MODELING SUPPORT FOR THE ATTOYAC BAYOU ASSESSMENT USING LOAD DURATION CURVES

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Abbreviations

BMPs	Best Management Practices
CFU	Coliform Forming Units
EPA	U.S Environmental Protection Agency
LDC	Load Duration Curve
TMDLs	Total Maximum Daily Loads
TSSWCB	Texas State Soil and Water Conservation Board
TWRI	Texas Water Resources Institute
USDA	U.S Department of Agriculture
USGS	U.S Geological Survey
WPP	Watershed Protection Plans

1. INTRODUCTION

A popular approach currently applied in the development of Watershed Protection Plans (WPP) and Total Maximum Daily Loads (TMDL) is to identify whether point or non-point sources are the primary pollutant contributors in a water body. The development of load duration curves (LDC) is an accepted method of accomplishing this goal (USEPA, 2006a). The LDC approach was developed for assessing nutrient loading in streams (Cleland, 2002) but has been adapted to assess bacteria loads as well. This graphical approach combines daily stream flow with water quality data for the pollutant to be evaluated. It is assumed that point sources are a constant loading that are present during all flow regimes where as non-point source loadings are present in streams during high flows due to runoff events (Cleland, 2003). This approach relies solely on the field data available, thus the LDC determines load reductions for the flow conditions at which measurements were taken (Li and Guo, 2003). A needed load reduction is calculated based on the percent exceedance above the maximum allowable load line. In Texas, the water quality standard to assess a water body's ability to meet primary contact recreation standards is a geometric mean concentration of 126 CFU/100 mL of *E. coli* and a single sample criterion of 399 CFU/100 mL. This bacterium is used as an indicator of potential fecal derived pathogen presence in the monitored water body (TCEQ, 2010).

Stream flow is separated into five categories when sufficient stream flow is present. These categories range from high to low or no-flow conditions and represent a designated amount of time that the stream had flow of that level or greater. Load reduction percentages are developed in association with each flow category and generally identify where the bulk of pollutant loading may be coming from; either point or non-point sources. In comparison, a watershed model computes loading across all flow regimes and uses the field data for calibration (Li and Guo, 2003). LDCs were used to calculate load reductions based on maximum allowable *E. coli* and ammonia loads in the Attoyac Bayou and its tributaries. LDCs were developed for each sampling site (Figure 1) that had sufficient stream flow and concentration data; at least 13 data points are required to run LoadEST. Based on these calculated load reductions, best management practices (BMPs) can be identified to appropriately address potential sources of pollution when broadly applied across the watershed.

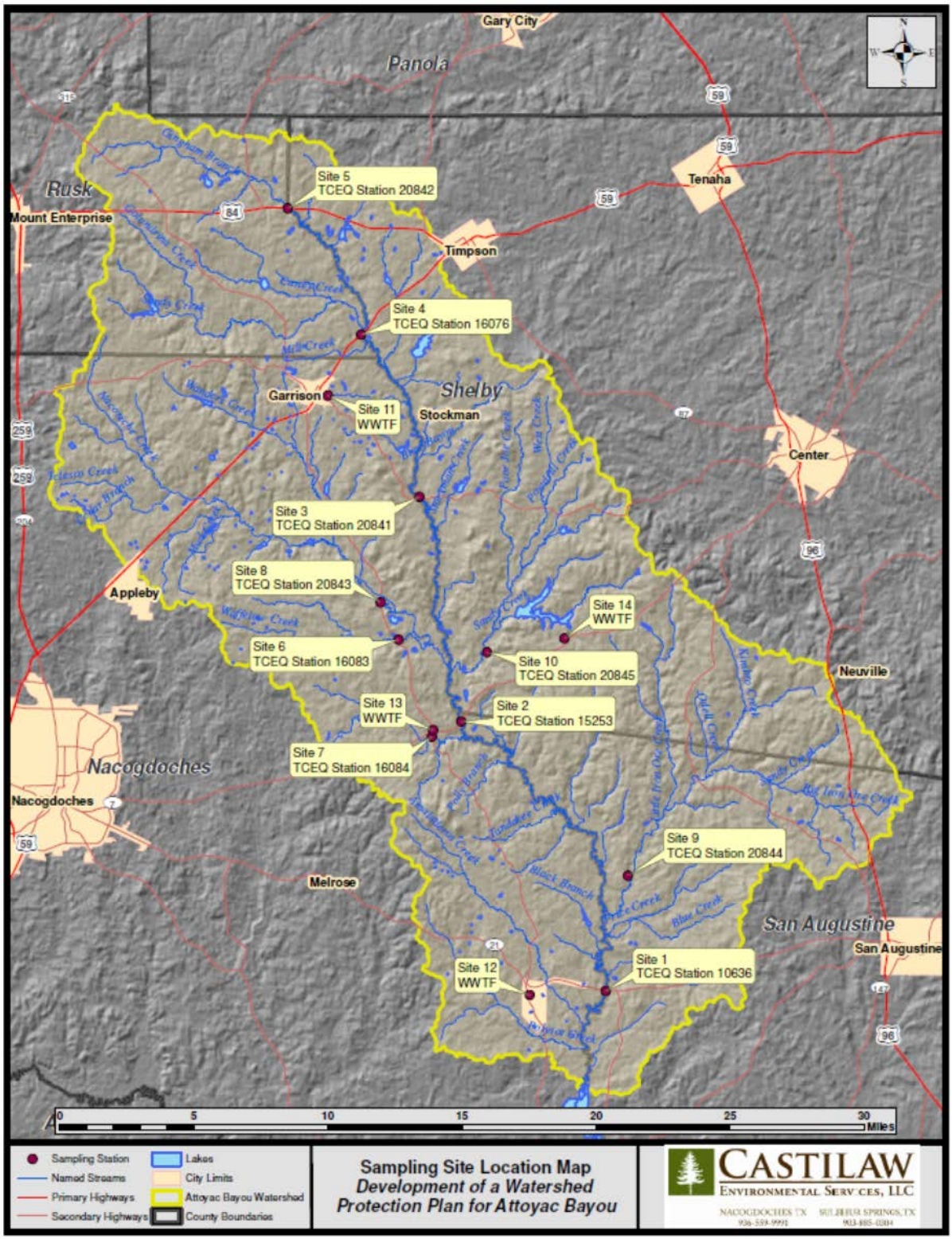

Figure 1. Attoyac Bayou watershed sampling sites.

2. LOAD DURATION CURVE ANALYSIS

LDCs were applied in the Attoyac Bayou watershed to aid in predicting whether pollutants are primarily derived from point and/or nonpoint sources. This is a widely accepted and utilized approach that has been applied nationally for various water quality pollutants. LDCs are developed by first constructing a flow duration curve using streamflow data. Flow data are then multiplied by a threshold concentration (such as a desired target or an official water quality criterion) of a pollutant; in this case *E. coli.* A threshold concentration of 126 CFU/100 mL for *E. coli* bacteria and the concentration of 0.33 mg/L for ammonia were used in developing the LDC analysis for this project and do not include a margin of safety subtracted from the *E. coli* or ammonia standard.

When flow and the threshold concentration are multiplied together, they produce the maximum allowable pollutant load. The resulting LDC can then be used to show the maximum load a stream can carry without exceeding regulatory criteria or screening criteria across the range of flow conditions (low flow to high flow). In addition, stream monitoring data for a pollutant can be plotted on the curve to show when and by how much criteria are exceeded.

A regression line following the trend of the stream is plotted through the stream monitoring data using the USGS program LOAD ESTimator (LOADEST). LOADEST is used to determine load reductions for different flow regimes using the load reduction percentage (Babbar-Sebens and Karthikeyan, 2009). To calculate the needed load reduction for a flow category, the allowable load was subtracted from the load estimation then divided by the load estimation and multiplied by 100 to yield a percent load reduction needed. The equation used is:

$$(\text{Loadest-TMDL/Loadest}) \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

The load reduction percentages were calculated into the standard flow regimes utilized by the U.S. Environmental Protection Agency (EPA) regimes, which are designated as:

Table 1. Flow breaks utilized in the Attoyac Bayou LDC analysis.

high flows	flow exceeds this level 0 to 10% of time
moist conditions	flow exceeds this level 10 to 40% of time
mid-range conditions	flow exceeds this level 40 to 60% of time
dry conditions	flow exceeds this level 60 to 90% of time
low flows	flow exceeds this level 90 to 100% of time

This system of flow breaks was used due to the limited amount of flow data available on each creek to determine the actual streamflow regime breaks for each of the different creeks.

Bi-weekly samples and flow data were collected at stations from July 26, 2010 until August 20, 2012. Five stations (20841, 20842, 20843, 20844, and 20845) were established specifically for this study and instantaneous flow data and instantaneous *E. coli* data were collected at these sites and were used in the LDC analyses. There were five other historic stations (10636, 15253, 16076, 16083, and 16084) where monitoring frequency was increased for this study to allow for the development of LDCs. Historic drought conditions did occur across Texas during 2011 and resulted in several sites being dry for an extended period of time. As a result, neither flow nor bacteria levels were recorded at these sites for a considerable number of sampling events.

A majority of the sampling stations experienced no flow conditions during the drought, but still had water present. In accordance with water quality monitoring guidance issued by the state as a result of the drought, several water quality samples were collected under these non-flowing conditions at the majority of monitoring stations. These samples proved quite useful in the development of LDCs presented here as they provided a reasonable measure of the amount of time water at each site was not flowing. Additionally, these non-flowing data points do not adversely impact the results of the LDCs as they consider both concentration of a pollutant and the flow. With flow measurements of 0 cfs, the pollutant load is also 0. This lack of pollutant loads is illustrated in Figures 2c – 2i and 3c – 3i with data points plotted on the X-axis.

2.1. *E. coli* LDC analysis

Ten monitoring stations, 10636, 15253, 16076, 16083, 16084, 20841, 20842, 20843, 20844, 20845, are located on Attoyac Bayou (Figure 1) and its tributaries. Bi-weekly water quality data were collected from July 26, 2010 to August 20, 2012. Differences in the number of samples available at each site are a result of samples not being taken due to no water being present, stream depth being too great to collect a flow measurement or the presence of unsafe weather conditions. The following summarizes data collection and availability at each sampling site.

2.1.1. Data Summary at 10636: Attoyac Bayou at SH 21

- Current instantaneous flow (in cfs) and *E. coli* data were used in the analyses between 07/26/2010 and 08/20/2012.
    - Total number of flow data points expressed in cfs: 62
    - Total number of *E. coli* expressed in MPN/100 mL and corresponding flow in cfs: 62
- Total number of discrete *E. coli* data used (Figure 2a): 62

2.1.2. Data Summary at 15253: Attoyac Bayou at SH 7

- Current instantaneous flow (in cfs) and *E. coli* data were used in the analyses between 07/26/2010 and 08/20/2012.
    - Total number of flow data expressed in cfs: 42
    - Total number of *E. coli* expressed in MPN/100 mL and corresponding flow in cfs: 42
- Total number of discrete *E. coli* data used (Figure 2b): 42

2.1.3. Data Summary at 16076: Attoyac Bayou at US 59

- Current instantaneous flow (in cfs) and *E. coli* data were used in the analyses between 07/26/2010 and 08/20/2012.
    - Total number of flow data expressed in cfs: 10
    - Total number of *E. coli* expressed in MPN/100 mL and corresponding flow in cfs: 5
- Total number of discrete *E. coli* data used: 5
- There was not enough data to perform analyses

2.1.4. Data Summary at 16083: Waffelow Creek at FM 95

- Current instantaneous flow (in cfs) and *E. coli* data were used in the analyses between 07/26/2010 and 08/20/2012.
    - Total number of flow data expressed in cfs: 32
    - Total number of *E. coli* expressed in MPN/100 mL and corresponding flow in cfs: 32
- Total number of discrete *E. coli* data used (Figure 2c): 32

2.1.5. Data Summary at 16084: Terrapin Creek at FM 95

- Current instantaneous flow (in cfs) and *E. coli* data were used in the analyses between 07/26/2010 and 08/20/2012.
    - Total number of flow data expressed in cfs: 37
    - Total number of *E. coli* expressed in MPN/100 mL and corresponding flow in cfs: 37
- Total number of discrete *E. coli* data used (Figure 2d): 37

2.1.6. Data Summary at 20841: Attoyac Bayou at FM 138

- Current instantaneous flow (in cfs) and *E. coli* data were used in the analyses between 07/26/2010 and 08/20/2012.
    - Total number of flow data expressed in cfs: 46
    - Total number of *E. coli* expressed in MPN/100 mL and corresponding flow in cfs: 46
- Total number of discrete *E. coli* data used (Figure 2e): 46

2.1.7. Data Summary at 20842: Attoyac Bayou at US 84

- Current instantaneous flow (in cfs) and *E. coli* data were used in the analyses between 07/26/2010 and 08/20/2012.
    - Total number of flow data expressed in cfs: 28
    - Total number of *E. coli* expressed in MPN/100 mL and corresponding flow in cfs: 28
- Total number of discrete *E. coli* data used (Figure 2f): 28

2.1.8. Data Summary at 20843: Naconiche Creek at FM 95

- Current instantaneous flow (in cfs) and *E. coli* data were used in the analyses between 07/26/2010 and 08/20/2012.

    - Total number of flow data expressed in cfs: 52
    - Total number of *E. coli* expressed in MPN/100 mL and corresponding flow in cfs: 52
- Total number of discrete *E. coli* data used (Figure 2g): 52

2.1.9. Data Summary at 20844: Big Iron Ore Creek at FM 354

- Current instantaneous flow (in cfs) and *E. coli* data were used in the analyses between 07/26/2010 and 08/20/2012.
    - Total number of flow data expressed in cfs: 63
    - Total number of *E. coli* expressed in MPN/100 mL and corresponding flow in cfs: 63
- Total number of discrete *E. coli* data used (Figure 2h): 63

2.1.10. Data Summary at 20845: West Creek at FM 2913

- Current instantaneous flow (in cfs) and *E. coli* data were used in the analyses between 07/26/2010 and 08/20/2012.
    - Total number of flow data expressed in cfs: 46
    - Total number of *E. coli* expressed in MPN/100 mL and corresponding flow in cfs: 46
- Total number of discrete *E. coli* data used (Figure 2i): 46

The *E. coli* loads for all the water quality monitoring stations; 10636 (Figure 2a, Table 2), 15253 (Figure 2b, Table 3), 16083 (Figure 2c, Table 4), 16084 (Figure 2d, Table 5), 20841 (Figure 2e, Table 6), 20842 (Figure 2f, Table 7), 20843 (Figure 2g, Table 8), 20844 (Figure 2h, Table 9), and 20845 (Figure 2i, Table 10) were above the maximum allowable *E. coli* load for high flow, moist conditions, and mid-range or normal conditions. The pollutant load reductions needed to meet instream water quality standards for all of these stations ranged from 87 percentage to not applicable. Not applicable percent reductions indicate no reduction is needed since the actual *E. coli* loads are already within the maximum allowable *E. coli* load using Texas' primary contact recreation standard, which is a geometric mean of 126 CFU/100 mL of *E. coli*.

Table 2. Needed Percent and Daily Loading Reductions for water quality monitoring station 10636: Attoyac Bayou at SH 21.

Flow Condition	% Exceedance	Percent Reduction	Daily Loading Reduction Needed (cfu/day)	Daily Loading (cfu/day)
High Flows	0-10	83	1.00E+13	1.20E+13
Moist Conditions	10-40	68	1.26E+12	1.70E+12
Mid-Range Flows	40-60	48	8.24E+10	1.65E+11
Dry Conditions	60-90	18	1.34E+10	4.25E+10
Low Flows	90-100	N/A	N/A	7.68E+08

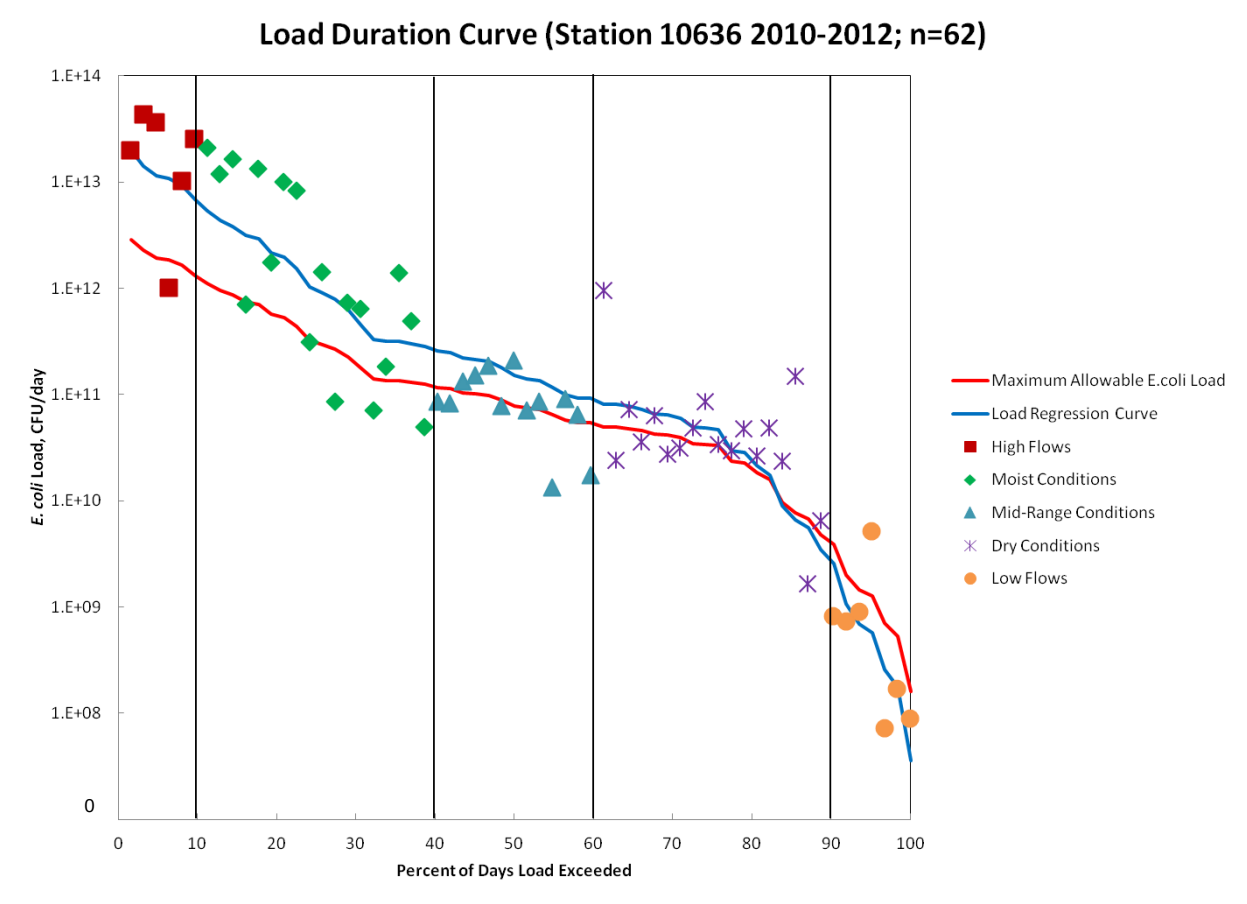

Figure 2a. Load Duration Curve for *E. coli* for water quality monitoring station 10636: Attoyac Bayou at SH 21.

Table 3. Needed Percent and Daily Loading Reductions for water quality monitoring station 15253: Attoyac Bayou at SH7.

Flow Condition	% Exceedance	Percent Reduction	Daily Loading Reduction Needed (cfu/day)	Daily Loading (cfu/day)
High Flows	0-10	49	6.54E+10	1.33E+11
Moist Conditions	10-40	37	2.37E+10	6.16E+10
Mid-Range Conditions	40-60	19	4.52E+09	2.24E+10
Dry Conditions	60-90	N/A	N/A	5.06E+09
Low Flows	90-100	N/A	N/A	5.82E+08

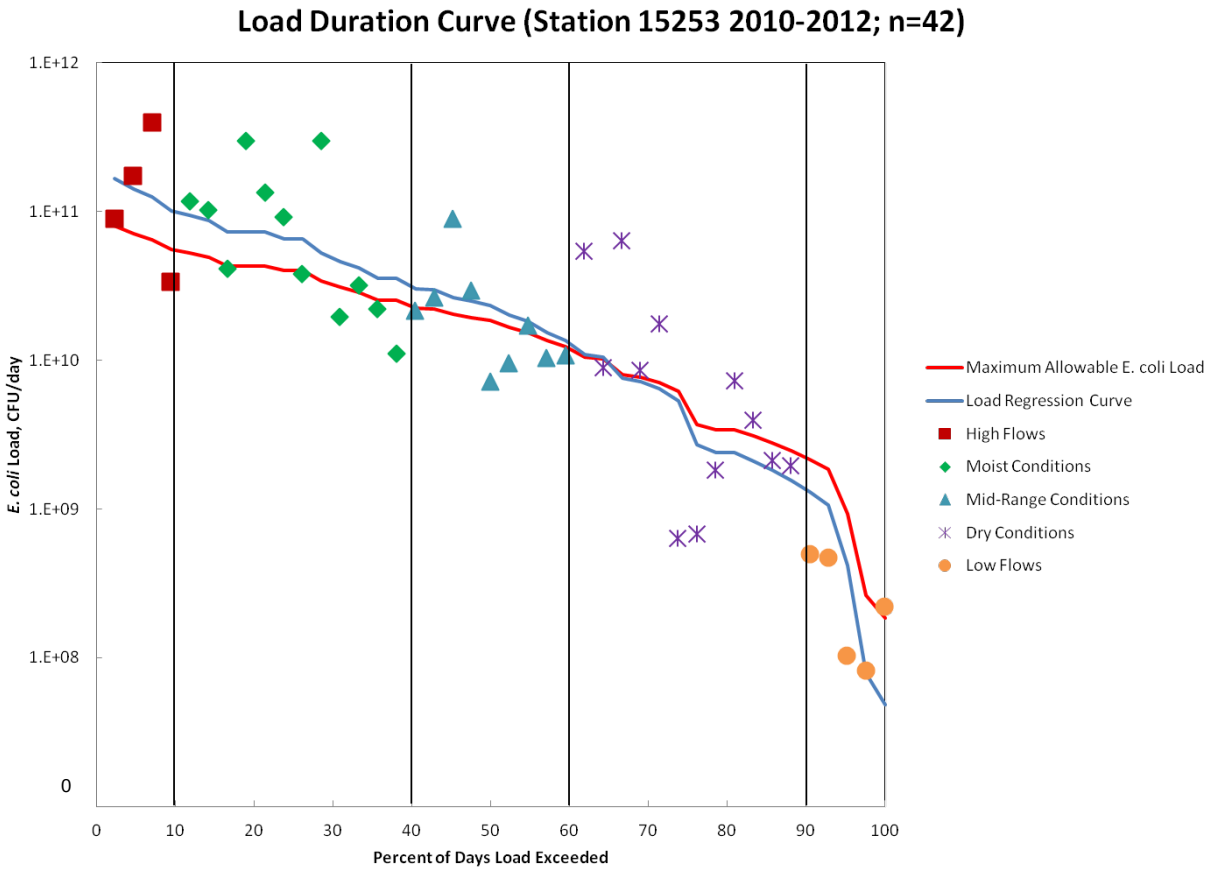

Figure 2b. Load Duration Curve for *E. coli* for water quality monitoring station 15253: Attoyac Bayou at SH 7.

Table 4. Needed Percent and Daily Loading Reductions for water quality monitoring station 16083: Waffelow Creek at FM 95.

Flow Condition	% Exceedance	Percent Reduction	Daily Loading Reduction Needed (cfu/day)	Daily Loading (cfu/day)
High Flows	0-10	62	1.55E+10	2.34E+10
Normal	10-50	5	4.34E+08	1.64E+09

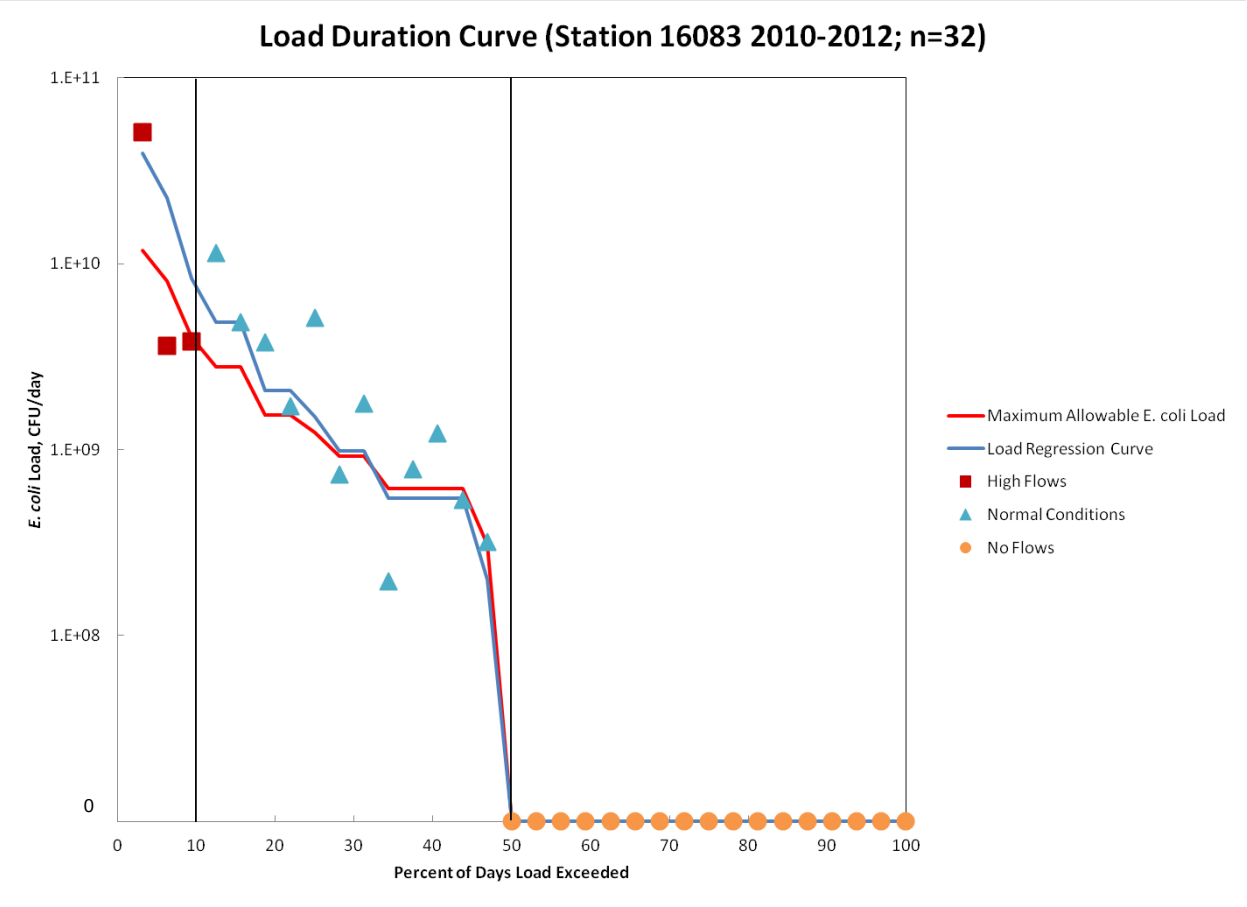

Figure 2c. Load Duration Curve for *E. coli* for water quality monitoring station 16083: Waffelow Creek at FM 95.

Table 5. Needed Percent and Daily Loading Reductions for water quality monitoring station 16084: Terrapin Creek at FM 95.

Flow Condition	% Exceedance	Percent Reduction	Daily Loading Reduction Needed (cfu/day)	Daily Loading (cfu/day)
High Flows	0-10	66	7.61E+10	1.09E+11
Moist Conditions	10-40	54	1.00E+10	1.80E+10
Mid-Range Flows	40-60	44	2.77E+09	6.17E+09
Dry Conditions	60-85	33	1.09E+09	2.96E+09

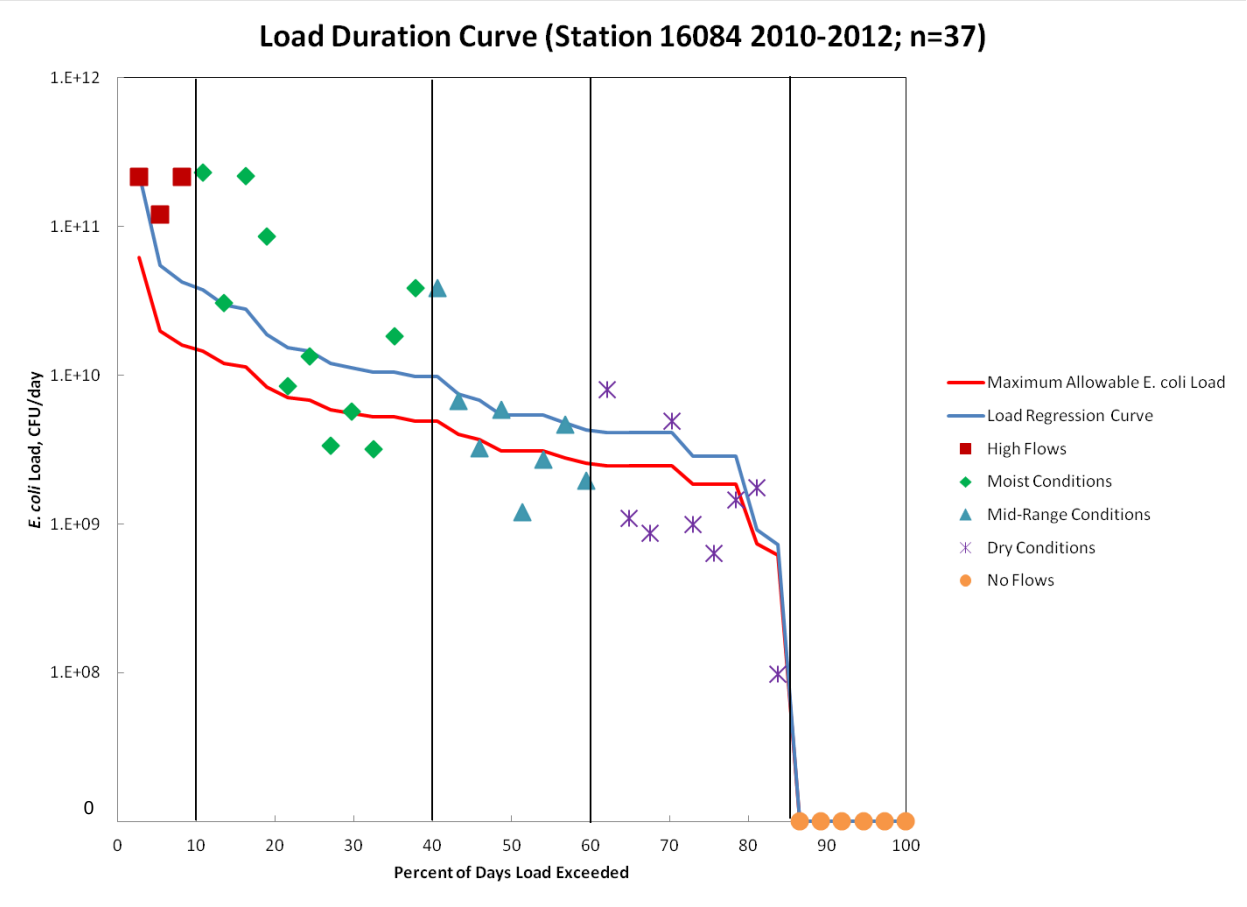

Figure 2d. Load Duration Curve for *E. coli* for water quality monitoring station 16084: Terrapin Creek at FM 95.

Table 6. Needed Percent and Daily Loading Reductions for water quality monitoring station 20841: Attoyac Bayou at FM 138.

Flow Condition	% Exceedance	Percent Reduction	Daily Loading Reduction Needed (cfu/day)	Daily Loading (cfu/day)
High Flows	0-10	82	3.55E+11	4.16E+11
Moist Conditions	10-40	69	3.78E+10	5.15E+10
Mid-Range Flows	40-60	55	5.66E+09	1.00E+10
Dry Conditions	60-76	30	1.09E+09	2.75E+09

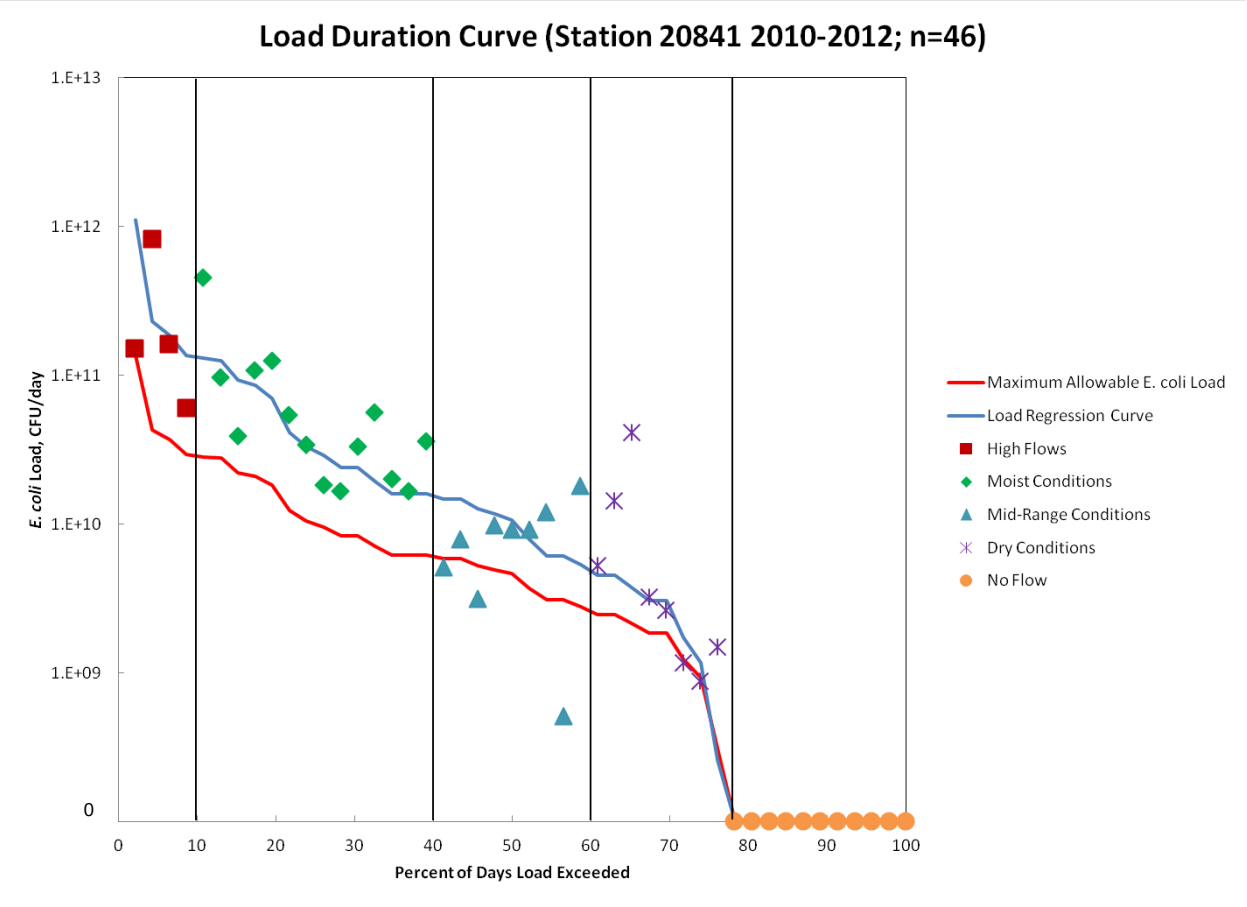

Figure 2e. Load Duration Curve for *E. coli* for water quality monitoring station 20841: Attoyac Bayou at FM 138.

Table 7. Needed Percent and Daily Loading Reductions for water quality monitoring station 20842: Attoyac Bayou at US 84.

Flow Condition	% Exceedance	Percent Reduction	Daily Loading Reduction Needed (cfu/day)	Daily Loading (cfu/day)
Normal Conditions	0-10	32	5.26E+08	1.61E+09

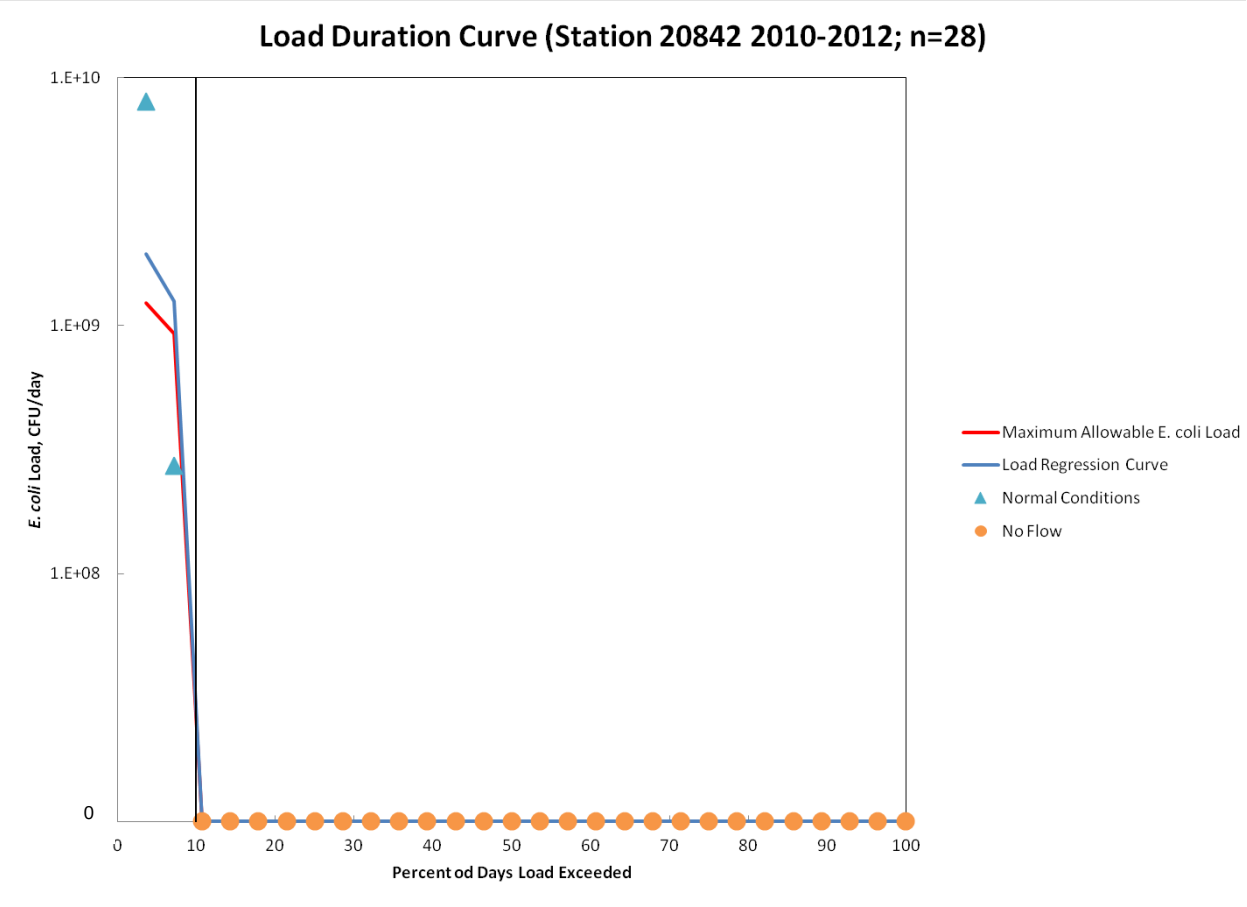

Figure 2f. Load Duration Curve for *E. coli* for water quality monitoring station 20842: Attoyac Bayou at US 84.

Table 8. Needed Percent and Daily Loading Reductions for water quality monitoring station 20843: Naconiche Creek at FM 95.

Flow Condition	% Exceedance	Percent Reduction	Daily Loading Reduction Needed (cfu/day)	Daily Loading (cfu/day)
High Flows	0-10	64	2.04E+11	3.12E+11
Moist Conditions	10-40	47	3.40E+10	6.77E+10
Mid-Range Flows	40-60	29	6.47E+09	1.98E+10
Dry Conditions	60-90	N/A	N/A	3.57E+09
Low Flows	90-98	N/A	N/A	3.29E+08

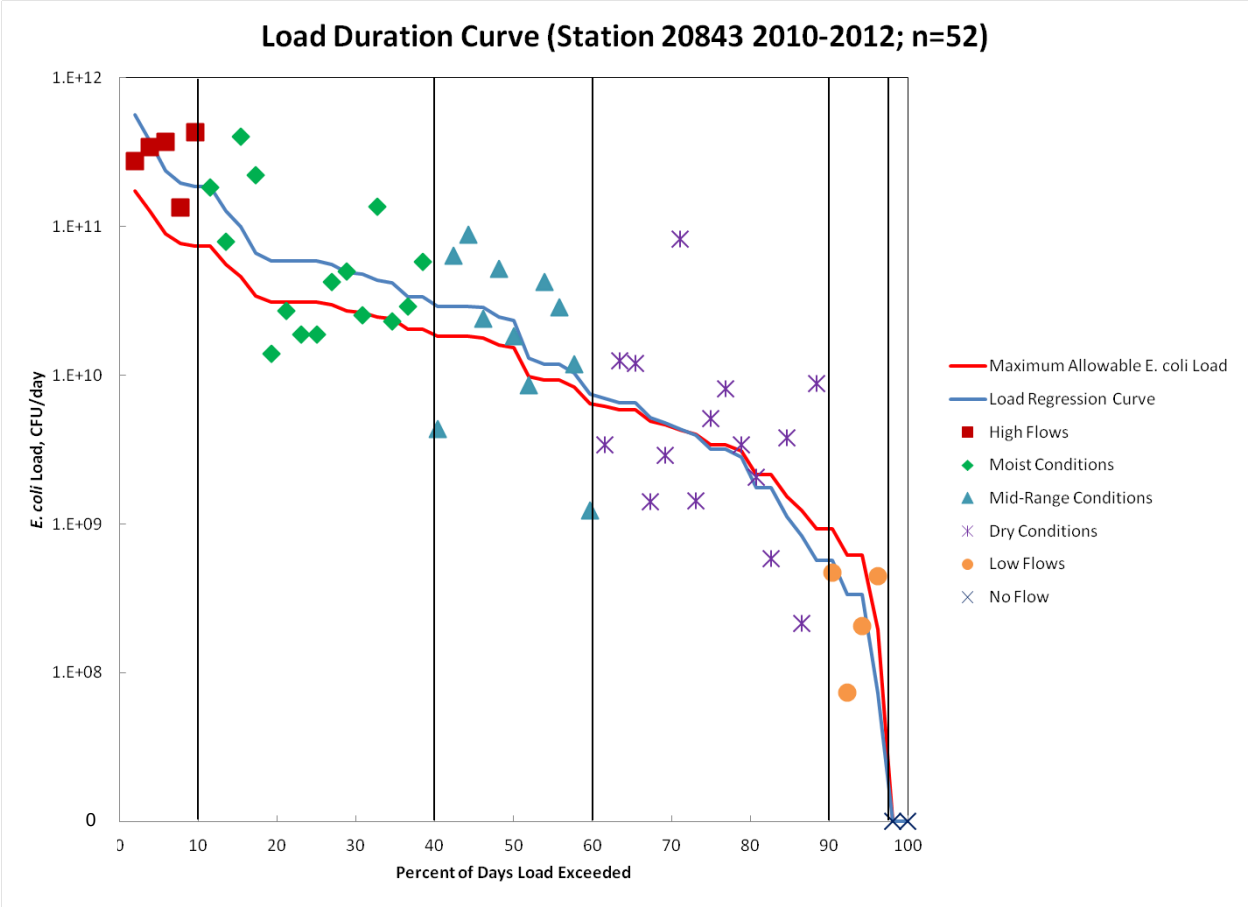

Figure 2g. Load Duration Curve for *E. coli* for water quality monitoring station 20843: Naconiche Creek at FM 95.

Table 9. Needed Percent and Daily Loading Reductions for water quality monitoring station 20844: Big Iron Ore Creek at FM 354.

Flow Condition	% Exceedance	Percent Reduction	Daily Loading Reduction Needed (cfu/day)	Daily Loading (cfu/day)
High Flows	0-10	87	5.70E+12	6.56E+12
Moist Conditions	10-40	80	8.22E+11	9.92E+11
Mid-Range Flows	40-60	74	1.05E+11	1.41E+11
Dry Conditions	60-90	63	1.70E+10	2.54E+10
Low Flows	90-98	21	2.73E+08	6.42E+08

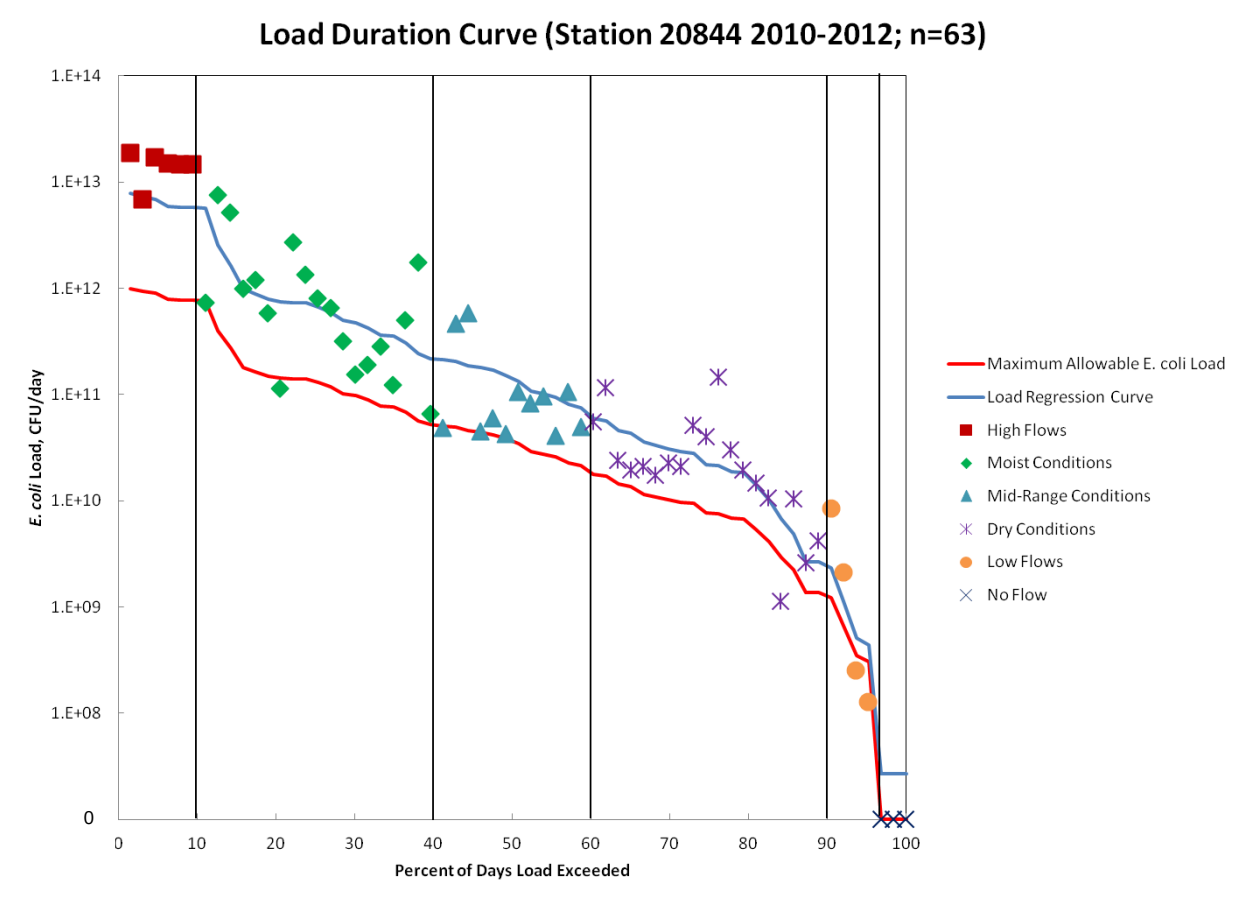

Figure 2h. Load Duration Curve for *E. coli* for water quality monitoring station 20844: Big Iron Ore Creek at FM 354.

Table 10. Needed Percent and Daily Loading Reductions for water quality monitoring station 20845: West Creek at FM 2913.

Flow Condition	% Exceedance	Percent Reduction	Daily Loading Reduction Needed (cfu/day)	Daily Loading (cfu/day)
High Flows	0-10	63	7.73E+10	1.19E+11
Moist Conditions	10-40	49	7.72E+09	1.51E+10
Mid-Range Flows	40-60	34	1.10E+09	2.99E+09
Dry Conditions	60-89	16	1.71E+08	7.56E+08

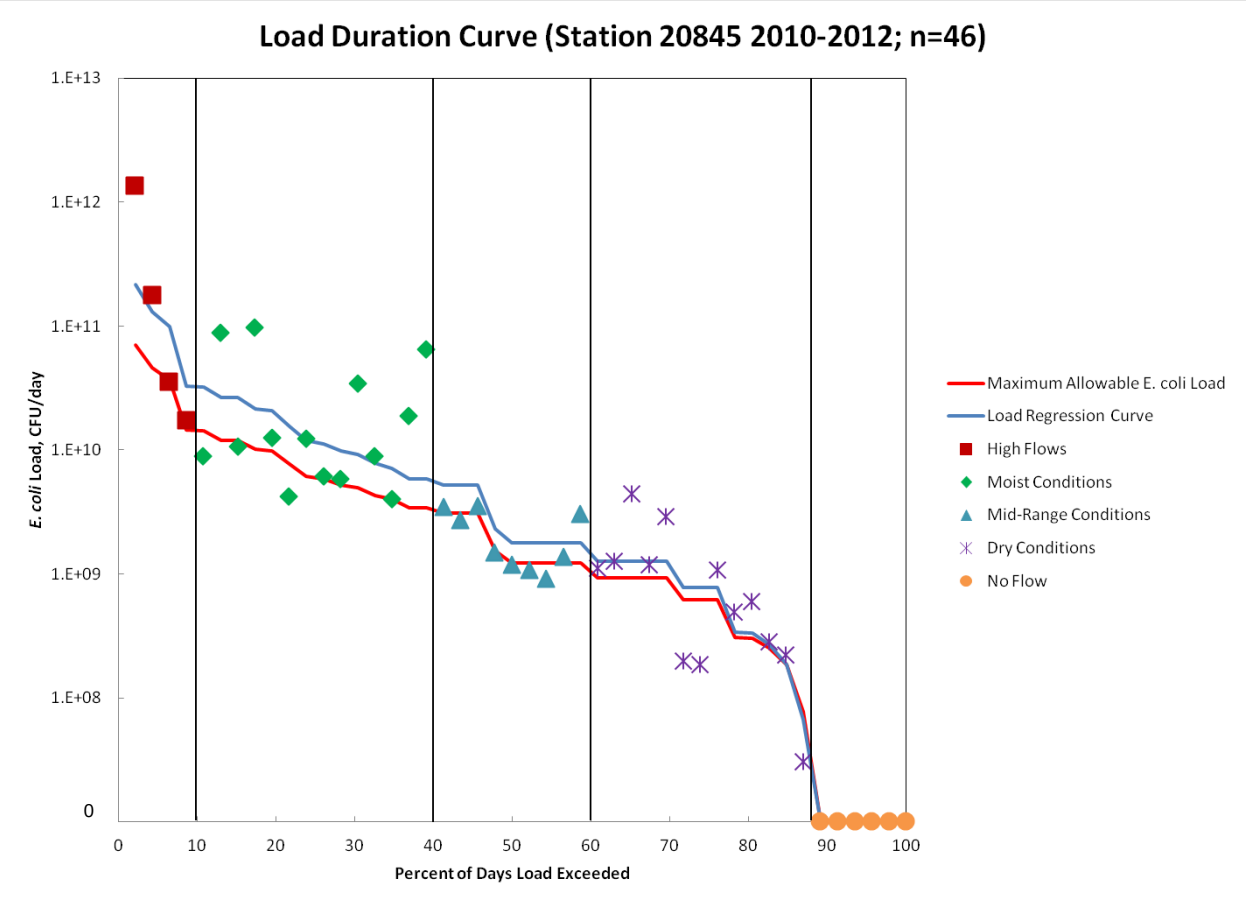

Figure 2i. Load Duration Curve for *E. coli* for water quality monitoring station 20845: West Creek at FM 2913.

2.2. Ammonia LDC analysis

Ten monitoring stations, 10636, 15253, 16076, 16083, 16084, 20841, 20842, 20843, 20844, 20845, are located on Attoyac Bayou (Figure 1). Bi-weekly water quality data were collected from July 26, 2010 to August 20, 2012. Differences in the number of samples available at each site are a result of samples not being taken due to no water being present, stream depth being too great to collect a flow measurement or the presence of unsafe weather conditions. The following summarizes data collection and availability at each sampling site.

2.2.1. Data Summary at 10636: Attoyac Bayou at SH 21

- Current instantaneous flow (in cfs) and ammonia data were used in the analyses between 07/26/2010 and 08/20/2012.
    - Total number of flow data expressed in cfs: 62
    - Total number of ammonia expressed in mg/L and corresponding flow in cfs: 62
- Total number of discrete ammonia data used (Figure 3a): 62

2.1.2. Data Summary at 15253: Attoyac Bayou at SH 7

- Current instantaneous flow (in cfs) and ammonia data were used in the analyses between 07/26/2010 and 08/20/2012.
    - Total number of flow data expressed in cfs: 42
    - Total number of ammonia expressed in mg/L and corresponding flow in cfs: 42
- Total number of discrete ammonia data used (Figure 3b): 42

2.2.3. Data Summary at 16076: Attoyac Bayou at US 59

- Current instantaneous flow (in cfs) and ammonia data were used in the analyses between 07/26/2010 and 08/20/2012.
    - Total number of flow data expressed in cfs: 10
    - Total number of ammonia expressed in mg/L and corresponding flow in cfs: 5
- Total number of discrete ammonia data used: 5
- There was not enough data to perform analyses

2.2.4. Data Summary at 16083: Waffelow Creek at FM 95

- Current instantaneous flow (in cfs) and ammonia data were used in the analyses between 07/26/2010 and 08/20/2012.
    - Total number of flow data expressed in cfs: 32
    - Total number of ammonia expressed in mg/L and corresponding flow in cfs: 32
- Total number of discrete ammonia data used (Figure 3c): 32

2.2.5. Data Summary at 16084: Terrapin Creek at FM 95

- Current instantaneous flow (in cfs) and ammonia data were used in the analyses between 07/26/2010 and 08/20/2012.
    - Total number of flow data expressed in cfs: 37
    - Total number of ammonia expressed in mg/L and corresponding flow in cfs: 37
- Total number of discrete ammonia data used (Figure 3d): 37

2.1.6. Data Summary at 20841: Attoyac Bayou at FM 138

- Current instantaneous flow (in cfs) and ammonia data were used in the analyses between 07/26/2010 and 08/20/2012.
    - Total number of flow data expressed in cfs: 46
    - Total number of ammonia expressed in mg/L and corresponding flow in cfs: 46
- Total number of discrete ammonia data used (Figure 3e): 46

2.2.7. Data Summary at 20842: Attoyac Bayou at US 84

- Current instantaneous flow (in cfs) and ammonia data were used in the analyses between 07/26/2010 and 08/20/2012.
    - Total number of flow data expressed in cfs: 28
    - Total number of ammonia expressed in mg/L and corresponding flow in cfs: 28
- Total number of discrete ammonia data used (Figure 3f): 28

2.2.8. Data Summary at 20843: Naconiche Creek at FM 95

- Current instantaneous flow (in cfs) and ammonia data were used in the analyses between 07/26/2010 and 08/20/2012.
    - Total number of flow data expressed in cfs: 52
    - *Total number of ammonia expressed in mg/L and corresponding flow in cfs: 52*
- *Total number of discrete ammonia data used (Figure 3g): 52*

2.2.9. Data Summary at 20844: Big Iron Ore Creek at FM 354

- Current instantaneous flow (in cfs) and ammonia data were used in the analyses between 07/26/2010 and 08/20/2012.
    - Total number of flow data expressed in cfs: 63
    - Total number of ammonia expressed in mg/L and corresponding flow in cfs: 63
- Total number of discrete ammonia data used (Figure 3h): 63

2.2.10. Data Summary at 20845: West Creek at FM 2913

- Current instantaneous flow (in cfs) and *Ammonia* data were used in the analyses between 07/26/2010 and 08/20/2012.
    - Total number of flow data expressed in cfs: 46
    - Total number of Ammonia expressed in mg/L and corresponding flow in cfs: 46
- Total number of discrete Ammonia data used (Figure 2i): 46

The actual ammonia loads for all the water quality monitoring stations; 10636 (Figure 3a, Table 11), 15253 (Figure 3b, Table 12), 16083 (Figure 3c, Table 13), 16084 (Figure 3d, Table 14), 20841 (Figure 3e, Table 15), 20842 (Figure 3f, Table 16), 20843 (Figure 3g, Table 17) , 20844 (Figure 3h, Table 18) and 20845 (Figure 3i, Table 19) were below the current screening level for ammonia established by TCEQ for all flow conditions. The percent reductions for all of these sites are not applicable since the actual ammonia loads are below the ammonia screening level of 0.33 mg/L.

Table 11. Daily ammonia loads and needed percent reductions for water quality monitoring station 10636: Attoyac Bayou at SH 21.

Flow Condition	% Exceedance	Percent Reduction Needed	Daily Loading (g/day)
High Flows	0-10	N/A	1.96E+05
Moist Conditions	10-40	N/A	6.85E+04
Mid-Range Flows	40-60	N/A	1.18E+04
Dry Conditions	60-90	N/A	5.77E+03
Low Flows	90-100	N/A	3.28E+03

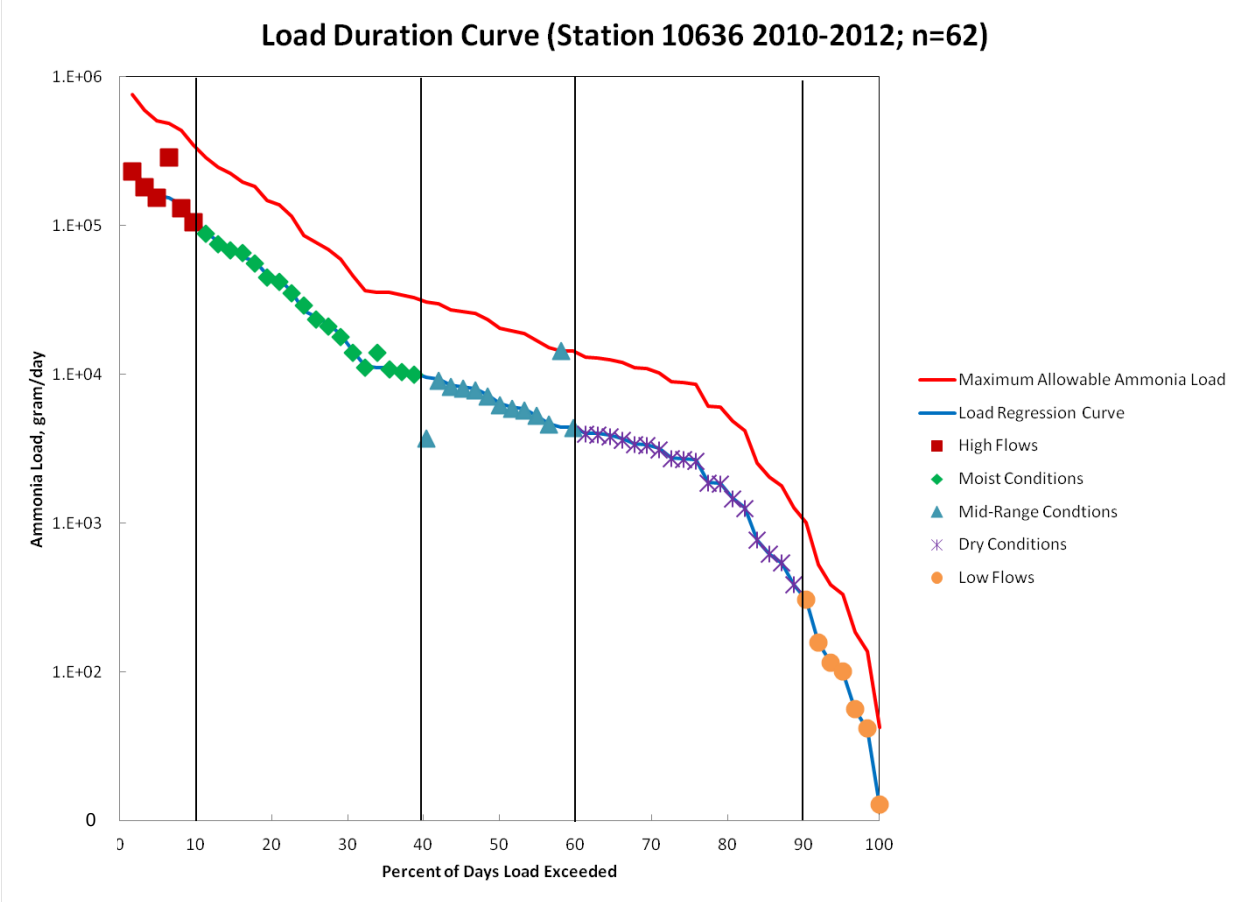

Figure 3a. Load Duration Curve for ammonia for water quality monitoring station 10636: Attoyac Bayou at SH 21.

Table 12. Daily ammonia loads and needed percent reductions for water quality monitoring station 15253: Attoyac Bayou at SH 7.

Flow Condition	% Exceedance	Percent Reduction Needed	Daily Loading (g/day)
High Flows	0-10	N/A	4785
Moist Conditions	10-40	N/A	2961
Mid-Range Flows	40-60	N/A	1598
Dry Conditions	60-90	N/A	616
Low Flows	90-100	N/A	152

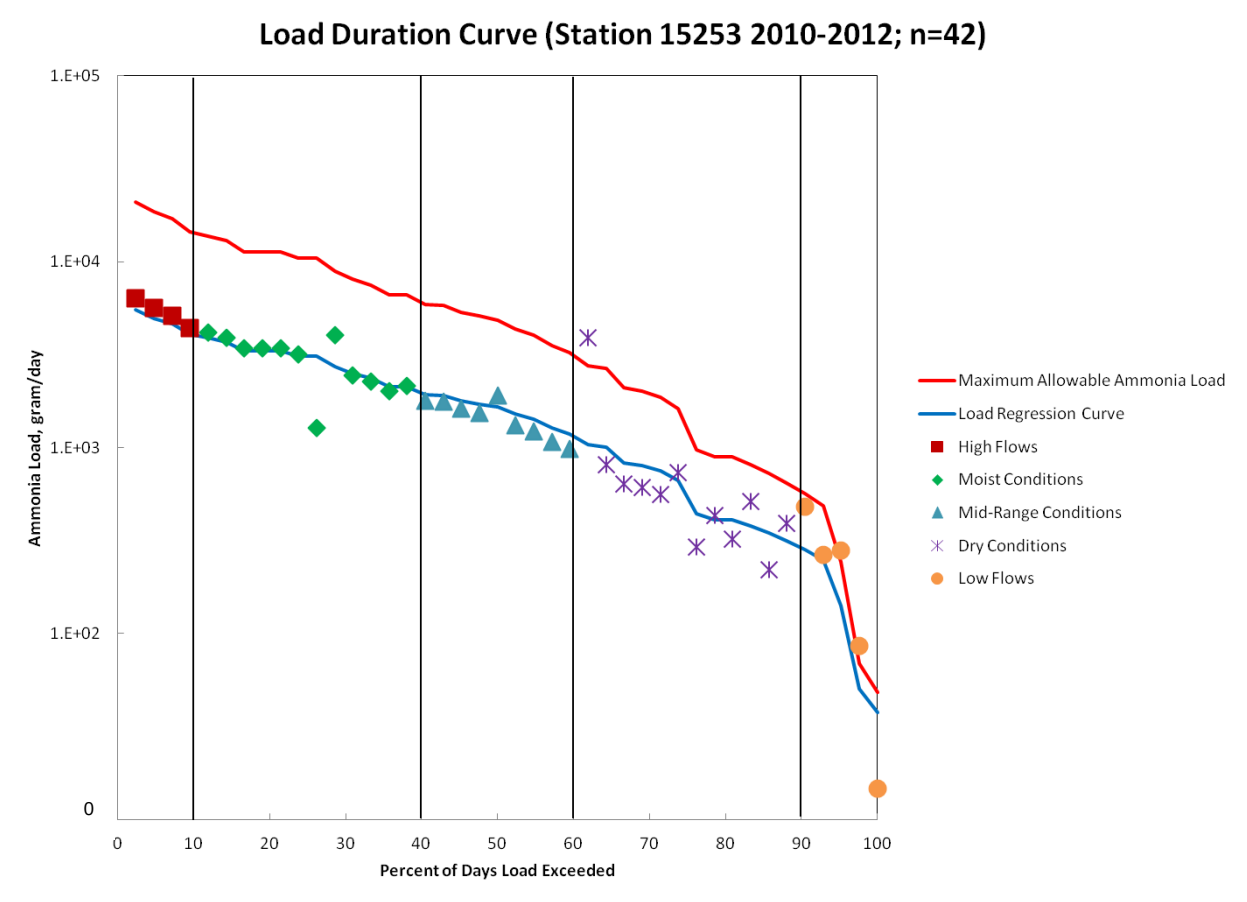

Figure 3b. Load Duration Curve for ammonia for water quality monitoring station 15253: Attoyac Bayou at SH 7.

Table 13. Daily ammonia loads and needed percent reductions for water quality monitoring station 16083: Waffelow Creek at FM 95.

Flow Condition	% Exceedance	Percent Reduction Needed	Daily Loading (g/day)
High Flows	0-10	N/A	1.18E+03
Normal	10-50	N/A	178

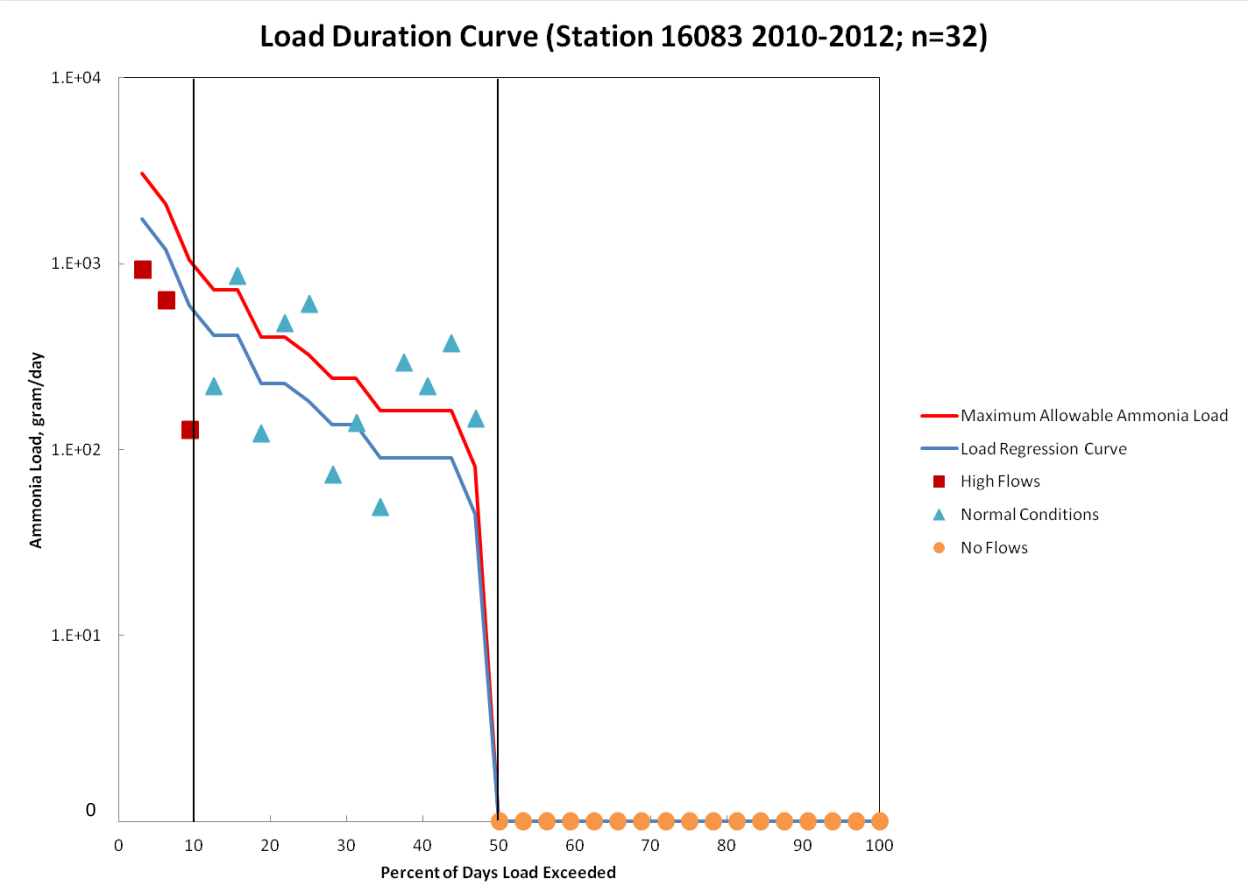

Figure 3c. Load Duration Curve for ammonia for water quality monitoring station 16083: Waffelow Creek at FM 95.

Table 14. Daily ammonia loads and needed percent reductions for water quality monitoring station 16084: Terrapin Creek at FM 95.

Flow Condition	% Exceedance	Percent Reduction Needed	Daily Loading (g/day)
High Flows	0-10	N/A	3.45E+03
Moist Conditions	10-40	N/A	9.04E+02
Mid-Range Flows	40-60	N/A	4.06E+02
Dry Conditions	60-85	N/A	2.28E+02

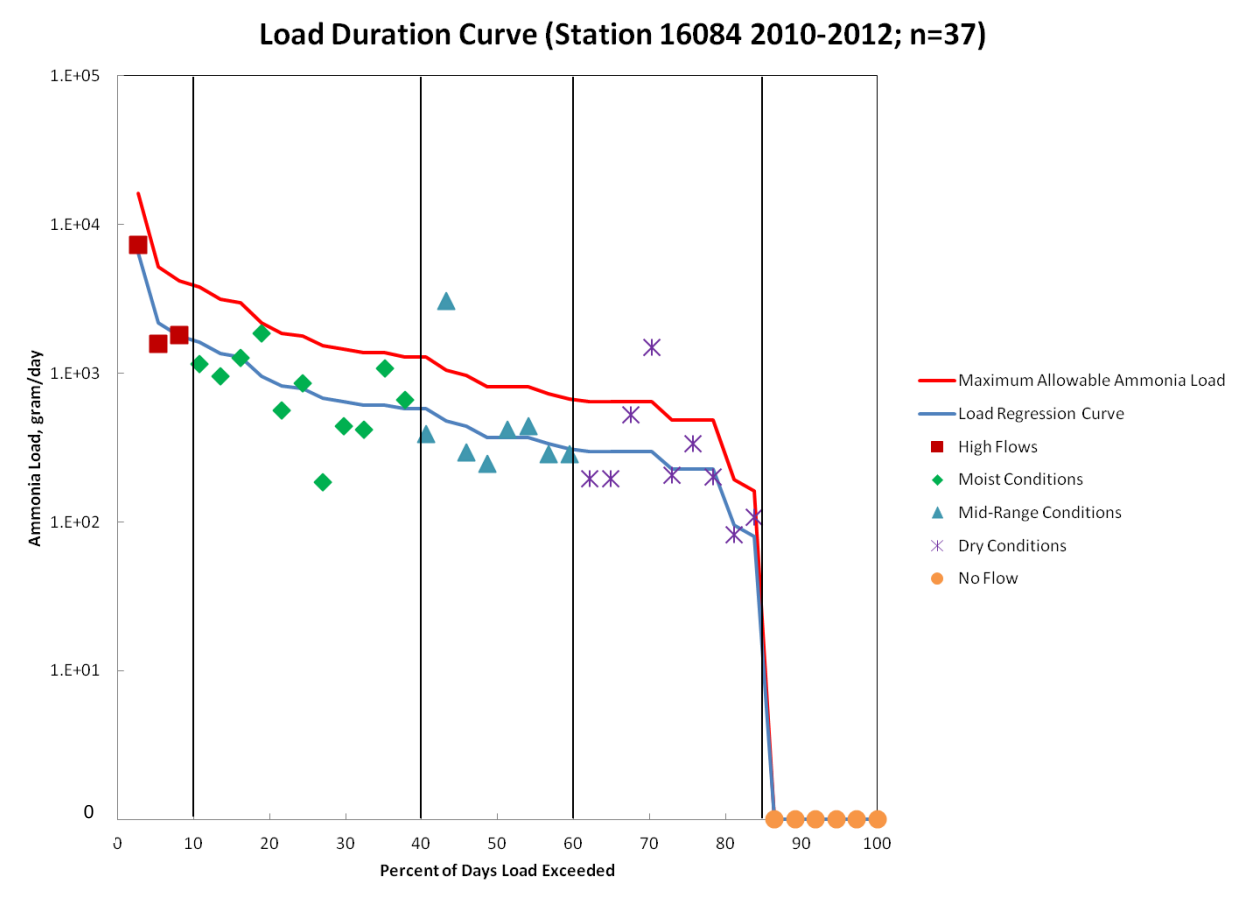

Figure 3d. Load Duration Curve for ammonia for water quality monitoring station 16084: Terrapin Creek at FM 95.

Table 15. Daily ammonia loads and needed percent reductions for water quality monitoring station 20841: Attoyac Bayou at FM 138.

Flow Condition	% Exceedance	Percent Reduction Needed	Daily Loading (g/day)
High Flows	0-10	N/A	4282
Moist Conditions	10-40	N/A	1154
Mid-Range Flows	40-60	N/A	425
Dry Conditions	60-76	N/A	180

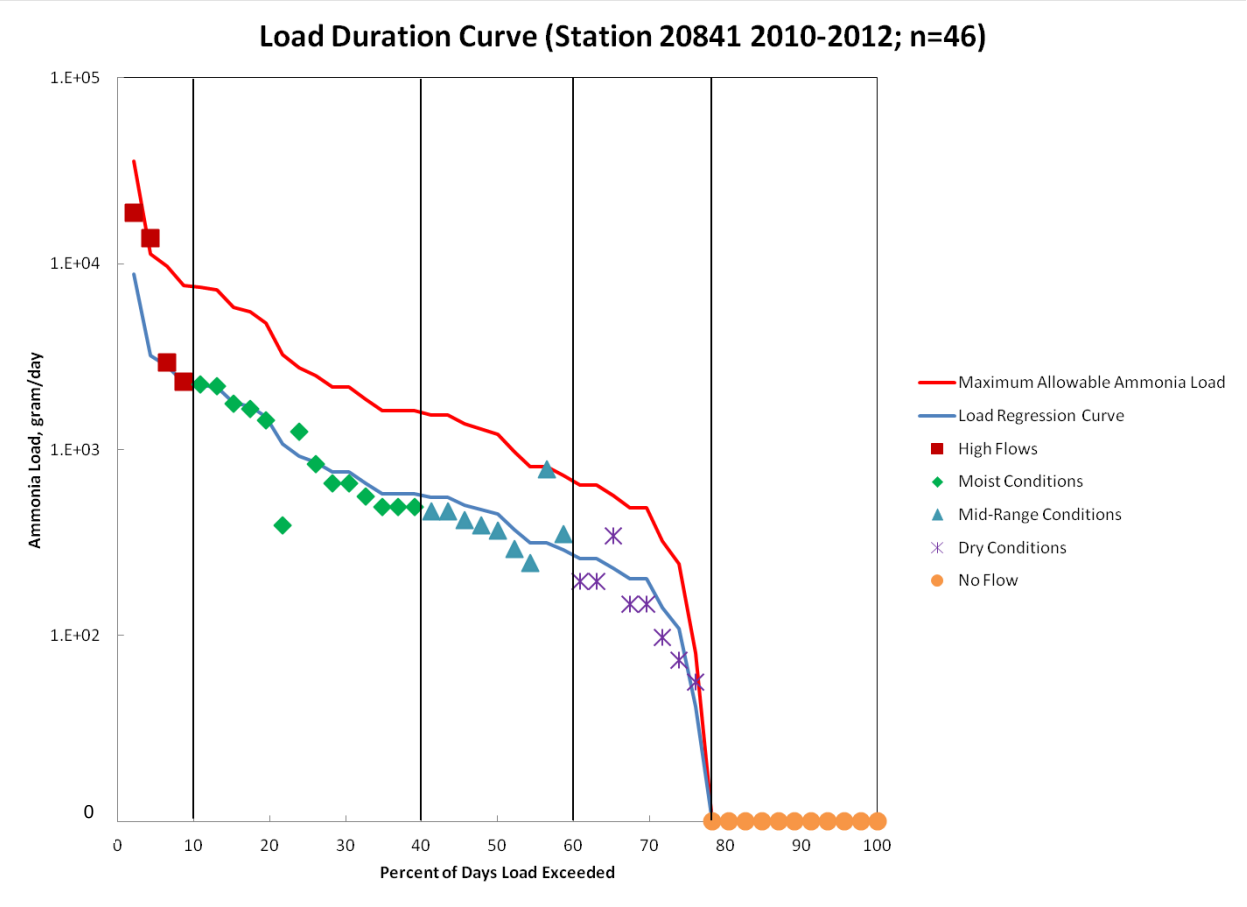

Figure 3e. Load Duration Curve for *E. coli* for water quality monitoring station 20841: Attoyac Bayou at FM 138.

Table 16. Daily ammonia loads and needed percent reductions for water quality monitoring station 20842: Attoyac Bayou at US 84.

Flow Condition	% Exceedance	Percent Reduction Needed	Daily Loading (g/day)
Normal Conditions	0-10	N/A	85.2586

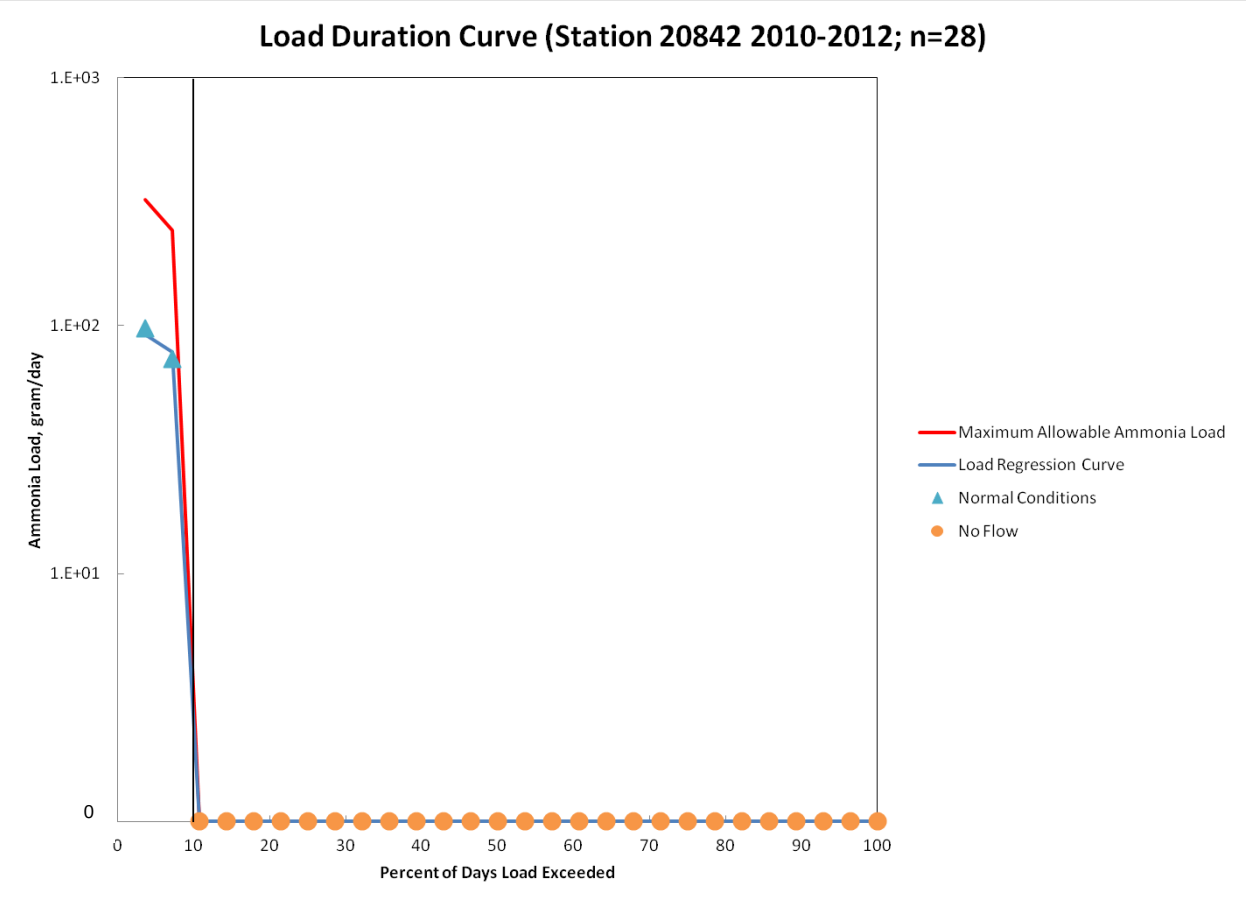

Figure 3f. Load Duration Curve for ammonia for water quality monitoring station 20842: Attoyac Bayou at US 59.

Table 17. Daily ammonia loads and needed percent reductions for water quality monitoring station 20843: Naconiche Creek at FM 95.

Flow Condition	% Exceedance	Percent Reduction Needed	Daily Loading (g/day)
High Flows	0-10	N/A	7649
Moist Conditions	10-40	N/A	2712
Mid-Range Flows	40-60	N/A	1193
Dry Conditions	60-90	N/A	367
Low Flows	90-98	N/A	74

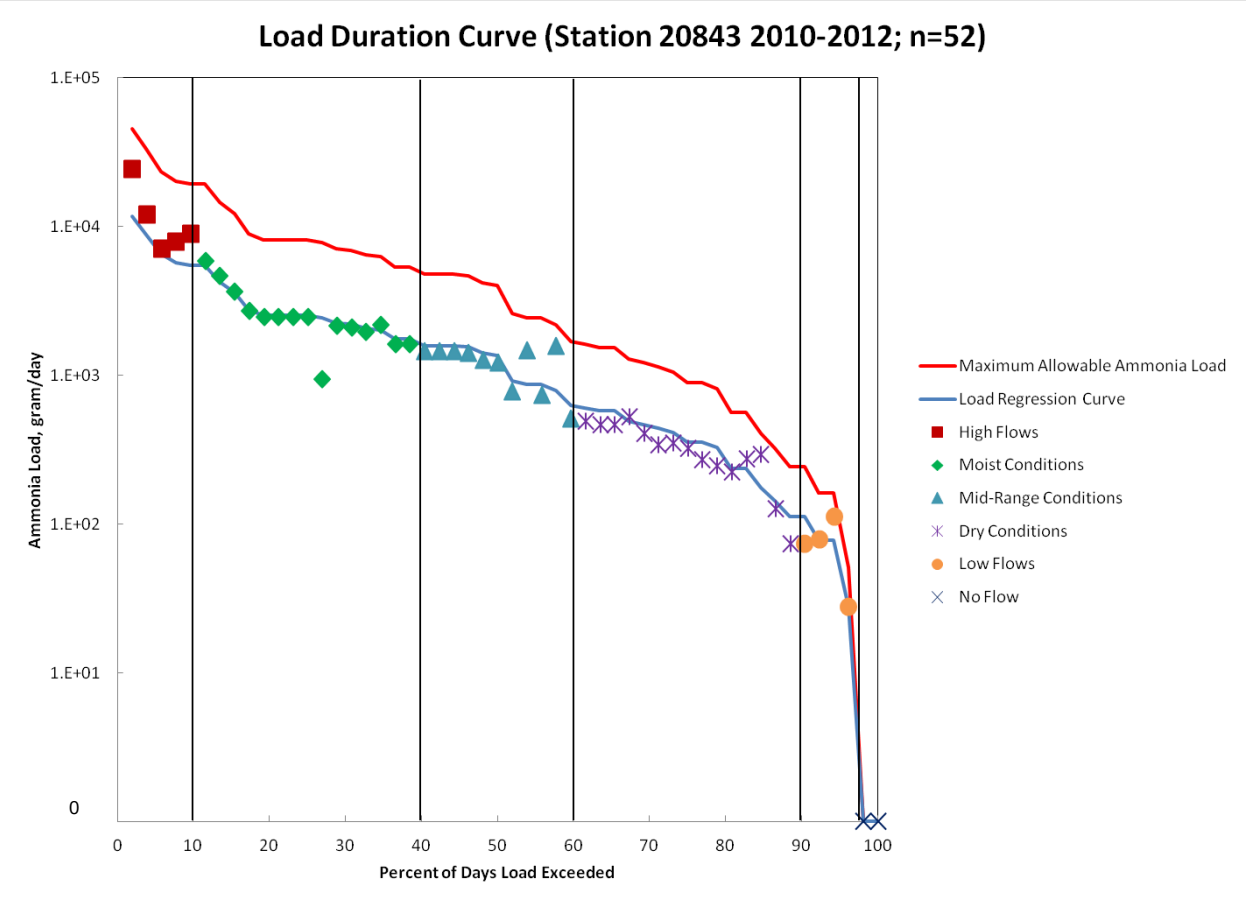

Figure 3g. Load Duration Curve for ammonia for water quality monitoring station 20843: Naconiche Creek at FM 95.

Table 18. Daily ammonia loads and needed percent reductions for water quality monitoring station 20844: Big Iron Ore Creek at FM 354.

Flow Condition	% Exceedance	Percent Reduction Needed	Daily Loading (g/day)
High Flows	0-10	N/A	6.68E+04
Moist Conditions	10-40	N/A	1.38E+04
Mid-Range Flows	40-60	N/A	3.09E+03
Dry Conditions	60-90	N/A	7.62E+02
Low Flows	90-98	N/A	3.71E+01

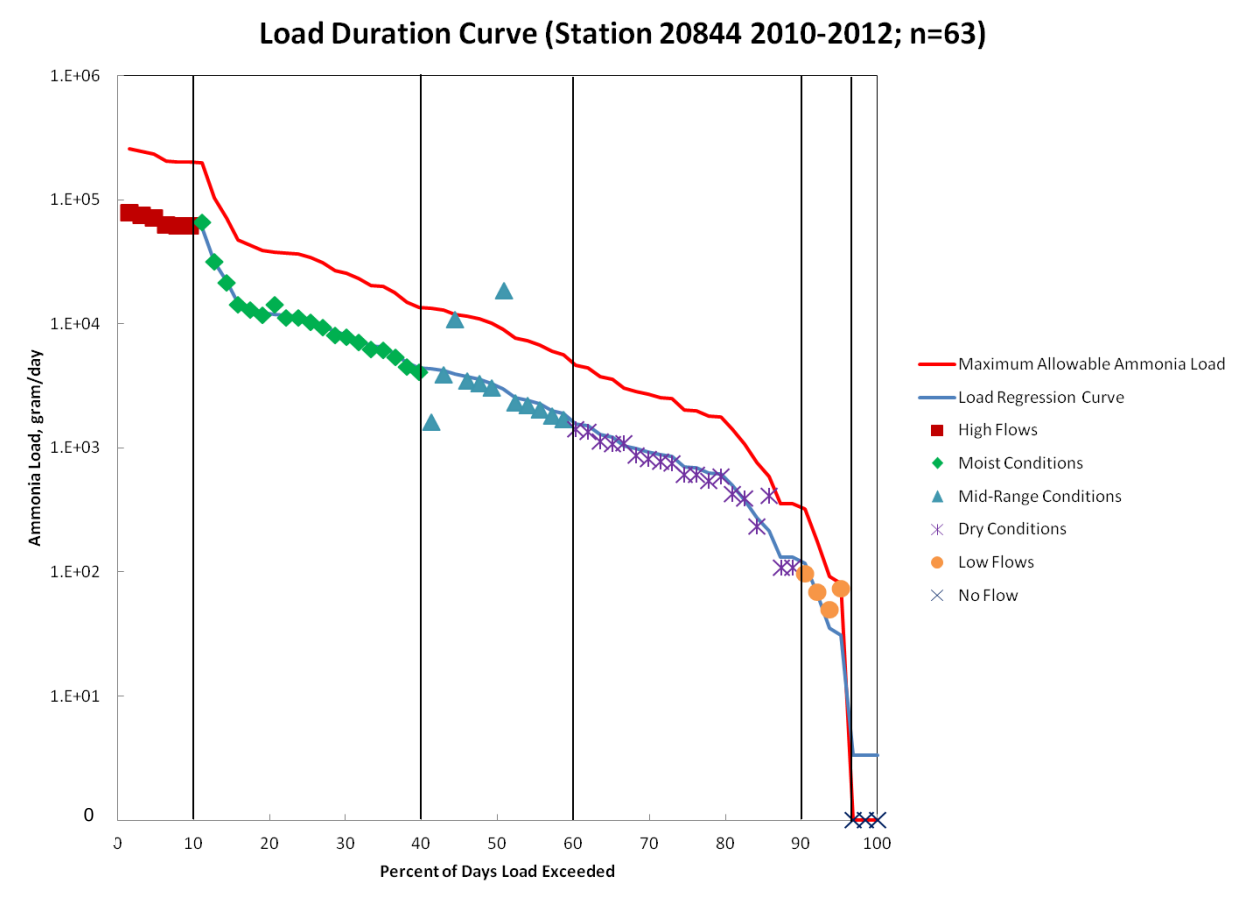

Figure 3h. Load Duration Curve for ammonia for water quality monitoring station 20844: Big Iron Ore Creek at FM 354.

Table 19. Needed Percent and Daily Loading Reductions for water quality monitoring station 20845: West Creek at FM 2913.

Flow Condition	% Exceedance	Percent Reduction Needed	Daily Loading (g/day)
High Flows	0-10	N/A	3.29E+03
Moist Conditions	10-40	N/A	5.92E+02
Mid-Range Flows	40-60	N/A	1.54E+02
Dry Conditions	60-89	N/A	4.87E+01

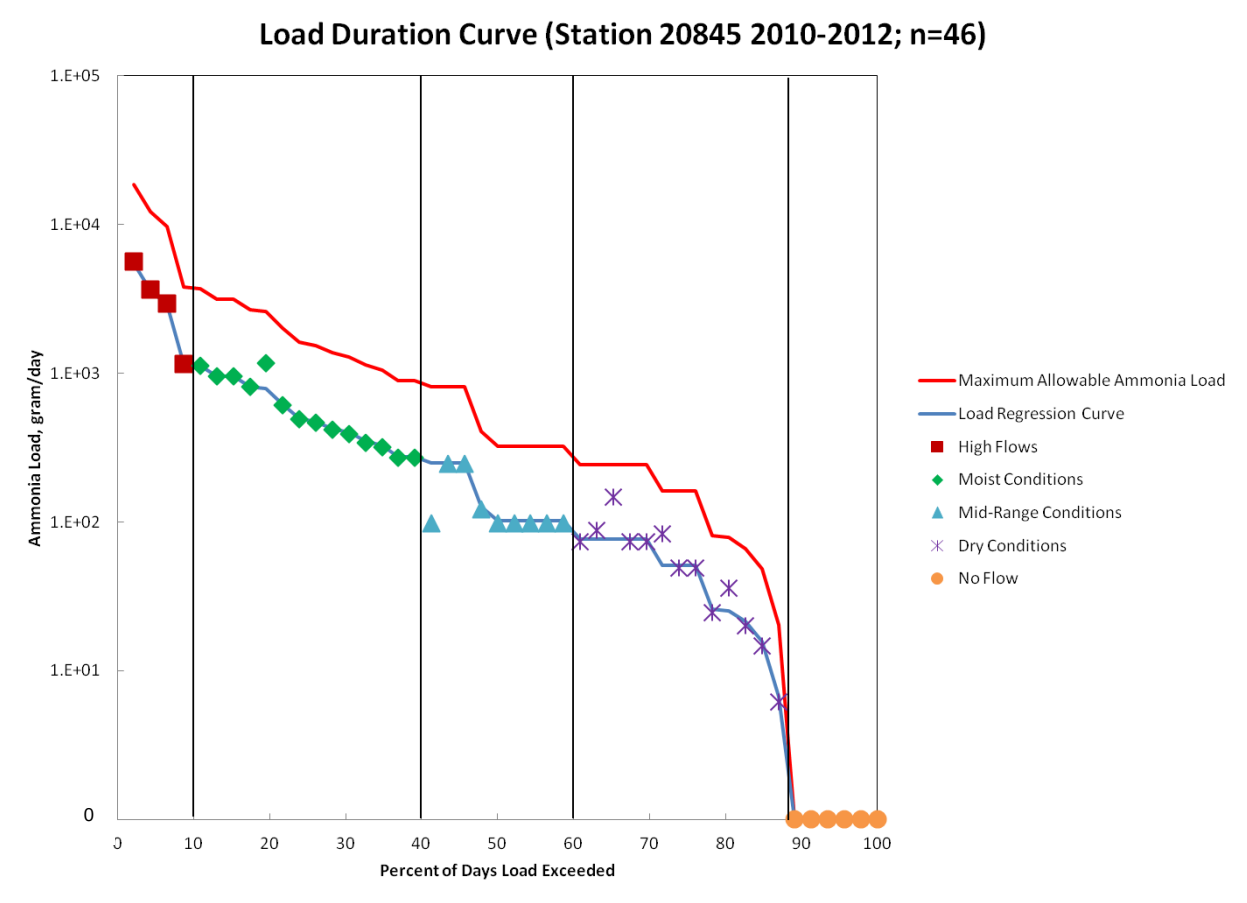

Figure 3i. Load Duration Curve for ammonia for water quality monitoring station 20845: West Creek at FM 2913.

3. SUMMARY

Using available water quality and stream flow data, load duration curves were developed to evaluate existing loads of ammonia and *E. coli* in the Attoyac Bayou and its tributaries. Load reductions needed to bring the existing load to the state's primary contact recreation standard were calculated based on these load duration curves. *E. coli* loads exceeded the water quality standard in all cases where stream flow was present. It should be noted that the geometric means of water quality data collected during the course of this project do not support the primary contact recreation standard, but will support the secondary contact recreation 1 standard (630 cfu/100mL) should it be designated for the water body in the future..

Alternatively, load duration curve analysis showed no ammonia loads above the current ammonia screening level. Several individual water samples did yield ammonia results higher than the screening level; however, the average levels within flow categories remains under the screening level.

3.1. Load Duration Curve Analysis

1. The *E. coli* loads are exceeding for high flows, moist conditions, and mid-range conditions or normal conditions for all of the stations exhibiting those types of flow.
2. Abnormally dry conditions during 2011 led to many monitoring locations going dry for a portion of time. This led to no flow conditions being documented in the load duration curves.
3. Load reductions are needed at each site to for *E. coli* loads to meet the contact recreation standard.
4. Load duration curve analysis indicates that nonpoint source pollution is likely the primary contributor of *E. coli* to the stream.
5. The ammonia loads for all water quality monitoring stations are below the screening level for all flow conditions.
6. No load reductions are needed for ammonia.

4. REFERENCES

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