Real-Time Water Quality Deployment Report

Lower Churchill River Network

July 5/6/12 to August 10, 2017

Newfoundland Labrador

Government of Newfoundland & Labrador
Department of Municipal Affairs & Environment
Water Resources Management Division

Contents

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Real Time Water Quality Monitoring

- Staff with the Department of Municipal Affairs & Environment monitor real-time water quality data on a regular basis.
- This deployment report discusses water quality related events occurring at three stations on the Lower Churchill River: Churchill River above Grizzle Rapids, Churchill River below Muskrat Falls and Churchill River at English Point.
- Real-time water quality monitoring instruments were deployed at all three stations on the Lower Churchill River. Instruments were deployed at Churchill River below Muskrat Falls on July 5th, Churchill River at English Point on July 6th, and Churchill River above Grizzle Rapids on July 12th, for deployment periods of 36, 35, and 29 days respectively.
- The station at above Muskrat Falls was not able to be deployed during this deployment period. This station was relocated in October 2016 as it was situated in the flood zone of the Muskrat Falls Reservoir and needed to be moved back to ensure the station did not flood as the reservoir water levels were raised (as was planned in the fall of 2016). However, due to unforeseen issues, water levels were raised and decreased again. As a result, the newly located above Muskrat Falls station is now situated approximately 650 feet from the edge of the reservoir (i.e. at current water levels) making it impractical to install monitoring equipment. Additionally, safety requirements with regards to working in and around the reservoir for the Muskrat Falls project further hindered the ability to deploy the instrument at this station.

Quality Assurance and Quality Control

- As part of the Quality Assurance and Quality Control protocol (QA/QC), an assessment of the reliability of data recorded by an instrument is made at the beginning and end of the deployment period. This procedure is based on the approach used by the United States Geological Survey.
- At deployment and removal, a QA/QC instrument is temporarily deployed alongside the field instrument. Values for temperature, pH, conductivity, dissolved oxygen and turbidity are compared between the two instruments**.** Based on the degree of difference between parameters recorded by the field instrument and QA/QC instrument at deployment and at removal, a qualitative statement is made on the data quality (Table 1).

Table 1: Instrument Performance Ranking classifications for deployment and removal

	Rank				
Parameter	**Excellent**	**Good**	**Fair**	**Marginal**	**Poor**
Temperature (C)	<=+/-0.2	>+/-0.2 to 0.5	>+/-0.5 to 0.8	>+/-0.8 to 1	<+/-1
pH (unit)	<=+/-0.2	>+/-0.2 to 0.5	>+/-0.5 to 0.8	>+/-0.8 to 1	>+/-1
Sp. Conductance (µS/cm)	<=+/-3	>+/-3 to 10	>+/-10 to 15	>+/-15 to 20	>+/-20
Sp. Conductance > 35µS/cm (%)	<=+/-3	>+/-3 to 10	>+/-10 to 15	>+/-15 to 20	>+/-20
Dissolved Oxygen (mg/l) (% Sat)	<=+/-0.3	>+/-0.3 to 0.5	>+/-0.5 to 0.8	>+/-0.8 to 1	>+/-1
Turbidity <40 NTU (NTU)	<=+/-2	>+/-2 to 5	>+/-5 to 8	>+/-8 to 10	>+/-10
Turbidity > 40 NTU (%)	<=+/-5	>+/-5 to 10	>+/-10 to 15	>+/-15 to 20	>+/-20

- It should be noted that the temperature sensor on any instrument is the most important. All other parameters can be broken down into three groups: temperature dependent, temperature compensated and temperature independent. Because the temperature sensor is not isolated from the rest of the instrument, the entire instrument must be at the same temperature before the sensor will stabilize. The values may take some time to climb to the appropriate reading; if a reading is taken too soon it may not accurately portray the water body.

- Deployment and removal comparison rankings for the Lower Churchill River stations deployed from July 5/6/12 to August 10, 2017 are summarized in Table 2.

Table 2: Comparison rankings for Lower Churchill River stations July 5/6/12 to August 10, 2017

Churchill River Station	Date	Action	Comparison Ranking				
			Temperature	pH	Conductivity	Dissolved Oxygen	Turbidity
Above Grizzle Rapids	July 12, 2017	Deployment	Good	Good	Excellent	Excellent	Excellent
	August 10, 2017	Removal	Good	Good	Excellent	Good	Excellent
Above Muskrat Falls	Not deployed	Deployment	N/A	N/A	N/A	N/A	N/A
	Not deployed	Removal	N/A	N/A	N/A	N/A	N/A
Below Muskrat Falls	July 5, 2017	Deployment	Excellent	Excellent	Excellent	Excellent	Excellent
	August 10, 2017	Removal	Excellent	Good	Excellent	Fair	Excellent
At English Point	July 6, 2017	Deployment	Fair	Good	Good	Excellent	Poor
	August 10, 2017	Removal	Good	Excellent	Fair	Fair	Excellent

- **Churchill River above Grizzle Rapids**
    - At deployment, temperature and pH were 'good', while conductivity, dissolved oxygen, and turbidity all ranked as 'excellent'.
    - At removal, temperature, pH, and dissolved oxygen all ranked as 'good', while conductivity and turbidity ranked as 'excellent'.
- **Churchill River below Muskrat Falls**
    - At deployment, all parameters ranked as 'excellent'
    - At removal, temperature, conductivity, and turbidity ranked as 'excellent', pH ranked as 'good', and dissolved oxygen was 'fair'.
- **Churchill River at English Point**
    - At deployment, dissolved oxygen was 'excellent', pH and conductivity were 'good', temperature was 'fair', and turbidity was 'poor'. The field turbidity value was 8.7NTU, the QA/QC value was 46.9NTU, and the grab sample value was 14.0. This discrepancy could either be due to the QA/QC instrument not being placed in close enough proximity to the field instrument, or due to sediment being suspended and disturbed around the QA/QC instrument as the value was being recorded.
    - At removal, pH and turbidity were 'excellent', temperature was 'good', while conductivity and dissolved oxygen were 'fair'.

Data Interpretation

- The following graphs and discussion illustrate water quality related events occurring from July 5,6,12 to August 10, 2017 on the Lower Churchill River Network.
- With the exception of water quantity data (stage & flow), all data used in the preparation of the graphs and subsequent discussion below adhere to this stringent QA/QC protocol. Water Survey of Canada is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.
- The station at Churchill River above Grizzle Rapids was deployed on July 12th, 2017. Since an area near the below Grizzle Rapids station (which contained both water quality and quantity monitoring capabilities) experienced a landslide in September 2016, a decision was made to relocate the water quality component of this station to the existing above Grizzle Rapids hydrometric station. Unforeseen power issues prevented transmission of data from this station; however, internal log file data is available for analysis in this report.
- The above Muskrat Falls station was inaccessible due to having been moved a significant distance from the water (i.e. outside of flood zone) and due to safety concerns associated with working in and around the reservoir.

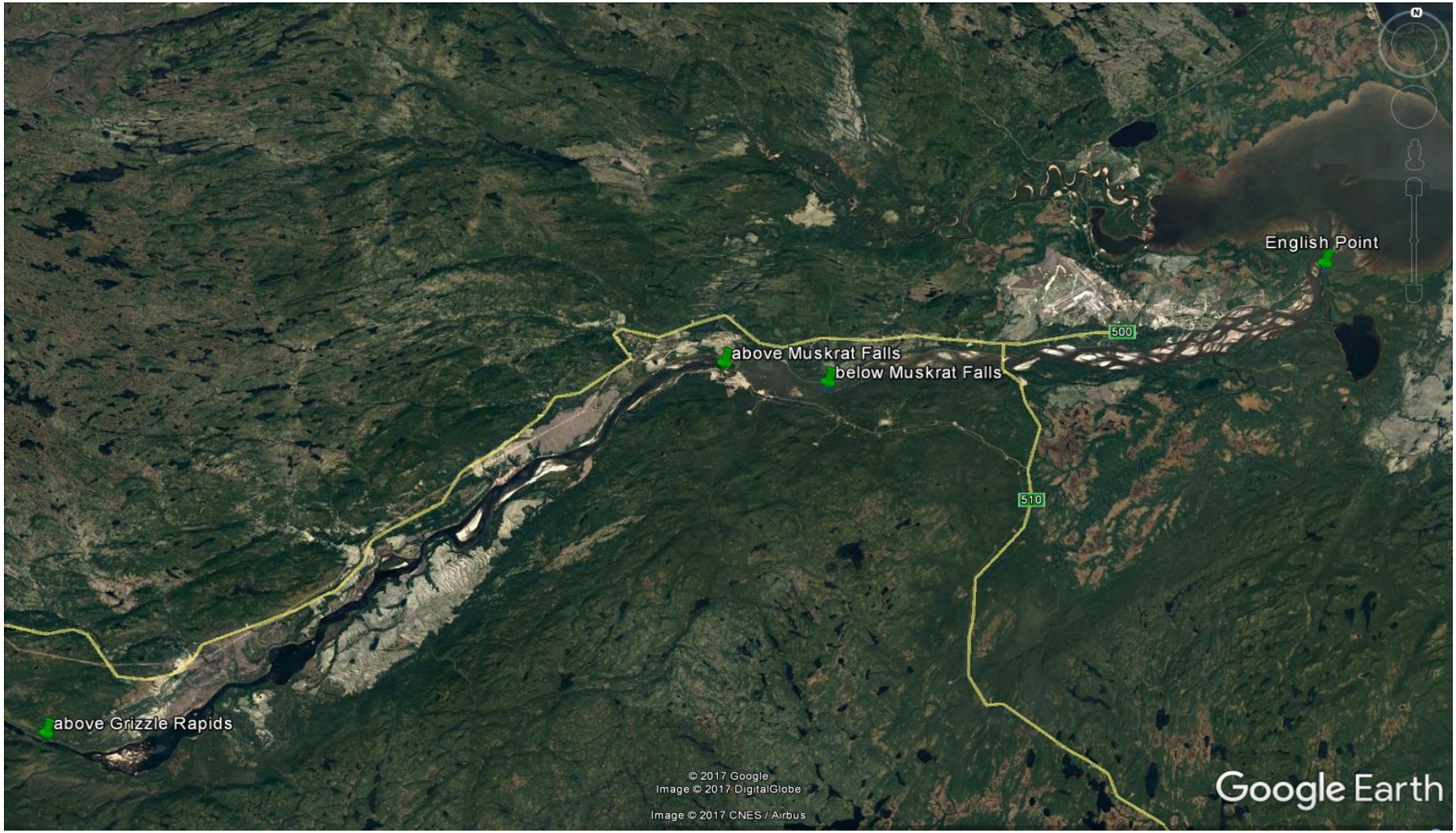

Figure 1: Lower Churchill Network of Real-Time Water Quality Stations

Churchill River above Grizzle Rapids

Water Temperature

- Water temperature ranged from 12.62°C to 17.57°C, with a median value of 15.04°C (Figure 2).
- Generally, water temperature slowly increases over the course of deployment – a trend that is expected as air temperatures warm through the summer months. Water temperature data exhibits a diurnal pattern as expected, and closely correlates with ambient air temperatures.
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

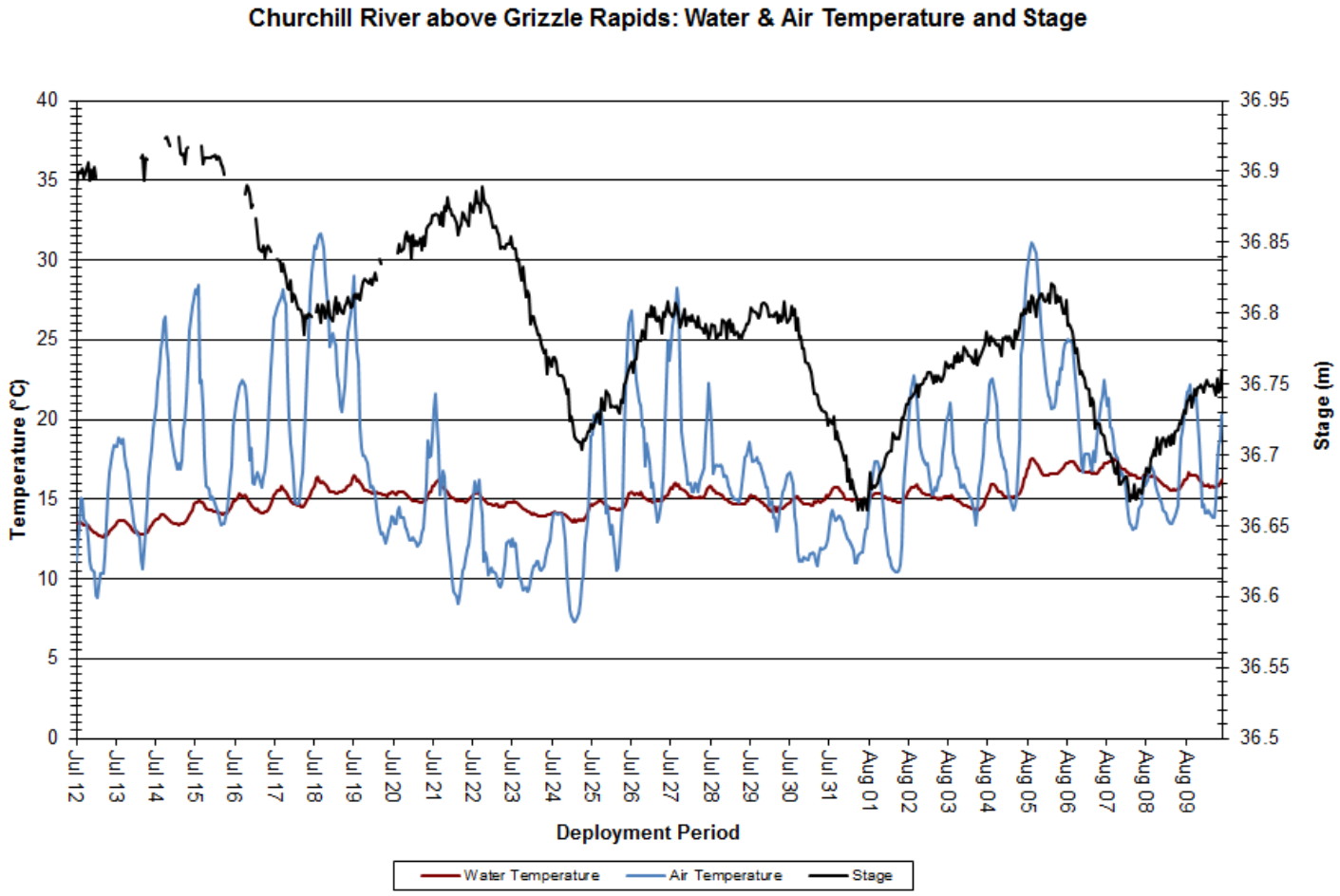

Figure 2: Water & Air Temperature and Stage at Churchill River above Grizzle Rapids

pH

- pH values ranged from 6.69 to 7.16 pH units, with a median value of 7.00 (Figure 3).
- pH values are stable over the deployment period and fall within the CCME Protection of Aquatic Life Guidelines.
- Photosynthesis uses up hydrogen molecules; this causes the concentration of hydrogen ions to decrease, which in turn causes pH to increase. For this reason, pH may be higher during daylight hours and during the growing season when photosynthesis is at a maximum. This is illustrated by the diurnal fluctuations in pH values (Figure 3).
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

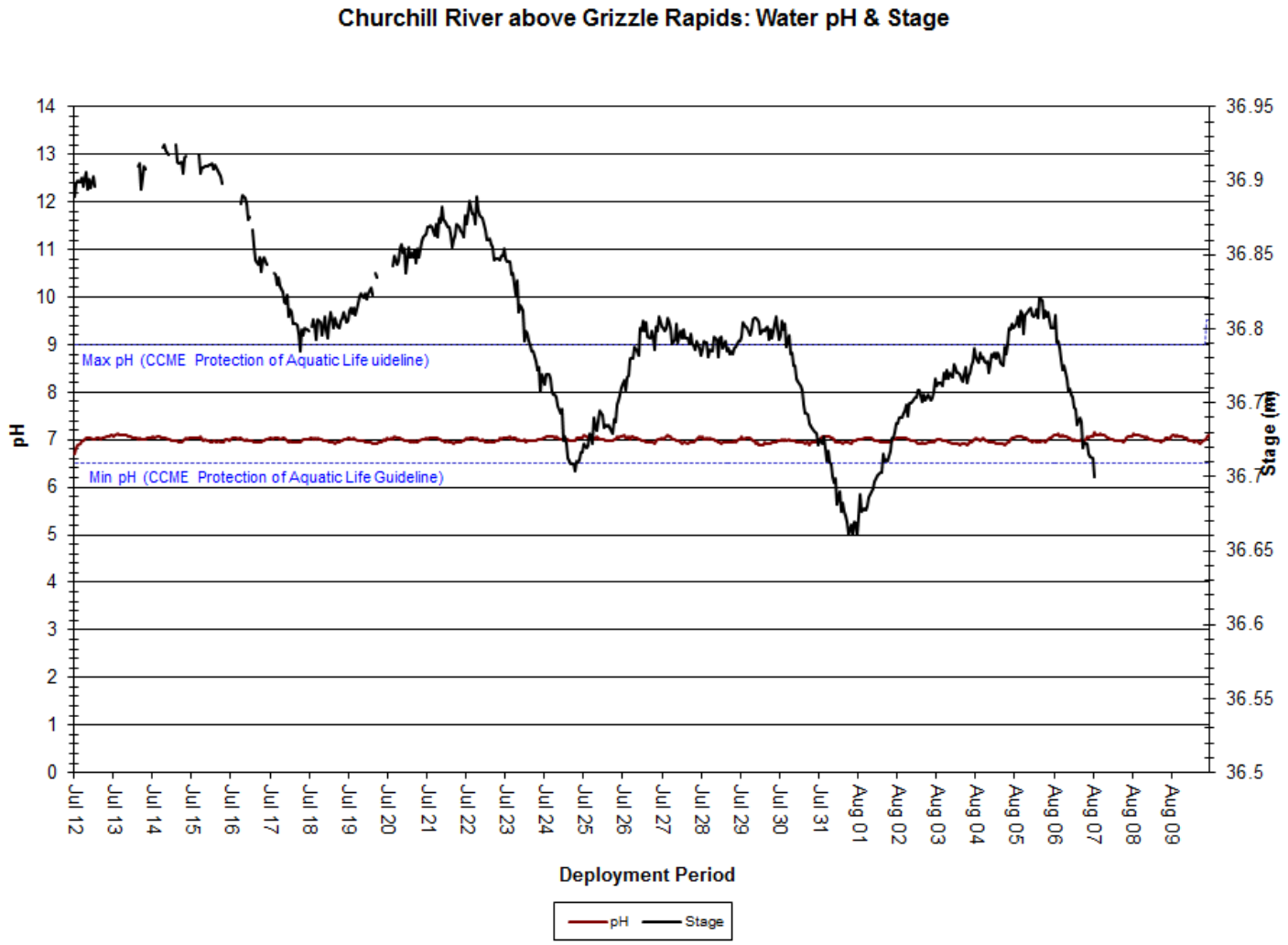

Figure 3: pH & Stage at Churchill River above Grizzle Rapids

Specific Conductivity

- Specific conductivity ranges from 16µS/cm to 19µS/cm, with a median of 18µS/cm (Figure 4).
- The relationship between conductivity and stage is inversed. When stage levels increase, specific conductance levels decrease as the increased amount of water in the river system dilutes solids that are present. This relationship is difficult to see in Figure 4 due to specific conductivity values in the internal log file being recorded as integers as opposed to decimals.
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

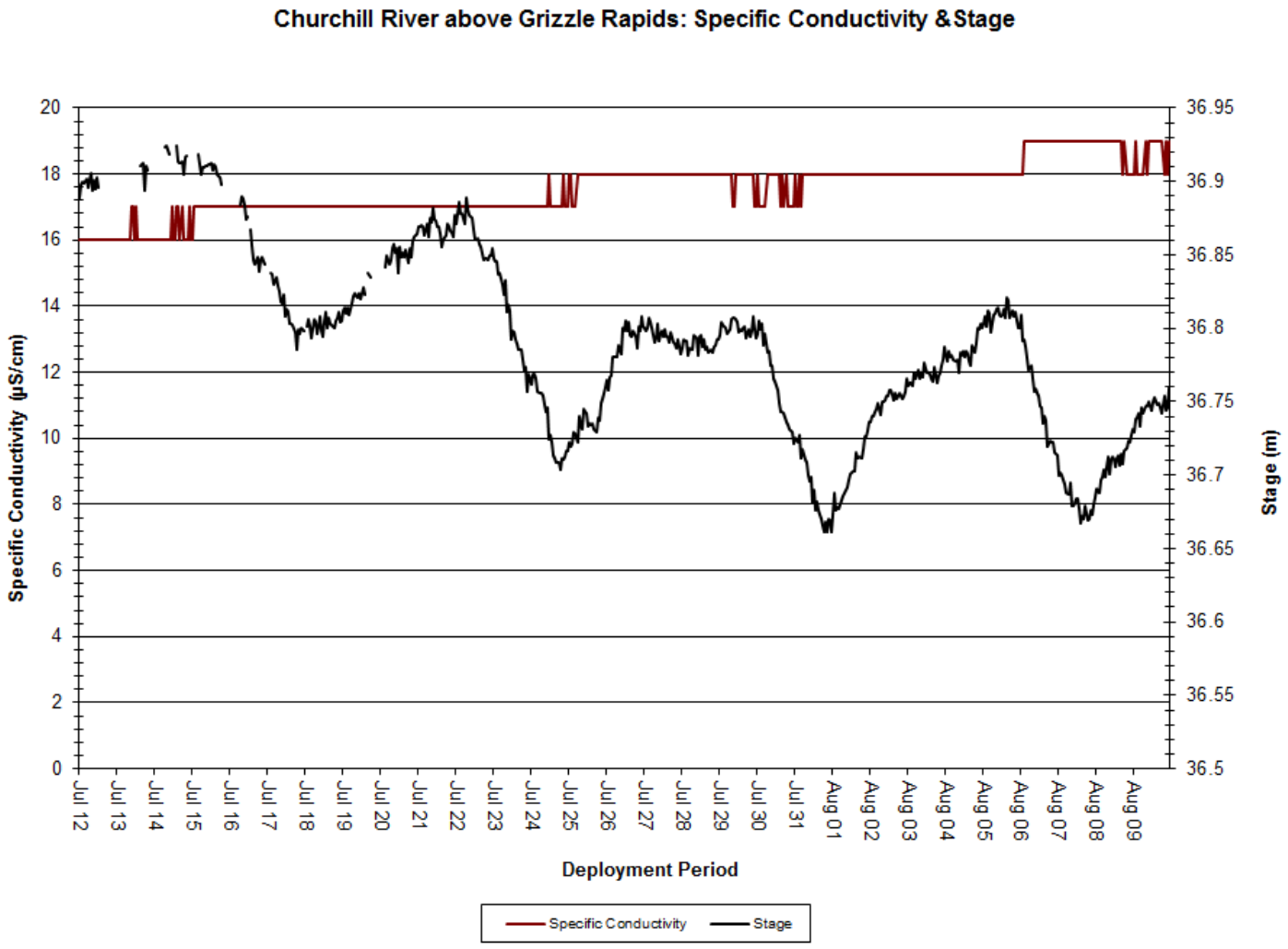

Figure 4: Specific Conductivity & Stage at Churchill River above Grizzle Rapids

Dissolved Oxygen

- Dissolved oxygen content ranged from 9.27mg/L to 10.26mg/L, with a median value of 9.78mg/L. The saturation of dissolved oxygen ranged from 93.9% to 101.2%, with a median value of 96.5% (Figure 5).
- There is an evident relationship between water temperature and dissolved oxygen. Over the deployment period, the dissolved oxygen levels are gradually falling as temperatures rise into the summer season. Dissolved oxygen also follows a diurnal pattern as the water temperature rises and falls under the influence of the ambient air temperature. Generally, dissolved oxygen levels are higher in a waterbody during cooler temperatures.
- Dissolved oxygen levels remained above the CCME Guidelines for the Protection of Other Life Stages; however, dissolved oxygen levels dipped slightly below the CCME Guideline for the Protection of Early Life Stages as water temperatures increased into the summer months.

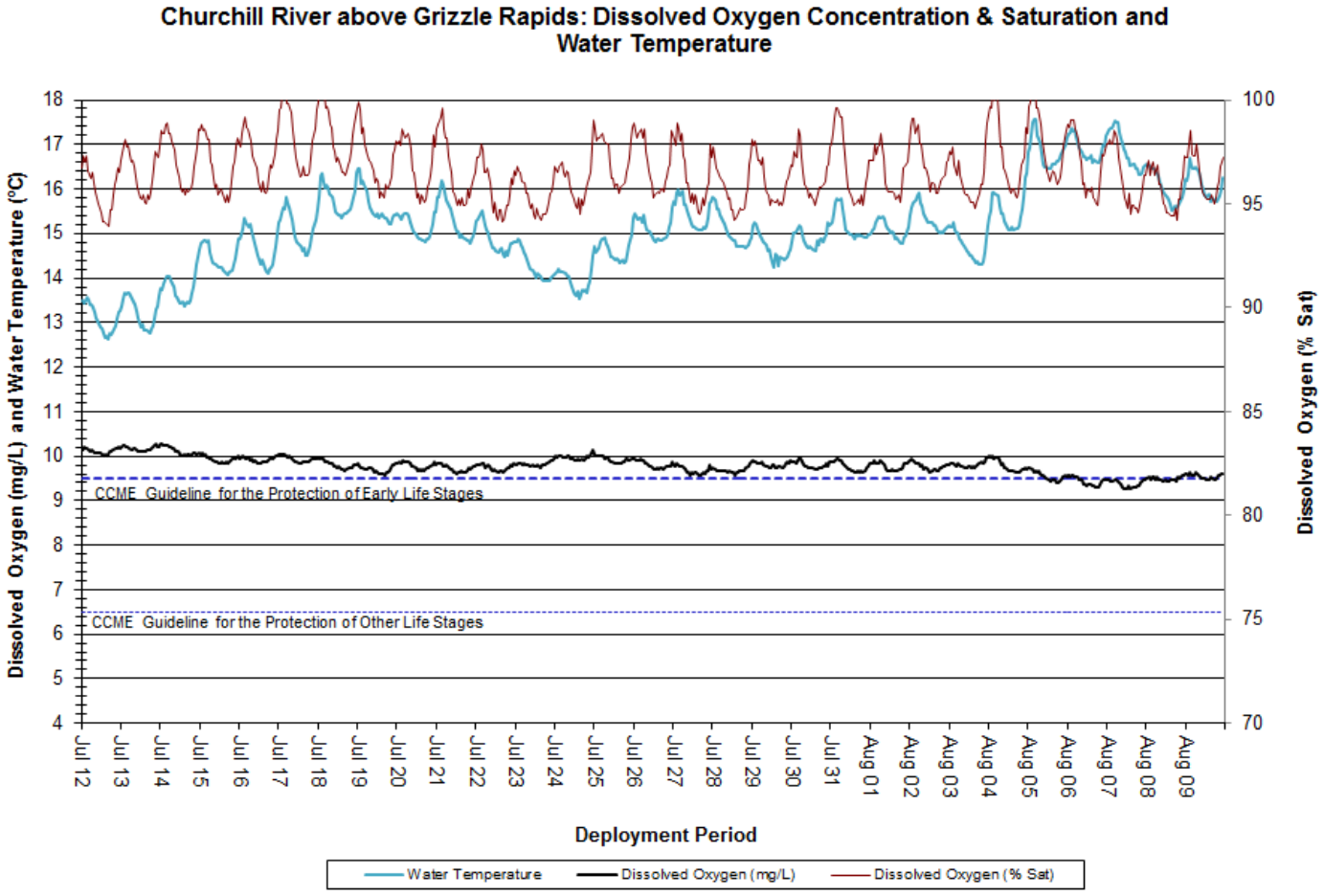

Figure 5: Dissolved Oxygen & Water Temperature at Churchill River above Grizzle Rapids

Turbidity

- Turbidity remained constant at 0.0NTU for the duration of deployment. Given the natural aquatic conditions at this station, this likely indicates a sensor failure and so turbidity data has been removed from the dataset.

Stage

- Stage levels ranged from 36.661m to 36.924m, with a median value of 36.79m (Figure 6).
- Stage was variable across the course of deployment, with precipitation events often correlating with temporary increases in stage.
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

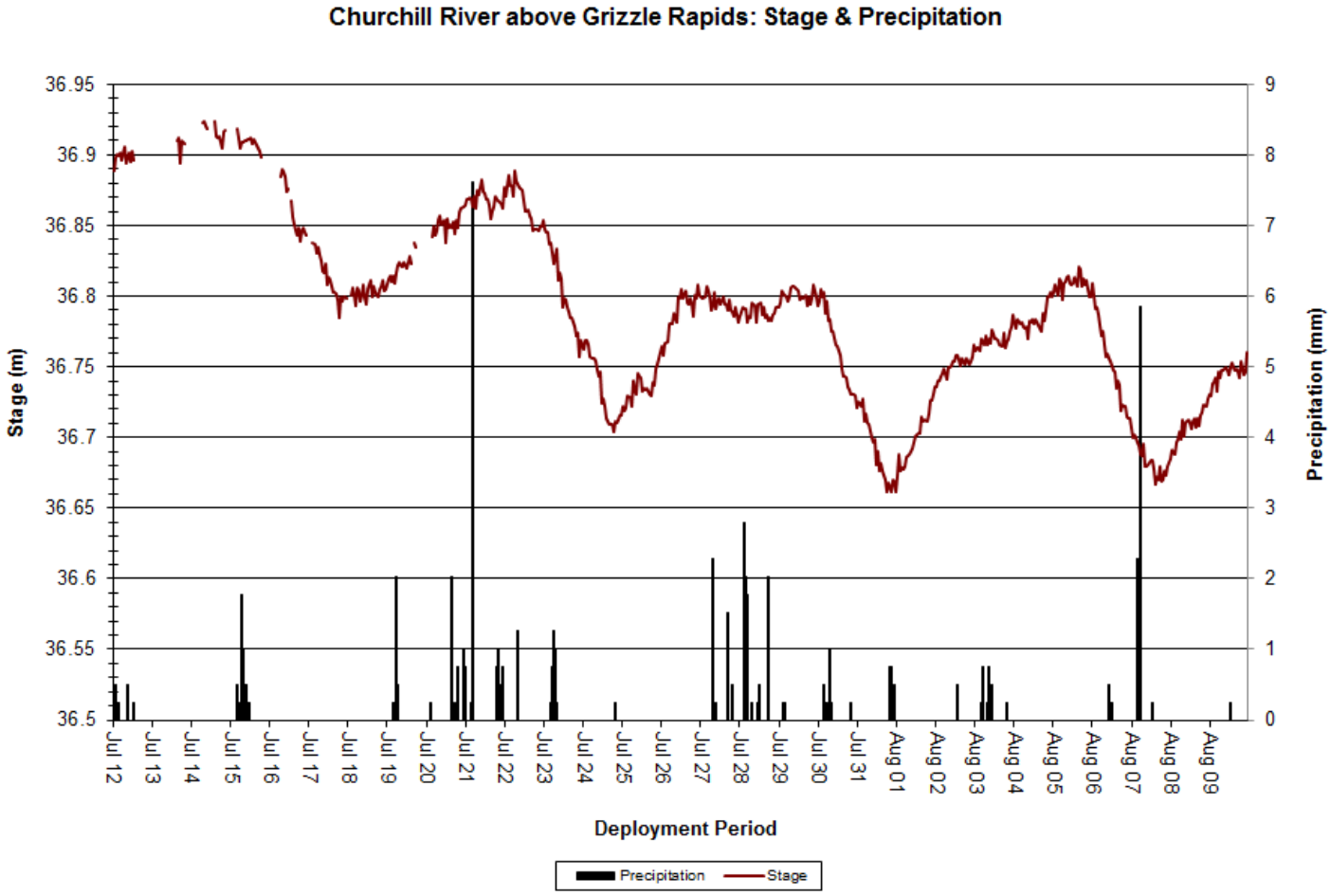

Figure 6: Stage & Precipitation at Churchill River above Grizzle Rapids

Churchill River below Muskrat Falls

Water Temperature

- Water temperature ranged from 12.00°C to 18.20°C, with a median value of 15.70°C (Figure 7).
- Water temperature gradually increases throughout deployment, a trend that is expected as air temperatures warm through the summer months. Water temperatures closely correlate with ambient air temperatures (Muskrat Falls Weather Station).
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

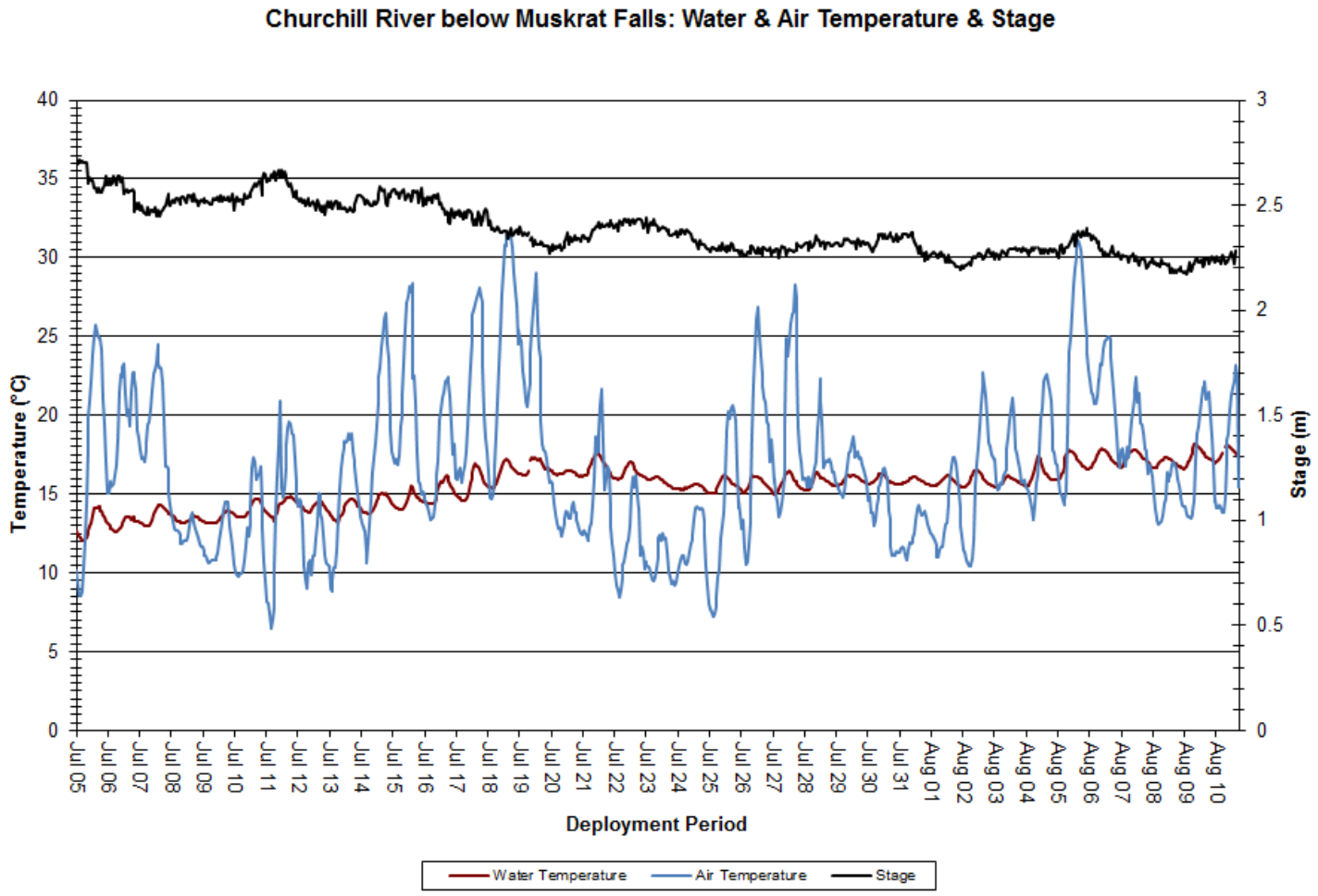

Figure 7: Water & Air Temperature and Stage at Churchill River below Muskrat Falls

pH

- pH ranged from 6.01 to 7.16 pH units, with a median value of 6.63 (Figure 8).
- pH values are relatively stable and within the CCME Protection of Aquatic Life Guidelines until July 24th, after which time they decrease quickly and stay below the CCME Guidelines for the remainder of deployment. This sudden decrease is likely related to rainfall events that occurred from July 21st through July 24th.
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

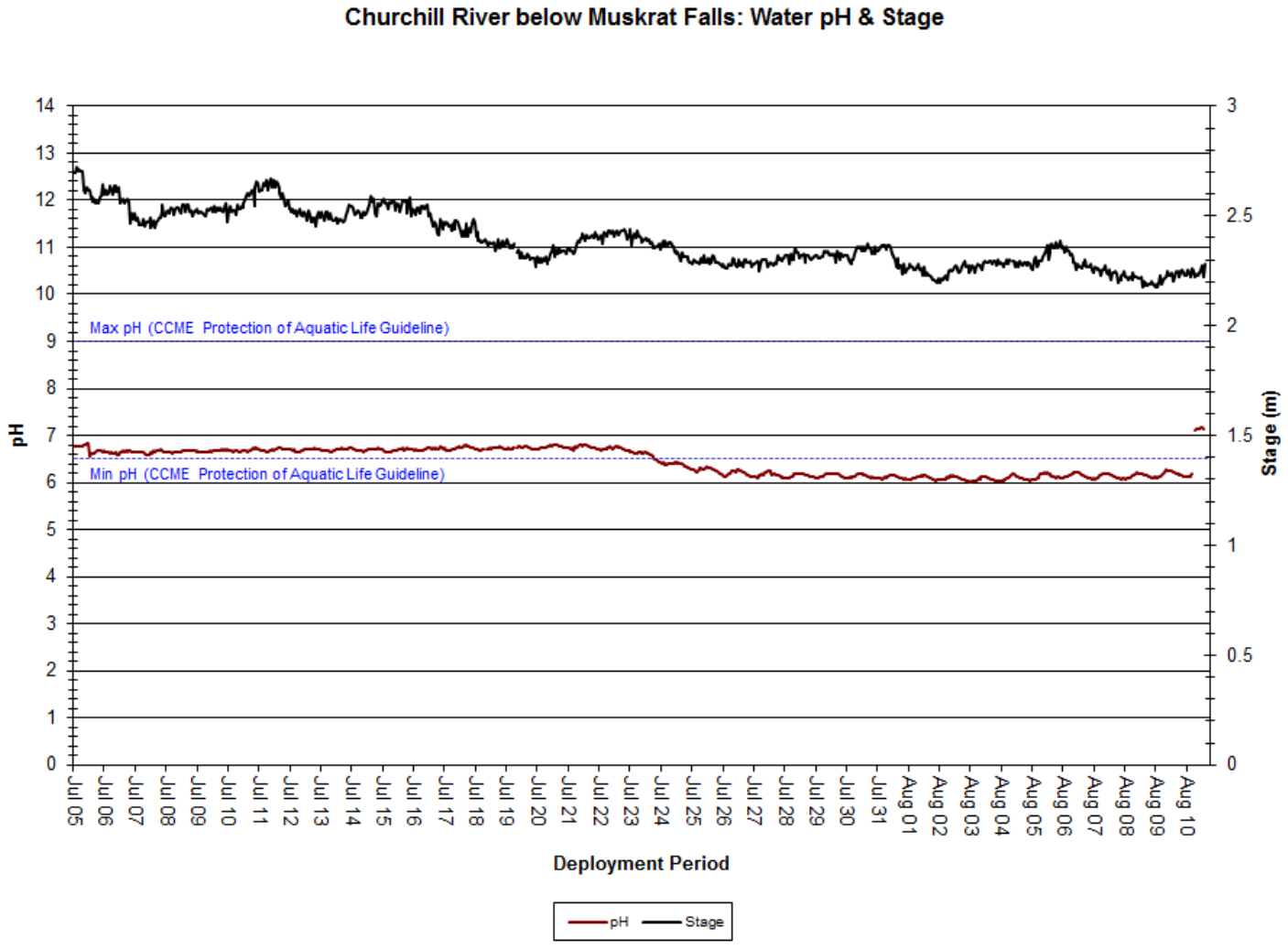

Figure 8: pH & Stage at Churchill River below Muskrat Falls

Specific Conductivity

- Specific conductivity ranged from 12.8µS/cm to 19.1µS/cm, with a median value of 16.5µS/cm (Figure 9).
- The relationship between conductivity and stage are inversed. When stage levels increase, specific conductance levels decrease as the increased amount of water in the river system dilutes solids that are present.
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

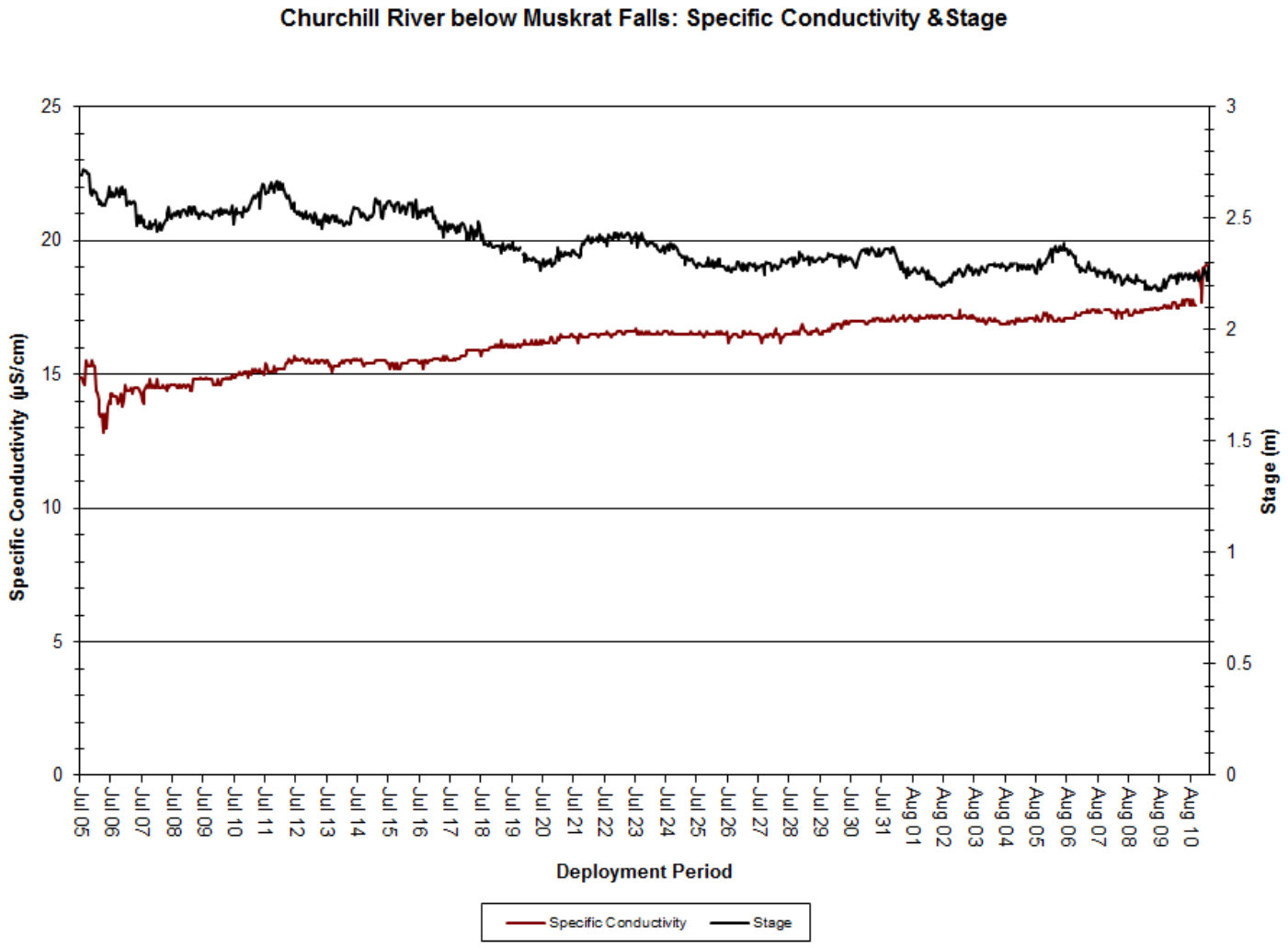

Figure 9: Specific Conductivity & Stage at Churchill River below Muskrat Falls

Dissolved Oxygen

- Dissolved oxygen concentration ranged from 9.54mg/L to 11.54mg/L, with a median value of 10.44mg/L. The saturation of dissolved oxygen ranged from 97.3% to 111.5%, with a median value of 104.4% (Figure 10).
- There is an evident relationship between water temperature and dissolved oxygen. Over the deployment period, dissolved oxygen levels are slowly decreasing as temperatures increase into the summer season. Dissolved oxygen also follows a diurnal pattern as water temperatures rise and fall under the influence of the ambient air temperature. Generally, dissolved oxygen levels are higher in a waterbody during cooler temperatures.
- Dissolved oxygen levels remained above the CCME Guidelines for the Protection of Other Life Stages and the CCME Guidelines for the Protection of Early Stages for the duration of deployment.

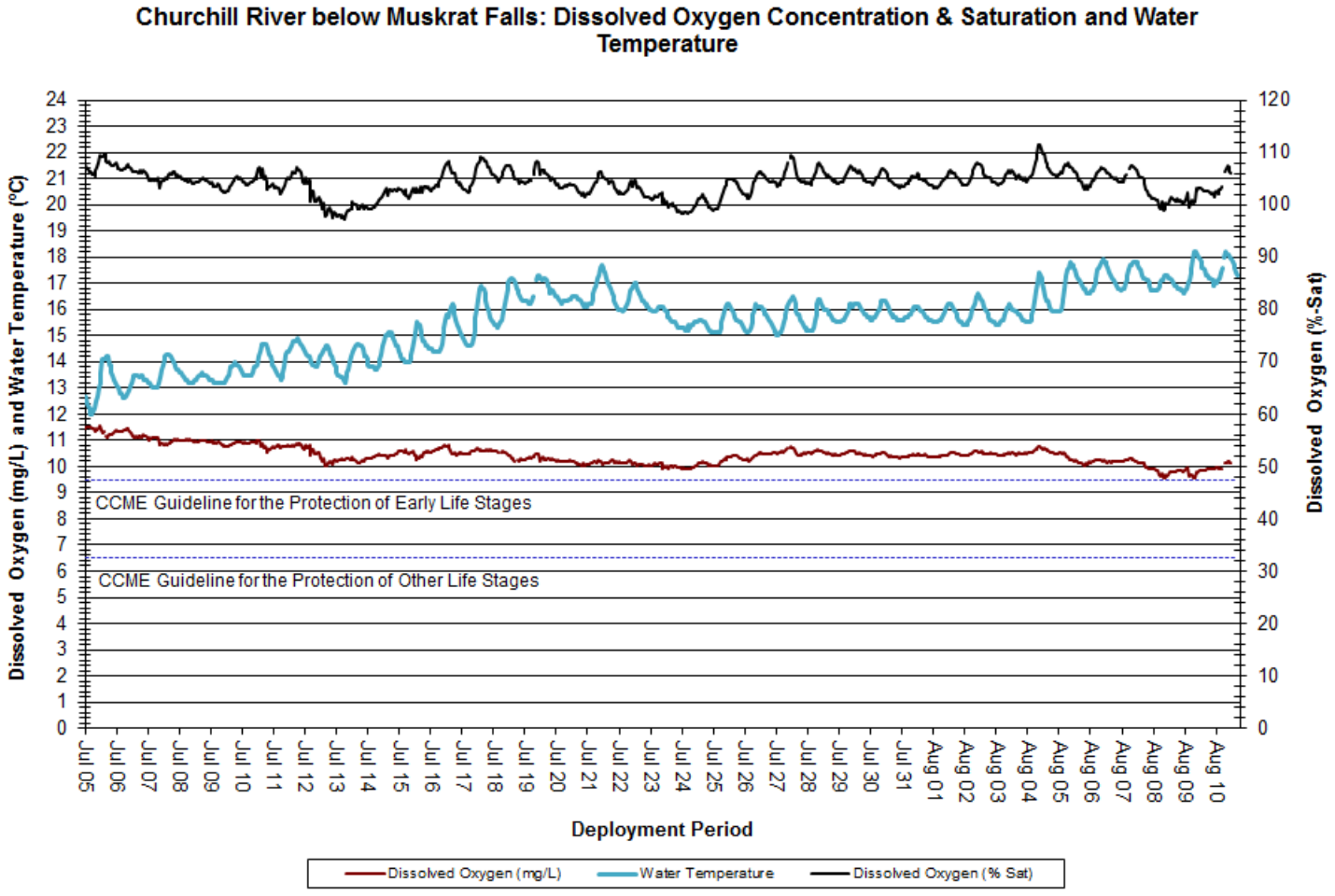

Figure 10: Dissolved Oxygen & Water Temperature at Churchill River below Muskrat Falls

Turbidity

- Turbidity ranged from 0.0NTU to 46.5NTU, with a median value of 1.3NTU (Figure 11).
- A median value of 1.3NTU indicates that there is a very low level of background turbidity at this station. Turbidity events during deployment often correlate with increases in stage and precipitation events. Precipitation can increase the presence of suspended material in water.
- Turbidity readings showed a significant increase from July 12th through July 15th. Construction reports from the Muskrat Falls work site indicate that sedimentation issues on site may have contributed to this turbidity spike. Increased sediment was observed being discharged from Sedimentation Pond 1, while bank erosion and sedimentation issues were observed at Laydown-11 near their diversion channel. In addition, high winds during this timeframe may have contributed to high turbidity readings given the sandy nature of the river bottom at this station.
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

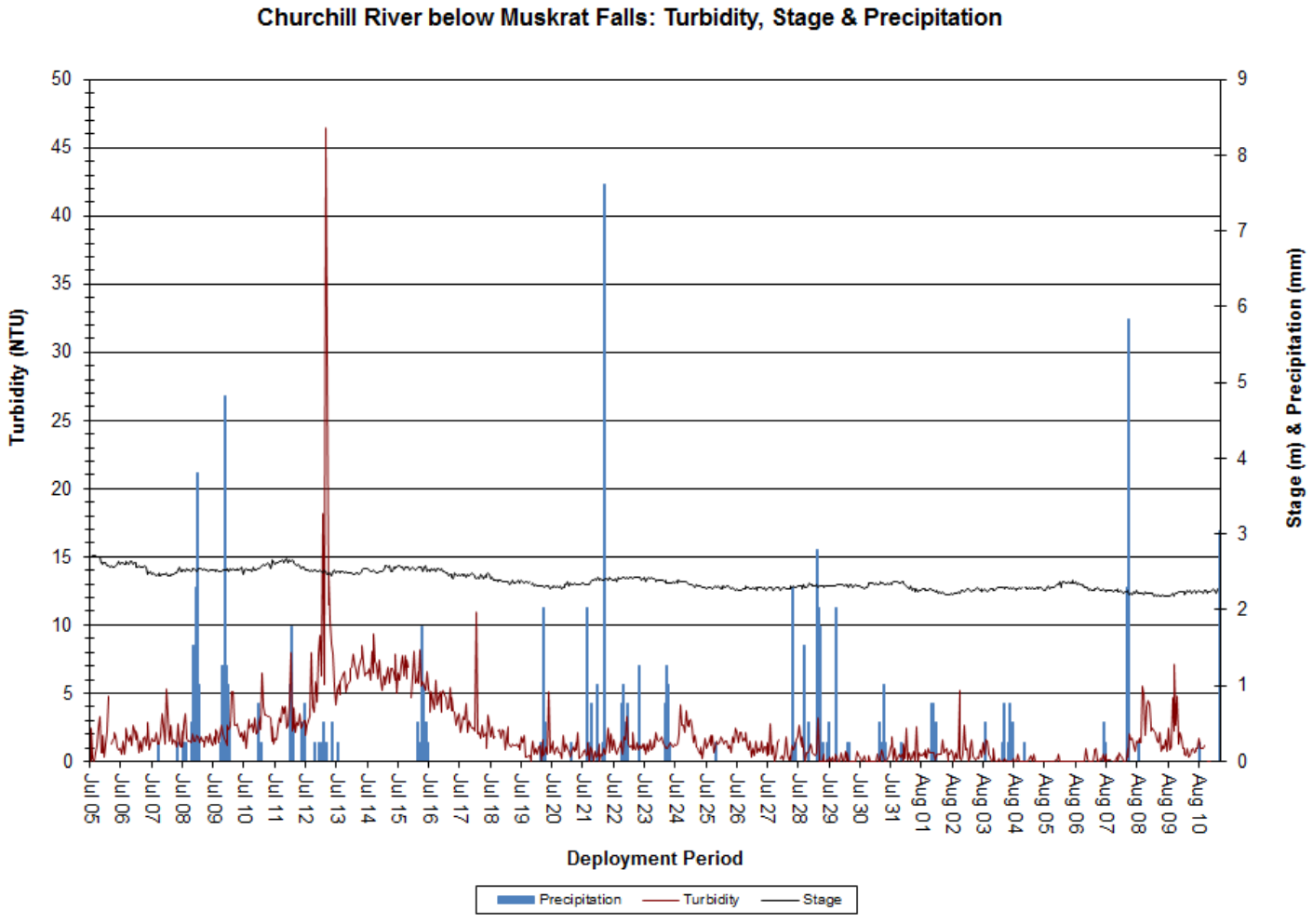

Figure 11: Turbidity. Stage & Precipitation (Muskrat Falls Weather Station) at Churchill River below Muskrat Falls

Stage

- Stage ranged from 2.17m to 2.72m, with a median value of 2.36m (Figure 12).
- Stage remained fairly consistent over the course of deployment, with precipitation events often correlating with temporary increases in stage.
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

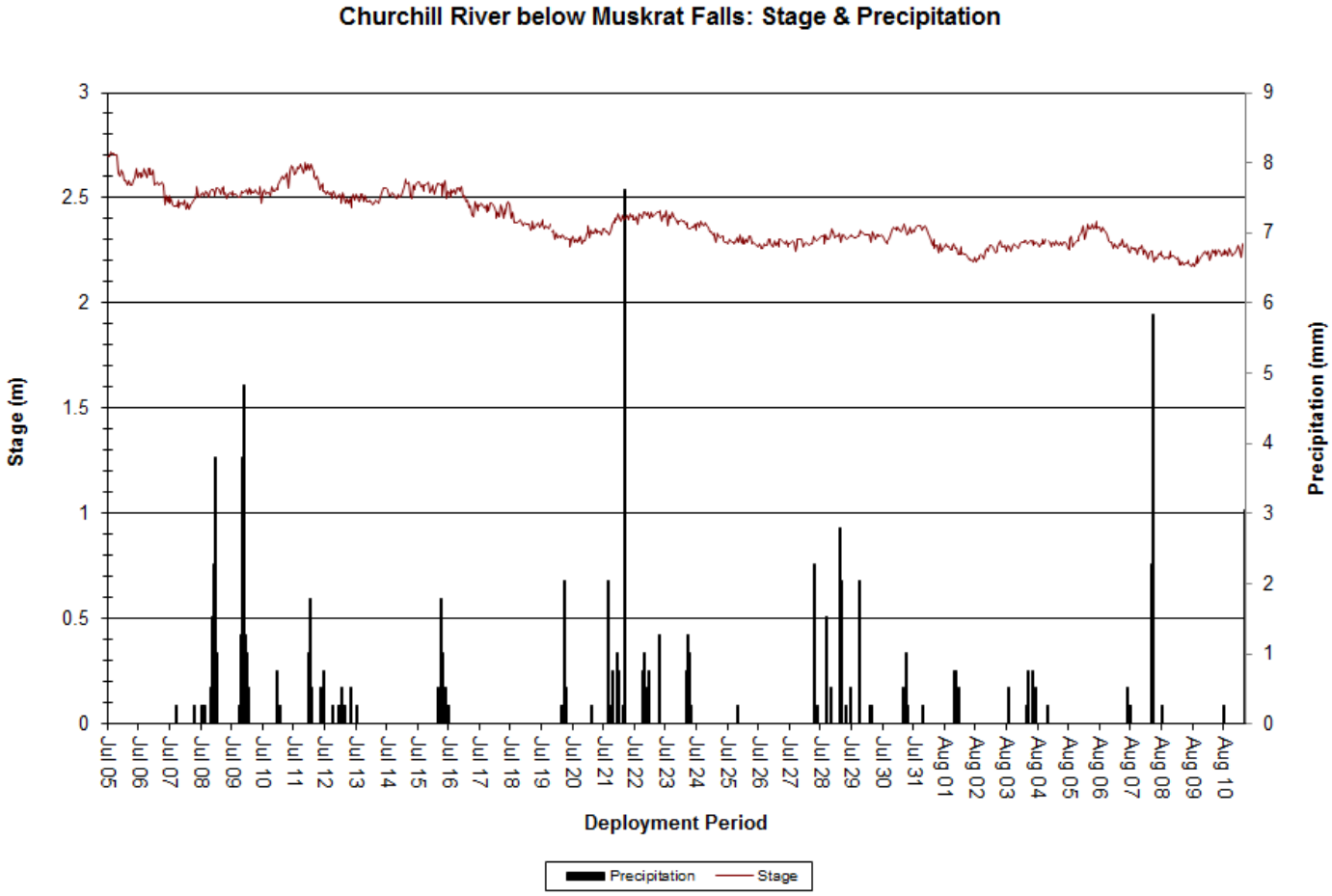

Figure 12: Stage & Precipitation at Churchill River below Muskrat Falls

Churchill River at English Point

Water Temperature

- Water temperature ranged from 12.50°C to 20.60°C, with a median value of 16.15°C (Figure 13).
- Water temperature gradually increases over the course of deployment, a trend that is expected as air temperatures warm through the summer months. Water temperatures closely correlate with ambient air temperatures (Mud Lake Weather Station).
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

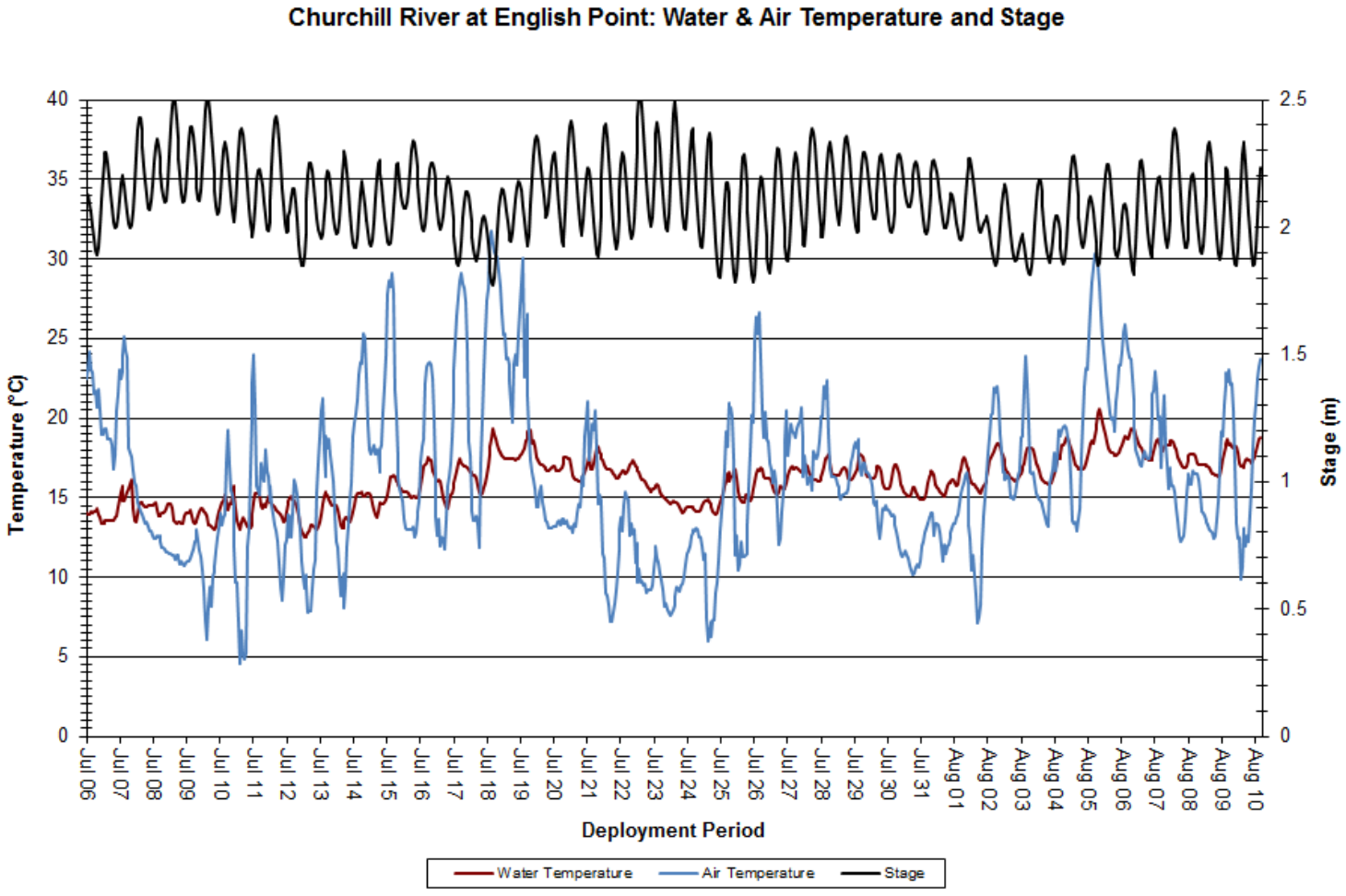

Figure 13: Water & Air Temperature (Mud Lake Weather Station) and Stage at Churchill River at English Point

pH

- pH ranged from 6.28 to 6.92 pH units, with a median value of 6.64 (Figure 14).
- For the duration of deployment, pH values hover around the minimum CCME Guideline for Protection of Aquatic Life. This is likely due to a large influx of freshwater from spring melt.
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

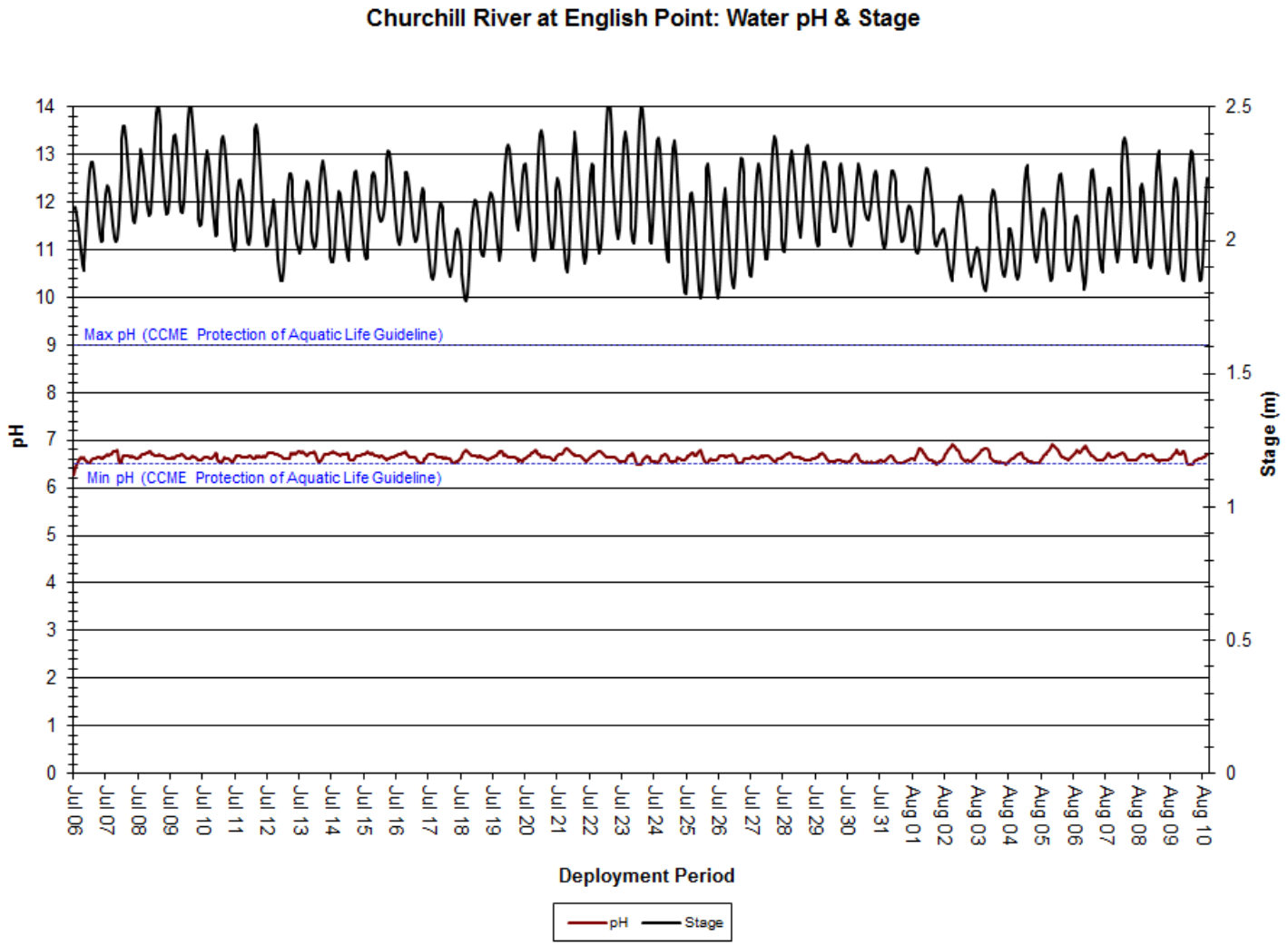

Figure 14: pH & Stage at Churchill River at English Point

Specific Conductivity

- Specific conductivity ranged from 18.8µS/cm to 60.9µs/cm, with a median value of 31.2µS/cm (Figure 15).
- Specific conductivity fluctuates considerably at this location due to the tidal influences of the Atlantic Ocean on Lake Melville. As the tide comes in, specific conductivity increases as dissolved solids and salinity increase, and vice versa as the tide goes out. This increase and decrease in specific conductivity and stage occurs twice daily. This pattern is generally consistent throughout the deployment period (Figure 15).
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

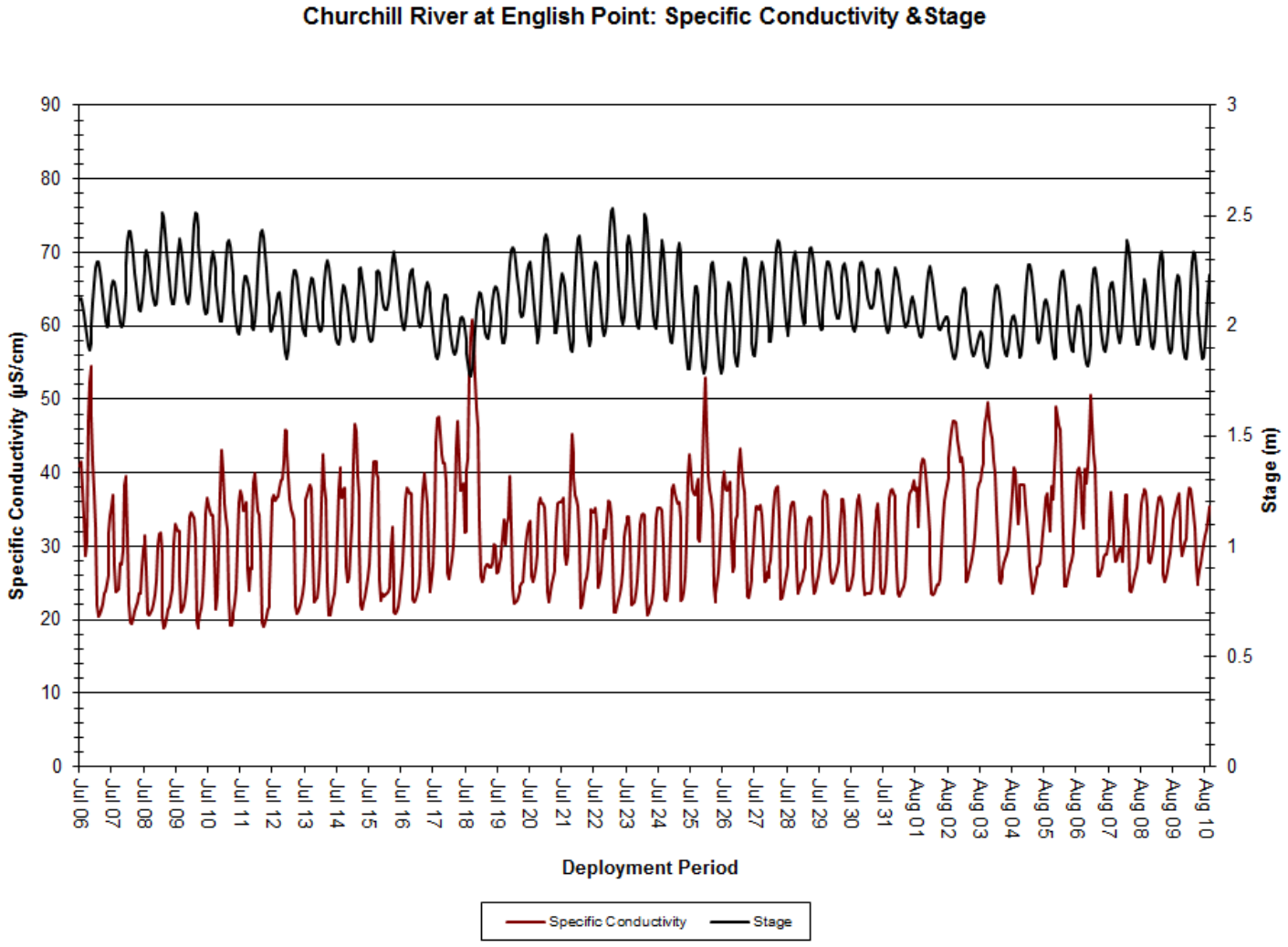

Figure 15: Specific Conductivity & Stage at Churchill River at English Point

Dissolved Oxygen

- Dissolved oxygen concentration ranged from 8.70mg/L to 10.50mg/L, with a median value of 9.48mg/L. The saturation of dissolved oxygen ranged from 86.9% to 103.8%, with a median value of 96.1% (Figure 16).
- There is an evident relationship between water temperature and dissolved oxygen. As water temperatures increase over the deployment period, dissolved oxygen levels slowly fall. Dissolved oxygen levels also follow a diurnal pattern as water temperature rises and falls under the influence of ambient air temperature. Generally, dissolved oxygen levels are higher in a waterbody during cooler temperatures.
- Dissolved oxygen levels remained above the CCME Guidelines for the Protection of Other Life Stages for the duration of deployment; however, dissolved oxygen levels continuously crossed over the CCME Guideline for the Protection of Early Life Stages until August 5th, after which dissolved oxygen levels remained below the CCME Guideline for the remainder of deployment (Figure 16). This is to be expected considering rising water temperatures.

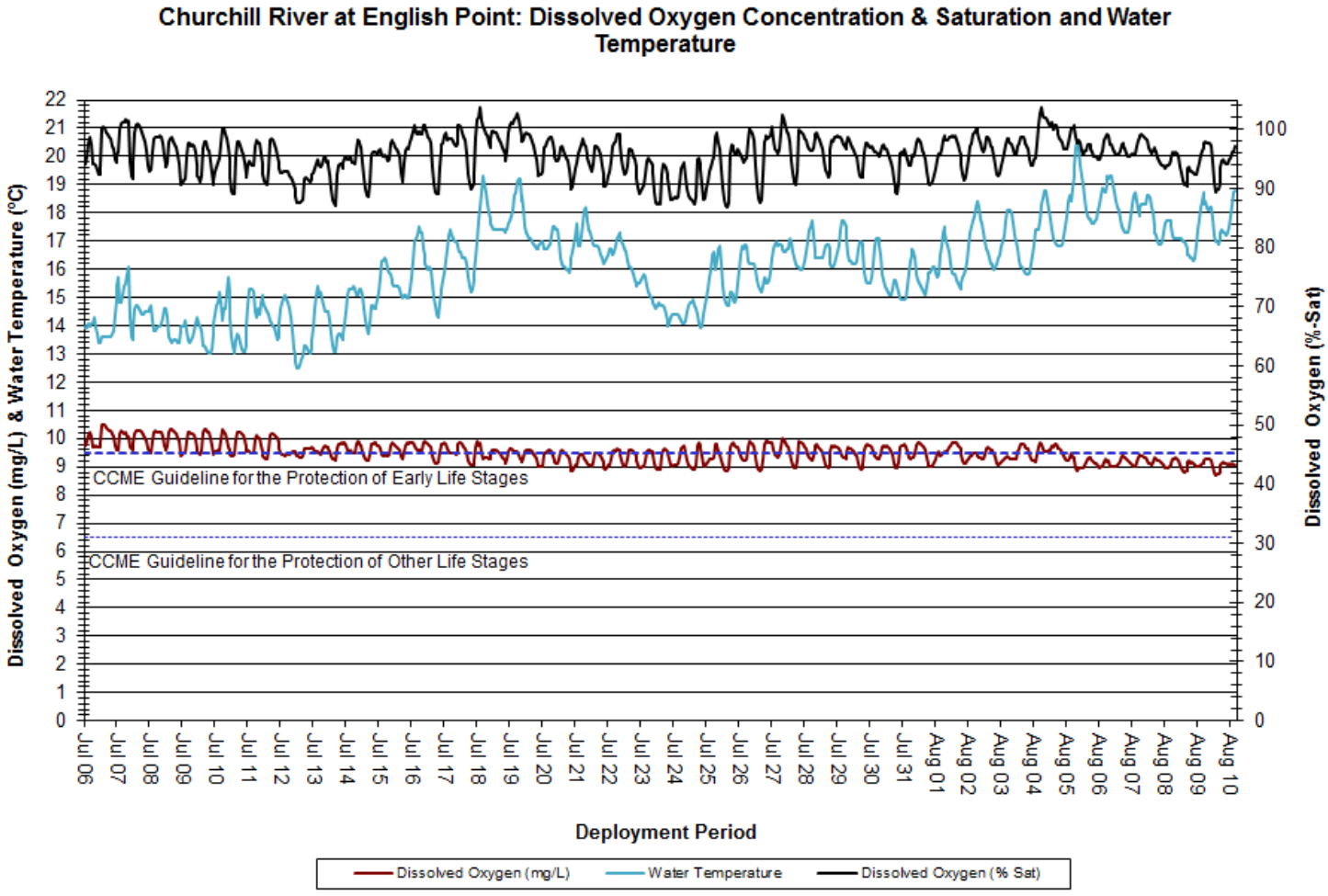

Figure 16: Dissolved Oxygen & Water Temperature at Churchill River at English Point

Turbidity

- Turbidity ranged from 0.0NTU to 100.1NTU, with a median value of 3.8NTU (Figure 17).
- Turbidity events often correlate with increases in stage and precipitation events. Precipitation can increase the presence of suspended material in water (Figure 17).
- The observed turbidity increase from July 12th through July 15th is similar to that observed at Churchill River below Muskrat Falls during the same period. Sedimentation issues at the Muskrat Falls work site are unlikely to influence this station at exactly the same time. As such, high winds from July 12th to July 15th are most likely to have caused the increased turbidity readings at this station. Similarly, the turbidity spike on July 6th is likely the result of high winds.
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

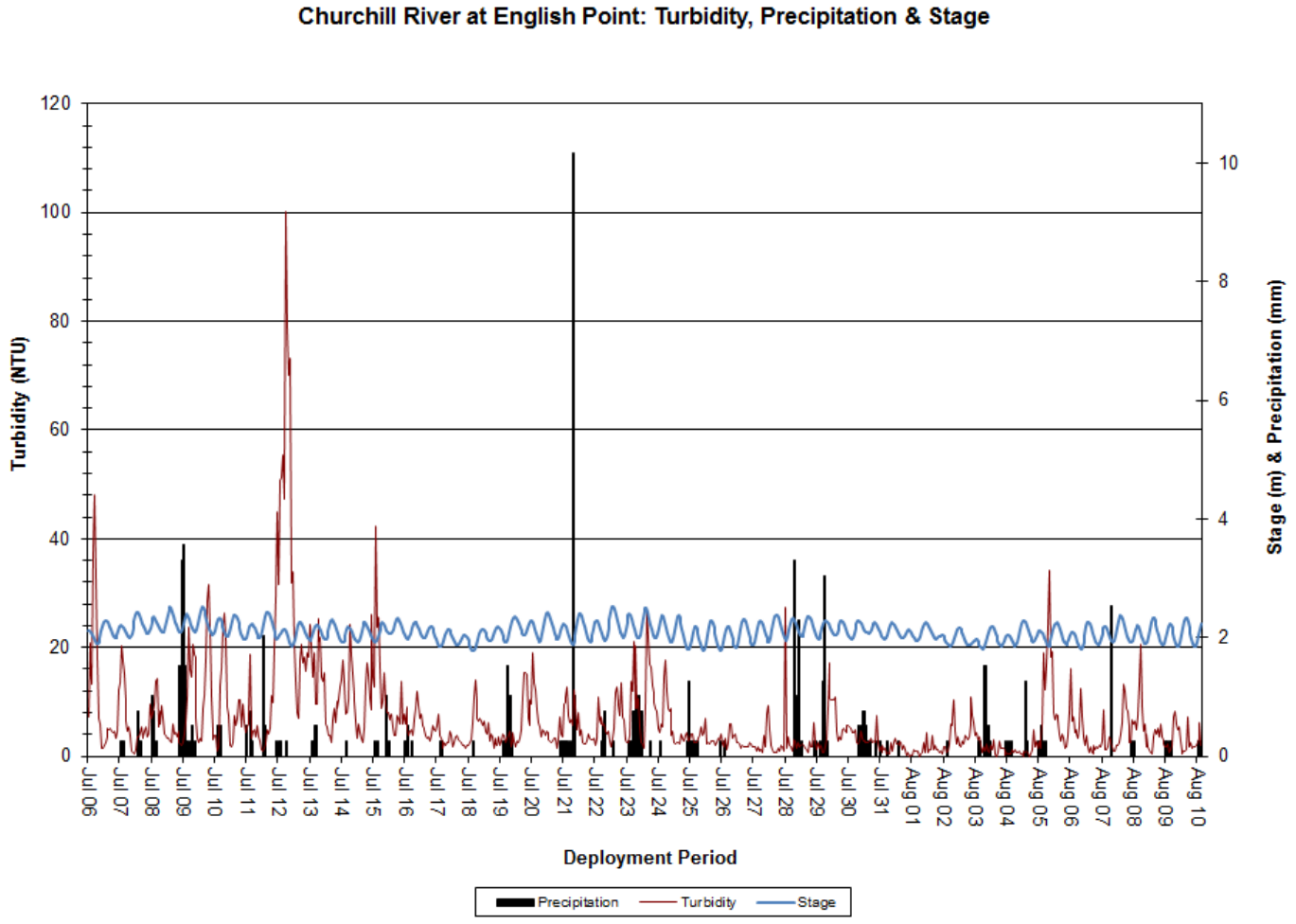

Figure 17: Turbidity, Stage & Precipitation (Mud Lake Weather Station) at Churchill River at English Point

Stage

- Stage ranged from 1.77m to 2.53m, with a median value of 2.10m (Figure 18).
- Stage fluctuates at this location due to the tidal influences of the Atlantic Ocean. As the tide comes in, stage increases causing tide related turbidity events, and vice versa as the tide goes out. This pattern is generally consistent throughout the deployment period (Figure 18). Tidal action may also suspend material in the water column, causing spikes in turbidity unrelated to precipitation events.
- Water Survey of Canada (Environment and Climate Change Canada) is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

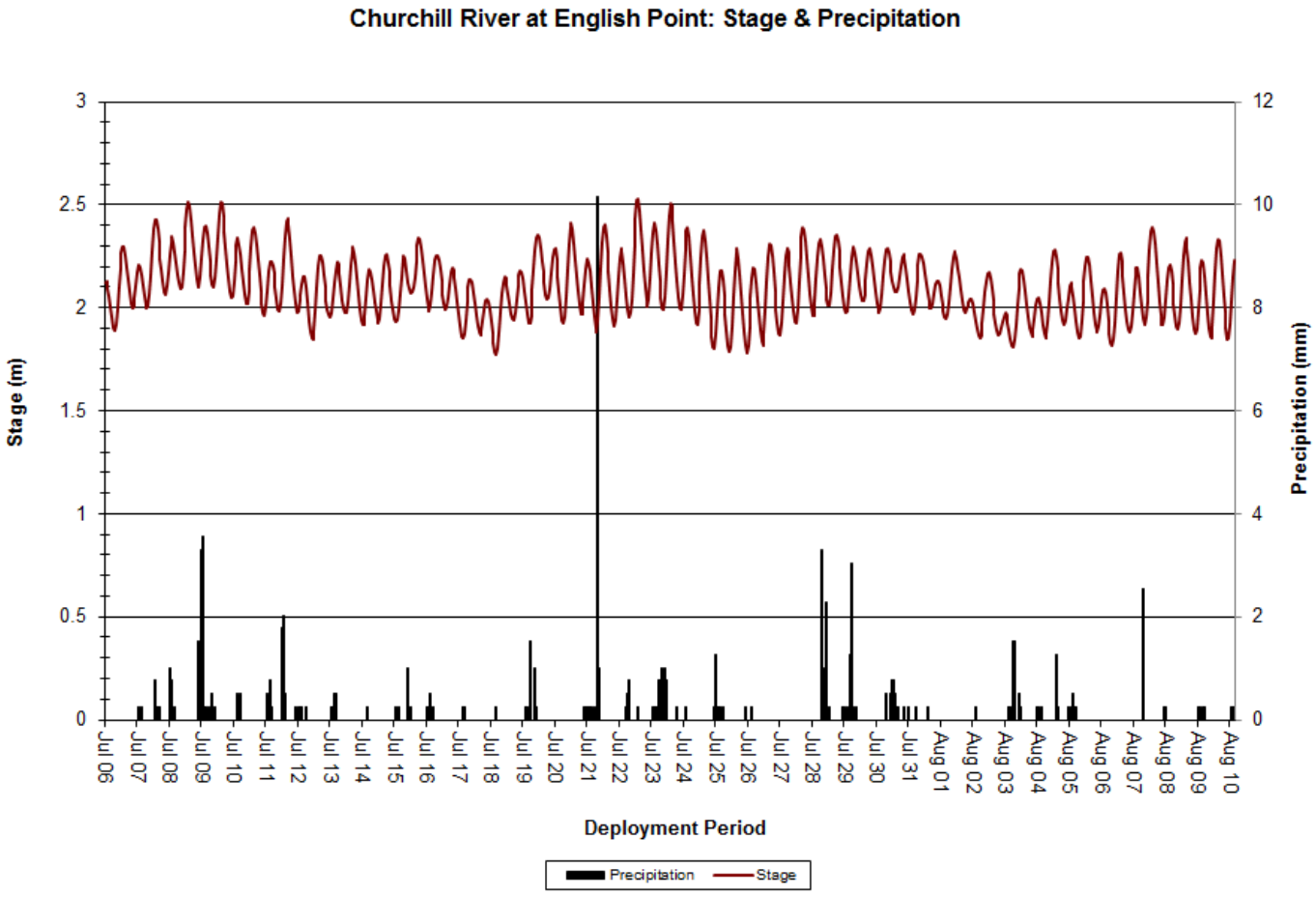

Figure 18: Stage & Precipitation at Churchill River at English Point

Conclusions

- Instruments at three water quality monitoring stations on the Lower Churchill River were deployed from July 5/6/12 to August 10 for periods of 29-36 days.
- Stage levels were relatively stable at all stations during the summer months. Water level changes at each of the stations ranged between 0.26m and 0.76m.
- Water temperature was increasing at all stations throughout the deployment period due to increasing ambient air temperatures in the region. A drop in water and air temperature was noted at all stations between July 21st and July 25th. Water temperature ranged from 12.00°C at Churchill River below Muskrat Falls to 20.60°C at Churchill River at English Point.
- pH was generally neutral and stable at stations along the Lower Churchill River, ranging from 6.01 at Churchill River below Muskrat Falls to 7.16 at both Churchill River below Muskrat Falls and above Grizzle Rapids. pH values at all stations were within the recommended CCME Guidelines for the Protection of Aquatic Life for the majority of the time, except during the second half of deployment at Churchill River below Muskrat Falls.
- Specific conductivity was relatively stable at the above Grizzle Rapids and below Muskrat Falls stations, ranging from 12.8 to 19.1µS/cm. Since English Point is influenced by tides in Lake Melville, specific conductivity values at the Churchill River at English Point station had a much wider range between 18.8µS/cm and 60.9µS/cm. This is comparable to other deployments at this location.
- Dissolved oxygen was generally decreasing slightly throughout the deployment period at all stations as water temperatures warmed into the summer months. Dissolved oxygen levels are generally higher in a waterbody at cooler temperatures. Dissolved oxygen values ranged from 8.70mg/L to 11.54mg/L, and only remained above the CCME Guideline for the Protection of Early Life Stages for the duration of deployment at one station (Churchill River below Muskrat Falls).
- Turbidity events occurred at all stations and were mainly related to precipitation events. At all stations, median turbidity values ranged from 0.0NTU to 3.8NTU, which indicates low background turbidity levels. Turbidity at all stations ranged from 0.0 to 100.1NTU. A significant spike in turbidity occured from July 12th through July 15th at both the below Muskrat Falls and English Point stations. Construction activities at the Muskrat Falls work site may have contributed to this increase, but high winds certainly played a significant factor considering the sandy bottom of the Churchill River.

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APPENDIX A

Station Comparisons

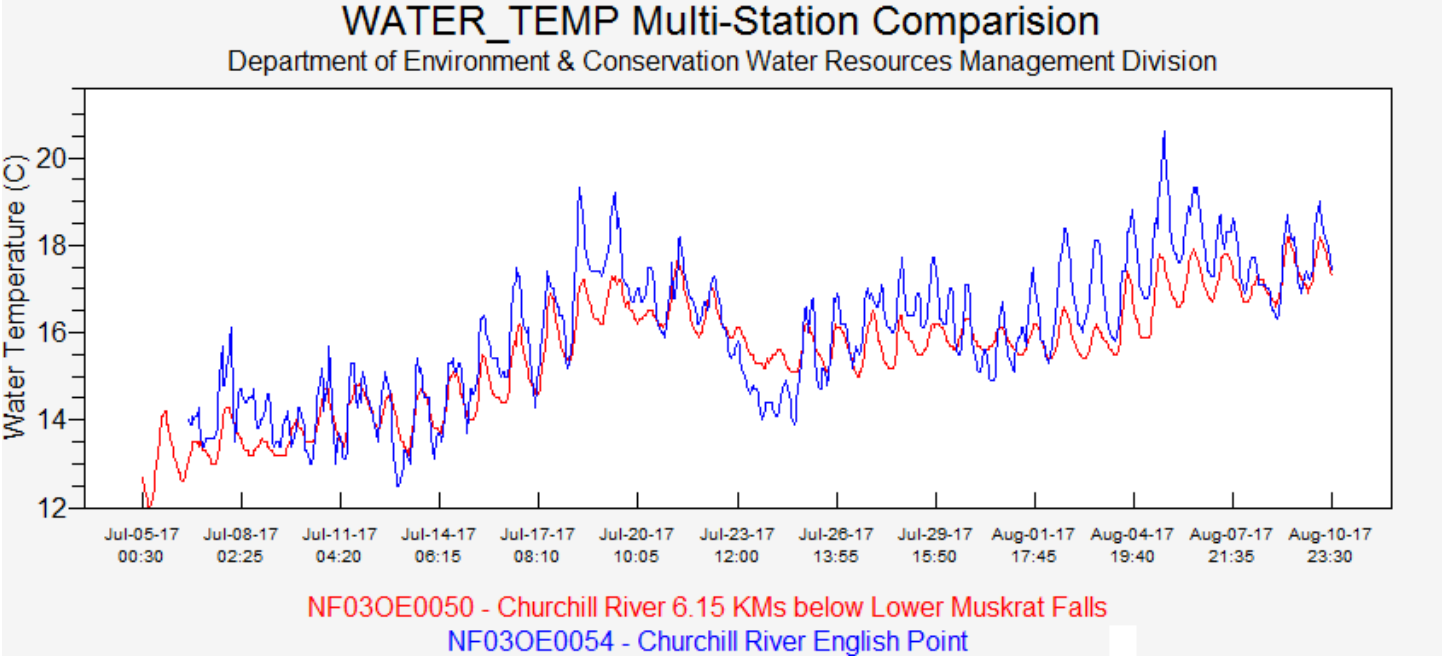

Figure A1: Comparison of Water Temperature at the Real-Time Stations on Churchill River

(Note: Grizzle Rapids station not included due to transmission issues)

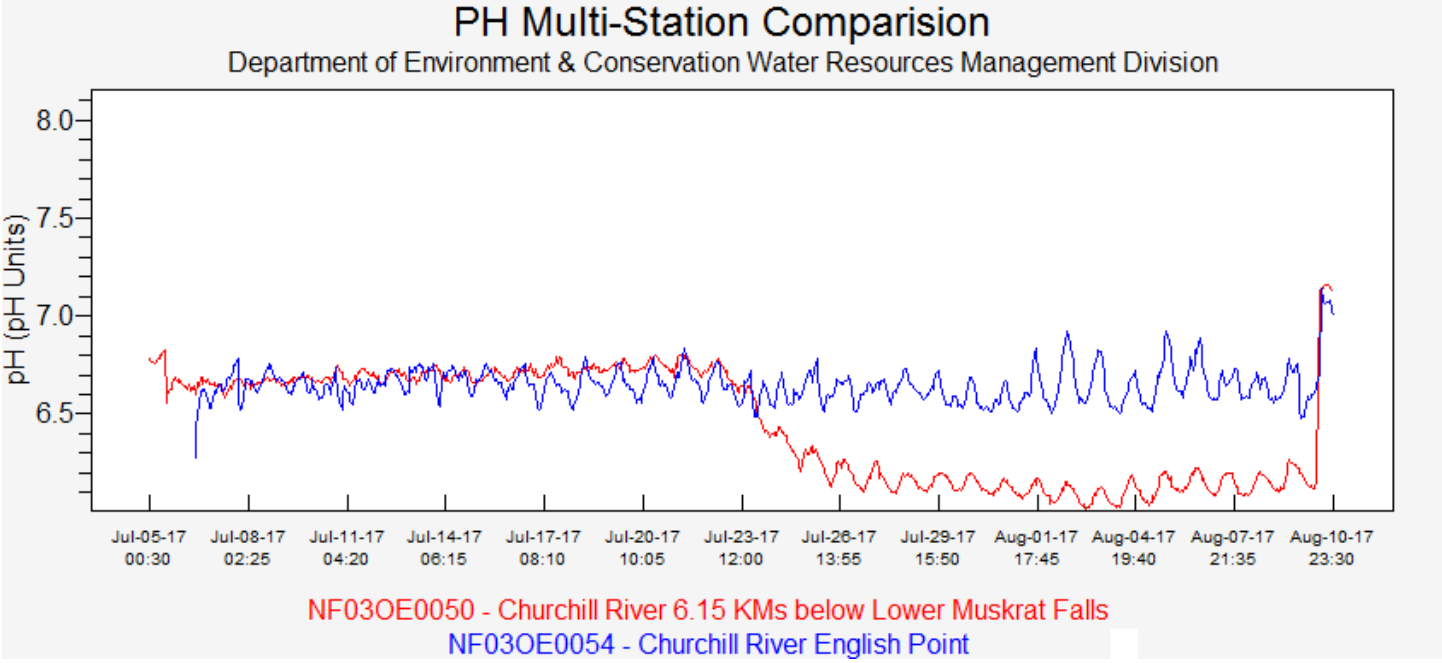

Figure A2: Comparison of pH at the Real-Time Stations on Churchill River

(Note: Grizzle Rapids station not included due to transmission issues)

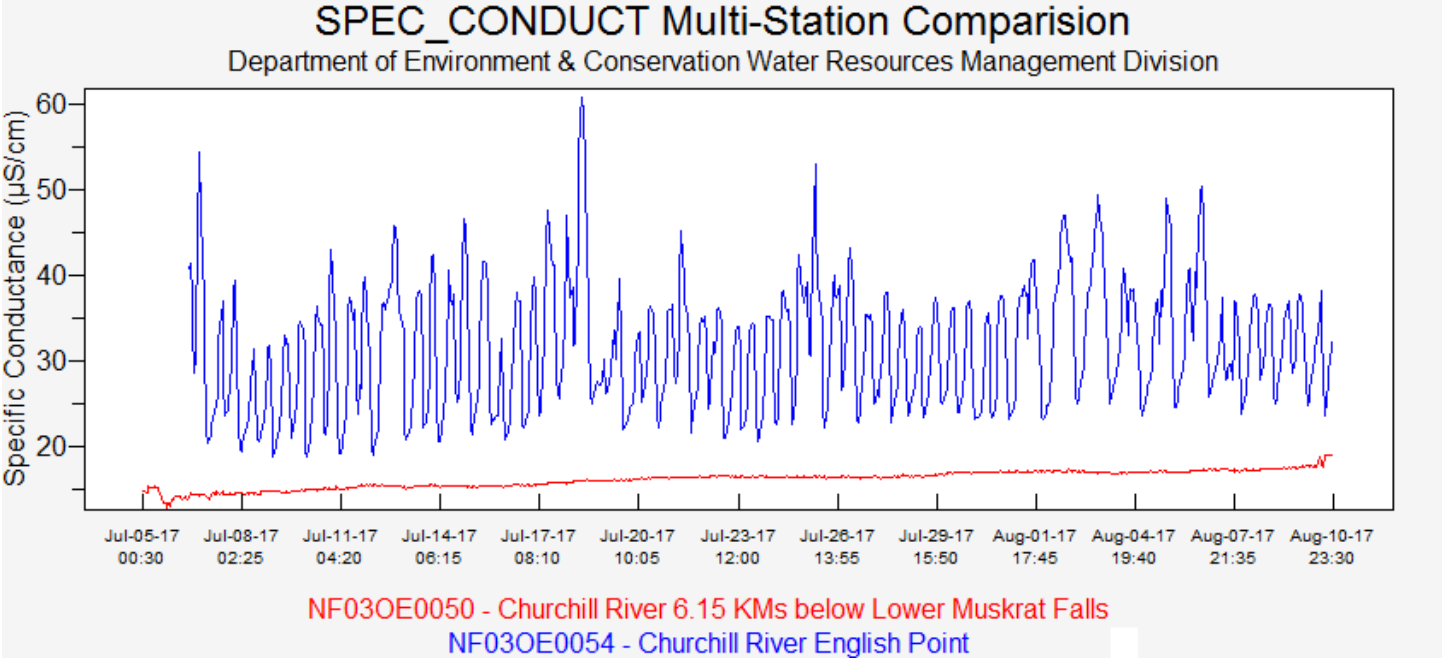

Figure A3: Comparison of Specific Conductivity at the Real-Time Stations on Churchill River

(Note: Grizzle Rapids station not included due to transmission issues)

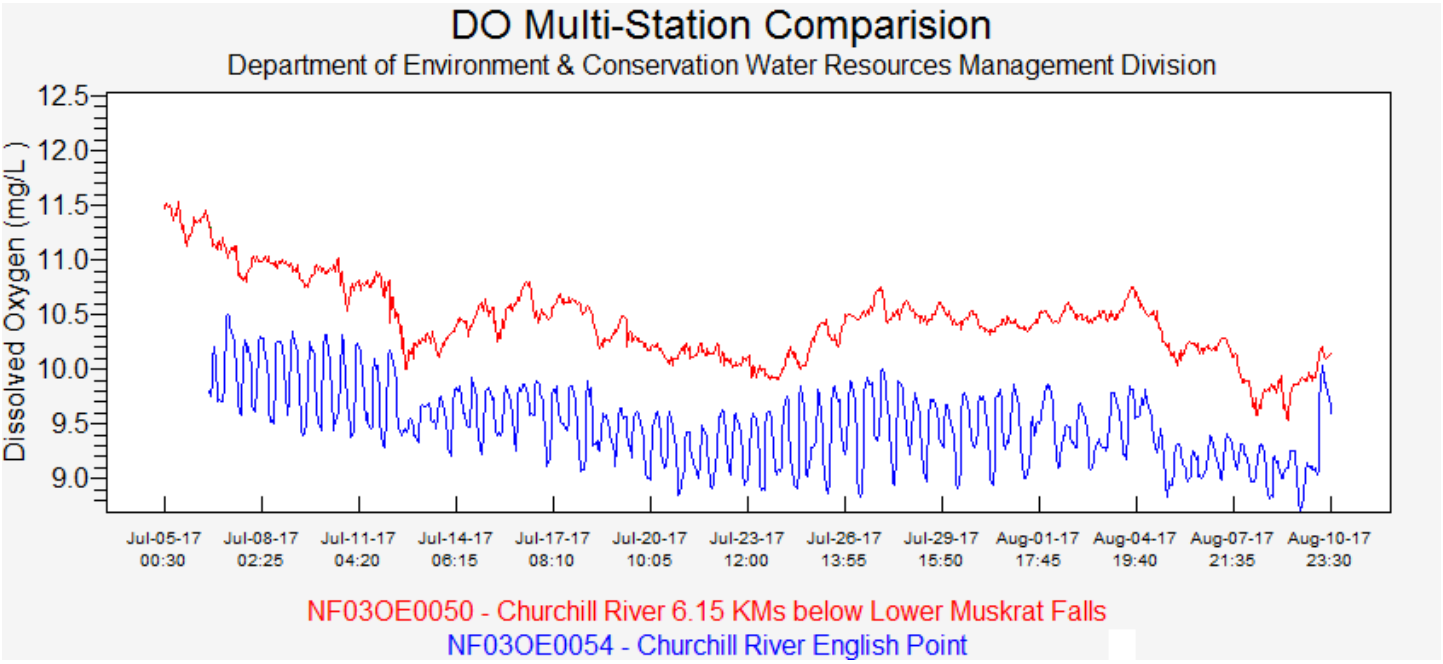

Figure A4: Comparison of Dissolved Oxygen at the Real-Time Stations on Churchill River

(Note: Grizzle Rapids station not included due to transmission issues)

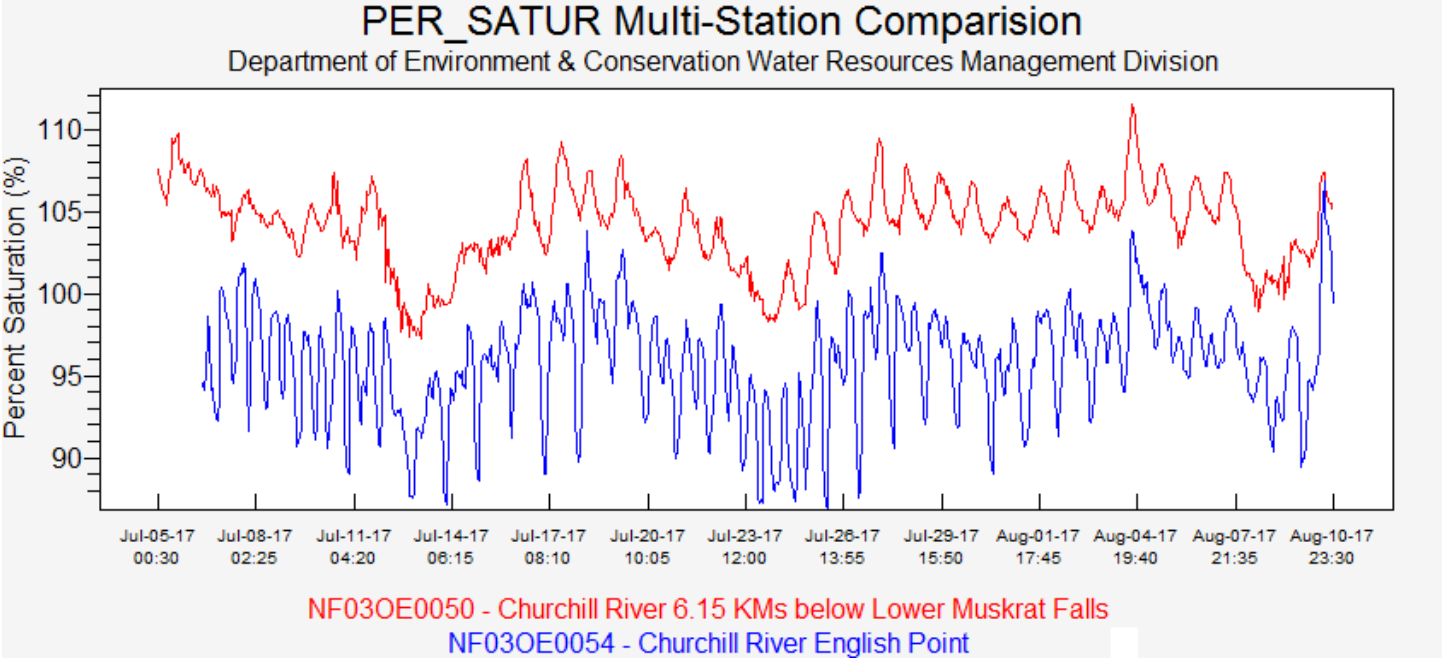

Figure A5: Comparison of Dissolved Oxygen (% Sat) at the Real-Time Stations on Churchill River

(Note: Grizzle Rapids station not included due to transmission issues)

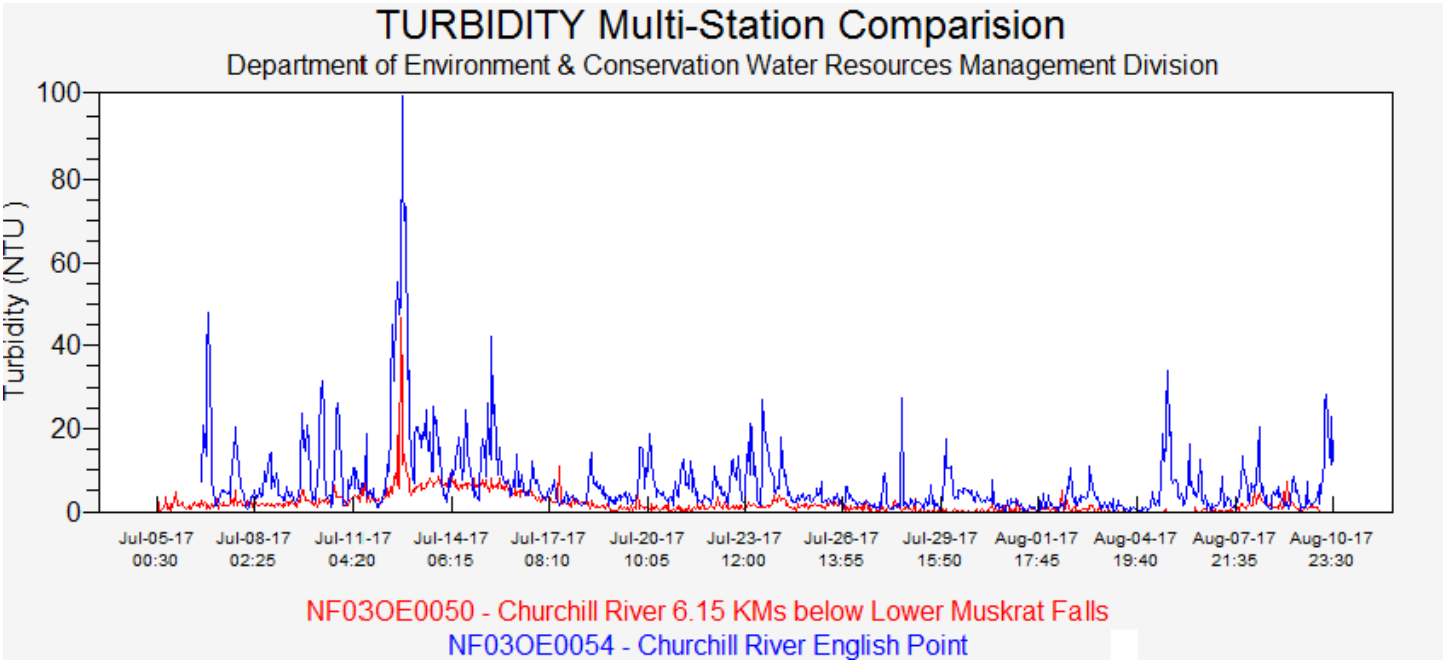

Figure A6: Comparison of Turbidity at the Real-Time Stations on Churchill River

(Note: Grizzle Rapids station not included due to transmission issues)

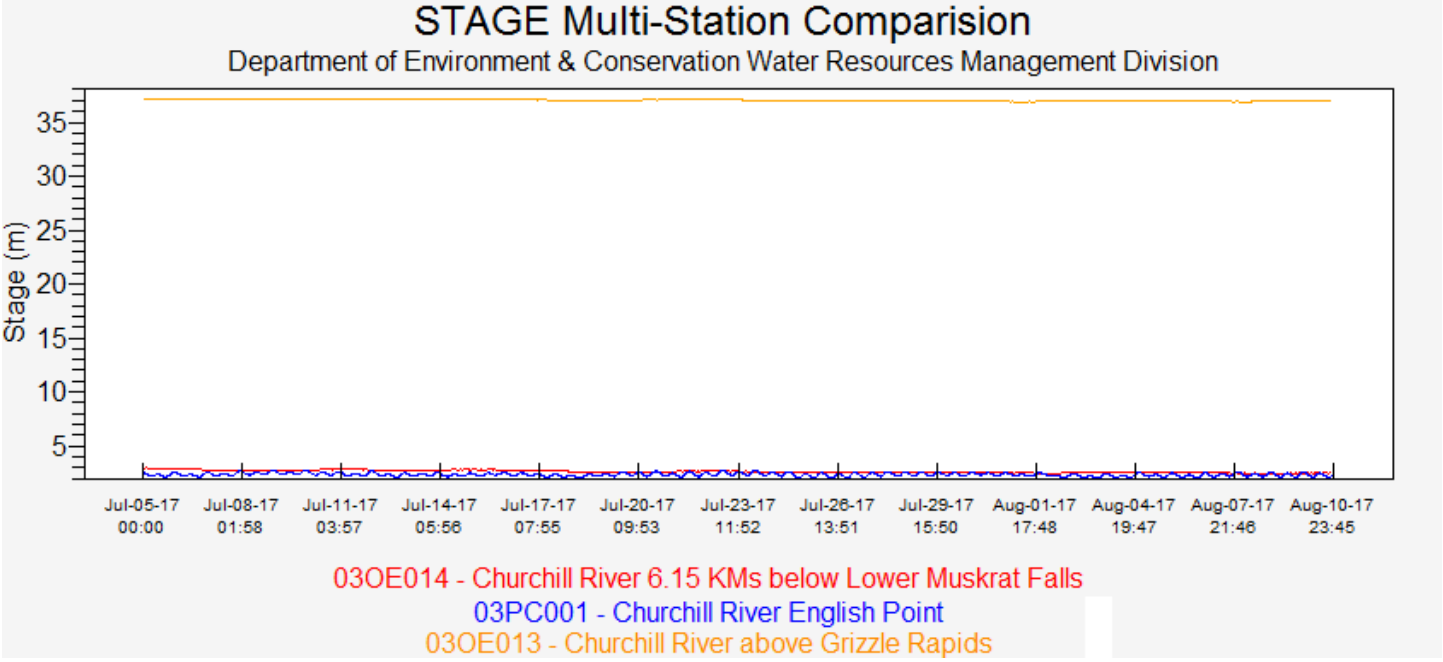

Figure A7: Comparison of Stage at the Real-Time Stations on Churchill River

APPENDIX B

Water Parameter Description

Water Parameter Description

Dissolved Oxygen - The amount of Dissolved Oxygen (DO) (mg/l or % saturation) in the water is vital to aquatic organisms for their survival. The concentration of DO is affected by such things as water temperature, water depth and flow (e.g., aeration by rapids, riffles etc.), consumption by aerobic organisms, consumption by inorganic chemical reactions, consumption by plants during darkness, and production by plants during the daylight (USGS, 2017).

Flow - Flow (m3/s) is a measure of how quickly a volume of water is displaced in streams, rivers, and other channels.

pH - pH is a measure of the relative amount of free hydrogen and hydroxyl ions in water. pH is an important indicator of chemically changing water, and determines the solubility and biological availability of nutrients and heavy metals in the water (USGS, 2017).

Specific conductivity - Specific conductivity (µs/cm) is a measure of water's ability to conduct electricity, with values normalized to a water temperature of 25°C. Specific conductance indicates the concentration of dissolved solids (such as salts) in the water, which can affect the growth and reproduction of aquatic life. Specific conductivity is affected by rainfall events, the composition of inflowing tributaries and their associated geology, saline inflow (e.g., road salt), agricultural run-off and industrial inputs (Fondriest Environmental Inc, 2016).

Stage - Stage (m) is the elevation of the water surface and is often used as a surrogate for the more difficult to measure flow.

Temperature - Essential to the measurement of most water quality parameters, temperature (°C) controls most aquatic processes. Water temperature is influenced by such things as ambient air temperature, solar radiation, meteorological events, industrial effluence, wastewater, inflowing tributaries, as well as water body size and depth. In turn, water temperature has an influence on the metabolic rates and biological activity of aquatic organisms (Fondriest Environmental Inc, 2016b).

Total Dissolved Solids - Total Dissolved Solids (TDS) (g/l) is a measure of alkaline salts dissolved in water or in fine suspension and can affect the growth and reproduction of aquatic life. It is affected by rainfall events, the composition of inflowing tributaries and their associated geology, saline inflow (e.g., road salt), agricultural run-off and industrial inputs (Swenson and Baldwin, 1965).

Turbidity - Turbidity (NTU) is a measure of the translucence of water and indicates the amount of suspended material in the water. Turbidity is caused by any substance that makes water cloudy (e.g., soil erosion, micro-organisms, vegetation, chemicals, etc.) and can correspond to precipitation events, high stage, and floating debris near the sensor (Swenson and Baldwin 1965).

APPENDIX C

Grab Sample Results

Maxxam Job #: B7E8932
Report Date: 2017/07/25

Department of Municipal Affairs and Environment
Site Location: CHURCHILL RIVER ABOVE GRIZZLE RAPIDS
Your P.O. #: 215062145-3

Sample Details/Parameters	Result	RDL	UNITS	MU	Extracted	Analyzed	By	Batch
ETB055 CR above GR								
Sampling Date 2017/07/12 12:30								
Matrix W								
Sample # 2017-6313-00-SI-SP								
Registration # SA-0000								
RESULTS OF ANALYSES OF WATER								
Calculated Parameters								
Calculated TDS	11	1.0	mg/L	N/A	2017/07/25	2017/07/25		5073057
Hardness (CaCO3)	6.8	1.0	mg/L	N/A	2017/07/20	2017/07/20		5073051
Nitrate (N)	<0.050	0.050	mg/L	N/A	2017/07/24	2017/07/24		5073054
Inorganics								
Conductivity	17	1.0	uS/cm	N/A	2017/07/19	2017/07/19	KMC	5080171
Bromide (Br-)	<1.0	1.0	mg/L	N/A	2017/07/17	2017/07/17	FD	5075948
Total Alkalinity (Total as CaCO3)	6.9	5.0	mg/L	N/A	2017/07/24	2017/07/24	NRG	5081965
Dissolved Chloride (Cl)	1.1	1.0	mg/L	N/A	2017/07/24	2017/07/24	NRG	5081968
Colour	33	5.0	TCU	N/A	2017/07/24	2017/07/24	NRG	5081977
Dissolved Fluoride (F-)	<0.10	0.10	mg/L	N/A	2017/07/19	2017/07/19	KMC	5080181
Total Kjeldahl Nitrogen (TKN)	<0.10	0.10	mg/L	N/A	2017/07/18	2017/07/20	BMO	5078946
Nitrite (N)	<0.010	0.010	mg/L	N/A	2017/07/24	2017/07/24	NRG	5081982
Nitrogen (Ammonia Nitrogen)	<0.050	0.050	mg/L	N/A	2017/07/24	2017/07/24	NRG	5082454
Dissolved Organic Carbon (C)	4.4	0.50	mg/L	N/A	2017/07/20	2017/07/20	SMT	5081914
Total Organic Carbon (C)	4.4	0.50	mg/L	N/A	2017/07/20	2017/07/20	SMT	5082399
pH	6.76	N/A	pH	N/A	2017/07/19	2017/07/19	KMC	5080169
Total Phosphorus	0.006	0.004	mg/L	+/- 0.004	2017/07/19	2017/07/20	ASP	5079645
Dissolved Sulphate (SO4)	<2.0	2.0	mg/L	N/A	2017/07/24	2017/07/24	NRG	5081972
Turbidity	0.58	0.10	NTU	N/A	2017/07/24	2017/07/24	JMV	5086822
MERCURY BY COLD VAPOUR AA (WATER)								
Metals								
Total Mercury (Hg)	<0.000013	0.000013	mg/L	N/A	2017/07/21	2017/07/24	ARS	5084083
ELEMENTS BY ICP/MS (WATER)								
Metals								
Total Aluminum (Al)	0.061	0.0050	mg/L	N/A	2017/07/19	2017/07/20	BAN	5079812
Total Antimony (Sb)	<0.0010	0.0010	mg/L	N/A	2017/07/19	2017/07/20	BAN	5079812
Total Arsenic (As)	<0.0010	0.0010	mg/L	N/A	2017/07/19	2017/07/20	BAN	5079812
Total Barium (Ba)	0.0067	0.0010	mg/L	N/A	2017/07/19	2017/07/20	BAN	5079812
Total Boron (B)	<0.050	0.050	mg/L	N/A	2017/07/19	2017/07/20	BAN	5079812
Total Cadmium (Cd)	<0.000010	0.000010	mg/L	N/A	2017/07/19	2017/07/20	BAN	5079812
Total Calcium (Ca)	1.8	0.10	mg/L	N/A	2017/07/19	2017/07/20	BAN	5079812
Total Chromium (Cr)	<0.0010	0.0010	mg/L	N/A	2017/07/19	2017/07/20	BAN	5079812
Total Copper (Cu)	<0.0020	0.0020	mg/L	N/A	2017/07/19	2017/07/20	BAN	5079812
Total Iron (Fe)	0.12	0.050	mg/L	N/A	2017/07/19	2017/07/20	BAN	5079812
Total Lead (Pb)	<0.00050	0.00050	mg/L	N/A	2017/07/19	2017/07/20	BAN	5079812
Total Magnesium (Mg)	0.56	0.10	mg/L	N/A	2017/07/19	2017/07/20	BAN	5079812
Total Manganese (Mn)	0.0066	0.0020	mg/L	N/A	2017/07/19	2017/07/20	BAN	5079812
Total Nickel (Ni)	<0.0020	0.0020	mg/L	N/A	2017/07/19	2017/07/20	BAN	5079812
Total Potassium (K)	0.19	0.10	mg/L	N/A	2017/07/19	2017/07/20	BAN	5079812

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Maxxam Job #: B7E8932
Report Date: 2017/07/25

Department of Municipal Affairs and Environment
Site Location: CHURCHILL RIVER ABOVE GRIZZLE RAPIDS
Your P.O. #: 215062145-3

Sample Details/Parameters	Result	RDL	UNITS	MU	Extracted	Analyzed	By	Batch
ETB055 CR above GR								
Sampling Date 2017/07/12 12:30								
Matrix W								
Sample # 2017-6313-00-SI-SP								
Registration # SA-0000								
ELEMENTS BY ICP/MS (WATER)								
Metals								
Total Selenium (Se)	<0.0010	0.0010	mg/L	N/A	2017/07/19	2017/07/20	BAN	5079812
Total Sodium (Na)	0.50	0.10	mg/L	N/A	2017/07/19	2017/07/20	BAN	5079812
Total Strontium (Sr)	0.010	0.0020	mg/L	N/A	2017/07/19	2017/07/20	BAN	5079812
Total Uranium (U)	<0.00010	0.00010	mg/L	N/A	2017/07/19	2017/07/20	BAN	5079812
Total Zinc (Zn)	<0.0050	0.0050	mg/L	N/A	2017/07/19	2017/07/20	BAN	5079812

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Maxxam Job #: B7E8937
Report Date: 2017/07/21

Department of Municipal Affairs and Environment
Site Location: CHURCHILL RIVER ABOVE GRIZZLE RAPIDS
Your P.O. #: 217000610

Sample Details/Parameters	Result	RDL	UNITS	MU	Extracted	Analyzed	By	Batch
ETB090 CR above GR								
Sampling Date 2017/07/12 12:30								
Matrix W								
Sample # 2017-6313-00-SI-SP								
Registration # SA-0000								
RESULTS OF ANALYSES OF WATER								
Inorganics								
Total Suspended Solids	16	1.0	mg/L	N/A	2017/07/19	2017/07/21	AM6	5079506

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Maxxam Job #: B7E4917
Report Date: 2017/07/18

Department of Municipal Affairs and Environment
Site Location: CHURCHILL RIVER
Your P.O. #: 215062145-3
Sampler Initials: MM

Sample Details/Parameters	Result	RDL	UNITS	MU	Extracted	Analyzed	By	Batch
ESH432 CR below MF								
Sampling Date 2017/07/05 11:50								
Matrix W								
Sample # 2017-6309-00-SI-SP								
Registration # WS-S-0000								
RESULTS OF ANALYSES OF WATER								
Calculated Parameters								
Calculated TDS	12	1.0	mg/L	N/A	2017/07/18	2017/07/18		5068739
Hardness (CaCO3)	7.8	1.0	mg/L	N/A	2017/07/14	2017/07/14		5068734
Nitrate (N)	0.084	0.050	mg/L	N/A	2017/07/18	2017/07/18		5068737
Inorganics								
Conductivity	15	1.0	uS/cm	N/A	2017/07/14	2017/07/14	JMV	5072930
Bromide (Br-)	<1.0	1.0	mg/L	N/A	2017/07/14	2017/07/14	FD	5072689
Total Alkalinity (Total as CaCO3)	7.8	5.0	mg/L	N/A	2017/07/17	2017/07/17	NRG	5075833
Dissolved Chloride (Cl)	<1.0	1.0	mg/L	N/A	2017/07/17	2017/07/17	NRG	5075847
Colour	37	5.0	TCU	N/A	2017/07/18	2017/07/18	NRG	5075852
Dissolved Fluoride (F-)	<0.10	0.10	mg/L	N/A	2017/07/14	2017/07/14	JMV	5072931
Total Kjeldahl Nitrogen (TKN)	0.15	0.10	mg/L	+/- <RDL	2017/07/14	2017/07/14	BMO	5073406
Nitrite (N)	<0.010	0.010	mg/L	N/A	2017/07/17	2017/07/17	NRG	5075855
Nitrogen (Ammonia Nitrogen)	<0.050	0.050	mg/L	N/A	2017/07/14	2017/07/14	NRG	5070992
Dissolved Organic Carbon (C)	4.3	0.50	mg/L	N/A	2017/07/14	2017/07/14	SMT	5073144
Total Organic Carbon (C)	4.5	0.50	mg/L	N/A	2017/07/14	2017/07/14	SMT	5073165
pH	6.86	N/A	pH	N/A	2017/07/14	2017/07/14	JMV	5072929
Total Phosphorus	0.024	0.004	mg/L	+/- 0.005	2017/07/14	2017/07/17	ASP	5073078
Dissolved Sulphate (SO4)	<2.0	2.0	mg/L	N/A	2017/07/17	2017/07/17	NRG	5075850
Turbidity	3.5	0.10	NTU	N/A	2017/07/13	2017/07/13	JMV	5070883
MERCURY BY COLD VAPOUR AA (WATER)								
Metals								
Total Mercury (Hg)	<0.000013	0.000013	mg/L	N/A	2017/07/15	2017/07/17	ARS	5074936
ELEMENTS BY ICP/MS (WATER)								
Metals								
Total Aluminum (Al)	0.37	0.0050	mg/L	N/A	2017/07/13	2017/07/14	BAN	5070854
Total Antimony (Sb)	<0.0010	0.0010	mg/L	N/A	2017/07/13	2017/07/14	BAN	5070854
Total Arsenic (As)	<0.0010	0.0010	mg/L	N/A	2017/07/13	2017/07/14	BAN	5070854
Total Barium (Ba)	0.010	0.0010	mg/L	N/A	2017/07/13	2017/07/14	BAN	5070854
Total Boron (B)	<0.050	0.050	mg/L	N/A	2017/07/13	2017/07/14	BAN	5070854
Total Cadmium (Cd)	<0.000010	0.000010	mg/L	N/A	2017/07/13	2017/07/14	BAN	5070854
Total Calcium (Ca)	1.9	0.10	mg/L	N/A	2017/07/13	2017/07/14	BAN	5070854
Total Chromium (Cr)	<0.0010	0.0010	mg/L	N/A	2017/07/13	2017/07/14	BAN	5070854
Total Copper (Cu)	<0.0020	0.0020	mg/L	N/A	2017/07/13	2017/07/14	BAN	5070854
Total Iron (Fe)	0.45	0.050	mg/L	N/A	2017/07/13	2017/07/14	BAN	5070854
Total Lead (Pb)	<0.00050	0.00050	mg/L	N/A	2017/07/13	2017/07/14	BAN	5070854
Total Magnesium (Mg)	0.72	0.10	mg/L	N/A	2017/07/13	2017/07/14	BAN	5070854
Total Manganese (Mn)	0.016	0.0020	mg/L	N/A	2017/07/13	2017/07/14	BAN	5070854
Total Nickel (Ni)	<0.0020	0.0020	mg/L	N/A	2017/07/13	2017/07/14	BAN	5070854
Total Potassium (K)	0.39	0.10	mg/L	N/A	2017/07/13	2017/07/14	BAN	5070854

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Maxxam Job #: B7E4917
Report Date: 2017/07/18

Department of Municipal Affairs and Environment
Site Location: CHURCHILL RIVER
Your P.O. #: 215062145-3
Sampler Initials: MM

Sample Details/Parameters	Result	RDL	UNITS	MU	Extracted	Analyzed	By	Batch
ESH432 CR below MF Sampling Date 2017/07/05 11:50 Matrix W Sample # 2017-6309-00-SI-SP Registration # WS-S-0000								
ELEMENTS BY ICP/MS (WATER)								
Metals								
Total Selenium (Se)	<0.0010	0.0010	mg/L	N/A	2017/07/13	2017/07/14	BAN	5070854
Total Sodium (Na)	0.63	0.10	mg/L	N/A	2017/07/13	2017/07/14	BAN	5070854
Total Strontium (Sr)	0.011	0.0020	mg/L	N/A	2017/07/13	2017/07/14	BAN	5070854
Total Uranium (U)	<0.00010	0.00010	mg/L	N/A	2017/07/13	2017/07/14	BAN	5070854
Total Zinc (Zn)	<0.0050	0.0050	mg/L	N/A	2017/07/13	2017/07/14	BAN	5070854

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Maxxam Job #: B7E4916
Report Date: 2017/07/14

Department of Municipal Affairs and Environment
Site Location: CHURCHILL RIVER
Your P.O. #: 217000610

Sample Details/Parameters	Result	RDL	UNITS	MU	Extracted	Analyzed	By	Batch
ESH420 CR below MF								
Sampling Date 2017/07/05 11:50								
Matrix W								
Sample # 2017-6309-00-SI-SP								
Registration # WS-S-0000								
RESULTS OF ANALYSES OF WATER								
Inorganics								
Total Suspended Solids	18	1.0	mg/L	N/A	2017/07/12	2017/07/14	AM6	5069369

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Maxxam Job #: B7E4917
Report Date: 2017/07/18

Department of Municipal Affairs and Environment
Site Location: CHURCHILL RIVER
Your P.O. #: 215062145-3
Sampler Initials: MM

Sample Details/Parameters	Result	RDL	UNITS	MU	Extracted	Analyzed	By	Batch
ESH434 CR @ EP								
Sampling Date 2017/07/06 10:10								
Matrix W								
Sample # 2017-6311-00-SI-SP								
Registration # WS-S-0000								
RESULTS OF ANALYSES OF WATER								
Calculated Parameters								
Calculated TDS	25	1.0	mg/L	N/A	2017/07/18	2017/07/18		5068739
Hardness (CaCO3)	10	1.0	mg/L	N/A	2017/07/14	2017/07/14		5068734
Nitrate (N)	0.053	0.050	mg/L	N/A	2017/07/18	2017/07/18		5068737
Inorganics								
Conductivity	39	1.0	uS/cm	N/A	2017/07/14	2017/07/14	JMV	5072930
Bromide (Br-)	<1.0	1.0	mg/L	N/A	2017/07/14	2017/07/14	FD	5071842
Total Alkalinity (Total as CaCO3)	7.4	5.0	mg/L	N/A	2017/07/17	2017/07/17	NRG	5075833
Dissolved Chloride (Cl)	6.7	1.0	mg/L	N/A	2017/07/17	2017/07/17	NRG	5075847
Colour	57(1)	10	TCU	N/A	2017/07/18	2017/07/18	NRG	5075852
Dissolved Fluoride (F-)	<0.10	0.10	mg/L	N/A	2017/07/14	2017/07/14	JMV	5072931
Total Kjeldahl Nitrogen (TKN)	0.15	0.10	mg/L	+/- <RDL	2017/07/14	2017/07/14	BMO	5073406
Nitrite (N)	<0.010	0.010	mg/L	N/A	2017/07/17	2017/07/17	NRG	5075855
Nitrogen (Ammonia Nitrogen)	<0.050	0.050	mg/L	N/A	2017/07/14	2017/07/14	NRG	5071087
Dissolved Organic Carbon (C)	5.8	0.50	mg/L	N/A	2017/07/14	2017/07/14	SMT	5073144
Total Organic Carbon (C)	6.0	0.50	mg/L	N/A	2017/07/14	2017/07/14	SMT	5073165
pH	6.93	N/A	pH	N/A	2017/07/14	2017/07/14	JMV	5072929
Total Phosphorus	0.042	0.004	mg/L	+/- 0.007	2017/07/14	2017/07/17	ASP	5073078
Dissolved Sulphate (SO4)	<2.0	2.0	mg/L	N/A	2017/07/17	2017/07/17	NRG	5075850
Turbidity	14	0.10	NTU	N/A	2017/07/13	2017/07/13	JMV	5070883
MERCURY BY COLD VAPOUR AA (WATER)								
Metals								
Total Mercury (Hg)	<0.000013	0.000013	mg/L	N/A	2017/07/15	2017/07/17	ARS	5074936
ELEMENTS BY ICP/MS (WATER)								
Metals								
Total Aluminum (Al)	0.74	0.0050	mg/L	N/A	2017/07/13	2017/07/13	BAN	5070857
Total Antimony (Sb)	<0.0010	0.0010	mg/L	N/A	2017/07/13	2017/07/13	BAN	5070857
Total Arsenic (As)	<0.0010	0.0010	mg/L	N/A	2017/07/13	2017/07/13	BAN	5070857
Total Barium (Ba)	0.013	0.0010	mg/L	N/A	2017/07/13	2017/07/13	BAN	5070857
Total Boron (B)	<0.050	0.050	mg/L	N/A	2017/07/13	2017/07/13	BAN	5070857
Total Cadmium (Cd)	0.000011	0.000010	mg/L	N/A	2017/07/13	2017/07/13	BAN	5070857
Total Calcium (Ca)	2.0	0.10	mg/L	N/A	2017/07/13	2017/07/13	BAN	5070857
Total Chromium (Cr)	0.0017	0.0010	mg/L	N/A	2017/07/13	2017/07/13	BAN	5070857
Total Copper (Cu)	<0.0020	0.0020	mg/L	N/A	2017/07/13	2017/07/13	BAN	5070857
Total Iron (Fe)	1.1	0.050	mg/L	N/A	2017/07/13	2017/07/13	BAN	5070857
Total Lead (Pb)	<0.00050	0.00050	mg/L	N/A	2017/07/13	2017/07/13	BAN	5070857
Total Magnesium (Mg)	1.3	0.10	mg/L	N/A	2017/07/13	2017/07/13	BAN	5070857
Total Manganese (Mn)	0.027	0.0020	mg/L	N/A	2017/07/13	2017/07/13	BAN	5070857
Total Nickel (Ni)	<0.0020	0.0020	mg/L	N/A	2017/07/13	2017/07/13	BAN	5070857

(1) Elevated reporting limit due to sample matrix.

Maxxam Analytics International Corporation o/a Maxxam Analytics 200 Bluewater Rd, Suite 105, Bedford, Nova Scotia Canada B4B 1G9 Tel: 902-420-0203 Toll-free: 800-565-7227 Fax: 902-420-8612 www.maxxamanalytics.com

Maxxam Job #: B7E4917
Report Date: 2017/07/18

Department of Municipal Affairs and Environment
Site Location: CHURCHILL RIVER
Your P.O. #: 215062145-3
Sampler Initials: MM

Sample Details/Parameters	Result	RDL	UNITS	MU	Extracted	Analyzed	By	Batch
ESH434 CR @ EP								
Sampling Date 2017/07/06 10:10								
Matrix W								
Sample # 2017-6311-00-SI-SP								
Registration # WS-S-0000								
ELEMENTS BY ICP/MS (WATER)								
Metals								
Total Potassium (K)	0.76	0.10	mg/L	N/A	2017/07/13	2017/07/13	BAN	5070857
Total Selenium (Se)	<0.0010	0.0010	mg/L	N/A	2017/07/13	2017/07/13	BAN	5070857
Total Sodium (Na)	4.5	0.10	mg/L	N/A	2017/07/13	2017/07/13	BAN	5070857
Total Strontium (Sr)	0.017	0.0020	mg/L	N/A	2017/07/13	2017/07/13	BAN	5070857
Total Uranium (U)	<0.00010	0.00010	mg/L	N/A	2017/07/13	2017/07/13	BAN	5070857
Total Zinc (Zn)	0.013	0.0050	mg/L	N/A	2017/07/13	2017/07/13	BAN	5070857

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Maxxam Job #: B7E4916
Report Date: 2017/07/14

Department of Municipal Affairs and Environment
Site Location: CHURCHILL RIVER
Your P.O. #: 217000610

Sample Details/Parameters	Result	RDL	UNITS	MU	Extracted	Analyzed	By	Batch
ESH422 CR @ EP								
Sampling Date 2017/07/06 10:10								
Matrix W								
Sample # 2017-6311-00-SI-SP								
Registration # WS-S-0000								
RESULTS OF ANALYSES OF WATER								
Inorganics								
Total Suspended Solids	32	1.0	mg/L	N/A	2017/07/13	2017/07/14	AM6	5070908

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