Allocation Support Document for Two Total Maximum Daily Loads for Bacteria in the Upper Trinity River, Dallas, Texas

Segment 0805

Assessment Units: 0805_03 and 0805_04

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December 2009

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Acknowledgements

Financial support for this study was provided by the U.S. Environmental Protection Agency and the Texas Commission on Environmental Quality. The lead agency for this study was the Texas Commission on Environmental Quality.

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List of Acronyms

AU	Assessment Unit
BMP	Best Management Practice
CFR	Code of Federal Regulations
DMR	Discharge Monitoring Report
EPA	Environmental Protection Agency
FDC	Flow Duration Curve
I-Plan	Implementation Plan
LA	Load Allocation
LDC	Load Duration Curve
MGD	Million Gallons per Day
mL	Milliliter
MOS	Margin of Safety
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer System
NCTCOG	North Central Texas Council Of Governments
NEIWPCC	New England Interstate Water Pollution Control Commission
NLCD	National Land Cover Database
NPDES	National Pollutant Discharge Elimination System
NWS	National Weather Service
OSSF	Onsite Sewage Facility
SSO	Sanitary Sewer Overflow
SWPPP	Storm Water Pollution Prevention Plan
TCEQ	Texas Commission on Environmental Quality
TMDL	Total Maximum Daily Load
TPDES	Texas Pollutant Discharge Elimination System
USGS	United States Geological Survey
WLA	Waste Load Allocation
WQMP	Water Quality Management Plan
WWTF	Wastewater Treatment Facility

Allocation Support Document for Two Total Maximum Daily Loads for Bacteria in the Upper Trinity River

Executive Summary

This document describes total maximum daily loads 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 in the 1996 version of the *Texas Water Quality Inventory and 303(d) List*.

The Upper Trinity River (Segment 805) 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 Upper Trinity River watershed as a whole drains an area of about 1,045 square miles and encompasses the cities of Fort Worth and Dallas. Two assessment units of Segment 0805, covering the area from the confluence with the Elm Fork Trinity River and West Fork Trinity River, downstream to the confluence with Fivemile Creek, are addressed by these TMDLs. Both assessment units lie entirely within Dallas County, in highly urbanized watersheds.

Escherichia coli (*E. coli*) is the preferred indicator bacteria for assessing the contact recreation use in freshwater. For this project *E. coli* data were used for total maximum daily load (TMDL) development. The criteria for assessing attainment of the contact recreation use are expressed as the number of indicator bacteria, typically given in most probable number (MPN) per hundred milliliters (100 mL) of water. The contact recreation use is not supported when the geometric mean of all *E. coli* samples exceeds 126 MPN per 100 mL.

Historical ambient water quality data for indicator bacteria (2001-2008) were analyzed on select TCEQ water quality monitoring stations in the Upper Trinity watershed. The geometric means of *E. coli* exceeded the standard in the two upstream assessment units of the Upper Trinity River, 805_03 and 805_04, with the geometric means calculated as 384 MPN/100 mL and 224 MPN/100 mL, respectively.

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

A load duration curve (LDC) 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 on TMDL Calculations and are presented in Table 12. The waste load allocation (WLA) for wastewater treatment facilities (WWTFs) was established as the permitted flow multiplied by the geometric mean criterion for the

indicator bacteria less the margin of safety. 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 is not limited by these TMDLs as long as the sources do not cause indicator bacteria to exceed the water quality standard. The assimilative capacity of streams increases as the amount of flow increases. Increases in flow allow for additional indicator bacteria loads if the concentrations are at or below the contact recreation standard. 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.

In simple terms, a TMDL is like a budget—it determines the amount of a particular pollutant that a water body can receive and still meet its applicable water quality standards. TMDLs are the best possible estimates of the assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load with units of mass per period of time, but may be expressed in other ways. 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 and assessment units covered by this document 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

The information in this report will be used by TCEQ to develop a TMDL report. Upon adoption of the TMDL report by the TCEQ Commission and subsequent 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 contract recreation use for the Upper Trinity River (Segment 0805) in the 1996 Texas Water Quality Inventory and 303(d) List (TCEQ, 2008b). The impaired assessment units (AUs) in Segment 0805 on the 2008 303(d) list are 805_03 and 0805_04 (TCEQ, 2008b), and these assessment units define the TMDL area addressed in this report.

These assessment units are listed due to impairment of the contact recreation use caused by elevated levels of indicator bacteria. *Escherichia coli (E. coli)* is the preferred indicator bacteria for assessing the contact recreation use in freshwater. 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. The criterion for assessing attainment of the contact recreation use is the number of indicator bacteria (*E. coli*), expressed as a most probable number per 100 milliliters of water (MPN/100 mL). The contact recreation use is not supported when the geometric mean of all *E. coli* samples exceeds 126 MPN/100 mL.

As described in the TCEQ's "2008 Guidance for Assessing and Reporting Surface Water Quality in Texas (March 19, 2008)" (TCEQ, 2008a), "The recreation use is not supported if the geometric average of the samples collected over the assessment period…exceeds the criterion or if the criteria for individual samples are exceeded greater than 25 percent of the time using the binomial method." Further, recent agency guidance defines a period of sample collection of seven years to be used for assessment purposes.

Ambient Indicator Bacteria Concentrations

Table 1 presents a summary of historical ambient indicator bacteria data from February 2001 – November 2008 for all assessment units in Segment 805. As indicated in Table 1, only TCEQ stations 10937 (in assessment unit 0805_04) and 10934 (in assessment unit

Table 1 Summary of routine monitoring *E. coli* data for February 2001 through November 2008 (downloaded from SWQMIS July – August 2009). Stations provided in an upstream to downstream order. Only assessment units 04 and 03 indicate nonsupport of contact recreation use due to geometric mean exceedance.

Assessment Unit	Station ID	No. of Samples Feb. 2001-Nov. 2008	Min. Measured *E. coli* Conc. (MPN/100 mL)	Max. Measured *E. coli* Conc. (MPN/100 mL)	Geometric Mean (MPN/100 mL)	Location
0805_04	10937	75	12	24200	224	Mockingbird Ln./ Dallas Co.
0805_03	10934	75	17	39700	384	South Loop 12/ Dallas Co.
0805_06	10932	13	11	980	85	Dowdy Ferry Rd./ Dallas Co.
0805_06	10930	60	3	1540	54	Belt Line Rd./ Dallas Co.
0805_06 Total	--	73	3	1540	59	--
0805_02	10925	82	2	4840	122	Downstream of SH 34/ Kaufman Co.
0805_01 & 05	10924	6	8	770	56	Near FM 85/ Henderson Co.

0805_03) exceeded the geometric mean criterion of 126 MPN/100 mL. Therefore, assessment units 0805_03 and 0805_04 are the focus of TMDL development.

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 boundaries of the two impaired assessment units are defined as follows:

- 0805_03 – from the confluence of Fivemile Creek upstream to the confluence of Cedar Creek, and
- 0805_04 – from the confluence of Cedar Creek upstream to the confluence of Elm Fork Trinity River and West Fork Trinity River (Figure 2).

Within the Upper Trinity River, urban landscapes give way to increasingly agricultural uses moving from upstream to downstream; however, the land use/land cover of the two impaired assessment units are predominately urban (Figure 3 and Table 2). Residential area is the predominate land use in watersheds of both assessment units, 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 temperature rarely exceeds 80° F at night (NWS, 2009). During winter, the average low temperature bottoms out at 33° F in early to mid January and periods of extreme cold generally do not last long (NWS, 2009). The frost-free period generally lasts for about 248 days, with the last frost occurring in mid March and the first frost occurring in mid to late November (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 also 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 assessment units (0805_04 and 0805_03).

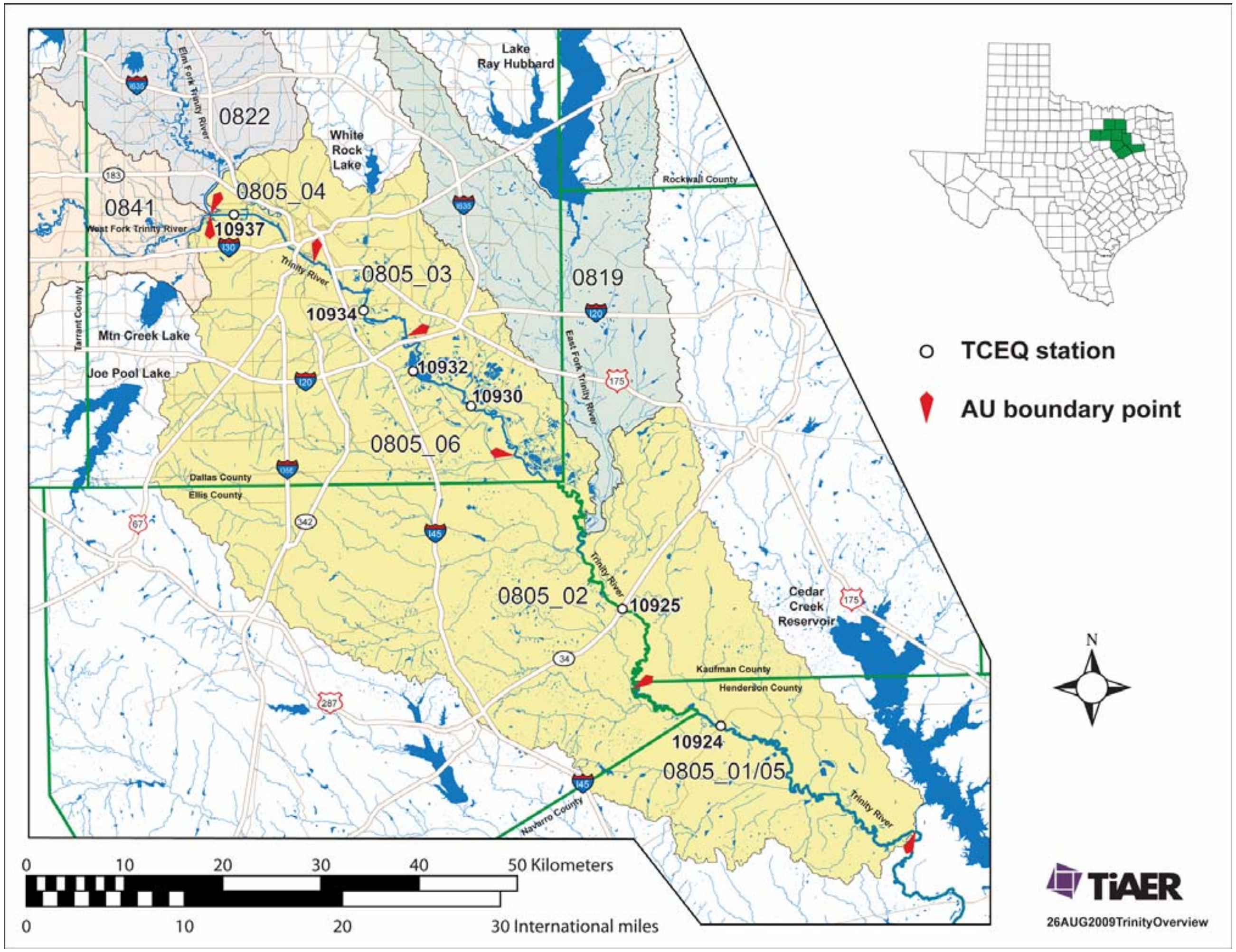

Figure 1 Map of the Upper Trinity River, Segment 805, including TCEQ sampling stations used in the assessment of historical bacteria data

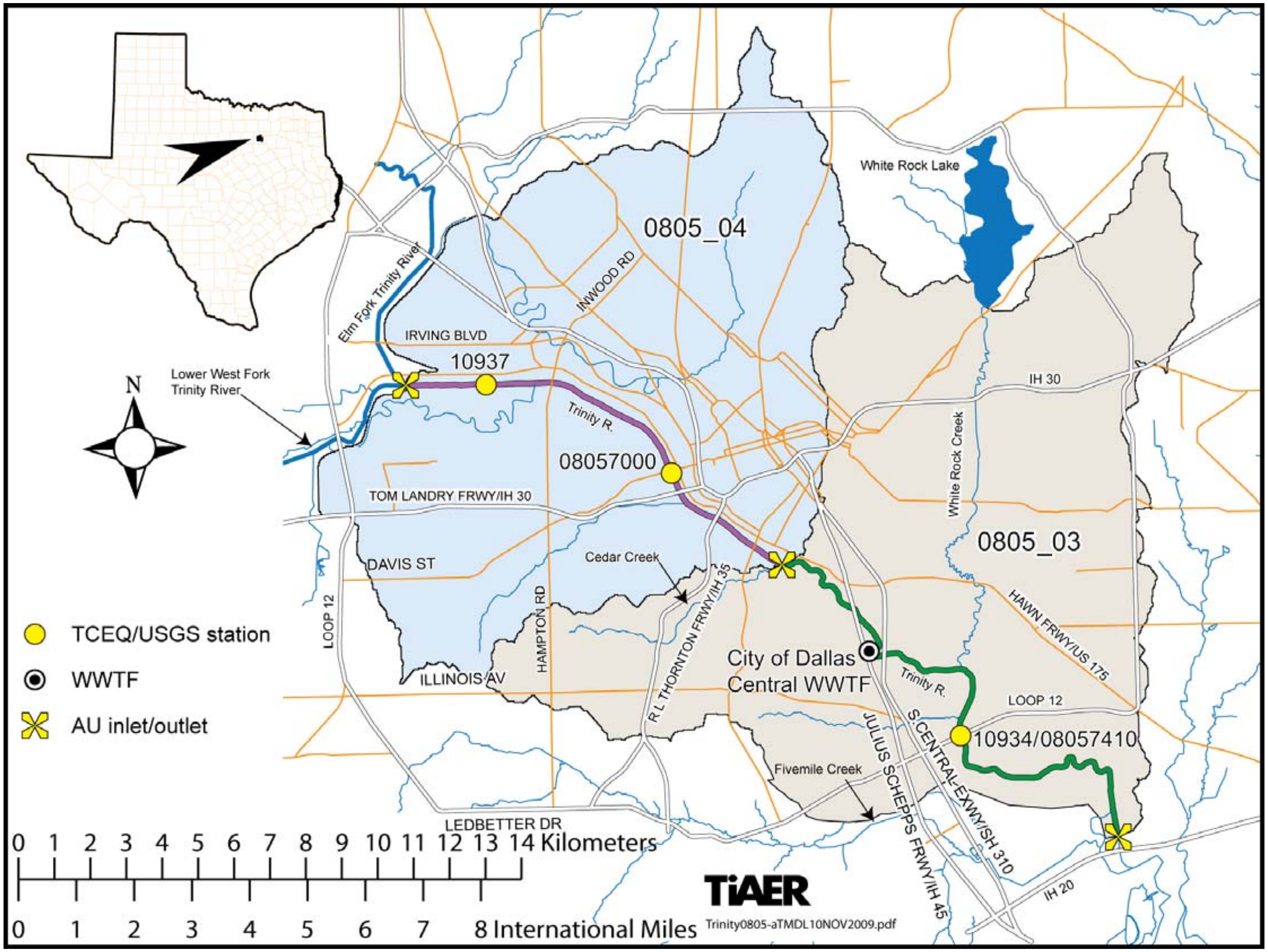

Figure 2 Impaired assessment units of the Upper Trinity River (805_04 and 805_03)

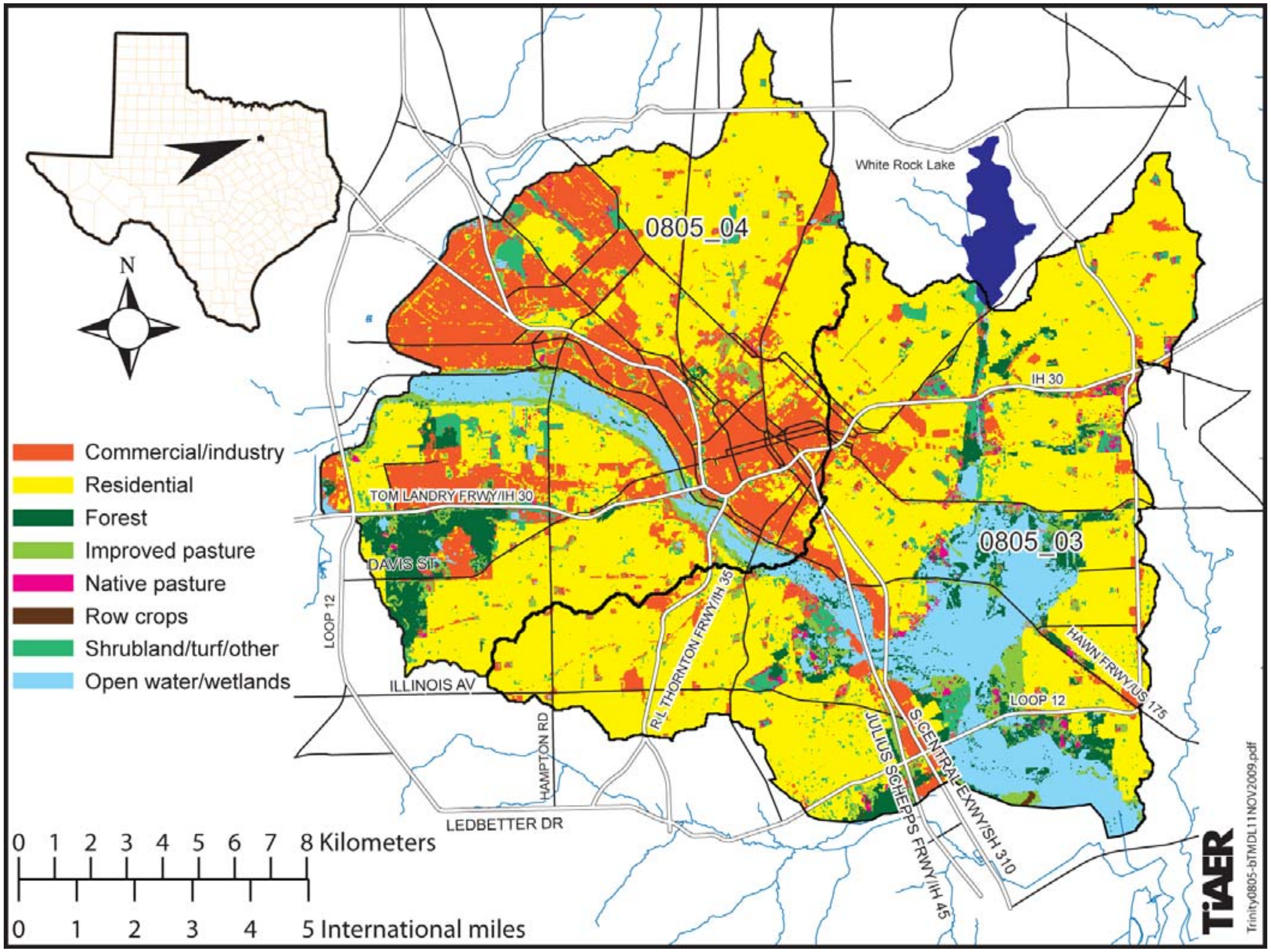

Figure 3 Land use/land cover of 0805_04 and 0805_03 of the Upper Trinity River (Source: National Land Cover Database (NLCD), http://www.mrlc.gov/nlcd.php. Accessed 25 September 2009).

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

Aggregated Land Use Category	Assessment Unit	
	0805_04	0805_03
Description	% of Total	% of Total
Commercial / Industrial	31.10	7.92
Residential	49.81	61.77
Forest	4.38	5.47
Open Water / Wetlands	5.49	15.02
Shrubland / Turf / Other	4.43	4.21
Native Pasture	0.51	1.17
Improved Pasture	4.12	4.27
Row Crops	0.17	0.17
Description	Area (ha)	Area (ha)
Commercial / Industrial	4829	1407
Residential	7732	10969
Forest	680	971
Open Water / Wetlands	852	2667
Shrubland / Turf / Other	687	747
Native Pasture	80	209
Improved Pasture	640	758
Row Crops	26	31
Total Hectares	**15526**	**17759**

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 are wastewater treatment facility (WWTF) discharges and storm water discharges from industries, construction, and municipal separate storm sewer systems (MS4s) of cities. Non-regulated sources are typically nonpoint source in nature; meaning the pollution originates from multiple locations and is usually carried to surface waters by rainfall runoff, and are not regulated by permit under the TPDES.

Permitted Sources

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

WWTF

The City of Dallas Central WWTF (Figure 2 and Table 3) operates the only WWTF discharge in the impaired assessment units 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.

Table 3 WWTF dischargers in the TMDL area watershed

AU	Receiving Stream Name	TPDES Permit Number	NPDES Permit Number	Facility Name	Full Permitted Annual Average Flow (MGD)	Average Reported Flow (MGD) [a]
805_03	Upper Trinity River	10060-001	TX0047830	City of Dallas Central	200	123.8

[a] Data are from discharge monitoring report (DMR) data reported for calendar year 2007, which was the most recent DMR data in the EPA Enforcement & Compliance History Online (ECHO) database.

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 maintains a database of 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 and 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 18 March 2008 alone, accounting for 12% of all SSOs, and 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. Volumes are presented in gallons which were estimated by the reporting entity.

No. of Incidences	Total Gallons [a]	Average Volume (gal)	Median Volume (gal)	Minimum Volume (gal)	Maximum Volume (gal)
992	8,746,294	8,898	135	3	3,167,914

[a] 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 permitting, 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 permitting, which is storm water originating from any area outside a storm water permitted-discharge area.

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 such that all storm water within the TMDL study area is subject to permitting.

Table 5 Permitted MS4 entities in assessment units 805_04 and 805_03. All Phase II entities are covered under TPDES General Permit No. TXR040000

MS4 Entity	TPDES Permit Number	NPDES Permit Number
City of Cockrell Hill	Phase II General Permit	TXR040274
City of Dallas	WQ0004396-000	TXS000701
Dallas Area Rapid Transit	Phase II General Permit	TXR040232
Town of Highland Park	Phase II General Permit	TXR040050
North Texas Tollway Authority	WQ0004400-000	TXS001801
City of University Park	Phase II General Permit	TXR040025

Dry Weather Discharges/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.

Nonpermitted Sources

Nonpermitted 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 (OSSFs), unmanaged animals, and domestic pets. Most of these nonpermitted 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, including wildlife such as mammals, birds, and unmanaged feral animals. In developing bacteria TMDLs, it is important to identify by watershed the potential for bacteria contributions from wildlife, birds, and unmanaged feral animals. Wildlife are 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. In the Upper Trinity River avian species also frequent the watershed and its riparian corridor in particular. However, there are currently insufficient data available to estimate populations and spatial distribution of wildlife and avian species in the watershed. Consequently, it is difficult to assess the magnitude of bacteria contributions from wildlife species as a general category. Studies in other watersheds have found avian species to be important contributors to the bacteria load (e.g., Hussong et al., 1979; Hyer and Moyer, 2003). There is also little information available on contributions from feral animals in the watershed.

Non-Permitted 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 as a significant contributor of bacteria loads.

Failing On-site Sewage Facilities

Failing onsite sewage facilities (OSSFs) were not considered a major source of bacteria loading in the TMDL study area because the entire drainage areas of assessment units 805_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. OSSF-related permitting and complaint investigations within the City of Dallas are handled by the TCEQ Region 4 Office. 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 assessment units of the TMDL area watershed and also 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 $5.4x10^8$ per day for cats and $3.3x10^9$ per day for dogs (Schueler 2000). Pet population estimates were calculated as the estimated number of dogs (0.632) and cats (0.713) per household (AVMA, 2009). The number of households was determined using North Central Texas Council of Government (NCTCOG) 2005 household numbers by population districts (NCTCOG, 2009a&b) with the estimate based on the percentage of each district located inside each assessment unit 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.

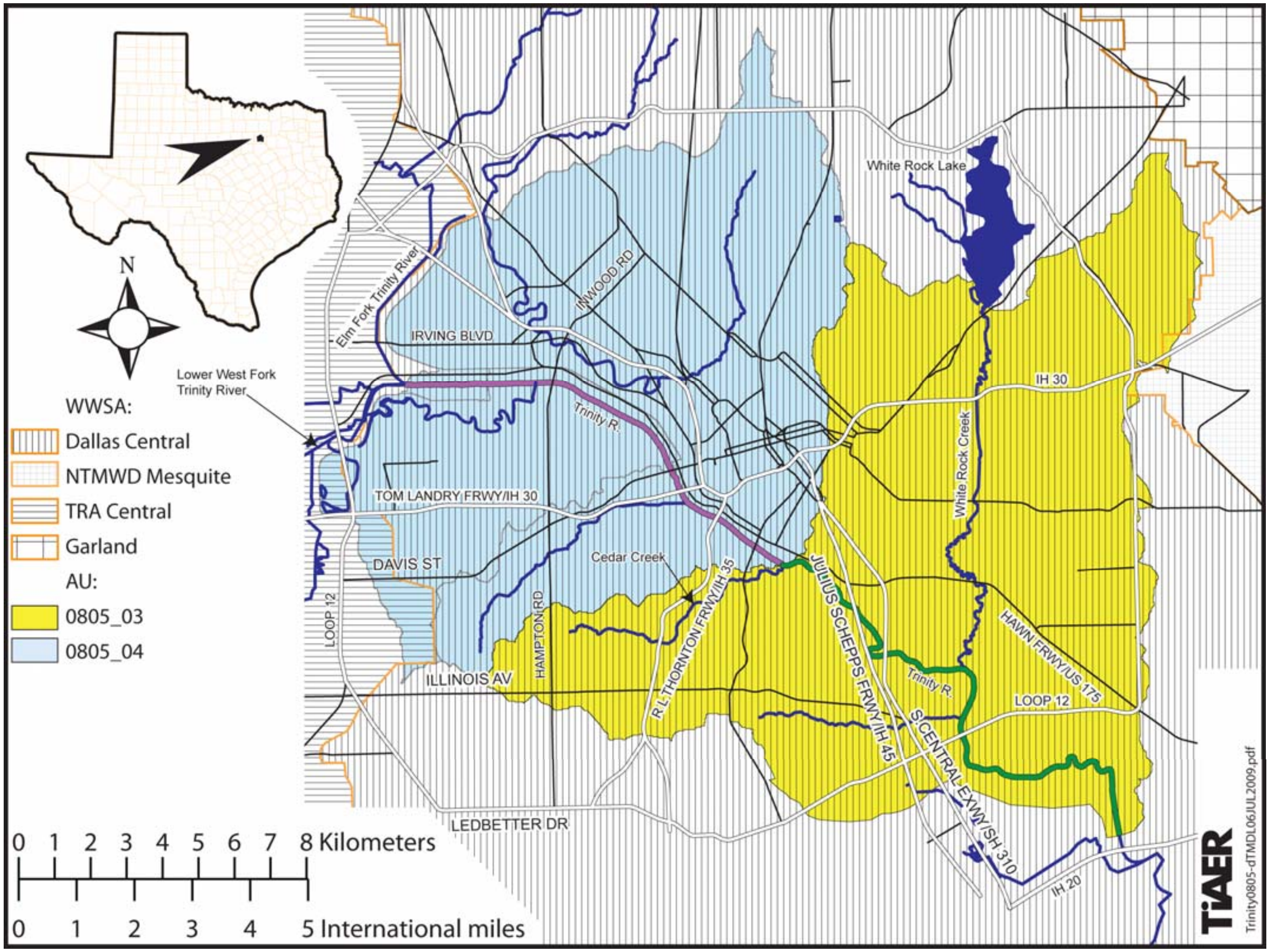

Figure 4 Centralized wastewater treatment and sewered collection areas within TMDL study area (data source: North Central Texas Council of Governments; WWSA = wastewater and sewered area)

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

Assessment Unit	Estimated No. of Households [a]	Estimated Number of Dogs and Cats [b]		Estimated Daily Fecal Coliform Production (10^9 organisms) [c]		
		Dogs	**Cats**	**Dogs**	**Cats**	**Total**
805_04	94,475	59,709	67,361	197,038	36,375	233,413
805_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: 3.3 x 109 dogs; 5.4 x 108 cats

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. 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 impact of point sources is typically diluted, and would therefore be a smaller part of the overall concentrations.

Bacteria contributions from permitted and non-permitted 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 analysis (LDC) analyses were used to examine the relationship between instream water quality, the broad sources of indicator bacteria loads (*i.e.*, point source and 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, and the Texas

Bacterial Task Force 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 allows for estimation of existing and TMDL loads by utilizing the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003). In addition to estimating stream loads, this method allows for the determination of the hydrologic conditions under which impairments are typically occurring, can give indications of the broad origins of the bacteria (*i.e.*, point source and 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 assessment units 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 assessment units 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 assessment unit (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) = 8.64E+08 100 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 SWQMIS database, and (2) various additional data collected by the TIAER Project Team. 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: high flows (0 – 20%), mid-range flows (20 – 60%), and low flows (60 – 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 NDEP (2003).

FDCs and LDCs were developed for the two TCEQ monitoring stations and at the most upstream and downstream points (inlets and outlets) from within each assessment unit.

The median loading of the high flow regime is used for the Upper Trinity River TMDL calculation. The median loading of the high 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 load duration curves 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 assessment units 0805_04 and 0805_03 do not have associated historical *E. coli* data and were constructed for developing the TMDL allocation for both impaired assessment units (Figure 7). The inlet LDC defines the upstream allowable loading entering the assessment unit and the outlet LDC defines the allowable loading leaving the assessment unit. 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 margin of safety 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.

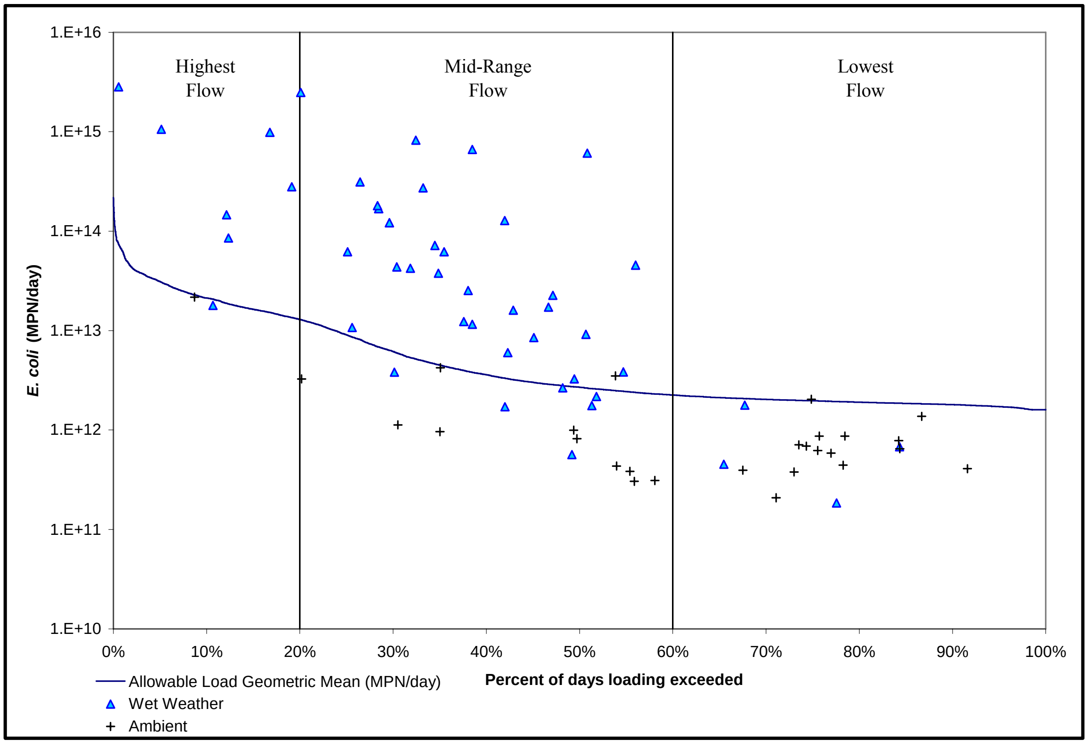

Figure 5 Load duration curve for station 10937 (assessment unit 0805_04). *E. coli* samples collected within 4 days of a precipitation event are designated as triangles.

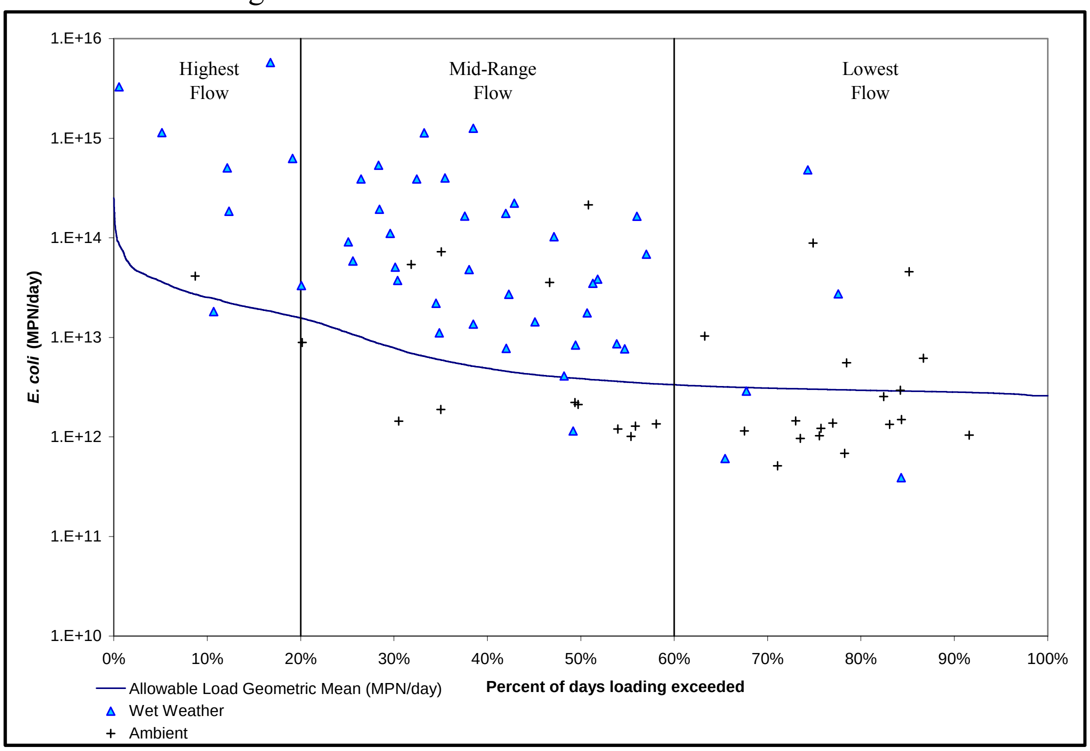

Figure 6 Load duration curve for station 10934 (assessment unit 0805_03). *E. coli* samples collected within 4 days of a precipitation event are designated as triangles.

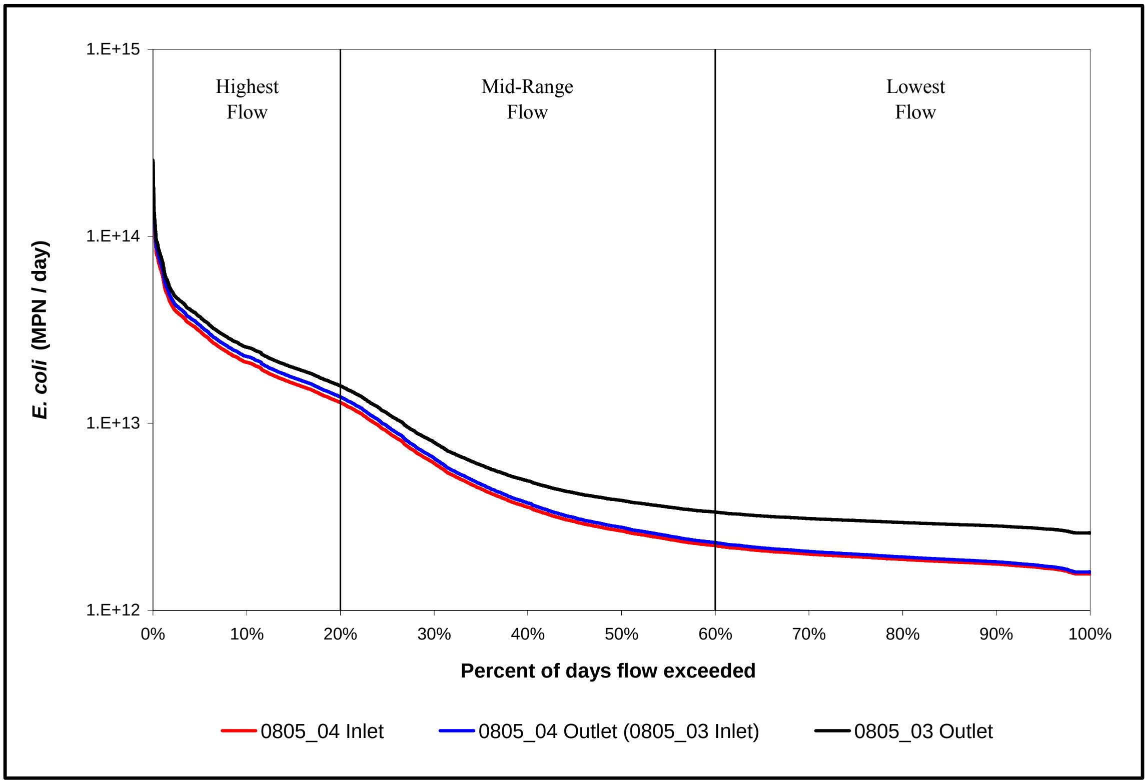

Figure 7 Load duration curves for the inlets and outlets of 0805_04 and 0805_03.

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:

$$\text{TMDL} = \Sigma\text{WLA} + \Sigma\text{LA} + \Sigma\text{FG} + \text{MOS}$$

Where:

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

LA = load allocation, the amount of pollutant allowed by non-permitted or non-regulated 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 assessment units 0805_04 and 0805_03 as covered in this report were derived using LDCs developed for the outlet of each assessment unit. The estimated maximum allowable loads of *E. coli* for each of the assessment units was determined as that corresponding to the median flow within the high flow regime.

Waste Load Allocation

TPDES-permitted wastewater treatment facilities are allocated a daily waste load (WLA_{WWTF}) calculated as their full permitted discharge flow rate multiplied by the instream geometric criterion after reductions for the MOS. This is expressed in the following equation:

$$WLA_{WWTF} = \text{criterion} * \text{flow (MGD)} * \text{conversion factor} * (1 - F_{MOS})$$

Where:

Criterion = 126 MPN/100 mL
Flow (MGD) = full permitted flow
Conversion factor = 3.7854E+07 100 mL / MGD
F_{MOS} = fraction of loading assigned to margin of safety (5% or 0.05)

In 0805_03 there is only one facility, Dallas Central WWTF (TPDES WQ0010060-001), and it represents the entire WLA_{WWTF} allocation in that assessment unit. Since assessment unit 0805_04 contains no WWTFs, its WLA_{WWTF} is zero.

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 as the permitted storm water 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 storm water runoff and the portion allocated to WLA_{SW}. Thus, WLA_{SW} is the sum of loads from regulated (or permitted) stormwater 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 assessment unit (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 either monitoring requirements or effluent limitations. 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 Update. 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. This 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 many 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 waste load allocations. For NPDES/ TPDES-regulated municipal and small-construction 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 22, 2002, memorandum from EPA relating to establishing WLAs for storm water sources). The EPA memo also 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 BMP 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 waste load 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 growth or other changing conditions. 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 Water Quality Management Plan. Any future changes to effluent limitations will be addressed through the permitting process and by updating the Water Quality Management Plan (WQMP).

Load Allocation

The load allocation is the sum of loads from non-permitted sources. The load allocation is the sum of the upstream bacteria load (LA_{USL}) entering the assessment unit and all remaining loads in the assessment unit from non-permitted sources (LA_{AU}):

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

Where:

LA = allowable load from non-permitted sources (predominately nonpoint sources)

LA_{AU} = allowable loads from non-permitted sources within the assessment unit

ΣLA_{USL} = upstream load allocations entering assessment unit

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 assessment unit

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 non-permitted sources within the assessment unit

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 assessment unit

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:

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

Future Growth

To account for the probability that additional flows from WWTF discharges may occur in both assessment units, 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). City of Dallas wastewater treatment is provided by two large facilities; the Central WWTF in assessment unit 0805_03 and the Southside WWTF, which discharges into the Upper Trinity River downstream of the impaired assessment units. The sewered collection areas of both facilities includes a greater area than the 0805_04 and 0805_03 drainage areas and also includes a significant area jointly serviced by both facilities, which complicates the estimate of additional WWTF discharges due to future growth. As a conservative approach for this TMDL, it is assumed that all estimated future growth associated with the Dallas Central WWTF sewered collection area results in future growth in both assessment units. The future growth computation includes the steps of 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 assessment units 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 (gpcd) 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 = 1.000E-06 MGD/gpcd

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

$$FG = \text{criterion} * FC\ (MGD) * FDA_{AU} * \text{conversion factor} * (1 - F_{MOS})$$

Where:

Criterion = 126 MPN/100 mL

FC = future capacity calculated from preceding equation in MGD

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

Conversion factor = 3.7854E+07 100 mL / MGD

F_{MOS} = fraction of loading assigned to margin of safety (5% or 0.05)

Assessment Unit 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 assessment unit (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 assessment unit. Table 8 summarizes the WLA_{WWTF} for the TPDES-permitted facility within the study area. Compliance is achieved when the discharge limits are met. 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 non-permitted areas within each assessment unit (LA_{UA}) are zero and all storm water loadings are assigned to WLA_{SW}.

Table 7 Summary of TMDL and LA_{USL} calculations for each assessment unit

Assessment Unit	Receiving Water	Upstream Allowable Loading		Downstream Allowable Loading	
		Q_{inlet} [a] (cms)	LA_{USL} [b] (MPN/day)	Outlet Flow [c] (cms)	TMDL [d] (MPN/day)
805_04	Upper Trinity River	195.75	2.131E+13	210.23	2.289E+13
805_03		210.23	2.289E+13	235.54	2.564E+13

[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 Waste load allocations for TPDES-permitted facilities

Receiving Water	Assessment Unit	TPDES Number	NPDES Number	Facility Name	Final Permitted Flow (MGD)	WLA_{WWTF} (MPN/day)
Upper Trinity River	805_04	—	—	—	—	0
	805_03	10060-001	TX0047830	Dallas Central	200	9.062E+11

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

Table 9 Future capacity calculations for impaired assessment units

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 Assessment Units (MGD)
153	151,106	200	110	14.9

Table 10 Future growth calculations for assessment units 0805_04 and 0805_03

Receiving Water	Assessment Unit	Fraction of Combined Drainage Area (%)	Apportioned Future Capacity (MGD)	Future Growth [a] (MPN/day)
Upper Trinity River	805_04	46.64%	6.950	3.149E+10
	805_03	53.36%	7.950	3.602E+10

[a] A 5% margin of safety was applied to the future growth

Table 11 summarizes the TMDL calculations for assessment units 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 are based on the current geometric mean criterion for *E. coli* in freshwater of 126 counts/100 mL.

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* currently under review by TCEQ. 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*.

Allowance for Future Growth

Compliance with these TMDLs is based on keeping the indicator bacteria concentrations in the selected waters below the limits that were set as criteria for the individual sites. Future growth of existing or new point sources is not limited by these TMDLs as long as the sources do not cause indicator bacteria to exceed the limits. The assimilative capacity of streams increases as the amount of flow increases. Increases in flow allow for additional indicator bacteria loads if the concentrations are at or below the contact recreation standard. Wastewater discharge facilities will be evaluated on a case-by-case basis. The LDC and tables in this TMDL will guide determination of the assimilative capacity of the stream under changing conditions, including future growth.

Additional 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 waste load allocation and the load allocation. This can be done without the need to reserve future capacity in waste load allocations for storm water. In un-urbanized areas, growth can be accommodated by shifting loads between the load allocation and the waste load allocation (for storm water). 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. Currently, it is envisioned that an iterative adaptive management BMP approach be used to address storm water discharges. This approach encourages the implementation of controls *(i.e.* structural or non-structural), implementation of mechanisms to evaluate the performance of the controls, and finally allowance to make adjustments (*i.e.*, more stringent controls or specific BMPs) as necessary to protect water quality.

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

AU	Criterion (MPN / 100mL)	TMDL[a] (MPN/day)	WLA_{WWTF}[b,c] (MPN/day)	WLA_{SW}[d] (MPN/day)	LA_{AU}[e] (MPN/day)	LA_{USL} (MPN/day)	Total LA[h] (MPN/day)	MOS[i] (MPN/day)	Future Growth[j] (MPN/day)
0805_04	126	2.289E+13	0	1.466E+12	0	2.131E+13[f]	2.131E+13	7.879E+10	3.149E+10
0805_03	126	2.564E+13	9.062E+11	1.676E+12	0	2.289E+13[g]	2.289E+13	1.378E+11	3.602E+10

[a] TMDL = Median flow (high flow regime) * 126 MPN/100 mL * Conversion Factor; where the Conversion Factor = 8.64 x 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 (126 MPN/day) * (1-F_{MOS}); where Permitted Flow = 200 MGD; Conversion Factor = 3.7854 x 10^7 100 mL/MGD; and F_{MOS} is the fraction of loading assigned to margin of safety (0.05)

[d] WLA_{SW} = (TMDL - WLA_{WWTF} - LA_{USL} - FG - MOS) * FDA_{SWP}; where FG = future growth loads from potential permitted facilities and FDA_{SWP} = 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} * Criteria (126 MPN/day) * Conversion Factor; where Q_{inlet} is from Table 7 for 0805_04; the Conversion Factor = 8.64 x 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 x 10^8 100 mL/m^3 * seconds/day

[h] Total LA = LA_{AU} + LA_{USL}; because LA_{AU} is zero for both AUs, the Total LA = LA_{USL}

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

[j] Future Growth = Criterion (126 MPN/day) * FC (MGD) * FDA_{AU} * Conversion Factor * (1 - F_{MOS}); where FC is from Table 9, FDA_{AU} is from Table 10; Conversion Factor = 3.7854 x 10^7 100 mL/MGD; and F_{MOS} = 0.05

Table 12 Final TMDL allocations

Assessment Unit	TMDL (MPN/day)	WLA_{WWTF}[a] (MPN/day)	WLA_{SW} (MPN/day)	LA (MPN/day)	MOS (MPN/day)
0805_04	2.289E+13	3.149E+10	1.466E+12	2.131E+13	7.879E+10
0805_03	2.564E+13	9.422E+11	1.676E+12	2.289E+13	1.378E+11

[a] WLA_{WWTF} = WLA_{WWTF} + Future Growth

The three-tiered antidegradation policy in the water quality 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' antidegradation policy.

Seasonal Variation

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. Seasonality in *E. coli* data was examined and found lacking in Upper Trinity River (Millican and Hauck, 2008) and is thus 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 and the Texas Institute for Applied Environmental Research are jointly 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. The meetings introduced the TMDL process, identified the impaired assessment units and the reason for the impairment, reviewed historical data, and described potential sources of bacteria within the watershed. In addition, the meeting 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 Web site at <http://www.tceq.state.tx.us/implementation/water/tmdl/66-trinitybacteria.html>.

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Appendix A – Daily Streamflow Record Development

Appendix A

Daily Streamflow Record Development

Introduction & Background

This appendix presents the development of the daily streamflow (or hydrologic) records and flow duration curves (FDCs), which form the bases of the load duration curves (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 month of January 2006 was included and January 1981 excluded, since the most recently available *E. coli* data were in January 2006 at the time the LDCs were developed.

The U.S. Geological Survey (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 assessment unit (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 on an areal basis, 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 wastewater treatment facilities (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,

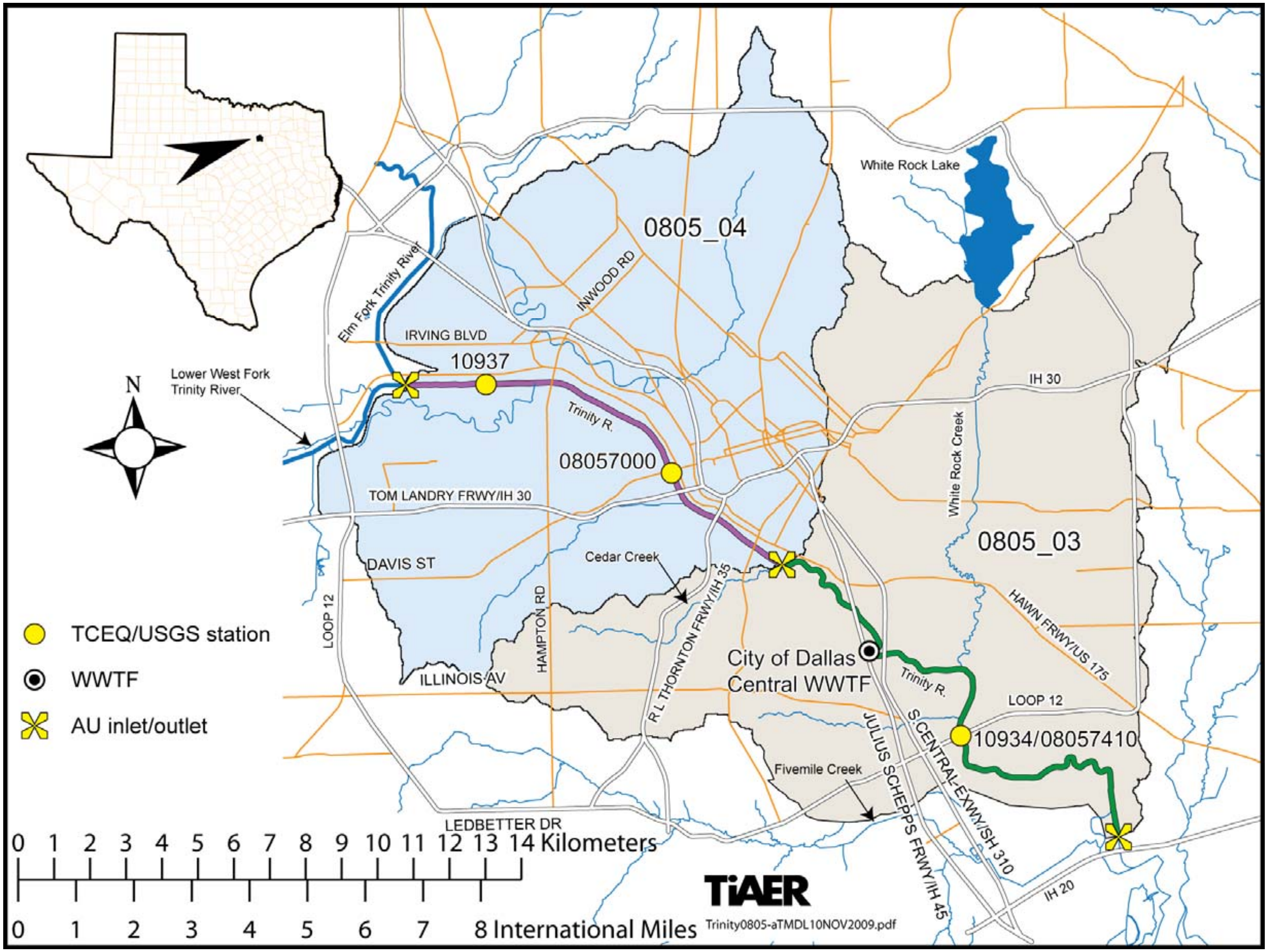

Figure A-1 Impaired assessment units of the Upper Trinity River (805_04 and 805_03) showing key locations these point-source originating flows should be removed from the portion of the record to which the DAR is applied.

The effluent from three major municipal wastewater treatment facilities (WWTFs) with permitted annual average discharges of well over one million gallons per day (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 discharge monitoring report (DMR) data for each of these WWTFs for the selected 25-year period.

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

Permit Id (TCEQ/EPA)	Permittee	Facility Name	Segment Name	Permitted Annual Average Flow (MGD)
WQ0010494-13 TX0047295	City of Fort Worth	Village Creek WWTF	West Fort 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 impact downstream hydrology, but also effectively reduce bacteria concentrations in releases as a result 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 described immediately above:

Step # 1: Calculate Appropriate Drainage Area Ratios (DARs) 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 impacting 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.

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

Location Description	Drainage Area [a] (km^2)	DAR
Inlet to 0805_04	1974.3	$DAR_1 = 0.9796$
TCEQ Station 10937	1976.1	$DAR_2 = 0.9805$
Reference Location: USGS gage 08057000	2015.4	—
Outlet of 0805_04 / Inlet to 0805_03	2129.5	$DAR_3 = 1.0566$
TCEQ Station 10934	2275.3	$DAR_4 = 1.1289$
Outlet to 0805_03	2307.1	$DAR_5 = 1.1448$

[a] The drainage areas above major reservoirs are excluded

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 geology, 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 time periods for the WWTFs; however, some limited DMR daily discharge data were available in more recent years. 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 (http://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

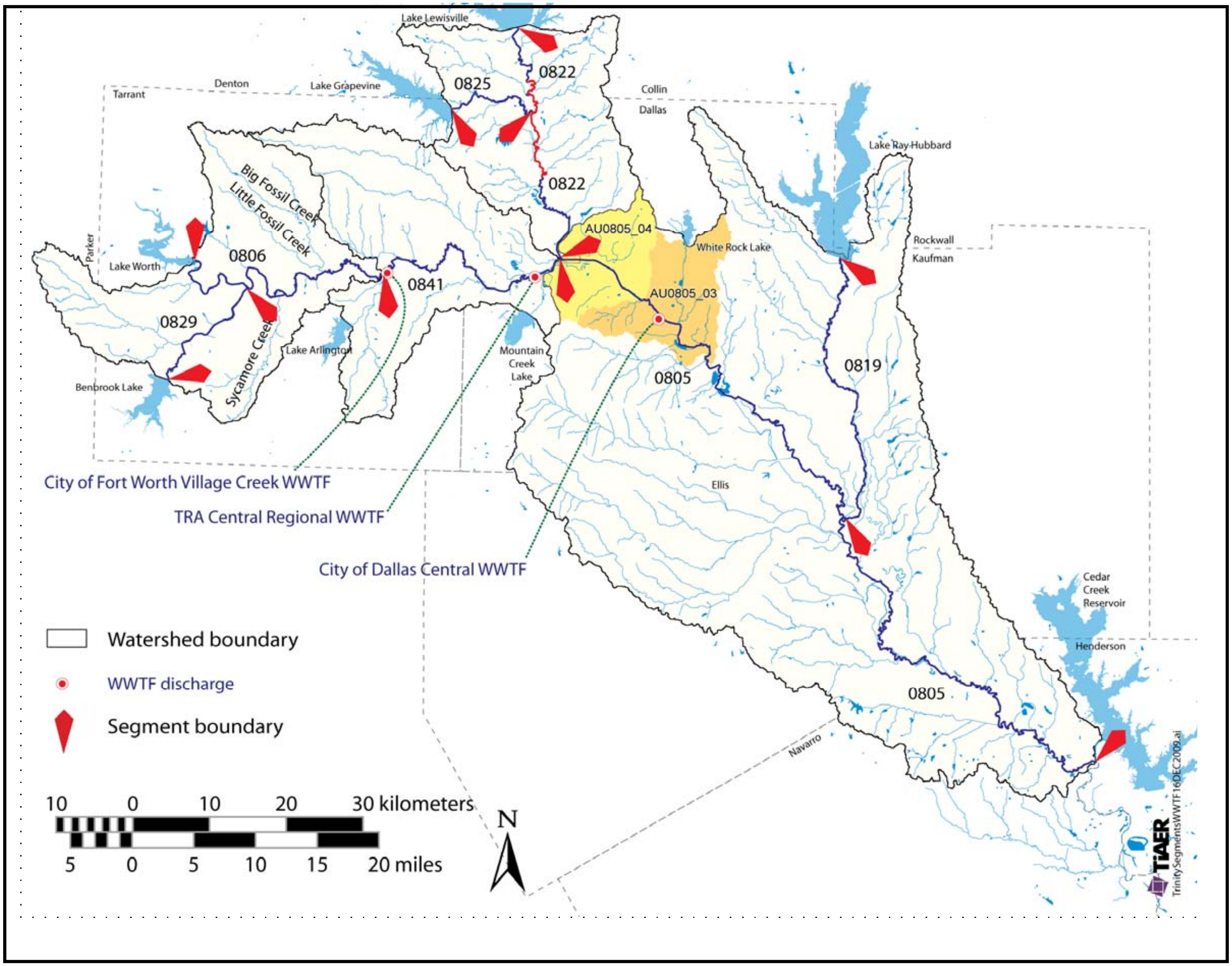

Figure A-2 Trinity River Basin showing major reservoirs, large wastewater treatment facilities, and study area

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 and to that calculated streamflow record was added the permitted daily average discharges from upstream WWTFs, including Future Growth, which 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 (cms) 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.

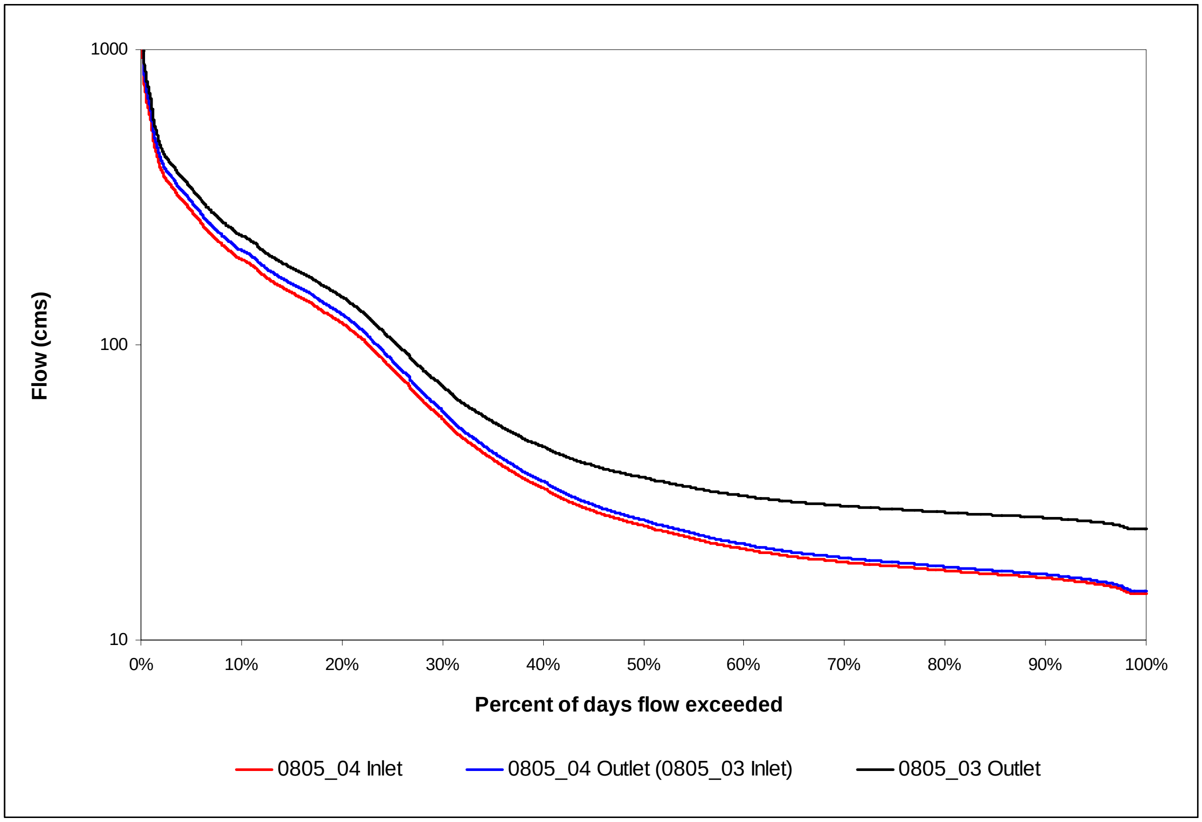

Figure A-3 Flow duration curves for 0805_04 and 0805_03

References for Appendix A

Di Luzio, M., R. Srinivasan, J. Arnold. 2004. A GIS-coupled hydrological model system for the watershed assessment of agricultural nonpoint and point source of pollution. *Transactions* in GIS 8(1):113-136.

Millican, J. and L. Hauck. 2008. Final Draft – Technical Support Document Segments 0806, 0841, 0822 and 0805 of the Trinity River Bacteria TMDL. Prepared for: Texas Commission on Environmental Equality, Prepared by: Texas Institute for Applied Environmental Research, Tarleton State University, Stephenville, TX. <www.tceq.state.tx.us/assets/public/implementation/water/tmdl/66trinitybact/66-tsd_trin_bact.pdf>. Accessed 28 October 2009.

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

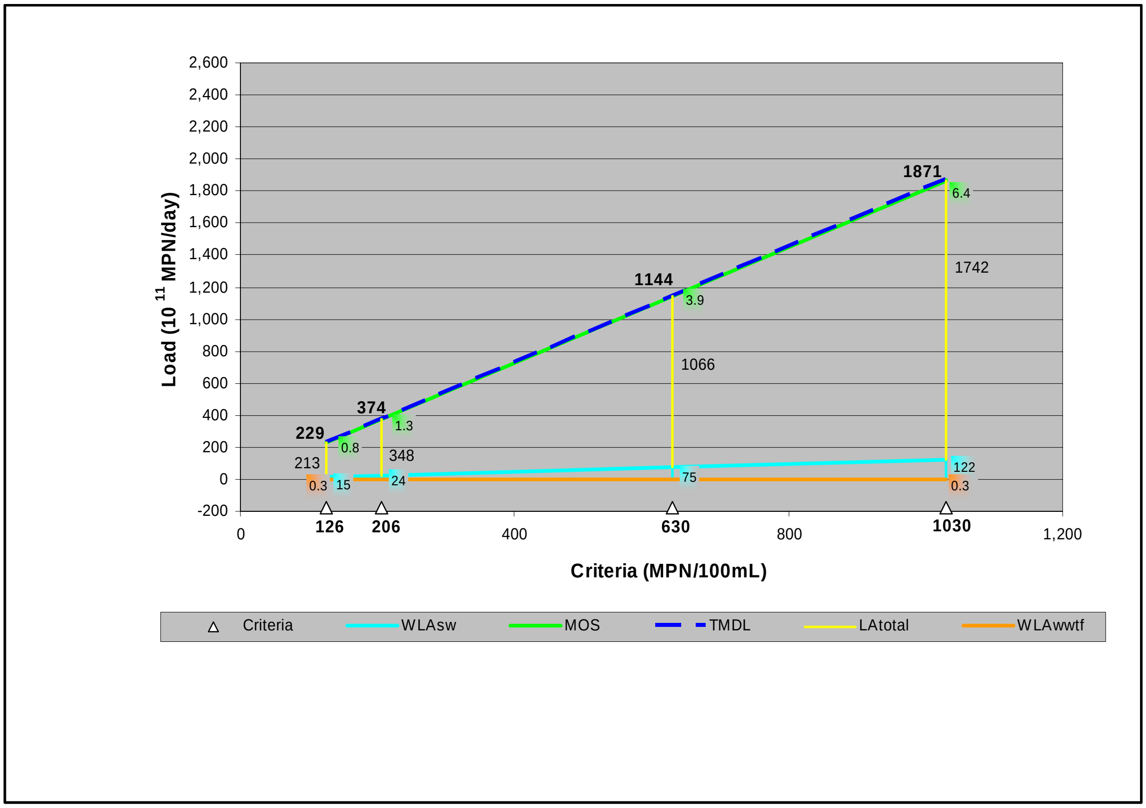

Figure B-1. Allocation loads for 0805_04 as a function of water quality criteria

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

TMDL = 1.81635 * Std
WLA_{WWTF} = 0 * 126 + 0.314917 = 0.3
WLA_{sw} = 0.118813 * Std - 0.314917
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

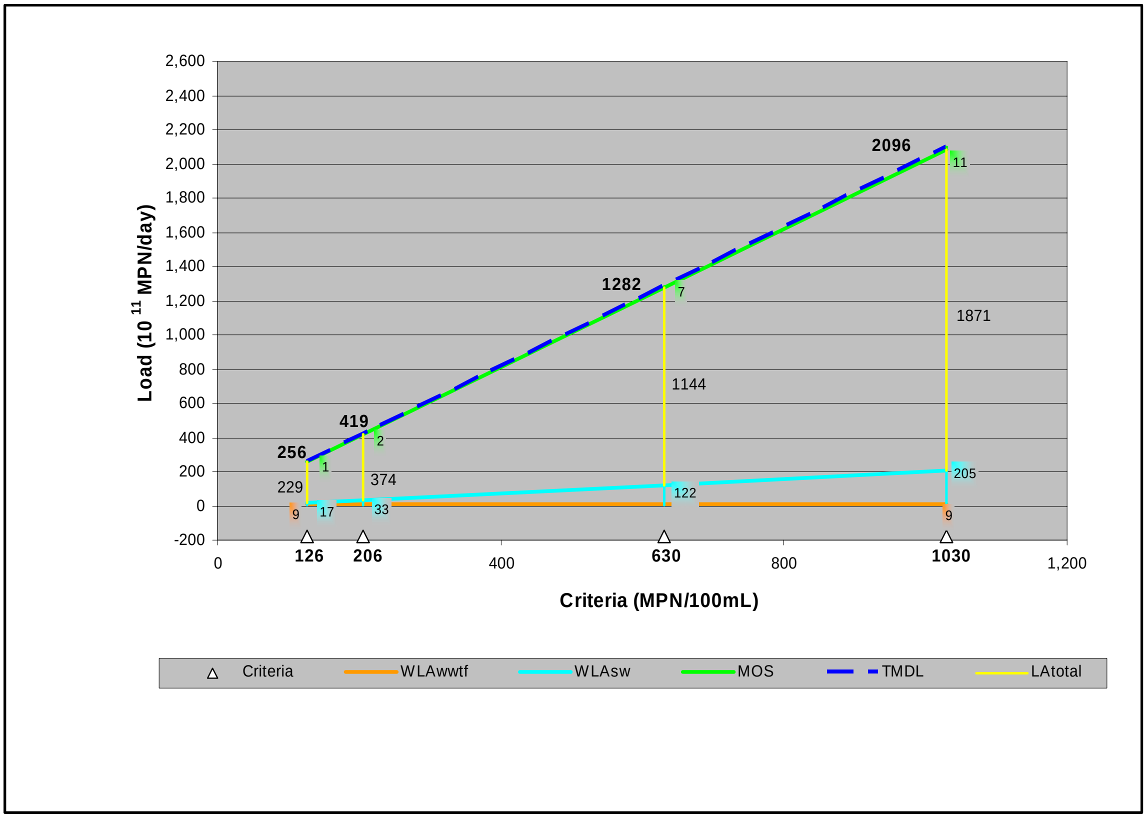

Figure B-2. Allocation loads for 0805_03 as a function of water quality criteria

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

TMDL = 2.03511 * Std
WLA_{WWTF} = 0 * 126 + 9.42250 = 9
WLA_{sw} = 0.207833 * Std - 9.42250
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