Real-Time Water Quality Deployment Report

Lower Churchill River Network

September 1 to October 1, 2015

Newfoundland Labrador

Government of Newfoundland & Labrador
Department of Environment and Conservation
Water Resources Management Division

Contents

Prepared by:
Kelly Maher – Environmental Scientist
Department of Environment and Conservation
Water Resources Management Division
Phone: 709.896.5542
Fax: 709.896.9566
kellymaher@gov.nl.ca

Newfoundland Labrador

Real-Time Water Quality Deployment Report

Lower Churchill River Network

September 1 to October 1, 2015

Real Time Water Quality Monitoring

- Department of Environment and Conservation staff monitors the 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: below Grizzle Rapids, above and below Muskrat Falls and at English Point.
- There was no instrument deployed at the station on Lake Melville east of Little River. Instrument deployments at this station have been suspended until a buoy system can be established at this site.
- On September 1 & 2, 2015, real-time water quality monitoring instruments were deployed at four of the Lower Churchill River Stations for a period of 29 days. The station below Lower Muskrat Falls was deployed on a trial basis due to improving sand conditions.

Quality Assurance and Quality Control

- As part of the Quality Assurance and Quality Control protocol (QAQC), an assessment of the reliability of data recorded by an instrument is made at the beginning and end of the deployment period. The procedure is based on the approach used by the United States Geological Survey.
- At deployment and removal, a QAQC 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 QAQC 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 dependant, 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 September 1 to October 1, 2015 are summarized in Table 2.

Table 2: Comparison rankings for Lower Churchill River stations September 1 to October 1, 2015

Churchill River Station and Instrument Number	Date	Action	Comparison Ranking				
			Temperature	pH	Conductivity	Dissolved Oxygen	Turbidity
Below Grizzle Rapids (45699)	September 1, 2015	Deployment	Marginal	Excellent	Excellent	Good	Excellent
	September 30, 2015	Removal	Excellent	Excellent	Good	Excellent	Excellent
Above upper Muskrat Falls (45700)	September 1, 2015	Deployment	Excellent	Excellent	Excellent	Excellent	Good
	September 30, 2015	Removal	Good	Good	Excellent	Excellent	Marginal
Below Muskrat Falls (45708)	September 2, 2015	Deployment	Excellent	Excellent	Excellent	Excellent	Excellent
	October 1, 2015	Removal	Good	Excellent	Excellent	Excellent	Excellent
At English Point (45701)	September 2, 2015	Deployment	Excellent	Excellent	Excellent	Excellent	Excellent
	October 1, 2015	Removal	Excellent	Excellent	Excellent	Excellent	Excellent

- At the station below Grizzle Rapids, pH, conductivity, dissolved oxygen, and turbidity all rank as 'good' or 'excellent' at deployment. Temperature ranks as 'marginal'. This discrepancy could be attributed to the QA/QC sonde not being acclimatized to the environment before the value was recorded. Upon removal temperature, pH, conductivity, dissolved oxygen, and turbidity all rank as 'good' or 'excellent'.
- At the station above Muskrat Falls, temperature, pH, conductivity, dissolved oxygen, and turbidity rank 'good' or 'excellent' at deployment. Upon removal temperature, pH, conductivity, and dissolved oxygen all rank as 'good' or 'excellent'. Turbidity ranks as 'marginal'. This discrepancy can be attributed to sediment being disturbed and a difference in location of the sondes.
- At the station below Muskrat Falls, temperature, pH, conductivity, dissolved oxygen, and turbidity all rank as 'excellent' at deployment. Upon removal temperature, pH, conductivity, dissolved oxygen, and turbidity all rank as 'good' or 'excellent'.

- At the station at English Point, temperature, pH, conductivity, dissolved oxygen, and turbidity all rank as 'excellent' at deployment. Upon removal temperature, pH, conductivity, and dissolved oxygen all rank as 'excellent'.

Data Interpretation

- The following graphs and discussion illustrate water quality related events occurring from September 1 to October 1, 2015 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 QAQC protocol. Water Survey of Canada is responsible for QAQC of water quantity data. Corrected data can be obtained upon request.
- The below Muskrat Falls station has been experiencing issues with sediment in the area. Due to improvements in the sand conditions the sonde was deployed on a trial basis for the monthly period.

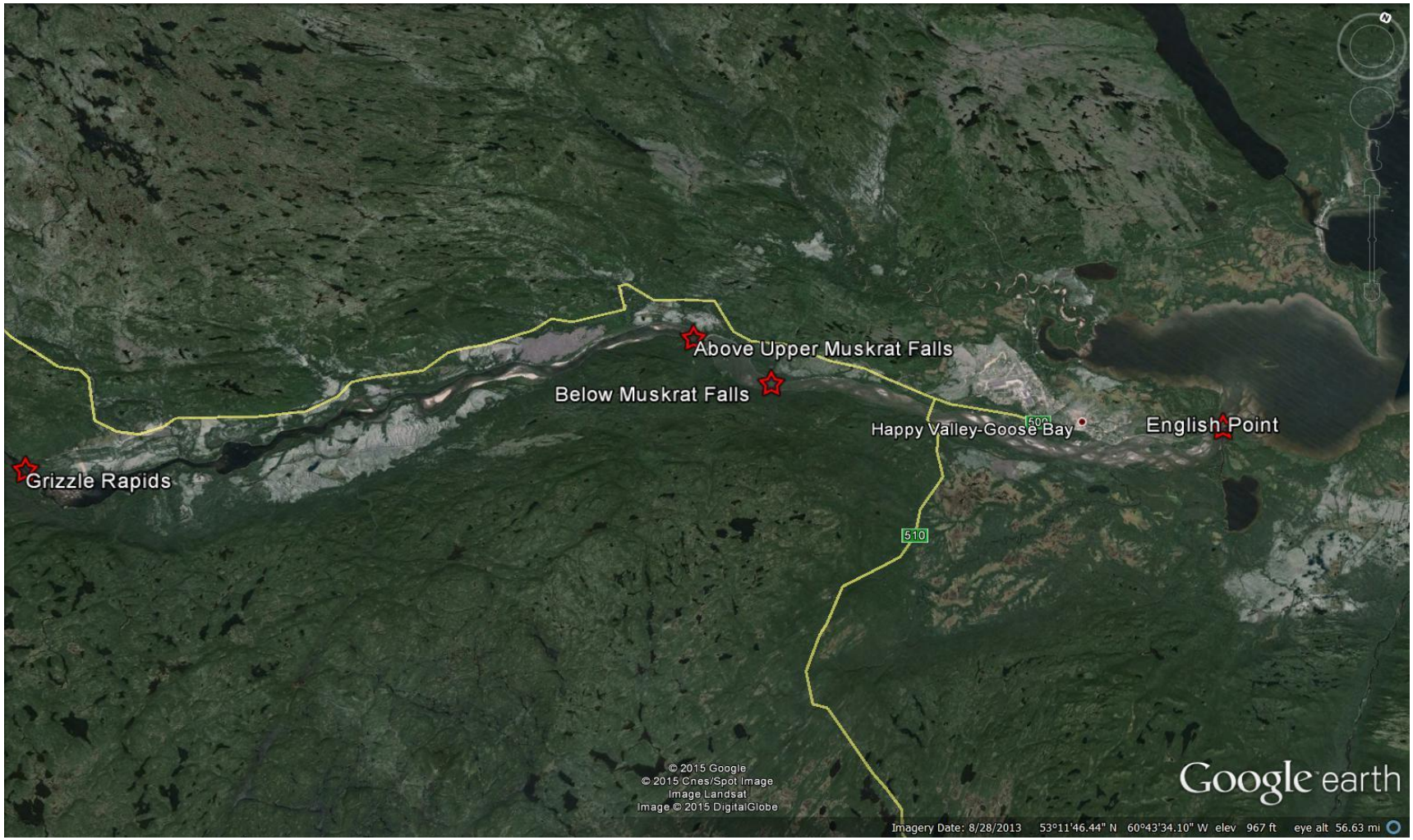

Figure 1: Lower Churchill Network- Station Locations

Churchill River below Grizzle Rapids

Water Temperature

- Water temperature ranges from 9.90°C to 17.10°C with a median value of 14.10°C (Figure 2).
- Water temperature is gradually decreasing throughout the deployment period. This trend is expected as air temperatures cool during the autumn months.

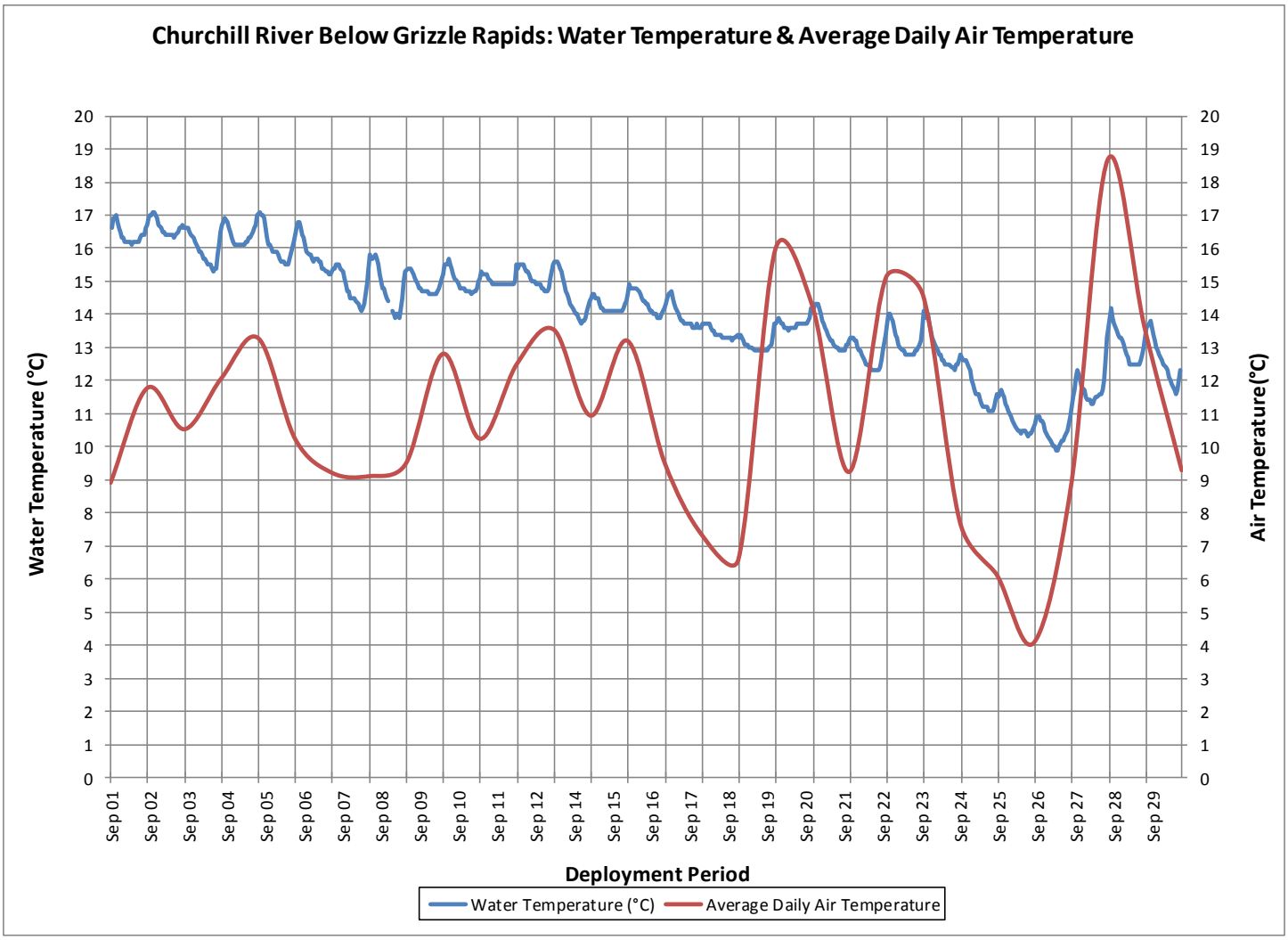

Figure 2: Water Temperature & Daily Average Air Temperature (Muskrat Falls Weather Station) at Churchill River below Grizzle Rapids

pH

- pH ranges between 7.03 and 7.35 pH units with a median value of 7.13 (Figure 3).
- pH values are stable and fall within the CCME Protection of Aquatic Life Guidelines.
- Photosynthesis uses up hydrogen molecules, which causes the concentration of hydrogen ions to decrease and therefore the pH to increase. For this reason, pH may be higher during daylight. This is illustrated by the diurnal fluctuations in Figure 3.

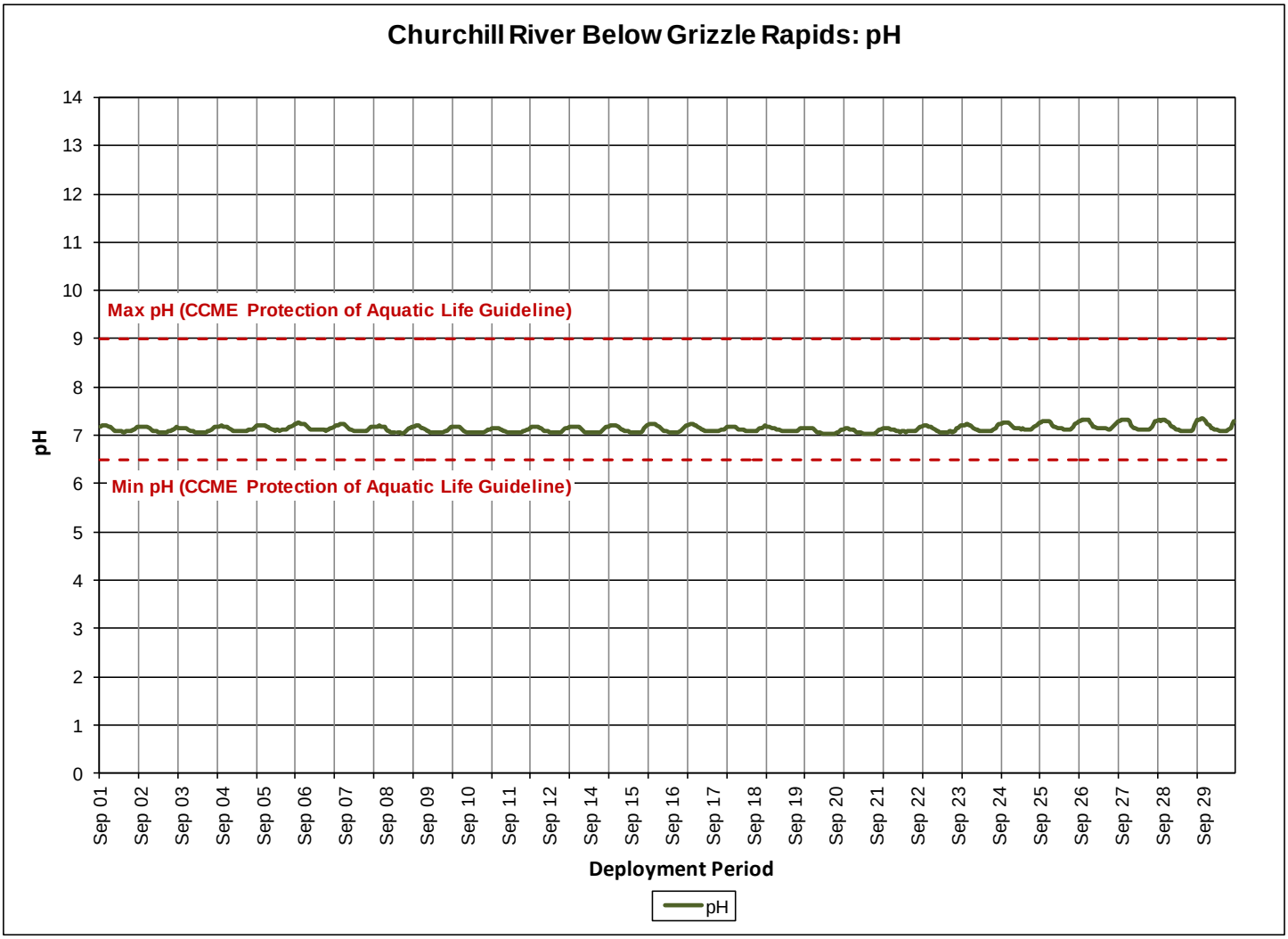

Figure 3: pH at Churchill River below Grizzle Rapids

Specific Conductivity, TDS and Stage

- Specific conductivity ranges from 17.6µS/cm to 19.8µS/cm with a median of 18.6µS/cm. (Figure 4).
- TDS (total dissolved solids) ranges from 0.0113 g/L to 0.0127 g/L with a median of 0.0119 g/L (Figure 4).
- Specific conductivity and TDS have a direct relationship but are two separate parameters. Specific conductivity is the ability of the water to conduct electricity. Therefore the value of TDS can be estimated by the conductivity of the water.
- The relationship between conductivity and stage are inversed. When stage level rises, the specific conductance levels drops in response as the increased amount of water in the river system dilutes the solids that are present. These parameters all remain relatively stable throughout the deployment period due to a stable stage level and minimal effects from precipitation events.
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

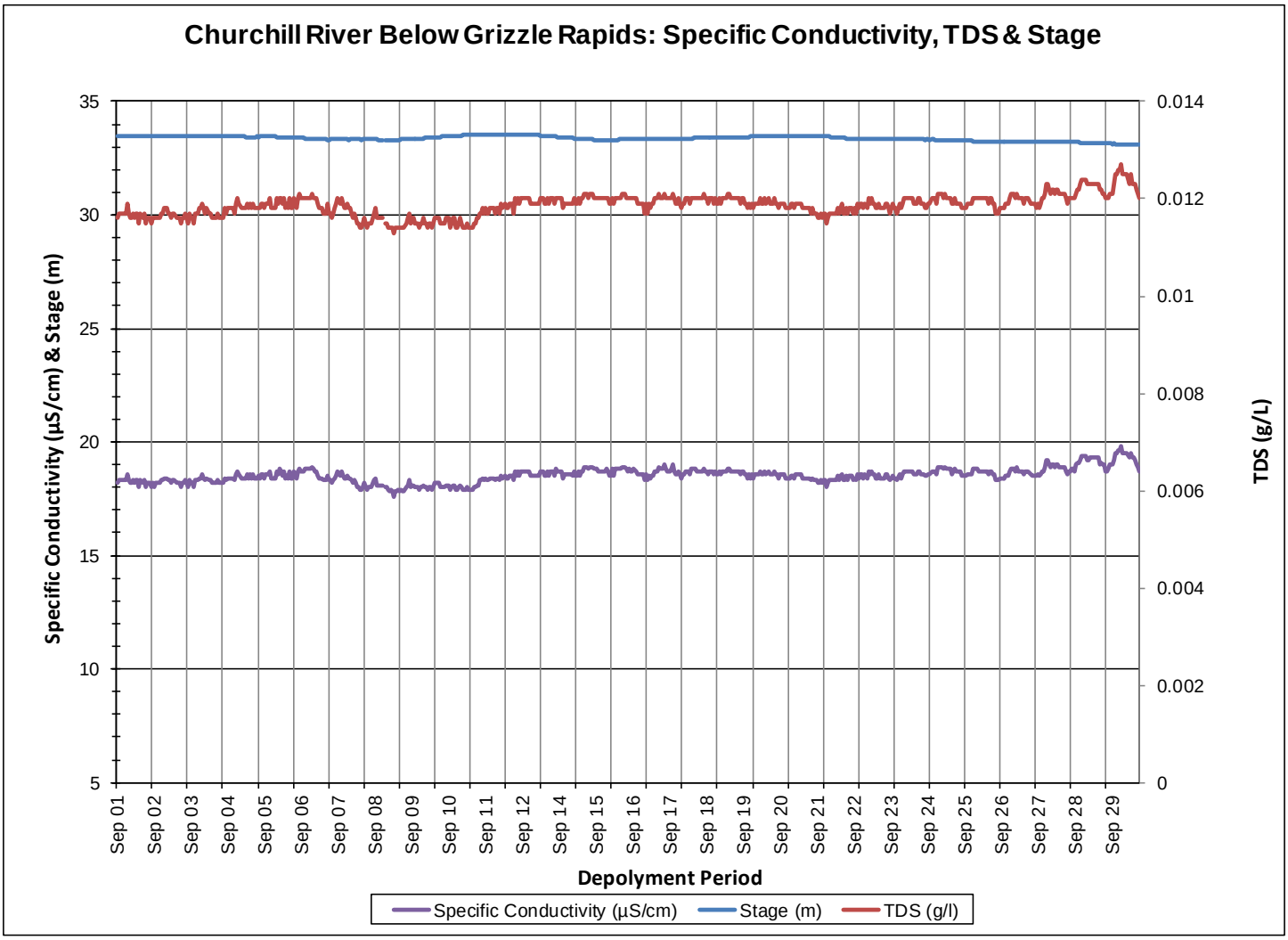

Figure 4: Specific Conductivity, TDS, and stage at Churchill River below Grizzle Rapids

Dissolved Oxygen

- Dissolved oxygen content ranges between 9.43mg/l and 11.20mg/l with a median value of 10.06mg/l. The saturation of dissolved oxygen ranges from 95.8% to 103.8% with a median value of 97.8% (Figure 5).
- There is an evident relationship between water temperature and dissolved oxygen. Over the deployment period the dissolved oxygen levels are increasing. The dissolved oxygen also follows a diurnal pattern as the water temperature rises and falls under the influence of the ambient air temperature. Generally there is more dissolved oxygen present in a waterbody during cooler temperatures.
- The dissolved oxygen levels remained above the CCME Guidelines for the Protection of Other Life Stages. However, the dissolved oxygen levels dip slightly below the CCME Guideline for the Protection of Early Stages for a short time at the beginning of the deployment period.

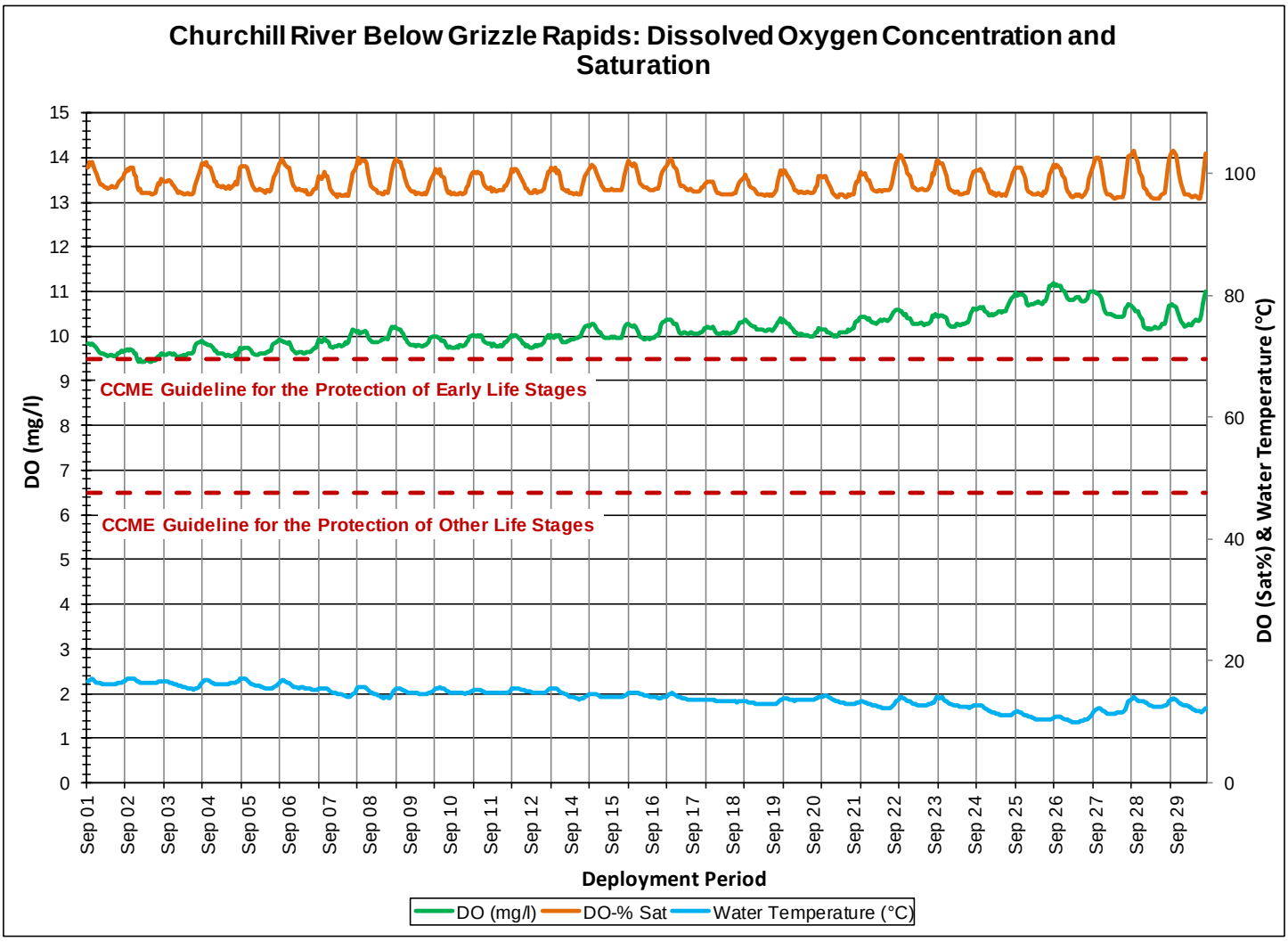

Figure 5: Dissolved Oxygen & Stage at Churchill River below Grizzle Rapids

Turbidity, Stage & Precipitation

- Turbidity ranges between 0.0NTU and 44.8NTU with a median value of 0.0NTU (Figure 7). A median value of 0.0NTU indicates this station has low background turbidity. The sonde may have been more susceptible to turbidity events this deployment period which were not precipitation influenced due to low water levels causing sediment to build up in the sonde casing (Figure 6, 7).
- Precipitation data was taken from the Muskrat Falls weather station. Precipitation occurs on 13 days during the deployment period and amounts are small in magnitude, with the largest on September 15th with 14.48 mm of rain (Figure 7).
- Stage ranges between 33.11m and 33.57m (Figure 7).
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

Figure 6: Low water level at Churchill River below Grizzle Rapids Station – September 30, 2015

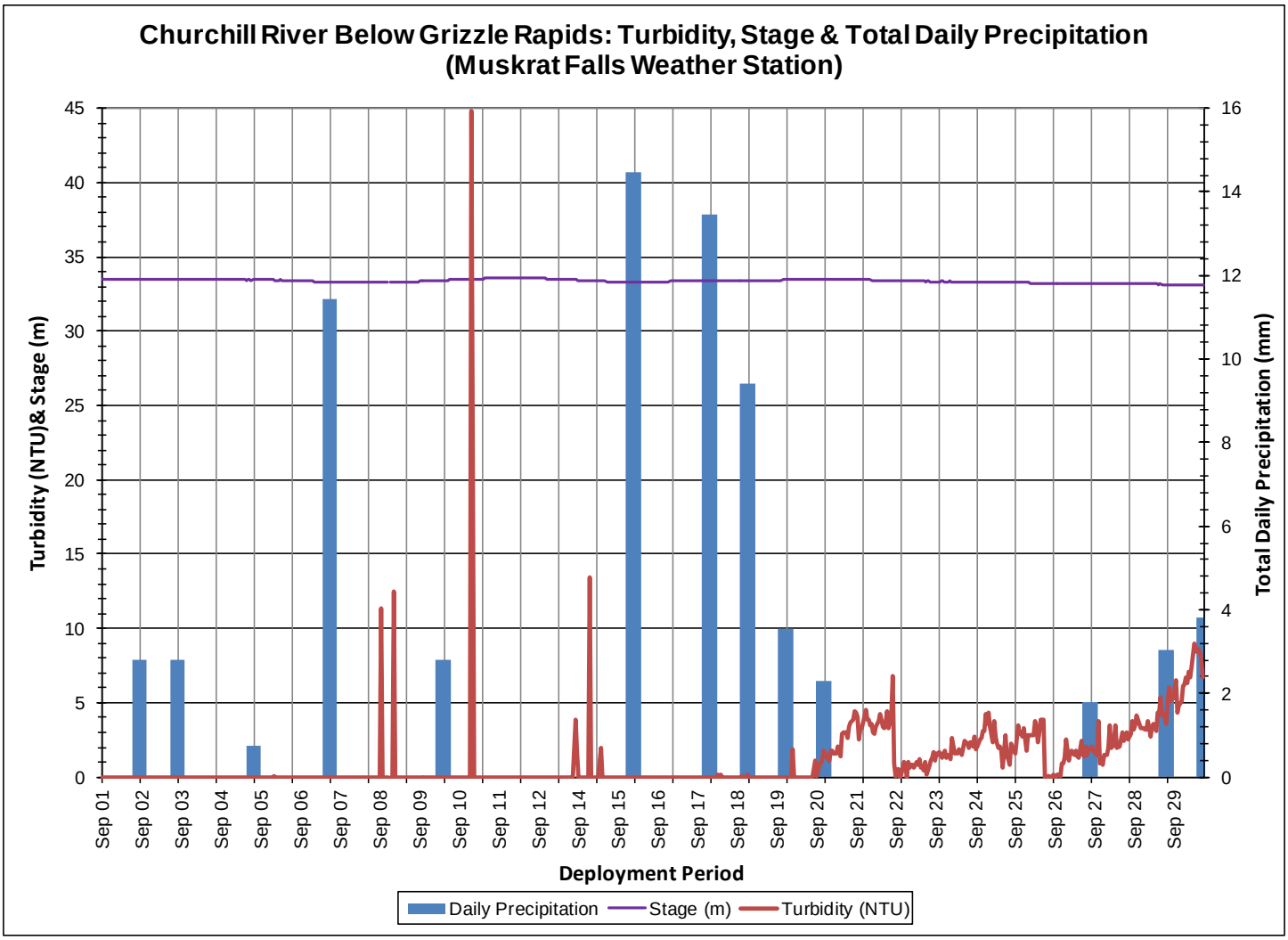

Figure 7: Turbidity, Stage, & Total Daily Precipitation (Muskrat Falls Weather Station) at Churchill River below Grizzle Rapids Station

Churchill River above upper Muskrat Falls

Water Temperature

- Water temperature ranges from 9.19°C to 16.10°C with a median value of 13.62°C (Figure 8).
- Water temperature is gradually decreasing throughout the deployment period. This trend is expected as air temperatures cool in the autumn months.

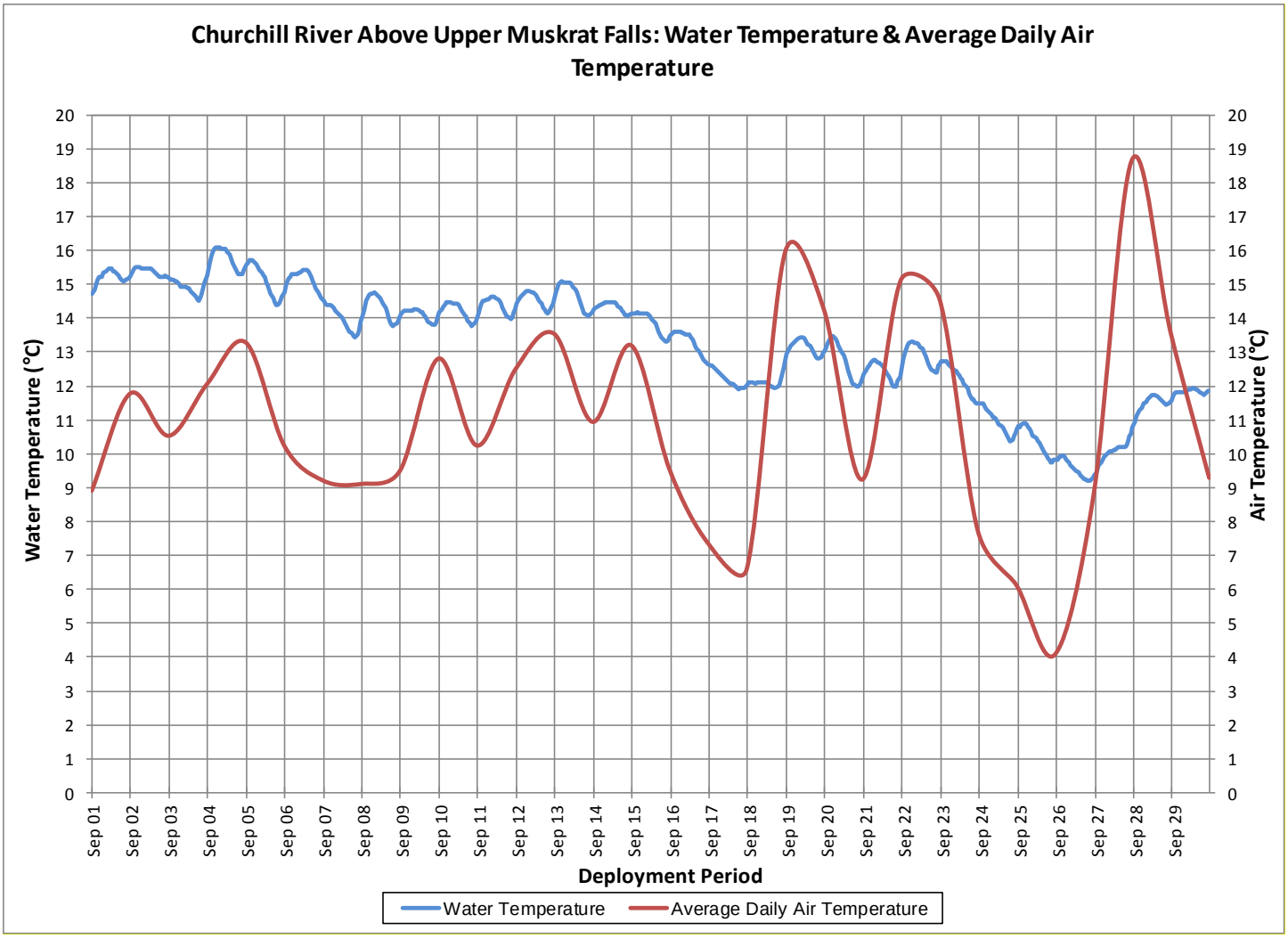

Figure 8: Water Temperature & Average Daily Air Temperature (Muskrat Falls Weather Station) at Churchill River above Upper Muskrat Falls

pH

- pH ranges between 6.95 and 7.08 pH units with a median value of 7.01 (Figure 9).
- pH values are very stable and fall within the CCME Protection of Aquatic Life Guidelines .

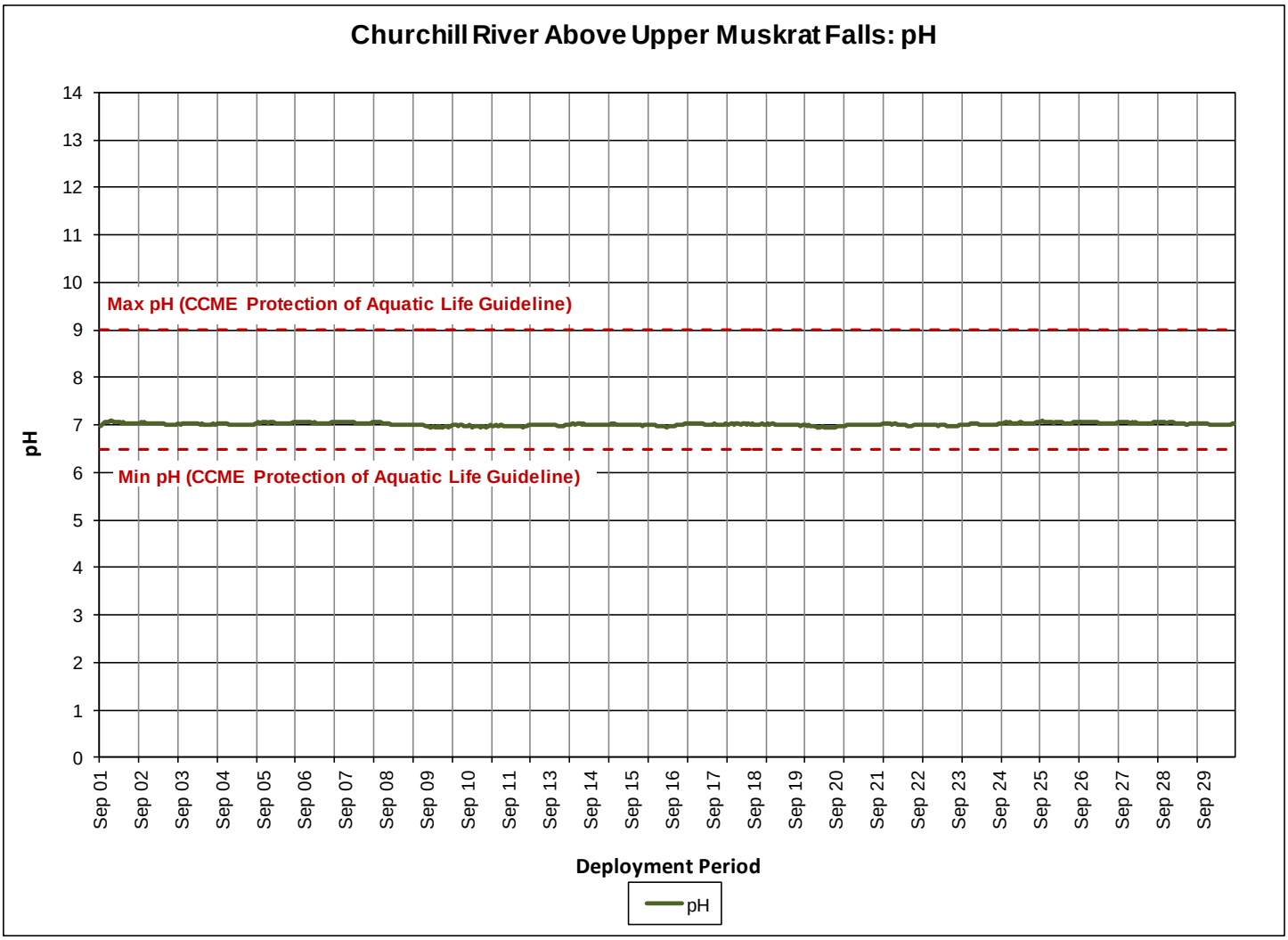

Figure 9: pH at Churchill River above Upper Muskrat Falls

Specific Conductivity, TDS and Stage

- Specific conductivity ranges from 18.5µS/cm to 21.4µS/cm with a median of 19.3µS/cm (Figure 10).
- TDS (total dissolved solids) ranges from 0.0118 g/L to 0.0137 g/L with a median of 0.0123 g/L (Figure 10).
- Specific conductivity and TDS have a direct relationship but are two separate parameters. Specific conductivity is the ability of the water to conduct electricity. Therefore the value of TDS can be estimated by the conductivity of the water (Figure 10).
- The relationship between conductivity and stage are inversed. When stage level rises, the specific conductance levels drops in response as the increased amount of water in the river system dilutes the solids that are present (Figure 10).
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

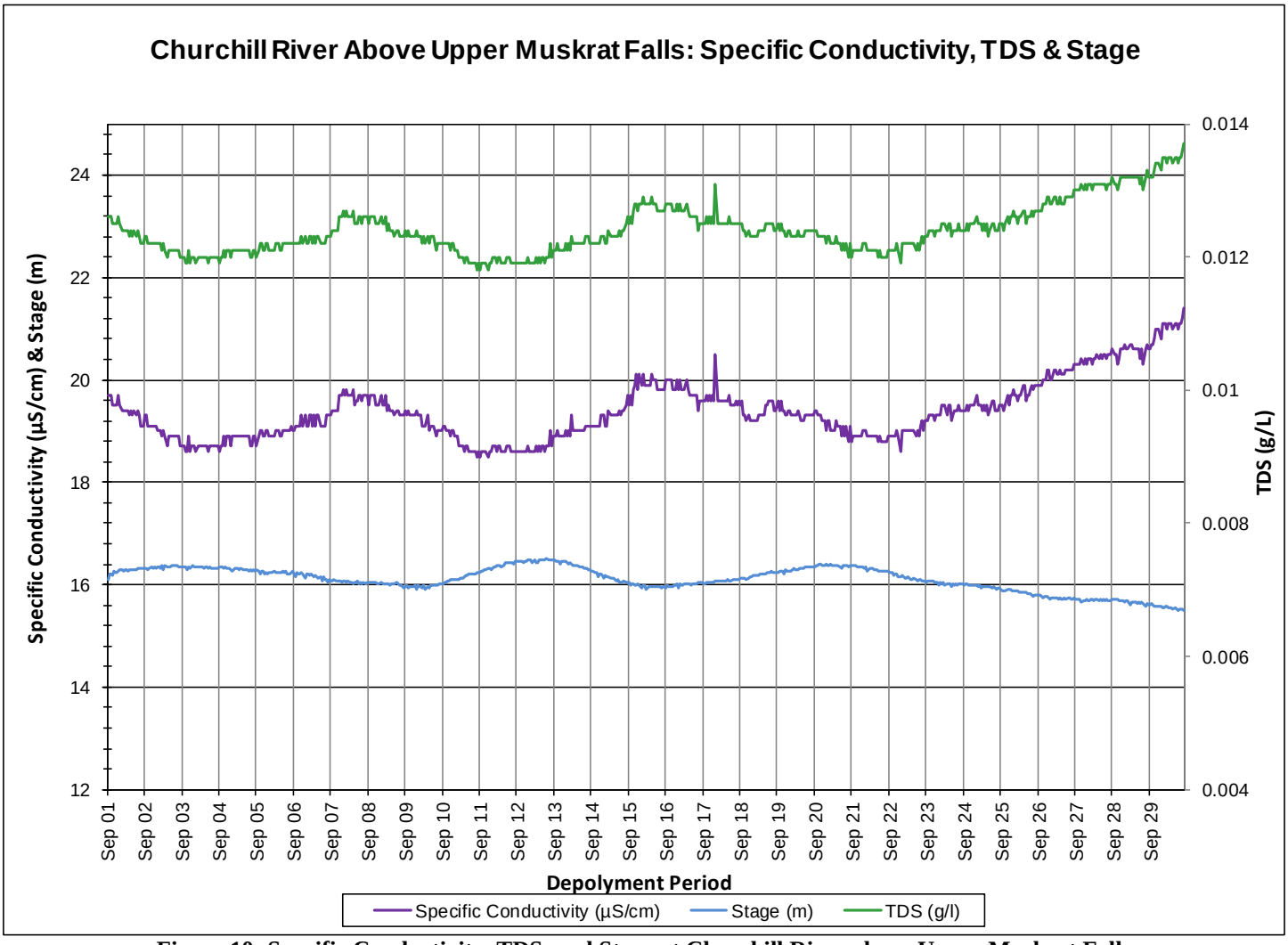

Figure 10: Specific Conductivity, TDS, and Stage at Churchill River above Upper Muskrat Falls

Dissolved Oxygen

- Dissolved oxygen content ranges between 9.56mg/l and 11.06mg/l with a median value of 10.02mg/l. The saturation of dissolved oxygen ranges from 94.8% to 99.6% with a median value of 97.1% (Figure 11).
- There is an evident relationship between water temperature and dissolved oxygen. Over the deployment period the dissolved oxygen levels are increasing as temperatures fall into the autumn months. The dissolved oxygen also follows a diurnal pattern as the water temperature rises and falls under the influence of the ambient air temperature. Generally there is more dissolved oxygen present in a waterbody during cooler temperatures.
- The dissolved oxygen levels remained above the CCME Guidelines for the Protection of Early Life Stages and Other Life Stages for the entire deployment period.

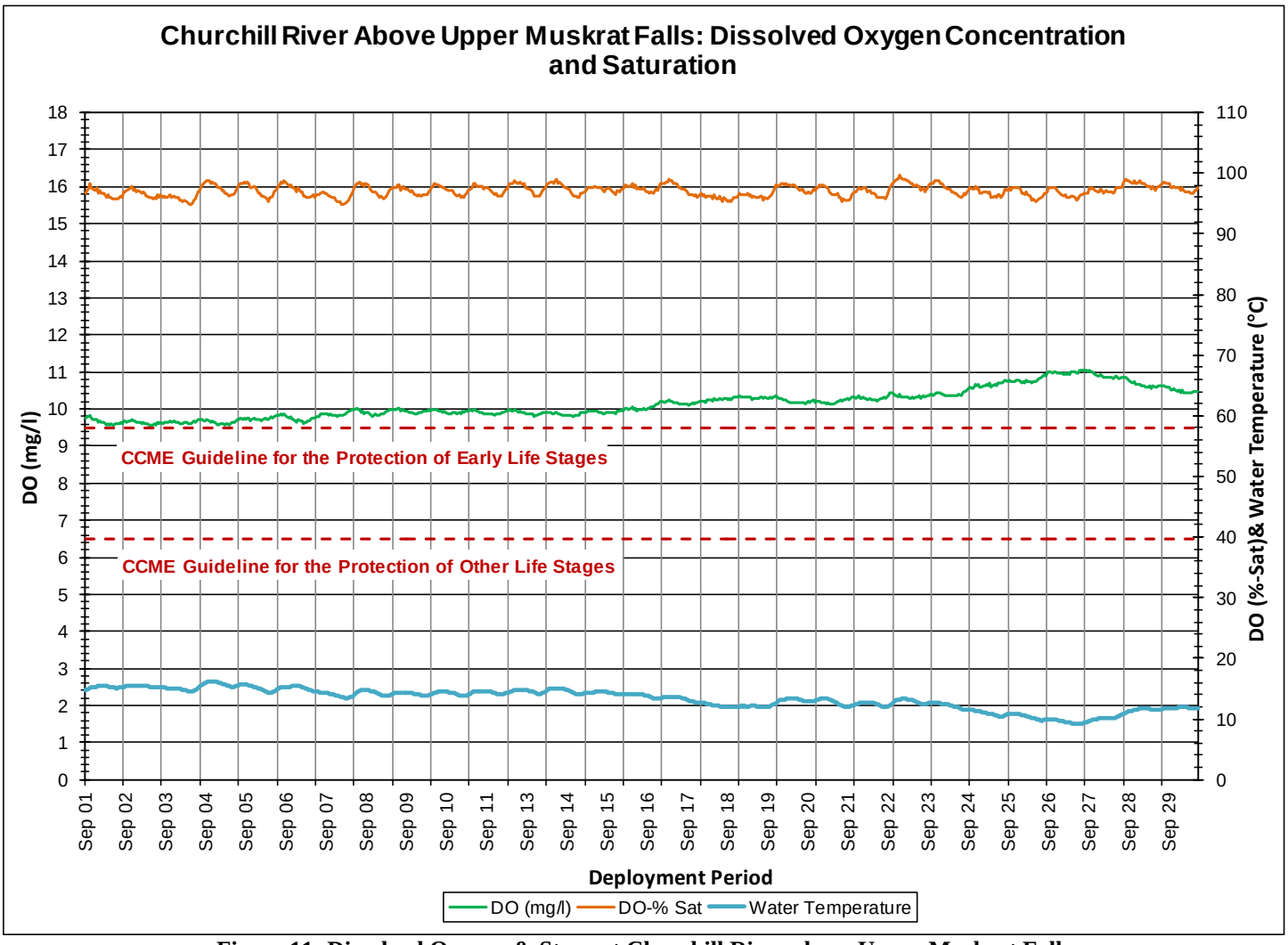

Figure 11: Dissolved Oxygen & Stage at Churchill River above Upper Muskrat Falls

Chlorophyll

- Chlorophyll ranges between 4.1ug/L and 7.3ug/L, with a median value of 5.4ug/L (Figure 12).
- 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.
- Chlorophyll values at the station above Upper Muskrat Falls indicate a Mesotrophic aquatic ecosystem (2.6.-7.3 ug/L). Mesotrophic water ecosystems have moderate productivity with medium levels of nutrients, and moderate macrophyte (submergent, emergent, and floating) coverage.

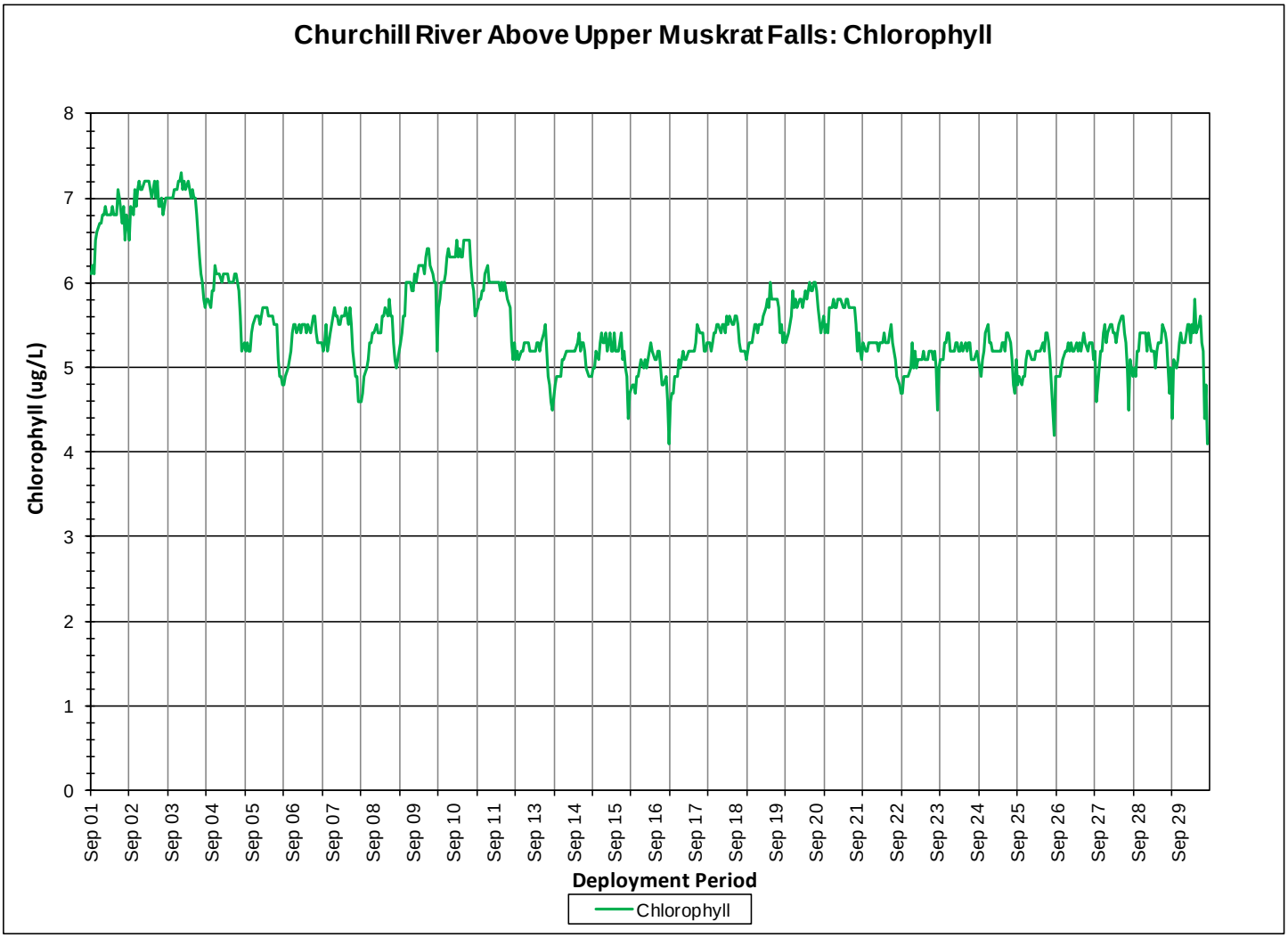

Figure 12: Chlorophyll at Churchill River above Upper Muskrat Falls

Stage, Flow, Turbidity and Precipitation

- Turbidity ranges between 0.3NTU and 261.7NTU with a median value of 2.8NTU (Figure 13).
- The turbidity sensor on this instrument can read values between 0NTU and 3000NTU. However a reading of 3000 NTU is always identified as an error reading and should not be used as a valid reading or included in any statistical analysis.
- The majority of turbidity events in the deployment period correlate with increases in stage and larger precipitation events. Precipitation can increase the presence of suspended material in water.
- Precipitation data was taken from the Muskrat Falls weather station. Precipitation occurs on 13 days during the deployment period and amounts are small in magnitude, with the exception of the largest on September 15th with 14.48mm of rain (Figure 13).
- Stage ranges between 15.49m and 16.50m, and streamflow ranges from 1056.94m^3/s to 1593.30 m^3/s (Figure 14). Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

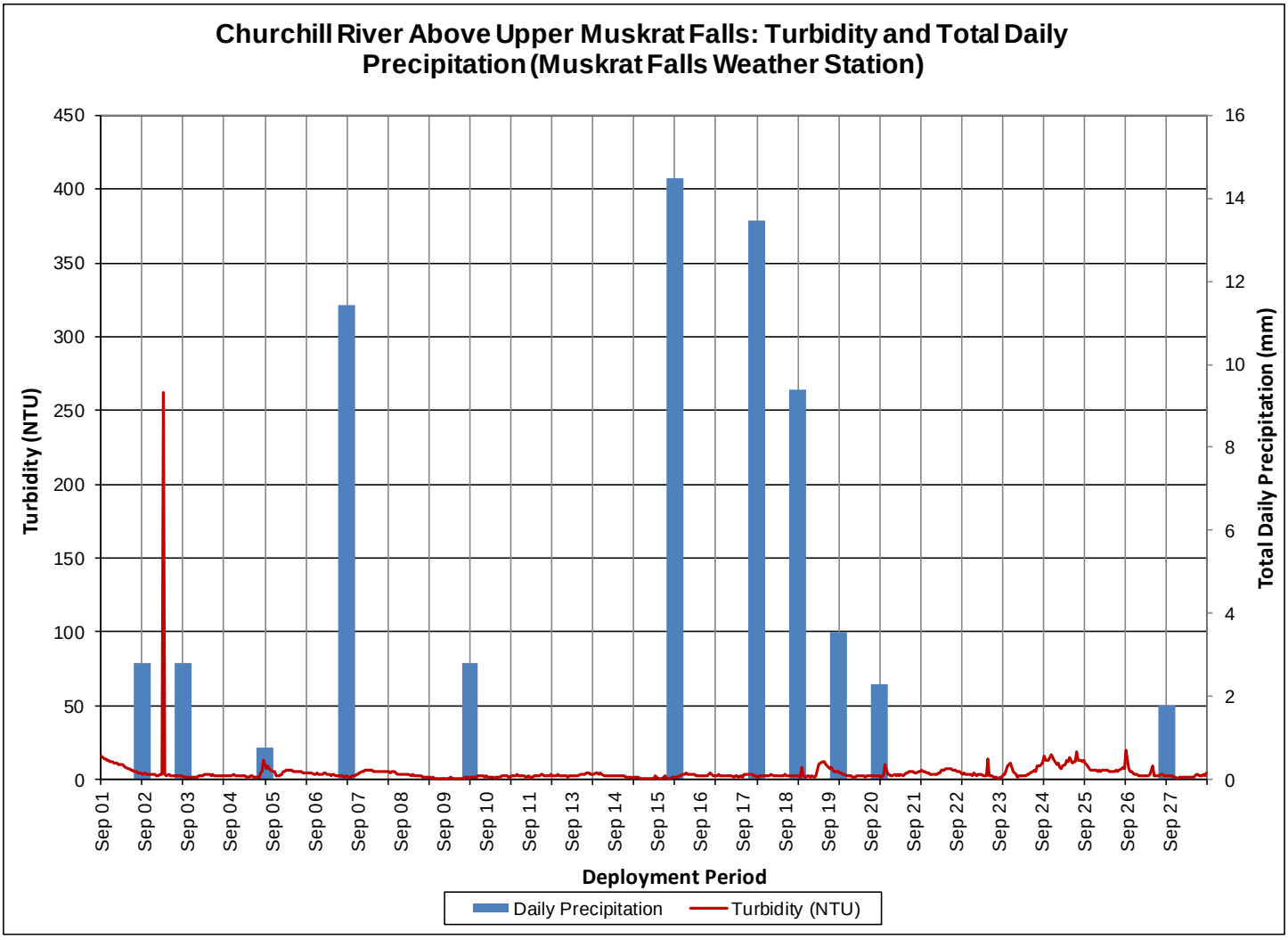

Figure 13: Turbidity and Total Daily Precipitation (Muskrat Falls Weather Station) at Churchill River above Upper Muskrat Falls

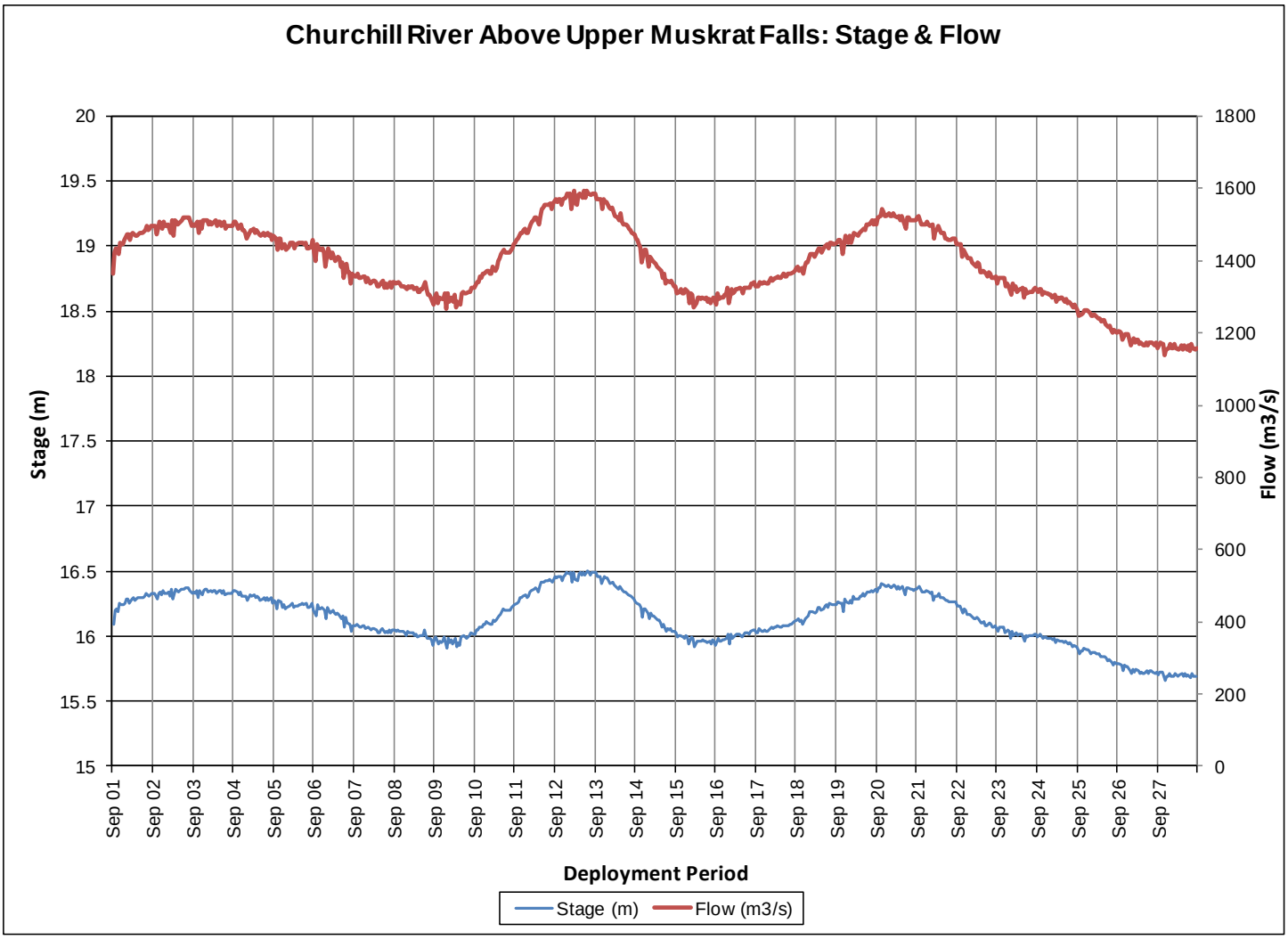

Figure 14: Stage and Flow at Churchill River above Upper Muskrat Falls

Churchill River below Muskrat Falls

- The sonde located at the below Muskrat Falls station has been repeatedly buried in sand during 2014. The decision to not redeploy the sonde until sand conditions in the area improve was made in August, 2014.
- The sonde was redeployed at the station below Muskrat Falls on September 2, 2015. Shoreline and riverbed conditions improved at the location (Figure 15, 16).

Figure 15: Sandy shoreline at Churchill River below Muskrat Falls – May 2015

Figure 16: Rocky shoreline at Churchill River below Muskrat Falls – September 2015

Water Temperature

- Water temperature ranges from 10.20°C to 16.40°C with a median value of 14.00°C (Figure 17).
- Water temperature is steadily decreasing throughout this deployment period. This trend is expected as ambient air temperatures cool into the autumn months. Water temperature fluctuates diurnally.

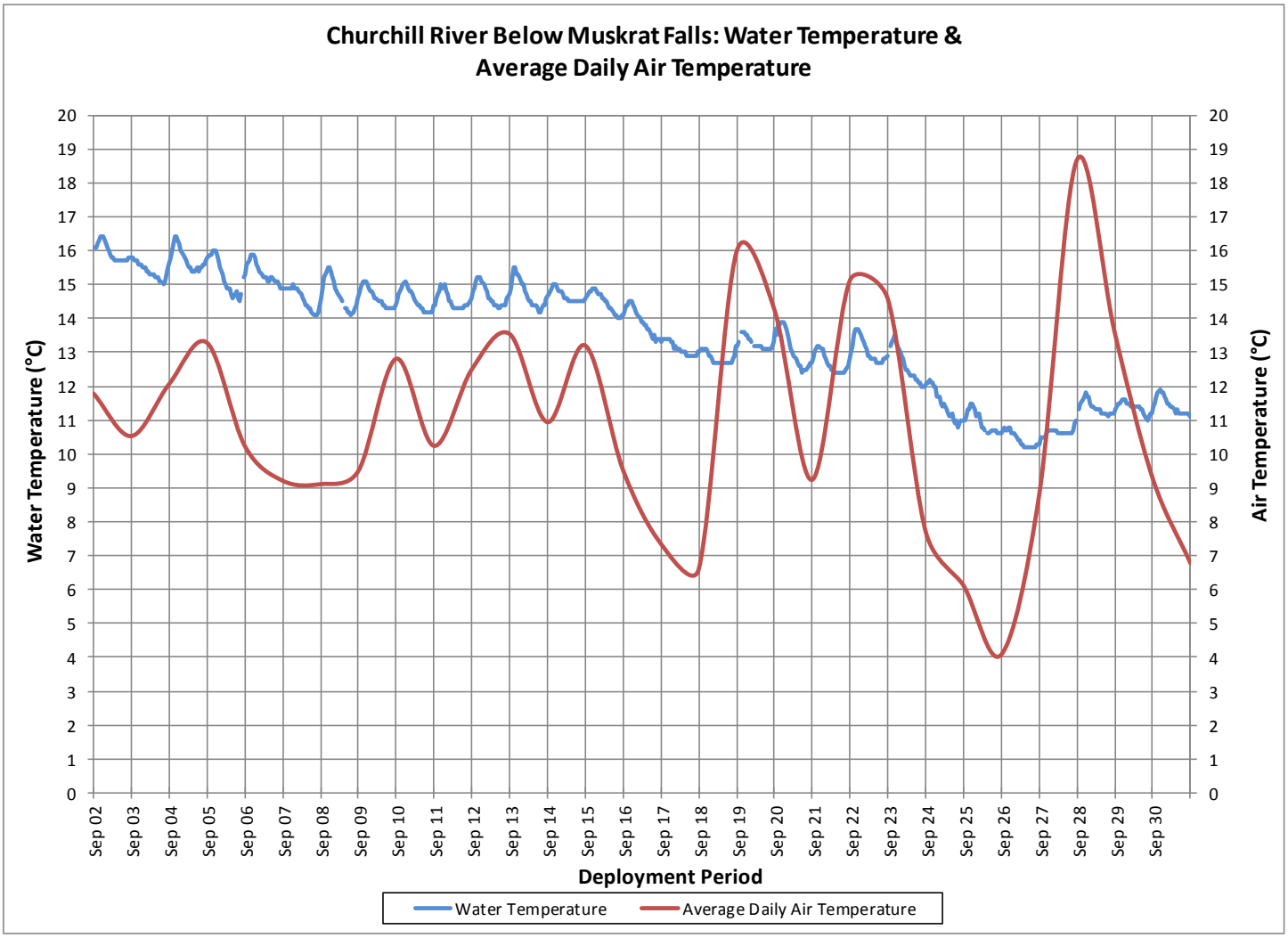

Figure 17: Water Temperature & Daily Average Air Temperature (Muskrat Falls Weather Station) at Churchill River below Muskrat Falls Station

pH

- pH ranges between 6.88 and 7.29 pH units with a median value of 7.15 (Figure 18).
- All pH values recorded during this deployment period remain within the CCME protection of Aquatic Life Guidelines.

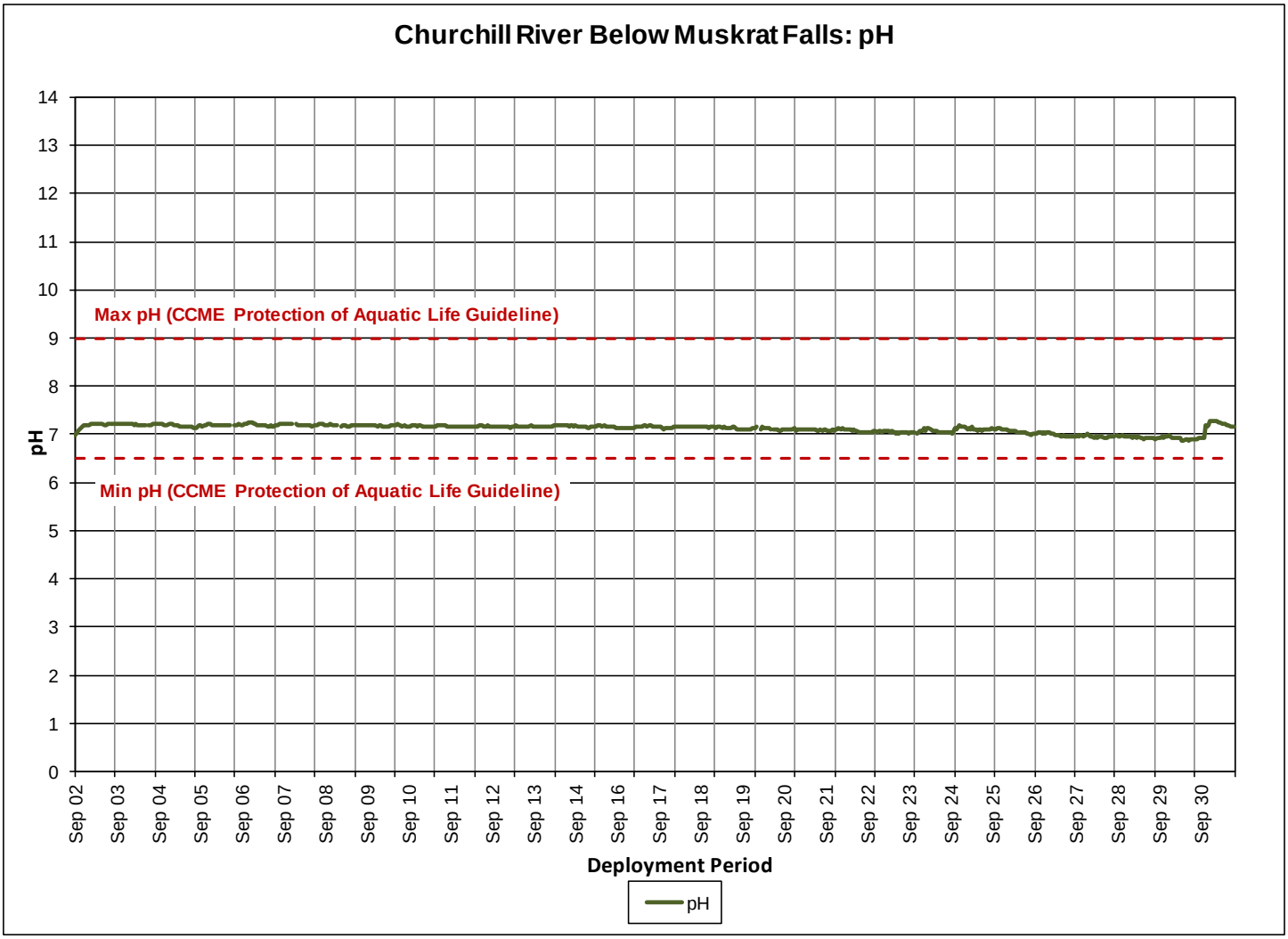

Figure 18: pH at Churchill River below Muskrat Falls Station

Specific Conductivity and TDS

- Specific conductivity ranges from 17.8µS/cm to 20.1µS/cm with a median of 19.1µS/cm (Figure 19).
- TDS (total dissolved solids) ranges from 0.0114 g/L to 0.0128 g/L with a median of 0.0122 g/L (Figure 19).
- Specific conductivity and TDS have a direct relationship but are two separate parameters. Specific conductivity is the ability of the water to conduct electricity. Therefore the value of TDS can be estimated by the conductivity of the water (Figure 19).
- The relationship between conductivity and stage are inversed. When stage level rises, the specific conductance levels drops in response as the increased amount of water in the river system dilutes the solids that are present (Figure 19).
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

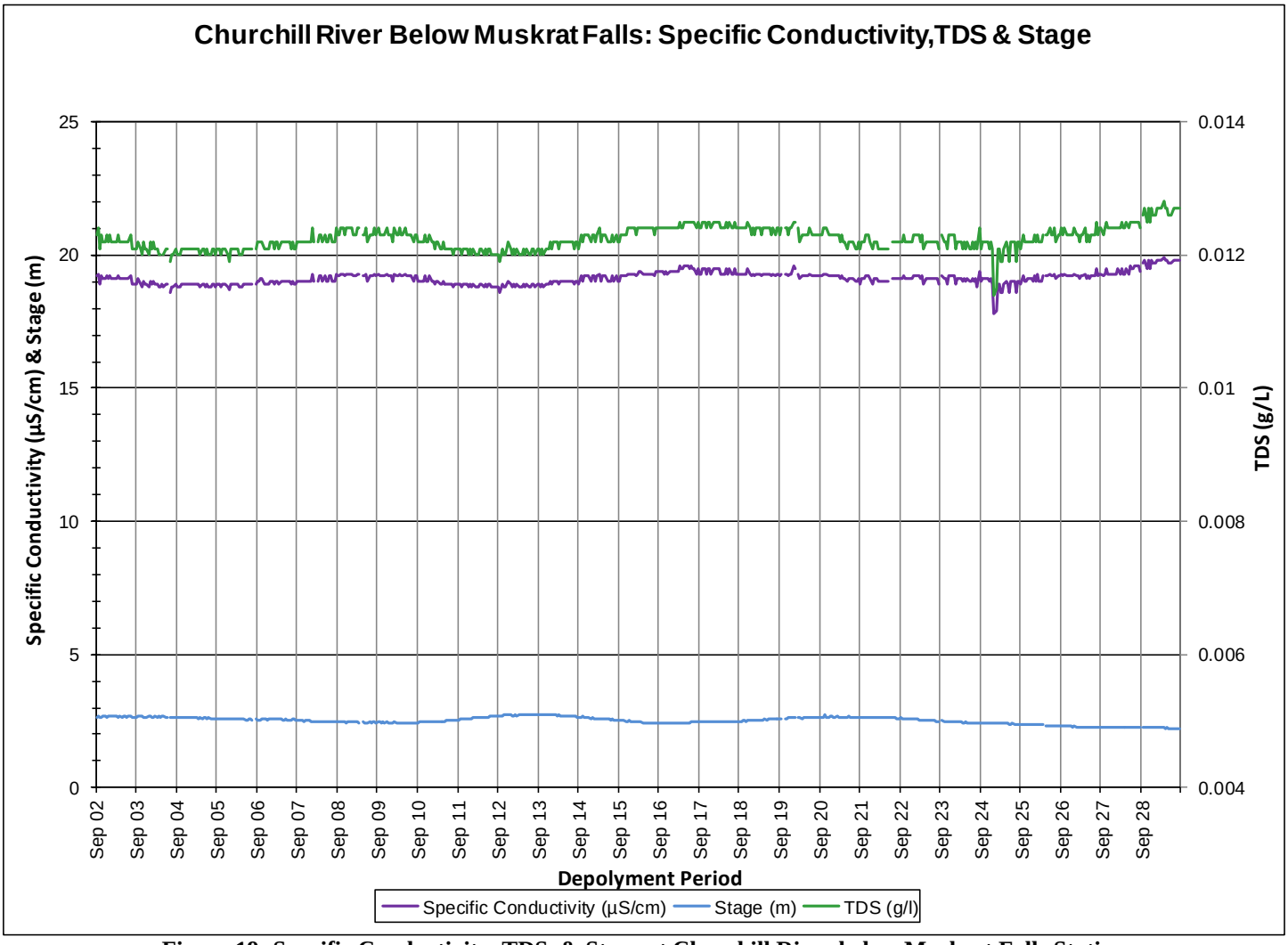

Figure 19: Specific Conductivity, TDS, & Stage at Churchill River below Muskrat Falls Station

Dissolved Oxygen

- Dissolved oxygen content ranges between 10.21mg/l and 11.95mg/l with a median value of 11.19g/l. The saturation of dissolved oxygen ranges from 100.9% to 113.2% with a median value of 108.2% (Figure 20).
- There is an evident relationship between water temperature and dissolved oxygen. Over the deployment period the dissolved oxygen levels are increasing as temperatures fall into the autumn months. The dissolved oxygen also follows a diurnal pattern as the water temperature rises and falls under the influence of the ambient air temperature. Generally there is more dissolved oxygen present in a waterbody during cooler temperatures.
- Dissolved oxygen is typically higher at this station compared to the other stations further upstream due to the addition of oxygen to the water at Muskrat Falls (Figure 20).
- The dissolved oxygen levels remained above the CCME Guidelines for the Protection of Early Life Stages and Other Life Stages for the entire deployment period.

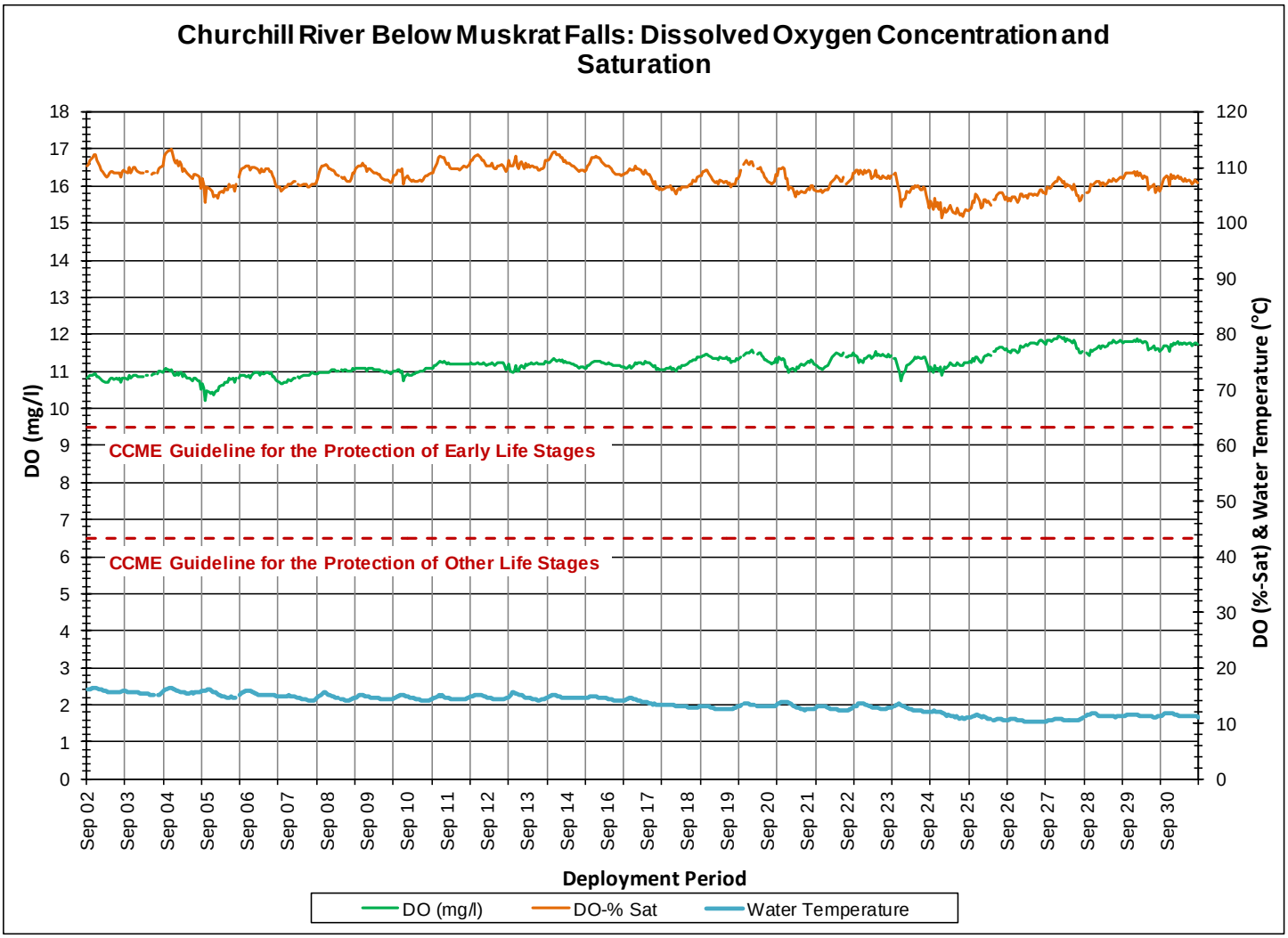

Figure 20: Dissolved Oxygen & Stage at Churchill River below Muskrat Falls Station

Stage, Turbidity & Precipitation

- Turbidity ranges from 2.0NTU to 328.7NTU during the deployment period, with a median value of 4.9NTU (Figure 21).
- The some turbidity events in the deployment period correlate with increases in stage and larger precipitation events. Precipitation can increase the presence of suspended material in water. However, there were many event occurring during the deployment period which can be attributed to moving sand sediment in the area. This location is known to have problems with sediment burying the instrument and disrupting the sensor (Figure 21).
- Precipitation data was taken from the Muskrat Falls weather station. Precipitation occurs on 13 days during the deployment period and amounts are small in magnitude, with the largest on September 15th with 14.48mm of rain (Figure 21).
- Stage ranges between 2.12m and 2.75m, with a median value of 2.50m (Figure 22).
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

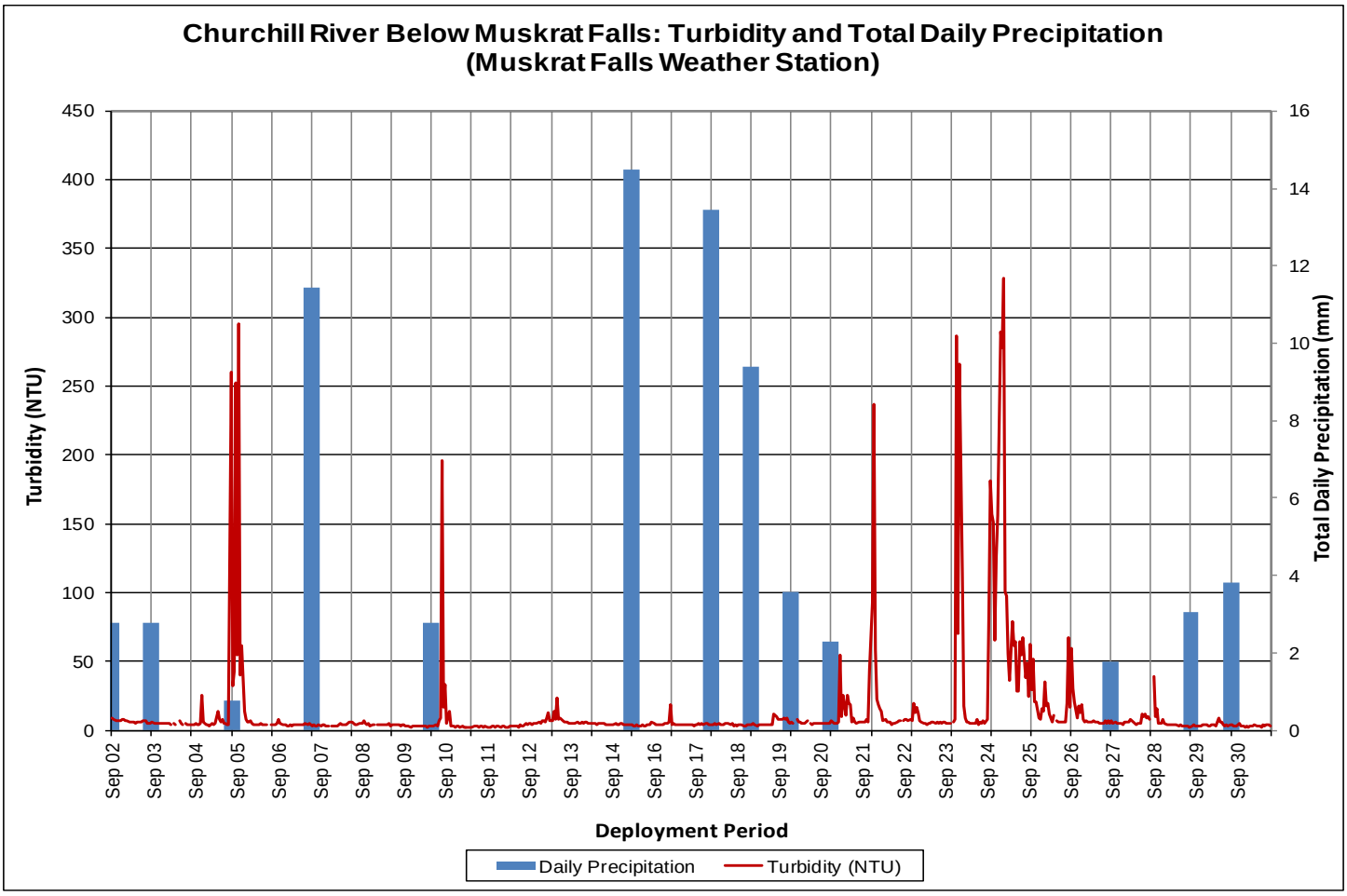

Figure 21: Turbidity & Total Daily Precipitation (Muskrat Falls Weather Station) at Churchill River below Muskrat Falls Station

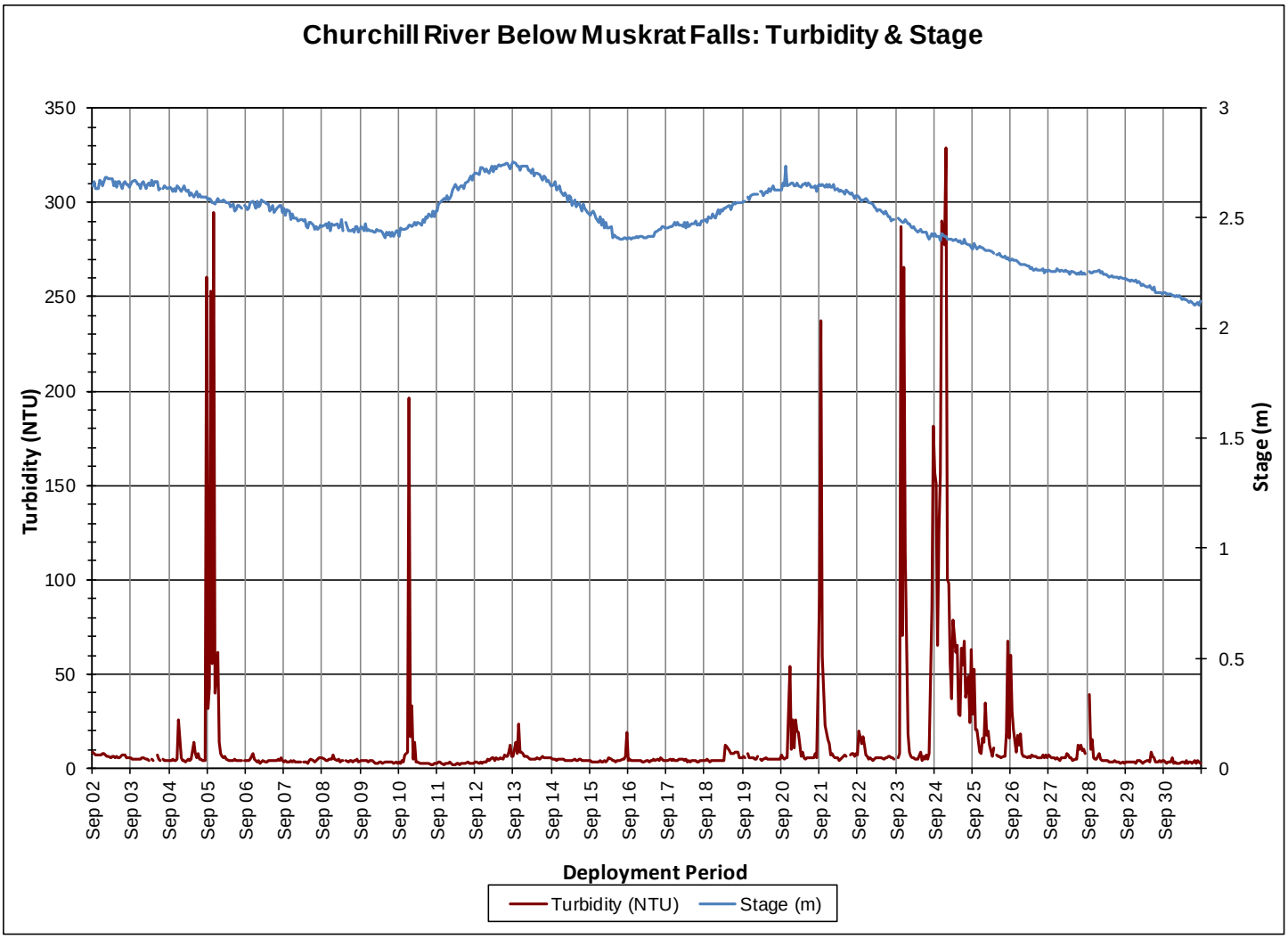

Figure 22: Turbidity & Stage at Churchill River below Muskrat Falls Station

Churchill River at English Point

Water Temperature

- Water temperature ranges from 9.40°C to 16.40°C with a median value of 13.70°C (Figure 23).
- Water temperature is steadily decreasing throughout this deployment period. This trend is expected as ambient air temperatures cool into the autumn months. Water temperature fluctuates diurnally.

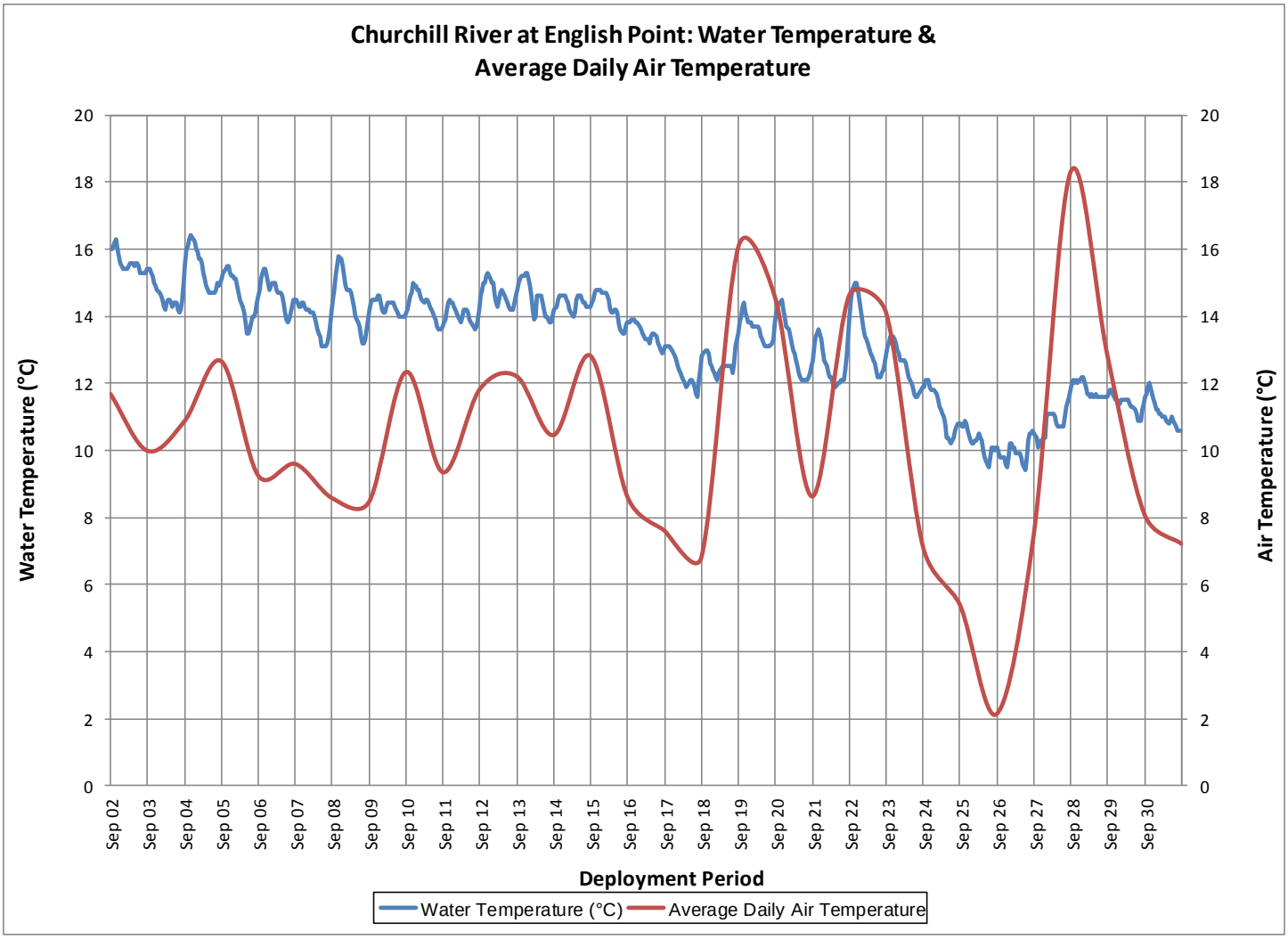

Figure 23: Water Temperature & Daily Average Air Temperature (Mud Lake Weather Station) at Churchill River at English Point

pH

- pH ranges between 6.86 and 7.21 pH units with a median value of 7.01 (Figure 24).
- All pH values recorded during this deployment period remain within the CCME protection of Aquatic Life Guidelines.

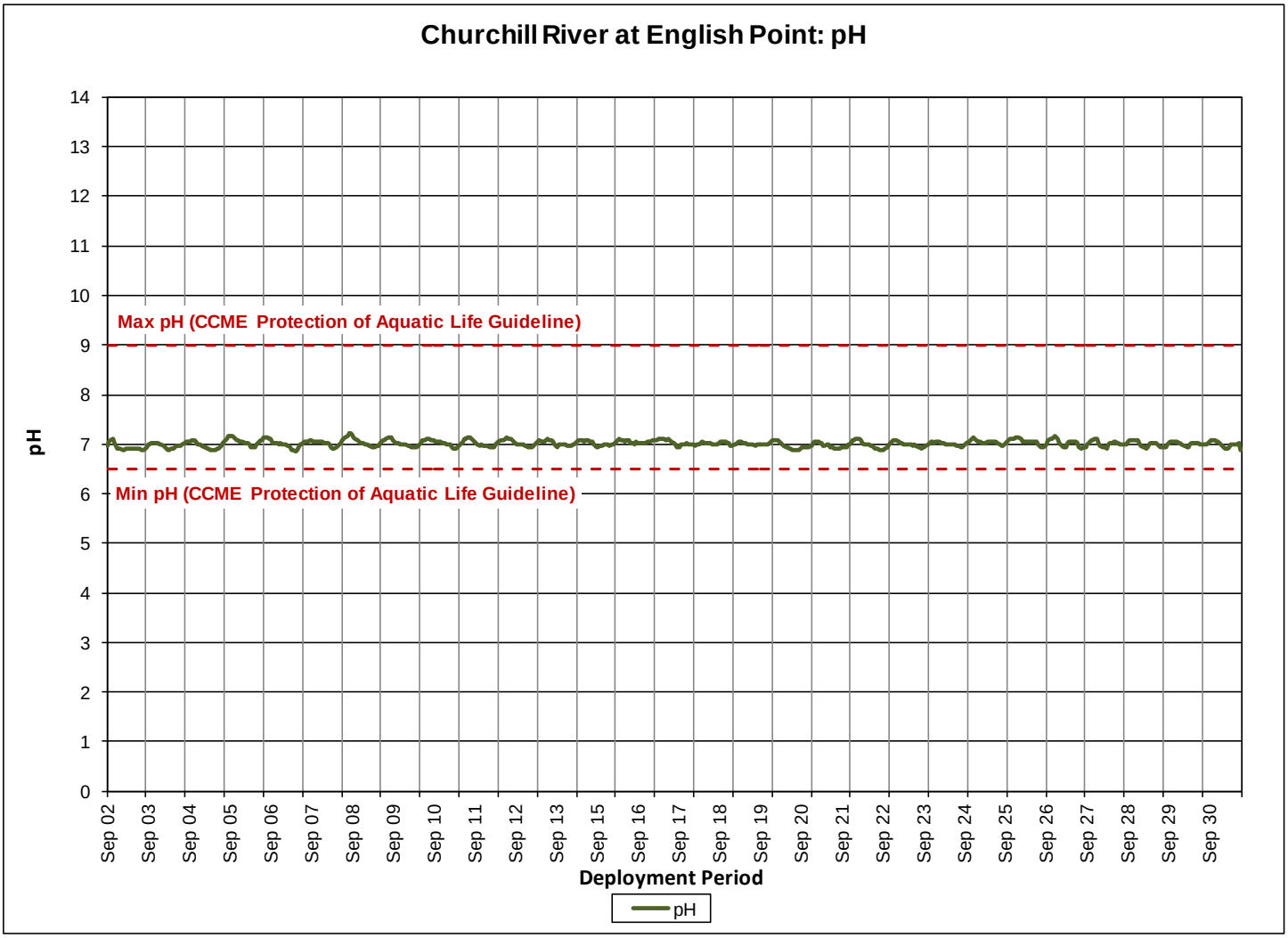

Figure 24: pH at Churchill River at English Point Station

Specific Conductivity and TDS

- Specific conductance ranges between 19.9µS/cm and 53.2µs/cm during the deployment period, with a median of 30.9µS/cm (Figure 25).
- TDS ranges between 0.0128 g/mL to 0.0341g/mL during the deployment period, with a median of 0.0198 g/mL (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, the specific conductivity increases as the 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 Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

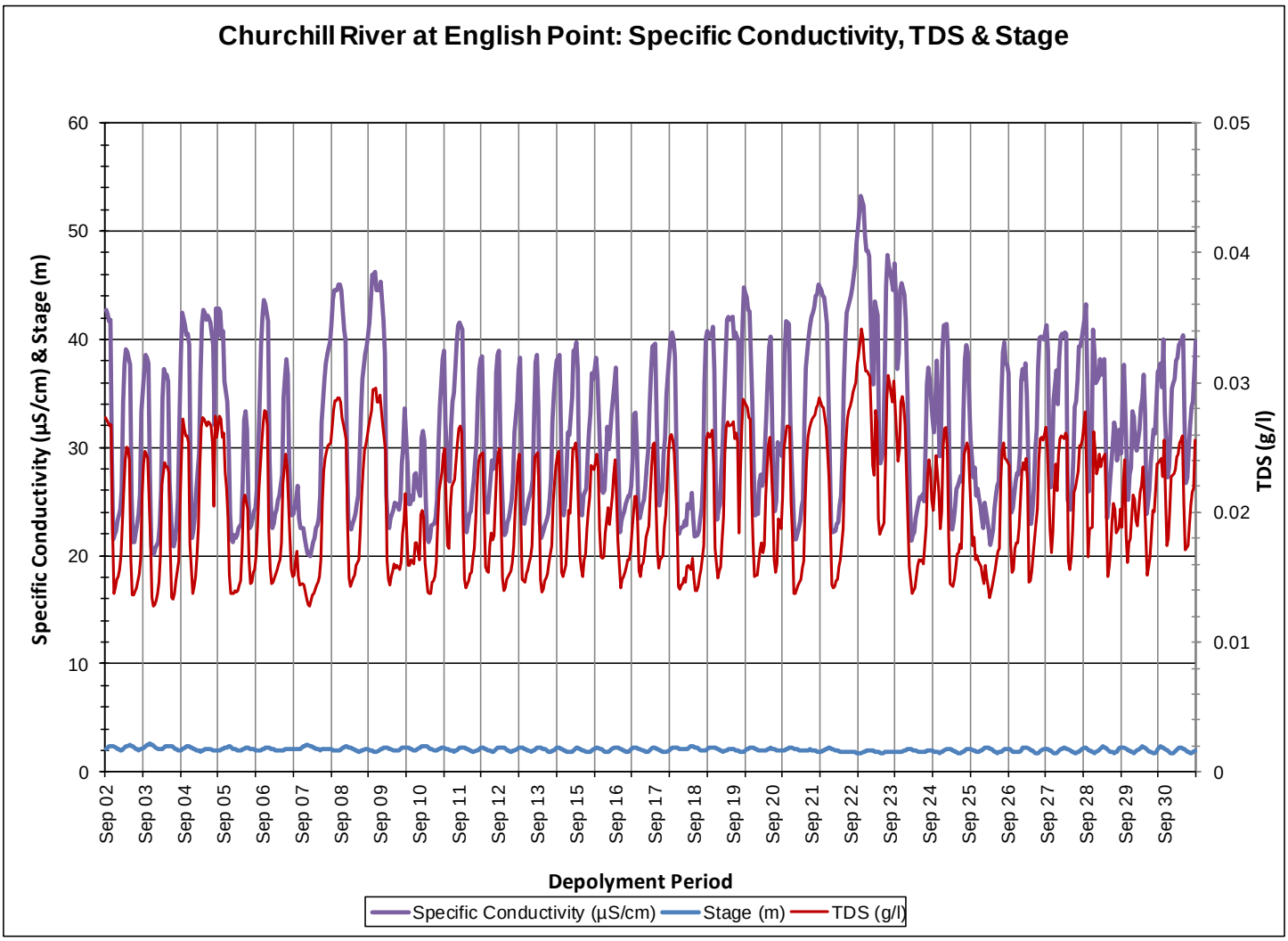

Figure 25: Specific Conductivity, TDS, & Stage at Churchill River at English Point Station

Dissolved Oxygen

- Dissolved oxygen content ranges between 9.16mg/l and 10.33mg/l during the deployment period. The saturation of dissolved oxygen ranges from 89.6% to 108.2% (Figure 26).
- There is an evident relationship between water temperature and dissolved oxygen. Over the deployment period the dissolved oxygen levels are slowly rising as temperatures fall into the autumn months. The dissolved oxygen also follows a diurnal pattern as the water temperature rises and falls under the influence of the ambient air temperature. Generally there is more dissolved oxygen present in a waterbody during cooler temperatures.
- The dissolved oxygen levels remained above the CCME Guidelines for the Protection of Other Life Stages for the entire deployment period. However, the dissolved oxygen levels dip slightly below the CCME Guideline for the Protection of Early Life Stages for a short time at the beginning of the deployment period.

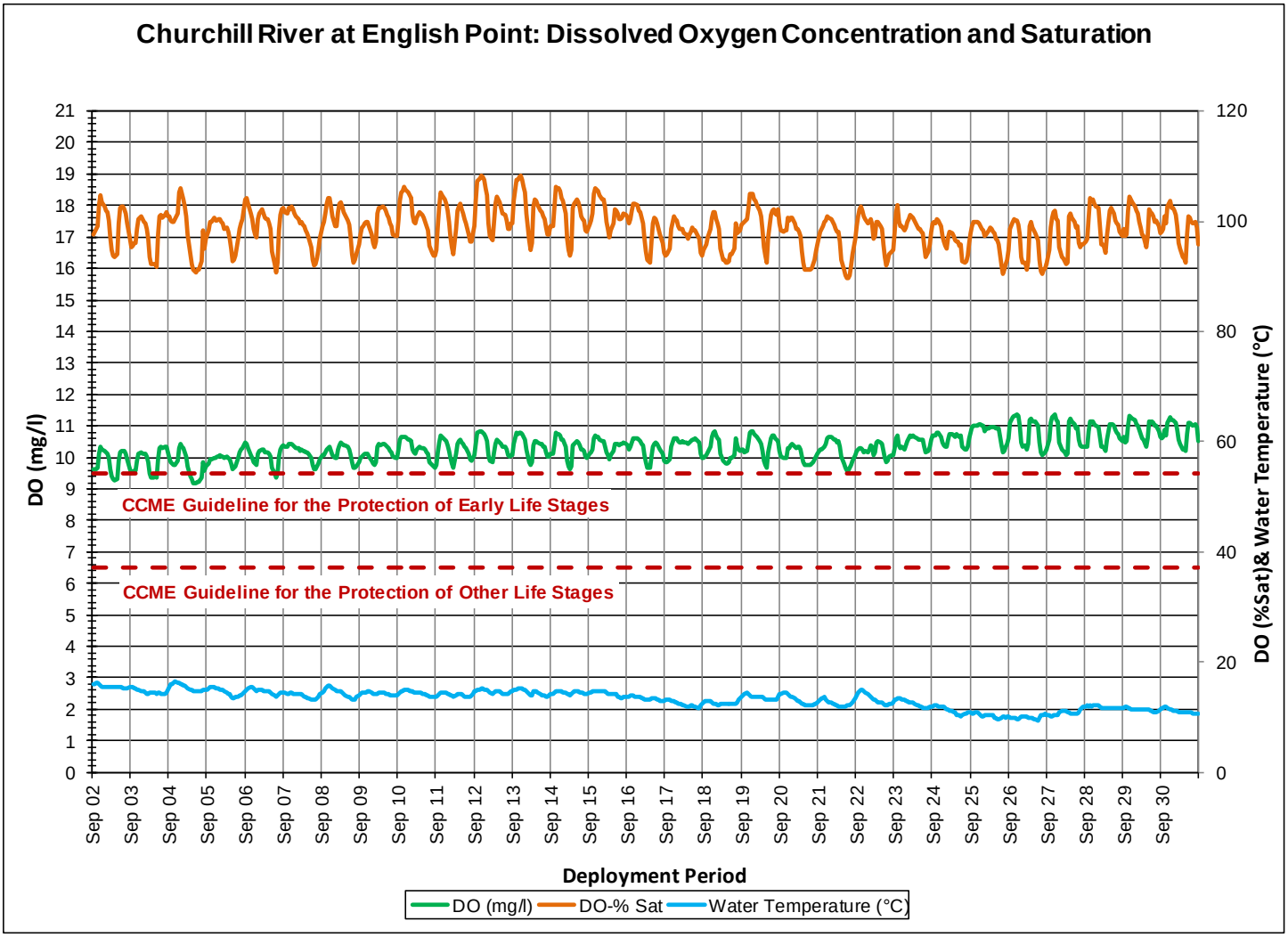

Figure 26: Dissolved Oxygen & Stage at Churchill River at English Point Station

Stage, Turbidity, & Precipitation

- Turbidity ranges from 3.5NTU to 541.0NTU during the deployment period, with a median value of 13.0NTU (Figure 27). The majority of turbidity events in the deployment period correlate with increases in stage and larger precipitation events. Precipitation can increase the presence of suspended material in water (Figure 27). This location is known to have background turbidity, some sensor fouling, and sediment that can bury an instrument. This is likely what contributed to large turbidity events between September 23rd and 24th.
- Precipitation occurs on 16 days during the deployment period and amounts are small in magnitude, with the largest on September 17th with 10.92mm of rain (Figure 27).
- Stage ranges between 1.73m and 2.60m, with a median value of 2.06m. Stage fluctuates considerably at this location due to the tidal influences of the Atlantic Ocean. As the tide comes in, the stage level increases causing tide related turbidity events, and vice versa as the tide goes out. This pattern is generally consistent throughout the deployment period (Figure 28).
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

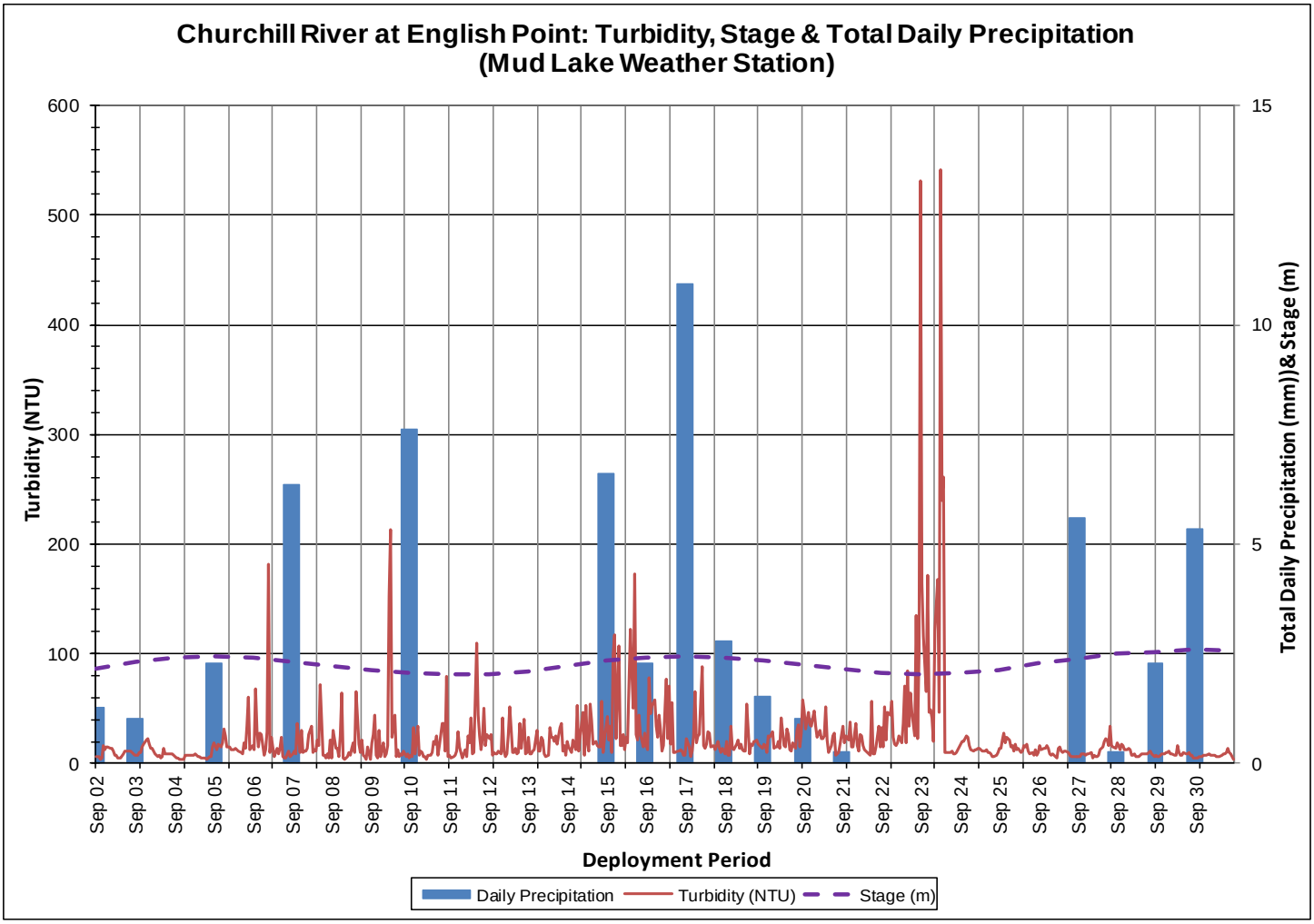

Figure 27: Turbidity, Stage & Total Precipitation (Mud Lake Weather Station) at Churchill River at English Point Station

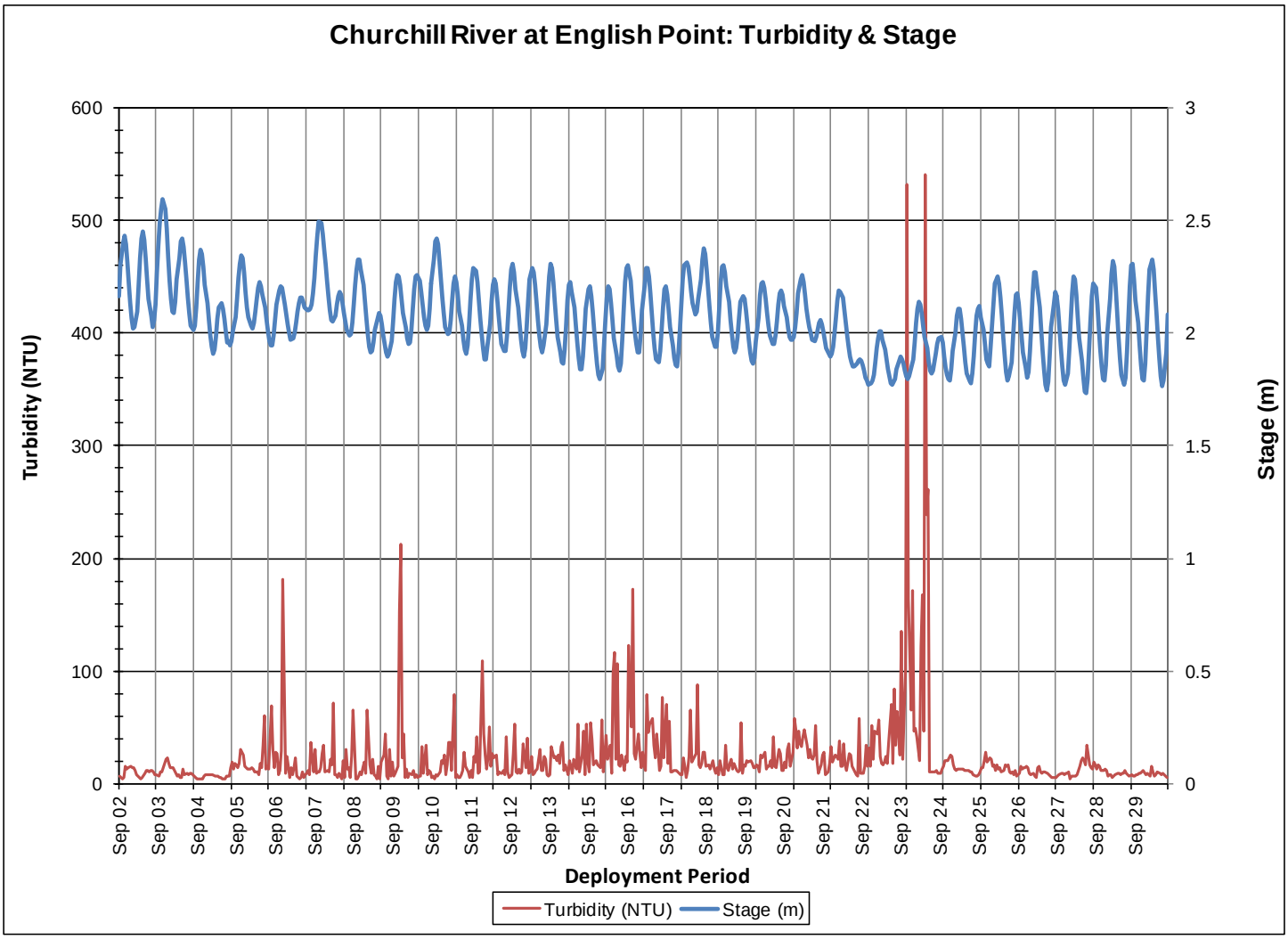

Figure 28: Turbidity & Stage at Churchill River at English Point Station

Conclusions

- Stage levels are generally stable at all stations throughout the deployment in the summer months. Water level changes at each of the stations ranged between 0.46m and 1.01m.
- Water temperature was decreasing at all stations throughout the deployment period due to the decreasing ambient air temperatures in the region during the autumn months. Water temperature typically ranged between 9.19°C and 17.10°C.
- pH is generally neutral and stable at stations along the Lower Churchill River ranging between 6.86 and 7.35 pH units. The pH values at all stations were within the recommended CCME Guidelines for the Protection of Aquatic Life.
- Specific conductivity was relatively stable at the stations below Grizzle Rapids, above upper Muskrat Falls, and below Muskrat Falls regardless of the fluctuating stage levels. All stations showed little variation in values except at English Point, which is influenced by the tides in Lake Melville. Specific conductivity values are higher at the English Point station ranging from 19.9µS/cm to 53.2µS/cm.
- Dissolved oxygen was increasing slightly throughout the deployment period at all stations. There is an evident relationship between water temperature and dissolved oxygen. Generally there is more dissolved oxygen present in a waterbody during cooler temperatures Values ranged between 9.43mg/l and 11.95mg/l.
- Turbidity events occurred at all stations and were mainly related to large rainfall events. At the below Grizzle Rapids station there is a median turbidity value of 0.0NTU which indicates a low background turbidity at this location. Turbidity at all stations ranged from 0.0 to 541.0NTU. Above and below Muskrat Falls and English Point have known background turbidity events at these stations due to the substrate at the locations, mixing due to Muskrat Falls, tidal wave action, and precipitation events.

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.
  - Online: http://st-ts.ccme.ca/en/index.html?chems=154,162&chapters=1
- Swanson, H.A., and Baldwin, H.L., 1965. A Primer on Water Quality, U.S. Geological Survey.
  - Online: http://ga.water.usgs.gov/edu/characteristics.html
- YSI a Xylem Brand. The Basics of Chlorophyll Measurement. Accessed December 9, 2015.
  - Online:https://www.ysi.com/File%20Library/Documents/Technical%20Notes/T606-The-Basics-of-Chlorophyll-Measurement.pdf
- An Introduction to Algae Measurements Using In Vivo Fluoresces. Accessed December 9, 2015.\
  - Online: http://www.ott.com/download/fluorescence-white-paper/
- Environment Canada. Water Quality. Fresh Water Quality Monitoring Date modified: 2015-11-26
  - Online:https://www.ec.gc.ca/eaudouce-freshwater/default.asp?lang=En&n=8C50C138-1&printfullpage=true#wsA92C85CB
- Volunteers Contributing to Our Understanding of Water Quality. Trophic State Equations
  - Online: http://www.secchidipin.org/index.php/monitoring-methods/trophic-state-equations/

APPENDIX A-Station Comparisons

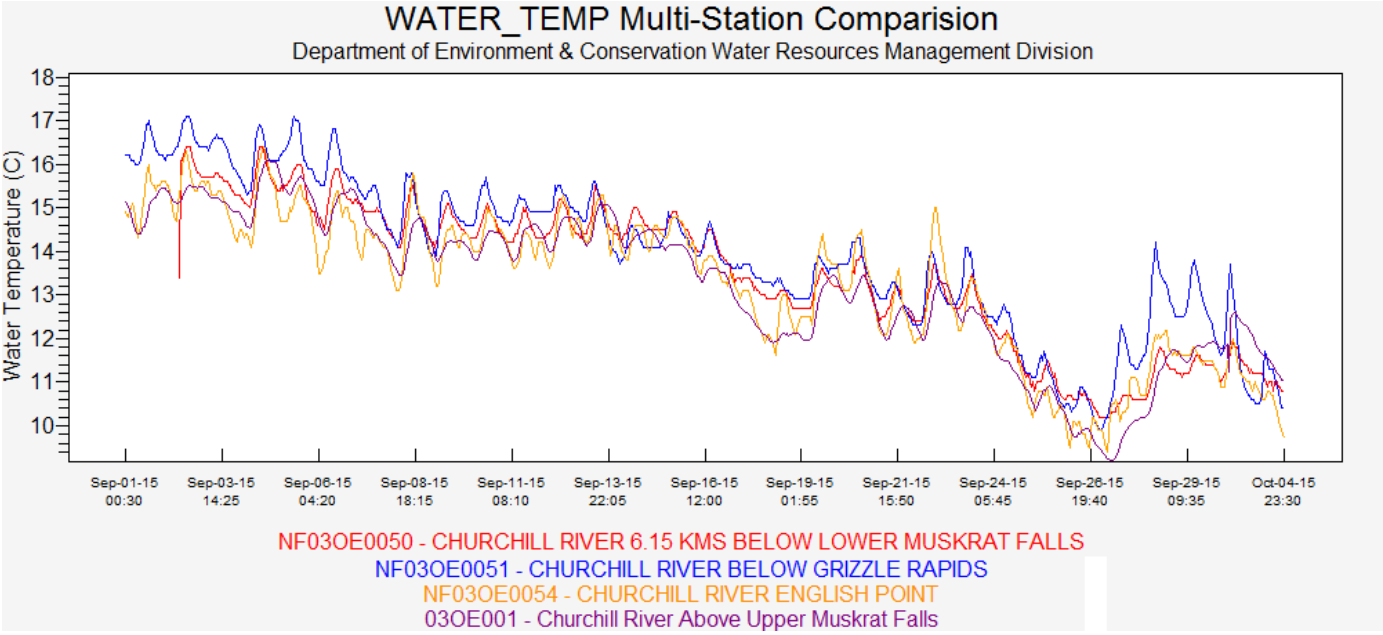

Figure A1: Comparison of Water Temperature at the Real-Time Stations on Churchill River

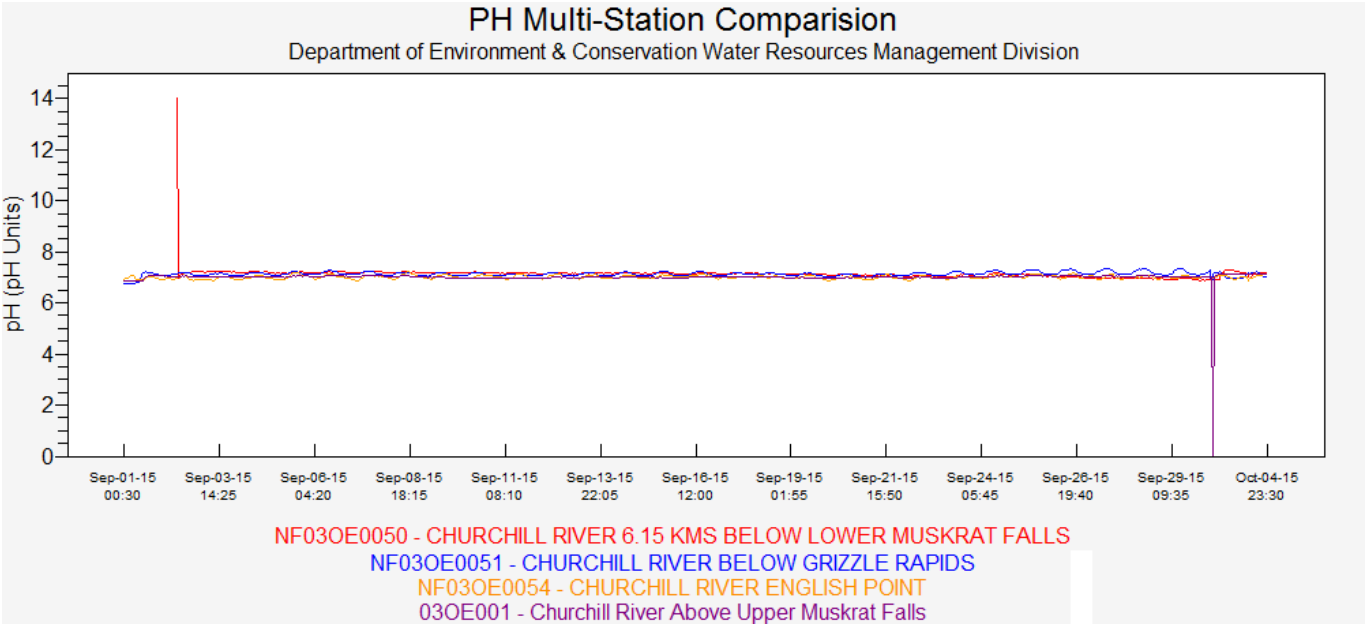

Figure A2: Comparison of pH at the Real-Time Stations on Churchill River

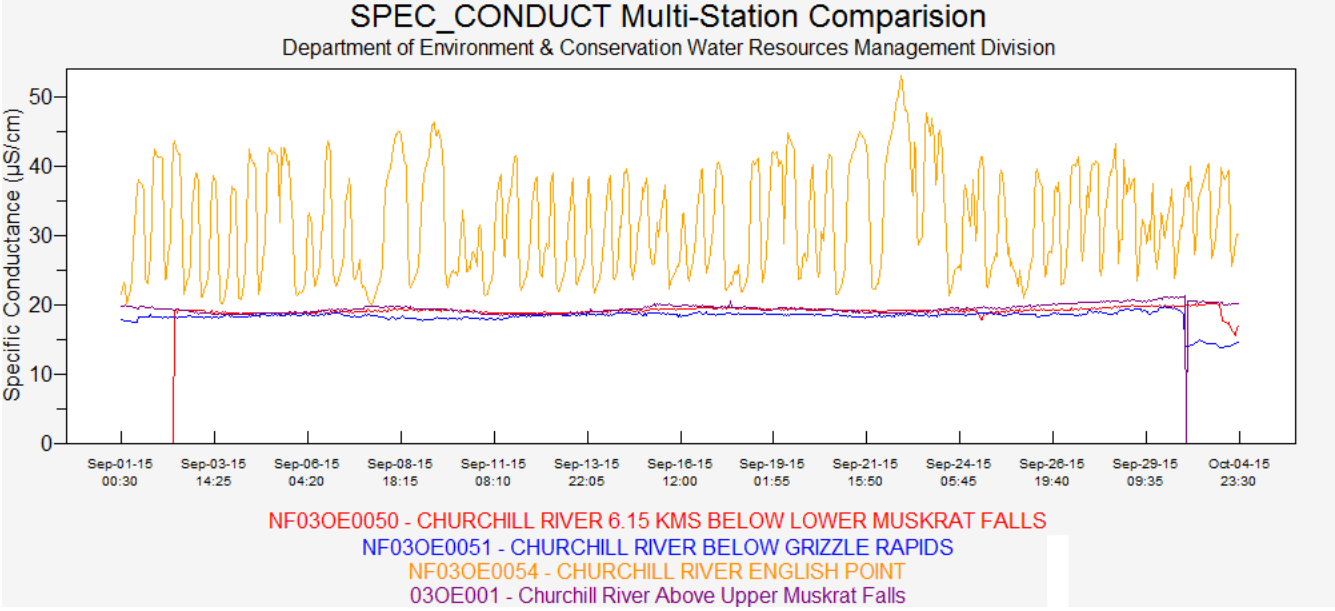

Figure A3: Comparison of Specific Conductivity at the Real-Time Stations on Churchill River

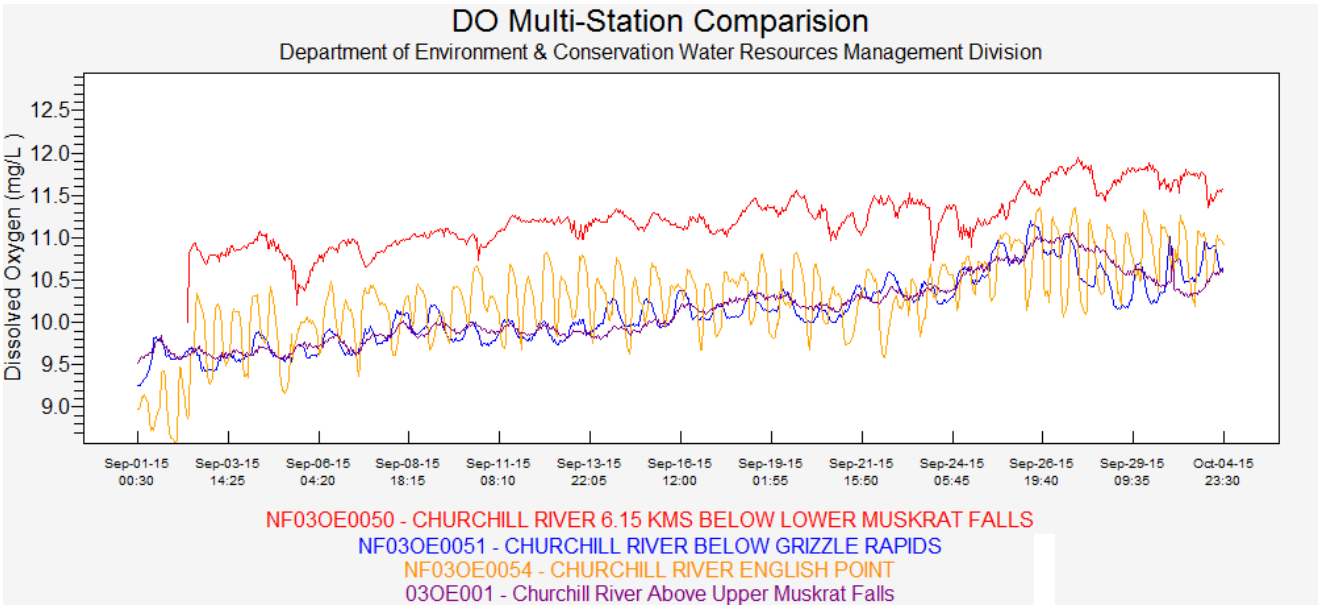

Figure A4: Comparison of Dissolved Oxygen at the Real-Time Stations on Churchill

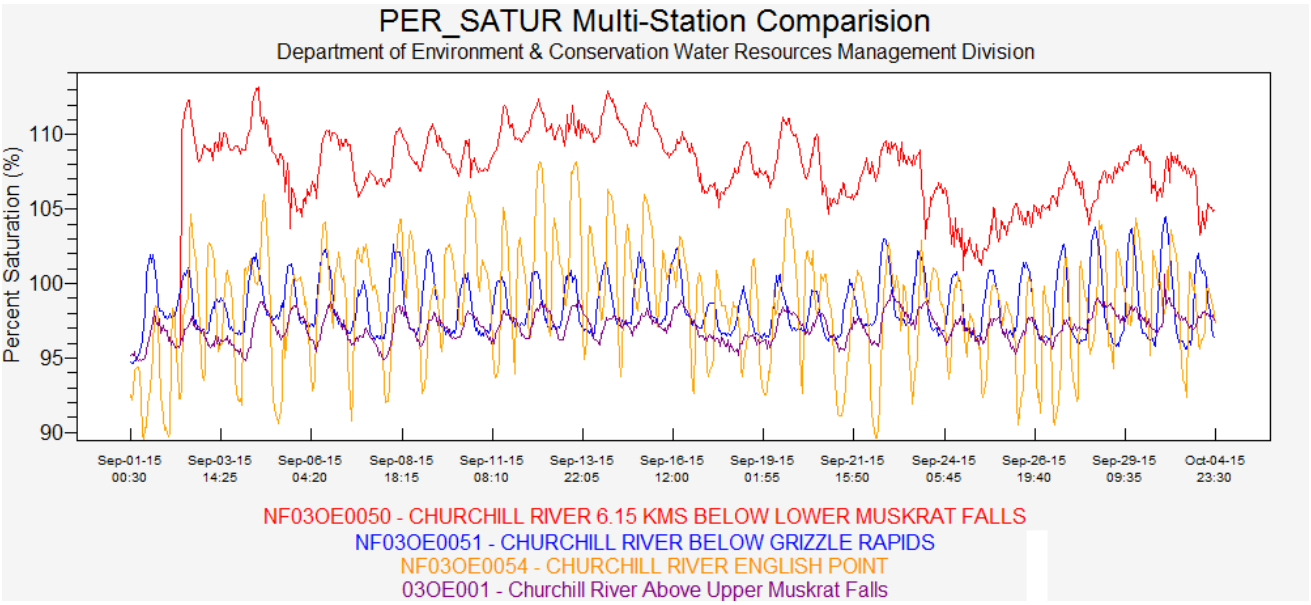

Figure A5: Comparison of Dissolved Oxygen (% Sat) at the Real-Time Stations on Churchill River

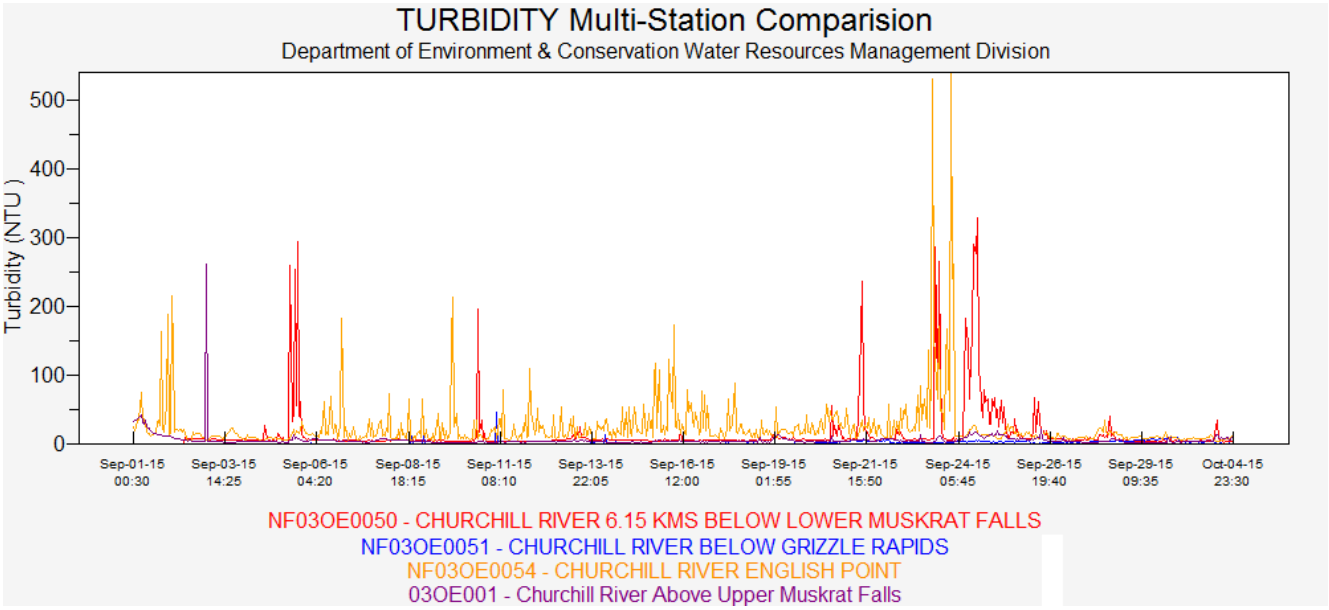

Figure A6: Comparison of Turbidity at the Real-Time Stations on Churchill River

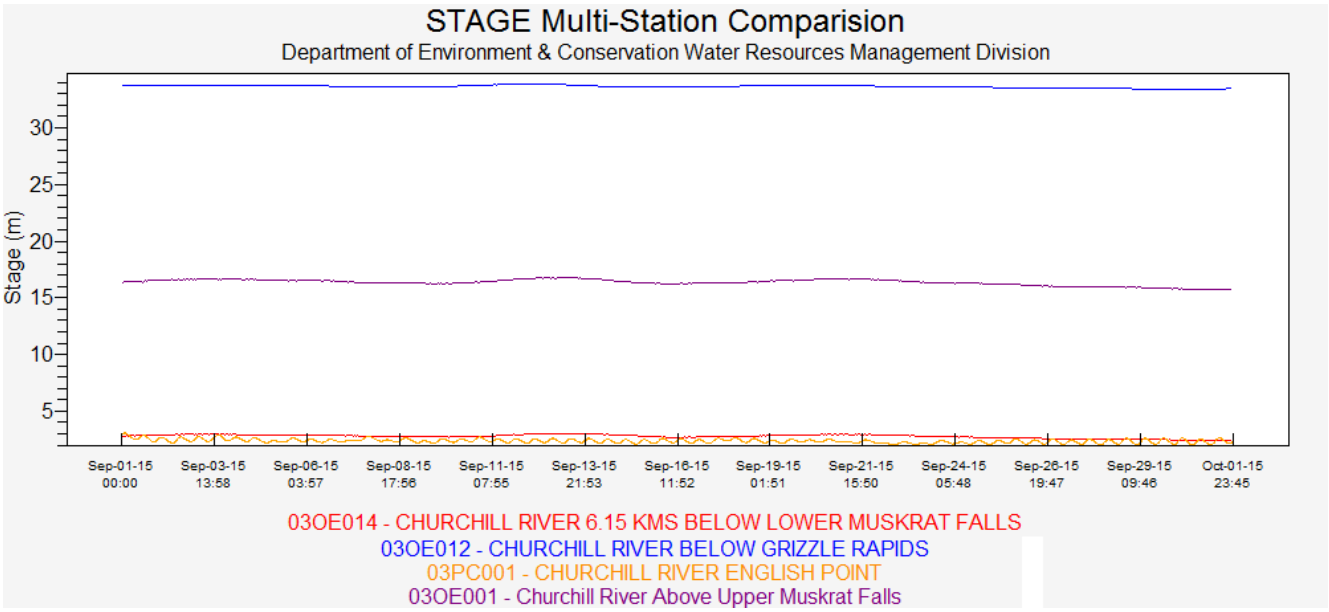

Figure A7: Comparison of Stage (m) at the Real-Time Stations on Churchill River

APPENDIX B- Grab Sample Results

REPORT OF ANALYSIS

Lab Report Number: 1517929

Cient:	Department of Environment	**COC Number:**	3384
Attention:	Ms. Annette Tobin	**Date Reported:**	2015-09-18
Client Project:	Happy Valley - Goose Bay	**Date Submitted:**	2015-09-10
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date
1200569	WS-S-0000 Below Grissle Rapids at CR	2015-6323-00-SI-SP	2015-09-01

Sample comment:

Holding time for turbidity analysis was exceeded for the entire report. Holding time for NO2 and NO3 analysis was exceeded.

Report comment:

ANALYTE	UNIT	MRL	RESULT
Alkalinity as CaCO3	mg/L	5	8
Bromide	mg/L	0.25	<0.25
Chloride	mg/L	1	<1
Colour	TCU	2	30
Conductivity	uS/cm	5	21
Dissolved Organic Carbon	mg/L	0.5	4.3
Fluoride	mg/L	0.10	<0.10
Hardness as CaCO3	mg/L	1	5
N-NH3 (Ammonia)	mg/L	0.025	0.157
N-NO2 (Nitrite)	mg/L	0.10	<0.10
N-NO3 (Nitrate)	mg/L	0.10	<0.10
pH		1.00	7.30
Sulphate	mg/L	1	<1
Total Dissolved Solids (COND - CALC)	mg/L	1	14
Total Kjeldahl Nitrogen	mg/L	0.07	0.26
Total Organic Carbon	mg/L	0.5	4.3
Total Phosphorus	mg/L	0.05	<0.05
Turbidity	NTU	0.1	0.6
Aluminum	mg/L	0.01	0.07
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

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: Nadine Pinsonneault

REPORT OF ANALYSIS

Lab Report Number: 1517929

Cient:	Department of Environment	**COC Number:**	3384
Attention:	Ms. Annette Tobin	**Date Reported:**	2015-09-18
Client Project:	Happy Valley - Goose Bay	**Date Submitted:**	2015-09-10
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1200569	WS-S-0000 Below Grissle Rapids at CR	2015-6323-00-SI-SP	2015-09-01	Copper	mg/L	0.001	<0.001
				Iron	mg/L	0.03	0.13
				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	0.015
				Uranium	mg/L	0.001	<0.001
				Zinc	mg/L	0.01	0.03
				Total Suspended Solids	mg/L	2	<2

Sample comment:

Holding time for turbidity analysis was exceeded for the entire report. Holding time for NO2 and NO3 analysis was exceeded.

Report comment:

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: Nadine Pinsonneault

REPORT OF ANALYSIS

Lab Report Number: 1517929

Cient:	Department of Environment	**COC Number:**	3384
Attention:	Ms. Annette Tobin	**Date Reported:**	2015-09-18
Client Project:	Happy Valley - Goose Bay	**Date Submitted:**	2015-09-10
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date
1200570	WS-S-0000 Upper Muskrat at CK	2015-6324-00-SI-SP	2015-09-01

Sample comment:

Holding time for NO2 and NO3 analysis was exceeded.

Report comment:

ANALYTE	UNIT	MRL	RESULT
Alkalinity as CaCO3	mg/L	5	8
Bromide	mg/L	0.25	<0.25
Chloride	mg/L	1	<1
Colour	TCU	2	39
Conductivity	uS/cm	5	23
Dissolved Organic Carbon	mg/L	0.5	4.9
Fluoride	mg/L	0.10	<0.10
Hardness as CaCO3	mg/L	1	7
N-NH3 (Ammonia)	mg/L	0.025	0.150
N-NO2 (Nitrite)	mg/L	0.10	<0.10
N-NO3 (Nitrate)	mg/L	0.10	<0.10
pH		1.00	7.29
Sulphate	mg/L	1	<1
Total Dissolved Solids (COND - CALC)	mg/L	1	15
Total Kjeldahl Nitrogen	mg/L	0.07	0.28
Total Organic Carbon	mg/L	0.5	4.8
Total Phosphorus	mg/L	0.05	<0.05
Turbidity	NTU	0.1	4.7
Aluminum	mg/L	0.01	0.50
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	3
Cadmium	mg/L	0.0001	<0.0001
Chromium	mg/L	0.001	<0.001

APPROVAL: Nadine Pinsonneault

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

REPORT OF ANALYSIS

Lab Report Number: 1517929

Cient:	Department of Environment	**COC Number:**	3384
Attention:	Ms. Annette Tobin	**Date Reported:**	2015-09-18
Client Project:	Happy Valley - Goose Bay	**Date Submitted:**	2015-09-10
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1200570	WS-S-0000 Upper Muskrat at CK	2015-6324-00-SI-SP	2015-09-01	Copper	mg/L	0.001	0.001
				Iron	mg/L	0.03	0.45
				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	0.013
				Uranium	mg/L	0.001	<0.001
				Zinc	mg/L	0.01	<0.01
				Total Suspended Solids	mg/L	1	8

Sample comment:

Holding time for NO2 and NO3 analysis was exceeded.

Report comment:

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: Nadine Pinsonneault

REPORT OF ANALYSIS

Lab Report Number: 1517929

Cient:	Department of Environment	**COC Number:**	3384
Attention:	Ms. Annette Tobin	**Date Reported:**	2015-09-18
Client Project:	Happy Valley - Goose Bay	**Date Submitted:**	2015-09-10
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date
1200572	WS-S-0000 CR Below Muskrat Falls	2015-6326-00-SI-SP	2015-09-02

Sample comment:

Holding time for NO2 and NO3 analysis was exceeded.

Report comment:

ANALYTE	UNIT	MRL	RESULT
Alkalinity as CaCO3	mg/L	5	12
Bromide	mg/L	0.25	<0.25
Chloride	mg/L	1	<1
Colour	TCU	2	37
Conductivity	uS/cm	5	28
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	0.025	0.135
N-NO2 (Nitrite)	mg/L	0.10	<0.10
N-NO3 (Nitrate)	mg/L	0.10	<0.10
pH		1.00	7.62
Sulphate	mg/L	1	<1
Total Dissolved Solids (COND - CALC)	mg/L	1	18
Total Kjeldahl Nitrogen	mg/L	0.07	0.22
Total Organic Carbon	mg/L	0.5	4.7
Total Phosphorus	mg/L	0.05	<0.05
Turbidity	NTU	0.1	3.6
Aluminum	mg/L	0.01	0.29
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

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: Nadine Pinsonneault

REPORT OF ANALYSIS

Lab Report Number: 1517929

Cient:	Department of Environment	**COC Number:**	3384
Attention:	Ms. Annette Tobin	**Date Reported:**	2015-09-18
Client Project:	Happy Valley - Goose Bay	**Date Submitted:**	2015-09-10
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1200572	WS-S-0000 CR Below Muskrat Falls	2015-6326-00-SI-SP	2015-09-02	Copper	mg/L	0.001	0.001
				Iron	mg/L	0.03	0.34
				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
				Uranium	mg/L	0.001	<0.001
				Zinc	mg/L	0.01	<0.01
				Total Suspended Solids	mg/L	1	5

Sample comment:

Holding time for NO2 and NO3 analysis was exceeded.

Report comment:

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: Nadine Pinsonneault

Exova

REPORT OF ANALYSIS

Lab Report Number: 1517929

Cient:	Department of Environment	**COC Number:**	3384
Attention:	Ms. Annette Tobin	**Date Reported:**	2015-09-18
Client Project:	Happy Valley - Goose Bay	**Date Submitted:**	2015-09-10
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date
1200573	WS-S-0000 English Point	2015-6327-00-SI-SP	2015-09-02

Sample comment:

Holding time for NO2 and NO3 analysis was exceeded.

Report comment:

ANALYTE	UNIT	MRL	RESULT
Alkalinity as CaCO3	mg/L	5	9
Bromide	mg/L	0.25	<0.25
Chloride	mg/L	1	8
Colour	TCU	2	49
Conductivity	uS/cm	5	49
Dissolved Organic Carbon	mg/L	0.5	5.7
Fluoride	mg/L	0.10	<0.10
Hardness as CaCO3	mg/L	1	9
N-NH3 (Ammonia)	mg/L	0.025	<0.025
N-NO2 (Nitrite)	mg/L	0.10	<0.10
N-NO3 (Nitrate)	mg/L	0.10	<0.10
pH		1.00	7.29
Sulphate	mg/L	1	1
Total Dissolved Solids (COND - CALC)	mg/L	1	32
Total Kjeldahl Nitrogen	mg/L	0.07	0.25
Total Organic Carbon	mg/L	0.5	5.4
Total Phosphorus	mg/L	0.05	<0.05
Turbidity	NTU	0.1	3.2
Aluminum	mg/L	0.01	0.22
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

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: Nadine Pinsonneault

REPORT OF ANALYSIS

Lab Report Number: 1517929

Cient:	Department of Environment	**COC Number:**	3384
Attention:	Ms. Annette Tobin	**Date Reported:**	2015-09-18
Client Project:	Happy Valley - Goose Bay	**Date Submitted:**	2015-09-10
Purchase Order:	214004545	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1200573	WS-S-0000 English Point	2015-6327-00-SI-SP	2015-09-02	Copper	mg/L	0.001	0.001
				Iron	mg/L	0.03	0.43
				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	5
				Strontium	mg/L	0.001	0.017
				Uranium	mg/L	0.001	<0.001
				Zinc	mg/L	0.01	<0.01
				Total Suspended Solids	mg/L	1	6

Sample comment:

Holding time for NO2 and NO3 analysis was exceeded.

Report comment:

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: Nadine Pinsonneault

APPENDIX C-Quality Assurance / Quality Control Procedures

- As part of the Quality Assurance / Quality Control (QA/QC) protocol, the performance of a station's water quality instrument (i.e., Field Sonde) is rated at the beginning and end of its deployment period. The procedure is based on the approach used by the United States Geological Survey (Wagner *et al.* 2006)[1].
- At the beginning of the deployment period, a newly calibrated QA/QC water quality instrument (i.e., QA/QC Sonde) is temporarily deployed *in-situ* and along side the newly calibrated Field Sonde. A grab sample is also taken from the water body at this time and sent away to a laboratory for analysis. Field Sonde performance ratings for *temperature (^oC)* and *Dissolved Oxygen (% saturation)* are based on differences recorded by the Field Sonde and QA/QC Sonde. Field Sonde performance ratings for *specific conductivity (µS/cm), pH (unit)* and *turbidity (NTU)* are based on differences between Field Sonde readings and grab sample results.
- At the end of the deployment period, water quality parameters are recorded by the Field Sonde before and after a thorough cleaning of its probes. Error caused by *bio-fouling* (E_f) is assessed by comparing these readings with readings made by a newly calibrated QA/QC Sonde, which is temporarily deployed *in-situ* and along side the Field Sonde. An assessment of *instrument drift error* (E_d) is made during laboratory calibration of the Field Sonde, and the two error values are added to give an estimate of total error ($E_t = E_f + E_d$). If E_t exceeds a predetermined data correction criterion, a correction factor is applied to the dataset based on linear interpolation of E_t. The Field Sonde performance is also rated at the end of the deployment period, based on the E_t value.
- Performance ratings are based on differences listed in the table below.

	Rating				
Parameter	**Excellent**	**Good**	**Fair**	**Marginal**	**Poor**
Temperature (^oC)	≤ ±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 > 35 µS/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

[1] Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51 p. + 8 attachments; accessed April 10, 2006, at *http://pubs.water.usgs.gov/tm1d3*

APPENDIX D-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 (Allan 2010).
- ***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 the measure of hydrogen ion activity and affects: (i) the availability of nutrients to aquatic life; (ii) the concentration of biochemical substances dissolved in water; (iii) the efficiency of hemoglobin in the blood of vertebrates; and (iv) the toxicity of pollutants. Changes in pH can be attributed to industrial effluence, saline inflows or aquatic organisms involved in the photosynthetic cycling of CO_2 (Allan 2010).
- ***Specific conductivity*** - Specific conductivity (μS/cm) is a measure of water's ability to conduct electricity, with values normalized to a water temperature of 25ºC. 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 (Allan 2010; Swanson and Baldwin 1965).
- ***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 (oC) controls most processes and dynamics of limnology. 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 (Allan 2010; Hach 2006).
- ***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 (Allan 2010; Swanson 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 (Allan 2010; Hach 2006; Swanson and Baldwin 1965)