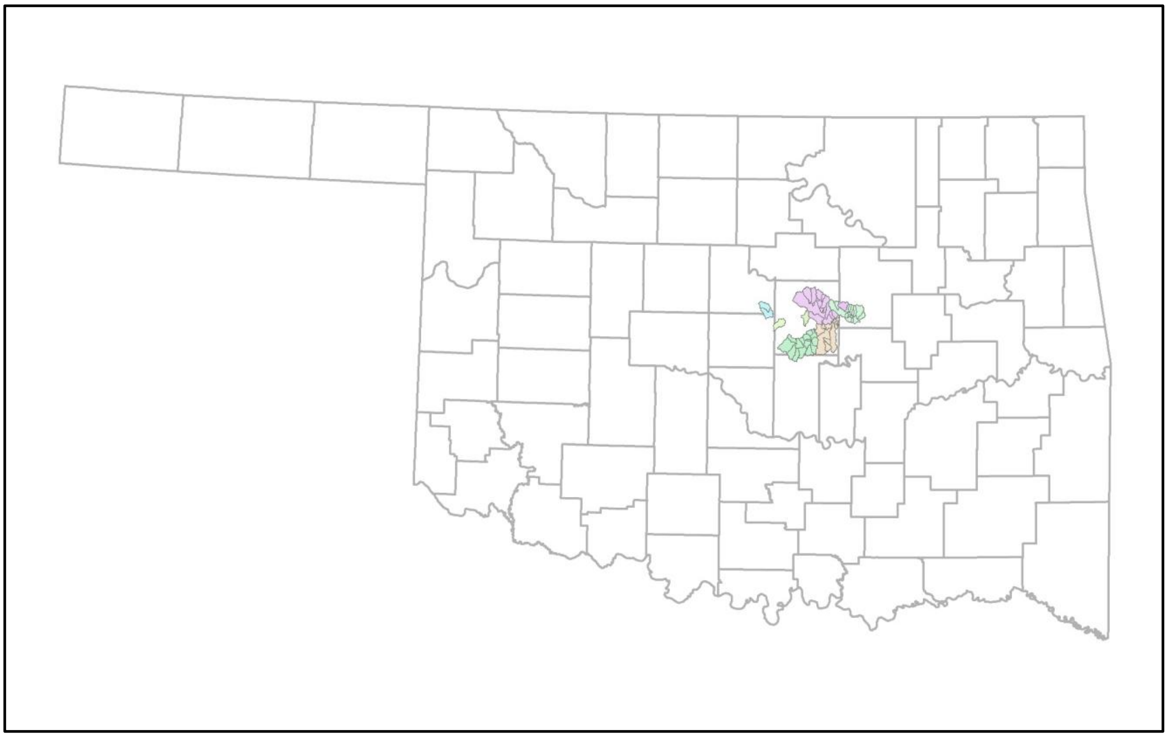
FINAL

BACTERIA AND TURBIDITY TOTAL MAXIMUM DAILY LOADS FOR THE UPPER DEEP FORK AREA, OKLAHOMA (OK520700)



OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

SEPTEMBER 2011

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BACTERIA AND TURBIDITY TOTAL MAXIMUM DAILY LOADS FOR THE UPPER DEEP FORK OF THE CANADIAN RIVER AREA, OKLAHOMA (OK520700)

OKWBID

OK520700030100_00, OK520700030220_00
OK520700040010_00, OK520700040020_00
OK520700040260_00, OK520700050020_00
OK520700050140_00, OK520700050200_00

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

DEQ
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DEPARTMENT OF ENVIRONMENTAL QUALITY

SEPTEMBER, 2011

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ACRONYMS AND ABBREVIATIONS

AEMS	Agricultural Environmental Management Service
ASAE	American Society of Agricultural Engineers
BMP	best management practice
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
cfs	Cubic feet per second
cfu	Colony-forming unit
CPP	Continuing planning process
CWA	Clean Water Act
DMR	Discharge monitoring report
HUC	Hydrologic unit code
IQR	Interquartile range
LA	Load allocation
LDC	Load duration curve
LOC	Line of organic correlation
mg	Million gallons
mgd	Million gallons per day
mg/L	Milligram per liter
mL	Milliliter
MOS	Margin of safety
MS4	Municipal separate storm sewer system
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NRMSE	Normalized root mean square error
NTU	Nephelometric turbidity unit
OLS	Ordinary least square
O.S.	Oklahoma statutes
ODAFF	Oklahoma Department of Agriculture, Food and Forestry
ODEQ	Oklahoma Department of Environmental Quality
OPDES	Oklahoma Pollutant Discharge Elimination System
OSWD	Onsite wastewater disposal
OWRB	Oklahoma Water Resources Board
PBCR	Primary body contact recreation
PRG	Percent reduction goal
RMSE	Root mean square error
SH	State Highway
SSO	Sanitary sewer overflow

TMDL	Total maximum daily load
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WLA	Wasteload allocation
WQM	Water quality monitoring
WQS	Water quality standard
WWTP	Wastewater treatment plant

Executive Summary

This report documents the data and assessment used to establish TMDLs for the pathogen indicator bacteria [fecal coliform, *Escherichia coli (E. coli),* Enterococci] and turbidity for certain waterbodies in the Upper Deep Fork of the Canadian River basin. Elevated levels of pathogen indicator bacteria in aquatic environments indicate that a waterbody is contaminated with human or animal feces and that a potential health risk exists for individuals exposed to the water. Elevated turbidity levels caused by excessive sediment loading and stream bank erosion impact aquatic communities. Data assessment and total maximum daily load (TMDL) calculations are conducted in accordance with requirements of Section 303(d) of the Clean Water Act (CWA), Water Quality Planning and Management Regulations (40 CFR Part 130), U.S. Environmental Protection Agency (USEPA) guidance, and Oklahoma Department of Environmental Quality (ODEQ) guidance and procedures. ODEQ is required to submit all TMDLs to USEPA for review and approval. Once the USEPA approves a TMDL, then the waterbody may be moved to Category 4a of a state's Integrated Water Quality Monitoring and Assessment Report, where it remains until compliance with water quality standards (WQS) is achieved (USEPA 2003).

The purpose of this TMDL report is to establish pollutant load allocations for indicator bacteria and turbidity in impaired waterbodies, which is the first step toward restoring water quality and protecting public health. TMDLs determine the pollutant loading a waterbody can assimilate without exceeding the WQS for that pollutant. TMDLs also establish the pollutant load allocation necessary to meet the WQS established for a waterbody based on the relationship between pollutant sources and instream water quality conditions. A TMDL consists of a wasteload allocation (WLA), load allocation (LA), and a margin of safety (MOS). The WLA is the fraction of the total pollutant load apportioned to point sources, and includes stormwater discharges regulated under the National Pollutant Discharge Elimination System (NPDES) as point sources. The LA is the fraction of the total pollutant load apportioned to nonpoint sources. The MOS is a percentage of the TMDL set aside to account for the lack of knowledge associated with natural process in aquatic systems, model assumptions, and data limitations.

This report does not stipulate specific control actions (regulatory controls) or management measures (voluntary best management practices) necessary to reduce bacteria or turbidity within each watershed. Watershed-specific control actions and management measures will be identified, selected, and implemented under a separate process.

E.1 Problem Identification and Water Quality Target

This TMDL report focuses on waterbodies in the Upper Deep Fork of the Canadian River Basin, identified in Table ES-1, that ODEQ placed in Category 5 [303(d) list] of the *Water Quality in Oklahoma, 2008 Integrated Report* (2008 Integrated Report) for nonsupport of primary body contact recreation (PBCR) or warm water aquatic community (WWAC).

Elevated levels of bacteria or turbidity above the WQS result in the requirement that a TMDL be developed. The TMDLs established in this report are a necessary step in the process to develop the pollutant loading controls needed to restore the primary body contact recreation or fish and wildlife propagation use designated for each waterbody.

Table ES-1 Excerpt from the 2008 Integrated Report – Oklahoma 303(d) List of Impaired Waters (Category 5)

Waterbody Name	Waterbody ID	Stream Miles	TMDL Date	Priority	ENT	*E. coli*	FC	Turbidity
Salt Creek	OK520700030100_00	22.35	2016	3	X	X		
Camp Creek	OK520700030220_00	5.14	2016	3				X
Canadian River, Deep Fork	OK520700040010_00	18.1	2013	2	X		X	X
Dry Creek	OK520700040020_00	28.27	2019	4	X			X
Quapaw Creek	OK520700040260_00	26.81	2013	2	X			
Bellcow Creek	OK520700050020_00	5.75	2016	3	X			
Captain Creek	OK520700050140_00	4.4	2019	4		X		
Opossum Creek	OK520700050200_00	7.37	2019	4				X

ENT = enterococci; FC = fecal coliform
N = Not attaining; X = Criterion exceeded
Source: 2008 Integrated Report, ODEQ 2008.
* TMDL completed in Sans Bios Bacteria TMDL report

Table ES-2 summarizes water quality data collected during primary contact recreation season (May 1 through September 30) from the water quality monitoring (WQM) stations for each bacterial indicator. The data summary in Table ES-2 provides a general understanding of the amount of water quality data available and the severity of exceedances of the water quality criteria. This data collected during the primary contact recreation season includes the data used to support the decision to place specific waterbodies within the Study Area on the ODEQ 2008 303(d) list (ODEQ 2008). It also includes the new date collected after the data cutoff date for the 2008 303(d) list.

Table ES-2 Summary of Indicator Bacteria Samples from Primary Body Contact Recreation Season

Stream Segments	Waterbody ID	Bacteria Indicator	Standards	GeoMean	# of Violations	# of Samples	% violations	2008 303(d)	Comments
Salt Creek	OK520700030100_00	ENT	108	101.5	6	10	60	X	TMDL required
		EC	406	98.2	0	10	0	X	Delist: less than 10%
		FC	400	No Samples					
Camp Creek	OK520700030220_00	ENT	108	194.9	7	10	70		Added, TMDL required
		EC	406	55.4	0	10	0		
		FC	400	No Samples					
Canadian River, Deep Fork	OK520700040010_00	ENT	108	199.2	7	11	64	X	TMDL required
		EC	406	80.1	2	11	18		
		FC	400	220.7	6	11	55	X	TMDL required
Dry Creek	OK520700040020_00	ENT	108	260.7	7	10	70	X	TMDL required
		EC	406	282.5	3	10	30		Added, TMDL required
		FC	400	No Samples					
Quapaw Creek	OK520700040260_00	ENT	108	160.7	5	10	50	X	TMDL required
		EC	406	112.0	2	10	20		
		FC	400	No Samples					
Bellcow Creek	OK520700050020_00	ENT	108	722.9	12	12	100	X	TMDL required
		EC	406	60.0	1	12	8		
		FC	400	223.8	2	12	17		
Captain Creek	OK520700050140_00	ENT	108	Not enough samples					
		EC	406	Not enough samples				X	Delist: not enough samples
		FC	400	271.3	3	8	38		Added, TMDL required
Opossum Creek	OK520700050200_00	ENT	108	Not enough samples					
		EC	406	Not enough samples					
		FC	400	204.0	1	8	13		

Fecal coliform (FC) water quality criterion = Geometric Mean of 400 counts/100 mL
E. coli (EC) water quality criterion = Geometric Mean of 126 counts/100 mL
Enterococci (ENT) water quality criterion = Geometric Mean of 33 counts/100 mL

To implement Oklahoma's WQS for PBCR, the Oklahoma Water Resources Board (OWRB) promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2008a). The abbreviated excerpt below from Chapter 46: 785:46-15-6, stipulates how water quality data will be assessed to determine support of the PBCR use as well as how the water quality target for TMDLs will be defined for each bacterial indicator.

(a) Scope. The provisions of this Section shall be used to determine whether the subcategory of Primary Body Contact of the beneficial use of Recreation designated in OAC 785:45 for a waterbody is supported during the recreation season from May 1 through September 30 each year. Where data exist for multiple bacterial indicators on the same waterbody or waterbody segment, the determination of use support shall be based upon the use and application of all applicable tests and data.

(b) Screening levels:

(1) The screening level for fecal coliform shall be a density of 400 colonies per 100 ml.

(2) The screening level for Escherichia coli shall be a density of 235 colonies per 100 ml in streams designated in OAC 785:45 as Scenic Rivers and in lakes, and 406 colonies per 100 ml in all other waters of the state designated as Primary Body Contact Recreation.

(3) The screening level for enterococci shall be a density of 61 colonies per 100 ml in streams designated in OAC 785:45 as Scenic Rivers and in lakes, and 108 colonies per 100 ml in all other waters of the state designated as Primary Body Contact Recreation.

(c) Fecal coliform:

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to fecal coliform if the geometric mean of 400 colonies per 100 ml is met and no greater than 25% of the sample concentrations from that waterbody exceed the screening level prescribed in (b) of this Section.

(d) Escherichia coli (E. coli):

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to E. coli if the geometric mean of 126 colonies per 100 ml is met, or the sample concentrations from that waterbody taken during the recreation season do not exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(e) Enterococci:

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to enterococci if the geometric mean of 33 colonies per 100 ml is met, or the sample concentrations from that waterbody taken during the recreation season do not exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

Where concurrent data exist for multiple bacterial indicators on the same waterbody or waterbody segment, each indicator group must demonstrate compliance with the numeric criteria prescribed (OWRB 2008). Waterbodies placed on the 303(d) list for not supporting the PBCR are the result of individual samples exceeding the instantaneous criteria or the long-term geometric mean of individual samples exceeding the geometric mean criteria for each respective bacterial indicator. Targeting the instantaneous criterion established for the primary contact recreation season (May 1st to September 30th) as the water quality goal for TMDLs corresponds to the basis for 303(d) listing and may be protective of the geometric mean criterion as well as the criteria for the secondary contact recreation season. However, both the instantaneous and geometric mean criteria for *E. coli* and Enterococci will be evaluated as water quality targets to ensure the most protective goal is established for each waterbody.

All TMDLs for fecal coliform must take into account that no more than 25 percent of the samples may exceed the instantaneous numeric criteria. For *E. coli* and Enterococci, no samples may exceed instantaneous criteria. Since the attainability of stream beneficial uses for *E. coli* and Enterococci is based on the compliance of either the instantaneous or a long-term geometric mean criterion, percent reductions goals will be calculated for both criteria. TMDLs will be based on the percent reduction required to meet either the instantaneous or the long-term geometric mean criterion, whichever is less.

Turbidity is a measure of water clarity and is caused by suspended particles in the water column. Because turbidity cannot be expressed as a mass load, total suspended solids (TSS) are used as a surrogate for the TMDLs in this report. Therefore, both turbidity and TSS data are presented.

Table ES-3 summarizes a subset of turbidity and TSS data collected from the WQM stations under base flow conditions, which ODEQ considers to be all flows less than the 25th flow exceedance percentile (i.e., the lower 75 percent of flows). Water quality samples collected under flow conditions greater than the 25th flow exceedance percentile (highest flows) were therefore excluded from the data set used for TMDL analysis.

Table ES-3 Summary of Turbidity and TSS Samples Collected Under Base Flow Condition

Waterbody ID	Waterbody Name	Number of turbidity samples	Number of TSS samples	Number of Turbidity samples greater than 50 NTU	% turbidity samples exceeding criterion	2008 303(d)	Comments
OK520700030100_00	Salt Creek	19	17	0	0		
OK520700030220_00	Camp Creek	18	17	0	0	X	Delist: no violations
OK520700040010_00	Canadian River, Deep Fork	22	0	6	27	X	TMDL required
OK520700040020_00	Dry Creek	15	15	3	20	X	TMDL required
OK520700040260_00	Quapaw Creek	19	20	2	11		Added, TMDL required
OK520700050020_00	Bellcow Creek	18	0	0	0		
OK520700050140_00	Captain Creek	13	12	1	8		
OK520700050200_00	Opossum Creek	11	12	3	27	X	TMDL required

The beneficial use of WWAC is one of several subcategories of the Fish and Wildlife Propagation use established to manage the variety of communities of fish and shellfish throughout the state (OWRB 2008). The numeric criteria for turbidity to maintain and protect the use of “Fish and Wildlife Propagation” from Title 785:45-5-12 (f) (7) is as follows:

(A) Turbidity from other than natural sources shall be restricted to not exceed the following numerical limits:

1. Cool Water Aquatic Community/Trout Fisheries: 10 NTUs;

2. Lakes: 25 NTU; and

3. Other surface waters: 50 NTUs.

(B) In waters where background turbidity exceeds these values, turbidity from point sources will be restricted to not exceed ambient levels.

(C) Numerical criteria listed in (A) of this paragraph apply only to seasonal base flow conditions.

(D) Elevated turbidity levels may be expected during, and for several days after, a runoff event.

The abbreviated excerpt below from Chapter 46: 785:46-15-5, stipulates how water quality data will be assessed to determine support of fish and wildlife propagation as well as how the water quality target for TMDLs will be defined for turbidity.

Assessment of Fish and Wildlife Propagation support

(a) Scope. The provisions of this Section shall be used to determine whether the beneficial use of Fish and Wildlife Propagation or any subcategory thereof designated in OAC 785:45 for a waterbody is supported.

(e) Turbidity. The criteria for turbidity stated in 785:45-5-12(f)(7) shall constitute the screening levels for turbidity. The tests for use support shall follow the default protocol in 785:46-15-4(b).

785:46-15-4. Default protocols

(b) Short term average numerical parameters.

(1) Short term average numerical parameters are based upon exposure periods of less than seven days. Short term average parameters to which this Section applies include, but are not limited to, sample standards and turbidity.

(2) A beneficial use shall be deemed to be fully supported for a given parameter whose criterion is based upon a short term average if 10% or less of the samples for that parameter exceed the applicable screening level prescribed in this Subchapter.

TMDLs for turbidity in streams designated as WWAC must take into account that no more than 10 percent of the samples may exceed the numeric criterion of 50 nephelometric turbidity units (NTU). However, as described above, because turbidity cannot be expressed as a mass load, TSS is used as a surrogate in this TMDL. Since there is no numeric criterion in the Oklahoma WQS for TSS, a regression method to convert the turbidity criterion to TSS based on a relationship between turbidity and TSS was used to establish TSS goals as surrogates. Table ES-4 provides the results of the waterbody specific regression analysis.

Table ES-4 Regression Statistics and TSS Goals

Waterbody Name	Waterbody ID	R-square	NRMSE	TSS Goal (mg/L)[a]
Canadian River, Deep Fork	OK520700040010_00	0.91	10.8%	145.7
Dry Creek	OK520700040020_00	0.86	11.7%	28.1
Quapaw Creek	OK520700040260_00	0.72	17.0%	21.1
Opossum Creek	OK520700050200_00	0.88	8.3%	36.0

After re-evaluating bacteria and turbidity/TSS data for the streams listed in Table ES-1, Table ES-5 shows the bacteria and turbidity TMDLs that will be developed in this report:

E.2 Pollutant Source Assessment

A pollutant source assessment characterizes known and suspected sources of pollutant loading to impaired waterbodies. Sources within a watershed are categorized and quantified to the extent that information is available. Bacteria originate from warm-blooded animals; some plant life and sources may be point or nonpoint in nature. Turbidity may originate from NPDES-permitted facilities, fields, construction sites, quarries, stormwater runoff and eroding stream banks.

Point sources are permitted through the NPDES program. NPDES-permitted facilities that discharge treated wastewater are required to monitor for one of the three bacterial indicators (fecal coliform, *E coli*, or Enterococci) and TSS in accordance with their permits. Nonpoint sources are diffuse sources that typically cannot be identified as entering a waterbody through a discrete conveyance at a single location. Nonpoint sources may emanate from land activities that contribute bacteria or TSS to surface water as a result of rainfall runoff. For the TMDLs in this report, all sources of pollutant loading not regulated by NPDES are considered nonpoint sources. Sediment loading of streams can originate from natural erosion processes, including the weathering of soil, rocks, and uncultivated land; geological abrasion; and other natural phenomena. There is insufficient data available to quantify contributions of TSS from these natural processes. TSS or sediment loading can also occur under non-runoff conditions as a result of anthropogenic activities in riparian corridors which cause erosive conditions. Given the lack of data to establish the background conditions for TSS/turbidity, separating background loading from nonpoint sources whether it is from natural or anthropogenic processes is not feasible in this TMDL development. Table ES-6 summarizes the point and nonpoint sources that contribute bacteria or TSS to each respective waterbody.

Table ES-5 Stream Segments and Pollutants for TMDL Development

Waterbody Name	Waterbody ID	Stream Miles	TMDL Date	Priority	ENT	*E. Coli*	Fecal Coliform	Turbidity
Salt Creek	OK520700030100_00	22.35	2016	3	X			
Camp Creek	OK520700030220_00	5.14	2016	3	X			
Canadian River, Deep Fork	OK520700040010_00	18.1	2013	2	X		X	X
Dry Creek	OK520700040020_00	28.27	2019	4	X	X		X
Quapaw Creek	OK520700040260_00	26.81	2013	2	X			X
Bellcow Creek	OK520700050020_00	5.75	2016	3	X			
Captain Creek	OK520700050140_00	4.4	2019	4			X	
Opossum Creek	OK520700050200_00	7.37	2019	4				X

Table ES-6 Summary of Potential Pollutant Sources by Category

Waterbody Name	Waterbody ID	Municipal NPDES Facility	Industrial NPDES Facility	MS4	NPDES No Discharge Facility	CAFO	Mines	Construction Stormwater Permit	Nonpoint Source
Salt Creek	OK520700030100_00	Bacteria							Bacteria
Camp Creek	OK520700030220_00								Bacteria
Canadian River, Deep Fork	OK520700040010_00	Bacteria							Bacteria, TSS
Dry Creek	OK520700040020_00								Bacteria, TSS
Quapaw Creek	OK520700040260_00	Bacteria							Bacteria, TSS
Bellcow Creek	OK520700050020_00	Bacteria							Bacteria
Captain Creek	OK520700050140_00								Bacteria
Opossum Creek	OK520700050200_00								TSS

No facility present in watershed.

Facility present in watershed, but not recognized as pollutant source.

E.3 Using Load Duration Curves to Develop TMDLs

The TMDL calculations presented in this report are derived from load duration curves (LDC). LDCs facilitate rapid development of TMDLs, and as a TMDL development tool are effective at identifying whether impairments are associated with point or nonpoint sources. The technical approach for using LDCs for TMDL development includes the following steps:

- Preparing flow duration curves for gaged and ungaged WQM stations;
- Estimating existing loading in the waterbody using ambient bacteria water quality data; and estimating loading in the waterbody using measured TSS water quality data and turbidity-converted data; and
- Using LDCs to identify the critical condition that will dictate loading reductions and the overall percent reduction goal (PRG) necessary to attain WQS.

Use of the LDC obviates the need to determine a design storm or selected flow recurrence interval with which to characterize the appropriate flow level for the assessment of critical conditions. For waterbodies impacted by both point and nonpoint sources, the "nonpoint source critical condition" would typically occur during high flows, when rainfall runoff would contribute the bulk of the pollutant load, while the "point source critical condition" would typically occur during low flows, when wastewater treatment plant (WWTP) effluents would dominate the base flow of the impaired water. However, flow range is only a general indicator of the relative proportion of point/nonpoint contributions. Violations have been noted under low flow conditions in some watersheds that contain no point sources.

LDCs display the maximum allowable load over the complete range of flow conditions by a line using the calculation of flow multiplied by a water quality criterion. The TMDL can be expressed as a continuous function of flow, equal to the line, or as a discrete value derived from a specific flow condition.

The basic steps to generating an LDC involve:

- obtaining daily flow data for the site of interest from the U.S. Geological Survey (USGS);
- sorting the flow data and calculating flow exceedance percentiles for the time period and season of interest;
- obtaining the water quality data from the primary contact recreation season (May 1 through September 30); or obtaining available turbidity and TSS water quality data;
- matching the water quality observations with the flow data from the same date;
- displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQS for each respective bacteria indicator; or displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQ_{goal} for TSS;
- converting measured concentration values to loads by multiplying the flow at the time the sample was collected by the water quality parameter concentration (for sampling events with both TSS and turbidity data, the measured TSS value is used; if only turbidity was measured, the value was converted to TSS using the regression equation); or multiplying the flow by the bacteria indicator concentration to calculate daily loads; then

- plotting the flow exceedance percentiles and daily load observations in a load duration plot.

For bacteria TMDLs the culmination of these steps is expressed in the following formula, which is displayed on the LDC as the TMDL curve:

TMDL (cfu/day) = WQS * flow (cfs) * unit conversion factor

Where: WQS = 400 cfu /100 mL (Fecal coliform); 406 cfu/100 mL (E. coli); or 108 cfu/100 mL (Enterococci)

unit conversion factor = 24,465,525 mL*s / ft3*day

For turbidity (TSS) TMDLs the culmination of these steps is expressed in the following formula, which is displayed on the LDC as the TMDL curve:

TMDL (lb/day) = WQ_{goal}* flow (cfs) * unit conversion factor

where: WQ_{goal} = waterbody specific TSS concentration derived from regression analysis results presented in Table 4-1

unit conversion factor = 5.39377 L*s*lb /(ft^3*day*mg)

Historical observations of bacteria, TSS and/or turbidity concentrations are paired with flow data and are plotted as separate LDCs. The fecal coliform load (or the y-value of each point) is calculated by multiplying the fecal coliform concentration (colonies/100 mL) by the instantaneous flow (cubic feet per second) at the same site and time, with appropriate volumetric and time unit conversions. Fecal coliform/*E. coli*/Enterococci loads representing exceedance of water quality criteria fall above the water quality criterion line. Likewise, the TSS load (or the y-value of each point) is calculated by multiplying the TSS concentration (measured or converted from turbidity) (mg/L) by the instantaneous flow (cfs) at the same site and time, with appropriate volumetric and time unit conversions. TSS loads representing exceedance of water quality criteria fall above the TMDL line.

E.4 TMDL Calculations

A TMDL is expressed as the sum of all WLAs (point source loads), LAs (nonpoint source loads), and an appropriate MOS, which attempts to account for the lack of knowledge concerning the relationship between effluent limitations and water quality.

This definition can be expressed by the following equation:

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

For each waterbody the TMDLs presented in this report are expressed as a percent reduction across the full range of flow conditions. The difference between existing loading and the water quality target is used to calculate the loading reductions required. PRG are calculated for each waterbody and bacterial indicator species as the reductions in load required so no existing instantaneous water quality observations would exceed the water quality target for *E. coli* and Enterococci and no more than 25 percent of the samples exceed the water quality target for fecal coliform.

Table ES-7 presents the percent reductions necessary for each bacterial indicator causing nonsupport of the PBCR use in each waterbody of the Study Area. Selection of the appropriate PRG for each waterbody in Table ES-7 is denoted by bold text. The TMDL PRG will be the lesser of that required to meet the geometric mean or instantaneous criteria for *E. coli* and

Enterococci because WQSs are considered to be met if, 1) either the geometric mean of all data is less than the geometric mean criteria, or 2) no samples exceed the instantaneous criteria. The PRGs range from 29 to 96 percent.

Table ES-7 TMDL Percent Reductions Required to Meet Water Quality Standards for Indicator Bacteria

Waterbody Name	Waterbody ID	Required Reduction Rate				
		FC	EC		ENT	
		Instant-aneous	Instant-aneous	Geo-mean	Instant-aneous	Geo-mean
Salt Creek	OK520700030100_00				75.7%	**71.2%**
Camp Creek	OK520700030220_00				93.3%	**85.3%**
Canadian River, Deep Fork	OK520700040010_00	**47.1%**			98.4%	**85.6%**
Dry Creek	OK520700040020_00		94.5%	**60.4%**	98.9%	**89.1%**
Quapaw Creek	OK520700040260_00				99.0%	**82.0%**
Bellcow Creek	OK520700050020_00				99.9%	**96.4%**
Captain Creek	OK520700050140_00	**29.4%**				

Similarly, percent reduction goals for TSS are calculated as the required overall reduction so that no more than 10 percent of the samples exceed the water quality target for TSS. The PRGs for the fourteen waterbodies included in this TMDL report are summarized in Table ES-8 and range from 51 to 94 percent.

Table ES-8 TMDL Percent Reductions Required to Meet Water Quality Targets for Total Suspended Solids

Waterbody Name	Waterbody ID	Required Reduction Rate
Canadian River, Deep Fork	OK520700040010_00	94.0%
Dry Creek	OK520700040020_00	59.8%
Quapaw Creek	OK520700040260_00	71.1%
Opossum Creek	OK520700050200_00	50.7%

The TMDL, WLA, LA, and MOS vary with flow condition, and are calculated at every 5th flow interval percentile. The WLA component of each TMDL is the sum of all WLAs within each contributing watershed. The sum of the WLAs can be represented as a single line below the LDC. The LDC and the simple equation of:

Average LA = average TMDL – MOS - $\sum$***WLA***

can provide an individual value for the LA in counts per day, which represents the area under the TMDL target line and above the WLA line.

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs include an MOS and account for seasonal variability. The MOS, which can be implicit or explicit, is a conservative measure incorporated into the TMDL equation that accounts for the lack of knowledge associated with calculating the allowable pollutant loading to ensure WQSs are attained.

For bacteria TMDLs, an explicit MOS was set at 10 percent.

For turbidity, the TMDLs are calculated for TSS instead of turbidity. Thus, the quality of the regression has a direct impact on confidence of the TMDL calculations. The better the regression is, the more confidence there is in the TMDL targets. As a result, it leads to a smaller margin of safety. The selection of MOS is based on the normalized root mean square error (NRMSE) for each waterbody. The explicit MOS was used in this report. Table 5-4 shows the MOS for each waterbody.

The bacteria TMDLs established in this report adhere to the seasonal application of the Oklahoma WQS which limits the PBCR use to the period of May 1st through September 30th. Similarly, the TSS TMDLs established in this report adhere to the seasonal application of the Oklahoma WQS for turbidity, which applies to seasonal base flow conditions only. Seasonal variation was also accounted for in these TMDLs by using more than 5 years of water quality data and by using the longest period of USGS flow records when estimating flows to develop flow exceedance percentiles.

E.5 Reasonable Assurance

As authorized by Section 402 of the CWA, ODEQ has delegation of the NPDES in Oklahoma, except for certain jurisdictional areas related to agriculture and the oil and gas industry retained by the Oklahoma Department of Agriculture and Oklahoma Corporation Commission, for which the USEPA has retained permitting authority. The NPDES program in Oklahoma is implemented via Title 252, Chapter 606 of the Oklahoma Pollution Discharge Elimination System (OPDES) Act, and in accordance with the agreement between ODEQ and USEPA relating to administration and enforcement of the delegated NPDES program. Implementation of WLAs for point sources is done through permits issued under the OPDES program. The reduction rates called for in this TMDL report are as high as 94 percent. The ODEQ recognizes that achieving such high reductions will be a challenge, especially since unregulated nonpoint sources are a major cause of both bacteria and TSS loading. The high reduction rates are not uncommon for pathogen- or TSS-impaired waters. Similar reduction rates are often found in other pathogen and TSS TMDLs around the nation.

SECTION 1
INTRODUCTION

1.1 TMDL Program Background

Section 303(d) of the Clean Water Act (CWA) and U.S. Environmental Protection Agency (USEPA) Water Quality Planning and Management Regulations (40 Code of Federal Regulations [CFR] Part 130) require states to develop total maximum daily loads (TMDLs) for waterbodies not meeting designated uses where technology-based controls are in place. TMDLs establish the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and instream water quality conditions, so states can implement water quality-based controls to reduce pollution from point and nonpoint sources and restore and maintain water quality (USEPA 1991).

This report documents the data and assessment used to establish TMDLs for the pathogen indicator bacteria [fecal coliform, *Escherichia coli (E. coli)*, Enterococci] and turbidity for selected waterbodies in part of the upper Deep Fork of the Canadian River Basin in Oklahoma, Logan, Lincoln, Creek and Pottawatomie Counties (The study area). (All future references to bacteria in this document imply these three classes of fecal pathogen indicator bacteria unless specifically stated otherwise.) Elevated levels of pathogen indicator bacteria in aquatic environments indicate that a waterbody is contaminated with human or animal feces and that a potential health risk exists for individuals exposed to the water. Elevated turbidity levels caused by excessive sediment loading and stream bank erosion impact aquatic biological communities. Data assessment and TMDL calculations are conducted in accordance with requirements of Section 303(d) of the CWA, Water Quality Planning and Management Regulations (40 CFR Part 130), USEPA guidance, and Oklahoma Department of Environmental Quality (ODEQ) guidance and procedures. ODEQ is required to submit all TMDLs to USEPA for review and approval. Once the USEPA approves a TMDL, then the waterbody may be moved to Category 4a of a state's Integrated Water Quality Monitoring and Assessment Report, where it remains until compliance with water quality standards (WQS) is achieved (USEPA 2003).

The purpose of this TMDL report is to establish pollutant load allocations for indicator bacteria and turbidity in impaired waterbodies, which is the first step toward restoring water quality and protecting public health. TMDLs determine the pollutant loading a waterbody can assimilate without exceeding the WQS for that pollutant. TMDLs also establish the pollutant load allocation necessary to meet the WQS established for a waterbody based on the relationship between pollutant sources and instream water quality conditions. A TMDL consists of a wasteload allocation (WLA), load allocation (LA), and a margin of safety (MOS). The WLA is the fraction of the total pollutant load apportioned to point sources, and includes stormwater discharges regulated under the National Pollutant Discharge Elimination System (NPDES). The LA is the fraction of the total pollutant load apportioned to nonpoint sources. The MOS is a percentage of the TMDL set aside to account for the lack of knowledge associated with natural process in aquatic systems, model assumptions, and data limitations.

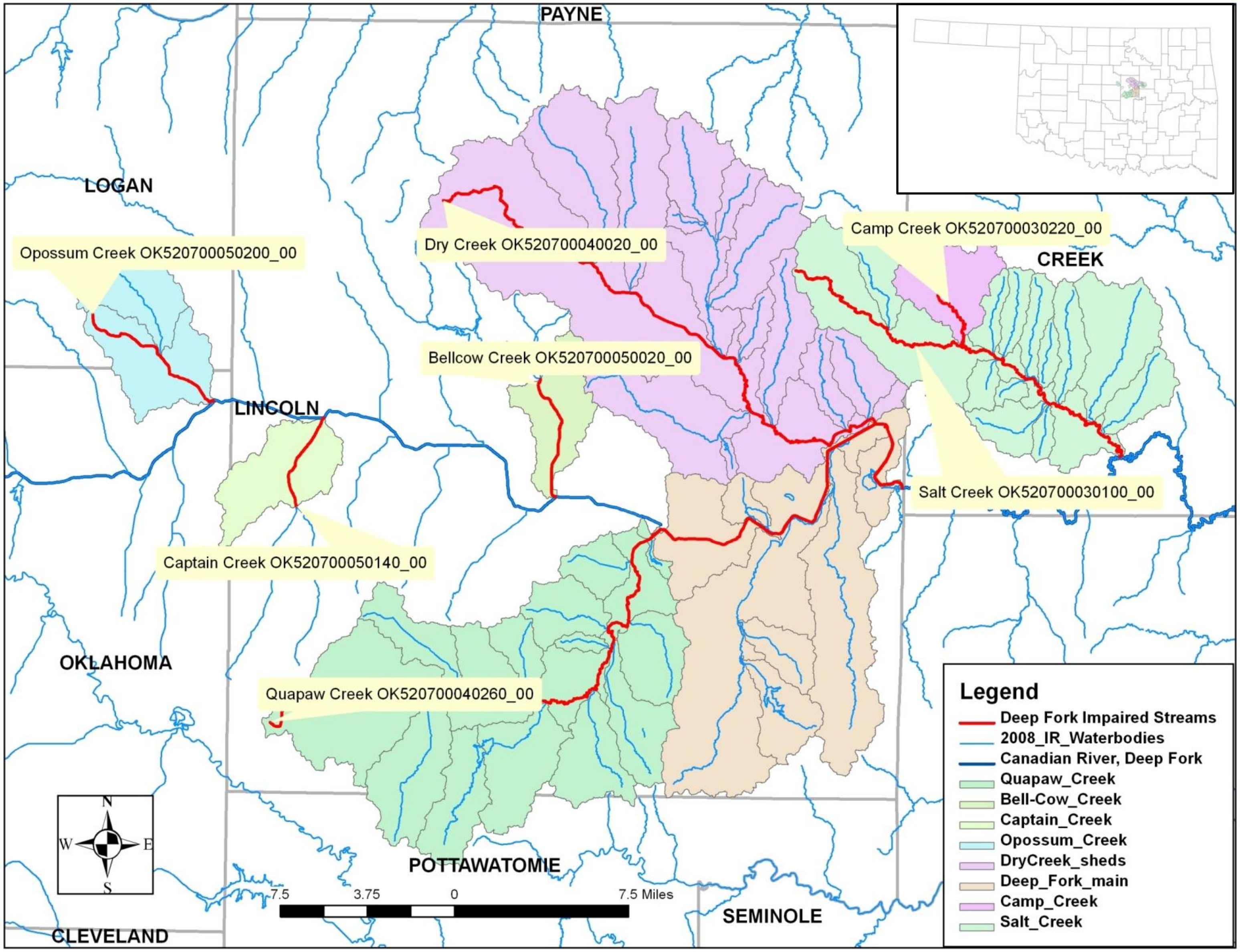
This report does not stipulate specific control actions (regulatory controls) or management measures (voluntary best management practices) necessary to reduce bacteria or turbidity within each watershed. Watershed-specific control actions and management measures will be identified, selected, and implemented under a separate process involving stakeholders who live and work in the watersheds, along with tribes, and local, state, and federal government agencies.

This TMDL report focuses on waterbodies that ODEQ placed in Category 5 [303(d) list] of the *Water Quality in Oklahoma, 2008 Integrated Report* (2008 Integrated Report) for nonsupport of primary body contact recreation (PBCR) or warm water aquatic community (WWAC) designated uses. The waterbodies addressed in this report include:

- Salt Creek OK520700030100_00
- Camp Creek OK520700030220_00
- Canadian River, Deep Fork OK520700040010_00
- Dry Creek OK520700040020_00
- Quapaw Creek OK520700040260_00
- Bellcow Creek OK520700050020_00
- Captain Creek OK520700050140_00
- Opossum Creek OK520700050200_00

Figure 1-1 is location maps showing these Oklahoma waterbodies and their contributing watersheds. These maps also display locations of the water quality monitoring (WQM) stations used as the basis for placement of these waterbodies on the Oklahoma 303(d) list. These waterbodies and their surrounding watersheds are hereinafter referred to as the Study Area.

Figure 1-1 Deep Fork of the Canadian River Watersheds Not Supporting Primary Body Contact Recreation or Fish and Wildlife Propagation



Elevated levels of pathogen indicator bacteria or turbidity above the WQS result in the requirement that a TMDL be developed. The TMDLs established in this report are a necessary step in the process to develop the pollutant loading controls needed to restore the primary body contact recreation or fish and wildlife propagation use designated for each waterbody. Table 1-1 provides a description of the locations of WQM stations on the 303(d)-listed waterbodies.

Table 1-1 Water Quality Monitoring Stations used for 2008 303(d) Listing Decision

WBID	Name	monitoring sites	Lat	Long	Agency
OK520700030100_00	Salt Creek	OK520700-03-0100B	35.6962	-96.4765	OCC
OK520700030220_00	Camp Creek	OK520700-03-0220G	35.7559	-96.5723	OCC
OK520700040010_00	Canadian River, Deep Fork	520700040010-001AT	35.6861	-96.6623	OWRB
OK520700040020_00	Dry Creek	OK520700-04-0020F	35.6848	-96.6949	OCC
OK520700040260_00	Quapaw Creek	OK520700-04-0260C	35.6221	-96.8196	OCC
OK520700050020_00	Bellcow Creek	520700050020-002SR	35.6665	-96.8930	OWRB
		520700050020-001SR	35.6953	-96.8853	OWRB
OK520700050140_00	Captain Creek	OK520700-05-0140C	35.6810	-97.0799	OCC
OK520700050200_00	Opossum Creek	OK520700-05-0200C	35.7100	-97.1639	OCC

1.2 Watershed Description

General. The Upper Deep Fork of the Canadian River basin is located in the east central portion of Oklahoma. The waterbodies addressed in this report are located in Logan, Oklahoma, Lincoln, Pottawatomie, and Creek counties. Table 1-2, derived from the 2000 U.S. Census, demonstrates that the counties in which these watersheds are located are mostly sparsely populated except Oklahoma County (U.S. Census Bureau 2000). Table 1-3 lists the towns and cities located in each watershed.

Table 1-2 County Population and Density

County Name	Population (2000 Census)	Area (square mile)	Population Density (per square mile)
Logan	33,924	744.45	45.6
Oklahoma	660,448	709.09	931.4
Lincoln	32,080	957.74	33.5
Pottawatomie	70,274	792.30	89.0
Creek	67,367	955.53	70.5

Table 1-3 Towns and Cities by Watershed

City Name	Waterbody ID	Stream Name
Tryon	OK520700040020_00	Dry Creek
Davenport	OK520700040020_00	Dry Creek
Wellston	OK520700050140_00	Captain Creek
Chandler	OK520700040020_00	Dry Creek
Chandler	OK520700050020_00	Bellcow Creek
Kendrick	OK520700040020_00	Dry Creek
Sparks	OK520700040260_00	Quapaw Creek
Agra	OK520700040020_00	Dry Creek
Shawnee	OK520700040260_00	Quapaw Creek
Prague	OK520700040010_00	Canadian River, Deep Fork
Meeker	OK520700040260_00	Quapaw Creek
Luther	OK520700050200_00	Opossum Creek
Stroud	OK520700040020_00	Dry Creek
Stroud	OK520700030100_00	Salt Creek
Stroud	OK520700030220_00	Camp Creek

Climate. Table 1-4 summarizes the average annual precipitation for each Oklahoma waterbody based on the approximate midpoint of each watershed. Average annual precipitation values among the watersheds in this portion of Oklahoma range between 40.1 and 45.2 inches (Oklahoma Climate Survey 2007).

Table 1-4 Average Annual Precipitation by Watershed

Precipitation Summary		
Waterbody ID	**Waterbody Name**	**Average Annual Precipitation (Inches)**
OK520700030100_00	Salt Creek	40.3
OK520700030220_00	Camp Creek	40.0
OK520700040010_00	Canadian River, Deep Fork	39.6
OK520700040020_00	Dry Creek	38.9
OK520700040260_00	Quapaw Creek	39.2
OK520700050020_00	Bellcow Creek	38.3
OK520700050140_00	Captain Creek	37.7
OK520700050200_00	Opossum Creek	36.6

Land Use. Tables1-5summarize the percentages and acreages of the land use categories for the contributing watershed associated with each respective Oklahoma waterbody addressed in the Study Area. The land use/land cover data were derived from the U.S. Geological Survey (USGS) 2001 National Land Cover Dataset (USGS 2007). The land use categories are displayed in Figure 1-2. The three most dominant land use categories throughout the Study Area are deciduous forest, grasslands/herbaceous and pasture/hay.

Figure 1-2 Land Use Map

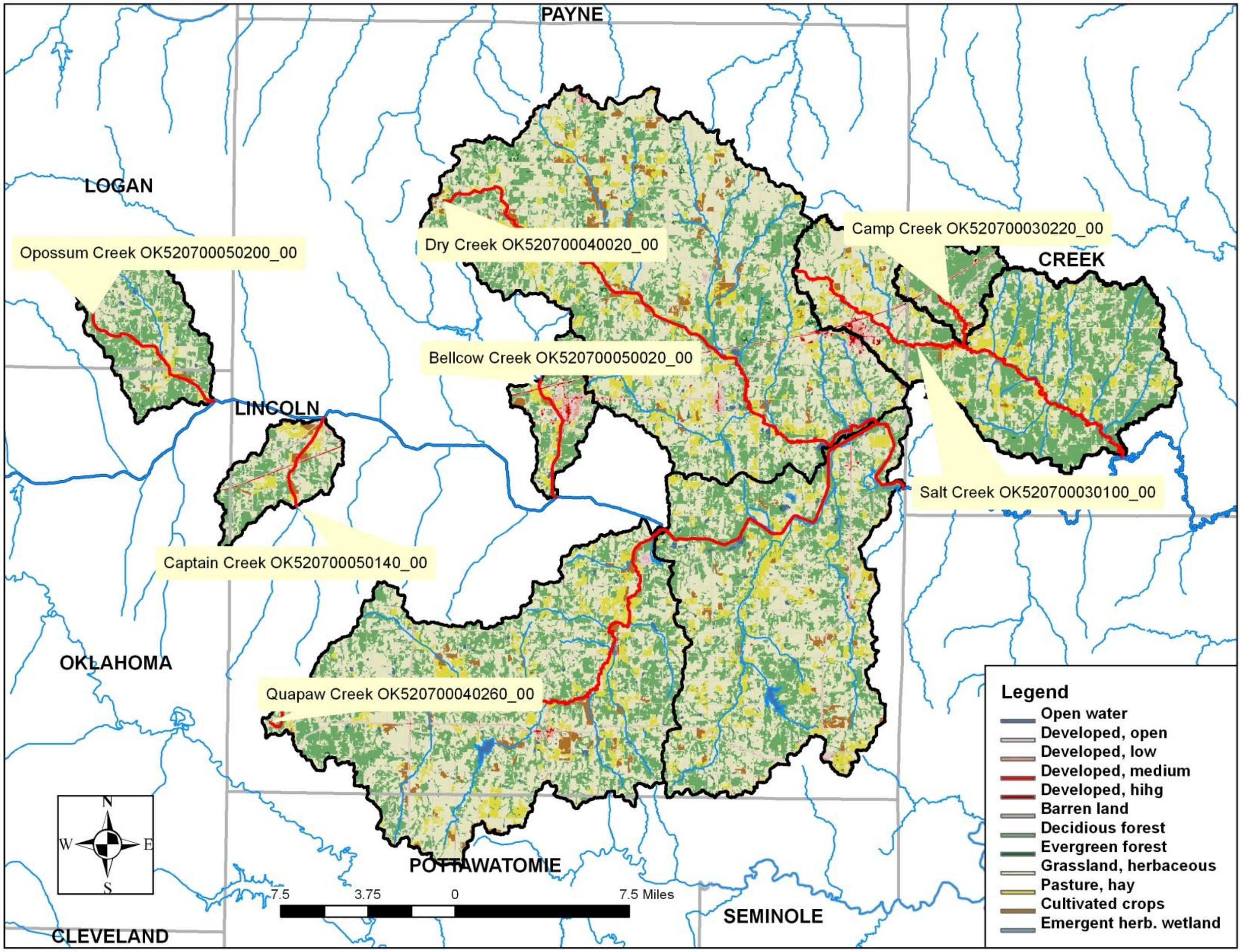


Table 1-5 Land Use Summaries by Watershed

Landuse Category	Stream Segments							
	Salt Creek	Camp Creek	Canadian River, Deep Fork	Dry Creek	Quapaw Creek	Bellcow Creek	Captain Creek	Opossum Creek
	OK5207000 30100_00	OK5207000 30220_00	OK5207000 40010_00	OK5207000 40020_00	OK5207000 40260_00	OK5207000 50020_00	OK5207000 50140_00	OK5207000 50200_00
Open water	273.1	161.9	1,095.6	1,058.3	1,077.9	64.6	14.9	158.6
Developed, open	2,523.1	601.8	3,833.4	6,532.9	4,901.9	953.4	898.6	784.1
Developed, low	269.3	16.1	260.0	490.6	395.0	363.9	80.9	17.6
Developed, medium	142.4	65.5	46.1	288.7	40.1	164.9	120.6	0.0
Developed, high	70.4	14.0	5.1	89.4	16.7	35.9	5.6	0.0
Barren land	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0
Deciduous forest	23,755.5	4,556.5	26,155.7	35,195.3	31,536.2	3,065.9	3,520.3	8,974.5
Evergreen forest	43.0	33.9	84.7	687.0	43.2	14.3	0.0	1.6
Grassland, herbaceous	22,800.7	2,194.5	36,049.8	63,237.1	46,537.7	2,790.1	4,337.1	7,959.1
Pasture, hay	6,426.0	433.9	7,902.1	11,283.5	8,798.4	940.3	828.8	616.3
Cultivated crops	542.8	145.1	1,495.3	4,632.5	3,412.2	347.1	478.3	269.2
Emergent herb. wetland	1.3	0.0	21.4	0.0	0.0	0.0	0.0	2.0
Total (Acres)	56,847.7	8,223.2	76,952.1	123,495.1	96,759.4	8,740.3	10,285.3	18,783.0
Open water	0.48	1.97	1.42	0.86	1.11	0.74	0.15	0.84
Developed, open	4.44	7.32	4.98	5.29	5.07	10.91	8.74	4.17
Developed, low	0.47	0.20	0.34	0.40	0.41	4.16	0.79	0.09
Developed, medium	0.25	0.80	0.06	0.23	0.04	1.89	1.17	0.00
Developed, high	0.12	0.17	0.01	0.07	0.02	0.41	0.05	0.00
Barren land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Deciduous forest	41.79	55.41	33.99	28.50	32.59	35.08	34.23	47.78
Evergreen forest	0.08	0.41	0.11	0.56	0.04	0.16	0.00	0.01
Grassland, herbaceous	40.11	26.69	46.85	51.21	48.10	31.92	42.17	42.37
Pasture, hay	11.30	5.28	10.27	9.14	9.09	10.76	8.06	3.28
Cultivated crops	0.95	1.77	1.94	3.75	3.53	3.97	4.65	1.43
Emergent herb. wetland	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.01
Total (percentage)	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1.3 Stream Flow Conditions

Stream flow characteristics and data are key information when conducting water quality assessments such as TMDLs. The USGS operates flow gages throughout Oklahoma, from which long-term stream flow records can be obtained. At various WQM stations additional flow measurements are available which were collected at the same time bacteria, total suspended solids (TSS) and turbidity water quality samples were collected. Not all of the waterbodies in this Study Area have historical flow data available. However, the flow data from the surrounding USGS gage stations and the instantaneous flow measurement data along with water quality samples have been used to estimate flows for ungaged streams. Flow data collected at the time of water quality sampling are included in Appendix A along with corresponding water chemistry data results. A summary of the method used to project flows for ungaged streams and flow exceedance percentiles from projected flow data are provided in Appendix C.

SECTION 2
PROBLEM IDENTIFICATION AND WATER QUALITY TARGET

2.1 Oklahoma Water Quality Standards

Title 785 of the Oklahoma Administrative Code contains Oklahoma's water quality standards and implementation procedures (OWRB 2008). The Oklahoma Water Resources Board (OWRB) has statutory authority and responsibility concerning establishment of state water quality standards, as provided under 82 Oklahoma Statute [O.S.], §1085.30. This statute authorizes the OWRB to promulgate rules …*which establish classifications of uses of waters of the state, criteria to maintain and protect such classifications, and other standards or policies pertaining to the quality of such waters.* [O.S. 82:1085:30(A)]. Beneficial uses are designated for all waters of the state. Such uses are protected through restrictions imposed by the antidegradation policy statement, narrative water quality criteria, and numerical criteria (OWRB 2008). An excerpt of the Oklahoma WQS (Title 785) summarizing the State of Oklahoma Antidegradation Policy is provided in Appendix D. Table 2-1, an excerpt from the 2008 Integrated Report (ODEQ 2008), lists beneficial uses designated for each bacteria and/or turbidity impaired stream segment in the Study Area. The beneficial uses include:

- AES – Aesthetics
- AG – Agriculture Water Supply
- Fish and Wildlife Propagation
  - WWAC – Warm Water Aquatic Community
- FISH – Fish Consumption
- PBCR – Primary Body Contact Recreation
- PPWS – Public & Private Water Supply

Table 2-2 summarizes the PBCR and WWAC use attainment status and the bacteria & turbidity impairment status for streams in the Study Area. The TMDL priority shown in Table 2-2 is directly related to the TMDL target date. The TMDLs established in this report, which are a necessary step in the process of restoring water quality, only address bacteria and/or turbidity impairments that affect the PBCR and Fish and Wildlife Propagation uses.

The definition of PBCR is summarized by the following excerpt from Chapter 45 of the Oklahoma WQSs.

(a) Primary Body Contact Recreation involves direct body contact with the water where a possibility of ingestion exists. In these cases the water shall not contain chemical, physical or biological substances in concentrations that are irritating to skin or sense organs or are toxic or cause illness upon ingestion by human beings.

(b) In waters designated for Primary Body Contact Recreation...limits...shall apply only during the recreation period of May 1 to September 30. The criteria for Secondary Body Contact Recreation will apply during the remainder of the year.

Table 2-1 Designated Beneficial Uses for Each Impaired Waterbody in the Study Area

Waterbody Name	Waterbody ID	AES	AG	WWAC	*FISH*	PBCR	PPWS
Salt Creek	OK520700030100_00	F	F	N	X	N	I
Camp Creek	OK520700030220_00	I	F	N	X	I	I
Canadian River, Deep Fork	OK520700040010_00	I	F	N	N	N	N
Dry Creek	OK520700040020_00	F	F	N	X	N	I
Quapaw Creek	OK520700040260_00	F	F	I	X	N	I
Bellcow Creek	OK520700050020_00	I	X	I	X	N	X
Captain Creek	OK520700050140_00	F	F	I	X	N	F
Opossum Creek	OK520700050200_00	F	F	N	X	I	

F – Fully supporting; N – Not supporting; I – Insufficient information; X – Not assessed

Table 2-2 Excerpt from the 2008 Integrated Report – Oklahoma 303(d) List of Impaired Waters (Category 5)

Waterbody Name	Waterbody ID	Stream Miles	TMDL Date	Priority	ENT	*E. coli*	FC	Turbidity
Salt Creek	OK520700030100_00	22.35	2016	3	X	X		
Camp Creek	OK520700030220_00	5.14	2016	3				X
Canadian River, Deep Fork	OK520700040010_00	18.1	2013	2	X		X	X
Dry Creek	OK520700040020_00	28.27	2019	4	X			X
Quapaw Creek	OK520700040260_00	26.81	2013	2	X			
Bellcow Creek	OK520700050020_00	5.75	2016	3	X			
Captain Creek	OK520700050140_00	4.4	2019	4		X		
Opossum Creek	OK520700050200_00	7.37	2019	4				X

ENT = Enterococci; FC = fecal coliform
X = Criterion exceeded
Source: 2008 Integrated Report, ODEQ 2008.

To implement Oklahoma's WQS for PBCR, OWRB promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2008a). The excerpt below from Chapter 46: 785:46-15-6, stipulates how water quality data will be assessed to determine support of the PBCR use as well as how the water quality target for TMDLs will be defined for each bacterial indicator.

(a) Scope. The provisions of this Section shall be used to determine whether the subcategory of Primary Body Contact of the beneficial use of Recreation designated in OAC 785:45 for a waterbody is supported during the recreation season from May 1 through September 30 each year. Where data exist for multiple bacterial indicators on the same waterbody or waterbody segment, the determination of use support shall be based upon the use and application of all applicable tests and data.

(b) Screening levels.

(1) The screening level for fecal coliform shall be a density of 400 colonies per 100 ml.

(2) The screening level for Escherichia coli shall be a density of 235 colonies per 100 ml in streams designated in OAC 785:45 as Scenic Rivers and in lakes, and 406 colonies per 100 ml in all other waters of the state designated as Primary Body Contact Recreation.

(3) The screening level for enterococci shall be a density of 61 colonies per 100 ml in streams designated in OAC 785:45 as Scenic Rivers and in lakes, and 108 colonies per 100 ml in all other waters of the state designated as Primary Body Contact Recreation.

(c) Fecal coliform:

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to fecal coliform if the geometric mean of 400 colonies per 100 ml is met and no greater than 25% of the sample concentrations from that waterbody exceed the screening level prescribed in (b) of this Section.

(2) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to fecal coliform if the geometric mean of 400 colonies per 100 ml is not met, or greater than 25% of the sample concentrations from that waterbody exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(d) Escherichia coli (E. coli):

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to E. coli if the geometric mean of 126 colonies per 100 ml is met, or the sample concentrations from that waterbody taken during the recreation season do not exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(2) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to E. coli if the geometric mean of 126 colonies per 100 ml is not met and any of the sample concentrations from that waterbody taken during the recreation season exceed a screening level prescribed in (b) of this Section.

(e) Enterococci:

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to enterococci if the geometric mean of 33 colonies per 100 ml is met, or the sample concentrations from that waterbody taken during the recreation season do not exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(2) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to enterococci if the geometric mean of 33 colonies per 100 ml is not met and any of the sample concentrations from that waterbody taken during the recreation season exceed a screening level prescribed in (b) of this Section.

Compliance with the Oklahoma WQS is based on meeting requirements for all three bacterial indicators. Where concurrent data exist for multiple bacterial indicators on the same waterbody or waterbody segment, each indicator group must demonstrate compliance with the numeric criteria prescribed (OWRB 2008).

As stipulated in the WQS, utilization of the geometric mean to determine compliance for any of the three indicator bacteria depends on the collection of five samples within a 30-day period. For most WQM stations in Oklahoma there are insufficient data available to calculate the 30-day geometric mean since most water quality samples are collected once a month. As a result, waterbodies placed on the 303(d) list for not supporting the PBCR are the result of individual samples exceeding the instantaneous criteria or the long-term geometric mean of individual samples exceeding the geometric mean criteria for each respective bacterial indicator. Targeting the instantaneous criterion established for the primary contact recreation season (May 1st to September 30th) as the water quality goal for TMDLs corresponds to the basis for 303(d) listing and may be protective of the geometric mean criterion as well as the criteria for the secondary contact recreation season. However, both the instantaneous and geometric mean criteria for *E. coli* and Enterococci will be evaluated as water quality targets to ensure the most protective goal is established for each waterbody.

A sample quantity exception exists for fecal coliform that allows waterbodies to be listed for nonsupport of PBCR if there are less than 10 samples. The assessment method states that if there are less than 10 samples and the existing sample set already assures a nonsupport determination, then the waterbody should be listed for TMDL development. This condition is true in any case where the small sample set demonstrates that at least three out of six samples exceed the single sample fecal coliform criterion. In this case if four more samples were available to meet minimum of 10 samples, this would still translate to >25 percent exceedance or nonsupport of PBCR (*i.e.*, three out of 10 samples = 33 percent exceedance). For *E. coli* and Enterococci, the 10-sample minimum was used, without exception, in attainment determination.

The beneficial use of WWAC is one of several subcategories of the Fish and Wildlife Propagation use established to manage the variety of communities of fish and shellfish throughout the state (OWRB 2008). The numeric criteria for turbidity to maintain and protect the use of "Fish and Wildlife Propagation" from Title 785:45-5-12 (f) (7) is as follows:

(A) Turbidity from other than natural sources shall be restricted to not exceed the following numerical limits:

i. Cool Water Aquatic Community/Trout Fisheries: 10 NTUs;

ii. Lakes: 25 NTU; and

iii. Other surface waters: 50 NTUs.

(B) In waters where background turbidity exceeds these values, turbidity from point sources will be restricted to not exceed ambient levels.

(C) Numerical criteria listed in (A) of this paragraph apply only to seasonal base flow conditions.

(D) Elevated turbidity levels may be expected during, and for several days after, a runoff event.

To implement Oklahoma's WQS for Fish and Wildlife Propagation, promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2008a). The excerpt below from Chapter 46: 785:46-15-5, stipulates how water quality data will be assessed to determine support of fish and wildlife propagation as well as how the water quality target for TMDLs will be defined for turbidity.

Assessment of Fish and Wildlife Propagation support

(a) Scope. The provisions of this Section shall be used to determine whether the beneficial use of Fish and Wildlife Propagation or any subcategory thereof designated in OAC 785:45 for a waterbody is supported.

(e) Turbidity. The criteria for turbidity stated in 785:45-5-12(f)(7) shall constitute the screening levels for turbidity. The tests for use support shall follow the default protocol in 785:46-15-4(b).

785:46-15-4. Default protocols

(b) Short term average numerical parameters.

(1) Short term average numerical parameters are based upon exposure periods of less than seven days. Short term average parameters to which this Section applies include, but are not limited to, sample standards and turbidity.

(2) A beneficial use shall be deemed to be fully supported for a given parameter whose criterion is based upon a short term average if 10% or less of the samples for that parameter exceed the applicable screening level prescribed in this Subchapter.

(3) A beneficial use shall be deemed to be fully supported but threatened if the use is supported currently but the appropriate state environmental agency determines that available data indicate that during the next five years the use may become not supported due to anticipated sources or adverse trends of pollution not prevented or controlled. If data from the preceding two year period indicate a trend away from impairment, the appropriate agency shall remove the threatened status.

(4) A beneficial use shall be deemed to be not supported for a given parameter whose criterion is based upon a short term average if at least 10% of the samples for that parameter exceed the applicable screening level prescribed in this Subchapter.

2.2 Problem Identification

In this subsection water quality data summarizing waterbody impairments caused by elevated levels of bacteria are summarized first followed by the data summarizing impairments caused by elevated levels of turbidity.

2.2.1 Bacteria Data Summary

Table 2-3 summarizes water quality data collected during primary contact recreation season from the WQM stations between 1999 and 2010 for each indicator bacteria. The data summary in Table 2-3 provides a general understanding of the amount of water quality data available and the severity of exceedances of the water quality criteria. This data collected during the primary contact recreation season was used to support the decision to place specific waterbodies within the Study Area on the ODEQ 2008 303(d) list (ODEQ 2008). Water quality data from the primary contact recreation seasons are provided in Appendix A. For the data collected between 1999 and 2010, evidence of nonsupport of the PBCR use based on Enterococci exceedances only was observed in four waterbodies: Salt Creek (OK520700030100_00), Camp Creek (OK520700030220_00), Quapaw Creek (OK520700040260_00) and Bellcow Creek (OK520700050020_00). Evidence of nonsupport of the PBCR use based on fecal coliform and Enterococci concentrations was observed in the Deep Fork of the Canadian River (OK520700040010_00). Evidence of nonsupport of the PBCR use based on *E. coli* and Enterococci concentrations was only observed in Dry Creek (OK520700040020_00). Evidence of nonsupport of the PBCR use based on fecal coliform only concentrations was observed in Captain Creek (OK520700050140_00).

2.2.2 Turbidity Data Summary

Turbidity is a measure of water clarity and is caused by suspended particles in the water column. Because turbidity cannot be expressed as a mass load, total suspended solids (TSS) are used as a surrogate in this TMDL. Therefore, both turbidity and TSS data are presented in this subsection.

Table 2-4 summarizes turbidity and TSS data collected from the WQM stations between 2000 and 2010. However, as stipulated in Title *785:45-5-12 (f) (7) (C),* numeric criteria for turbidity only apply under base flow conditions. While the base flow condition is not specifically defined in the Oklahoma Water Quality Standards, ODEQ considers base flow conditions to be all flows less than the 25th flow exceedance percentile (i.e., the lower 75 percent of flows) which is consistent with the USGS Streamflow Conditions Index (USGS 2007a). Therefore, Water quality samples collected under flow conditions greater than the 25th flow exceedance percentile (highest flows) were therefore excluded from the data set used for TMDL analysis. Table 2-5 was prepared to represent the subset of these data for samples collected during base flow conditions. For the data collected between 2000 and 2010, evidence of nonsupport of the Fish and Wildlife Propagations was observed in the Deep Fork of the Canadian River (OK520700040010_00), Dry Creek (OK520700040020_00), Quapaw Creek (OK520700040260_00), and Opossum Creek (OK520700050200_00). Water quality data for turbidity and TSS are provided in Appendix A.

Table 2-3 Summary of Indicator Bacteria Samples from Primary Body Contact Recreation Season

Stream Segments	Waterbody ID	Bacteria Indicator	Standards	GeoMean	# of Violations	# of Samples	% violations	2008 303(d)	Comments
Salt Creek	OK520700030100_00	ENT	108	101.5	6	10	60	X	TMDL required
		EC	406	98.2	0	10	0	X	Delist: less than 10%
		FC	400	No Samples					
Camp Creek	OK520700030220_00	ENT	108	194.9	7	10	70		Added, TMDL required
		EC	406	55.4	0	10	0		
		FC	400	No Samples					
Canadian River, Deep Fork	OK520700040010_00	ENT	108	199.2	7	11	64	X	TMDL required
		EC	406	80.1	2	11	18		
		FC	400	220.7	6	11	55	X	TMDL required
Dry Creek	OK520700040020_00	ENT	108	260.7	7	10	70	X	TMDL required
		EC	406	282.5	3	10	30		Added, TMDL required
		FC	400	No Samples					
Quapaw Creek	OK520700040260_00	ENT	108	160.7	5	10	50	X	TMDL required
		EC	406	112.0	2	10	20		
		FC	400	No Samples					
Bellcow Creek	OK520700050020_00	ENT	108	722.9	12	12	100	X	TMDL required
		EC	406	60.0	1	12	8		
		FC	400	223.8	2	12	17		
Captain Creek	OK520700050140_00	ENT	108	Not enough samples					
		EC	406	Not enough samples				X	Delist: not enough samples
		FC	400	271.3	3	8	38		Added, TMDL required
Opossum Creek	OK520700050200_00	ENT	108	Not enough samples					
		EC	406	Not enough samples					
		FC	400	204.0	1	8	13		

Fecal coliform (FC) water quality criterion = Geometric Mean of 400 counts/100 mL
E. coli (EC) water quality criterion = Geometric Mean of 126 counts/100 mL
Enterococci (ENT) water quality criterion = Geometric Mean of 33 counts/100 mL

Table 2-4 Summary of All Turbidity and TSS Samples

Waterbody ID	Waterbody Name	Number of turbidity samples	Number of TSS samples	Number of turbidity samples greater than 50 NTU	% turbidity samples exceeding criterion	Sampling period
OK520700030100_00	Salt Creek	22	20	0	0	2008-2010
OK520700030220_00	Camp Creek	22	20	0	0	2008-2010
OK520700040010_00	Canadian River, Deep Fork	30	0	12	40	2006-2010
OK520700040020_00	Dry Creek	20	19	7	35	2008-2010
OK520700040260_00	Quapaw Creek	21	20	3	14	2008-2010
OK520700050020_00	Bellcow Creek	18	0	0	0	2001-2002
OK520700050140_00	Captain Creek	13	12	1	8	2000-2001
OK520700050200_00	Opossum Creek	13	12	3	23	2000-2001

Table 2-5 Summary of Turbidity and TSS Samples Excluding High Flow Samples

Waterbody ID	Waterbody Name	Number of turbidity samples	Number of TSS samples	Number of Turbidity samples greater than 50 NTU	% turbidity samples exceeding criterion	2008 303(d)	Comments
OK520700030100_00	Salt Creek	19	17	0	0		
OK520700030220_00	Camp Creek	18	17	0	0	X	Delist: no violations
OK520700040010_00	Canadian River, Deep Fork	22	0	6	27	X	TMDL required
OK520700040020_00	Dry Creek	15	15	3	20	X	TMDL required
OK520700040260_00	Quapaw Creek	19	20	2	11		Added, TMDL required
OK520700050020_00	Bellcow Creek	18	0	0	0		
OK520700050140_00	Captain Creek	13	12	1	8		
OK520700050200_00	Opossum Creek	11	12	3	27	X	TMDL required

After re-evaluating both bacteria and turbidity data following Oklahoma's assessment protocol, TMDLs will be developed only for the streams and pollutants listed in Table 2-6. A total of 13 bacteria/turbidity TMDLs will be developed in this report.

Table 2-6 Stream Segments and Pollutants for TMDL Development

Waterbody Name	Waterbody ID	Stream Miles	TMDL Date	Priority	ENT	*E. Coli*	Fecal Coliform	Turbidity
Salt Creek	OK520700030100_00	22.35	2016	3	X			
Camp Creek	OK520700030220_00	5.14	2016	3	X			
Canadian River, Deep Fork	OK520700040010_00	18.1	2013	2	X		X	X
Dry Creek	OK520700040020_00	28.27	2019	4	X	X		X
Quapaw Creek	OK520700040260_00	26.81	2013	2	X			X
Bellcow Creek	OK520700050020_00	5.75	2016	3	X			
Captain Creek	OK520700050140_00	4.4	2019	4			X	
Opossum Creek	OK520700050200_00	7.37	2019	4				X

2.3 Water Quality Target

The Code of Federal Regulations (40 CFR §130.7(c)(1)) states that, "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards." For the WQM stations requiring bacteria TMDLs in this report, defining the water quality target is somewhat complicated by the use of three different bacterial indicators each with different numeric criterion for determining attainment of PBCR use as defined in the Oklahoma WQSs. An individual water quality target is established for each bacterial indicator since each indicator group must demonstrate compliance with the numeric criteria prescribed in the Oklahoma WQS (OWRB 2008). As previously stated, because available bacteria data were collected on an approximate monthly basis (see Appendix A) instead of at least five samples over a 30–day period, data for these TMDLs are analyzed and presented in relation to both the instantaneous and a long-term geometric mean for each bacterial indicator.

All TMDLs for fecal coliform must take into account that no more than 25 percent of the samples may exceed the instantaneous numeric criteria. For *E. coli* and Enterococci, no samples may exceed the instantaneous criteria. Since the attainability of stream beneficial uses for *E. coli* and Enterococci is based on the compliance of either the instantaneous or a long-term geometric mean criterion, percent reductions goals will be calculated for both criteria. TMDLs will be based on the percent reduction required to meet either the instantaneous or long-term geometric mean criterion, whichever is less.

The water quality target for bacteria will also incorporate an explicit 10 percent MOS. For example, if fecal coliform is utilized to establish the TMDL, then the water quality target is 360 organisms per 100 milliliters (mL), 10 percent lower than the instantaneous water quality criteria (400/100 mL). For *E. coli* the instantaneous water quality target is 365 organisms/100 mL, which is 10 percent lower than the criterion value (406/100 mL), and the geometric mean water quality target is 113 organisms/100 mL, which is 10 percent lower than the criterion value (126/100 mL). For Enterococci the instantaneous water quality target is 97/100 mL, which is 10 percent lower than the criterion value (108/100 mL) and the geometric mean water quality target is 30 organisms/100 mL, which is 10 percent lower than the criterion value (33/100 mL).

The allowable bacteria load is derived by using the actual or estimated flow record multiplied by the water quality target. The line drawn through the allowable load data points is the water quality target which represents the maximum load for any given flow that still satisfies the WQS.

An individual water quality target established for turbidity must demonstrate compliance with the numeric criteria prescribed in the Oklahoma WQS (OWRB 2008). According to the Oklahoma WQS [785:45-5-12(f)(7)], the turbidity criterion for streams with WWAC beneficial use is 50 NTUs (OWRB 2008). The turbidity of 50 NTUs applies only to seasonal base flow conditions. Turbidity levels are expected to be elevated during, and for several days after, a storm event.

TMDLs for turbidity in streams designated as WWAC must take into account that no more than 10 percent of the samples may exceed the numeric criterion of 50 NTU. However, as described above, because turbidity cannot be expressed as a mass load, TSS is used as a surrogate for TMDL development. Since there is no numeric criterion in the Oklahoma WQS for TSS, a specific method must be developed to convert the turbidity criterion to TSS based on a relationship between turbidity and TSS. The method for deriving the relationship between turbidity and TSS and for calculating a water body specific water quality goal using TSS is summarized in Section 4 of this report.

The MOS for the TSS TMDLs varies by waterbody and is related to the goodness-of-fit metrics of the turbidity-TSS regressions. The method for defining MOS percentages is described in Section 5 of this report.

SECTION 3
POLLUTANT SOURCE ASSESSMENT

A pollutant source assessment characterizes known and suspected sources of pollutant loading to impaired waterbodies. Sources within a watershed are categorized and quantified to the extent that information is available. Pathogen indicator bacteria originate from the digestive tract of warm-blooded animals; some plant life and sources may be point or nonpoint in nature. Turbidity may originate from NPDES-permitted facilities, fields, construction sites, quarries, stormwater runoff and eroding stream banks.

Point sources are permitted through the NPDES program. NPDES-permitted facilities that discharge treated wastewater are required to monitor for one of the three bacterial pathogen indicators (fecal coliform, *E coli*, or Enterococci) and TSS in accordance with their permits. Nonpoint sources are diffuse sources that typically cannot be identified as entering a waterbody through a discrete conveyance at a single location. Nonpoint sources may emanate from land activities that contribute bacteria or TSS to surface water as a result of rainfall runoff. For the TMDLs in this report, all sources of pollutant loading not regulated by NPDES are considered nonpoint sources.

The 2008 Integrated Water Quality Assessment Report (ODEQ 2008) listed potential sources of turbidity as clean sediment, grazing in riparian corridors of streams and creeks, highway/road/bridge runoff (non-construction related), non-irrigated crop production, petroleum/natural gas activities, rangeland grazing, as well as other unknown sources. The following discussion describes what is known regarding point and nonpoint sources of bacteria in the impaired watersheds. Where information was available on point and nonpoint sources of indicator bacteria or TSS, data were provided and summarized as part of each category. .

3.1 NPDES-Permitted Facilities

Under 40 CFR, §122.2, a point source is described as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Certain NPDES-permitted municipal plants are classified as no-discharge facilities. NPDES-permitted facilities classified as point sources that may contribute bacteria or TSS loading include:

- NPDES municipal wastewater treatment plant (WWTP);
- NPDES Industrial WWTP Discharges;
- NPDES municipal no-discharge WWTP;
- NPDES Concentrated Animal Feeding Operation (CAFO);
- NPDES municipal separate storm sewer system (MS4) discharges;
- NPDES multi-sector general permits; and
- NPDES construction stormwater discharges.

Continuous point source discharges such as WWTPs could result in discharge of elevated concentrations of fecal coliform bacteria if the disinfection unit is not properly maintained, is of poor design, or if flow rates are above the disinfection capacity. It is possible that continuous point source discharges from municipal and industrial WWTPs could result in discharge of elevated concentrations of TSS if a facility is not properly maintained, is of poor design, or flow rates exceed capacity. However, in most cases suspended solids discharged by WWTPs consist primarily of organic solids rather than inorganic suspended solids (i.e., soil and sediment particles from erosion or sediment resuspension). Discharges of organic suspended solids from WWTPs are addressed by ODEQ through its permitting of point sources to maintain WQS for dissolved oxygen and are not considered a potential source of turbidity in this TMDL. Discharges of TSS will be considered to be organic suspended solids if the discharge permit includes a limit for BOD or CBOD. Only WWTP discharges of inorganic suspended solids will be considered and will receive wasteload allocations.

While the no-discharge facilities do not discharge wastewater directly to a waterbody, it is possible that the collection systems associated with each facility may be a source of bacteria loading to surface waters. CAFOs are recognized by USEPA as significant sources of pollution, and may have the potential to cause serious impacts to water quality if not properly managed.

Stormwater runoff from MS4 areas, which is now regulated under the USEPA NPDES Program, can also contain high fecal coliform bacteria concentrations. Stormwater runoff from MS4 areas, facilities under multi-sector general permits, and NPDES construction stormwater discharges, which are regulated under the USEPA NPDES Program, can contain TSS concentrations. 40 C.F.R. § 130.2(h) requires that NPDES-regulated stormwater discharges must be addressed by the wasteload allocation component of a TMDL. However, any stormwater discharge by definition occurs during or immediately following periods of rainfall and elevated flow conditions when Oklahoma Water Quality Standard for turbidity does not apply. Oklahoma Water Quality Standards specify that the criteria for turbidity "apply only to seasonal base flow conditions" and go on to say "Elevated turbidity levels may be expected during, and for several days after, a runoff event" [OAC 785:45-5-12(f)(7)]. In other words, the turbidity impairment status is limited to base flow conditions and stormwater discharges from MS4 areas or construction sites do not contribute to the violation of Oklahoma's turbidity standard. Therefore, WLAs for NPDES-regulated stormwater discharges is essentially considered unnecessary in this TMDL report and will not be included in the TMDL calculations.

There are five NPDES-permitted municipal wastewater treatment facilities in the contributing watersheds of Quapaw Creek (OK520700040260_00), Bellcow Creek (OK520700050020_00), Deep Fork of the Canadian River (OK520700040010_00), Salt Creek (OK520700030100_00), and Dry Creek (OK520700040020_00). The remaining three watersheds in the Study Area do not have any NPDES-permitted facility.

3.1.1 Continuous Point Source Dischargers

The locations of the NPDES-permitted facilities that discharge wastewater to surface waters addressed in these TMDLs are listed in Table 3-1 and displayed in Figure 3-1. There are 5 continuous point source discharging facilities within the Study Area but they are not all sources of concern for bacteria or TSS loading. All of the facilities in Table 3-1 discharge TSS and have specific permit limits for TSS which are provided in Table 3-1. However, the municipal WWTPs designated with a Standard Industrial Code number 4952 in Table 3-1 discharge organic TSS and therefore are not considered a potential source of turbidity within their respective watershed.

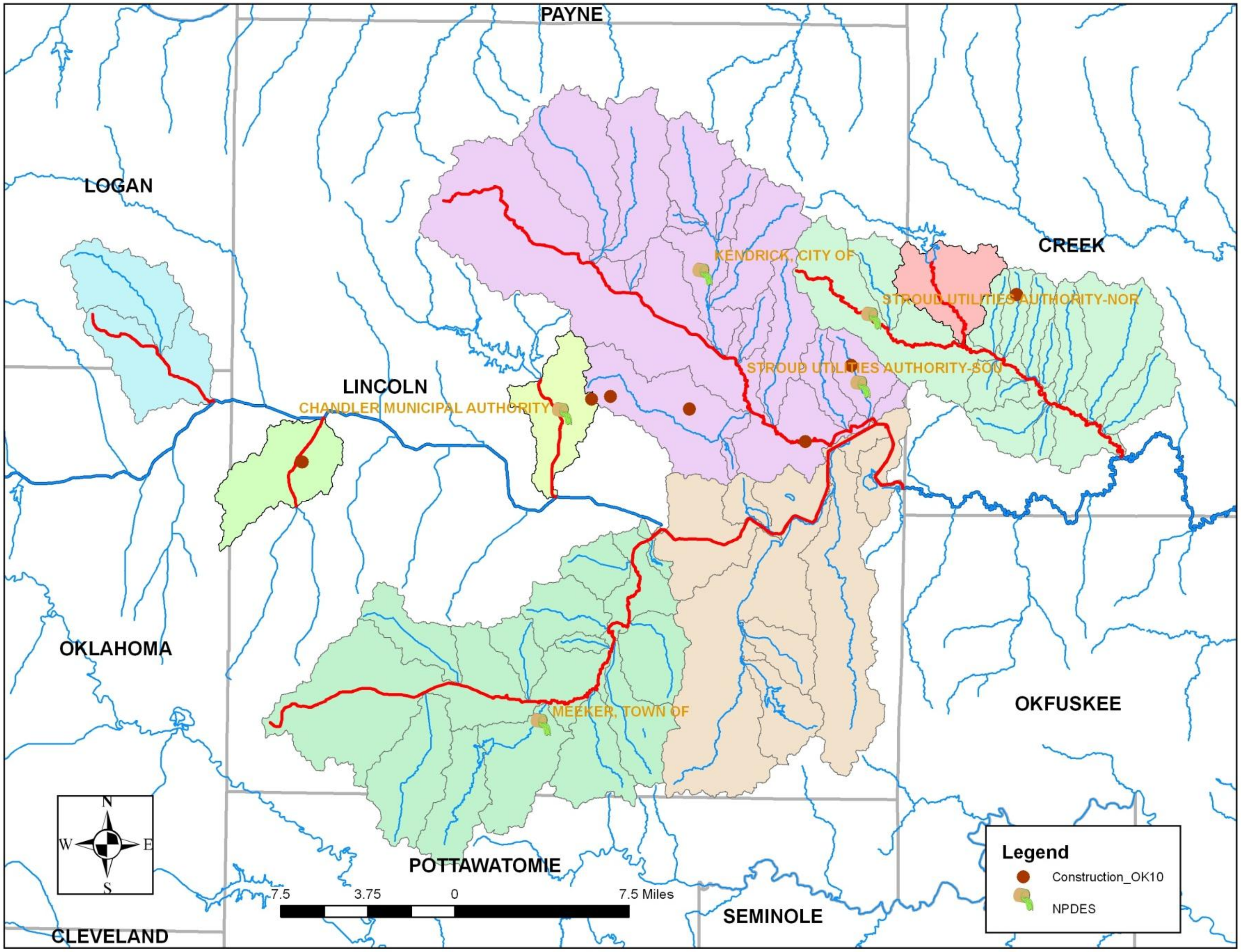
WWTP dischargers for TSS impaired watersheds were reviewed for availability of DMR data. DMR data from 2001 through January 2011 for fecal coliform and TSS from these facilities are provided in Appendix B. The Town of Meeker wastewater treatment facility had frequent effluent limit violations before 2004 for both fecal coliform and TSS. After 2004, only four violations occurred, of which only one was for bacteria. The Chandler and Stroud-South facilities have not had any violations in the period. Stroud-North had six violations. The Kendrick facility had outflow in only two occasions in the period. No violations occurred. On December 30, 2009, Kendrick became a non-discharge facility.

Table 3-1 Point Source Discharges in the Study Area

Waterbody name	Waterbody ID	FACILITY	NPDES#	STATE_ID	SIC code	Design Flow (MGD)	FC [1] (cfu /100mL)	TSS [2] (mg/L)	Permit Expiration Date
Quapaw Creek	OK520700040260_00	MEEKER, TOWN OF	OK0026883	S20711	4952	0.2	200/400	30/45	11/30/2014
Bellcow Creek	OK520700050020_00	CHANDLER MUNICIPAL AUTHORITY	OK0027120	S20710	4952	0.8	200/400	30/45	6/30/2013
Canadian River, Deep Fork	OK520700040010_00	STROUD UTILITIES AUTHORITY-SOUTH	OK0027359	S20725	4952	0.5	200/400	90/135	8/31/2014
Salt Creek	OK520700030100_00	STROUD UTILITIES AUTHORITY-NORTH	OK0027367	S20750	4952	0.22	200/400	30/45	3/30/2016
Dry Creek	OK520700040020_00	KENDRICK, CITY OF	OK0043915	S20754	4952	0.06	--	90/135	4/30/2010*

1: Fecal coliform limits, monthly average/weekly average
2. Total suspended solids, monthly average/weekly average
* Became a non-discharge facility on 12/30/2009.

Figure 3-1 Locations of NPDES-Permitted Facilities in the Study Area



3.1.2 NPDES No-Discharge Facilities and Sanitary Sewer Overflows

For the purposes of these TMDLs, it is assumed that no-discharge facilities do not contribute indicator bacteria or TSS loading. However, it is possible the wastewater collection systems associated with these no-discharge facilities could be a source of indicator bacteria loading, or that discharges from the wastewater plant may occur during large rainfall events that exceed the systems' storage capacities. There are five no-discharge facilities in the study area (Table 3-1a).

Table 3-1a Sanitary Sewer Overflow Summary

Facility	Facility ID	County	Facility Type	Type	Watershed
Agra WWTF C/O Lincoln RWGSD #4	S30907	Lincoln	Total Retention	Municipal	Dry Creek (OK520700040020_00)
Oak Glen Rv WWT	S20741	Lincoln	Total Retention	Municipal	Dry Creek (OK520700040020_00)
Pine Ridge MHP WWT	S20730	Lincoln	Total Retention	Municipal	Dry Creek (OK520700040020_00)
Sac & Fox Juv Det Fac WWT	S20756	Lincoln	Total Retention	Municipal	Deep Fork of the Canadian River (OK520700040010_00)
Sac And Fox Tribe WWT	S20731	Lincoln	Total Retention	Municipal	Deep Fork of the Canadian River (OK520700040010_00)

Sanitary sewer overflows (SSO) from wastewater collection systems, although infrequent, can be a major source of indicator bacteria loading to streams. SSOs have existed since the introduction of separate sanitary sewers, and most are caused by blockage of sewer pipes by grease, tree roots, and other debris that clog sewer lines, by sewer line breaks and leaks, cross connections with storm sewers, and inflow and infiltration of groundwater into sanitary sewers. SSOs are permit violations that must be addressed by the responsible NPDES permittee. The reporting of SSOs has been strongly encouraged by USEPA, primarily through enforcement and fines. While not all sewer overflows are reported, ODEQ has some data on SSOs available. There were a total of 24 SSO occurrences within the Study Area from 2006 to 2010, ranging from 25 gallons (negligible amount) to 10,000 gallons. The average reported release flow volume was 1700 gallons during this five year period. SSO data are summarized in Table 3-2. Additional data on each individual SSO event are provided in Appendix B.

Table 3-2 Sanitary Sewer Overflow Summary

Facility Name	NPDES Permit No.	Receiving Water	Facility ID	Number of Occurrences	Date Range		Amount (Gallons)*	
					From	To	Min	Max
Meeker, Town of	OK0026883	Quapaw Creek	S20711	9	8/16/2006	3/3/2011	NA	500
Chandler Municipal Authority	OK0027120	Bellcow Creek	S20710	5	5/23/2006	7/30/2010	500	3500
Stroud Utilities Authority-South	OK0027359	Canadian River, Deep Fork	S20725	3	5/23/2006	7/2/2010	25	4000
Stroud Utilities Authority-North	OK0027367	Salt Creek	S20750	9	6/7/2006	6/14/2010	9	10000

*Estimated

3.1.3 Concentrated Animal Feeding Operations

There are no CAFOs located in the Study area.

3.1.4 Stormwater Permits Construction Activities

A general stormwater permit (OKR10) is required for any stormwater discharges associated with construction activities that result in land disturbance of equal to or greater than one (1) acre, or less than one (1) acre if they are part of a larger common plan of development or sale that totals at least one (1) acre. The permit also authorizes any stormwater discharges from support activities (e.g. concrete or asphalt batch plants, equipment staging yards, material storage areas, excavated material disposal areas, and borrow areas) that are directly related to a construction site that is required to have permit coverage, and is not a commercial operation serving unrelated different sites (ODEQ 2007). Stormwater discharges occur only during or immediately following periods of rainfall and elevated flow conditions when the turbidity criteria do not apply and are not considered potential contributors to turbidity impairment. The construction permits are summarized in Table 3-3.

3.1.5 Rock, Sand and Gravel Quarries

Operators of rock, sand and gravel quarries in Oklahoma are regulated with a general permit (OKG950000). The general permit does not allow discharge of wastewater to waterbodies included in Oklahoma's 303(d) List of impaired water bodies listed for turbidity for which a TMDL has not been performed or the result of the TMDL indicates that discharge limits more stringent than 45 mg/l for TSS are required (ODEQ 2009). According to the data from the Oklahoma Department of Mines, there are no rock, sand or gravel quarries located within the Study Area.

Table 3-3 Construction Permits Summary

Company Name	County	Permit ID	Date Issued	Eventual Receiving Water	Waterbody ID	Estimated Acres
ODOT JP #13402(04)	Lincoln	7898	1/19/2008	Captain Creek	OK520700050140_00	17
ODOT JP# 20730(04)	Lincoln	9261	N/A	Dry Creek	OK520700040020_00	5
MID-WAY ENVIRONMENTAL SERVIC	Lincoln	8939	5/23/2008	Dry Creek	OK520700040020_00	9
CHANDLER EIGHT PLEXES	Lincoln	8826	3/13/2008	Bellcow Creek	OK520700050020_00	6
IBC-CHANDLER	Lincoln	9266	N/A	Dry Creek	OK520700040020_00	N/A
ODOT JP#12539(30)	Lincoln	9055	5/23/2008	Dry Creek	OK520700040020_00	24
HIDDEN OAKS	Logan	5831	5/8/2008	Salt Creek	OK520700030100_00	30

3.2 Nonpoint Sources

Nonpoint sources include those sources that cannot be identified as entering the waterbody at a specific location. The relatively homogeneous land use/land cover categories throughout the Study Area associated with rural agricultural, forest and range management activities has an influence on the origin and pathways of pollutant sources to surface water. Pathogen indicator bacteria originate from warm-blooded animals in rural, suburban, and urban areas. These sources include wildlife, various agricultural activities and domesticated animals, land application fields, urban runoff, failing onsite wastewater disposal (OSWD) systems and domestic pets. Water quality data collected from streams draining urban communities often show existing concentrations of fecal coliform bacteria at levels greater than a state's instantaneous standards. A study under USEPA's National Urban Runoff Project indicated that the average fecal coliform concentration from 14 watersheds in different areas within the United States was approximately 15,000/100 mL in stormwater runoff (USEPA 1983). Runoff from urban areas not permitted under the MS4 program can be a significant source of fecal coliform bacteria. Water quality data collected from streams draining many of the non-permitted communities show existing loads of fecal coliform bacteria at levels greater than the State's instantaneous standards.

Various potential nonpoint sources of TSS as indicated in the 2008 Integrated Report include sediments originating from grazing in riparian corridors of streams and creeks, highway/road/bridge runoff, non-irrigated crop production, rangeland grazing and other sources of sediment loading (ODEQ 2008). Elevated turbidity measurements can be caused by stream bank erosion processes, stormwater runoff events and other channel disturbances. The following section provides general information on nonpoint sources contributing bacteria or TSS loading within the Study Area.

3.2.1 Wildlife

Fecal coliform bacteria are produced by all warm-blooded animals, including wildlife such as mammals and birds. In developing bacteria TMDLs it is important to identify the potential for bacteria contributions from wildlife by watershed. Wildlife is naturally attracted to riparian corridors of streams and rivers. With direct access to the stream channel, wildlife can be a concentrated source of bacteria loading to a waterbody. Fecal coliform bacteria from wildlife are also deposited onto land surfaces, where it may be washed into nearby streams by rainfall runoff. Currently there are insufficient data available to estimate populations of wildlife and avian species by watershed. Consequently it is difficult to assess the magnitude of bacteria contributions from wildlife species as a general category.

However, adequate data are available by county to estimate the number of deer by watershed. This report assumes that deer habitat includes forests, croplands, and pastures. Using Oklahoma Department of Wildlife and Conservation county data, the population of deer can be roughly estimated from the actual number of deer harvested and harvest rate estimates. Because harvest success varies from year to year based on weather and other factors, the average harvest from 1999 to 2003 was combined with an estimated annual harvest rate of 20 percent to predict deer population by county. Using the estimated deer population by county and the percentage of the watershed area within each county, a wild deer population can be calculated for each watershed.

According to a study conducted by the American Society of Agricultural Engineers (ASAE), deer release approximately 5×10^8 fecal coliform units per animal per day (ASAE 1999). Although only a fraction of the total fecal coliform loading produced by the deer population may actually enter a waterbody, the estimated fecal coliform production based on the estimated deer population provided in Table 3-4 in cfu/day provides a relative magnitude of loading in each watershed.

Table 3-4 Estimated Population and Fecal Coliform Production for Deer

Waterbody ID	Waterbody Name	Watershed Area (acres)	Wild Deer Population	Estimated Wild Deer per acre	Fecal Production ($\times 10^9$ cfu/day) of Deer Population
OK520700030100_00	Salt Creek	56,848	684	0.01	342
OK520700030220_00	Camp Creek	8,223	102	0.01	51
OK520700040010_00	Canadian River, Deep Fork	76,952	796	0.01	398
OK520700040020_00	Dry Creek	123,495	1,277	0.01	639
OK520700040260_00	Quapaw Creek	96,759	997	0.01	499
OK520700050020_00	Bellcow Creek	8,740	90	0.01	45
OK520700050140_00	Captain Creek	10,285	102	0.01	51
OK520700050200_00	Opossum Creek	18,783	172	0.01	86

3.2.2 Non-Permitted Agricultural Activities and Domesticated Animals

There are a number of non-permitted agricultural activities that can also be sources of bacteria or TSS loading. Agricultural activities of greatest concern are typically those associated with livestock operations (Drapcho and Hubbs 2002). Examples of commercially raised farm animal activities that can contribute to bacteria sources include:

Processed commercially raised farm animal manure is often applied to fields as fertilizer, and can contribute to fecal bacteria loading to waterbodies if washed into streams by runoff.

Animal grazing in pastures deposit manure containing fecal bacteria onto land surfaces. These bacteria may be washed into waterbodies by runoff.

Animal often have direct access to waterbodies and can provide a concentrated source of fecal bacteria loading directly into streams or can cause unstable stream banks which can contribute TSS.

Table 3-5 provides estimated numbers of selected commercially raised farm animals by watershed based on the 2002 U.S. Department of Agriculture (USDA) county agricultural census data (USDA 2002). The estimated commercially raised farm animal populations in Table 3-5 were derived by using the percentage of the watershed within each county. Because the watersheds are generally much smaller than the counties, and commercially raised farm animals are not evenly distributed across counties or constant with time, these are rough estimates only. Cattle are clearly the most abundant species of commercially raised farm animals in the Study Area and often have direct access to the impaired waterbodies or their tributaries.

Detailed information is not available to describe or quantify the relationship between instream concentrations of bacteria and land application of manure from commercially raised farm animal. Nor is sufficient information available to describe or quantify the contributions of sediment loading caused by commercially raised farm animal responsible for destabilizing stream banks or erosion in pasture fields. The estimated acreage by watershed where manure was applied in 2002 is shown in Table 3-5. These estimates are also based on the county level reports from the 2002 USDA county agricultural census, and thus, represent approximations of the commercially raised farm animal populations in each watershed. Despite the lack of specific data, for the purpose of these TMDLs, land application of commercially raised farm animal manure is considered a potential source of bacteria loading to the watersheds in the Study Area.

According to a livestock study conducted by the ASAE, the daily fecal coliform production rates by livestock species were estimated as follows (ASAE 1999):

Beef cattle release approximately 1.04E+11 fecal coliform counts per animal per day;

Dairy cattle release approximately 1.01E+11 per animal per day

Swine release approximately 1.08E+10 per animal per day

Chickens release approximately 1.36E+08 per animal per day

Sheep release approximately 1.20E+10 per animal per day

Horses release approximately 4.20E+08 per animal per day;

Turkey release approximately 9.30E+07 per animal per day

Ducks release approximately 2.43E+09 per animal per day

Geese release approximately 4.90E+10 per animal per day

Using the estimated animal populations and the fecal coliform production rates from ASAE, an estimate of fecal coliform production from each group of commercially raised farm animal was calculated in each watershed of the Study Area in Table 3-6. Note that only a small fraction of these fecal coliform are expected to represent loading into waterbodies, either washed into streams by runoff or by direct deposition from wading animals. Cattle again appear to represent the most likely commercially raised farm animal source of fecal bacteria.

Table 3-5 Commercially Raised Farm Animal Population and Manure Application Estimates by Watershed

Waterbody ID	Waterbody Name	Cattle & Calves-all	Dairy Cows	Horses & Ponies	Goats	Sheep & Lambs	Hogs & Pigs	Ducks & Geese	Chicken & Turkeys	Acres of Manure Application
OK520700030100_00	Salt Creek	4,390	62	370	3	119	114	99	2,614	395.8
OK520700030220_00	Camp Creek	585	6	54	0	15	17	16	442	81.2
OK520700040010_00	Canadian River, Deep Fork	8,349	214	479	10	249	139	42	483	1,128.1
OK520700040020_00	Dry Creek	13,416	345	768	17	401	210	67	776	3,076.8
OK520700040260_00	Quapaw Creek	10,305	254	599	12	309	310	58	605	2,233.6
OK520700050020_00	Bellcow Creek	950	24	54	1	28	15	5	55	361.6
OK520700050140_00	Captain Creek	1,061	27	67	1	33	17	6	64	140.0
OK520700050200_00	Opossum Creek	2,249	19	119	0	131	19	7	69	180.2

Table 3-6 Fecal Coliform Production Estimates for Commercially Raised Farm Animals (x10^9 number/day)

Waterbody ID	Waterbody Name	Cattle & Calves-all	Dairy Cows	Horses & Ponies	Goats	Sheep & Lambs	Hogs & Pigs	Ducks & Geese	Chickens & Turkeys	Total
OK520700030100_00	Salt Creek	456,560	6,262	155	36	1,428	1,231	241	356	466,269
OK520700030220_00	Camp Creek	60,840	606	23	0	180	184	39	60	61,931
OK520700040010_00	Canadian River, Deep Fork	868,296	21,614	201	120	2,988	1,501	102	66	894,888
OK520700040020_00	Dry Creek	1,395,264	34,845	323	204	4,812	2,268	163	106	1,437,984
OK520700040260_00	Quapaw Creek	1,071,720	25,654	252	144	3,708	3,348	141	82	1,105,049
OK520700050020_00	Bellcow Creek	98,800	2,424	23	12	336	162	12	7	101,776
OK520700050140_00	Captain Creek	110,344	2,727	28	12	396	184	15	9	113,714
OK520700050200_00	Opossum Creek	233,896	1,919	50	0	1,572	205	17	9	237,669

3.2.3 Failing Onsite Wastewater Disposal Systems and Illicit Discharges

ODEQ is responsible for implementing the regulations of Title 252, Chapter 641 of the Oklahoma Administrative Code, which defines design standards for individual and small public onsite sewage disposal systems (ODEQ 2004). OSWD systems and illicit discharges can be a source of bacteria loading to streams and rivers. Bacteria loading from failing OSWD systems can be transported to streams in a variety of ways, including runoff from surface ponding or through groundwater. Fecal coliform-contaminated groundwater discharges to creeks through springs and seeps.

To estimate the potential magnitude of OSWDs fecal bacteria loading, the number of OSWD systems was estimated for each watershed. The estimate of OSWD systems was derived by using data from the 1990 U.S. Census (U.S. Census Bureau 2000). The density of OSWD systems within each watershed was estimated by dividing the number of OSWD systems in each census block by the number of acres in each census block. This density was then applied to the number of acres of each census block within a WQM station watershed. Census blocks crossing a watershed boundary required additional calculation to estimate the number of OSWD systems based on the proportion of the census tracking falling within each watershed. This step involved adding all OSWD systems for each whole or partial census block.

Over time, most OSWD systems operating at full capacity will fail. OSWD system failures are proportional to the adequacy of a state's minimum design criteria (Hall 2002). The 1995 American Housing Survey conducted by the U.S. Census Bureau estimates that, nationwide, 10 percent of occupied homes with OSWD systems experience malfunctions during the year (U.S. Census Bureau 1995). A study conducted by Reed, Stowe & Yanke, LLC (2001) reported that approximately 12 percent of the OSWD systems in east Texas and 8 percent in the Texas Panhandle were chronically malfunctioning. Most studies estimate that the minimum lot size necessary to ensure against contamination is roughly one-half to one acre (Hall 2002). Some studies, however, found that lot sizes in this range or even larger could still cause contamination of ground or surface water (University of Florida 1987). It is estimated that areas with more than 40 OSWD systems per square mile (6.25 septic systems per 100 acres) can be considered to have potential contamination problems (Canter and Knox 1986). Table 3-7 summarizes estimates of sewered and unsewered households for each watershed in the Study Area.

Table 3-7 Estimates of Sewered and Unsewered Households

Waterbody ID	Waterbody Name	Public Sewer	Septic Tank	Other Means	Housing Units	% Sewered
OK520700030100_00	Salt Creek	308	366	15	689	44.7
OK520700030220_00	Camp Creek	15	60	1	76	19.7
OK520700040010_00	Canadian River, Deep Fork	891	700	36	1,627	54.8
OK520700040020_00	Dry Creek	1,329	1,102	33	2,464	53.9
OK520700040260_00	Quapaw Creek	537	1,869	72	2,478	21.7
OK520700050020_00	Bellcow Creek	228	127	5	360	63.3
OK520700050140_00	Captain Creek	51	143	3	197	25.9
OK520700050200_00	Opossum Creek	75	145	12	232	32.3

For the purpose of estimating fecal coliform loading in watersheds, an OSWD failure rate of 10 percent was used in the calculations made to characterize fecal coliform loads in each watershed.

Fecal coliform loads were estimated using the following equation (USEPA 2001):

$$\#\frac{counts}{day} = \left(\#Failing\_systems\right) \times \left(\frac{10^6 counts}{100ml}\right) \times \left(\frac{70gal}{personday}\right) \times \left(\#\frac{person}{household}\right) \times \left(3785.2\frac{ml}{gal}\right)$$

The average of number of people per household was calculated to be 2.44 for counties in the Study Area (U.S. Census Bureau 2000). Approximately 70 gallons of wastewater were estimated to be produced on average per person per day (Metcalf and Eddy 1991). The fecal coliform concentration in septic tank effluent was estimated to be 10^6 per 100 mL of effluent based on reported concentrations from a number of publications (Metcalf and Eddy 1991; Canter and Knox 1985; Cogger and Carlile 1984). Using this information, the estimated load from failing septic systems within the watersheds was summarized below in Table 3-8.

Table 3-8 Estimated Fecal Coliform Load from OSWD Systems

Waterbody ID	Waterbody Name	Acres	Septic Tank	# of Failing Septic Tanks	Estimated Loads from Septic Tanks (x 10^9 counts/day)
OK520700030100_00	Salt Creek	56848	366	37	237
OK520700030220_00	Camp Creek	8223	60	6	39
OK520700040010_00	Canadian River, Deep Fork	76952	700	70	453
OK520700040020_00	Dry Creek	123495	1102	110	712
OK520700040260_00	Quapaw Creek	96759	1869	187	1208
OK520700050020_00	Bellcow Creek	8740	127	13	82
OK520700050140_00	Captain Creek	10285	143	14	92
OK520700050200_00	Opossum Creek	18783	145	15	94

3.2.4 Domestic Pets

Fecal matter from dogs and cats, which is transported to streams by runoff from urban and suburban areas, can be a potential source of bacteria loading. On average 37.2 percent of the nation's households own dogs and 32.4 percent own cats and in these households the average number of dogs is 1.7 and 2.2 cats per household (American Veterinary Medical Association 2007). Using the U.S. Census data at the block level (U.S. Census Bureau 2000), dog and cat populations can be estimated for each watershed. Table 3-9 summarizes the estimated number of dogs and cats for the watersheds of the Study Area.

Table 3-9 Estimated Numbers of Pets

Waterbody ID	Waterbody Name	Dogs	Cats
OK520700030100_00	Salt Creek	1,375	1,565
OK520700030220_00	Camp Creek	133	151
OK520700040010_00	Canadian River, Deep Fork	1,985	2,259
OK520700040020_00	Dry Creek	3,564	4,055
OK520700040260_00	Quapaw Creek	3,349	3,811
OK520700050020_00	Bellcow Creek	1,296	1,474
OK520700050140_00	Captain Creek	316	359
OK520700050200_00	Opossum Creek	255	290

Table 3-10 provides an estimate of the fecal coliform load from pets. These estimates 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).

Table 3-10 Estimated Fecal Coliform Daily Production by Pets ($\times 10^9$ counts/day)

Waterbody ID	Waterbody Name	Dogs	Cats	Total
OK520700030100_00	Salt Creek	4,538	845	5,383
OK520700030220_00	Camp Creek	439	82	520
OK520700040010_00	Canadian River, Deep Fork	6,552	1,220	7,772
OK520700040020_00	Dry Creek	11,760	2,190	13,949
OK520700040260_00	Quapaw Creek	11,051	2,058	13,109
OK520700050020_00	Bellcow Creek	4,276	796	5,072
OK520700050140_00	Captain Creek	1,043	194	1,237
OK520700050200_00	Opossum Creek	842	157	998

3.3 Summary of Bacteria Sources

There are four continuous, permitted point sources of bacteria in the Study Area. The various nonpoint sources are considered to be the major source of bacteria loading in each watershed that requires a TMDL for bacteria.

Table 3-11 below provides a summary of the estimated fecal coliform loads in cfu/day for the four major nonpoint source categories (commercially raised farm animals, pets, deer, and septic tanks) that contribute to the elevated bacteria concentrations in each watershed. Livestock are estimated to be the largest contributors of fecal coliform loading to land surfaces. It must be noted that while no data are available to estimate populations and fecal loading of wildlife other than deer, a number of bacteria source tracking studies around the nation demonstrate that wild birds and mammals represent a major source of the fecal bacteria found in streams.

Table 3-11 Summary of Fecal Coliform Load Estimates from Nonpoint Sources to Land Surfaces (% of Total Watershed Load)

Waterbody ID	Waterbody Name	All Livestock	Pets	Deer	Estimated Loads from Septic Tanks
OK520700030100_00	Salt Creek	98.74	1.14	0.07	0.05
OK520700030220_00	Camp Creek	99.02	0.83	0.08	0.06
OK520700040010_00	Canadian River, Deep Fork	99.05	0.86	0.04	0.05
OK520700040020_00	Dry Creek	98.95	0.96	0.04	0.05
OK520700040260_00	Quapaw Creek	98.68	1.17	0.04	0.11
OK520700050020_00	Bellcow Creek	95.14	4.74	0.04	0.08
OK520700050140_00	Captain Creek	98.80	1.07	0.04	0.08
OK520700050200_00	Opossum Creek	99.51	0.42	0.04	0.04

The magnitude of loading to a stream may not reflect the magnitude of loading to land surfaces. While no studies have quantified these effects, bacteria may die off or survive at different rates depending on the manure characteristics and a number of other environmental conditions. Also, the structural properties of some manure, such as cow patties, may limit their washoff into streams by runoff. In contrast, malfunctioning septic tank effluent may be present in standing water on the surface, or in shallow groundwater, which may enhance its conveyance to streams.

Of the 4 watersheds in the Study Area that require turbidity TMDLs, None of them have industrial permitted sources of TSS that will necessitate a WLA. Therefore, nonsupport of WWAC use in the all watersheds is caused primarily by nonpoint sources of TSS. Sediment loading of streams can originate from natural erosion processes, including the weathering of soil, rocks, and uncultivated land; geological abrasion; and other natural phenomena. There is insufficient data available to quantify contributions of TSS from these natural processes. TSS or sediment loading can also occur under non-runoff conditions as a result of anthropogenic activities in riparian corridors which cause erosive conditions. Given the lack of data to establish the background conditions for TSS/turbidity, separating background loading from nonpoint sources whether it is from natural or anthropogenic processes is not feasible in this TMDL development.

SECTION 4
TECHNICAL APPROACH AND METHODS

The objective of a TMDL is to estimate allowable pollutant loads and to allocate these loads to the known pollutant sources in the watershed so appropriate control measures can be implemented and the WQS achieved. A TMDL is expressed as the sum of three elements as described in the following mathematical equation:

$$\textbf{TMDL} = \Sigma\ \textbf{WLA} + \Sigma\ \textbf{LA} + \textbf{MOS}$$

The WLA is the portion of the TMDL allocated to existing and future point sources. The LA is the portion of the TMDL allocated to nonpoint sources, including natural background sources. The MOS is intended to ensure that WQSs will be met. Thus, the allowable pollutant load that can be allocated to point and nonpoint sources can then be defined as the TMDL minus the MOS.

40 CFR, §130.2(1), states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For fecal coliform, *E. coli*, or Enterococci bacteria, TMDLs are expressed as colony-forming units per day, where possible, or as a percent reduction goal (PRG), and represent the maximum one-day load the stream can assimilate while still attaining the WQS. Turbidity TMDLs will be derived from TSS calculations and expressed in pounds (lbs) per day which will represent the maximum one-day load the stream can assimilate while still attaining the WQS, as well as a PRG.

4.1 Determining a Surrogate Target for Turbidity

Turbidity is a commonly measured indicator of the suspended solids load in streams. However, turbidity is an optical property of water, which measures scattering of light by suspended solids and colloidal matter. To develop TMDLs, a gravimetric (mass-based) measure of solids loading is required to express loads. There is often a strong relationship between the total suspended solids concentration and turbidity. Therefore, the TSS load, which is expressed as mass per time, is used as a surrogate for turbidity.

To determine the relationship between turbidity and TSS, a linear regression between TSS and turbidity was developed using data collected at stations within the Study Area. Prior to developing the regression the following steps were taken to refine the dataset:

- Replace TSS samples of "<10" with 9.99;
- Remove data collected under high flow conditions exceeding the base-flow criterion. This means that measurements corresponding to flow exceedance percentiles lower than 25^{th} were not used in the regression;
- Check rainfall data on the day when samples were collected and on the previous two days. If there was a significant rainfall event (>= 1.0 inch) in any of these days, the sample will be excluded from regression analysis with one exception. If the significant rainfall happened on the sampling day and the turbidity reading was less than 25 NTUs (half of turbidity standard for streams), the sample will not be excluded from analysis because most likely the rainfall occurred after the sample was taken, and
- Log-transform both turbidity and TSS data to minimize effects of their non-linear data distributions.

When ordinary least squares regression (OLS) is applied to ascertain the best relationship between two variables (i.e., X and Y), one variable (Y) is considered "dependent" on the other variable (X), but X must be considered "independent" of the other, and known without measurement error. OLS minimizes the differences, or residuals, between measured Y values and Y values predicted based on the X variable.

For current purposes, a relationship is necessary to predict TSS concentrations from measured turbidity values, but also to translate the TSS-based TMDL back to instream turbidity values. For this purpose, an alternate regression fitting procedure known as the line of organic correlation (LOC) was applied. The LOC has three advantages over OLS (Helsel and Hirsch 2002):

- LOC minimizes fitted residuals in both the X and Y directions;
- It provides a unique best-fit line regardless of which parameter is used as the independent variable; and
- Regression-fitted values have the same variance as the original data.

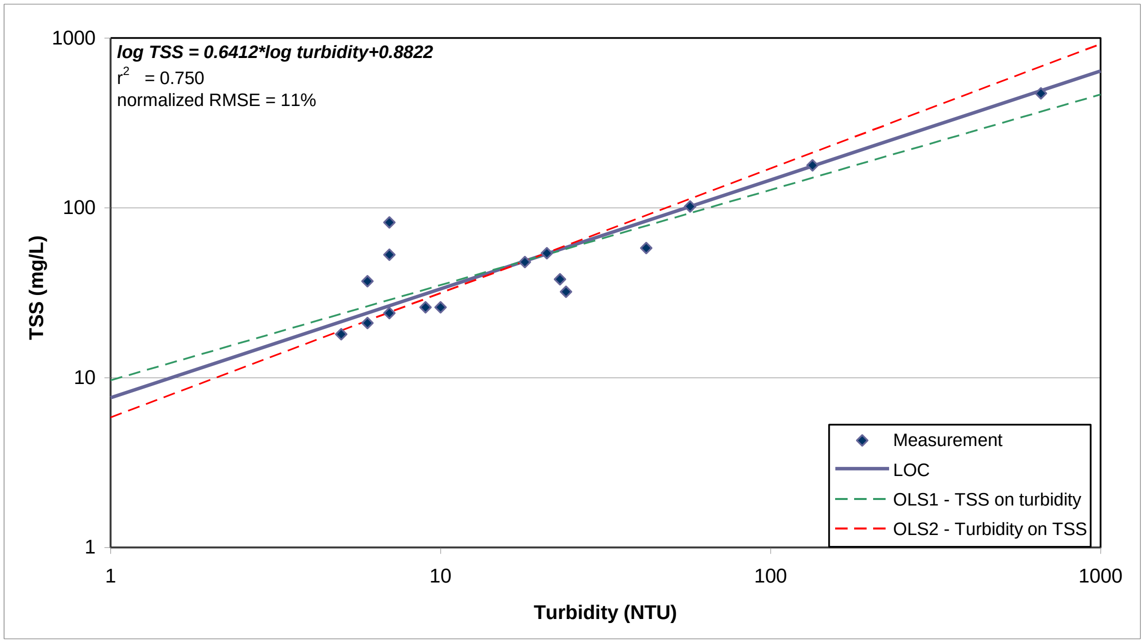
The LOC minimizes the areas of the right triangles formed by horizontal and vertical lines drawn from observations to the fitted line. The slope of the LOC line equals the geometric mean of the Y on X (TSS on turbidity) and X on Y (turbidity on TSS) OLS slopes, and is calculated as:

$$m1 = \sqrt{m \cdot m'} = sign[r] \cdot \frac{s_y}{s_x}$$

where $m1$ is the slope of the LOC line, m is the TSS on turbidity OLS slope, m' is the turbidity on TSS OLS slope, r is the TSS-turbidity correlation coefficient, s_y is the standard deviation of the TSS measurements, and s_x is the standard deviation of the turbidity measurements.

The intercept of the LOC ($b1$) is subsequently found by fitting the line with the LOC slope through the point (mean turbidity, mean TSS). Figure 4-1 shows an example of the correlation between TSS and turbidity, along with the LOC and the OLS lines.

Figure 4-1 Linear Regression for TSS-Turbidity for the Red River, North Fork, Headrick (OK311500010020_10)



The NRMSE and R-square (r^2) were used as the primary measures of goodness-of-fit. As shown in Figure 4-1, the LOC yields a NRMSE value of 11% which means the root mean square error (RMSE) is 11% of the average of the measured TSS values. The R-square (r^2) value indicates the fraction of the total variance in TSS or turbidity observations that is explained by the LOC. The regression equation can be used to convert turbidity standard of 50 NTUs to TSS goals.

It was noted that there may be a few outliers that exerted undue influence on the regression relationship. These outliers were identified by applying the Tukey's Boxplot method (Tukey 1977) to the dataset of the distances from observed points to the regression line. The Tukey Method is based on the interquartile range (IQR), the difference between the 75th percentile (Q_3) and 25th percentile (Q_1) of distances between observed points and the LOC. Using the Tukey method, any point with an error greater than Q_3 + 1.5* IQR or less than Q_1 – 1.5*IQR was identified as an outlier and removed from the regression dataset. The above regressions were calculated using the dataset with outliers removed.

The Tukey Method is equivalent to using three times the standard deviation to identify outliers if the residuals (observed - predicted) follow a normal distribution. The probability of sampling results being within three standard deviations of the mean is 99.73% while the probability for the Tukey Method is 99.65%. If three times the standard deviation is used to identify outliers, it is necessary to first confirm that the residuals are indeed normally distributed. This is difficult to do because of the size limitations of the existing turbidity &

TSS dataset. Tukey's method does not rely on any assumption about the distribution of the residuals. It can be used regardless of the shape of distribution.

Outliers were removed from the dataset only for calculating the turbidity-TSS relationship, not from the dataset used to develop the TMDL.

The regression between TSS and turbidity and its statistics for each turbidity impaired stream segments will be shown in Section 5.1.

4.2 Using Load Duration Curves to Develop TMDLs

The TMDL calculations presented in this report are derived from load duration curves (LDC). LDCs facilitate rapid development of TMDLs, and as a TMDL development tool are effective at identifying whether impairments are associated with point or nonpoint sources. The technical approach for using LDCs for TMDL development includes the following steps that are described in Subsections 4.3 through 4.5 below:

Preparing flow duration curves for gaged and ungaged WQM stations;

- Estimating existing loading in the waterbody using ambient bacteria water quality data; and estimating loading in the waterbody using measured TSS water quality data and turbidity-converted data; and

Using LDCs to identify the critical condition that will dictate loading reductions and the overall percent reduction goal (PRG) necessary to attain WQS.

Historically, in developing WLAs for pollutants from point sources, it was customary to designate a critical low flow condition (*e.g.*, 7Q2) at which the maximum permissible loading was calculated. As water quality management efforts expanded in scope to quantitatively address nonpoint sources of pollution and types of pollutants, it became clear that this single critical low flow condition was inadequate to ensure adequate water quality across a range of flow conditions. Use of the LDC obviates the need to determine a design storm or selected flow recurrence interval with which to characterize the appropriate flow level for the assessment of critical conditions. For waterbodies impacted by both point and nonpoint sources, the "nonpoint source critical condition" would typically occur during high flows, when rainfall runoff would contribute the bulk of the pollutant load, while the "point source critical condition" would typically occur during low flows, when WWTP effluents would dominate the base flow of the impaired water. However, flow range is only a general indicator of the relative proportion of point/nonpoint contributions. It is not used in this report to quantify point source or nonpoint source contributions. Violations that occur during low flows may not be caused exclusively by point sources. Violations have been noted in some watersheds that contain no point sources.

LDCs display the maximum allowable load over the complete range of flow conditions by a line using the calculation of flow multiplied by a water quality criterion. The TMDL can be expressed as a continuous function of flow, equal to the line, or as a discrete value derived from a specific flow condition.

4.3 Development of Flow Duration Curves

Flow duration curves serve as the foundation of LDCs and are graphical representations of the flow characteristics of a stream at a given site. Flow duration curves utilize the historical hydrologic record from stream gages to forecast future recurrence frequencies. Many WQM stations throughout Oklahoma do not have long-term flow data and therefore, flow frequencies must be estimated. The default approach used to develop flow frequencies necessary to establish flow duration curves considers watershed differences in rainfall, land use, and the hydrologic properties of soil that govern runoff and retention. A detailed explanation of the methods for estimating flow for ungaged streams is provided in Appendix C. The most basic method to estimate flows at an ungaged site involves 1) identifying an upstream or downstream flow gage; 2) calculating the contributing drainage areas of the ungaged sites and the flow gage; and 3) calculating daily flows at the ungaged site by using the flow at the gaged site multiplied by the drainage area ratio.

Flow duration curves are a type of cumulative distribution function. The flow duration curve represents the fraction of flow observations that exceed a given flow at the site of interest. The observed flow values are first ranked from highest to lowest, then, for each observation, the percentage of observations exceeding that flow is calculated. The flow value is read from the ordinate (y-axis), which is typically on a logarithmic scale since the high flows would otherwise overwhelm the low flows. The flow exceedance frequency is read from the abscissa, which is numbered from 0 to 100 percent, and may or may not be logarithmic. The lowest measured flow occurs at an exceedance frequency of 100 percent indicating that flow has equaled or exceeded this value 100 percent of the time, while the highest measured flow is found at an exceedance frequency of 0 percent. The median flow occurs at a flow exceedance frequency of 50 percent. The flow exceedance percentiles for each waterbody addressed in this report are provided in Appendix C.

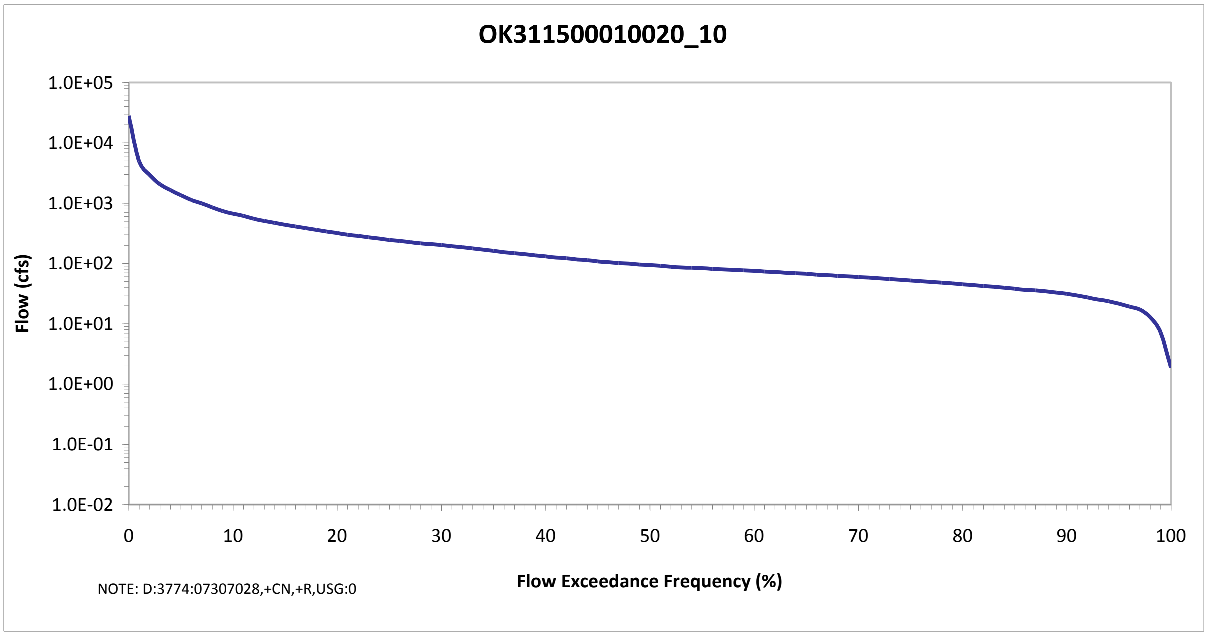
While the number of observations required to develop a flow duration curve is not rigorously specified, a flow duration curve is usually based on more than 1 year of observations, and encompasses inter-annual and seasonal variation. Ideally, the drought of record and flood of record are included in the observations. For this purpose, the long-term flow gaging stations operated by the USGS are utilized (USGS 2007a) to support the Oklahoma TMDL Toolbox.

The USGS National Water Information System serves as the primary source of flow measurements for the Oklahoma TMDL Toolbox. All available daily average flow values for all gages in Oklahoma, as well as the nearest upstream and downstream gages in adjacent states, were retrieved for use in the Oklahoma TMDL Toolbox to generate flow duration curves for gaged and ungaged waterbodies. The application includes a data update module that automatically downloads the most recent USGS data and appends it to the existing flow database.

Some instantaneous flow measurements were available from various agencies. These were not combined with the daily average flows or used in calculating flow percentiles, but were matched to bacteria, turbidity, or TSS grab measurements collected at the same site and time. When available, these instantaneous flow measurements were used in lieu of projected flows to calculate pollutant loads.

A typical semi-log flow duration curve exhibits a sigmoidal shape, bending upward near a flow exceedance frequency value of 0 percent and downward at a frequency near 100 percent, often with a relatively constant slope in between. For sites that on occasion exhibit no flow, the curve will intersect the abscissa at a frequency less than 100 percent. As the number of observations at a site increases, the line of the LDC tends to appear smoother. However, at extreme low and high flow values, flow duration curves may exhibit a “stair step” effect due to the USGS flow data rounding conventions near the limits of quantitation. An example of a typical flow duration curve was shown in Figure 4-2.

Figure 4-2 Flow Duration Curve for the Red River, North Fork, Headrick (OK311500010020_10)



4.4 Estimating Existing Loading

A key step in the use of LDCs for TMDL development is the estimation of existing instream loads. This is accomplished by:

- matching the water quality observations with the flow data from the same date;
- converting measured concentration values to loads by multiplying the flow at the time the sample was collected by the water quality parameter concentration (for sampling events with both TSS and turbidity data, the measured TSS value is used; if only turbidity was measured, the value was converted to TSS using the regression equations described); or multiplying the flow by the bacteria indicator concentration to calculate daily loads.

4.5 Development of TMDLs Using Load Duration Curves

The final step in the TMDL calculation process involves a group of additional computations derived from the preparation of LDCs. These computations are necessary to derive a PRG (which is one method of presenting how much pollutant loads must be reduced to meet WQSs in the impaired watershed).

Step 1: Generate Bacteria LDCs. LDCs are similar in appearance to flow duration curves; however, for bacteria the ordinate is expressed in terms of a bacteria load in cfu/day, and for TSS the ordinate is expressed in terms of a load in lbs/day. The curve represents the single sample water quality criterion for fecal coliform (400 cfu/100 mL), *E. coli* (406 cfu/100 mL), or Enterococci (108 cfu/100 mL) expressed in terms of a load through multiplication by the continuum of flows historically observed at the site. For turbidity, the curve represents the water quality target for TSS from Table 5-1 expressed in terms of a load obtained through multiplication of the TSS goal by the continuum of flows historically observed at the site. The basic steps to generating an LDC involve:

- obtaining daily flow data for the site of interest from the USGS;
- sorting the flow data and calculating flow exceedance percentiles for the time period and season of interest;
- obtaining the water quality data from the primary contact recreation season (May 1 through September 30); or obtaining available turbidity and TSS water quality data;
- displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQS for each respective bacteria indicator; or displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQ_{goal} for TSS;
- matching the water quality observations with the flow data from the same date and determining the corresponding exceedance percentile;
- plotting the flow exceedance percentiles and daily load observations in a load duration plot (See Section 5).

For bacteria TMDLs the culmination of these steps is expressed in the following formula, which is displayed on the LDC as the TMDL curve:

TMDL (cfu/day) = WQS * flow (cfs) * unit conversion factor

Where: WQS = 400 cfu /100 mL (Fecal coliform); 406 cfu/100 mL (E. coli); or 108 cfu/100 mL (Enterococci)

unit conversion factor = 24,465,525 mL*s / ft3*day

For turbidity (TSS) TMDLs the culmination of these steps is expressed in the following formula, which is displayed on the LDC as the TMDL curve:

TMDL (lb/day) = WQ_{goal} * flow (cfs) * unit conversion factor

where: WQ_{goal} = waterbody specific TSS concentration derived from regression analysis results presented in Table 5-1

unit conversion factor = 5.39377 L*s*lb /(ft^3*day*mg)

The flow exceedance frequency (x-value of each point) is obtained by looking up the historical exceedance frequency of the measured or estimated flow, in other words, the percent of historical observations that equal or exceed the measured or estimated flow. Historical observations of bacteria, TSS and/or turbidity concentrations are paired with flow data and are plotted as separate LDCs. The fecal coliform load (or the y-value of each point) is calculated by multiplying the fecal coliform concentration (colonies/100 mL) by the instantaneous flow (cubic feet per second) at the same site and time, with appropriate volumetric and time unit conversions. Fecal coliform/*E. coli*/Enterococci loads representing exceedance of water quality criteria fall above the water quality criterion line. Likewise, the TSS load (or the y-value of each point) is calculated by multiplying the TSS concentration (measured or converted from turbidity) (mg/L) by the instantaneous flow (cfs) at the same site and time, with appropriate volumetric and time unit conversions. TSS loads representing exceedance of water quality criteria fall above the TMDL line. Regarding bacteria data, it is noted that only those flows and water quality samples observed in the months comprising the primary contact recreation season are used to generate the LDCs. It is inappropriate to compare single sample bacteria observations and instantaneous or daily flow durations to a 30-day geometric mean water quality criterion in the LDC.

As noted earlier, runoff has a strong influence on loading of nonpoint pollution. Yet flows do not always correspond directly to runoff; high flows may occur in dry weather and runoff influence may be observed with low or moderate flows.

Step 2: Define MOS. The MOS may be defined explicitly or implicitly. A typical explicit approach would reserve some specific fraction of the TMDL as the MOS. In an implicit approach, conservative assumptions used in developing the TMDL are relied upon to provide an MOS to assure that WQSs are attained. For bacteria TMDLs in this report, an explicit MOS of 10 percent was selected. The 10 percent MOS has been used in other approved bacteria TMDLs. For turbidity (TSS) TMDLs an explicit MOS is derived from the NRMSE established by the turbidity/TSS regression analysis conducted for each waterbody. This approach for setting an explicit MOS has been used in other approved turbidity TMDLs.

Step 3: Calculate WLA. As previously stated, the pollutant load allocation for point sources is defined by the WLA. For bacteria TMDLs a point source can be either a wastewater (continuous) or stormwater (MS4) discharge. Stormwater point sources are typically associated with urban and industrialized areas, and recent USEPA guidance includes NPDES-permitted stormwater discharges as point source discharges and, therefore, part of the WLA. For TMDL development purposes when addressing turbidity or TSS, a WLA will be established for wastewater (continuous) discharges in impaired watersheds that do not have a BOD or CBOD permit limit but do have a TSS limit. These point source discharges of inorganic suspended solids will be assigned a TSS WLA as part of turbidity TMDLs to ensure WQS can be maintained. As discussed in Section 3.1 a WLA for TSS is not necessary for MS4s.

The LDC approach recognizes that the assimilative capacity of a waterbody depends on the flow, and that maximum allowable loading will vary with flow condition. TMDLs can be expressed in terms of maximum allowable concentrations, or as different maximum loads allowable under different flow conditions, rather than single maximum load values. For bacteria TMDLs a concentration-based approach meets the requirements of 40 CFR, 130.2(i) for expressing TMDLs "in terms of mass per time, toxicity, or other appropriate measures" and is consistent with USEPA's Protocol for Developing Pathogen TMDLs (USEPA 2001). For turbidity (TSS) TMDLs a load-based approach also meets the requirements of 40 CFR, 130.2(i) for expressing TMDLs "in terms of mass per time, toxicity, or other appropriate measures."

WLA for WWTP. WLAs may be set to zero in cases of watersheds with no existing or planned continuous permitted point sources. For watersheds with permitted point sources, NPDES permit limits are used to derive WLAs. The permitted flow rate used for each point source discharge and the water quality concentration defined in a permit are used to estimate the WLA for each wastewater facility. In cases where a permitted flow rate is not available for a WWTP, then the average of monthly flow rates derived from DMRs can be used. WLA values for each NPDES wastewater discharger are then summed to represent the total WLA for a given watershed. Using this information bacteria and TSS WLAs can be calculated using a mass balance approach as shown in the equations below.

WLA for bacteria:

WLA = WQS * flow * unit conversion factor (#/day)

Where:

WQS = 200 cfu /100 mL (Fecal coliform); 126 cfu/100 mL (E. coli); or 33 cfu/100 mL (Enterococci)

flow (10^6 gal/day) = permitted flow

unit conversion factor = 37,854,120-10^6gal/day

WLA for TSS:

WLA = WQ goal * flow * unit conversion factor (lb/day)

Where:

WQ goal is provided in Table 5-1;

flow (10^6 gal/day) = permitted flow or average monthly flow

unit conversion factor = 8.3445 L*lb/(gal*mg)

Step 4: Calculate LA and WLA for MS4s. Given the lack of data and the variability of storm events and discharges from storm sewer system discharges, it is difficult to establish numeric limits on stormwater discharges that accurately address projected loadings. As a result, EPA regulations and guidance recommend expressing NPDES permit limits for MS4s as BMPs.

LAs can be calculated under different flow conditions as the water quality target load minus the WLA. The LA is represented by the area under the LDC but above the WLA. The LA at any particular flow exceedance is calculated as shown in the equation below.

LA = TMDL - WLA_WWTP - WLA_MS4 - MOS

WLA for MS4s. For bacteria TMDLs, if there are no permitted MS4s in the study area, WLA_MS4 is set to zero. When there are permitted MS4s in the watershed, we can first calculate the sum of LA + WLA_MS4 using the above formula, then separate WLA for MS4s from the sum based on the percentage of a watershed that is under a MS4 jurisdiction. This WLA for MS4s may not be the total load allocated for permitted MS4s unless the whole MS4 area is located within the study watershed boundary. However, in most case the study watershed intersects only a portion of the permitted MS4 coverage areas.

For turbidity TMDLs, WLAs for permitted stormwater such as MS4s, construction, and multi-sector general permits are not calculated since these discharges occur under high flow conditions when the turbidity criteria do not apply.

Step 5: Estimate WLA Load Reduction. The WLA load reduction for bacteria was not calculated as it was assumed that continuous dischargers (NPDES-permitted WWTPs) are adequately regulated under existing permits to achieve water quality standards at the end-of-pipe and, therefore, no WLA reduction would be required. If there are no MS4s located within the Study Area requiring a TMDL then there is no need to establish a PRG for permitted stormwater.

The WLA load reduction for TSS for dischargers without BOD/CBOD limits can be determined as follows:

If permitted TSS limit is less than TSS goal for the receiving stream, there will be no reductions;

If permitted TSS limit is greater than TSS goal for the receiving stream, the permit limit will be set at the TSS goal.

Step 6: Estimate LA Load Reduction. After existing loading estimates are computed for each pollutant, nonpoint load reduction estimates for each WQM station are calculated by using the difference between estimated existing loading and the allowable load expressed by the LDC (TMDL-MOS). This difference is expressed as the overall PRG for the impaired waterbody. For fecal coliform the PRG which ensures that no more than 25 percent of the samples exceed the TMDL based on the instantaneous criteria allocates the loads in manner that is also protective of the geometric mean criterion. For *E. coli* and Enterococci, because WQSs are considered to be met if 1) either the geometric mean of all data is less than the geometric mean criteria, or 2) no sample exceeds the instantaneous criteria, the TMDL PRG will be the lesser of that required to meet the geometric mean or instantaneous criteria. For turbidity, the PRG is the load reduction that ensures that no more than 10 percent of the samples under flow-base conditions exceed the TMDL.

SECTION 5
TMDL CALCULATIONS

5.1 Surrogate TMDL Target for Turbidity

Using the LOC method described in Section 4.1, the correlation between TSS and turbidity were developed for all streams impaired streams (Figures 5-1 to 5-4). And the statistics of the regressions and the resultant TSS goals were shown in Table 5-1. In general, all available pairs of TSS and turbidity were used for the LOC regression while only the most recent five years of data (2006-2010) were used for TMDL purpose. There were no concurrent TSS and turbidity data for the Deep Fork of the Canadian River (OK520700040010_00) during the most recent five years of assessment and TMDL development. As a result, concurrent TSS and turbidity data from 1998 to 2000 were used. Turbidity and TSS data for Opossum Creek (OK520700050200_00) are available from only 1999-2001.

Figure 5-1 Linear Regression for TSS-Turbidity for the Deep Fork of the Canadian River (OK520700040010_00)

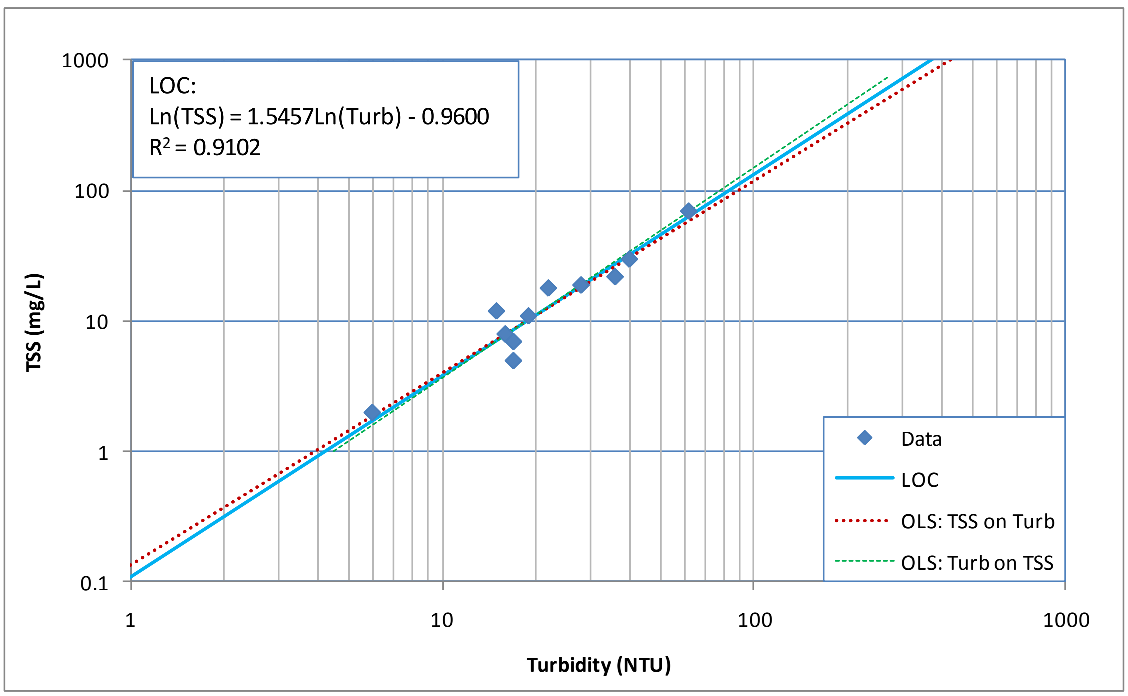


Figure 5-2 Linear Regression for TSS-Turbidity for Dry Creek (OK520700040020_00)

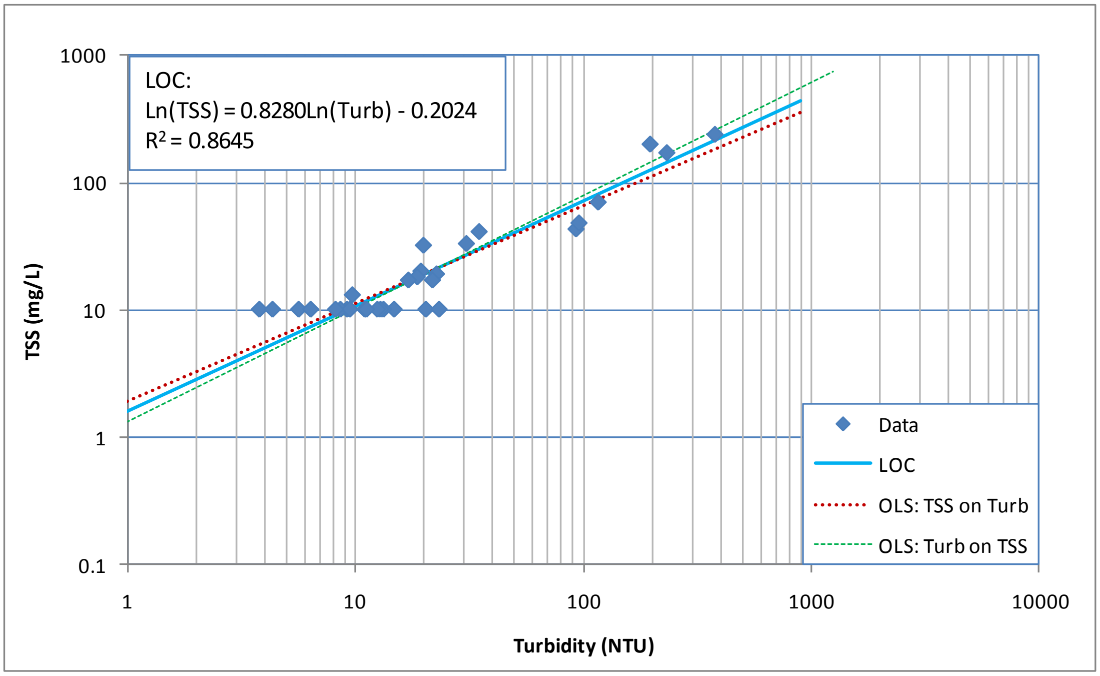


Figure 5-3 Linear Regression for TSS-Turbidity for Quapaw Creek (OK520700040260_00)

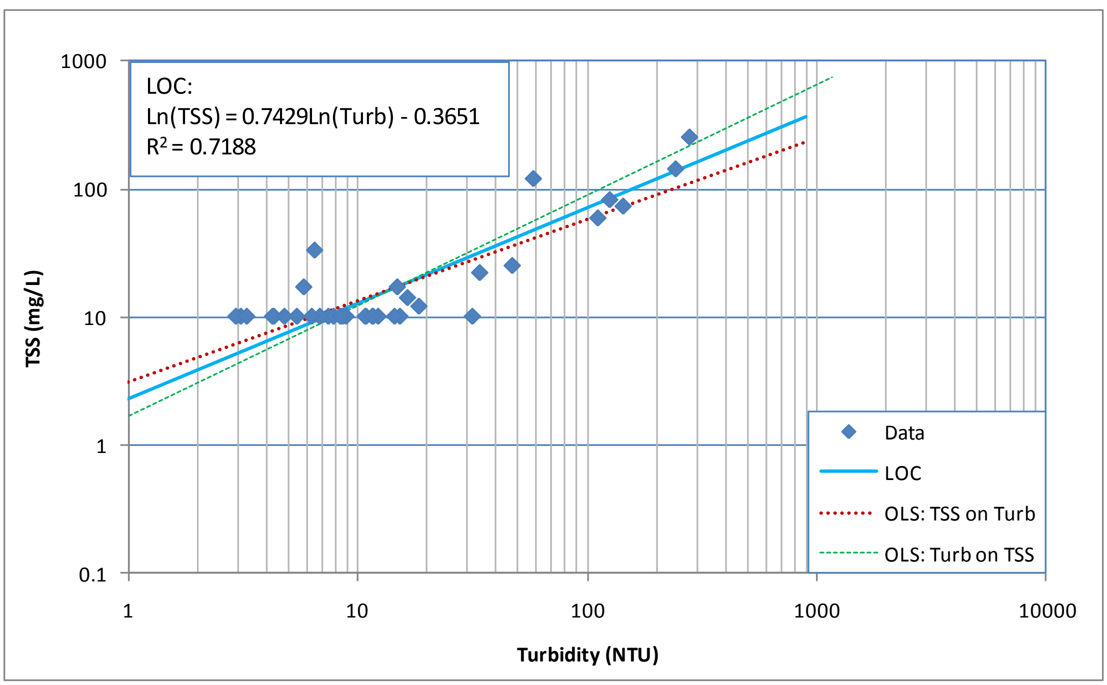


Figure 5-4 Linear Regression for TSS-Turbidity for Opossum Creek (OK520700050200_00)

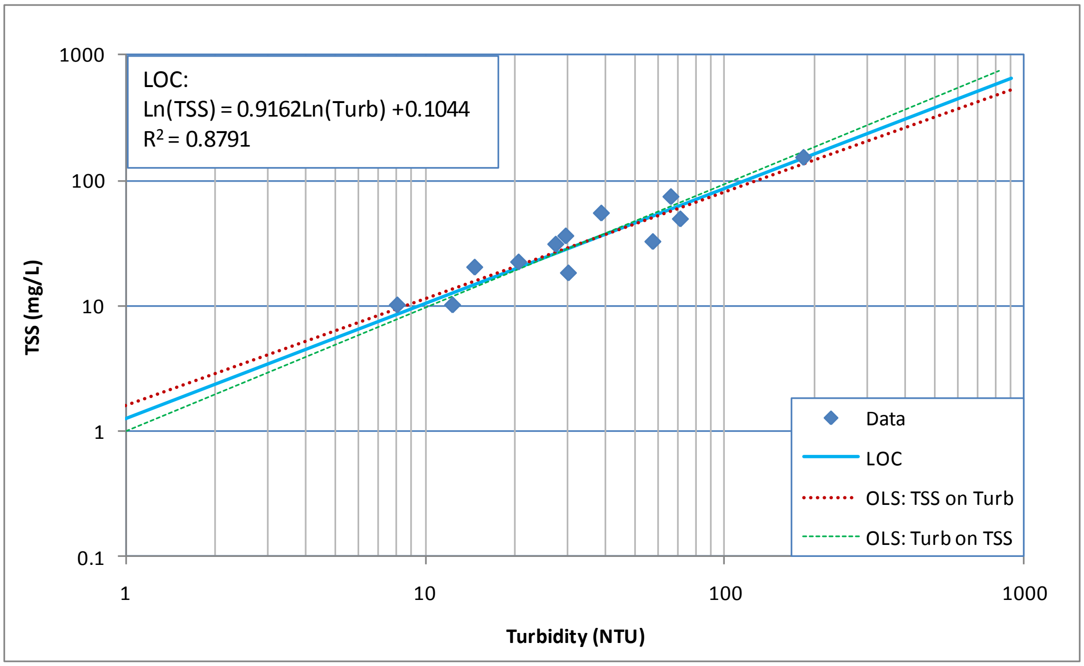


Table 5-1 LOC Regression Statistics and TSS Goals

Waterbody Name	Waterbody ID	R-square	NRMSE	TSS Goal (mg/L)[a]	MOS[b]
Canadian River, Deep Fork	OK520700040010_00	0.91	10.8%	145.7	10%
Dry Creek	OK520700040020_00	0.86	11.7%	28.1	10%
Quapaw Creek	OK520700040260_00	0.72	17.0%	21.1	20%
Opossum Creek	OK520700050200_00	0.88	8.3%	36.0	10%

[a] Calculated using the regression equation and the turbidity standard (50 NTU)
[b] Based on the goodness-of-fit of the turbidity-TSS regression (NRMSE)

5.2 Estimated Loading and Critical Conditions

USEPA regulations at 40 CFR 130.7(c) (1) require TMDLs to take into account critical conditions for stream flow, loading, and all applicable water quality standards. To accomplish this, available instream WQM data were evaluated with respect to flows and magnitude of water quality criteria exceedance using LDCs.

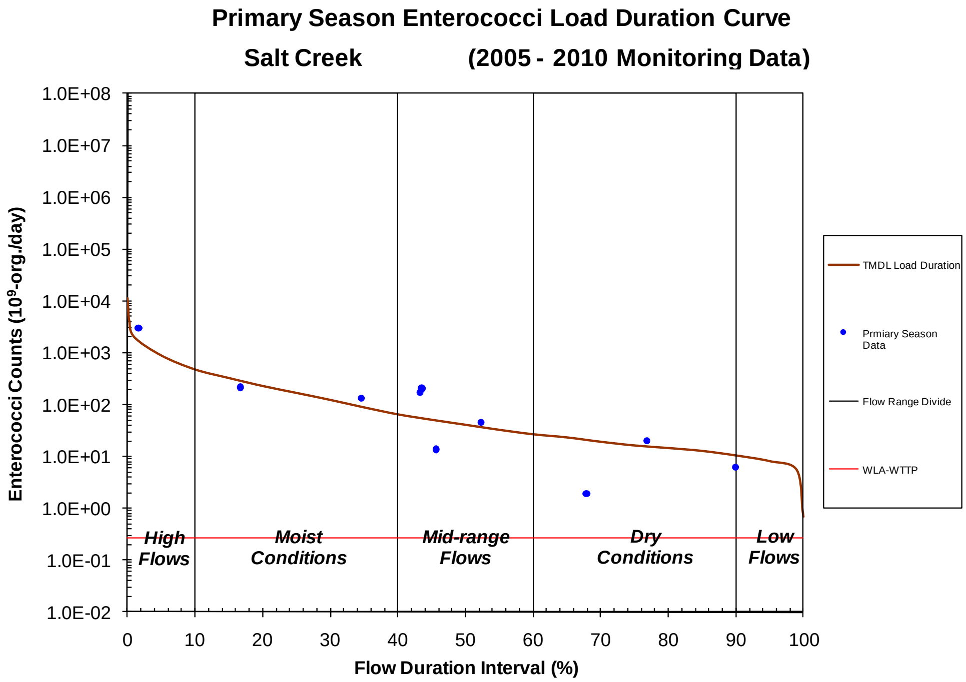
Bacteria LDC: To calculate the bacteria load, the flow rate at each flow exceedance percentile is multiplied by a unit conversion factor (*24,465,525 mLs / ft^3 day*) and the criterion specific to each bacterial indicator. This calculation produces the maximum bacteria load in the stream without exceeding the instantaneous standard over the range of flow conditions. The allowable bacteria (fecal coliform, *E. coli*, or Enterococci) loads at the WQS establish the TMDL and are plotted versus flow exceedance percentile as a LDC. The x-axis indicates the flow exceedance percentile, while the y-axis is expressed in terms of a bacteria load.

To estimate existing loading, bacteria observations for the primary contact recreation season (May 1^{st} through September 30^{th}) from 2002 to 2009 are paired with the flows measured or estimated in that waterbody on the same date. Pollutant loads are then calculated by multiplying the measured bacteria concentration by the flow rate and the unit conversion factor of *24,465,756 mLs / ft^3 day*. The associated flow exceedance percentile is then matched with the measured flow from the tables provided in Appendix C. The observed bacteria loads are then added to the LDC plot as points. These points represent individual ambient water quality samples of bacteria. Points above the LDC indicate the bacteria instantaneous standard was exceeded at the time of sampling. Conversely, points under the LDC indicate the sample met the WQS.

The bacteria LDCs developed for each impaired waterbody (representing the primary contact recreation season) are shown in Figures 5-5 through 5-13. Waterbodies may have more than one LDC because for the PBCR use to be supported, criteria for each bacterial indicator must be met in each impaired waterbody.

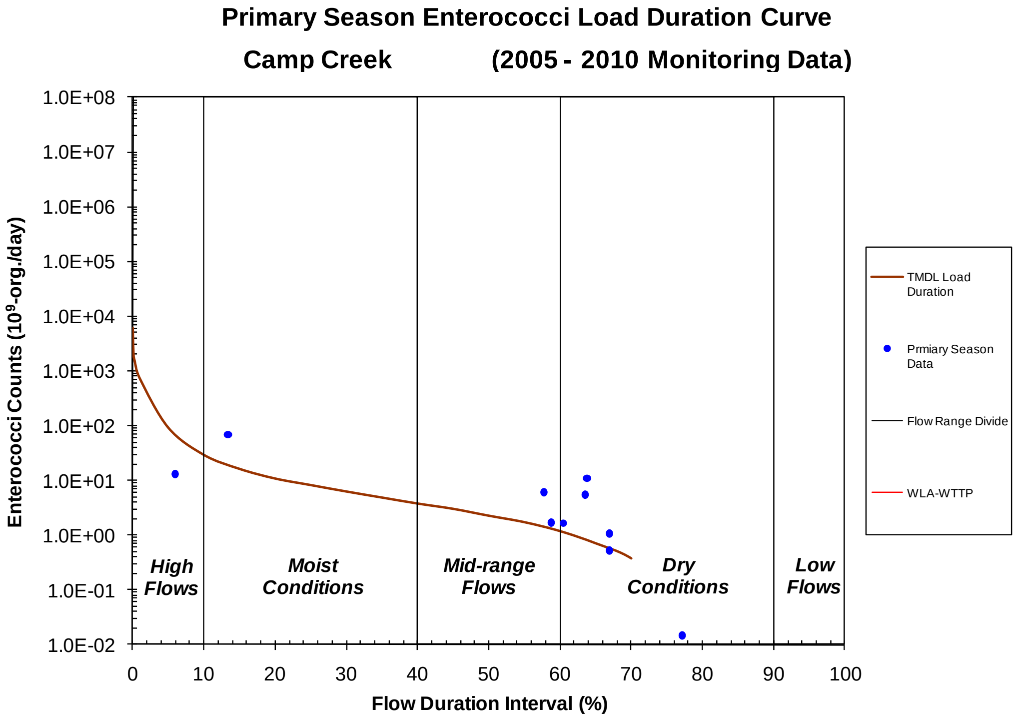
The LDC for Salt Creek (OK520700030100_00) (Figure 5-5) is based on Enterococci bacteria measurements collected during primary contact recreation season. The LDC indicates that levels of Enterococci exceed the instantaneous water quality criteria under all flow conditions except the low flows.

Figure 5-5 Load Duration Curve for *Enterococci* in Salt Creek (OK520700030100_00)



The LDC for Camp Creek (OK520700030220_00) (Figure 5-6) is based on Enterococci measurements during primary contact recreation season. The LDC indicates that Enterococci levels exceed the instantaneous water quality criteria under moderate and dry flow conditions.

Figure 5-6 Load Duration Curve for *Enterococci* in Camp Creek (OK520700030220_00)



The LDCs for Deep Fork of the Canadian River (OK520700040010_00) (Figures 5-7 and 5-8) are based on fecal coliform and Enterococci bacteria measurements collected during primary contact recreation season. The LDCs indicate that levels of both fecal coliform and Enterococci typically exceed the instantaneous water quality criteria under dry and low flow conditions.

Figure 5-7 Load Duration Curve for Enterococci in Deep Fork of the Canadian River (OK520700040010_00)

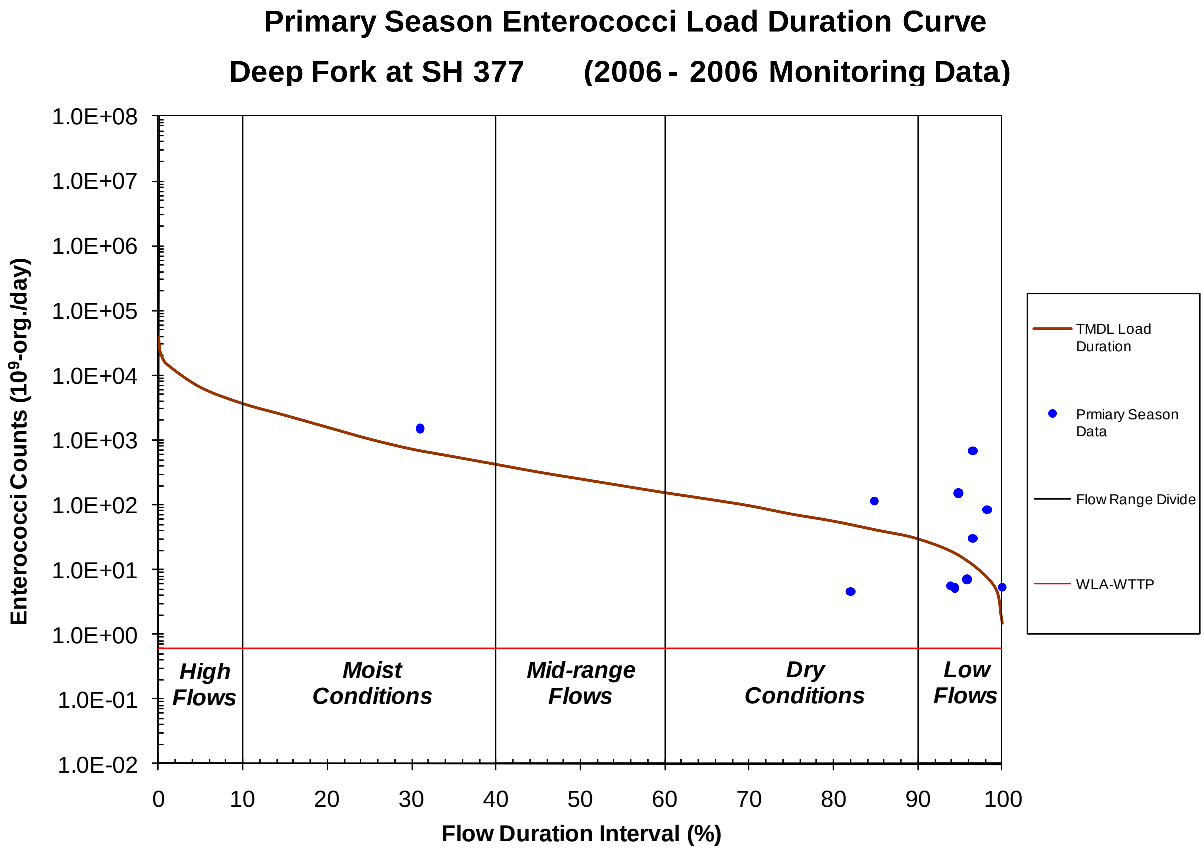
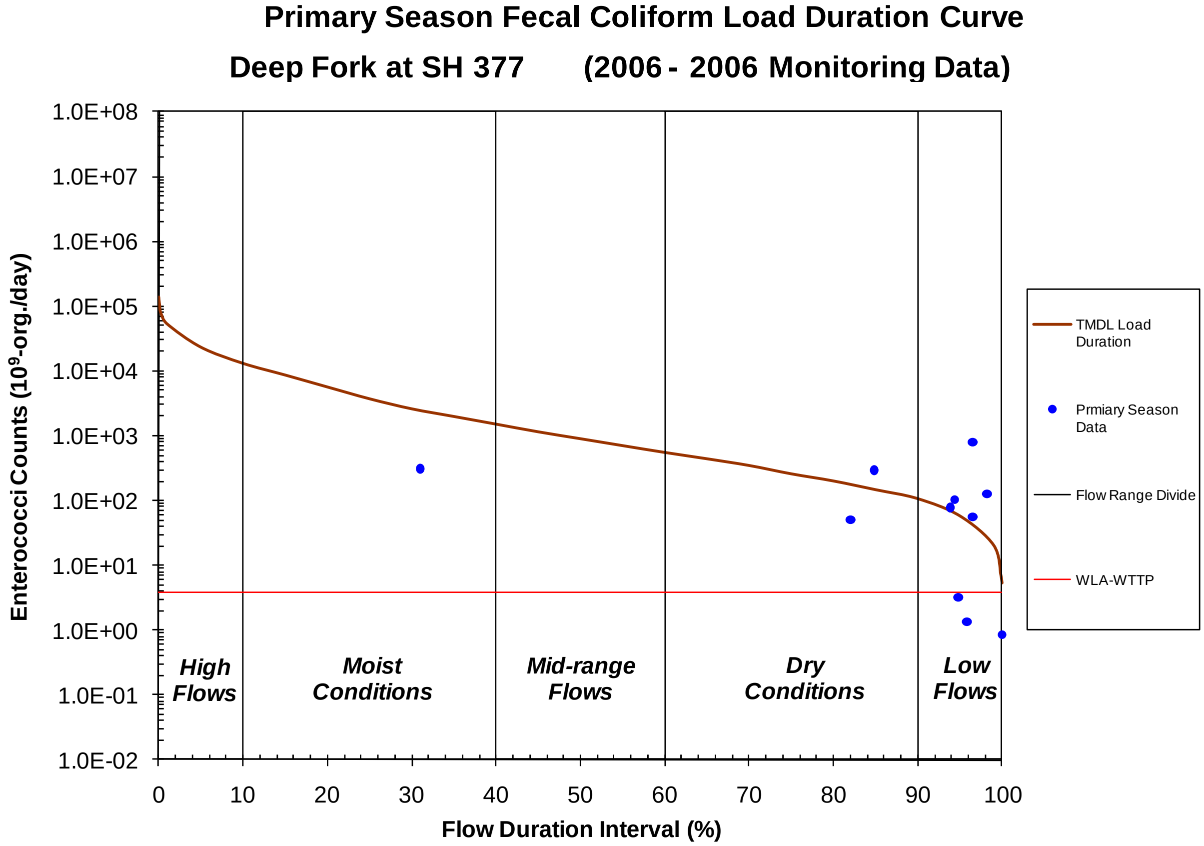


Figure 5-8 Load Duration Curve for fecal coliform in Deep Fork of the Canadian River (OK520700040010_00)



The LDCs for Dry Creek (OK520700040020_00) (Figures 5-9 and 5-10) are based on Enterococci and *E. coli* measurements during primary contact recreation season. The LDCs indicate that Enterococci levels exceeded the instantaneous water quality criteria under all flow conditions except low flows, indicative of loading from nonpoint sources. *E. coli* levels exceeded its instantaneous water quality criteria under high flow and moist conditions, indicative of loading from nonpoint sources.

Figure 5-9 Load Duration Curve for Enterococci in Dry Creek (OK520700040020_00)

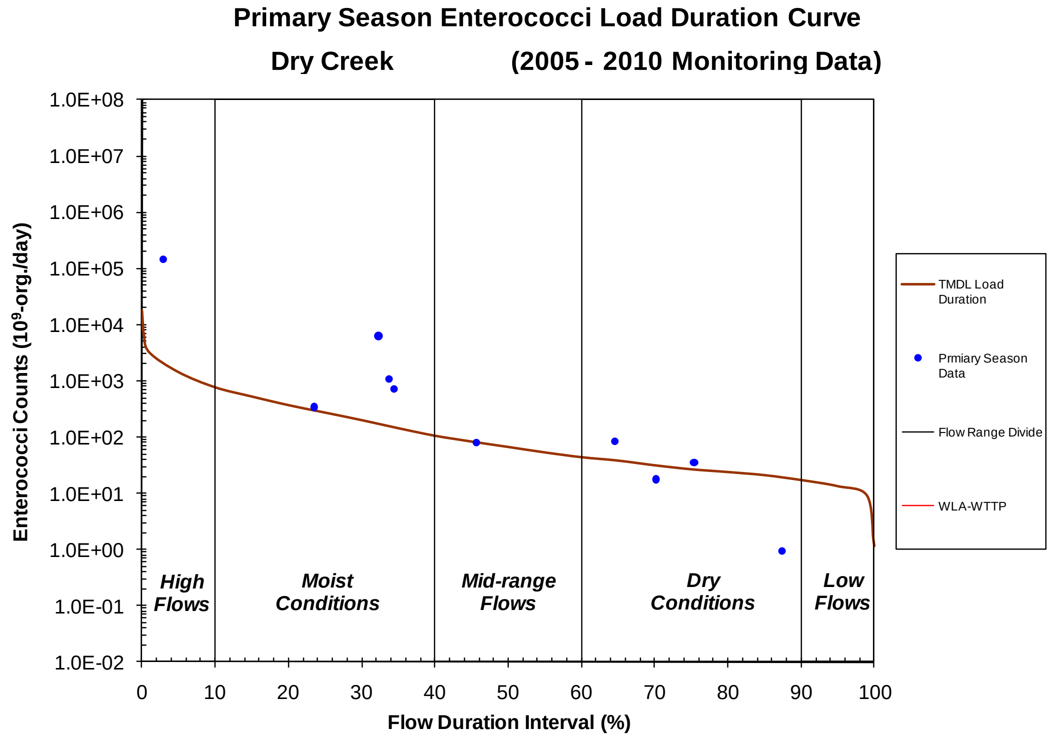
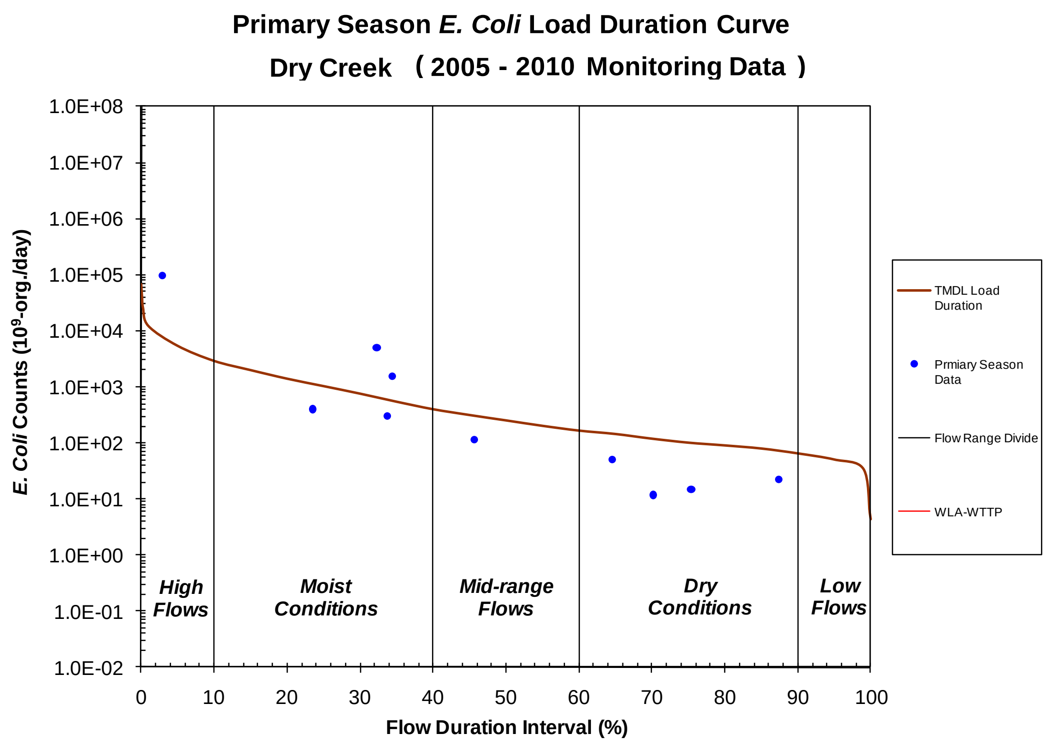
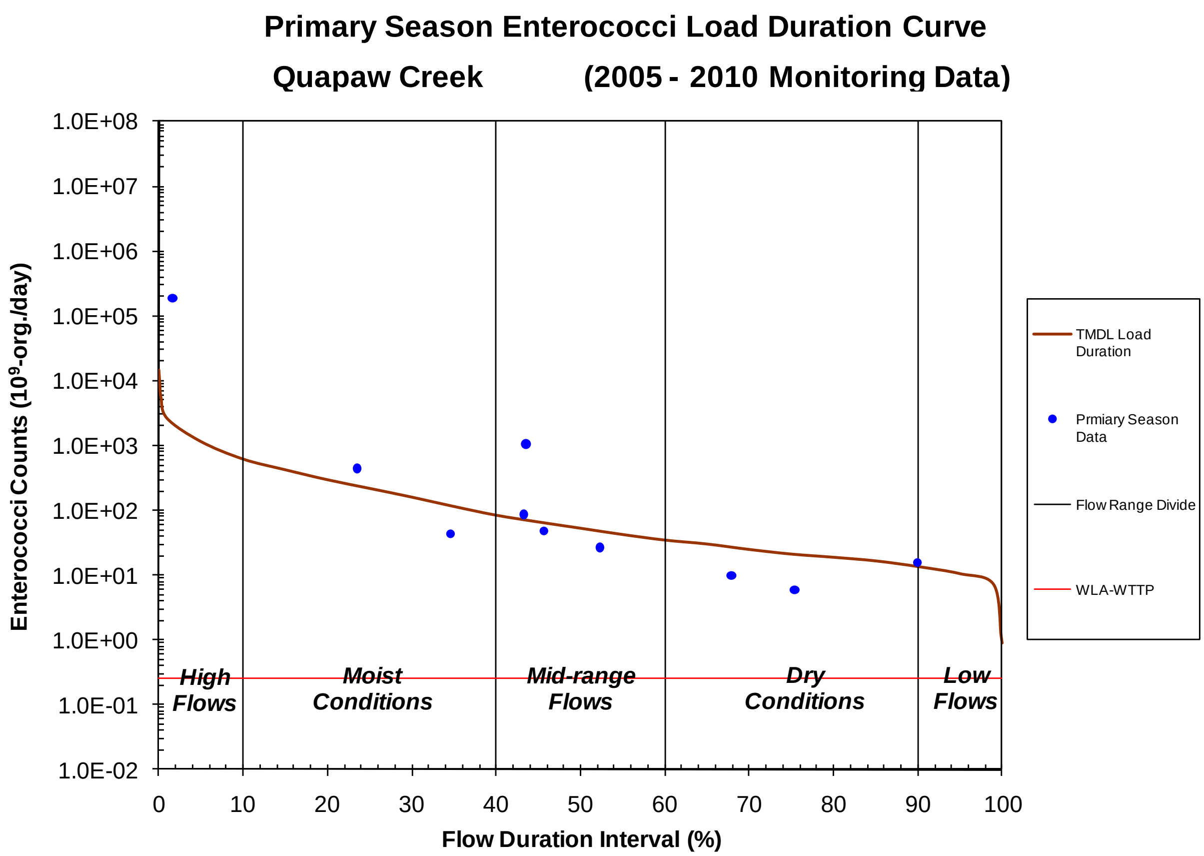


Figure 5-10 Load Duration Curve for *E. coli* in Dry Creek (OK520700040020_00)



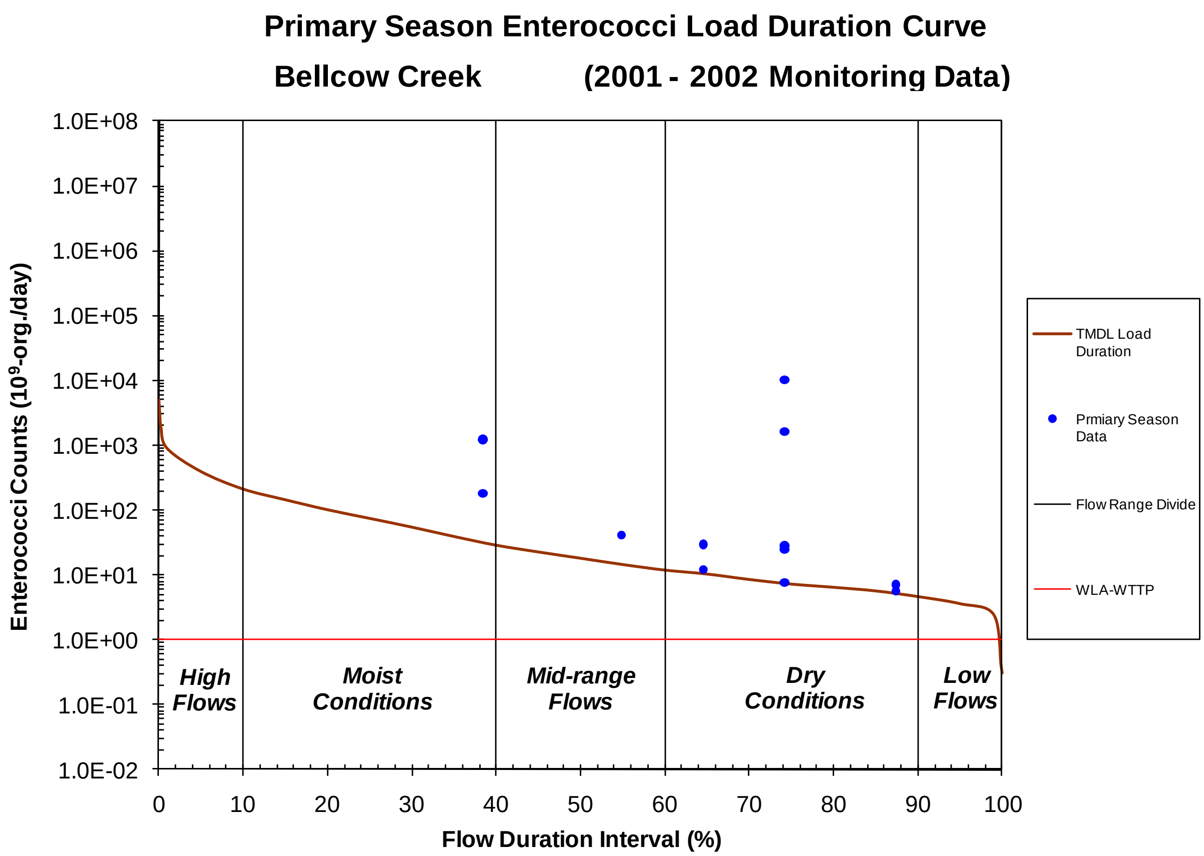
The LDC for Quapaw Creek (OK520700040260_00) (Figure 5-11) is based on Enterococci bacteria measurements collected during primary contact recreation season. The LDC indicates that Enterococci levels exceeded the instantaneous water quality criteria under all flow conditions.

Figure 5-11 Load Duration Curve for Enterococci in Quapaw Creek (OK520700040260_00)



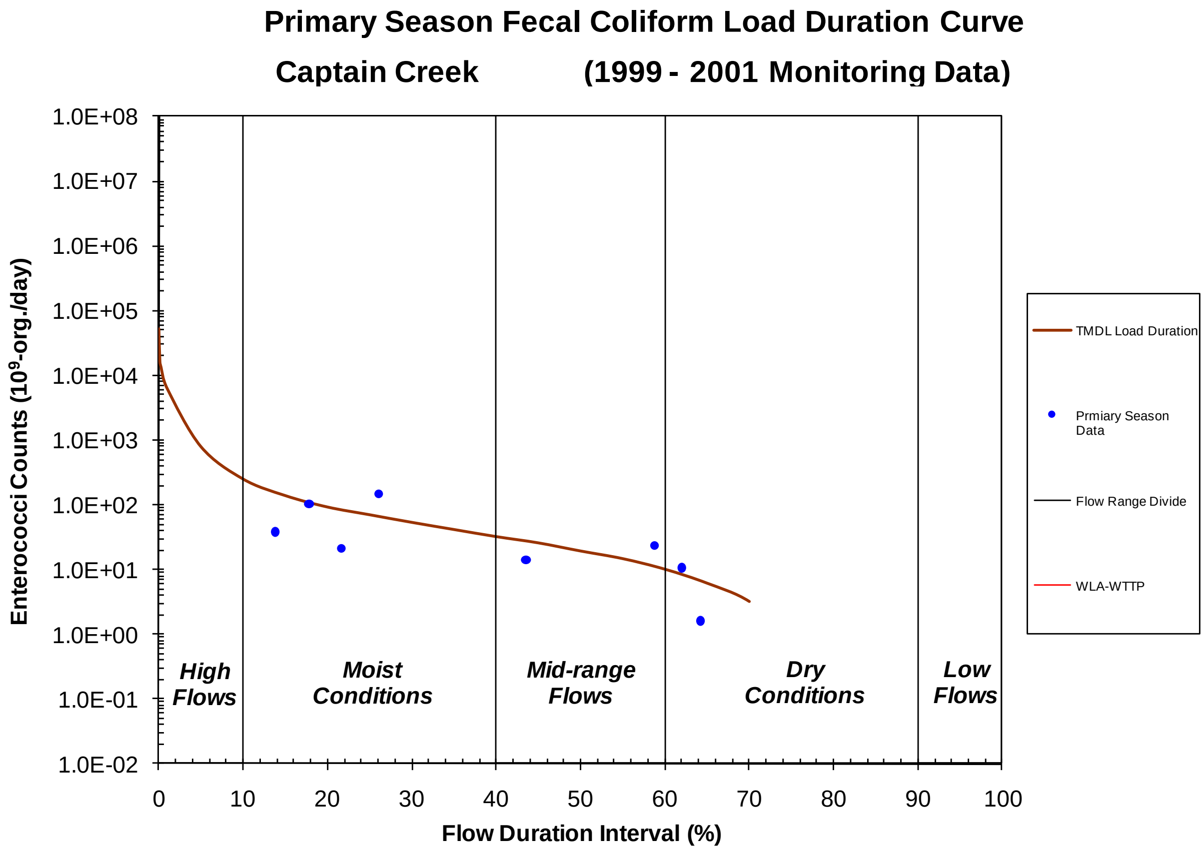
The LDC for Bellcow Creek (OK520700050020_00) (Figure 5-12) is based on Enterococci bacteria measurements collected during primary contact recreation. The LDC indicates that Enterococci levels exceeded the instantaneous water quality criteria under all flow conditions, except the very high and very low flows.

Figure 5-12 Load Duration Curve for Enterococci in Bellcow Creek (OK520700050020_00), Dry Creek (OK520700040020_00)



The LDC for Captain Creek (OK520700050140_00) (Figure 5-13) is based on fecal coliform bacteria measurements collected during primary contact recreation. The LDC indicates that fecal coliform levels exceeded the instantaneous water quality criteria under mid-range flow conditions.

Figure 5-13 Load Duration Curve for Fecal Coliform in Captain Creek (OK520700050140_00)



TSS LDC: To calculate the TSS load at the WQ target, the flow rate at each flow exceedance percentile is multiplied by a unit conversion factor (*5.39377 L*s*lb /ft³/day/mg*) and the TSS goal for each waterbody. This calculation produces the maximum TSS load in the waterbody that will result in attainment of the 50 NTU target for turbidity. The allowable TSS loads at the WQS establish the TMDL and are plotted versus flow exceedance percentile as a LDC. The x-axis indicates the flow exceedance percentile, while the y-axis is expressed in terms of a TSS load in pounds per day.

To estimate existing loading, TSS and turbidity observations are paired with the flows measured or projected on the same date for the waterbody. For sampling events with both TSS and turbidity data, the measured TSS value is used. Pollutant loads are then calculated by multiplying the TSS concentration by the flow rate and the unit conversion factor. The associated flow exceedance percentile is then matched with the flow from the tables provided in Appendix C. The observed TSS or converted turbidity loads are then added to the LDC plot as points. These points represent individual ambient water quality samples of TSS. Points above the LDC indicate the TSS goal was exceeded at the time of sampling. Conversely, points under the LDC indicate the sample did not exceed the TSS goal.

Figures 5-14 through 5-17 show the TSS LDCs developed for the four waterbodies addressed in this TMDL report. Data in the figures indicate that TSS levels exceed the water quality target during all flow conditions, indicating water quality impairments due to nonpoint sources or a combination of point and nonpoint sources. Wet weather influenced samples found during low flow conditions can be caused by an isolated rainfall event during dry weather conditions. It is noted that the LDC plots include data under all flow conditions to show the overall condition of the waterbody. However, the turbidity standard only applies for base-flow conditions. Thus, when interpreting the LDC to derive TMDLs for TSS, only the portion of the graph corresponding to flows above the 25th flow exceedance percentile should be used.

Figure 5-14 Load Duration Curve for Total Suspended Solids in Deep Fork of the Canadian River (OK520700040010_00)

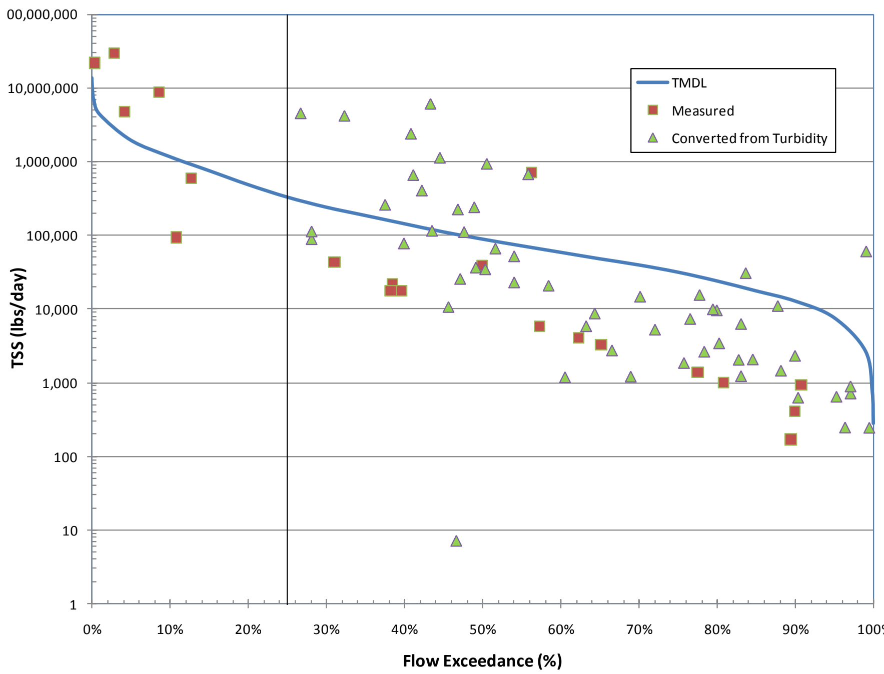


Figure 5-15 Load Duration Curve for Total Suspended Solids in Dry Creek (OK520700040020_00)

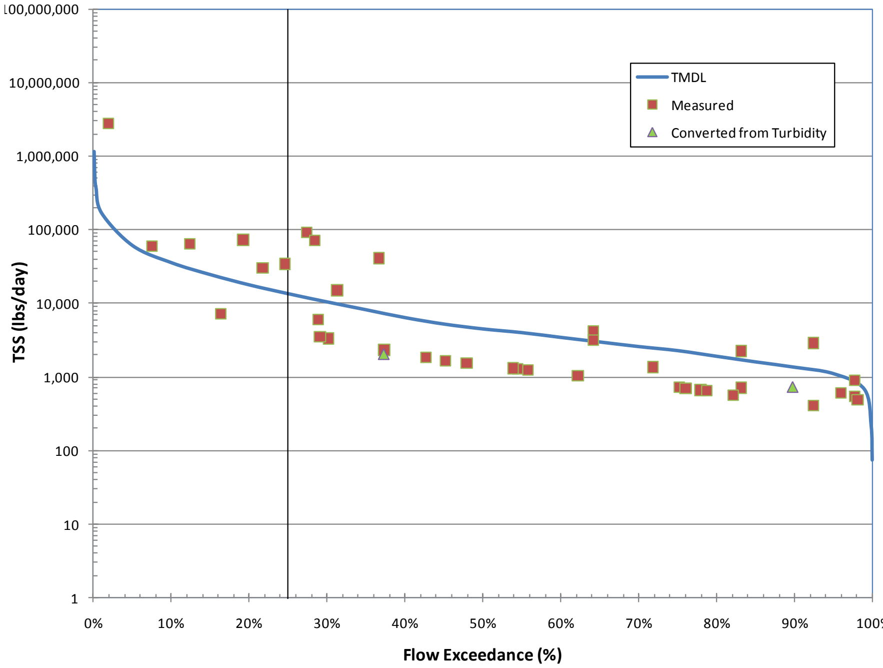


Figure 5-16 Load Duration Curve for Total Suspended Solids in Quapaw Creek (OK520700040260_00)

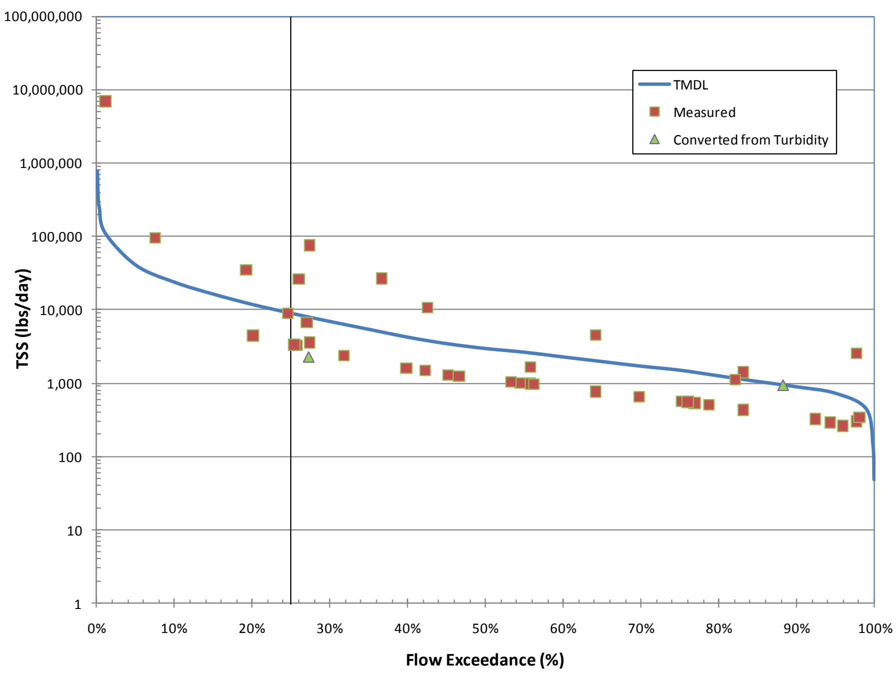
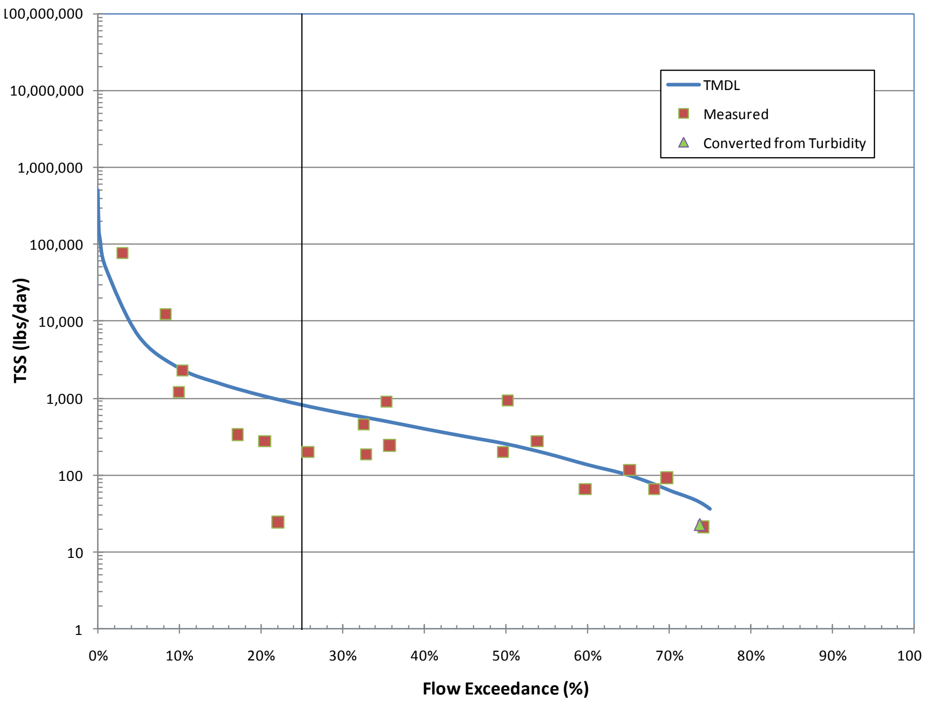


Figure 5-17 Load Duration Curve for Total Suspended Solids in Opossum Creek (OK520700050200_00)



Establishing Percent Reduction Goals: The LDC approach recognizes that the assimilative capacity of a waterbody depends on the flow, and that maximum allowable loading varies with flow condition. Existing loading and load reductions required to meet the TMDL water quality target can also be calculated under different flow conditions. The difference between existing loading and the water quality target is used to calculate the loading reductions required. Percent reduction goals are calculated through an iterative process of taking a series of percent reduction values applying each value uniformly between the concentrations of samples and verifying that no more than a fixed percent of the samples exceed the water quality target concentration. PRG are calculated for each watershed and bacterial indicator species as the reductions in load required so no existing instantaneous water quality observations would exceed the water quality targets for *E. coli* and Enterococci and no more than 25 percent of the samples exceed the water quality target for fecal coliform. This is because for the PBCR use to be supported, criteria for each bacterial indicator must be met in each impaired waterbody. Table 5-2 presents the percent reductions necessary to meet the TMDL water quality target for each bacterial indicator in each of the impaired waterbodies in the Study Area. The PRGs range from 29 to 96 percent.

Table 5-2 TMDL Percent Reductions Required to Meet Water Quality Standards for Indicator Bacteria

Waterbody Name	Waterbody ID	Required Reduction Rate				
		FC	EC		ENT	
		Instant-aneous	Instant-aneous	Geo-mean	Instant-aneous	Geo-mean
Salt Creek	OK520700030100_00				75.7%	**71.2%**
Camp Creek	OK520700030220_00				93.3%	**85.3%**
Canadian River, Deep Fork	OK520700040010_00	**47.1%**			98.4%	**85.6%**
Dry Creek	OK520700040020_00		94.5%	**60.4%**	98.9%	**89.1%**
Quapaw Creek	OK520700040260_00				99.0%	**82.0%**
Bellcow Creek	OK520700050020_00				99.9%	**96.4%**
Captain Creek	OK520700050140_00	**29.4%**				

Similarly, percent reduction goals for TSS are calculated as the required overall reduction so that no more than 10 percent of the samples exceed the water quality target for TSS. The PRGs for the fourteen waterbodies included in this TMDL report are summarized in Table 5-3 and range from 51 to 94 percent.

Table 5-3 TMDL Percent Reductions Required to Meet Water Quality Targets for Total Suspended Solids

Waterbody Name	Waterbody ID	Required Reduction Rate
Canadian River, Deep Fork	OK520700040010_00	94.0%
Dry Creek	OK520700040020_00	59.8%
Quapaw Creek	OK520700040260_00	71.1%
Opossum Creek	OK520700050200_00	50.7%

5.3 Wasteload Allocation

5.3.1 Indicator Bacteria

For bacteria TMDLs, NPDES-permitted facilities are allocated a daily wasteload calculated as their permitted flow rate multiplied by the instream geometric mean water quality criterion. In other words, the facilities are required to meet instream criteria in their discharge. Table 5-3 summarizes the WLA for the NPDES-permitted facilities within the study area. The WLA for each facility discharging to a bacteria-impaired reach is derived from the following equation:

WLA = WQS * flow * unit conversion factor (#/day)

Where:

WQS = 33, 200, and 126 cfu/100 mL for Enterococci, fecal coliform, and E. coli respectively

flow (10^6 gal/day) = permitted flow

unit conversion factor = 37,854,120-10^6gal/day

When multiple NPDES facilities occur within a watershed, individual WLAs are summed and the total WLA for continuous point sources is included in the TMDL calculation for the corresponding waterbody. When there are no NPDES WWTPs discharging into the contributing watershed of a WQM station, then the WLA is zero. Compliance with the WLA will be achieved by adhering to the fecal coliform limits and disinfection requirements of NPDES permits. There are no NPDES WWTPs discharging into the contributing watersheds of stream segments that require bacteria TMDLs.

Permitted stormwater discharges are considered point sources; however, there are no areas designated as MS4s within the watersheds of the waterbodies impaired for contact recreation, so the WLA for MS4 is zero.

5.3.2 Total Suspended Solids

NPDES-permitted facilities discharging inorganic TSS are allocated a daily wasteload calculated by using the average of self-reported monthly flow multiplied by the water quality target. In other words, the facilities are required to meet instream criteria in their discharge. If the current monthly TSS limits of a facility are greater than instream TSS criteria, the new limits equal to instream criteria will be applied to the facility as their permit is renewed. The WLA for each facility is derived as follows:

WLA_WWTP = WQ goal * flow * unit conversion factor (lb/day)

Where:

WQ goal = waterbody-specific water quality goal as summarized in Table 4-1

flow (10^6 gal/day) = average monthly flow

unit conversion factor = 8.3445 L*lb/(10^6 gal * mg)

There are no NPDES permitted facilities discharge inorganic TSS in the study area.

No wasteload allocations are needed for stormwater dischargers in the Study Area. By definition, any stormwater discharge occurs during periods of rainfall and elevated flow conditions. Oklahoma's Water Quality Standards specify that the criteria for turbidity "apply only to seasonal base flow conditions" and go on to say "Elevated turbidity levels may be expected during, and for several days after, a runoff event" [OAC 785:45-5-12(f)(7)]. To accommodate the potential for future growth in those watersheds with no WLA for TSS, 1 percent of TSS loading is reserved as part of the WLA.

5.4 Load Allocation

As discussed in Section 3, nonpoint source bacteria loading to each waterbody emanate from a number of different sources. The data analysis and the LDCs indicate that exceedances for each waterbody are the result of a variety of nonpoint source loading. The LAs for each bacterial indicator in waterbodies not supporting the PBCR use are calculated as the difference between the TMDL, MOS, and WLA, as follows:

LA = TMDL – WLA_WWTP– MOS

This equation is used to calculate the LA for TSS however the LA is further reduced by allocating 1 percent of the TMDL as part of the WLA:

LA = TMDL – WLA_WWTP – WLA_growth – MOS

5.5 Seasonal Variability

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. The bacteria TMDLs established in this report adhere to the seasonal application of the Oklahoma WQS which limits the PBCR use to the period of May 1st through September 30th. Similarly, the turbidity TMDLs established in this report adhere to the seasonal application of the Oklahoma WQS for turbidity, which applies to seasonal base flow conditions only. Seasonal variation was also accounted for in these TMDLs by using more than five years of water quality data and by using the longest period of USGS flow records when estimating flows to develop flow exceedance percentiles.

5.6 Margin of Safety

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs include an MOS. The MOS is a conservative measure incorporated into the TMDL equation that accounts for the lack of knowledge associated with calculating the allowable pollutant loading to ensure WQSs are attained. USEPA guidance allows for use of implicit or explicit expressions of the MOS, or both. When conservative assumptions are used in development of the TMDL, or conservative factors are used in the calculations, the MOS is implicit. When a specific percentage of the TMDL is set aside to account for the lack of knowledge, then the MOS is considered explicit.

For bacteria TMDLs, an explicit MOS was set at 10 percent.

For turbidity, the TMDLs are calculated for TSS instead of turbidity. Thus, the quality of the regression has a direct impact on confidence of the TMDL calculations. The better the regression is, the more confidence there is in the TMDL targets. As a result, it leads to a smaller margin of safety. The selection of MOS is based on the NRMSE for each waterbody. Table 5-4 shows the MOS for each waterbody.

Table 5-4 Explicit Margin of Safety for Total Suspended Solids TMDLs

Waterbody Name	Waterbody ID	NRMSE	Margin of Safety
Canadian River, Deep Fork	OK520700040010_00	10.8%	10%
Dry Creek	OK520700040020_00	11.7%	10%
Quapaw Creek	OK520700040260_00	17.0%	20%
Opossum Creek	OK520700050200_00	8.3%	10%

5.7 TMDL Calculations

The TMDLs for the 303(d)-listed waterbodies covered in this report were derived using LDCs. A TMDL is expressed as the sum of all WLAs (point source loads), LAs (nonpoint source loads), and an appropriate MOS, which attempts to account for the lack of knowledge concerning the relationship between effluent limitations and water quality.

This definition can be expressed by the following equation:

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

The TMDL represents a continuum of desired load over all flow conditions, rather than fixed at a single value, because loading capacity varies as a function of the flow present in the stream. The higher the flow is, the more wasteload the stream can handle without violating water quality standards. Regardless of the magnitude of the WLA calculated in these TMDLs, future new discharges or increased load from existing discharges will be considered consistent with the TMDL provided the NPDES permit requires instream criteria to be met.

The TMDL, WLA, LA, and MOS will vary with flow condition, and are calculated at every 5th flow interval percentile. Tables 5-5 through 5-13 summarize the allocations for indicator bacteria and Tables 5-14 to 5-17 present the allocations for total suspended solids.

Table 5-5 Enterococci TMDL Calculations for Salt Creek (OK520700030100_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	4,189.3	1.11E+13	2.75E+08	0.00E+00	9.96E+12	1.11E+12
5	332.9	8.80E+11	2.75E+08	0.00E+00	7.91E+11	8.80E+10
10	178.8	4.72E+11	2.75E+08	0.00E+00	4.25E+11	4.72E+10
15	122.4	3.23E+11	2.75E+08	0.00E+00	2.91E+11	3.23E+10
20	86.0	2.27E+11	2.75E+08	0.00E+00	2.04E+11	2.27E+10
25	63.3	1.67E+11	2.75E+08	0.00E+00	1.50E+11	1.67E+10
30	46.4	1.23E+11	2.75E+08	0.00E+00	1.10E+11	1.23E+10
35	33.3	8.81E+10	2.75E+08	0.00E+00	7.90E+10	8.81E+09
40	24.5	6.47E+10	2.75E+08	0.00E+00	5.79E+10	6.47E+09
45	19.3	5.09E+10	2.75E+08	0.00E+00	4.55E+10	5.09E+09
50	15.4	4.08E+10	2.75E+08	0.00E+00	3.64E+10	4.08E+09
55	12.3	3.26E+10	2.75E+08	0.00E+00	2.91E+10	3.26E+09
60	10.1	2.68E+10	2.75E+08	0.00E+00	2.38E+10	2.68E+09
65	8.8	2.33E+10	2.75E+08	0.00E+00	2.07E+10	2.33E+09
70	7.3	1.92E+10	2.75E+08	0.00E+00	1.70E+10	1.92E+09
75	6.2	1.63E+10	2.75E+08	0.00E+00	1.44E+10	1.63E+09
80	5.51	1.46E+10	2.75E+08	0.00E+00	1.28E+10	1.46E+09
85	4.85	1.28E+10	2.75E+08	0.00E+00	1.13E+10	1.28E+09
90	3.97	1.05E+10	2.75E+08	0.00E+00	9.16E+09	1.05E+09
95	3.09	8.16E+09	2.75E+08	0.00E+00	7.06E+09	8.16E+08
100	0.26	6.99E+08	2.75E+08	0.00E+00	3.54E+08	6.99E+07

Table 5-6 Enterococci TMDL Calculations for Camp Creek (OK520700030220_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	2,308.9	6.10E+12	0.00E+00	0.00E+00	5.49E+12	6.10E+11
5	35.0	9.25E+10	0.00E+00	0.00E+00	8.32E+10	9.25E+09
10	11.2	2.95E+10	0.00E+00	0.00E+00	2.65E+10	2.95E+09
15	6.2	1.64E+10	0.00E+00	0.00E+00	1.47E+10	1.64E+09
20	4.1	1.09E+10	0.00E+00	0.00E+00	9.82E+09	1.09E+09
25	3.1	8.29E+09	0.00E+00	0.00E+00	7.46E+09	8.29E+08
30	2.4	6.33E+09	0.00E+00	0.00E+00	5.70E+09	6.33E+08
35	1.9	4.91E+09	0.00E+00	0.00E+00	4.42E+09	4.91E+08
40	1.4	3.82E+09	0.00E+00	0.00E+00	3.44E+09	3.82E+08
45	1.2	3.06E+09	0.00E+00	0.00E+00	2.75E+09	3.06E+08
50	0.9	2.29E+09	0.00E+00	0.00E+00	2.06E+09	2.29E+08
55	0.7	1.75E+09	0.00E+00	0.00E+00	1.57E+09	1.75E+08
60	0.5	1.20E+09	0.00E+00	0.00E+00	1.08E+09	1.20E+08
65	0.3	7.20E+08	0.00E+00	0.00E+00	6.48E+08	7.20E+07
70	0.1	3.82E+08	0.00E+00	0.00E+00	3.44E+08	3.82E+07
75	0.0	1.09E+08	0.00E+00	0.00E+00	9.82E+07	1.09E+07
80	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
85	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
90	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
95	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
100	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 5-7 Enterococci TMDL Calculations for Deep Fork of the Canadian River (OK520700040010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	14,286.4	3.77E+13	6.25E+08	0.00E+00	3.40E+13	3.77E+12
5	2,408.0	6.36E+12	6.25E+08	0.00E+00	5.72E+12	6.36E+11
10	1,354.9	3.58E+12	6.25E+08	0.00E+00	3.22E+12	3.58E+11
15	894.1	2.36E+12	6.25E+08	0.00E+00	2.13E+12	2.36E+11
20	585.3	1.55E+12	6.25E+08	0.00E+00	1.39E+12	1.55E+11
25	384.6	1.02E+12	6.25E+08	0.00E+00	9.14E+11	1.02E+11
30	269.1	7.11E+11	6.25E+08	0.00E+00	6.39E+11	7.11E+10
35	205.1	5.42E+11	6.25E+08	0.00E+00	4.87E+11	5.42E+10
40	156.2	4.13E+11	6.25E+08	0.00E+00	3.71E+11	4.13E+10
45	118.9	3.14E+11	6.25E+08	0.00E+00	2.82E+11	3.14E+10
50	93.1	2.46E+11	6.25E+08	0.00E+00	2.21E+11	2.46E+10
55	72.8	1.92E+11	6.25E+08	0.00E+00	1.73E+11	1.92E+10
60	57.1	1.51E+11	6.25E+08	0.00E+00	1.35E+11	1.51E+10
65	45.6	1.21E+11	6.25E+08	0.00E+00	1.08E+11	1.21E+10
70	35.9	9.50E+10	6.25E+08	0.00E+00	8.48E+10	9.50E+09
75	26.7	7.06E+10	6.25E+08	0.00E+00	6.29E+10	7.06E+09
80	20.74	5.48E+10	6.25E+08	0.00E+00	4.87E+10	5.48E+09
85	15.21	4.02E+10	6.25E+08	0.00E+00	3.55E+10	4.02E+09
90	11.06	2.92E+10	6.25E+08	0.00E+00	2.57E+10	2.92E+09
95	5.99	1.58E+10	6.25E+08	0.00E+00	1.36E+10	1.58E+09
100	0.55	1.46E+09	6.25E+08	0.00E+00	6.90E+08	1.46E+08

Table 5-8 Fecal Coliform TMDL Calculations for Deep Fork of the Canadian River (OK520700040010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	14,286.4	1.40E+14	3.79E+09	0.00E+00	1.26E+14	1.40E+13
5	2,408.0	2.36E+13	3.79E+09	0.00E+00	2.12E+13	2.36E+12
10	1,354.9	1.33E+13	3.79E+09	0.00E+00	1.19E+13	1.33E+12
15	894.1	8.75E+12	3.79E+09	0.00E+00	7.87E+12	8.75E+11
20	585.3	5.73E+12	3.79E+09	0.00E+00	5.15E+12	5.73E+11
25	384.6	3.76E+12	3.79E+09	0.00E+00	3.38E+12	3.76E+11
30	269.1	2.63E+12	3.79E+09	0.00E+00	2.37E+12	2.63E+11
35	205.1	2.01E+12	3.79E+09	0.00E+00	1.80E+12	2.01E+11
40	156.2	1.53E+12	3.79E+09	0.00E+00	1.37E+12	1.53E+11
45	118.9	1.16E+12	3.79E+09	0.00E+00	1.04E+12	1.16E+11
50	93.1	9.11E+11	3.79E+09	0.00E+00	8.16E+11	9.11E+10
55	72.8	7.12E+11	3.79E+09	0.00E+00	6.37E+11	7.12E+10
60	57.1	5.59E+11	3.79E+09	0.00E+00	4.99E+11	5.59E+10
65	45.6	4.46E+11	3.79E+09	0.00E+00	3.98E+11	4.46E+10
70	35.9	3.52E+11	3.79E+09	0.00E+00	3.13E+11	3.52E+10
75	26.73	2.62E+11	3.79E+09	0.00E+00	2.32E+11	2.62E+10
80	20.74	2.03E+11	3.79E+09	0.00E+00	1.79E+11	2.03E+10
85	15.21	1.49E+11	3.79E+09	0.00E+00	1.30E+11	1.49E+10
90	11.06	1.08E+11	3.79E+09	0.00E+00	9.36E+10	1.08E+10
95	5.99	5.86E+10	3.79E+09	0.00E+00	4.90E+10	5.86E+09
100	0.55	5.41E+09	3.79E+09	0.00E+00	1.08E+09	5.41E+08

Table 5-9 Enterococci TMDL Calculations for Dry Creek (OK520700040020_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	6,892.9	1.82E+13	0.00E+00	0.00E+00	1.64E+13	1.82E+12
5	547.8	1.45E+12	0.00E+00	0.00E+00	1.30E+12	1.45E+11
10	294.1	7.77E+11	0.00E+00	0.00E+00	6.99E+11	7.77E+10
15	201.3	5.32E+11	0.00E+00	0.00E+00	4.79E+11	5.32E+10
20	141.5	3.74E+11	0.00E+00	0.00E+00	3.36E+11	3.74E+10
25	104.1	2.75E+11	0.00E+00	0.00E+00	2.48E+11	2.75E+10
30	76.4	2.02E+11	0.00E+00	0.00E+00	1.82E+11	2.02E+10
35	54.9	1.45E+11	0.00E+00	0.00E+00	1.30E+11	1.45E+10
40	40.3	1.06E+11	0.00E+00	0.00E+00	9.58E+10	1.06E+10
45	31.7	8.38E+10	0.00E+00	0.00E+00	7.54E+10	8.38E+09
50	25.4	6.71E+10	0.00E+00	0.00E+00	6.04E+10	6.71E+09
55	20.3	5.37E+10	0.00E+00	0.00E+00	4.83E+10	5.37E+09
60	16.7	4.41E+10	0.00E+00	0.00E+00	3.97E+10	4.41E+09
65	14.5	3.83E+10	0.00E+00	0.00E+00	3.45E+10	3.83E+09
70	12.0	3.16E+10	0.00E+00	0.00E+00	2.85E+10	3.16E+09
75	10.2	2.68E+10	0.00E+00	0.00E+00	2.42E+10	2.68E+09
80	9.07	2.40E+10	0.00E+00	0.00E+00	2.16E+10	2.40E+09
85	7.98	2.11E+10	0.00E+00	0.00E+00	1.90E+10	2.11E+09
90	6.53	1.73E+10	0.00E+00	0.00E+00	1.55E+10	1.73E+09
95	5.08	1.34E+10	0.00E+00	0.00E+00	1.21E+10	1.34E+09
100	0.44	1.15E+09	0.00E+00	0.00E+00	1.04E+09	1.15E+08

Table 5-10 E. coli TMDL Calculations for Dry Creek (OK520700040020_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	6,892.9	6.85E+13	0.00E+00	0.00E+00	6.16E+13	6.85E+12
5	547.8	5.44E+12	0.00E+00	0.00E+00	4.90E+12	5.44E+11
10	294.1	2.92E+12	0.00E+00	0.00E+00	2.63E+12	2.92E+11
15	201.3	2.00E+12	0.00E+00	0.00E+00	1.80E+12	2.00E+11
20	141.5	1.41E+12	0.00E+00	0.00E+00	1.26E+12	1.41E+11
25	104.1	1.03E+12	0.00E+00	0.00E+00	9.31E+11	1.03E+11
30	76.4	7.59E+11	0.00E+00	0.00E+00	6.83E+11	7.59E+10
35	54.9	5.45E+11	0.00E+00	0.00E+00	4.90E+11	5.45E+10
40	40.3	4.00E+11	0.00E+00	0.00E+00	3.60E+11	4.00E+10
45	31.7	3.15E+11	0.00E+00	0.00E+00	2.83E+11	3.15E+10
50	25.4	2.52E+11	0.00E+00	0.00E+00	2.27E+11	2.52E+10
55	20.3	2.02E+11	0.00E+00	0.00E+00	1.82E+11	2.02E+10
60	16.7	1.66E+11	0.00E+00	0.00E+00	1.49E+11	1.66E+10
65	14.5	1.44E+11	0.00E+00	0.00E+00	1.30E+11	1.44E+10
70	12.0	1.19E+11	0.00E+00	0.00E+00	1.07E+11	1.19E+10
75	10.2	1.01E+11	0.00E+00	0.00E+00	9.08E+10	1.01E+10
80	9.07	9.01E+10	0.00E+00	0.00E+00	8.11E+10	9.01E+09
85	7.98	7.93E+10	0.00E+00	0.00E+00	7.13E+10	7.93E+09
90	6.53	6.49E+10	0.00E+00	0.00E+00	5.84E+10	6.49E+09
95	5.08	5.04E+10	0.00E+00	0.00E+00	4.54E+10	5.04E+09
100	0.44	4.32E+09	0.00E+00	0.00E+00	3.89E+09	4.32E+08

Table 5-11 Enterococci TMDL Calculations for Quapaw Creek (OK520700040260_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	5,392.9	1.42E+13	2.50E+08	0.00E+00	1.28E+13	1.42E+12
5	428.6	1.13E+12	2.50E+08	0.00E+00	1.02E+12	1.13E+11
10	230.1	6.08E+11	2.50E+08	0.00E+00	5.47E+11	6.08E+10
15	157.5	4.16E+11	2.50E+08	0.00E+00	3.74E+11	4.16E+10
20	110.7	2.92E+11	2.50E+08	0.00E+00	2.63E+11	2.92E+10
25	81.5	2.15E+11	2.50E+08	0.00E+00	1.93E+11	2.15E+10
30	59.8	1.58E+11	2.50E+08	0.00E+00	1.42E+11	1.58E+10
35	42.9	1.13E+11	2.50E+08	0.00E+00	1.02E+11	1.13E+10
40	31.5	8.32E+10	2.50E+08	0.00E+00	7.47E+10	8.32E+09
45	24.8	6.55E+10	2.50E+08	0.00E+00	5.87E+10	6.55E+09
50	19.9	5.25E+10	2.50E+08	0.00E+00	4.70E+10	5.25E+09
55	15.9	4.20E+10	2.50E+08	0.00E+00	3.75E+10	4.20E+09
60	13.1	3.45E+10	2.50E+08	0.00E+00	3.08E+10	3.45E+09
65	11.4	3.00E+10	2.50E+08	0.00E+00	2.67E+10	3.00E+09
70	9.4	2.47E+10	2.50E+08	0.00E+00	2.20E+10	2.47E+09
75	7.9	2.10E+10	2.50E+08	0.00E+00	1.86E+10	2.10E+09
80	7.10	1.87E+10	2.50E+08	0.00E+00	1.66E+10	1.87E+09
85	6.24	1.65E+10	2.50E+08	0.00E+00	1.46E+10	1.65E+09
90	5.11	1.35E+10	2.50E+08	0.00E+00	1.19E+10	1.35E+09
95	3.97	1.05E+10	2.50E+08	0.00E+00	9.20E+09	1.05E+09
100	0.34	9.00E+08	2.50E+08	0.00E+00	5.60E+08	9.00E+07

Table 5-12 Enterococci TMDL Calculations for Bellcow Creek (OK520700050020_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA $_{MS4}$ (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	1,875.0	4.95E+12	9.99E+08	0.00E+00	4.46E+12	4.95E+11
5	149.0	3.94E+11	9.99E+08	0.00E+00	3.53E+11	3.94E+10
10	80.0	2.11E+11	9.99E+08	0.00E+00	1.89E+11	2.11E+10
15	54.8	1.45E+11	9.99E+08	0.00E+00	1.29E+11	1.45E+10
20	38.5	1.02E+11	9.99E+08	0.00E+00	9.05E+10	1.02E+10
25	28.3	7.48E+10	9.99E+08	0.00E+00	6.63E+10	7.48E+09
30	20.8	5.49E+10	9.99E+08	0.00E+00	4.84E+10	5.49E+09
35	14.9	3.94E+10	9.99E+08	0.00E+00	3.45E+10	3.94E+09
40	11.0	2.89E+10	9.99E+08	0.00E+00	2.50E+10	2.89E+09
45	8.6	2.28E+10	9.99E+08	0.00E+00	1.95E+10	2.28E+09
50	6.9	1.83E+10	9.99E+08	0.00E+00	1.54E+10	1.83E+09
55	5.5	1.46E+10	9.99E+08	0.00E+00	1.21E+10	1.46E+09
60	4.5	1.20E+10	9.99E+08	0.00E+00	9.79E+09	1.20E+09
65	3.9	1.04E+10	9.99E+08	0.00E+00	8.39E+09	1.04E+09
70	3.3	8.60E+09	9.99E+08	0.00E+00	6.74E+09	8.60E+08
75	2.8	7.30E+09	9.99E+08	0.00E+00	5.57E+09	7.30E+08
80	2.47	6.52E+09	9.99E+08	0.00E+00	4.87E+09	6.52E+08
85	2.17	5.74E+09	9.99E+08	0.00E+00	4.16E+09	5.74E+08
90	1.78	4.69E+09	9.99E+08	0.00E+00	3.22E+09	4.69E+08
95	1.38	3.65E+09	9.99E+08	0.00E+00	2.29E+09	3.65E+08
100	0.12	3.13E+08	9.99E+08	0.00E+00	-7.18E+08	3.13E+07

Table 5-13 Fecal Coliform TMDL Calculations for Captain Creek (OK520700050140_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	5,217.3	5.11E+13	0.00E+00	0.00E+00	4.59E+13	5.11E+12
5	79.5	7.78E+11	0.00E+00	0.00E+00	7.00E+11	7.78E+10
10	25.2	2.47E+11	0.00E+00	0.00E+00	2.22E+11	2.47E+10
15	14.0	1.37E+11	0.00E+00	0.00E+00	1.23E+11	1.37E+10
20	9.3	9.13E+10	0.00E+00	0.00E+00	8.22E+10	9.13E+09
25	7.1	6.94E+10	0.00E+00	0.00E+00	6.25E+10	6.94E+09
30	5.4	5.30E+10	0.00E+00	0.00E+00	4.77E+10	5.30E+09
35	4.2	4.11E+10	0.00E+00	0.00E+00	3.70E+10	4.11E+09
40	3.3	3.20E+10	0.00E+00	0.00E+00	2.88E+10	3.20E+09
45	2.6	2.56E+10	0.00E+00	0.00E+00	2.30E+10	2.56E+09
50	2.0	1.92E+10	0.00E+00	0.00E+00	1.73E+10	1.92E+09
55	1.5	1.46E+10	0.00E+00	0.00E+00	1.32E+10	1.46E+09
60	1.0	1.00E+10	0.00E+00	0.00E+00	9.04E+09	1.00E+09
65	0.6	6.12E+09	0.00E+00	0.00E+00	5.51E+09	6.12E+08
70	0.3	3.20E+09	0.00E+00	0.00E+00	2.88E+09	3.20E+08
75	0.09	9.13E+08	0.00E+00	0.00E+00	8.22E+08	9.13E+07
80	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
85	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
90	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
95	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
100	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 5-14 Total Suspended Solids TMDL Calculations for Deep Fork of the Canadian River (OK520700040010_00)

Flow Exceedance Frequency	Flow (cfs)	TMDL (lbs/day)	WWTP (lbs/day)	MS4 (lbs/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	15,853.3	N/A	0.0	0.0	N/A	N/A	N/A
5	2,257.9	N/A	0.0	0.0	N/A	N/A	N/A
10	1,345.7	N/A	0.0	0.0	N/A	N/A	N/A
15	871.0	N/A	0.0	0.0	N/A	N/A	N/A
20	562.2	N/A	0.0	0.0	N/A	N/A	N/A
25	381.1	332,441.5	0.0	0.0	3,324.4	295,872.9	33,244.1
30	277.8	242,276.3	0.0	0.0	2,422.8	215,625.9	24,227.6
35	214.3	186,923.0	0.0	0.0	1,869.2	166,361.4	18,692.3
40	165.4	144,312.6	0.0	0.0	1,443.1	128,438.2	14,431.3
45	128.1	111,751.8	0.0	0.0	1,117.5	99,459.1	11,175.2
50	102.3	89,240.6	0.0	0.0	892.4	79,424.2	8,924.1
55	83.0	72,357.3	0.0	0.0	723.6	64,398.0	7,235.7
60	67.7	59,091.8	0.0	0.0	590.9	52,591.7	5,909.2
65	55.3	48,238.2	0.0	0.0	482.4	42,932.0	4,823.8
70	45.6	39,796.5	0.0	0.0	398.0	35,418.9	3,979.6
75	36.4	31,756.8	0.0	0.0	317.6	28,263.6	3,175.7
80	27.7	24,119.1	0.0	0.0	241.2	21,466.0	2,411.9
85	20.3	17,687.3	0.0	0.0	176.9	15,741.7	1,768.7
90	14.7	12,863.5	0.0	0.0	128.6	11,448.5	1,286.4
95	8.8	7,637.7	0.0	0.0	76.4	6,797.6	763.8
100	0.3	281.4	0.0	0.0	2.8	250.4	28.1

Table 5-15 Total Suspended Solids TMDL Calculations for Dry Creek (OK520700040020_00)

Flow Exceedance Frequency	Flow (cfs)	TMDL (lbs/day)	WWTP (lbs/day)	MS4 (lbs/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	6,892.9	N/A	0.0	0.0	N/A	N/A	N/A
5	359.7	N/A	0.0	0.0	N/A	N/A	N/A
10	210.8	N/A	0.0	0.0	N/A	N/A	N/A
15	145.1	N/A	0.0	0.0	N/A	N/A	N/A
20	105.2	N/A	0.0	0.0	N/A	N/A	N/A
25	79.8	13,430.5	0.0	0.0	134.3	11,953.1	1,343.1
30	61.7	10,378.1	0.0	0.0	103.8	9,236.5	1,037.8
35	48.3	8,119.3	0.0	0.0	81.2	7,226.2	811.9
40	37.7	6,349.0	0.0	0.0	63.5	5,650.6	634.9
45	30.8	5,189.1	0.0	0.0	51.9	4,618.3	518.9
50	26.5	4,456.5	0.0	0.0	44.6	3,966.3	445.6
55	23.6	3,968.1	0.0	0.0	39.7	3,531.6	396.8
60	20.3	3,418.7	0.0	0.0	34.2	3,042.6	341.9
65	17.6	2,960.8	0.0	0.0	29.6	2,635.1	296.1
70	15.2	2,564.0	0.0	0.0	25.6	2,282.0	256.4
75	13.4	2,258.8	0.0	0.0	22.6	2,010.3	225.9
80	11.2	1,892.5	0.0	0.0	18.9	1,684.3	189.2
85	9.4	1,587.2	0.0	0.0	15.9	1,412.6	158.7
90	8.0	1,343.1	0.0	0.0	13.4	1,195.3	134.3
95	6.5	1,098.9	0.0	0.0	11.0	978.0	109.9
100	0.4	73.3	0.0	0.0	0.7	65.2	7.3

Table 5-16 Total Suspended Solids TMDL Calculations for Quapaw Creek (OK520700040260_00)

Flow Exceedance Frequency	Flow (cfs)	TMDL (lbs/day)	WWTP (lbs/day)	MS4 (lbs/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	5,392.9	N/A	0.0	0.0	N/A	N/A	N/A
5	281.4	N/A	0.0	0.0	N/A	N/A	N/A
10	164.9	N/A	0.0	0.0	N/A	N/A	N/A
15	113.5	N/A	0.0	0.0	N/A	N/A	N/A
20	82.3	N/A	0.0	0.0	N/A	N/A	N/A
25	62.4	8,863.1	0.0	0.0	88.6	7,001.9	1,772.6
30	48.3	6,848.8	0.0	0.0	68.5	5,410.5	1,369.8
35	37.8	5,358.2	0.0	0.0	53.6	4,232.9	1,071.6
40	29.5	4,189.8	0.0	0.0	41.9	3,310.0	838.0
45	24.1	3,424.4	0.0	0.0	34.2	2,705.3	684.9
50	20.7	2,940.9	0.0	0.0	29.4	2,323.3	588.2
55	18.4	2,618.6	0.0	0.0	26.2	2,068.7	523.7
60	15.9	2,256.1	0.0	0.0	22.6	1,782.3	451.2
65	13.8	1,953.9	0.0	0.0	19.5	1,543.6	390.8
70	11.9	1,692.0	0.0	0.0	16.9	1,336.7	338.4
75	10.5	1,490.6	0.0	0.0	14.9	1,177.6	298.1
80	8.8	1,248.9	0.0	0.0	12.5	986.6	249.8
85	7.4	1,047.5	0.0	0.0	10.5	827.5	209.5
90	6.2	886.3	0.0	0.0	8.9	700.2	177.3
95	5.1	725.2	0.0	0.0	7.3	572.9	145.0
100	0.3	48.3	0.0	0.0	0.5	38.2	9.7

Table 5-17 Total Suspended Solids TMDL Calculations for Opossum Creek (OK520700050200_00)

Flow Exceedance Frequency	Flow (cfs)	TMDL (lbs/day)	WWTP (lbs/day)	MS4 (lbs/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	2,373.7	N/A	0.0	0.0	N/A	N/A	N/A
5	30.1	N/A	0.0	0.0	N/A	N/A	N/A
10	11.5	N/A	0.0	0.0	N/A	N/A	N/A
15	7.2	N/A	0.0	0.0	N/A	N/A	N/A
20	5.1	N/A	0.0	0.0	N/A	N/A	N/A
25	3.8	823.4	0.0	0.0	8.2	732.8	82.3
30	3.0	640.4	0.0	0.0	6.4	570.0	64.0
35	2.4	512.3	0.0	0.0	5.1	456.0	51.2
40	1.9	402.5	0.0	0.0	4.0	358.3	40.3
45	1.5	320.2	0.0	0.0	3.2	285.0	32.0
50	1.2	256.2	0.0	0.0	2.6	228.0	25.6
55	0.9	192.1	0.0	0.0	1.9	171.0	19.2
60	0.6	137.2	0.0	0.0	1.4	122.1	13.7
65	0.5	100.6	0.0	0.0	1.0	89.6	10.1
70	0.3	64.0	0.0	0.0	0.6	57.0	6.4
75	0.2	36.6	0.0	0.0	0.4	32.6	3.7
80	0.0	9.1	0.0	0.0	0.1	8.1	0.9
85	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	0.0	0.0	0.0	0.0	0.0	0.0	0.0
95	0.0	0.0	0.0	0.0	0.0	0.0	0.0
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0

5.8 Reasonable Assurances

ODEQ will collaborate with a host of other state agencies and local governments working within the boundaries of state and local regulations to target available funding and technical assistance to support implementation of pollution controls and management measures. Various water quality management programs and funding sources provide reasonable assurance that the pollutant reductions as required by these TMDLs can be achieved and water quality can be restored to maintain designated uses. ODEQ's Continuing Planning Process (CPP), required by the CWA §303(e)(3) and 40 CFR 130.5, summarizes Oklahoma's commitments and programs aimed at restoring and protecting water quality throughout the State (ODEQ 2006). The CPP can be viewed from ODEQ's website at http://www.deq.state.ok.us/WQDnew/pubs.html Table 5-15 provides a partial list of the state partner agencies ODEQ will collaborate with to address point and nonpoint source reduction goals established by TMDLs.

Table 5-18 Partial List of Oklahoma Water Quality Management Agencies

Agency	Web Link
Oklahoma Conservation Commission	http://www.ok.gov/conservation/Agency_Divisions/Water_Quality_Division
Oklahoma Department of Wildlife Conservation	http://www.wildlifedepartment.com/watchabl.htm
Oklahoma Department of Agriculture, Food, and Forestry	http://www.ok.gov/~okag/aems
Oklahoma Water Resources Board	http://www.owrb.state.ok.us/quality/index.php

Nonpoint source pollution in Oklahoma is managed by the Oklahoma Conservation Commission. The Oklahoma Conservation Commission works with state partners such as ODAFF and federal partners such as the USEPA and the National Resources Conservation Service of the U.S. Department of Agriculture, to address water quality problems similar to those seen in the Study Area. The primary mechanisms used for management of nonpoint source pollution are incentive-based programs that support the installation of BMPs and public education and outreach. Other programs include regulations and permits for CAFOs. The CAFO Act, as administered by the ODAFF, provides CAFO operators the necessary tools and information to deal with the manure and wastewater animals produce so streams, lakes, ponds, and groundwater sources are not polluted.

As authorized by Section 402 of the CWA, the ODEQ has delegation of the NPDES Program in Oklahoma, except for certain jurisdictional areas related to agriculture and the oil and gas industry retained by State Department of Agriculture and Oklahoma Corporation Commission, for which the USEPA has retained permitting authority. The NPDES Program in Oklahoma is implemented via Title 252, Chapter 606 of the Oklahoma Pollution Discharge Elimination System (OPDES) Act and in accordance with the agreement between ODEQ and USEPA relating to administration and enforcement of the delegated NPDES Program.

Implementation of point source WLAs is done through permits issued under the OPDES program.

The reduction rates called for in this TMDL report are as high as 94 percent. The ODEQ recognizes that achieving such high reductions will be a challenge, especially since unregulated nonpoint sources are a major cause of both bacteria and TSS loading. The high reduction rates are not uncommon for pathogen- or TSS-impaired waters. Similar reduction rates are often found in other pathogen and TSS TMDLs around the nation. The suitability of the current criteria for pathogens and the beneficial uses of a waterbody should be reviewed. For example, the Kansas Department of Environmental Quality has proposed to exclude certain high flow conditions during which pathogen standards will not apply, although that exclusion was not approved by the USEPA. Additionally, USEPA has been conducting new epidemiology studies and may develop new recommendations for pathogen criteria in the near future.

Revisions to the current pathogen provisions of Oklahoma's WQSs should be considered. There are three basic approaches to such revisions that may apply.

- Removing the PBCR use: This revision would require documentation in a Use Attainability Analysis that the use is not an existing use and cannot be attained. It is unlikely that this approach would be successful since there is evidence that people do swim in this segment of the river, thus constituting an existing use. Existing uses cannot be removed.
- Modifying application of the existing criteria: This approach would include considerations such as an exemption under certain high flow conditions, an allowance for wildlife or "natural conditions," a sub-category of the use or other special provision for urban areas, or other special provisions for storm flows. Since large bacteria violations occur over all flow ranges, it is likely that large reductions would still be necessary. However, this approach may have merit and should be considered.
- Revising the existing numeric criteria: Oklahoma's current pathogen criteria are based on USEPA guidelines (See Implementation Guidance for Ambient Water Quality Criteria for Bacteria, May 2002 Draft; and Ambient Water Quality Criteria for Bacteria-1986, January 1986). However, those guidelines have received much criticism and USEPA studies that could result in revisions to their recommendations are ongoing. The use of the three indicators specified in Oklahoma's standards should be evaluated. The numeric criteria values should also be evaluated using a risk-based method such as that found in USEPA guidance.

Unless or until the WQSs are revised and approved by USEPA, federal rules require that the TMDLs in this report must be based on attainment of the current standards. If revisions to the pathogen standards are approved in the future, reductions specified in these TMDLs will be re-evaluated.

SECTION 6
PUBLIC PARTICIPATION

The Upper Deep Fork of the Canadian River Bacteria and Turbidity TMDL Report was sent to other related governmental agencies for peer review and then submitted to EPA to be Preliminarily Reviewed on May 20, 2011. EPA completed their review on July 18, 2011. On July 26, 2011 a public notice about the Upper Deep Fork of the Canadian River Bacterial and Turbidity TMDL Report was sent to all persons on the DEQ contact list who either have requested all notices or live in the watershed of interest. In addition, the public notice was posted on the DEQ webpage at http://www.deq.state.ok.us/wqdnew/index.htm and sent to local newspapers and/or other publications in the watershed area affected by this TMDL.

The public was given a 45-day opportunity to review the Upper Deep Fork of the Canadian River Bacterial and Turbidity TMDL Report, submit comments to DEQ, and/or request a public meeting. DEQ did not receive any public comments or requests for a public meeting by the time the public comment period ended on September 9, 2011.

SECTION 7
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APPENDIX A

AMBIENT WATER QUALITY DATA

BACTERIA DATA — 1999 - 2010

TURBIDITY AND TOTAL SUSPENDED SOLIDS DATA — 2000 TO 2010

Ambient Water Quality Bacteria Data, 1999-2010

Waterbody ID	Streams	WQM Station	Date[1]	FC[2]	EC[2]	ENT[2]
OK520700030100_00	Salt Creek	OK520700-03-0100B	5/25/2005		280	140
OK520700030100_00	Salt Creek	OK520700-03-0100B	6/3/2008		310	330
OK520700030100_00	Salt Creek	OK520700-03-0100B	6/23/2008		260	80
OK520700030100_00	Salt Creek	OK520700-03-0100B	7/8/2008		190	130
OK520700030100_00	Salt Creek	OK520700-03-0100B	8/12/2008		180	400
OK520700030100_00	Salt Creek	OK520700-03-0100B	9/16/2008		180	160
OK520700030100_00	Salt Creek	OK520700-03-0100B	6/2/2009		100	<10
OK520700030100_00	Salt Creek	OK520700-03-0100B	7/7/2009		<10	60
OK520700030100_00	Salt Creek	OK520700-03-0100B	8/11/2009		10	210
OK520700030100_00	Salt Creek	OK520700-03-0100B	5/5/2010		60	30
OK520700030220_00	Camp Creek	OK520700-03-0220G	5/24/2005		70	200
OK520700030220_00	Camp Creek	OK520700-03-0220G	6/3/2008		140	390
OK520700030220_00	Camp Creek	OK520700-03-0220G	6/23/2008		<20	20
OK520700030220_00	Camp Creek	OK520700-03-0220G	7/8/2008		240	130
OK520700030220_00	Camp Creek	OK520700-03-0220G	8/12/2008		80	1440
OK520700030220_00	Camp Creek	OK520700-03-0220G	9/16/2008		200	100
OK520700030220_00	Camp Creek	OK520700-03-0220G	6/2/2009		120	150
OK520700030220_00	Camp Creek	OK520700-03-0220G	7/7/2009		<10	60
OK520700030220_00	Camp Creek	OK520700-03-0220G	8/11/2009		10	700
OK520700030220_00	Camp Creek	OK520700-03-0220G	5/5/2010		30	430
OK520700040010_00	Canadian River, Deep Fork	520700040010-001AT	5/23/2006	110	10	10
OK520700040010_00	Canadian River, Deep Fork	520700040010-001AT	6/12/2006	20	20	960
OK520700040010_00	Canadian River, Deep Fork	520700040010-001AT	6/26/2006	50	269	243
OK520700040010_00	Canadian River, Deep Fork	520700040010-001AT	7/5/2006	430	295	31
OK520700040010_00	Canadian River, Deep Fork	520700040010-001AT	7/24/2006	10	<10	52
OK520700040010_00	Canadian River, Deep Fork	520700040010-001AT	8/7/2006	50	10	314
OK520700040010_00	Canadian River, Deep Fork	520700040010-001AT	8/21/2006	500	148	265
OK520700040010_00	Canadian River, Deep Fork	520700040010-001AT	8/22/2006	600	121	31
OK520700040010_00	Canadian River, Deep Fork	520700040010-001AT	9/5/2006	760	31	301
OK520700040010_00	Canadian River, Deep Fork	520700040010-001AT	9/18/2006	7000	1785	6131
OK520700040010_00	Canadian River, Deep Fork	520700040010-001AT	9/20/2006	1600	556	1092
OK520700040020_00	Dry Creek	OK520700-04-0020F	5/24/2005		60	140
OK520700040020_00	Dry Creek	OK520700-04-0020F	6/9/2008		5600	8500
OK520700040020_00	Dry Creek	OK520700-04-0020F	6/24/2008		140	120
OK520700040020_00	Dry Creek	OK520700-04-0020F	7/14/2008		3100	3900
OK520700040020_00	Dry Creek	OK520700-04-0020F	8/19/2008		200	720
OK520700040020_00	Dry Creek	OK520700-04-0020F	9/22/2008		140	230
OK520700040020_00	Dry Creek	OK520700-04-0020F	5/4/2009		1100	500

Waterbody ID	Streams	WQM Station	Date[1]	FC[2]	EC[2]	ENT[2]
OK520700040020_00	Dry Creek	OK520700-04-0020F	6/8/2009		40	60
OK520700040020_00	Dry Creek	OK520700-04-0020F	7/13/2009		120	<5
OK520700040020_00	Dry Creek	OK520700-04-0020F	5/10/2010		150	105
OK520700040260_00	Quapaw Creek	OK520700-04-0260C	5/24/2005		5	30
OK520700040260_00	Quapaw Creek	OK520700-04-0260C	6/3/2008		120	130
OK520700040260_00	Quapaw Creek	OK520700-04-0260C	6/24/2008		340	200
OK520700040260_00	Quapaw Creek	OK520700-04-0260C	7/8/2008		30	60
OK520700040260_00	Quapaw Creek	OK520700-04-0260C	8/12/2008		1600	1600
OK520700040260_00	Quapaw Creek	OK520700-04-0260C	9/16/2008		60	40
OK520700040260_00	Quapaw Creek	OK520700-04-0260C	6/2/2009		70	40
OK520700040260_00	Quapaw Creek	OK520700-04-0260C	7/7/2009		30	120
OK520700040260_00	Quapaw Creek	OK520700-04-0260C	8/11/2009		6300	>10000
OK520700040260_00	Quapaw Creek	OK520700-04-0260C	5/5/2010		40	80
OK520700050020_00	Bellcow Creek	520700050020-001SR	6/26/2001	50	41	300
OK520700050020_00	Bellcow Creek	520700050020-002SR	6/26/2001	145	62	120
OK520700050020_00	Bellcow Creek	520700050020-001SR	7/17/2001	660	<10	110
OK520700050020_00	Bellcow Creek	520700050020-002SR	7/17/2001	150	25	350
OK520700050020_00	Bellcow Creek	520700050020-001SR	8/14/2001	400	22	300
OK520700050020_00	Bellcow Creek	520700050020-001SR	9/5/2001	90	20	110
OK520700050020_00	Bellcow Creek	520700050020-002SR	9/5/2001	20	20	140
OK520700050020_00	Bellcow Creek	520700050020-002SR	7/24/2002	17000	1576	23000
OK520700050020_00	Bellcow Creek	520700050020-001SR	8/26/2002	200	72	400
OK520700050020_00	Bellcow Creek	520700050020-002SR	8/26/2002	300	135	144000
OK520700050020_00	Bellcow Creek	520700050020-001SR	9/25/2002	300	121	4000
OK520700050020_00	Bellcow Creek	520700050020-002SR	9/25/2002	100	209	600
OK520700050140_00	Captain Creek	OK520700-05-0140C	5/25/1999	400		
OK520700050140_00	Captain Creek	OK520700-05-0140C	6/22/1999	100		
OK520700050140_00	Captain Creek	OK520700-05-0140C	7/20/1999	200		
OK520700050140_00	Captain Creek	OK520700-05-0140C	8/23/1999	100		
OK520700050140_00	Captain Creek	OK520700-05-0140C	5/8/2000	100		
OK520700050140_00	Captain Creek	OK520700-05-0140C	6/12/2000	900		
OK520700050140_00	Captain Creek	OK520700-05-0140C	8/22/2000	510	813	
OK520700050140_00	Captain Creek	OK520700-05-0140C	9/26/2000	800	1046	1700
OK520700050200_00	Opossum Creek	OK520700-05-0200C	5/25/1999	100		
OK520700050200_00	Opossum Creek	OK520700-05-0200C	6/22/1999	400		
OK520700050200_00	Opossum Creek	OK520700-05-0200C	7/20/1999	<100		
OK520700050200_00	Opossum Creek	OK520700-05-0200C	8/23/1999	<100		
OK520700050200_00	Opossum Creek	OK520700-05-0200C	5/8/2000	<100		
OK520700050200_00	Opossum Creek	OK520700-05-0200C	6/12/2000	1200		
OK520700050200_00	Opossum Creek	OK520700-05-0200C	8/22/2000	390	85	

Waterbody ID	Streams	WQM Station	Date[1]	FC[2]	EC[2]	ENT[2]
OK520700050200_00	Opossum Creek	OK520700-05-0200C	9/26/2000	160	158	5000

FC = fecal coliform (STORET Code: 31610); EC = *E. coli* (STORET Code: 31609); ENT = enterococci (STORET Code: 31649)

[1] Samples collected during secondary contact recreation season (October 1st and April 30th) are included in Appendix A but were not used in TMDL calculations.

[2] Units = counts/100 mL

Ambient Water Quality Turbidity and TSS Data, 2000 - 2010

Station ID	Stream Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow (cfs)	Flow Condition	Data Sources
OK520700-03-0100B	Salt Creek	6/3/2008	26.6	25	21.17		OCC
OK520700-03-0100B	Salt Creek	7/2/2008	11.4		18.52		OCC
OK520700-03-0100B	Salt Creek	7/8/2008	8.22	<10	14.11		OCC
OK520700-03-0100B	Salt Creek	8/12/2008	7.6	<10	20.95		OCC
OK520700-03-0100B	Salt Creek	9/16/2008	6.67	<10	34.40		OCC
OK520700-03-0100B	Salt Creek	10/21/2008	6.1	<10	9.48		OCC
OK520700-03-0100B	Salt Creek	12/2/2008	7.99	<10	7.28		OCC
OK520700-03-0100B	Salt Creek	1/6/2009	12.7	<10	7.72		OCC
OK520700-03-0100B	Salt Creek	2/18/2009	10.9	<10	13.89		OCC
OK520700-03-0100B	Salt Creek	3/24/2009	20.2	<10	63.94	High flow	OCC
OK520700-03-0100B	Salt Creek	4/28/2009	14.3	<10	42.77		OCC
OK520700-03-0100B	Salt Creek	6/2/2009	5.08	<10	7.94		OCC
OK520700-03-0100B	Salt Creek	7/7/2009	2.89	<10	4.19		OCC
OK520700-03-0100B	Salt Creek	8/11/2009	8.79	<10	588.70	High flow	OCC
OK520700-03-0100B	Salt Creek	9/15/2009	9.92	<10	46.74		OCC
OK520700-03-0100B	Salt Creek	10/10/2009	9.59	<10	132.29	High flow	OCC
OK520700-03-0100B	Salt Creek	12/1/2009	7.86	<10	14.99		OCC
OK520700-03-0100B	Salt Creek	1/12/2010	6.32	<10	17.86		OCC
OK520700-03-0100B	Salt Creek	2/17/2010	14.2	<10	23.15		OCC
OK520700-03-0100B	Salt Creek	3/23/2010	48.6	23	46.30		OCC
OK520700-03-0100B	Salt Creek	5/5/2010	6.41	<10	18.74		OCC
OK520700-03-0220G	Camp Creek	6/3/2008	20.6	<10	7.24	High flow	OCC
OK520700-03-0220G	Camp Creek	6/26/2008	22		11.19	High flow	OCC
OK520700-03-0220G	Camp Creek	7/8/2008	4.4	<10	0.53		OCC
OK520700-03-0220G	Camp Creek	8/12/2008	8.3	30	0.31		OCC
OK520700-03-0220G	Camp Creek	9/16/2008	5.41	<10	0.21		OCC
OK520700-03-0220G	Camp Creek	10/8/2008	6.62		0.06		OCC
OK520700-03-0220G	Camp Creek	10/21/2008	5.57	<10	0.11		OCC
OK520700-03-0220G	Camp Creek	12/2/2008	7.14	<10	0.00		OCC
OK520700-03-0220G	Camp Creek	1/6/2009	7.6	<10	0.00		OCC
OK520700-03-0220G	Camp Creek	2/18/2009	8.1	<10	0.30		OCC
OK520700-03-0220G	Camp Creek	3/24/2009	11.9	<10	0.47		OCC
OK520700-03-0220G	Camp Creek	4/28/2009	9.92	<10	0.48		OCC
OK520700-03-0220G	Camp Creek	6/2/2009	9.99	<10	0.45		OCC
OK520700-03-0220G	Camp Creek	7/7/2009	3.58	<10	0.01		OCC
OK520700-03-0220G	Camp Creek	8/11/2009	9.79	<10	0.32		OCC
OK520700-03-0220G	Camp Creek	9/15/2009	5.3	<10	0.09		OCC
OK520700-03-0220G	Camp Creek	10/20/2009	8.09	<10	0.08		OCC

Station ID	Stream Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow (cfs)	Flow Condition	Data Sources
OK520700-03-0220G	Camp Creek	12/1/2009	5.66	<10	0.00		OCC
OK520700-03-0220G	Camp Creek	1/12/2010	11.2	<10	0.01		OCC
OK520700-03-0220G	Camp Creek	2/17/2010	5.71	<10	6.68	High flow	OCC
OK520700-03-0220G	Camp Creek	3/23/2010	14.9	<10	35.20	High flow	OCC
OK520700-03-0220G	Camp Creek	5/5/2010	24.7	18	0.57		OCC
520700040010-001AT	Canadian River, Deep Fork	1/23/2006	11		17.05		OWRB
520700040010-001AT	Canadian River, Deep Fork	2/28/2006	14		27.65		OWRB
520700040010-001AT	Canadian River, Deep Fork	4/3/2006	66		22.58		OWRB
520700040010-001AT	Canadian River, Deep Fork	5/8/2006	338		247.48		OWRB
520700040010-001AT	Canadian River, Deep Fork	6/12/2006	15		6.45		OWRB
520700040010-001AT	Canadian River, Deep Fork	7/17/2006	16		57.15		OWRB
520700040010-001AT	Canadian River, Deep Fork	9/20/2006	364		3.18		OWRB
520700040010-001AT	Canadian River, Deep Fork	10/18/2006	34		31.80		OWRB
520700040010-001AT	Canadian River, Deep Fork	1/30/2007	104		147.93		OWRB
520700040010-001AT	Canadian River, Deep Fork	3/13/2007	27		29.03		OWRB
520700040010-001AT	Canadian River, Deep Fork	4/11/2007	289		341.03		OWRB
520700040010-001AT	Canadian River, Deep Fork	5/8/2007	1001		2631.47	High flow	OWRB
520700040010-001AT	Canadian River, Deep Fork	7/18/2007	197		5438.06	High flow	OWRB
520700040010-001AT	Canadian River, Deep Fork	8/15/2007	11		124.89		OWRB
520700040010-001AT	Canadian River, Deep Fork	10/2/2007	0		119.36		OWRB
520700040010-001AT	Canadian River, Deep Fork	11/6/2007	4		66.36		OWRB
520700040010-001AT	Canadian River, Deep Fork	12/19/2007	44		668.24	High flow	OWRB
520700040010-001AT	Canadian River, Deep Fork	2/20/2008	196		1705.15	High flow	OWRB
520700040010-001AT	Canadian River, Deep Fork	3/18/2008	1000		1516.20	High flow	OWRB
520700040010-001AT	Canadian River, Deep Fork	4/29/2008	47		783.45	High flow	OWRB
520700040010-001AT	Canadian River, Deep Fork	5/28/2008	409		765.01	High flow	OWRB
520700040010-001AT	Canadian River, Deep Fork	9/9/2008	11		30.88		OWRB
520700040010-001AT	Canadian River, Deep Fork	10/27/2008	5		47.93		OWRB
520700040010-001AT	Canadian River, Deep Fork	1/5/2009	8		52.54		OWRB
520700040010-001AT	Canadian River, Deep Fork	3/4/2009	12		59.91		OWRB
520700040010-001AT	Canadian River, Deep Fork	4/1/2009	276		1041.53	High flow	OWRB
520700040010-001AT	Canadian River, Deep Fork	6/23/2009	8		35.49		OWRB
520700040010-001AT	Canadian River, Deep Fork	8/18/2009	66		191.25		OWRB

Station ID	Stream Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow (cfs)	Flow Condition	Data Sources
520700040010-001AT	Canadian River, Deep Fork	10/28/2009	28		312.92		OWRB
520700040010-001AT	Canadian River, Deep Fork	5/4/2010	20.3		116.60		OWRB
OK520700-04-0020F	Dry Creek	6/9/2008	769	734	696.54	High flow	OCC
OK520700-04-0020F	Dry Creek	6/27/2008	10.6		43.53		OCC
OK520700-04-0020F	Dry Creek	7/14/2008	196	201	66.39		OCC
OK520700-04-0020F	Dry Creek	8/19/2008	13.3	10	61.67		OCC
OK520700-04-0020F	Dry Creek	9/22/2008	17.1	17	14.87		OCC
OK520700-04-0020F	Dry Creek	10/27/2008	12.9	<10	12.33		OCC
OK520700-04-0020F	Dry Creek	12/8/2008	8.2	10	19.23		OCC
OK520700-04-0020F	Dry Creek	1/12/2009	5.65	<10	13.06		OCC
OK520700-04-0020F	Dry Creek	2/24/2009	6.38	<10	34.10		OCC
OK520700-04-0020F	Dry Creek	3/30/2009	132	59	95.77	High flow	OCC
OK520700-04-0020F	Dry Creek	5/4/2009	95.6	48	58.05		OCC
OK520700-04-0020F	Dry Creek	7/13/2009	116	70	7.62		OCC
OK520700-04-0020F	Dry Creek	8/17/2009	111		142.21	High flow	OCC
OK520700-04-0020F	Dry Creek	9/21/2009	23.1	<10	133.50	High flow	OCC
OK520700-04-0020F	Dry Creek	10/26/2009	23.3	<10	64.94		OCC
OK520700-04-0020F	Dry Creek	12/7/2009	3.8	<10	24.31		OCC
OK520700-04-0020F	Dry Creek	1/19/2010	12.5	<10	28.30		OCC
OK520700-04-0020F	Dry Creek	2/23/2010	160	68	175.22	High flow	OCC
OK520700-04-0020F	Dry Creek	3/29/2010	11.2	<10	43.17		OCC
OK520700-04-0020F	Dry Creek	5/10/2010	4.34	<10	30.84		OCC
OK520700-04-0260C	Quapaw Creek	6/3/2008	10.8	<10	27.25		OCC
OK520700-04-0260C	Quapaw Creek	6/5/2008	9.45		55.35		OCC
OK520700-04-0260C	Quapaw Creek	7/8/2008	6.86	<10	18.17		OCC
OK520700-04-0260C	Quapaw Creek	8/12/2008	143	73	26.96		OCC
OK520700-04-0260C	Quapaw Creek	9/16/2008	8.64	<10	44.28		OCC
OK520700-04-0260C	Quapaw Creek	10/21/2008	5.45	<10	12.20		OCC
OK520700-04-0260C	Quapaw Creek	12/2/2008	4.33	<10	9.37		OCC
OK520700-04-0260C	Quapaw Creek	1/6/2009	11.7	<10	9.93		OCC
OK520700-04-0260C	Quapaw Creek	2/18/2009	15.3	<10	17.88		OCC
OK520700-04-0260C	Quapaw Creek	3/24/2009	10.5	<10	82.31	High flow	OCC
OK520700-04-0260C	Quapaw Creek	4/28/2009	18.5	12	55.06		OCC
OK520700-04-0260C	Quapaw Creek	6/2/2009	6.33	<10	10.22		OCC
OK520700-04-0260C	Quapaw Creek	7/7/2009	4.81	<10	5.39		OCC
OK520700-04-0260C	Quapaw Creek	8/11/2009	1000	1692	757.84	High flow	OCC
OK520700-04-0260C	Quapaw Creek	9/15/2009	14.5	<10	60.17		OCC
OK520700-04-0260C	Quapaw Creek	10/20/2009	12.3	<10	61.59		OCC
OK520700-04-0260C	Quapaw Creek	12/1/2009	3.3	<10	19.30		OCC

Station ID	Stream Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow (cfs)	Flow Condition	Data Sources
OK520700-04-0260C	Quapaw Creek	1/12/2010	11.6	<10	22.99		OCC
OK520700-04-0260C	Quapaw Creek	2/17/2010	31.6	<10	29.80		OCC
OK520700-04-0260C	Quapaw Creek	3/23/2010	125	82	59.61		OCC
OK520700-04-0260C	Quapaw Creek	5/5/2010	8.43	<10	24.13		OCC
520700050020-001SR	Bellcow Creek	6/26/2001	30				OWRB
520700050020-001SR	Bellcow Creek	7/17/2001	6				OWRB
520700050020-001SR	Bellcow Creek	8/14/2001	5				OWRB
520700050020-001SR	Bellcow Creek	12/10/2001	5				OWRB
520700050020-001SR	Bellcow Creek	2/13/2002	10				OWRB
520700050020-001SR	Bellcow Creek	3/26/2002	35				OWRB
520700050020-001SR	Bellcow Creek	4/24/2002	33				OWRB
520700050020-001SR	Bellcow Creek	10/15/2002	5				OWRB
520700050020-001SR	Bellcow Creek	11/13/2002	12				OWRB
520700050020-002SR	Bellcow Creek	6/26/2001	31				OWRB
520700050020-002SR	Bellcow Creek	7/17/2001	14				OWRB
520700050020-002SR	Bellcow Creek	8/14/2001	16				OWRB
520700050020-002SR	Bellcow Creek	12/10/2001	3				OWRB
520700050020-002SR	Bellcow Creek	2/13/2002	9				OWRB
520700050020-002SR	Bellcow Creek	3/26/2002	31				OWRB
520700050020-002SR	Bellcow Creek	4/24/2002	35				OWRB
520700050020-002SR	Bellcow Creek	10/15/2002	6				OWRB
520700050020-002SR	Bellcow Creek	11/13/2002	12				OWRB
OK520700-05-0140C	Captain Creek	1/18/2000	10.1				OCC
OK520700-05-0140C	Captain Creek	2/22/2000	15.1				OCC
OK520700-05-0140C	Captain Creek	3/27/2000	48.5				OCC
OK520700-05-0140C	Captain Creek	5/8/2000	28.8				OCC
OK520700-05-0140C	Captain Creek	6/12/2000	19.9				OCC
OK520700-05-0140C	Captain Creek	7/18/2000	20.3				OCC
OK520700-05-0140C	Captain Creek	8/22/2000	17.2				OCC
OK520700-05-0140C	Captain Creek	9/26/2000	78.8				OCC
OK520700-05-0140C	Captain Creek	10/31/2000	46.2				OCC
OK520700-05-0140C	Captain Creek	12/4/2000	11.2				OCC
OK520700-05-0140C	Captain Creek	1/17/2001	16.7				OCC
OK520700-05-0140C	Captain Creek	2/21/2001	10.4				OCC
OK520700-05-0140C	Captain Creek	3/27/2001	8.75				OCC

Station ID	Stream Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow (cfs)	Flow Condition	Data Sources
OK520700-05-0200C	Opossum Creek	1/18/2000	27.4	30.5	1.21		OCC
OK520700-05-0200C	Opossum Creek	2/22/2000	38.9	54	0.95		OCC
OK520700-05-0200C	Opossum Creek	3/27/2000	66.4	73	2.30		OCC
OK520700-05-0200C	Opossum Creek	5/8/2000	47.8	13	2.62		OCC
OK520700-05-0200C	Opossum Creek	6/12/2000	184	150	1.16		OCC
OK520700-05-0200C	Opossum Creek	7/18/2000	30.2	18	0.67		OCC
OK520700-05-0200C	Opossum Creek	8/22/2000	20.6	22	0.18		OCC
OK520700-05-0200C	Opossum Creek	9/26/2000	24.6		0.20		OCC
OK520700-05-0200C	Opossum Creek	10/31/2000	57.8	32	2.64		OCC
OK520700-05-0200C	Opossum Creek	12/4/2000	14.7	20	2.26		OCC

APPENDIX B
NPDES PERMIT DISCHARGE MONITORING REPORT DATA AND SANITARY SEWER OVERFLOW DATA

NPDES Permit Discharge Monitoring Report Data 1997-2007

NPDES	Report Date	Parameter	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter	Monthly Average Conc. (cfu/100mL)	Weekly Average Conc. (cfu/100mL)	Parameter	Monthly Average Conc. (mg/L)	Weekly Average Conc. (mg/L)
Meeker (2001 - 2011):										
OK0026883	5/31/2001	Flow	0.17	0.246	FC	146	290	TSS	12	16
OK0026883	6/30/2001	Flow	0.176	0.224	FC	80	84	TSS	4	5
OK0026883	7/31/2001	Flow	0.173	0.224	FC	686	1350	TSS	8	10
OK0026883	8/31/2001	Flow	0.152	0.178	FC	2	3	TSS	1	2
OK0026883	9/30/2001	Flow	0.13	0.19	FC	5875	7700	TSS	3	5
OK0026883	10/31/2001	Flow	0.139	0.184	FC			TSS	47	61
OK0026883	11/30/2001	Flow	0.172	0.184	FC			TSS	8	10
OK0026883	12/31/2001	Flow	0.167	0.196	FC			TSS	16	19
OK0026883	1/31/2002	Flow	NODI=E	NODI=E	FC			TSS	15	18
OK0026883	2/28/2002	Flow	0.143	0.199	FC			TSS	14.25	10.62
OK0026883	3/31/2002	Flow	0.145	0.281	FC			TSS	23.5	16
OK0026883	4/30/2002	Flow	0.169	0.223	FC			TSS	18.3	29
OK0026883	5/31/2002	Flow	0.168	0.195	FC	1485	2300	TSS	11.8	16
OK0026883	6/30/2002	Flow	0.159	0.236	FC	2665	4600	TSS	16	12
OK0026883	7/31/2002	Flow	0.014	0.176	FC	2200	5200	TSS	14.5	8.5
OK0026883	8/31/2002	Flow	0.017	0.078	FC	7100	3576.5	TSS	21	13
OK0026883	9/30/2002	Flow	0.01	0.114	FC	6.7	17	TSS	540	569
OK0026883	10/31/2002	Flow	0.005	0.216	FC			TSS	48	60
OK0026883	11/30/2002	Flow	0.048	0.212	FC			TSS	15	9
OK0026883	12/31/2002	Flow	0.051	0.154	FC			TSS	20.5	17
OK0026883	1/31/2003	Flow	0.032	0.049	FC			TSS	16	8.5
OK0026883	2/28/2003	Flow	0.027	0.145	FC			TSS	31	17
OK0026883	3/31/2003	Flow	0.064	0.191	FC			TSS	40	53
OK0026883	4/30/2003	Flow	0.056	0.141	FC			TSS	23.5	20
OK0026883	5/31/2003	Flow	0.024	0.156	FC	11900	6000	TSS	13.5	8

NPDES	Report Date	Parameter	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter	Monthly Average Conc. (cfu/100mL)	Weekly Average Conc. (cfu/100mL)	Parameter	Monthly Average Conc. (mg/L)	Weekly Average Conc. (mg/L)
OK0026883	6/30/2003	Flow	0.077	0.173	FC	2884	6150	TSS	6.5	11
OK0026883	7/31/2003	Flow	0.078	0.117	FC	4255	6100	TSS	23	13
OK0026883	8/31/2003	Flow	0.065	0.102	FC	6601	6600	TSS	12	6.5
OK0026883	9/30/2003	Flow	0.099	0.121	FC	3446	4050	TSS	13.5	14
OK0026883	10/31/2003	Flow	0.099	0.127	FC			TSS	29	16
OK0026883	11/30/2003	Flow	0.084	0.128	FC			TSS	15.5	17
OK0026883	12/31/2003	Flow	0.073	0.126	FC			TSS	2.5	2.9
OK0026883	1/31/2004	Flow	0.079	0.139	FC			TSS	4.5	4.5
OK0026883	2/29/2004	Flow	0.071	0.218	FC			TSS	14.3	23
OK0026883	3/31/2004	Flow	0.053	0.13	FC			TSS	13	18
OK0026883	4/30/2004	Flow	0.062	0.099	FC			TSS	14	16
OK0026883	5/31/2004	Flow	0.058	0.091	FC	.5	1	TSS	10.5	12
OK0026883	6/30/2004	Flow	0.087	0.164	FC	8.4	20	TSS	17	16
OK0026883	7/31/2004	Flow	0.065	0.163	FC	.5	1	TSS	5.8	7
OK0026883	8/31/2004	Flow	0.069	0.113	FC	2.1	3	TSS	10	10
OK0026883	9/30/2004	Flow	0.06	0.095	FC	7.9	11.5	TSS	15.5	23
OK0026883	10/31/2004	Flow	0.056	0.133	FC			TSS	3.8	10
OK0026883	11/30/2004	Flow	0.092	0.188	FC			TSS	11.5	14
OK0026883	12/31/2004	Flow	0.073	0.158	FC			TSS	12	14
OK0026883	1/31/2005	Flow	0.081	0.287	FC			TSS	7.9	16
OK0026883	2/28/2005	Flow	0.093	0.194	FC			TSS	12	14
OK0026883	3/31/2005	Flow	0.085	0.134	FC			TSS	23	28
OK0026883	4/30/2005	Flow	0.085	0.128	FC			TSS	8.5	9.5
OK0026883	5/31/2005	Flow	0.085	0.1	FC	1.9	3	TSS	10	10
OK0026883	6/30/2005	Flow	0.095	0.138	FC	1.6	2	TSS	10.3	12
OK0026883	7/31/2005	Flow	0.081	0.148	FC	1.1	1.5	TSS	7.8	10
OK0026883	8/31/2005	Flow	0.093	0.16	FC	2.2	3	TSS	5.3	8.5
OK0026883	9/30/2005	Flow	0.091	0.156	FC	3.6	3	TSS	6.3	7.5

NPDES	Report Date	Parameter	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter	Monthly Average Conc. (cfu/100mL)	Weekly Average Conc. (cfu/100mL)	Parameter	Monthly Average Conc. (mg/L)	Weekly Average Conc. (mg/L)
OK0026883	10/31/2005	Flow	0.068	0.143	FC			TSS	6.5	8
OK0026883	11/30/2005	Flow	0.053	0.085	FC			TSS	13	14
OK0026883	12/31/2005	Flow	0.053	0.092	FC			TSS	5.5	5
OK0026883	1/31/2006	Flow	0.056	0.091	FC			TSS	3.8	4
OK0026883	2/28/2006	Flow	0.075	0.211	FC			TSS	3	4
OK0026883	3/31/2006	Flow	0.072	0.136	FC			TSS	3.5	4
OK0026883	4/30/2006	Flow	0.087	0.175	FC			TSS	2	2
OK0026883	5/31/2006	Flow	0.072	0.178	FC	.5	1	TSS	5	7
OK0026883	6/30/2006	Flow	0.064	0.115	FC	1.7	3	TSS	5.3	5.3
OK0026883	7/31/2006	Flow	0.069	0.15	FC	.9	1	TSS	9.8	11
OK0026883	8/31/2006	Flow	0.112	0.25	FC	310	3	TSS	14	14
OK0026883	9/30/2006	Flow	0.077	0.134	FC	6.6	11.5	TSS	8.5	12
OK0026883	10/31/2006	Flow	0.084	0.221	FC			TSS	10	12
OK0026883	11/30/2006	Flow	0.088	0.171	FC			TSS	6	7
OK0026883	12/31/2006	Flow	0.09	0.201	FC			TSS	15	17
OK0026883	1/31/2007	Flow	0.07	0.122	FC			TSS	39	53
OK0026883	2/28/2007	Flow	0.077	0.137	FC			TSS	28.5	30
OK0026883	3/31/2007	Flow	0.073	0.174	FC			TSS	13	15
OK0026883	4/30/2007	Flow	0.153	0.297	FC			TSS	13.5	19
OK0026883	5/31/2007	Flow	0.151	0.336	FC	1.5	2	TSS	3	3
OK0026883	6/30/2007	Flow	0.146	0.316	FC	1.5	2	TSS	15	20
OK0026883	7/31/2007	Flow	0.132	0.307	FC	2	1	TSS	6.8	7
OK0026883	8/31/2007	Flow	0.14	0.383	FC	1	1	TSS	12	15
OK0026883	9/30/2007	Flow	0.149	0.187	FC	2	1	TSS	7.3	8
OK0026883	10/31/2007	Flow	0.13	0.233	FC			TSS	14.5	15
OK0026883	11/30/2007	Flow	0.117	0.18	FC			TSS	15.3	21
OK0026883	12/31/2007	Flow	0.11	0.176	FC			TSS	17	20
OK0026883	1/31/2008	Flow	0.103	0.145	FC			TSS	20	24

NPDES	Report Date	Parameter	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter	Monthly Average Conc. (cfu/100mL)	Weekly Average Conc. (cfu/100mL)	Parameter	Monthly Average Conc. (mg/L)	Weekly Average Conc. (mg/L)
OK0026883	2/29/2008	Flow	0.118	0.249	FC			TSS	13.4	15.7
OK0026883	3/31/2008	Flow	0.129	0.277	FC			TSS	12	16
OK0026883	4/30/2008	Flow	0.137	0.29	FC			TSS	11	16
OK0026883	5/31/2008	Flow	0.107	0.24	FC	3	3	TSS	6.3	7.5
OK0026883	6/30/2008	Flow	0.177	0.346	FC	1	3	TSS	14.5	18
OK0026883	7/31/2008	Flow	NODI=C	NODI=C	FC	NODI=C	NODI=C	TSS	NODI=C	NODI=C
OK0026883	8/31/2008	Flow	0.029	0.19	FC	1	2	TSS	34	40
OK0026883	9/30/2008	Flow	0.079	0.19	FC	1	4	TSS	31	39
OK0026883	10/31/2008	Flow	0.08	0.192	FC			TSS	19.3	24
OK0026883	11/30/2008	Flow	0.088	0.15	FC			TSS	5.5	6
OK0026883	12/31/2008	Flow	0.098	0.155	FC			TSS	6.5	8
OK0026883	1/31/2009	Flow	0.08	0.167	FC			TSS	24	25
OK0026883	2/28/2009	Flow	0.083	0.145	FC			TSS	22	27
OK0026883	3/31/2009	Flow	0.106	0.162	FC			TSS	6	5.5
OK0026883	4/30/2009	Flow	0.117	0.174	FC			TSS	15.3	17.5
OK0026883	5/31/2009	Flow	0.149	0.282	FC	75	2800	TSS	20.3	32
OK0026883	6/30/2009	Flow	0.132	0.185	FC	1	1	TSS	3.8	11
OK0026883	7/31/2009	Flow	0.103	0.15	FC	4	1	TSS	9.5	11
OK0026883	8/31/2009	Flow	0.121	0.209	FC	1	2	TSS	19.2	29
OK0026883	9/30/2009	Flow	0.11	0.218	FC	1	2	TSS	7.5	10
OK0026883	10/31/2009	Flow	0.13	0.318	FC			TSS	14	15
OK0026883	11/30/2009	Flow	0.099	0.148	FC			TSS	10	11
OK0026883	12/31/2009	Flow	0.124	0.172	FC			TSS	13.3	14.5
OK0026883	1/31/2010	Flow	0.11	0.187	FC			TSS	5.8	6.5
OK0026883	2/28/2010	Flow	0.135	0.255	FC			TSS	8.5	11
OK0026883	3/31/2010	Flow	0.15	0.28	FC			TSS	15.5	17
OK0026883	4/30/2010	Flow	0.122	0.323	FC			TSS	5.3	5.5
OK0026883	5/31/2010	Flow	0.129	0.238	FC	6	3	TSS	6.5	8

NPDES	Report Date	Parameter	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter	Monthly Average Conc. (cfu/100mL)	Weekly Average Conc. (cfu/100mL)	Parameter	Monthly Average Conc. (mg/L)	Weekly Average Conc. (mg/L)
OK0026883	6/30/2010	Flow	0.108	0.302	FC	1	3.2	TSS	9.8	12
OK0026883	7/31/2010	Flow	0.122	0.233	FC	1	6.4	TSS	6	6
OK0026883	8/31/2010	Flow	0.096	0.231	FC	1	1	TSS	5	5
OK0026883	9/30/2010	Flow	0.082	0.131	FC	1	3	TSS	5	5
OK0026883	10/31/2010	Flow	0.043	0.066	FC			TSS	5.8	6.5
OK0026883	11/30/2010	Flow	0.038	0.068	FC			TSS	4	4
OK0026883	12/31/2010	Flow	0.044	0.064	FC			TSS	19.8	22
OK0026883	1/31/2011	Flow	0.056	0.076	FC			TSS	22.8	13
Chandler (2001 - 2011):										
OK0027120	8/31/2003	Flow	0.0384	0.0961	FC	0	<1	TSS	16.9	23.6
OK0027120	9/30/2003	Flow	0.348	0.812	FC	4.7	6	TSS	11.8	22.3
OK0027120	10/31/2003	Flow	0.367	0.831	FC			TSS	9.2	12
OK0027120	11/30/2003	Flow	0.233	0.33	FC			TSS	13.8	14.3
OK0027120	12/31/2003	Flow	0.223	0.355	FC			TSS	12.7	15.6
OK0027120	1/31/2004	Flow	0.267	0.625	FC			TSS	10.5	14.6
OK0027120	2/29/2004	Flow	0.275	0.428	FC			TSS	10.1	11
OK0027120	3/31/2004	Flow	0.369	0.826	FC			TSS	6.5	8.3
OK0027120	4/30/2004	Flow	0.306	0.473	FC			TSS	7.3	9
OK0027120	5/31/2004	Flow	0.242	0.402	FC	10.7	25	TSS	6.9	7
OK0027120	6/30/2004	Flow	0.29	0.585	FC	.3	1	TSS	10.4	13.6
OK0027120	7/31/2004	Flow	0.266	0.405	FC	5.7	10	TSS	4.8	5.3
OK0027120	8/31/2004	Flow	0.251	0.389	FC	6.7	15	TSS	5.4	7.3
OK0027120	9/30/2004	Flow	0.197	0.261	FC	127	280	TSS	10.8	18
OK0027120	10/31/2004	Flow	0.221	0.555	FC			TSS	8.8	11.6
OK0027120	11/30/2004	Flow	0.298	0.516	FC			TSS	5.8	8
OK0027120	12/31/2004	Flow	0.288	0.444	FC			TSS	6.8	10
OK0027120	1/31/2005	Flow	0.309	0.692	FC			TSS	9.5	13

NPDES	Report Date	Parameter	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter	Monthly Average Conc. (cfu/100mL)	Weekly Average Conc. (cfu/100mL)	Parameter	Monthly Average Conc. (mg/L)	Weekly Average Conc. (mg/L)
OK0027120	2/28/2005	Flow	0.365	0.491	FC			TSS	9.3	10
OK0027120	3/31/2005	Flow	0.296	0.431	FC			TSS	8.2	13.6
OK0027120	4/30/2005	Flow	0.239	0.348	FC			TSS	7.4	10
OK0027120	5/31/2005	Flow	0.217	0.447	FC	9.5	25.5	TSS	13.8	17.6
OK0027120	6/30/2005	Flow	0.285	0.679	FC	4.7	12	TSS	14.3	16.3
OK0027120	7/31/2005	Flow	0.283	0.573	FC	1.7	3	TSS	9.1	11
OK0027120	8/31/2005	Flow	0.24	0.374	FC	5.3	9	TSS	8.8	17
OK0027120	9/30/2005	Flow	0.255	0.368	FC	.7	1	TSS	11.7	15.3
OK0027120	10/31/2005	Flow	0.226	0.316	FC			TSS	9.5	13.3
OK0027120	11/30/2005	Flow	0.222	0.294	FC			TSS	9.5	10.6
OK0027120	12/31/2005	Flow	0.228	0.282	FC			TSS	14.5	18.6
OK0027120	1/31/2006	Flow	0.207	0.269	FC			TSS	9	10.3
OK0027120	2/28/2006	Flow	0.206	0.262	FC			TSS	11.1	11.3
OK0027120	3/31/2006	Flow	0.232	0.382	FC			TSS	11.1	14.3
OK0027120	4/30/2006	Flow	0.168	0.452	FC			TSS	9.6	13.6
OK0027120	5/31/2006	Flow	0.121	0.454	FC	100	300	TSS	13.8	17.6
OK0027120	6/30/2006	Flow	0.171	0.302	FC	30.7	83	TSS	10.2	11.6
OK0027120	7/31/2006	Flow	0.19	0.232	FC	1.7	5	TSS	10	10.6
OK0027120	8/31/2006	Flow	0.216	0.302	FC	2.7	6	TSS	4.2	5.6
OK0027120	9/30/2006	Flow	0.208	0.278	FC	.7	2	TSS	3.3	5
OK0027120	10/31/2006	Flow	0.215	0.375	FC			TSS	4.9	9.4
OK0027120	11/30/2006	Flow	0.198	0.309	FC			TSS	11.6	12.3
OK0027120	12/31/2006	Flow	0.241	0.435	FC			TSS	5.1	7.6
OK0027120	1/31/2007	Flow	0.273	0.446	FC			TSS	11.7	13.6
OK0027120	2/28/2007	Flow	0.247	0.294	FC			TSS	13.9	20.6
OK0027120	3/31/2007	Flow	0.252	0.611	FC			TSS	8.6	14.6
OK0027120	4/30/2007	Flow	0.264	0.366	FC			TSS	13.5	18.6
OK0027120	5/31/2007	Flow	0.343	0.461	FC	58	107	TSS	6.5	9

NPDES	Report Date	Parameter	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter	Monthly Average Conc. (cfu/100mL)	Weekly Average Conc. (cfu/100mL)	Parameter	Monthly Average Conc. (mg/L)	Weekly Average Conc. (mg/L)
OK0027120	6/30/2007	Flow	0.427	0.598	FC	10.3	31	TSS	8.9	17.3
OK0027120	7/31/2007	Flow	0.509	0.686	FC	13	20	TSS	11.1	14.3
OK0027120	8/31/2007	Flow	0.442	0.783	FC	112	180	TSS	12.4	14.4
OK0027120	9/30/2007	Flow	0.389	0.63	FC	12.3	19	TSS	4.6	5.3
OK0027120	10/31/2007	Flow	0.27	0.363	FC			TSS	12.5	13.6
OK0027120	11/30/2007	Flow	0.27	0.341	FC			TSS	8.8	9.6
OK0027120	12/31/2007	Flow	0.38	0.533	FC			TSS	10.3	11
OK0027120	1/31/2008	Flow	0.326	0.441	FC			TSS	8	9.3
OK0027120	2/29/2008	Flow	0.354	0.643	FC			TSS	5.6	7
OK0027120	3/31/2008	Flow	0.379	0.657	FC			TSS	22.6	45
OK0027120	4/30/2008	Flow	0.426	0.695	FC			TSS	12.8	17
OK0027120	5/31/2008	Flow	0.358	0.593	FC	33.7	84	TSS	8	10.7
OK0027120	6/30/2008	Flow	0.349	0.66	FC	1.7	4	TSS	12.1	17.3
OK0027120	7/31/2008	Flow	0.258	0.379	FC	130.7	250	TSS	17	22
OK0027120	8/31/2008	Flow	0.2361	0.311	FC	29.3	46	TSS	21	8.66
OK0027120	9/30/2008	Flow	0.228	0.305	FC	1.3	2	TSS	12.3	15.7
OK0027120	10/31/2008	Flow	0.216	0.343	FC			TSS	6	9.66
OK0027120	11/30/2008	Flow	0.229	323	FC			TSS	9.4	17
OK0027120	12/31/2008	Flow	0.2208	0.285	FC			TSS	15.3	21
OK0027120	1/31/2009	Flow	0.235	0.304	FC			TSS	16.4	25.7
OK0027120	2/28/2009	Flow	0.235	0.339	FC			TSS	9.2	12
OK0027120	3/31/2009	Flow	0.254	0.551	FC			TSS	9.3	14
OK0027120	4/30/2009	Flow	0.354	0.613	FC			TSS	10.2	12
OK0027120	5/31/2009	Flow	0.396	0.593	FC	45.3	98	TSS	6.3	8
OK0027120	6/30/2009	Flow	0.2	0.264	FC	121.7	210	TSS	10.8	14.3
OK0027120	7/31/2009	Flow	0.2709	0.577	FC	113	220	TSS	8.5	14
OK0027120	8/31/2009	Flow	0.325	0.495	FC	151	320	TSS	6.1	7
OK0027120	9/30/2009	Flow	0.278	0.52	FC	91.7	260	TSS	19.8	41

NPDES	Report Date	Parameter	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter	Monthly Average Conc. (cfu/100mL)	Weekly Average Conc. (cfu/100mL)	Parameter	Monthly Average Conc. (mg/L)	Weekly Average Conc. (mg/L)
OK0027120	10/31/2009	Flow	0.385	0.68	FC			TSS	5.8	6.3
OK0027120	11/30/2009	Flow	0.319	0.411	FC			TSS	7.6	9.66
OK0027120	12/31/2009	Flow	0.321	0.478	FC			TSS	16.1	24
OK0027120	1/31/2010	Flow	0.359	0.546	FC			TSS	21.3	37.7
OK0027120	2/28/2010	Flow	0.519	0.853	FC			TSS	10.1	14.7
OK0027120	3/31/2010	Flow	0.461	0.958	FC			TSS	11.4	17
OK0027120	4/30/2010	Flow	0.37	0.623	FC			TSS	21.1	28.3
OK0027120	5/31/2010	Flow	0.355	0.621	FC	17.5	33.5	TSS	18.7	22.6
OK0027120	6/30/2010	Flow	0.389	0.694	FC	6.7	10	TSS	24.2	29
OK0027120	7/31/2010	Flow	0.33	0.624	FC	136.3	300	TSS	21	24
OK0027120	8/31/2010	Flow	0.251	0.304	FC	170	310	TSS	14	21.3
OK0027120	9/30/2010	Flow	0.29	0.244	FC	123.3	300	TSS	22.1	34.6
OK0027120	10/31/2010	Flow	0.217	0.272	FC			TSS	10.5	14
OK0027120	11/30/2010	Flow	0.228	0.303	FC			TSS	11.8	15
OK0027120	12/31/2010	Flow	0.217	0.256	FC			TSS	25.6	38
OK0027120	1/31/2011	Flow	0.207	0.229	FC			TSS	22.7	29
Stroud South (2001 - 2009):										
OK0027359	5/31/2001	Flow	0.098	0.205	FC			TSS	27.9	34.7
OK0027359	6/30/2001	Flow	0.114	0.169	FC			TSS	38.5	57.2
OK0027359	7/31/2001	Flow	0.107	0.16	FC			TSS	29.9	41.2
OK0027359	8/31/2001	Flow	0.0087	0.016	FC			TSS	60.7	66.7
OK0027359	9/30/2001	Flow	NODI=C	NODI=C	FC			TSS	NODI=C	NODI=C
OK0027359	10/31/2001	Flow	0.056	0.077	FC			TSS	64	90.2
OK0027359	11/30/2001	Flow	0.066	0.086	FC			TSS	87	88.7
OK0027359	12/31/2001	Flow	0.054	0.076	FC			TSS	38.5	48
OK0027359	1/31/2002	Flow	0.054	0.076	FC			TSS	29.3	43.6
OK0027359	2/28/2002	Flow	0.077	0.095	FC			TSS	29.2	33.1

NPDES	Report Date	Parameter	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter	Monthly Average Conc. (cfu/100mL)	Weekly Average Conc. (cfu/100mL)	Parameter	Monthly Average Conc. (mg/L)	Weekly Average Conc. (mg/L)
OK0027359	3/31/2002	Flow	0.088	0.209	FC			TSS	37.9	45
OK0027359	4/30/2002	Flow	0.099	0.139	FC			TSS	22.8	28.9
OK0027359	5/31/2002	Flow	0.0148	0.0382	FC			TSS	50.3	50.6
OK0027359	6/30/2002	Flow	0.102	0.275	FC			TSS	65	72.7
OK0027359	7/31/2002	Flow	0.078	0.374	FC			TSS	23.4	33.6
OK0027359	8/31/2002	Flow	0.045	0.162	FC			TSS	32.2	32.5
OK0027359	9/30/2002	Flow	0.029	0.088	FC			TSS	25.1	25.8
OK0027359	10/31/2002	Flow	0.085	0.29	FC			TSS	46.7	63.3
OK0027359	11/30/2002	Flow	0.069	0.16	FC			TSS	36	41.1
OK0027359	12/31/2002	Flow	0.116	0.31	FC			TSS	23.4	31.7
OK0027359	1/31/2003	Flow	0.063	0.122	FC			TSS	36.7	55.3
OK0027359	2/28/2003	Flow	0.0785	0.14	FC			TSS	40.6	42.5
OK0027359	3/31/2003	Flow	0.1	0.265	FC			TSS	40.7	50
OK0027359	4/30/2003	Flow	0.062	0.113	FC			TSS	42.3	53.3
OK0027359	5/31/2003	Flow	0.118	0.252	FC			TSS	52.8	57.5
OK0027359	6/30/2003	Flow	0.12	0.272	FC			TSS	30.1	51.7
OK0027359	7/31/2003	Flow	0.196	0.432	FC			TSS	41.5	46.9
OK0027359	8/31/2003	Flow	0.268	0.463	FC			TSS	46.6	47.3
OK0027359	9/30/2003	Flow	0.222	0.326	FC			TSS	67.5	75
OK0027359	10/31/2003	Flow	NODI=C	NODI=C	FC			TSS	NODI=C	NODI=C
OK0027359	11/30/2003	Flow	NODI=C	NODI=C	FC			TSS	NODI=C	NODI=C
OK0027359	12/31/2003	Flow	NODI=C	NODI=C	FC			TSS	NODI=C	NODI=C
OK0027359	1/31/2004	Flow	0.086	0.193	FC			TSS	36.5	43.3
OK0027359	2/29/2004	Flow	0.072	0.153	FC			TSS	47	60
OK0027359	3/31/2004	Flow	0.12	0.423	FC			TSS	20.7	25
OK0027359	4/30/2004	Flow	0.052	0.13	FC			TSS	15	17.6
OK0027359	5/31/2004	Flow	0.034	0.099	FC			TSS	63.1	76.1
OK0027359	6/30/2004	Flow	Not	Not	FC			TSS	Not	Not Received

NPDES	Report Date	Parameter	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter	Monthly Average Conc. (cfu/100mL)	Weekly Average Conc. (cfu/100mL)	Parameter	Monthly Average Conc. (mg/L)	Weekly Average Conc. (mg/L)
			Received	Received					Received	
OK0027359	7/31/2004	Flow	0.145	0.252	FC			TSS	14.4	17.7
OK0027359	8/31/2004	Flow	0.055	0.126	FC			TSS	40.3	43.9
OK0027359	9/30/2004	Flow	0.0067	0.023	FC			TSS	41.4	45
OK0027359	10/31/2004	Flow	0.047	0.157	FC			TSS	35.9	41.7
OK0027359	11/30/2004	Flow	0.212	0.392	FC			TSS	33.9	35.5
OK0027359	12/31/2004	Flow	0.134	0.32	FC			TSS	24.9	26.9
OK0027359	1/31/2005	Flow	0.14	0.432	FC			TSS	21.8	21.9
OK0027359	2/28/2005	Flow	0.21	0.341	FC			TSS	20.9	22.8
OK0027359	3/31/2005	Flow	0.187	0.288	FC			TSS	30.6	33.9
OK0027359	4/30/2005	Flow	0.0385	0.097	FC			TSS	24.9	28.9
OK0027359	5/31/2005	Flow	0.027	0.108	FC			TSS	15.6	21.1
OK0027359	6/30/2005	Flow	0.074	0.376	FC			TSS	34.6	38.3
OK0027359	7/31/2005	Flow	0.0438	0.266	FC			TSS	40.1	44.7
OK0027359	8/31/2005	Flow	0.079	0.262	FC			TSS	30	31
OK0027359	9/30/2005	Flow	0.01	0.023	FC			TSS	44.7	55.8
OK0027359	10/31/2005	Flow	0.0177	0.041	FC			TSS	26.2	40
OK0027359	11/30/2005	Flow	0.011	0.02	FC			TSS	25.8	27.5
OK0027359	12/31/2005	Flow	0.0255	0.045	FC			TSS	30.4	36.4
OK0027359	1/31/2006	Flow	0.025	0.059	FC			TSS	36.8	40.3
OK0027359	2/28/2006	Flow	0.0248	0.049	FC			TSS	17.4	18.9
OK0027359	3/31/2006	Flow	0.043	0.142	FC			TSS	13.8	15.8
OK0027359	4/30/2006	Flow	0.015	0.058	FC			TSS	18.9	20
OK0027359	5/31/2006	Flow	0.115	0.433	FC			TSS	22.9	32.5
OK0027359	6/30/2006	Flow	0.000181	0.004	FC			TSS	38.1	40
OK0027359	7/31/2006	Flow	0.03	0.074	FC			TSS	33.5	41.1
OK0027359	8/31/2006	Flow	0.041	0.077	FC			TSS	37.8	40
OK0027359	9/30/2006	Flow	0.019	0.037	FC			TSS	23.4	26.7

NPDES	Report Date	Parameter	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter	Monthly Average Conc. (cfu/100mL)	Weekly Average Conc. (cfu/100mL)	Parameter	Monthly Average Conc. (mg/L)	Weekly Average Conc. (mg/L)
OK0027359	10/31/2006	Flow	0.028	0.099	FC			TSS	39.2	47
OK0027359	11/30/2006	Flow	0.008	0.033	FC			TSS	51	55
OK0027359	12/31/2006	Flow	0.019	0.03	FC			TSS	67	74
OK0027359	1/31/2007	Flow	0.107	0.235	FC			TSS	82.5	95
OK0027359	2/28/2007	Flow	0.055	0.109	FC			TSS	84.5	98
OK0027359	3/31/2007	Flow	0.034	0.096	FC			TSS	74.3	101
OK0027359	4/30/2007	Flow	0.077	0.189	FC			TSS	66.5	98
OK0027359	5/31/2007	Flow	0.293	0.466	FC			TSS	24.5	35.5
OK0027359	6/30/2007	Flow	0.35	0.477	FC			TSS	40.3	50.9
OK0027359	7/31/2007	Flow	0.078	0.299	FC			TSS	40.5	47.7
OK0027359	8/31/2007	Flow	0.075	0.135	FC			TSS	40.5	44
OK0027359	9/30/2007	Flow	0.088	0.135	FC			TSS	50.1	50.6
OK0027359	10/31/2007	Flow	0.074	0.107	FC			TSS	47.5	54.6
OK0027359	11/30/2007	Flow	0.075	0.099	FC			TSS	47.3	50.4
OK0027359	12/31/2007	Flow	0.089	0.109	FC			TSS	52.9	56.2
OK0027359	1/31/2008	Flow	0.083	0.117	FC			TSS	54.4	58.2
OK0027359	2/29/2008	Flow	0.203	0.255	FC			TSS	45	76
OK0027359	3/31/2008	Flow	0.114	0.149	FC			TSS	60	64.4
OK0027359	4/30/2008	Flow	0.095	0.143	FC			TSS	45.6	50.6
OK0027359	5/31/2008	Flow	0.26	0.322	FC			TSS	44.1	46.7
OK0027359	6/30/2008	Flow	0.147	0.193	FC			TSS	45.5	49
OK0027359	7/31/2008	Flow	0.027	0.085	FC			TSS	45	60
OK0027359	8/31/2008	Flow	0.094	0.275	FC			TSS	24.7	24.7
OK0027359	9/30/2008	Flow	0.085	0.132	FC			TSS	18	21
OK0027359	10/31/2008	Flow	0.035	0.099	FC			TSS	11	10.5
OK0027359	11/30/2008	Flow	0.164	0.204	FC			TSS	34	38
OK0027359	12/31/2008	Flow	0.36	0.36	FC			TSS	27	28
OK0027359	1/31/2009	Flow	0.0142	0.35	FC			TSS	15	20

NPDES	Report Date	Parameter	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter	Monthly Average Conc. (cfu/100mL)	Weekly Average Conc. (cfu/100mL)	Parameter	Monthly Average Conc. (mg/L)	Weekly Average Conc. (mg/L)
OK0027359	2/28/2009	Flow	0.032	0.35	FC			TSS	13.5	19
OK0027359	3/31/2009	Flow	0.038	0.51	FC			TSS	9	12
OK0027359	4/30/2009	Flow	0.055	0.083	FC			TSS	7.8	15.5
OK0027359	5/31/2009	Flow	0.16	0.4	FC			TSS	7	14.4
OK0027359	6/30/2009	Flow	0.012	0.48	FC			TSS	16	38.6
OK0027359	7/31/2009	Flow	0.03	0.04	FC			TSS	9.2	15
OK0027359	8/31/2009	Flow	0.033	0.049	FC			TSS	23	43
Stroud North (2001 - 2011):										
OK0027367	8/31/2001	Flow	0.222	0.275	FC	125.8	136	TSS	2.5	3.8
OK0027367	9/30/2001	Flow	0.214	0.316	FC	169.5	307	TSS	3	3.6
OK0027367	10/31/2001	Flow	0.201	0.265	FC	66.7	81	TSS	2.5	2.7
OK0027367	11/30/2001	Flow	0.199	0.27	FC	172.8	221.8	TSS	3.5	3.9
OK0027367	12/31/2001	Flow	0.194	0.297	FC	196.2	324.2	TSS	3.22	4.8
OK0027367	1/31/2002	Flow	0.1932	0.304	FC	160.2	227.1	TSS	5.01	5.6
OK0027367	2/28/2002	Flow	0.194	0.311	FC	159.5	160.5	TSS	5.6	5.7
OK0027367	3/31/2002	Flow	0.209	0.358	FC	189.7	221.3	TSS	4.1	4.2
OK0027367	4/30/2002	Flow	0.244	0.335	FC	48.2	51.8	TSS	5.9	7.1
OK0027367	5/31/2002	Flow	0.253	0.322	FC	166.4	195.2	TSS	6.4	7.7
OK0027367	6/30/2002	Flow	0.255	0.312	FC	109.3	140	TSS	2.9	4.4
OK0027367	7/31/2002	Flow	0.249	0.312	FC	149.2	176.2	TSS	6.4	8.5
OK0027367	8/31/2002	Flow	0.222	0.303	FC	195.9	281.3	TSS	4.1	4.4
OK0027367	9/30/2002	Flow	0.216	0.311	FC	142.4	216.3	TSS	1.6	4.1
OK0027367	10/31/2002	Flow	0.214	0.309	FC	94	113	TSS	3	3.3
OK0027367	11/30/2002	Flow	0.183	0.283	FC	100.8	106.1	TSS	2.5	3.5
OK0027367	12/31/2002	Flow	0.223	0.315	FC	122	134.7	TSS	2.3	2.7
OK0027367	1/31/2003	Flow	0.19	0.242	FC	118.5	124	TSS	3.6	4
OK0027367	2/28/2003	Flow	0.21	0.28	FC	80.7	81.4	TSS	8.2	8.3

NPDES	Report Date	Parameter	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter	Monthly Average Conc. (cfu/100mL)	Weekly Average Conc. (cfu/100mL)	Parameter	Monthly Average Conc. (mg/L)	Weekly Average Conc. (mg/L)
OK0027367	3/31/2003	Flow	0.224	0.3	FC	80.5	115.5	TSS	3.9	4.1
OK0027367	4/30/2003	Flow	0.238	0.288	FC	135	176.5	TSS	2.3	2.7
OK0027367	5/31/2003	Flow	0.252	0.293	FC	115.5	147.3	TSS	2.3	2.6
OK0027367	6/30/2003	Flow	0.253	0.285	FC	163.9	196.1	TSS	4.5	5.4
OK0027367	7/31/2003	Flow	0.207	0.252	FC	164.1	198.5	TSS	1.9	2
OK0027367	8/31/2003	Flow	0.194	0.313	FC	150.6	164.3	TSS	3.1	3.3
OK0027367	9/30/2003	Flow	0.216	0.284	FC	191.8	238.8	TSS	3	3.3
OK0027367	10/31/2003	Flow	0.211	0.294	FC	57.9	61.5	TSS	4.5	5
OK0027367	11/30/2003	Flow	0.192	0.276	FC	99	121.7	TSS	4.4	6.3
OK0027367	12/31/2003	Flow	0.193	0.275	FC	155.6	189.1	TSS	6.1	10.5
OK0027367	1/31/2004	Flow	0.224	0.42	FC	107	125	TSS	16.9	28.1
OK0027367	2/29/2004	Flow	0.242	0.286	FC	183	215.7	TSS	2.27	2.7
OK0027367	3/31/2004	Flow	0.236	0.286	FC	138	151.3	TSS	4	4.5
OK0027367	4/30/2004	Flow	0.214	0.331	FC	237.8	252.1	TSS	6.1	10.6
OK0027367	5/31/2004	Flow	0.206	0.269	FC	107	119.2	TSS	1.94	2.7
OK0027367	6/30/2004	Flow	0.226	0.27	FC	80.3	80.8	TSS	2.3	2.4
OK0027367	7/31/2004	Flow	0.247	0.374	FC	179.2	185.2	TSS	5.6	6.9
OK0027367	8/31/2004	Flow	0.22	0.251	FC	163.8	169.2	TSS	1.8	2.5
OK0027367	9/30/2004	Flow	0.189	0.405	FC	187	187.2	TSS	3.5	3.5
OK0027367	10/31/2004	Flow	0.196	0.261	FC	146.6	183.3	TSS	3.2	4.6
OK0027367	11/30/2004	Flow	0.247	0.28	FC	189.7	190.8	TSS	6.9	7.7
OK0027367	12/31/2004	Flow	0.23	0.275	FC	88.7	89	TSS	3.6	5
OK0027367	1/31/2005	Flow	0.247	0.369	FC	171.3	204.4	TSS	6.3	6.5
OK0027367	2/28/2005	Flow	0.268	0.337	FC	178.8	183.7	TSS	5.3	5.4
OK0027367	3/31/2005	Flow	0.239	0.258	FC	155.1	174.6	TSS	3.9	4.3
OK0027367	4/30/2005	Flow	Not Received	Not Received	FC	Not Received	Not Received	TSS	Not Received	Not Received
OK0027367	5/31/2005	Flow	0.204	0.25	FC	160.6	216.5	TSS	6.8	7.4

NPDES	Report Date	Parameter	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter	Monthly Average Conc. (cfu/100mL)	Weekly Average Conc. (cfu/100mL)	Parameter	Monthly Average Conc. (mg/L)	Weekly Average Conc. (mg/L)
OK0027367	6/30/2005	Flow	0.219	0.259	FC	171	183	TSS	4.4	5.6
OK0027367	7/31/2005	Flow	0.224	0.283	FC	173	198.1	TSS	6	6.9
OK0027367	8/31/2005	Flow	0.226	0.299	FC	168	204	TSS	5.5	6
OK0027367	9/30/2005	Flow	0.218	0.371	FC	183.7	217.4	TSS	7.2	8
OK0027367	10/31/2005	Flow	0.181	0.371	FC	170	172.2	TSS	7.7	10.2
OK0027367	11/30/2005	Flow	0.17	0.192	FC	142.8	162.9	TSS	6.9	8
OK0027367	12/31/2005	Flow	0.168	0.23	FC	211.2	247.8	TSS	4.1	5.1
OK0027367	1/31/2006	Flow	0.163	0.198	FC	155.1	198.7	TSS	3.5	4
OK0027367	2/28/2006	Flow	0.16	0.202	FC	180.7	207.7	TSS	9.7	12.8
OK0027367	3/31/2006	Flow	0.17	0.245	FC	168	205	TSS	3	3.1
OK0027367	4/30/2006	Flow	0.157	0.216	FC	189	210	TSS	5.1	5.8
OK0027367	5/31/2006	Flow	0.203	0.245	FC	214.5	428.9	TSS	4.2	4.2
OK0027367	6/30/2006	Flow	0.19	0.253	FC	199	271	TSS	4.9	5.5
OK0027367	7/31/2006	Flow	0.197	0.244	FC	191.1	218.4	TSS	7.4	9.9
OK0027367	8/31/2006	Flow	0.198	0.232	FC	183	196	TSS	6.2	7.1
OK0027367	9/30/2006	Flow	0.175	0.289	FC	Not Received	Not Received	TSS	4.3	5.4
OK0027367	10/31/2006	Flow	0.12	0.172	FC			TSS	6.6	8.7
OK0027367	11/30/2006	Flow	0.107	0.151	FC			TSS	5.9	7.5
OK0027367	12/31/2006	Flow	0.162	0.229	FC			TSS	6.4	6.7
OK0027367	1/31/2007	Flow	0.192	0.384	FC			TSS	8.4	9.5
OK0027367	2/28/2007	Flow	0.174	0.218	FC			TSS	7.9	11.3
OK0027367	3/31/2007	Flow	0.179	0.208	FC			TSS	13	15.7
OK0027367	4/30/2007	Flow	0.202	0.233	FC			TSS	16	22.7
OK0027367	5/31/2007	Flow	0.27	0.313	FC	184.5	323.6	TSS	5.2	5.9
OK0027367	6/30/2007	Flow	0.28	0.435	FC	143	255	TSS	6.5	13.3
OK0027367	7/31/2007	Flow	0.223	0.347	FC	179.3	216.4	TSS	8.2	10.6
OK0027367	8/31/2007	Flow	0.202	0.27	FC	140	152	TSS	7.4	8.3

NPDES	Report Date	Parameter	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter	Monthly Average Conc. (cfu/100mL)	Weekly Average Conc. (cfu/100mL)	Parameter	Monthly Average Conc. (mg/L)	Weekly Average Conc. (mg/L)
OK0027367	9/30/2007	Flow	0.19	0.223	FC	160	170	TSS	8.6	8.9
OK0027367	10/31/2007	Flow	0.179	0.217	FC			TSS	10.2	12.6
OK0027367	11/30/2007	Flow	0.14	0.177	FC			TSS	9.8	10.6
OK0027367	12/31/2007	Flow	0.122	0.159	FC			TSS	11.6	12.8
OK0027367	1/31/2008	Flow	0.15	0.203	FC			TSS	19	24.4
OK0027367	2/29/2008	Flow	0.18	0.217	FC			TSS	20.8	21.6
OK0027367	3/31/2008	Flow	0.137	0.198	FC			TSS	22.2	26
OK0027367	4/30/2008	Flow	0.171	0.227	FC			TSS	17.6	26
OK0027367	5/31/2008	Flow	0.211	0.292	FC	114.6	155.5	TSS	8.8	9.4
OK0027367	6/30/2008	Flow	0.173	0.211	FC	166	280	TSS	5.9	6.5
OK0027367	7/31/2008	Flow	0.151	0.189	FC	140.2	213.6	TSS	8.4	10.9
OK0027367	8/31/2008	Flow	0.178	0.282	FC	2465.7	3200	TSS	34.3	34.3
OK0027367	9/30/2008	Flow	0.215	0.304	FC	2015	2900	TSS	8.5	12
OK0027367	10/31/2008	Flow	0.157	0.193	FC			TSS	22	20
OK0027367	11/30/2008	Flow	0.167	0.21	FC			TSS	8.5	12
OK0027367	12/31/2008	Flow	0.153	0.188	FC			TSS	17.25	24.5
OK0027367	1/31/2009	Flow	0.142	0.21	FC			TSS	11.15	13.3
OK0027367	2/28/2009	Flow	0.185	0.21	FC			TSS	7	9
OK0027367	3/31/2009	Flow	0.17	0.23	FC			TSS	19.5	39
OK0027367	4/30/2009	Flow	0.16	0.23	FC			TSS	4.4	7
OK0027367	5/31/2009	Flow	0.25	0.29	FC	112	160	TSS	2	4.2
OK0027367	6/30/2009	Flow	0.18	0.223	FC	92	112	TSS	7.4	17
OK0027367	7/31/2009	Flow	0.219	0.24	FC	86	116	TSS	4.8	8.2
OK0027367	8/31/2009	Flow	0.197	0.224	FC	3	11	TSS	11	19.5
OK0027367	9/30/2009	Flow	0.194	0.251	FC	2	2	TSS	14	19
OK0027367	10/31/2009	Flow	0.237	0.281	FC			TSS	17	22
OK0027367	11/30/2009	Flow	0.179	0.215	FC			TSS	7.4	8.8
OK0027367	12/31/2009	Flow	0.122	0.175	FC			TSS	20	16

NPDES	Report Date	Parameter	Monthly Average Flow (MGD)	Monthly Maximum Flow (MGD)	Parameter	Monthly Average Conc. (cfu/100mL)	Weekly Average Conc. (cfu/100mL)	Parameter	Monthly Average Conc. (mg/L)	Weekly Average Conc. (mg/L)
OK0027367	1/31/2010	Flow	0.18	0.27	FC			TSS	6.9	14.3
OK0027367	2/28/2010	Flow	0.199	0.29	FC			TSS	7.8	15.6
OK0027367	3/31/2010	Flow	0.2	0.24	FC			TSS	28	20.2
OK0027367	4/30/2010	Flow	0.191	0.255	FC			TSS	4	9.8
OK0027367	5/31/2010	Flow	0.203	0.261	FC	116	138	TSS	8	9.6
OK0027367	6/30/2010	Flow	0.31	0.4	FC	130	275	TSS	9.5	15.6
OK0027367	7/31/2010	Flow	0.3	0.4	FC	90	110	TSS	23	36
OK0027367	8/31/2010	Flow	0.29	0.361	FC	114	138	TSS	20.5	28
OK0027367	9/30/2010	Flow	0.213	0.27	FC	142	192	TSS	8.5	10
OK0027367	10/31/2010	Flow	0.153	0.184	FC			TSS	11.2	17.5
OK0027367	11/30/2010	Flow	0.247	0.273	FC			TSS	15.4	17
OK0027367	12/31/2010	Flow	0.178	0.224	FC			TSS	43.5	82
OK0027367	1/31/2011	Flow	0.19	0.22	FC			TSS	12.8	13
Kendrick (2001 - 2009):										
Discharges in only two occasions in this period. No violations.										

APPENDIX C

GENERAL METHOD FOR ESTIMATING FLOW FOR UNGAGED STREAMS

AND

ESTIMATED FLOW EXCEEDANCE PERCENTILES

Appendix C
General Method for Estimating Flow for Ungaged Streams

Flows duration curve will be developed using existing USGS measured flow where the data exist from a gage on the stream segment of interest, or by estimating flow for stream segments with no corresponding flow record. Flow data to support flow duration curves and load duration curves will be derived for each Oklahoma stream segment in the following priority:

i) In cases where a USGS flow gage occurs on, or within one-half mile upstream or downstream of the Oklahoma stream segment.

   a. If simultaneously collected flow data matching the water quality sample collection date are available, these flow measurements will be used.

   b. If flow measurements at the coincident gage are missing for some dates on which water quality samples were collected, the gaps in the flow record will be filled, or the record will be extended, by estimating flow based on measured streamflows at a nearby gages. All gages within 150 km radius are identified. For each of the identified gage with a minimum of 99 flow measurements on matching dates, four different regressions are calculated including linear, log linear, logarithmic and exponential regressions. The regression with the lowest root mean square error (RMSE) is chosen for each gage. The potential filling gages are ranked by RMSE from lowest to highest. The record is filled from the first gage (lowest RMSE) for those dates that exist in both records. If dates remain unfilled in the desired timespan of the timeseries, the filling process is repeated with the next gage with the next lowest RMSE and proceeds in this fashion until all missing values in the desired timespan are filled.

   c. The flow frequency for the flow duration curves will be based on measured flows only. The filled timeseries described above is used to match flows to sampling dates to calculate loads.

   d. On a stream impounded by dams to form reservoirs of sufficient size to impact stream flow, only flows measured after the date of the most recent impoundment will be used to develop the flow duration curve. This also applies to reservoirs on major tributaries to the stream.

ii) In the case no coincident flow data are available for a stream segment, but flow gage(s) are present upstream and/or downstream without a major reservoir between, flows will be estimated for the stream segment from an upstream or downstream gage using a watershed area ratio method derived by delineating subwatersheds, and relying on the NRCS runoff curve numbers and antecedent rainfall condition. Drainage subbasins will first be delineated for all impaired 303(d)-listed WQM stations, along with all USGS flow stations located in the 8-digit HUCs with impaired streams. Parsons will then identify all the USGS gage stations upstream and downstream of the subwatersheds with 303(d) listed WQM stations.

   a. Watershed delineations are performed using ESRI Arc Hydro with a 30 m resolution National Elevation Dataset digital elevation model, and National

Hydrography Dataset (NHD) streams. The area of each watershed will be calculated following watershed delineation.

b. The watershed average curve number is calculated from soil properties and land cover as described in the U.S. Department of Agriculture (USDA) Publication *TR-55: Urban Hydrology for Small Watersheds*. The soil hydrologic group is extracted from NRCS STATSGO soil data, and land use category from the 2001 National Land Cover Dataset (NLCD). Based on land use and the hydrologic soil group, SCS curve numbers are estimated at the 30-meter resolution of the NLCD grid as shown in the table below. The average curve number is then calculated from all the grid cells within the delineated watershed.

c. The average rainfall is calculated for each watershed from gridded average annual precipitation datasets for the period 1971-2000 (Spatial Climate Analysis Service, Oregon State University, http://www.ocs.oregonstate.edu/prism/, created February 20, 2004).

Runoff Curve Numbers for Various Land Use Categories

and Hydrologic Soil Groups

NLCD Land Use Category	Curve number for hydrologic soil group			
	A	B	C	D
0 in case of zero	100	100	100	100
11 Open Water	100	100	100	100
12 Perennial Ice/Snow	100	100	100	100
21 Developed, Open Space	39	61	74	80
22 Developed, Low Intensity	57	72	81	86
23 Developed, Medium Intensity	77	85	90	92
24 Developed, High Intensity	89	92	94	95
31 Barren Land (Rock/Sand/Clay)	77	86	91	94
32 Unconsolidated Shore	77	86	91	94
41 Deciduous Forest	37	48	57	63
42 Evergreen Forest	45	58	73	80
43 Mixed Forest	43	65	76	82
51 Dwarf Scrub	40	51	63	70
52 Shrub/Scrub	40	51	63	70
71 Grasslands/Herbaceous	40	51	63	70
72 Sedge/Herbaceous	40	51	63	70
73 Lichens	40	51	63	70
74 Moss	40	51	63	70
81 Pasture/Hay	35	56	70	77
82 Cultivated Crops	64	75	82	85
90-99 Wetlands	100	100	100	100

d. The method used to project flow from a gaged location to an ungaged location was adapted by combining aspects of two other flow projection methodologies developed by Furness (Furness 1959) and Wurbs (Wurbs 1999).

Furness Method

The Furness method has been employed in Kansas by both the USGS and Kansas Department of Health and Environment to estimate flow-duration curves. The method typically uses maps, graphs, and computations to identify six unique factors of flow duration for ungaged sites. These factors include:

- the mean streamflow and percentage duration of mean streamflow;
- the ratio of 1-percent-duration streamflow to mean streamflow;
- the ratio of 0.1-percent-duration streamflow to 1-percent-duration streamflow;
- the ratio of 50-percentduration streamflow to mean streamflow;
- the percentage duration of appreciable (0.10 ft /s) streamflow; and
- average slope of the flow-duration curve.

Furness defined appreciable flow as 0.10 ft/s. This value of streamflow was important because, for many years, this was the smallest non-zero streamflow value reported in most Kansas streamflow records. The average slope of the duration curve is a graphical approximation of the variability index, which is the standard deviation of the logarithms of the streamflows (Furness 1959, p. 202-204, figs. 147 and 148). On a duration curve that fits the log-normal distribution exactly, the variability index is equal to the ratio of the streamflow at the 15.87-percent-duration point to the streamflow at the 50-percent-duration point. Because duration curves usually do not exactly fit the log-normal distribution, the average-slope line is drawn through an arbitrary point, and the slope is transferred to a position approximately defined by the previously estimated points.

The method provides a means of both describing shape of the flow duration curve and scaling the magnitude of the curve to another location, basically generating a new flow duration curve with a very similar shape but different magnitude at the ungaged location.

Wurbs Modified NRCS Method

As a part of the Texas water availability modeling (WAM) system developed by Texas Natural Resources Conservation Commission, now known as the Texas Commission on Environmental Quality (TCEQ), and partner agencies, various contractors developed models of all Texas rivers. As a part of developing the model code to be used, Dr. Ralph Wurbs of Texas A&M University researched methods to distribute flows from gaged locations to ungaged locations. (Wurbs 2006) His results included the development of a modified NRCS curve-number (CN) method for distributing flows from gaged locations to ungaged locations.

This modified NRCS method is based on the following relationship between rainfall depth, P in inches, and runoff depth, Q in inches (NRCS 1985; McCuen 2005):

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad (1)$$

where:

Q = runoff depth (inches)

P = rainfall (inches)

S = potential maximum retention after runoff begins (inches)

I_a = initial abstraction (inches)

If $P < 0.2$, $Q = 0$. Initial abstraction has been found to be empirically related to S by the equation

$$I_a = 0.2*S \qquad (2)$$

Thus, the runoff curve number equation can be rewritten:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad (3)$$

S is related to the curve number (CN) by:

$$S = \frac{1000}{CN} - 10 \qquad (4)$$

P and Q in inches must be multiplied by the watershed area to obtain volumes. The potential maximum retention, S in inches, represents an upper limit on the amount of water that can be abstracted by the watershed through surface storage, infiltration, and other hydrologic abstractions. For convenience, S is expressed in terms of a curve number CN, which is a dimensionless watershed parameter ranging from 0 to 100. A CN of 100 represents a limiting condition of a perfectly impervious watershed with zero retention and thus all the rainfall becoming runoff. A CN of zero conceptually represents the other extreme with the watershed abstracting all rainfall with no runoff regardless of the rainfall amount.

First, S is calculated from the average curve number for the gaged watershed. Next, the daily historic flows at the gage are converted to depth basis (as used in equations 1 and 3) by dividing by its drainage area, then converted to inches. Equation 3 is then solved for daily precipitation depth of the gaged site, Pgaged. The daily precipitation depth for the ungaged site is then calculated as the precipitation depth of the gaged site multiplied by the ratio of the long-term average precipitation in the watersheds of the ungaged and gaged sites:

$$P_{ungaged} = P_{gaged}\left(\frac{M_{ungaged}}{M_{gaged}}\right) \tag{5}$$

where M is the mean annual precipitation of the watershed in inches. The daily precipitation depth for the ungaged watershed, along with the average curve number of the ungaged watershed, are then used to calculate the depth equivalent daily flow Q of the ungaged site. Finally, the volumetric flow rate at the ungaged site is calculated by multiplying by the area of the watershed of the ungaged site and converted to cubic feet.

In a subsequent study (Wurbs 2006), Wurbs evaluated the predictive ability of various flow distribution methods including:

- Distribution of flows in proportion to drainage area;
- Flow distribution equation with ratios for various watershed parameters;
- Modified NRCS curve-number method;
- Regression equations relating flows to watershed characteristics;
- Use of recorded data at gaging stations to develop precipitation-runoff relationships; and
- Use of watershed (precipitation-runoff) computer models such as SWAT.

As a part of the analysis, the methods were used to predict flows at one gaged station to another gage station so that fit statistics could be calculated to evaluate the efficacy of each of the methods. Based upon similar analyses performed for many gaged sites which reinforced the tests performed as part of the study, Wurbs observed that temporal variations in flows are dramatic, ranging from zero flows to major floods. Mean flows are reproduced reasonably well with the all flow distribution methods and the NRCS CN method reproduces the mean closest. Accuracy in predicting mean flows is much better than the accuracy of predicting the flow-frequency relationship. Performance in reproducing flow-frequency relationships is better than for reproducing flows for individual flows.

Wurbs concluded that the NRCS CN method, the drainage area ratio method, and drainage area – CN – mean annual precipitation depth (MP) ratio methods all yield similar levels of accuracy. If the CN and MP are the same for the gaged and ungaged watersheds, the three alternative methods yield identical results. Drainage area is the most important watershed parameter. However, the NRCS method adaptation is preferable in those situations in which differences in CN (land use and soil type) and long-term MP are significantly different between the gaged and ungaged watersheds. The CN and MP are usually similar but not identical.

Generalized Flow Projection Methodology

In the first several versions of the Oklahoma TMDL toolbox, all flows at ungaged sites that required projection from a gaged site were performed with the Modified NRCS CN method. This led a number of problems with flow projections in the early versions. As described previously, the NRCS method, in common with all others, reproduces the mean or central tendency best but the accuracy of the fit degrades towards the extremes of the frequency spectrum. Part of the degradation in accuracy is due to the quite non-linear nature of the NRCS equations. On the low flow end of the frequency spectrum, Equation 2 above constitutes a low flow limit below which the NRCS equations are not applicable at all. Given the flashy nature of most streams in locations for which the toolbox was developed, high and low flows are relatively more common and spurious results from the limits of the equations abounded.

In an effort to increase the flow prediction efficacy and remedy the failure of the NRCS CN method at the extremes of the flow spectrum, a hybrid of the NRCS CN method and the Furness method was developed. Noting the facts that all tested projection methods, and particularly the NRCS CN method, perform best near the central tendency or mean and that none of the methods predict the entire flow frequency spectrum well, an assumption that is implicit in the Furness method is applied. The Furness method implicitly assumes that the shape of the flow frequency curve at an upstream site is related to and similar to the shape of the flow frequency curve at a site downstream. As described previously, the Furness method employs several relationships derived between the mean flows and flows at differing frequencies to replicate the shape of the flow frequency curve at the projected site, while utilizing other regressed relationships to scale the magnitude of the curve. Since, as part of the toolbox calculations, the entire flow frequency curve at a 1% interval is calculated for every USGS gage utilizing very long periods of record, this vector in association with the mean flow was used to project the flow frequency curve.

In the ideal situation flows are projected from an ungaged location from a downstream gaged location. The toolbox also has the capability to project flows from and upstream gaged location if there is no useable downstream gage.

iii) In the rare case where no coincident flow data are available for a WQM station <u>and</u> no gages are present upstream or downstream, flows will be estimated for the WQM station from a gage on an adjacent watershed of similar size and properties, via the same procedure described above for upstream or downstream gages.

References

Furness, L.W., 1959, *Kansas Streamflow Characteristics- Part 1, Flow Duration*: Kansas Water Resources Board Technical Report No. 1.

Wurbs, R.A., and E.D. Sisson, *Evaluation of Methods for Distributing Naturalized Streamflows from Gaged Watersheds to Ungaged Subwatersheds*, Technical Report 179, Texas Water Resources Institute and Texas Natural Resource Conservation Commission, August 1999.

Wurbs, R.A . 2006. *Methods for Developing Naturalized Monthly Flows at Gaged and Ungaged Sites*. Journal of Hydrologic Engineering, January/February 2006, ASCE

Estimated Flow Exceedance Percentiles

WBID Segment	OK520700030 100_00	OK520700030 220_00	OK520700040 010_00	OK520700040 020_00	OK520700040 260_00	OK520700050 020_00	OK520700050 140_00	OK520700050 200_00
Stream Name	Salt Creek	Camp Creek	Canadian River, Deep Fork	Dry Creek	Quapaw Creek	Bellcow Creek	Captain Creek	Opossum Creek
USGS Gage Reference	07242380	07243000	07243500	07242380	07242380	07242380	07243000	07243000
Drainage Area (sq. mile)	117.8	28.5	930	193	151	52.5	64.4	29.3
NRCS Curve Number	63.9	63.3	67.3	66.1	66.7	63.0	64.2	61.4
Average Annual Rainfall (inch)	40.3	40.0	39.6	38.9	39.2	38.3	37.7	36.6
Flow Exceedance Frequency	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**
0	4,189.3	2,308.9	15,853.3	6,892.9	5,392.9	1,875.0	5,217.3	2,373.7
5	218.6	29.3	2,257.9	359.7	281.4	97.8	66.3	30.1
10	128.1	11.2	1,345.7	210.8	164.9	57.3	25.2	11.5
15	88.2	7.0	871.0	145.1	113.5	39.5	15.9	7.2
20	63.9	5.0	562.2	105.2	82.3	28.6	11.2	5.1
25	48.5	3.7	381.1	79.8	62.4	21.7	8.4	3.8
30	37.5	2.9	277.8	61.7	48.3	16.8	6.5	3.0
35	29.3	2.3	214.3	48.3	37.8	13.1	5.2	2.4
40	22.9	1.8	165.4	37.7	29.5	10.3	4.1	1.9
45	18.7	1.4	128.1	30.8	24.1	8.4	3.3	1.5
50	16.1	1.2	102.3	26.5	20.7	7.2	2.6	1.2
55	14.3	0.9	83.0	23.6	18.4	6.4	2.0	0.9
60	12.3	0.6	67.7	20.3	15.9	5.5	1.4	0.6
65	10.7	0.4	55.3	17.6	13.8	4.8	1.0	0.5
70	9.3	0.3	45.6	15.2	11.9	4.1	0.7	0.3

75	8.2	0.2	36.4	13.4	10.5	3.7	0.4	0.2
80	6.8	0.0	27.7	11.2	8.8	3.1	0.1	0.0
85	5.7	0.0	20.3	9.4	7.4	2.6	0.0	0.0
90	4.9	0.0	14.7	8.0	6.2	2.2	0.0	0.0
95	4.0	0.0	8.8	6.5	5.1	1.8	0.0	0.0
100	0.3	0.0	0.3	0.4	0.3	0.1	0.0	0.0

APPENDIX D

STATE OF OKLAHOMA ANTIDEGRADATION POLICY

Appendix D
State of Oklahoma Antidegradation Policy

785:45-3-1. Purpose; Antidegradation policy statement

(a) Waters of the state constitute a valuable resource and shall be protected, maintained and improved for the benefit of all the citizens.

(b) It is the policy of the State of Oklahoma to protect all waters of the state from degradation of water quality, as provided in OAC 785:45-3-2 and Subchapter 13 of OAC 785:46.

785:45-3-2. Applications of antidegradation policy

(a) Application to outstanding resource waters (ORW). Certain waters of the state constitute an outstanding resource or have exceptional recreational and/or ecological significance. These waters include streams designated "Scenic River" or "ORW" in Appendix A of this Chapter, and waters of the State located within watersheds of Scenic Rivers. Additionally, these may include waters located within National and State parks, forests, wilderness areas, wildlife management areas, and wildlife refuges, and waters which contain species listed pursuant to the federal Endangered Species Act as described in 785:45-5-25(c)(2)(A) and 785:46-13-6(c). No degradation of water quality shall be allowed in these waters.

(b) Application to high quality waters (HQW). It is recognized that certain waters of the state possess existing water quality which exceeds those levels necessary to support propagation of fishes, shellfishes, wildlife, and recreation in and on the water. These high quality waters shall be maintained and protected.

(c) Application to beneficial uses. No water quality degradation which will interfere with the attainment or maintenance of an existing or designated beneficial use shall be allowed.

(d) Application to improved waters. As the quality of any waters of the state improve, no degradation of such improved waters shall be allowed.

785:46-13-1. Applicability and scope

(a) The rules in this Subchapter provide a framework for implementing the antidegradation policy stated in OAC 785:45-3-2 for all waters of the state. This policy and framework includes three tiers, or levels, of protection.

(b) The three tiers of protection are as follows:

  (1) Tier 1. Attainment or maintenance of an existing or designated beneficial use.

  (2) Tier 2. Maintenance or protection of High Quality Waters and Sensitive Public and Private Water Supply waters.

  (3) Tier 3. No degradation of water quality allowed in Outstanding Resource Waters.

(c) In addition to the three tiers of protection, this Subchapter provides rules to implement the protection of waters in areas listed in Appendix B of OAC 785:45. Although Appendix B areas are not mentioned in OAC 785:45-3-2, the framework for protection of Appendix B areas is similar to the implementation framework for the antidegradation policy.

(d) In circumstances where more than one beneficial use limitation exists for a waterbody, the most protective limitation shall apply. For example, all antidegradation policy implementation rules applicable to Tier 1 waterbodies shall be applicable also to Tier 2 and Tier 3 waterbodies or areas, and implementation rules applicable to Tier 2 waterbodies shall be applicable also to Tier 3 waterbodies.

(e) Publicly owned treatment works may use design flow, mass loadings or concentration, as appropriate, to calculate compliance with the increased loading requirements of this section if those flows, loadings or concentrations were approved by the Oklahoma Department of Environmental Quality as a portion of Oklahoma's Water Quality Management Plan prior to the application of the ORW, HQW or SWS limitation.

785:46-13-2. Definitions

The following words and terms, when used in this Subchapter, shall have the following meaning, unless the context clearly indicates otherwise:

"Specified pollutants" means

(A) Oxygen demanding substances, measured as Carbonaceous Biochemical Oxygen Demand (CBOD) and/or Biochemical Oxygen Demand (BOD);

(B) Ammonia Nitrogen and/or Total Organic Nitrogen;

(C) Phosphorus;

(D) Total Suspended Solids (TSS); and

(E) Such other substances as may be determined by the Oklahoma Water Resources Board or the permitting authority.

785:46-13-3. Tier 1 protection; attainment or maintenance of an existing or designated beneficial use

(a) General.

(1) Beneficial uses which are existing or designated shall be maintained and protected.

(2) The process of issuing permits for discharges to waters of the state is one of several means employed by governmental agencies and affected persons which are designed to attain or maintain beneficial uses which have been designated for those waters. For example, Subchapters 3, 5, 7, 9 and 11 of this Chapter are rules for the permitting process. As such, the latter Subchapters not only implement numerical and narrative criteria, but also implement Tier 1 of the antidegradation policy.

(b) Thermal pollution. Thermal pollution shall be prohibited in all waters of the state. Temperatures greater than 52 degrees Centigrade shall constitute thermal pollution and shall be prohibited in all waters of the state.

(c) Prohibition against degradation of improved waters. As the quality of any waters of the state improves, no degradation of such improved waters shall be allowed.

785:46-13-4. Tier 2 protection; maintenance and protection of High Quality Waters and Sensitive Water Supplies

(a) General rules for High Quality Waters. New point source discharges of any pollutant after June 11, 1989, and increased load or concentration of any specified pollutant from any point source discharge existing as of June 11, 1989, shall be prohibited in any waterbody or watershed designated in Appendix A of OAC 785:45 with the limitation "HQW". Any discharge of any pollutant to a waterbody designated "HQW" which would, if it occurred, lower existing water quality shall be prohibited. Provided however, new point source discharges or increased load or concentration of any specified pollutant from a discharge existing as of June 11, 1989, may be approved by the permitting authority in circumstances where the discharger demonstrates to the satisfaction of the permitting authority that such new discharge or increased load or concentration would result in maintaining or improving the level of water quality which exceeds that necessary to support recreation and propagation of fishes, shellfishes, and wildlife in the receiving water.

(b) General rules for Sensitive Public and Private Water Supplies. New point source discharges of any pollutant after June 11, 1989, and increased load of any specified pollutant from any point source discharge existing as of June 11, 1989, shall be prohibited in any waterbody or watershed designated in Appendix A of OAC 785:45 with the limitation "SWS". Any discharge of any pollutant to a waterbody designated "SWS" which would, if it occurred, lower existing water quality shall be prohibited. Provided however, new point source discharges or increased load of any specified pollutant from a discharge existing as of June 11, 1989, may be approved by the permitting authority in circumstances where the discharger demonstrates to the satisfaction of the permitting authority that such new discharge or increased load will result in maintaining or improving the water quality in both the direct receiving water, if designated SWS, and any downstream waterbodies designated SWS.

(c) Stormwater discharges. Regardless of subsections (a) and (b) of this Section, point source discharges of stormwater to waterbodies and watersheds designated "HQW" and "SWS" may be approved by the permitting authority.

(d) Nonpoint source discharges or runoff. Best management practices for control of nonpoint source discharges or runoff should be implemented in watersheds of waterbodies designated "HQW" or "SWS" in Appendix A of OAC 785:45.

785:46-13-5. Tier 3 protection; prohibition against degradation of water quality in outstanding resource waters

(a) General. New point source discharges of any pollutant after June 11, 1989, and increased load of any pollutant from any point source discharge existing as of June 11, 1989, shall be prohibited in any waterbody or watershed designated in Appendix A of OAC 785:45 with the limitation "ORW" and/or "Scenic River", and in any waterbody located within the watershed of any waterbody designated with the limitation "Scenic River". Any discharge of any pollutant to a waterbody designated "ORW" or "Scenic River" which would, if it occurred, lower existing water quality shall be prohibited.

(b) Stormwater discharges. Regardless of 785:46-13-5(a), point source discharges of stormwater from temporary construction activities to waterbodies and watersheds designated "ORW" and/or "Scenic River" may be permitted by the permitting authority. Regardless of 785:46-13-5(a), discharges of stormwater to waterbodies and watersheds designated "ORW" and/or "Scenic River" from point sources existing as of June 25, 1992, whether or not such stormwater discharges were permitted as point sources prior to June 25, 1992, may be permitted by the permitting authority; provided, however, increased load of any pollutant from such stormwater discharge shall be prohibited.

(c) Nonpoint source discharges or runoff. Best management practices for control of nonpoint source discharges or runoff should be implemented in watersheds of waterbodies designated "ORW" in Appendix A of OAC 785:45, provided, however, that development of conservation plans shall be required in sub-watersheds where discharges or runoff from nonpoint sources are identified as causing or significantly contributing to degradation in a waterbody designated "ORW".

(d) LMFO's. No licensed managed feeding operation (LMFO) established after June 10, 1998 which applies for a new or expanding license from the State Department of Agriculture after March 9, 1998 shall be located...[w]ithin three (3) miles of any designated scenic river area as specified by the Scenic Rivers Act in 82 O.S. Section 1451 and following, or [w]ithin one (1) mile of a waterbody [2:9-210.3(D)] designated in Appendix A of OAC 785:45 as "ORW".

785:46-13-6. Protection for Appendix B areas

(a) General. Appendix B of OAC 785:45 identifies areas in Oklahoma with waters of recreational and/or ecological significance. These areas are divided into Table 1, which includes national and state parks, national forests, wildlife areas, wildlife management areas and wildlife refuges; and Table 2, which includes areas which contain threatened or endangered species listed as such by the federal government pursuant to the federal Endangered Species Act as amended.

(b) Protection for Table 1 areas. New discharges of pollutants after June 11, 1989, or increased loading of pollutants from discharges existing as of June 11, 1989, to waters within the boundaries of areas listed in Table 1 of Appendix B of OAC 785:45 may be approved by the permitting authority under such conditions as ensure that the recreational and ecological significance of these waters will be maintained.

(c) Protection for Table 2 areas. Discharges or other activities associated with those waters within the boundaries listed in Table 2 of Appendix B of OAC 785:45 may be restricted through agreements between appropriate regulatory agencies and the United States Fish and Wildlife Service. Discharges or other activities in such areas shall not substantially disrupt the threatened or endangered species inhabiting the receiving water.

(d) Nonpoint source discharges or runoff. Best management practices for control of nonpoint source discharges or runoff should be implemented in watersheds located within areas listed in Appendix B of OAC 785:45.