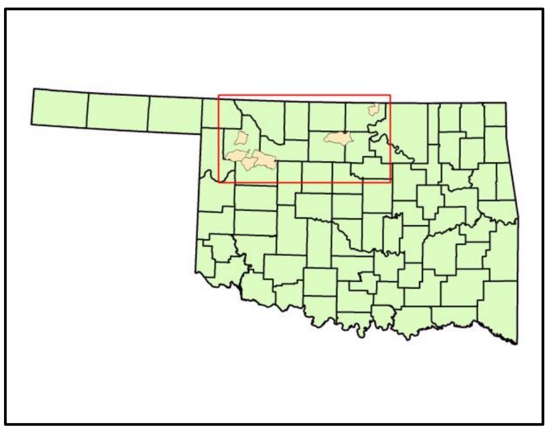
FINAL

2014 BACTERIAL AND TURBIDITY TOTAL MAXIMUM DAILY LOADS FOR OKLAHOMA STREAMS IN THE

ARKANSAS RIVER AND NORTH CANADIAN RIVER STUDY AREA
(OK621200, OK621210, OK720500)

Oklahoma Waterbody Identification Numbers

Red Rock Creek	OK621200050010_10
Arkansas River	OK621210000030_10
North Canadian River	OK720500010010_00
Bent Creek	OK720500010070_00
Beaver River	OK720500010140_10
Persimmon Creek	OK720500010150_00
Indian Creek	OK720500010200_00



Prepared by:

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

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ACRONYMS AND ABBREVIATIONS

AEMS	Agricultural Environmental Management Service
AFO	Animal Feeding Operation
AgPDES	Agriculture Pollutant Discharge Elimination System
ASAE	American Society of Agricultural Engineers
BMP	Best management practices
BOD	Biochemical Oxygen Demand
CAFO	Concentrated Animal Feeding Operation
CBOD	Carbonaceous Biochemical Oxygen Demand
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfu	colony-forming unit
CPP	Continuing Planning Process
CWA	Clean Water Act
DEQ	Oklahoma Department of Environmental Quality
DMR	Discharge monitoring report
E. coli	*Escherichia coli*
ENT	Enterococci
EPA	U.S. Environmental Protection Agency
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
MSGP	Multi-Sector General Permit
NPDES	National Pollutant Discharge Elimination System

NPS	Nonpoint source
NRCS	Natural Resources Conservation Service
NRMSE	Normalized root mean square error
NTU	Nephelometric turbidity unit
OAC	Oklahoma Administrative Code
OLS	Ordinary least square
O.S.	Oklahoma statute
ODAFF	Oklahoma Department of Agriculture, Food and Forestry
OKWBID	Oklahoma Waterbody Identification Number
OPDES	Oklahoma Pollutant Discharge Elimination System
OSWD	Onsite wastewater disposal
OWQS	Oklahoma Water Quality Standards
OWRB	Oklahoma Water Resources Board
PBCR	Primary Body Contact Recreation
PRG	Percent reduction goal
$\mathbf{r^2}$	Correlation coefficient
RMSE	Root mean square error
SH	State Highway
SSO	Sanitary sewer overflow
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
USACE	United States Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WWAC	warm water aquatic community
WLA	wasteload allocation
WQ	Water Quality
WQM	Water quality monitoring
WQMP	Water Quality Management Plan
WQS	Water quality standard
WWTF	wastewater treatment facility

EXECUTIVE SUMMARY

ES - 1 OVERVIEW

As promulgated by Section 402 of the Clean Water Act (CWA), the U.S. Environmental Protection Agency (EPA) has delegated authority to the Oklahoma Department of Environmental Quality (DEQ) to partially oversee the National Pollutant Discharge Elimination System (NPDES) Program in the State of Oklahoma. Exceptions are agriculture (retained by State Department of Agriculture, Food, and Forestry), and the oil & gas industry (retained by the Oklahoma Corporation Commission) for which EPA has retained permitting authority. The NPDES Program in Oklahoma, in accordance with an agreement between DEQ and EPA, was implemented via the Oklahoma Pollutant Discharge Elimination System (OPDES) Act [Title 252, Chapter 606 (http://www.deq.state.ok.us/rules/606.pdf)].

This total maximum daily load (TMDL) report documents the data and assessment used to establish TMDLs for the pathogen indicator bacteria [*Escherichia coli (E. coli),* Enterococci] and turbidity for selected waterbodies in the Arkansas River watershed and the North Canadian River watershed in Oklahoma. 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 TMDL calculations were conducted in accordance with requirements of Section 303(d) of the CWA, Water Quality Planning and Management Regulations (40 CFR Part 130), EPA guidance, and DEQ guidance and procedures. DEQ is required to develop TMDLs for all impaired waterbodies which are on the 303(d) list. Then the draft TMDL goes to EPA for review before submitting it for public comment. After the public comment period, the TMDL was submitted to EPA for final approval. Once EPA approves the final TMDL, then the waterbody was moved to Category 4a of the Integrated Report, where it remains until it reaches compliance with Oklahoma's water quality standards (WQS).

The purpose of this TMDL study was to establish pollutant load allocations for indicator bacteria and turbidity in impaired waterbodies, which was 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 in-stream 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 NPDES as point sources. The LA is the fraction of the total pollutant load apportioned to nonpoint sources. MOS can be implicit and/or explicit. The implicit MOS is achieved by using conservative assumptions in the TMDL calculations. An explicit 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.

ES - 2 PROBLEM IDENTIFICATION AND WATER QUALITY TARGET

This TMDL report focused on waterbodies in the Arkansas River watershed and the North Canadian River watershed, identified in **Table ES-1**, that DEQ placed in Category 5 [303(d) list] of the *Water Quality in Oklahoma, 2012 Integrated Report* for nonsupport of primary body contact recreation (PBCR) or warm water aquatic community (WWAC) subcategory of the Fish and Wildlife Propagation beneficial uses.

Elevated levels of bacteria or turbidity above the WQS necessitated the development of a TMDL. The TMDLs established in this report are a necessary step in the process to develop the pollutant loading controls needed to restore the PBCR or Fish & Wildlife Propagation beneficial uses designated for each waterbody.

Table ES-2 summarizes water quality data collected during primary contact recreation season from the water quality monitoring (WQM) stations between 2001 and 2012 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 DEQ 2012 303(d) list (DEQ 2013). It also includes the new data collected after the cutoff date for the 2012 303(d) list.

ES-2.1 Chapter 45: Criteria for Bacteria

The definitions of PBCR and the bacterial WQSs for PBCR are summarized by the following excerpt from Title 785, Chapter 45-5-16 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.*

(c). *Compliance with 785:45-5-16 shall be based upon meeting the requirements of one of the options specified in (1) or (2) of this subsection (c) for bacteria. Upon selection of one (1) group or test method, said method shall be used exclusively over the time period prescribed therefore. Provided, where concurrent data exist for multiple bacterial indicators on the same waterbody or waterbody segment, no criteria exceedances shall be allowed for any indicator group.*

(Chapter 45-5-16 continues on page ES-4)

Table ES- 1 Excerpt from the 2012 Integrated Report – Oklahoma 303(d) List of Impaired Waters (Category 5)

Waterbody ID	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	*E. coli*	Designated Use Primary Body Contact Recreation	Turbidity	Designated Use Warm Water Aquatic Life
OK621200050010_10	Red Rock Creek	46.09	2023	4	X		N		N
OK621210000030_10	Arkansas River	14.44	2023	4	X		N	X	N
OK720500010010_00	North Canadian River	37.36	2020	3	X		N		F
OK720500010070_00	Bent Creek	18.13	2023	4	X	X	N		F
OK720500010140_10	Beaver River	11.5	2023	4	X		N		F
OK720500010150_00	Persimmon Creek	13.45	2023	4	X	X	N		F
OK720500010200_00	Indian Creek	17.03	2023	4	X	X	N		F

ENT = Enterococci; N = Not attaining; X = Criterion exceeded
Source: 2012 Integrated Report, DEQ 2013

Table ES- 2 Summary of Indicator Bacterial Samples from Primary Body Contact Recreation Subcategory Season May 1 to September 30, 2001-2012

Waterbody ID	Waterbody Name	Indicator	Number of samples	Geometric Mean Concentration (cfu/100 ml)	Assessment Results
OK621200050010_10	Red Rock Creek	EC	10	622	2011 TMDL
		ENT	10	556	TMDL required
OK621210000030_10	Arkansas River	EC	7	151	Insufficient number of samples
		ENT	7	440	Insufficient number of samples, but existing samples indicated "not attained".
OK720500010010_00	North Canadian River	EC	14	43	
		ENT	14	52	TMDL required
OK720500010070_00	Bent Creek	EC	14	282	TMDL required
		ENT	10	426	TMDL required
OK720500010140_10	Beaver River	EC	14	26	
		ENT	14	57	TMDL required
OK720500010150_00	Persimmon Creek	EC	15	302	TMDL required
		ENT	11	511	TMDL required
OK720500010200_00	Indian Creek	EC	10	220	TMDL required
		ENT	10	202	TMDL required

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
TMDLs were developed for waterbodies highlighted in green

(Text from 785:45-15-6 on page ES-2 continues below)

(1) *Escherichia coli (E. coli): The E. coli geometric mean criterion is 126/100 ml. For swimming advisory and permitting purposes, E. coli shall not exceed a monthly geometric mean of 126/100 ml based upon a minimum of not less than five (5) samples collected over a period of not more than thirty (30) days. For swimming advisory and permitting purposes, no sample shall exceed a 75% one-sided confidence level of 235/100 ml in lakes and high use waterbodies and the 90% one-sided confidence level of 406/100 ml in all other Primary Body Contact Recreation beneficial use areas. These values are based upon all samples collected over the recreation period. For purposes of sections 303(d) and 305(b) of the federal Clean Water Act as amended, beneficial use support status shall be assessed using only the geometric mean criterion of 126/100 milliliters compared to the geometric mean of all samples collected over the recreation period.*

(2) Enterococci: The Enterococci geometric mean criterion is 33/100 ml. For swimming advisory and permitting purposes, Enterococci shall not exceed a monthly geometric mean of 33/100 ml based upon a minimum of not less than five (5) samples collected over a period of not more than thirty (30) days. For swimming advisory and permitting purposes, no sample shall exceed a 75% one-sided confidence level of 61/100 ml in lakes and high use waterbodies and the 90% one-sided confidence level of 108/100 ml in all other Primary Body Contact Recreation beneficial use areas. These values are based upon all samples collected over the recreation period. For purposes of sections 303(d) and 305(b) of the federal Clean Water Act as amended, beneficial use support status shall be assessed using only the geometric mean criterion of 33/100 milliliters compared to the geometric mean of all samples collected over the recreation period.

ES-2.2 Chapter 46: Implementation of OWQS for PBCR

To implement Oklahoma's WQS for PBCR, OWRB promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2013a). The following excerpt from Chapter 46: 785:46-15-6, stipulates how water quality data was assessed to determine support of the PBCR use as well as how the water quality target for TMDLs was 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). ***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. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

(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. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

(c). ***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. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

(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. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

Where concurrent data exist for multiple bacterial indicators on the same waterbody, each indicator group must demonstrate compliance with the numeric criteria prescribed (OWRB 2013).

As stipulated in the WQS, only the geometric mean of all samples collected over the recreation period shall be used to assess the impairment status of a stream. Therefore, only the geometric mean criteria were used to develop TMDLs for *E. coli* and Enterococci bacterial indicators.

It is worth noting that the Oklahoma Water Quality Standards (OWQS) prior to July 1, 2011 contains three bacterial indicators (fecal coliform, *E. coli* and Enterococci) and the new OWQS effective on July 1, 2011 contains only *E. coli* and Enterococci. Therefore, fecal coliform TMDLs were not be developed for any stream in this report. Bacterial TMDLs were developed only for *E. coli* and/or Enterococci impaired streams.

ES-2.3 Chapter 45: Criteria for Turbidity

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 2013). 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.

ES-2.4 Chapter 46: Implementation of OWQS for Fish and Wildlife Propagation

Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2013a) describes Oklahoma's WQS for Fish and Wildlife Propagation. The excerpt below from Chapter 46: 785:46-15-5, stipulates how water quality data was assessed to determine support of fish and wildlife propagation as well as how the water quality target for TMDLs was defined for turbidity.

785:46-15-5 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 exceeds 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.*

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) were 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 water quality data collected for turbidity and TSS under base flow conditions, which DEQ considers to be all flows less than the 25th flow exceedance percentile (i.e., the lower 75% 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.

TMDLs for turbidity in streams designated as WWAC must take into account that no more than 10% of the samples may exceed the numeric criterion of turbidity, 50 nephelometric turbidity units (NTU). However, as described above, because turbidity cannot be expressed as a mass load, TSS was 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-5 shows the bacterial and turbidity TMDLs that were developed in this report.

Table ES- 3 Summary of Turbidity Data Excluding High Flow Samples, 2001-2013

Waterbody ID	Waterbody Name	WQM Stations	Number of turbidity samples	Number of samples greater than 50 NTU	% samples exceeding criterion	Average Turbidity (NTU)	Assessment Results
OK621200050010_10	Red Rock Creek	OK621200-05-0010M	11	3	27.3%	32	2011 TMDL
OK621210000030_10	Arkansas River	621210000010-001AT	13	8	61.5%	241	TMDL Required
OK720500010010_00	North Canadian River	720500010010-001AT	41	3	7.3%	24	
OK720500010070_00	Bent Creek	OK720500-01-0070D	30	0	0	4	
OK720500010140_10	Beaver River	720500010140-001AT	43	1	2.3%	19	
OK720500010150_00	Persimmon Creek	OK720500-01-0150G	29	3	10.3%	21	Not listed, but criteria exceed the WQS
OK720500010200_00	Indian Creek	OK720500-01-0200D	20	0	0	13	

Table ES- 4 Regression Statistics and TSS Goals

Waterbody ID	Waterbody Name	R-square	NRMSE	TSS Goal (mg/L)[a]	MOS[b]
OK621210000030_10	Arkansas River	0.88	4.9%	92.4	5%
OK720500010150_00	Persimmon Creek	0.93	5.4%	71.8	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)

Table ES- 5 Stream and Pollutants for TMDL Development

Waterbody ID	HUC 8 Codes	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	*E. coli*	Turbidity
OK621200050010_10	11060006	**Red Rock Creek**	46.09	2023	4	X		
OK621210000030_10	11060001	**Arkansas River**	14.44	2023	4	X		X
OK720500010010_00	11100301	**North Canadian River**	37.36	2020	3	X		
OK720500010070_00	11100301	**Bent Creek**	18.13	2023	4	X	X	
OK720500010140_10	11100301	**Beaver River**	11.5	2023	4	X		
OK720500010150_00	11100301	**Persimmon Creek**	13.45	2023	4	X	X	X
OK720500010200_00	11100301	**Indian Creek**	17.03	2023	4	X	X	

ES - 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. Bacteria originate from warm-blooded animals and sources may be point or nonpoint in nature. Turbidity may originate from OPDES-permitted facilities, fields, construction sites, quarries, stormwater runoff and eroding stream banks.

Point sources are permitted through the OPDES program. OPDES-permitted facilities that discharge treated sanitary wastewater are required to monitor fecal coliform under the current permits and will be required to monitor *E. coli* when their permits come to renew. These facilities are also required to monitor TSS in accordance with their permits. There is each one active municipal and industrial facility.

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 OPDES permits 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 was 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 was from natural or anthropogenic processes was not feasible in this TMDL development. **Table ES-6** summarizes the point and nonpoint sources that contribute bacteria or TSS to each respective waterbody.

ES - 4 USING LOAD DURATION CURVES TO DEVELOP TMDLS

The TMDL calculations presented in this report were derived from load duration curves (LDC). LDCs facilitate rapid development of TMDLs, and as a TMDL development tool can provide some information for identifying whether impairments are associated with point or nonpoint sources. The efficiency and simplicity of the LDC method should not be considered as bad descriptors of this powerful tool for displaying the changing water quality over changing flows that provides information as to the sources of the pollutant that was not apparent in the raw data. The LDC has additional valuable uses in the post-TMDL implementation phase of the restoration of the water quality for a waterbody. Plotting future monitoring information on the LDC can show trends of improvement to sources that will identify areas for revision to the watershed restoration plan. The low cost of the LDC method allows accelerated development of TMDL plans on more waterbodies and the evaluation of the implementation of WLAs and BMPs. The technical approach for using LDCs for TMDL development includes the following steps:

(Text continues on page ES-11)

Table ES- 6 Summary of Potential Pollutant Sources by Category

Waterbody ID	Waterbody Name	Municipal OPDES Facility	Industrial OPDES Facility	MS4	OPDES No Discharge Facility	AFO	Mines	Construction Stormwater Permit	Nonpoint Source
OK621200050010_10	**Red Rock Creek**								Bacteria
OK621210000030_10	**Arkansas River**								Bacteria Turbidity
OK720500010010_00	**North Canadian River**								Bacteria
OK720500010070_00	**Bent Creek**								Bacteria
OK720500010140_10	**Beaver River**								Bacteria
OK720500010150_00	**Persimmon Creek**								Bacteria Turbidity
OK720500010200_00	**Indian Creek**								Bacteria

Facility present in watershed and potential as contributing pollutant source

Facility present in watershed, but not recognized as pollutant source

No facility present in watershed

(Text continued from page ES-9)

Prepare flow duration curves for gaged and ungaged WQM stations.

Estimate existing loading in the waterbody using ambient bacterial water quality data.

Estimate loading in the waterbody using measured TSS water quality data and turbidity-converted data.

Use 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 facilities (WWTF) 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 following are the basic steps in developing an LDC:

1. Obtain daily flow data for the site of interest from the U.S. Geological Survey (USGS), or if unavailable, projected from a nearby USGS site.

2. Sort the flow data and calculate flow exceedance percentiles.

3. Obtain the water quality data from the primary contact recreation season (May 1 through September 30).

4. For turbidity, obtain available turbidity and TSS water quality data.

5. Match the water quality observations with the flow data from the same date.

6. Display a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQS for each respective bacterial indicator.

7. Display a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQ_{goal} for TSS.

8. For bacterial TMDLs, display and differentiate another curve derived by plotting the geometric mean of all existing bacterial samples continuously along the full spectrum of flow exceedance percentiles which represents the observed load in the stream.

9. For turbidity TMDLs, match the water quality observations with the flow data from the same date and determining the corresponding exceedance percentile. Plot the flow exceedance percentiles and daily load observations in a load duration plot (See Section 5).

ES-4.1 Bacterial LDC

For bacterial 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 = 126 cfu/100 mL (E. coli); or 33 cfu/100 mL (Enterococci)

Unit conversion factor = 24,465,525

ES-4.2 TSS LDC

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

ES-4.3 LDC Summary

Historical observations of bacteria were plotted as a separate LDC based on the geometric mean of all samples. Historical observations of TSS and/or turbidity concentrations were paired with flow data and were plotted on the LDC for a stream. It is noted that the LDCs for bacteria were based on the geometric mean standards or geometric mean of all samples. It is inappropriate to compare single sample bacterial observations to a geometric mean water quality criterion in the LDC; therefore individual bacterial samples were not plotted on the LDCs.

ES - 5 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 pollutant loading and water quality. This definition can be expressed by the following equation:

$$TMDL = WLA\_{WWTF} + WLA\_{MS4} + LA + MOS$$

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.

ES-5.1 Bacterial PRG

For each waterbody, the TMDLs presented in this report were expressed as colony forming units (cfu) per day across the full range of flow conditions. For information purpose, percent reductions are also provided. The difference between existing loading and the water quality target was used to calculate the loading reductions required. For bacteria, the PRG is calculated by reducing all samples by the same percentage until the geometric mean of the reduced sample values meets the corresponding bacterial geometric mean standard (126 cfu/100 ml for *E. coli* and 33 cfu/100 ml for Enterococci) with 10% of MOS. For turbidity, the PRG is the load reduction that ensures that no more than 10% of the samples under base-flow conditions exceed the TMDL.

Table ES-7 presents the percent reductions necessary for each bacterial indicator that caused nonsupport of the PBCR use in each waterbody of the Study Area.

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

Waterbody ID	Waterbody Name	Required Reduction Rate	
		EC	ENT
OK621200050010_10	**Red Rock Creek**	-	**94.7%**
OK621210000030_10	**Arkansas River**	-	**93.3%**
OK720500010010_00	**North Canadian River**	-	**42.5%**
OK720500010070_00	**Bent Creek**	**59.8%**	**93.0%**
OK720500010140_10	**Beaver River**	-	**48.0%**
OK720500010150_00	**Persimmon Creek**	**62.5%**	**94.2%**
OK720500010200_00	**Indian Creek**	**48.5%**	**85.3%**

ES-5.2 TSS PRG

Similarly, PRGs for TSS are calculated as the required overall reduction so that no more than 10% of the samples exceed the water quality target for TSS. The PRGs for the waterbodies requiring turbidity TMDLs in this report are summarized in **Table ES-8**.

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

Waterbody ID	Waterbody Name	Required Reduction Rate
OK621210000030_10	**Arkansas River**	**92.4%**
OK720500010150_00	**Persimmon Creek**	**1.3%**

ES-5.3 Seasonal Variation

The TMDL, WLA, LA, and MOS vary with flow condition, and were calculated at every 5th flow interval percentile. The WLA component of each TMDL is the sum of all WLAs within each contributing watershed. The LA was then calculated as follows:

$$LA = TMDL - MOS - \sum WLA$$

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading.

The bacterial 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. 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 five years of water quality data and by using the longest period of USGS flow records when estimating flows to develop flow exceedance percentiles.

ES-5.4 MOS

Federal regulations (40 CFR §130.7(c)(1)) also require that TMDLs include an MOS. 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 bacterial TMDLs, an explicit MOS was set at 10%. 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 MOS. The selection of MOS is based on the normalized root mean square error (NRMSE) for each waterbody (**Table ES-4**).

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 OPDES permit requires in-stream criteria to be met.

ES - 6 Reasonable Assurance

Reasonable assurance is required by the EPA rules for a TMDL to be approvable only when a waterbody is impaired by both point and nonpoint sources and where a point source is given a less stringent WLA based on an assumption that nonpoint source load reductions will occur. In such a case, "reasonable assurances" that nonpoint (NPS) load reductions will actually occur must be demonstrated. In this report, all point source discharges either already have or were given based on this study discharge limitations less than or equal to the water quality standard numerical criteria. The TMDLs ensure that the impairments of the waterbodies in this report will not be caused by point sources. Since the point source WLAs in this TMDL report are not dependent on NPS load reduction, reasonable assurance does not apply.

ES - 7 Public Participation

A public notice was sent to local newspapers, to stakeholders in the Study Area affected by these draft TMDLs, and to stakeholders who have requested copies of all TMDL public notices. The public notice, draft TMDL report, and draft 208 Factsheet were posted at the following DEQ website: www.deq.state.ok.us/wqdnew/index.htm. The public had 45 days (July 9, 2014 to August 25, 2014) to review the draft TMDL report and make written comments. No comments were received and there were no requests for a public meeting.

The *Arkansas-North Canadian Bacterial and Turbidity TMDL Report* was finalized and submitted to EPA for final approval.

SECTION 1 INTRODUCTION

1.1 TMDL Program Background

As promulgated by Section 402 of the Clean Water Act (CWA), the U.S. Environmental Protection Agency (EPA) has delegated authority to the Oklahoma Department of Environmental Quality (DEQ) to partially oversee the National Pollutant Discharge Elimination System (NPDES) Program in the State of Oklahoma. Exceptions are agriculture (retained by State Department of Agriculture, Food, and Forestry), and the oil & gas industry (retained by the Oklahoma Corporation Commission) for which EPA has retained permitting authority. The NPDES Program in Oklahoma, in accordance with an agreement between DEQ and EPA, was implemented via the Oklahoma Pollutant Discharge Elimination System (OPDES) Act [Title 252, Chapter 606 (http://www.deq.state.ok.us/rules/606.pdf)].

Section 303(d) of the Clean Water Act (CWA) and U.S. Environmental Protection Agency (EPA) Water Quality Planning and Management Regulations [40 Code of Federal Regulations (CFR) Part 130] require states to develop total maximum daily loads (TMDL) for all waterbodies and pollutants identified by the Regional Administrator as suitable for TMDL calculation. Waterbodies and pollutants identified on the approved 303(d) list as not meeting designated uses where technology-based controls are in place will be given a higher priority for development of TMDLs. TMDLs establish the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream 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 (EPA 1991).

This report documents the data and assessment used to establish TMDLs for the pathogen indicator bacteria [*Escherichia coli (E. coli),* Enterococci] [1] and turbidity for selected waterbodies in the Arkansas River watershed and the North Canadian River watershed in Oklahoma. 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), EPA guidance, and Oklahoma Department of Environmental Quality (DEQ) guidance and procedures. DEQ is required to submit all TMDLs to EPA for review. Approved 303(d) listed waterbody-pollutant pairs or surrogates TMDLs will receive notification of the approval or disapproval action. Once the EPA 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 (EPA 2003).

[1] All future references to bacteria in this document imply these two fecal pathogen indicator bacterial groups unless specifically stated otherwise

The purpose of this TMDL study was 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 in-stream 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. MOS can be implicit and/or explicit. An implicit MOS is achieved by using conservative assumptions in the TMDL calculations. An explicit 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.

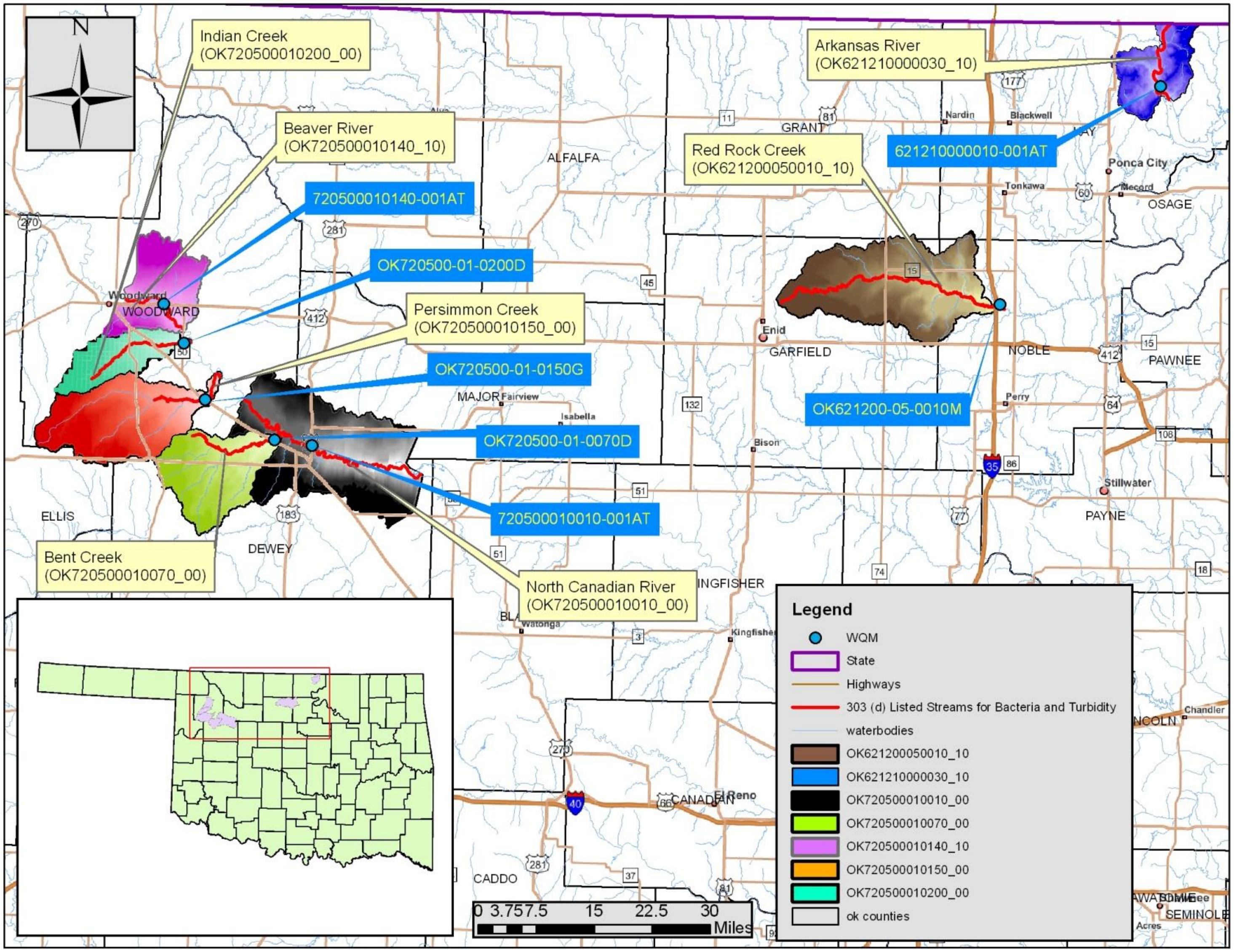
This TMDL report focuses on waterbodies that DEQ placed in Category 5 [303(d) list] of the *Water Quality in Oklahoma, 2012 Integrated Report* (aka 2012 Integrated Report) for nonsupport of primary body contact recreation (PBCR) or Fish and Wildlife Propagation beneficial uses. The waterbodies considered for TMDL development in this report are listed in Table 1-1.

Table 1-1 TMDL Waterbodies

Waterbody Name	Waterbody Identification Number (WBID)
Red Rock Creek	OK621200050010_10
Arkansas River	OK621210000030_10
North Canadian River	OK720500010010_00
Bent Creek	OK720500010070_00
Beaver River	OK720500010140_10
Persimmon Creek	OK720500010150_00
Indian Creek	OK720500010200_00

Figure 1-1 shows 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 Arkansas River and North Canadian River Watersheds Not Supporting Primary Body Contact Recreation or Fish and Wildlife Propagation Use



TMDLs are required to be developed whenever elevated levels of pathogen indicator bacteria or turbidity are above the WQS numeric criterion. The TMDLs established in this report are a necessary step in the process to develop the pollutant loading controls needed to restore the PBCR or Fish and Wildlife Propagation use designated for each waterbody. **Table 1-2** provides a description of the locations of WQM stations on the 303(d)-listed waterbodies.

Table 1-2 Water Quality Monitoring Stations used for Assessment of Streams

WQM Station	Waterbody Name	Station Location	Waterbody ID
OK621200-05-0010M	**Red Rock Creek**	Long.:-97.3183, Lat.: 36.4743	OK621200050010_10
621210000010-001AT	**Arkansas River**	Long.: -96.9462, Lat.: 36.8832	OK621210000030_10
720500010010-001AT	**North Canadian River**	Long.: -98.9205, Lat.: 36.1836	OK720500010010_00
OK720500-01-0070D	**Bent Creek**	Long.: -99.0091, Lat.: 36.1920	OK720500010070_00
720500010140-001AT	**Beaver River**	Long.:-99.2784, Lat.: 36.4369	OK720500010140_10
OK720500-01-0150G	**Persimmon Creek**	Long.:-99.1737, Lat.: 36.2619	OK720500010150_00
OK720500-01-0200D	**Indian Creek**	Long.:-99.2283, Lat.: 36.3659	OK720500010200_00

1.2 Watershed Description

1.2.1 General

The Arkansas River watershed and the North Canadian River watershed are located in the northern section of Oklahoma, bordered on the north by the State of Kansas. The majority of the waterbodies addressed in this report are located in Dewey, Ellis, Garfield, Grant, Kay, Major, Noble, and Woodward counties. In addition, the Arkansas River flows through Cowley and Sumner counties, Kansas. These counties are part of the Central Great Plains and Flint Hills Level III ecoregions (Woods, A.J, Omerik, J.M., et al 2005). The Arkansas River watershed in the Study Area is located in the Anadarko Shelf, Nemaha Uplift, and Cherokee Platform geological province and the North Canadian River watershed in the Study Area is located in the Anadarko Basin and Anadarko Shelf geological province. **Table 1-3**, derived from the 2010 U.S. Census, demonstrates that the counties in which these watersheds are located are mostly sparsely populated. **Table 1-4** lists the towns and cities located in each watershed.

About 32% of the Arkansas River (OK621210000030_10) watershed acreage is located in Kansas and the impaired portion of it starts from Kansas/Oklahoma state boarder and ends in Kay County, Oklahoma. Red Rock Creek (OK621200050010_10) is the tributary of the Arkansas River and run through Garfield and Noble Counties, Oklahoma. The impaired portion of the North Canadian River starts at Woodward County and ends in Dewey County, Oklahoma. The Beaver River is the upstream of the North Canadian River and the impaired portion of it is in Woodward County, Oklahoma. Bent Creek, Persimmon Creek and Indian Creek are the tributary of the North Canadian River and the impaired portion of them is located in Woodward County, Oklahoma.

Table 1-3 County Population and Density

County Name	Population (2010 Census)	Population Density (per square mile)
Oklahoma		
Dewey	4,810	5
Ellis	4,151	3
Garfield	60,580	57
Grant	4,527	5
Kay	46,562	49
Major	7,527	8
Noble	11,561	16
Woodward	20,081	16
Kansas		
Cowley	36,311	32
Sumner	24,132	20

Table 1-4 Major Municipalities by Watershed

Waterbody Name	Waterbody ID	Municipalities
Red Rock Creek	OK621200050010_10	Billings, Breckinridge, Ceres, Covington, Enid, Garber, Hunter, Lamont, Lucien, Perry, Tonkawa
Arkansas River	OK621210000030_10	Hardy, Kaw City, Kidare, Newkirk, Pecham, Uncas
North Canadian River	OK720500010010_00	Canton, Hucmac, Orion, Seiling, Taloga
Bent Creek	OK720500010070_00	Aledo, Lenora, , Seiling, Webb
Beaver River	OK720500010140_10	Booker, Clear Lake, Gaylord, Gate, Knowles, Laverne, Logan, Mocane, Rosston
Persimmon Creek	OK720500010150_00	Camargo, Harmon, Mutual, Vici
Indian Creek	OK720500010200_00	Sharon, Woodward

1.2.2 Climate

Table 1-5 summarizes the average annual precipitation for each Oklahoma waterbody derived from a geospatial layer developed to display annual precipitation using data collected from Oklahoma weather stations between 1971 through 2000. Average annual precipitation values among the watersheds in this portion of Oklahoma range between 26 and 38 inches (Oklahoma Climatological Survey 2005).

Table 1-5 Average Annual Precipitation by Watershed

Waterbody Name	Waterbody ID	Average Annual Precipitation (inches)
Red Rock Creek	OK621200050010_10	35
Arkansas River	OK621210000030_10	38
North Canadian River	OK720500010010_00	29
Bent Creek	OK720500010070_00	27
Beaver River	OK720500010140_10	26
Persimmon Creek	OK720500010150_00	27
Indian Creek	OK720500010200_00	26

1.2.3 Land Use

Table 1-6 summarizes 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) 2006 National Land Cover Dataset (USGS 2013). The percentages provided in **Table 1-6** are rounded. The land use categories are displayed in **Figure 1-3**. The top two dominant land use categories in the order of dominance are grasslands/herbaceous and cultivated crops for all sub-watersheds except Red Rock Creek (OK621200050010_10). The top two dominant land use categories for Red Rock Creek watershed are cultivated crops and grassland/herbaceous. The aggregated total of developed land ranges from approximately 3.4% of the land use in the Arkansas River (OK621210000030_10) watershed to 7.9% of the land use in the Beaver River (OK720500010140_10) watershed. The watersheds targeted for TMDL development in this Study Area range in size from 48,102 acres (Indian Creek, OK720500010200_00) to 168,961 acres (North Canadian River, OK720500010010_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. Not all of the waterbodies in this Study Area have historical flow data available. 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. Flow data from the surrounding USGS gage stations and the instantaneous flow measurement data taken with water quality samples have been used to estimate flows for ungaged streams. Flow conditions recorded during the time of water quality sampling for turbidity 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 B**.

Figure 1-2 Land Use Map

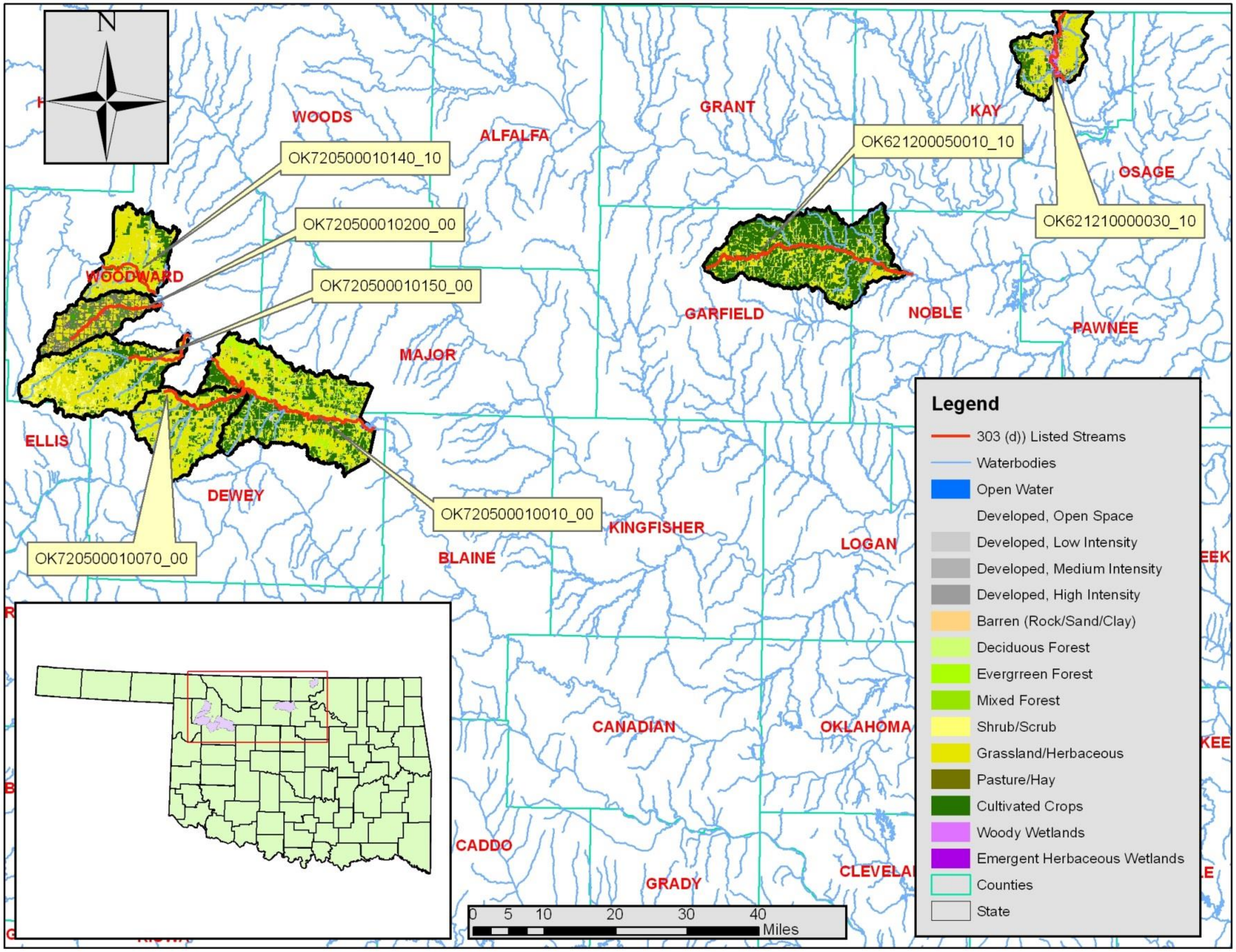


Table 1-6 Land Use Summaries by Watershed

Landuse Category	Watershed						
	Red Rock Creek	Arkansas River	North Canadian River	Bent Creek	Beaver River	Persimmon Creek	Indian Creek
Waterbody ID	OK621200050010_10	OK621210000030_10	OK720500010010_00	OK720500010070_00	OK720500010140_10	OK720500010150_00	OK720500010200_00
Open Water	1,017.9	1,529.3	469.4	50.5	80.5	89.0	19.9
Developed, Open Space	7,107.1	1,702.6	8,043.0	4,223.3	3,470.5	5,187.3	2,458.0
Developed, Low Intensity	490.5	76.1	896.7	87.2	1,225.0	354.7	370.8
Developed, Medium Intensity	81.2	6.6	157.0	7.2	375.3	39.1	33.4
Developed, High Intensity	17.3		35.0	10.0	167.1	5.7	
Bare Rock/Sand/Clay	23.0	86.3	3.9		34.0	12.3	7.6
Deciduous Forest	3,313.0	2,727.0	3,224.6	2.2	11.4		1.7
Evergreen Forest	126.7	4.1	18,675.3	5,254.9	3,276.9	2,553.3	720.9
Mixed Forest		52.9	3,259.3		18.4	17.0	8.9
Shrub/Scrub		0.8	195.7	1,015.8	1,422.8	14,329.7	1,939.5
Grasslands/Herbaceous	40,590.8	28,867.0	77,455.4	51,897.5	45,837.4	65,547.3	32,236.7
Pasture/Hay	468.0	1,998.9				379.4	
Cultivated Crops	100,686.9	11,050.5	56,316.2	21,271.1	10,632.1	21,468.3	10,304.8
Woody Wetlands		4,384.7					
Emergent Herbaceous Wetlands	5.8	798.9	229.6		3.0		
Total (Acres)	**153,928**	**53,286**	**168,961**	**83,820**	**66,555**	**109,983**	**48,102**
Open Water	0.66	2.87	0.28	0.06	0.12	0.08	0.04
Developed, Open Space	4.62	3.20	4.76	5.04	5.21	4.72	5.11
Developed, Low Intensity	0.32	0.14	0.53	0.10	1.84	0.32	0.77
Developed, Medium Intensity	0.05	0.01	0.09	0.01	0.56	0.04	0.07
Developed, High Intensity	0.01		0.02	0.01	0.25	0.01	
Bare Rock/Sand/Clay	0.01	0.16	0.002		0.05	0.01	0.02
Deciduous Forest	2.15	5.12	1.91	0.003	0.02		0.004
Evergreen Forest	0.08	0.01	11.05	6.27	4.92	2.32	1.50
Mixed Forest		0.10	1.93		0.03	0.02	0.02
Shrub/Scrub		0.001	0.12	1.21	2.14	13.03	4.03
Grasslands/Herbaceous	26.37	54.17	45.84	61.92	68.87	59.60	67.02
Pasture/Hay	0.30	3.75				0.34	
Cultivated Crops	65.41	20.74	33.33	25.38	15.98	19.52	21.42
Woody Wetlands		8.23					
Emergent Herbaceous Wetlands	0.004	1.50	0.14		0.005		
Total (%):	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	100.0	100.0

SECTION 2 PROBLEM IDENTIFICATION AND WATER QUALITY TARGET

2.1 OKLAHOMA WATER QUALITY STANDARDS

Title 785 of the Oklahoma Administrative Code contains Oklahoma Water Quality Standards (OWQS) and implementation procedures (OWRB 2013). The Oklahoma Water Resources Board (OWRB) has statutory authority and responsibility concerning establishment of State WQS, 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 2013). An excerpt of the Oklahoma WQS (Title 785) summarizing the State of Oklahoma Antidegradation Policy is provided in **Appendix C**. **Table 2-1**, an excerpt from the 2012 Integrated Report (DEQ 2013), lists beneficial uses designated for each bacterial 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 2-1 Designated Beneficial Uses for Each Stream Segment in the Study Area

Waterbody ID	Waterbody Name	AES	AG	WWAC	FISH	PBCR	PPWS
OK621200050010_10	**Red Rock Creek**	F	N	N	X	N	
OK621210000030_10	**Arkansas River**	I	N	N	I	N	I
OK720500010010_00	**North Canadian River**	F	F	F	N	N	F
OK720500010070_00	**Bent Creek**	F	N	F	X	N	I
OK720500010140_10	**Beaver River**	F	F	F	F	N	
OK720500010150_00	**Persimmon Creek**	I	F	F	X	N	I
OK720500010200_00	**Indian Creek**	I	F	F	X	N	I

F – Fully supporting	**N – Not supporting**	I – Insufficient information	X – Not assessed	Source: 2012 Integrated Report

2.1.1 Chapter 45: Definition of PBCR and Bacterial WQSs

The definitions of PBCR and the bacterial WQSs for PBCR are summarized by the following excerpt from Title 785, Chapter 45-5-16 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.

(c). Compliance with 785:45-5-16 shall be based upon meeting the requirements of one of the options specified in (1) or (2) of this subsection (c) for bacteria. Upon selection of one (1) group or test method, said method shall be used exclusively over the time period prescribed therefore. Provided, where concurrent data exist for multiple bacterial indicators on the same waterbody or waterbody segment, no criteria exceedances shall be allowed for any indicator group.

(1) Escherichia coli (E. coli): The E. coli geometric mean criterion is 126/100 ml. For swimming advisory and permitting purposes, E. coli shall not exceed a monthly geometric mean of 126/100 ml based upon a minimum of not less than five (5) samples collected over a period of not more than thirty (30) days. For swimming advisory and permitting purposes, no sample shall exceed a 75% one-sided confidence level of 235/100 ml in lakes and high use waterbodies and the 90% one-sided confidence level of 406/100 ml in all other Primary Body Contact Recreation beneficial use areas. These values are based upon all samples collected over the recreation period. For purposes of sections 303(d) and 305(b) of the federal Clean Water Act as amended, beneficial use support status shall be assessed using only the geometric mean criterion of 126/100 milliliters compared to the geometric mean of all samples collected over the recreation period.

(2) Enterococci: The Enterococci geometric mean criterion is 33/100 ml. For swimming advisory and permitting purposes, Enterococci shall not exceed a monthly geometric mean of 33/100 ml based upon a minimum of not less than five (5) samples collected over a period of not more than thirty (30) days. For swimming advisory and permitting purposes, no sample shall exceed a 75% one-sided confidence level of 61/100 ml in lakes and high use waterbodies and the 90% one-sided confidence level of 108/100 ml in all other Primary Body Contact Recreation beneficial use areas. These values are based upon all samples collected over the recreation period.

For purposes of sections 303(d) and 305(b) of the federal Clean Water Act as amended, beneficial use support status shall be assessed using only the geometric mean criterion of 33/100 milliliters compared to the geometric mean of all samples collected over the recreation period.

2.1.2 Chapter 46: Implementation of OWQS for PBCR

To implement Oklahoma's WQS for PBCR, OWRB promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2013a). The following excerpt from Chapter 46: 785:46-15-6, stipulates how water quality data were assessed to determine support of the PBCR use as well as how the water quality target for TMDLs were 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). ***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. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

(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. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

(c). ***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. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

(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. These values are based upon all samples collected over the recreation period in accordance with OAC 785:46-15-3(c).

Compliance with the Oklahoma WQS is based on meeting requirements for both *E. coli* and Enterococci bacterial indicators in addition to the minimum sample requirements for assessment. 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 2013).

As stipulated in the WQS, only the geometric mean of all samples collected over the primary recreation period shall be used to assess the impairment status of a stream segment. Therefore, only the geometric mean criteria were used to develop TMDLs for *E. coli* and Enterococci.

2.1.3 Chapter 45: Criteria for Turbidity

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 2013). 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.

2.1.4 Chapter 46: Implementation of OWQS for Fish and Wildlife Propagation

Chapter 46, *Implementation of Oklahoma’s Water Quality Standards* (OWRB 2013a) describes Oklahoma’s WQS for Fish and Wildlife Propagation. The following excerpt (785:46-15-5) stipulates how water quality data was assessed to determine support of fish and wildlife propagation as well as how the water quality target for TMDLs was defined for turbidity:

785:46-15-5 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 exceeds 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.

2.1.5 Prioritization of TMDL Development

Table 2-2 summarizes the PBCR and WWAC use attainment status and the bacterial and 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 bacterial and/or turbidity impairments that affect the PBCR and WWAC beneficial uses.

After the 303(d) list is compiled, the ODEQ assigns a four-level rank to each of the Category 5a waterbodies. This rank helps in determining the priority for TMDL development. The rank is based on criteria developed using the procedure outlined in the 2012 Continuing Planning Process (pp. 139-140). The TMDL prioritization point totals calculated for each watershed were broken down into the following four priority levels[1]:

Priority 1 watersheds - above the 90th percentile (32 watersheds)

Priority 2 watersheds - 70th to 90th percentile (68 watersheds)

Priority 3 watersheds - 40th to 70th percentile (81 watersheds)

Priority 4 watersheds - below the 40th percentile (143 watersheds)

Each waterbody on the 2012 303(d) list has been assigned a potential date of TMDL development based on the priority level for the corresponding HUC 11 watershed.

Priority 1 watersheds are targeted for TMDL development within the next two years.

2.2 Problem Identification

This subsection summarizes water quality data caused by elevated levels of impairments.

2.2.1 Bacterial Data Summary

Table 2-3 summarizes water quality data collected during primary contact recreation season from the WQM stations between 2001 and 2012 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 DEQ 2012 303(d) list (DEQ 2013). Water quality data from the primary contact recreation season are provided in **Appendix A**. For the data collected between 2001 and 2012, evidence of nonsupport of the PBCR use was observed based on elevated *E.coli* or Enterococci concentrations. Four of the waterbodies within the Study Area have elevated concentration of E. coli and seven of the waterbodies have elevated concentration of Enterococci. The bacterial TMDL for *E.coli* on the Red Rock Creek (OK621200050010_10) was not done in this study because it was already developed previously in 2011 (*Bacteria and Turbidity Total Maximum Daily Loads for the Salt Fork of Arkansas River OK621000, OK621010, OK621100, OK621200, OK621210*). Rows highlighted in green in **Table 2-3** require TMDLs.

Detailed review of the data collected between 2001 and 2012 indicated an insufficient number of samples were available for the Arkansas River (OK621210000030_10). Therefore, no TMDLs are required for this waterbody. However, there are enough data to show it is impaired for Enterococci, not for *E. coli*. TMDLs are required for Enterococci only in the Arkansas River.

[1] Source: Appendix C, 2012 Integrated Report

Table 2-2 Excerpt from the 2012 Integrated Report – Oklahoma 303(d) List of Impaired Waters (Category 5)

Waterbody ID	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	*E. coli*	Designated Use Primary Body Contact Recreation	Turbidity	Designated Use Warm Water Aquatic Life
OK621200050010_10	Red Rock Creek	46.09	2023	4	X		N		N
OK621210000030_10	Arkansas River	14.44	2023	4	X		N	X	N
OK720500010010_00	North Canadian River	37.36	2020	3	X		N		F
OK720500010070_00	Bent Creek	18.13	2023	4	X	X	N		F
OK720500010140_10	Beaver River	11.5	2023	4	X		N		F
OK720500010150_00	Persimmon Creek	13.45	2023	4	X	X	N		F
OK720500010200_00	Indian Creek	17.03	2023	4	X	X	N		F

ENT = Enterococci; N = Not attaining; X = Criterion exceeded
Source: 2012 Integrated Report, DEQ 2013

Table 2-3 Summary of Indicator Bacterial Samples from Primary Body Contact Recreation Subcategory Season May 1 to September 30, 2001-2012

Waterbody ID	Waterbody Name	Indicator	Number of samples	Geometric Mean Concentration (cfu/100 ml)	Assessment Results
OK621200050010_10	Red Rock Creek	EC	10	622	2011 TMDL
		ENT	10	556	TMDL required
OK621210000030_10	Arkansas River	EC	7	151	Insufficient number of samples
		ENT	7	440	Insufficient number of samples, but existing samples indicated “not attained”.
OK720500010010_00	North Canadian River	EC	14	43	
		ENT	14	52	TMDL required
OK720500010070_00	Bent Creek	EC	14	282	TMDL required
		ENT	10	426	TMDL required
OK720500010140_10	Beaver River	EC	14	26	
		ENT	14	57	TMDL required
OK720500010150_00	Persimmon Creek	EC	15	302	TMDL required
		ENT	11	511	TMDL required
OK720500010200_00	Indian Creek	EC	10	220	TMDL required
		ENT	10	202	TMDL required

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
TMDLs were developed for waterbodies highlighted in green

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 water quality data collected from the WQM stations between 2001 and 2013 for turbidity. 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 OWQS, DEQ considers base flow conditions to be all flows greater than the 25th flow exceedance frequency (i.e., the lower 75% of flows) which is consistent with the USGS Streamflow Conditions Index (USGS 2009). Therefore, **Table 2-5** was prepared to represent the subset of these data when samples under high flow conditions were excluded.

Water quality samples collected under flow conditions less than the 25th flow exceedance frequency (highest flows) were therefore excluded from the data set used for TMDL analysis. Three of the seven waterbodies listed on **Table 2-5** for nonsupport of the Fish and Wildlife Propagation use were based on turbidity levels observed in the waterbody. The turbidity TMDL for the Red Rock Creek (OK621200050010_10) was not done in this study because it was already developed previously in 2011 (*Bacteria and Turbidity Total Maximum Daily Loads for the Salt Fork of Arkansas River OK621000, OK621010, OK621100, OK621200, OK621210*). **Table 2-6** summarizes TSS data collected from the WQM stations between 1998 and 2009. **Table 2-7** presents a subset of these data when samples under high flow conditions were excluded. Water quality data for turbidity and TSS are provided in **Appendix A**.

Table 2-4 Summary of All Turbidity Samples, 2001-2013

Waterbody ID	Waterbody Name	WQM Stations	Number of turbidity samples	Number of samples greater than 50 NTU	% samples exceeding criterion	Average Turbidity (NTU)
OK621200050010_10	Red Rock Creek	OK621200-05-0010M	19	11	57.9%	121
OK621210000030_10	Arkansas River	621210000010-001AT	14	9	64.3%	269
OK720500010010_00	North Canadian River	720500010010-001AT	43	4	9.3%	25
OK720500010070_00	Bent Creek	OK720500-01-0070D	32	1	3.1%	6
OK720500010140_10	Beaver River	720500010140-001AT	44	1	2.3%	19
OK720500010150_00	Persimmon Creek	OK720500-01-0150G	32	6	18.8%	33
OK720500010200_00	Indian Creek	OK720500-01-0200D	21	0	0	13

Table 2-5 Summary of Turbidity Samples Excluding High Flow Samples, 2001-2013

Waterbody ID	Waterbody Name	WQM Stations	Number of turbidity samples	Number of samples greater than 50 NTU	% samples exceeding criterion	Average Turbidity (NTU)	Assessment Results
OK621200050010_10	Red Rock Creek	OK621200-05-0010M	11	3	27.3%	32	2011 TMDL
OK621210000030_10	Arkansas River	621210000010-001AT	13	8	61.5%	241	TMDL Required
OK720500010010_00	North Canadian River	720500010010-001AT	41	3	7.3%	24	
OK720500010070_00	Bent Creek	OK720500-01-0070D	30	0	0	4	
OK720500010140_10	Beaver River	720500010140-001AT	43	1	2.3%	19	
OK720500010150_00	Persimmon Creek	OK720500-01-0150G	29	3	10.3%	21	TMDL Required
OK720500010200_00	Indian Creek	OK720500-01-0200D	20	0	0	13	

Table 2-6 Summary of All TSS Samples, 1998-2009

Waterbody ID	Waterbody Name	WQM Stations	Number of TSS samples	Average TSS (mg/L)
OK621200050010_10	**Red Rock Creek**	OK621200-05-0010M	20	154
OK621210000030_10	**Arkansas River**	621210000010-001AT	13	185
OK720500010010_00	**North Canadian River**	720500010010-001AT	23	106
OK720500010070_00	**Bent Creek**	OK720500-01-0070D	20	19
OK720500010140_10	**Beaver River**	720500010140-001AT	2	59
OK720500010150_00	**Persimmon Creek**	OK720500-01-0150G	20	65
OK720500010200_00	**Indian Creek**	OK720500-01-0200D	21	13

Table 2-7 Summary of TSS Samples Excluding High Flow Samples, 1998-2009

Waterbody ID	Waterbody Name	WQM Stations	Number of TSS samples	Average TSS (mg/L)
OK621200050010_10	**Red Rock Creek**	OK621200-05-0010M	17	81
OK621210000030_10	**Arkansas River**	621210000010-001AT	11	141
OK720500010010_00	**North Canadian River**	720500010010-001AT	23	106
OK720500010070_00	**Bent Creek**	OK720500-01-0070D	20	19
OK720500010140_10	**Beaver River**	720500010140-001AT	2	59
OK720500010150_00	**Persimmon Creek**	OK720500-01-0150G	18	52
OK720500010200_00	**Indian Creek**	OK720500-01-0200D	20	13

2.3 WATER QUALITY TARGETS

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." The water quality targets for *E. coli* and Enterococci are geometric mean standards of 126 cfu/100ml and 33 cfu/100ml, respectively. The TMDLs for bacteria incorporated an explicit 10% margin of safety.

An individual water quality target established for turbidity must demonstrate compliance with the numeric criteria prescribed in the Oklahoma WQS (OWRB 2013). According to the Oklahoma WQS [785:45-5-12(f)(7)], the turbidity criterion for streams with WWAC beneficial use is 50 NTUs (OWRB 2013). 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% 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 was 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

3.1 OVERVIEW

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 was available. Pathogen indicator bacteria originate from the digestive tract of warm-blooded animals, and sources may be point or nonpoint in nature. Turbidity may originate from OPDES-permitted facilities, fields, construction sites, quarries, stormwater runoff and eroding stream banks.

Point sources are permitted through the OPDES program. OPDES-permitted facilities that discharge treated wastewater are currently required to monitor for fecal coliform and TSS in accordance with their permits. The discharges with bacterial limits will be required to monitor for *E. coli* when their permits come to renew. 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 OPDES permits are considered nonpoint sources.

The potential nonpoint sources for bacteria were compared based on the fecal coliform load produced in each subwatershed. Although fecal coliform is no longer used as a bacterial indicator in the Oklahoma WQS, it is still valid to use fecal coliform concentration or loading estimates to compare the potential contributions of different nonpoint sources because *E. coli* is a subset of fecal coliform. Currently there was insufficient data available in the scientific arena to quantify counts of *E. coli* in feces from warm-blooded animals discussed in Section 3.

The following nonpoint sources were considered in this report:

- Wildlife (deer)
- Non-Permitted Agricultural Activities and Domesticated Animals
- Failing Onsite Wastewater Disposal (OSWD) Systems and Illicit Discharges
- Pets (dogs and cats)

The 2012 Integrated Water Quality Assessment Report (DEQ 2013) listed potential sources of turbidity as:

- Grazing in riparian corridors of streams and creeks
- Municipal point source discharges
- Onsite treatment system
- Non-irrigated crop production
- Rangeland grazing
- Unknown sources

The following discussion describes what is known regarding point and nonpoint sources of bacteria and/or TSS in the impaired watersheds. Where information was available on point and nonpoint sources of indicator bacteria and/or TSS, data were provided and summarized as part of each category.

3.2 OPDES-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. OPDES-permitted facilities classified as point sources that may contribute bacterial or TSS loading includes:

- Continuous Point Source Dischargers
  - OPDES municipal wastewater treatment facilities (WWTF)
  - OPDES Industrial WWTF Discharges
- OPDES-regulated stormwater discharges
  - Municipal separate storm sewer system (MS4) discharges
    - Phase 1 MS4
    - Phase 2 MS4
  - Multi-sector general permits
    - Regulated Sector J Discharges
    - Rock, Sand and Gravel Quarries
  - Construction stormwater discharges
- No-discharge WWTF
- Sanitary sewer overflow (SSO)
- NPDES Animal Feeding Operations (AFO)
  - Concentrated Animal Feeding Operations (CAFO)
  - Swine Feeding Operation (SFO)
  - Poultry Feeding Operation (PFO)

Six watersheds in the Study Area [Red Rock Creek, the Arkansas River, the North Canadian River, Bent Creek, Persimmon Creek, and Indian Creek] have no OPDES permitted facilities within their contributing watershed. There are two OPDES-permitted facilities in the Beaver River (OK720500010140_10) watershed.

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 bacterial loading to surface waters. CAFOs are recognized by EPA as potential significant sources of pollution, and may have the potential to cause serious impacts to water quality if not properly managed.

3.2.1 Continuous Point Source Dischargers

Continuous point source discharges such as WWTFs could result in discharge of elevated concentrations of indicator bacteria if the disinfection unit is not properly maintained, is of poor design, or if flow rates are above the disinfection capacity. While the no-discharge facilities do not discharge wastewater directly to a waterbody, it is possible that continuous point source discharges from municipal and industrial WWTFs 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 WWTFs 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 WWTFs are addressed by DEQ 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 are considered to be organic suspended solids if the discharge permit includes a limit for Biochemical Oxygen Demand (BOD) or Carbonaceous Biochemical Oxygen Demand (CBOD). Only WWTF discharges of inorganic suspended solids considered and receive WLAs.

The locations of the OPDES-permitted facilities that discharge wastewater to surface waters addressed in these TMDLs are listed in **Table 3-1** and displayed in **Figure 3-1**.

3.2.1.1 Municipal OPDES WWTF

There is one active permitted municipal source facility (Woodward WWTF) within the Study Area. Municipal WWTFs are designated with the Standard Industrial Code (SIC) number 4952. They discharge organic TSS with limits for $CBOD_5$ so they are not considered a potential source of turbidity. Woodward WWTF discharges to a waterbody that requires a TMDL for Enterococci, so it received a WLA for bacteria.

3.2.1.2 Industrial OPDES WWTF

There is one active industrial WWTF in the Beaver River (OK720500010140_10) watershed. Western Farmers Electric Cooperative-Mooreland plant is discharging to a waterbody that requires a TMDL for Enterococci and it was not considered a potential source of bacteria. Therefore, it did not receive a WLA for bacteria.

Table 3-1 Point Source Discharges in the Study Area

Waterbody ID & Waterbody Name	OPDES Permit No.	Facility	SIC code	Facility Type	Design Flow (mgd)	Ave/Max FC cfu/100mL	Avg/Max TSS mg/L	Expiration Date	Notes
Beaver River OK720500010140_10	OK0000647	Western Farmers Electric Cooperative – Mooreland Plant	4911	Gas-fired steam electric generation plant	1.28	NA	30/100	7/31/2016	Active
	OK0044016	Kline Materials, Inc.	NA	NA		NA		4/22/2002	Inactive
	OK0034509	Woodward Public Works Authority Wastewater Treatment Facility	4952	Wastewater Treatment Facility	4.0	200/400	15/- (Jun – Oct) 30/- (Nov – May)	9/30/2016	Active

NA = not available or not applicable.

Table 3-2 Permits Summary

Company Name	County	Permit ID	Date Issued	Waterbody ID	Watershed	Estimated Acres
Construction General Permits (OKR10)						
Shale Pit Project	Garfield	OKR107170	1/19/2008	OK621200050010_10	Red Rock Creek	5
Koda Services Inc.	Woodward	OKR107202	2/11/2008	OK720500010140_10	Beaver River	5
Aspen Substation	Woodward	OKR107787	1/18/2008	OK720500010140_10	Beaver River	10
ODOT JP#20246 (04)	Noble	OKR108208	9/27/2007	OK621200050010_10	Red Rock Creek	20
La Quinta Inn and Suites	Woodward	OKR108240	9/27/2007	OK720500010140_10	Beaver River	2
ODOT JP#17671 (04)	Dewey	OKR108502		OK720500010010_00	North Canadian River	91
Quail Ridge Addition	Dewey	OKR108518	11/20/2007	OK720500010010_00	North Canadian River	10
ODOT JP#21310 (04)	Major	OKR108682	1/19/2008	OK720500010010_00	North Canadian River	2.9
85 Car Unit Train Expansion	Garfield	OKR109083		OK621200050010_10	Red Rock Creek	43
Multi-Sector General Permits (OKR05)						
Western Farmers Electric Cooperative	Woodward	OKR050419	6/29/2006	OK720500010140_10	Beaver River	N/A
Broce Construction Co.	Woodward	OKR050708	3/7/2006	OK720500010140_10	Beaver River	N/A
City of Miami	Ottawa	OKR051020	8/24/2006	OK621210000030_10	Arkansas River	N/A
Hamm & Phillips Service Company	Major	OKR051165	9/29/2006	OK720500010010_00	North Canadian River	N/A
Garber Used Auto Parts	Garfield	OKR051244	11/10/2006	OK621200050010_10	Red Rock Creek	N/A

Table 3-3 OPDES No-Discharge Facilities in the Study Area

Facility	Facility ID	County	Facility Type	Type	Waterbody ID	Waterbody Name
Broce Construction Company Inc.	77000490	Woodward	Total Retention	Industrial	OK720500010140_10	**Beaver River**
Leroy's Ready Mix Inc.	77000370	Woodward	Total Retention	Industrial	OK720500010140_10	**Beaver River**
Sharon WWT	S20523	Woodward	Total Retention	Municipal	OK720500010170_00	**Persimmon Creek, North**
Vici WWT	S20602	Dewey	Total Retention	Municipal	OK720500010170_00	**Persimmon Creek, North**
Duke Energyfield Service, LP	77000390	Woodward	Total Retention	Industrial	OK720500010010_00	**North Canadian River**
Seiling WWT	S20524	Dewey	Total Retention	Municipal	OK720500010010_00	**North Canadian River**
Hunter WWT	S21203	Garfield	Total Retention	Municipal	OK621200050010_10	**Red Rock Creek**
Billings Lagoon WWT	S21204	Noble	Total Retention	Municipal	OK621200050010_10	**Red Rock Creek**

Table 3-4 Sanitary Sewer Overflow Summary (1989-2001)

Facility Name	OPDES Permit No.	Receiving Water	Facility ID	Number of Occurrences	Date Range		Amount (Gallons)	
					From	To	Min	Max
Woodward WWT	OK0034509	OK620900010250_00	S20520	48	6/27/1993	8/10/2000	14	28,000,000
Seiling WWT		OK720500010010_00	S20524	11	5/13/1993	3/27/2000	5,460	>38,000,000
Vici WWT		OK720500010170_00	S20602	3	12/27/1989	6/7/1993	50	75
Billings Lagoon WWT		OK621200050010_10	S21204	15	6/7/1990	2/2/2001	30	12,000.000

Figure 3-1 Locations of OPDES-permitted Facilities and NPDES-permitted SFOs in the Study Area

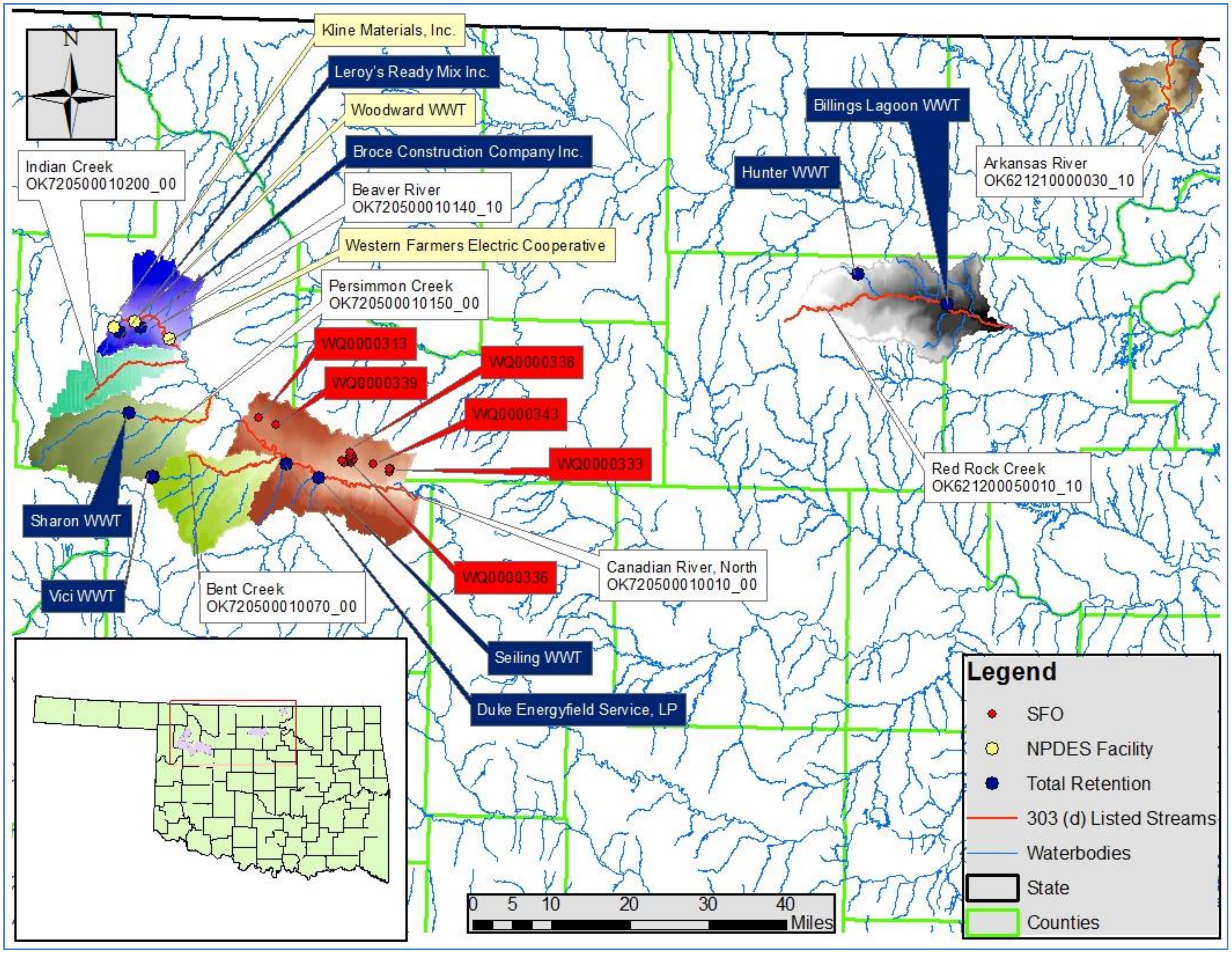
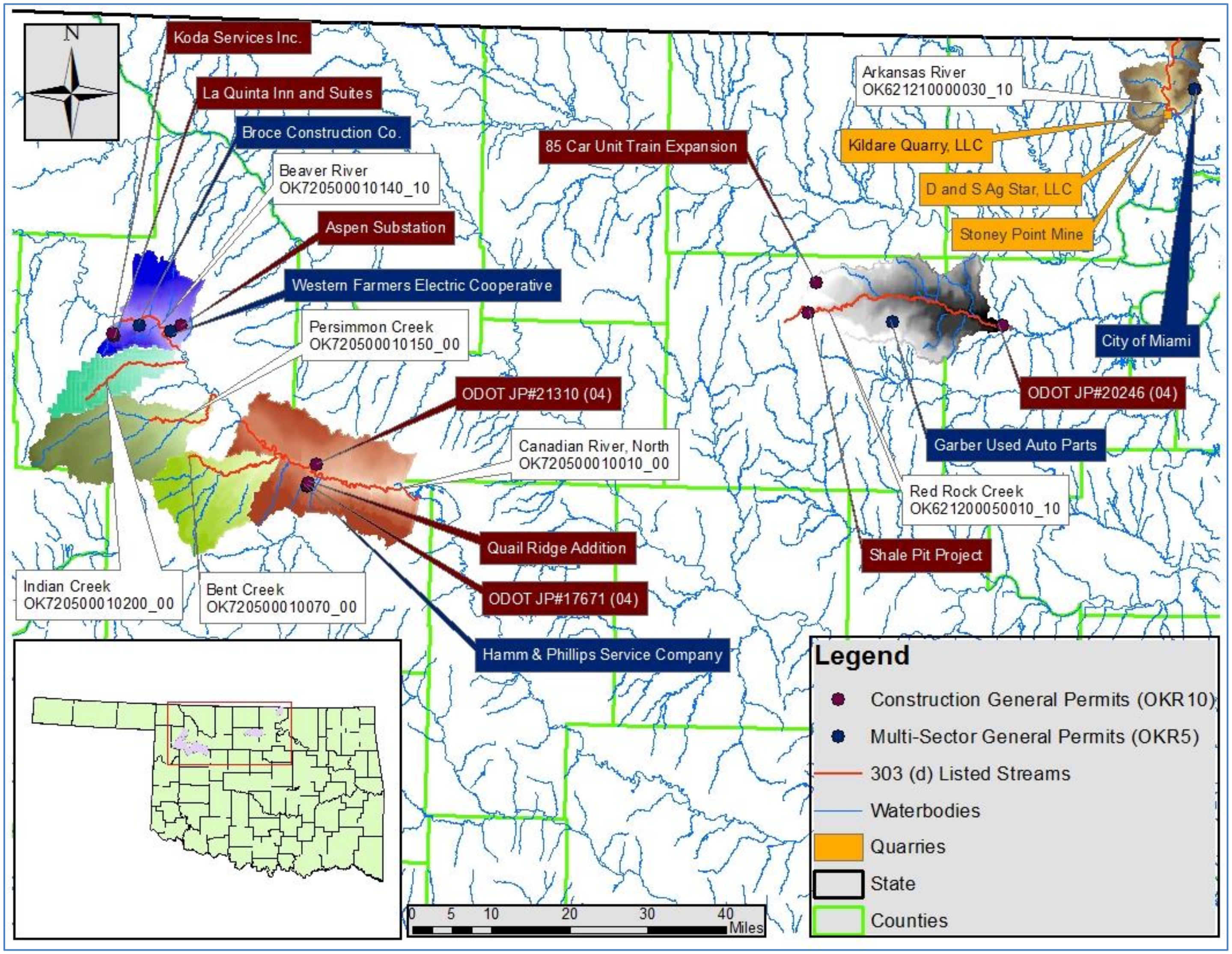


Figure 3-2 Locations of Multi-sector Industrial Permits and Construction Activities in the Study Area



3.2.2 Stormwater Permits

Stormwater runoff from OPDES-permitted facilities (MS4s, facilities with multi-sector general permits, and construction sites) can contain impairments. The National Stormwater Quality Database (NSQD) summarizes concentrations for a number of pollutants of concern in stormwater runoff from around the country (Pitt et. al. 2008). Based on data summarized in the NSQD, median cencentraion in stormwater ranged from 570 to 9,000 cfu/100mL for E.coli and from 9 to 1,770 mg/L for TSS.

EPA regulations [40 C.F.R. §130.2(h)] require that NPDES-regulated stormwater discharges must be addressed by the WLA 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. OWQS 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 so permitted stormwater discharges do not impair streams with TSS. Therefore, TSS WLAs for NPDES-regulated stormwater discharges are considered unnecessary in this TMDL report and was not be included in the TMDL calculations. Stormwater runoff from permitted areas can contain high fecal coliform.

3.2.2.1 Municipal Separate Storm Sewer System (OKR04)

3.2.2.1.1 Phase I MS4

In 1990 the EPA developed rules establishing Phase I of the NPDES Stormwater Program, designed to prevent harmful pollutants from being washed by stormwater runoff into MS4s (or from being dumped directly into the MS4) and then discharged into local waterbodies (EPA 2005). Phase I of the program required operators of medium and large MS4s (those generally serving populations of 100,000 or greater) to implement a stormwater management program as a means to control polluted discharges. Approved stormwater management programs for medium and large MS4s are required to address a variety of water quality-related issues, including roadway runoff management, municipal-owned operations, and hazardous waste treatment. There are no Phase I MS4 permits in the Study Area.

3.2.2.1.2 Phase II MS4

In 1999, Phase II began requiring certain small MS4s to comply with the NPDES stormwater program. Small MS4s are defined as any MS4 that is not a medium or large MS4 covered by Phase I of the NPDES Stormwater Program. Phase II requires operators of regulated small MS4s to obtain NPDES permits and develop a stormwater management program. Programs are designed to reduce discharges of pollutants to the “maximum extent practicable,” to protect water quality, and to satisfy appropriate water quality requirements of the CWA. Phase II MS4 stormwater programs must address the following six minimum control measures:

- Public Education and Outreach
- Public Participation/Involvement
- Illicit Discharge Detection and Elimination
- Construction Site Runoff Control
- Post- Construction Runoff Control
- Pollution Prevention/Good Housekeeping

The Phase II small MS4 General Permit (OKR04) for communities in Oklahoma has been effective since 2005. Information about DEQ's MS4 program can be found on-line at the following DEQ website: www.deq.state.ok.us/WQDnew/stormwater/ms4/. There are no Phase II MS4 permits in the Study Area.

3.2.2.2 Multi-Sector General Permits

A DEQ multi-sector industrial general permit (OKR05) is required for stormwater discharges from all industrial facilities (DEQ 2011) whose Standard Industrial Classification (SIC) code is listed on Table 1-2 of the MSGP. Stormwater discharges from all industrial facilities occur only during or immediately following periods of rainfall and elevated flow conditions. Since turbidity criteria do not apply during these periods, stormwater was not considered a potential source of turbidity impairment.

There are five facilities within the Study Area with multi-sector general permits. They are listed in **Table 3-2** and displayed in **Figure 3-2**.

3.2.2.2.1 Regulated Sector J Discharges

Sector J facilities include crushed stone, construction sand & gravel, and industrial sand mines. The activities in these facilities include the exploration and mining of minerals (e.g., stone, sand, clay, chemical and fertilizer minerals, non-metallic minerals, etc.). A "*mine*" refers to an area of land actively mined for the production of sand and gravel from natural deposits. Under the MSGP (OKR05), effluent from Sector J facilities include stormwater discharges associated with industrial activity from active and inactive mineral mining and mine dewatering. "*Mine dewatering*" is any water that is impounded or that collects in the mine and is pumped, drained, or otherwise removed from the mine through the efforts of the mine operator. This term also includes wet pit overflows caused solely by direct rainfall and uncontaminated ground water seepage. Specific requirements for Sector J stormwater discharges can be found in Part 12 of the MSGP. Specific effluent limitation guidelines for Sector J SIC codes (1422 - 1429, 1442, 1446) are referenced in Table 1-3 of the MSGP. The effluent guidelines [40 CFR part 436, Subpart B, C and D] are adopted by reference in the OPDES under OAC 252:606-1-3(b)(8).

Mine dewatering discharges can happen at any time and have the following specific effluent limitations:

- pH 6.0 to 9.0
- TSS Daily Maximum: 45 mg/L
- TSS Monthly Average: 25 mg/L

If the TMDL shows that a TSS limit more stringent than 45 mg/L was required, additional TSS limitations and monitoring requirements were required. These additional requirements are implemented under the multi-sector general permit. Only the City of Miami (OKR051020) is in the Arkansas River watershed that the receiving stream is impaired for TSS. However, the City of Miami (OKR051020) in the Arkansas River (OK621210000030_10) watershed, as an air transportation, scheduled (SIC 4512), was not given a wasteload allocation because stormwater discharge from such industry occurs only during or immediately following periods of rainfall and elevated flow conditions when the turbidity criteria do not apply.

3.2.2.2.2 Rock, Sand and Gravel Quarries

Stormwater from rock, sand and gravel quarries in Oklahoma fall under the MSGP. But wastewater generated at quarries (mining of stone, sand, and gravel, crushing stone to size, washing and stockpiling of materials, vehicle/equipment washing and maintenance) is regulated under DEQ general permit (OKG950000). Wastewater discharges regulated by this Permit are process wastewater and stormwater runoff that comes in direct contact with active process areas associated with the mining of stone, sand, and gravel; cutting stone; crushing stone to size; washing and stockpiling of processed stone and sand; and washing and maintenance areas of vehicles and equipment. Permitted activities include discharge of industrial wastewater, construction or operation of industrial surface water impoundments, land application of industrial wastewater for dust suppression, and recycling of wastewater as wash water or cooling water.

Wastewater and stormwater runoff from mining activities have the potential to contain elevated pH due to contact with minerals. Suspended solids, as well as fugitive dust from operations, are a potential source of metals. Oil and grease may be generated due to equipment washing activities.

General Permit OKG950000 does not allow discharge of wastewater into Outstanding Resource Waters, High Quality Waters, Sensitive Public & Private Water Supplies, and Appendix B Waters [OAC 785:45-5-25(c)(2)]. In addition, no discharge is allowed into waterbodies listed as impaired for turbidity in Oklahoma's 303(d) list for which a TMDL has not been performed. Discharges into turbidity-impaired streams are also not allowed if their TMDL indicated that discharge limits more stringent than 45 mg/l for TSS or 6.5-9.0 standard units for pH are required (DEQ 2013).

The permit contains technology-based effluent limits of 45 mg/L for TSS, 15 mg/L for oil and grease, and pH range of 6.0–9.0. However, the permit includes a provision that when exceedances of water quality criteria are determined to be the result of a facility's discharge to receiving waters, DEQ may determine that the facility is no longer eligible for coverage under the general permit and require the facility to apply for an individual discharge permit with additional chemical-specific limits or toxicity testing requirements as necessary to protect the beneficial uses of the receiving stream.

There are three quarries in the Arkansas River (OK621210000030_10) watershed which shown in **Figure 3-2** and summarized in **Table 3-5**. However, they don't discharge wastewater to receive WLAs.

Table 3-5 Rock, Sand, and Gravel Quarries

Company Name	County	Permit ID	Product	Permitted Acres	Watershed
Kildare Quarry, LLC	Kay	L.E.-1608-C	Limestone	150	Arkansas River
Stoney Point Mine	Kay	L.E.-2402-A	Limestone	55	Arkansas River
D and S Ag Star, LLC	Kay	L.E.-2433-A	Limestone	22.4	Arkansas River

3.2.2.3 General Permit for Construction Activities (OKR10)

A DEQ stormwater general permit for construction activities (OKR10) is required for any stormwater discharges in the State of Oklahoma associated with construction activities that result in land disturbance of equal to or greater than one acre or less than one acre if they are part of a larger common plan of development or sale that totals at least one 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 (DEQ 2012). 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 permits for construction projects that were active during the time period that samples were taken are summarized in **Table 3-2** and shown in **Figure 3-2**.

3.2.3 No-Discharge Facilities

For the purposes of these TMDLs, it was assumed that no-discharge facilities do not contribute indicator bacterial or TSS loading. However, it is possible the wastewater collection systems associated with these no-discharge facilities could be a source of indicator bacterial loading, or that discharges from the wastewater facility may occur during large rainfall events that exceed the systems' storage capacities.

There are eight no-discharge facilities, including three industrial and five municipal facilities in the Study Area, which is listed in **Table 3-3**. They could be contributing to the elevated levels of in-stream indicator bacterial loading.

3.2.4 Sanitary Sewer Overflows

Sanitary sewer overflow (SSO) from wastewater collection systems, although infrequent, can be a major source of indicator bacterial 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 OPDES permittee. The reporting of SSOs has been strongly encouraged by EPA, primarily through enforcement and fines. While not all sewer overflows are reported, DEQ has some data on SSOs available. SSOs were reported between 1989 and 2001. During that period, 77 overflows were reported ranging from a minimal quantity to over 38 million gallons. **Table 3-4** summarizes the SSO occurrences by OPDES facilities. Historical data of reported SSOs are provided in **Appendix D**.

3.2.5 Animal Feeding Operations

The Agricultural Environmental Management Services (AEMS) of the Oklahoma Department of Agriculture, Food and Forestry (ODAFF) was created to help develop, coordinate, and oversee environmental policies and programs aimed at protecting the Oklahoma environment from pollutants associated with agricultural animals and their waste. ODAFF is the NPDES-permitting authority for CAFOs and SFOs in Oklahoma under what ODAFF calls the Agriculture Pollutant Discharge Elimination System (AgPDES). Through regulations (rules) established by the Oklahoma Concentrated Animal Feeding Operation (CAFO) Act (Title 2, Chapter 1, Article 20 – 40 to Article 20 – 64 of the State Statutes), Swine Feeding Operation (SFO) Act (Title 2, Chapter 1, Article 20 – 1 to Article 20 – 29 of the State Statutes), and Poultry Feeding Operation (PFO) Registration Act (Title 2, Chapter 10-9.1 to 10-9.25 of the State Statutes), AEMS works with producers and concerned citizens to ensure that animal waste does not impact the waters of the State. All of these animal feeding operations (AFO) require an Animal Waste Management Plan (AWMP) to prevent animal waste from entering any Oklahoma waterbody. These plans outline how the animal feeding operator will prevent direct discharges of animal waste into waterbodies as well as any runoff of waste into waterbodies. The rules for all of these AFOs recommend using the USDA NRCS' Agricultural Waste Management Field Handbook to develop their Plan. NRCS has developed Animal Waste Management software to develop this Plan.

3.2.5.1 CAFO

A CAFO is an animal feeding operation that confines and feeds at least 1,000 animal units for 45 days or more in a 12-month period (ODAFF 2014). AWMP (Section 35:17-4-12) specified in Oklahoma's CAFO regulations[1] are designed to protect water quality through the use of structures such as dikes,

[1] CAFO Animal Waste Management Plan Requirements [Title 35 (ODAFF), Chapter 17 (Water Quality), Subchapter 4 (Concentrated Animal Feeding Operations)] can be found in 35:17-4-12.

berms, terraces, ditches, to isolate animal waste from outside surface drainage, except for a 25-year, 24–hour rainfall event. AWMPs may include, but are not limited to, a Comprehensive Nutrient Management Plan per NRCS guidance or Nutrient Management Plan per EPA guidance.

CAFOs are considered no-discharge facilities for the purpose of the TMDL calculations in this report, they are not considered a source of TSS loading, and runoff of animal waste into surface waterbodies or groundwater is prohibited. CAFOs are designated by EPA as significant sources of pollution and may have the potential to cause serious impacts to water quality if not managed properly. Potential problems for CAFOs can include animal waste discharges to waters of the State and failure to properly operate wastewater lagoons. There are no CAFOs in the Study Area.

3.2.5.2 SFO

The purpose of the SFO Act is to provide for environmentally responsible construction and expansion of swine feeding operations and to protect the safety, welfare and quality of life of persons who live in the vicinity of a swine feeding operation[2]. According to the SFO Act, a "Concentrated swine feeding operation" is a lot or facility where swine kept for at least ninety (90) consecutive days or more in any twelve-month period and where crops, vegetation, forage growth or post-harvest residues are not grown during the normal growing season on any part of the lot.

A "concentrated swine feeding operation" has a certain number of swine and either discharges its pollutants into nearby waterbodies through a ditch, flushing system or other constructed device, or the pollutants flow directly into waterbodies that flow through or come into direct contact with swine at the facility.

SFOs are required to develop a Swine Waste Management Plan[3], to prevent swine waste from being discharged into surface or groundwaters. This Plan includes the BMPs being used to prevent runoff & erosion. The Swine Waste Management Plan may include, but is not limited to, a Comprehensive Nutrient Management Plan (CNMP) per NRCS guidance or Nutrient Management Plan (NMP) per EPA guidance. SFOs are not allowed to discharge to State waterbodies. The locations of the SFOs are shown in **Figure 3-1** and listed in **Table 3-6**.

[2] A concentrated swine feeding operation has at least 750 swine that each weighs over 25 kilograms (about 55 pounds), 3,000 weaned swine weighing under 25 kilograms, or 300 swine animal units. A swine animal unit is a unit of measurement for any swine feeding operation calculated by adding the following numbers: The number of swine weighing over twenty-five (25) kilograms, multiplied by four-tenths (0.4), plus the number of weaned swine weighing under twenty-five (25) kilograms multiplied by one-tenth (0.1)

[3] Swine Animal Waste Management Plan Requirements [Title 35 (ODAFF), Chapter 17 (Water Quality), Subchapter 3 (Swine Feeding Operations)] can be found in 35:17-3-14.

Table 3-6 NPDES-Permitted SFOs in Study Area

ODAFF Owner ID	EPA Facility ID	ODAFF ID	ODAFF License Number	Max # of Swine > 55 lbs	Total # of Animal Units at Facility	County	Waterbody ID and Waterbody Name
WQ0000313	OKU000403	407	990015	15,360	15,360	Woodward	**North Canadian River** OK720500010010_00
WQ0000339	OKU00025	219	1350	1,604	1,604	Woodward	
WQ0000333	OKU000227	220	1351	2,400	2,400	Major	
WQ0000338	OKU000452	221	1352	7,200	7,200	Major	
WQ0000343	OKU000396	222	1353	2,400	2,400	Major	
WQ0000336	OKU000246	365	1356	9,600	9,600	Major	

3.2.5.3 PFO

Poultry feeding operations not licensed under the Oklahoma Concentrated Animal Feeding Operation Act must register with the State Board of Agriculture. A registered PFO is an animal feeding operation which raises poultry and generates more than 10 tons of poultry waste (litter) per year. PFOs are required to develop an AWMP or an equivalent nutrient management plan (NMP) such as the ODAFF Nutrient Management Plan or Comprehensive Nutrient Management Plan per NRCS guidance. These plans describe how litter is to be stored and applied properly in order to protect water quality of streams and lakes located in the watershed. A PFO AWMP must address both nitrogen and phosphorus. In order to comply with this TMDL, the registered PFOs in the watershed and their associated management plans must be reviewed. Further actions to reduce bacterial loads and achieve progress toward meeting the specified reduction goals must be implemented.

According to the PFO rules, runoff of poultry waste from the application site is prohibited. BMPs and practices must be used to minimize movement of poultry waste to waterbodies. Grassed strips at the edge of the field must be used to prevent runoff from carrying eroded soil and poultry waste into the waterbodies. Poultry waste is not allowed to be applied to land when the ground is saturated or while it is raining; and poultry waste application is prohibited on land with excessive erosion.[4]

PFOs located in nutrient limited watersheds should have a nutrient sample analysis from that year to make available.[5] PFOs in non-nutrient limited watersheds need to have available the most recent nutrient sample analysis.

There are no PFOs located in this Study Area.

4 PFO Animal Waste Management Plan Requirements [Title 35 (ODAFF), Chapter 17 (Water Quality), Subchapter 5 (Registered Poultry Feeding Operations)] can be found in 35:17-5-5.

5 Nutrient limited watersheds are defined in the Oklahoma Water Quality Standards (Title 785, Chapter 45). Nutrient limited watersheds can be found in Appendix A of the OWQS. They are the ones designated “NLW” in the “Remarks” column.

3.2.6 Section 404 permits

Section 404 of the CWA establishes a program to regulate the discharge of dredged or fill-material into waters of the United States, including wetlands. Activities in waters of the United States regulated under this program include fill for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports) and mining projects. Section 404 requires a permit before dredged or fill material may be discharged into waters of the United States, unless the activity is exempt from Section 404 regulation (e.g. certain farming and forestry activities). Discharge of dredged or fill material in waters can be a significant source of turbidity/TSS. The State of Oklahoma uses its Section 401 Certification authority to ensure Section 404 Permits protect Oklahoma WQS.

Section 404 Permits are administrated by the U.S. Army Corps of Engineers (USACE). EPA reviews and provides comments on each permit application to make sure it adequately protects water quality and complies with applicable guidelines. Both USACE and EPA can take enforcement actions for violations of Section 404.

3.3 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. 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 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 water quality standards. A study under EPA'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 (EPA 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 a high level of fecal coliform bacteria.

Various potential nonpoint sources of TSS as indicated in the 2012 Integrated Report include sediments originating from grazing in riparian corridors of streams and creeks, municipal point source discharges, on-site treatment system, non-irrigated crop production, rangeland grazing and other sources of sediment loading (DEQ 2013). 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.

3.3.1 Wildlife

Fecal coliform bacteria are produced by all warm-blooded animals, including wildlife such as mammals and birds. In developing bacterial TMDLs it was important to identify the potential for bacterial contributions from wildlife by watershed. Wildlife is naturally attracted to riparian corridors of streams and rivers due to habitat and resource availability. With direct access to the stream channel, wildlife can be a concentrated source of bacterial 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 was difficult to assess the magnitude of bacterial 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 (ODWC) 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 2005 to 2009 was combined with an estimated annual harvest rate of 20% 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 3-7** in cfu/day provides a relative magnitude of loading in each of the TMDL watersheds impaired for bacteria.

Table 3-7 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 (x 10^9 cfu/day) of Deer Population
OK621200050010_10	Red Rock Creek	153,928	1,046	0.007	523
OK621210000030_10	Arkansas River	53,286	465	0.009	233
OK720500010010_00	North Canadian River	168,961	1,213	0.007	607
OK720500010070_00	Bent Creek	83,820	452	0.005	226
OK720500010140_10	Beaver River	66,555	6	0.0001	3
OK720500010150_00	Persimmon Creek	109,983	64	0.0006	32
OK720500010200_00	Indian Creek	48,102	4	0.0001	2

3.3.2 Non-Permitted Agricultural Activities and Domesticated Animals

There are a number of non-permitted agricultural activities that can also be sources of bacterial 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 bacterial sources include:

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

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

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

Table 3-8 provides estimated numbers of selected livestock by watershed based on the 2007 U.S. Department of Agriculture (USDA) county agricultural census data. The estimated commercially raised farm animal populations in **Table 3-8** 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 waterbodies and their tributaries.

Detailed information was not available to describe or quantify the relationship between in-stream concentrations of bacteria and land application or direct deposition of manure from commercially raised farm animal. Nor was 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 2007 is shown in **Table 3-8**. These estimates are also based on the county level reports from the 2007 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 was considered a potential source of bacterial 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

Table 3-8 Commercially Raised Farm Animals and Manure Application Area Estimates by Watershed

Waterbody ID	Waterbody Name	Cattle	Dairy Cows	Horses	Goats	Sheep	Hogs & Pigs	Ducks & Geese	Acres of Manure Application
OK621200050010_10	Red Rock Creek	19,731	104	236	0	704	141	20	433
OK621210000030_10	Arkansas River	4,187	88	106	0	342	78	25	83
OK720500010010_00	North Canadian River	19,949	109	221	0	301	40	9	287
OK720500010070_00	Bent Creek	8,105	26	103	0	133	25	5	52
OK720500010140_10	Beaver River	6,731	6	114	0	209	0	6	96
OK720500010150_00	Persimmon Creek	10,930	14	183	0	326	82	9	196
OK720500010200_00	Indian Creek	4,877	4	84	0	154	0	4	70

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

Waterbody ID	Waterbody Name	Cattle	Dairy Cows	Horses	Goats	Sheep	Hogs & Pigs	Ducks & Geese	Total
OK621200050010_10	Red Rock Creek	2,052,024	10,504	99	0	8,448	1,523	514	2,073.142
OK621210000030_10	Arkansas River	435,448	8,888	45	0	4,104	842	643	450,013
OK720500010010_00	North Canadian River	2,074,696	11,009	93	0	3,612	432	231	2,090,104
OK720500010070_00	Bent Creek	842,920	2,626	43	0	1,596	270	129	847,596
OK720500010140_10	Beaver River	700,024	606	48	0	2,508	0	154	703,349
OK720500010150_00	Persimmon Creek	1,136,720	1,414	77	0	3,912	886	231	1,143,254
OK720500010200_00	Indian Creek	507,208	404	35	0	1,848	0	103	509,605

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. These estimates are presented in **Table 3-9**. 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. Because of their numbers, cattle again appear to represent the most likely commercially raised farm animal source of fecal bacteria.

3.3.3 Domestic Pets

Fecal matter from dogs and cats, which can be transported to streams by runoff from urban and suburban areas, is a potential source of bacterial loading. On average 37.2% of the nation's households own dogs and 32.4% own cats. In 2007, the average number of pets per household was 1.7 dogs and 2.2 cats (American Veterinary Medical Association 2007). Using the U.S. Census data at the block level (U.S. Census Bureau 2010), dog and cat populations can be estimated for each watershed. **Table 3-10** summarizes the estimated number of dogs and cats for the watersheds of the Study Area.

Table 3-10 Estimated Numbers of Pets

Waterbody ID	Waterbody Name	Dogs	Cats
OK621200050010_10	**Red Rock Creek**	572	644
OK621210000030_10	**Arkansas River**	356	401
OK720500010010_00	**North Canadian River**	486	548
OK720500010070_00	**Bent Creek**	283	320
OK720500010140_10	**Beaver River**	1,705	1,922
OK720500010150_00	**Persimmon Creek**	243	274
OK720500010200_00	**Indian Creek**	231	261

Table 3-11 provides an estimate of the fecal coliform production 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 3-11 Estimated Fecal Coliform Daily Production by Pets ($\times10^{9}$ counts/day)

Waterbody ID	Waterbody Name	Dogs	Cats	Total
OK621200050010_10	**Red Rock Creek**	1,887	348	2,235
OK621210000030_10	**Arkansas River**	1,175	217	1,392
OK720500010010_00	**North Canadian River**	1,604	296	1,900
OK720500010070_00	**Bent Creek**	935	173	1,108
OK720500010140_10	**Beaver River**	5,626	1,038	6,664
OK720500010150_00	**Persimmon Creek**	803	148	951
OK720500010200_00	**Indian Creek**	764	141	905

3.3.4 Failing Onsite Wastewater Disposal Systems and Illicit Discharges

DEQ 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 (DEQ 2011a). OSWD systems and illicit discharges can be a source of bacterial loading to streams and rivers. Bacterial 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 may discharge to creeks through springs and seeps.

To estimate the potential magnitude of OSWDs fecal bacterial 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 which was the last year in which there were Census questions about plumbing facilities (U.S. Department of Commerce, Bureau of the Census 1990). 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 block 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 1990 American Housing Survey for Oklahoma conducted by the U.S. Census Bureau estimates that, nationwide, 10% of occupied homes with OSWD systems experience malfunctions during the year (U.S. Department of Commerce, Bureau of the Census 1990). A study conducted by Reed, Stowe & Yanke, LLC (2001) reported that approximately 12% of the OSWD systems in east Texas and 8% 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 was 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 3-12** summarizes estimates of sewered and unsewered households and the average number of septic tanks per square mile for each watershed in the Study Area.

For the purpose of estimating fecal coliform loading in watersheds, an OSWD failure rate of 12% was used in the calculations made to characterize fecal coliform loads in each watershed.

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

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

Table 3-12 Estimates of Sewered and Unsewered Households

Waterbody ID	Waterbody Name	Public Sewer	Septic Tank	Other Means	Housing Units	# of Septic Tanks / Mile^2
OK621200050010_10	**Red Rock Creek**	474	417	13	904	1.73
OK621210000030_10	**Arkansas River**	347	208	8	563	2.50
OK720500010010_00	**North Canadian River**	320	430	19	769	1.63
OK720500010070_00	**Bent Creek**	252	195	1	448	1.49
OK720500010140_10	**Beaver River**	2,369	323	4	2,696	3.1
OK720500010150_00	**Persimmon Creek**	93	287	5	385	1.67
OK720500010200_00	**Indian Creek**	217	146	3	366	1.94

The average of number of people per household was calculated to be 2.3 for counties in the Study Area (U.S. Census Bureau 2010). 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 3-13**.

Table 3-13 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)
OK621200050010_10	**Red Rock Creek**	153,928	417	50	305
OK621210000030_10	**Arkansas River**	53,286	208	25	152
OK720500010010_00	**North Canadian River**	168,961	430	52	315
OK720500010070_00	**Bent Creek**	83,820	195	23	143
OK720500010140_10	**Beaver River**	66,555	323	39	236
OK720500010150_00	**Persimmon Creek**	109,983	287	34	210
OK720500010200_00	**Indian Creek**	48,102	146	18	107

3.4 Summary of Sources of Impairment

3.4.1 Bacteria

There are no continuous, permitted point sources of bacteria in the Study Area, except the Beaver River (OK720500010140_10) watershed, which require bacterial TMDLs. The Beaver River (OK720500010140_10) watershed has one continuous point source discharger [Woodward WWT (OK0034509)] which contributes bacteria, but the available data suggests that the proportion of bacteria from that point source was minor since that discharger has a bacterial limit in their permit. Therefore, the conclusion was that nonsupport of PBCR use in these watersheds was caused by nonpoint sources of bacteria. There are six SFOs in the North Canadian River

(OK720500010010_00) watersheds. But since SFOs are not allowed to discharge or allow the runoff of animal waste, they are not considered to be major sources of the bacteria in the North Canadian River watershed. Therefore, the various nonpoint sources are considered to be the major source of bacterial loading in each watershed that requires a TMDL.

Table 3-14 below provides a summary of the estimated fecal coliform loads in percentage for the four major nonpoint source categories (commercially raised farm animals, domesticated dogs & cats, deer, and septic tanks) that contribute to the elevated bacterial concentrations in each watershed. Because of their numbers and animal unit production of bacteria, 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 bacterial source tracking studies around the nation demonstrate that wild birds and mammals represent a major source of the fecal bacteria found in streams.

Table 3-14 Percentage Contribution of Fecal Coliform Load Estimates from Nonpoint Sources to Land Surfaces

Waterbody ID	Waterbody Name	Commercially Raised Farm Animals	Pets	Deer	Estimated Loads from Septic Tanks
OK621200050010_10	**Red Rock Creek**	99.85%	0.11%	0.03%	0.01%
OK621210000030_10	**Arkansas River**	99.54%	0.37%	0.05%	0.05%
OK720500010010_00	**North Canadian River**	99.87%	0.09%	0.03%	0.01%
OK720500010070_00	**Bent Creek**	99.83%	0.13%	0.03%	0.02%
OK720500010140_10	**Beaver River**	99.03%	0.94%	0.0004%	0.03%
OK720500010150_00	**Persimmon Creek**	99.9%	0.08%	0.003%	0.02%
OK720500010200_00	**Indian Creek**	99.8%	0.18%	0.0004%	0.02%

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.

3.4.2 Turbidity

Of the two watersheds in the Study Area that require turbidity TMDLs, neither has a permitted point source for TSS. Stormwater runoff was not considered as the cause of turbidity impairment because the turbidity standard does not apply. In addition, stormwater dischargers have a TSS limit in their permit and must use BMPs to prevent sediment from leaving their site and entering a waterbody. Therefore nonsupport of WWAC use, in the Study Area, was 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 was 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 was from natural or anthropogenic processes was not feasible in this TMDL development.

SECTION 4 TECHNICAL APPROACH AND METHODS

4.1 POLLUTANT LOADS AND TMDLS

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:

$$TMDL = WLA\_{WWTF} + WLA\_{MS4} + LA + MOS$$

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 are met.

For *E. coli* or Enterococci bacteria, TMDLs are expressed as colony-forming units per day, and represent the maximum one-day load the stream can assimilate while still attaining the WQS. Percent reduction goals are also calculated to aid to characterizing the possible magnitude of the effort to restore the segment to meeting water quality criterion. Turbidity TMDLs are derived from TSS calculations and expressed in pounds (lbs) per day which represents the maximum one-day load the stream can assimilate while still attaining the WQS, as well as a PRG.

4.2 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 from 1999 to 2009 at stations within the Study Area.

4.2.1 Steps Prior to Regression

Prior to developing the regression, the following steps were taken to refine the dataset:

- Remove data collected under high flow conditions exceeding the base-flow criterion. This means that measurements corresponding to flow exceedance percentiles lower than 25th were not be 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 was 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 was not excluded from analysis because most likely the rainfall occurred after the sample was taken,

- Check the non-detect rate of TSS data in order to determine which regression method in this section was used. Non-detects are TSS sample observations less than the detection limit (10 mg/L).

4.2.2 Non-Detect Rate Less Than or Equal to (≤) 15%

For observed data where the non-detect rate is less than or equal to (≤) 15%, EPA (2006) recommends using substitution. When ordinary least squares (OLS) regression 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 in-stream 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 was 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 was calculated as:

$$m1 = \sqrt{m \cdot m'} = \sin(r) \cdot \frac{s_y}{s_x}$$

$m1$ was the slope of the LOC line

m was the TSS on turbidity OLS slope

m' was the turbidity on TSS OLS slope

r was the TSS-turbidity correlation coefficient

s_y was the standard deviation of the TSS measurements

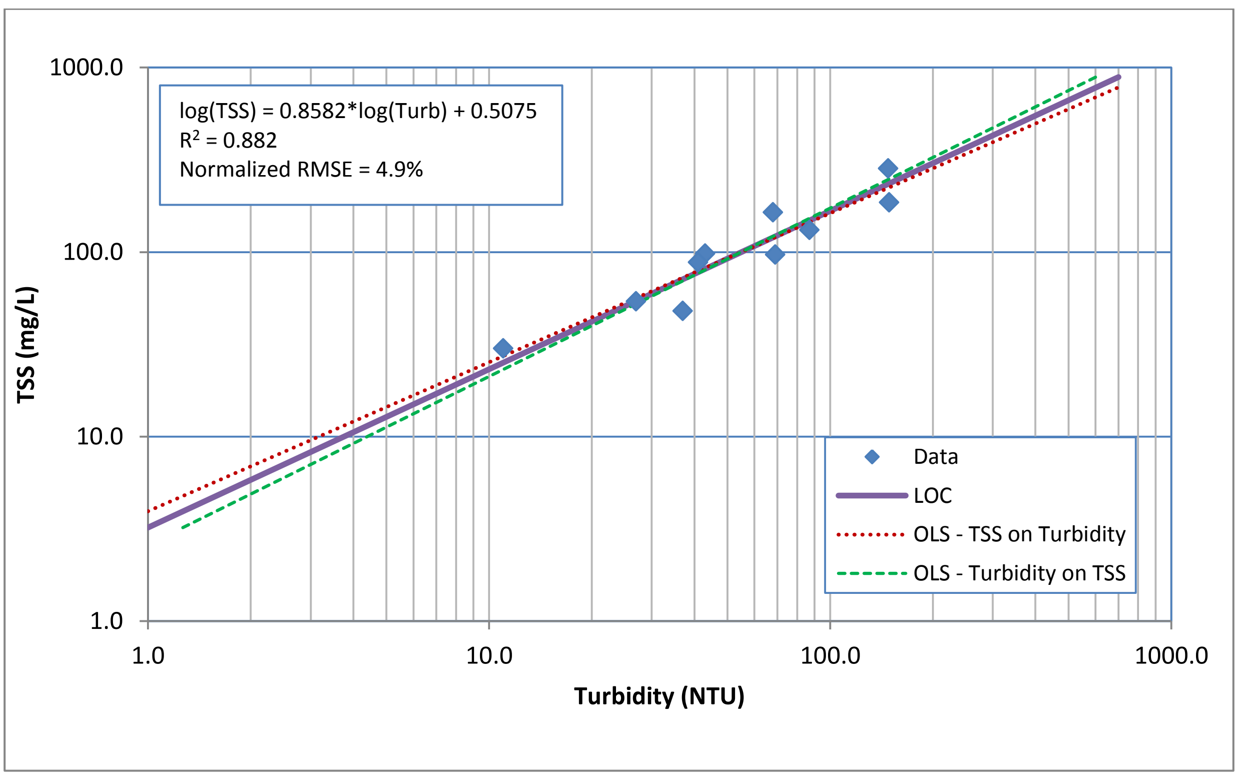
s_x was the standard deviation of the turbidity measurements

The r can range from -1 to 1 with 0 indicating no correlation, and negative r indicating an inverse correlation. Correlation values of 0 to 0.5 indicate a weaker correlation whereas values greater than 0.5 indicate a strong correlation. As a result, correlations of approximately 0.5 or greater are commonly used in TMDL studies (Christensen, Jian, and Ziegler; 2000). This Study considered an R-square (R^2 or coefficient of determination) value of approximately 0.5 or greater to represent a satisfactory relationship between turbidity and TSS, if based on at least 10 observations.

The intercept of the LOC (b1) was 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.

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 4.9% which means the root mean square error (RMSE) was 4.9% 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 was explained by the LOC. The regression equation can be used to convert the turbidity standard of 50 NTUs to TSS goals.

Figure 4-1 Linear Regression for TSS-Turbidity for the Arkansas River (OK621210000030_10)



It was noted that there were 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 (Q3) and 25th percentile (Q1) of distances between observed points and the LOC. Using the Tukey method, any point with an error greater than Q3 + 1.5* IQR or less than Q1 – 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 was 99.73% while the probability for the Tukey Method was 99.65%. If three times the standard deviation was used to identify outliers, it was necessary to first confirm that the residuals are indeed normally distributed. This was 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 segment is provided in Section 5.1.

4.2.3 Observed Data of Non-Detect Rate Greater than 15%

For observed data where the non-detect rate was greater than 15%, follow these steps:

- If the number of samples was less than 25 (Helsel, 2002; p. 360), combine sample data based on their ecoregion, geological area, and beneficial use.
- Log-transform both turbidity and TSS data to minimize effects of their non-linear data distributions.
- Use methods for estimating summary statistics of data which include non-detects: simple substitution, distributional, and robust methods (Helsel and Hirsch, 2002).
- Compare results for the mean and the variance for desirable methods. Extrapolated values are not considered as estimates for specific samples, but only used collectively to estimate summary statistics.
- Choose regression methods for data-sets containing non-detects depend on distribution of data. If the data are linear and normally distributed without

outliers, parametric methods may be used. Non-parametric methods may be used regardless of whether or not they are linear (Huston and Juarez-Colunga, 2009).

- Use statistical software (such as Excel, JMP, R, Minitab, or SAS) to calculate the turbidity-TSS relationship. Then, the TSS goal was computed based on regression coefficients.

- Replace Less-thans with their detection limits for percentage reduction goal (PRG) calculation. Detection limit substitution may not be the best estimation method, but it was the best conservative method for calculating PRG.

If a small proportion of the observations are not detected, these may be substituted with a value (EPA 2006), the detection limit (dl) in this study. However, substituting for non-detects may incorrectly alter the mean and the variance. Therefore, censored data regression was issued for the data set of censoring greater than 15%. Before determine the relationship between turbidity and TSS, censored data were set as a range from one (TSS=1[1] mg/L) to detection limit (TSS=10 mg/L). Then, turbidity and TSS data were log-transformed and statistical software R determined regression relationships.

With statistical software R, maximum likelihood estimation (MLE) or non-parametric approaches can estimate correlation and regression coefficients. If extreme outliers were not present in the sample data and the distributions of points were close to trend line, parametric method (MLE) performed similar or slightly better than non-parametric method (Kendall's tau).

After computing TSS goal with estimated regression, censored data were replaced with their detection limit (dl). This simple substitution was the most conservative to calculate PRG among estimation methods for censored data. Then, NRMSE and R-square (R^2) were computed as:

$$RMSE = (Standard\ Error\ of\ Slope) \cdot \sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

$$NRMSE = \frac{RMSE}{\bar{y}}$$

$$R^2 = 1 - \left[\frac{exp(loglik_{intercept})}{exp(loglik_{model})}\right]^{\frac{2}{n}}$$

Where xi = log(turbidity)i, yi = log(TSS)i, i = 1…n, x¯ = average of xi, y¯ = average of yi, and n = number of observes.

[1] Having a TSS of "0" would be almost impossible because there is always some sediment in the background. Consequently, "1" is used as the lowest amount of TSS.

4.3 STEPS TO CALCULATING 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 can help 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 4.3.1 through 4.3.3 below:

1. Prepare flow duration curves for gaged and ungaged WQM stations.

2. Estimate existing loading in the waterbody using ambient bacterial water quality data.

3. Estimate loading in the waterbody using measured TSS water quality data and turbidity-converted data.

4. Use LDCs to identify if there was a critical condition.

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 WWTF effluents would dominate the base flow of the impaired water. However, flow range was only a general indicator of the relative proportion of point/nonpoint contributions. It was 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 during low flows 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.

4.3.1 Development of Flow Duration Curves

Flow duration curves (FDC) 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. Four of the seven waterbodies in the Study Area do not have USGS gage stations. 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 B**.

To estimate flows at an ungaged site:

- Identify an upstream or downstream flow gage
- Calculate the contributing drainage areas of the ungaged sites and the flow gage
- Calculate 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 was calculated. The flow value was 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 (x-axis), which is numbered from 0% to 100%, and may or may not be logarithmic. The lowest measured flow occurs at an exceedance frequency of 100% indicating that flow has equaled or exceeded this value 100% of the time, while the highest measured flow was found at an exceedance frequency of 0%. The median flow occurs at a flow exceedance frequency of 50%. The flow exceedance percentiles for each waterbody addressed in this report are provided in **Appendix B**.

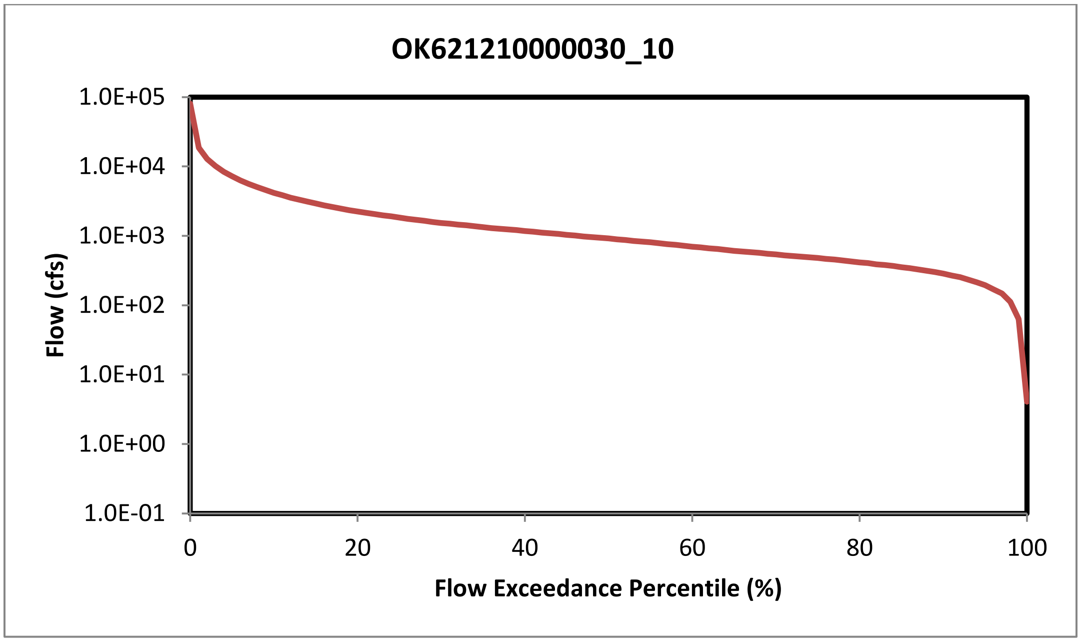
While the number of observations required to develop a flow duration curve was not rigorously specified, a flow duration curve is usually based on more than one year of observations, and encompasses inter-annual and seasonal variation. Ideally, the drought of record and flood of record are included in the observations. For this purpose, the long-term flow gaging stations operated by the USGS are utilized (USGS 2009) 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 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% and downward at a frequency near 100%, often with a relatively constant slope in between. For sites that on occasion exhibit no flow, the curve intersects the abscissa at a frequency less than 100%. 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 quantization. An example of a typical flow duration curve is shown in **Figure 4-2**. Flow duration curves for each impaired waterbody in the Study Area are provided in Section 5.2.

Figure 4-2 Flow Duration Curve for the Arkansas River (OK621210000030_10)



4.3.2 Using Flow Duration Curves to Calculate Load Duration Curves

4.3.2.1 Bacteria

Existing in-stream loads can be estimated using FDCs. For bacteria:

- Calculate the geometric mean of all water quality observations from the period of record selected for the waterbody.
- Convert the geometric mean concentration value to loads by multiplying the flow duration curve by the geometric mean of the ambient water quality data for each bacterial indicator.

4.3.2.3 TSS

For TSS:

- Match the water quality observations with the flow data from the same date.

- Convert 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 multiply the flow by the TSS concentration to calculate daily loads.

4.3.3 Using Load Duration Curves to Develop TMDLs

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).

4.3.3.1 Step 1 - Generate LDCs

LDCs are similar in appearance to flow duration curves. However for bacteria, the ordinate is expressed in terms of a bacterial load in cfu/day, and for TSS the ordinate is expressed in terms of a load in lbs/day. The bacterial curve represents the geometric mean water quality criterion for *E. coli* or Enterococci bacteria expressed in terms of a load through multiplication by the continuum of flows historically observed at the site. Bacterial TMDLs are not easily expressed in mass per day, the following equation calculates a load in the units of cfu per day. The cfu is a total for the day at a specific flow for bacteria, which is the best equivalent to a mass per day of a pollutant such as sulfate. Expressing bacterial TMDLs as cfu per day is consistent with EPA's Protocol for Developing Pathogen TMDLs (EPA 2001).

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 following are the basic steps in developing an LDC:

1. Obtain daily flow data for the site of interest from the USGS.

2. Sort the flow data and calculating flow exceedance percentiles.

3. Obtain the water quality data from the primary contact recreation season (May 1 through September 30).

4. Obtain available turbidity and TSS water quality data.

5. Display a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQS numerical criterion for each parameter (geometric mean standard for bacterial and TSS goal for turbidity).

6. For bacterial TMDLs, display another curve derived by plotting the geometric mean of all existing bacteria samples continuously along the full spectrum of flow exceedance percentiles which represents LDC (See Section 5).

7. For turbidity TMDLs, match the water quality observations with the flow data from the same date and determining the corresponding exceedance percentile (See Section 5).

The flow exceedance frequency (x-value of each point) was obtained by looking up the historical exceedance frequency of the measured or estimated flow, in other words, the percent of historical observations that are equal to or exceed the measured or estimated flow.

As noted earlier, runoff has a strong influence on loading of nonpoint pollution. Flows do not always correspond directly to runoff. High flows may occur in dry weather (e.g., lake release to provide water downstream) and runoff influence may be observed with low or moderate flows (e.g., persistent high turbidity due to previous storm).

4.3.3.1.1 Bacterial LDC

For bacterial 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 = 126 cfu/100 mL (E. coli); or 33 cfu/100 mL (Enterococci)

Unit conversion factor = 24,465,525

Historical observations of bacteria were plotted as a separate LDC based on the geometric mean of all samples. It is noted that the LDCs for bacteria were based on the geometric mean standards or geometric mean of all samples. It is inappropriate to compare single sample bacterial observations to a geometric mean water quality criterion in the LDC; therefore individual bacterial samples are not plotted on the LDCs.

4.3.3.1.2 Turbidity LDC

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

Historical observations of TSS and/or turbidity concentrations are paired with flow data and are plotted on the LDC for a stream. TSS loads representing exceedance of water quality criteria fall above the TMDL line.

4.3.3.2 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 bacterial TMDLs in this report, an explicit MOS of 10% was selected. The 10% MOS has been used in other approved bacterial 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. MOS is set to be the next percentile (count by 5%) greater than the NRMSE. For example, for any NRMSE greater than 10% but less than 15%, MOS will be 15%.

4.3.3.3 Step 3 - Calculate WLA

As previously stated, the pollutant load allocation for point sources was defined by the WLA. For bacterial 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 EPA guidance includes OPDES-permitted stormwater discharges as point source discharges and, therefore, part of the WLA. For TMDL development purposes when addressing turbidity or TSS, a WLA 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 were 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 was not necessary for MS4s.

The LDC approach recognizes that the assimilative capacity of a waterbody depends on the flow, and that maximum allowable loading varies with flow condition. WLAs can be expressed in terms of a single load, or as different loads allowable under different flows. WLAs may be set to zero in cases of watersheds with no existing or planned continuous permitted point sources.

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 WWTF

For watersheds with permitted point sources discharging the pollutant of concern, OPDES permit limits are used to derive WLAs for evaluation as appropriate for use in the TMDL. 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 was not available for a WWTF, then the average of monthly flow rates derived from DMRs can be used. WLA values for each OPDES wastewater discharger are then summed to represent the total WLA for a given segment. Using this information bacterial and TSS WLAs can be calculated using the approach as shown in the equations below.

4.3.3.3.1 WLA for Bacteria

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

Where:

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

Flow (mgd) = permitted flow unit conversion factor = 37,854,120

4.3.3.3.2 WLA for TSS

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

Where:

WQ goal= Waterbody specific water quality goal provided in **Table 5-1*****, or monthly TSS limit in the current permit, whichever is smaller***

Flow (mgd) = permitted flow or average monthly flow

Unit conversion factor = 8.3445

4.3.3.4 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 OPDES permit limits for MS4s as BMPs.

LAs can be calculated under different flow conditions. The LA at any particular flow exceedance is calculated as shown in the equation below.

LA = TMDL - WLA_WWTF - WLA_MS4 – MOS

4.3.3.4.1 Bacterial WLA for MS4s

For bacterial TMDLs, if there are no permitted MS4s in the Study Area, WLA_MS4 is set to zero. When there are permitted MS4s in a watershed, 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.

4.3.3.4.2 Turbidity WLA for MS4s

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.

4.3.3.5 Step 5 - Estimate Percent Load Reduction

Percent load reductions are not required items and are provided for informational purposes when making inferences about individual TMDLs or between TMDLs usually in regard to implementation of the TMDL.

The LDC approach recognizes that the assimilative capacity of a waterbody depends on stream flow and that the maximum allowable loading varies with flow condition. Existing loading and load reductions required to meet the TMDL can also be calculated under different flow conditions. The difference between existing loading and the TMDL is used to calculate the loading reductions required. Percent reduction goals (PRG) are calculated through an iterative process of taking a series of percent reduction values applying each value uniformly to the measured concentrations of samples and verifying:

1. If the geometric mean of the reduced values of all samples is less than the geometric mean standards (for bacteria) or

2. If no more than 10% of the reduced values of the samples under flow-base conditions exceed the TMDL (for turbidity).

4.3.3.5.1 WLA Load Reduction

The WLA load reduction for bacteria was not calculated as it was assumed that continuous dischargers (OPDES-permitted WWTFs) are adequately regulated under existing permits to achieve WQS at the end-of-pipe and, therefore, no WLA reduction would be required. Currently, bacterial limits are not required for lagoon systems. Lagoon systems located within a sub-watershed of bacterially-impaired stream segment required to meet *E. coli* standards at the discharge when their permits are renewed.

MS4s are classified as point sources, but they are nonpoint sources in nature. Therefore, the percent reduction goal calculated for LA is also applied to the MS4 area within the bacterially-impaired sub-watershed. If there are no MS4s located within the Study Area requiring a TMDL, then there was 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 were no reductions
- If permitted TSS limit is greater than TSS goal for the receiving stream, the permit limit was set at the TSS goal.

4.3.3.5.2 LA Load Reduction

After existing loading estimates are computed for each pollutant, nonpoint load reduction estimates for each segment are calculated by using the difference between the estimate of existing loading and the allowable loading (TMDL) under all flow conditions. This difference is expressed as the overall PRG for the impaired waterbody. The PRG serves as a guide for the amount of pollutant reduction necessary to meet the TMDL.

E. coli and Enterococci: Because WQSs are considered to be met if the geometric mean of all future data is maintained below the geometric mean criteria (TMDL).

Turbidity: The PRG is the load reduction that ensures that no more than 10% of the samples under flow-base conditions exceed the TMDL.

SECTION 5 TMDL CALCULATIONS

5.1 SURROGATE TMDL TARGET FOR TURBIDITY

The non-detect rates for both turbidity impaired streams are less than 15%. Using the LOC method described in Section 4.1, correlations between TSS and turbidity were developed for establishing the statistics of the regressions and the resulting TSS goals were provided in **Table 5-1**. The regression analysis for each impaired waterbody in the Study Area using the LOC method is displayed in **Figures 5-1** through **5-2**.

Table 5-1 Regression Statistics and TSS Goals

Waterbody ID	Waterbody Name	R-square	NRMSE	TSS Goal (mg/L)[a]	MOS[b]
OK621210000030_10	**Arkansas River**	0.88	4.9%	92.4	5%
OK720500010150_00	**Persimmon Creek**	0.93	5.4%	71.8	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)

Figure 5-1 Linear Regression for TSS-Turbidity for the Arkansas River (OK621210000030_10)

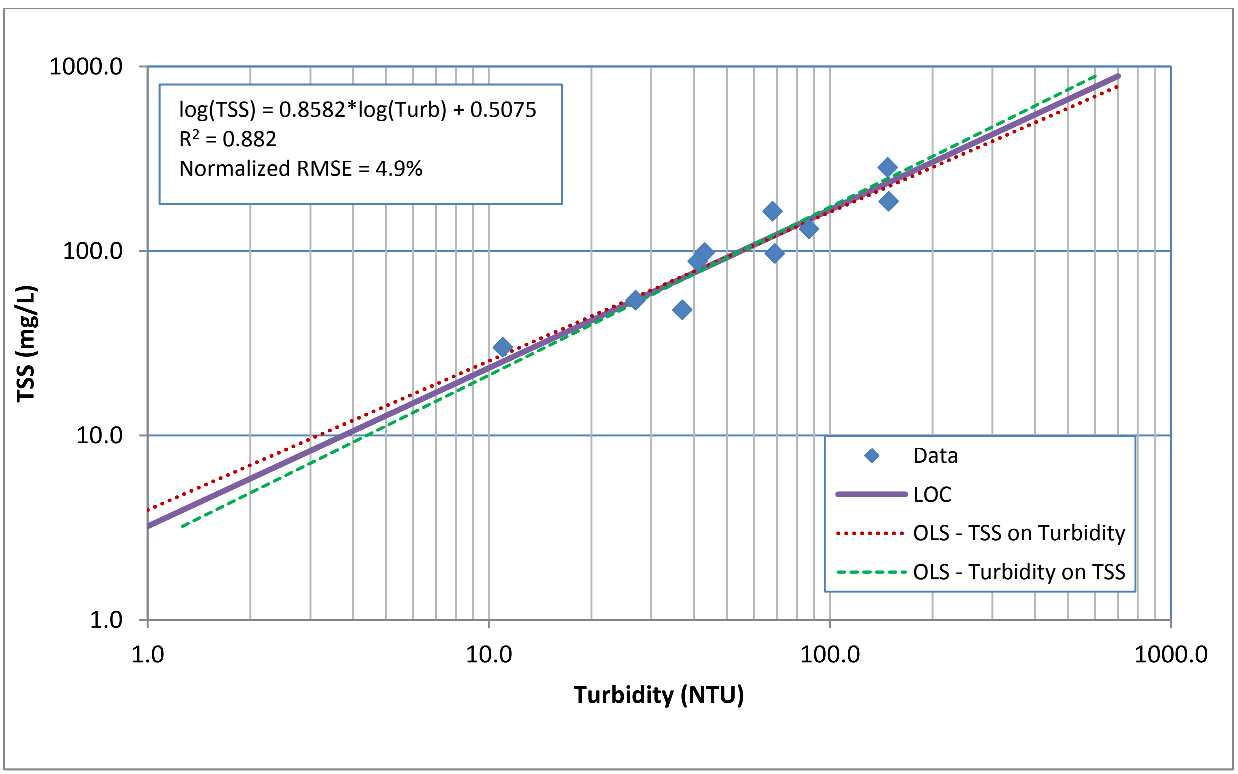
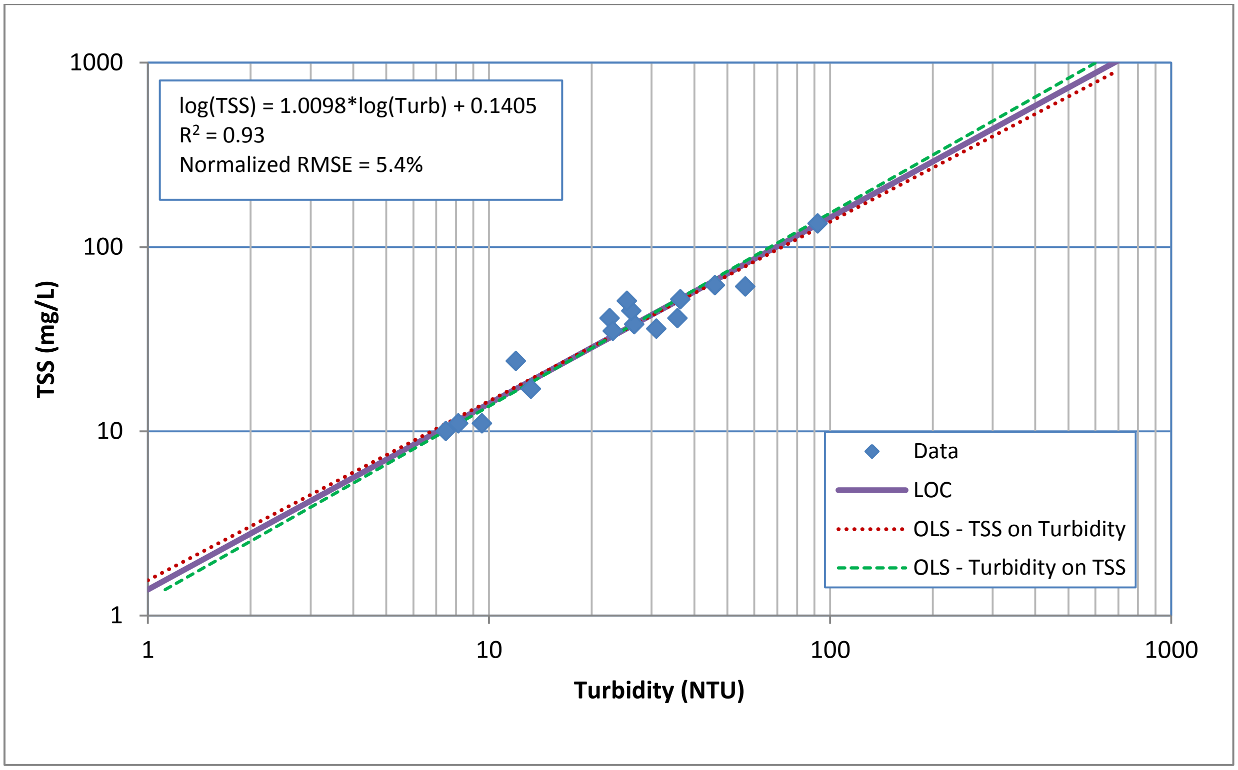


Figure 5-2 Linear Regression for TSS-Turbidity for Persimmon Creek (OK720500010150_00)



5.2 Flow Duration Curve

Following the same procedures described in Section 4.3, a flow duration curve for each stream segment in this study was developed. These are shown in **Figures 5-3** through **Figure 5-9**.

No flow gage exists on Red Rock Creek (OK621200050010_10). Therefore, flows for this waterbody were estimated using the watershed area ratio method based on measured flows at USGS gage station 07153000 located in an adjacent watershed (Black Bear Creek at Pawnee, OK) since they are geographically close and have similar land uses. The flow duration curve was based on measured flows from 1944 to 2013.

The flow duration curve for the Arkansas River (OK621210000030_10) was estimated based on measured flows at USGS gage station 07146500 on the Arkansas River at Arkansas City, KS. USGS flow data used to develop the flow duration curve range from 1902 to 2013.

The flow duration curve for the North Canadian River (OK720500010010_00) was estimated based on measured flows at USGS gage station 07238000 on the North Canadian River near Seiling, OK. USGS flow data used to develop the flow duration curve range from 1946 to 2013.

No flow gage exists on Bent Creek (OK720500010070_00), Persimmon Creek (OK720500010150_00), and Indian Creek (OK720500010200_00). Therefore, flows for these waterbodies were estimated using the watershed area ratio method based on measured flows at USGS gage station 07301420 located in an adjacent watershed (Sweetwater Creek near Sweetwater, OK) since they are geographically close and have similar land uses. The flow duration curve was based on measured flows from 1986 to 2013.

The flow duration curve for the Beaver River (OK720500010140_10) was estimated based on measured flows at USGS gage station 07237500 on the North Canadian River at Woodward, OK. USGS flow data used to develop the flow duration curve range from 1905 to 2013.

Figure 5-3 Flow Duration Curve for Red Rock Creek (OK621200050010_10)

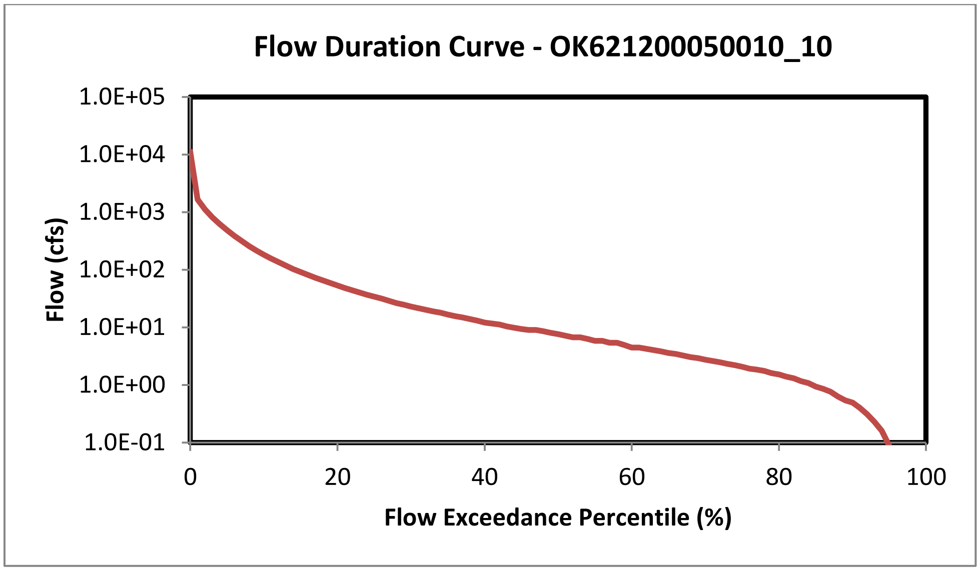


Figure 5-4 Flow Duration Curve for the Arkansas River (OK621210000030_10)

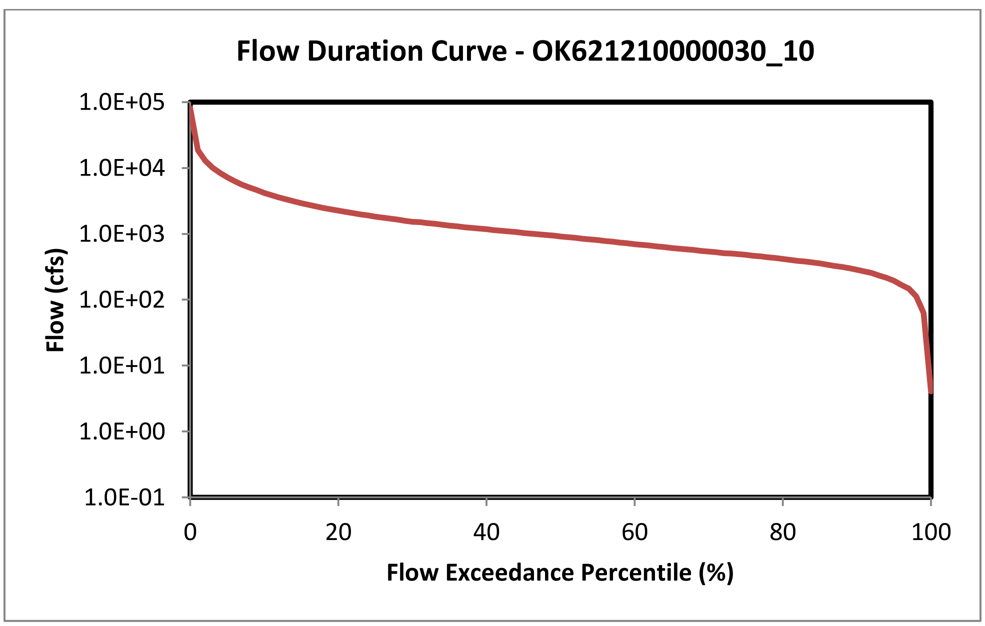


Figure 5-5 Flow Duration Curve for the North Canadian River (OK720500010010_00)

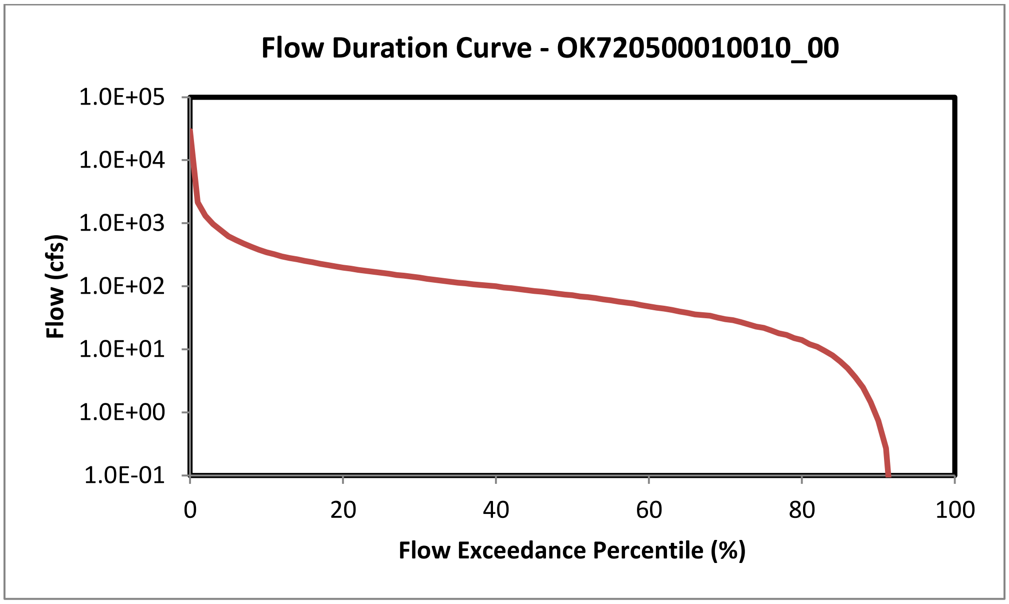


Figure 5-6 Flow Duration Curve for Bent Creek (OK720500010070_00)

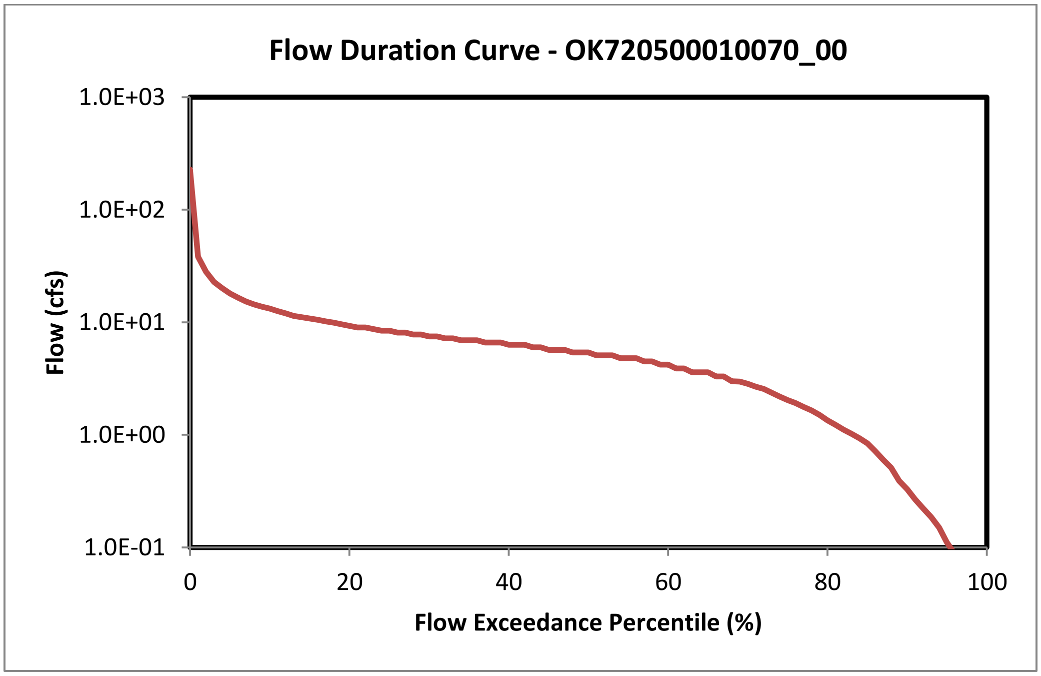


Figure 5-7 Flow Duration Curve for the Beaver River (OK720500010140_10)

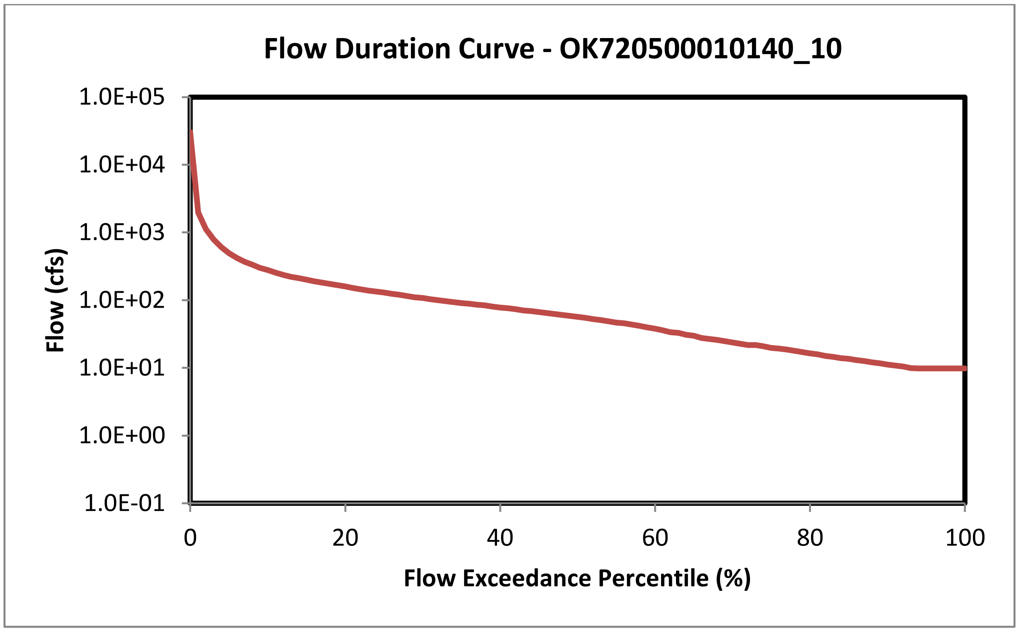


Figure 5-8 Flow Duration Curve for Persimmon Creek (OK720500010150_00)

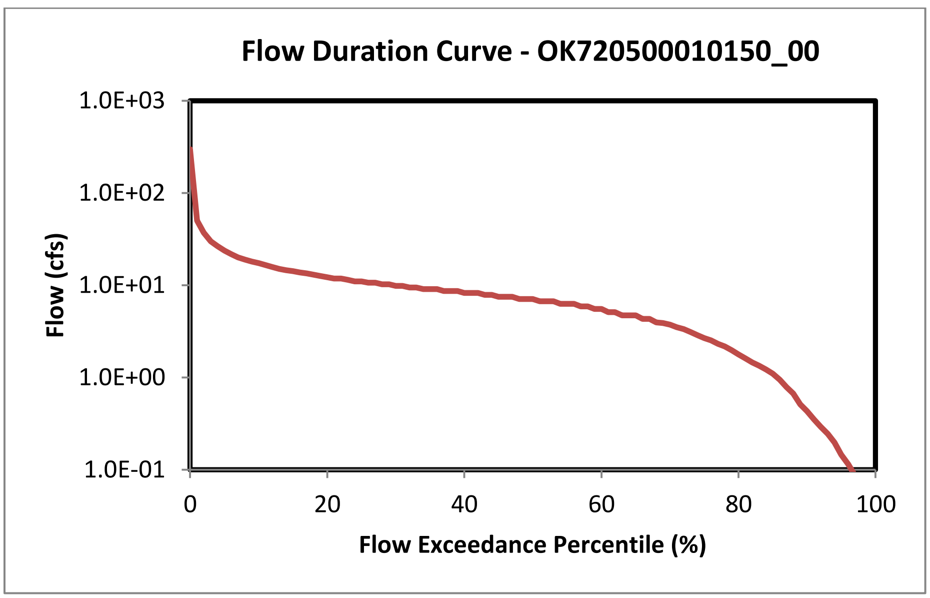
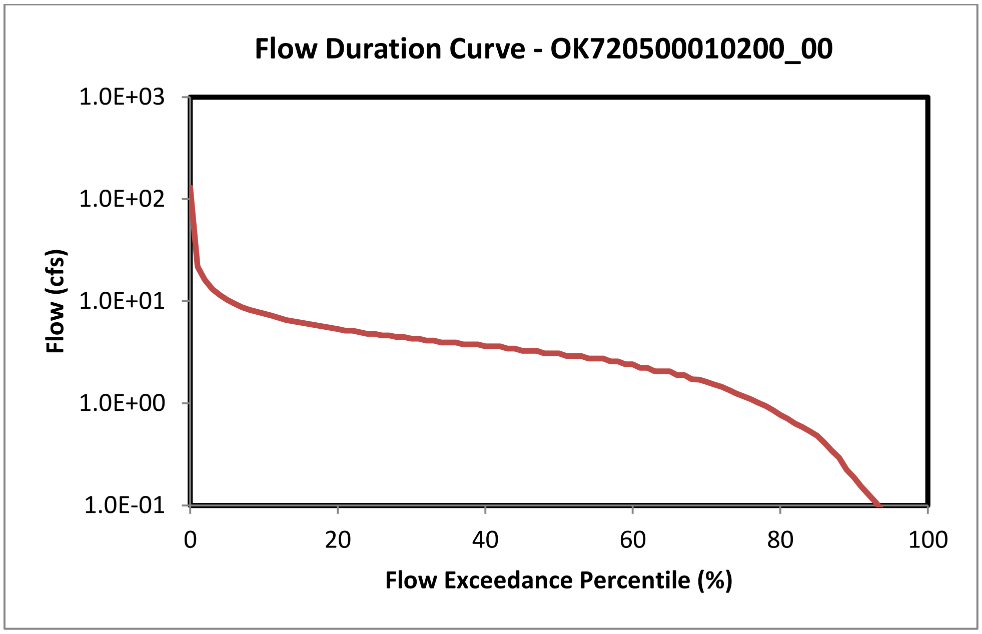


Figure 5-9 Flow Duration Curve for Indian Creek (OK720500010200_00)



5.3 Estimated Loading and Critical Conditions

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

5.3.1 Bacterial LDC

To calculate the allowable bacterial load, the flow rate at each flow exceedance percentile was multiplied by a unit conversion factor (*24,465,525*) and the geometric mean water quality criterion for each bacterial indicator. This calculation produces the maximum bacterial load in the stream over the range of flow conditions. The allowable bacterial (*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 was expressed in terms of a bacterial load.

To estimate existing loading, the geometric mean of all bacterial observations (concentrations) for the primary contact recreation season (May 1st through September 30th) from 2001 to 2012 are paired with the flows measured or estimated in that waterbody. Pollutant loads are then calculated by multiplying the measured bacterial concentration by the flow rate and the unit conversion factor of *24,465,525*. The bacterial LDCs developed for each impaired waterbody are shown in **Figures 5-10** through **5-19**. Each waterbody had an LDC for Enterococci and three out of seven waterbodies had an LDC for *E.coli*.

- The LDCs for Red Rock Creek (**Figure 5-10**) were based on Enterococci bacterial measurements collected during primary contact recreation season at WQM stations OK621200-05-0010M.

- The LDC for the Arkansas River (**Figure 5-11**) was based on Enterococci measurements during primary contact recreation season at WQM stations 621210000010-001AT.

- The LDC for the North Canadian River (**Figure 5-12**) was based on Enterococci measurements during primary contact recreation season at WQM stations 720500010010-001AT.

- The LDCs for the Bent Creek (**Figure 5-13** and **5-14**) were based on *E.coli* and Enterococci measurements during primary contact recreation season at WQM stations OK720500-01-0070D.

- The LDC for the Beaver River (**Figure 5-15**) was based on Enterococci measurements during primary contact recreation season at WQM stations 720500010140-001AT. The horizontal WLA reflects the influence of the continuous discharge using the permitted design flow (4.0 mgd) of the municipal discharger, Woodward WWT (OK0034509).

- The LDCs for the Persimmon Creek (**Figure 5-16** and **5-17**) were based on *E.coli* and Enterococci measurements during primary contact recreation season at WQM stations OK720500-01-0150G.

- The LDCs for the Indian Creek (**Figure 5-18** and **5-19**) were based on *E.coli* and Enterococci measurements during primary contact recreation season at WQM stations OK720500-01-0200D.

Figure 5-10 Load Duration Curve for Enterococci in Red Rock Creek (OK621200050010_10)

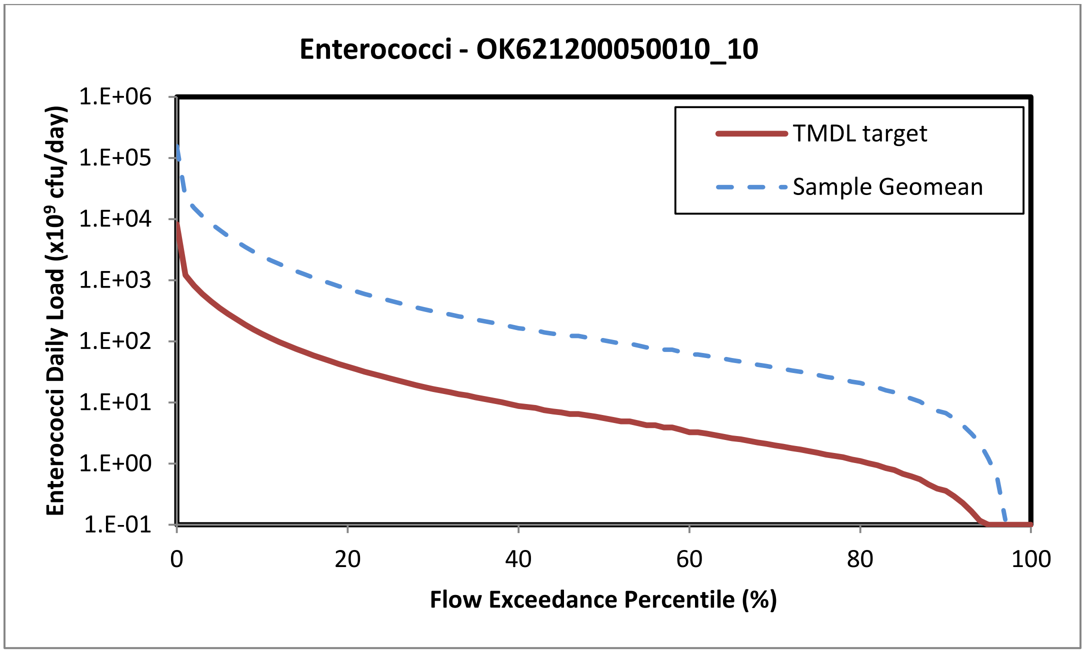


Figure 5-11 Load Duration Curve for Enterococci in the Arkansas River (OK621210000030_10)

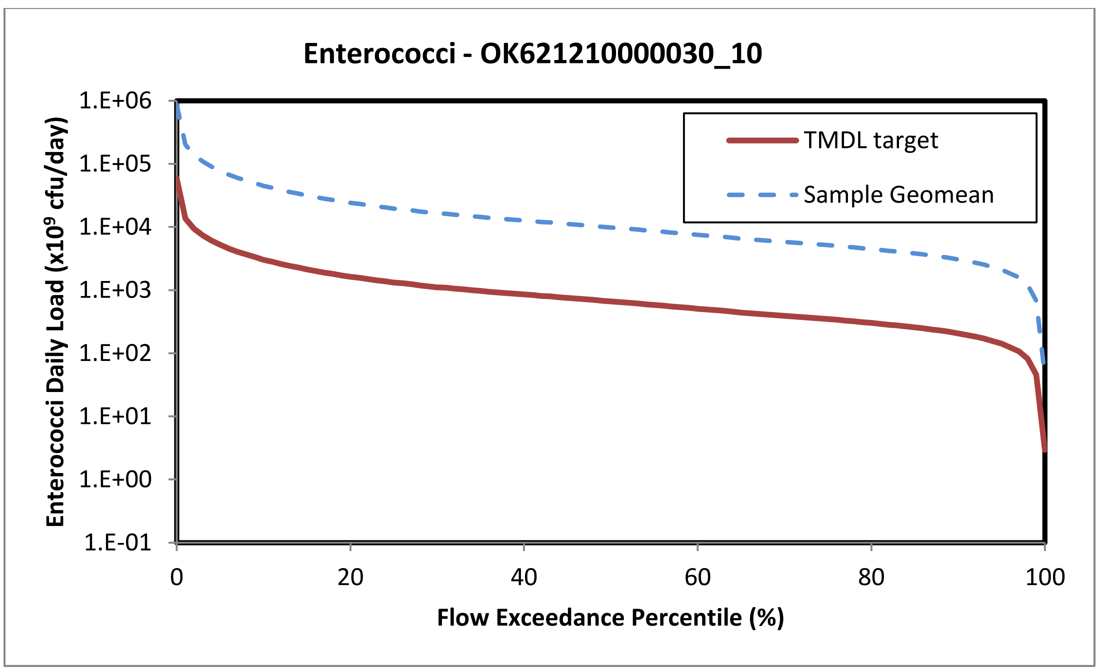


Figure 5-12 Load Duration Curve for Enterococci in the North Canadian River (OK720500010010_00)

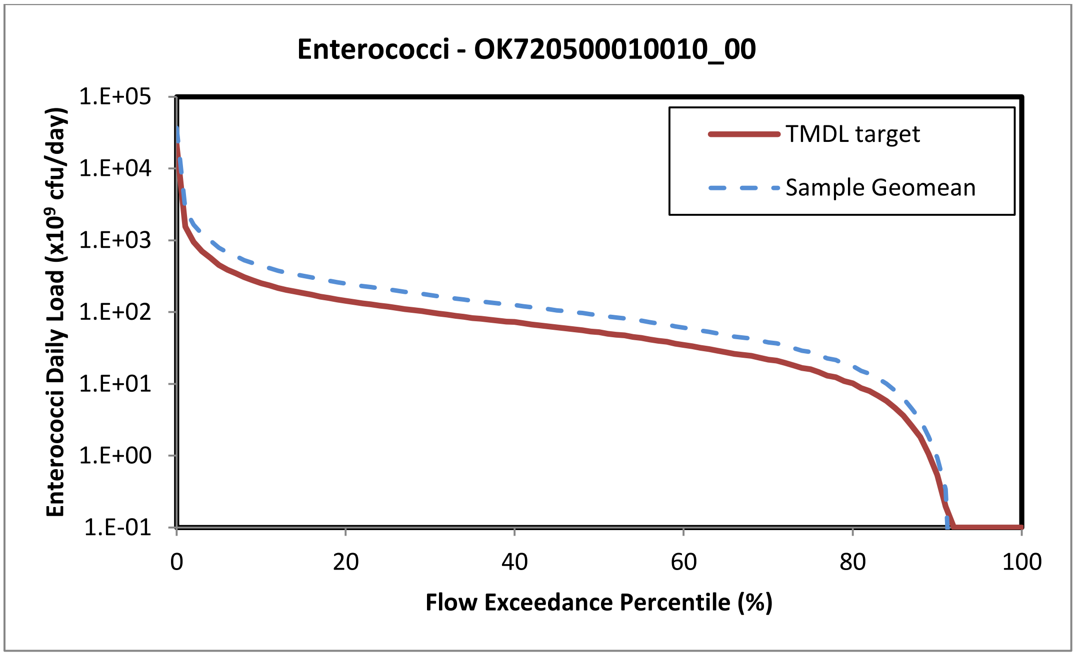


Figure 5-13 Load Duration Curve for *E. coli* in Bent Creek (OK720500010070_00)

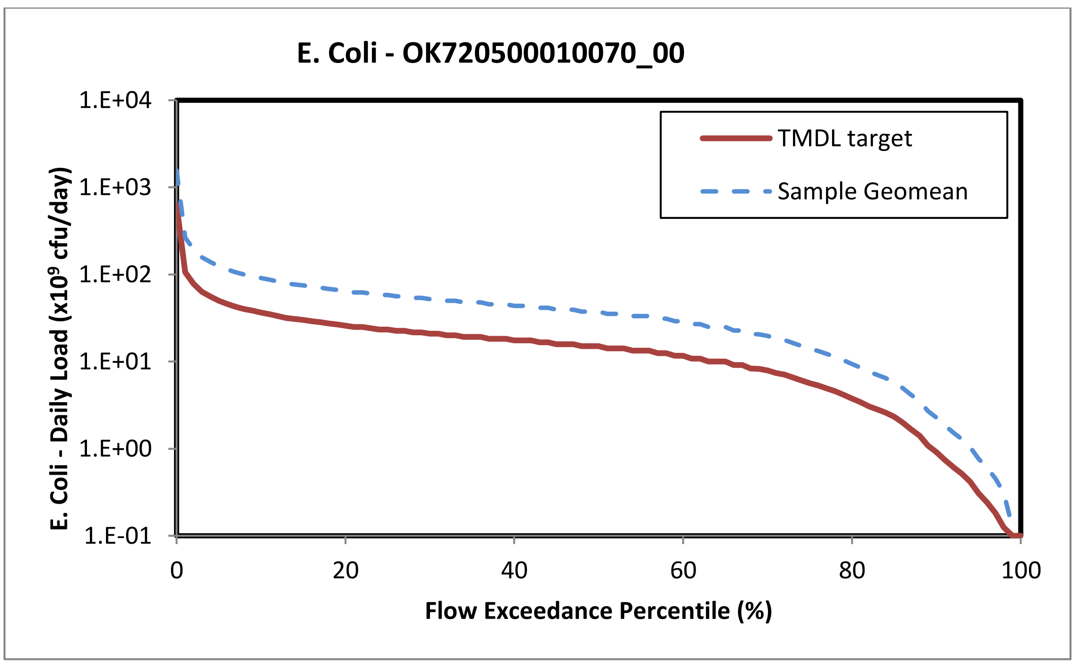


Figure 5-14 Load Duration Curve for Enterococci in Bent Creek (OK720500010070_00)

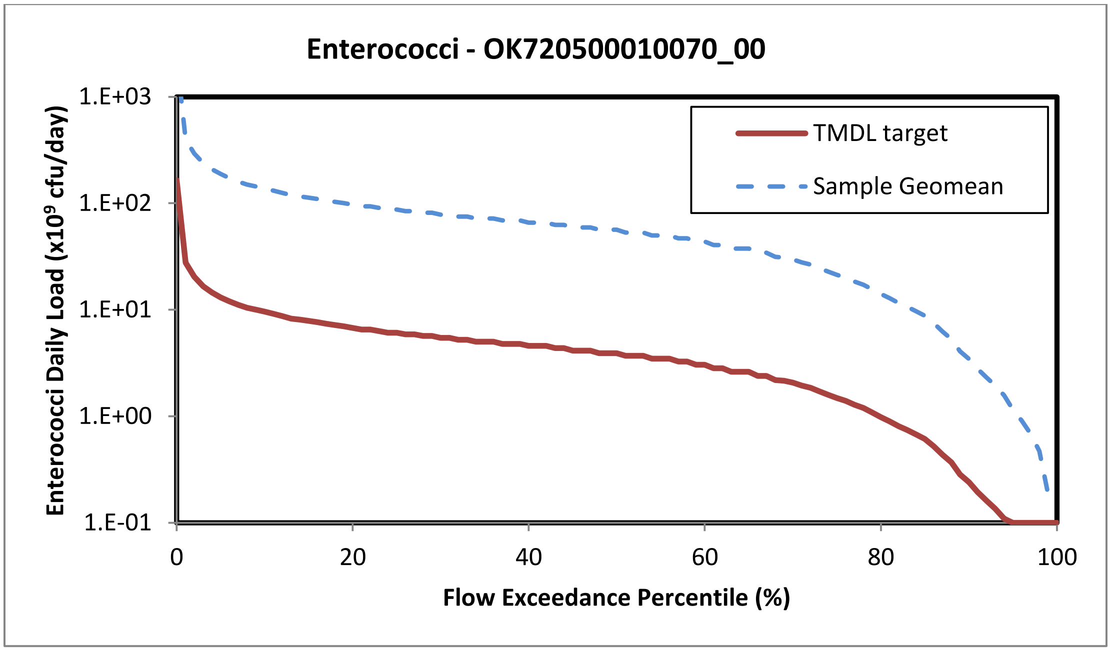


Figure 5-15 Load Duration Curve for Enterococci in the Beaver River (OK720500010140_10)

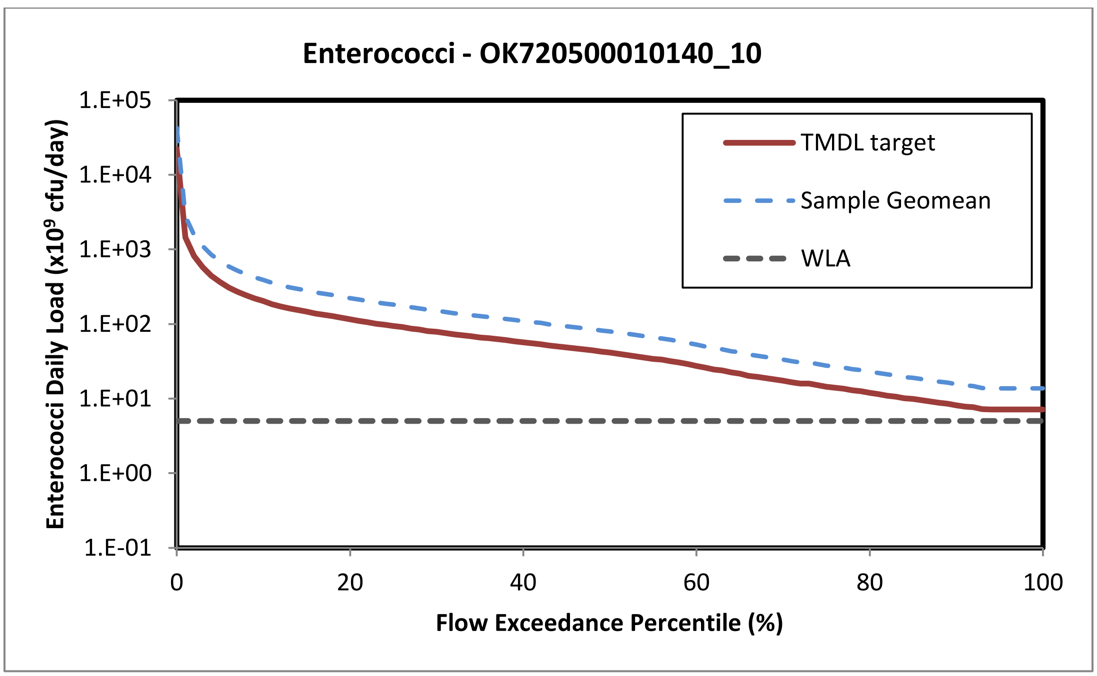


Figure 5-16 Load Duration Curve for *E. coli* in Persimmon Creek (OK720500010150_00)

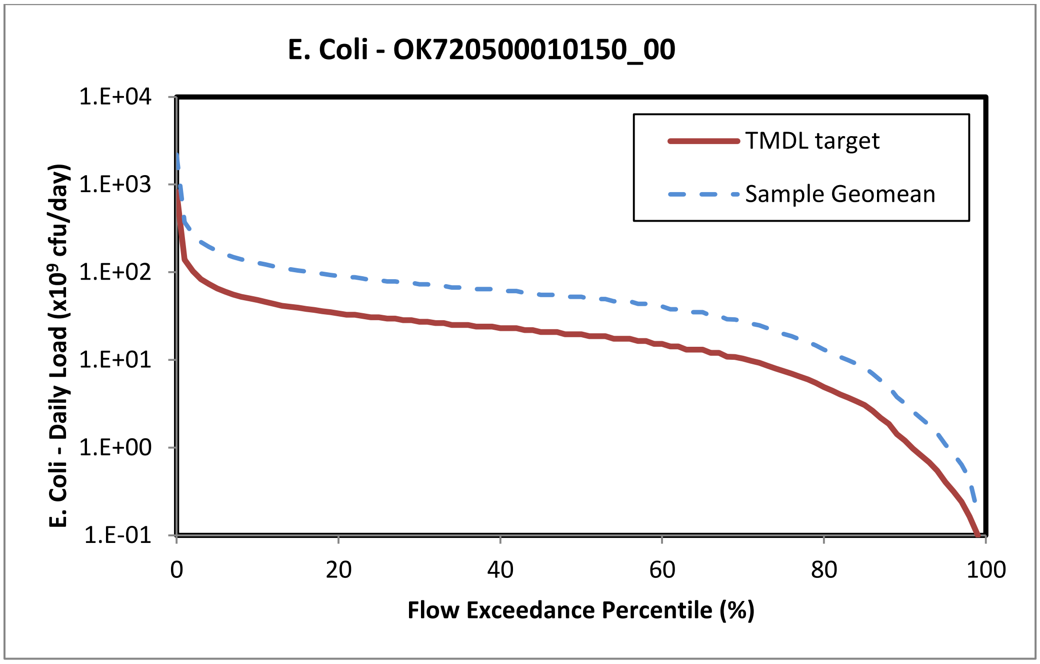


Figure 5-17 Load Duration Curve for Enterococci in Persimmon Creek (OK720500010150_00)

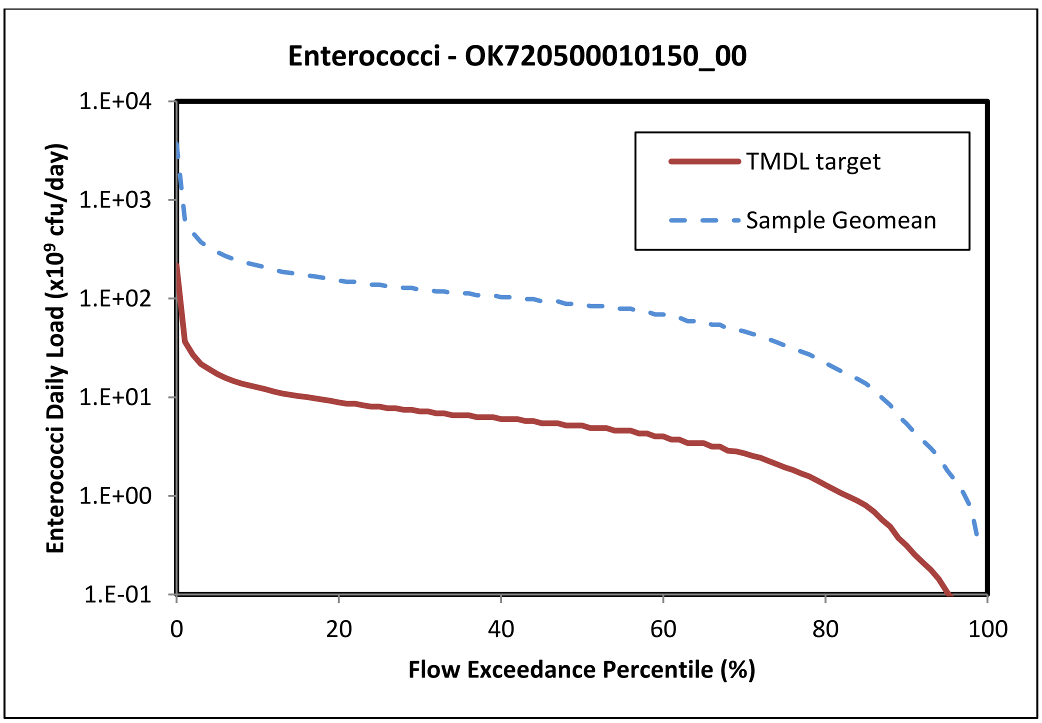


Figure 5-18 Load Duration Curve for *E. coli* in Indian Creek (OK720500010200_00)

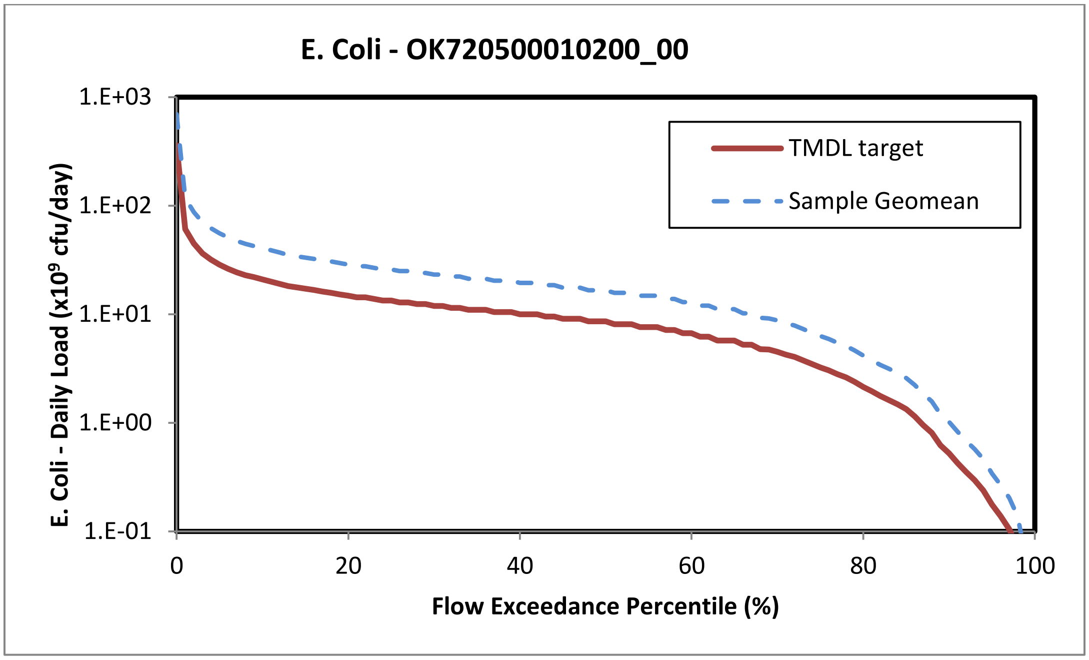
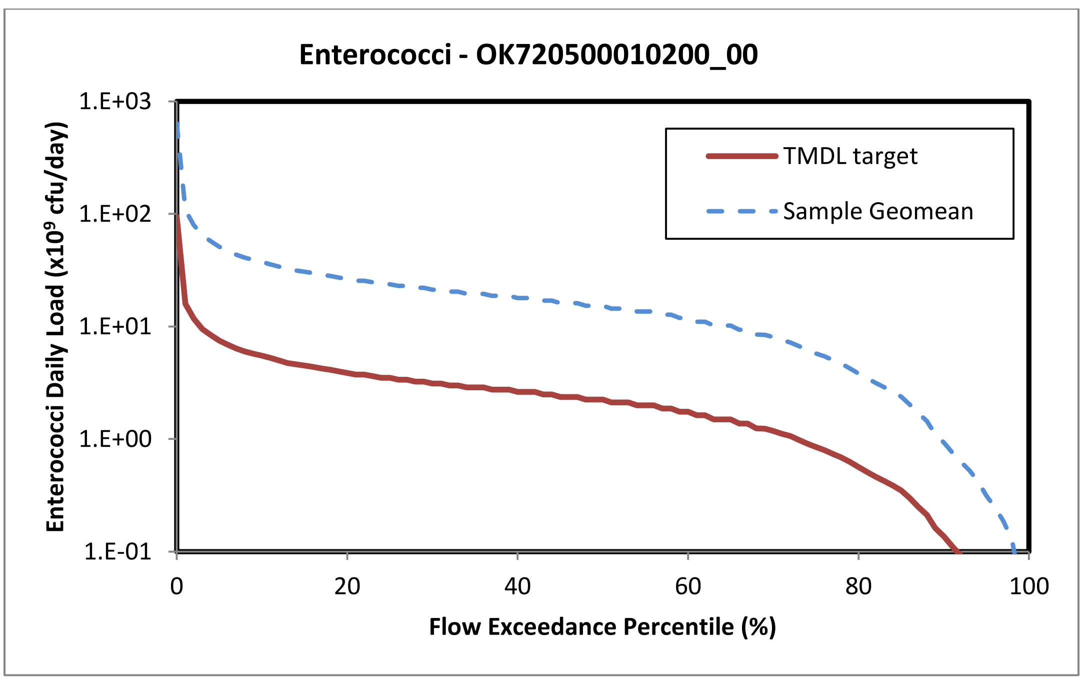


Figure 5-19 Load Duration Curve for Enterococci in Indian Creek (OK720500010200_00)



1.1.2 TSS LDC

To calculate the TSS load at the WQ target, the flow rate (cfs) at each flow exceedance percentile was multiplied by a unit conversion factor (*5.39377*) and the TSS goal (mg/L) for each waterbody. This calculation produced the maximum TSS load in the waterbody that results 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 was expressed in terms of a TSS load in pounds per day.

To estimate existing loading, TSS and turbidity observations from 1998 to 2011 were 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 was 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 was then matched with the flow from the tables provided in **Appendix B**. 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 5-20 and **Figure 5-21** show the TSS LDCs developed for the waterbodies addressed in this TMDL report. Data in the figures indicate that for both waterbodies, TSS levels exceed the water quality target during elevated flow conditions, indicating water quality impairments due to nonpoint sources (No point source was identified in the watershed required turbidity TMDLs). Wet weather influenced samples found during low flow conditions can be caused by an isolated rainfall event during dry weather conditions. It was 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 to 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. WLAs for point sources discharges (continuous) of inorganic TSS are shown on a LDC as a horizontal line which represents the sum of all WLAs for TSS in a given watershed.

Figure 5-20 Load Duration Curve for Total Suspended Solids in the Arkansas River (OK621210000030_10)

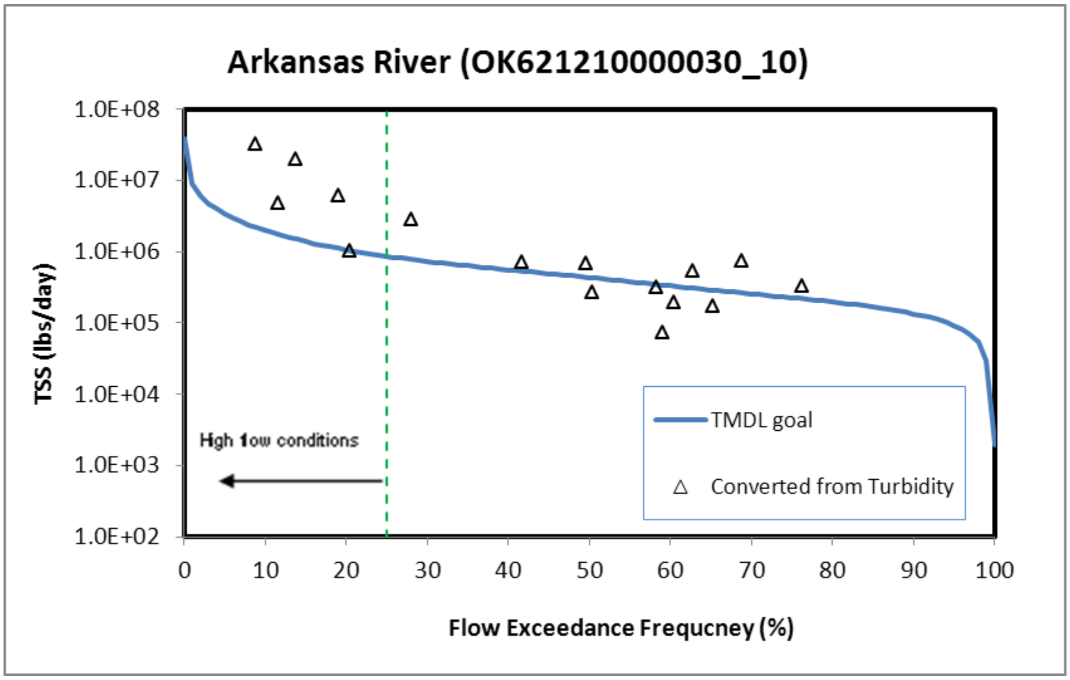
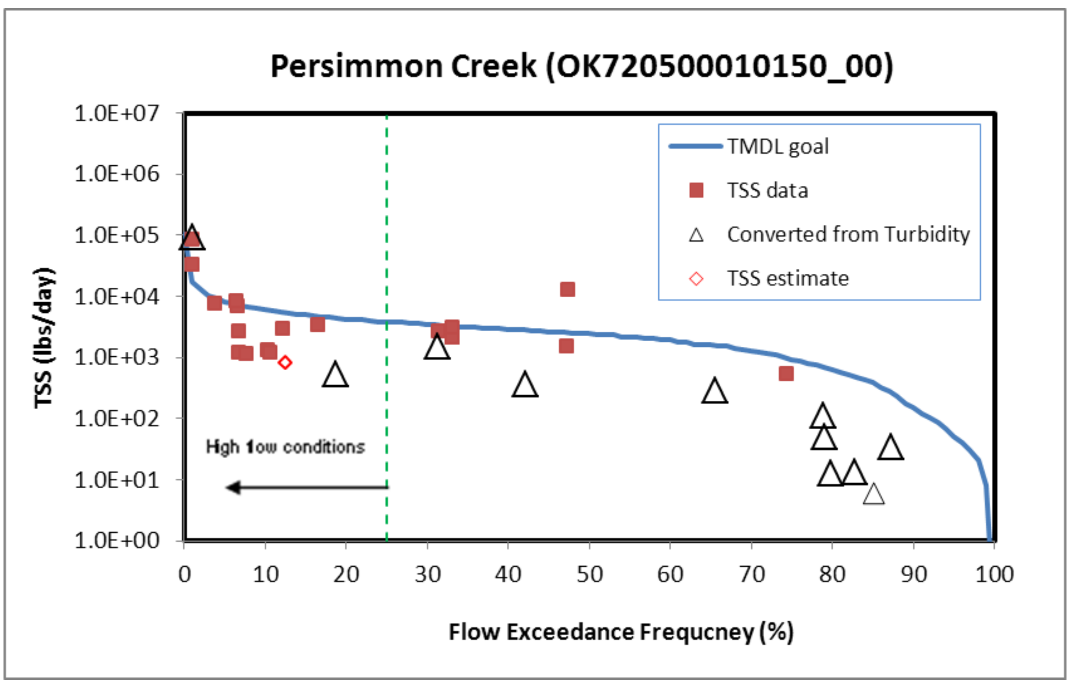


Figure 5-21 Load Duration Curve for Total Suspended Solids in Persimmon Creek (OK720500010150_00)



5.3.3 Establish 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 can also be calculated under different flow conditions. The difference between existing loading and the TMDL was used to calculate the loading reductions required.

5.3.3.1 Bacterial PRGs

PRGs for bacteria are calculated through an iterative process of taking a series of percent reduction values, applying each value uniformly to the concentrations of samples and verifying if the geometric mean of the reduced values of all samples was less than the WQS geometric mean. **Table 5-3** represents 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 42.5% to 94.7%.

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

Waterbody ID	Waterbody Name	Required Reduction Rate	
		EC	ENT
OK621200050010_10	**Red Rock Creek**	-	**94.7%**
OK621210000030_10	**Arkansas River**	-	**93.3%**
OK720500010010_00	**North Canadian River**	-	**42.5%**
OK720500010070_00	**Bent Creek**	**59.8%**	**93.0%**
OK720500010140_10	**Beaver River**	-	**48.0%**
OK720500010150_00	**Persimmon Creek**	**62.5%**	**94.2%**
OK720500010200_00	**Indian Creek**	**48.5%**	**85.3%**

5.3.3.2 TSS PRGs

PRGs for TSS are calculated as the required overall reduction so that no more than 10% of the samples exceed the water quality target for TSS. The PRGs for the two waterbodies included in this TMDL report are summarized in **Table 5-4** and are 92.4% and 1.3%.

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

Waterbody ID	Waterbody Name	Required Reduction Rate
OK621210000030_10	Arkansas River	**92.4%**
OK720500010150_00	Persimmon Creek	**1.3%**

5.4 WASTELOAD ALLOCATION

5.4.1 Indicator Bacteria

For bacterial TMDLs, OPDES-permitted facilities are allocated a daily wasteload calculated as their permitted flow rate multiplied by the in-stream geometric mean water quality criterion. In other words, the facilities are required to meet in-stream criteria in their discharge. **Table 5-4** summarizes the WLA for the OPDES-permitted facilities within the Study Area. The WLA for each facility discharging to a bacterially-impaired waterbody is derived from the following equation:

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

Where:

WQS = 33 and 126 cfu/100 mL for Enterococci and E. coli respectively

Flow (mgd) = permitted flow

Unit conversion factor = 37,854,120

When multiple OPDES facilities occur within a watershed, individual WLAs are summed and the total WLA for continuous point sources was included in the TMDL calculation for the corresponding waterbody. When there are no OPDES WWTFs discharging into the contributing watershed of a stream segment, then the WLA is zero. Compliance with the WLA will be achieved by adhering to the fecal coliform or *E. coli* limits and disinfection requirements of OPDES permits. Currently, facilities that discharge treated wastewater are currently required to monitor for fecal coliform. These discharges or any other discharges with a bacterial WLA are required to monitor for *E. coli* as their permits are renewed.

Table 5-4 indicates which point source dischargers within the Study Area currently have a disinfection requirement in their permit. Certain facilities that utilize lagoons for treatment have not been required to provide disinfection since storage time and exposure to ultraviolet radiation from sunlight should reduce bacterial levels.

Permitted stormwater discharges are considered point sources; however, there are no areas designated as MS4s within the watersheds of the Study Area impaired for contact recreation, so there aren't any WLAs for MS4s.

Table 5-4 Bacterial Wasteload Allocations for OPDES-Permitted Facilities

Waterbody ID	Stream Name	Name	OPDES Permit No.	Disinfection	Design Flow (mg/d)	Wasteload Allocation ($x10^9$ cfu/day)	
						EC	ENT
OK720500010140_00	Beaver River	**Woodward WWTF**	OK0034509	Yes	4.0 [a]	19.1	5.0

[a] Maximum 30-day flow ($Q_{e(30)}$).

5.4.2 Total Suspended Solids WLA

OPDES-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 in-stream criteria in their discharge. If the current monthly TSS limits of a facility are greater than in-stream TSS criteria, the new limits equal to in-stream criteria are applied to the facility as their permit is renewed. The WLA for each facility is derived as follows:

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

Where:

WQ goal = Waterbody specific water quality goal provided in* Table 5-1*, or monthly TSS limit in the current permit, whichever is smaller

Flow (mgd) = average monthly flow

Unit conversion factor = 8.3445

However, there are no point sources of TSS in the watershed required for turbidity TMDLs.

No TSS WLAs are needed for MS4s 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 % of TSS loading was reserved as part of the WLA.

5.4.3 Permit Implication

5.4.3.1 Bacterial Permit limitations

All point source dischargers, except MS4s, were assigned a wasteload allocation in **Table 5-4** and will receive a permit limit equal to the water quality standard as their permits are reissued. They are also required to meet water quality standards at the end of pipe. MS4s are considered as point sources and are assigned a wasteload allocation. However, due the nature of stormwater discharges and the typical lack of information on which to base numeric water quality-based effluent limitations, the TMDL requirements are implemented through establishing a comprehensive stormwater management program (SWMP) or storm water pollution prevention plan (SWPPP).

Regardless of the magnitude of the WLA calculated in these TMDLs, future new discharges of bacteria or increased bacterial load from existing discharges are considered consistent with the TMDL provided that the OPDES permits require in-stream criteria to be met.

5.4.3.2 TSS Permit Limitations

Stormwater discharges from MS4, industrial facilities, constructions occur only during or immediately following periods of rainfall and elevated flow conditions when the turbidity criteria do not apply and therefore are not considered potential contributors of turbidity impairment in this TMDL report.

The general permit for rock, sand and gravel quarries (OKG950000) does not allow discharge of wastewater to waterbodies included in Oklahoma's 303(d) List of impaired waterbodies 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.

The TSS limits for water treatment plant with backwash discharge, mines with dewatering operations or any other facilities with TSS limits but without BOD or CBOD limitations can be determined as follows:

- If the corresponding TSS target in **Table 5-1** was equal to or greater than the daily maximum limit in the current permit, the permit TSS limits stay the same and the TMDL has no impact on the permit limits when a permit is renewed.
- If the corresponding TSS target in **Table 5-1** was less than the daily maximum limit in the current permit, the corresponding TSS target in **Table 5-1** will become the daily maximum limit when the permit is renewed.
- The TMDLs do not place specific requirements for monthly average limit. The permitting authority will determine the proper monthly average limit. However, under no circumstances, will the monthly average limit in the renewed permit be greater than the monthly average limit in the current permit (anti-backsliding rule).

5.4.4 Section 404 permits

No TSS WLAs were set aside for Section 404 Permits. The State uses its Section 401 Certification authority to ensure Section 404 Permits protect Oklahoma WQS and comply with TSS TMDLs in this report. One of the following two conditions must be met in order to receive Section 401 Certification by the State:

- Include TSS limits in the permit and establish a monitoring requirement to ensure compliance with turbidity standards and TSS TMDLs; or
- Submit to DEQ a BMP turbidity reduction plan which should include all practicable turbidity control techniques. The turbidity reduction plan must be approved first before a Section 401 Certification can be issued.

Compliance with Section 401 Certification conditions are considered to be compliance with this TMDL.

5.5 Load Allocation

As discussed in Section 3, nonpoint source bacterial 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:

$$\mathbf{LA = TMDL - WLA\_{_{WWTF}} - WLA\_{_{MS4}} - MOS}$$

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

$$\mathbf{LA = TMDL - WLA\_{_{WWTF}} - WLA\_{_{MS4}} - WLA\_{_{growth}} - MOS}$$

5.6 Seasonal Variability

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. The bacterial 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 five years of water quality data and by using the longest period of USGS flow records when estimating flows to develop flow exceedance percentiles.

5.7 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. EPA guidance allows for use of implicit or explicit expressions of the MOS, or both. For bacterial TMDLs, an explicit MOS was set at 10%.

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 MOS. The selection of MOS is based on the NRMSE for each waterbody. The explicit MOS ranged from 5% to 10%. **Table 5-1** shows the MOS for each waterbody.

5.8 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 pollutant loading and water quality.

This definition can be expressed by the following equation:

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

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 WQS. Regardless of the magnitude of the WLA calculated in these TMDLs, future new discharges or increased load from existing discharges are considered to be consistent with the TMDL provided that the OPDES permit requires in-stream criteria to be met.

The TMDL, WLA, LA, and MOS vary with flow condition and were calculated at every 5th flow interval percentile. **Tables 5-5** through **5-14** summarize the allocations for indicator bacteria. The bacterial TMDLs calculated in these tables apply to the recreation season (May 1 through September 30) only. **Tables 5-15** to **5-16** present the allocations for total suspended solids.

Table 5-5 Enterococci TMDL Calculations for Red Rock Creek (OK621200050010_10)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTF} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	11,378	9.19E+12	0	0	8.27E+12	9.19E+11
5	483.8	3.91E+11	0	0	3.52E+11	3.91E+10
10	181.0	1.46E+11	0	0	1.32E+11	1.46E+10
15	90.9	7.34E+10	0	0	6.61E+10	7.34E+09
20	53.3	4.30E+10	0	0	3.87E+10	4.30E+09
25	34.0	2.75E+10	0	0	2.47E+10	2.75E+09
30	22.9	1.84E+10	0	0	1.66E+10	1.84E+09
35	16.6	1.34E+10	0	0	1.20E+10	1.34E+09
40	12.1	9.76E+09	0	0	8.79E+09	9.76E+08
45	9.41	7.59E+09	0	0	6.84E+09	7.59E+08
50	7.62	6.15E+09	0	0	5.53E+09	6.15E+08
55	5.82	4.70E+09	0	0	4.23E+09	4.70E+08
60	4.48	3.62E+09	0	0	3.25E+09	3.62E+08
65	3.58	2.89E+09	0	0	2.60E+09	2.89E+08
70	2.73	2.21E+09	0	0	1.99E+09	2.21E+08
75	2.06	1.66E+09	0	0	1.50E+09	1.66E+08
80	1.52	1.23E+09	0	0	1.11E+09	1.23E+08
85	0.94	7.59E+08	0	0	6.84E+08	7.59E+07
90	0.49	3.98E+08	0	0	3.58E+08	3.98E+07
95	0.09	7.23E+07	0	0	6.51E+07	7.23E+06
100	0	0	0	0	0	0

Table 5-6 Enterococci TMDL Calculations for the Arkansas River (OK621210000030_10)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTF} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	80,654	6.51E+13	0	0	5.86E+13	6.51E+12
5	7,175	5.79E+12	0	0	5.21E+12	5.79E+11
10	4,169	3.37E+12	0	0	3.03E+12	3.37E+11
15	2,914	2.35E+12	0	0	2.12E+12	2.35E+11
20	2,247	1.81E+12	0	0	1.63E+12	1.81E+11
25	1,822	1.47E+12	0	0	1.32E+12	1.47E+11
30	1,528	1.23E+12	0	0	1.11E+12	1.23E+11
35	1,336	1.08E+12	0	0	9.71E+11	1.08E+11
40	1,174	9.48E+11	0	0	8.53E+11	9.48E+10
45	1,032	8.33E+11	0	0	7.50E+11	8.33E+10
50	913	7.37E+11	0	0	6.63E+11	7.37E+10
55	803	6.49E+11	0	0	5.84E+11	6.49E+10
60	699	5.65E+11	0	0	5.08E+11	5.65E+10
65	608	4.91E+11	0	0	4.42E+11	4.91E+10
70	539	4.35E+11	0	0	3.92E+11	4.35E+10
75	479	3.86E+11	0	0	3.48E+11	3.86E+10
80	415	3.35E+11	0	0	3.01E+11	3.35E+10
85	354	2.86E+11	0	0	2.57E+11	2.86E+10
90	284	2.29E+11	0	0	2.06E+11	2.29E+10
95	194	1.57E+11	0	0	1.41E+11	1.57E+10
100	4.0	3.27E+09	0	0	2.94E+09	3.27E+08

Table 5-7 Enterococci TMDL Calculations for the North Canadian River (OK720500010010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTF} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	29,100	2.35E+13	0	0	2.11E+13	2.35E+12
5	624.6	5.04E+11	0	0	4.54E+11	5.04E+10
10	347.0	2.80E+11	0	0	2.52E+11	2.80E+10
15	252.0	2.03E+11	0	0	1.83E+11	2.03E+10
20	198.0	1.60E+11	0	0	1.44E+11	1.60E+10
25	164.0	1.32E+11	0	0	1.19E+11	1.32E+10
30	137.0	1.11E+11	0	0	9.95E+10	1.11E+10
35	114.0	9.20E+10	0	0	8.28E+10	9.20E+09
40	100.0	8.07E+10	0	0	7.27E+10	8.07E+09
45	84.0	6.78E+10	0	0	6.10E+10	6.78E+09
50	72.0	5.81E+10	0	0	5.23E+10	5.81E+09
55	60.0	4.84E+10	0	0	4.36E+10	4.84E+09
60	48.0	3.88E+10	0	0	3.49E+10	3.88E+09
65	38.0	3.07E+10	0	0	2.76E+10	3.07E+09
70	30.0	2.42E+10	0	0	2.18E+10	2.42E+09
75	22.0	1.78E+10	0	0	1.60E+10	1.78E+09
80	14.0	1.13E+10	0	0	1.02E+10	1.13E+09
85	6.4	5.17E+09	0	0	4.65E+09	5.17E+08
90	0.74	5.97E+08	0	0	5.38E+08	5.97E+07
95	0	0	0	0	0	0
100	0	0	0	0	0	0

Table 5-8 *E. coli* TMDL Calculations for Bent Creek (OK720500010070_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTF} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	226	6.98E+11	0	0	6.28E+11	6.98E+10
5	18	5.54E+10	0	0	4.99E+10	5.54E+09
10	13	4.07E+10	0	0	3.66E+10	4.07E+09
15	11	3.33E+10	0	0	2.99E+10	3.33E+09
20	9.3	2.86E+10	0	0	2.58E+10	2.86E+09
25	8.4	2.59E+10	0	0	2.33E+10	2.59E+09
30	7.5	2.31E+10	0	0	2.08E+10	2.31E+09
35	6.9	2.13E+10	0	0	1.91E+10	2.13E+09
40	6.3	1.94E+10	0	0	1.75E+10	1.94E+09
45	5.7	1.76E+10	0	0	1.58E+10	1.76E+09
50	5.4	1.66E+10	0	0	1.50E+10	1.66E+09
55	4.8	1.48E+10	0	0	1.33E+10	1.48E+09
60	4.2	1.29E+10	0	0	1.16E+10	1.29E+09
65	3.6	1.11E+10	0	0	9.98E+09	1.11E+09
70	2.8	8.74E+09	0	0	7.87E+09	8.74E+08
75	2.0	6.28E+09	0	0	5.66E+09	6.28E+08
80	1.3	4.16E+09	0	0	3.74E+09	4.16E+08
85	0.8	2.59E+09	0	0	2.33E+09	2.59E+08
90	0.3	1.02E+09	0	0	9.15E+08	1.02E+08
95	0.1	3.42E+08	0	0	3.08E+08	3.42E+07
100	0	0	0	0	0	0

Table 5-9 Enterococci TMDL Calculations for Bent Creek (OK720500010070_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTF} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	226	1.83E+11	0	0	1.64E+11	1.83E+10
5	18	1.45E+10	0	0	1.31E+10	1.45E+09
10	13	1.06E+10	0	0	9.58E+09	1.06E+09
15	11	8.71E+09	0	0	7.84E+09	8.71E+08
20	9.3	7.50E+09	0	0	6.75E+09	7.50E+08
25	8.4	6.78E+09	0	0	6.10E+09	6.78E+08
30	7.5	6.05E+09	0	0	5.45E+09	6.05E+08
35	6.9	5.57E+09	0	0	5.01E+09	5.57E+08
40	6.3	5.08E+09	0	0	4.57E+09	5.08E+08
45	5.7	4.60E+09	0	0	4.14E+09	4.60E+08
50	5.4	4.36E+09	0	0	3.92E+09	4.36E+08
55	4.8	3.87E+09	0	0	3.49E+09	3.87E+08
60	4.2	3.39E+09	0	0	3.05E+09	3.39E+08
65	3.6	2.90E+09	0	0	2.61E+09	2.90E+08
70	2.8	2.29E+09	0	0	2.06E+09	2.29E+08
75	2.0	1.65E+09	0	0	1.48E+09	1.65E+08
80	1.3	1.09E+09	0	0	9.80E+08	1.09E+08
85	0.8	6.78E+08	0	0	6.10E+08	6.78E+07
90	0.3	2.66E+08	0	0	2.40E+08	2.66E+07
95	0.1	8.95E+07	0	0	8.06E+07	8.95E+06
100	0	0	0	0	0	0

Table 5-10 Enterococci TMDL Calculations for the Beaver River (OK720500010140_10)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTF} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	30,510	2.46E+13	5.00E+09	0	2.22E+13	2.46E+12
5	497	4.01E+11	5.00E+09	0	3.56E+11	4.01E+10
10	278	2.24E+11	5.00E+09	0	1.97E+11	2.24E+10
15	201	1.62E+11	5.00E+09	0	1.41E+11	1.62E+10
20	159	1.28E+11	5.00E+09	0	1.10E+11	1.28E+10
25	130	1.05E+11	5.00E+09	0	8.93E+10	1.05E+10
30	108	8.70E+10	5.00E+09	0	7.33E+10	8.70E+09
35	90.8	7.33E+10	5.00E+09	0	6.10E+10	7.33E+09
40	77.8	6.28E+10	5.00E+09	0	5.15E+10	6.28E+09
45	66.8	5.39E+10	5.00E+09	0	4.35E+10	5.39E+09
50	56.8	4.58E+10	5.00E+09	0	3.63E+10	4.58E+09
55	46.8	3.78E+10	5.00E+09	0	2.90E+10	3.78E+09
60	37.8	3.05E+10	5.00E+09	0	2.25E+10	3.05E+09
65	29.8	2.41E+10	5.00E+09	0	1.66E+10	2.41E+09
70	23.8	1.92E+10	5.00E+09	0	1.23E+10	1.92E+09
75	19.8	1.60E+10	5.00E+09	0	9.38E+09	1.60E+09
80	16.4	1.32E+10	5.00E+09	0	6.91E+09	1.32E+09
85	13.6	1.10E+10	5.00E+09	0	4.87E+09	1.10E+09
90	11.2	9.03E+09	5.00E+09	0	3.13E+09	9.03E+08
95	9.8	7.90E+09	5.00E+09	0	2.11E+09	7.90E+08
100	9.8	7.90E+09	5.00E+09	0	2.11E+09	7.90E+08

Table 5-11 *E. coli* TMDL Calculations for Persimmon Creek (OK720500010150_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTF} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	297	9.16E+11	0	0	8.24E+11	9.16E+10
5	24	7.28E+10	0	0	6.55E+10	7.28E+09
10	17	5.34E+10	0	0	4.80E+10	5.34E+09
15	14	4.37E+10	0	0	3.93E+10	4.37E+09
20	12	3.76E+10	0	0	3.39E+10	3.76E+09
25	11	3.40E+10	0	0	3.06E+10	3.40E+09
30	10	3.03E+10	0	0	2.73E+10	3.03E+09
35	9.1	2.79E+10	0	0	2.51E+10	2.79E+09
40	8.3	2.55E+10	0	0	2.29E+10	2.55E+09
45	7.5	2.31E+10	0	0	2.07E+10	2.31E+09
50	7.1	2.18E+10	0	0	1.97E+10	2.18E+09
55	6.3	1.94E+10	0	0	1.75E+10	1.94E+09
60	5.5	1.70E+10	0	0	1.53E+10	1.70E+09
65	4.7	1.46E+10	0	0	1.31E+10	1.46E+09
70	3.7	1.15E+10	0	0	1.03E+10	1.15E+09
75	2.7	8.25E+09	0	0	7.43E+09	8.25E+08
80	1.8	5.46E+09	0	0	4.91E+09	5.46E+08
85	1.1	3.40E+09	0	0	3.06E+09	3.40E+08
90	0.4	1.33E+09	0	0	1.20E+09	1.33E+08
95	0.1	4.49E+08	0	0	4.04E+08	4.49E+07
100	0	0	0	0	0	0

Table 5-12 Enterococci TMDL Calculations for Persimmon Creek (OK720500010150_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTF} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	297	2.40E+11	0	0	2.16E+11	2.40E+10
5	24	1.91E+10	0	0	1.72E+10	1.91E+09
10	17	1.40E+10	0	0	1.26E+10	1.40E+09
15	14	1.14E+10	0	0	1.03E+10	1.14E+09
20	12	9.85E+09	0	0	8.87E+09	9.85E+08
25	11	8.90E+09	0	0	8.01E+09	8.90E+08
30	10	7.94E+09	0	0	7.15E+09	7.94E+08
35	9.1	7.31E+09	0	0	6.58E+09	7.31E+08
40	8.3	6.67E+09	0	0	6.01E+09	6.67E+08
45	7.5	6.04E+09	0	0	5.43E+09	6.04E+08
50	7.1	5.72E+09	0	0	5.15E+09	5.72E+08
55	6.3	5.08E+09	0	0	4.58E+09	5.08E+08
60	5.5	4.45E+09	0	0	4.00E+09	4.45E+08
65	4.7	3.81E+09	0	0	3.43E+09	3.81E+08
70	3.7	3.01E+09	0	0	2.71E+09	3.01E+08
75	2.7	2.16E+09	0	0	1.94E+09	2.16E+08
80	1.8	1.43E+09	0	0	1.29E+09	1.43E+08
85	1.1	8.90E+08	0	0	8.01E+08	8.90E+07
90	0.4	3.50E+08	0	0	3.15E+08	3.50E+07
95	0.1	1.18E+08	0	0	1.06E+08	1.18E+07
100	0	0	0	0	0	0

Table 5-13 *E. coli* TMDL Calculations for Indian Creek (OK720500010200_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTF} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	130	3.99E+11	0	0	3.59E+11	3.99E+10
5	10	3.17E+10	0	0	2.86E+10	3.17E+09
10	7.6	2.33E+10	0	0	2.10E+10	2.33E+09
15	6.2	1.90E+10	0	0	1.71E+10	1.90E+09
20	5.3	1.64E+10	0	0	1.48E+10	1.64E+09
25	4.8	1.48E+10	0	0	1.33E+10	1.48E+09
30	4.3	1.32E+10	0	0	1.19E+10	1.32E+09
35	3.9	1.22E+10	0	0	1.10E+10	1.22E+09
40	3.6	1.11E+10	0	0	1.00E+10	1.11E+09
45	3.3	1.01E+10	0	0	9.05E+09	1.01E+09
50	3.1	9.52E+09	0	0	8.57E+09	9.52E+08
55	2.7	8.47E+09	0	0	7.62E+09	8.47E+08
60	2.4	7.41E+09	0	0	6.67E+09	7.41E+08
65	2.1	6.35E+09	0	0	5.71E+09	6.35E+08
70	1.6	5.00E+09	0	0	4.50E+09	5.00E+08
75	1.2	3.60E+09	0	0	3.24E+09	3.60E+08
80	0.8	2.38E+09	0	0	2.14E+09	2.38E+08
85	0.5	1.48E+09	0	0	1.33E+09	1.48E+08
90	0.2	5.82E+08	0	0	5.24E+08	5.82E+07
95	0.1	1.96E+08	0	0	1.76E+08	1.96E+07
100	0	0	0	0	0	0

Table 5-14 Enterococci TMDL Calculations for Indian Creek (OK720500010200_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTF} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	130	1.05E+11	0	0	9.42E+10	1.05E+10
5	10	8.31E+09	0	0	7.48E+09	8.31E+08
10	7.6	6.10E+09	0	0	5.49E+09	6.10E+08
15	6.2	4.99E+09	0	0	4.49E+09	4.99E+08
20	5.3	4.30E+09	0	0	3.87E+09	4.30E+08
25	4.8	3.88E+09	0	0	3.49E+09	3.88E+08
30	4.3	3.46E+09	0	0	3.12E+09	3.46E+08
35	3.9	3.19E+09	0	0	2.87E+09	3.19E+08
40	3.6	2.91E+09	0	0	2.62E+09	2.91E+08
45	3.3	2.63E+09	0	0	2.37E+09	2.63E+08
50	3.1	2.49E+09	0	0	2.24E+09	2.49E+08
55	2.7	2.22E+09	0	0	2.00E+09	2.22E+08
60	2.4	1.94E+09	0	0	1.75E+09	1.94E+08
65	2.1	1.66E+09	0	0	1.50E+09	1.66E+08
70	1.6	1.31E+09	0	0	1.18E+09	1.31E+08
75	1.2	9.42E+08	0	0	8.48E+08	9.42E+07
80	0.8	6.24E+08	0	0	5.61E+08	6.24E+07
85	0.5	3.88E+08	0	0	3.49E+08	3.88E+07
90	0.2	1.52E+08	0	0	1.37E+08	1.52E+07
95	0.1	5.13E+07	0	0	4.61E+07	5.13E+06
100	0	0	0	0	0	0

Table 5-15 Total Suspended Solids TMDL Calculations for the Arkansas River (OK621210000030_10)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)			LA (lb/day)	MOS (lb/day)
			WWTF	MS4	Future growth		
0	80,654	N/A	N/A	N/A	N/A	N/A	N/A
5	7,175	N/A	N/A	N/A	N/A	N/A	N/A
10	4,169	N/A	N/A	N/A	N/A	N/A	N/A
15	2,914	N/A	N/A	N/A	N/A	N/A	N/A
20	2,247	N/A	N/A	N/A	N/A	N/A	N/A
25	1,822	906,793	0	0	9,068	852,386	45,340
30	1,528	760,699	0	0	7,607	715,057	38,035
35	1,336	664,982	0	0	6,650	625,083	33,249
40	1,174	584,378	0	0	5,844	549,315	29,219
45	1,032	513,849	0	0	5,138	483,018	25,692
50	913	454,404	0	0	4,544	427,140	22,720
55	803	399,997	0	0	4,000	375,997	20,000
60	699	348,108	0	0	3,481	327,221	17,405
65	608	302,768	0	0	3,028	284,602	15,138
70	539	268,512	0	0	2,685	252,401	13,426
75	479	238,285	0	0	2,383	223,988	11,914
80	415	206,547	0	0	2,065	194,154	10,327
85	354	176,321	0	0	1,763	165,742	8,816
90	284	141,258	0	0	1,413	132,783	7,063
95	194	96,725	0	0	967	90,921	4,836
100	4.0	2,015	0	0	20	1,793	202

NA = Not Applicable

Table 5-16 Total Suspended Solids TMDL Calculations for Persimmon Creek (OK720500010150_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)			LA (lb/day)	MOS (lb/day)
			WWTF	MS4	Future growth		
0	297	N/A	N/A	N/A	N/A	N/A	N/A
5	24	N/A	N/A	N/A	N/A	N/A	N/A
10	17	N/A	N/A	N/A	N/A	N/A	N/A
15	14	N/A	N/A	N/A	N/A	N/A	N/A
20	12	N/A	N/A	N/A	N/A	N/A	N/A
25	11	4,263	0	0	43	3,794	426
30	10	3,806	0	0	38	3,388	381
35	9.1	3,502	0	0	35	3,117	350
40	8.3	3,197	0	0	32	2,846	320
45	7.5	2,893	0	0	29	2,575	289
50	7.1	2,741	0	0	27	2,439	274
55	6.3	2,436	0	0	24	2,168	244
60	5.5	2,132	0	0	21	1,897	213
65	4.7	1,827	0	0	18	1,626	183
70	3.7	1,440	0	0	14	1,282	144
75	2.7	1,035	0	0	10	921	104
80	1.8	685	0	0	7	610	69
85	1.1	426	0	0	4	379	43
90	0.4	167	0	0	2	149	17
95	0.1	56	0	0	0.6	50	5.6
100	0	0	0	0	0	0	0

NA = Not Applicable

5.9 TMDL IMPLEMENTATION

DEQ collaborates with 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 are utilized so that the pollutant reductions, as required by these TMDLs, can be achieved; and water quality can be restored so that these waterbodies meet their designated uses. DEQ'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 (DEQ 2012). The CPP can be viewed at DEQ's website: http://www.deq.state.ok.us/wqdnew/305b_303d/Final%20CPP.pdf. **Table 5-17** provides a partial list of the State partner agencies DEQ collaborates with to address point and nonpoint source reduction goals established by TMDLs.

Table 5-17 Partial List of Oklahoma Water Quality Management Agencies

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

5.9.1 Point Sources

Point source WLAs are outlined in the Oklahoma Water Quality Management Plan (aka the 208 Plan) under the OPDES program.

5.9.2 Nonpoint Sources

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 EPA and the National Resources Conservation Service of the USDA, 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.

The reduction rates called for in this TMDL report are as high as 94.7%. DEQ recognizes that achieving such high reductions can be a challenge, especially since unregulated nonpoint sources are a major cause of both bacterial 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 Health and Environment proposed to exclude certain high flow conditions during which pathogen standards will not apply though that exclusion was not approved by the EPA. Additionally, EPA has been conducting new epidemiology studies and may develop new recommendations for pathogen criteria in the future.

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

- **Remove 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 bacterially-impaired waterbodies, thus constituting an existing use. Existing uses cannot be removed.

- **Modify 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 bacterial 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.

- **Revisie the existing numeric criteria**: Oklahoma's current pathogen criteria, revised in 2011, are based on EPA guidelines (See the *2012 Draft Recreational Water Quality Criteria*, December 2011; 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 EPA studies that could result in revisions to their recommendations are ongoing. The numeric criteria values should also be evaluated using a risk-based method such as that found in EPA guidance.

Unless or until the WQSs are revised and approved by EPA, 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.

5.10 Reasonable Assurances

Reasonable assurance is required by the EPA guidance for a TMDL to be approvable only when a waterbody is impaired by both point and nonpoint sources and where a point source is given a less stringent wasteload allocation based on an assumption that nonpoint source load reductions will occur. In such a case, "reasonable assurance" that the NPS load reductions will actually occur must be demonstrated. In this Report, all point source discharges either already have or will be given discharge limitations less than or equal to the water quality standards numerical criteria. This ensures that the impairments of the waterbodies in this Report will not be caused by point sources. Since the point source WLAs in this TMDL report are not dependent on NPS load reduction, reasonable assurance does not apply.

SECTION 6 PUBLIC PARTICIPATION

The draft TMDL report was preliminarily reviewed by EPA before being sent out for public notice on July 9, 2014. The public notice and draft 208 Factsheet was sent to local newspapers, to stakeholders in the Study Area affected by these draft TMDLs, and to stakeholders who have requested copies of all TMDL public notices. The public notice, draft 208 Factsheet, and draft TMDL report was also posted at the following DEQ website:
http://www.deq.state.ok.us/wqdnew/index.htm.

The public comment period lasted 45 days and was open until August 25, 2014. During that time, the public had the opportunity to review the draft TMDL report and make written comments. No comments were received during the public notice period and there were no requests for a public meeting.

The *Arkansas-North Canadian Bacterial and Turbidity TMDL Report* was finalized and submitted to EPA for final approval.

After EPA's final approval, the 208 Factsheet and each TMDL & WLA were adopted into Oklahoma's Water Quality Management Plan (WQMP). These TMDLs provide a mathematical solution to meet ambient water quality criteria with a given set of facts. The adoption of these TMDLs into the WQMP provides a mechanism to recalculate acceptable loads when information changes in the future. Updates to the WQMP demonstrate compliance with the water quality criteria. The updates to the WQMP are also useful when the water quality criteria change and the loading scenario is reviewed to ensure that the in-stream criterion is predicted to be met.

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APPENDIX A: AMBIENT WATER QUALITY DATA

Table Appendix A-1 Bacterial Data: 2001 to 2012

Waterbody Name	WQM Station	Date	EC[1]	ENT[2]
OK621200050010_10	OK621200-05-0010M	06/01/04	240	310
OK621200050010_10	OK621200-05-0010M	05/29/07	1,900	1,900
OK621200050010_10	OK621200-05-0010M	06/26/07	800	3,850
OK621200050010_10	OK621200-05-0010M	07/30/07	150	90
OK621200050010_10	OK621200-05-0010M	09/10/07	5,000	5,000
OK621200050010_10	OK621200-05-0010M	05/12/08	300	620
OK621200050010_10	OK621200-05-0010M	06/16/08	2,600	3,700
OK621200050010_10	OK621200-05-0010M	07/21/08	220	90
OK621200050010_10	OK621200-05-0010M	08/25/08	220	230
OK621200050010_10	OK621200-05-0010M	09/30/08	800	150
OK621210000030_10	621210000010-001AT	06/06/2001	317	11,000
OK621210000030_10	621210000010-001AT	08/08/2001	10	10
OK621210000030_10	621210000010-001AT	05/15/2002	638	1,000
OK621210000030_10	621210000010-001AT	07/10/2002	20	20
OK621210000030_10	621210000010-001AT	08/28/2002	148	110
OK621210000030_10	621210000010-001AT	09/25/2002	30	100
OK621210000030_10	621210000010-001AT	06/05/2002	9,804	132,000
OK720500010010_00	720500010010-001AT	5/2/2006	30	20
OK720500010010_00	720500010010-001AT	5/30/2006	31	10
OK720500010010_00	720500010010-001AT	6/12/2006	197	213
OK720500010010_00	720500010010-001AT	6/27/2006	50	41
OK720500010010_00	720500010010-001AT	7/11/2006	10	31
OK720500010010_00	720500010010-001AT	7/19/2006	73	830
OK720500010010_00	720500010010-001AT	8/1/2006	140	583
OK720500010010_00	720500010010-001AT	8/8/2006	110	256
OK720500010010_00	720500010010-001AT	9/13/2006	41	119
OK720500010010_00	720500010010-001AT	5/13/2008	31	20
OK720500010010_00	720500010010-001AT	6/3/2008	93	20
OK720500010010_00	720500010010-001AT	6/24/2008	20	30
OK720500010010_00	720500010010-001AT	7/15/2008	10	10
OK720500010010_00	720500010010-001AT	8/5/2008	31	10
OK720500010070_00	OK720500-01-0070D	06/04/2007	740	720
OK720500010070_00	OK720500-01-0070D	06/18/2007	890	420
OK720500010070_00	OK720500-01-0070D	07/09/2007	330	770
OK720500010070_00	OK720500-01-0070D	08/06/2007	130	690
OK720500010070_00	OK720500-01-0070D	09/17/2007	370	480
OK720500010070_00	OK720500-01-0070D	05/19/2008	440	100

Waterbody Name	WQM Station	Date	EC[1]	ENT[2]
OK720500010070_00	OK720500-01-0070D	06/24/2008	420	140
OK720500010070_00	OK720500-01-0070D	07/16/2008	840	1,000
OK720500010070_00	OK720500-01-0070D	07/29/2008	425	360
OK720500010070_00	OK720500-01-0070D	09/03/2008	290	510
OK720500010070_00	OK720500-01-0070D	05/14/2012	240	
OK720500010070_00	OK720500-01-0070D	06/18/2012	45	
OK720500010070_00	OK720500-01-0070D	07/30/2012	95	
OK720500010070_00	OK720500-01-0070D	08/27/2012	100	
OK720500010140_10	720500010140-001AT	5/2/2006	31	10
OK720500010140_10	720500010140-001AT	5/30/2006	61	97
OK720500010140_10	720500010140-001AT	6/13/2006	86	31
OK720500010140_10	720500010140-001AT	6/27/2006	86	10
OK720500010140_10	720500010140-001AT	7/11/2006	10	10
OK720500010140_10	720500010140-001AT	7/19/2006	10	62
OK720500010140_10	720500010140-001AT	8/1/2006	20	1,333
OK720500010140_10	720500010140-001AT	8/8/2006	30	1,236
OK720500010140_10	720500010140-001AT	9/13/2006	10	199
OK720500010140_10	720500010140-001AT	5/13/2008	98	109
OK720500010140_10	720500010140-001AT	6/3/2008	41	10
OK720500010140_10	720500010140-001AT	6/23/2008	20	20
OK720500010140_10	720500010140-001AT	7/14/2008	10	10
OK720500010140_10	720500010140-001AT	8/4/2008	10	294
OK720500010150_00	OK720500-01-0150G	06/04/07	840	510
OK720500010150_00	OK720500-01-0150G	06/18/07	600	470
OK720500010150_00	OK720500-01-0150G	07/09/07	360	580
OK720500010150_00	OK720500-01-0150G	08/06/07	610	720
OK720500010150_00	OK720500-01-0150G	09/17/07	570	840
OK720500010150_00	OK720500-01-0150G	05/19/08	290	490
OK720500010150_00	OK720500-01-0150G	06/24/08	640	240
OK720500010150_00	OK720500-01-0150G	07/16/08	1,000	1,000
OK720500010150_00	OK720500-01-0150G	07/29/08	500	330
OK720500010150_00	OK720500-01-0150G	09/03/08	670	310
OK720500010150_00	OK720500-01-0150G	09/14/08	270	610
OK720500010150_00	OK720500-01-0150G	05/14/12	60	
OK720500010150_00	OK720500-01-0150G	06/18/12	40	
OK720500010150_00	OK720500-01-0150G	07/30/12	15	
OK720500010150_00	OK720500-01-0150G	08/27/12	420	
OK720500010200_00	OK720500-01-0200D	06/04/07	330	220

Waterbody Name	WQM Station	Date	EC[1]	ENT[2]
OK720500010200_00	OK720500-01-0200D	06/18/07	170	330
OK720500010200_00	OK720500-01-0200D	07/09/07	310	360
OK720500010200_00	OK720500-01-0200D	08/06/07	140	980
OK720500010200_00	OK720500-01-0200D	09/17/07	140	550
OK720500010200_00	OK720500-01-0200D	05/19/08	60	10
OK720500010200_00	OK720500-01-0200D	06/24/08	220	20
OK720500010200_00	OK720500-01-0200D	07/16/08	1,000	1,000
OK720500010200_00	OK720500-01-0200D	07/29/08	330	270
OK720500010200_00	OK720500-01-0200D	09/03/08	180	150

[1] EC = *E. coli*; according to the DEQ 2010 303(d) List none of the studied waterbodies is impaired for EC; data not presented here.

[2] ENT = Enterococci; units = counts/100 mL.

Table Appendix A-2 Turbidity and Total Suspended Solids Data: 1998-2011

Waterbody Name	Waterbody ID	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK621200050010_10	OK621200-05-0010M	05/29/07	405	352	Elevated
OK621200050010_10	OK621200-05-0010M	06/26/07	208	259	Elevated
OK621200050010_10	OK621200-05-0010M	07/30/07	57.9	56	Elevated
OK621200050010_10	OK621200-05-0010M	09/10/07		1,051	High Flow
OK621200050010_10	OK621200-05-0010M	10/16/07	55.8	35	Slightly Elevated
OK621200050010_10	OK621200-05-0010M	11/13/07	35.5	25	Base Flow
OK621200050010_10	OK621200-05-0010M	12/17/07	30.7	10	Slightly Elevated
OK621200050010_10	OK621200-05-0010M	01/22/08	8.92	10	
OK621200050010_10	OK621200-05-0010M	03/03/08	298	266	High Flow
OK621200050010_10	OK621200-05-0010M	04/07/08	343	272	Elevated
OK621200050010_10	OK621200-05-0010M	05/12/08	194	122	Elevated
OK621200050010_10	OK621200-05-0010M	06/16/08	299	384	High Flow
OK621200050010_10	OK621200-05-0010M	07/21/08	147	115	Elevated
OK621200050010_10	OK621200-05-0010M	08/06/08	63.1		Low Flow
OK621200050010_10	OK621200-05-0010M	08/25/08	73	57	Base Flow
OK621200050010_10	OK621200-05-0010M	09/30/08	20.8	15	Slightly Elevated
OK621200050010_10	OK621200-05-0010M	11/04/08	21.2	16	Slightly Elevated
OK621200050010_10	OK621200-05-0010M	12/15/08		<10	
OK621200050010_10	OK621200-05-0010M	02/02/09	3.87	<10	Base Flow
OK621200050010_10	OK621200-05-0010M	03/03/09	3.69	<10	Base Flow
OK621200050010_10	OK621200-05-0010M	04/06/09	35	<10	Slightly Elevated
OK621210000030_10	621210000010-001AT	09/08/1999	149	186	
OK621210000030_10	621210000010-001AT	10/19/1999	43	98	
OK621210000030_10	621210000010-001AT	11/16/1999	27	54	
OK621210000030_10	621210000010-001AT	12/14/1999	148	284	
OK621210000030_10	621210000010-001AT	02/01/2000	11	30	
OK621210000030_10	621210000010-001AT	02/23/2000	87	132	
OK621210000030_10	621210000010-001AT	03/22/2000	113		
OK621210000030_10	621210000010-001AT	04/18/2000	69	97	
OK621210000030_10	621210000010-001AT	05/16/2000	72	372	
OK621210000030_10	621210000010-001AT	06/21/2000	42	52	4
OK621210000030_10	621210000010-001AT	07/25/2000	937	800	4
OK621210000030_10	621210000010-001AT	08/22/2000	68	164	3
OK621210000030_10	621210000010-001AT	09/20/2000	45		2
OK621210000030_10	621210000010-001AT	10/17/2000	41	88	2
OK621210000030_10	621210000010-001AT	11/14/2000	37	48	3

Waterbody Name	Waterbody ID	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK621210000030_10	621210000010-001AT	02/07/2001	27		3
OK621210000030_10	621210000010-001AT	03/07/2001	150		3
OK621210000030_10	621210000010-001AT	04/04/2001	47		3
OK621210000030_10	621210000010-001AT	05/09/2001	337		3
OK621210000030_10	621210000010-001AT	06/06/2001	1,085		3
OK621210000030_10	621210000010-001AT	07/11/2001	65		2
OK621210000030_10	621210000010-001AT	08/08/2001	75		2
OK621210000030_10	621210000010-001AT	10/03/2001	80		3
OK621210000030_10	621210000010-001AT	02/06/2002	26		3
OK621210000030_10	621210000010-001AT	03/13/2002	26		2
OK621210000030_10	621210000010-001AT	04/10/2002	42		3
OK621210000030_10	621210000010-001AT	05/15/2002	628		5
OK621210000030_10	621210000010-001AT	07/10/2002	159		1
OK621210000030_10	621210000010-001AT	08/28/2002	210		2
OK621210000030_10	621210000010-001AT	09/25/2002	90		
OK621210000030_10	621210000010-001AT	12/04/2002	8		2
OK621210000030_10	621210000010-001AT	06/05/2002	936		3
OK720500010010_00	720500010010-001AT	1/11/2006	18		2
OK720500010010_00	720500010010-001AT	2/15/2006	15		3
OK720500010010_00	720500010010-001AT	3/29/2006	37		3
OK720500010010_00	720500010010-001AT	4/24/2006	39		2
OK720500010010_00	720500010010-001AT	5/30/2006	22		2
OK720500010010_00	720500010010-001AT	7/11/2006	7		1
OK720500010010_00	720500010010-001AT	8/8/2006	3		1
OK720500010010_00	720500010010-001AT	9/13/2006	3		2
OK720500010010_00	720500010010-001AT	10/25/2006	1		2
OK720500010010_00	720500010010-001AT	11/29/2006	1		2
OK720500010010_00	720500010010-001AT	1/9/2007	8		1
OK720500010010_00	720500010010-001AT	2/28/2007	16		2
OK720500010010_00	720500010010-001AT	3/28/2007	38		3
OK720500010010_00	720500010010-001AT	5/2/2007	34		3
OK720500010010_00	720500010010-001AT	6/6/2007	29		4
OK720500010010_00	720500010010-001AT	7/11/2007	73		3
OK720500010010_00	720500010010-001AT	8/8/2007	28		2
OK720500010010_00	720500010010-001AT	9/12/2007	29		3
OK720500010010_00	720500010010-001AT	10/17/2007	10		2
OK720500010010_00	720500010010-001AT	1/30/2008	22		3
OK720500010010_00	720500010010-001AT	2/27/2008	26		3
OK720500010010_00	720500010010-001AT	3/31/2008	25		2
OK720500010010_00	720500010010-001AT	5/7/2008	118		2

Waterbody Name	Waterbody ID	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK720500010010_00	720500010010-001AT	7/14/2008	31		2
OK720500010010_00	720500010010-001AT	8/25/2008	4		2
OK720500010010_00	720500010010-001AT	10/20/2008	21		2
OK720500010010_00	720500010010-001AT	1/20/2009	18.6		2
OK720500010010_00	720500010010-001AT	3/16/2009	24		2
OK720500010010_00	720500010010-001AT	4/6/2009	38		2
OK720500010010_00	720500010010-001AT	5/4/2009	68		3
OK720500010010_00	720500010010-001AT	8/24/2009	21		1
OK720500010010_00	720500010010-001AT	11/2/2009	15		2
OK720500010010_00	720500010010-001AT	1/4/2010	7		2
OK720500010010_00	720500010010-001AT	3/22/2010	11		2
OK720500010010_00	720500010010-001AT	5/17/2010	42		
OK720500010010_00	720500010010-001AT	7/15/2010	49		3
OK720500010010_00	720500010010-001AT	9/27/2010	6		2
OK720500010010_00	720500010010-001AT	11/15/2010	61.3		5
OK720500010010_00	720500010010-001AT	2/22/2011	28.3		3
OK720500010010_00	720500010010-001AT	3/21/2011	16		
OK720500010010_00	720500010010-001AT	5/3/2011	14.3		3
OK720500010010_00	720500010010-001AT	8/1/2011	13.3		
OK720500010010_00	720500010010-001AT	11/7/2011	1.3		1
OK720500010010_00	720500010010-001AT	1/9/2012	3		2
OK720500010010_00	720500010010-001AT	2/27/2012	40.3		3
OK720500010010_00	720500010010-001AT	5/7/2012	26.3		2
OK720500010010_00	720500010010-001AT	7/16/2012	2		1
OK720500010070_00	OK720500-01-0070D	06/04/2007	32.7	65	Elevated
OK720500010070_00	OK720500-01-0070D	07/09/2007	8.57	23	Base Flow
OK720500010070_00	OK720500-01-0070D	07/26/2007	4.99		Slightly Elevated
OK720500010070_00	OK720500-01-0070D	08/06/2007	2.38	<10	Base Flow
OK720500010070_00	OK720500-01-0070D	09/17/2007	2.5	<10	Base Flow
OK720500010070_00	OK720500-01-0070D	10/22/2007	2.03	<10	Base Flow
OK720500010070_00	OK720500-01-0070D	11/26/2007	1.11	<10	Base Flow
OK720500010070_00	OK720500-01-0070D	01/07/2008	2.06	<10	Base Flow
OK720500010070_00	OK720500-01-0070D	02/04/2008	4.81	<10	Base Flow
OK720500010070_00	OK720500-01-0070D	03/10/2008	4.17	<10	Base Flow
OK720500010070_00	OK720500-01-0070D	04/14/2008	3.36	<10	Base Flow
OK720500010070_00	OK720500-01-0070D	05/19/2008	1.24	<10	Base Flow
OK720500010070_00	OK720500-01-0070D	06/24/2008	20	35	Base Flow
OK720500010070_00	OK720500-01-0070D	07/29/2008	6.15	<10	Low Flow
OK720500010070_00	OK720500-01-0070D	09/03/2008	7.73	<10	Low Flow

Waterbody Name	Waterbody ID	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK720500010070_00	OK720500-01-0070D	10/07/2008	61.9	88	Elevated
OK720500010070_00	OK720500-01-0070D	11/18/2008	1.46	<10	Base Flow
OK720500010070_00	OK720500-01-0070D	12/29/2008	1.9	<10	Base Flow
OK720500010070_00	OK720500-01-0070D	02/10/2009	3.46	<10	Base Flow
OK720500010070_00	OK720500-01-0070D	03/03/2009	2.61	<10	Base Flow
OK720500010070_00	OK720500-01-0070D	04/14/2009	4.26	<10	Slightly Elevated
OK720500010070_00	OK720500-01-0070D	5/14/2012	3.2		Base Flow
OK720500010070_00	OK720500-01-0070D	6/18/2012	3.14		Base Flow
OK720500010070_00	OK720500-01-0070D	6/20/2012	2.47		Base Flow
OK720500010070_00	OK720500-01-0070D	7/30/2012	2.89		Trace
OK720500010070_00	OK720500-01-0070D	8/27/2012	1.35		Low Flow
OK720500010070_00	OK720500-01-0070D	10/1/2012	1.66		Base Flow
OK720500010070_00	OK720500-01-0070D	11/5/2012	1.71		Base Flow
OK720500010070_00	OK720500-01-0070D	12/17/2012	2.72		Base Flow
OK720500010070_00	OK720500-01-0070D	1/28/2013	1.94		Base Flow
OK720500010070_00	OK720500-01-0070D	3/4/2013	4.18		Slightly Elevated
OK720500010070_00	OK720500-01-0070D	4/1/2013	2.09		Base Flow
OK720500010140_10	720500010140-001AT	1/8/2007	5		2
OK720500010140_10	720500010140-001AT	2/28/2007	6		3
OK720500010140_10	720500010140-001AT	3/28/2007	35		2
OK720500010140_10	720500010140-001AT	5/2/2007	19		3
OK720500010140_10	720500010140-001AT	6/6/2007	26		5
OK720500010140_10	720500010140-001AT	7/11/2007	42		3
OK720500010140_10	720500010140-001AT	8/8/2007	27		3
OK720500010140_10	720500010140-001AT	9/12/2007	27		3
OK720500010140_10	720500010140-001AT	10/16/2007	15		2
OK720500010140_10	720500010140-001AT	1/30/2008	17		3
OK720500010140_10	720500010140-001AT	2/26/2008	16		3
OK720500010140_10	720500010140-001AT	3/31/2008	33		2
OK720500010140_10	720500010140-001AT	5/6/2008	71		High Flow
OK720500010140_10	720500010140-001AT	7/14/2008	10		2
OK720500010140_10	720500010140-001AT	8/25/2008	123		3
OK720500010140_10	720500010140-001AT	10/20/2008	6		2
OK720500010140_10	720500010140-001AT	1/21/2009	13		2
OK720500010140_10	720500010140-001AT	3/16/2009	23.25		2
OK720500010140_10	720500010140-001AT	4/6/2009	32.6		
OK720500010140_10	720500010140-001AT	5/5/2009	30.5		3
OK720500010140_10	720500010140-001AT	8/25/2009	5		1
OK720500010140_10	720500010140-001AT	11/2/2009	2		2

Waterbody Name	Waterbody ID	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK720500010140_10	720500010140-001AT	1/5/2010	8.3		2
OK720500010140_10	720500010140-001AT	3/22/2010	7		2
OK720500010140_10	720500010140-001AT	5/18/2010	12		2
OK720500010140_10	720500010140-001AT	7/14/2010	41.3		2
OK720500010140_10	720500010140-001AT	9/28/2010	2.8		2
OK720500010140_10	720500010140-001AT	11/16/2010	2.8		2
OK720500010140_10	720500010140-001AT	2/23/2011	15.3		2
OK720500010140_10	720500010140-001AT	3/22/2011	38.5		3
OK720500010140_10	720500010140-001AT	5/4/2011	7.8		2
OK720500010140_10	720500010140-001AT	8/2/2011	2.8		2
OK720500010140_10	720500010140-001AT	9/21/2011	2.3		2
OK720500010140_10	720500010140-001AT	1/10/2012	2		2
OK720500010140_10	720500010140-001AT	2/28/2012	43.5		3
OK720500010140_10	720500010140-001AT	5/8/2012	4.3		2
OK720500010140_10	720500010140-001AT	7/17/2012	3		3
OK720500010140_10	720500010140-001AT	9/11/2012	2.3		2
OK720500010150_00	OK720500-01-0150G	06/04/07	92	134	Slightly Elevated
OK720500010150_00	OK720500-01-0150G	07/09/07	26.7	38	Base Flow
OK720500010150_00	OK720500-01-0150G	07/27/07	45.6		Base Flow
OK720500010150_00	OK720500-01-0150G	08/06/07	22.6	41	Slightly Elevated
OK720500010150_00	OK720500-01-0150G	09/17/07	23.1	35	Base Flow
OK720500010150_00	OK720500-01-0150G	10/22/07	7.48	<10	Slightly Elevated
OK720500010150_00	OK720500-01-0150G	11/26/07	9.54	11	Base Flow
OK720500010150_00	OK720500-01-0150G	01/07/08	26.2	45	Base Flow
OK720500010150_00	OK720500-01-0150G	02/04/08	25.4	51	Base Flow
OK720500010150_00	OK720500-01-0150G	03/10/08	13.3	17	Base Flow
OK720500010150_00	OK720500-01-0150G	05/19/08	36.4	52	Base Flow
OK720500010150_00	OK720500-01-0150G	06/24/08	35.7	41	Base Flow
OK720500010150_00	OK720500-01-0150G	07/29/08	31	36	Low Flow
OK720500010150_00	OK720500-01-0150G	09/03/08	56.5	61	Slightly Elevated
OK720500010150_00	OK720500-01-0150G	09/14/08	46	62	Base Flow
OK720500010150_00	OK720500-01-0150G	10/07/08	189	252	Elevated
OK720500010150_00	OK720500-01-0150G	11/18/08	8.14	11	Base Flow
OK720500010150_00	OK720500-01-0150G	12/29/08	12	24	Slightly Elevated
OK720500010150_00	OK720500-01-0150G	02/10/09	50.5	74	Slightly Elevated
OK720500010150_00	OK720500-01-0150G	03/03/09	8.49	13	Base Flow
OK720500010150_00	OK720500-01-0150G	4/14/2009	65.8		Elevated

Waterbody Name	Waterbody ID	Date	Turbidity (NTU)	TSS (mg/L)	Flow Condition
OK720500010150_00	OK720500-01-0150G	5/14/2012	7.35		Base Flow
OK720500010150_00	OK720500-01-0150G	6/18/2012	3.43		Base Flow
OK720500010150_00	OK720500-01-0150G	6/20/2012	5.9		Base Flow
OK720500010150_00	OK720500-01-0150G	7/30/2012	1.2		Low Flow
OK720500010150_00	OK720500-01-0150G	8/27/2012	1.26		Low Flow
OK720500010150_00	OK720500-01-0150G	10/1/2012	0.74		Base Flow
OK720500010150_00	OK720500-01-0150G	11/5/2012	0.94		Base Flow
OK720500010150_00	OK720500-01-0150G	12/17/2012	8.33		Base Flow
OK720500010150_00	OK720500-01-0150G	1/28/2013	5.87		Base Flow
OK720500010150_00	OK720500-01-0150G	3/4/2013	182		High Flow
OK720500010150_00	OK720500-01-0150G	4/1/2013	5.42		Slightly Elevated
OK720500010200_00	OK720500-01-0200D	06/04/07	22.1	45	Slightly Elevated
OK720500010200_00	OK720500-01-0200D	07/09/07	17.8	35	Slightly Elevated
OK720500010200_00	OK720500-01-0200D	07/26/07	10.7		Base Flow
OK720500010200_00	OK720500-01-0200D	08/06/07	24.9	46	Base Flow
OK720500010200_00	OK720500-01-0200D	09/17/07	13.4	24	Base Flow
OK720500010200_00	OK720500-01-0200D	10/22/07	7.16	16	Slightly Elevated
OK720500010200_00	OK720500-01-0200D	11/26/07	6.44	<10	Base Flow
OK720500010200_00	OK720500-01-0200D	01/07/08	7.86	12	Base Flow
OK720500010200_00	OK720500-01-0200D	02/04/08	9.96	16	Base Flow
OK720500010200_00	OK720500-01-0200D	03/10/08	7.79	<10	Base Flow
OK720500010200_00	OK720500-01-0200D	04/14/08	19.6	38	Base Flow
OK720500010200_00	OK720500-01-0200D	05/19/08	10.5	23	Base Flow
OK720500010200_00	OK720500-01-0200D	06/24/08	25.8	45	Base Flow
OK720500010200_00	OK720500-01-0200D	07/29/08	27	40	Base Flow
OK720500010200_00	OK720500-01-0200D	09/03/08	13.9	19	Base Flow
OK720500010200_00	OK720500-01-0200D	10/07/08	14.6	27	Elevated
OK720500010200_00	OK720500-01-0200D	11/18/08	3.7	<10	Base Flow
OK720500010200_00	OK720500-01-0200D	12/29/08	5.03	<10	Base Flow
OK720500010200_00	OK720500-01-0200D	02/10/09	12.7	23	Slightly Elevated
OK720500010200_00	OK720500-01-0200D	03/03/09	7.01	14	Base Flow
OK720500010200_00	OK720500-01-0200D	04/14/09	7.56	<10	Slightly Elevated

APPENDIX B: GENERAL METHOD FOR ESTIMATING FLOW FOR UNGAGED STREAMS AND ESTIMATED FLOW EXCEEDANCE PERCENTILES

Appendix B
General Method for Estimating Flow for Ungaged Streams

Flows duration curve were 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 were derived for each Oklahoma stream segment in the following priority:

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

  1. If simultaneously collected flow data matching the water quality sample collection date were available, those flow measurements were used.

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

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

  4. On streams impounded by dams to form reservoirs of sufficient size to impact stream flow, only flows measured after the date of the most recent impoundment was used to develop the flow duration curve. This also applied to reservoirs on major tributaries to the streams.

B. In the case no coincident flow data were available for a stream segment, but flow gage(s) were present upstream and/or downstream without a major reservoir between, flows were 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 Natural Resources Conservation Service (NRCS) runoff curve numbers and antecedent rainfall condition. Drainage sub-basins were first delineated for all impaired 303(d)-listed WQM stations, along with all USGS flow stations located in the 8-digit HUCs with impaired streams. Then all the USGS gage stations were identified upstream and downstream of the sub-watersheds with 303(d) listed WQM stations.

1. Watershed delineations were 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 was calculated following watershed delineation.

2. The watershed average curve number was 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 soil data, and land use category from the National Land Cover Dataset (NLCD). Based on land use and the hydrologic soil group, SCS curve numbers were estimated at the 30-meter resolution of the NLCD grid as shown in **Table Appendix B-1**. The average curve number was then calculated from all the grid cells within the delineated watershed.

3. The average rainfall was 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).

Table Appendix B-1 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

4. 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 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-percent-duration streamflow to mean streamflow
- The percentage duration of appreciable (0.10 ft /s) streamflow
- 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):

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

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

$$I_a = 0.2*S \qquad \textbf{(2)}$$

Thus, the runoff curve number equation can be rewritten:

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

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

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

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 = 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
- 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.

C. 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

Table Appendix B-2 Estimated Flow Exceedance Percentiles

Stream Name	Red Rock Creek	Arkansas River	North Canadian River	Bent Creek	Beaver River	Persimmon Creek	Indian Creek
WBID	OK621200050010_10	OK621210000030_10	OK720500010010_00	OK720500010070_00	OK720500010140_10	OK720500010150_00	OK720500010200_00
USGS Gage Reference	07153000 (adjacent)	07146500 (Upstream)	07238000 (In-stream)	07301420 (adjacent)	07237500 (In-stream)	07301420 (adjacent)	07301420 (adjacent)
Drainage Area (square miles)	538	44,236	12,555	437	11,883	172	75
Flow Exceedance Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
0	11,378	80,654	29,100	226	30,510	297	130
1	1,657	18,606	2,140	38	1,984	50	22
2	1,112	12,852	1,310	28	1,120	37	16
3	815	10,085	971	23	792	30	13
4	618	8,399	780	20	609	26	11
5	484	7,175	625	18	497	24	10
6	388	6,264	537	16	423	22	9.4
7	314	5,566	476	15	370	20	8.8
8	258	5,040	420	14	333	19	8.2
9	215	4,582	382	14	302	18	7.9
10	181	4,169	347	13	278	17	7.6

Stream Name	Red Rock Creek	Arkanasas River	North Canadian River	Bent Creek	Beaver River	Persimmon Creek	Indian Creek
WBID	OK621200050010_10	OK621210000030_10	OK720500010010_00	OK720500010070_00	OK720500010140_10	OK720500010150_00	OK720500010200_00
USGS Gage Reference	07153000 (adjacent)	07146500 (Upstream)	07238000 (In-stream)	07301420 (adjacent)	07237500 (In-stream)	07301420 (adjacent)	07301420 (adjacent)
Drainage Area (square miles)	538	44,236	12,555	437	11,883	172	75
Flow Exceedance Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
11	155	3,845	322	13	254	17	7.2
12	135	3,555	298	12	237	16	6.9
13	117	3,309	281	11	222	15	6.5
14	103	3,117	267	11	212	15	6.4
15	91	2,914	252	11	201	14	6.2
16	81	2,753	240	10	190	14	6.0
17	73	2,591	227	10	182	13	5.8
18	65	2,469	216	10	175	13	5.7
19	59	2,348	207	10	167	13	5.5
20	53	2,247	198	9.3	159	12	5.3
21	48	2,145	190	9.0	152	12	5.1
22	44	2,054	183	9.0	145	12	5.1

Stream Name	Red Rock Creek	Arkanasas River	North Canadian River	Bent Creek	Beaver River	Persimmon Creek	Indian Creek
WBID	OK621200050010_10	OK621210000030_10	OK720500010010_00	OK720500010070_00	OK720500010140_10	OK720500010150_00	OK720500010200_00
USGS Gage Reference	07153000 (adjacent)	07146500 (Upstream)	07238000 (In-stream)	07301420 (adjacent)	07237500 (In-stream)	07301420 (adjacent)	07301420 (adjacent)
Drainage Area (square miles)	538	44,236	12,555	437	11,883	172	75
Flow Exceedance Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
23	40	1,963	176	8.7	139	11	5.0
24	37	1,902	170	8.4	134	11	4.8
25	34	1,822	164	8.4	130	11	4.8
26	31	1,761	158	8.1	125	11	4.6
27	29	1,700	151	8.1	120	11	4.6
28	26	1,639	147	7.8	115	10	4.5
29	25	1,579	142	7.8	111	10	4.5
30	23	1,528	137	7.5	108	10	4.3
31	22	1,498	131	7.5	104	10	4.3
32	20	1,447	127	7.2	100	9.4	4.1
33	19	1,417	122	7.2	97	9.4	4.1
34	18	1,376	118	6.9	94	9.1	3.9

Stream Name	Red Rock Creek	Arkanasas River	North Canadian River	Bent Creek	Beaver River	Persimmon Creek	Indian Creek
WBID	OK621200050010_10	OK621210000030_10	OK720500010010_00	OK720500010070_00	OK720500010140_10	OK720500010150_00	OK720500010200_00
USGS Gage Reference	07153000 (adjacent)	07146500 (Upstream)	07238000 (In-stream)	07301420 (adjacent)	07237500 (In-stream)	07301420 (adjacent)	07301420 (adjacent)
Drainage Area (square miles)	538	44,236	12,555	437	11,883	172	75
Flow Exceedance Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
35	17	1,336	114	6.9	91	9.1	3.9
36	16	1,295	111	6.9	89	9.1	3.9
37	15	1,265	108	6.6	86	8.7	3.8
38	14	1,235	105	6.6	84	8.7	3.8
39	13	1,204	102	6.6	81	8.7	3.8
40	12	1,174	100	6.3	78	8.3	3.6
41	12	1,144	96	6.3	76	8.3	3.6
42	11	1,113	93	6.3	74	8.3	3.6
43	10	1,093	90	6.0	71	7.9	3.4
44	10	1,063	87	6.0	69	7.9	3.4
45	9.4	1,032	84	5.7	67	7.5	3.3
46	9.0	1,009	82	5.7	65	7.5	3.3

Stream Name	Red Rock Creek	Arkanasas River	North Canadian River	Bent Creek	Beaver River	Persimmon Creek	Indian Creek
WBID	OK621200050010_10	OK621210000030_10	OK720500010010_00	OK720500010070_00	OK720500010140_10	OK720500010150_00	OK720500010200_00
USGS Gage Reference	07153000 (adjacent)	07146500 (Upstream)	07238000 (In-stream)	07301420 (adjacent)	07237500 (In-stream)	07301420 (adjacent)	07301420 (adjacent)
Drainage Area (square miles)	538	44,236	12,555	437	11,883	172	75
Flow Exceedance Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
47	9.0	983	79	5.7	63	7.5	3.3
48	8.5	961	77	5.4	61	7.1	3.1
49	8.1	936	74	5.4	59	7.1	3.1
50	7.6	913	72	5.4	57	7.1	3.1
51	7.2	891	69	5.1	55	6.7	2.9
52	6.7	868	67	5.1	53	6.7	2.9
53	6.7	845	65	5.1	51	6.7	2.9
54	6.3	823	62	4.8	49	6.3	2.7
55	5.8	803	60	4.8	47	6.3	2.7
56	5.8	780	57	4.8	46	6.3	2.7
57	5.4	759	55	4.5	44	5.9	2.6
58	5.4	739	53	4.5	42	5.9	2.6

Stream Name	Red Rock Creek	Arkanasas River	North Canadian River	Bent Creek	Beaver River	Persimmon Creek	Indian Creek
WBID	OK621200050010_10	OK621210000030_10	OK720500010010_00	OK720500010070_00	OK720500010140_10	OK720500010150_00	OK720500010200_00
USGS Gage Reference	07153000 (adjacent)	07146500 (Upstream)	07238000 (In-stream)	07301420 (adjacent)	07237500 (In-stream)	07301420 (adjacent)	07301420 (adjacent)
Drainage Area (square miles)	538	44,236	12,555	437	11,883	172	75
Flow Exceedance Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
59	4.9	717	50	4.2	40	5.5	2.4
60	4.5	699	48	4.2	38	5.5	2.4
61	4.5	681	46	3.9	36	5.1	2.2
62	4.3	663	44	3.9	34	5.1	2.2
63	4.0	647	42	3.6	33	4.7	2.1
64	3.8	627	40	3.6	31	4.7	2.1
65	3.6	608	38	3.6	30	4.7	2.1
66	3.4	594	36	3.3	28	4.3	1.9
67	3.2	580	35	3.3	27	4.3	1.9
68	3.0	567	34	3.0	26	3.9	1.7
69	2.9	552	32	3.0	25	3.9	1.7
70	2.7	539	30	2.8	24	3.7	1.6

Stream Name	Red Rock Creek	Arkanasas River	North Canadian River	Bent Creek	Beaver River	Persimmon Creek	Indian Creek
WBID	OK621200050010_10	OK621210000030_10	OK720500010010_00	OK720500010070_00	OK720500010140_10	OK720500010150_00	OK720500010200_00
USGS Gage Reference	07153000 (adjacent)	07146500 (Upstream)	07238000 (In-stream)	07301420 (adjacent)	07237500 (In-stream)	07301420 (adjacent)	07301420 (adjacent)
Drainage Area (square miles)	538	44,236	12,555	437	11,883	172	75
Flow Exceedance Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
71	2.6	523	29	2.7	23	3.5	1.5
72	2.5	511	27	2.5	22	3.3	1.5
73	2.3	501	25	2.4	22	3.1	1.4
74	2.2	490	23	2.2	21	2.9	1.3
75	2.1	479	22	2.0	20	2.7	1.2
76	1.9	467	20	1.9	19	2.5	1.1
77	1.8	453	18	1.8	19	2.3	1.0
78	1.7	442	17	1.6	18	2.2	0.9
79	1.6	428	15	1.5	17	2.0	0.9
80	1.5	415	14	1.3	16	1.8	0.8
81	1.4	404	12	1.2	16	1.6	0.7
82	1.3	390	11	1.1	15	1.5	0.6

Stream Name	Red Rock Creek	Arkanasas River	North Canadian River	Bent Creek	Beaver River	Persimmon Creek	Indian Creek
WBID	OK621200050010_10	OK621210000030_10	OK720500010010_00	OK720500010070_00	OK720500010140_10	OK720500010150_00	OK720500010200_00
USGS Gage Reference	07153000 (adjacent)	07146500 (Upstream)	07238000 (In-stream)	07301420 (adjacent)	07237500 (In-stream)	07301420 (adjacent)	07301420 (adjacent)
Drainage Area (square miles)	538	44,236	12,555	437	11,883	172	75
Flow Exceedance Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
83	1.2	379	9.4	1.0	15	1.3	0.6
84	1.1	366	8.0	0.9	14	1.2	0.5
85	0.94	354	6.4	0.8	14	1.1	0.5
86	0.85	341	5.0	0.7	13	0.9	0.4
87	0.76	327	3.6	0.6	13	0.8	0.3
88	0.63	314	2.5	0.5	12	0.7	0.3
89	0.54	301	1.5	0.4	12	0.5	0.2
90	0.49	284	0.74	0.3	11	0.4	0.2
91	0.40	268	0.27	0.3	11	0.4	0.2
92	0.31	253	0	0.2	10	0.3	0.13
93	0.23	234	0	0.2	10	0.2	0.11
94	0.16	215	0	0.15	10	0.2	0.09

Stream Name	Red Rock Creek	Arkanasas River	North Canadian River	Bent Creek	Beaver River	Persimmon Creek	Indian Creek
WBID	OK621200050010_10	OK621210000030_10	OK720500010010_00	OK720500010070_00	OK720500010140_10	OK720500010150_00	OK720500010200_00
USGS Gage Reference	07153000 (adjacent)	07146500 (Upstream)	07238000 (In-stream)	07301420 (adjacent)	07237500 (In-stream)	07301420 (adjacent)	07301420 (adjacent)
Drainage Area (square miles)	538	44,236	12,555	437	11,883	172	75
Flow Exceedance Percentile	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
95	0.09	194	0	0.11	10	0.15	0.06
96	0.04	169	0	0.09	10	0.11	0.05
97	0.01	147	0	0.07	10	0.09	0.04
98	0	112	0	0.04	10	0.06	0.03
99	0	63	0	0.02	10	0.02	0.01
100	0	4.0	0	0	10	0	0

* US Army Corp of Engineers gage station

APPENDIX C: STATE OF OKLAHOMA ANTIDEGRADATION POLICY

Appendix C
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.

APPENDIX D: DEQ SANITARY SEWER OVERFLOW DATA: 1989-2001

Table Appendix D-1 DEQ Sanitary Sewer Overflow Data -- 1989-2001

Facility Name	Facility ID	Date	Duration (hrs)	Location	Amount (gallons)	Raw	Treated	Cause
WOODWARD	S20520	5/19/1997		42ND ST.	>3,000	X		BROKEN LINES
WOODWARD	S20520	9/18/1996	336	NW 1/4 SEC. 29 R20W T23N	28			
WOODWARD	S20520	4/27/1998	169	LAGOONS	11.9 MILLION			RAINS
WOODWARD	S20520	5/4/1998	1	1522 9TH ST.	300	X		LINE PLUGGED
WOODWARD	S20520	4/20/1998		N.W. INN MOTEL / 1 & 270 HWY	500			
WOODWARD	S20520	2/23/1998	.4	19TH & SANTE FE	500	X		STOPPED MAIN
WOODWARD	S20520	3/18/1998		SEWER LAGOONS	11 MILLION			
WOODWARD	S20520	1/7/1998	192	LAGOONS	11 MILLION			RAINS
WOODWARD	S20520	12/13/1997		2ND. & WALNUT	250			
WOODWARD	S20520	11/26/1997		LAGOONS	23 MILLI			FULL CAPACITY
WOODWARD POLLUTION CONTROL	S20520	1/30/2001	240	NORTH UNPERMITTED POND	5000000		X	COLD WEATHER. UNABLE TO IRRIGATE
WOODWARD	S20520	4/2/1998		LAGOONS				RAINS
WOODWARD	S20520	7/24/1996	3.0	1114 2ND				RAIN
WOODWARD	S20520	5/12/1998		LAGOONS				RAINS
WOODWARD	S20520	8/3/1996	2.0	1114 2ND		X		RAIN
WOODWARD	S20520	7/19/1997	1	11TH & MADISON	750	X		MAIN LINE STOPPED
WOODWARD	S20520	4/25/1997	336	NW 1/4 SEC. 29 R20W T23N.	22 MILLION			
WOODWARD	S20520	6/3/1997		NW 1/4 SEC. 29 R20W T23N.	27 MILLION			
WOODWARD	S20520	8/29/1996		NW 1/4 SEC. 29 R20W T23N	19			
WOODWARD	S20520	4/25/1997		TO N. CANADIAN RIVER			X	LAGOONS FULL DO TO RAIN
WOODWARD	S20520	2/27/1997	336	NW 1/4 SEC. 29 R20W T23N	14	X		RAIN
WOODWARD	S20520	2/27/1997		DISCHARGE INTO THE N. CANADIAN RIVER			X	LAGOONS FULL OF WATER, BANKS ARE WASHING AWAY
WOODWARD	S20520	1/20/1997	1.0	S. HWY 270 MARIES VILLA	20	X		LINE PLUGGED
WOODWARD	S20520	1/17/1997	0.0	11TH & MADISON AVE.	500	X		MAIN PLUGGED
WOODWARD	S20520	12/24/1996	0.0	1116 WASHINGTON AVE.		X		SEWER LINES PLUGGED

Facility Name	Facility ID	Date	Duration (hrs)	Location	Amount (gallons)	Raw	Treated	Cause
WOODWARD	S20520	7/26/1996	2.0	SEWER PLANT		X		RAIN
WOODWARD	S20520	4/13/1999		FROM FOUR STORAGE PONDS TO UNPERMITTED 5TH POND/HEADWORKS			X	RAIN
WOODWARD POLUTION CONTROL	S20520	1/30/2001	240	NORTH UNPERMITED POND			X	COLD WEATHER, UNABLE TO IRRIGATE
WOODWARD	S20520	6/27/1993	6.0	WWTP	300000	X		ELECTRICAL OUTAGE DUE TO STORM
WOODWARD	S20520	12/11/2000		N. NON-PERMITTED POND	7 MILLION		X	UNABLE TO IRRIGATE DUE TO LOW TEMP.
WOODWARD POLLUTION CONTROL	S20520	3/8/2001		NORTH UNPERMITTED POND			X	UNABLE TO IRRIGATE DUE TO COLD WEATHER & GROUND SATURATION
WOODWARD	S20520	11/1/2000	120	N. UNPERMITTED POND	5 MILLION		X	RAIN
WOODWARD	S20520	10/25/2000		HEADWORKS	5,000	X		RAIN
WOODWARD	S20520	8/10/2000	1.5	HEADWORKS	10,000	X		RAIN
WOODWARD	S20520	5/26/2000	1.3	HEADWORKS	100,000	X		RAIN
WOODWARD	S20520	9/12/1999	2	HEADWORKS (LIFT STATION)	30,000	X		POWER OUTAGE
WOODWARD	S20520	6/12/1999		HEADWORKS	10,000	X		RAIN
WOODWARD	S20520	4/29/1999	120	NORTH UNPERMITTED POND	>5 MILLION		X	RAIN
WOODWARD	S20520	10/20/1997		NW 1/4 SEC. 29 R20W T23N	21.97 MI			
WOODWARD	S20520	8/15/1994	3.0	LAKEVIEW DRIVE		X	X	CONSTRUCTION
WOODWARD	S20520	4/13/1999		HEADWORKS N. OF PUMP BUILDING	10,000	X		RAIN
WOODWARD	S20520	4/14/1999	125	N. UNPERMITTED POND	20 MILLION		X	RAIN
WOODWARD	S20520	2/21/2000		L.S.	1,500	X		PUMP FAILURE
WOODWARD	S20520	3/23/2000	96	N. UNPERMITTED POND			X	RAIN
WOODWARD	S20520	10/17/1998	4			X		PLUGGED LINE
WOODWARD	S20520	6/11/1998	1.5	701 COMANCHE	500	X		MAIN LINE PLUGGED
WOODWARD	S20520	5/14/1998		LAGOONS	28 MILLION			
WOODWARD	S20520	10/25/1993	8.0	WEST SIDE HW 270 SOUTH OF SANTS FE TRACKS	13500	X		DAMAGE TO TRUNK LINE

Facility Name	Facility ID	Date	Duration (hrs)	Location	Amount (gallons)	Raw	Treated	Cause
SEILING	S20524	6/8/1995	24	ON COUNTY LINE ROAD	0	X		RAIN I/I
SEILING	S20524	5/13/1993	36	MH ON LINE TO PLANT	100000	X		EXCESSIVE RAINFALL(10")
SEILING	S20524	6/9/1995	0.0	TRAILER HOUSE TAPS	5460	X		RAIN I/I
SEILING	S20524	6/3/1995	24	HYWAY 270 & COUNTYLINE	26000	X		RAIN I/I
SEILING	S20524	6/5/1995	24	ON COUNTY LINE ROAD	0	X		RAIN I/I
SEILING	S20524	3/30/1999		LAGOONS				RAIN
SEILING	S20524	3/30/1999		LAGOON	>38 MILLION			
SEILING	S20524	3/30/1999		LAGOON				
SEILING	S20524	4/21/1998		LAGOON	24 MILLION			RAINS
SEILING	S20524	3/27/2000		DIKES	>6 MILLION			RAIN
SEILING	S20524	9/24/1997		LAGOON	21 MILLION			
VICI	S20602	6/7/1991	5.0	NEW TANK PUT IN LAST MARCH	50			ELECTRIC LINES THAT WENT TO THE PUMPS PULLED APART
VICI	S20602	12/27/1989		BETWEEN CLEVELAND AND NURSING HOME IN ALLEY	0			MANHOLE OVERFLOW
VICI	S20602	6/7/1993	2.0	MANHOLE OVER FLOWED	75	X		LINE STOPPAGE
BILLINGS	S21204	9/23/1997						HIGH WATER LEVELS
BILLINGS	S21204	6/7/1990			30			
BILLINGS	S21204	12/23/1991		AT TOTAL RETENTION LAGOON SITE	432	X		EXCESSIVE RAINFALL CAUSED OVERFLOW OF WEIRS
BILLINGS	S21204	6/14/1992	240	LAGOON 2ND CELL	4320000		X	PLANT OVERLOAD FROM RAINSTORMS
BILLINGS	S21204	2/2/2001		LAGOONS				RAIN
BILLINGS	S21204	6/28/1999		N.E. CORNER OF #3 CELL TO RED ROCK CREEK	12 MILLION		X	CONTROL WEIRS INUNDATED
BILLINGS	S21204	2/18/2000		LAGOONS				
BILLINGS	S21204	4/8/1999		LAGOONS				
BILLINGS	S21204	10/20/1996						HIGH CELL WATER LEVELS
BYRON-AMARITA	S21204	5/6/1995	24	FORCE MAIN FROM LIFT STATION	3000	X		BROKEN MAIN

Facility Name	Facility ID	Date	Duration (hrs)	Location	Amount (gallons)	Raw	Treated	Cause
BILLINGS	S21204	3/18/1999		N.E. CORNER OF #3 CELL TO RED ROCK CREEK	11 MILLION			
BILLINGS	S21204	12/30/1998		N.E. CORNER OF #3 FINISHING CELL	1.3 MGD		X	RAIN
BILLINGS	S21204	3/13/1998		2 MILES S. OF TOWN, HWY 15 INTERSECTION				RAIN
BILLINGS	S21204	3/17/2000		LAGOON				
BILLINGS	S21204	4/16/1997		TOTAL RETENTION LAGOON				