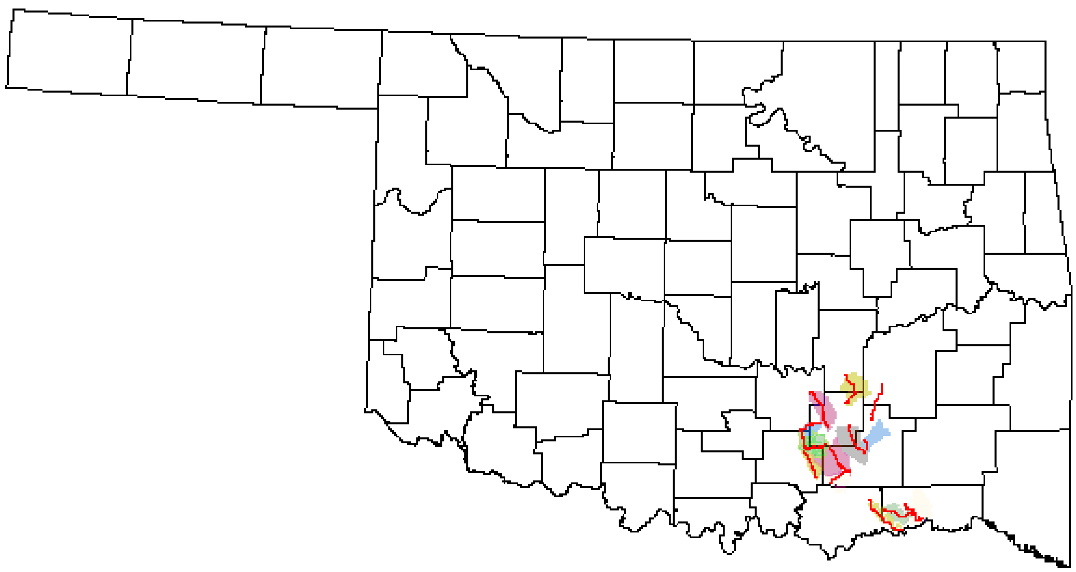
FINAL

BACTERIA AND TURBIDITY TOTAL MAXIMUM DAILY LOADS FOR THE MUDDY BOGGY CREEK AREA, OKLAHOMA (OK410400)



OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

SEPTEMBER 2012

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OKWBID

OK410400010070_00
OK410400010130_00
OK410400010210_00
OK410400030010_00
OK410400030370_00
OK410400030490_00
OK410400050270_10
OK410400060120_00

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

OKLAHOMA
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ACRONYMS AND ABBREVIATIONS

AEMS	Agricultural Environmental Management Service
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
NPDES	National Pollutant Discharge Elimination System
NPS	Non-point 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
RMSE	Root mean square error
SH	State Highway
SSO	Sanitary sewer overflow
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WWAC	warm water aquatic community
WLA	wasteload allocation
WQM	Water quality monitoring
WQMP	Water Quality Management Plan
WQS	Water quality standard
WWTP	wastewater treatment plant

Executive Summary

This report documents the data and assessment used to establish TMDLs for the pathogen indicator bacteria [*E. coli and* Enterococci] and turbidity for certain waterbodies in the Muddy Boggy Creek area. Elevated levels of pathogen indicator bacteria in aquatic environments indicate that a waterbody is contaminated with human or animal feces and that a potential health risk exists for individuals exposed to the water. Elevated turbidity levels caused by excessive sediment loading and stream bank erosion impact aquatic communities. Data assessment and total maximum daily load (TMDL) calculations are conducted in accordance with requirements of Section 303(d) of the Clean Water Act (CWA), Water Quality Planning and Management Regulations (40 CFR Part 130), U.S. Environmental Protection Agency (EPA) guidance, and Oklahoma Department of Environmental Quality (DEQ) guidance and procedures. DEQ is required to submit all TMDLs to EPA for review. TMDLs for approved 303(d) listed waterbody-pollutant pairs or surrogates will receive notification of EPA's 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).

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

E.1 Problem Identification and Water Quality Target

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

Elevated levels of bacteria or turbidity above the WQS necessitates 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 primary body contact recreation or fish and wildlife propagation beneficial uses designated for each waterbody.

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

Waterbody ID	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	EC	PBCR	SBCR	Turbidity	WWAC
OK410400010070_00	Muddy Boggy Creek	21.59	2013	2			N		X	N
OK410400010130_00	Lick Creek	20.19	2013	2			I		X	N
OK410400010210_00	Whitegrass Creek	29.71	2016	3			I		X	N
OK410400030010_00	Clear Boggy Creek	22.76	2013	2			N		X	N
OK410400030020_00	Caney Creek	12.42	2013	2	X			N		F
OK410400030240_00	Delaware Creek	29.01	2016	3	X		N			F
OK410400030370_00	Leader Creek	29.58	2019	4	X	X	N		X	N
OK410400030490_00	Goose Creek	15.09	2019	4			I		X	N
OK410400050270_10	Muddy Boggy Creek	22.25	2013	2			N		X	N
OK410400060120_00	Caney Boggy Creek	26.49	2016	3	X		N		X	N
~~OK410400080010_00~~** OK410400050410_00	Boggy Creek, North	7.25	2010	1	X		N			N
OK410400010070_00	Muddy Boggy Creek	21.59	2013	2			N		X	F

ENT = Enterococci; EC = *E. coli*

PBCR = Primary Body Contact Recreation

SBCR = Secondary Body Contact Recreation

WWAC = Warm Water Aquatic Community

N – Not supporting; I – Insufficient information

** This segment was split into two segments for the 2010 Integrated Report: the old segment (OK410400080010_00) above Atoka Lake and the new segment (OK410400050410_00) below Atoka Lake. The segment above the lake (OK410400080010_00) is not impaired. **In this report, Boggy Creek, North is identified by its new segment number (OK410400050410_00) as given in the 2010 Integrated Report.**

Source: 2008 Integrated Report, DEQ 2008.

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

Table ES-2 Summary of Indicator Bacteria Samples from Primary Body Contact Recreation Season, 2001 - 2008

Waterbody ID	Stream Segments	Bacteria Indicator	Standards	GeoMean	# of Samples	2008 303(d)	Impaired	Comments
OK410400010070_00	Muddy Boggy Creek	EC	126	58.7	26			
		ENT	33	75.6	26		Yes	TMDL Required
OK410400010130_00	Lick Creek	EC	126	78.9	7			
		ENT	33	106.7	7			
OK410400010210_00	Whitegrass Creek	EC	126	107.7	8			
		ENT	33	129.2	8			
OK410400030010_00	Clear Boggy Creek	EC	126	52.4	22			
		ENT	33	93.2	22		Yes	TMDL Required
OK410400030020_00	Caney Creek	EC	126	40.5	7			
		ENT	33	266.3	7	X		Delisting: <10 samples
OK410400030240_00	Delaware Creek	EC	126	142.7	9			
		ENT	33	95.6	9	X		Delisting: <10 samples
OK410400030370_00	Leader Creek	EC	126	285.1	8	X		Delisting: <10 samples
		ENT	33	155.3	8	X		Delisting: <10 samples
OK410400030490_00	Goose Creek	EC	126	180.1	7			
		ENT	33	131.3	7			
OK410400050270_10	Muddy Boggy Creek	EC	126	63.8	20			
		ENT	33	98.6	20		Yes	TMDL Required
OK410400050410_00	Boggy Creek, North	EC	126	79.4	8			
		ENT	33	56.6	8	X		Delisting: <10 samples
OK410400060120_00	Caney Boggy Creek	EC	126	62.5	9			
		ENT	33	78.5	9	X		Delisting: <10 samples
OK410600020020_00	Sandy Creek	EC	126	65.6	8			
		ENT	33	90.6	8	X		Delisting: <10 samples

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

The definition of PBCR and the bacteria WQSs for PBCR are summarized by the following excerpt from Chapter 45 of the Oklahoma WQSs.

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

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

(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 therefor. 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.

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

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

(b) ***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 or waterbody segment, each indicator group must demonstrate compliance with the numeric criteria prescribed (OWRB 2011).

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

It is worth noting that the Oklahoma Water Quality Standards (OWQS) prior to July 1, 2011 contains three bacteria indicators (fecal coliform, *E. coli* and Enterococci) and the new OWQS effective on July 1, 2011 contains only *E. coli* and Enterococci. Because the new OWQS no longer have a standard for fecal coliform, fecal coliform TMDLs will not be developed for any stream segment in this report even though the stream segments were listed for fecal coliform impairment in the 2008 303(d) list. Bacteria TMDLs will be developed only for *E. coli* and/or Enterococci impaired streams.

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

Table ES-3 summarizes a subset of turbidity and TSS data collected from the WQM stations under base flow conditions, which 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.

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

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

1. *Cool Water Aquatic Community/Trout Fisheries: 10 NTUs;*
2. *Lakes: 25 NTU; and*
3. *Other surface waters: 50 NTUs.*

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

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

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

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

Assessment of Fish and Wildlife Propagation support

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

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

Table ES-3 Summary of Turbidity and TSS Samples Collected During Base Flow Conditions, 1997 - 2010

Waterbody ID	Waterbody Name	Number of turbidity samples	Number of TSS samples	Number of Turbidity samples greater than 50 NTU	% turbidity samples exceeding criterion	2008 303(d)	Comments
OK410400010070_00	Muddy Boggy Creek	31	0	12	39%	X	TMDL required
OK410400010130_00	Lick Creek	15	14	5	33%	X	TMDL required
OK410400010210_00	Whitegrass Creek	17	17	8	47%	X	TMDL required
OK410400030010_00	Clear Boggy Creek	40	0	10	25%	X	TMDL required
OK410400030020_00	Caney Creek	19	18	1	5%		
OK410400030240_00	Delaware Creek	20	19	1	5%		
OK410400030370_00	Leader Creek	19	18	16	84%	X	TMDL required
OK410400030490_00	Goose Creek	18	17	3	17%	X	TMDL required
OK410400050270_10	Muddy Boggy Creek	33	0	17	52%	X	TMDL required
OK410400050410_00	Boggy Creek, North	21	20	1	5%		
OK410400060120_00	Caney Boggy Creek	19	19	6	32%	X	TMDL required
OK410600020020_00	Sandy Creek	20	19	0	0%		

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.

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 nephelometric turbidity units (NTU). However, as described above, because turbidity cannot be expressed as a mass load, TSS is used as a surrogate in this TMDL. Since there is no numeric criterion in the Oklahoma WQS for TSS, a regression method to convert the turbidity criterion to TSS based on a relationship between turbidity and TSS was used to establish TSS goals as surrogates. Table ES-4 provides the results of the waterbody specific regression analysis.

Table ES-4 Regression Statistics and TSS Goals

Waterbody ID	Waterbody Name	R-square	NRMSE	TSS Goals (mg/L)	MOS
OK410400010070_00	Muddy Boggy Creek	0.81	8.9%	39.9	10%
OK410400010130_00	Lick Creek	0.92	7.0%	26.9	10%
OK410400010210_00	Whitegrass Creek	0.65	15.0%	23.0	15%
OK410400030010_00	Clear Boggy Creek	0.81	8.9%	39.9	10%
OK410400030370_00	Leader Creek	0.84	10.1%	18.9	10%
OK410400030490_00	Goose Creek	0.78	11.5%	29.0	15%
OK410400050270_10	Muddy Boggy Creek	0.81	8.9%	39.9	10%
OK410400060120_00	Caney Boggy Creek	0.55	10.6%	18.6	10%

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

E.2 Pollutant Source Assessment

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

Point sources are permitted through the NPDES program. NPDES-permitted facilities that discharge treated 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. Nonpoint sources are diffuse sources that typically cannot be identified as entering a waterbody through a discrete conveyance at a single location. Nonpoint sources may emanate from land activities that contribute bacteria or TSS to surface water as a result of rainfall runoff. For the TMDLs in this report, all sources of pollutant loading not regulated by NPDES 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 is insufficient data available to quantify contributions of TSS from these natural processes. TSS or sediment loading can also occur under non-runoff conditions as a result of anthropogenic activities in riparian corridors which cause erosive conditions. Given the lack of data to establish the background conditions for TSS/turbidity, separating background loading from nonpoint sources whether it is from natural or anthropogenic processes is not feasible in this TMDL development. Table ES-6 summarizes the point and nonpoint sources that contribute bacteria or TSS to each respective waterbody.

Table ES-5 Stream Segments and Pollutants for TMDL Development

Waterbody ID	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	Turbidity
OK410400010070_00	Muddy Boggy Creek	21.59	2013	2	X	X
OK410400010130_00	Lick Creek	20.19	2013	2		X
OK410400010210_00	Whitegrass Creek	29.71	2016	3		X
OK410400030010_00	Clear Boggy Creek	22.76	2013	2	X	X
OK410400030370_00	Leader Creek	29.58	2019	4		X
OK410400030490_00	Goose Creek	15.09	2019	4		X
OK410400050270_10	Muddy Boggy Creek	22.25	2013	2	X	X
OK410400060120_00	Caney Boggy Creek	26.49	2016	3		X

Table ES-6 Summary of Potential Pollutant Sources by Category

Waterbody ID	Waterbody Name	Municipal NPDES Facility	Industrial NPDES Facility	MS4	NPDES No Discharge Facility	CAFO	Mines	Construction Stormwater Permit	Nonpoint Source
OK410400010070_00	Muddy Boggy Creek								Bacteria/Turbidity
OK410400010130_00	Lick Creek								Turbidity
OK410400010210_00	Whitegrass Creek								Turbidity
OK410400030010_00	Clear Boggy Creek								Bacteria/Turbidity
OK410400030370_00	Leader Creek								Turbidity
OK410400030490_00	Goose Creek								Turbidity
OK410400050270_10	Muddy Boggy Creek								Bacteria/Turbidity
OK410400060120_00	Caney Boggy Creek								Turbidity

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.

E.3 Using Load Duration Curves to Develop TMDLs

The TMDL calculations presented in this report are derived from load duration curves (LDC). LDCs facilitate rapid development of TMDLs, and as a TMDL development tool 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 is 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 segment. Plotting future monitoring information on the LDC will show trends of improvement to sources that will identify areas for revision to the segment restoration plan. The low cost of the LDC method allows the development of TMDL plans on more segments and the evaluation of the implementation of WLAs and BMPs on more segments. The technical approach for using LDCs for TMDL development includes the following steps:

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

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

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

The basic steps to generating an LDC involve:

- Obtaining daily flow data for the site of interest from the U.S. Geological Survey (USGS), or if unavailable, projected from a nearby USGS site;
- Sorting the flow data and calculating flow exceedance percentiles
- Obtaining the water quality data from the primary contact recreation season (May 1 through September 30); or obtaining available turbidity and TSS water quality data;
- Displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQS for each respective bacteria

indicator; or displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQ_{goal} for TSS;

- for bacteria TMDLs, displaying and differentiating another curve derived by plotting the geometric mean of all existing bacteria samples continuously along the full spectrum of flow exceedance percentiles which represents the observed load in the stream; or
- for turbidity TMDLs, matching the water quality observations with the flow data from the same date and determining the corresponding exceedance percentile. Plotting the flow exceedance percentiles and daily load observations in a load duration plot (See Section 5).

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

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

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

unit conversion factor = 24,465,525

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 bacteria were plotted as a separate LDC based on the the geometric mean of all samples. Historical observations of TSS and/or turbidity concentrations are paired with flow data and are 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 bacteria observations to a geometric mean water quality criterion in the LDC; therefore individual bacteria samples are not plotted on the LDCs.

E.4 TMDL Calculations

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

This definition can be expressed by the following equation:

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

For each waterbody the TMDLs presented in this report are expressed as colony forming units 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 is used to calculate the loading reductions required. For bacteria, the PRG is calculated by reducing all samples by the same percentage until the geomean of the reduced sample values meets the corresponding bacteria geomean standard (126 cfu/100 ml for *E. coli* and 33 cfu/100 ml for Enterococci) with 10% of margin of safety. For turbidity, the PRG is the load reduction that ensures that no more than 10% of the samples under flow-base conditions exceed the TMDL.

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

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

Waterbody ID	Waterbody Name	Geomean		Reduction Rate	
		EC	ENT	EC	ENT
OK410400010070_00	Muddy Boggy Creek	61.4	73.1	-	54.9%
OK410400010130_00	Lick Creek	58.4	88.4	-	62.7%
OK410400010210_00	Whitegrass Creek	52.4	93.2	-	64.6%

Similarly, percent reduction goals 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 four waterbodies included in this TMDL 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	Reduction Rate
OK410400010070_00	Muddy Boggy Creek	31.5%
OK410400010130_00	Lick Creek	64.0%
OK410400010210_00	Whitegrass Creek	74.2%
OK410400030010_00	Clear Boggy Creek	40.1%
OK410400030370_00	Leader Creek	85.2%
OK410400030490_00	Goose Creek	38.0%
OK410400050270_10	Muddy Boggy Creek	57.8%
OK410400060120_00	Caney Boggy Creek	44.2%

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

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

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

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

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

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

E.5 Reasonable Assurance

Reasonable assurance is required by the EPA rules for a TMDL to be approvable only when a waterbody is impaired by both point and non-point 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 assurance" that the non-point source (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 standard 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 1
INTRODUCTION

1.1 TMDL Program Background

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 segments and pollutants identified by the Regional Administrator as suitable for TMDL calculation. Segments 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 instream water quality conditions, so states can implement water quality-based controls to reduce pollution from point and nonpoint sources and restore and maintain water quality (EPA 1991).

This report documents the data and assessment used to establish TMDLs for the pathogen indicator bacteria (*E. coli* and Enterococci) and turbidity for selected waterbodies in the Muddy Boggy Creek basin. (All future references to bacteria in this document imply these two fecal pathogen indicator bacteria groups unless specifically stated otherwise.) Elevated levels of pathogen indicator bacteria in aquatic environments indicate that a waterbody is contaminated with human or animal feces and that a potential health risk exists for individuals exposed to the water. Elevated turbidity levels caused by excessive sediment loading and stream bank erosion impact aquatic biological communities. Data assessment and TMDL calculations are conducted in accordance with requirements of Section 303(d) of the CWA, Water Quality Planning and Management Regulations (40 CFR Part 130), 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 received 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).

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

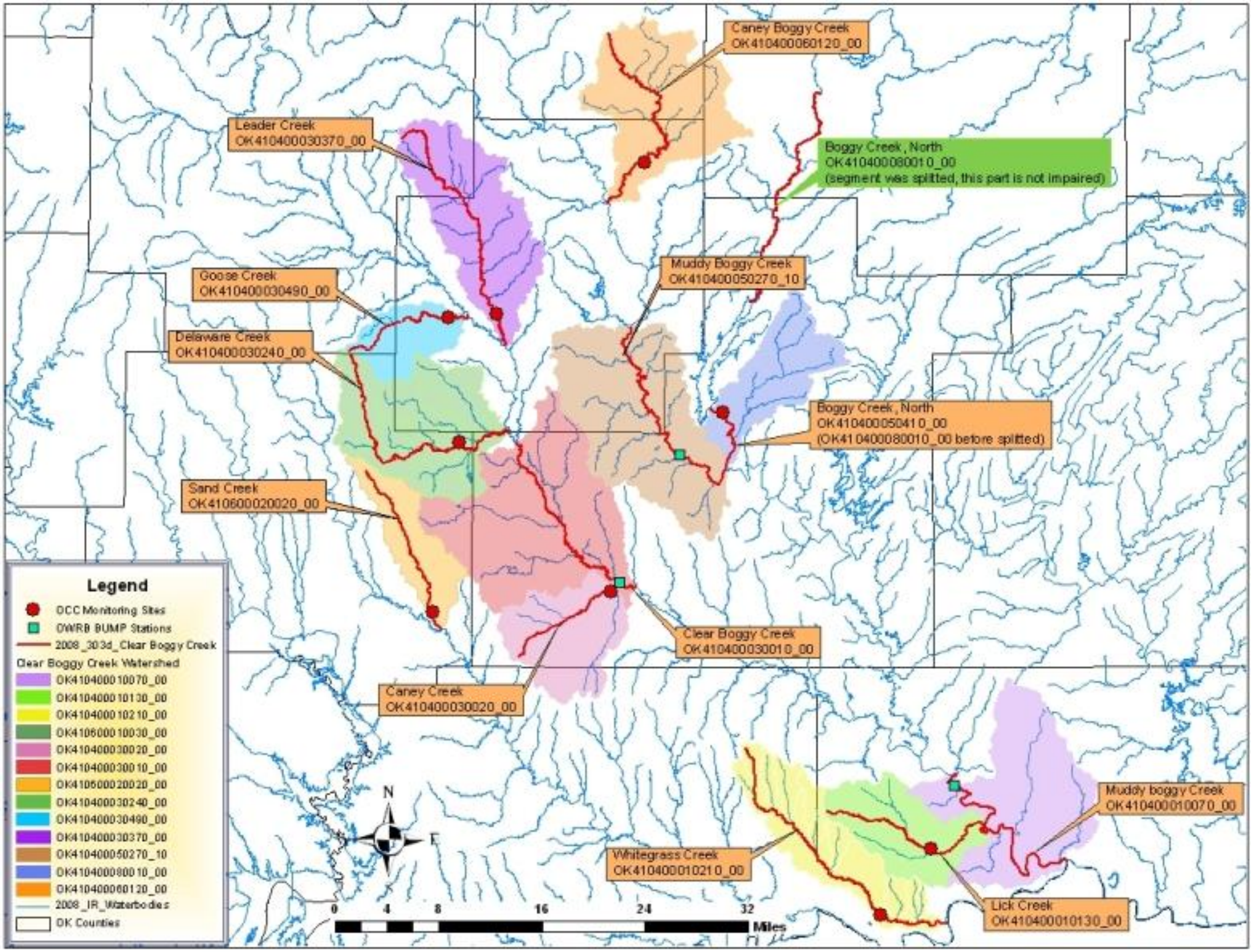
This TMDL report focuses on waterbodies that DEQ placed in Category 5 [303(d) list] of the *Water Quality in Oklahoma, 2008 Integrated Report* (2008 Integrated Report) for nonsupport of primary body contact recreation (PBCR) or warm water aquatic community (WWAC) designated uses. The waterbodies addressed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

- Muddy Boggy Creek OK410400010070_00
- Lick Creek OK410400010130_00
- Whitegrass Creek OK410400010210_00
- Clear Boggy Creek OK410400030010_00
- Caney Creek OK410400030020_00
- Delaware Creek OK410400030240_00
- Leader Creek OK410400030370_00
- Goose Creek OK410400030490_00
- Muddy Boggy Creek OK410400050270_10
- Caney Boggy Creek OK410400060120_00
- Boggy Creek, North ~~OK410400080010_00~~** OK410400050410_00
- Sandy Creek OK410600020020_00

** This segment was split into two segments for the 2010 Integrated Report: the old segment (OK410400080010_00) above Atoka Lake and the new segment (OK410400050410_00) below Atoka Lake. The segment above the lake (OK410400080010_00) is not impaired. **In this report, Boggy Creek, North is identified by its new segment number (OK410400050410_00) as given in the 2010 Integrated Report.**

Figure 1-1 is 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 Muddy Boggy Creek Area Not Supporting Primary Body Contact Recreation or Fish and Wildlife Propagation



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

Table 1-1 Water Quality Monitoring Stations Used for Assessment of Stream Segments

WBID	Name	Monitoring Sites	Lat	Long	Agency
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	34.02512	-95.75118	OWRB
OK410400010130_00	Lick Creek	OK410400-01-0130G	33.95413	-95.78193	OCC
OK410400010210_00	Whitegrass Creek	OK410400-01-0210G	33.88108	-95.85132	OCC
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	34.25148	-96.20527	OWRB
OK410400030020_00	Caney Creek	OK410400-03-0020C	34.24100	-96.21708	OCC
OK410400030240_00	Delaware Creek	OK410400-03-0240M	34.40700	-96.42440	OCC
OK410400030370_00	Leader Creek	OK410400-03-0370B	34.55015	-96.37448	OCC
OK410400030490_00	Goose Creek	OK410400-03-0490G	34.54597	-96.44043	OCC
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	34.39421	-96.12436	OWRB
OK410400060120_00	Caney Boggy Creek	OK410400-06-0120G	34.71950	-96.17310	OCC
OK410400050410_00	Boggy Creek, North	OK410400-08-0010M	34.44047	-96.06523	OCC
OK410600020020_00	Sandy Creek	OK410600-02-0020G	34.21688	-96.45925	OCC

1.2 Watershed Description

General. The Muddy Boggy Creek basin is located in the south-east portion of Oklahoma. The waterbodies addressed in this report are located in Choctaw, Bryan, Atoka, Johnston, Coal, Pontotoc, Pittsburg and Hughes counties. Table 1-2, derived from the 2010 U.S. Census, demonstrates that the counties in which these watersheds are located are sparsely populated (U.S. Census Bureau 2010). Table 1-3 lists the towns and cities located in each watershed.

Table 1-2 County Population and Density

County Name	Population (2010 Census)	Area (square mile)	Population Density (per square mile)
Choctaw	15,342	799.7	19
Bryan	42,416	943.1	45
Atoka	14,182	989.4	14
Johnston	10,957	657.9	17
Coal	5,925	521.0	11
Pontotoc	37,492	725.6	52
Pittsburg	45,837	1378.5	33
Hughes	14,003	814.1	17

Table 1-3 Towns and Cities by Watershed

Towns and Cities	Stream Name	Waterbody ID
Rock Creek	OK410400060120_00	Caney Boggy Creek
Non	OK410400060120_00	Caney Boggy Creek
Ashland	OK410400060120_00	Caney Boggy Creek
Parker	OK410400060120_00	Caney Boggy Creek
Jaydee	OK410400030370_00	Leader Creek
Leader	OK410400030370_00	Leader Creek
Lula	OK410400030370_00	Leader Creek
Centrahoma	OK410400030370_00	Leader Creek
Tupelo	OK410400030370_00	Leader Creek
Clarita	OK410400030240_00	Delaware Creek
Bromide	OK410400030240_00	Delaware Creek
Bromide Junction	OK410400030240_00	Delaware Creek
Wapanucka	OK410400030240_00	Delaware Creek
Wilson	OK410400030010_00	Clear Boggy Creek
Coleman	OK410400030010_00	Clear Boggy Creek
Cook	OK410400030010_00	Clear Boggy Creek
Taloah	OK410400030010_00	Clear Boggy Creek
Hopewell	OK410400030010_00	Clear Boggy Creek
Caney	OK410400030020_00	Caney Creek
Caddo	OK410400030020_00	Caney Creek
Phillips	OK410400050270_10	Muddy Boggy Creek
Lehigh	OK410400050270_10	Muddy Boggy Creek
Atoka	OK410400050270_10	Muddy Boggy Creek
Bruno	OK410400050270_10	Muddy Boggy Creek
Stringtown	OK410400050410_00	Boggy Creek, North
Fillmore	OK410600020020_00	Sandy Creek
Old Bennington	OK410400010210_00	Whitegrass Creek
New Oberlin	OK410400010210_00	Whitegrass Creek
Oberlin	OK410400010210_00	Whitegrass Creek
Weeks	OK410400010210_00	Whitegrass Creek
Boswell	OK410400010130_00	Lick Creek
Nelson	OK410400010070_00	Muddy Boggy Creek
Soper	OK410400010070_00	Muddy Boggy Creek
Forney	OK410400010070_00	Muddy Boggy Creek
Jasper	OK410400010070_00	Muddy Boggy Creek
Unger	OK410400010070_00	Muddy Boggy Creek
Gay	OK410400010070_00	Muddy Boggy Creek

Climate. Table 1-4 summarizes the average annual precipitation for each Oklahoma waterbody based on the approximate midpoint of each watershed. Average annual precipitation values among the watersheds in this portion of Oklahoma range between 40.1 and 42.2 inches (Oklahoma Climate Survey 2007).

Table 1-4 Average Annual Precipitation by Watershed

Precipitation Summary		
Waterbody Name	**Waterbody ID**	**Average Annual Precipitation (Inches)**
OK410400010070_00	Muddy Boggy Creek	47.2
OK410400010130_00	Lick Creek	46.2
OK410400010210_00	Whitegrass Creek	45.7
OK410400030010_00	Clear Boggy Creek	44.2
OK410400030020_00	Caney Creek	44.5
OK410400030240_00	Delaware Creek	43.4
OK410400030370_00	Leader Creek	43.5
OK410400030490_00	Goose Creek	43.1
OK410400050270_10	Muddy Boggy Creek	44.6
OK410400060120_00	Caney Boggy Creek	44.3
OK410400050410_00	Boggy Creek, North	44.8
OK410600020020_00	Sandy Creek	43.5

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

Figure 1-2 Land Use Map

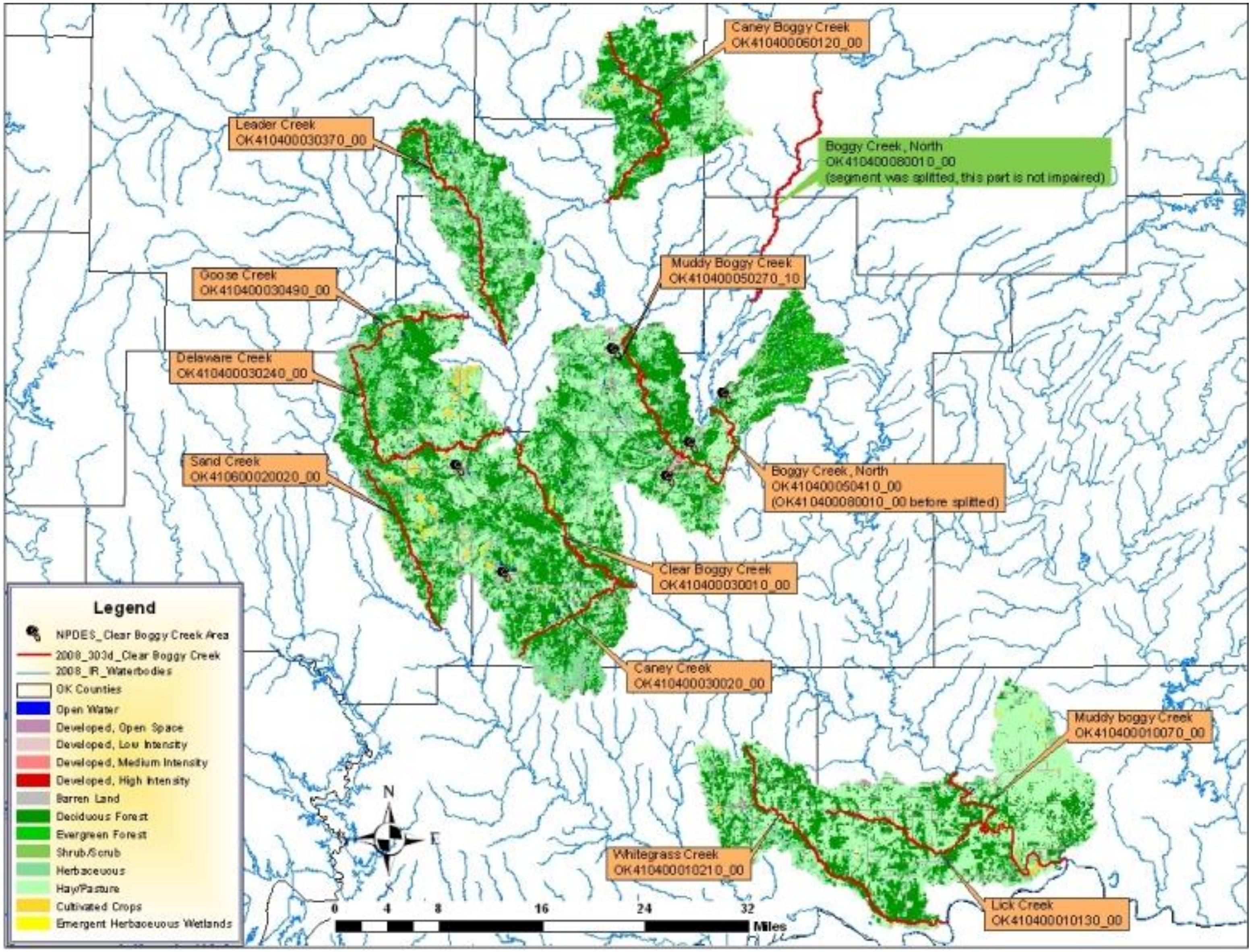


Table 1-5 Land Use Summaries by Watershed

Landuse Category	Muddy Boggy Creek	Lick Creek	Whitegrass Creek	Clear Boggy Creek	Caney Creek	Delaware Creek
Waterbody ID	OK410400010070_00	OK410400010130_00	OK410400010210_00	OK410400030010_00	OK410400030020_00	OK410400030240_00
Open Water	372.7	169.3	174.0	604.6	359.7	376.0
Medium Intensity Residential	109.9	52.0	3.1	91.8	232.0	53.2
High Intensity Residential	0.0	1.6	0.0	0.4	3.6	8.2
Bare Rock/Sand/Clay	26.0	0.0	2.7	246.9	1.1	58.9
Deciduous Forest	16643.0	12153.5	20889.0	38035.8	16256.3	22417.4
Evergreen Forest	234.6	30.0	30.0	852.5	125.0	183.9
Grasslands/Herbaceous	6820.5	5541.7	9817.2	28435.7	16546.3	20750.7
Pasture/Hay	44905.7	19025.4	17051.8	23744.9	5770.4	17506.6
Row Crops	830.0	0.0	140.8	1744.0	181.7	2095.7
Urban/Recreational Grasses	2802.9	1456.9	1375.1	2781.5	1569.3	1934.0
Woody Wetlands	64.5	30.7	9.8	99.2	0.0	0.0
Emergent Herbaceous	361.4	22.2	19.6	106.1	8.7	3.6
Total (Acres):	73171	38483	49513	96743	41054	65388
Open Water	0.51%	0.44%	0.35%	0.62%	0.88%	0.58%
Medium Intensity Residential	0.15%	0.14%	0.01%	0.09%	0.57%	0.08%
High Intensity Residential	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%
Bare Rock/Sand/Clay	0.04%	0.00%	0.01%	0.26%	0.00%	0.09%
Deciduous Forest	22.75%	31.58%	42.19%	39.32%	39.60%	34.28%
Evergreen Forest	0.32%	0.08%	0.06%	0.88%	0.30%	0.28%
Grasslands/Herbaceous	9.32%	14.40%	19.83%	29.39%	40.30%	31.73%
Pasture/Hay	61.37%	49.44%	34.44%	24.54%	14.06%	26.77%
Row Crops	1.13%	0.00%	0.28%	1.80%	0.44%	3.20%
Urban/Recreational Grasses	3.83%	3.79%	2.78%	2.88%	3.82%	2.96%
Woody Wetlands	0.09%	0.08%	0.02%	0.10%	0.00%	0.00%
Emergent Herbaceous	0.49%	0.06%	0.04%	0.11%	0.02%	0.01%
Total (percentage):	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Landuse Category	Leader Creek	Goose Creek	Muddy Boggy Creek	Caney Boggy Creek	Boggy Creek, North	Sandy Creek
Waterbody ID	OK410400030370_00	OK410400030490_00	OK410400050270_10	OK410400060120_00	OK410400050410_00	OK410600020020_00
Open Water	555.9	195.0	1005.2	604.4	20429.1	109.8
Medium Intensity Residential	129.7	0.4	844.0	6.7	452.4	7.8
High Intensity Residential	0.0	0.0	147.5	1.6	16.9	0.9
Bare Rock/Sand/Clay	1.6	0.0	12.9	4.4	172.2	39.1
Deciduous Forest	21989.9	9278.9	39804.3	30984.9	99344.0	10516.4
Evergreen Forest	33.1	8.2	255.1	592.0	8847.3	30.0
Grasslands/Herbaceous	24322.3	7463.9	33266.2	14506.4	29515.0	9621.4
Pasture/Hay	12685.6	4625.9	26527.5	14995.0	29509.2	4795.8
Row Crops	38.0	139.4	92.1	703.5	238.8	1002.8
Urban/Recreational Grasses	2458.0	373.0	4608.8	1829.7	6873.9	855.4
Woody Wetlands	0.0	0.0	165.5	11.6	682.3	1.6
Emergent Herbaceous	6.7	2.7	76.5	10.0	117.4	0.0
Total (Acres):	62221	22088	106806	64250	196198	26981
Open Water	0.89%	0.88%	0.94%	0.94%	10.41%	0.41%
Medium Intensity Residential	0.21%	0.00%	0.79%	0.01%	0.23%	0.03%
High Intensity Residential	0.00%	0.00%	0.14%	0.00%	0.01%	0.00%
Bare Rock/Sand/Clay	0.00%	0.00%	0.01%	0.01%	0.09%	0.15%
Deciduous Forest	35.34%	42.01%	37.27%	48.23%	50.63%	38.98%
Evergreen Forest	0.05%	0.04%	0.24%	0.92%	4.51%	0.11%
Grasslands/Herbaceous	39.09%	33.79%	31.15%	22.58%	15.04%	35.66%
Pasture/Hay	20.39%	20.94%	24.84%	23.34%	15.04%	17.77%
Row Crops	0.06%	0.63%	0.09%	1.09%	0.12%	3.72%
Urban/Recreational Grasses	3.95%	1.69%	4.32%	2.85%	3.50%	3.17%
Woody Wetlands	0.00%	0.00%	0.15%	0.02%	0.35%	0.01%
Emergent Herbaceous	0.01%	0.01%	0.07%	0.02%	0.06%	0.00%
Total (percentage):	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

1.3 Stream Flow Conditions

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

SECTION 2
PROBLEM IDENTIFICATION AND WATER QUALITY TARGET

2.1 Oklahoma Water Quality Standards

Title 785 of the Oklahoma Administrative Code contains Oklahoma's water quality standards and implementation procedures (OWRB 2011 & OWRB 2011a). The Oklahoma Water Resources Board (OWRB) has statutory authority and responsibility concerning establishment of state water quality standards, as provided under 82 Oklahoma Statute [O.S.], §1085.30. This statute authorizes the OWRB to promulgate rules …*which establish classifications of uses of waters of the state, criteria to maintain and protect such classifications, and other standards or policies pertaining to the quality of such waters.* [O.S. 82:1085:30(A)]. Beneficial uses are designated for all waters of the state. Such uses are protected through restrictions imposed by the antidegradation policy statement, narrative water quality criteria, and numerical criteria (OWRB 2011). An excerpt of the Oklahoma WQS (Title 785) summarizing the State of Oklahoma Antidegradation Policy is provided in Appendix D. Table 2-1, an excerpt from the 2008 Integrated Report (DEQ 2008), lists beneficial uses designated for each bacteria and/or turbidity impaired stream segment in the Study Area. The beneficial uses include:

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

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

The definition of PBCR the bacteria WQSs for PBCR are summarized by the following excerpt from the Oklahoma Water Quality Standards (785-:45-5-16):

(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 therefor. 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.

Table 2-1 Designated Beneficial Uses for Each Stream Segment in This Report

Waterbody ID	Waterbody Name	AES	AG	WWAC	*FISH*	PBCR	SBCR	PPWS	SWS
OK410400010070_00	Muddy Boggy Creek	I	F	N	N	N		I	
OK410400010130_00	Lick Creek	F	F	N	X	I		X	
OK410400010210_00	Whitegrass Creek	I	F	N	X	I		X	
OK410400030010_00	Clear Boggy Creek	I	F	N	N	N		I	
OK410400030020_00	Caney Creek	F	F	F	X		N		
OK410400030240_00	Delaware Creek	F	F	F	X	N		X	
OK410400030370_00	Leader Creek	F	F	N	X	N			
OK410400030490_00	Goose Creek	F	F	N	X	I			
OK410400050270_10	Muddy Boggy Creek	I	F	N	N	N		I	
OK410400060120_00	Caney Boggy Creek	F	F	N	X	N		X	
OK410400050410_00	Boggy Creek, North	F	N	N	X	N		X	*
OK410600020020_00	Sandy Creek	F	F	F	X	N		X	

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

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

Waterbody ID	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	*E. coli*	Turbidity
OK410400010070_00	Muddy Boggy Creek	21.59	2013	2			X
OK410400010130_00	Lick Creek	20.19	2013	2			X
OK410400010210_00	Whitegrass Creek	29.71	2016	3			X
OK410400030010_00	Clear Boggy Creek	22.76	2013	2			X
OK410400030020_00	Caney Creek	12.42	2013	2	X*		
OK410400030240_00	Delaware Creek	29.01	2016	3	X		
OK410400030370_00	Leader Creek	29.58	2019	4	X	X	X
OK410400030490_00	Goose Creek	15.09	2019	4			X
OK410400050270_10	Muddy Boggy Creek	22.25	2013	2			X
OK410400060120_00	Caney Boggy Creek	26.49	2016	3	X		X
~~OK410400080010_00~~** OK410400050410_00	Boggy Creek, North	7.25	2010	1	X		
OK410600020020_00	Sandy Creek	15.35	2016	3	X		

ENT = Enterococci; EC = *E. coli*
X = Criterion exceeded
* = Only for Secondary Body Contact Recreation
** This segment was split into two segments for the 2010 Integrated Report: the old segment (OK410400080010_00) above Atoka Lake and the new segment (OK410400050410_00) below Atoka Lake. The segment above the lake (OK410400080010_00) is not impaired. **In this report, Boggy Creek, North is identified by its new segment number (OK410400050410_00) as given in the 2010 Integrated Report.**

Source: 2008 Integrated Report, DEQ 2008

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To implement Oklahoma's WQS for PBCR, OWRB promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2011a). The excerpt below from Chapter 46: 785:46-15-6, stipulates how water quality data will be assessed to determine support of the PBCR use as well as how the water quality target for TMDLs will be defined for each bacterial indicator.

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

(b) ***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 2011).

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 segment. Therefore, only the geometric mean criteria will be used to develop TMDLs for *E. coli* and Enterococci bacteria indicators.

It is worth noting that the Oklahoma Water Quality Standards (OWQS) prior to July 1, 2011 contains three bacteria indicators (fecal coliform, *E. coli*, and Enterococci) and the new OWQS effective on July 1, 2011 contains only *E. coli* and Enterococci. Because the new OWQS no longer have a standard for fecal coliform, fecal coliform TMDLs will not be developed for any stream segment in this report even though the stream segments were listed for fecal coliform impairment in the 2008 303(d) list. Bacteria TMDLs will be developed only for *E. coli* and/or Enterococci impaired streams.

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 2011). The numeric criteria for turbidity to maintain and protect the use of "Fish and Wildlife Propagation" from Title 785:45-5-12 (f) (7) is as follows:

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

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

ii. Lakes: 25 NTU; and

iii. Other surface waters: 50 NTUs.

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

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

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

To implement Oklahoma's WQS for Fish and Wildlife Propagation, promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2011a). The excerpt below from Chapter 46: 785:46-15-5, stipulates how water quality data will be assessed to determine support of fish and wildlife propagation as well as how the water quality target for TMDLs will be defined for turbidity.

Assessment of Fish and Wildlife Propagation support

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

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

785:46-15-4. Default protocols

(b) Short term average numerical parameters.

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

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

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

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

2.2 Problem Identification

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

2.2.1 Bacteria Data Summary

Table 2-3 summarizes water quality data collected during primary contact recreation season from the WQM stations between 2001 and 2008 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 2008 303(d) list (DEQ 2008). Water quality data from the primary contact recreation seasons are provided in Appendix A. For the data collected between 2001 and 2008, evidence of nonsupport of the PBCR use based on elevated *E. coli* and Enterococci concentrations was observed in three sub-watersheds.

2.2.2 Turbidity Data Summary

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

Table 2-4 summarizes turbidity and TSS data collected from the WQM stations between 1997 and 2010. However, as stipulated in Title *785:45-5-12 (f) (7) (C),* numeric criteria for turbidity only apply under base flow conditions. While the base flow condition is not specifically defined in the Oklahoma Water Quality Standards, DEQ considers base flow conditions to be all flows less than the 25th flow exceedance percentile (i.e., the lower 75% of flows) which is consistent with the USGS Streamflow Conditions Index (USGS 2007a). Therefore, Water quality samples collected under flow conditions greater than the 25th flow exceedance percentile (highest flows) were therefore excluded from the data set used for TMDL analysis. Table 2-5 was prepared to represent the subset of these data when samples under high flow conditios were excluded. An impairment assessment was performed based on this subset of the turbidity data and the results were shown in Table 2-5. Water quality data for turbidity and TSS are provided in Appendix A.

Table 2-3 Summary of Assessment of Indicator Bacteria Samples from Primary Body Contact Recreation Subcategory Season May 1 to September 30, 2001 - 2008

Waterbody ID	Stream Segments	Bacteria Indicator	Standards (cfu/100 ml)	GeoMean (cfu/100 ml)	# of Samples	2008 303(d)	Impaired	Assessment Results
OK410400010070_00	Muddy Boggy Creek	EC	126	58.7	26			Meet standard
		ENT	33	75.6	26		Yes	TMDL Required
OK410400010130_00	Lick Creek	EC	126	78.9	7			
		ENT	33	106.7	7			
OK410400010210_00	Whitegrass Creek	EC	126	107.7	8			
		ENT	33	129.2	8			
OK410400030010_00	Clear Boggy Creek	EC	126	52.4	22			Meet standard
		ENT	33	93.2	22		Yes	TMDL Required
OK410400030020_00	Caney Creek	EC	126	40.5	7			Classified as SBCR
		ENT	33	266.3	7	X		Delisting: <10 samples
OK410400030240_00	Delaware Creek	EC	126	142.7	9			
		ENT	33	95.6	9	X		Delisting: <10 samples
OK410400030370_00	Leader Creek	EC	126	285.1	8	X		Delisting: <10 samples
		ENT	33	155.3	8	X		Delisting: <10 samples
OK410400030490_00	Goose Creek	EC	126	180.1	7			
		ENT	33	131.3	7			
OK410400050270_10	Muddy Boggy Creek	EC	126	63.8	20			Meet standard
		ENT	33	98.6	20		Yes	TMDL Required
OK410400050410_00	Boggy Creek, North	EC	126	79.4	8			
		ENT	33	56.6	8	X		Delisting: <10 samples
OK410400060120_00	Caney Boggy Creek	EC	126	62.5	9			
		ENT	33	78.5	9	X		Delisting: <10 samples
OK410600020020_00	Sandy Creek	EC	126	65.6	8			
		ENT	33	90.6	8	X		Delisting: <10 samples

Table 2-4 Summary of All Turbidity and TSS Samples, 1997 - 2010

Waterbody ID	Waterbody Name	Number of turbidity samples	Number of TSS samples	Number of turbidity samples greater than 50 NTU	% turbidity samples exceeding criterion	Sampling period
OK410400010070_00	Muddy Boggy Creek	41	0	22	54%	2007-2010
OK410400010130_00	Lick Creek	15	14	5	33%	2005-2007
OK410400010210_00	Whitegrass Creek	20	20	11	55%	2005-2007
OK410400030010_00	Clear Boggy Creek	47	0	17	36%	2005-2011
OK410400030020_00	Caney Creek	20	19	2	10%	2005-2007
OK410400030240_00	Delaware Creek	21	20	2	10%	2005-2007
OK410400030370_00	Leader Creek	20	19	17	85%	2005-2007
OK410400030490_00	Goose Creek	19	18	3	16%	2005-2007
OK410400050270_10	Muddy Boggy Creek	63	22	25	40%	1998-2011
OK410400050410_00	Boggy Creek, North	21	20	1	5%	2005-2007
OK410400060120_00	Caney Boggy Creek	20	20	7	35%	2005-2007
OK410600020020_00	Sandy Creek	20	19	0	0%	2005-2007

Table 2-5 Summary of Turbidity and TSS Samples Collected During Base Flow Conditions, 1997 - 2010

Waterbody ID	Waterbody Name	Number of turbidity samples	Number of TSS samples	Number of Turbidity samples greater than 50 NTU	% turbidity samples exceeding criterion	2008 303(d)	Assessment Resluts
OK410400010070_00	Muddy Boggy Creek	31	0	12	39%	X	TMDL required
OK410400010130_00	Lick Creek	15	14	5	33%	X	TMDL required
OK410400010210_00	Whitegrass Creek	17	17	8	47%	X	TMDL required
OK410400030010_00	Clear Boggy Creek	40	0	10	25%	X	TMDL required
OK410400030020_00	Caney Creek	19	18	1	5%		
OK410400030240_00	Delaware Creek	20	19	1	5%		
OK410400030370_00	Leader Creek	19	18	16	84%	X	TMDL required
OK410400030490_00	Goose Creek	18	17	3	17%	X	TMDL required
OK410400050270_10	Muddy Boggy Creek	33	0	17	52%	X	TMDL required
OK410400050410_00	Boggy Creek, North	21	20	1	5%		
OK410400060120_00	Caney Boggy Creek	19	19	6	32%	X	TMDL required
OK410600020020_00	Sandy Creek	20	19	0	0%		

After re-evaluating both bacteria and turbidity data following Oklahoma's assessment protocol, TMDLs will be developed only for the streams and pollutants listed in Table 2-6. A total of 11 bacteria/turbidity TMDLs will be developed in this report.

Table 2-6 Stream Segments and Pollutants for TMDL Development

Waterbody ID	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	Turbidity
OK410400010070_00	Muddy Boggy Creek	21.59	2013	2	X	X
OK410400010130_00	Lick Creek	20.19	2013	2		X
OK410400010210_00	Whitegrass Creek	29.71	2016	3		X
OK410400030010_00	Clear Boggy Creek	22.76	2013	2	X	X
OK410400030370_00	Leader Creek	29.58	2019	4		X
OK410400030490_00	Goose Creek	15.09	2019	4		X
OK410400050270_10	Muddy Boggy Creek	22.25	2013	2	X	X
OK410400060120_00	Caney Boggy Creek	26.49	2016	3		X

2.3 Water Quality Target

The Code of Federal Regulations (40 CFR §130.7(c)(1)) states that, "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards." The water quality targets for *E. coli* and Enterococci are geometric mean standards of 126 cfu/100ml and 33 cfu/100ml, respectively.

The TMDL for bacteria will incorporate 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 2011a). According to the Oklahoma WQS [785:45-5-12(f)(7)], the turbidity criterion for streams with WWAC beneficial use is 50 NTUs (OWRB 2008). The turbidity of 50 NTUs applies only to seasonal base flow conditions. Turbidity levels are expected to be elevated during, and for several days after, a storm event.

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

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

SECTION 3
POLLUTANT SOURCE ASSESSMENT

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

Point sources are permitted through the NPDES program. NPDES-permitted facilities that discharge treated wastewater in Oklahoma are currently required to monitor for fecal coliform and TSS in accordance with their permits. The discharges with bacteria 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 NPDES 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 bacteria 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 is 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 non-point sources were considered in this report:

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

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

3.1 NPDES-Permitted Facilities

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

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

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

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

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

There is at least one NPDES-permitted facility in each sub-watershed.

3.1.1 Continuous Point Source Dischargers

The locations of the NPDES-permitted facilities that discharge wastewater to surface waters addressed in these TMDLs are listed in Table 3-1 and displayed in Figures 3-1 and 3-2. For some continuous point source discharge facilities the permitted design flow was not available and therefore is not provided in Table 3-1. There are four active continuous point source discharging facilities within the Study Area but they are not all sources of concern for bacteria or TSS loading. All of these facilities are discharging to a waterbody that requires a TMDL for bacteria. All of the facilities in Table 3-1 discharge TSS and have specific permit limits for TSS which are provided in Table 3-1. However, the municipal WWTPs designated with a Standard Industrial Code number 4952 in Table 3-1 discharge organic TSS and therefore are not considered a potential source of turbidity within their respective watershed. There is one active NPDES-permitted industrial facility (SIC Code: 2099, Food Preparations) operating in the Study Area. This facility also discharges organic TSS and therefore is not considered a potential source of turbidity.

3.1.2 No-Discharge Facilities and Sanitary Sewer Overflows

For the purposes of these TMDLs, it is assumed that no-discharge facilities do not contribute indicator bacteria or TSS loading. However, it is possible the wastewater collection systems associated with these no-discharge facilities could be a source of indicator bacteria loading, or that discharges from the wastewater plant may occur during large rainfall events that exceed the systems' storage capacities. There is only one no-discharge facilitiy in the Study Area (Table 3-2).

Sanitary sewer overflows (SSO) from wastewater collection systems, although infrequent, can be a major source of indicator bacteria loading to streams. SSOs have existed since the introduction of separate sanitary sewers, and most are caused by blockage of sewer pipes by grease, tree roots, and other debris that clog sewer lines, by sewer line breaks and leaks, cross connections with storm sewers, and inflow and infiltration of groundwater into sanitary sewers. SSOs are permit violations that must be addressed by the responsible NPDES permittee. The reporting of SSOs has been strongly encouraged by EPA, primarily through enforcement and fines. While not all sewer overflows are reported, DEQ has data on reported SSOs. Table 3-3 summarizes the SSO occurrences by NPDES facility. SSO data are provided in Appendix D.

Table 3-1 Point Source Discharges in the Study Area

Waterbody name	Waterbody ID	FACILITY	Permit ID	STATE_ID	SIC code	Design Flow (MGD)	Ave/Max FC (cfu/100mL)	Avg/Max TSS (mg/L)	Expiration Date	Notes
Muddy Boggy Creek	OK410400050270_10	Coalgate Public Works Auth	OKG580028	S10402	4952	0.22	NA	90/135	6/30/2016	
		Atoka, City Of	OK0028576	S10403	4952	0.8	200/400	30/45	10/31/2014	
		Love's Country Stores #268-ATO	OK0042901	I-3000130	NA	NA	NA	NA	NA	Inactive
Clear Boggy Creek	OK410400030010_00	Dolese Brothers Co.-Coleman	OKG950030	I-3000090	3273	report	NA	-/45	2/3/2013	

NA = not available.

Table 3-2 Total Retention Facilities in the Study Area

Waterbody ID	Waterbody Name	Facility	State ID	OWRB	County
OK410400050270_10	Muddy Boggy Creek	Wills Ready Mix Atoka Plant		WD94-017	Atoka

Table 3-3 Sanitary Sewer Overflow (SSO) Summary

Facility Name	Facility ID	Receiving Stream	Waterbody ID	Number of Occurrences	Date Range		Amount (Gallons)	
					From	To	Min	Max
Coalgate	S10402	Muddy Boggy Creek	OK410400050270_10	12	2005	2011	0	50,000
Atoka	S10403	Muddy Boggy Creek	OK410400050270_10	59	2005	2011	50	250,000

Figure 3-1 Locations of NPDES-Permitted Facilities for Discharges and Constructions in the Study Area

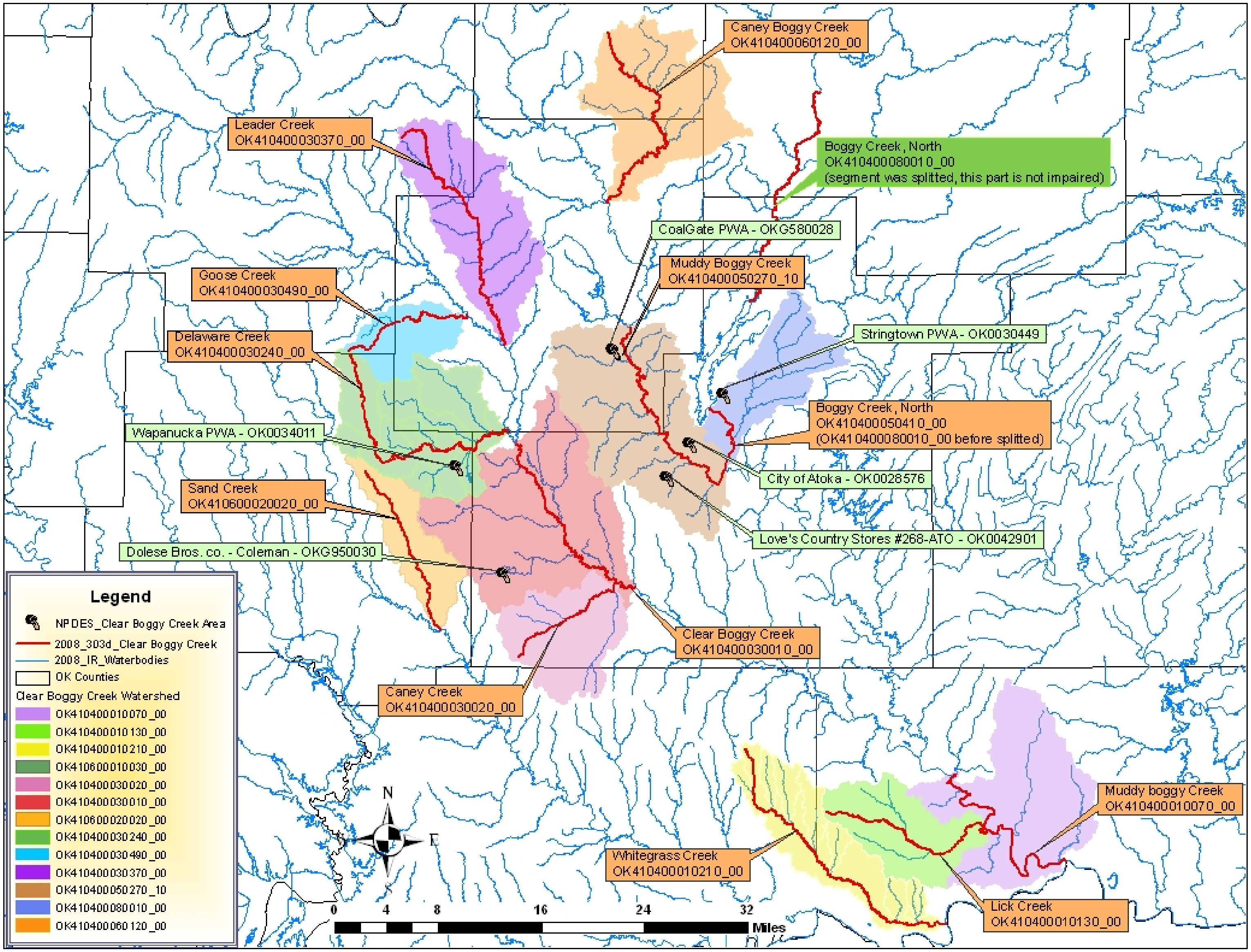
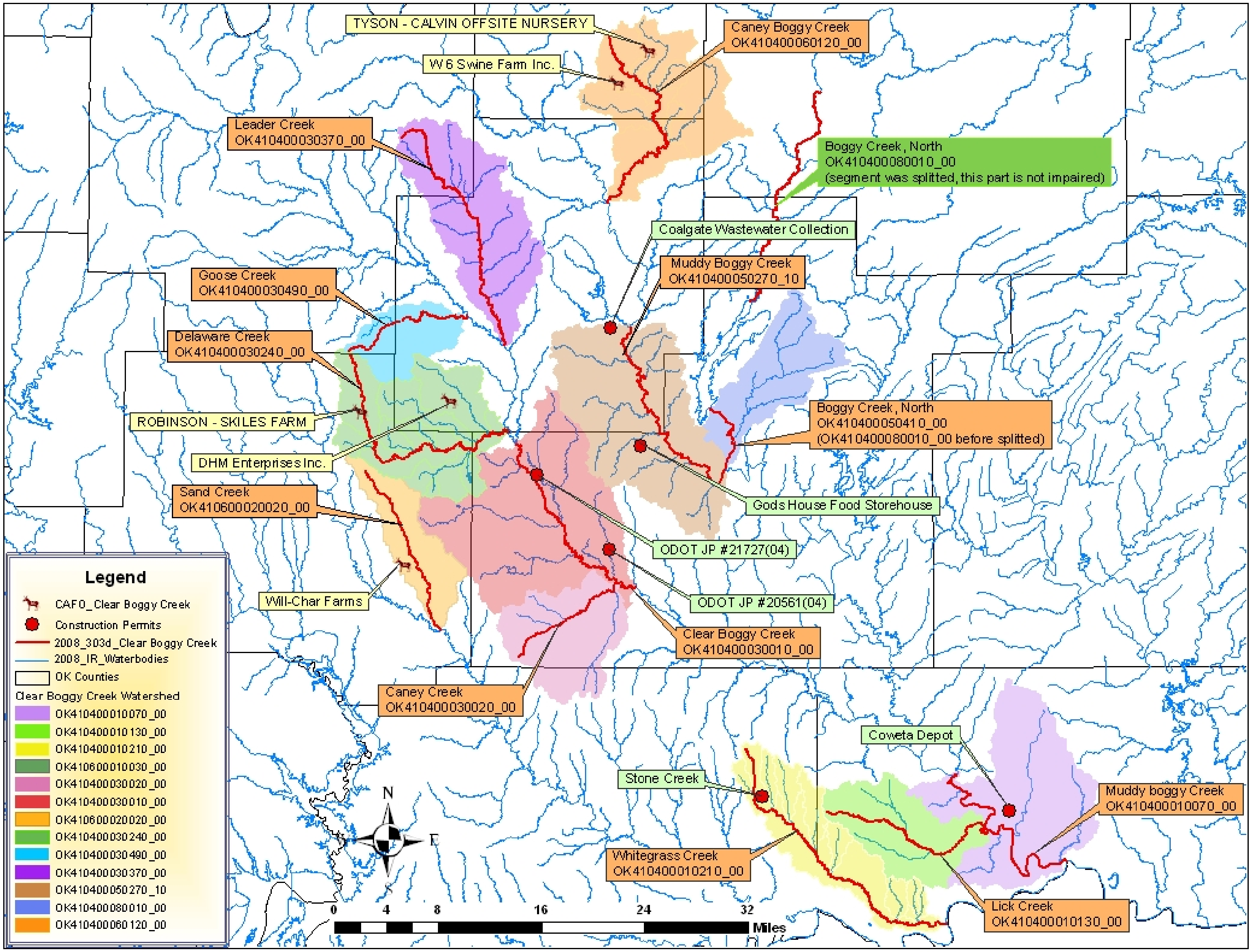


Figure 3-2 Locations of CAFOs, Poultry, Total Retention Facilities and Land Application Sites in the Study Area



3.1.3 NPDES Municipal Separate Storm Sewer System

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 water bodies (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.

Phase II MS4

Phase II of the rule extends coverage of the NPDES stormwater program to certain small MS4s. 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," protect water quality, and satisfy appropriate water quality requirements of the CWA. Small MS4 stormwater programs must address the following minimum control measures:

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

- The small MS4 General Permit for communities in Oklahoma became effective on February 8, 2005. DEQ provides information on the current status of the MS4 program on its website, which can be found at: http://www.deq.state.ok.us/WQDnew/stormwater/ms4/.

There are no permitted MS4s in the Study Area.

3.1.4 Concentrated Animal Feeding Operations and Poultry 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. Through regulations established by the Oklahoma Concentrated Animal Feeding Operation (CAFO) Act, Swine Feeding Operation (SFO) Act, and Poultry Feeding Operation (PFO) Registration Act, AEMS works with producers and concerned citizens to ensure that animal waste does not impact the waters of the state.

(1) CAFOs

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 2005). The CAFO Act and SFO Act are designed to protect water quality through the use of best management practices (BMP) such as dikes, berms, terraces, ditches, or other similar structures used to isolate animal waste from outside surface drainage, except for a 25-year, 24–hour rainfall event (ODAFF 2009). CAFOs are considered no-discharge facilities for the purpose of the TMDL calculations in this report.

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 (ODAFF 2009a). Potential problems from CAFOs can include unauthorized discharges of bacteria or nutrient loads to waters of the state and failure to properly operate wastewater lagoons. CAFOs are not considered a source of TSS loading. The location of each CAFO is shown in Figure 3-2 and is listed in Table 3-4. CAFO data used in this report were provided by ODAFF in May of 2011.

Regulated CAFOs within the watershed operate under state CAFO licenses issued and overseen by ODAFF and NPDES permits by EPA. In order to comply with this TMDL, those CAFO permits in the watershed and their associated management plans must be reviewed and evaluated. Further actions to reduce bacteria loads and achieve progress toward meeting the specified reduction goals must be implemented. This provision will be forwarded to EPA and ODAFF for follow up.

Table 3-4 NPDES-Permitted CAFOs in Study Area

ODAFF Location ID	EPA Facility	License #	Company	Max # of Swine >55 lbs units at facility	Max # of Swine <55 lbs units at facility	Total # of Animal Units at Facility	County	Waterbody Name and ID
AGN035234	OKU000231	1464	Tyson - Calvin Offsite Nursery	0	0	1000	Hughes	Caney Boggy Creek OK410400060120_00
WQ0000322	OKG010294	1310	W 6 Swine Farm Inc.	1920	1920	1920	Hughes	Caney Boggy Creek OK410400060120_00

(2). PFOs

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 Animal Waste Management Plan (AWMP) or an equivalent document such as a Nutrient Management Plan (NMP). These plans describe how little will be stored and applied properly in order to protect water quality of streams and lakes located in the watershed. Applicable BMPs shall be included in the Plan.

In order to comply with this TMDL, the registered PFOs in this Study Area and their associated management plans must be reviewed. Further actions to reduce bacteria loads and achieve progress toward meeting the specified reduction goals must be implemented. This provision will be forwarded to EPA and ODAFF for follow up.

Per data provided by ODAFF in May 2011, there are no PFOs located in this Study Area.

3.1.5 Stormwater Permits

3.1.5.1 Construction Activities

A general stormwater permit (OKR10) is required by the DEQ for any stormwater discharges associated with construction activities that result in land disturbance of equal to or greater than one (1) acre, or less than one (1) acre if they are part of a larger common plan of development or sale that totals at least one (1) acre. The permit also authorizes any stormwater discharges from support activities (e.g. concrete or asphalt batch plants, equipment staging yards, material storage areas, excavated material disposal areas, and borrow areas) that are directly related to a construction site that is required to have permit coverage, and is not a commercial operation serving unrelated different sites (DEQ 2007). Stormwater discharges occur only during or immediately following periods of rainfall and elevated flow conditions when the turbidity criteria do not apply and are not considered potential contributors to turbidity impairment. The permits for construction projects that were active during the time period that samples were taken are summarized in Table 3-5.

3.1.5.2 Multi-Sector General Permits

A multi-sector industrial general permit (OKR05) is also required by the DEQ for stormwater discharges from industrial facilities (DEQ 2011). Stormwater discharges from all industrial facilities, except mine dewatering discharges at crushed stone, construction sand and gravel, or industrial sand mining facilities, 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. Mine dewatering discharges can happen at any time and have the following specific number effluent limitations for TSS:

- Daily Maximum: 45 mg/L
- Monthly Average: 25 mg/L

If the TMDL shows that a TSS limit more stringent than 45 mg/L is required, additional TSS limitations and monitoring requirements will be required. These additional requirements will be implemented under the multi-sector general permit (MSGP). Table 3-5a summarizes the general permits for two dewatering discharges in the Study Area.

3.1.6 Rock, Sand and Gravel Quarries

Operators of rock, sand and gravel quarries in Oklahoma are regulated with a general permit (OKG950000) issued by the DEQ. The general permit does not allow discharge of wastewater to waterbodies included in Oklahoma's 303(d) List of impaired water bodies listed for turbidity for which a TMDL has not been performed or the result of the TMDL indicates that discharge limits more stringent than 45 mg/l for TSS are required (DEQ 2009). If the TMDL shows that a TSS limit more stringent than 45 mg/L is required, an individual discharge permit with the TMDL required TSS limit will be issued to the facility. There is one rock, sand and gravel quarry located within the Study Area.

Table 3-4a NPDES-Permitted Rock Sand and Gravel Quarries in Study Area

Waterbody ID	Facility	Permit ID	Design Flow (MGD)	Avg/Max TSS (mg/L)	Expiration Date
OK410400030010_00	Dolese Brothers Co.-Coleman	OKG950030	Report	-/45	2/3/2013

3.1.7 Section 404 permits

Section 404 of the Clean Water Act (CWA) establishes a program to regulate the discharge of dredged or fills 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).

Section 404 Permits are administrated by the U.S. Army Corps of Engineers. 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.

Discharge of dredged or fill material in waters can be a significant source of turbidity/TSS. The federal Clean Water Act requires that a permit be issued for activities which discharge dredged or fill materials into the waters of the United States, including wetlands. The State of Oklahoma will use its Section 401 Certification authority to ensure Section 404 Permits protect Oklahoma Water Quality Standards.

Table 3-5 Construction Permits Summary

Company Name	County	Permit ID	Date Issued	Waterbody ID	Receiving Water (Permit)	Estimated Acres
Coweta Depot	Wagoner	OKR107771	12/13/2010	OK410400010070_00	Coweta Creek	68.52
Stone Creek	Pontotoc	OKR108941	5/23/2008	OK410400010210_00	Little Sandy Creek	14
ODOT JP #20561(04)	Atoka	OKR107894	1/18/2008	OK410400030010_00	Big Branch Creek	3
ODOT JP #21727(04)	Atoka	OKR107520	1/11/2008	OK410400030010_00	Clear Boggy Creek	16.98
Gods House Food Storehouse	Atoka	OKR107320	3/5/2008	OK410400050270_10	Thompson Creek	2
Coalgate Wastewater Collection	Coal	OKR108972	5/8/2008	OK410400050270_10	Muddy Boggy Creek	5

Table 3-5a Multi-Sector Industrial General Permit for Mine Dewatering Discharges

Company Name	SIC Code	County	Permit ID	Date Issued	Waterbody ID	Receiving Water (Permit)
Coleman Quarry *	1422	Atoka	OKR050677	7/27/2006	OK410400030010_00	Rock Creek
Eastok Pit	1446	Atoka	OKR050363	7/4/2006	OK410400050410_00	Unnamed Trib to Boggy Creek North

* DMR data is available under NPDES permit# OKG950030.

3.2 Nonpoint Sources

Nonpoint sources include those sources that cannot be identified as entering the waterbody at a specific location. The relatively homogeneous land use/land cover categories throughout the Study Area associated with rural agricultural, forest and range management activities has an influence on the origin and pathways of pollutant sources to surface water. Pathogen indicator bacteria originate from warm-blooded animals in rural, suburban, and urban areas. These sources include wildlife, various agricultural activities and domesticated animals, land application fields, urban runoff, failing onsite wastewater disposal (OSWD) systems and domestic pets. Water quality data collected from streams draining urban communities often show existing concentrations of fecal coliform bacteria at levels greater than a state's 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 2008 Integrated Report include sediments originating from grazing in riparian corridors of streams and creeks, highway/road/bridge runoff, non-irrigated crop production, rangeland grazing and other sources of sediment loading (DEQ 2008). Elevated turbidity measurements can be caused by stream bank erosion processes, stormwater runoff events and other channel disturbances. The following section provides general information on nonpoint sources contributing bacteria or TSS loading within the Study Area.

3.2.1 Wildlife

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

However, adequate data are available by county to estimate the number of deer by watershed. This report assumes that deer habitat includes forests, croplands, and pastures. Using Oklahoma Department of Wildlife and Conservation county data, the population of deer can be roughly estimated from the actual number of deer harvested and harvest rate estimates. Because harvest success varies from year to year based on weather and other factors, the average harvest from 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 $5x10^8$ 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 3-6 in cfu/day provides a relative magnitude of loading in each watershed.

Table 3-6 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
OK410400010070_00	Muddy Boggy Creek	74408	592	0.0080	296
OK410400010130_00	Lick Creek	38644	309	0.0080	154
OK410400010210_00	Whitegrass Creek	49707	347	0.0070	173
OK410400030010_00	Clear Boggy Creek	96743	1381	0.0143	691
OK410400030370_00	Leader Creek	62221	524	0.0084	262
OK410400030490_00	Goose Creek	22088	779	0.0353	390
OK410400050270_10	Muddy Boggy Creek	107527	694	0.0065	347
OK410400060120_00	Caney Boggy Creek	64250	251	0.0039	126

3.2.2 Non-Permitted Agricultural Activities and Domesticated Animals

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

- Processed commercially raised farm animal manure is often applied to fields as fertilizer, and can contribute to fecal bacteria loading to waterbodies if washed into streams by runoff.
- 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 bacteria loading directly into streams or can cause unstable stream banks which can contribute TSS.

Table 3-7 provides estimated numbers of selected livestock by watershed based on the 2007 U.S. Department of Agriculture (USDA) county agricultural census data (USDA 2007). The estimated commercially raised farm animal populations in Table 3-7 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 is not available to describe or quantify the relationship between instream concentrations of bacteria and land application or direct deposition of manure from commercially raised farm animal. Nor is sufficient information available to describe or quantify the contributions of sediment loading caused by commercially raised farm animal responsible for destabilizing stream banks or erosion in pasture fields. The estimated acreage by watershed where manure was applied in 2007 is shown in Table 3-7. 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 is considered a potential source of bacteria loading to the watersheds in the Study Area.

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

- Beef cattle release approximately 1.04E+11 fecal coliform counts per animal per day;
- Dairy cattle release approximately 1.01E+11 per animal per day
- Swine release approximately 1.08E+10 per animal per day
- Chickens release approximately 1.36E+08 per animal per day
- Sheep release approximately 1.20E+10 per animal per day
- Horses release approximately 4.20E+08 per animal per day;
- Turkey release approximately 9.30E+07 per animal per day
- Ducks release approximately 2.43E+09 per animal per day
- Geese release approximately 4.90E+10 per animal per day

Using the estimated animal populations and the fecal coliform production rates from ASAE, an estimate of fecal coliform production from each group of commercially raised farm animal was calculated in each watershed of the Study Area. These estimates are presented in Table 3-8. 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 and animal unit production of bacteria, cattle again appear to represent the most likely commercially raised farm animal source of fecal bacteria.

Table 3-7 Commercially Raised Farm Animals and Manure Application Area Estimates by Watershed

Waterbody ID	Waterbody Name	Cattle & Calves-all	Dairy Cows	Horses & Ponies	Goats	Sheep & Lambs	Hogs & Pigs	Ducks & Geese	Chicken & Turkeys	Acres of Manure Application
OK410400010070_00	Muddy Boggy Creek	9,955	25	334	0	44	49	28	181	322
OK410400010130_00	Lick Creek	5,168	13	174	0	23	25	14	94	167
OK410400010210_00	Whitegrass Creek	7,947	220	212	0	157	51	38	187	260
OK410400030010_00	Clear Boggy Creek	10,972	57	289	2	66	66	142	332	1,246
OK410400030370_00	Leader Creek	5,282	78	135	1	57	26	63	165	495
OK410400030490_00	Goose Creek	7,332	117	186	0	179	168	15	110	444
OK410400050270_10	Muddy Boggy Creek	8,238	101	282	5	339	361	17	277	296
OK410400060120_00	Caney Boggy Creek	2,801	37	87	1	106	114	5	80	112

Table 3-8 Fecal Coliform Production Estimates for Commercially Raised Farm Animals (x10^9 number/day)

Waterbody ID	Waterbody Name	Cattle & Calves-all	Dairy Cows	Horses & Ponies	Goats	Sheep & Lambs	Hogs & Pigs	Ducks & Geese	Chickens & Turkeys	Total
OK410400010070_00	Muddy Boggy Creek	1,035,323	2,504	140	0	523	525	67	25	1,039,106
OK410400010130_00	Lick Creek	537,437	1,278	73	0	271	272	35	13	539,379
OK410400010210_00	Whitegrass Creek	826,462	22,225	89	0	1,879	548	92	25	851,319
OK410400030010_00	Clear Boggy Creek	1,141,094	5,792	121	24	787	711	346	45	1,148,922
OK410400030370_00	Leader Creek	549,290	7,890	57	12	685	281	154	22	558,391
OK410400030490_00	Goose Creek	762,566	11,821	78	0	2,146	1,817	36	15	778,479
OK410400050270_10	Muddy Boggy Creek	856,764	10,192	118	60	4,064	3,900	40	38	875,175
OK410400060120_00	Caney Boggy Creek	291,284	3,732	37	12	1,274	1,233	12	11	297,595

3.2.3 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 2010a). OSWD systems and illicit discharges can be a source of bacteria loading to streams and rivers. Bacteria loading from failing OSWD systems can be transported to streams in a variety of ways, including runoff from surface ponding or through groundwater. Fecal coliform-contaminated groundwater may discharges to creeks through springs and seeps.

To estimate the potential magnitude of OSWDs fecal bacteria loading, the number of OSWD systems was estimated for each watershed. The estimate of OSWD systems was derived by using data from the 1990 U.S. Census 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 is estimated that areas with more than 40 OSWD systems per square mile (6.25 septic systems per 100 acres) can be considered to have potential contamination problems (Canter and Knox 1986). Table 3-9 summarizes estimates of sewered and unsewered households and the average number of septic tanks per square mile for each watershed in the Study Area.

Table 3-9 Estimates of Sewered and Unsewered Households

Waterbody ID	Waterbody Name	Public Sewer	Septic Tank	Other Means	Housing Units	# of Septic Tanks / Mile^2
OK410400010070_00	Muddy Boggy Creek	182	377	18	577	3.06
OK410400010130_00	Lick Creek	102	147	9	258	2.30
OK410400010210_00	Whitegrass Creek	85	177	16	278	2.15
OK410400030010_00	Clear Boggy Creek	154	606	21	781	3.78
OK410400030370_00	Leader Creek	92	255	8	355	2.48
OK410400030490_00	Goose Creek	196	358	6	560	9.79
OK410400050270_10	Muddy Boggy Creek	145	327	6	478	1.84
OK410400060120_00	Caney Boggy Creek	66	115	2	183	1.08

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):

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

The average of number of people per household was calculated to be 2.36 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 3-10.

Table 3-10 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)
OK410400010070_00	Muddy Boggy Creek	74,408	377	38	258
OK410400010130_00	Lick Creek	38,644	147	15	100
OK410400010210_00	Whitegrass Creek	49,707	177	18	121
OK410400030010_00	Clear Boggy Creek	96,743	606	61	414
OK410400030370_00	Leader Creek	62,221	255	26	174
OK410400030490_00	Goose Creek	22,088	358	36	245
OK410400050270_10	Muddy Boggy Creek	107,527	327	33	224
OK410400060120_00	Caney Boggy Creek	64,250	115	12	79

3.2.4 Domestic Pets

Fecal matter from dogs and cats, which is transported to streams by runoff from urban and suburban areas, can be a potential source of bacteria loading. On average 37.2% of the nation's households own dogs and 32.4% own cats and in these households the average number of dogs is 1.7 and 2.2 cats per household (American Veterinary Medical Association 2007). Using the U.S. Census data at the block level (U.S. Census Bureau 2010), dog and cat populations can be estimated for each watershed. Table 3-11 summarizes the estimated number of dogs and cats for the watersheds of the Study Area.

Table 3-11 Estimated Numbers of Pets

Waterbody ID	Waterbody Name	Dogs	Cats
OK410400010070_00	Muddy Boggy Creek	363	406
OK410400010130_00	Lick Creek	162	182
OK410400010210_00	Whitegrass Creek	175	196
OK410400030010_00	Clear Boggy Creek	491	550
OK410400030370_00	Leader Creek	223	250
OK410400030490_00	Goose Creek	352	394
OK410400050270_10	Muddy Boggy Creek	301	337
OK410400060120_00	Caney Boggy Creek	115	129

Table 3-12 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 3-12 Estimated Fecal Coliform Daily Production by Pets ($\times 10^9$ counts/day)

Waterbody ID	Waterbody Name	Dogs	Cats	Total
OK410400010070_00	Muddy Boggy Creek	1,198	219	1,417
OK410400010130_00	Lick Creek	536	98	634
OK410400010210_00	Whitegrass Creek	577	106	683
OK410400030010_00	Clear Boggy Creek	1,621	297	1,918
OK410400030370_00	Leader Creek	737	135	872
OK410400030490_00	Goose Creek	1,162	213	1,375
OK410400050270_10	Muddy Boggy Creek	992	182	1,174
OK410400060120_00	Caney Boggy Creek	380	70	449

3.3 Summary of Sources of Impairments

3.3.1 Bacteria

There are three watersheds in the Study Area that will require bacterial TMDLs: Muddy Boggy Creek (OK410400050270_10) with two active continuous point source dischargers, Muddy Boggy Creek (OK410400010070_00) with no point source dischargers, and Clear Boggy Creek (OK410400030010_00) with one continuous point source discharger. One of the watersheds [Muddy Boggy Creek (OK410400050270_10)], has a facility which will need a WLA for bacteria (Coalgate Public Works Authority). There are two CAFOs in the Caney Boggy Creek (OK410400060120_00) watershed. Except for a twenty-five year, 24–hour rainfall event, CAFOs are considered “no discharge” facilities. As a result, the various nonpoint sources are considered to be the major source of bacteria loading in each watershed that requires a TMDL for bacteria.

Table 3-13 below provides a summary of the estimated fecal coliform loads in cfu/day for the four major nonpoint source categories (commercially raised farm animals, pets, deer, and septic tanks) that contribute to the elevated bacteria concentrations in each watershed. 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 bacteria source tracking studies around the nation demonstrate that wild birds and mammals may represent a major source of the fecal bacteria found in streams.

Table 3-13 Summary 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
OK410400010070_00	Muddy Boggy Creek	99.81%	0.14%	0.03%	0.02%
OK410400010130_00	Lick Creek	99.84%	0.12%	0.03%	0.02%
OK410400010210_00	Whitegrass Creek	99.89%	0.08%	0.02%	0.01%
OK410400030010_00	Clear Boggy Creek	99.74%	0.17%	0.06%	0.04%
OK410400030370_00	Leader Creek	99.77%	0.16%	0.05%	0.03%
OK410400030490_00	Goose Creek	99.74%	0.18%	0.05%	0.03%
OK410400050270_10	Muddy Boggy Creek	99.80%	0.13%	0.04%	0.03%
OK410400060120_00	Caney Boggy Creek	99.78%	0.15%	0.04%	0.03%

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.

3.3.2 Turbidity

Of the eight watersheds in the Study Area that require turbidity TMDLs, one of them, Clear Boggy Creek (OK410400030010_00) has an industrial permitted source of TSS that will necessitate a WLA [Dolese Brothers Coleman Quarry (OKR050677)]. The other watersheds have other permitted activities such as construction and/or mining that contribute some TSS loading. Therefore, nonsupport of WWAC use in the all watersheds is caused primarily by nonpoint sources of TSS. Sediment loading of streams can originate from natural erosion processes, including the weathering of soil, rocks, and uncultivated land; geological abrasion; and other natural phenomena. There is insufficient data available to quantify contributions of TSS from these natural processes. TSS or sediment loading can also occur under non-runoff conditions as a result of anthropogenic activities in riparian corridors which cause erosive conditions. Given the lack of data to establish the background conditions for TSS/turbidity, separating background loading from nonpoint sources whether it is from natural or anthropogenic processes is not feasible in this TMDL development.

SECTION 4
TECHNICAL APPROACH AND METHODS

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

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

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.

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 will be derived from TSS calculations and expressed in pounds (lbs) per day which will represent the maximum one-day load the stream can assimilate while still attaining the WQS, as well as a PRG.

4.1 Determining a Surrogate Target for Turbidity

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

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

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

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

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

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

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

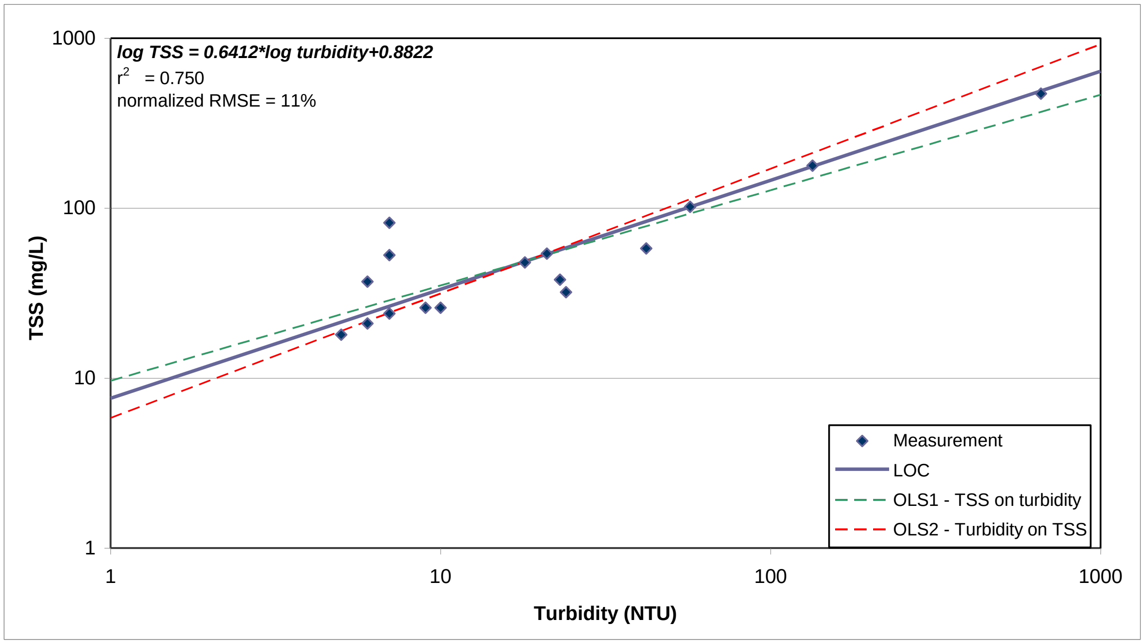
$$m1 = \sqrt{m \cdot m'} = sign[r] \cdot \frac{s_y}{s_x}$$

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

The intercept of the LOC ($b1$) is subsequently found by fitting the line with the LOC slope through the point (mean turbidity, mean TSS). Figures 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 11% which means the root mean square error (RMSE) is 11% of the average of the measured TSS values. The R-square (r^2) value indicates the fraction of the total variance in TSS or turbidity observations that is explained by the LOC. The regression equation can be used to convert turbidity standard of 50 NTUs to TSS goals.

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



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

The Tukey Method is equivalent to using three times the standard deviation to identify outliers if the residuals (observed - predicted) follow a normal distribution. The probability of sampling results being within three standard deviations of the mean is 99.73% while the probability for the Tukey Method is 99.65%. If three times the standard deviation is used to identify outliers, it is necessary to first confirm that the residuals are indeed normally distributed. This is difficult to do because of the size limitations of the existing turbidity & TSS dataset. Tukey's method does not rely on any assumption about the distribution of the residuals. It can be used regardless of the shape of distribution.

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

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

4.2 Using Load Duration Curves to Develop TMDLs

The TMDL calculations presented in this report are derived from load duration curves (LDC). LDCs facilitate rapid development of TMDLs, and as a TMDL development tool 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 through 4.5 below:

- Preparing flow duration curves for gaged and ungaged WQM stations;
- Estimating existing loading in the waterbody using ambient bacteria water quality data; and estimating loading in the waterbody using measured TSS water quality data and turbidity-converted data; and
- Using LDCs to identify if there is 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 WWTP effluents would dominate the base flow of the impaired water. However, flow range is only a general indicator of the relative proportion of point/nonpoint contributions. It is not used in this report to quantify point source or nonpoint source contributions. Violations that occur during low flows may not be caused exclusively by point sources. Violations 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 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. Seventeen of the twenty-four 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. The most basic method to estimate flows at an ungaged site involves

1) identifying an upstream or downstream flow gage; 2) calculating the contributing drainage areas of the ungaged sites and the flow gage; and 3) calculating daily flows at the ungaged site by using the flow at the gaged site multiplied by the drainage area ratio.

Flow duration curves are a type of cumulative distribution function. The flow duration curve represents the fraction of flow observations that exceed a given flow at the site of interest. The observed flow values are first ranked from highest to lowest, then, for each observation, the percentage of observations exceeding that flow is calculated. The flow value is read from the ordinate (y-axis), which is typically on a logarithmic scale since the high flows would otherwise overwhelm the low flows. The flow exceedance frequency is read from the abscissa (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 is 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.

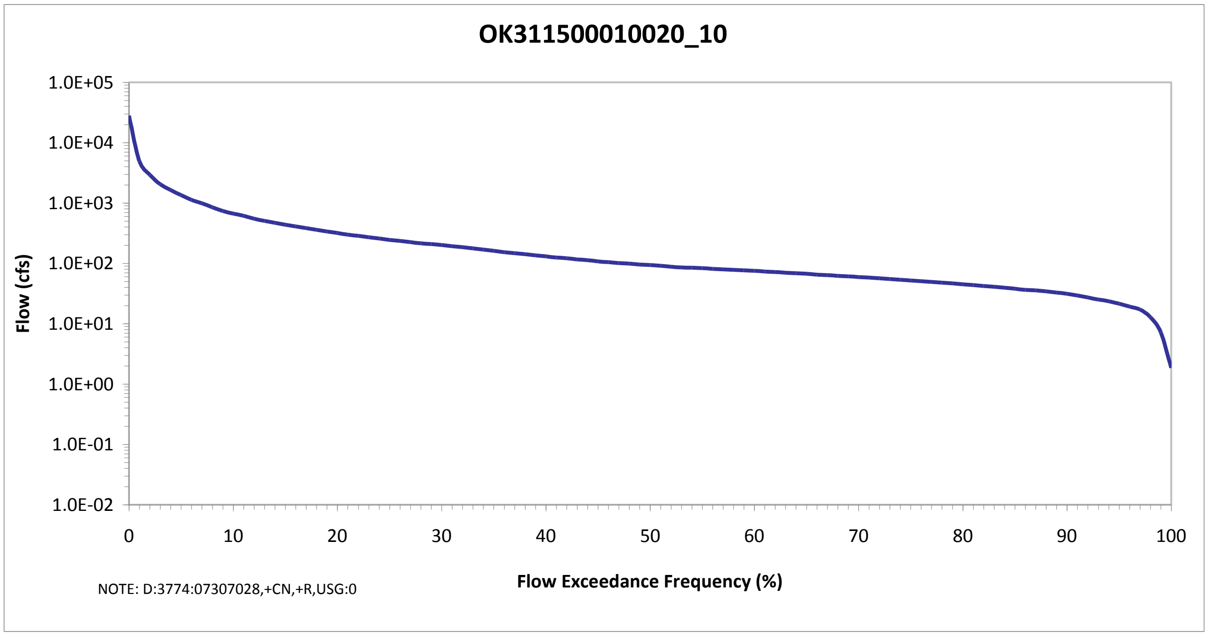
While the number of observations required to develop a flow duration curve is not rigorously specified, a flow duration curve is usually based on more than one year of observations, and encompasses inter-annual and seasonal variation. Ideally, the drought of record and flood of record are included in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

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

Some instantaneous flow measurements were available from various agencies. These were not combined with the daily average flows or used in calculating flow percentiles, but were matched to 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 will intersect 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 quantitation. An example of a typical flow duration curve was shown in Figure 4-2.

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



Flow duration curve for each stream segment in this study will be developed in Section 5.2.

4.4 Estimating Existing Loading

Existing instream loads can be estimated using FDCs. For bacteria, this is accomplished by:

- Calculating the geometric mean of all water quality observations from the period of record selected for the waterbody;
- Converting 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 bacteria indicator.

For TSS, this is accomplished by:

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

4.5 Development of TMDLs Using Load Duration Curves

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

Step 1: Generate LDCs. LDCs are similar in appearance to flow duration curves; however, for bacteria the ordinate is expressed in terms of a bacteria load in cfu/day, and for TSS the ordinate is expressed in terms of a load in lbs/day. The bacteria 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. Bacteria 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 bacteria 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 basic steps to generating an LDC involve:

- Obtaining daily flow data for the site of interest from the USGS;
- Sorting the flow data and calculating flow exceedance percentiles;
- Obtaining the water quality data from the primary contact recreation season (May 1 through September 30); or obtaining available turbidity and TSS water quality data;
- Displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQS numerical criterion for each parameter (geometric mean standard for bacteria and TSS goal for turbidity); and
- For bacteria TMDLs, displaying 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); or
- For turbidity TMDLs, matching the water quality observations with the flow data from the same date and determining the corresponding exceedance percentile (See Section 5).

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

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

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

unit conversion factor = 24,465,525

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) = $\boldsymbol{WQ_{goal}}$ **** flow (cfs) * unit conversion factor***

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

unit conversion factor = 5.39377

The flow exceedance frequency (x-value of each point) is obtained by looking up the historical exceedance frequency of the measured or estimated flow, in other words, the percent of historical observations that are equal to or exceed the measured or estimated flow. Historical observations of bacteria were plotted as a separate LDC based on the the geometric mean of all samples. 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. 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 bacteria observations to a geometric mean water quality criterion in the LDC; therefore individual bacteria samples are not plotted on the LDCs.

As noted earlier, runoff has a strong influence on loading of nonpoint pollution. Yet flows do not always correspond directly to runoff; high flows may occur in dry weather (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).

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

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

The LDC approach recognizes that the assimilative capacity of a waterbody depends on the flow, and that maximum allowable loading will vary with flow condition. 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 WWTP. For watersheds with permitted point sourcesdischarging the pollutant of concern, NPDES 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 is not available for a WWTP, then the average of monthly flow rates derived from DMRs can be used. WLA values for each NPDES wastewater discharger are then summed to represent the total WLA for a given segment. Using this information bacteria and TSS WLAs can be calculated using the approach as shown in the equations below.

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

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 flowunit conversion factor = 8.3445

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

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

LA = TMDL - WLA_WWTP - WLA_MS4 – MOS

WLA for MS4s. For bacteria TMDLs, if there are no permitted MS4s in the Study Area, WLA_MS4 is set to zero. When there are permitted MS4s in 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.

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

Step 5: Estimate 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 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 if the geometric mean of the reduced values of all samples is less than the geomean standards.

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

MS4s are classified as point sources, but they are non-point sources in nature. Therefore, the percent reduction goal calculated for LA will also apply to the MS4 area within the bacteria impaired sub-watershed. If there are no MS4s located within the Study Area requiring a TMDL, then there is no need to establish a PRG for permitted stormwater.

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

- If permitted TSS limit is less than TSS goal for the receiving stream, there will be no reductions;
- If permitted TSS limit is greater than TSS goal for the receiving stream, the permit limit will be set at the TSS goal.

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. For *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). For 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

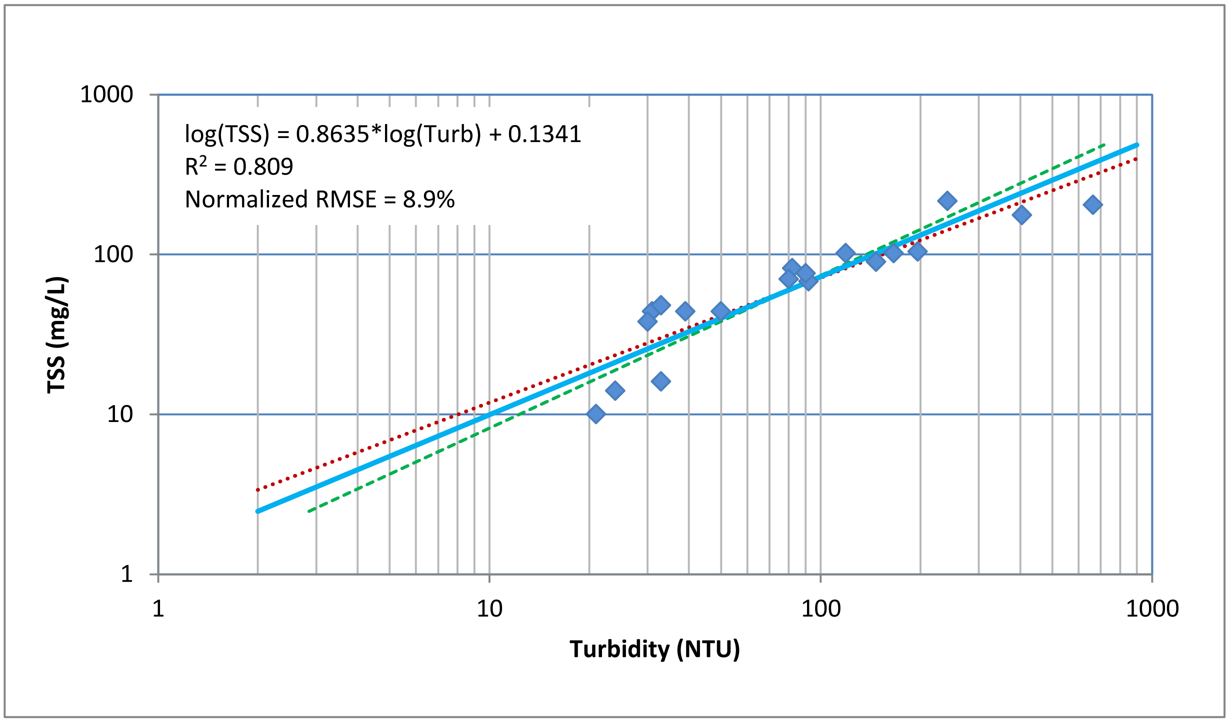
Using the LOC method described in Section 4.1, the correlation between TSS and turbidity were developed for Muddy Boggy Creek (OK410400050270_10), Lick Creek, Whitegrass Creek, Leader Creek, Goose Creek, Caney Boggy Creek (Figure 5-1 through 5-6). No concurrent turbidity and TSS were found for Muddy Boggy Creek (OK410400010070_00) and Clear Boggy Creek. The regression relationship developed for Muddy Boggy Creek (OK410400050270_10) was used for these two stream segments. The statistics of the regressions and the resultant TSS goals were shown in Table 5-1.

Table 5-1 Regression Statistics and TSS Goals

Waterbody ID	Waterbody Name	R-square	NRMSE	TSS Goal (mg/L)[a]	MOS[b]
OK410400010070_00	Muddy Boggy Creek	0.81	8.9%	39.9	10%
OK410400010130_00	Lick Creek	0.92	7.0%	26.9	10%
OK410400010210_00	Whitegrass Creek	0.65	15.0%	23.0	15%
OK410400030010_00	Clear Boggy Creek	0.81	8.9%	39.9	10%
OK410400030370_00	Leader Creek	0.84	10.1%	18.9	10%
OK410400030490_00	Goose Creek	0.78	11.5%	29.0	15%
OK410400050270_10	Muddy Boggy Creek	0.81	8.9%	39.9	10%
OK410400060120_00	Caney Boggy Creek	0.55	10.6%	18.6	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 Muddy Boggy Creek (OK410400050270_10)



* Muddy Boggy Creek (OK410400050270_10) and Clear Boggy Creek (OK410400030010_00) will also use this regression due to lack of specific data for the segments.

Figure 5-2 Linear Regression for TSS-Turbidity for Lick Creek (OK410400010130_00)

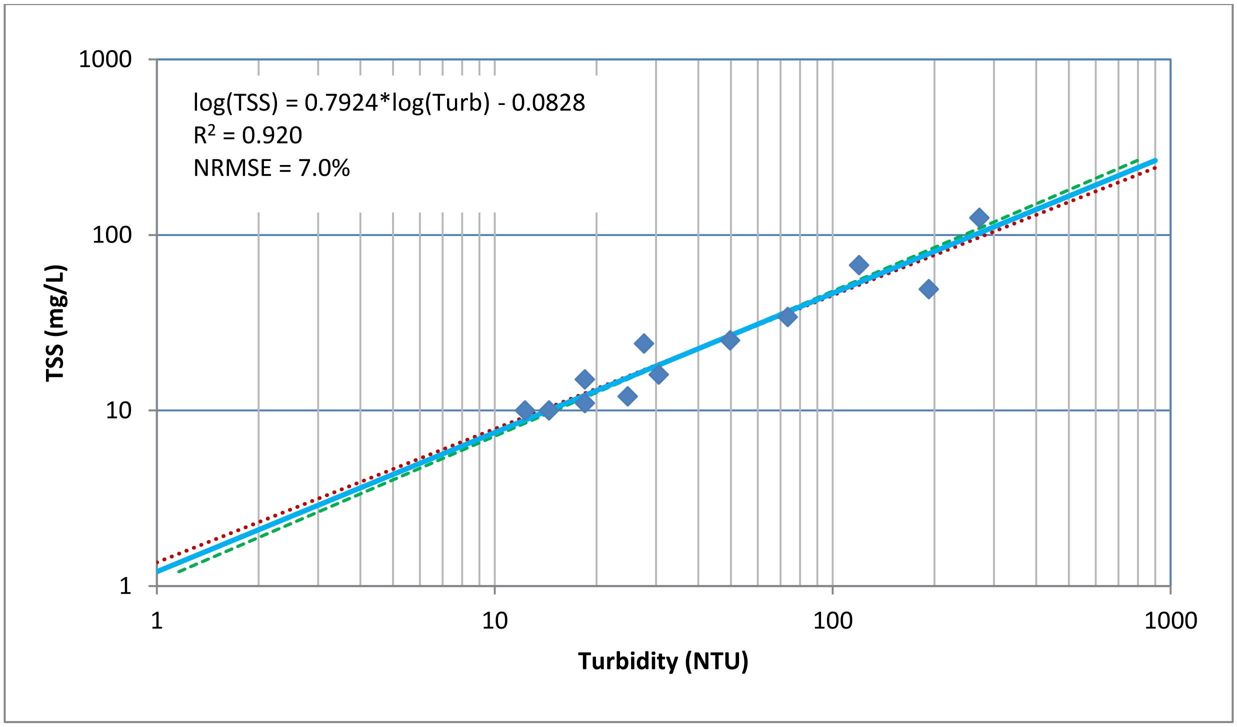


Figure 5-3 Linear Regression for TSS-Turbidity for Whitegrass Creek (OK410400010210_00)

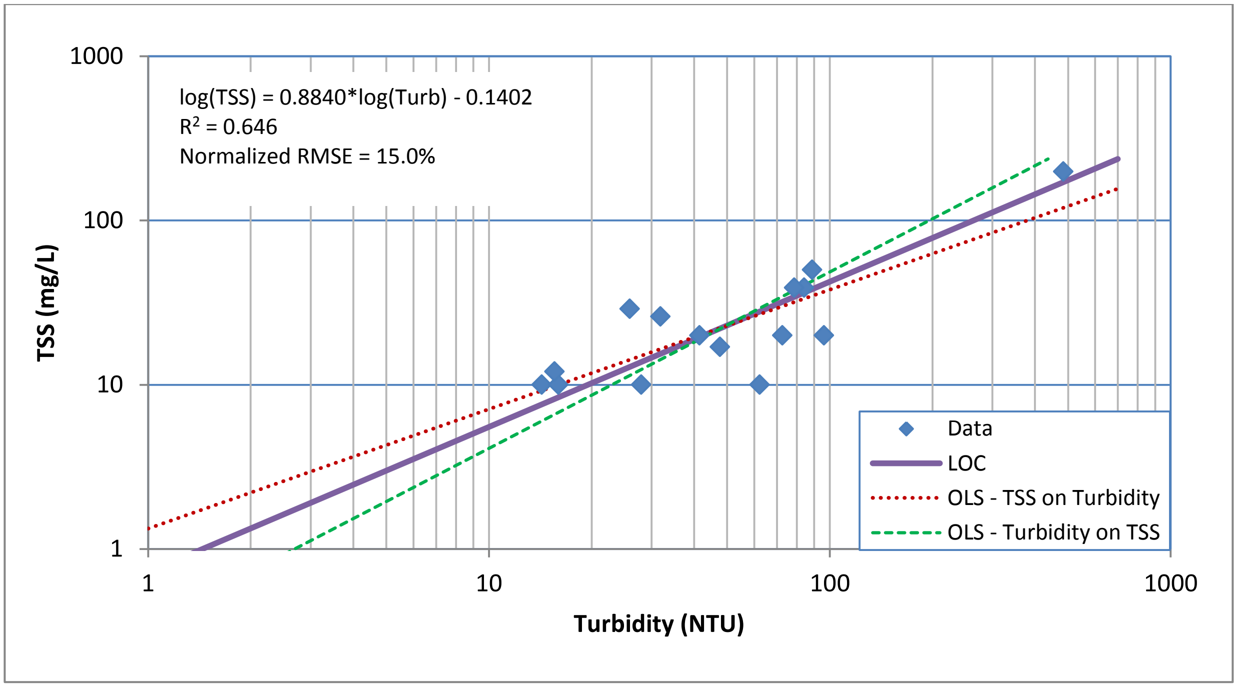


Figure 5-4 Linear Regression for TSS-Turbidity for Leader Creek (OK410400030370_00)

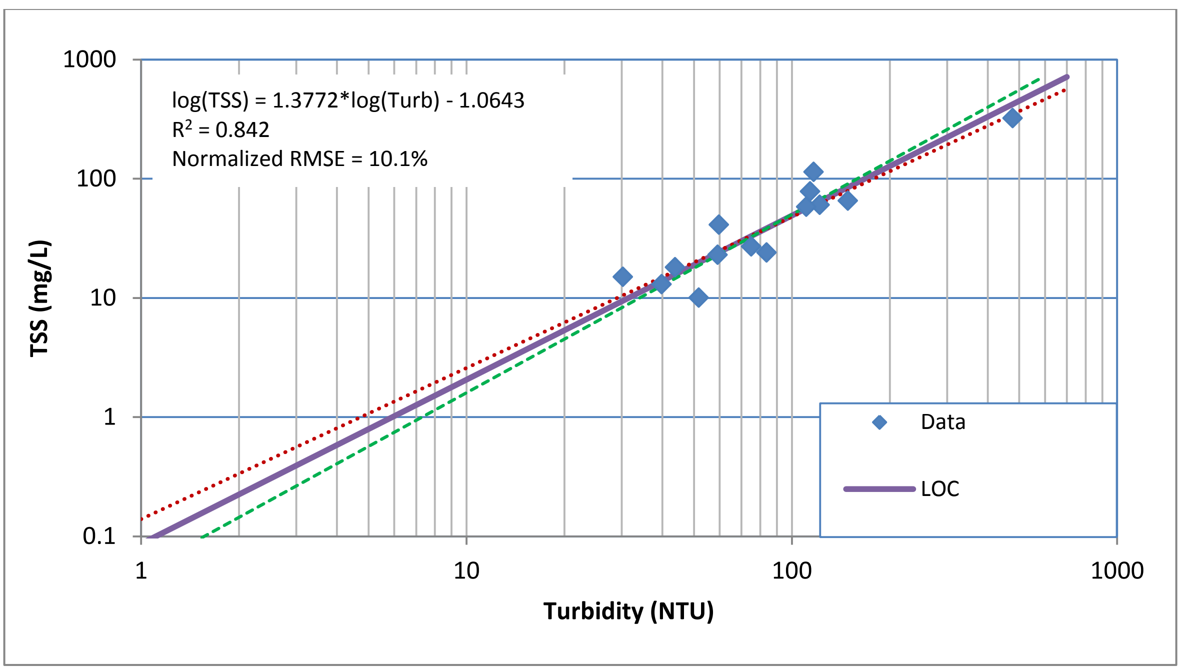


Figure 5-5 Linear Regression for TSS-Turbidity for Goose Creek (OK410400030490_00)

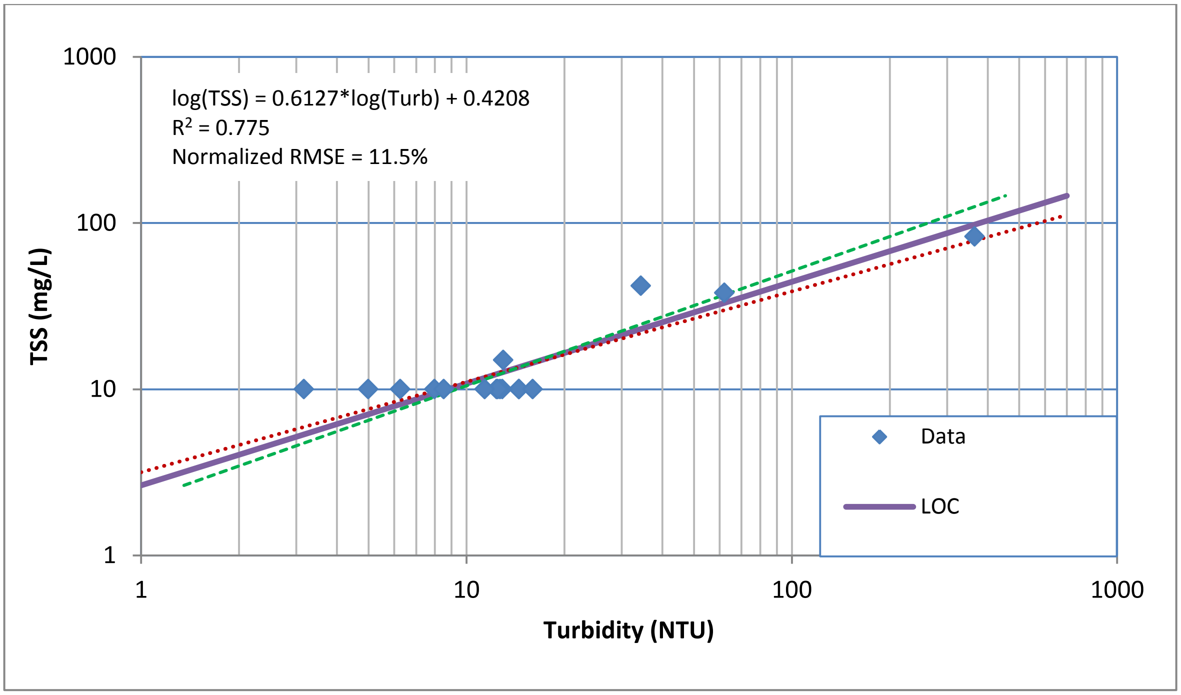
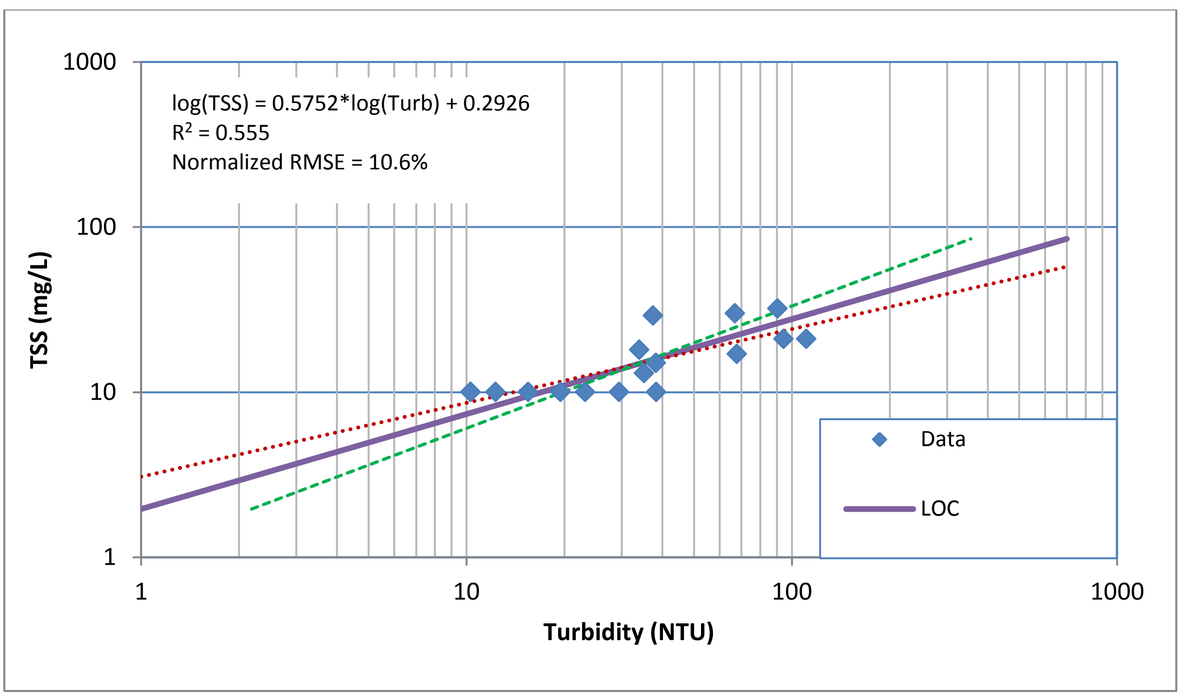


Figure 5-6 Linear Regression for TSS-Turbidity for Caney Boggy Creek (OK410400060120_00)

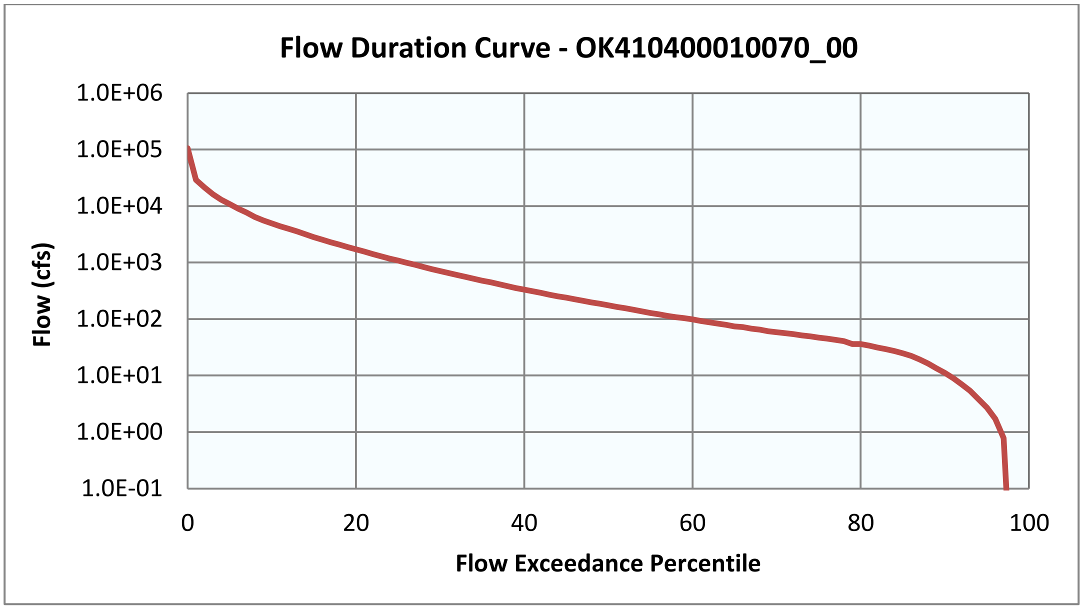


5.2 Flow Duration Curve

Following the same procedures described in Section 4.3, flow duration curve for each stream segment in this study was developed and shown in Figure 5-7 through Figure 5-14.

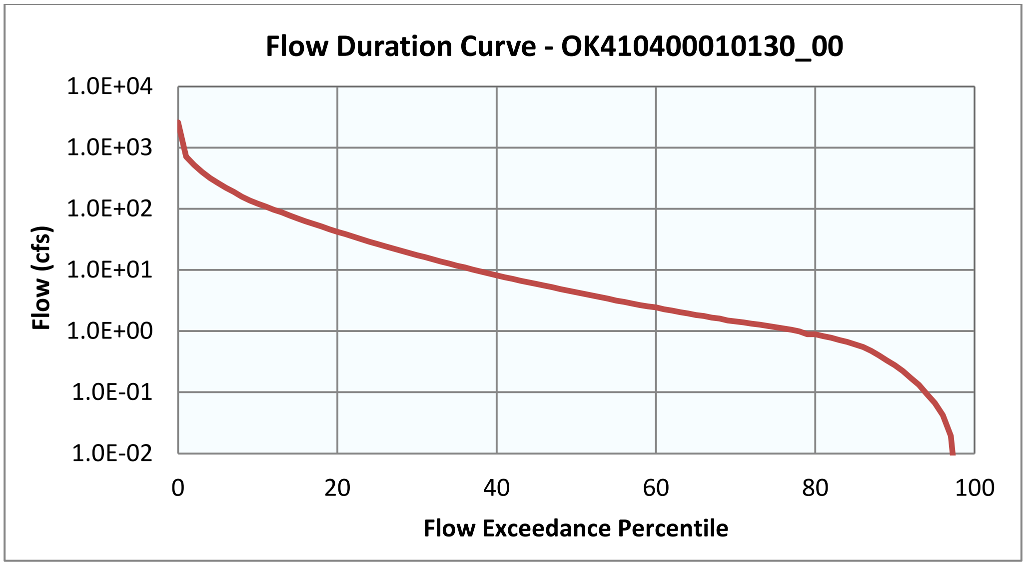
The flow duration curve for Muddy Boggy Creek (OK410400010070_00) was estimated based on measured flows at USGS gage station 07334000 on Muddy Boggy Creek near Farris, Oklahoma. USGS flow data used to develop the flow duration curve range from 1937 to 2011.

Figure 5-7 Flow Duration Curve for Muddy Boggy Creek (OK410400010070_00)



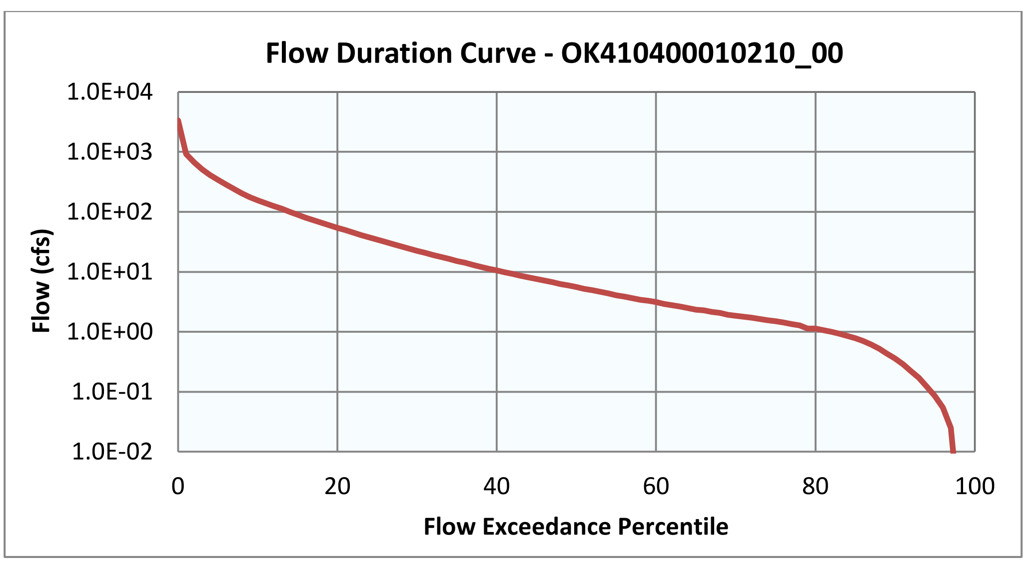
The flow duration curve for Lick Creek (OK410400010130_00) was estimated based on measured flows at USGS gage station 07334000 on Muddy Boggy Creek near Farris, Oklahoma. USGS flow data used to develop the flow duration curve range from 1937 to 2011.

Figure 5-8 Flow Duration Curve for Lick Creek (OK410400010130_00)



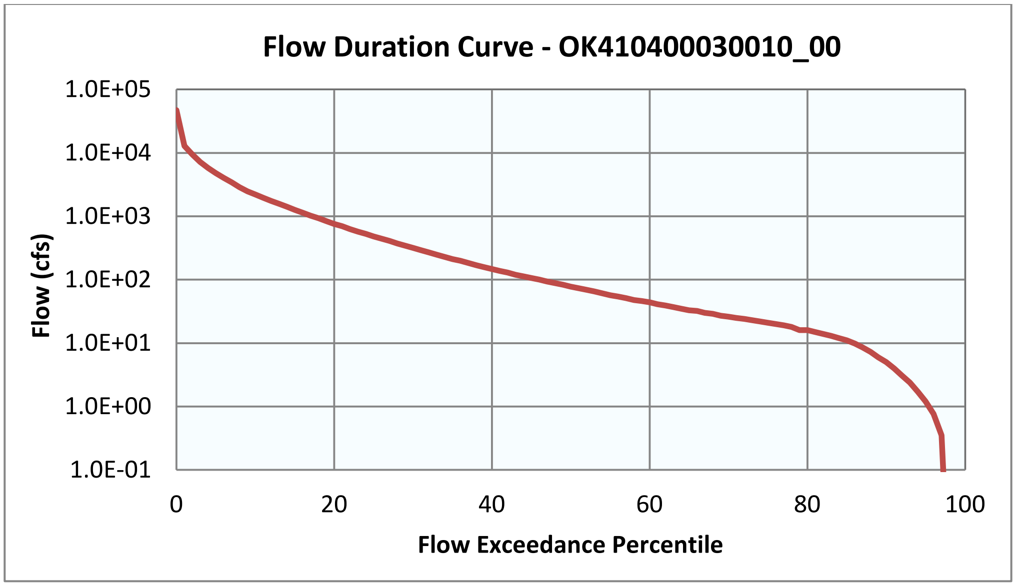
The flow duration curve for Whitegrass Creek (OK410400010210_00) was estimated based on measured flows at USGS gage station 07334000 on Muddy Boggy Creek near Farris, Oklahoma. USGS flow data used to develop the flow duration curve range from 1937 to 2011.

Figure 5-9 Flow Duration Curve for Whitegrass Creek (OK410400010210_00)



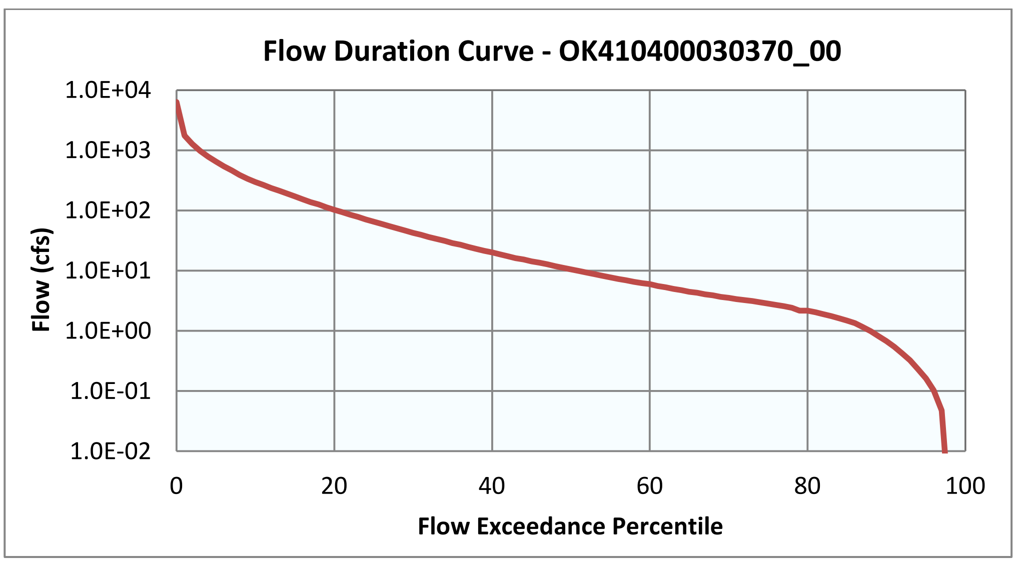
The flow duration curve for Clear Boggy Creek (OK410400030010_00) was based on measured flows at USGS gage station 07335000 on Clear Boggy Creek near Caney, Oklahoma. USGS flow data used to develop the flow duration curve range from 1942 to 2011.

Figure 5-10 Flow Duration Curve for Clear Boggy Creek (OK410400030010_00)



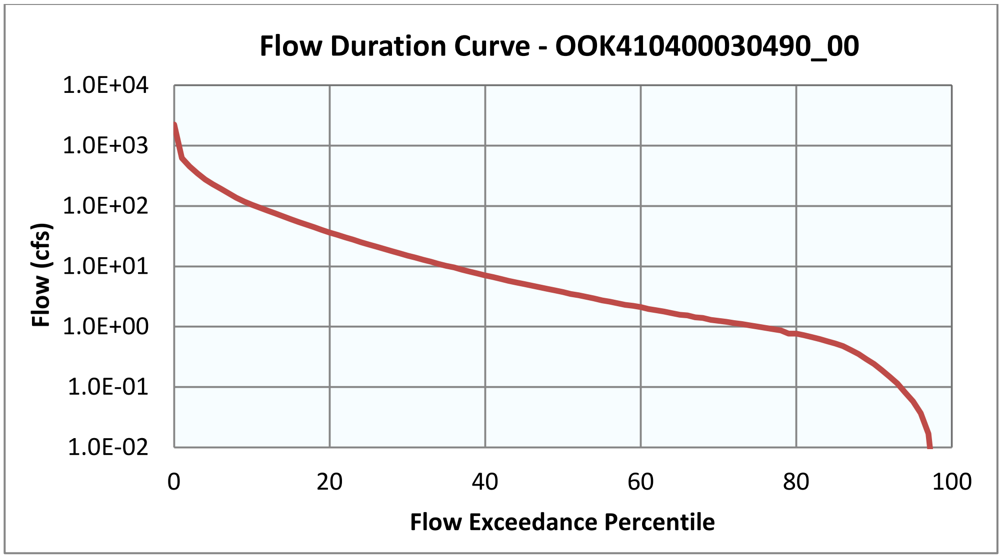
The flow duration curve for Leader Creek (OK410400030370_00) was estimated based on measured flows at USGS gage station 07335000 on Clear Boggy Creek near Caney, Oklahoma. USGS flow data used to develop the flow duration curve range from 1942 to 2011.

Figure 5-11 Flow Duration Curve for Leader Creek (OK410400030370_00)



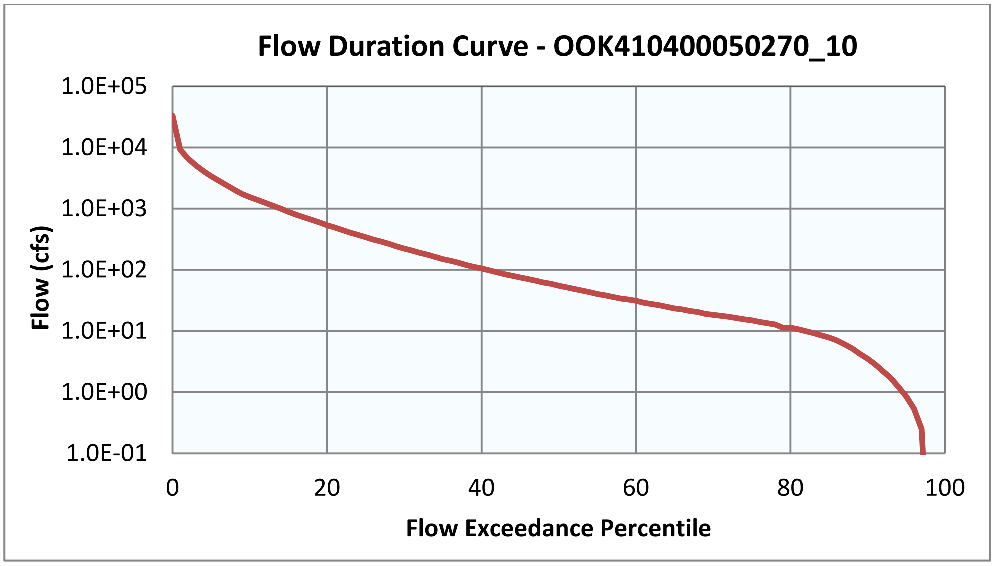
The flow duration curve for Goose Creek (OK410400030490_00) was estimated based on measured flows at USGS gage station 07335000 on Clear Boggy Creek near Caney, Oklahoma. USGS flow data used to develop the flow duration curve range from 1942 to 2011.

Figure 5-12 Flow Duration Curve for Goose Creek (OK410400030490_00)



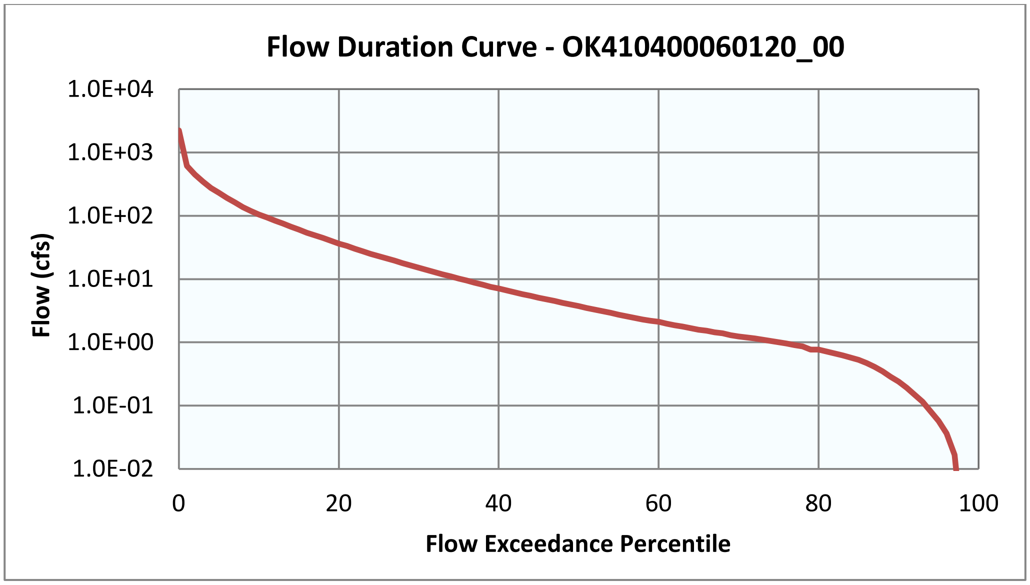
The flow duration curve for Muddy Boggy Creek (OK410400050270_00) was estimated based on measured flows at USGS gage station 07334000 on Muddy Boggy Creek near Farris, Oklahoma. USGS flow data used to develop the flow duration curve range from 1937 to 2011.

Figure 5-13 Flow Duration Curve for Muddy Boggy Creek (OK410400050270_10)



The flow duration curve for Caney Boggy Creek (OK410400060120_00) was estimated based on measured flows at USGS gage station 07334000 on Muddy Boggy Creek near Farris, Oklahoma. USGS flow data used to develop the flow duration curve range from 1937 to 2011.

Figure 5-14 Flow Duration Curve for Caney Boggy Creek (OK410400060120_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 water quality standards. To accomplish this, available instream WQM data were evaluated with respect to flows and magnitude of water quality criteria exceedance using LDCs.

5.3.1 Bacteria LDC

To calculate the allowable bacteria load, the flow rate at each flow exceedance percentile is 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 allowable bacteria load in the stream over the range of flow conditions. The allowable bacteria (*E. coli* or Enterococci) loads at the WQS establishes the TMDL and are plotted versus flow exceedance percentile as a LDC. The x-axis indicates the flow exceedance percentile, while the y-axis is expressed in terms of a bacteria load.

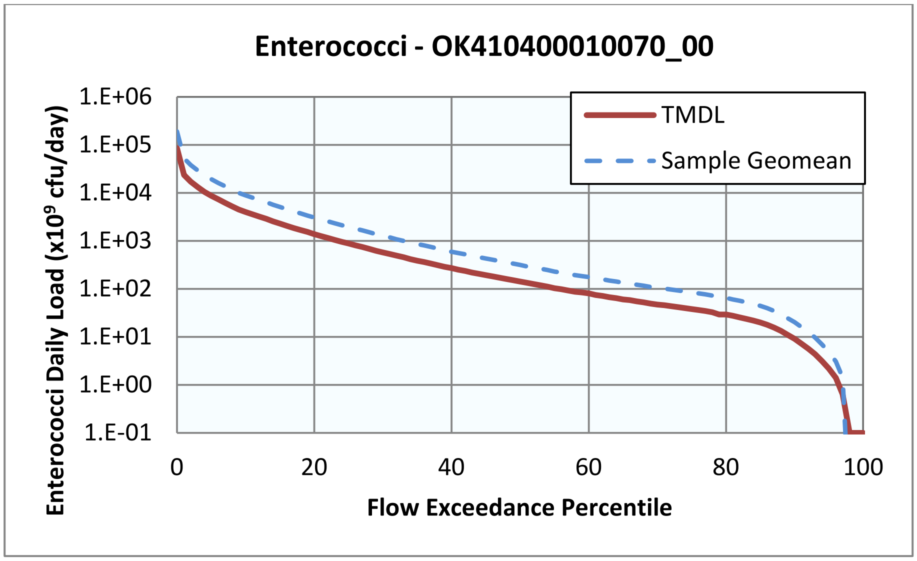
To estimate existing loading, the geometric mean of all bacteria observations (concentrations) for the primary contact recreation season (May 1st through September 30th) from 2001 to 2008 are paired with the flows measured or estimated in that waterbody. Pollutant loads are then calculated by multiplying the measured bacteria concentration by the flow rate and the unit conversion factor of *24,465,756*.

The bacteria LDCs developed for each impaired waterbody (representing the primary contact recreation season from 2001 through 2008) are shown in Figures 5-15 through 5-17.

Waterbodies may have more than one LDC because for the PBCR use to be supported, criteria for each bacterial indicator must be met in each impaired waterbody.

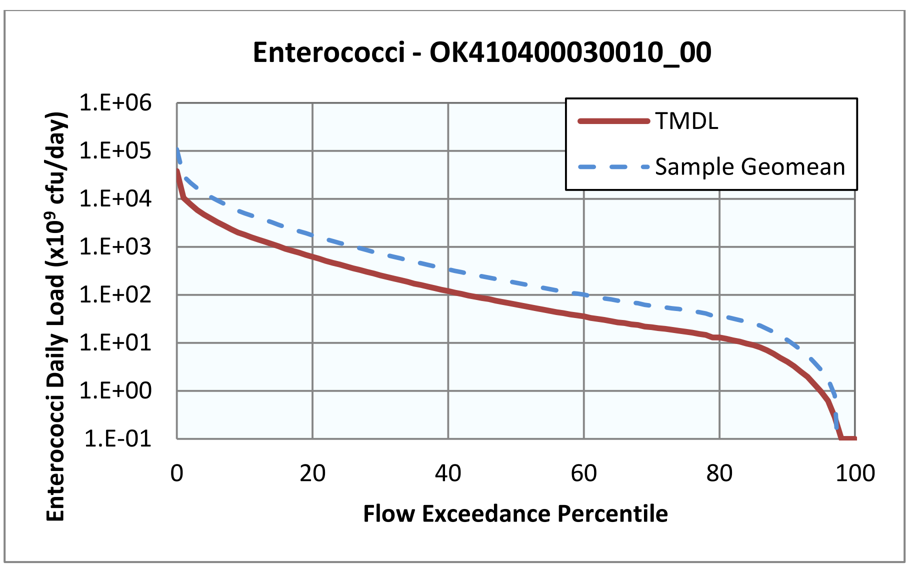
The LDC (Figure 5-15) for Muddy Boggy Creek (OK410400010070_00) is based on Enterococci bacteria measurements collected during primary contact recreation season at WQM station 410400010070-001AT.

Figure 5-15 Load Duration Curve for *Enterococci in Muddy Boggy Creek* (OK410400010070_00)



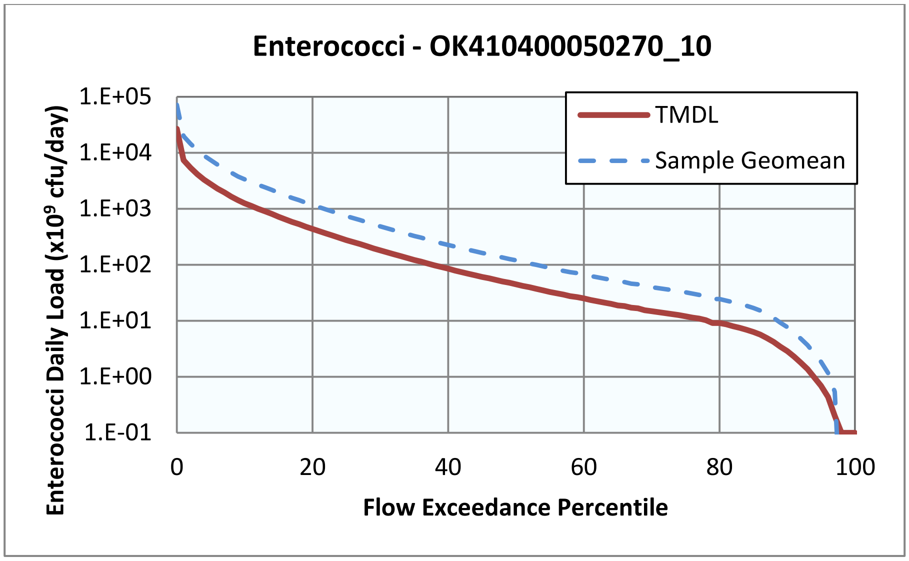
The LDC (Figure 5-16) for Clear Boggy Creek (OK410400030010_00) is based on Enterococci bacteria measurements collected during primary contact recreation season at WQM station 410400030010-001AT.

Figure 5-16 Load Duration Curve for *Enterococci Clear Boggy Creek* (OK410400030010_00)



The LDC (Figure 5-17) for Muddy Boggy Creek (OK410400050270_10) is based on Enterococci bacteria measurements collected during primary contact recreation season at WQM station 410400050270-001AT.

Figure 5-17 Load Duration Curve for *Enterococci in Muddy Boggy Creek* (OK410400050270_10)



5.3.2 Turbidity LDC

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

To estimate existing loading, TSS and turbidity observations from 1997 to 2010 are paired with the flows measured or projected on the same date for the waterbody. For sampling events with both TSS and turbidity data, the measured TSS value is used. Pollutant loads are then calculated by multiplying the TSS concentration by the flow rate and the unit conversion factor. The associated flow exceedance percentile is then matched with the flow from the tables provided in Appendix 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. For sampling events with only turbidity data, the turbidity data were converted to TSS with the corresponding regression relation developed in Section 5.1.

Figures 5-18 through Figure 5-25 show the TSS LDCs developed for the eight turbidity impaired waterbodies addressed in this TMDL report. Data in the figures indicate that TSS levels exceed the water quality target during all flow conditions, indicating water quality impairments due to nonpoint sources or a combination of point and nonpoint sources. Wet weather influenced samples found during low flow conditions can be caused by an isolated rainfall event during dry weather conditions. It is noted that the LDC plots include data under all flow conditions to show the overall condition of the waterbody. However, the turbidity standard only applies for base-flow conditions. Thus, when interpreting the LDC to derive TMDLs for TSS, only the portion of the graph corresponding to flows above the 25th flow exceedance percentile should be used. 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 5-18 Load Duration Curve for Total Suspended Solids in Muddy Boggy Creek (OK410400010070_00)

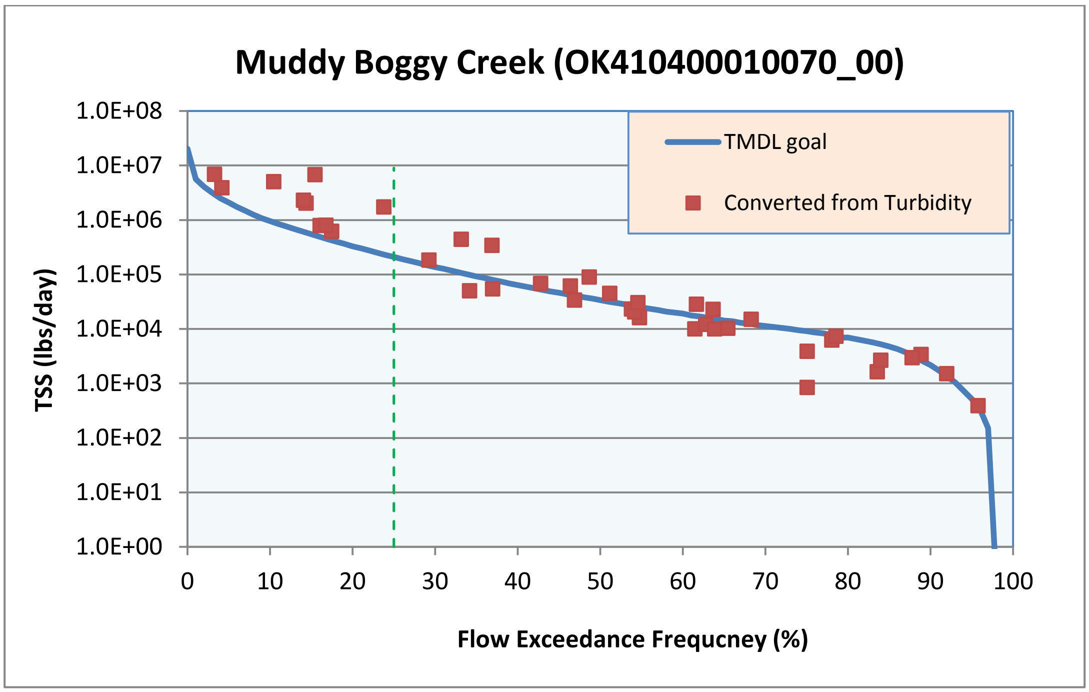


Figure 5-19 Load Duration Curve for Total Suspended Solids in Lick Creek (OK410400010130_00)

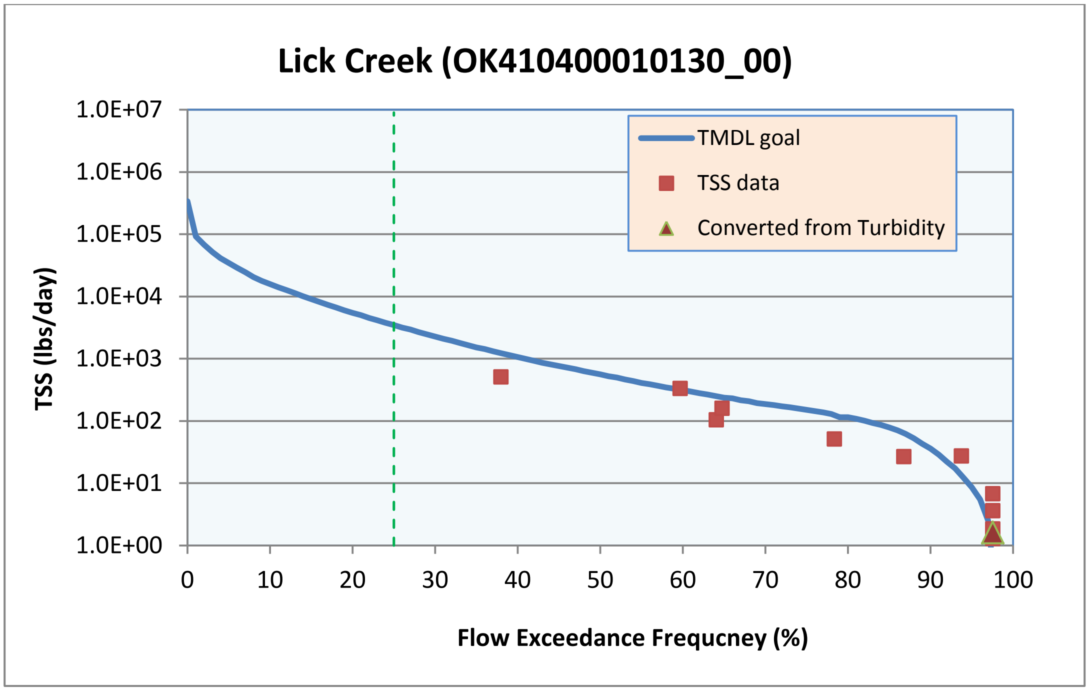


Figure 5-20 Load Duration Curve for Total Suspended Solids in Whitegrass Creek (OK410400010210_00)

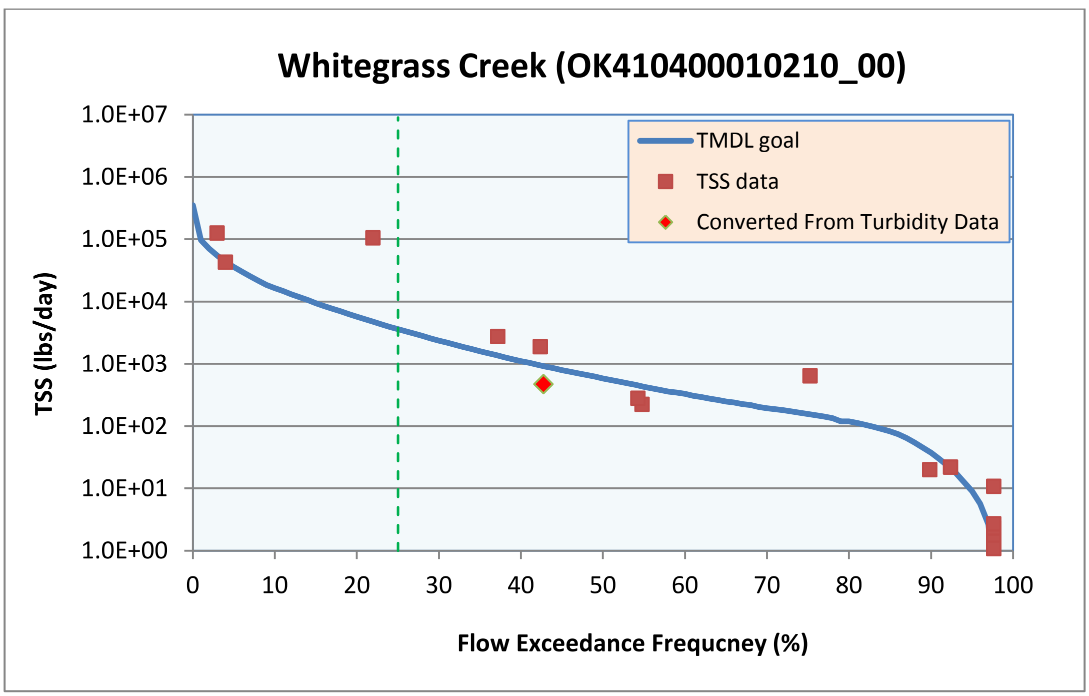


Figure 5-21 Load Duration Curve for Total Suspended Solids in Clear Boggy Creek (OK410400030010_00)

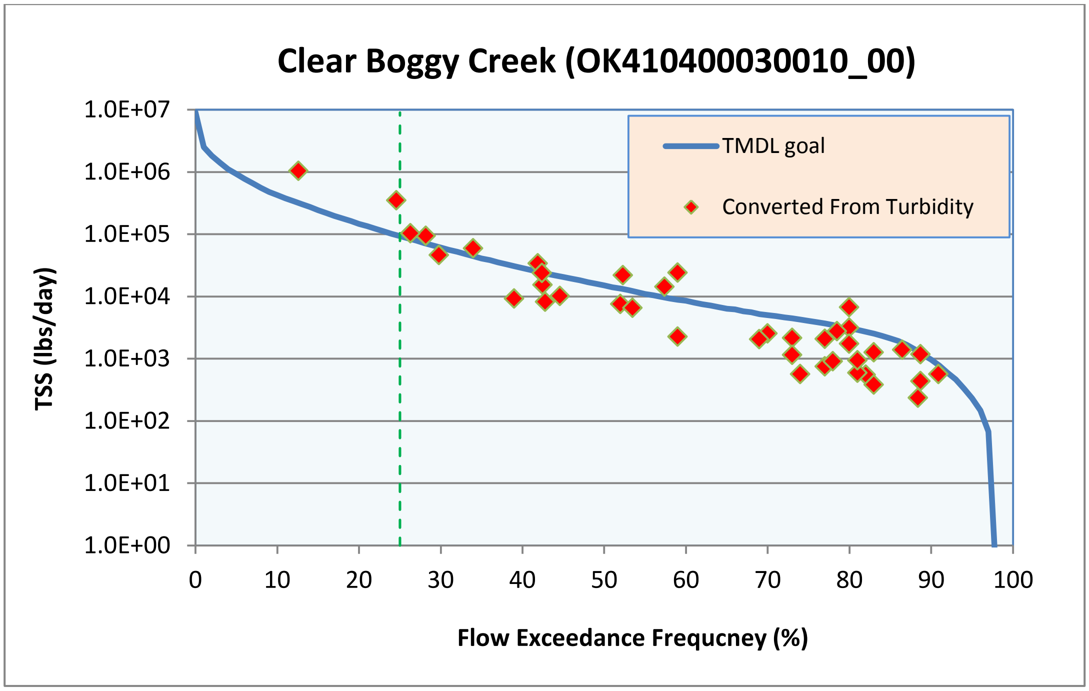


Figure 5-22 Load Duration Curve for Total Suspended Solids in Leader Creek (OK410400030370_00)

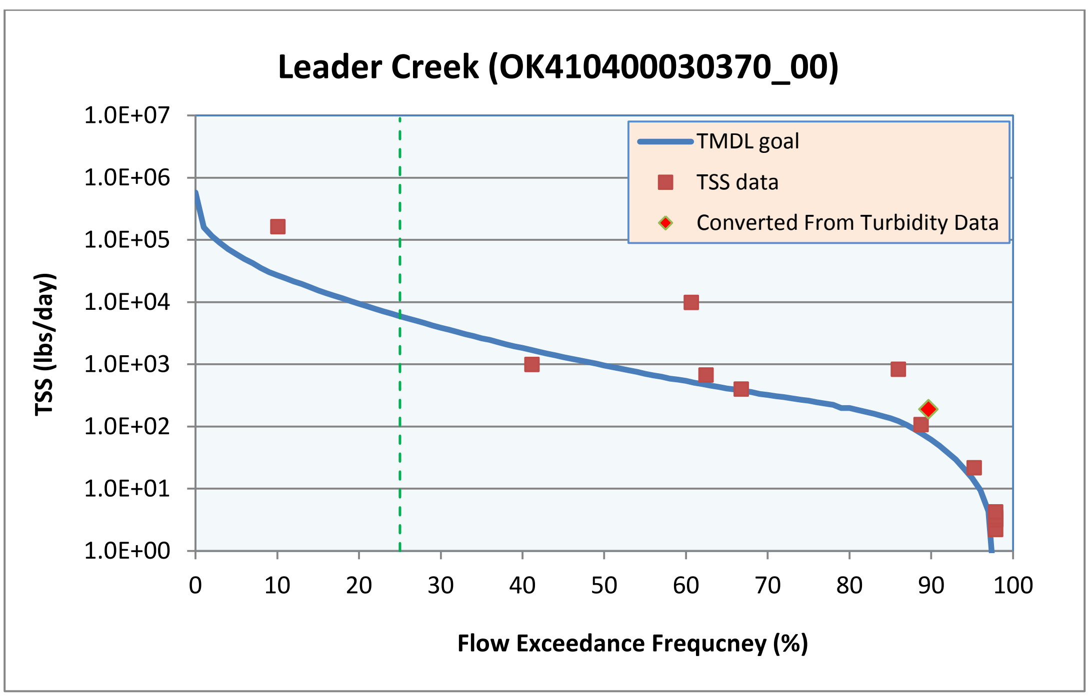


Figure 5-23 Load Duration Curve for Total Suspended Solids in Goose Creek (OK410400030490_00)

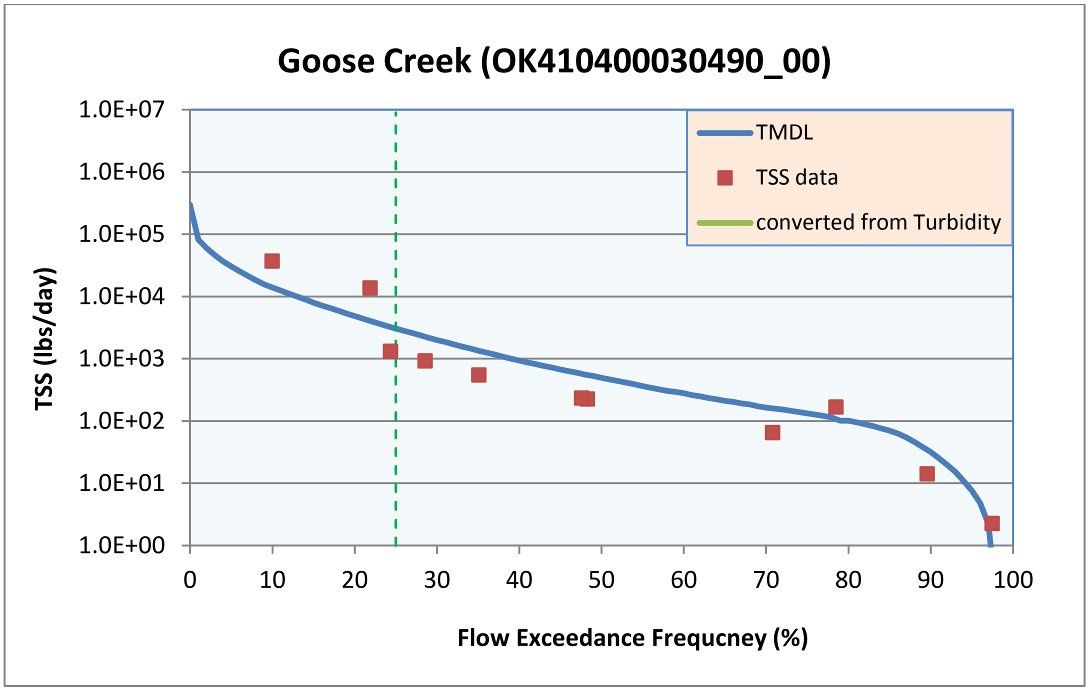


Figure 5-24 Load Duration Curve for Total Suspended Solids in Muddy Boggy Creek (OK410400050270_10)

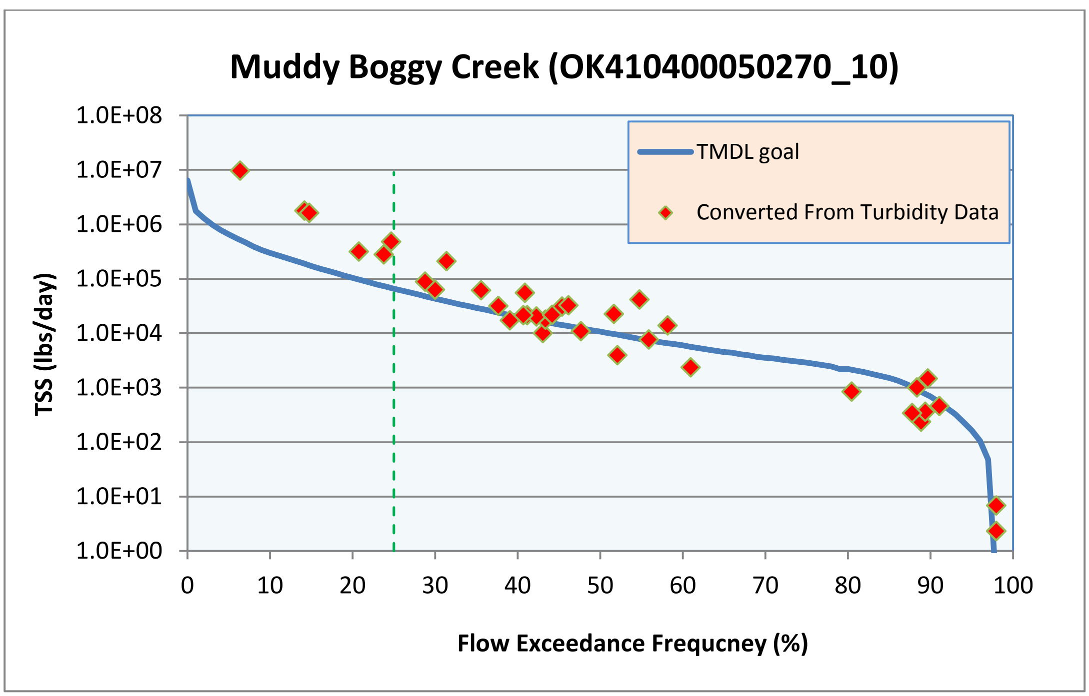
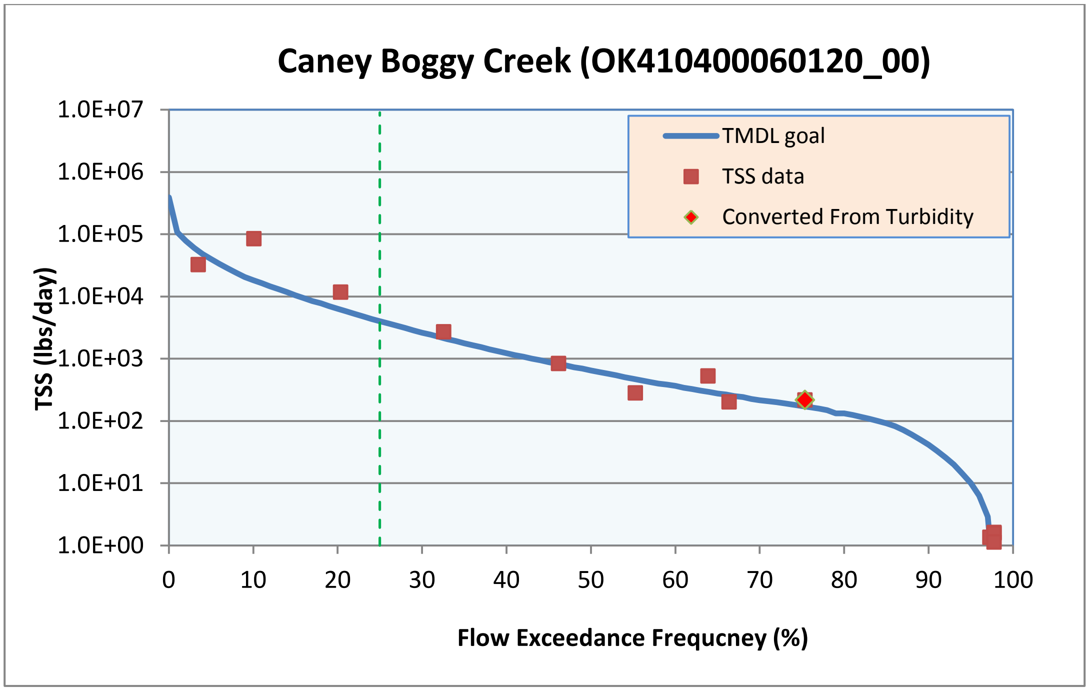


Figure 5-25 Load Duration Curve for Total Suspended Solids in Caney Boggy Creek (OK410400060120_00)



5.3.3 Establishing Percent Reduction Goals

The LDC approach recognizes that the assimilative capacity of a waterbody depends on the flow, and that maximum allowable loading varies with flow condition. Existing loading and load reductions required to meet the TMDL 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 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 is less than the geomean standards. Table 5-2 presents the percent reductions necessary to meet the TMDL water quality target for each bacterial indicator in each of the impaired waterbodies in the Study Area. The PRGs range from 55% to 67%.

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

Waterbody ID	Waterbody Name	Geomean		Reduction Rate	
		EC	ENT	EC	ENT
OK410400010070_00	Muddy Boggy Creek	61.4	73.1	-	54.9%
OK410400050270_10	Muddy Boggy Creek	63.8	98.6	-	66.5%
OK410400030010_00	Clear Boggy Creek	52.4	93.2	-	64.6%

Similarly, percent reduction goals 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 three waterbodies included in this TMDL report are summarized in Table 5-3 and range from 32% to 85%.

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

Waterbody ID	Waterbody Name	Required Reduction Rate
OK410400010070_00	Muddy Boggy Creek	31.5%
OK410400010130_00	Lick Creek	64.0%
OK410400010210_00	Whitegrass Creek	74.2%
OK410400030010_00	Clear Boggy Creek	40.1%
OK410400030370_00	Leader Creek	85.2%
OK410400030490_00	Goose Creek	38.0%
OK410400050270_10	Muddy Boggy Creek	57.8%
OK410400060120_00	Caney Boggy Creek	44.2%

5.4 Wasteload Allocation

5.4.1 Indicator Bacteria

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

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

Where:

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

flow (mgd) = permitted flow

unit conversion factor = 37,854,120-

When multiple NPDES facilities occur within a watershed, individual WLAs are summed and the total WLA for continuous point sources is included in the TMDL calculation for the corresponding waterbody. When there are no NPDES WWTPs discharging into the contributing watershed of a 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 NPDES permits. Currently, facilities that discharge treated wastewater are currently required to monitor for fecal coliform. These discharges or any other discharges with bacteria WLA will be 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 bacteria levels. In the future, all point source dischargers which are assigned a wasteload allocation but do not currently have a bacteria limit in their permit will receive a permit limit consistent with the wasteload allocation as their permits are reissued. Regardless of the magnitude of the WLA calculated in these TMDLs, future new discharges of bacteria or increased bacteria load from existing discharges will be considered consistent with the TMDL provided that the NPDES permit requires instream criteria to be met.

Table 5-4 Permit Information for NPDES-Permitted Facilities

Waterbody ID	Facility Name	NPDES Permit No.	Dis-infection	Design Flow (MGD)	WLA (cfu/day)	Expiration Date
OK410400050270_10	Coalgate Public Works Auth	OKG580028	No	0.22	2.75E+08	6/30/2016
	Atoka, City Of	OK0028576	Yes	0.8	1.00E+09	10/31/2014

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

5.4.2 Total Suspended Solids

NPDES-permitted facilities discharging inorganic TSS are allocated a daily wasteload calculated by using the average of self-reported monthly flow multiplied by the water quality target. In other words, the facilities are required to meet instream criteria in their discharge. If the current monthly TSS limits of a facility are greater than instream TSS criteria, the new limits equal to instream criteria will be applied to the facility as their permit is renewed. The instream TSS criteria for each stream segment can be found in Table 5-1. The WLA for each facility is derived as follows:

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

Where:

WQ_{goal} = Waterbody specific water quality goal 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

There is one NPDES permitted facility discharging inorganic TSS in the Study Area. Table 5-4a summarizes the WLA of inorganic TSS for that facility:

Table 5-4a WLAs for NPDES-Permitted Facilities Discharging Inorganic TSS

Waterbody ID	Instream TSS Criteria (mg/L)	NPDES Permit No.	Name	Average Monthly Flow (mgd)	Wasteload Allocation (lb/day)
OK410400030010_00	39.9	OKR050677	Dolese Brothers Coleman Quarry	0.06 [a]	12.5

[a] Average monthly flow according to available DMRs. DMR data is available under NPDES permit# OKG950030.

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

5.4.3 Section 404 permits

No TSS wasteload allocations were set aside for Section 404 permits. The state will use its Section 401 certification authority to ensure Section 404 permits protect Oklahoma water quality standards and comply with the turbidity TMDLs in this report. For any project requiring a Section 404 permit that is located on a waterbody with a turbidity TMDL established in this report, the Section 401 water quality certification will be conditioned to include one of the following two conditions:

- Include TSS limits consistent with this TMDL in the certification and establish a monitoring requirement to ensure compliance with the turbidity standards and TSS TMDLs.

or

- Submit to DEQ a BMP-based turbidity reduction plan which should include all practicable turbidity control techniques. The turbidity reduction plan must be approved by DEQ before a Section 401 water quality certification will be issued. The certification will include a condition requiring compliance with the approved plan.

Compliance with the Section 401 certification condition will be considered compliance with this TMDL.

5.5 Load Allocation

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

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

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:

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

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 bacteria TMDLs established in this report adhere to the seasonal application of the Oklahoma WQS which limits the PBCR use to the period of May 1st through September 30th. Similarly, the turbidity TMDLs established in this report adhere to the seasonal application of the Oklahoma WQS for turbidity, which applies to seasonal base flow conditions only. Seasonal variation was also accounted for in these TMDLs by using 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.

For bacteria 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 margin of safety. The selection of MOS is based on the NRMSE for each waterbody. Table 5-5 shows the MOS for each waterbody.

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

Waterbody ID	Waterbody Name	NRMSE	Margin of Safety
OK410400010070_00	Muddy Boggy Creek	8.9%	10%
OK410400010130_00	Lick Creek	7.0%	10%
OK410400010210_00	Whitegrass Creek	15.0%	15%
OK410400030010_00	Clear Boggy Creek	8.9%	10%
OK410400030370_00	Leader Creek	10.1%	10%
OK410400030490_00	Goose Creek	11.5%	15%
OK410400050270_10	Muddy Boggy Creek	8.9%	10%
OK410400060120_00	Caney Boggy Creek	10.6%	10%

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:

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

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 water quality standards. Regardless of the magnitude of the WLA calculated in these TMDLs, future new discharges or increased load from existing discharges will be considered consistent with the TMDL provided the NPDES permit requires instream criteria to be met.

The TMDL, WLA, LA, and MOS will vary with flow condition, and are calculated at every 5th flow interval percentile. Table 6 & 7 summarize the TMDL, WLA, LA and MOS loadings at the 50% flow percentile. Tables 5-8 through 5-10 summarize the allocations for indicator bacteria. The bacteria TMDLs calculated in these tables apply to the recreation season (May 1 through September 30) only. Tables 5-11 to 5-18 present the allocations for total suspended solids.

Table 5-6 Summaries of Bacteria TMDLs

Waterbody ID	Stream Name	Pollutant	TMDL (cfu/day)	$WLA_{\_WWTP}$ (cfu/day)	$WLA_{\_MS4}$ (cuf/day)	LA (cfu/day)	MOS (cfu/day)
OK410400010070_00	Muddy Boggy Creek	ENT	1.41E+11	1.27E+09	0	1.26E+11	1.41E+10
OK410400050270_10	Muddy Boggy Creek	ENT	1.46E+11	0.00E+00	0	1.31E+11	1.46E+10
OK410400030010_00	Clear Boggy Creek	ENT	2.06E+11	0.00E+00	0	1.85E+11	2.06E+10

Table 5-7 Summaries of TSS TMDLs

Waterbody ID	Stream Name	Pollutant	TMDL (lbs/day)	WLA (lbs/day)	$WLA_{\_Growth}$ (lbs/day)	LA (lbs/day)	MOS (lbs/day)
OK410400010070_00	Muddy Boggy Creek	TSS	37610.9	0.0	376.1	33473.7	3761.1
OK410400010130_00	Lick Creek	TSS	624.0	0.0	6.2	555.3	62.4
OK410400010210_00	Whitegrass Creek	TSS	688.2	0.0	6.9	578.1	103.2
OK410400030010_00	Clear Boggy Creek	TSS	16773.2	12.5	167.7	14915.7	1677.3
OK410400030370_00	Leader Creek	TSS	1069.8	0.0	10.7	952.1	107.0
OK410400030490_00	Goose Creek	TSS	583.0	0.0	5.8	489.7	87.4
OK410400050270_10	Muddy Boggy Creek	TSS	11847.7	0.0	118.5	10544.5	1184.8
OK410400060120_00	Caney Boggy Creek	TSS	722.6	0.0	7.2	643.1	72.3

Table 5-8 *Enterococci* TMDL Calculations for Muddy Boggy Creek (OK410400010070_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	105164.73	8.49E+13	1.27E+09	0	7.64E+13	8.49E+12
5	10763.13	8.69E+12	1.27E+09	0	7.82E+12	8.69E+11
10	4912.92	3.97E+12	1.27E+09	0	3.57E+12	3.97E+11
15	2825.32	2.28E+12	1.27E+09	0	2.05E+12	2.28E+11
20	1704.16	1.38E+12	1.27E+09	0	1.24E+12	1.38E+11
25	1083.04	8.74E+11	1.27E+09	0	7.86E+11	8.74E+10
30	707.00	5.71E+11	1.27E+09	0	5.12E+11	5.71E+10
35	475.37	3.84E+11	1.27E+09	0	3.44E+11	3.84E+10
40	331.86	2.68E+11	1.27E+09	0	2.40E+11	2.68E+10
45	237.69	1.92E+11	1.27E+09	0	1.71E+11	1.92E+10
50	174.90	1.41E+11	1.27E+09	0	1.26E+11	1.41E+10
55	127.81	1.03E+11	1.27E+09	0	9.16E+10	1.03E+10
60	98.66	7.97E+10	1.27E+09	0	7.04E+10	7.97E+09
65	74.00	5.97E+10	1.27E+09	0	5.25E+10	5.97E+09
70	58.30	4.71E+10	1.27E+09	0	4.11E+10	4.71E+09
75	47.09	3.80E+10	1.27E+09	0	3.29E+10	3.80E+09
80	35.88	2.90E+10	1.27E+09	0	2.48E+10	2.90E+09
85	24.67	1.99E+10	1.27E+09	0	1.66E+10	1.99E+09
90	11.21	9.05E+09	1.27E+09	0	6.87E+09	9.05E+08
95	2.69	2.17E+09	1.27E+09	0	6.80E+08	2.17E+08
100	0.00	1.27E+09	1.27E+09	0	0	0

Table 5-9 Enterococci TMDL Calculations for Clear Boggy Creek (OK410400030010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	46900.00	3.79E+13	0	0	3.41E+13	3.79E+12
5	4800.00	3.88E+12	0	0	3.49E+12	3.88E+11
10	2191.00	1.77E+12	0	0	1.59E+12	1.77E+11
15	1260.00	1.02E+12	0	0	9.16E+11	1.02E+11
20	760.00	6.14E+11	0	0	5.52E+11	6.14E+10
25	483.00	3.90E+11	0	0	3.51E+11	3.90E+10
30	315.30	2.55E+11	0	0	2.29E+11	2.55E+10
35	212.00	1.71E+11	0	0	1.54E+11	1.71E+10
40	148.00	1.19E+11	0	0	1.08E+11	1.19E+10
45	106.00	8.56E+10	0	0	7.70E+10	8.56E+09
50	78.00	6.30E+10	0	0	5.67E+10	6.30E+09
55	57.00	4.60E+10	0	0	4.14E+10	4.60E+09
60	44.00	3.55E+10	0	0	3.20E+10	3.55E+09
65	33.00	2.66E+10	0	0	2.40E+10	2.66E+09
70	26.00	2.10E+10	0	0	1.89E+10	2.10E+09
75	21.00	1.70E+10	0	0	1.53E+10	1.70E+09
80	16.00	1.29E+10	0	0	1.16E+10	1.29E+09
85	11.00	8.88E+09	0	0	7.99E+09	8.88E+08
90	5.00	4.04E+09	0	0	3.63E+09	4.04E+08
95	1.20	9.69E+08	0	0	8.72E+08	9.69E+07
100	0.00	8.07E+05	0	0	7.27E+05	8.07E+04

Table 5-10 Enterococci TMDL Calculations for Muddy Boggy Creek (OK410400050270_10)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	WLA_{MS4} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	33127.71	2.67E+13	0	0	2.41E+13	2.67E+12
5	3390.47	2.74E+12	0	0	2.46E+12	2.74E+11
10	1547.61	1.25E+12	0	0	1.12E+12	1.25E+11
15	890.00	7.19E+11	0	0	6.47E+11	7.19E+10
20	536.82	4.33E+11	0	0	3.90E+11	4.33E+10
25	341.17	2.75E+11	0	0	2.48E+11	2.75E+10
30	222.71	1.80E+11	0	0	1.62E+11	1.80E+10
35	149.75	1.21E+11	0	0	1.09E+11	1.21E+10
40	104.54	8.44E+10	0	0	7.60E+10	8.44E+09
45	74.87	6.04E+10	0	0	5.44E+10	6.04E+09
50	55.10	4.45E+10	0	0	4.00E+10	4.45E+09
55	40.26	3.25E+10	0	0	2.93E+10	3.25E+09
60	31.08	2.51E+10	0	0	2.26E+10	2.51E+09
65	23.31	1.88E+10	0	0	1.69E+10	1.88E+09
70	18.37	1.48E+10	0	0	1.33E+10	1.48E+09
75	14.83	1.20E+10	0	0	1.08E+10	1.20E+09
80	11.30	9.12E+09	0	0	8.21E+09	9.12E+08
85	7.77	6.27E+09	0	0	5.65E+09	6.27E+08
90	3.53	2.85E+09	0	0	2.57E+09	2.85E+08
95	0.85	6.84E+08	0	0	6.16E+08	6.84E+07
100	0.00	8.07E+05	0	0	7.27E+05	8.07E+04

Table 5-11 Total Suspended Solids TMDL Calculations for Muddy Boggy Creek (OK410400010070_00)

Flow Exceedance Frequency	Flow (cfs)	TMDL (lbs/day)	WWTP (lbs/day)	MS4 (lbs/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	105164.7	N/A	0	0	N/A	N/A	N/A
5	10763.1	N/A	0	0	N/A	N/A	N/A
10	4912.9	N/A	0	0	N/A	N/A	N/A
15	2825.3	N/A	0	0	N/A	N/A	N/A
20	1704.2	N/A	0	0	N/A	N/A	N/A
25	1083.0	232898.2	0	0	2329.0	207279.4	23289.8
30	707.0	152034.8	0	0	1520.3	135311.0	15203.5
35	475.4	102224.5	0	0	1022.2	90979.8	10222.4
40	331.9	71364.3	0	0	713.6	63514.2	7136.4
45	237.7	51112.2	0	0	511.1	45489.9	5111.2
50	174.9	37610.9	0	0	376.1	33473.7	3761.1
55	127.8	27484.9	0	0	274.8	24461.5	2748.5
60	98.7	21216.4	0	0	212.2	18882.6	2121.6
65	74.0	15912.3	0	0	159.1	14161.9	1591.2
70	58.3	12537.0	0	0	125.4	11157.9	1253.7
75	47.1	10126.0	0	0	101.3	9012.1	1012.6
80	35.9	7715.1	0	0	77.2	6866.4	771.5
85	24.7	5304.1	0	0	53.0	4720.6	530.4
90	11.2	2411.0	0	0	24.1	2145.7	241.1
95	2.7	578.6	0	0	5.8	515.0	57.9
100	0.0	0.2	0	0	0.0	0.2	0.0

Table 5-12 Total Suspended Solids TMDL Calculations for Lick Creek (OK410400010130_00)

Flow Exceedance Frequency	Flow (cfs)	TMDL (lbs/day)	WWTP (lbs/day)	MS4 (lbs/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	2593.1	N/A	0	0	N/A	N/A	N/A
5	265.4	N/A	0	0	N/A	N/A	N/A
10	121.1	N/A	0	0	N/A	N/A	N/A
15	69.7	N/A	0	0	N/A	N/A	N/A
20	42.0	N/A	0	0	N/A	N/A	N/A
25	26.7	3863.9	0	0	38.6	3438.9	386.4
30	17.4	2522.4	0	0	25.2	2244.9	252.2
35	11.7	1696.0	0	0	17.0	1509.4	169.6
40	8.2	1184.0	0	0	11.8	1053.7	118.4
45	5.9	848.0	0	0	8.5	754.7	84.8
50	4.3	624.0	0	0	6.2	555.3	62.4
55	3.2	456.0	0	0	4.6	405.8	45.6
60	2.4	352.0	0	0	3.5	313.3	35.2
65	1.8	264.0	0	0	2.6	235.0	26.4
70	1.4	208.0	0	0	2.1	185.1	20.8
75	1.2	168.0	0	0	1.7	149.5	16.8
80	0.9	128.0	0	0	1.3	113.9	12.8
85	0.6	88.0	0	0	0.9	78.3	8.8
90	0.3	40.0	0	0	0.4	35.6	4.0
95	0.1	9.6	0	0	0.1	8.5	1.0
100	0.0	0.1	0	0	0.0	0.1	0.0

Table 5-13 Total Suspended Solids TMDL Calculations for Whitegrass Creek (OK410400010210_00)

Flow Exceedance Frequency	Flow (cfs)	TMDL (lbs/day)	WWTP (lbs/day)	MS4 (lbs/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	3339.5	N/A	0	0	N/A	N/A	N/A
5	341.8	N/A	0	0	N/A	N/A	N/A
10	156.0	N/A	0	0	N/A	N/A	N/A
15	89.7	N/A	0	0	N/A	N/A	N/A
20	54.1	N/A	0	0	N/A	N/A	N/A
25	34.4	4261.7	0	0	42.6	3579.9	639.3
30	22.5	2782.0	0	0	27.8	2336.9	417.3
35	15.1	1870.6	0	0	18.7	1571.3	280.6
40	10.5	1305.9	0	0	13.1	1096.9	195.9
45	7.5	935.3	0	0	9.4	785.6	140.3
50	5.6	688.2	0	0	6.9	578.1	103.2
55	4.1	502.9	0	0	5.0	422.5	75.4
60	3.1	388.2	0	0	3.9	326.1	58.2
65	2.3	291.2	0	0	2.9	244.6	43.7
70	1.9	229.4	0	0	2.3	192.7	34.4
75	1.5	185.3	0	0	1.9	155.6	27.8
80	1.1	141.2	0	0	1.4	118.6	21.2
85	0.8	97.1	0	0	1.0	81.5	14.6
90	0.4	44.1	0	0	0.4	37.1	6.6
95	0.1	10.6	0	0	0.1	8.9	1.6
100	0.0	0.1	0	0	0.0	0.1	0.0

Table 5-14 Total Suspended Solids TMDL Calculations for Clear Boggy Creek (OK410400030010_00)

Flow Exceedance Frequency	Flow (cfs)	TMDL (lbs/day)	WWTP (lbs/day)	MS4 (lbs/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	46900	N/A	12.5	0	N/A	N/A	N/A
5	4800	N/A	12.5	0	N/A	N/A	N/A
10	2191	N/A	12.5	0	N/A	N/A	N/A
15	1260	N/A	12.5	0	N/A	N/A	N/A
20	760	N/A	12.5	0	N/A	N/A	N/A
25	483	103864.9	12.5	0	1038.6	92427.3	10386.5
30	315.3	67802.5	12.5	0	678.0	60331.7	6780.3
35	212	45588.7	12.5	0	455.9	40561.5	4558.9
40	148	31826.1	12.5	0	318.3	28312.7	3182.6
45	106	22794.4	12.5	0	227.9	20274.5	2279.4
50	78	16773.2	12.5	0	167.7	14915.7	1677.3
55	57	12257.4	12.5	0	122.6	10896.5	1225.7
60	44	9461.8	12.5	0	94.6	8408.5	946.2
65	33	7096.4	12.5	0	71.0	6303.3	709.6
70	26	5591.1	12.5	0	55.9	4963.5	559.1
75	21	4515.9	12.5	0	45.2	4006.6	451.6
80	16	3440.7	12.5	0	34.4	3049.7	344.1
85	11	2365.5	12.5	0	23.7	2092.7	236.5
90	5	1075.2	12.5	0	10.8	944.4	107.5
95	1.2	258.0	12.5	0	2.6	217.2	25.8
100	0.0	12.5	12.5	0	0.0	0.0	0.0

Table 5-15 Total Suspended Solids TMDL Calculations for Leader Creek (OK410400030370_00)

Flow Exceedance Frequency	Flow (cfs)	TMDL (lbs/day)	WWTP (lbs/day)	MS4 (lbs/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	6331.5	N/A	0	0	N/A	N/A	N/A
5	648.0	N/A	0	0	N/A	N/A	N/A
10	295.8	N/A	0	0	N/A	N/A	N/A
15	170.1	N/A	0	0	N/A	N/A	N/A
20	102.6	N/A	0	0	N/A	N/A	N/A
25	65.2	6624.4	0	0	66.2	5895.7	662.4
30	42.6	4324.4	0	0	43.2	3848.7	432.4
35	28.6	2907.6	0	0	29.1	2587.8	290.8
40	20.0	2029.8	0	0	20.3	1806.6	203.0
45	14.3	1453.8	0	0	14.5	1293.9	145.4
50	10.5	1069.8	0	0	10.7	952.1	107.0
55	7.7	781.8	0	0	7.8	695.8	78.2
60	5.9	603.5	0	0	6.0	537.1	60.3
65	4.5	452.6	0	0	4.5	402.8	45.3
70	3.5	356.6	0	0	3.6	317.4	35.7
75	2.8	288.0	0	0	2.9	256.3	28.8
80	2.2	219.4	0	0	2.2	195.3	21.9
85	1.5	150.9	0	0	1.5	134.3	15.1
90	0.7	68.6	0	0	0.7	61.0	6.9
95	0.2	16.5	0	0	0.2	14.6	1.6
100	0.0	0.1	0	0	0.0	0.1	0.0

Table 5-16 Total Suspended Solids TMDL Calculations for Goose Creek (OK410400030490_00)

Flow Exceedance Frequency	Flow (cfs)	TMDL (lbs/day)	WWTP (lbs/day)	MS4 (lbs/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	2247.3	N/A	0	0	N/A	N/A	N/A
5	230.0	N/A	0	0	N/A	N/A	N/A
10	105.0	N/A	0	0	N/A	N/A	N/A
15	60.4	N/A	0	0	N/A	N/A	N/A
20	36.4	N/A	0	0	N/A	N/A	N/A
25	23.1	3610.0	0	0	36.1	3032.4	541.5
30	15.1	2356.6	0	0	23.6	1979.6	353.5
35	10.2	1584.5	0	0	15.8	1331.0	237.7
40	7.1	1106.2	0	0	11.1	929.2	165.9
45	5.1	792.3	0	0	7.9	665.5	118.8
50	3.7	583.0	0	0	5.8	489.7	87.4
55	2.7	426.0	0	0	4.3	357.9	63.9
60	2.1	328.9	0	0	3.3	276.2	49.3
65	1.6	246.6	0	0	2.5	207.2	37.0
70	1.2	194.3	0	0	1.9	163.2	29.1
75	1.0	157.0	0	0	1.6	131.8	23.5
80	0.8	119.6	0	0	1.2	100.5	17.9
85	0.5	82.2	0	0	0.8	69.1	12.3
90	0.2	37.4	0	0	0.4	31.4	5.6
95	0.1	9.0	0	0	0.1	7.5	1.3
100	0.0	0.2	0	0	0.0	0.1	0.0

Table 5-17 Total Suspended Solids TMDL Calculations for Muddy Boggy Creek (OK410400050270_10)

Flow Exceedance Frequency	Flow (cfs)	TMDL (lbs/day)	WWTP (lbs/day)	MS4 (lbs/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	33127.7	N/A	0	0	N/A	N/A	N/A
5	3390.5	N/A	0	0	N/A	N/A	N/A
10	1547.6	N/A	0	0	N/A	N/A	N/A
15	890.0	N/A	0	0	N/A	N/A	N/A
20	536.8	N/A	0	0	N/A	N/A	N/A
25	341.2	73364.8	0	0	733.6	65294.6	7336.5
30	222.7	47892.2	0	0	478.9	42624.0	4789.2
35	149.7	32201.5	0	0	322.0	28659.3	3220.2
40	104.5	22480.3	0	0	224.8	20007.5	2248.0
45	74.9	16100.8	0	0	161.0	14329.7	1610.1
50	55.1	11847.7	0	0	118.5	10544.5	1184.8
55	40.3	8658.0	0	0	86.6	7705.6	865.8
60	31.1	6683.3	0	0	66.8	5948.2	668.3
65	23.3	5012.5	0	0	50.1	4461.1	501.2
70	18.4	3949.2	0	0	39.5	3514.8	394.9
75	14.8	3189.8	0	0	31.9	2838.9	319.0
80	11.3	2430.3	0	0	24.3	2163.0	243.0
85	7.8	1670.8	0	0	16.7	1487.0	167.1
90	3.5	759.5	0	0	7.6	675.9	75.9
95	0.8	182.3	0	0	1.8	162.2	18.2
100	0.0	0.2	0	0	0.0	0.2	0.0

Table 5-18 Total Suspended Solids TMDL Calculations for Caney Boggy Creek (OK410400060120_00)

Flow Exceedance Frequency	Flow (cfs)	TMDL (lbs/day)	WWTP (lbs/day)	MS4 (lbs/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	4331.9	N/A	0	0	N/A	N/A	N/A
5	443.3	N/A	0	0	N/A	N/A	N/A
10	202.4	N/A	0	0	N/A	N/A	N/A
15	116.4	N/A	0	0	N/A	N/A	N/A
20	70.2	N/A	0	0	N/A	N/A	N/A
25	44.6	4474.7	0	0	44.7	3982.4	447.5
30	29.1	2921.0	0	0	29.2	2599.7	292.1
35	19.6	1964.0	0	0	19.6	1748.0	196.4
40	13.7	1371.1	0	0	13.7	1220.3	137.1
45	9.8	982.0	0	0	9.8	874.0	98.2
50	7.2	722.6	0	0	7.2	643.1	72.3
55	5.3	528.1	0	0	5.3	470.0	52.8
60	4.1	407.6	0	0	4.1	362.8	40.8
65	3.0	305.7	0	0	3.1	272.1	30.6
70	2.4	240.9	0	0	2.4	214.4	24.1
75	1.9	194.6	0	0	1.9	173.1	19.5
80	1.5	148.2	0	0	1.5	131.9	14.8
85	1.0	101.9	0	0	1.0	90.7	10.2
90	0.5	46.3	0	0	0.5	41.2	4.6
95	0.1	11.1	0	0	0.1	9.9	1.1
100	0.0	0.1	0	0	0.0	0.1	0.0

5.9 TMDL Implementation

DEQ will collaborate with a host of other state agencies and local governments working within the boundaries of state and local regulations to target available funding and technical assistance to support implementation of pollution controls and management measures. Various water quality management programs and funding sources will be utilized so that the pollutant reductions as required by these TMDLs can be achieved and water quality can be restored to maintain 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 2006). The CPP can be viewed from DEQ's website at http://www.deq.state.ok.us/wqdnew/pubs/2006_CPP_final.pdf.

Table 5-19 provides a partial list of the state partner agencies DEQ will collaborate with to address point and nonpoint source reduction goals established by TMDLs.

Table 5-19 Partial List of Oklahoma Water Quality Management Agencies

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

5.9.1 Point Sources

As authorized by Section 402 of the CWA, the DEQ has delegation of the NPDES Program in Oklahoma, except for certain jurisdictional areas related to agriculture (retained by State Department of Agriculture, Food, and Forestry), and the oil & gas industry (retained by the Oklahoma Corporation Commission) for which the EPA has retained permitting authority. The NPDES Program in Oklahoma, in accordance with an agreement between DEQ and EPA relating to administration and enforcement of the delegated NPDES Program, is implemented via the Oklahoma Pollution Discharge Elimination System (OPDES) Act [Title 252, Chapter 606 (http://www.deq.state.ok.us/rules/611.pdf)]. Point source WLAs are outlined in the Oklahoma Water Quality Management Plan (aka the 208 Plan) under the OPDES program.

5.9.2 Non-Point 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 U.S. Department of Agriculture, to address water quality problems similar to those seen in the Study Area. The primary mechanisms used for management of nonpoint source pollution are incentive-based programs that support the installation of BMPs and public education and outreach. Other programs include regulations and permits for CAFOs. The CAFO Act, as administered by the ODAFF, provides CAFO operators the necessary tools and information to deal with the manure and wastewater animals produce so streams, lakes, ponds, and groundwater sources are not polluted.

The reduction rates called for in this TMDL report are as high as 85.2%. The DEQ recognizes that achieving such high reductions will be a challenge, especially since unregulated nonpoint sources are a major cause of both bacteria and TSS loading. The high reduction rates are not uncommon for pathogen- or TSS-impaired waters. Similar reduction rates are often found in other pathogen and TSS TMDLs around the nation. The suitability of the current criteria for pathogens and the beneficial uses of a waterbody should be reviewed. For example, the Kansas Department of Environmental Quality has proposed to exclude certain high flow conditions during which pathogen standards will not apply, although that exclusion was not approved by the EPA. Additionally, EPA has been conducting new epidemiology studies and may develop new recommendations for pathogen criteria in the near future.

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

- Removing the PBCR use: This revision would require documentation in a Use Attainability Analysis that the use is not an existing use and cannot be attained. It is unlikely that this approach would be successful since there is evidence that people do swim in this segment of the river, thus constituting an existing use. Existing uses cannot be removed.
- Modifying application of the existing criteria: This approach would include considerations such as an exemption under certain high flow conditions, an allowance for wildlife or "natural conditions," a sub-category of the use or other special provision for urban areas, or other special provisions for storm flows. Since large bacteria violations occur over all flow ranges, it is likely that large reductions would still be necessary. However, this approach may have merit and should be considered.
- Revising the existing numeric criteria: Oklahoma's current pathogen criteria, 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 non-point 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 discharging discharge limitations less than or equal to the water quality standards numerical criteria. This ensures that the impairments to 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

This report was preliminarily reviewed by EPA prior to the public notice. The public notice was then sent to local newspapers, to stakeholders in the area affected by the TMDLs in this Study Area, and to stakeholders who have requested all copies of TMDL public notices. The public notice was also posted at the DEQ website: http://www.deq.state.ok.us/wqdnew/index.htm.

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

After EPA's final approval, each TMDL will be adopted into the 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 instream criterion is predicted to be met.

SECTION 7
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APPENDIX A

AMBIENT WATER QUALITY DATA

BACTERIA DATA — –2001-2008

TURBIDITY AND TOTAL SUSPENDED SOLIDS DATA — 1998 TO 2011

Ambient Water Quality Bacteria Data, 2001-2008

Waterbody ID	Streams	WQM Station	Date[1]	EC[2]	ENT[2]
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	06/12/01	63	30
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	07/17/01	10	90
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	05/13/02	160	8000
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	06/10/02	10	1600
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	09/09/02	529	4000
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	05/10/04	63	100
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	05/25/04	10	10
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	05/25/04	31	10
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	06/08/04	73	700
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	06/29/04	350	300
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	07/20/04	86	50
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	08/03/04	75	210
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	08/24/04	41	10
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	09/07/04	63	31
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	09/22/04	10	20
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	06/07/06	51	20
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	07/12/06	10	10
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	07/26/06	10	10
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	08/02/06	20	10
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	08/14/06	10	20
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	09/20/06	52	97
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	10/04/06	199	31
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	05/20/08	195	52
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	06/10/08	2755	826
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	07/01/08	148	41
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	07/22/08	20	10
OK410400010070_00	Muddy Boggy Creek	410400010070-001AT	08/12/08	2613	535
OK410400010130_00	Lick Creek	OK410400-01-0130G	06/21/05	30	40
OK410400010130_00	Lick Creek	OK410400-01-0130G	07/26/05	30	190
OK410400010130_00	Lick Creek	OK410400-01-0130G	09/07/05	5	5
OK410400010130_00	Lick Creek	OK410400-01-0130G	04/04/06	45	95
OK410400010130_00	Lick Creek	OK410400-01-0130G	05/09/06	260	140
OK410400010130_00	Lick Creek	OK410400-01-0130G	06/19/06	340	200
OK410400010130_00	Lick Creek	OK410400-01-0130G	05/07/07	1060	1560
OK410400010210_00	Whitegrass Creek: Lower	OK410400-01-0210G	06/21/05	90	80
OK410400010210_00	Whitegrass Creek: Lower	OK410400-01-0210G	07/26/05	30	<10
OK410400010210_00	Whitegrass Creek: Lower	OK410400-01-0210G	09/07/05	5	15
OK410400010210_00	Whitegrass Creek: Lower	OK410400-01-0210G	04/04/06	150	170

Waterbody ID	Streams	WQM Station	Date[1]	EC[2]	ENT[2]
OK410400010210_00	Whitegrass Creek: Lower	OK410400-01-0210G	05/09/06	210	380
OK410400010210_00	Whitegrass Creek: Lower	OK410400-01-0210G	06/20/06	200	80
OK410400010210_00	Whitegrass Creek: Lower	OK410400-01-0210G	07/24/06	40	140
OK410400010210_00	Whitegrass Creek: Lower	OK410400-01-0210G	08/28/06	>2000	>2000
OK410400010210_00	Whitegrass Creek: Lower	OK410400-01-0210G	05/07/07	400	760
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	06/12/01	74	130
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	07/17/01	95	150
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	08/14/01	20	10
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	05/15/02	619	5000
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	07/17/02	121	400
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	09/11/02	169	400
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	05/06/03	63	270
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	06/10/03	197	500
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	06/25/03	10	20
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	07/15/03	121	130
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	07/30/03	10	30
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	08/19/03	350	200
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	09/03/03	573	3600
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	09/23/03	382	530
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	06/07/06	52	20
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	06/27/06	31	10
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	07/12/06	10	10
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	07/26/06	10	52
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	08/02/06	10	10
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	08/14/06	10	63
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	09/20/06	20	52
OK410400030010_00	Clear Boggy Creek	410400030010-001AT	10/04/06	10	10
OK410400030020_00	Caney Creek: HWY 69	OK410400-03-0020C	06/20/05	10	180
OK410400030020_00	Caney Creek: HWY 69	OK410400-03-0020C	07/25/05	90	260
OK410400030020_00	Caney Creek: HWY 69	OK410400-03-0020C	08/29/05	100	90
OK410400030020_00	Caney Creek: HWY 69	OK410400-03-0020C	10/03/05	20	75
OK410400030020_00	Caney Creek: HWY 69	OK410400-03-0020C	04/03/06	65	65
OK410400030020_00	Caney Creek: HWY 69	OK410400-03-0020C	05/08/06	>2000	>2000
OK410400030020_00	Caney Creek: HWY 69	OK410400-03-0020C	06/12/06	10	470
OK410400030020_00	Caney Creek: HWY 69	OK410400-03-0020C	07/17/06	5	45
OK410400030020_00	Caney Creek: HWY 69	OK410400-03-0020C	09/25/06	980	4000
OK410400030020_00	Caney Creek: HWY 69	OK410400-03-0020C	04/16/07	170	70
OK410400030240_00	Delaware Creek	OK410400-03-0240M	06/21/05	150	200
OK410400030240_00	Delaware Creek	OK410400-03-0240M	07/25/05	330	100

Waterbody ID	Streams	WQM Station	Date[1]	EC[2]	ENT[2]
OK410400030240_00	Delaware Creek	OK410400-03-0240M	08/29/05	90	100
OK410400030240_00	Delaware Creek	OK410400-03-0240M	10/03/05	60	25
OK410400030240_00	Delaware Creek	OK410400-03-0240M	04/04/06	40	60
OK410400030240_00	Delaware Creek	OK410400-03-0240M	05/08/06	1680	840
OK410400030240_00	Delaware Creek	OK410400-03-0240M	06/12/06	620	240
OK410400030240_00	Delaware Creek	OK410400-03-0240M	07/17/06	10	15
OK410400030240_00	Delaware Creek	OK410400-03-0240M	08/21/06	110	40
OK410400030240_00	Delaware Creek	OK410400-03-0240M	09/25/06	80	110
OK410400030240_00	Delaware Creek	OK410400-03-0240M	04/16/07	85	110
OK410400030370_00	Leader Creek	OK410400-03-0370B	06/21/05	230	220
OK410400030370_00	Leader Creek	OK410400-03-0370B	07/25/05	60	10
OK410400030370_00	Leader Creek	OK410400-03-0370B	08/29/05	170	100
OK410400030370_00	Leader Creek	OK410400-03-0370B	10/03/05	>1000	135
OK410400030370_00	Leader Creek	OK410400-03-0370B	04/04/06	240	320
OK410400030370_00	Leader Creek	OK410400-03-0370B	05/08/06	360	500
OK410400030370_00	Leader Creek	OK410400-03-0370B	06/12/06	220	240
OK410400030370_00	Leader Creek	OK410400-03-0370B	07/17/06	460	190
OK410400030370_00	Leader Creek	OK410400-03-0370B	08/22/06	510	500
OK410400030370_00	Leader Creek	OK410400-03-0370B	04/16/07	260	430
OK410400030490_00	Goose Creek	OK410400-03-0490G	06/21/05	100	210
OK410400030490_00	Goose Creek	OK410400-03-0490G	07/25/05	440	30
OK410400030490_00	Goose Creek	OK410400-03-0490G	08/29/05	410	370
OK410400030490_00	Goose Creek	OK410400-03-0490G	10/03/05	190	145
OK410400030490_00	Goose Creek	OK410400-03-0490G	04/04/06	175	180
OK410400030490_00	Goose Creek	OK410400-03-0490G	05/08/06	770	220
OK410400030490_00	Goose Creek	OK410400-03-0490G	06/13/06	160	105
OK410400030490_00	Goose Creek	OK410400-03-0490G	07/17/06	20	75
OK410400030490_00	Goose Creek	OK410400-03-0490G	04/16/07	135	110
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	05/06/03	31	140
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	06/10/03	41	90
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	06/25/03	156	80
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	07/15/03	<10	900
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	07/30/03	41	100
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	08/19/03	10	100
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	09/03/03	<10	1600
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	09/23/03	1081	1270
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	06/07/06	10	31
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	06/27/06	52	52
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	07/12/06	52	52

Waterbody ID	Streams	WQM Station	Date[1]	EC[2]	ENT[2]
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	07/26/06	20	10
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	08/02/06	20	10
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	08/14/06	10	10
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	09/20/06	31	41
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	10/04/06	10	10
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	05/20/08	145	30
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	06/10/08	19863	19863
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	07/01/08	132	52
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	07/22/08	292	74
OK410400050270_10	Muddy Boggy Creek	410400050270-001AT	08/12/08	379	52
OK410400050410_00	North Boggy Creek	OK410400-08-0010M	06/20/05	40	30
OK410400050410_00	North Boggy Creek	OK410400-08-0010M	07/25/05	30	<10
OK410400050410_00	North Boggy Creek	OK410400-08-0010M	08/29/05	110	10
OK410400050410_00	North Boggy Creek	OK410400-08-0010M	10/03/05	100	40
OK410400050410_00	North Boggy Creek	OK410400-08-0010M	04/03/06	5	5
OK410400050410_00	North Boggy Creek	OK410400-08-0010M	05/08/06	1460	900
OK410400050410_00	North Boggy Creek	OK410400-08-0010M	06/12/06	10	20
OK410400050410_00	North Boggy Creek	OK410400-08-0010M	07/17/06	80	90
OK410400050410_00	North Boggy Creek	OK410400-08-0010M	08/21/06	170	270
OK410400050410_00	North Boggy Creek	OK410400-08-0010M	09/25/06	60	80
OK410400050410_00	North Boggy Creek	OK410400-08-0010M	04/16/07	75	105
OK410400060120_00	Caney Boggy Creek: Lower	OK410400-06-0120G	06/20/05	170	110
OK410400060120_00	Caney Boggy Creek: Lower	OK410400-06-0120G	07/25/05	30	40
OK410400060120_00	Caney Boggy Creek: Lower	OK410400-06-0120G	08/29/05	<10	110
OK410400060120_00	Caney Boggy Creek: Lower	OK410400-06-0120G	10/03/05	70	115
OK410400060120_00	Caney Boggy Creek: Lower	OK410400-06-0120G	04/03/06	95	115
OK410400060120_00	Caney Boggy Creek: Lower	OK410400-06-0120G	05/08/06	600	740
OK410400060120_00	Caney Boggy Creek: Lower	OK410400-06-0120G	06/12/06	40	230
OK410400060120_00	Caney Boggy Creek: Lower	OK410400-06-0120G	07/17/06	170	60
OK410400060120_00	Caney Boggy Creek: Lower	OK410400-06-0120G	08/21/06	20	<10
OK410400060120_00	Caney Boggy Creek: Lower	OK410400-06-0120G	09/25/06	50	20
OK410400060120_00	Caney Boggy Creek: Lower	OK410400-06-0120G	04/16/07	180	450
OK410600020020_00	Sandy Creek	OK410600-02-0020G	06/20/05	75	215
OK410600020020_00	Sandy Creek	OK410600-02-0020G	07/25/05	60	30
OK410600020020_00	Sandy Creek	OK410600-02-0020G	08/30/05	20	90
OK410600020020_00	Sandy Creek	OK410600-02-0020G	10/04/05	55	155
OK410600020020_00	Sandy Creek	OK410600-02-0020G	04/04/06	5	45
OK410600020020_00	Sandy Creek	OK410600-02-0020G	05/09/06	630	260
OK410600020020_00	Sandy Creek	OK410600-02-0020G	06/13/06	35	10

Waterbody ID	Streams	WQM Station	Date[1]	EC[2]	ENT[2]
OK410600020020_00	Sandy Creek	OK410600-02-0020G	07/18/06	35	105
OK410600020020_00	Sandy Creek	OK410600-02-0020G	09/26/06	90	185
OK410600020020_00	Sandy Creek	OK410600-02-0020G	04/17/07	385	225

EC = *E. coli* (STORET Code: 31609); ENT = Enterococci (STORET Code: 31649)

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

[2] Units = counts/100 mL

Ambient Water Quality Turbidity and TSS Data, 1997 - 2010

Station ID	Stream Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow (cfs)	Flow Condition*	Data Sources
410400010070-001AT	Muddy Boggy Creek	09/29/08	34		40.0	1	OWRB
410400010070-001AT	Muddy Boggy Creek	12/08/08	11		28.0	1	OWRB
410400010070-001AT	Muddy Boggy Creek	03/09/09	16.5		47.0	1	OWRB
410400010070-001AT	Muddy Boggy Creek	02/06/06	23		90.0	2	OWRB
410400010070-001AT	Muddy Boggy Creek	07/31/06	49		7.1	2	OWRB
410400010070-001AT	Muddy Boggy Creek	09/05/06	57		14.0	2	OWRB
410400010070-001AT	Muddy Boggy Creek	10/09/06	39		17.0	2	OWRB
410400010070-001AT	Muddy Boggy Creek	12/18/06	35		213.0	2	OWRB
410400010070-001AT	Muddy Boggy Creek	02/12/07	28		413.0	2	OWRB
410400010070-001AT	Muddy Boggy Creek	07/30/07	76		2530.0	2	OWRB
410400010070-001AT	Muddy Boggy Creek	11/13/07	31		84.0	2	OWRB
410400010070-001AT	Muddy Boggy Creek	02/04/08	26		130.0	2	OWRB
410400010070-001AT	Muddy Boggy Creek	05/12/08	57		753.0	2	OWRB
410400010070-001AT	Muddy Boggy Creek	08/19/08	67		220.0	2	OWRB
410400010070-001AT	Muddy Boggy Creek	02/09/09	27		79.0	2	OWRB
410400010070-001AT	Muddy Boggy Creek	03/30/09	37		139.0	2	OWRB
410400010070-001AT	Muddy Boggy Creek	07/20/09	68.5		80.0	2	OWRB
410400010070-001AT	Muddy Boggy Creek	06/14/10	59		275.0	2	OWRB
410400010070-001AT	Muddy Boggy Creek	06/29/10	123.7		190.0	2	OWRB
410400010070-001AT	Muddy Boggy Creek	10/04/10	43.5		38.0	2	OWRB
410400010070-001AT	Muddy Boggy Creek	12/13/10	2.8		47.0	2	OWRB
410400010070-001AT	Muddy Boggy Creek	02/28/11	66.3		162.0	2	OWRB
410400010070-001AT	Muddy Boggy Creek	03/28/11	30.3		73.0	2	OWRB
410400010070-001AT	Muddy Boggy Creek	04/17/06	55		64.0	3	OWRB
410400010070-001AT	Muddy Boggy Creek	05/23/06	33		135.0	3	OWRB
410400010070-001AT	Muddy Boggy Creek	06/26/06	78		89.0	3	OWRB
410400010070-001AT	Muddy Boggy Creek	03/19/07	20		27.0	3	OWRB
410400010070-001AT	Muddy Boggy Creek	05/21/07	44		2.0	3	OWRB
410400010070-001AT	Muddy Boggy Creek	10/08/07	54		132.0	3	OWRB
410400010070-001AT	Muddy Boggy Creek	12/14/09	20		508.0	3	OWRB
410400010070-001AT	Muddy Boggy Creek	03/29/10	68.3		2190.0	3	OWRB
410400010070-001AT	Muddy Boggy Creek	03/21/06	322		4690.0	4	OWRB
410400010070-001AT	Muddy Boggy Creek	04/16/07	446		1210.0	4	OWRB
410400010070-001AT	Muddy Boggy Creek	08/27/07	857		2680.0	4	OWRB
410400010070-001AT	Muddy Boggy Creek	03/10/08	84		2360.0	4	OWRB
410400010070-001AT	Muddy Boggy Creek	04/07/08	185		3030.0	4	OWRB
410400010070-001AT	Muddy Boggy Creek	05/19/09	76		12500.0	4	OWRB
410400010070-001AT	Muddy Boggy Creek	11/06/06	230		550.0	5	OWRB

Station ID	Stream Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow (cfs)	Flow Condition*	Data Sources
410400010070-001AT	Muddy Boggy Creek	06/24/07	117		15300.0	5	OWRB
410400010070-001AT	Muddy Boggy Creek	09/16/09	235		417.0	5	OWRB
410400010070-001AT	Muddy Boggy Creek	02/22/10	203		3160.0	5	OWRB
OK410400-01-0130G	Lick Creek	06/21/05	193	49	0.104		OCC
OK410400-01-0130G	Lick Creek	07/19/05	92.4		0		OCC
OK410400-01-0130G	Lick Creek	07/26/05	73.8	34	0		OCC
OK410400-01-0130G	Lick Creek	09/07/05	18.5	11	0		OCC
OK410400-01-0130G	Lick Creek	09/13/05			0		OCC
OK410400-01-0130G	Lick Creek	10/11/05	27.7	24	0		OCC
OK410400-01-0130G	Lick Creek	02/28/06	120	67	0		OCC
OK410400-01-0130G	Lick Creek	04/04/06	18.5	15	0.918		OCC
OK410400-01-0130G	Lick Creek	05/09/06	49.8	25	2.476		OCC
OK410400-01-0130G	Lick Creek	06/19/06	24.8	12	0		OCC
OK410400-01-0130G	Lick Creek	11/06/06	272	125	11.596		OCC
OK410400-01-0130G	Lick Creek	12/12/06	30.1	10	0.497		OCC
OK410400-01-0130G	Lick Creek	01/22/07	40.7	10	9.461		OCC
OK410400-01-0130G	Lick Creek	02/20/07	14.5	10	1.933		OCC
OK410400-01-0130G	Lick Creek	03/26/07	12.3	10	0.952		OCC
OK410400-01-0130G	Lick Creek	05/07/07	30.6	16	1.85		OCC
OK410400-01-0210G	Whitegrass Creek: Lower	04/04/06	62.4	10	4.126		OCC
OK410400-01-0210G	Whitegrass Creek: Lower	06/21/05	14.3	10	0.368		OCC
OK410400-01-0210G	Whitegrass Creek: Lower	07/19/05	98.8		1.48		OCC
OK410400-01-0210G	Whitegrass Creek: Lower	07/26/05	41.5	20	0.203		OCC
OK410400-01-0210G	Whitegrass Creek: Lower	09/07/05	25.9	29	0		OCC
OK410400-01-0210G	Whitegrass Creek: Lower	09/13/05			0		OCC
OK410400-01-0210G	Whitegrass Creek: Lower	10/11/05	28	10	0		OCC
OK410400-01-0210G	Whitegrass Creek: Lower	11/08/05	26.4	43	0		OCC
OK410400-01-0210G	Whitegrass Creek: Lower	12/13/05	88.8	50	0		OCC
OK410400-01-0210G	Whitegrass Creek: Lower	01/24/06	47.7	17	8.087		OCC
OK410400-01-0210G	Whitegrass Creek: Lower	02/28/06	84.1	39	8.95		OCC
OK410400-01-0210G	Whitegrass Creek: Lower	05/09/06	78.7	39	12.994		OCC
OK410400-01-0210G	Whitegrass Creek: Lower	06/20/06		21	0		OCC
OK410400-01-0210G	Whitegrass Creek: Lower	07/24/06	31.9	26	0		OCC
OK410400-01-0210G	Whitegrass Creek: Lower	08/28/06	485	199	0		OCC
OK410400-01-0210G	Whitegrass Creek: Lower	10/02/06	72.7	20	0		OCC
OK410400-01-0210G	Whitegrass Creek: Lower	12/12/06	96.2	20	11.276		OCC
OK410400-01-0210G	Whitegrass Creek: Lower	02/20/07	16	10	8.699		OCC
OK410400-01-0210G	Whitegrass Creek: Lower	03/26/07	15.6	12	4.282		OCC
OK410400-01-0210G	Whitegrass Creek: Lower	11/06/06	790	434		High Flow	OCC

Station ID	Stream Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow (cfs)	Flow Condition*	Data Sources
OK410400-01-0210G	Whitegrass Creek: Lower	01/22/07	104	45		High Flow	OCC
OK410400-01-0210G	Whitegrass Creek: Lower	05/07/07	62.7	19		High Flow	OCC
410400030010-001AT	Clear Boggy Creek	01/24/05	31		323.0	3	OWRB
410400030010-001AT	Clear Boggy Creek	06/27/05	70		50.0	2	OWRB
410400030010-001AT	Clear Boggy Creek	08/01/05	45		16.0	2	OWRB
410400030010-001AT	Clear Boggy Creek	10/03/05	20		13.0	2	OWRB
410400030010-001AT	Clear Boggy Creek	11/07/05	7		14.0	2	OWRB
410400030010-001AT	Clear Boggy Creek	12/19/05	7		15.0	2	OWRB
410400030010-001AT	Clear Boggy Creek	02/06/06	7		19.0	2	OWRB
410400030010-001AT	Clear Boggy Creek	04/17/06	20		26.0	2	OWRB
410400030010-001AT	Clear Boggy Creek	05/23/06	23		69.0	3	OWRB
410400030010-001AT	Clear Boggy Creek	06/26/06	36		17.0	2	OWRB
410400030010-001AT	Clear Boggy Creek	07/31/06	41		6.5	2	OWRB
410400030010-001AT	Clear Boggy Creek	09/05/06	33		9.3	2	OWRB
410400030010-001AT	Clear Boggy Creek	10/09/06	13		6.5	2	OWRB
410400030010-001AT	Clear Boggy Creek	12/18/06	9		46.0	2	OWRB
410400030010-001AT	Clear Boggy Creek	02/12/07	19		109.0	3	OWRB
410400030010-001AT	Clear Boggy Creek	03/19/07	13		122.0	3	OWRB
410400030010-001AT	Clear Boggy Creek	05/21/07	26		125.0	3	OWRB
410400030010-001AT	Clear Boggy Creek	08/27/07	195		501.0	3	OWRB
410400030010-001AT	Clear Boggy Creek	10/08/07	23		19.0	2	OWRB
410400030010-001AT	Clear Boggy Creek	11/13/07	12		15.0	2	OWRB
410400030010-001AT	Clear Boggy Creek	02/04/08	15		27.0	2	OWRB
410400030010-001AT	Clear Boggy Creek	03/10/08	62		230.0	3	OWRB
410400030010-001AT	Clear Boggy Creek	04/07/08	61		369.0	3	OWRB
410400030010-001AT	Clear Boggy Creek	05/12/08	63		130.0	2	OWRB
410400030010-001AT	Clear Boggy Creek	08/18/08	108		16.0	2	OWRB
410400030010-001AT	Clear Boggy Creek	09/29/08	30		4.1	2	OWRB
410400030010-001AT	Clear Boggy Creek	12/08/08	6		6.8	1	OWRB
410400030010-001AT	Clear Boggy Creek	02/09/09	22.6		16.0	1	OWRB
410400030010-001AT	Clear Boggy Creek	03/09/09	5		13.0	1	OWRB
410400030010-001AT	Clear Boggy Creek	03/30/09	19		23.0	3	OWRB
410400030010-001AT	Clear Boggy Creek	05/18/09	174		1650.0	3	OWRB
410400030010-001AT	Clear Boggy Creek	07/20/09	140		46.0	2	OWRB
410400030010-001AT	Clear Boggy Creek	09/14/09	80		68.0	3	OWRB
410400030010-001AT	Clear Boggy Creek	12/14/09	11		158.0	3	OWRB
410400030010-001AT	Clear Boggy Creek	03/29/10	56.7		433.0	3	OWRB
410400030010-001AT	Clear Boggy Creek	06/14/10	43		126.0	2	OWRB
410400030010-001AT	Clear Boggy Creek	06/28/10	21.7		63.0	2	OWRB

Station ID	Stream Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow (cfs)	Flow Condition*	Data Sources
410400030010-001AT	Clear Boggy Creek	10/04/10	9.3		18.0	2	OWRB
410400030010-001AT	Clear Boggy Creek	12/13/10	4.3		22.0	2	OWRB
410400030010-001AT	Clear Boggy Creek	03/28/11	9.3		23.0	2	OWRB
410400030010-001AT	Clear Boggy Creek	04/11/05	262		809.0	4	OWRB
410400030010-001AT	Clear Boggy Creek	03/21/06	375		1040.0	4	OWRB
410400030010-001AT	Clear Boggy Creek	11/06/06	879		1600.0	5	OWRB
410400030010-001AT	Clear Boggy Creek	04/16/07	84		295.0	4	OWRB
410400030010-001AT	Clear Boggy Creek	06/25/07	333		2530.0	4	OWRB
410400030010-001AT	Clear Boggy Creek	07/30/07	62		506.0	4	OWRB
410400030010-001AT	Clear Boggy Creek	02/22/10	479		2090.0	4	OWRB
OK410400-03-0020C	Caney Creek: HWY 69	10/03/05	4	10	0.001		OCC
OK410400-03-0020C	Caney Creek: HWY 69	04/03/06	7.03	12	2.735		OCC
OK410400-03-0020C	Caney Creek: HWY 69	04/16/07	10.8	10	5.254		OCC
OK410400-03-0020C	Caney Creek: HWY 69	06/20/05	6.63	10	0.297		OCC
OK410400-03-0020C	Caney Creek: HWY 69	07/01/05	4.24		0.025		OCC
OK410400-03-0020C	Caney Creek: HWY 69	07/25/05	8.79	10	0		OCC
OK410400-03-0020C	Caney Creek: HWY 69	08/29/05	2.26	10	0		OCC
OK410400-03-0020C	Caney Creek: HWY 69	09/01/05			0		OCC
OK410400-03-0020C	Caney Creek: HWY 69	11/07/05	2.75	25	0.008		OCC
OK410400-03-0020C	Caney Creek: HWY 69	12/12/05	3	10	0.211		OCC
OK410400-03-0020C	Caney Creek: HWY 69	01/23/06	11.3	10	1.206		OCC
OK410400-03-0020C	Caney Creek: HWY 69	02/27/06	5.4	10			OCC
OK410400-03-0020C	Caney Creek: HWY 69	06/12/06	8.38	10	0.11		OCC
OK410400-03-0020C	Caney Creek: HWY 69	07/17/06	3.79	10	0		OCC
OK410400-03-0020C	Caney Creek: HWY 69	09/25/06	119	46	0		OCC
OK410400-03-0020C	Caney Creek: HWY 69	10/30/06	10.1	12	0		OCC
OK410400-03-0020C	Caney Creek: HWY 69	12/04/06	45	36	11.575		OCC
OK410400-03-0020C	Caney Creek: HWY 69	01/08/07	20.9	15	7.349		OCC
OK410400-03-0020C	Caney Creek: HWY 69	02/12/07	18.4	29	7.455		OCC
OK410400-03-0020C	Caney Creek: HWY 69	03/19/07	6.99	10	4.915		OCC
OK410400-03-0020C	Caney Creek: HWY 69	05/08/06	310	1080		High Flow	OCC
OK410400-03-0240M	Delaware Creek	04/04/06	6.95	10	6.838		OCC
OK410400-03-0240M	Delaware Creek	04/16/07	5.41	10	28.133		OCC
OK410400-03-0240M	Delaware Creek	06/21/05	14	10	12.594		OCC
OK410400-03-0240M	Delaware Creek	07/18/05	6.17		3.818		OCC
OK410400-03-0240M	Delaware Creek	07/25/05	6.11	10	0		OCC
OK410400-03-0240M	Delaware Creek	08/29/05	4.75	10	0		OCC
OK410400-03-0240M	Delaware Creek	10/03/05	4.24	10	0		OCC
OK410400-03-0240M	Delaware Creek	11/08/05	4.23	10	0		OCC

Station ID	Stream Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow (cfs)	Flow Condition*	Data Sources
OK410400-03-0240M	Delaware Creek	12/12/05	3.04	10	0		OCC
OK410400-03-0240M	Delaware Creek	01/23/06	4	10	0		OCC
OK410400-03-0240M	Delaware Creek	02/28/06	5.28	10			OCC
OK410400-03-0240M	Delaware Creek	06/12/06	24.2	10	0.454		OCC
OK410400-03-0240M	Delaware Creek	07/17/06	13.8	10	0		OCC
OK410400-03-0240M	Delaware Creek	08/21/06	39.2	42	0		OCC
OK410400-03-0240M	Delaware Creek	09/25/06	68.4	29	0		OCC
OK410400-03-0240M	Delaware Creek	10/30/06	4.49	10	0		OCC
OK410400-03-0240M	Delaware Creek	12/05/06	26.9	10	90.374		OCC
OK410400-03-0240M	Delaware Creek	01/09/07	17.1	10	30.551		OCC
OK410400-03-0240M	Delaware Creek	02/12/07	11.3	10	13.342		OCC
OK410400-03-0240M	Delaware Creek	03/19/07	3.9	10	11.744		OCC
OK410400-03-0240M	Delaware Creek	05/08/06	184	159		High Flow	OCC
OK410400-03-0370B	Leader Creek	04/04/06	72.4	63	0.785		OCC
OK410400-03-0370B	Leader Creek	04/16/07	87.5	20	13.942		OCC
OK410400-03-0370B	Leader Creek	06/15/05	98.7		0.728		OCC
OK410400-03-0370B	Leader Creek	06/21/05	117	114	1.34		OCC
OK410400-03-0370B	Leader Creek	07/25/05	59.8	41	0		OCC
OK410400-03-0370B	Leader Creek	08/29/05	59.2	23	0.86		OCC
OK410400-03-0370B	Leader Creek	10/03/05	75.2	27	0.148		OCC
OK410400-03-0370B	Leader Creek	11/07/05	122	60	0		OCC
OK410400-03-0370B	Leader Creek	12/12/05	51.9	10	0		OCC
OK410400-03-0370B	Leader Creek	01/23/06	39.9	13	0		OCC
OK410400-03-0370B	Leader Creek	02/27/06	30.3	15			OCC
OK410400-03-0370B	Leader Creek	06/12/06	111	58			OCC
OK410400-03-0370B	Leader Creek	07/17/06	149	65	0		OCC
OK410400-03-0370B	Leader Creek	08/22/06	114	78	0		OCC
OK410400-03-0370B	Leader Creek	10/30/06	117	15	0		OCC
OK410400-03-0370B	Leader Creek	12/05/06	95.2	10	18.425		OCC
OK410400-03-0370B	Leader Creek	01/09/07	83.8	24	5.149		OCC
OK410400-03-0370B	Leader Creek	02/12/07	478	321	5.672		OCC
OK410400-03-0370B	Leader Creek	03/19/07	43.8	18	4.113		OCC
OK410400-03-0370B	Leader Creek	05/08/06	142	102		High Flow	OCC
OK410400-03-0490G	Goose Creek	04/04/06	14.5	10	0		OCC
OK410400-03-0490G	Goose Creek	04/16/07	14.5	10	10.118		OCC
OK410400-03-0490G	Goose Creek	06/17/05	61.6		4.583		OCC
OK410400-03-0490G	Goose Creek	06/21/05	62.1	38	0.821		OCC
OK410400-03-0490G	Goose Creek	07/25/05	34.4	42	0		OCC
OK410400-03-0490G	Goose Creek	08/29/05	16	10	1.211		OCC

Station ID	Stream Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow (cfs)	Flow Condition*	Data Sources
OK410400-03-0490G	Goose Creek	10/03/05	7.99	10	0.261		OCC
OK410400-03-0490G	Goose Creek	11/07/05	4.99	10	0.016		OCC
OK410400-03-0490G	Goose Creek	12/12/05	12.4	10	0		OCC
OK410400-03-0490G	Goose Creek	01/24/06	12.9	10	0		OCC
OK410400-03-0490G	Goose Creek	02/28/06	8.52	10	0		OCC
OK410400-03-0490G	Goose Creek	06/13/06	12.7	10	4.167		OCC
OK410400-03-0490G	Goose Creek	07/17/06	13	15	0		OCC
OK410400-03-0490G	Goose Creek	10/30/06	3.17	10			OCC
OK410400-03-0490G	Goose Creek	12/04/06	12.5	10	24.455		OCC
OK410400-03-0490G	Goose Creek	01/09/07	11.4	10	17.09		OCC
OK410400-03-0490G	Goose Creek	02/13/07	365	83	30.549		OCC
OK410400-03-0490G	Goose Creek	03/19/07	6.26	10	4.333		OCC
OK410400-03-0490G	Goose Creek	05/08/06	45.1	65		High Flow	OCC
410400050270-001AT	Muddy Boggy Creek	11/10/98	147	90		2	OWRB
410400050270-001AT	Muddy Boggy Creek	12/15/98	119	102		3	OWRB
410400050270-001AT	Muddy Boggy Creek	01/12/99	21	10		2	OWRB
410400050270-001AT	Muddy Boggy Creek	02/10/99	166	102		#N/A	OWRB
410400050270-001AT	Muddy Boggy Creek	03/10/99	664	204		3	OWRB
410400050270-001AT	Muddy Boggy Creek	04/14/99	24	14		3	OWRB
410400050270-001AT	Muddy Boggy Creek	05/05/99	85	64		4	OWRB
410400050270-001AT	Muddy Boggy Creek	06/14/99	92	68		3	OWRB
410400050270-001AT	Muddy Boggy Creek	09/08/99	39	44		2	OWRB
410400050270-001AT	Muddy Boggy Creek	10/06/99	16	1		#N/A	OWRB
410400050270-001AT	Muddy Boggy Creek	11/09/99	31	44		#N/A	OWRB
410400050270-001AT	Muddy Boggy Creek	12/01/99	82	82		1	OWRB
410400050270-001AT	Muddy Boggy Creek	01/12/00	405	176		#N/A	OWRB
410400050270-001AT	Muddy Boggy Creek	02/09/00	90	76		#N/A	OWRB
410400050270-001AT	Muddy Boggy Creek	03/07/00	196	104		#N/A	OWRB
410400050270-001AT	Muddy Boggy Creek	05/03/00	241	216		#N/A	OWRB
410400050270-001AT	Muddy Boggy Creek	06/07/00	50	44		1	OWRB
410400050270-001AT	Muddy Boggy Creek	07/12/00	80	70		3	OWRB
410400050270-001AT	Muddy Boggy Creek	08/09/00	30	38		2	OWRB
410400050270-001AT	Muddy Boggy Creek	09/13/00	33	48		1	OWRB
410400050270-001AT	Muddy Boggy Creek	10/04/00	33	16		1	OWRB
410400050270-001AT	Muddy Boggy Creek	11/08/00	398	384		4	OWRB
410400050270-001AT	Muddy Boggy Creek	02/06/06	25		84.49	1	OWRB
410400050270-001AT	Muddy Boggy Creek	04/17/06	108		73.49	1	OWRB
410400050270-001AT	Muddy Boggy Creek	06/26/06	38		63.84	1	OWRB
410400050270-001AT	Muddy Boggy Creek	07/31/06	16		48.64	1	OWRB

Station ID	Stream Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow (cfs)	Flow Condition*	Data Sources
410400050270-001AT	Muddy Boggy Creek	09/05/06	10			1	OWRB
410400050270-001AT	Muddy Boggy Creek	10/09/06	5		0	1	OWRB
410400050270-001AT	Muddy Boggy Creek	11/13/07	16		29	1	OWRB
410400050270-001AT	Muddy Boggy Creek	09/29/08	120		70	1	OWRB
410400050270-001AT	Muddy Boggy Creek	02/09/09	15		11	1	OWRB
410400050270-001AT	Muddy Boggy Creek	07/20/09	36		2.8	1	OWRB
410400050270-001AT	Muddy Boggy Creek	12/14/09	49.3		83	1	OWRB
410400050270-001AT	Muddy Boggy Creek	12/13/10	10		4.39	1	OWRB
410400050270-001AT	Muddy Boggy Creek	03/28/11	47.3		4.87	1	OWRB
410400050270-001AT	Muddy Boggy Creek	12/08/08	18		4	1	OWRB
410400050270-001AT	Muddy Boggy Creek	05/23/06	51		96.37	2	OWRB
410400050270-001AT	Muddy Boggy Creek	12/18/06	53		89.32	2	OWRB
410400050270-001AT	Muddy Boggy Creek	02/12/07	45		38.47	2	OWRB
410400050270-001AT	Muddy Boggy Creek	03/19/07	49		100.23	2	OWRB
410400050270-001AT	Muddy Boggy Creek	05/21/07	54			2	OWRB
410400050270-001AT	Muddy Boggy Creek	10/08/07	105		33.7	2	OWRB
410400050270-001AT	Muddy Boggy Creek	02/04/08	12		5.36	2	OWRB
410400050270-001AT	Muddy Boggy Creek	05/12/08	150		98.7	2	OWRB
410400050270-001AT	Muddy Boggy Creek	06/14/10	54			2	OWRB
410400050270-001AT	Muddy Boggy Creek	06/21/10	117		49.75	2	OWRB
410400050270-001AT	Muddy Boggy Creek	10/04/10	97.7		3.8	2	OWRB
410400050270-001AT	Muddy Boggy Creek	01/18/11	65.3		79	2	OWRB
410400050270-001AT	Muddy Boggy Creek	07/30/07	34		111.54	3	OWRB
410400050270-001AT	Muddy Boggy Creek	03/10/08	109		144.55	3	OWRB
410400050270-001AT	Muddy Boggy Creek	08/18/08	299		41	3	OWRB
410400050270-001AT	Muddy Boggy Creek	03/30/09	60.25		124	3	OWRB
410400050270-001AT	Muddy Boggy Creek	05/18/09	190			3	OWRB
410400050270-001AT	Muddy Boggy Creek	03/29/10	67.3		224	3	OWRB
410400050270-001AT	Muddy Boggy Creek	04/07/08	89		248.45	3	OWRB
410400050270-001AT	Muddy Boggy Creek	04/16/07	422		351.28	4	OWRB
410400050270-001AT	Muddy Boggy Creek	03/21/06	587		974.82	4	OWRB
410400050270-001AT	Muddy Boggy Creek	06/25/07	171		502.36	4	OWRB
410400050270-001AT	Muddy Boggy Creek	11/06/06	568			5	OWRB
410400050270-001AT	Muddy Boggy Creek	09/14/09	310		200	5	OWRB
410400050270-001AT	Muddy Boggy Creek	05/23/11	206		380	5	OWRB
410400050270-001AT	Muddy Boggy Creek	02/22/10	1277.3		2701.85	5	OWRB
410400050270-001AT	Muddy Boggy Creek	08/27/07	293			#N/A	OWRB
OK410400-08-0010M	North Boggy Creek	10/03/05	3.82	10	0.155		OCC
OK410400-08-0010M	North Boggy Creek	04/03/06	5.8	12			OCC

Station ID	Stream Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow (cfs)	Flow Condition*	Data Sources
OK410400-08-0010M	North Boggy Creek	04/16/07	24.3	10	0.763		OCC
OK410400-08-0010M	North Boggy Creek	06/20/05	9.88	10	0.269		OCC
OK410400-08-0010M	North Boggy Creek	07/25/05	19.9	11	0.065		OCC
OK410400-08-0010M	North Boggy Creek	08/22/05	4.39		0.076		OCC
OK410400-08-0010M	North Boggy Creek	08/29/05	8.24	14	0.128		OCC
OK410400-08-0010M	North Boggy Creek	11/07/05	2.4	10			OCC
OK410400-08-0010M	North Boggy Creek	12/12/05	3.91	10			OCC
OK410400-08-0010M	North Boggy Creek	01/23/06	10.9	10	0.636		OCC
OK410400-08-0010M	North Boggy Creek	02/27/06	4.69	10			OCC
OK410400-08-0010M	North Boggy Creek	05/08/06	73.6	43			OCC
OK410400-08-0010M	North Boggy Creek	06/12/06	6.06	10			OCC
OK410400-08-0010M	North Boggy Creek	07/17/06	9.1	10	0		OCC
OK410400-08-0010M	North Boggy Creek	08/21/06	14.6	10	0		OCC
OK410400-08-0010M	North Boggy Creek	09/25/06	9.64	10	0		OCC
OK410400-08-0010M	North Boggy Creek	10/30/06	6.24	10	0		OCC
OK410400-08-0010M	North Boggy Creek	12/04/06	25.6	10	1.209		OCC
OK410400-08-0010M	North Boggy Creek	01/08/07	12.4	10	1.557		OCC
OK410400-08-0010M	North Boggy Creek	02/12/07	24.3	10	0.766		OCC
OK410400-08-0010M	North Boggy Creek	03/19/07	12.5	10	0.392		OCC
OK410400-06-0120G	Caney Boggy Creek: Lower	04/03/06	35.2	13	2.888		OCC
OK410400-06-0120G	Caney Boggy Creek: Lower	04/16/07	90.5	32	68.087		OCC
OK410400-06-0120G	Caney Boggy Creek: Lower	06/20/05	67	30	3.262		OCC
OK410400-06-0120G	Caney Boggy Creek: Lower	07/25/05	36.4	30	0		OCC
OK410400-06-0120G	Caney Boggy Creek: Lower	08/22/05	61.9		1.911		OCC
OK410400-06-0120G	Caney Boggy Creek: Lower	08/29/05	29.5	10	0.088		OCC
OK410400-06-0120G	Caney Boggy Creek: Lower	10/03/05	12.3	10	0.025		OCC
OK410400-06-0120G	Caney Boggy Creek: Lower	11/07/05	38.3	15	0		OCC
OK410400-06-0120G	Caney Boggy Creek: Lower	12/12/05	10.3	10	0		OCC
OK410400-06-0120G	Caney Boggy Creek: Lower	01/23/06	37.5	29	0		OCC
OK410400-06-0120G	Caney Boggy Creek: Lower	02/27/06	10.3	10	0		OCC
OK410400-06-0120G	Caney Boggy Creek: Lower	06/12/06	23.2	10			OCC
OK410400-06-0120G	Caney Boggy Creek: Lower	07/17/06		13	0		OCC
OK410400-06-0120G	Caney Boggy Creek: Lower	08/21/06	19.5	10	0		OCC
OK410400-06-0120G	Caney Boggy Creek: Lower	09/25/06	34	18	0		OCC
OK410400-06-0120G	Caney Boggy Creek: Lower	10/30/06	94.5	21	0		OCC
OK410400-06-0120G	Caney Boggy Creek: Lower	12/04/06	111	21	23.762		OCC
OK410400-06-0120G	Caney Boggy Creek: Lower	01/08/07	67.9	17	9.128		OCC
OK410400-06-0120G	Caney Boggy Creek: Lower	02/12/07	38.4	10	5.208		OCC
OK410400-06-0120G	Caney Boggy Creek: Lower	03/19/07	15.5	10	600.44		OCC

Station ID	Stream Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow (cfs)	Flow Condition*	Data Sources
OK410400-06-0120G	Caney Boggy Creek: Lower	05/08/06	96.7	78		High Flow	OCC
OK410600-02-0020G	Sandy Creek	04/17/07	7.59	10	3.351		OCC
OK410600-02-0020G	Sandy Creek	04/04/06	3.36	10	0.406		OCC
OK410600-02-0020G	Sandy Creek	06/16/05	2.27		2.195		OCC
OK410600-02-0020G	Sandy Creek	06/20/05	1.91	10	1.056		OCC
OK410600-02-0020G	Sandy Creek	07/25/05	1.73	10	0		OCC
OK410600-02-0020G	Sandy Creek	08/30/05	6.9	10	0		OCC
OK410600-02-0020G	Sandy Creek	10/04/05	1.78	10	0		OCC
OK410600-02-0020G	Sandy Creek	11/08/05	1.32	10	0.03		OCC
OK410600-02-0020G	Sandy Creek	12/13/05	0.53	10	0.071		OCC
OK410600-02-0020G	Sandy Creek	01/24/06	5.17	10	0.32		OCC
OK410600-02-0020G	Sandy Creek	02/28/06	2.16	12			OCC
OK410600-02-0020G	Sandy Creek	05/09/06	44.8	38	40.779		OCC
OK410600-02-0020G	Sandy Creek	06/13/06	2.06	10	0		OCC
OK410600-02-0020G	Sandy Creek	07/18/06	31.8	30	0		OCC
OK410600-02-0020G	Sandy Creek	09/26/06	24.8	26	0		OCC
OK410600-02-0020G	Sandy Creek	10/31/06	0.95	10			OCC
OK410600-02-0020G	Sandy Creek	12/05/06	17	10	5.778		OCC
OK410600-02-0020G	Sandy Creek	01/09/07	7.06	10	3.786		OCC
OK410600-02-0020G	Sandy Creek	02/13/07	25	16	11.933		OCC
OK410600-02-0020G	Sandy Creek	03/20/07	4.98	10	3.03		OCC

* Stream flow conditions (1=none, 2=light, 3=moderate, 4=heavy, 5=stormwater)

Cells in red are best estimates based on other information

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

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

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

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

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

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

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

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

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

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

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

Runoff Curve Numbers for Various Land Use Categories and Hydrologic Soil Groups

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

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

Furness Method

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

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

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

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

Wurbs Modified NRCS Method

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

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

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

where:

Q = runoff depth (inches)

P = rainfall (inches)

S = potential maximum retention after runoff begins (inches)

I_a = initial abstraction (inches)

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

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

Thus, the runoff curve number equation can be rewritten:

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

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

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

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

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

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

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

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

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

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

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

Generalized Flow Projection Methodology

In the first several versions of the Oklahoma TMDL toolbox, all flows at ungaged sites that required projection from a gaged site were performed with the Modified NRCS CN method. This led a number of problems with flow projections in the early versions. As described previously, the NRCS method, in common with all others, reproduces the mean or central tendency best but the accuracy of the fit degrades towards the extremes of the frequency spectrum. Part of the degradation in accuracy is due to the quite non-linear nature of the NRCS equations. On the low flow end of the frequency spectrum, Equation 2 above constitutes a low flow limit below which the

NRCS equations are not applicable at all. Given the flashy nature of most streams in locations for which the toolbox was developed, high and low flows are relatively more common and spurious results from the limits of the equations abounded.

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

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

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

References

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

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

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

Estimated Flow Exceedance Percentiles

Stream Name	Muddy Boggy Creek	Lick Creek	Whitegrass Creek	Clear Boggy Creek	Leader Creek	Goose Creek	Muddy Boggy Creek	Caney Boggy Creek
WBID Segment	OK410400010070_00	OK410400010130_00	OK410400010210_00	OK410400030010_00	OK410400030370_00	OK410400030490_00	OK410400050270_10	OK410400060120_00
USGS Gage Reference	USGS 07334000	USGS 07334000	USGS 07334000	USGS 07335000	USGS 07335000	USGS 07335000	USGS 07334000	USGS 07334000
Drainage Area (sq. mile)	2437.4	60.1	77.4	720	97.2	34.5	767.8	100.4
NRCS Curve Number	70.7	65.8	64.3	67.0	66.5	66.7	64.6	66.3
Average Annual Rainfall (inch)	47.2	46.2	45.7	44.2	43.5	43.1	44.6	44.3
Exceedance Frequency	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
0	33127.7	2593.1	3339.5	46900.0	6331.5	2247.3	105164.7	4331.9
1	9111.9	713.2	918.5	12900.0	1741.5	618.1	28925.9	1191.5
2	6645.5	520.2	669.9	9408.2	1270.1	450.8	21096.2	869.0
3	5099.8	399.2	514.1	7220.0	974.7	346.0	16189.5	666.9
4	4068.6	318.5	410.1	5760.0	777.6	276.0	12915.8	532.0
5	3390.5	265.4	341.8	4800.0	648.0	230.0	10763.1	443.3
6	2832.5	221.7	285.5	4010.0	541.4	192.1	8991.7	370.4
7	2408.6	188.5	242.8	3410.0	460.4	163.4	7646.3	315.0
8	2027.2	158.7	204.4	2870.0	387.5	137.5	6435.5	265.1
9	1746.0	136.7	176.0	2471.9	333.7	118.4	5542.8	228.3
10	1547.6	121.1	156.0	2191.0	295.8	105.0	4912.9	202.4
11	1384.4	108.4	139.6	1960.0	264.6	93.9	4394.9	181.0
12	1236.1	96.8	124.6	1750.0	236.3	83.9	3924.1	161.6
13	1114.8	87.3	112.4	1578.3	213.1	75.6	3539.1	145.8
14	996.0	78.0	100.4	1410.0	190.4	67.6	3161.7	130.2
15	890.0	69.7	89.7	1260.0	170.1	60.4	2825.3	116.4
16	798.2	62.5	80.5	1130.0	152.6	54.1	2533.8	104.4

Stream Name	Muddy Boggy Creek	Lick Creek	Whitegrass Creek	Clear Boggy Creek	Leader Creek	Goose Creek	Muddy Boggy Creek	Caney Boggy Creek
WBID Segment	OK410400010070_00	OK410400010130_00	OK410400010210_00	OK410400030010_00	OK410400030370_00	OK410400030490_00	OK410400050270_10	OK410400060120_00
USGS Gage Reference	USGS 07334000	USGS 07334000	USGS 07334000	USGS 07335000	USGS 07335000	USGS 07335000	USGS 07334000	USGS 07334000
Drainage Area (sq. mile)	2437.4	60.1	77.4	720	97.2	34.5	767.8	100.4
NRCS Curve Number	70.7	65.8	64.3	67.0	66.5	66.7	64.6	66.3
Average Annual Rainfall (inch)	47.2	46.2	45.7	44.2	43.5	43.1	44.6	44.3
Exceedance Frequency	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
17	720.5	56.4	72.6	1020.0	137.7	48.9	2287.2	94.2
18	656.2	51.4	66.1	929.0	125.4	44.5	2083.1	85.8
19	591.9	46.3	59.7	838.0	113.1	40.2	1879.1	77.4
20	536.8	42.0	54.1	760.0	102.6	36.4	1704.2	70.2
21	491.6	38.5	49.6	696.0	94.0	33.4	1560.7	64.3
22	445.7	34.9	44.9	631.0	85.2	30.2	1414.9	58.3
23	406.1	31.8	40.9	575.0	77.6	27.6	1289.3	53.1
24	370.8	29.0	37.4	525.0	70.9	25.2	1177.2	48.5
25	341.2	26.7	34.4	483.0	65.2	23.1	1083.0	44.6
26	312.2	24.4	31.5	442.0	59.7	21.2	991.1	40.8
27	288.2	22.6	29.1	408.0	55.1	19.6	914.9	37.7
28	264.2	20.7	26.6	374.0	50.5	17.9	838.6	34.5
29	241.8	18.9	24.4	342.4	46.2	16.4	767.7	31.6
30	222.7	17.4	22.5	315.3	42.6	15.1	707.0	29.1
31	206.3	16.1	20.8	292.0	39.4	14.0	654.8	27.0
32	190.1	14.9	19.2	269.1	36.3	12.9	603.5	24.9
33	175.9	13.8	17.7	249.0	33.6	11.9	558.3	23.0
34	162.5	12.7	16.4	230.0	31.1	11.0	515.7	21.2
35	149.7	11.7	15.1	212.0	28.6	10.2	475.4	19.6

Stream Name	Muddy Boggy Creek	Lick Creek	Whitegrass Creek	Clear Boggy Creek	Leader Creek	Goose Creek	Muddy Boggy Creek	Caney Boggy Creek
WBID Segment	OK410400010070_00	OK410400010130_00	OK410400010210_00	OK410400030010_00	OK410400030370_00	OK410400030490_00	OK410400050270_10	OK410400060120_00
USGS Gage Reference	USGS 07334000	USGS 07334000	USGS 07334000	USGS 07335000	USGS 07335000	USGS 07335000	USGS 07334000	USGS 07334000
Drainage Area (sq. mile)	2437.4	60.1	77.4	720	97.2	34.5	767.8	100.4
NRCS Curve Number	70.7	65.8	64.3	67.0	66.5	66.7	64.6	66.3
Average Annual Rainfall (inch)	47.2	46.2	45.7	44.2	43.5	43.1	44.6	44.3
Exceedance Frequency	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
36	140.6	11.0	14.2	199.0	26.9	9.5	446.2	18.4
37	130.0	10.2	13.1	184.0	24.8	8.8	412.6	17.0
38	120.1	9.4	12.1	170.0	23.0	8.1	381.2	15.7
39	111.6	8.7	11.3	158.0	21.3	7.6	354.3	14.6
40	104.5	8.2	10.5	148.0	20.0	7.1	331.9	13.7
41	97.5	7.6	9.8	138.0	18.6	6.6	309.4	12.7
42	91.1	7.1	9.2	129.0	17.4	6.2	289.3	11.9
43	84.8	6.6	8.5	120.0	16.2	5.8	269.1	11.1
44	79.8	6.2	8.0	113.0	15.3	5.4	253.4	10.4
45	74.9	5.9	7.5	106.0	14.3	5.1	237.7	9.8
46	70.6	5.5	7.1	100.0	13.5	4.8	224.2	9.2
47	66.4	5.2	6.7	94.0	12.7	4.5	210.8	8.7
48	62.2	4.9	6.3	88.0	11.9	4.2	197.3	8.1
49	58.6	4.6	5.9	83.0	11.2	4.0	186.1	7.7
50	55.1	4.3	5.6	78.0	10.5	3.7	174.9	7.2
51	51.6	4.0	5.2	73.0	9.9	3.5	163.7	6.7
52	48.7	3.8	4.9	69.0	9.3	3.3	154.7	6.4
53	45.9	3.6	4.6	65.0	8.8	3.1	145.8	6.0
54	43.1	3.4	4.3	61.0	8.2	2.9	136.8	5.6

Stream Name	Muddy Boggy Creek	Lick Creek	Whitegrass Creek	Clear Boggy Creek	Leader Creek	Goose Creek	Muddy Boggy Creek	Caney Boggy Creek
WBID Segment	OK410400010070_00	OK410400010130_00	OK410400010210_00	OK410400030010_00	OK410400030370_00	OK410400030490_00	OK410400050270_10	OK410400060120_00
USGS Gage Reference	USGS 07334000	USGS 07334000	USGS 07334000	USGS 07335000	USGS 07335000	USGS 07335000	USGS 07334000	USGS 07334000
Drainage Area (sq. mile)	2437.4	60.1	77.4	720	97.2	34.5	767.8	100.4
NRCS Curve Number	70.7	65.8	64.3	67.0	66.5	66.7	64.6	66.3
Average Annual Rainfall (inch)	47.2	46.2	45.7	44.2	43.5	43.1	44.6	44.3
Exceedance Frequency	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
55	40.3	3.2	4.1	57.0	7.7	2.7	127.8	5.3
56	38.1	3.0	3.8	54.0	7.3	2.6	121.1	5.0
57	36.0	2.8	3.6	51.0	6.9	2.4	114.4	4.7
58	33.9	2.7	3.4	48.0	6.5	2.3	107.6	4.4
59	32.5	2.5	3.3	46.0	6.2	2.2	103.1	4.2
60	31.1	2.4	3.1	44.0	5.9	2.1	98.7	4.1
61	29.0	2.3	2.9	41.0	5.5	2.0	91.9	3.8
62	27.5	2.2	2.8	39.0	5.3	1.9	87.5	3.6
63	26.1	2.0	2.6	37.0	5.0	1.8	83.0	3.4
64	24.7	1.9	2.5	35.0	4.7	1.7	78.5	3.2
65	23.3	1.8	2.3	33.0	4.5	1.6	74.0	3.0
66	22.6	1.8	2.3	32.0	4.3	1.5	71.8	3.0
67	21.2	1.7	2.1	30.0	4.1	1.4	67.3	2.8
68	20.5	1.6	2.1	29.0	3.9	1.4	65.0	2.7
69	19.1	1.5	1.9	27.0	3.6	1.3	60.5	2.5
70	18.4	1.4	1.9	26.0	3.5	1.2	58.3	2.4
71	17.7	1.4	1.8	25.0	3.4	1.2	56.1	2.3
72	17.0	1.3	1.7	24.0	3.2	1.2	53.8	2.2
73	16.2	1.3	1.6	23.0	3.1	1.1	51.6	2.1

Stream Name	Muddy Boggy Creek	Lick Creek	Whitegrass Creek	Clear Boggy Creek	Leader Creek	Goose Creek	Muddy Boggy Creek	Caney Boggy Creek
WBID Segment	OK410400010070_00	OK410400010130_00	OK410400010210_00	OK410400030010_00	OK410400030370_00	OK410400030490_00	OK410400050270_10	OK410400060120_00
USGS Gage Reference	USGS 07334000	USGS 07334000	USGS 07334000	USGS 07335000	USGS 07335000	USGS 07335000	USGS 07334000	USGS 07334000
Drainage Area (sq. mile)	2437.4	60.1	77.4	720	97.2	34.5	767.8	100.4
NRCS Curve Number	70.7	65.8	64.3	67.0	66.5	66.7	64.6	66.3
Average Annual Rainfall (inch)	47.2	46.2	45.7	44.2	43.5	43.1	44.6	44.3
Exceedance Frequency	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
74	15.5	1.2	1.6	22.0	3.0	1.1	49.3	2.0
75	14.8	1.2	1.5	21.0	2.8	1.0	47.1	1.9
76	14.1	1.1	1.4	20.0	2.7	1.0	44.8	1.8
77	13.4	1.1	1.4	19.0	2.6	0.9	42.6	1.8
78	12.7	1.0	1.3	18.0	2.4	0.9	40.4	1.7
79	11.3	0.9	1.1	16.0	2.2	0.8	35.9	1.5
80	11.3	0.9	1.1	16.0	2.2	0.8	35.9	1.5
81	10.6	0.8	1.1	15.0	2.0	0.7	33.6	1.4
82	9.9	0.8	1.0	14.0	1.9	0.7	31.4	1.3
83	9.2	0.7	0.9	13.0	1.8	0.6	29.2	1.2
84	8.5	0.7	0.9	12.0	1.6	0.6	26.9	1.1
85	7.8	0.6	0.8	11.0	1.5	0.5	24.7	1.0
86	7.0	0.5	0.7	9.9	1.3	0.5	22.2	0.9
87	6.1	0.5	0.6	8.6	1.2	0.4	19.3	0.8
88	5.2	0.4	0.5	7.3	1.0	0.3	16.4	0.7
89	4.2	0.3	0.4	6.0	0.8	0.3	13.5	0.6
90	3.5	0.3	0.4	5.0	0.7	0.2	11.2	0.5
91	2.8	0.2	0.3	4.0	0.5	0.2	9.0	0.4
92	2.2	0.2	0.2	3.1	0.4	0.1	7.0	0.3

Stream Name	Muddy Boggy Creek	Lick Creek	Whitegrass Creek	Clear Boggy Creek	Leader Creek	Goose Creek	Muddy Boggy Creek	Caney Boggy Creek
WBID Segment	OK410400010070_00	OK410400010130_00	OK410400010210_00	OK410400030010_00	OK410400030370_00	OK410400030490_00	OK410400050270_10	OK410400060120_00
USGS Gage Reference	USGS 07334000	USGS 07334000	USGS 07334000	USGS 07335000	USGS 07335000	USGS 07335000	USGS 07334000	USGS 07334000
Drainage Area (sq. mile)	2437.4	60.1	77.4	720	97.2	34.5	767.8	100.4
NRCS Curve Number	70.7	65.8	64.3	67.0	66.5	66.7	64.6	66.3
Average Annual Rainfall (inch)	47.2	46.2	45.7	44.2	43.5	43.1	44.6	44.3
Exceedance Frequency	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)	Q (cfs)
93	1.7	0.1	0.2	2.4	0.3	0.1	5.4	0.2
94	1.2	0.1	0.1	1.7	0.2	0.1	3.8	0.2
95	0.8	0.1	0.1	1.2	0.2	0.1	2.7	0.1
96	0.5	0.0	0.1	0.8	0.1	0.0	1.7	0.1
97	0.2	0.0	0.0	0.4	0.0	0.0	0.8	0.0
98	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

SANITARY SEWER OVERFLOWS DATA

Sanitary Sewer Overflows (SSO) Data since 2008

Facility Name	Bypass Date	Facility Id	Amount (Gallons)	Cause	Cleanup	Preventive	Type Of Source
Atoka	03/03/08	S10403	25,000	I&I	Clean	Improve Manholes	Manhole
Atoka	03/18/08	S10403	250,000	Rain	Cleaned		Manhole
Atoka	04/04/08	S10403	20,000	Rain	Clean		Manhole
Atoka	04/09/08	S10403	200,000	Flooding	Clean	Upgrade System	Manhole
Atoka	04/28/08	S10403	100,000	Malfunction	Clean	Repair	Clarifier
Atoka	04/29/08	S10403	500	Stopped Main	Cleaned		Pipe
Atoka	05/18/08	S10403	750	Grease	Cleaned	Jetted	Manhole
Atoka	08/22/08	S10403	150,000	Flooding	Cleaned	Improving Ststem	Manhole
Atoka	10/21/08	S10403	3,000	Blockage	Lime	Check Daily	Pipe
Atoka	01/05/09	S10403	2,000	Blockage	Washed	Cleared	Manhole
Atoka	01/06/09	S10403	2,000	Blockage	Lime		Manhole
Atoka	01/07/09	S10403	1,000	Grease Ball	Lime	Sewer Machine	Manhole
Atoka	01/08/09	S10403	10,000	Grease	Lime		Manhole
Atoka	01/23/09	S10403	1,000	Blockage	Lime	Clear	Manhole
Atoka	01/28/09	S10403	1,000	Blockage	Lime	Jetted	Manhole
Atoka	03/02/09	S10403	5,000	Flooding	Clean	Talk To Homeowner	Pipe
Atoka	03/03/09	S10403	20,000	Grease	Lime	Jetted	Manhole
Atoka	05/05/09	S10403	10,000	Rain	Lime	Upgrade	Manhole
Atoka	05/10/09	S10403	100,000	Rain	Clean		Manhole
Atoka	05/19/09	S10403	50,000	Debris	Lime		Manhole
Atoka	06/02/09	S10403	100,000	Flooding	Cleaned	Minimal	Manhole
Atoka	06/03/09	S10403	5,000	I&I	Lime	Test & Repair	Pipe
Atoka	06/03/09	S10403	10,000	I&I	Lime	Replace Main	Pipe
Atoka	06/03/09	S10403	20,000	I&I	Lime	Smoke Test & Repair	Manhole
Atoka	08/03/09	S10403	1,000	Collapsed Main	C & S	Repair	Manhole
Atoka	08/20/09	S10403	1,000	Malfunction	Lime	Repair	Pipe
Atoka	09/27/09	S10403	20,000	Pump Failure	Lime	Rebuild	Lift Station
Atoka	10/09/09	S10403	20,000	Rains	Lime	Replace & Upgrade	Manhole
Atoka	10/19/09	S10403	20,000	Overflow From Putting In New Equipment	C & S		Lift Station
Atoka	10/22/09	S10403	20,000	Flooding	C & S	Replace Lines	Manhole
Atoka	10/22/09	S10403	100,000	Flooding	C & S	Repair Pipe	Pipe
Atoka	10/26/09	S10403					Manhole
Atoka	12/17/09	S10403	3,000	Blockage	C & S	Follow Up Checking	Manhole
Atoka	12/18/09	S10403	3,000	Blockage	C & S	Recheck	Manhole
Atoka	01/08/10	S10403	1,500	Blockage	Limed	Replacing Line	Pipe

Facility Name	Bypass Date	Facility Id	Amount (Gallons)	Cause	Cleanup	Preventive	Type Of Source
Atoka	01/23/10	S10403	1,000	Grease	Lime	Jetted	Manhole
Atoka	01/25/10	S10403	10,00	Blockage	Limed	Jetted	Manhole
Atoka	02/05/10	S10403	5,000	Grease	C & D	Check Daily & Treat	Pipe
Atoka	03/18/10	S10403	10,000	Power Failure	Clean	Backup Generator	Lift Station
Atoka	03/22/10	S10403	5,000	Blockage	Limed	Reclean	Manhole
Atoka	03/29/10	S10403	10,000	Collapsed Main	Limed	Replaced	Pipe
Atoka	05/05/10	S10403	20,000	Pump Failure	C & D	Completed Connection To New System	Manhole
Atoka	06/22/10	S10403	1,500	Clogged Pump	Lime	Clean	
Atoka	10/14/10	S10403	100	Blockage		Rodded	Manhole
Atoka	11/30/10	S10403	20,000	Pump Malfunction	C & S	Repair	Lift Station
Atoka	12/13/10	S10403	1,000	Debris	Lime	Install Screen	Lift Station
Atoka	12/21/10	S10403	2,000	Collapsed Main	Lime	Repair	Pipe
Atoka	12/31/10	S10403	500	Debris	Lime	Apply For Grant To Replace Main	Pipe
Atoka	01/05/11	S10503	10,000	Electrical Failure	Lime	Install Generator	Lift Station
Atoka	01/19/11	S10403	5,000	Grease	Lime	Grease Control	Manhole
Atoka	01/20/11	S10403	2,000	Blockage	C & S	Monitor & Upgrade	Pipe
Atoka	03/06/11	S10403	3,000	Grease	Limed	Degreaser	Manhole
Atoka	03/22/11	S10403	1,000	Grease	Lime	None	Manhole
Atoka	04/06/11	S10422	50	Blockage	Limed	Removed	Manhole
Atoka	04/11/11	S10403	20,000	Debris	Lime	Repairing	Manhole
Atoka	05/01/11	S10403	100,000	Rain	Lime	Smoke Testing	Manhole
Atoka	05/12/11	S10403	3,000	Flood	Lime	Repair Pump	Manhole
Atoka	05/16/11	S10403	1,000	Pump Failure	Limed	Install A Grinder Pump	Manhole
Atoka	08/12/11	S10403	60,000	Power Outage Caused Power Failure To Lift Station Pumps	Limed Area	Will Be Upgrading Pump Station W/ Sewer Plant Renovations	Pipe
Coalgate	01/16/07	S10402	10,000	Power Outage			Lift Station
Coalgate	05/09/07	S10402	10,000	Main Break	Washed	Filled Sink Hole	Pipe
Coalgate	05/09/07	S10402	15,000	Main Break	Washed	Repair	Manhole
Coalgate	10/24/09	S10402	50,000	Pipe Cave In	None	Replacing	Pipe
Coalgate	10/24/09	S10402		Pipe Collapsed	Sewer Confined In Ditch Line	Repair	
Coalgate	10/24/09	S10402		Broken Pipe		Repairing	Pipe
Coalgate	10/24/09	S10402		Broken Pipe		Repairing	Pipe
Coalgate	10/24/09	S10402		Broken Pipe		Replace	Pipe
Coalgate	10/24/09	S10402		Broken Pipe		Repairing	Pipe

Facility Name	Bypass Date	Facility Id	Amount (Gallons)	Cause	Cleanup	Preventive	Type Of Source
Coalgate	10/24/09	S10402		Broken Pipe		Repairing	Pipe
Coalgate	10/24/09	S10402		Broken Pipe		Repairing	Pipe
Coalgate	10/24/09	S10402		Broken Pipe		Repairing	Pipe