Adopted
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Two Total Maximum Daily Loads for Indicator Bacteria in the Upper Trinity River, Dallas, Texas

Segment 0805

Assessment Units: 0805_03 and 0805_04

Water Quality Planning Division, Office of Water

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

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"Technical Support Document: Segments 0806, 0841, 0822 and 0805
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and
"Allocation Support Document for Two Total Maximum Daily Loads for Bacteria
in the Upper Trinity River, Dallas, Texas"
prepared by the Texas Institute for Applied Environmental Research

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List of Abbreviations

AU	assessment unit
AVMA	American Veterinary Medical Association
BMP	best management practice
CFR	Code of Federal Regulations
cfs	cubic feet per second
cms	cubic meters per second
DAR	drainage area ratio
DEM	Digital Elevation Model
DMR	Discharge Monitoring Report
E. coli	*Escherichia coli*
EHD	Environmental Health Division
EPA	Environmental Protection Agency
FC	future capacity
FDC	flow duration curve
GIS	Geographic Information System
gpcd	gallons per capita per day
I/I	inflow and infiltration
I-Plan	implementation plan
km	kilometer
LA	load allocation
LDC	load duration curve
mL	milliliter
MGD	million gallons per day
MOS	margin of safety
MPN	most probable number
MS4	municipal separate storm sewer system
NDEP	Nevada Division for Environmental Protection
NCTCOG	North Central Texas Council of Governments
NEIWPCC	New England Interstate Water Pollution Control Commission
NPDES	National Pollutant Discharge Elimination System
NWS	National Weather Service
PCS	Permit Compliance System
OSSF	on-site sewage facility
SSO	sanitary sewer overflow
SWPPP	Storm Water Pollution Prevention Plan
SWQMIS	Surface Water Quality Management Information System
TCEQ	Texas Commission on Environmental Quality
TIAER	Texas Institute for Applied Environmental Research
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
TRA	Trinity River Authority
USGS	United States Geological Survey
WLA	wasteload allocation
WQBEF	water quality-based effluent limitations
WQMP	Water Quality Management Plan
WTP	water treatment plant
WWSA	wastewater and sewered area
WWTF	wastewater treatment facility

Two Total Maximum Daily Loads for Indicator Bacteria in Upper Trinity River

Executive Summary

This document describes total maximum daily loads (TMDLs) for the Upper Trinity River where 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 on the 1996 303(d) List. In the *2008 Texas Water Quality Inventory and 303(d) List*, the impairments were more precisely identified as confined within two assessment units of the river segment.

The Upper Trinity River (Segment 0805) is located in central Dallas County, flowing through the heart of the City of Dallas. It continues in a southeasterly direction through Ellis, Kaufman, Navarro, and Henderson Counties. The watershed drains an area of about 1,045 square miles and encompasses a large portion of the City of Dallas.

Two of the five assessment units (AUs) of Segment 0805 are addressed by these TMDLs, covering the area from the confluence with the Elm Fork Trinity River and West Fork Trinity River, downstream to the confluence with Fivemile Creek. Both AUs lie entirely within Dallas County in highly urbanized watersheds.

Escherichia coli (E. coli) are the preferred indicator bacteria for assessing the contact recreation use in freshwater, and were used for development of the TMDL. The criteria for assessing attainment of the contact recreation use are expressed as the number (or "counts") of *E. coli* bacteria, typically given as the most probable number (MPN). The contact recreation use is not supported when the geometric mean of all *E. coli* samples exceeds 126 MPN per 100 milliliter (mL), or if individual samples exceed 394 MPN per 100 mL more than 25 percent of the time.

Historical ambient water quality data for indicator bacteria (2001–2008) were analyzed on select TCEQ monitoring stations in the Upper Trinity watershed. The geometric means of *E. coli* exceeded the standard in the two upstream AUs of the Upper Trinity River—0805_03 and 0805_04—with geometric means of 384 MPN/100 mL and 224 MPN/100 mL, respectively.

The most probable sources of indicator bacteria within the watersheds of the impaired AUs are storm water runoff from permitted storm sewer sources, dry weather discharges (illicit discharges) from storm sewers, sanitary sewer overflows, and unregulated sources such as wildlife, unmanaged feral animals and pets.

A load duration curve analysis was used to quantify allowable pollutant loads and specific TMDL allocations for point and nonpoint sources of indicator bacteria. The TMDL allocations are discussed in the section "TMDL Calculations."

The wasteload allocation for wastewater treatment facilities (WWTFs) was established as the permitted flow multiplied by one-half the geometric mean criterion for the indicator bacteria. Compliance with these TMDLs is based on keeping the indicator bacteria concentrations in the selected waters below the geometric mean criterion of 126 MPN/100 mL.

Future growth of existing or new point sources was determined using population projections. The TMDL calculations in this report will guide determination of the assimilative capacity of each stream under changing conditions, including future growth. Wastewater discharge facilities will be evaluated on a case-by-case basis.

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 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 standards. TMDLs are the best possible estimates of the assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load with units of mass per time, but may be expressed in other ways. TMDLs must also estimate how much the pollutant load must be reduced from current levels in order to achieve water quality standards.

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 due to exceeding indicator bacteria criteria in the Upper Trinity River.

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 segment was first included on the 1996 303(d) List; the AUs were included in the 2008 303(d) List under category 5a, indicating that they are a priority for developing a TMDL.

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
- Seasonal Variation
- Margin of Safety
- Pollutant Load Allocation
- Public Participation
- Implementation and Reasonable Assurance

Upon EPA approval, these TMDLs will become an update to the state's Water Quality Management Plan.

Problem Definition

TCEQ first identified the impairment to the contact recreation use for the Upper Trinity River (Segment 0805) in the 1996 303(d) List. The impairments were identified more precisely as AUs 0805_03 and 0805_04 in the *2008 Texas Water Quality Inventory and 303(d) List* (TCEQ 2008b); these AUs define the TMDL area addressed in this report.

The standards for water quality are defined in the *Texas Surface Water Quality Standards* (TCEQ 2000). The specific uses assigned to Segment 0805 are contact recreation, high aquatic life, general, and fish consumption.

E. coli are the preferred indicator bacteria for assessing the contact recreation use in freshwater, and were used for analysis and modeling to support TMDL development for the watershed. The criteria for assessing attainment of the contact recreation use are expressed as the number (or "counts") of *E. coli* bacteria, typically given as the most probable number (MPN). For the *E. coli* indicator, if the minimum sample requirement is met, the contact recreation use is not supported when:

- the geometric mean of all *E. coli* samples exceeds 126 MPN per 100 mL;
- and/or individual samples exceed 394 MPN per 100 mL more than 25 percent of the time.

Ambient Indicator Bacteria Concentrations

Table 1 presents a historical summary of ambient indicator bacteria data from February 2001 through November 2008 for all AUs in Segment 0805. As indicated in Table 1, only TCEQ stations 10937 (in AU 0805_04) and 10934 (in AU 0805_03) exceeded the geometric mean criterion of 126 MPN/100 mL.

Watershed Overview

The Upper Trinity River (Figure 1) is a 100-mile freshwater stream beginning at the confluence with Cedar Creek Reservoir's discharge canal along the Henderson / Navarro County line and ending at the confluence of the Elm Fork Trinity River (Segment 0822) and the West Fork Trinity River (Segment 0841). The stream segment consists of five AUs (see Figure 1) defined in the Draft 2010 Texas Integrated Report as follows.

- 0805_04 – from the confluence of Cedar Creek upstream to the confluence of Elm Fork Trinity River and West Fork Trinity River,
- 0805_03 – from the confluence of Fivemile Creek upstream to the confluence of Cedar Creek,
- 0805_06 –from the confluence with Ten Mile Creek upstream to the confluence with Five Mile Creek,
- 0805_02 – from the confluence of Smith Creek upstream to confluence of Tenmile Creek, and
- 0805_01 – from the confluence of the Cedar Creek Reservoir discharge canal upstream to the confluence of Smith Creek.

AUs 0805_03 and 0805_04 are the focus of TMDL development (Figure 2).

Table 1. Summary of routine monitoring *E. coli* data for February 2001 - November 2008 (Downloaded from SWQMIS, July – August 2009).

Stations provided in an upstream to downstream order.
Only AUs 04 and 03 indicate nonsupport of contact recreation use.

AU	Station ID	Location	No. of Samples (02/2001-11/2008)	Range of Measured *E. coli* Conc. (MPN/100mL)	Geometric Mean (MPN/100mL)
0805_04	10937	Mockingbird Ln./ Dallas Co.	75	12 – 24,200	224
0805_03	10934	South Loop 12/ Dallas Co.	75	17 – 39,700	384
0805_06	10932	Dowdy Ferry Rd./ Dallas Co.	13	11 – 980	85
	10930	Belt Line Rd./ Dallas Co.	60	3 – 1,540	54
	0805_06 Total		**73**	**3 – 1,540**	**59**
0805_02	10925	Downstream of SH 34/ Kaufman Co.	82	2 – 4,840	122
0805_01 & 0805_05*	10924	Near FM 85/ Henderson Co.	6	8 – 770	56

*For the Draft 2010 Texas Integrated Report, 0805_01 and 0805_05 have been consolidated into one AU, now known as 0805_01.

Within the Upper Trinity River watershed, urban landscapes transition to increasingly agricultural uses moving from upstream to downstream; however, the land use/land cover of the two impaired AUs are predominately urban (Figure 3 and Table 2). Residential area is the predominant land use in the watersheds of both AUs—62% in 0805_03 and 50% in 0805_04. Including the commercial/industrial use category brings the overall urban land use to 70% and 81%, respectively, in 0805_03 and _04.

The Upper Trinity River lies within North Central Texas, which has a subtropical climate characterized by hot summers and mild winters, resulting in a wide annual temperature range (National Weather Service (NWS), 2009). Average high temperatures generally reach their peak of 96° F between late July and mid August. Fair skies generally accompany the highest temperatures of summer, which are often above 100° F; however, the low summer temperature rarely exceeds 80° F at night (NWS, 2009). During winter, the average low temperature is 33° F in early to mid January and periods of extreme cold generally do not last long (NWS, 2009). Annual average precipitation is 34.7 inches (881 mm) of rain and 2.5 inches (64 mm) of snow.

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 serves to focus the technical work to be accomplished and as a criterion against which to evaluate future conditions.

The endpoint for the TMDLs in this report is to maintain concentrations of *E. coli* below the geometric mean criterion of 126 MPN/100 mL. This is the endpoint in the Upper Trinity River in both impaired AUs (0805_04 and 0805_03).

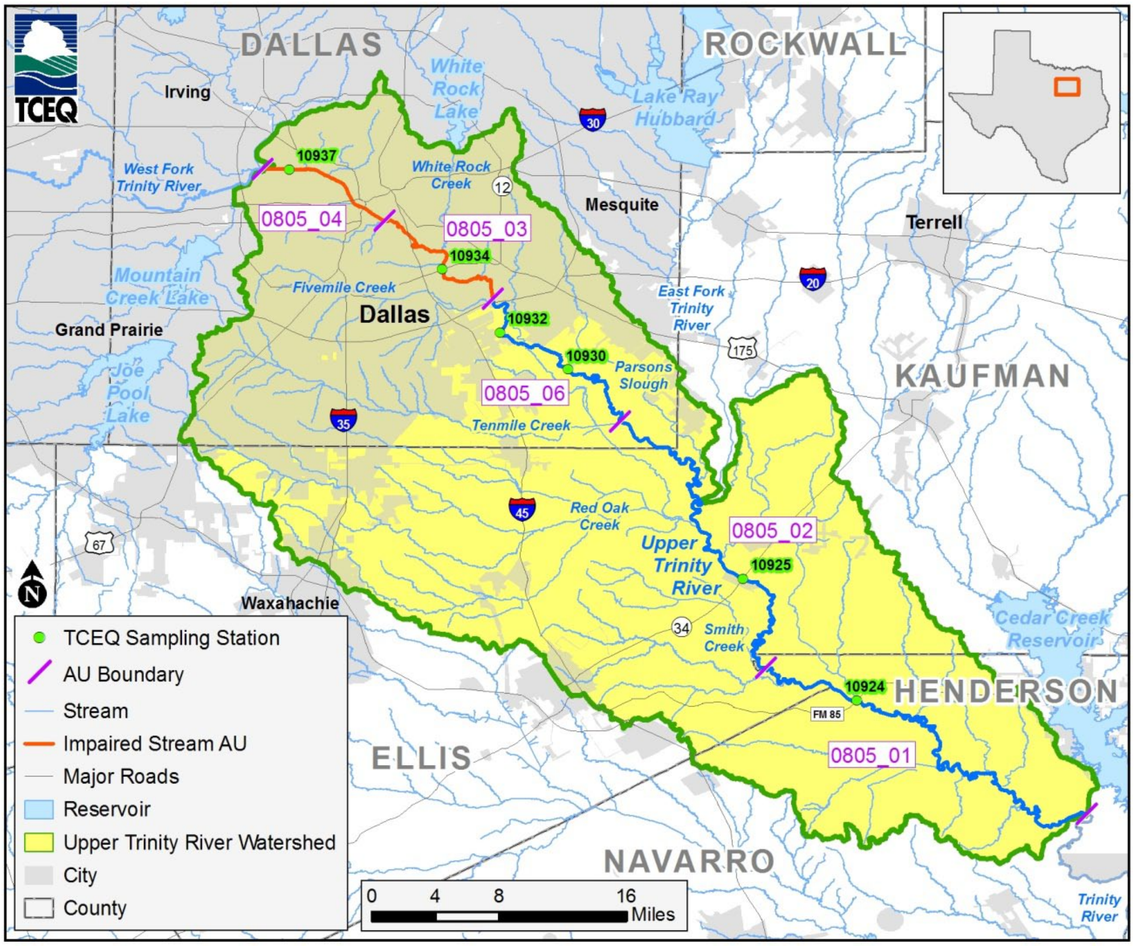

Figure 1. Map of the Upper Trinity River, Segment 0805

Table 2. Land use/land cover summaries for impaired AUs 03 and 04 of the Upper Trinity River

Aggregated Land Use Category	0805_03 Area	0805_03 % of Total	0805_04 Area	0805_04 % of Total
Commercial / Industrial	1,407	7.92	4,829	31.10
Residential	10,969	61.77	7,732	49.81
Forest	971	5.47	680	4.38
Open Water / Wetlands	2,667	15.02	852	5.49
Shrubland / Turf / Other	747	4.21	687	4.43
Native Rangeland	209	1.17	80	0.51
Improved Pasture	758	4.27	640	4.12
Row Crops	31	0.17	26	0.17
TOTAL	**17,759 hectares**	**100%**	**15,526 hectares**	**100%**

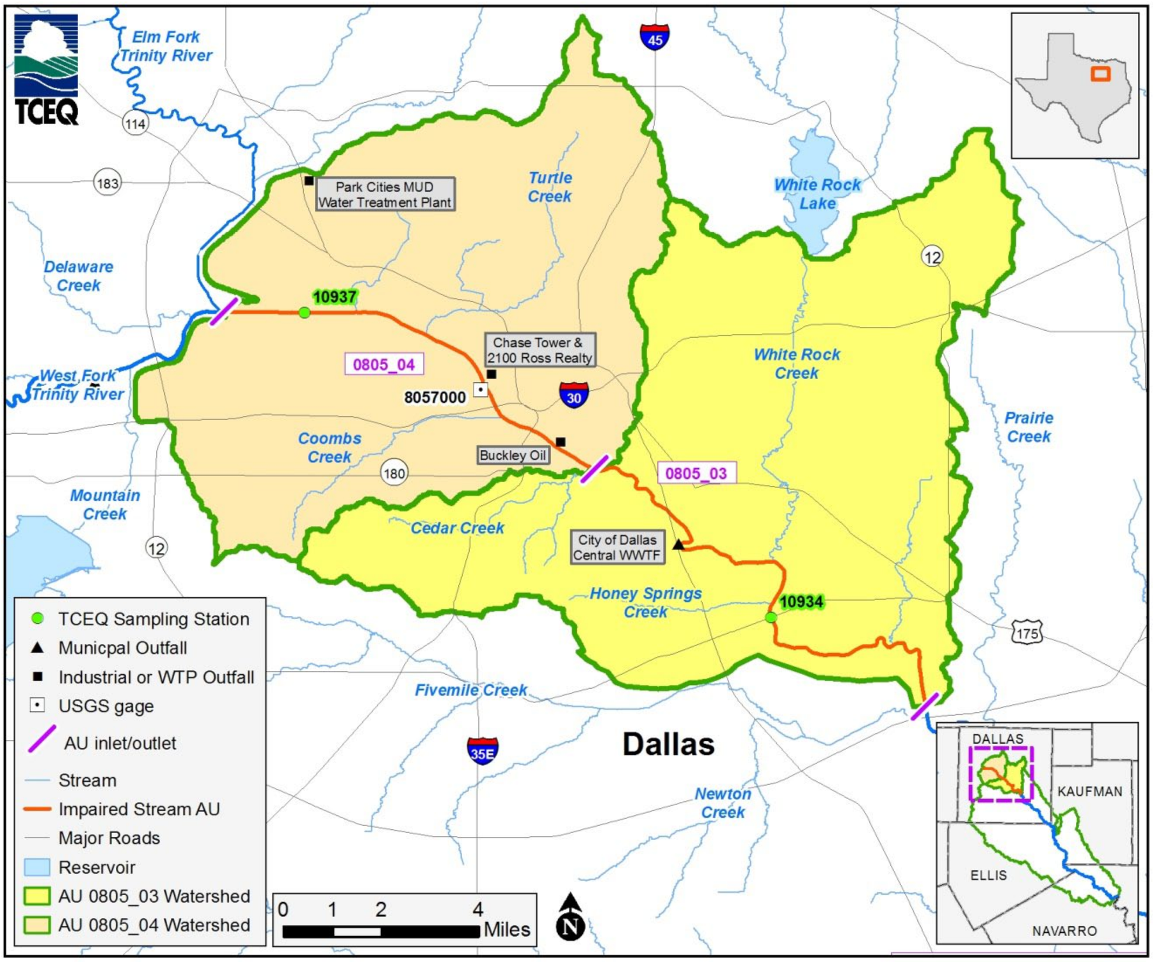

Figure 2. Impaired AUs of the Upper Trinity River (0805_03 and 0805_04)

Source Analysis

Potential sources of indicator bacteria pollution can be divided into two primary categories: *regulated* and *non-regulated*. Pollution sources that are regulated have permits under the Texas Pollutant Discharge Elimination System (TPDES) and the National Pollution Discharge Elimination System (NPDES). Examples of regulated sources include:

- municipal and private domestic wastewater treatment facility (WWTF) discharges;
- industrial facilities with individual storm water permits and/or discharging treated industrial wastewater and/or groundwater; and
- storm water discharges from industries, construction, and municipal separate storm sewer systems (MS4s).

Nonpoint source pollution originates from multiple locations, usually carried to surface waters by rainfall runoff. It is not regulated by permit under the TPDES or NPDES.

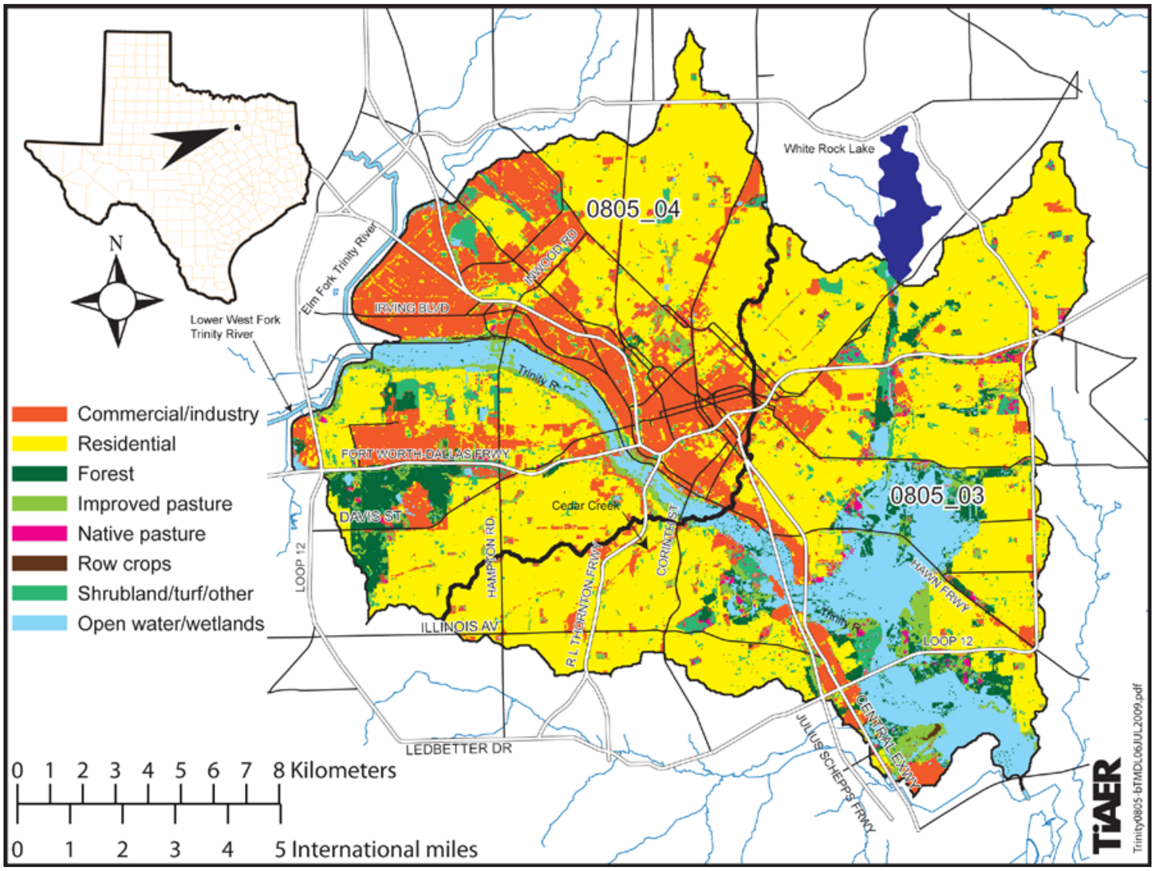

Figure 3. Land use/land cover of 0805_03 and 0805_04 of the Upper Trinity River

(Source: National Land Cover Database, 2001. <www.mrlc.gov/nlcd.php>. Accessed September 25, 2009.)

Permitted Sources

Permitted sources are regulated by permit under the TPDES and the NPDES. WWTF outfalls, industrial outfalls, and storm water discharges from industries, construction, and MS4s represent the permitted sources in impaired AUs 0805_04 and 0805_03.

Domestic and Industrial Wastewater Facilities

There are five TPDES-permitted domestic and industrial WWTFs in impaired AUs 0805_04 and 0805_03. They consist of one domestic WWTF, one water treatment plant (WTP), and three industrial facilities (Table 3). Buckley Oil Company (TPDES WQ0004663-000) discharges storm water and is discussed in the TPDES-Regulated Storm Water section of this report. The other two industrial facilities (TPDES WQ0004161-000 and WQ0004765-000) discharge treated groundwater. The WTP (TPDES WQ0014699-001) discharges treated filter backwash water.

Chase Tower and 2100 Ross Realty collect and treat groundwater seepage containing chemicals associated with an adjacent former dry cleaning facility. Permits associated with these facilities do not contain bacteria limits or disinfection requirements since they are not located in an area where failing onsite sewage facilities (OSSF) are expected to contaminant the shallow groundwater. Monitoring required as part of the 2006 permit application for Chase Tower yielded an average effluent concentration of 56 colonies/100 mL of fecal coliform. Monitoring required as part of 2009 permit application for 2100 Ross Realty resulted in “non-detect” results for *E. coli* in the effluent samples.

The Dallas County Parks Cities MUD WTP effluent is discharged to the Old Channel of the Elm Fork Trinity River more than four stream miles from the Upper Trinity River. The WTP treats surface waters not affected by industrial or domestic wastewaters. Effluent is generated from filter backwash water settling ponds where excess water is typically pumped back to the headworks of the WTP. Discharge of effluents is only conducted under emergency conditions, not on a routine basis, when the pump capacity is exceeded. Since effluents are from settling ponds where bacteria have likely settled out before discharge it is unlikely that discharge will contribute significant bacteria loads to the impaired AUs.

Table 3. Individual domestic and industrial wastewater dischargers in the TMDL area watershed

Facility Name	TPDES (NPDES)	Effluent Type	Receiving Stream AU	Full Permitted Annual Average Flow (MGD)	Average Reported Flow (MGD)[a]
City of Dallas Central	10060-001 (TX0047830)	treated domestic wastewater	0805_03	200	123.8
Buckley Oil Company	04663-000 (TX0126080)	storm water	0805_04	b	.007
Chase Tower	04161-000 (TX0119784)	groundwater	0805_04	0.155	0.139
2100 Ross Realty	04765-000 [c] 04927-000 (TX0127779)	groundwater	0805_04	0.0291	None reported
Dallas County Park Cities MUD WTP	14699-001 (TX0128686)	filter backwash water	0805_04	0.72	0.063

[a] Data are from discharge monitoring reports (DMRs) during the 2007 calendar year, which are the most recent recorded in the EPA's Permit Compliance System (PCS) database.

[b] Flow is permitted as *intermittent and variable* with a requirement to measure and report the actual amount.

[c] Permit 04765-000 expired December 1, 2009. A permit application for the same facility was received December 2, 2009 and was assigned permit number 04927-000.

Effluents from the treated groundwater and water treatment plant are only expected to contain nominal concentrations of bacteria. Additionally, their discharge flows are infrequent and minute. For these reasons, these facilities are not expected to contribute significant bacteria loads into the impaired AUs. Only the City of Dallas Central WWTF is expected to discharge bacteria into the impaired AUs. A daily wasteload was allocated for the WWTF permit expected to contribute bacteria loadings.

The City of Dallas Central WWTF (Figure 2) operates the only major WWTF discharge in the impaired AUs of the Upper Trinity River and its discharge is into 0805_03. The Central WWTF permit issued November 2007 has a permitted discharge of 200 million gallons per day (MGD). The facility is not currently required to report effluent *E. coli* data; therefore, existing *E. coli* loads from this WWTF are not estimated in the TMDL.

Sanitary Sewer Overflows

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

The TCEQ has SSO data collected from municipalities in the Upper Trinity River (Segment 0805) watershed. The SSO data from September 2003 – February 2009 is summarized in Table 4. While these data are for the urban area of all of Segment 0805, and not exclusively for 0805_04 and 0805_03, these results are informative of the nature of SSOs in the TMDL study area. There were approximately 992 SSOs reported in the Upper Trinity River watershed and they averaged 8,898 gallons per event. The volume of the median was much lower at 135 gallons per event because most SSO events are relatively small. The three largest SSOs, all of which occurred at a single location within the TMDL study area, were 1-2 orders of magnitudes larger than the next largest SSO. The two reporting entities with over 10 occurrences were the City of Dallas and the Town of Highland Park.

Within the Upper Trinity watershed there were 118 SSOs reported on March 18, 2008 alone, accounting for 12% of all SSOs. These were coincident with a large storm event (rainfall exceeded 5 in. in 48 hrs.). Corrective actions were not always reported but most commonly included containment with barricades and monitoring.

Table 4. Summary of SSO incidences reported in the Upper Trinity River watershed from September 2003 – February 2009

All volumes are in gallons.

No. of Incidences	Total Gallons*	Average Volume	Median Volume	Minimum Volume	Maximum Volume
992	8,746,294	8,898	135	3	3,167,914

* Nine incidences did not report estimated gallons.

TPDES-Regulated Storm Water

When evaluating storm water for a TMDL allocation, a distinction must be made between storm water originating from an area under a TPDES-regulated discharge permit and storm water originating from areas not under a TPDES-regulated discharge permit. Storm water discharges fall into two categories:

1) storm water subject to regulation, which is any storm water originating from TPDES Phase I and Phase II MS4-permitted discharges (Table 5), permitted industrial storm water areas, and permitted construction site areas; and
2) storm water not subject to regulation.

All of the drainage areas of 0805_04 and 0805_03 are within the city limits of the City of Dallas and included under various TPDES Phase I and II MS4 permits. Consequently, all storm water within the TMDL study area is subject to permitting.

Illicit Discharges

Bacteria loads from regulated storm water can enter the streams from permitted outfalls and illicit discharges under both dry and wet weather conditions. The term "illicit discharge" is defined in TPDES General Permit No. TXR040000 for Phase II MS4s as "Any discharge to a municipal separate storm sewer that is not entirely composed of storm water, except discharges pursuant to this general permit or a separate authorization and discharges resulting from emergency fire fighting activities." Illicit discharges can be categorized as either direct or indirect contributions. Examples of illicit discharges identified in the *Illicit Discharge Detection and Elimination Manual: A Handbook for Municipalities* (NEIWPCC, 2003) include:

Direct illicit discharges:

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

Indirect illicit discharges:

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

Table 5. Regulated storm water dischargers in AUs 0805_04 and 0805_03.

MS4 Entity	TPDES Permit Number	NPDES Permit Number
Buckley Oil Company [a]	WQ004663	TX0126080
City of Cockrell Hill	TXR040000	TXR040274
City of Dallas	WQ0004396	TXS000701
City of Highland Park	TXR040000	TXR040050
City of University Park	TXR040000	TXR040025
Dallas Area Rapid Transit	TXR040000	TXR040232
North Texas Tollway Authority	WQ0004400	TXS000703

[a] Individual industrial storm water permit included as part of the MS4 allocation (see text for details).

Unregulated Sources

Unregulated sources of indicator bacteria are generally nonpoint and can emanate from wildlife, various agricultural activities, agricultural animals, land application fields, urban runoff not covered by a permit, failing onsite sewage facilities, unmanaged feral animals, and domestic pets. Most of these unregulated sources are limited in scale in the TMDL study area because of the highly urban nature of the area.

Wildlife and Unmanaged Animal Contributions

E. coli bacteria are common inhabitants of the intestines of all warm-blooded animals, such as mammals and birds. In developing bacteria TMDLs, it is important to identify by watershed the potential for bacteria contributions from wildlife, birds, and unmanaged feral animals. 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 it may be washed into nearby streams by rainfall runoff. Avian species also frequent the watershed, particularly in its riparian corridor.

However, there are insufficient data available to reliably estimate populations and spatial distribution of wildlife and avian species in the watershed. There is also little information available on contributions from feral animals in the watershed. Consequently, it is difficult to assess the magnitude of bacteria contributions from wildlife and feral species as a general category.

Unregulated Agricultural Activities and Domesticated Animals

A number of agricultural activities that do not require permits can also be sources of fecal bacteria loading. Given the fact that the TMDL study area of the Upper Trinity River watershed is highly urbanized, livestock and other domesticated animals are either not found in the watershed or exist in very small numbers. Therefore, livestock and other domesticated animals are not considered a contributor of bacteria loads in the two impaired AUs.

Failing On-Site Sewage Facilities

Failing OSSFs were not considered a major source of bacteria loading in the TMDL study area because the entire drainage areas of AUs 0805_04 and 0805_03 are served by centralized wastewater collection and treatment systems (Figure 4). Areas serviced by centralized treatment and collection systems typically contain very few OSSFs and this is the situation for the TMDL area. The TCEQ Region 4 Office handles OSSF-related permitting and complaint investigations within the City of Dallas. Those in unincorporated areas of Dallas County are under the jurisdiction of the Dallas County Environmental Health Division (EHD). OSSF issues in other incorporated parts of the TMDL watershed are handled either by TCEQ Region 4 or by Dallas County EHD if the city has executed an agreement with the county.

Domestic Pets

Based on the urban nature of this project and the availability of relevant data, dogs and cats are the only pets considered in calculating loads for domestic pets. Fecal matter from dogs and cats is transported to streams by runoff from urban and suburban areas and can be a potential source of bacteria loading. Table 6 summarizes the estimated number of dogs and cats for the AUs of the TMDL area watershed and provides an estimate of the fecal coliform load from domestic dogs and cats.

The estimated loadings are based on estimated fecal coliform production rates of 5.4×10^8 per day for cats and 3.3×10^9 per day for dogs (Schueler 2000). Pet population estimates were calculated based on American Veterinary Medical Association (AVMA) estimated number of dogs (0.632) and cats (0.713) per household (AVMA, 2009).

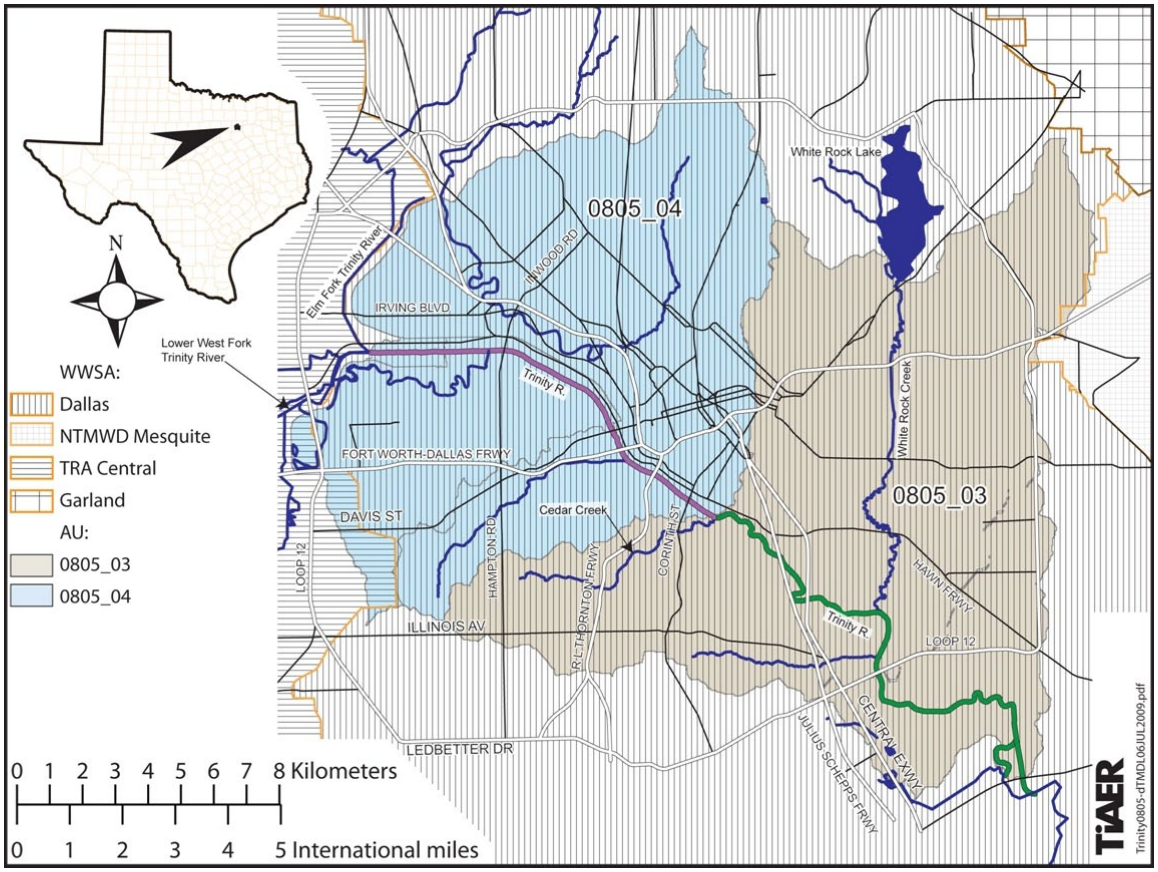

Figure 4. Centralized wastewater treatment and sewered collection areas within TMDL study area

(Data source: North Central Texas Council of Governments; WWSA = wastewater and sewered area)

Table 6. Estimated numbers of pets in the TMDL area watershed and their estimated fecal coliform daily production (x 10^9)

AU	Estimated No. of Households [a]	Estimated Number of Dogs and Cats [b]		Estimated Daily Fecal Coliform Production (billion organisms) [c]		
		Dogs	Cats	Dogs	Cats	Total
0805_04	94,475	59,709	67,361	197,038	36,375	233,413
0805_03	93,765	59,259	66,854	195,556	36,101	231,657

[a] 2005 NCTCOG population district-based estimate
[b] 2008 AVMA national per-household estimate: 0.632 dogs; 0.713 cats
[c] Schueler (2000) estimated fecal coliform load per animal per day at 3.3 x 109 dogs and 5.4 x 108 cats

The number of households was determined using North Central Texas Council of Governments (NCTCOG) 2005 household numbers by population districts (NCTCOG, 2009a&b), with the estimate based on the percentage of each district located inside each AU and an assumed even spatial distribution of households within each district. The actual contribution and significance of fecal coliform loads from pets reaching the impaired reaches of the Upper Trinity River is unknown.

Linkage Analysis

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

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

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

Load Duration Curve Analysis

Load duration curve (LDC) analyses were used to examine the relationship between instream water quality, the broad sources of indicator bacteria loads (i.e., regulated point source and regulated/unregulated storm water), and are the basis of the TMDL allocations. The strength of this TMDL is the use of the LDC method to determine the TMDL allocations.

LDCs are a simple statistical method that provides a basic description of the water quality problem. This tool is easily developed and explained to stakeholders, and uses available water quality and flow data. The LDC method does not require any assumptions regarding loading rates, stream hydrology, land use conditions, and other conditions in the watershed. The U.S. EPA supports the use of this approach to characterize pollutant sources. The TCEQ and the Texas State Soil and Water Conservation Board, identified this method as a tool for TMDL development. In addition, many other states are using this method to develop TMDLs.

The weaknesses of this method include the limited information it provides regarding the magnitude or specific origin of the various sources. Only limited information is gathered regarding point and nonpoint sources in the watershed. The general difficulty in analyzing and characterizing *E. coli* in the environment is also a weakness of this method.

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

Data requirements for the LDC are minimal, consisting of continuous daily streamflow records and historical bacteria data. While the number of observations required to develop a flow duration curve is not rigorously specified, the curves are usually based on more than five years of observations, and encompasses inter-annual and seasonal variation. Ideally, the drought of record and flood of record are included in the observations. Daily average stream flows over a period of 25 years (01 February 1981 – 31 January 2006) were used for this project.

It was necessary to estimate flows within the TMDL area since there is a lack of long-term flow data at several needed locations. Daily average flows were obtained from U.S. Geological Survey (USGS) gage 08057000 (Trinity River at Dallas) to estimate flows within AUs 0805_04 and 0805_03 based on application of drainage area ratios. For purposes of the pollutant load computations, the hydrologic records were adjusted to reflect full permitted flows from all WWTFs and future capacity estimates that account for the probability that additional flows from WWTF discharges may occur as a result of future population increases. (See Appendix A for more on development of hydrologic data.)

Flow duration curves (FDCs) and LDCs for AUs 0805_04 and 0805_03 were developed for the two TCEQ monitoring stations in the study area (10934 and 10937) and at the most upstream and downstream points (inlets and outlets) from within each AU (Figure 2). The daily flow data in units of cubic meters per second (cms) were used to first develop a flow duration curve for each station.

The flow duration curve 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). Exceedance values along the x-axis 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 high flow or flood conditions.

Bacteria LDCs were then developed based on the current numeric water quality criterion (126 MPN/100 mL) and the data from the streamflow duration curves. LDCs were developed by multiplying each streamflow value along the flow duration curves by the *E. coli* criterion (126 MPN/100 mL) and by the conversion factor to convert to loading in colonies per day. This effectively displays the LDC as the TMDL curve of maximum allowable loading:

TMDL (MPN/day) = criterion * flow (cms) * conversion factor

Where:

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

Conversion factor (to MPN/day) = 864,000,000 100 mL/m^3 * seconds/day

The resulting curve plots each bacteria load value (y-axis) against its exceedance value (x-axis). Exceedance values along the x-axis represent the percent of days that the bacteria load was at or above the allowable load on the y-axis.

Historical bacteria data were then superimposed on the allowable bacteria LDC. Historical *E. coli* data from September 2000 – January 2006 were obtained from two sources:

1) routine data collected under the TCEQ Surface Water Quality Monitoring Program and obtained from the TCEQ Surface Water Quality Management Information System (SWQMIS) database, and
2) various additional data collected by the Texas Institute of Applied Environmental Research (TIAER, the TMDL contractor selected for the Upper Trinity River TMDL Project.).

Each historical *E. coli* measurement was associated with the streamflow on the day of measurement and converted to a bacteria load.

The associated streamflow for each bacteria loading was compared to the flow duration curve data to determine its value for "percent days flow exceeded," which becomes the "percent of days load exceeded" value for purposes of plotting the *E. coli* loading. Each load was then plotted on the load duration curve at its percent exceedance. This process was repeated for each *E. coli* measurement at each station. Points above a curve represent exceedances of the bacteria criterion and its associated allowable loadings.

The flow exceedance frequency can be subdivided into hydrologic condition classes to facilitate the diagnostic and analytical uses of FDCs and LDCs. The hydrologic classification scheme utilized for the Upper Trinity River TMDL is as follows: highest flows (0 to 20%), mid-range flows (20 to 60%), and lowest flows (60 to 100%). These three flow regimes were based on hydrology (slope of the FDCs and LDCs) and patterns in the historical observations (predominance of *E. coli* loading data either above or below the allowable loading). Additional information explaining the load duration curve method may be found in Cleland (2003) and Nevada Division for Environmental Protection (NDEP) (2003).

The median loading of the highest flow regime is used for the Upper Trinity River TMDL calculation because it represents a reasonable yet high value for the allowable pollutant load allocation.

Load Duration Curve Results

At the TCEQ monitoring station locations (Figure 2), load relationships and possible sources were defined through LDCs created with historical *E. coli* data and the associated daily average flow for the flow duration curves (Figures 5 and 6). Exceedances in the historical data above the geometric mean criterion of 126 MPN/100 mL at stations 10937 and 10934 occurred at a much greater frequency for higher flows than lower flows. At both sites, the data were predominately below the geometric mean for the low flow regime, transitioning toward a greater frequency of exceedances as flows increased within the mid-range flow regime, and predominately in exceedance within the high flow regime.

The LDCs for the inlets and outlets of AUs 0805_04 and 0805_03 do not have associated historical *E. coli* data. The LDCs for the inlet and outlets of the AUs were constructed using streamflow records and a simple drainage area ratio method (see Appendix A). The LDCs used for developing the TMDL allocation for both impaired AUs is provided in Figure 7. The inlet LDC defines the upstream allowable loading entering the AU; the outlet LDC defines the allowable loading leaving the AU. The allowable loading increases in the downstream direction.

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 two methods:

- implicitly incorporating the MOS using conservative model assumptions to develop allocations; or
- explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

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

The TMDLs covered by this report incorporate an explicit MOS by setting a target for indicator bacteria loads that is 5 percent lower than the geometric mean criterion. For contact recreation, this equates to a geometric mean target of 120 MPN/100 mL of *E. coli*. The net effect of the TMDL with MOS is that the assimilative capacity or allowable pollutant loading of each water body is slightly reduced.

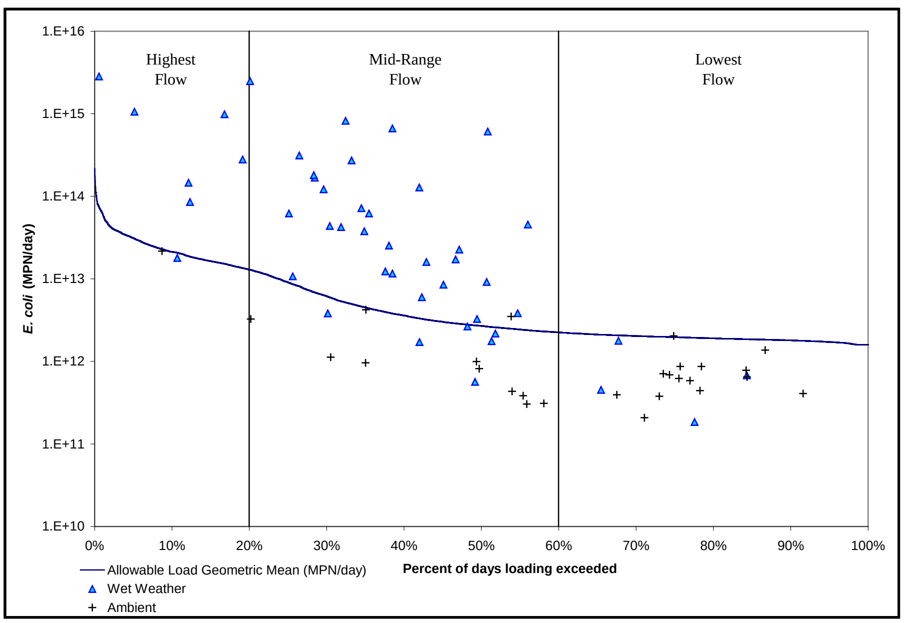

Figure 5. Load duration curve for station 10937 (AU 0805_04). *E. coli* samples collected within 4 days of a precipitation event are designated as triangles.

Median flows in each range at this station are: Highest = 6929 cfs (196.2 cms); Mid-range = 1207 cfs (34.2 cms); Lowest = 658.8 cfs (18.7 cms).

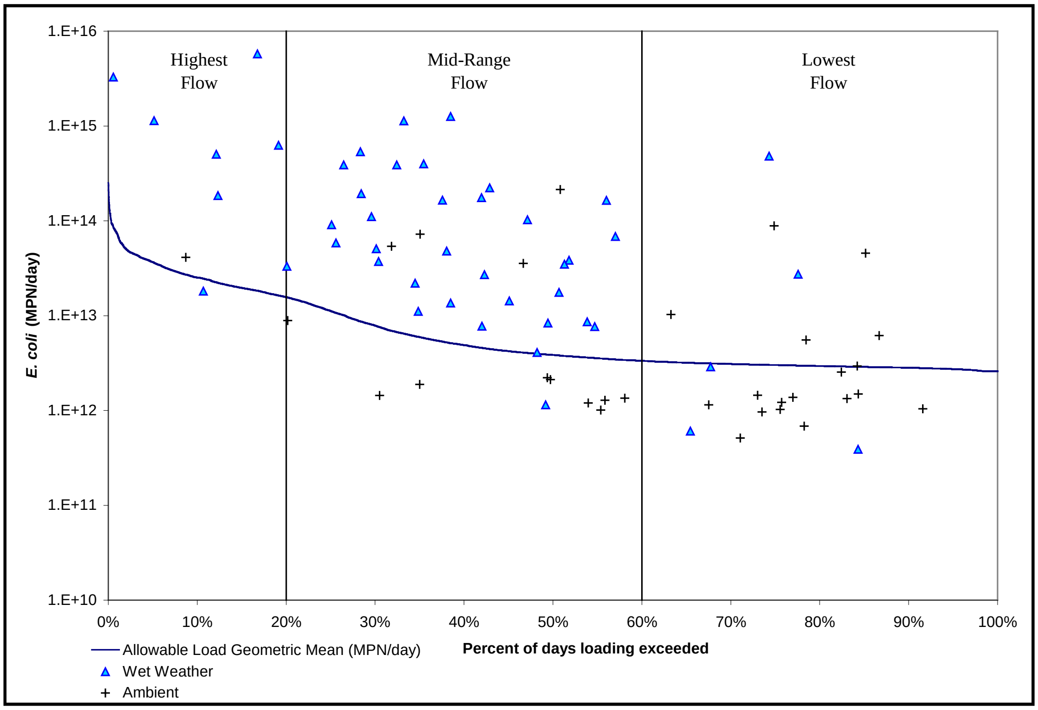

Figure 6. Load duration curve for station 10934 (AU 0805_03). *E. coli* samples collected within 4 days of a precipitation event are designated as triangles.

Median flows in each range at this station are: Highest = 8215 cfs (232.6 cms); Mid-range = 1627 cfs (46.1 cms); Lowest = 995.5 cfs (28.2 cms).

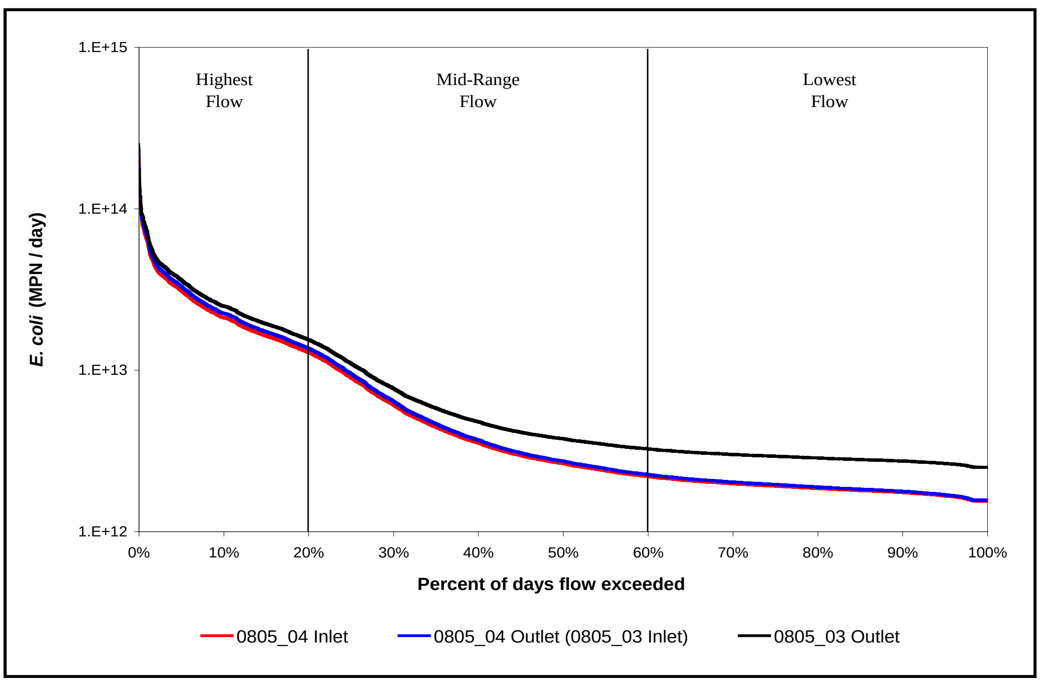

Figure 7. Load duration curves for the inlets and outlets of 0805_04 and 0805_03.

Median flow in each range for each location provided in Appendix A, Table A-3.

The explicit MOS is computed as 5 percent of the allowable loading entering each AU. This is expressed in the following equation:

$$MOS = 0.05 * (TMDL - LA_{USL})$$

Where:

TMDL = total maximum allowable load

LA_{USL} = upstream load allocations entering AU (see Load Allocation section)

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 pollutant load allocations for the selected scenarios were calculated using the following equation:

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

Where:

WLA = wasteload allocation, the amount of pollutant allowed by permitted or regulated dischargers

LA = load allocation, the amount of pollutant allowed by unregulated sources

FG = loadings associated with future growth from potential permitted 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 one-day load the stream can assimilate while still attaining the standards for surface water quality.

The bacteria TMDLs for the 303(d)-listed AUs 0805_04 and 0805_03 as covered in this report were derived using LDCs developed for the outlet of each AU. The estimated maximum allowable loads of *E. coli* for each of the AUs was determined as that corresponding to the median flow within the high flow regime.

Wasteload Allocation

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

$$WLA_{WWTF} = Criterion/2 * flow (MGD) * conversion factor$$

Where:

Criterion = 126 MPN/100 mL

Flow (MGD) = full permitted flow

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

In 0805_03, there is only one facility, Dallas Central WWTF (TPDES WQ0010060-001), and it represents the entire WLA_{WWTF} allocation in that AU. AU 0805_04 contains no WWTFs, but does contain three permitted industrial facilities and one permitted domestic water treatment plant. Based on the effluent type of these facilities (see Table 3), daily waste loads were not allocated for these permits and permit limits for bacteria are not anticipated to be necessary for them.

Additional storm water dischargers represent additional flow that is not accounted for in the current allocations. In urbanized areas currently regulated by an MS4 permit, development and/or re-development of land in urbanized areas must implement the control measures/programs outlined in an approved Storm Water Pollution Prevention Plan (SWPPP). 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 BMPs as specified in both the NPDES permit and the SWPPP.

An iterative, adaptive management approach will be used to address storm water 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.

Storm water discharges from MS4, industrial, and construction areas are considered permitted point sources. Therefore, the WLA calculations must also include an allocation for permitted storm water discharges (WLA_{SW}). A simplified approach for estimating the WLA for these areas was used in the development of these TMDLs due to the limited amount of data available, the complexities associated with simulating rainfall runoff, and the variability of storm water loading. The percentage of each watershed that is under the jurisdiction of storm water permits is used to estimate the amount of the overall runoff load that should be allocated in the WLA_{SW} as the permitted storm water contribution.

The LA component of the TMDL corresponds to direct nonpoint runoff and is the difference between the total load from storm water runoff and the portion allocated to WLA_{SW}. Thus, WLA_{SW} is the sum of loads from regulated (or permitted) storm water sources and is calculated as follows:

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

Where:

ΣWLA_{SW} = sum of all permitted storm water loads
TMDL = total maximum allowable load
ΣWLA_{WWTF} = sum of all WWTF loads
LA_{USL} = upstream load allocations entering AU (see Load Allocation section below)
ΣFG = sum of future growth loads from potential permitted facilities
MOS = margin of safety load
FDA_{SWP} = fractional proportion of drainage area under jurisdiction of storm water permits

The TCEQ intends to implement the individual WLAs through the permitting process as monitoring requirements and/or effluent limitations as required by the amendment of 30 Texas Administrative Code Chapter 319 which became effective November 26, 2009. WWTFs discharging to the TMDL Segment AUs will be assigned an effluent limit based on the TMDL. Monitoring requirements are based on permitted flow rates and are listed in §319.9. The permit requirements will be implemented during the routine permit renewal process. However, there may be a more economical or technically feasible means of achieving the goal of improved water quality and circumstances may warrant changes in individual WLAs after this TMDL is adopted. Therefore, the individual WLAs, as well as the

WLAs for storm water, are non-binding until implemented via a separate TPDES permitting action, which may involve preparation of an update to the state's Water Quality Management Plan. Regardless, all permitting actions will demonstrate compliance with the TMDL.

The executive director or commission may establish interim effluent limits and/or monitoring-only requirements at a permit amendment or permit renewal. These interim limits will allow a permittee time to modify effluent quality in order to attain the final effluent limits necessary to meet the TCEQ and EPA approved TMDL allocations. The duration of any interim effluent limits may not be any longer than three years from the date of permit re-issuance. New permits will not contain interim effluent limits because compliance schedules are not allowed for a new permit.

Where a TMDL has been approved, domestic WWTF TPDES permits will require conditions consistent with the requirements and assumptions of the wasteload allocations. For NPDES/ TPDES-regulated municipal, construction storm water discharges, and industrial storm water discharges, water quality-based effluent limits that implement the WLA for storm water may be expressed as best management practices (BMPs) or other similar requirements, rather than as numeric effluent limits (November 12, 2010, memorandum from EPA relating to establishing WLAs for storm water sources). The EPA memo states that:

> "The CWA provides that storm water permits for MS4 discharges shall contain controls to reduce the discharge of pollutants to the "maximum extent practicable" and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants. CWA section 402(p)(3)(8)(iii). Under this provision, the NPDES permitting authority has the discretion to include requirements for reducing pollutants in storm water discharges as necessary for compliance with water quality standards. Defenders of Wildlife v. Browner, 191 F.3d 1159, 1166 (9th Cir. 1999).
>
> The permitting authority's decision about how to express the water quality-based effluent limitations (WQBELs)—either as numeric effluent limitations or BMPs, including BMPs accompanied by numeric benchmarks—should be based on an analysis of the facts and circumstances surrounding the permit, and/or the underlying WLA. The decision should include factors such as the nature of the storm water discharge, available data, modeling results or other relevant information. As discussed in the 2002 memorandum, the permit's administrative record needs to provide an adequate demonstration that, where a BMP-based approach to permit limitations is selected, the BMPs required by the permit will be sufficient to implement applicable WLAs. Improved knowledge of BMP effectiveness gained since 2002 should be reflected in the demonstration and supporting rationale that implementation of the BMPs will attain water quality standards and WLAs."

The November 22, 2002, memorandum from EPA relating to establishing WLAs for storm water sources states that:

> "...the Interim Permitting Approach Policy recognizes the need for an iterative approach to control pollutants in storm water discharges...[s]pecifically, the policy anticipates that a suite of BMPs will be used in the initial rounds of permits and that these BMPs will be tailored in subsequent rounds."

Using this iterative adaptive approach to the maximum extent practicable is appropriate to address the storm water component of this TMDL.

This TMDL is, by definition, the total of the sum of the wasteload allocation, the sum of the load allocation, and the margin of safety. Changes to individual WLAs may be necessary in the future in order to accommodate changing conditions within the watershed. These changes to individual WLAs do not ordinarily require a revision of the TMDL document; instead, changes will be made through updates to the TCEQ's WQMP. Any future changes to effluent limitations will be addressed through the permitting process and by updating the WQMP.

Load Allocation

The load allocation (LA) is the sum of loads from unregulated sources. The LA is the sum of the upstream bacteria load (LA_{USL}) entering the AU and all remaining loads in the AU from unregulated sources (LA_{AU}):

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

Where:

LA = allowable load from unregulated sources (predominately nonpoint sources)
LA_{AU} = allowable loads from unregulated sources within the AU
ΣLA_{USL} = upstream load allocations entering the AU

The LA_{USL} is calculated as:

$$LA_{USL} = Q_{inlet} * \text{criterion}$$

Where:

Criterion = 126 MPN/100 mL
Q_{inlet} = median value of the high flow regime entering the AU

The LA_{AU} is calculated as:

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

Where:

LA_{AU} = allowable load from unregulated sources within the AU
TMDL = total maximum allowable load
ΣWLA_{WWTF} = sum of all WWTF loads
ΣWLA_{SW} = sum of all permitted storm water loads
LA_{USL} = upstream load allocations entering AU
ΣFG = sum of future growth loads from potential permitted facilities
MOS = margin of safety load

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

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

In addition, the three-tiered antidegradation policy in the Standards prohibits an increase in loading that would cause or contribute to degradation of an existing use. The antidegradation policy applies to both point and nonpoint source pollutant discharges. In general, antidegradation procedures establish a process for reviewing individual proposed actions to determine if the activity will degrade water quality. The TMDLs in this document will result in protection of existing beneficial uses and conform to Texas's antidegradation policy.

Future Growth

To account for the probability that additional flows from WWTF discharges may occur in both AUs, a provision for future growth was included in the TMDL calculations based on the population increase from year 2005 estimates to year 2030 projections and an estimate of the amount of wastewater generated per person per day or gallons per capita per day (gpcd). Wastewater treatment for the City of Dallas is provided by two large facilities—the Central WWTF in AU 0805_03 and the Southside WWTF, which discharges into the Upper Trinity River downstream of the impaired AUs. The sewered collection areas of both facilities include a greater area than the 0805_04 and 0805_03 drainage areas. The collection areas also include a significant area serviced jointly by both facilities, which complicates the estimate of additional WWTF discharges due to future growth.

Using a conservative approach for the TMDL, it is assumed that all estimated future growth associated with the sewered collection area of the Dallas Central WWTF results in future growth in both AUs. The future growth computation includes: calculating the estimated increase in future capacity required for the sewered collection area of the present Dallas Central WWTF using available data (NCTCOG, 2009a&b); proportioning the future capacity between AUs 0805_04 and 0805_03; and the final computation to determine an *E. coli* loading for future capacity.

Future capacity (FC), in MGD, is calculated as follows:

$$FC = Flow_{2005} * Pop_{05/30} * [DC_{permit} / (DC_{permit} + DS_{permit})] * \text{conversion factor}$$

Where:

$Flow_{2005}$ = gallons per capita per day based on the average combined discharges of Dallas Central and Dallas Southside WWTFs from year 2005 Discharge Monitoring Report (DMR) data divided by the year 2005 Dallas wastewater collection area population estimate

$Pop_{05/30}$ = Dallas wastewater collection area population increase for 2005 to 2030

DC_{permit} = Full permitted discharge of Dallas Central WWTF

DS_{permit} = Full permitted discharge of Dallas Southside WWTF

Conversion factor = 0.000001 MGD/gpcd

In the next step, the computed future capacity is apportioned to the two impaired AUs based on the fraction of the drainage area of each AU to the combined drainage area of the two AUs. The estimated future growth term is then calculated as follows:

$$FG = Criterion/2 * FC\ (MGD) * FDA_{AU} * \text{conversion factor}$$

Where:

Surface water quality standard = 126 MPN/100 mL

FC = future capacity calculated from preceding equation in MGD

FDA_{AU} = fraction of the each AU's drainage area to combined drainage areas

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

Additional storm water dischargers represent additional flow that is not accounted for in the current allocations. Changes in MS4 jurisdiction or additional development associated with population increases in the watershed can be accommodated by shifting allotments between the WLA and the LA. This can be done without the need to reserve future-capacity WLAs for storm water. In non-urbanized areas, growth can be accommodated by shifting loads between the LA and the WLA (for storm water).

TMDL Calculations

The TMDL was calculated based on the median flow in the 0-20 percentile range (highest flow regime) from the LDC developed for the outlet of each AU (Figure 7). Each term in the TMDL equation was determined based on the equations provided previously.

Table 7 summarizes the calculation of the TMDL and LA_{USL} terms for each AU. Table 8 summarizes the WLA_{WWTF} for the TPDES-permitted facility within the study area. Compliance is achieved when the discharge limits are met. Table 8 does not provide wasteload allocations for permitted facilities not expected to contribute bacteria loadings. The future growth component for AU 0805_04 of the TMDL will be available to the permitted facilities if future in-steam monitoring indicates the need for specific wasteload allocations. Because the entire drainage areas of both 0805_04 and 0805_03 are under the jurisdiction of storm water permits, storm water loadings originating from unregulated areas within each AU (LA_{UA}) are zero and all storm water loadings are assigned to WLA_{SW}.

Table 9 summarizes the computation of future capacity for the combined AUs. The computation of future growth for AUs 0805_04 and 0805_03 is summarized in Table 10.

Table 11 summarizes the TMDL calculations for AUs 0805_04 and 0805_03. The final TMDL allocations needed to comply with the requirements of 40 CFR 130.7 are presented in Table 12. In Table 12, the future capacity for WWTF has been added to the WLA_{WWTF} and LA_{AU} and LA_{USL} have been added to give LA. The allocations for WLA_{WWTF} are based on one-half of the water quality criterion for *E. coli* in freshwater of 126 MPN/100 mL.

Table 7. Summary of TMDL and LA_{USL} calculations for each AU

Loading is expressed as Billion MPN/day

AU	Receiving Water	Upstream Allowable Loading Q_{inlet}[a] (cms)	Upstream Allowable Loading LA_{USL}[b]	Downstream Allowable Loading Outlet Flow[c] (cms)	Downstream Allowable Loading TMDL[d]
0805_04	Upper Trinity River	195.75 (6913 cfs)	21,310	210.23 (7424 cfs)	22,890
0805_03	Upper Trinity River	210.23 (7424 cfs)	22,890	235.54 (8318 cfs)	25,640

[a] Inlet median value from highest flow regime
[b] Inlet allowable loading; median value from highest flow regime (Figure 7)
[c] Outlet median value from highest flow regime
[d] Outlet allowable loading; median value from highest flow regime (Figure 7)

Table 8. Wasteload allocations for TPDES-permitted facilities

Receiving Water	AU	TPDES Number	NPDES Number	Facility Name	Final Permitted Flow (MGD)	WLA_{WWTF} (Billion MPN/day)
Upper Trinity River	0805_04[a]	—	—	—	—	0
Upper Trinity River	0805_03	10060-001	TX0047830	Dallas Central	200	477.0

[a] Wasteload allocations are not provided for TPDES WQ0004161-000, WQ0004663-000, WQ0004765-000, and WQ0014699-001.

In the event that the criteria change due to future revisions in the state's surface water quality standards, Appendix B provides guidance for recalculating the allocations in Table 12. Figures B-1 and B-2 of Appendix B were developed to demonstrate how assimilative capacity, TMDL calculations, and pollutant load allocations change in relation to a number of hypothetical water quality criteria for *E. coli*. The equations provided, along with Figures B-1 and B-2, allow calculation of new TMDLs and pollutant load allocations based on any potential new water quality criterion for *E. coli*.

Table 9. Future capacity calculations for impaired AUs

2005 Wastewater Flow (gpcd)	Population Increase 2005 to 2030	Dallas Central Full Permitted Flow (MGD)	Dallas Southside Full Permitted Flow (MGD)	Future Capacity of Impaired AUs (MGD)
153	151,106	200	110	14.9

Table 10. Future growth calculations for AUs 0805_04 and 0805_03

Receiving Water	AU	Percent of Combined Drainage Area	Apportioned Future Capacity (MGD)	Future Growth(Billion MPN/day)
Upper Trinity River	0805_04	46.64%	6.950	16.57
	0805_03	53.36%	7.950	18.96

Table 11. *E. coli* TMDL summary calculations for the Upper Trinity River AUs 0805_04 and 0805_03

All loads expressed as Billion MPN/day

AU	TMDL[a]	WLA_{WWTF}[b,c]	WLA_{SW}[d]	LA_{AU}[e]	LA_{USL}	MOS[h]	Future Growth[i]
0805_04	22,890	0	1,480	0	21,310[f]	78.79	16.57
0805_03	25,640	477.0	2,123	0	22,890[g]	137.8	18.96

[a] TMDL = Median flow (high flow regime) * Criterion (126 MPN/100 mL) * Conversion Factor; where the Conversion Factor = 8.64×10^8 100 mL/m^3 * seconds/day; Median Flow from Table 7

[b] No WWTF discharges into AU04

[c] Loads from the Dallas Central WWTF calculated as Permitted Flow (MGD) * Conversion Factor * Criterion/2 (63 MPN/day); where Permitted Flow = 200 MGD; Conversion Factor = 3.7854×10^7 100 mL/MGD

[d] WLA_{SW} = (TMDL - WLA_{WWTF} - LA_{USL} - FG - MOS) * FDA_{SWP}; where FG = future growth loads from potential permitted facilities and FDA_{SWP} (fractional proportion of drainage under jurisdiction of storm water permits) = 1.000

[e] LA_{AU} = TMDL - MOS - WLA_{WWTF} - WLA_{SW} - LA_{USL} - FG; because the entire drainage area of AU04 and AU03 is covered by MS4 permits the LA_{AU} = 0.000

[f] LA_{USL} = Q_{inlet} * Criterion (126 MPN/day) * Conversion Factor; where Q_{inlet} is from Table 7 for 0805_04; the Conversion Factor = 8.64×10^8 100 mL/m^3 * seconds/day

[g] LA_{USL} = Q_{inlet} * Criterion (126 MPN/day) * Conversion Factor; where Q_{inlet} is from Table 7 for 0804_03; the Conversion Factor = 8.64×10^8 100 mL/m^3 * seconds/day

[h] MOS = 0.05 * (TMDL - LA_{USL})

[i] Future Growth = surface water quality standard/2 (63 MPN/day) * FC (MGD) * FDA_{AU} * Conversion Factor; where FC is from Table 9, FDA_{AU} is from Table 10; Conversion Factor = 3.7854×10^7 100 mL/MGD

Table 12. Final TMDL allocations

All loads expressed as Billion MPN/day

AU	TMDL[a]	WLA_{WWTF}[a]	WLA_{SW}	LA[b]	MOS
0805_04	22,890	16.57	1,480	21,310	78.79
0805_03	25,640	495.96	2,123	22,890	137.8

[a] WLA_{WWTF} = WLA_{WWTF} + Future Growth
[b] LA = LA_{AU} + LA_{USL}

Seasonal Variation

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. No statistically significant seasonal variation was found in *E. coli* data examined in Upper Trinity River (Millican and Hauck, 2008). Consequently, seasonal variation is not considered in the TMDL calculations.

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.

TCEQ is providing coordination for public participation in this project. A series of public meetings have been conducted over recent years to keep the public aware of the TMDL process and to engage public participation. Public meetings were held at the North Central Texas Council of Governments in Arlington on November 15, 2005, March 20, 2007, July 18, 2007, and March 12, 2008. A meeting was also held December 1, 2005 at the Ennis Public Library and on January 12, 2010, at ECO Park in Dallas.

The meetings introduced the TMDL process, identified the impaired AUs and reason for the impairment, reviewed historical data, and described potential sources of bacteria within the watershed. In addition, the meetings gave TCEQ the opportunity to solicit input from all interested parties within the study area. Information on past and future meetings for the Upper Trinity Bacteria TMDL can be found on the TCEQ website at: <www.tceq.texas.gov/implementation/water/tmdl/66-trinitybacteria.html>.

Implementation and Reasonable Assurances

The issuance of permits consistent with TMDLs through TPDES provides reasonable assurance that wasteload allocations in this TMDL report will be achieved. Consistent with federal requirements, each TMDL is a plan element of an update to Texas' WQMP.

The TCEQ's 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.

Based on the TMDL and Implementation Plan (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. BMPs 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 storm water permit through an effluent limitation update. Rather, the TCEQ might revise a storm water permit, require a revised Storm Water Management Program or Pollution Prevention Plan, or implement other specific revisions affecting storm water dischargers in accordance with an adopted I-Plan.

Strategies for achieving pollutant loads in TMDLs from both point and 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. EPA does not approve I-Plans for Texas TMDLs.

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 I-Plan begins during development of TMDLs, but the plan is not completed until sometime after the EPA approves the TMDLs. The cooperation required to develop an I-Plan for approval by the commission becomes a cornerstone for the shared responsibility necessary for carrying out the plan.

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 adopted may not approximate the predicted loadings identified category-by-category in the TMDL and its underlying assessment. However, with certain exceptions, the I-Plan must nonetheless meet the overall loading goal established by the EPA-approved TMDL.

The NCTCOG is working with the TCEQ to lead development of the I-Plan. Through the stakeholder group led by the NCTCOG, the resources and expertise of the local organizations and individuals will be brought together to set priorities, provide flexibility, and consider appropriate social and economic factors.

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Appendix A.
Daily Streamflow Record Development

Introduction and Background

This appendix presents the development of the daily streamflow (or hydrologic) records and FDCs, which form the bases of the LDCs within this report. Determination of the length of hydrologic record used in the FDCs is described in Millican and Hauck (2008). The selected period was the 25 years from February 1, 1981 through January 31, 2006.

The USGS operates two streamflow gages in the study area, which provide extended periods of daily hydrologic records suitable for use in development of FDCs and LDCs. USGS gage 08057000 (Trinity River at Commerce Street in Dallas, Texas) is located within 0805_04 and has an associated daily streamflow record from 1902 to the present. USGS gage 08057410 (Trinity River at South Loop 12 below Dallas, Texas) is located within 0805_03 and has an associated streamflow record from 1956 to the present with a data gap from October 1, 1999 through September 30, 2002. Because of the gap in the streamflow record at gage 08057410, the data from this location were not considered optimal for the needs of this project. Therefore, the daily streamflow record from USGS gage 08057000 for the period February 1981 through January 2006 was used to develop the required FDCs.

For development and application of FDCs and LDCs under for the 25-year time period stipulated in this study, a daily streamflow record must be estimated for each desired location, which included two TCEQ monitoring stations and the most upstream and downstream points (inlets and outlets) from within each AU (Figure A-1). The required streamflow records were developed at each needed location from the USGS gage 0805700 daily record using a simple drainage area ratio (DAR) method. Under the DAR method, the hydrologic record at a location on the Trinity River can be estimated as the ratio of the drainage area of that location to the reference drainage area (drainage area of USGS gage 08057700) multiplied by each daily streamflow value in the 25-year record. The DAR method assumes similarity of streamflow contribution by area, which is a reasonable assumption in this situation because of common watershed areas of each location to that of the watershed above the USGS gage, and because the highly urbanized nature of the area means there are no major land use differences throughout the watershed.

The DAR method is best applied to that portion of each daily streamflow record that does not include point source contributions, such as from municipal WWTFs, as the method inherently presumes that the adjusted streamflow is a function solely of drainage area and is directly proportional to the size of the drainage area. Consequently, if a streamflow record is known to be influenced by upstream point sources, these point-source originating flows should be removed from the portion of the record to which the DAR is applied.

The effluent from three major municipal WWTFs with permitted annual average discharges of well over one MGD each are upstream of various portions of 0805_04 and 0805_03. The City of Fort Worth Village Creek WWTF and the Trinity River Authority Central Regional Facility discharge into the West Fork Trinity River upstream of the study area, and the City of Dallas Central WWTF discharges into 0805_03 (Table A-1). Monthly average discharge information was available from DMR data for each of these WWTFs for the selected 25-year period.

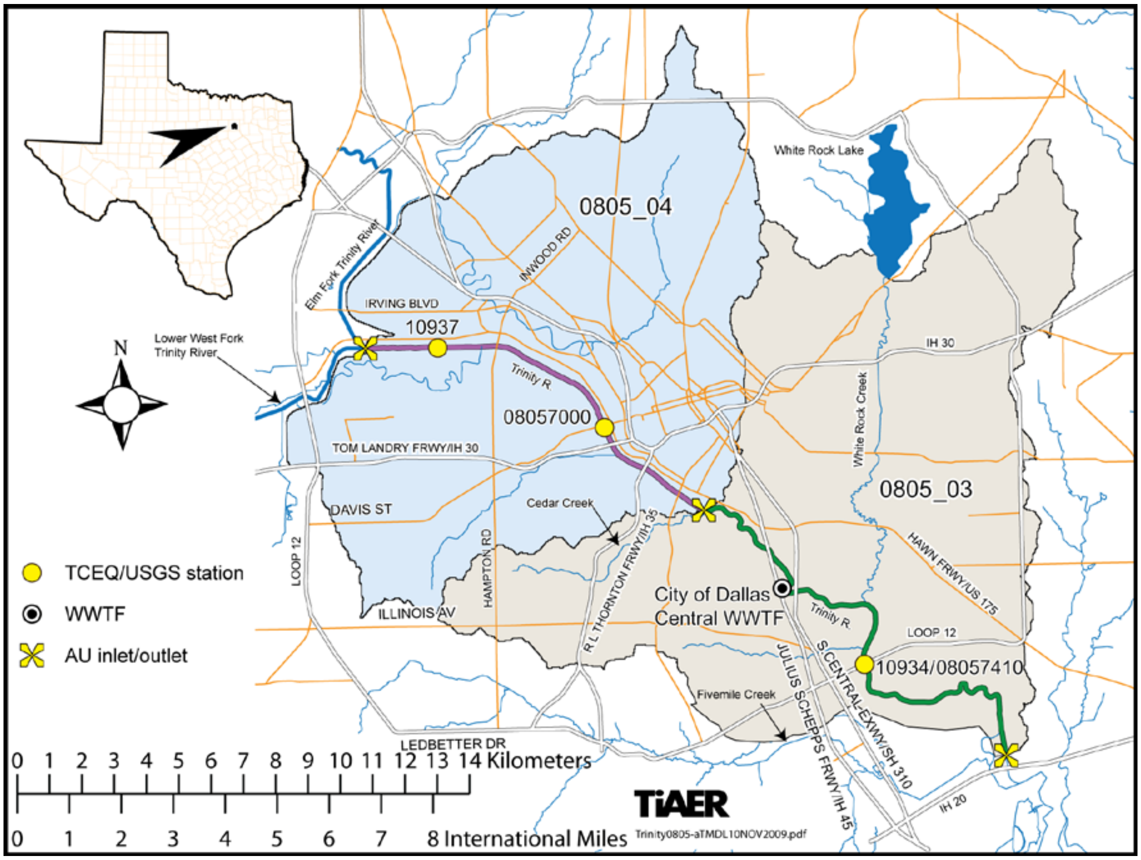

Figure A-1. Impaired AUs of the Upper Trinity River (0805_04 and 0805_03) showing key locations

Table A-1. Major domestic WWTFs influencing study area. (permitted values as of Nov. 2007)

Permit No. (TCEQ/EPA)	Permittee	Facility Name	Receiving Stream (Segment ID)	Permitted Annual Average Flow (MGD)
WQ0010494-13 TX0047295	City of Fort Worth	Village Creek WWTF	West Fork Trinity River	166
WQ0010303-001 TX0022802	Trinity River Authority	Central Regional WWTF	West Fork Trinity River	189
WQ0010060-001 TX0047830	City of Dallas	Central WWTF	Upper Trinity River	200

Develop Daily Streamflow Records

Using the selected hydrologic period of record and station locations, the next step was to develop the 25-year daily streamflow record for each station. The daily streamflow records were developed from the USGS gage 08057000 records modified by the imposition of certain rules necessitated by hydrologic complicating factors. The following factors complicate the use of USGS streamflow records in the DAR method:

- Large reservoirs on several tributaries to the Upper Trinity River not only highly affect downstream hydrology, but also effectively reduce bacteria concentrations in releases because of their large detention times and enhanced conditions over typical run-of-river conditions for bacterial settling and die-off.

- The discharge locations of three large WWTFs influence the streamflow within the study area with two implications. First, their flow contribution should be removed from the analysis prior to applying the DAR method. Second, Dallas Central WWTF, which is located within 0805_04, should be evaluated at its full permitted daily average discharge limits within the TMDL allocation process.

The following step-wise procedure was used to apply the DAR method accounting for the complicating factors.

Step 1: Calculate Appropriate Drainage Area Ratios Considering Reservoirs

To address the complications imposed by the presence of reservoirs, the drainage-area ratio method was applied excluding the drainage area above major reservoirs from the computation, since these reservoirs substantively reduce immediately downstream flows under most hydrologic conditions. As labeled on Figure A-2, the reservoirs affecting the ratios were Lake Worth, Benbrook Lake, Marine Creek Lake, Lake Arlington, Mountain Creek Lake, Lake Grapevine, Lake Lewisville, and White Rock Lake. Drainage area computations were based on the Digital Elevation Models (DEM) data of the USGS (GeoCommunity™, 2006). Individual drainage areas were developed using the Geographic Information System (GIS) interface called AVSWATX (Di Luzio et al., 2004), and the areas with the drainage areas above the major reservoirs excluded are provided in Table A-2.

Step 2: Correct Reference Streamflow Record for Actual WWTF Discharges

To compensate for the complication from two upstream WWTF discharges (Fort Worth Village Creek WWTF and Trinity River Authority (TRA) Central Regional WWTF), that portion of the reference streamflow originating from these two point sources was removed (subtracted) and a corrected daily streamflow record was developed prior to applying the drainage area ratio. Because accuracy of the drainage area ratio is dependent upon similarity of hydrologic response based on similarity of landscape features such as geomorphology, soils, and land use/land cover, point source derived flows should be removed from the flow record prior to application of the ratio. Typically, only DMR monthly average discharge values were available for most periods recorded for the WWTFs; however, in recent years, limited daily discharge data were available in DMRs. Monthly DMR data were obtained from the TCEQ, and a small portion of DMR discharge data were also obtained from the EPA Enforcement and Compliance History Online database (<www.epa-echo.gov/echo/>). When only monthly discharge data were available, that average was applied to each day of the month. When the subtraction process resulted in negative numbers, that daily flow was set to zero. The equation to develop the corrected referenced daily streamflow is as follows:

$$Q_{R,C} = Q_R - Q_{V,R} - Q_{T,R} \qquad \text{if } Q_{R,C} < 0.0\text{, then } Q_{R,C} = 0.0$$

Where:

$Q_{R,C}$ = corrected referenced daily flow at Trinity River at Dallas, TX (gage 08057000)

Q_R = referenced daily flow at Trinity River at Dallas, TX (gage 08057000)

$Q_{V,R}$ = DMR flow (discharge) for Fort Worth Village Creek WWTF

$Q_{T,R}$ = DMR flow (discharge) for TRA Central Regional WWTF

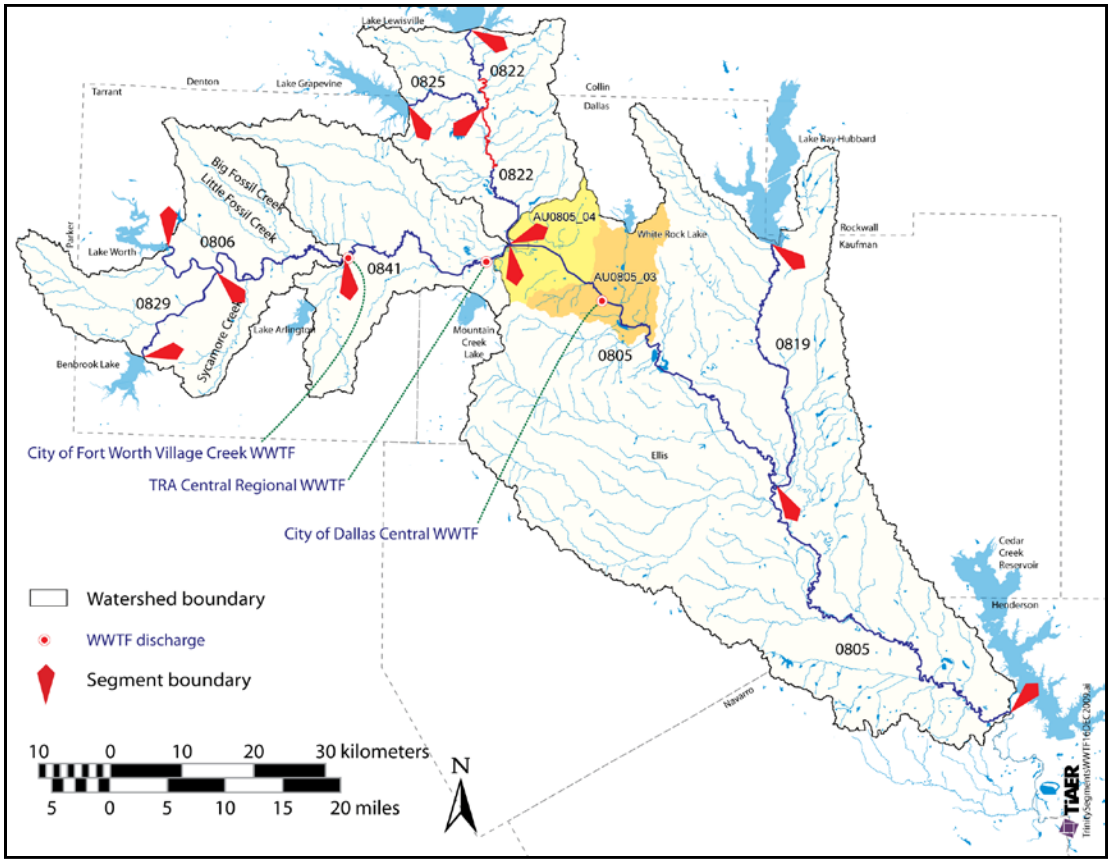

Figure A-2. Upper Trinity River and major tributaries showing large wastewater treatment facilities and study area

Table A-2 Drainage area ratios used to develop flow duration curves

Location Description	Drainage Area[a] (km^2)	DAR
Inlet to 0805_04	1,974.3	DAR_1 = 0.9796
TCEQ Station 10937	1,976.1	DAR_2 = 0.9805
Reference Location: USGS gage 08057000	2,015.4	—
Outlet of 0805_04 / Inlet to 0805_03	2,129.5	DAR_3 = 1.0566
TCEQ Station 10934	2,275.3	DAR_4 = 1.1289
Outlet to 0805_03	2,307.1	DAR_5 = 1.1448

[a] The drainage areas above major reservoirs are excluded

Step 3: Apply DARs and Add Full Permitted WWTF Discharges

To account for WWTFs at their daily permitted discharge limit, as required in the TMDL, the DAR method was applied at each location. To that calculated streamflow record, the permitted daily average discharges from upstream WWTFs were added, including future growth. Future growth represents estimates that account for the probability of additional flows from WWTF discharges that may occur with future population increases. The following equations provide the basis of developing the final daily flows needed for FDC development:

0805_04 Inlet Equation ($Q_{inlet04}$):

$$Q_{inlet04} = DAR_1 * Q_{R,C} + Q_{V,FP} + Q_{T,FP}$$

TCEQ Station 10937 (Q_{10937}):

$$Q_{10937} = DAR_2 * Q_{R,C} + Q_{V,FP} + Q_{T,FP} + Q_{FG04}$$

0805_04 $_{Outlet}$ (0805_03 $_{Inlet}$) Equation ($Q_{outlet04}$):

$$Q_{outlet04} = DAR_3 * Q_{R,C} + Q_{V,FP} + Q_{T,FP} + Q_{FG04}$$

TCEQ Station 10934 Equation (Q_{10934}):

$$Q_{10934} = DAR_4 * Q_{R,C} + Q_{V,FP} + Q_{T,FP} + Q_{D,FP} + Q_{FG04} + Q_{FG03}$$

0805_03 Outlet Equation ($Q_{outlet03}$):

$$Q_{outlet03} = DAR_5 * Q_{R,C} + Q_{V,FP} + Q_{T,FP} + Q_{D,FP} + Q_{FG04} + Q_{FG03}$$

Where:

DAR_i = drainage area ratio for location i as found in Table A-2
$Q_{R,C}$ = corrected referenced daily flow at gage 08057000
$Q_{V,FP}$ = full permitted flow (discharge) for Fort Worth Village Creek WWTF
$Q_{T,FP}$ = full permitted flow (discharge) for TRA Central Regional WWTF
$Q_{D,FP}$ = full permitted flow (discharge) for Dallas Central WWTF
Q_{FG04} = future growth entering 0805_04
Q_{FG03} = future growth entering 0805_03

Step 4: Develop Flow Duration Curves

The daily flow data in units of cubic meters per second were used to develop a FDC for each location. The 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 ÷ number of data points plus 1), and 3) plotting each flow value (y-axis) against its exceedance value (x-axis). Exceedance values along the x-axis 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 high flow or flood conditions.

Because of similarity of shape and close proximity of FDCs on a graph, only the inlet and outlet FDCs are shown for 0805_04 and 0805_03 and the FDCs for TCEQ stations 10937 and 10934 are intentionally omitted (Figure A-3). The separation between the inlet and outlet FDCs of 0805_03 on Figure A-3 is greater than the inlet and outlet FDCs of 0805_04 because of the greater drainage area of 0805_03 and the entry of the Dallas Central WWTF discharge into 0805_03. Median streamflow values for the key locations are provided in Table A.3

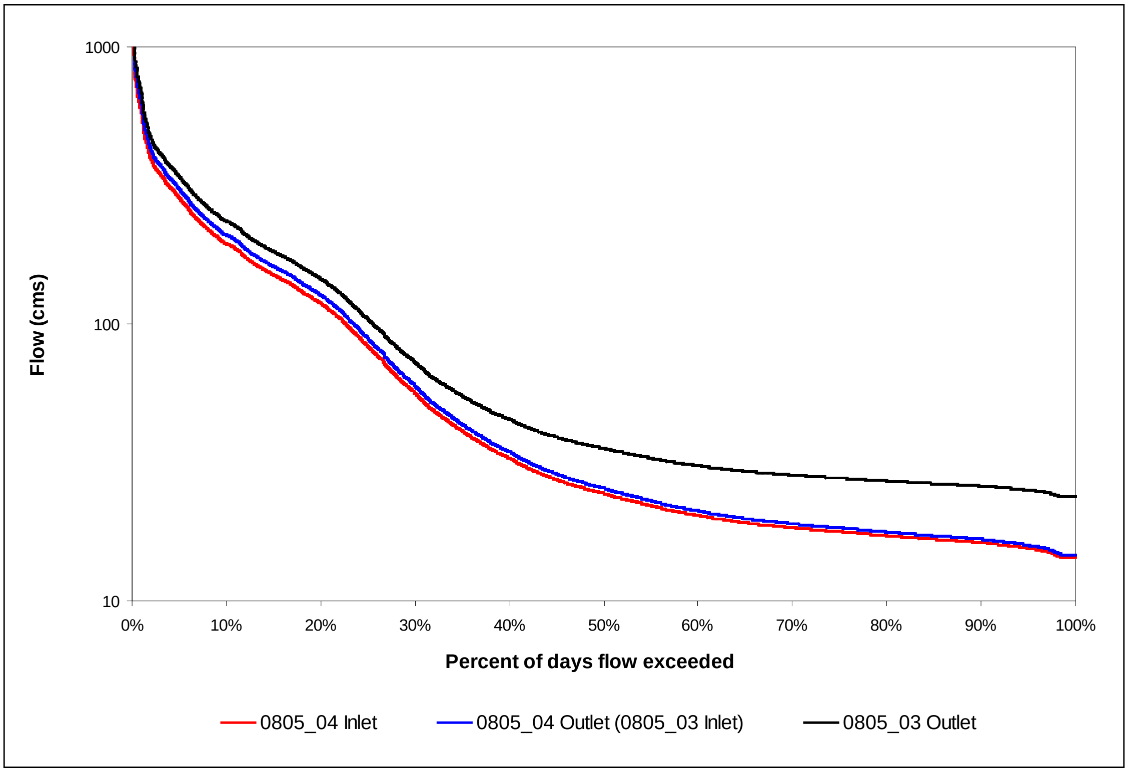

Figure A-3. Flow duration curves for 0805_04 and 0805_03

Table A-3 Median streamflow values from flow duration curve flow regimes.

* Values provided for key locations.

Segment & AU	Location	Highest Flow Regime (0% - 20%)		Mid-Range Flow Regime (20% - 60%)		Lowest Flow Regime (60% - 100%)	
		Median (10th Percentile) Flow		Median (40th Percentile) Flow		Median (80th Percentile) Flow	
		(cfs)	(cms)	(cfs)	(cms)	(cfs)	(cms)
0805_04	Inlet	6913	195.75	1196	33.867	648.0	18.349
0805_04	Outlet	7424	210.23	1257	35.594	666.5	18.873
0805_04	Station 10937	6929	196.21	1207	34.179	658.8	18.655
0805_03	Inlet	7424	210.23	1257	35.594	666.5	18.873
0805_03	Outlet	8318	235.54	1637	46.355	997.1	28.235
0805_03	Station 10934	8215	232.62	1627	46.072	995.5	28.190

* Streamflow values determined from USGS gage 08057000 daily streamflow records for the 25-year period of February 1, 1989 - January 31, 2006. Flows adjusted to account for upstream full permitted discharges from WWTFs and future growth flows.

References for Appendix A

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

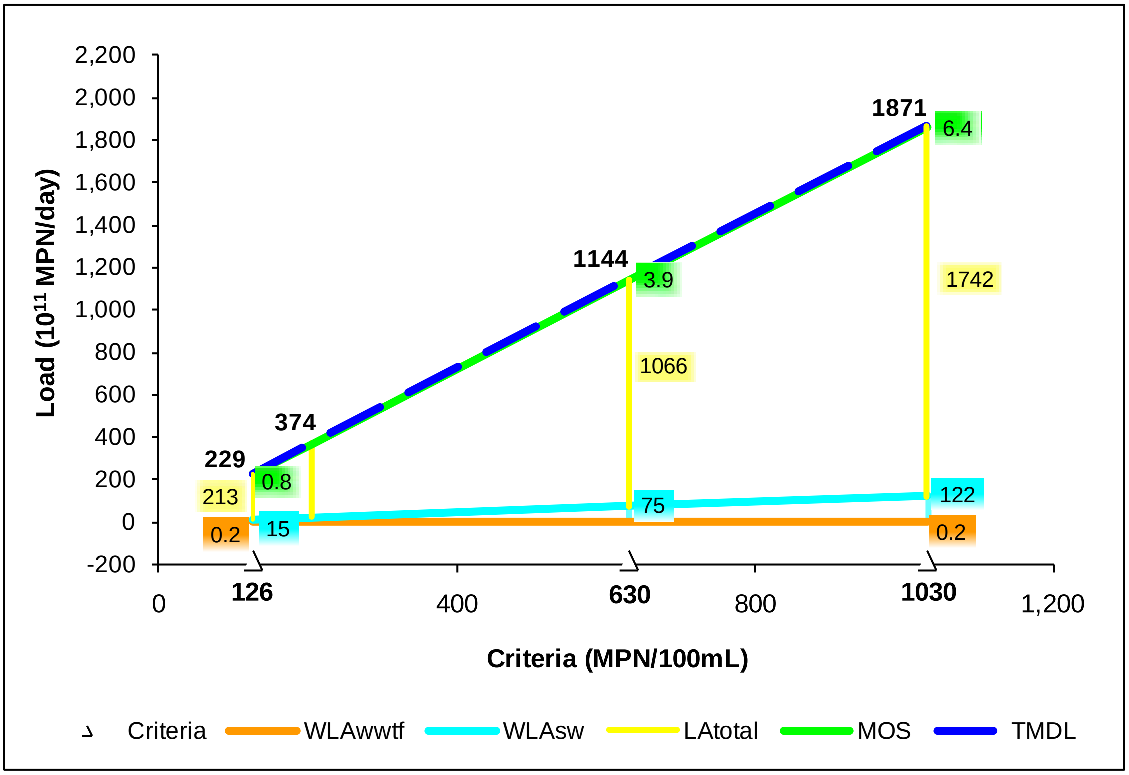

Figure B-1. Allocation loads for 0805_04 as a function of water quality criteria

Equations for calculating new TMDL and allocations (in 10^{11} MPN/day)

$TMDL = 1.81635 * Std$
$WLA_{WWTF} = 0 * 63 + 0.165746 = 0.2$
$WLA_{sw} = 0.118813 * Std - 0.165746$
$Total\ LA = 1.69128 * Std$
$LA_{USL} = 1.69128 * Std$
$LA_{AU} = 0$
$MOS = 0.05 * (TMDL - LA_{USL}) = 0.006253 * Std$

Where:

Std = Revised Contact Recreation Standard
WLA_{WWTF} = waste load allocation (permitted WWTF load + future growth)
WLA_{SW} = waste load allocation (permitted storm water)
Total LA = total load allocation (non-permitted source contributions)
LA_{USL} = upstream (inlet) load allocation
LA_{AU} = load allocation within assessment unit
MOS = Margin of Safety

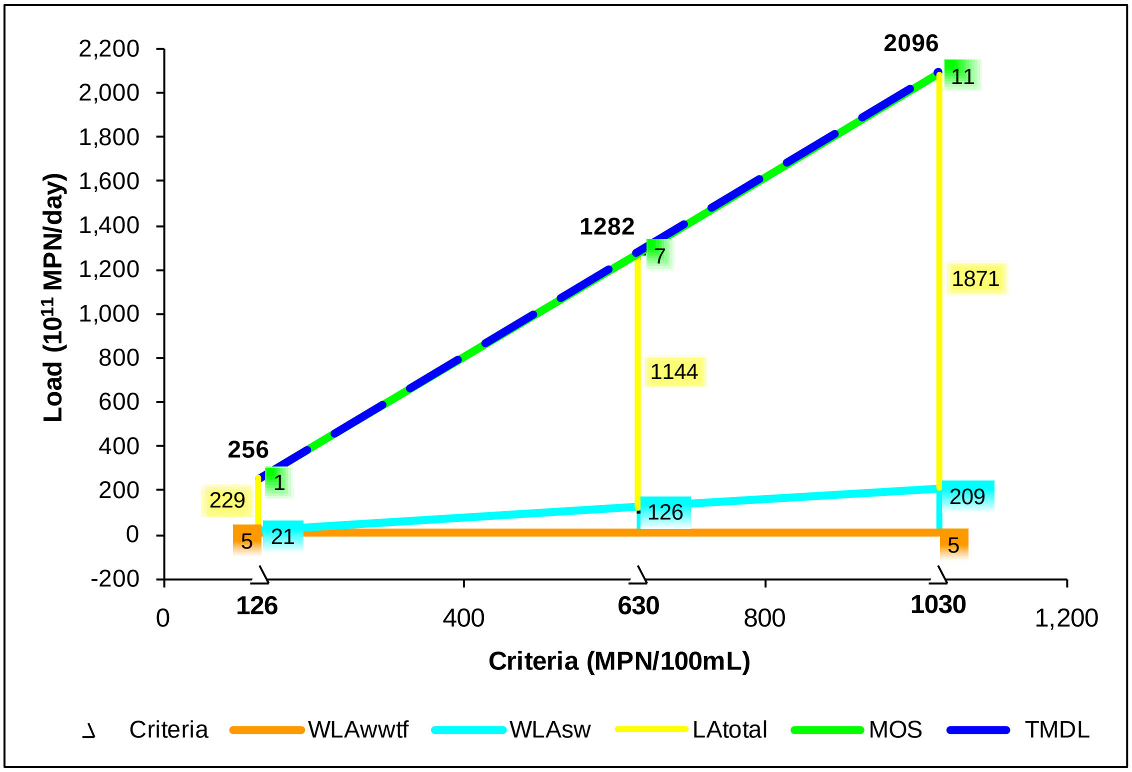

Figure B-2. Allocation loads for 0805_03 as a function of water quality criteria

Equations for calculating new TMDL and allocations (in 10^{11} MPN/day)

$TMDL = 2.03511 * Std$
$WLA_{WWTF} = 0 * 63 + 4.95921 = 5$
$WLA_{sw} = 0.207822 * Std - 4.95921$
$Total\ LA = 1.81635 * Std$
$LA_{USL} = 1.81635 * Std$
$LA_{AU} = 0$
$MOS = 0.05 * (TMDL - LA_{USL}) = 0.010938 * Std$

Where:

Std = Revised Contact Recreation Standard
WLA_{WWTF} = waste load allocation (permitted WWTF)
WLA_{SW} = waste load allocation (permitted storm water)
Total LA = total load allocation (non-permitted source contributions)
LA_{USL} = upstream (inlet) load allocation
LA_{AU} = load allocation within assessment unit
MOS = Margin of Safety