Tulsa Port of Inola Wasteload Allocation Study

Tulsa Ports

Tulsa Port of Inola Industrial Park
Project No. 134600

Revision F
11/16/2023

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prepared for

Tulsa Ports
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Inola, Oklahoma

Project No. 134600

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prepared by

Burns & McDonnell Engineering Company, Inc.
Oklahoma City, Oklahoma

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LIST OF ABBREVIATIONS

Abbreviation	**Term/Phrase/Name**
°C	degrees Celsius
7Q2	seven-day, two-year low flow
7T2	Seven-day, two-year high temperature
BUMP	Beneficial Use Monitoring Program
Burns & McDonnell	Burns & McDonnell Engineering Company, Inc.
CFR	Code of Federal Regulations
cfs	cubic feet per second
CBOD5	Carbonaceous BOD – 5 Day
CBOD20	Carbonaceous BOD – 20 Day
CaCO3	Calcium Carbonate
CDT	Central Daylight Time
CFU	colony forming units
CTOO2	USACE Verdigris River near Catoosa, OK stream gage
CWA	Clean Water Act
CWT	Centralized Waste Treatment
DEM	digital elevation maps
DMR	discharge monitoring report
DOC	Dissolved Organic Carbon
DO	Dissolved Oxygen
ft	feet
gpcd	gallons per capita per day

Abbreviation	**Term/Phrase/Name**
GPD	gallons per day
INCOG	Indian Nation Council of Governments
INLO2	USACE Newt Graham Lock and Dam 18 stream gage
km	Kilometers
METAR	meteorological aerodrome reports
MGD	million gallons per day
mg/L	milligrams per liter
MPN	most probable number
MoS	Margin of Safety
NAVD88	North American Vertical Datum of 1988
NH3	Ammonia
NPS	non-point sources
NO3	Nitrate
NO2	Nitrite
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
OAC	Oklahoma Administrative Code
ODEQ	Oklahoma Department of Environmental Quality
OOWA	Oklahoma Ordinance Works Authority
Ortho-P	Orthophosphorus
OWRB	Oklahoma Water Resources Board
Port of Inola	Tulsa Port of Inola Industrial Park

Abbreviation	**Term/Phrase/Name**
POTW	publicly owned treatment works
SFE	Single Family Equivalents
TBELs	Technology Based Effluent Limits
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
Town	Town of Inola
TP	Total Phosphorus
TSS	Total Suspended Solids
Tulsa Ports	City of Tulsa-Rogers County Port Authority
umhos/cm	micromhos per centimeter
US-412	US Highway 412
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VS	Volatile Solids
WLA	wasteload allocation
WQS	water quality standards
WSE	water surface elevation
WWAC	warm water aquatic community
WWTP	wastewater treatment plant
YOY	year over year

1.0 PROJECT OVERVIEW

The purpose of this project was to perform a Wasteload Allocation (WLA) study for the Town of Inola (Town) and the Tulsa Ports for the future Tulsa Port of Inola Industrial Park (Port of Inola). Burns & McDonnell Engineering Company, Inc. (Burns & McDonnell) was retained by the City of Tulsa-Rogers County Port Authority (Tulsa Ports) to develop the WLA for the Port of Inola and expansion of the Town's Wastewater Treatment Plant (WWTP). Burns & McDonnell subcontracted the field sampling and laboratory testing to Green Country Testing and subcontracted the QUAL2K modeling to Carollo Engineers. The work plan describing the proposed process was approved by the Oklahoma Department of Environmental Quality (ODEQ) and is provided in Appendix A.

1.1 Purpose and Background

This document provides a summary report of the field activities and WLA study for the Port of Inola proposed industrial park development consisting of a variety of industries that encompass manufacturing, industrial, and warehousing operations. The proposed industrial park site includes approximately 2,400 acres of undeveloped land located southwest of the intersection of E 620 Road and S 4200 Road located adjacent to the Verdigris River, Oklahoma's corporate boundary. In addition to the 2,400 acres of land that has already been acquired for the Port of Inola, Tulsa Ports is also in the process to purchase an additional 1,200 acres of land adjacent to the current site for additional development. The proposed development includes the design and construction of wastewater treatment plants designed to separately treat the industrial and domestic wastewaters generated at the industrial park by tenants and port facilities. Additionally, the Port of Inola may partner with the Town to treat and discharge both The Port of Inola wastewaters and the Town's domestic wastewaters. Town's National Pollutant Discharge Elimination System (NPDES) permit OK0033618 includes an established permitted wasteload allocation, which would be combined with the approved allocations that result from this study.

1.2 Proposed Discharge

Three discharge options were initially proposed in the Wasteload Allocation Work Plan (Work Plan) that was approved by ODEQ on March 1, 2022. Each of the three proposed discharge options was modeled and assessed to determine the best discharge scenario for the future development of the Port of Inola. Discharge Option 2 from the Work Plan was ultimately selected. However, the proposed discharge point has been relocated to approximately 2,000 feet upstream of the original Discharge Option 2 (36.094401°, -95.555803°) to just north of the southernmost point of the Port of Inola's property. The revised proposed outfall location has been modeled and assessed for the combined industrial and domestic wastewaters from the Port of Inola and the Town. The Port of Inola's combined wastewater flows for the initial discharge would be 3.45 MGD and based on the 20-year population projections for the Town and the Port of Inola operating at full capacity, the final design flow from the Port of Inola would be 18.72 MGD, see Table 1-1. The combined treated effluent would be piped approximately one and a half (1.5) miles south of the Port of Inola and discharged to the Verdigris River (36.097717°, -95.558592°). The individual wastewater sources are discussed below in Sections 1.2.1 and 1.2.2. Figure 1-1 presents the proposed outfall locations assessed in this study.

Table 1-1: Discharge Flow Projections

Flow Component	Initial Phase Flows (MGD)	Final Phase Flows (MGD)
Industrial Wastewater	**2.6**	**17.6**
Non-Cooling Water Flows	*2.6*	*6.6*
Cooling Water	*NA*	*11*
Domestic Wastewater	**0.85**	**1.12**
Industrial Area Employees	*0.05*	*0.32*
Town of Inola	*0.8*	*0.8*
Total Wastewater Projection	**3.45**	**18.72**

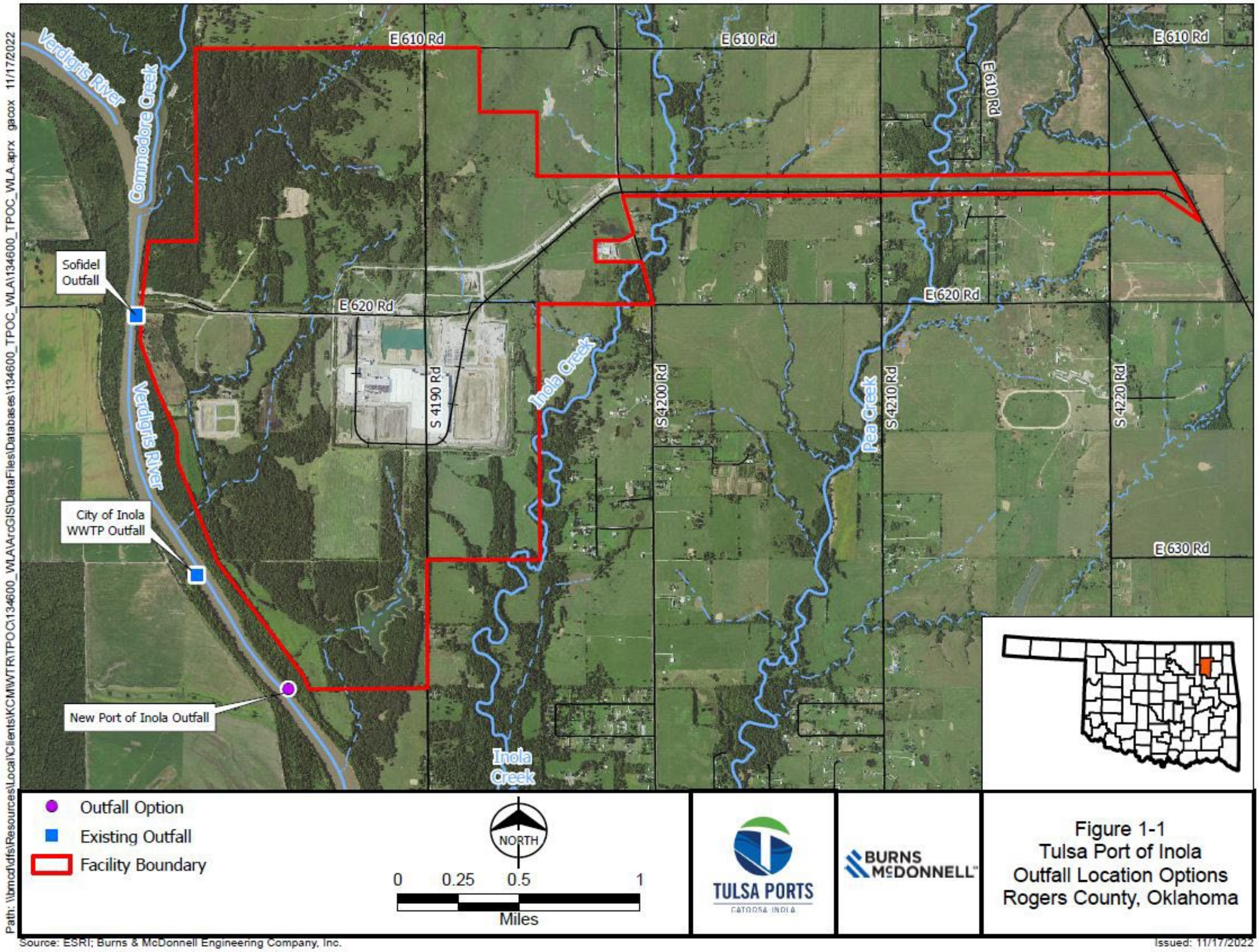

Figure 1-1: Potential Outfall Option Locations

1.2.1 Port of Inola Wastewaters

Based on current site development discussions, the Port of Inola is expecting approximately 0.85 MGD of combined domestic wastewater from the Port of Inola and Town and 2.6 MGD of industrial wastewaters in the initial phase of the industrial park development. The final phase is projecting, and 1.12 MGD, 6.6 MGD, and 11.1 MGD of domestic, industrial, and cooling, respectively, wastewater (total) to be produced once the industrial park is fully developed. This would result in a total design discharge of 3.45 MGD for the initial phase of the industrial park and 18.72 MGD for the final phase of the industrial park. Table 1-1 summarizes the flows for these phases.

1.2.1.1 Industrial Wastewaters

While at the onset of developing this report the Tulsa Port of Inola had not yet secured an industrial tenant, it now has development commitment from Enel North America's 3Sun USA Solar Panel Manufacturing Facility. This project will help define the character and composition of the industrial wastewaters. In addition, the following list of target industries serves as a general guide for the types of future wastewaters that may be produced and treated at the wastewater treatment plant. However, the following list of target industries serves as a general guide for the types of industrial wastewaters that may be produced and treated at the wastewater treatment plant:

- Plastic, resin, and composite manufacturing
- Nonferrous metal rolling and alloying
- Iron and steel manufacturing
- Solar panel component manufacturing & assembly
- Semiconductor manufacturing
- Battery & battery component manufacturing
- Electric vehicle component manufacturing & assembly
- Advanced aerial vehicle manufacturing & assembly

There have been over 40 individual entities who have submitted inquiries to locate future projects at the Port of Inola. These prospective clients have varying industrial wastewater flows that range from 625 gallons per day up to 6.0 MGD, see Table 1-2 below. Using the wastewater and acreage requirements provided by interested projects, the average project would require approximately 265 acres and discharge approximately 0.91 MGD of industrial wastewater. Based on this average, the Port of Inola could host approximately nine projects on the 2,400-acre site. If each facility were to produce the average wastewater requirement, then the Port of Inola would produce approximately 8.2 MGD for discharge or disposal. The QUAL2K modeling has demonstrated that the Verdigris River does not have the available capacity for the combined domestic flows from the Town and the Port of Inola in addition to the 8.19 MGD of industrial wastewater. This WLA Report is only seeking 6.6 MGD of industrial wastewater plus 11 MGD for cooling waters for the final buildout of 17.6 MGD, see Section 1.2.1.2. for cooling water discussions.

Table 1-2: Prospective Dischargers for Port of Inola

Project Name	Industry Type	Acreage	New Jobs	Wastewater Requirement (MGD)
35	General Manufacturing	25	300	0.73
910	Paper Manufacturing	250	800	3.2
Boojum/Anthem	Software/IT	200	150	0.036
Boomer	Lithium-ion Battery Recycling	20	150	Not Provided
Braveheart	Automotive	200	3,000	Not Provided
Bronze	Energy	100	800	0.1
BRT	Battery Recycling	75	435	2.5
Bugatti	General Manufacturing	10	100	Not Provided
Calgary 1,2,3	General Manufacturing	Not Provided	75	0.1
Connect	Automotive	1,550	20,000	1.1
Epsilon	Automotive	500	3,500	1.5
Galahad	Energy	25	777	0.172
Galaxy	Aerospace	400	200	0.026
GO	Automotive	80	1,600	Not Provided
Gold	Energy	Not Provided	982	0.1
Groot	Automotive	300	1,000	TBD
Heart	Battery-grad Lithium	50	1,000	0.154
Hickory	Automotive	500	Unknown	0.6
Hornet	General Manufacturing	75	50	0.009
Illuminate	Automotive	300	1,123	0.017
Iron	General Manufacturing	100	200	1.0
Iron Eagle	Automotive	35	200	Not Provided
Lucille	Battery Manufacturing	100	650	0.0075
Maple	General Manufacturing	400	1,500	1.0
Nora	General Manufacturing	2,000	1,000	1.0
Ocean	Automotive	400	8,000	0.5
Osbourne	General Manufacturing	120	300	0.07
Pearl	General Manufacturing	250	731	0.25

Project Name	Industry Type	Acreage	New Jobs	Wastewater Requirement (MGD)
Phoenix	Metal Manufacturing	260	1,000	0.082
Quartz	Automotive	25	600	0.000625
Raptor	General Manufacturing	40	115	2.0
Rock	Energy	50	200	0.12
Scout 2022	Energy	45	300	0.01
Sea Salt	Automotive	Not Provided	1,000	Not Provided
Singularity B	General Manufacturing	50	500	Not Provided
Sirius	Energy	400	1,800	2.58
Spark2	General Manufacturing	100	200	TBD
Spoonman	General Manufacturing	15	300	0.25
Sunlight	Energy	25	500	0.1
Talon	Energy	200	1,200	6.0
Thunderball	Battery Manufacturing	1,000	4,000	0.1
Titanium	Energy	76.4	500	4.1
Torus	High-Tech Manufacturing	420	1,400	0.535
Vegas	Semi-Conductor	60	3,500	2.0
Wildflower	Automotive	300	2,300	0.6
Total		**11,131**	**68,038**	**32.65**
Average		**265**	**1,546**	**0.91**

As previously mentioned, the Port of Inola currently has one customer, Enel North America/3Sun USA (Enel/3Sun USA), who is signed to locate its first solar panel production facility in United States at this site. Enel/3Sun USA will produce approximately 1.97 MGD of industrial wastewater from its solar panel manufacturing for discharge to the WWTP. A second entity is committed to locate at the Port of Inola and would need to discharge approximately 0.1 MGD of industrial wastewaters to the WWTP. These two entities would equal approximately 2.1 MGD of industrial wastewater for treatment and discharge by the Port of Inola. Additionally, a supplier for Enel/3Sun has determined that the Port of Inola is one of two sites included in their final round of site selection. For this reason, an additional 0.4 MGD has been included in the initial design phase to account for future developments prior to the final phase implementation.

1.2.1.2 Cooling Waters

Many of the potential clients that have submitted inquiries to locate at the Port of Inola will produce cooling waters in addition to their other industrial wastewaters. The information provided to Tulsa Ports from these prospective clients does not break down the individual wastewater types, which would allow for a more accurate reflection of potential cooling water needs. However, it is well established that some of the industry types, such as the Energy sector (including battery manufacturing), that have interest in locating at the Port of Inola have large cooling water needs. The total wastewater needs from the Energy sector listed in Table 1-2 is approximately 9.3 MGD, and it is assumed that the majority of these wastewaters are cooling waters. Because the risk of under estimating cooling water needs would be detrimental to the future development and business prospects for the Port of Inola, a 20% margin of safety was added to account for the uncertainty of future cooling water needs which resulted in the 11 MGD request for cooling waters. Since cooling waters have a low biological oxygen demand, discussed in the paragraphs below, they pose less risk to the dissolved oxygen levels of the Verdigris River than the industrial and domestic wastewaters proposed for discharge from the Port of Inola WWTP.

Source water for industrial cooling will be the Verdigris River upstream of the proposed outfall. Section 316(b) of the Clean Water Act (CWA) requires power plants and other businesses that intake more than 2 MGD to utilize cooling technology that minimizes adverse impacts to local marine life. Facilities located at the Port of Inola will need to utilize closed-cycle recirculating cooling water systems in order to comply with requirements found in 40 CFR §125, Subpart I, Requirements Applicable to Cooling Water Intake Structures for New Facilities under Section 316(b) of the Act. Cooling waters from closed-loop systems are treated with biocides and other additives to prevent fouling of the cooling systems from biological growth. Cooling waters have a low biological oxygen demand from the use of biocides and additives used for antifouling within cooling units. It is anticipated that the customers of the park will utilize biocides and other additives in their cooling units for this same reason. Therefore, the expected cooling water influence from the customers will have low biological oxygen demand as will the cooling water effluent discharged by the Port of Inola WWTP. These cooling waters will be discharged back to the river at the same outfall that discharges the domestic and other industrial wastewaters.

Due to large volume of cooling waters proposed for discharge and their low biological oxygen demand, these wastewaters can produce a dilution effect in the QUAL2K model which artificially inflates the available capacity of the receiving water body for biological oxygen demanding constituents. For this reason, cooling waters were not included in the QUAL2K modeling to determine the available capacity of the Verdigris River. However, it is expected that the cooling water discharges will have some level of suspended solids. Therefore, it is requested that the cooling waters be given a TSS waste load allocation.

1.2.1.3 Port of Inola Domestic Wastewaters

The domestic wastewater flows from the park have been revised to reflect the anticipated number of employees that will be onsite per day based on the average acreage and employee requirements provided by the prospective clients as shown in Table 1-2. The average project requires around 265 acres of land and will create approximately 1,550 jobs. The current 2,400 acres that have been acquired for the Port of Inola development could host nine projects based on the average acreage requirements for each project resulting in final employee count of approximately 14,000 employees onsite per day. In addition to the 2,400 acres that the Port of Inola currently has for the site buildout, the Tulsa Port is also in the process of acquiring an additional 1,200 acres to be developed once the original area has been allocated. Using the same average acre and employee requirement, this new area could host an additional 4.3 projects and approximately 7,000 new employees. Based on these averages, the Port of Inola is anticipating over 21,000 employees on site per day for the final buildout.

The *Typical wastewater flowrates from commercial sources in the United States: Table 3-3* in the Fifth Edition of Wastewater Engineering Treatment and Resource Recovery by Metcalf and Eddy was used to estimate the total domestic wastewater generated. The value used was the typical flowrate for industrial buildings, published in the same source material at 15 gallons per person a day resulting in approximately 0.21 MGD of domestic wastewater produced each day for the current Port of Inola current area, plus over 0.10 MGD for the additional land that is set to be acquired. The final facility buildout is expected to produce approximately 0.32 MGD of domestic wastewater from employees at the Port of Inola.

Table 1-3: Port of Inola Domestic Wastewater

	No. of Facilities Based on Area Requirements	Total Employees	Domestic Wastewater (gal/shift)
Current Port of Inola Property, 2,400 acres	9	13,914	208,710
Future Port of Inola Property, 1,200 acres	4.5	6,957	104,355
Total	**13.5**	**20,871**	**313,065**

The initial phase domestic wastewater needs for the Port of Inola is based on the anticipated number of employees for the three entities that have either committed to locate at the site or are anticipated to commit. These groups include the 1,900 employees for Enel/3Sun USA, 1,500 employees for the Enel/3Sun USA supplier, and 200 employees for the other entity who has committed to locate at the site. These three entities would have approximately 3,600 employees at the Port of Inola for the initial phase and would produce approximately 50,000 gallons of domestic wastewater daily.

1.2.2 Town of Inola Wastewaters

Port of Inola and the Town have agreed to combine the treatment and discharge of the domestic wastewater for the Town's Wastewater Treatment Plant (WWTP) in combination with the Port of Inola wastewaters. The Town's NPDES permit OK0033618 is based on a flow of 0.40 MGD. In a signed Resolution of the Board of Trustee of the Town of Inola and the Port of Inola proposes to combine the WLA that is currently included in the Town's WWTP NPDES permit OK0033618 in addition to the available loadings identified herein. The Town's WWTP currently operates as a Publicly Owned Treatment Works (POTW) but does not treat wastewater from industrial dischargers.

In the initial WLA Report submitted to ODEQ on April 11, 2022, Burns & McDonnell had projected the 20-year population for the Town of Inola at 2,040 people based on a 1.5% year over year (yoy) increase. However, it is anticipated that the development of Port of Inola will increase both local residential and commercial development, resulting in a population growth greater than the 1.5% yoy historical trend. Oklahoma Department of Transportation (ODOT) has funding for the conversion of a 27-mile section of US Highway 412 (US-412) immediately north of the Town of Inola into an interstate highway. The Town is anticipating 40-acres of additional commercial development and 390-acres of residential development over the next 20 years to accommodate the population growth from both the Port of Inola and the conversion of US-412 to an interstate highway. Therefore, the current population growth seen in the Town over the last 20-years is not expected to be representative of the future population growth.

Burns & McDonnell estimated the 20-year population growth for the Town using the Town of Pryor Creek, Oklahoma as a proxy. Pryor Creek, Oklahoma is located approximately 22 miles away and adjacent to the current MidAmerica Industrial Park, formerly the Oklahoma Ordinance Works Authority (OOWA). The OOWA was constructed in the 1940's and sold to create the MidAmerica Industrial Park in 1960. Based on United States Census Bureau data, Pryor Creek had an accelerated population growth of 6% yoy from 1940-1950 and 3.7% yoy growth from 1950 to 1960, resulting in an overall 5.0% yoy growth for this 20 year period of time, see in Table 1-4. During this same time, Oklahoma experienced a population growth of 0.024% yoy from 1940-1960. To account for the accelerated population growth that is expected by the Town for the next 20-years, the Pryor Creek population growth percent of 5% yoy from 1940 to 1960 was used in calculating population growth for the Town of Inola.

Table 1-4: Pryor Creek's Population Growth, 1920 to 1990

Year	Population	Annual Growth Rate from Previous Census
1920	1,767	-0.17%
1930	1,828	0.34%
1940	2,501	3.2%
1950	4,486	6.0%
1960	6,476	3.7%
1970	7,057	0.86%
1980	8,483	1.9%
1990	8,374	-0.13%

Table 1-5: Pryor Creek's Year Over Year Population Growth, 1940 to 1960

Year	Population Increase, 1940-1960	Percent Population Increase, 1940-1960	YOY Population Increase, 1940-1960
Pryor Creek	3,975	159%	5.0%
Oklahoma	11,000	0.47%	0.024%

In 2020, the Town had a population of 1,797 people with an average household of 2.6 individuals, based U.S Census Bureau's report. The fact sheet of the existing permit, effective December 2019, cites the current design daily average flow of the Inola WWTP is 0.4 MGD. The Discharge Monitoring Reports (DMR) data from EPA's ECHO database, show that between 2019 to 2020, the Town's WWTP discharged an average monthly average of 0.351 MGD and a maximum daily maximum of 0.498 MGD, indicating the plant is currently at capacity, and additional capacity is needed.

In 2022, the Town's WWTP currently serves 769 single family equivalents (SFE). Using the 5% yoy growth rate from Pryor Creek, in 2042 the Town will have approximately 2040 SFEs, and a population of 5,305 people, contribute an additional 0.4 MGD of new domestic flows to the WWTP (Table 1-6). This results 0.8 MGD total domestic wastewater capacity required for the Town.

Table 1-6: Town of Inola 20-Year Projection

Year	SFE	Population	Population Increase	New Residential Flow	Total Residential Flow
				MGD	MGD
2022	769	1999	202	0.02	0.4
2023	807	2099	302	0.03	0.4
2024	848	2204	407	0.04	0.4
2025	890	2315	518	0.05	0.5
2026	935	2430	633	0.06	0.5
2027	981	2552	755	0.08	0.5
2028	1031	2679	882	0.09	0.5
2029	1082	2813	1016	0.1	0.5
2030	1136	2954	1157	0.1	0.5
2031	1193	3102	1305	0.1	0.5
2032	1253	3257	1460	0.1	0.5
2033	1315	3420	1623	0.2	0.6
2034	1381	3591	1794	0.2	0.6
2035	1450	3770	1973	0.2	0.6
2036	1523	3959	2162	0.2	0.6
2037	1599	4157	2360	0.2	0.6
2038	1679	4364	2567	0.3	0.7
2039	1763	4583	2786	0.3	0.7
2040	1851	4812	3015	0.3	0.7
2041	1943	5052	3255	0.3	0.7
2042	2040	5305	3508	0.4	0.8

1.3 Receiving Water

The minimum dissolved oxygen (DO) concentrations are dependent upon the designated use for the river as specified in the Oklahoma Water Quality Standards (Oklahoma Administrative Code Title 252, Chapter 730) as published and updated by the ODEQ. Per the current Water Quality Standards, this reach of the Verdigris River, identified as stream segment 121500020120, is designated as a Warm Water Aquatic Community (WWAC), which governs the minimum allowable concentrations of DO during the spring (April 1st through June 15th) at 6.0 mg/L and 5.0 mg/L the rest of the year. To meet this criterion, less than 10 percent of the sample results can fall below 6.0 mg/L April 1st through June 15th, or 5.0 mg/L the remainder of the year.

To confirm that the minimum DO concentrations are maintained during these time periods, water quality modeling was performed to simulate DO concentrations in the Verdigris River during the critical periods of the year (i.e., high temperature, low flow). The ODEQ provided a QUAL2K model developed and calibrated for a previous study (Sofidel, 2017) conducted on the same reach of the river, and the project team adjusted model parameters and updated the calibration data based on the field data collected by the project team in September 2021. The laboratory collected samples from seven locations along approximately 30,000 feet of the Verdigris River for one sampling period. At each location, four replicate samples were collected, totaling twenty-eight samples for analyses, see Figure 1-2.

The WLA was determined from the model. WLA limits were then generated from the WLA after a Margin of Safety was applied to the WLA.

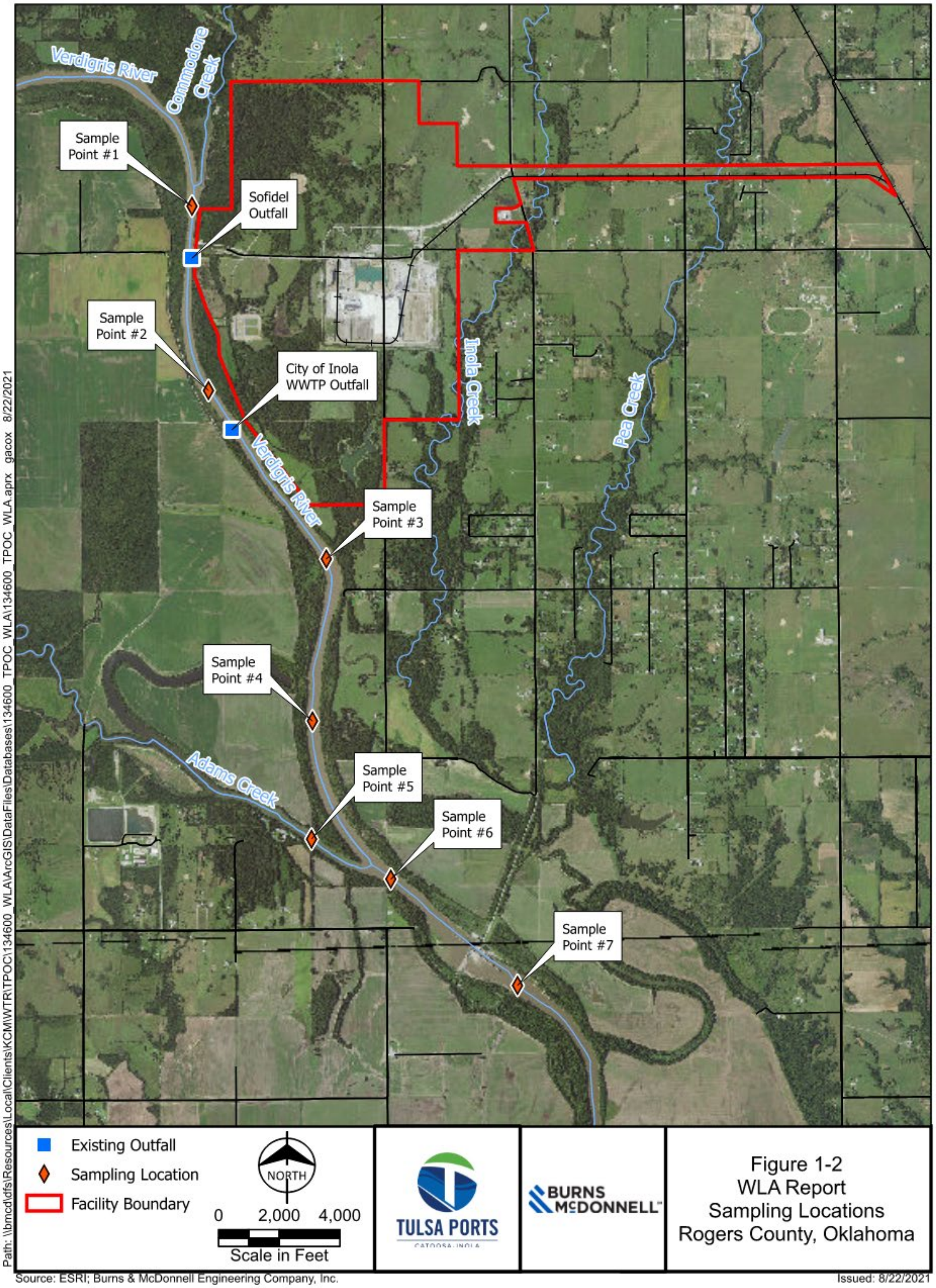

Figure 1-2: Sampling Locations

2.0 DATA COLLECTION

The QUAL2K model required information about the local hydraulics and hydrology, water quality, and meteorology. This information was important to develop and calibrate the model by comparing it to measured data discussed herein. For this model, various physical parameters were obtained from site-specific sampling and supplemented with publicly available hydraulic and meteorological data.

2.1 Water Quality Sampling

The geographical extent of the sampling locations, Figure 1-2, was the same as the geographical extent of the model. The sampling locations included six sampling points along the Verdigris River that start approximately 1,500 feet upstream of the Sofidel outfall and 11,000 feet upstream of the Town's WWTP outfall to approximately 20,000 feet downstream of the proposed new outfall location. A sampling location was included on Adams Creek approximately 2,000 feet upstream of where Adams Creek enters the Verdigris River. Four grab samples (A to D) and field measurements were collected at each location for a total of 28 samples over the seven locations. Sample locations are described in Table 2-1.

Table 2-1: Sample Locations

Site ID	Type of Sample	Site Description	Latitude, Longitude
1	Grab Samples and Field Measurements	~1,600 feet upstream of Sofidel Outfall	36.122796°, -95.569749°
2		Downstream of Sofidel Outfall Mixing Zone	36.106986°, -95.567904°
3		~1,600 feet downstream of the proposed New Outfall	36.092498°, -95.554101°
4		~7,200 feet Downstream of Proposed New Outfall	36.078611°, -95.555819°
5		~2,000 feet Upstream of Confluence of Adams Creek and Verdigris River (on Adams Creek)	36.068478°, -95.555994°
6		~1,000 feet Downstream of Confluence	36.065021°, -95.546668°
7		~ 1 mile Downstream of Confluence, Downstream of USACE Newt Graham Lock and Dam 18	36.055845°, -95.531802°

The samples were collected on August 31, 2021 and September 1, 2021, which had a high temperature of 93 °F with a 2% chance of precipitation, Figure 2-1. The National Oceanic and Atmospheric Administration (NOAA) Claremore Regional Airport Weather Station was used to project field mobilization timeframes for sampling efforts. These conditions resembled the critical summertime conditions for high water temperature and low flow that is likely to occur in one out of every two years (7T2 and 7Q2, respectively), which was preferred for calibrating the water quality model.

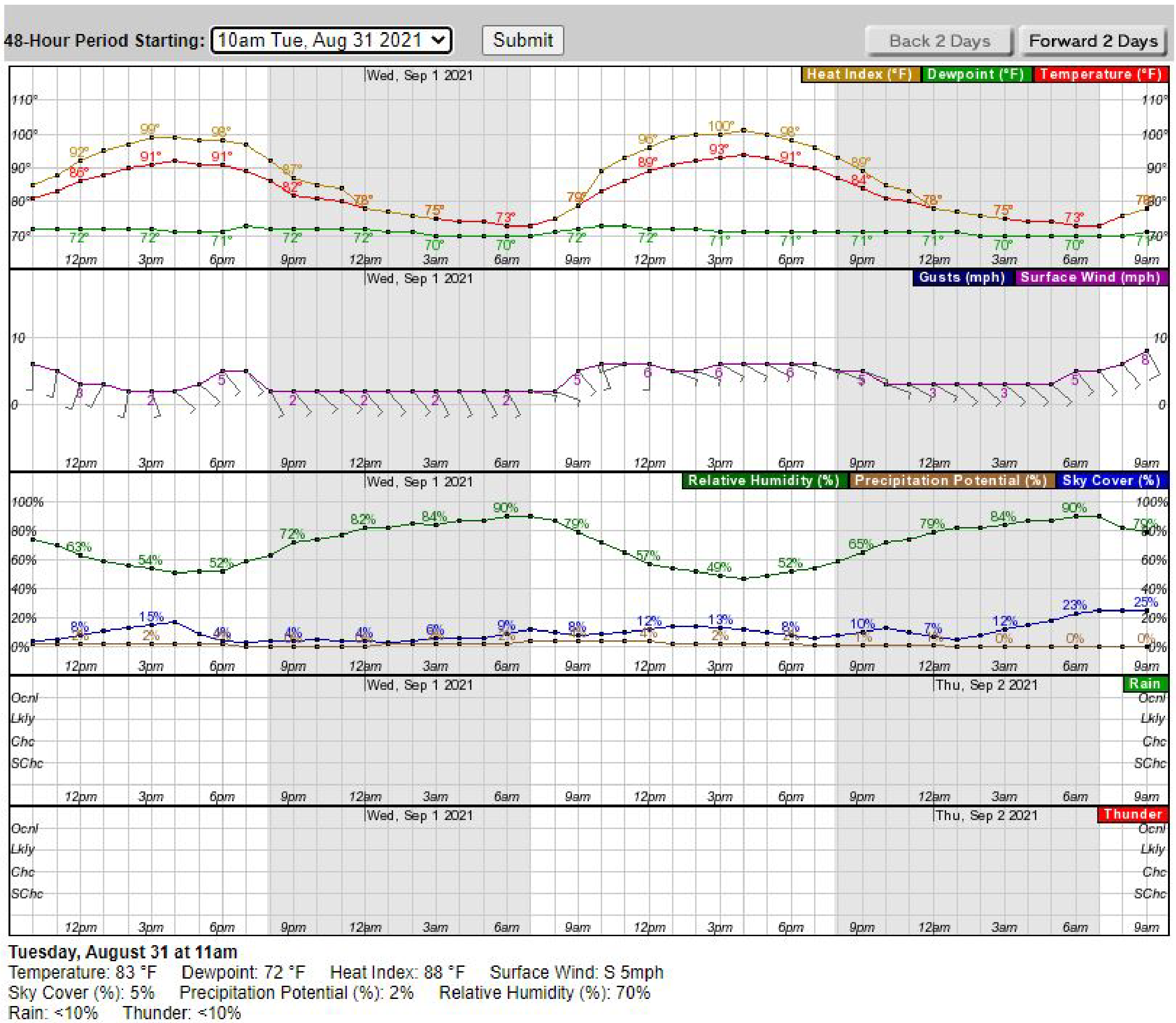

Figure 2-1: NOAA Claremore Regional Airport Weather Forecast, August 31, 2021

Field work was performed in adherence to the Green Country Testing Quality Assurance Manual. Water grab samples were collected via boat at the locations detailed in Table 2-1 and field measurements were recorded. No composite samples were collected. No hydraulic or channel measurements were obtained because of the maintained, controlled nature of this reach and flow data available through the United States Army Corps of Engineers (USACE). The analytes evaluated for each sample are provided in Table 2-2. Grab sample results are listed in Table 2-3 through Table 2-9 for Sample Locations 1 through 7, respectively. Laboratory reports are provided in Appendix B. The Quality Control Summary Reports were prepared by Green Country Testing for the grab samples are also provided in Appendix B.

Table 2-2: Water Quality Sampling Analyses

Analyte	Description	Units	Reporting Limit
$CBOD_5$ Soluble	Soluble Carbonaceous BOD – 5 Day	milligrams per liter (mg/L)	1.0
$CBOD_5$	Carbonaceous BOD – 5 Day	mg/L	1.0
$CBOD_{20}$ Soluble	Soluble Carbonaceous BOD – 20 Day	mg/L	1.0
$CBOD_{20}$	Carbonaceous BOD – 20 Day	mg/L	1.0
BOD_{20}	BOD – 20 Day	mg/L	1.0
TKN	Total Kjeldahl Nitrogen in Water	mg/L	0.5
NH_3	Ammonia as Nitrogen in Water	mg/L	0.1
NO_3	Nitrate as Nitrogen in Water	mg/L	0.4
NO_2	Nitrite as Nitrogen in Water	mg/L	0.4
TP	Total Phosphorus	mg/L	0.05
Ortho-P	Orthophosphorus	mg/L	0.05
Enterococci	*Enterococci* Bacteria	Colony Forming Units (CFU)/100 mL	Varies with Dilution
E. Coli	*E. Coli* Bacteria	Most Probable Number (MPN)/100 mL	
Chlorophyll-a	Chlorophyll a	mg/m^3	0.1
TSS	Total Suspended Solids	mg/L	5
VS	Volatile Solids	mg/L	6
TOC	Total Organic Carbon	mg/L	3.0
DOC	Dissolved Organic Carbon	mg/L	3.0
Alkalinity	Alkalinity as $CaCO_3$	mg/L as Calcium Carbonate ($CaCO_3$)	2.5
Temperature	Water Temperature	Degrees Celsius (°C)	-
pH	Water pH	Standard Units	-
DO	Dissolved Oxygen in Water	mg/L	0.1
Conductivity	Specific Conductivity in Water	micromhos per centimeter (umhos/cm)	1.0

Table 2-3: Sampling Point 1 Grab Sample Results

Analyte	1A	1B	1C	1D
Date and Time (CDT)	08/31/2021 0915	08/31/2021 0946	8/31/2021 1006	8/31/2021 1026
$CBOD_5$ Soluble – mg/L	1.0	< 1	< 1.0	< 1.0
$CBOD_5$ – mg/L	1.0	< 1	< 1.0	< 1.0
$CBOD_{20}$ Soluble – mg/L	2.0	8	2	2
$CBOD_{20}$ – mg/L	5.0	4	< 1.0	4
BOD_{20} – mg/L	13	9	8	8
TKN – mg/L	1.01	0.778	0.715	0.75
NH_3 – mg/L	< 0.10	< 0.1	< 0.1	< 0.1
NO_3 – mg/L	< 0.40	< 0.4	< 0.4	< 0.4
NO_2 – mg/L	< 0.40	< 0.4	< 0.4	< 0.4
TP– mg/L	0.162	0.117	0.137	0.124
Ortho-P– mg/L	0.12	0.105	0.122	0.108
Enterococci – CFU/100 mL	11	10.8	4.1	5.2
E. Coli – MPN/100 mL	< 2.00	< 2.0	< 2.0	2
Chlorophyll-a – mg/m^3	7.38	8.44	8.33	7.48
TSS – mg/L	9	9	13	5
VS – mg/L	163	87	52	75
TOC – mg/L	7.9	10.1	9.7	9.9
DOC – mg/L	10.2	9.4	9.1	10.4
Alkalinity – mg/L as $CaCO_3$	99	100	99	98
Temperature - °C	29.9	29.8	29.9	30.0
pH - Standard Units	7.72	7.78	7.80	7.82
DO – mg/L	6.2	6.4	6.3	6.3
Conductivity - umhos/cm	367	344	336	325

Table 2-4: Sampling Point 2 Grab Sample Results

Analyte	2A	2B	2C	2D
Date and Time (CDT)	8/31/2021 0927	8/31/2021 0952	8/31/2021 1012	8/31/2021 1055
$CBOD_5$ Soluble – mg/L	< 1.0	< 1.0	< 1.0	< 1.0
$CBOD_5$ – mg/L	< 1.0	< 1.0	1	1
$CBOD_{20}$ Soluble – mg/L	8	2	2	8
$CBOD_{20}$ – mg/L	1	< 1.0	3	1
BOD_{20} – mg/L	7	8	9	8
TKN – mg/L	0.61	0.722	0.533	0.643
NH_3 – mg/L	< 0.1	< 0.1	< 0.1	< 0.1
NO_3 – mg/L	< 0.4	< 0.4	< 0.4	< 0.4
NO_2 – mg/L	< 0.4	< 0.4	< 0.4	< 0.4
TP– mg/L	0.141	0.125	0.148	0.109
Ortho-P– mg/L	0.128	0.109	0.121	0.108
Enterococci – CFU/100 mL	6.3	5.2	7.2	14.2
E. Coli – MPN/100 mL	< 2.0	< 2.0	2	4
Chlorophyll-a – mg/m^3	10.7	10.7	13.1	11.8
TSS – mg/L	7	< 5	8	< 5
VS – mg/L	24	98	39	87
TOC – mg/L	9.7	8.9	11.2	11.7
DOC – mg/L	9.1	9.2	9	10
Alkalinity – mg/L as $CaCO_3$	98	100	99	99
Temperature - °C	30.0	30.2	30.4	30.6
pH - Standard Units	7.77	7.70	7.80	7.82
DO – mg/L	6.1	6.3	6.3	6.7
Conductivity - umhos/cm	346	345	338	330

Table 2-5: Sampling Point 3 Grab Sample Results

Analyte	3A	3B	3C	3D
Date and Time (CDT)	8/31/2021 0931	8/31/2021 0959	8/31/2021 1017	8/31/2021 1110
$CBOD_5$ Soluble – mg/L	< 1.0	< 1.0	< 1.0	< 1.0
$CBOD_5$ – mg/L	1	< 1.0	1	< 1.0
$CBOD_{20}$ Soluble – mg/L	8	2	2	8
$CBOD_{20}$ – mg/L	1	3	1	4
BOD_{20} – mg/L	8	8	8	7
TKN – mg/L	0.63	< 0.5	0.522	< 0.5
NH_3 – mg/L	< 0.1	< 0.1	< 0.1	< 0.1
NO_3 – mg/L	< 0.4	< 0.4	< 0.4	< 0.4
NO_2 – mg/L	< 0.4	< 0.4	< 0.4	< 0.4
TP– mg/L	0.131	0.103	0.126	0.106
Ortho-P– mg/L	0.132	0.113	0.125	0.101
Enterococci – CFU/100 mL	12.2	2	8.5	4.1
E. Coli – MPN/100 mL	2	2	4	< 2.0
Chlorophyll-a – mg/m^3	12.7	12.5	11.2	8.44
TSS – mg/L	6	< 5	7	7
VS – mg/L	45	36	64	24
TOC – mg/L	8	7.3	7.2	6.6
DOC – mg/L	10.1	10.1	9.1	14.8
Alkalinity – mg/L as $CaCO_3$	100	99	100	100
Temperature - °C	30.3	30.4	30.4	30.8
pH - Standard Units	7.96	7.90	7.92	7.98
DO – mg/L	6.7	6.4	6.4	6.8
Conductivity - umhos/cm	354	347	337	330

Table 2-6: Sampling Point 4 Grab Sample Results

Analyte	4A	4B	4C	4D
Date and Time (CDT)	8/31/2021 1107	8/31/2021 1124	8/31/2021 1137	8/31/2021 1144
$CBOD_5$ Soluble – mg/L	< 1.0	1	< 1.0	< 1.0
$CBOD_5$ – mg/L	1	< 1.0	1	2
$CBOD_{20}$ Soluble – mg/L	2	3	2	2
$CBOD_{20}$ – mg/L	1	4	< 1.0	2
BOD_{20} – mg/L	8	7	8	9
TKN – mg/L	0.502	0.811	0.682	0.558
NH_3 – mg/L	< 0.1	< 0.1	< 0.1	< 0.1
NO_3 – mg/L	< 0.4	< 0.4	< 0.4	< 0.4
NO_2 – mg/L	< 0.4	< 0.4	< 0.4	< 0.4
TP– mg/L	0.118	0.086	0.106	0.095
Ortho-P– mg/L	0.109	0.086	0.103	0.079
Enterococci – CFU/100 mL	1	2	1	1
E. Coli – MPN/100 mL	< 2.0	4	< 2.0	< 2.0
Chlorophyll-a – mg/m^3	15.2	11.1	14.1	18.3
TSS – mg/L	< 5	< 5	< 5	< 5
VS – mg/L	56	110	98	128
TOC – mg/L	7	8	7.8	10
DOC – mg/L	9.9	6	11	8.4
Alkalinity – mg/L as $CaCO_3$	102	100	101	101
Temperature - °C	30.8	30.9	31.2	31.1
pH - Standard Units	7.97	8.04	8.05	8.07
DO – mg/L	6.8	7.0	7.1	7.1
Conductivity - umhos/cm	335	337	334	335

Table 2-7: Sampling Point 5 Grab Sample Results

Analyte	5A	5B	5C	5D
Date and Time (CDT)	8/31/2021 1115	8/31/2021 1129	8/31/2021 1144	8/31/2021 1152
$CBOD_5$ Soluble – mg/L	< 1.0	< 1.0	< 1.0	< 1.0
$CBOD_5$ – mg/L	< 1.0	< 1.0	5	1
$CBOD_{20}$ Soluble – mg/L	2	9	8	2
$CBOD_{20}$ – mg/L	4	4	6	2
BOD_{20} – mg/L	8	8	7	6
TKN – mg/L	0.834	0.903	1.34	0.618
NH_3 – mg/L	< 0.1	< 0.1	< 0.1	< 0.1
NO_3 – mg/L	< 0.4	< 0.4	< 0.4	< 0.4
NO_2 – mg/L	< 0.4	< 0.4	< 0.4	< 0.4
TP– mg/L	0.102	0.068	0.093	0.076
Ortho-P– mg/L	0.097	0.078	0.102	0.087
Enterococci – CFU/100 mL	3	4.1	21.1	6.1
E. Coli – MPN/100 mL	2	2	5	< 2.0
Chlorophyll-a – mg/m^3	9.84	9.84	8.44	8.33
TSS – mg/L	6	< 5	6	10
VS – mg/L	43	84	141	41
TOC – mg/L	9.5	8.8	8.2	10.2
DOC – mg/L	11.3	11.5	6.4	12.7
Alkalinity – mg/L as $CaCO_3$	101	100	100	100
Temperature - °C	31.1	31.6	31.5	31.4
pH - Standard Units	8.00	8.02	8.07	8.09
DO – mg/L	7.0	7.2	7.2	7.1
Conductivity - umhos/cm	338	333	336	341

Table 2-8: Sampling Point 6 Grab Sample Results

Analyte	6A	6B	6C	6D
Date and Time (CDT)	8/31/2021 1119	8/31/2021 1135	8/31/2021 1148	8/31/2021 1207
$CBOD_5$ Soluble – mg/L	< 1.0	< 1.0	< 1.0	< 1.0
$CBOD_5$ – mg/L	< 1.0	1	< 1.0	< 1.0
$CBOD_{20}$ Soluble – mg/L	11	9	11	9
$CBOD_{20}$ – mg/L	11	10	12	12
BOD_{20} – mg/L	10	8	8	10
TKN – mg/L	0.643	0.582	0.801	< 0.5
NH_3 – mg/L	< 0.1	< 0.1	< 0.1	< 0.1
NO_3 – mg/L	< 0.4	< 0.4	< 0.4	< 0.4
NO_2 – mg/L	< 0.4	< 0.4	< 0.4	< 0.4
TP– mg/L	0.091	0.074	0.094	0.06
Ortho-P– mg/L	0.083	0.105	0.086	0.109
Enterococci – CFU/100 mL	2	4.1	5.1	5
E. Coli – MPN/100 mL	4	< 2.0	2	< 2.0
Chlorophyll-a – mg/m^3	6.85	9.72	8.33	7.12
TSS – mg/L	12	11	12	8
VS – mg/L	28	29	24	20
TOC – mg/L	8.5	9	10.4	11.1
DOC – mg/L	12	12.6	12.8	10
Alkalinity – mg/L as $CaCO_3$	104	103	104	102
Temperature - °C	31.2	31.5	31.4	31.3
pH - Standard Units	8.01	8.04	8.01	8.02
DO – mg/L	7.0	7.2	7.1	7.1
Conductivity - umhos/cm	345	341	343	341

Table 2-9: Sampling Point 7 Grab Sample Results

Analyte	7A	7B	7C	7D
Date and Time (CDT)	9/1/2021 1000	9/1/2021 1010	9/1/2021 1020	9/1/2021 1030
$CBOD_5$ Soluble – mg/L	< 1.0	< 1	1	1
$CBOD_5$ – mg/L	2	2	2	2
$CBOD_{20}$ Soluble – mg/L	9	9	9	9
$CBOD_{20}$ – mg/L	12	25	22	14
BOD_{20} – mg/L	13	14	18	13
TKN – mg/L	0.601	0.698	0.779	< 0.5
NH_3 – mg/L	< 0.1	< 0.1	< 0.1	< 0.1
NO_3 – mg/L	2.41	2.43	1.16	0.845
NO_2 – mg/L	< 0.4	< 0.4	< 0.4	< 0.4
TP– mg/L	0.109	0.097	0.103	0.095
Ortho-P– mg/L	0.093	0.101	0.084	0.09
Enterococci – CFU/100 mL	21.3	38.8	52	649
E. Coli – MPN/100 mL	31	40	209	1260
Chlorophyll-a – mg/m^3	20.8	26.4	21.1	22.2
TSS – mg/L	20	60	36	57
VS – mg/L	35	12	169	32
TOC – mg/L	8	9.9	9.9	10.2
DOC – mg/L	9.8	10.2	9.8	9.6
Alkalinity – mg/L as $CaCO_3$	104	103	106	104
Temperature - °C	30.8	31.0	31.2	30.9
pH - Standard Units	8.23	8.01	8.02	7.83
DO – mg/L	8.2	8.6	8.6	8.6
Conductivity - umhos/cm	367	354	354	358

Summary statistics (average, median, maximum, and minimum) were determined for each sampling location based on results from the four grab samples. For values reported below the reporting limit, half the reporting limit was used. Summary statistics used for modeling efforts are presented in Table 2-10.

Table 2-10: Summary Statistics for Sampling Locations

Analyte	1				2				3				4				5				6				7			
	Mean	Min	Max	St Dev	Mean	Min	Max	St Dev	Mean	Min	Max	St Dev	Mean	Min	Max	St Dev	Mean	Min	Max	St Dev	Mean	Min	Max	St Dev	Mean	Min	Max	St Dev
$CBOD_5$ Soluble – mg/L	0.63	0.50	1.00	0.25	0.50	0.50	0.50	0.00	0.50	0.50	0.50	0.00	0.63	0.50	1.00	0.25	0.50	0.50	0.50	0.00	0.50	0.50	0.50	0.00	0.75	0.50	1.00	0.29
$CBOD_5$ – mg/L	0.63	0.50	1.00	0.25	0.75	0.50	1.00	0.29	0.75	0.50	1.00	0.29	1.13	0.50	2.00	0.63	1.75	0.50	5.00	2.18	0.63	0.50	1.00	0.25	2.00	2.00	2.00	0.00
$CBOD_{20}$ Soluble – mg/L	3.50	2.00	8.00	3.00	5.00	2.00	8.00	3.46	5.00	2.00	8.00	3.46	2.25	2.00	3.00	0.50	5.25	2.00	9.00	3.77	10.00	9.00	11.00	1.15	9.00	9.00	9.00	0.00
$CBOD_{20}$ – mg/L	3.38	0.50	5.00	1.97	1.38	0.50	3.00	1.11	2.25	1.00	4.00	1.50	1.88	0.50	4.00	1.55	4.00	2.00	6.00	1.63	11.25	10.00	12.00	0.96	18.25	12.00	25.00	6.24
BOD_{20} – mg/L	9.50	8.00	13.00	2.38	8.00	7.00	9.00	0.82	7.75	7.00	8.00	0.50	8.00	7.00	9.00	0.82	7.25	6.00	8.00	0.96	9.00	8.00	10.00	1.15	14.50	13.00	18.00	2.38
TKN – mg/L	0.81	0.72	1.01	0.13	0.63	0.53	0.72	0.08	0.41	0.25	0.63	0.19	0.64	0.50	0.81	0.14	0.92	0.62	1.34	0.30	0.57	0.25	0.80	0.23	0.58	0.25	0.78	0.23
NH_3 – mg/L	0.05	0.05	0.05	0.00	0.05	0.05	0.05	0.00	0.05	0.05	0.05	0.00	0.05	0.05	0.05	0.00	0.05	0.05	0.05	0.00	0.05	0.05	0.05	0.00	0.05	0.05	0.05	0.00
NO_3 – mg/L	0.20	0.20	0.20	0.00	0.20	0.20	0.20	0.00	0.20	0.20	0.20	0.00	0.20	0.20	0.20	0.00	0.20	0.20	0.20	0.00	0.20	0.20	0.20	0.00	1.71	0.85	2.43	0.83
NO_2 – mg/L	0.20	0.20	0.20	0.00	0.20	0.20	0.20	0.00	0.20	0.20	0.20	0.00	0.20	0.20	0.20	0.00	0.20	0.20	0.20	0.00	0.20	0.20	0.20	0.00	0.20	0.20	0.20	0.00
TP– mg/L	0.14	0.12	0.16	0.02	0.13	0.11	0.15	0.02	0.12	0.10	0.13	0.01	0.10	0.09	0.12	0.01	0.08	0.07	0.10	0.02	0.08	0.06	0.09	0.02	0.10	0.10	0.11	0.01
Ortho-P– mg/L	0.11	0.11	0.12	0.01	0.12	0.11	0.13	0.01	0.12	0.10	0.13	0.01	0.09	0.08	0.11	0.01	0.09	0.08	0.10	0.01	0.10	0.08	0.11	0.01	0.09	0.08	0.10	0.01
Enterococci – CFU/100 mL	1.25	1.00	2.00	0.50	2.00	1.00	4.00	1.41	2.25	1.00	4.00	1.26	1.75	1.00	4.00	1.50	2.50	1.00	5.00	1.73	2.00	1.00	4.00	1.41	385	31.0	1260	589
E. Coli – MPN/100 mL	7.78	4.10	11.00	3.64	8.23	5.20	14.20	4.07	6.70	2.00	12.20	4.56	1.25	1.00	2.00	0.50	8.58	3.00	21.10	8.45	4.05	2.00	5.10	1.44	190	21.3	649	306
Chlorophyll-a – mg/m^3	7.91	7.38	8.44	0.55	11.58	10.70	13.10	1.14	11.21	8.44	12.70	1.96	14.68	11.10	18.30	2.97	9.11	8.33	9.84	0.84	8.01	6.85	9.72	1.31	22.63	20.80	26.40	2.59
TSS – mg/L	9	5	13	3	5	3	8	3	6	3	7	2	3	3	3	0	6	3	10	3	11	8	12	2	43	20	60	19
VS – mg/L	94	52	163	48	62	24	98	36	42	24	64	17	98	56	128	31	77	41	141	47	25	20	29	4	62	12	169	72
TOC – mg/L	9.40	7.90	10.10	1.01	10.38	8.90	11.70	1.30	7.28	6.60	8.00	0.57	8.20	7.00	10.00	1.28	9.18	8.20	10.20	0.87	9.75	8.50	11.10	1.21	9.50	8.00	10.20	1.01
DOC – mg/L	9.78	9.10	10.40	0.62	9.33	9.00	10.00	0.46	11.03	9.10	14.80	2.56	8.83	6.00	11.00	2.16	10.48	6.40	12.70	2.79	11.85	10.00	12.80	1.28	9.85	9.60	10.20	0.25
Alkalinity – mg/L as $CaCO_3$	99	98	100	1	99	98	100	1	100	99	100	1	101	100	102	1	100	100	101	1	103	102	104	1	104	103	106	1
Temperature - °C	29.9	29.8	30.0	0.1	30.3	30.0	30.6	0.3	30.5	30.3	30.8	0.2	31.0	30.8	31.2	0.2	31.4	31.1	31.6	0.2	31.4	31.2	31.5	0.1	31.0	30.8	31.2	0.2
pH - Standard Units	7.78	7.72	7.82	0.04	7.77	7.70	7.82	0.05	7.94	7.90	7.98	0.04	8.03	7.97	8.07	0.04	8.05	8.00	8.09	0.04	8.02	8.01	8.04	0.01	8.02	7.83	8.23	0.16
DO – mg/L	6.3	6.2	6.4	0.1	6.4	6.1	6.7	0.3	6.6	6.4	6.8	0.2	7.0	6.8	7.1	0.1	7.1	7.0	7.2	0.1	7.1	7.0	7.2	0.1	8.5	8.2	8.6	0.2
Conductivity - umhos/cm	343	325	367	18	340	330	346	7	342	330	354	11	335	334	337	1	337	333	341	3	343	341	345	2	358	354	367	6

Data from this field study were used to confirm model calibration for the water quality analysis. No second field study or model validation was performed or is planned at this time. Green Country Testing collected data regarding the pH, DO, temperature, and specific conductivity of the grab samples during field collection. However, continuous *in situ* measurements were not collected.

2.2 Hydraulic and River Geometry Data

For oxygen-demanding parameters, Oklahoma Water Quality Standards (WQS) define the seven-day, two-year low flow (7Q2) as the receiving stream flow for determining allowable discharge load to a stream. The flow is calculated as a moving average of seven consecutive days for each year or season in a given record and represents a yearly or seasonal low flow value.

The USACE Verdigris River near Catoosa, OK (CTOO2) stream gage measures stage and flow approximately 10 miles northeast of the of the project site, and downstream stage and flow observations are measured at the USACE Newt Graham Lock and Dam 18 (INLO2) stream gage located approximately 4 miles south of the project site. Based on these available data sources, no velocity dye study or additional flow measurements were performed for this study.

Seasonal 7Q2 flows for the Verdigris River were calculated using flow data obtained from the USACE CTOO2 stream gage. The most recent ten years of daily flow measurements were used to calculate a 7Q2 for each season. The USACE INLO2 stream gage was also reviewed for flow data, but due to operations at the Newt Graham Lock and Dam 18, the INLO2 stream gauge flow data contained uncharacteristically low flows for certain periods of the year along with artifacts in the data that led to questions regarding the validity of the dataset, particularly for low flow conditions. Outside of the low flow days, the flows between the CTOO2 and INLO2 stream gages mirrored each other, see Figure 2-2. In addition, daily flow data for the nearest upstream United States Geological Survey (USGS) stream gauges (Verdigris River near Claremore and Bird Creek at State Highway 266 near Catoosa) were compared to and found to closely match the flows recorded at the CTOO2 stream gage, thus verifying the flow data for USACE CTOO2. Therefore, it was determined that flow data from the CTOO2 stream gage provided the most accurate estimate of flow, and CTOO2 flow data were used to develop the seasonal 7Q2 flow rates used in the QUAL2K model (Table 2-11). Given the highly controlled hydraulics in this reach, and the lack of minor streams and tributaries entering the Verdigris River, the flow measured at the CTOO2 stream gage was assumed equivalent to the flow at the proposed Port of Inola discharge point. Flow data and calculations are provided in Appendix C.

Table 2-11: Seasonal 7Q2 Flows from CTOO2 Stream Gage

	Spring	Summer	Winter
Seasonal 7Q2 (cfs)	960	349	267

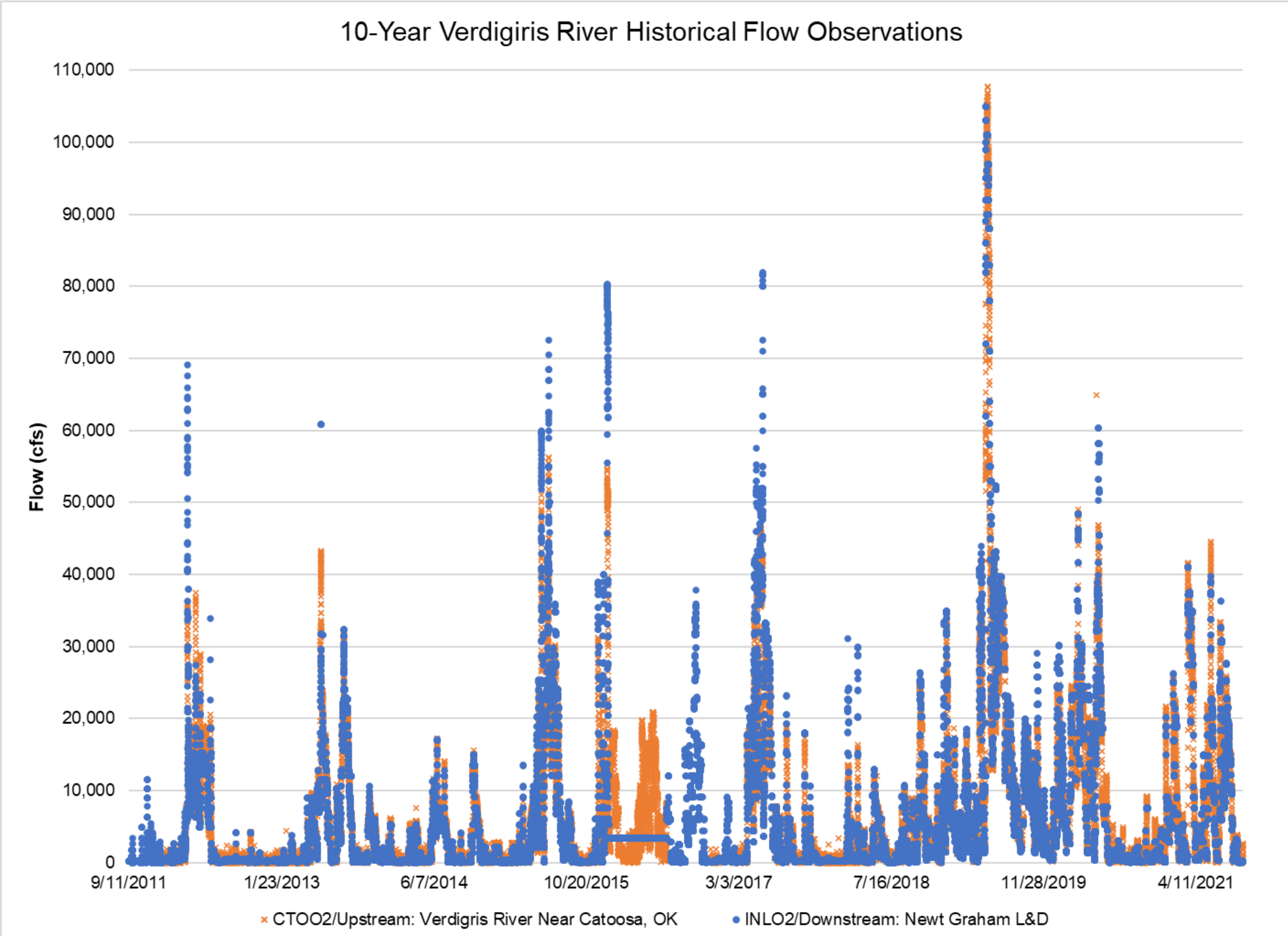

Figure 2-2: Flow Data USACE CTOO2 vs. INLO2 (2011 to 2021)

No field surveys of the Verdrigis River in the subject reach were performed for this study. A base assumption in the modeling and calibration was that the geometry of the Verdigris River is relatively static between CTOO2 and INOL2. Because of its use as a navigation channel, the Verdigris River is regularly dredged and maintained by the USACE; therefore, the channel depth and width were assumed constant throughout the model domain. To estimate a channel slope that would represent the required 9-feet navigable depth throughout the modeled river segment and represent the dam and lock operation, it was assumed that the water surface elevation (WSE) at Newt Graham Lock and Dam 18 would remain constant regardless of flow, thus the weir flow would be equal to the river flow. Because the water surface elevation (WSE) in the river at Newt Graham Lock and Dam 18 would be relatively constant, it was assumed that the WSE recorded by Digital Elevation Maps (DEM) and available from the USGS would be representative of the typical WSE and could be used in conjunction with the navigable depth assumption to estimate an upstream water depth. Assuming the channel depth on the upstream side of Newt Graham Lock and Dam 18 in the model provided by ODEQ from a previous study was representative of actual conditions and a constant bed slope between the headwater and Newt Graham Lock and Dam 18, a linear relationship was used to determine the depth of the other model reach segments. Knowing the channel width, channel depth, manning's n, and flow rate, the slope of the hydraulic grade line using the Continuity of Flow and Manning's equations was estimated. The calculated slope for each model reach upstream of Newt Graham Lock and Dam 18 was input as the slope for the manning formula in QUAL2K.

2.3 Meteorological Data

The Oklahoma WQS requires that allowable loadings to meet dissolved oxygen criteria be calculated using the 7Q2 and the appropriate seasonal temperature. The values for the appropriate seasonal temperature are given in the Oklahoma WQS as a seasonal temperature associated with a particular fishery class, applicable season date, and associated DO criteria. Applicable temperatures for WWAC from Table 1 of Oklahoma Administrative Code (OAC) 252:730 Appendix G are summarized in Table 2-12.

Table 2-12: Seasonal Temperatures for WWAC

WWAC	Dates Applicable	Seasonal Temperature (°C)
Early Life Stages	4/1 – 6/15	25
Other Life Stages		
Summer Conditions	6/16 – 10/15	32
Winter Conditions	10/16 – 3/31	18

QUAL2K required meteorological data (e.g., solar radiation, air temperature, dew point, wind speed, and cloud cover). Cloud cover data were obtained from the Tulsa International Airport (Station KTUL, 20 miles northwest of the project location) meteorological aerodrome reports (METAR) observations, while the USACE INLO2 station's hourly observations were used for the remaining meteorological parameters due to its proximity to the project location.

3.0 QUAL2K MODEL SETUP

The QUAL2K water quality model provided by ODEQ from a previous study (Sofidel, 2017) was updated and recalibrated using the grab sample data and publicly available information. QUAL2K is a one-dimensional steady-state river water quality model (Chapra et al., 2012). QUAL2K assumes well-mixed stream channels (both vertically and laterally), and employs a diel, or 24-hour period, heat budget. The model was previously calibrated during the earlier study; however, ODEQ expressed several concerns regarding the calibration of this model. Therefore, the calibration of the model was updated as part of this effort. All model input data, hydraulic and rate parameters, and boundary conditions were reviewed and updated as needed and described in the following sections. Calibration model input and output files are provided in Appendix D.

The QUAL2K model was set up, parameterized, and calibrated to represent conditions observed during collection of field water quality samples; this was the calibration scenario. The calibrated model was then used to evaluate the proposed WLA under conditions of critical low flow (7Q2) and critical water temperatures, which vary by season.

The model calibration was reviewed by updating the model input data for flow and meteorological conditions using data for the days of water quality sampling, August 31 – September 1, 2021, which represented a period of high temperatures and low flow, corresponding to higher nutrient concentrations and lower DO concentrations, mimicking the summer critical low flow conditions. Calibration parameters include the water quality analytes listed in Section 2.1. The calibration model simulates repeating diel conditions for a period of 30 days to allow the model to reach steady state conditions.

3.1 Model Extent and Reach Segmentation

The Verdigris River QUAL2K model represents a 9.14 km reach of the river starting 0.61 km downstream of the Newt Graham Lock and Dam and extending upstream beyond the Town of Inola's outfall location (at 5.72 km upstream) and the permitted location for the Sofidel Autumn Plant II facility (at 8.53 km upstream).

Eight reaches were defined in the model; these reach lengths varied from 0.3 to 2.06 kilometers (km). The reaches were selected to encompass the sample points and proposed outfall location, in addition to the Newt Graham Lock and Dam 18 inline structure at the downstream end of Reach 7. The upstream and downstream locations for each reach were measured from the downstream boundary of Reach 8, which was defined as the beginning station. Table 3-1 provides reach definitions used in the model. See Section 2.2 for information on reach slope assumptions. No reach-specific rate parameters were used in the model.

Table 3-1: Model Reach Information

Reach	Reach Length (km)	Upstream Station (km)	Downstream Station (km)
1	0.30	9.144	8.839
2	0.91	8.839	7.925
3	1.52	7.925	6.401
4	1.60	6.401	4.800
5	2.06	4.800	2.743
6	1.52	2.743	1.219
7	0.61	1.219	0.610
8	0.61	0.610	0.000

3.2 Flow Boundary Conditions

Hourly river flow data are monitored and recorded at the USACE CTOO2 station approximately 17 miles upstream of the subject reach. Because no major tributaries enter the Verdigris River between CTOO2 station and the upstream boundary of the model, the flow and water temperature time series at CTOO2 were applied as headwater boundaries. Hourly water quality parameters are not measured at CTOO2; therefore, water quality headwater conditions were defined from Sample Point 1 mean values (Table 2-10) and held constant through the calibration simulation as the headwater boundary condition.

QUAL2K uses two forms of carbonaceous BOD to represent organic carbon—a rapidly oxidizing form (fast CBOD) typically associated with sewage effluent and autochthonous carbon from the aquatic food chain, and a slowly oxidizing form (slow CBOD) found in some industrial wastewaters such as such as pulp and paper mill effluent. However, no economically-feasible options are currently available to quantify the slow and fast CBOD fractions in a sample (Chapra, 2012). Thus, for calibration purposes, the fraction of fast CBOD was estimated using the measured CBOD20 from the sample data. Because of the long incubation time of 20 days, it was assumed that most of the readily degradable organic carbon would be oxidized so that measured CBOD20 could be used to represent CBODult in model inputs, consistent with other WLA studies approved by ODEQ (refer to Sofidel WLAS report Section 3.0). Laboratory data for the samples collected in August 2021 indicate low concentrations of BOD; these results are consistent with data collected in September 2017 for the Sofidel permit application. For model calibration, slow CBOD was estimated and adjusted during calibration based on the observed dissolved organic carbon (DOC) in the water quality samples.

The USACE Newt Graham Lock and Dam 18, where the INLO2 station is located, is approximately four miles downstream of the project site. The 1,630-feet embankment is a combined earthfill and concrete gravity dam. The spillway is a gated concrete ogee weir with a crest elevation of +506.0 feet (NAVD88). The total width of the spillway is 220 feet with a net flow width of 180 feet. There are three 60 feet wide by 27 feet high tainter gates with 10-feet wide concrete piers. The right bank overflow section is 596 feet, at crest elevation +533.5 feet (NAVD88), and the left bank overflow section is 813 feet at crest elevation +542.0 feet (NAVD88). A 5-feet wide service bridge was constructed on the piers for personnel access to the gates.

Upstream of the structure, the WSE is maintained at a normal pool stage between +532.5 to +533.0 feet (NAVD88). The inline structure was represented in the QUAL2K model at the end of Reach 7. There was no requirement to explicitly define the downstream boundary in the QUAL2K model; therefore, that functionality was not used. A weir height of 4.7 meters provided the best fit of the model hydraulics to those observed upstream of the model domain (USACE CTOO2 gage) and at Newt Gram Lock and Dam 18 (USACE INLO2 gage).

3.3 Initial Conditions

Initial conditions were prescribed for the calibration scenario based on the observed water quality data. Initial conditions were assigned for temperature, specific conductance, inorganic suspended solids, DO, BOD, organic nitrogen, organic and inorganic phosphorus, phytoplankton, detritus, alkalinity, and pH in reaches 2, 3, 5, 6, and 8 based on corresponding field sample locations.

3.4 Air Temperature

Hourly air temperatures were obtained from USACE INLO2 station at the Newt Lock and Dam 18 (USACE, 2021). These hourly air temperatures were applied to each model reach from 8/31/2021 12:00 AM Central Daylight Time (CDT) to 9/1/2021 12:00 AM CDT.

3.5 Dew Point Temperature

The USACE INLO2 recorded hourly air temperature and relative humidity values (USACE, 2021), which can be used to calculate the local dew point temperature from these observations (Lawrence, 2005).

$$\boldsymbol{T_d = T_a - \left(\frac{100 - RH}{5}\right)} \qquad \textit{Equation 3-1}$$

where:

T_d = dew point temperature (°C)

T_a = air temperature (°C)

RH = relative humidity

3.6 Wind Speed

Hourly wind speed records were obtained from USACE INLO2 (USACE, 2021). These wind speed observations were applied to each model reach from 8/31/2021 12:00 AM CDT to 9/1/2021 12:00 AM CDT.

3.7 Cloud Cover

QUAL2K requires an hourly cloud cover estimate (percentage between 0 to 100) as an input condition to the solar radiation computations. Cloud cover estimations were obtained from the Tulsa International Airport station (KTUL).

3.8 Shade

As described in the QUAL2K manual (Chapra et al., 2012), shade is defined as the fraction of potential solar radiation that is blocked by topography and vegetation. As recommended by Chapra et al. (2012), the Shade Excel/VBA program from the Washington Department of Ecology (Washington Department of Ecology, 2015) was used to estimate hourly shade percentages for each reach of the model domain from 8/31/2021 12:00 AM CDT to 9/1/2021 12:00 AM CDT.

3.9 Solar Radiation

USACE INLO2 (USACE, 2021) records hourly solar radiation (W/m^2). These values were applied to reach model reach from 8/31/2021 12:00 AM CDT to 9/1/2021 12:00 AM CDT.

3.10 Light Parameters and Surface Heat Transfer Models

The light parameters and surface heat transfer models used in the calibration run are provided in Table 3-2.

Table 3-2: Light Parameters and Surface Heat Transfer Models

Parameters	Value	Unit	Symbol
Photosynthetically Availability Radiation	0.47		
Background Light Extinction	0.2	1/m	k_{eb}
Linear Chlorophyll Light Extinction	0.0088	1/m-(ugA/L)	α_p
Nonlinear Chlorophyll Light Extinction	0.054	1/m-(ugA/L)$^{2/3}$	α_{pn}
ISS Light Extinction	0.052	1/m-(mgD/L)	α_s
Detritus Light Extinction	0174	1/m-(mgD/L)	α_o
Macrophyte Light Extinction	0.015	1/m-(gD/m^3)	α_{mac}
Atmospheric Attenuation Model for Solar	Bras		
Atmospheric Turbidity Coefficient (2=clear, 5=smoggy, default=2) (Used if Bras Solar Model is Selected)	2		n_{fac}

Parameters	Value	Unit	Symbol
Atmospheric Transmission Coefficient (0.70-0.91, default is 0.8) (Used if Ryan-Stolzenbach Solar Model is Selected)	0.8		α_{tc}
Atmospheric Longwave Emissivity Model	Brunt		
Parameter for Emissivity Using the Brutsaert Equation (used if Brutsaert Longwave Model is Selected)	1.24		k_{brut}
Wind Speed Function for Evaporation and Air Convection/Conduction	Brady-Graves-Geyer		
Coefficient for Attenuation of Solar Radiation by Cloud Cover	0.65		*KCL1*
Exponent for Attenuation of Solar Radiation by Cloud Cover	2		*KCL2*
Model Equation for Cloudy Sky Adjustment of Longwave Radiation	Eqn 1		
Coefficient for Cloudy Sky Adjustment of Longwave Radiation	0.17		*KCL3*
Exponent for Cloudy Sky Adjustment of Longwave Radiation	2		*KCL4*
Include Evaporation in Flow Balance	No		

3.11 Point Sources

Three point sources were considered in the model:

- Permitted Sofidel America, Corp. Autumn II Wastewater Treatment Plant discharge (OK0100676),
- Town of Inola Wastewater Treatment Plant discharge (OK0033618), and
- Proposed Port of Inola industrial and domestic discharges for this WLA study.

The Town of Inola and Sofidel plant discharges were included in the Calibration and WLA scenarios. Information for existing and permitted point sources was obtained via NPDES permits and DMRs for the calibration period and is summarized in Table 3-3. For input to the model, CBOD is expressed as $CBOD_{ult}$ while permit limits are expressed as $CBOD_5$. The default conversion factor of 2.3 ($CBOD_{ult}/CBOD_5$) was used for all discharges except Sofidel. For the Sofidel discharge, the $CBOD_5$ limit was converted to $CBOD_{ult}$ using an assumed conversion factor of 4.0 for paper mill discharges (TCEQ, 2012). Organic particulate (detritus) was represented using 50 percent of TSS for both discharges. The existing Town of Inola Wastewater Treatment Plant utilizes a lagoons system which requires an ammonia limit of 7.2 mg/L for summer and 15.4 mg/L for spring and winter, in accordance with the domestic secondary treatment limits in the Oklahoma Administrative Code.

Table 3-3: Point Source Model Inputs

Parameters	Sofidel		Town of Inola	
	Proposed WLA Scenario	Calibration	Proposed WLA Scenario	Calibration
Flowrate (MGD)	3.0	0.64	0.4/0.8	0.43
Ammonia (mg/L)	10	4.0	12*	7.2
$CBOD_5$ (mg/L)	60	8.03	25	24.7
Detritus (mg/L)	40	4.5	22.5	18.8
Source	NPDES Permit OK0100676	DMR for August 2021	NPDES Permit OK0033618	DMR for August 2021

*Ammonia limits for the proposed WLA scenario revised based on assumed upgrade to a mechanical wastewater treatment facility.

Point source model inputs for the proposed Port of Inola industrial and domestic discharges are discussed subsequently in Section 4.1.

3.12 Diffuse Sources

No diffuse sources (i.e., non-point sources) were assigned in the model. Although a constant 500 pounds per day of oxygen demand was assumed for nonpoint sources for calculating the WLA (see Section 4.3), no nonpoint sources were input in the model.

3.13 Continuous Sources

No continuous sources were assigned in the model, which was not simulated in continuous mode.

3.14 Instantaneous Sources

No instantaneous sources were assigned in the model.

3.15 Model Calibration

A weight-of-evidence approach was used to evaluate the model calibration and determine model acceptance for use in this application. The weight-of-evidence approach is widely used and accepted for environmental modeling and consists of multiple graphical and statistical comparisons to assess model performance (Donigian, 2002). The primary measures of model performance for this calibration included:

- Graphical comparison between simulated and observed mean, minimum, and maximum daily concentrations for each water quality constituent. The objective was to achieve the best fit between simulated and observed concentrations.

- Calculation of error statistics (root mean squared error (RMSE) and coefficient of variation (CV) of the RMSE).

3.15.1 QUAL2K Calibration Evaluation Parameters

A total of 13 water quality parameters, shown in Table 3-4, were included in the evaluation of model calibration (note that model performance criteria and weighting factors presented in this table are explained subsequently in Section 3.15.3). Several parameters were excluded from the calibration evaluation because the measured results were either very low or all non-detect, and therefore, use of these parameters to evaluation the calibration was meaningless. The excluded parameters included nitrate, ammonia, organic P, and total $CBOD_{ult}$. Nitrate and ammonia data were all non-detect. Organic P values were either non-detect or low values near the detection limit which limited the usefulness of the data for calibration. Simulated values were similar to observed values excluding non-detects. For $CBOD_{ult}$, the observed values were estimated from measured $CBOD_{20}$ which were primarily just above the detection limit. Because of the uncertainty in this data, it was excluded from the calibration. For all parameters, observed values collected below the lock and dam were excluded from the calibration because water quality below the dam is strongly influenced by aeration and scouring as the water passes over the dam, and these processes are not fully represented by the model.

Table 3-4: Calibration Evaluation Parameters

Parameters	RMSE	RMSCV	Observed Mean	Weighting Factor
Temperature (°C)	0.37	1.22%	30.6	1
Specific conductance (umhos)	1.45	0.42%	341	1
Dissolved oxygen (mgO2/L)	0.08	1.18%	6.7	5
Organic N (ugN/L)	31.6	4.87%	650	2
Inorganic P (ugP/L)	4.38	4.07%	108	4
Phytoplankton (ugA/L)	1.31	12.3%	10.7	1
Alkalinity (mgCaCO3/L)	0.88	0.88%	100	4
pH	0.036	0.45%	7.9	4
Total Kjeldahl N (ugN/L)	153.9	23.7%	650	3
Total P (ugP/L)	23.5	20.9%	113	3
Total suspended solids (mgD/L)	1.62	21.7%	7.5	1
Total organic C (mgC/L)	0.685	7.60%	9.0	1
Dissolved organic C (mgC/L)	1.08	10.7%	10.2	1
Working RMSCV		7.3%		$\sum = 31$

3.15.2 QUAL2K Calibration Process

Among other changes to the model, the reaction rate parameters for several constituents, including slow and fast CBOD oxidation, slow CBOD hydrolysis, nitrification, denitrification, organic nitrogen hydrolysis, and organic phosphorus hydrolysis were updated as part of this calibration effort. Initial values for these parameters were unchanged from the approved QUAL2K water quality model provided by ODEQ from a previous study (Sofidel, 2017).

Calibration within this effort consisted of a number of manual calibration steps followed by attempted autocalibration using the genetic algorithm within QUAL2Kw. Manual calibration was focused on adjusting nutrient kinetic reaction rates within established limits to maximize the fit of simulated to observed values. Following the manual calibration, several attempts to use the genetic algorithm autocalibration capability of QUAL2Kw were made, but none of the auto-calibrated models improved the results compared to the manual calibration.

The final calibrated BOD and nutrient rate parameters are shown in Table 3-5. For comparison, calibrated rate parameters for fast and slow CBOD oxidation from other water quality modeling studies in northeast Oklahoma and surrounding states are summarized in Table 3-6. The calibrated values for this model are similar to and within the ranges reported for these other model applications, several of which have been approved by ODEQ and/or EPA.

Table 3-5: Calibrated QUAL2K Rate Parameters

Parameters	Calibrated Value (1/d)
Fast CBOD Oxidation	0.25
Slow CBOD Oxidation	0.035
Slow CBOD Hydrolysis	0.075
Organic Nitrogen Hydrolysis	0.254
Nitrification	0.50
Denitrification	1.95
Organic Phosphorus Hydrolysis	0.26

Table 3-6: Reported Calibrated Vales for Slow and Fast CBOD Oxidation Rates

Fast CBOD Oxidation (1/day)	Reference
0.115	Municipal Secondary Effluent (Lung, 2001)
0.06	Sofidel Autumn II WLA Study (2017)

Fast CBOD Oxidation (1/day)	Reference
0.1 – 0.9	TMDL for Dog and Cat Creeks, Claremore, OK (2002)
0.15	Caney River WLA Study, Bartlesville, OK (2018)
0.34	Bear Creek TMDL Study, Adair County, MO (2010)
Not Reported	WLA Study for Shawnee, OK (2020)
0.02	WLA Study for Verdigris River, Inola, OK (2006)
0.3 – 0.35	Washita River WLA Study, Ardmore Airpark, OK (2021)
0.3 – 0.35	Chambers Creek WLA Study, Rogers County, OK (2021)
Slow CBOD Oxidation (1/day)	**Reference**
0.02	Pulp and Paper Mill Discharges (NCASI, 1982)
0.083	Sofidel Autumn II WLA Study (2017)
0.05	Caney River WLA Study, Bartlesville, OK (2018)

3.15.3 Model Performance Criteria

Within QUAL2Kw, overall model goodness of fit is summarized by a single value calculated from the coefficient of variation of the RMSE (model results versus observed data) between each constituent along with appropriate, individual weighting factors. While this value is user-defined and will therefore be different for each model application, it can still provide a useful measure of the quality of model calibration. Weighting factors were assigned as shown in Table 3-4 based on recommended values by Neilson et al. (2012). The highest weight was assigned to dissolved oxygen, followed by alkalinity, pH, inorganic P, total Kjeldahl N, and total P, as appropriate based on the available water quality data.

No single statistic or error tolerance has been agreed upon in the model-related literature to determine acceptable model performance; however, it is agreed that error is inherent in both measuring and modeling of natural systems, and therefore some level of error is inherent. Donigian (2002) proposed an error target of <15 percent as being very good for water quality/nutrient parameters and <25 percent as being good. In addition, several completed and EPA-approved TMDL studies that utilized calibrated QUAL2Kw models to assess DO impairment were reviewed for acceptable error tolerances. This review found coefficient of variation (CV%) up to 175 percent for some nutrients in approved, calibrated water quality models. In the Port of Inola calibrated QUAL2Kw model, the root mean square error (RMSE), or standard error, for dissolved oxygen was 0.05 mg/L with a CV of 0.7 percent. Calibration errors for nutrient parameters were higher with CV ranging from 4.0 to 24 percent indicating good calibration of the model. Similarly, the overall weighted CV for the calibration is 7.2 percent indicating very good overall calibration. Plots of calibrated DO, inorganic P, and organic N are shown in Figures 3-1 through 3-3. The full calibrated model input and output can be found in Appendix D.

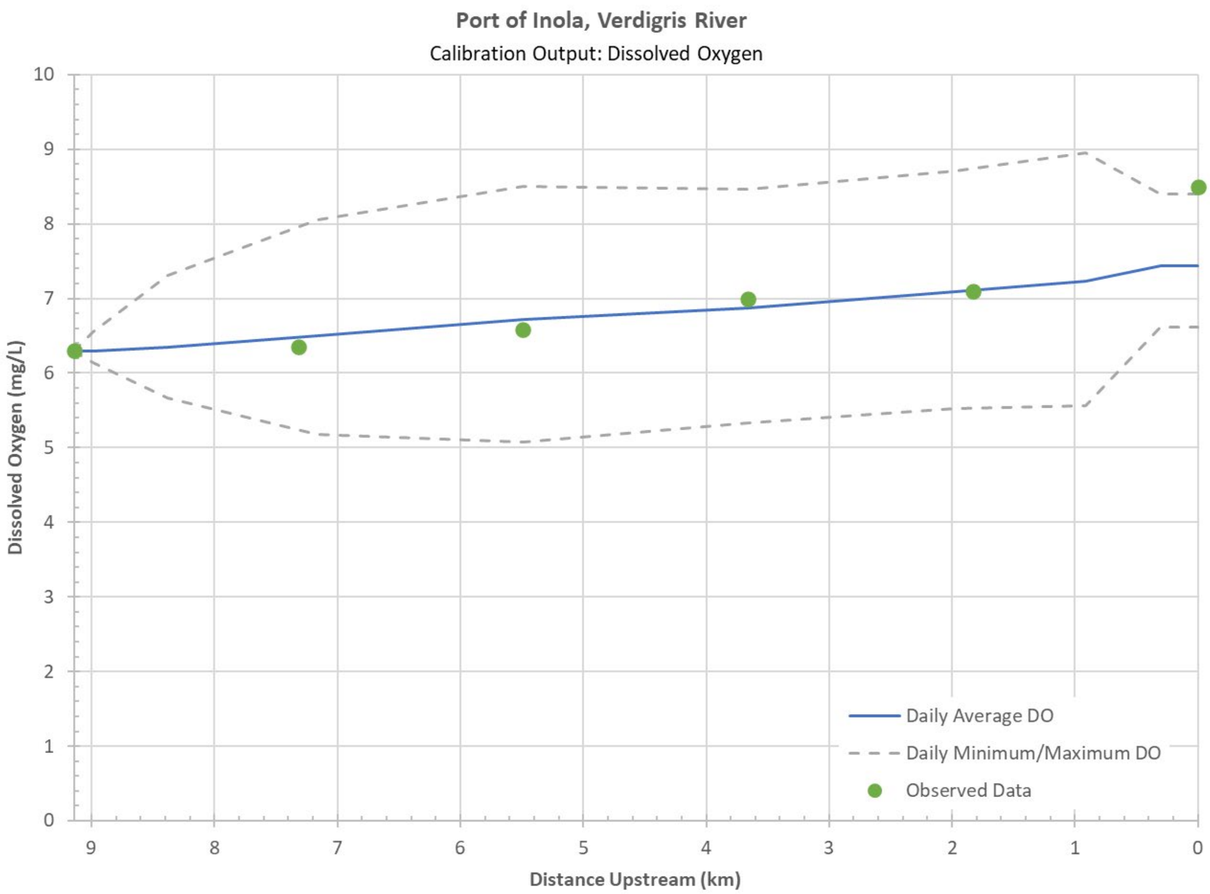

Figure 3-1: Calibration Model Dissolved Oxygen

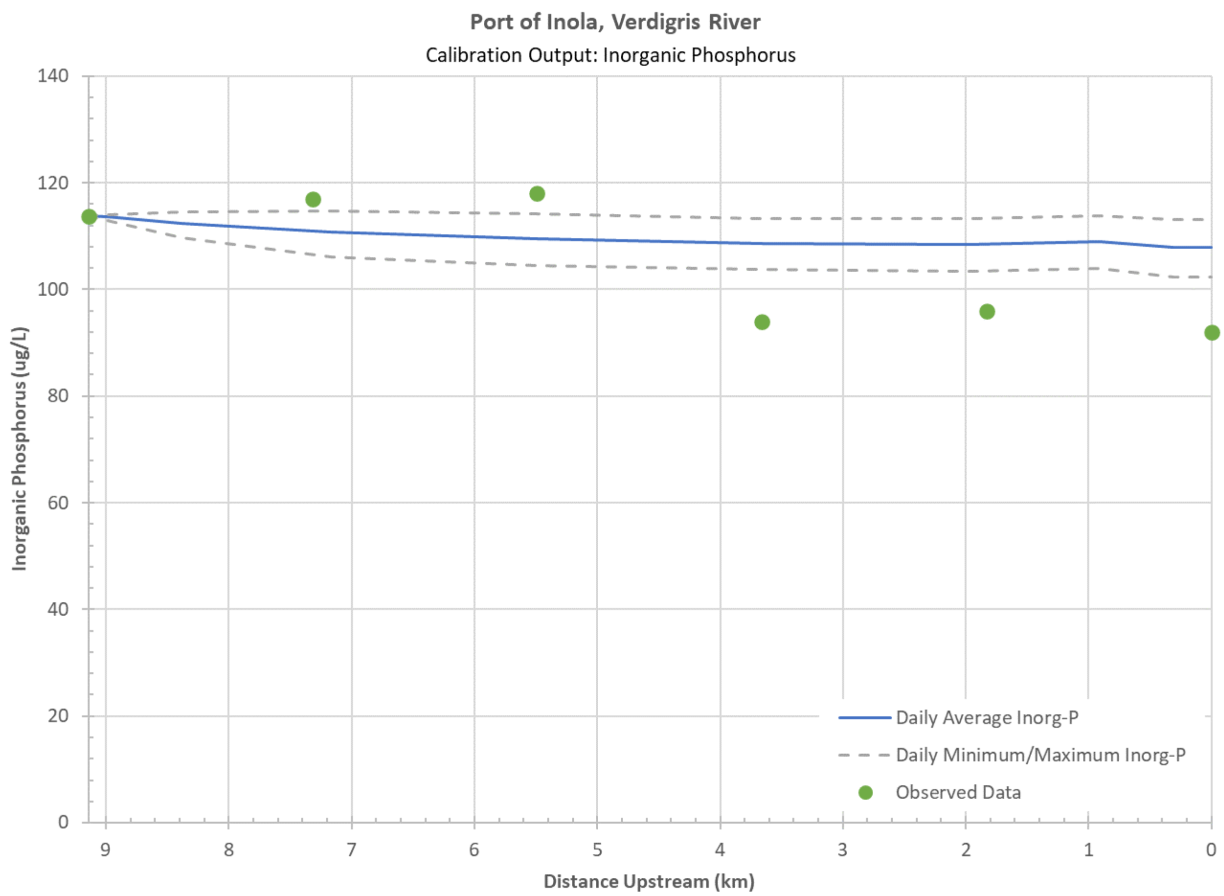

Figure 3-2: Calibration Model Inorganic Phosphorus

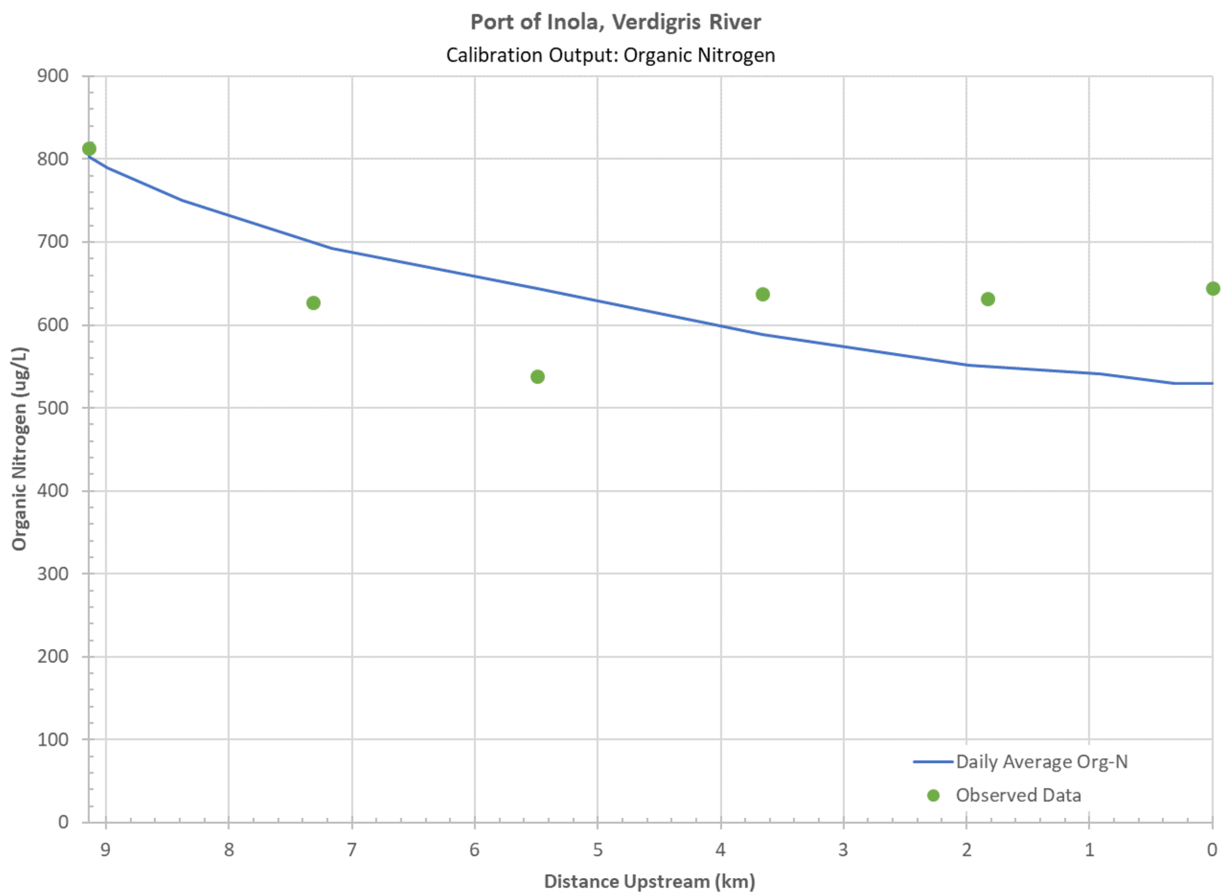

Figure 3-3: Calibration Model Organic Nitrogen

3.15.4 QUAL2K Model Sensitivity Analysis

Two series of sensitivity analyses were conducted to analyze the various impact of key model parameters on the simulation of DO. In the first series, model rate parameters for fast CBOD oxidation, slow CBOD oxidation, and slow CBOD hydrolysis were varied to confirm that the selected input rate value for these parameters produced the best fit of model-simulated DO concentrations to observed values for the calibration conditions. The results of this series of sensitivity analyses, shown in Figure 3-4, demonstrate that the values selected for these parameters through the calibration process described previously produce the minimum error in DO concentrations. The RMSE for DO increases substantially with changes in these rate parameters indicating the model is sensitive to the CBOD rates.

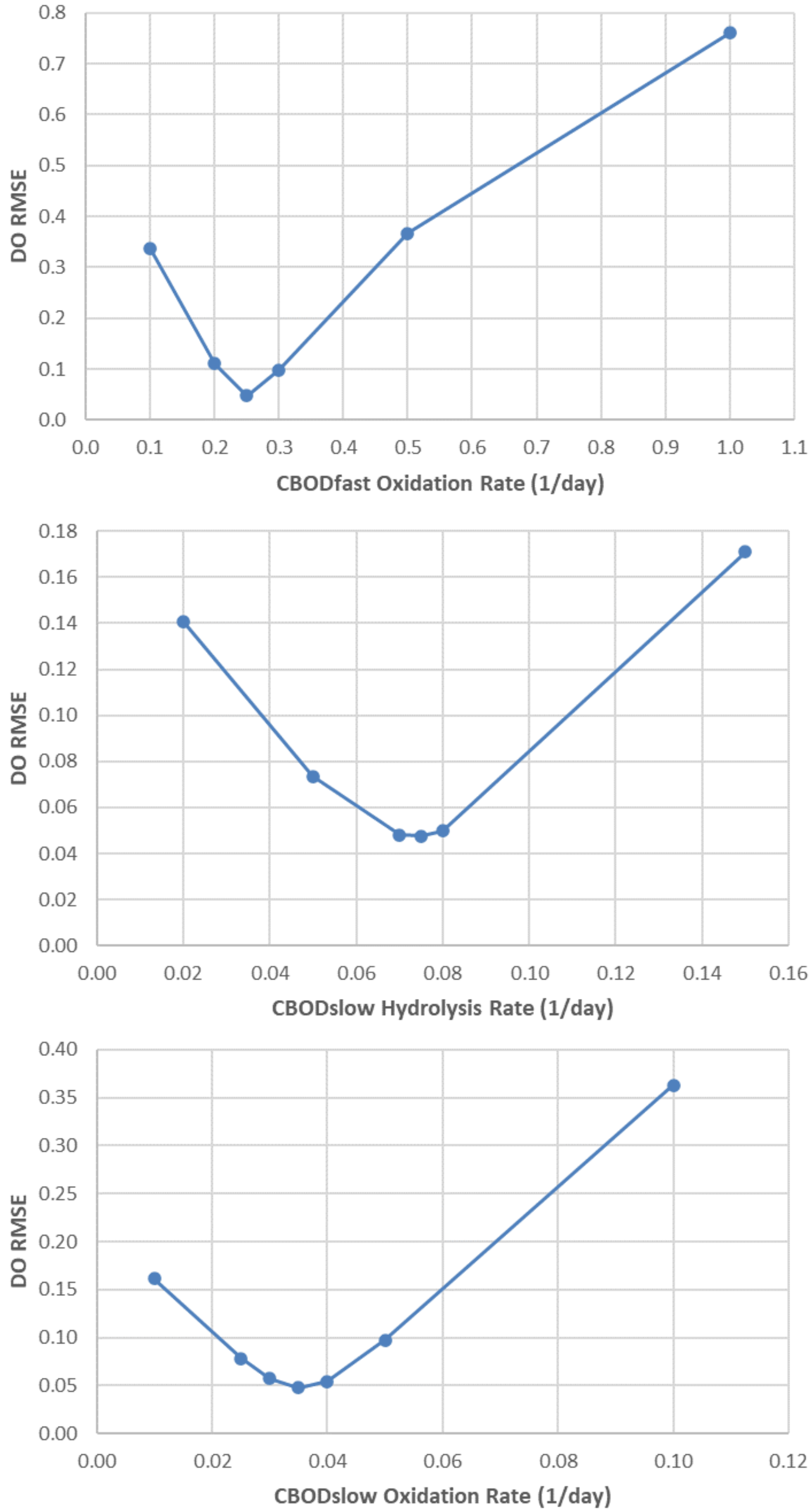

Figure 3-4: Sensitivity Analysis: Fast and Slow CBOD Rates

The second series of sensitivity analyses examined the sensitivity of the model to non-calibrated input parameters including hourly wind speed, bottom SOD coverage, and boundary condition inputs for phytoplankton concentration, flow, and DO concentration. Each parameter was adjusted by +25 percent and -25 percent relative to the calibration model for each sensitivity run with all other parameters held to baseline calibrated conditions.

The sensitivity tests were used to compare the baseline calibrated model with each parameter input change individually to explore the impact on mean DO concentration along the river. For each parameter change, the departure from the average DO concentration is depicted on a tornado diagram to show the relative sensitivity of each parameter (Figure 3-5).

Of the parameters tested here, the average DO concentration was most sensitive to boundary DO concentrations and boundary flows. Average DO was least sensitive to boundary Chl-a concentrations, bottom SOD coverage, and wind speed comparatively. Increasing flow resulted in an increase in mean DO because of increased reaeration. Increasing bottom SOD coverage resulted in a decrease in mean DO because the excursion of oxygen demand depletes DO in the water column. Alternatively, increasing boundary DO concentrations increases the DO in the system in response. Note that these parameters tested do not necessarily represent the breadth of possible parameters which may impact DO concentrations, but they provide insight into the level of sensitivity of the model to a cross-section of relevant parameter inputs.

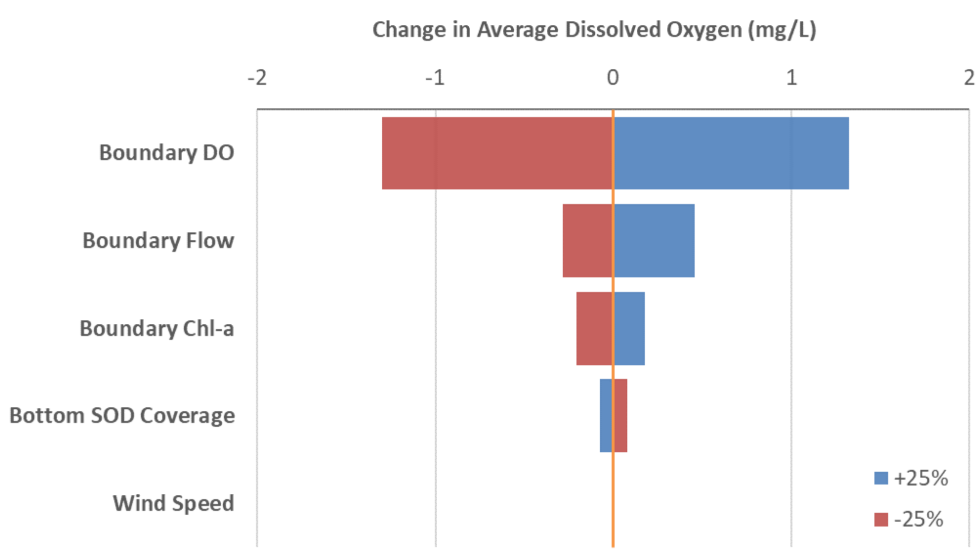

Figure 3-5: Sensitivity Analysis: Non-Calibrated Input Parameters

3.16 Global Rate Parameters

Global rate parameters for stoichiometry, settling velocity, oxygen (reaeration), hydrolysis, oxidation, nitrification, and phytoplankton parameters were initially set according to the calibrated values from the previous modeling study and were revised through the model calibration process described in the previous section. The QUAL2K user-defined reaeration model (A = 5.04, B = 0.86, and C = -1.72) was used. Because of the large number of rate parameters used in the model, the assigned values have not been presented here; the rate parameters are specified in the model input files included in Appendix D.

4.0 PROPOSED WASTELOAD ALLOCATION

To develop the proposed wasteload allocation, the calibrated model was used to determine the seasonal maximum assimilative capacity of the river with a margin of safety applied to seasonal inputs to develop the WLA.

4.1 Seasonal Assimilative Capacity

The QUAL2K model was used to determine the river's maximum assimilative capacity during three seasons' proposed discharge. Modeled effluent discharge limits for the industrial and domestic discharges were derived from the Technology Based Effluent Limits (TBELs) shown in Table 4.1. For secondary treated domestic wastewater effluent, the corresponding $CBOD_5$ is 25 mg/L. The ammonia limit for secondary domestic effluent was assumed to be 12.0 mg/L in accordance with the domestic secondary treatment limits in the Oklahoma Administrative Code. The bioavailable fraction of dissolved organic-nitrogen in the domestic effluent discharge was assumed to be 3.0 mg/L, or 25 percent of the ammonia limit (EPA, 2009; Pehlivanoglu and Sedlak, 2004). Because the industries expected for the Port of Inola Industrial Park do not generally have high levels of ammonia in their wastewaters, the ammonia limit for industrial effluent was assumed to be 5.0 mg/L, or approximately 10 percent of the CBOD limit.

Table 4-1: Applicable TBELs

Applicable TBEL	BOD5 Monthly Average (mg/L)	BOD5 Daily Max (mg/L)
CWT Limits (40 CFR 437)	53	163
POTW Domestic Limits (40 CFR 133)	30	45

CFR = Code of Federal Regulations; CWT = Centralized Waste Treatment; POTW = Publicly Owned Treatment Works

For each season, the predicted minimum daily average DO concentration (sag) downstream of the discharge was compared to the DO criteria, defined as 6.0 mg/L for spring and 5.0 mg/L for summer and winter, with the Port of Inola point source in the model set to the maximum final phase industrial flow of 6.6 MGD and domestic flow of 0.8 MGD. The Port of Inola is only requesting 0.32 MGD for domestic flows from the Port of Inola, however the model was not rerun with this revised value. The Town of Inola's discharge was included at an increased flow of 0.8 MGD, which is consistent with the projected increase in domestic wastewater described in Section 1.2. An additional point source was added to the model to determine the total assimilative capacity of the river for each season.

Headwater boundary conditions for flow, temperature, and water quality are provided in Table 4-2. Seasonal headwater flows are based on the 7Q2 flows described in Section 2.2; seasonal temperatures are defined in the Oklahoma WQS as shown in Table 2-12. Background water quality for the Verdigris River was determined from data collected as part of the OWRB's Beneficial Use Monitoring Program (BUMP) for sampling site 121500020260-001AT, Verdigris River near Inola (US 412), queried from OWRB's Ambient Water Quality Monitoring System (OWRB, 2023). Seasonal input values were estimated using the median value for each parameter having at least 10 seasonal measurements for the period from November 2000 through April 2021, the most recent sampling event. For water quality parameters that were not included in the BUMP, i.e., CBOD, the data collected at Sampling Location 1 for this project were used. Detritus inputs for background conditions were based on assumed 20 percent of observed TSS, consistent with other recent water quality modeling studies completed in Oklahoma (i.e., WLA for City of Shawnee, December 2020, Bartlesville Caney River WLA Studies, November 2018).

No direct measurements or observations were collected for non-point source (NPS) loadings to the river. Since this analysis simulated low flow, high temperature conditions, NPS are not a significant factor. Therefore, NPS BOD was assumed to be 500 pounds per day as used for previous studies (INCOG, 2006; Sofidel, 2017). Durations for the seasonal simulations were 30 days to ensure that downstream conditions achieved steady state.

Table 4-2: Verdigris River Seasonal Background Conditions

Headwater Inputs	Summer (June – October)	Winter (November – March)	Spring (April – May)	Basis of Assumption
Flowrate (cfs)	349	267	960	7Q2
Temperature (°C)	32	18	25	Oklahoma WQS
Conductivity (uS/cm @25°C)	332	359	313	OWRB BUMP Median
Inorganic Solids (mg/L)	7.2	7.2	7.2	80% of mean observed TSS
Dissolved Oxygen (mg/L)	6.28	8.14	7.10	86% of DO saturation at required temperature[1]
CBODfast (mg/L)	3.38	3.38	3.38	Mean of measured $CBOD_{20}$
Organic Nitrogen (mg/L)	0.65	0.75	0.73	OWRB BUMP median (TKN−NH3)
Ammonia Nitrogen (mg/L)	0.055	0.11	0.12	OWRB BUMP median
Nitrate (mg/L)	0.49	0.95	0.43	OWRB BUMP median
Organic Phosphorus (ug/L)	79	126	81	OWRB BUMP median (50% of TP)
Inorganic Phosphorus (SRP) (ug/L)	79	126	81	OWRB BUMP median (50% of TP)
Phytoplankton (mg/L)	5.6	9.9	5.0	OWRB BUMP median
Detritus (POM) (mg/L)	1.8	1.8	1.8	20% of mean observed TSS
Alkalinity (mg $CaCO_3$/L)	100	111	103	Mean observed
pH	7.8	7.9	7.7	OWRB BUMP median

[1]Tetra Tech/City of Bartlesville, 2018.

4.2 Margin of Safety

The Margin of Safety (MoS) values are established by the ODEQ and listed in Table 4-3 from the ODEQ 2012 Continuing Planning Process. A 15% MoS was applied in the determination of WLA for the Port of Inola and Town of Inola domestic discharges. The MoS was applied to the modeled TBELs shown in Table 4-1 for the Port of Inola and Town of Inola discharges. For example, for the industrial discharge with $CBOD_5$ limit of 53 mg/L, the limit was converted to $CBOD_{ult}$ for input to the model, then increased by 15% to add the MoS. For this example, the $CBOD_{ult}$ is 122 mg/L (53 mg/L x 2.3), and the model input value is 140 mg/L (122 mg/L ×1.15). The MoS was applied to the effluent limits for all CBOD, ammonia-nitrogen, and organic-nitrogen discharges for all proposed Port of Inola discharge streams (domestic and industrial), as applicable, as well as for the domestic discharge for the Town of Inola. Thus, the MoS is implicitly incorporated into all evaluations of potential wasteloads for the proposed Port of Inola discharges.

Table 4-3: ODEQ Margin of Safety Percentages based on Model Type and System Complexity

Model	System Complexity	Margin of Safety
Uncalibrated	Multiple Source/Complex Waste	25%
	Single Source/Uniform Waste	20%
Calibrated	Multiple Source/Complex Waste	15%
	Single Source/Uniform Waste	10%
Validated	-----	5%

4.3 Maximum Assimilative Capacity

The maximum assimilative capacity was calculated from the final model input dataset for each season as the sum of total oxygen demand for each point source discharge (Town of Inola, Sofidel Autumn Plant II, and Port of Inola), and any additional wasteload needed to meet the critical DO limit downstream, plus the background oxygen demand in the river and non-point source loads. The maximum assimilative capacity for each of the three seasons is summarized in Table 4-4.

Table 4-4: Maximum Assimilative Capacity (lbs/day)

Season	Assimilative Capacity
Spring (April – May)	51,556
Summer (June – October)	34,200
Winter (November – March)	30,618

A sample plot of simulated dissolved oxygen in the model is provided as Figure 4-1; additional dissolved oxygen plots for all modeled seasons are provided in Appendix E. QUAL2K model input and output files for all seasons are also provided in Appendix E.

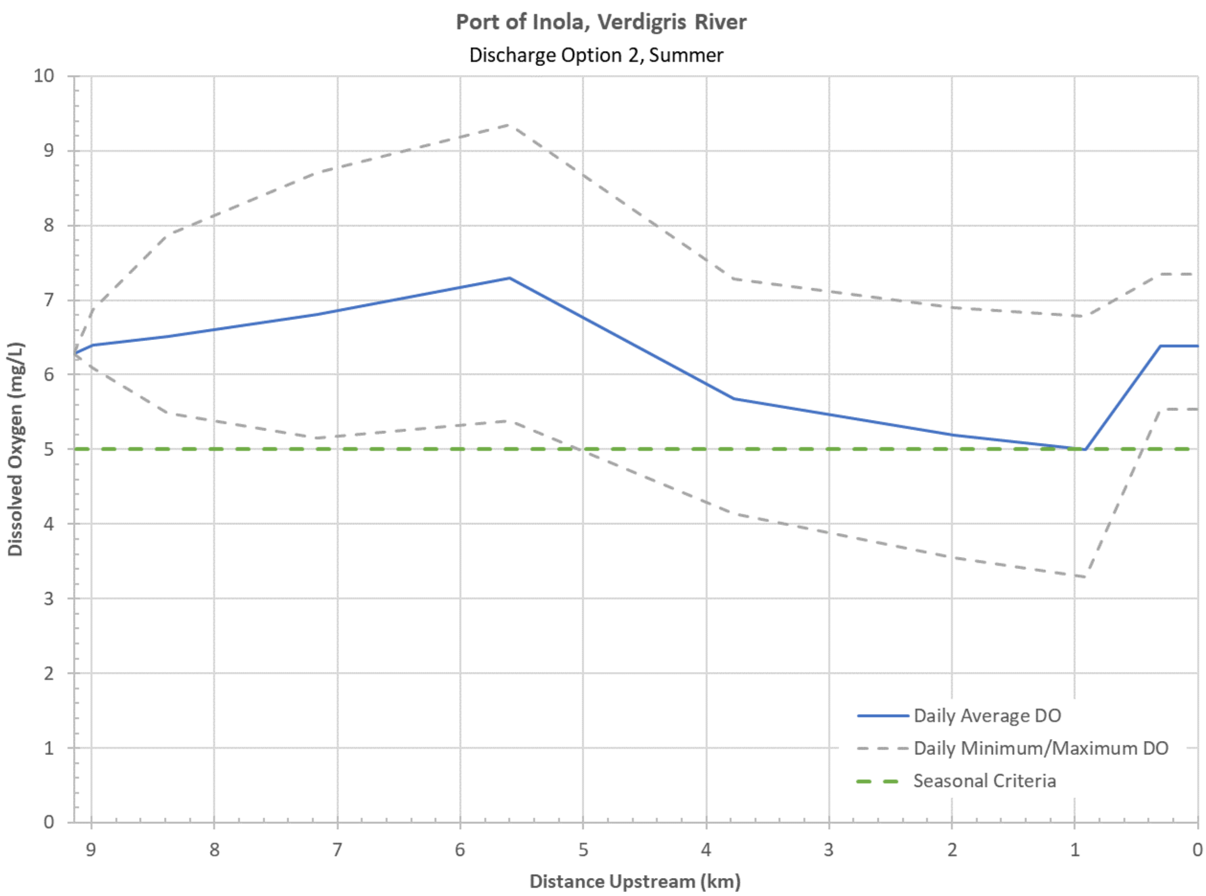

Figure 4-1: Simulated Dissolved Oxygen for Summer

4.4 Wasteload Allocations and Limits

Table 4-5 details the wasteload allocation based on the maximum assimilative capacity, background concentrations, NPS loading, MoS, and reserved capacity. For this analysis, the Port's effluent limits were set to the TBELs shown in Table 4-1 with the 15% MoS added to those limits, discharge flow rates were assigned as described in Section 1.2. The WLA for the Port of Inola for each season was calculated as the sum of the point source loads for domestic and industrial discharges at the TBELs without the MoS added. The increase in WLA for the Town's proposed 0.4 MGD increase in domestic discharge (total of 0.8 MGD) was calculated similarly with the 15% MoS added to the effluent limits.

These calculations were completed for each of the three seasons; assimilative capacities and wasteload allocations are summarized in Table 4-5. These simulations indicate that the desired final phase flows for the Port of Inola can be achieved in Spring, Summer, and Winter while maintaining the critical DO limits downstream with the MoS applied to the effluent discharge limits.

Table 4-5: Allocation Summary (lb/day)

Season	Assimilative Capacity	Wasteload Allocations[1]	Background Allocations[2]	NPS Loading[3]	Margin of Safety	Reserved Capacity after MOS
Spring	51,556	16,022	20,265	500	1,844	12926
Summer	34,200	16,022	6,837	500	1,844	8,998
Winter	30,618	16,022	5,574	500	1,844	6,679

[1]Sum of wasteload allocations for existing and proposed discharges.
[2]Oxygen demand of ambient water quality in the river (CBOD and ammonia).
[3]Non-point source loading assumed to be 500 pounds per day for low-flow conditions.

Wasteload allocations for the Port of Inola are provided in Table 4-6. The effluent flows by discharge type corresponding to these wasteload are provided in Table 4-7. These calculations are provided in Appendix F. The model was run using the 0.8 MGD of domestic wastewater that was originally anticipated for the employees at the Port of Inola. As the Port of Inola project has progressed, new information that better reflects actual employment needs of prospective customers has become available. Therefore, the method of calculating the domestic wastewater produced daily by the Port of Inola was revised to better reflect the employment needs of the interested entities. The Port of Inola is anticipating 0.32 MGD domestic wastewater will be produced onsite after final buildout, which is 40% of the original requested 0.8 MGD. The model was run using the original 0.8 MGD for the Port of Inola. Since the model demonstrates that the Verdigris River has the capacity to accept the combined 0.8 MGD domestic from the Port of Inola, 0.8 MGD domestic wastewater from the Town of Inola, and 6.6 MGD of industrial wastewater, the reduced 0.32 MGD of domestic wastewater for employees will be more protective than the modeled allocations. and the revised 0.8 MGD for the Town.

Wasteload allocations for the Town of Inola are provided in Table 4-8 showing the existing permitted WLA associated with the Town’s current discharge limit of 0.4 MGD and the proposed increased WLA associated with the 0.4 MGD increase in discharge.

Table 4-6: Port of Inola Wasteload Allocation (lb/day)

Season	Modeled Discharge	Proposed Discharge
Spring (April – May)	8,637	**8,199**
Summer (June – October)	8,637	**8,199**
Winter (November – March)	8,637	**8,199**

Table 4-7: Port of Inola Flow Limits (MGD)

Season	Discharge Type	Modeled Discharge	Proposed Discharge
Spring (April – May)	Domestic (Port)	0.8	**0.32**
	Domestic (Inola)	0.8	**0.8**
	Industrial	6.6	**6.6**
Summer (June – October)	Domestic (Port)	0.8	**0.32**
	Domestic (Inola)	0.8	**0.8**
	Industrial	6.6	**6.6**
Winter (November – March)	Domestic (Port)	0.8	**0.32**
	Domestic (Inola)	0.8	**0.8**
	Industrial	6.6	**6.6**

Table 4-8: Town of Inola Wasteload Allocation (lb/day)

Season	Existing* (0.4 MGD)	Proposed (0.8 MGD)
Spring (April – May)	415	731
Summer (June – October)	296	731
Winter (November – March)	415	731

*Ammonia limits for existing plant are based on the Lagoon Secondary ammonia limits of 7.2 mg/L for summer and 15.4 mg/L for spring and winter

5.0 CONCLUSION

This document summarizes the field activities and WLA study for the Port of Inola proposed industrial park development consisting of a variety of industries that encompass manufacturing, industrial, and warehousing operations. The proposed industrial park site includes approximately 2,400 acres of undeveloped land located southwest of the intersection of E 620 Rd and S 4200 Rd located adjacent to the Verdigris River in the Town of Inola (Town), Oklahoma's corporate boundary. The proposed development includes the design and construction of a wastewater treatment plant designed to treat both the industrial and domestic wastewaters generated at the industrial park by tenants and port facilities. Additionally, the Port of Inola will work with the Town of Inola to construct the necessary updates to the Town's domestic wastewater treatment plant and combine the associated wasteload allocations established in NPDES permit OK0033618 with the new discharges from the Port of Inola at a new outfall located south of the Town's existing permitted outfall.

Wasteload allocations for the Port of Inola are provided in Table 5-1. The effluent flows by discharge type (domestic and industrial) corresponding to these wasteloads are provided in Table 5-2. Wasteload allocations for the Town of Inola are provided in Table 5-3. These calculations are provided in Appendix F.

Table 5-1: Port of Inola Wasteload Allocation (lb/day)

Season	Modeled Discharge	Proposed Discharge
Spring (April – May)	8,637	**8,199**
Summer (June – October)	8,637	**8,199**
Winter (November – March)	8,637	**8,199**

Table 5-2: Port of Inola Flow Limits (MGD)

Season	Discharge Type	Modeled Discharge	Proposed Discharge
Spring (April – May)	Domestic (Port) Domestic (Inola) Industrial	0.8 0.8 6.6	**0.32** **0.8** **6.6**
Summer (June – October)	Domestic (Port) Domestic (Inola) Industrial	0.8 0.8 6.6	**0.32** **0.8** **6.6**
Winter (November – March)	Domestic (Port) Domestic (Inola) Industrial	0.8 0.8 6.6	**0.32** **0.8** **6.6**

Table 5-3: Town of Inola Wasteload Allocation (lb/day)

Discharge Option	Existing* (0.4 MGD)	Total (0.8 MGD)
Spring (April – May)	415	731
Summer (June – October)	296	731
Winter (November – March)	415	731

*Ammonia limits for existing plant are based on the Lagoon Secondary ammonia limits of 7.2 mg/L for summer and 15.4 mg/L for spring and winter

Following ODEQ review and approval of the WLA Report, the Port of Inola understands that the report will be submitted to EPA for review and approval. Once EPA approval has been granted, the WLA will need to be posted for a 45-day public comment period, which may include a public meeting. Pending EPA approval of the WLA, the Port of Inola expects to prepare an NPDES permit discharge application for submittal to ODEQ.

6.0 REFERENCES

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APPENDIX A – APPROVED TULSA PORT OF INOLA WASTELOAD ALLOCATION WORK PLAN

APPENDIX B – GREEN COUNTRY TESTING WATER QUALITY RESULTS

APPENDIX C – FLOW DATA AND 7Q2 CALCULATIONS

(Appendix provided in a digital format only)

APPENDIX D – QUAL2K CALIBRATION MODEL INPUT

(Appendix also provided in a digital format)

APPENDIX E – QUAL2K INPUT AND OUTPUT, SPRING, SUMMER, AND WINTER DO LIMIT (DISCHARGE OPTIONS 1, 2, AND 4)

(Appendix also provided in a digital format)

APPENDIX F – WLA WORKSHEETS

APPENDIX G – SIGNED RESOLUTION OF THE BOARD OF TRUSTEE OF THE TOWN OF INOLA TO SUBMIT APPLICATION TO OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY FOR NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) PERMIT

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