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Five Total Maximum Daily Loads for Indicator Bacteria in Four Austin Streams

Segments 1403J, 1403K, 1428B, and 1429C

Assessment Units: 1403J_01, 1403K_01, 1428B_05, 1429C_02, and 1429C_03

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TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

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Abbreviations

AU	assessment unit
AVMA	American Veterinary Medical Association
BMP	best management practice
CFR	Code of Federal Regulations
cfu	colony forming units (Note: cfu/100 mL, cfu/dL, MPN/100 mL, and MPN/dL are all equivalent.)
CFS	cubic feet per second
COA	City of Austin
CPPDR	Center of Public Policy Dispute Resolution (University of Texas Law School)
dL	deciliter, equals 100 mL
E. coli	*Escherichia coli*
EPA	Environmental Protection Agency (U.S.)
FDA_{SWP}	Fractional of drainage area under jurisdiction of stormwater permits
FDC	flow duration curve
FG	future growth
FM-	Farm to Market road
GIS	geographic information system
I-	Interstate highway
I-Plan	implementation plan
I/I	inflow and infiltration
LA	load allocation for non-point sources (non-permitted)
LA_{AU}	load from unregulated sources within the AU
LA_{USL}	load for upstream / downstream loads
LCRA	Lower Colorado River Authority
LDC	load duration curve
mL	milliliter
MLK	Martin Luther King Blvd. in Austin
MGD	million gallons per day
M	meter
MOPAC	Loop-1 Expressway in Austin
MOS	margin of safety
MPN	most probable number (Note: cfu/100 mL, cfu/dL, MPN/100 mL, MPN/dL are all equivalent.)
MS4	municipal separate storm sewer system
NA	Not applicable
NASS	National Agricultural Statistics Service
NEIWPCC	New England Interstate Water Pollution Control Commission
NOAA	National Oceanographic & Atmospheric Administration
NPS	Nonpoint source
NPDES	National Polluant Discharge Elimination System (permit)
OSSF	onsite sewage facility
SSO	sanitary sewer overflow
SPRR	Southern Pacific Railroad

SWAT	Soil and Water Assessment Tool hydrodynamic model
SWMP	Stormwater Management Program
SWQMIS	Surface Water Quality Monitoring Information System
TAC	Texas Administrative Code
TAMU	Texas A&M University
TCEQ	Texas Commission on Environmental Quality
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System (permit)
TPWD	Texas Parks and Wildlife Department
USGS	United States Geological Survey
UT	University of Texas
WLA	wasteload allocation for point sources (NPDES or TPDES permit)
WLA_{SW}	wasteload allocation for stormwater (MS4 with NPDES or TPDES permit)
WLA_{WWTF}	wasteload allocation for wastewater treatment plants (NPDES or TPDES permit)
WS	Watershed
WQMP	Water Quality Management Plan
WWTF	wastewater treatment facility

Five Total Maximum Daily Loads for Indicator Bacteria in Four Austin Streams

Executive Summary

This document describes total maximum daily loads (TMDLs) for four Austin streams and their tributaries in which concentrations of indicator bacteria exceed the criteria used to evaluate attainment of the contact recreation use. The Texas Commission on Environmental Quality (TCEQ) first identified the impairments to the Spicewood Tributary to Shoal Creek (Segment 1403J) and Taylor Slough South (1403K) in the *2002 State of Texas Clean Water Act Section 303(d) List* (TCEQ, 2002), adding Waller Creek (1429C) and Walnut Creek (1428B) when the list was updated in 2006. The impaired segments and corresponding assessment units (AUs) are:

- Spicewood Tributary to Shoal Creek (1403J_01);
- Taylor Slough South (1403K_01);
- Walnut Creek (1428B_05);
- Waller Creek (1429C_02, 1429C_03);

Together these four freshwater streams total approximately 31.6 miles in length with watersheds covering 63.465 square miles. They are almost entirely within the City of Austin full purpose, planning, or exterritorial jurisdiction. They are almost entirely within Travis County, except that the Walnut Creek watershed includes a very small portion of Williamson County.

Currently, there are not any permitted domestic wastewater discharges within the watersheds of any of these streams. The Walnut Creek Wastewater Treatment Facility (WWTF), operated by the City of Austin, discharges its effluent directly into the Colorado River instead of Walnut Creek. There are not any permitted industrial bacteria discharges within the watersheds. The Freescale Semiconductor WWTF only discharges bacteria-free process water. The primary loads are from various nonpoint sources that enter the streams via stormwater.

The Spicewood Tributary to Shoal Creek is an intermittent freshwater stream approximately 1.4 mile in length from MOPAC/Loop-1 upstream to its headwaters near Spicewood Springs Road and Mesa Drive. The watershed is about 0.650 square miles and is entirely located in the City of Austin. There are no regulated wastewater discharges within this watershed.

Taylor Slough South is a perennial freshwater stream approximately 1.1 mile in length from Lake Austin upstream to its headwaters near West 35^{th} Street and MOPAC/Loop-1. The watershed is 0.650 square miles and is entirely located in the City of Austin. There are no regulated wastewater discharges within this watershed.

Waller Creek is a perennial freshwater stream approximately 6.7 miles in length from its confluence with Lady Bird Lake upstream to its headwaters near Northcrest Boulevard and West St. Johns Avenue. The watershed is 5.648 square miles and is entirely located in the City of Austin. There are no regulated domestic wastewater discharges within this watershed.

Walnut Creek is a perennial freshwater stream approximately 22.4 miles in length from its confluence with the Colorado River upstream to its headwaters near McNeil Drive and Parmer Lane. The watershed is approximately 56.517 square miles and is mostly in the City of Austin full purpose jurisdiction. However portions are in the planning, or exterritorial jurisdictions. Currently, there is only one industrial wastewater discharge located within its watershed, the Freescale Semiconductor plant, which only discharges bacteria-free process water into Walnut Creek AU 1428B_01.

Escherichia coli (*E. coli*) are the preferred indicator bacteria for assessing the contact recreation use in freshwater, and were used for development of the TMDLs, with one exception. Fecal coliform bacteria were used for assessment of Walnut Creek AU 1428B_02 because it was the standard when data were collected in 1999. *E. coli* data are not currently available, but will be collected in the future.

The criteria for assessing attainment of the contact recreation use are expressed as the number (or “counts”) of bacteria. The primary contact recreation use is not supported when the geometric mean of *E. coli* samples exceeds 126 most probable number (MPN) per 100 milliliters (mL), or the geometric mean of fecal coliform samples exceeds 200 MPN per 100 mL.

For the 2012 assessment period, the geometric means of all AUs examined exceeded 126 MPN/100 mL *E. coli* or 200 MPN/100 mL fecal coliform, indicating non-support of primary contact recreation.

Possible sources of indicator bacteria within the watersheds of the impaired AUs are stormwater runoff from regulated storm sewers, illicit discharges from storm sewers, sanitary sewer overflows (SSOs), and unregulated sources such as wildlife, unmanaged feral animals, and pets.

Load duration curve (LDC) analyses of instream flows were used to estimate allowable pollutant loads and specific TMDL allocations. Because bacteria loads are usually highest at high flow, the very high flow regime was used as the critical flow for determining the TMDL.

Predictions of future growth of existing or new domestic point sources were not necessary. The City of Austin has informed TCEQ that it intends to accommodate all growth with its central wastewater treatment system, which discharges directly into the Colorado River instead of these watersheds.

The wasteload allocation (WLA) for regulated stormwater was based on the percentage of each watershed regulated under a Phase I or Phase II Texas Pollutant Discharge Elimination System (TPDES) stormwater permit.

Compliance with these TMDLs is based on keeping indicator bacteria concentrations in the selected waters below the geometric mean criterion of *E. coli* less than 126 MPN/100 mL or fecal coliform less than 200 MPN/100 mL.

Introduction

Section 303(d) of the federal Clean Water Act requires all states to identify waters that do not meet, or are not expected to meet, applicable surface water quality standards. States must develop a TMDL for each pollutant that contributes to the impairment of a listed water body. The 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 standard. 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 bacteria per period of time, typically as billion MPN/day, but may be expressed in other ways.

The 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.

This TMDL addresses impairments to the contact recreation use in four Austin streams: Spicewood Tributary to Shoal Creek (1403J), Taylor Slough South (1403K), Walnut Creek (1428B), and Waller Creek (1429C). The TMDL uses a watershed approach to address indicator bacteria impairments. Whenever possible, the entire watershed for each impaired water body (Figure 1) is included in this TMDL.

Section 303(d) of the Clean Water Act and the implementing regulations of the U.S. Environmental Protection Agency (EPA) in Title 40 of the Code of Federal

Regulations (CFR), Part 130 (40 CFR 130) describe the statutory and regulatory requirements for acceptable TMDLs. The EPA provides further direction in its Guidance for Water Quality-Based Decisions: The TMDL Process (EPA, 1991). This TMDL document has been prepared in accordance with those regulations and guidelines.

The TCEQ must consider certain elements in developing a TMDL. They are described in the following sections of this report:

- Problem Definition
- Endpoint Identification
- Source Analysis
- Linkage Analysis
- Margin of Safety
- Pollutant Load Allocation
- Seasonal Variation
- Public Participation
- Implementation and Reasonable Assurance

Upon adoption of the TMDL report by the TCEQ and subsequent EPA approval, these TMDLs will become an update to the state's Water Quality Management Plan (WQMP).

Problem Definition

The TCEQ first identified bacteria impairments within these Austin streams, shown in Figure 1, in the 2002 *Texas Water Quality Inventory and 303(d) List* (TCEQ, 2002). More recent editions of this list are titled the *Texas Integrated Report of Surface Water Quality for Clean Water Sections 305(b) and 303 (d)* (*Texas Integrated Report*). All of these streams have been included in subsequent editions of the *Texas Integrated Report* through 2012 (TCEQ, 2012a).

An AU is the smallest geographic area of use support reported in the assessment of surface water quality. Completion of the Waller Creek flood control tunnel and associated redevelopment will dramatically change the hydrodynamics of the lowest AU of Waller Creek (1429C_01), so is not included in this TMDL. The lower AUs of Walnut Creek (1428B_01, 1428B_02, 1428B_03, and 1428B_04) were not identified as impaired for elevated bacteria concentrations on the 2012 *Texas Integrated Report*. However, these four AUs are currently listed as of concern, so the City of Austin has requested they be included in this TMDL.

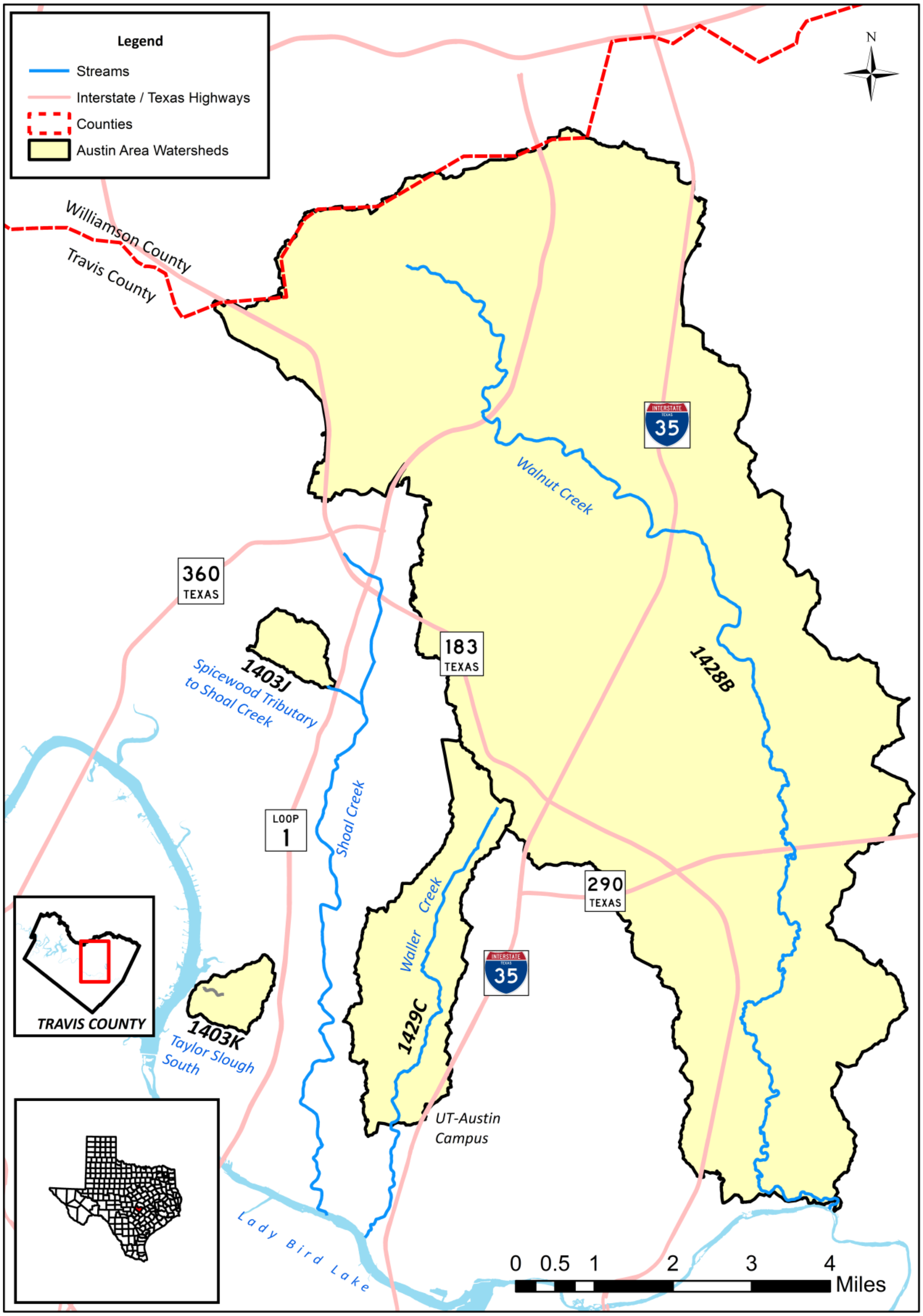

Figure 1. Overview map showing the watersheds of the four Austin streams

For the four Austin streams, TMDLs have been developed for bacteria impairments in five AUs, and for concerns in four AUs (Figure 2) based on data in the *2012 Texas Integrated Report*.

Table 1 identifies the nine AUs and relevant 303(d) listing information from the *2012 Texas Integrated Report*. The assessment period for these water bodies was December 1, 2003 through November 30, 2010.

Table 1. TMDL segments and AUs for four Austin streams

AU	Segment Name	2012 Integrated Report Level of Support
1403J_01	Spicewood Tributary to Shoal Creek	Non-Supporting
1403K_01	Taylor Slough South	Non-Supporting
1428B_01	Walnut Creek	Concern for Use
1428B_02	Walnut Creek	Concern for Use
1428B_03	Walnut Creek	Concern for Use
1428B_04	Walnut Creek	Concern for Use
1428B_05	Walnut Creek	Non-Supporting
1429C_02	Waller Creek	Non-Supporting
1429C_03	Waller Creek	Non-Supporting

Based on the *2012 Texas Integrated Report*, the drainage area for the four Austin streams includes:

§ Segments that are non-supporting (impaired) of the contact recreation use, and

§ Segments that have concerns about contact recreation use.

The standards for water quality are defined in the *Texas Surface Water Quality Standards* (TCEQ, 2010b, 2012b). *E. coli* are the preferred indicator bacteria for assessing the contact recreation use in freshwater. When *E. coli* data are not available, fecal coliform may be used for assessment. The criteria for assessing attainment of the contact recreation use are expressed as the number (or "counts") of bacteria, typically given in MPN—for *E. coli* or colony-forming units (cfu)—for fecal coliform) 100 mL of water. The primary contact recreation use is not supported when the geometric mean of all *E. coli* samples exceeds 126 MPN per 100 milliliters (mL), or fecal coliform exceeds 200 MPN per 100 milliliters (mL).

Ambient Indicator Bacteria Concentrations

This TMDL is based upon *E. coli* except for Walnut Creek 1428B_02, where only fecal coliform data are available. Tables 2 and 3 present a summary of all ambient indicator bacteria data for monitoring stations in the four Austin streams. Table 2 contains *E. coli* data, which is compared to the *E. coli* standard of 126 cfu/100mL. Table 3 contains fecal coliform data, which is compared to the fecal coliform standard of 200 cfu/100mL. These tables contain data from not only the TCEQ Surface Water Quality Monitoring Information System (SWQMIS) database, but also supplemental data collected by the City of Austin. Temporally, they contain all dates available, including dates both before and after the assessment period. Figure 2 shows the station locations and AUs.

Table 2. Summary of all *E. coli* monitoring data available (Includes data not used in the 2012 assessment)

TCEQ Station Id	COA Station Id	Station Description	Station AU	No. Of Samples	Date Range	*E. Coli* Max (MPN/dL) [a]	*E. Coli* Geometric Mean (Billion MPN/dL) [a]
16316	930, 582	Spicewood Trib of Shoal Creek at Spicewood Spring Dr at Ceberry N of Wood Hollow Dr at Far West	1403J_01	56	4/29/97 - 8/18/10	2,420	637
17294	890, 318	Taylor Slough South 20 M Downstream of Pecos Street South of River Road in Austin	1403K_01	39	3/10/04 - 9/12/12	2,900	442
12222	38, 485	Waller Creek at 2nd Street/Red River Street in Austin to the Northwest of Lady Bird Lake	1429C_01	84	12/18/03 - 9/21/11	24,200	841
15962	624, 4349	Waller Creek at 24th Street on UT Campus in Austin	1429C_02	43	12/18/03 - 8/18/10	24,000	839
12228	N/A	Waller Creek at Denson Avenue in Austin	1429C_03	1	2/22/2006	100	100

TCEQ Station Id	COA Station Id	Station Description	Station AU	No. Of Samples	Date Range	*E. Coli* Max (MPN/dL) [a]	*E. Coli* Geometric Mean (Billion MPN/dL) [a]
16331	781	Waller Creek at Avenue H at the Elisabet Ney Museum	1429C_03	51	12/18/03 - 8/18/10	6,500	303
12231	4021	Walnut Creek at Southern Pacific RR Approximately 26 M Downstream of Austin and Northwestern 1.2 Miles South of FM-969 in east Austin	1428B_01	16	3/23/04 - 12/1/10	2,200	129
N/A	503	Walnut Creek Upstream of Freescale	1428B_01	30	3/23/04 - 3/23/11	2,200	135
17469	502	Walnut Creek 5 M Downstream of Old Manor Road and 175 M east of Intersection of Old Manor Road and Ferguson Cutoff North of Preserve	1428B_03	33	3/23/04 - 6/7/11	1,600	123
15743	464	Walnut Creek at IH-35 West Frontage Road In Austin	1428B_04	47	3/23/04 - 3/23/11	580	130
N/A	895	Walnut Creek Downstream of Metric Blvd	1428B_04	30	3/23/04 - 9/21/11	4,839	267
17251	N/A	Walnut Creek Immediately Downstream of Loop 1/MOPAC Expwy In Austin	1428B_05	19	9/8/04 - 6/7/11	3,500	807

[a] The unit cfu/100mL is equivalent to the units cfu/dL, MPN/100 mL, and MPN/dL.

[b] The *E. coli* standard is 126 MPN/dL.

Table 3. Summary of all fecal coliform monitoring data available (Includes data not used in the 2012 assessment)

TCEQ Station ID	COA Station ID	Station Description	AU	No. of Samples	Date Range	Fecal Coliform Max (MPN/dL) [a]	Fecal Coliform Geometric Mean (MPN/dL) [a, b]
16187 b	N/A	Walnut Creek Adjacent to NE District Park 681 Ft East of the Intersection of Crystal Brook Dr and Ute Dr in Austin	1428B_02	16	3/5/96 - 5/19/2003	420	99
12232	495	Walnut Creek Approximately 61 M Downstream of Webberville Road/FM-969 in east Austin	1428B_02	121	10/6/81 - 11/3/1999	440,000	3,741

[a] The unit cfu/100 mL is equivalent to the units cfu/dL, MPN/100 mL, and MPN/dL.

[b] The fecal coliform standard is 200 MPN/dL.

Tables 4 and 5 are similar to Tables 2 and 3, but present only the subset of data collected by the City of Austin, which did not meet the very strict quality control measures required for assessment by EPA. These quality control measures result in much higher data collection and analytical costs, which the City of Austin balanced with the need for source identification, broader spatial coverage, and screening-level programs like the Environmental Integrity Index.

Table 4. Summary of supplemental *E. coli* monitoring data not used in the 2012 assessment

TCEQ Station ID	COA Station ID	Station Description	Station AU	No. of Samples	Date Range	*E. coli* Max (MPN/dL) [a]	*E. coli* Geometric Mean (MPN/dL) [a]
16316	930, 582	Spicewood Trib of Shoal Creek at Spicewood Spring Dr at Ceberry N of Wood Hollow Dr at Far West	1403J_01	26	4/29/97 - 8/18/10	2,420	572

TCEQ Station ID	COA Station ID	Station Description	Station AU	No. of Samples	Date Range	*E. coli* Max (MPN/dL) [a]	*E. coli* Geometric Mean (MPN/dL) [a]
17294	890, 318	Taylor Slough South 20 M Downstream of Pecos Street South of River Road in Austin	1403K_01	24	3/10/04 - 9/12/12	890	429
12222	38, 485	Waller Creek at 2nd Street/Red River Street in Austin to the Northwest of Lady Bird Lake	1429C_01	47	2/22/06 - 9/21/11	24,200	795
15962	624, 4349	Waller Creek at 24th Street on UT Campus in Austin	1429C_02	8	5/18/06 - 5/15/09	5,853	646
12228	*N/A*	Waller Creek at Denson Avenue in Austin	1429C_03	N/A	N/A	N/A	N/A
16331	781	Waller Creek at Avenue H at the Elisabet Ney Museum	1429C_03	20	4/14/08 - 6/15/10	6,490	643
12231	4021	Walnut Creek at Southern Pacific RR Approximately 26 M Downstream of Austin and Northwestern 1.2 miles south of FM-969 in east Austin	1428B_01	1	12/1/2010	156	156
N/A	503	Walnut Creek upstream of Freescale	1428B_01	30	3/23/04 - 3/23/11	2,200	135
17469	502	Walnut Creek 5 M downstream of Old Manor Road and 175 M east of Intersection of Old Manor Road and Ferguson Cutoff north of Preserve	1428B_03	12	2/22/06 - 12/16/09	1,550	199

TCEQ Station ID	COA Station ID	Station Description	Station AU	No. of Samples	Date Range	*E. coli* Max (MPN/dL) [a]	*E. coli* Geometric Mean (MPN/dL) [a]
15743	464	Walnut Creek at IH-35 West Frontage Road in Austin	1428B_04	26	3/23/04 - 3/23/11	579	145
N/A	895	Walnut Creek Downstream Of Metric Blvd	1428B_04	30	3/23/04 - 9/21/11	4,839	267
17251	*N/A*	Walnut Creek Immediately Downstream Of Loop 1/MOPAC Expwy In Austin	1428B_05	N/A	N/A	N/A	N/A

[a] The unit MPN/100mL is equivalent to the units MPN/dL, cfu/100mL, and cfu/dL.

Table 5. Summary of fecal coliform supplemental monitoring data not used in the 2012 assessment

TCEQ Station ID	COA Station ID	Description	Station AU	No. of Samples	Date Range	Fecal Coliform Max [a] (MPN/dL)	Fecal Coliform Geometric Mean [a, b] (MPN/dL)
12232 b	495	Walnut Creek Approximately 61 M Downstream at Webberville Road/FM-969 in east Austin	1428B_02	8	1/7/00 - 9/17/01	24,000 [b]	1,140 [b]

[a] The unit MPN/100mL is equivalent to the units MPN/dL, cfu/100 mL, and cfu/dL.

[b] The fecal coliform standard is 200 MPN/dL.

Tables 6 and 7 are similar to Tables 2 through 5, but summarize only the data used in the 2012 assessment. These tables contain only official data collected during the 2012 assessment period, which is 12/01/2003 – 11/30/2010.

Table 6. Summary of *E. coli* monitoring data used in the 2012 assessment

TCEQ Station ID	COA Station ID	Description	Station AU	No. of Samples	Date Range	*E. coli* Max (MPN/dL) [a]	*E. coli* Geometric Mean a (MPN/dL) [a]
16316	930, 582	Spicewood Tributary downstream of Spicewood Springs, Spicewood Spring (USGS)	1403J_01	30	11/15/07 - 8/18/10	2,400	727
17294	890, 318	Taylor Slough South 20 M downstream of Pecos Street south of River Road in Austin	1403K_01	14	1/28/08 - 8/18/10	2,400	545
15962	624, 4349	Waller Creek at 24th Street	1429C_02	35	12/18/03 - 8/18/10	24,000	891
12228	N/A	Waller Creek at Denson Avenue	1429C_03	1	2/22/2006	100	100
16331	781	Waller Creek at Shipe Park	1429C_03	32	12/18/03 - 8/18/10	6,500	182
12231	4021	Walnut Creek south of FM-969	1428B_01	15	3/23/04 - 12/16/09	2,200	127
17469	502	Walnut Creek at Old Manor Rd	1428B_03	18	3/23/04 - 12/16/2009	1,600	153
15743	464	Walnut Creek at IH35	1428B_04	18	3/23/04 - 12/16/2009	580	129
17251	N/A	Walnut Creek downstream of Loop 1	1428B_05	16	9/8/04 - 12/16/2009	3,500	865

[a] The unit MPN/100mL is equivalent to the units MPN/dL, cfu/100 mL, and cfu/dL.

Table 7. Summary of fecal coliform monitoring data used in the 2012 assessment

TCEQ Station ID	COA Station ID	Description	Station AU	No. of Samples	Date Range	Fecal Coliform Max [a] (MPN/dL)	Fecal Coliform Geometric Mean [a] (MPN/dL)
16187	N/A	Walnut Creek at NE District Park	1428B_02	5	6/10/2002 – 5/19/2003	420 [b]	205 [b]

[a] The unit MPN/100mL is equivalent to the units MPN/dL, cfu/100 mL, and cfu/dL.

[b] The fecal coliform standard is 200 MPN/dL.

TCEQ monitoring stations are depicted in Figure 2. *E. coli* data collected at these stations were used in assessing attainment of the primary contact recreation use as reported in the *2012 Texas Integrated Report* (TCEQ, 2012a).

Watershed Overview

The Austin area is located where the Edwards Plateau (commonly called the Texas Hill Country) meets the Blackland Prairie at the Balcones Fault (Texas Almanac, 2013).

Central and west Austin are located on the Balcones Escarpment, which is the eastern edge of the Edwards Plateau. It is characterized by hills, steep limestone cliffs, outcroppings, and bluffs; and dry creeks, springs, caves, and small sinkholes. The very thin topsoil covers layers of fractured limestone and caliche, alternating with limestone bedrock. Infrequent rains are often heavy, resulting in large amounts of runoff and flash flooding. The creek beds usually occur over exposed karst, which is limestone with dissolution features such as fissures and holes. Water flows through the karst to recharge the Edwards Aquifer as well as small springs, so small caves and sinkholes are common.

The limestone based clay soils of the Edwards Plateau support a mixture of bunchgrasses including several varieties of bluestem and grama grasses, as well as small trees. Live oak, oak, mesquite, and juniper trees dominate the woody vegetation (Texas Almanac, 2013).

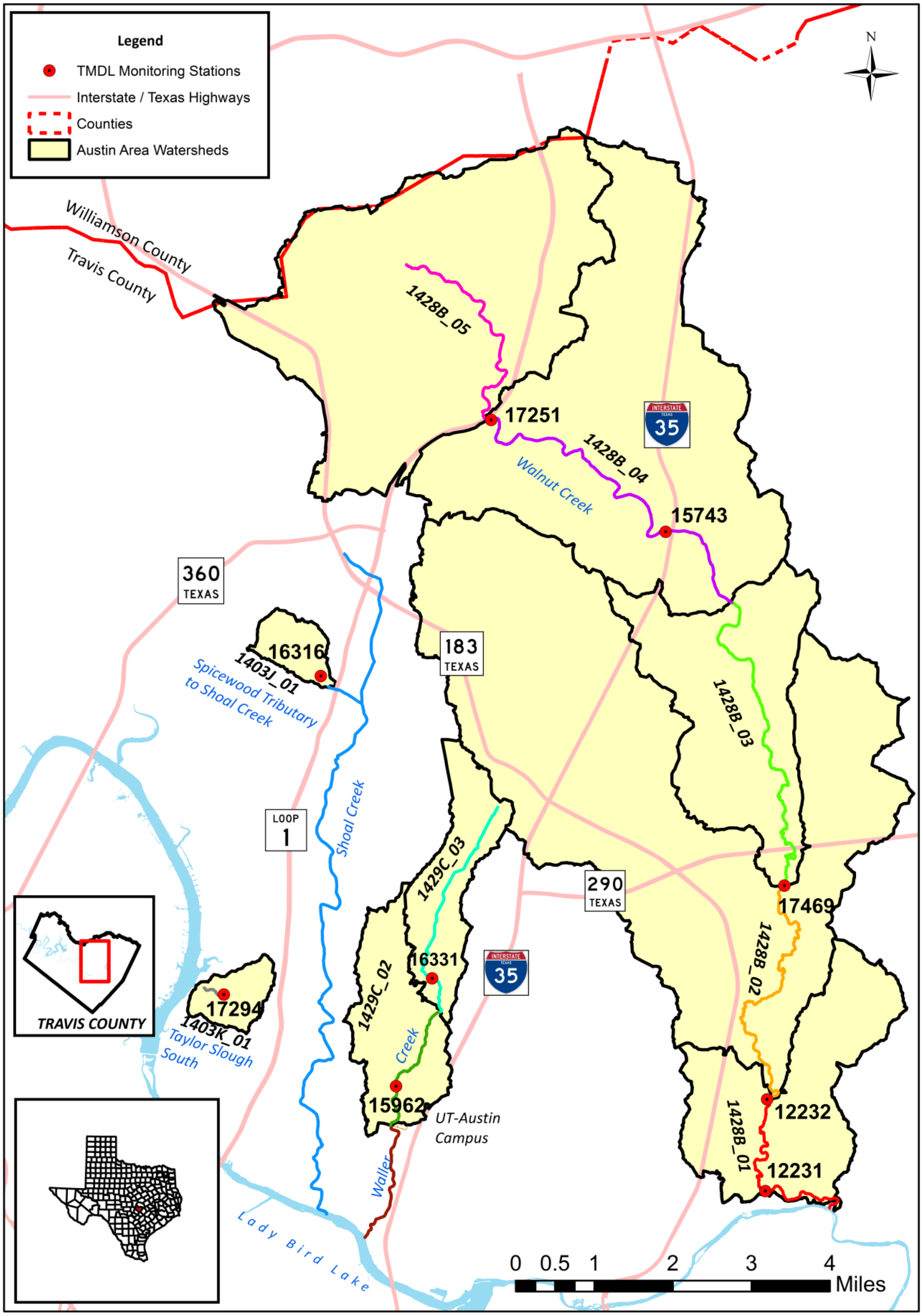

Figure 2. Monitoring stations on the four Austin streams used for this TMDL

East Austin is on the eastern side of the Balcones Escarpment, and is Blackland Prairie, which is characterized by flat land composed of very rich black soil. The original native vegetation was a mixture similar to the Edwards Plateau, but in heavily grazed pastures, these bunchgrasses have been reduced to a few species. Timber along the streams includes a variety of oaks, pecan, elm, bois d'arc, and mesquite. Large portions have been previously converted to farmland, but more recently, portions near Austin have been developed (Texas Almanac, 2013).

Austin has a humid subtropical climate, alternating between the continental regime and a modified maritime regime, resulting in hot summers and mild winters (NOAA, 2013).

Summers are usually hot; highs are over 90°F more than 80% of the time (116 days per year), and some years they are frequently over 100°F. The highest recorded temperature was 112°F in 2000, but cool fronts may drop overnight lows to the 50s on some occasions.

Winters in Austin are mild and relatively dry. Austin averages 88 days below 45°F, and 13 days when the minimum temperature falls below freezing. The area is alternately influenced by continental winds from the north and west, and by south and southeast maritime winds from the Gulf of Mexico. Mild weather prevails during most of the winter, but north winds with strong cold fronts usher in frigid conditions an average of 25 days each year.

On the average, precipitation is evenly distributed throughout the year, but is highly variable both month to month and year to year. Annual rainfall varies from 10 to 65 inches, with an average of 33 inches (LCRA, 2011). The heaviest amounts of rain usually occur in May and September, primarily because of stalled cool fronts or tropical cyclones. In addition, extended dry periods may be randomly interrupted by severe thunderstorms. Precipitation from April through September usually results from thunderstorms, with large amounts of rain falling within a short time (NOAA, 2013). Rainfall from these storms can exceed 6 inches in several hours, causing flash floods. The current record, set in 1935, is 22 inches of rain in three hours (Flood Safety, 2013). Potential incidence of high-magnitude flooding is greater in the Balcones Escarpment area than in any other region of the United States. Rates of precipitation and discharge per unit drainage area approach world maxima. The intensity of rainstorms is compounded by rapid runoff and limited infiltration, producing episodic flooding. (Caran & Baker, 1986).

Figure 1 is an overview map of Austin showing the locations and watersheds of the four streams (City of Austin, 2010). Together these four streams total approximately 31.6 miles in length, with watersheds covering 63.465 square miles. They are generally within the City of Austin and Travis County, except that the Walnut Creek watershed includes very small portions of Williamson County. Directly or indirectly, all of these streams drain into the Colorado River. Walnut Creek (1428B) drains directly into the Colorado River (1428). Waller Creek (1429C) drains into Lady Bird Lake (1429), which is a reservoir on the Colorado River. Spicewood Tributary drains in to Shoal Creek (1403J), which also drains into Lady Bird Lake. Taylor Slough South (1403K) drains into Lake Austin (1403), which also is a reservoir on the Colorado River.

As shown in figure 2, the following water bodies are included in this document.

- Segment 1403J, Spicewood Tributary to Shoal Creek: From the confluence of an unnamed tributary west of the MOPAC Expressway in north Austin in Travis County upstream to the head waters north of Williamsburg Circle in Travis
    - 1403J_01: Entire water body

- Segment 1403K, Taylor Slough South: From the confluence of Lake Austin in Travis County to the headwaters near South Meadow Circle on the Texas Department of Aging and Disability Services campus in Austin in Travis County
    - 1403K_01: Entire water body

- Segment 1428B, Walnut Creek: From the confluence of the Colorado River in east Austin in Travis County to the upstream perennial portion of the stream in north Austin in Travis County
    - 1428B_01: From the Colorado River upstream to FM-969
    - 1428B_02: From FM-969 upstream to Old Manor Rd.
    - 1428B_03: From old Manor Road upstream to Dessau Road
    - 1428B_04: From Dessau Rd. upstream to MOPAC/Loop 1
    - 1428B_05: From MOPAC/Loop 1 upstream to Union Pacific Railroad tracks south of McNeil Drive

Walnut Creek (Segment 1428B) AUs 1428B_01, 1428B_02, 1428B_03, and 1428B_04 are currently listed of concern, but not listed in the 2012 303(d) list (TCEQ, 2012a). However, they have been both on and off the 303(d) list in previous assessments, so the City of Austin requested that they be included in this TMDL.

- Segment 1429C, Waller Creek: From the confluence of Lady Bird Lake in central Austin in Travis County to the upstream portion of the stream in north Austin in Travis County
    - 1429C_01: From the confluence with Lady Bird Lake to East MLK Blvd. Waller Creek AU 1429C_01 is included in the 2012 303(d) list, but omitted

from this TMDL because the City of Austin Waller Creek Tunnel will significantly change both its hydrology and assimilative capacity.

- 1429C_02: From East MLK Blvd. to East 41st Street
- 1429C_03: Upper portion of creek

Stream flow within the Colorado River Basin, including the four Austin streams, generally follows the rainfall pattern in the area. The natural flow of these streams is highly variable. Many of the smaller streams cease to flow within a few days or weeks without rain. However, other streams are spring fed and have small perennial base flows.

The lowest AU of Walnut Creek (1428B_01) receives a small amount of bacteria free industrial wastewater effluent from Freescale Semiconductor, which has only a modest effect on streamflow. While, the City of Austin Walnut Creek WWTF is physically located within the watershed, it discharges its effluent directly into the nearby Colorado River, having no effect on Walnut Creek stream flow. The other streams do not receive any industrial or sanitary wastewater discharges, so all flow is a result of stormwater or spring water.

The land use/land cover data for the Austin streams watershed were obtained from the City of Austin (City of Austin, 2010) and represent land use/land cover estimates for 2010. The land use/land cover is represented by the following categories and definitions.

§ **Residential**

- Large-Lot Single Family

  The designation for low-density residential areas that is not suitable or desirable for urban development.
- Single Family or Duplex

  Single-family detached or two-family residential uses at typical urban and/or suburban densities.
- Multifamily Residential

  Higher-density housing with three or more units on one lot.

§ **Commercial and Industrial**

- Office

  An area that provides for office uses as a transition from residential to commercial uses, or for large planned office areas.
- Commercial

  Lots or parcels containing retail sales, services, hotel/motels, and all recreational services. Private institutional uses, but not hospitals, are included.

- Industrial

  Areas reserved for manufacturing and related uses that are not compatible with other uses. Industry includes general warehousing, manufacturing, research and development, mining, landfills, and storage of hazardous materials.

§ **Civic and Open Space**

- Recreational and Open Space

  Large public parks and recreation areas such as golf courses, trails and easements, drainage ways and detention basins, and any other public usage of large areas on permanent open land.

- Civic

  Any site for public or semi-public facilities, including governmental offices, police and fire facilities, hospitals, public and private schools, and religious facilities.

§ **Transportation**

- Areas dedicated to vehicle, air, or rail transportation.
- Streets and Roads

  Existing and platted streets; planned and dedicated rights-of-way.

The maps and 2010 land use/land cover data from the City of Austin are provided for the Austin streams watersheds in Figures 3 through 10, and in tabular form in Tables 8 through 12, for each of the four Austin streams watersheds.

Table 8 shows single family and duplex housing are the largest land use in all watersheds. Generally, streets and roads are the second largest; however there are exceptions. In the Spicewood Creek watershed, multi-family housing is greater than roads, and undeveloped land is greater in the Walnut Creek watershed. Land used for offices is significant in the Spicewood watershed. Civic land use is significant in both Taylor Slough South and Waller Creek. This discussion is expanded below.

Table 8. Summary of land use in the four stream watersheds (Areas in square miles)

Land Use	Spicewood Tributary to Shoal Creek 1403J (sq. mi.)	Spicewood Tributary to Shoal Creek 1403J (%)	Taylor Slough South 1403K (sq. mi.)	Taylor Slough South 1403K (%)	Walnut Creek 1428B (sq. mi.)	Walnut Creek 1428B (%)	Waller Creek 1429C (sq. mi.)	Waller Creek 1429C (%)
Single Family or Duplex	0.202	31%	0.363	56%	11.859	21%	1.429	25%
Streets and Roads	0.134	21%	0.092	14%	8.470	15%	1.356	24%
Multi-family	0.150	23%	0.008	1%	3.956	7%	0.375	7%
Office	0.078	12%	0.003	1%	2.446	4%	0.245	4%
Undeveloped	0.003	1%	-	-	10.148	18%	0.064	1%
Open Space	0.009	1%	0.021	3%	4.830	9%	0.236	4%
Industrial	-	-	-	-	4.539	8%	0.176	3%
Commercial	0.027	4%	0.007	1%	3.212	6%	0.369	7%
Civic	0.039	6%	0.156	24%	2.895	5%	1.256	22%
Mining	-	-	-	-	1.004	2%	-	-
Large-lot Single Family	-	-	-	-	0.803	1%	-	-
Utilities (870)	0.008	1%	-	-	0.725	1%	0.021	1%
Landfill	-	-	-	-	0.697	1%	-	-
Mobile Homes	-	-	-	-	0.555	1%	-	-
Transportation	-	-	-	-	0.378	1%	0.121	2%
Total	0.650	100%	0.650	100%	56.517	100%	5.648	100%

Spicewood Tributary to Shoal Creek

Figure 3 is a map of the Spicewood Tributary to Shoal Creek (1403J) watershed. It is a minor tributary to Shoal Creek, about 1.4 mile long, with intermittent flow and a watershed of 0.650 square miles. It is entirely within the Austin city limits and the Edwards Aquifer Recharge Zone

Land use within the Spicewood Tributary to Shoal Creek watershed is shown in Figure 4 and summarized in Table 9. The largest land use is single family residential; followed by multifamily residential along Spicewood Springs Road, Steck Avenue, and Mesa Drive. Roads are the third largest land use, followed by offices along Spicewood Springs Road. Civic land use includes a high school and several churches.

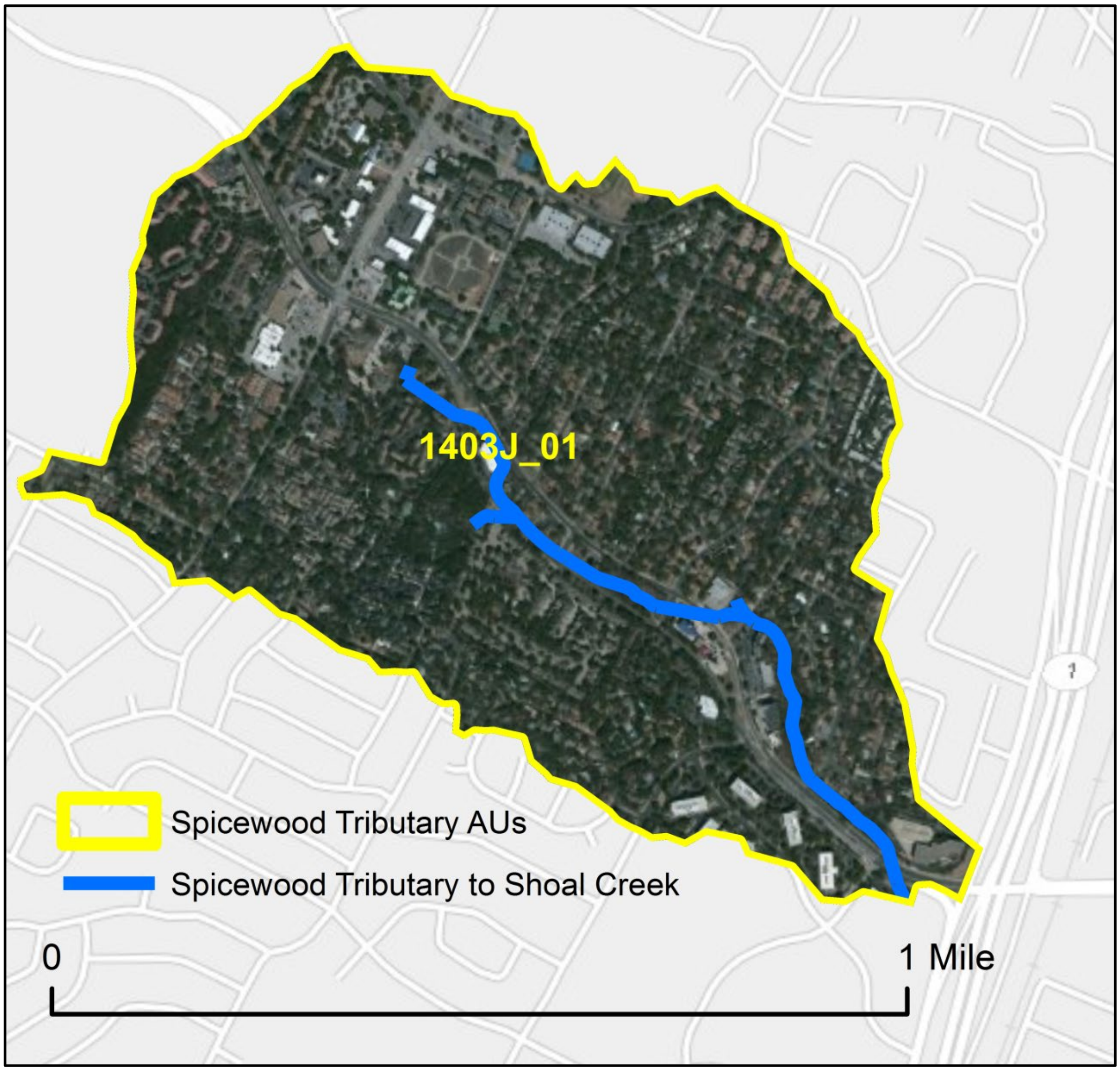

Figure 3. Map of the Spicewood Tributary to Shoal Creek watershed 1403J

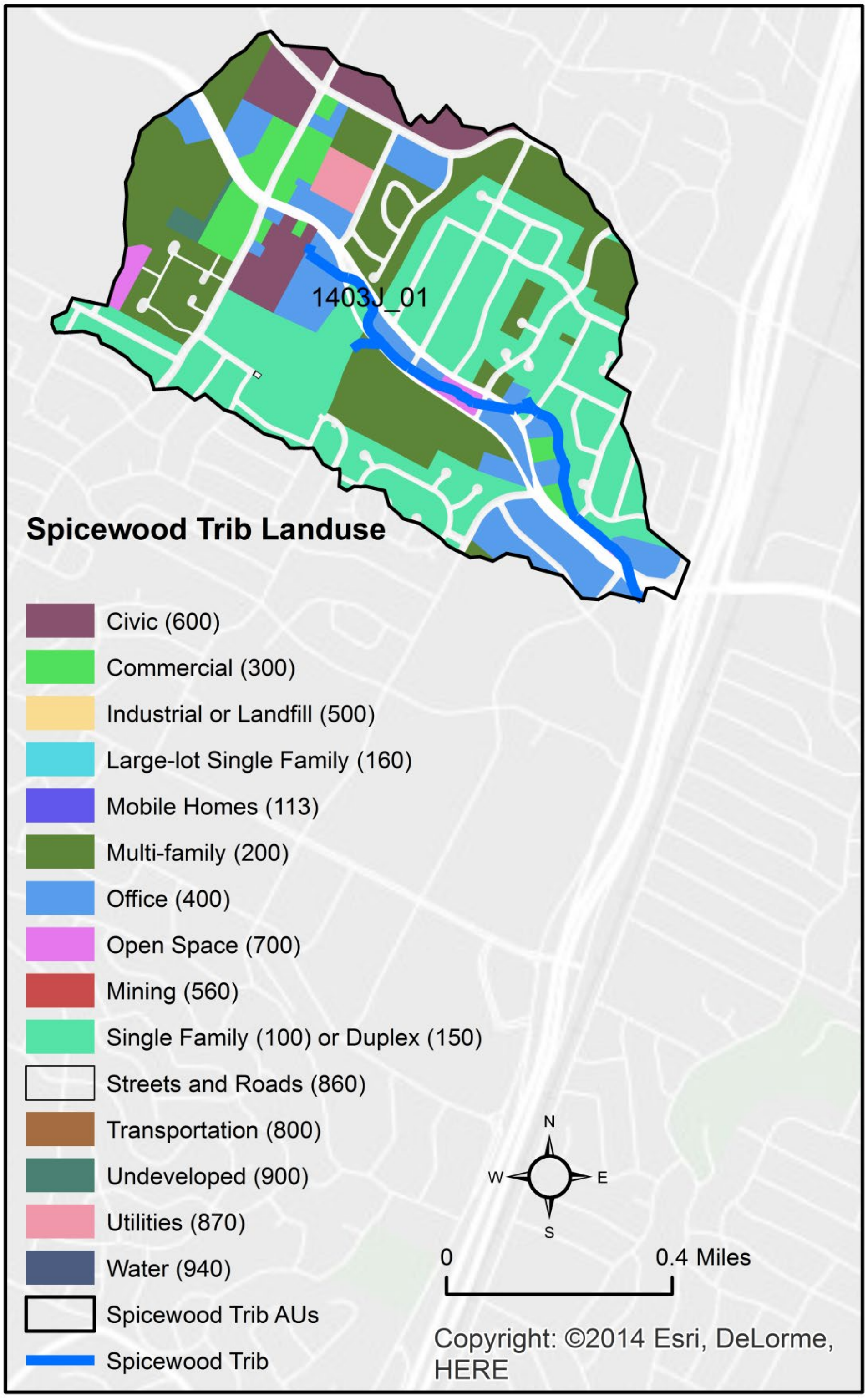

Figure 4. Land use map of the Spicewood Tributary to Shoal Creek 1403J

Table 9. Summary of land use in the watershed of Spicewood Tributary to Shoal Creek

Land Use	Area (sq. mi.)	Area (%)
Single Family or Duplex	0.202	31%
Multi-family	0.150	23%
Streets and Roads	0.134	21%
Office	0.078	12%
Civic	0.039	6%
Commercial	0.027	4%
Open Space	0.009	1%
Utilities	0.008	1%
Undeveloped	0.003	1%
Total	0.650	100%

Taylor Slough South

Figure 5 is a photo of the Taylor Slough South (1403K) watershed. Taylor Slough South is a minor tributary to Lake Austin. It is an intermittent stream about 1.1 miles long, with a watershed of 0.65 square miles watershed. It is entirely within the Austin city limits and in the Edwards Aquifer Recharge Zone.

As shown in Figure 6 and Table 10, the largest land use in the Taylor Slough South watershed is single family residences. This is followed by civic land use, which includes the Austin State Supported Living Center (commonly known as the Austin State School), and a small portion of Texas State Guard Camp Mabry.

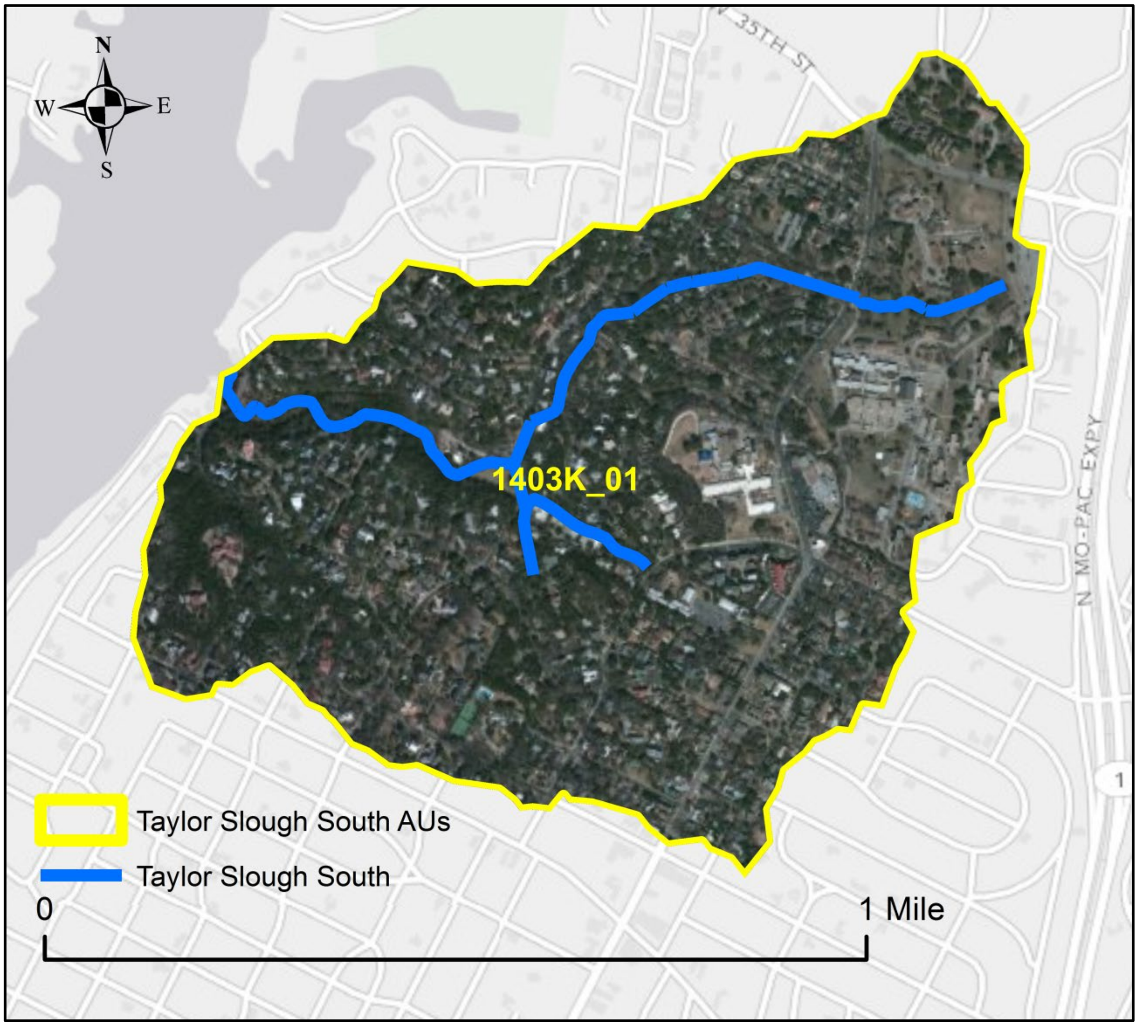

Figure 5. Map of the Taylor Slough South watershed 1403K

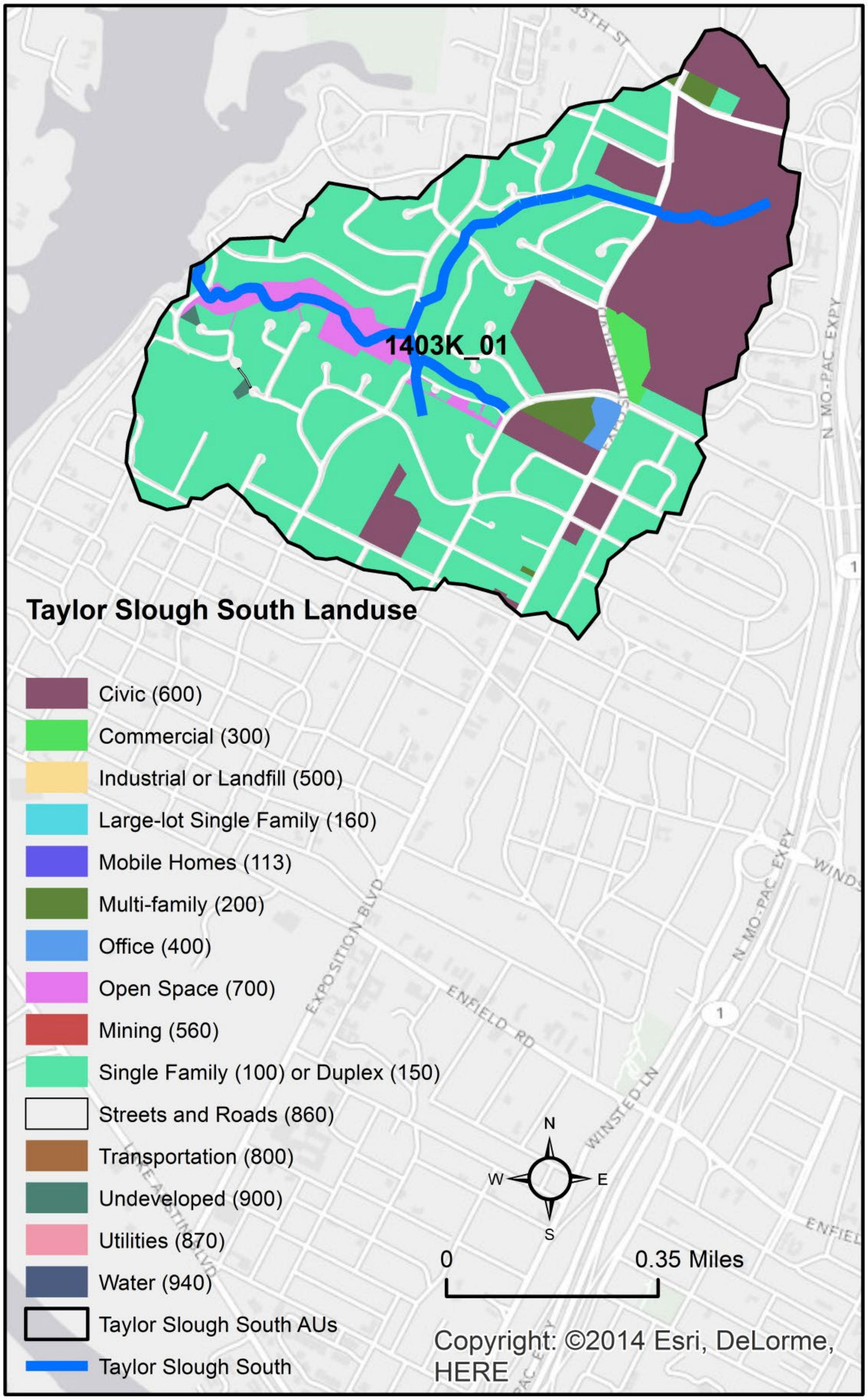

Figure 6. Land use map of the Taylor Slough South watershed 1403K

Table 10. Summary of land use in the Taylor Slough South watershed

Land Use	Area (sq. mi.)	Area (%)
Single Family or Duplex	0.363	56%
Civic	0.156	24%
Streets and Roads	0.092	14%
Open Space	0.021	3%
Commercial	0.007	1%
Multi-family	0.008	1%
Office	0.003	1%
Total	0.650	100%

Walnut Creek

Figure 7 is a photo of the Walnut Creek (1428B) watershed. It is both the largest and most diverse of the streams in this TMDL. The creek is 22.4miles long, with perennial flow. It has a 56.517 square-mile watershed almost entirely in the Austin full purpose, planning, or extraterritorial jurisdiction. It is almost entirely in Travis County, although there are very small portions in Williamson County.

The headwaters are located in ranchland on the Balcones Escarpment near the northwest city limits, where the creek flows southeast past the Austin White Lime mine and processing plant. After passing through several suburban areas, it enters the Blackland Prairie near MOPAC/Loop-1, and then slowly turns south to the Colorado River. It passes the Freescale Semiconductor facility, which discharges a small amount of bacteria free process water into it. Finally, Walnut Creek flows past the Walnut Creek WWTF near FM-969, but that facility does not discharge into it.

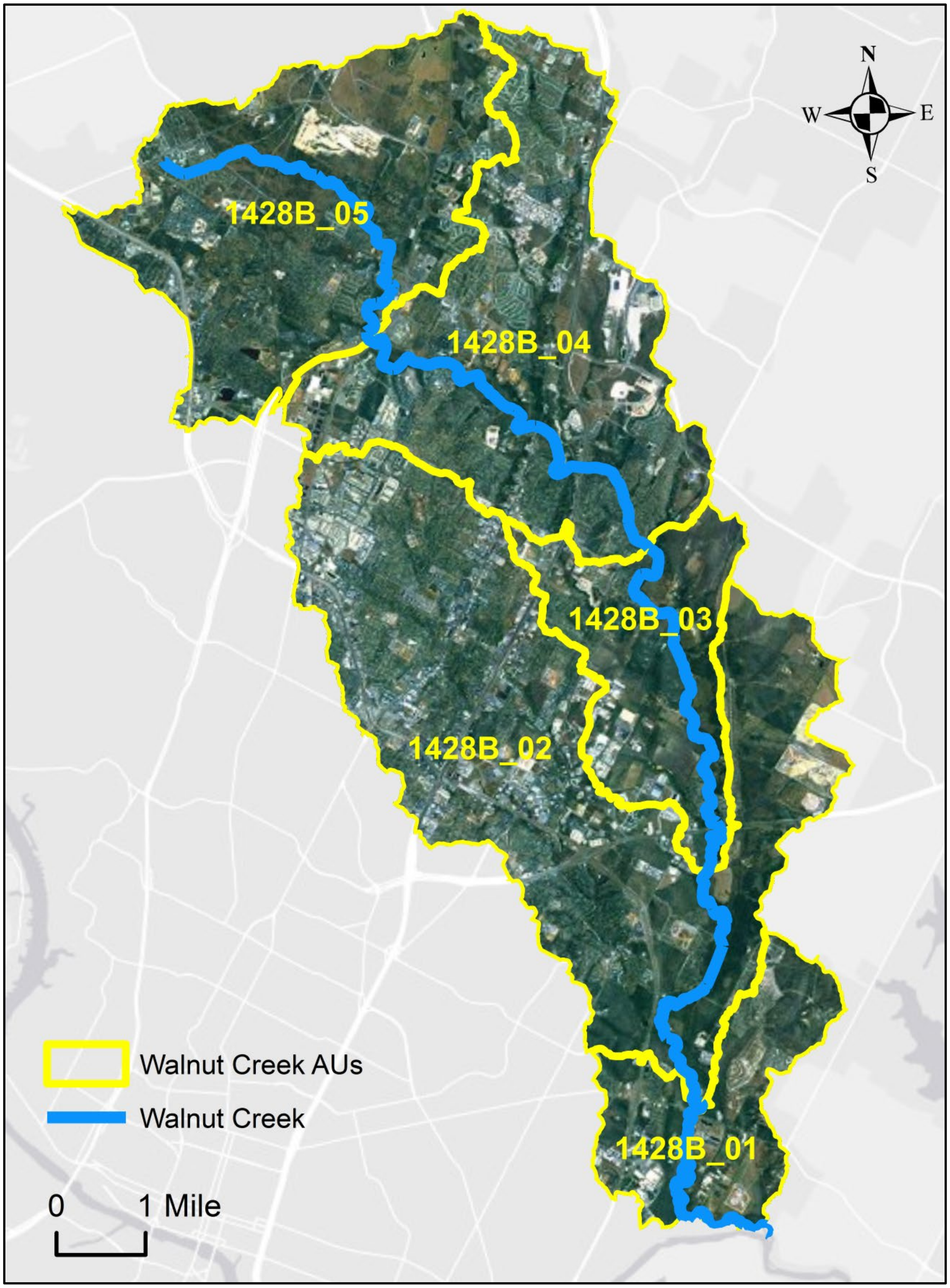

Figure 7. Map of the Walnut Creek watershed 1428B

As shown in Figure 8 and Table 11, the largest land uses in the Walnut Creek watershed are single-family residential and undeveloped land. As in other areas, streets and roads are a major road use. Land use in AU 1428B_05 includes the Austin White Lime mine; and land use in 1428B_02 includes portions of several large landfills near US-290.

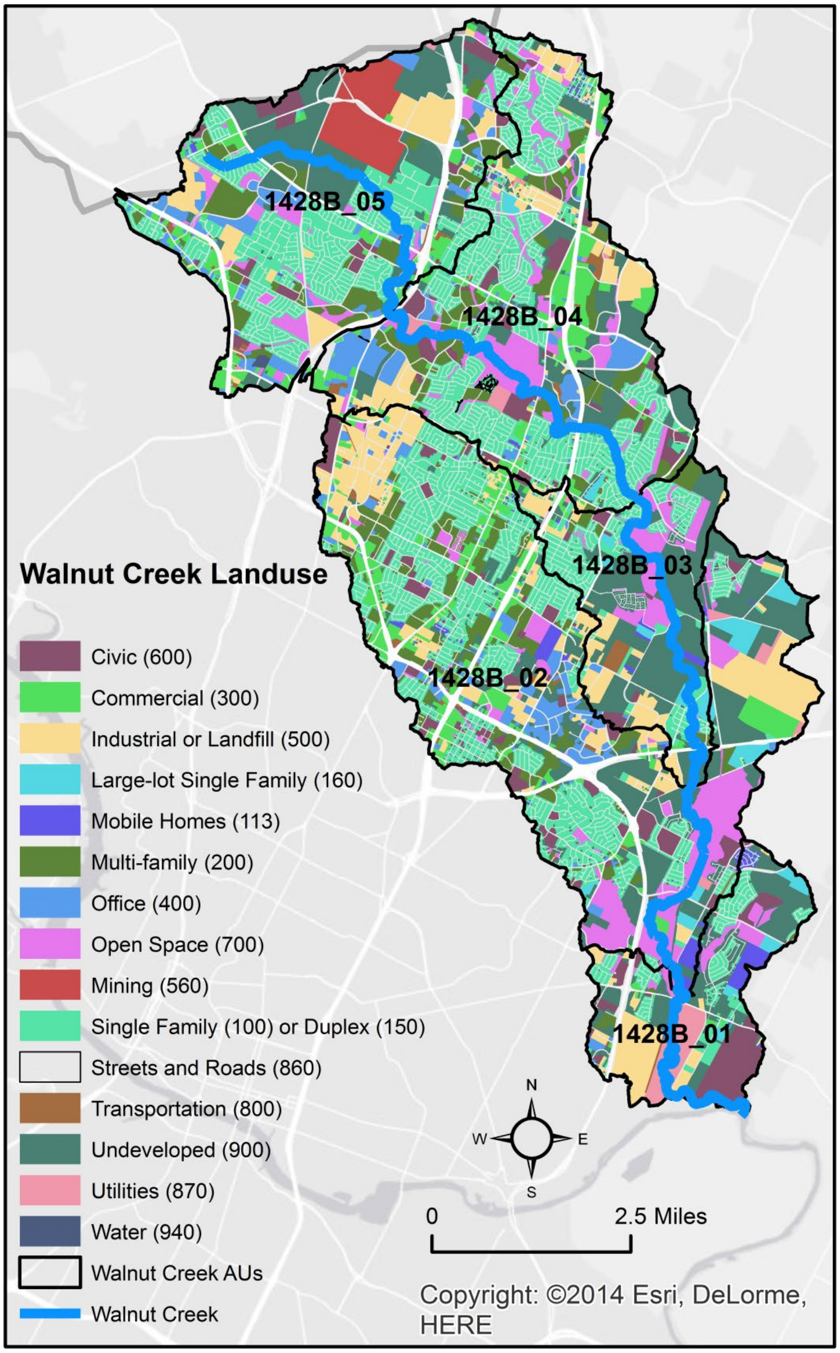

Figure 8. Land use map of the Walnut Creek watershed 1428B

Table 11. Summary of land use in the Walnut Creek watershed.

Land Use	Area (sq. mi.)	Area (%)
Single Family or Duplex	11.859	21%
Undeveloped	10.148	18%
Streets and Roads	8.470	15%
Open Space	4.830	9%
Industrial	4.539	8%
Multi-family	3.956	7%
Commercial	3.212	6%
Civic	2.895	5%
Office	2.446	4%
Mining	1.004	2%
Large-lot Single Family	0.803	1%
Utilities	0.725	1%
Landfill	0.697	1%
Mobile Homes	0.555	1%
Transportation	0.378	1%
Total	56.517	100%

Waller Creek

Figure 9 is a photo of the Waller Creek (1429C) watershed, which is about 5.67 square miles and is entirely within the Austin city limits. Waller Creek is a 6.7-mile long perennial stream. It begins in the north central residential area, runs through the University of Texas campus, and continues through downtown to the Colorado River. It is on the extreme eastern portion of the Edwards Plateau and the limestone bedrock is prone to flash flooding in the downtown area.

Construction of the Waller Creek Flood Control Tunnel and associated redevelopment will dramatically change the hydrodynamics of the lower portion of the creek. Under high flow conditions, stormwater will be diverted through the tunnel to bypass the lowest AU of Waller Creek and reduce flooding. Under low flow conditions, water from the Colorado River will be pumped upstream to supplement natural flow, which will reduce bacteria concentrations. Because these major hydrologic changes are already in progress, the lowest AU of Waller Creek (1429C_01) is not included in the TMDL.

Figure 9. Map of the Waller Creek watershed 1429C

As shown in Figure 10 and Table 12, the major land uses in the Waller Creek watershed are residential, and civic, which includes the UT campus, state offices, and parkland, followed by streets and roads.

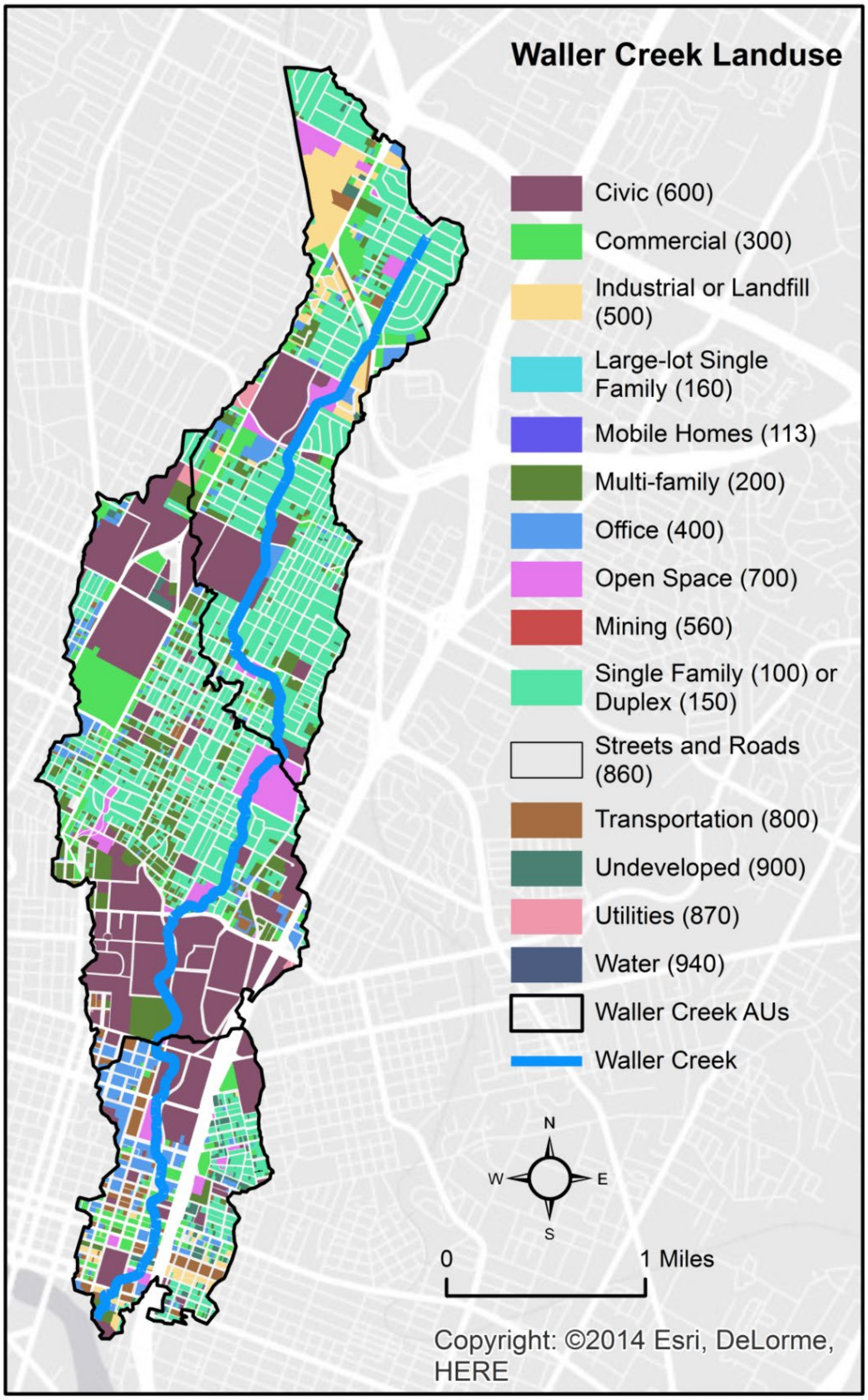

Figure 10. Land use map of in the Waller Creek watershed 1429C

Table 12. Summary of land use in the Waller Creek watershed

Land Use	Area (sq. mi.)	Area (%)
Single Family or Duplex	1.429	25%
Streets and Roads	1.356	24%
Civic	1.256	22%
Multi-family	0.375	7%
Commercial	0.369	7%
Office	0.245	4%
Open Space	0.236	4%
Industrial	0.176	3%
Transportation	0.121	2%
Undeveloped	0.064	1%
Utilities	0.021	1%
Total	5.648	100%

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 endpoints for the TMDLs in this report are to maintain concentrations of *E. coli* below the geometric mean criterion of 126 MPN/100 mL. This is the endpoint for all nine AUs addressed by this TMDL

Source Analysis

Pollutants may come from several sources, both regulated and unregulated. Regulated pollutants, referred to as “point sources,” come from a single definable point, such as a pipe, and are regulated by permit under the Texas Pollutant Discharge Elimination System (TPDES) permitting program. Wastewater treatment facility and stormwater discharges from industries, construction, and the separate storm sewer systems of cities are considered point sources of pollution.

Unregulated sources are typically nonpoint source in origin, meaning the pollutants originate from multiple locations and rainfall runoff washes them into to surface waters. Nonpoint sources are not regulated by permit.

With the exception of WWTFs, which receive individual WLAs (see the "Wasteload Allocation" section); the regulated and unregulated sources in this section are presented to give a general account of the different sources of bacteria expected in the watershed. Because these are only estimates, they are not meant to be used for allocating bacteria loads or interpreted as precise inventories and loadings.

Regulated Sources

Permitted sources are regulated under the TPDES and the National Polluant Discharge Elimination System (NPDES) programs. The regulated sources in the four Austin streams watersheds include WWTF outfalls and stormwater discharges from industries, construction, and municipal separate storm sewer system (MS4s).

Domestic and Industrial Wastewater Treatment Facilities

As shown in Figure 11, the Freescale Semiconductor plant on Ed Bluestein Boulevard discharges bacteria-free industrial process water into Walnut Creek (1428B_01). The Freescale plant is the only regulated industrial facility that discharges into any of the four streams

The Walnut Creek WWTF, operated by the City of Austin, discharges its effluent directly into the Colorado River instead of Walnut Creek. The City of Austin has indicated it does not intend to build any facility that discharges bacteria into these four streams in the future (City of Austin, 2014).

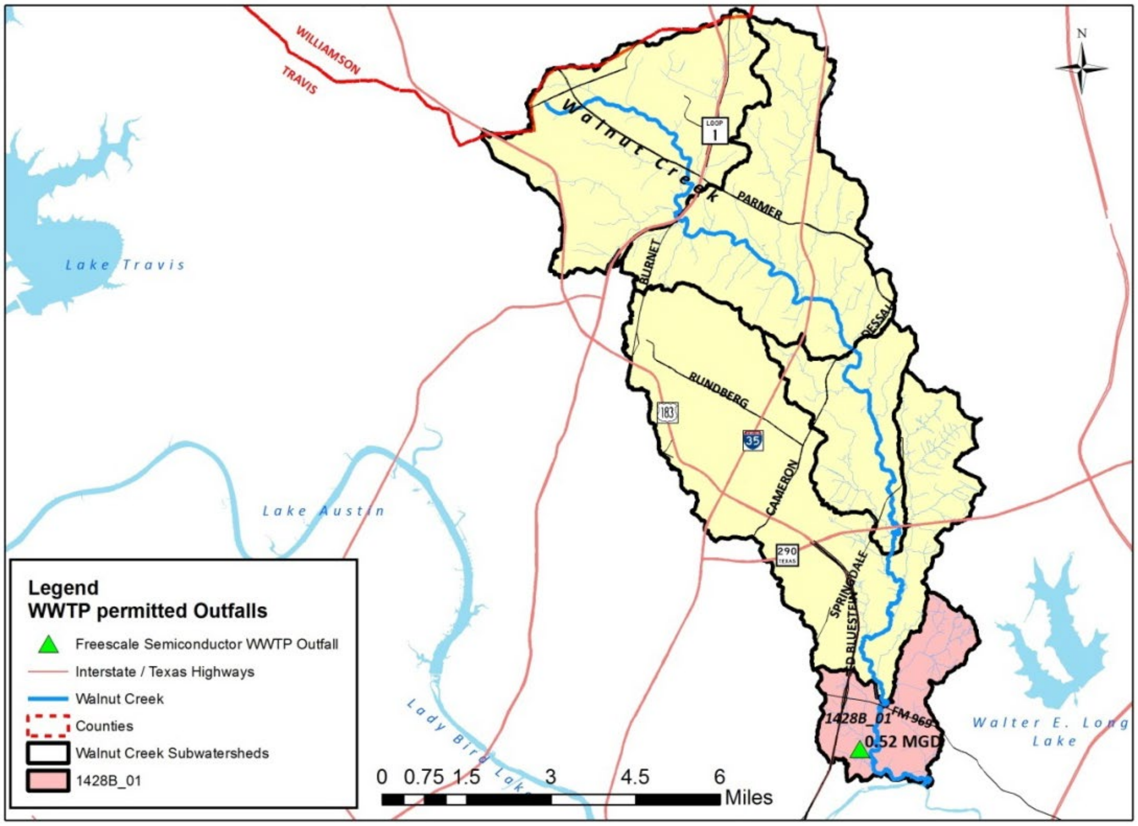

Figure 11. TPDES permitted outfall locations in the Walnut Creek watershed

The permitted discharge limits for each facility are provided in Table 13.

Table 13. Regulated discharge facilities

Segment Name	AU	TPDES Number	NPDES Number	Facility Name	Type	Permitted Flow (MGD) [a]
Walnut Creek	1428B_01	02876-000	TX0101702	Freescale Semiconductor	Industrial Wastewater	0.52

[a] MGD denotes million gallons per day

Sanitary Sewer Overflows

SSOs are unauthorized discharges that must be addressed by the responsible party, which is 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 lines caused by tree roots, grease, and other debris. Inflow and infiltration (I/I) of stormwater through leaky sewer collection lines are typical causes of SSOs under conditions of high flow. Blockages in lines may exacerbate the I/I problem. Other causes, such as a collapsed sewer lines, may occur under any conditions.

The City of Austin maintains databases of reported SSO events, the locations of which are shown in Figure 12. Information on SSO events is provided in Table 14 (City of Austin, 2013). While some SSOs are only a few thousand gallons, others are quite large; with the largest single event being 294,000 gallons.

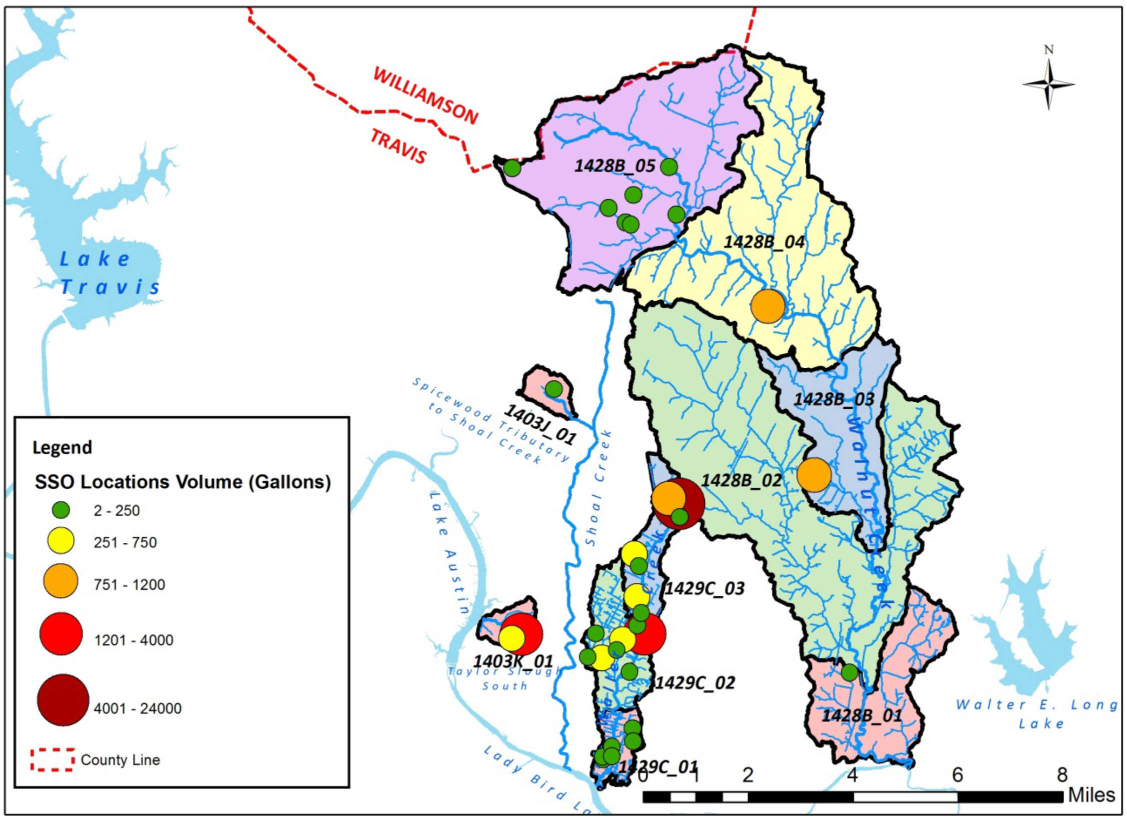

Figure 12. Average sanitary sewer overflows June 1998 – December 2012

Table 14. Summary of sanitary sewer overflows in the Austin-area TMDL watersheds

June 1998 – December 2011. Estimated volumes in gallons, provided by the City of Austin.

AU	Count	Total (gallons)	Maximum (gallons)	Average (gallons)
1403J_01	2	40,040	40,000	20,020
1403K_01	2	4,500	4,000	2,250
1428B_01	8	382,500	294,000	47,813
1428B_02	5	17,600	10,000	3,520
1428B_03	1	1,000	1,000	1,000
1428B_04	11	51,550	25,000	4,686
1428B_05	11	273,797	250,000	22,816
1429C_02	15	39,920	18,000	2,348
1429C_03	19	307,820	190,000	15,391
Total	74	1,118,727	NA	NA
Maximum	19	NA	294,000	NA
Average	8	NA	NA	13,316

TPDES-Regulated Stormwater

When evaluating stormwater for a TMDL allocation, a distinction must be made between stormwater originating from an area under a TPDES or NPDES-regulated discharge permit and stormwater originating from areas that are not regulated.

Stormwater discharges fall into two categories:

§ Stormwater subject to regulation
- Stormwater originating from a TPDES-regulated MS4 system
- Industrial facilities covered under the TPDES Multi-Sector Industrial General Permit for Stormwater
- Regulated construction activities covered under the TPDES Construction General Permit.

§ Direct stormwater runoff, which is not subject to regulation.

- This includes all stormwater that enters the water body without passing through an MS4 system.

The TPDES/NPDES MS4 Phase I and II rules require municipalities and certain other entities in urban areas to obtain permits for their stormwater systems. Both the Phase I and II permits include any conveyance such as ditches, curbs, gutters, and storm sewers that do not connect to a wastewater collection system or treatment facility. Phase I permits are individual permits for large and medium sized communities with populations exceeding 100,000, whereas Phase II permits are usually for smaller communities within an EPA-defined urbanized area that are regulated by a general permit. EPA has designated Travis County as an urbanized county, and requires it to have a Phase II permit (TXR040000). The purpose of an MS4 permit is to reduce discharges of pollutants in stormwater to the “maximum extent practicable” by developing and implementing a Stormwater Management Program (SWMP).

The geographic region of the TMDL watersheds covered by Phase I and II MS4 permits is determined by the jurisdiction of the regulated entity. For Phase I permits, the geographic region of the permit is defined as the jurisdiction of the permittee. For city Phase II permits, the geographic region is defined as the intersection or overlapping areas of the city limits and the 2010 Census Urbanized Area (U.S. Census Bureau, 2010).

The TMDL watersheds contain entities that are regulated under either Phase I individual MS4 permits or Phase II general permits (Table 15). These include Travis County, the City of Austin, the University of Texas, and the Texas Department of Transportation. Each of these Phase I and Phase II permits covers a portion of the watershed, and the Travis County permit covers the remainder of the county. Since these watersheds are almost entirely within Travis County, all of them are covered by a TPDES / NPDES MS4 Phase I or Phase II permit.

Illicit Discharges

Pollutant loads can enter streams from MS4 outfalls that carry authorized sources as well as illicit discharges under both dry and wet weather conditions. The term “illicit discharge” is defined in TPDES General Permit No. TXR040000 for Phase II MS4s 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 are identified in the *Illicit Discharge Detection and Elimination Manual: A Handbook for Municipalities* (NEIWPCC, 2003).

Table 15. TPDES MS4 permits associated with the TMDL watersheds

(Compiled July 2013)

Entity	MS4 Permit Type	TPDES	NPDES
Travis County	Phase II	TXR040000	TXR040327
City of Austin	Phase I	WQ0004705-000	TXS000401
The University of Texas	Phase I	WQ0004704-000	TXS000403
Texas Department of Transportation	Phase I	WQ0004645-000	TXS000402
Texas Department of Transportation	Phase I	WQ0005011-000	TXS002101

Examples of Direct illicit discharges

§ Sanitary wastewater piping that is directly connected from a home to the storm sewer;

§ Materials that have been dumped illegally into a storm drain catch basin;

§ A floor drain that is connected to the storm sewer; and

§ A cross-connection between the sanitary sewer and storm sewer systems.

Examples of Indirect illicit discharges

§ A 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.

Unregulated Sources

Unregulated sources of bacteria are generally nonpoint. Nonpoint source (NPS) loading enters the impaired segment from distributed, nonspecific locations, which may include urban runoff not covered by a permit, wildlife, various agricultural activities and agricultural animals, land application fields, failing on-site sewage facilities (OSSFs), unmanaged animals, and domestic pets.

Managed and Unmanaged Animals

E. coli bacteria are common inhabitants of the intestines of all warm blooded animals, including wildlife such as mammals and birds. In developing bacteria

TMDLs, it is important to identify by watershed the potential for bacteria contributions from wildlife.

Wildlife is naturally attracted to riparian corridors of streams and rivers. With direct access to the stream channel, the direct deposition of wildlife waste can be a concentrated source of bacteria loading to a water body. Fecal bacteria from wildlife are also deposited onto land surfaces, where they may be washed into nearby streams by rainfall runoff. The estimated cattle and wildlife populations in each of the watersheds are shown in Table 16.

The cattle population of the Walnut Creek watershed is estimated from analysis of the National Agricultural Statistics Service (NASS, 2013) Travis County cattle census and land use. Assuming most cattle ranching occurs on land use category "undeveloped", gives an average Travis County operation of 35 head on 500 acres, with a density of 13 acres per head. The smallest viable cattle operation is assumed to be only 50 acres. However, there are only a few tracts of undeveloped land this large in the Walnut Creek watershed, and none in the other watersheds. The resulting estimate is 120 head for the Walnut Creek watershed, but drought, economic conditions, and urban expansion may have reduced this by an unknown amount.

The deer density is obtained using the Travis County 1976-2002 deer census by the Texas Parks and Wildlife Department (TPWD, 2013), extrapolated to 2012. This gives a density of 29 animals per square mile, which is approximately 22 acres per animal. Although this suggests 22 acres is the smallest viable habitat, small tracts of undeveloped land are frequently adjacent, so all tracts of undeveloped land greater than 1 acre are assumed to be habitat. This yields an estimate of 208 deer in the Walnut Creek watershed. The other watersheds are highly developed, and have very few undeveloped tracts this large.

While transient urban deer may graze in small tracts of developed land, it is debatable whether or not they actually reside there. Anecdotal evidence suggests that many urban deer problems are the result of transient deer living in large undeveloped tracts, but occasionally grazing in small adjacent tracts of developed land.

The feral hog population is obtained using the high estimate of the Texas A&M University (TAMU, 2012) statewide feral hog density of 8.9-16.4 per square mile, which is approximately 39 acres per animal. This hog density is applied to tracts of undeveloped land greater than 100 acres, giving 10 animals in the Walnut Creek watershed. The other watersheds are highly developed, and do not have undeveloped tracts of land this large.

Table 16. Estimated managed and unmanaged animal population

Segment	Watershed	Undeveloped >1 acre	Undeveloped >50 acres	Undeveloped >100 acres	Cattle	Deer	Feral Hogs
1403J	Spicewood	2	0	0	0	0	0
1403K	Taylor Slough South	0	0	0	0	0	0
1428B	Walnut	4,573	1,560	393	120	208	10
1429C	Waller	9	0	0	0	0	0

Pets can also be sources of *E. coli* bacteria, because storm runoff carries dry-land deposits of animal wastes into streams. The number of domestic pets in the four Austin streams watersheds is estimated based on human population and number of households, which were obtained from the U.S. Census Bureau (U.S. Census Bureau, 2010). The 2010 census tract data is multiplied by the proportion of each census tract within the watershed, yielding an estimate of each watershed's human population and number of households. This estimation assumes that the population and households are uniformly distributed within the area of each census tract. It is the best estimate that can be made with the available data.

The estimated number of dogs and cats for each segment of the watershed with elevated bacteria levels is summarized in Table 17. Pet population estimates are calculated as the estimated number of dogs (0.632) and cats (0.713) per household (AVMA, 2009).

Table 17. Estimated households and pet populations within TMDL watersheds

AU	Estimated Number of Households	Estimated Dog Population	Estimated Cat Population
1403J_01	1,129	714	805
1403K_01	769	486	548
1428B_01	2,129	1,346	1,518
1428B_02	28,887	18,257	20,596
1428B_03	4,406	2,785	3,141
1428B_04	21,314	13,470	15,197
1428B_05	17,429	11,015	12,427
1429C_02	8,042	5,083	5,734
1429C_03	6,151	3,887	4,386

Failing On-site Sewage Facilities

Except for Walnut Creek, failing OSSFs are not considered a major source of bacteria loading, because these streams are in areas served by centralized wastewater collection and treatment systems. However, data from the City of Austin, shown in Figure 13 and Table 18, indicates that some older neighborhoods in Walnut Creek AUs 1428B_02, 1428B_03, 1428B_04, and 1428B_05, were once served primarily by OSSFs, and many of these continue to be in service.

Age is the most reliable indication of probability of OSSF failure, but the failure itself can be caused by many factors. Common failure factors are under-sizing of the system, particularly if the load has increased; installation problems; wrong type of system for the soil type; and inadequate maintenance, including failure to pump out in a timely manner.

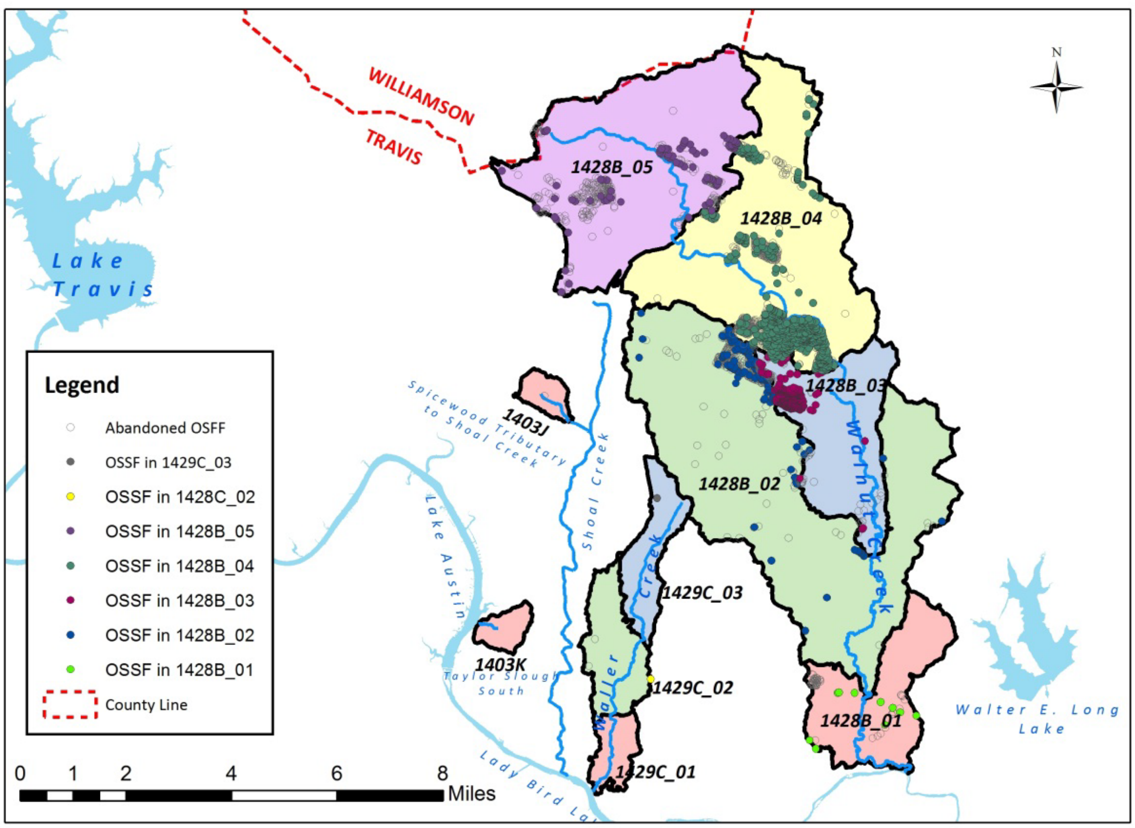

Figure 13. OSSFs in the four Austin streams watershed

Table 18. Estimated number of failing OSSFs in the four Austin streams watersheds

Segment Name	Assessment Unit	Number of OSSFs	Abandoned	In Service	Estimated Number of Failing OSSFs
Spicewood Tributary to Shoal Creek	1403J	1	1	0	0
Taylor Slough South	1403K	0	0	0	0
Waller Creek	1429C_01	0	0	0	0
	1429C_02	3	2	1	0
	1429C_03	1	0	1	0
	Total	4	2	2	0
Walnut Creek	1428B_01	59	49	10	1
	1428B_02	500	364	136	16
	1428B_03	344	95	249	30
	1428B_04	1,313	885	428	51
	1428B_05	386	305	81	10
	Total	2,602	1,698	904	108

Bacteria Re-growth and Die-off

Bacteria are living organisms that survive and die. Certain intestinal bacteria can survive and replicate in organic materials if appropriate conditions prevail (such as warm temperature). Fecal organisms can survive and replicate from improperly treated effluent during their transport in pipe networks, and they can survive and replicate in organically 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 in natural waters is less well understood. Both replication and die-off are instream processes and are not considered in the bacteria source loading estimates for the TMDLs in this report.

Linkage Analysis

Flow Duration Curve Analysis

Instream water quality, and the TMDL required to maintain it, is dependent on the flow, because the amount of flow determines the assimilative capacity of the water body. The bacteria criterion for evaluating the contact recreation use is a concentration—the number of bacteria per volume of water. While the load is the number of bacteria discharged in a given time period, the flow determines the volume of water into which the bacteria are distributed.

In a flow duration curve (FDC), historic flow data is related to the percent of time that specific flow values have been exceeded. Flow exceedance values are plotted along the x-axis and represent the percent of days that flow was at or above the associated flow value on the y-axis. Exceedance values near 100% occur during low flow or drought conditions while values approaching 0% occur during periods of very high flow or flood conditions. In the case of intermittent flow streams, the flow may be zero for a large range of exceedances.

Because bacteria loads carried by stormwater are highest at very high flow, it is the critical flow condition used to determine the TMDL.

For these TMDLs, the City of Austin used the Soil and Water Assessment Tool (SWAT) hydrodynamic model to estimate the daily flow at the outlet of each AU. That estimate was then used to plot the FDCs. For Walnut Creek AU 1428B_01, the hydrologic records from the SWAT model were adjusted to reflect full permitted flows from the Freescale plant, which is the only WWTF in the four watersheds (Table 13).

In order to systematically develop the TMDL allocation for each TMDL watershed, an inlet/outlet approach was used with the FDCs. Under this approach, each TMDL watershed has an outlet point located at the most downstream end of the water body within the watershed. It is at this outlet location that the TMDL allocation is defined through the FDC.

The FDC method allows for estimation of existing and TMDL loads by utilizing the cumulative frequency distribution of stream flow. This method allows for the determination of the hydrologic conditions and provides a means to allocate allowable loadings.

Data requirements for the FDC were minimal, consisting only of continuous daily stream flow records. The curves were based on all available data to encompass inter-annual and seasonal variation.

The flow exceedance frequency was subdivided into hydrologic condition classes to facilitate the diagnostic and analytical uses of FDCs and LDCs. The hydrologic classification scheme utilized for these Austin streams TMDLs was:

- Very high flow (0 – 10%)
- High flow (10 – 50%)
- Low flow (50 – 100%)

These three flow regimes were based on hydrology (slope of the FDCs).

The median loading of the critical very-high flow regime (0-10% exceedance) was used for the TMDL calculations of the impaired AUs in the Austin streams watersheds, because the source loads are the highest under these flow conditions.

Each FDC was generated by:

1) Ranking the daily flow data from highest to lowest,
2) Calculating the percent of days each flow was exceeded (rank ÷ quantity of the number of data points + 1), and
3) Plotting each flow value (y-axis) against its exceedance value (x-axis).
4) For streams with multiple AUs, they were plotted on a single chart.

Flow duration curves for the nine TCEQ monitoring stations in the impaired watersheds are presented in Figures 14 through 17.

As shown in Figure 14, Spicewood Tributary to Shoal Creek (1403J) is a small stream with intermittent flow. Since it flows only 38% of the time, the FDC ends at 38% exceedance. As shown previously in Figure 2, it is the headwater of a small tributary of Shoal Creek, and its overall flow varies from 0 to 78 cubic feet per second (cfs). Under the very high flow regime, it varies from one to 78 cfs. The critical flow is 3.87 cfs, which is approximately 25 gallons per second.

The FDC for each of the remaining streams is shown in Figures 15 through 17, and the critical flows are summarized in Tables 19 and 20. Taylor Slough South (1403K) is an even smaller stream with a critical flow of only 3.22 cfs (Figure 15). But it has perennial flow, so the flow curve extends to 100%.

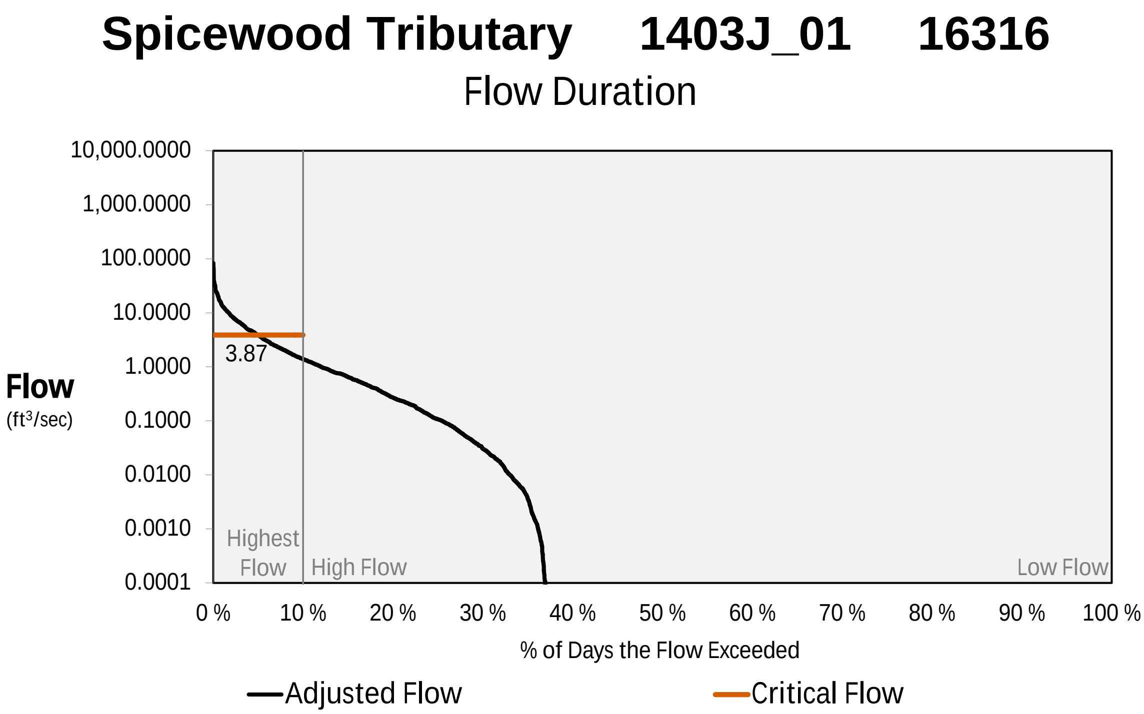

Figure 14. Flow Duration Curve for Segment 1403J, Spicewood Tributary to Shoal Creek

Waller Creek (1429C) has two AUs in this TMDL, which are shown on the same FDC (Figure 16). The upper AU (1429C_03) is intermittent flow, ending at 58%, with a critical flow of 11.97 cfs. The middle AU (1429C_02) is perennial flow with a critical flow of 29.29 cfs. The lowest AU (1429C_01) is not considered in the TMDL because the Waller Creek Tunnel project will change its hydrology.

Walnut Creek (1428B) has five AUs, all with perennial flow. Critical flows range from 24.30 cfs near the headwaters, to 91.92 cfs at its confluence with the Colorado River (Figure 17).

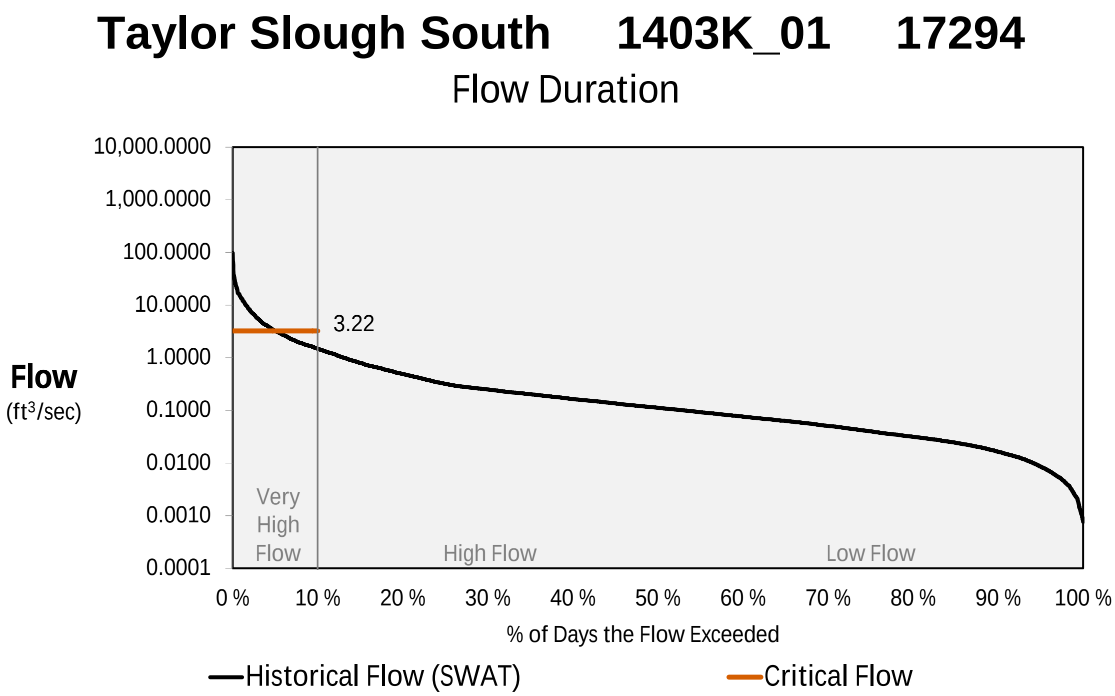

Figure 15. Flow Duration Curve for Segment 1403K, Taylor Slough South

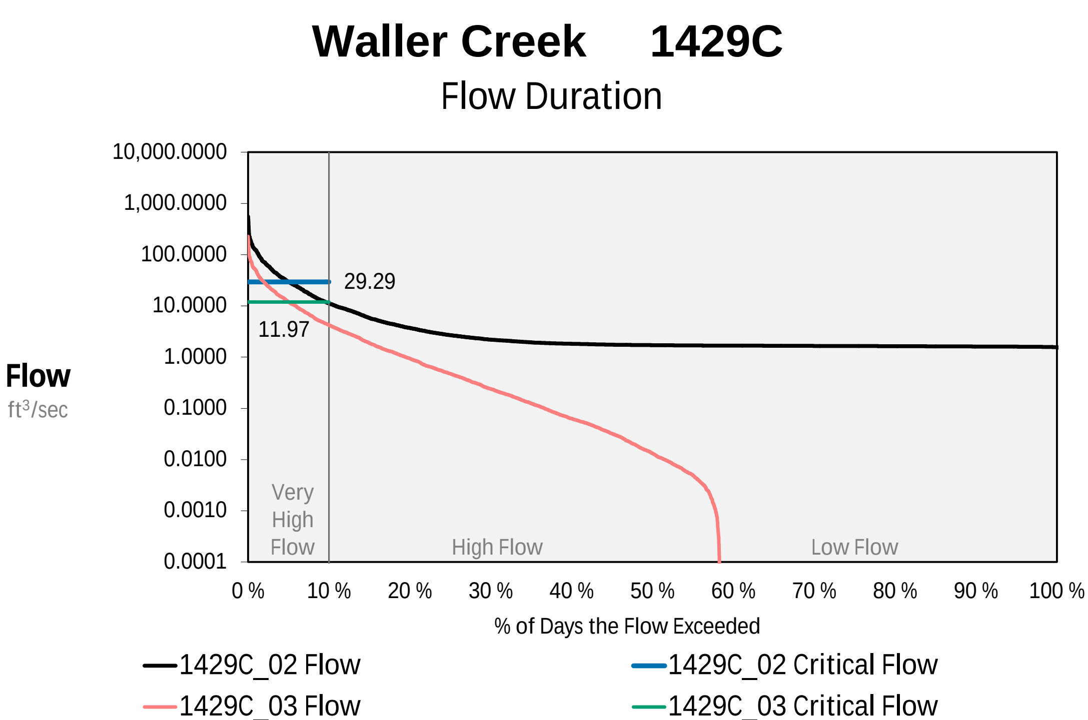

Figure 16. Flow Duration Curves for Segment 1429C, Waller Creek

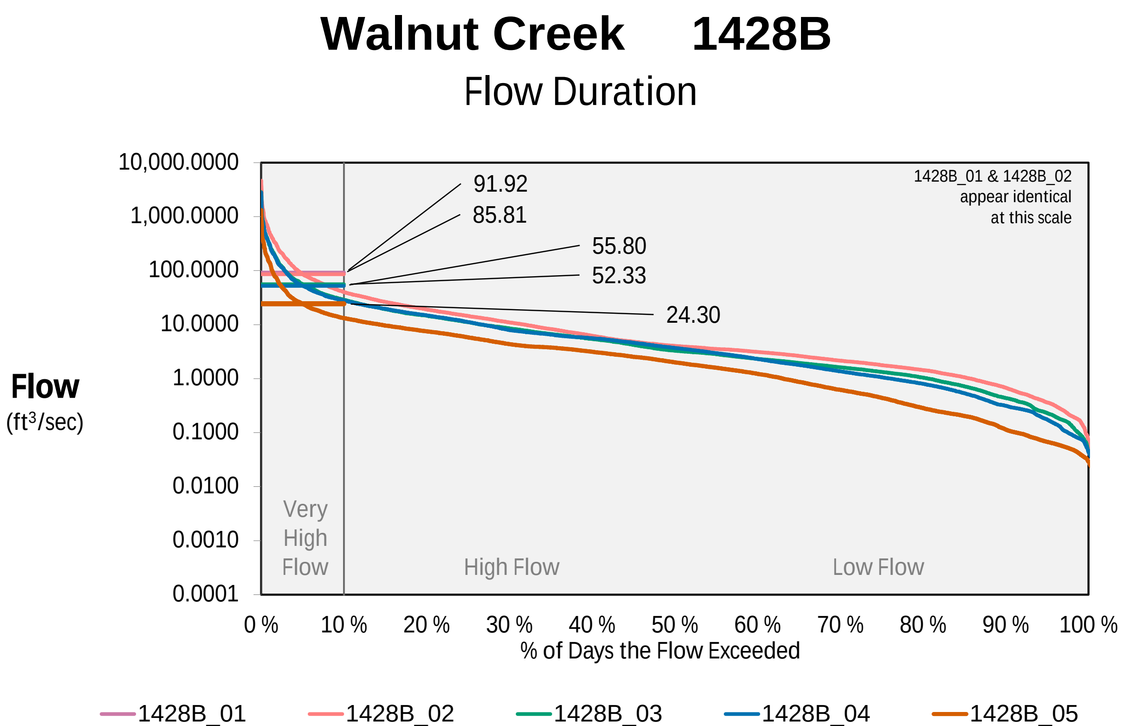

Figure 17. Flow Duration Curves for Segment 1428B, Walnut Creek

Table 19. Critical flows by AU for non-supporting water bodies

Stream	AU	Inlet Critical Flow [a] (cfs)	Outlet Critical Flow [a] (cfs)
Spicewood Tributary to Shoal Creek	1403J_01	0.00 [b]	3.87
Taylor Slough South	1403K_01	0.00 [b]	3.22
Walnut Creek	1428B_05	0.00 [b]	24.30
Waller Creek	1428C_02	11.97	29.29
Waller Creek	1428C_03	0.00 [b]	11.97

[a] From Flow Duration Curves

[b] Headwaters have Inlet Flow of zero

Table 20. Critical flows by AU for water bodies with concerns for use

Stream	AU	Inlet Critical Flow [a] (cfs)	Outlet Critical Flow [a] (cfs)
Walnut Creek	1428B_01	85.81	91.92
Walnut Creek	1428B_02	55.80	85.81
Walnut Creek	1428B_03	52.33	55.80
Walnut Creek	1428B_04	24.30	52.33

[a] From Flow Duration Curves

Load Duration Curve 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.

LDCs were used to examine the relationship between instream water quality and broad classes of sources. LDCs are a simple statistical method that provides a basic description of the water quality problem. The allowed load is estimated solely from flow data, and then compared to the available water quality data to give broad indications of the source types.

The LDC method allows for estimation of the TMDL by utilizing the cumulative frequency distribution of stream flow (Cleland, 2003). In addition to estimating stream capacity, this method allows for the determination of the hydrologic conditions (e.g. high or low flow) under which impairments are typically occurring and can give broad indications of the origins of the bacteria (e.g. continuous sources versus stormwater runoff).

Continuous sources are usually point sources, illicit discharges, and other sources that may arise under non-runoff conditions. These sources usually dominate low flow conditions, and may cause an impairment under those conditions. However at higher flow, the load capacity of the stream may increase sufficiently to rectify the impairment.

Bacteria load contributions from non-regulated stormwater sources are greatest during runoff events. Rainfall runoff, depending upon the severity of the storm, has the capacity to carry bacteria from the land surface into the receiving stream, and also increases the likelihood of SSO's because of I/I into the sanitary sewer system.

Stormwater loading follows a pattern of low concentrations in the water body prior to the rain event, followed by a rapid increase in bacteria concentrations in the water body as the first flush of storm runoff carries accumulated bacterial waste into the receiving stream. Over time, the bacteria concentrations are attenuated as runoff washes the land surface clean.

The strength of the LDC tool is that it is easily developed and explained to stakeholders. Because it only uses flow and available water quality data, the LDC method does not require any assumptions regarding loading rates, stream hydrology, land use conditions, or other conditions in the watershed. The weakness of the LDC method is the limited information it provides regarding the magnitude or specific origin of the various sources.

Data requirements for the LDC are minimal, consisting of the FDCs and historical bacteria data for the AUs. The SWQMIS data collected during the 2010 assessment period, which is analyzed in the *2012 Texas Integrated Report*, were the source of the flow and bacteria values used.

LDCs were developed by multiplying the stream flows from the FDCs by the *E. coli* criterion (126 MPN/100 mL). The resulting values were then multiplied by a conversion factor to convert the loading to colonies per day. This effectively displays the LDC as the TMDL curve of maximum allowable loading:

Allowable Load (MPN/day) = Flow (cfs) × *E. coli* Criterion × Conversion factor

Where:

Criterion = 126 (MPN/100mL)

Conversion factor [a] = 24,465,755 (100mL/ft^3) × (sec/day)

Historical bacteria loads from the TCEQ SWQMIS database were superimposed on the allowable bacteria LDC. This was accomplished by multiplying each observed concentration by the stream flow on that day to convert that bacteria concentration to a bacteria load. Each load was then plotted on the LDC at the flow percent exceedance on the day the load was measured. Points above the LDC represent exceedances of the bacteria criterion and its associated allowable loadings.

At low to median flows, the main contributing sources are continuous discharges. They are likely to be continuous point sources, such as malfunctioning or poorly

[a] Conversion factor = 283.16846592 (100mL/ft^3) × 86,400 (sec/day) = 24,465,755 (100mL/ft^3) × (sec/day)

maintained WWTFs, failing OSSFs, or illicit discharges into MS4s. These are constant loads that depend on the magnitude of the sources, but not the flow rate in the receiving water.

At median to high flows, moderate runoff has the capacity to carry bacteria from the land surface into the receiving stream. The bacteria load contributions in runoff include low flow sources, plus those that originate from storm water runoff. These additional loads include SSO and contributions caused by increased inflow and infiltration into the sanitary sewer system. A complete set of LDCs for all AUs is presented in Appendix A, Figures A-1 through A-9.

Margin of Safety

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

a) Implicitly incorporating the MOS using conservative model assumptions to develop allocations; or

b) 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 an MOS.

The TMDLs covered by this report incorporate a five percent explicit MOS by including it in the TMDL calculations, as shown in the Pollutant Load Allocation section below. The net effect is to reduce the TMDL and the assimilative capacity or allowable pollutant loading of each water body by five percent, as shown in Tables 23 and 24.

Pollutant Load Allocation

The TMDL represents the maximum amount of a pollutant that the stream can receive in a single day without exceeding water quality standards. The daily pollutant load allocations (LAs) were developed for the five AUs that are on the 2012 Texas 303(d) list of impaired water bodies. In addition, TMDL allocations were developed for the four AUs with concerns for use, as requested by the City of Austin.

The TMDL allocations for the nine AUs were calculated using the following equation:

$$TMDL = \Sigma WLA + \Sigma LA + \Sigma FG + MOS$$

Where:

WLA (wasteload allocation) = the amount of pollutant allowed by regulated discharges per day

LA (load allocation) = the amount of pollutant allowed by unregulated sources per day

FG (future growth) = loadings associated with future growth from potential regulated facilities

MOS = margin of safety load

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 load the stream can assimilate in a single, average day while still attaining the standards for surface water quality.

The bacteria TMDLs for the AUs covered in this report were derived using the median of the very high flow regime of the LDC developed for the outlet of each AU.

Wasteload Allocation

The WLA is the sum of loads from regulated sources.

WWTFs

No TPDES-regulated WWTFs discharge bacteria waste into any of the watersheds and the City of Austin does not plan any additional WWTFs in the future. Currently, there are two WWTFs within the TMDL watersheds, but their discharges do not affect the TMDLs. The Walnut Creek WWTF (TCEQ Permit R11-10543011) is located at the confluence of Walnut Creek with the Colorado River. While the plant is named after Walnut Creek, its discharge is piped directly into the nearby Colorado River. Freescale Semiconductor plant (TCEQ Permit R11-02876) discharges only bacteria-free process water into Walnut Creek. Because of this, the WLA for WWTF discharges in the TMDL watersheds is zero.

Stormwater

Stormwater discharges from MS4, industrial, and construction areas are considered regulated point sources. Therefore, the WLA calculations must also include an allocation for regulated stormwater discharges (WLA_{SW}). A simplified approach for estimating the WLA for these areas was used in the development of these TMDLs because of the limited amount of data available, the complexities associated with simulating rainfall runoff, the interconnected and overlapping nature of permitted stormwater, and the variability of stormwater loading.

The percentage of each watershed that is under the jurisdiction of stormwater permits (i.e., the area designated as urbanized in the 2010 US Census) is used to estimate the amount of the overall runoff load. That load is allocated as the regulated 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}.

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

$$\Sigma WLA_{SW} = (TMDL - \Sigma WLA_{WWTF} - LA_{USL} - \Sigma FG - MOS) \times FDA_{SWP}$$

Where:

ΣWLA_{SW} = sum of all regulated stormwater loads (municipal, industrial, construction)

TMDL = total maximum daily load

ΣWLA_{WWTF} = sum of all WWTF loads

LA_{USL} = sum of loading from tributary and upstream AUs

ΣFG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

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

In urbanized areas currently regulated by an MS4 permit, development or re-development of land in the urbanized area requires implementation of control measures and/or programs outlined in an approved SWMP. Although additional flow may occur from development or re-development, loading of the pollutant of concern should be controlled and/or reduced through the implementation of best management practices (BMPs) specified in both the permit and the SWMP.

An iterative, adaptive management approach will be used to address stormwater discharges. This approach encourages the implementation of structural or non-structural controls, implementation of mechanisms to evaluate the performance of the controls, and finally, allowance to make adjustments (e.g., more stringent controls or specific BMPs) as necessary to protect water quality.

Load Allocation

The LA is the sum of loads from unregulated sources. The LA is the sum of the bacteria load that arises from unregulated sources within the AU (LA_{AU}) and upstream loadings from a tributary or upstream AU that enters into an AU (LA_{USL}):

$$LA = LA_{AU} + \Sigma LA_{USL}$$

Where:

LA = allowable load from unregulated sources (predominantly nonpoint sources)

ΣLA_{USL} = sum of loading from tributary and upstream AUs

LA_{AU} = allowable loads from unregulated sources within the AU

The LA_{USL} is calculated as:

$$LA_{USL} = \text{Criterion} \times Q_{Inlet} \times \text{conversion factor}$$

Where:

Criterion = 126 MPN/100 mL

Q_{Inlet} = median value of the very high flow regime at the tributary or upstream AU outlet(s) to an impaired AU.

Conversion factor (to MPN/day) = 24,465,755 (100mL/ft^3) × (sec/day)

The unregulated loading within the AU (LA_{AU}) is calculated as:

$$LA_{AU} = TMDL - \Sigma WLA_{WWTF} - \Sigma WLA_{SW} - \Sigma LA_{USL} - \Sigma FG - MOS$$

Where:

LA_{AU} = allowable loads from unregulated sources within the AU

$TMDL$ = total maximum daily load

ΣWLA_{WWTF} = sum of all WWTF loads

ΣWLA_{SW} = sum of all regulated stormwater loads (municipal, industrial, construction)

ΣLA_{USL} = sum of loading from tributary and upstream AUs

ΣFG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

The TMDL equation can thus be expanded to show the components of WLA and LA:

$$TMDL = \Sigma WLA_{WWTF} + \Sigma WLA_{SW} + LA_{AU} + LA_{USL} + \Sigma FG + MOS$$

Margin of Safety Equation

The MOS is only applied to the allowable loading for an AU and is not applied to the LA_{USL} that enters the segment as an external loading (i.e., originates outside the segment). Therefore, the MOS is expressed mathematically as the following:

$$MOS = 5\% \times (TMDL - \Sigma LA_{USL})$$

Where:

MOS = margin of safety load

TMDL = total maximum allowable load

ΣLA_{USL} = sum of loading from tributary and upstream AUs

Allowance for Future Growth

The future growth component of the TMDL equation addresses the requirement to account for future loadings that may occur due to population growth, changes in community infrastructure, and development. Specifically, this TMDL component takes into account the probability that new flows from WWTF discharges may occur in the future. The assimilative capacity of streams increases as the amount of flow increases. The allowance for future growth will result in protection of existing beneficial uses and conform to Texas's antidegradation policy.

The four Austin streams watersheds are serviced by the City of Austin Walnut Creek WWTF (Figure 11). However, this facility discharges directly into the Colorado River, and not into the four Austin streams watershed. The City of Austin has stated it does not intend to build any wastewater facilities in the watershed, and that it intends to accommodate all future growth with the existing facility. So, the future growth component was not explicitly derived and is set to a value of zero.

Compliance with these TMDLs is based on keeping the bacteria concentrations in the selected waters below the limits that were set as criteria for the individual sites. Future growth of new point sources is not limited by these TMDLs as long as the sources do not cause bacteria to exceed the limits. The assimilative capacity of streams increases as the amount of flow increases. Consequently, increases in flow allow for increased loadings. The LDC and tables in this TMDL will guide determination of the assimilative capacity of the stream under changing conditions, including future growth.

TMDL Calculations

The TMDLs were calculated based on the median flow in the 0-10 percentile range (very high flow regime) from the FDCs developed for the outlet of each impaired AU (Figures 15 through 17).

Tables 21 and 22 summarize the calculation of the TMDL and LA_{USL} for each segment. For each AU with tributary and upstream LAs, the LA_{USL} is the sum of downstream allowable loading calculated at the outlet of the applicable tributary. Spicewood Tributary to Shoal Creek (1403J) and Taylor Slough South (1403K) are single AUs and do not have any tributaries. Walnut Creek (1428B) and Waller Creek (1429C) have multiple AUs, but no tributaries.

Table 21. TMDL and LA_{USL} loadings for AUs for non-supporting water bodies

Stream	AU	Q_{Inlet} [a] (cfs)	LA_{USL} [b] (Billion MPN/day)	Q_{Outlet} [c] (cfs)	TMDL [d] (Billion MPN/day)
Spicewood Tributary to Shoal Creek	1403J_01	0.00	0.00	3.87	11.93
Taylor Slough South	1403K_01	0.00	0.00	3.22	9.93
Walnut Creek	1428B_05	0.00	0.00	24.30	74.91
Waller Creek	1429C_02	11.97	36.90	29.29	90.29
Waller Creek	1429C_03	0.00	0.00	11.97	36.90

[a] Inlet median flow from all tributaries and upstream AUs; from Table 19

[b] Inlet allowable loading LA_{USL} from upstream tributaries and upstream AUs; $LA_{USL} = Q_{Inlet} \times$ Criterion × Conversion Factor; Conversion Factor = 24,465,755

[c] Outlet median flow from very high flow regime; from Table 19

[d] Outlet allowable loading; TMDL = $Q_{Outlet} \times$ Criterion × Conversion Factor

Table 22. TMDL and LA_{USL} loadings for AUs for water bodies with concerns for use

Stream	AU	Q_{Inlet} [a] (cfs)	LA_{USL} [b] (Billion MPN/day)	Q_{Outlet} [c] (cfs)	TMDL [d] (Billion MPN/day)
Walnut Creek	1428B_01	85.81	264.53	91.92	283.36
Walnut Creek	1428B_02	55.80	172.01	85.81	264.53
Walnut Creek	1428B_03	52.33	161.32	55.80	172.01
Walnut Creek	1428B_04	24.30	74.91	52.33	161.32

[a] Inlet median flow from all tributaries and upstream AUs; from Table 20

[b] Inlet allowable loading LA_{USL} from upstream tributaries and upstream AUs; $LA_{USL} = Q_{Inlet} \times$ Criterion × Conversion Factor; Conversion Factor = 24,465,755

[c] Outlet median flow from very high flow regime; from Table 20

[d] Outlet allowable loading; TMDL = $Q_{Outlet} \times$ Criterion × Conversion Factor

Tables 23 and 24 show computation of the MOS, which is based on the information in Tables 21 and 22.

Table 23. MOS allocations for AUs for non-supporting water bodies

Stream	AU	TMDL [a] (Billion MPN/day)	LA_{USL} [b] (Billion MPN/day)	MOS [c] (Billion MPN/day)
Spicewood Tributary to Shoal Creek	1403J_01	11.93	0.00	0.60
Taylor Slough South	1403K_01	9.93	0.00	0.50
Walnut Creek	1428B_05	74.91	0.00	3.75
Waller Creek	1428C_02	90.29	36.90	2.67
Waller Creek	1428C_03	36.90	0.00	1.85

[a] TMDL from Table 21

[b] LA_{USL} from Table 21

[c] MOS = 5% × (TMDL - LA_{USL})

Table 24. MOS allocations for AUs for water bodies with concerns for use

Stream	AU	TMDL [a] (Billion MPN/day)	LA_{USL} [b] (Billion MPN/day)	MOS [c] (Billion MPN/day)
Walnut Creek	1428B_01	283.36	264.53	0.94
Walnut Creek	1428B_02	264.53	172.01	4.63
Walnut Creek	1428B_03	172.01	161.32	0.53
Walnut Creek	1428B_04	161.32	74.91	4.32

[a] TMDL from Table 22

[b] LA_{USL} from Table 22

[c] MOS = 5% × (TMDL - LA_{USL})

Tables 25 and 26 show the regulated stormwater load based on MS4 regulation of all AUs within the four Austin streams watersheds.

Table 25. Regulated stormwater computation for non-supporting water bodies

Stream	AU	TMDL [a] (Billion MPN/day)	WLA_{WWTF} [b] (Billon MPN/day)	LA_{USL} [c] (Billion MPN/day)	MOS [d] (Billion MPN/day)	FDA_{SW} [e] (%)	WLA_{SW} [f] (Billion MPN/day)
Spicewood Tributary to Shoal Creek	1403J_01	11.93	0.00	0.00	0.60	100%	11.33
Taylor Slough South	1403K_01	9.93	0.00	0.00	0.50	100%	9.43
Walnut Creek	1428B_05	74.91	0.00	0.00	3.75	100%	71.16
Waller Creek	1429C_02	90.29	0.00	36.90	2.67	100%	50.72
Waller Creek	1429C_03	36.90	0.00	0.00	1.85	100%	35.05

[a] TMDL from Table 21

[b] For all AUs, WLA_{WWTF} = 0.00 because there are no bacteria WWTFs

[c] LA_{USL} from Table 21

[d] MOS from Table 23

[e] FDA_{SW} = percentage area covered by MS4; 100% for all AUs

[f] WLA_{SW} = (TMDL–LA_{USL}-MOS) ×FDA_{SW}

Table 26. Regulated stormwater computation for water bodies with concerns for use

Stream	AU	TMDL [a] (Billion MPN/day)	WLA_{WWTF} [b] (Billon MPN/day)	LA_{USL} [c] (Billion MPN/day)	MOS [d] (Billon MPN/day)	FDA_{SW} [e] (%)	WLA_{SW} [f] (Billion MPN/day)
Walnut Creek	1428B_01	283.36	0.00	264.53	0.94	100%	17.89
Walnut Creek	1428B_02	264.53	0.00	172.01	4.63	100%	87.89
Walnut Creek	1428B_03	172.01	0.00	161.32	0.53	100%	10.16
Walnut Creek	1428B_04	161.32	0.00	74.91	4.32	100%	82.09

[a] TMDL from Table 22

[b] For all AUs, WLA_{WWTF} = 0.00 because there are no bacteria WWTFs

[c] LA_{USL} from Table 22

[d] MOS from Table 24

[e] FDA_{SW} = percentage area covered by MS4; 100% for all AUs

[f] $WLA_{SW} = (TMDL - LA_{USL} - MOS) \times FDA_{SW}$

The LA_{AU} is the allowable bacteria loading assigned to unregulated stormwater sources within each TMDL watershed. Tables 27 and 28 summarize the TMDL calculations of the term LA_{AU} for the nine AUs comprising the TMDL watersheds. Each of the TMDLs was calculated based on the median flow in the 0-10 percentile range (very high flow regime) for flow exceedance from the LDC developed for the outlet of each AU. Allocations are based on the current median criterion for *E. coli* in freshwater of 126 MPN/100 mL.

The final TMDL allocations needed to comply with the requirements of 40 CFR 130.7 are provided in Tables 29 and 30. The LA component of the final TMDL allocations includes both tributary and upstream bacteria loadings (LA_{USL}) and loadings arising from within each segment from unregulated sources (LA_{AU}).

In the event that the criterion changes due to future revisions in the state's surface water quality standards, Appendix B provides guidance for recalculating the allocations in Tables 29 and 30. Figures B-1 through B9 were developed to demonstrate how assimilative capacity, TMDL calculations, and LAs change in relation to a number of proposed water quality criteria for *E. coli*. The equations provided along with the figures allow calculation of new TMDLs and LAs based on any potential water quality criterion for *E. coli*.

Table 27. TMDL allocation summary for all AUs for non-supporting water bodies

Stream	AU	TMDL[a] (Billion MPN/day)	WLA_{WWTF}[b] (Billon MPN/day)	WLA_{SW}[c] (Billion MPN/day)	MOS[d] (Billion MPN/day)	LA_{USL}[e] (Billion MPN/day)	LA_{AU}[f] (Billion MPN/day)	LA_{Total}[g] (Billion MPN/day)
Spicewood Tributary to Shoal Creek	1403J_01	11.93	0.00	11.33	0.60	0.00	0.00	0.00
Taylor Slough South	1403K_01	9.93	0.00	9.43	0.50	0.00	0.00	0.00
Walnut Creek	1428B_05	74.91	0.00	71.16	3.75	0.00	0.00	0.00
Waller Creek	1429C_02	90.29	0.00	50.72	2.67	36.90	0.00	36.90
Waller Creek	1429C_03	36.90	0.00	35.05	1.85	0.00	0.00	0.00

[a] TMDL from Table 21

[b] For all AUs, WLA_{WWTF} = 0.00 because there are no WWTFs

[c] WLA_{SW} from Table 25

[d] MOS from Table 23

[e] LA_{USL} = from Table 25

[f] LA_{AU} = TMDL - WLA_{SW} – LA_{USL} - MOS

[g] LA_{Total} = LA_{AU} + LA_{USL}

Table 28. TMDL allocation summary for all AUs for water bodies with concerns for use

Stream	AU	TMDL[a] (Billion MPN/day)	WLA_{WWTF}[b] (Billon MPN/day)	WLA_{SW}[c] (Billion MPN/day)	MOS[d] (Billion MPN/day)	LA_{USL}[e] (Billion MPN/day)	LA_{AU}[f] (Billion MPN/day)	LA_{Total}[g] (Billion MPN/day)
Walnut Creek	1428B_01	283.36	0.00	17.89	0.94	264.53	0.00	264.53
Walnut Creek	1428B_02	264.53	0.00	87.89	4.63	172.01	0.00	172.01
Walnut Creek	1428B_03	172.01	0.00	10.16	0.53	161.32	0.00	161.32
Walnut Creek	1428B_04	161.32	0.00	82.09	4.32	74.91	0.00	74.91

[a] TMDL from Table 22

[b] For all AUs, WLA_{WWTF} = 0.00 because there are no WWTFs

[c] WLA_{SW} from Table 26

[d] MOS from Table 24

[e] LA_{USL} = from Table 26

[f] LA_{AU} = TMDL - WLA_{SW} – LA_{USL} - MOS

[g] LA_{Total} = LA_{AU} + LA_{USL}

Table 29. Final TMDL allocations for all AUs of non-supporting water bodies

Stream	AU	TMDL [a] (Billion MPN/day)	WLA_{WWTF} [b] (Billion MPN/day)	WLA_{SW} [c] (Billion MPN/day)	LA_{Total} [d] (Billion MPN/day)	MOS [e] (Billion MPN/day)
Spicewood Tributary to Shoal Creek	1403J_01	11.93	0.00	11.33	0.00	0.60
Taylor Slough South	1403K_01	9.93	0.00	9.43	0.00	0.50
Walnut Creek	1428B_05	74.91	0.00	71.16	0.00	3.75
Waller Creek	1429C_02	90.29	0.00	50.72	36.90	2.67
Waller Creek	1429C_03	36.90	0.00	35.05	0.00	1.85

[a] Total TMDL allowed from all sources, calculated from median very high flow; from Table 21

[b] For all AUs, WLA_{WWTF} = 0.00 because there are no WWTFs

[c] Permitted loads from MS4 stormwater; WLA_{SW} from Table 25

[d] Non-permitted loads from all sources, including non-MS4 stormwater; from Table 27

[e] MOS from Table 23

Table 30. Final TMDL allocations for all AUs for water bodies with concerns for use

Stream	AU	TMDL [a] (Billion MPN/day)	WLA_{WWTF} [b] (Billion MPN/day)	WLA_{SW} [c] (Billion MPN/day)	LA_{Total} [d] (Billion MPN/day)	MOS [e] (Billion MPN/day)
Walnut Creek	1428B_01	283.36	0.00	17.89	264.53	0.94
Walnut Creek	1428B_02	264.53	0.00	87.89	172.01	4.63
Walnut Creek	1428B_03	172.01	0.00	10.16	161.32	0.53
Walnut Creek	1428B_04	161.32	0.00	82.09	74.91	4.32

[a] Total TMDL allowed from all sources, calculated from median very high flow; from Table 22

[b] For all AUs, WLA_{WWTF} = 0.00 because there are no WWTFs

[c] Permitted loads from MS4 stormwater; WLA_{SW} from Table 26

[d] Non-permitted loads from all sources, including non-MS4 stormwater; from Table 28

[e] MOS from Table 24

Seasonal Variation

Federal regulations (40 CFR 130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. Seasonal variation was accounted for in these TMDLs by using more than five years of water quality data and by using the longest period of US Geological Survey flow records when estimating flows to develop flow exceedance percentiles.

Analysis of the available data for *E. coli* shown in Table 31 and Figure 18 shows a very large standard deviation, which causes a large uncertainty. This makes the minor differences in the geomean insignificant, making it difficult to draw conclusions about seasonal impacts.

Table 31. Seasonal variation of observations

E. coli	**Summer** (June – November)	**Winter** (December – May)
Count	105	112
Geomean	372	497
Median	620	514
Mean	1,041	1,517
StDev	1,544	3,947
Max	12,000	24,000

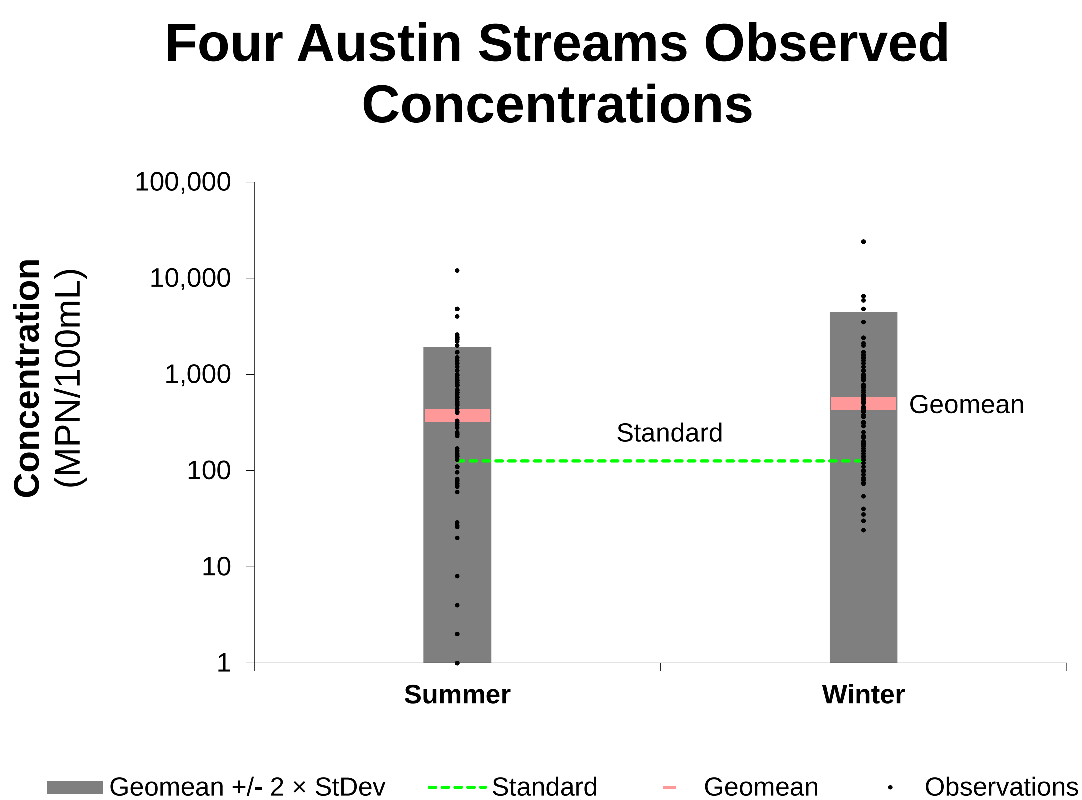

Figure 18. Box & Whisker Plot of All Stations Concentration

Public Participation

The TCEQ maintains an inclusive public participation process. From the inception of the investigation, the project team sought to ensure that stakeholders were informed and involved. Communication and comments from the stakeholders in the watershed strengthen TMDL projects and their implementation.

The TCEQ held a series of meetings with stakeholders to get their advice on elements of the project and to keep them informed of progress. These meetings were coordinated by the City of Austin's Watershed Protection Department, and The University of Texas Law School's Center of Public Policy Dispute Resolution (CPPDR). Notices of meetings were posted on all of the websites listed in Table 32, and included websites for the City of Austin, CPPDR, TCEQ, as well as the TMDL program public calendars.

The CPPDR initiated efforts in fall 2012 with the TCEQ to lead development of the Implementation Plan (I-Plan) for this TMDL project. These I-Plan development efforts, which are discussed under "Key Elements of an I-Plan" later in this report, continued in parallel with development of this TMDL, and included the same stakeholders. The I-Plan effort includes a Coordination Committee and four work groups. Between November 2012 and December 2013, CPPDR facilitated three general stakeholder meetings, two field trips to watersheds, seven Coordination Committee meetings, and 15 work group meetings. The Coordination Committee completed its draft I-Plan and submitted the document to TCEQ for review in December 2013. The TCEQ released the draft I-Plan for formal public review in 2014. The I-Plan is set for a January 2015 Agenda.

The initial public meeting to outline the need for the Four Austin Streams TMDL and IP was held at the City of Austin offices on the evening of November 28, 2012. Public service announcements in local news media occurred before the meeting and the meeting itself was covered by six local news media. The meeting introduced the TMDL and I-Plan process, identified the impaired segments and the reasons for the impairments, reviewed historical data, and described potential sources of bacteria within the watersheds. Additional public meetings to develop the Coordination Committee and work groups for the I-Plan were held in January 2013 at the City of Austin offices. Subsequent meetings were focused on the development of the I-Plan, in the context of the work being done on the TMDL.

To ensure that absent or new stakeholders could get information about past meetings and pertinent material, the CPPDR's project Web page provides meeting summaries and documents for review. These materials can be found on the CPPDR website shown in Table 32.

Table 32. Meeting notices posted on websites

Posting Entity	Web Address
City of Austin	<austintexas.gov/fullcalendar>
The University of Texas Law School, Center of Public Policy Dispute Resolution	<www.utexas.edu/law/centers/cppdr/services/tmdl.php>
TCEQ Four Austin Streams TMDL	<www.tceq.texas.gov/waterquality/tmdl/101-austinbacteria>
TMDL Program Online Calendar	<www.tceq.texas.gov/waterquality/tmdl/tmdlcalendar.html>
TCEQ Online Calendar	<www.tceq.texas.gov/events>

Implementation and Reasonable Assurance

The issuance of TPDES permits consistent with TMDLs provides reasonable assurance that WLAs in this TMDL report will be achieved. Per federal requirements, each TMDL is included in an update to the Texas WQMP as a plan element.

The WQMP coordinates and directs the state's efforts to manage water quality and maintain or restore designated uses throughout Texas. The WQMP is continually updated with new, more specifically focused plan elements, as identified in federal regulations (40 CFR 130.6(c)). Commission adoption of a TMDL is the state's certification of the associated WQMP update.

This TMDL report applies to all segments in the four Austin streams watersheds (Figure 1). Future water quality monitoring may identify additional segments with contact recreation use impairments not specifically addressed in this TMDL. If necessary, the TMDL allocations in this report will be revised to incorporate additional impaired segments and included in an update to the Texas WQMP.

Because the TMDL does not reflect or direct specific implementation by any single pollutant discharger, the TCEQ certifies additional elements to the WQMP after the I-Plan is approved by the commission. Based on the TMDL and I-Plan, the TCEQ will propose and certify WQMP updates to establish required water-quality-based effluent limitations necessary for specific TPDES wastewater discharge permits.

For MS4 permits, the TCEQ will normally establish BMPs, which are a substitute for effluent limitations, as allowed by federal rules, where numeric effluent limitations are infeasible. When such practices are established in an MS4 permit, the TCEQ will not identify specific implementation requirements applicable to a specific TPDES stormwater permit through an effluent limitation update. Rather, the TCEQ might revise a stormwater permit, require a revised SWMP or Pollution Prevention Plan, or implement other specific revisions affecting stormwater dischargers in accordance with an adopted I-Plan.

Strategies for achieving pollutant loads in TMDLs from nonpoint sources are reasonably assured by the state's use of an I-Plan. The TCEQ is committed to supporting implementation of all TMDLs adopted by the commission.

I-Plans for Texas TMDLs use an adaptive management approach that allows for refinement or addition of methods to achieve environmental goals. This adaptive approach reasonably assures that the necessary regulatory and voluntary activities to achieve pollutant reductions will be implemented. Periodic, repeated evaluations of the effectiveness of implementation methods ascertain whether progress is occurring, and may show that the original distribution of loading among sources should be modified to increase efficiency. I-Plans will be adapted as necessary to reflect needs identified in evaluations of progress.

Key Elements of an I-Plan

An I-Plan includes a detailed description and schedule of the regulatory and voluntary management measures to implement the WLAs and LAs of particular TMDLs within a reasonable time. I-Plans also identify the organizations responsible for carrying out management measures, and a plan for periodic evaluation of progress.

Strategies to optimize compliance and oversight are identified in an I-Plan when necessary. Such strategies may include additional monitoring and reporting of effluent discharge quality to evaluate and verify loading trends, adjustment of an inspection frequency or a response protocol to public complaints, and escalation of an enforcement remedy to require corrective action of a regulated entity contributing to an impairment.

The TCEQ works with stakeholders and interested governmental agencies to develop and support I-Plans and track their progress. Work on the four Austin streams Bacteria I-Plan to address the TMDLs in this report began in fall 2012 and was facilitated locally by the CPPDR.

Ultimately, the I-Plan will identify the commitments and requirements to be implemented through specific permit actions and other means. For these reasons, the I-Plan that is approved may not approximate the predicted loadings identified category-by-category in the TMDL and its underlying assessment. The I-Plan is adaptive for this very reason; it allows for continuous update and improvement.

In most cases, it is not practical or feasible to approach all TMDL implementation as a one-time, short-term restoration effort. This is particularly true when a challenging wasteload reduction or load reduction is required by the TMDL, there is high uncertainty with the TMDL analysis, there is a need to reconsider or revise the established water quality standard, or the pollutant load reduction would require costly infrastructure and capital improvements.

The CPPDR is working with the TCEQ to lead development of the I-Plan. Through the stakeholder group led by the CPPDR, the resources and expertise of the local organizations and individuals are brought together to set priorities, provide flexibility, and consider appropriate social and economic factors. Information on I-Plan development and related material are on the CPPDR Web page shown in Table 32.

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Appendix A.
Load Duration Curves for TCEQ Monitoring Stations

The LDCs for water quality monitoring stations are provided in Figures A-1 through A-9. The LDCs for the water quality monitoring stations provide a means of identifying the stream flow conditions under which exceedances in *E. coli* concentrations have occurred. The LDCs depict the allowable loadings at each station under the *E. coli* geometric mean criterion (126 MPN/100 mL), except at station 12232 (AU 1428B_02) where the fecal coliform criterion (200 MPN/100 mL) is used. These LDCs show that existing loadings often exceed the applicable criterion.

On each graph, the measured *E. coli* data are classified as a "wet weather event" or a "dry weather event." A sample was determined to be influenced by a wet weather event based on the reported "days since last precipitation" was three days or less. All other events were classified as "dry weather events."

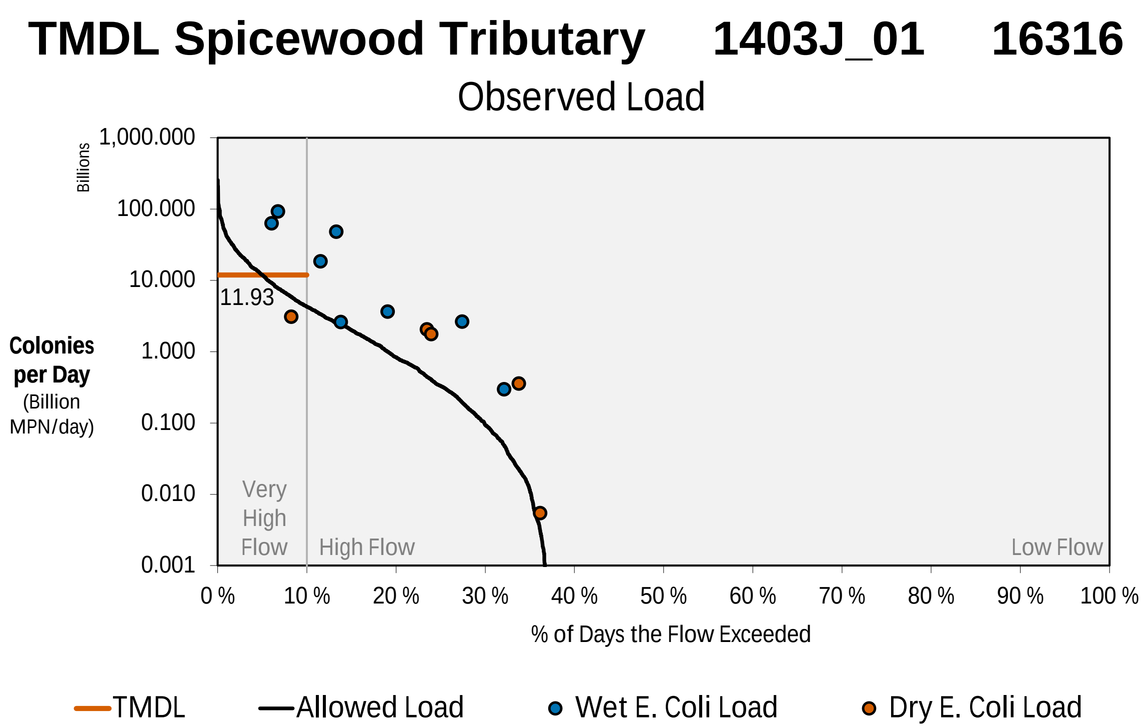

Figure A-1. Load duration curve for station 16316, Spicewood Tributary (1403J)

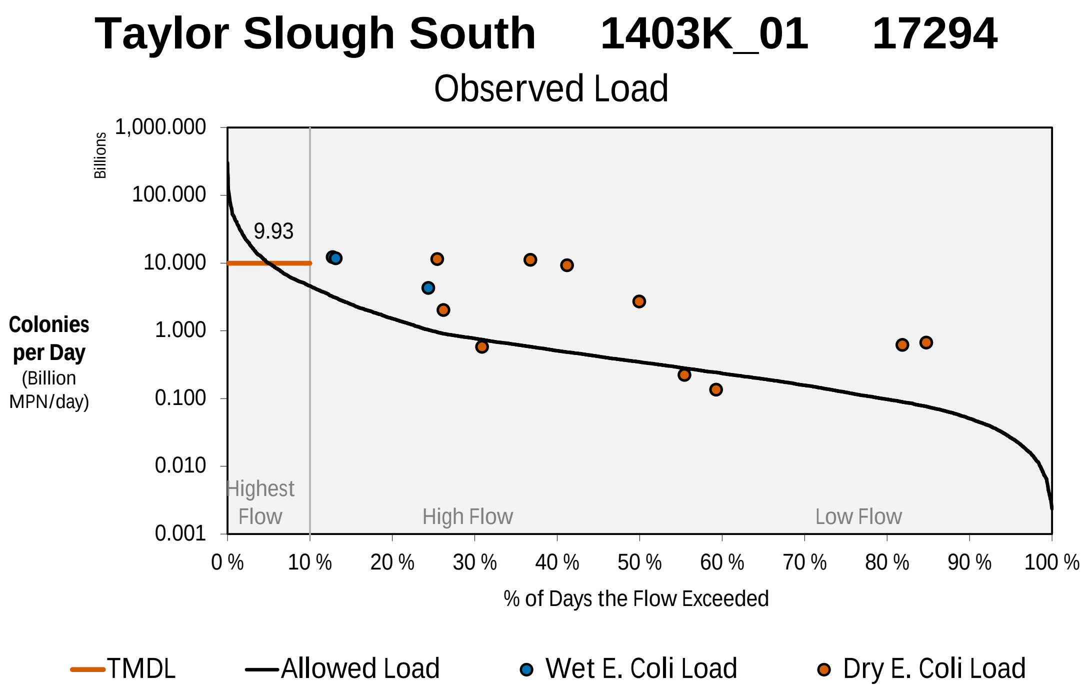

Figure A-2. Load duration curve for station 17294, Taylor Slough South (1403K_01)

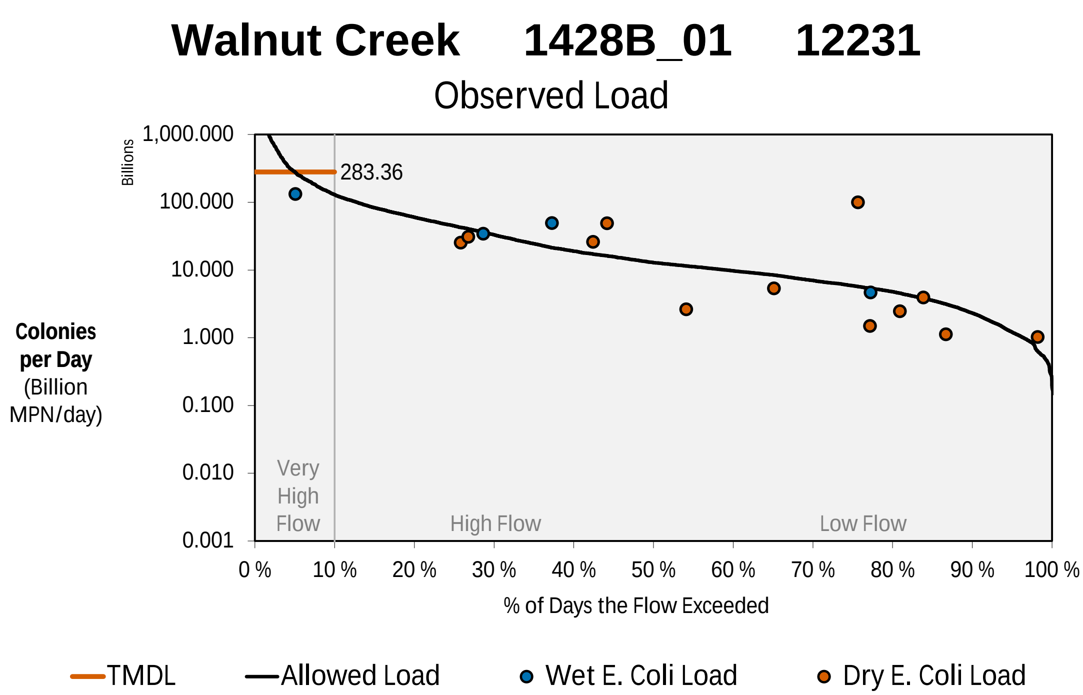

Figure A-3. Load duration curve for station 12231, Walnut Creek (1428B_01)

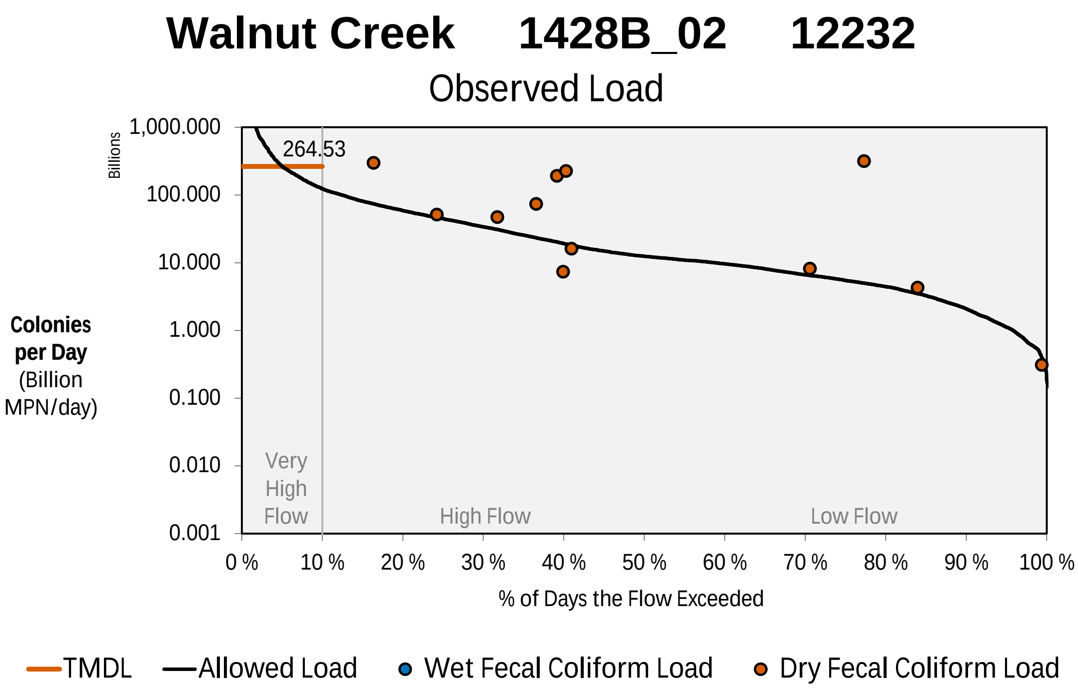

Figure A-4. Load duration curve for station 12232, Walnut Creek (1428B_02)

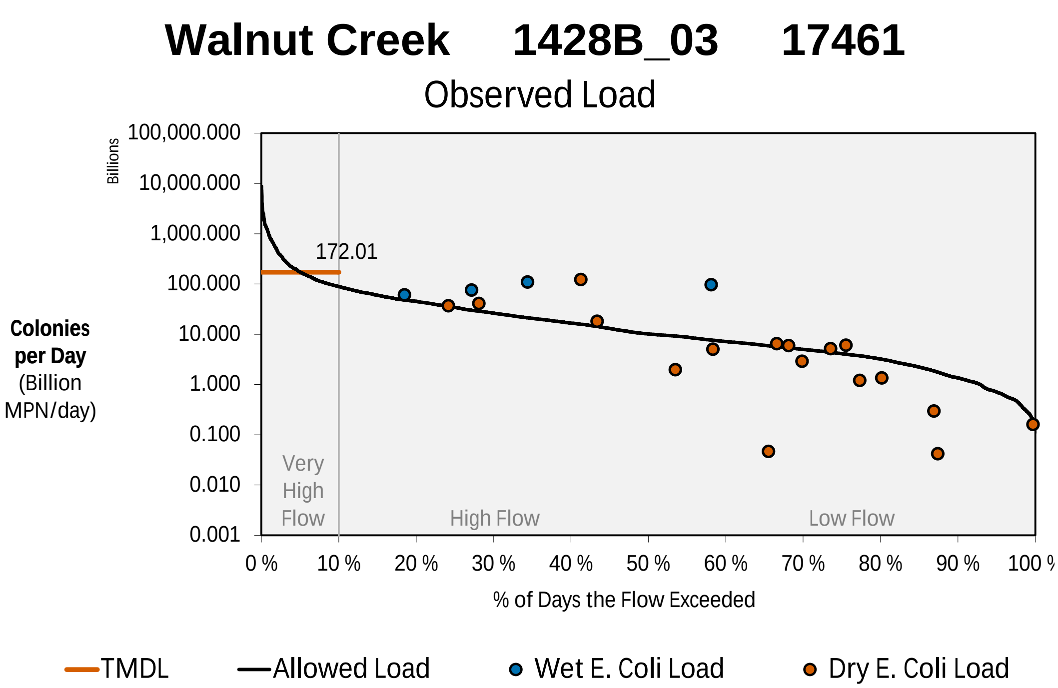

Figure A-5. Load duration curve for station 17469, Walnut Creek (1428B_03)

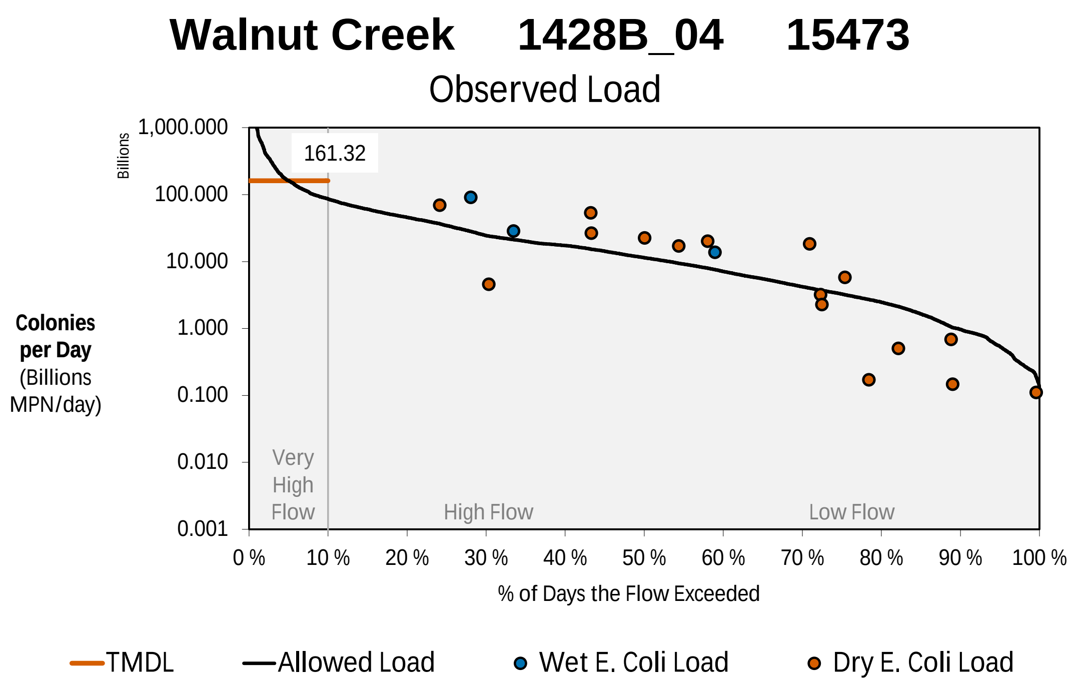

Figure A-6. Load duration curve for station 15743, Walnut Creek (1428B_04)

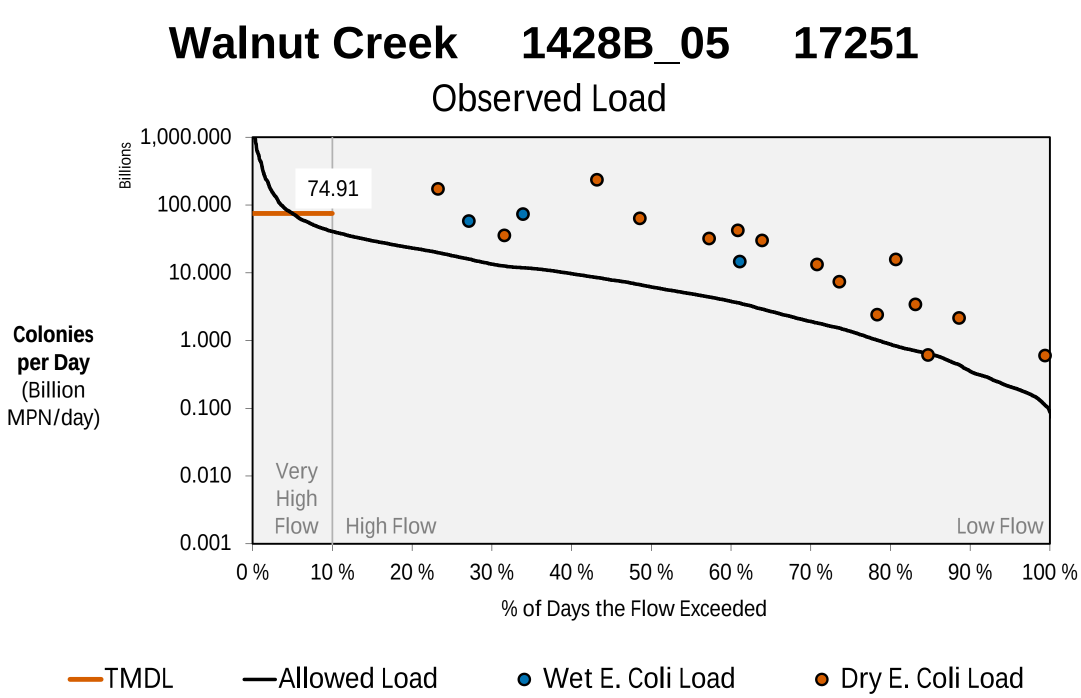

Figure A-7. Load duration curve for station 17251, Walnut Creek (1428B_05)

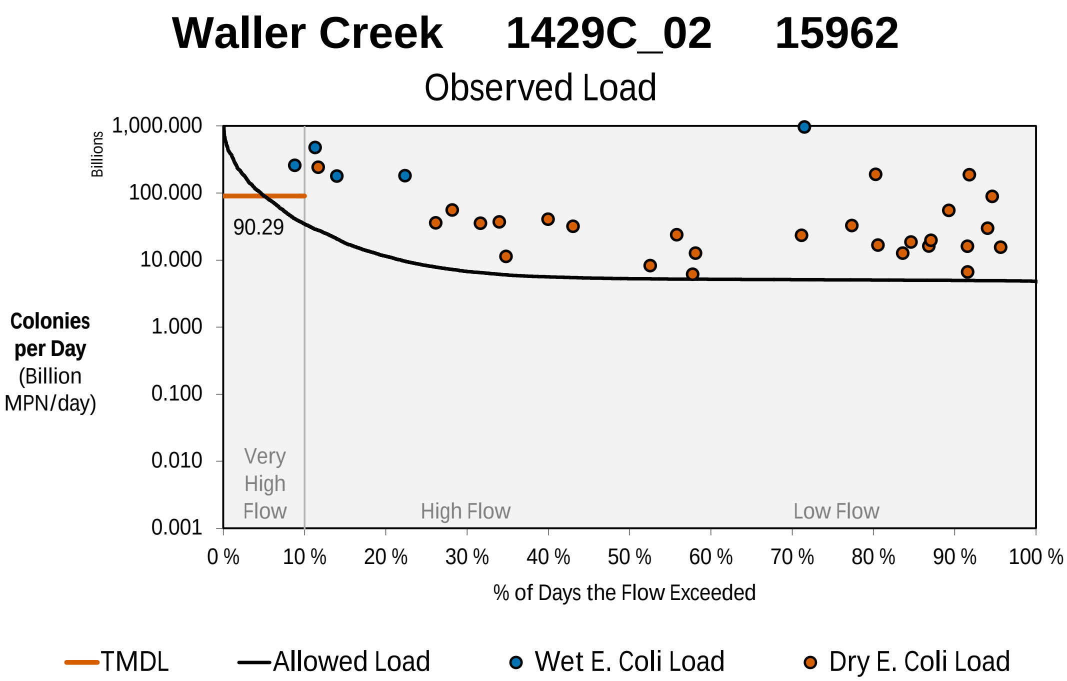

Figure A-8. Load duration curve for station 15962, Waller Creek (1429C_02)

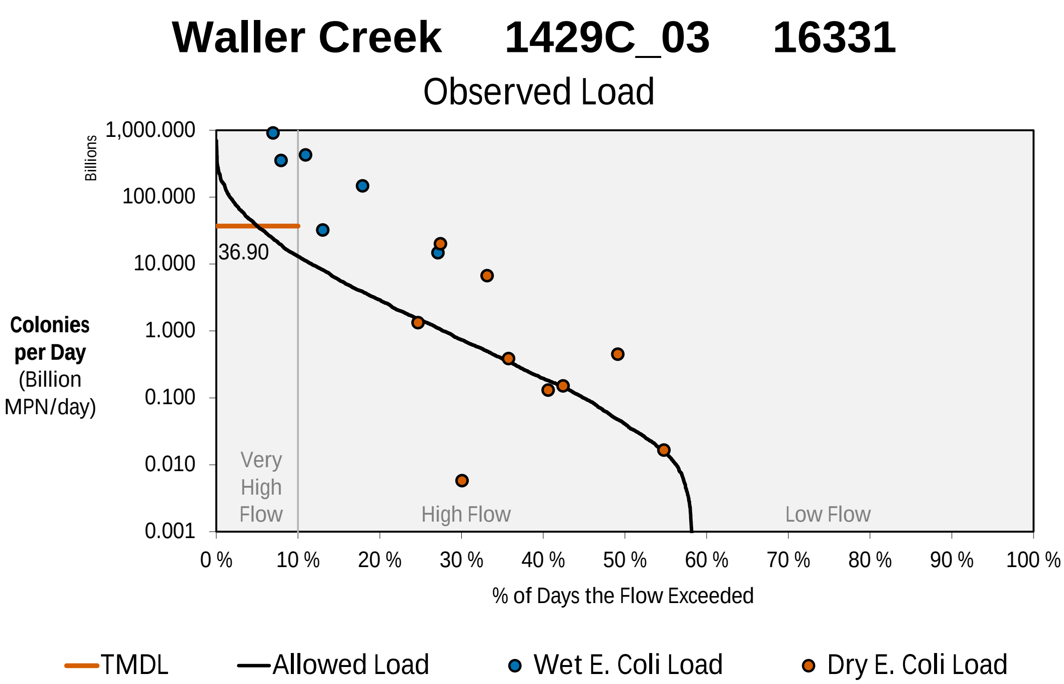

Figure A-9. Load duration curve for station 16331, Waller Creek (1429C_03)

Appendix B.
Equations for Calculating TMDL Allocations for Changed Contact Recreation Standard

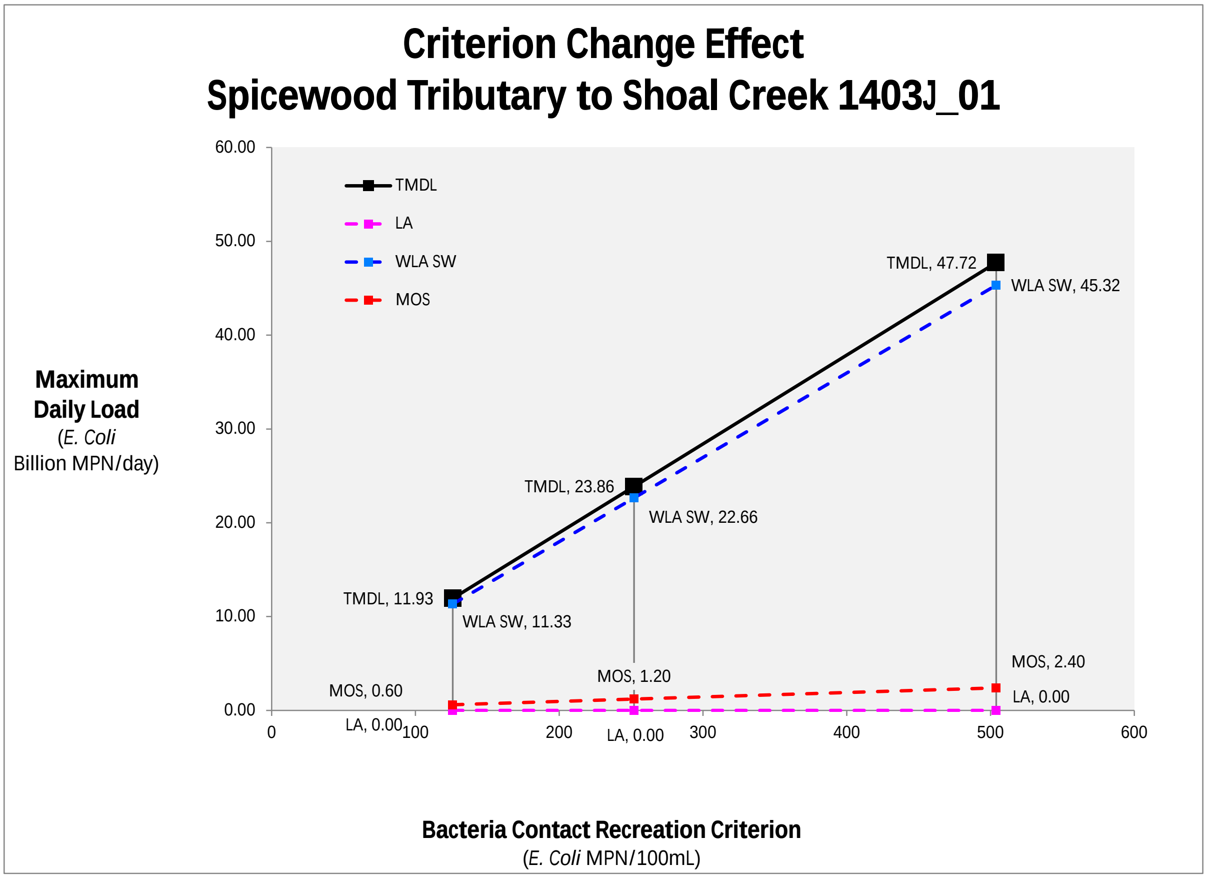

Figure B-1. Allocation of loads for Spicewood Tributary to Shoal Creek (1403J_01) as a function of the water criteria

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

$$TMDL = 0.094683 \times Std$$
$$MOS = 0.004762 \times Std$$
$$WLA_{WWTF} = 0.000000 \times Std$$
$$WLA_{SW} = 0.089921 \times Std$$
$$LA = 0.000000 \times Std$$

Where:

Std = Revised Contact Recreation Standard TMDL
TMDL = Revised TMDL
MOS = Revised MOS
WLA_{WWTF} = Revised Waste load allocation = 0 (no permits)
WLA_{SW} = Revised Waste load allocation (permitted stormwater)
LA = Revised Total load allocation (non-permitted)

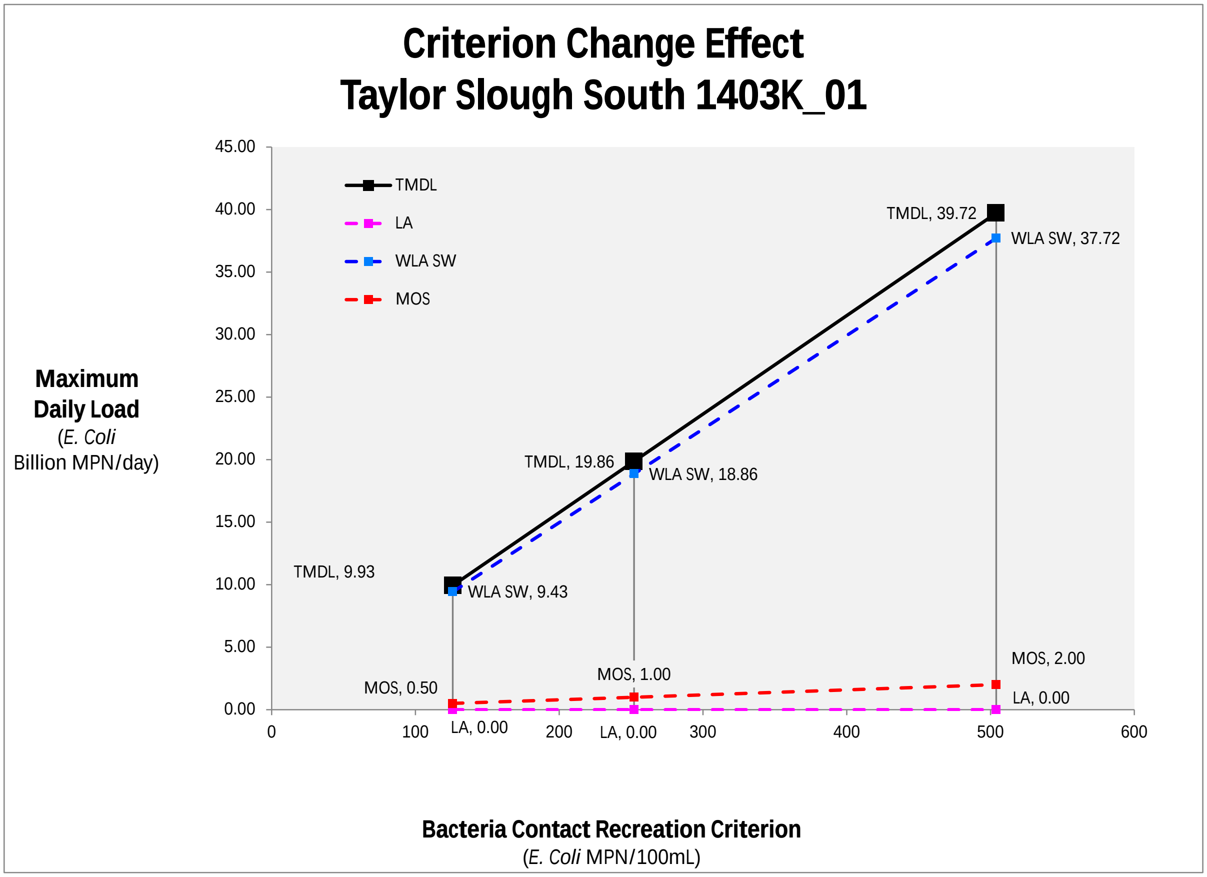

Figure B-2. Allocation loads for Taylor Slough South (1403K_01) as a function of water quality criteria

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

$$TMDL = 0.078810 \times Std$$

$$MOS = 0.003968 \times Std$$

$$WLA_{WWTF} = 0.000000 \times Std$$

$$WLA_{SW} = 0.074841 \times Std$$

$$LA = 0.000000 \times Std$$

Where:

- Std = Revised Contact Recreation Standard TMDL
- TMDL = Revised TMDL
- MOS = Revised MOS
- WLA_{WWTF} = Revised Waste load allocation = 0 (no permits)
- WLA_{SW} = Revised Waste load allocation (permitted stormwater)
- LA = Revised Total load allocation (non-permitted)

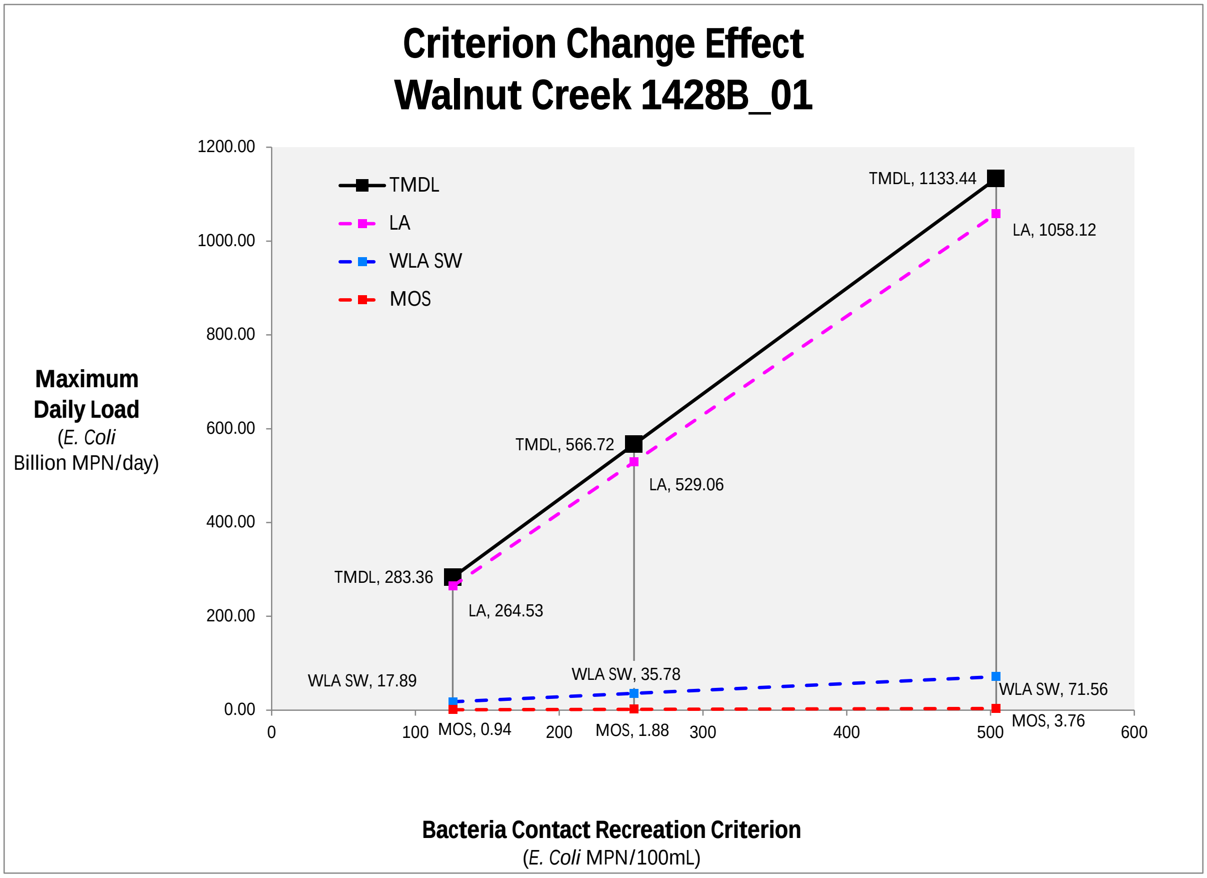

Figure B-3. Allocation loads for Walnut Creek (1428B_01) as a function of water quality criteria

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

TMDL	=	2.248889	× Std
MOS	=	0.007460	× Std
WLA_{WWTF}	=	0.000000	× Std
WLA_{SW}	=	0.141984	× Std
LA	=	2.099444	× Std

Where:

Std = Revised Contact Recreation Standard TMDL
TMDL = Revised TMDL
MOS = Revised MOS
WLA_{WWTF} = Revised Waste load allocation = 0 (no permits)
WLA_{SW} = Revised Waste load allocation (permitted stormwater)
LA = Revised Total load allocation (non-permitted)

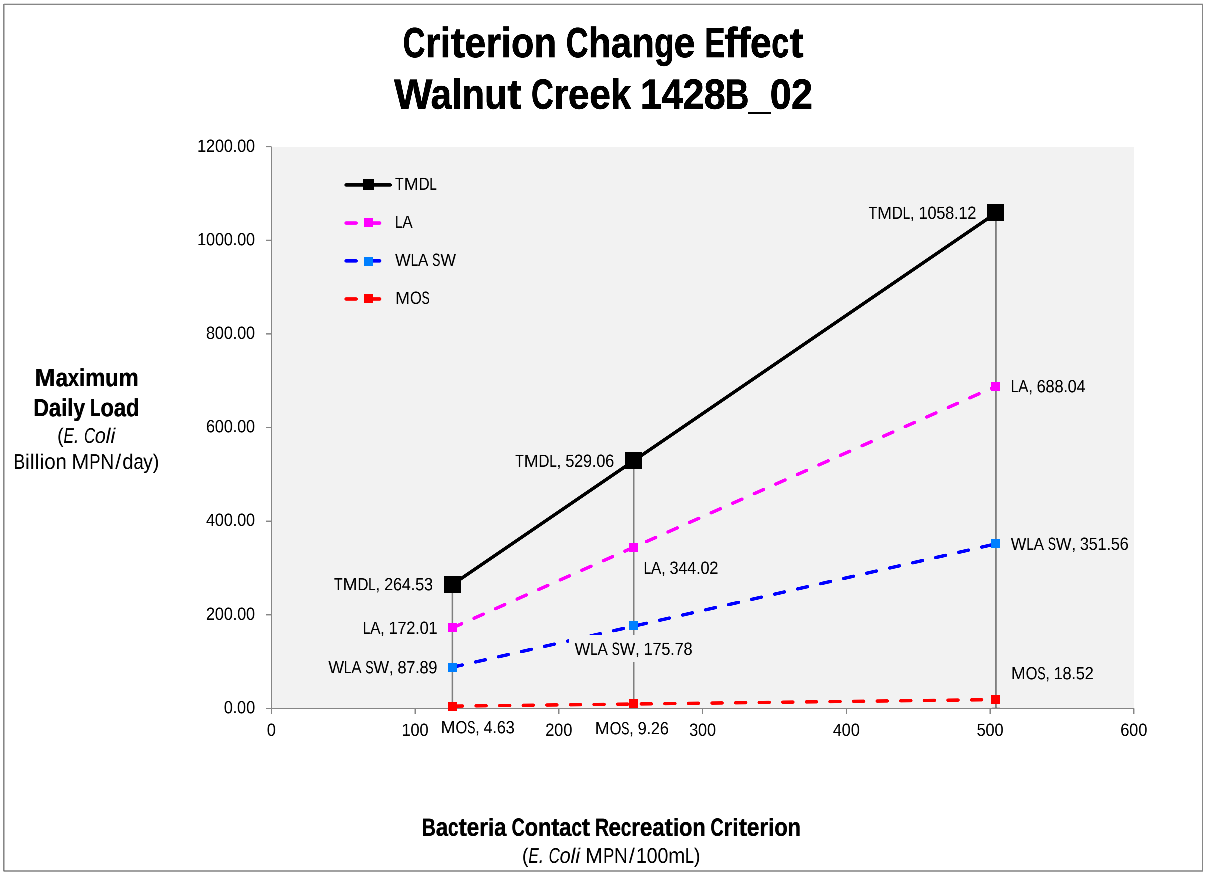

Figure B-4. Allocation loads for Walnut Creek (1428B_02) as a function of water quality criteria

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

$$\begin{aligned}
TMDL &= 2.099444 \times Std \\
MOS &= 0.036746 \times Std \\
WLA_{WWTF} &= 0.000000 \times Std \\
WLA_{SW} &= 0.697540 \times Std \\
LA &= 1.365159 \times Std
\end{aligned}$$

Where:

- Std = Revised Contact Recreation Standard TMDL
- TMDL = Revised TMDL
- MOS = Revised MOS
- WLA_{WWTF} = Revised Waste load allocation = 0 (no permits)
- WLA_{SW} = Revised Waste load allocation (permitted stormwater)
- LA = Revised Total load allocation (non-permitted)

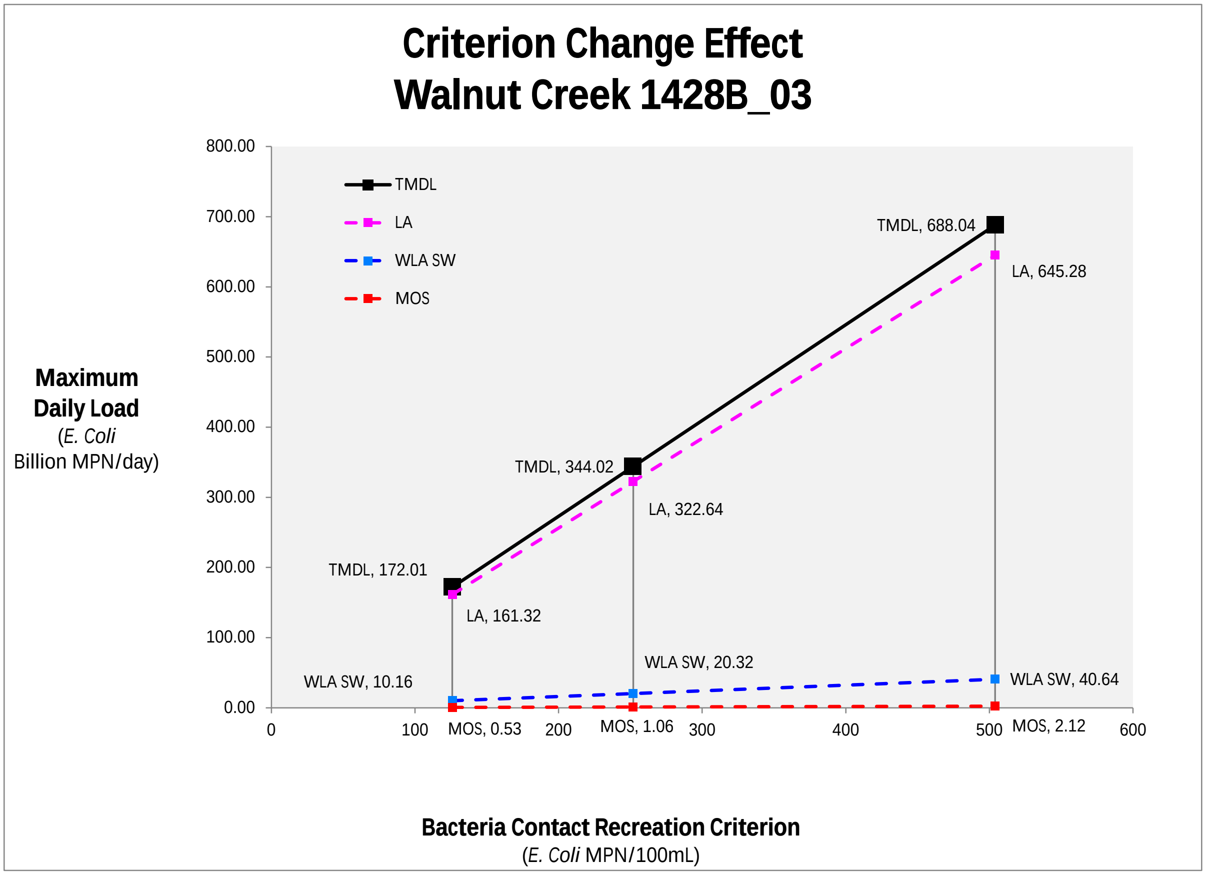

Figure B-5. Allocation loads for Walnut Creek (1428B_03) as a function of water quality criteria

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

$$TMDL = 1.365159 \times Std$$
$$MOS = 0.004206 \times Std$$
$$WLA_{WWTF} = 0.000000 \times Std$$
$$WLA_{SW} = 0.080635 \times Std$$
$$LA = 1.280317 \times Std$$

Where:

- Std = Revised Contact Recreation Standard TMDL
- TMDL = Revised TMDL
- MOS = Revised MOS
- WLA_{WWTF} = Revised Waste load allocation = 0 (no permits)
- WLA_{SW} = Revised Waste load allocation (permitted stormwater)
- LA = Revised Total load allocation (non-permitted)

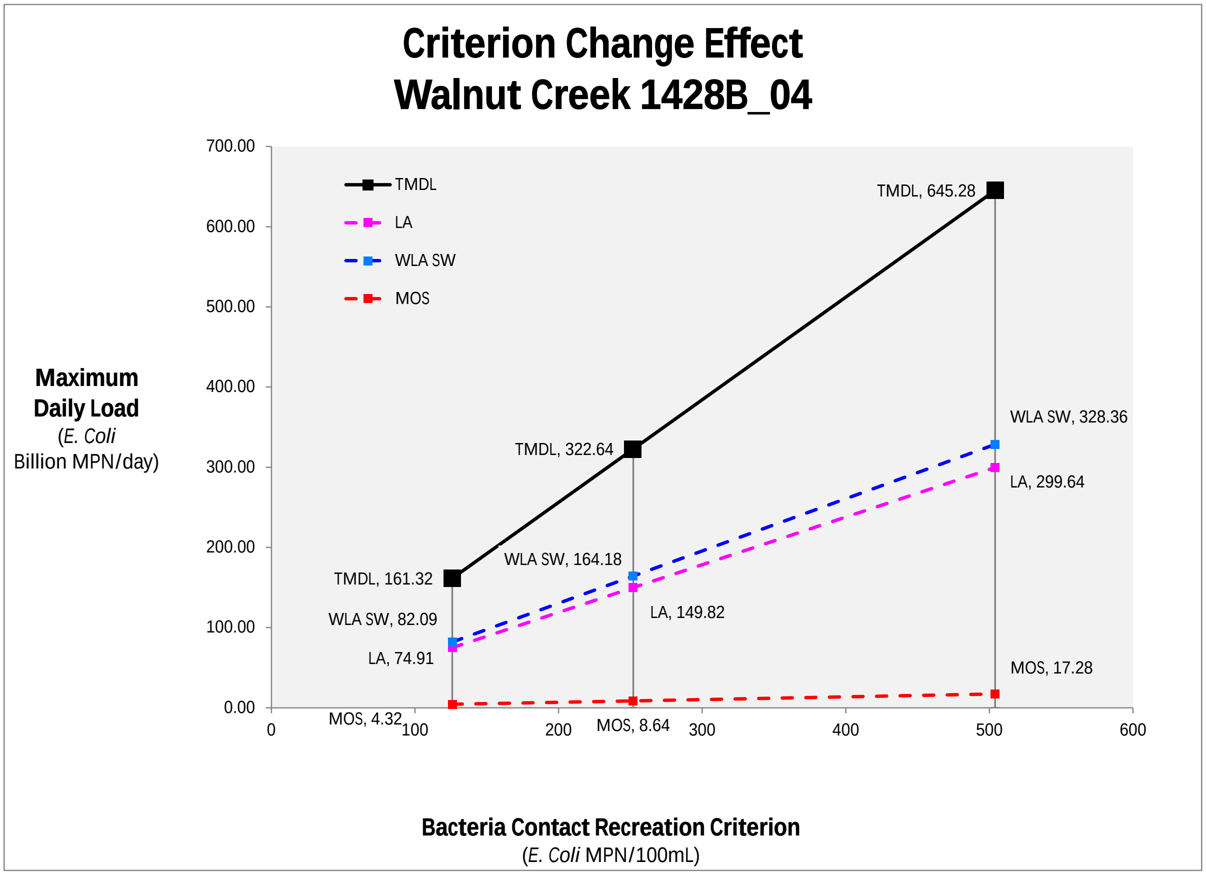

Figure B-6. Allocation loads for Walnut Creek (1428B_04) as a function of water quality criteria

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

$$TMDL = 1.280317 \times Std$$
$$MOS = 0.034286 \times Std$$
$$WLA_{WWTF} = 0.000000 \times Std$$
$$WLA_{SW} = 0.651508 \times Std$$
$$LA = 0.594524 \times Std$$

Where:

Std = Revised Contact Recreation Standard TMDL
TMDL = Revised TMDL
MOS = Revised MOS
WLA_{WWTF} = Revised Waste load allocation = 0 (no permits)
WLA_{SW} = Revised Waste load allocation (permitted stormwater)
LA = Revised Total load allocation (non-permitted)

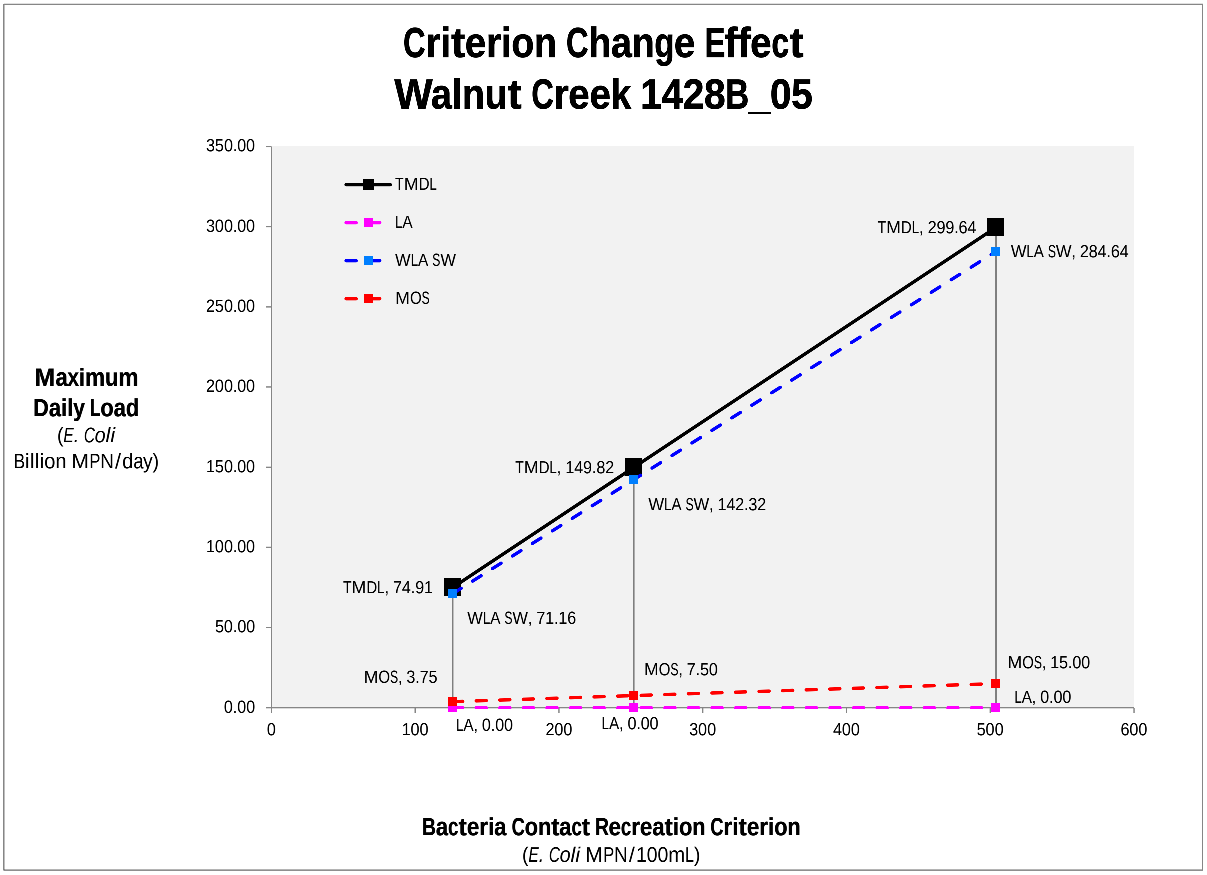

Figure B-7. Allocation loads for Walnut Creek (1428B_05) as a function of water quality criteria

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

$$\text{TMDL} = 0.594524 \times \text{Std}$$
$$\text{MOS} = 0.029762 \times \text{Std}$$
$$\text{WLA}_{\text{WWTF}} = 0.000000 \times \text{Std}$$
$$\text{WLA}_{\text{SW}} = 0.564762 \times \text{Std}$$
$$\text{LA} = 0.000000 \times \text{Std}$$

Where:

Std = Revised Contact Recreation Standard TMDL
TMDL = Revised TMDL
MOS = Revised MOS
WLA_{WWTF} = Revised Waste load allocation = 0 (no permits)
WLA_{SW} = Revised Waste load allocation (permitted stormwater)
LA = Revised Total load allocation (non-permitted)

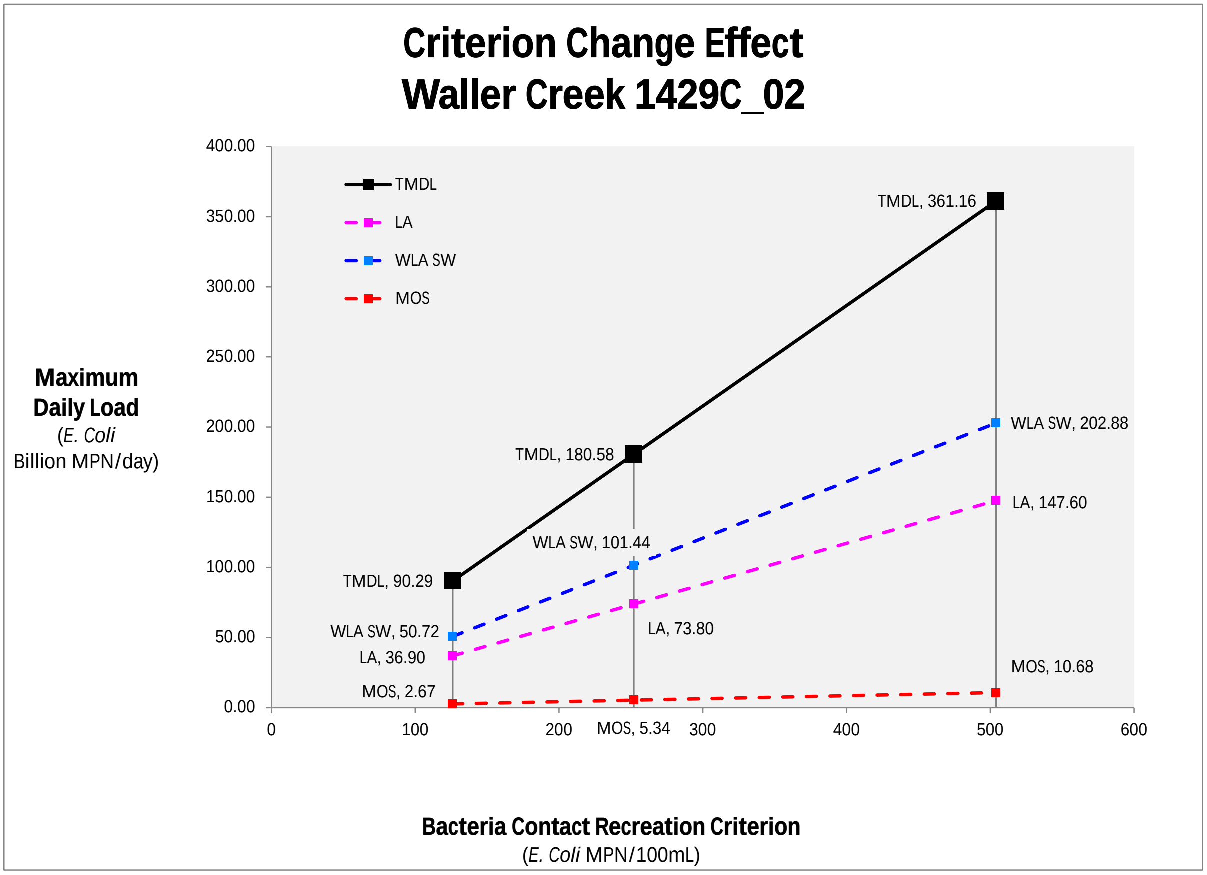

Figure B-8. Allocation loads for Waller Creek (1429C_02) as a function of water quality criteria

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

TMDL	=	0.716587	× Std
MOS	=	0.021190	× Std
WLA_{WWTF}	=	0.000000	× Std
WLA_{SW}	=	0.402540	× Std
LA	=	0.292857	× Std

Where:

Std = Revised Contact Recreation Standard TMDL
TMDL = Revised TMDL
MOS = Revised MOS
WLA_{WWTF} = Revised Waste load allocation = 0 (no permits)
WLA_{SW} = Revised Waste load allocation (permitted stormwater)
LA = Revised Total load allocation (non-permitted)

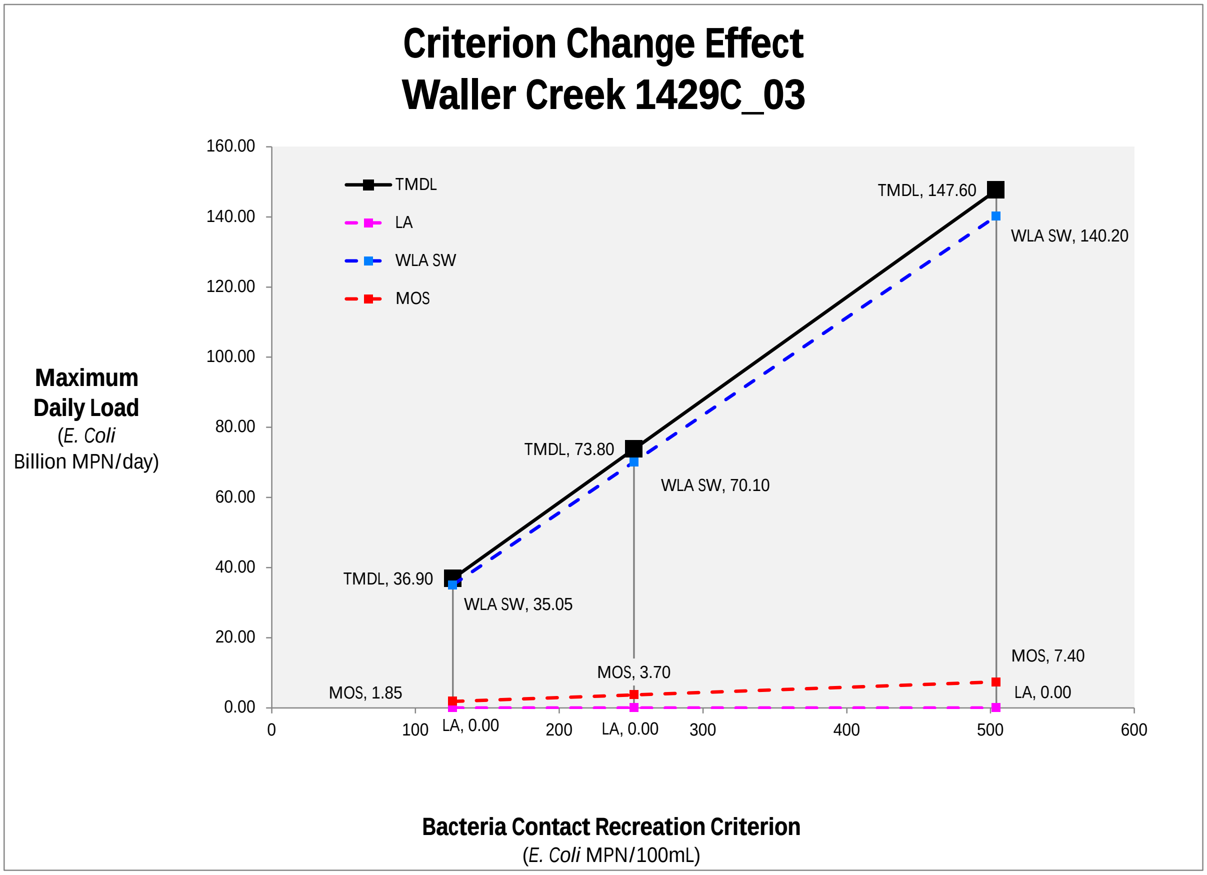

Figure B-9. Allocation loads for Waller Creek (1429C_03) as a function of water quality criteria

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

$$TMDL = 0.292857 \times Std$$
$$MOS = 0.014683 \times Std$$
$$WLA_{WWTF} = 0.000000 \times Std$$
$$WLA_{SW} = 0.278175 \times Std$$
$$LA = 0.000000 \times Std$$

Where:

- Std = Revised Contact Recreation Standard TMDL
- TMDL = Revised TMDL
- MOS = Revised MOS
- WLA_{WWTF} = Revised Waste load allocation = 0 (no permits)
- WLA_{SW} = Revised Waste load allocation (permitted stormwater)
- LA = Revised Total load allocation (non-permitted)