Real-Time Water Quality Deployment Report

Lower Churchill River Network

July 3/9/16 to September 3/4, 2019

Newfoundland Labrador

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

Contents

Prepared by:
Brenda Congram
Environmental Scientist
Department of Municipal Affairs & Environment
Water Resources Management Division
brendacongram@gov.nl.ca

Real-Time Water Quality Deployment Report

Lower Churchill River Network

July 3/9/16 to September 3/4, 2019

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 four stations on the Lower Churchill River: Churchill River below Metchin River, Churchill River above Grizzle Rapids, Churchill River below Muskrat Falls and Churchill River at English Point.
- A real-time water quality monitoring instrument was deployed at Churchill River above Grizzle Rapids on July 3rd. Instruments at Churchill River below Muskrat Falls and Churchill River at English Point were deployed on July 9th. The instrument at Churchill River below Metchin River was deployed on July 16th.
- Instruments at Churchill River below Metchin River and Churchill River above Grizzle Rapids were removed on September 3rd for a deployment period of 49 and 62 days, respectively. Churchill River below Muskrat Falls and Churchill River at English Point were removed on September 4th for a deployment period of 57 days.
- 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 3/9/16 to September 3/4, 2019 are summarized in Table 2.

Table 2: Comparison rankings for Lower Churchill River stations July 3/9/16 to September 3/4, 2019

Churchill River Station	Date	Action	Comparison Ranking				
			Temperature	pH	Conductivity	Dissolved Oxygen	Turbidity
Below Metchin River	July 16, 2019	Deployment	Excellent	Excellent	Excellent	Excellent	Excellent
	September 3, 2019	Removal	Good	Excellent	Excellent	Excellent	Excellent
Above Grizzle Rapids	July 3, 2019	Deployment	Excellent	Excellent	Excellent	Excellent	Excellent
	September 3, 2019	Removal	Excellent	Excellent	Excellent	Excellent	Excellent
Below Muskrat Falls	July 9, 2019	Deployment	Excellent	Fair	Excellent	Excellent	Poor
	September 4, 2019	Removal	Good	Good	Excellent	Excellent	Poor
At English Point	July 9, 2019	Deployment	Excellent	Good	Excellent	Excellent	Good
	September 4, 2019	Removal	Excellent	Good	Excellent	Excellent	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

- **Churchill River below Metchin River**
  - At deployment, all parameters ranked as 'excellent'.
  - At removal, temperature was 'good', while all other parameters ranked as 'excellent'.
- **Churchill River above Grizzle Rapids**
  - At deployment, all parameters ranked as 'excellent'.
  - At removal, all parameters again ranked as 'excellent'.
- **Churchill River below Muskrat Falls**
  - At deployment, temperature, conductivity, and dissolved oxygen were 'excellent', while pH was 'fair' and turbidity was 'poor'.
  - At removal, temperature and pH were 'good', conductivity and dissolved oxygen were 'excellent', while turbidity again ranked as 'poor'. This discrepancy is likely due to the QA/QC sonde not being placed in close enough proximity to the field sonde, or the field sonde having a build-up of sediment around its sensors.

- **Churchill River at English Point**
    - At deployment, all parameters ranked as either 'excellent' or 'good'.
    - At removal, all parameters ranked as either 'excellent' or 'good'.

Data Interpretation

- The following graphs and discussion illustrate water quality related events occurring from July 3/9/16 to September 3/4, 2019 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 stringent QA/QC protocol. Water Survey of Canada is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

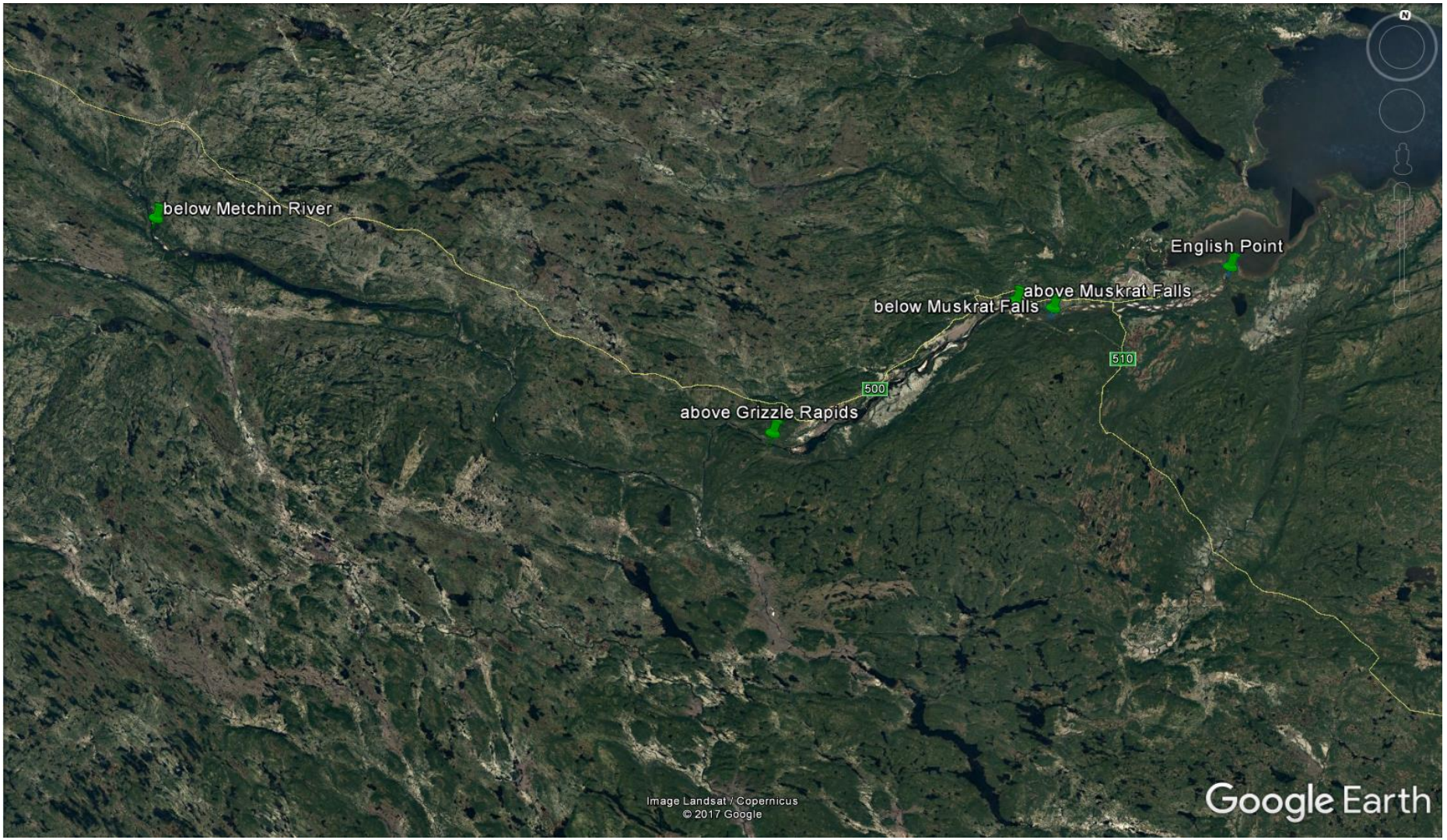

Figure 1: Lower Churchill Network of Real-Time Water Quality Stations

Churchill River below Metchin River

Water Temperature

- Over the deployment period, water temperature ranged from 12.80°C to 17.20°C, with a median value of 14.90°C (Figure 2). Air temperature data was obtained from the Metchin River near TLH Weather Station.
- Water temperature was quite stable over the course of deployment, decreasing slightly towards the very end of deployment. This is to be expected as air temperatures were also quite consistent across the summer season. 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.

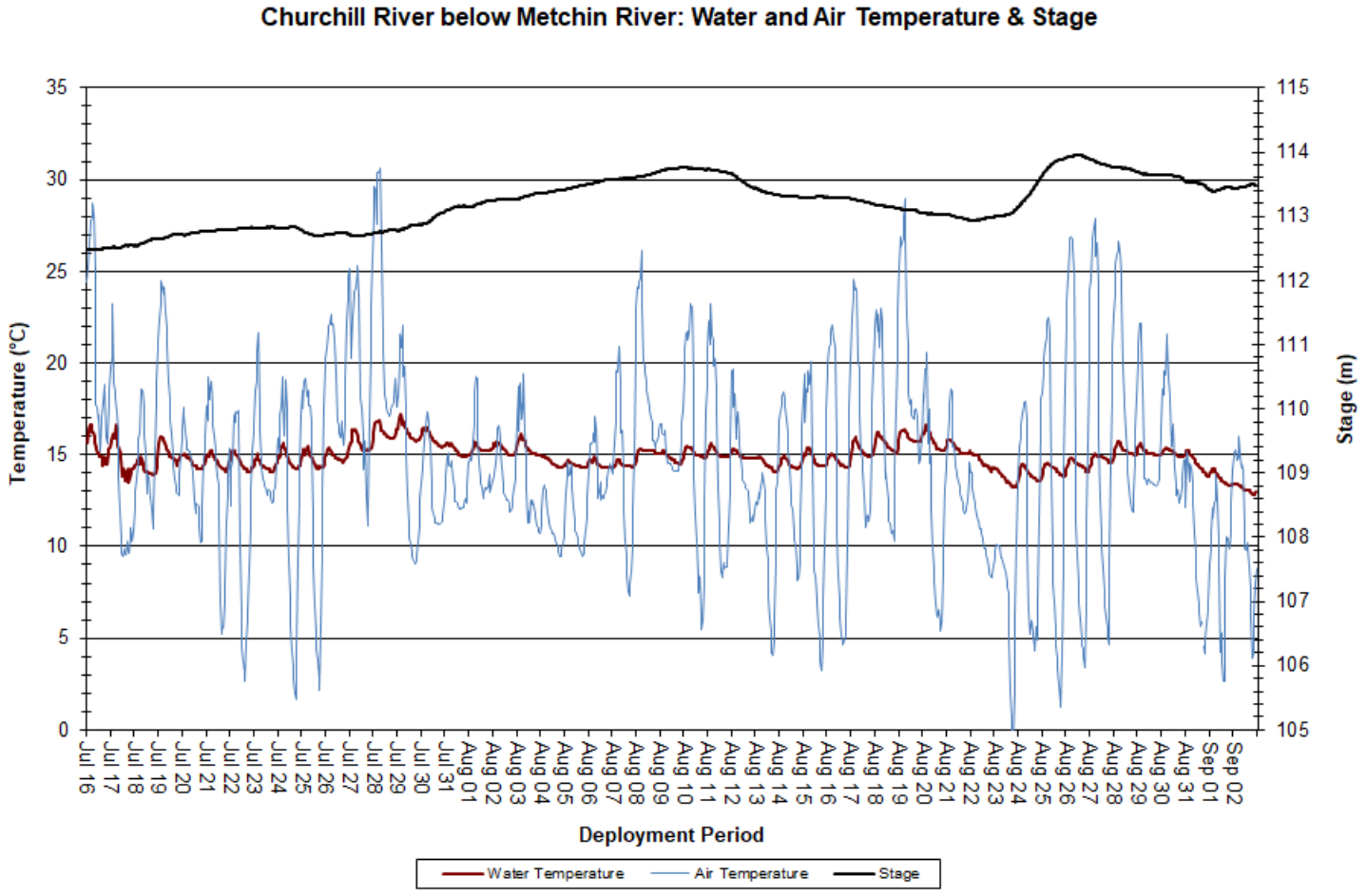

Figure 2: Water and Air Temperature & Stage at Churchill River below Metchin River

pH

- Over the deployment period, pH values ranged from 6.67 to 7.23 pH units, with a median value of 6.97 (Figure 3).
- pH values were stable over the course of deployment and remained within the CCME's Guidelines for the Protection of Aquatic Life for the duration of deployment.
- 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.

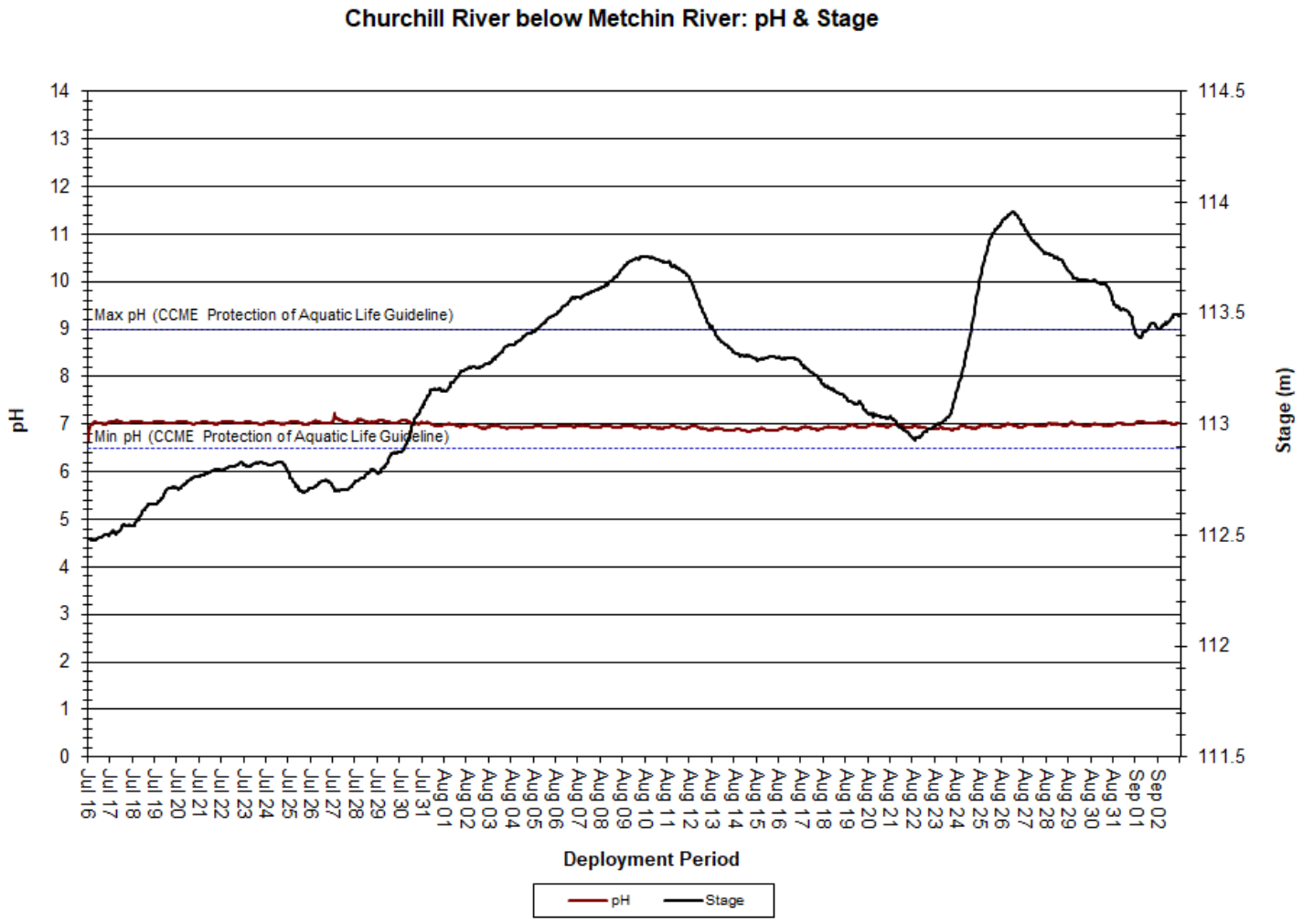

Figure 3: pH & Stage at Churchill River below Metchin River

Specific Conductivity

- Over the deployment period, specific conductivity ranged from 16.8µS/cm to 34.6µS/cm, with a median value of 17.8µS/cm (Figure 4).
- The relationship between conductivity and stage is generally inversed. When stage levels increase, specific conductivity levels decrease as the increased amount of water in the river system dilutes solids that are present. This relationship is evident in the graph below (Figure 4).
- 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.

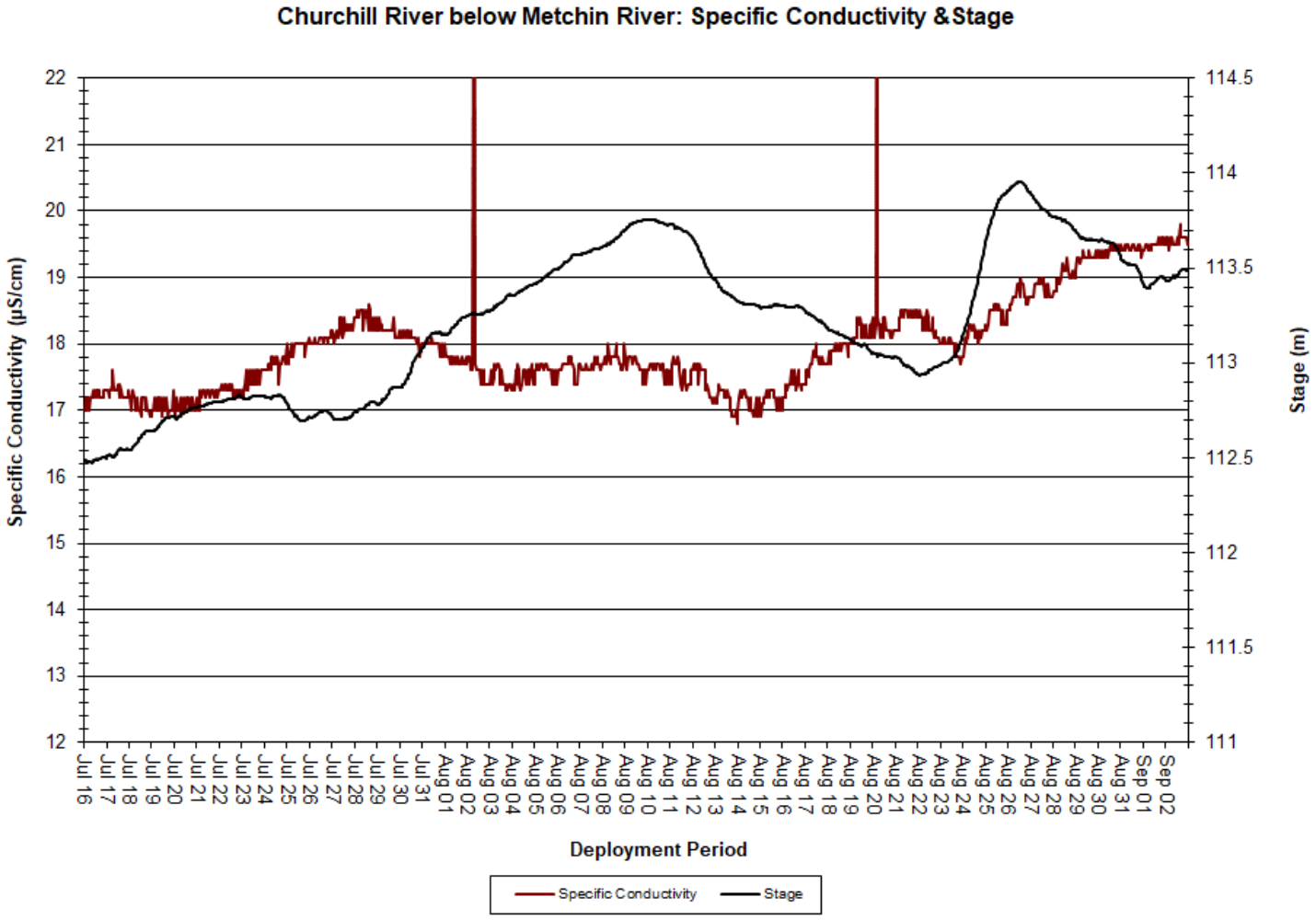

Figure 4: Specific Conductivity & Stage at Churchill River below Metchin River

Dissolved Oxygen

- Over the deployment period, dissolved oxygen content ranged from 9.15mg/L to 9.84mg/L, with a median value of 9.42mg/L. Saturation of dissolved oxygen ranged from 92.9% to 98.8%, with a median value of 95.3% (Figure 5).
- There is an evident relationship between water temperature and dissolved oxygen. Over the deployment period, dissolved oxygen levels were stable and lower, as water temperatures were stable and warmer. Dissolved oxygen also follows a diurnal pattern as water temperatures rise and fall under the influence of ambient air temperatures. Generally, dissolved oxygen levels are higher in a waterbody during cooler temperatures.
- Dissolved oxygen levels hovered around the CCME's Guideline for the Protection of Early Life Stages for the majority of deployment, and remained above the CCME's Guideline for the Protection of Other Life Stages for the duration of deployment.

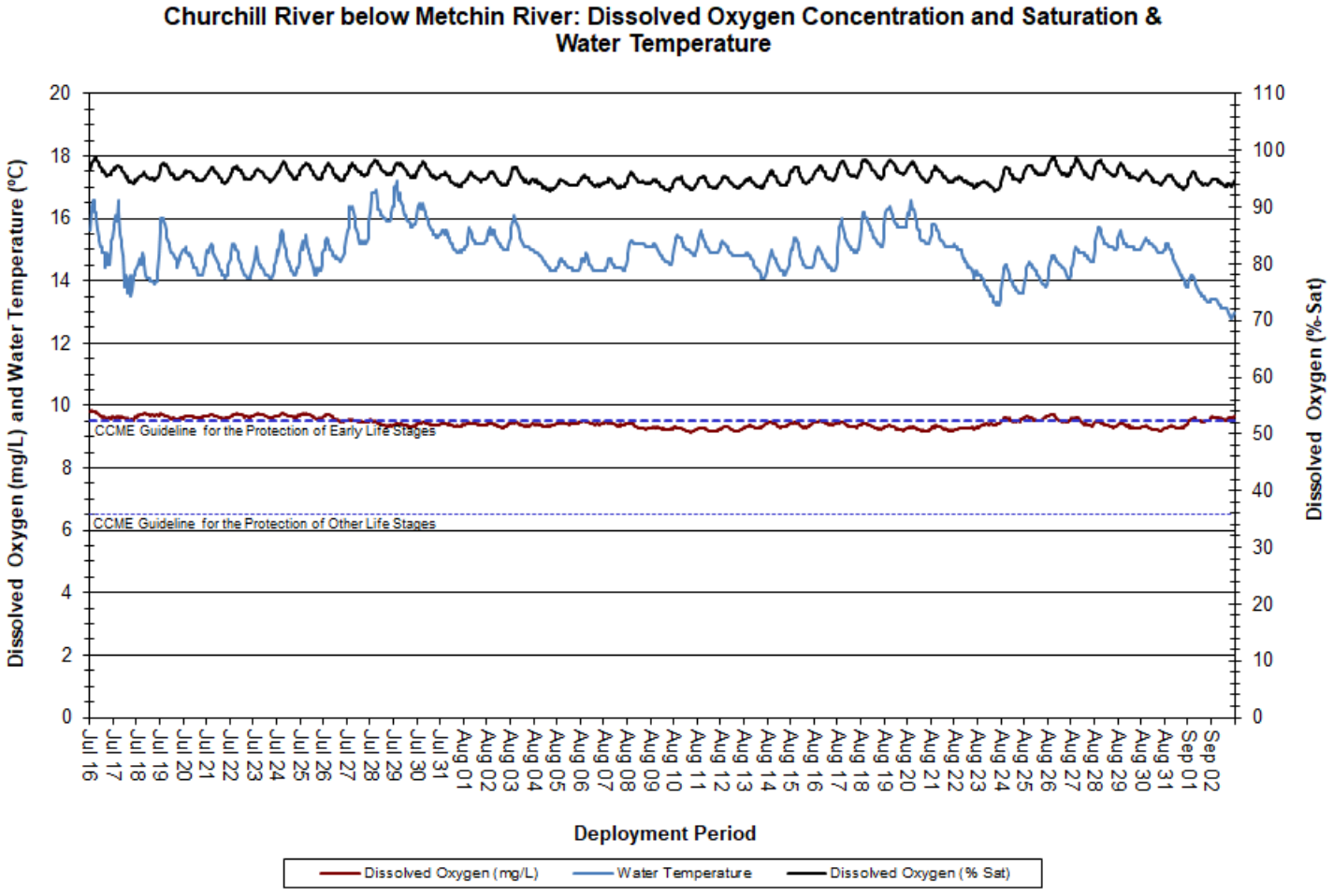

Figure 5: Dissolved Oxygen & Water Temperature at Churchill River below Metchin River

Turbidity

- Over the deployment period, turbidity ranged from 0.0NTU to 13.4NTU, with a median value of 0.0NTU (Figure 6). A median value of 0.0NTU indicates a very low level of natural background turbidity in the waterbody. Precipitation data was obtained from the Metchin River near TLH Weather Station.
- Many of the turbidity spikes observed throughout the deployment period correlate closely with precipitation events (Figure 6); however, some turbidity events do not coincide with any precipitation. This station is located at a wide and deep section of the Churchill River and therefore turbidity levels are likely less susceptible to precipitation events as compared to other areas. Turbidity levels returned to background levels following each observed increase.
- 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.

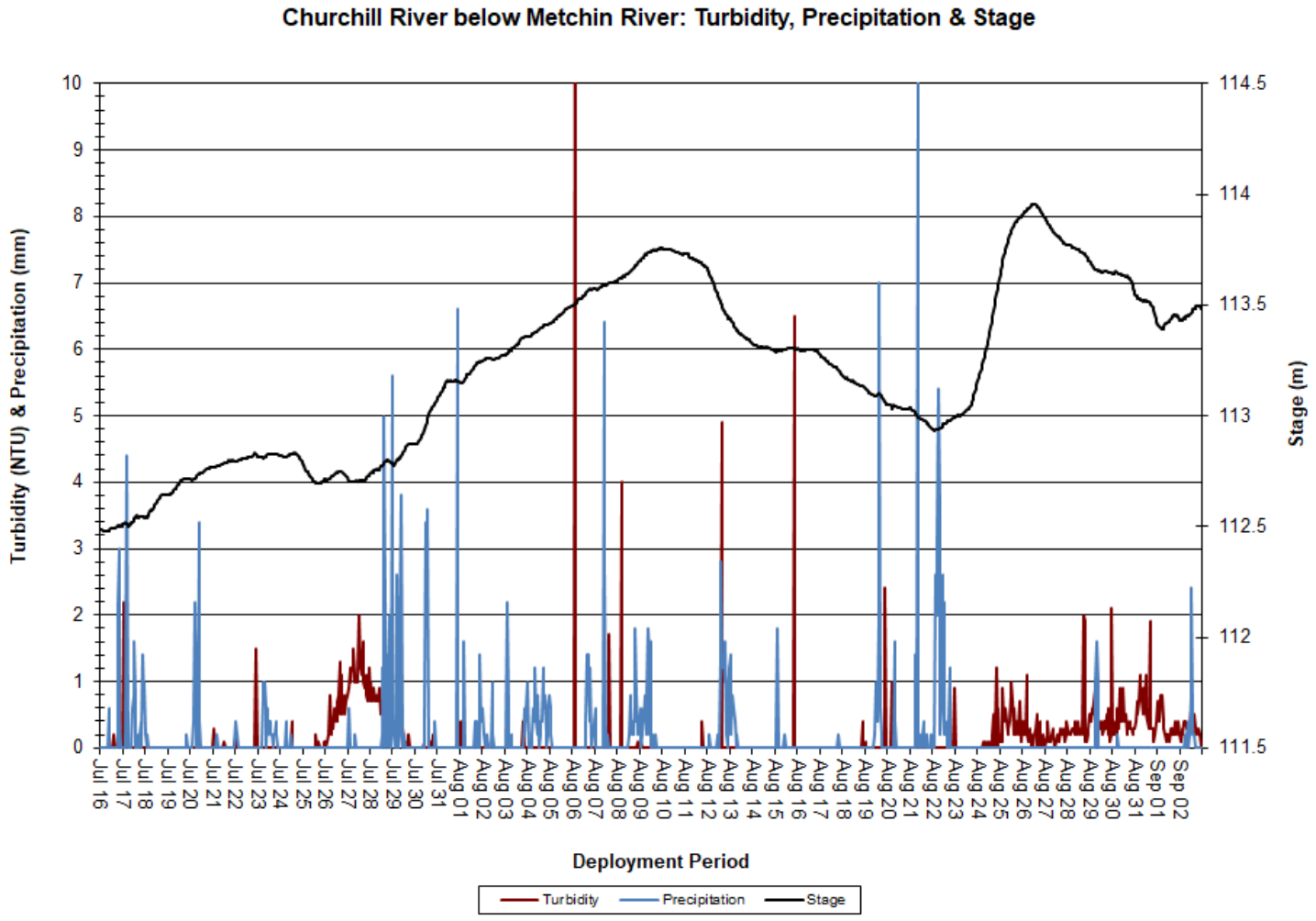

Figure 6: Turbidity, Precipitation & Stage at Churchill River below Metchin River

Stage and Flow

- Over the deployment period, stage levels ranged from 112.48m to 113.96m, with a median value of 113.26m. Flow ranged from 1053.90m^3/s to 1512.04m^3/s, with a median value of 1317.90m^3/s (Figure 7). Precipitation data was obtained from the Metchin River near TLH Weather Station.
- Stage and flow were slightly variable across the deployment period and followed a similar trend. Precipitation amounts across the same period correlate with increases in both stage and flow (Figure 8).
- 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.

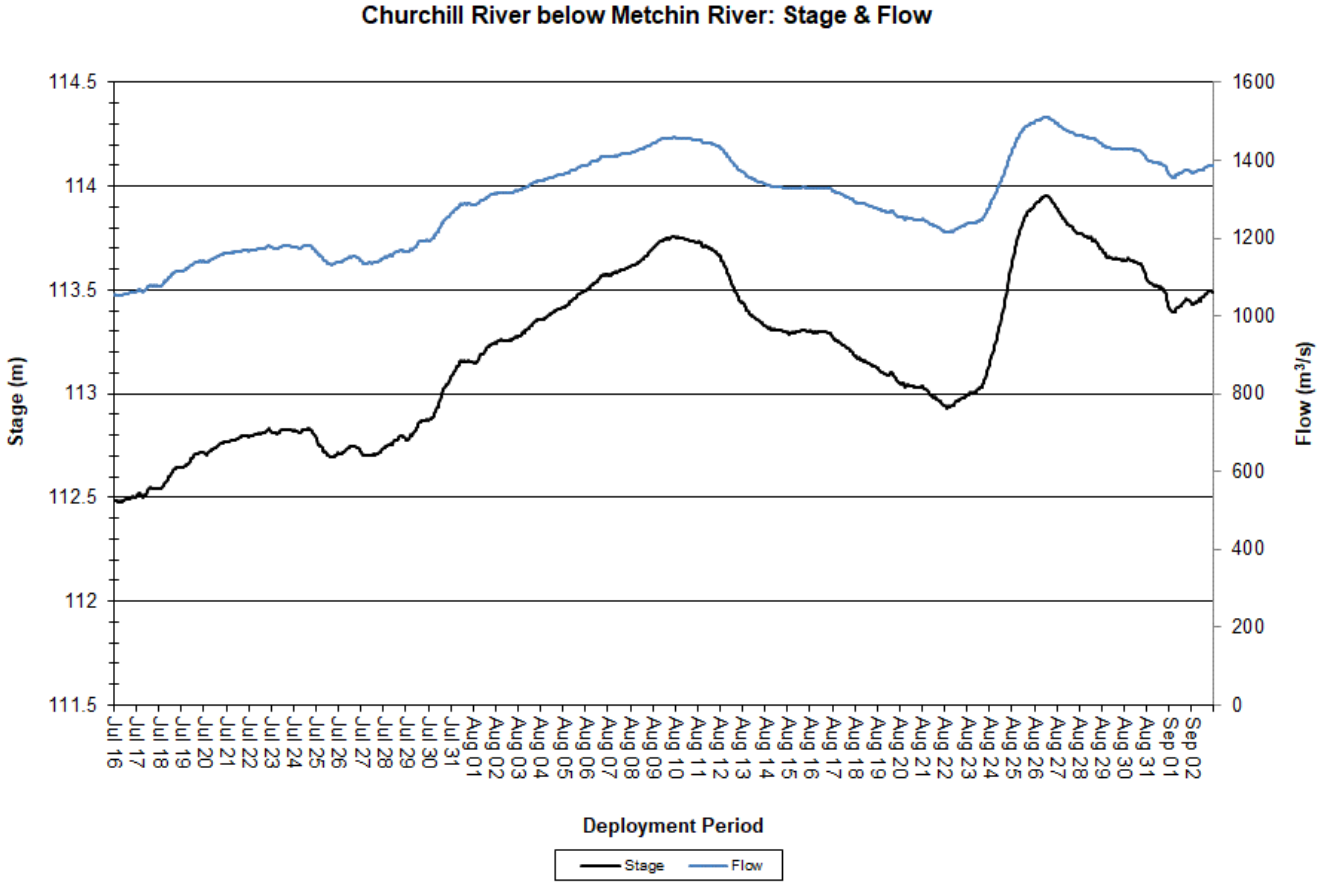

Figure 7: Stage & Flow at Churchill River below Metchin River

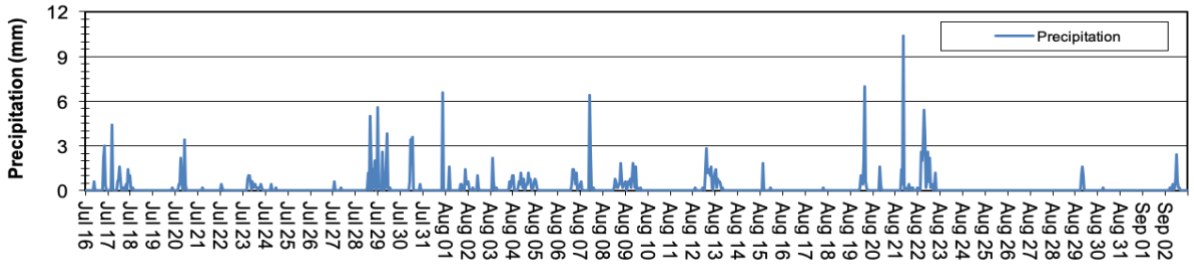

Figure 8: Precipitation at Churchill River below Metchin River

Churchill River above Grizzle Rapids

Water Temperature

- Over the deployment period, water temperature ranged from 9.80°C to 18.20°C, with a median value of 15.30°C (Figure 9). Air temperature data was obtained from the Muskrat Falls MET Station.
- Water temperature slowly increased across the deployment period. This trend is to be expected as air temperatures also increased through summer and fall. Water temperature data exhibits a diurnal pattern, 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.

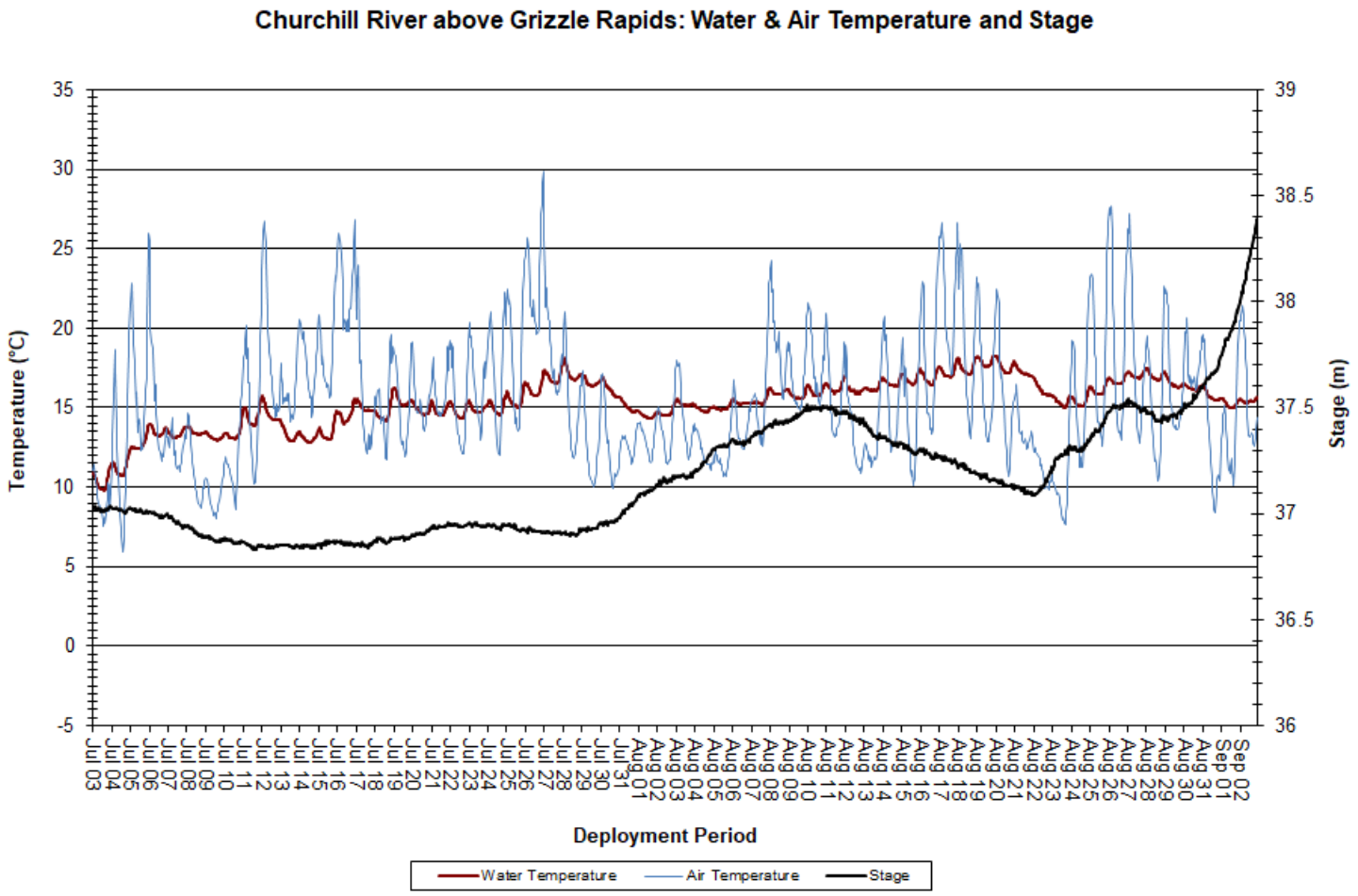

Figure 9: Water and Air Temperature & Stage at Churchill River above Grizzle Rapids

pH

- Over the deployment period, pH values ranged from 6.54 pH units to 6.87 pH units, with a median value of 6.71 (Figure 10).
- pH values were quite stable and remained within the CCME's Guidelines for the Protection of Aquatic Life for the duration of deployment.
- 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 10).
- 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.

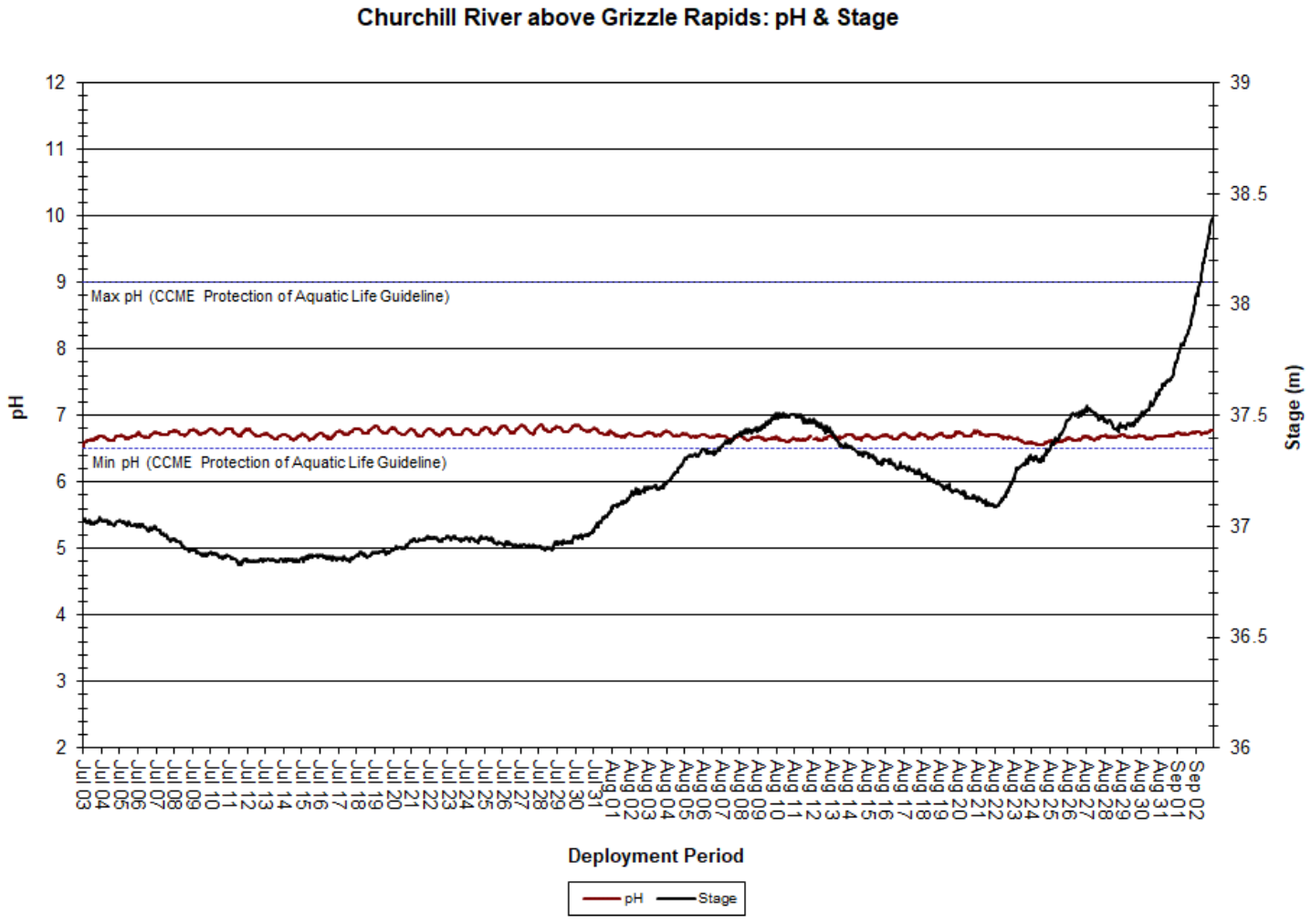

Figure 10: pH & Stage at Churchill River above Grizzle Rapids

Specific Conductivity

- Over the deployment period, specific conductivity ranged from 12.1µS/cm to 16.2µS/cm, with a median of 15.1µS/cm (Figure 11).
- The relationship between conductivity and stage is generally inversed. When stage levels increase, specific conductivity 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.

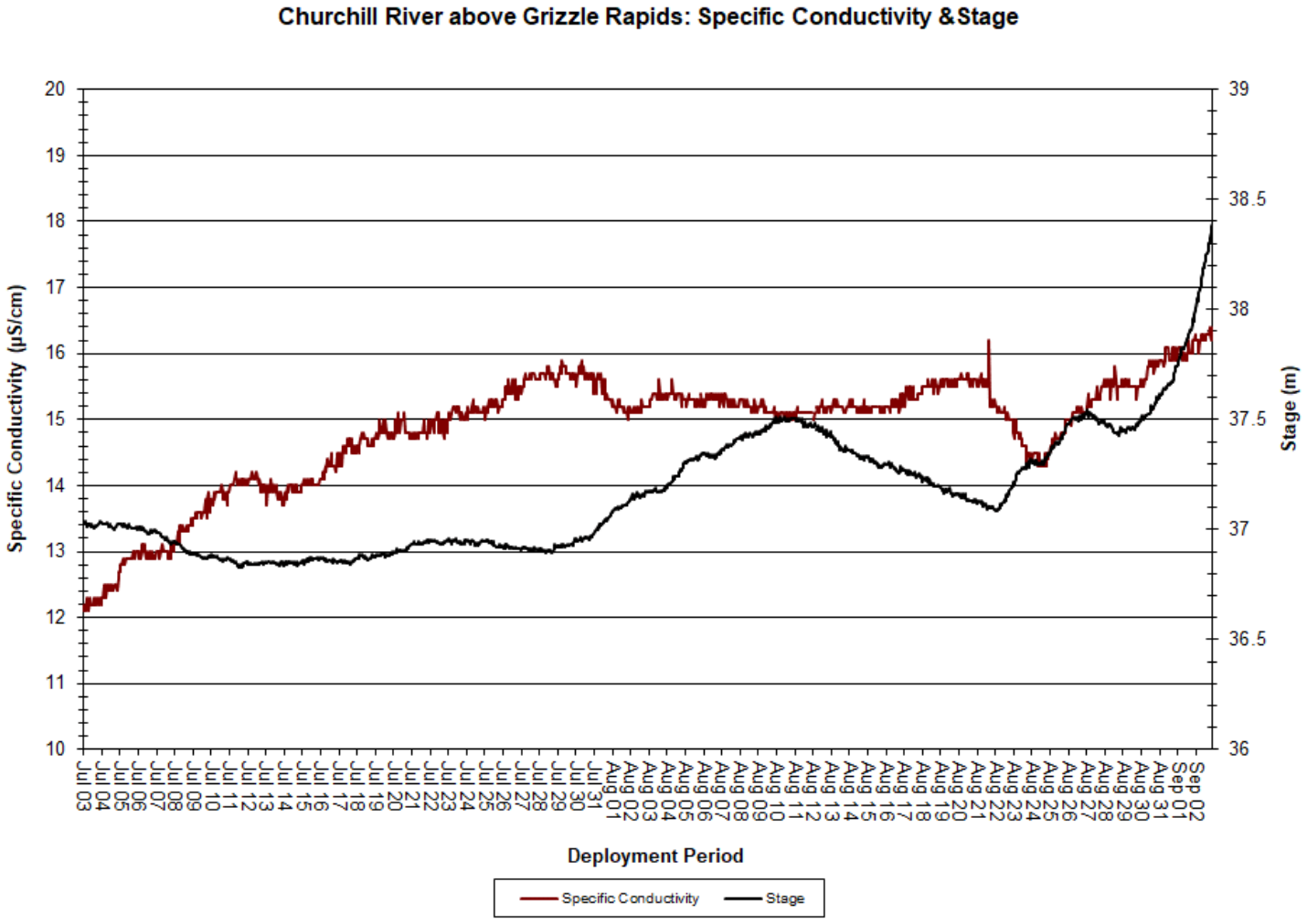

Figure 11: Specific Conductivity & Stage at Churchill River above Grizzle Rapids

Dissolved Oxygen

- Over the deployment period, dissolved oxygen content ranged from 8.92mg/L to 10.84mg/L, with a median value of 9.50mg/L. Saturation of dissolved oxygen ranged from 92.7% saturation to 100.2% saturation, with a median value of 94.8% (Figure 12).
- There is an evident relationship between water temperature and dissolved oxygen. Over the deployment period, dissolved oxygen levels gradually decreased as water temperatures increased through the spring and summer seasons. Dissolved oxygen also follows a diurnal pattern as water temperatures rise and fall under the influence of ambient air temperatures. Generally, dissolved oxygen levels are higher in a waterbody during cooler temperatures.
- Dissolved oxygen levels were above the CCME's Guideline for the Protection of Early Life Stages for the beginning of deployment, after which levels hovered around and fell below the CCME's Guideline for the Protection of Early Life Stages. This is to be expected given the warmer water temperatures observed through August. Dissolved oxygen levels were above the CCME's Guideline for the Protection of Other Life Stages for the duration of deployment.

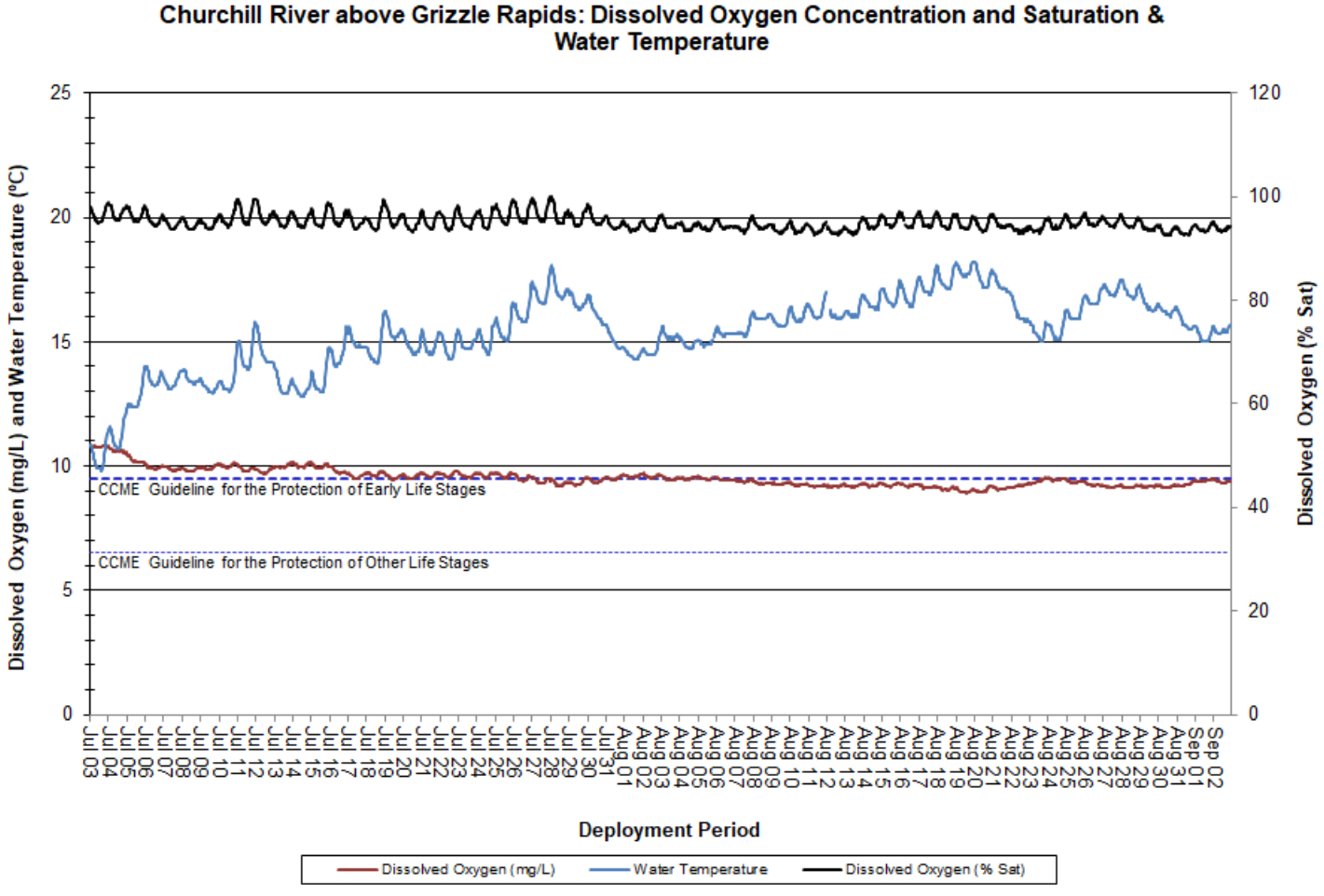

Figure 12: Dissolved Oxygen & Water Temperature at Churchill River above Grizzle Rapids

Turbidity

- Over the deployment period, turbidity ranged from 0.0NTU to 12.3NTU, with a median value of 0.2NTU (Figure 13). A median value of 0.2NTU indicates a very low level of natural background turbidity in the waterbody.
- Turbidity spikes observed over the deployment period generally correlate with precipitation events (Figure 13). Turbidity levels returned to background levels following each observed increase.
- 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.

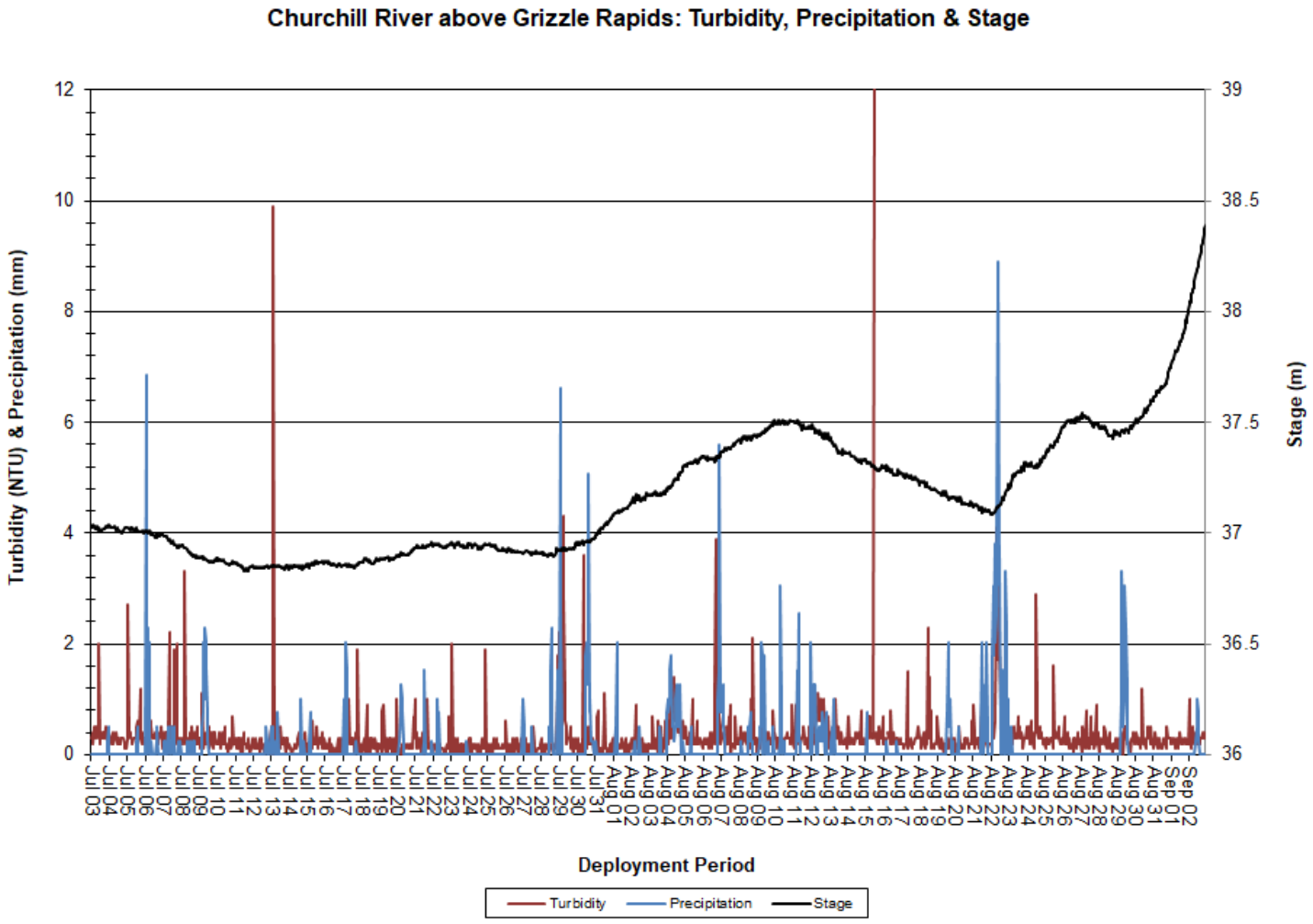

Figure 13: Turbidity, Precipitation & Stage at Churchill River above Grizzle Rapids

Stage & Flow

- Over the deployment period, stage ranged from 36.83m to 37.55m, with a median value of 37.03m (Figure 14). Flow ranged from 1247.81m^3/s to 2263.35m^3/s, with a median value of 1492.32m^3/s (Figure 14). Precipitation data was obtained from the Muskrat Falls MET Station.
- Stage and flow were variable across the course of deployment but followed a very similar trend. Precipitation across the same period is graphed below (Figure 15) to show that precipitation events often correlate with increases in both stage and flow. This is particularly evident from August 23rd through 28th.
- 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.

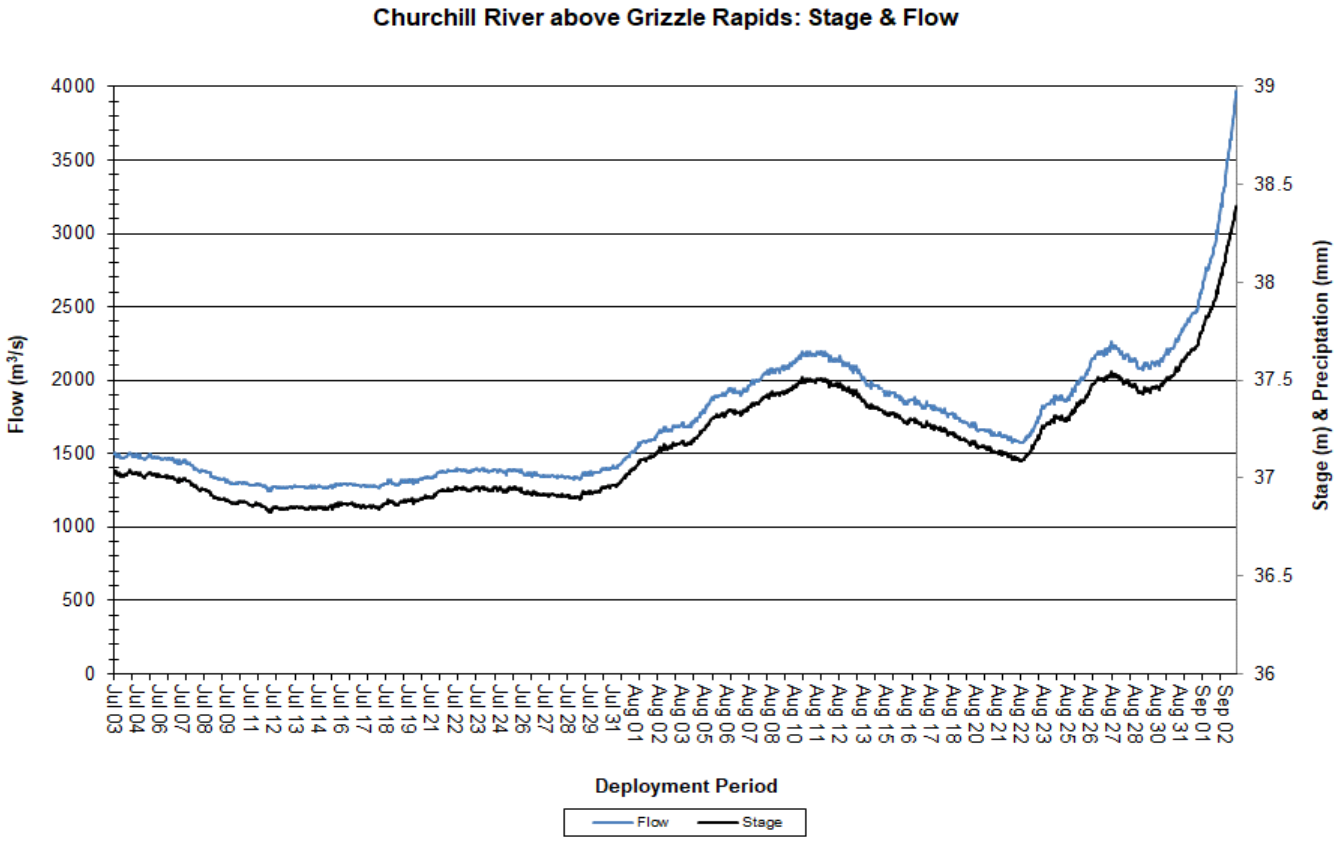

Figure 14: Stage & Flow at Churchill River above Grizzle Rapids

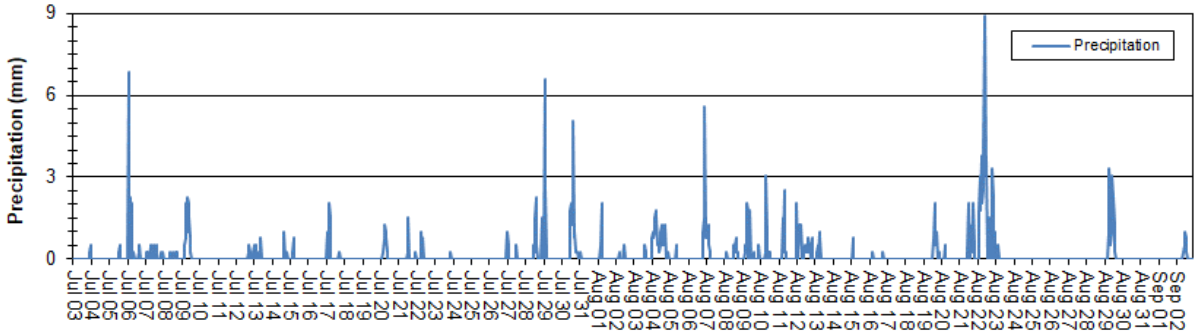

Figure 15: Precipitation at Churchill River above Grizzle Rapids

Churchill River below Muskrat Falls

Water Temperature

- Over the deployment period, water temperature ranged from 11.70°C to 17.90°C, with a median value of 15.80°C (Figure 16). Air temperature data was obtained from the Muskrat Falls MET Station.
- Water temperature slowly increased over the course of the deployment period. This is to be expected as ambient air temperatures also increased through July and August. Water temperatures closely correlate 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.

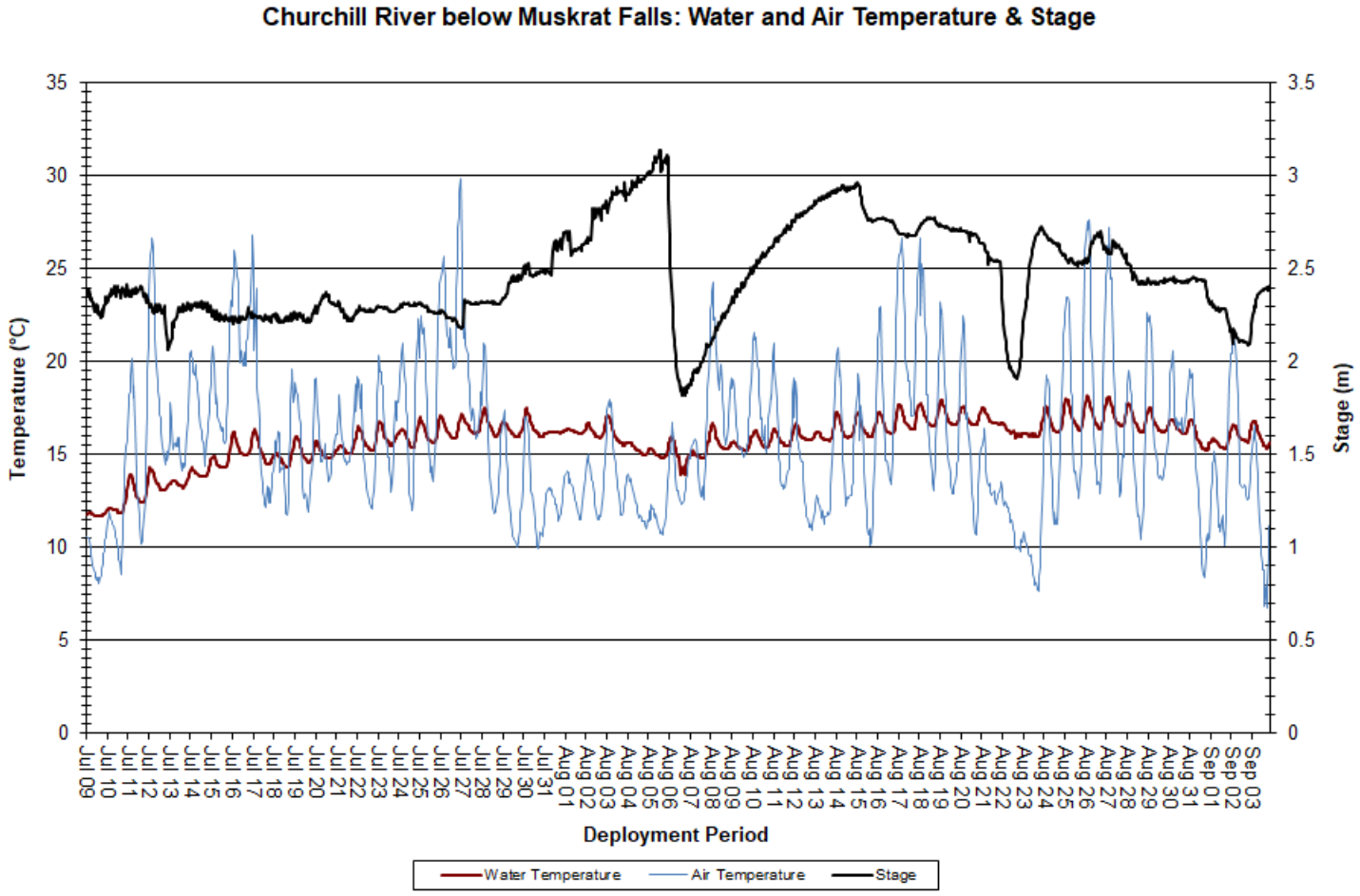

Figure 16: Water and Air Temperature & Stage at Churchill River below Muskrat Falls

pH

- Over the deployment period, pH ranged from 5.91 pH units to 7.19 pH units, with a median value of 6.22 (Figure 17).
- pH values were relatively stable over the course of deployment, and remained below the CCME's Guidelines for the Protection of Aquatic Life for the duration of deployment. A single exception occurred on August 7, which correlated closely with a significant decrease in stage (Figure 17). The irregular pH readings observed here may be the result of the water quality instrument being out of the water briefly before stage levels began to increase again.
- 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.

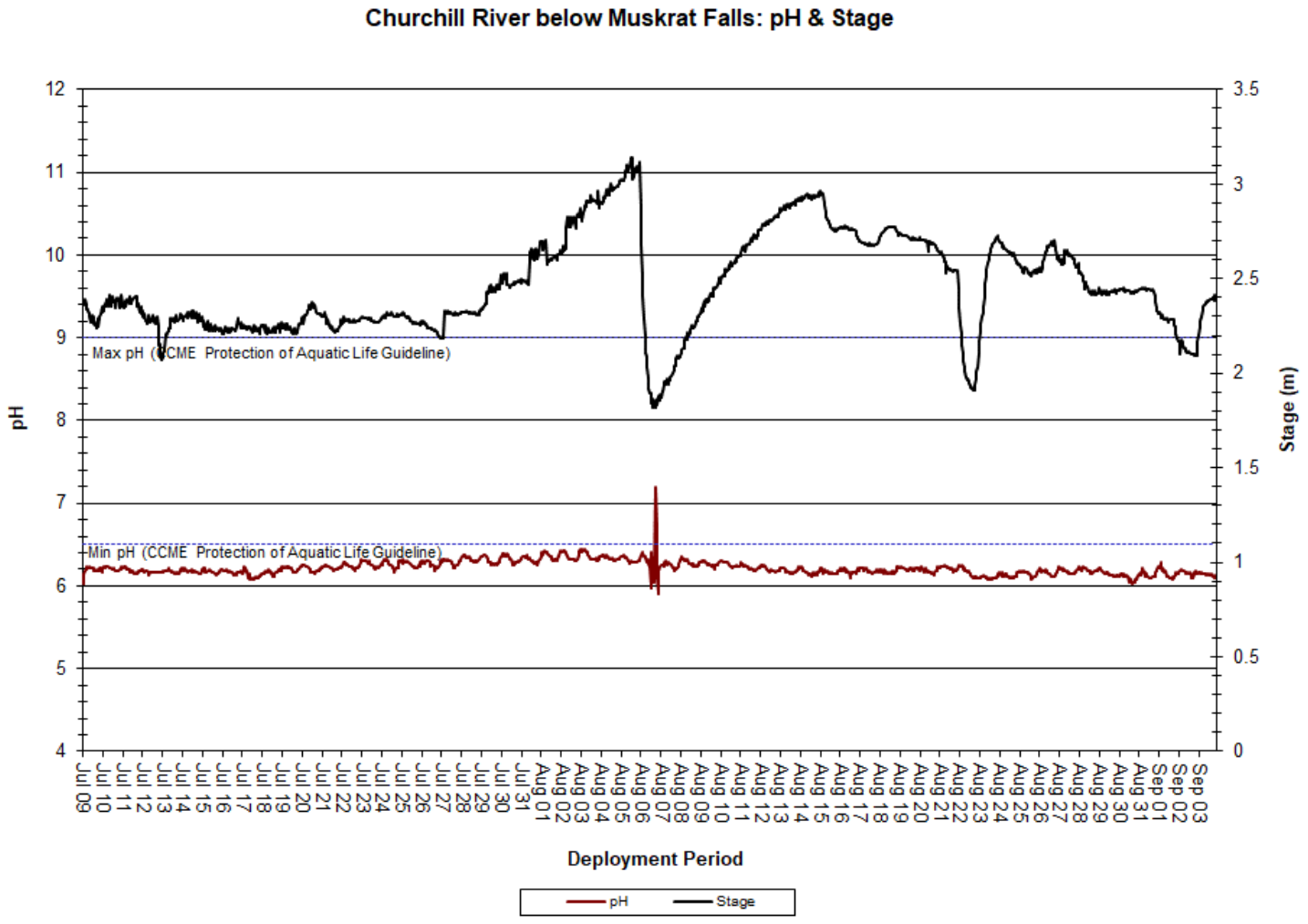

Figure 17: pH & Stage at Churchill River below Muskrat Falls

Specific Conductivity

- Over the deployment period, specific conductivity ranged from 0.0µS/cm to 18.4µS/cm, with a median value of 16.4µS/cm (Figure 18).
- The relationship between conductivity and stage is generally inversed. When stage decreases, specific conductivity increases as the decreased amount of water in the river system concentrates solids that are present, and vice versa. This relationship is somewhat apparent in the graph below (Figure 18).
- The significant drop in specific conductivity observed on August 7th corresponds closely with a significant decrease in stage. It is possible that the water quality instrument was out of the water briefly before stage levels began to increase again.
- 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.

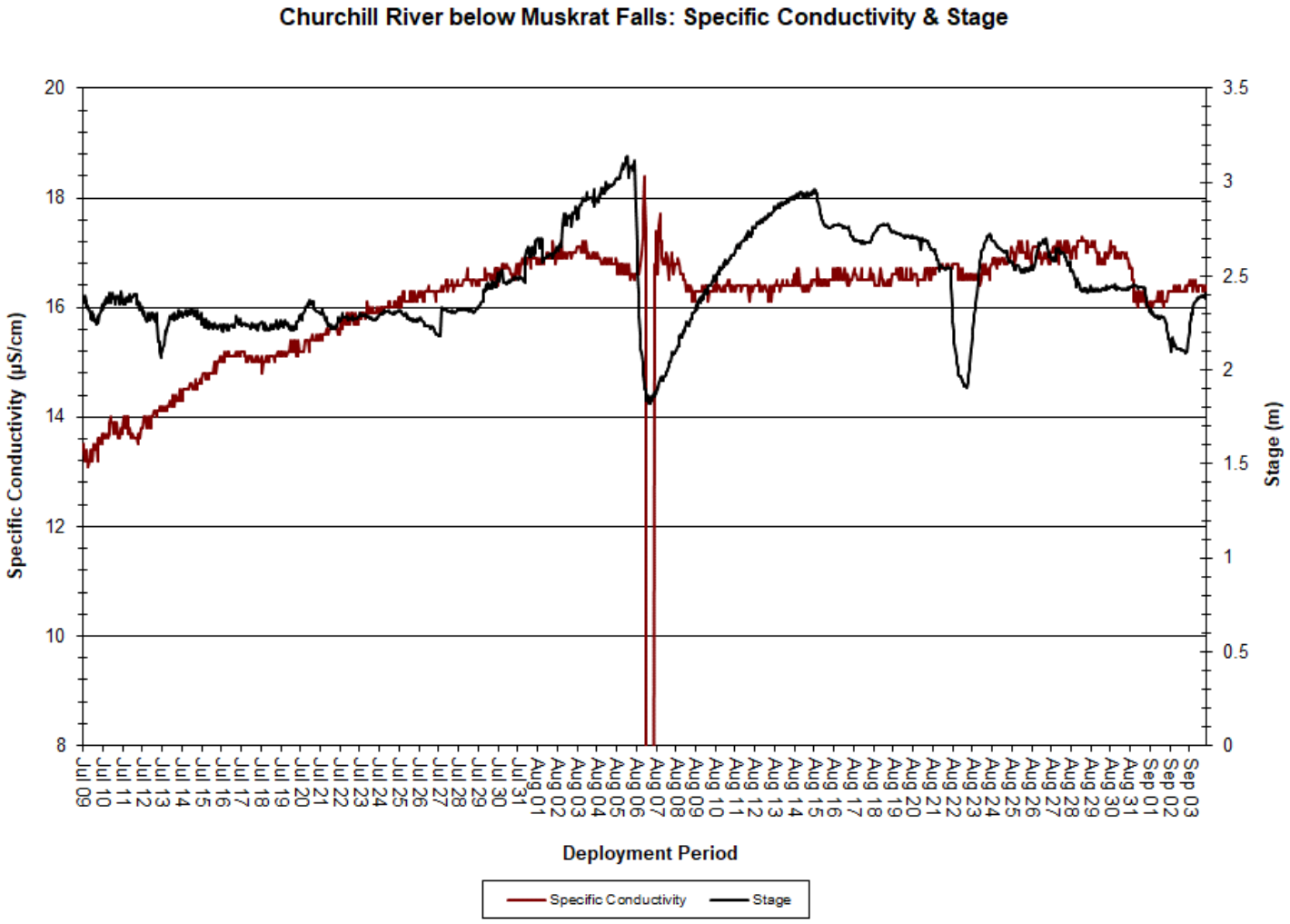

Figure 18: Specific Conductivity & Stage at Churchill River below Muskrat Falls

Dissolved Oxygen

- Over the deployment period, dissolved oxygen concentration ranged from 10.06mg/L to 12.54mg/L, with a median value of 11.39mg/L. Saturation of dissolved oxygen ranged from 99.1% to 126.5%, with a median value of 115.9% (Figure 19).
- Dissolved oxygen and water temperature exhibit an inverse relationship: as one parameter increases, the other decreases, and vice versa. Dissolved oxygen levels slowly decreased over the course of deployment. This is to be expected since water temperatures were slowly increasing over the same period. Dissolved oxygen also follows a diurnal pattern as water temperatures rise and fall under the influence of ambient air temperatures.
- Dissolved oxygen levels remained above the CCME's Guidelines for the Protection of Early and Other Life Stages for the duration of deployment.

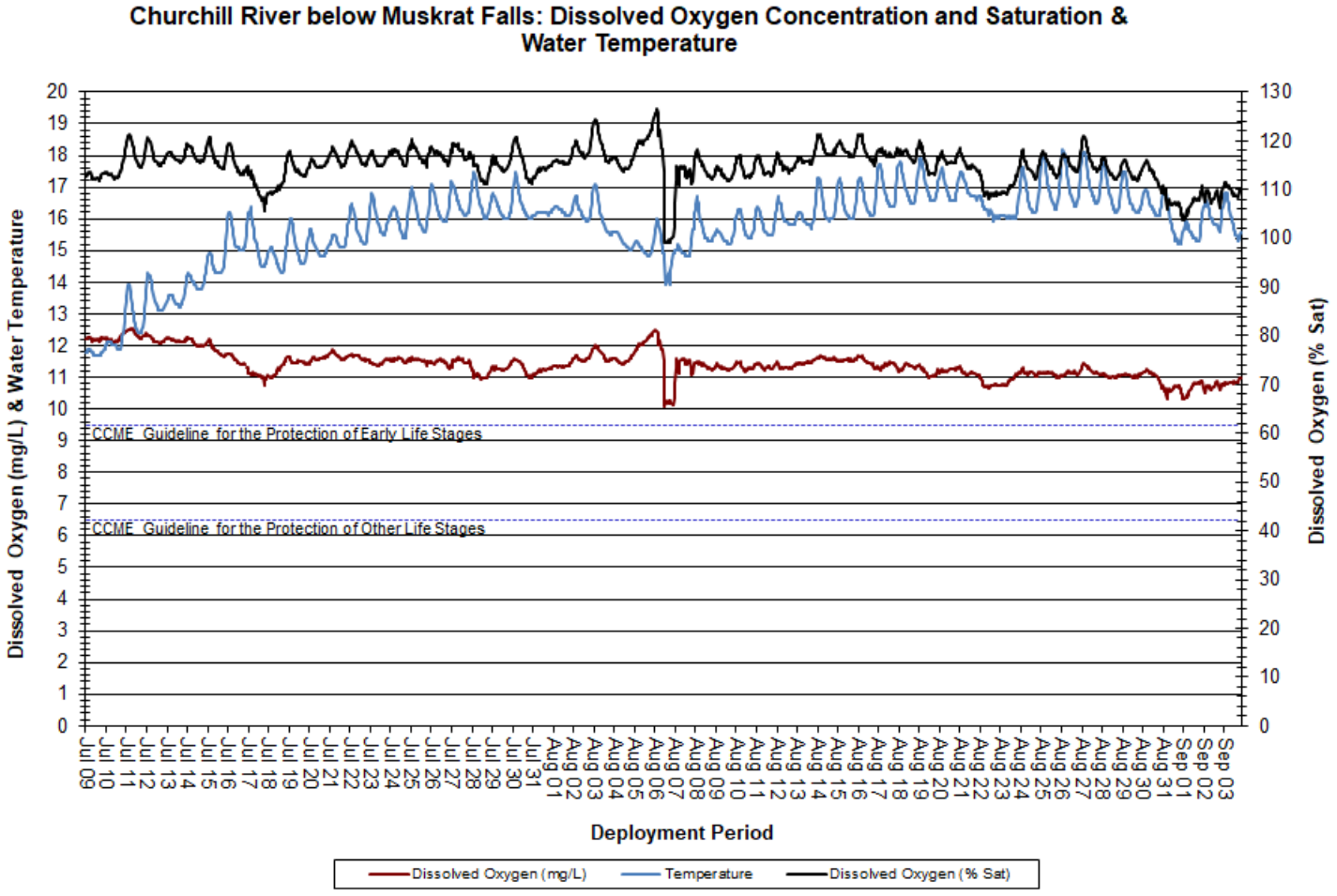

Figure 19: Dissolved Oxygen & Water Temperature at Churchill River below Muskrat Falls

Turbidity

- Over the deployment period, turbidity ranged from 0.0NTU to 2756.0NTU, with a median value of 5.7NTU. A median value of 5.7NTU indicates a small amount of natural background turbidity in the waterbody. Precipitation data was obtained from the Muskrat Falls MET Station.
- Many of the larger turbidity spikes observed over the deployment period correlate closely with changes in stage and precipitation events (Figure 20). This station is located at a wide and deep section of the Churchill River with a sandy bottom, and therefore turbidity levels are likely less susceptible to precipitation events as compared to other areas.
- Increased turbidity levels observed from August 7th onwards may be associated with decreased stage levels. It is also possible that sediment built up around the instrument sensors during the initial stage decrease, as evidenced by the fact that turbidity levels did not return to baseline levels after August 7th.
- 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.

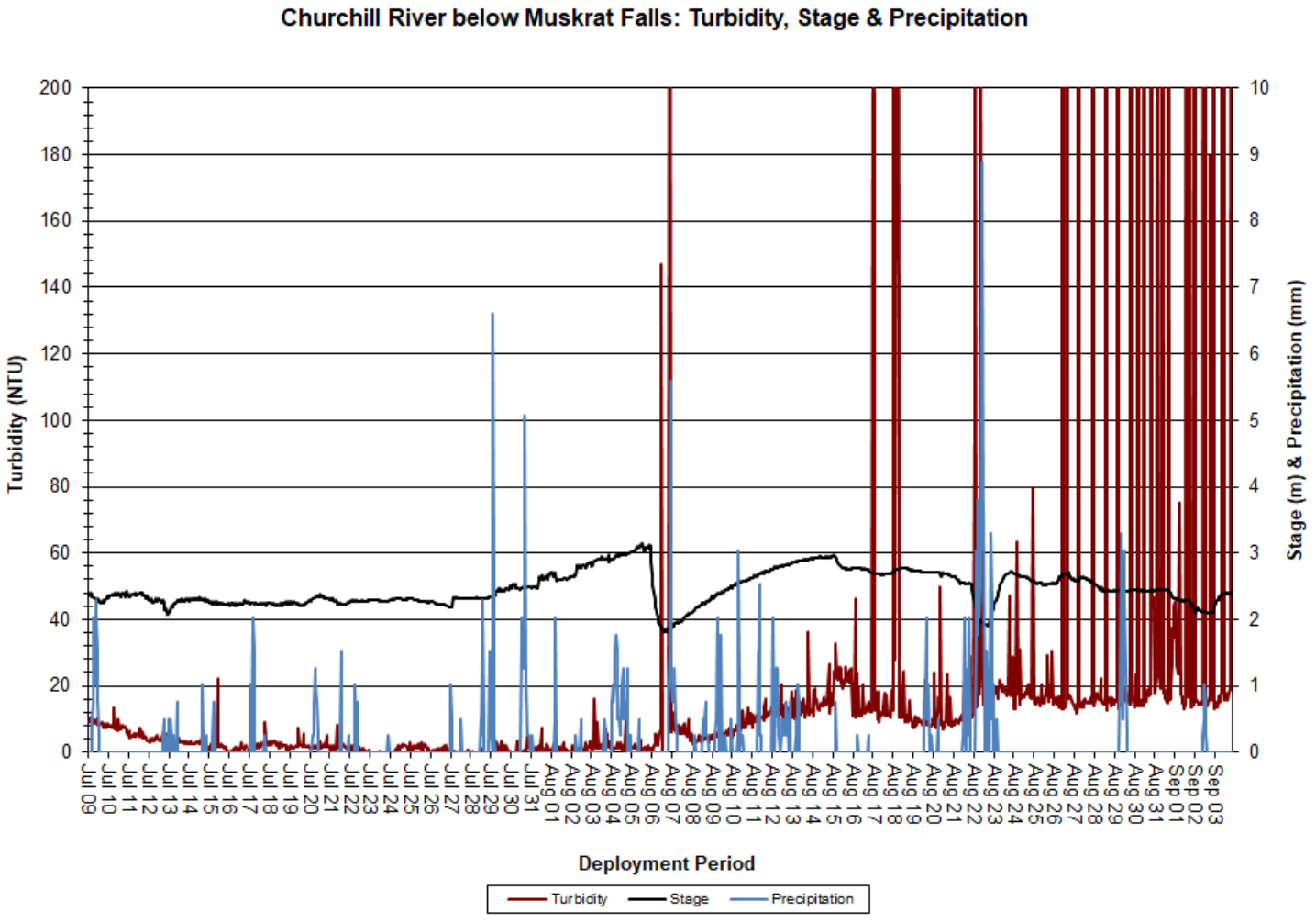

Figure 20: Turbidity, Precipitation & Stage at Churchill River below Muskrat Falls

Stage

- Over the deployment period, stage ranged from 1.82m to 3.14m, with a median value of 2.42m (Figure 21). Precipitation data was obtained from the Muskrat Falls MET Station.
- Stage was variable over the course of deployment; however, correlation between stage and precipitation events is not particularly close as evidenced in the graph below. This is partly related to the fact that this station is located on a very wide section of the Churchill River and therefore not as easily influenced by smaller precipitation events. This is also partly related to impoundment activities occurring at the Muskrat Falls hydroelectric project from early August through early September, which altered stage levels at this station and, in turn, influenced water quality parameters as evidenced in the preceding graphs.
- 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.

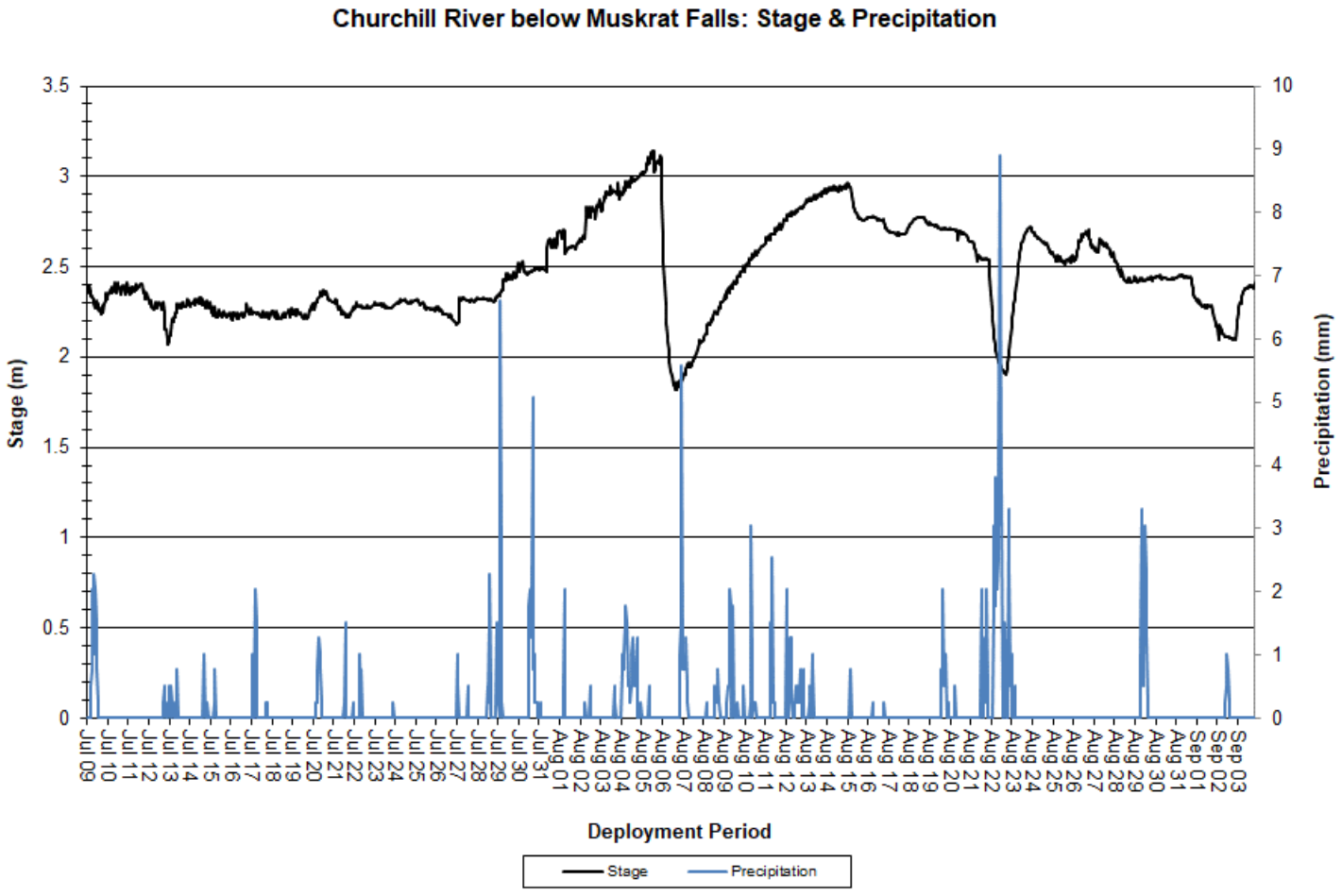

Figure 21: Stage & Precipitation at Churchill River below Muskrat Falls

Chlorophyll

- Over the deployment period, chlorophyll ranged from 0.54ug/L to 80.46ug/L, with a median value of 2.57ug/L (Figure 22).
- Chlorophyll is found within living cells of photosynthetic organisms like phytoplankton and cyanobacteria. The amount of chlorophyll found in water can be used to understand the general biological health of an ecosystem. Chlorophyll can also be used to identify algal bloom events and is an indicator of nutrient loading in ecosystems.
- 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.

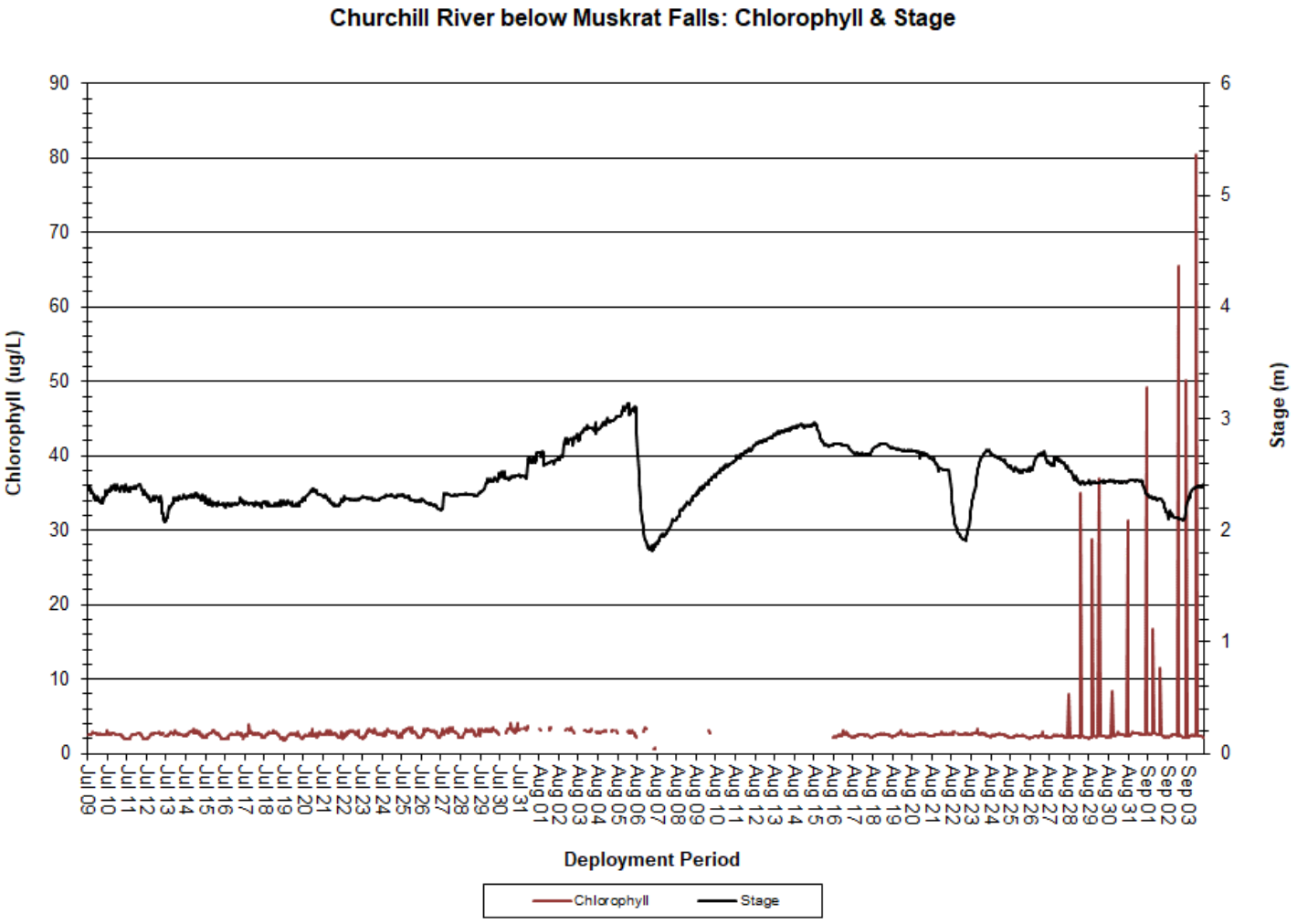

Figure 22: Chlorophyll & Stage at Churchill River below Muskrat Falls

Churchill River at English Point

Water Temperature

- Water temperature ranged from 10.50°C to 19.30°C, with a median value of 16.30°C (Figure 23). Air temperature data was obtained from the Muskrat Falls MET Station.
- Water temperature increased at the start of deployment but was then fairly stable for the remainder of deployment. Water temperatures closely correlated with ambient air temperatures, which followed a similar trend across the same period.
- 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.

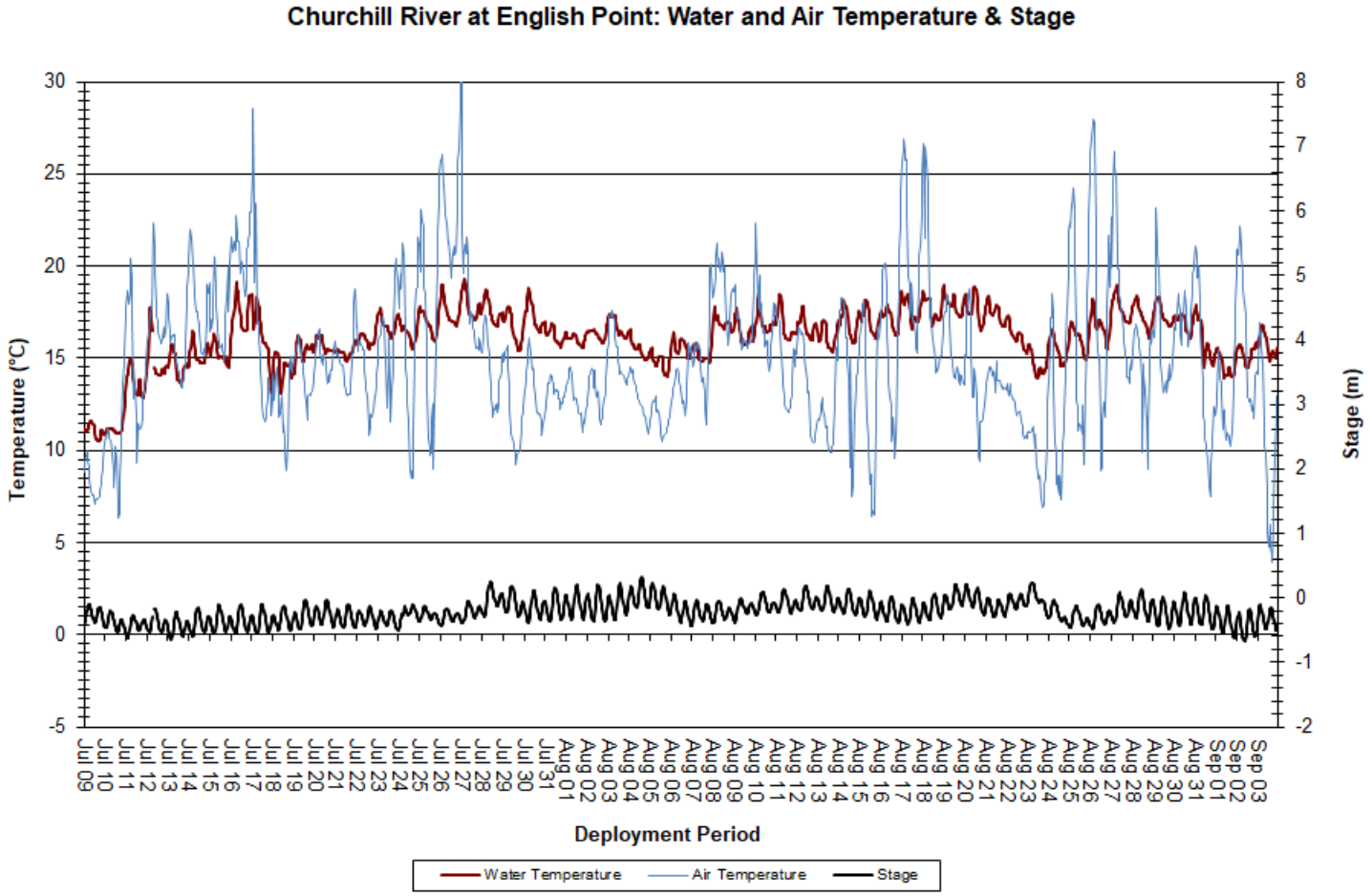

Figure 23: Water and Air Temperature & Stage at Churchill River at English Point

pH

- Over the deployment period, pH ranged from 5.97 pH units to 6.82 pH units, with a median value of 6.51 (Figure 24).
- pH values were relatively stable and hovered around the CCME's Guidelines for the Protection of Aquatic Life for the duration of deployment.
- 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.

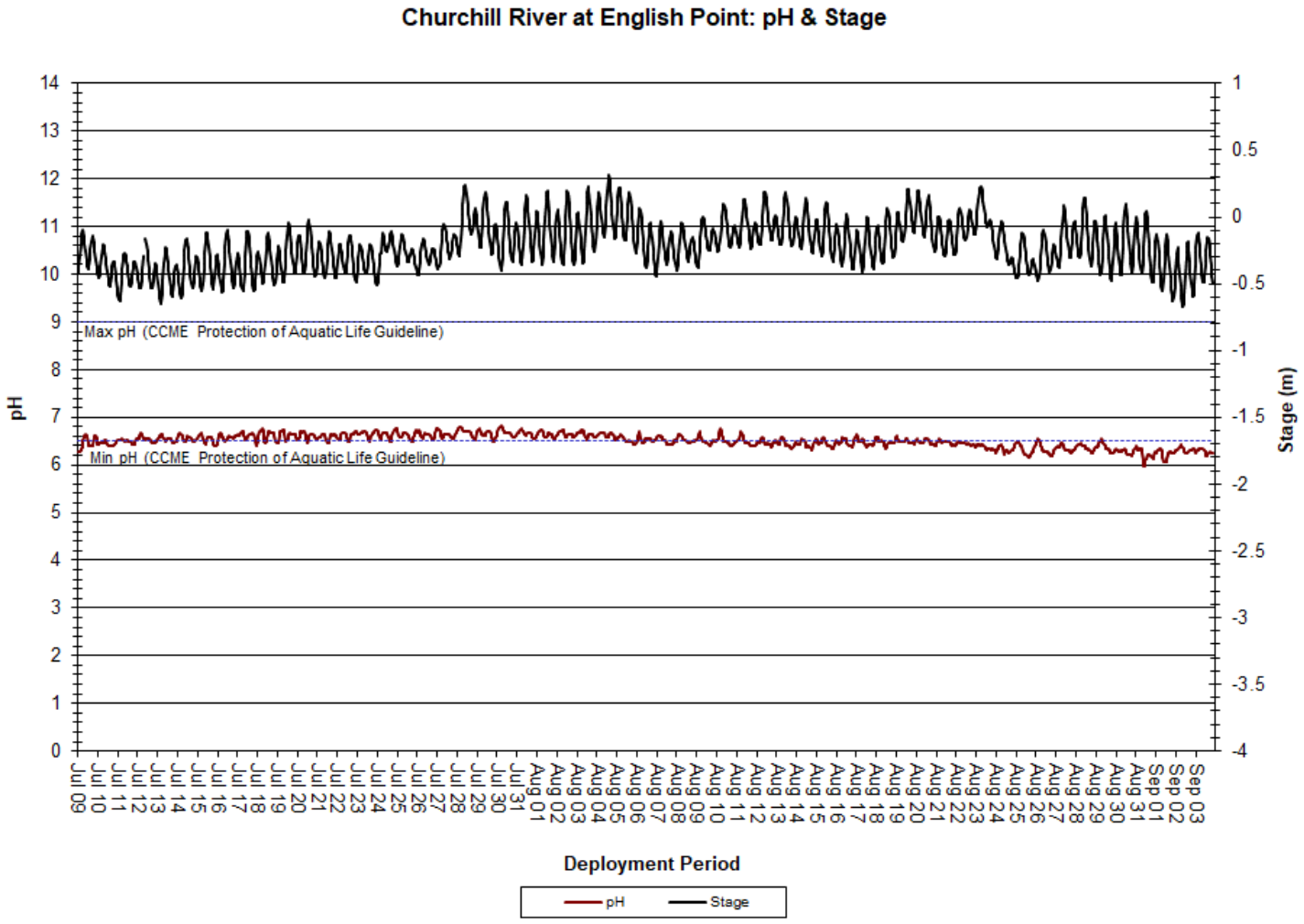

Figure 24: pH & Stage at Churchill River at English Point

Specific Conductivity

- Over the deployment period, specific conductivity ranged from 17.3µS/cm to 51.6µs/cm, with a median value of 25.4µS/cm (Figure 25).
- 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 25).
- 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.

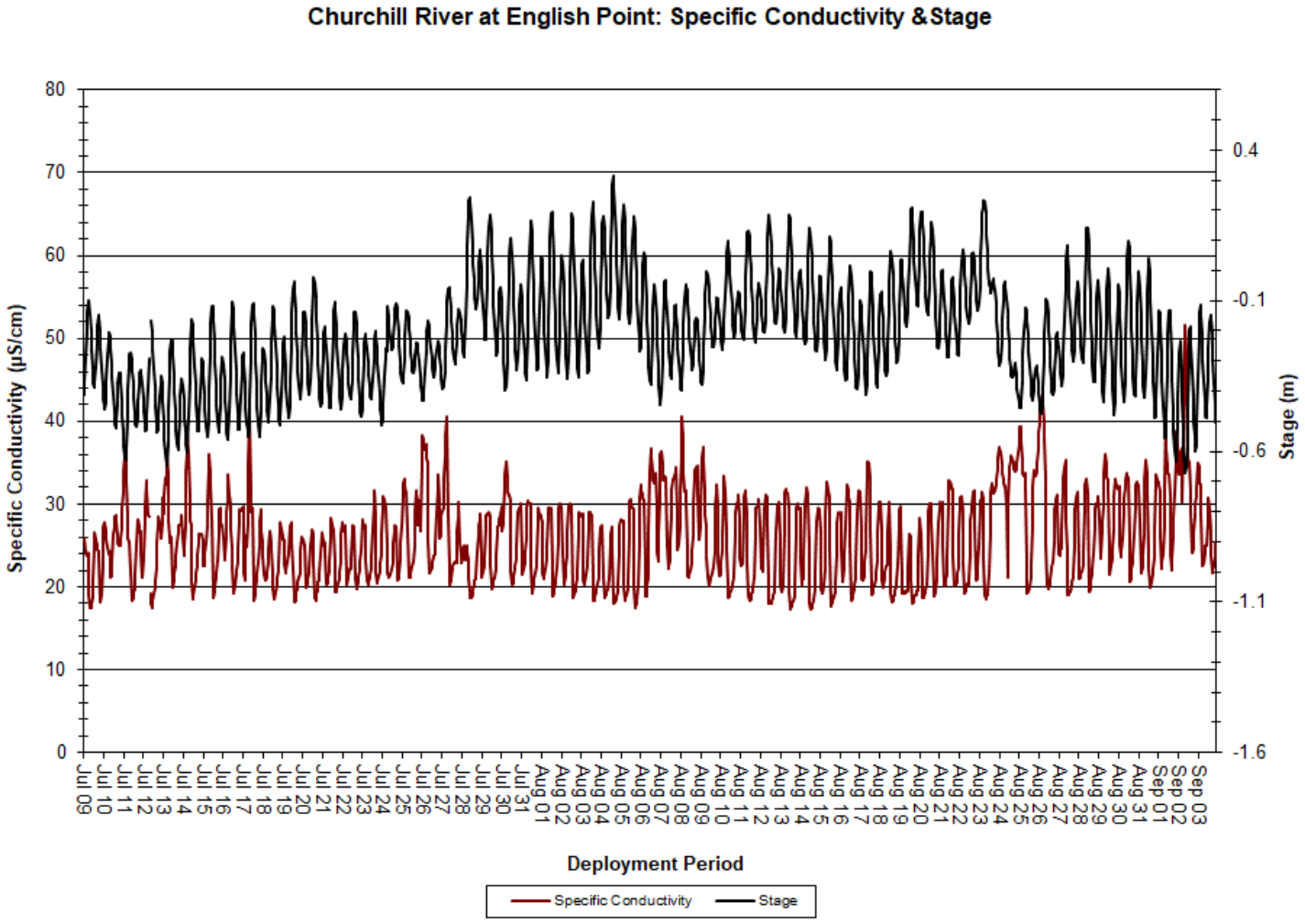

Figure 25: Specific Conductivity & Stage at Churchill River at English Point

Dissolved Oxygen

- Over the deployment period, dissolved oxygen concentration ranged from 8.99mg/L to 11.41mg/L, with a median value of 10.11mg/L. Saturation of dissolved oxygen ranged from 88.2% to 113.7% saturation, with a median value of 102.7% (Figure 26).
- There is an evident relationship between water temperature and dissolved oxygen. As water temperatures increased and then stabilized over the deployment period, dissolved oxygen levels decreased and stabilized. Dissolved oxygen levels also follow a diurnal pattern as water temperatures rise and fall under the influence of ambient air temperatures. Generally, dissolved oxygen levels are higher in a waterbody during cooler temperatures.
- Dissolved oxygen levels fell below the CCME's Guideline for the Protection of Early Life Stages on several brief occasions throughout deployment; these instances correlated closely with warmer water temperatures. Dissolved oxygen levels were above the CCME's Guideline for the Protection of Other Life Stages for the duration of deployment (Figure 26).

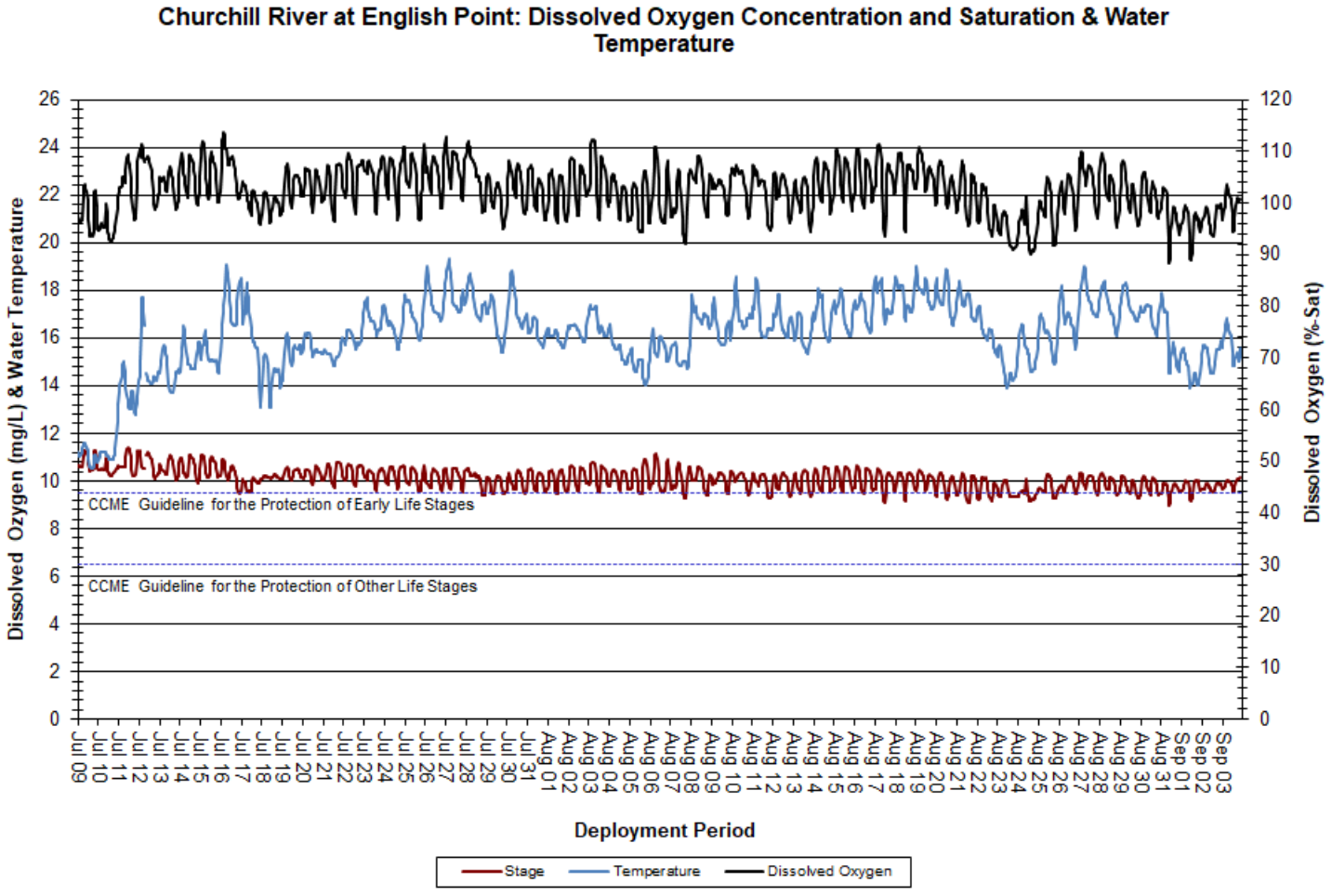

Figure 26: Dissolved Oxygen & Water Temperature at Churchill River at English Point

Turbidity

- Over the deployment period, turbidity ranged from 2.2NTU to 100.6NTU, with a median value of 8.9NTU (Figure 27). A median value of 8.9NTU indicates a low level of background turbidity; this is to be expected considering the sandy river bed and tidal influences present at this station. Precipitation data was obtained from the Muskrat Falls MET Station.
- Turbidity events generally correlate with precipitation events, as these can increase the presence of suspended material in water. High winds and tidal influences can also contribute to turbidity events at this station by disturbing sediment from the river bed (Figure 27). Wind speed data was obtained from the Churchill River at End of Mud Lake Road 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.

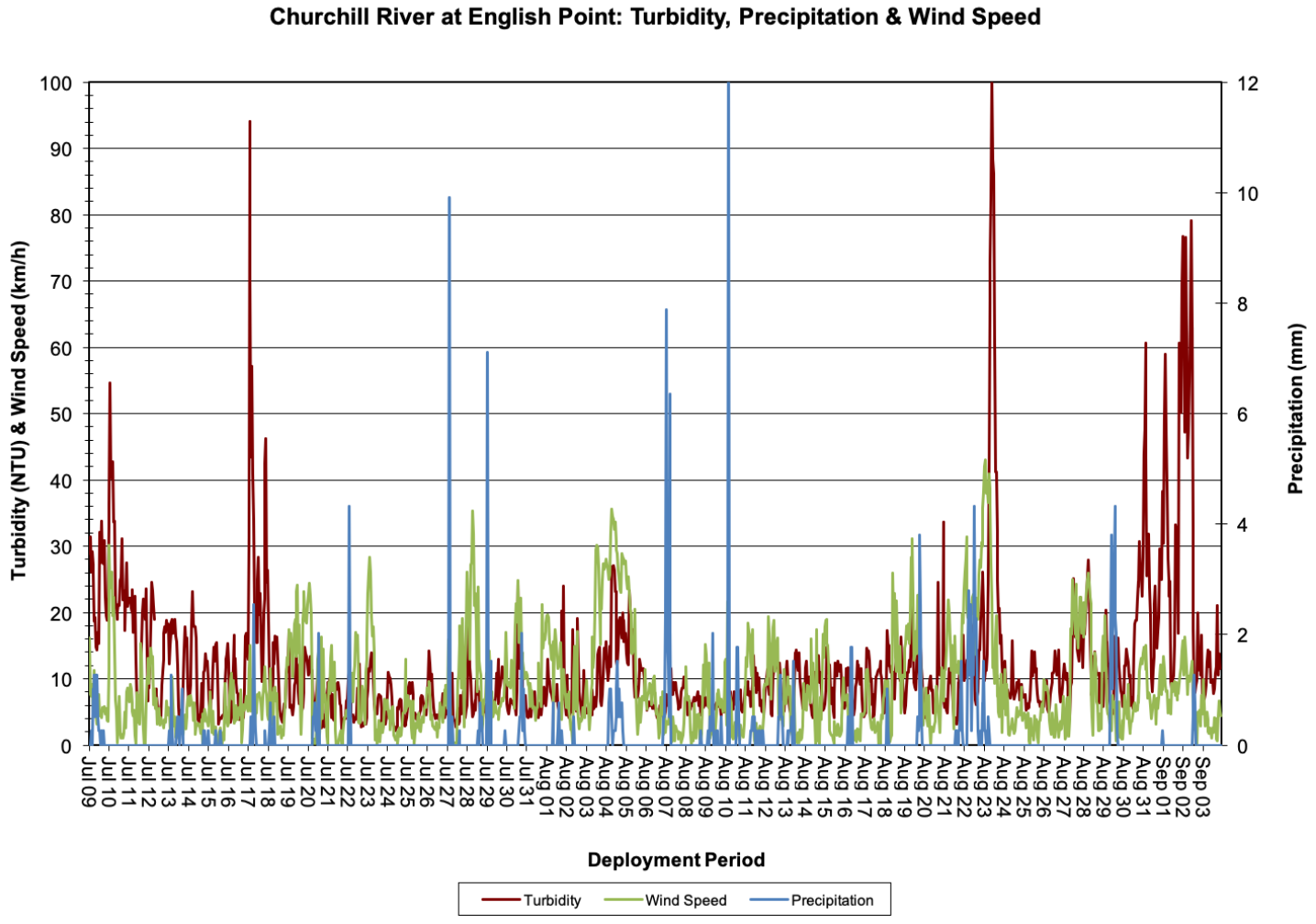

Figure 27: Turbidity, Precipitation & Wind Speed at Churchill River at English Point

Stage

- Over the deployment period, stage ranged from -0.67m to 0.31m, with a median value of -0.22m (Figure 28). Precipitation data was obtained from the Muskrat Falls MET Station.
- Stage fluctuates considerably at this location due to the tidal influences of the Atlantic Ocean. This pattern is consistent over the deployment period. Increases in stage often correlate with 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.

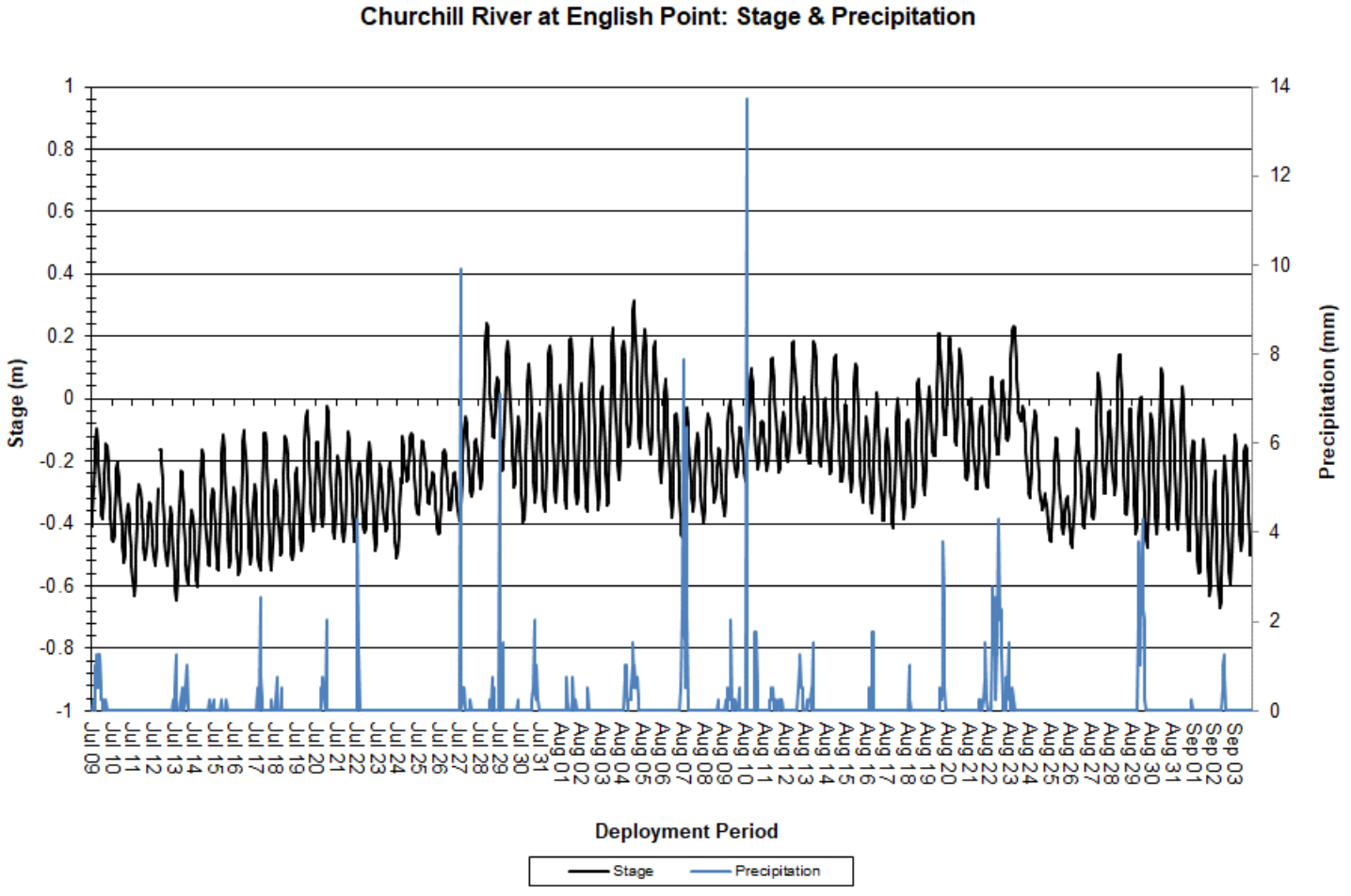

Figure 28: Stage & Precipitation at Churchill River at English Point

Conclusions

- Instruments at four water quality monitoring stations on the Lower Churchill River were deployed from July 3/9/16 through September 3/4, 2019.
- Impoundment activities were occurring at the Muskrat Falls site from early August through early September, which contributed to alterations in stage levels observed at the Churchill River below Muskrat Falls site and, in turn, likely influenced water quality parameters across the same period at this station.
- Water temperature increased slowly and/or stabilized at all stations over the course of deployment. This is to be expected based on ambient air temperature trends during the same period through July and August.
- pH was relatively stable at all stations over the course of deployment. pH was within the CCME's Guidelines for the Protection of Aquatic Life for the duration of deployment at Churchill River below Metchin River and above Grizzle Rapids, while pH hovered around the Guidelines at English Point and fell below the Guidelines below Muskrat Falls.
- Specific conductivity generally increased over the course of deployment at all stations. 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, which is comparable to other deployments at this location.
- Dissolved oxygen levels slowly decreased over the course of deployment at all stations as water temperatures increased through the summer. Dissolved oxygen levels are generally higher in water at cooler temperatures. Dissolved oxygen levels remained above the CCME's Guideline for the Protection of Early Life Stages for the duration of deployment at Churchill River below Muskrat Falls. Dissolved oxygen levels at the other three stations started deployment above the CCME's Guideline for the Protection of Early Life Stages, but gradually fell to and below the guideline as deployment progressed. Dissolved oxygen levels were above the CCME's Guideline for the Protection of Other Life Stages for the duration of deployment at all stations.
- Turbidity events occurred at all stations and were generally related to precipitation, wind or tidal events. In most cases, turbidity values returned to background levels following each observed event.

References

Canadian Council of Ministers of the Environment. 2007. Canadian water quality guidelines for the protection of aquatic life: Summary table. Updated December, 2007. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg. Available at: http://st-ts.ccme.ca/en/index.html?chems=154,162&chapters=1 [Accessed December 12, 2017].

Fondriest Environmental Inc. (2016a). Fundamentals of Environmental Measurements [Online]. Available at: http://www.fondriest.com/environmental-measurements/parameters/water-quality/conductivity-salinity-tds/#cond15 [Accessed December 12, 2017].

Fondriest Environmental Inc. (2016b). Fundamentals of Environmental Measurements [Online]. Available at: http://www.fondriest.com/environmental-measurements/parameters/water-quality/water-temperature/#watertemp1 [Accessed December 12, 2017].

Swenson, H.A., and Baldwin, H.L. (1965). A Primer on Water Quality, U.S. Geological Survey. Available at: https://pubs.usgs.gov/gip/7000057/report.pdf [Accessed December 12, 2017].

United States Geological Survey. (2017). Water properties: Dissolved oxygen [Online]. Available at: https://water.usgs.gov/edu/dissolvedoxygen.html [Accessed December 12, 2017].

APPENDIX A

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 B

Grab Sample Results

REPORT OF ANALYSIS

Lab Report Number: **1912986**

Cient:	Department of Environment	**COC Number:**	846791
Attention:	Ms. Leona Hyde	**Date Reported:**	2019-08-06
Client Project:		**Date Submitted:**	2019-07-23
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1442904	WS-S-0000	2019-6313-00-SI-SP	2019-07-16	Alkalinity as CaCO3	mg/L	5	7
	CR below MR			Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	<1
				Colour	TCU	2	22
				Conductivity	uS/cm	5	18
				Dissolved Organic Carbon	mg/L	0.5	3.5
				Fluoride	mg/L	0.10	<0.10
				Hardness as CaCO3	mg/L	1	5
				N-NH3 (Ammonia)	mg/L	0.010	<0.010
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	6.97
				Sulphate	mg/L	1	<1
				Total Dissolved Solids (COND - CALC)	mg/L	1	12
				Total Kjeldahl Nitrogen	mg/L	0.15	<0.15
				Total Organic Carbon	mg/L	0.5	4.0
				Turbidity	NTU	0.1	3.0
				Aluminum	mg/L	0.01	0.03

Sample comment:

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at http://www.cala.ca/scopes/2602.pdf.
Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: 

Sarah Horner

REPORT OF ANALYSIS

Lab Report Number: **1912986**

Cient:	Department of Environment	**COC Number:**	846791
Attention:	Ms. Leona Hyde	**Date Reported:**	2019-08-06
Client Project:		**Date Submitted:**	2019-07-23
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1442904	WS-S-0000	2019-6313-00-SI-SP	2019-07-16	Antimony	mg/L	0.0005	<0.0005
	CR below MR			Arsenic	mg/L	0.001	<0.001
				Barium	mg/L	0.01	<0.01
Sample comment:				Boron	mg/L	0.01	<0.01
				Calcium	mg/L	1	2
				Cadmium	mg/L	0.0001	<0.0001
Report comment:				Chromium	mg/L	0.001	<0.001
				Copper	mg/L	0.001	<0.001
				Iron	mg/L	0.03	0.09
				Lead	mg/L	0.001	<0.001
				Magnesium	mg/L	1	<1
				Manganese	mg/L	0.01	0.01
				Mercury	mg/L	0.0001	<0.0001
				Nickel	mg/L	0.005	<0.005
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	<2
				Strontium	mg/L	0.001	0.011

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at http://www.cala.ca/scopes/2602.pdf.
Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: Sarah Horner

REPORT OF ANALYSIS

Lab Report Number: **1912986**

Cient:	Department of Environment	**COC Number:**	846791
Attention:	Ms. Leona Hyde	**Date Reported:**	2019-08-06
Client Project:		**Date Submitted:**	2019-07-23
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1442904	WS-S-0000	2019-6313-00-SI-SP	2019-07-16	Uranium	mg/L	0.001	<0.001
	CR below MR			Zinc	mg/L	0.01	<0.01
				Phosphorus	mg/L	0.002	0.003
Sample comment:				Total Suspended Solids	mg/L	2	<2

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at http://www.cala.ca/scopes/2602.pdf.
Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: Sarah Horner

REPORT OF ANALYSIS

Lab Report Number: **1911730**

Cient:	Department of Environment	**COC Number:**	845853
Attention:	Ms. Leona Hyde	**Date Reported:**	2019-07-16
Client Project:		**Date Submitted:**	2019-07-08
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1439268	WS-S-0000 CR above GR	2019-6308-00-SI-SP	2019-07-03	Alkalinity as CaCO3	mg/L	5	5
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	<1
				Colour	TCU	2	37
				Conductivity	uS/cm	5	15
				Dissolved Organic Carbon	mg/L	0.5	4.5
				Fluoride	mg/L	0.10	<0.10
				Hardness as CaCO3	mg/L	1	5
				N-NH3 (Ammonia)	mg/L	0.020	0.036
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	7.16
				Sulphate	mg/L	1	1
				Total Dissolved Solids (COND - CALC)	mg/L	1	10
				Total Kjeldahl Nitrogen	mg/L	0.15	<0.15
				Total Organic Carbon	mg/L	0.5	4.9
				Turbidity	NTU	0.1	2.1
				Aluminum	mg/L	0.01	0.26

Sample comment:

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at http://www.cala.ca/scopes/2602.pdf.
Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: Sarah Horner

REPORT OF ANALYSIS

Lab Report Number: **1911730**

Cient:	Department of Environment	**COC Number:**	845853
Attention:	Ms. Leona Hyde	**Date Reported:**	2019-07-16
Client Project:		**Date Submitted:**	2019-07-08
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1439268	WS-S-0000	2019-6308-00-SI-SP	2019-07-03	Antimony	mg/L	0.0005	<0.0005
	CR above GR			Arsenic	mg/L	0.001	<0.001
				Barium	mg/L	0.01	0.01
Sample comment:				Boron	mg/L	0.01	<0.01
				Calcium	mg/L	1	2
				Cadmium	mg/L	0.0001	<0.0001
Report comment:				Chromium	mg/L	0.001	<0.001
				Copper	mg/L	0.001	<0.001
				Iron	mg/L	0.03	0.47
				Lead	mg/L	0.001	<0.001
				Magnesium	mg/L	1	<1
				Manganese	mg/L	0.01	0.04
				Mercury	mg/L	0.0001	<0.0001
				Nickel	mg/L	0.005	<0.005
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	<2
				Strontium	mg/L	0.001	0.010

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at http://www.cala.ca/scopes/2602.pdf.
Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: Sarah Horner

REPORT OF ANALYSIS

Lab Report Number: **1911730**

Cient:	Department of Environment	**COC Number:**	845853
Attention:	Ms. Leona Hyde	**Date Reported:**	2019-07-16
Client Project:		**Date Submitted:**	2019-07-08
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1439268	WS-S-0000	2019-6308-00-SI-SP	2019-07-03	Uranium	mg/L	0.001	<0.001
	CR above GR			Zinc	mg/L	0.01	<0.01
				Phosphorus	mg/L	0.002	0.062
Sample comment:				Total Suspended Solids	mg/L	2	20

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at http://www.cala.ca/scopes/2602.pdf.
Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: 

Sarah Horner

REPORT OF ANALYSIS

Lab Report Number: 1912273

Cient:	Department of Environment	**COC Number:**	
Attention:	Ms. Leona Hyde	**Date Reported:**	2019-07-26
Client Project:		**Date Submitted:**	2019-07-12
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1440897	WS-S-0000	2019-6309-00-SI-SP	2019-07-09	Alkalinity as CaCO3	mg/L	5	5
	CR below MF			Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	<1
				Colour	TCU	2	40
				Conductivity	uS/cm	5	14
				Dissolved Organic Carbon	mg/L	0.5	4.7
				Fluoride	mg/L	0.10	<0.10
				Hardness as CaCO3	mg/L	1	5
				N-NH3 (Ammonia)	mg/L	0.01	<0.010
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	6.96
				Sulphate	mg/L	1	<1
				Total Dissolved Solids (COND - CALC)	mg/L	1	9
				Total Kjeldahl Nitrogen	mg/L	0.15	0.16
				Total Organic Carbon	mg/L	0.5	4.5
				Turbidity	NTU	0.1	3.1
				Aluminum	mg/L	0.01	0.19

Sample comment:

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at http://www.cala.ca/scopes/2602.pdf.
Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL:

Addrine Thomas

REPORT OF ANALYSIS

Lab Report Number: 1912273

Cient:	Department of Environment	**COC Number:**	
Attention:	Ms. Leona Hyde	**Date Reported:**	2019-07-26
Client Project:		**Date Submitted:**	2019-07-12
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1440897	WS-S-0000	2019-6309-00-SI-SP	2019-07-09	Antimony	mg/L	0.0005	<0.0005
	CR below MF			Arsenic	mg/L	0.001	<0.001
				Barium	mg/L	0.01	<0.01
Sample comment:				Boron	mg/L	0.01	<0.01
				Calcium	mg/L	1	2
				Cadmium	mg/L	0.0001	<0.0001
Report comment:				Chromium	mg/L	0.001	<0.001
				Copper	mg/L	0.001	<0.001
				Iron	mg/L	0.03	0.22
				Lead	mg/L	0.001	<0.001
				Magnesium	mg/L	1	<1
				Manganese	mg/L	0.01	<0.01
				Mercury	mg/L	0.0001	<0.0001
				Nickel	mg/L	0.005	<0.005
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	<2
				Strontium	mg/L	0.001	0.012

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at http://www.cala.ca/scopes/2602.pdf.
Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: A. Thomas

Addrine Thomas

REPORT OF ANALYSIS

Lab Report Number: 1912273

Cient:	Department of Environment	**COC Number:**	
Attention:	Ms. Leona Hyde	**Date Reported:**	2019-07-26
Client Project:		**Date Submitted:**	2019-07-12
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1440897	WS-S-0000	2019-6309-00-SI-SP	2019-07-09	Uranium	mg/L	0.001	<0.001
	CR below MF			Zinc	mg/L	0.01	<0.01
				Phosphorus	mg/L	0.002	0.008
Sample comment:				Total Suspended Solids	mg/L	2	<2

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at http://www.cala.ca/scopes/2602.pdf.
Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: A. Thomas

Addrine Thomas

REPORT OF ANALYSIS

Lab Report Number: 1912273

Cient:	Department of Environment	**COC Number:**	
Attention:	Ms. Leona Hyde	**Date Reported:**	2019-07-26
Client Project:		**Date Submitted:**	2019-07-12
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1440899	WS-S-0000 CR @ Eng Pt	2019-6311-00-SI-SP	2019-07-09	Alkalinity as CaCO3	mg/L	5	6
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	3
				Colour	TCU	2	52
				Conductivity	uS/cm	5	24
				Dissolved Organic Carbon	mg/L	0.5	5.5
				Fluoride	mg/L	0.10	<0.10
				Hardness as CaCO3	mg/L	1	5
				N-NH3 (Ammonia)	mg/L	0.01	<0.010
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	6.83
				Sulphate	mg/L	1	1
				Total Dissolved Solids (COND - CALC)	mg/L	1	16
				Total Kjeldahl Nitrogen	mg/L	0.15	0.20
				Total Organic Carbon	mg/L	0.5	5.7
				Turbidity	NTU	0.1	10.7
				Aluminum	mg/L	0.01	0.51

Sample comment:

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at http://www.cala.ca/scopes/2602.pdf.
Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: Addrine Thomas

REPORT OF ANALYSIS

Lab Report Number: 1912273

Cient:	Department of Environment	**COC Number:**	
Attention:	Ms. Leona Hyde	**Date Reported:**	2019-07-26
Client Project:		**Date Submitted:**	2019-07-12
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1440899	WS-S-0000 CR @ Eng Pt	2019-6311-00-SI-SP	2019-07-09	Antimony	mg/L	0.0005	<0.0005
				Arsenic	mg/L	0.001	<0.001
				Barium	mg/L	0.01	0.01
				Boron	mg/L	0.01	<0.01
				Calcium	mg/L	1	2
				Cadmium	mg/L	0.0001	<0.0001
				Chromium	mg/L	0.001	0.001
				Copper	mg/L	0.001	0.001
				Iron	mg/L	0.03	0.67
				Lead	mg/L	0.001	<0.001
				Magnesium	mg/L	1	<1
				Manganese	mg/L	0.01	0.02
				Mercury	mg/L	0.0001	<0.0001
				Nickel	mg/L	0.005	<0.005
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	2
				Strontium	mg/L	0.001	0.017

Sample comment:

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at http://www.cala.ca/scopes/2602.pdf.
Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: Addrine Thomas

REPORT OF ANALYSIS

Lab Report Number: 1912273

Cient:	Department of Environment	**COC Number:**	
Attention:	Ms. Leona Hyde	**Date Reported:**	2019-07-26
Client Project:		**Date Submitted:**	2019-07-12
Purchase Order:	2180014303	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1440899	WS-S-0000	2019-6311-00-SI-SP	2019-07-09	Uranium	mg/L	0.001	<0.001
	CR @ Eng Pt			Zinc	mg/L	0.01	<0.01
				Phosphorus	mg/L	0.002	0.036
Sample comment:				Total Suspended Solids	mg/L	2	<2

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at http://www.cala.ca/scopes/2602.pdf.
Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: A. Thomas

Addrine Thomas