Shoal Creek Watershed Action Plan
Final Modeling Report

Prepared in cooperation with the Texas Commission on Environmental Quality
and the U.S. Environmental Protection Agency

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Table of Contents

List of Maps

List of Figures

List of Tables

EXECUTIVE SUMMARY

The modeling report presents the data sources, modeling approach, hydrologic data, computed loads, and load reductions for a potential management strategy as modeled by the SELECT (Systems Effectiveness and Life Cycle Costs Tooll) and the LDC (Load Duration Curves) for total suspended solids, total phosphorus, total nitrogen, and bacteria. The models were applied to existing and future land use conditions in the Shoal Creek watershed and will serve as a key tool in evaluating water quality management strategies in the preparation of the Watershed Protection Plan (WPP). Existing and future pollutant loads were modeled by SELECT for each of the 12 subareas and are summarized in the report tables. Load duration curves were developed at the 12th Street stream gage on Shoal Creek were data was obtained from the United States Geological Survey and the City of Austin. LoadEST, a United States Geological Survey (USGS) program was used to determine the total instream pollutant load for the watershed. Results from SELECT and LoadEST were used to calculate load reductions from BMPs that are not adjacent to the creek to account for the natural processes that occur between the BMP and waterbody. SELECT determines total source load and a ratio between source and instream load was developed through the use of LoadEST.

National pollutant data was compared to the local City of Austin (COA) data to compare loads and potential best management practice (BMP) performance. Based on the extensive local data and data management procedures, it is recommended to use the COA data in further analyses.

The WPP stakeholder process will begin the development and evaluation of various management strategies to determine their effectiveness and ability to meet stakeholder goals and or state standards. In this process, the SELECT model will be used to define load reductions due to potential management activities and then the findings will be applied to the Load Duration Curves to illustrate water quality improvements and their potential ability to meet watershed improvement goals.

Modeling performed during the evaluation of various water quality management strategies and in the preparation of the WPP will be fully documented in the Final Modeling Report. This report will provide documentation of causes and sources of pollution for current and future watershed conditions (Element A), estimate load reductions from potential management strategies (Element B), and provide a description of management strategies and their performance (Element C).

1.0 INTRODUCTION

Water quality modeling was performed to help define the current water quality conditions and begin the process of assessing management measure benefits to help craft the Watershed Protection Plan (WPP).

The primary role of the modeling effort is to quantify source and instream loadings for the current and future watershed conditions along with identifying needed load reductions to meet state and stakeholder identified water quality goals. In addition, future modeling tasks will work hand-in-hand with watershed planning to identify needed NPS management measures, their availability, and implementation areas to achieve water quality standards or the stakeholder goals.

The modeling assessed total suspended solids (TSS), nutrients (total nitrogen and total phosphorus), and bacteria.

The project team, including the City of Austin, evaluated potential models and tools to meet the project goals and work within the project budget. The Texas Commission on Environmental Quality (TCEQ) staff supported the use of the Systems Effectiveness and Life Cycle Costs Tool (SELECT), Load Duration Curves (LDC) and LoadEST.

Monitoring data used in this project was acquired from the National Climactic Data Center (NCDC), Texas Water Development Board (TWDB), United States Geological Survey (USGS),and the City of Austin. Data use included:

- LDCs
    - Daily average stream flow
    - E. *coli* and fecal coliform
    - TSS
    - Total Nitrogen
    - Total Phosphorus

- SELECT
    - Precipitation
    - Evaporation
    - Current and Future Land Use
    - Bioretention BMP assessment

2.0 WATERSHED DESCRIPTION

Stretching from north to central Austin, the Shoal Creek watershed has an area of 8,300 acres, a length of 16 miles, and includes more than 30 miles of streams. Once home to popular swimming and fishing destinations, the creek suffers from poor water quality, including elevated fecal bacteria and nutrient levels. Since 2002, elevated bacteria concentrations have been found in a tributary to Shoal Creek, the Spicewood Tributary (Segment 1403J), which is currently listed as impaired for bacteria the Draft 2016 Texas Integrated Report of Surface Water Quality, as well as a concern for nitrate. In 2012, a Total Maximum Daily Load (TMDL) was developed to address bacteria and to evaluate attainment of the contact recreation use in Waller Creek, Walnut Creek, Spicewood Tributary on Shoal Creek and Taylor Slough South. TMDL compliance is based on maintaining bacteria mean concentrations below 126 MPN/100 mL (TCEQ, 2015). Water quality monitoring shows that bacteria in Shoal Creek often exceeds these levels and storm flows also have high levels of nutrients, sediments, and other contaminants.

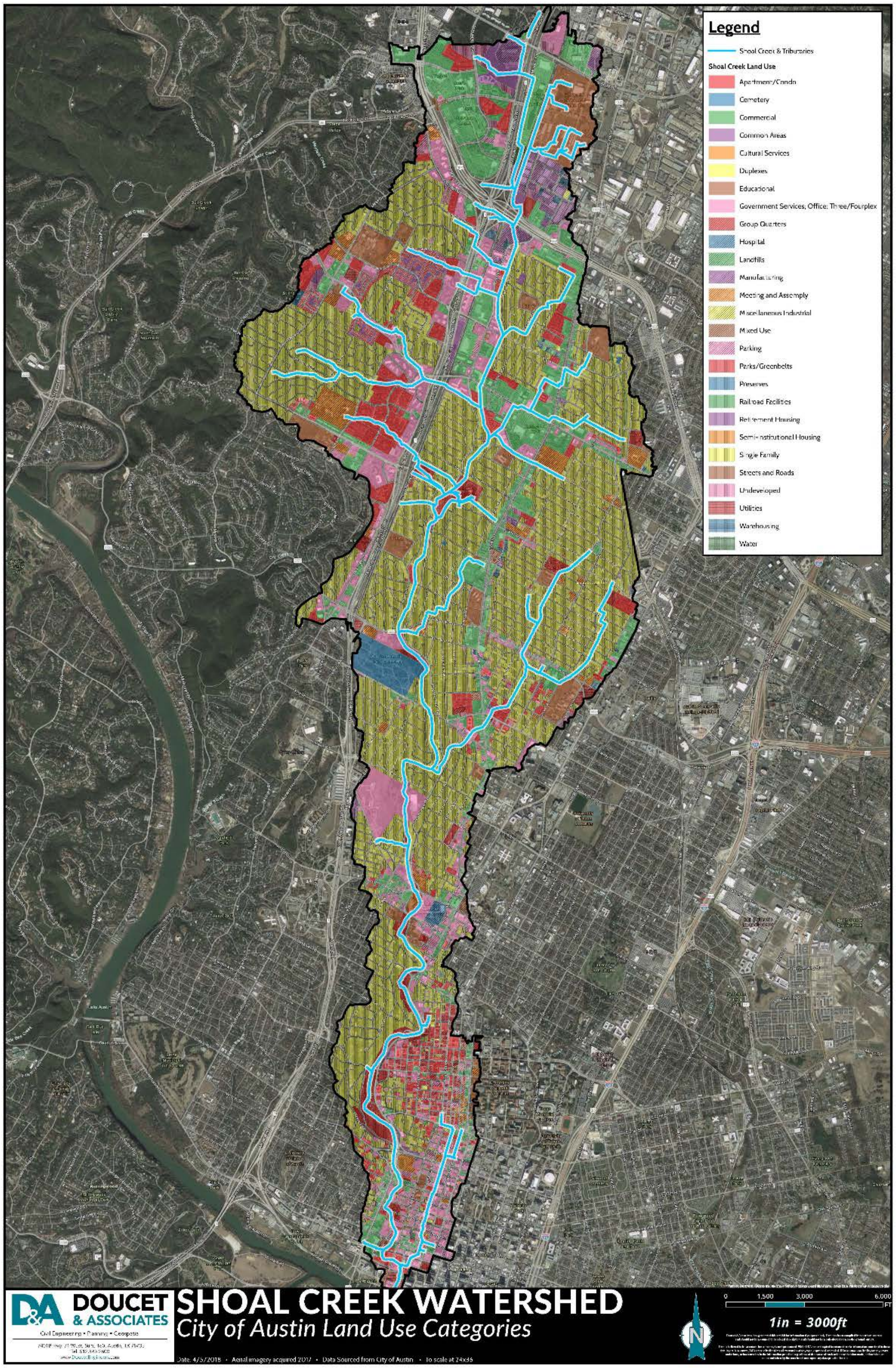
The Shoal Creek watershed is highly impervious and was developed prior to a modern understanding of the impact of development on watershed systems. This combination presents special challenges and requires a multifaceted approach to restoring water quality. The watershed is the fourth most impervious watershed in the city, with approximately 54% of the watershed surfaced in impervious cover. Based on a City of Austin Watershed Protection Department (COA-WPD) analysis, Shoal Creek watershed could reach approximately 64% impervious cover if each site is developed to maximum allowed impervious cover (COA-WPD, 2018). However, new development will be subject to the COA Watershed Ordinance water quality treatment requirements and will minimize the increase in future pollutant load as a result of land use change.

3.0 LAND USE AND LAND COVER

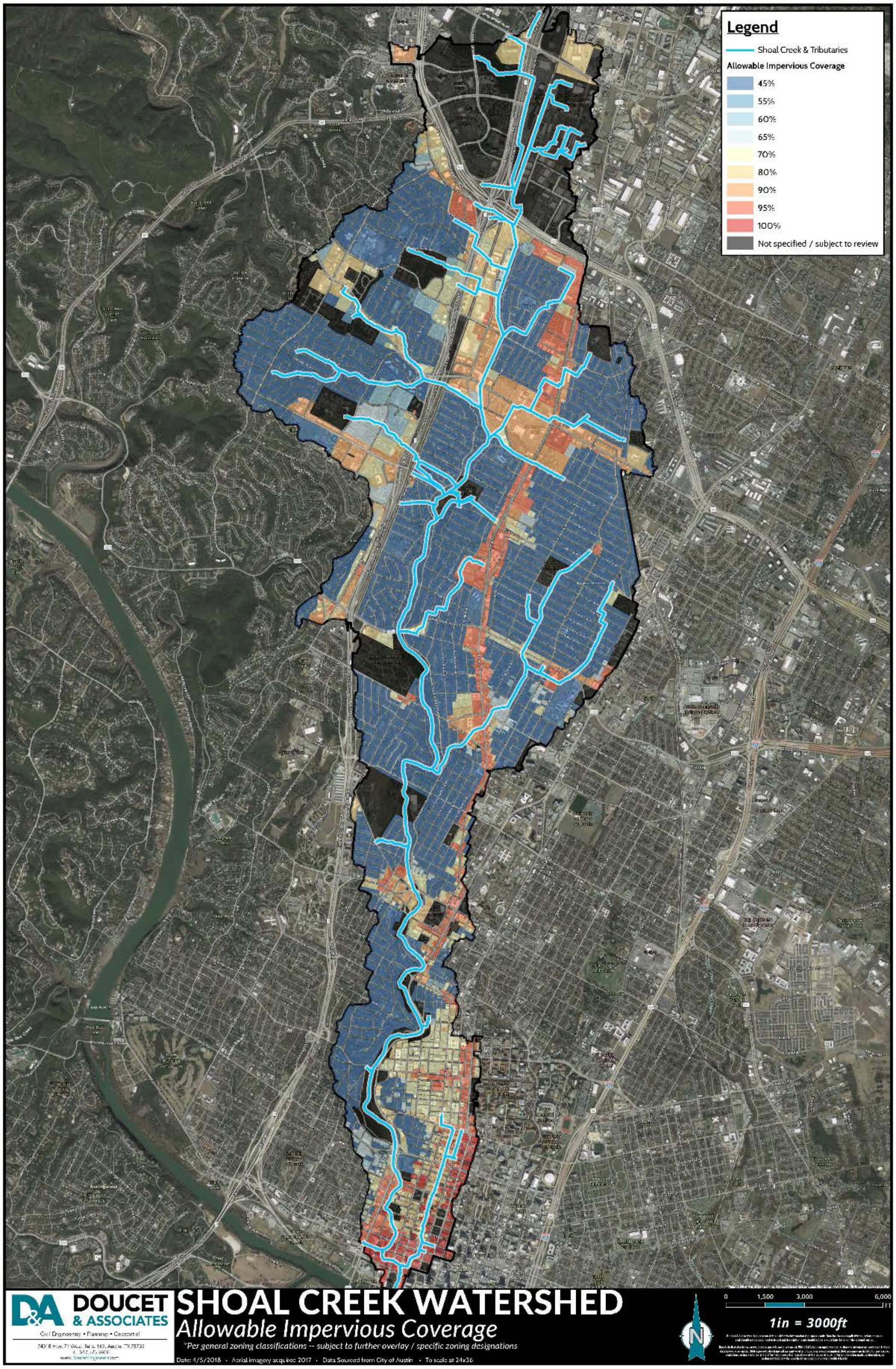
Water quality is directly related to the land cover and land use of the surrounding area. Land cover refers to the type of features that cover a landscape such as: trees, buildings, parking lots, roads, grassland, cropland, etc. Whereas, land use refers to how the land is utilized such as commercial, residential, industrial, etc. Each sub-basin has a distinct and unique composition of land use and land cover which influences the modeled water quality and quantity loadings. Both aspects of land use and land cover were accounted for within this analysis using the highest resolution data available.

The City of Austin Watershed Protection Department staff provided the existing and planned future land use conditions in GIS format. The SELECT model has 12 subareas to define loads and assist in the prioritization of watershed subareas for management activities. The subareas were defined based on tributaries and consistent sized subareas to model the nearly 13 square mile watershed.

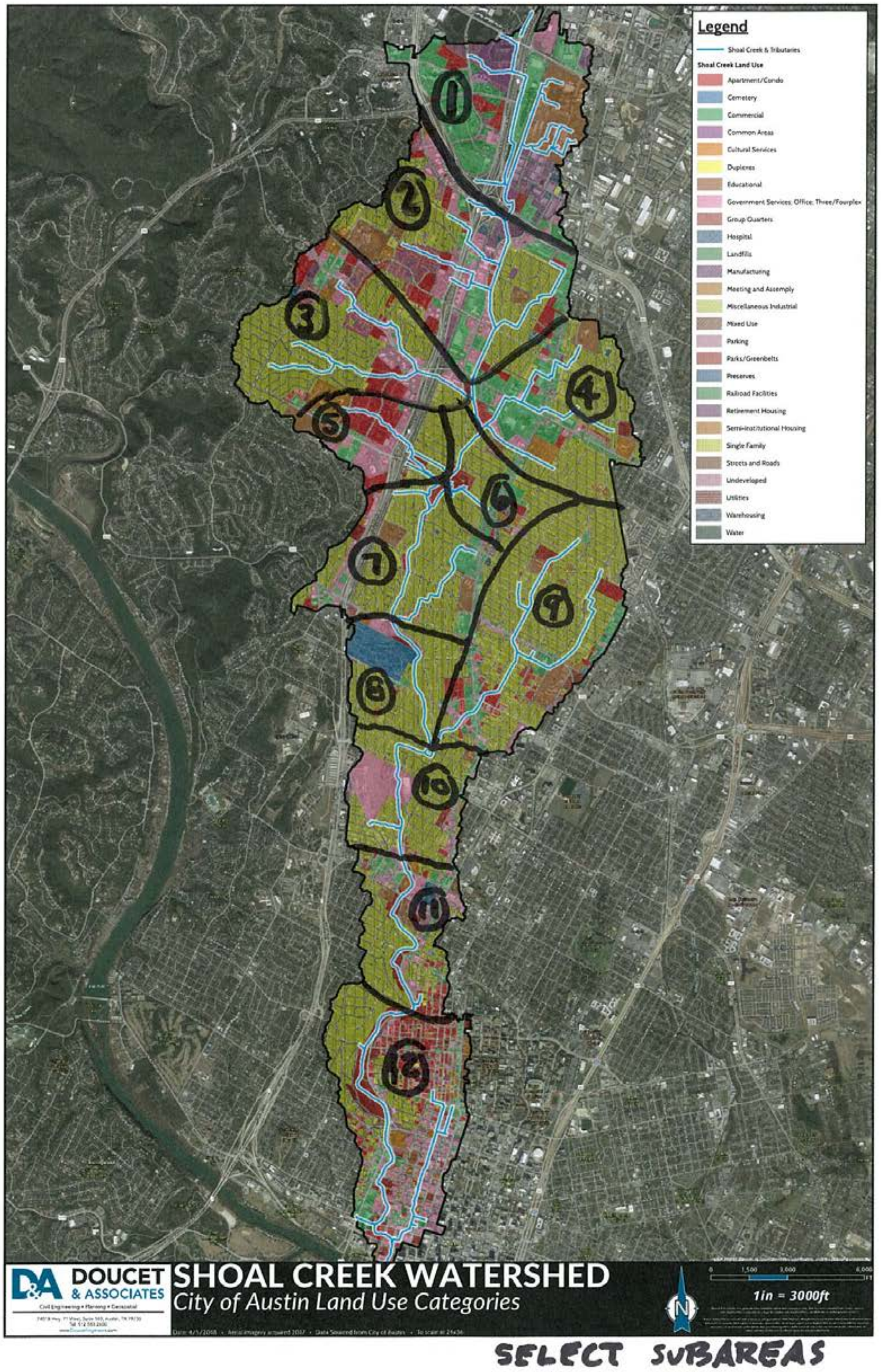
The existing and future land uses are shown on Maps 1 and 2 respectively. The future land use reflects the maximum impervious cover based on the City of Austin land development policies. Map 3 illustrates the SELECT model subareas.



Map 1 – Existing Land Use



Map 2 – Future Land Use (Maximum Impervious Cover)



Map 3 – Select Model Subareas

4.0 SELECT MODEL

Overview

SELECT is a planning level spreadsheet tool with a focus on limiting the extent and complexity of input data needed to generate results for pollutant loadings and BMP effectiveness within a watershed area. The tool can be used in the early planning stage and model output can provide guidance on the impacts of new watershed development and retrofits/watershed programs to manage runoff quality. SELECT is an appropriate tool when making decisions/recommendations on the potential location and type of BMPs and an approximation is required.

Long-term hourly continuous precipitation data is used in the SELECT model. Runoff coefficients translate rainfall into effective runoff. Initial abstraction is represented by depression storage which is subject to evaporation between rainfall events. When runoff occurs, the model tracks the volume and uses an event mean concentration for modeled pollutants to calculate pollutant loading. Pollutants modeled for this analysis are total phosphorus, total nitrogen, total suspended solids, and fecal coliform. If BMPs are modeled, a water quality capture volume is used to determine how much of the runoff is routed through the BMP and how much is bypassed. Event mean concentrations are also used for BMP effluent calculations.

Hydrology

Hourly precipitation data from the National Climatic Data Center (NCDC) for the Austin Camp Mabry station was downloaded for approximately a ten-year period (10/2000 – 9/24/2010). Monthly evaporation rates were downloaded from the Texas Water Development Board, and the average monthly evaporation from 2001 – 2011 was used in the model.

Model Input Parameters

Land uses within the Shoal Creek watershed were obtained from the City of Austin (COA). The overall watershed was broken into twelve sub-areas, and the percentage of various land uses within each sub-area was calculated for existing and projected future land uses.

Default (national) values for percent impervious area, depression storage, and runoff coefficients for various land uses from nationwide data were supplied by the model. To calculate these values for each sub-area in the Shoal Creek model, a weighted value based on the fraction of each land use within a sub-area was used. Default values for pollutant concentrations were also supplied by the model, and weighted values were again calculated for each Shoal Creek sub-area based on land use. Default values from nationwide studies for BMP effluent concentrations were supplied by the model. Tables 1 and 2 show input values for each sub-area under existing and future land uses, respectively, and Table 3 shows the BMP effluent concentrations for bioretention that was modeled as an example BMP approach to evaluate model function and potential BMP performance in achieving pollutant reductions.

Table 1: Existing Land Use Subarea Input (SELECT Default (National) Values)

Sub Area	Percent Impervious	Runoff Coefficient	Depression Storage (inches)	Avg. Phosphorus (mg/L)	Avg. Nitrogen (mg/L)	Avg. Suspended Solids (mg/L)	Avg. Fecal Coliform (#/dl)
1	73.88	0.57	0.06	0.22	2.18	50	4,165
2	61.87	0.47	0.07	0.25	2.19	49	4,621
3	52.42	0.39	0.08	0.27	2.18	49	5,007
4	58.64	0.44	0.08	0.26	2.19	49	4,741
5	60.19	0.45	0.07	0.25	2.19	49	4,689
6	47.86	0.36	0.09	0.27	2.16	49	5,228
7	55.19	0.41	0.08	0.26	2.18	49	4,892
8	38.06	0.29	0.11	0.27	2.11	50	5,738
9	53.59	0.40	0.08	0.26	2.19	49	4,951
10	57.23	0.43	0.08	0.26	2.18	49	4,808
11	55.98	0.42	0.08	0.25	2.16	49	4,908
12	60.07	0.46	0.08	0.24	2.17	49	4,732

Table 2: Future Land Use Subarea Input (SELECT Default Values)

Sub Area	Percent Impervious	Runoff Coefficient	Depression Storage (inches)	Avg. Phosphorus (mg/L)	Avg. Nitrogen (mg/L)	Avg. Suspended Solids (mg/L)	Avg. Fecal Coliform (#/dl)
1	80.54	0.62	0.05	0.21	2.20	50	3,850
2	64.31	0.49	0.07	0.25	2.19	49	4,504
3	56.02	0.42	0.08	0.26	2.19	49	4,848
4	62.41	0.47	0.07	0.25	2.19	49	4,587
5	65.02	0.49	0.07	0.24	2.19	49	4,491
6	50.22	0.38	0.09	0.26	2.17	49	5,127
7	57.62	0.43	0.08	0.26	2.19	49	4,791
8	38.83	0.30	0.11	0.27	2.11	50	5,706
9	54.87	0.41	0.08	0.26	2.19	49	4,896
10	57.43	0.43	0.08	0.25	2.18	49	4,806
11	57.91	0.44	0.08	0.25	2.16	49	4,827
12	65.18	0.50	0.07	0.23	2.17	50	4,522

Table 3 Bioretention BMP Effluent Event Mean Concentration Values

	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Total Suspended Solids (mg/L)	Total Fecal Coliform (mpn/100ML)
SELECT Default	0.11	0.99	7.69	2,350
From City of Austin Studies	0.10	1.07	20.62	17,990

In addition to using the default values in the model, an attempt was made to provide more watershed specific values based on City of Austin statistical analysis and studies. Land use, impervious cover, runoff coefficients, and depression storage parameters were all modified based on City of Austin data. As before, weighted values were calculated based on land use percentages for each sub-area. Likewise, BMP performance data from City of Austin studies were used to set BMP effluent concentrations. Tables 4 and 5 show input values for each sub-area under existing and future land uses for this scenario, respectively, and Table 3 shows the City of Austin derived BMP effluent concentrations.

Table 4: Existing Land Use Subarea Input (Values From City of Austin Studies)

Sub Area	Percent Impervious	Runoff Coefficient	Depression Storage (inches)	Avg. Phosphorus (mg/L)	Avg. Nitrogen (mg/L)	Avg. Suspended Solids (mg/L)	Avg. Fecal Coliform (#/dl)
1	73.88	0.58	0.06	0.37	2.12	166	53,427
2	61.87	0.51	0.07	0.39	2.18	166	55,626
3	52.42	0.44	0.08	0.39	2.19	166	55,794
4	58.64	0.49	0.08	0.39	2.20	166	56,401
5	60.19	0.49	0.07	0.39	2.18	166	55,688
6	47.86	0.41	0.09	0.37	2.14	166	53,853
7	55.19	0.46	0.08	0.39	2.19	166	55,883
8	38.06	0.34	0.12	0.33	1.97	166	47,576
9	53.59	0.45	0.08	0.39	2.20	166	56,272
10	57.23	0.48	0.08	0.39	2.19	166	55,902
11	55.98	0.46	0.09	0.37	2.11	166	53,008
12	60.07	0.49	0.08	0.37	2.13	166	53,502

Table 5: Future Land Use Subarea Input (Values From City of Austin Studies)

Sub Area	Percent Impervious	Runoff Coefficient	Depression Storage (inches)	Avg. Phosphorus (mg/L)	Avg. Nitrogen (mg/L)	Avg. Suspended Solids (mg/L)	Avg. Fecal Coliform (#/dl)
1	80.54	0.63	0.05	0.39	2.19	166	55,864
2	64.31	0.52	0.07	0.39	2.21	166	56,636
3	56.02	0.47	0.08	0.39	2.20	166	56,470
4	62.41	0.51	0.07	0.39	2.20	166	56,343
5	65.02	0.53	0.07	0.39	2.18	166	55,683
6	50.22	0.43	0.09	0.38	2.14	166	54,095
7	57.62	0.48	0.08	0.39	2.19	166	55,925
8	38.83	0.34	0.12	0.33	1.97	166	47,614
9	54.87	0.46	0.08	0.39	2.20	166	56,427
10	57.43	0.48	0.08	0.39	2.18	166	55,513
11	57.91	0.48	0.08	0.37	2.12	166	53,117
12	65.18	0.53	0.07	0.37	2.13	166	53,482

SELECT Model Results

For each of the above input data sets, the model was run for both existing and future land uses. To look at the potential for load reduction, the future land use input sets were also modeled with a conceptual bioretention basin BMP for each sub-area. Each basin was sized to capture one-half inch of runoff from the sub-area with a 48-hour retention time.

In the Watershed Action Plan, we will evaluate the use of watershed maps to aid in the prioritization of management measure locations. There is the potential due to the completely urbanized watershed, that it will be challenging to highlight priority watershed subareas.

In the default scenario, existing and future land use loadings for each of the modeled pollutants were compared. Next, a bioretention basin was added for each sub-area in the future model run. A comparison of future conditions with and without the BMP was performed to model potential pollutant reductions. Pollutant loadings and comparisons, along with the calculated BMP volume for each sub-area and the calculated reduction in pollutant loadings due to the BMP are presented in Tables 6 through 9.

Table 6 : Comparison of Total Phosphorus Loadings and Potential Pollutant Loading Reduction due to BMPs (SELECT default input values)

		Weighted Impervious Cover %				Load over 10-yr Period (kg)				Load over 10-yr Period (kg)		
Subarea	Area (ac)	Existing	Future	% Change		Existing	Future	% Change		BMP Volume (ac-ft)	Future w/BMP	% Change
1	942.95	73.9	80.5	9.02%		3,717	3,979	7.1%		39.29	3,598	-9.6%
2	996.79	61.9	64.3	3.93%		3,629	3,838	5.8%		41.53	3,274	-14.7%
3	959.84	52.4	56.0	6.86%		3,089	3,248	5.1%		39.99	2,666	-17.9%
4	761.56	58.6	62.4	6.42%		2,700	2,813	4.2%		31.73	2,381	-15.3%
5	339.31	60.2	65.0	8.02%		1,183	1,254	6.0%		14.14	1,076	-14.2%
6	300.93	47.9	50.2	4.94%		894	909	1.6%		12.54	726	-20.1%
7	699.61	55.2	57.6	4.40%		2,311	2,424	4.9%		29.15	1,999	-17.5%
8	383.35	38.1	38.8	2.03%		894	894	0.0%		15.97	647	-27.6%
9	1022.38	53.6	54.9	2.39%		3,295	3,377	2.5%		42.6	2,757	-18.4%
10	527.44	57.2	57.4	0.35%		1,827	1,757	-3.8%		21.98	1,458	-17.0%
11	432.73	56.0	57.9	3.44%		1,389	1,475	6.2%		18.03	1,230	-16.6%
12	932.26	60.1	65.2	8.51%		3,189	3,322	4.2%		38.84	2,869	-13.6%

Table 7: Comparison of Total Nitrogen Loadings and Potential Pollutant Loading Reduction due to BMPs (SELECT default input values)

		Weighted Impervious Cover %				Load over 10-yr Period (kg)				Load over 10-yr Period (kg)		
Subarea	**Area (ac)**	**Existing**	**Future**	**% Change**		**Existing**	**Future**	**% Change**		**BMP Volume (ac-ft)**	**Future w/BMP**	**% Change**
1	942.95	73.9	80.5	9.02%		36,829	41,689	13.2%		39.29	37,074	-11.1%
2	996.79	61.9	64.3	3.93%		31,792	33,622	5.8%		41.53	28,784	-14.4%
3	959.84	52.4	56.0	6.86%		24,944	27,357	9.7%		39.99	22,698	-17.0%
4	761.56	58.6	62.4	6.42%		22,739	24,639	8.4%		31.73	20,942	-15.0%
5	339.31	60.2	65.0	8.02%		10,361	11,445	10.5%		14.14	9,798	-14.4%
6	300.93	47.9	50.2	4.94%		7,153	7,585	6.0%		12.54	6,149	-18.9%
7	699.61	55.2	57.6	4.40%		19,376	20,414	5.4%		29.15	17,018	-16.6%
8	383.35	38.1	38.8	2.03%		6,984	6,984	0.0%		15.97	5,253	-24.8%
9	1022.38	53.6	54.9	2.39%		27,751	28,445	2.5%		42.6	23,483	-17.4%
10	527.44	57.2	57.4	0.35%		15,320	15,320	0.0%		21.98	12,782	-16.6%
11	432.73	56.0	57.9	3.44%		11,999	12,744	6.2%		18.03	10,696	-16.1%
12	932.26	60.1	65.2	8.51%		28,835	31,343	8.7%		38.84	26,893	-14.2%

Table 8: Comparison of Total Suspended Solids Loadings and Potential Pollutant Loading Reduction due to BMPs (SELECT default input values)

		Weighted Impervious Cover %				Load over 10-yr Period (kg)				Load over 10-yr Period (kg)		
Subarea	Area (ac)	Existing	Future	% Change		Existing	Future	% Change		BMP Volume (ac-ft)	Future w/BMP	% Change
1	942.95	73.9	80.5	9.02%		841,497	939,509	11.6%		39.29	779,995	-17.0%
2	996.79	61.9	64.3	3.93%		712,194	751,508	5.5%		41.53	585,481	-22.1%
3	959.84	52.4	56.0	6.86%		557,798	608,721	9.1%		39.99	449,767	-26.1%
4	761.56	58.6	62.4	6.42%		507,006	550,721	8.6%		31.73	423,890	-23.0%
5	339.31	60.2	65.0	8.02%		231,832	256,806	10.8%		14.14	200,030	-22.1%
6	300.93	47.9	50.2	4.94%		162,091	171,201	5.6%		12.54	121,088	-29.3%
7	699.61	55.2	57.6	4.40%		433,828	455,623	5.0%		29.15	339,344	-25.5%
8	383.35	38.1	38.8	2.03%		164,729	164,795	0.0%		15.97	99,999	-39.3%
9	1022.38	53.6	54.9	2.39%		617,121	632,679	2.5%		42.6	463,457	-26.7%
10	527.44	57.2	57.4	0.35%		343,442	344,004	0.2%		21.98	256,188	-25.5%
11	432.73	56.0	57.9	3.44%		274,153	291,392	6.3%		18.03	218,574	-25.0%
12	932.26	60.1	65.2	8.51%		656,168	715,537	9.0%		38.84	558,048	-22.0%

Table 9: Comparison of Fecal Coliform Loadings and Potential Pollutant Loading Reduction due to BMPs (SELECT default input values)

		Weighted Impervious Cover %				Load over 10-yr Period (kg)				Load over 10-yr Period (kg)		
Subarea	Area (ac)	Existing	Future	% Change		Existing	Future	% Change		BMP Volume (ac-ft)	Future w/BMP	% Change
1	942.95	73.9	80.5	9.02%		7.036E+11	7.295E+11	3.7%		39.29	5.830E+11	-20.1%
2	996.79	61.9	64.3	3.93%		6.186E+11	6.915E+11	11.8%		41.53	5.104E+11	-26.2%
3	959.84	52.4	56.0	6.86%		5.729E+11	6.056E+11	5.7%		39.99	4.180E+11	-31.0%
4	761.56	58.6	62.4	6.42%		4.923E+11	5.161E+11	4.8%		31.73	3.752E+11	-27.3%
5	339.31	60.2	65.0	8.02%		2.218E+11	2.347E+11	5.8%		14.14	1.732E+11	-26.2%
6	300.93	47.9	50.2	4.94%		1.731E+11	1.792E+11	3.5%		12.54	1.170E+11	-34.7%
7	699.61	55.2	57.6	4.40%		4.348E+11	4.466E+11	2.7%		29.15	3.114E+11	-30.3%
8	383.35	38.1	38.8	2.03%		1.899E+11	1.889E+11	-0.6%		15.97	1.011E+11	-46.4%
9	1022.38	53.6	54.9	2.39%		6.274E+11	6.359E+11	1.4%		42.6	4.341E+11	-31.7%
10	527.44	57.2	57.4	0.35%		3.379E+11	3.377E+11	0.0%		21.98	2.355E+11	-30.3%
11	432.73	56.0	57.9	3.44%		2.727E+11	2.848E+11	4.4%		18.03	2.006E+11	-29.6%
12	932.26	60.1	65.2	8.51%		6.288E+11	6.531E+11	3.9%		38.84	4.831E+11	-26.0%

The modeling using City of Austin specific parameters followed the same steps as the default model. Comparison of existing and future pollutant loadings, BMP volumes and pollutant loading reductions for future and future with BMPs for each sub-area are presented in Tables 10 through 13.

Table 10: Comparison of Total Phosphorus Loadings and Potential Pollutant Loading Reduction due to BMPs (City of Austin input values)

		Weighted Impervious Cover %				Load over 10-yr Period (kg)				Load over 10-yr Period (kg)		
Subarea	Area (ac)	Existing	Future	% Change		Existing	Future	% Change		BMP Volume (ac-ft)	Future w/BMP	% Change
1	942.95	73.9	80.5	9.02%		6,460	7,513	16.3%		39.29	6,405	-14.7%
2	996.79	61.9	64.3	3.93%		6,235	6,357	2.0%		41.53	5,186	-18.4%
3	959.84	52.4	56.0	6.86%		5,107	5,455	6.8%		39.99	4,327	-20.7%
4	761.56	58.6	62.4	6.42%		4,512	4,764	5.6%		31.73	3,869	-18.8%
5	339.31	60.2	65.0	8.02%		2,039	2,206	8.2%		14.14	1,807	-18.1%
6	300.93	47.9	50.2	4.94%		1,396	1,504	7.7%		12.54	1,163	-22.7%
7	699.61	55.2	57.6	4.40%		3,891	4,060	4.3%		29.15	3,238	-20.2%
8	383.35	38.1	38.8	2.03%		1,266	1,266	0.0%		15.98	909	-28.2%
9	1022.38	53.6	54.9	2.39%		5,563	5,687	2.2%		42.60	4,485	-21.1%
10	527.44	57.2	57.4	0.35%		3,061	3,061	0.0%		21.98	2,441	-20.2%
11	432.73	56.0	57.9	3.44%		2,253	2,383	5.8%		18.03	1,909	-19.9%
12	932.26	60.1	65.2	8.51%		5,240	5,749	9.7%		38.84	4,729	-17.8%

Table 11 Comparison of Total Nitrogen Loadings and Potential Pollutant Loading Reduction due to BMPs (City of Austin input values)

		Weighted Impervious Cover %				Load over 10-yr Period (kg)				Load over 10-yr Period (kg)		
Subarea	Area (ac)	Existing	Future	% Change		Existing	Future	% Change		BMP Volume (ac-ft)	Future w/BMP	% Change
1	942.95	73.9	80.5	9.02%		37,012	42,188	14.0%		39.29	37,916	-10.1%
2	996.79	61.9	64.3	3.93%		34,853	36,026	3.4%		41.53	31,427	-12.8%
3	959.84	52.4	56.0	6.86%		28,676	30,772	7.3%		39.99	26,383	-14.3%
4	761.56	58.6	62.4	6.42%		25,454	26,872	5.6%		31.73	23,390	-13.0%
5	339.31	60.2	65.0	8.02%		11,399	12,329	8.2%		14.14	10,805	-12.4%
6	300.93	47.9	50.2	4.94%		8,076	8,470	4.9%		12.54	7,167	-15.4%
7	699.61	55.2	57.6	4.40%		21,852	22,801	4.3%		29.15	19,630	-13.9%
8	383.35	38.1	38.8	2.03%		7,556	7,556	0.0%		15.98	6,161	-18.5%
9	1022.38	53.6	54.9	2.39%		31,382	32,079	2.2%		42.6	27,404	-14.6%
10	527.44	57.2	57.4	0.35%		17,191	17,112	-0.5%		21.98	14,743	-13.8%
11	432.73	56.0	57.9	3.44%		12,847	13,653	6.3%		18.03	11,814	-13.5%
12	932.26	60.1	65.2	8.51%		30,168	33,098	9.7%		38.84	29,098	-12.1%

Table 12: Comparison of Total Suspended Solids Loadings and Potential Pollutant Loading Reduction due to BMPs (City of Austin input values)

		Weighted Impervious Cover %				Load over 10-yr Period (kg)				Load over 10-yr Period (kg)		
Subarea	Area (ac)	Existing	Future	% Change		Existing	Future	% Change		BMP Volume (ac-ft)	Future w/BMP	% Change
1	942.95	73.9	80.5	9.02%		2,898,089	3,197,833	10.3%		39.29	2,644,319	-17.3%
2	996.79	61.9	64.3	3.93%		2,653,932	2,705,998	2.0%		41.53	2,120,929	-21.6%
3	959.84	52.4	56.0	6.86%		2,173,652	2,321,880	6.8%		39.99	1,758,745	-24.3%
4	761.56	58.6	62.4	6.42%		1,920,608	2,027,638	5.6%		31.73	1,580,675	-22.0%
5	339.31	60.2	65.0	8.02%		867,978	938,834	8.2%		14.14	739,663	-21.2%
6	300.93	47.9	50.2	4.94%		626,451	657,010	4.9%		12.54	480,507	-26.9%
7	699.61	55.2	57.6	4.40%		1,656,351	1,728,292	4.3%		29.15	1,317,831	-23.7%
8	383.35	38.1	38.8	2.03%		636,670	636,670	0.0%		15.98	412,522	-35.2%
9	1022.38	53.6	54.9	2.39%		2,367,900	2,420,520	2.2%		42.6	1,820,731	-24.8%
10	527.44	57.2	57.4	0.35%		1,303,025	1,303,025	0.0%		21.98	993,563	-23.7%
11	432.73	56.0	57.9	3.44%		1,010,678	1,069,047	5.8%		18.03	815,154	-23.7%
12	932.26	60.1	65.2	8.51%		2,351,103	2,579,461	9.7%		38.84	2,032,235	-21.2%

Table 13: Comparison of Fecal Coliform Loadings and Potential Pollutant Loading Reduction due to BMPs (City of Austin input values)

		Weighted Impervious Cover %				Load over 10-yr Period (kg)				Load over 10-yr Period (kg)		
Subarea	Area (ac)	Existing	Future	% Change		Existing	Future	% Change		BMP Volume (ac-ft)	Future w/BMP	% Change
1	942.95	73.9	80.5	9.02%		9.327E+12	1.076E+13	15.4%		39.29	8.636E+12	-19.8%
2	996.79	61.9	64.3	3.93%		8.893E+12	9.232E+12	3.8%		41.53	6.954E+12	-24.7%
3	959.84	52.4	56.0	6.86%		7.306E+12	7.899E+12	8.1%		39.99	5.712E+12	-27.7%
4	761.56	58.6	62.4	6.42%		6.526E+12	6.882E+12	5.5%		31.73	5.151E+12	-25.2%
5	339.31	60.2	65.0	8.02%		2.912E+12	3.149E+12	8.2%		14.14	2.387E+12	-24.2%
6	300.93	47.9	50.2	4.94%		2.032E+12	2.141E+12	5.3%		12.54	1.485E+12	-30.7%
7	699.61	55.2	57.6	4.40%		5.576E+12	5.823E+12	4.4%		29.15	4.245E+12	-27.1%
8	383.35	38.1	38.8	2.03%		1.825E+12	1.826E+12	0.1%		15.98	1.093E+12	-40.2%
9	1022.38	53.6	54.9	2.39%		8.027E+12	8.228E+12	2.5%		42.6	5.901E+12	-28.3%
10	527.44	57.2	57.4	0.35%		4.388E+12	4.358E+12	-0.7%		21.98	3.177E+12	-27.1%
11	432.73	56.0	57.9	3.44%		3.227E+12	3.421E+12	6.0%		18.03	2.494E+12	-27.1%
12	932.26	60.1	65.2	8.51%		7.578E+12	8.311E+12	9.7%		38.84	6.298E+12	-24.2%

5.0 Load Duration Curves (LDC)

Overview

The LDC approach was selected as it is perhaps the simplest and most straightforward method of determining desired load reductions through the use of flow and load duration curve graphs. Where no water quality standard exists, screening criteria from TCEQ can be used as threshold concentrations. LDCs will be used for bacteria, TSS, and nutrients (nitrogen and phosphorus).

A LDC is developed from a flow duration curve (FDC). Flow data is multiplied by a threshold concentration, either a water quality standard or desired target concentration of a pollutant, producing a maximum allowable pollutant load for each flow in the period of record.

A FDC is essentially a graph showing the percentage of time a stream exceeds various flow rates. Daily average stream flows over long periods are generally used in developing an FDC. If observed pollutant concentrations were available for every day, multiplying the pollutant concentration by the flow would result in a daily pollutant load over the flow period. Typically, observed data is available much less frequently than flow data, and a load regression curve is developed so that a pollutant concentration is calculated for every day of the flow record. The regression curve uses the assumption that the pollutant concentration is a function of stream flow. An LDC is developed by plotting this information on a graph to show the percentage of time a stream's pollutant load is exceeded. By choosing a constant "target" concentration for a pollutant, another line can be created on the LDC that allows a visual comparison of existing and "desired" loadings. A target could be a state standard or a stakeholder recommended goal.

Hydrology

Daily data mean flows were obtained from the United States Geological Survey (USGS) stream for Shoal Creek flow gages at 12th Street. The data period obtained was from 01/09/1983 through 07/31/2018.

LDC Input Parameters

Observed data for total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS) were obtained from the COA and USGS at sampling locations at or near 12th Street. LDC's were developed for each of the pollutants and are presented in Figures 1 through 3. Target concentration LDCs will be generated once stakeholder review and input has been obtained.

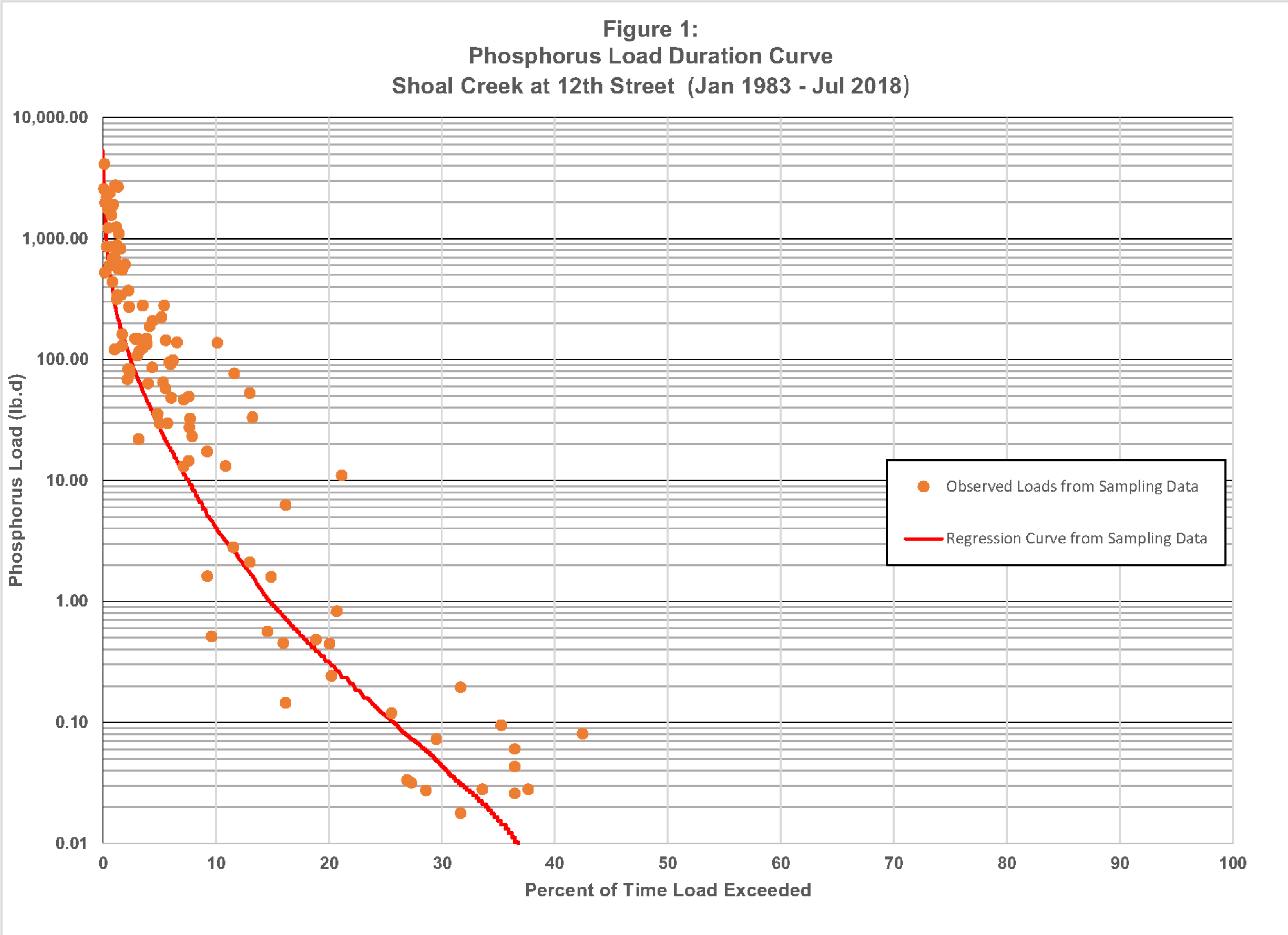


Figure 1 – Phosphorus Load Duration Curve

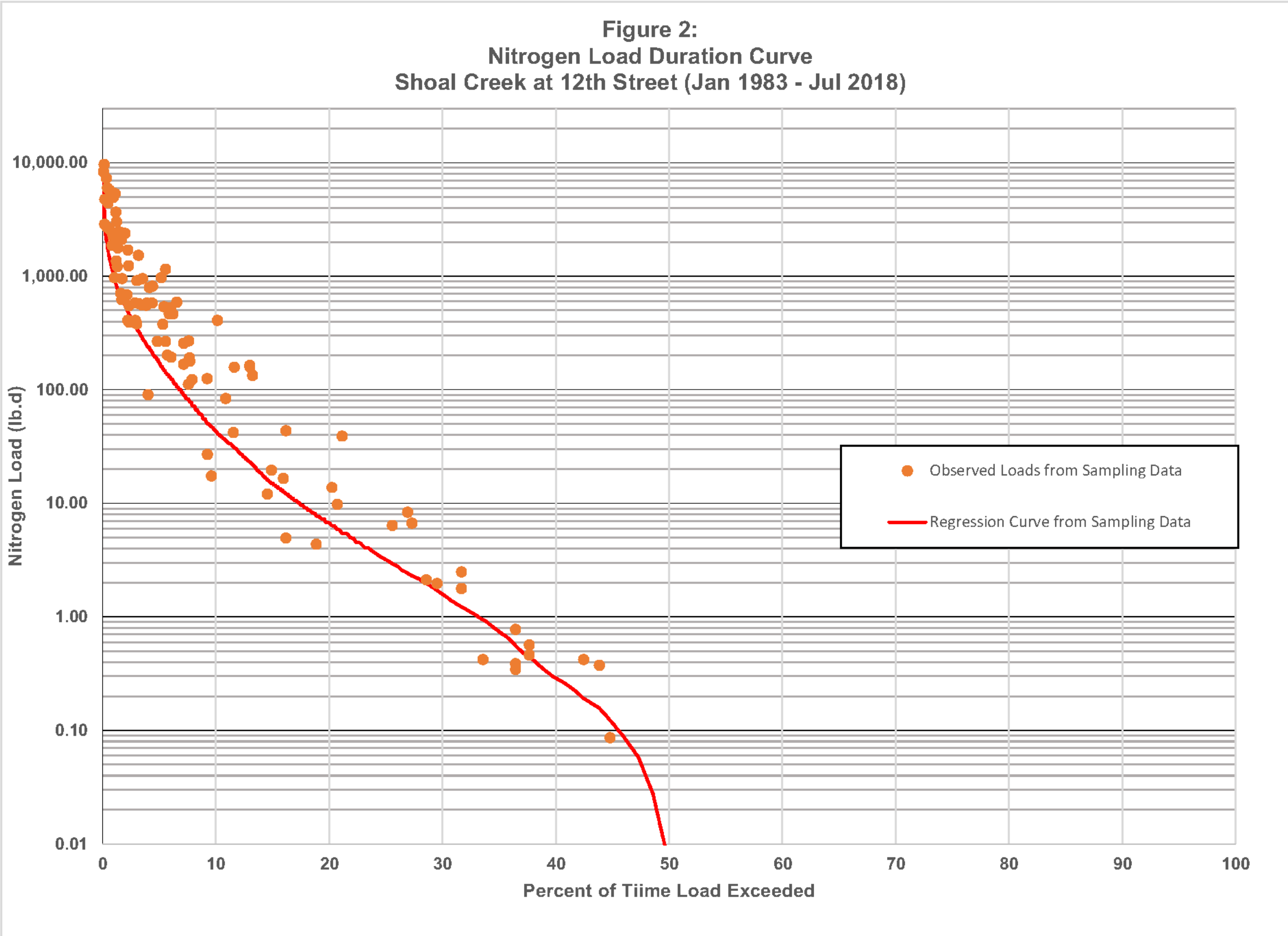


Figure 2 – Nitrogen Load Duration Curve

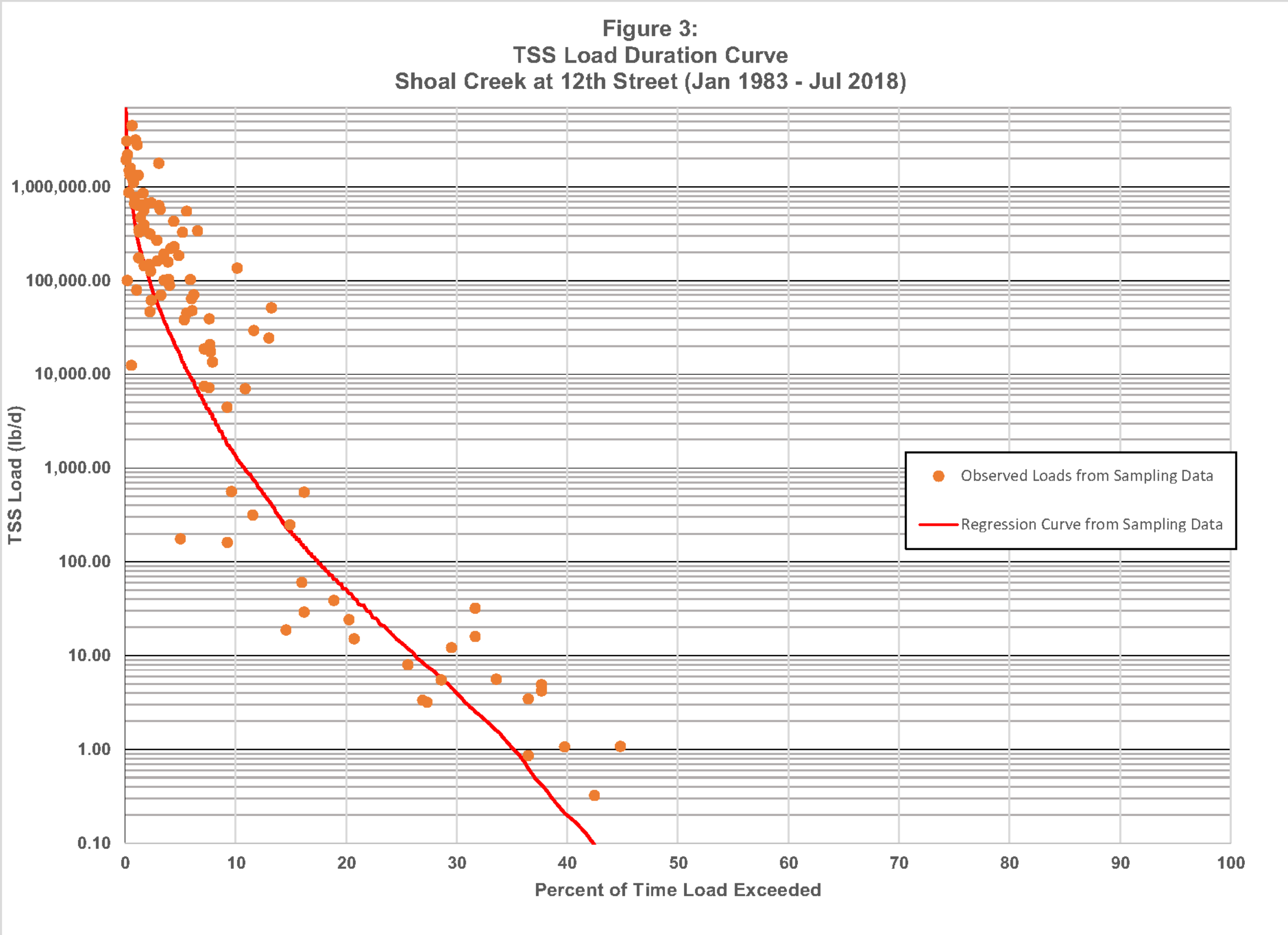


Figure 3 – TSS Load Duration Curve

For Fecal Coliform bacteria (FC), an LDC was developed using a regression curve based on observed data. A target FC curve was also plotted based on the previous state surface water quality standard of 200 colony forming units per 100ml. Based on SELECT model results, fecal coliform numbers would be reduced approximately 30% by adding a conceptual bioretention BMP in each sub-area of the watershed. A curve showing a hypothetical 30% reduction from the existing fecal coliform loading was also developed in order to graphically show this potential loading reduction. This graph is shown in Figure 4.

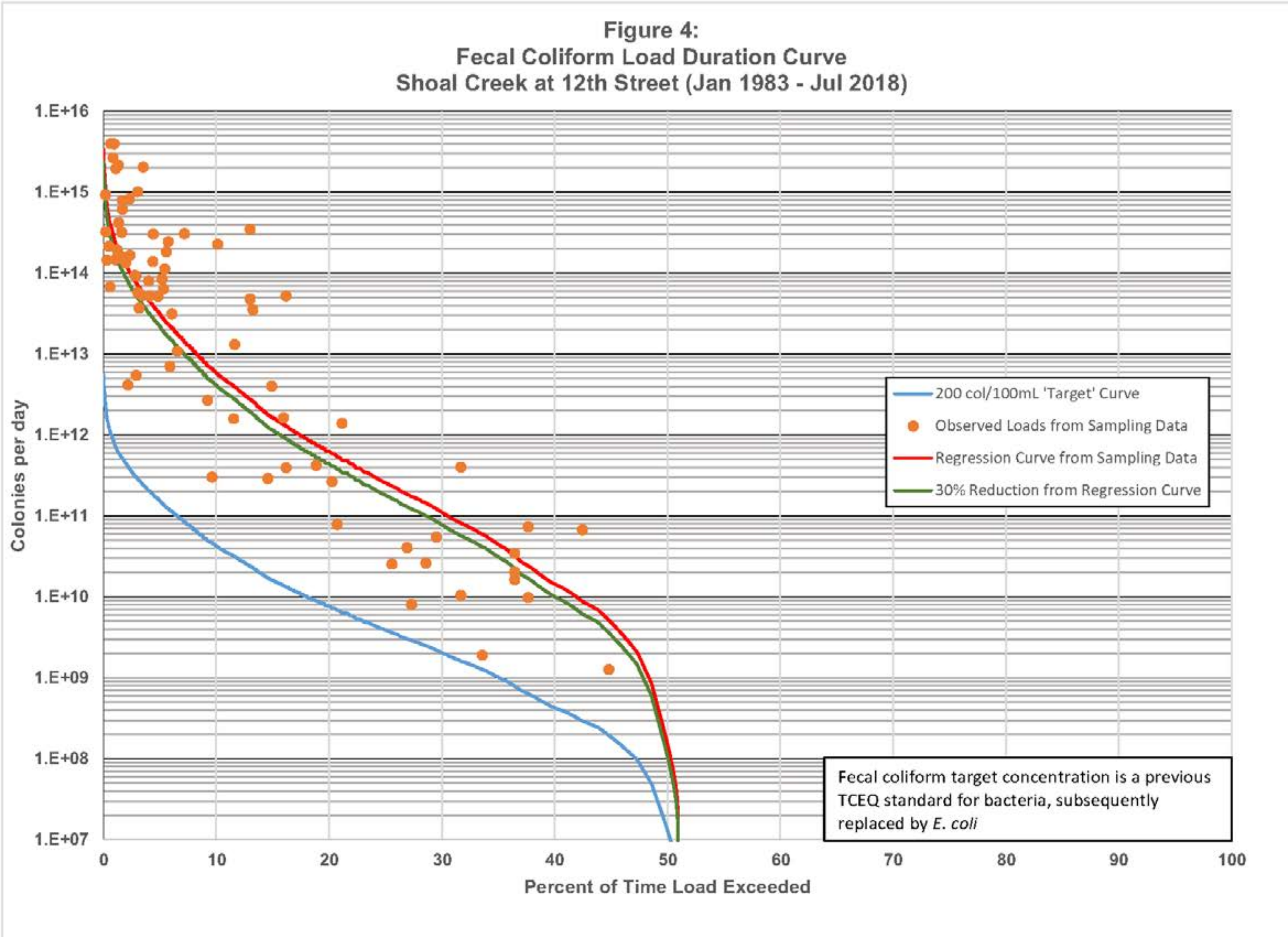


Figure 4 – Fecal Coliform Load Duration Curve

An LDC was also created for *Escherichia coli* (*E. coli*), which is the current state water quality standard for bacteria. The current standard for *E. coli* is 126 MPN/100ml (MPN stands for 'Most Probable Number', a probability calculation method to determine the approximate number of viable cells in a given volume of sample). Samples for *E. coli* samples were only analyzed after 2008. This was done at the stakeholders' request to try and avoid any results prior to the end of the Austin Clean Water Program in Shoal Creek, which relocated many wastewater lines that were in creek beds. There were much fewer *E. coli* data points than FC. From a review of the LDCs, there does not appear to be a significant difference between the *E. coli* and FC sampling data, thus, there may have only been a slight wastewater influence on the FC data. The *E. coli* LDC is presented in Figure 5.

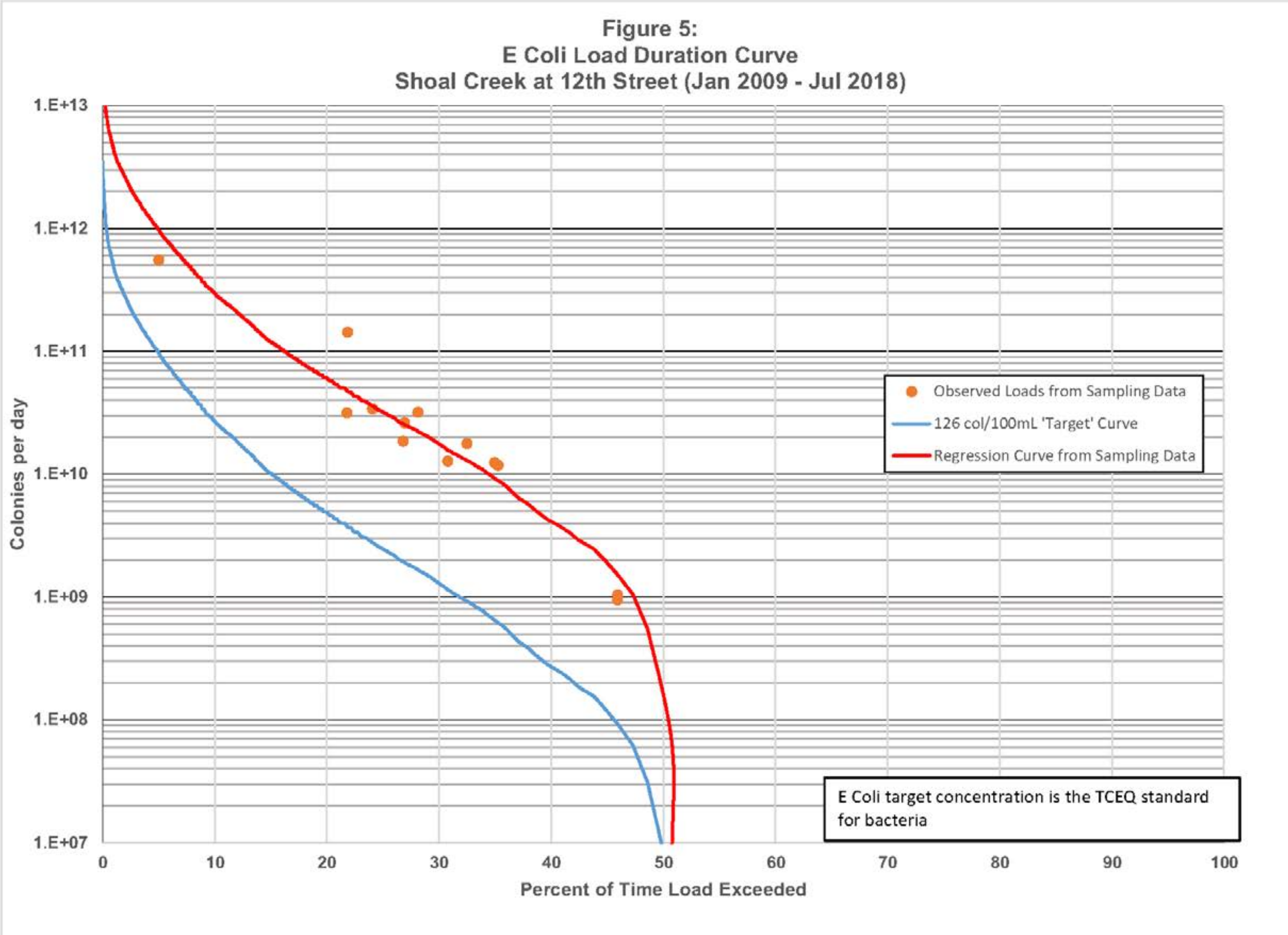


Figure 5 – E Coli Load Duration Curve

LDC Results

For a perennial stream, the LDC can be separated into categories such as low flows, mid-range flows, and high flows to see if load exceedance occurs more frequently in one category than another (i.e. exceedance loads during low flows may point to a continuous point source). For an intermittent stream such as Shoal Creek, it is much more difficult to determine sources of pollutants, as the creek generally flows only in response to a precipitation event, and so all runoff is assumed to be non-point source related. Additional stormwater sampling (samples taken during runoff events) would likely help in determining any proposed BMP water quality capture volume offering the greatest reduction in pollutant loading balance with cost.

For FC, results indicate existing FC concentrations would need to be reduced by about 98% in order to meet the previous state water quality standard. It should be noted that the majority of sampling occurred during either low or very low flow conditions, and extrapolation to the full range of flows adds uncertainty to the analysis. Additionally, these samples included data ranging back to the 1980's, which may not be representative of the current conditions for Shoal Creek. Thus, a recommendation in the WPP could be the expansion of the monitoring program to further define conditions.

For *E. coli*, results indicate existing concentrations would need to be reduced by approximately 98% in order to meet the current state water quality standard. It must be noted that this analysis was based on a very limited number of samples, again with most samples taken during low or very low flow conditions. Creating a regression curve on limited data increases the uncertainty in the results. No USGS flow data was found at the Spicewood Springs Tributary to Shoal Creek. We will evaluate bacteria management options in the "Implementation Plan for Five Total Maximum Daily Loads for Bacteria in Four Austin Streams," 2015 for use on Shoal Creek in developing the WPP.

Desired percent reductions for TP, TN, and TSS will be based on the State's screening levels and input from the stakeholders.

LoadEST

LoadEST is a USGS program for estimating constituent loads in streams and rivers. Given a time series of streamflow, additional data variables, and constituent concentration, LoadEST assists the user in developing a regression model for the estimation of constituent load. Flow and water quality data from the COA and USGS will be used. For more information on LoadEST see the user guide located here: https://pubs.usgs.gov/tm/2005/tm4A5/pdf/508final.pdf

LoadEST was used to determine the instream daily load from the monitoring data. Then, a ratio of source load (watershed-wide modeling from SELECT) to instream load was computed to determine BMP effectiveness in managing pollutants. In other words, BMPs not located adjacent to the stream generate a lower instream load reduction. For bacteria, the source load to instream load ratio is 116. This is applied to the watershed BMP to determine the load reduction in the stream. For example, a watershed BMP load reduction is determined to be X, then, that load reduction is divided by 116 to define the instream load reduction. The load reduction from all the recommended bacteria management BMPs is summed to achieve the target bacteria reduction to achieve compliance with contact recreation standards.

6.0 FINAL MODELING RESULTS

The WPP stakeholder process evaluated various management strategies to determine their effectiveness and ability to meet stakeholder goals and/or state standards. In this process, the SELECT model will be used to define load reductions due to potential management activities and then the findings will be applied to the Load Duration Curves to illustrate water quality improvements and their potential ability to meet watershed improvement goals. SELECT provides a source load reduction. This is then converted to an instream load reduction through the use of LoadEST to account for natural processes that occur on the land between the BMP and the waterbody. The source:instream ratio of 116 as noted above was applied to BMPs that are not adjacent to the creek to determine the load reduction in the stream from that BMP. For example, the City of Austin water quality control inspection program manages runoff from about 1,580 acres. The water quality controls are not adjacent to the creek and need to apply the source:instream load reduction factor. The analysis found that the needed stream loading reduction is 9.82E+10 MPN/day as noted in Table 14. The instream bacteria reduction by each BMP is summed to determine the total BMP load reduction to ensure that the bacteria reduction target is met. See Table 15 for the recommended BMP bacteria management measures and their corresponding load reductions.

Modeling performed during the evaluation of various water quality management strategies and in the preparation of the WPP is summarized below. This report will provide documentation of causes and sources of pollution for current and future watershed conditions (Element A), estimate load reductions from potential management strategies (Element B), and provide a description of management strategies and their performance (Element C).

Causes and Sources of Pollution – Element A

Non-point source pollution from urban runoff is the cause of pollution in the watershed. Total watershed impervious cover is about 54% with most of the urbanized areas directly connected to Shoal Creek via storm drain systems. The conveyance system readily conveys pollutants (sediment, nutrients, bacteria, oil, grease, metals, etc.) from streets, residential lots, and parking lots to the creek. The Spicewood Tributary to Shoal Creek was identified as being impaired by bacteria in the 2015 City of Austin TMDL for five urban watersheds.

Estimated Load Reductions – Bacteria – Element B

Since the water quality monitoring determined that the Shoal Creek water quality does not meet the State's contact recreation standards, the required bacteria reduction was computed using the LDC approach. As noted above, bacteria must be reduced by about 98 percent to satisfy this standard.

Table 14 – Required Bacteria Load Reductions

Constituent	Annual Existing Source Load (MPN/YR)	Average Concentration in sampling (MPN/mL)	State Screening Criteria Concentration (MPN/mL)	Meets Criteria (Y/N)	Required reduction to meet state criteria (MPN/yr)	Required Instream reduction to meet state criteria (MPN/day)
Bacteria (E.Coli)	4.25E+15	1,915	126	N	4.16E+15	9.82E+10

The above table summarizes the bacteria management requirements across the watershed to meet state contact recreation standards. The bacteria sources include wildlife, pets, wastewater leaks, human waste, and other sources.

Management Measures - Element C

The following management measures were identified during the drafting of the Watershed Protection Plan to reduce bacteria to meet the bacteria contact recreation standard. When employing these measures to the levels noted in the table, bacteria concentrations were computed to be reduced by 98 percent to meet the required load reduction. Key management measures are listed below and followed by Table 16 that provides guidance on the potential designated partner and location.

Key Management Measures

Scoop the Poop Program – The COA's Scoop the Poop Program educates residents on the importance of bagging and disposing of dog poop in an appropriate receptacle to reduce the instance of E. coli in City streams. The program provides pet waste bag dispensers, units that dispense pet waste bags to the public and provide a receptacle for the disposal of waste, to city parks and partnering programs.

Sanitary Sewer Overflow Response - An SSO response plan presents a strategy to mobilize the resources required to correct any infrastructure failure which may cause or contribute to an un-permitted discharge from deteriorating sewer infrastructure, flooding, or other causes.

Private Wastewater Lateral Inspection and Repair - A private lateral is the segment of the sanitary sewer system located on private property that connects a residence or business to the City's sanitary sewer system. Inspection of private laterals can prevent sewage leakage into streams.

Riparian Grow Zones – A grow zone is an effort to halt mowing along streams and allow the growth of more dense, diverse riparian vegetation. This improves water quality, lessens erosion, increases wildlife habitat, and provides other ecosystem services.

Water Quality Control inspection – Increasing the COA's inspection of commercial water quality controls in the watershed such as detention ponds and stormwater drainage systems can prevent nonpoint source pollution and control flooding by addressing the deterioration of aging systems.

Rain Gardens – A rain garden is intended to be an aesthetic way to capture stormwater runoff temporarily to encourage infiltration.

Rainwater Harvesting – The capture and storage of rainwater from roofs and other impervious surfaces for landscape, domestic, or other uses.

Fertilizer, Herbicide, Pesticide Education and Outreach – The COA's Avoid Weed & Feed and Grow Green programs educate residents and businesses on the benefit of managing fertilizer, herbicide, and pesticide application and utilizing native landscaping and integrated pest management for watershed health concerns.

Streambank Restoration – Involves the implementation of measures to reduce erosion in problematic areas can include rock boulders, bioengineering, gabions, and other measures.

Water Quality Retrofits – Potential water quality retrofits include the installation, inspection, and repair of devices such as retention and detention ponds, sedimentation-filtration basins, inlet protection devices, green streets, and green roofs.

Table 15 - Bacteria Management Measures to Meet Contact Recreation Goal

Management Measure	Location	Measured Milestone	Bacteria Managed MPN/Day
Scoop the Poop Program: increase number and servicing of pet waste stations	Emphasis on creek side parks trails, new kiosks and trash cans	Number of dispensers installed, pounds of waste collected	6.200E+10
Scoop the Poop Program: watershed wide education programs focused on pet waste	Watershed-wide emphasis	Tracking number of community surveys, web posts, social media, meetings, flyers	9.921E+09
Rainwater Programs: Education and outreach, projects at residences	Watershed-wide neighborhoods	Number of installations with target of 250 rain tanks and rain gardens	5.343E+07
Grow Zones: enhance existing and initiate new on private residences along the creek	Pease Park, Shoal Creek Trail, NW Park, upper watershed homes on the creek	40 acres of parkland and 325 residences	3.044E+9 (parks) 2.496E+10 (residential)
Total			9.998E+10