

Wasteload Allocation
Arkansas River at Muskogee
OKWBID #120400010060 & #120400010260



Oklahoma Department of Environmental Quality
Water Quality Division
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**Arkansas River (OK120400010260_00)
DRAFT WASTELOAD ALLOCATION REPORT**

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1. Problem Definition

Georgia Pacific – Muskogee Mill (formerly Georgia Pacific Consumer Products) is still operating under a permit issued in 1997 under the name of Fort Howard Corporation. The current permit needs to be updated to reflect the condition changes in both the facility and receiving streams. On the facility side, the production has changed over the years. On the receiving stream side, this part of Arkansas River is no longer listed for dissolved oxygen (DO) impairment as it was in the Oklahoma 1998 303(d) list when the previous stream model and wasteload allocation for the facility were developed.

A wasteload allocation (WLA) for Georgia Pacific – Muskogee Mill was originally developed in 2003. The WLA was technically reviewed and approved by the EPA. However, the technically approved WLAs were not incorporated into the Oklahoma 208 Plan. The previous water quality model was a MultiSMP model which is no longer supported by EPA and is not compatible with our current computer operating system. EPA is currently supporting the QUAL2K model. The approved MultiSMP model was converted to a QUAL2K model (Version 2.11b8) with all stream segmentation, stream characteristics, background loadings and kinetics etc. intact. The converted QUAL2K model was compared to the MultiSMP model and was able to duplicate the results of the MultiSMP model.

The receiving stream, Arkansas River (OK120400010260_00), is currently on Oklahoma’s 2012 303(d) List of Impaired Waters as being impaired for TDS (Total dissolved solids). The downstream segment of Arkansas River is Webbers Falls Lake (OK120400010070_00) which is listed for enterococci and turbidity impairments. This wasteload allocation only addresses the impact of DO-demanding substances (CBOD and Ammonia). Therefore, the TDS, bacteria and turbidity impairments will not have any impact on this WLA. The point sources having an impact on the DO in this segment of the river are the City of Muskogee Municipal Treatment System and Georgia Pacific – Muskogee Mill Industrial Wastewater Facility.

Table 1 is an excerpt of 2012 Oklahoma Integrated Water Quality Report which shows the designated beneficial uses of the receiving streams and their support status.

Table 1. Designated Beneficial Uses of Receiving Streams

Waterbody ID	Waterbody Name	Size (miles)	type	Category	Monitoring Date	Aesthetic	Agriculture	CWAC	HLAC	Trout Fishery	WWAC	Fish Consumption	Navigation	PBCR	SBCR	PPWS	EWS	HQW	SWS
OK120400010260_00	Arkansas River	11.17	R	5a	2012	I	N				F	F	F	F			F		
OK120400010070_00	Arkansas River		L	5a	2012	F	F				N	X	F	N			F		

CWAC – Cool Water Aquatic Community
 PBCR – Primary Body Contact Recreation
 EWS – Emergency Water Supply
 I – In-sufficient data
 X – Not assessed

HLAC – Habitat Limited Aquatic Community
 SBCR – Secondary Body Contact Recreation
 HQW – High Quality Water
 N – Not support

WWAC – Warm Water Aquatic Community
 PPWS – Public & Private Water Supply
 SWS – Sensitive Water Supply
 F – Fully support

This segment of the Arkansas River is part of the McClellan-Kerr Navigation System currently regulated by the Corps of Engineers. This system consists of a series of locks and dams creating navigation pools with Webber Falls Dam 24 miles downstream of the point source outfalls. There are not currently any flow gauging stations in this segment designed to monitor low flow conditions.

This wasteload allocation was developed in order to ensure that the limits assigned to the discharges will maintain DO standards under critical conditions and support the Warm Water Aquatic Community beneficial use designation. Non-point source impacts are accounted for through the use of conservative kinetic inputs and assumptions of the background water quality conditions.

Maps of the study area and the locations of the discharges are attached (Figure 1 & 2).

2. Water Quality Standards/Criteria

The dissolved oxygen criteria for this subcategory are listed in Table 2. The minimum criteria were used as the target values in the modeling if a diurnal fluctuation was allowed. In winter an adjustment of 1mg/l was made to the criteria since the model predictions are average and not minimum values.

Table 2. Dissolved Oxygen Criteria to Protect Fish and Wildlife Propagation

Subcategory of Fish and Wildlife Propagation (Fishery Class)	Dates Applicable	Minimum D.O. Criteria (mg/l)	Seasonal Temperature (°C)
WARM WATER AQUATIC COMMUNITY			
Early Life Stages	Apr-1 - Jun-15	6 ¹	25 ²
Other Life Stages			P
Summer Conditions	Jun-16 - Oct-15	5 ¹	32
Winter Conditions	Oct-16 - Mar-31	5	18

¹ Because of natural diurnal dissolved oxygen fluctuation, a 1.0 mg/l dissolved oxygen concentration deficit shall be allowed for not more than eight (8) hours during any twenty-four (24) hour period.

² Discharge limits necessary to meet summer conditions will apply from June 1 of each year. However, where discharge limits based on Early Life Stage (spring) conditions are more restrictive, those limits may be extended to July 1.

3. Source Analysis

Point Sources

Muskogee Wastewater Treatment Facility (WWTF)

Facility Location:

SW/4 of the SW/4 of the SE/4 of Section 33,
 Township 15 North, Range 19 East, Indian Meridian,
 Muskogee County, Oklahoma

Point of Discharge:

Latitude: 35°-44'-13.89" N [GPS: NAD-27 CONUS]
 Longitude: 95°-16'-56.47" W [GPS: NAD-27 CONUS]
 Planning Segment No. 120400

Current Wasteload Allocation (WLA):

Design Flow: 13.7 MGD
 Limits: 30 mg/l BOD₅, 30 mg/l TSS (Secondary)

Georgia Pacific – Muskogee Mill Wastewater Treatment Facility

Facility Location:

Sections 33 and 34, Township 15N, Range 19 East, Indian Meridian
Muskogee County, Oklahoma

Point of Discharge:

Latitude: 35°-44'-23" N
Longitude: 95°-17'-12" W
Planning Segment No. 120400

Current Permit Limits (WLA):

Maximum 30 day Flow (Q_{e30}):	19.34 MGD
Limits:	Daily Average: BOD ₅ – 91 mg/l (14,737 lb/day)
	Daily Maximum: BOD ₅ – 175 mg/l (28,242 lb/day)

Non-Point Sources

The allocations in this waterbody assessment are driven by critical instream dissolved oxygen conditions (low-flow, high temperature) as defined in the Oklahoma Water Quality Standards. Low-flow conditions, by definition, assume little or no runoff.

Background

The summer temperature for this segment was developed utilizing the provisions defined in **Title 252** (Department of Environmental Quality) **Chapter 690** Water Quality Standards Implementation listed below.

252:690-3-60. Receiving water characterization for the implementation of dissolved oxygen criteria to protect the Fish and Wildlife Propagation beneficial use

DO modeling will be performed under conditions that are most critical with respect to processes that determine instream concentration of DO as outlined below.

*(2) **Temperature.** The seasonal regulatory temperatures specified in the OWQS shall be modeled as background conditions unless site-specific data is available. If at least one year of average daily stream temperature values is available, the upper 90th percentile value calculated from the dataset for the season will be used.*

Using temperature data collected for the Arkansas River at Tulsa (USGS 07164500) a 90th percentile value of 29°C for summer was used as the critical summer temperature. The regulatory temperatures contained in the OWQS were used for spring and winter.

Since the navigation channel was constructed there are no low flow gauging stations on the Arkansas River below its confluence with the Verdigris River. There was a USGS station at Muskogee but discontinued in 1952. In order to establish a low flow for this location the low flow measurements were taken for the contributing rivers upstream and then adjusted based on drainage area. The flows were taken from the USGS publication "Statistical Summaries of Stream flow in Oklahoma through 2007". The flows and calculation adjustments are summarized below in Table 3. The calculated 7Q2 flows are different from those used in the previously approved model because more flow data are available now.

Table 3. Arkansas River at Muskogee - Low Flow Calculations

Station	Period of Record	Drainage Area	Flow - 7Q ₂			
			Yearly	Spring	Summer	Winter
		mi ²	cfs	cfs	cfs	cfs
Arkansas River near Haskell (#07165570)	1973-2007	75,473	918	4300	1130	1350
Neosho River below Ft. Gibson (#07193500)	1955-1989	12,495	191	1,750	407	664
Verdigris River near Claremore (#07176000)	1964-2007	6,514	46.0	546	51.9	92.1
Totals		<i>94,482</i>	<i>1155</i>	<i>6596</i>	<i>1589</i>	<i>2106</i>
Adjustment Factor - cfs/mi ²			<i>0.012</i>	<i>0.070</i>	<i>0.017</i>	<i>0.022</i>
Arkansas River near Muskogee	1927-1952	96,674				
Adjusted Flow			1182	6749	1626	2155

The following background conditions for the Arkansas River were used:

Flow: See Table 3
 CBOD₅: 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 streams can be established through typical water quality models such as spreadsheet mass balance, desktop Streeter-Phelps model, modified Streeter-Phelps model (SOD included), MultiSMP, LA-QUAL, QUAL2K, SWAT, and HSPF etc. A MultiSMP model was used to determine the wasteload allocations in 2005. The MultiSMP model was reviewed and approved by the EPA. However, since the MultiSMP model is no longer supported, the model was converted to a QUAL2K model.

Model Inputs

The water quality model used to determine the impact of DO-demanding substances on the instream DO concentration is QUAL2K. The inputs into the model are calculated, based on historical information or estimated from literature data. The segment of the river included in this study is 16 miles long and divided into 10 reaches using the USACE cross-section data.

Cross-sections of the river furnished by the Corps of Engineers Tulsa District (Appendix B) were examined and cross-sectional areas were developed for the river reaches. The velocities for each reach were developed using the cross-sectional areas along with the seasonal low flows. These calculated velocities should reflect the low flow characteristics of the river and be an acceptable representation of those that would occur under critical conditions.

The kinetics used in the model were derived primarily from literature values. The CBOD decay rate for the first reach is based on data from an NCASI technical bulletin "A Review of Ultimate BOD Estimation and its Kinetic Formulation for Pulp and Paper Mill Effluents", with a K_d of 0.02/day used for the reach downstream of the paper mill. The K_d for the reaches downstream of Muskogee's WWTF were calculated on a flow weighted basis using the permit or design flows for the two discharges and the ratio of ultimate CBOD to CBOD5 assuming a K_d for the Muskogee WWTF discharge of 0.3/day. A sediment oxygen demand (SOD) of 0.5 g/m²/day and a NBOD decay rate (K_n) of 0.2/day were used and are accepted literature values for this stream type. The Reaeration rate (K_a) was based on the formula ($K_a = K_L / \text{depth}$, where K_L = surface transfer rate) used for lakes and estuaries, since the characteristics of the river are influenced by the lock and dam downstream at Webber Falls. A surface transfer rate of 2.0 m/day was used based on work done by Di Toro and Connolly (1980) for lakes.

As stated in the previous section, a temperature of 29° C for the summer is used in this WLA. The regulatory temperature of 25° C and 18° C are used for the spring and winter. The velocities are quite low but should be representative. The velocities were calculated based on the flow and cross-section area. The kinetic rates used are also based on literature values.

The range of inputs and kinetic rates used in the model are listed below:

Average Velocity:	0.033 fps – 0.56 fps
Average Depth:	7.2 ft – 20.6 ft
CBOD decay rate (K_d):	0.02/day – 0.07/day
Reaeration Rate & Formula (K_a):	0.31/day – 0.89/day
NBOD decay rate (K_n):	0.20/day
Sediment Oxygen Demand (SOD):	0.50 g/m ² /day

Effluent temperatures for both facilities were set at the regulatory temperature of 32 °C for the summer because there are no temperature data to show otherwise. It is more conservative to assume the effluent temperature equal to the regulatory temperature (32 °C) than to assume the effluent temperature equal to the ambient water temperature (29 °C).

The technology based limit for Georgia Pacific – Muskogee Mill is only for BOD₅. There is no ammonia limit, but ammonia must be accounted for the model. There are 27 ammonia sample results available through Georgia Pacific – Muskogee Mill's permit application with the maximum NH₃ concentration of 1.77 mg/L and average of 0.71 mg/L. To be conservative, 4.0 mg/L ammonia concentration was used in the QUAL2K model.

Once the QUAL2K model was set up, the model was used to check if the technology-based concentration limits would protect the Oklahoma DO standard in the receiving stream for each season. If the technology-based limits are sufficient, the technology-based limits will be the permit limits. The permit flow for technology based limits is the LTA (Long Term Average) flow of the facility. If the

QUAL2K model shows that the technology-based limits are not stringent enough to protect the water quality standards, water quality-based concentration limits will be developed. The permit flow for water quality-based limits is the highest 30-day average effluent flow over the last 2 years or $Q_{e(30)}$.

The model inputs and results are included in Appendix A.

5. Margin of Safety and Maximum Assimilative Capacity

The Oklahoma Continuing Planning Process (CPP), 2012 ed., specifies a 25% margin of safety (MOS) for uncalibrated, multiple source models. This is implemented by increasing the CBOD and ammonia concentrations from both background and point discharges by the same percentage until DO standards are just met in the receiving stream. The total of the resultant loads from background and discharges will be the stream’s maximum assimilative capacity. The MOS will be 25% of the maximum assimilative capacity. The quantified maximum assimilative capacity is given along with wasteload allocations, load allocations (background), MOS and reserve capacity in the next element.

6. Allocations

The table below shows the maximum daily loads for the Arkansas River at Muskogee. The NPS loading is included as part of the load allocation and is based on the assumed background concentrations.

Table 4. Maximum Daily Loads - Arkansas River at Muskogee

SEASON	MAXIMUM LOADING		WASTELOAD ALLOCATION		BACKGROUND LOAD		MARGIN OF SAFETY (25%)		RESERVE CAPACITY	
	CBOD ₅	NH ₃ -N	CBOD ₅	NH ₃ -N	CBOD ₅	NH ₃ -N	CBOD ₅	NH ₃ -N	CBOD ₅	NH ₃ -N
	lbs/day		lbs/day		lbs/day		lbs/day		lbs/day	
SUMMER	39310	4310	11962	1918	17521	1314	9827	1077	0	0
SPRING	148868	11935	18087	1826	72722	5454	37217	2984	20842	1671
WINTER	79438	6861	18087	1826	23221	1742	19859	1715	18271	1578

7. Final Recommendations

The WLA for Muskogee WWTF is unchanged.

WLA, Muskogee WWTF

Design Flow: 13.7 MGD
 Effluent Limits (Year-round): 30mg/l BOD₅, 30 mg/l TSS

The following changes are recommended for inclusion in the Oklahoma Water Quality Management Plan (208 Plan).

WLA, Georgia Pacific – Muskogee Mill WWTF (Outfall #1)

Summer (Jun – Oct) – water quality based effluent limits

Permit Flow ($Q_{e(30)}$): 16.28 MGD
Summer Limits: Average: 67 mg/l CBOD₅, 4.0 mg/l NH₃-N

Spring & Winter (Nov – May) – Technology-based effluent limits

Permit Flow (LTA): 13.52 MGD
Spring & Winter Limits: Average: 135 mg/l BOD₅

8. Public Participation

After EPA's technical review and acceptance, the proposed WLAs will be sent for public comments. Public comments received during this period will be responded to and changes, if necessary, will be made. Then, the final WLAs will be sent to EPA for final approval and be incorporated into the Oklahoma Water Quality Management (208) Plan.

9. References

1. *Title 785, Oklahoma Administrative Code, Chapter 45 Oklahoma's Water Quality Standards*, State of Oklahoma, 2011. http://www.owrb.ok.gov/util/rules/pdf_rul/RulesCurrent2011/Ch45-Current2011.pdf
2. *Oklahoma Continuing Planning Process, 2012 Version*, Oklahoma Department of Environmental Quality, State of Oklahoma, 2012. http://www.deq.state.ok.us/wqdnew/305b_303d/Final%20CPP.pdf
3. Chapra, S.C. and Pelletier, G.J. 2008. *QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality, Version 2.11: Documentation and Users Manual*, Tufts University.
4. Raymond C. Whittmore and Jeffrey Hovis, 1982. *A Review of Ultimate BOD Estimation and Its Kinetic Formulation for Pulp and Paper Mill Effluents, Issue 382 of NCASI technical bulletin*. New York, NY, 1982.
5. Jason M. Lewis and Rachel A. Esralew, 2009. *Statistical Summaries of Stream flow in Oklahoma through 2007*, Scientific Investigations Report 2009-5135, U.S. Department of the Interior and U.S. Geological Survey.

Figure 1. Arkansas River & Location of Discharges

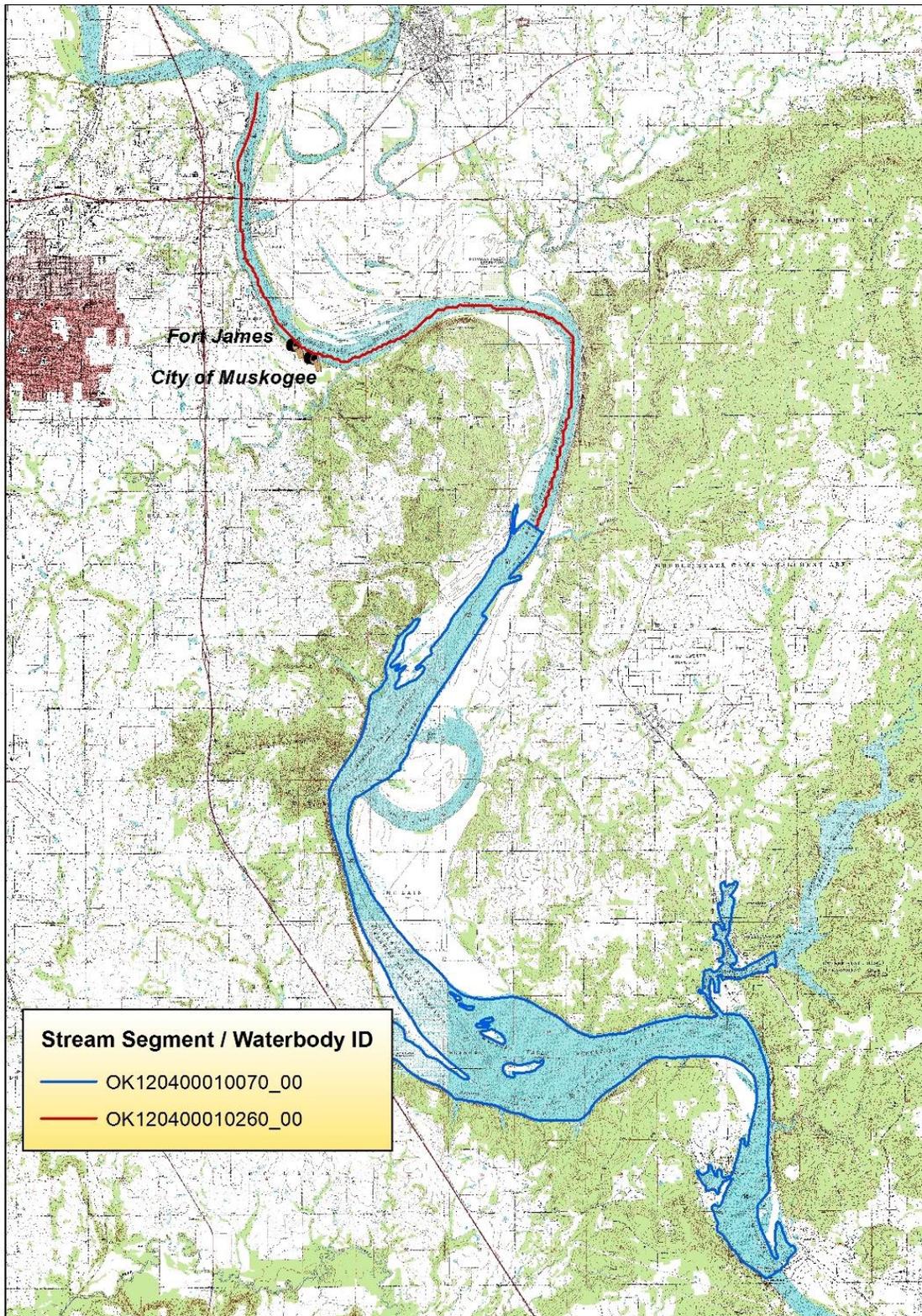
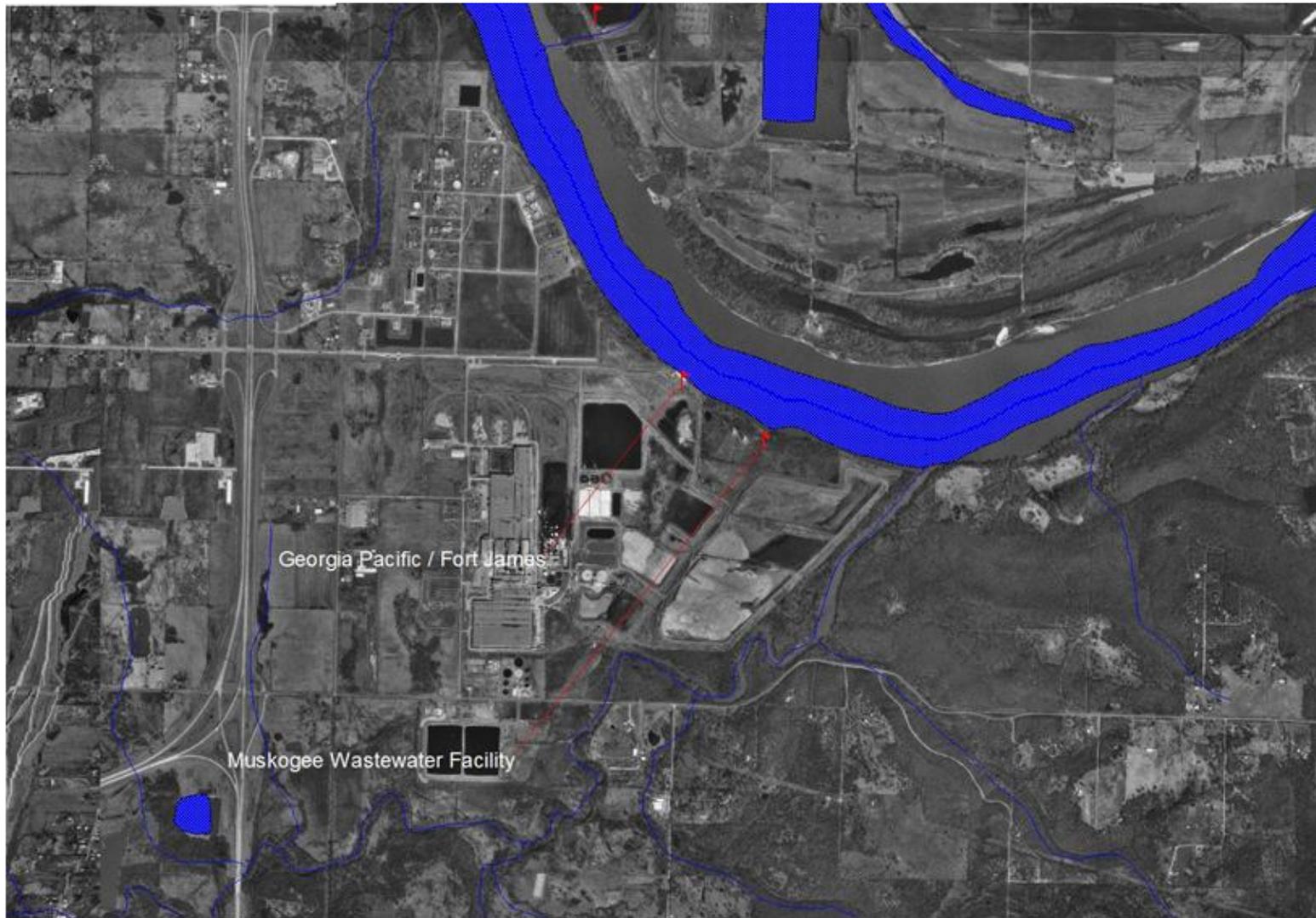


Figure 2. Aerial Photo – Location of Major Discharges



10. APPENDIX A - Modeling Results

Due to the size of the QUAL2K input & output files, only the dissolved oxygen profiles for each season are attached. These DO profiles include loadings from background, wasteload allocations, and 25% margin of safety. The electronic files will be submitted together with this report and are listed as follows:

- 1). Input files for determining stream's maximum assimilative capacity
 - Summer WLA – MOS.q2k
 - Spring WLA – max.q2k
 - Winter WLA – max.q2k

- 2). Input files for WLAs with 25% MOS
 - Summer WLA – MOS.q2k
 - Spring WLA – MOS.q2k
 - Winter WLA – MOS.q2k

- 3). Input files of the previous approved model (Converted to QUAL2K)
 - Summer WLA – previous model.q2k

Figure A-1. Dissolved Oxygen Concentration for the Summer (DO standard: 5 mg/L)

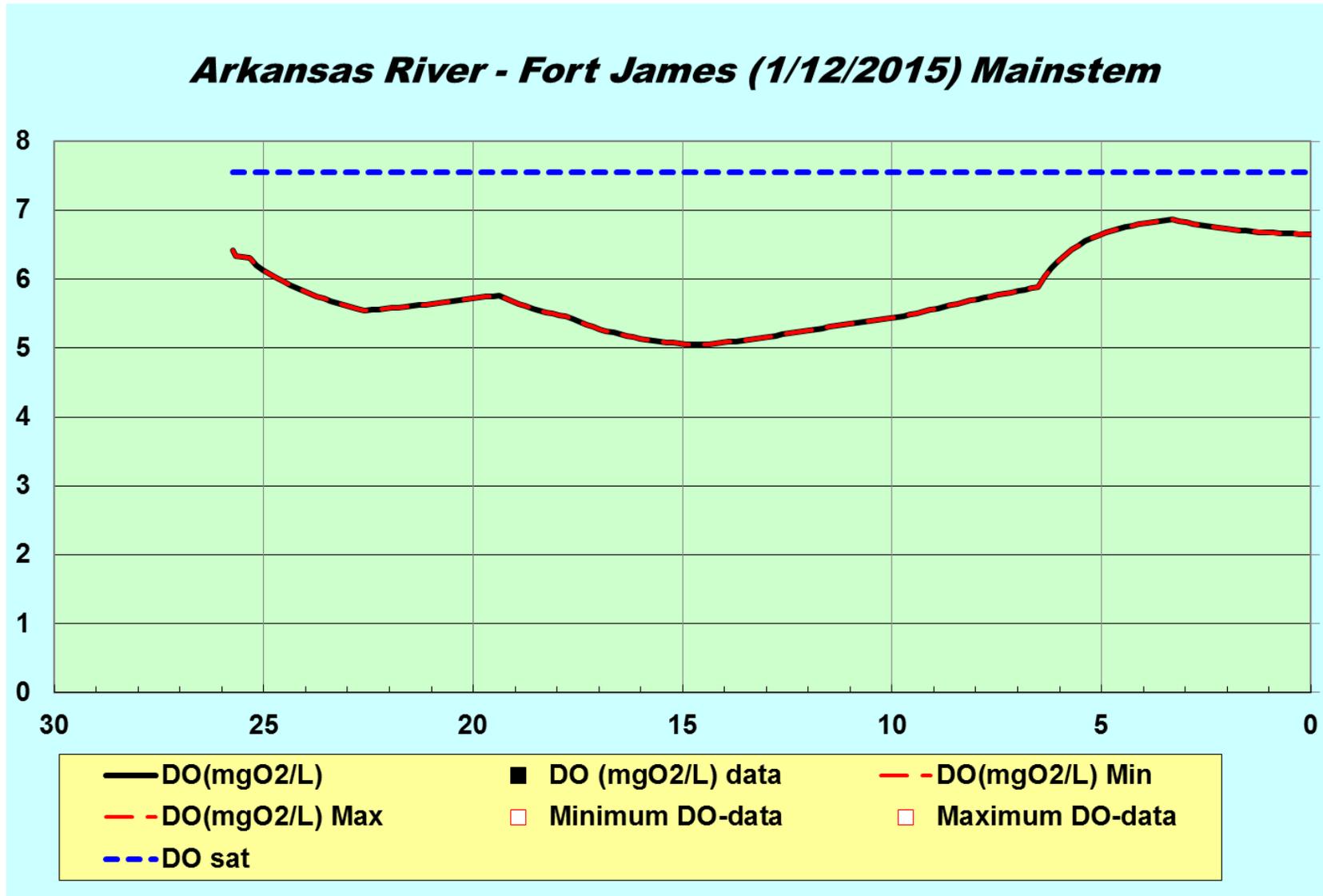


Figure A-2. Dissolved Oxygen Concentration for the Spring (DO standard: 6 mg/L)

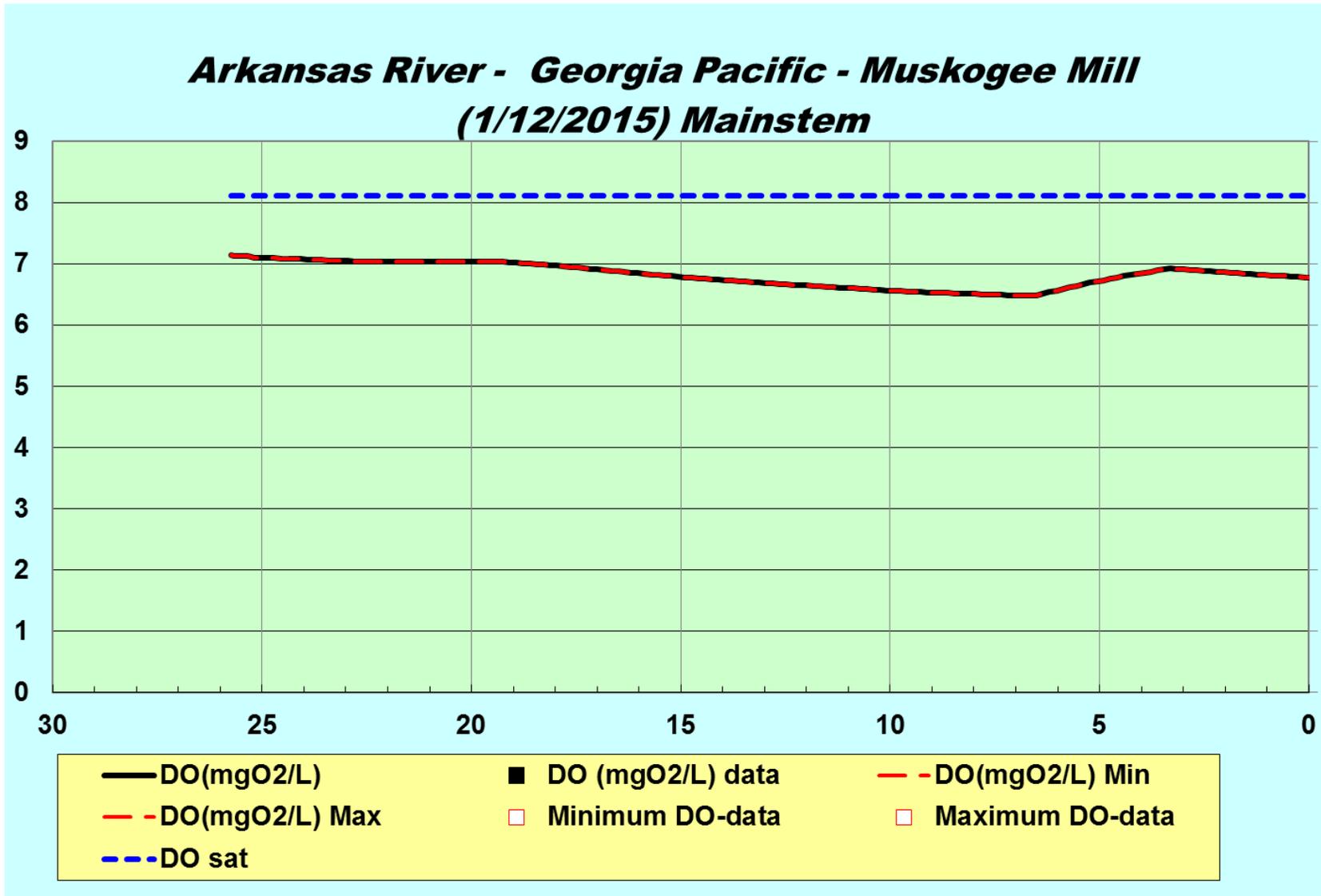
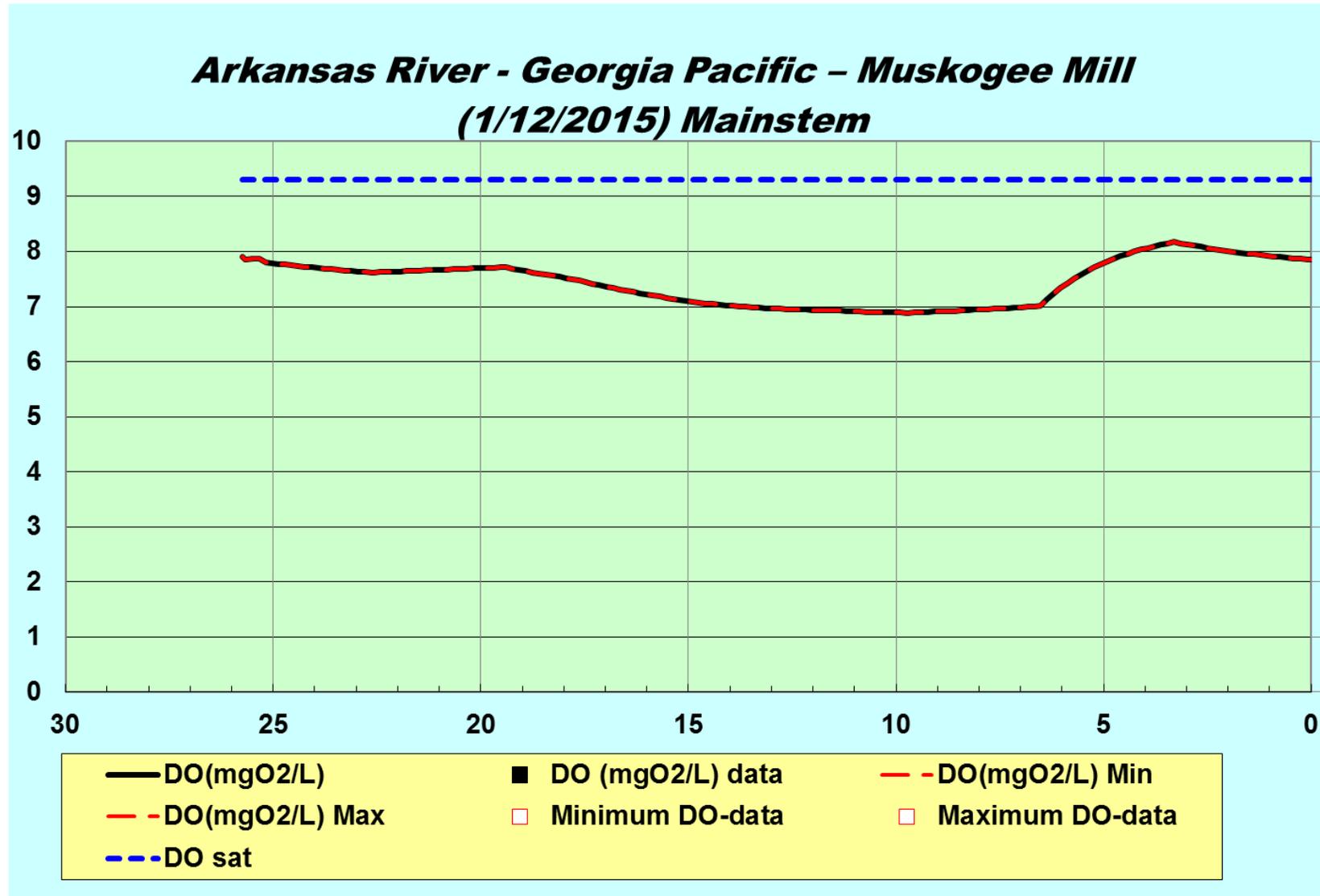


Figure A-3. Dissolved Oxygen Concentration for the Winter (DO standard: 6 mg/L)



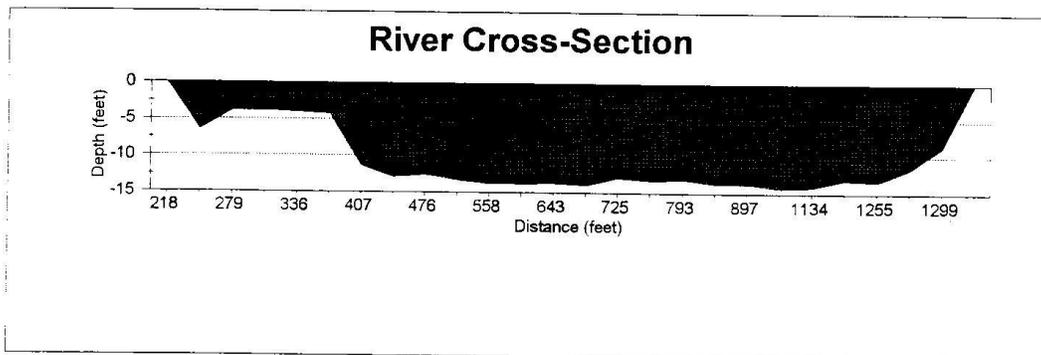
11. APPENDIX B - Arkansas River Cross-Sections

Project: **Muskogee** Site: **SR-26**

Elevation	Distance	Depth		
487.0	218	0.0	0.00	
480.5	252	-6.5	-0.20	
483.1	279	-3.9	-0.09	
483.1	310	-3.9	-0.11	
482.9	336	-4.1	-0.10	
482.7	376	-4.3	-0.15	
475.6	407	-11.4	-0.32	
474.1	448	-12.9	-0.47	
474.4	476	-12.6	-0.32	
473.7	519	-13.3	-0.51	
473.2	558	-13.8	-0.48	
473.2	608	-13.8	-0.62	
473.3	643	-13.7	-0.43	
473.0	679	-14.0	-0.45	
474.1	725	-12.9	-0.53	
473.7	759	-13.3	-0.41	
473.9	793	-13.1	-0.40	
473.3	861	-13.7	-0.84	
473.3	897	-13.7	-0.44	
472.7	1045	-14.3	-1.90	
472.9	1134	-14.1	-1.13	
473.9	1219	-13.1	-1.00	
473.6	1255	-13.4	-0.43	
475.3	1290	-11.7	-0.37	
478.3	1299	-8.7	-0.07	
487.0	1333	0.0	0.00	
		Average Depth	11.76	Cross-Sectional Area 13115

	Elevation	Distance
1	478.3	1299
2	490	1345
	0.25641	1333.205

Side Slope = 0.02110 Velocity = 0.171

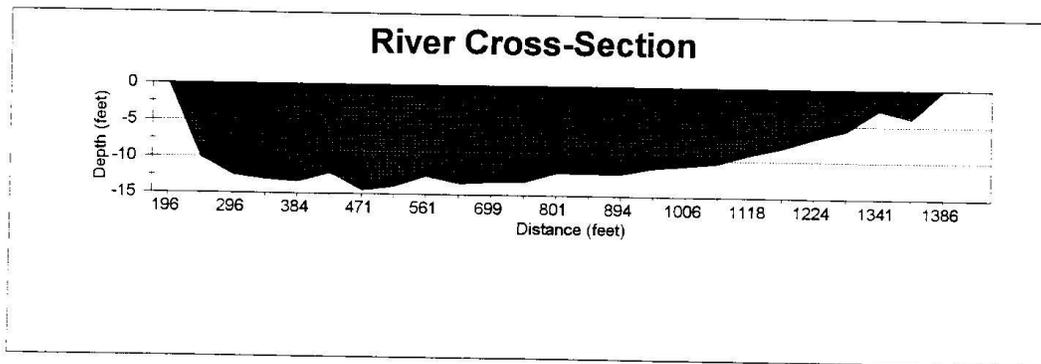


Project: **Muskogee** Site: **SR-25**

Elevation	Distance	Depth		
487.0	196	0.0	0.00	
476.9	244	-10.1	-0.40	
474.5	296	-12.5	-0.53	
473.9	324	-13.1	-0.30	
473.6	384	-13.4	-0.66	
474.8	413	-12.2	-0.29	
472.5	471	-14.5	-0.69	
473.1	510	-13.9	-0.45	
474.5	561	-12.5	-0.52	
473.5	643	-13.5	-0.91	
473.8	699	-13.2	-0.61	
473.8	739	-13.2	-0.43	
475.1	801	-11.9	-0.61	
475.0	835	-12.0	-0.33	
475.0	894	-12.0	-0.58	
475.9	928	-11.1	-0.31	
476.2	1006	-10.8	-0.69	
476.6	1060	-10.4	-0.46	
477.9	1118	-9.1	-0.43	
478.8	1164	-8.2	-0.31	
480.2	1224	-6.8	-0.33	
481.3	1288	-5.7	-0.30	
484.2	1341	-2.8	-0.12	
483.0	1365	-4.0	-0.08	
487.0	1386	0.0	0.00	
487.0	1414	0.0	0.00	
		Average Depth	10.35	Cross-Sectional Area 12612

	Elevation	Distance
1	483	1365
2	487.8	1390
		0.166667 1385.833

Side Slope = 0.01700 Velocity = 0.178

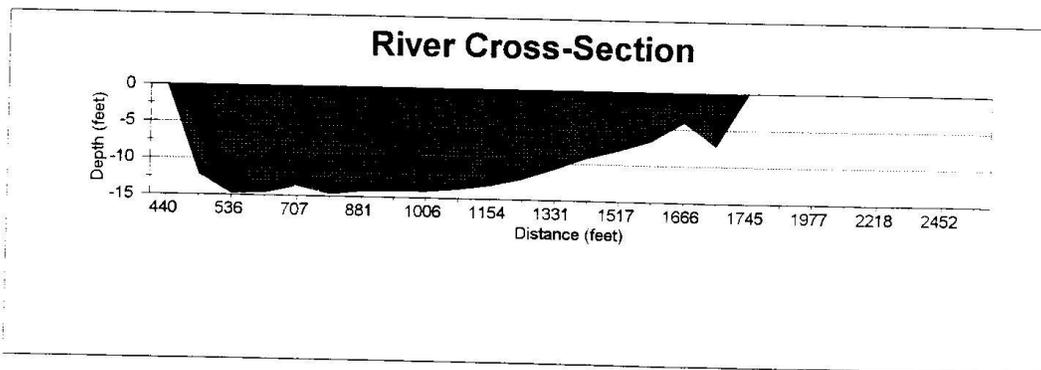


Project: **Muskogee** Site: **SR-24**

Elevation	Distance	Depth		
487.0	440	0.0	0.00	
474.8	467	-12.2	-0.16	
472.2	536	-14.8	-0.49	
472.4	613	-14.6	-0.54	
473.4	707	-13.6	-0.61	
472.3	790	-14.7	-0.59	
472.8	881	-14.2	-0.62	
472.9	972	-14.1	-0.62	
472.9	1006	-14.1	-0.23	
473.3	1062	-13.7	-0.37	
473.9	1154	-13.1	-0.58	
474.8	1241	-12.2	-0.51	
476.3	1331	-10.7	-0.46	
477.9	1424	-9.1	-0.41	
479.0	1517	-8.0	-0.36	
480.4	1610	-6.6	-0.29	
482.9	1666	-4.1	-0.11	
479.8	1689	-7.2	-0.08	
487.0	1745	0.0	0.00	
487.0	1870	0.0	0.00	
487.0	1977	0.0	0.00	
487.0	2177	0.0	0.00	
487.0	2218	0.0	0.00	
487.0	2415	0.0	0.00	
487.0	2452	0.0	0.00	
487.0	2524	0.0	0.00	
		Average Depth	7.02	Cross-Sectional Area 14624

	Elevation	Distance
1	490.0	433
2	474.8	467
	0.802632	439.7105

Side Slope = 0.00673 Velocity = 0.153



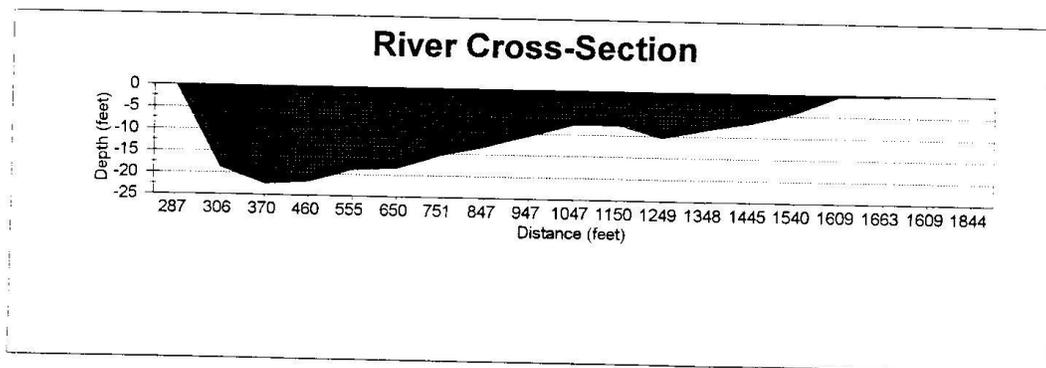
Project: **Muskogee** Site: **SR-23**

Elevation	Distance	Depth	
487.0	287	0.0	0.00
468.3	306	-18.7	-0.17
464.6	370	-22.4	-0.67
465.2	460	-21.8	-0.92
468.1	555	-18.9	-0.84
468.6	650	-18.4	-0.82
471.7	751	-15.3	-0.73
473.8	847	-13.2	-0.60
476.5	947	-10.5	-0.49
479.2	1047	-7.8	-0.37
479.2	1150	-7.8	-0.38
476.5	1249	-10.5	-0.49
478.5	1348	-8.5	-0.40
480.2	1445	-6.8	-0.31
482.7	1540	-4.3	-0.19
486.6	1609	-0.4	-0.01
486.7	1663	-0.3	-0.01
487.0	1609	0.0	0.00
487.0	1844	0.0	0.00
487.0	1959	0.0	0.00
487.0	2083	0.0	0.00
487.0	2192	0.0	0.00
487.0	2310	0.0	0.00
487.0	2362	0.0	0.00
487.0	2402	0.0	0.00
487.0	2415	0.0	0.00

	Elevation	Distance
1	490.0	284
2	468.3	306
	0.861751	287.0415

Average Depth 7.39 Cross-Sectional Area 15733

Side Slope = 0.00695 Velocity = 0.143



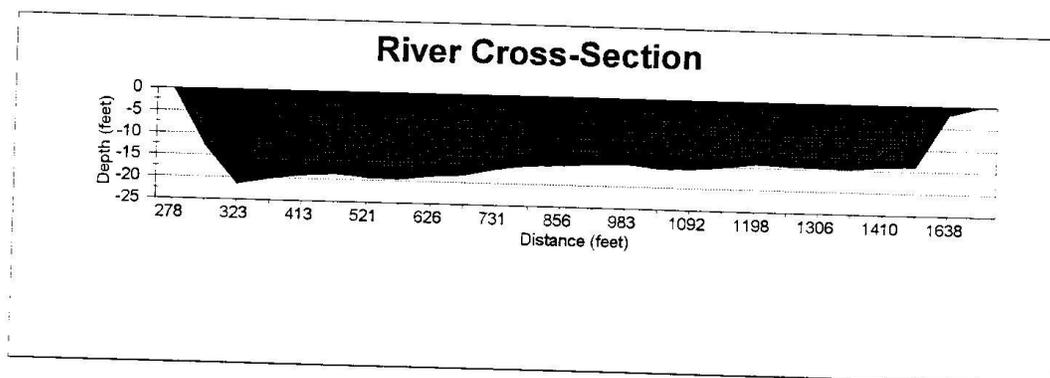
Project: **Muskogee** Site: **SR-22**

Elevation	Distance	Depth	
487.0	278	0.0	0.00
474.1	297	-12.9	-0.18
465.6	323	-21.4	-0.40
466.9	356	-20.1	-0.48
467.8	413	-19.2	-0.79
468.3	456	-18.7	-0.58
467.5	521	-19.5	-0.92
467.4	561	-19.6	-0.57
468.3	626	-18.7	-0.88
468.7	666	-18.3	-0.53
470.3	731	-16.7	-0.79
471.1	773	-15.9	-0.48
471.4	856	-15.6	-0.94
471.8	920	-15.2	-0.71
472.0	983	-15.0	-0.69
471.3	1048	-15.7	-0.74
471.4	1092	-15.6	-0.50
471.9	1156	-15.1	-0.70
472.8	1198	-14.2	-0.43
472.5	1263	-14.5	-0.68
472.4	1306	-14.6	-0.46
472.3	1369	-14.7	-0.67
472.9	1410	-14.1	-0.42
473.1	1494	-13.9	-0.85
485.0	1638	-2.0	-0.21
487.0	1656	0.0	0.00

	Elevation	Distance
1	490	1682
2	485	1638
	0.4	1655.6

Average Depth 14.61 Cross-Sectional Area 20128

Side Slope = 0.02120 Velocity = 0.111



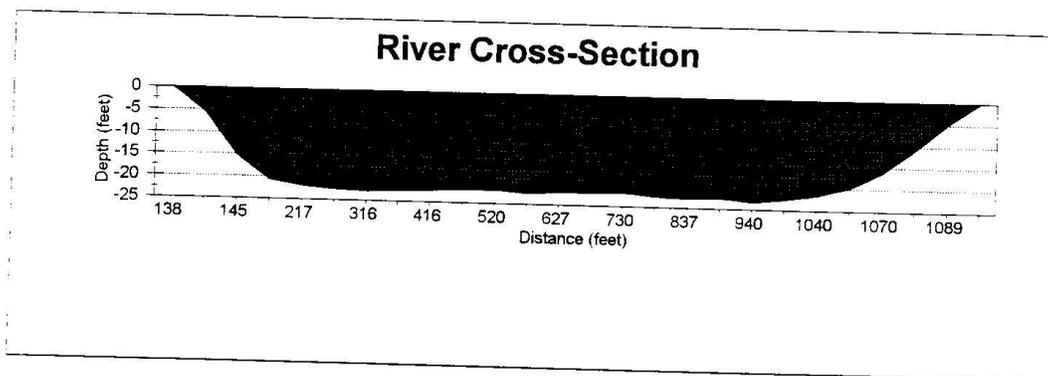
Project: **Muskogee** Site: **SR-21**

Elevation	Distance	Depth	
487.0	138	0.0	0.00
481.3	140	-5.7	-0.01
471.7	145	-15.3	-0.08
466.3	188	-20.7	-0.91
465.0	217	-22.0	-0.65
464.3	273	-22.7	-1.30
464.0	316	-23.0	-1.01
464.4	376	-22.6	-1.39
464.6	416	-22.4	-0.92
464.9	479	-22.1	-1.43
464.9	520	-22.1	-0.93
464.4	585	-22.6	-1.51
464.8	627	-22.2	-0.96
464.8	687	-22.2	-1.36
465.0	730	-22.0	-0.97
464.3	794	-22.7	-1.49
464.1	837	-22.9	-1.01
464.3	897	-22.7	-1.40
463.6	940	-23.4	-1.03
464.4	1003	-22.6	-1.46
465.4	1040	-21.6	-0.82
467.2	1055	-19.8	-0.30
470.7	1070	-16.3	-0.25
476.1	1077	-10.9	-0.08
482.1	1089	-4.9	-0.06
487.0	1114	0.0	0.00

	Elevation	Distance
1	490	1130
2	482.1	1089
	0.620253	1114.43

Average Depth 21.32 Cross-Sectional Area 20811

Side Slope = 0.04369 Velocity = 0.108



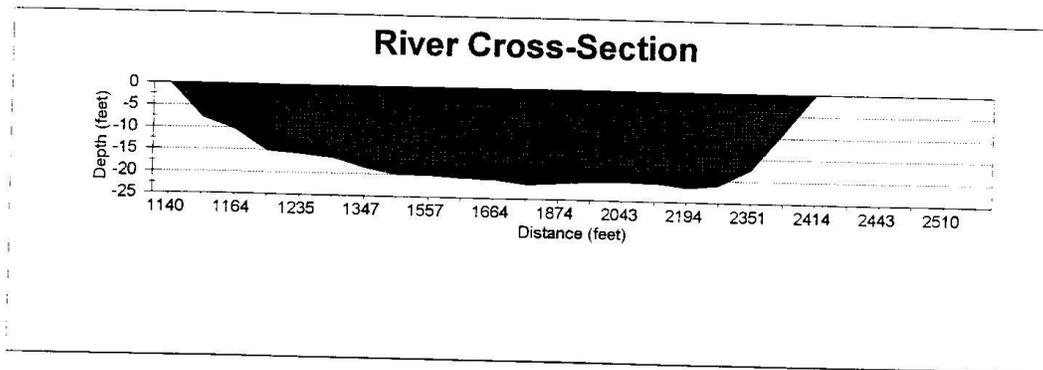
Project: **Muskogee** Site: **SR-19**

Elevation	Distance	Depth	
487.0	1140	0.0	0.00
479.2	1155	-7.8	-0.08
476.6	1164	-10.4	-0.07
471.8	1207	-15.2	-0.47
471.3	1235	-15.7	-0.32
470.5	1263	-16.5	-0.33
468.4	1347	-18.6	-1.12
466.9	1451	-20.1	-1.50
466.9	1557	-20.1	-1.53
466.4	1621	-20.6	-0.95
466.3	1664	-20.7	-0.64
465.2	1768	-21.8	-1.63
465.7	1874	-21.3	-1.62
466.1	1979	-20.9	-1.58
466.3	2043	-20.7	-0.95
466.1	2089	-20.9	-0.69
465.3	2194	-21.7	-1.64
465.9	2297	-21.1	-1.56
469.6	2351	-17.4	-0.68
478.1	2376	-8.9	-0.16
487.0	2414	0.0	0.00
487.0	2433	0.0	0.00
487.0	2443	0.0	0.00
487.0	2485	0.0	0.00
487.0	2510	0.0	0.00
487.0	2530	0.0	0.00

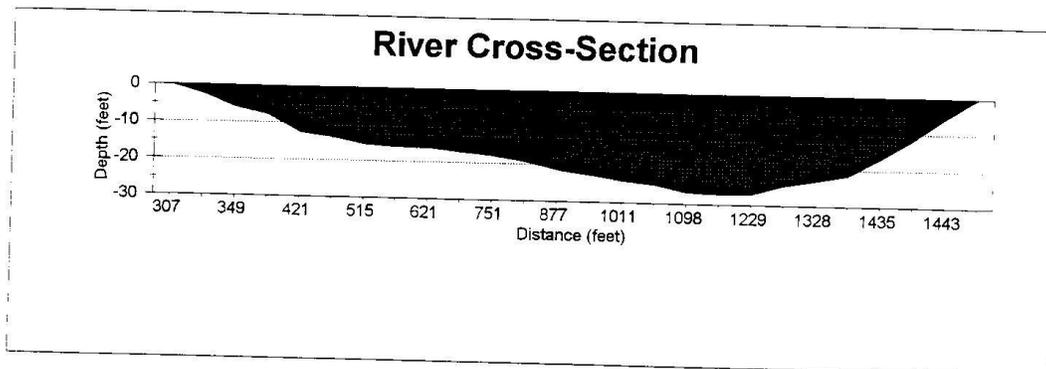
	Elevation	Distance
1	490.0	2427
2	478.1	2376
	0.747899	2414.143

Average Depth 17.54 Cross-Sectional Area 24377

Side Slope = 0.02523 Velocity = 0.092

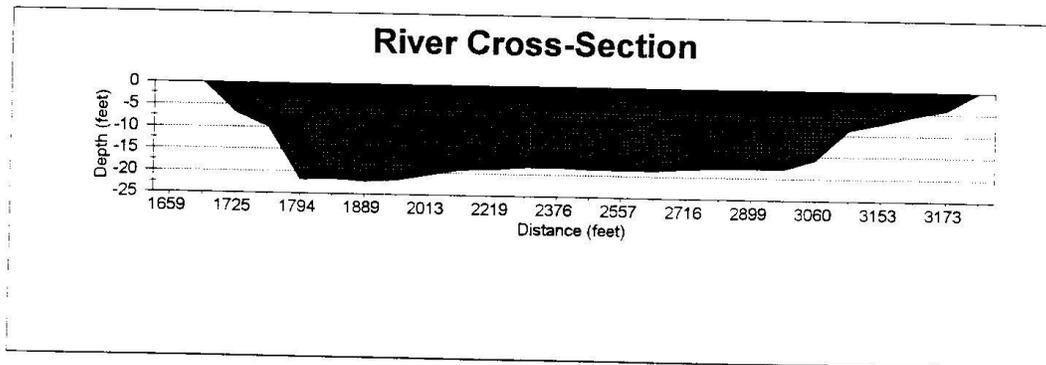


Project:	Muskogee		Site:	SR-20	
Elevation	Distance	Depth		Elevation	Distance
487.0	307	0.0		1	481.3 1443
484.5	325	-2.5		2	490 1514
481.0	349	-6.0			0.344828 1489.517
479.1	371	-7.9			
474.4	421	-12.6			
473.2	450	-13.8			
471.4	515	-15.6			
471.0	550	-16.0			
470.8	621	-16.2			
469.9	655	-17.1			
469.0	751	-18.0			
467.6	811	-19.4			
465.6	877	-21.4			
464.4	934	-22.6			
462.9	1011	-24.1			
462.1	1040	-24.9			
460.1	1098	-26.9			
459.8	1139	-27.2			
459.9	1229	-27.1			
462.5	1282	-24.5			
463.9	1328	-23.1			
465.4	1379	-21.6			
470.1	1435	-16.9			
475.4	1439	-11.6			
481.3	1443	-5.7			
487.0	1490	0.0			
		Average Depth	18.99	Cross-Sectional Area	22462
		Side Slope =	0.03210	Velocity =	0.100



Project: **Muskogee** Site: **SR-18**

Elevation	Distance	Depth		Elevation	Distance
487.0	1659	0.0	0.00		
487.0	1700	0.0	0.00		
480.2	1725	-6.8	-0.11	1	482.8 3173
476.9	1744	-10.1	-0.13	2	490 3176
465.1	1794	-21.9	-0.72		0.416667 3174.75
465.4	1856	-21.6	-0.88		
464.8	1889	-22.2	-0.48		
465.3	1920	-21.7	-0.44		
466.6	2013	-20.4	-1.25		
467.8	2149	-19.2	-1.72		
468.0	2219	-19.0	-0.88		
468.6	2263	-18.4	-0.53		
468.6	2376	-18.4	-1.37		
468.3	2489	-18.7	-1.39		
468.3	2557	-18.7	-0.84		
468.3	2600	-18.7	-0.53		
468.7	2716	-18.3	-1.40		
469.0	2830	-18.0	-1.35		
469.1	2899	-17.9	-0.81		
469.0	2944	-18.0	-0.53		
471.3	3060	-15.7	-1.20		
478.1	3148	-8.9	-0.52		
479.7	3153	-7.3	-0.02		
481.4	3166	-5.6	-0.05		
482.8	3173	-4.2	-0.02		
487.0	3175	0.0	0.00		
		Average Depth	17.20	Cross-Sectional Area	26080
		Side Slope =	0.02270	Velocity =	0.086

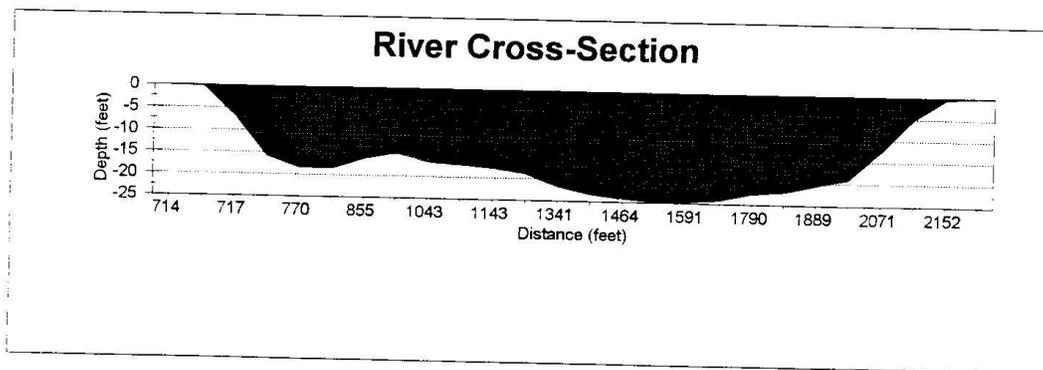


Project: **Muskogee** Site: **SR-17**

Elevation	Distance	Depth			
487.0	714	0.0	0.00		
486.9	716	-0.1	-0.00		
480.1	717	-6.9	-0.00		
471.2	744	-15.8	-0.29		
468.6	770	-18.4	-0.33		
468.5	799	-18.5	-0.37		
470.8	855	-16.2	-0.63		
472.3	966	-14.7	-1.13		
470.2	1043	-16.8	-0.89		
469.8	1093	-17.2	-0.59		
469.2	1143	-17.8	-0.61		
468.0	1221	-19.0	-1.02		
465.2	1341	-21.8	-1.81		
463.6	1415	-23.4	-1.20		
462.7	1464	-24.3	-0.82		
462.1	1514	-24.9	-0.86		
462.2	1591	-24.8	-1.32		
462.8	1714	-24.2	-2.05		
464.3	1790	-22.7	-1.19		
464.9	1840	-22.1	-0.76		
466.5	1889	-20.5	-0.69		
467.9	1962	-19.1	-0.96		
474.4	2071	-12.6	-0.95		
481.9	2125	-5.1	-0.19		
486.5	2152	-0.5	-0.01		
487.0	2163	0.0	0.00		
		Average Depth	18.68	Cross-Sectional Area	27074

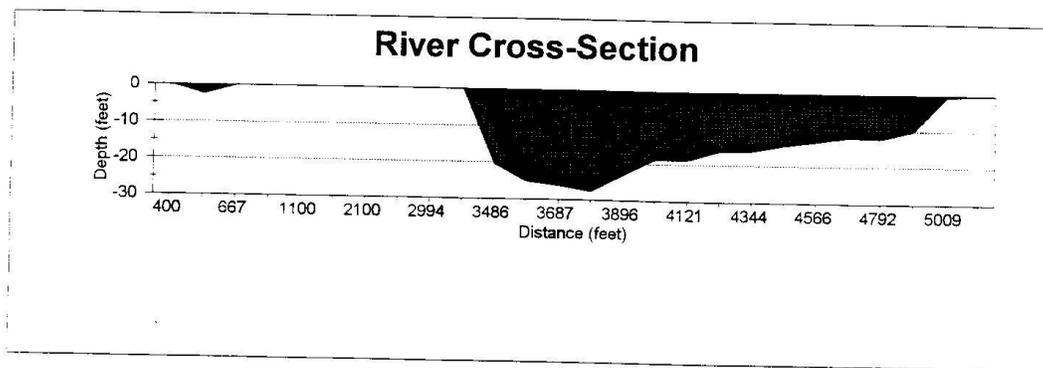
	Elevation	Distance
1	486.5	2152
2	490	2230
		0.857143 2163.143

Side Slope = 0.02579 Velocity = 0.083



Project: **Muskogee** Site: **SR-16**

Elevation	Distance	Depth		Elevation	Distance
487.0	400	0.0	0.00		
484.5	460	-2.5	-0.03	1	490 5136
487.0	667	0.0	0.00	2	486.5 5009
487.0	748	0.0	0.00		0.142857 5027.143
487.0	1100	0.0	0.00		
487.0	1600	0.0	0.00		
487.0	2100	0.0	0.00		
487.0	2600	0.0	0.00		
487.0	2994	0.0	0.00		
487.0	3300	0.0	0.00		
466.5	3486	-20.5	-2.21		
461.8	3587	-25.2	-1.47		
460.8	3687	-26.2	-1.52		
459.3	3789	-27.7	-1.64		
463.9	3896	-23.1	-1.43		
468.2	4008	-18.8	-1.22		
468.2	4121	-18.8	-1.23		
470.8	4234	-16.2	-1.06		
470.9	4344	-16.1	-1.03		
472.7	4455	-14.3	-0.92		
473.7	4566	-13.3	-0.85		
475.0	4680	-12.0	-0.79		
474.7	4792	-12.3	-0.80		
476.9	4902	-10.1	-0.64		
486.5	5009	-0.5	-0.03		
487.0	5027	0.0	0.00		
		Average Depth	16.87	Cross-Sectional Area	29132
		Side Slope =	0.007	Velocity =	0.077



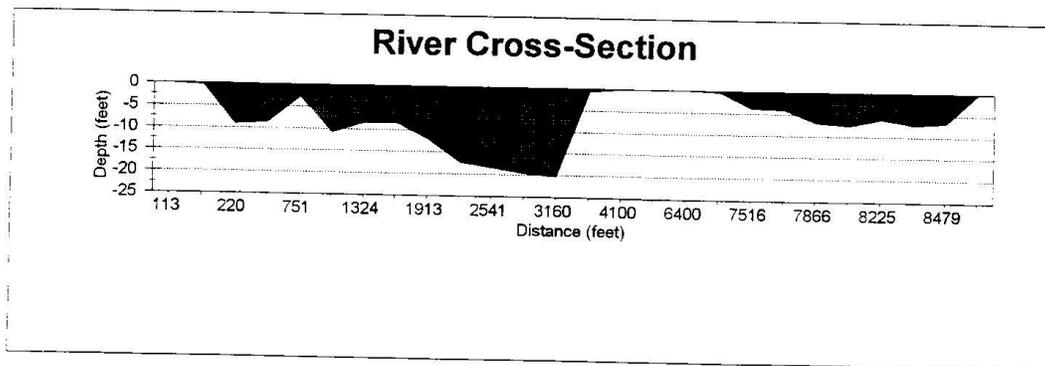
Project: **Muskogee** Site: **SR-14**

Elevation	Distance	Depth	
487.0	113	0.0	0.00
486.6	114	-0.4	-0.00
477.9	220	-9.1	-0.15
478.4	417	-8.6	-0.27
484.2	751	-2.8	-0.15
476.2	973	-10.8	-0.38
478.5	1324	-8.5	-0.48
478.5	1565	-8.5	-0.33
475.0	1913	-12.0	-0.67
469.7	2162	-17.3	-0.69
468.5	2541	-18.5	-1.12
467.3	2787	-19.7	-0.78
466.7	3160	-20.3	-1.21
486.3	3378	-0.7	-0.02
487.0	4100	0.0	0.00
487.0	4900	0.0	0.00
487.0	6400	0.0	0.00
486.7	7388	-0.3	-0.05
483.1	7516	-3.9	-0.08
482.9	7653	-4.1	-0.09
479.9	7866	-7.1	-0.24
479.4	8017	-7.6	-0.18
481.0	8225	-6.0	-0.20
479.7	8312	-7.3	-0.10
480.2	8479	-6.8	-0.18
487.0	8537	0.0	0.00

	Elevation	Distance
1	480.2	8479
2	490	8563
	0.306122	8537.286

Average Depth 7.40 Cross-Sectional Area 45290

Side Slope = 0.002 Velocity = 0.050



Project: **Muskogee** Site: **SR-12**

Elevation	Distance	Depth		
487.0	264	0.0	0.00	
475.5	317	-11.5	-0.40	
459.3	369	-27.7	-0.94	
458.6	422	-28.4	-0.98	
458.2	447	-28.8	-0.47	
458.3	488	-28.7	-0.77	
457.6	525	-29.4	-0.71	
456.9	598	-30.1	-1.43	
457.3	645	-29.7	-0.91	
457.0	771	-30.0	-2.46	
457.5	844	-29.5	-1.40	
457.8	884	-29.2	-0.76	
458.3	955	-28.7	-1.33	
458.6	1003	-28.4	-0.89	
459.8	1083	-27.2	-1.42	
460.4	1126	-26.6	-0.74	
461.9	1225	-25.1	-1.62	
463.6	1264	-23.4	-0.59	
470.6	1382	-16.4	-1.26	
475.0	1451	-12.0	-0.54	
476.9	1502	-10.1	-0.34	
480.0	1576	-7.0	-0.34	
481.0	1626	-6.0	-0.20	
485.0	1712	-2.0	-0.11	
485.4	1751	-1.6	-0.04	
487.0	1801	0.0	0.00	
		Average Depth	20.61	Cross-Sectional Area 31683
		Side Slope =	0.023	Velocity = 0.071

	Elevation	Distance
1	490	1896
2	485.4	1751
		0.347826 1801.435

