Intended for
Callidus Technologies, LLC

Submitted to
Oklahoma Department of Environmental Quality

Date
April 26, 2022; updated May 2, 2022

WASTELOAD ALLOCATION REPORT FOR NEW INDIVIDUAL OPDES PERMIT

CALLIDUS TECHNOLOGIES, LLC, BEGGS, OKLAHOMA

RAMBOLL Bright ideas. Sustainable change.

WASTELOAD ALLOCATION REPORT FOR NEW INDIVIDUAL OPDES PERMIT
CALLIDUS TECHNOLOGIES, LLC, BEGGS, OKLAHOMA

Project name	**Wasteload Allocation Report for new Individual OPDES Permit**
Project no.	**1690020113**
Recipient	**Oklahoma Department of Environmental Quality**
Date	**May 2, 2022**
Prepared by	**Robin L. Richards, REM**
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APPENDICES

1. BACKGROUND

Callidus Technologies, LLC., a subsidiary of Honeywell UOP, conducts testing on a variety of flares, burners, kilns, and incinerators. The facility is located in the SW ¼ of Section 28, Township 15N, Range 11E, Okmulgee County, Oklahoma at 2499 Highway 16, Beggs, OK 74421-2981. The General Industrial Stormwater Permit was issued when the facility was operating under the primary standard industrial classification (SIC) code 8734 for Industrial Furnaces and Ovens. The facility currently operates under the SIC code 8734 for Testing Laboratories and is no longer a manufacturing operation. The associated North American industry classification system (NAICS) codes is 541380 for Testing Laboratories. Currently, facility wastewater is collected and sent for offsite disposal. Recently, a new cooling tower was installed, which will include an occasional blowdown.

With the new cooling tower, the facility is requesting an individual OPDES Permit (application submitted July 2021) to discharge the following wastewaters via Proposed Outfall 001:

Source	Maximum Monthly Total Volume (gallons)
Cooling Tower Blowdown (CTBD)	375
Boiler Water Blowdown (BB)	480
Probe Cooling Water (PCW)	70
Ductwork Cooling Water (DCW)	120
Total Wastewater Flow	1,045

These facility wastewater dischargers are sporadic, intermittent, and infrequent. As agreed to with ODEQ for the purpose of developing a maximum monthly average effluent flow, the following hypothetical operational month (most likely in the summer given cooling tower blowdown) was developed:

Table 2: Hypothetical Operational Month

Summer Month Day	Total Volume gals	Total Time hrs	Source	Total Volume gallons
1	0	0		0
2	0	0		0
3	0	0		0
4	0	0		0
5	375	10	CTBD	375
6	0	0		0
7	0	0		0
8	0	0		0

Table 2: Hypothetical Operational Month				
Summer Month Day	**Total Volume gals**	**Total Time hrs**	**Source**	**Total Volume gallons**
9	480	8	BB	480
10	0	0		0
11	0	0		0
12	0	0		0
13	0	0		0
14	0	0		0
15	0	0		0
16	0	0		0
17	0	0		0
18	0	0		0
19	0	0		0
20	0	0		0
21	0	0		0
22	0	0		0
23	0	0		0
24	70	1	PCW	70
25	0	0		0
26	0	0		0
27	0	0		0
28	0	0		0
29	120	4	DCW	120
30	0	0		0
Sum =	1045	23 hrs		1045
Average =		4 days		***261.25***

Outfall 001 will be a discharge pipe dedicated to conveying only the facility wastewaters to an unnamed tributary that also receives the permitted stormwater associated with industrial activity. The unnamed tributary (UNT) connects to Tiger Creek at 35.73075º, -96.13845º. Tiger Creek (OK520700020160_00) is a 7.09 mile long stream with beneficial uses of:

- Agriculture
- Aesthetics
- Warm Water Aquatic Community
- Primary Body Contact Recreation
- Fish Consumption

Tiger Creek is not listed in the 2020 303(d) list as being impaired for beneficial use, and is listed as Category 3 - Insufficient or no data and information to determine if any designated use is

attained. Tiger Creek flows into Salt Creek about 1.3 miles from where the UNT joins Tiger Creek. Salt Creek flows into the Deep Fork of the Canadian River.

2. PROBLEM DEFINITION

This Wasteload Allocation (WLA) has been developed as this is a new discharge of $cBOD_5$ to Tiger Creek. The source of $cBOD_5$ in Outfall 001 is the cooling tower blowdown, which can contain residuals of a non-oxidizing biocide with an active ingredient of glutaraldehyde. There are no known sources of ammonia-N or other sources of $cBOD_5$ other than that contained in the facility supply water from Okmulgee Rural Water District.

As the discharge of wastewaters is sporadic, intermittent and infrequent, and models for wasteload allocation are developed for continuous flowing and steady-state conditions, assumptions, with agreement of ODEQ, had to be utilized, for example:

- The max Q_e30 flow of 261.25 gpd is continuous
- The same max Q_e30 of 261.25 gpd occurs for the three seasons

3. 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 1.0 cfs, whichever is greater. For Tiger Creek, 1.0 cfs is utilized. Nuisance condition (DO below 2 mg/L) applies only when there is no upstream flow for an intermittent stream and applies for Tiger Creek.

The following numerical dissolved oxygen criteria for Warm Water Aquatic Community (WWAC) apply to Tiger Creek at Critical Low-Flow Condition (7Q2)

- Summer (Jun–Oct) at 32°C: 5.0 mg/L
- Spring (Apr–May) at 25°C: 6.0 mg/L
- Winter (Nov–Mar) at 18°C: 5.0 mg/L

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 regards for all elements of the Oklahoma Water Quality standards that include the antidegradation policy

4. SOURCE ANALYSIS

4.1 Point Source

At this time, the exact location of the Outfall 001 discharge pipe to the UNT is not known. The facility is constructing a series of pipes inside the fenceline to collect contact cooling waters, boiler blowdown, and cooling tower blowdown, that will then convey via a single pipeline to the UNT, as new Outfall 001, potentially at 36,74136°, -96.151850°. The unnamed tributary (UNT) connects to Tiger Creek at 35.73075°, -96.13845°.

As per the public notice of the Permit Application: "The discharge, which will consist of cooling water blowdown, boiler blowdown, process contact cooling water, and stormwater runoff will be

to an unnamed tributary to the nearby Tiger Creek in the SE ¼, SE ¼, SW ¼ of Section 28, Township 15N, Range 11E of Oklahoma.

4.2 Non-Point Sources

The allocations in this waterbody assessment are driven by critical instream dissolved oxygen conditions (low-flow and high temperature) as defined in the Oklahoma Water Quality Standards. Low-flow conditions, by definition, assume little or no runoff. This assumption, combined with the use of background loadings from upstream flow and conservative kinetic inputs, accounts for any non-point source (NPS) impact that may exist in the study area.

4.3 Tiger Creek Ambient Conditions

- Flow: 1 cfs
- $cBOD_5$: 2.0 mg/L
- Ammonia-N: 0.15 mg/L
- DO: 6 mg/L except summer at 5.5 mg/L

5. LINKAGE BETWEEN SOURCES AND RECEIVING WATER

ODEQ requested that modeling be conducted utilizing a steady-state model versus a BOD_5 mass balance spreadsheet. A desktop Streeter-Phelps model was utilized to determine the impact of DO-demanding substances on the in-stream DO concentration.

5.1 Tiger Creek Model Inputs

The primary kinetic inputs were derived from literature values and the past WLAs performed by ODEQ and are presented under "River" column on the spreadsheet presented in Appendix A. The Tiger Creek inputs remained the same for each season except temperature and DO.

5.2 Margin of Safety

ODEQ requested for the hypothetical max Q_e30, and the projected effluent (discharge does not exist at this time) ammonia-N, $cBOD_5$, and DO be subjected to a 20% margin of safety (MOS) as, obviously, this is an uncalibrated, simple source models. In addition, $cBOD_5$ was increased beyond the 20% MOS until the DO criteria are met. Ammonia-N was not increased as there are no known sources of ammonia-N to Outfall 001. The effluent inputs can be found in Appendix A under the column labeled "Effluent."

5.3 Allocations

Appendix A presents the results from modeling 0.58 lb/d $cBOD_5$ and 0.00082 lb/d Ammonia-N for the three seasons; the DO in-stream criteria are attained.

6. FINAL RECOMMENDATIONS

ODEQ has recommended the following limits for Outfall 001:

- Monthly Average flow = 314 gpd (model input = 314 gpd)
- Monthly Average $cBOD_5$ = 185 mg/L (model input = 222 mg/L)
- Monthly Average NH3-N = 0.26 mg/L (model input = 0.312 mg/L)
- Monthly Average DO = 5.0 mg/L (model input = 4 mg/L)

APPENDIX A
STREETER-PHELPS WASTELOAD ALLOCATION SPREADSHEETS

Streeter-Phelps Dissolved Oxygen Model

20% MOS

Effluent		
Temp (C)	25	=T Ck
DO(mg/L)	4	20%▼
$CBOD_5$(mg/L)	222	
NH_3-N(mg/L)	0.312	20% ▲
TKN (mg/L)	0.36	20% ▲
Q_e (mgd)	0.000314	20% ▲
K_1(@20 C)	0.35	0.4258

River		
Temp (C)	25	
DO	6	
CBOD5	2	
NH3	0.15	
TKN	0.2	
Qr (cfs)	1	
K_d	0.3	0.377
K_{oa}	0.701	1.030
K_{ai}	0.700	1.029
K_{in}	0.702	1.031
K_s	0.03	
K_r	0.407	
Depth(ft)	3.1	
Width (ft)	12	
U (fps)	0.03	
U (mpd)	0.44	
K_n (see comment)	1.810	2.038
K_a (see comment)	0.388	0.436
S_B g O2/m2 day	2	2.740

Temperature coefficients	
Theta CBOD	1.047
Theta O2	1.024
Theta SOD	1.065
Theta NBOD	1.08

r_{oa}	3.43
r_{oi}	1.14
Cai	9943.7949
Coa	-19718.642
Cin	9775.2077

K_d Equations	
K_d (10.3Q$^{-.49}$)	10.3000
K_d (39.6Q$^{-.84}$)	3.461268

Note:
black = entered values
blue = calculated values

RM counter	0.1

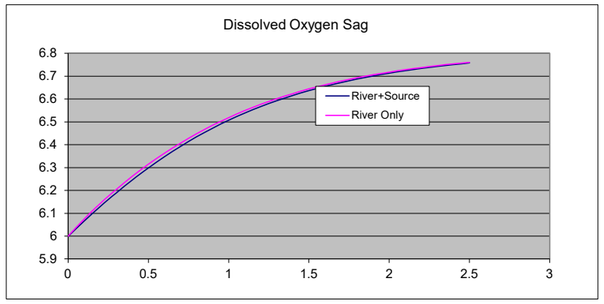
Calculations		
Tmix	25.0	298.2
UBODe (mg/L)	268.7	
UBODr (mg/L)	2.574	
$UBOD_m$ (L_o)	2.70	
$NH3_m$	0.15	
$Norg_m$	0.05	
DO_{sat} mix	8.25	
DO mix	6.00	
Do	2.25	

Rearation equations	
O'Connor Dobbins	0.388
Churchill (1962)	0.053
Owens (1964)	0.237

DO 100% sat mg/L	
8.25	
0	Salinity
50	Elevation

PARAMETERS	
$CBOD_5$	5-day CBOD (mg/L)
K_d	effective deoxygenation rate (/day)
K_{in}	NO_2 to NO_3 conversion rate (/day)
K_n	NBOD reaction rate (/day)
K_{oa}	Organic to NH_3 conversion rate (/day)
K_r	K_d+K_s (/day)
K_s	settling rate (/day)
L_N	Initial NBOD (mg/L)
$NH3_m$	Ammonia mixed (mg/L)
NH_3-N	ammonia as N (mg/L)
$Norg_m$	Organic nitrogen mixed (mg/L)
Q_e	effluent flow (mgd)
Q_r	ambient flow (cfs)
S_B	Sediment Oxygen Demand g O_2/m^2 day
Temp	Temperature (degrees C)
TKN	Total Kjeldahl Nitrogen (mg/L)
Tmix	Temperature mixed (deg C)
U	velocity (fps or mpd)
UBODe (mg/L)	Ultimate effluent CBOD (mg/L)
$UBOD_m$ (L_o)	Ultimate CBOD mixed (mg/L)
UBODr (mg/L)	Ultimate river CBOD (mg/L)
Width	Average stream width (ft)

RM (mi)	Time (days)	Deficit CBOD	Deficit NBOD	River Only DO	River+Source DO	Source-Ambient DO Deficit	Remaining CBOD	Remaining Organic N	Remaining NH3-N	Remaining Nitrite	Remaining Nitrate
0.00	0.00	2.25	0.00	6.00	6.00	0.0010	2.70	0.050	0.15	0.00	0.00
0.10	0.23	2.12	0.06	6.08	6.07	0.0091	2.46	0.040	0.13	0.03	0.00
0.20	0.45	2.02	0.10	6.14	6.13	0.0134	2.25	0.031	0.11	0.05	0.01
0.30	0.68	1.95	0.11	6.20	6.19	0.0155	2.05	0.025	0.09	0.06	0.03
0.40	0.91	1.89	0.12	6.26	6.25	0.0161	1.87	0.020	0.08	0.06	0.04
0.50	1.14	1.84	0.11	6.31	6.30	0.0160	1.70	0.016	0.06	0.07	0.05
0.60	1.36	1.79	0.11	6.36	6.35	0.0154	1.55	0.012	0.05	0.06	0.07
0.70	1.59	1.76	0.10	6.41	6.39	0.0145	1.41	0.010	0.05	0.06	0.08
0.80	1.82	1.73	0.09	6.45	6.43	0.0136	1.29	0.008	0.04	0.06	0.10
0.90	2.05	1.70	0.08	6.48	6.47	0.0126	1.18	0.006	0.03	0.05	0.11
1.00	2.27	1.67	0.07	6.52	6.51	0.0116	1.07	0.005	0.03	0.05	0.12
1.10	2.50	1.65	0.06	6.55	6.54	0.0106	0.98	0.004	0.02	0.04	0.13
1.20	2.73	1.63	0.05	6.58	6.57	0.0097	0.89	0.003	0.02	0.04	0.14
1.30	2.95	1.61	0.04	6.60	6.59	0.0089	0.81	0.002	0.01	0.03	0.15
1.40	3.18	1.59	0.04	6.62	6.62	0.0081	0.74	0.002	0.01	0.03	0.16
1.50	3.41	1.58	0.03	6.64	6.64	0.0074	0.67	0.001	0.01	0.02	0.16
1.60	3.64	1.57	0.03	6.66	6.66	0.0068	0.61	0.001	0.01	0.02	0.17
1.70	3.86	1.55	0.02	6.68	6.67	0.0062	0.56	0.001	0.01	0.02	0.17
1.80	4.09	1.54	0.02	6.69	6.69	0.0056	0.51	0.001	0.01	0.02	0.18
1.90	4.32	1.53	0.02	6.71	6.70	0.0051	0.47	0.001	0.00	0.01	0.18
2.00	4.54	1.52	0.01	6.72	6.71	0.0047	0.42	0.000	0.00	0.01	0.18
2.10	4.77	1.51	0.01	6.73	6.72	0.0043	0.39	0.000	0.00	0.01	0.19
2.20	5.00	1.50	0.01	6.74	6.73	0.0039	0.35	0.000	0.00	0.01	0.19
2.30	5.23	1.50	0.01	6.75	6.74	0.0036	0.32	0.000	0.00	0.01	0.19
2.40	5.45	1.49	0.01	6.75	6.75	0.0032	0.29	0.000	0.00	0.01	0.19
2.50	5.68	1.48	0.01	6.76	6.76	0.0030	0.27	0.000	0.00	0.00	0.19



RM	DO River+Source	DO River Only	Source-Ambient DO Deficit
0	5.9990305	6	0.000969499
0.1	6.0660587	6.075133812	0.009075097
0.2	6.1294956	6.142921564	0.013425934
0.3	6.1894476	6.2049278	0.015480232
0.4	6.2458392	6.261989042	0.016149861
0.5	6.2985639	6.314567235	0.016003342
0.6	6.3475539	6.362947435	0.015393577
0.7	6.3928054	6.407343601	0.014538196
0.8	6.4343812	6.447951286	0.013570089
0.9	6.4724014	6.484970572	0.012569172
1	6.5070307	6.518613077	0.011582352
1.1	6.538465	6.549101072	0.010636064
1.2	6.5669191	6.576663229	0.00974413
1.3	6.5926168	6.601529471	0.008912685
1.4	6.6157829	6.623926128	0.008143257
1.5	6.6366373	6.644071953	0.00743468
1.6	6.6553909	6.662175132	0.00678428
1.7	6.6722427	6.678431264	0.006188612
1.8	6.6873783	6.693022171	0.005643897
1.9	6.7009691	6.706115383	0.005146294
2	6.7131721	6.717864133	0.004692049
2.1	6.7241302	6.728407741	0.004277585
2.2	6.7339727	6.737872252	0.003899542
2.3	6.7428164	6.746371244	0.003554797
2.4	6.7507663	6.754006724	0.003240463
2.5	6.7579162	6.760870079	0.002953887

RM	Organic N	NH3-N	Nitrite	Nitrate	Remaining CBOD
0	0.04999903	0.1500786	0	0	2.7035173
0.1	0.039565756	0.1280629	0.0288374	0.0036116	2.4644595
0.2	0.031309589	0.1087028	0.0473523	0.0127129	2.2465403
0.3	0.024776232	0.0918482	0.0582397	0.0252135	2.0478905
0.4	0.019606188	0.0772959	0.0635939	0.0395816	1.8668064
0.5	0.015514974	0.0648188	0.0650263	0.0547176	1.7017345
0.6	0.012277472	0.0541841	0.0637634	0.0698527	1.551259
0.7	0.009715538	0.045166	0.0607275	0.0844685	1.4140894
0.8	0.007688201	0.0375528	0.0566027	0.0982339	1.2890489
0.9	0.006083908	0.0311507	0.0518878	0.1109551	1.1750651
1	0.004814382	0.0257857	0.0469393	0.1225382	1.0711602
1.1	0.003809767	0.0213036	0.0420051	0.1329591	0.9764432
1.2	0.003014785	0.0175695	0.0372511	0.1422422	0.8901014
1.3	0.002385691	0.0144664	0.0327826	0.1504429	0.8113944
1.4	0.00188787	0.0118934	0.0286603	0.1576361	0.7396471
1.5	0.001493929	0.0097645	0.0249126	0.1639066	0.674244
1.6	0.001182192	0.0080062	0.0215457	0.1693435	0.6146241
1.7	0.000935504	0.0065567	0.0185503	0.1740352	0.5602762
1.8	0.000740293	0.0053635	0.0159073	0.1780665	0.5107339
1.9	0.000585816	0.0043829	0.0135917	0.1815172	0.4655724
2	0.000463574	0.003578	0.0115752	0.1844609	0.4244043
2.1	0.000366841	0.0029182	0.0098285	0.1869641	0.3868764
2.2	0.000290292	0.002378	0.0083226	0.1890868	0.352667
2.3	0.000229717	0.0019361	0.0070298	0.190882	0.3214825
2.4	0.000181782	0.0015752	0.0059241	0.1923966	0.2930555
2.5	0.00014385	0.0012806	0.0049816	0.1936716	0.2671421

Deficit Equation

$$D = D_o \exp(-K_a \frac{x}{u}) + \frac{K_d}{K_a - K_r}\left[\exp(-K_r \frac{x}{u}) - \exp(-K_a \frac{x}{u})\right]L_o + \frac{K_n}{K_a - K_n}\left[\exp(-K_n \frac{x}{u}) - \exp(-K_a \frac{x}{u})\right]L_o^n + (1 - \exp(-K_a \frac{x}{u}))(\frac{S_B}{HK_a})$$

deep fork
k1 = 0.35 ; 0.3
k2=1.81
nbod=0.3
bod set=0.03
sod0.075g/ft2/d

Wagoner County
k1 = 0.30
k2=17.03
nbod=0.3
bod set=0.03
sod0.075g/ft2/d

Ardmore
k1=0.3 / 0.35
k2 = 2.08-2.79
kn
nbod k 0.3
ks
cbod set=0.03
SOD 0.11 g/ft2/d

Rogers Cnty
k1 = 0.35 ; 0.3
k2=14.94
nbod=0.3
bod set=0.03
sod0.011g/ft2/d

Streeter-Phelps Dissolved Oxygen Model

20% MOS

Effluent		
Temp (C)	32	=T Ck
DO(mg/L)	4	20%▼
$CBOD_5$(mg/L)	222	
NH_3-N(mg/L)	0.312	20% ▲
TKN (mg/L)	0.36	20% ▲
Q_e (mgd)	0.000314	20% ▲
K_1(@20 C)	0.35	0.5604
River		
Temp (C)	32	
DO	5.5	
CBOD5	2	
NH3	0.15	
TKN	0.2	
Qr (cfs)	1	
K_d	0.3	0.521
K_{oa}	0.701	1.765
K_{ai}	0.700	1.763
K_{in}	0.702	1.768
K_s	0.03	
K_r	0.551	
Depth(ft)	3.1	
Width (ft)	12	
U (fps)	0.03	
U (mpd)	0.44	
K_a (see comment)	1.810	2.406
K_a (see comment)	0.388	0.515
S_B g O2/m2 day	2	4.258
Temperature coefficients		
Theta CBOD	1.047	
Theta O2	1.024	
Theta SOD	1.065	
Theta NBOD	1.08	

r_{oa}	3.43
r_{oi}	1.14
Cai	9943.7949
Coa	-19718.642
Cin	9775.2077

K_d Equations	
K_d (10.3Q$^{-.49}$)	10.3000
K_d (39.6Q$^{-.84}$)	3.461268

Note:
black = entered values
blue = calculated values

RM counter	0.1

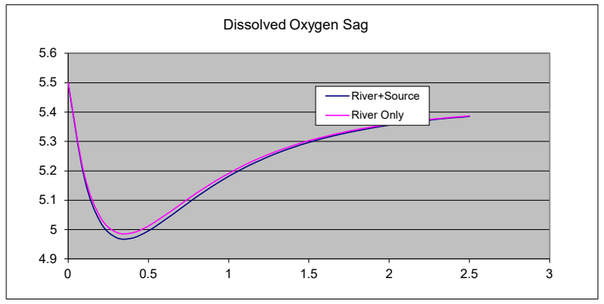
Calculations		
Tmix	32.0	305.2
UBODe (mg/L)	268.7	
UBODr (mg/L)	2.574	
$UBOD_m$ (L_o)	2.70	
$NH3_m$	0.15	
$Norg_m$	0.05	
DO_{sat} mix	7.29	
DO mix	5.50	
Do	1.79	

Rearation equations	
O'Connor Dobbins	0.388
Churchill (1962)	0.053
Owens (1964)	0.237

DO 100% sat
mg/L
7.29
0 Salinity
50 Elevation

PARAMETERS	
$CBOD_5$	5-day CBOD (mg/L)
K_d	effective deoxygenation rate (/day)
K_{in}	NO_2 to NO_3 conversion rate (/day)
K_n	NBOD reaction rate (/day)
K_{oa}	Organic to NH_3 conversion rate (/day)
K_r	K_d+K_s (/day)
K_s	settling rate (/day)
L_N	Initial NBOD (mg/L)
$NH3_m$	Ammonia mixed (mg/L)
NH_3-N	ammonia as N (mg/L)
$Norg_m$	Organic nitrogen mixed (mg/L)
Q_e	effluent flow (mgd)
Q_r	ambient flow (cfs)
S_B	Sediment Oxygen Demand g O_2/m^2 day
Temp	Temperature (degrees C)
TKN	Total Kjeldahl Nitrogen (mg/L)
Tmix	Temperature mixed (deg C)
U	velocity (fps or mpd)
UBODe (mg/L)	Ultimate effluent CBOD (mg/L)
$UBOD_m$ (L_o)	Ultimate CBOD mixed (mg/L)
UBODr (mg/L)	Ultimate river CBOD (mg/L)
Width	Average stream width (ft)

RM (mi)	Time (days)	Deficit CBOD	Deficit NBOD	River Only DO	River+Source DO	Source-Ambient DO Deficit	Remaining CBOD	Remaining Organic N	Remaining NH3-N	Remaining Nitrite	Remaining Nitrate
0.00	0.00	1.79	0.00	5.50	5.50	0.0007	2.70	0.050	0.15	0.00	0.00
0.10	0.23	2.06	0.06	5.19	5.18	0.0114	2.39	0.033	0.11	0.04	0.01
0.20	0.45	2.18	0.08	5.04	5.03	0.0163	2.11	0.022	0.09	0.06	0.03
0.30	0.68	2.23	0.09	4.99	4.97	0.0180	1.86	0.015	0.06	0.06	0.06
0.40	0.91	2.24	0.08	4.99	4.97	0.0180	1.64	0.010	0.05	0.06	0.08
0.50	1.14	2.22	0.07	5.01	5.00	0.0171	1.45	0.007	0.03	0.05	0.11
0.60	1.36	2.20	0.06	5.05	5.03	0.0158	1.28	0.005	0.02	0.05	0.13
0.70	1.59	2.17	0.05	5.09	5.07	0.0143	1.13	0.003	0.02	0.04	0.14
0.80	1.82	2.14	0.04	5.12	5.11	0.0129	0.99	0.002	0.01	0.03	0.16
0.90	2.05	2.11	0.03	5.16	5.15	0.0115	0.88	0.001	0.01	0.02	0.17
1.00	2.27	2.09	0.02	5.19	5.18	0.0102	0.77	0.001	0.01	0.02	0.17
1.10	2.50	2.06	0.02	5.22	5.21	0.0091	0.68	0.001	0.00	0.01	0.18
1.20	2.73	2.04	0.01	5.24	5.24	0.0080	0.60	0.000	0.00	0.01	0.19
1.30	2.95	2.02	0.01	5.27	5.26	0.0071	0.53	0.000	0.00	0.01	0.19
1.40	3.18	2.00	0.01	5.29	5.28	0.0063	0.47	0.000	0.00	0.01	0.19
1.50	3.41	1.99	0.01	5.30	5.30	0.0055	0.41	0.000	0.00	0.00	0.19
1.60	3.64	1.98	0.00	5.32	5.31	0.0049	0.37	0.000	0.00	0.00	0.20
1.70	3.86	1.96	0.00	5.33	5.33	0.0043	0.32	0.000	0.00	0.00	0.20
1.80	4.09	1.95	0.00	5.34	5.34	0.0038	0.28	0.000	0.00	0.00	0.20
1.90	4.32	1.94	0.00	5.35	5.35	0.0034	0.25	0.000	0.00	0.00	0.20
2.00	4.54	1.94	0.00	5.36	5.36	0.0030	0.22	0.000	0.00	0.00	0.20
2.10	4.77	1.93	0.00	5.37	5.36	0.0026	0.20	0.000	0.00	0.00	0.20
2.20	5.00	1.92	0.00	5.37	5.37	0.0023	0.17	0.000	0.00	0.00	0.20
2.30	5.23	1.92	0.00	5.38	5.38	0.0020	0.15	0.000	0.00	0.00	0.20
2.40	5.45	1.91	0.00	5.38	5.38	0.0018	0.13	0.000	0.00	0.00	0.20
2.50	5.68	1.91	0.00	5.39	5.39	0.0016	0.12	0.000	0.00	0.00	0.20



RM	DO River+Source	DO River Only	Source-Ambient DO Deficit
0	5.4992729	5.5	0.000727124
0.1	5.1769026	5.188345585	0.011443011
0.2	5.0268245	5.043170733	0.016346226
0.3	4.9729893	4.991027586	0.018038263
0.4	4.9710552	4.989062152	0.018006907
0.5	4.9954382	5.012535558	0.017097353
0.6	5.0316157	5.047400426	0.015784705
0.7	5.0715532	5.08588468	0.014331511
0.8	5.1109887	5.123867479	0.012878758
0.9	5.1478258	5.159324177	0.011498372
1	5.1811857	5.191409132	0.010223459
1.1	5.2108531	5.219918752	0.009065668
1.2	5.2369556	5.244980721	0.008025118
1.3	5.2597812	5.266877194	0.007096042
1.4	5.2796769	5.28594682	0.006269958
1.5	5.2969953	5.302532688	0.005537421
1.6	5.3120677	5.316956621	0.004888967
1.7	5.3251927	5.32950825	0.004315589
1.8	5.3366331	5.340442094	0.003808966
1.9	5.3466172	5.349978732	0.003361537
2	5.3553413	5.358307854	0.002966508
2.1	5.3629742	5.365591964	0.002617811
2.2	5.3696601	5.371970115	0.002310052
2.3	5.3755229	5.377561353	0.002038445
2.4	5.380669	5.382467759	0.001798758
2.5	5.3851898	5.386777069	0.001587245

RM	Organic N	NH3-N	Nitrite	Nitrate	Remaining CBOD
0	0.04999903	0.1500786	0	0	2.7035173
0.1	0.033478414	0.1139794	0.0429385	0.0096813	2.3856002
0.2	0.022416519	0.0853561	0.0611029	0.0312021	2.1050683
0.3	0.015009681	0.0632077	0.0649871	0.0568732	1.8575251
0.4	0.010050201	0.0463792	0.0612481	0.0824001	1.6390916
0.5	0.006729426	0.0337724	0.053966	0.1056098	1.4463444
0.6	0.004505898	0.0244342	0.0455332	0.1256043	1.2762632
0.7	0.003017065	0.0175805	0.0372661	0.142214	1.1261825
0.8	0.00202017	0.0125888	0.0298155	0.1556531	0.9937503
0.9	0.001352668	0.0089768	0.0234373	0.1663108	0.8768914
1	0.000905721	0.0063775	0.0181644	0.1746299	0.7737743
1.1	0.000606454	0.004516	0.0139147	0.1810404	0.6827832
1.2	0.00040607	0.0031885	0.0105555	0.1859276	0.6024921
1.3	0.000271897	0.0022453	0.0079407	0.1896198	0.5316427
1.4	0.000182057	0.0015773	0.0059307	0.1923876	0.4691248
1.5	0.000121902	0.0011056	0.0044016	0.1944485	0.4139586
1.6	8.16233E-05	0.0007735	0.0032486	0.1959739	0.3652796
1.7	5.46534E-05	0.0005401	0.0023858	0.197097	0.3223249
1.8	3.65949E-05	0.0003766	0.0017444	0.1979201	0.2844215
1.9	2.45033E-05	0.0002621	0.0012703	0.1985207	0.2509753
2	1.64069E-05	0.0001822	0.0009217	0.1989573	0.2214621
2.1	1.09858E-05	0.0001265	0.0006665	0.1992736	0.1954195
2.2	7.35587E-06	8.768E-05	0.0004806	0.199502	0.1724394
2.3	4.92535E-06	6.072E-05	0.0003455	0.1996665	0.1521616
2.4	3.29792E-06	4.2E-05	0.0002478	0.1997846	0.1342683
2.5	2.20823E-06	2.903E-05	0.0001772	0.1998691	0.1184792

Deficit Equation

$$D = D_o \exp(-K_a \frac{x}{u}) + \frac{K_d}{K_a - K_r}\left[\exp(-K_r \frac{x}{u}) - \exp(-K_a \frac{x}{u})\right]L_o + \frac{K_n}{K_a - K_n}\left[\exp(-K_n \frac{x}{u}) - \exp(-K_a \frac{x}{u})\right]L_o^n + (1 - \exp(-K_a \frac{x}{u}))(\frac{S_B}{HK_a})$$

deep fork
k1 = 0.35 ; 0.3
k2=1.81
nbod=0.3
bod set=0.03
sod0.075g/ft2/d

Wagoner County
k1 = 0.30
k2=17.03
nbod=0.3
bod set=0.03
sod0.075g/ft2/d

Ardmore
k1=0.3 / 0.35
k2 = 2.08-2.79
kn
nbod k 0.3
ks
cbod set=0.03
SOD 0.11 g/ft2/d

Rogers Cnty
k1 = 0.35 ; 0.3
k2=14.94
nbod=0.3
bod set=0.03
sod0.011g/ft2/d

Streeter-Phelps Dissolved Oxygen Model

20% MOS

Effluent		
Temp (C)	18	=T Ck
DO(mg/L)	4	20%▼
$CBOD_5$(mg/L)	222	
NH_3-N(mg/L)	0.312	20% ▲
TKN (mg/L)	0.36	20% ▲
Q_e (mgd)	0.000314	20% ▲
K_1(@20 C)	0.35	0.3236

River		
Temp (C)	18	
DO	6	
CBOD5	2	
NH3	0.15	
TKN	0.2	
Qr (cfs)	1	
K_d	0.3	0.274
K_{oa}	0.701	0.601
K_{ai}	0.700	0.600
K_{in}	0.702	0.602
K_s	0.03	
K_r	0.304	
Depth(ft)	3.1	
Width (ft)	12	
U (fps)	0.03	
U (mpd)	0.44	
K_n (see comment)	1.810	1.726
K_s (see comment)	0.388	0.370
S_B g O2/m2 day	2	1.763

Temperature coefficients	
Theta CBOD	1.047
Theta O2	1.024
Theta SOD	1.065
Theta NBOD	1.08

r_{oa}	3.43
r_{oi}	1.14
Cai	9943.7949
Coa	-19718.642
Cin	9775.2077

K_d Equations	
K_d (10.3Q$^{-.49}$)	10.3000
K_d (39.6Q$^{-.84}$)	3.461268

Note:
black = entered values
blue = calculated values

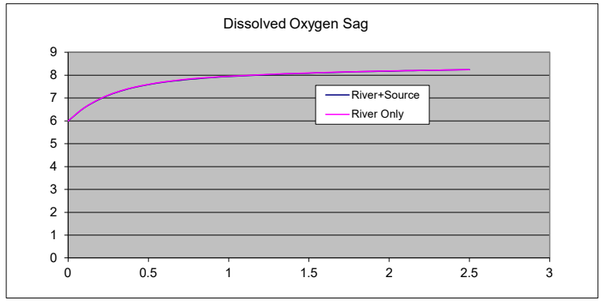
RM counter	0.1

Calculations		
Tmix	18.0	291.2
UBODe (mg/L)	268.7	
UBODr (mg/L)	2.574	
$UBOD_m$ (L_o)	2.70	
$NH3_m$	0.15	
$Norg_m$	0.05	
DO_{sat} mix	9.45	
DO mix	6.00	
Do	3.45	

Rearation equations	
O'Connor Dobbins	0.388
Churchill (1962)	0.053
Owens (1964)	0.237

DO 100% sat
mg/L
9.45
0 Salinity
50 Elevation

RM	Time	Deficit	Deficit	River Only	River+Source	Source-Ambient	Remaining				
(mi)	(days)	CBOD	NBOD	DO	DO	DO Deficit	CBOD	Organic N	NH3-N	Nitrite	Nitrate
0.00	0.00	3.45	0.00	6.00	6.00	0.0010	2.70	0.050	0.15	0.00	0.00
0.10	0.23	2.82	0.07	6.57	6.57	0.0071	2.52	0.044	0.14	0.02	0.00
0.20	0.45	2.38	0.11	6.98	6.96	0.0108	2.36	0.038	0.12	0.03	0.00
0.30	0.68	2.07	0.13	7.26	7.24	0.0129	2.20	0.033	0.11	0.04	0.01
0.40	0.91	1.86	0.14	7.46	7.44	0.0139	2.05	0.029	0.10	0.05	0.02
0.50	1.14	1.71	0.15	7.60	7.59	0.0143	1.91	0.025	0.09	0.06	0.02
0.60	1.36	1.60	0.15	7.71	7.70	0.0142	1.79	0.022	0.08	0.06	0.03
0.70	1.59	1.52	0.15	7.80	7.78	0.0139	1.67	0.019	0.08	0.06	0.04
0.80	1.82	1.46	0.14	7.86	7.85	0.0133	1.56	0.017	0.07	0.06	0.05
0.90	2.05	1.41	0.13	7.91	7.90	0.0127	1.45	0.015	0.06	0.06	0.06
1.00	2.27	1.38	0.13	7.96	7.94	0.0120	1.36	0.013	0.06	0.06	0.07
1.10	2.50	1.35	0.12	7.99	7.98	0.0114	1.27	0.011	0.05	0.06	0.08
1.20	2.73	1.33	0.11	8.02	8.01	0.0107	1.18	0.010	0.05	0.06	0.08
1.30	2.95	1.30	0.10	8.05	8.04	0.0100	1.10	0.008	0.04	0.06	0.09
1.40	3.18	1.29	0.10	8.08	8.07	0.0094	1.03	0.007	0.04	0.06	0.10
1.50	3.41	1.27	0.09	8.10	8.09	0.0088	0.96	0.006	0.03	0.05	0.11
1.60	3.64	1.26	0.08	8.12	8.11	0.0082	0.90	0.006	0.03	0.05	0.11
1.70	3.86	1.24	0.07	8.14	8.13	0.0077	0.84	0.005	0.03	0.05	0.12
1.80	4.09	1.23	0.07	8.16	8.15	0.0072	0.78	0.004	0.02	0.04	0.13
1.90	4.32	1.22	0.06	8.17	8.16	0.0067	0.73	0.004	0.02	0.04	0.13
2.00	4.54	1.21	0.06	8.19	8.18	0.0063	0.68	0.003	0.02	0.04	0.14
2.10	4.77	1.20	0.05	8.20	8.19	0.0058	0.63	0.003	0.02	0.04	0.14
2.20	5.00	1.20	0.05	8.21	8.21	0.0055	0.59	0.002	0.01	0.03	0.15
2.30	5.23	1.19	0.04	8.22	8.22	0.0051	0.55	0.002	0.01	0.03	0.15
2.40	5.45	1.18	0.04	8.23	8.23	0.0048	0.52	0.002	0.01	0.03	0.16
2.50	5.68	1.17	0.04	8.24	8.24	0.0044	0.48	0.002	0.01	0.03	0.16



RM	DO River+Source	DO River Only	Source-Ambient DO Deficit
0	5.9990305	6	0.000969499
0.1	6.5677738	6.574864117	0.00709028
0.2	6.9642328	6.975028155	0.010795336
0.3	7.2438417	7.25673879	0.012897122
0.4	7.4440138	7.457956409	0.013942589
0.5	7.5900014	7.604300882	0.014299453
0.6	7.6988515	7.713065914	0.014214464
0.7	7.7820762	7.795928991	0.013852758
0.8	7.847456	7.860780416	0.013324444
0.9	7.9002549	7.9129575	0.012702552
1	7.944042	7.956077142	0.01203515
1.1	7.9812437	7.992597277	0.011353529
1.2	8.0135176	8.024195331	0.010677725
1.3	8.042003	8.052023202	0.010020244
1.4	8.0674904	8.076878933	0.009388571
1.5	8.0905354	8.099322226	0.008786866
1.6	8.111535	8.119752095	0.008217102
1.7	8.1307792	8.138459019	0.00767983
1.8	8.1484852	8.15565993	0.007174692
1.9	8.1648209	8.171521659	0.006700765
2	8.1799198	8.186176629	0.006256791
2.1	8.193892	8.199733343	0.005841326
2.2	8.2068306	8.212283395	0.005452842
2.3	8.2188164	8.223906147	0.00508979
2.4	8.2299212	8.234671859	0.004750642
2.5	8.2402099	8.244643782	0.004433916

RM	Organic N	NH3-N	Nitrite	Nitrate	Remaining CBOD
0	0.04999903	0.1500786	0	0	2.7035173
0.1	0.043616859	0.1369041	0.0182593	0.0012974	2.5232624
0.2	0.038049346	0.1246486	0.0325656	0.004814	2.3550259
0.3	0.033192503	0.1132921	0.0435403	0.0100527	2.1980064
0.4	0.028955616	0.1028047	0.0517218	0.0165955	2.0514561
0.5	0.02525955	0.0931493	0.0575757	0.0240931	1.9146769
0.6	0.022035272	0.0842844	0.0615027	0.0322552	1.7870173
0.7	0.01922256	0.0761655	0.063847	0.0408426	1.6678694
0.8	0.016768879	0.0687464	0.064903	0.0496593	1.5566655
0.9	0.014628401	0.0619807	0.0649216	0.0585469	1.4528761
1	0.012761145	0.0558225	0.0641155	0.0673784	1.3560067
1.1	0.011132238	0.0502269	0.0626648	0.0760538	1.265596
1.2	0.009711253	0.0451504	0.0607206	0.0844954	1.1812134
1.3	0.008471651	0.0405518	0.0584094	0.0926447	1.102457
1.4	0.00739028	0.0363918	0.0558366	0.100459	1.0289515
1.5	0.006446941	0.0326332	0.0530889	0.1079086	0.960347
1.6	0.005624015	0.0292413	0.0502377	0.1149746	0.8963166
1.7	0.004906133	0.0261838	0.0473407	0.121647	0.8365554
1.8	0.004279885	0.0234305	0.0444444	0.1279228	0.7807788
1.9	0.003733575	0.0209536	0.0415858	0.1338047	0.728721
2	0.003257	0.0187273	0.0387934	0.1392999	0.6801341
2.1	0.002841257	0.0167281	0.0360892	0.1444191	0.6347867
2.2	0.002478582	0.0149342	0.0334895	0.1491754	0.5924628
2.3	0.002162201	0.0133257	0.0310057	0.153584	0.5529608
2.4	0.001886205	0.0118846	0.0286454	0.1576614	0.5160926
2.5	0.001645439	0.0105943	0.0264132	0.1614247	0.4816825

PARAMETERS	
$CBOD_5$	5-day CBOD (mg/L)
K_d	effective deoxygenation rate (/day)
K_{in}	NO_2 to NO_3 conversion rate (/day)
K_n	NBOD reaction rate (/day)
K_{oa}	Organic to NH_3 conversion rate (/day)
K_r	K_d+K_s (/day)
K_s	settling rate (/day)
L_N	Initial NBOD (mg/L)
$NH3_m$	Ammonia mixed (mg/L)
NH_3-N	ammonia as N (mg/L)
$Norg_m$	Organic nitrogen mixed (mg/L)
Q_e	effluent flow (mgd)
Q_r	ambient flow (cfs)
S_B	Sediment Oxygen Demand g O_2/m^2 day
Temp	Temperature (degrees C)
TKN	Total Kjeldahl Nitrogen (mg/L)
Tmix	Temperature mixed (deg C)
U	velocity (fps or mpd)
UBODe (mg/L)	Ultimate effluent CBOD (mg/L)
$UBOD_m$ (L_o)	Ultimate CBOD mixed (mg/L)
UBODr (mg/L)	Ultimate river CBOD (mg/L)
Width	Average stream width (ft)

deep fork k1 = 0.35 ; 0.3
k2=1.81
nbod=0.3
bod set=0.03
sod0.075g/ft2/d

Wagoner County
k1 = 0.30
k2=17.03
nbod=0.3
bod set=0.03
sod0.075g/ft2/d

Ardmore k1=0.3 / 0.35
k2 = 2.08-2.79
kn nbod k 0.3
ks cbod set=0.03
SOD 0.11 g/ft2/d

Rogers Cnty k1 = 0.35 ; 0.3
k2=14.94
nbod=0.3
bod set=0.03
sod0.011g/ft2/d

Deficit Equation

$$D = D_o \exp(-K_a \frac{x}{u}) + \frac{K_d}{K_a - K_r}\left[\exp(-K_r \frac{x}{u}) - \exp(-K_a \frac{x}{u})\right]L_o + \frac{K_n}{K_a - K_n}\left[\exp(-K_n \frac{x}{u}) - \exp(-K_a \frac{x}{u})\right]L_o^n + (1 - \exp(-K_a \frac{x}{u}))(\frac{S_B}{HK_a})$$