Draft Wasteload Evaluation for City of Skiatook and Town of Sperry

Lower Hominy Creek
OKWBID # OK121300040010_00

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1. Problem Definition

This waste load allocation (WLA) addresses the impact of in-stream organic enrichment on dissolved oxygen (DO) due to the discharge of treated wastewater from the Skiatook and Sperry municipal wastewater treatment plants (WWTPs) by allocating DO-demanding substances (BOD and Ammonia) under critical flow conditions. It also accounts for non-point source impacts through the use of conservative kinetic inputs / assumptions, and through the use of Sediment Oxygen Demand (SOD) to calculate the Load Allocation (LA). Lower Hominy Creek has sustained releases from the upstream Lake Skiatook reservoir established by Corps of Engineers agreement to maintain a regulatory base flow as measured at the downstream USGS Sperry gage on Bird Creek for downstream water quality and use in Tulsa's Northside WWTP WLA. ODEQ and EPA continue to allow the seasonal Agreement flows for WLA purposes for all WWTPs on Hominy Creek (Sperry and Skiatook), Bird Creek (Tulsa Northside and Tulsa's Lower Bird Creek Regional)), and the Verdigris River (Claremore and Inola WWTPs). For this WLA study, ODEQ instructed INCOG to continue to use the seasonal Corps Agreement flows, minus the design flows from the Skiatook and Sperry WWTPs), to be used for modeling purposes.

The City of Skiatook presently has two separate WWTPs, one discharging to Bird Creek (permit # OK0028118) and the other (Skiatook West) to Hominy Creek (permit # OK0040461). The city's engineering study in 2012 recommended discontinuation of the Bird Creek WWTP and diverting all wastewater flows to an upgraded plant on Hominy Creek. Based upon the anticipated population increases for Skiatook by 2040 in the engineering study, the city requested modeling for a new WLA of 2.5 MGD daily design flow to Hominy Creek. Since the Town of Sperry also discharges to Hominy Creek (permit # OK0033464) about 5 river miles downstream, INCOG included Sperry discharge in the model. The Sperry consulting engineer and town officials recommended that the WLA should be increased from their present design flow of 0.132 MGD to 0.25 MGD to accommodate future growth. Therefore, both facilities have been modeled for future wastewater treatment needs.

The Skiatook West facility discharges to lower Hominy Creek at river mile 7.5 in Osage County, Oklahoma. The Sperry WWTP discharges at river mile 2.6. The Skiatook West existing WLA in the State's Water Quality Management Plan (208 Plan) is based upon 0.9 MGD design flow, and the Skiatook Bird Creek design flow is 0.35 MGD in the 208 Plan. The City of Skiatook has requested an increase in design flow to 2.50 MGD along with elimination of the Skiatook WWTP discharge to Bird Creek.

The Oklahoma Waterbody Identification (WBID) segment for lower Hominy Creek is OK121300040010_00. It is classified in the Oklahoma Water Quality Standards for the following beneficial uses:

- Warm Water Aquatic Community (WWAC)
- Primary Body Contact Recreation (PBCR)
- Public and Private Water Supply (PPWS)
- Agriculture
- Aesthetics

This Hominy Creek WBID segment is not listed in Oklahoma's 2012 303(d) list for any impairments; therefore this modeling assessment, which focuses only on DO demanding substances, does not have any impact on the current 303(d) list status.

This WLA has been developed in order to ensure that the limits assigned to the discharge are stringent enough to maintain DO standards under critical conditions.

A map of the study area (Figure 1) is included in the report.

2. Endpoint Identification

The Oklahoma Water Quality Standards define DO criteria for two flow regimes: critical low-flow and nuisance conditions. The critical low-flow will be either 7Q2 (or for this study, the Corps Agreement flows) or 1.0 cfs, whichever is greater. Nuisance conditions apply only when there is no upstream flow. Since lower Hominy Creek has a regulatory base flow greater than 1.0 cfs, nuisance condition determination is not needed.

The following numerical dissolved oxygen criteria for WWAC apply to lower Hominy Creek:

	Critical Low-Flow Condition
Summer (Jun–Oct):	5.0 mg/L
Spring (Apr–May):	6.0 mg/L
Winter (Nov–Mar):	6.0 mg/L

Lower Hominy Creek has perennial flow which is regulated by the upstream Lake Skiatook reservoir releases maintained by the US Corps of Engineers as part of the original design plans for Skiatook Lake construction to protect downstream water quality of Hominy Creek and Bird Creek. The USGS flow gage on Bird Creek at 86th Street North near Sperry (07177500), approximately 2.4 river miles downstream of the confluence with Hominy Creek, provides the daily determinations of minimum seasonal flows that must be maintained by the Corps of Engineers and which are used for all modeling within the Tulsa area of lower Hominy Creek, lower Bird Creek and the Verdigris River. This gage is monitored daily by City of Tulsa and Corps of Engineers. There is also perennial flow in Bird Creek upstream of the Hominy Creek confluence as measured by the USGS gage at Avant. Therefore, the seasonal headwater flows used in the modeling for lower Hominy Creek are the Agreement flows minus the combined future design flows of Skiatook and Sperry (2.50 MGD + 0.25 MGD) and minus the 7Q2 seasonal flows from the Avant gage. These headwater flows are:

- Summer: 128.0 cfs
- Spring: 80.7 cfs
- Winter: 37.8 cfs

Oklahoma antidegradation policy (OAC 785:45-3) requires protecting all waters of the state from degradation of water quality. The allocated loadings/concentrations in this report were set with regard to all elements of the Oklahoma Water Quality standards which includes the antidegradation policy.

3. Source Analysis

3.1. Point Sources

Skiatook West (WWTF)

Facility Legal Description:	W/2 NE S33 T22N R12E
Receiving Stream:	Hominy Creek
Point of Discharge (POD)	SW SE SE S33 T22N R12E

Current Wasteload Allocation (WLA):

Permitted Flow:	0.9 MGD
Summer (Jun - Oct):	Secondary
Spring (Apr - May):	Secondary
Winter (Nov - Mar):	Secondary

Skiatook Bird Creek (WWTF)

Facility Legal Description:	SW NW NW S25 T22N R12E
Receiving Stream:	Bird Creek
Point of Discharge (POD)	SW NW NW S25 T22N R12E

Current Wasteload Allocation (WLA):

Permitted Flow:	0.35 MGD
Summer (Jun - Oct):	Secondary
Spring (Apr - May):	Secondary
Winter (Nov - Mar):	Secondary

Sperry (WWTF)

Facility Legal Description:	NW NW NW S13 T21N R12E
Receiving Stream:	Hominy Creek
Point of Discharge (POD)	NW NW NW S13 T21N R12E

Current Wasteload Allocation (WLA):

Permitted Flow:	0.132 MGD
Summer (Jun - Oct):	Secondary
Spring (Apr - May):	Secondary
Winter (Nov - Mar):	Secondary

The Skiatook WWTP discharge is approximately 5 river miles upstream of the Sperry WWTP discharge (see Figure 1). Owing to the great distance apart and high dilution of both effluents, there is no overlap of DO sag or mixing zones. Therefore the modeling is not considered a complex waste scenario.

3.2. Non-Point Sources

The modeling for DO focuses on non-runoff critical conditions (i.e., low-flow and high temperature); therefore, only minor impacts are expected from non-point source (NPS) runoff during low flow conditions. The model incorporates a separate safety factor (see below), which should also account for the uncertainties in NPS loadings. It is assumed that the Sediment Oxygen Demand (SOD) includes the residual effects from NPS at low flows. The SOD was used in the calculation of the Load Allocation (LA) at low flow.

3.3. Background

The following background (headwater) conditions of Hominy Creek were used:

Upstream Flow:	Seasonal flows cited above
$CBOD_5$:	2.0 mg/L
Ammonia:	0.15 mg/L
DO:	85% saturation at the regulatory seasonal temperature

4. Linkage between Sources and Receiving Water

The links between sources and the receiving stream can be established through the LAQUAL desktop water quality model used by INCOG. This model is a one-dimensional, steady-state, mass balance, Streeter-Phelps model, developed originally by Texas Natural Resource Conservation Commission as a DOS-based program called QUALTX. The State of Louisiana hired the programmer to develop a Windows text-entry GUI version, now called LAQUAL. LAQUAL is used extensively by Louisiana and has been used to prepare numerous WLA and TMDL studies for Oklahoma approved by ODEQ and EPA. The model conforms with modeling requirements found in Oklahoma's Continuing Planning Process (CPP).

The last 208 Plan modeling for both towns was performed in 1991 by INCOG using a Streeter-Phelps DO model. In 2004 and again in 2008, INCOG set up seasonal LAQUAL models to examine potential discharge scenarios for Sperry and later Skiatook. In both cases the requests never resulted in submitting 208 Plan amendments. For this present study, INCOG performed two reconnaissance surveys of Hominy Creek under 100 cfs and 30 cfs flow conditions. These field observations were used to revise the model's hydraulics and reach configurations to conform to the observations of widths and depths noted during the two surveys.

The Texas reaeration equation was used for this study. Field measurements at the 100 cfs survey were made for temperature and DO at several stream sites. To test the reasonableness of the LAQUAL models, a "partial calibration" model was run by setting headwater flows to 100 cfs and model temperatures to those measured during the survey. Best judgment of discharge flows and concentrations of CBOD5 and ammonia were made as well. The "partial calibration" model results showed a DO profile of around 1 mg/L lower DO than what was measured in the stream. Since field DO measurements were made in the morning, and the stream channel had significant shading, it is unlikely that the higher measured DO was due to algal production. It is more likely that the model under-predicts reaeration, or that SOD is set higher than needed. However, there was too little field data to be determinative, so these model conditions were not adjusted, and the model can be considered to have additional conservative assumptions.

The LAQUAL models used in this WLA report show a steady decline of DO downstream to the Bird Creek confluence. While this could be the result of upstream wastewater discharge impacts on stream DO from Skiatook and Sperry, there was no localized "DO sag" in the model. To confirm that this steady gradual DO decline was a modeling artifact, INCOG reduced both discharges to zero and re-ran the summer model. Even with no WWTP discharges, there was the same steady and gradual decline in DO to Bird Creek. When SOD was reduced by about half, there was still a steady DO decline. Finally, the WWTP dischargers were re-inserted into the test model, and the temperatures were lowered from the summer default of 32 ^{o}C to 23 ^{o}C and the DO no longer declined downstream, even with the WWTP discharges. This confirmed that the declining DO is due to non-discharge related factors inherent in the model itself at higher modeling temperatures, most likely causing lower reaeration rates and increased SOD and decay rates for CBOD and NH3-N.

4.1. Model Inputs

The LAQUAL model used in this study determines the impact of DO-demanding substances on the instream DO concentration based upon a modified version of the Streeter-Phelps equation. The primary kinetic inputs were derived from literature values and the past WLAs performed by INCOG and ODEQ. The Texas equation was used to calculate the reaeration rates used in the model. This equation has been used frequently and approved by ODEQ and EPA as most suitable for these types of streams having depths of a few feet and velocities of around 1 fps or less. The other primary kinetic inputs (20ºC) were derived from literature values and are as follows:

Hominy Creek:

BOD decay rate ($\mathbf{K_1}$):	0.30/day
Reaeration Rate & Formula ($\mathbf{K_2}$):	1.62 – 1.64/day
NBOD decay rate ($\mathbf{K_n}$):	0.30/day
BOD settling rate ($\mathbf{K_s}$):	0.03/day
Sediment Oxygen Demand (**SOD**):	0.070 g/ft^2/day

INCOG used a spreadsheet to develop the hydraulic equation coefficients and exponents for the LAQUAL model that gave a good fit to the field observations of widths and depths during the two surveys. The following exponential equations were used to calculate appropriate LAQUAL coefficients and exponents for velocity and depth of each reach:

$V = a*Q^b$ $\quad\quad$ $D = c*Q^d + e$

Where: V = mean velocity (ft/sec)
Q = mean discharge (ft3/sec)
D = mean depth (ft)
a,b,c,d,e = constants

INCOG performed sensitivity analysis on four model kinetics. LAQUAL was set to calculate ±10% and ±30% for BOD decay rate (K1), ammonia decay rate (KN), reaeration rate (KA) and SOD. The results of the sensitivity analyses (see Appendix A) show that there were only minor changes to stream DO with ±30% manipulation of the four rate parameters, with all rates except reaeration no greater than 3.3% change. Reaeration rate change resulted in a percent change in DO of 4.9% and -6.7% for 30% increase and decrease, respectively . These model kinetics were considered to be the most sensitive aspects of the model.

4.2. Maximum Assimilative Capacity

The LAQUAL model and an Excel spreadsheet that has been jointly developed by INCOG and ODEQ were used to determine the stream's maximum assimilative capacity during various seasons under seasonal regulatory flow conditions. To do this, the concentrations of BOD_5 and NH_3-N of the point source are increased at the same rate until the predicted instream DO reaches the DO criteria. The resultant mass loading, when added to the mass loading of the river's headwater conditions, represents the maximum assimilative capacity of the stream for DO-demanding substances. Results of this method are presented in Table 1.

Because this method required inputting very large loads for the Skiatook and Sperry discharges, the 20% MOS was also calculated more simply by increasing both BOD and ammonia proportionately by 20% for both dischargers over the seasonal limits modeled in the WLA. For CBOD20, the 20% increases were to 41.4 mg/L and 69.0 mg/L for Skiatook and Sperry, respectively. For NH3-N, the 20% increases were to 9.6 mg/L and 8.64 mg/L for Skiatook and Sperry, respectively. The same +20% proportional increases were made to the WLAs for Spring and Winter as well. The 20% MOS increases in BOD and ammonia were then modeled under all three seasons to ensure that DO in the receiving stream did not fall below the seasonal DO targets. This method showed that an increase in effluent loads by exactly 20% total oxygen demand had no significant change over impacts from effluent with no MOS increase. All inputs and results are presented in Table 2.

Table 1. Maximum Assimilative Capacity

Season	MAC Maximum Assimilative Capacity (lbs/day)
Summer (Jun–Oct)	7462.14
Spring (Apr–May)	5,608.43
Winter (Nov–Mar)	5,494.16

Max. Assimil. Cap. = Max. Effluent load (lbs/d) + Headwater load (lbs/d) + SOD (lbs/d)

Where: Max. BODu Effluent Load = {max. [BOD5] to just meet DO target x 2.3 x 8.34 x MGD} + {max. [NH3] to just meet DO target x 4.33 x 8.34 x MGD}

Headwater BODu Load = {[BOD5] x 2.3 x 8.34 x MGD} + {[NH3] x 4.33 x 8.34 x MGD}

SOD Load = {SOD / Depth} x 35.316 x MGD x 8.34

5. Margin of Safety

The CPP specifies a 20% Margin of Safety (MOS) for uncalibrated, simple source desktop models. The quantified MOS is equal to 20% of maximum assimilative capacity. The MOS, load allocation, wasteload allocation and reserved capacity are calculated in the model and presented in the next section. Because there are no other significant oxygen demand dischargers within 5 miles upstream or downstream of either the Skiatook or Sperry discharges, and because the two discharges are highly diluted with no overlapping mixing zones, a MOS of 20% was used.

Table 2. Results of +20% Margin of Safety Modeling

SEASON	MODEL	CBOD5 (mg/L)	CBOD20 (mg/L)	NH3 (mg/L)	Min. DO (mg/L)	Target DO (mg/L)
Summer	Skiatook WLA	15	34.6	8	5.29	5.00
	Sperry WLA	25	57.5	7.2		
	Skiatook +20% MOS	18	41.4	9.6	5.23	5.00
	Sperry +20% MOS	30	69	8.64		
Spring	Skiatook WLA	17	39.1	8	6.41	6.00
	Sperry WLA	25	57.5	7.2		
	Skiatook +20% MOS	20.4	46.9	9.6	6.21	6.00
	Sperry +20% MOS	30	69	8.64		
Winter	Skiatook WLA	25	57.5	12	6.77	6.00
	Sperry WLA	25	57.5	15.4		
	Skiatook +20% MOS	30	69	14.4	6.53	6.00
	Sperry +20% MOS	30	69	18.5		

The Min. DO column reflects the minimum DO concentrations in any model element for the modeled WLA and for the +20% MOS added to each system's WLA. The Target DO is the minimum DO established in the Oklahoma Water Quality Standards. Table 2 shows that there is adequate assimilative capacity in Hominy Creek for the Skiatook and Sperry WWTPs even with 20% MOS added to each effluent.

6. Allocations

The seasonal allocation of loads calculated by the INCOG/ODEQ spreadsheets are shown in Table 3. The Load Allocation represents the loads from the Hominy Creek headwater concentrations of BOD5 and NH3-N converted to mass loads (lbs/d) at each seasonal low flow and added to each season's NPS loads. Seasonal NPS loads, in turn, are calculated from the seasonal SOD ($g/ft^2/d$) and depth (ft) converted to lbs/day. The Wasteload Allocation represented by mass loads in Table 3 are derived from the seasonal modeling concentrations (mg/L) for each discharger for CBOD5 and NH3-N at their requested average daily design flows in MGD. The 20% MOS represents 20% of the river's Maximum Assimilative Capacity for each season. The Reserved Capacity represents the Maximum Assimilative Capacity of the river minus the sum of all oxygen-demanding loads from the WLA, LA and MOS.

Table 3. Allocations

Season	LA Load Allocation (lb/day)	WLA Wasteload Allocation (lb/day)	MOS (20%) (lbs/day)	RC Reserved Capacity (lbs/day)
Summer	4,278.30	1,626.46	1,492.43	64.95
Spring	2,731.81	1,722.37	1,121.69	32.57
Winter	1,298.66	2,541.16	1,098.83	555.51

A convenient way to express the relationship of these various loads is:

TMDL = WLA + LA + MOS + RC
LA = Background + NPS
NPS = SOD / Depth converted to lbs/d

RC = MAC - WLA - LA - MOS
MAC = WLA_{max} + NPS + HWTR
Background = HWTR

7. Final Recommendations

The following changes are recommended for inclusion in the Oklahoma Water Quality Management Plan (208 Plan). The model was run for each facility at average daily design effluent flow rates of 2.50 MGD and 0.25 MGD for Skiatook and Sperry, respectively.

Skiatook WWTF

Average Daily Design Effluent Flow (Q_e): 2.50 MGD
Summer (Jun - Oct): 15 mg/L CBOD5 and 8 mg/L NH3-N at 5 mg/L DO.
Spring (Apr - May): 17 mg/L CBOD5 and 8 mg/L NH3-N at 6 mg/L DO).
Winter (Nov - Mar): Secondary Limits (25 mg/L CBOD5 and 12 mg/L NH3-N at 2 mg/L DO).

Sperry WWTF

Average Daily Design Effluent Flow (Q_e): 0.25 MGD
Summer (Jun - Oct): Secondary Limits (25 mg/L CBOD5 and 7.2 mg/L NH3-N) at 5 mg/L DO.
Spring (Apr - May): Secondary Limits (25 mg/L CBOD5 and 7.2 mg/L NH3-N) at 6 mg/L DO).
Winter (Nov - Mar): Secondary Limits (25 mg/L CBOD5 and 15.4 mg/L NH3-N at 2 mg/L DO).

The WLA evaluation indicates that lower Hominy Creek can assimilate water quality based mass loads from both the Skiatook and Sperry WWTPs without affecting the seasonal target DO concentrations including a 20% MOS. There is reserve capacity left in Hominy Creek for all three seasons at the modeled permit limits.

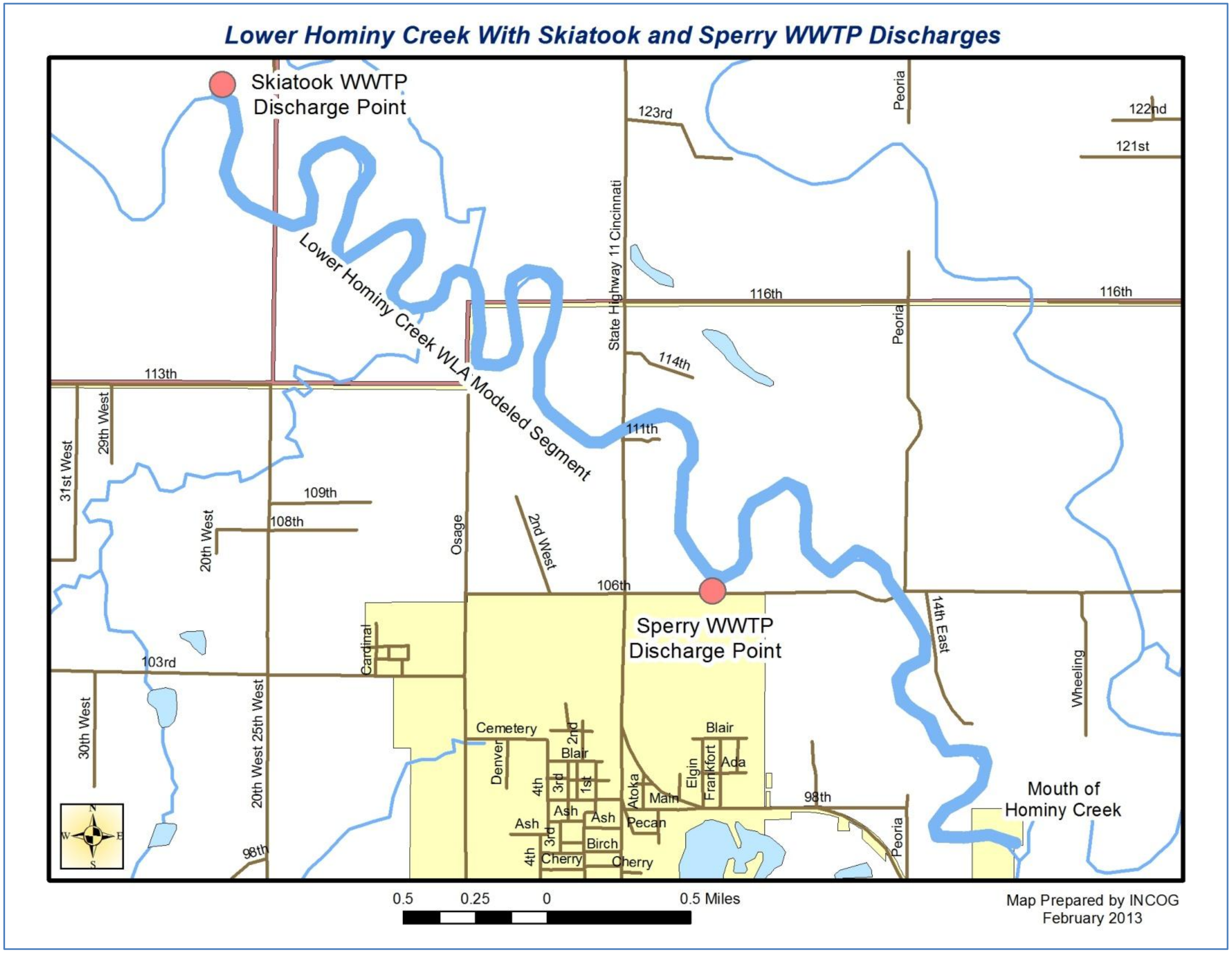
8. Public Participation

This is a revised draft Wasteload Allocation that has received technical review by ODEQ; changes have been made to reflect responses to ODEQ comments on the original draft WLA. The ODEQ will review the changes, and if approved, will send the report to EPA for their review and approval. The proposed permit limits will be sent for public comments and the public comments process will be completed after technical approval is received.

The proposed limits will be implemented through the OPDES permit for Skiatook and Sperry, which represents an adequate implementation of the wasteload allocation. The water quality model in this report shows clearly that the recommended allocation of dissolved oxygen-demanding substances adequately addresses the stream’s dissolved oxygen requirements. With the recommended limits in place, the stream will meet Oklahoma Water Quality Standards.

Both Skiatook and Sperry are required to submit monthly Discharge Monitoring Reports (DMR) to the Oklahoma Department of Environmental Quality. The DMRs will continue to ensure that the beneficial uses will be maintained in Hominy Creek.

Figure 1: Location of Skiatook and Sperry Discharges on Lower Hominy Creek



Appendix A: Desktop Model Outputs:

(Files of all models will be emailed to ODEQ)

Table A.1: Results of Sensitivity Analysis:

RATE	DEVIATION	MIN. DO (mg/l)	PERCENT CHANGE
Base: No Change	0	**5.29**	n/a
BOD Decay (K1)	+10%	5.23	-1.1%
	+30%	5.12	-3.3%
	-10%	5.35	1.1%
	-30%	5.47	3.3%
SOD	+10%	5.23	-1.1%
	+30%	5.11	-3.5%
	-10%	5.35	1.1%
	-30%	5.46	3.1%
Ammonia Decay (KN)	+10%	5.27	-0.4%
	+30%	5.22	-1.3%
	-10%	5.31	0.4%
	-30%	5.36	1.3%
Reaeration (KA)	+10%	5.39	1.9%
	+30%	5.56	4.9%
	-10%	5.19	-1.9%
	-30%	4.96	-6.7%

Percent change = (Change - Base) / Base

Figure A.1: Summer Seasonal Model Outputs for DO:

Element	Reach	River Miles	FLOW (cfs)	TEMP (deg C)	DO (mg/L)	CBOD20 (mg/L)	NH3-N (mg/L)	DEPTH (ft)	WIDTH (ft)	Velocity (fps)	
		HDWTR	128	32	6.2	4.6	0.15				
1	1	7.15	131.87	32	6.10	5.42	0.38	2.56	43.5	1.18	Skiatook WWTP (2.5 MGD)
2	1	6.80	131.87	32	6.04	5.37	0.37	2.56	43.5	1.18	
3	1	6.45	131.87	32	5.98	5.32	0.37	2.56	43.5	1.18	
4	1	6.10	131.87	32	5.92	5.27	0.36	2.56	43.5	1.18	
5	1	5.75	131.87	32	5.87	5.22	0.36	2.56	43.5	1.18	
6	1	5.40	131.87	32	5.82	5.17	0.35	2.56	43.5	1.18	
7	1	5.05	131.87	32	5.77	5.12	0.35	2.56	43.5	1.18	
8	1	4.70	131.87	32	5.72	5.07	0.34	2.56	43.5	1.18	
9	1	4.35	131.87	32	5.68	5.02	0.34	2.56	43.5	1.18	
10	1	4.00	131.87	32	5.64	4.97	0.33	2.56	43.5	1.18	
11	1	3.65	131.87	32	5.60	4.93	0.33	2.56	43.5	1.18	
12	1	3.30	131.87	32	5.57	4.88	0.32	2.56	43.5	1.18	
13	1	2.95	131.87	32	5.53	4.83	0.32	2.56	43.5	1.18	
14	1	2.60	131.87	32	5.50	4.79	0.32	2.56	43.5	1.18	
15	2	2.40	132.26	32	5.48	4.91	0.33	2.56	45.2	1.14	Sperry Lagoon (0.25 MGD)
16	2	2.20	132.26	32	5.46	4.88	0.33	2.56	45.2	1.14	
17	2	2.00	132.26	32	5.44	4.86	0.33	2.56	45.2	1.14	
18	2	1.80	132.26	32	5.42	4.83	0.33	2.56	45.2	1.14	
19	2	1.60	132.26	32	5.41	4.80	0.32	2.56	45.2	1.14	
20	2	1.40	132.26	32	5.39	4.77	0.32	2.56	45.2	1.14	
21	2	1.20	132.26	32	5.37	4.75	0.32	2.56	45.2	1.14	
22	2	1.00	132.26	32	5.36	4.72	0.32	2.56	45.2	1.14	
23	2	0.80	132.26	32	5.34	4.69	0.31	2.56	45.2	1.14	
24	2	0.60	132.26	32	5.33	4.66	0.31	2.56	45.2	1.14	
25	2	0.40	132.26	32	5.31	4.64	0.31	2.56	45.2	1.14	
26	2	0.20	132.26	32	5.30	4.61	0.31	2.56	45.2	1.14	
27	2	0.00	132.26	32	5.29	4.58	0.30	2.56	45.2	1.14	

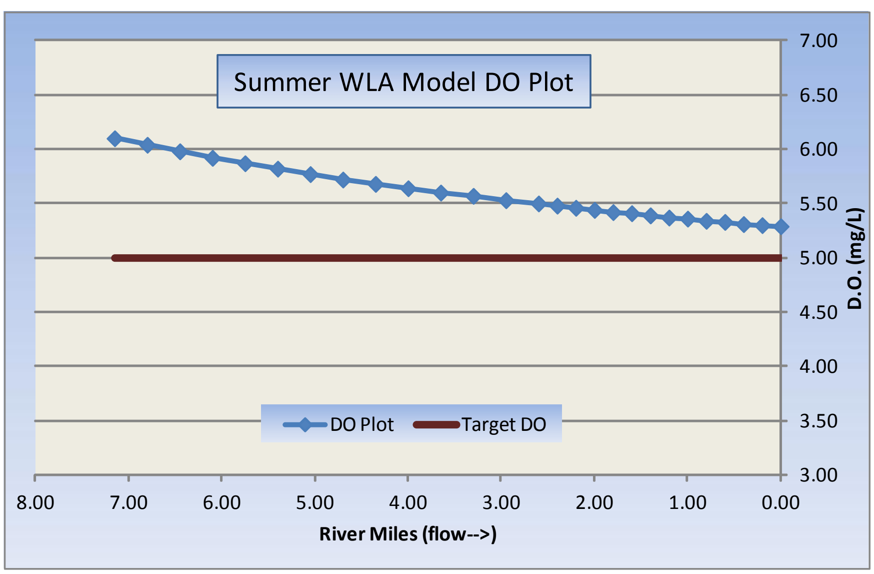


Figure A.2: Winter Seasonal Model Outputs for DO:

Element	Reach	River Miles	FLOW (cfs)	TEMP (deg C)	DO (mg/L)	CBOD20 (mg/L)	NH3-N (mg/L)	DEPTH (ft)	WIDTH (ft)	Velocity (fps)	
		HDWTR	37.8	18	8.05	4.6	0.15				
1	1	7.15	41.67	18	7.41	9.39	1.24	2.12	41.4	0.48	Skiatook WWTP (2.5 MGD)
2	1	6.80	41.67	18	7.34	9.27	1.22	2.12	41.4	0.48	
3	1	6.45	41.67	18	7.28	9.15	1.21	2.12	41.4	0.48	
4	1	6.10	41.67	18	7.22	9.04	1.20	2.12	41.4	0.48	
5	1	5.75	41.67	18	7.17	8.92	1.18	2.12	41.4	0.48	
6	1	5.40	41.67	18	7.12	8.81	1.17	2.12	41.4	0.48	
7	1	5.05	41.67	18	7.08	8.70	1.16	2.12	41.4	0.48	
8	1	4.70	41.67	18	7.05	8.59	1.14	2.12	41.4	0.48	
9	1	4.35	41.67	18	7.02	8.48	1.13	2.12	41.4	0.48	
10	1	4.00	41.67	18	6.99	8.37	1.12	2.12	41.4	0.48	
11	1	3.65	41.67	18	6.96	8.26	1.11	2.12	41.4	0.48	
12	1	3.30	41.67	18	6.94	8.16	1.10	2.12	41.4	0.48	
13	1	2.95	41.67	18	6.93	8.05	1.08	2.12	41.4	0.48	
14	1	2.60	41.67	18	6.91	7.95	1.07	2.12	41.4	0.48	
15	2	2.40	42.06	18	6.85	8.34	1.20	2.12	43.2	0.46	Sperry Lagoon (0.25 MGD)
16	2	2.20	42.06	18	6.84	8.28	1.19	2.12	43.2	0.46	
17	2	2.00	42.06	18	6.83	8.22	1.18	2.12	43.2	0.46	
18	2	1.80	42.06	18	6.82	8.15	1.17	2.12	43.2	0.46	
19	2	1.60	42.06	18	6.81	8.09	1.16	2.12	43.2	0.46	
20	2	1.40	42.06	18	6.80	8.03	1.16	2.12	43.2	0.46	
21	2	1.20	42.06	18	6.80	7.97	1.15	2.12	43.2	0.46	
22	2	1.00	42.06	18	6.79	7.91	1.14	2.12	43.2	0.46	
23	2	0.80	42.06	18	6.78	7.85	1.13	2.12	43.2	0.46	
24	2	0.60	42.06	18	6.78	7.79	1.13	2.12	43.2	0.46	
25	2	0.40	42.06	18	6.78	7.73	1.12	2.12	43.2	0.46	
26	2	0.20	42.06	18	6.77	7.67	1.11	2.12	43.2	0.46	
27	2	0.00	42.06	18	6.77	7.60	1.10	2.12	43.2	0.46	

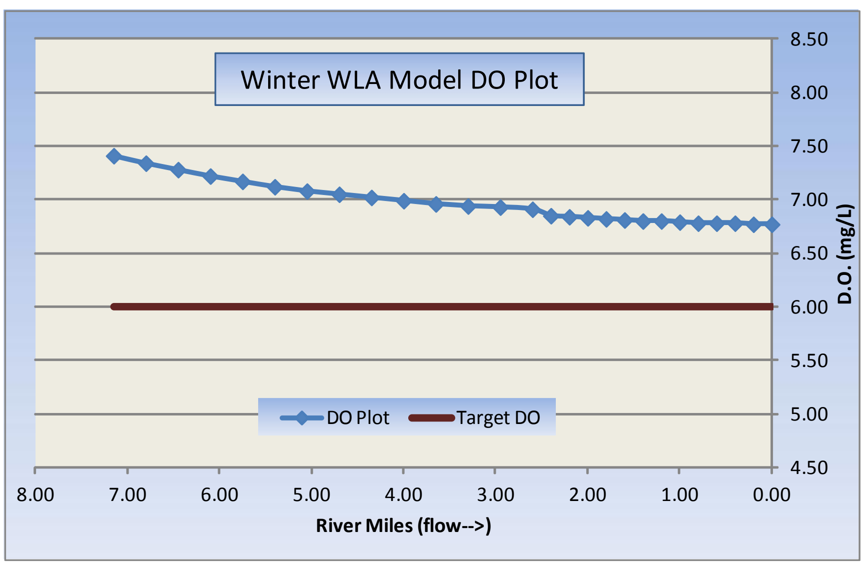
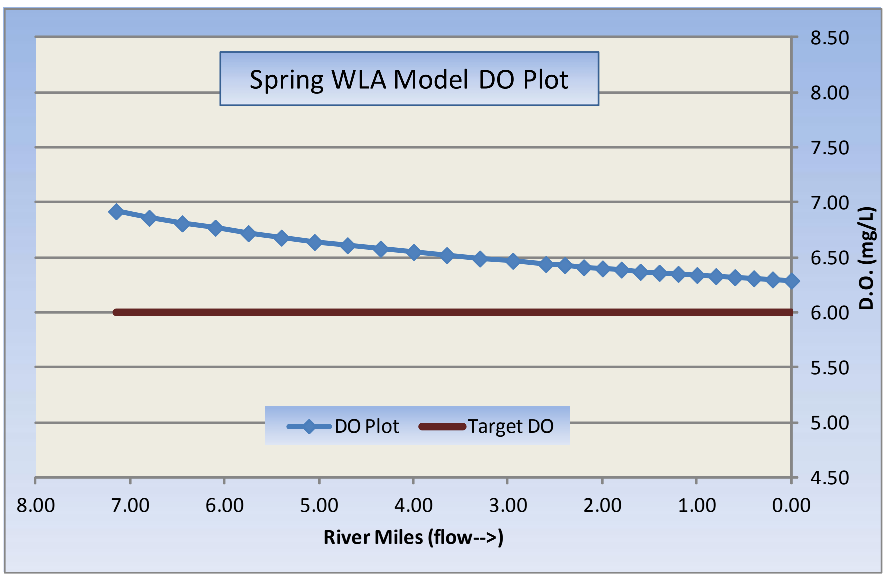


Figure A.3: Spring Seasonal Model Outputs for DO:

Element	Reach	River Miles	FLOW (cfs)	TEMP (deg C)	DO (mg/L)	CBOD20 (mg/L)	NH3-N (mg/L)	DEPTH (ft)	WIDTH (ft)	Velocity (fps)	
		HDWTR	80.7	25	7.02	4.6	0.15				
1	1	7.15	84.57	25	6.92	6.12	0.50	2.38	42.7	0.83	Skiatook WWTP (2.5 MGD)
2	1	6.80	84.57	25	6.86	6.06	0.50	2.38	42.7	0.83	
3	1	6.45	84.57	25	6.81	6.00	0.49	2.38	42.7	0.83	
4	1	6.10	84.57	25	6.77	5.94	0.49	2.38	42.7	0.83	
5	1	5.75	84.57	25	6.72	5.88	0.48	2.38	42.7	0.83	
6	1	5.40	84.57	25	6.68	5.82	0.48	2.38	42.7	0.83	
7	1	5.05	84.57	25	6.64	5.76	0.47	2.38	42.7	0.83	
8	1	4.70	84.57	25	6.61	5.70	0.47	2.38	42.7	0.83	
9	1	4.35	84.57	25	6.58	5.65	0.46	2.38	42.7	0.83	
10	1	4.00	84.57	25	6.55	5.59	0.46	2.38	42.7	0.83	
11	1	3.65	84.57	25	6.52	5.53	0.45	2.38	42.7	0.83	
12	1	3.30	84.57	25	6.49	5.48	0.45	2.38	42.7	0.83	
13	1	2.95	84.57	25	6.47	5.42	0.44	2.38	42.7	0.83	
14	1	2.60	84.57	25	6.44	5.37	0.44	2.38	42.7	0.83	
15	2	2.40	84.96	25	6.43	5.57	0.46	2.38	44.4	0.80	Sperry Lagoon (0.25 MGD)
16	2	2.20	84.96	25	6.41	5.54	0.46	2.38	44.4	0.80	
17	2	2.00	84.96	25	6.40	5.51	0.46	2.38	44.4	0.80	
18	2	1.80	84.96	25	6.39	5.48	0.46	2.38	44.4	0.80	
19	2	1.60	84.96	25	6.37	5.44	0.45	2.38	44.4	0.80	
20	2	1.40	84.96	25	6.36	5.41	0.45	2.38	44.4	0.80	
21	2	1.20	84.96	25	6.35	5.38	0.45	2.38	44.4	0.80	
22	2	1.00	84.96	25	6.34	5.35	0.44	2.38	44.4	0.80	
23	2	0.80	84.96	25	6.33	5.32	0.44	2.38	44.4	0.80	
24	2	0.60	84.96	25	6.32	5.28	0.44	2.38	44.4	0.80	
25	2	0.40	84.96	25	6.31	5.25	0.44	2.38	44.4	0.80	
26	2	0.20	84.96	25	6.30	5.22	0.43	2.38	44.4	0.80	
27	2	0.00	84.96	25	6.29	5.18	0.43	2.38	44.4	0.80	



LAQUAL SUMMER WASTELOAD ALLOCATION MODEL INPUT AND OUTPUT FILES

```
LA-QUAL Version 9.05
Louisiana Department of Environmental Quality

Input file is \\server-file\users\rsmith\Modeling Projects\LAQUAL Projects\Skiatook-Hominy Cr 2013-14\LAQUAL Models\Final Rpt Models Sperry
250\SkiatookHC-sum32 Sperry250 bkup.txt
Running in steady-state mode using TX defaults
Output produced at 11:13 on 08/01/2014

$$$ DATA TYPE 1 (TITLES AND CONTROL CARDS) $$$

CARD TYPE       CONTROL TITLES

TITLE01         LA-QUAL UNCALIB MODEL, Sum 32C Skiatook/Sperry: Jul 201
TITLE02         Hominy Cr. 128.0cfs 7Q2, Spry .250 Sktk 2.5 MGD - BCKUP
CNTROL03  YES   ECHO DATA INPUT             <Warning: legacy control - line ignored>
CNTROL04  YES   INTERMEDIATE SUMMARY        <Warning: legacy control - line ignored>
CNTROL05   NO   CAPSULE SUMMARY             <Warning: legacy control - line ignored>
CNTROL06  YES   FINAL REPORT                <Warning: legacy control - line ignored>
CNTROL07   NO   LOADING SUMMARY             <Warning: legacy control - line ignored>
CNTROL08  YES   SPECIAL REPORT              <Warning: legacy control - line ignored>
CNTROL09   NO   LINE PRINTER PLOT           <Warning: legacy control - line ignored>
CNTROL10   NO   GRAPHICS CAPABILITY         <Warning: legacy control - line ignored>
CNTROL11   NO   SEQUENCING OUTPUT           <Warning: legacy control - line ignored>
CNTROL12   NO   METRIC UNITS
CNTROL13  YES   OXYGEN DEPENDENT RATES      <Warning: legacy control - line ignored>
CNTROL14   NO   SENSITIVITY ANALYSIS        <Warning: legacy control - line ignored>
CNTROL15   NO   FLOW AUGMENTATION           <Warning: legacy control - line ignored>
ENDATA01

$$$ DATA TYPE 2 (MODEL OPTIONS) $$$

CARD TYPE       MODEL OPTION

MODOPT01   NO   TEMPERATURE
MODOPT02   NO   SALINITY
MODOPT03   NO   CONSERVATIVE MATERIAL  I =
MODOPT04   NO   CONSERVATIVE MATERIAL II
MODOPT05  YES   DISSOLVED OXYGEN
MODOPT06  YES   BIOCHEMICAL OXYGEN DEMAND
MODOPT07  YES   NITROGEN
MODOPT08   NO   PHOSPHORUS
MODOPT09   NO   CHLOROPHYLL A
MODOPT10   NO   MACROPHYTES
MODOPT11   NO   COLIFORM
MODOPT12   NO   NONCONSERVATIVE MATERIAL =
ENDATA02

$$$ DATA TYPE 3 (PROGRAM CONSTANTS) $$$

CARD TYPE       DESCRIPTION OF CONSTANT                       VALUE

PROGRAM         FINAL REPORT TYPE                =         1.00000 <Warning: legacy constant - value ignored>
```

```
PROGRAM         SPECIAL REPORT TYPE                =        1.00000 <Warning: legacy constant - value ignored>
PROGRAM         BAROMETRIC PRESSURE (MBARS)        =     1013.25000 millibars
PROGRAM         INHIBITION CONTROL VALUE           =        4.00000 (inhibit all rates)
PROGRAM         MAXIMUM ITERATION LIMIT            =      900.00000
PROGRAM         KL MINIMUM (FT/DAY)                =        0.60000 meters/day
PROGRAM         OXYGEN DEPENDENCE THRESHOLD        =        2.00000 <Warning: legacy constant - value ignored>
PROGRAM         ORGN OXYGEN UPTAKE RATE            =        0.00000 mg O/mg N
PROGRAM         NH3 OXYGEN UPTAKE RATE             =        4.33000 mg O/mg N
PROGRAM         BENTHAL MAXIMUM RATE               =       10.00000 gm/sq m/day
PROGRAM         NITRATE UPTAKE RATE                =        0.66000 mg NO3/mg O
PROGRAM         TOTAL DAILY RADIATION (LANGLEYS)   =      500.00000 langleys
PROGRAM         SECCHI DISC CONSTANT               =        1.70000
PROGRAM         EFFECTIVE BOD DUE TO ALGAE (MG/UG) =        0.00000 mg/L BOD1 per ug/L chl a
PROGRAM         ALGAE OXYGEN PROD (MG O/UG CHLA/D) =        0.05000 mg O/ug chl a/day
PROGRAM         N ALGAL UPTAKE (MG N/UG CHLA/D)    =        0.00250 mg N/ug chl a/day
PROGRAM         K2 MAXIMUM                         =      100.00000 per day
PROGRAM         N MACROPHYTE UPTAKE (MG N/MG M/D)  =        0.00250 mg N/mg periphyton/day
PROGRAM         P MACROPHYTE UPTAKE (MG P/MG M/D)  =        0.00020 mg P/mg periphyton/day
PROGRAM         N PREFERENCE                       =        0.50000 (0.0=NH3 1.0=NO3)
ENDATA03

$$$ DATA TYPE 4 (TEMPERATURE CORRECTION CONSTANTS FOR RATE COEFFICIENTS) $$$

 CARD TYPE     RATE CODE     THETA VALUE

ENDATA04

$$$ CONSTANTS TYPE 5 (TEMPERATURE DATA) $$$

CARD TYPE       DESCRIPTION OF CONSTANT                        VALUE

ENDATA05

$$$ DATA TYPE 6 (PHYTOPLANKTON CONSTANTS) $$$

CARD TYPE       DESCRIPTION OF CONSTANT                        VALUE

ENDATA06

$$$ DATA TYPE 7 (PERIPHYTON CONSTANTS) $$$

CARD TYPE       DESCRIPTION OF CONSTANT                        VALUE

ENDATA07

$$$ DATA TYPE 8 (REACH IDENTIFICATION DATA) $$$
                                                           BEGIN         END     ELEM    REACH     ELEMS   BEGIN    END
CARD TYPE  REACH  ID  NAME                                 REACH       REACH   LENGTH   LENGTH    PER RCH   ELEM   ELEM
                                                              mi          mi       mi       mi              NUM    NUM

REACH ID      1   SK  Skiatook WWTP to Sperry WWTP          7.50  TO    2.60   0.3500     4.90        14       1     14
REACH ID      2   SP  Sperry WWTP to BC Confluence          2.60  TO    0.00   0.2000     2.60        13      15     27
ENDATA08
```

$$$ DATA TYPE 9 (ADVECTIVE HYDRAULIC COEFFICIENTS) $$$

CARD TYPE	REACH	ID	VELOCITY "A"	VELOCITY "B"	DEPTH "D"	DEPTH "E"	DEPTH "F"	MANNINGS "N"
HYDR-1	1	SK	0.02500000	0.7900	1.1400	0.1660	0.0000	0.020
HYDR-1	2	SP	0.02350000	0.7950	1.1400	0.1660	0.0000	0.020

ENDATA09

$$$ DATA TYPE 10 (DISPERSIVE HYDRAULIC COEFFICIENTS) $$$

CARD TYPE	REACH	ID	TIDAL RANGE	DISPERSION "A"	DISPERSION "B"	DISPERSION "C"	DISPERSION "D"

ENDATA10

$$$ DATA TYPE 11 (INITIAL CONDITIONS) $$$

CARD TYPE	REACH	ID	TEMP deg C	SALIN ppt	DO mg/L	NH3-N mg/L	NO3-N mg/L	PO4-P mg/L	CHL A µg/L	PERIP mg/ft^2	BOD1 mg/L	BOD2 mg/L	ORG-N mg/L	ORG-P mg/L	COLI #/100mL	NCM	CM-1	CM-2
INITIAL	1	SK	32.00	0.00	5.00	0.02	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INITIAL	2	SP	32.00	0.00	5.00	0.02	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ENDATA11

$$$ DATA TYPE 12 (REAERATION, SEDIMENT OXYGEN DEMAND, BOD COEFFICIENTS) $$$

CARD TYPE	RCH NUM	RCH ID	K2 OPT	K2 "A"	K2 "B"	K2 "C"	BKGRND SOD mg/ft^2/d	AEROB BOD DECAY per day	BOD SETT ft/d	SETTLD SOD AVAIL frac	ANAER BOD DECAY per day	AEROB BOD2 DECAY per day	BOD2 SETT ft/d	ANAER BOD2 DECAY per day	BOD2 HYDR TO BOD1 per day
COEF-1	1	SK	11 TEXAS	0.000	0.000	0.000	70.000	0.300	0.030	1.000	0.000	0.000	0.000	0.000	0.000
COEF-1	2	SP	11 TEXAS	0.000	0.000	0.000	70.000	0.300	0.030	1.000	0.000	0.000	0.000	0.000	0.000

ENDATA12

$$$ DATA TYPE 13 (NITROGEN AND PHOSPHORUS COEFFICIENTS) $$$

CARD TYPE	REACH	ID	ORG-N DECA per day	ORG-N SETT ft/d	SETTLD ORGN AVAIL frac	NH3 DECA per day	BKGRND NH3 SRCE mg/ft^2/d	BKGRND PO4 SRCE mg/ft^2/d	DENIT RATE per day	ORGP DECA per day	ORGP SETT ft/d	SETTLD ORGP AVAIL frac
COEF-2	1	SK	0.000	0.000	0.000	0.300	0.000	0.000	0.000	0.000	0.000	0.000
COEF-2	2	SP	0.000	0.000	0.000	0.300	0.000	0.000	0.000	0.000	0.000	0.000

ENDATA13

```
$$$ DATA TYPE 14 (ALGAE PHYTOPLANKTON AND PERIPHYTON COEFFICIENTS) $$$
                                                                       MAX                            MAX
CARD TYPE      REACH  ID      SECCHI    CHL A:     PHYTO     PHYTO    PHYTO     PHYTO     PERIP     PERIP     PERIP       BANK
                               DEPTH     ALGAE      SETT     DEATH     GROW      RESP     DEATH      GROW      RESP    SHADING
                                  ft      frac      ft/d   per day  per day   per day   per day   per day   per day       frac

ENDATA14

$$$ DATA TYPE 15 (COLIFORM AND NONCONSERVATIVE COEFFICIENTS) $$$

CARD TYPE      REACH  ID    COLIFORM       NCM       NCM
                             DIE-OFF     DECAY      SETT
                             per day   per day      ft/d

ENDATA15

$$$ DATA TYPE 16 (INCREMENTAL DATA FOR FLOW, TEMPERATURE, SALINITY, AND CONSERVATIVES) $$$

CARD TYPE      REACH  ID       OUTFLOW      INFLOW      TEMP     SALIN      CM-1      CM-2   IN/DIST  OUT/DIST
                                   cfs         cfs     deg C       ppt

ENDATA16

$$$ DATA TYPE 17 (INCREMENTAL DATA FOR DO, BOD, AND NITROGEN) $$$

CARD TYPE      REACH  ID          DO      BOD1     ORG-N     NH3-N     NO3-N      BOD2
                                mg/L      mg/L      mg/L      mg/L      mg/L      mg/L

ENDATA17

$$$ DATA TYPE 18 (INCREMENTAL DATA FOR PHOSPHORUS, PHYTOPLANKTON, COLIFORM, AND NONCONSERVATIVES) $$$
                                         PHYTO
 CARD TYPE      REACH  ID         PO4     CHL A      COLI       NCM      ORGP
                                 mg/L      µg/L   #/100mL                mg/L

ENDATA18

$$$ DATA TYPE 19 (NONPOINT SOURCE DATA) $$$

CARD TYPE      REACH  ID        BOD1     ORG-N      COLI       NCM        DO      BOD2     ORG-P
                                lb/d      lb/d     #/day                lb/d      lb/d      lb/d

ENDATA19

$$$ DATA TYPE 20 (HEADWATER FOR FLOW, TEMPERATURE, SALINITY AND CONSERVATIVES) $$$
                                                                                                           HDW DISP
CARD TYPE     ELEMENT   NAME                  UNIT      FLOW       FLOW    TEMP    SALIN      CM-1      CM-2    EXCHG
                                                        m³/s        cfs   deg C      ppt                         frac

HDWTR-1           1     Lower Hominy Creek      0    3.62504  128.00000   32.00     1.00     0.000     0.000     0.000
ENDATA20

$$$ DATA TYPE 21 (HEADWATER DATA FOR DO, BOD, AND NITROGEN) $$$
```

CARD TYPE	ELEMENT	NAME	DO mg/L	BOD#1 mg/L	ORG-N mg/L	NH3-N mg/L	NO3-N mg/L	BOD2 mg/L
HDWTR-2	1	Lower Hominy Creek	6.20	4.60	0.00	0.15	0.02	0.00
ENDATA21								

$$$ DATA TYPE 22 (HEADWATER DATA FOR PHOSPHORUS, PHYTOPLANKTON, COLIFORM, AND NONCONSERVATIVES) $$$

CARD TYPE	ELEMENT	NAME	PO4-P mg/L	PHYTO CHL A µg/L	COLI #/100mL	NCM	ORG-P mg/L
HDWTR-3	1	Lower Hominy Creek	0.00	0.00	0.00	0.00	0.00
ENDATA22							

$$$ DATA TYPE 23 (JUNCTION DATA) $$$

CARD TYPE	JUNCTION ELEMENT	UPSTRM ELEMENT	RIVER KILOM	NAME

ENDATA23

$$$ DATA TYPE 24 (WASTELOAD DATA FOR FLOW, TEMPERATURE, SALINITY, AND CONSERVATIVES) $$$

CARD TYPE	ELEMENT	RMILE	NAME	FLOW m³/s	FLOW cfs	FLOW MGD	TEMP deg C	SALIN ppt	CM-1	CM-2
WSTLD-1	1	7.50	Skiatook WWTP	0.10960	3.87000	2.502	32.00	0.00	0.000	0.000
WSTLD-1	15	2.60	Sperry Lagoon	0.01096	0.38700	0.250	32.00	0.00	0.000	0.000
ENDATA24										

$$$ DATA TYPE 25 (WASTELOAD DATA FOR DO, BOD, AND NITROGEN) $$$

CARD TYPE	ELEMENT	NAME	DO mg/L	BOD mg/L	% BOD RMVL	ORG-N mg/L	NH3-N mg/L	% NITRIF	NO3-N mg/L	BOD2 mg/L
WSTLD-2	1	Skiatook WWTP	5.00	34.50	0.00	0.00	8.00	0.00	0.02	0.00
WSTLD-2	15	Sperry Lagoon	5.00	57.50	0.00	0.00	7.20	0.00	0.02	0.00
ENDATA25										

$$$ DATA TYPE 26 (WASTELOAD DATA FOR PHOSPHORUS, PHYTOPLANTON, COLIFORM, AND NONCONSERVATIVES) $$$

CARD TYPE	ELEMENT	NAME	PO4-P mg/L	PHYTO CHL A µg/L	COLI #/100mL	NCM	ORG-P mg/L

ENDATA26

$$$ DATA TYPE 27 (LOWER BOUNDARY CONDITIONS) $$$

CARD TYPE	CONSTITUENT	CONCENTRATION

ENDATA27

$$$ DATA TYPE 28 (DAM DATA) $$$

```
CARD TYPE     ELEMENT   NAME                  EQN      "A"       "B"       "H"

ENDATA28

$$$ DATA TYPE 29 (SENSITIVITY ANALYSIS DATA) $$$

CARD TYPE       PARAMETER     COL 1     COL 2     COL 3     COL 4     COL 5     COL 6     COL 7     COL 8

ENDATA29

$$$ DATA TYPE 30 (PLOT CONTROL CARDS) $$$

ENDATA30

$$$ DATA TYPE 31 (OVERLAY PLOT DATA) $$$


ENDATA31



     .....NO ERRORS DETECTED IN INPUT DATA
     .....HYDRAULIC CALCULATIONS COMPLETED
     .....TRIDIAGONAL MATRIX TERMS INITIALIZED
     .....OXYGEN DEPENDENT RATES CONVERGENT IN    7 ITERATIONS
     .....CONSTITUENT CALCULATIONS COMPLETED


INTERMEDIATE REPORT
 Dissolved Oxygen                                                  LA-QUAL UNCALIB MODEL, Sum 32C Skiatook/Sperry: Jul 201
     mg/L                                                          Hominy Cr. 128.0cfs 7Q2, Spry .250 Sktk 2.5 MGD - BCKUP


  ID   RCH  ELEM         +0        +1        +2        +3        +4        +5        +6        +7        +8        +9

  SK     1     1        6.10      6.04      5.98      5.92      5.87      5.82      5.77      5.72      5.68      5.64
  SK     1    11        5.60      5.57      5.53      5.50
  SP     2    15        5.48      5.46      5.44      5.42      5.41      5.39      5.37      5.36      5.34      5.33
  SP     2    25        5.31      5.30      5.29


     .....EXECUTION COMPLETED
```