Modeling Support for Buck Creek Watershed Protection Plan Development

Prepared for:

Texas State Soil and Water Conservation Board

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1. INTRODUCTION

Buck Creek is an intermittent stream located in the Texas Panhandle spanning across portions of Childress, Collingsworth and Donley Counties. This rural watershed encompasses approximately 187,000 acres, most of which are agricultural lands including cultivated land, rangeland, and managed pasture land. Buck Creek originates southwest of the town Hedley and flows 68 miles to its confluence with the Prairie Dog Town Fork of the Red River across the Oklahoma border. The project area of Buck Creek only contains the portion of the watershed located within Texas. Buck Creek is part of the Red River basin and is classified as an impaired water body due to bacterial and nitrate contamination under the EPA Clean Rivers Act 303 (d).

To address Buck Creek's bacteria impairment, intensive watershed monitoring and watershed assessment were initiated (TSSWCB Project #03-07) and followed by efforts to develop a watershed protection plan (WPP) (TSSWCB Project #06-11). In support of the efforts to develop the WPP, the "Modeling Support for Buck Creek Watershed Protection Plan Development" project (TSSWCB Project 08-05) was developed as a means to apply watershed based modeling to help stakeholders in identifying priority areas of the watershed where recommended management measures included in the WPP should be located. This project utilizes two popular approaches currently applied in other WPP and Total Maximum Daily Load (TMDL) development processes across Texas and the U.S.

The Load Duration Curve (LDC) method (USEPA, 2006a) is the first approach applied and aids stakeholders and watershed managers in determining the primary pollutant source categories; either point or nonpoint source, contributing to the waterbody. The LDC approach was developed for assessing nutrient loading in streams (Cleland, 2002) and has been adapted to assess bacteria loadings as well. LDCs are a graphical assessment that 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). Loading reduction is based on the percent exceedance above the maximum allowable load line. In Texas, the applicable water quality standard to support contact recreation applied to all waterbodies in the state is a geometric mean concentration of 126 CFU/100 mL of *E. coli* (TCEQ, 2000). Based on estimated load reductions needed to meet the water quality standard or other water quality goal, best management practices (BMPs) can be planned broadly to address identified pollutant sources within defined source categories. Needed percent load reductions are delineated by flow category and are representative of the percent of time the stream is exceeding the standard during a given flow range. In comparison, a watershed model computes loading across all flow regimes and uses field data for calibration (Li and Guo, 2003). A look at various WPP and TMDL approaches indicates that a multi-pronged approach to source identification that addresses flow regimes as well as source specific assessments of location and magnitude of pollutant sources is preferred.

Historically, watershed models have been applied to study the nonpoint source pollution and aid in developing WPPs and TMDLs; however, many watershed models do not include bacterial transport processes and are cumbersome to apply. To remedy these model issues, a simple semi-quantitative approach that can aid the initial stages of TMDL or WPP development was devised. Specifically, this model can identify priority areas within a watershed where management is needed to address specific bacteria pollution load. This model, the Spatially Explicit Load Enrichment Calculation Tool (SELECT), was developed to assist in the source characterization component of the WPP and TMDL development process where bacterial contamination is a concern. SELECT is a pathogen load assessment tool which can be combined with a watershed-scale water quality model using spatially variable governing factors such as land use, soil condition, and distance to streams to support TMDL and WPP development. This tool can be used to determine the actual contaminant loads resulting in streams when used in conjunction with a fate and transport watershed model. SELECT can simulate potential pathogen loading in a watershed for various management scenarios based on user defined inputs.

Using LDCs and SELCT in the Buck Creek watershed allowed for enhanced assessments of pollutant loadings and sources of pollutant loading to be conducted. SELECT was applied to estimate daily potential *E. coli* loads resulting from cattle, deer and feral hogs in the Buck Creek watershed. Load Duration Curves (LDCs) were used to calculate bacteria load reductions based on maximum allowable *E. coli* loads and nitrate load reductions needed to meet the current nitrates screening level of 1.95 mg/L.

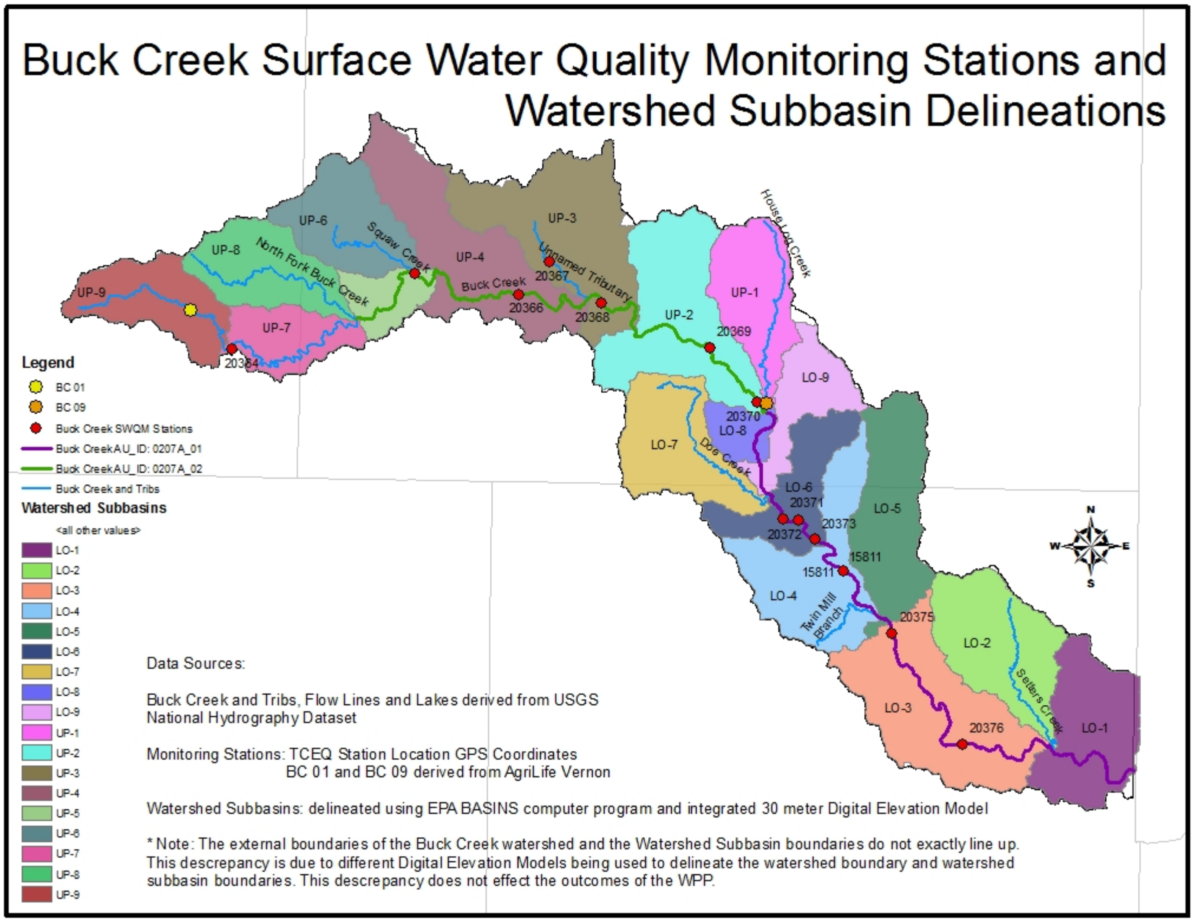


Figure 1. Buck Creek watershed and monitored sampling sites.

2. LOAD DURATION CURVE ANALYSIS

A widely accepted and utilized approach for predicting whether pollutants are coming from point and/or nonpoint sources is the use of LDC analysis. An LDC is 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 screening level concentration of 1.95 mg/L for nitrate were used in developing the LDC analysis for this project. A margin of safety was not subtracted from the *E. coli* or nitrate thresholds as the primary stakeholder goal was meeting the water quality standard and nitrate screening level.

When flow and the threshold concentration are multiplied together, they produce the maximum allowable pollutant load. The resulting load duration curve 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:

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

The load reduction percentages were calculated into the standard flow regimes utilized by the U.S. Environmental Protection Agency. Table 1 illustrates the designated flow regime categories utilized. This system of flow breaks was used due to the limited amount of flow data available on each monitoring station. Additional flow data would allow for customized flow breaks to be developed that better represent annual flow variability at each monitoring station.

Table 1. Flow breaks utilized in the Buck Creek 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

2.1. E. coli LDC analysis

Water quality and stream flow data were collected by Texas AgriLife Research personnel from Vernon on a monthly basis; however, the stream's intermittent nature yielded a less than monthly data set. Samples collected during the November 2007 to July 2009 time frame had corresponding flow data and were thus utilized in LDC analyses. In total, data from six monitoring stations was utilized. These were stations 15811, 20365, 20367, 20368, 20371, and 20373 (Figure 1). Station 15811 also has historical water quality and stream flow data available and was used to supplement the data set used to develop the LDC at this location.

2.1.1. Data Summary at 20365

- Current instantaneous flow (in cfs) and *E. coli* data were used in the analyses between 12/13/2007 and 05/13/2009.
  - Total number of flow data expressed in cfs: 12
  - *Total number of E. coli expressed in MPN/100 mL and corresponding flow in cfs: 12*
- *Total number of discrete E. coli data used (Figure 2a): 12*

2.1.2. Data Summary at 20367

- Current instantaneous flow (in cfs) and *E. coli* data were used in the analyses between 11/07/2007 and 06/04/2009.
  - Total number of flow data expressed in cfs: 20
  - *Total number of E. coli expressed in MPN/100 mL and corresponding flow in cfs: 20*
- *Total number of discrete E. coli data used (Figure 2b): 20*

2.1.3. Data Summary at 20368

- Current instantaneous flow (in cfs) and *E. coli* data were used in the analyses between 12/05/2007 and 07/31/2009.
  - Total number of flow data expressed in cfs: 15
  - *Total number of E. coli expressed in MPN/100 mL and corresponding flow in cfs: 15*
- *Total number of discrete E. coli data used (Figure 2c): 15*

2.1.4. Data Summary at 20371

- Current instantaneous flow (in cfs) and *E. coli* data were used in the analyses between 11/07/2007 and 07/31/2009.
    - Total number of flow data expressed in cfs: 16
    - *Total number of E. coli expressed in MPN/100 mL and corresponding flow in cfs: 16*
- *Total number of discrete E. coli data used (Figure 2d): 16*

2.1.5. Data Summary at 20373

- Current instantaneous flow (in cfs) and *E. coli* data were used in the analyses between 11/07/2007 and 07/31/2009.
    - Total number of flow data expressed in cfs: 18
    - *Total number of E. coli expressed in MPN/100 mL and corresponding flow in cfs: 18*
- *Total number of discrete E. coli data used (Figure 2e): 18*

2.1.6. Data Summary at 15811

- Historic instantaneous flow and *E. coli* data were collected from 12/11/1997 to 06/20/2005.
    - Total number of instantaneous flow expressed in cfs: 30
    - *Total number of E. coli data expressed in MPN/100 mL and corresponding flow in cfs: 30*

- Current instantaneous flow (in cfs) and *E. coli* data were used in the analyses between 11/7/2007 and 07/31/2009.
    - Total number of flow data expressed in cfs: 26
    - *Total number of E. coli expressed in MPN/100 mL and corresponding flow in cfs: 23*
- *Total number of discrete E. coli data used (Figure 2f): 57*

The actual *E. coli* loads for all the current water quality monitoring stations; 20365 (Figure 2a), 20367 (Figure 2b), 20368 (Figure 2c), 20371 (Figure 2d), and 20373 (Figure 2e) were below the maximum allowable *E. coli* load for all flow conditions. The percent reductions for all of these sites are not applicable since the actual *E. coli* loads are below the maximum allowable *E. coli* load using the *E. coli* standard of 126 CFU/100 mL.

Table 2. Daily and Annual *E. coli* loads and needed percent reductions for water quality monitoring station 20365.

Flow Condition	% Exceedance	Needed % Reduction	Daily Loading (CFU/day)	Annual Loading (CFU/year)
High Flows	0-10%	N/A	1.20E+10	4.38E+12
Moist Conditions	10-40%	N/A	4.10E+09	1.50E+12
Mid-Range	40-60%	N/A	2.61E+09	9.52E+11
Dry Conditions	60-90%	N/A	1.89E+08	6.91E+10
Low Flows	90-100%	N/A	2.33E+06	8.49E+08

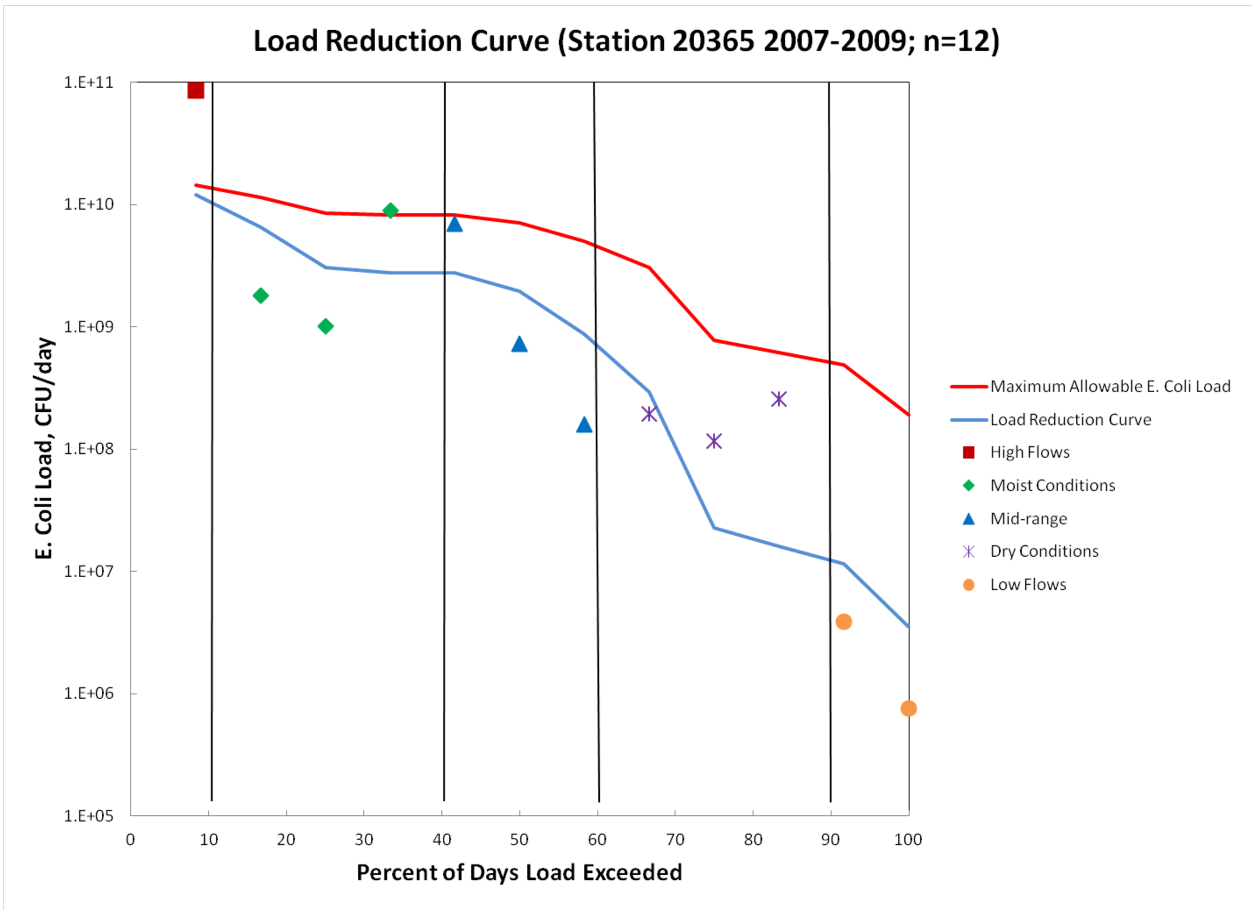


Figure 2a. Load Duration Curve for *E. coli* for water quality monitoring station 20365.

Table 3. Daily and Annual *E. coli* loads and needed percent reductions for water quality monitoring station 20367.

Flow Condition	% Exceedance	Needed % Reduction	Daily Loading (CFU/day)	Annual Loading (CFU/year)
High Flows	0-10%	N/A	1.03E+09	3.77E+11
Moist Conditions	10-40%	N/A	6.13E+08	2.24E+11
Mid-Range	40-60%	N/A	4.65E+08	1.70E+11
Dry Conditions	60-90%	N/A	2.63E+08	9.59E+10
Low Flows	90-100%	N/A	1.64E+08	5.98E+10

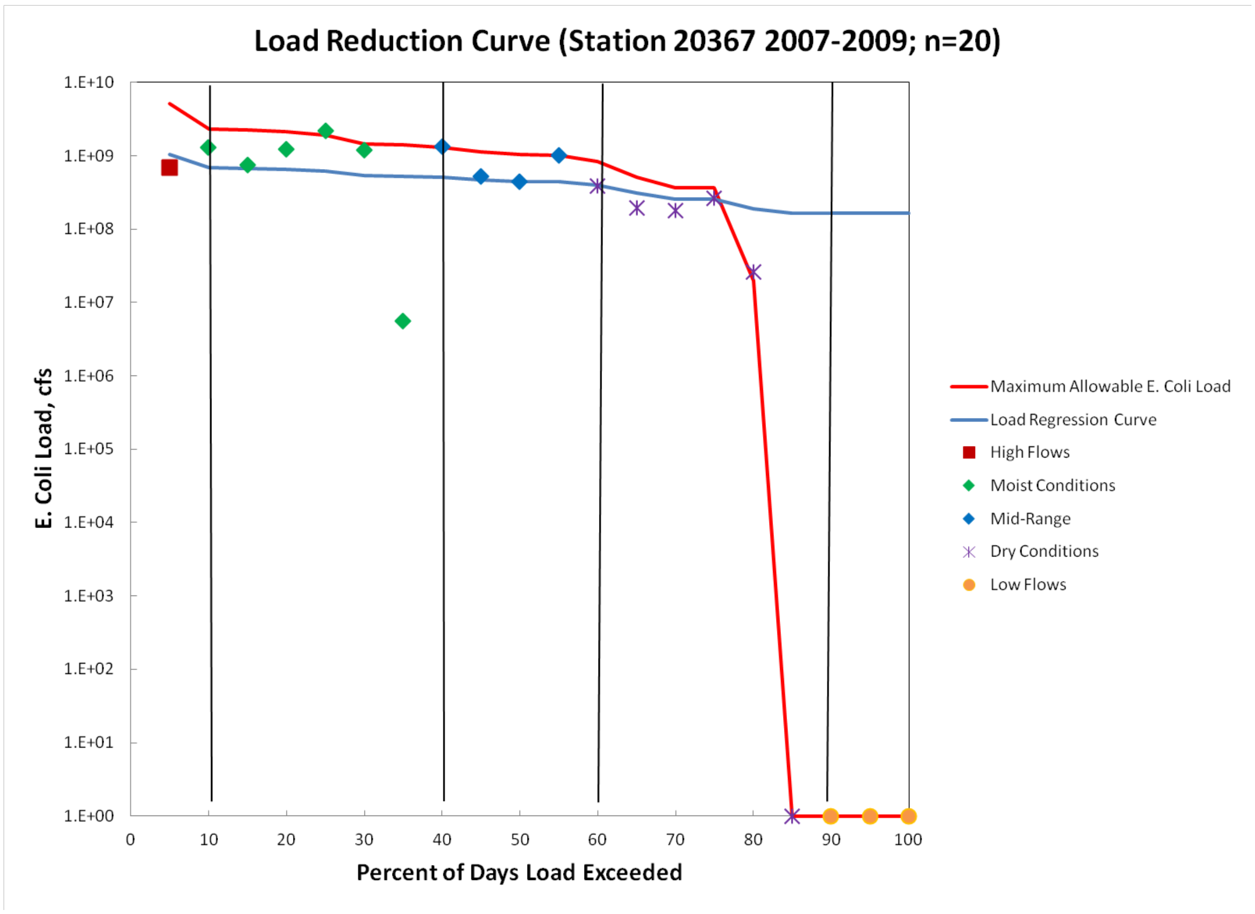


Figure 2b. Load Duration Curve for *E. coli* for water quality monitoring station 20367.

Table 4. Daily and Annual *E. coli* loads and needed percent reductions for water quality monitoring station 20368.

Flow Condition	% Exceedance	Needed % Reduction	Daily Loading (CFU/day)	Annual Loading (CFU/year)
High Flows	0-10%	N/A	3.91E+08	1.43E+11
Moist Conditions	10-40%	N/A	2.37E+08	8.66E+10
Mid-Range	40-60%	N/A	1.09E+08	3.98E+10
Dry Conditions	60-90%	N/A	6.38E+07	2.33E+10
Low Flows	90-100%	N/A	2.50E+07	9.14E+09

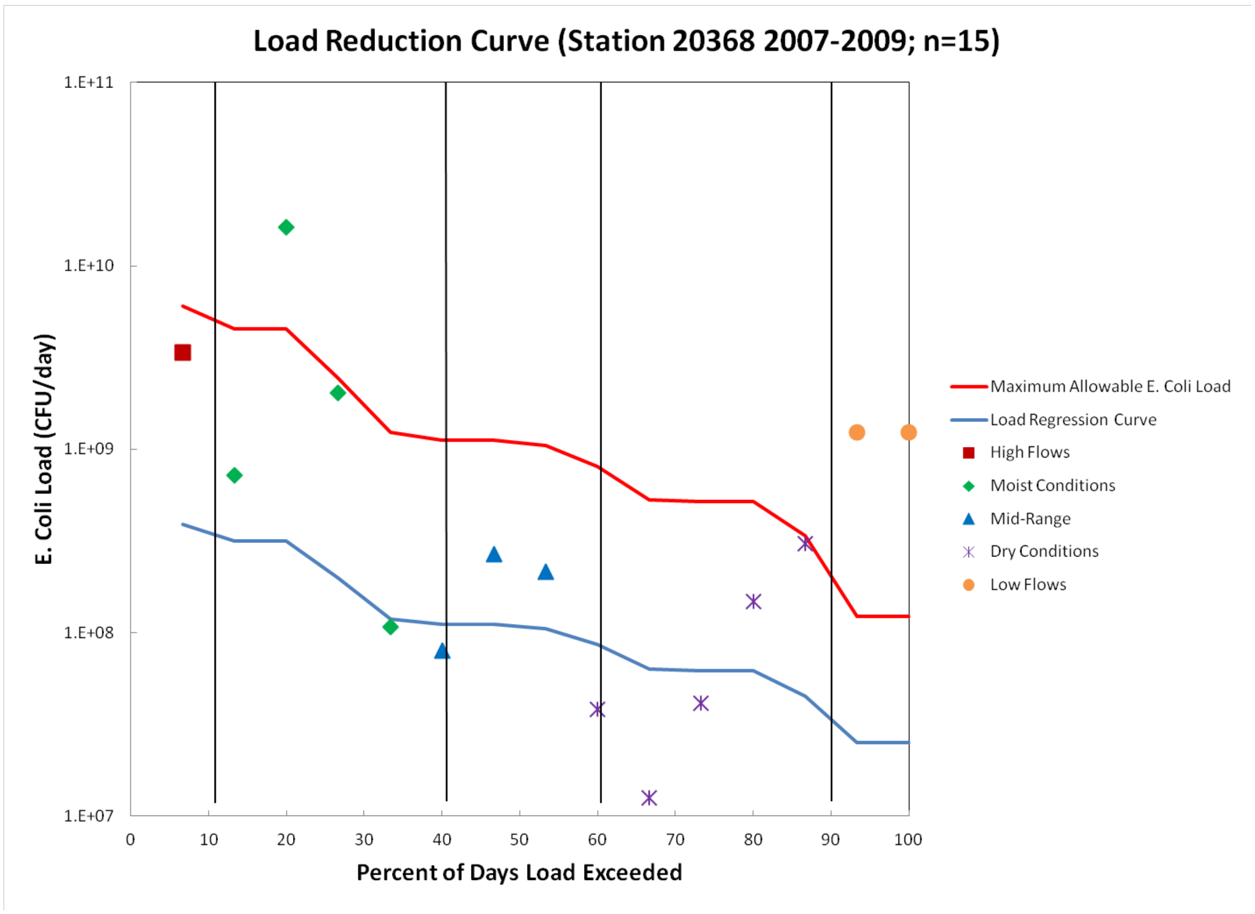


Figure 2c. Load Duration Curve for *E. coli* for water quality monitoring station 20368.

Table 5. Daily and Annual *E. coli* loads and needed percent reductions for water quality monitoring station 20371.

Flow Condition	% Exceedance	Needed % Reduction	Daily Loading (CFU/day)	Annual Loading (CFU/year)
High Flows	0-10%	N/A	8.24E+09	3.01E+12
Moist Conditions	10-40%	N/A	5.25E+09	1.92E+12
Mid-Range	40-60%	N/A	1.79E+09	6.55E+11
Dry Conditions	60-90%	N/A	1.17E+09	4.25E+11
Low Flows	90-100%	N/A	6.96E+08	2.54E+11

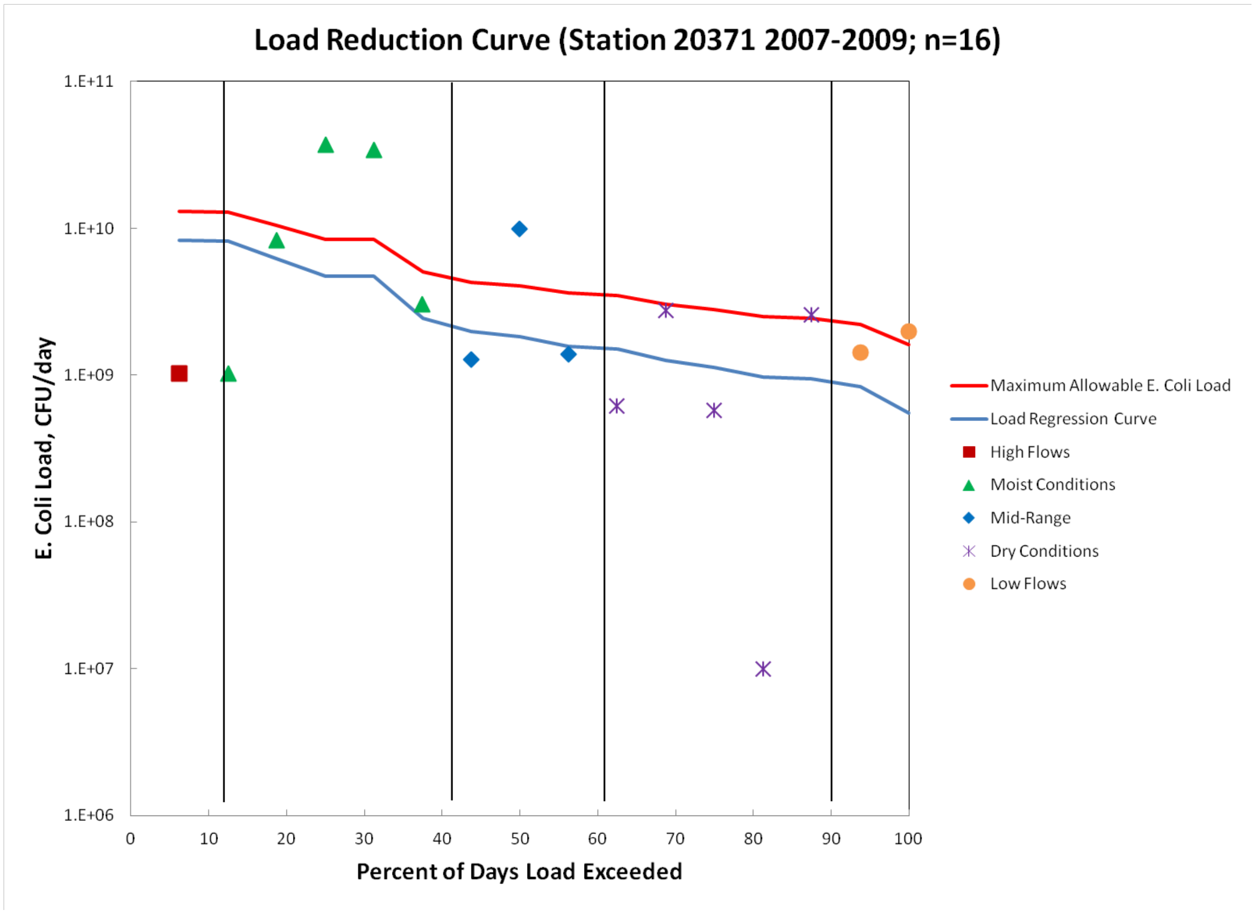


Figure 2d. Load Duration Curve for *E. coli* for water quality monitoring station 20371.

Table 6. Daily and Annual *E. coli* loads and needed percent reductions for water quality monitoring station 20373.

Flow Condition	% Exceedance	Needed % Reduction	Daily Loading (CFU/day)	Annual Loading (CFU/year)
High Flows	0-10%	N/A	2.22E+10	8.11E+12
Moist Conditions	10-40%	N/A	8.09E+09	2.95E+12
Mid-Range	40-60%	N/A	9.00E+08	3.28E+11
Dry Conditions	60-90%	N/A	6.65E+08	2.43E+11
Low Flows	90-100%	N/A	3.89E+08	1.42E+11

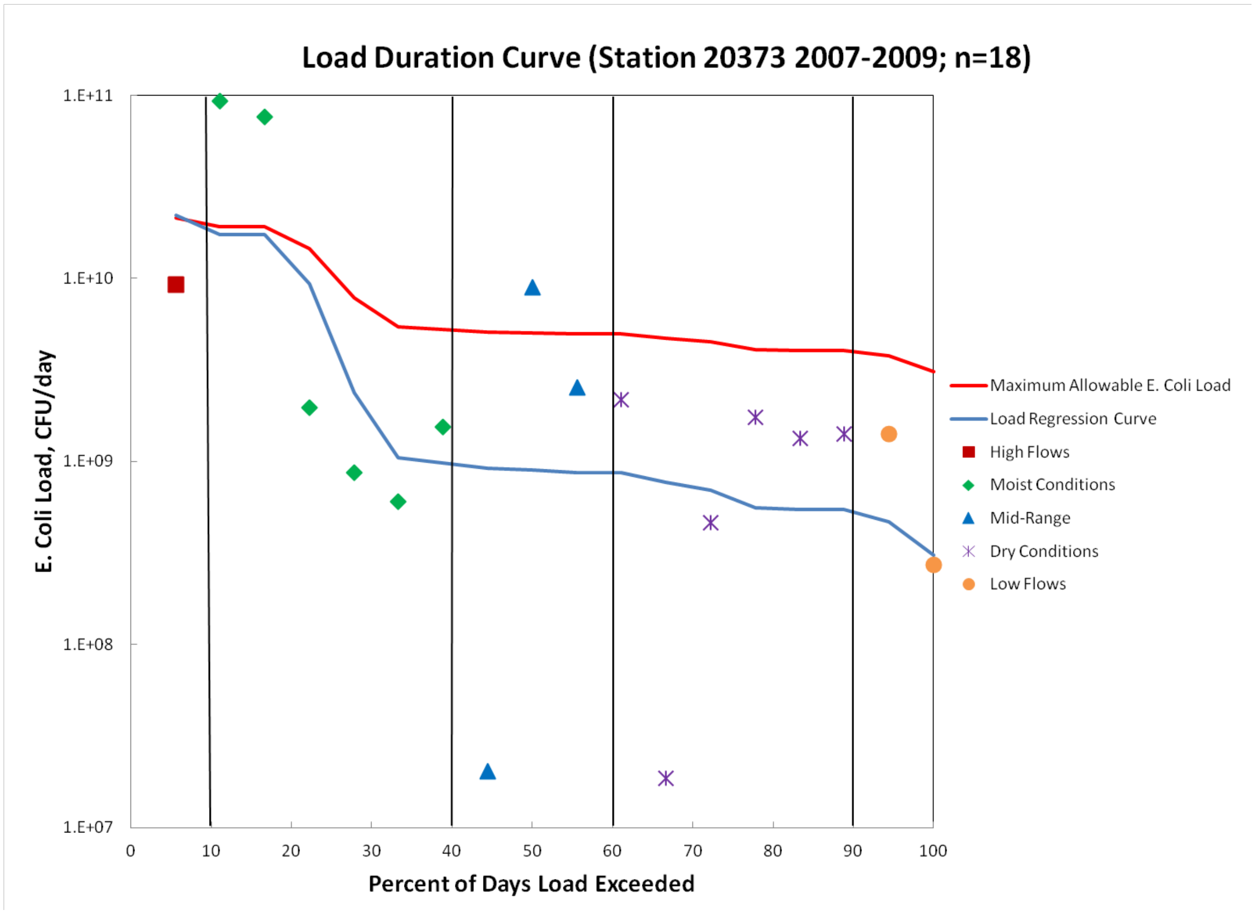


Figure 2e. Load Duration Curve for *E. coli* for water quality monitoring station 20373.

The actual *E. coli* loads for the historic water quality monitoring station 15811 were below the maximum allowable *E. coli* load for all flow conditions except for high flows. The percent reduction required for station 15811 ranged from 35 to not applicable (Table 2 and Figure 2f).

Table 7. Daily and Annual *E. coli* loads and needed percent reductions for water quality monitoring station 15811.

Flow Condition	% Exceedance	Needed % Reduction	Daily Loads (CFU/day)	Annual Loads (CFU/year)
High Flows	0-10%	35	1.17E+11	4.27E+13
Moist Conditions	10-40%	N/A	1.58E+10	5.78E+12
Mid-Range	40-60%	N/A	3.16E+09	1.15E+12
Dry Conditions	60-90%	N/A	1.04E+09	3.78E+11
Low Flows	90-100%	N/A	6.30E+07	2.30E+10

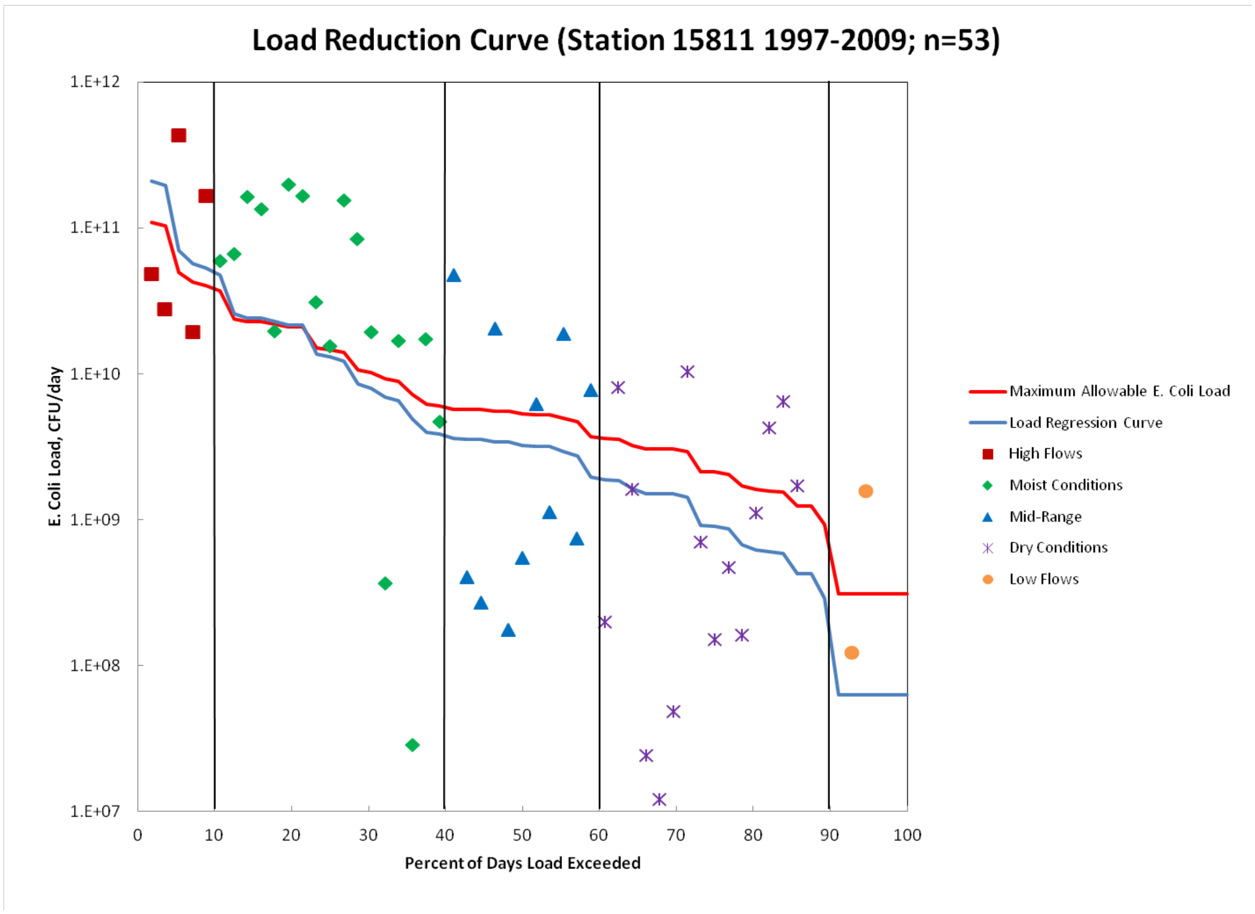


Figure 2f. Load Duration Curve for *E. coli* for water quality monitoring station 15811.

2.2. Nitrate LDC analysis

One water quality monitoring station 15811 was used to conduct the nitrate LDC analysis for the Buck Creek watershed (Figure 1) due to a lack of monitoring data available for additional monitoring sites. Nitrate data was not taken on a regular basis with sampling ranging from 1997 to 2009.

2.2.1. Data Summary at 15811

- Historic instantaneous flow and Nitrate data were collected from 12/11/1997 to 06/20/2005.
  - Total number of instantaneous flow expressed in cfs: 30
  - *Total number of Nitrate data expressed in mg/L and corresponding flow in cfs: 17*

- Current instantaneous flow (in cfs) and Nitrate data were used in the analyses between 11/07/2007 and 07/31/2009.
  - Total number of flow data expressed in cfs: 26
  - *Total number of Nitrate expressed in mg/L and corresponding flow in cfs: 6*
- *Total number of discrete E. coli data used (Figure 3): 23*

The actual nitrate loads for the historic water quality monitoring station 15811 were below the maximum allowable nitrate load for low flow and dry flow conditions. The percent reduction ranged from 56 to not applicable (Table 8 and Figure 3).

Table 8. Nitrate load reductions for water quality monitoring station 15811.

Flow Condition	% Exceedance	Needed % Reduction	Daily Loading (CFU/day)	Annual Loading (CFU/year)
High Flows	0-10%	56	2.58E+05	9.41E+07
Moist Conditions	10-40%	32	3.98E+04	1.45E+07
Mid-Range	40-60%	10	8.98E+03	3.28E+06
Dry Conditions	60-90%	N/A	3.16E+03	1.15E+06
Low Flows	90-100%	N/A	1.24E+02	4.52E+04

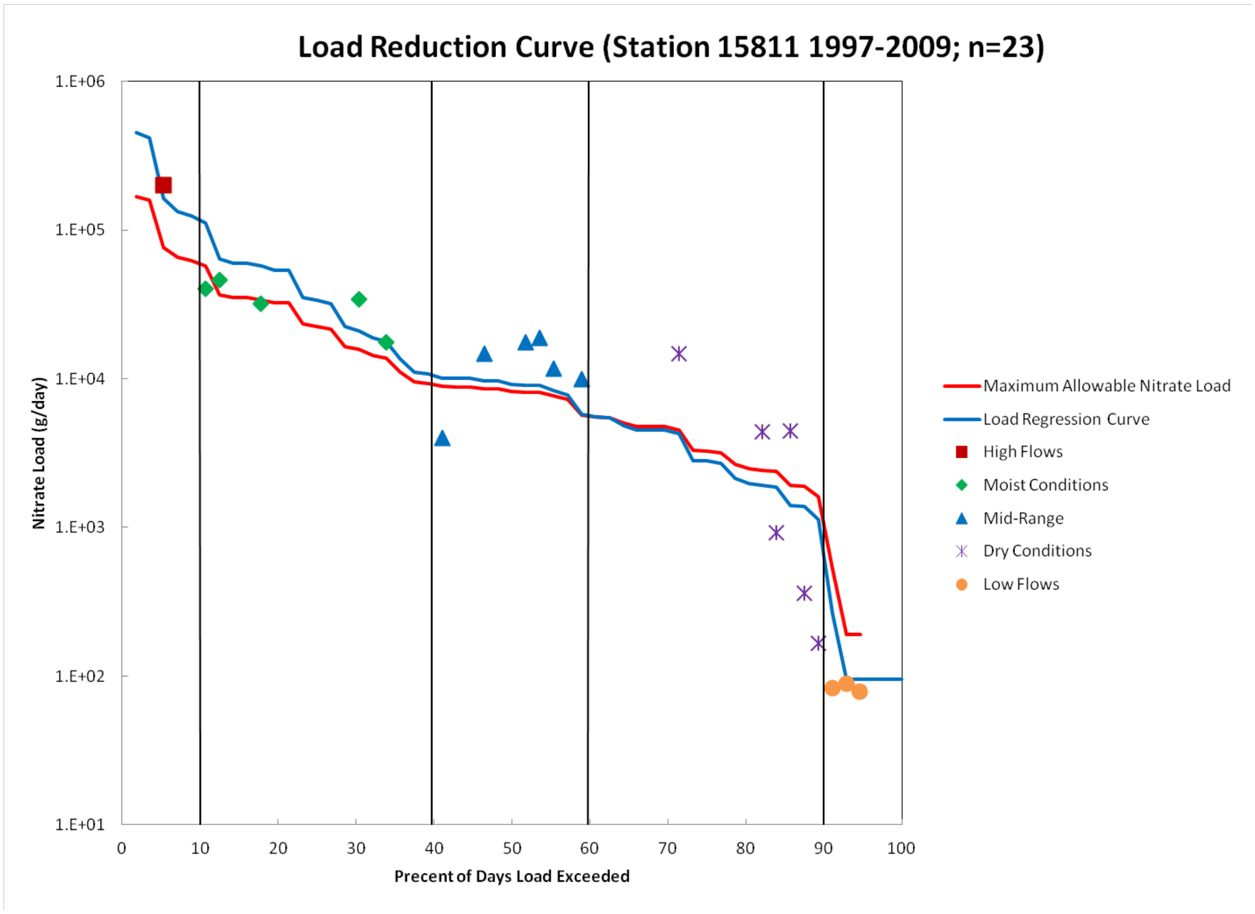


Figure 3. Load Duration Curve for nitrate for water quality monitoring station 15811.

3. POTENTIAL *E. coli* SOURCES USING SPATIALLY EXPLICIT LOAD ENRICHMENT CALCULATION TOOL (SELECT)

The Spatially Explicit Load Enrichment Calculation Tool (SELECT) methodology developed by Biological and Agricultural Engineering Department and Spatial Sciences Laboratory at Texas A&M University was used to independently characterize potential *E. coli* sources and estimate daily potential *E. coli* loads for the Buck Creek watershed. SELECT is an analytical approach for developing an inventory of potential bacterial sources, particularly nonpoint source contributors, and distributing their potential bacterial loads based on land use and geographical location. A thorough understanding of the watershed and potential contributors that exist is necessary to estimate and assess bacterial load inputs. Land use classification data and data from state agencies, municipal sources, and local stakeholders on the number and distribution of pollution sources are used as inputs in a Geographical Information Systems (GIS) software format. The watershed is divided into multiple smaller subwatersheds based on elevation changes along tributaries and the main segment of the water body. Pollutant sources in the landscape can then be identified and targeted where they are most likely to have significant effects on water quality, rather than looking at contributions on a whole-watershed basis.

The SELECT is a pathogen load assessment tool which can be combined with a watershed-scale water quality model using spatially variable governing factors such as land use, soil condition, and distance to streams to support TMDLs and WPPs. This tool can be used to estimate the actual contaminant loads resulting in streams when used in conjunction with a fate and transport watershed model. SELECT simulated potential *E. coli* loadings in the watersheds resulting from various sources based on user defined inputs such as stocking rates, animal population, location of WWTPs, and *E. coli* production rates resulting from various sources. The land use was verified by stakeholders and it was suggested that the land use categorized as crop land should be categorized as managed pasture. Livestock other than cattle were not considered as potential sources because stakeholders determined that these sources did not have a significant influence on the watershed.

Visual outputs of the program allow a decision maker or stakeholder to easily identify areas of a watershed with the greatest potential for contamination contribution and enable the decision maker to use that information to help formulate management strategies to include in the Buck Creek WPP. Specific model details and information about its development can be found in Teague et al. (2009) and Riebschleager (2008).

3.1. Potential E. coli Sources

The following potential *E. coli* sources, population estimates, densities, and distributions as well as *E. coli* production rates were considered in estimating total potential *E. coli* loads resulting from each source in the watershed.

3.1.1. Livestock –Cattle

Populations of cattle in the Buck Creek watershed consist of those grazed on rangeland and managed pasture and those temporarily housed at the auction barn at Wellington and feedlot near Hedley. For SELECT modeling purposes, only those cattle grazed on rangeland or managed pasture were considered. The watershed stakeholder derived estimate of 6,640 head of cattle was utilized and applied to the watershed at recommended NRCS stocking rate for rangeland (25 ac/animal) and managed pasture (8 ac/animal). This rate was calculated using recommended stocking rates for Childress, Collingsworth and Donley counties. These cattle numbers and distributions were verified with watershed stakeholders and determined to be representative of the Buck Creek watershed. The *E. coli* production rate used was 5×10^{10} CFU per animal per day. This was derived by applying a fecal coliform to *E. coli* conversion factor of 0.5 as recommended by Doyle and Erikson (2006) to the maximum fecal coliform production concentrations reported in USEPA's *Protocol for Developing Pathogen TMDLs* (2001). The Using these stocking rates and *E. coli* concentration, daily potential *E. coli* loads resulting from pasture cattle and range cattle were estimated. The pasture cattle and range cattle results were then added together spatially to create the resulting potential loadings from cattle for the watershed.

3.1.2. Deer

Estimations of the deer population in Buck Creek are a combination of white-tailed and mule deer. TPWD provided initial population estimates and associated animal densities for areas as near to Buck Creek as possible. Using this information as a starting point, stakeholders were asked to provide input on the size and distribution of the deer herds in the watershed. In total, 5,143 deer (990 mule deer and 4,153 white-tailed deer) are assumed to reside in the watershed and are assumed to be evenly distributed over the rangeland, managed pasture, deciduous forest, riparian forest and cultivated land uses at an average rate of 36 acres per animal. The *E. coli* production rate used was 1.75×10^8 CFU per animal per day. Applying the 0.5 fecal coliform to *E. coli* conversion factor recommended by Doyle and Erickson (2006) to the daily fecal coliform production rate of 3.5×10^8 CFU per deer per day as reported by Zeckoski et al. (2005) yields the rate used. Mule deer are assumed to have the same fecal production and *E. coli* levels per gram of fecal material as white-tailed deer since no data were found quantifying these numbers. Using this deer density and *E. coli* concentration in deer fecal material, daily potential *E. coli* loads resulting from deer were estimated.

3.1.3. Feral Hogs

No accurate estimate of feral hog numbers in the Buck Creek watershed exist; as a result, stakeholder feedback regarding feral hog numbers in Buck Creek was used. This feedback produced a population density estimate of 25 acres per animal. Stakeholders also indicated that the feral hog population should be evenly distributed across rangeland, barren land, managed pasture, cultivated land, mixed forest and riparian forest land uses to attain an appropriate number of animals. Using this information, an estimated feral hog population of 7,310 animals was developed for the entire watershed. The *E. coli* production rate used was 5.5×10^9 CFU per animal per day This rate was developed by applying the 0.5 fecal coliform to *E. coli* conversion rate recommended by Doyle and Erickson (2006) to the maximum fecal coliform concentration report for hogs in USEPA (2001). Using this feral hog density and *E. coli* concentration in hog fecal material, daily potential *E. coli* loads resulting from feral hogs were estimated.

3.2. Land Use Analysis and Subbasin Delineation

The Spatial Sciences Laboratory (SSL) at Texas A&M University classified land uses of the Buck Creek watershed in 2008 through TSSWCB Project 08-52, *Classification of Current Land Use/Land Cover for Certain Watersheds Where Total Maximum Daily Loads or Watershed Protection Plans Are In Development.* For Buck Creek, the land use and land cover was determined using several available datasets. National Agriculture Imagery Program images collected in 2005 were paired with 2003 Landsat Satellite Imagery to develop land use and land cover classifications. Additionally, managed pastures were further delineated utilizing USDA Farm Service Agency data thus enabling a more accurate assessment of watershed land use and land cover. These classifications were verified utilizing 2001 National Land Cover Dataset classifications and ground truthed data thus providing an accurate and up-to-date description of land uses and land covers in the watershed. The land use for the Buck Creek watershed was categorized into 10 different categories and consists mostly of agricultural areas with very little developed areas (Figure 4 and Table 9). This assessment verifies that the watershed consists predominantly of cropland and rangeland with little development.

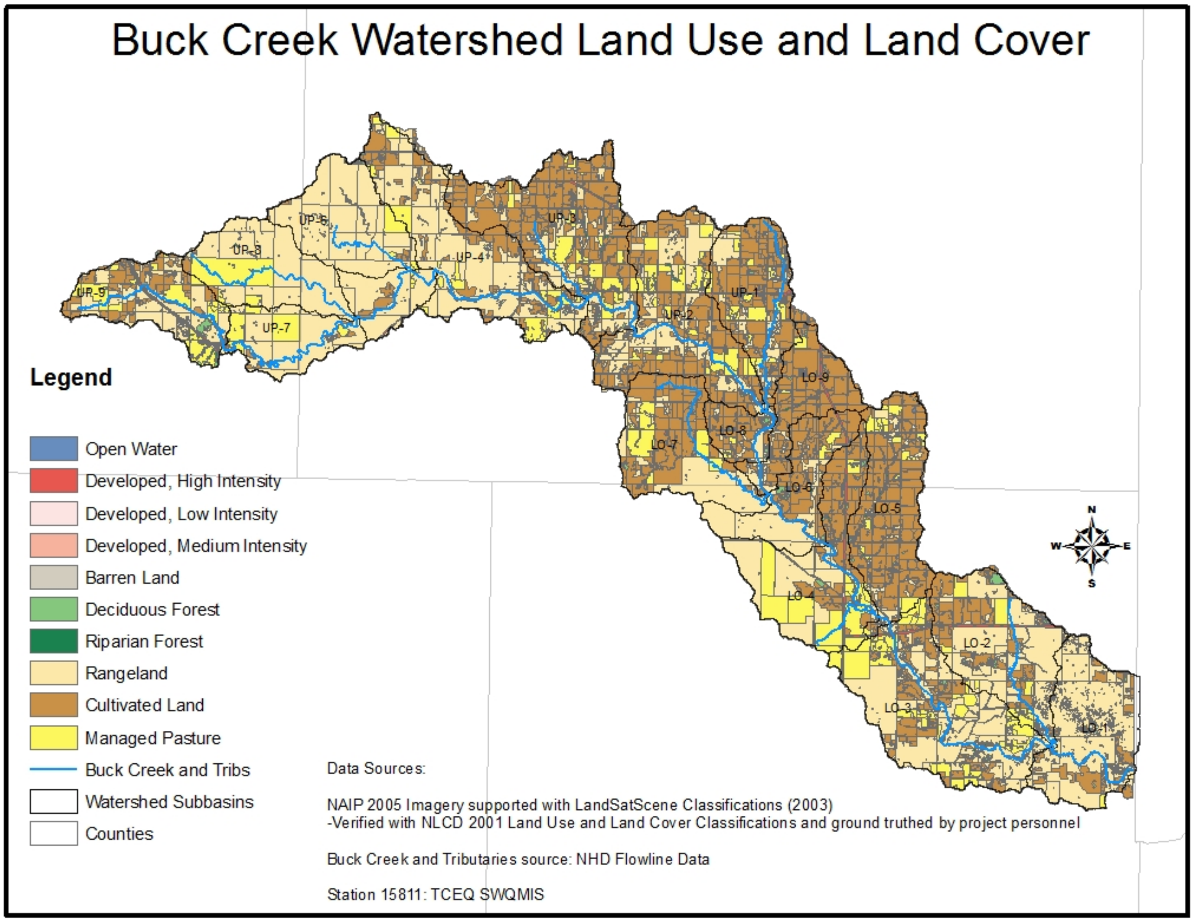
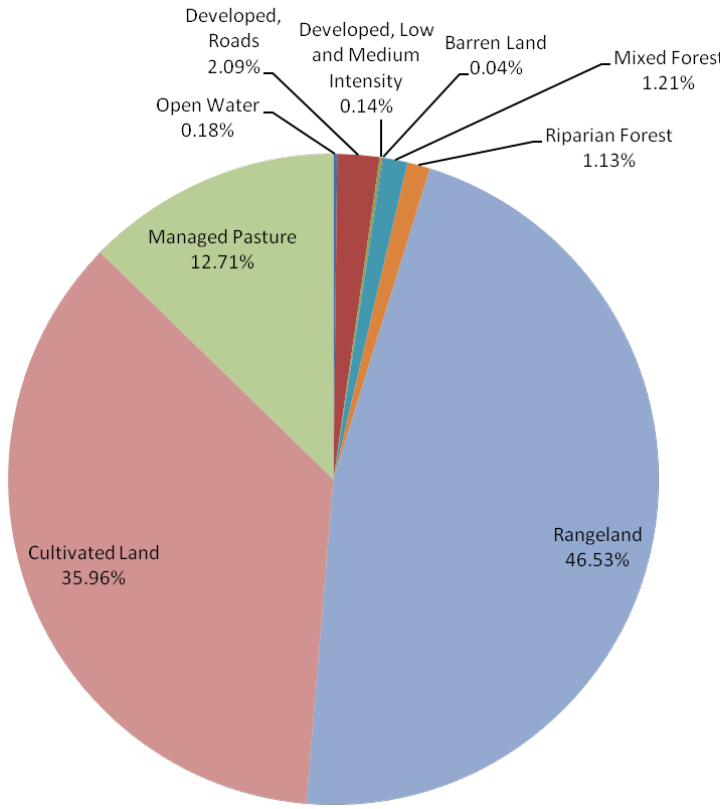


Figure 4. Land use Distribution in the Buck Creek Watershed.

Table 9. Land Use Distribution in the Buck Creek Watershed by Acreage.

Land Use / Land Cover	**Acres**
Open Water	342
Developed, High Intensity	3,920
Developed, Low Intensity	261
Developed, Medium Intensity	3
Barren Land	73
Deciduous Forest	2,265
Riparian Forest	2,121
Rangeland	87,141
Cultivated Land	67,335
Managed Pasture	23,809
Total Watershed	187,270



Watershed subbasins illustrated in Figures 1 and 4 were delineated within the Buck Creek watershed. The SELECT model operates on a subbasin scale and thus subbasins are an input requirement of the SELECT model. Further, delineating the watershed into hydrologically connected subbasins helps in targeting management measure that will be included in the WPP. Water quality data collected throughout the watershed can also be tied back to the subbasins as well thus helping to identify what areas of the watershed are contributing to pollutant loading at a specific monitoring station.

3.3. SELECT Analysis Results

SELECT was used to develop loading estimates for cattle, deer and feral hogs. These three sources were identified by watershed stakeholders to be major contributors of bacteria to the watershed and were thus the focus of SELECT modeling efforts. Other wildlife (opossums, raccoons, coyotes, rabbits, squirrels, etc.) is thought to be problematic in Buck Creek as well, but information needed to model potential loads from these sources is not available (animal densities, fecal production rates, etc.). Opossums and raccoons, two species known to inhabit riparian areas, have been found to produce average *E. coli* counts per gram of fecal material much higher than cattle, deer or feral hogs (R. Karthikeyan, personal communication). While these species are considerably smaller and produce less fecal material per day, they do congregate in riparian areas and are known to contribute pollutants to the watershed. It is also recognized that other sources of potential pollution exist in the watershed (a CAFO, OSSFs, a WWTF, etc.); however, they were considered miniscule by watershed stakeholders and not modeled.

3.3.1. Total Potential *E. coli* Load from Cattle

SELECT model results from cattle are presented below in Figure 5 and as expected, are strongly tied to land use/land cover type within each watershed subbasin. Watershed subbasins dominated by rangeland or managed pasture exhibit the highest potential loading while those dominated by forests or cultivated land have a lower potential.

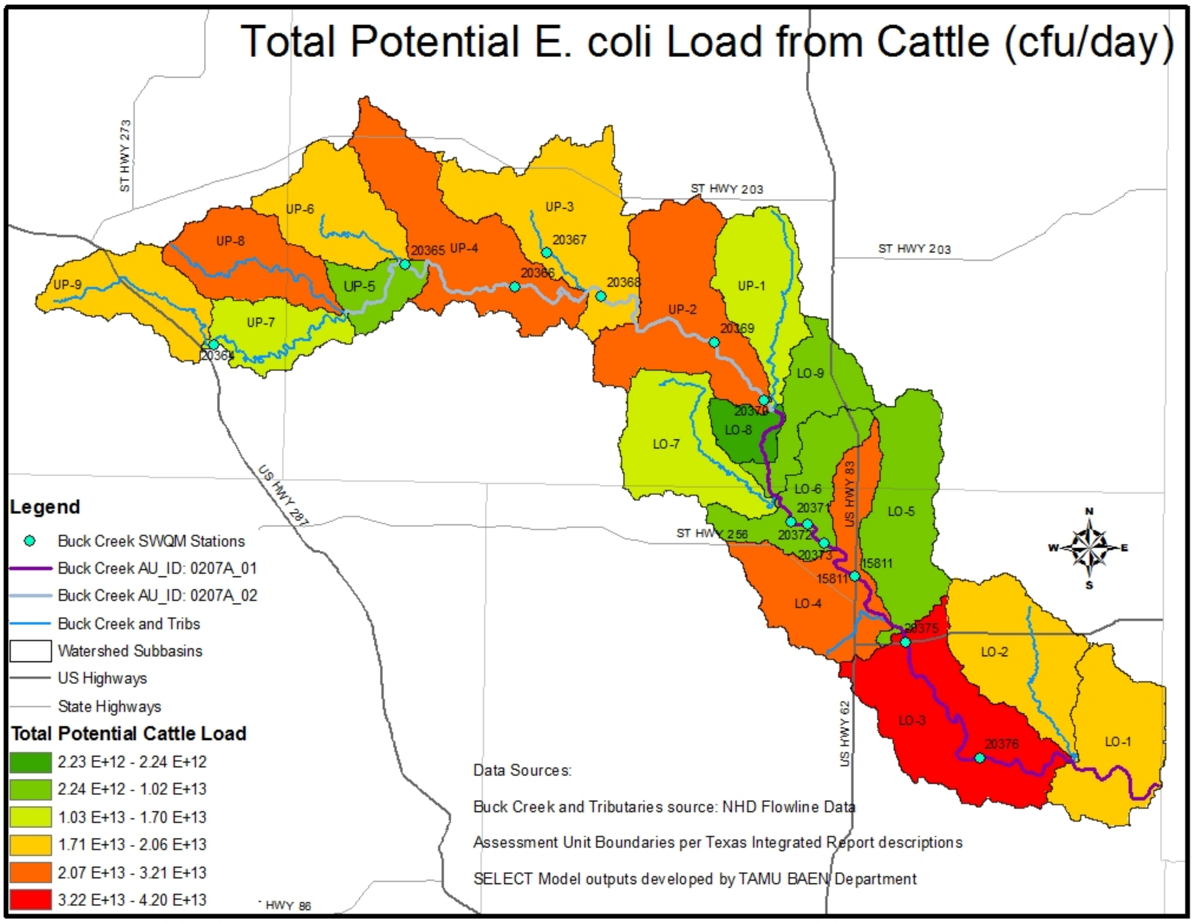


Figure 5. Potential *E. coli* Load resulting from Cattle for the Buck Creek Watershed.

3.3.2. Total Potential *E. coli* Load from Deer

Potential *E. coli* loadings from deer as predicted by the SELECT model are presented in Figure 6 below. Land use and land cover have less of an influence on predicted loadings than does subbasin size in this case. Deer populations were applied evenly across rangeland, managed pasture, deciduous forest, riparian forest and cultivated land thus encompassing all but the smallest land uses in the Buck Creek watershed. Subbasin size is the larger determining factor in predicting which of the 18 subbasins has the highest potential for *E. coli* loading from deer.

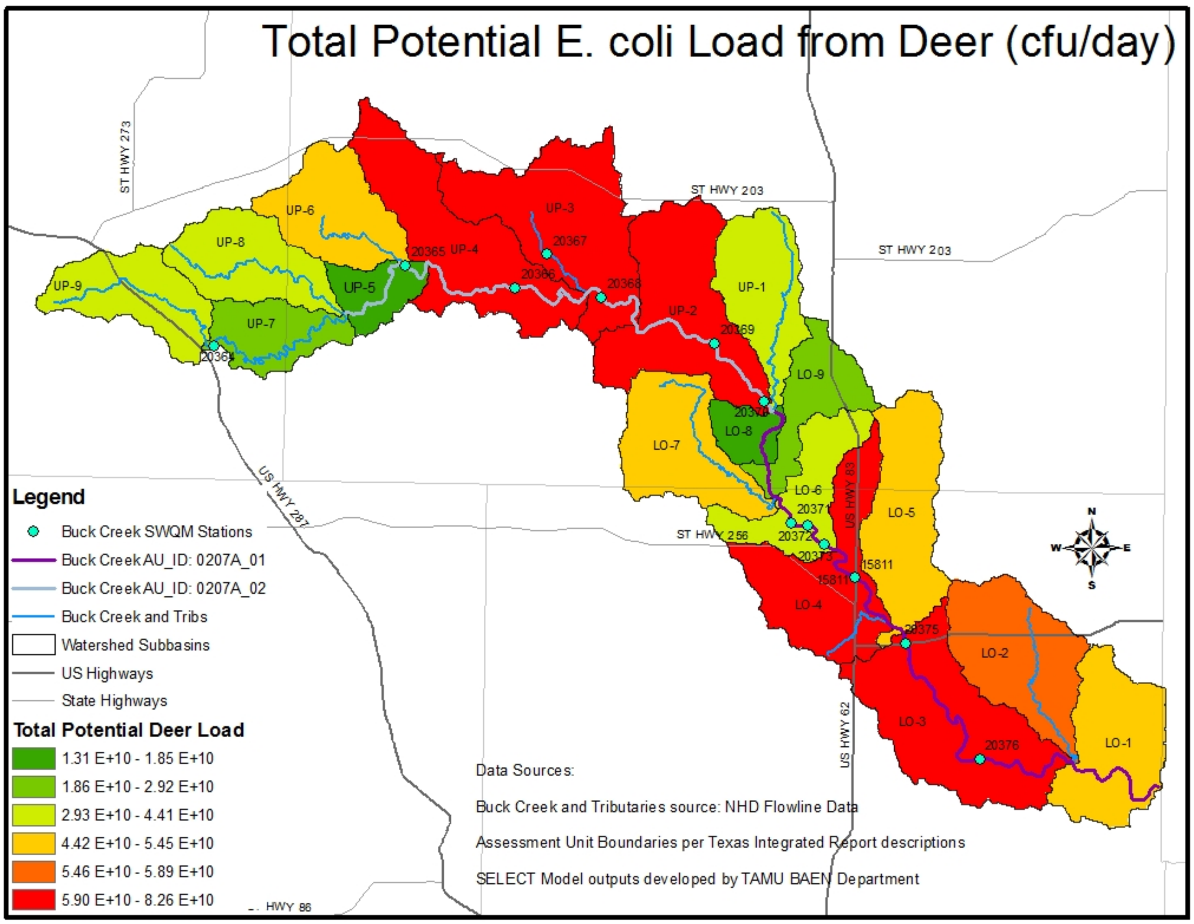


Figure 6. Potential *E. coli* Load resulting from Deer for the Buck Creek Watershed.

3.3.3. Total Potential *E. coli* Load from Feral Hogs

SELECT model results predicting *E. coli* loading from feral hogs are shown below in Figure 7. For feral hogs, a density of 25 acres per animal unit was applied uniformly across barren lands, range lands, managed pasture lands, cultivated land, mixed forest, and riparian forests within a 100 m buffer around the stream network of the watershed depicted by National Hydrography Dataset flowlines. The extent of the stream network within each watershed subbasin strongly influenced the SELECT model predictions as did the amount of the land uses and land covers listed above.

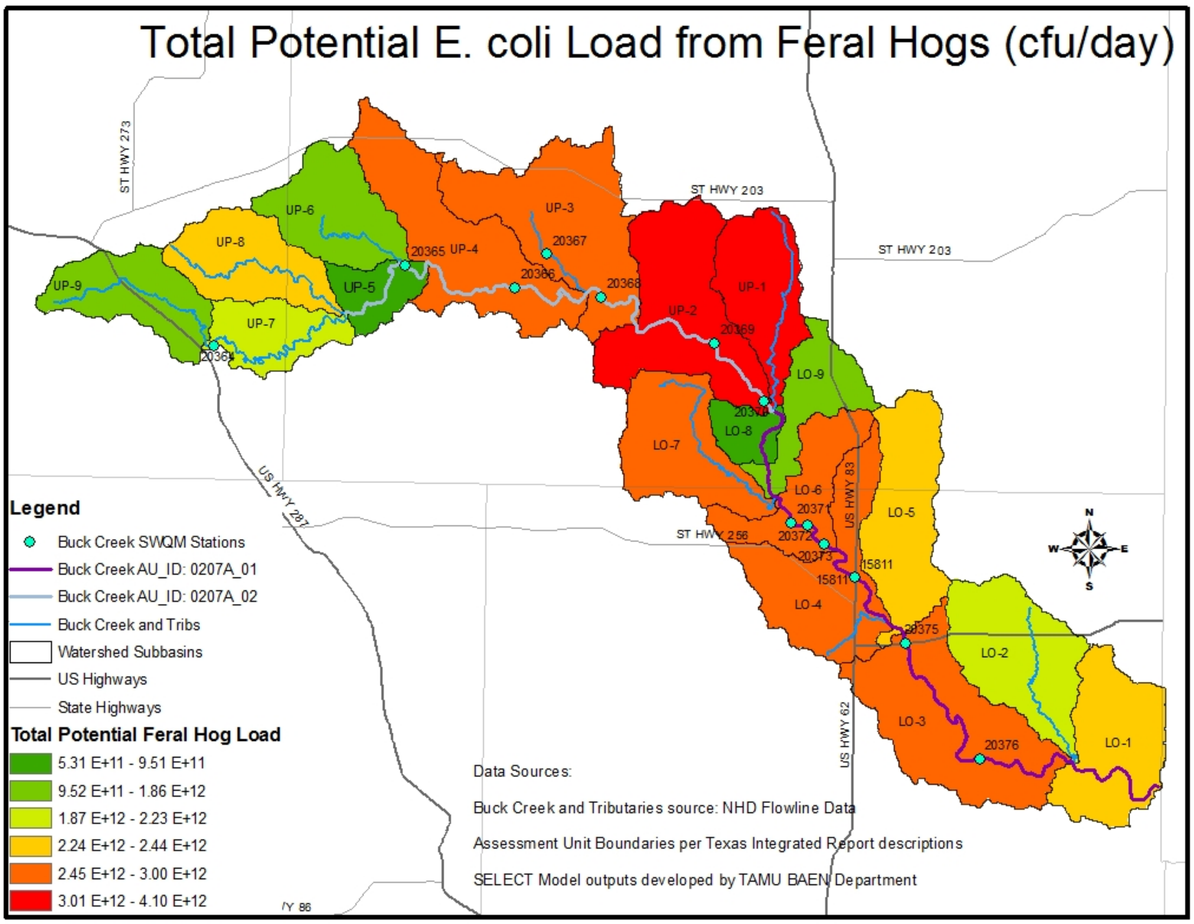


Figure 7. Potential *E. coli* Load resulting from Feral Hogs for the Buck Creek Watershed.

3.3.4. Total Potential *E. coli* Load

The daily potential *E. coli* load range for the watershed predicted by the SELECT model including all modeled contributing sources was 2.78×10^{12} to 4.49×10^{13} CFU per day (Figure 5). This potential load consists of the potential loads form cattle, deer and feral hogs combined. The contributor with the highest daily potential *E. coli* load in the watershed was cattle, the medium contributor was feral hogs and the lowest contributor was deer (Table 5). As seen in Figures 5 and 6, Total *E. coli* loading potential mirrors *E. coli* loading potential of cattle. This is due to the relatively larger potential to contribute *E. coli* possessed by cattle than deer and feral hogs.

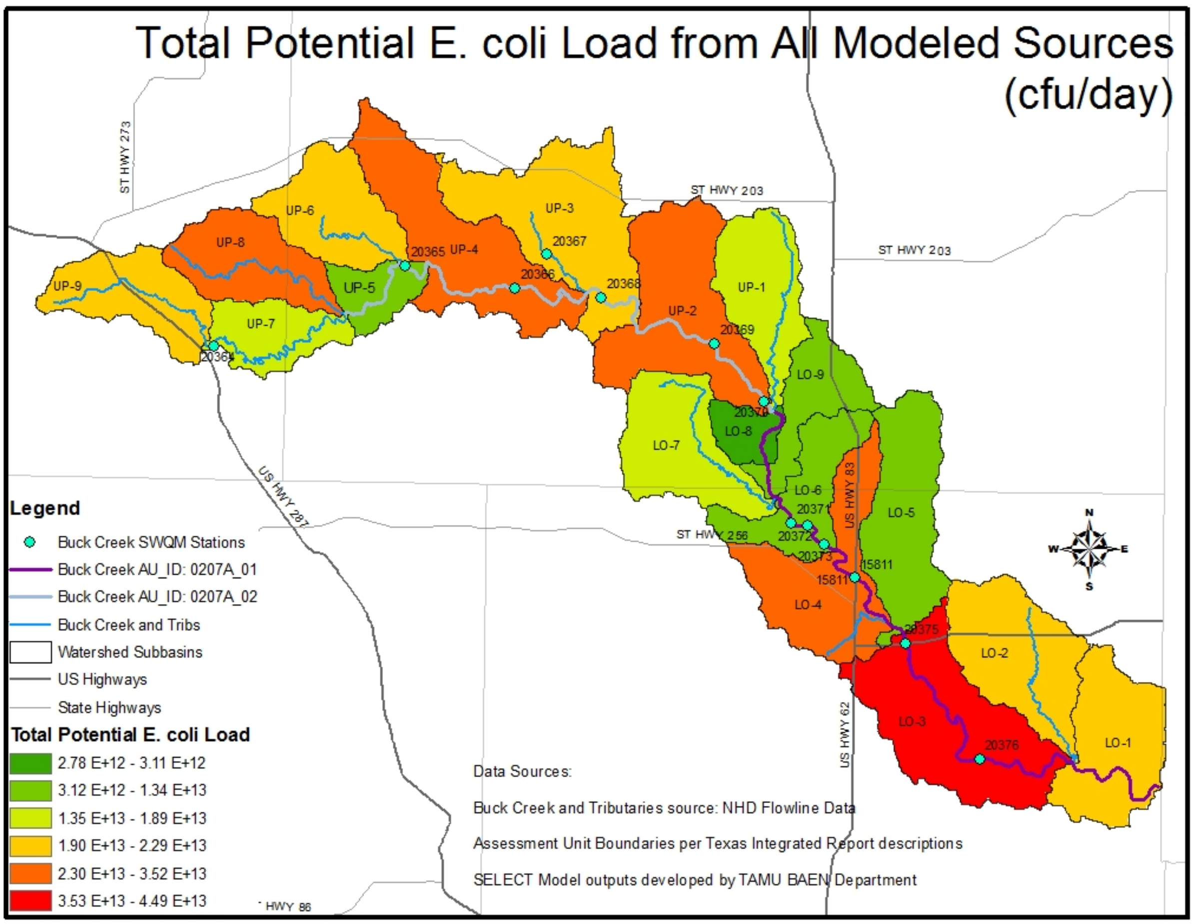


Figure 8. Daily Total Potential *E. coli* Load for the Buck Creek Watershed.

Table 10. Daily Total Potential *E. coli* Load for Various Sources.

Potential *E. coli* sources	**Daily Potential *E. coli* Load (CFU/day)**
Cattle (Range and Pasture)	2.23×10^{12} to 4.20×10^{13}
Deer	1.31×10^{10} to 8.26×10^{10}
Feral Hogs	5.31×10^{11} to 4.10×10^{12}

Table 11. Potential *E. coli* loads (cfu/day) and ranking for watershed subbasins by individual and collective pollutant sources

Subbasins	**Cattle Load**	**Rank***	**Deer Load**	**Rank***	**Feral Hog Load**	**Rank***	**Total Load**	**Total Rank***
LO 1	1.88E+13	3	5.36E+10	3	2.32E+12	3	2.11E+13	3
LO 2	2.06E+13	3	5.64E+10	2	2.22E+12	4	2.29E+13	3
LO 3	4.20E+13	1	8.26E+10	1	2.78E+12	2	4.49E+13	1
LO 4	3.22E+13	2	5.89E+10	1	2.96E+12	2	3.52E+13	2
LO 5	9.22E+12	5	5.44E+10	3	2.34E+12	3	1.16E+13	5
LO 6	9.24E+12	5	3.71E+10	4	2.45E+12	2	1.17E+13	5
LO 7	1.60E+13	4	5.06E+10	3	2.75E+12	2	1.88E+13	4
LO 8	2.23E+12	6	1.31E+10	6	5.31E+11	6	2.78E+12	6
LO 9	2.25E+12	5	2.92E+10	5	9.57E+11	5	3.23E+12	5
UP 1	1.03E+13	4	4.21E+10	4	3.01E+12	1	1.34E+13	4
UP 2	2.53E+13	2	7.43E+10	1	4.10E+12	1	2.95E+13	2
UP 3	1.93E+13	3	7.71E+10	1	2.71E+12	2	2.20E+13	3
UP 4	3.09E+13	2	7.45E+10	1	2.76E+12	2	3.37E+13	2
UP 5	7.20E+12	5	1.86E+10	6	9.51E+11	6	8.17E+12	5
UP 6	1.95E+13	3	4.42E+10	3	1.39E+12	5	2.09E+13	3
UP 7	1.70E+13	4	2.91E+10	5	1.87E+12	4	1.89E+13	4
UP 8	2.62E+13	2	4.37E+10	4	2.24E+12	3	2.85E+13	2
UP 9	1.98E+13	3	4.00E+10	4	1.83E+12	5	2.17E+13	3
Potential Daily *E. coli* Load for All Subbasins	**3.28E+14**		**8.80E+11**		**4.01E+13**		**3.69E+14**	
Potential Annual *E. coli* Load for All Subbasins	**1.20E+17**		**3.21E+14**		**1.47E+16**		**1.35E+17**	

* Subbasin rankings illustrate the potential *E. coli* load from individual subbasins for a given pollutant source as compared to the potential pollutant load from the same source in other subbasins. The ranking is used to help direct where management measures are recommended.

4. SUMMARY

E. coli load reductions were calculated based on Load Duration Curves for Buck Creek. Potential *E. coli* sources in the watersheds were spatially identified. Daily potential *E. coli* sources resulting from various sources were estimated using a spatially explicit load estimation tool. The results of the Load Duration Curve analysis showed little to no bacterial contamination in Buck Creek above the regulatory standard. This could be due to the watershed being in an extremely rural area with few sources contributing to fecal contamination. Buck Creek is located in an area with low average rainfall with only non point sources contributing to fecal contamination; without surface runoff carrying the bacteria into the creek from the sources, it is unlikely that these sources would contribute to the bacteria occurring in the creek.

4.1. Load Duration Curve Analysis

1. The actual *E. coli* loads for all five current water quality monitoring sites are below the regulatory standard for all flow conditions. These sites do not require any reductions in *E. coli* to meet regulatory standards.
2. The actual *E. coli* loads for historic station 15811 are only exceeding in high flow conditions. Best management practices cannot be feasibly applied to prevent exceedance at high flows.
3. The nitrate loads are exceeding for high flows, moist conditions, and mid-range conditions with dry conditions and low flows below the regulatory standard. However, this analysis is based on an extremely limited data set that does not include adequate temporal representation of water quality data collected at this and other monitoring locations to make solid conclusions about current nitrate loadings.

4.2. Daily Potential E. coli Loads

1. The highest potential *E. coli* contributors in the watershed are cattle. The medium and low contributors are feral hogs and deer.
2. Best management practices should be focused on high and medium contributors to help reduce the *E. coli* loads entering the water bodies.
3. Cattle and feral hogs were high contributors in this watershed, even with below average stocking rates and population densities for contributing animals, because the watershed is extremely rural and does not have many other sources contributing to fecal contamination.

4. A majority of the land use in the watershed is rangeland and managed pasture. Cattle were considered high contributors because they were able to be distributed on a majority of the land in the watershed. Since, feral hogs were distributed on almost all land use categories; they also had a high potential bacterial contribution.

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