Technical Support Document for Total Maximum Daily Load for Indicator Bacteria for Mound Creek

Segment: 1015A
Assessment Unit: 1015A_01

Mound Creek at sampling station 17937

Technical Support Document for Total Maximum Daily Load for Indicator Bacteria in Mound Creek

Segment: 1015A

Assessment Unit: 1015A_01

Prepared for
Total Maximum Daily Load Program
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MC-203
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Abbreviations

AU	assessment unit
C-Cap	Coastal Change Analysis Program
cfs	cubic feet per second
DAR	drainage-area ratio
DMU	Deer Management Unit
DSLP	days since last precipitation
ECHO	Enforcement and Compliance History Online
E. coli	*Escherichia coli*
$\mathrm{FDA_{SWP}}$	fractional drainage area stormwater permit
FDC	flow duration curve
FIB	fecal indicator bacteria
FG	future growth
GIS	Geographic Information System
H-GAC	Houston-Galveston Area Council
I&I	inflow and infiltration
I-Plan	implementation plan
LA	load allocation
LDC	load duration curve
mL	milliliter
MOS	margin of safety
MPN	most probable number
MS4	municipal separate storm sewer system
MSGP	multi-sector general permit
NOAA	National Oceanic and Atmospheric Association
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
OSSF	on-site sewage facility
SSO	sanitary sewer overflow
SSURGO	soil survey geographic database
SWQM	surface water quality monitoring
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TIAER	Texas Institute for Applied Environmental Research
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

WLA	waste load allocation
WLA_{SW}	waste load allocation stormwater
WLA_{WWTF}	waste load allocation wastewater treatment facilities
WWTF	wastewater treatment facility

SECTION 1
INTRODUCTION

1.1 Background

Section 303(d) of the federal Clean Water Act requires all states to identify waters that do not meet, or not expected to meet, applicable water quality standards. States must develop a Total Maximum Daily Load (TMDL) for each pollutant that contributes to the impairment of a listed water body. The Texas Commission on Environmental Quality (TCEQ) is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas.

A TMDL is like a budget—it determines the amount of a particular pollutant that a water body can receive and still meet its applicable water quality standards. TMDLs are the best possible estimates of the assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load with units of mass per period of time, but may be expressed in other ways. In addition to the TMDL an implementation plan (I-Plan) is developed, which is a description of the regulatory and voluntary management measures necessary to improve water quality and restore full use of the water body.

The TCEQ's TMDL Program is a major component of Texas' overall process for managing the quality of its surface waters. The program addresses impaired or threatened streams, reservoirs, lakes, bays, and estuaries (water bodies) in, or bordering on, the state of Texas. The primary objective of the TMDL Program is to restore and maintain the beneficial uses—such as drinking water supply, recreation, support of aquatic life, or fishing—of impaired or threatened water bodies.

The TCEQ identified the bacteria impairments within Mound Creek in the 2014 edition of the Texas *Water Quality Integrated Report of Surface Waters for Clean Water Act Sections 305(b) and 303 (d) (*formerly called the *Texas Water Quality Inventory and 303(d) List)*.

This document will consider bacteria impairments in the downstream assessment unit (AU) within the segment: 1015A_01.

1.2 Water Quality Standards

To protect public health, aquatic life, and development of industries and economies throughout Texas, water quality standards were established by the TCEQ. The water quality standards describe the limits for indicators that are monitored in an effort to assess the quality of available water for specific users. The TCEQ is charged with monitoring and assessing water bodies based on these water quality standards, and publishes the Texas Water Quality Integrated Report list biennially.

The *Texas Surface Water Quality Standards* (TCEQ, 2010) are rules that:

- *designate the uses, or purposes, for which the state's water bodies should be suitable;*
- *establish numerical and narrative goals for water quality throughout the state; and*
- *provide a basis on which TCEQ regulatory programs can establish reasonable methods to implement and attain the state's goals for water quality.*

Standards are established to protect uses assigned to water bodies of which the primary uses assigned in the *Texas Surface Water Quality Standards* to water bodies are:

- *aquatic life use*
- *contact recreation*
- *domestic water supply*
- *general use*

Fecal indicator bacteria (FIB) are used to assess the risk of illness during contact recreation (*e.g.*, swimming) from ingestion of water. FIBs are present in the intestinal tracts of humans and other warm-blooded animals. The presence of these bacteria in water indicates that associated pathogens from the wastes that may be reaching water bodies because of such sources as inadequately treated sewage, improperly managed animal waste from livestock, pets, aquatic birds, wildlife, and failing septic systems (TCEQ, 2006). *Escherichia coli* (*E. coli)* is a member of the fecal coliform bacteria group and is used in the State of Texas as the FIB in freshwater.

On June 30, 2010, the TCEQ adopted revisions to the Texas Surface Water Quality Standards (TCEQ, 2010) and on June 29, 2011, the U.S. Environmental Protection Agency (USEPA) approved the categorical levels of recreational use and their associated criteria. Recreational use consists of four categories:

- Primary contact recreation is that with a significant risk of ingestion of water (such as swimming), and has a geometric mean criterion for *E. coli* of 126 most probable number (MPN) per 100 milliliter (mL) and an additional single sample criterion of 399 MPN per 100 mL;
- Secondary contact recreation 1 covers activities with limited body contact and a less significant risk of ingestion of water (such as fishing), and has a geometric mean criterion for *E. coli* of 630 MPN per 100 mL;
- Secondary contact recreation 2 is similar to secondary contact 1, but activities occur less frequently. It has a geometric mean criterion for *E. coli* of 1,030 MPN per 100 mL; and
- Noncontact recreation is that with no significant risk of ingestion of water, where contact recreation should not occur due to unsafe conditions. It has a geometric mean criterion for *E. coli* of 2,060 MPN per 100 mL (TCEQ, 2010).

Mound Creek is presumed for primary contact recreation and has the associated *E. coli* geometric mean criterion of a 126 MPN per 100 mL and single sample criterion of 399 MPN per 100 mL.

1.3 Report Purpose and Organization

The Mound Creek TMDL project was initiated through a contract between the TCEQ and Texas Institute for Applied Environmental Research (TIAER). The tasks of this project were to (1) develop, have approved, and adhere to a quality assurance project plan; (2) develop a technical support document for the impaired watershed; and (3) assist the TCEQ with public participation. The purpose of this report is to provide technical documentation and supporting information for developing the bacteria TMDL for the impaired watershed of Mound Creek. This report contains:

- information on historical data,
- watershed properties and characteristics,
- summary of historical bacteria data that confirm the State of Texas 303(d) listings of impairment due to presence of indicator bacteria (*E. coli*),
- development of load duration curves (LDCs), and
- application of the LDC approach for the pollutant load allocation process.

Whenever it was feasible, the data development and computations for developing the LDC and pollutant load allocation were performed in a manner to remain consistent with the previously completed *Seven Total Maximum Daily Loads for Indicator Bacteria in Lake Houston, East Fork San Jacinto River, West Fork San Jacinto River, and Crystal Creek Watersheds* (TCEQ, 2016).

SECTION 2
HISTORICAL DATA REVIEW AND WATERSHED PROPERTIES

2.1 Description of Study Area

The Mound Creek watershed is located in a predominantly rural area west of the City of Conroe (Figure 1). Mound Creek (Segment 1015A is a perennial freshwater stream that is a tributary of Lake Creek (Segment 1015), which in turn is a tributary of the West Fork San Jacinto River (Segment 1004). Mound Creek was considered a fully supporting contributing watershed to the West Fork San Jacinto River in a previous TMDL (Figure 2, TCEQ, 2016). The Mound Creek watershed has a drainage area of 20.97 square miles (13,422 acres) entirely located within Montgomery County. Segment 1015A is approximately 15.41 miles long and is comprised of two AUs. AU 1015A_01 has a stream length of 10.77 miles and AU 1015A_02 has a stream length of 4.64 miles. This study incorporates a watershed approach where the drainage area of the stream is considered.

The 2014 *Texas Water Quality Integrated* Report (TCEQ, 2015) provides the following segment and AU descriptions for Mound Creek:

- Segment 1015A (Mound Creek) - From the confluence with Lake Creek to a point 0.69 km east of FM 149 near Conroe.
  - 1015A_01 – Perennial stream from the confluence with Lake Creek upstream to the confluence with an unnamed tributary approximately 0.75 km downstream of Rabon-Chapel Road.
  - AU_ID: 1015A_02 - From the confluence with an unnamed tributary approximately 0.75 km downstream of Rabon-Chapel Road to a point approximately 0.69 km east of FM 149

Using a watershed-based approach and because the impaired AU 1015A_01 is downstream of non-impaired AU 1015A_2, the entire watershed of Mound Creek will be considered in this report.

2.2 Watershed Climate and Hydrology

The Mound Creek watershed is located within the Lake Houston watershed of the San Jacinto River Basin. There are currently no municipalities located within the Mound Creek watershed.

The Mound Creek watershed is within the Upper Coast and East Texas climatic divisions. The Gulf of Mexico is the principal source of moisture that drives precipitation in the region. For the period from 1981-2010, average annual precipitation in the Mound Creek watershed was 47.8 inches (Figure 3, Prism, 2012).

For the more recent 15-year period from 2002-2016 weather data were obtained from the National Climatic Data Center for the Conroe North Houston Regional Airport (Figure 3, NOAA, 2017). Data from this 15-year period indicates that the average high temperatures typically peak in August (89.4 °F). During winter, the average low temperature generally bottoms out at 36.8 °F in January (Figure 4). The wettest month was October (5.7 inches) while August (2.8 inches) was the driest month, with rainfall occurring throughout the year.

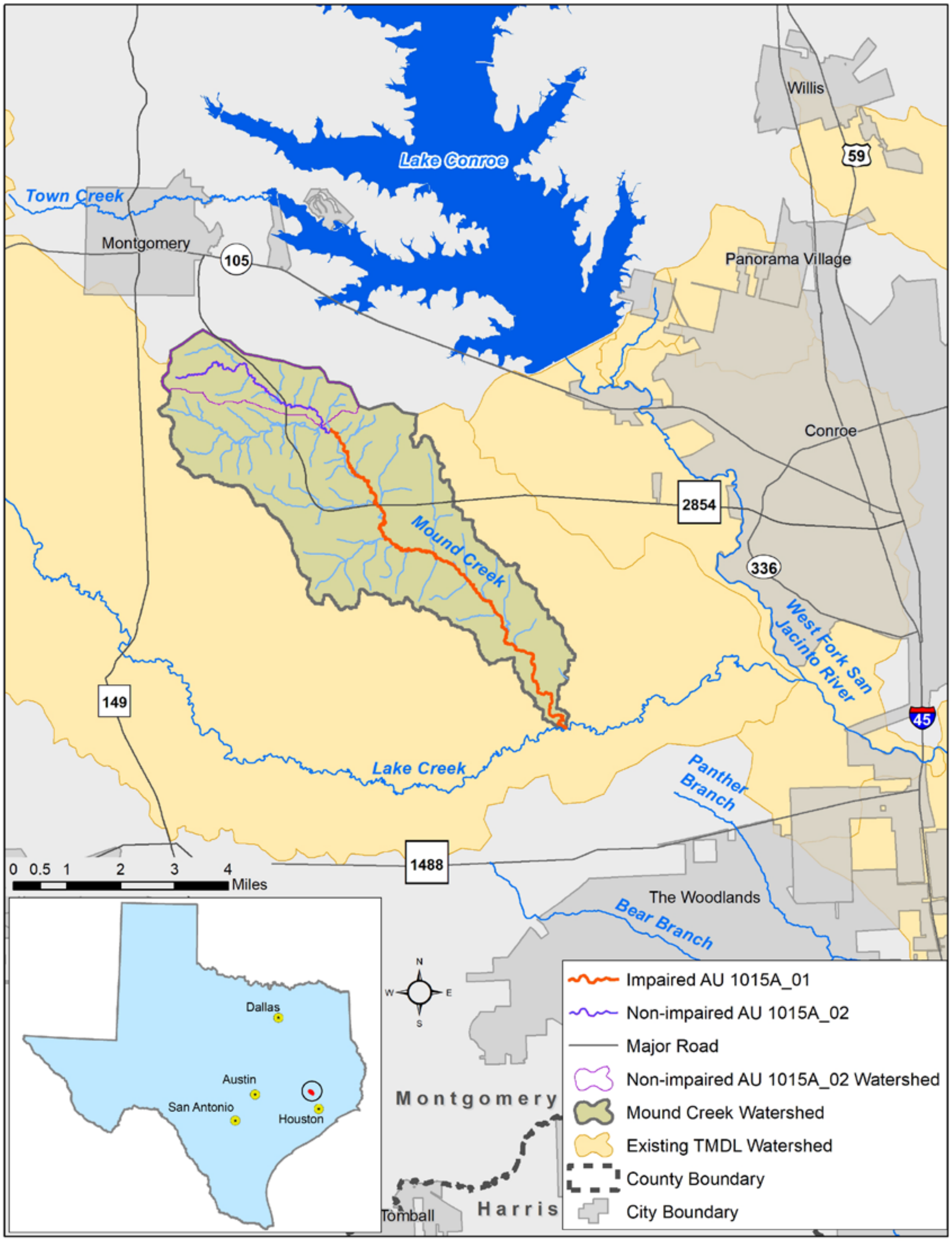

Figure 1. Overview map showing the total contributing drainage area for the Mound Creek watershed and separate drainage areas of its two AUs.

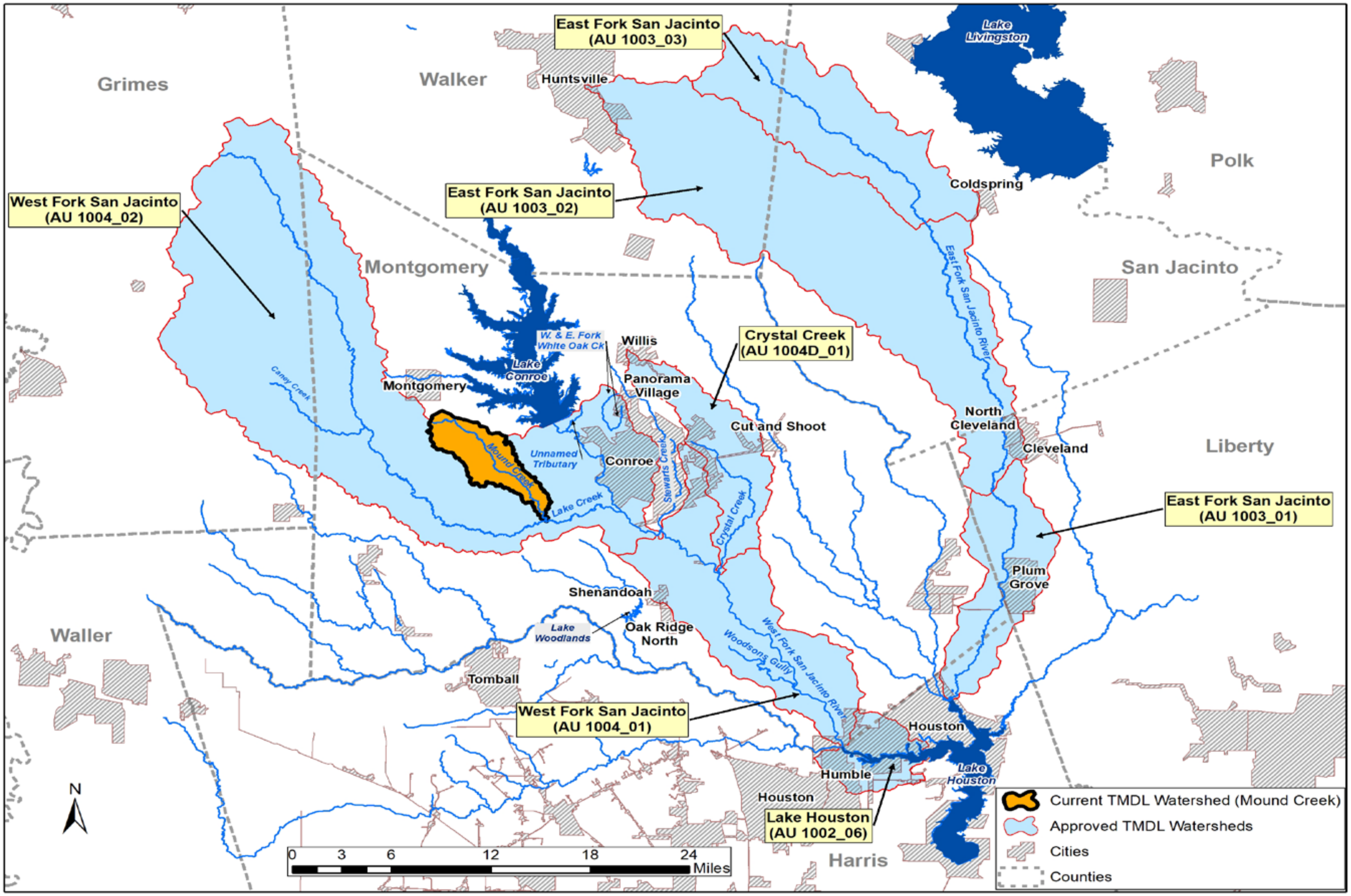

Figure 2. Map showing the seven approved TMDL watersheds and the current Mound Creek watershed considered in this addendum.

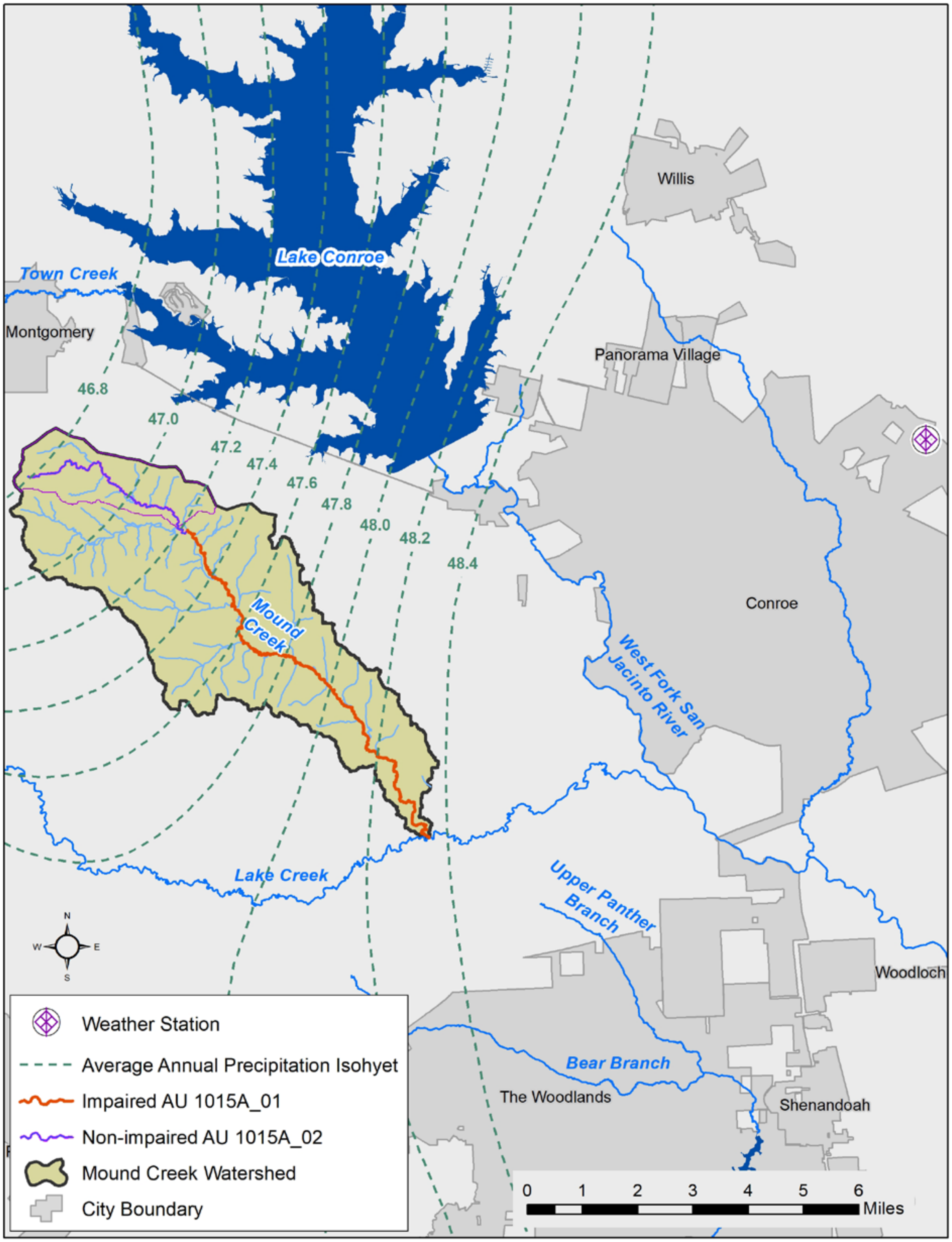

Figure 3. Annual average precipitation isohyets (in inches) in the Mound Creek watershed (1981-2010).

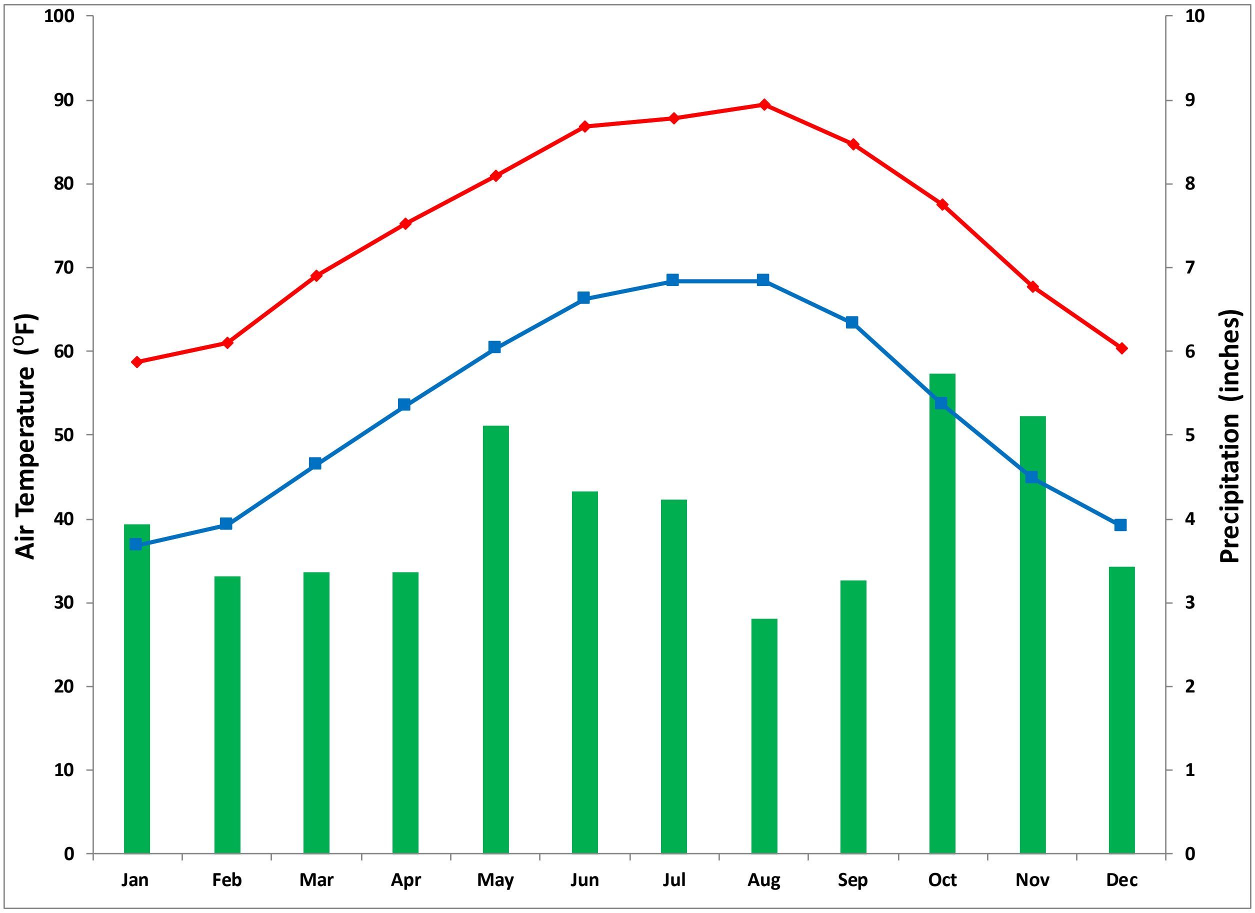

Figure 4. Average minimum and maximum air temperature and total precipitation by month from Jan 2002 –Dec 2016 for Conroe North Houston Regional Airport.

Source: NOAA (2017)

2.3 Watershed Population and Population Projections

As depicted in Figure 1, the Mound Creek watershed is geographically located entirely within Montgomery County, and outside of any municipal boundaries. The relatively rural nature of the watershed is evident in that the predominant current population densities found throughout the watershed is zero to two people per acre (Figure 5). According to the 2010 Census data (USCB, 2017), the Mound Creek watershed has an estimated population of 3,102 people.

Population projections from 2010 – 2040 were developed by utilizing data from the 2010 U.S. Census and Houston-Galveston Area Council (H-GAC) 2040 regional growth forecast (H-GAC, 2017). According to the growth projections, a population increase of 329.6 percent is expected in the Mound Creek watershed by 2040. Table 1 provides a summary of the 2010 population and 2040 population projection.

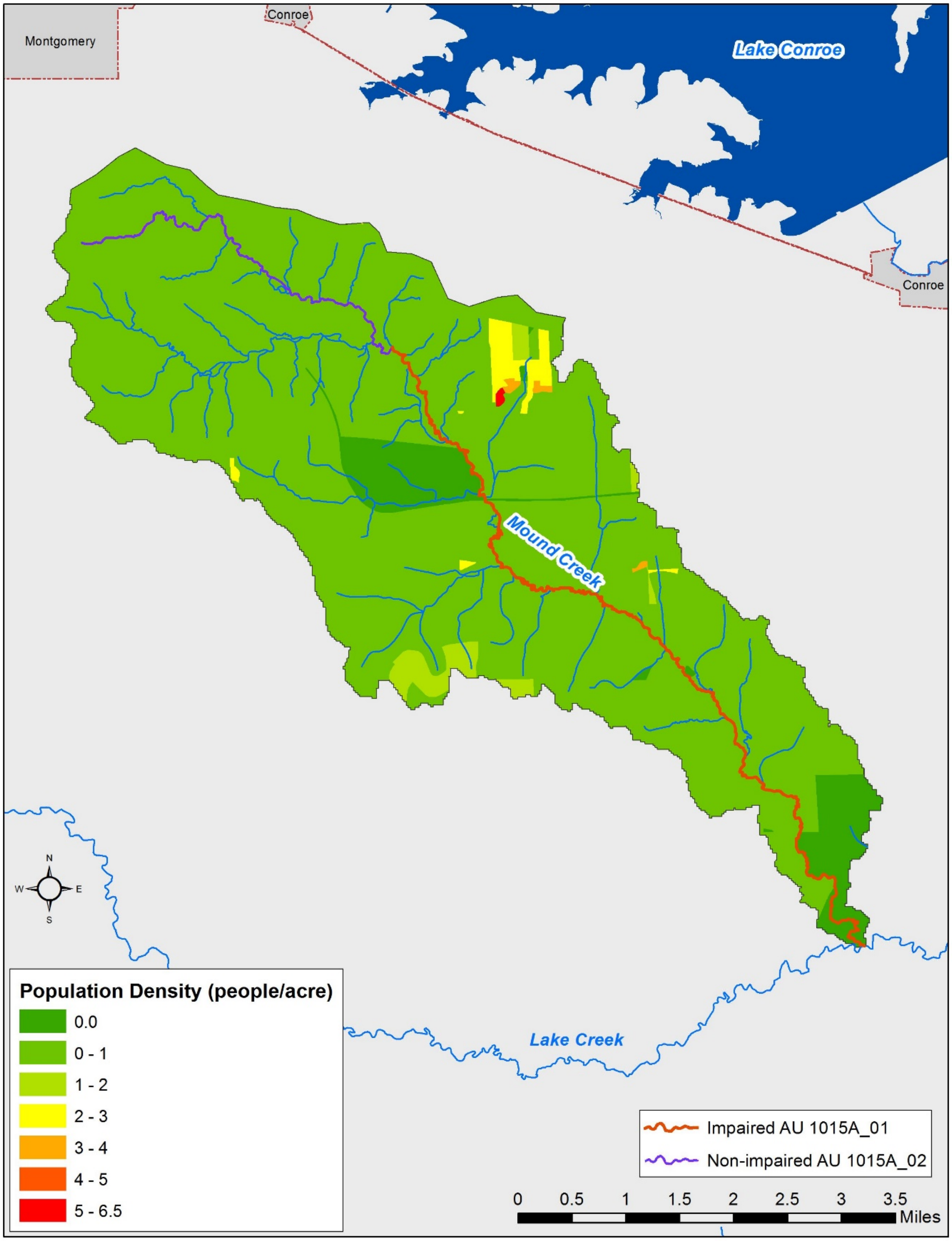

Figure 5. Population density for the Mound Creek watershed based on the 2010 U.S. Census blocks. Source: USCB (2017)

Table 1. 2010 Population and 2040 Population Projections for the Mound Creek watershed.
Source: H-GAC (2017) and USCB (2017)

Location	2010 U. S. Census	2040 Population Projection	Projected Population Increase (2010-2040)	Percent Change
Mound Creek Watershed	3,102	13,326	10,224	329.6%

2.4 Review of Routine Monitoring Data

2.4.1 Data Acquisition

Ambient *E. coli* data were obtained from the TCEQ Surface Water Quality Monitoring Information System (SWQMIS) on November 10, 2017 (TCEQ, 2017a). The data represent all the historical routine ambient water quality data collected in the Mound Creek watershed, and include *E. coli* data collected from October 2007 through May 2017. General assessment criteria methodologies established by TCEQ were used in data evaluations.

2.4.2 Analysis of Bacteria Data

Recent environmental monitoring within the Mound Creek watershed has occurred at TCEQ monitoring station 17937 (Figure 6). *E. coli* data collected at this station over the seven-year period of 1 December 2005 through 30 November 2012 were used in assessing attainment of the primary contact recreation use as reported in the *2014 Texas Integrated Report* (TCEQ, 2015) and are summarized in Table 2. The 2014 assessment data for the Mound Creek watershed indicate non-support of the primary contact recreation use because geometric mean concentrations exceed the *E. coli* geometric mean criterion of 126 MPN/100 mL. The Draft 2016 Texas Integrated Report (TCEQ, 2018) is out for public review at the time of development of this document. The 2016 assessment data also indicate non-support of the primary geometric mean concentration, and for completeness the draft assessment results are included in Table 2.

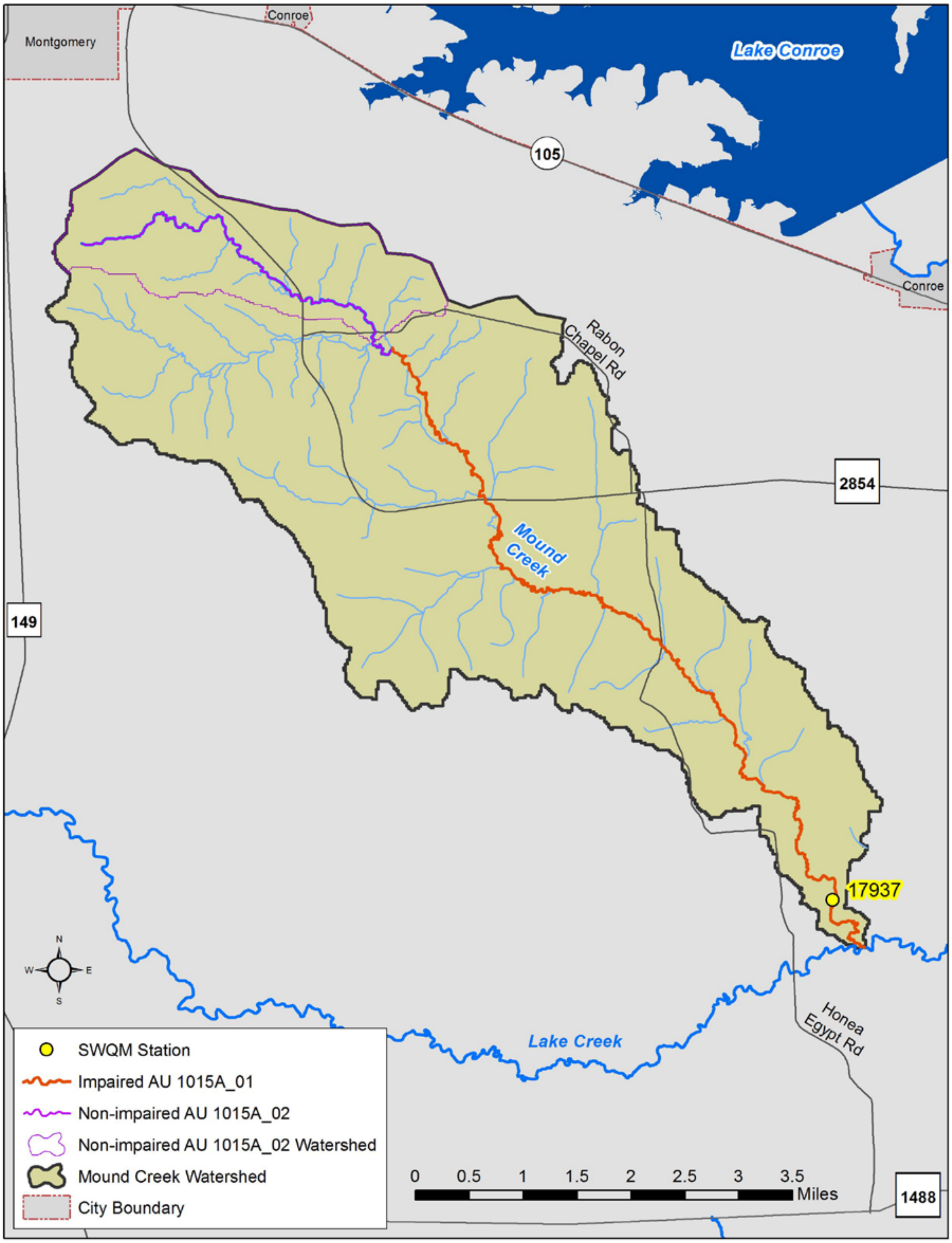

Figure 6. Mound Creek watershed (Segment 1015A) showing TCEQ surface water quality monitoring (SWQM) station used to assess primary contact recreation.

Source: TCEQ (2015)

Table 2. 2014 and Draft 2016 Integrated Report Summaries for the Mound Creek watershed. Sources: TCEQ (2015) and TCEQ (2018)

Integrated Report Year	AU	Parameter	Station	No. of Samples	Data Date Range	Geometric Mean (MPN/100 mL)
2014	1015A_01	*E. coli*	17937	21	2005-2012	387
2016 (draft)	1015A_01	*E. coli*	17937	27	2007-2014	334

2.5 Land Use

The land use/land cover data presented in this report are from the National Oceanic and Atmospheric Association (NOAA) Coastal Change Analysis Program (C-CAP) as obtained from H-GAC and indicated to be for the year 2011 (NOAA, 2011). The land use/ land cover is represented by the following categories and definitions:

- **Developed (High Intensity)** – High intensity includes heavily built up urban centers and large constructed surfaces in suburban and rural areas. Constructed surfaces account for 80% to 100% of the total cover.
- **Developed (Medium Intensity)** – Medium intensity developed areas most commonly include multi- and single-family housing areas. Constructed surfaces account for 50% to 79% of the total cover.
- **Developed (Low Intensity)** – Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. These areas most commonly include single-family housing units. Constructed surfaces account for 20% to 49% percent of total cover.
- **Developed (Open Space)** – Areas with a mixture of constructed materials and vegetation. Constructed surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
- **Cultivated** – Areas intensely managed for the production of annual crops. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.
- **Grassland/Scrub/Shrub** – A combined category composed of grassland and scrub/shrub. Grassland areas are dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing. Scrub/shrub areas are dominated by shrubs less than five meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes

true shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.

- **Forest** – Areas characterized by tree cover greater than five meters tall and tree canopy accounting for greater than 20% of the cover. The forest category includes deciduous, evergreen, and mixed forests.
- **Wetland** – Areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water, or areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
- **Pasture/Hay** – Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
- **Bare Land** – Areas of bedrock, scarps, talus, slides, sand dunes, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 10% of total cover.
- **Water and Unconsolidated Shore** – Areas of open water, generally with less than 25% cover of vegetation or soil, and unconsolidated shore comprised of silt, sand, and gravel that is subject to inundation and redistribution due to the action of water.

The land use/land cover data is provided for the entire Mound Creek watershed in Figure 7. A summary of the land use/land cover data for the Mound Creek watershed provided in Table 3 indicates that grassland/scrub/shrub and forest are the dominant land covers comprising approximately 55% of the total land cover.

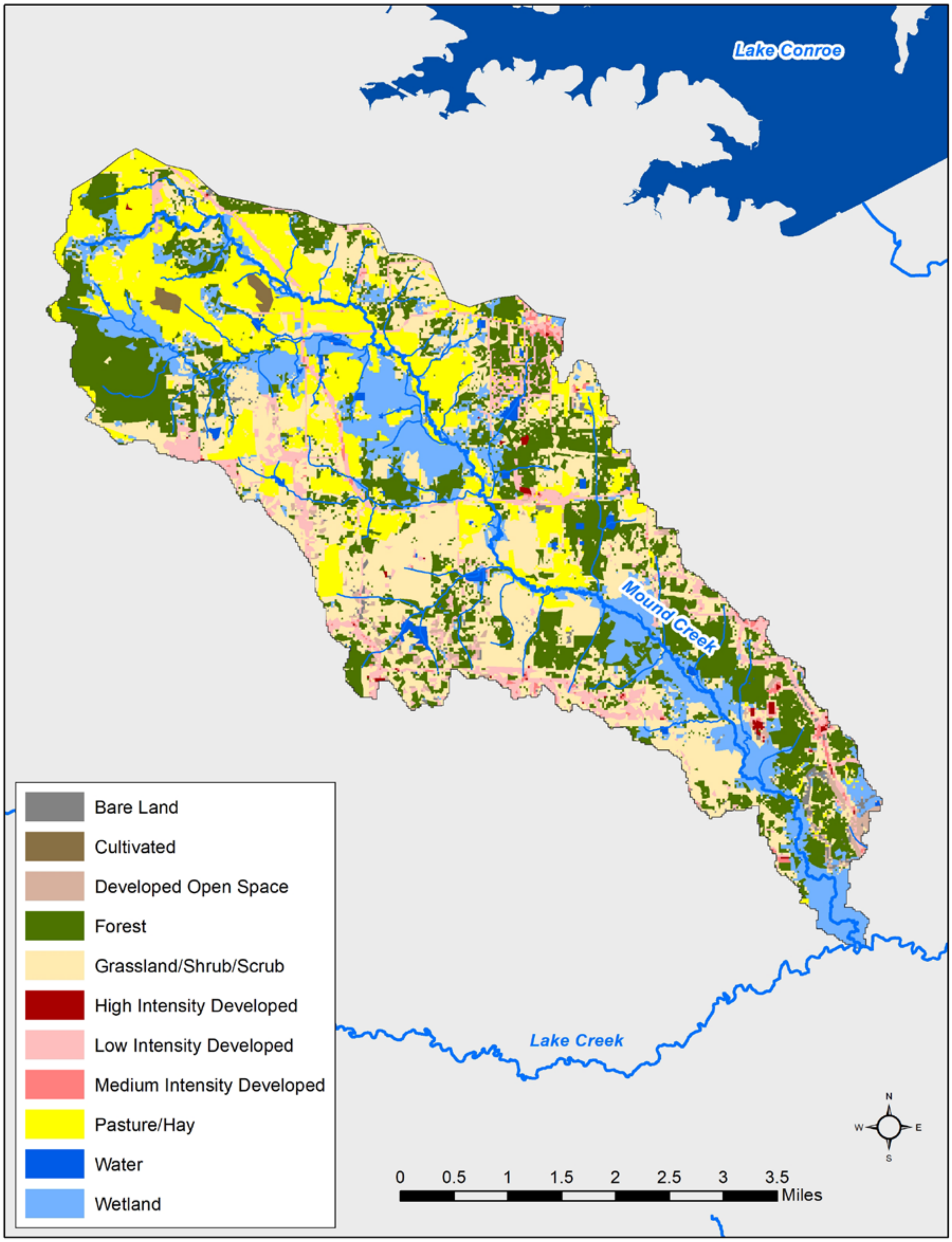

Figure 7. Land use / land cover within the Mound Creek watershed.

Source: NOAA (2011)

Table 3. Land Use/Land Cover within the Mound Creek watershed.

Source: NOAA (2011)

Classification	**Area (Acres)**	**% of Total**
Grassland/Scrub/Shrub	3,917	29.2%
Forest	3,436	25.6%
Pasture/Hay	2,496	18.6%
Wetland	2,051	15.3%
Low Intensity Developed	957	7.1%
Developed Open Space	150	1.1%
Water and Unconsolidated Shore	137	1.0%
Bare Land	106	0.8%
Medium Intensity Developed	81	0.6%
Cultivated	56	0.4%
High Intensity Developed	35	0.3%
Total	13,422	100%

2.6 Soils

Soils within the Mound Creek watershed, categorized by their septic tank absorption field ratings, are shown in Figure 8. These data were obtained through the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database (NRCS, 2015).

Soil properties and features such as saturated hydraulic conductivity, flooding, depth to bedrock, depth to cemented pan, ponding, rocks, fractured bedrock, subsidence, and excessive slope, can affect septic tank effluent absorption, construction and maintenance, and public health (NRCS, 2015). The dominant soil condition within a septic drainage field can be used to identify soils that may prove problematic regarding septic system installation/performance and potentially lead to system failures such as effluent surfacing or downslope seepage.

Soils are rated based on the limiting factors (or conditions) affecting proper effluent drainage and filtering capacity. Soil conditions for septic tank drainage fields are expressed by the following rating terms and definitions (NRCS, 2015):

- *Not Limited – Indicates that the soil has features that are very favorable for the specific use. Good performance and very low maintenance can be expected.*
- *Somewhat Limited – Indicates that the soil has one or more features that are moderately favorable for the specified use. The limitations can be overcome or minimized with special planning, design, installation procedures. Fair performance and moderate maintenance can be expected.*
- *Very limited - Indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome*

without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

- *Not Rated – Indicates insufficient data exists for soil limitation interpretation.*

Within the Mound Creek watershed, nearly all of the soils are rated as "Very Limited" based on the dominant soil condition for septic drainage field installation and operation.

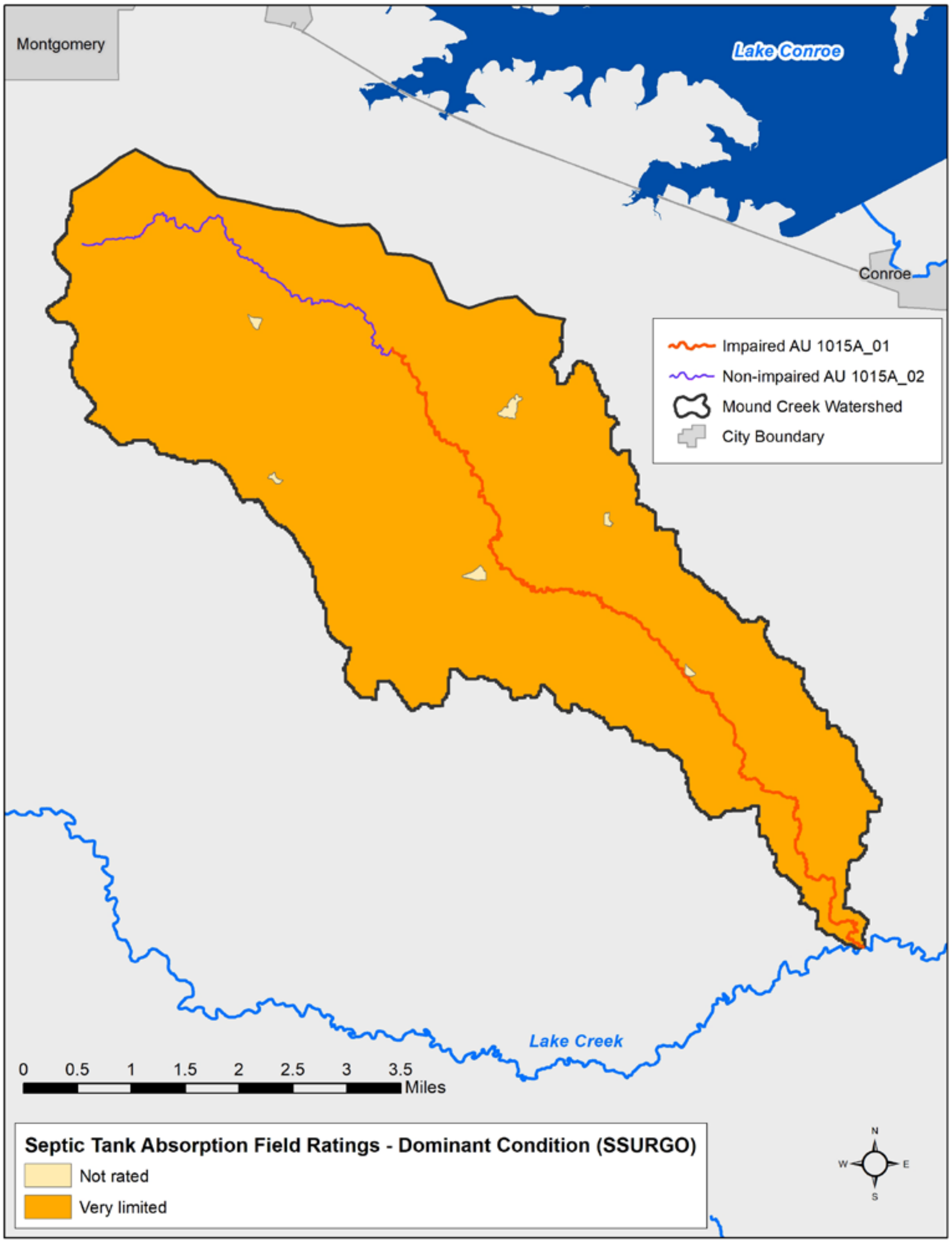

Figure 8. Septic tank absorption field limitation ratings within the Mound Creek watershed.

Source: NRCS (2015)

2.7 Potential Sources of Fecal Indicator Bacteria

Potential sources of indicator bacteria pollution can be divided into two primary categories: *regulated* and *unregulated*. Pollution sources that are regulated have permits under the Texas Pollutant Discharge Elimination System (TPDES) and National Pollutant Discharge Elimination System (NPDES) programs. Examples of regulated sources are wastewater treatment facility (WWTF) discharges and stormwater discharges from industries, construction, and municipal separate storm sewer systems (MS4) of cities.

Unregulated sources are typically nonpoint source in nature, meaning the pollution originates from multiple locations and is usually carried to surface waters by rainfall runoff. Nonpoint sources are not regulated by permit.

With the exception of WWTFs, which receive individual waste load allocations or WLAs (see report Section 4.7.3, Waste Load Allocation), the regulated and unregulated sources in this section are presented to give a general account of the potential sources of bacteria in the watershed.

2.7.1 Permitted Sources

Permitted sources are regulated by permit under the TPDES and the NPDES programs. Three WWTFs and stormwater discharges from one industrial facility and thirteen construction sites represent the permitted sources in the Mound Creek watershed.

2.7.1.1 Domestic Wastewater Treatment Facility Discharges

As of February 2018, there are three domestic WWTFs with TPDES/NPDES permits within the Mound Creek Watershed (Figure 9 and Table 4). Recent discharge data are presented in Table 4 from Discharge Monitoring Report Data (USEPA, 2018).

2.7.1.2 Sanitary Sewer Overflows

Sanitary sewer overflows (SSOs) are unauthorized discharges that must be addressed by the responsible party, either the TPDES permittee or the owner of the collection system that is connected to a permitted system. SSOs in dry weather most often result from blockages in the sewer collection pipes caused by tree roots, grease and other debris. Inflow and infiltration (I&I) are typical causes of SSOs under conditions of high flow in the WWTF system. Blockages in the line may exacerbate the I&I problem. Other causes, such as a collapsed sewer line, may occur under any condition.

The TCEQ Region 12 Office maintains a database of SSO data reported by municipalities. These SSO data typically contain estimates of the total gallons spilled, responsible entity, and a general location of the spill. A summary of SSO incidents that occurred during a two-year period from 2016-2017 in Montgomery County was obtained from the TCEQ Central Office in Austin. The summary data indicated no SSO incidents were reported for any locations within the Mound Creek Watershed.

Table 4. Permitted domestic wastewater treatment facilities in the Mound Creek watershed.

Permittee	Facility	TPDES No.	NPDES No.	Receiving Waters	Permitted Discharge (MGD)	Recent Discharge 2014-2017 (MGD)
Crane Co.	Crane Co. WWTP	WQ0012456001	TX0088901	Drainage ditch; thence to Mound Creek	0.005	0.00003
MSEC Enterprises Inc.	MSEC WWTP No. 1	WQ0014638001	TX0128121	Unnamed tributary of Mound Creek; thence to Mound Creek	0.02	0.0025
MSEC Enterprises Inc.	MSEC WWTP No. 2	WQ0015341001	TX0136191	Mound Creek	0.130	0.00275*

* Only the most recent seven months of data (June 2016-December 2017) were available for this facility since it was just recently permitted to discharge.

Figure 9. Mound Creek watershed showing WWTFs.

2.7.1.3 Dry Weather Discharges/Illicit Discharges

Bacteria loads from regulated stormwater can enter the streams from permitted outfalls and illicit discharges under both dry and wet weather conditions. The term "illicit discharge" is defined in TPDES General Permit No. TXR040000 for Phase II (Small) Municipal Separate Storm Sewer Systems as "Any discharge to a municipal separate storm sewer that is not entirely composed of stormwater, except discharges pursuant to this general permit or a separate authorization and discharges resulting from emergency firefighting activities." Illicit discharges can be categorized as either direct or indirect contributions. Examples of illicit discharges identified in the *Illicit Discharge Detection and Elimination Manual: A Handbook for Municipalities* (NEIWPCC, 2003) include:

Direct illicit discharges:

- sanitary wastewater piping that is directly connected from a home to the storm sewer;
- materials (*e.g.*, used motor oil) that have been dumped illegally into a storm drain catch basin;
- a shop floor drain that is connected to the storm sewer; and
- a cross-connection between the municipal sewer and storm sewer systems.

Indirect illicit discharges:

- an old and damaged sanitary sewer line that is leaking fluids into a cracked storm sewer line; and
- a failing septic system that is leaking into a cracked storm sewer line or causing surface discharge into the storm sewer.

2.7.1.4 TPDES General Wastewater Permits

In addition to the individual wastewater discharge permits listed in Table 4, discharges of processed wastewater from certain types of facilities are required to be covered by one of several TPDES general permits:

- TXG110000 – concrete production facilities
- TXG130000 – aquaculture production facilities
- TXG340000 – petroleum bulk stations and terminals
- TXG500000 – quarries in John Graves Scenic Riverway
- TXG670000 – hydrostatic test water
- TXG830000 – petroleum fuel or petroleum substances
- TXG870000 – pesticides
- TXG920000 – concentrated animal feeding operations
- TXG100000 – wastewater evaporation
- WQG20000 – livestock manure compost operations (irrigation only)

A review of active general permit coverage (TCEQ, 2017b) in the Mound Creek watershed as of 12 December 2017 found no operations or facilities of the types described above.

2.7.1.5 Stormwater General Permits

Discharges of Stormwater from a Phase II urbanized area, industrial facility, construction site, or other facility involved in certain activities are required to be covered under the following TPDES general permits:

- TXR040000 – Stormwater Phase II Municipal Separate Storm Sewer System (MS4) general permit
- TXR050000 – stormwater multi-sector general permit (MSGP) for industrial facilities
- TXR150000 – Stormwater from construction activities disturbing more than one acre
- TXG110000 – concrete production facilities
- TXG340000 – petroleum bulk stations and terminals

Three of these permits (MS4, MSGP, and construction) pertain solely to stormwater discharges. The other two (concrete production facilities and petroleum bulk stations and terminals) also authorize the discharge of process wastewater as discussed above under TPDES General Wastewater Permits.

A review of active stormwater general permit coverage (TCEQ, 2017b) in the Mound Creek watershed as of 12 December 2017 found 1 active industrial MSGP facility and 13 active construction permits. There are currently no Phase II Ms4s, concrete production facilities, or petroleum bulk stations and terminals in the Mound Creek watershed. See Section 4.7.3 for more detailed information.

2.7.1.6 Review of Compliance Information on Permitted Sources

A review of the USEPA Enforcement & Compliance History Online (ECHO) database (USEPA, 2018), conducted 1 Feb 2018, revealed one non-compliance issue at the MSEC WWTP 2 (WQ0015341-001) regarding *E. coli* limit violation (Table 5). It should be noted that only one *E. coli* value was available for the MSEC WWTP 2 facility. The *E. coli* permit limit for all three facilities requires quarterly sampling. The MSEC WWTP 2 facility is relatively new and began operation in June 2017, which allowed for a maximum of only two quarterly samples. Only one quarterly sample was taking because in the previous quarter there was no discharge due to a natural disaster (Hurricane Harvey).

No other non-compliance issues were reported from the other two WWTFs regarding *E. coli* permit limits.

Table 5. Bacteria monitoring requirements and compliance status for the WWTFs in the Mound Creek watershed.

Source: Individual TPDES permits, EPA ECHO

Facility	TPDES No.	Min. Self-Monitoring Requirement Frequency	Daily Average (Geometric Mean) Limitation	Single Grab (or Daily Max Limitation	% Monthly Exceedances Daily Average	% Monthly Exceedances Single Grab
Crane Co. WWTF	WQ0012456001	One/quarter	126	399	0	0
MSEC WWTF	WQ0014638001	One/quarter	126	399	0	0
MSEC WWTF No. 2	WQ15341001	One/quarter	126	399	100*	0

* Only one quarter of *E. coli* self-monitoring data was available

2.7.2 Unregulated Sources

Unregulated sources of indicator bacteria are generally nonpoint and can emanate from wildlife, feral hogs, various agricultural activities, agricultural animals, land application fields, urban runoff not covered by a permit, failing onsite sewage facilities (OSSFs), and domestic pets.

2.7.2.1 Wildlife and Unmanaged Animal Contributions

E. coli bacteria are common inhabitants of the intestines of all warm-blooded animals, including feral hogs and wildlife such as mammals and birds. In developing bacteria TMDLs, it is important to identify by watershed the potential for bacteria contributions from wildlife and feral hogs. Wildlife and feral hogs are naturally attracted to riparian corridors of streams and rivers. With direct access to the stream channel, the direct deposition of wildlife and feral hog waste can be a concentrated source of bacteria loading to a water body. Fecal bacteria from wildlife and feral hogs are also deposited onto land surfaces, where it may be washed into nearby streams by rainfall runoff.

Unfortunately, quantitative estimates of wildlife are rare, inexact, and often limited to discrete taxa groups or geographical areas of interest so that even county-wide approximations of wildlife numbers are difficult or impossible to acquire. However, population estimates for feral hogs and deer, as well as many species of birds, are readily available for the Mound Creek watershed.

For feral hogs, the Institute of Renewable Natural Resources (IRNR, 2013) estimated a range of feral hog densities within Texas (1.33 to 2.45 hogs/square mile). The average hog density (1.89 hogs/square mile) was multiplied by the hog-habitat area in the Mound Creek watershed (18.7 square miles). Habitat deemed suitable for hogs followed as closely as possible to the land use selections of the IRNR study and include from the H-GAC 2015 land use and include: forest, cultivated crops, wetlands, pasture/hay, and grasslands. Using this methodology, there are an estimated 35 feral hogs in the Mound Creek watershed.

For deer, the Texas Parks and Wildlife Department published data showing deer population-density estimates by Deer Management Unit (DMU) and Ecoregion in the state (TPWD, 2017). The Mound Creek watershed is located within DMU 12, for which the deer density in 2016 was estimated to be 32.1 deer/square mile. Applying this value to the area of the entire watershed returns an estimated 674 deer within the Mound Creek watershed.

For birds, the Cornell Lab of Ornithology and the National Audubon Society maintain an online database (eBird, 2018) that provides bird abundance and distribution information at a variety of spatial scales. A query of Montgomery County revealed that there have been 272 species of birds observed within the last 5 years.

2.7.2.2 On-Site Sewage Facilities

Private residential OSSFs, commonly referred to as septic systems, consist of various designs based on physical conditions of the local soils. Typical designs consist of 1) one or more septic tanks and a drainage or distribution field (anaerobic system) and 2) aerobic systems that have an aerated holding tank and often an above ground sprinkler system for distributing the liquid. In simplest terms, household waste flows into the septic tank or aerated tank, where solids settle out. The liquid portion of the water flows to the distribution system that may consist of buried perforated pipes or an above ground sprinkler system.

Several pathways of the liquid waste in OSSFs afford opportunities for bacteria to enter ground and surface waters, if the systems are not properly operating. Properly designed and operated, however, OSSFs would be expected to contribute virtually no fecal bacteria to surface waters. For example, it has been reported that less than 0.01 percent of fecal coliforms originating in household wastes move further than 6.5 feet down gradient of the drain field of a septic system (Weikel et al., 1996). Reed, Stowe, and Yanke LLC (2001) provide information on estimated failure rates of OSSFs for different regions of Texas. Mound Creek is located within the east-central Texas region, which has a reported failure rate of about 12 percent, providing insights into expected failure rates for the area.

Estimates of the number of OSSFs in the Mound Creek watershed were determined using H-GAC supplied data for Montgomery County. The H-GAC data indicate that there are 631 OSSFs located within the Mound Creek watershed (Figure 10).

2.7.2.3 Non-Permitted Agricultural Activities and Domesticated Animals

The number of livestock within the Mound Creek watershed was estimated from county level data obtained from the 2012 Census of Agriculture (USDA NASS, 2014). The county level data were refined to better reflect actual numbers within the Mound Creek watershed. The refinement was performed by dividing the total area of the Mound Creek watershed by the total area of Montgomery County. This ratio was then applied to the county-level livestock data (Table 6). The livestock numbers in Table 6 are provided to demonstrate that livestock are a potential source of bacteria in the TMDL watersheds. These livestock numbers are not used to develop an allocation of allowable bacteria loading to livestock.

Table 6. Estimated distributed domesticated animal populations within the Mound Creek watershed, based on proportional area.

Cattle and Calves	Hogs and Pigs	Sheep and Lambs	Goats	Horses and Ponies	Mules, Burros, and Donkeys	Poultry	Deer (captive)
382	10	13	54	98	12	140	11

Fecal matter from dogs and cats is transported to streams by runoff in both urban and rural areas and can be a potential source of bacteria loading. Table 7 summarizes the estimated number of dogs and cats within the Mound Creek watershed. Pet population estimates were calculated as the estimated number of dogs (0.584) and cats (0.638) per household according to data from the American Veterinary Medical Association 2012 U.S Pet Statistics (AVMA, 2015). The actual contribution and significance of fecal coliform loads from pets reaching the water bodies of the Mound Creek watershed is unknown.

Table 7. Estimated distribution of dog and cat populations within the Mound Creek watershed.

Source: AVMA (2015).

Households	Dogs	Cats
1,084	633	692

2.7.2.4 Bacteria Survival and Die-off

Bacteria are living organisms that survive and die in the environment. Certain enteric bacteria can survive and replicate in organic materials if appropriate conditions prevail (*e.g.*, warm temperature). Fecal organisms from improperly treated effluent can survive and replicate during their transport in pipe networks, and they can survive and replicate in organic rich materials such as compost and sludge. While the die-off of indicator bacteria has been demonstrated in natural water systems due to the presence of sunlight and predators, the potential for their re-growth is less well understood. Both processes (replication and die-off) are in-stream processes and are not considered in the bacteria source loading estimates for Mound Creek.

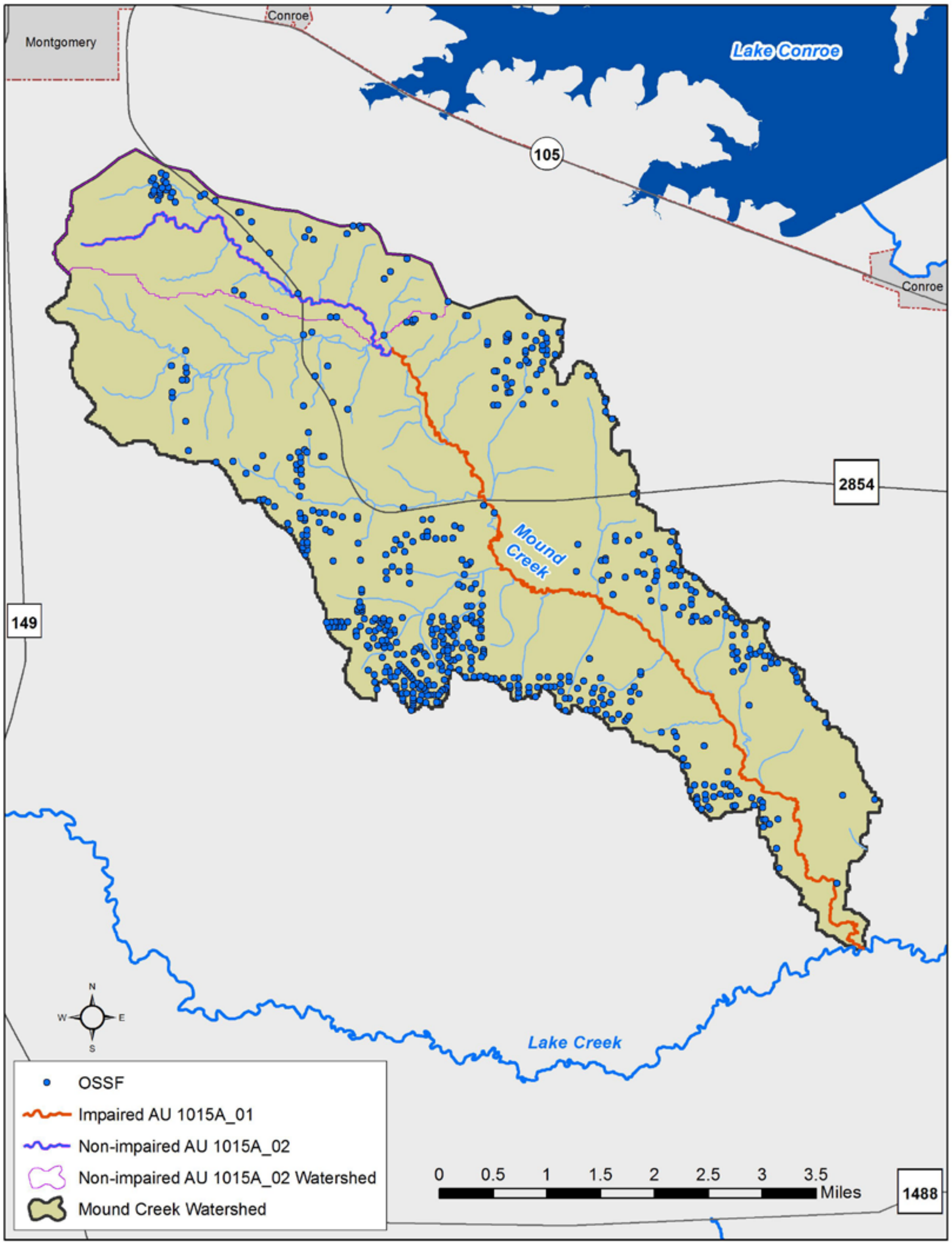

Figure 10. OSSFs located within the Mound Creek watershed.

SECTION 3
BACTERIA TOOL DEVELOPMENT

This section describes the rationale of the bacteria tool selection for TMDL development and details the procedures and results of load duration curve (LDC) development.

3.1 Tool Selection

For consistency between this TMDL and the previously completed TMDLs in the Lake Houston watershed, the pollutant load allocation activities for Mound Creek used the LDC method. The LDC method has been previously used on TCEQ-adopted and USEPA-approved TMDLs for the *Seven Total Maximum Daily Loads for Indicator Bacteria in Lake Houston, East Fork San Jacinto River, West Fork San Jacinto River, and Crystal Creek Watersheds* (TCEQ, 2016), and *Fifteen Total Maximum Daily Loads for Indicator Bacteria in Watersheds Upstream of Lake Houston* (TCEQ, 2011). Development activities of LDCs under the present project were covered under a TCEQ-approved QAPP (TIAER, 2017).

The LDC method allows for estimation of existing and allowable loads by utilizing the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003). In addition to estimating stream loads, the LDC method allows for the determination of the hydrologic conditions under which impairments are typically occurring. This information can be used to identify broad categories of sources (point and nonpoint) that may be contributing to the impairment. The LDC method has found relatively broad acceptance among the regulatory community, primarily due to the simplicity of the approach and ease of application. The regulatory community recognizes the frequent information limitations, often associated with bacteria TMDLs that constrain the use of more powerful mechanistic models. Further, the bacteria task force appointed by the TCEQ and the Texas State Soil and Water Conservation Board supports application of the LDC method within their three-tiered approach to TMDL development (Jones *et al.*, 2009). The LDC method provides a means to estimate the difference in bacteria loads and relevant criterion, and can give indications of broad sources of the bacteria, *i.e.*, point source and nonpoint source.

3.2 Mound Creek Data Resources

Successful application of the LDC method requires two basic types of data: continuous daily streamflow data and historical bacteria data for the relevant indicator bacteria, which in this case is *E. coli*.

Hydrologic data in the form of daily streamflow records were unavailable for the Mound Creek watershed; however, streamflow records were available for the nearby Bear Branch watershed. Streamflow records for Bear Creek are collected and made readily available by the U.S. Geological Survey (USGS; USGS, 2017), which operates the streamflow gauge (Table 8, Figure 11). USGS streamflow gauge 08068390 is located along the mainstem of Bear Creek and is in close enough proximity to Mound Creek that the same precipitation events would likely impact both watersheds. The determination was made to modify the streamflow records for Bear Branch by using a drainage area ratio (DAR) approach. This approach is explained in more detail in Section 3.3.3. The modified streamflow records from Bear Branch serve as the primary source for streamflow records in this document.

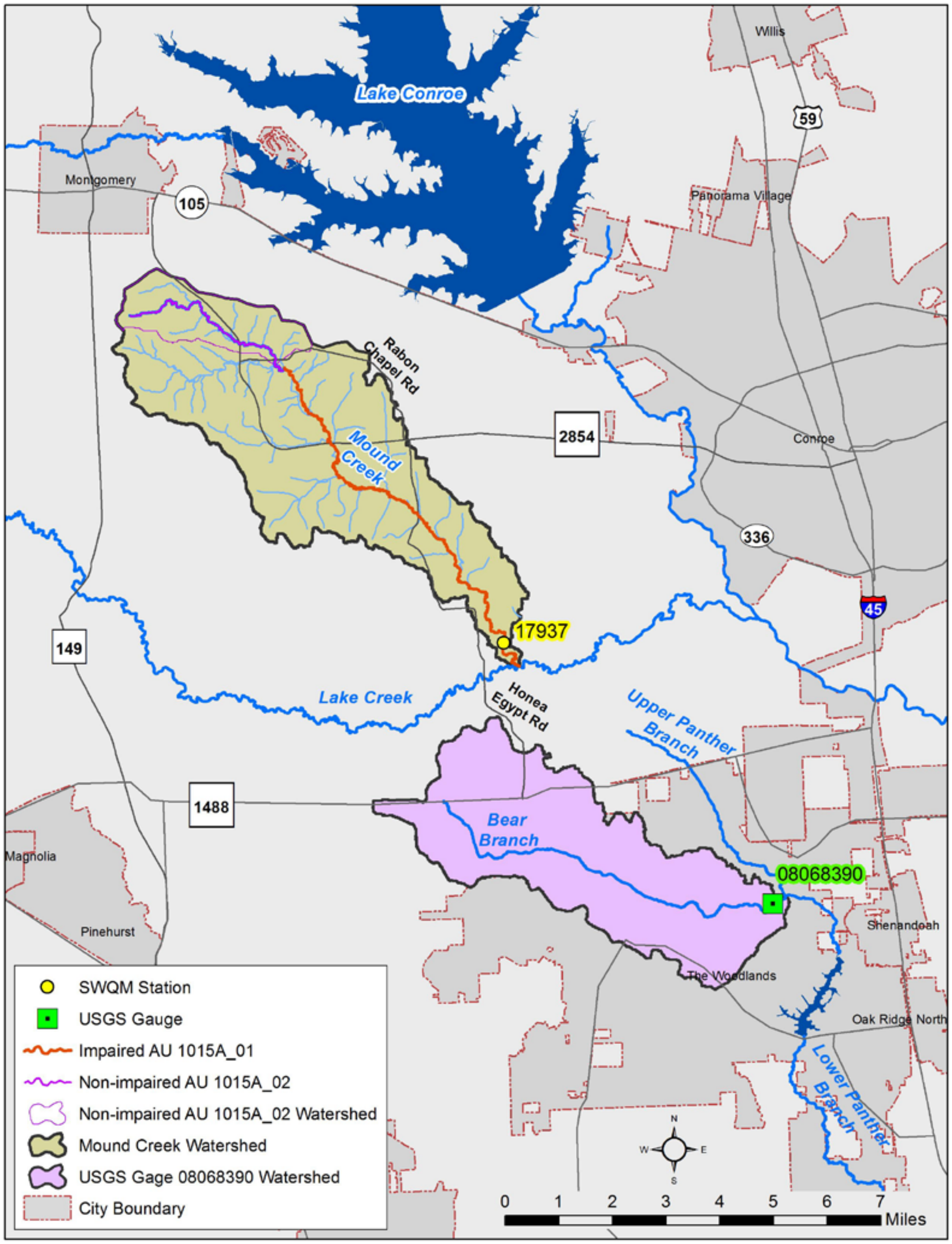

Figure 11. Mound Creek watershed and USGS Station 08068390.

Source: USGS (2017)

Table 8. Basic information on Bear Branch USGS streamflow gauge

Gauge No.	Site Description	Drainage Area (acres)	Daily Streamflow Record (beginning & end date)
08068390	Bear Branch at Research Boulevard, The Woodlands, TX	9,856	Jan. 1999 – present

Ambient *E. coli* data were available through the TCEQ SWQMIS for Mound Creek sampling station 17937, and consisted of 36 *E. coli* sample results with a geometric mean of 296 MPN/100mL collected over a period from October 2007 to May 2017.

3.3 Methodology for Flow Duration & Load Duration Curve Development

To develop the flow duration curve (FDC) and LDC, the previously discussed data resources were used in the following series of sequential steps.

- **Step 1:** Determine the hydrologic period of record to be used in developing the FDC.
- **Step 2:** Determine stream location for which FDC and LDC development is desired.
- **Step 3:** Develop daily streamflow records at the desired stream location using the daily gauged streamflow records and DAR.
- **Step 4:** Develop a FDC at the desired stream location, segmented into discrete flow regimes.
- **Step 5** Develop the allowable bacteria LDC at the same stream location based on the relevant criteria and the data from the FDC.
- **Step 6:** Superpose historical bacteria data on each allowable bacteria LDC.

Additional information explaining the LDC method may be found in Cleland (2003) and NDEP (2003).

3.3.1 Step 1: Determine Hydrologic Period

A 20-year daily hydrologic (streamflow) record was available for USGS gauge 08068390 located on nearby Bear Branch (Table 7, Figure 11). Optimally, the period of record to develop FDCs should include as much data as possible in order to capture extremes of high and low streamflow and hydrologic variability from high to low precipitation years, but the flow during the period of record selected should also be representative of recent conditions experienced within the watershed and when the *E. coli* data were collected. Therefore, a 10-year record of daily streamflow from 1 October 2007 through 30 September 2017 was selected to develop the FDCs at the sampling station location, and this period includes the collection dates of all available *E. coli* data at the time this work effort was undertaken. A 10-year period is of sufficient duration to contain a reasonable variation from dry months and years to wet months and years and at the same time is short enough in duration to contain a hydrology that is responding to recent and current conditions in the watershed. A 10-year hydrologic period was also used in the previously completed *Seven Total Maximum Daily Loads for Indicator Bacteria in Lake Houston, East Frok San Jacinto River, West Fork San Jacinto River, and Crystal Creek Watersheds* (TCEQ, 2016), which maintains consistency of the Mound Creek TMDL with the previous TMDLs.

3.3.2 Step 2: Determine Desired Stream Locations

Surface Water Quality Monitoring (SWQM) station 17937, which is located near the downstream outlet of Mound Creek (Figure 6), is the only location within Mound Creek where *E. coli* have been collected under a TCEQ QAPP and analyses performed by a laboratory accredited under The NELAC Institute. The 36 *E. coli* sampling results for station 17937 were determined to be adequate to develop pollutant load allocations and exceed the minimum of 24 samples suggested in Jones *et al.* (2009).

3.3.3 Step 3: Develop Daily Streamflow Records

Once the hydrologic period of record and station location were determined, the next step was to develop the 10-year daily streamflow record for the monitoring station. The daily streamflow records were developed from extant USGS records.

The method to develop the necessary streamflow record for the FDC/LDC location (SWQM station location) involved a drainage-area ratio (DAR) approach. The DAR approach involves multiplying a USGS gaging station daily streamflow value by a factor to estimate the flow at a desired SWQM station location. The factor is determined by dividing the drainage area above the desired monitoring station by the drainage area above the USGS gauge (Table 9).

Because an assumption of the DAR approach is similarity of hydrologic response based on commonality of landscape features such as geology, soils, and land use/land cover, point source derived flows from within the USGS gauge watershed should first be removed from the flow record prior to application of the ratio. In practice, this complication was addressed by determining the average discharge for each of the WWTFs located above the Bear Branch USGS gauge. The average discharge for each WWTF was computed by averaging the data obtained from the USEPA Enforcement and Compliance History Online database (http://www.epa-echo.gov/echo/). The WWTF discharge averages were summed and then subtracted from the Bear Branch USGS daily record.

After removing the average daily WWTF discharge values from the daily streamflow gauge record, each daily flow record was multiplied by the DAR. Following application of the DAR, the full permitted flows from WWTFs located within the Mound Creek watershed (Table 4) were added to the streamflow record along with future growth flows (calculated in Section 4.7.4) that account for the probability that additional flows from WWTF discharges may occur as a result of population increases.

Table 9. DAR for the Mound Creek watershed based on the drainage area of the Bear Branch USGS gauge.

Water Body	Gauge/Station	Drainage Area (acres)	DAR
Mound Creek	17937	13,264	1.346
Bear Branch	08068390	9,856	--

3.3.4 Steps 4-6: Flow Duration Curve and Load Duration Curve Method

FDCs and LDCs are graphs indicating the percentage of time during which a certain value of flow or load is equaled or exceeded. To develop a FDC for a location the following steps were undertaken:

- order the daily streamflow data for the location from highest to lowest and assign a rank to each data point (1 for the highest flow, 2 for the second highest flow, and so on);
- compute the percent of days each flow was exceeded by dividing each rank by the total number of data point plus 1; and
- plot the corresponding flow data against exceedance percentages.

Further, when developing a LDC:

- multiply the streamflow in cubic feet per second (cfs) by the appropriate water quality criterion for *E. coli* (geometric mean of 126 MPN/100 mL) and by a conversion factor (2.44658×10^7), which gives a loading in units of MPN/day; and
- plot the exceedance percentages, which are identical to the value for the streamflow data points, against geometric mean criterion of *E. coli*.

The resulting curve represents the maximum allowable daily loadings for the geometric mean criterion. The next step was to plot the sampled *E. coli* data on the developed LDC using the following two steps:

- using the unique data for the monitoring station, compute the daily loads for each sample by multiplying the measured *E. coli* concentrations on a particular day by the corresponding streamflow on that day and the conversion factor (2.44658×10^7), which gives a loading in units of MPN/day; and
- plot on the LDC the load for each measurement at the exceedance percentage for its corresponding streamflow.

The plots of the LDC with the measured loads (*E. coli* concentration multiplied by the daily streamflow) display the frequency and magnitude that measured loads exceed the maximum allowable loadings for the geometric mean criterion. Measured loads that are above a maximum allowable loading curve indicate an exceedance of the water quality criterion, while those below a curve show compliance.

3.4: Flow Duration Curve for Sampling Station 17937

The FDC was developed for monitoring station 17937 located on Mound Creek AU 1015A_01 (Figure 12). For this report, the FDC was developed by applying the DAR method using the Bear Branch USGS gauge 10-year period of record described in the previous sections. Flow exceedances less than 30 percent typically represent streamflow influenced by storm runoff while higher flow exceedances represent receding hydrographs after a runoff event, base flow and no flow conditions.

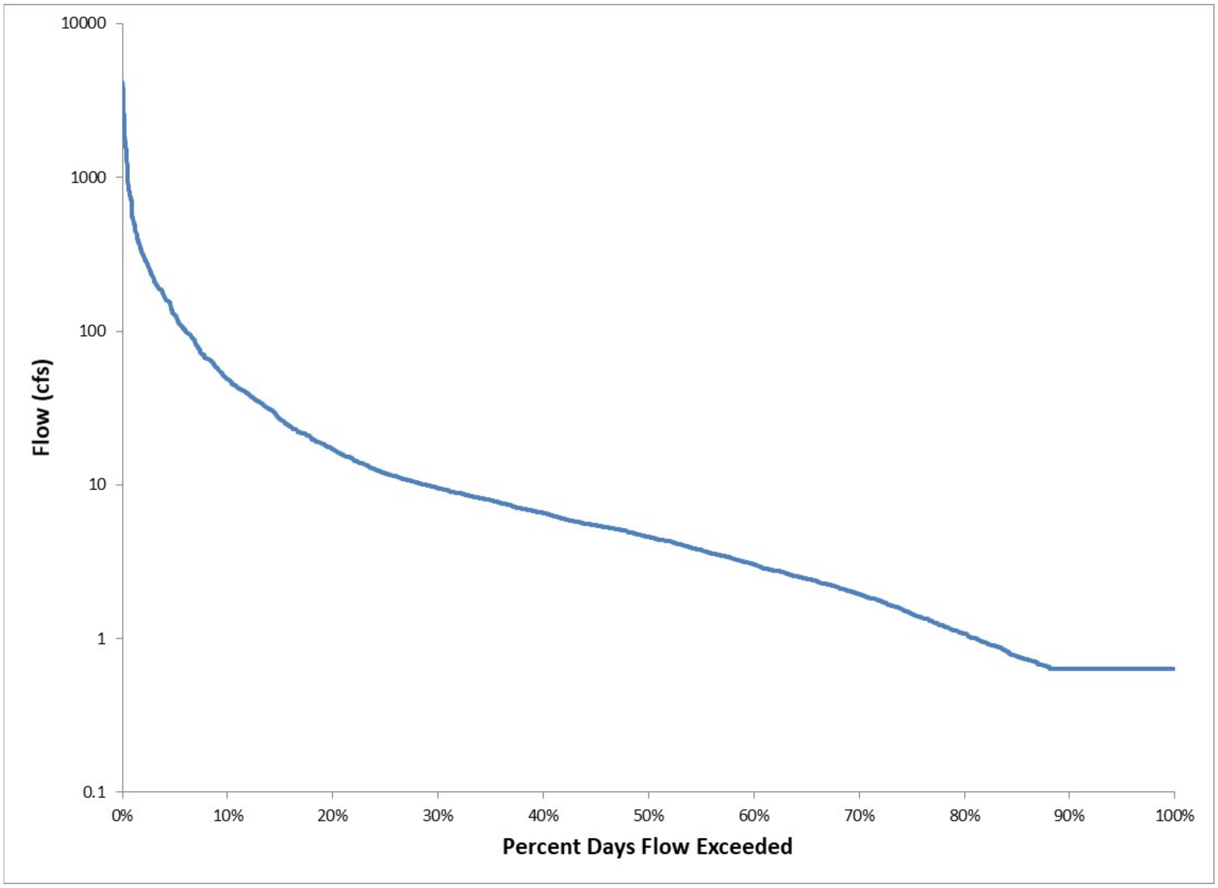

Figure 12. Flow duration curve for Mound Creek AU 1015A_01 (station 17937).

3.5: Load Duration Curve for the Sampling Station within the Mound Creek Watershed

A LDC was developed for Mound Creek using data obtained from Station 17937 (Figure 13). A useful refinement of the LDC approach is to divide the curve into flow-regime regions to analyze exceedance patterns in smaller portions of the duration curves. This approach can assist in determining streamflow conditions under which exceedances are occurring. A commonly used set of regimes that is provided in Cleland (2003) is based on the following five intervals along the x-axis of the FDCs and LDCs: (1) 0-10 percent (high flows); (2) 10-40 percent (moist conditions); (3) 40-60 percent (mid-range flows); (4) 60-90 percent (dry conditions); and (5) 90-100 percent (low flows).

For the Mound Creek watershed, streamflow distribution was divided into three flow regimes: Wet, Moderate, and Dry conditions, which maintains consistency with the previously completed TMDLs (TCEQ, 2016). Wet conditions correspond to large storm-induced runoff events. Moderate conditions typically represent periods of medium base flows, but can also represent small runoff events and periods of flow recession following large storm events. Dry conditions represent relatively low flow conditions, resulting from extended periods of little or no rainfall and are maintained primarily by WWTF flows (Table 10).

Table 10. Flow Regime Classifications

Flow Regime Classification	Flow Exceedance Percentile
Wet Conditions	0 – 30%
Moderate Conditions	30 – 70%
Dry Conditions	70 – 100%

The LDC with these three flow regimes for station 17937 is provided in Figure 13, and was constructed for developing the TMDL allocation for AU 1015A_01. Geometric mean loadings for the data points within each flow regime have also been distinguished on each figure to aid interpretation. The LDC for water quality monitoring station 17937 provides a means of identifying the streamflow conditions under which exceedances in *E. co*li concentrations have occurred. The LDC depicts the allowable loadings at the station under the geometric mean criterion (126 MPN/100 mL) and show that existing loadings often exceed the criterion. In addition, the LDC also presents the allowable loading at the station under the single sample criterion (399 MPN/100 mL).

On the graph, the measured *E. coli* data are presented as associated with a “wet weather event” or a “non-wet weather event.” A sample was determined to be influenced by a wet weather event based on the reported “days since last precipitation” (DSLP) as noted on field data sheets associated with each sampling event. DSLP (TCEQ water quality parameter code 72053) is a field parameter that may be noted during a sampling event to inform of the general climatic and hydrologic conditions. For station 17937, a DSLP ≤ 3 days was defined as a wet weather event.

The *E. coli* event data plotted on the LDC for station 17937 in Figure 13 show a pattern of increasing tendency for the *E. coli* event data to plot below the geometric mean criterion allowable loading curve as flows decrease, which is indicated in a left to right direction along the graph. This pattern of decreasing occurrence of exceedances in the event data are summarized by the geometric means of the existing data plotted for each of the three flow regimes as compared to the allowable load line for the geometric mean criterion.

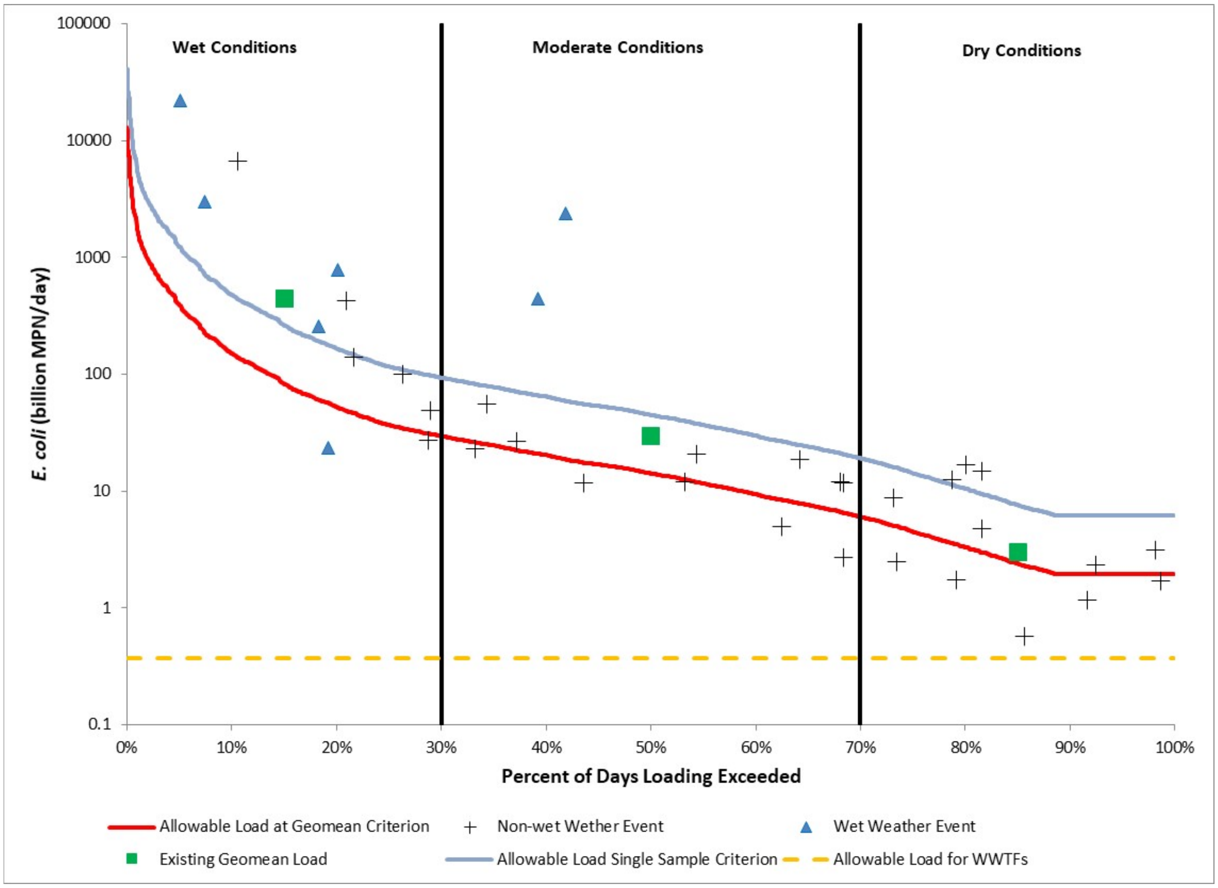

Figure 13. LDC for Mound Creek AU 1015A_01 (Station 17937)

SECTION 4

TMDL ALLOCATION ANALYSIS

Presented in this report section is the development of the bacteria TMDL allocation for the Mound Creek watershed. The tool used for developing TMDL allocations was the LDC method previously described in Section 3– Bacteria Tool Development. Endpoint identification, margin of safety (MOS), load reduction analysis, TMDL allocations, and other TMDL components are described herein.

The LDC method provided a flow-based approach to determine necessary reductions in bacteria loadings and allowable loadings within the Mound Creek watershed. As developed previously in this report, the LDC method uses frequency distributions to assess a bacteria criterion over the historical range of flows, providing a means to determine maximum allowable loadings and the load reduction necessary to achieve support of the primary contact recreation use.

For the purposes of this TMDL study, the Mound Creek watershed is considered to be the entire Mound Creek watershed (AU 1015A_01) as shown in the overview map (Figure 1). Data from only one SWQM station (17937) is available for the Mound Creek watershed; therefore, TMDL calculations are based on the location of SWQM station 17937.

Additionally, a DAR approach using historical streamflow records from a nearby USGS gauge on Bear Branch was employed to estimate the daily flow for the station 17937 within the Mound Creek watershed.

4.1 Endpoint Identification

All TMDLs must identify a quantifiable water quality target that indicates the desired water quality condition and provides a measurable goal for the TMDL. The TMDL endpoint also serves to focus the technical work to be accomplished and as a criterion against which to evaluate future conditions. The Mound Creek watershed has a use of primary contact recreation, which is measured against a numeric criterion for the indicator bacteria *E. coli*. Indicator bacteria are not generally pathogenic and are indicative of potential viral, bacterial, and protozoan contamination originating from the feces of warm-blooded animals. The *E. coli* criterion to protect contact recreation in freshwater streams consists of a geometric mean concentration not to exceed 126 MPN/100 mL (TCEQ, 2010).

The endpoint for this TMDL is to maintain concentrations of *E. coli* below the geometric mean criterion of 126 MPN/100 mL. This endpoint is identical to the geometric mean criterion in the 2010 Surface Water Quality Standards (TCEQ, 2010).

4.2 Seasonality

Seasonal variations or seasonality occur(s) when there is a cyclic pattern in streamflow and, more importantly, in water quality constituents. Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. Analysis of the seasonal differences in indicator bacteria concentrations were assessed by comparing *E. coli* concentrations obtained from eleven years (2007 – 2017) of routine monitoring collected in the warmer months (April - September) against those collected during the cooler months (October – March). Differences in *E. coli* concentrations obtained in warmer versus cooler months were then evaluated by performing a t-test on the natural log transformed dataset. This analysis of *E. coli* data indicated that there was no significant difference (α=0.05) in indicator bacteria between cool and warm weather seasons for Mound Creek AU 1015A_01 (α=0.7361).

4.3 Linkage Analysis

Establishing the relationship between instream water quality and the source of loadings is an important component in developing a TMDL. It allows for the evaluation of management options that will achieve the desired endpoint. The relationship may be established through a variety of techniques.

Generally, if high bacteria concentrations are measured in a water body at low to median flow in the absence of runoff events, the main contributing sources are likely to be point sources and direct fecal material deposition into the water body. During ambient flows, these inputs to the system will increase pollutant concentrations depending on the magnitude and concentration of the sources. As flows increase in magnitude, the impact of point sources and direct deposition is typically diluted, and would therefore be a smaller part of the overall concentrations.

Bacteria load contributions from regulated and unregulated stormwater sources are greatest during runoff events. Rainfall runoff, depending upon the severity of the storm, has the capacity to carry indicator bacteria from the land surface into the receiving stream. Generally, this loading follows a pattern of lower concentrations in the water body just before the rain event, followed by a rapid increase in bacteria concentrations in the water body as the first flush of storm runoff enters the receiving stream. Over time, the concentrations decline because the sources of indicator bacteria are attenuated as runoff washes them from the land surface and the volume of runoff decrease following the rain event.

Load duration curves were used to examine the relationship between instream water quality and the source of indicator bacteria loads. Inherent to the use of LDCs as the mechanism of linkage analysis is the assumption of a one-to-one relationship between instream loadings and loadings originating from point sources and the landscape as regulated and non-regulated sources. Further, this one-to-one relationship was also inherently assumed when using LDCs to define the TMDL pollutant load allocation (Section 4.7).

4.4 Load Duration Curve Analysis

A LDC method was used to examine the relationship between instream water quality, the broad sources of indicator bacteria load, and are the basis of the TMDL allocations. The strength of this TMDL is the use of the LDC method to determine the TMDL allocations. LDCs are a simple statistical method that provides a basic description of the water quality problem. This tool is easily developed and explained to stakeholders, and uses available water quality and flow data. The LDC method does not require any assumptions regarding loading rates, stream hydrology, land use conditions, and other conditions in the watershed. The USEPA supports the use of the basic LDC approach to characterize pollutant sources. In addition, many other states are using this basic method to develop TMDLs. As discussed in more detail in Section 4.7 (Pollutant Load Allocation), the TMDL loads were based on the median flow within the Wet Conditions flow regime (or 15 percent flow), where exceedances of the primary contact recreation criteria are most pronounced.

The LDC method allows for estimation of existing and TMDL loads by utilizing the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003). In addition to estimating stream loads, this method allows for the determination of the hydrologic conditions under which impairments are typically occurring, can give indications of the broad origins of the bacteria (*i.e.*, point source and stormwater) and provides a means to allocate allowable loadings.

Based on the LDC used in the pollutant load allocation process with historical *E. coli* data added to the graphs (Figure 13) and Section 2.7 (Potential Sources of Fecal Indicator Bacteria), the following broad linkage statements can be made. For the Mound Creek watershed, the historical *E. coli* data indicate that elevated bacteria loadings occur under all three flow regimes. There is some moderation of the elevated loadings under moderate and dry conditions. On Figure 13, the geometric means of the measured data for each flow regime generally support these observations of decreasing concentration with decreasing flow.

4.5 Margin of Safety

The MOS is used to account for uncertainty in the analysis performed to develop the TMDL and thus provides a higher level of assurance that the goal of the TMDL will be met. According to USEPA guidance (USEPA, 1991), the MOS can be incorporated into the TMDL using two methods:

1) Implicitly incorporating the MOS using conservative model assumptions to develop allocations; or
2) Explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

The MOS is designed to account for any uncertainty that may arise in specifying water quality control strategies for the complex environmental processes that affect water quality. Quantification of this uncertainty, to the extent possible, is the basis for assigning a margin of safety.

The TMDL covered by this report incorporates an explicit MOS by setting a target for indicator bacteria loads that is 5 percent lower than the geometric mean criterion. For primary contact recreation, this equates to a geometric mean target for *E. coli* of 119.7 MPN/100 mL. The net effect of the TMDL with MOS is that the assimilative capacity or allowable pollutant loading of each water body is slightly reduced.

4.6 Load Reduction Analysis

While the TMDL for the Mound Creek AU 1015A_01 was developed using LDC and associated load allocations, additional insight may, in certain situations, be gained through a load reduction analysis. A single percent load reduction required to meet the allowable loading for each of the three flow regimes was determined using the historical *E. coli* data obtained from the monitoring station within the impaired water body.

For each flow regime the percent reduction required to achieve the geometric mean criterion was determined by calculating the difference in the existing (or measured) geometric mean concentration and the 126MPN/100 mL criterion and dividing that difference by the existing geometric mean concentration (Table 11).

Table 11. Percent reduction calculations for Mound Creek station 17937 (AU 1015A_01).

Flow Regime	Number of Samples	Geometric Mean by Flow Regime (MPN/100 mL)	Percent Reduction by Flow Regime
Wet Conditions (0-30%)	11	677	81.4%
Moderate Conditions (30-70%)	13	262	51.9%
Dry Conditions (70-100%)	12	158	20.3%

4.7. Pollutant Load Allocation

A TMDL represents the maximum amount of a pollutant that the water body can receive in a single day without exceeding water quality standards. The pollutant load allocations for the selected scenarios were calculated using the following basic equation:

$$\text{TMDL} = \text{WLA} + \text{LA} + \text{FG} + \text{MOS} \qquad \text{(Eq. 1)}$$

Where:

TMDL = total maximum daily load

WLA = waste load allocation, the amount of pollutant allowed by existing regulated or permitted dischargers

LA = load allocation, the amount of pollutant allowed by unregulated or non-permitted sources

FG = loadings associated with future growth from potential permitted facilities

MOS = margin of safety

As stated in 40 CFR, §130.2(1), TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For *E. coli*, TMDLs are expressed as MPN/day, and represent the maximum one-day load the stream can assimilate while still attaining the standards for surface water quality.

4.7.1 AU-Level TMDL Calculations

The bacteria TMDL for Mound Creek (AU 1015A_01) was developed as a pollutant load allocation based on information from the LDC for Mound Creek monitoring station 17937 (Figure 13). As discussed in more detail in Section 3, the bacteria LDC was developed by multiplying each flow value along the flow duration curve by the *E. coli* criterion (126 MPN/100 mL) and by the conversion factor used to represent maximum loading in MPN/day. Effectively, the "Allowable Load" displayed in the LDC at 15 percent exceedance (the median value of the wet conditions-flow regime) is the TMDL:

TMDL (MPN/day) = Criterion * Flow (cfs) * Conversion Factor (Eq. 2)

Where:

Criterion = 126 MPN/100 mL (*E. coli*)

Conversion Factor (to MPN/day) = 283.1685 100 mL/ft^3 * 86,400 sec/day

The allowable loading of *E. coli* that the impaired AU 1015A_01 can receive on a daily basis was determined using Equation 2 based on the median value within the high flows regime of the FDC (or 15 percent flow exceedance value) for the SWQM station 17937 (Table 12).

Table 12. Summary of allowable loading calculations for Mound Creek (AU 1015A_01).

Water Body	AU	15% Exceedance Flow (cfs)	15% Exceedance Load (MPN/day)	TMDL (Billion MPN/day)
Mound Creek	1015A_01	26.740	8.2431 E+10	82.431

4.7.2 Margin of Safety

The margin of safety is only applied to the allowable loading for a watershed. Therefore, the margin of safety is expressed mathematically as the following:

MOS = 0.05 * TMDL (Eq. 3)

Where:

MOS = margin of safety load

TMDL = total maximum allowable load

Using the values of TMDL for AU 1015A_01 provided in Table 11, the MOS may be readily computed by proper substitution into Equation 3 (Table 13).

Table 13. MOS calculations for the Mound Creek watershed.

All loads expressed as billion MPN/day *E. coli*

Water Body	AU	TMDL[a]	MOS
Mound Creek	1015A_01	82.431	4.122

[a] TMDL from Table 12.

4.7.3 Wasteload Allocation

The Waste Load Allocation (WLA) consists of two parts – the waste load that is allocated to TPDES-regulated wastewater treatment facilities (WLA_{WWTF}) and the waste load that is allocated to regulated stormwater dischargers (WLA_{SW}).

$$WLA = WLA_{WWTF} + WLA_{SW} \qquad \text{(Eq. 4)}$$

TPDES-permitted wastewater treatment facilities are allocated a daily waste load (WLA_{WWTF}) calculated as their full permitted discharge flow rate multiplied by one-half the instream geometric criterion. One-half of the water quality criterion (63 MPN/100mL) is used as the WWTF target to provide instream and downstream load capacity. Thus, WLA_{WWTF} is expressed in the following equation:

$$WLA_{WWTF} = \text{Target} * \text{Flow} * \text{Conversion Factor} \qquad \text{(Eq. 5)}$$

Where:

Target= 63 MPN/100 mL

Flow = full permitted flow (MGD)

Conversion Factor (to MPN/day) = 1.54723 cfs/MGD *283.1685 100 mL/ft3 * 86,400 s/d

The daily allowable loading of *E. coli* assigned to WLA_{WWTF} was determined based on the combined full permitted flow of the three permitted WWTFs within the Mound Creek watershed, using equation 5. Table 14 presents the waste load allocation for each WWTF and the resulting total allocation for AU 1015A_01.

Stormwater discharges from MS4, industrial, and construction areas are considered permitted or regulated point sources. Therefore, the WLA calculations must also include an allocation for permitted stormwater discharges (WLA_{SW}). A simplified approach for estimating the WLA for these areas was used in the development of these TMDLs due to the limited amount of data available, the complexities associated with simulating rainfall runoff, and the variability of stormwater loading. The percentage of the land area included in the Mound Creek watershed that is under the jurisdiction of stormwater permits is used to estimate the amount of the overall runoff load that should be allocated as the permitted stormwater contribution in the WLA_{SW} component of the TMDL. The LA component of the TMDL corresponds to direct nonpoint runoff and is the difference between the total load from stormwater runoff and the portion allocated to WLA_{SW}.

Table 14. Waste load allocations for TPDES-permitted facilities in the Mound Creek watershed.

All loads expressed as billion MPN/day *E. coli*

TPDES Permit No.	NPDES Permit No.	Facility	Full Permitted Flow (MGD)[a]	*E. coli* WLA_{WWTF}
WQ0012456001	TX0088901	Crane Co. WWTF	0.005	0.012
WQ0014638001	TX0128121	MSEC WWTF	0.02	0.048
WQ0015341001	TX0136191	MSEC WWTF No. 2	0.130	0.310
Mound Creek Watershed Total				0.370

[a] Full Permitted Flow from Table 5.

WLA_{SW} is the sum of loads from regulated stormwater sources and is calculated as follows:

$$WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP} \qquad \text{(Eq. 6)}$$

Where:

WLA_{SW} = sum of all regulated stormwater loads

TMDL = total maximum daily load

FG = sum of future growth loads from potential permitted facilities

MOS = margin of safety load

FDA_{SWP} = fractional proportion of drainage area under jurisdiction of stormwater permits

The fractional proportion of the drainage area under the jurisdiction of stormwater permits (FDA_{SWP}) must be determined in order to estimate the amount of overall runoff load that should be allocated to WLA_{SW}. The term FDA_{SWP} was calculated based on the combined area under regulated stormwater permits. As described in Section 2.7.1.5, a search for all five categories of stormwater general permits was performed. The search results are presented in Table 15.

There are no MS4 permits held in the Mound Creek watershed. The acreage associated with the one industrial storm water permit was estimated by importing the location information associated with the facility into a Geographic Information System (GIS), and measuring the estimated disturbed area based on the most recently available aerial imagery. For the Construction Activities general permits, the authorization contains an "Area Disturbed" field, which for this TMDL serves as the area covered under Construction Activities stormwater permits.

Table 15. Stormwater General Permit areas and calculation of the FDASWP term for the Mound Creek watershed (AU 1015A_01).

Water Body	AU	MS4 General Permit (acres)	Multi-sector General Permit (acres)	Construction Activities (acres)	Concrete Production Facilities (acres)	Petroleum Bulk Stations (acres)	Total Area of Permits (acres)	Watershed Area (acres)	FDA_{SWP}
Mound Creek	1015A_01	-	9	98.95	-	-	107.95	13,422	0.0080

The daily allowable loading of *E. coli* assigned to WLA_{SW} was determined based on the combined area under regulated stormwater permits. In order to calculate the WLA_{SW} (Eq. 6), the Future Growth (FG) term must be known. The calculation for the FG term is presented in the next section, but the results will be included here for continuity. Table 16 provides the information needed to compute WLA_{SW}.

Table 16. Regulated stormwater calculations for the Mound Creek Watershed (AU 1015A_01).

All loads expressed as billion MPN/day *E. coli*

Water Body	AU	TMDL[a]	WLA_{WWTF}[b]	FG[c]	MOS[d]	FDA_{SWP}[e]	WLA_{SW}
Mound Creek	1015A_01	82.431	0.370	1.219	4.122	0.0080	0.614

[a] TMDL from Table 12

[b] WLA_{WWTF} from Table 14

[c] FG from Table 17

[d] MOS from Table 13

[e] FDA_{SWP} from Table 15

[f] WLA_{SW} = (TMDL – WLA_{WWTF} – FG MOS) *FDA_{SWP} (Eq. 6)

4.7.4 Future Growth

The FG component of the TMDL equation addresses the requirement of TMDLs to account for future loadings that may occur because of population growth, changes in community infrastructure, and development. The assimilative capacity of streams increases as the amount of flow increases due to future growth of permitted discharges. Increases in flow allow for additional indicator bacteria loads if the concentrations are at or below the contact recreation standard.

The allowance for future growth will result in protection of existing beneficial uses and conform to Texas's antidegradation policy.

The future growth component of impaired AU 1015A_01 was based on population projections and current permitted wastewater dischargers for the entire Mound Creek watershed. Recent population and projected population growth between 2010 and 2040 for the Mound Creek watershed are provided in Table 1. The projected population percentage increase within the watershed was multiplied by the corresponding WLA_{WWTF} to calculate future WLA_{WWTF}. The permitted flows were increased by the expected population growth per AU between 2010 and 2040 to determine the estimated future flows.

Thus, the FG is calculated as follows:

$$FG = WWTF_{FP} * POP_{2010\text{-}2040} * \text{conversion factor} * \text{target} \qquad \text{(Eq. 7)}$$

Where:

$WWTF_{FP}$ = full permitted WWTF discharge (MGD)

$POP_{2010\text{-}2040}$ = estimated percent increase in population between 2010 and 2040

Conversion factor = 37,854,000 100mL/MGD

Target = 63 MPN/100 mL

The calculation results for the impaired Mound Creek watershed (AU 1015A_01) are shown in Table 17.

Table 17. Future Growth calculations for the Mound Creek watershed (AU 1015A_01).

Water Body	AU	Full Permitted Flow (MGD)	% Population Increase (2010-2040)	Future Growth (MGD)	Future Growth (*E. coli* Billion MPN/Day)[a]
Mound Creek	1015A_01	0.155	329.6%	0.511	1.219

[a] $FG = WWTF_{FP} * POP_{2010\text{-}2040} * \text{conversion factor} * \text{target}$ (Eq. 7)

4.7.5 Load Allocation

The load allocation (LA) is the load from unregulated sources, and is calculated as:

$$LA = TMDL - WLA_{WWTF} - WLA_{SW} - FG - MOS \qquad \text{(Eq. 8)}$$

Where:

LA = allowable loads from unregulated sources within the AU

TMDL = total maximum daily load

WLA_{WWTF} = sum of all WWTF loads

WLA_{SW} = sum of all regulated stormwater loads

FG = sum of future growth loads from potential permitted facilities

MOS = margin of safety load

The calculation results are shown in Table 18.

Table 18. Load allocation calculations for the Mound Creek Watershed (AU 1015A_01). All loads expressed as billion MPN/day *E. coli*

Water Body	AU	TMDL[a]	$\mathrm{WLA}_{\mathrm{WWTF}}$[b]	$\mathrm{WLA}_{\mathrm{SW}}$[c]	FG[d]	MOS[e]	LA[f]
Mound Creek	1015A_01	82.431	0.370	0.614	1.219	4.122	76.106

[a] TMDL from Table 12

[b] $\mathrm{WLA}_{\mathrm{WWTF}}$ from Table 14

[c] $\mathrm{WLA}_{\mathrm{SW}}$ from Table 16

[d] FG from Table 17

[e] MOS from Table 13

[f] LA = TMDL – $\mathrm{WLA}_{\mathrm{WWTF}}$ – $\mathrm{WLA}_{\mathrm{SW}}$ – FG – MOS (Eq. 8)

4.8 Summary of TMDL Calculations

Table 19 summarizes the TMDL calculations for Mound Creek AU 1015A_01. The TMDL was calculated based on the median flow in the 0-30 percentile range (15 percent exceedance, Wet Conditions flow regime) for flow exceedance from the LDC developed for the downstream SWQM station 17937. Allocations are based on the current geometric mean criterion for *E. coli* of 126 MPN/100 mL for each component of the TMDL.

Table 19. TMDL allocation summary for Mound Creek AU 1015A_01. Units expressed as billion MPN/ day *E. coli*

Water Body	AU	TMDL[a]	$\mathrm{WLA}_{\mathrm{WWTF}}$[b]	$\mathrm{WLA}_{\mathrm{SW}}$[c]	LA[d]	FG[e]	MOS[f]
Mound Creek	1015A_01	82.431	0.370	0.614	76.106	1.219	4.122

[a] TMDL = from Table 12

[b] $\mathrm{WLA}_{\mathrm{WWTF}}$ = from Table 14

[c] $\mathrm{WLA}_{\mathrm{SW}}$ = from Table 16

[d] LA = from Table 18

[e] FG = From Table 17

[f] MOS = from Table 13

The final TMDL allocations (Table 20) needed to comply with the requirements of 40 CFR 130.7 include the FG component within the $\mathrm{WLA}_{\mathrm{WWTF}}$.

In the event that the criterion changes due to future revisions in the state's surface water quality standards, Appendix A provides guidance for recalculating the allocations in Table 17. Figure A-1 and Table A-1 of Appendix A was developed to demonstrate how assimilative capacity, TMDL calculations, and pollutant load allocations change in relation to a number of proposed water quality criteria for *E. coli*. The equations provided, along with Figure A-1 and Table A-1 allow calculation of new TMDLs and pollutant load allocations based on any potential new water quality criterion for *E. coli*.

Table 20. Final TMDL allocations for the Mound Creek Watershed (AU 1015A_01)

Units expressed as billion MPN/ day *E. coli*

Water Body	**AU**	**TMDL**	**WLA_{WWTF}[a]**	**WLA_{SW}**	**LA**	**MOS**
Mound Creek	1015A_01	82.431	1.589	0.614	76.106	4.122

[a] WLA_{WWTF} = WLA_{WWTF} includes the FG component

Section 5
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APPENDIX A

EQUATIONS FOR CALCULATING TMDL ALLOCATIONS FOR CHANGED CONTACT RECREATION STANDARD

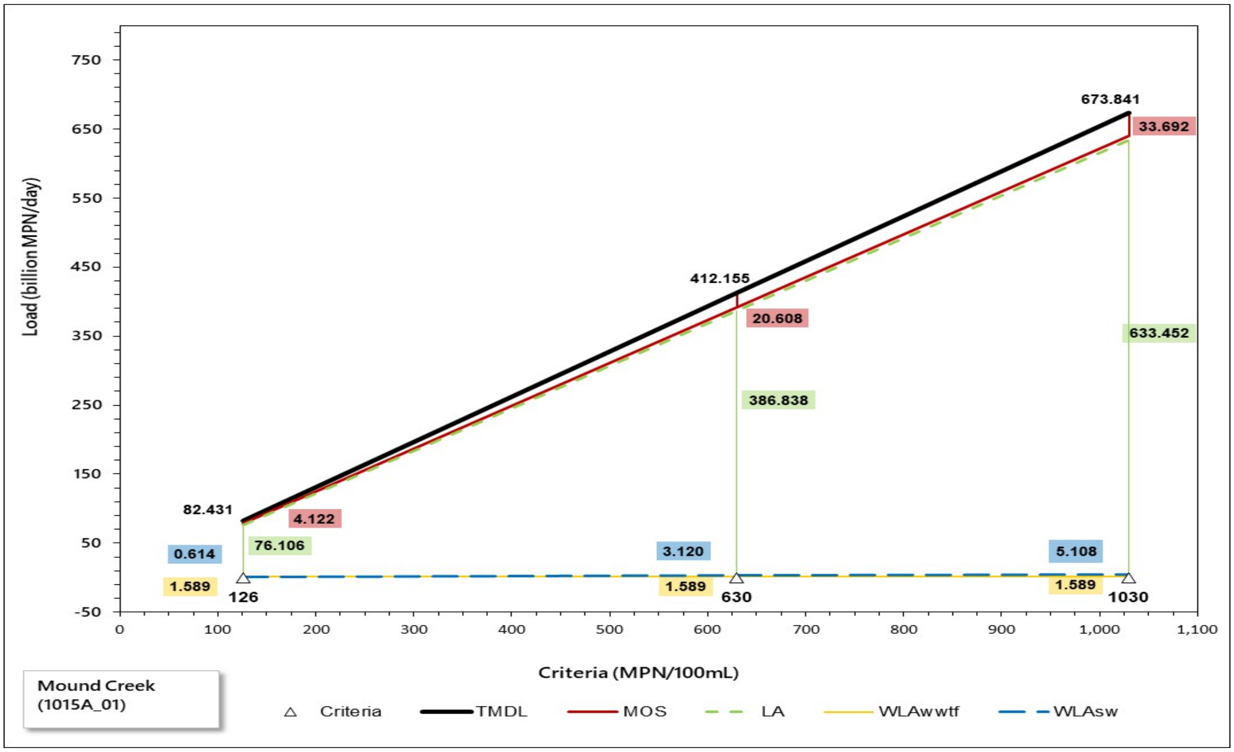

Figure A-1. Allocation loads for the Mound Creek watershed (1015A_01) as a function of water quality criteria

Equations for calculating new TMDL and allocations (in billion MPN/day)

TMDL = 0.6542146 * Std
MOS = 0.03271020 * Std + 0.0005377
LA = 0.61653310 * Std -1.5773868
$\mathrm{WLA}_{\mathrm{WWTF}}$ = 1.589
$\mathrm{WLA}_{\mathrm{sw}}$ =0.00497130 * Std -0.0122358

Where:

Std = Revised Contact Recreation Standard
MOS = Margin of Safety
LA = Total load allocation (unregulated sources)
$\mathrm{WLA}_{\mathrm{WWTF}}$ = Waste load allocation (permitted WWTF load + future growth)
$\mathrm{WLA}_{\mathrm{SW}}$ = Waste load allocation (permitted stormwater)

Table A-1 TMDL allocations for the Mound Creek watershed for potential changed contact recreation standards.

Units expressed as billion MPN/ day *E. coli* except contact recreation criterion

Contact Recreation Criterion (MPN/100 mL)	TMDL	WLA$_{\mathrm{WWTF}}$	WLA$_{\mathrm{SW}}$	LA	MOS
126	82.431	1.589	0.614	76.106	4.122
630	412.155	1.589	3.120	386.838	20.608
1,030	673.841	1.589	5.108	633.452	33.692