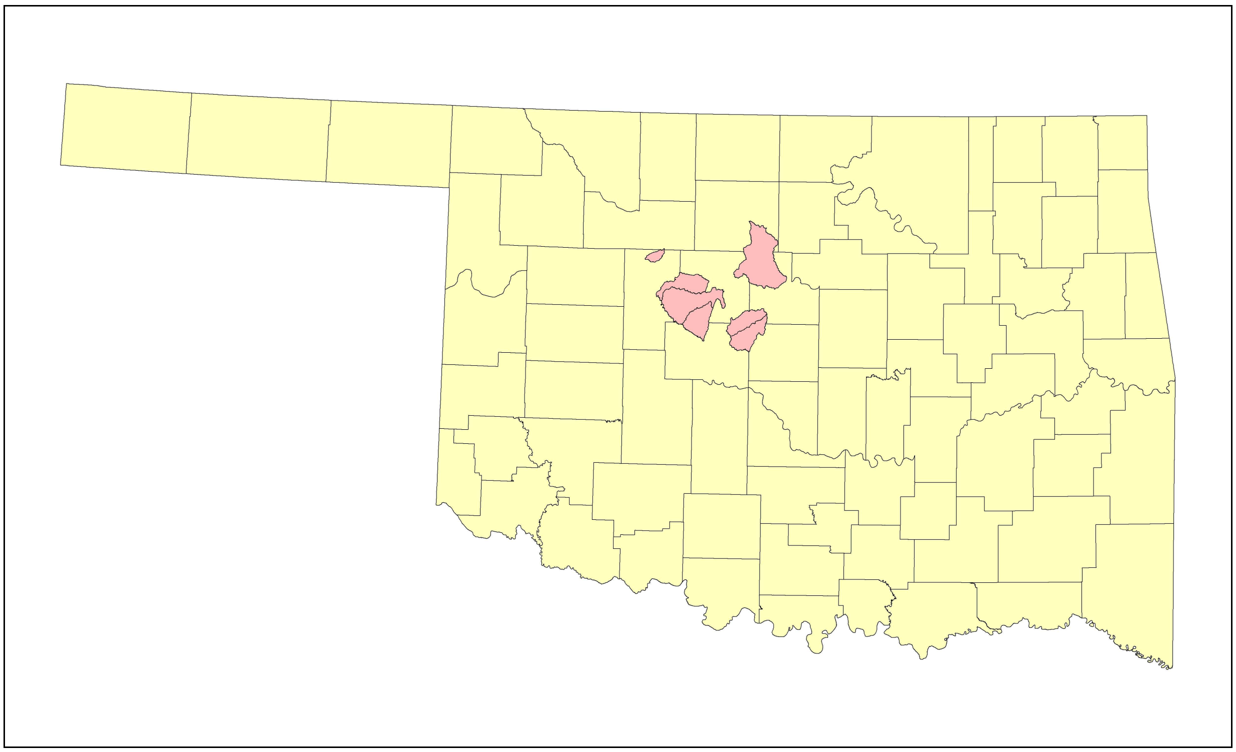
FINAL

TURBIDTY TOTAL MAXIMUM DAILY LOADS FOR THE LOWER CIMARRON RIVER-SKELETON CREEK AREA (OK620910)



Prepared by:

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

APRIL 2010

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OKWBID

OK620910020040_00, OK620910020270_00, OK620910030010_00, OK620910040010_20, OK620910040120_00, OK620910050010_00, OK620910050080_00

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ACRONYMS AND ABBREVIATIONS

BMP	best management practice
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
cfs	Cubic feet per second
CPP	Continuing planning process
CWA	Clean Water Act
DMR	Discharge monitoring report
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	microgram per liter
MOS	Margin of safety
MS4	Municipal separate storm sewer system
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resources Conservation Service
NTU	nephelometric turbidity unit
OLS	ordinary least square regression
O.S.	Oklahoma statutes
ODAFF	Oklahoma Department of Agriculture, Food and Forestry
ODEQ	Oklahoma Department of Environmental Quality
OPDES	Oklahoma Pollutant Discharge Elimination System
OWRB	Oklahoma Water Resources Board
PRG	Percent reduction goal
TMDL	Total maximum daily load
TSS	Total suspended solids
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WLA	Wasteload allocation
WQM	Water quality monitoring
WQS	Water quality standard
WWTP	Wastewater treatment plant

EXECUTIVE SUMMARY

This report documents the data and assessment used to establish turbidity TMDLs for seven stream segments in the Lower Cimarron River-Skeleton Creek study area. Data assessment and TMDL calculations are conducted in accordance with requirements of Section 303(d) of the CWA, Water Quality Planning and Management Regulations (40 CFR Part 130), USEPA guidance, and ODEQ guidance and procedures. ODEQ is required to submit all TMDLs to USEPA for review and approval. Once the USEPA approves a TMDL, the waterbody may be moved to Category 4a of a state's Integrated Water Quality Monitoring and Assessment Report, where it remains until compliance with water quality standards (WQS) is achieved (USEPA 2003).

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

This report does not stipulate specific control actions (regulatory controls) or management measures (voluntary best management practices) necessary to reduce turbidity loadings 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 watershed; tribes; and local, state, and federal government agencies.

E.1 Problem Identification and Water Quality Target

The TMDL in this report address fish and wildlife propagation for the subcategory warm water aquatic community. Table ES-1, an excerpt from Appendix B of the 2008 Integrated Report (ODEQ 2008), summarizes the warm water aquatic community use attainment status and the scheduled date for TMDL development established by ODEQ for the impaired waterbody of the Study Area.

Table ES-1 Excerpt from the 2008 Integrated Report – Comprehensive Waterbody Assessment Category List

Waterbody ID	Waterbody Name	Stream Miles	Category	TMDL Date	Priority	Warm Water Aquatic Community
OK620910020040_00	Cooper Creek	40.27	5a	2016	3	N
OK620910020270_00	Elm Creek	14.15	5a	2019	4	N
OK620910030010_00	Skeleton Creek	32.84	5a	2019	4	N
OK620910040010_20	Cottonwood Creek	24.39	5a	2010	1	N
OK620910040120_00	Deer Creek	12.67	5a	2010	1	N
OK620910050010_00	Kingfisher Creek	47.37	5a	2019	4	N
OK620910050080_00	Dead Indian Creek	24.23	5a	2019	4	N

N = Not Supporting;
5a = TMDL is underway or will be scheduled
Source: 2008 Integrated Report, ODEQ 2008

The data in Table ES-2 were used to support the decision to place the seven stream segments on the ODEQ 2008 303(d) list (ODEQ 2008 for nonsupport of the Fish and Wildlife Propagation use based on turbidity levels observed in the waterbody. 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) is used as a surrogate in this TMDL. Therefore, both turbidity and TSS data are presented to support TMDL development.

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 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." An individual water quality target established for turbidity must demonstrate compliance with the numeric criteria prescribed in the Oklahoma WQS (OWRB 2008a). According to the Oklahoma WQS [785:45-5-12(f)(7)], the turbidity criterion for streams with warm water aquatic community (WWAC) beneficial use is 50 NTUs (OWRB 2008a). 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.

Table ES-2 Summary of Turbidity Samples Collected During Base Flow Conditions 1998 – 2008

WQM Station	Stream	Number of Turbidity Samples	Number of Samples Exceed 50 (NTU)	Percentage of Samples Exceeding Criterion	Average Turbidity (NTU)
OK620910-02-0040C	Cooper Creek	19	6	31.6%	47.0
OK620910-02-0270G	Elm Creek	18	5	27.8%	38.4
OK620910030010-001AT OK620910-03-0010F OK620910-03-0010S	Skeleton Creek	108	68	63.0%	81.9
OK620910-04-0010G	Cottonwood Creek	19	2	10.5%	38.5
OK620910-04-0120B	Deer Creek	15	6	40.0%	41.6
OK620910-05-0010G OK620910-05-0010J	Kingfisher Creek	12	4	33.3%	62.8
OK620910-05-0080D	Dead Indian Creek	17	3	17.6%	24.5

TMDLs for turbidity in streams designated as warm water aquatic community must take into account that no more than 10 percent of the samples may exceed the numeric criterion of 50 NTU. However, as described above, because turbidity cannot be expressed as a mass load, TSS is used as a surrogate in this TMDL. 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 target using TSS, is summarized in Section 4 of 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. Turbidity may originate from NPDES-permitted facilities, fields, construction sites, quarries, stormwater runoff and eroding stream banks.

The 2008 Integrated Water Quality Assessment Report (ODEQ 2008) listed potential sources of turbidity in Cooper Creek (OK620910020040_00), Skeleton Creek (OK620910030010_00), Kingfisher Creek (OK620910050010_00) and Dead Indian Creek (OK620910050080_00) as clean sediment, grazing in riparian corridors of streams and creeks, highway/road/bridge runoff (non-construction related), non-irrigated crop production, rangeland grazing, and other unknown sources. Cooper Creek also had petroleum/natural gas activities as a turbidity source and Skeleton, Kingfisher, and Dead Indian Creeks also had other spill related impacts as a source. Elm Creek (OK620910020270_00) and Deer Creek (OK620910040120_00) had agriculture and other unknown sources while turbidity sources of Cottonwood Creek (OK620910040010_20) are unknown.

There are five active NPDES-permitted municipal WWTPs in the study area. These facilities discharge organic TSS and are not considered a potential source of turbidity for this TMDL. There is one active NPDES-permitted industrial facility operated by Duke Energy located in the Dead Indian Creek watershed. There is a small portion of the Deer Creek watershed located in the Oklahoma City urbanized area designated as an MS4. 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. There are two CAFOs in the study area: one located in the Dead Indian Creek watershed and the other partially located in the Cooper Creek watershed.

The relatively homogeneous land use/land cover categories within the Study Area are associated with agricultural and range management activities. This suggests that various nonpoint sources of TSS include sediments originating from grazing in riparian corridors of streams and creeks, highway/road/bridge runoff (non-construction related), non-irrigated crop production, rangeland grazing and other sources of sediment loading (ODEQ 2008). Elevated turbidity measurements can be caused by stream bank erosion processes, stormwater runoff events and other channel disturbances. However, there is insufficient data available to quantify contributions of TSS from these 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. Sediment loading of streams can also originate from natural erosion processes, including the weathering of soil, rocks, and uncultivated land; geological abrasion; and other natural phenomena. Given the lack of data to establish the background conditions for TSS/turbidity, separating background loading from nonpoint sources is not feasible in this TMDL development.

E.3 Using Load Duration Curves to Develop TMDLs

Turbidity is a commonly measured indicator of the suspended solids load in streams. However, turbidity is an optical property of water, and 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 and the maximum one-day load the stream can assimilate while still attaining the WQS is calculated in terms of TSS load.

To determine the relationship between turbidity and TSS, a linear regression between TSS and turbidity was developed using data collected from 1998 to 2008 at one station within the

Study Area. Prior to developing the regression the following steps were taken to refine the dataset:

- Replace TSS samples of "<10" mg/L with 5 mg/L;
- Remove data collected under high flow conditions exceeding the base-flow criterion. This means that measurements corresponding to flow exceedance percentiles lower than 25th were not used in the regression;
- Check the Oklahoma Mesonet rainfall data (http://www.mesonet.org) on the day where samples were collected and on the previous two days. If there was a significant rainfall event (≥ 1 inch) on any of these three days, the sample is deemed a rain event sample and is excluded from regression analysis (and the turbidity-based use attainment assessment). This is done to ensure a few potentially high flow samples are not included in the regression analysis (and the use attainment assessment), especially for stream segments with a small overall number of turbidity samples. An exception to this procedure is that if the significant rainfall happened on the sampling day and the turbidity reading was less than 25 NTUs (half of the 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-normal data distributions.

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, may provide insight into whether impairments are associated with point or nonpoint sources. The basic steps to generating an LDC involve:

- obtaining daily flow data for the site of interest from available measured flow when samples were collected, the USGS, or projected flow using Oklahoma TMDL Toolbox if station is ungaged;
- sorting the flow data and calculating flow exceedance percentiles for the time period and season of interest;
- obtaining available turbidity and TSS water quality data;
- matching the water quality observations with the flow data from the same date;
- displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQ_{target} for TSS;
- converting measured concentration values to loads by multiplying the flow at the time the sample was collected by the water quality parameter concentration (for sampling events with both TSS and turbidity data, the measured TSS value is used; if only turbidity was measured, the value was converted to TSS using the regression equation in Figure 4-1 through Figure 4-3); then
- plotting the flow exceedance percentiles and daily load observations in a load duration plot.

The culmination of these steps is expressed in the following example formula for Cooper Creek, which is displayed on the LDC as the TMDL curve:

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

where: WQ_{target} *= 48 mg/L (TSS) for Cooper Creek*

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

The flow exceedance frequency (x-value of each point) is obtained by looking up the historical exceedance frequency of the measured or estimated flow; in other words, the percent of historical observations that equal or exceed the measured or estimated flow. Historical observations of TSS and/or turbidity concentrations are paired with flow data and are plotted on the LDC. The TSS load (or the y-value of each point) is calculated by multiplying the TSS concentration (measured or converted from turbidity) (mg/L) by the instantaneous flow (cfs) at the same site and time, with appropriate volumetric and time unit conversions. TSS loads representing exceedance of water quality criteria fall above the TMDL line.

E.4 TMDL Calculations

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:

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

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 WQS will be met. Thus, the allowable pollutant load that can be allocated to point and nonpoint sources can then be defined as the TMDL minus the MOS.

The overall Percent Reduction Goal (PRG) is calculated as the reduction in load required so no more than 10 percent of the samples collected under base-flow conditions would exceed TMDL targets for TSS. The required reduction rates are provided in Table ES-3.

Table ES-3 TMDL Reduction Rate for Each Stream

Stream ID	Stream Name	Reduction Rate
OK620910020040_00	Cooper Creek	**63%**
OK620910020270_00	Elm Creek	**55%**
OK620910030010_00	Skeleton Creek	**75%**
OK620910020040_00	Cottonwood Creek	**71%**
OK620910020040_00	Deer Creek	**18%**
OK620910020040_00	Kingfisher Creek	**18%**
OK620910020040_00	Dead Indian Creek	**11%**

The maximum assimilative capacity of a stream depends on the flow conditions of the stream. The higher the flow is, the more wasteload the stream can handle without violating water quality standards. Thus, the TMDL, WLA, LA, and MOS will vary with flow condition, and are calculated at every 5th flow interval percentile. Table ES-4 is an example of TMDL calculations for Cooper Creek.

Table ES-4 Turbidity TMDL based on Total Suspended Solids Calculations for Cooper Creek (OK620910020040_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WWTP (lbs/day)	MS4 (lbs/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	3,347.5	N/A	0.0	0.0	N/A	N/A	N/A
5	64.0	N/A	0.0	0.0	N/A	N/A	N/A
10	24.8	N/A	0.0	0.0	N/A	N/A	N/A
15	16.3	N/A	0.0	0.0	N/A	N/A	N/A
20	12.1	N/A	0.0	0.0	N/A	N/A	N/A
25	9.1	2,359.1	0.0	0.0	23.6	2,099.6	235.9
30	7.9	2,044.6	0.0	0.0	20.4	1,819.7	204.5
35	6.6	1,730.0	0.0	0.0	17.3	1,539.7	173.0
40	6.0	1,572.7	0.0	0.0	15.7	1,399.7	157.3
45	5.6	1,462.6	0.0	0.0	14.6	1,301.8	146.3
50	5.0	1,305.4	0.0	0.0	13.1	1,161.8	130.5
55	4.5	1,163.8	0.0	0.0	11.6	1,035.8	116.4
60	4.1	1,069.5	0.0	0.0	10.7	951.8	106.9
65	3.7	975.1	0.0	0.0	9.8	867.8	97.5
70	3.4	880.7	0.0	0.0	8.8	783.9	88.1
75	3.0	786.4	0.0	0.0	7.9	699.9	78.6
80	2.7	692.0	0.0	0.0	6.9	615.9	69.2
85	2.2	581.9	0.0	0.0	5.8	517.9	58.2
90	1.7	440.4	0.0	0.0	4.4	391.9	44.0
95	1.2	314.5	0.0	0.0	3.1	279.9	31.5
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0

E.5 Reasonable Assurance

ODEQ will collaborate with a host of other state agencies and local governments working within the boundaries of state and local regulations to target available funding and technical assistance to support implementation of pollution controls and management measures. Various water quality management programs and funding sources provide a reasonable assurance that the pollutant reductions as required by this TMDL can be achieved and water quality can be restored to maintain designated uses. ODEQ's Continuing Planning Process (CPP), required by the CWA §303(e)(3) and 40 CFR 130.5, summarizes Oklahoma's commitments and programs aimed at restoring and protecting water quality throughout the state (ODEQ 2006). The CPP can be viewed from ODEQ's website. Table 5-9 provides a partial list of the state partner agencies ODEQ will collaborate with to address point and nonpoint source reduction goals established by TMDLs.

SECTION 1
INTRODUCTION

1.1 TMDL Program Background

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

This report documents the data and assessment used to establish turbidity TMDLs for seven stream segments in the Lower Cimarron River-Skeleton Creek: Cooper Creek, Elm Creek, Skeleton Creek, Cottonwood Creek, Deer Creek, Kingfisher Creek, and Dead Indian Creek. The 2008 Integrated Water Quality Assessment Report (Oklahoma Department of Environmental Quality [ODEQ] 2008) identified these seven streams as impaired for turbidity. Data assessment and TMDL calculations are conducted in accordance with requirements of Section 303(d) of the CWA, Water Quality Planning and Management Regulations (40 CFR Part 130), USEPA guidance, and ODEQ guidance and procedures. ODEQ is required to submit all TMDLs to USEPA for review and approval. Once the USEPA approves a TMDL, the waterbody may be moved to Category 4a of a state's Integrated Water Quality Monitoring and Assessment Report, where it remains until compliance with water quality standards (WQS) is achieved (USEPA 2003).

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

This report does not stipulate specific control actions (regulatory controls) or management measures (voluntary best management practices) necessary to reduce turbidity loadings 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 watershed; tribe;, and local, state, and federal government agencies.

This TMDL report focuses on waterbodies that ODEQ placed in Category 5 [303(d) list] of the *Water Quality in Oklahoma, 2008 Integrated Report* (2008 Integrated Report) for the beneficial use category Fish and Wildlife Propagation for:

- Cooper Creek (OK620910020040_00),
- Elm Creek (OK620910020270_00),
- Skeleton Creek (OK620910030010_00),
- Cottonwood Creek (OK620910040010_20),
- Deer Creek (OK620910040120_00),
- Kingfisher Creek (OK620910050010_00), and
- Dead Indian Creek (OK620910050080_00).

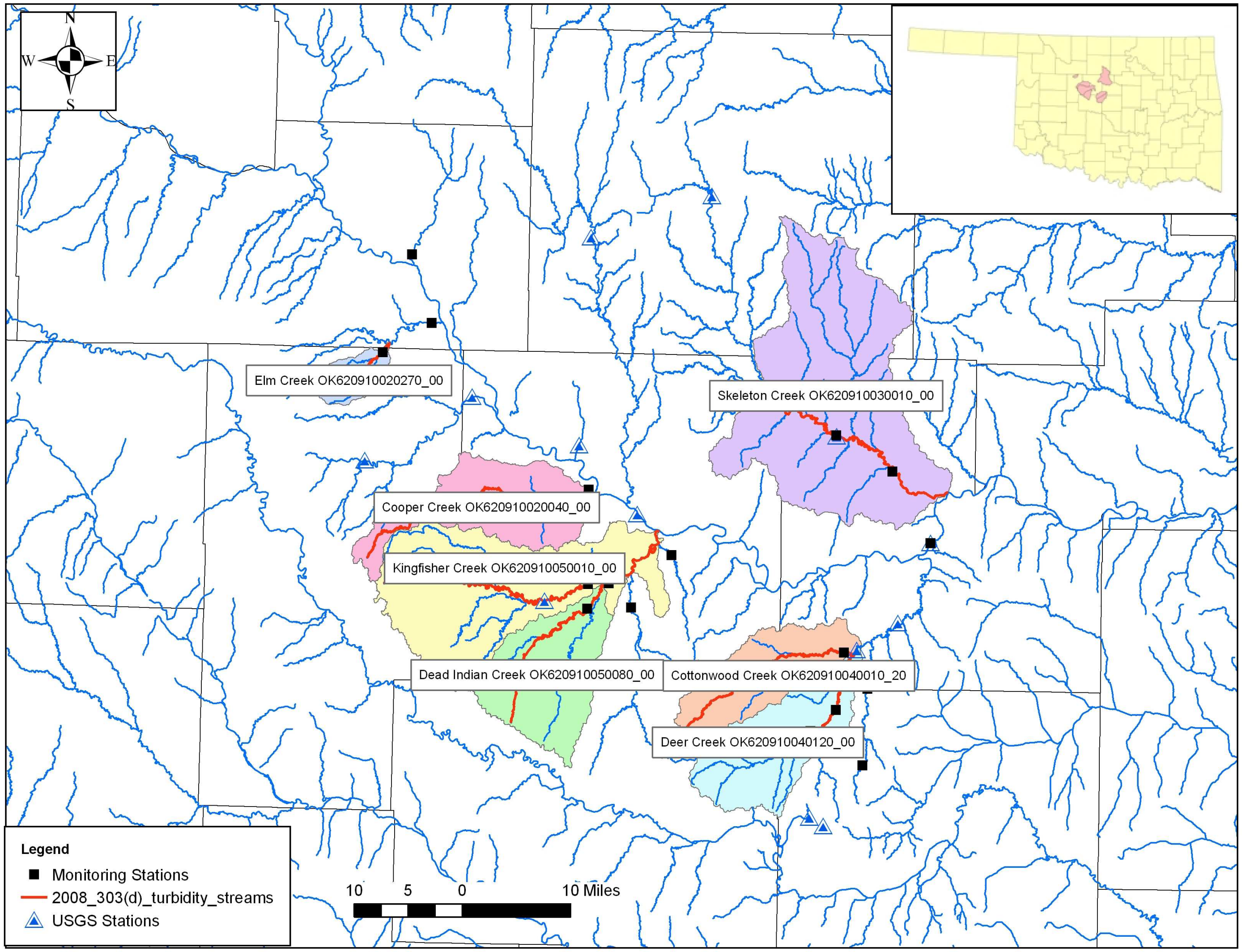
Figure 1-1 is a location map showing the impaired segments of these Oklahoma waterbodies and their contributing watershed. This map also displays the locations of the water quality monitoring (WQM) stations used as the basis for placement of these waterbodies on the Oklahoma 303(d) list. The waterbodies and surrounding watershed are hereinafter referred to as the Study Area.

The TMDLs established in this report are a necessary step in the process to develop the turbidity controls needed to restore the fish and wildlife propagation use designated for the waterbody. Table 1-1 provides a description of the locations of the WQM stations on the 303(d)-listed waterbody.

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

Waterbody Name	Waterbody ID	WQM Station	WQM Station Location Descriptions
Cooper Creek	OK620910020040_00	OK620910-02-0040C	Cooper Creek
Elm Creek	OK620910020270_00	OK620910-02-0270G	Elm Creek
Skeleton Creek	OK620910030010_00	OK620910030010-001AT OK620910-03-0010F OK620910-03-0010S	Skeleton Creek, SH74, Lovell Skeleton Creek: Lower Skeleton Creek: Upper
Cottonwood River	OK620910040010_20	OK620910-04-0010G	Cottonwood Creek
Deer Creek	OK620910040120_00	OK620910-04-0120B	Deer Creek: Logan County
Kingfisher Creek	OK620910050010_00	OK620910-05-0010G OK620910-05-0010J	Kingfisher Creek
Dead Indian Creek	OK620910050080_00	OK620910-05-0080D	Dead Indian Creek

Figure 1-1 Watersheds Not Supporting Fish and Wildlife Propagation Use within the Study Area



1.2 Watershed Description

General. The watersheds in the Lower Cimarron River-Skeleton Creek area addressed in these TMDLs are located in north-central Oklahoma. The 7 waterbodies included in this report are located in Garfield, Blaine, Kingfisher, Logan, Canadian, and Oklahoma Counties.

Within the Level IV ecoregion classification, most of the study area falls into the Prairie Tableland ecoregion. The Pleistocene Sand Dunes ecoregion is sandwiched in the middle section of the basin. The Cross Timbers Transition and the North Cross Timbers ecoregions lie to the east edge of the basin in Logan and Oklahoma counties.

Table 1-2, derived from the 2000 U.S. Census, demonstrates that with the exception of Oklahoma County and the metropolitan Oklahoma City portion of the Canadian and Garfield counties, the study area is mostly sparsely populated (U.S. Census Bureau 2000).

Table 1-2 County Population and Density

County Name	Population (2000 Census)	Population Density (per square mile)
Garfield	57,813	54.6
Blaine	11,976	12.9
Kingfisher	13,926	15.4
Logan	33,924	45.6
Canadian	87,697	97.4
Oklahoma	660,448	931.5

Climate. Table 1-3 summarizes the average annual precipitation for each watershed. Average annual precipitation values among the watersheds studied in this portion of Oklahoma ranges between 30.32 and 35.64 inches, increasing from the west to east (Oklahoma Climate Survey, 2005).

Land Use. Table 1-4 summarize the acreages and the corresponding percentages of the land use categories for the contributing watershed associated with each respective Oklahoma waterbody. 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 combination of pasture/hay and cultivated crops are the dominant land use categories in all of the watersheds.

Table 1-3 Average Annual Precipitation by Watershed

Study Area Precipitation Summary		
Waterbody Name	**Waterbody ID**	**Average Annual (Inches)**
Cooper Creek	OK620910020040_00	32.14
Elm Creek	OK620910020270_00	30.80
Skeleton Creek	OK620910030010_00	34.06
Cottonwood Creek	OK620910040010_20	34.76
Deer Creek	OK620910040120_00	35.26
Kingfisher Creek	OK620910050010_00	32.25
Dead Indian Creek	OK620910050080_00	33.11

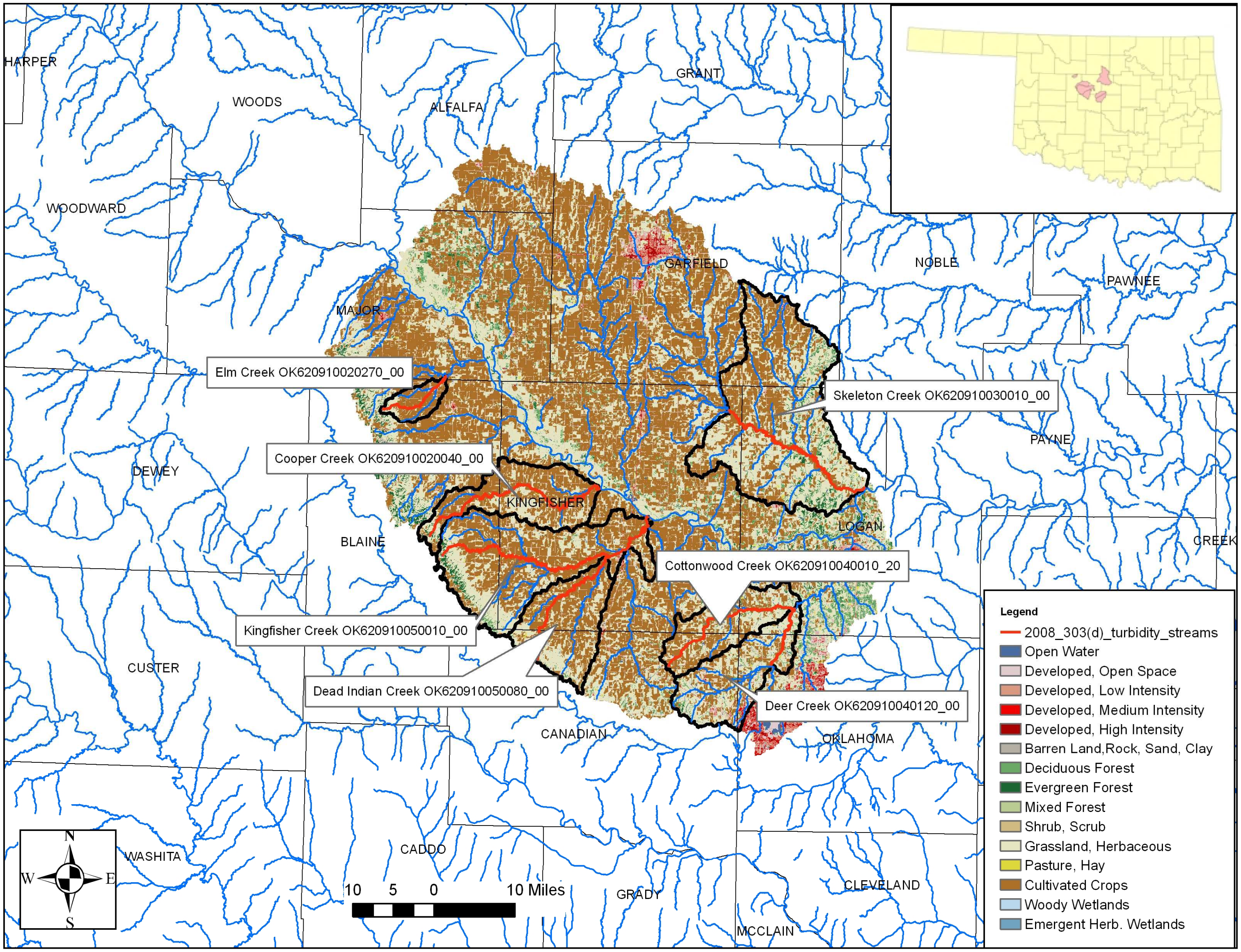
The four cities entirely or partially located in the Skeleton Creek (OK620910030010_00) watershed are Covington, Marshall, Douglas, and Crescent. The City of Kingfisher is scattered in the Kingfisher Creek watershed and its neighboring watersheds. The City of Okarche straddles on Dead Indian Creek watershed and the neighboring Uncle Johns Creek watershed. The City of Piedmont is located mainly in the Deer Creek and Cottonwood Creek watersheds, with small portions in the neighboring Uncle Johns Creek watershed. Cottonwood Creek watershed also has the city of Cashion. A small portion of the City of Oklahoma City is located in the Deer Creek watershed.

Table 1-4 Land Use Summaries by Watershed

Landuse Category	Cooper Creek	Elm Creek	Skeleton Creek	Cottonwood Creek	Deer Creek	Kingfisher Creek	Dead Indian Creek
Waterbody ID	OK620910020040_00	OK620910020270_00	OK620910030010_00	OK620910040010_20	OK620910040120_00	OK620910050010_00	OK620910050080_00
Percent of Open Water	0.24	0.07	0.62	1.56	1.58	0.59	0.53
Percent of Developed, Open Space	4.53	3.50	4.31	4.45	5.98	3.87	3.39
Percent of Developed, Low Intensity	0.26	1.36	0.11	0.27	2.21	0.60	0.42
Percent of Developed, Medium Intensity	0.01	0.01	0.02	0.04	1.32	0.10	0.00
Percent of Developed, High Intensity	0.00	0.01	0.01	0.03	0.13	0.05	0.00
Percent of Barren Land (Rock/Sand/ Clay)	0.04	0.01	0.00	0.00	0.05	0.09	0.07
Percent of Deciduous Forest	0.56	0.17	6.31	3.98	6.86	1.58	1.22
Percent of Evergreen Forest	0.68	0.60	2.07	0.36	0.48	1.80	0.09
Percent of Mixed Forest	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Percent of Shrub/Scrub	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Percent of Grassland/Herbaceous	29.87	27.12	45.38	39.96	49.93	35.69	35.41
Percent of Pasture/Hay	0.14	0.32	0.17	0.08	0.40	0.10	0.29
Percent of Cultivated Crops	63.66	66.85	41.01	49.25	31.07	55.53	58.56
Percent of Woody Wetlands	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Percent of Emergent Herbaceous Wetlands	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Landuse Category	Cooper Creek	Elm Creek	Skeleton Creek	Cottonwood Creek	Deer Creek	Kingfisher Creek	Dead Indian Creek
Waterbody ID	OK620910020040_00	OK620910020270_00	OK620910030010_00	OK620910040010_20	OK620910040120_00	OK620910050010_00	OK620910050080_00
Acres Open Water	182	12	1,339	939	1,144	875	390
Acres Developed, Open Space	3,437	574	9,257	2,676	4,335	5,690	2,509
Acres[a] Developed, Low Intensity	195	222	242	161	1,605	885	310
Acres Developed, Medium Intensity	6	2	45	24	957	147	1
Acres Developed, High Intensity	4	2	13	20	96	70	0
Acres Barren Land (Rock/Sand/Clay)	32	1	0	2	39	137	50
Acres Deciduous Forest	424	27	13,551	2,394	4,974	2,322	905
Acres Evergreen Forest	513	99	4,439	216	344	2,650	65
Acres Mixed Forest	0	2	0	0	0	0	0
Acres Shrub/Scrub	0	0	0	0	0	0	0
Acres Grassland/Herbaceous	22,643	4,444	97,463	24,030	36,189	52,507	26,171
Acres Pasture/Hay	103	53	355	50	287	148	212
Acres Cultivated Crops	48,248	10,955	88,081	29,616	22,516	81,691	43,281
Acres Woody Wetlands	0	0	0	0	0	0	0
Acres Emergent Herbaceous Wetlands	0	0	0	0	0	0	0
Total (Acres)	**75,788**	**16,394**	**214,785**	**60,126**	**72,487**	**147,123**	**73,893**

Figure 1-2 Watershed Land Use Map



1.3 Stream Flow Data

Stream flow characteristics and data are key information when conducting water quality assessments such as TMDLs. The USGS operates flow gages throughout Oklahoma. Kingfisher Creek, Cottonwood Creek, and Skeleton Creek have had a USGS flow gage located in the study watershed currently or previously (Figure 1-1). Some flow measurements were collected at the same time TSS and turbidity water quality samples were collected at various WQM stations. These data are included in Appendix A along with turbidity and TSS data.

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 2008a and 2008b). The 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 2008a). The beneficial uses designated for Cooper Creek (OK620910020040_00), Elm Creek (OK620910020270_00), Skeleton Creek (OK620910030010_00), Cottonwood Creek (OK620910040010_20), Deer Creek (OK620910040120_00), Kingfisher Creek (OK620910050010_00), and Dead Indian Creek (OK620910050080_00) include primary body contact recreation, warm water aquatic community, fish consumption, agriculture and aesthetics. The TMDL in this report addresses the fish and wildlife propagation beneficial use for the subcategory warm water aquatic community. Table 2-1, an excerpt from Appendix B of the 2008 Integrated Report (ODEQ 2008), summarizes the warm water aquatic community use attainment status and the scheduled date for TMDL development established by ODEQ for the impaired waterbody of the Study Area. The 2008 Integrated Report (ODEQ 2008) identifies the target date for TMDL development. The TMDL priority is directly related to the target date and shown in Table 2-1. The TMDL established in this report is a necessary step in the process to restore the fish and wildlife propagation designation for this waterbody.

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:

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

5. Lakes: 25 NTU; and

6. 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.

Table 2-1 Excerpt from the 2008 Integrated Report – Comprehensive Waterbody Assessment Category List

Waterbody ID	Waterbody Name	Stream Miles	Category	TMDL Date	Priority	Warm Water Aquatic Community
OK620910020040_00	Cooper Creek	40.27	5a	2016	3	N
OK620910020270_00	Elm Creek	14.15	5a	2019	4	N
OK620910030010_00	Skeleton Creek	32.84	5a	2019	4	N
OK620910040010_20	Cottonwood Creek	24.39	5a	2010	1	N
OK620910040120_00	Deer Creek	12.67	5a	2010	1	N
OK620910050010_00	Kingfisher Creek	47.37	5a	2019	4	N
OK620910050080_00	Dead Indian Creek	24.23	5a	2019	4	N

N = Not Supporting;
5a = TMDL is underway or will be scheduled
Source: 2008 Integrated Report, ODEQ 2008

To implement Oklahoma's WQS for Fish and Wildlife Propagation, OWRB promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2008b). 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

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) is used as a surrogate in this TMDL. Therefore, both turbidity and TSS data are presented in this section.

Table 2-2 summarizes water quality data collected from the WQM stations between 1998 and 2008 for turbidity. However, as stipulated in Title *785:45-5-12 (f) (7) (C)*, numeric criteria for turbidity only apply under base flow conditions. While the base flow condition is not specifically defined in the Oklahoma Water Quality Standards, DEQ considers base flow conditions to be all flows less than the 25^{th} flow exceedance percentile (i.e., the lower 75 percent of flows) which is consistent with the USGS Streamflow Conditions Index (USGS 2009). Therefore, Table 2-3 was prepared to represent the subset of these data for samples collected during base flow conditions. Water quality samples collected under flow conditions greater than the 25^{th} flow exceedance percentile were therefore excluded from the data set used for TMDL analysis. The data in Table 2-3 were used to support the decision to place the seven stream segments on the ODEQ 2008 303(d) list (ODEQ 2008) for nonsupport of the Fish and Wildlife Propagation use based on turbidity levels observed in the waterbody.

Table 2-2 Summary of All Turbidity Samples 1998 - 2008

WQM Station	Stream	Number of Turbidity Samples	Number of Samples Exceed 50 (NTU)	Percentage of Samples Exceeding Criterion	Average Turbidity (NTU)
OK620910-02-0040C	Cooper Creek	34	12	35.3%	89.3
OK620910-02-0270G	Elm Creek	20	7	35.0%	93.0
OK620910030010-001AT OK620910-03-0010F OK620910-03-0010S	Skeleton Creek	158	107	67.7%	130.7
OK620910-04-0010G	Cottonwood Creek	20	3	15.0%	44.7
OK620910-04-0120B	Deer Creek	21	10	47.6%	55.6
OK620910-05-0010G OK620910-05-0010J	Kingfisher Creek	54	20	37%	87.3
OK620910-05-0080D	Dead Indian Creek	34	9	26.5%	59.2

Table 2-3 Summary of Turbidity Samples Collected During Base Flow Conditions 1998 – 2008

WQM Station	Stream	Number of Turbidity Samples	Number of Samples Exceed 50 (NTU)	Percentage of Samples Exceeding Criterion	Average Turbidity (NTU)
OK620910-02-0040C	Cooper Creek	19	6	31.6%	47.0
OK620910-02-0270G	Elm Creek	18	5	27.8%	38.4
OK620910030010-001AT OK620910-03-0010F OK620910-03-0010S	Skeleton Creek	108	68	63.0%	81.9
OK620910-04-0010G	Cottonwood Creek	19	2	10.5%	38.5
OK620910-04-0120B	Deer Creek	15	6	40.0%	41.6
OK620910-05-0010G OK620910-05-0010J	Kingfisher Creek	12	4	33.3%	62.8
OK620910-05-0080D	Dead Indian Creek	17	3	17.6%	24.5

Table 2-4 summarizes water quality data collected from the WQM stations between 1991 and 2007 for TSS. Table 2-5 presents a subset of these data for samples collected during base flow conditions. Water quality data for turbidity and TSS are provided in Appendix A.

Table 2-4 Summary of All TSS Samples 1998 - 2008

WQM Station	Stream	Number of TSS Samples	Average TSS (mg/L)
OK620910-02-0040C	Cooper Creek	31	73.4
OK620910-02-0270G	Elm Creek	19	50.5
OK620910030010-001AT OK620910-03-0010F OK620910-03-0010S	Skeleton Creek	83	238.3
OK620910-04-0010G	Cottonwood Creek	19	53.3
OK620910-04-0120B	Deer Creek	20	82.3
OK620910-05-0010G OK620910-05-0010J	Kingfisher Creek	51	104.7
OK620910-05-0080D	Dead Indian Creek	31	57.7

Table 2-5 Summary of TSS Samples During Base Flow Conditions 1998 -2008

WQM Station	Stream	Number of TSS Samples	Average TSS (mg/L)
OK620910-02-0040C	Cooper Creek	18	45.9
OK620910-02-0270G	Elm Creek	17	46.5
OK620910030010-001AT OK620910-03-0010F OK620910-03-0010S	Skeleton Creek	48	66.4
OK620910-04-0010G	Cottonwood Creek	18	44.9
OK620910-04-0120B	Deer Creek	14	78.1
OK620910-05-0010G OK620910-05-0010J	Kingfisher Creek	12	33.8
OK620910-05-0080D	Dead Indian Creek	16	22.4

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." An individual water quality target established for turbidity must demonstrate compliance with the numeric criteria prescribed in the Oklahoma WQS (OWRB 2008a). According to the Oklahoma WQS [785:45-5-12(f)(7)], the turbidity criterion for streams with warm water aquatic community (WWAC) beneficial use is 50 NTUs (OWRB 2008a). 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 warm water aquatic community must take into account that no more than 10 percent of the samples may exceed the numeric criterion of 50 NTU. However, as described above, because turbidity cannot be expressed as a mass load, TSS is used as a surrogate in this TMDL. 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 target using TSS is summarized in Section 4 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. Turbidity may originate from NPDES-permitted facilities, fields, construction sites, quarries, stormwater runoff and eroding stream banks.

Point sources are permitted through the NPDES program. NPDES-permitted facilities that discharge treated wastewater are required to monitor for TSS in accordance with their permit. Nonpoint sources are diffuse sources that typically cannot be identified as entering a waterbody through a discrete conveyance at a single location. These sources may involve land activities that contribute TSS to surface water as a result of rainfall runoff. For the TMDL in this report, all sources of pollutant loading not regulated by NPDES permits are considered nonpoint sources.

The 2008 Integrated Water Quality Assessment Report (ODEQ 2008) listed potential sources of turbidity in Cooper Creek (OK620910020040_00), Skeleton Creek (OK620910030010_00), Kingfisher Creek (OK620910050010_00) and Dead Indian Creek (OK620910050080_00) as clean sediment, grazing in riparian corridors of streams and creeks, highway/road/bridge runoff (non-construction related), non-irrigated crop production, rangeland grazing, and other unknown sources. Cooper Creek also had petroleum/natural gas activities as a turbidity source and Skeleton, Kingfisher, and Dead Indian Creeks also had other spill related impacts as a source. Elm Creek (OK620910020270_00) and Deer Creek (OK620910040120_00) had agriculture and other unknown sources while turbidity sources of Cottonwood Creek (OK620910040010_20) are unknown.

3.1 NPDES-Permitted Facilities

Under 40CFR, §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. NPDES-permitted facilities can be characterized as continuous or stormwater related discharges. NPDES-permitted facilities classified as point sources include:

- NPDES municipal wastewater treatment plant (WWTP);
- NPDES Industrial WWTP Discharges;
- NPDES municipal separate storm sewer discharge (MS4);
- NPDES Concentrated Animal Feeding Operation (CAFO);
- NPDES multi-sector general permits; and
- NPDES construction stormwater discharges.

Continuous point source discharges from municipal and industrial WWTPs, could result in discharge of elevated concentrations of TSS if a facility is not properly maintained, is of poor design, or flow rates exceed capacity. However, in most cases suspended solids discharged by WWTPs consist primarily of organic solids rather than inorganic suspended solids (i.e., soil and sediment particles from erosion or sediment resuspension). Discharges of organic suspended solids from WWTPs are addressed by ODEQ through its permitting of point sources to maintain WQSs 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.

Stormwater runoff from MS4 areas, facilities under multi-sector general permits, and NPDES construction stormwater discharges, which are regulated under the USEPA NPDES Program, can contain TSS concentrations. 40 C.F.R. § 130.2(h) requires that NPDES-regulated storm water 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 where Oklahoma's water quality standard for turbidity does not apply. 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)]. 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, WLA for NPDES-regulated storm water discharges is essentially considered unnecessary in this TMDL report and will not be included in the TMDL calculations.

CAFOs are recognized by USEPA as potential significant sources of pollution, and may cause serious impacts to water quality if not properly managed.

3.1.1 Continuous Point Source Discharges

There are five active NPDES-permitted municipal WWTPs in the study area. These facilities discharge organic TSS and is not considered a potential source of turbidity for this TMDL. There is one active NPDES-permitted industrial facility operated by Duke Energy located in the Dead Indian Creek watershed. The location of the discharge is shown in Figure 3-1 and the facility information is listed in Table 3-1. Monthly Discharge Monitoring Report (DMR) data for TSS available for the facility are shown in Table 3-2. There are several permit violations.

Table 3-1 Point Source Discharges in the Study Area

NPDES Permit No.	Name	Receiving Water	Facility Type	County Name	Design Flow (mgd)	Active/ Inactive	Facility ID
OK0036994	Duke Energy Field Services, LP	Unnamed Tributary to Dead Indian Creek	Industrial	Kingfisher	N/A	Active	37000290

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

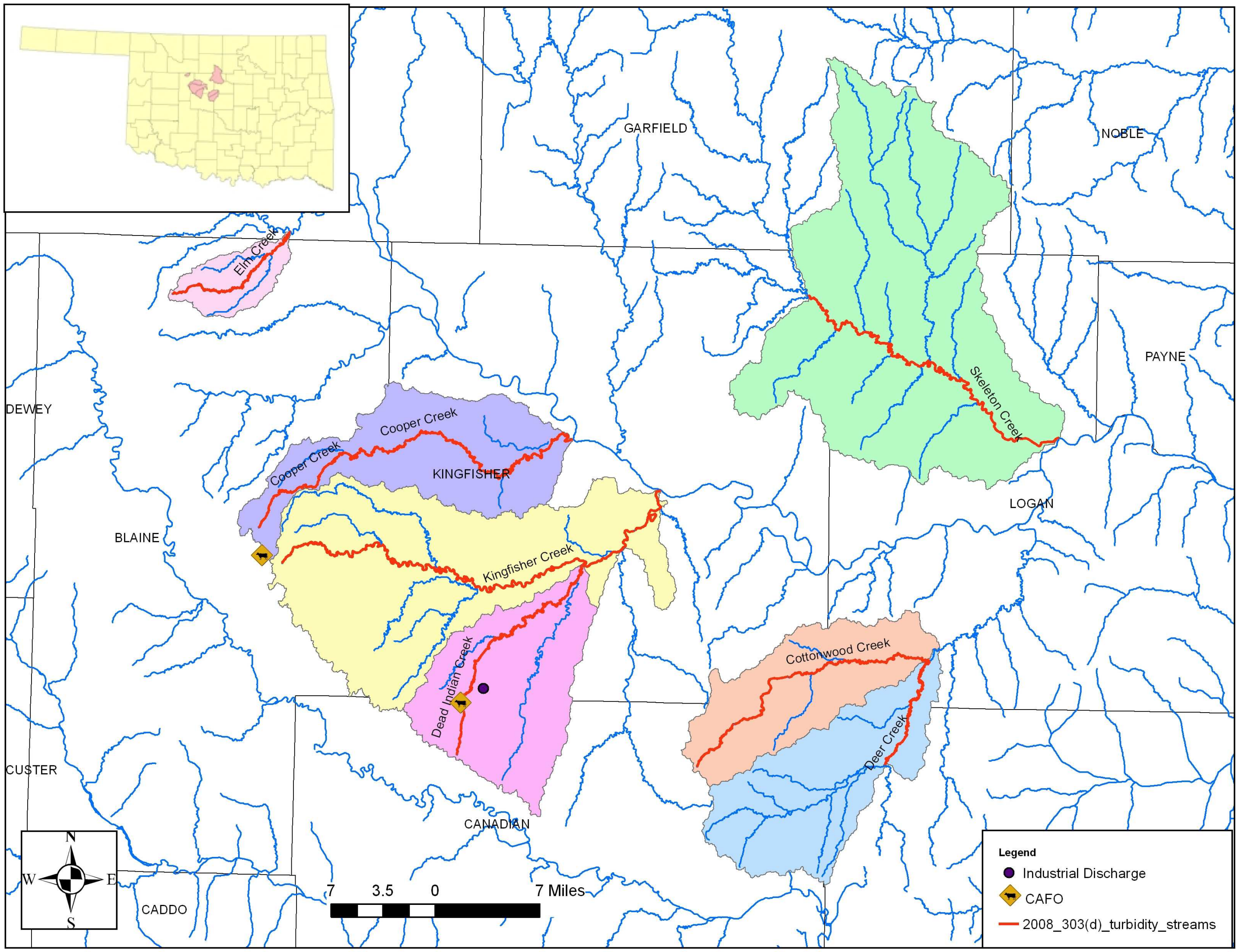


Table 3-2 Discharge Monitoring Data for Industrial Facilities in the Study Area*

NPDES	Monitoring End Date	Outfall	Ave Flow (MGD)	Max Flow (MGD)	Ave TSS (mg/L)	Max TSS (mg/L)
OK0036994	8/31/2006	001A	0.027	0.086	39.7	48
OK0036994	9/30/2006	001A	0.028	0.062	17	17
OK0036994	10/31/2006	001A	0.022	0.064	22	22
OK0036994	11/30/2006	001A	0.019	0.054	< 4.0	< 4.0
OK0036994	12/31/2006	001A	0.02	0.055	18	18
OK0036994	1/31/2007	001A	0.018	0.062	19	19
OK0036994	2/28/2007	001A	0.02	0.053	19	19
OK0036994	3/31/2007	001A	0.023	0.06	17	17
OK0036994	4/30/2007	001A	0.02	0.085	20	20
OK0036994	5/31/2007	001A	0.029	0.066	29	29
OK0036994	6/30/2007	001A	0.025	0.074	30	30
OK0036994	7/31/2007	001A	0.023	0.068	13	13
OK0036994	8/31/2007	001A	0.028	0.062	14	14
OK0036994	9/30/2007	001A	0.015	0.066	29	29
OK0036994	10/31/2007	001A	No discharge	No discharge	No discharge	No discharge
OK0036994	11/30/2007	001A	0.016	0.06	25	25
OK0036994	12/31/2007	001A	0.017	0.065	19	19
OK0036994	1/31/2008	001A	0.011	0.049	24	24
OK0036994	2/29/2008	001A	0.014	0.055	38	38
OK0036994	3/31/2008	001A	0.012	0.054	26	26
OK0036994	4/30/2008	001A	0.013	0.093	28	28
OK0036994	5/31/2008	001A	0.016	0.061	34	34
OK0036994	6/30/2008	001A	0.016	0.054	28	42
OK0036994	7/31/2008	001A	0.02	0.06	31.6	44
OK0036994	8/31/2008	001A	0.02	0.06	18	18
OK0036994	9/30/2008	001A	0.02	0.06	29	29
OK0036994	10/31/2008	001A	0.01	0.08	26	26
OK0036994	11/30/2008	001A	0.01	0.05	33.5	43
OK0036994	12/31/2008	001A	0.01	0.04	20	20
OK0036994	1/31/2009	001A	0.01	0.04	5	5
OK0036994	2/28/2009	001A	0.01	0.04	11	11
OK0036994	3/31/2009	001A	0.01	0.04	26	26
OK0036994	4/30/2009	001A	0.01	0.04	28	28
OK0036994	8/31/08-4/30/09	003A	No Discharge			

* During the current permit cycle.

3.1.2 Concentrated Animal Feeding Operations

The Agricultural Environmental Management Services (AEMS) of the Oklahoma Department of Agriculture, Food and Forestry (ODAFF) was created to help develop, coordinate, and oversee environmental policies and programs aimed at protecting the Oklahoma environment from pollutants associated with agricultural animals and their waste. Through regulations established by the Oklahoma Concentrated Animal Feeding Operation Act, AEMS works with producers and concerned citizens to ensure that animal waste does not impact the waters of the state. 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 is 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 2005). CAFOs are considered no-discharge facilities.

There are two CAFOs located in the study area: one located in the Dead Indian Creek watershed and the other partially located in the Cooper Creek watershed (Table 3-3 and Figure 3-1). Regulated CAFOs within the watershed operate under NPDES permits issued and overseen by EPA. In order to comply with this TMDL, those CAFO permits in the watershed and their associated management plans must be reviewed. Further actions to reduce suspended sediment loads and achieve progress toward meeting the specified reduction goals must be implemented. This provision will be forwarded to EPA, as the responsible permitting agency, and ODAFF for follow up.

Table 3-3 NPDES-Permitted CAFOs in Study Area

ODAFF Owner ID	EPA Facility	ODAFF ID	ODAFF License Number	Maximum Number of Permitted Animals at Facility			Total # of Animal Units at Facility	County	Watershed
				Dairy Heifers	Dairy Cattle	Slaughter Feeder Cattle			
AGN007154	OKG010026	59	4	0	0	3000	3000	Canadian	OK620910050080_00 Dead Indian Creek
AGR001534	OKG010081	309	97	0	0	45,000	45,000	Blaine	OK620910020040_00 Cooper Creek

3.1.3 Stormwater Permits for MS4 and Construction Activities

There is a small portion of the Deer Creek watershed located in the Oklahoma City urbanized area designated as an MS4. A general stormwater permit is required for construction activities. Permittees are authorized to discharge pollutants in stormwater runoff associated with construction activities for construction sites. 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.

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 within the

Study Area are associated with agricultural and range management activities. This suggests that various nonpoint sources of TSS include sediments originating from grazing in riparian corridors of streams and creeks, highway/road/bridge runoff (non-construction related), non-irrigated crop production, rangeland grazing and other sources of sediment loading (ODEQ 2008). Elevated turbidity measurements can be caused by stream bank erosion processes, stormwater runoff events and other channel disturbances. However, there is insufficient data available to quantify contributions of TSS from these 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. Sediment loading of streams can also originate from natural erosion processes, including the weathering of soil, rocks, and uncultivated land; geological abrasion; and other natural phenomena. Given the lack of data to establish the background conditions for TSS/turbidity, separating background loading from nonpoint sources 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:

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

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 WQS will be met. Thus, the allowable pollutant load that can be allocated to point and nonpoint sources can then be defined as the TMDL minus the MOS.

4.1 Determining a Surrogate Target

40 CFR, §130.2(1), states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. Turbidity is a commonly measured indicator of the suspended solids load in streams. However, turbidity is an optical property of water, and 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, expressed as mass per time, is used as a surrogate for turbidity

To determine the relationship between turbidity and TSS, a linear regression between TSS and turbidity was developed using data collected from 1998 to 2008 at one station within the Study Area. Prior to developing the regression the following steps were taken to refine the dataset:

- Replace TSS samples of "<10" mg/L with 5 mg/L;
- 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 the Oklahoma Mesonet rainfall data (http://www.mesonet.org) on the day where samples were collected and on the previous two days. If there was a significant rainfall event (≥ 1 inch) on any of these three days, the sample is deemed a rain event sample and is excluded from regression analysis (and the turbidity-based use attainment assessment). This is done to ensure a few potentially high flow samples are not included in the regression analysis (and the use attainment assessment), especially for stream segments with a small overall number of turbidity samples. An exception to this procedure is that if the significant rainfall happened on the sampling day and the turbidity reading was less than 25 NTUs (half of the 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-normal 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 in-stream turbidity values. For this purpose, an alternate regression fitting procedure known as the line of organic correlation (LOC) was applied. The LOC has three advantages over OLS (Helsel and Hirsch 2002):

- LOC minimizes fitted residuals in both the X and Y directions;
- It provides a unique best-fit line regardless of which parameter 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 *m*1 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 (*b*1) is subsequently found by fitting the line with the LOC slope through the point (mean turbidity, mean TSS). The correlation between TSS and turbidity, along with the LOC and the OLS lines are shown in Figure 4-1 through Figure 4-7.

Figure 4-1 Linear Regression for TSS-Turbidity for Cooper Creek (OK620910020040_00)

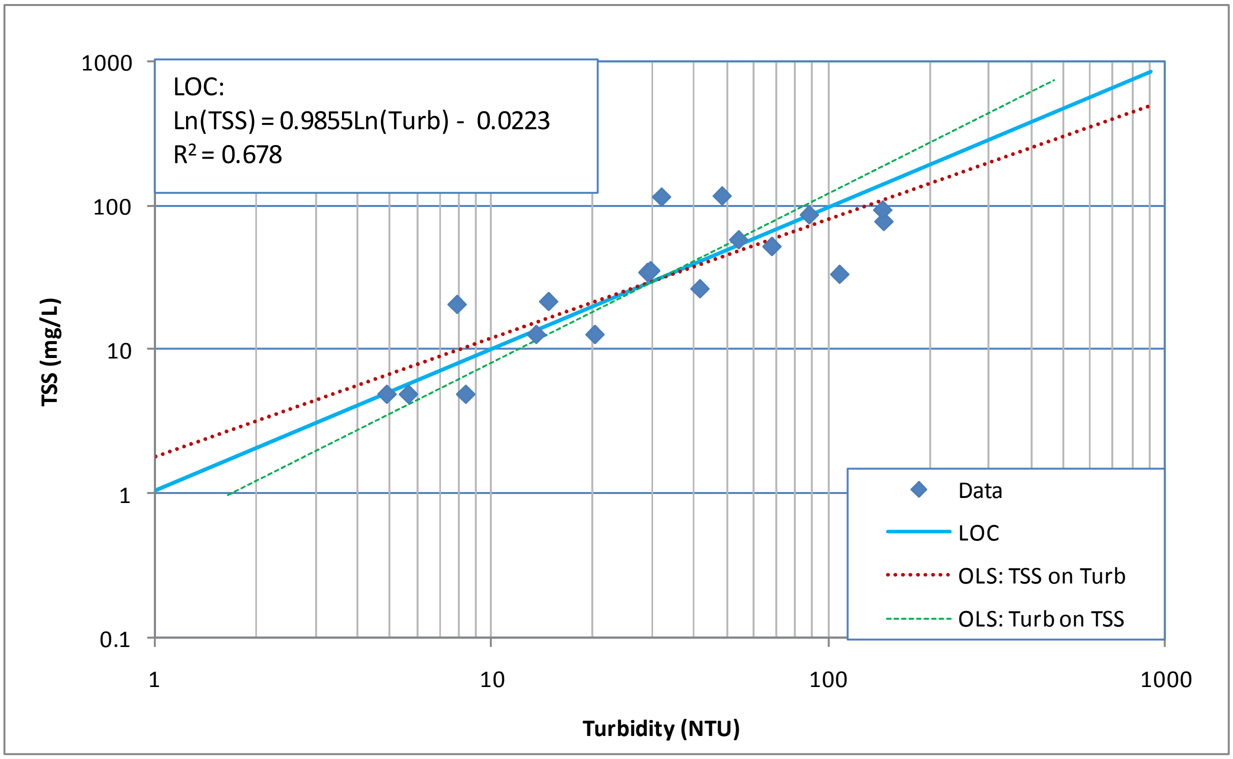


Figure 4-2 Linear Regression for TSS-Turbidity for Elm Creek (OK620910020270_00)

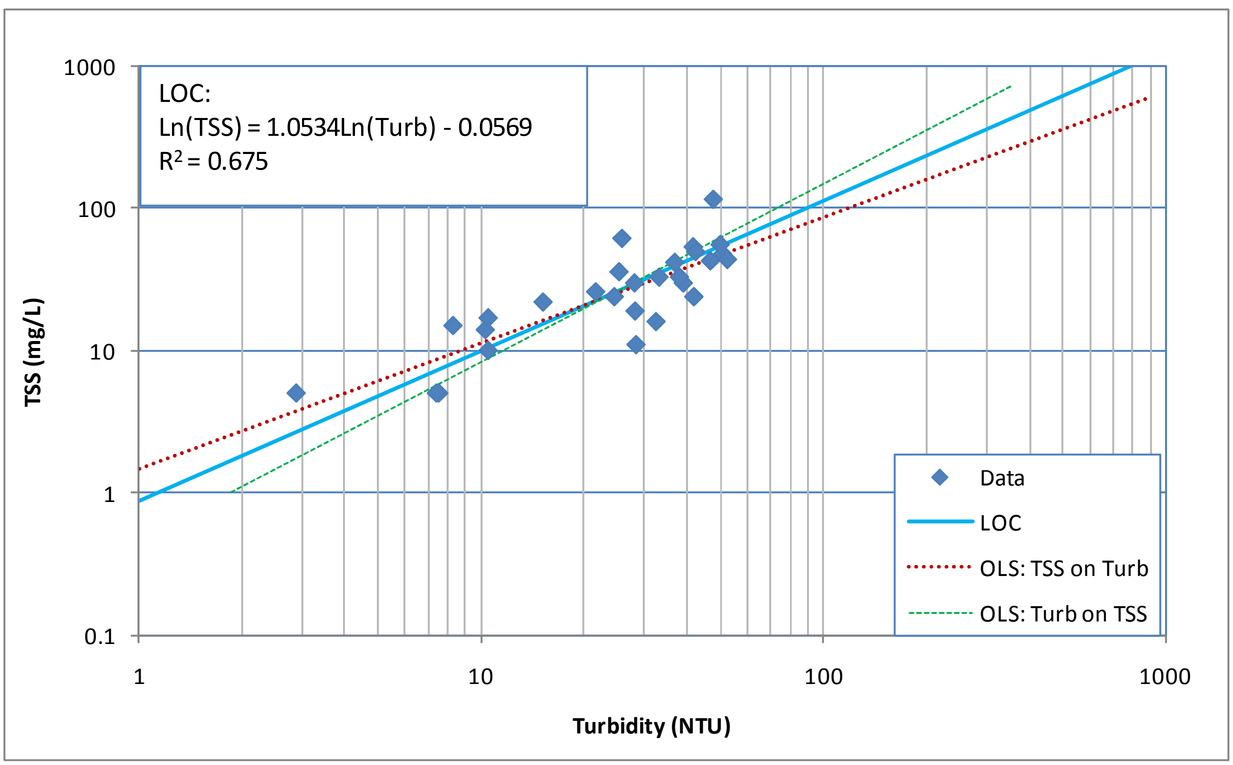


Figure 4-3 Linear Regression for TSS-Turbidity for Skeleton Creek (OK620910030010_00)

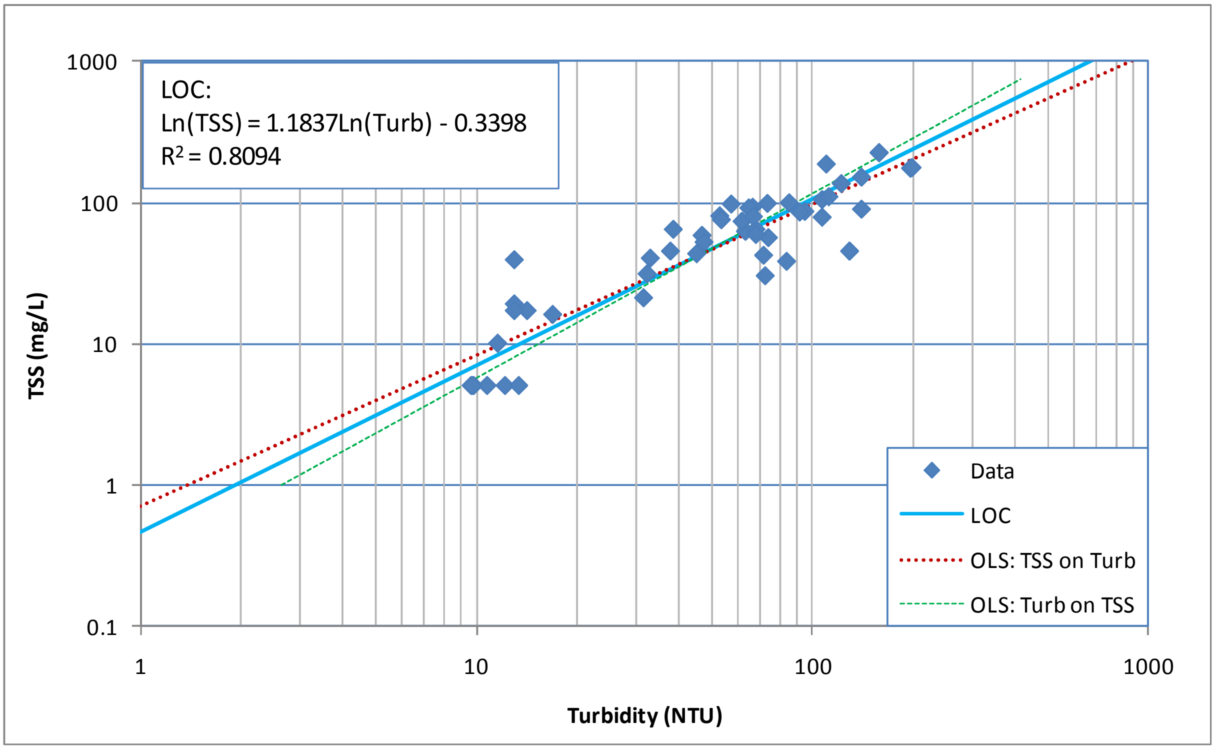


Figure 4-4 Linear Regression for TSS-Turbidity for Cottonwood Creek (OK620910040010_20)

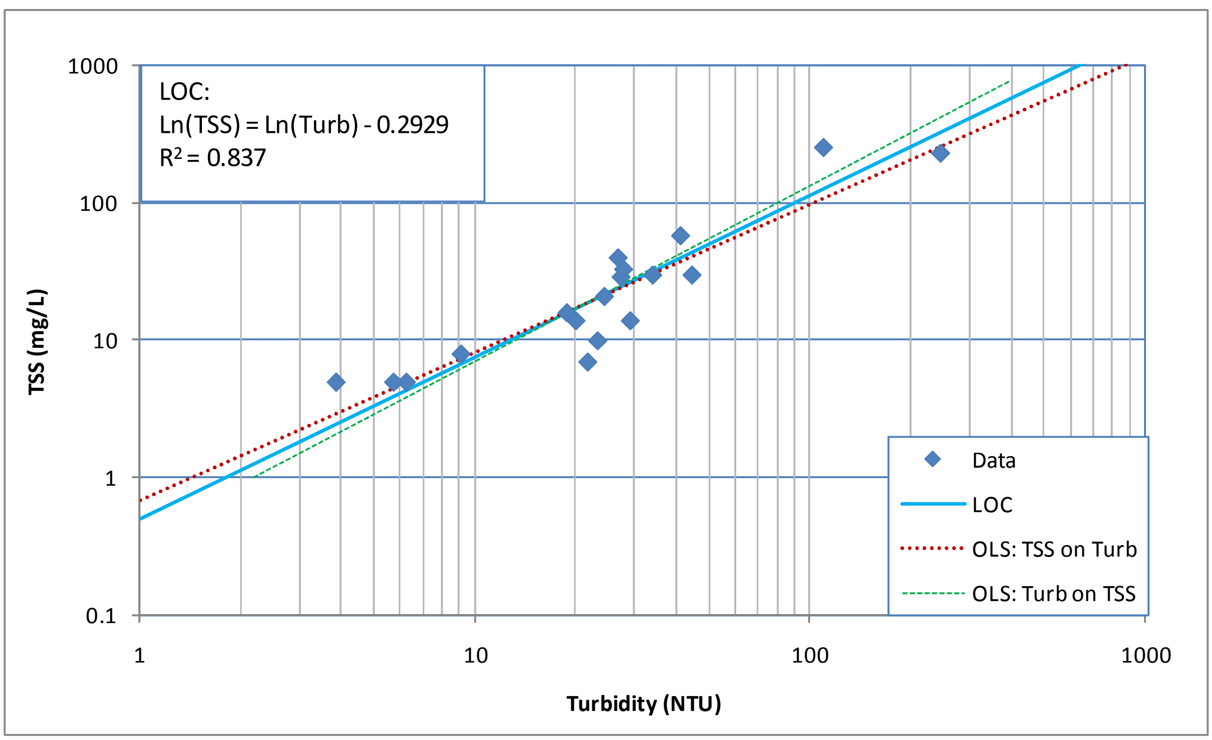


Figure 4-5 Linear Regression for TSS-Turbidity for Deer Creek (OK620910040120_00)

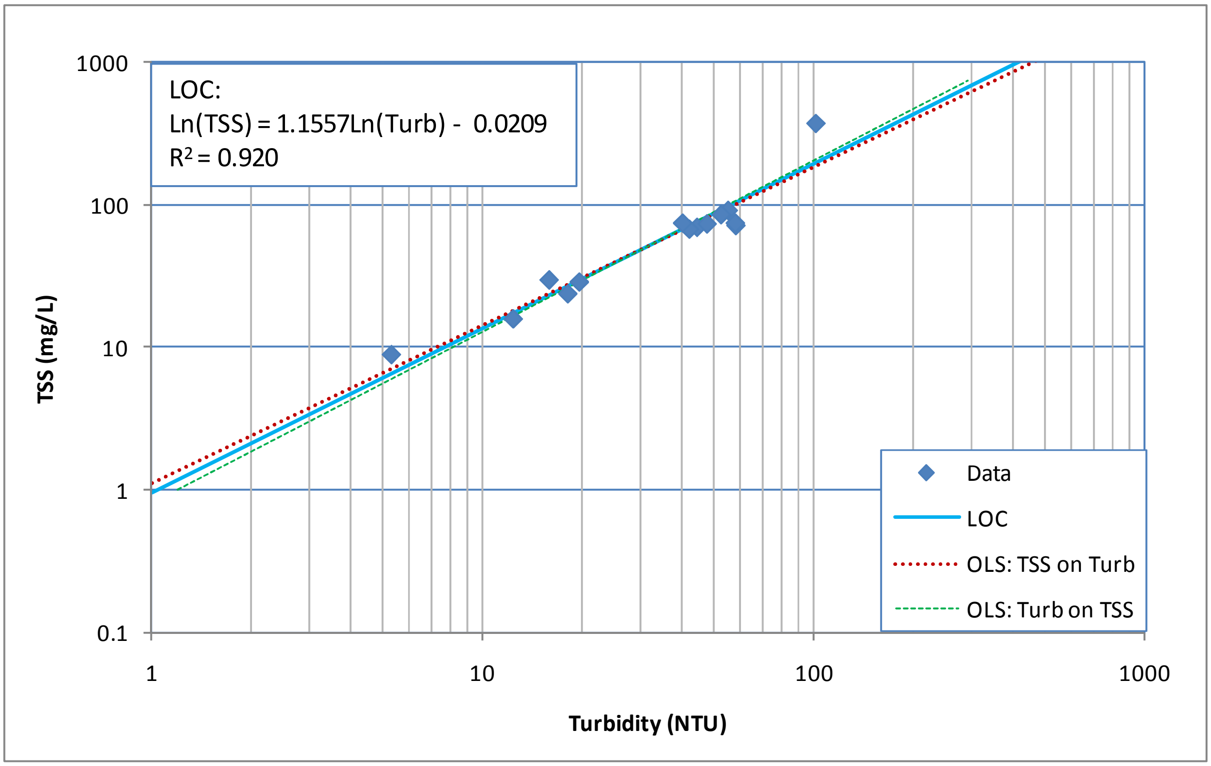


Figure 4-6 Linear Regression for TSS-Turbidity for Kingfisher Creek (OK620910050020_00)

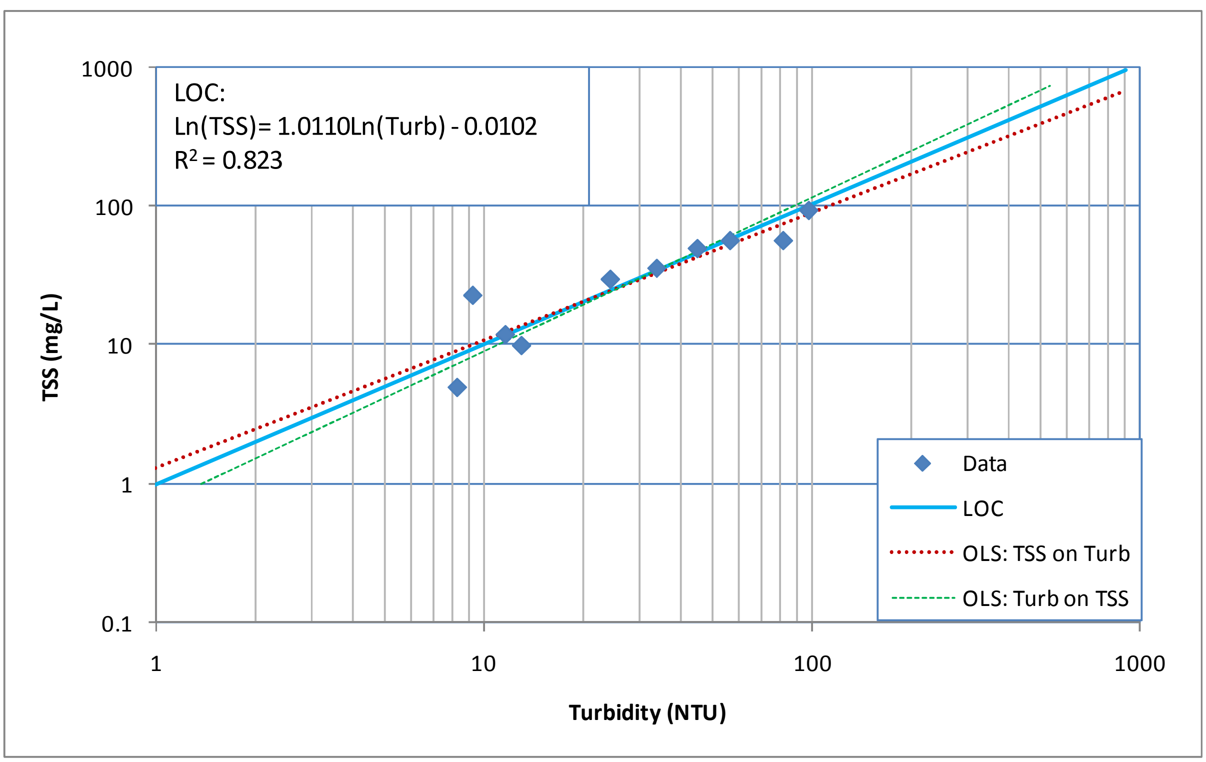
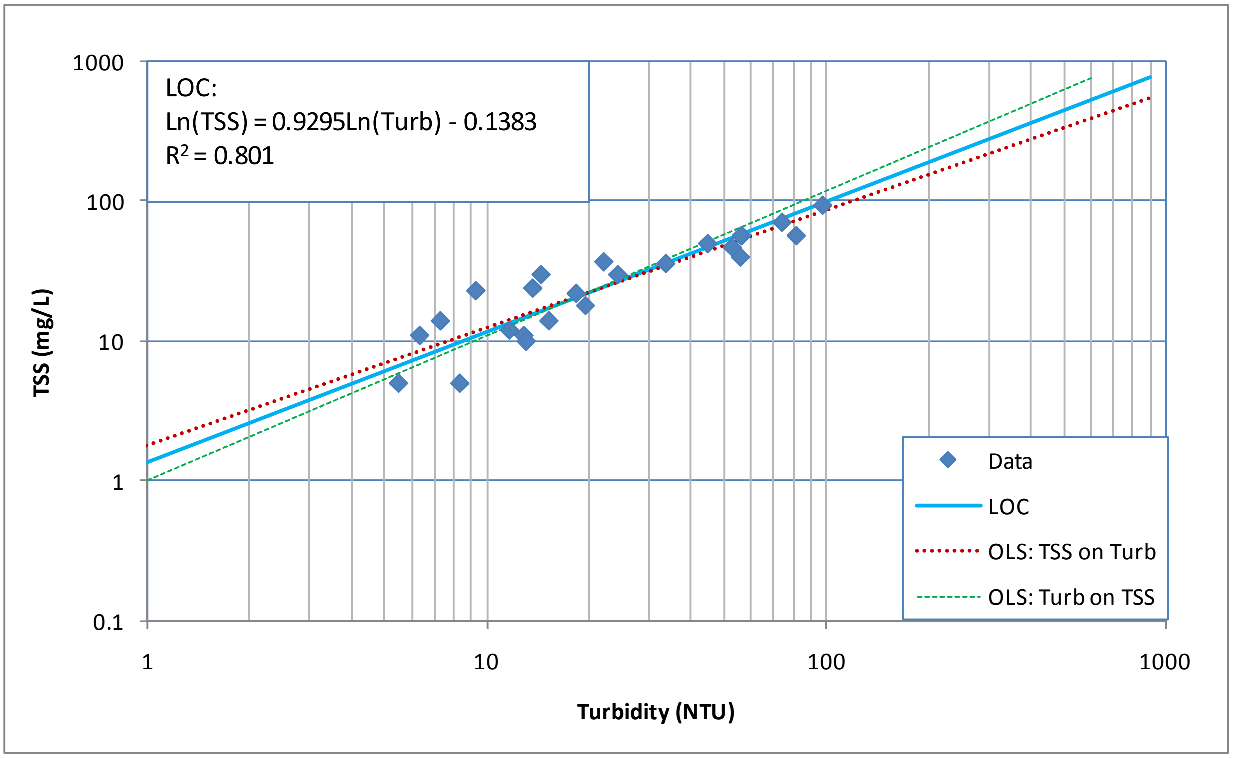


Figure 4-7 Linear Regression for TSS-Turbidity for Dead Indian Creek (OK620910050080_00)



The normalized root mean square error (NRMSE) and R-square (R2) were used as the primary measures of goodness-of-fit. For example, as shown in Figure 4-1, the LOC yields a NRMSE value of 17.3, which means the root mean square error (RMSE) is 17.3% 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. Table 4-1 shows the statistics of the regressions and TSS targets.

Table 4-1 Regression Statistics and TSS Targets

Stream ID	stream Name	R^2	NRMSE	Turbidity Criterion (NTU)	TSS Target (mg/L)
OK620910020040_00	Cooper Creek	0.68	17.3%	50	48
OK620910020270_00	Elm Creek	0.67	13.9%	50	58
OK620910030010_00	Skeleton Creek	0.81	12.1%	50	73
OK620910020040_00	Cottonwood Creek	0.84	15.1%	50	74
OK620910020040_00	Deer Creek	0.92	6.3%	50	90
OK620910020040_00	Kingfisher Creek	0.82	11.2%	50	52
OK620910020040_00	Dead Indian Creek	0.80	11.1%	50	44

It was noted that there were a few outliers that exerted undue influence on the regression relationship. These outliers were identified by applying the Tukey's Boxplot method (Tukey 1977) to the dataset of the distances from observed points to the regression line. The Tukey Method is based on the interquartile range (IQR), the difference between the 75th percentile (Q3) and 25th percentile (Q1) of distances between observed points and the LOC. Using the Tukey method, any point with an error greater than Q3 + 1.5* IQR or less than Q1 – 1.5*IQR was identified as an outlier and removed from the regression dataset. The above regressions were calculated using the dataset with outliers removed.

The Tukey Method is equivalent to using three times the standard deviation to identify outliers if the residuals (observed - predicted) follow a normal distribution. The probability of sampling results being within three standard deviations of the mean 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.

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, may indicate whether impairments are associated with point or nonpoint sources. The technical approach for using LDCs for TMDL development includes the four following steps described in Subsections 4.3 through 4.5 below:

- Preparing flow duration curves for gaged and ungaged WQM stations;
- Estimating loading in the receiving water using measured TSS water quality data and turbidity-converted data; and
- Determining the overall percent reduction goal (PRG) necessary to attain WQS.

Historically, in developing WLAs for pollutants from point sources, it was customary to designate a critical low flow condition (*e.g.*, 7Q2) at which the maximum permissible loading was calculated. As water quality management efforts expanded in scope to quantitatively address nonpoint sources of pollution and various 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 point source discharges would dominate the base flow of the impaired water. However, flow range is only a general indicator of the relative proportion of point/nonpoint contributions. It is not used in this report to quantify point source or nonpoint source contributions. Violations that occur during low flows may not be caused exclusively by point sources. Violations have been noted in some watersheds that contain no point sources.

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

4.3 Development of Flow Duration Curves

Flow duration curves serve as the foundation of LDCs and are graphical representations of the flow characteristics of a stream at a given site. Flow duration curves utilize the historical hydrologic record from stream gages to forecast future recurrence frequencies. Many streams throughout Oklahoma do not have long term flow data and therefore, flow frequencies must be estimated. 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. A more complex approach also considers watershed differences in rainfall, land use, and the hydrologic properties of soil that govern runoff and retention. More than one flow gage may also be considered. A more detailed explanation of the methods for estimating flow at ungaged streams is provided in Appendix B.

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 percent, and may or may not be logarithmic. The lowest measured flow occurs at an exceedance frequency of 100 percent indicating that flow has equaled or exceeded this value 100 percent of the time, while the highest measured flow is found at an exceedance frequency of 0 percent. The median flow occurs at a flow exceedance frequency of 50 percent.

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

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

Flow duration curves were developed when the bacteria TMDLs were developed for these seven streams. The same flow duration curves were used in this report. Please refer to the TMDL report, *Bacteria Total Maximum Daily Loads for the Lower Cimarron River-Skeleton Creek Area (OK620910)* for more details [ODEQ, 2009].

Figure 4-8 through Figure 4-14 show the flow duration curves for the seven stream segments in the study area.

Figure 4-8 Flow Duration Curve for Cooper Creek (OK620910020040_00)

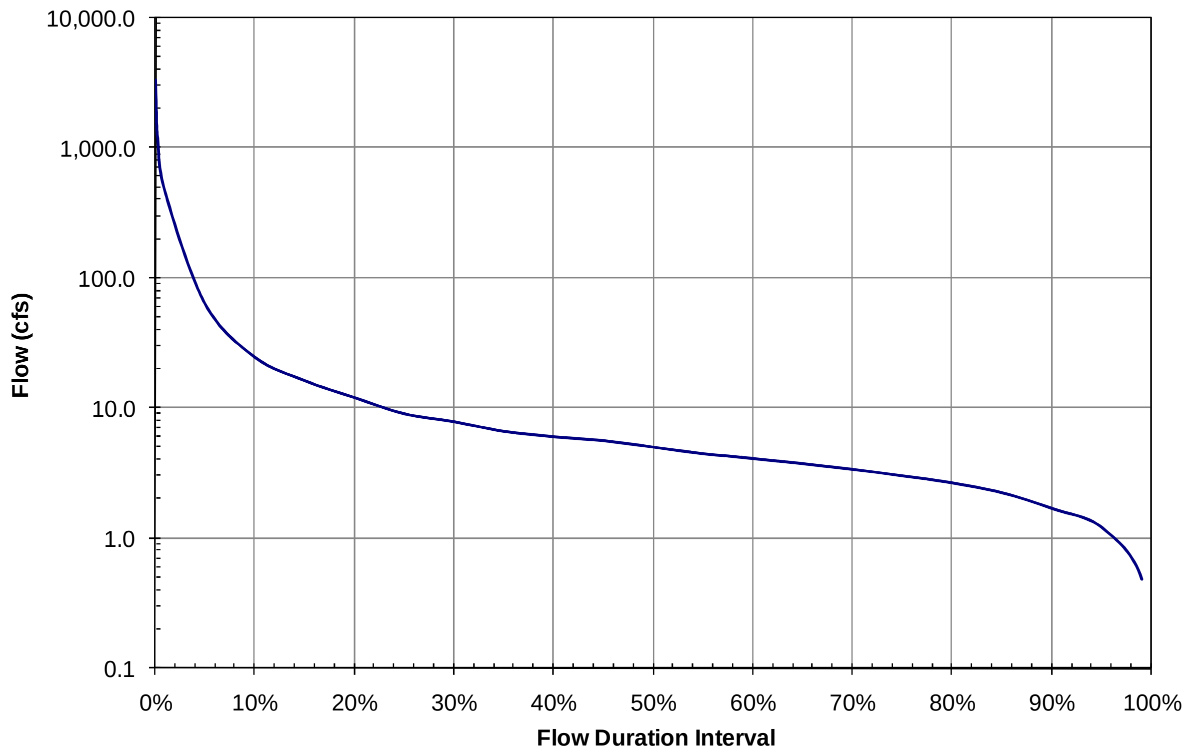


Figure 4-9 Flow Duration Curve for Elm Creek (OK620910020270_00)

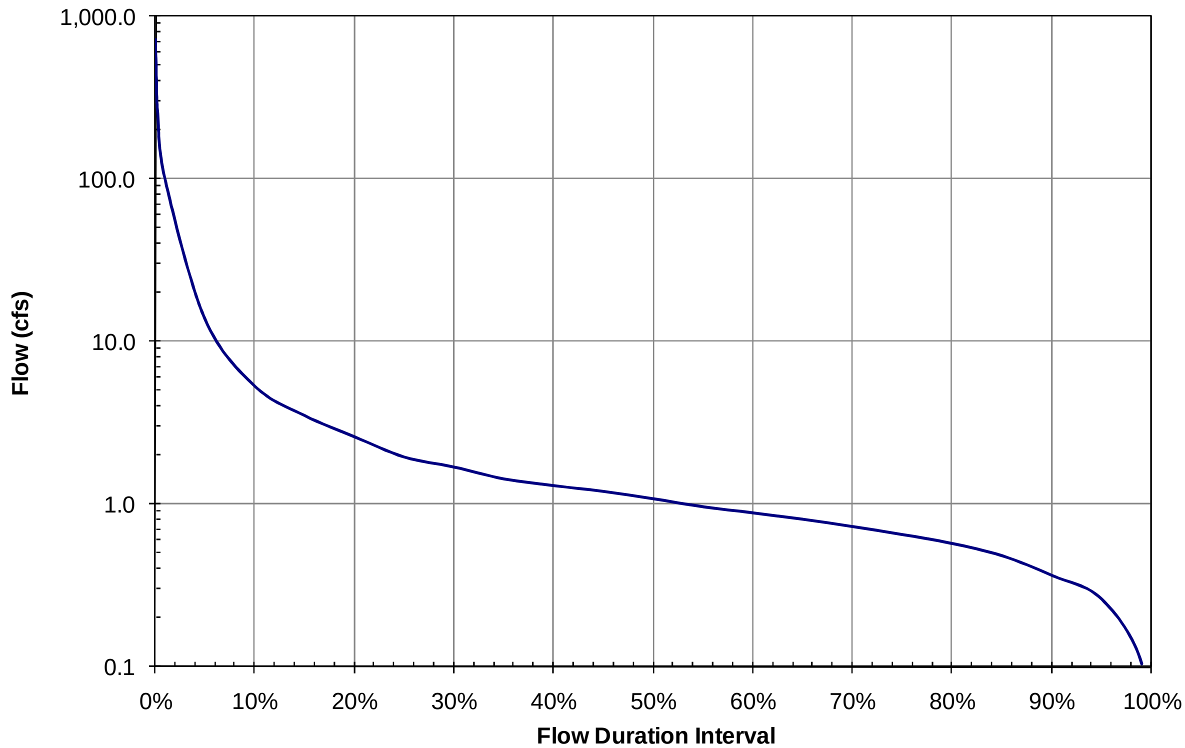


Figure 4-10 Flow Duration Curve for Skeleton Creek (OK620910030010_00)

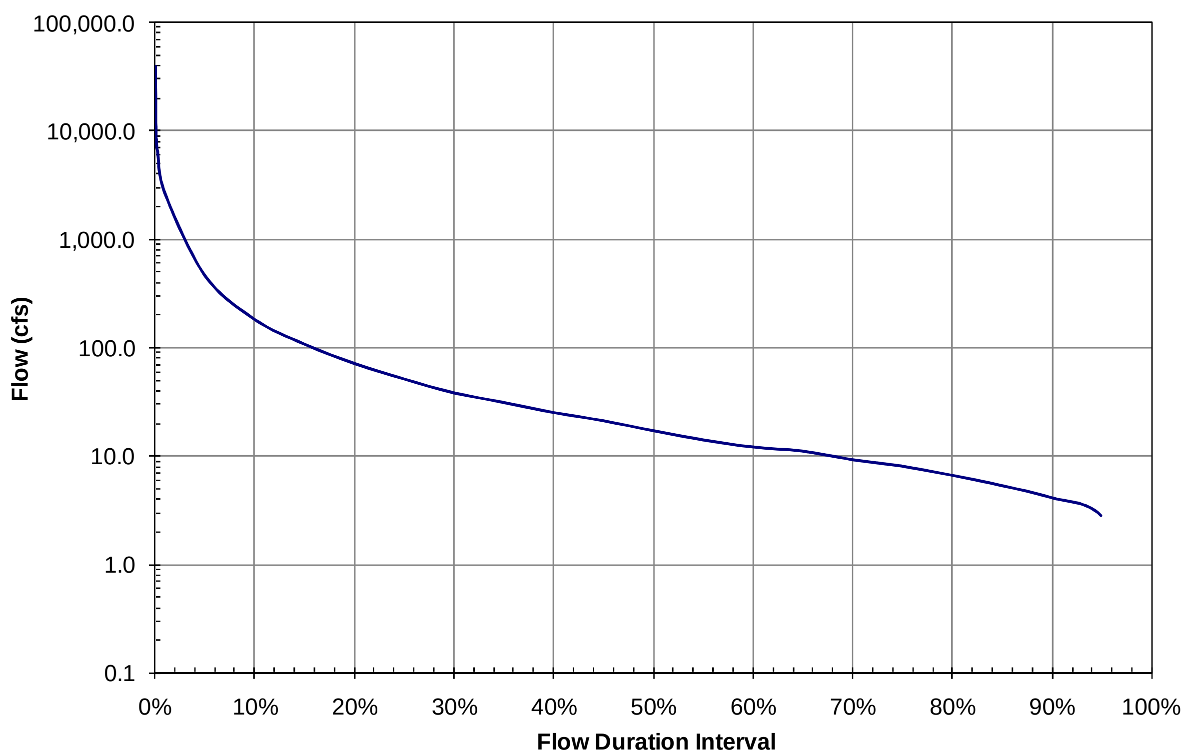


Figure 4-11 Flow Duration Curve for Cottonwood Creek (OK620910040010_20)

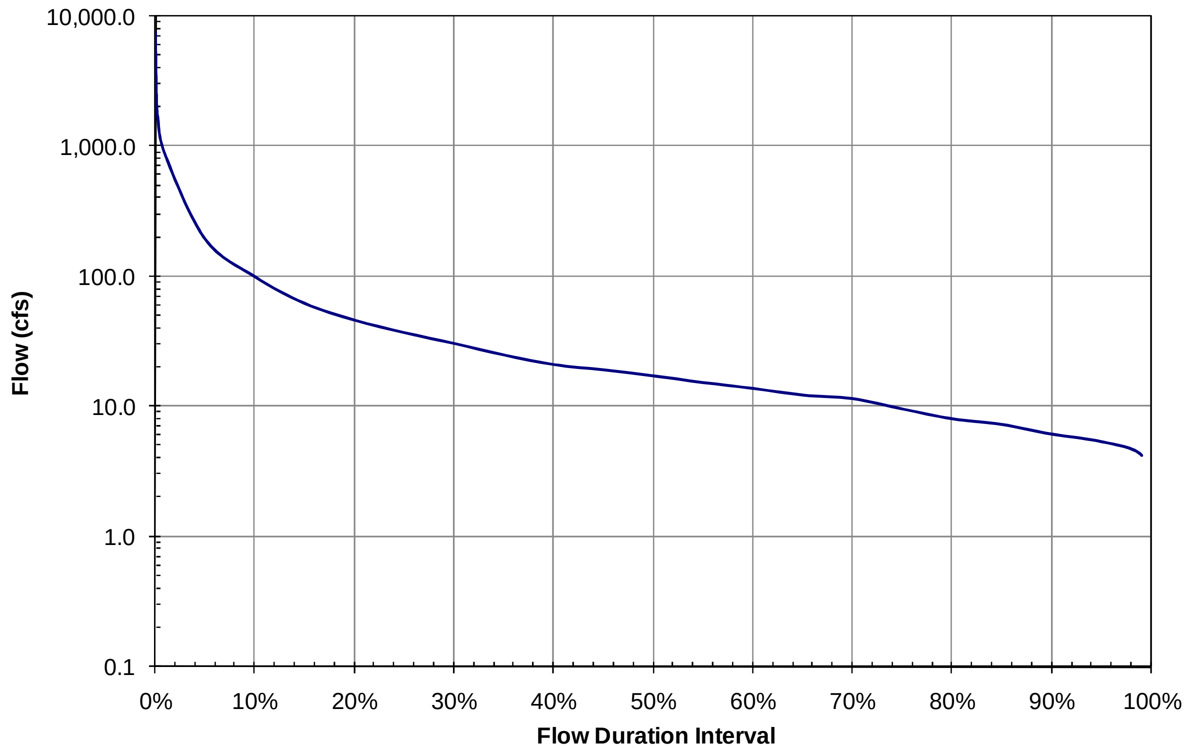


Figure 4-12 Flow Duration Curve for Deer Creek (OK620910040120_00)

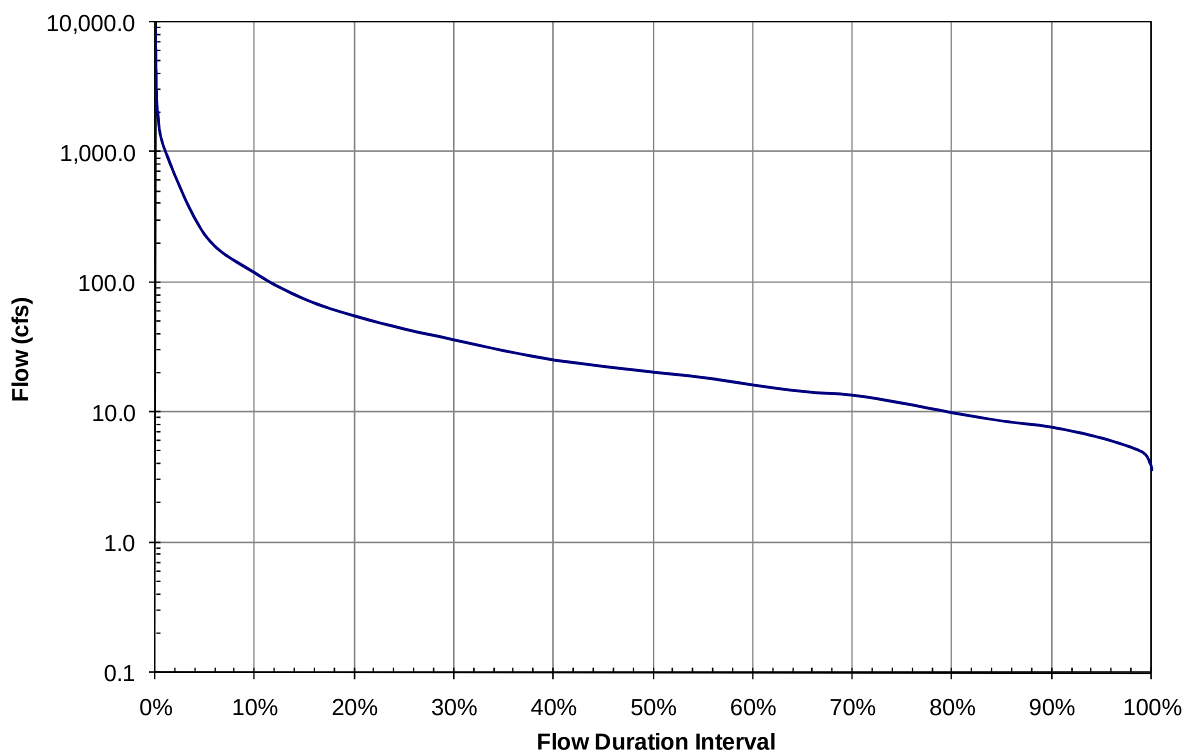


Figure 4-13 Flow Duration Curve for Kingfisher Creek (OK620910050010_00)

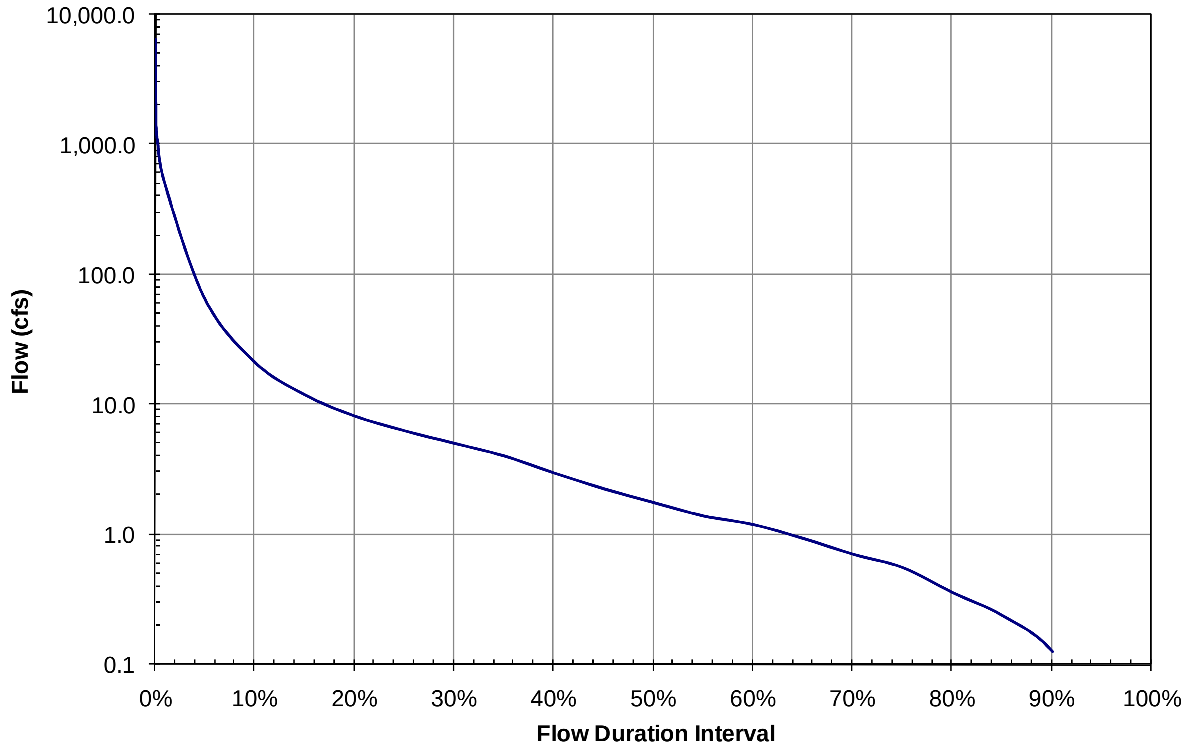
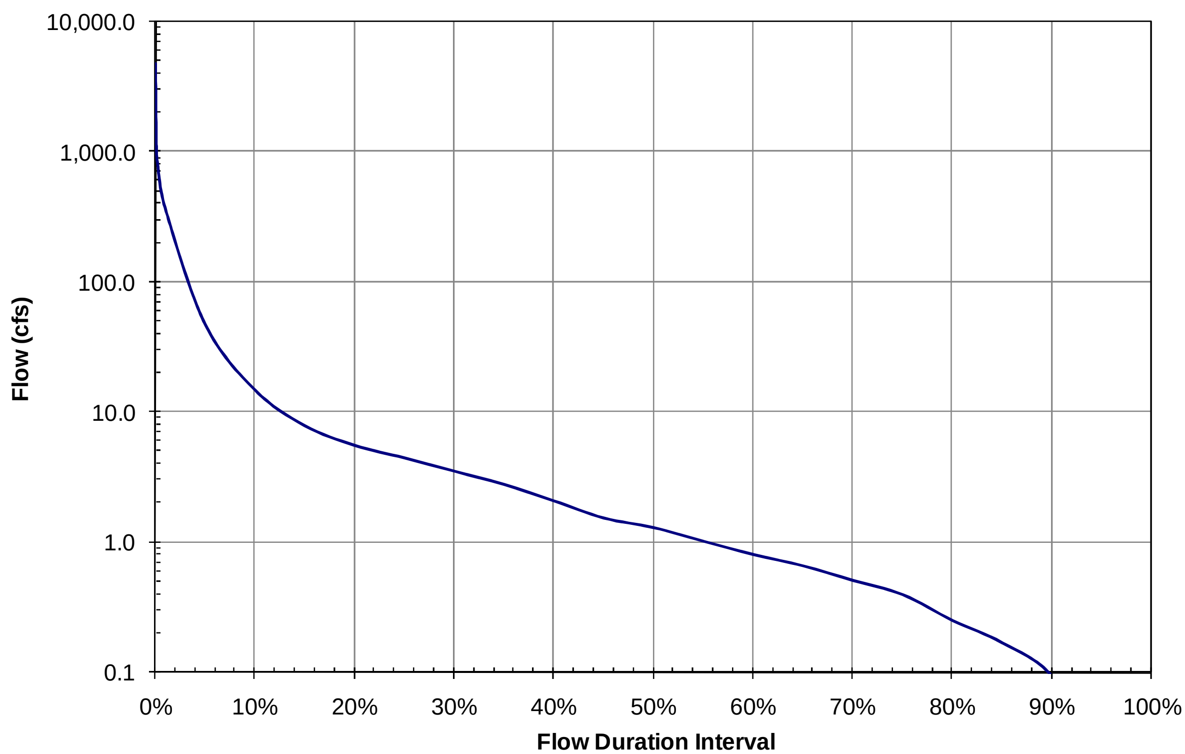


Figure 4-14 Flow Duration Curve for Dead Indian Creek (OK620910050080_00)



4.4 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 TSS loading must be reduced to meet turbidity WQS in the impaired watershed).

Step 1: Generate LDCs. LDCs are similar in appearance to flow duration curves; however, the ordinate is expressed in terms of a load typically in lbs/day. The curve represents the water quality targets for TSS from Table 4-1 expressed in terms of a load obtained through multiplication of the TSS target 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 available measured flow when samples were collected, the USGS, or projected flow using Oklahoma TMDL Toolbox if station is ungaged;
- sorting the flow data and calculating flow exceedance percentiles for the time period and season of interest;
- obtaining available turbidity and TSS water quality data;
- matching the water quality observations with the flow data from the same date;
- displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQ_{target} for TSS;
- converting measured concentration values to loads by multiplying the flow at the time the sample was collected by the water quality parameter concentration (for sampling events with both TSS and turbidity data, the measured TSS value is used; if only turbidity was measured, the value was converted to TSS using the regression equation in Figure 4-1 through Figure 4-3); then
- plotting the flow exceedance percentiles and daily load observations in a load duration plot.

The culmination of these steps is expressed in the following example formula for Cooper Creek, which is displayed on the LDC as the TMDL curve:

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

where: $WQ_{target} = 48\ mg/L\ (TSS)$ *for Cooper Creek*

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

The flow exceedance frequency (x-value of each point) is obtained by looking up the historical exceedance frequency of the measured or estimated flow; in other words, the percent of historical observations that equal or exceed the measured or estimated flow. Historical observations of TSS and/or turbidity concentrations are paired with flow data and are plotted on the LDC. The TSS load (or the y-value of each point) is calculated by multiplying the TSS concentration (measured or converted from turbidity) (mg/L) by the instantaneous flow (cfs) at the same site and time, with appropriate volumetric and time unit conversions. TSS loads representing exceedance of water quality criteria fall above the TMDL line.

As noted earlier, runoff has a strong influence on loading of nonpoint source pollution yet flows do not always correspond directly to local runoff. High flows may occur in dry weather due to upstream precipitation events or releases from upstream dams. Runoff influence may be observed with low or moderate flows depending on antecedent conditions.

Step 2: Develop 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 the TMDL in this report, an explicit MOS of 10% (See Section 5-5) has been selected to slightly reduce assimilative capacity in the watershed. This is a reasonable reduction that has been used in other turbidity TMDLs. The MOS at any given percent flow exceedance, therefore, is defined as 10% of the TMDL.

Step 3: Calculate WLA. As previously stated, the pollutant load allocation for point sources is defined by 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.

The LDC approach recognizes that the assimilative capacity of a waterbody depends on the flow, and that maximum allowable loading will vary with flow condition. TMDLs can be expressed in terms of maximum allowable concentrations, or as different maximum loads allowable under different flow conditions, rather than single maximum load values. A load-based approach meets the requirements of 40 CFR, 130.2(i) for expressing TMDLs "in terms of mass per time, toxicity, or other appropriate measures."

WLA for WWTP. WLAs are zero for these watersheds since there are no permitted inorganic TSS dischargers in the study area.

WLA for Permitted Stormwater. 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 4: Calculate LA. Given the lack of data and the variability of storm events, it is difficult to quantify discharges that accurately represent projected loadings from nonpoint sources. LAs can be calculated under different flow conditions as the water quality target load minus the WLA. The LA is represented by the area under the LDC but above the WLA. The LA at any particular flow exceedance is calculated as shown in the equation below.

$$\textbf{LA = TMDL - WLA - MOS}$$

Step 5: Estimate LA Load Reduction. After existing loading estimates are computed, nonpoint load reduction estimates are calculated by using the difference between estimated existing loading and the allowable load expressed by the LDC (TMDL-MOS). This difference is expressed as the overall PRG for the impaired waterbody. For turbidity, the PRG is the load reduction that ensures that no more than 10 percent of the samples under flow-base conditions exceed the TMDL.

SECTION 5
TMDL CALCULATIONS

5.1 Estimated Loading and Critical Conditions

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

To calculate the TSS load at the WQ_{target}, the flow rate at each flow exceedance percentile is multiplied by a unit conversion factor (*5.39377 L*s*lb /ft^3/day/mg*) and the TSS target.. This calculation produces the maximum TSS load in the stream that will result in attainment of the 50 NTU standard 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 1998 to 2008 are paired with the flows measured or estimated in that segment on the same date. For sampling events with both TSS and turbidity data, the measured TSS value is used; if only turbidity was measured, the value was converted to TSS using the regression equation in Figure 4-1 through 4-7. 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 target was exceeded at the time of sampling. Conversely, points under the LDC indicate the sample did not exceed the WQ_{target}. Figures 5-1 through 5-7 show the LDCs developed for the seven stream segments in the study area. It is noted that the LDC plot includes data under all flow conditions to show the overall condition of the stream. However, the turbidity standard only applies for base-flow conditions. Thus, when assessing beneficial use assessment, only the portion of the graph corresponding to flows above the 25th flow exceedance percentile should be used.

The LDC approach recognizes that the assimilative capacity of a waterbody depends on the flow, and that maximum allowable loading varies with flow condition. Existing loading, and load reductions required to meet the TMDL water quality target can also be calculated under different flow conditions. The difference between existing loading and the water quality target is used to calculate the loading reductions required. The overall PRG is calculated as the reduction in load required so no more than 10 percent of the samples collected under base-flow conditions would exceed TMDL targets for TSS. This is done through an iterative process of taking a series of percent reduction values applying each value uniformly between the concentrations of samples and verifying that no more than 10 percent of the samples exceed the water quality target concentration. The targets are derived from only those samples after high flow samples are excluded. The PRGs for the seven stream segments in the study area are provided in Table 5-1.

Table 5-1 TMDL Reduction Rate

Stream ID	Stream Name	Reduction Rate
OK620910020040_00	Cooper Creek	**63%**
OK620910020270_00	Elm Creek	**55%**
OK620910030010_00	Skeleton Creek	**75%**
OK620910020040_00	Cottonwood Creek	**71%**
OK620910020040_00	Deer Creek	**18%**
OK620910020040_00	Kingfisher Creek	**18%**
OK620910020040_00	Dead Indian Creek	**11%**

Figure 5-1 Load Duration Curve for Total Suspended Solids in Cooper Creek (OK620910020040_00)

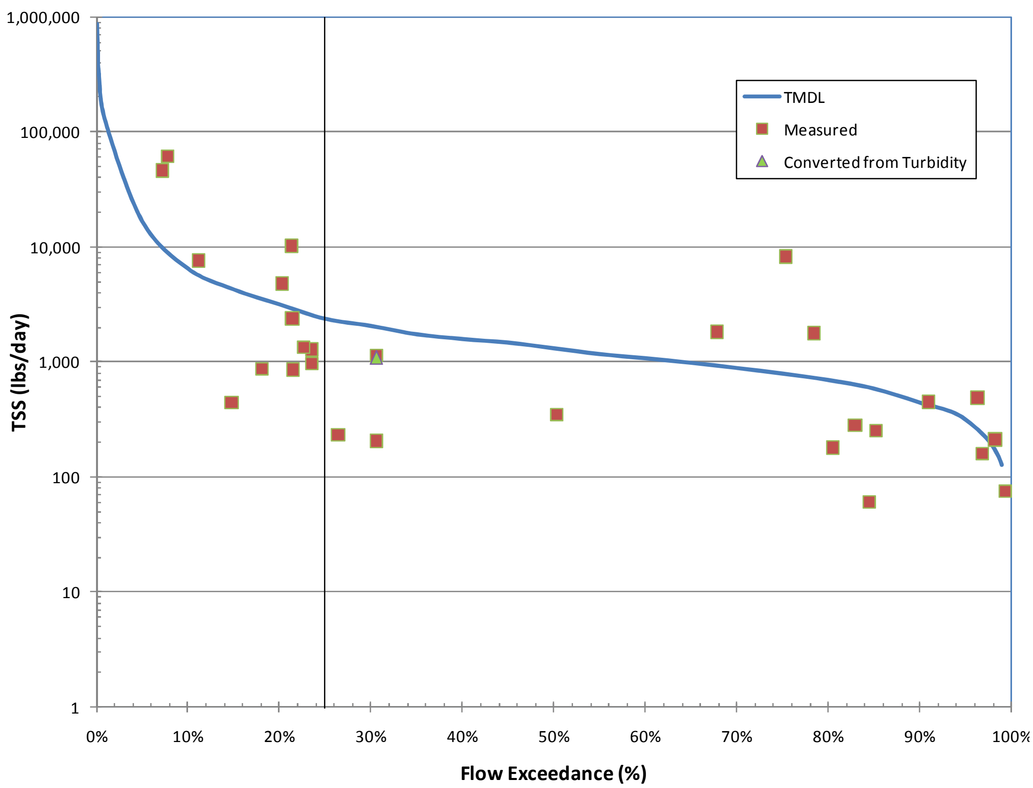


Figure 5-2 Load Duration Curve for Total Suspended Solids in Elm Creek (OK620910020270_00)

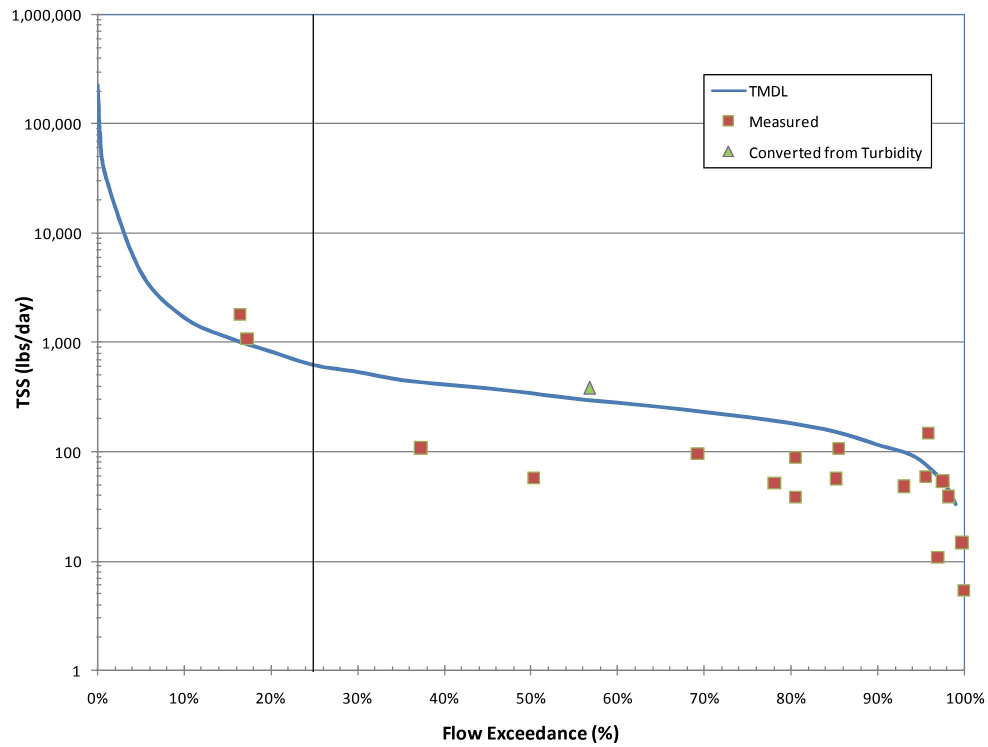


Figure 5-3 Load Duration Curve for Total Suspended Solids in Skeleton Creek (OK620910030010_00)

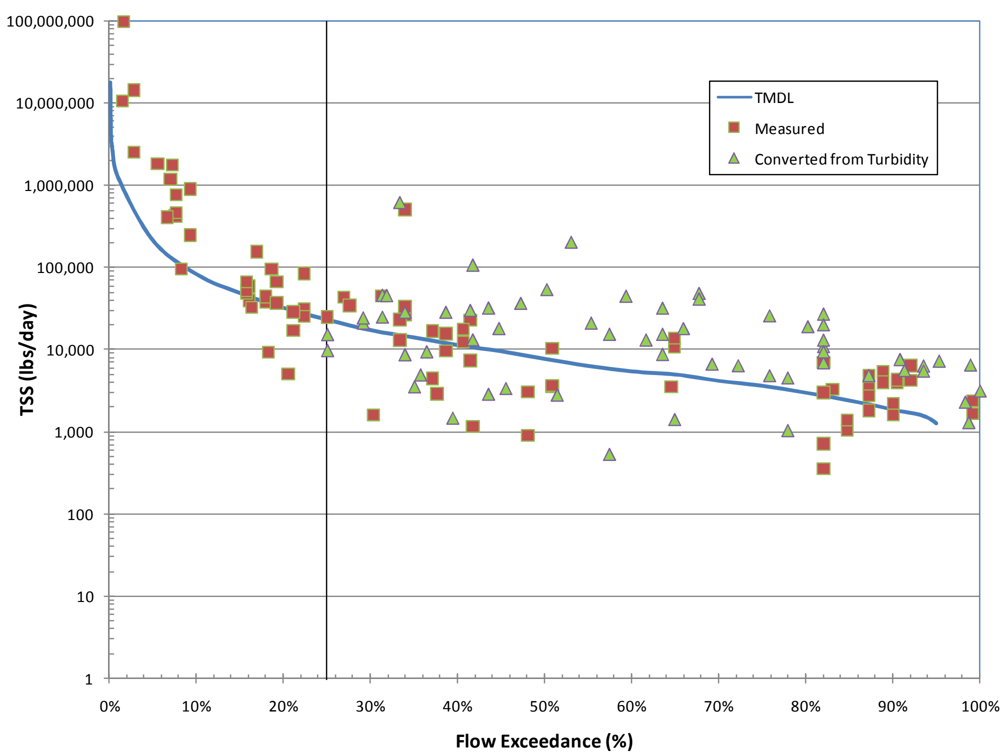


Figure 5-4 Load Duration Curve for Total Suspended Solids in Cottonwood Creek (OK620910020040_00)

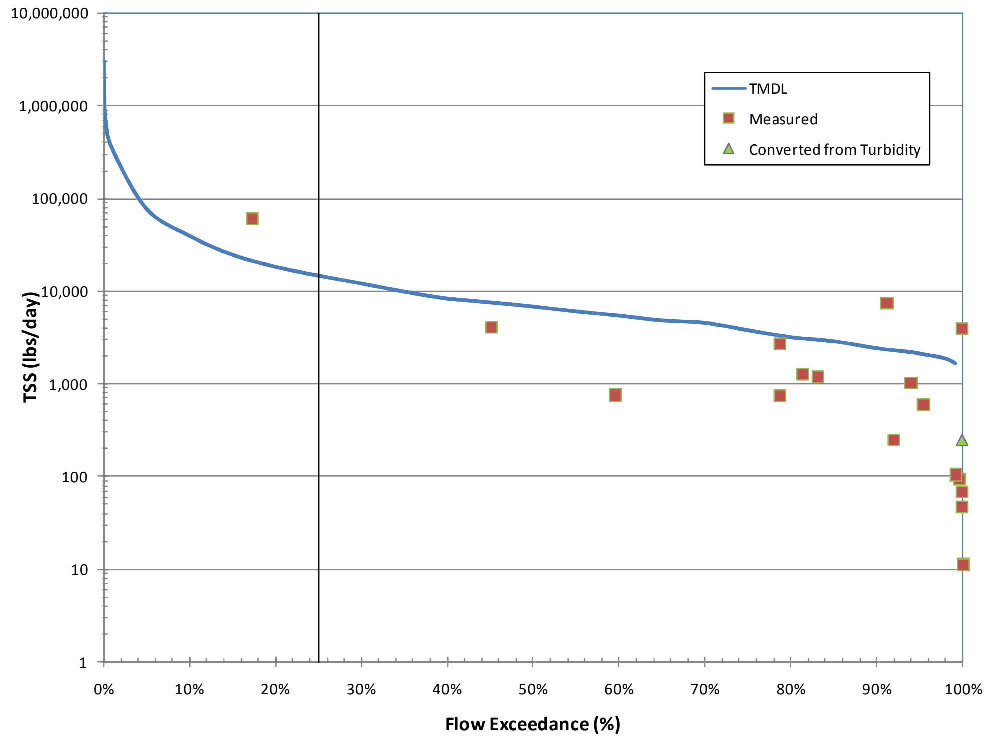


Figure 5-5 Load Duration Curve for Total Suspended Solids in Deer Creek (OK620910020040_00)

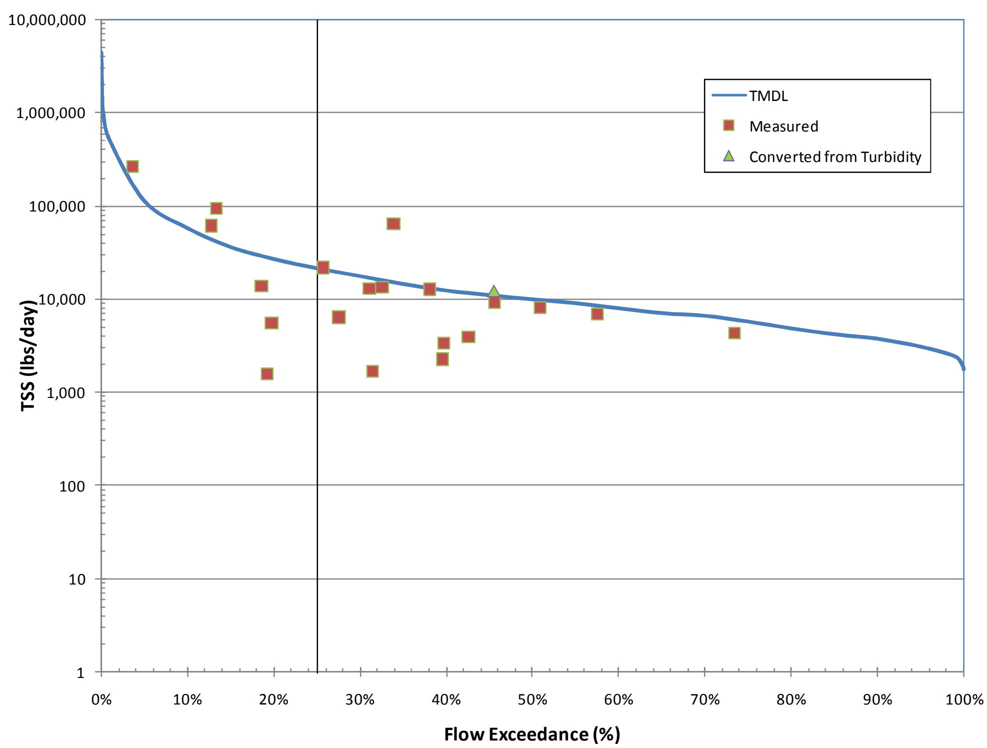


Figure 5-6 Load Duration Curve for Total Suspended Solids in Kingfisher Creek (OK620910020040_00)

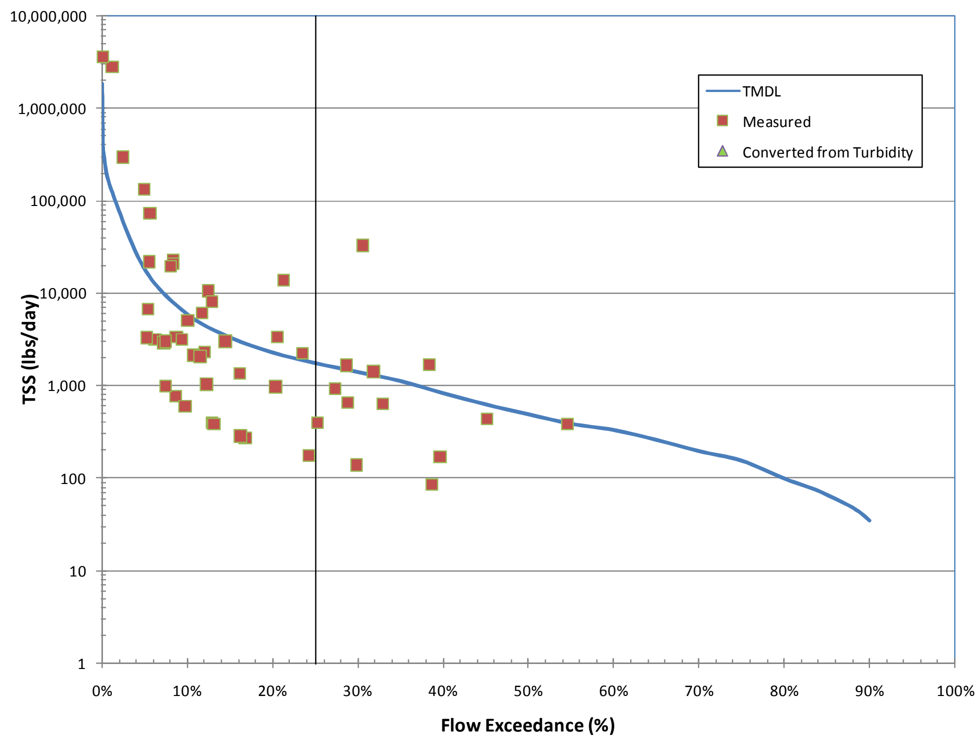
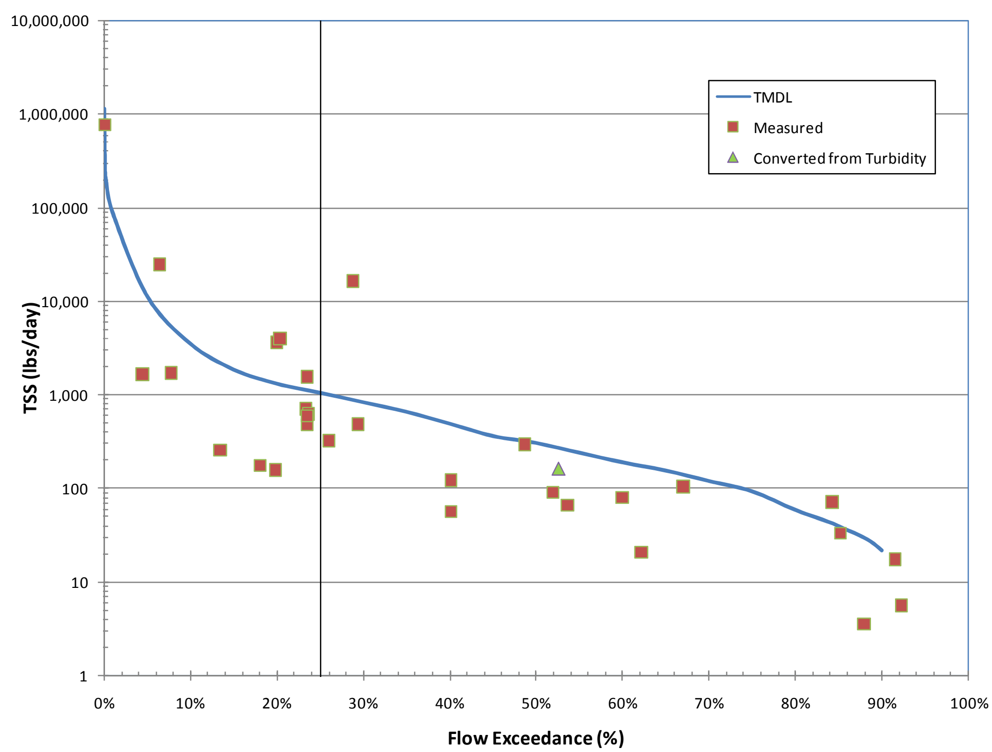


Figure 5-7 Load Duration Curve for Total Suspended Solids in Dead Indian Creek (OK620910020040_00)



5.2 Wasteload Allocation

NPDES-permitted facilities discharging inorganic TSS are allocated a daily wasteload calculated as their permitted flow rate multiplied by the water quality target. In other words, the facilities are required to meet instream criteria in their discharge. There is only one NPDES-permitted facilities (OK0036994) discharging inorganic TSS to the Dead Indian Creek (OK620910050080_00) via a tributary. The WLA for the facility is derived as follows:

$$WLA\_WWTP = WQ_{target} \times flow \times unit\ conversion\ factor\ (lbs/day)$$

$$WLA = 43.6\ mg/L \times 0.029\ MGD \times 8.3445 L \cdot lb/gal/mg = 10.5\ lbs/day$$

$$Flow = 0.029\ MGD = maximum\ monthly\ average\ DMR\ data\ for\ OK0036994\ (Table\ 3\text{-}2)$$

No wasteload allocations are needed for stormwater dischargers. 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)]. Therefore, WLA for NPDES-regulated storm water discharges is essentially considered unnecessary in this TMDL report and will not be included in the TMDL calculations. Conditions in existing stormwater permits are sufficient to protect receiving waters and comply with this TMDL.

To accommodate the potential for future growth in the watershed, 1% of TSS loading is reserved as part of the WLA.

5.3 Load Allocation

As discussed in Section 3.2, pollutant loading to the receiving streams of each waterbody emanate from a number of different nonpoint sources. The data analysis and the LDCs demonstrate that exceedances of the turbidity WQS at the WQM stations are the result of a variety of nonpoint sources. The LA is calculated as the difference between the TMDL, MOS, and WLA as follows:

LA = TMDL – WLA_WWTP – WLA_growth - MOS

5.4 Seasonal Variability

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. The TMDL 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 this TMDL by using more than 5 years of water quality data and by using the longest period of USGS flow records possible when estimating flows to develop flow exceedance percentiles.

5.5 Margin of Safety

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

Since the TMDL is calculated for TSS instead of Turbidity, the quality of the regression has a direct impact on confidence of the TMDL calculations. The better the regression is, the more confident we are on the TMDL targets. As a result, it leads to a smaller margin of safety. The selection of MOS is based on NRMSE and R-square for each stream. Because of the good regression achieved in all seven stream segments in the study area (Table 4-1), the explicit MOS of 10 percent is used for all of them.

The explicit MOS is applied by reducing the water quality target of TSS by the percentage of the MOS. For example, the water quality target of TSS for Cooper Creek is 48.3 mg/L and the MOS is 10%. The resulting TMDL water quality target will be 43.5 mg/L (48.3 x (1 - 0.1) = 43.5). This target is used to calculate the reduction rate for TSS.

5.6 TMDL Calculations

This TMDL was derived using the LDC method. 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 lack of knowledge concerning the relationship between effluent limitations and water quality.

This definition can be expressed by the following equation:

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

The TMDL represents a continuum of desired load over all flow conditions, rather than fixed at a single value, because loading capacity varies as a function of the flow present in the stream. The higher the flow is, the more wasteload the stream can assimilate without violating water quality standards. The TMDL, WLA, LA, and MOS are calculated at every 5^{th} flow interval percentile (Tables 5-2 through 5-8).

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.

Table 5-2 Turbidity TMDL based on Total Suspended Solids Calculations for Cooper Creek (OK620910020040_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WWTP (lbs/day)	MS4 (lbs/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	3,347.5	N/A	0.0	0.0	N/A	N/A	N/A
5	64.0	N/A	0.0	0.0	N/A	N/A	N/A
10	24.8	N/A	0.0	0.0	N/A	N/A	N/A
15	16.3	N/A	0.0	0.0	N/A	N/A	N/A
20	12.1	N/A	0.0	0.0	N/A	N/A	N/A
25	9.1	2,359.1	0.0	0.0	23.6	2,099.6	235.9
30	7.9	2,044.6	0.0	0.0	20.4	1,819.7	204.5
35	6.6	1,730.0	0.0	0.0	17.3	1,539.7	173.0
40	6.0	1,572.7	0.0	0.0	15.7	1,399.7	157.3
45	5.6	1,462.6	0.0	0.0	14.6	1,301.8	146.3
50	5.0	1,305.4	0.0	0.0	13.1	1,161.8	130.5
55	4.5	1,163.8	0.0	0.0	11.6	1,035.8	116.4
60	4.1	1,069.5	0.0	0.0	10.7	951.8	106.9
65	3.7	975.1	0.0	0.0	9.8	867.8	97.5
70	3.4	880.7	0.0	0.0	8.8	783.9	88.1
75	3.0	786.4	0.0	0.0	7.9	699.9	78.6
80	2.7	692.0	0.0	0.0	6.9	615.9	69.2
85	2.2	581.9	0.0	0.0	5.8	517.9	58.2
90	1.7	440.4	0.0	0.0	4.4	391.9	44.0
95	1.2	314.5	0.0	0.0	3.1	279.9	31.5
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5-3 Turbidity TMDL based on Total Suspended Solids Calculations for Elm Creek (OK620910020270_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WWTP (lbs/day)	MS4 (lbs/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	723.6	N/A	0.0	0.0	N/A	N/A	N/A
5	13.9	N/A	0.0	0.0	N/A	N/A	N/A
10	5.4	N/A	0.0	0.0	N/A	N/A	N/A
15	3.5	N/A	0.0	0.0	N/A	N/A	N/A
20	2.6	N/A	0.0	0.0	N/A	N/A	N/A
25	2.0	614.5	0.0	0.0	6.1	546.9	61.4
30	1.7	532.5	0.0	0.0	5.3	474.0	53.3
35	1.4	450.6	0.0	0.0	4.5	401.0	45.1
40	1.3	409.6	0.0	0.0	4.1	364.6	41.0
45	1.2	376.9	0.0	0.0	3.8	335.4	37.7
50	1.1	340.0	0.0	0.0	3.4	302.6	34.0
55	1.0	303.1	0.0	0.0	3.0	269.8	30.3
60	0.9	278.6	0.0	0.0	2.8	247.9	27.9
65	0.8	254.0	0.0	0.0	2.5	226.0	25.4
70	0.7	229.4	0.0	0.0	2.3	204.2	22.9
75	0.7	204.8	0.0	0.0	2.0	182.3	20.5
80	0.6	180.2	0.0	0.0	1.8	160.4	18.0
85	0.5	151.6	0.0	0.0	1.5	134.9	15.2
90	0.4	114.7	0.0	0.0	1.1	102.1	11.5
95	0.3	81.9	0.0	0.0	0.8	72.9	8.2
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5-4 Turbidity TMDL based on Total Suspended Solids Calculations for Skeleton Creek (OK620910030010_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WWTP (lbs/day)	MS4 (lbs/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	39,200.0	N/A	0.0	0.0	N/A	N/A	N/A
5	463.0	N/A	0.0	0.0	N/A	N/A	N/A
10	181.1	N/A	0.0	0.0	N/A	N/A	N/A
15	107.0	N/A	0.0	0.0	N/A	N/A	N/A
20	71.0	N/A	0.0	0.0	N/A	N/A	N/A
25	51.0	20,069.1	0.0	0.0	200.7	17,861.5	2,006.9
30	38.0	14,953.4	0.0	0.0	149.5	13,308.6	1,495.3
35	31.0	12,198.9	0.0	0.0	122.0	10,857.0	1,219.9
40	25.0	9,837.8	0.0	0.0	98.4	8,755.6	983.8
45	21.0	8,263.7	0.0	0.0	82.6	7,354.7	826.4
50	17.0	6,689.7	0.0	0.0	66.9	5,953.8	669.0
55	14.0	5,509.2	0.0	0.0	55.1	4,903.2	550.9
60	12.0	4,722.1	0.0	0.0	47.2	4,202.7	472.2
65	11.0	4,328.6	0.0	0.0	43.3	3,852.5	432.9
70	9.2	3,620.3	0.0	0.0	36.2	3,222.1	362.0
75	8.0	3,148.1	0.0	0.0	31.5	2,801.8	314.8
80	6.6	2,597.2	0.0	0.0	26.0	2,311.5	259.7
85	5.3	2,085.6	0.0	0.0	20.9	1,856.2	208.6
90	4.1	1,613.4	0.0	0.0	16.1	1,435.9	161.3
95	2.8	1,101.8	0.0	0.0	11.0	980.6	110.2
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5-5 Turbidity TMDL based on Total Suspended Solids Calculations for Cottonwood Creek (OK620910020040_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WWTP (lbs/day)	MS4 (lbs/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	7,570.1	N/A	0.0	0.0	N/A	N/A	N/A
5	195.0	N/A	0.0	0.0	N/A	N/A	N/A
10	99.5	N/A	0.0	0.0	N/A	N/A	N/A
15	62.0	N/A	0.0	0.0	N/A	N/A	N/A
20	46.0	N/A	0.0	0.0	N/A	N/A	N/A
25	36.9	14,642.2	0.0	0.0	146.4	13,031.6	1,464.2
30	30.4	12,076.0	0.0	0.0	120.8	10,747.7	1,207.6
35	24.8	9,849.5	0.0	0.0	98.5	8,766.1	985.0
40	20.9	8,302.3	0.0	0.0	83.0	7,389.0	830.2
45	19.0	7,547.5	0.0	0.0	75.5	6,717.3	754.8
50	17.1	6,792.8	0.0	0.0	67.9	6,045.6	679.3
55	15.2	6,038.0	0.0	0.0	60.4	5,373.8	603.8
60	13.7	5,434.2	0.0	0.0	54.3	4,836.5	543.4
65	12.2	4,830.4	0.0	0.0	48.3	4,299.1	483.0
70	11.4	4,528.5	0.0	0.0	45.3	4,030.4	452.9
75	9.5	3,773.8	0.0	0.0	37.7	3,358.6	377.4
80	8.0	3,170.0	0.0	0.0	31.7	2,821.3	317.0
85	7.2	2,868.1	0.0	0.0	28.7	2,552.6	286.8
90	6.1	2,415.2	0.0	0.0	24.2	2,149.5	241.5
95	5.3	2,113.3	0.0	0.0	21.1	1,880.8	211.3
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5-6 Turbidity TMDL based on Total Suspended Solids Calculations for Deer Creek (OK620910020040_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WWTP (lbs/day)	MS4 (lbs/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	9,123.4	N/A	0.0	0.0	N/A	N/A	N/A
5	235.5	N/A	0.0	0.0	N/A	N/A	N/A
10	120.1	N/A	0.0	0.0	N/A	N/A	N/A
15	75.3	N/A	0.0	0.0	N/A	N/A	N/A
20	55.9	N/A	0.0	0.0	N/A	N/A	N/A
25	44.5	21,569.6	0.0	0.0	215.7	19,196.9	2,157.0
30	36.7	17,789.4	0.0	0.0	177.9	15,832.5	1,778.9
35	30.3	14,676.2	0.0	0.0	146.8	13,061.8	1,467.6
40	25.7	12,452.6	0.0	0.0	124.5	11,082.8	1,245.3
45	22.9	11,118.3	0.0	0.0	111.2	9,895.3	1,111.8
50	20.6	10,006.5	0.0	0.0	100.1	8,905.8	1,000.7
55	18.8	9,117.0	0.0	0.0	91.2	8,114.2	911.7
60	16.5	8,005.2	0.0	0.0	80.1	7,124.6	800.5
65	14.7	7,115.7	0.0	0.0	71.2	6,333.0	711.6
70	13.8	6,671.0	0.0	0.0	66.7	5,937.2	667.1
75	11.9	5,781.5	0.0	0.0	57.8	5,145.6	578.2
80	10.1	4,892.1	0.0	0.0	48.9	4,353.9	489.2
85	8.7	4,225.0	0.0	0.0	42.2	3,760.2	422.5
90	7.8	3,780.2	0.0	0.0	37.8	3,364.4	378.0
95	6.4	3,113.1	0.0	0.0	31.1	2,770.7	311.3
100	3.7	1,778.9	0.0	0.0	17.8	1,583.3	177.9

Table 5-7 Turbidity TMDL based on Total Suspended Solids Calculations for Kingfisher Creek (OK620910020040_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WWTP (lbs/day)	MS4 (lbs/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	6,480.0	N/A	0.0	0.0	N/A	N/A	N/A
5	65.7	N/A	0.0	0.0	N/A	N/A	N/A
10	21.4	N/A	0.0	0.0	N/A	N/A	N/A
15	12.0	N/A	0.0	0.0	N/A	N/A	N/A
20	8.2	N/A	0.0	0.0	N/A	N/A	N/A
25	6.3	1,762.2	0.0	0.0	17.6	1,568.3	176.2
30	5.1	1,409.7	0.0	0.0	14.1	1,254.7	141.0
35	4.1	1,127.8	0.0	0.0	11.3	1,003.7	112.8
40	3.0	835.1	0.0	0.0	8.4	743.2	83.5
45	2.3	630.6	0.0	0.0	6.3	561.2	63.1
50	1.8	493.4	0.0	0.0	4.9	439.1	49.3
55	1.4	389.7	0.0	0.0	3.9	346.8	39.0
60	1.2	334.0	0.0	0.0	3.3	297.3	33.4
65	0.9	261.7	0.0	0.0	2.6	232.9	26.2
70	0.7	197.6	0.0	0.0	2.0	175.9	19.8
75	0.6	155.9	0.0	0.0	1.6	138.7	15.6
80	0.4	100.2	0.0	0.0	1.0	89.2	10.0
85	0.2	66.8	0.0	0.0	0.7	59.5	6.7
90	0.1	35.2	0.0	0.0	0.4	31.4	3.5
95	0.03	8.4	0.0	0.0	0.1	7.4	0.8
100	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5-8 Turbidity TMDL based on Total Suspended Solids Calculations for Dead Indian Creek (OK620910020040_00)

Percentile	Flow (cfs)	TMDL (lbs/day)	WWTP (lbs/day)	MS4 (lbs/day)	Growth (lbs/day)	LA (lbs/day)	MOS (lbs/day)
0	4,766.3	N/A	0.0	0.0	N/A	N/A	N/A
5	47.9	N/A	0.0	0.0	N/A	N/A	N/A
10	14.9	N/A	0.0	0.0	N/A	N/A	N/A
15	7.9	N/A	0.0	0.0	N/A	N/A	N/A
20	5.6	N/A	0.0	0.0	N/A	N/A	N/A
25	4.5	1,049.4	10.5	0.0	10.5	923.4	104.9
30	3.5	830.7	10.5	0.0	8.3	728.8	83.1
35	2.8	656.1	10.5	0.0	6.6	573.4	65.6
40	2.1	491.1	10.5	0.0	4.9	426.5	49.1
45	1.5	362.6	10.5	0.0	3.6	312.2	36.3
50	1.3	306.1	10.5	0.0	3.1	261.9	30.6
55	1.0	240.5	10.5	0.0	2.4	203.5	24.0
60	0.8	189.9	10.5	0.0	1.9	158.5	19.0
65	0.7	155.4	10.5	0.0	1.6	127.8	15.5
70	0.5	120.2	10.5	0.0	1.2	96.5	12.0
75	0.4	93.2	10.5	0.0	0.9	72.4	9.3
80	0.3	59.1	10.5	0.0	0.6	42.0	5.9
85	0.2	39.7	10.5	0.0	0.4	24.8	4.0
90	0.1	21.9	10.5	0.0	0.2	8.9	2.2
95*	0.045	10.5	10.4	0.0	0.1	0.0	0.0
100*	0.045	10.5	10.4	0.0	0.1	0.0	0.0

*At the 95th and 100th percentiles, the projected flows are smaller than the 0.045 cfs (0.029 MGD) maximum monthly average of the point source in the watershed. As a result, the TMDL is set at the wasteload allocation (10.5 lbs/day) for the point source. The actual WWTP wasteload allocation is reduced by 1% (0.1 lbs/day) to allow for the future growth allocation.

5.7 Reasonable Assurances

ODEQ will collaborate with a host of other state agencies and local governments working within the boundaries of state and local regulations to target available funding and technical assistance to support implementation of pollution controls and management measures. Various water quality management programs and funding sources provide a reasonable assurance that the pollutant reductions as required by this TMDL can be achieved and water quality can be restored to maintain designated uses. ODEQ's Continuing Planning Process (CPP), required by the CWA §303(e)(3) and 40 CFR 130.5, summarizes Oklahoma's commitments and programs aimed at restoring and protecting water quality throughout the state (ODEQ 2006). The CPP can be viewed from ODEQ's website at 2006 Continuing Planning Process. Table 5-9 provides a partial list of the state partner agencies ODEQ will collaborate with to address point and nonpoint source reduction goals established by TMDLs.

Table 5-9 Partial List of Oklahoma Water Quality Management Agencies

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

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

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

USEPA relating to administration and enforcement of the delegated NPDES Program. Implementation of point source WLAs is done through permits issued under the OPDES program.

The reduction rate called for in this TMDL report is shown in Table 5-1 for the stream segments in the study area. The ODEQ recognizes that achieving such reduction may be difficult, especially since unregulated nonpoint sources are a major cause of the impairment.

SECTION 6
PUBLIC PARTICIPATION

This TMDL report was sent to other related state agencies and local government agencies for peer review and was submitted to EPA for technical review on August 28, 2009. The technical approval was received on January 25, 2010. A public notice was circulated to the local newspapers and/or other publications in the area affected by this TMDL on February 26, 2010. The public was given an opportunity to review the TMDL report and submit comments. The DEQ accepted written comments during a 45-day public comment period.

All written comments received became a part of the record of this TMDL. All comments were considered and responded. The TMDL report was revised according to the comments. The response to comments is included as Appendix D.

SECTION 7
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APPENDIX A
AMBIENT WATER QUALITY DATA
1998 - 2008

Appendix A
Ambient Water Quality Data
1998 – 2008

Station ID	Stream Name	Date	Turbidity (NTU)	TSS (mg/L)	Flow (cfs)	Flow Condition
OK620910-02-0040C	Cooper Creek	6/12/2002	41		1.9	Rain event
OK620910-02-0040C	Cooper Creek	7/22/2002	108	34	0.4	
OK620910-02-0040C	Cooper Creek	9/3/2002	146	79	0.0	
OK620910-02-0040C	Cooper Creek	10/7/2002	48.4	119	2.77	
OK620910-02-0040C	Cooper Creek	11/12/2002	21	24	10.0	High flow
OK620910-02-0040C	Cooper Creek	12/10/2002	44.2	64	21.9	High flow
OK620910-02-0040C	Cooper Creek	1/22/2003	8.4	<10	8.6	
OK620910-02-0040C	Cooper Creek	3/4/2003	11.4	12	13.4	High flow
OK620910-02-0040C	Cooper Creek	4/1/2003	14.8	22	2.4	
OK620910-02-0040C	Cooper Creek	5/13/2003	68	53	1.6	
OK620910-02-0040C	Cooper Creek	6/10/2003	145	95	3.6	
OK620910-02-0040C	Cooper Creek	7/15/2003	87.8	88	1.0	
OK620910-02-0040C	Cooper Creek	8/19/2003	54.2	59	0.7	
OK620910-02-0040C	Cooper Creek	9/22/2003	29.1	35	0.8	
OK620910-02-0040C	Cooper Creek	10/27/2003	4.9	<10	2.3	
OK620910-02-0040C	Cooper Creek	12/8/2003	7.92	21	2.2	
OK620910-02-0040C	Cooper Creek	1/12/2004	13.6	13	2.6	
OK620910-02-0040C	Cooper Creek	2/17/2004	41.6	27	7.8	
OK620910-02-0040C	Cooper Creek	3/22/2004	7.61	<10	16.4	High flow
OK620910-02-0040C	Cooper Creek	4/26/2004	32	117	0.0	
OK620910-02-0040C	Cooper Creek	6/7/2004	29.7	36	0.0	
OK620910-02-0040C	Cooper Creek	5/29/2007	55.4	39	11.3	High flow
OK620910-02-0040C	Cooper Creek	6/25/2007	312	228	37.6	High flow
OK620910-02-0040C	Cooper Creek	7/31/2007	795	510	3.0	Rain event
OK620910-02-0040C	Cooper Creek	8/8/2007	4.57		10.7	High flow
OK620910-02-0040C	Cooper Creek	9/18/2007	14.8	14	11.3	High flow
OK620910-02-0040C	Cooper Creek	10/16/2007	28.3	24	10.3	High flow
OK620910-02-0040C	Cooper Creek	11/14/2007	5.68	<10	7.6	
OK620910-02-0040C	Cooper Creek	12/17/2007	20.3	13	5.0	
OK620910-02-0040C	Cooper Creek	1/23/2008	27.9		7.4	
OK620910-02-0040C	Cooper Creek	3/4/2008	410	167	11.3	High flow
OK620910-02-0040C	Cooper Creek	4/8/2008	94.6	75	11.9	High flow
OK620910-02-0040C	Cooper Creek	5/13/2008	30.8	18	10.0	High flow
OK620910-02-0040C	Cooper Creek	6/7/2008	272	270	42.0	High flow
OK620910-02-0270G	Elm Creek	5/15/2000	72.5	22	0.48	
OK620910-02-0270G	Elm Creek	6/19/2000	107	30	0.30	

OK620910-02-0270G	Elm Creek	7/24/2000	71.7	48	0.15	
OK620910-02-0270G	Elm Creek	8/28/2000	83	54	0.05	
OK620910-02-0270G	Elm Creek	10/2/2000	9.84	36	0.03	
OK620910-02-0270G	Elm Creek	11/6/2000	12.2	104	3.19	High flow
OK620910-02-0270G	Elm Creek	12/12/2000	13.4	10	1.06	
OK620910-02-0270G	Elm Creek	1/23/2001	83.8	14	1.43	
OK620910-02-0270G	Elm Creek	2/26/2001	63.3	64	3.11	High flow
OK620910-02-0270G	Elm Creek	4/2/2001	95	44	0.45	
OK620910-02-0270G	Elm Creek	5/8/2001	140	42	0.26	
OK620910-02-0270G	Elm Creek	6/12/2001	87	56	0.18	
OK620910-02-0270G	Elm Creek	6/22/2001	68		0.94	
OK620910-02-0270G	Elm Creek	7/24/2001	85.4	224	0.00	
OK620910-02-0270G	Elm Creek	8/21/2001	45.3	117	0.23	
OK620910-02-0270G	Elm Creek	9/25/2001	11.6	13	0.55	
OK620910-02-0270G	Elm Creek	12/11/2001	16.9	11	0.19	
OK620910-02-0270G	Elm Creek	1/15/2002	204	30	0.55	
OK620910-02-0270G	Elm Creek	2/20/2002	82.1	24	0.74	
OK620910-02-0270G	Elm Creek	3/26/2002	37.9	16	0.60	
OK620910-03-0010F	Skeleton Creek: Lower	8/6/2002	72.5	30	11	
OK620910-03-0010F	Skeleton Creek: Lower	9/4/2002	107	78	9.2	
OK620910-03-0010F	Skeleton Creek: Lower	10/1/2002	71.7	42	13	
OK620910-03-0010F	Skeleton Creek: Lower	11/5/2002	83	73	78	High flow
OK620910-03-0010F	Skeleton Creek: Lower	12/3/2002	9.84	<10	33	
OK620910-03-0010F	Skeleton Creek: Lower	1/15/2003	12.2	<10	58	
OK620910-03-0010F	Skeleton Creek: Lower	2/19/2003	13.4	<10	42	
OK620910-03-0010F	Skeleton Creek: Lower	3/25/2003	83.8	69	105	High flow
OK620910-03-0010F	Skeleton Creek: Lower	4/29/2003	63.3	62	46	
OK620910-03-0010F	Skeleton Creek: Lower	6/2/2003	95	86	23	
OK620910-03-0010F	Skeleton Creek: Lower	7/8/2003	140	89	8.6	
OK620910-03-0010F	Skeleton Creek: Lower	7/29/2003	87		3.5	
OK620910-03-0010F	Skeleton Creek: Lower	8/12/2003	68	64	4.7	
OK620910-03-0010F	Skeleton Creek: Lower	9/16/2003	85.4	99	10	
OK620910-03-0010F	Skeleton Creek: Lower	10/21/2003	45.3	43	9.4	
OK620910-03-0010F	Skeleton Creek:	12/2/2003	11.6	10	13	

	Lower					
OK620910-03-0010F	Skeleton Creek: Lower	1/5/2004	16.9	16	12	
OK620910-03-0010F	Skeleton Creek: Lower	2/10/2004	204	216	210	High flow
OK620910-03-0010F	Skeleton Creek: Lower	3/16/2004	82.1	84	106	High flow
OK620910-03-0010F	Skeleton Creek: Lower	4/20/2004	37.9	45	53	
OK620910-03-0010F	Skeleton Creek: Lower	6/2/2004	68	59	11	
OK620910-03-0010F	Skeleton Creek: Lower	5/30/2007		1907	1370	High flow
OK620910-03-0010F	Skeleton Creek: Lower	6/26/2007	51.6	500	278	High flow
OK620910-03-0010F	Skeleton Creek: Lower	7/31/2007	45	67	261	High flow
OK620910-03-0010F	Skeleton Creek: Lower	9/11/2007	906	635	340	High flow
OK620910-03-0010S	Skeleton Creek: Lower	10/15/2007	47.7	52	43	
OK620910-03-0010S	Skeleton Creek: Lower	11/14/2007	14.2	17	48	
OK620910-03-0010S	Skeleton Creek: Lower	12/18/2007	19.9	11	84	High flow
OK620910-03-0010S	Skeleton Creek: Lower	1/23/2008	11.3		40	
OK620910-03-0010S	Skeleton Creek: Lower	3/4/2008	361	271	285	High flow
OK620910-03-0010S	Skeleton Creek: Lower	4/7/2008	50	38	82	High flow
OK620910-03-0010S	Skeleton Creek: Lower	5/13/2008	80	76	89	High flow
OK620910-03-0010S	Skeleton Creek: Lower	6/17/2008		6857	2590	High flow
OK620910-03-0010S	Skeleton Creek: Upper	8/6/2002	129	45	11	
OK620910-03-0010S	Skeleton Creek: Upper	9/4/2002	91.8	85	9.2	
OK620910-03-0010S	Skeleton Creek: Upper	9/12/2002	81.8		9.1	
OK620910-03-0010S	Skeleton Creek: Upper	10/1/2002	57.4	97	13	
OK620910-03-0010S	Skeleton Creek: Upper	11/5/2002	81	59	78	High flow
OK620910-03-0010S	Skeleton Creek: Upper	12/3/2002	13	17	33	
OK620910-03-0010S	Skeleton Creek: Upper	1/15/2003	10.8	<10	58	
OK620910-03-0010S	Skeleton Creek: Upper	2/19/2003	9.68	<10	42	
OK620910-03-0010S	Skeleton Creek: Upper	3/25/2003	93.3	103	105	High flow
OK620910-03-0010S	Skeleton Creek:	4/29/2003	83.8	38	46	

	Upper					
OK620910-03-0010S	Skeleton Creek: Upper	6/2/2003	112	109	23	
OK620910-03-0010S	Skeleton Creek: Upper	7/8/2003	122	135	8.6	
OK620910-03-0010S	Skeleton Creek: Upper	8/12/2003	66.5	92	4.7	
OK620910-03-0010S	Skeleton Creek: Upper	9/16/2003	61.8	73	10	
OK620910-03-0010S	Skeleton Creek: Upper	10/21/2003	32.3	31	9.4	
OK620910-03-0010S	Skeleton Creek: Upper	12/2/2003	9.77	<10	13	
OK620910-03-0010S	Skeleton Creek: Upper	1/5/2004	31.5	21	12	
OK620910-03-0010S	Skeleton Creek: Upper	2/10/2004	900	783	210	High flow
OK620910-03-0010S	Skeleton Creek: Upper	3/16/2004	64.8	91	106	High flow
OK620910-03-0010S	Skeleton Creek: Upper	4/20/2004	53.1	80	53	
OK620910-03-0010S	Skeleton Creek: Upper	6/2/2004	66.8	79	11	
OK620910-03-0010S	Skeleton Creek: Upper	5/30/2007	346	332	1370	High flow
OK620910-03-0010S	Skeleton Creek: Upper	6/25/2007	520	623	531	High flow
OK620910-03-0010S	Skeleton Creek: Upper	7/30/2007	48.2	57	104	High flow
OK620910-03-0010S	Skeleton Creek: Upper	8/14/2007	80.4		56	
OK620910-03-0010S	Skeleton Creek: Upper	9/18/2007	73.5	98	64	
OK620910-03-0010S	Skeleton Creek: Upper	10/15/2007	53.7	75	43	
OK620910-03-0010S	Skeleton Creek: Upper	11/14/2007	38.6	64	48	
OK620910-03-0010S	Skeleton Creek: Upper	12/17/2007	23	18	94	High flow
OK620910-03-0010S	Skeleton Creek: Upper	1/22/2008	14.6		50	
OK620910-03-0010S	Skeleton Creek: Upper	3/3/2008	36.9	304	278	High flow
OK620910-03-0010S	Skeleton Creek: Upper	4/7/2008	68.4	64	82	High flow
OK620910-03-0010S	Skeleton Creek: Upper	5/12/2008	114	115	106	High flow
OK620910-03-0010S	Skeleton Creek: Upper	6/16/2008	195	192	388	High flow
620910030010-001AT	Skeleton Creek: Lovell	12/2/1998	140	150	33	
620910030010-001AT	Skeleton Creek: Lovell	1/19/1999	13	39	17	

620910030010-001AT	Skeleton Creek: Lovell	2/8/1999	1000	216	81	High flow
620910030010-001AT	Skeleton Creek: Lovell	3/7/1999	196	174	46	
620910030010-001AT	Skeleton Creek: Lovell	4/5/1999	299	304	93	High flow
620910030010-001AT	Skeleton Creek: Lovell	5/5/1999	904	936	339	High flow
620910030010-001AT	Skeleton Creek: Lovell	6/7/1999		89	51	
620910030010-001AT	Skeleton Creek: Lovell	7/6/1999	169	160	77	High flow
620910030010-001AT	Skeleton Creek: Lovell	8/2/1999	78	79	86	High flow
620910030010-001AT	Skeleton Creek: Lovell	9/7/1999	105	114	17	Rain event
620910030010-001AT	Skeleton Creek: Lovell	10/18/1999	33	40	17	
620910030010-001AT	Skeleton Creek: Lovell	11/15/1999	74	56	24	
620910030010-001AT	Skeleton Creek: Lovell	12/13/1999	311	252	61	High flow
620910030010-001AT	Skeleton Creek: Lovell	1/31/2000	13	19	28	
620910030010-001AT	Skeleton Creek: Lovell	2/22/2000	64	94	86	High flow
620910030010-001AT	Skeleton Creek: Lovell	4/17/2000	158	224	36	
620910030010-001AT	Skeleton Creek: Lovell	5/15/2000	110	186	33	
620910030010-001AT	Skeleton Creek: Lovell	6/20/2000	198	176	24	
620910030010-001AT	Skeleton Creek: Lovell	7/24/2000	779	2860	33	Rain event
620910030010-001AT	Skeleton Creek: Lovell	8/21/2000	107	104	6	
620910030010-001AT	Skeleton Creek: Lovell	9/19/2000	96		5	
620910030010-001AT	Skeleton Creek: Lovell	10/16/2000	801	804	2,387	High flow
620910030010-001AT	Skeleton Creek: Lovell	11/13/2000	47	58	11	
620910030010-001AT	Skeleton Creek: Lovell	2/6/2001	51		21	
620910030010-001AT	Skeleton Creek: Lovell	3/6/2001	143		17	
620910030010-001AT	Skeleton Creek: Lovell	4/3/2001	55		17	
620910030010-001AT	Skeleton Creek: Lovell	5/8/2001	165		15	
620910030010-001AT	Skeleton Creek: Lovell	6/5/2001	170		66	High flow
620910030010-001AT	Skeleton Creek: Lovell	7/10/2001	109		11	

620910030010-001AT	Skeleton Creek: Lovell	8/7/2001	150		4	
620910030010-001AT	Skeleton Creek: Lovell	9/11/2001	156		10	
620910030010-001AT	Skeleton Creek: Lovell	10/2/2001	81		7.7	
620910030010-001AT	Skeleton Creek: Lovell	2/6/2002	75		28	
620910030010-001AT	Skeleton Creek: Lovell	3/13/2002	41		18	
620910030010-001AT	Skeleton Creek: Lovell	4/10/2002	119		24	
620910030010-001AT	Skeleton Creek: Lovell	5/15/2002	171		13	
620910030010-001AT	Skeleton Creek: Lovell	6/5/2002	463		259	High flow
620910030010-001AT	Skeleton Creek: Lovell	7/10/2002	82		13	
620910030010-001AT	Skeleton Creek: Lovell	8/28/2002	121		14	
620910030010-001AT	Skeleton Creek: Lovell	9/25/2002	185		21	
620910030010-001AT	Skeleton Creek: Lovell	10/30/2002	641		616	High flow
620910030010-001AT	Skeleton Creek: Lovell	12/4/2002	57		76	High flow
620910030010-001AT	Skeleton Creek: Lovell	1/22/2003	11		51	
620910030010-001AT	Skeleton Creek: Lovell	3/4/2003	17		85	High flow
620910030010-001AT	Skeleton Creek: Lovell	4/2/2003	40		61	
620910030010-001AT	Skeleton Creek: Lovell	6/9/2003	147		31	
620910030010-001AT	Skeleton Creek: Lovell	7/7/2003	65		8.9	
620910030010-001AT	Skeleton Creek: Lovell	8/11/2003	119		4.9	
620910030010-001AT	Skeleton Creek: Lovell	9/15/2003	36		15	Rain event
620910030010-001AT	Skeleton Creek: Lovell	10/20/2003	57		13	
620910030010-001AT	Skeleton Creek: Lovell	11/17/2003	39		20	
620910030010-001AT	Skeleton Creek: Lovell	12/15/2003	14		30	
620910030010-001AT	Skeleton Creek: Lovell	1/12/2004	11		15	
620910030010-001AT	Skeleton Creek: Lovell	3/1/2004	64		46	
620910030010-001AT	Skeleton Creek: Lovell	5/4/2004	53		37	
620910030010-001AT	Skeleton Creek: Lovell	6/15/2004	134		13	

620910030010-001AT	Skeleton Creek: Lovell	7/19/2004	95		13	
620910030010-001AT	Skeleton Creek: Lovell	8/24/2004	146		26	
620910030010-001AT	Skeleton Creek: Lovell	9/29/2004	72		7.7	
620910030010-001AT	Skeleton Creek: Lovell	12/7/2004	72		123	High flow
620910030010-001AT	Skeleton Creek: Lovell	2/1/2005	47		109	High flow
620910030010-001AT	Skeleton Creek: Lovell	5/3/2005	163		21	
620910030010-001AT	Skeleton Creek: Lovell	6/21/2005	250		97	High flow
620910030010-001AT	Skeleton Creek: Lovell	7/18/2005	66		24	
620910030010-001AT	Skeleton Creek: Lovell	8/16/2005	680		53	
620910030010-001AT	Skeleton Creek: Lovell	9/20/2005	100		34	
620910030010-001AT	Skeleton Creek: Lovell	10/26/2005	14		36	
620910030010-001AT	Skeleton Creek: Lovell	12/6/2005	4		27	
620910030010-001AT	Skeleton Creek: Lovell	2/2/2006	42		24	
620910030010-001AT	Skeleton Creek: Lovell	2/28/2006	10		23	
620910030010-001AT	Skeleton Creek: Lovell	4/5/2006	60		27	
620910030010-001AT	Skeleton Creek: Lovell	5/9/2006	79		40	
620910030010-001AT	Skeleton Creek: Lovell	6/14/2006	73		13	
620910030010-001AT	Skeleton Creek: Lovell	8/22/2006	451		29	
620910030010-001AT	Skeleton Creek: Lovell	10/3/2006	49		5.2	
620910030010-001AT	Skeleton Creek: Lovell	12/13/2006	32		5	
620910030010-001AT	Skeleton Creek: Lovell	1/31/2007	36		16	
620910030010-001AT	Skeleton Creek: Lovell	3/7/2007	139		16	
620910030010-001AT	Skeleton Creek: Lovell	4/4/2007	218		110	High flow
620910030010-001AT	Skeleton Creek: Lovell	5/23/2007	45		61	
620910030010-001AT	Skeleton Creek: Lovell	6/6/2007	76		77	High flow
620910030010-001AT	Skeleton Creek: Lovell	7/18/2007	265		300	High flow
620910030010-001AT	Skeleton Creek: Lovell	8/15/2007	49		56	

620910030010-001AT	Skeleton Creek: Lovell	9/26/2007	81		55	
620910030010-001AT	Skeleton Creek: Lovell	10/24/2007	288		171	High flow
620910030010-001AT	Skeleton Creek: Lovell	11/28/2007	6		45	
620910030010-001AT	Skeleton Creek: Lovell	1/29/2008	25		49	
620910030010-001AT	Skeleton Creek: Lovell	3/5/2008	128		139	High flow
620910030010-001AT	Skeleton Creek: Lovell	4/18/2008	117		117	High flow
620910030010-001AT	Skeleton Creek: Lovell	9/16/2008	200		42	
620910030010-001AT	Skeleton Creek: Lovell	11/11/2008	37		42	
OK620910-04-0010G	Cottonwood Creek	5/15/2000	44.2	30	7.92	
OK620910-04-0010G	Cottonwood Creek	7/24/2000	109	254	2.87	
OK620910-04-0010G	Cottonwood Creek	8/28/2000	28.9	14	0	
OK620910-04-0010G	Cottonwood Creek	10/2/2000	19.9	14	0.15	
OK620910-04-0010G	Cottonwood Creek	11/7/2000	33.7	30	7.43	
OK620910-04-0010G	Cottonwood Creek	12/12/2000	9.04	8	5.79	
OK620910-04-0010G	Cottonwood Creek	1/23/2001	23.1	10	14.03	
OK620910-04-0010G	Cottonwood Creek	2/26/2001	162	204	54.66	High flow
OK620910-04-0010G	Cottonwood Creek	4/3/2001	26.6	40	18.69	
OK620910-04-0010G	Cottonwood Creek	5/8/2001	40.8	58	8.54	
OK620910-04-0010G	Cottonwood Creek	6/12/2001	24.2	21	5.26	
OK620910-04-0010G	Cottonwood Creek	7/2/2001	17.9		2.08	
OK620910-04-0010G	Cottonwood Creek	7/17/2001	21.6	7	1.25	
OK620910-04-0010G	Cottonwood Creek	8/21/2001	27.1	29	0.07	
OK620910-04-0010G	Cottonwood Creek	9/25/2001	244	230	5.92	
OK620910-04-0010G	Cottonwood Creek	10/31/2001	6.2	<10	2.51	
OK620910-04-0010G	Cottonwood Creek	12/11/2001	3.83	<10	3.50	
OK620910-04-0010G	Cottonwood Creek	1/15/2002	5.68	<10	3.87	
OK620910-04-0010G	Cottonwood Creek	2/19/2002	18.7	16	8.67	

OK620910-04-0010G	Cottonwood Creek	3/25/2002	27.6	33	5.68	
OK620910-04-0120B	Deer Creek: Logan Co.	5/15/2000	58	72	17.73	
OK620910-04-0120B	Deer Creek: Logan Co.	6/19/2000	179	157	310.22	High flow
OK620910-04-0120B	Deer Creek: Logan Co.	7/24/2000	101	374	31.67	
OK620910-04-0120B	Deer Creek: Logan Co.	8/28/2000	44.3	70	11.23	
OK620910-04-0120B	Deer Creek: Logan Co.	10/2/2000	47.5	74	20.31	
OK620910-04-0120B	Deer Creek: Logan Co.	11/7/2000	135	126	90	High flow
OK620910-04-0120B	Deer Creek: Logan Co.	12/12/2000	5.33	9	34.41	
OK620910-04-0120B	Deer Creek: Logan Co.	1/23/2001	13.9	18	56.76	High flow
OK620910-04-0120B	Deer Creek: Logan Co.	2/26/2001	128	204	85.79	High flow
OK620910-04-0120B	Deer Creek: Logan Co.	4/3/2001	24.9	42	60.27	High flow
OK620910-04-0120B	Deer Creek: Logan Co.	5/8/2001	55	92	43.77	
OK620910-04-0120B	Deer Creek: Logan Co.	6/12/2001	42	68	34.86	
OK620910-04-0120B	Deer Creek: Logan Co.	7/3/2001	54.1		22.79	
OK620910-04-0120B	Deer Creek: Logan Co.	7/17/2001	52.4	86	27.46	
OK620910-04-0120B	Deer Creek: Logan Co.	8/21/2001	57.8	75	22.74	
OK620910-04-0120B	Deer Creek: Logan Co.	9/26/2001	63.6	<10	58.30	High flow
OK620910-04-0120B	Deer Creek: Logan Co.	10/31/2001	18.1	24	25.81	
OK620910-04-0120B	Deer Creek: Logan Co.	12/11/2001	15.9	30	23.94	
OK620910-04-0120B	Deer Creek: Logan Co.	1/15/2002	12.4	16	26.05	
OK620910-04-0120B	Deer Creek: Logan Co.	2/19/2002	40.1	75	32.90	
OK620910-04-0120B	Deer Creek: Logan Co.	3/25/2002	19.6	29	40.65	
OK620910-05-0010G	Kingfisher Creek	5/15/2000	20.4	26	16.443	High flow
OK620910-05-0010G	Kingfisher Creek	6/15/2000	30.9		13.154	High flow
OK620910-05-0010G	Kingfisher Creek	6/19/2000	420	343	70.878	High flow
OK620910-05-0010G	Kingfisher Creek	7/24/2000	113	136	30.51	High flow
OK620910-05-0010G	Kingfisher Creek	8/28/2000	24.4	30	5.745	

OK620910-05-0010G	Kingfisher Creek	10/2/2000	13.1	10	3.16	
OK620910-05-0010G	Kingfisher Creek	11/6/2000	1000	1115	460	High flow
OK620910-05-0010G	Kingfisher Creek	12/11/2000	4.44	5	28.081	High flow
OK620910-05-0010G	Kingfisher Creek	1/22/2001	14.44	12	48.124	High flow
OK620910-05-0010G	Kingfisher Creek	2/27/2001	284	288	187.82	High flow
OK620910-05-0010G	Kingfisher Creek	4/2/2001	9.94	10	60.636	High flow
OK620910-05-0010G	Kingfisher Creek	5/7/2001	198	230	57.692	High flow
OK620910-05-0010G	Kingfisher Creek	6/11/2001	22.1	43	21.576	High flow
OK620910-05-0010G	Kingfisher Creek	7/16/2001	36.3	45	12.377	High flow
OK620910-05-0010G	Kingfisher Creek	8/20/2001	56.5	57	4.596	
OK620910-05-0010G	Kingfisher Creek	9/26/2001	68	<10	14.575	High flow
OK620910-05-0010G	Kingfisher Creek	10/30/2001	8.97	<10	6.431	High flow
OK620910-05-0010G	Kingfisher Creek	12/10/2001	3.67	<10	9.978	High flow
OK620910-05-0010G	Kingfisher Creek	1/14/2002	7.57	<10	10.588	High flow
OK620910-05-0010G	Kingfisher Creek	2/20/2002	25.3	20	19.68	High flow
OK620910-05-0010G	Kingfisher Creek	3/26/2002	6.27	<10	14.226	High flow
OK620910-05-0010J	Kingfisher Creek	6/12/2002	34.3		12.962	High flow
OK620910-05-0010J	Kingfisher Creek	7/22/2002	23	<10	3.17	
OK620910-05-0010J	Kingfisher Creek	9/3/2002	98	94	3.276	
OK620910-05-0010J	Kingfisher Creek	10/7/2002	8.6	22	17.299	High flow
OK620910-05-0010J	Kingfisher Creek	11/12/2002	19.6	22	27.905	High flow
OK620910-05-0010J	Kingfisher Creek	12/10/2002	11.7	14	38.216	High flow
OK620910-05-0010J	Kingfisher Creek	1/22/2003	11.4	<10	22.187	High flow
OK620910-05-0010J	Kingfisher Creek	3/4/2003	12.3	24	24.217	High flow
OK620910-05-0010J	Kingfisher Creek	4/1/2003	33.7	123	15.751	High flow
OK620910-05-0010J	Kingfisher Creek	5/13/2003	72.6	80	7.681	High flow
OK620910-05-0010J	Kingfisher Creek	6/10/2003	76.5	67	16.877	High flow

OK620910-05-0010J	Kingfisher Creek	7/15/2003	348	27	4.308	
OK620910-05-0010J	Kingfisher Creek	8/10/2003	44.9	50	1.408	
OK620910-05-0010J	Kingfisher Creek	9/22/2003	33.8	36	2.24	
OK620910-05-0010J	Kingfisher Creek	10/27/2003	8.35	<10	5.113	
OK620910-05-0010J	Kingfisher Creek	12/8/2003	9.31	23	5.315	
OK620910-05-0010J	Kingfisher Creek	1/12/2004	11.7	12	6.109	
OK620910-05-0010J	Kingfisher Creek	2/17/2004	10.6	23	10.759	High flow
OK620910-05-0010J	Kingfisher Creek	3/22/2004	13.4	<10	36.14	High flow
OK620910-05-0010J	Kingfisher Creek	4/26/2004	99.2	124	30.533	High flow
OK620910-05-0010J	Kingfisher Creek	6/9/2004	82	57	5.387	
OK620910-05-0010J	Kingfisher Creek	5/29/2007	136	111	32.494	High flow
OK620910-05-0010J	Kingfisher Creek	6/25/2007	>1000	1200	5	Rain event
OK620910-05-0010J	Kingfisher Creek	7/31/2007	209	102	14.596	High flow
OK620910-05-0010J	Kingfisher Creek	8/8/2007	17.5		23.916	High flow
OK620910-05-0010J	Kingfisher Creek	9/18/2007	14.1	15	36.893	High flow
OK620910-05-0010J	Kingfisher Creek	10/16/2007	57.4	69	58.176	High flow
OK620910-05-0010J	Kingfisher Creek	11/14/2007	15.5	21	58.474	High flow
OK620910-05-0010J	Kingfisher Creek	12/17/2007	14	12	15.839	High flow
OK620910-05-0010J	Kingfisher Creek	1/23/2008	14.6		8.91	High flow
OK620910-05-0010J	Kingfisher Creek	3/4/2008	456	331	7.74	High flow
OK620910-05-0010J	Kingfisher Creek	4/8/2008	22.5	22	8.12	High flow
OK620910-05-0010J	Kingfisher Creek	5/13/2008	86	60	6.90	High flow
OK620910-05-0010J	Kingfisher Creek	6/17/2008	239	184	3537	High flow
OK620910-05-0080D	Dead Indian Creek	6/11/2002	28.5		1.159	
OK620910-05-0080D	Dead Indian Creek	7/22/2002	17.9	<10	0.132	
OK620910-05-0080D	Dead Indian Creek	9/3/2002	74.4	71	0.185	
OK620910-05-0080D	Dead Indian Creek	10/7/2002	5.51	<10	2.087	

OK620910-05-0080D	Dead Indian Creek	11/12/2002	16.8	18	4.894	High flow
OK620910-05-0080D	Dead Indian Creek	12/10/2002	7.32	14	4.251	
OK620910-05-0080D	Dead Indian Creek	1/22/2003	16	26	5.028	High flow
OK620910-05-0080D	Dead Indian Creek	3/4/2003	13.7	24	3.732	
OK620910-05-0080D	Dead Indian Creek	4/1/2003	12.9	11	2.053	
OK620910-05-0080D	Dead Indian Creek	5/13/2003	15.3	14	1.188	
OK620910-05-0080D	Dead Indian Creek	6/10/2003	56.1	40	1.351	
OK620910-05-0080D	Dead Indian Creek	7/15/2003	22.2	37	0.166	
OK620910-05-0080D	Dead Indian Creek	8/19/2003	53.1	47	0.068	
OK620910-05-0080D	Dead Indian Creek	9/22/2003	18.4	22	0.047	
OK620910-05-0080D	Dead Indian Creek	10/27/2003	17.5	<10	0	
OK620910-05-0080D	Dead Indian Creek	12/8/2003	14.5	30	0.639	
OK620910-05-0080D	Dead Indian Creek	1/12/2004	19.6	18	0.82	
OK620910-05-0080D	Dead Indian Creek	2/17/2004	6.36	11	1.108	
OK620910-05-0080D	Dead Indian Creek	3/22/2004	4.19	<10	6.384	High flow
OK620910-05-0080D	Dead Indian Creek	4/26/2004	60.7	59	4.828	High flow
OK620910-05-0080D	Dead Indian Creek	6/9/2004	33.5	<10	0.759	
OK620910-05-0080D	Dead Indian Creek	5/29/2007	9.72	24	4.818	High flow
OK620910-05-0080D	Dead Indian Creek	6/7/2007	21.1		6.132	High flow
OK620910-05-0080D	Dead Indian Creek	6/25/2007	235	139	32.599	High flow
OK620910-05-0080D	Dead Indian Creek	7/31/2007	812	800	3.8	Rain event
OK620910-05-0080D	Dead Indian Creek	9/18/2007	4.08	<10	60.679	High flow
OK620910-05-0080D	Dead Indian Creek	10/16/2007	175	116	5.752	High flow
OK620910-05-0080D	Dead Indian Creek	11/14/2007	4.53	<10	5.77	High flow
OK620910-05-0080D	Dead Indian Creek	12/17/2007	4.53	<10	9.367	High flow
OK620910-05-0080D	Dead Indian Creek	1/23/2008	3.49		5.049	High flow
OK620910-05-0080D	Dead Indian Creek	3/4/2008	13.7	13	24.258	High flow

OK620910-05-0080D	Dead Indian Creek	4/8/2008	101	133	5.5	High flow
OK620910-05-0080D	Dead Indian Creek	5/13/2008	31.8	23	4.8	High flow
OK620910-05-0080D	Dead Indian Creek	6/17/2008	81.7	58	2423	High flow

High flow = Sample was not collected under base flow conditions (sample collected at flows greater than 75th flow percentile or noted rain events.

APPENDIX B
PROJECTED FLOW EXCEEDANCE PERCENTILES FOR FLOW DURATION CURVES

Estimated Flow Exceedance Percentiles

WQ Station	OK620910-02-0040C Cooper Creek	OK620910-02-0270G Elm Creek	OK620910030010-001AT OK620910-03-0010F OK620910-03-0010S Skeleton Creek	OK620910-04-0010G Cottonwood Creek	OK620910-04-0120B Deer Creek	OK620910-05-0010G OK620910-05-0010J Kingfisher Creek	OK620910-05-0080D Dead Indian Creek
WBID Segment	OK620910020040_00	OK620910020270_00	OK620910030010_00	OK620910040010_20	OK620910040120_00	OK620910050010_00	OK620910050080_00
USGS Gage Reference	07158400	07158400	07160500	07159720	07159720	07159200 07259000	07159200 07259000
Watershed Area (sq. mile)	118.4	25.6	335.6	94.0	113.2	229.9	115.4
NRCS Curve Number	75.2	80.5	73.2	77.4	74.4	74.0	74.2
Average Annual Rainfall (inch)	32.1	30.8	34.6	34.8	35.0	32.3	33.1
Percentile	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**	**Q (cfs)**
0	3,347.5	723.6	39,200.0	7,570.1	9,123.4	6,480.0	4,766.3
5	64.0	13.9	463.0	195.0	235.5	65.7	47.9
10	24.8	5.4	181.1	99.5	120.1	21.4	14.9
15	16.3	3.5	107.0	62.0	75.3	12.0	7.9
20	12.1	2.6	71.0	46.0	55.9	8.2	5.6
25	9.1	2.0	51.0	36.9	44.5	6.3	4.5
30	7.9	1.7	38.0	30.4	36.7	5.1	3.5
35	6.6	1.4	31.0	24.8	30.3	4.1	2.8
40	6.0	1.3	25.0	20.9	25.7	3.0	2.1
45	5.6	1.2	21.0	19.0	22.9	2.3	1.5
50	5.0	1.1	17.0	17.1	20.6	1.8	1.3
55	4.5	1.0	14.0	15.2	18.8	1.4	1.0
60	4.1	0.9	12.0	13.7	16.5	1.2	0.8
65	3.7	0.8	11.0	12.2	14.7	0.9	0.7
70	3.4	0.7	9.2	11.4	13.8	0.7	0.5
75	3.0	0.7	8.0	9.5	11.9	0.6	0.4
80	2.7	0.6	6.6	8.0	10.1	0.4	0.3
85	2.2	0.5	5.3	7.2	8.7	0.2	0.2
90	1.7	0.4	4.1	6.1	7.8	0.1	0.1
95	1.2	0.3	2.8	5.3	6.4	0.03	0.02
100	0.0	0.0	0.0	0.0	3.7	0.0	0

Appendix B
General Methodology for Estimating Stream Flow

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 gage. First, the most appropriate nearby stream gage is identified. All flow data are first log-transformed to linearize the data because flow data are highly skewed. Linear regressions are then developed between 1) daily streamflow at the gage to be filled/extended, and 2) streamflow at all gages within 95 miles that have at least 300 daily flow measurements on matching dates. The station with the best flow relationship, as indicated by the highest r-squared value, is selected as the index gage. R-squared indicates the fraction of the variance in flow explained by the regression. The regression is then used to estimate flow at the gage to be filled/extended from flow at the index station. Flows will not be estimated based on regressions with r-squared values less than 0.25, even if that is the best regression. In some cases, it will be necessary to fill/extend flow records from two or more index gages. The flow record will be filled/extended to the extent possible based on the best index gage (highest r-squared value), and remaining gaps will be filled from the next best index gage (second highest r-squared value), and so forth.

c. Flow duration curves will be based on both measured flows only and on the filled or extended flow time series calculated from other gages using regression.

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 (NED) 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 Table 7. 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 20 Feb 2004).

Table B-1 Runoff Curve Numbers for Various Land Use Categories and Hydrologic Soil Groups

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

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, 2000).

Furness Method

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

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

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

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

Wurbs Modified NRCS Method

As a part of the Texas water availability modeling (WAM) system developed by Texas Natural Resources Conservation Commission (TNRCC), 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 Natural Resource Conservation Service (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 < 0.2S, 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, P_{gaged}. 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:

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

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 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, we developed what is effectively a hybrid of the NRCS CN method and the Furness method. 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, we decided to adopt an assumption that is implicit in the Furness method. 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 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, we decided to use this vector in association with the mean flow to project the flow frequency curve.

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

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

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

REPONSE TO PUBLIC COMMENTS

Comment E-mailed from Ms. Patricia Billingsley, Oklahoma Corporation Commission:

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From: Patricia Billingsley [mailto:P.Billingsley@occemail.com]
Sent: Monday, March 01, 2010 10:21 AM
To: Miles, Karen
Cc: Tim Baker
Subject: DEQ TMDL Kingfisher & Dead Indian Creeks

Dr. Karen Miles
Water Quality Division
Oklahoma Department of Environmental Quality
P.O. Box 1677
Oklahoma City, OK 73101-1677

Re: Availability of draft turbidity TMDL for the lower Cimarron river-Skeleton creek study area Request for public comments

Dr. Miles -

We have no problems with the TMDL limits outlined. However, there may be a source of the high levels or turbidity/sediment in area creeks that DEQ is unaware of.

Our sampling in Kingfisher and Dead Indian Creek from 2002-2006 demonstrated relatively high levels of boron in these and several other 62091005 HUC watershed streams. Boron was not a parameter we analyzed for prior to 2002; we have since developed boron cleanup guidance, since it sometimes occurs in produced water. Two other creeks in this area, Okarche Creek and Winter Camp Creek, also had high boron levels, and may also need a TMDL.

Boron begins to adversely many fruits and nut trees exposed to or irrigated with high boron water at 0.75 mg/l, and grain crops at 1.0 mg/l. Where boron levels are higher, even grasses will be affected. When vegetation holding soils is damaged, the soil will erode. If this is along the stream banks and in fields near these streams, it could be one reason for the higher sediment/turbidity levels found in these streams.

We do not know the source of the high boron levels in this area. The Na/Cl ratio is not that of produced water, even though much of the sampling was originally done because of natural gas leaks in the area. Additional detailed sampling along the creeks and their tributaries may be necessary in order to learn if the boron is still present, and exactly where it is coming into the hydrologic system in these watersheds; perhaps there are springs feeding the headwaters of some tributaries, or pockets of high boron deposits in soil or bedrock in the area. It is possible that there are much higher boron levels in upstream or tributary areas where we did not sample, becoming diluted with more flow downstream.

Attached via email is a table detailing the 2003-2007 sampling data we have for all of the streams we have in HUCS 62091002, 62091003, 62091004, and 62091005, including those with and without elevated boron levels. Several of these streams also had elevated sulfate levels. I have highlighted the elevated boron samples in the Excel table.

Sincerely,

Patricia Billingsley

Pollution Abatement, Oil & Gas Conservation Division

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Response: This information is duly noticed by DEQ. However, because of the uncertainty of the origin of the high boron levels and the indirect connection between high boron levels and potential increase of turbidity, this information cannot be included in the TMDL analysis in this report. The Oklahoma Water Quality Standards do not have a boron criterion. Okarche Creek and Winter Camp Creek are not currently listed for turbidity impairment according to the 2008 Oklahoma Integrated Report. Therefore, no boron or turbidity TMDL analysis will be conducted on either stream. No change was made as a result of this comment.