

YUKON WWTP WATER QUALITY MODEL RESULTS AND WLA REPORT

CITY OF YUKON, OKLAHOMA

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0	04/06/2026	City of Yukon submitted to ODEQ Yukon WWTP Water Quality Model Results and WLA Report
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Distribution List

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EXECUTIVE SUMMARY

A water quality model (QUAL2Kw Ver 5) was developed for the North Canadian River to support a Waste Load Allocation (WLA) study for the proposed expansion of the Yukon Wastewater Treatment Plant (WWTP). The study evaluates the regulatory impacts of increasing the WWTP flow to 4.5 MGD. QUAL2Kw was chosen due to its effectiveness in simulating water quality with limited site-specific data, particularly for dissolved oxygen (DO) and related parameters.

Model calibration, focused on September 2023 data, showed excellent agreement with field measurements for flow (PBIAS 4%), depth (14%), temperature (3%), DO (8%) and phytoplankton 18%. While model predictions for CBOD_f and ammonia (NH₄) and were less accurate with PBIAS 112% and 79% respectively. The model successfully captured the DO dynamics, including the effects of algal decay and DO consumption.

Simulation results indicate localized DO sag, increased ammonia, and higher bottom algae near the WWTP discharge, with recovery downstream. Importantly, predicted minimum daily average DO concentrations downstream meet all regulatory Water Quality Standards (6.0 mg/L in spring; 5.0 mg/L in summer and winter) after applying a 15% Margin of Safety (MOS).

1.0 PROJECT INTRODUCTION AND BACKGROUND

The purpose of this project has been to develop a water quality model for the North Canadian River and perform a Waste Load Allocation (WLA) study for the Yukon Wastewater Treatment Plant (WWTP) expansion. AECOM is a subconsultant to TEIM DESIGN to evaluate hydraulic and wastewater treatment capacities of the existing Yukon Wastewater Treatment Plant (WWTP) and to develop wastewater treatment alternatives for future wastewater flow conditions. The Waste Load Allocation (WLA) study as part of the preliminary Wastewater Treatment Plan Design Report (AECOM, 2022). The water quality model selected for this study is QUAL2Kw Ver 5 model. This report presents the model development, model calibration, and model scenario runs carried out by AECOM and AECOM subcontracted the field sampling to GEI consultants. AECOM's modeling and field sampling workplan was presented to the Oklahoma Department of Environmental Quality (ODEQ) and carried out after ODEQ approval. The intent of this document is to evaluate the regulatory impacts of a proposed expansion of the City of Yukon Wastewater Treatment Plant (WWTP).

1.1 PROPOSED EL RENO AND YUKON WWTP DISCHARGES

The proposed discharge capacity for Yukon Wastewater Treatment Plant (WWTP) is 4.5 MGD and for the El Reno Wastewater Treatment Plant (WWTP) is 4 MGD. ODEQ requested development of North Canadian River water quality model in 2021 during the initial permit application process. In 2023 ODEQ requested AECOM to expand the water quality modeling program to include additional North Canadian River water quality sampling and flow measurements that extended approximately fifteen miles further upstream of the Yukon WWTP (at the El Reno USGS station). The modeling program was expanded to address the ODEQ requirements and two Canadian River flow measuring and water sampling events were completed in 2023. The subsequent water quality modeling has been progressing since early 2024. ODEQ has indicated that the main water quality constituent of concern is dissolved oxygen (DO) and the impacts of the Yukon WWTP discharges to the Canadian River DO concentrations. TEIM DESIGN has estimated that the design wastewater flows after expansion of the WWTP to meet the demands of future growth in the city is 4.5 MGD.

1.2 BACKGROUND

The background data used to develop and run QUAL2Kw model are presented in Section 2. The modelling methodology, modelling inputs, statistical analysis, and results are presented in Section 3. Waste Load Allocation (WLA) results are presented in Section 4. A map of the North Canadian River Study Area is presented in Figure 1.

2.0 DATA COLLECTION

2.1 DESIGN WASTEWATER FLOWS FROM YUKON WWTP

The proposed design wastewater flows from Yukon WWTP WLA was approved by ODEQ in 2025. The proposed discharge option was modeled and assessed to determine the best discharge scenario for the future development of the Yukon WWTP. The discharge location is 35°31'58.24"N and 97°45'20.42"W. The QUAL2Kw model was run with both El Reno and Yukon outfall and water quality was assessed for the Yukon WWTP wastewater flows for the discharge 4.5 MGD. Figure 2 shows the location of the Yukon WWTP Outfall.

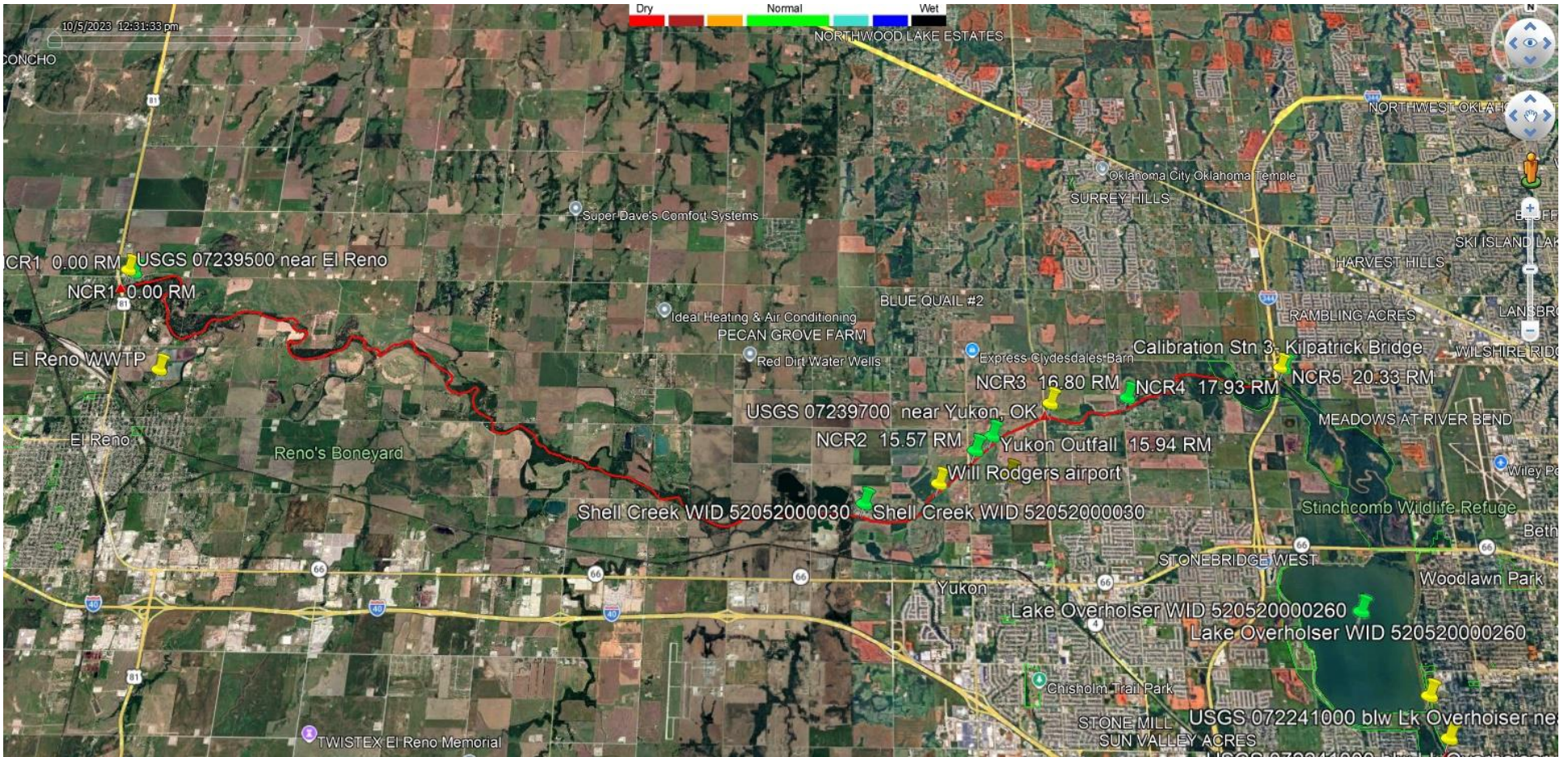


Figure 1 North Canadian River Study AREA

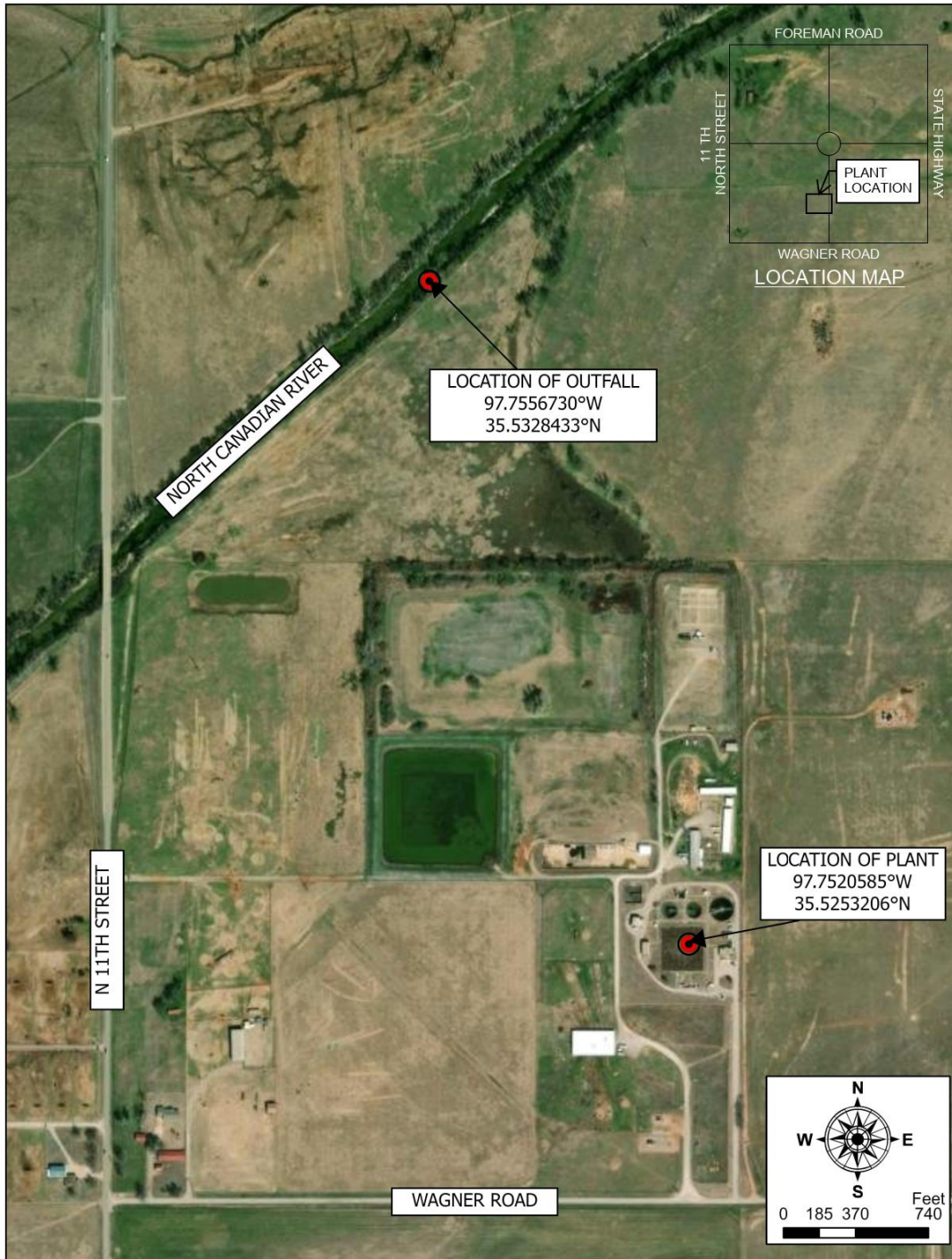


FIGURE 2 YUKON WWTP OUTFALL LOCATION

2.2 RIVER DISCHARGE AND WATER QUALITY CONDITIONS

The North Canadian River is classified as a perennial stream. It is a tributary of the Canadian River (Figure 1).

The Oklahoma Water Quality Standards (OWQS, OAC 252:730) lists the North Canadian River as having the following beneficial uses:

1. Public and Private Water Supplies
2. Fish and Wildlife Propagation / Warm Water Aquatic Community
3. Agriculture
4. Primary Body Contact Recreation
5. Aesthetics and
6. Fish Consumption

For assessing water quality in the North Canadian River in the vicinity of the Yukon WWTP discharge point, data from United States Geological Survey (USGS) gauging station (USGS 07239500 (14 miles upstream from the Yukon WWTP's outfall on North Canadian River) were processed (Figure 3). This gauging station is located near El Reno at the U.S. Highway 81 crossing.

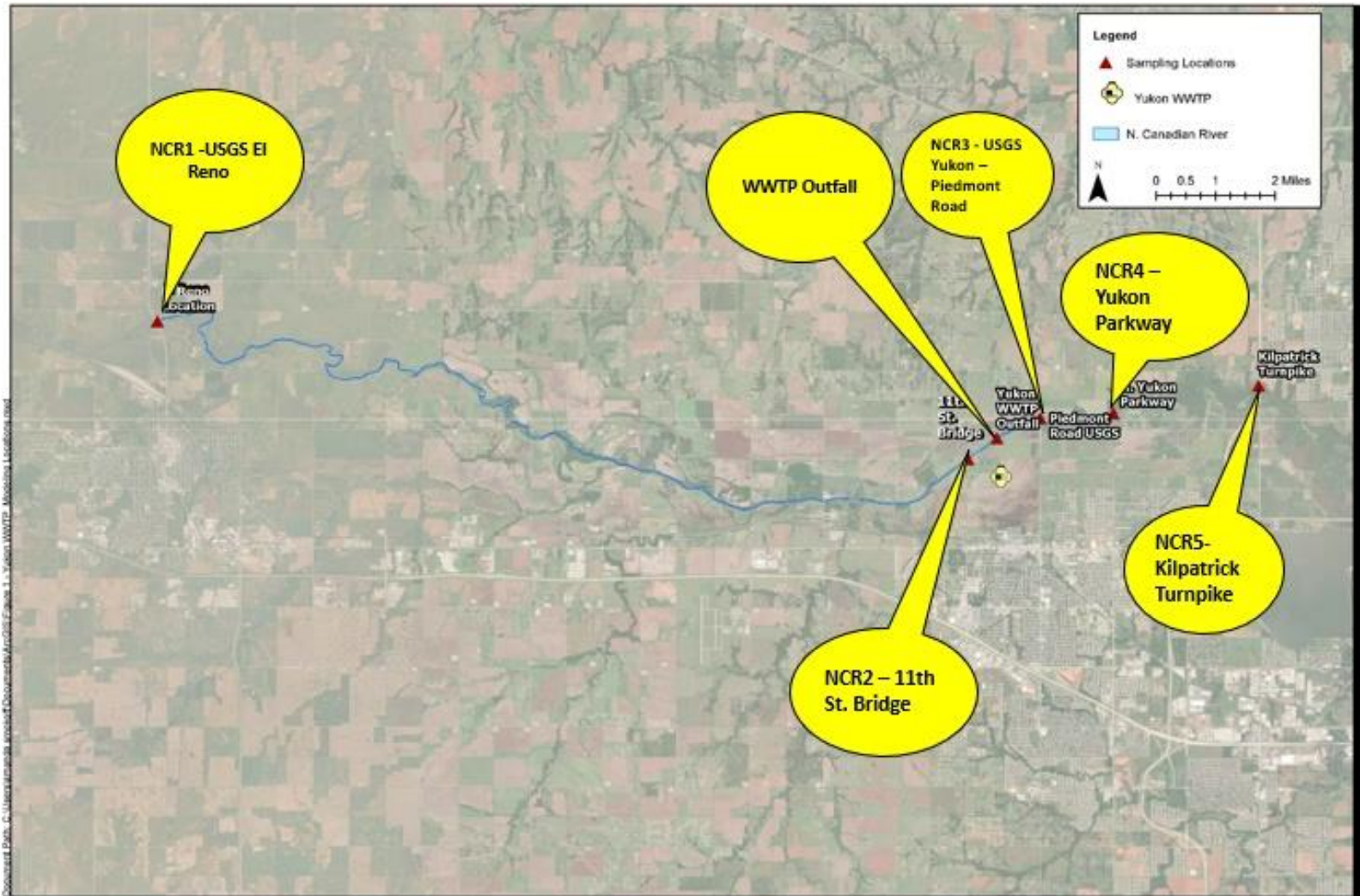


Figure 3 NORTH CANADIAN RIVER SAMPLING LOCATION

2.2.1 NORTH CANADIAN RIVER SAMPLING LOCATIONS

Water quality and flow data on the North Canadian River, near Yukon Oklahoma, were collected to calibrate the water quality model. The water quality model was developed to identify and resolve concerns with water quality conditions in particular Dissolved Oxygen (DO) concentrations in the water column related to the expansion of the City of Yukon's wastewater treatment plant (WWTP). Yukon's WWTP during the field measurements were rated as 3 MGD. TEIM DESIGN has estimated that the design wastewater flows after expansion of the WWTP to meet the demands of future growth in the city is 4.5 MGD.

Two synoptic water quality monitoring events were made on the North Canadian River from the North 11th Street Bridge downstream to the John Kilpatrick Turnpike Bridge. This includes four monitoring stations on the North Canadian River, including one monitoring station that characterizes the WWTP outfall. one of the four stations was collocated at the USGS 07239700 (North Canadian River near Yukon, OK) stream gaging station which is 0.87 river miles downstream of the WWTP outfall. One station was established upstream of the WWTP outfall to characterize background conditions while the remaining two stations were downstream of the USGS gage. The measurements were made along 4.7 river miles of the North Canadian River.

The water quality measurements were made synoptically during streamflow conditions that represent critical periods in terms of water quality for aquatic life use, as well as the typical regulatory low flow periods for permitted discharges.

Based on USGS 07239700 flow and temperature data and various constraints measurements were made in September 2023 and November 2023 that generally represent the time frame when seasonal maximum water temperatures are observed in the study reach, which naturally reduce instream dissolved oxygen conditions.

An ISCO 6712 portable water sampler was installed, equipped with a pressure transducer to monitor water elevations that were translated into flow for model development. Each ISCO sampler was programmed to collect three two-hour composite samples in a 24-hour period for analysis of selected water quality parameters (Table 1). Each ISCO sampler was programmed to collect nine sample aliquots over each two-hour period. Following each sample period, the

aliquots were composited to create one sample, per period, per station and submitted for testing. All samples were stored on ice and in the dark, complete the chain of custody form and submitted the samples daily to Accurate Environmental Laboratories in Oklahoma City, OK.

The sampling program created three samples per day for each monitoring station. The in-situ water quality conditions were measured (e.g., temperature, pH, conductivity, and dissolved oxygen) at each station. Stream discharge was measured at the station upstream of the outfall and at the furthest downstream station each day of the study.

Three HOBO U26 DO Loggers were installed, one upstream of the outfall and two downstream of outfall to continuously measure and record dissolved oxygen concentrations and temperature. These data loggers recorded how conditions changed over a diurnal cycle and longitudinally instream. The ISCO water level and HOBO dissolved oxygen and temperature data were downloaded from each station. Figures 4 to 11 show the water quality sampling analyses plots for September and November 2023

TABLE 1 LIST OF PARAMETERS ANALYZED FOR EACH COMPOSITE WATER QUALITY SAMPLE.

Parameter	Method
Alkalinity, Total	SM 2320 B
Ammonia, Total	SM 4500 NH3 C
Ammonium, as NH4	SM 4500 NH3 C
CBOD 5-day	SM 5210 B
Kjeldahl Nitrogen	SM 4500 Norg C
Nitrate as N	EPA 300.0
Nitrite as N	EPA 300.0
Ortho-Phosphorus, as P	SM 4500 P E
Phosphate, Total as PO4	SM 4500 P E
Phosphorus, Total as P	SM 4500 P E
Total Suspended Solids	SM 2540 D
pH, Lab	SM 4500 H+ B

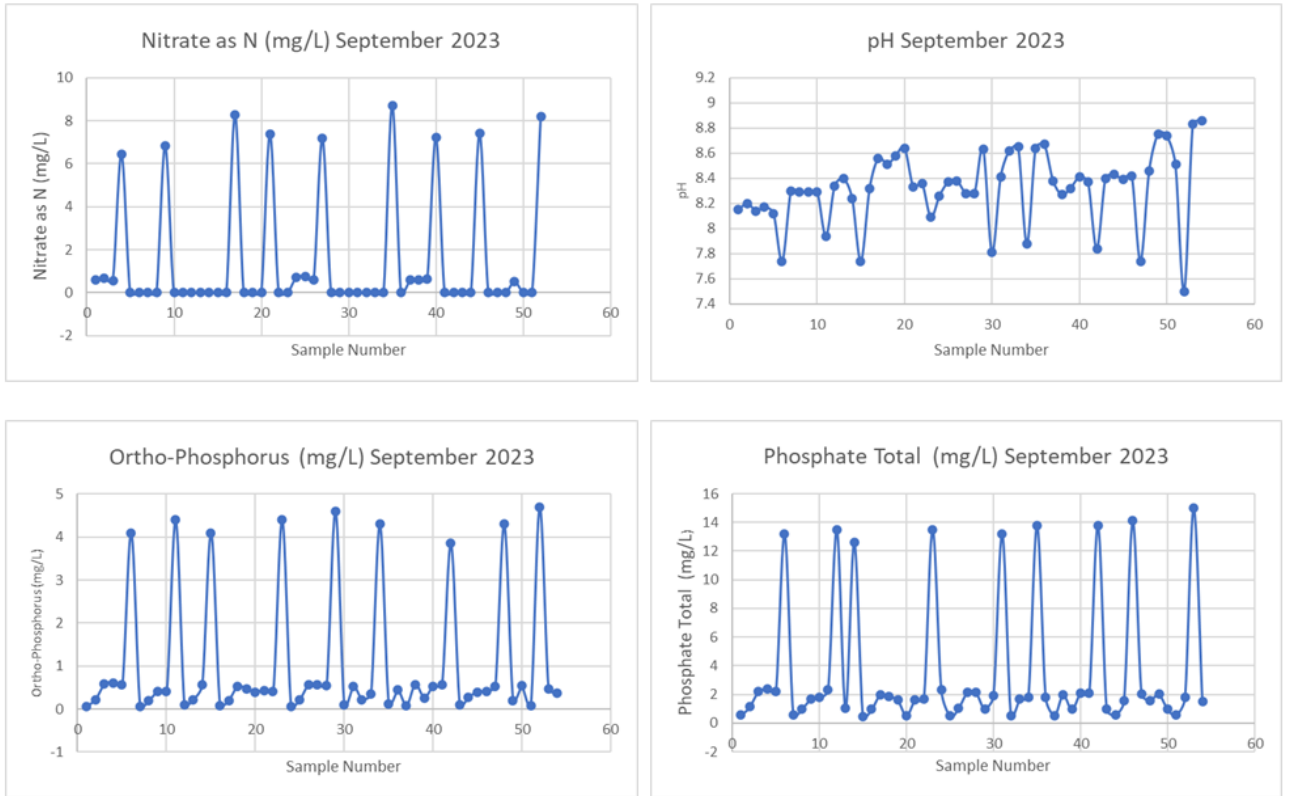


FIGURE 4 WATER QUALITY SAMPLING ANALYSES PLOTS SEPTEMBER 2023. X-AXIS IS SAMPLE NUMBER. THE DATA IS ALL STATIONS TO SHOW DATA RANGE.

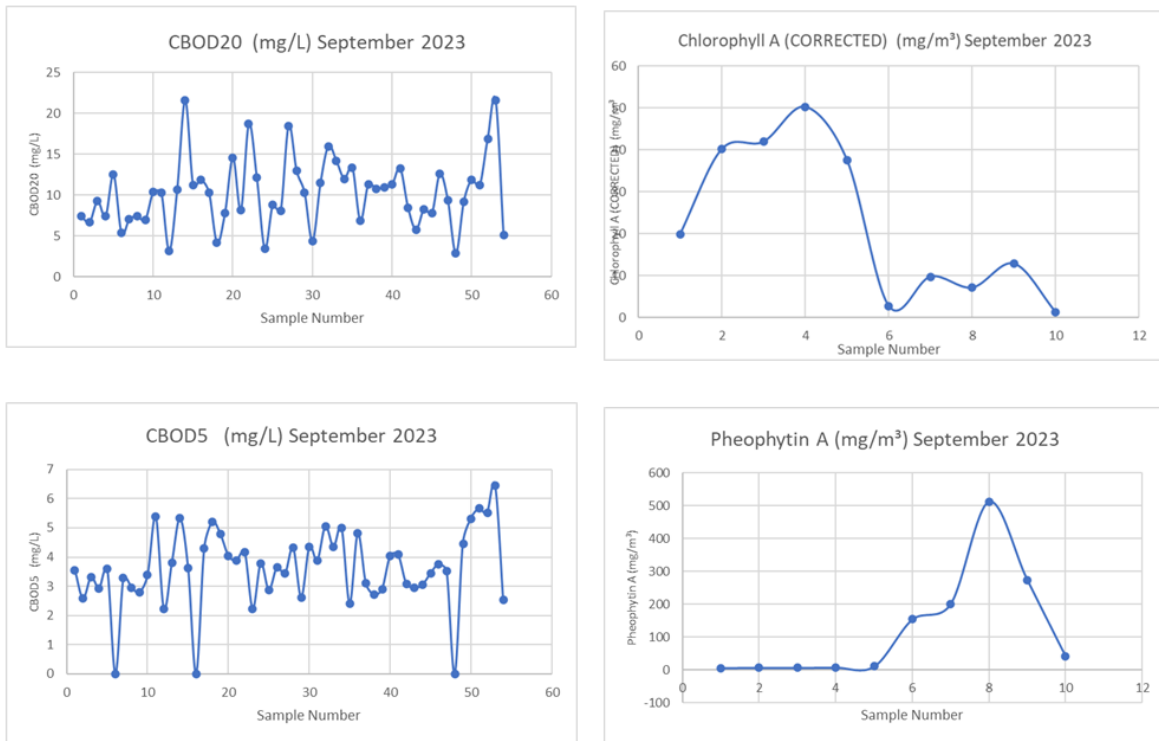


FIGURE 5 WATER QUALITY SAMPLING ANALYSES PLOTS SEPTEMBER 2023. X-AXIS IS SAMPLE NUMBER. THE DATA IS ALL STATIONS TO SHOW DATA RANGE.

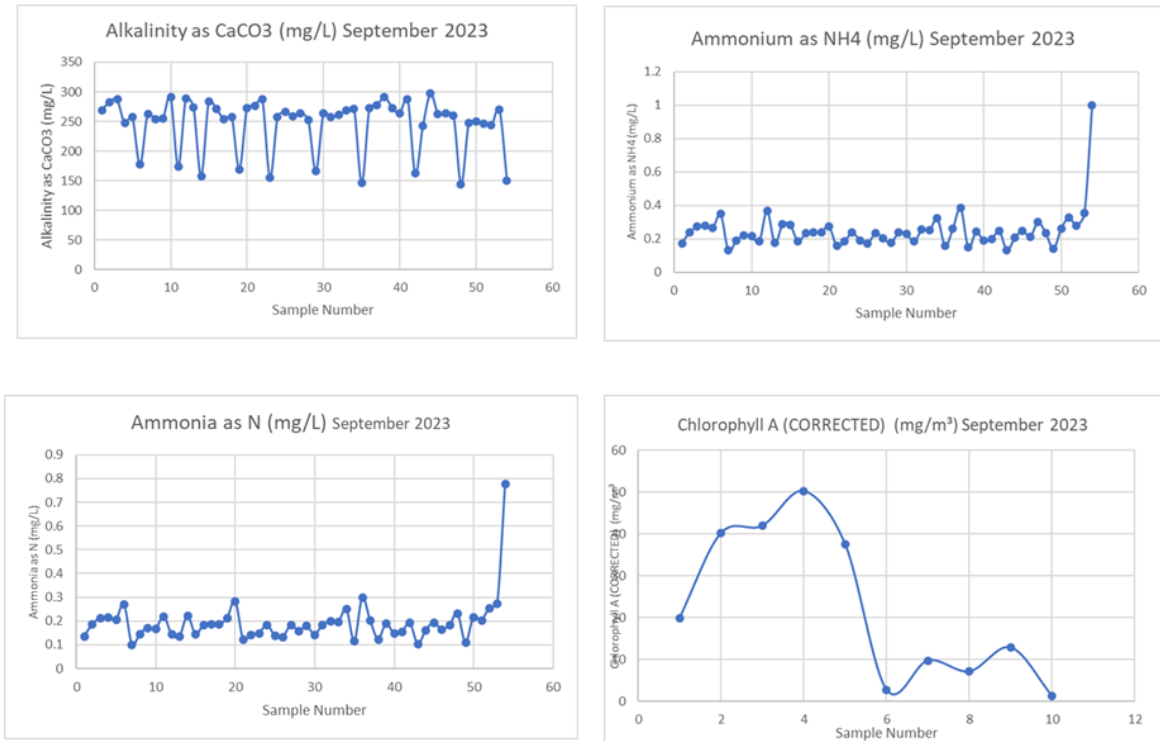


FIGURE 6 WATER QUALITY SAMPLING ANALYSES PLOTS SEPTEMBER 2023. X-AXIS IS SAMPLE NUMBER. THE DATA IS ALL STATIONS TO SHOW DATA RANGE.

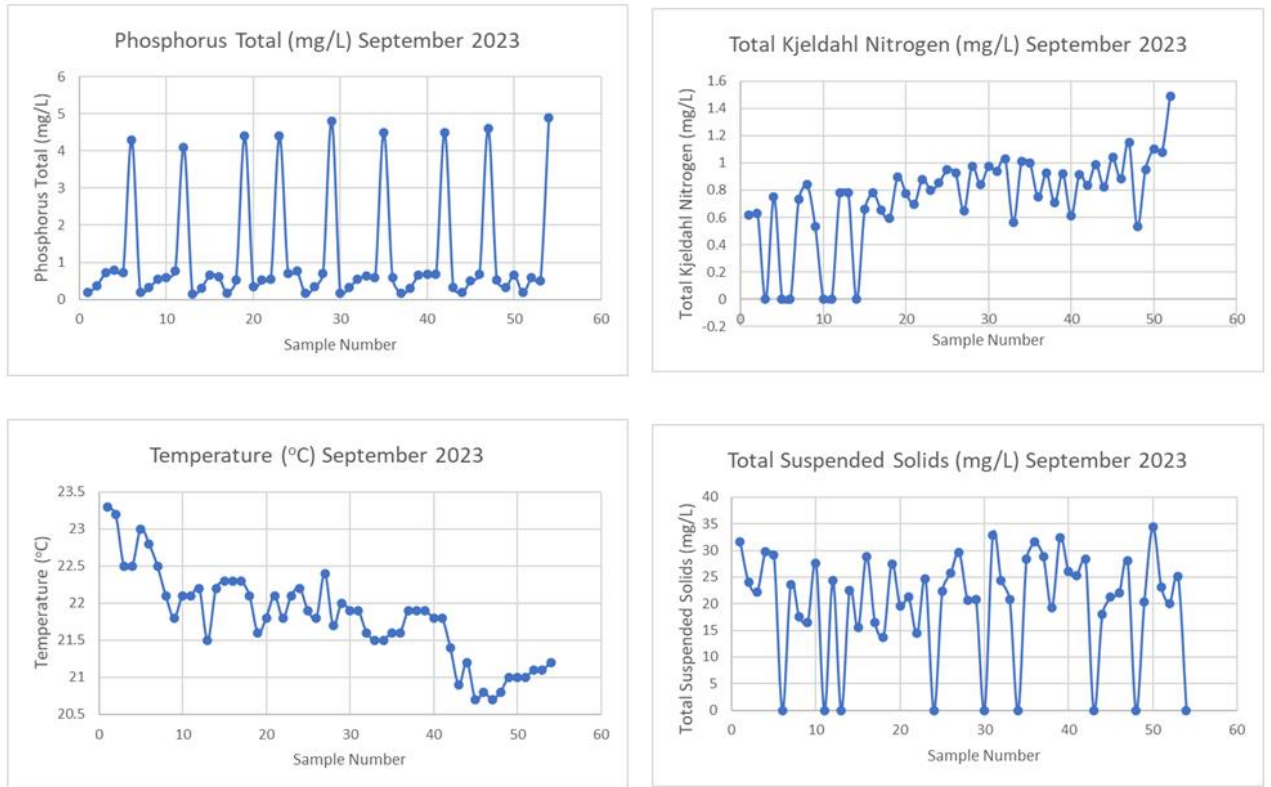


FIGURE 7 WATER QUALITY SAMPLING ANALYSES PLOTS SEPTEMBER 2023. X-AXIS IS SAMPLE NUMBER. THE DATA IS ALL STATIONS TO SHOW DATA RANGE.

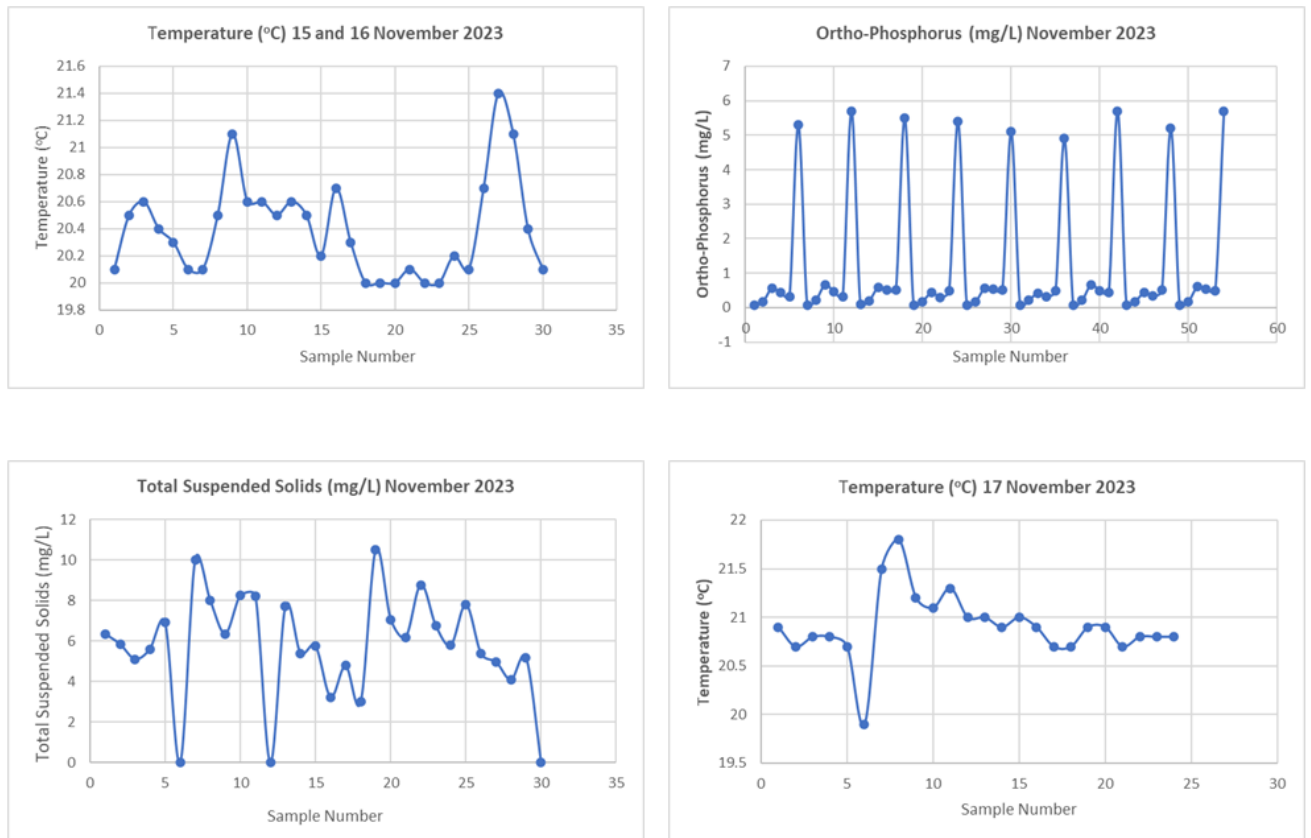


FIGURE 8 WATER QUALITY SAMPLING ANALYSES PLOTS NOVEMBER 2023. X-AXIS IS SAMPLE NUMBER. THE DATA IS ALL STATIONS TO SHOW DATA RANGE.

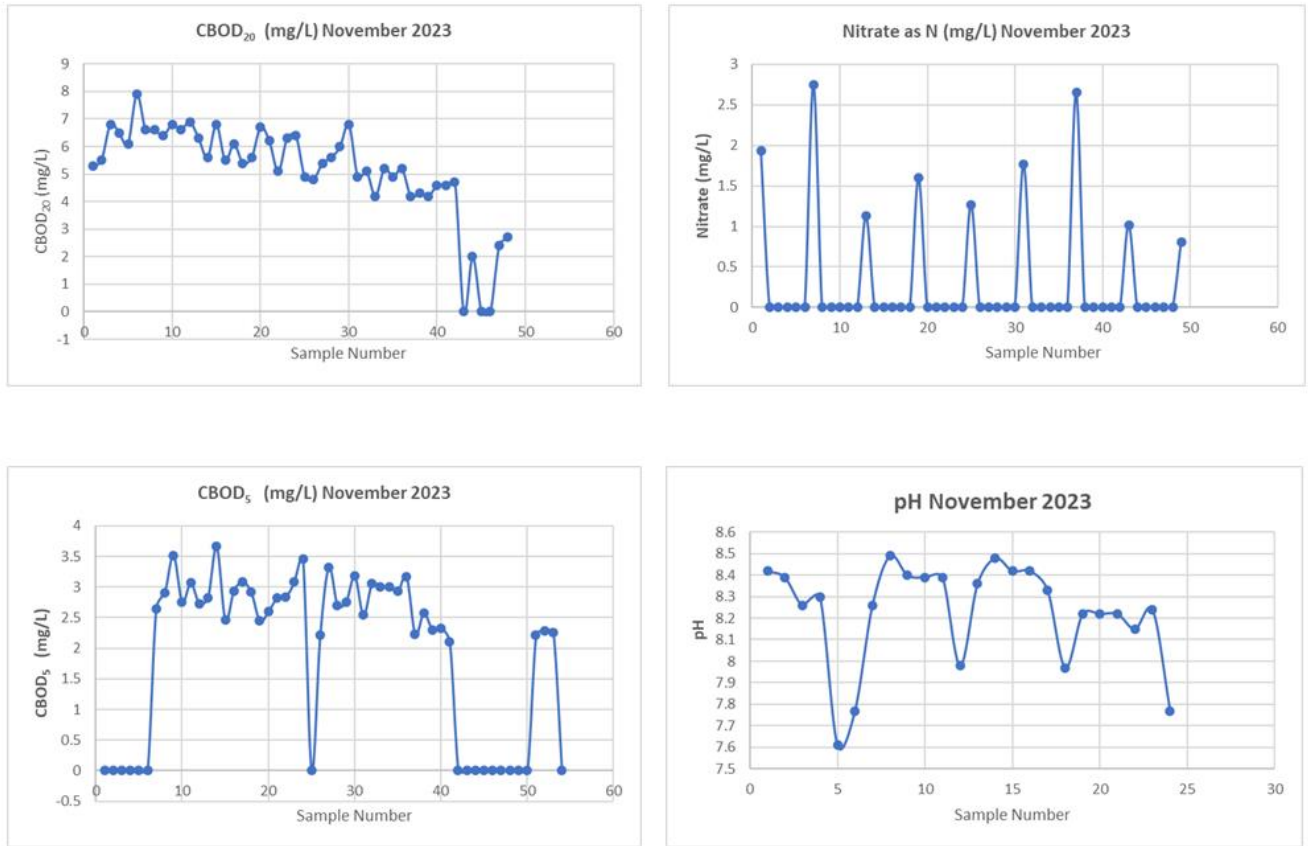


FIGURE 9 WATER QUALITY SAMPLING ANALYSES PLOTS NOVEMBER 2023. X-AXIS IS SAMPLE NUMBER. THE DATA IS ALL STATIONS TO SHOW DATA RANGE.

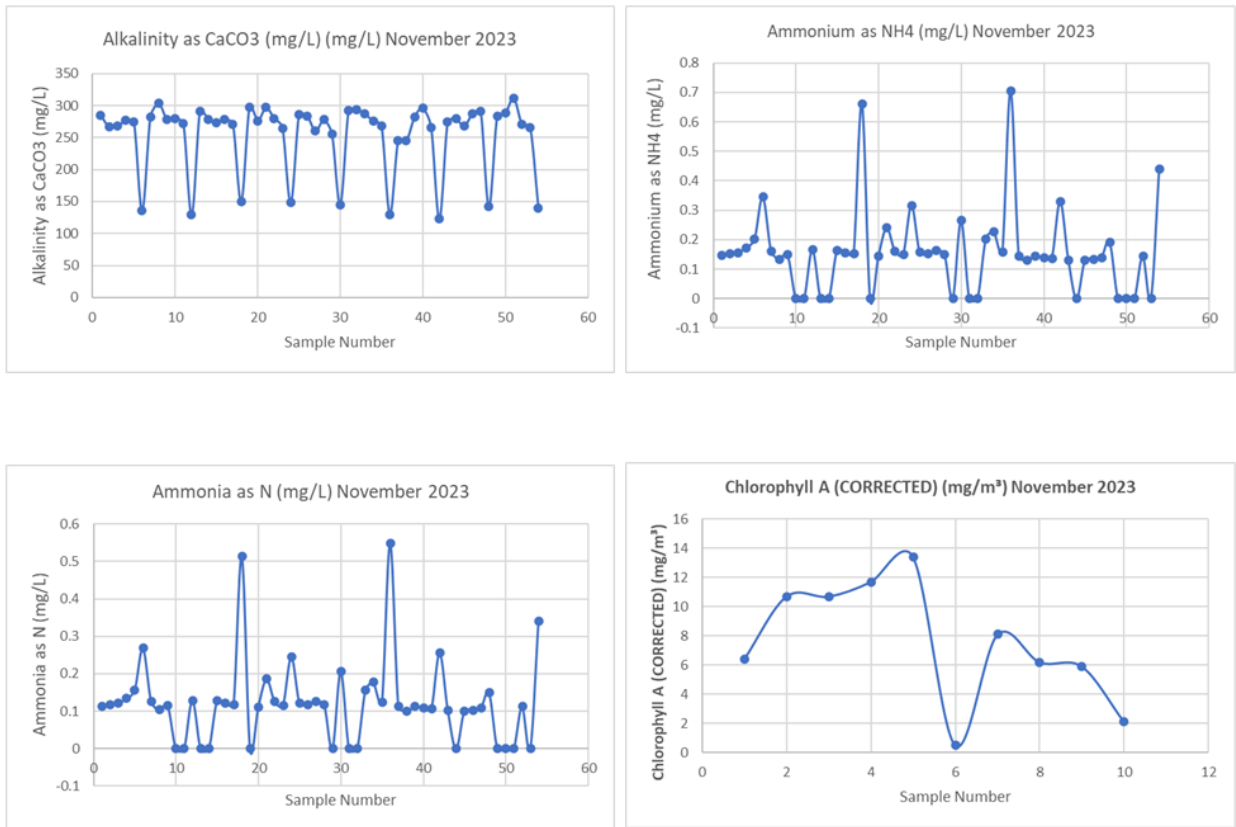


FIGURE 10 WATER QUALITY SAMPLING ANALYSES PLOTS NOVEMBER 2023. X-AXIS IS SAMPLE NUMBER. THE DATA IS ALL STATIONS TO SHOW DATA RANGE.

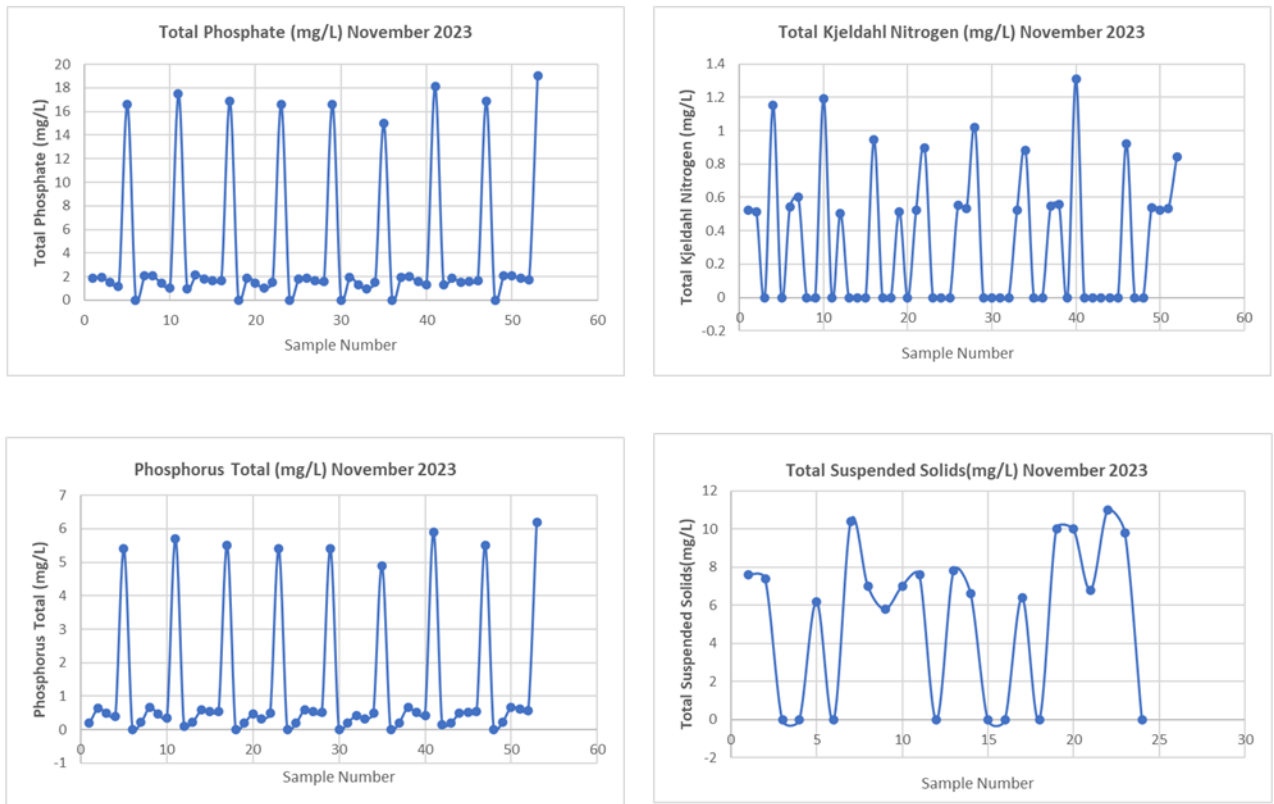


FIGURE 11 WATER QUALITY SAMPLING ANALYSES PLOTS NOVEMBER 2023. X-AXIS IS SAMPLE NUMBER. THE DATA IS ALL STATIONS TO SHOW DATA RANGE.

3.0 QUAL2KW MODEL DEVELOPMENT AND CALIBRATION

3.1 MODEL DEVELOPMENT AND CALIBRATION

The model used for this study was QUAL2Kw version 5 to represent the North Canadian River from El Reno to Kilpatrick Turnpike Bridge. The QUAL2Kw water quality model is a widely used one-dimensional model designed for rivers and streams under steady-state flow conditions. Numerous studies have used QUAL2Kw to model the impacts on water quality of both point and non-point pollution sources, to assess pollution load capacity, and to frame control strategies for water quality management of rivers and streams. Its flexible kinetic structure and genetic algorithm-based calibration make it a preferred tool for researchers and policymakers. However, there are few model limitations that includes steady-state flow assumption, simplified hydrodynamics, and challenges in representing temporal variability.

QUAL2Kw Model was used in a steady state mode to simulate flow, river water depth, temperature, phytoplankton, CBOD, Dissolved Oxygen, NH₃, NH₄, TP, and TN. Model calibration steps include the adjustment of model coefficients and parameters until the model predictions best match the observations. The calibration of the model to the ambient river conditions was carried out using the following steps:

Step 1. Calibrate river hydraulics (flow, river water depth) by reproducing measurements of velocity and depth of flow at selected river transects.

Step 2. water quality constituents, temperature, phytoplankton, CBOD, NH₃, NH₄, TP, and TN were calibrated. The DO balance was calibrated as a final step.

The average values observed during the September and November 2023 sampling period were used to develop model initial conditions and boundary conditions.

QUAL2Kw model calibration was carried out by adjusting the kinetic rates and coefficients to match simulated water quality results with field data utilizing manual trial-and-error. The auto-calibration feature of the model was not used at the request of ODEQ.

3.2 STATISTICAL ANALYSIS METHODS

The statistical calculations used to compare model calculated versus measured values consisted of percent bias (PBIAS) and regression analysis including coefficient of determination (R²). PBIAS measures the average tendency of the simulated data to be larger or smaller than corresponding observed values. The optimal value of PBIAS is 0.0, with low-magnitude values indicating accurate model simulation. Positive values indicate model underestimation bias, and negative values indicate model overestimation bias.

PBIAS is calculated with Equation 1 where PBIAS is the deviation of data being evaluated, expressed as a percentage.

$$PBIAS = \left[\frac{\sum_{i=1}^n (Y_i^{obs} - Y_i^{sim}) * (100)}{\sum_{i=1}^n (Y_i^{obs})} \right] \quad (\text{Equation 1})$$

These metrics are a direct measure of the model's performance and error tolerance and provide a useful measure of the quality of model calibration. This tolerance needs to consider errors inherent in both measuring and modeling of watershed water quality. Donigian (2002) proposed a PBIAS target of less than 15% as being very good for water quality/nutrient parameters and less than 25% as being good.

The regression equations are shown Tables 2 to 8 show a good linear relationship between model and measured values. Regression equations closer to "y model = 1.0 * x measured" show better model accuracy.

Model calibration results are presented on Figures 12 to 23. PBIAS and regression analysis results are presented in Tables 2 to 8.

3.3 MODEL CALIBRATION RESULTS AND DISCUSSIONS

QUAL2Kw model is preferable over other water quality models for this project because of its ability in evaluating and controlling water quality since limited site-specific data is available for model

calibration. The focus has been to calibrate the model for dissolved oxygen and other parameters that affect dissolved oxygen concentration.

Figures 12 to 14 show the effect of Yukon WWTP discharges to river flow, water depth, and temperature of the North Canadian River (The river) 9.2 km upstream of Kilpatrick Bridge. The effect of water quality changes is more pronounced in the calibration period (September 2023) for dissolved oxygen, ammonia, and bottom algae in the profile plots (Figures 16, 18 and 20).

In these Figures, the solid black line represents the steady state model results, the red dotted line represents diurnal fluctuation, and square black dots represent measured values. These profiles show DO sag, ammonia increase, and bottom algae increase at the location of WWTP discharges showing its effect on water quality and recover further downstream. The river meets the dissolved oxygen standard (above 5mg/L) during the calibration period all along the river model domain.

The model calibration results show excellent agreement with the measured data with PBIAS for flow 4%, PBIAS for depth 14%, PBIAS for temperature 3%, and PBIAS for phytoplankton 18% (Tables 2 to 4 and 8). Good agreement was found between the model predictions and field data for DO since QUAL2Kw has capability to simulate the conversion of algal death to BOD, DO production and DO consumption. The water quality model calibration results also show good agreement for dissolved oxygen with the measured data with PBIAS for DO 8%. However, agreement between model results for CBOD_f and NH₄ are not as good as DO with PBIAS 112%, 79% respectively (Tables 6 and 7).

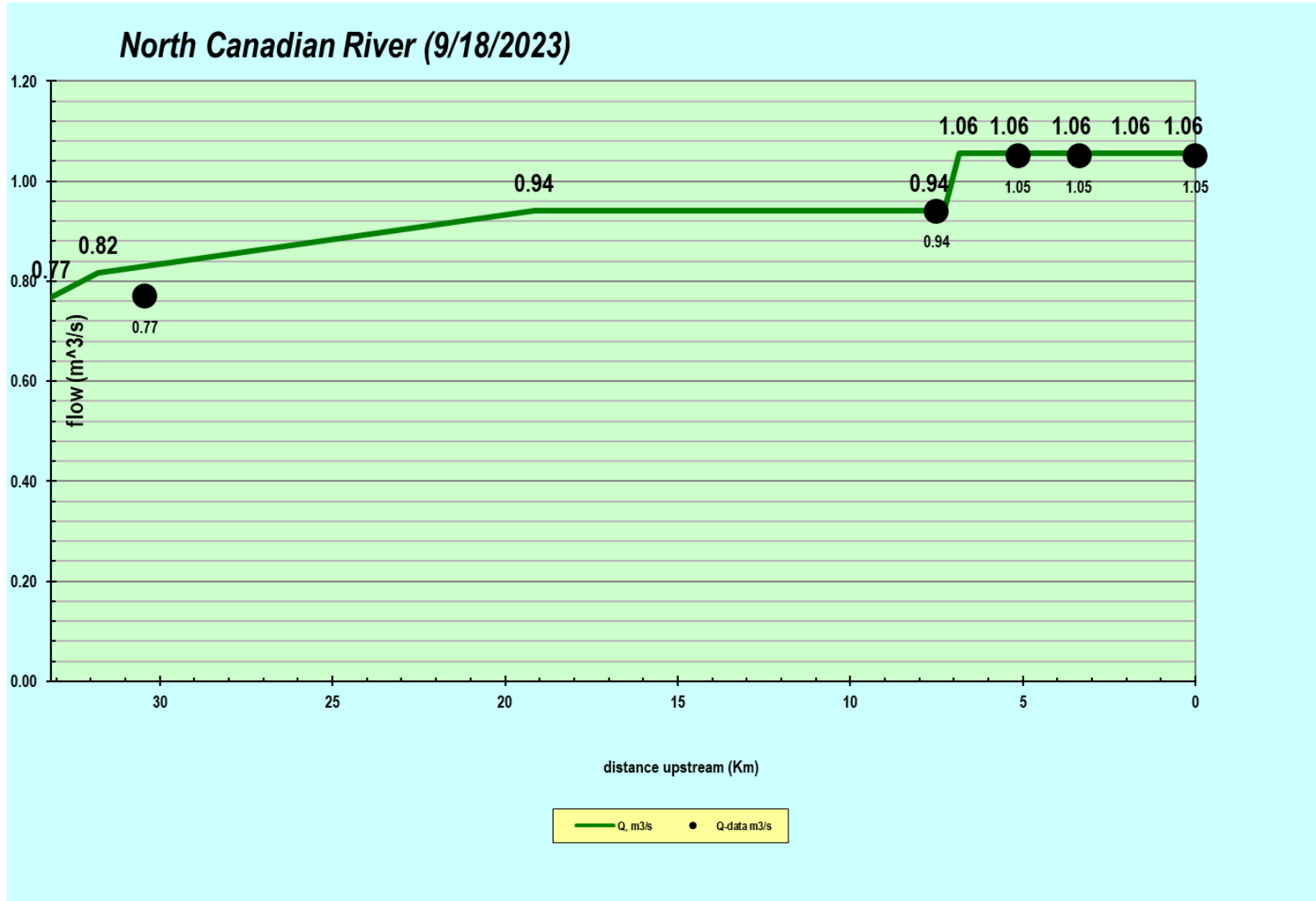


FIGURE 12 QUAL2Kw CALIBRATION RESULTS FOR RIVER FLOW (M3/S). THE SOLID BLACK LINE REPRESENTS THE STEAD STATE MODEL RESULTS. CIRCLE AND SQUARE BLACK DOTS REPRESENT MEASURED VALUES.

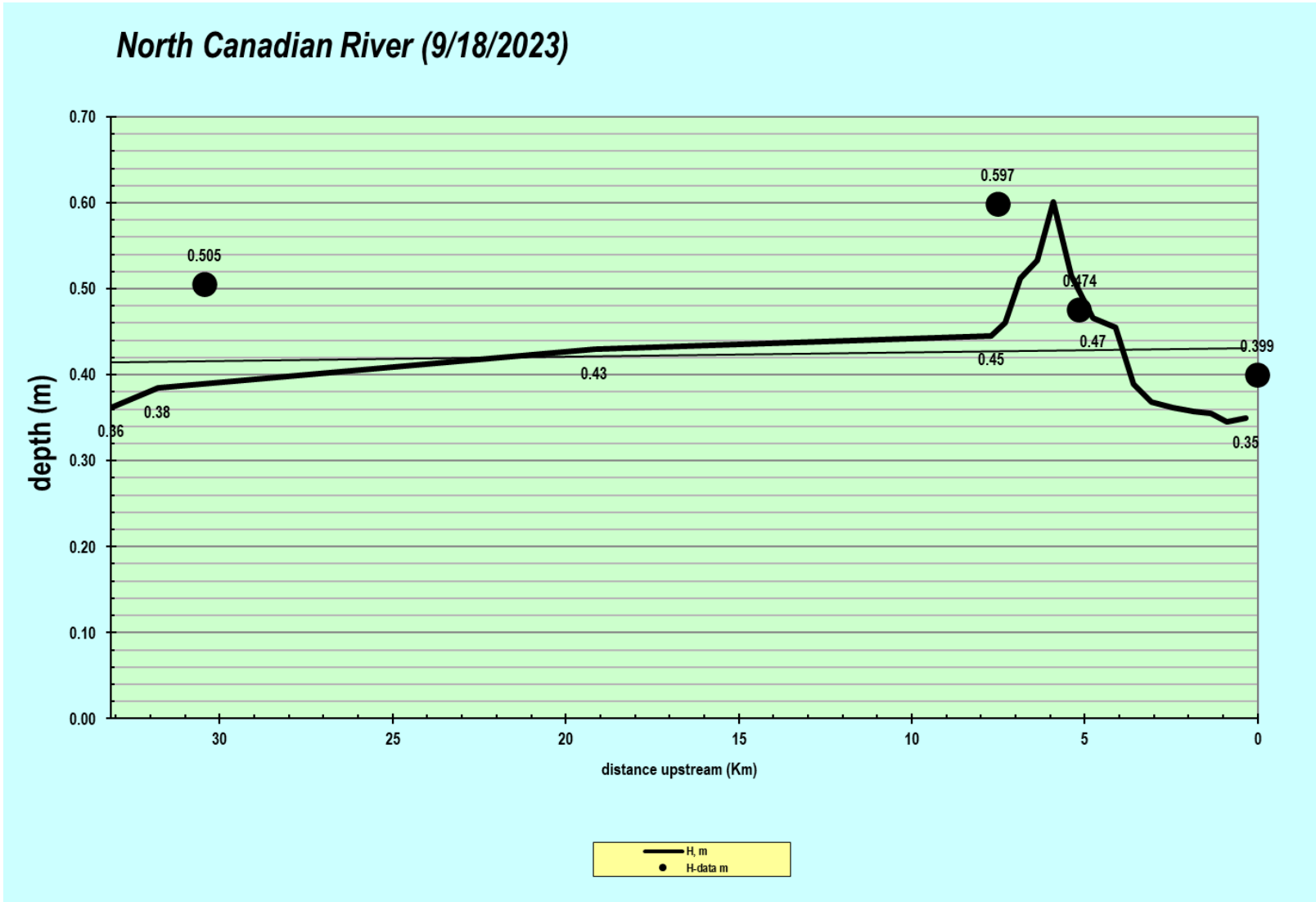


FIGURE 13 QUAL2KW CALIBRATION RESULTS FOR RIVER WATER DEPTH (M), THE SOLID BLACK LINE REPRESENTS THE STEAD STATE MODEL RESULTS. CIRCLE AND SQUARE BLACK DOTS REPRESENT MEASURED VALUES.

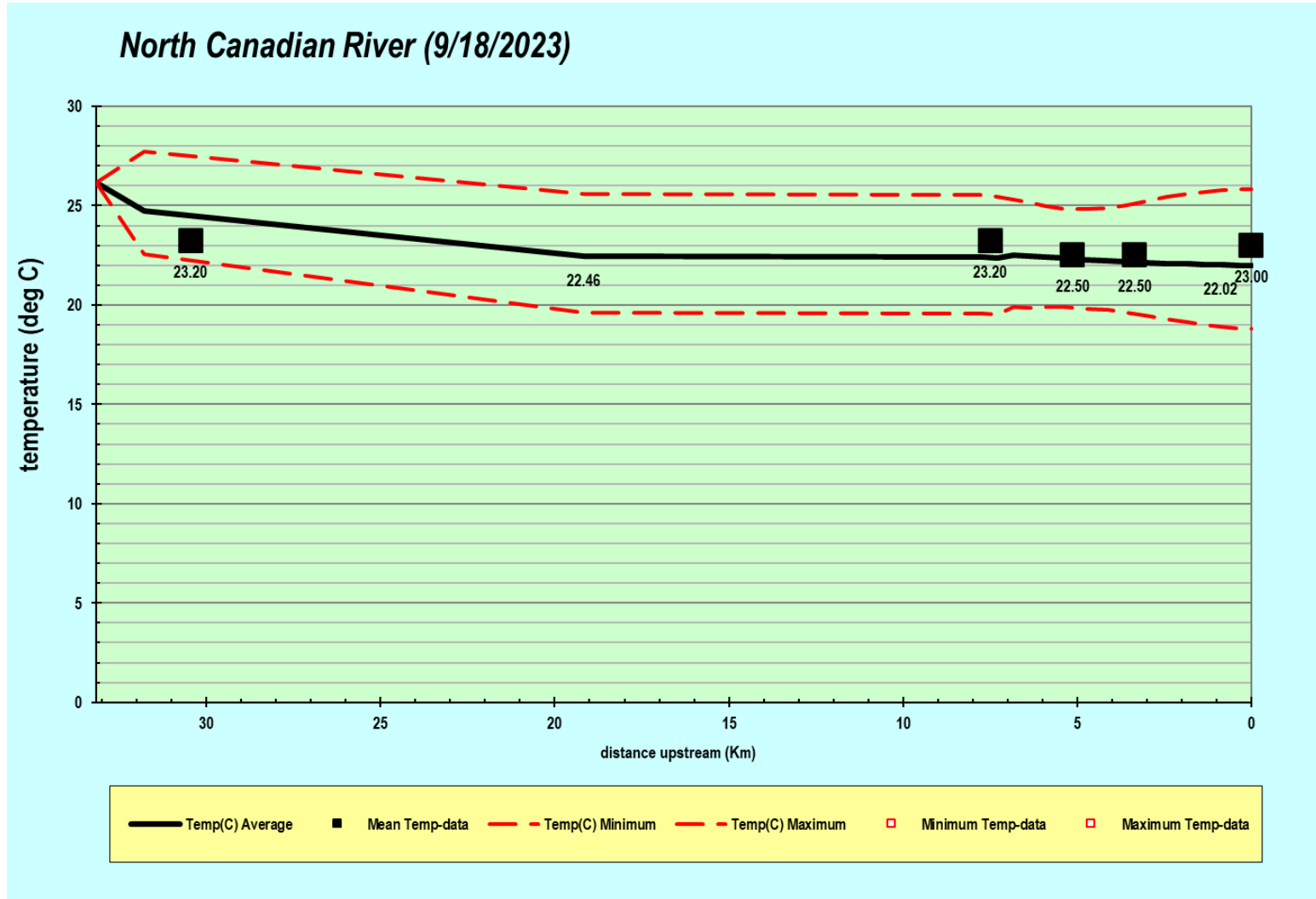


FIGURE 14 QUAL2KW CALIBRATION RESULTS FOR RIVER TEMPERATURE (OC). THE SOLID BLACK LINE REPRESENTS THE STEAD STATE MODEL RESULTS USED FOR REGULATORY EVALUATION. NOTE: THE RED DOTTED LINE REPRESENTS DIURNAL FLUCTUATION AND CIRCLE AND SQUARE BLACK DOTS REPRESENT MEASURED VALUES.

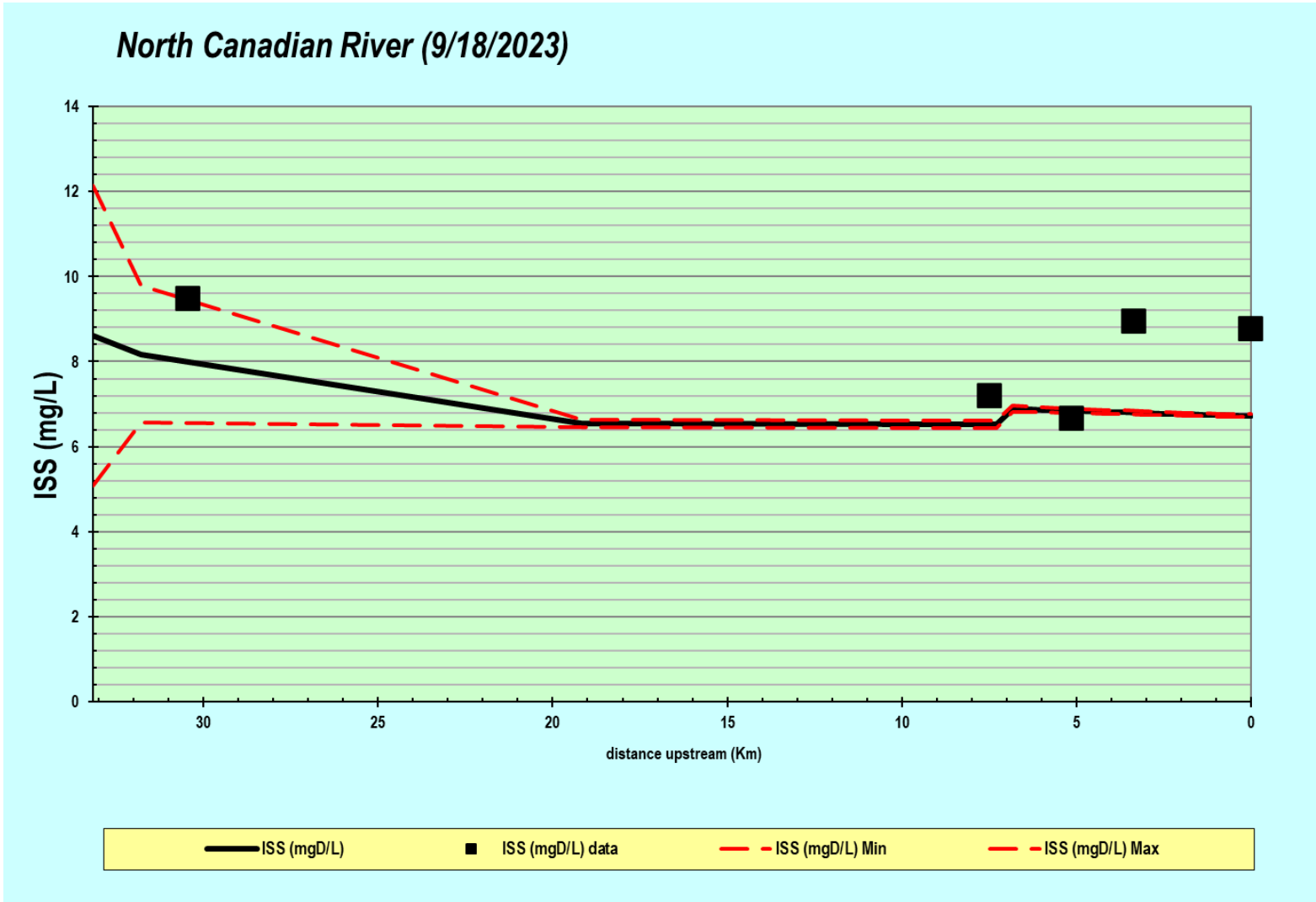


FIGURE 15 QUAL2KW CALIBRATION RESULTS FOR RIVER ISS (MG/L)

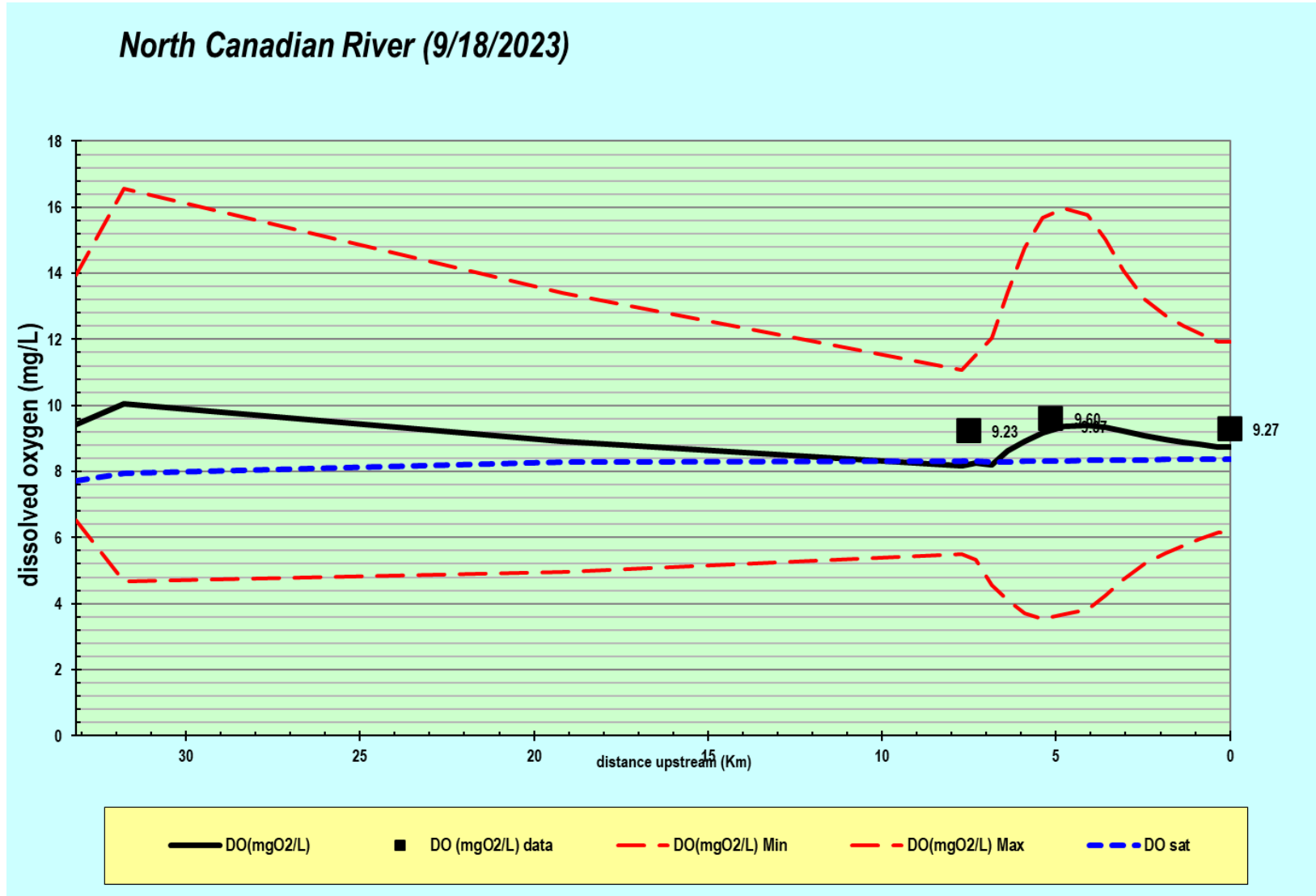


FIGURE 16 QUAL2KW CALIBRATION RESULTS FOR RIVER DISSOLVED OXYGEN (MG/L)

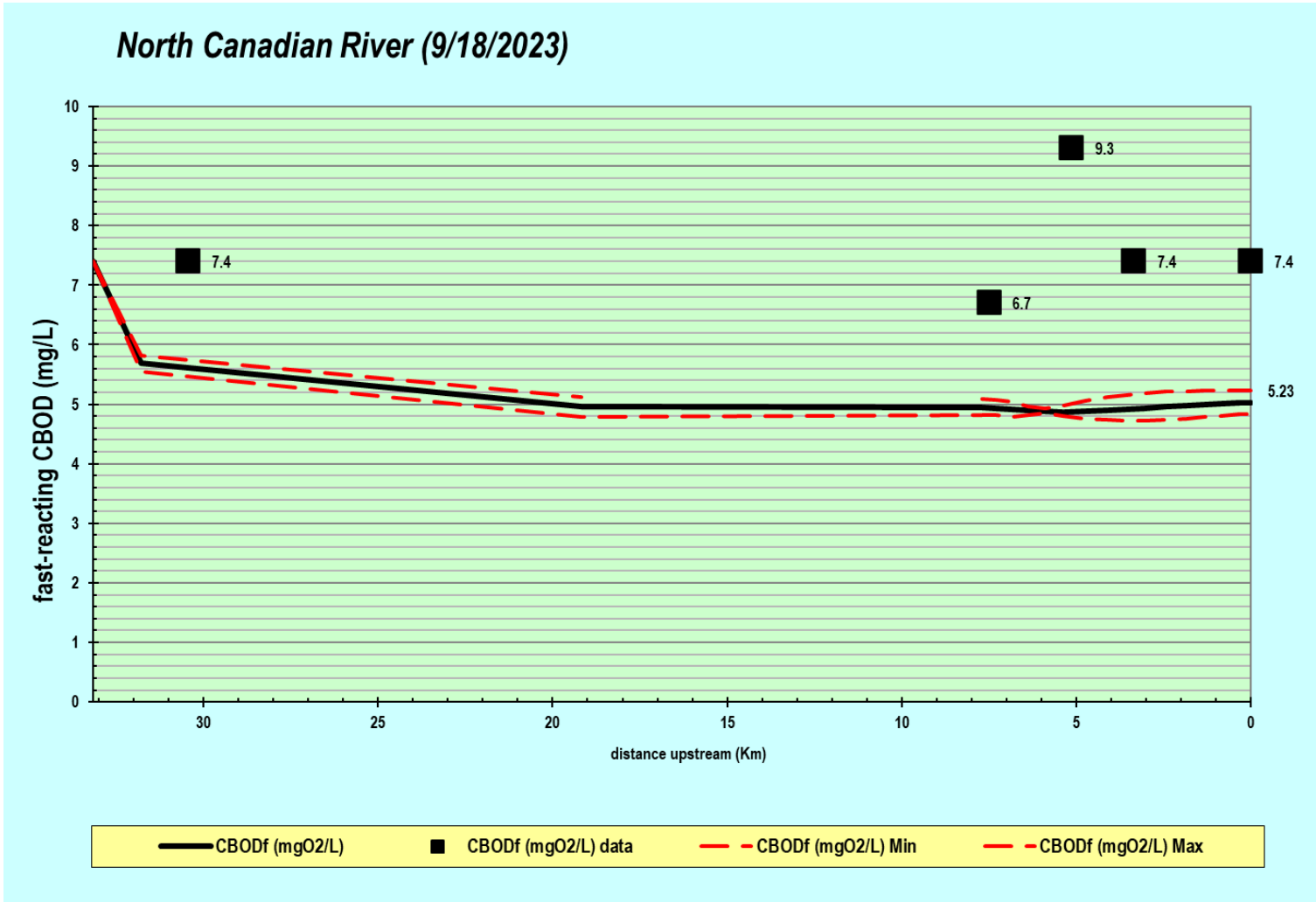


FIGURE 17 QUAL2KW CALIBRATION RESULTS FOR RIVER CBODF (MG/L)

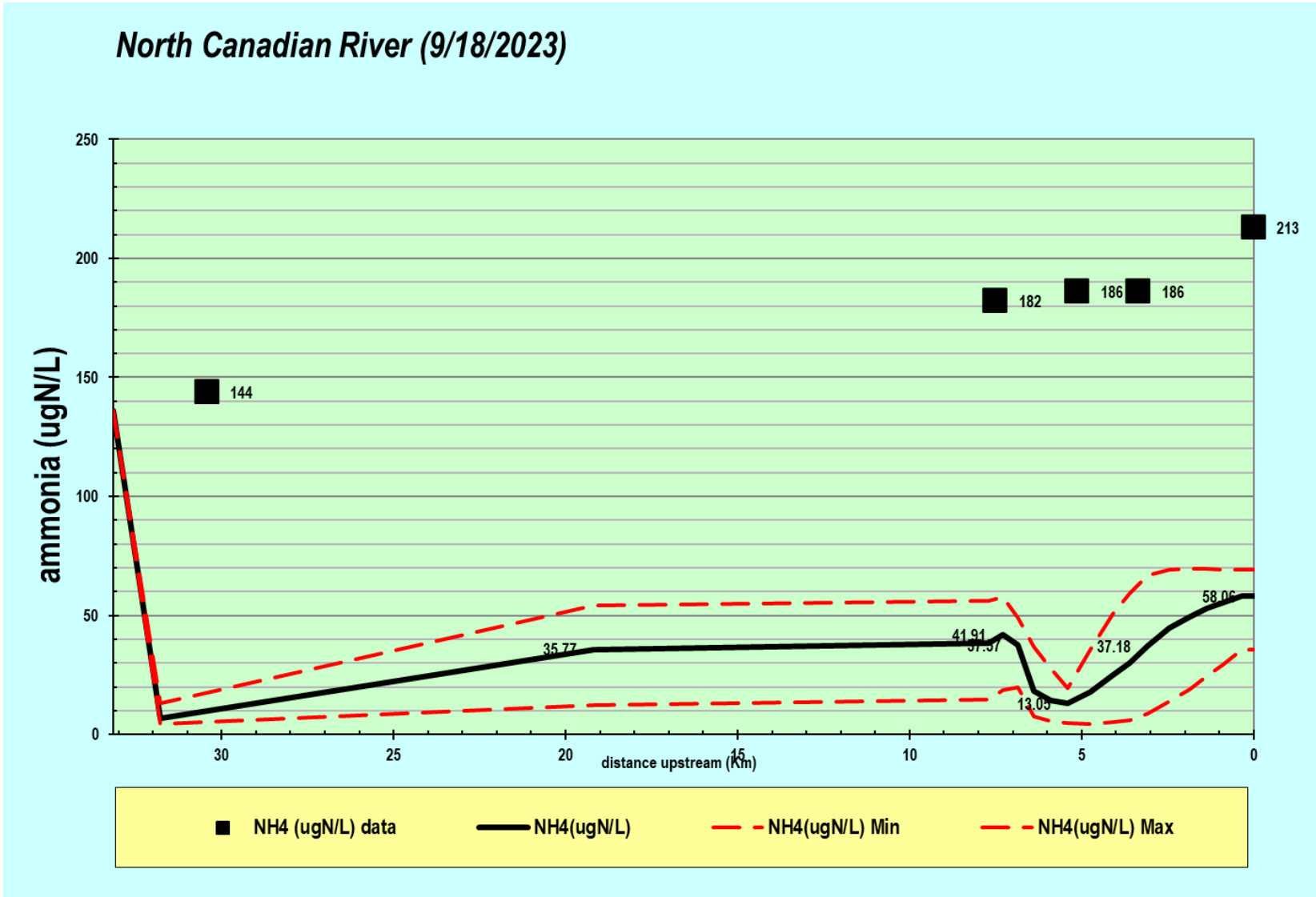


FIGURE 18 QUAL2KW CALIBRATION RESULTS FOR RIVER AMMONIA (MG/L)

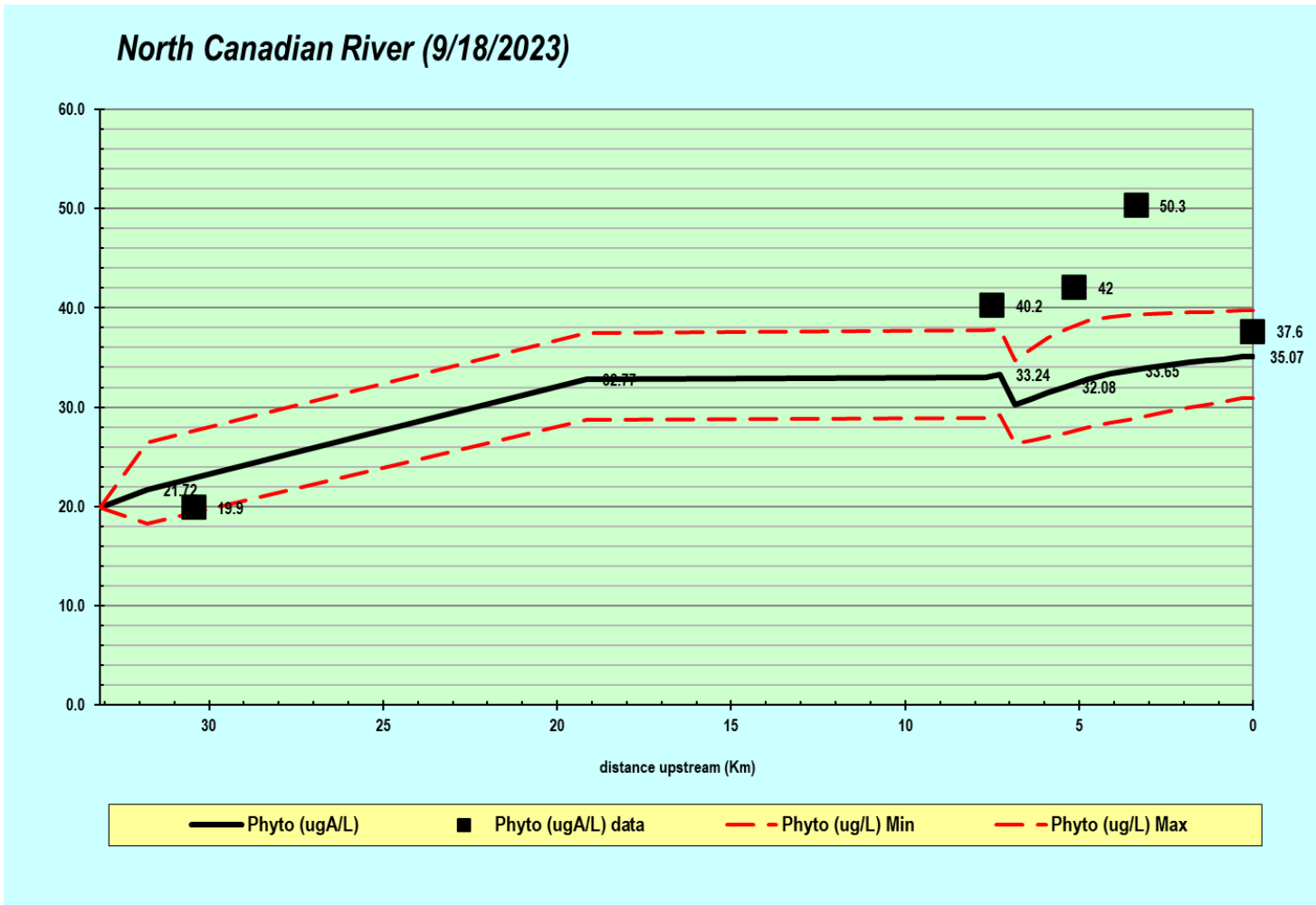


FIGURE 19 QUAL2KW CALIBRATION RESULTS FOR PHYTOPLANKTON (UG A/L)

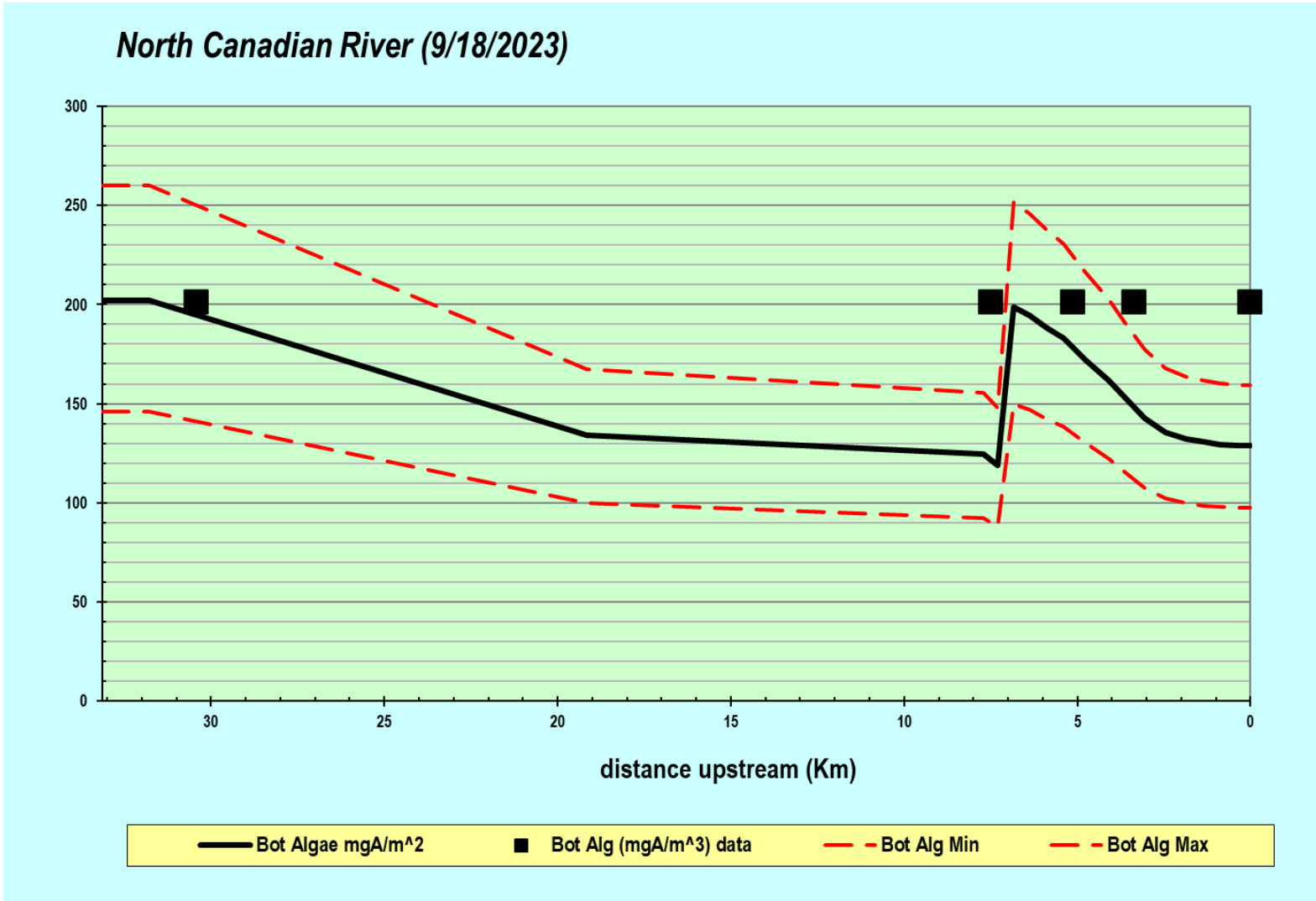


FIGURE 20 QUAL2Kw CALIBRATION RESULTS FOR BOTTOM ALGAE ($\mu\text{G A/L}$)

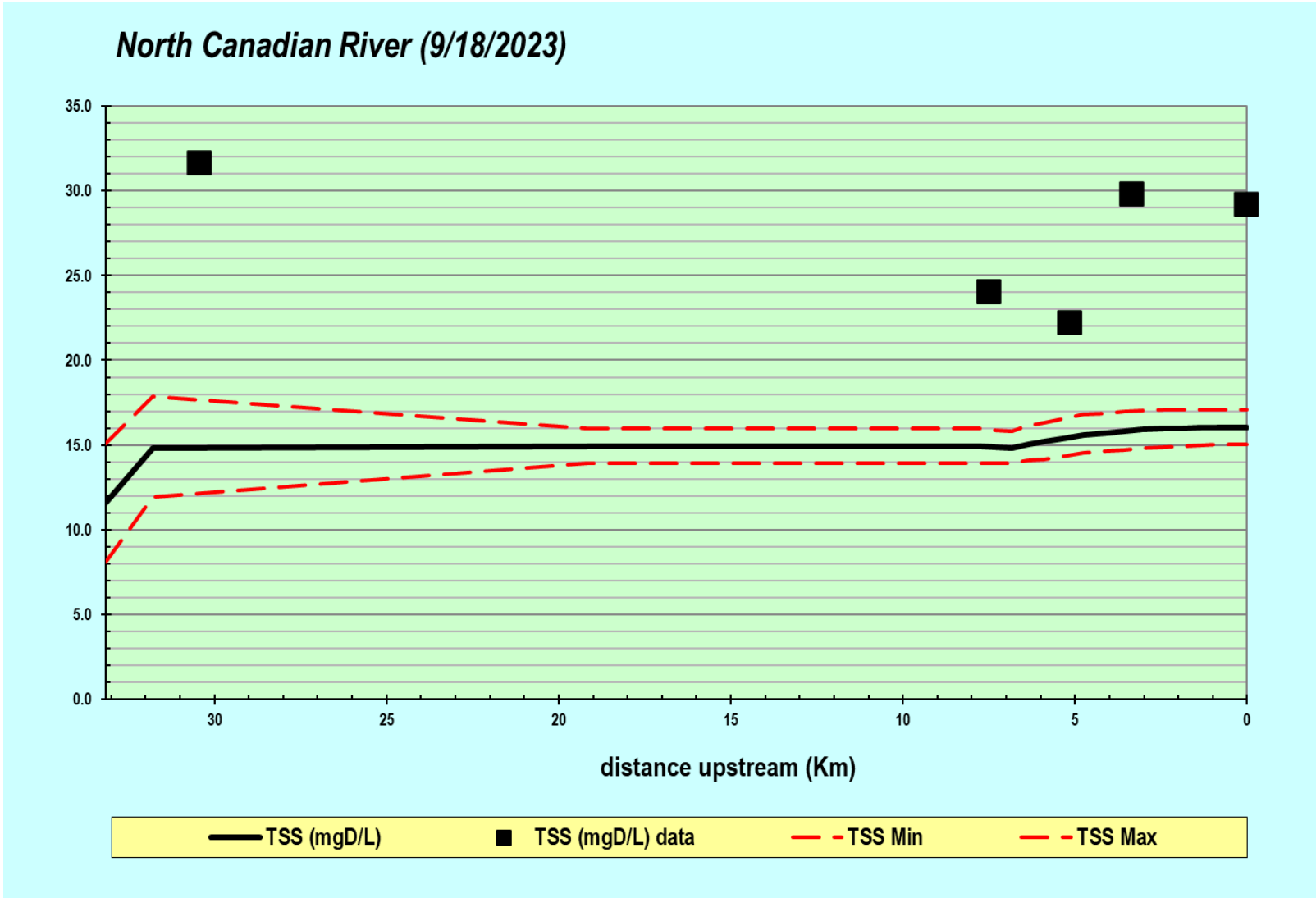


FIGURE 21 QUAL2KW CALIBRATION RESULTS FOR TSS (MG/L)

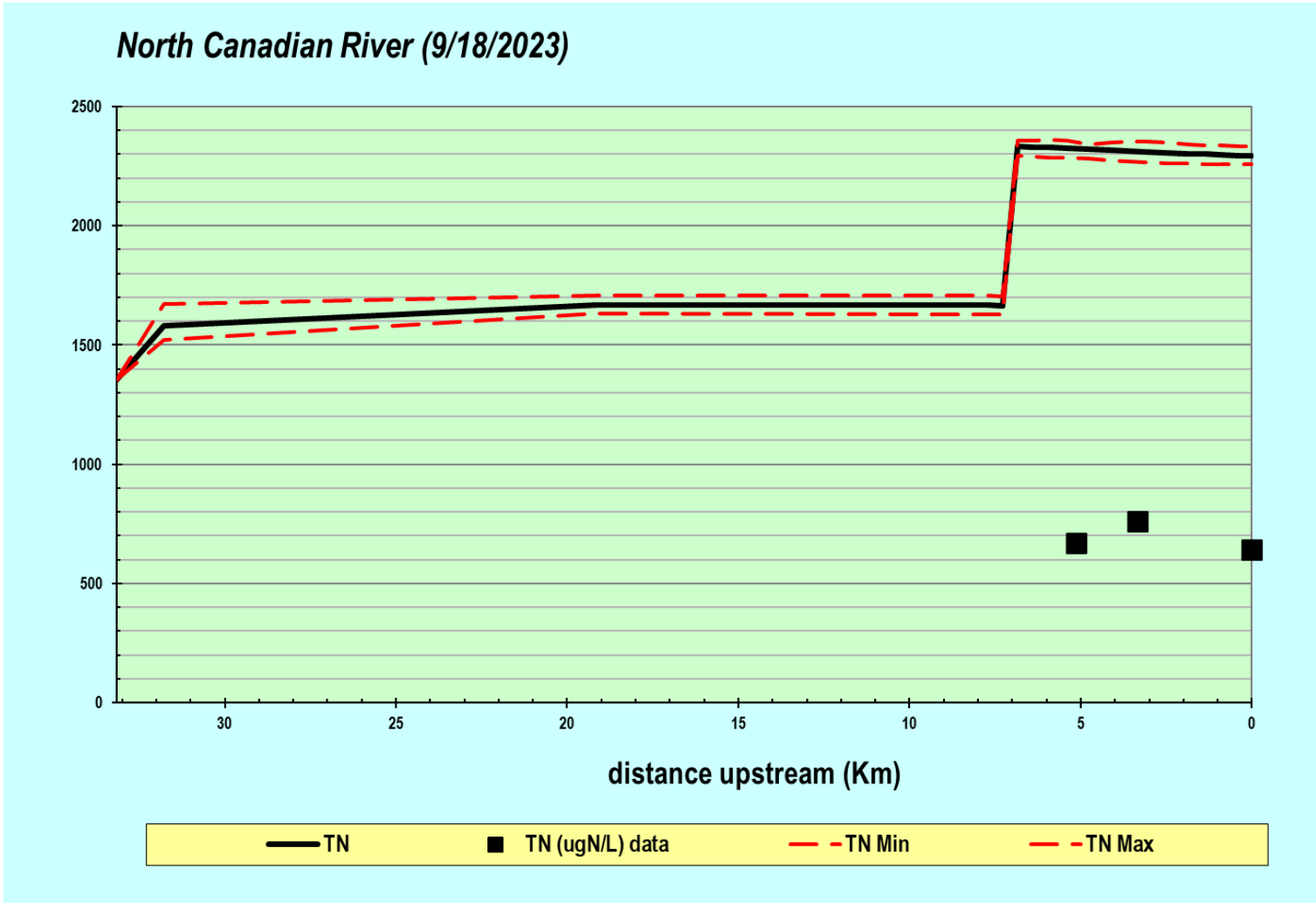


FIGURE 22 QUAL2KW CALIBRATION RESULTS FOR TN (MG/L)

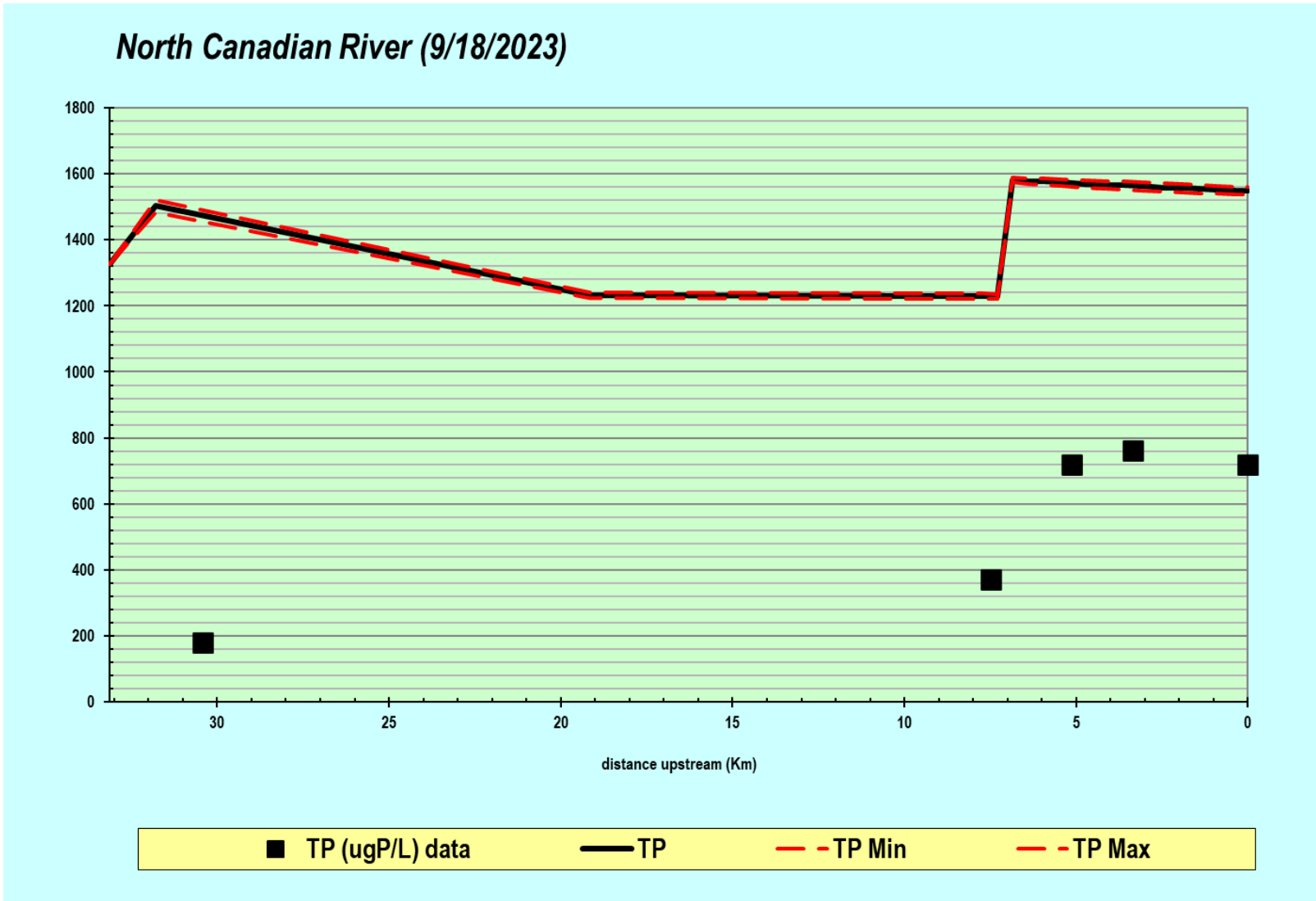


FIGURE 23 QUAL2KW CALIBRATION RESULTS FOR TP (MG/L)

TABLE 2 RIVER FLOW MEASURED VS MODEL PBIAS AND REGRESSION ANALYSIS.

North Canadian River Flow measured vs Model				
	Distance upstream (Km)	Measured flow (m3/s)	Model flow (m3/s)	Notes
	30.430	0.767	0.940	
	7.497	0.941	0.940	
	5.132	1.051	1.060	
	3.355	1.051	1.060	
	0.000	1.051	1.060	
				Limited measured data
Average Flow (m3/s)		0.972	1.012	
PBIAS		-4.094		

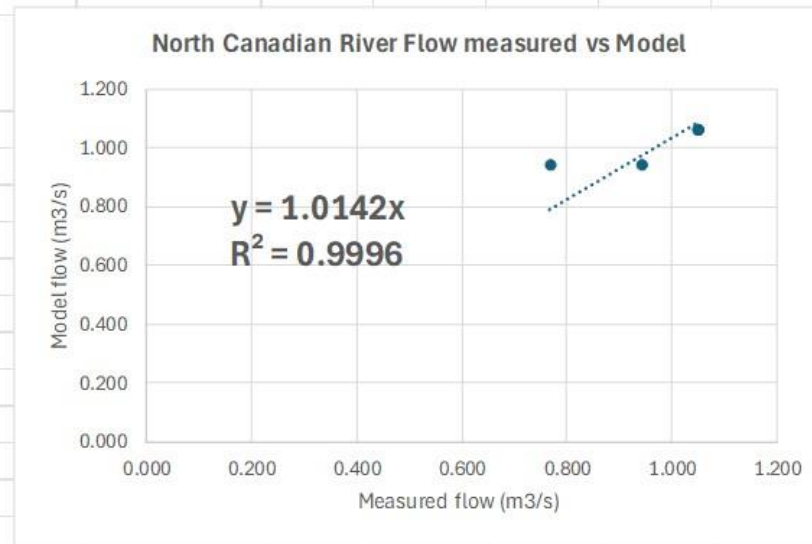


TABLE 3 NORTH CANADIAN RIVER WATER DEPTH (M) MEASURED VS MODEL.

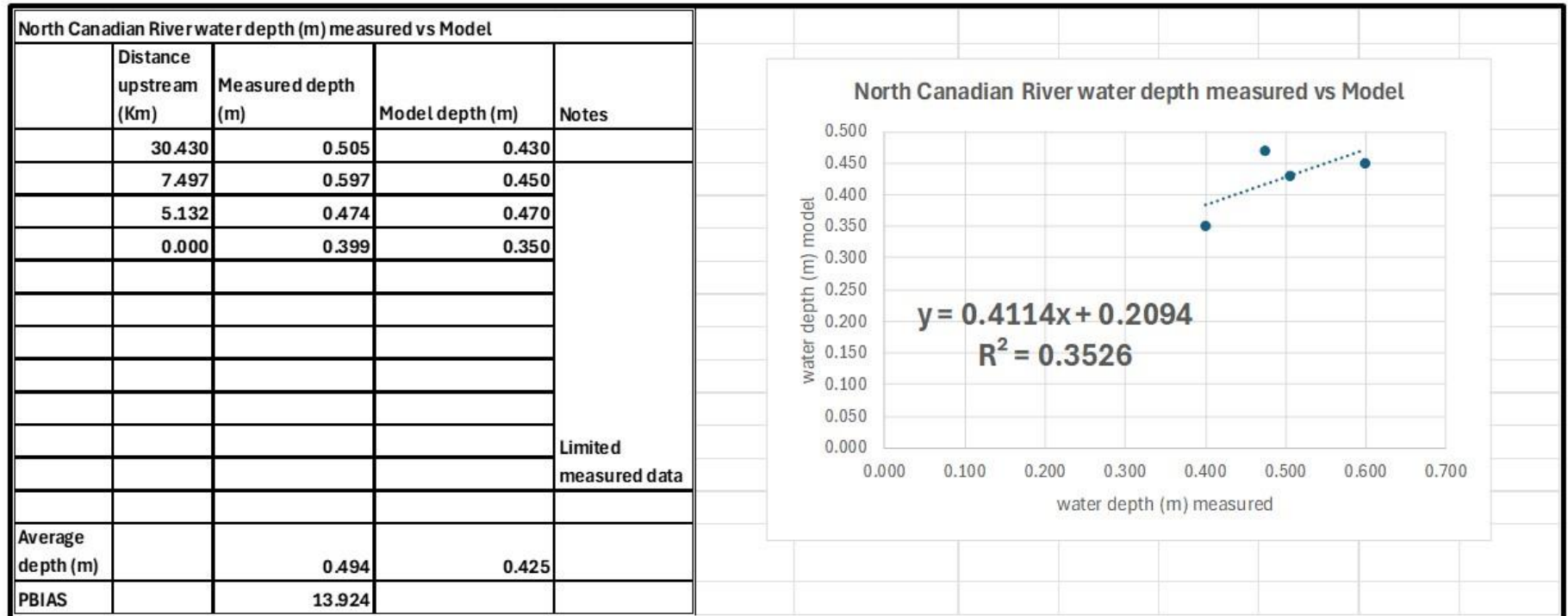


TABLE 4 NORTH CANADIAN RIVER TEMPERATURE MEASURED VS MODEL.

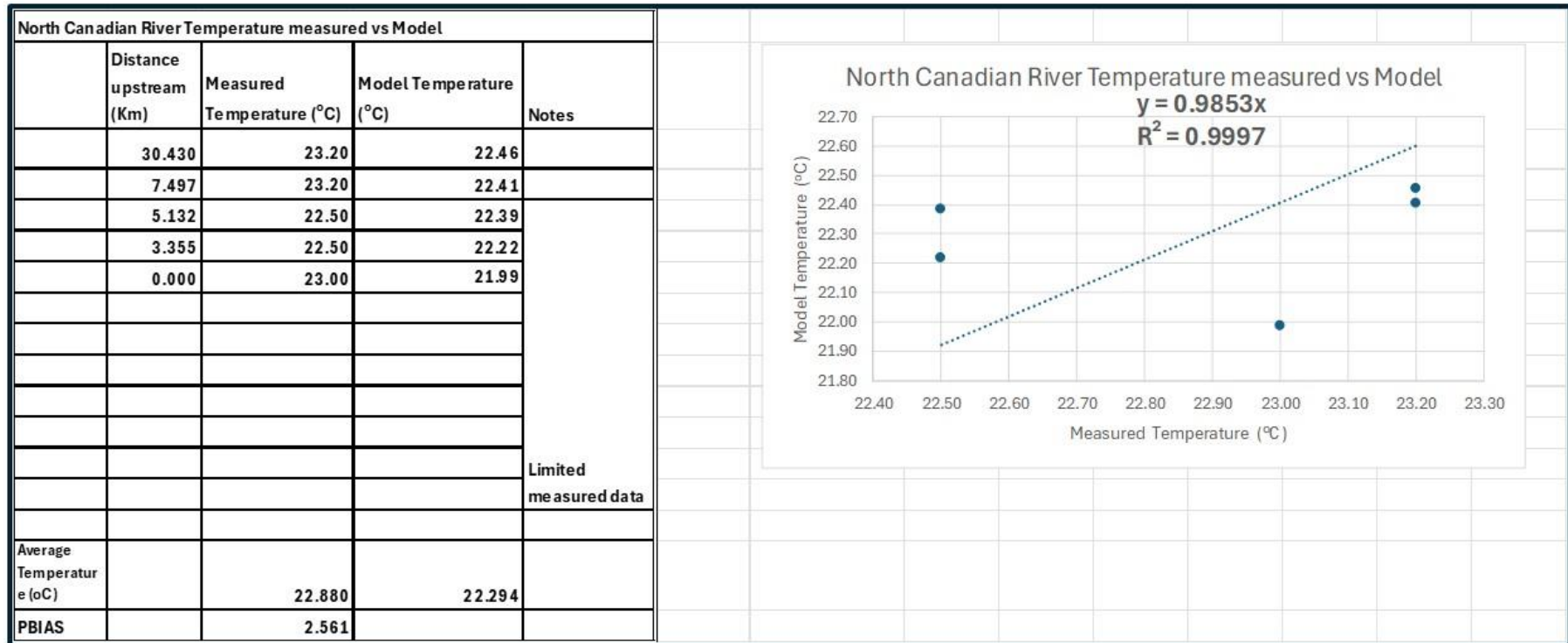


TABLE 5 NORTH CANADIAN RIVER DO MEASURED VS MODEL.

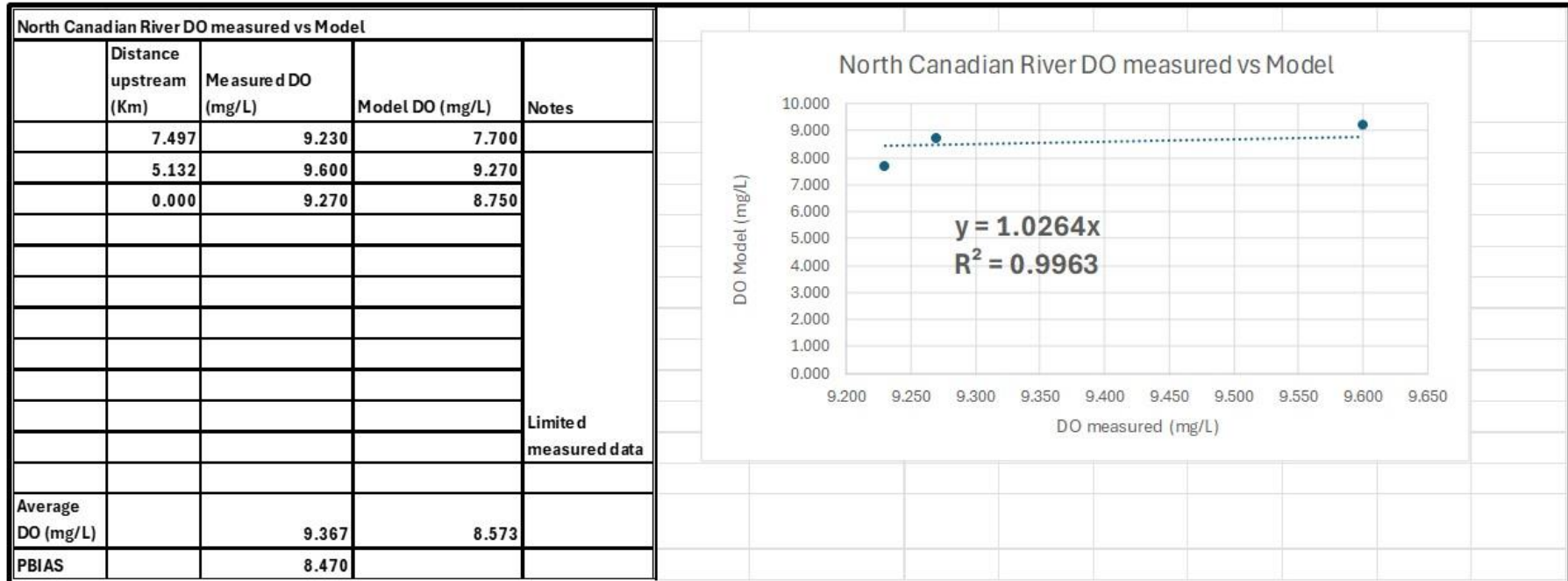


TABLE 6 NORTH CANADIAN RIVER CBODf MEASURED VS MODEL.

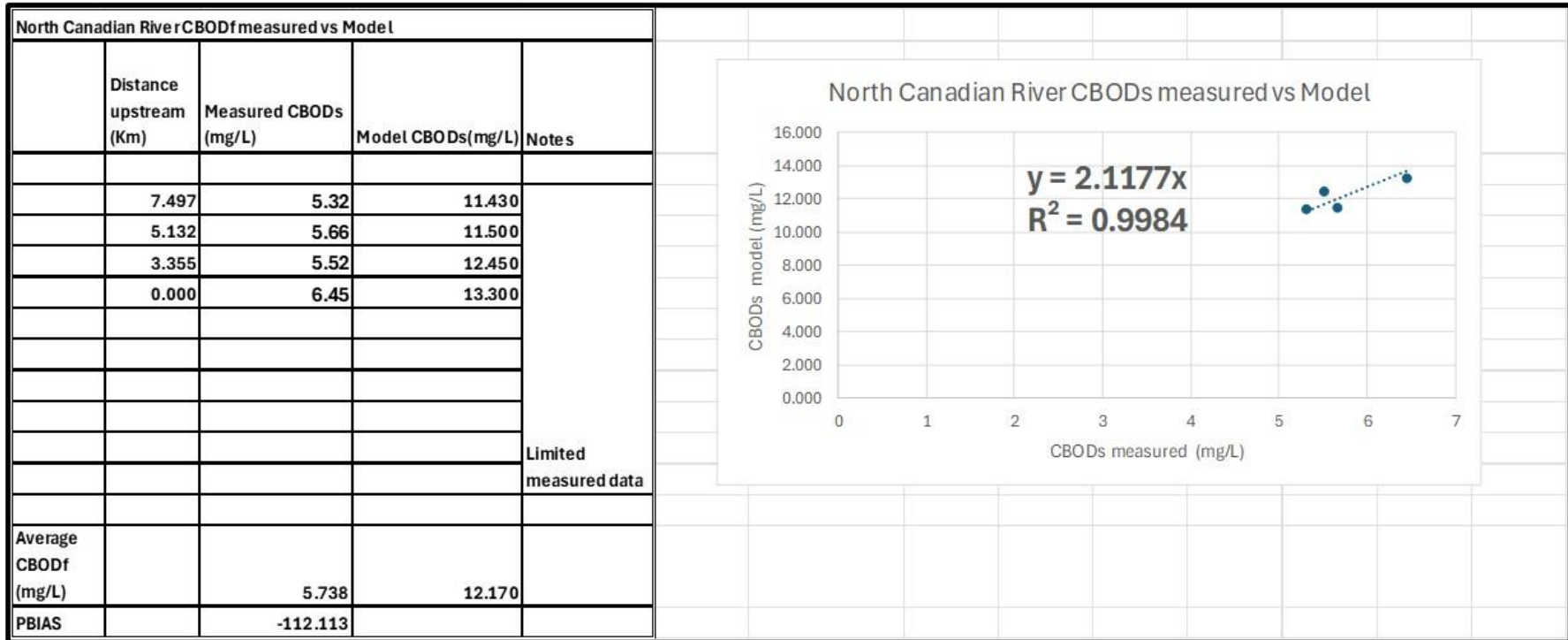


TABLE 7 NORTH CANADIAN RIVER NH4 MEASURED VS MODEL

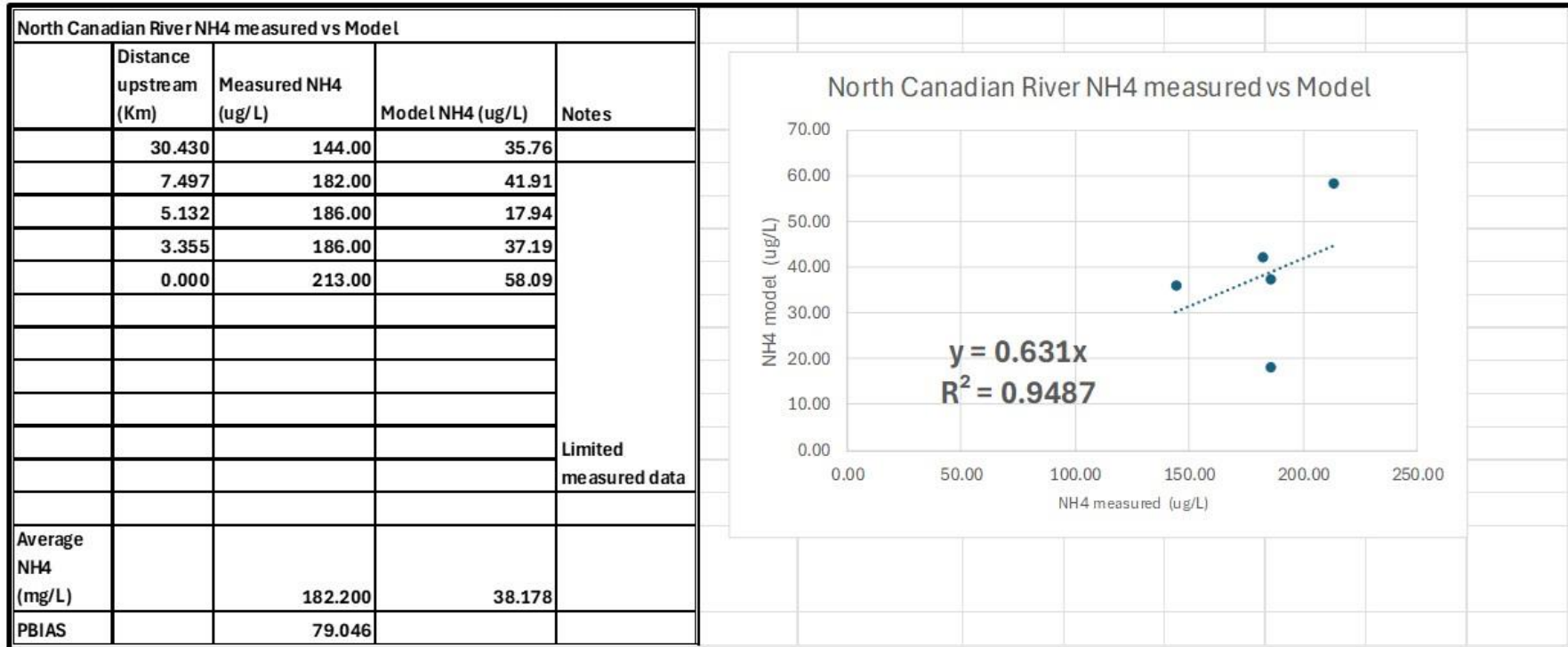
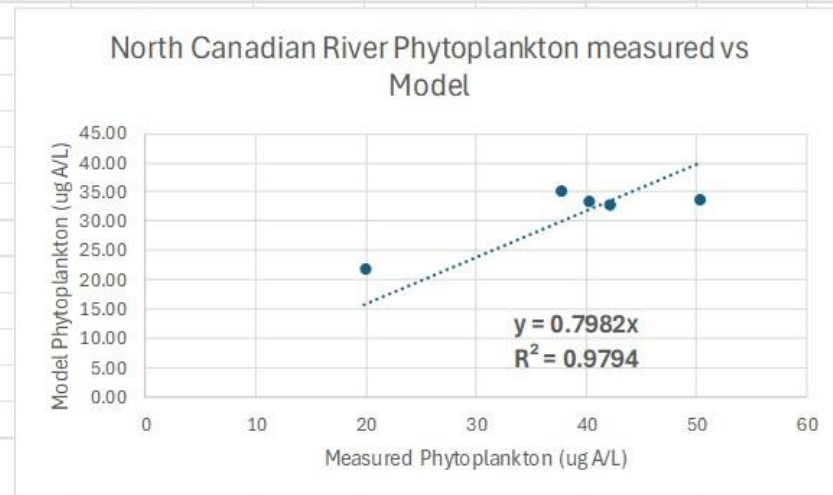


TABLE 8 NORTH CANADIAN RIVER PHYTOPLANKTON MEASURED VS MODEL.

North Canadian River Phytoplankton measured vs Model				
	Distance upstream (Km)	Measured Phytoplankton (ug A/L)	Model Phytoplankton (ug A/L)	Notes
	30.430	19.9	21.72	
	7.497	40.2	33.26	
	5.132	42	32.86	
	3.355	50.3	33.67	
	0.000	37.6	35.08	
				Limited measured data
Average Phytoplankton (ug A/L)		38.000	31.318	
PBIAS		17.584		



4.0 WASTELOAD ALLOCATION

The waste load allocation (WLA) was calculated using the calibrated model to determine the seasonal maximum assimilative capacity of the north Canadian River.

4.1 MARGIN OF SAFETY

The Margin of Safety (MoS) value is established by the ODEQ. A 15% MoS was applied since QUAL2Kw model is calibrated and two WWTP discharges in the river are modeled in the determination of WLA.

4.2 SPRING, SUMMER, WINTER RIVER ASSIMILATIVE CAPACITY

QUAL2Kw Ver 5 model was used to determine the river's seasonal (Winter, Spring, and Summer) maximum assimilative capacity for proposed discharges. Modeled effluent discharge limits for the El Reno and Yukon WWTP discharges were 4 and 4.5 MGD respectively.

The seasonal values of critical temperature (°C), DO saturation, and 85% DO saturation used for model runs are shown in Table 4.1. The Dissolved Oxygen (DO) distribution along the river for each season are shown in Figures 24 to 26.

The model input assume diffuse source temperatures as the seasonal critical temperatures. The parameter values used in modeling are shown in Table 4.2. Assumed CBOD_f and Ammonia for Yukon WWTP are:

Assumed CBOD_f for Yukon: $25 \text{ mg/L (proposed CBOD}_5) * 2.3 \text{ (CBOD}_u\text{/CBOD}_5\text{ ratio)} * 1.15 \text{ (15\% MOS)} = 66.13 \text{ mg/L.}$

Assumed Ammonia for Yukon: $4.1 \text{ mg/L (proposed NH}_3) * 1.15 \text{ (15\% MOS)} = 4.715 \text{ mg/L} = 4,715 \text{ }\mu\text{g/L.}$

Table 4.1 Critical temperature (°C), DO saturation, and 85% DO saturation used for model runs

Season	Critical temperature (oC)	DO saturation	85% DO saturation
Spring	25	8.25	7.01
Summer	32	7.29	6.20
Winter	18	9.45	8.03

Table 4.2 Parameter values used in modeling

Parameters	Value used for calibration
Bottom Algae Coverage	30%
S0D Coverage	5%
Photosynthetically Available Radiation	0.5
Reaeration	O'Connor-Dobbins
Detritus Dissolution Rate	0.5
CBODf Oxidation	0.5
Partial pressure of carbon dioxide	417.4
Phytoplankton Death rate	0.2
Headwater flow (Spring)	3.3
Headwater flow (Summer)	0.8016
Headwater flow (Winter)	0.8948
Yukon ammonia input for scenarios	4715

Seasonal headwater flows are based on the 7Q2 flows; seasonal temperatures are defined in the Oklahoma WQS. Seasonal input values were estimated using the median value for each parameter having many measurements during September and November 2023. Detritus inputs for background conditions were based on assumed 20 percent of observed TSS. 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 considered to be a significant factor in the WLA calculations.

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 Yukon WWTP point source in the model set to the maximum final phase WWTP flow of 4.5 MGD.

The model results presented show that, the model predicted minimum daily average DO concentration (sag) downstream of the discharge meets all required regulatory Water Quality Standards (WQS) for DO, such as, 6.0 mg/L for spring and 5.0 mg/L for summer and winter for the final phase of Yukon WWTP flow of 4.5 MGD.

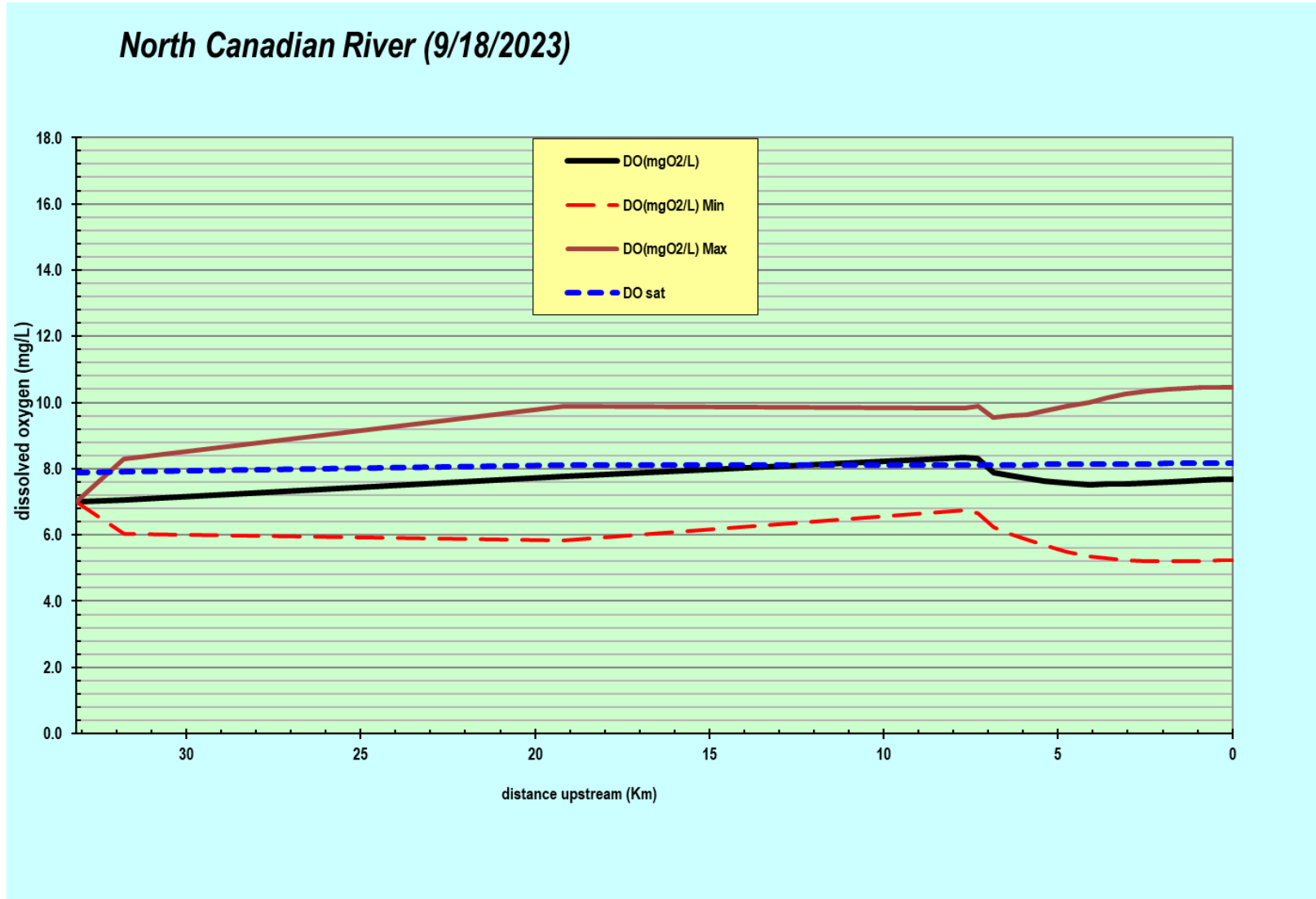


FIGURE 24 WASTE LOAD ALLOCATION (WLA) SPRING. THE SOLID BLACK LINE REPRESENTS THE STEAD STATE MODEL RESULTS USED FOR REGULATORY EVALUATION. THE RED DOTTED LINE REPRESENTS DIURNAL FLUCTUATION.

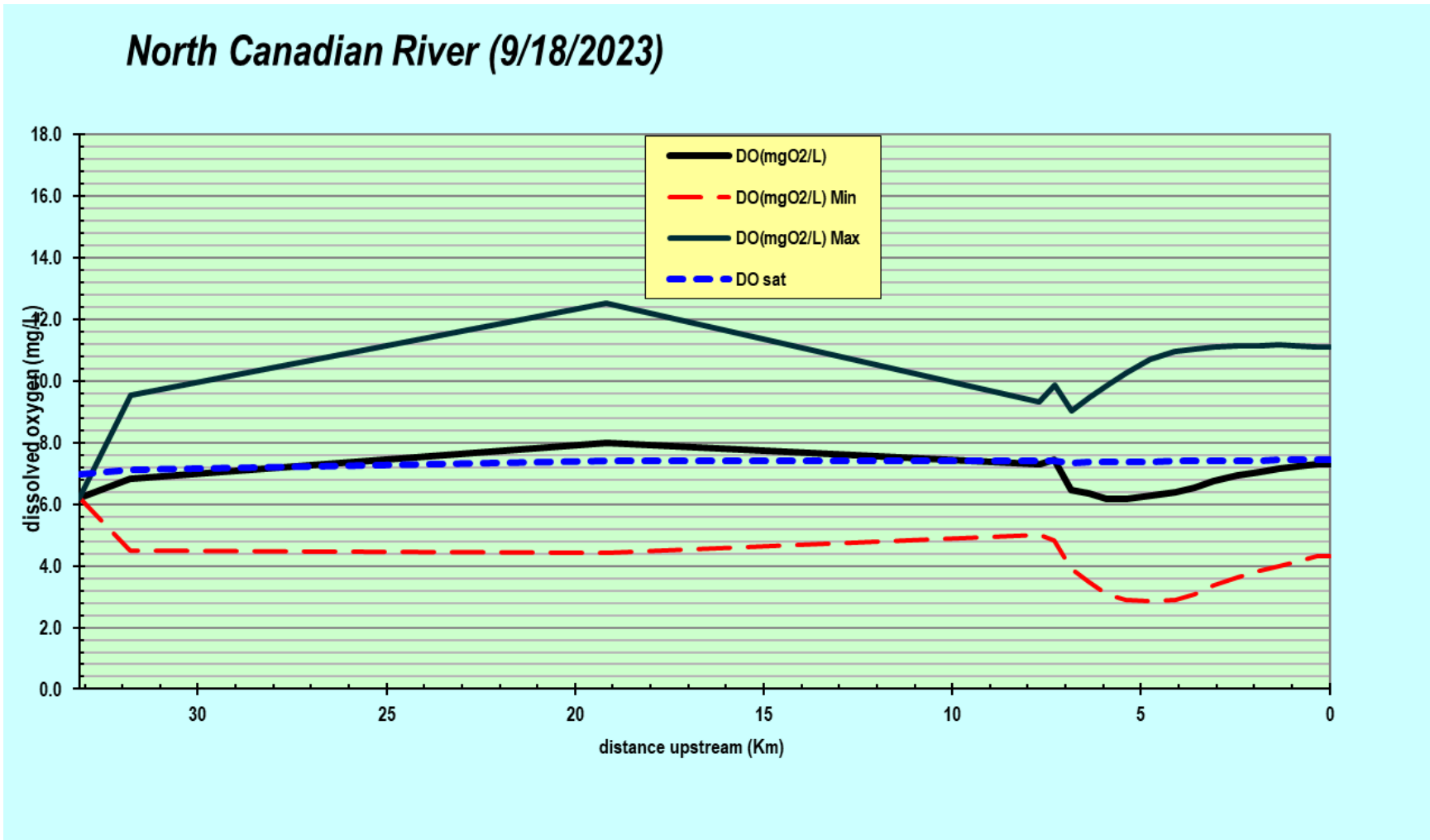


FIGURE 25 WASTE LOAD ALLOCATION (WLA) SUMMER. THE SOLID BLACK LINE REPRESENTS THE STEAD STATE MODEL RESULTS USED FOR REGULATORY EVALUATION. THE RED DOTTED LINE REPRESENTS DIURNAL FLUCTUATION.

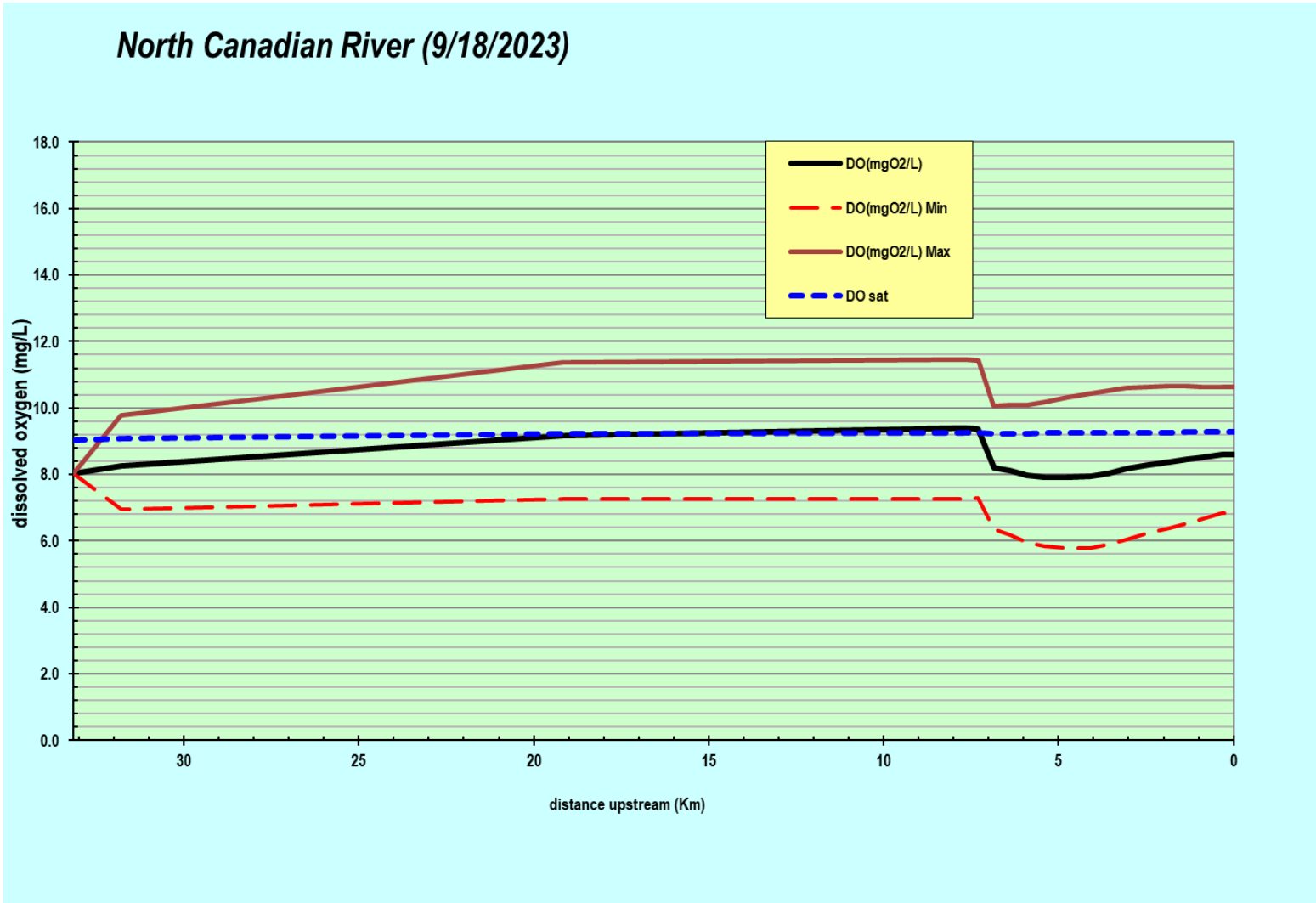


FIGURE 26 WASTE LOAD ALLOCATION (WLA) WINTER. THE SOLID BLACK LINE REPRESENTS THE STEAD STATE MODEL RESULTS USED FOR REGULATORY EVALUATION. THE RED DOTTED LINE REPRESENTS DIURNAL FLUCTUATION.

5.0 CONCLUSIONS

This report presents the results of the water quality modeling, field data collected for model calibration, and waste load allocation (WLA) calculation for the Yukon WWTP expansion. QUAL2Kw model was selected over other water quality models for this project because of its ability in evaluating and controlling water quality since limited site-specific data is available for model calibration. The main focus has been to calibrate the model for dissolved oxygen and other parameters that affect dissolved oxygen concentration. The effect of water quality changes is more pronounced in the calibration period (September 2023) for dissolved oxygen, ammonia, and bottom algae.

The model shows DO sag, ammonia increase, and bottom algae increase at the location of WWTP discharges showing its effect on water quality and recovery further downstream. Model calibration, focused on September 2023 data, showed excellent agreement with field measurements for flow (PBIAS 4%), depth (14%), temperature (3%), DO (8%) and phytoplankton 18%. Model predictions for CBOD_f and ammonia (NH₄) were less accurate with PBIAS 112% and 79% respectively. The model successfully captured the DO dynamics, including the effects of algal decay and DO consumption.

Simulation results indicate localized DO sag, increased ammonia, and higher bottom algae near the WWTP discharge, with recovery downstream. Importantly, predicted minimum daily average DO concentrations downstream meet all regulatory Water Quality Standards (6.0 mg/L in spring; 5.0 mg/L in summer and winter) after applying a 15% Margin of Safety (MOS).

6.0 REFERENCES

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