Real-Time Water Quality 2015 Annual Report

Lower Churchill River Network

May 27 to November 10, 2015

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

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Acknowledgements

The Real-Time Water Quality (RTWQ) monitoring network on the Lower Churchill River is successful in tracking emerging water quality issues as well as creating a database of baseline water quality data due to the hard work and diligence of certain individuals. The management and staff of Nalcor work in cooperation with the management and staff of the Department of Environment and Conservation (ENVC) as well as Environment Canada (EC) to ensure the protection of ambient water resources in the Lower Churchill River.

ENVC employees have been integral in ensuring the smooth operation of such a technologically advanced network. In 2015, ENVC Environmental Scientist, Kelly Maher, was responsible for deployment and removal of instruments including cleaning, calibration and maintenance. In addition, Kelly Maher was responsible for the preparation of monthly deployment reports. Maria Murphy and Melissa McComiskey are acknowledged for their efforts during deployment and removal procedures in 2015.

EC staff, with the Water Survey of Canada plays an essential role in the data logging/communication aspect of the network. These individuals visit the site regularly to ensure the data logging equipment is operating properly and transmitting the data efficiently. Finally, they play the lead role in dealing with hydrological quantity and flow issues.

The managers from each agency (Peter Madden/David Haley – Nalcor; Renee Paterson - ENVC; Howie Wills – EC) are fully committed to improving this network and ensuring it provides meaningful and accurate water quality/quantity data that can be used in the decision-making process. Throughout the summer and fall months in 2015, there was continued communication in the form of small meetings and email correspondence between ENVC and Nalcor. This network is continually successful due to the participation and collaboration of all three agencies.

Abbreviations

EC	Environment Canada
ENVC	Department of Environment and Conservation
CRaboveMF	Station at Churchill River above Muskrat Falls
CRbelowGR	Station at Churchill River below Grizzle Rapids
CRbelowMF	Station at Churchill River below Muskrat Falls
CRatEP	Station at Churchill River at English Point
DO	Dissolved Oxygen
NL	Newfoundland and Labrador
QAQC	Quality Assurance and Quality Control
RTWQ	Real-Time Water Quality
SC	Specific Conductivity
WRMD	Water Resources Management Division
%Sat	Percent Saturation

History

- The RTWQ monitoring network on the Lower Churchill River was successfully established by ENVC and EC in cooperation with Nalcor Energy in September 2008.
- The objective of the network is to identify and track emerging water quality or quantity management issues and ensure protection of ambient water resources along the Lower Churchill River. The information being collected will serve as a baseline from which changes throughout the several phases of the Lower Churchill Hydroelectric Generation Project can be monitored.
- The original network, established in 2008, consisted of 4 water quality/quantity monitoring stations along the Lower Churchill River from just below the confluence with Metchin River to just below Muskrat Falls. In addition, there were two water quantity monitoring stations on the Churchill River below the Tailrace and above Grizzle Rapids, which strictly recorded stage level continuously along with hydrometric stations on select tributaries to the Churchill River (Figure 1).
- In 2011, ENVC in cooperation with EC established another water quality/quantity monitoring station at the mouth of the Churchill River (Churchill River at English Point). This station is included in this annual report for comparison purposes (Figure 1).
- During the 2014 deployment year, one water quality/quantity monitoring station (Churchill River below Metchin River) and three water quantity monitoring stations (Churchill River above Churchill Falls Tailrace, East Metchin River below Highway Bridge and Minipi River below Minipi Lake) were ‘mothballed’ or discontinued as per changes to the Memorandum of Agreement between ENVC and Nalcor. An additional water quantity monitoring station (Churchill River Mid Pool) was added to the agreement in 2014.
- Continuous monitoring at four water quality/quantity monitoring stations in the Lower Churchill River Network recommenced in spring 2015. This annual deployment report illustrates, discusses and summarizes water quality related events from May 27 to November 10, 2015. During this time, five visits were made to each of the four RTWQ sites. Instruments were deployed for 4-5 month-long intervals referred to as deployment periods.
- Issues were encountered at a few of the stations during the deployment season. Due to the presence of an ice wall at below Grizzle Rapids it was not deployed until the end of June. Below Muskrat Falls station continued to experience issues throughout the season due to the accumulation of sand around the instrument thus it was not redeployed until September 2015
- Construction at the Muskrat Falls Hydroelectric Generation site began in 2013. In 2015, construction continued on the worksite with progress on the powerhouse and spillway. Site water controls at Muskrat Falls continue to direct run-off flows to one of two discharge points either above or below the lower falls. Significant forestry activity continues, including transmission line and reservoir clearing. Construction is scheduled to continue until 2017.

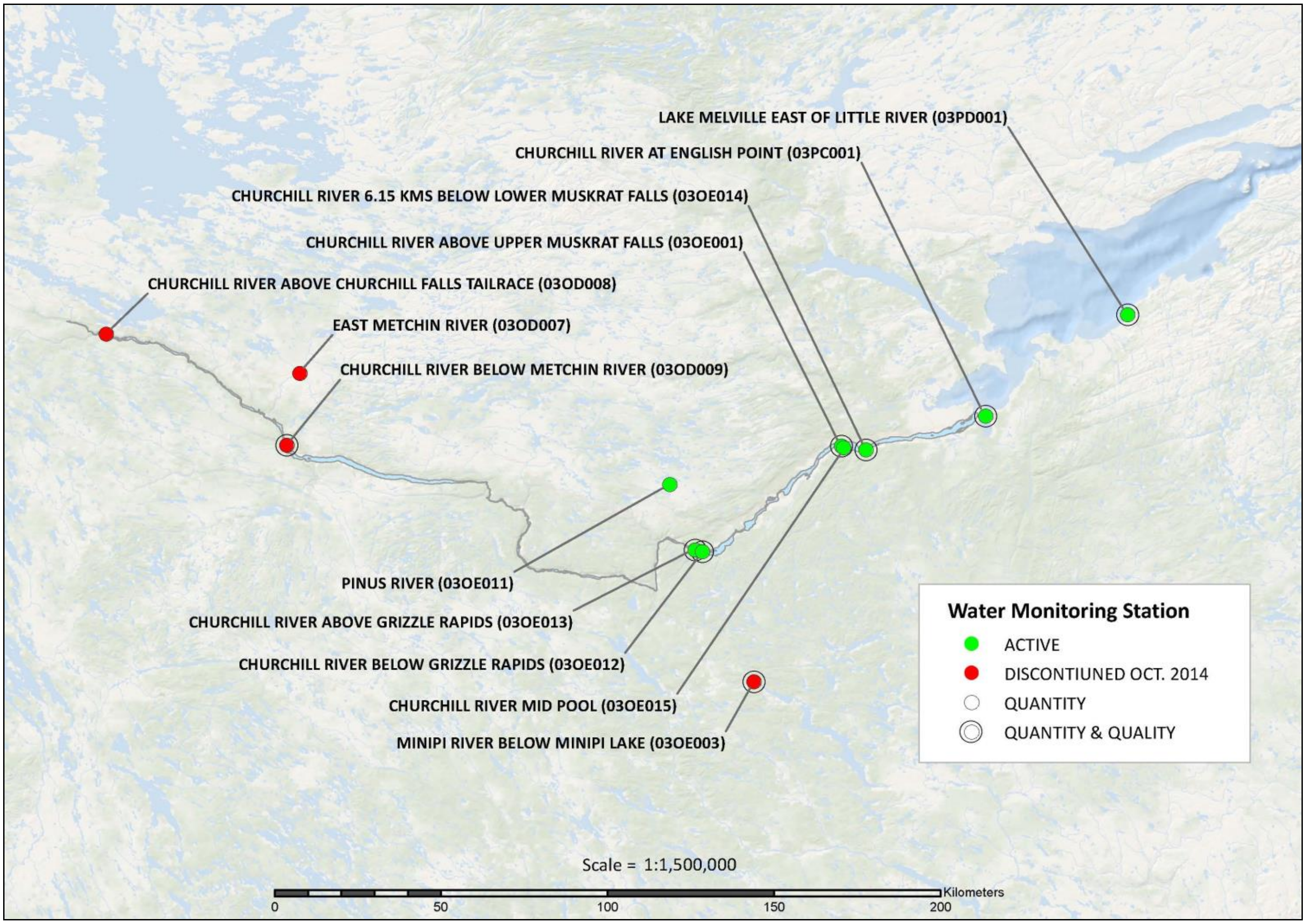


Figure 1: Lower Churchill River Station Map

Maintenance and Calibration

- It is recommended that regular maintenance and calibration of the instruments take place on a monthly basis to ensure accurate data collection. This procedure is the responsibility of the ENVC staff and is performed preferably every 30 days.
- Maintenance includes a thorough cleaning of the instrument and replacement of any small sensor parts that are damaged or unsuitable for reuse. Once the instrument is cleaned, ENVC staff carefully calibrates each sensor attachment for pH, specific conductivity, dissolved oxygen and turbidity.
- An extended deployment period (>30 days) can result in instrument sensor drift which may result in skewed data. The instrument sensors will still work to capture any water quality event even though the exact data values collected may be inaccurate. Installation and removal dates for each station in the 2015 deployment season are summarized in Table 1.

Table 1: Installation and removal dates for 2015 deployment periods

Installation	Removal	Deployment
May 27	June 24/25	27-28 days
June 24/25	August 5	40-41 days
August 5	September 1/2	26-27 days
September 1/2	September 30/October 1	29 days
September 30/October 1	November 6/November 10	35-40 days

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 2).

Table 2: 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 > 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

- 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.
- Comparison rankings for the Lower Churchill River stations, deployed for four deployment periods from May 27 to November 10, 2015, are summarized in Table 3.
- For additional information and explanations of rankings including “n/a” rankings, please refer to the monthly deployment reports.

Table 3: Comparison rankings for Lower Churchill River stations, May 27 – November 10, 2015

Station	Date	Action	Instrument #	Temperature	pH	Specific Conductivity	Dissolved Oxygen	Turbidity
Below Grizzle Rapids	May 27	Deployment	n/a	Not deployed due to ice wall limiting access to station				
	June 24	Removal						
	June 24	Deployment	45699	Good	Fair	Excellent	Excellent	Excellent
	August 5	Removal		Excellent	Good	Excellent	Good	Excellent
	August 5	Deployment	45709	Excellent	Excellent	Excellent	Good	Excellent
	September 1	Removal		Excellent	Excellent	Excellent	Excellent	Excellent
	September 1	Deployment	45699	Marginal	Excellent	Excellent	Good	Excellent
	September 30	Removal		Fair	Good	Excellent	Excellent	Good
	September 30	Deployment	45709	Excellent	Good	Good	Excellent	Excellent
	November 10	Removal		Excellent	Good	Excellent	Excellent	Excellent
Above Muskrat Falls	May 27	Deployment	45708	Good	Excellent	Excellent	Excellent	Good
	June 24	Removal		Instrument out of the water upon retrieval				
	June 24	Deployment	45700	Good	Fair	Excellent	Good	Marginal
	August 5	Removal		Good	Excellent	Excellent	Excellent	Excellent
	August 5	Deployment	45708	Good	Excellent	Excellent	Good	Good
	September 1	Removal		Excellent	Excellent	Excellent	Excellent	Good
	September 1	Deployment	45700	Excellent	Excellent	Excellent	Excellent	Good
	September 30	Removal		Good	Good	Excellent	Excellent	Marginal
	September 30	Deployment	47590	Excellent	Good	Excellent	Excellent	Fair
	November 6	Removal		Excellent	Fair	Good	Excellent	Good
Below Muskrat Falls	May 27	Deployment	n/a	Instrument not deployed due to sand conditions				
	June 24	Removal						
	June 24	Deployment	n/a	Instrument not deployed due to sand conditions				
	August 5	Removal						
	August 5	Deployment	n/a	Instrument not deployed due to sand conditions				
	September 2	Removal						
	September 2	Deployment	45708	Excellent	Excellent	Excellent	Excellent	Excellent
	October 1	Removal		Good	Excellent	Excellent	Excellent	Excellent
	October 1	Deployment	45700	Good	Good	Excellent	Excellent	Marginal
	November 6	Removal		Good	Good	Good	Excellent	Good
At English Point	May 27	Deployment	45042	Fair	Good	Excellent	Good	Poor
	June 25	Removal		Good	Good	Excellent	Good	Poor
	June 25	Deployment	43820	Excellent	Good	Excellent	Excellent	Poor
	August 5	Removal		Excellent	Excellent	Good	Good	Excellent
	August 5	Deployment	45042	Excellent	Good	Excellent	Marginal	Fair
	September 2	Removal		Excellent	Excellent	Excellent	Marginal	Marginal
	September 2	Deployment	45701	Excellent	Excellent	Excellent	Excellent	Excellent
	October 1	Removal		Excellent	Excellent	Excellent	Excellent	Excellent
	October 1	Deployment	45042	Good	Excellent	Good	Excellent	Good
	November 6	Removal		Good	Good	Good	Good	Good

Data Interpretation and Review

- The following graphs and discussion illustrate significant water quality-related trends from May 27 to November 10 in the Lower Churchill River Network. In this summary of the deployment periods for 2015, general patterns will be discussed. More detailed analysis and discussion of specific events can be found in the monthly deployment reports.
- With the exception of water quantity data (stage), 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.
- For a general comparison, 2013 and 2014 data has been included in the following graphs to show differences in trends in water quality on the Lower Churchill River over the past 3 years.
- Summary statistics are calculated using the entire data set. This means that the number of values used to calculate the median, min and max vary from year to year depending on the length of the deployment season. The 2015 deployments season was 163 days long while the 2014 and 2013 seasons used for comparison purposes in this report are 156 and 169 days each, respectively.

Churchill River below Grizzle Rapids

- Water temperature ranges from 1.5°C to 19.8°C during the 2015 deployment season, with a median value of 14.1°C (Figure 2).
- Water temperatures during summer were cooler in 2015 than in 2014, but were on par with 2013 temperatures. Temperature trends into the fall months are slightly warmer in 2015 than the previous two years.

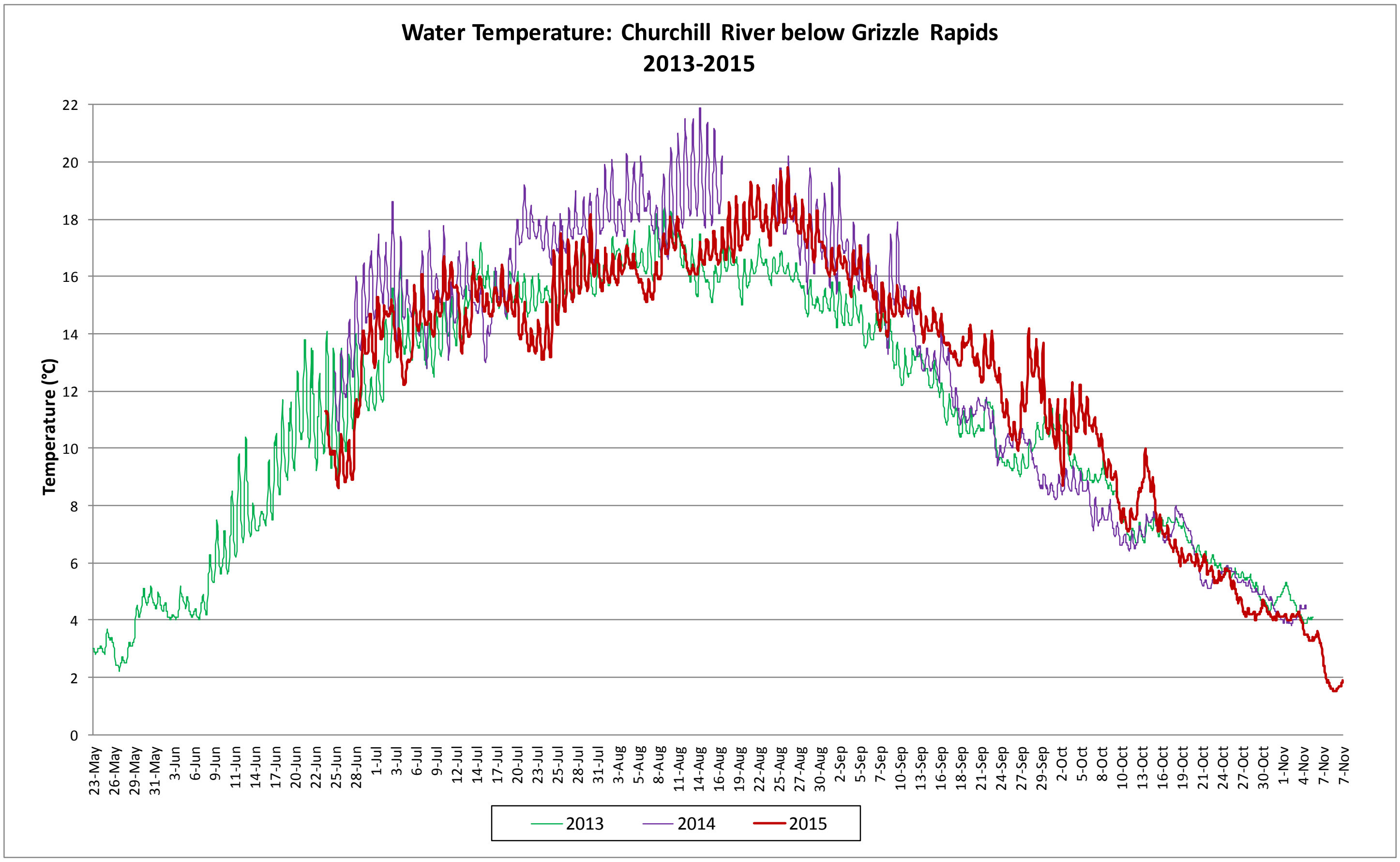


Figure 2: Water temperature at Churchill River below Grizzle Rapids

Temperature	2015	2014	2013
Min	1.5	3.8	2.2
Max	19.8	21.9	18.4
Median	14.1	14.7	11.6

- Water temperature values show a typical seasonal trend (Figure 3). Water and air temperatures are increasing throughout the spring and summer with water temperatures peaking in August before steadily decreasing into the fall months.

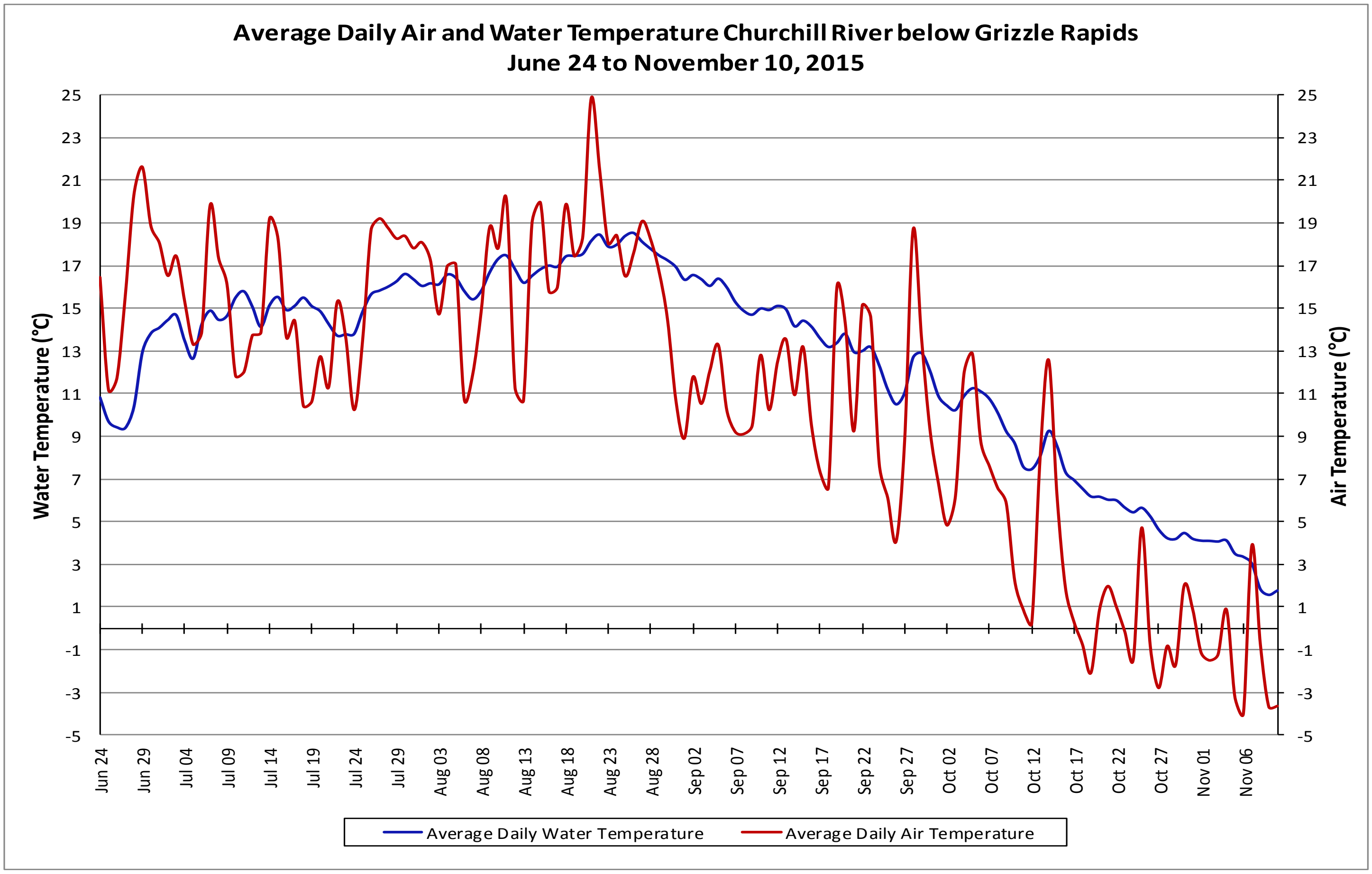


Figure 3: Average daily air and water temperatures at Churchill River below Grizzle Rapids (weather data recorded at Muskrat Falls)

- pH ranges between 6.62 and 7.35 pH units during the 2015 deployment season, with a median value of 7.02 pH units (Figure 4). The median values from 2013-2015 remain very similar in value showing consistency over the past three seasons.
- pH values are consistent throughout the deployment season with a clear diurnal fluctuation.
- A drop in pH values during the August deployment is lower than expected and is likely due to significant rain events.
- All values during the 2015 deployment season are within the CCME Guidelines for the Protection of Aquatic Life (>6.5 and <9.0 pH units). The guidelines are indicated in red on Figure 4.

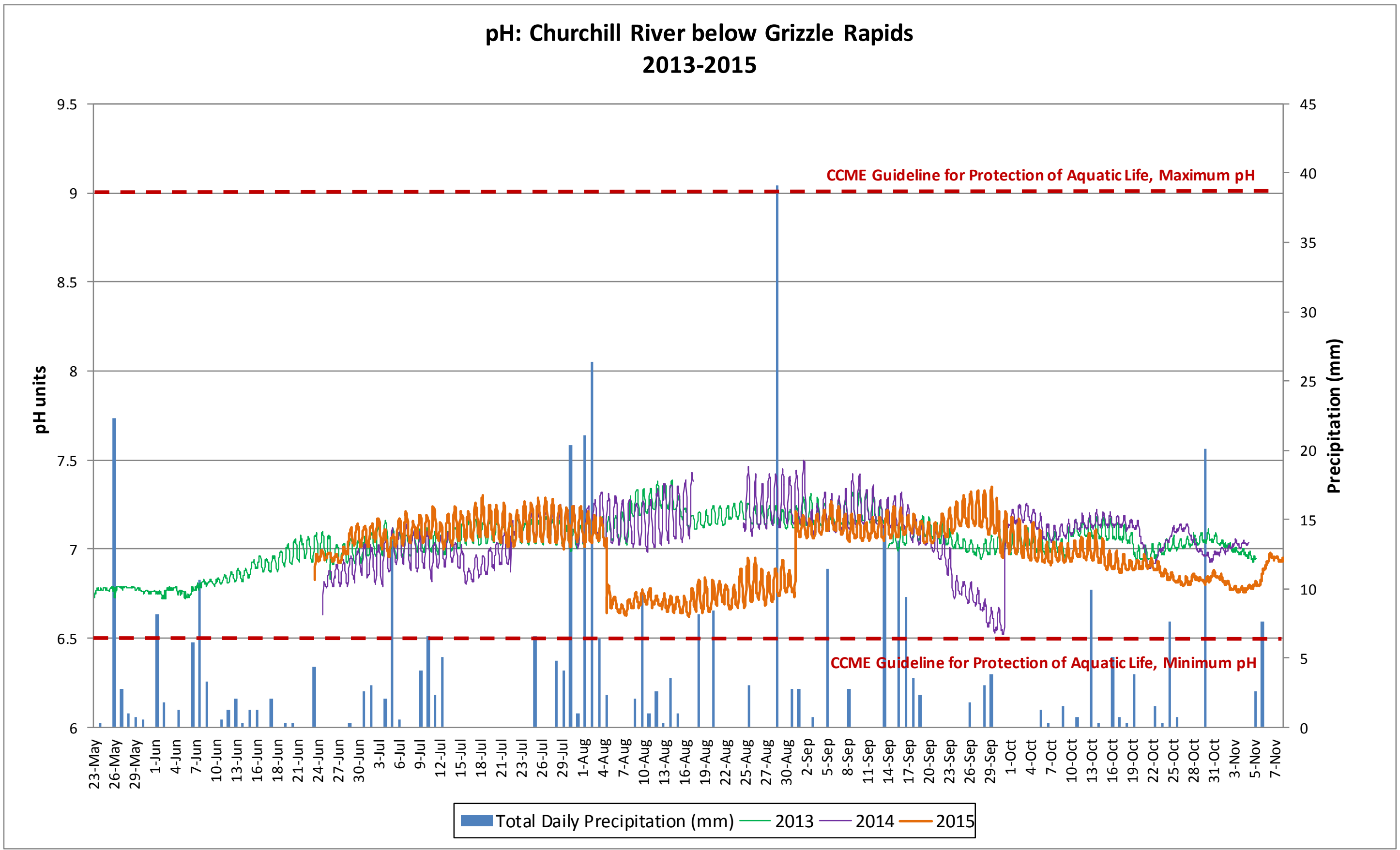


Figure 4: pH at Churchill River below Grizzle Rapids

pH (units)	2015	2014	2013
Min	6.62	6.52	6.72
Max	7.35	7.50	7.39
Median	7.02	7.09	7.05

- Specific conductivity ranges from 12.3µS/cm to 19.8µS/cm during the 2015 deployment season, with a median value of 16.6µS/cm (Figure 5).
- Specific conductivity is increasing in the spring and early summer, peaking in late September. Specific conductivity then begins to decrease throughout the remainder of the deployment season into the fall months.
- There is a drop in conductivity as a result of an instrument switch-out on September 30th causing lower values for the final deployment period. The QA/QC ranking for this switch-out was "good" and upon removal the ranking was "excellent" thus the values are acceptable.
- Increases and decreases in specific conductivity are most times clearly related to fluctuations in stage. As stage decreases, specific conductivity usually increases as the concentration of dissolved solids increases. Inversely, when stage increases, specific conductivity generally decreases due to the dilution of dissolved solids in the water column.
- Specific conductivity trends in 2013 and 2014 are somewhat similar, increasing throughout the summer when stage is typically decreasing and decreasing again in the fall season when stage typically increases. The majority of 2015 values are slightly lower than the previous two years, reaching lower median and maximum values.

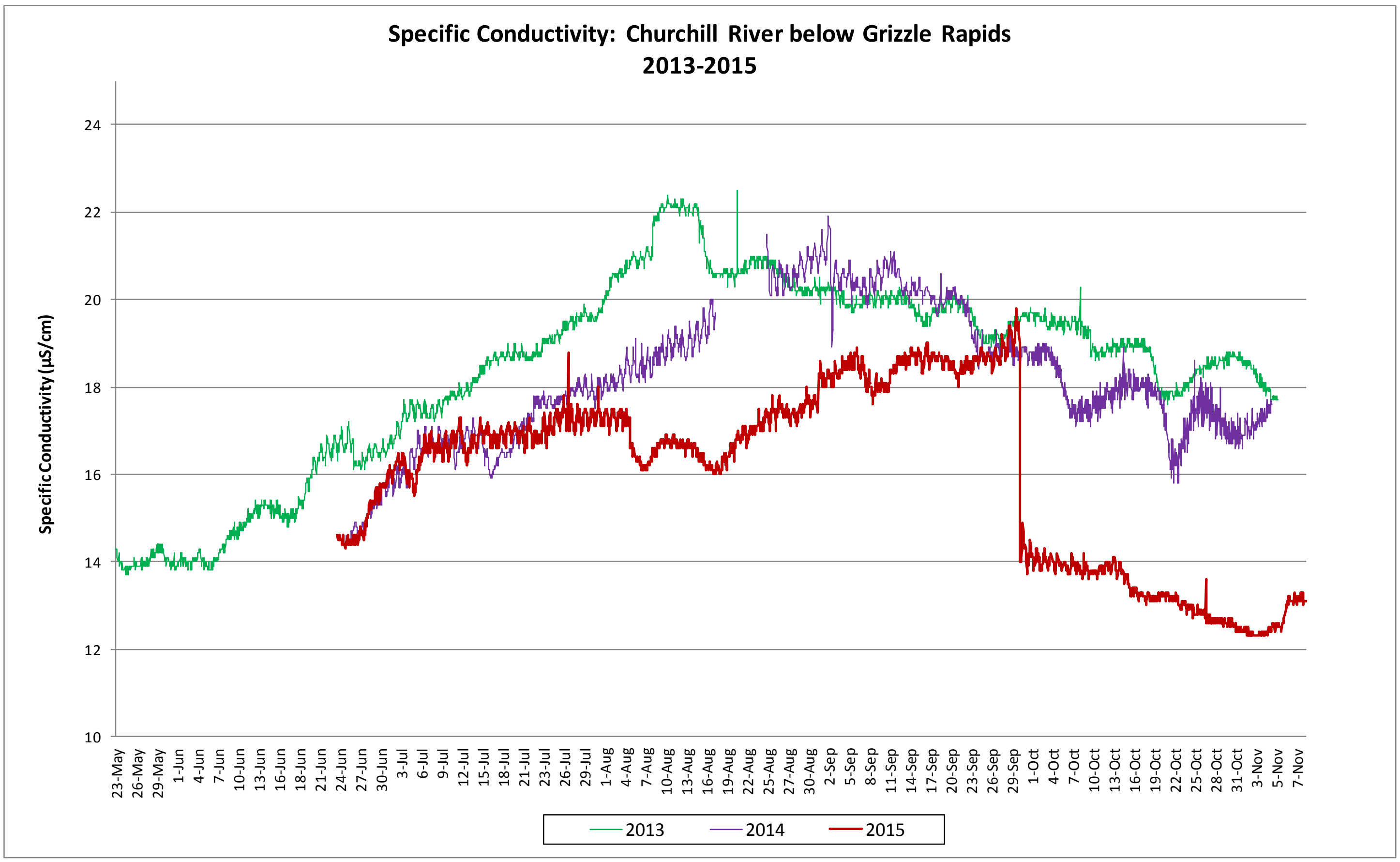


Figure 5: Specific conductivity at Churchill River below Grizzle Rapids

Specific Conductivity (µS/cm)	2015	2014	2013
Min	12.3	14.4	13.7
Max	19.8	21.9	22.5
Median	16.6	18.0	18.9

- During the 2015 deployment season, dissolved oxygen ranges from 9.00mg/l and 13.01mg/l, with a median value of 10.07mg/l, while percent saturation ranges from 91% to 104.5%, with a median value of 96.7% (Figure 6).
- Dissolved oxygen content shows a typical seasonal fluctuation in 2015. Dissolved oxygen content fluctuates regularly on a daily basis. Percent saturation is generally consistent throughout the deployment season.
- All values were above the minimum CCME Guideline for the Protection of Cold Water Biota at Other Life Stages (6.5 mg/l). During late July to early September, dissolved oxygen values hovered around the minimum CCME Guideline for the Protection of Aquatic life at Early Life Stages (9.5mg/l), coinciding with warm temperatures recorded at this time which decrease the amount of oxygen the water can hold. As air and water temperatures cool into the fall, the dissolved oxygen content increases above 9.5mg/l. The guidelines are indicated in red on Figure 6.
- Dissolved oxygen and percent saturation values are comparable to the data collected in 2013 and 2014.

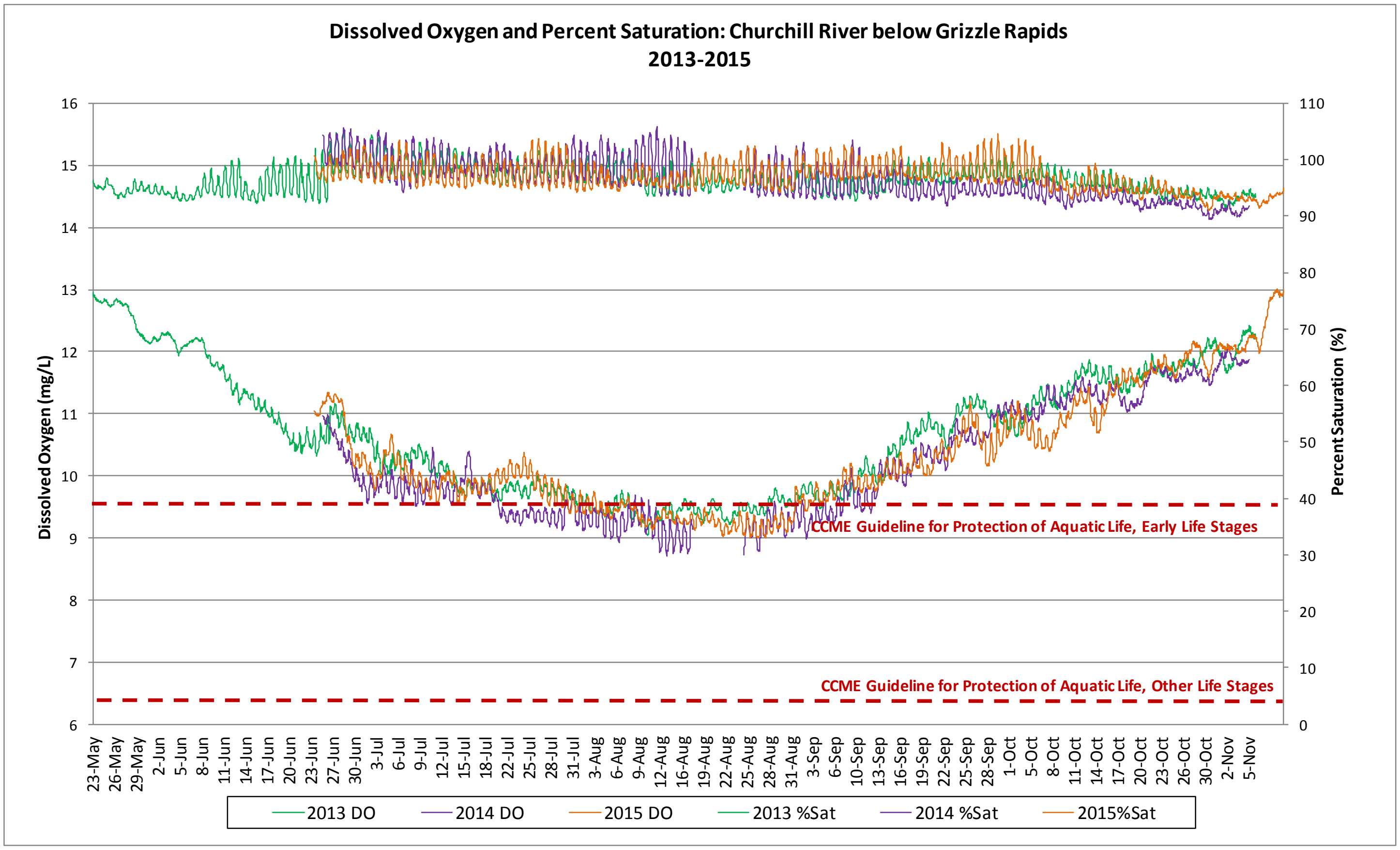


Figure 6: Dissolved oxygen and percent saturation at Churchill River below Grizzle Rapids

Dissolved Oxygen (mg/L)	2015	2014	2013		Percent Saturation	2015	2014	2013
Min	9	8.7	9.04		Min	91	89.4	91.4
Max	13.01	12.11	12.95		Max	104.5	105.9	105.2
Median	10.07	9.93	10.63		Median	96.7	95.8	96.3

- Turbidity generally remains at 0NTU for the majority of the 2015 deployment season (Figure 7). A median value of 0 NTU from 2013 to 2015 indicates there is no natural background turbidity value at this station.
- There are a couple of instances where turbidity increases minimally in 2015 to as high as 105NTU. These are not considered water quality events as they are isolated and infrequent occurrences, likely caused by debris interfering with the turbidity sensor. Towards the end of July the turbidity sensor is showing what looks like a sediment build up.
- Similar trends have been identified in the 2013 and 2015 datasets for this station.
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

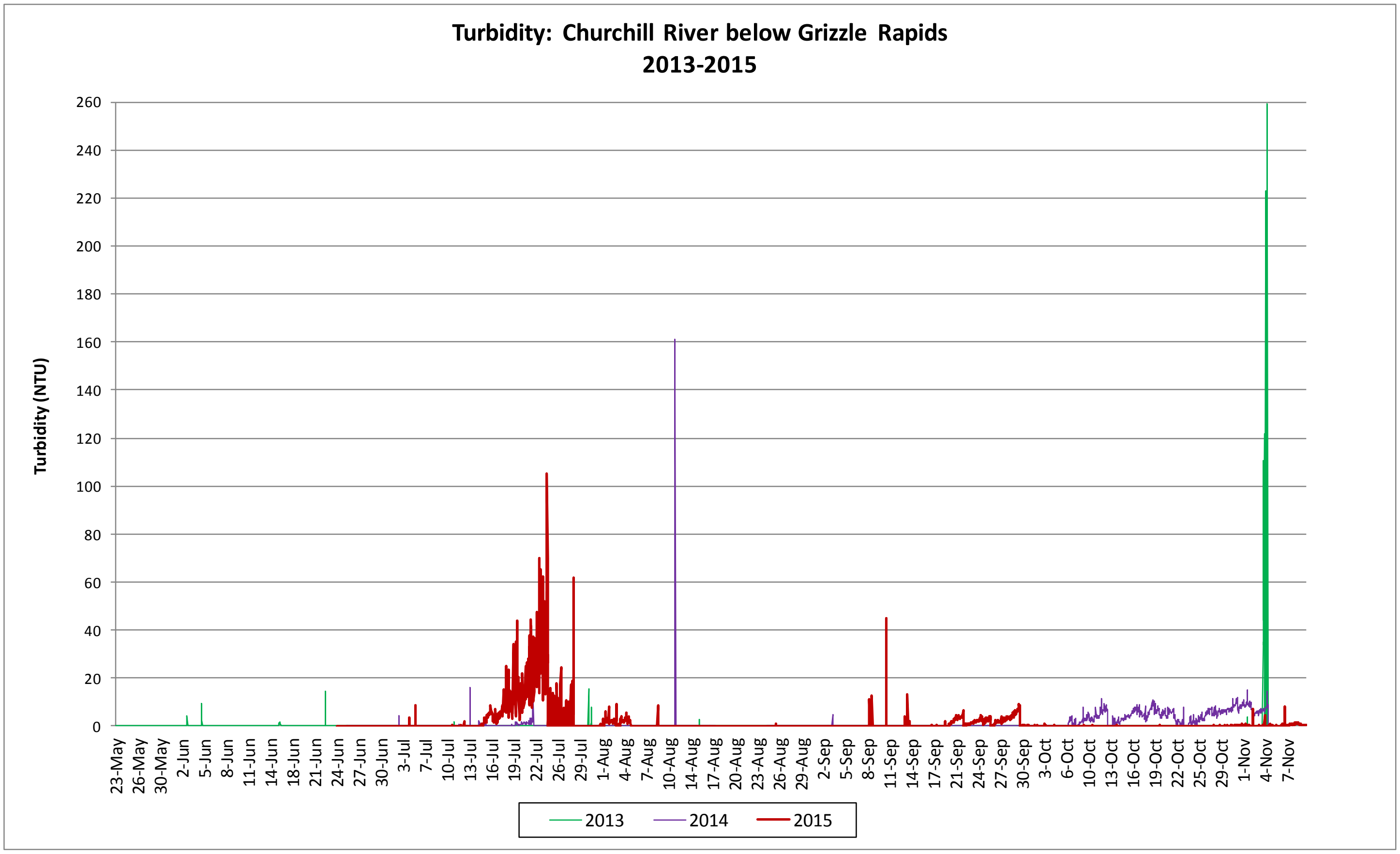


Figure 7: Turbidity at Churchill River below Grizzle Rapids

Turbidity (NTU)	2015	2014	2013
Min	0.0	0	0
Max	105	161.2	259.4
Median	0.0	0.0	0.0

- Stage levels in 2015 decreased after the spring freshet, before rising again slightly due to precipitation events in July and dropping to a seasonal low in late September (Figure 8). Stage levels rose steadily into the fall months.
- Stage levels from 2013-2014 are graphed below to show how stage levels vary throughout the season and from year to year. The seasonal low of 2014 was reached in mid-August and was significantly lower than levels reached during the 2013 and 2015 seasons. Stage range for 2015 is larger overall at 1.584m.
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

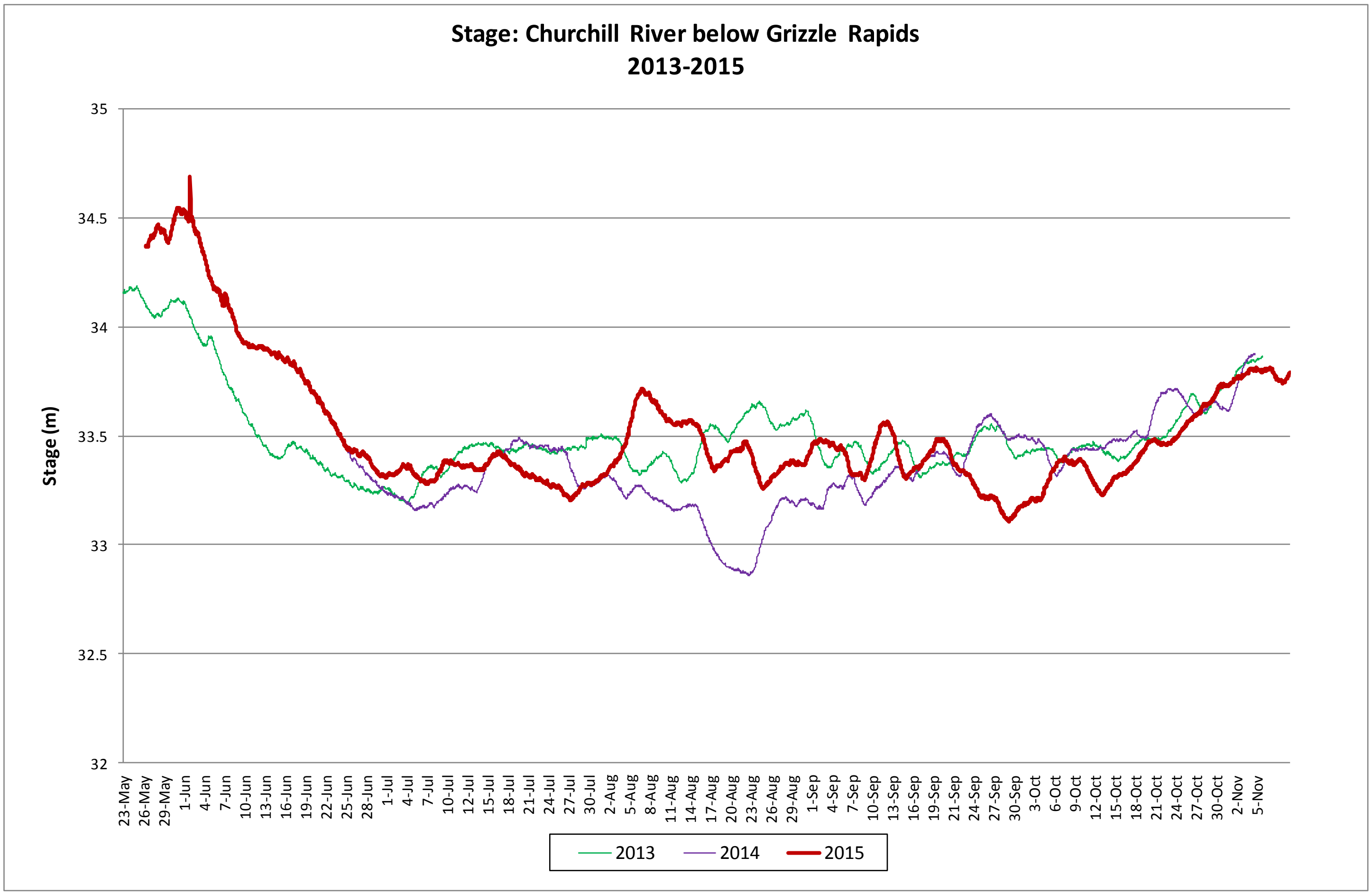


Figure 8: Stage level at Churchill River below Grizzle Rapids

Stage (m)	2015	2014	2013
Min	33.106	32.86	33.19
Max	34.69	33.878	34.189
Median	33.41	33.327	33.448
Range	1.584	1.018	0.999

- Stage and precipitation are graphed below to show the relationship between rainfall and water level (Figure 9).
- Stage is decreasing in the first week of the deployment season, as expected after the spring freshet. Stage increases in early to late July, before decreasing to a seasonal low in late September. Numerous precipitation events cause stage levels to increase steadily into fall. Water levels at this station do not fluctuate as greatly when compared to other stations in the network.
- Precipitation events are frequent and range from low to high in magnitude.
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

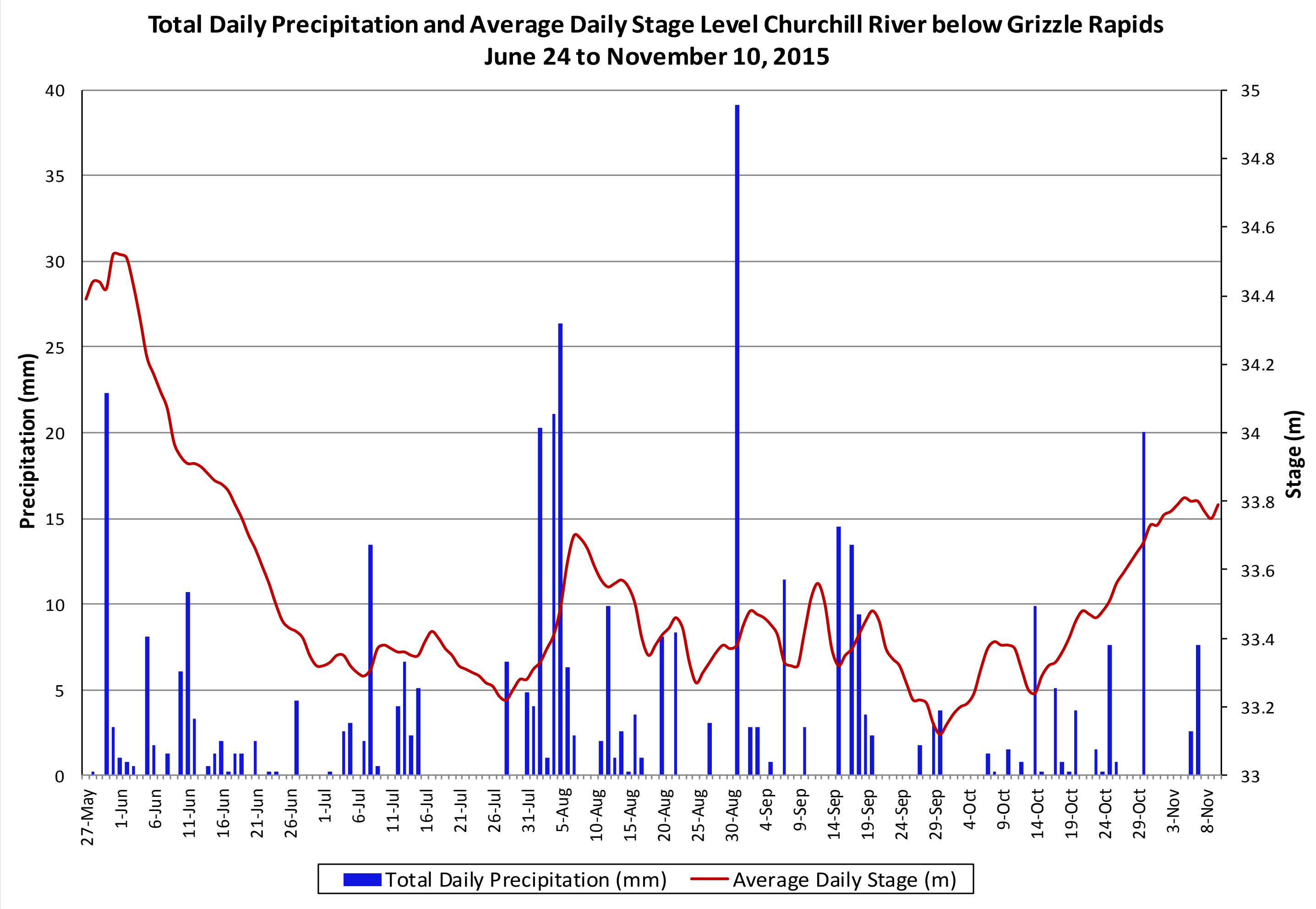


Figure 9: Daily precipitation and average daily stage level at Churchill River below Grizzle Rapids (weather data recorded at Muskrat Falls)

Churchill River above Muskrat Falls

- Water temperature ranges from 2.71°C to 19.46°C during the 2015 deployment season, with a median value of 13.79°C (Figure 10).
- Water temperatures appear slightly cooler at times in 2015, especially in the spring and summer seasons when compared to data collected in 2014. Temperature in the fall months is on par to the previous years.

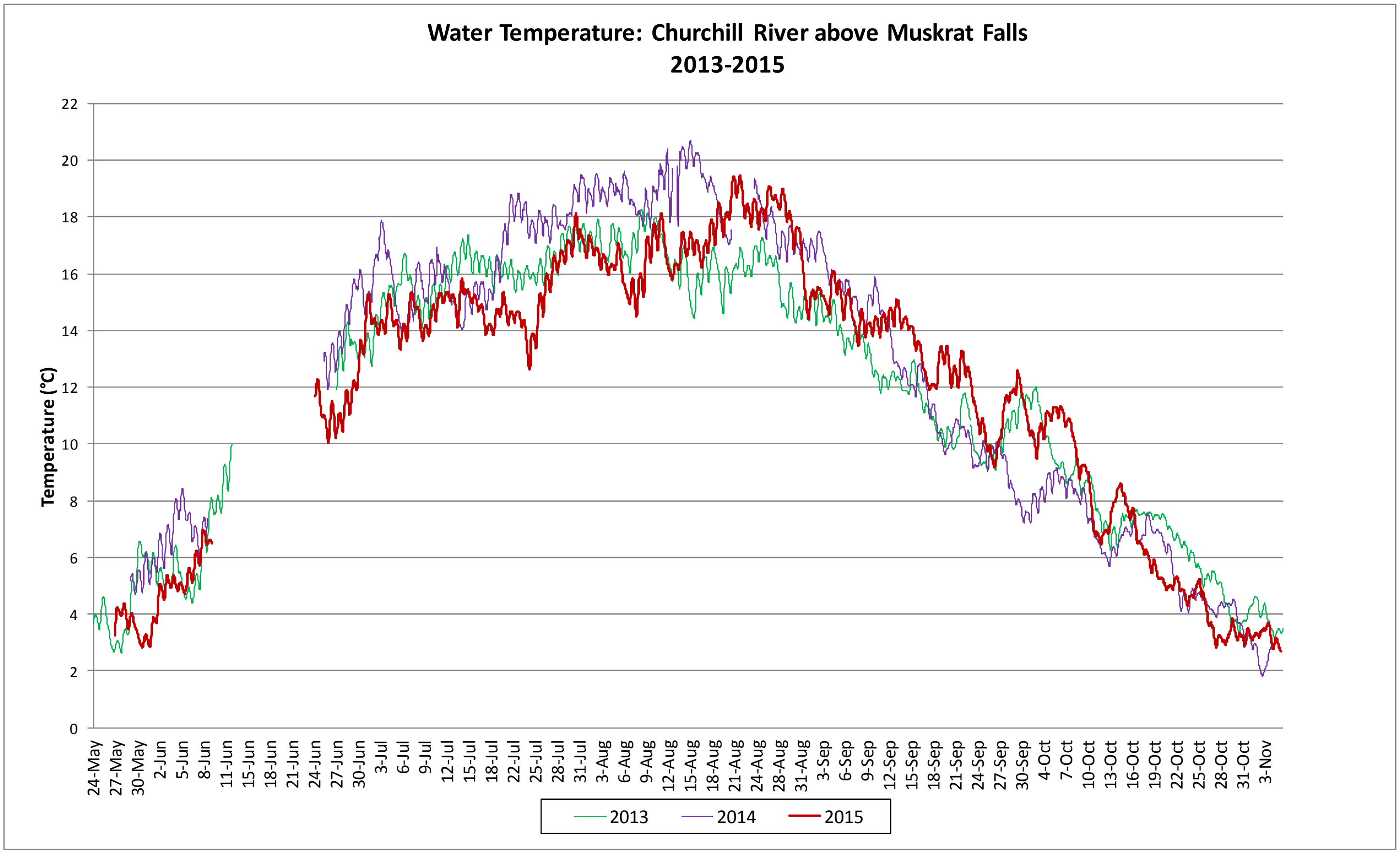


Figure 10: Water temperature at Churchill River above Muskrat Falls

Temperature	2015	2014	2013
Min	2.71	1.81	2.63
Max	19.46	20.68	18.28
Median	13.79	14.29	12.54

- Water temperature values show a typical seasonal trend (Figure 11). Water and air temperatures are increasing throughout the spring and early summer with water temperatures peaking in mid-August. Average air and water temperatures decrease throughout the late summer and into fall.

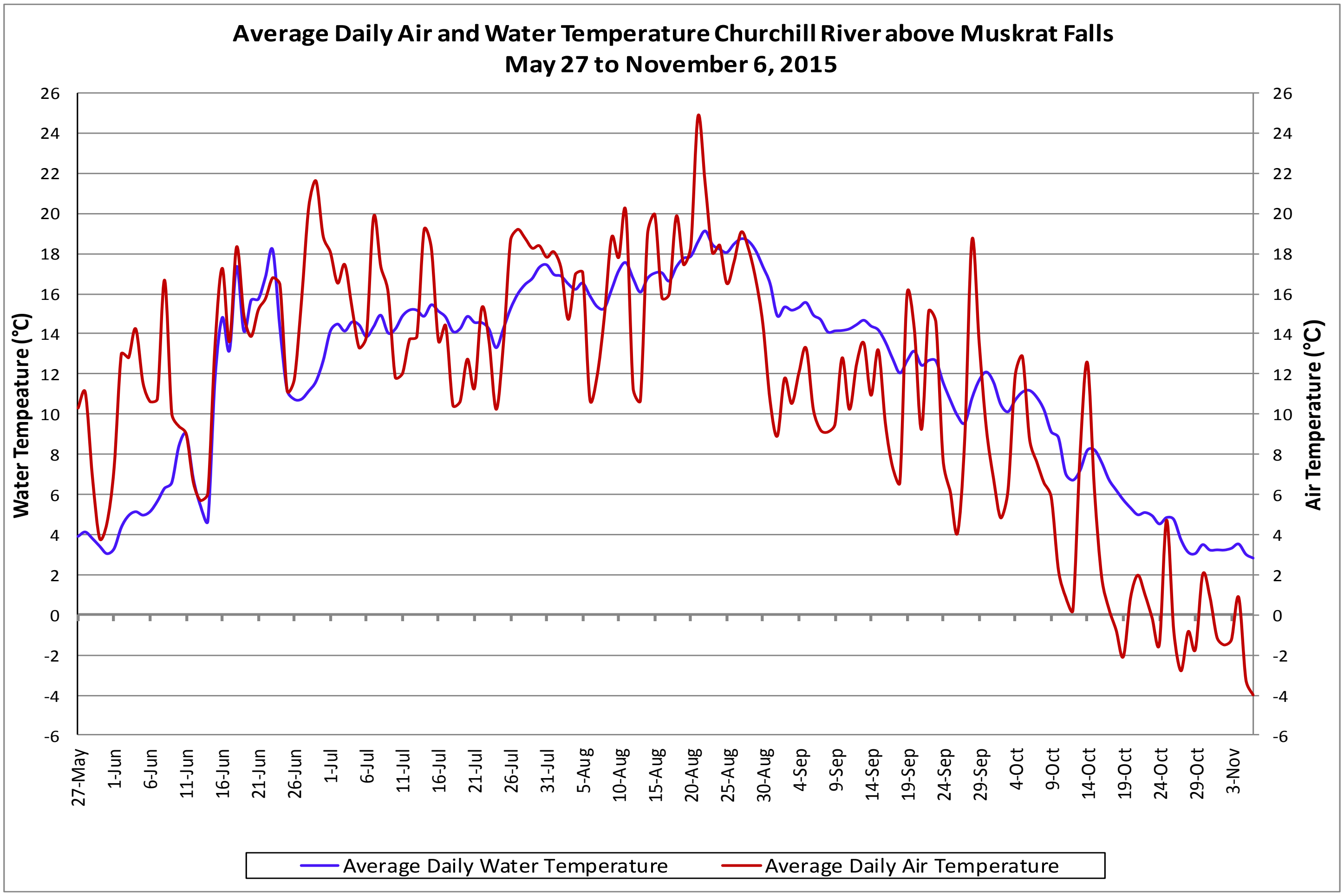


Figure 11: Average daily air and water temperatures at Churchill River above Muskrat Falls (weather data recorded at Muskrat Falls)

- pH ranges between 6.54 and 7.19 pH units during the 2015 deployment season, with a median value of 7.00 pH units (Figure 12).
- pH values increased throughout the spring and early summer before leveling off in August. Values then decrease slightly into the fall months.
- All values during the 2015 deployment season are within the CCME Guidelines for the Protection of Aquatic Life (>6.5 and <9.0 pH units) pH values are comparable to data collected in years previous.

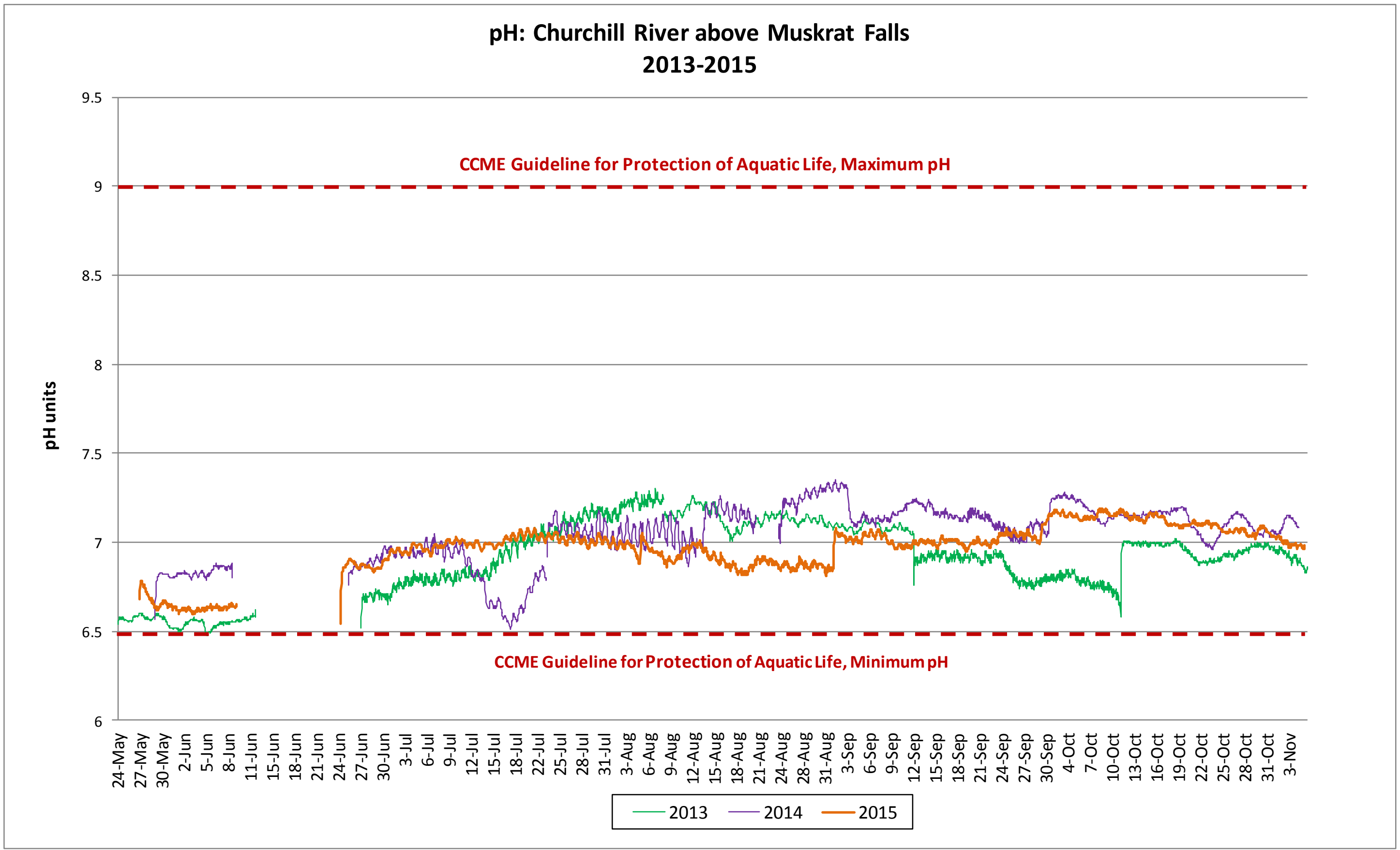


Figure 12: pH at Churchill River above Muskrat Falls

pH (units)	2015	2014	2013
Min	6.54	6.51	6.48
Max	7.19	7.35	7.3
Median	7.00	7.09	6.94

- Specific conductivity ranges from 8.3µS/cm to 21.4µS/cm during the 2015 deployment season, with a median value of 17.8µS/cm (Figure 13).
- Specific conductivity is increasing throughout the spring and most of the summer before gradually decreasing again from late August into the fall months. Generally, specific conductivity does not vary greatly in the Lower Churchill River.
- Increases and decreases in specific conductivity are most times clearly related to fluctuations in stage. As stage decreases, specific conductivity usually increases as the concentration of dissolved solids increases. Inversely, when stage increases, specific conductivity generally decreases due to the dilution of dissolved solids in the water column.
- Data collected in 2013-2014 is similar in trend, but 2015 values are slightly lower than the previous two years, with the lowest median value of the three years of the data.

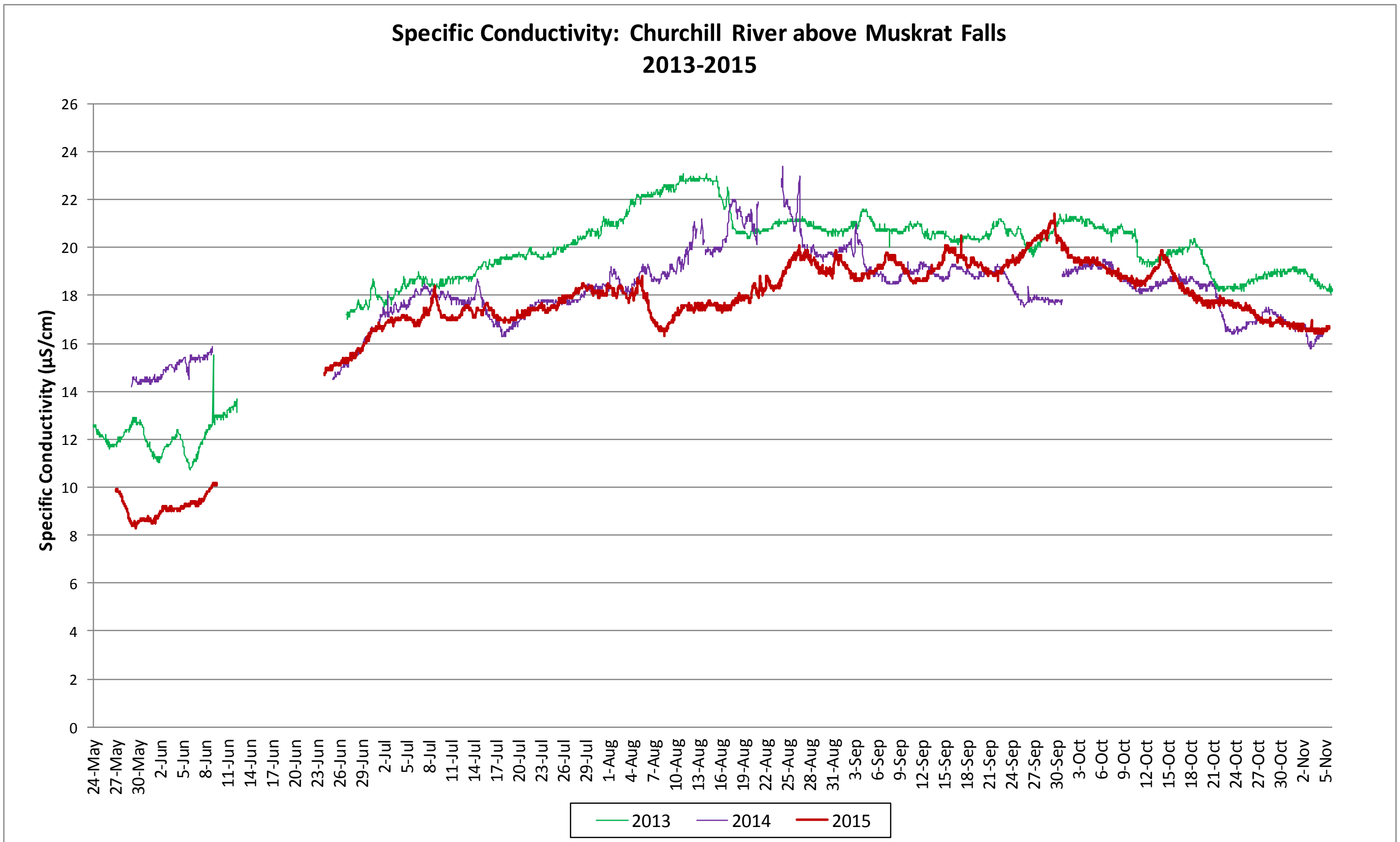


Figure 13: Specific conductivity at Churchill River above Muskrat Falls

Specific Conductivity (µS/cm)	2015	2014	2013
Min	8.3	14.2	10.7
Max	21.4	23.4	23.1
Median	17.8	18.3	20.1

- Throughout the 2015 deployment season, dissolved oxygen ranges from 9.04mg/l to 12.77mg/l, with a median value of 10.24mg/L, while percent saturation ranges from 92.9% to 103.2%, with a median value of 97.2% (Figure 14).
- Dissolved oxygen content shows a typical seasonal fluctuation in 2015 and is similar to data collected in previous years. Dissolved oxygen content fluctuates regularly on a daily basis and is lower during the summer (July-August). This corresponds to warmer temperatures during this time period, which decreases the amount of oxygen present in the water. Percent saturation is consistent throughout the season.
- All values were above the minimum CCME Guideline for the Protection of Cold Water Biota at Other Life Stages (6.5 mg/l). For the months of July and August, dissolved oxygen values hovered around the minimum CCME Guideline for the Protection of Aquatic life at Early Life Stages (9.5mg/l). In early September as air and water temperatures cool, the dissolved oxygen content increases above 9.5mg/l. The guidelines are indicated in red on Figure 14.
- Dissolved oxygen and percent saturation values are similar to data collected in 2013 and 2014.

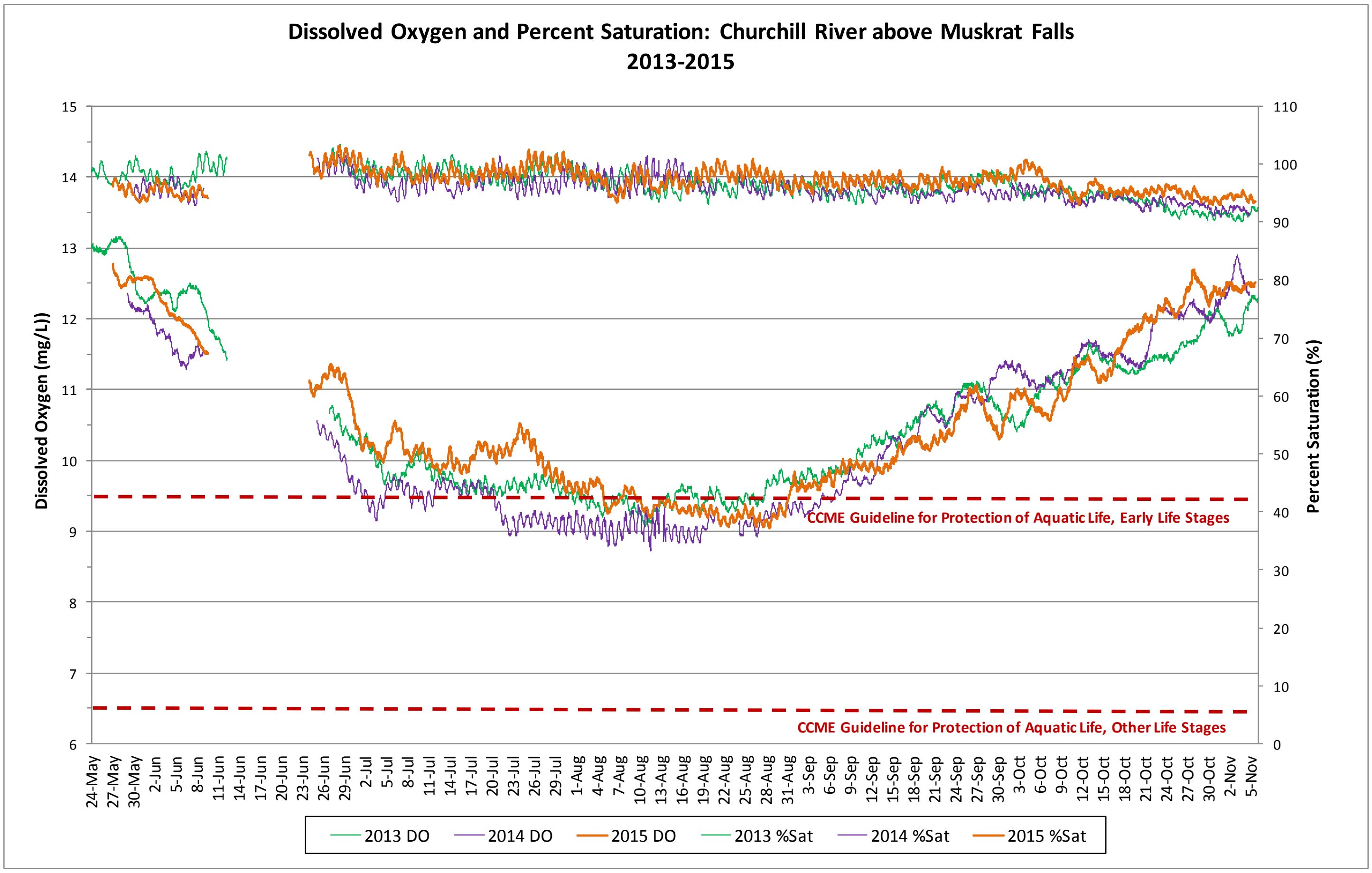


Figure 14: Dissolved oxygen and percent saturation at Churchill River above Muskrat Falls

Dissolved Oxygen (mg/L)	2015	2014	2013		Percent Saturation	2015	2014	2013
Min	9.04	8.73	9.06		Min	92.9	90.8	90
Max	12.77	12.9	13.16		Max	103.2	101.6	103.4
Median	10.24	9.76	10.3		Median	97.2	95.5	96.6

- The majority of turbidity values (95%) were <20.01NTU during the 2015 deployment season (Figure 15 a & b). A median value of 6.3NTU indicates there is a consistent natural background turbidity value at this station. Turbidity values from 2013 to 2015 are depicted in Figures 15 a & b.
- Figure 15a shows data on a scale up to 450NTU. On a number of occasions in 2015, turbidity increased above median background levels for short periods of time throughout the deployment season, to as high as 428NTU. 2015 values are notably higher than those from the previous two years, particularly in late August to September, coinciding with the period of lowest stage levels during the year. Mixing sediment due to low water levels may have contributed to high values during this time.
- Figure 15b shows data at a smaller scale, focusing on the regular consistent background levels, below 50NTU. In the 2015 season, the median value was calculated to be 6.3NTU and the 95th percentile value was 20.01NTU. When data from all years is combined (2013 to 2015), the median value decreases to 5.7NTU and the 95th percentile is 37.6NTU.

Turbidity (NTU)	2015	2014	2013	2013-15
Min	0.3	0	0	0
Max	428	258.7	54.3	428
Median	6.3	9	1.3	5.7
95%	20.01	58.1	14.6	37.6
75%	10.5	23.4	5.2	11.3

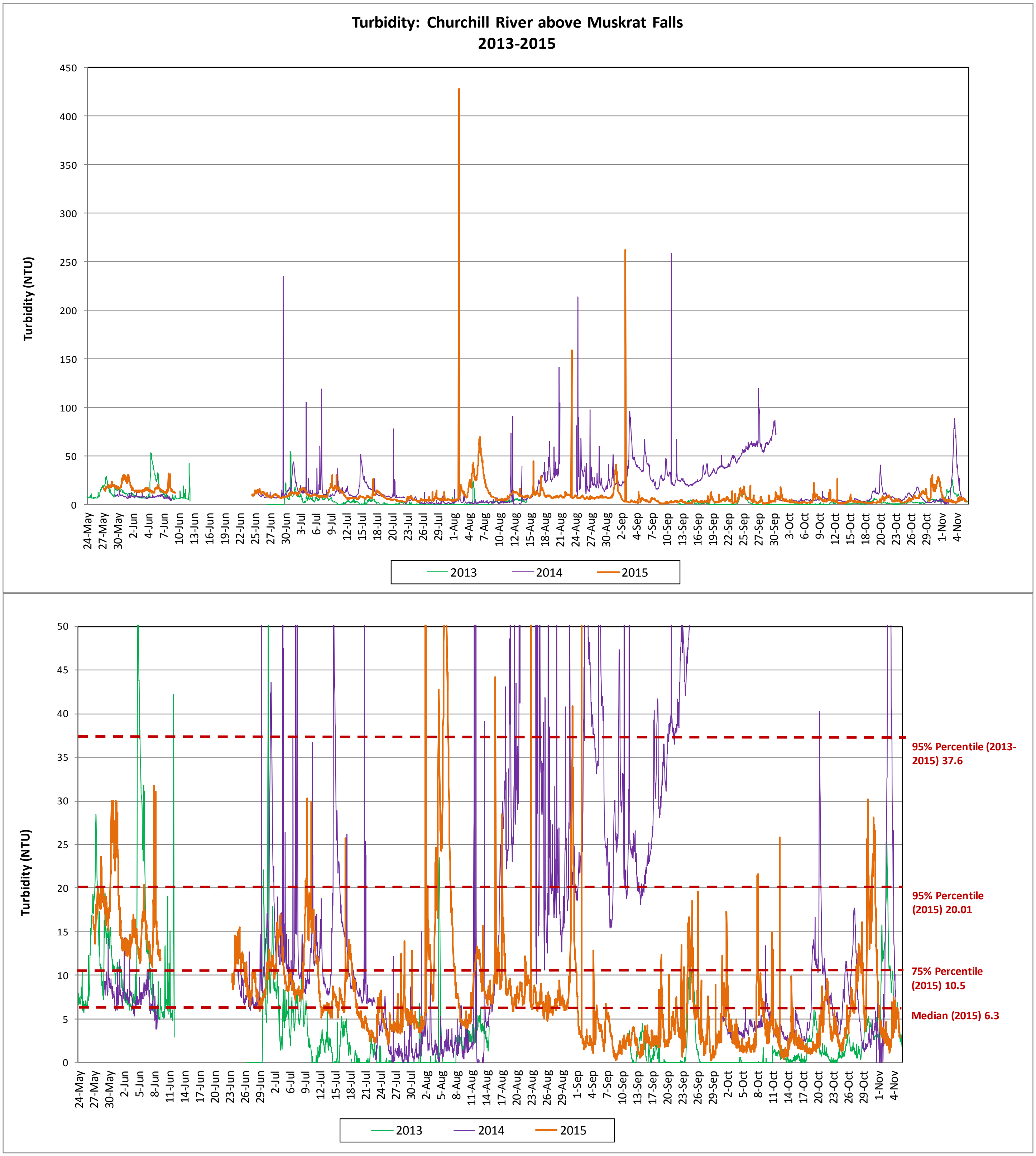


Figure 15a (top): Turbidity to 450NTU at Churchill River above Muskrat Falls
Figure 15b (bottom): Turbidity to 50NTU at Churchill River above Muskrat Falls

- Stage levels in 2015 decrease in the spring and summer months reaching a seasonal low in late September before increasing again into the fall months (Figure 16).
- Stage levels from 2013-2015 are graphed below to show how stage levels vary throughout the season and from year to year. The 2015 seasonal low was reached much later in the season than in 2013 and later than 2014. Stage ranges between 2.63m and 3.94m each year.
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

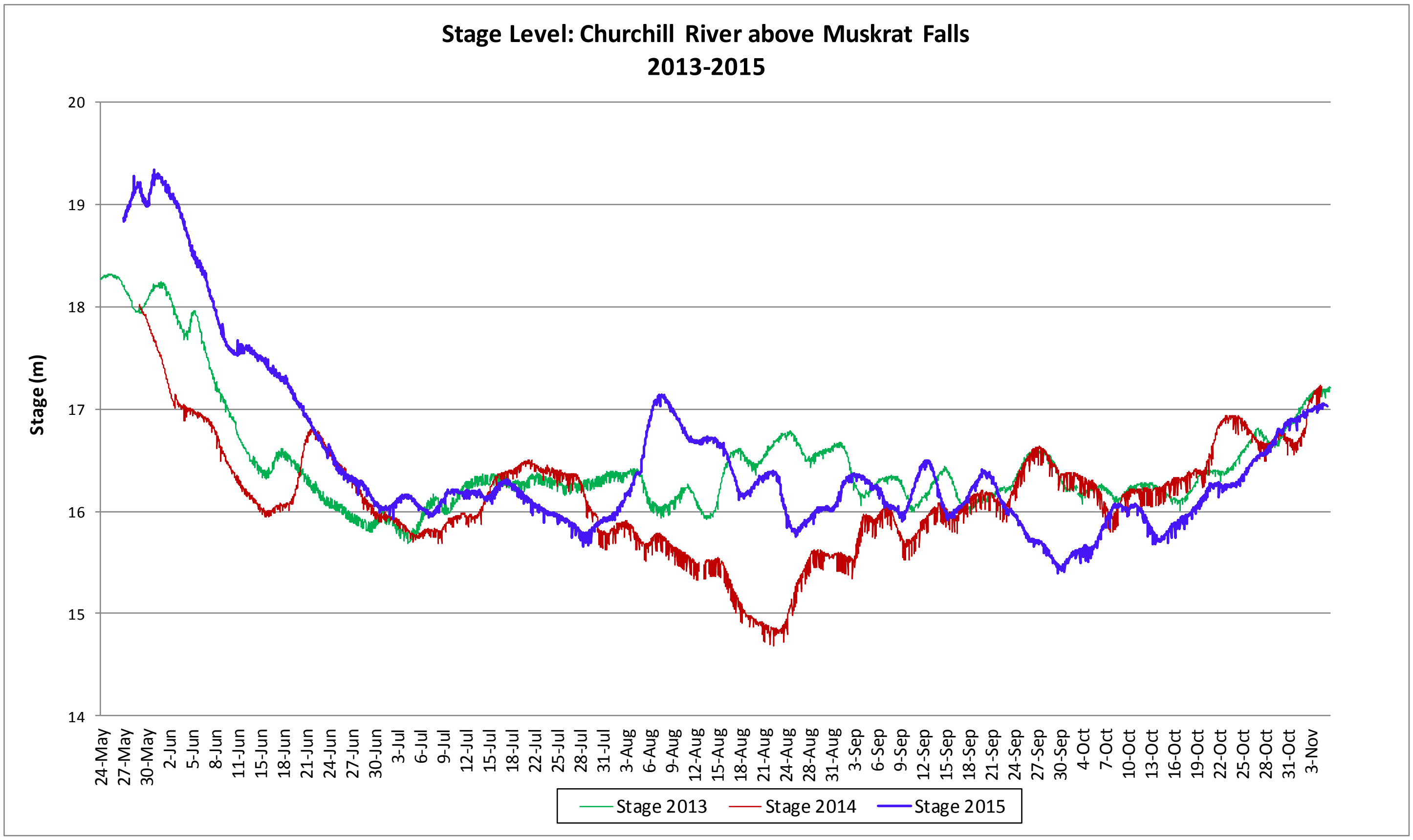


Figure 16: Daily stage level at Churchill River above Muskrat Falls

Stage (m)	2015	2014	2013
Min	15.041	14.685	15.69
Max	19.339	18.021	18.232
Median	16.217	16.12	16.314
Range	3.938	3.336	2.633

- Stage and precipitation are graphed below to show the relationship between rainfall and water level (Figure 17).
- Stage is generally decreasing in the first half of the deployment season, reaching a low in late September before increasing steadily into the fall months.
- Precipitation events are frequent and range from low to high in magnitude.
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

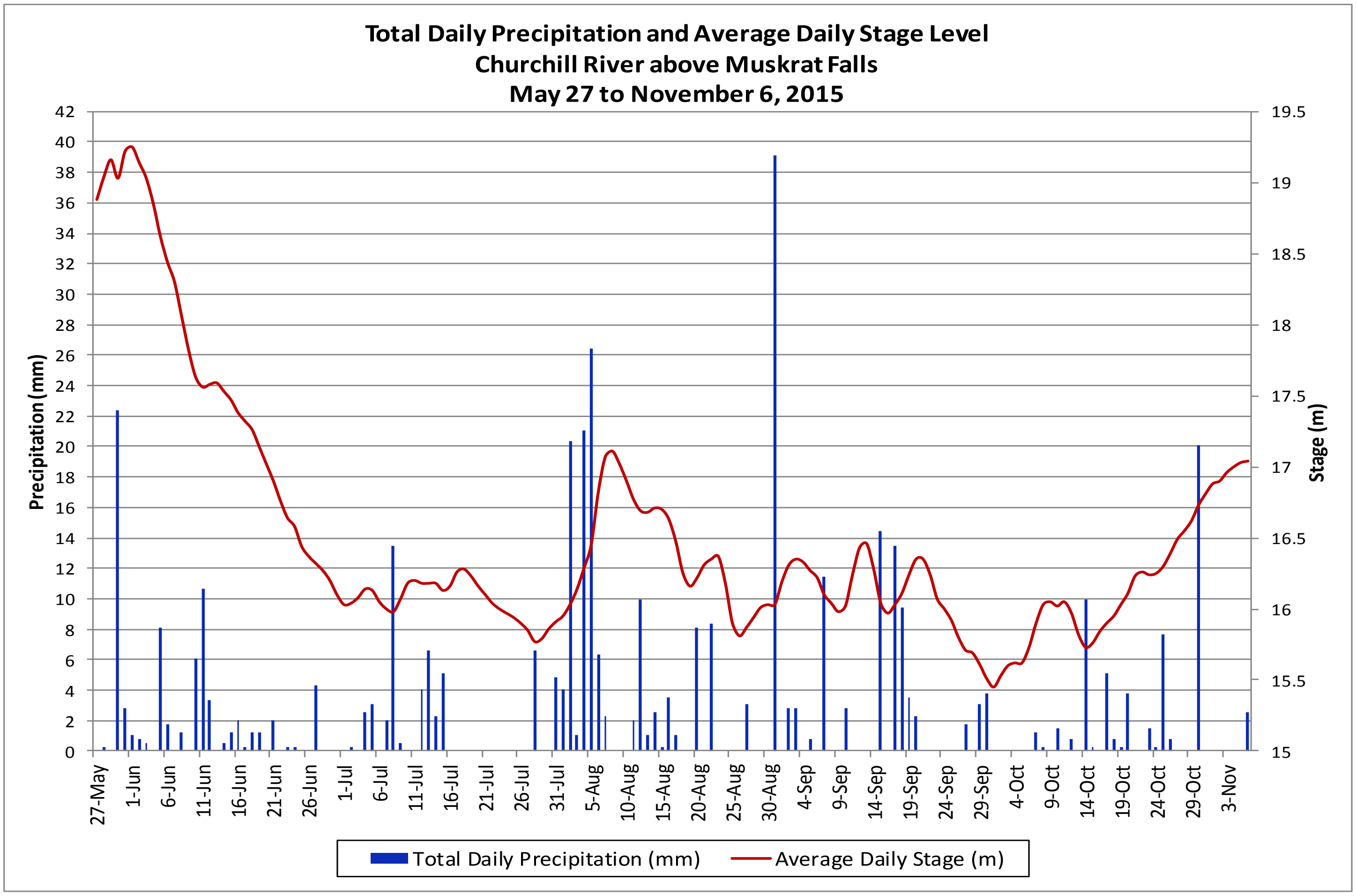


Figure 17: Daily precipitation and average daily stage level at Churchill River above Muskrat Falls (weather data recorded at Muskrat Falls)

Churchill River below Muskrat Falls

- Over the past couple deployment seasons the below Muskrat Falls station has been experiencing sediment issues. The riverbed and shoreline significantly changed from a rocky composition to mainly sand which ended up burying the instrument and causing damage to the sensors. In addition, in the winter of 2014 large amounts of ice shifted the helicopter landing pad and hut.
- Subsequent deployment trips were able to avail of the shifting sand which had created a 'beach area', allowing the helicopter to land at the water's edge When the instrument was not deployed a grab sample was taken instead at the location to provide some information in the data gap period.
- The instrument was not redeployed from August 2014 until September 2015 when the shoreline saw a reappearance of a rocky substrate which is more ideal for deployment of the instrument.
- The photos below show the extent of the sand that accumulated at the below Muskrat Falls station between 2013 and 2015 (Figure 18-25).

Figure 18: 2013

Figure 19: June 2014

Figure 20: August 2014

Figure 21: August 2014

Figure 22: October 2014

Figure 23: November 2014

Figure 24: May 2015

Figure 25: September 2015

- Significant amounts of data are missing from the 2014 and 2015 season due to sediment conditions at the station below Muskrat Falls.
- Fall temperatures at this station are slightly lower than in 2013 (Figure 26).

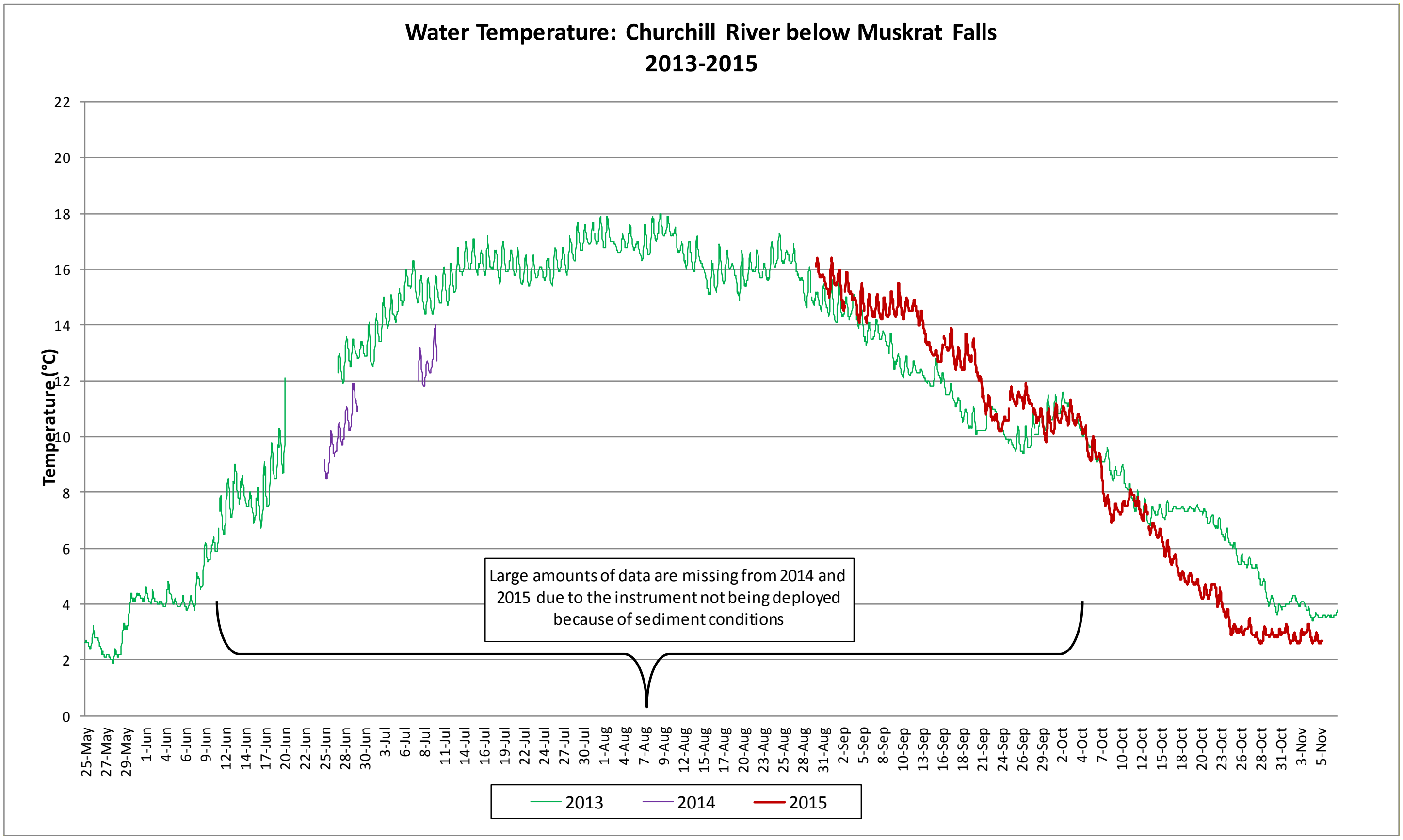


Figure 26: Water temperature at Churchill River below Muskrat Falls

Temperature	*2015	*2014	2013
Min	2.6	8.5	1.9
Max	16.4	14	18
Median	10.4	10.9	12

***data set not complete cannot be compared to previous years**

- Significant amounts of data are missing from the 2015 season due to sediment conditions at the station below Muskrat Falls.
- Water temperature values that were recorded show a typical seasonal trend (Figure 27). Average air and water temperatures decrease throughout the late summer and into fall.

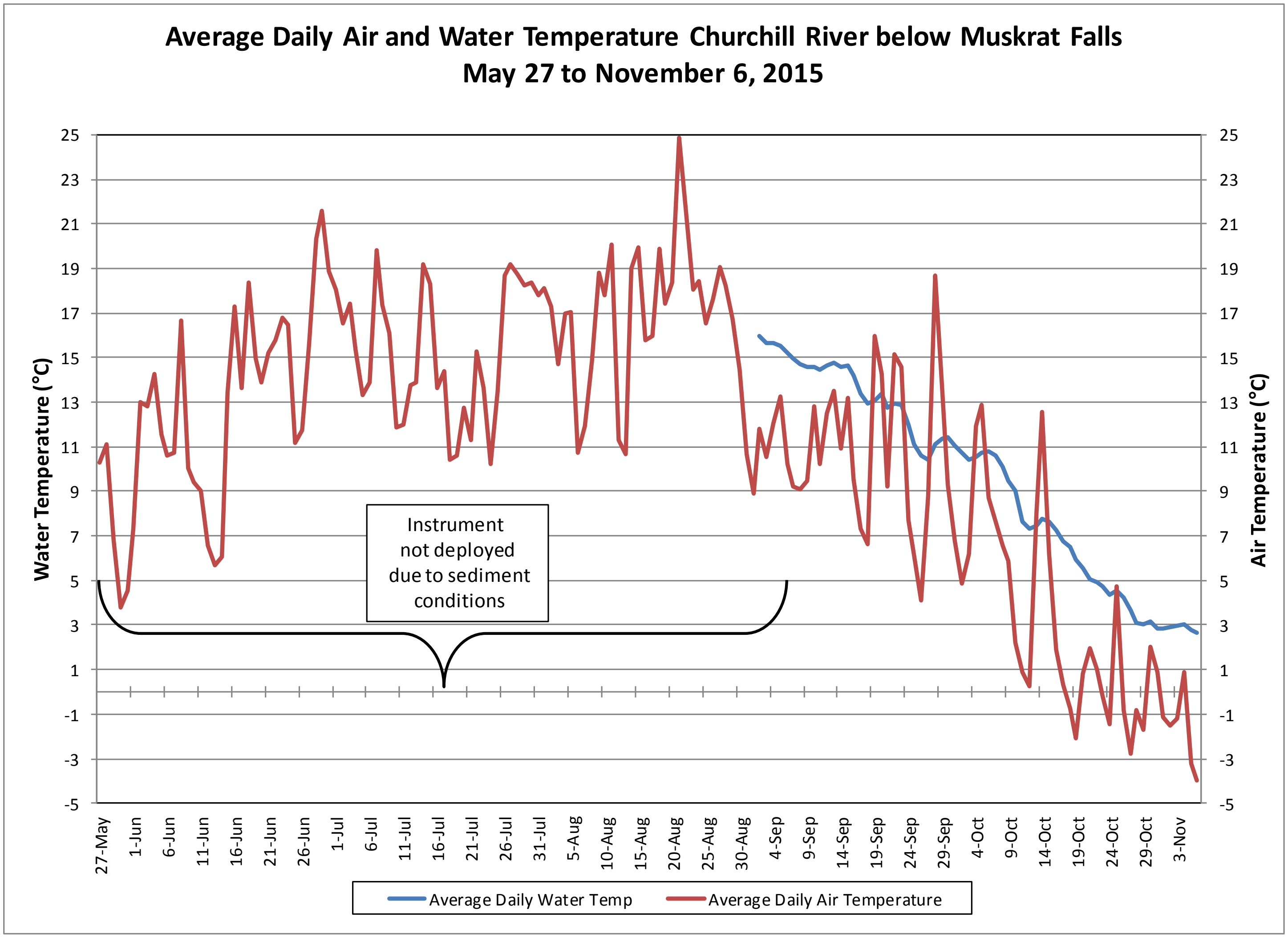


Figure 27: Average daily air and water temperatures at Churchill River below Muskrat Falls (weather data recorded at Muskrat Falls)

- Significant amounts of data are missing from the 2014 and 2015 season due to sediment conditions at the station below Muskrat Falls (Figure 28).
- All values recorded during the 2015 deployment season are within the CCME Guidelines for the Protection of Aquatic Life (>6.5 and <9.0 pH units).

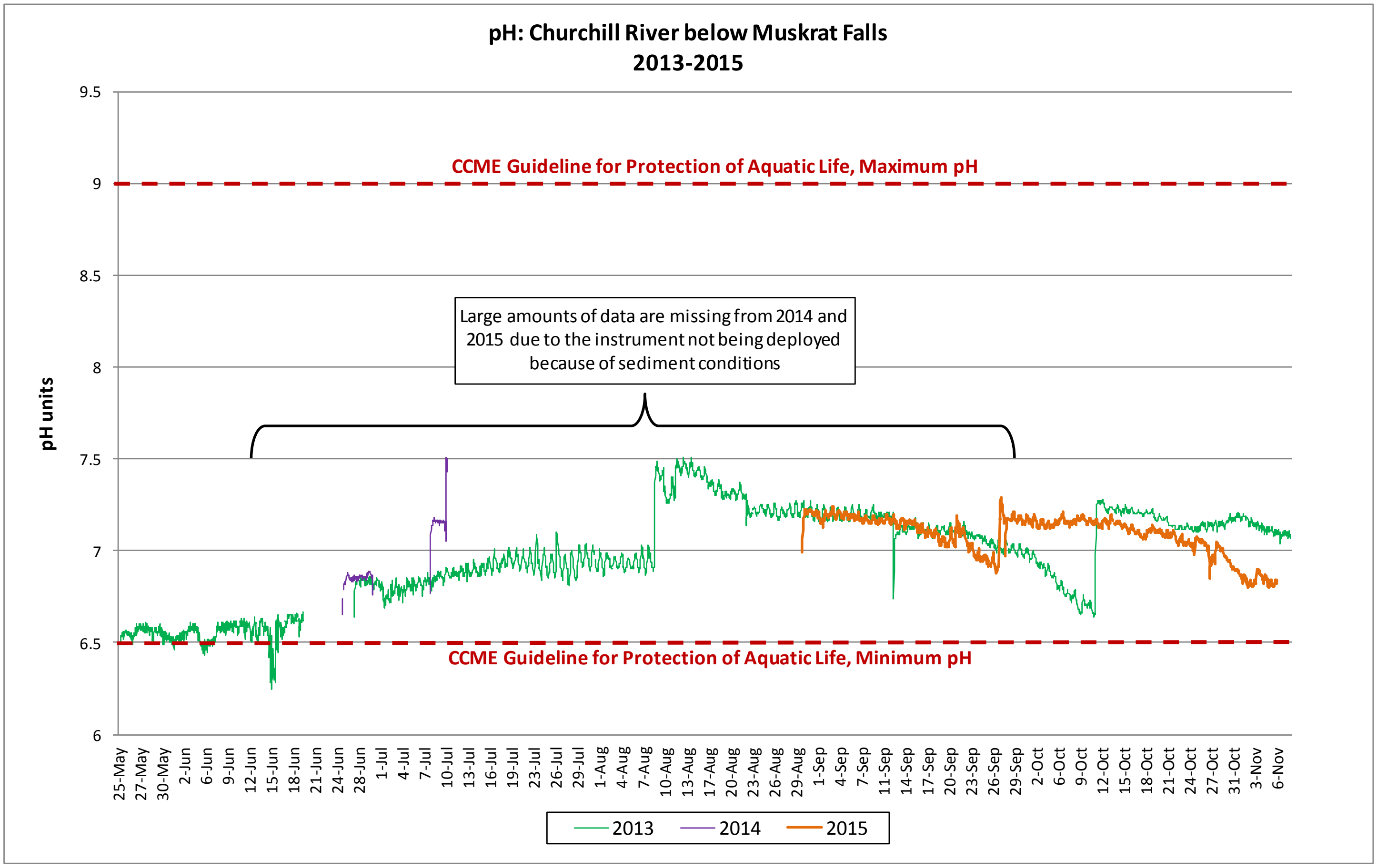


Figure 28: pH at Churchill River below Muskrat Falls

pH (units)	*2015	*2014	2013
Min	6.8	6.65	6.25
Max	7.29	7.51	7.51
Median	7.13	6.87	7.01

***data set not complete cannot be compared to previous years**

- Significant amounts of data are missing from the 2014 and 2015 season due to sediment conditions.at the station below Muskrat Falls (Figure 29)

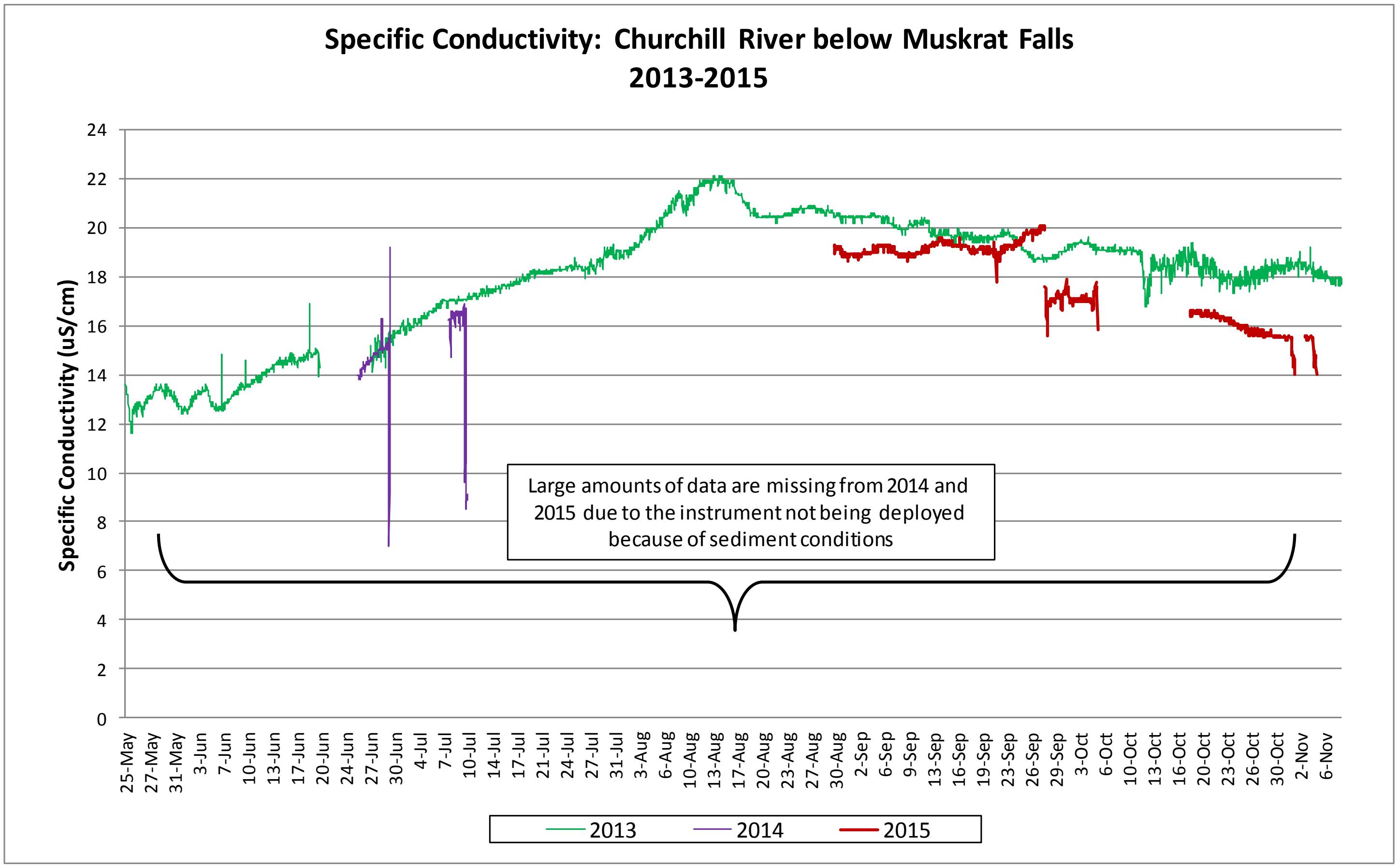


Figure 29: Specific conductivity at Churchill River below Muskrat Falls

Specific Conductivity (µS/cm)	*2015	*2014	2013
Min	14	7	11.6
Max	20.1	19.2	22.1
Median	18.9	15	18.6

***data set not complete cannot be compared to previous years**

- Significant amounts of data are missing from the 2014 and 2015 season due to sediment conditions at the station below Muskrat Falls (Figure 30).
- For the dissolved oxygen content that was recorded in 2015 a typical seasonal fluctuation is displayed. Dissolved oxygen content fluctuates regularly on a daily basis. Percent saturation is generally consistent throughout the deployment season.

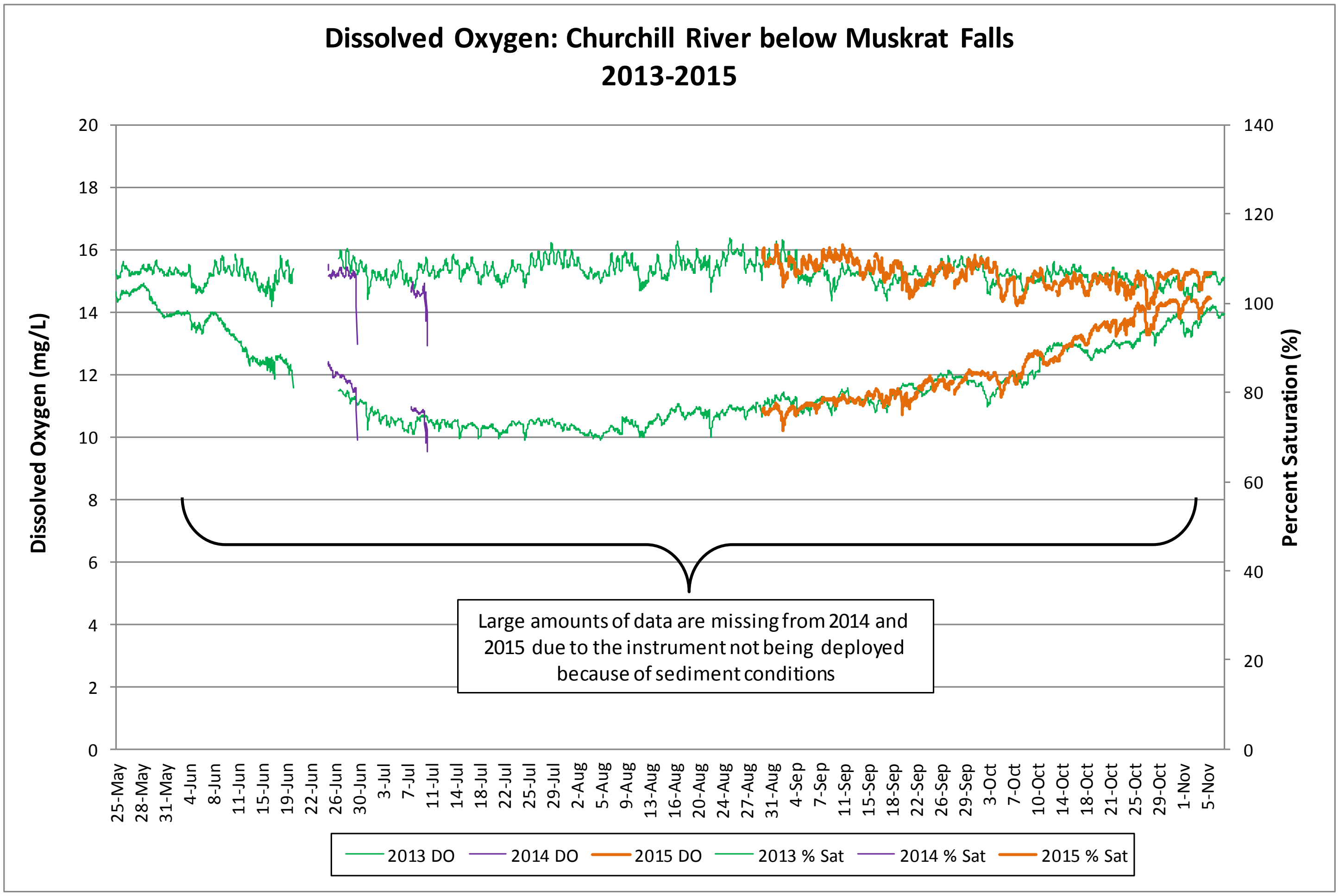


Figure 30: Dissolved oxygen and percent saturation at Churchill River below Grizzle Rapids

Dissolved Oxygen (mg/L)	*2015	*2014	2013		Percent Saturation	*2015	*2014	2013
Min	10.21	9.51	9.9		Min	98.6	90.5	99.1
Max	14.46	12.39	14.9		Max	113.2	108.7	114.6
Median	1192	11.71	11.28		Median	106.4	106	106.8

***data set not complete cannot be compared to previous years**

- Significant amounts of data are missing from the 2014 and 2015 season due to sediment conditions at the station below Muskrat Falls (Figure 31).
- The moving sand conditions may impact the turbidity sensor thus causing variability in the data.

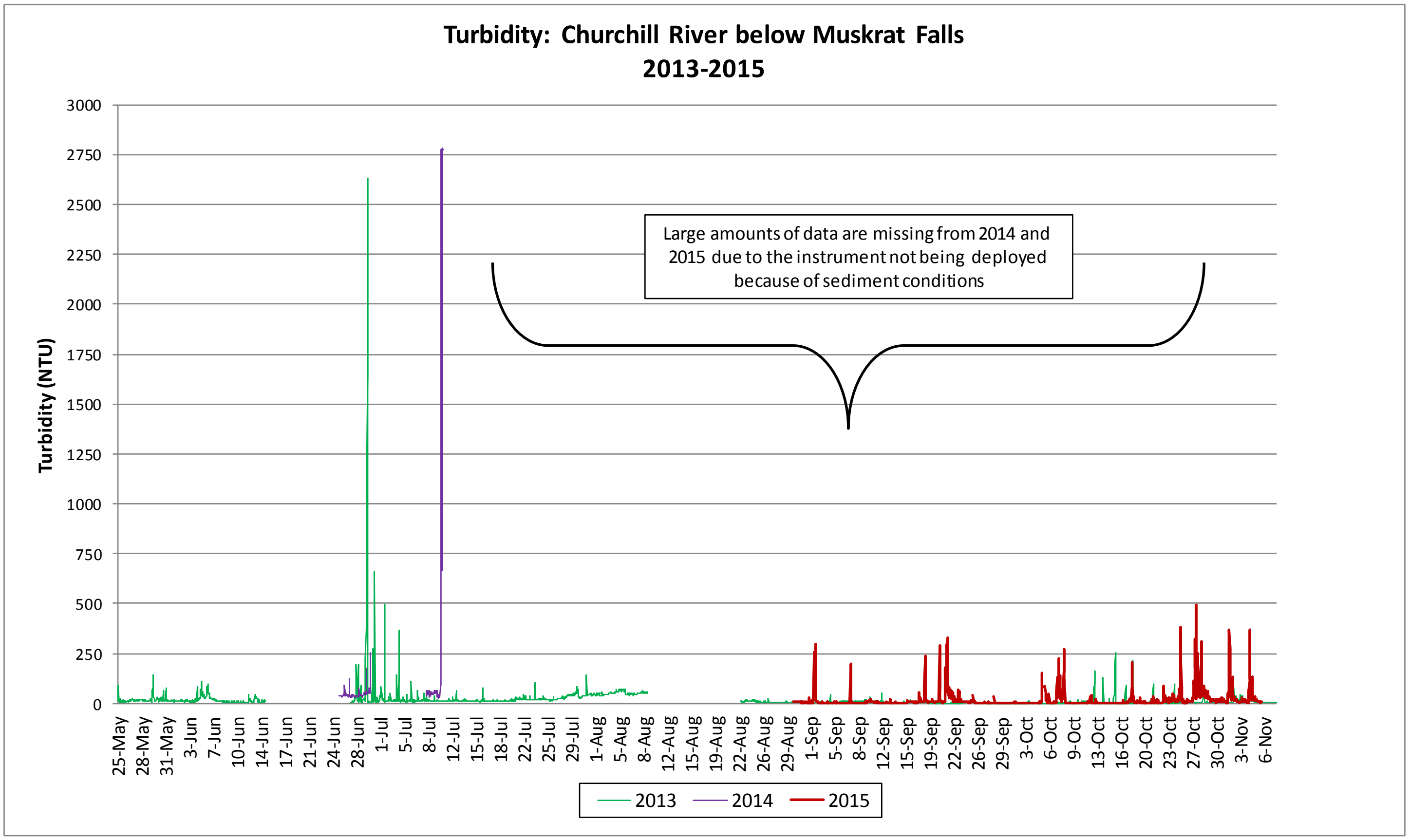


Figure 31: Turbidity at Churchill River below Muskrat Falls

Turbidity (NTU)	*2015	*2014	2013	2013-15
Min	0	27	0	0
Max	492	2784	2631	2784
Median	4.9	43.4	8.4	7.4
95%	66.99	2470.6	50.65	54.9
75%	9.1	50.1	14.7	15.4

***data set not complete cannot be compared to previous years**

- Stage levels from 2013-2015 are graphed below to show how stage levels vary throughout the season and from year to year (Figure 32). The seasonal low was reached later in the season in 2015 when compared to 2013 and 2014. Stage ranges between 1.611 m and 2.415 m each year.
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

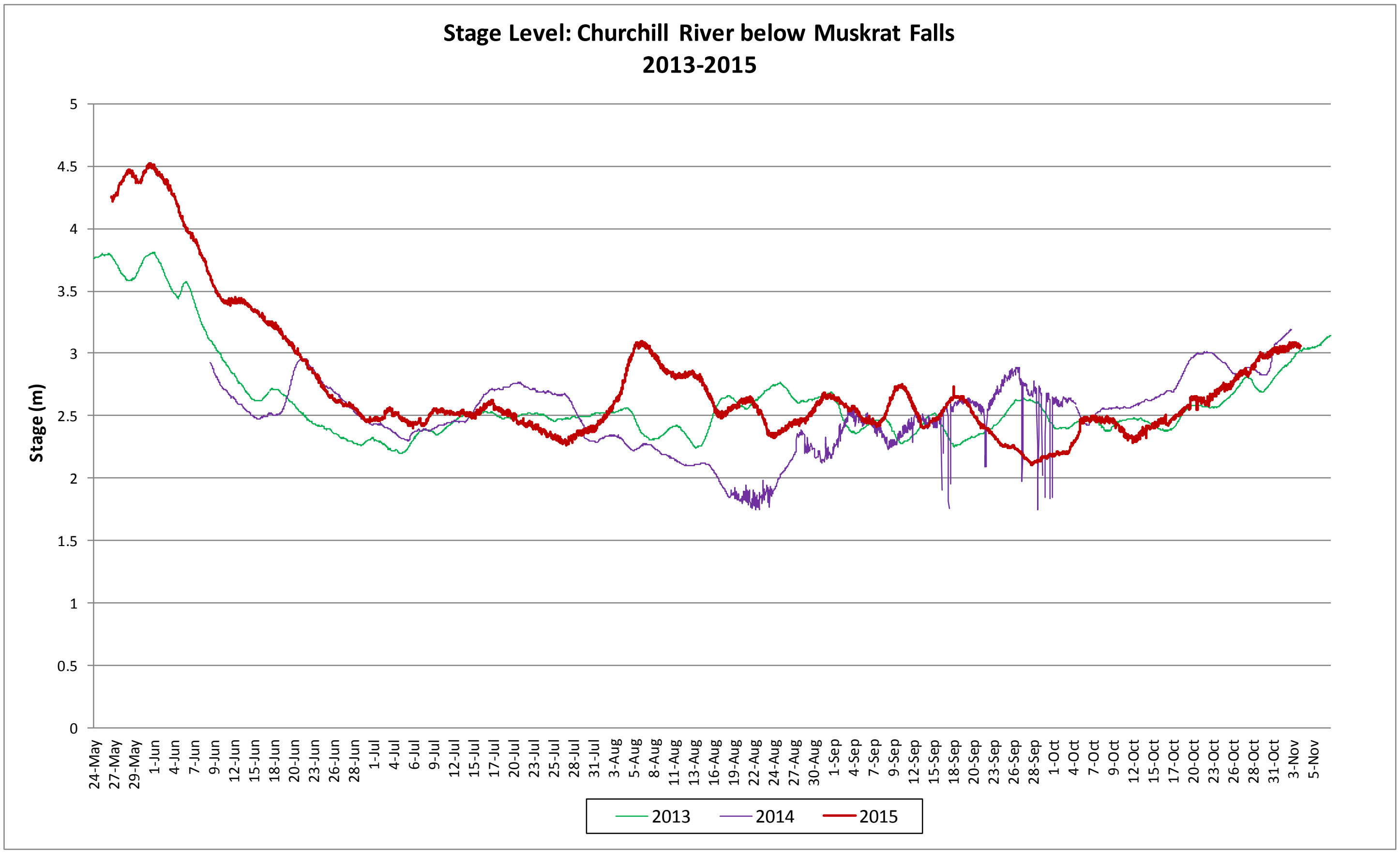


Figure 32: Stage level at Churchill River below Muskrat Falls

Stage (m)	2015	2014	2013
Min	2.106	0.955	2.198
Max	4.521	3.193	3.809
Median	2.567	2.485	2.51
Range	2.415	2.238	1.611

- Stage and precipitation are graphed below to show the relationship between rainfall and water level (Figure 33).
- Stage is generally decreasing June-August, with increases occurring after precipitation events. Stage reaches a low in late September before gradually increasing into the fall months. Fluctuations in stage levels are associated with precipitation events.
- Precipitation events are frequent and range from low to high in magnitude.
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

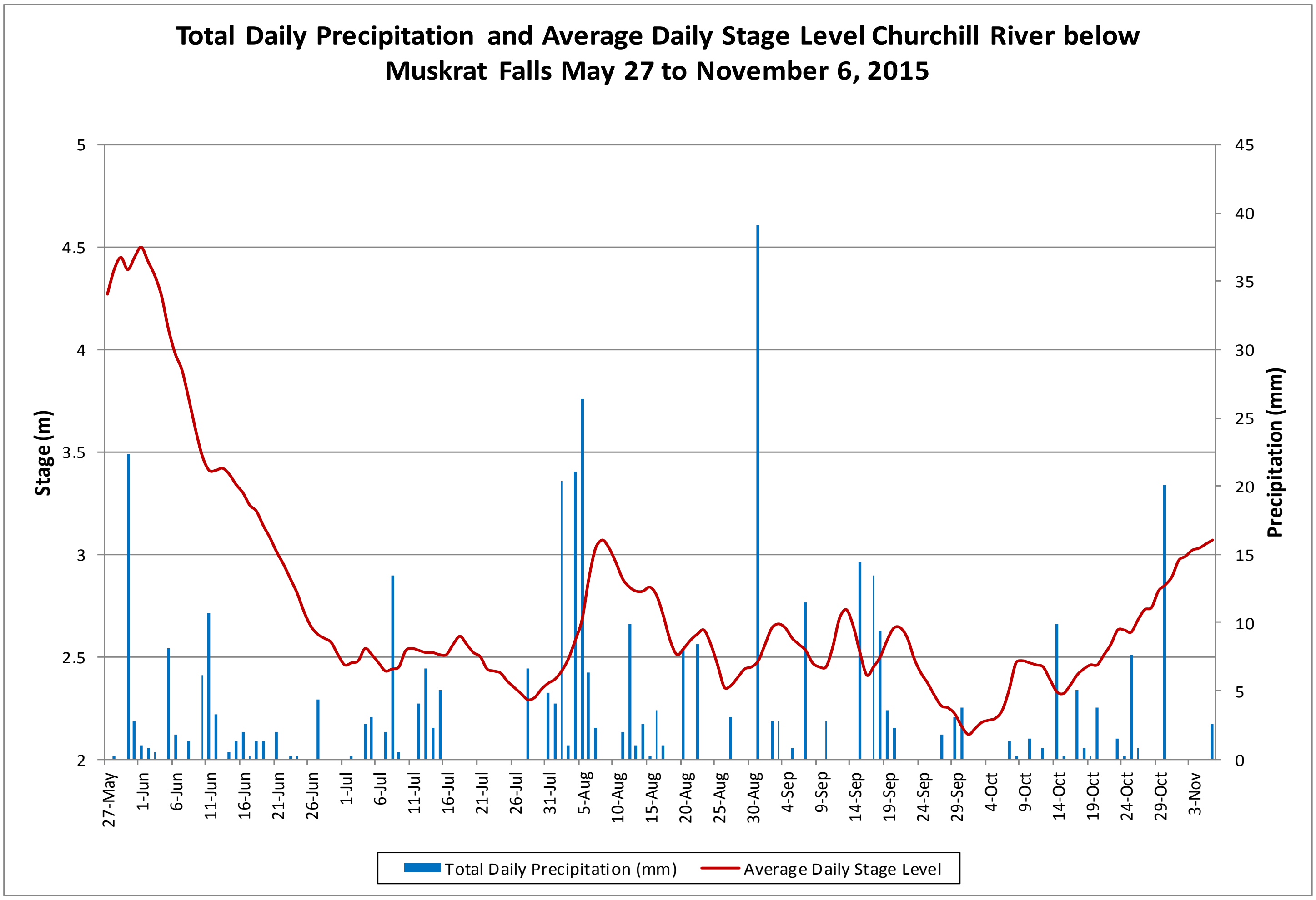


Figure 33: Daily precipitation and average daily stage level at Churchill River below Muskrat Falls (weather data recorded at Muskrat Falls)

Churchill River at English Point

- Water temperature ranges from 1.50°C to 20.20°C during the 2015 deployment season, with a median value of 13.6°C (Figure 34).
- There are greater daily fluctuations at this station due to the influence of the tides in the Atlantic Ocean and Lake Melville.

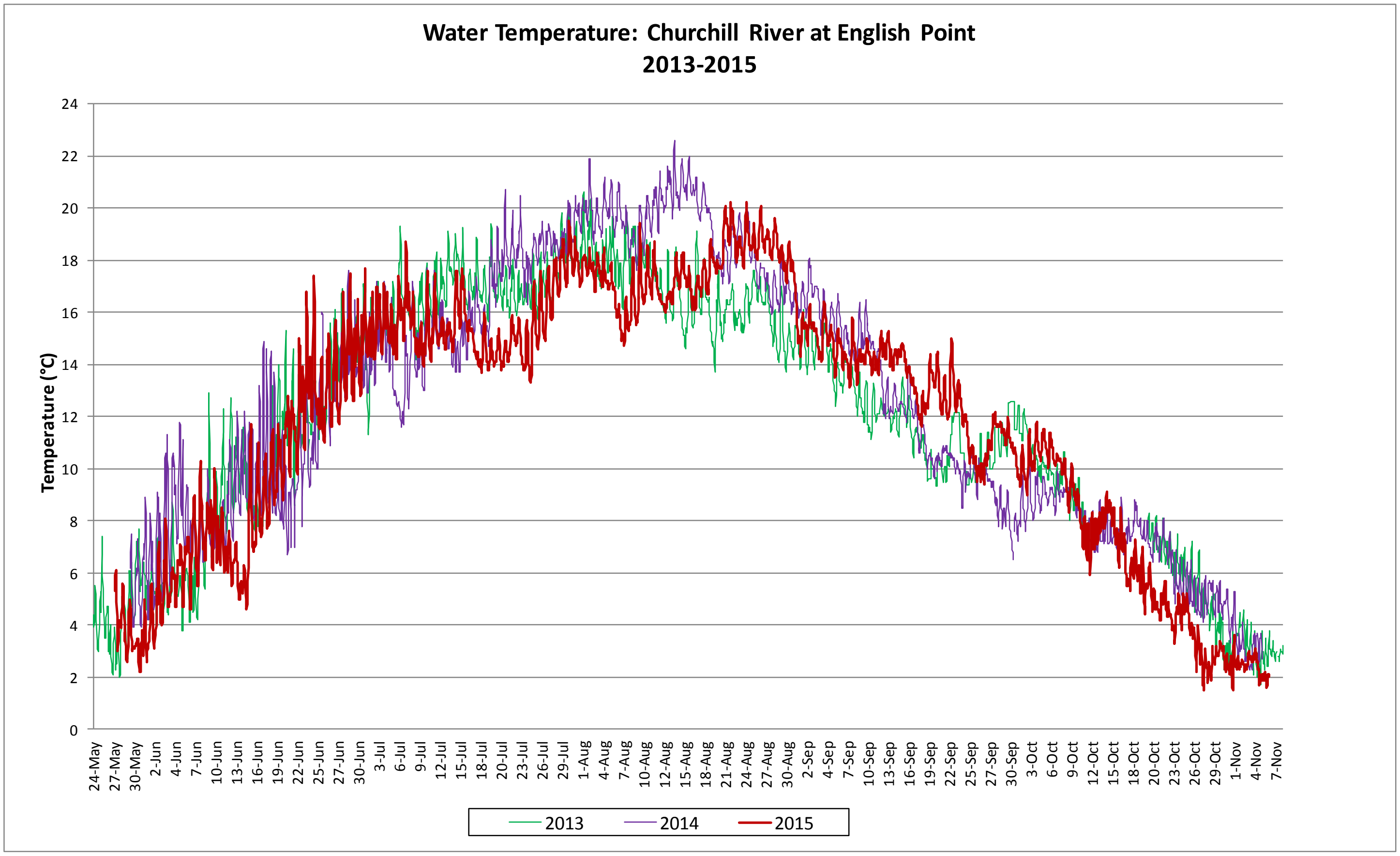


Figure 34: Water temperature at Churchill River at English Point

Temperature	2015	2014	2013
Min	1.50	2.30	1.70
Max	20.20	22.60	20.60
Median	13.60	12.60	12.43

- Water temperature values show a typical seasonal trend (Figure 35). Water and air temperatures are increasing throughout the spring and early summer with water temperatures peaking in mid-August. Average air and water temperatures decrease throughout the late summer and fall.

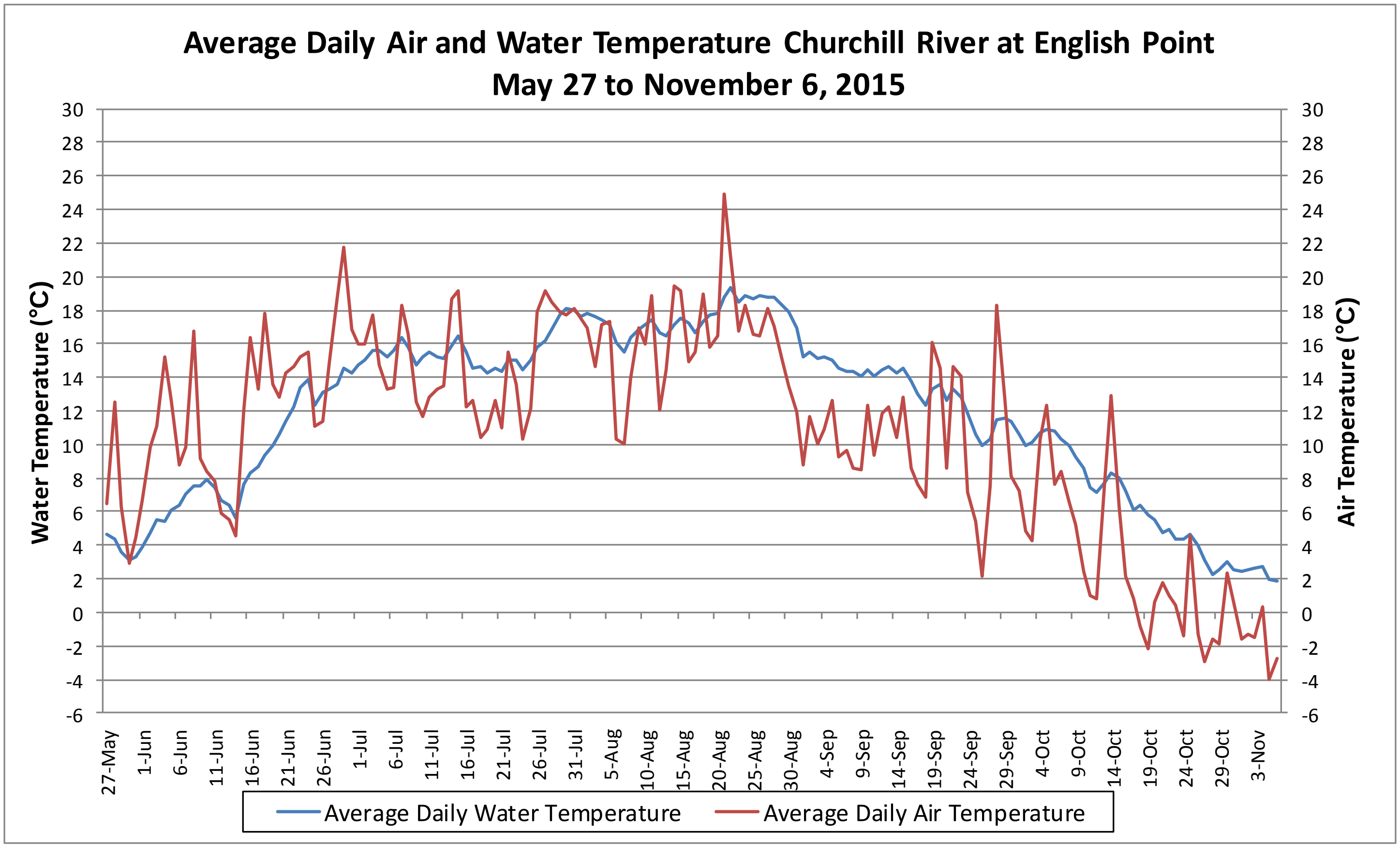


Figure 35: Average daily air and water temperatures at Churchill River at English Point (weather data recorded at Mud Lake)

- pH ranges between 6.09 and 7.43 pH units during the 2015 deployment season, with a median value of 7.00 pH units (Figure 36).
- Most pH values during the 2015 deployment season are within the CCME Guidelines for the Protection of Aquatic Life (>6.5 and <9.0 pH units). pH values drop below this guideline for a period of time in May and June after several large precipitation events. Guidelines are indicated in red on Figure 36.

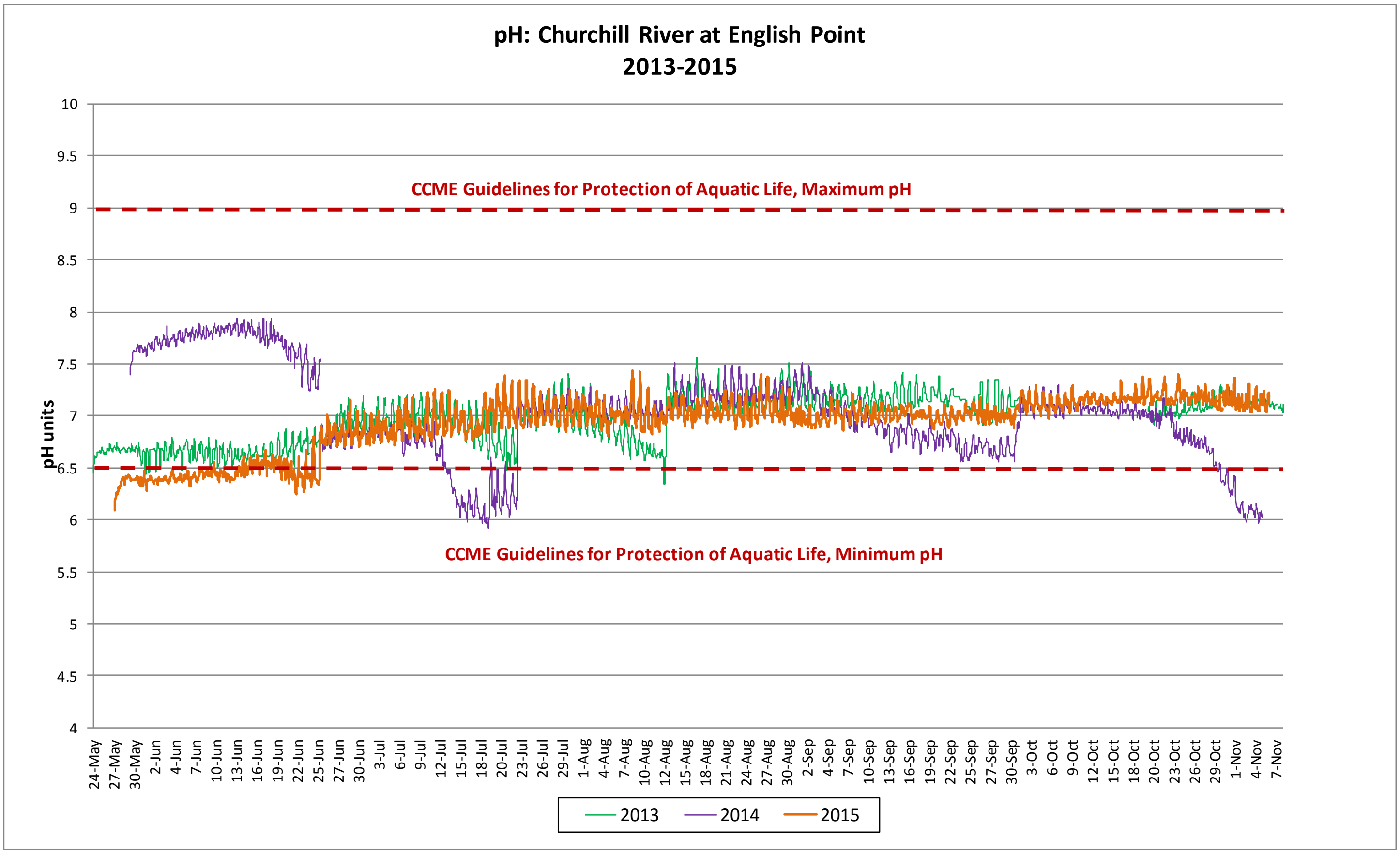


Figure 36: pH at Churchill River at English Point

pH (units)	2015	2014	2013
Min	6.09	5.92	6.34
Max	7.43	7.93	7.56
Median	7.00	7.04	7.03

- Specific conductance ranges between 10.3µS/cm and 59.80µS/cm, with a median value of 29.90µS/cm during the 2015 deployment season (Figure 37).
- Specific conductance is highly variable at this station, fluctuating significantly each day. The consistent fluctuations at this location are due to the tidal influences of the Atlantic Ocean. 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.
- Trends and values from 2013 and 2015 are similar for the same time period.

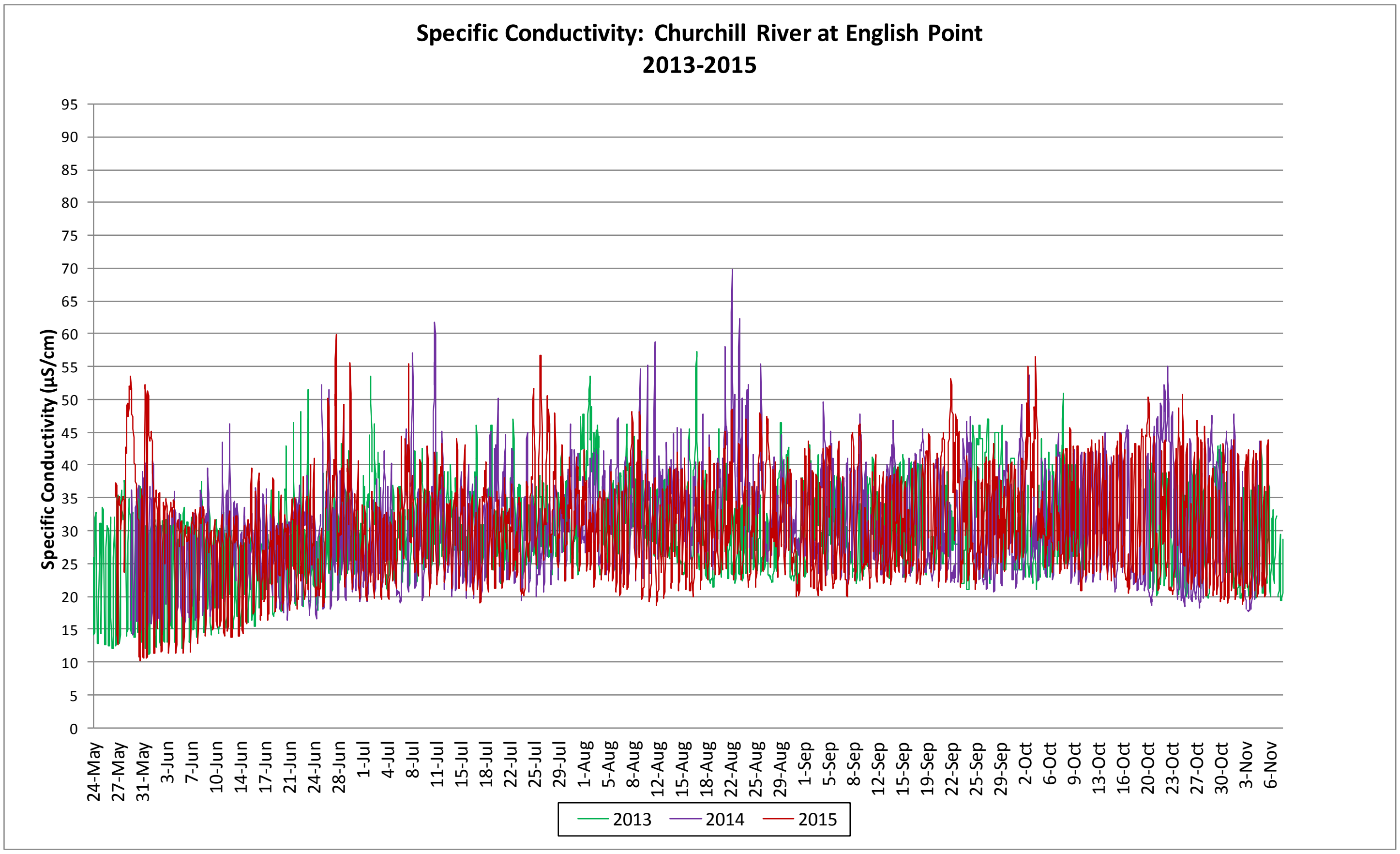


Figure 37: Specific Conductivity at Churchill River at English Point

Specific Conductivity (µS/cm)	2015	2014	2013
Median	10.30	14.10	11.20
Max	59.80	69.70	57.20
Min	29.90	30.60	29.00

- Throughout the 2015 deployment season, dissolved oxygen ranges from 8.48mg/l and 13.66mg/l, with a median value of 10.42mg/l, while percent saturation ranges from 73.80% to 112.60%, with a median value of 99.0% (Figure 38).
- Dissolved oxygen content shows a typical seasonal fluctuation in 2015. Dissolved oxygen content fluctuates considerably on a regular daily basis. Percent saturation is generally consistent throughout the deployment season.
- All values were above the minimum CCME Guideline for the Protection of Cold Water Biota at Other Life Stages (6.5 mg/l). Between late-July and early September, dissolved oxygen content fluctuated above and below the minimum CCME Guideline for the Protection of Aquatic life at Early Life Stages (9.5mg/l). In September, as air and water temperatures cool, the dissolved oxygen content increases above 9.5mg/l. The guidelines are indicated in red on Figure 38.
- Dissolved oxygen and percent saturation values were very similar to the data collected in 2013 and 2014.

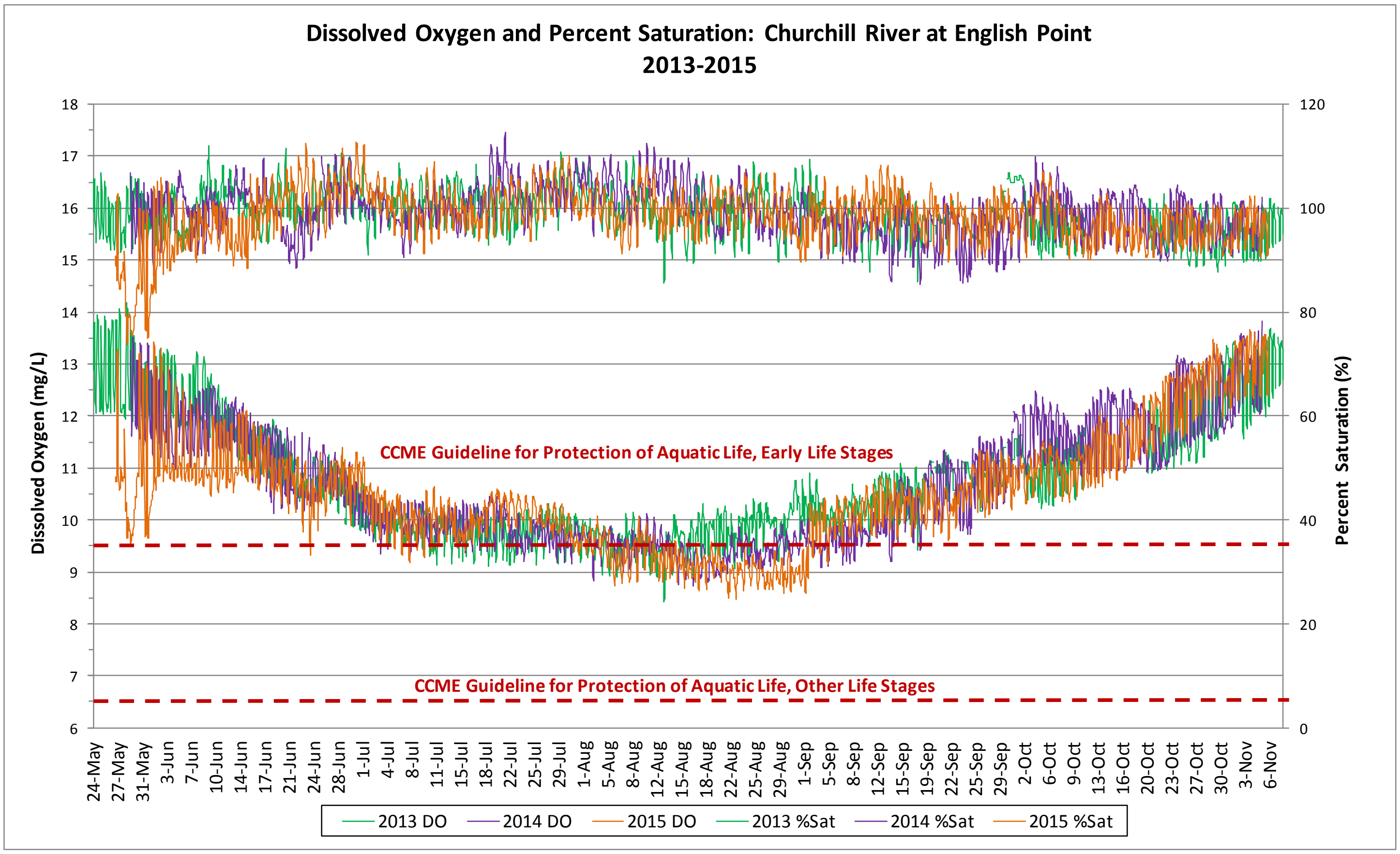
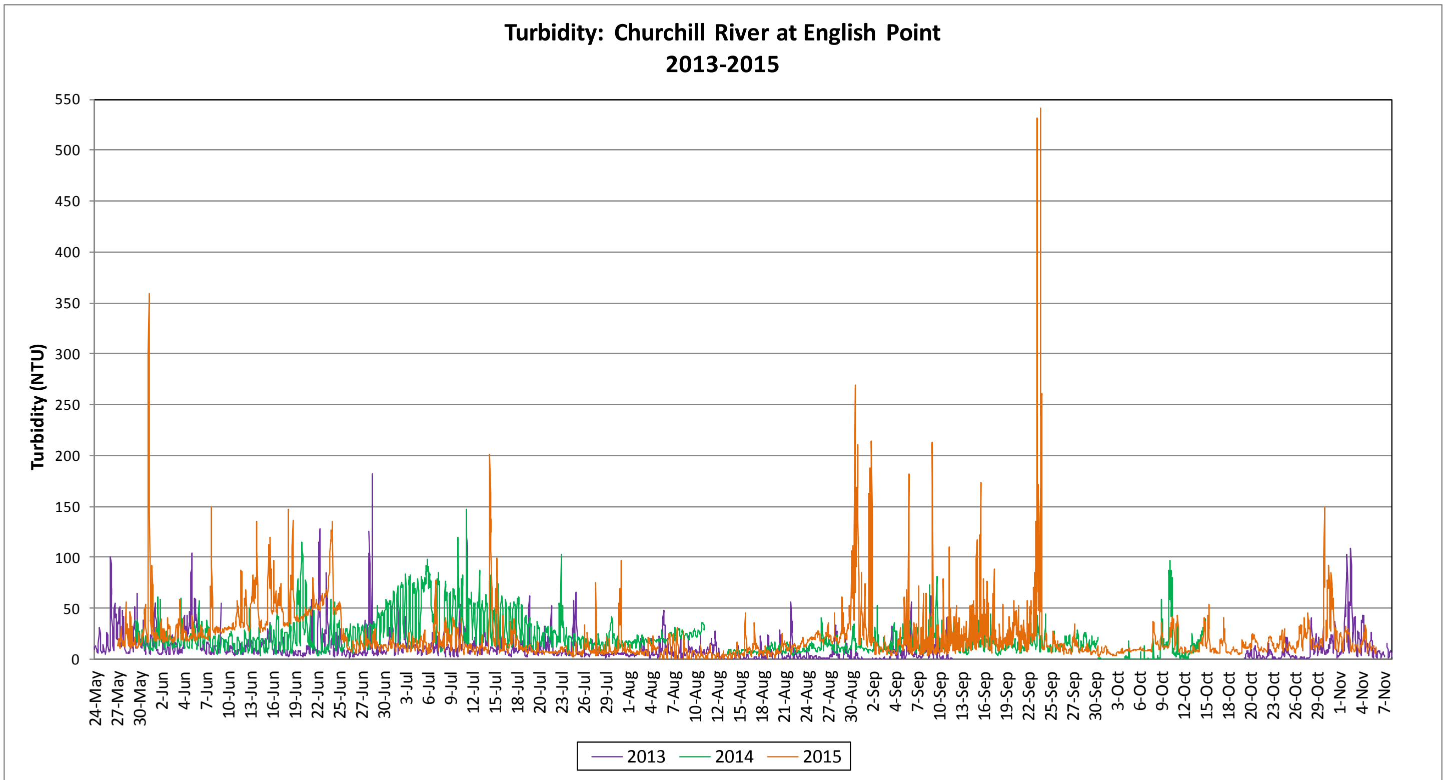


Figure 38: Dissolved oxygen and percent saturation at Churchill River at English Point

Dissolved Oxygen (mg/L)	2015	2014	2013		Percent Saturation	2015	2014	2013
Median	8.48	8.72	8.42		Median	73.80	85.40	85.50
Max	13.66	13.83	14.17		Max	112.60	114.50	111.90
Min	10.42	10.34	10.55		Min	99.00	99.60	99.40

- The majority of turbidity values (95%) were <59.87NTU during the 2015 deployment season (Figure 39 a & b). A median value of 13.30NTU indicates there is a consistent natural background turbidity value at this station. Turbidity values from 2013 to 2015 are depicted in Figures 39 a & b.
- Figure 39a shows data on a scale up to 550NTU. On a number of occasions in 2015, turbidity increased above median background levels for short periods of time throughout the deployment season, to as high as 541NTU. 2015 values are on par with 2014 and higher than those from 2013, particularly in late August to September, coinciding with the period of lowest stage levels during the year. Mixing sediment due to low water levels may have contributed to high values during this time.
- Figure 39b shows data at a smaller scale, focusing on the regular consistent background levels, below 70NTU. In the 2015 season, the median value was calculated to be 13.30NTU and the 95th percentile value was 59.87NTU. When data from all years is combined (2013 to 2015), the median value decreases to 11.8NTU and the 95th percentile is 54.1NTU. In 2015, there appears to be more fluctuating values, though data from all years is similar and comparable in trend.

Turbidity (NTU)	2015	2014	2013	2013-15
Min	0.0	0.0	0.0	0
Max	541.0	708.0	181.30	541
Median	13.30	18.20	6.80	11.8
95%	59.87	58.9	34.6	54.1
75%	24.4	24.7	12.6	21.2



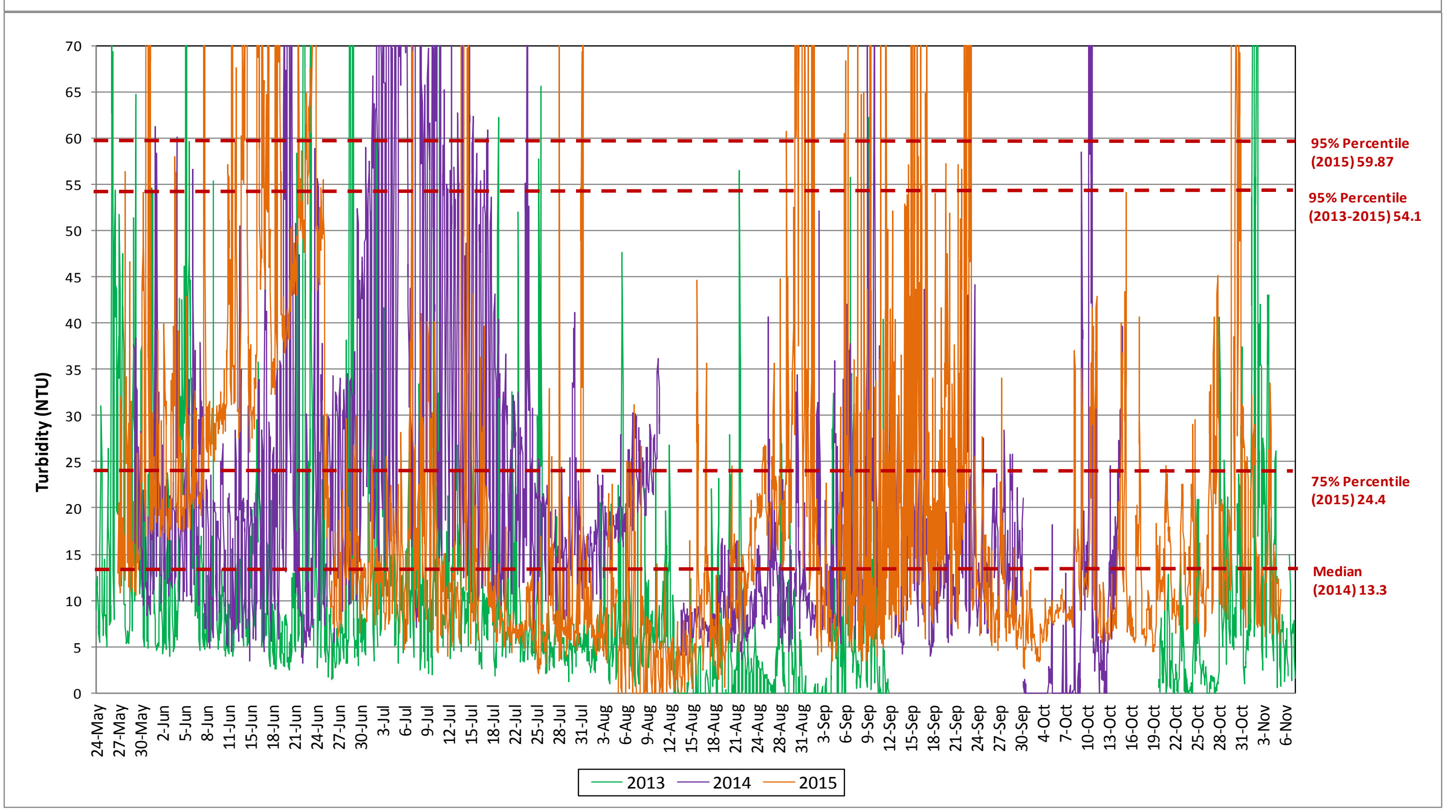


Figure 39a (top): Turbidity to 550NTU at Churchill River at English Point
Figure 39b (bottom): Turbidity to 70NTU at Churchill River at English Point

- Stage levels in 2015 are very consistent and do not fluctuate greatly on a seasonal level (Figure 40). Instead, stage values fluctuate considerably with tidal influences on a daily basis.
- Stage levels from 2013-2015 are graphed below to show how stage levels vary throughout the season and from year to year. Stage levels in previous years were very similar when compared data collected in 2015. Stage ranges between 0.97m and 1.34m each year.
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

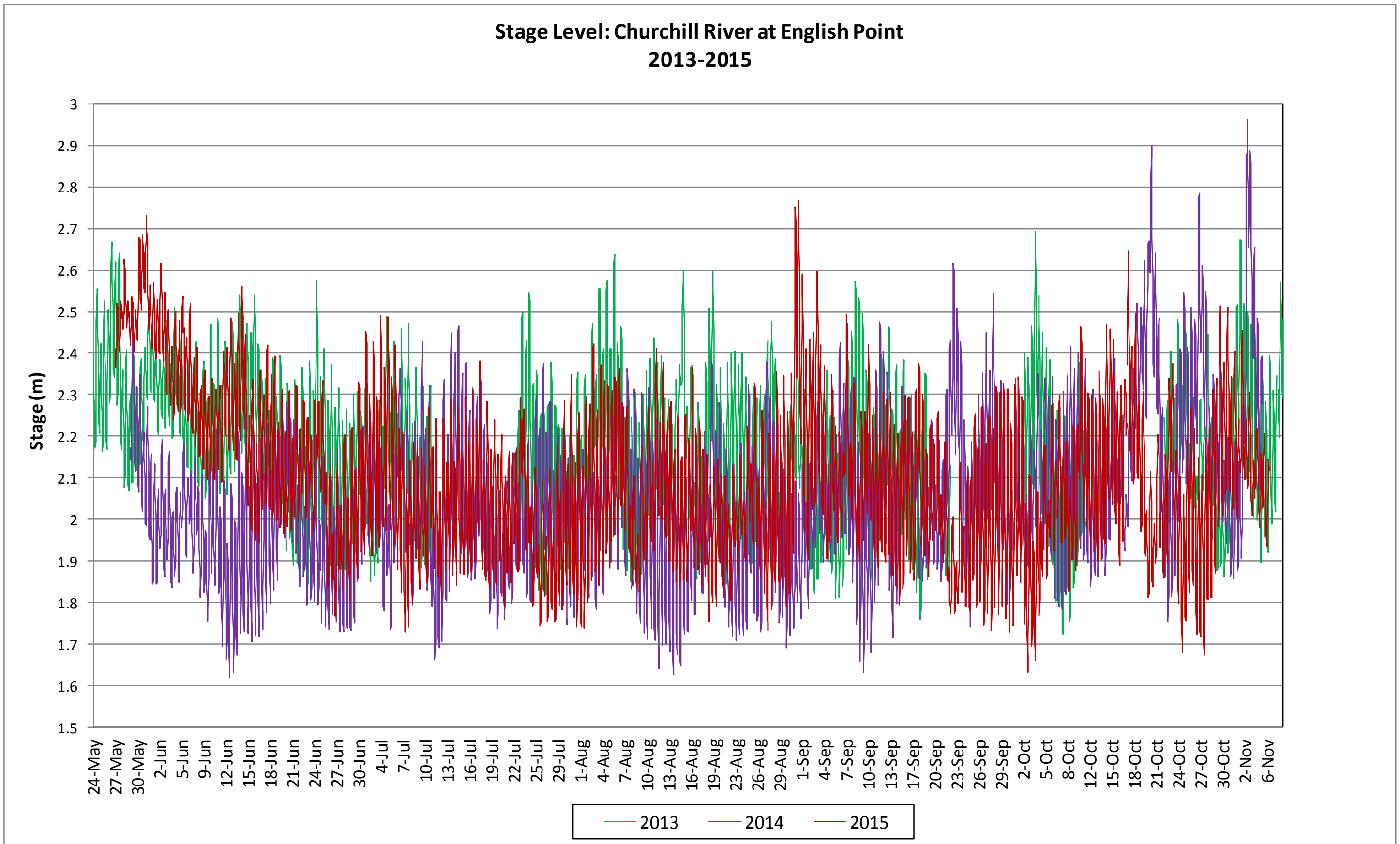


Figure 40: Stage level at Churchill River at English Point

Stage (m)	2015	2014	2013
Min	1.63	1.62	1.72
Max	2.77	2.96	2.69
Median	2.09	2.04	2.18
Range	1.14	1.34	0.97

- Stage and precipitation are graphed below to show the relationship between rainfall and water level (Figure 41).
- Stage is consistent throughout the deployment season. This trend is very different from all other network stations due to its location at the mouth of the Lower Churchill River and the tidal influences affecting water level.
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

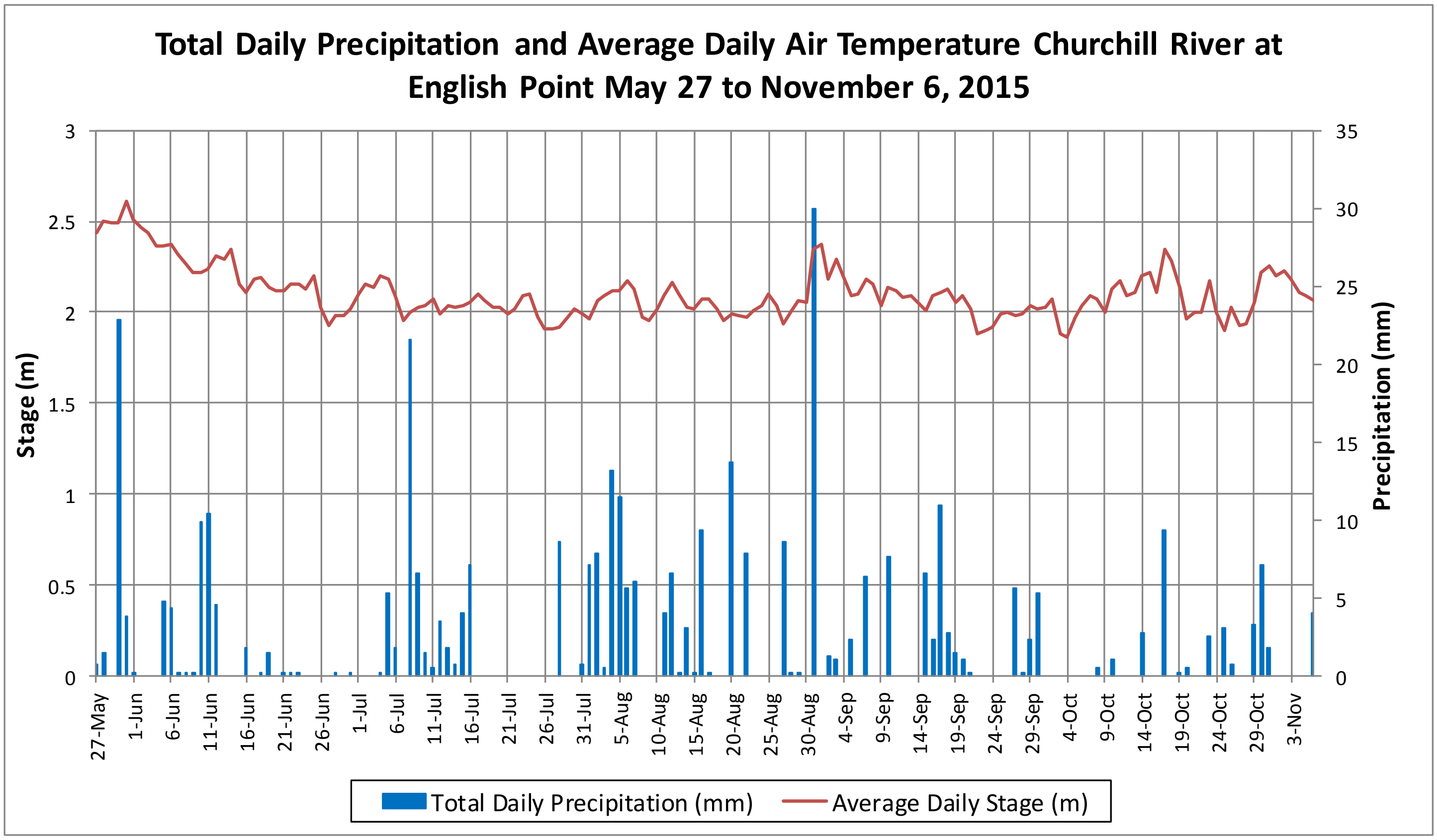


Figure 41: Daily precipitation and average daily stage level at Churchill River at English Point (weather data recorded at Mud Lake)

Station Comparison

- Water temperature at each of the four stations monitored shows a similar trend throughout the 2015 deployment season (Figure 42).
- Water temperature is generally warmest at Churchill River below Grizzle Rapids, while English Point has the greatest diurnal fluctuations. In the spring and early summer, English Point recorded the highest and lowest temperatures daily. Into the summer, the coolest water temperatures were recorded at below Grizzle Rapids, while the warmest were recorded at English Point. As water temperatures began to cool mid-August into November, Churchill River at English Point had the lowest water temperatures when compared to other stations in the network.

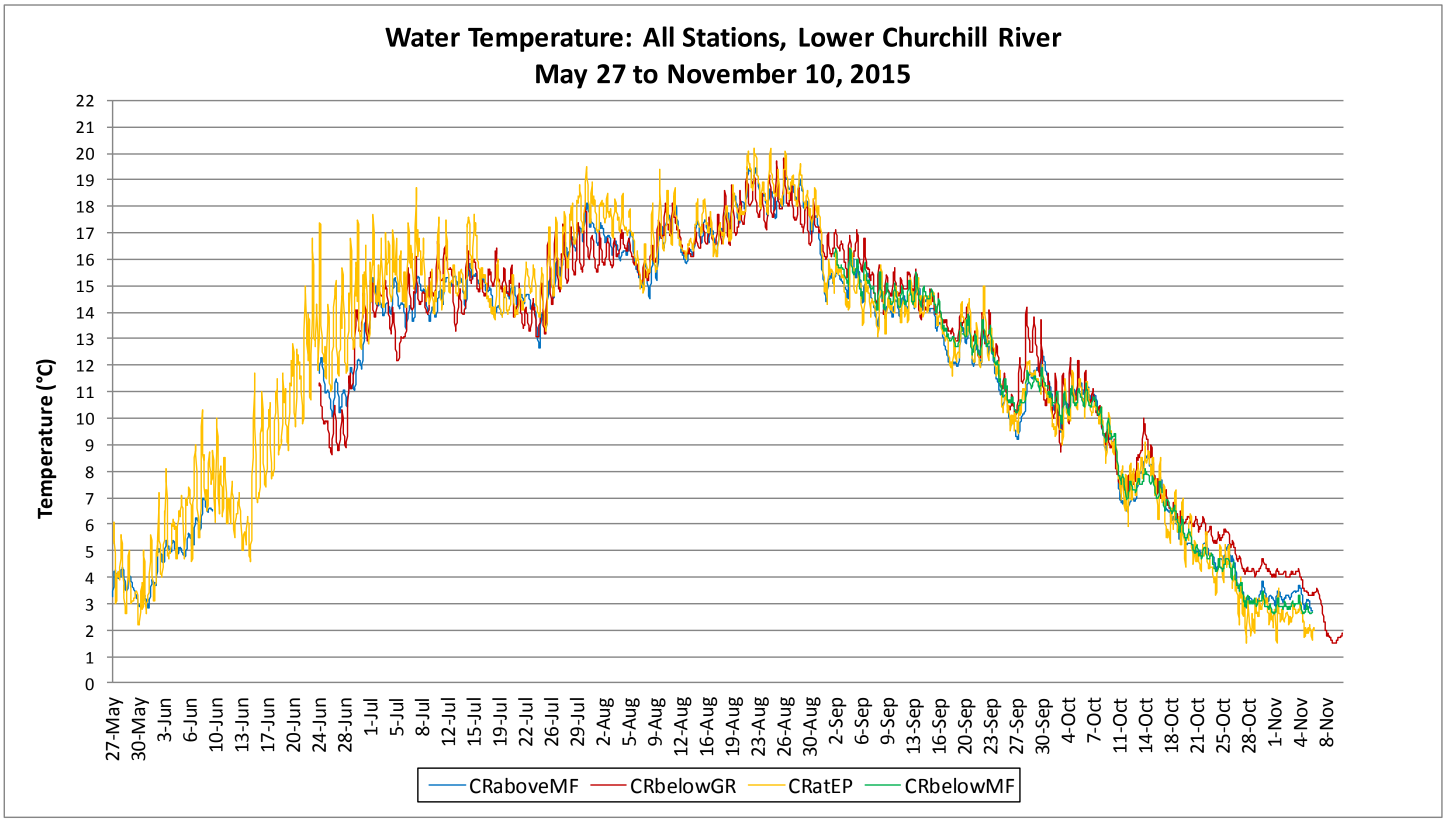


Figure 42: Temperature at all stations in 2015, Lower Churchill River

Temperature	CRaboveMF	CRbelowGR	*CRbelowMF	CRatEP
Min	2.71	1.5	2.6	1.5
Max	19.46	19.8	16.4	20.2
Median	13.79	14.1	10.6	13.6

***data set not complete cannot be compared to previous years**

- Water temperatures at all four stations display clear seasonal trends in response to changes in air temperatures throughout the deployment season (Figure 43).
- Average Daily water temperatures peak at all stations in late August.

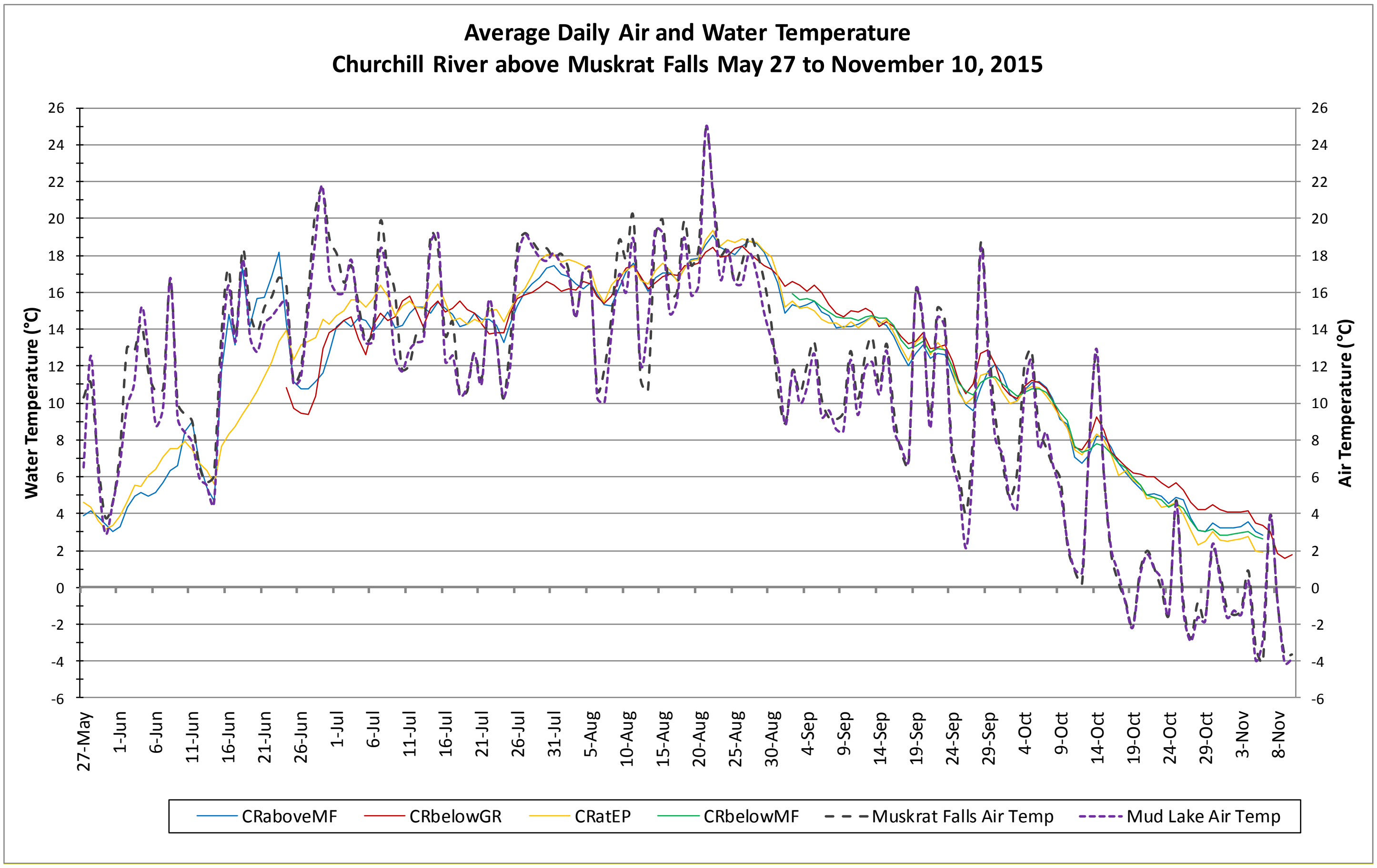


Figure 43: Average daily air and water temperatures at all stations in 2015, Lower Churchill River

- pH values are similar at the four monitoring sites throughout the 2015 deployment season (Figure 44).
- The median values for above Muskrat Falls and at English Point were the same at 7, while median value for below Grizzle Rapids was 7.02. Values at the station at English Point are the most variable day to day throughout the deployment season due to the position of the station at the mouth of the Lower Churchill River and the tidal impact on the station water level and water quality.

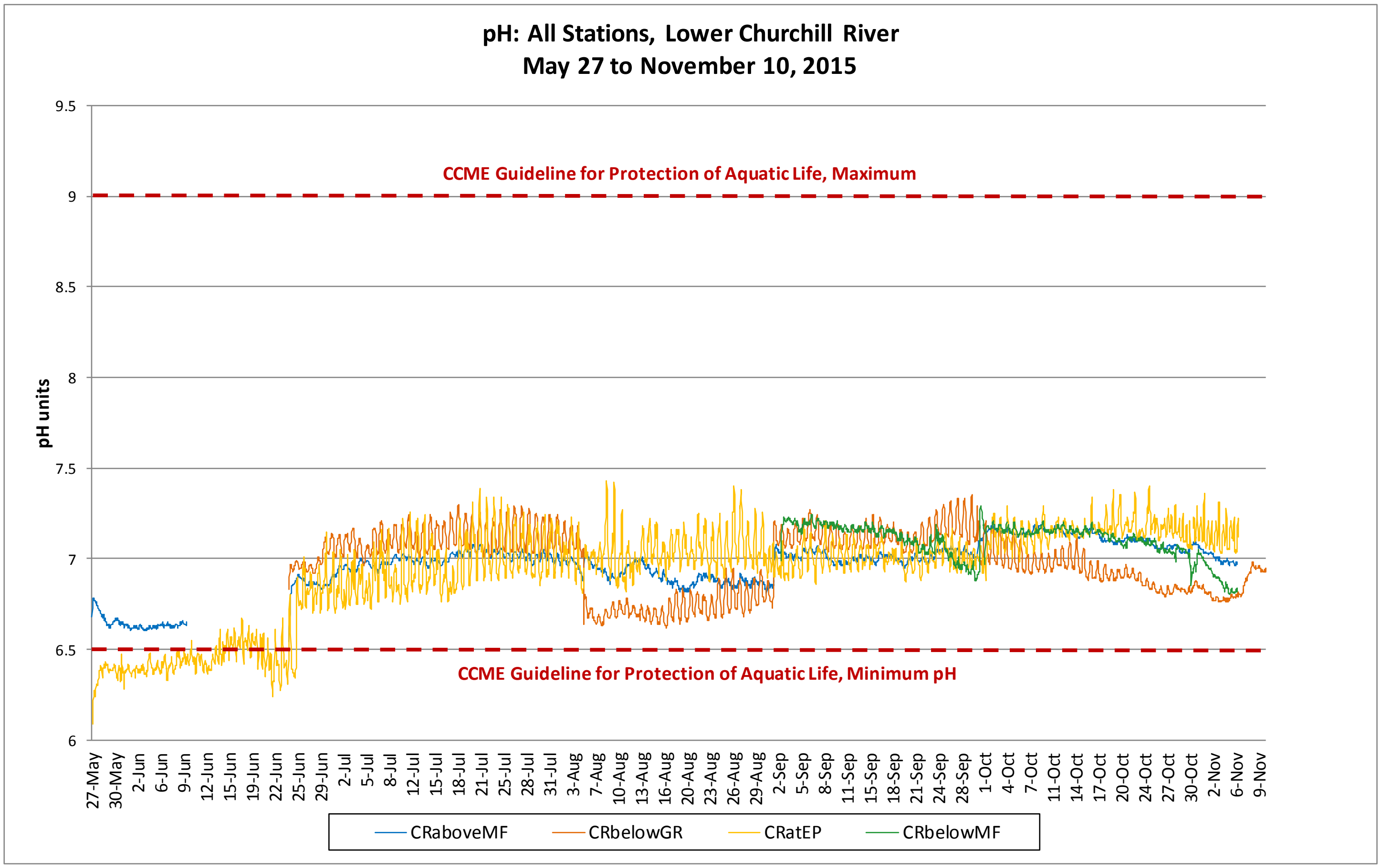


Figure 44: Temperature at all stations in 2015, Lower Churchill River

pH	CRaboveMF	CRbelowGR	*CRbelowMF	CRatEP
Min	6.54	6.62	6.8	6.09
Max	7.19	7.35	7.29	7.43
Median	7	7.02	7.13	7

***data set not complete cannot be compared to previous years**

- Specific conductivity trends are similar along the Lower Churchill River except at English Point (Figure 45).
- Specific conductivity is generally very stable on the Lower Churchill River (above English Point), fluctuating only a few micro Siemens during a deployment period.
- Seasonal trends are notable at these stations and show specific conductivity increasing from the time of deployment in May to mid-August. Specific conductivity then decreases into the fall.
- At the station at English Point, specific conductance is highly variable, fluctuating significantly each day due to the tidal influences of the Atlantic Ocean. 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.

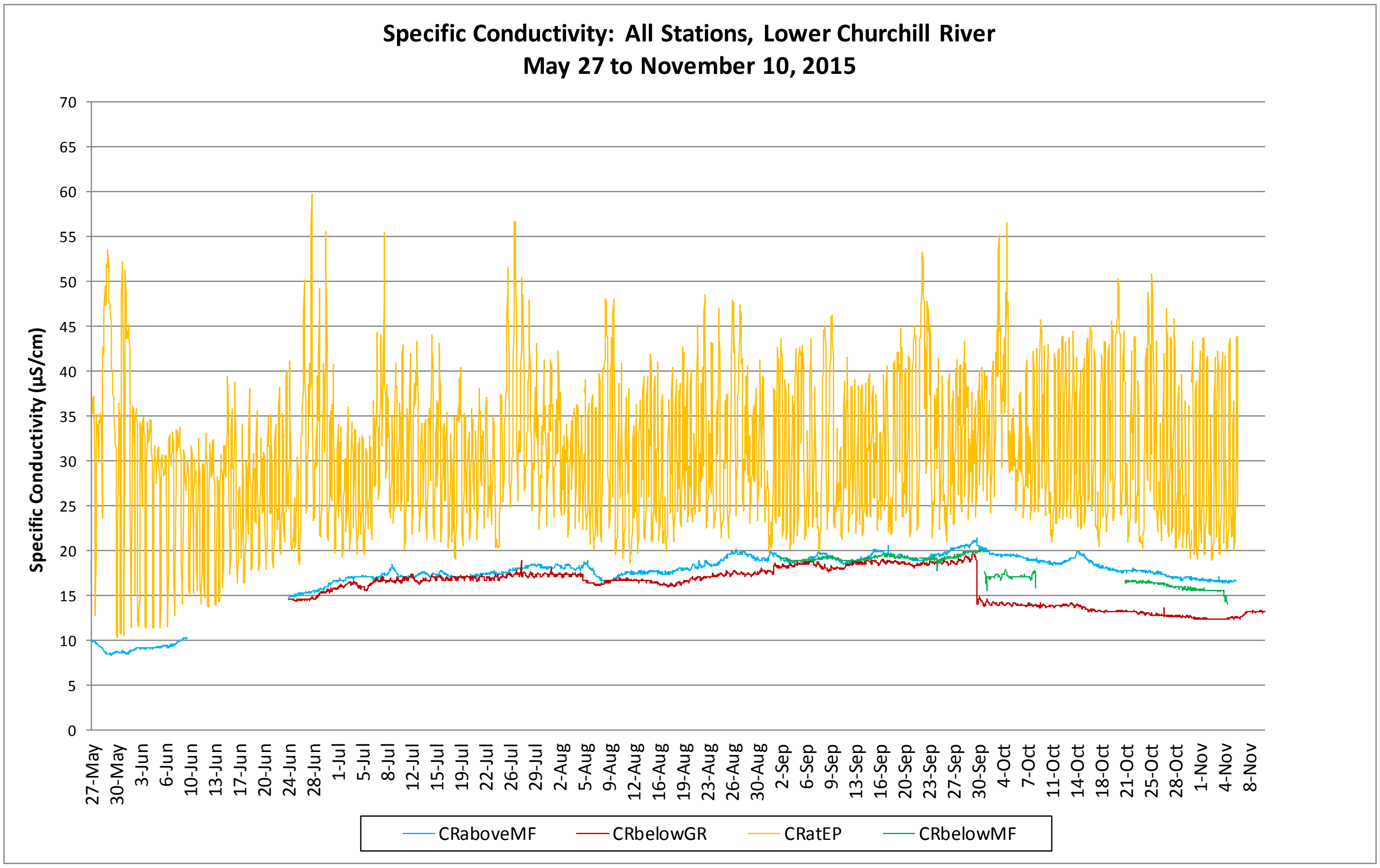


Figure 45: Specific conductivity at all stations in 2015, Lower Churchill River

Specific Conductivity (µS/cm)	CRaboveMF	CRbelowGR	*CRbelowMF	CRatEP
Min	8.3	12.3	14	10.3
Max	21.4	19.8	20.1	59.8
Median	17.8	16.6	18.9	29.9

***data set not complete cannot be compared to previous years**

- Dissolved oxygen content and percent saturation values are very similar throughout the network with median values from 10.07mg/l (below Grizzle Rapids) to 12.98mg/l (at below Muskrat Falls) and 96.7% (below Grizzle Rapids) to 105.15% (at Muskrat Falls) (Figure 46).
- Dissolved oxygen content shows a very clear inverse relationship to water temperature and has a distinct seasonal trend decreasing in the spring and early summer, and increasing in the late summer and fall.
- Generally, dissolved oxygen content at the below Muskrat Falls station is higher than all other stations throughout the deployment season due to its location downstream from Muskrat Falls. However, this data was only recorded during the fall months in 2015 due to issues with sand; English Point consistently recorded the highest dissolved oxygen levels throughout the season compared to the other deployed stations. All stations (except below Muskrat Falls) recorded values below the minimum CCME Guideline for the Protection of Early Life Stage Cold Water Biota value at 9.5 mg/l during the summer months. Guidelines are indicated in red on Figure 46.

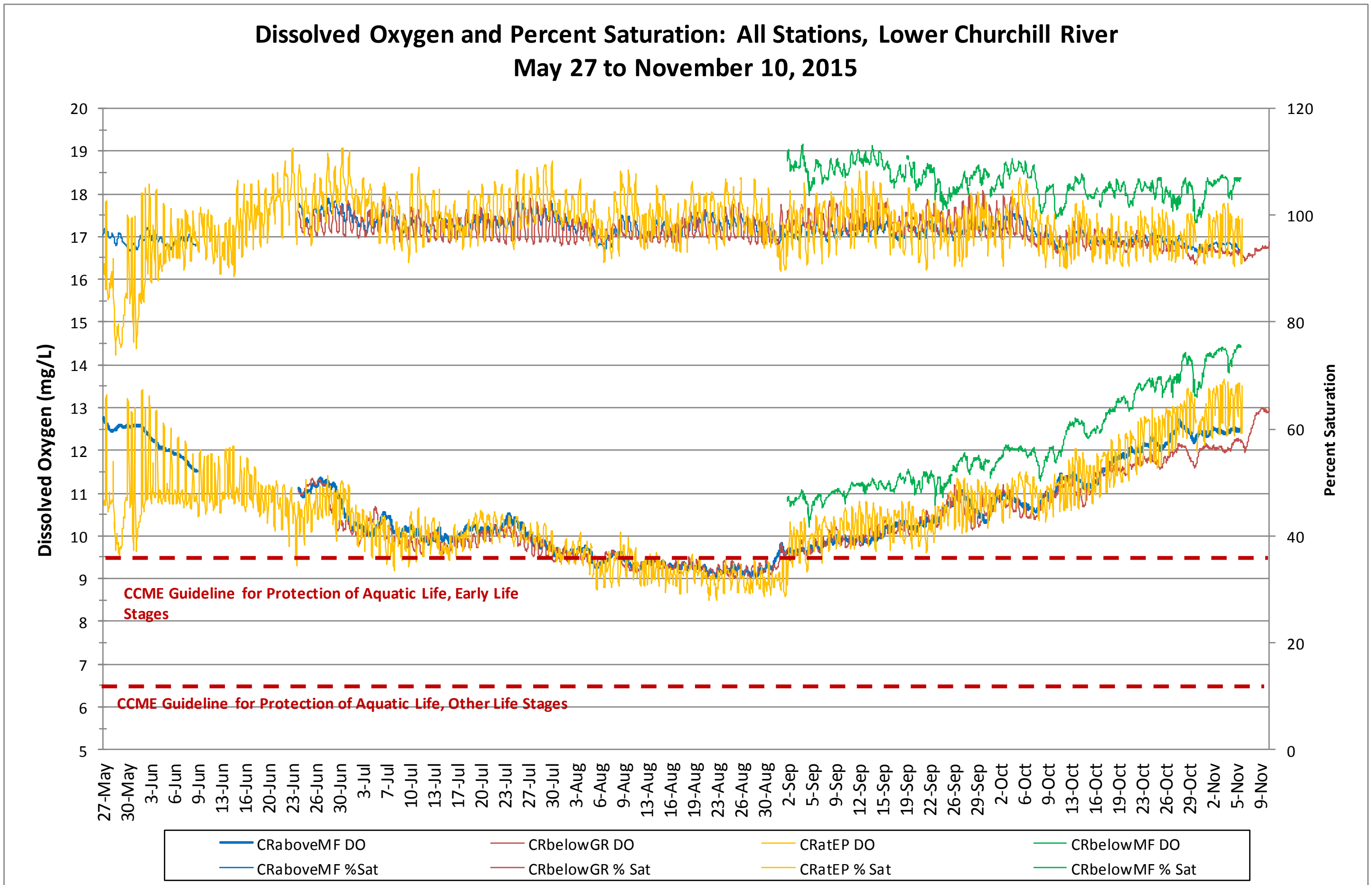


Figure 46: Dissolved oxygen and percent saturation at all stations in 2015, Lower Churchill River

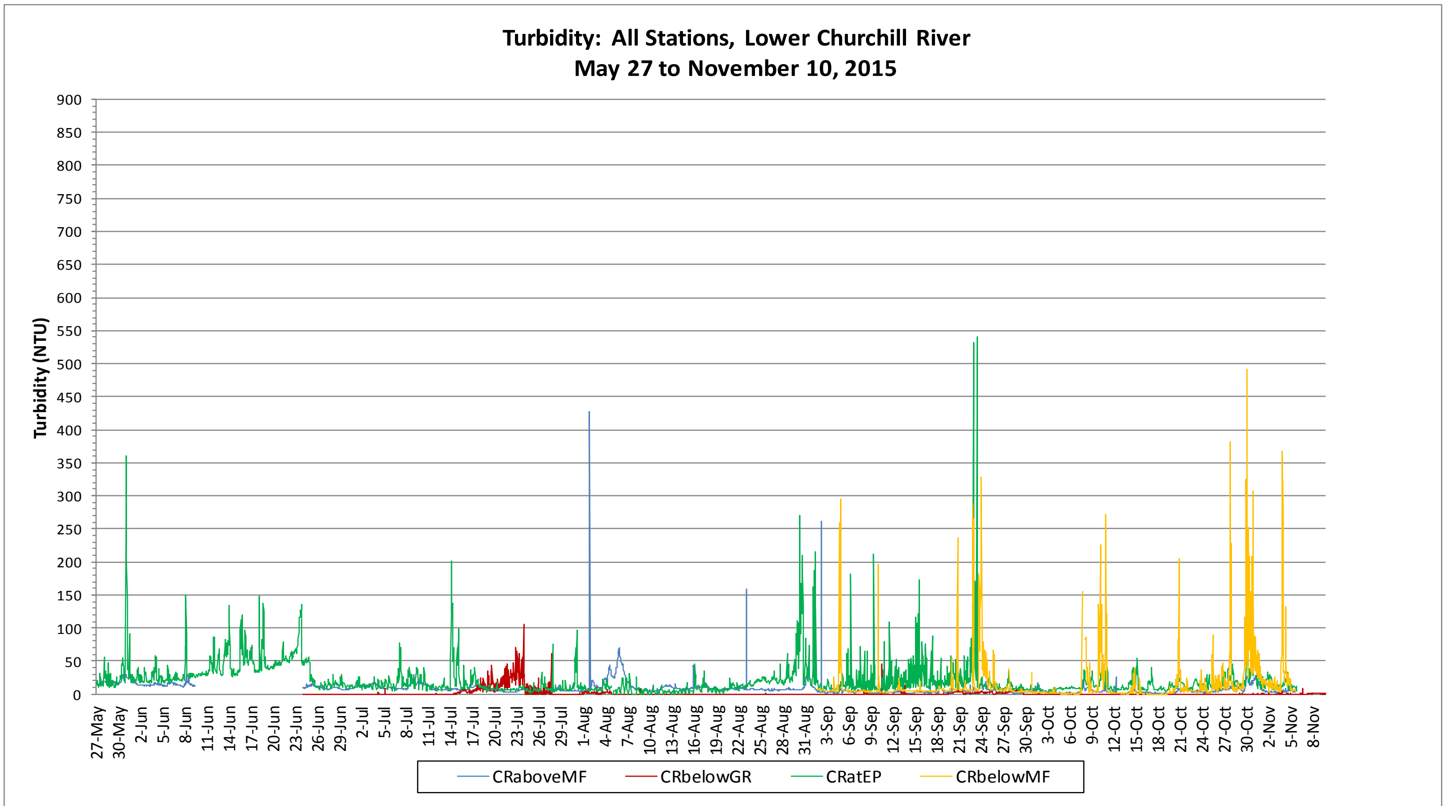
	Dissolved Oxygen (mg/l)					Percent Saturation (%)			
	CRaboveMF	CRbelowGR	*CRbelowMF	CRatEP		CRaboveMF	CRbelowGR	*CRbelowMF	CRatEP
Min	9.04	9	10.21	8.48		92.9	91	98.6	73.8
Max	12.77	13.01	14.46	13.66		103.2	104.5	113.2	112.6
Median	10.24	10.07	11.86	10.42		97.2	96.7	106.3	99

***data set not complete cannot be compared to previous years**

- Turbidity values at stations below Grizzle Rapids are generally 0NTU with minimal, short lived turbidity events (Figure 47 a & b). In the lower reaches of the Lower Churchill River, the stations above Muskrat Falls and at English Point have consistent natural background turbidity values.
- Background turbidity values are 5.3NTU and 13.3NTU for the stations above Muskrat Falls and at English Point, respectively.

Turbidity (NTU)	CRaboveMF	CRbelowGR	*CRbelowMF	CRatEP
Min	0.3	0	0	0
Max	428	105	492	541
Median	5.3	0	4.7	13.3
95th Percentile	20.01	8.4	66.99	120.04

***data set not complete cannot be compared to previous years**



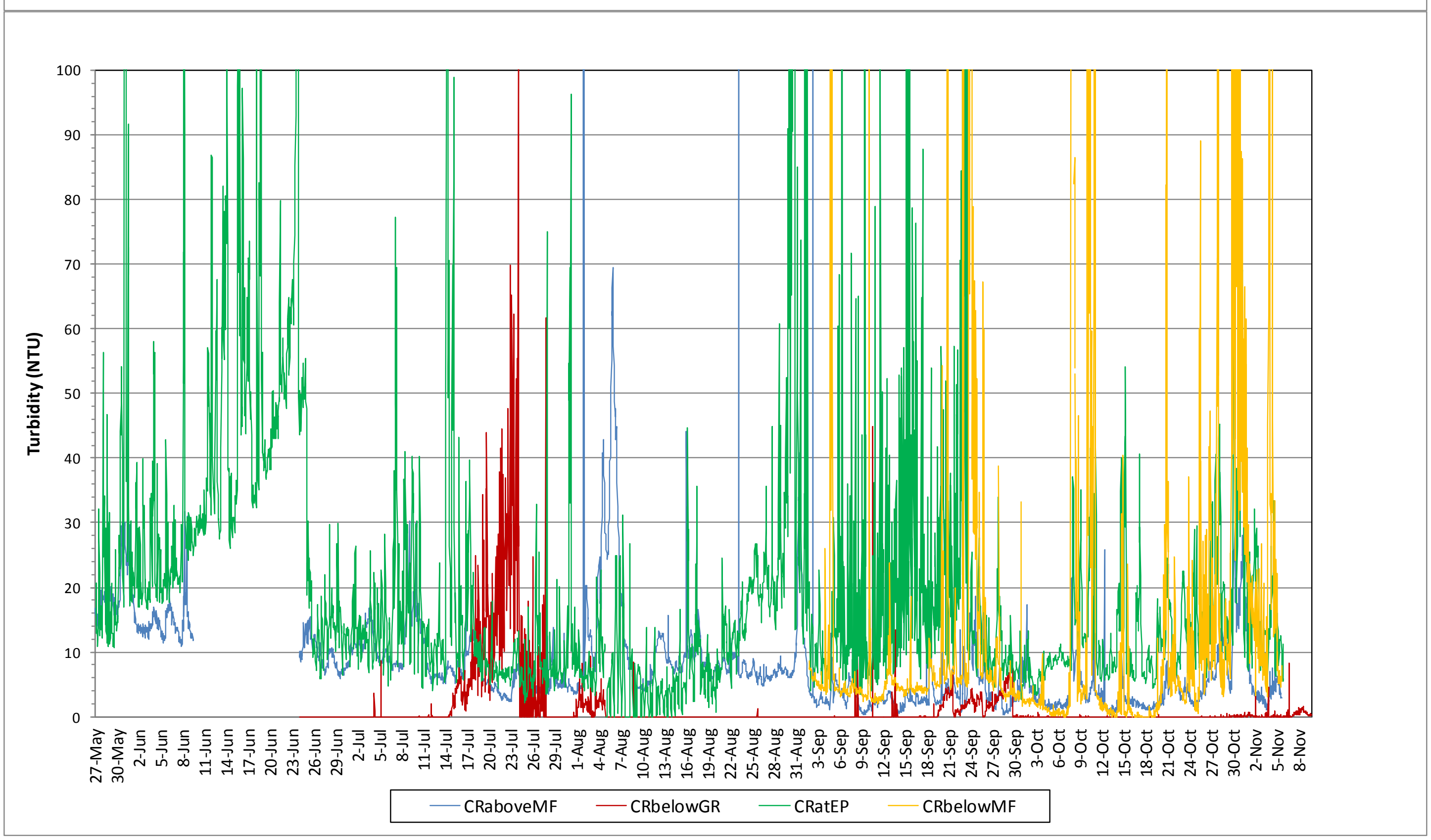


Figure 47a (top): Turbidity to 900NTU at all stations in 2015, Churchill River
Figure 47b (bottom): Turbidity to 100NTU at all stations in 2015, Churchill River

- Stage levels are similar across the network throughout the 2015 deployment season (Figure 48). Stage is generally decreasing at all stations from May into August. Stage levels reach a seasonal low at all stations above English Point in late September and early October before gradually increasing into the fall months.
- Stage ranges between 1.137m and 3.938m depending on the station. Most increases and decreases captured are noticeable at all stations in the network. The stage level at English Point is greatly affected by the tidal influence of the Atlantic Ocean and varies widely on a daily basis compared to the other stations in the network.
- Water Survey of Canada (Environment Canada) is responsible for QAQC of water quantity data (stage and flow). Corrected data can be obtained upon request.

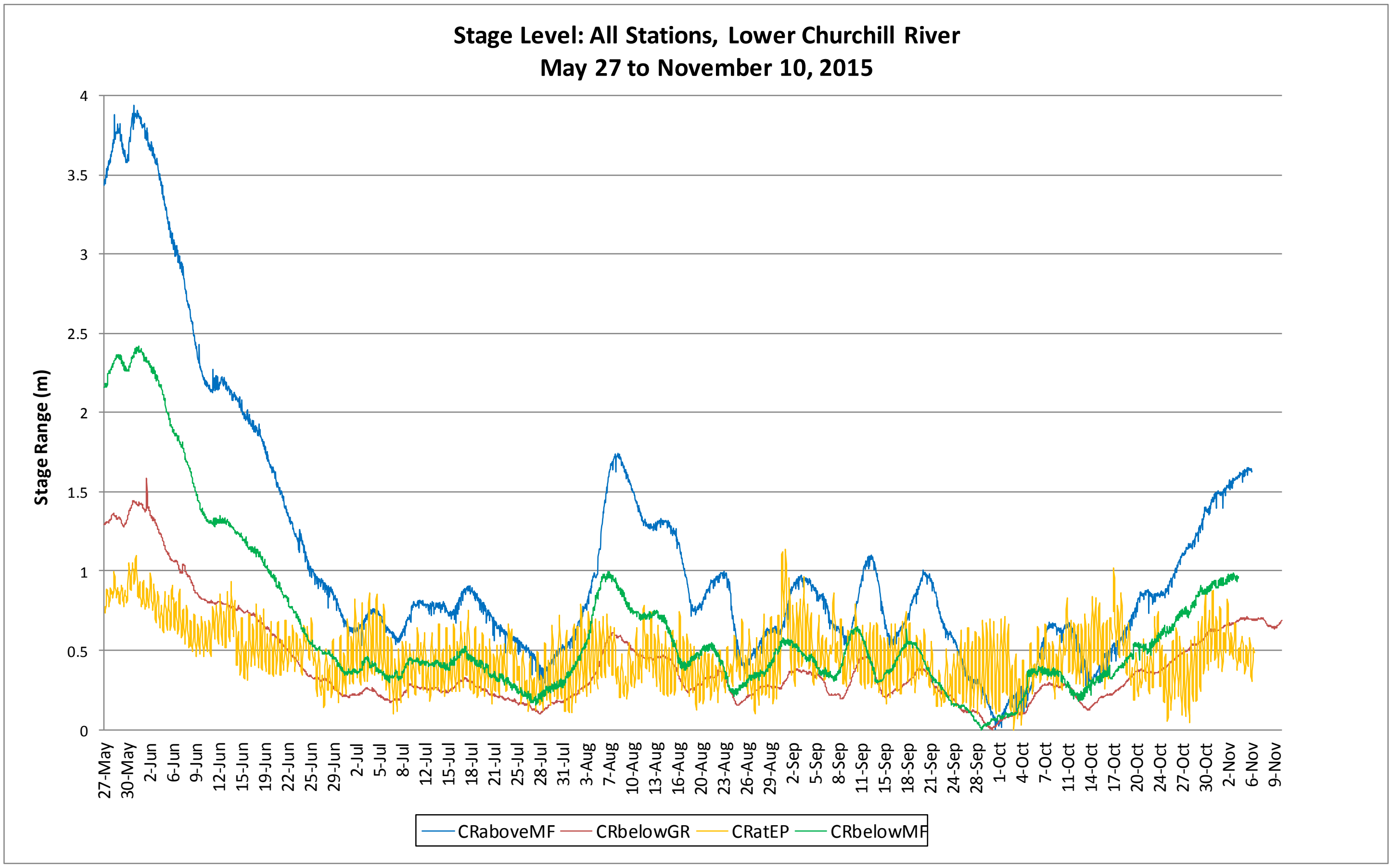


Figure 48: Stage Range at all stations in 2015, Lower Churchill River

	CRaboveMF	CRbelowGR	CRbelowMF	CRatEP
Stage Range (m)	3.938	1.584	2.415	1.137

Conclusions

- Water quality monitoring instruments were successfully deployed on the Lower Churchill River at stations above Muskrat Falls and at English Point from May 27 to November 6. The below Grizzle Rapids station was not deployed until June 24 due to the presence of an ice wall blocking accessibility to the site in May. The below Muskrat Falls station was deployed from September 2 to November 6, the station provided reliable data for temperature, DO, and pH; however data variances were noted for conductivity and turbidity.
- In most cases, weather related events explain the fluctuations in water levels. In 2015, the three deployed original stations continue to perform well at capturing water quality baseline data along different reaches of the river. The English Point station provides a last measurement of water quality in the lower Churchill River before entering Lake Melville. This station is affected by tidal influences from the Atlantic Ocean.
- Regular visits on a near 30 day deployment schedule have been adhered to for the most part. This has provided good quality data with limited drift. The effects of bio fouling rarely impact the instruments due to the cold pristine nature of the river and the regular maintenance each month.
- The instruments performed well for much of the deployment season with limited disruptions to data collection.
    - Rapid water level decreases left the instrument exposed to air at the river’s edge at the above Muskrat Falls from June 9-24. Data for this time periods has been removed from the data set. Turbidity data has been removed for some stations due to data inaccuracies resulting from the instrument being in very shallow water before running dry.
    - Some data collected from the below Muskrat Falls station was still affected by moving sediment and sand.
    - Finally, transmission errors were infrequent across the network during 2015.
- Data collected in 2015 is comparable with datasets from previous years in 2013 and 2014. Water quality parameters do not tend to vary significantly. Stage appears to be one of the greatest variables from year to year.
- Water temperatures were seasonal at all stations in the network peaking at seasonal highs in mid-August at all stations in the network. Water temperatures had median values between 13.6°C (at English Point) and 14.1°C (below Grizzle Rapids).
- All values recorded were within ranges as suggested by the CCME Guidelines for the Protection of Aquatic Life for pH except for a short period of time at the station at English Point immediately following the initial deployment in May. Median pH values were 7 at above Muskrat Falls and at English Point, and 7.02 at below Grizzle.
- During the warm summer months of early July to early September, dissolved oxygen at all stations fell below the minimum CCME Guideline for the Protection of Aquatic Life during early life stages (9.5mg/L). All values at all stations remained above the minimum CCME Guideline for the Protection of Aquatic Life during other life stages (6.5mg/L) throughout the deployment period. Median values for dissolved oxygen and percent saturation ranged between 10.07mg/l (96.7%) (below Grizzle Rapids) and 10.42 (99%) (at English Point).
- Specific conductivity is generally very stable on the Lower Churchill River (above English Point), fluctuating only a few micro Siemens during a deployment period. At the station at English Point, specific conductance is highly variable, fluctuating significantly each day due to the tidal influences of the Atlantic Ocean. 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. Median values for specific conductivity ranged between 16.6uS/cm (below Grizzle Rapids) and 29.9 uS/cm (at English Point)

- Background turbidity values at the stations below Grizzle Rapids were 0NTU and turbidity events were short lived and insignificant. At stations above Muskrat Falls and at English Point, median turbidity values were 5.3NTU and 13.3NTU respectively. Turbidity events were frequent, most often corresponding with precipitation events and visible at each of these two stations.

Path Forward

In order for this agreement to be successful, it is essential to continually evaluate and move forward. The 2015 deployment season was successful in providing water quality data for the Lower Churchill Project at all four stations. The following is a list of planned activities to be carried out in the upcoming year. The list also includes some multi-year activities planned in the previous year that are still in progress.

- ENVC staff will deploy RTWQ instruments in spring 2016 when ice conditions allow and perform regular site visits throughout the 2016 deployment season for calibration and maintenance of the instruments.
- EC staff will perform regular site visits to ensure water quantity instrumentation is correctly calibrated and providing accurate measurements.
- Nalcor will continue to be informed of data trends and any significant water quality events in the form of a monthly deployment report when the deployment season begins. Nalcor will also receive an annual report summarizing the events of the deployment season.
- Nalcor will continue to receive batch datasets of all RTWQ data. Raw data will be provided if requested.
- Open communication lines will continue to be maintained between ENVC, EC and Nalcor employees involved with the agreement in order to respond to emerging issues on a proactive basis.
- The instrument at the original below Muskrat Falls station (real-time water quality and quantity data) will be redeployed in 2016, but also a backup instrument at Muskrat Island (water quality data not in real time) will be deployed in conjunction to capture data for the below Muskrat Falls portion of the Churchill River.
- ENVC will continuously update the TSS-Turbidity model for the stations above and below Muskrat Falls as new grab sample data becomes available. The model will then be tested and validated in consultation with Nalcor or their consultants as necessary.
- Research into the use of remote sensing (using satellite imagery) to predict/map water quality parameters (i.e. turbidity and TSS) will continue in 2016. Satellite imagery will be acquired by WRMD to further this area of research.
- The Lake Melville station remains a water quantity station. RTWQ monitoring was stopped in 2012 following continual damage to the deployed instrument.
- ENVC purchased a NexSens BC-450 data buoy that was deployed in August 2015.
- The Lake Melville Buoy was deployed in August 2015 however due to heavy ice at the end of the season some damage was sustained. This trial project is being reassessed for the 2016 deployment season as data collected from Lake Melville is very important to assessing the water quality of the Lower Churchill River ecosystem.
- During the 2016 field season, reservoir filling and water diversion will be taken into consideration. Some stations will need to be relocated to the high water level. This will be done in conjunction with Environment Canada and Nalcor. This will be a continuous process and communication lines will be maintained to make sure the moving of stations is done effectively

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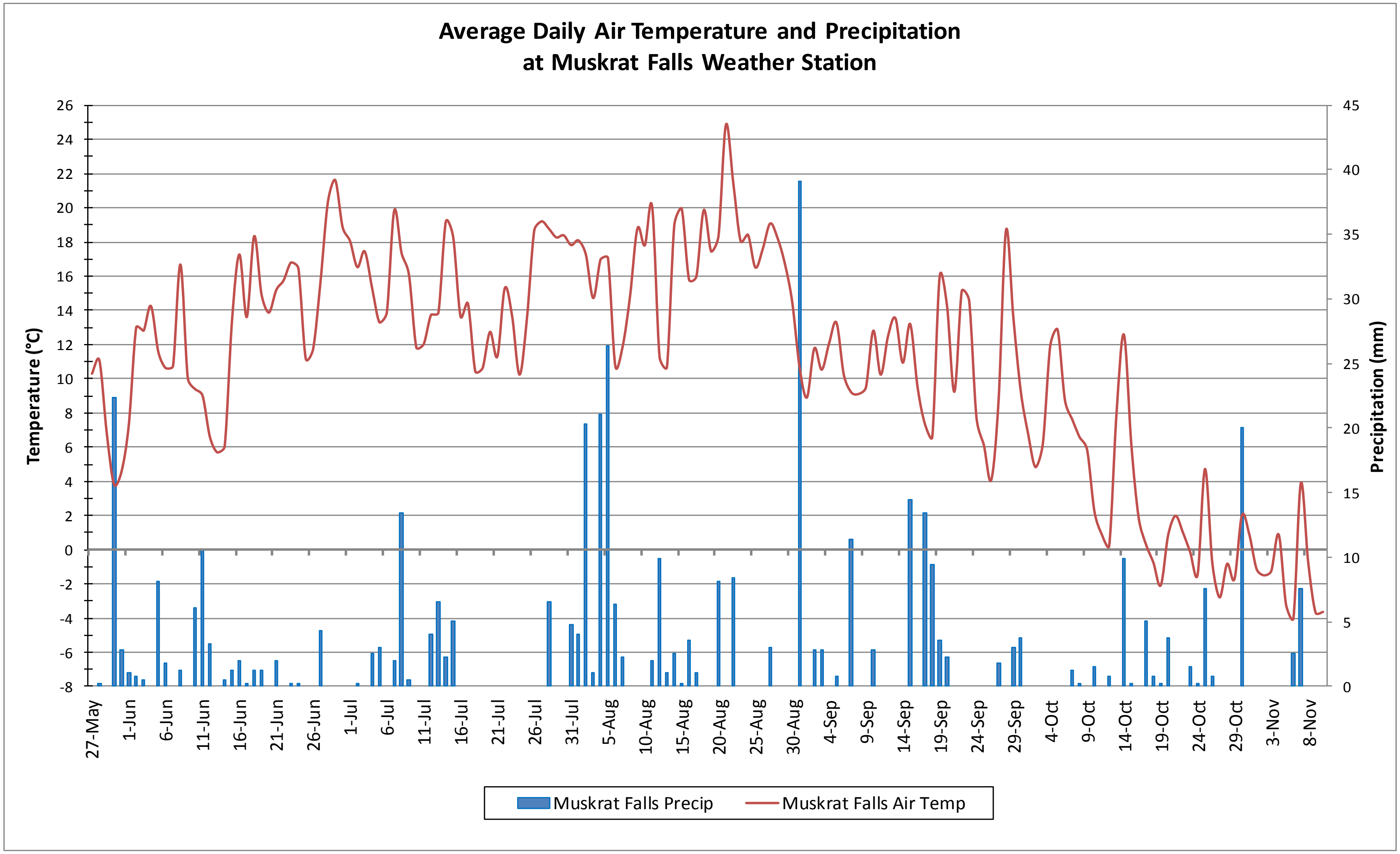
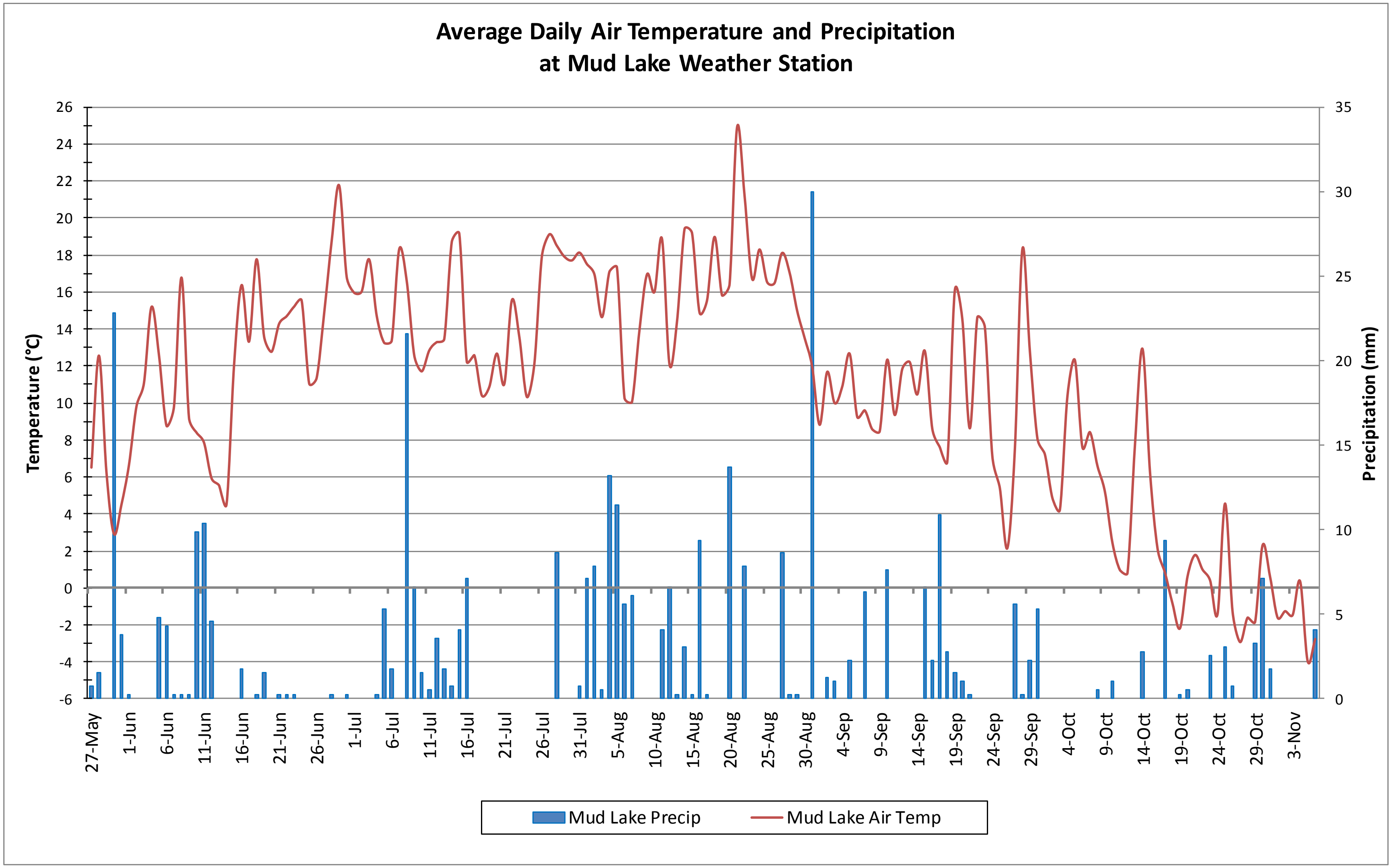
Appendix 1


Average Daily Air Temperature and Precipitation
at Muskrat Falls Weather Station
Temperature (°C)
Precipitation (mm)
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
45
40
35
30
25
20
15
10
5
0
27-May
1-Jun
6-Jun
11-Jun
16-Jun
21-Jun
26-Jun
1-Jul
6-Jul
11-Jul
16-Jul
21-Jul
26-Jul
31-Jul
5-Aug
10-Aug
15-Aug
20-Aug
25-Aug
30-Aug
4-Sep
9-Sep
14-Sep
19-Sep
24-Sep
29-Sep
4-Oct
9-Oct
14-Oct
19-Oct
24-Oct
29-Oct
3-Nov
8-Nov
Muskrat Falls Precip
Muskrat Falls Air Temp

Appendix 2


Average Daily Air Temperature and Precipitation
at Mud Lake Weather Station
Temperature (°C)
Precipitation (mm)
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
35
30
25
20
15
10
5
0
27-May
1-Jun
6-Jun
11-Jun
16-Jun
21-Jun
26-Jun
1-Jul
6-Jul
11-Jul
16-Jul
21-Jul
26-Jul
31-Jul
5-Aug
10-Aug
15-Aug
20-Aug
25-Aug
30-Aug
4-Sep
9-Sep
14-Sep
19-Sep
24-Sep
29-Sep
4-Oct
9-Oct
14-Oct
19-Oct
24-Oct
29-Oct
3-Nov
Mud Lake Precip
Mud Lake Air Temp