0.589	-1.14

Simply, the exceedance probability is the percent of time that a stream site equals or exceeds a specific flow. For example, if a stream has a 25% exceedance value of 10 cfs, it means that 25% of the time, the flow at that site is at or above 10 cfs; conversely, 75% of the time it is below 10 cfs. FDC graphs are presented in Figure 6 and selected exceedance values are summarized in Table 3. The FDCs show that the system is quite flashy, with only two of the sites, B3 and B4, having flow at least 75% of the time. B3 is supplemented by effluent discharge and B4 is likely draining localized, urban irrigation runoff. The median flows for B1, B2, and B5 are below 0.2 cfs, barely above a trickle, while B3 and B4 median flows were at least an order of magnitude greater at 1.4 cfs and 2.2 cfs, respectively. At the upper end of the graphs - the 10% exceedance - B4 has the highest flow by far at 44.5 cfs. Interestingly, B2, which has no flow 25% of the time, has the second highest at 10.6 cfs. These exceedance values are important when considering potential pollutant loadings, which is discussed in the following section.

Table 3. Table showing selected exceedance flows for Joe Pool Lake tributary sites.

[1] The methods are fully described in Computed Statistics at Streamgages, and Methods for Estimating Low-Flow Frequency Statistics and Development of Regional Regression Equations for Estimating Low-Flow Frequency Statistics at Ungaged Locations in Missouri, USGS Scientific Investigations Report 2013–5090

Exceedance	B1 (cfs)	B2 (cfs)	B3 (cfs)	B4 (cfs)	B5 (cfs)
10%	1.7	10.6	9.1	44.5	3.4
25%	0.4	1.4	2.6	10.2	0.8
50%	0.1	0.1	1.4	2.2	0.2
75%	0.0	0.0	0.7	0.7	0.0
90%	0.0	0.0	0.4	0.2	0.0



Site	Nash-Sutcliffe E Value (ENS)*
B1	-1.50
B2	0.63
B3	0.83
B4	-0.54
B5	-1.14

*ENS values >0.5 = satisfactory model validation
Values <0.5 should be use with caution

Figure 6. Flow duration curves from the tributary sites.

Water Quality Analysis

The data used in this report has been quality assured using standard best management practices and much of the more recent data was collected under a TCEQ approved Quality Assurance Project Plan which is designed to ensure that field and laboratory data are consistent, comparable, and of known, high quality. Older data has been quality assured to the best level possible, and any historic data deemed questionable was not used in this analysis. To best understand the water quality in Joe Pool Lake, data were analyzed four ways:

1. Review of the most recent 2022 TCEQ Texas Integrated Report of Surface Water Quality (Assessment);
2. Comparison of results to water quality standards and screening levels;
3. Trend analysis; and
4. Load duration curves.

Review of the 2022 Assessment for the Joe Pool Lake Watershed

Joe Pool Lake is designated in the Texas Surface Water Quality Standards (Standards) as supporting primary contact recreation, high aquatic life use, and public water supply. Each of these designated uses is protected by a set of one or more ***Standards*** for specific constituents (Appendix C). If water quality is insufficient to support any of those uses, the respective segment is referred to as ***Listed*** or ***Impaired*** on the Assessment. ***Screening Levels*** are numerical values that the TCEQ believes indicate potential problems that do not currently impair the segment. If a parameter does not meet its screening level, it can be designated as a ***Concern*** on the Assessment.

Joe Pool Lake was listed in 1998 and 2000 for elevated sulfate and total dissolved solids (TDS) as well as Atrazine in finished drinking water. Additional sampling demonstrated that standards for those constituents were inappropriately-low and the listings were removed. The 2006 Assessment identified Walnut Creek as impaired for bacteria (as measured by *E. coli*). In 2014, the Mountain Creek arm of the Joe Pool Lake was identified as having a concern based on screening levels for nitrate (NO3). During the 2018 assessment, new water quality data indicated that the bacteria standard was attained in Walnut Creek and the bacteria impairment was removed. Additionally, in 2018, data no longer supported the nitrate concern for the Mountain Creek arm of Joe Pool Lake and that concern was removed. In the 2022 assessment, a concern for bacteria was identified in Walnut Creek. Table 4 below summarizes the TCEQ impairment and concern history of Joe Pool Lake and its tributaries.

Table 4. TCEQ impairment and concern history for Joe Pool Lake and its tributaries since 2006.

Assessment Year	Segment and Name	Parameter	Type
2006	0838C Walnut Creek	Bacteria	Listing
	838 Joe Pool Lake Mountain Creek Arm	Nitrate	Concern
	838B Sugar Creek	Bacteria	Concern
2008	0838C Walnut Creek	Bacteria	Listing
	838B Sugar Creek	Bacteria	Concern
2010	0838C Walnut Creek	Bacteria	Listing
	838 Joe Pool Lake Mountain Creek Arm	Nitrate	Concern
	838B Sugar Creek	Bacteria	Concern
2012	0838C Walnut Creek	Bacteria	Listing
	838 Joe Pool Lake Mountain Creek Arm	Nitrate	Concern
	838B Sugar Creek	Bacteria	Concern Removed
2014	0838C Walnut Creek	Bacteria	Listing
	838 Joe Pool Lake Mountain Creek Arm	Nitrate	Concern
2016	0838C Walnut Creek	Bacteria	Listing
	838 Joe Pool Lake Mountain Creek Arm	Nitrate	Concern Removed
2018	0838C Walnut Creek	Bacteria	Delisted - New Data
2022	0838C Walnut Creek	Bacteria	Concern

Criteria/Screening Level Analysis

Standards and screening levels are thresholds at which TCEQ considers an individual water sample acceptable or unacceptable. While the 2022 Integrated Report assesses some parameters with this binomial method, it generally considers the total number of exceedances, long-term averages, or some combination of both when making listing decisions. To better understand the variability of the data compared with standards and screening levels, boxplots of selected parameters are Appendix D. In summary, of the 5,969 individual surface water sample results (samples collected in ≤0.3 meters of water), only four individual lake samples and 39 individual tributary samples exceeded its screening level or criteria (Table 5). Selected parameters are discussed in more detail below.

Table 5 and Figure 7 show that instantaneous exceedances were only observed for two categories of constituents (nutrients and bacteria). The lake sites showed two exceedances for Nitrate + Nitrite (NO2 + NO3) in the Mountain Creek arm and two at the main body site in consecutive quarters, spring and summer of 2019. When considering the larger dataset from January of 2013, there is only one additional exceedance in the summer of 2016 (Figure 7). For the stream sites, only B3, which receives effluent discharge from MCRWS, showed exceedances for the nutrient screening levels (Figure 7 & Table 5).

None of the lake sites had exceedances of the *E. coli* single sample standard (399 MPN/100 mL) or the current geometric mean standard (126 MPN/100 mL). All of the stream sites showed at least three exceedances of the single sample standard for *E. coli* (Figure 7, Table 5, & Table 6) and three of the sites had a geometric mean above the 126 MPN/100 mL geomean standard. *E. coli* is further discussed in the Load Duration Curve section of this report.

Table 5. Number of exceedances or standards or screening levels between 2017-2021.

Site *Standard (Lake/stream)*	NO2 + NO3 *0.37/1.95 mg/L*	**NH3** *0.11/0.33 mg/L*	**TP** *0.2/0.69 mg/L*	**OP** *0.05/0.37 mg/L*	***E. coli*** *399 MPN/100ml*
A1	2 (3/2019, 5/2019)				
A2					
A3	2 (3/2019, 5/2019)				
B1					4 (2/17, 4/20, 1/21, 5/21)
B2					4 (4/17, 4/20, 1/21, 5/21)
B3	11 (2/17, 10/17, 2/18, 5/18, 12/18, 3/19, 11/19, 2/20, 11/20, 1/21, 11/21)	1 (8/2020)	2 (2/2018, 4/2020)	3 (2/2017, 2/2018, 11/2019)	5 (8/17, 10/17, 5/18, 4/20, 5/21)
B4					8 (8/17, 10/17, 5/18, 9/18, 4/20, 1/21, 5/21, 8/21)
B5					3 (8/17, 9/18, 4/20)

Table 6 *E. coli* statistics between 1997-2021.

Station	**Count**	**Minimum value of *E. coli* (MPN/100 mL)**	**Maximum value of *E. coli* (MPN/100 mL)**	**Geometric Mean* (MPN/100 mL)**	**Percentage of samples exceeding 399 (%)**
A1	51	<1	79	3.20	0
A2	50	<1	649	3.39	2.0%
A3	50	<1	119	3.76	0
I1	31	1	125	4.21	0
B1	39	2	4,352	59.74	12.8%
B2	23	1	2,420	121.60	34.8%
B3	46	4	9,768	183.00	30.4%
B4	33	12	24,166	245.64	36.4%
B5	49	6	41,100	133.36	22.5%

*Geometric mean criterion for *E. coli* is 126 MPN/100 mL.

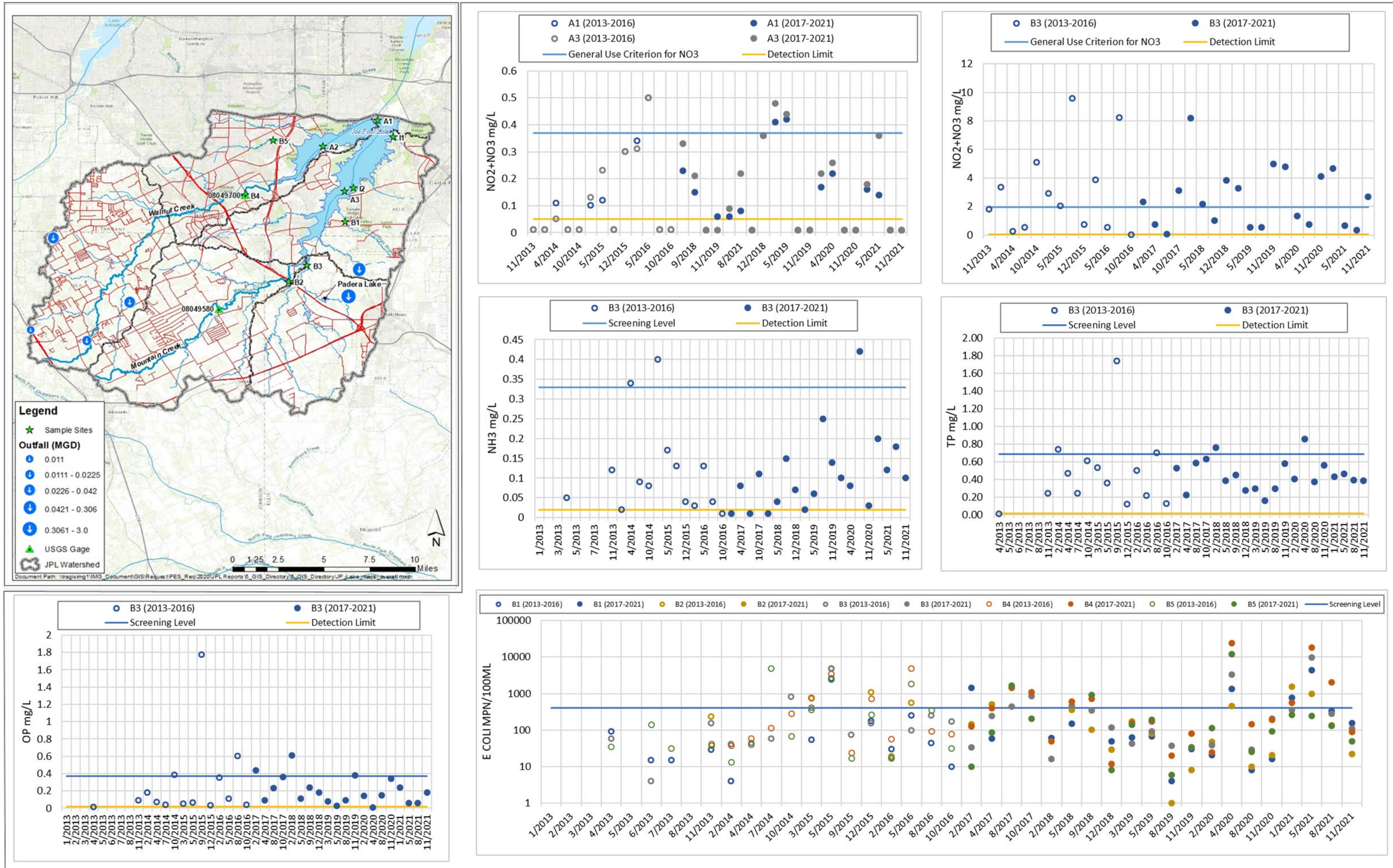


Figure 7. Chart of the parameters with exceedances of a criterion or screening level.

None of the dissolved metals results at the lake sites approached the standards and all organophosphorus pesticides, chlorinated herbicides, PCBs, and VOCs were non-detects. No cryptosporidium oocysts were detected during sampling, however, there were two individual giardia cysts detected, a single cyst in September of 2015 and another single cyst in August of 2021. According to the EPA, reported giardia levels in surface and tap water have range <10, so there is no indication that these two individual cysts are an issue at this time, but giardia levels should continue to be tracked.

For atrazine, 36 of 48 samples were non-detects and no results were above 1.22 ug/L which is less than ½ of the U.S. Environmental Protection Agency's finished drinking water maximum contaminant level (MCL). Geosmin and methylisoborneol (MIB) are naturally occurring compounds that have an earthy/musty taste and odor and can be detected by people in the 5-10 ng/L range. Though harmless to humans, these compounds can cause taste and odor issues for water treatment plants. Values for MIB averaged 26 ng/L (range <1 to 110 ng/L) and geosmin averaged 11.5 ng/L (range <1 to 35) between 2017 and 2021.

Water Quality Trend Analysis

While it is important to compare sample results to standards and screening levels, it is also important to look for increasing or decreasing trends over time. Lakes in Texas are generally quite stable in the short-term, but they can evolve over longer periods of time due to eutrophication, shoreline and watershed development, or other factors. Trend analyses for selected parameters and sites were run for an extended dataset (1997 to 2021) by site and then aggregated by type (either lake or tributary) in order to examine longer-term trends which may not be apparent when looking at shorter time frames, or may be masked by severe hydrologic events. For the Joe Pool Lake sites, statistically significant increasing trends were found for dissolved oxygen (DO), total suspended solids (TSS), and Chlorophyll-*a* at lake sites (Table 7), while decreasing trends were observed for pH, total kjeldahl nitrogen (TKN), and hardness. For the tributary sites, decreasing trends were identified for hardness and total dissolved solids (Table 7) and B1 showed an increasing trend for hardness.

When compared to the last report (1997 to 2016), the majority of the trends identified continued. With the new decreasing trend identified for pH at site A1, all lake sites are show decreasing pH trends. A new decreasing trend for TKN was identified at both lake arm sites, A2 and A3, but A1 continued to showed no trend. Interestingly, when data from all of the lake sites were aggregated, no overall trend was identified for TKN. For Chlorophyll-*a* two new increasing trends were identified at A1 and A2, but the increasing trend identified previously at A3 was no longer significant. However, an increasing trend for Chlorophyll-*a* was identified when all lake data were aggregated. At the tributary sites, site B4 showed decreasing trends for hardness and TDS, B3 showed a new decreasing trend for hardness, and B1 showed an increasing trend for hardness. When all of the tributary sites were aggregated, decreasing trends for hardness and TDS were identified. Though several trends were identified, it is important to note that the slope of these trends were generally quite shallow indicating that the change over time, if real, is very gradual. While trend analysis can be an important indicator of change over time, it can be sensitive to dataset size and distribution and should be considered in the context of the other data analysis methods.

Table 7. Trend tests of select parameters, 1997-2021

		1997-2016 (19-year POR)				1997-2021 (24-year POR)				Slope Δ	1997-2021 (24-year POR) Aggregated by Type		
Location	Parameter	Station	# of Data	Trend of Test (p=0.05)	Slope	Station	# of Data	Trend of Test (p=0.05)	Slope		# of Data	Trend of Test (p=0.05)	Slope
Main body	TEMPERATURE, WATER	A1	197	No Trend		A1	218	No Trend			618	No Trend	
		A2	210	No Trend		A2	230	No Trend					
		A3	211	No Trend		A3	231	No Trend					
	OXYGEN, DISSOLVED	A1	191	Increasing	0.00020	A1	212	Increasing	0.00019	2%	598	Increasing	0.00023
		A2	203	Increasing	0.00021	A2	223	Increasing	0.00020	5%			
		A3	204	Increasing	0.00030	A3	224	Increasing	0.00029	6%			
	PH	A1	196	No Trend		A1	217	Decreasing	-0.00003	Δ	615	Decreasing	-0.00003
		A2	209	Decreasing	-0.00004	A2	228	Decreasing	-0.00003	6%			
		A3	210	Decreasing	-0.00004	A3	230	Decreasing	-0.00004	6%			
	TSS	A1	77	No Trend		A1	96	No Trend			239	Increasing	0.00024
		A2	80	No Trend		A2	99	No Trend					
		A3	82	Increasing	0.00067	A3	101	Increasing	0.00047	30%			
	NO2 + NO3	A1	88	No Trend		A1	218	No Trend			270	No Trend	
		A2	90	No Trend		A2	230	No Trend					
		A3	92	No Trend		A3	231	No Trend					
	NH3	A1	85	No Trend		A1	218	No Trend			266	No Trend	
		A2	90	No Trend		A2	230	No Trend					
		A3	91	No Trend		A3	231	No Trend					
	TKN	A1	85	No Trend		A1	105	No Trend			266	No Trend	
		A2	90	No Trend		A2	110	Decreasing	-0.00002	Δ			
		A3	91	No Trend		A3	111	Decreasing	-0.00002	Δ			
	TP	A1	85	No Trend		A1	105	No Trend			265	No Trend	
		A2	89	No Trend		A2	109	No Trend					
		A3	91	No Trend		A3	111	No Trend					
	HARDNESS	A1	171	Decreasing	-0.00418	A1	191	Decreasing	-0.00357	15%	540	Decreasing	-0.00309
		A2	185	Decreasing	-0.00317	A2	205	Decreasing	-0.00305	4%			
		A3	184	Decreasing	-0.00253	A3	204	Decreasing	-0.00271	-7%			
	E. COLI	A1	31	No Trend		A1	51	No Trend			91	No Trend	
		A2	30	No Trend		A2	50	No Trend					
		A3	30	No Trend		A3	50	No Trend					
		I1	11	No Trend		I1	31	No Trend					
	CHLOROPHYLL-A	A1	73	No Trend		A1	93	Increasing	0.00056	Δ	222	Increasing	0.00041
		A2	74	No Trend		A2	94	Increasing	0.00054	Δ			
		A3	75	Increasing	0.00040	A3	95	No Trend		Δ			
	D-OPO4-P	A1	86	No Trend		A1	218	No Trend			269	No Trend	
		A2	91	No Trend		A2	230	No Trend					
		A3	92	No Trend		A3	231	No Trend					
Tributary	HARDNESS	B1	39	No Trend		B1	55	Increasing	0.010387	Δ	392	Decreasing	-0.00789
		B2	103	No Trend		B2	120	No Trend					
		B3	42	No Trend		B3	62	Decreasing	-0.01203	Δ			
		B4	158	Decreasing	-0.01611	B4	178	Decreasing	-0.01654	-3%			
		B5	50	No Trend		B5	68	No Trend					
	E. COLI	B1	22	No Trend		B1	39	No Trend			98	No Trend	
		B2	6	No Trend		B2	23	No Trend					
		B3	26	No Trend		B3	46	No Trend					
		B4	13	No Trend		B4	33	No Trend					
		B5	31	No Trend		B5	49	No Trend					
	TDS	B1	38	No Trend		B1	55	No Trend			391	Decreasing	-0.01637
		B2	109	No Trend		B2	126	No Trend					
		B3	41	No Trend		B3	61	No Trend					
		B4	158	No Trend		B4	178	Decreasing	-0.03024	Δ			
		B5	45	No Trend		B5	63	No Trend					

As noted above, significant increasing trends for DO, Chlorophyll-*a*, and TSS were observed in the lake from 1997-2021. As algae can cause increases in TSS and DO during the day, these are believed to be related. Although the chlorophyll-*a* trend (Figure 8) could be a factor of hydrology more than actual increased algal growth, the continued higher than average results during the last 3 years of near-normal annual hydrologic conditions indicates this should be monitored closely. The long-term increasing trend in chlorophyll-*a* is disconcerting, but there is a tremendous amount of variability in the dataset. Figure 8 also shows that, should this trend continue, the measurements could approach the screening level in approximately 10 years, although to date, there have been no exceedances. The next 5-year water quality assessment should better inform the long-term projections.

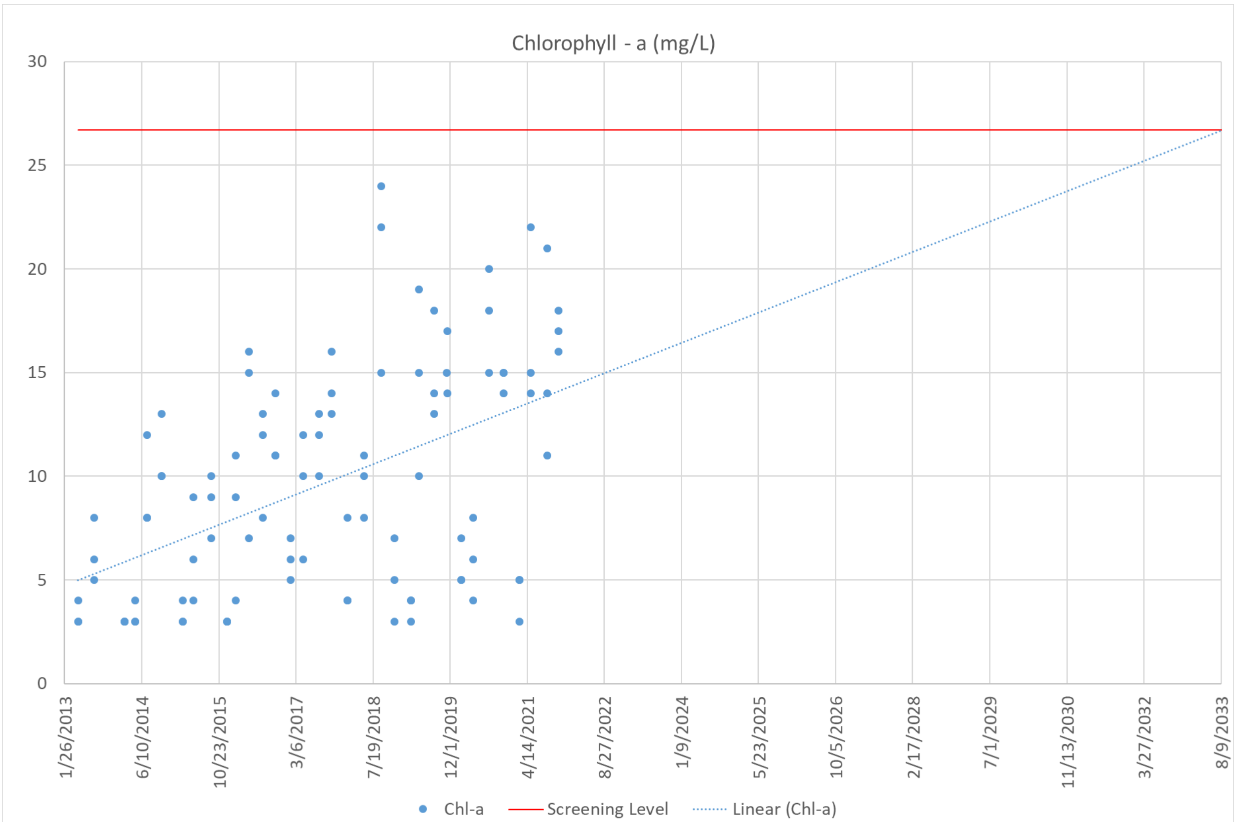


Figure 8. Chlorophyll-*a* at all lake sites compared to the screening level and linear regression intercept.

NO2 + NO3 concentrations in Joe Pool Lake showed no trends, but it is interesting to consder how hydrology can influence nutrient concentraitons. Looking at Figure 9, several patterns appear. Between 2013 and 2015, NO2 + NO3 values were low during a period of low inflow. Once flooding began in 2015 and 2016, the NO2 + NO3 vaules increased. Once Joe Pool Lake began to stabalize, the NO2 + NO3 values began to decrease and they remained low until there was another large inflow in 2018. Over the last three years, a period of "average" annual rainfall and inflow, the NO2 + NO3 values have decreased and the data does not show any discernable impact from wastewater discharges on the reservoir. Additionally, this dataset demonstrates how much the date range of a dataset can affect trend analysis. If this date range were shorter, or missed one part of the normal hydrologic variation of the lake, it would likely show an *increasing or decreasing* trend.

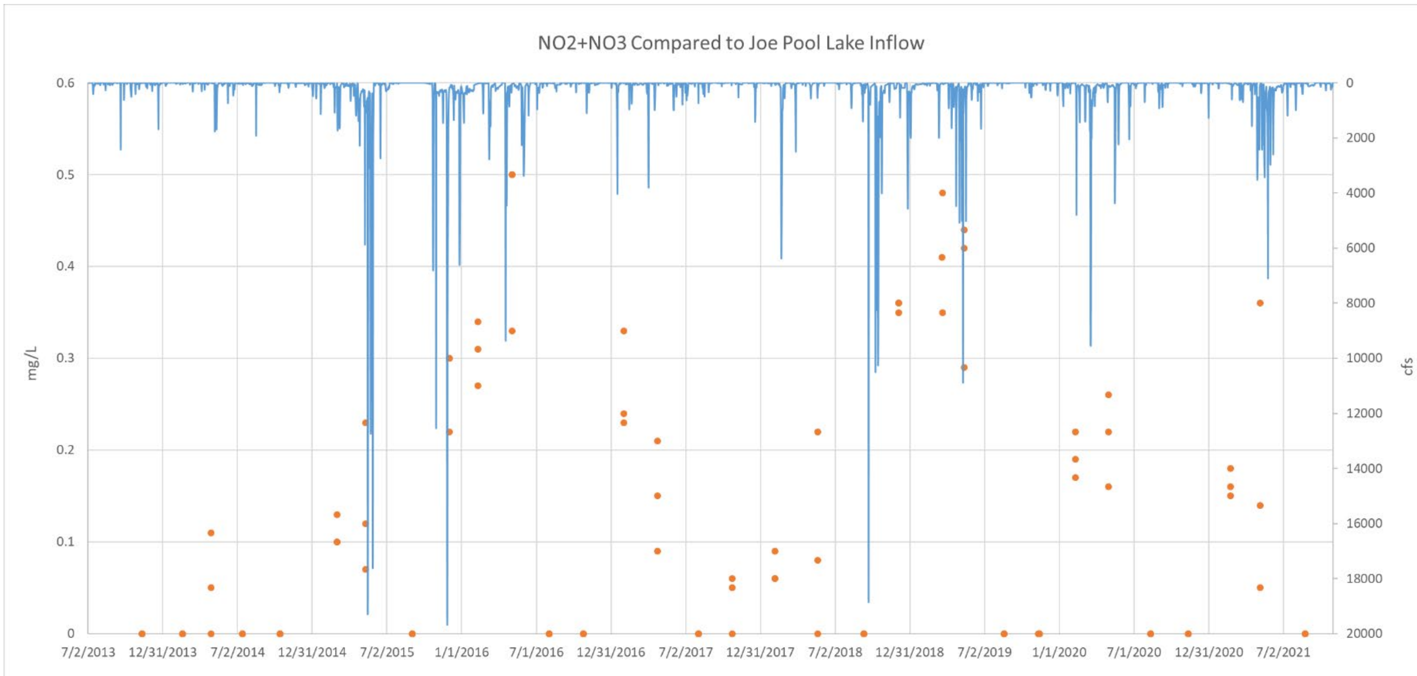


Figure 9. Comparison of NO2 + NO3 concentrations in the entire lake to Joe Pool Lake inflows.

Parameters for which no trends exist are as important and those with trends. These include Total Phosphorus (TP) and Atrazine which have shown trends historically. This could indicate a positive development in water quality, but is more likely an artifact of unusual hydrology and the impact of a larger dataset. Data for water temperature, TP, NO2 + NO3, NH3, and *E. coli* did not show trends.

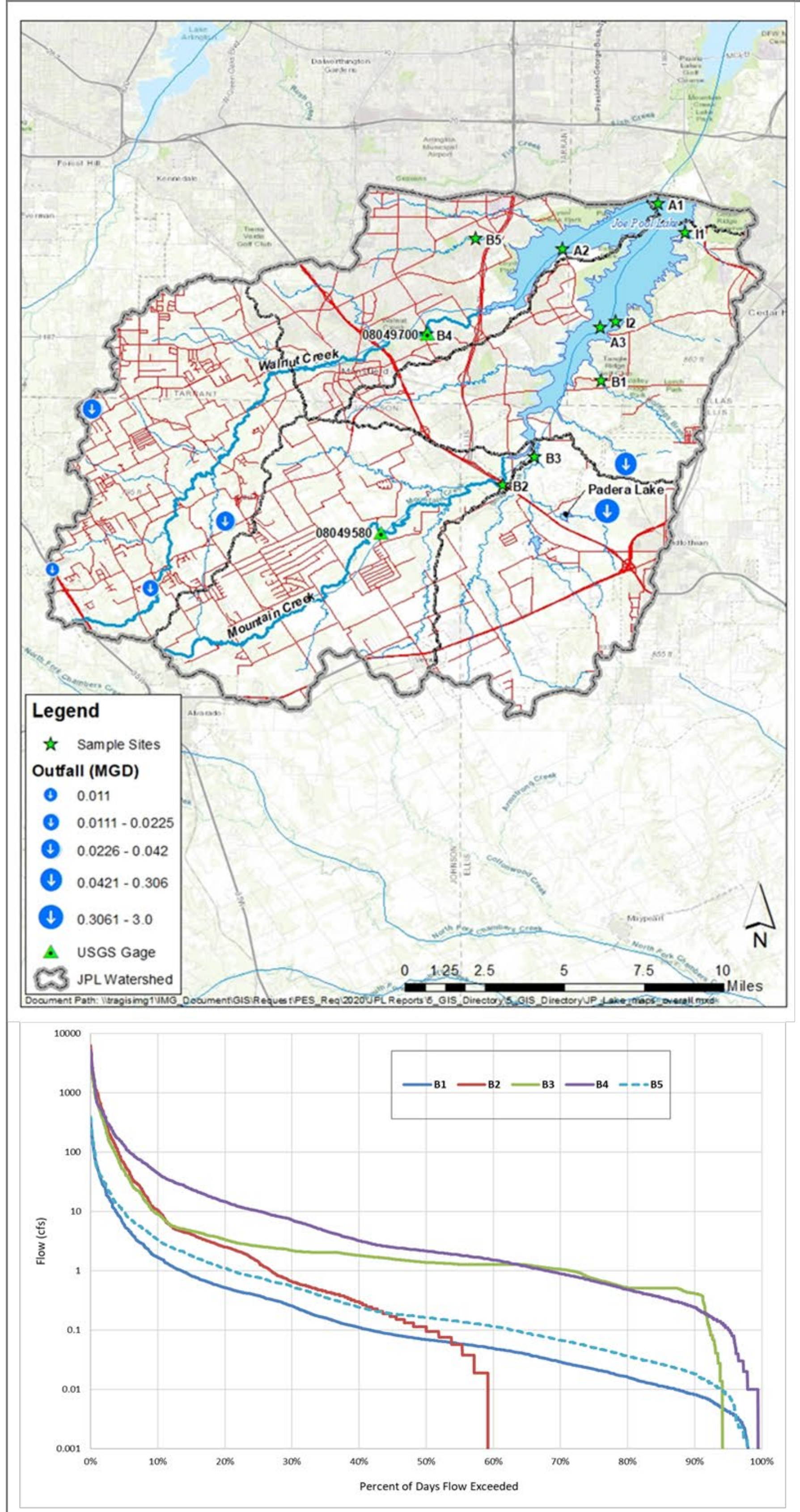
Load Duration Curve Analysis

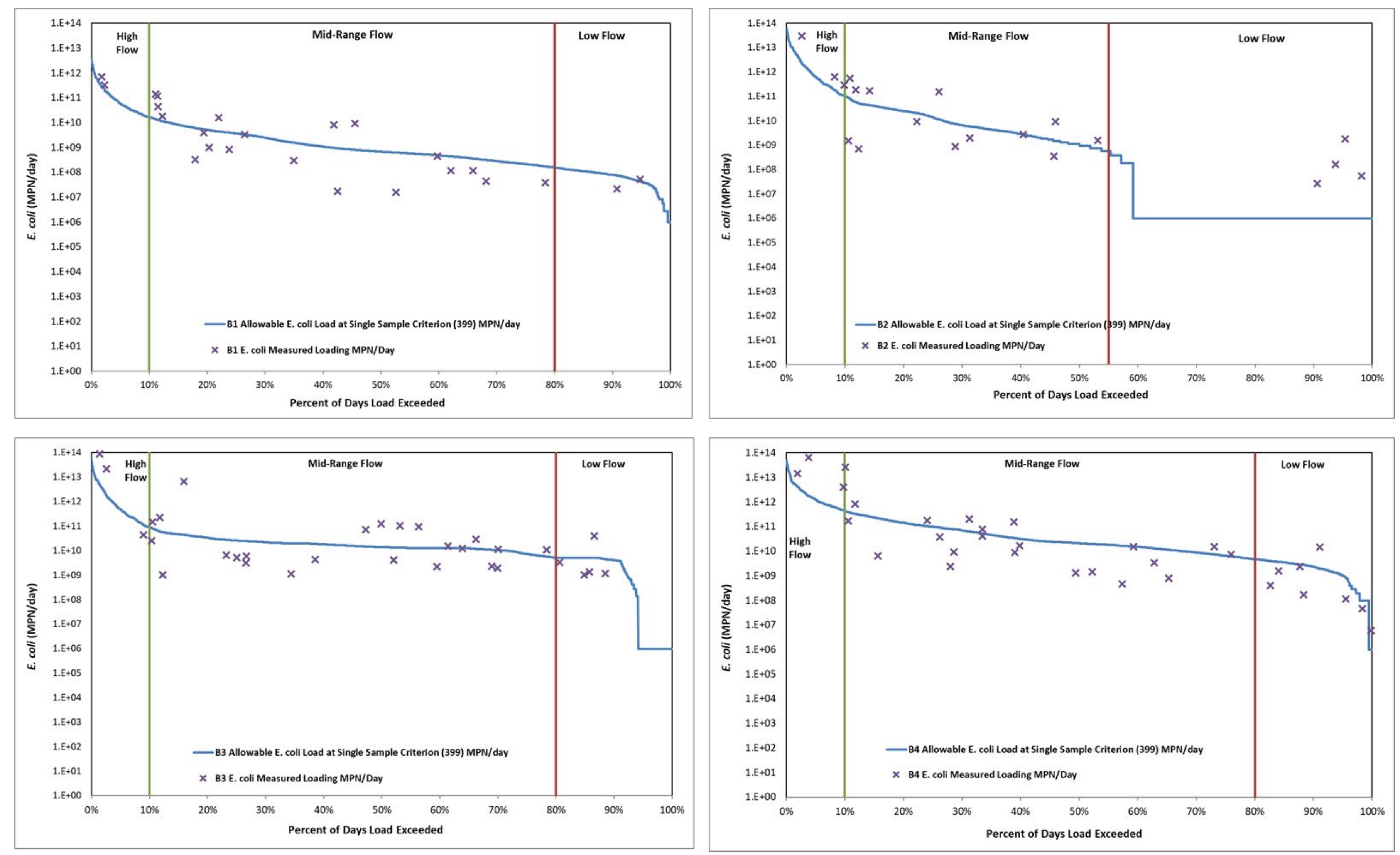
Load Duration Curves (LDCs) were created for the stream sites by taking the FDCs discussed in the Joe Pool Lake Basin Hydrology Section and distributing a daily allowable loading (TCEQ screening level or standard) of a constituent to that cumulative flow distribution. Once the LDCs are created, measured constituent data is plotted against its corresponding streamflows. If the observed data is above the LDC, it represents a load exceedance. LDCs can help to identify potential sources of contaminants. For example, if there are exceedances at low flows, then a consistent or point source is likely. If exceedances are in the higher range of flows, then it is likely that non-point source runoff washing into the stream during rain events are causing the exceedances. Figure 10 through Figure 14 show the watershed map, FDCs, and the LDCs for *E. coli*, NH3, NO2 + NO3, OP and TP, which are constituents for which screening levels or standards exist. Table 8 summarizes the LDC analysis.

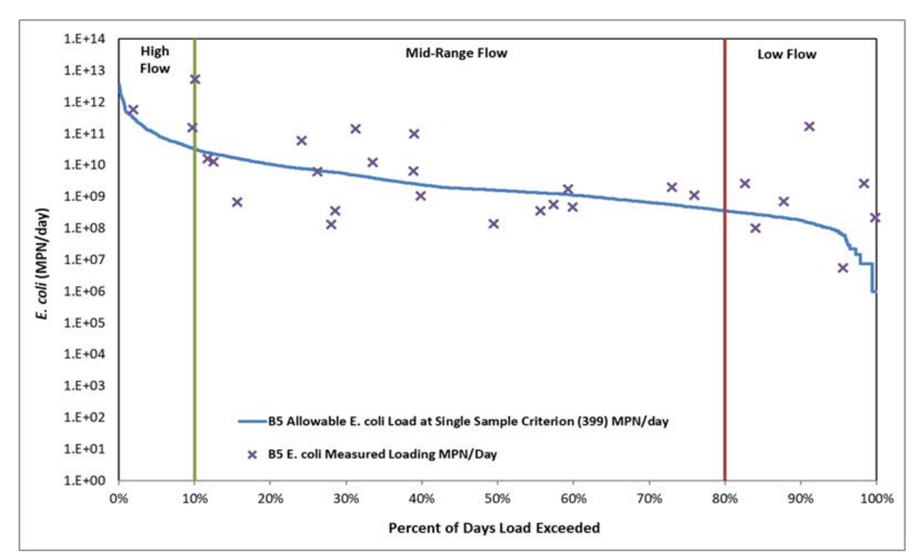
Site B1, Hollings Branch, is a small, undeveloped watershed on the west side of the lake; some being within a state park. LDCs indicate that the *E. coli* loadings are from non-point source runoff and the sources are likely wildlife or range animals like horses and cows. NO2 + NO3 follows the same pattern as *E. coli*, and the sources are likely fertilizers applied to agriculture fields, other agriculture practices, and native soils. For NH3, OP, and TP, the loadings did not exceed the screening levels at any flow. Site B2, Mountain Creek, is a large watershed comprised of mostly rangeland and pastureland. The LDCs indicate that *E. coli* loads are both point (or constant) sources and likely from wildlife and range animals. NO2 + NO3 comes from non-point source runoff, while OP and TP come from point sources. NH3 impacts were minor. Site B3, Soap Creek, is a large watershed with a majority of rangeland and pastureland. As stated previously, this site receives MCRWS effluent flows which likely contributes to the constant point source inputs for NH3, OP, and TP, while NO2 + NO3 appears to be from non-point source runoff. *E. coli* was shown as exceeding the allowable load across the range of flows, but MCRWS is likely not the point source or constant input because the disinfection processes at MCRWS. Further, every other site showed point sources as inputs for *E. coli*, except B1. Site B4, Walnut Creek, is a large urban-rural mosaic. The *E. coli* sources were indicated as both constant point and non-point sources. Interestingly, there were no exceedances or minimal inputs for nutrients (NO2 + NO3, NH3, OP, and TP). Site B5, Bowman Branch, is mostly urban with some pasture and rangeland. *E. coli* sources were indicated as both constant point and non-point sources. While NO2 + NO3 indicated the sources were both constant point and non-point runoff, TP indicated constant point sources, likely originating from irrigation runoff of landscape and lawn fertilizers during low flows. NH3 and OP loadings were minimal or had no exceedances.

Table 8. Table showing a summary of the LDCs for sites B1-B5.

Site	Stream Name	Site Description	E. coli	NO2 + NO3	NH3	OP	TP
B1	Hollings Branch	Small, undeveloped	NPS	NPS	NE	NE	NE
B2	Mountain Creek	Large, range and pasture	P, NPS	NPS	M	P	P
B3	Soap Creek	Medium, range and pasture	P, NPS	NPS	P. NPS	P. NPS	P
B4	Walnut Creek	Urban-rural mosaic	P, NPS	NE	M	NE	M
B5	Bowman Branch	Mostly Urban, some pasture/range	P, NPS	P, NPS	M	NE	P, NE
P - Point/Constant Source, NPS - Non-point Source Runoff, M - Minor, or Minimal Count, NE - No Exceedances							



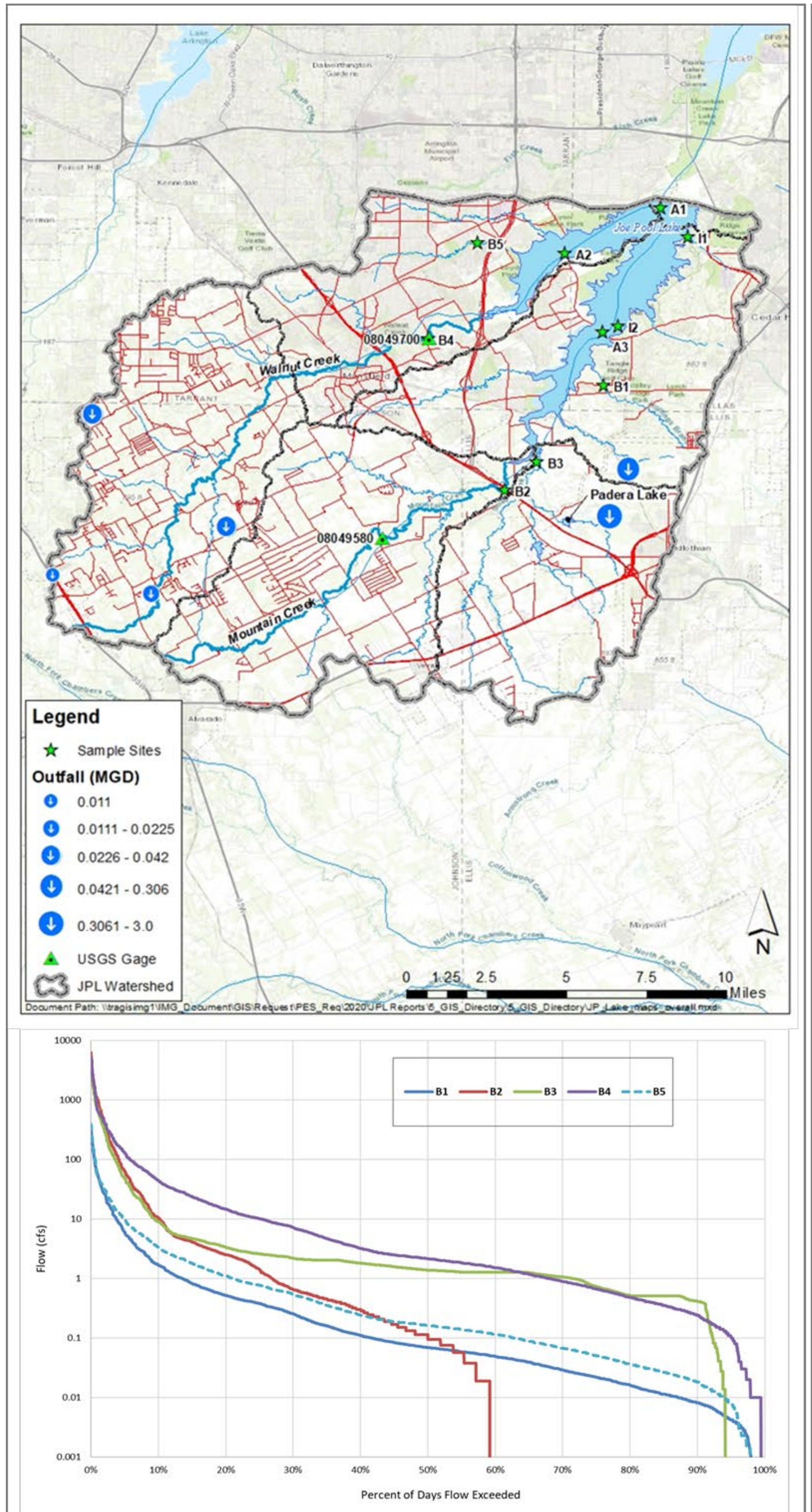


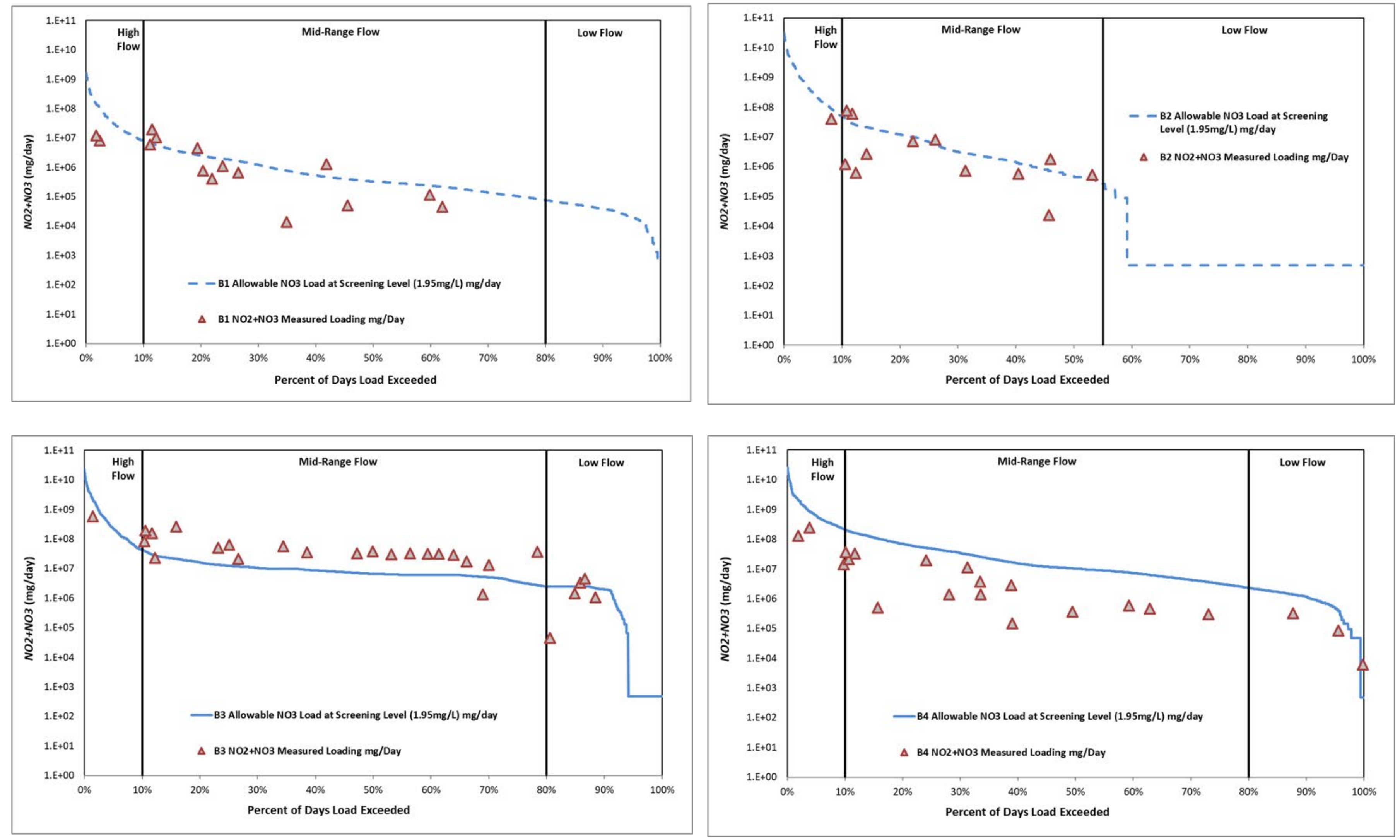


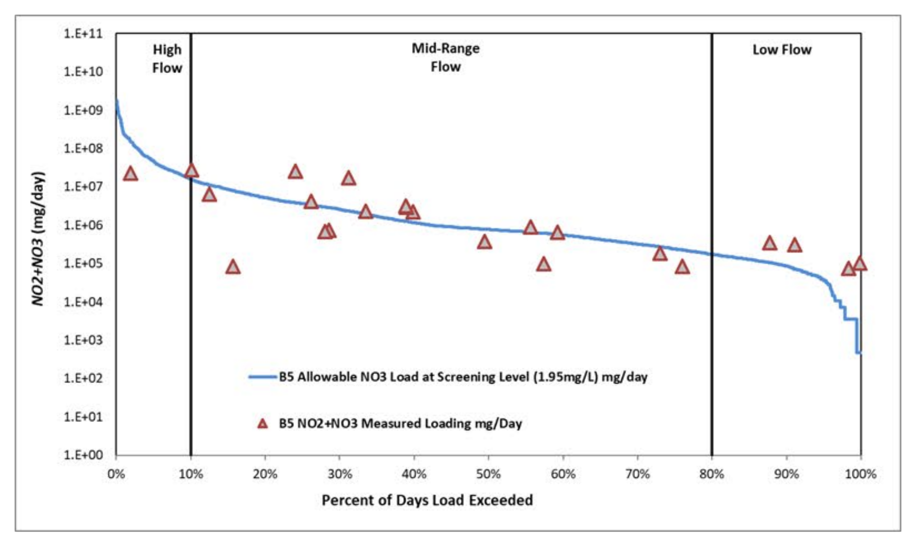
For *E. coli*, the LDCs indicate that the sources for B1 and B4 are likely non-point source runoff because there are minimal exceedances until the flows reach the 50% exceedance level.

For B2, B3, and B5, exceedances are found at both high and low flows, indicating the sources of *E. coli* are both non-point source runoff and consistent or point sources.

Figure 10. Joe Pool Lake load duration curves for *E. coli*.

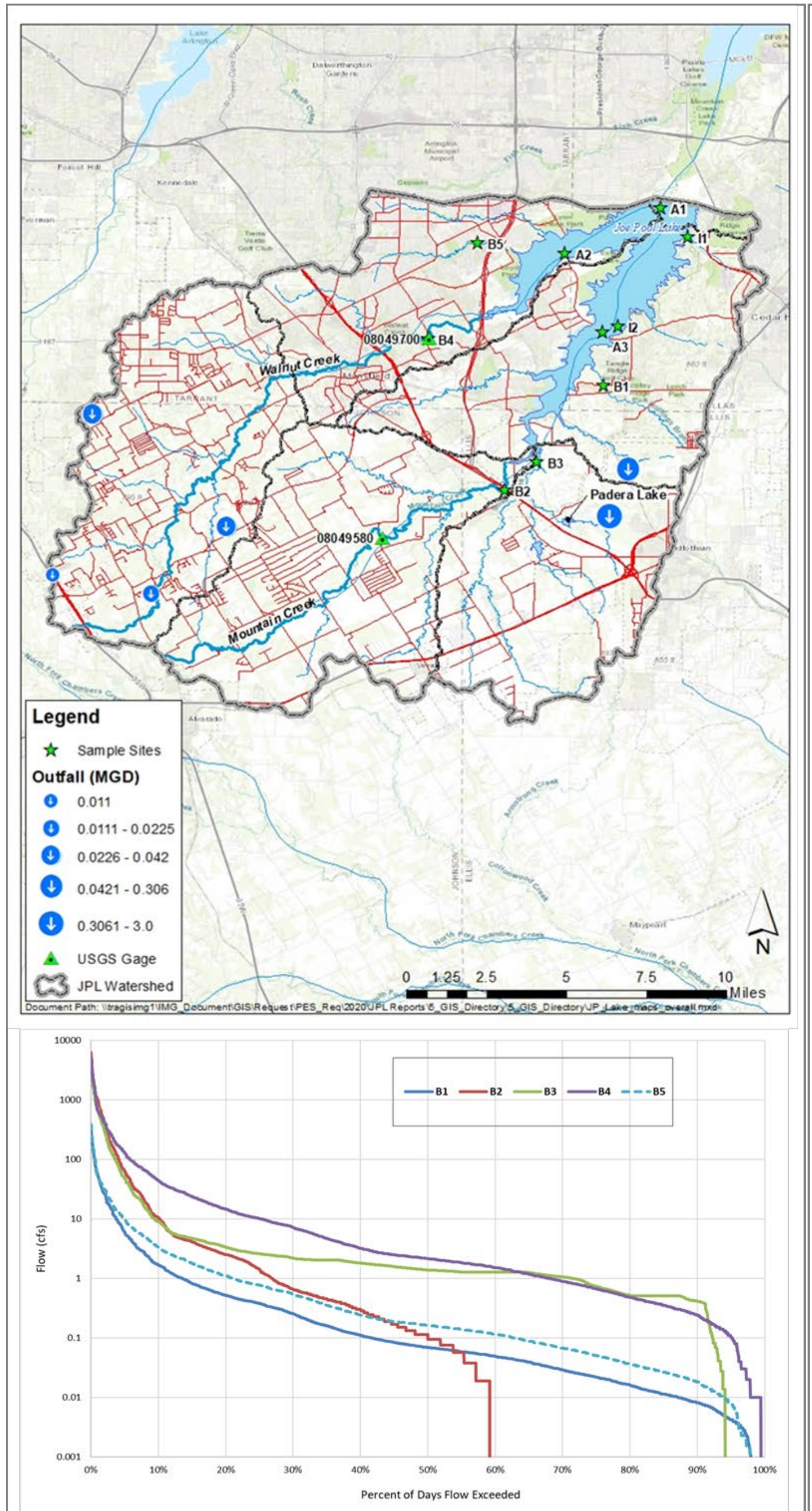


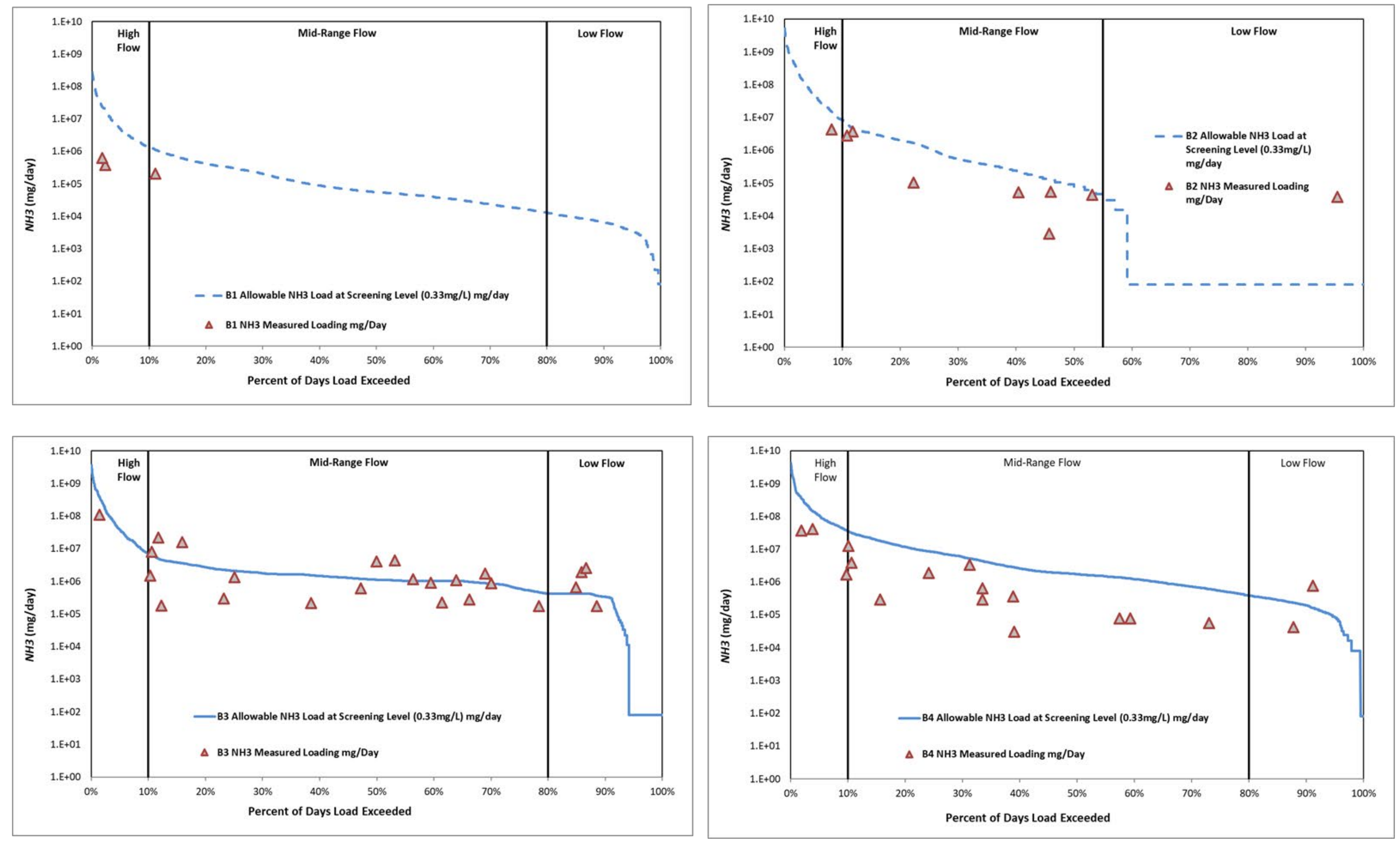


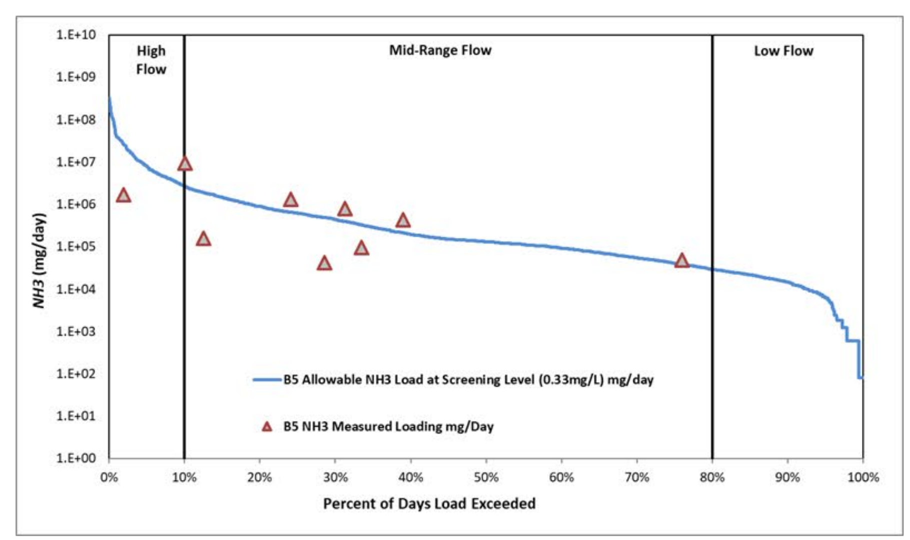


For NO2 + NO3, B1 and B2, both largely undeveloped watersheds, showed some exceedances in the mid to higher flows indicating non-point source runoff loadings. B4 results are under the allowable load across the range of flows. As expected, B3, downstream from the TRA WWTP, showed the highest loadings. B5 results indicate non-point runoff sources are the likely cause of the loadings.

Figure 11. Joe Pool Lake load duration curves for NO2 + NO3.

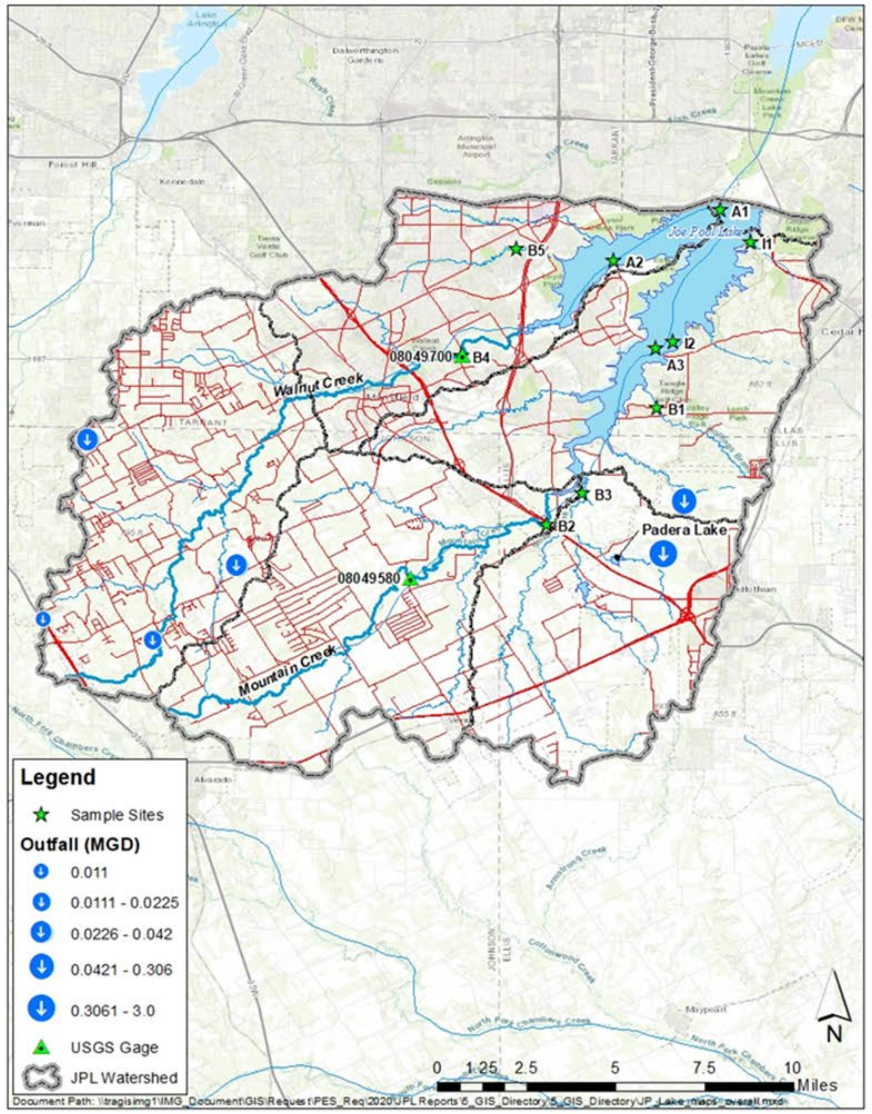


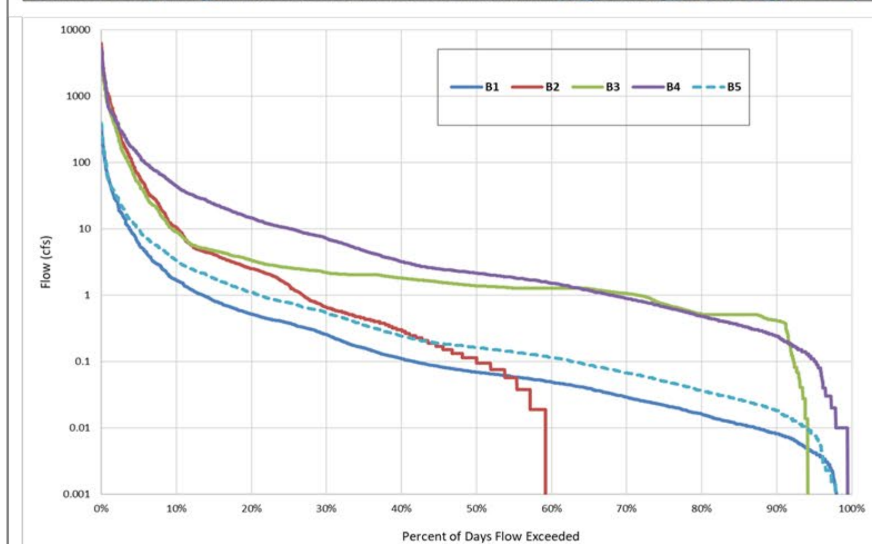


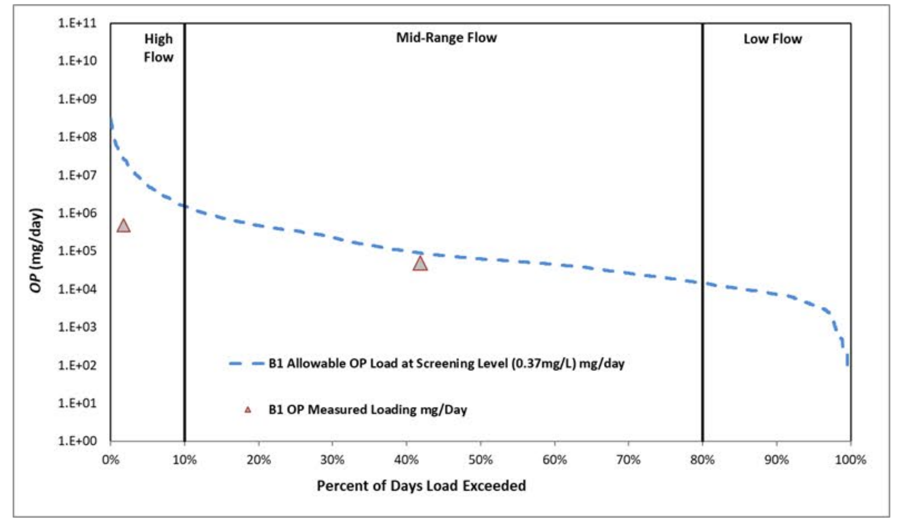


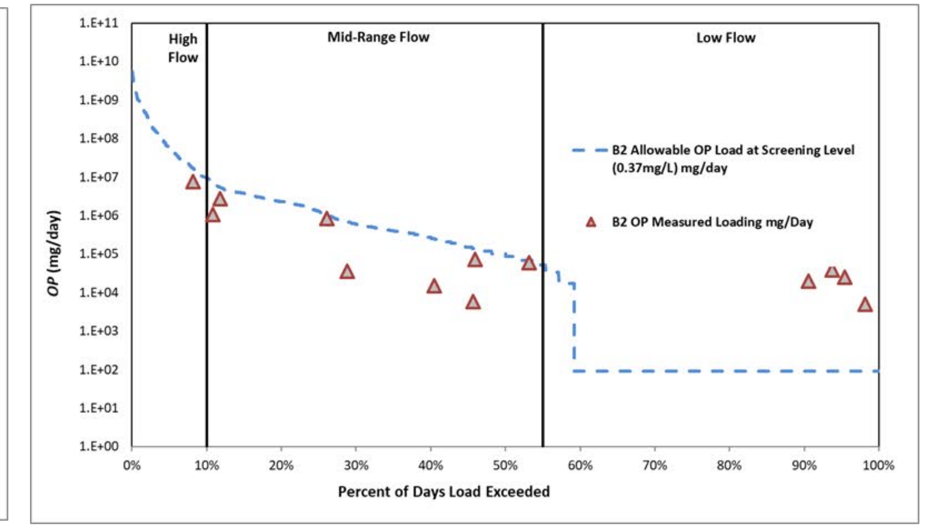
For NH3, B1, the smallest, most undeveloped watershed, values were mostly below the detection limit. B2, and B4 are generally under the allowable load, though each site has one elevated sample at low flow. As expected, B3, downstream from the TRA WWTP, showed the highest loadings. B5 results indicate non-point runoff sources are the likely cause of the loadings.

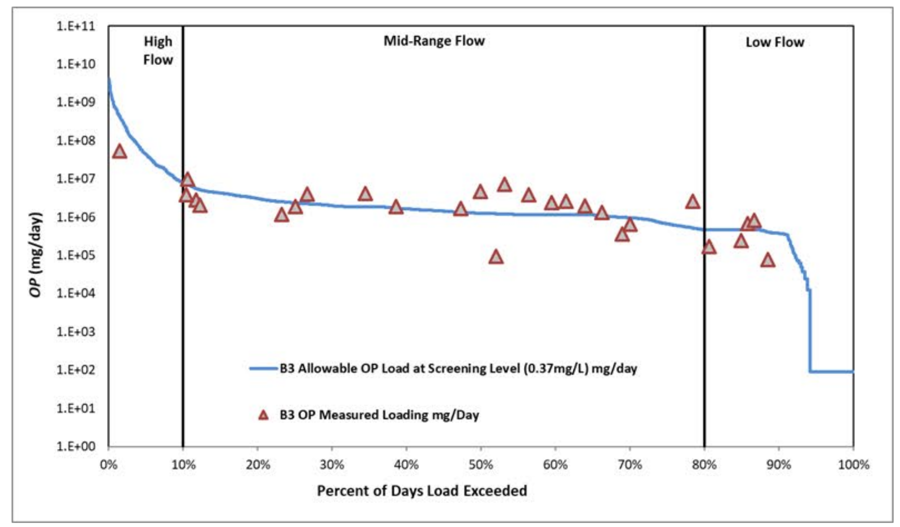
Figure 12. Joe Pool Lake load duration curves for NH3.

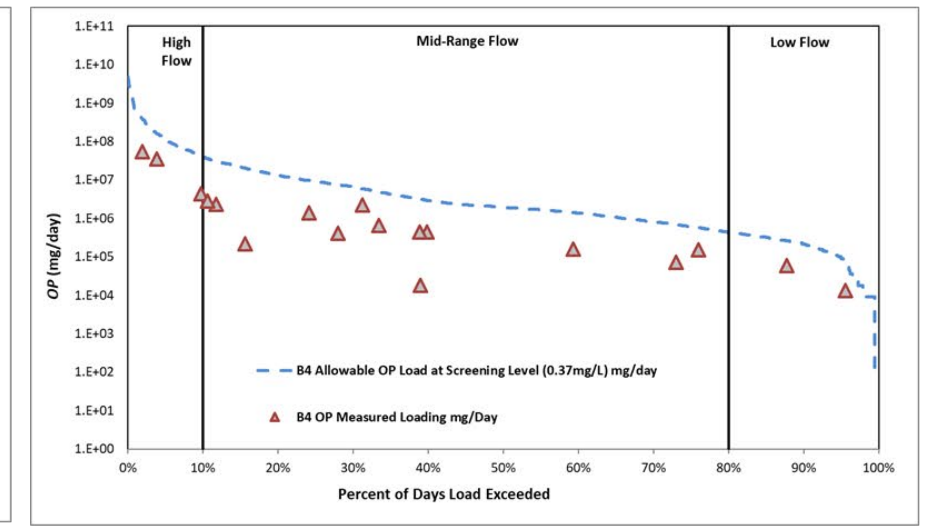


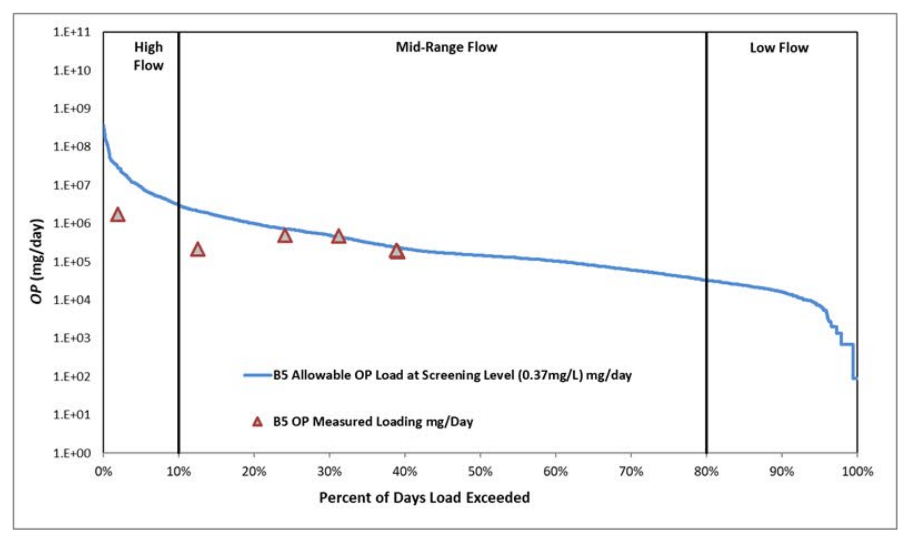






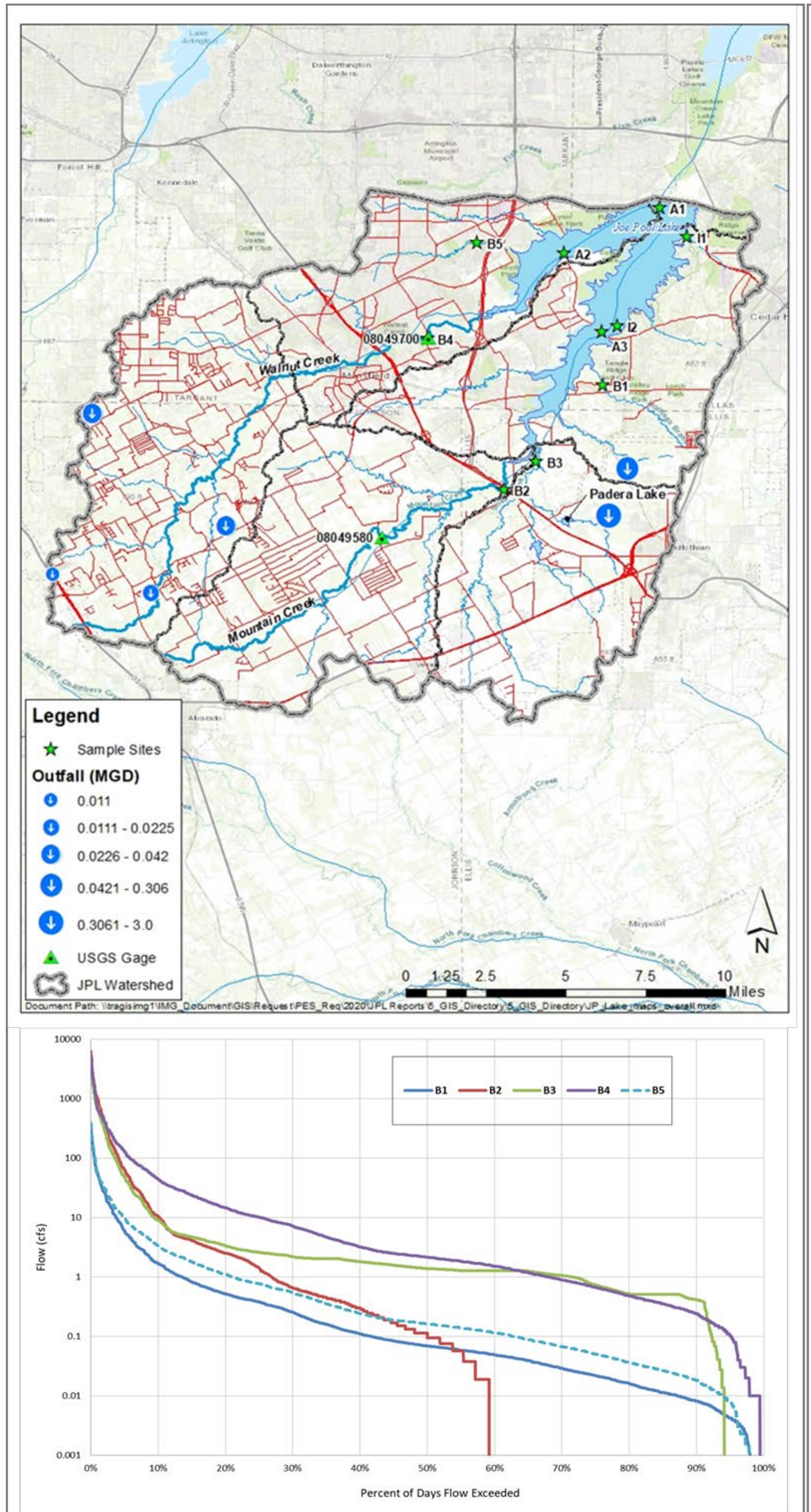


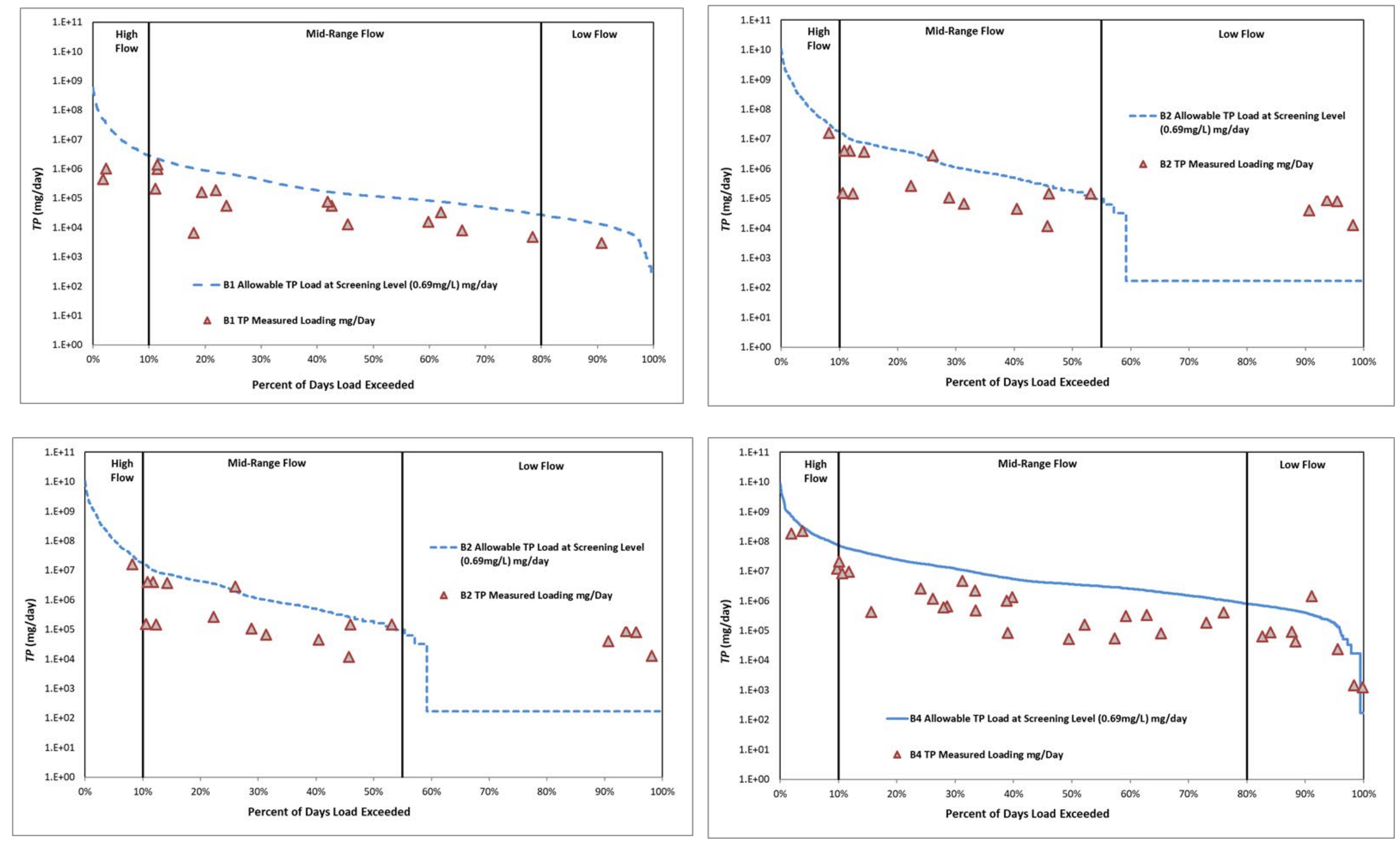


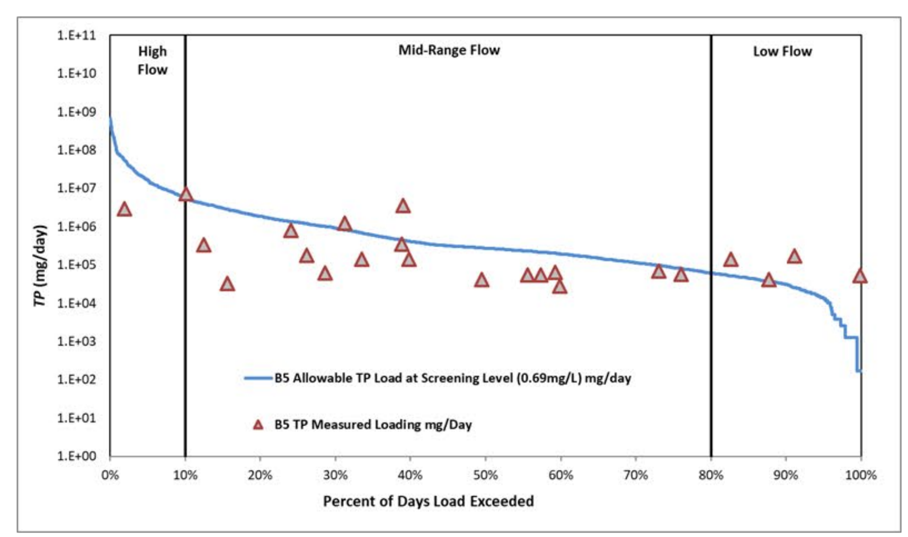


For B1, B2, B4, and B5, except for a few background low-flow loadings at B2, OP results were below the loading allowance. As expected, B3 showed elevated OP values across the range of flows due to effluent discharge from TRA's Mountain Creek Regional Wastewater Treatment Plant which is known to carry higher than normal nutrient loads.

Figure 13. Joe Pool Lake load duration curves for OP.







For B1, B2, B4, and B5, except for a few background low-flow loadings at B2, TP results were generally below the loading allowance. As expected, B3 showed elevated TP values at low flows due to effluent discharge from TRA's Mountain Creek Regional Wastewater Treatment Plant which is known to carry higher than normal nutrient loads.

Figure 14. Joe Pool Lake load duration curves for TP.

2017-2021 Water Quality Summary

Overall, the water quality in Joe Pool Lake is quite good. Data collected between 2017 and 2021 continue to support the conclusions made in the last 5-year summary report. Nutrients appear to be closely correlated to runoff. Storm events can change water quality within the main body of the reservoir over a short period of time, then these inputs are assimilated during periods of low inflow. Flow duration curves, and their accompanying load duration curves, support this conclusion because the tributaries conduct the vast majority of their flow only under the influence of rain events.

Chlorophyll-*a*, a surrogate for algae that is often related to nutrient concentrations, continued its long-term increasing trend. The continued increase in Chlorophyll-*a* is potentially problematic in the long term and two episodes of high geosmin (a nuisance, taste and odor inducing compound) were noted.

Since the last report, all curent imparments for the tributarues have been removed from the TCEQ Integrated Report although a concern for E. coli exists in Walnut Creek. However, new *E. coli* data collected at Soap Creek, Walnut Creek, and Bowman Branch indicate that these streams could be listed as having impairments on the next Integrated Report. *E. coli* measurements within the lake did not show any exceedances between 2017 and 2021.

References

Cleland, B. 2003. TMDL Development from the “Bottom Up” — Part III: Duration Curves and Wet-Weather Assessments. America’s Clean Water Foundation, Washington, D.C.

Moriasi, D.N., J.G. Arnold, M.W. Van Liew, R.L. Bingner, R.D. Harmel, and T.L. Veith. 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. Transactions of the American Society of Agricultural and Biological Engineers, 50 (3): 885–900.

Nash, J.E., and J.E. Sutcliffe. 1970. River flow forecasting through conceptual models: Part 1—A discussion of principles. J. Hydrology. 10(3): 282-290.

Appendix A - Relevant Assessment Summaries in 2022 Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d)

2022 Texas Integrated Report - Waterbodies Evaluated

Seg ID	Seg Name	Segment Description	Segment Type	AU ID	AU Description	Flow Type	Flow Type Source	ALU Designation	ALU Designation Source	Station ID(s)
0838	Joe Pool Lake	From Joe Pool Dam in Dallas County up to the normal pool elevation of 522 feet (impounds Mountain Creek)	Reservoir	0838_01	Lowermost portion of reservoir adjacent to the dam	Reservoir	TSWQS Appendix A	High	TSWQS Appendix A	No Stations
				0838_02	Mountain Creek arm	Reservoir	TSWQS Appendix A	High	TSWQS Appendix A	No Stations
				0838_03	Walnut Creek arm	Reservoir	TSWQS Appendix A	High	TSWQS Appendix A	No Stations

Seg ID	Seg Name	Segment Description	Segment Type	AU ID	AU Description	Flow Type	Flow Type Source	ALU Designation	ALU Designation Source	Station ID(s)
0838A	Mountain Creek	From the confluence with Joe Pool Lake approximately 1.25 km north of US 287 upstream to the headwaters north of Alvarado in Johnson County	Freshwater Stream	0838A_01	From the confluence with Joe Pool Lake approximately 1.25 km north of US 287 upstream to the headwaters north of Alvarado in Johnson County	Intermittent w/pools	Routine Flow Data	Limited	Presumption from flow type	13622

Seg ID	Seg Name	Segment Description	Segment Type	AU ID	AU Description	Flow Type	Flow Type Source	ALU Designation	ALU Designation Source	Station ID(s)
0838B	Sugar Creek	A 1.6 mi stretch of Sugar Creek running upstream from Tarrant/Dallas County line, to just upstream of Britton Road in Mansfield, Tarrant County.	Freshwater Stream	0838B_01	A 1.6 mi stretch of Sugar Creek running upstream from Tarrant/Dallas County line, to just upstream of Britton Road in Mansfield, Tarrant County.	Intermittent w/pools	Routine Flow Data	Limited	Presumption from flow type	17680

Seg ID	Seg Name	Segment Description	Segment Type	AU ID	AU Description	Flow Type	Flow Type Source	ALU Designation	ALU Designation Source	Station ID(s)
0838C	Walnut Creek	From the confluence with Joe Pool Lake up to the headwaters at Spring Street in Burleson.	Freshwater Stream	0838C_01	From the confluence with Joe Pool Lake up to the headwaters at Spring Street in Burleson.	Intermittent w/pools	Routine Flow Data	Limited	Presumption from flow type	13621; 20790; 21990

Seg ID	Seg Name	Segment Description	Segment Type	AU ID	AU Description	Flow Type	Flow Type Source	ALU Designation	ALU Designation Source	Station ID(s)
0838D	Hollings Branch	Hollings Branch from the confluence of the Mountain Creek arm of Joe Pool Lake upstream to the headwater 500 m downstream of US 67 in Midlothian	Freshwater Stream	0838D_01	Hollings Branch from the confluence of the Mountain Creek arm of Joe Pool Lake upstream to the headwater 500 m downstream of US 67 in Midlothian	Intermittent	Flow Questionnaire	Minimal	Presumption from flow type	16433

Seg ID	Seg Name	Segment Description	Segment Type	AU ID	AU Description	Flow Type	Flow Type Source	ALU Designation	ALU Designation Source	Station ID(s)
0838E	Soap Creek	Soap Creek from the confluence of the Mountain Creek arm of Joe Pool Lake upstream to the headwater 6.6 km (3.98 mi) upstream of US 67 in Midlothian	Freshwater Stream	0838E_01	Soap Creek from the confluence of the Mountain Creek arm of Joe Pool Lake upstream to the headwater 6.6 km (3.98 mi) upstream of US 67 in Midlothian	Intermittent	Flow Questionnaire	Minimal	Presumption from flow type	16435

Seg ID	Seg Name	Segment Description	Segment Type	AU ID	AU Description	Flow Type	Flow Type Source	ALU Designation	ALU Designation Source	Station ID(s)
0838F	Unnamed tributary of Mountain Creek	Intermittent stream from the confluence with Mountain Creek south of Mansfield upstream to the headwaters approximately 2.0 km upstream of FM 157 in Mansfield	Freshwater Stream	0838F_01	Intermittent stream from the confluence with Mountain Creek south of Mansfield upstream to the headwaters approximately 2.0 km upstream of FM 157 in Mansfield	Intermittent	Routine Flow Data	Minimal	Presumption from flow type	21123

Seg ID: 0838B - Sugar Creek
AU ID: 0838B_01

Use	Method	Parameter	Start Date	End Date	Criteria	#Data Assessed	Mean Data Assessed	#Exceedances	Mean Exceedances	DS Qualifier	LOS	CF	Int LOS	TCEQ Cause	Cat
Aquatic Life Use	Acute Toxic Substances in water	Zinc (dissolved)	12/01/13	11/30/20	86.62	1	.	0	.	ID	NA	N	NA		
		Lead (dissolved)	12/01/13	11/30/20	43.71	1	.	0	.	ID	NA	N	NA		
		Copper (dissolved)	12/01/13	11/30/20	10.15	1	.	0	.	ID	NA	N	NA		
		Chromium (Tri)(dissolved)	12/01/13	11/30/20	425.43	1	.	0	.	ID	NA	N	NA		
		Cadmium (dissolved)	12/01/13	11/30/20	6.07	1	.	0	.	ID	NA	N	NA		
	Chronic Toxic Substances in water	Lead (dissolved)	12/01/13	11/30/20	3.99	1	0.5	0	.	ID	NA	N	NA		
		Zinc (dissolved)	12/01/13	11/30/20	169.39	1	2.5	0	.	ID	NA	N	NA		
		Copper (dissolved)	12/01/13	11/30/20	13.62	1	2.58	0	.	ID	NA	N	NA		
		Chromium (Tri)(dissolved)	12/01/13	11/30/20	104.99	1	2.5	0	.	ID	NA	N	NA		
		Cadmium (dissolved)	12/01/13	11/30/20	0.33	1	0.15	0	.	ID	NA	N	NA		
	Dissolved Oxygen grab minimum	Dissolved oxygen Grab	12/01/13	11/30/20	2	10	.	0	.	AD	FS	N	FS		
	Dissolved Oxygen grab screening level	Dissolved oxygen Grab	12/01/13	11/30/20	3	10	.	1	2.9	AD	NC	N	NC		
Fish Consumption Use	HH Bioaccumulative Toxics in water	Lead (dissolved)	12/01/13	11/30/20	38.3	1	0.5	0	.	ID	NA	N	NA		
General Use	Nutrient Screening Levels	Total phosphorus	12/01/13	11/30/20	0.69	3	.	0	.	ID	NA	N	NA		
		Nitrate	12/01/13	11/30/20	1.95	3	.	0	.	ID	NA	N	NA		
		Chlorophyll-a	12/01/13	11/30/20	14.1	3	.	1	15	ID	NA	N	NA		
		Ammonia	12/01/13	11/30/20	0.33	3	.	1	0.54	ID	NA	N	NA		
Recreation Use	Bacteria Geomean	E. coli	12/01/13	11/30/20	126	10	7.87	0	.	LD	NC	N	NC		

Seg ID: 0838C - Walnut Creek
AU ID: 0838C_01

Use	Method	Parameter	Start Date	End Date	Criteria	#Data Assessed	Mean Data Assessed	#Exceedances	Mean Exceedances	DS Qualifier	LOS	CF	Int LOS	TCEQ Cause	Cat
Aquatic Life Use	Dissolved Oxygen 24hr average	Dissolved oxygen 24hr Avg	12/01/13	11/30/20	3	2	.	0	.	ID	NA	N	NA		
	Dissolved Oxygen 24hr minimum	Dissolved oxygen 24hr Min	12/01/13	11/30/20	2	2	.	0	.	ID	NA	N	NA		
	Dissolved Oxygen grab minimum	Dissolved oxygen Grab	12/01/13	11/30/20	2	9	.	0	.	LD	NC	N	NC		
	Dissolved Oxygen grab screening level	Dissolved oxygen Grab	12/01/13	11/30/20	3	9	.	0	.	LD	NC	N	NC		
	Fish Community (Regional)	Fish community	12/01/13	11/30/20	11	2	46	.	.	AD	FS	N	FS		
	Habitat	Habitat	12/01/13	11/30/20	4	2	22	.	.	AD	NC	N	NC		
	Macrobenthic community (Qualitative)	Macrobenthic community	12/01/13	11/30/20	11	2	24	.	.	AD	FS	N	FS		
General Use	Nutrient Screening Levels	Total phosphorus	12/01/13	11/30/20	0.69	1	.	0	.	ID	NA	N	NA		
		Nitrate	12/01/13	11/30/20	1.95	1	.	0	.	ID	NA	N	NA		
		Chlorophyll-a	12/01/13	11/30/20	14.1	1	.	0	.	ID	NA	N	NA		
		Ammonia	12/01/13	11/30/20	0.33	1	.	0	.	ID	NA	N	NA		
Recreation Use	Bacteria Geomean	E. coli	12/01/13	11/30/20	126	8	.	1	.	LD	CN	N	CN	Bacteria in water	

Seg ID: 0838D - Hollings Branch
AU ID: 0838D_01

Use	Method	Parameter	Start Date	End Date	Criteria	#Data Assessed	Mean Data Assessed	#Exceedances	Mean Exceedances	DS Qualifier	LOS	CF	Int LOS	TCEQ Cause	Cat
Aquatic Life Use	Acute Toxic Substances in water	Zinc (dissolved)	12/01/13	11/30/20	332.97	1	.	0	.	ID	NA	N	NA		
		Lead (dissolved)	12/01/13	11/30/20	239.71	1	.	0	.	ID	NA	N	NA		
		Copper (dissolved)	12/01/13	11/30/20	45.36	1	.	0	.	ID	NA	N	NA		
		Chromium (Tri)(dissolved)	12/01/13	11/30/20	1563.51	1	.	0	.	ID	NA	N	NA		
		Cadmium (dissolved)	12/01/13	11/30/20	28.4	1	.	0	.	ID	NA	N	NA		
	Chronic Toxic Substances in water	Zinc (dissolved)	12/01/13	11/30/20	169.39	1	12.92	0	.	ID	NA	N	NA		
		Lead (dissolved)	12/01/13	11/30/20	3.99	1	0.5	0	.	ID	NA	N	NA		
		Copper (dissolved)	12/01/13	11/30/20	13.62	1	0.5	0	.	ID	NA	N	NA		
		Chromium (Tri)(dissolved)	12/01/13	11/30/20	104.99	1	2.5	0	.	ID	NA	N	NA		
		Cadmium (dissolved)	12/01/13	11/30/20	0.33	1	0.15	0	.	ID	NA	N	NA		
	Dissolved Oxygen grab minimum	Dissolved oxygen Grab	12/01/13	11/30/20	1.5	8	.	0	.	LD	NC	N	NC		
	Dissolved Oxygen grab screening level	Dissolved oxygen Grab	12/01/13	11/30/20	2	8	.	0	.	LD	NC	N	NC		
Fish Consumption Use	HH Bioaccumulative Toxics in water	Lead (dissolved)	12/01/13	11/30/20	3.83	1	0.5	0	.	ID	NA	N	NA		
General Use	Nutrient Screening Levels	Nitrate	12/01/13	11/30/20	1.95	3	.	0	.	ID	NA	N	NA		
		Total phosphorus	12/01/13	11/30/20	0.69	3	.	0	.	ID	NA	N	NA		
		Chlorophyll-a	12/01/13	11/30/20	14.1	3	.	0	.	ID	NA	N	NA		
		Ammonia	12/01/13	11/30/20	0.33	3	.	0	.	ID	NA	N	NA		
Recreation Use	Bacteria Geomean	E. coli	12/01/13	11/30/20	126	8	10.89	0	.	LD	NC	N	NC		

Seg ID: 0838E - Soap Creek
AU ID: 0838E_01

Use	Method	Parameter	Start Date	End Date	Criteria	#Data Assessed	Mean Data Assessed	#Exceedances	Mean Exceedances	DS Qualifier	LOS	CF	Int LOS	TCEQ Cause	Cat
Aquatic Life Use	Acute Toxic Substances in water	Zinc (dissolved)	12/01/13	11/30/20	267.59	1	.	0	.	ID	NA	N	NA		
		Lead (dissolved)	12/01/13	11/30/20	183.22	1	.	0	.	ID	NA	N	NA		
		Copper (dissolved)	12/01/13	11/30/20	35.57	1	.	0	.	ID	NA	N	NA		
		Chromium (Tri)(dissolved)	12/01/13	11/30/20	1265.71	1	.	0	.	ID	NA	N	NA		
		Cadmium (dissolved)	12/01/13	11/30/20	22.12	1	.	0	.	ID	NA	N	NA		
	Chronic Toxic Substances in water	Lead (dissolved)	12/01/13	11/30/20	3.99	1	0.5	0	.	ID	NA	N	NA		
		Copper (dissolved)	12/01/13	11/30/20	13.62	1	2.59	0	.	ID	NA	N	NA		
		Chromium (Tri)(dissolved)	12/01/13	11/30/20	104.99	1	2.5	0	.	ID	NA	N	NA		
		Cadmium (dissolved)	12/01/13	11/30/20	0.33	1	0.15	0	.	ID	NA	N	NA		
		Zinc (dissolved)	12/01/13	11/30/20	169.39	1	29.23	0	.	ID	NA	N	NA		
	Dissolved Oxygen grab minimum	Dissolved oxygen Grab	12/01/13	11/30/20	1.5	4	.	0	.	LD	NC	N	NC		
	Dissolved Oxygen grab screening level	Dissolved oxygen Grab	12/01/13	11/30/20	2	4	.	0	.	LD	NC	N	NC		
Fish Consumption Use	HH Bioaccumulative Toxics in water	Lead (dissolved)	12/01/13	11/30/20	3.83	1	0.5	0	.	ID	NA	N	NA		
General Use	Nutrient Screening Levels	Total phosphorus	12/01/13	11/30/20	0.69	1	.	0	.	ID	NA	N	NA		
		Nitrate	12/01/13	11/30/20	1.95	1	.	0	.	ID	NA	N	NA		
		Chlorophyll-a	12/01/13	11/30/20	14.1	1	.	0	.	ID	NA	N	NA		
		Ammonia	12/01/13	11/30/20	0.33	1	.	0	.	ID	NA	N	NA		
Recreation Use	Bacteria Geomean	E. coli	12/01/13	11/30/20	126	4	89.93	0	.	ID	NA	N	NA		

Seg ID: 0838F - Unnamed tributary of Mountain Creek
AU ID: 0838F_01

Use	Method	Parameter	Start Date	End Date	Criteria	#Data Assessed	Mean Data Assessed	#Exceedances	Mean Exceedances	DS Qualifier	LOS	CF	Int LOS	TCEQ Cause	Cat
Aquatic Life Use	Dissolved Oxygen grab minimum	Dissolved oxygen Grab	12/01/13	11/30/20	1.5	3	.	0	.	ID	NA	N	NA		
	Dissolved Oxygen grab screening level	Dissolved oxygen Grab	12/01/13	11/30/20	2	3	.	0	.	ID	NA	N	NA		
Recreation Use	Bacteria Geomean	E. coli	12/01/13	11/30/20	126	3	95.24	0	.	ID	NA	N	NA		

2022 Texas Integrated Report - Potential Sources of Impairments and Concerns

Seg Id: 0838C - Walnut Creek				
AU ID	**Assessment Method**	**Parameter**	**LOS**	**Sources**
0838C_01	Bacteria Geomean	E. coli	CN	NPS - Non-Point Source; UNK - Source Unknown

2022 Texas Integrated Report - Water Bodies with Concerns for Use Attainment and Screening Levels

Segment ID	Segment Name	AU ID	Parameters	Level of Concern
0838C	Walnut Creek	0838C_01	Bacteria in water (Recreation Use)	CN

Appendix B - Current Monitoring Sites, Schedule and Water Quality Parameters

Monitoring Schedule

Season	Site	Field	NH3	NO2 + NO3	TKN	OP	TP	TDS	TSS	VSS	Hardness	SO4	TOC	*E. coli*	Chlorophyll-*a*	Crypto	Giardia	Dissolved Metals	Sediment Metals	Herbicides	Pesticides	PCBs	Atrazine	Geosmin
Winter	A1	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x			x	x	x	x
	A2	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x			x	x	x	x
	A3	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x			x	x	x	x
	B1	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
	B2	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
	B3	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
	B4	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
	B5	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
	I1													x										
	I2																							
Spring	A1	x	x	x	x	x	x	x	x	x	x	x	x	x	x				x	x	x	x	x	x
	A2	x	x	x	x	x	x	x	x	x	x	x	x	x	x				x	x	x	x	x	x
	A3	x	x	x	x	x	x	x	x	x	x	x	x	x	x				x	x	x	x	x	x
	B1	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
	B2	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
	B3	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
	B4	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
	B5	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
	I1													x		x	x							
	I2															x	x							
Summer	A1	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x
	A2	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x
	A3	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x
	B1	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
	B2	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
	B3	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
	B4	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
	B5	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
	I1													x		x	x							
	I2															x	x							
Fall	A1	x	x	x	x	x	x	x	x	x	x	x	x	x	x						x	x	x	x
	A2	x	x	x	x	x	x	x	x	x	x	x	x	x	x						x	x	x	x
	A3	x	x	x	x	x	x	x	x	x	x	x	x	x	x						x	x	x	x
	B1	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
	B2	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
	B3	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
	B4	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
	B5	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
	I1													x										
	I2																							

Figure 15 Current Monitoring Schedule. Note: x - analytical cost is paid for by Joe Pool Lake Customers, o – analytical costs paid for by the TRA's Clean Rivers Program.

Description of Water Quality Parameters

Chlorophyll-*a* is used as a measure of the amount of algae in the reservoir. Too much algae can cause aesthetic problems with taste and odor. It can also impact recreation and harm aquatic organisms.

E. coli is bacteria used as a surrogate to indicate contamination with pathogens from human sewage. Although imperfect in that regard, it is a standard test with accepted criteria and is used by State and Federal agencies to determine if water bodies are safe for swimming and other forms of contact recreation.

Atrazine is an herbicide applied in late winter to early spring. It can cause taste and odor problems as well as health concerns at higher concentrations.

NO2 + NO3 is a measure of the amount of nitrogen, which acts like fertilizer for algae, available for biological use. **Total phosphorus** is a fertilizer like nitrogen and can cause algal blooms when too much of it is present.

Hardness is caused by compounds of calcium and magnesium, and by a variety of other minerals. Hardness does not pose a health risk but has implications for the treatment of raw water. Similarly, **Sulfate** is a substance that occurs naturally in drinking water and has been associated with taste and odor problems as well as diarrhea when water with very high levels is ingested.

Metals include toxic elements such as lead and cadmium (primarily from industrial or commercial activities). Non-toxic metals, such as manganese, can cause complications in the treatment of raw water. Metals often have very low standards because they can accumulate in a person's body over time, especially in individuals who consume large amounts of fish from a contaminated reservoir.

Total dissolved solids (TDS) is a measure of the total amount of dissolved inorganic solids in the water. Along with hardness, dissolved solids can affect the treatment process by changing the amount of certain chemicals that need to be added. TDS can also be a good indicator of drought conditions, since TDS levels rise in dry weather.

Geosmin and MIB are compounds produced by some species of algae that are associated with aesthetic issues in drinking water. Specifically, they are known to import a musty-earthy taste and odor to drinking water.

Crypto and Giardia are infectious organisms that can cause diarrhea, cramps, fever and other gastro-intestinal symptoms when ingested. Giardia and Crypto both come from the intestinal tracts of warm-blooded animals and can be introduced to water supplies through contamination with raw sewage.

Water Quality Data Preparation

The data used in this report consists of datasets from different time periods: The dataset from 2017-2021 is used to assess the Joe Pool Lake water quality in the recent 5 years; the dataset 2013-2016 for select water quality parameters is used for comparison purposes. In addition, quality-assured dataset from 1997-2012 is included for long-term trend evaluations.

The data were pre-processed as follows:

The records of “right censored” or “<” were adjusted to “0” (the exception is *E. coli*, which is multiply by 0.5); the records of “left censored” or “>” were set to the existing values. Those records of “right censored were set to zero because there was a wide range with the less than value. Those records of “left censored” were set to the existing values because it was not clear what values actually were.

Appendix C TCEQ 2022 Screening Levels for the 2022 Surface Water Quality Assessment 1/2017 to 12/2021

Water Quality Criteria and Screening Levels for Joe Pool Lake and Adjacent Tributaries (Note: * denotes minimum criterion, ** screening level, a-*a*cute, c-chronic)

TCEQ Segment	TRA Sampling Site	Designated Use	Ammonia	Dissolved Oxygen	*E. coli*	Total Phosphorus	Nitrate	OP	Chlorophyll-*a*	pH	Sulfate	Temperature	TDS	Benzene	Ethylbenzene	Toluene	Cadmium	Chromium	Copper	Lead	Zinc
0838 Joe Pool Lake	**A1**	Aquatic Life Use		3*/5**																	
		Fish Consumption Use												5	700		5	62		1.15	
		General Use	0.11			0.2	0.4	0.05	26.7	9-6.5	250	32.2	500								
		Public Water Supply Use					10							5	700	1000	5			1.15	
0838 Joe Pool Lake	**A3**	Aquatic Life Use		3*/5**													16.83a 0.33c	1005.17a 104.99c	27.29a 13.62c	136.14a 3.99c	210.82a 169.39c
		Fish Consumption Use													700		5	62		1.15	
		General Use	0.11			0.2	0.4		26.7	9-6.5	250	32.2	500								
		Public Water Supply Use					10							5	700	1000	5			1.15	
		Recreation Use			126																
0838 Joe Pool Lake	**A2**	Aquatic Life Use		3*/5**																	
		Fish Consumption Use													700		5	62		1.15	
		General Use	0.11			0.2	0.4	0.05		9-6.5	250	32.2	500								
		Public Water Supply Use					10							5	700	1000	5			1.15	
0838A Mountain Creek	**B2**	Aquatic Life Use		2*/3**													44.89a 0.33c	2301.72a 104.99c	70.78a 13.62c	388.05a 3.99c	496.78a 169.39c
		Fish Consumption Use				0.69	2											502		3.83	
		General Use	0.33			0.69	2	0.37													
0838C Walnut Creek	**B4**	Aquatic Life Use		2*/3**													36.48a 0.33c	1931.53a 104.99c	22.11a 13.62c	312.47a 3.99c	414.36a 169.39c
		Fish Consumption Use																502		3.83	
		General Use	0.33			0.69	2	0.37	14.1												
		Recreation Use			126																
0838D Hollings Branch	**B1**	Aquatic Life Use		1.5*/2**																	
		General Use	0.33			0.69	2	0.37	14.1												
		Recreation Use			126																
0838E Soap Creek	**B3**	Aquatic Life Use		1.5*/2**																	
		General Use	0.33			0.69	2	0.37	14.1												
		Recreation Use			126																

<u>Measured Water Quality Data from 1/2017 to 12/2021</u>

Parameter	Date	A1	A2	A3	B1	B2	B3	B4	B5
Total Suspended Solids (mg/L)	2/2017	6	9	4	8	4	165	16	5
	4/2017	9	8	14	<2	11	80	62	6
	8/2017	3	6	13	Site dry	Site dry	152	51	280
	10/2017	7	11	13	No flow	No flow	47	37	12
	2/2018	6	10	13	3	No flow	15	6	No flow
	5/2018	5	6	7	8	13	361	41	No flow
	9/2018	5	24	15	No flow	14	58	10	17
	12/2018	12	9	17	2	3	38	6	3
	3/2019	3	6	14	3	8	52	6	6
	5/2019	Error	Error	Error	Error	Error	Error	Error	Error
	8/2019	5	6	10	9	24	112	12	12
	11/2019	9	8	11	8	11	60	12	5
	2/2020	8	10	17	16	9	107	12	<2
	4/2020	4	6	17	88	55	936	110	94
	8/2020	8	8	13	56	5	48	30	2
	11/2020	5	5	9	23	5	77	18	15
	2/2021	5	5	5	8	32	66	17	11
	5/2021	8	7	11	100	84	441	Error	3
	8/2021	4	6	10	12	13	104	22	4
	11/2021	6	6	7	3	15	81	11	5
Volatile Suspended Solids (mg/L)	2/2017	<2	<2	<2	<2	<2	<13	2	<2
	4/2017	<2	2	<3	<2	<2	<11	9	<2
	8/2017	<2	2	<3	Site dry	Site dry	44	<7	29
	10/2017	<2	<3	<3	No flow	No flow	7	<6	<4
	2/2018	<2	<2	<2	<2	No flow	7	<2	No flow
	5/2018	<2	2	<2	<2	2	47	<5	No flow
	9/2018	<2	<4	<3	No flow	<2	11	3	<4
	12/2018	2	<3	3	<2	<3	<7	<2	<2
	3/2019	<2	<2	2	<2	2	10	<2	<2
	5/2019	Error	Error	Error	Error	Error	Error	Error	Error
	8/2019	<2	3	<3	<2	<2	<20	<2	3
	11/2019	<3	<2	<3	<2	<3	18	<3	<2
	2/2020	<2	2	<3	<2	2	<20	3	<2
	4/2020	<2	<2	<4	<10	<7	<80	<20	12
	8/2020	4	4	4	4	<2	19	9	<2
	11/2020	2	<2	<3	<3	<3	13	<4	<2
	2/2021	<2	<2	<2	<2	6	11	3	2
	5/2021	3	3	4	12	14	51	81	<2
	8/2021	3	3	4	<2	2	21	4	<2
	11/2021	3	3	4	<2	2	15	2	<2

Parameter	Date	A1	A2	A3	B1	B2	B3	B4	B5
Nitrite and Nitrate Nitrogen (mg/L) **Standards:** **0.37 (lake-general use)** **1.95 (tributary-general use)**	2/2017	0.23	0.24	0.33	0.08	0.55	2.33	0.35	0.28
	4/2017	0.15	0.09	0.21	0.15	1	0.74	0.15	0.31
	8/2017	<0.05	<0.05	<0.05	Site dry	Site dry	0.06	0.24	0.47
	10/2017	0.06	0.05	<0.05	No flow	No flow	3.14	0.21	0.19
	2/2018	0.06	0.06	0.09	<0.05	No flow	8.18	<0.05	No flow
	5/2018	0.08	<0.05	0.22	0.07	0.75	2.16	0.29	No flow
	9/2018	<0.05	<0.05	<0.05	No flow	0.35	1.03	0.41	1.1
	12/2018	0.36	0.35	0.36	0.56	0.24	3.82	0.07	0.41
	3/2019	0.41	0.35	0.48	0.13	1.34	3.29	<0.05	0.95
	5/2019	0.42	0.29	0.44	0.4	0.19	0.56	0.22	0.32
	8/2019	<0.05	<0.05	<0.05	<0.05	<0.05	0.55	<0.05	0.07
	11/2019	<0.05	<0.05	<0.05	<0.05	<0.05	5	0.11	<0.05
	2/2020	0.17	0.19	0.22	0.08	<0.05	4.79	<0.05	0.38
	4/2020	0.22	0.16	0.24	0.58	0.07	1.33	0.35	0.62
	8/2020	<0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.74
	11/2020	<0.05	<0.05	<0.05	<0.05	<0.05	4.11	<0.05	0.07
	2/2021	0.16	0.15	0.18	0.2	2.18	4.65	0.19	0.49
	5/2021	0.14	0.05	0.36	0.78	0.64	0.65	0.71	1.22
	8/2021	<0.05	<0.05	<0.05	0.53	<0.05	0.33	0.38	0.62
	11/2021	<0.05	<0.05	<0.05	<0.05	<0.05	2.67	0.07	0.06
Ammonia (mg/L) **Standard:** **0.11 (lake-general use)** **0.33 (tributary-general use)**	2/2017	<0.02	0.05	0.06	<0.02	<0.02	<0.02	<0.02	<0.02
	4/2017	0.02	<0.02	<0.02	<0.02	0.03	0.08	0.02	<0.02
	8/2017	<0.02	<0.02	<0.02	Site dry	No flow	<0.02	0.05	0.07
	10/2017	<0.02	<0.02	<0.02	No flow	No flow	0.11	0.04	<0.02
	2/2018	0.05	<0.02	0.03	<0.02	No flow	<0.02	<0.02	No flow
	5/2018	<0.02	<0.02	<0.02	<0.02	0.07	0.04	0.05	No flow
	9/2018	0.06	0.02	<0.02	No flow	0.03	0.15	0.12	0.05
	12/2018	<0.02	<0.02	<0.02	<0.02	<0.02	0.07	<0.02	<0.02
	3/2019	0.02	0.02	0.03	<0.02	0.02	0.02	<0.02	<0.02
	5/2019	<0.02	<0.02	<0.02	<0.02	0.03	0.06	0.04	<0.02
	8/2019	<0.02	<0.02	<0.02	<0.02	<0.02	0.25	<0.02	<0.02
	11/2019	0.04	0.04	0.03	<0.02	<0.02	0.14	<0.02	<0.02
	2/2020	0.1	0.07	0.08	<0.02	<0.02	0.1	<0.02	<0.02
	4/2020	<0.02	<0.02	<0.02	0.02	<0.02	0.08	0.12	0.21
	8/2020	<0.02	<0.02	<0.02	<0.02	0.42	<0.02	<0.02	<0.02
	11/2020	<0.02	<0.02	<0.02	<0.02	<0.02	0.03	<0.02	0.04
	2/2021	0.09	0.05	0.08	<0.02	0.08	0.2	0.04	0.02
	5/2021	<0.02	<0.02	<0.02	0.04	0.07	0.12	0.12	0.03
	8/2021	<0.02	<0.02	<0.02	<0.02	0.03	0.18	0.05	<0.02
	11/2021	0.02	<0.02	<0.02	No flow	<0.02	0.10	0.04	<0.02

Parameter	Date	A1	A2	A3	B1	B2	B3	B4	B5
TKN (mg/L)	2/2017	0.51	0.33	0.44	<0.2	0.65	0.72	0.3	0.51
	4/2017	0.46	0.44	0.49	<0.2	0.78	0.87	0.54	0.32
	8/2017	0.47	0.5	0.55	Site dry	No flow	1.68	1.57	1.29
	10/2017	0.54	0.51	0.49	No flow	No flow	1.98	0.67	0.75
	2/2018	5.71	<0.2	0.64	<0.2	No flow	2	0.41	No flow
	5/2018	0.404	0.489	0.302	0.36	0.737	0.89	0.48	No flow
	9/2018	0.52	0.52	0.59	No flow	0.74	1.7	0.66	0.49
	12/2018	0.05	0.26	<0.2	<0.2	0.2	0.76	<0.2	<0.2
	3/2019	<0.2	<0.2	0.42	<0.2	0.63	<0.2	<0.2	<0.2
	5/2019	0.51	0.6	0.64	0.31	0.53	0.75	0.42	0.62
	8/2019	0.34	0.34	0.29	<0.2	0.4	0.85	0.34	0.24
	11/2019	0.32	0.23	0.39	<0.2	0.54	1.17	0.75	0.36
	2/2020	0.29	0.27	0.42	<0.2	0.49	1.58	0.37	<0.2
	4/2020	0.33	0.42	0.32	0.4	0.57	2.35	0.94	1.29
	8/2020	<0.2	<0.2	<0.2	<0.2	0.36	2.39	0.5	<0.2
	11/2020	0.277	0.337	0.355	<0.2	0.671	1.36	0.429	0.412
	2/2021	0.21	0.2	0.22	<0.2	0.68	1.48	0.23	<0.2
	5/2021	0.31	0.28	0.2	0.42	0.7	1.48	2.08	0.34
	8/2021	0.53	0.51	0.29	<0.2	0.30	2.28	0.37	<0.2
	11/2021	0.20	<0.2	0.29	No flow	0.3	1.09	<0.2	0.314
TP (mg/L) Standard: 0.2 (lake-general use) 0.69 (tributary-general use)	2/2017	0.04	0.05	0.05	<0.02	0.05	0.53	0.05	0.03
	4/2017	0.03	0.03	0.03	<0.02	0.08	0.23	0.08	0.03
	8/2017	<0.02	0.02	0.03	Site dry	No flow	0.59	0.14	0.57
	10/2017	0.03	0.04	0.04	No flow	No flow	0.63	0.13	0.07
	2/2018	0.02	0.03	0.03	<0.02	No flow	0.76	0.05	No flow
	5/2018	<0.02	<0.02	<0.02	<0.02	0.06	0.39	0.17	No flow
	9/2018	0.03	0.04	0.04	No flow	0.1	0.45	0.17	0.08
	12/2018	0.05	0.05	0.05	<0.02	0.03	0.28	0.03	<0.02
	3/2019	0.04	0.04	0.05	<0.02	0.05	0.30	0.05	0.04
	5/2019	0.03	0.03	0.04	0.06	0.08	0.16	0.09	0.06
	8/2019	0.02	0.03	0.04	0.02	0.05	0.3	0.05	0.02
	11/2019	0.03	0.03	0.03	0.03	0.12	0.58	0.08	0.02
	2/2020	0.02	0.03	0.04	<0.02	0.06	0.41	0.04	0.06
	4/2020	<0.02	0.02	0.03	0.09	0.10	0.89	0.19	0.16
	8/2020	<0.02	0.03	0.06	0.03	0.02	0.37	0.08	<0.02
	11/2020	<0.02	0.02	0.02	0.03	0.11	0.56	0.11	0.05
	2/2021	0.02	0.02	<0.02	0.03	0.11	0.44	0.07	0.03
	5/2021	0.02	0.02	0.04	0.13	0.25	0.47	0.65	0.06
	8/2021	<0.02	0.03	0.03	0.04	0.07	0.40	0.14	0.07
	11/2021	0.02	0.02	0.02	No flow	0.05	0.39	0.06	0.02

Parameter	Date	A1	A2	A3	B1	B2	B3	B4	B5
TOC (mg/L)	2/2017	4.8	4.2	4.2	1.8	6.4	6.4	3.9	3.7
	4/2017	4.2	4.2	4.3	2	8	6.1	4.9	3.6
	8/2017	4.6	4.2	4.5	Site dry	No flow	8.6	5.7	5.9
	10/2017	3.8	4.1	4	No flow	No flow	7.8	5	5.6
	2/2018	4.4	4.5	4.1	1.9	No flow	8.8	4.1	No flow
	5/2018	4.9	4.6	4.6	3	7.1	6.1	5.6	No flow
	9/2018	4.5	4.7	4.6	No flow	8.5	9.7	7.4	5
	12/2018	5	4.8	4.6	2.7	6.5	5.2	4.6	3.8
	3/2019	4.3	4.3	4.4	2.1	7.6	6	5	3.1
	5/2019	4.7	4.9	4.9	2.9	5.7	5.3	5.1	5.4
	8/2019	4.7	4.8	4.4	2	7.3	8.2	4.1	4.4
	11/2019	4.9	4.5	4.4	3.4	15.8	9.7	6.4	5.5
	2/2020	4.2	4.4	4.3	2.3	7.4	6.8	5.3	3.3
	4/2020	4.5	4.9	4.6	4.6	6	7	6.9	7.6
	8/2020	4.4	4.6	4.1	2.8	6	9.7	5.4	3.7
	11/2020	4.3	4.3	4.2	4.1	14.6	7.1	9	4.2
	2/2021	3.9	4.1	4	4.8	8.3	6.8	5	5.5
	5/2021	3.8	4.2	4.3	6.2	10	7.3	12	5.9
	8/2021	4.7	4.8	4.9	3.9	6.7	8.0	6.4	5.5
	11/2021	4.7	4.9	4.7	2.5	7.2	7.4	5.2	4.4
Hardness (mg/L)	2/2017	145	144	140	375	343	220	468	507
	4/2017	155	155	154	351	286	173	381	367
	8/2017	130	127	128	Site dry	No flow	131	128	230
	10/2017	136	138	137	No flow	No flow	191	125	240
	2/2018	147	148	152	441	No flow	206	487	No flow
	5/2018	140	140	148	324	344	216	216	No flow
	9/2018	140	128	132	No flow	212	168	164	292
	12/2018	128	128	136	276	670	264	544	600
	3/2019	164	160	164	324	392	240	452	670
	5/2019	160	156	156	336	356	184	428	232
	8/2019	136	136	144	288	404	132	532	280
	11/2019	144	140	152	448	168	184	184	472
	2/2020	152	156	156	392	296	236	296	532
	4/2020	156	156	160	268	392	548	252	308
	8/2020	132	132	136	360	164	120	264	372
	11/2020	144	148	148	376	204	208	308	460
	2/2021	156	160	164	336	320	248	200	228
	5/2021	160	160	160	300	200	204	156	320
	8/2021	140	140	140	292	176	128	184	220
	11/2021	144	140	144	No flow	172	176	188	316

Parameter	Date	A1	A2	A3	B1	B2	B3	B4	B5
Sulfate (mg/L) **Standard: 250 (lake-general use)**	2/2017	76.1	74	78.3	164.6	215.3	220.3	256.9	430.4
	4/2017	85.1	85	84.8	161.4	173.5	159.1	222.1	292.2
	8/2017	91.2	88.3	90.7	Site dry	No flow	122.1	82.4	139.4
	10/2017	104.6	103.2	108.1	No flow	No flow	158.4	82.2	199.6
	2/2018	98.2	94.8	97.7	269.1	No flow	205.6	344.1	No flow
	5/2018	93.1	93.6	90.7	144.6	253.9	233.8	130.2	No flow
	9/2018	95.4	92	95.6	No flow	154.6	218	89.2	192.9
	12/2018	67.7	68.1	70.3	121.2	522.6	218.9	339	524.7
	3/2019	86.8	90.3	96.5	115.9	279.8	229.4	272.5	548.3
	5/2019	88.6	85	85.3	76.8	218.5	132.2	235.2	150.3
	8/2019	87.3	87.6	86.2	129.2	318.9	171.2	427.5	238.9
	11/2019	90.3	89.1	92.1	271.1	208.3	184	101.9	394
	2/2020	94.9	96.2	98.9	223.4	255.3	260.8	194.1	488
	4/2020	93.9	98	95.5	96.6	342.2	360.5	146.8	278.2
	8/2020	95.3	90.8	91.5	169.8	195.8	168.7	170.7	356.8
	11/2020	97.4	97.8	98.1	159.9	214	212.4	191.3	351.4
	2/2021	102.3	103.8	103.8	176.1	236.9	231.4	115.6	144.4
	5/2021	104.1	102.5	103.1	103	85.8	78	47.4	197.8
	8/2021	87.4	87.3	87.9	115.6	182.0	133.4	96.1	140.4
	11/2021	87.0	87.7	87.1	118.9	149.4	132.3	97.1	215.7
TDS (mg/L) **Standard: 500 (lake-general use)**	2/2017	259	264	264	542	559	679	768	921
	4/2017	268	262	274	536	501	472	628	649
	8/2017	265	266	281	Site dry	No flow	529	287	352
	10/2017	258	260	268	No flow	No flow	617	240	445
	2/2018	297	296	299	678	No flow	651	871	No flow
	5/2018	279	276	293	441	636	679	449	No flow
	9/2018	277	272	No data	No flow	402	642	315	493
	12/2018	240	240	238	407	1147	593	946	1077
	3/2019	284	296	300	465	686	614	769	1156
	5/2019	282	267	270	460	572	400	724	394
	8/2019	241	278	251	481	643	605	979	536
	11/2019	262	252	237	694	638	666	316	802
	2/2020	278	240	266	589	619	767	512	933
	4/2020	274	275	287	358	743	758	426	544
	8/2020	265	258	266	488	438	500	497	764
	11/2020	267	252	224	500	586	630	442	730
	2/2021	300	304	290	526	649	684	369	408
	5/2021	296	299	304	413	345	280	273	540
	8/2021	265	270	274	446	567	461	346	399
	11/2021	258	264	261	465	485	546	308	543

Parameter	Date	A1	A2	A3	B1	B2	B3	B4	B5
OP (mg/L) **Screening Level: 0.05 (lake) 0.37 (tributary)**	2/2017	<0.02	<0.02	<0.02	<0.02	<0.02	0.44	<0.02	<0.02
	4/2017	<0.02	<0.02	<0.02	<0.02	0.04	0.09	0.04	<0.02
	8/2017	<0.02	<0.02	<0.02	Site dry	No flow	0.23	0.03	0.03
	10/2017	<0.02	<0.02	<0.02	No flow	No flow	0.36	0.05	<0.02
	2/2018	<0.02	<0.02	<0.02	<0.02	No flow	0.61	<0.02	No flow
	5/2018	<0.02	<0.02	<0.02	<0.02	0.02	0.11	0.05	No flow
	9/2018	<0.02	<0.02	<0.02	No flow	0.04	0.24	0.08	0.03
	12/2018	0.03	0.02	0.02	<0.02	<0.02	0.18	0.02	<0.02
	3/2019	<0.02	<0.02	<0.02	<0.02	<0.02	0.08	<0.02	<0.02
	5/2019	<0.02	<0.02	<0.02	<0.02	0.04	0.03	0.03	<0.02
	8/2019	<0.02	<0.02	<0.02	<0.02	<0.02	0.09	<0.02	<0.02
	11/2019	<0.02	<0.02	<0.02	<0.02	0.06	0.38	<0.02	<0.02
	2/2020	<0.02	<0.02	<0.02	<0.02	0.02	0.14	<0.02	<0.02
	4/2020	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
	8/2020	<0.02	<0.02	<0.02	<0.02	<0.02	0.15	<0.02	<0.02
	11/2020	<0.02	<0.02	<0.02	<0.02	0.05	0.34	0.04	<0.02
	2/2021	<0.02	<0.02	<0.02	<0.02	0.03	0.24	<0.02	<0.02
	5/2021	<0.02	<0.02	<0.02	0.03	0.12	0.06	0.1	0.04
	8/2021	<0.02	<0.02	<0.02	0.02	0.02	0.06	0.06	0.04
	11/2021	<0.02	<0.02	0.02	<0.02	0.02	0.18	0.03	<0.02
E. COLI **(MPN/100ml)** **Standard 399**	2/2017	12	21	4	1,454	147	34	125	10
	4/2017	<4	<4	4	58	510	241	395	85
	8/2017	<2	19	24	Site dry	No flow	440	1,462	1,642
	10/2017	<2	6	4	No flow	No flow	870	1,095	209
	2/2018	16	<4	<4	60	No flow	16	49	No flow
	5/2018	2	4	2	152	362	473	606	No flow
	9/2018	4	105	25	No flow	104	345	722	922
	12/2018	16	16	8	49	29	119	12	8
	3/2019	15	4	2	64	172	43	158	141
	5/2019	12	16	8	68	80	92	174	192
	8/2019	<2	4	2	4	<2	37	20	6
	11/2019	21	4	4	30	8	34	81	34
	2/2020	51	2	2	21	48	39	25	115
	4/2020	4	4	8	1,354	453	3,328	>24,166	12,033
	8/2020	<2	4	2	8	10	29	147	26
	11/2020	4	4	4	16	21	205	192	93
	2/2021	2	<2	6	774	1,549	353	572	260
	5/2021	2	<2	15	4,352	985	9,768	18,416	241
	8/2021	<2	<2	<2	334	138	278	2,069	132
	11/2021	1.56	<4	<4	154	22	110	88	49

Note: highlighted data exceeds water quality standard/screening level

Parameter	Date	A1	A2	A3
Chlorophyll-*a* (ug/L) **Screening Level: 26.7**	1/2017	6	7	5
	4/2017	6	12	10
	8/2017	10	Error	Error
	10/2017	16	13	14
	2/2018	4	8	4
	5/2018	10	8	11
	9/2018	15	24	22
	12/2018	<3	5	7
	3/2019	<3	4	4
	5/2019	10	15	19
	8/2019	13	14	18
	11/2019	15	14	17
	2/2020	5	7	5
	4/2020	4	8	6
	8/2020	15	18	20
	11/2020	14	15	15
	2/2021	5	5	<3
	5/2021	15	14	22
	8/2021	11	14	21
	11/2021	17	16	18
Dissolved Antimony (ug/L)	1/2017	<1	<1	<1
	8/2017	<1	<1	<1
	2/2018	<1	<1	<1
	9/2018	<1	<1	<1
	3/2019	<1	<1	<1
	8/2019	<1	<1	<1
	2/2020	<1	<1	<1
	8/2020	<1	<1	<1
	2/2021	<1	<1	<1
	8/2021	<1	<1	<1
Dissolved Cadmium (ug/L) **Standard: 5**	1/2017	<0.3	<0.3	<0.3
	8/2017	<0.3	<0.3	<0.3
	2/2018	<0.3	<0.3	<0.3
	9/2018	<0.3	<0.3	<0.3
	3/2019	<0.3	<0.3	<0.3
	8/2019	<0.3	<0.3	<0.3
	2/2020	<0.3	<0.3	<0.3
	8/2020	<0.3	<0.3	<0.3
	2/2021	<0.3	<0.3	<0.3
	8/2021	<0.3	<0.3	<0.3
Dissolved Chromium (ug/L) **Standard: 62**	1/2017	<5	<5	<5
	8/2017	<5	<5	<5
	2/2018	<5	<5	<5
	9/2018	<5	<5	<5
	3/2019	<5	<5	<5
	8/2019	<5	<5	<5
	2/2020	<5	<5	<5
	8/2020	<5	<5	<5
	2/2021	<5	<5	<5
	8/2021	<5	<5	<5

Parameter	Date	A1	A2	A3
Dissolved Copper (ug/L)	1/2017	<1	<1	<1
	8/2017	<1	<1	<1
	2/2018	<1	<1	<1
	9/2018	<1	<1	<1
	3/2019	<1	<1	<1
	8/2019	<1	1.1	<1
	2/2020	<1	<1	<1
	8/2020	1.01	<1	<1
	2/2021	<1	<1	<1
	8/2021	<1	<1	<1
Dissolved Iron (ug/L)	1/2017	<5	11	12.47
	8/2017	<5	10.62	<5
	2/2018	7.85	8.54	8.58
	9/2018	7.11	149.05	<5
	3/2019	16.07	13.76	8.13
	8/2019	9.83	28.67	15.12
	2/2020	6.44	9.89	8.35
	8/2020	<5	<5	<5
	2/2021	15.3	<5	5.23
	8/2021	<5	<5	<5
Dissolved Lead (ug/L) **Standard: 1.15**	1/2017	<1	<1	<1
	8/2017	<1	<1	<1
	2/2018	<1	<1	<1
	9/2018	<1	<1	<1
	3/2019	<1	<1	<1
	8/2019	<1	<1	<1
	2/2020	<1	<1	<1
	8/2020	<1	<1	<1
	2/2021	<1	<1	<1
	8/2021	<1	<1	<1
Dissolved Manganese (ug/L)	1/2017	<1	2.3	2.44
	8/2017	<1	2.89	<1
	2/2018	1.07	1.07	<1
	9/2018	5.79	29.61	<1
	3/2019	<1	<1	<1
	8/2019	4.36	9.21	5.28
	2/2020	1.05	<1	1.29
	8/2020	<1	<1	1.03
	2/2021	1.86	1.41	1.43
	8/2021	<1	<1	<1
Dissolved Nickel (ug/L)	1/2017	<1	1.77	1.73
	8/2017	1.18	1.13	<1
	2/2018	1.34	1.37	1.4
	9/2018	1.19	1.39	1.23
	3/2019	1.3	1.17	1.26
	8/2019	1.19	1.18	1.32
	2/2020	1.4	1.43	1.48
	8/2020	1.08	1.12	1.27
	2/2021	1.45	1.39	1.47
	8/2021	1.11	<1	<1.34

Parameter	Date	A1	A2	A3
Dissolved Zinc (mg/L)	1/2017	<5	<5	<5
	8/2017	<5	<5	<5
	2/2018	<5	<5	<5
	9/2018	<5	<5	<5
	3/2019	<5	<5	<5
	8/2019	<5	<5	<5
	2/2020	<5	<5	<5
	8/2020	<5	<5	<5
	2/2021	<5	<5	<5
	8/2021	<5	<5	<5
Sediment Cadmium (mg/kg)	4/2017	<1	<1	<1
	5/2018	<1	<1	<1
	5/2019	<1	<1	<1
	5/2021	<1	<1	<1
Sediment Chromium (mg/kg)	4/2017	25.1	18.7	31
	5/2018	21	14.3	32.4
	5/2019	17.8	8.52	26.5
	5/2021	20.9	14.7	30.2
Sediment Iron (mg/kg)	4/2017	19,100	22,400	27,800
	5/2018	29,400	44,600	29,700
	5/2019	21,900	28,900	24,900
	5/2021	23,000	20,300	26,100
Sediment Lead (mg/kg)	4/2017	13.5	15.8	14.5
	5/2018	13	8.06	13.5
	5/2019	13.4	7.07	16
	5/2021	11.8	13.6	12.8
Sediment Manganese (mg/kg)	4/2017	466	601	595
	5/2018	492	524	617
	5/2019	452	412	702
	5/2021	499	534	567
Sediment Nickel (mg/kg)	4/2017	29.5	29.8	41.1
	5/2018	31.8	33.9	41.4
	5/2019	25.4	18.6	37
	5/2021	26	25	35.9
Sediment Zinc (mg/kg)	4/2017	69.5	72.4	86.2
	5/2018	70.1	70.6	85.4
	5/2019	62.6	59.2	76.6
	5/2021	69.7	68.8	82.3
Sediment Antimony (mg/kg)	4/2017	<1	<1	<1
	5/2018	<1	<1	<1
	5/2019	<1	<1	<1
	5/2021	<1	<1	<1
Sediment Copper (mg/kg)	4/2017	20.7	24.2	26
	5/2018	21.1	13.3	26.7
	5/2019	17.8	8.88	24.1
	5/2021	19.6	22.2	24.1

Parameter	Date	A1	A2	A3
Atrazine (ug/L)	1/2017	ND	ND	ND
	4/2017	1.05	0.875	1.18
	8/2017	<6	<6	<6
	10/2017	<3	<3	<3
	2/2018	ND	ND	ND
	5/2018	ND	ND	ND
	9/2018	ND	ND	ND
	3/2019	ND	ND	ND
	5/2019	0.89	0.98	1.3
	8/2019	0.63	0.63	0.65
	11/2019	ND	ND	ND
	2/2020	ND	ND	ND
	4/2020	ND	ND	ND
	8/2020	ND	ND	ND
	11/2020	ND	ND	ND
	2/2021	ND	ND	ND
	5/2021	<10	<10	<10
	8/2021	ND	ND	ND
	11/2021	1.03	0.876	1.22
Chlorinated Herbicides (ug/L)	4/2017	ND	ND	ND
	8/2017	ND	ND	ND
	5/2018	ND	ND	ND
	9/2018	ND	ND	ND
	5/2019	<RL	<RL	No data
	8/2019	ND	ND	ND
	4/2020	ND	<RL	<RL
	8/2020	ND	ND	ND
	5/2021	ND	ND	ND
	8/2021	ND	ND	ND
Geosmin (ng/L)	1/2017	<10	<10	<10
	5/2017	9.15	22.9	10.6
	8/2017	<5	<5	<5
	10/2017	<5	<5	<5
	2/2018	<5	<5	<5
	5/2018	<10	<10	<10
	9/2018	<10	<10	<10
	12/2018	<15	<15	<15
	3/2019	<5	<5	<5
	5/2019	<5	<5	<5
	8/2019	<5	<5	<5
	11/2019	<5	6	<5
	2/2020	<5	<5	<5
	4/2020	35	34	15
	8/2020	<10	<10	<10
	11/2020	<5	<5	<5
	2/2021	<5	<5	<5
	5/2021	<5	<5	<5
	8/2021	6.08	6.34	4.29
	11/2021	<5	<5	<5

Parameter	Date	A1	A2	A3
Methylisoborneol (MIB ng/L)	1/2017	<10	<10	<10
	5/2017	<10	<10	<10
	8/2017	32	23.6	27.8
	10/2017	<10	<10	<10
	2/2018	<5	<5	<5
	5/2018	<10	<10	<10
	9/2018	<10	<10	<10
	12/2018	<15	<15	<15
	3/2019	<5	<5	<5
	5/2019	<5	<5	<5
	8/2019	20	17	15
	11/2019	<5	<5	<5
	2/2020	<5	<5	<5
	4/2020	<5	<5	<5
	8/2020	<15	<15	18.6
	11/2020	<5	6	<5
	2/2021	<5	<5	<5
	5/2021	<5	<5	<5
	8/2021	110	68.4	17
	11/2021	7	7	<5

Parameter	Date	A1	A2	A3
Organophosphorus Pesticides (ug/L)	4/2017	ND	ND	ND
	8/2017	ND	ND	ND
	5/2018	ND	ND	ND
	9/2018	ND	ND	ND
	5/2019	ND	ND	ND
	8/2019	ND	ND	ND
	4/2020	ND	ND	ND
	5/2021	ND	ND	ND
	8/2021	ND	ND	ND
PCBs (ug/L)	4/2017	ND	ND	ND
	8/2017	ND	ND	ND
	5/2018	ND	ND	ND
	9/2018	ND	ND	ND
	5/2019	ND	ND	ND
	8/2019	ND	ND	ND
	4/2020	ND	ND	ND
	5/2021	ND	ND	ND
	8/2021	ND	ND	ND

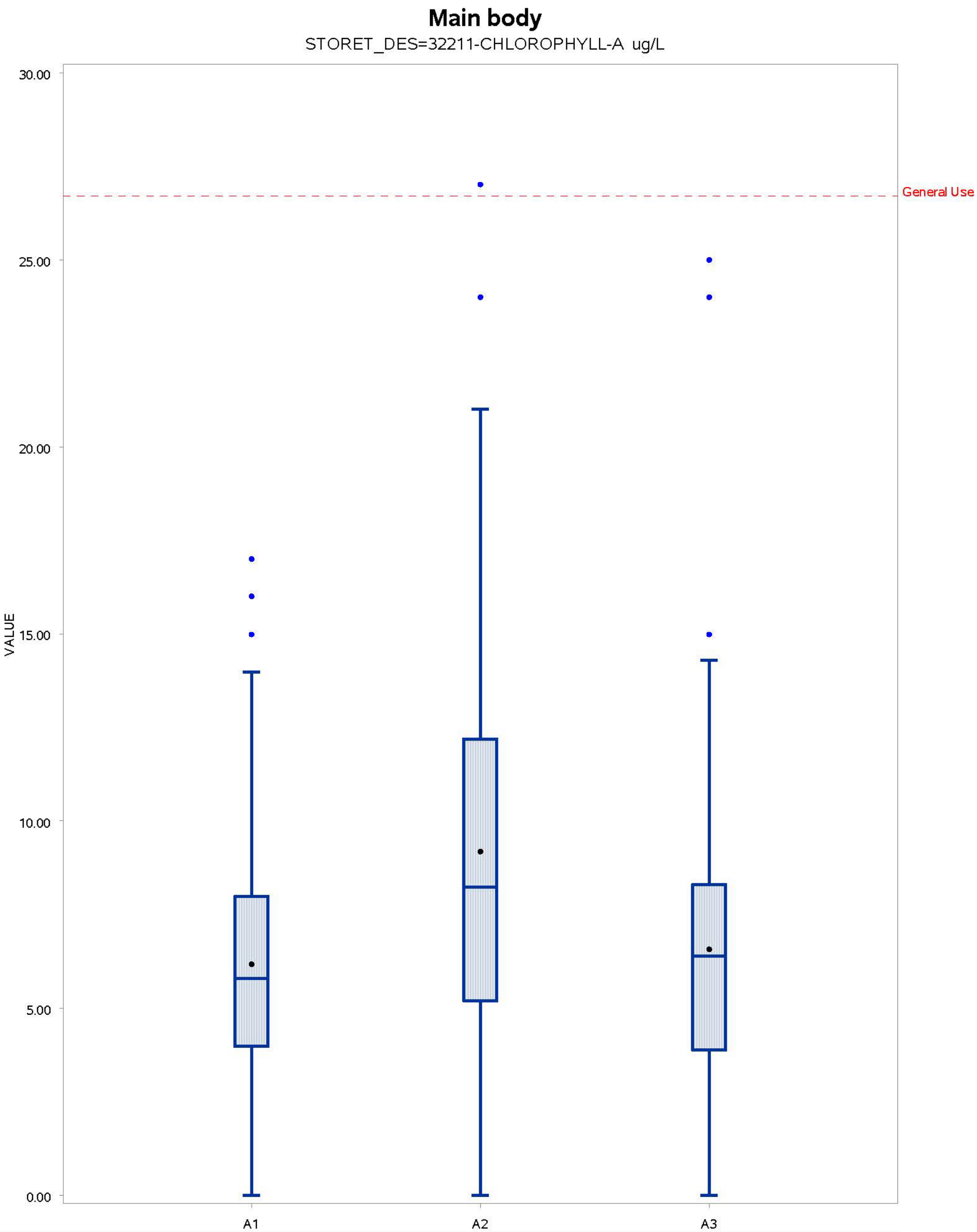
*ND denotes that non-detect

Parameter	Date	I1	I2
Giardia (cysts/L)	4/2017	ND	ND
	8/2017	ND	No data
	5/2018	ND	ND
	9/2018	ND	ND
	5/2019	ND	No data
	8/2019	ND	ND
	5/2020	ND	ND
	8/2020	ND	ND
	5/2021	ND	ND
	8/2021	ND	0.09
Crypto (oocysts/L)	4/2017	ND	ND
	8/2017	ND	No data
	5/2018	ND	ND
	9/2018	ND	ND
	5/2019	ND	No data
	8/2019	ND	ND
	5/2020	ND	ND
	8/2020	ND	ND
	5/2021	ND	ND
	8/2021	ND	0.09

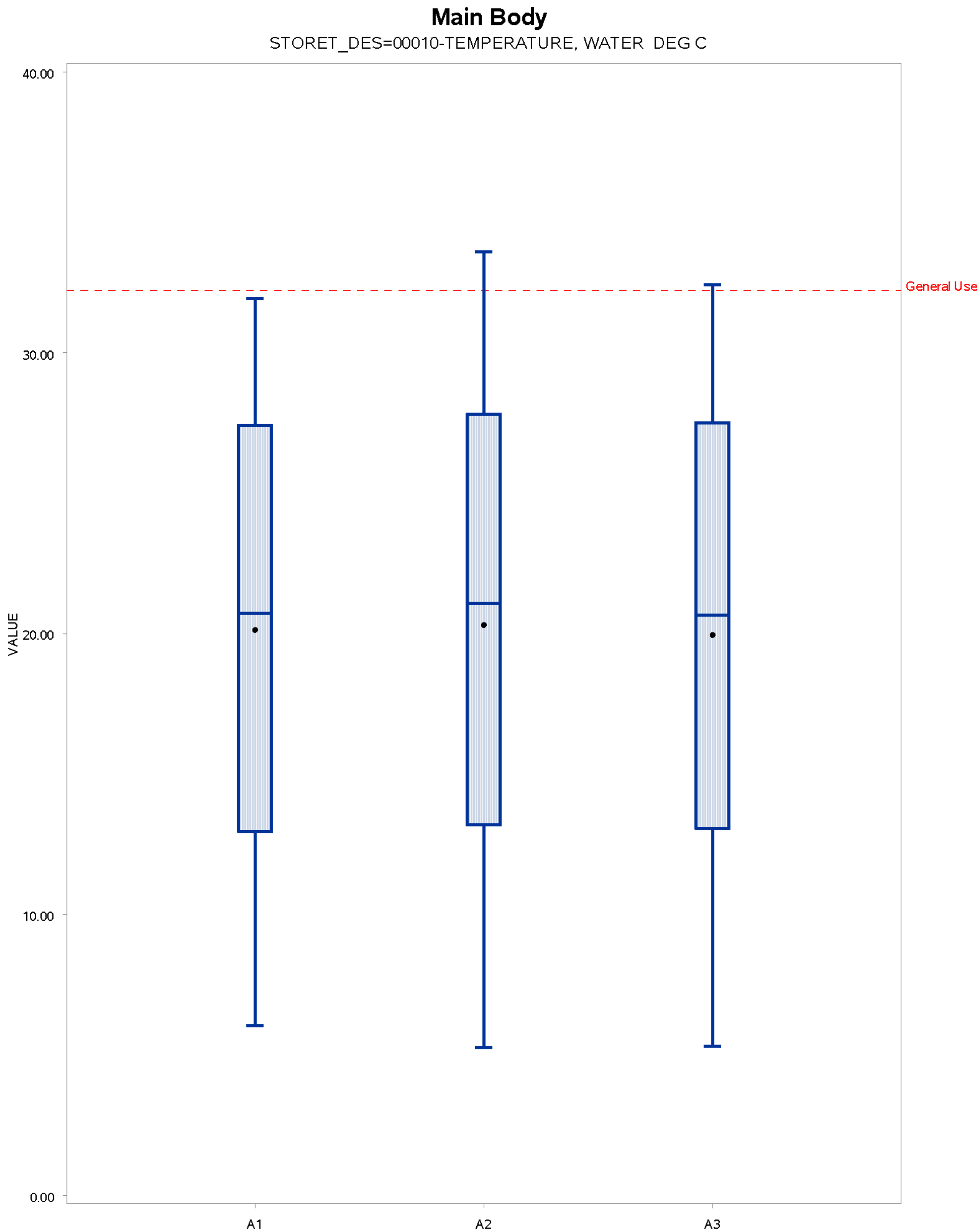
Parameter	Date	I1	I2
E. COLI (MPN/100ml)	1/2017	25	
	4/2017	<4	
	8/2017	2	
	10/2017	<2	
	2/2018	21	
	5/2018	<2	
	9/2018	<4	
	12/2018	4	
	3/2019	13	
	5/2019	4	
	8/2019	<2	
	11/2019	4	
	2/2020	24	
	4/2020	8	
	8/2020	2	
	11/2020	4	
	2/2021	10	
	5/2021	<2	
	8/2021	<2	
	11/2021	<4	
Total Petroleum Hydrocarbons (TPH mg/L)	4/2017	<0.58	
	8/2017	ND	
	5/2018	ND	
	9/2018	ND	
	5/2019	ND	
	4/2020	ND	
VOC (ug/L)	4/2017	ND	
	8/2017	ND	
	5/2018	ND	
	9/2018	ND	
	5/2019	ND	
	4/2020	ND	

*ND denotes that non-detect

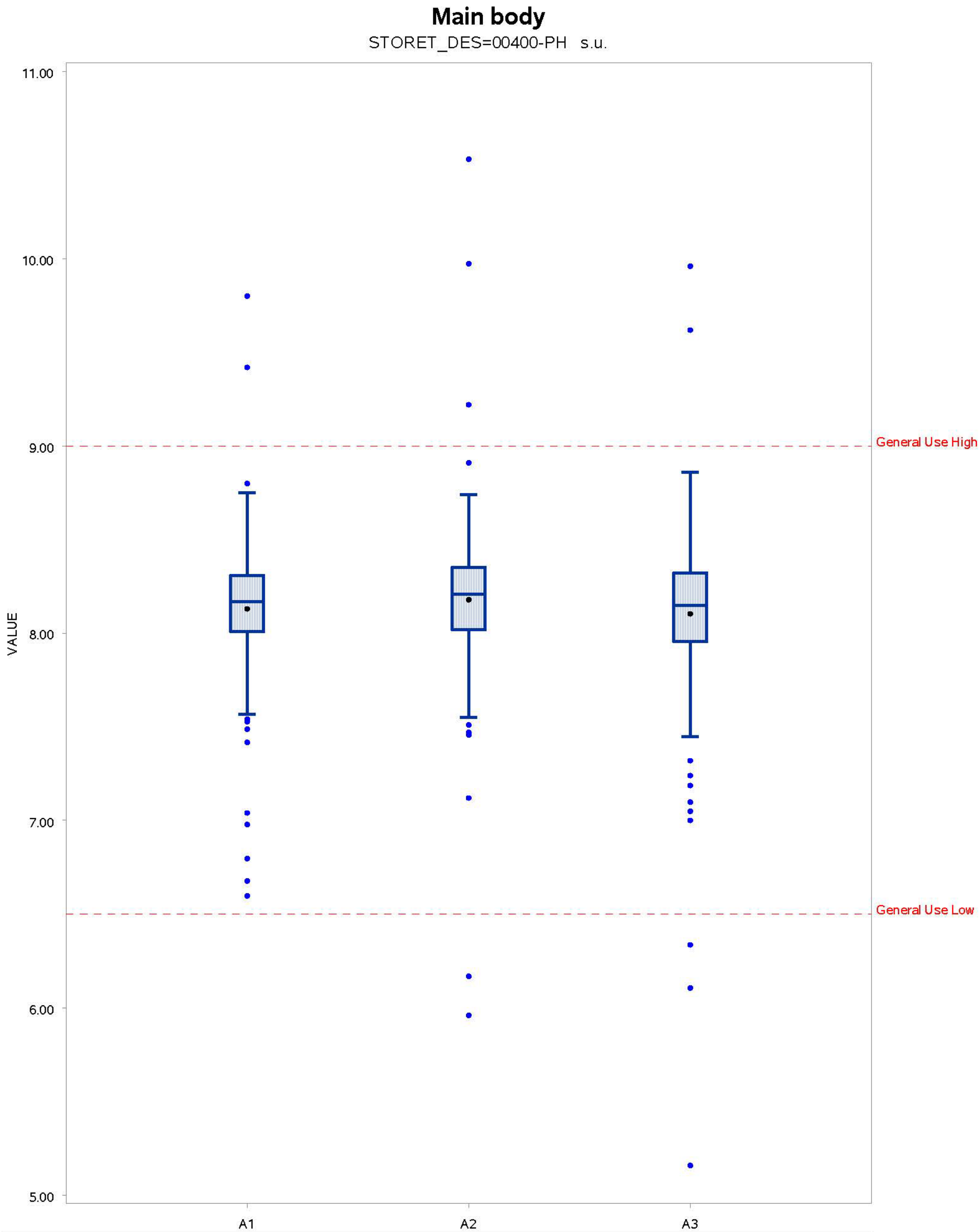
Appendix D Box-Plots of Select Parameters from 1997 to 2021



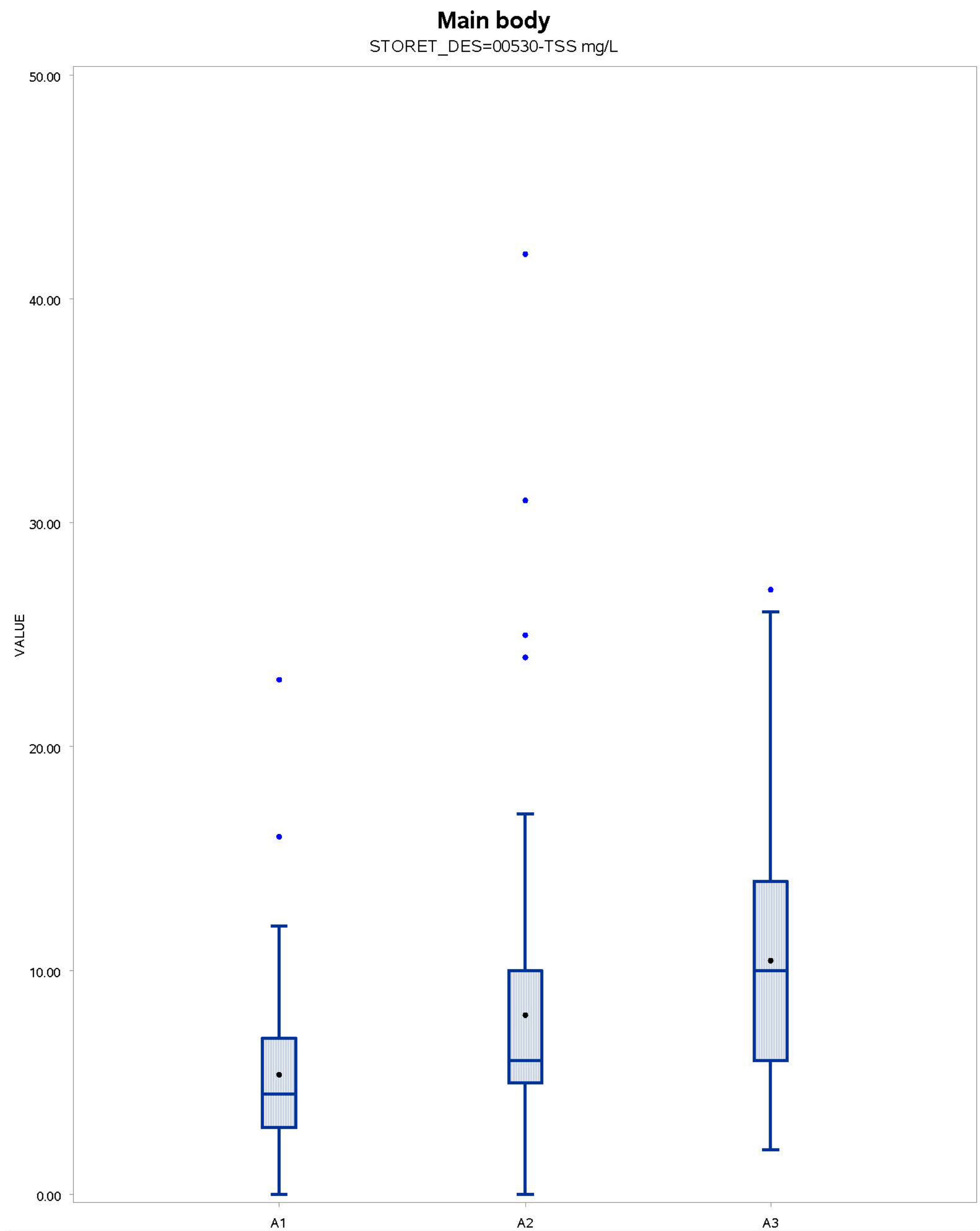
Number of Data in Each Site		
N 93	94	95



Number of Data in Each Site			
N	218	230	231



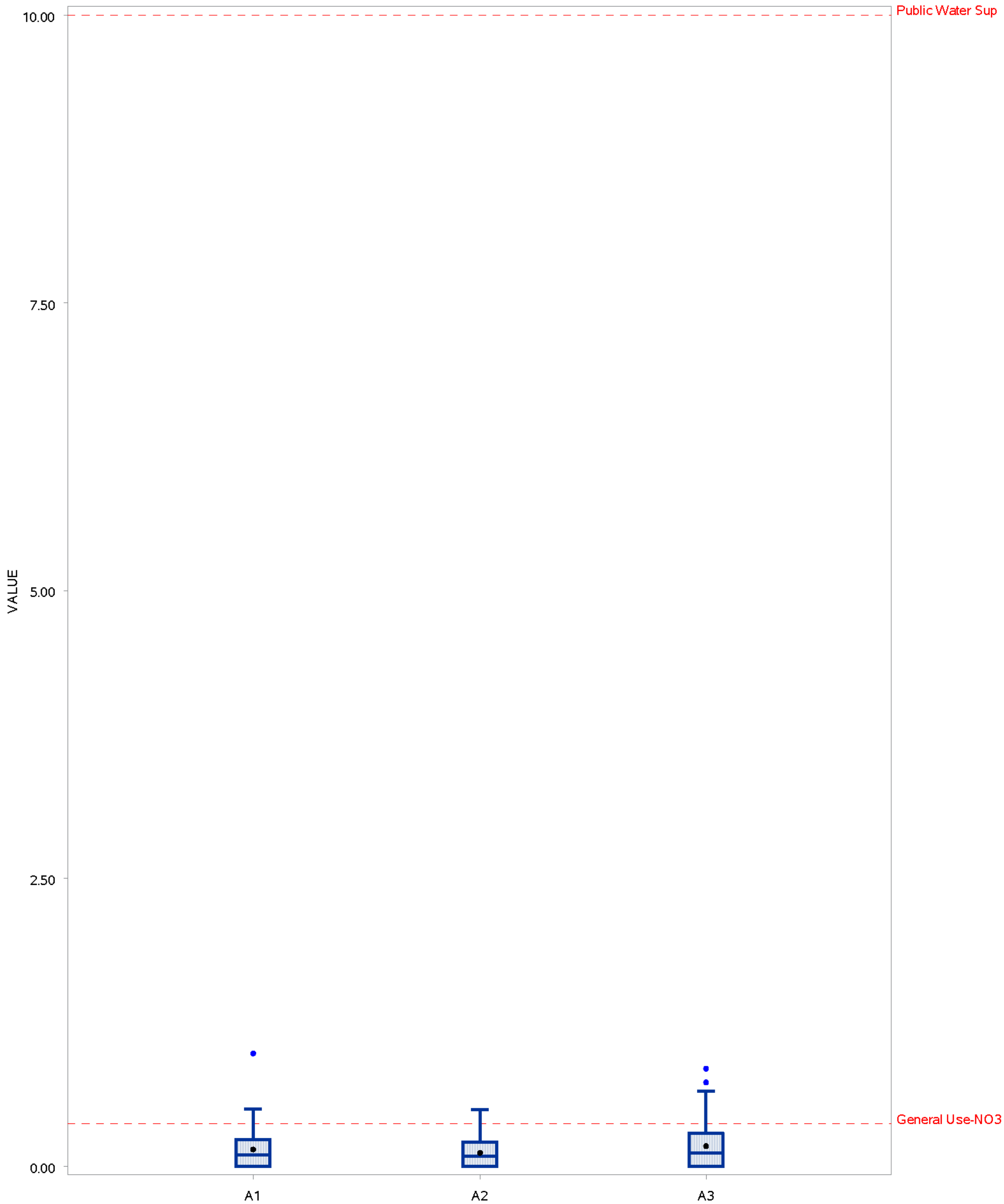
Number of Data in Each Site			
N	217	228	230



Number of Data in Each Site			
N	96	99	101

Main Body

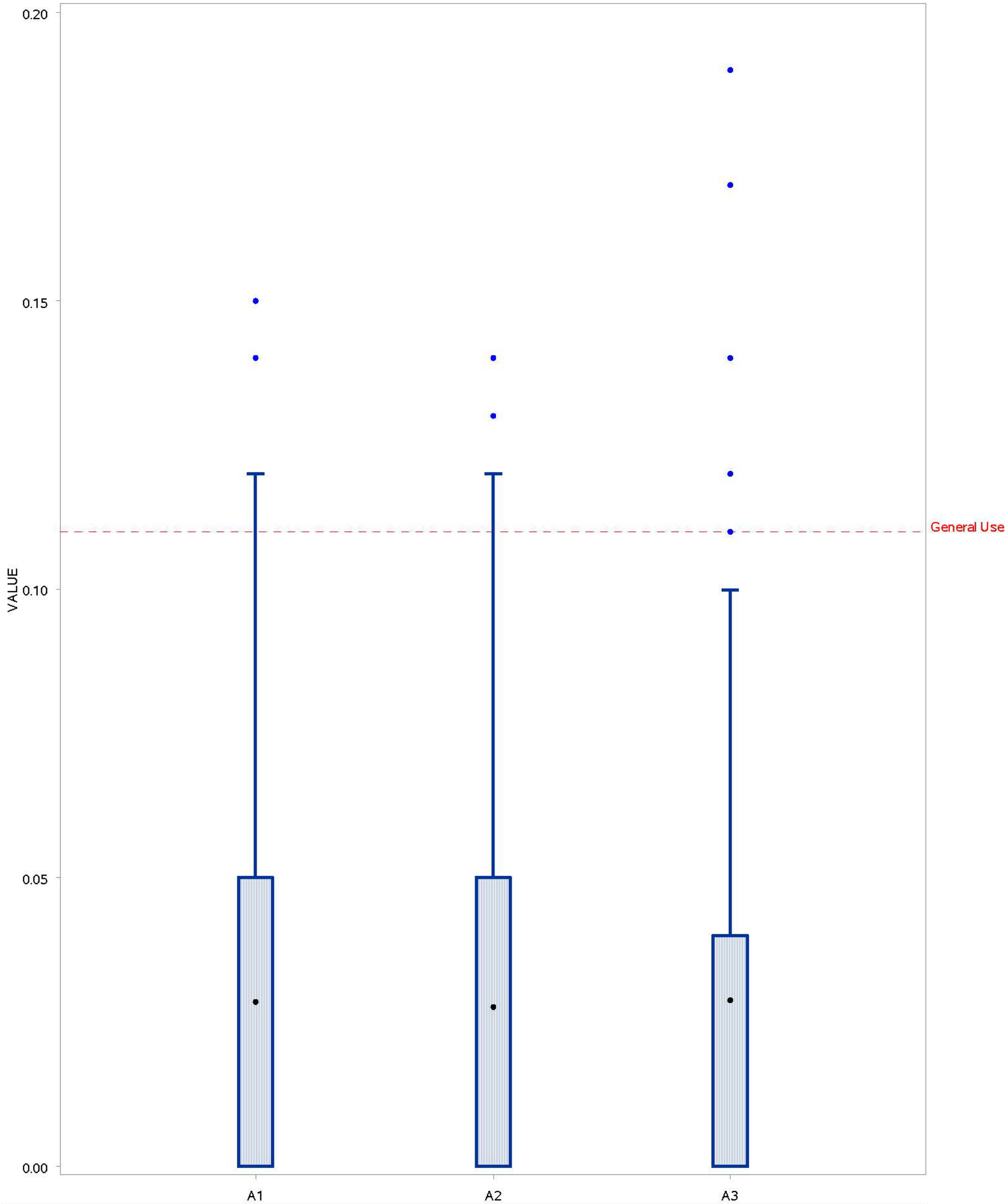
STORET_DES=00593-NO2 + NO3 mg/l



Number of Data in Each Site			
N	108	110	112

Main body

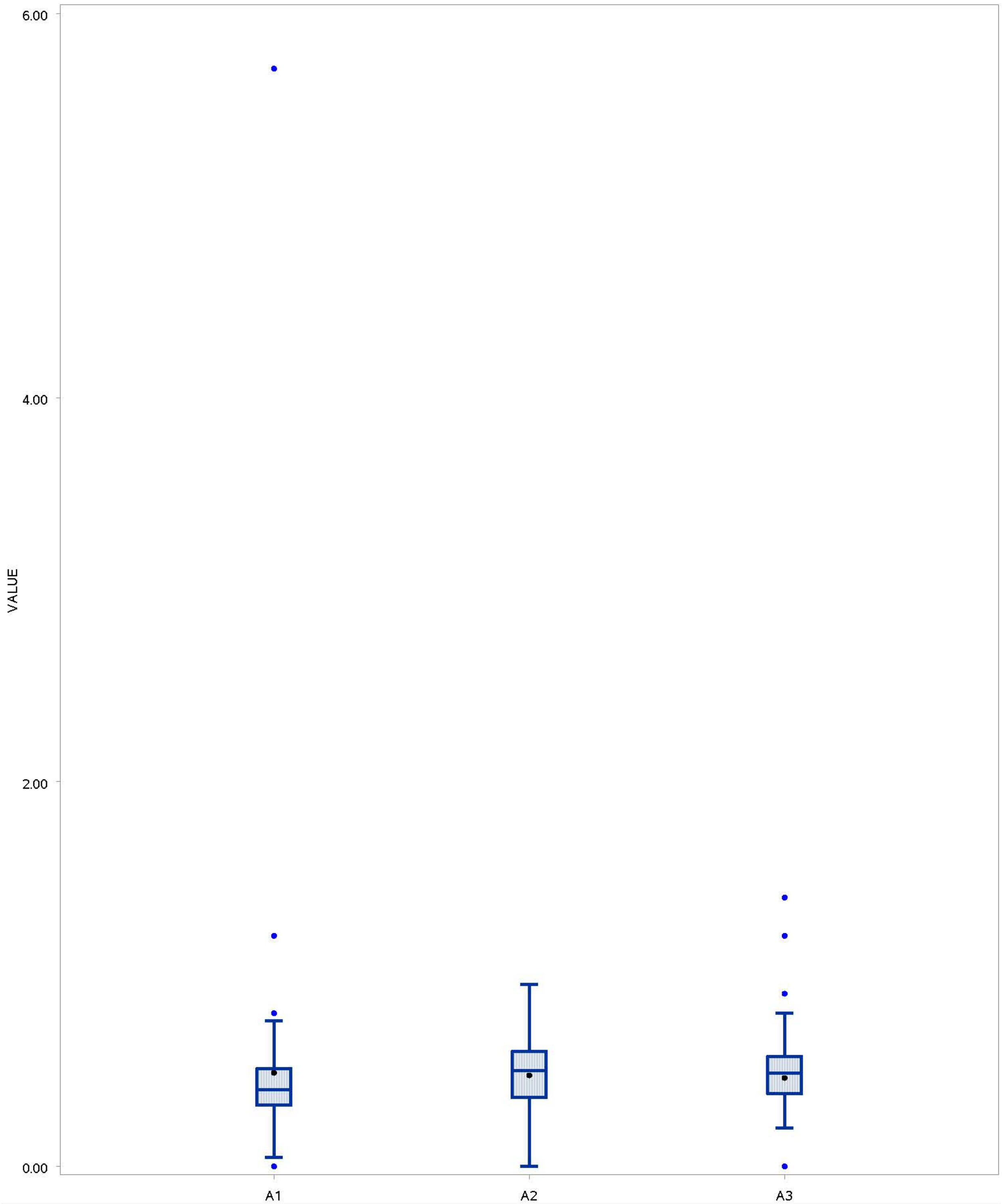
STORET_DES=00610-NH3 mg/L



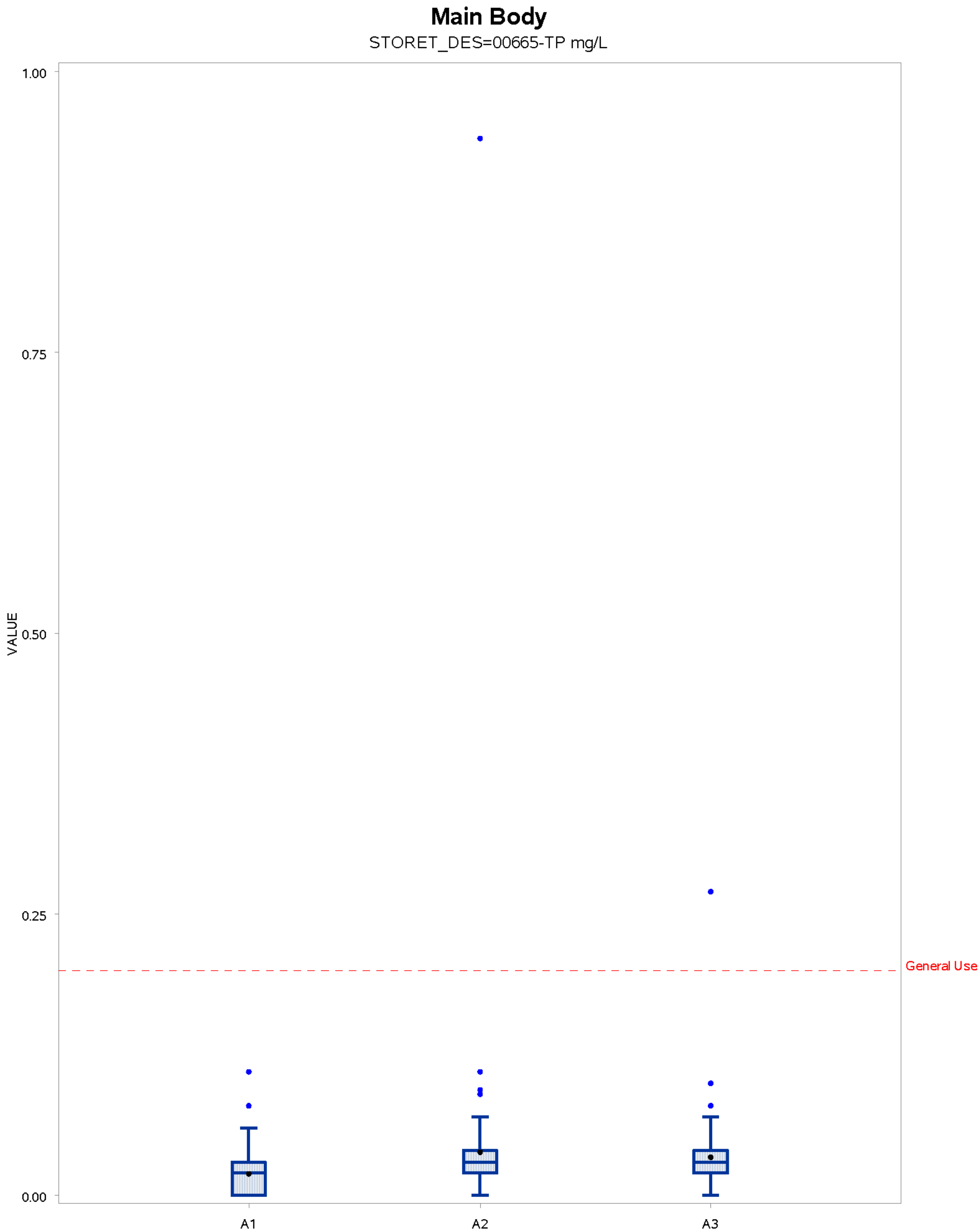
Number of Data in Each Site			
N	105	110	111

Main body

STORET_DES=00625-TKN mg/L



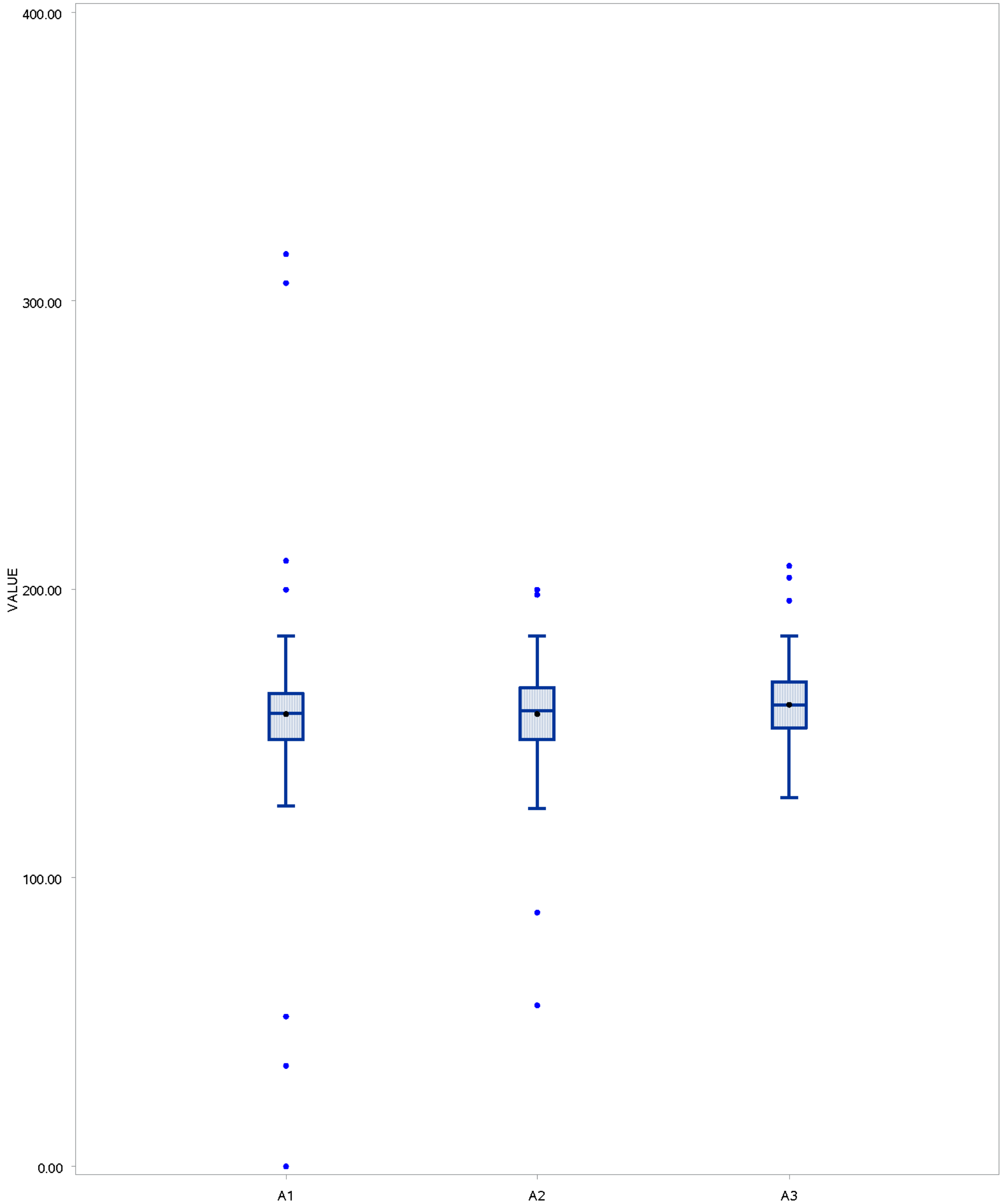
Number of Data in Each Site			
N	105	110	111



Number of Data in Each Site			
N	105	109	111

Main Body

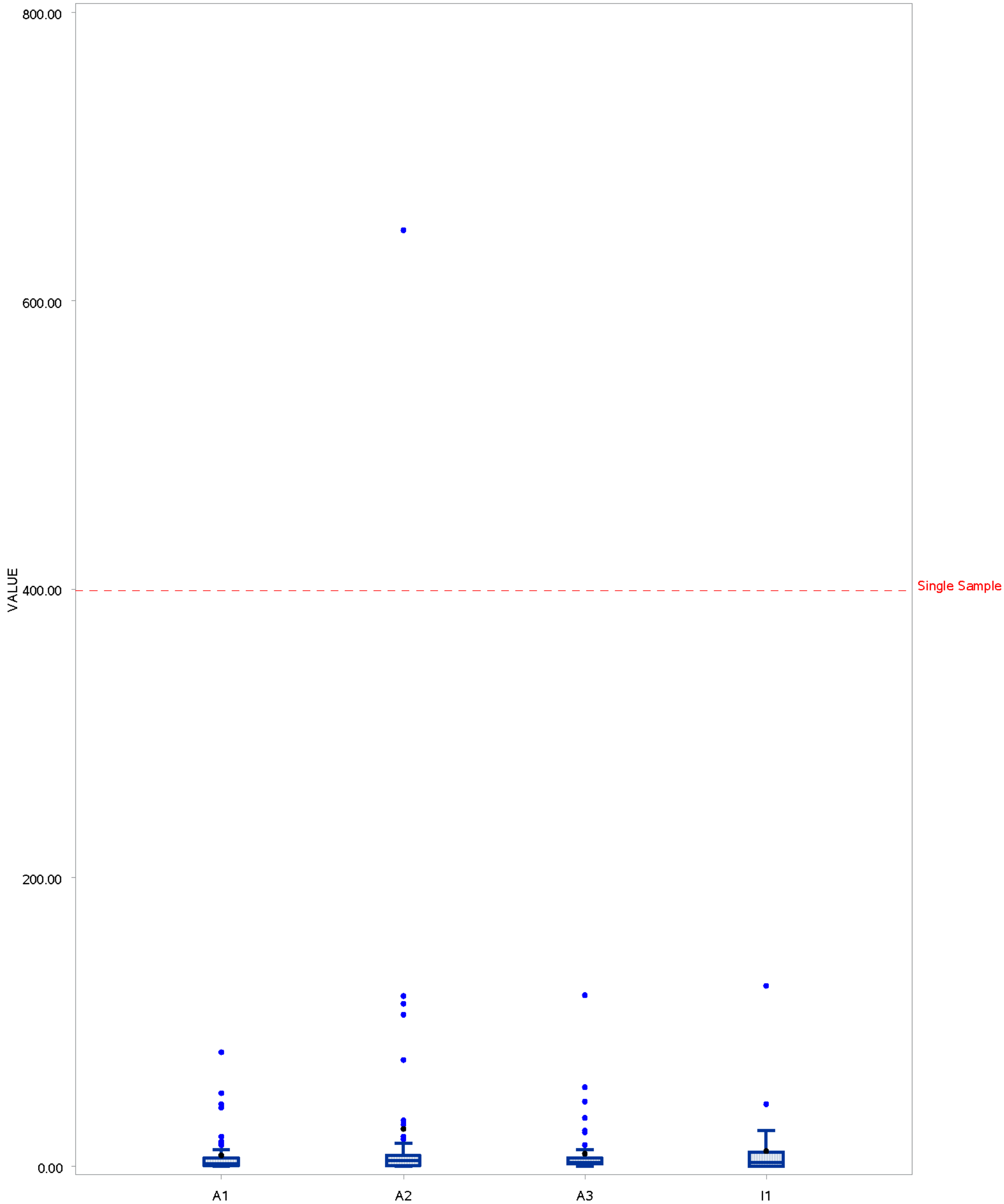
STORET_DES=00900-HARDNESS mg/L



Number of Data in Each Site			
N	191	205	204

Main Body

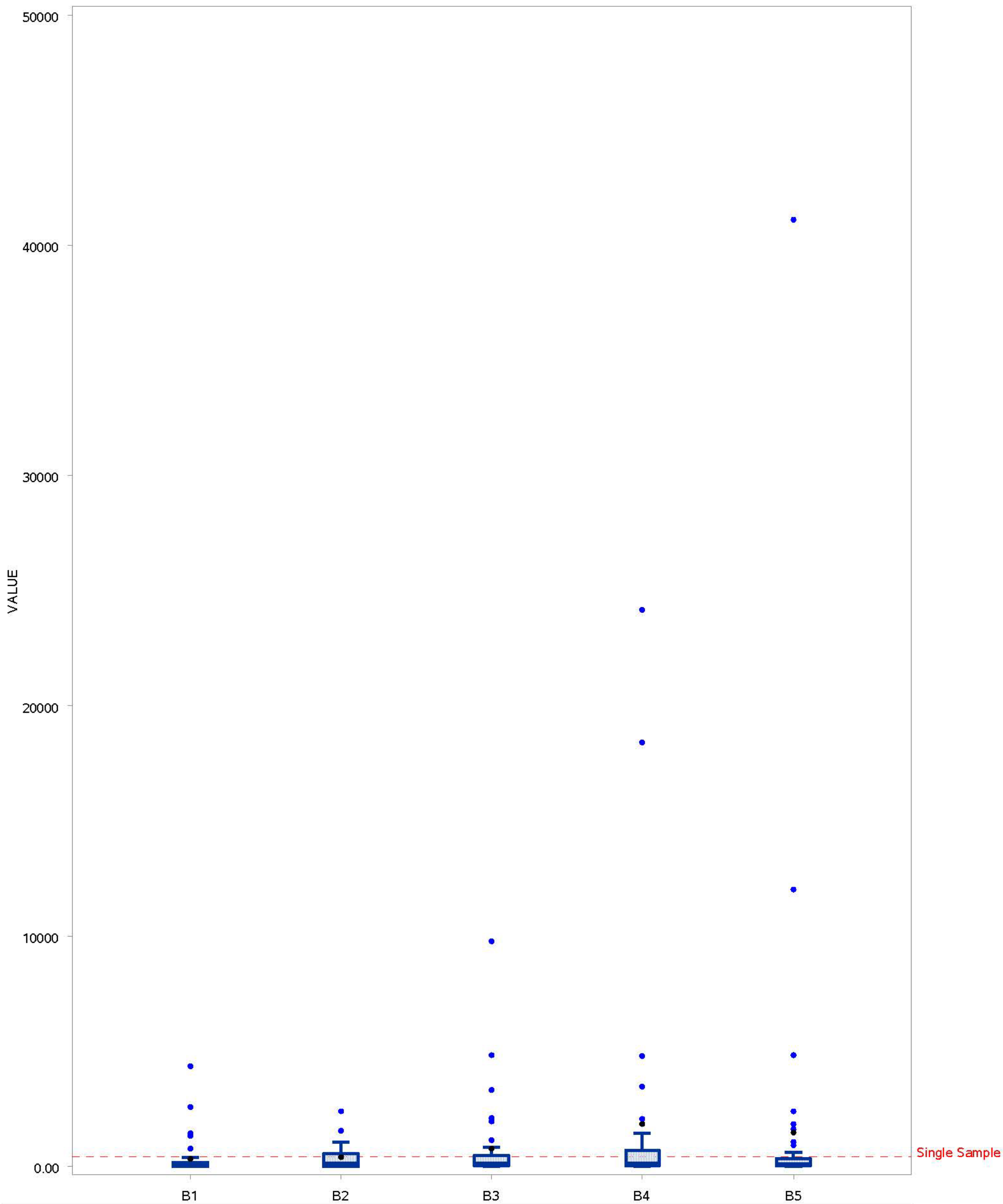
STORET_DES=31699-E. COLI MPN/100 mL



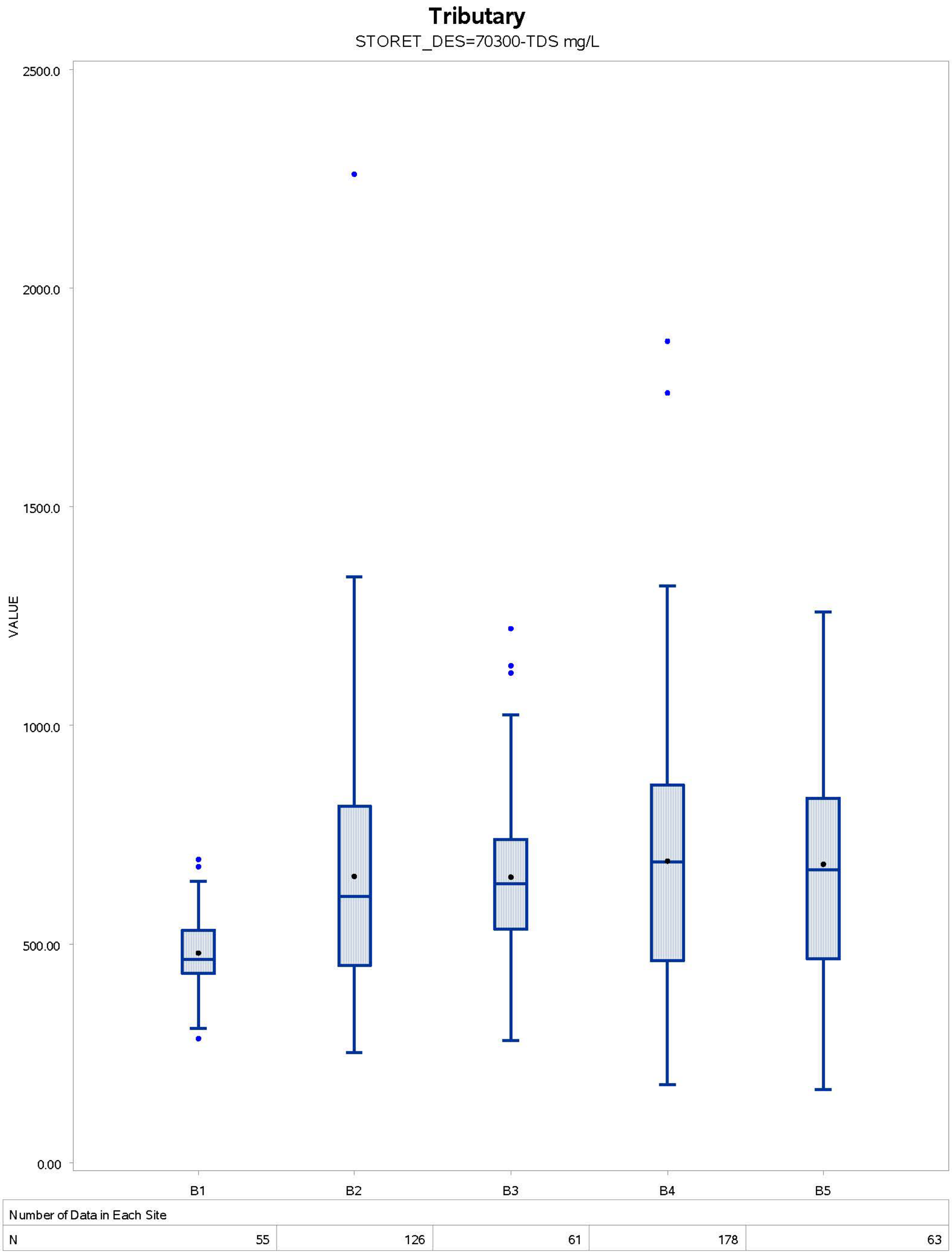
Number of Data in Each Site				
N	51	50	50	31

Tributary

STORET_DES=31699-E. COLI MPN/100 mL

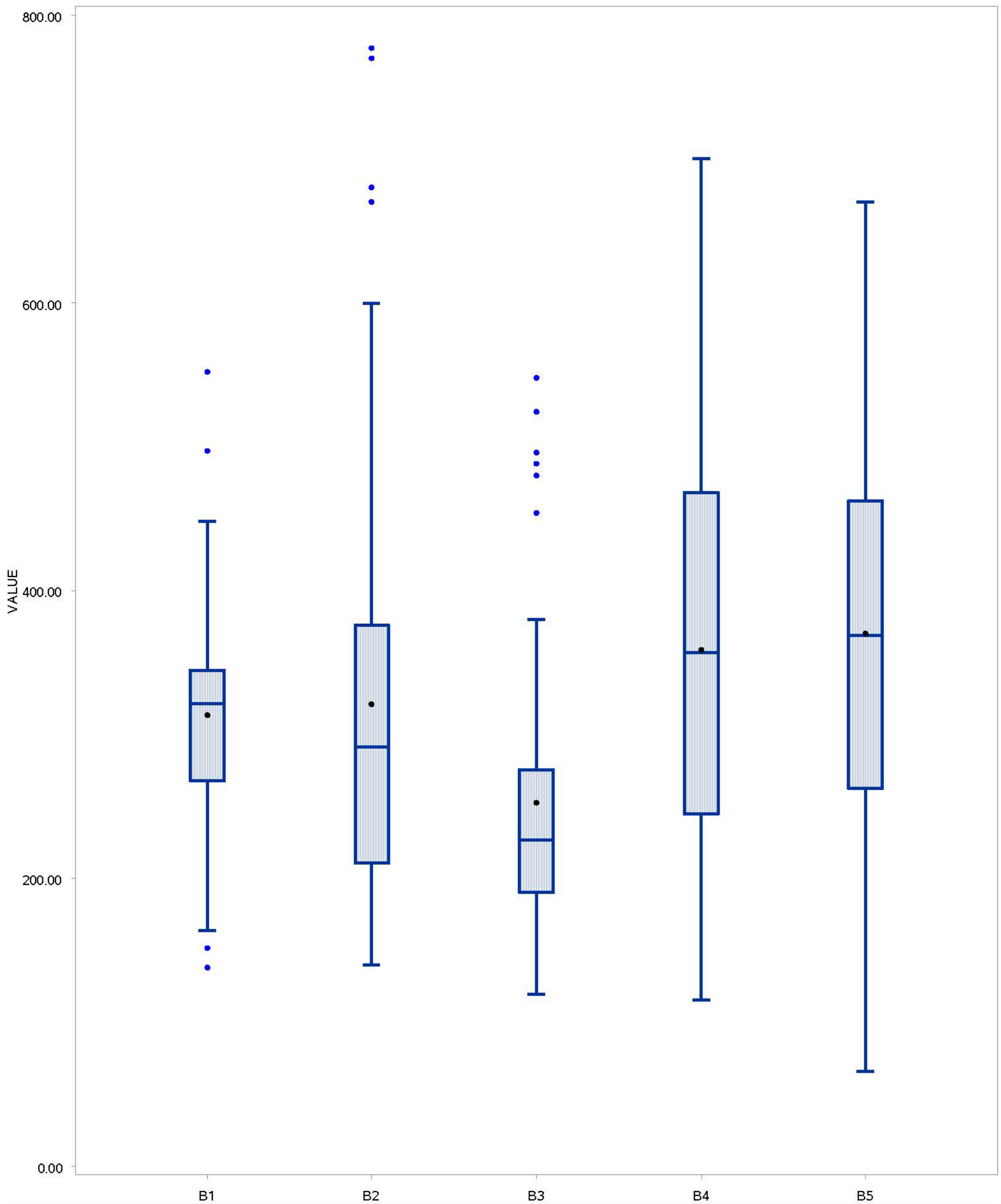


Number of Data in Each Site					
N	39	23	46	33	49


Tributary
STORET_DES=70300-TDS mg/L
2500.0
2000.0
1500.0
1000.0
500.00
0.00
VALUE
B1
B2
B3
B4
B5
Number of Data in Each Site
N
55
126
61
178
63

Tributary

STORET_DES=00900-HARDNESS mg/L



Number of Data in Each Site					
N	55	120	62	178	68

Appendix E Methods to Develop Flow Duration Curves and Load Duration Curves

To develop an FDC for a location the following steps are used:

- order the DAR-simulated daily streamflow data for a specific site from highest to lowest and assign a rank to each data point;
- compute the percent of days that each flow is exceeded by dividing each rank by the total number of data point plus 1; and
- plot the corresponding flow data against exceedance percentages.

Further, developing an LDC follows the steps:

- multiply the DAR-simulated streamflow in cubic foot per second by the appropriate water quality criterion for the concerned parameter (for example 399 MPN/100 mL for *E. coli* and by a conversion factor ($8.64x10^8$), which give a loading per day; and
- plot the exceedance percentages, which are identical to the value for the streamflow data points, against the criterion of *E. coli*.)

The resulting curve represents the maximum allowable daily loadings for the criterion for the concerned parameter. The next step was to plot the sampled data on the developed LDC using the following two steps:

- compute the daily loads for each sample by multiplying the measured concentration on a particular day by the corresponding streamflow on that day and the conversion factor ($8.64x10^8$); and
- plot on the LDC for each site the load for each measurement at the exceedance percentage for its corresponding streamflow.

The plots of the LDC with the measured loads display the frequency and magnitude that measured loads exceed the maximum allowable loadings for the criterion. Measured loads that are above a maximum allowable loading curve indicate an exceedance of the water quality criterion, while those below a curve show compliance.

A useful refinement of the LDC method is to divide the curve into flow-regime regions to analyze exceedance patterns in smaller portions of the duration curves.

- High flow regime: 0-10 percentile range, related to flood flows,
- Mid-range flow regime: 10-80 percentile range, and
- Low flow regime: 90-100 percentile range, related to low and dry flow condition

The above flow regime applies to all sites except B2, in which 10-50 percentile is mid-range and 50-100 percentile is low flow regime. The plots of the LDC with the measured loads (concentrations of a constituent times corresponding streamflow) illustrate the frequency and magnitude that measured loads exceed the maximum allowable loadings for the water quality standards. Measured loads that are above a maximum allowable loading curve indicate an exceedance of the water quality criterion, while those below a curve show compliance. The load duration curves for *E. coli*, NH3, NO2 + NO3, OP and TP, with the three flow regimes for the tributary sites are displayed in the following sections.

Load Duration Curves for *E. coli*

According to 2018 Texas Surface Water Quality Standards, *E. coli* criteria for freshwater are:

- The geometric mean criterion for *E. coli* for primary contact recreation is 126 per 100 ml. The single sample criterion for *E. coli* is 399 per 100 ml.
- The geometric mean criterion for *E. coli* for primary contact recreation 2 is 206 per 100 ml.
- The geometric mean criterion for *E. coli* for secondary contact recreation 1 is 630 per 100 ml.
- The geometric mean criterion for *E. coli* for secondary contact recreation 2 is 1,030 per 100 ml.
- The geometric mean criterion for *E. coli* for noncontact recreation is 2,060 per 100 ml.

As can be seen, the measured bacteria loadings exceeded the Allowable Load at the Single Sample Criterion of 399 MPN/100ml (the solid blue lines) at all three flow regimes and at all five tributary sites. If *E. coli* exceedances are seen in the low flow ranges, it may indicate leaking sewer lines or ineffective septic systems. Exceedances on the higher end of the graph, as seen below, indicate that the loadings are washing in to the reservoir during high flow pulses. Watershed management practices would help reduce those loadings.

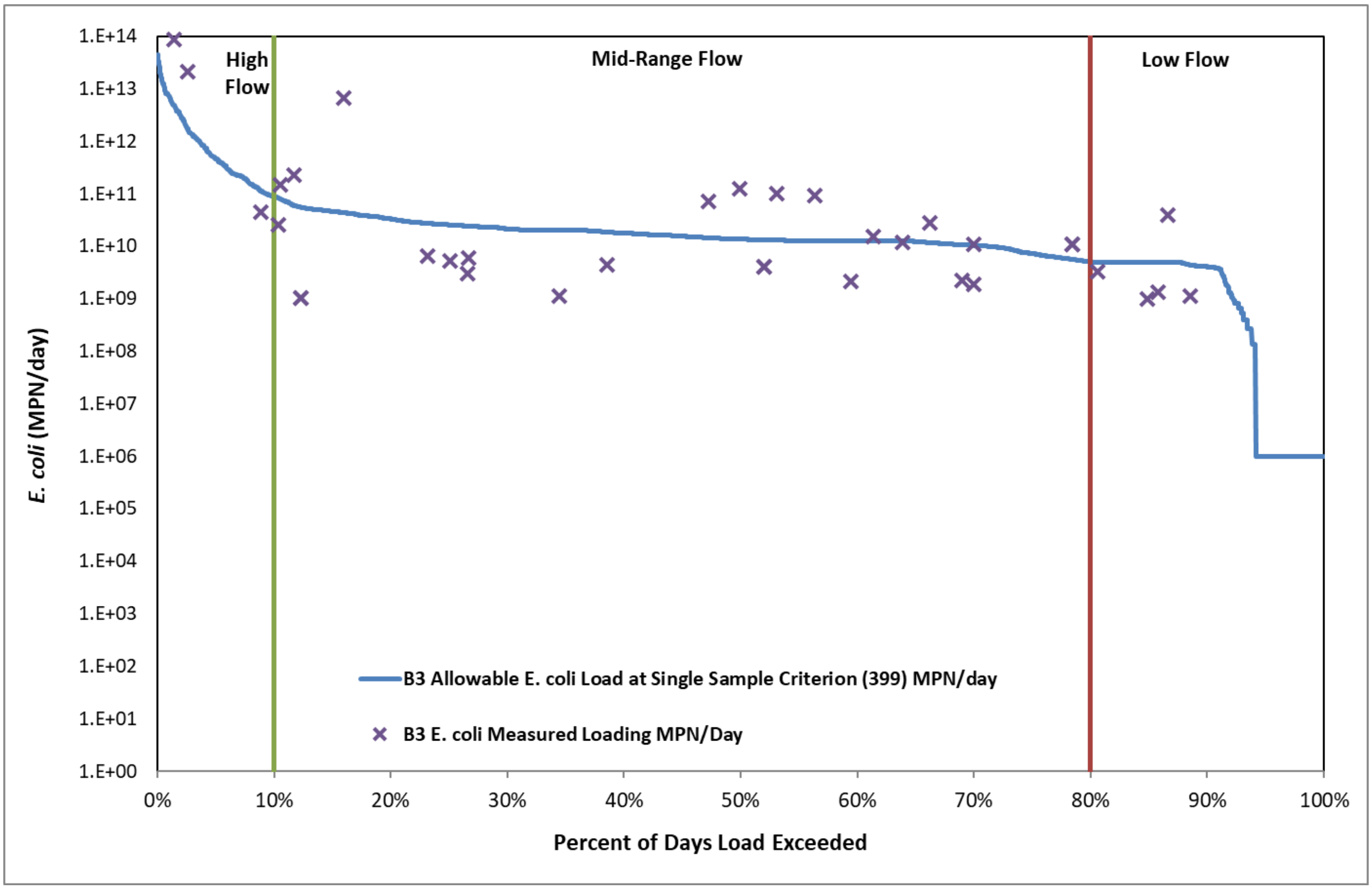


Figure 16 *E. coli* Load Duration Curve and Measured Loads at B3

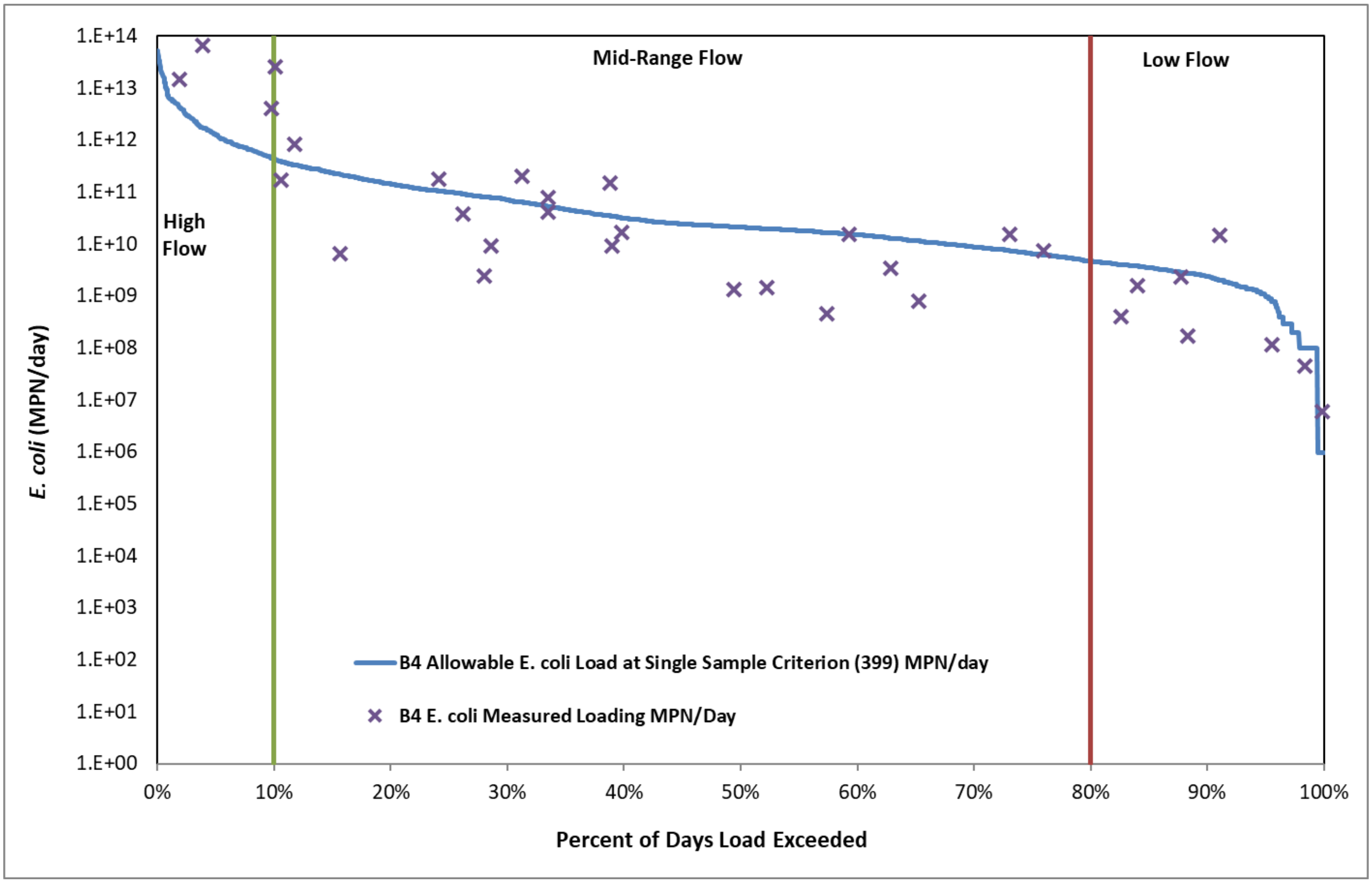


Figure 17 *E. coli* Load Duration Curve and Measured Loads at B4

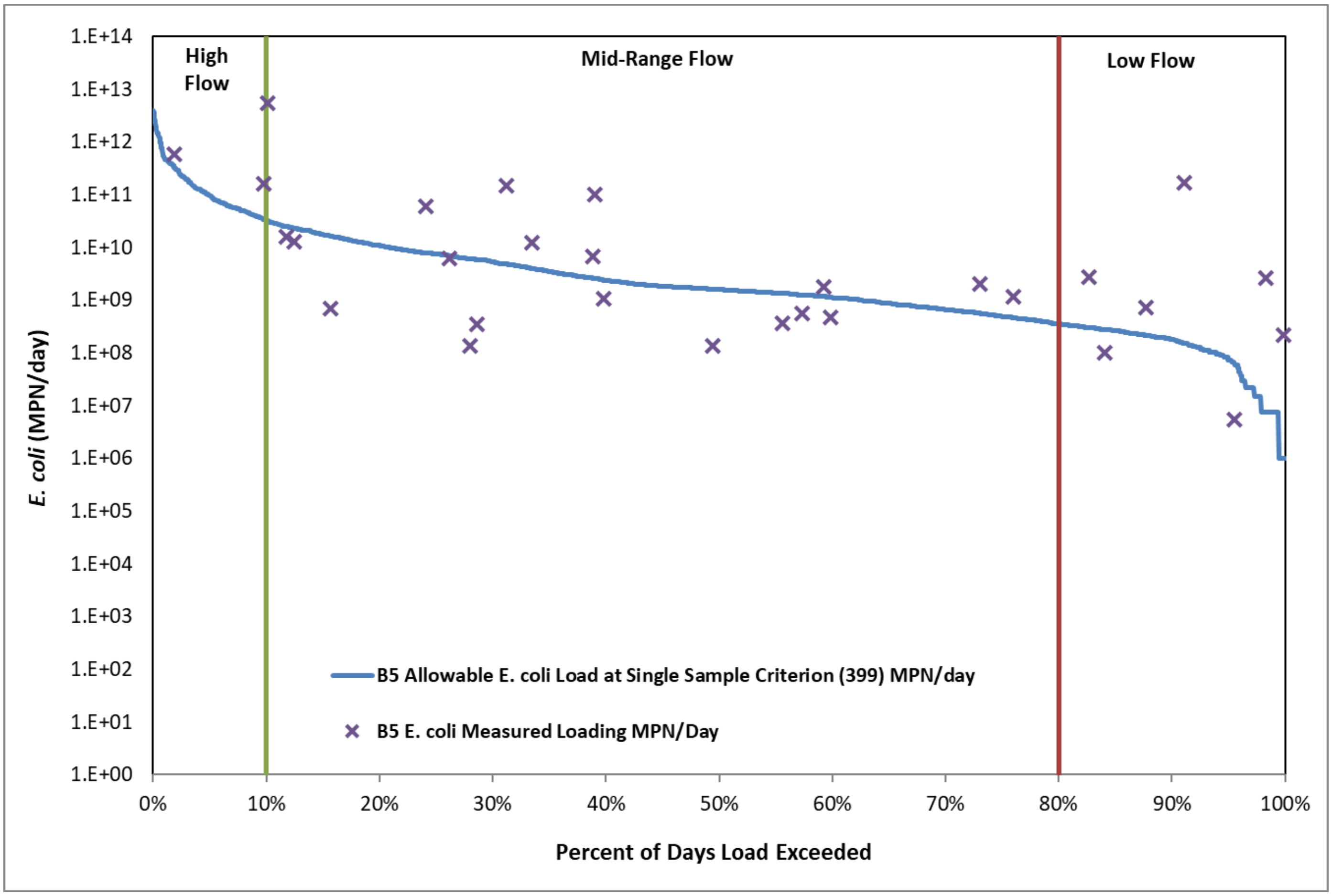


Figure 18 *E. coli* Load Duration Curve and Measured Loads at B5

Load Duration Curves for NH3

Measured NH3 loadings occasionally exceeded the Allowable Load Criterion at Screening Level of 0.33 mg/L at mid-low flow regimes at B3 and B5.

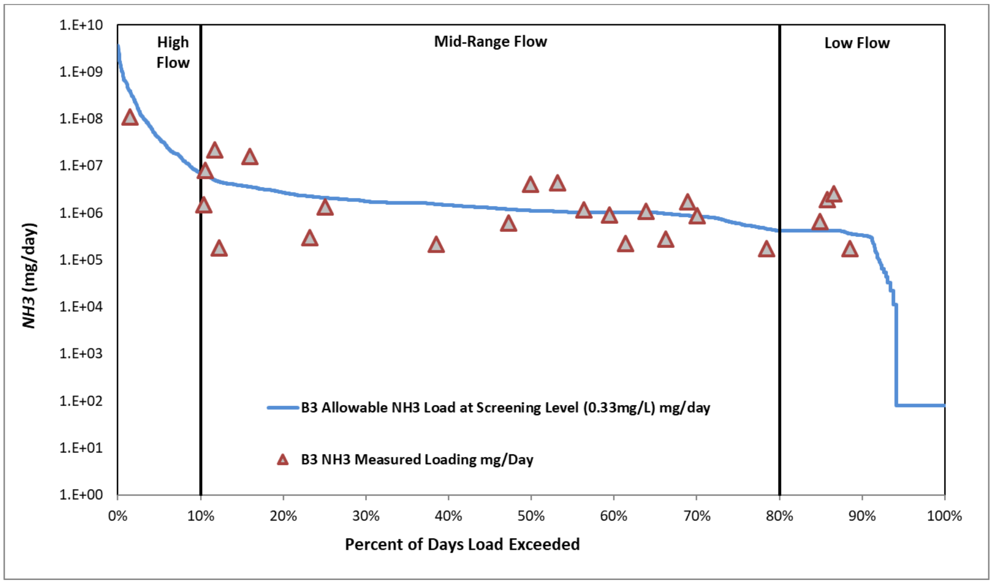


Figure 19 NH3 Load Duration Curve and Measured Loads with Flow Regimes at B3

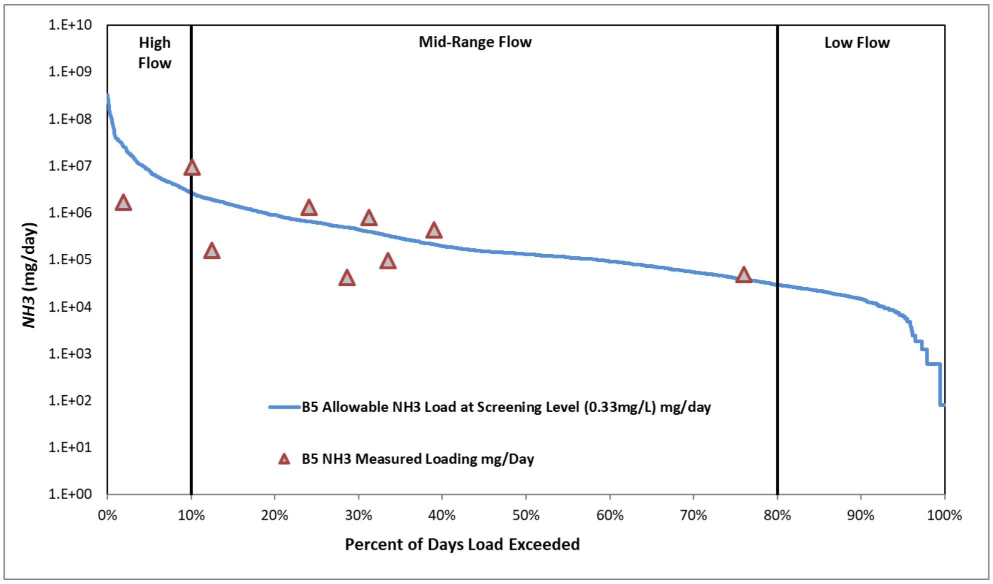


Figure 20 NH3 Load Duration Curve and Measured Loads with Flow Regimes at B5

Load Duration Curves for NO2 + NO3

Measured NO2 + NO3 loadings frequently exceeded the Allowable Load Criterion at Screening Level of 1.95 mg/L at mid-low flow regimes at B3 and B5.

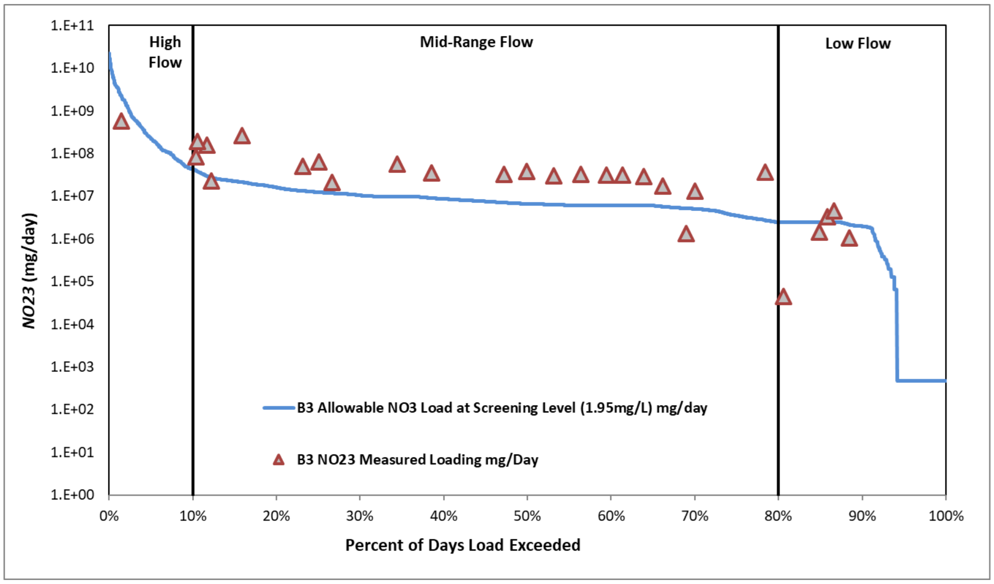


Figure 21 NO2 + NO3 Load Duration Curve and Measured Loads with Flow Regimes at B3

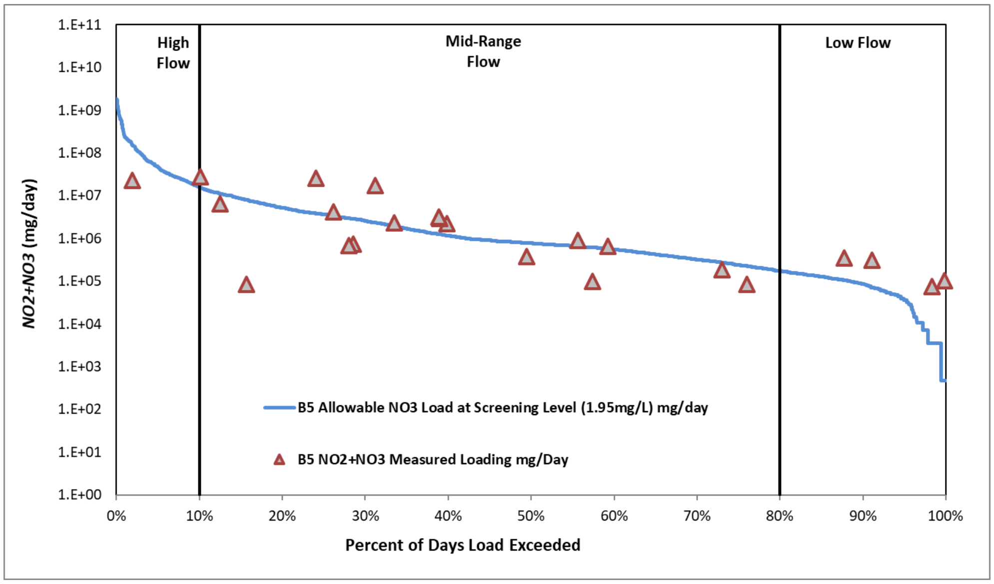


Figure 22 NO2 + NO3 Load Duration Curve and Measured Loads with Flow Regimes at B5

Load Duration Curves for OP

Majority of the measured OP loadings were below the Allowable Load Criterion at Screening Level of 0.37 mg/L. Only two sites are shown because many OP samples at the other three sites were non-detects.

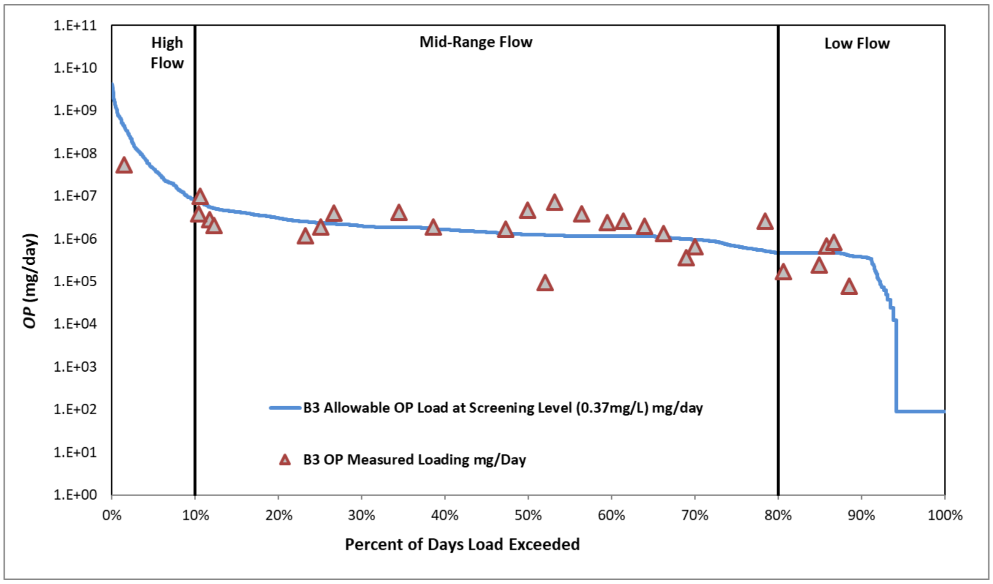


Figure 23 OP Load Duration Curves and Measured Loads with Flow Regimes at B3

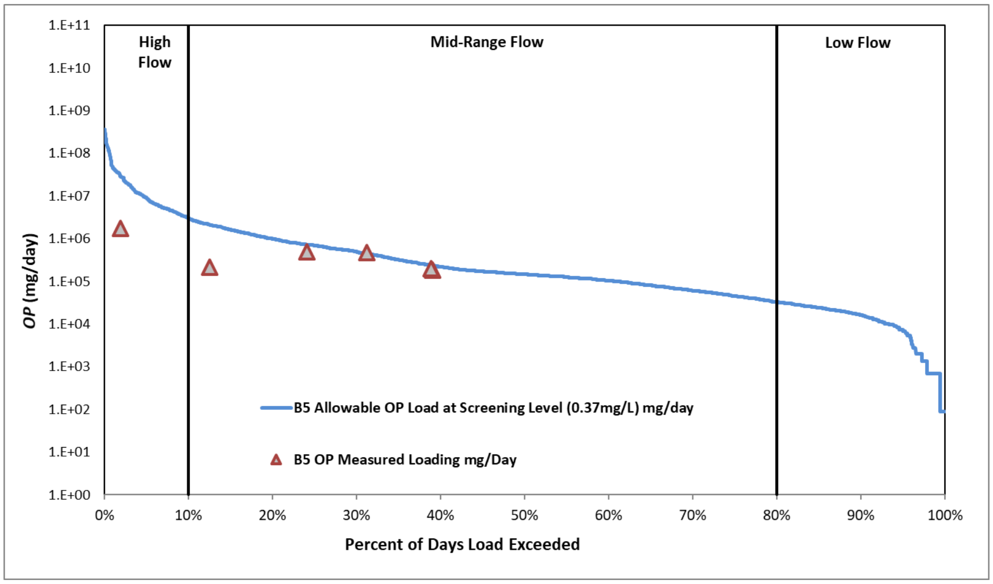


Figure 24 OP Load Duration Curves and Measured Loads with Flow Regimes at B5

Load Duration Curves for TP

Measured TP loadings occasionally exceeded the Allowable Load Criterion at Screening Level of 0.69 mg/L at the following three sites.

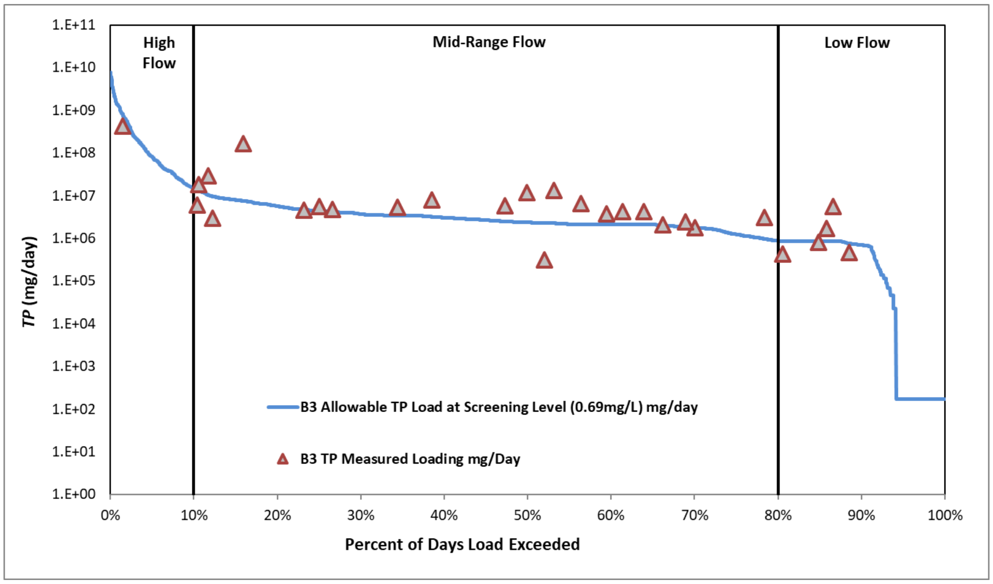


Figure 25 TP Load Duration Curve and Measured Loads with Flow Regimes at B3

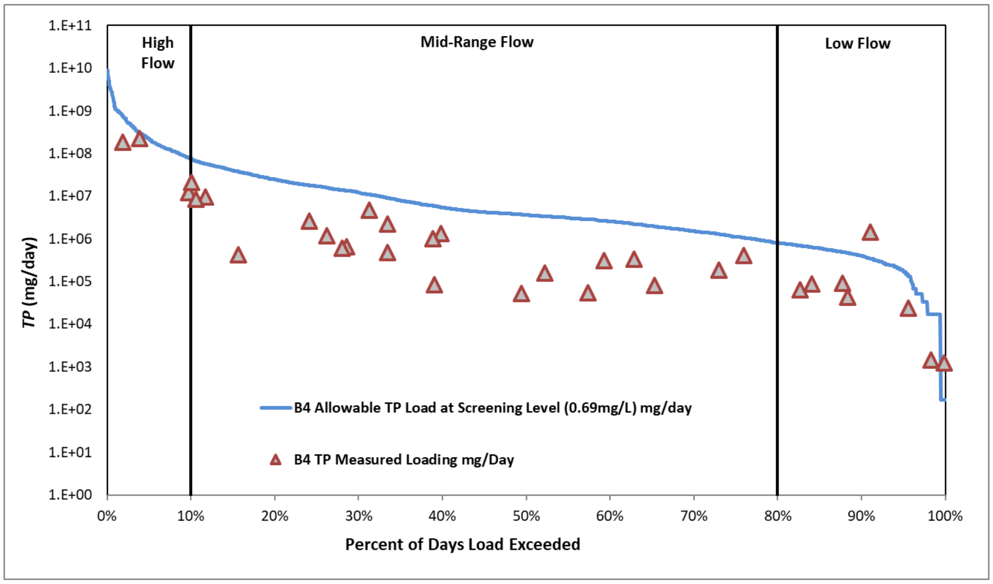


Figure 26 TP Load Duration Curve and Measured Loads with Flow Regimes at B4

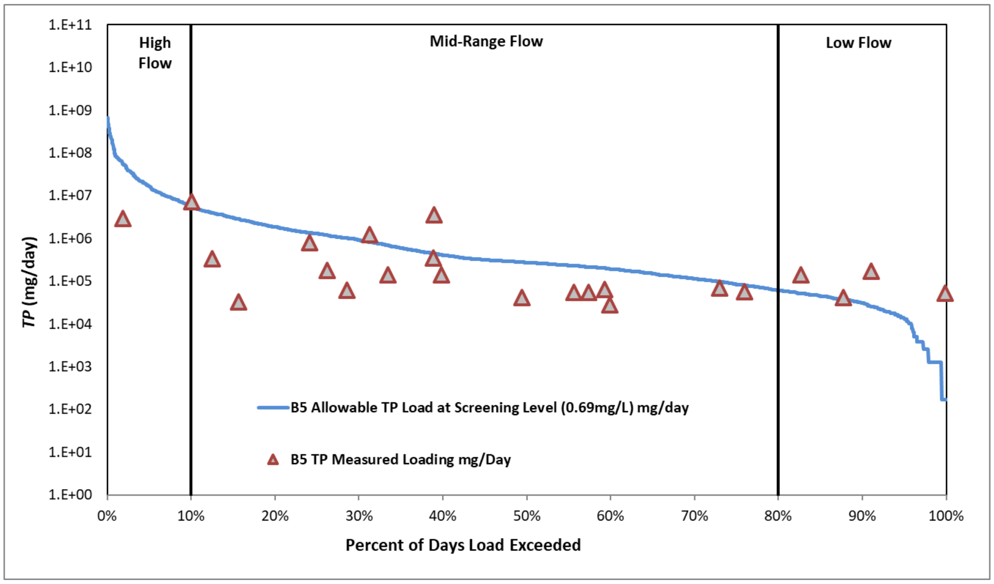


Figure 27 TP Load Duration Curve and Measured Loads with Flow Regimes at B5

Appendix F - Special Studies

Development of CE-QUAL-W2 Water Quality Model of Joe Pool Lake

From September 2015 to November 2018, the Technical Service and Basin Planning (TSBP) of TRA, with assistance of Tarleton State University, developed and applied a CE-QUAL-W2 water quality model for Joe Pool Lake. The developed CE- QUAL- W2 model provides a two dimensional (vertical and longitudinal directions) representation of the Joe Pool Lake capable of predict various water quality parameter constituents, including phytoplankton, dissolved oxygen (DO), suspended particulates, and various nutrient forms. The Joe Pool Lake model was developed in a manner so that it can be linked to a watershed model, in the event that such a combined modeling tool is desired. Model development included creating a two-dimensional segmentation of the lake; creating the required model input of streamflow and water quality loadings for the Mountain Creek, Walnut Creek and other smaller tributaries; creating additional model input such a meteorological data; organizing the historical water quality data collected in the reservoir. The model was verified for water quality parameters against the historical data collected in the lake. The Joe Pool Lake model provides reasonable predictions of water temperature, and water quality parameters such as total suspended solids (TSS), ammonium (NH4), nitrite plus nitrate (NO2 + NO3), DO, Chlorophyll-*a* (Chl-*a*), total organic carbon (TOC), total Kjeldahl nitrogen (TKN) and total phosphorus (TP). The Joe Pool Lake model is a sophisticated mathematical tool to assist in water quality and quantity planning for Joe Pool Lake. As an example, the model has been operated to evaluate water quality implications related to inter-basin transfer of water to supplement water supplies of the lake.

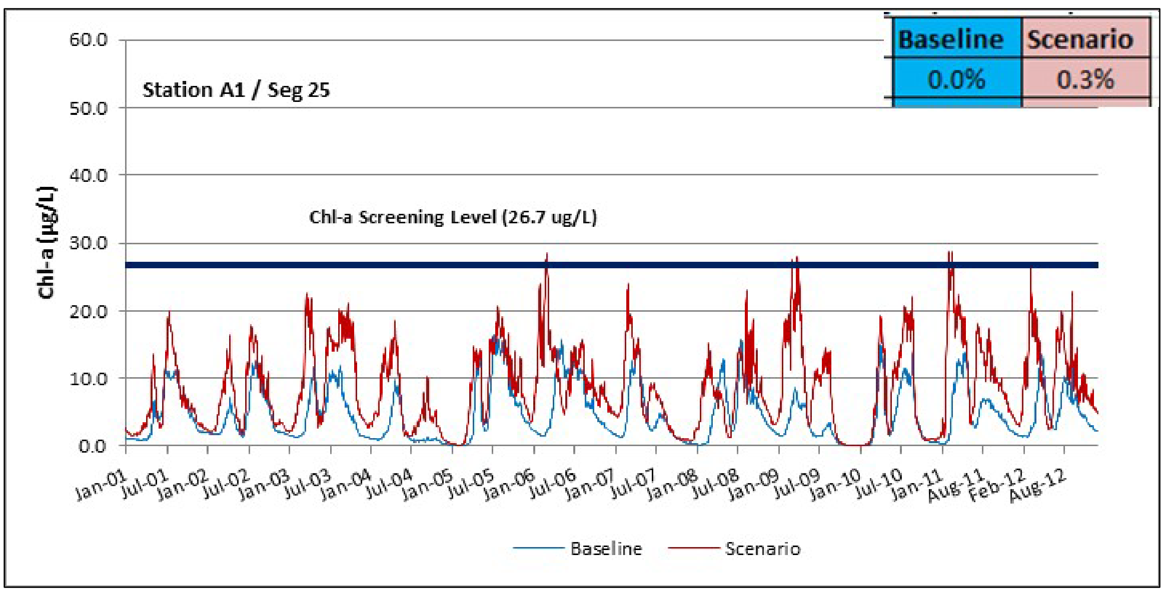


Figure 28 Time-series of model predicted near-surface Chl-*a* from baseline and water-transfer scenario at Station A1/ Segment 25

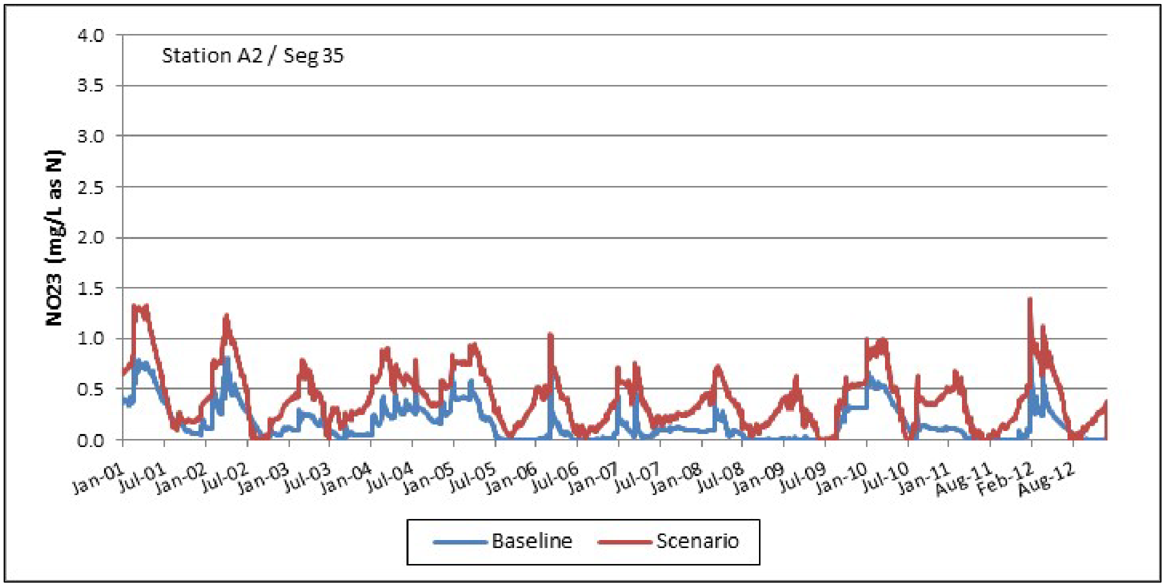


Figure 29 Time-series of model predicted near-surface NO2 + NO3 from baseline and water-transfer scenario at Station A2/ Segment 35.

Joe Pool Lake Watershed Protection Plan

Development of the Watershed Protection Plan

In 2014, TCEQ identified elevated levels of nitrate in Mountain Creek and elevated levels of bacteria in Walnut Creek. In 2018, the Trinity River Authority of Texas received a CWA Section 319(h) grant to address the bacteria impairment and nutrient concern through watershed characterization. In 2019, the Trinity River Authority of Texas received a CWA Section 319(h) grant to develop a watershed protection plan. These projects progressed concurrently with the goal of improving water quality and mitigating future impacts of rapid urbanization.

Based on the results of water quality data, modeling, land uses, and stakeholder input, the Joe Pool Lake Partnership identified potential pollutant sources and recommended management measures and education resources to address them. The Draft Joe Pool Lake Watershed Protection Plan was submitted in December of 2021 and is currently under review by TCEQ with implementation measures currently in the planning phases.

Stakeholders involved in developing the plan included a group of 203 attendees, 40 on average per meeting, representing a range of interests in the watershed including business owners, residents, researchers and educators, government representatives, and environmental nonprofit organizations. Additionally, a steering committee was formed to provide continued leadership as the watershed protection plan moves into implementation. The steering committee is composed of representatives from public and private sector entities whose participation is critical to implementation.

Education and Outreach

Education and outreach events have been challenging due to COVID-19. Since the start of fiscal year 2022, two steering committee meetings have occurred virtually to review the Draft WPP and review public comments. A stakeholder meeting also occurred virtually to review the Draft WPP. Other outreach programs that supported watershed protection plan goals included an in-person Urban Stream Processes and Restoration Program, a hybrid Understanding Urban Wildlife Workshop, and a hybrid Healthy Lawns and Healthy Waters Workshop.