Real Time Water Quality Report

Tata Steel Minerals Canada
Elross Lake Network

Annual Deployment Report 2016

2016-05-31 to 2016-10-05

Newfoundland Labrador

Government of Newfoundland & Labrador
Department of Environment and Climate Change
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Acknowledgements

The Real-Time Water Quality/Quantity Monitoring Network in the vicinity of the Elross Lake Iron Ore Mine in western Labrador is fully funded by Tata Steel Minerals Canada Limited (TSMC) and its success is dependent on a joint partnership between TSMC, Environment and Climate Change Canada (ECCC), and the Newfoundland & Labrador Department of Environment & Climate Change (ECC). Managers and program leads from each organization, namely Loic Didillon (TSMC), Renee Paterson (ECC), and Howie Wills (ECCC), are committed to the operation of this network and ensuring that it provides meaningful and accurate water quality/quantity data.

In addition to funding this program, TSMC also assisted ECC and ECCC staff with fieldwork operations. TSMC employees who were helpful in this regard included Loic Didillon, Michael Lewis, Morgan Michaud, Shane Jackson, and Jean-Francois Dion.

ECCC plays an essential role in the data logging/communication aspect of the network. In particular, ECCC staff of the Water Survey of Canada, including Perry Pretty, Roger Ellsworth, Taylor Krupa, Dwayne Ackerman and Mike Ludwicki visited network stations regularly to ensure that the data logging and data transmitting equipment was working properly. ECCC also plays the lead role in dealing with stage and flow issues.

ECC is responsible for recording and managing water quality data. Ian Bell, under the supervision of Renee Paterson, is ECC's main contact for Real-Time Water Quality Monitoring operations at the Elross Lake Mine, and was responsible for maintaining and calibrating water quality instruments, as well as grooming, analyzing and reporting on water quality data recorded at the stations. Paul Rideout with the Water Resources Management Division provided assistance with field work for two deployments during the 2016 field season. Instrument performance evaluation and repairs, during the winter of 2015-2016, were conducted in-house by Tara Clinton.

Introduction

- An agreement was signed on April 18, 2011, between the Newfoundland & Labrador Department of Environment & Climate Change (ECC) and Tata Steel Minerals Canada Limited (TSMC), to establish two real-time water quality/quantity stations in the vicinity of Elross Lake Iron Ore Mine in western Labrador, near Schefferville, QC.
- An amendment to the original agreement was signed on February 10, 2015, to establish an additional station at Joan Brook below the outlet of Joan Lake. The purpose of this station was to monitor the impacts of mining activity on surface water downstream of the five pits (Kivivic 1, 2, 3N, 4 and 5) which are included in the DSO4 Project 2B mining operation. The DSO4 Project 2B mining operation is located approximately 24 km northwest of the main mine complex.
- The official name of each station is ELROSS CREEK BELOW PINETTE LAKE INFLOW, GOODREAM CREEK 2KM NORTHWEST OF TIMMINS 6, and JOAN BROOK BELOW OUTLET OF JOAN LAKE, hereafter referred to as the *Elross Creek Station*, the *Goodream Creek Station*, and the *Joan Brook Station* respectively (Figure 1).

a. Elross Creek Station b. Goodream Creek Station c. Joan Brook Station

Figure 1: RTWQ stations are located alongside (a) Elross Creek, (b) Goodream Creek & (c) Joan Brook

- Table 1 lists the geographic coordinates of each station, including the location of the water quality instrument, gauge house, and helicopter pad.

Table 1. Geographic coordinates of the Elross Creek Station and Goodream Creek Station components.

	Elross Creek Station		Goodream Creek Station		Joan Brook Station	
	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
Instrument	54.877757	-67.099728	54.917549	-67.124027	*55.03334	*-67.17597
Gauge house	54.877698	-67.099848	54.917564	-67.123939	*55.03334	*-67.17597
Helicopter pad	54.877604	-67.100014	54.917699	-67.123763	*55.03334	*-67.17597

*General Site Location

- Station sites were selected to monitor all surface water outflows from the Elross Lake mining site and the DSO4 Project 2B mining sites (Figure 2).
- The Elross Creek Station monitors surface water downstream of the Timmins 1 pit, and downstream of Pinette Lake.
- The Goodream Creek Station monitors potential impacts from groundwater flowing from Timmins 6 pit into the surface water of Goodream Creek.
- The Joan Brook station monitors surface water downstream of the five pits (Kivivic 1, 2, 3N, 4 and 5) which are included in the DSO4 Project 2B mining operation.
- The Elross Creek and Goodream Creek stations went into operation October 17-18, 2011, recording only stage values for the first 7 months until June 5, 2012, when water quality instruments were first deployed. The Joan Brook station went into operation for stage values and water quality in June of 2016.
- Six parameters are measured at each station during ice-free months, including five water quality parameters (i.e., temperature, pH, specific conductivity, dissolved oxygen and turbidity) and one water quantity parameter (i.e., stage).
- Water quality parameters are recorded on an hourly basis, typically from early-June to early-October, when streams are ice-free. ECC is responsible for collecting and managing this dataset.
- Stage is recorded year-round on an hourly basis. ECCC is responsible for collecting and managing this dataset.
- ECCC is responsible for logging and transmitting all water quality and water quantity data to a central repository via satellite communications.
- The purpose of the real-time network at these stations is to monitor, process, and distribute water quality and water quantity data to TSMC, ECC, and ECCC, for assessment and management of water resources, as well as to provide an early warning of any potential or emerging water issues, such that mitigative measures can be implemented in a timely manner.
- ECC informs TSMC of any significant water quality events by email notification. Monthly and annual deployment reports serve to document water parameters measured at these stations.
- This annual deployment report presents water quality and water quantity data recorded at the Elross Creek, Goodream Creek and Joan Brook stations from May 31, 2016 to October 5, 2016.

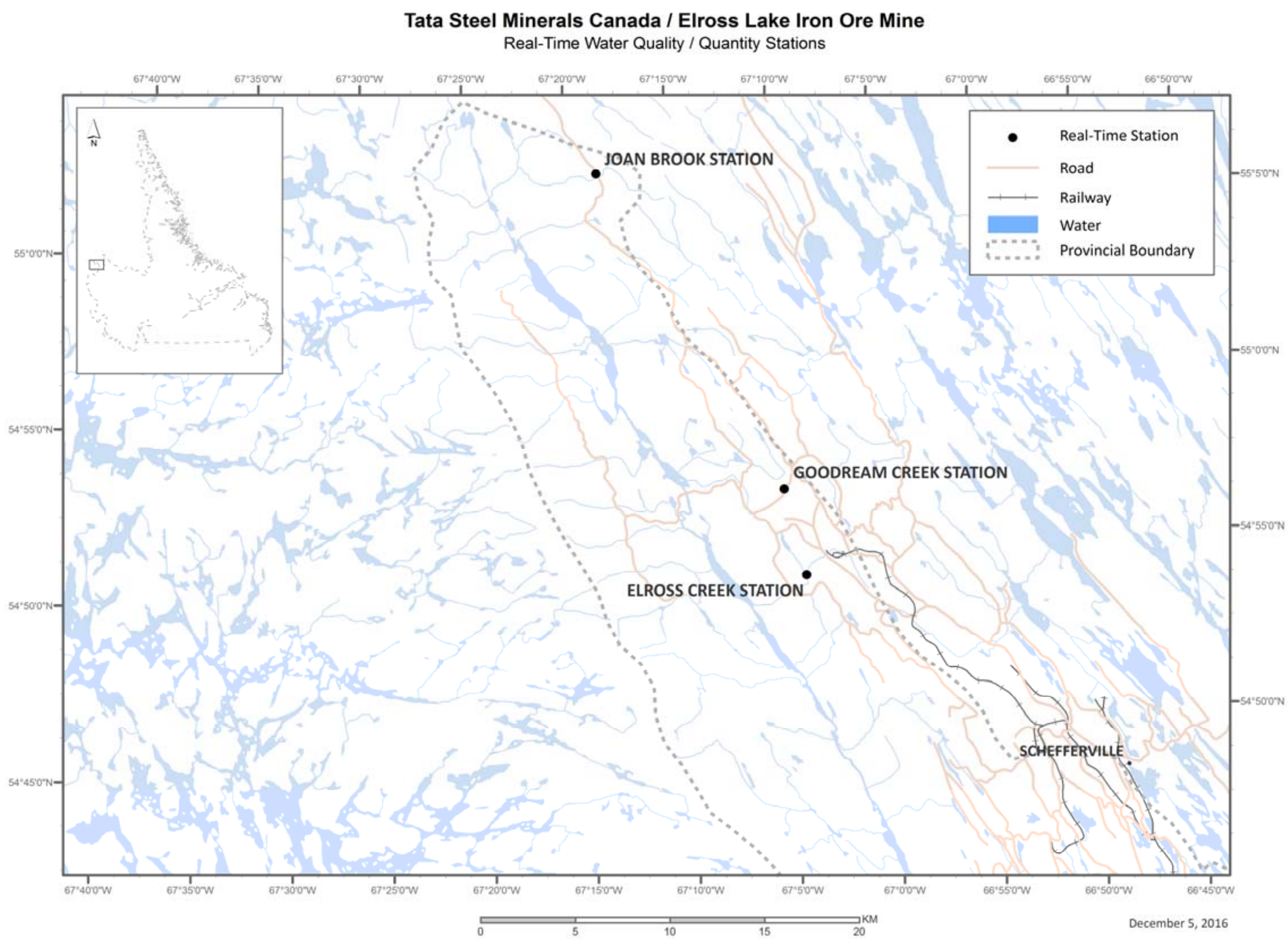

Figure 2. Map of real-time water quality/quantity stations in the vicinity of Elross Lake Iron Ore Mine in Western Labrador.

Quality Assurance & Quality Control

- Water quality parameters are measured at each station using a Hydrolab DataSonde instrument (Figure 3).

Figure 3. Hydrolab DataSonde used for monitoring five water quality parameters.

- To ensure accurate data collection, water quality instruments are subjected to quality assurance procedures, in order to mitigate any errors caused by biofouling and/or sensor drift.
- Quality assurance procedures include: (i) a thorough cleaning of the instrument, (ii) replacement of any small sensor parts that are damaged or unsuitable for reuse, and (iii) the calibration of four instrument sensors (i.e., pH, specific conductivity, dissolved oxygen, and turbidity sensors).
- Quality assurance procedures are carried out every 27-36 days, before the start of a new deployment period. Deployment start and end dates are summarized in Table 2.

Table 2. Water quality instrument deployment start and end dates for 2016 at Elross Creek, Goodream Creek and Joan Brook.

Station	Start date	End date	Duration (days)	Instrument
Elross Creek	2016-06-01	2016-07-06	35	62068
	2016-07-06	2016-08-03	28	62068
	2016-08-03	2016-09-07	35	62065
	2016-09-07	2016-10-05	28	62065
Goodream Creek	2016-05-31	2016-07-06	36	62065
	2016-07-06	2016-08-03	28	62065
	2016-08-03	2016-09-07	35	66462
	2016-09-07	2016-10-04	27	66462
Joan Brook	2016-06-01	2016-07-06	35	66462
	2016-07-06	2016-08-02	27	66462
	2016-08-02	2016-09-06	35	62069
	2016-09-07	2016-10-04	34	43793

- As part of quality control procedures, instrument performance is tested at the start and end of its deployment period. The process is outlined in Appendix A.

- Instruments are assigned a performance rating (i.e., poor, marginal, fair, good or excellent) for each water quality parameter measured.
- Table 3 shows the performance ratings of the instrument sensors (i.e., temperature, pH, conductivity, dissolved oxygen and turbidity) deployed at Elross Creek, Goodream Creek, and Joan Brook. Based on quality control procedures, instrument sensor performance ranged from marginal-to-excellent with the majority of rankings being "good" and "excellent" in 2016. The marginal rating for turbidity at Elross creek was to due relatively high and highly variable turbidity at the time of deployment. At Goodream Creek the marginal rating was for a pH probe that was getting towards the end of its life and was very slow to stabilize in the extremely low specific conductivity water. The poor oxygen comparison at the end of the third deployment at Joan Brook was due to a malfunctioning oxygen sensor on the field instrument. The poor comparison for turbidity at the end of the last deployment at Joan Brook was most likely due to relatively high turbidity over the deployment period causing a buildup on the sensor which the wiper could not keep up with, and/or a malfunctioning wiper.

Table 3. Instrument sensor performance at the start and end of each deployment period for the Elross Creek, Goodream Creek and Joan Brook RTWQ stations.

Station	Stage of deployment	Date (yyyy-mm-dd)	Instrument	Temperature (°C)	pH	Specific conductivity (µS/cm)	Dissolved oxygen (mg/L)	Turbidity (NTU)
Elross Creek	Start	2016-06-01	62068	Excellent	Excellent	Excellent	Good	Marginal
	End	2016-07-06		Excellent	Fair	Good	Excellent	Good
	Start	2016-07-06	62068	Excellent	Excellent	Excellent	Excellent	Excellent
	End	2016-08-03		Excellent	Fair	Excellent	Excellent	NA
	Start	2016-08-03	62065	Excellent	Excellent	Excellent	Excellent	Excellent
	End	2016-09-07		Excellent	Fair	Good	Fair	Good
	Start	2016-09-07	62065	Excellent	Excellent	Excellent	Excellent	Excellent
	End	2016-10-05		Excellent	Excellent	Excellent	Excellent	Excellent
Goodream Creek	Start	2016-05-31	62065	Excellent	Fair	Excellent	Excellent	Excellent
	End	2016-07-06		Excellent	Good	Excellent	Excellent	Excellent
	Start	2016-07-06	62065	Excellent	Excellent	Excellent	Excellent	Excellent
	End	2016-08-03		Good	Fair	Excellent	Excellent	Excellent
	Start	2016-08-03	66462	Excellent	Marginal	Excellent	Excellent	Excellent
	End	2016-09-07		Excellent	Fair	Excellent	Fair	Good
	Start	2016-09-07	66462	Excellent	Excellent	Excellent	Excellent	Excellent
	End	2016-10-04		Excellent	Good	Excellent	Excellent	Excellent
Joan Brook	Start	2016-06-01	66462	Excellent	Excellent	Excellent	Excellent	Good
	End	2016-07-06		Excellent	Excellent	Excellent	Excellent	Excellent
	Start	2016-07-06	66462	Excellent	Excellent	Excellent	Excellent	Excellent
	End	2016-08-02		Excellent	Good	Excellent	Excellent	Excellent
	Start	2016-08-02	62069	Good	Good	Excellent	Excellent	Excellent
	End	2016-09-06		Excellent	Fair	Excellent	Poor	Excellent
	Start	2016-09-07	43793	Excellent	Fair	Excellent	Good	Excellent
	End	2016-10-04		Good	Good	Excellent	Good	Poor

- Bath tests conducted in the winter of 2016 prior to the commencement of the field season showed that all sensors performed well for all instruments. The discrepancies between field instruments and QA/QC instruments for the 2016 field season were relatively minor and within the range normally experienced under rigours field conditions.

Deployment Notes

- 2016 Operations at TSMC's DSO Project recommenced in June from DSO Area 3 and DSO Area 4. Run of Mine (ROM) was hauled to two dry processing plants where the ore was crushed and sized prior to evacuation via rail to Sept-Iles. Product was loaded at the Port of Sept-Iles for onward shipment to customers in Europe and China. TSMC also dispatched two trial shipments from port facilities of Pointe Noire following the acquisition of the facilities by the Government of Quebec in 2016. TSMC's reputation for ensuring safe operations was acknowledged by the Canadian Institute of Mining and Metallurgy (CIM) which in 2016 awarded TSMC the coveted John T. Ryan Award for Eastern Canada. TSMC's operations will be limited in the winter of 2017 and are planned to resume in the spring of 2017.
- The 2016 field season at TSMC ran from May 31st, 2016 until October 5th, 2016 with four back-to-back deployment periods. There were no significant operational issues with any of the equipment deployed during the 2016 field season. It should be noted that during the first three deployment periods there were occasions at Goodream Creek where streamflow was extremely low and water quality parameters such as specific conductivity, pH and dissolved oxygen were impacted.

Data Interpretation

- Performance issues and data records were interpreted for each station during the deployment period for the following seven parameters:

  (i.) Stage (m)
  (ii.) Temperature (^oC)
  (iii.) pH
  (iv.) Specific conductivity (µs/cm)
  (v.) Total dissolved solids (g/l)
  (vi.) Dissolved oxygen (mg/l)
  (vii.) Turbidity (NTU)

- A description of each parameter is provided in Appendix B.

Stage

- Figures 4, 5 and 6, display stage values recorded at the three stations from May 31st, 2016 to October 5th, 2016. These values are provisional. A complete dataset of quality assured and quality controlled stage values should be available upon request through ECCC after March 2017 (http://www.ec.gc.ca/rhc-wsc/default.asp).
- Stage values ranged from 1.06 m to 1.26m at Elross Creek, from 1.73 m to 2.05 m at Goodream Creek, and from 1.48 m to 1.72 at Joan Brook from May 31st, 2016 to October 5th, 2016.
- Fluctuations in stage corresponded well with rainfall events (Climate data located in Appendix C). For example, at all three stations a significant spike in stage height can be seen around August 5th and 6th (see inside red ovals – Figures 4, 5 & 6). These spikes correspond with a period of heavy rainfall from August 5th to 7th, when a total rainfall of 82.5 mm was recorded for the Schefferville area.
- During the middle of the field season there were a number of occasions when the stage height and associated streamflow at the Goodream Creek station were critically low, and some water quality parameters were pushed outside their normal range. The three most significant dips in stage height are indicated with green ovals in Figure 5. Despite the fact that stage height was very low, the deployed hydrolab remained fully submerged in water and did not have to be removed. These low flow periods are natural occurrences at Goodream Creek during extended dry spells in the summer season.
- Stage values are based on a vertical reference that is unique to each station. As a result, absolute values of stage are not comparable between stations, but relative changes in stage are.

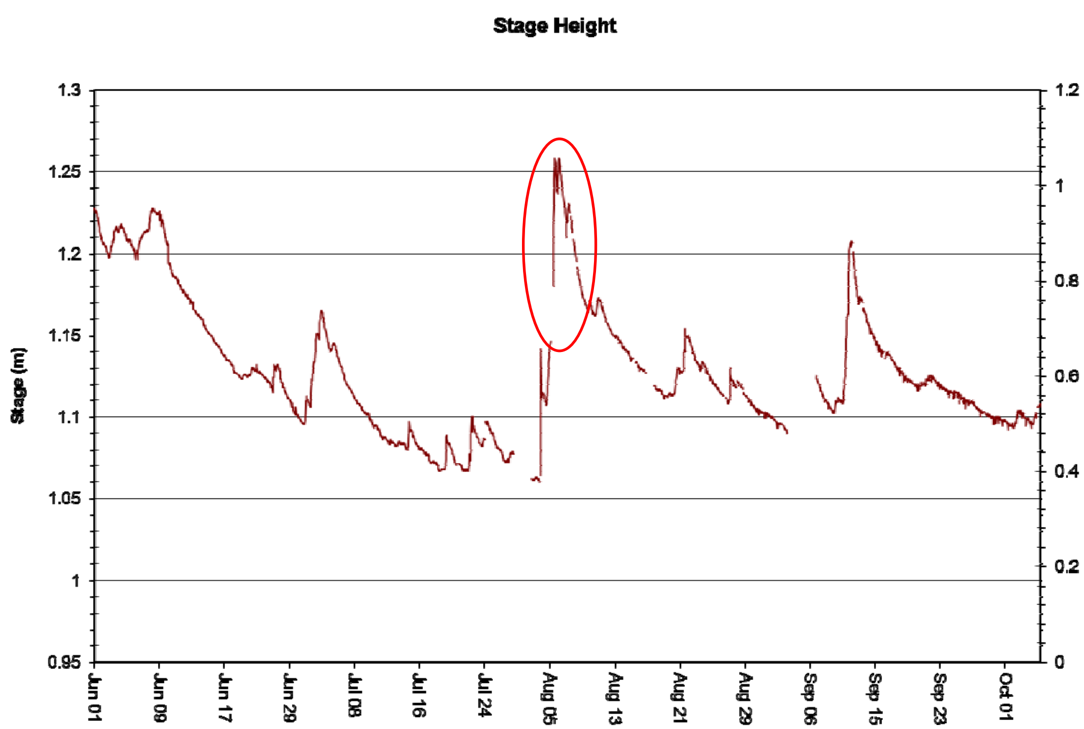

Figure 4. Elross Creek - Stage Height (m) - June 1, 2016 to October 5, 2016.

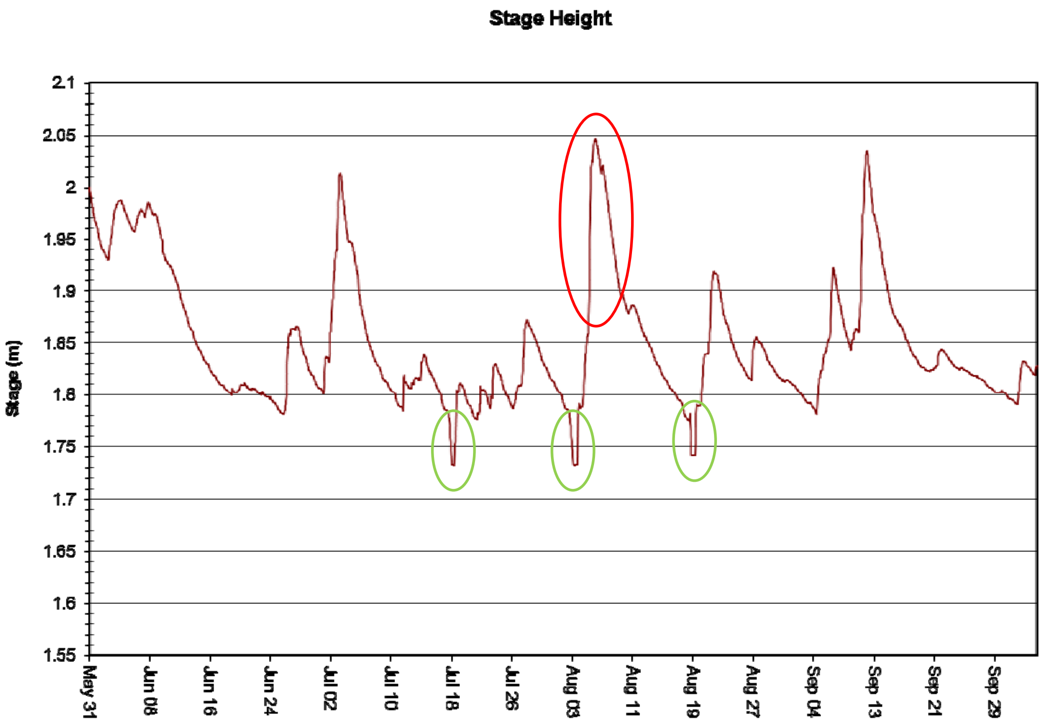

Figure 5. Goodream Creek Stage Height (m) - May 31, 2016 to October 4, 2016.

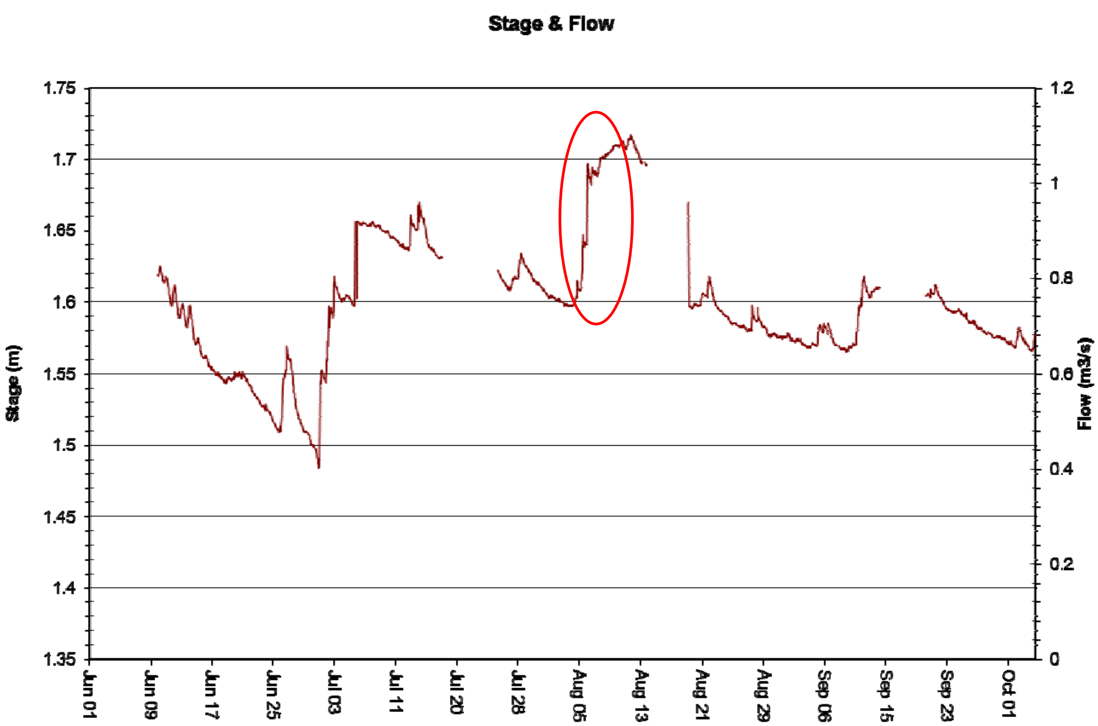

Figure 6. Joan Brook - Stage Height (m) - June 1, 2016 to October 4, 2016.

Temperature

- Water temperature ranged from 1.30˚C to 15.60˚C at Elross Creek, from 0.50˚C to 19.10˚C at Goodream Creek, and from 0.18˚C to 16.20˚C at Joan Brook from May 31st, 2016 to October 5th, 2016 (Figures 7, 8 & 9).
- Water temperatures at all three stations display large diurnal variations. This is typical of shallow water streams and ponds that are highly influenced by diurnal variations in ambient air temperatures.
- Trends in water temperature corresponded very well with trends in air temperatures recorded by ECCC at the Schefferville weather station (Figure 2 in Appendix C). Temperature trends at all three stations are very similar. Temperature increases from June through early July, is stable for most of July and early August, and decreases after that as fall sets in.

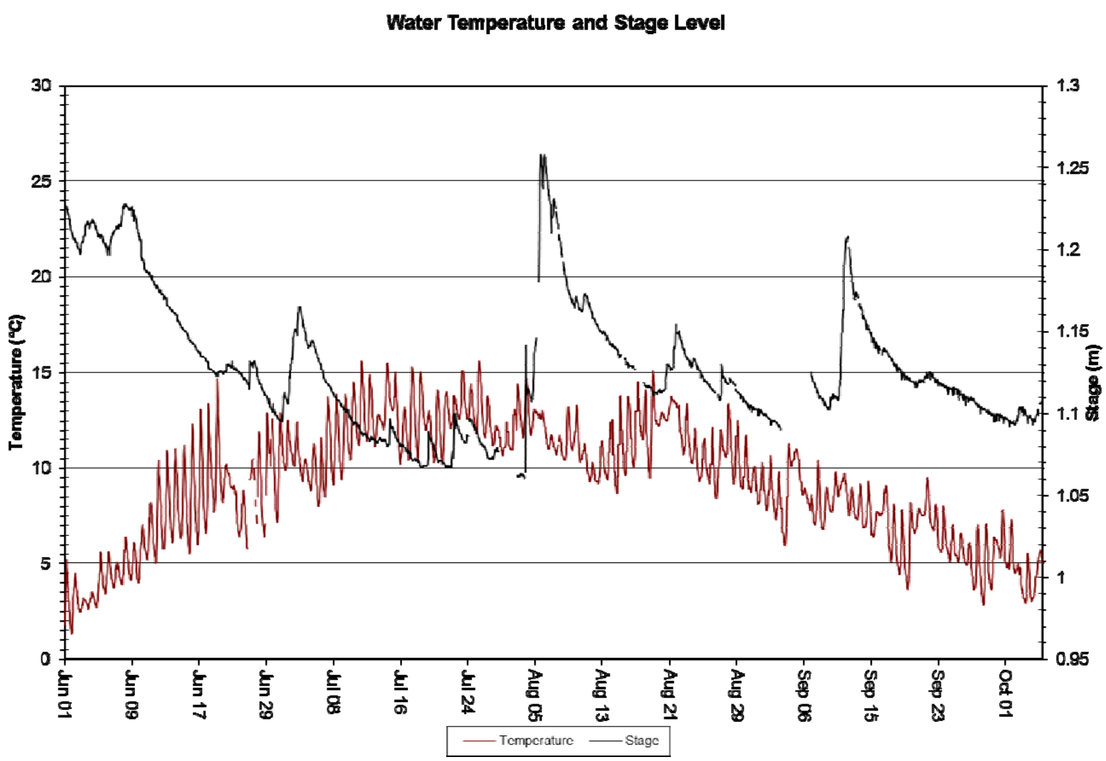

Figure 7. Elross Creek - Water Temperature (^oC) - June 1, 2016 to October 5, 2016.

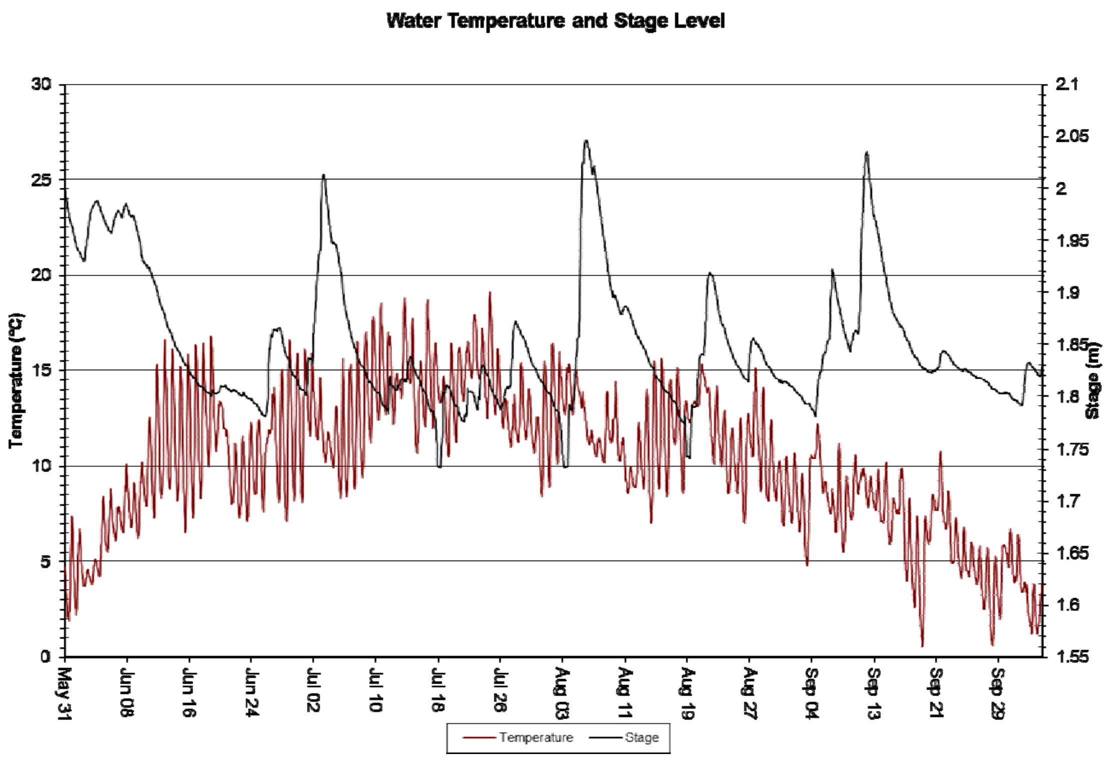

Figure 8. Goodream Creek - Water Temperature (°C) - May 31, 2016 to October 4, 2016

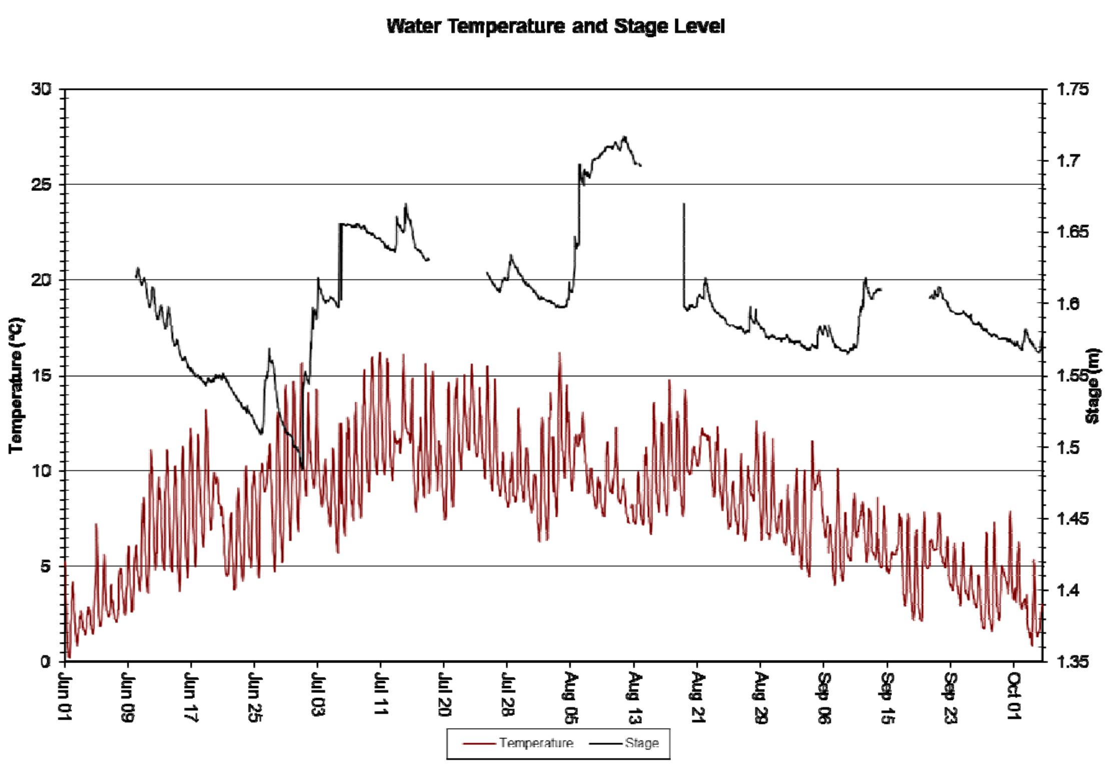

Figure 9. Joan Brook - Water Temperature (°C) - June 1, 2016 to October 4, 2016

pH

- pH values ranged from 5.97 units to 7.20 units at Elross Creek, from 4.87 to 6.68 at Goodream Creek, and from 5.66 units to 7.00 units at Joan Brook, from May 31st, 2016 to October 5th, 2016 (Figures 10. 11 & 12).
- pH values show diurnal variations at all three stations. These diurnal variations are related to diurnal fluctuations in temperature, oxygen and photosynthetic cycling of CO_2 by aquatic organisms.
- pH values at Elross creek are relatively stable throughout the deployment season, however it is possible to see the impact of significant increases in flow as indicated by stage height, when pH take a noticeable dip (see inside red ovals, Figure 10)
- At Goodream Creek pH is fairly variable due to both low flow conditions and significant increases in flow. During low flow conditions around August, 3rd and August 19th it appears that pH is affected and a notable dip can be seen(see inside red ovals, Figure 11). During periods with rapidly increasing flow, pH is also affected and appears to make noticeable dips. For example during rapid increases in flow around June 3rd, August 4th and September 12th pH appears to make a noticeable drop (see inside green ovals, Figure 11).
- At Joan Brook pH is relatively stable during the deployment period. Towards the end of the first deployment period it is possible to see how the pH readings are dropping and showing more diurnal variation as they drift off calibration (see inside red oval, Figure 12). At the beginning of the fourth deployment period pH drops significantly (see inside green oval, Figure 12) which is most likely a combination of pH having drifted off calibration in the third deployment period and the replacement hydrolab having an older pH probe which was very slow to stabilize.
- With a median value of 6.65 most pH values recorded at Elross Creek were slightly above the minimum pH guideline set for the protection of aquatic life (i.e., 6.5 units), as defined by the Canadian Council of Ministers of the Environment (2007). At Goodream Creek the median pH value was 6.11 and most of the values were below the minimum pH guideline. At Joan Brook the median pH value was 6.65 and most of the pH values recorded were above the minimum pH guideline. In general low pH levels are considered normal for this area, based on baseline data collected around July 17-19, 2008 and September 10-12, 2008 (AMEC 2009, as cited in NML 2009). It should be noted that acidic waters are quite common in Canada, particularly in boreal and northern ecoregions, and pH is often naturally below the 6.5 unit guideline.

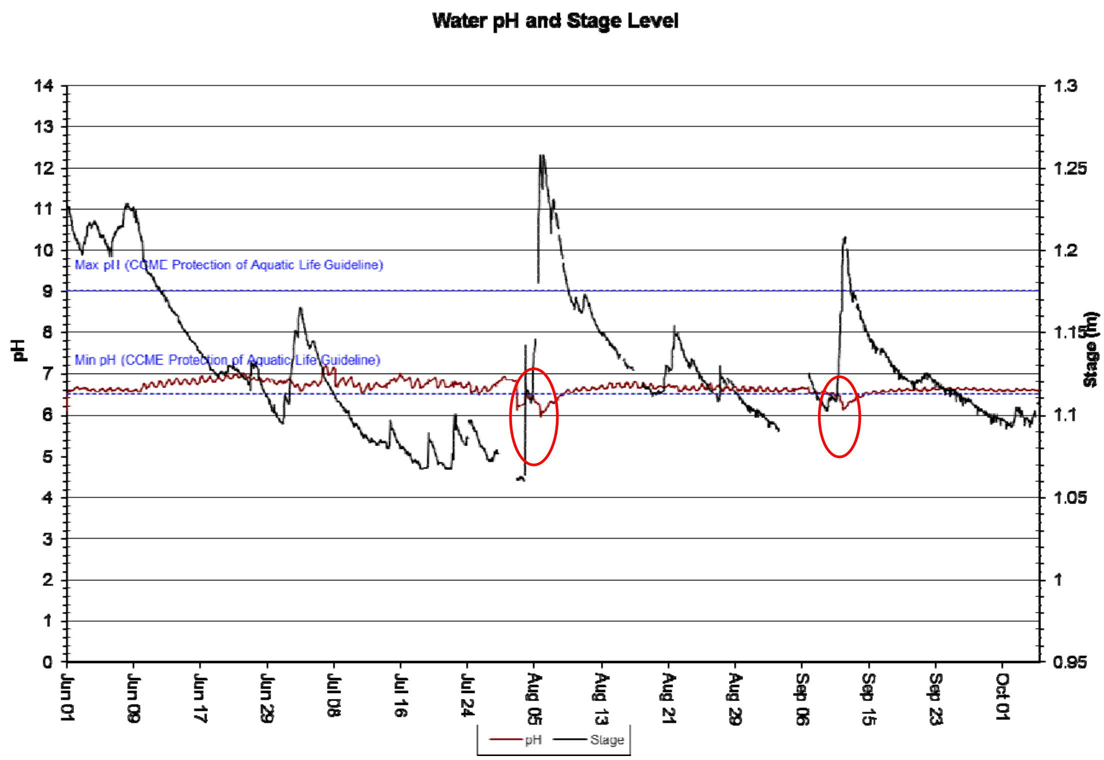

Figure 10. Elross Creek - pH Values - June 1, 2016 to October 5, 2016.

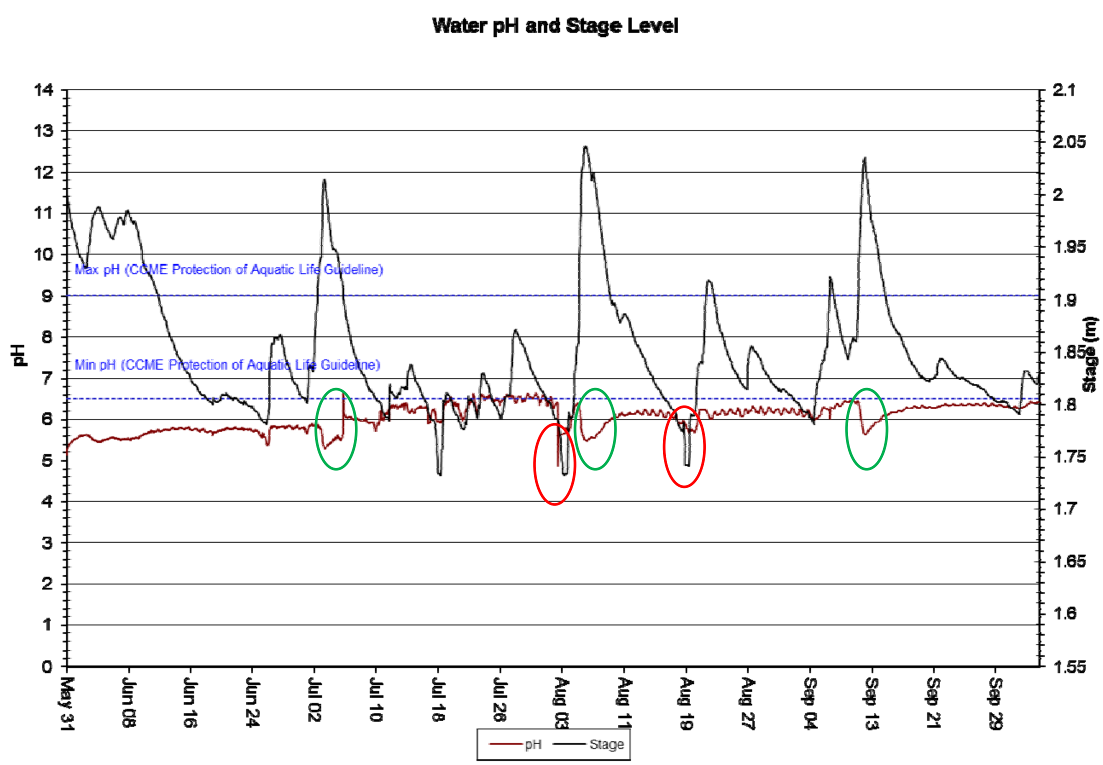

Figure 11. Goodream Creek - pH Values - May 31, 2016 to October 4, 2016.

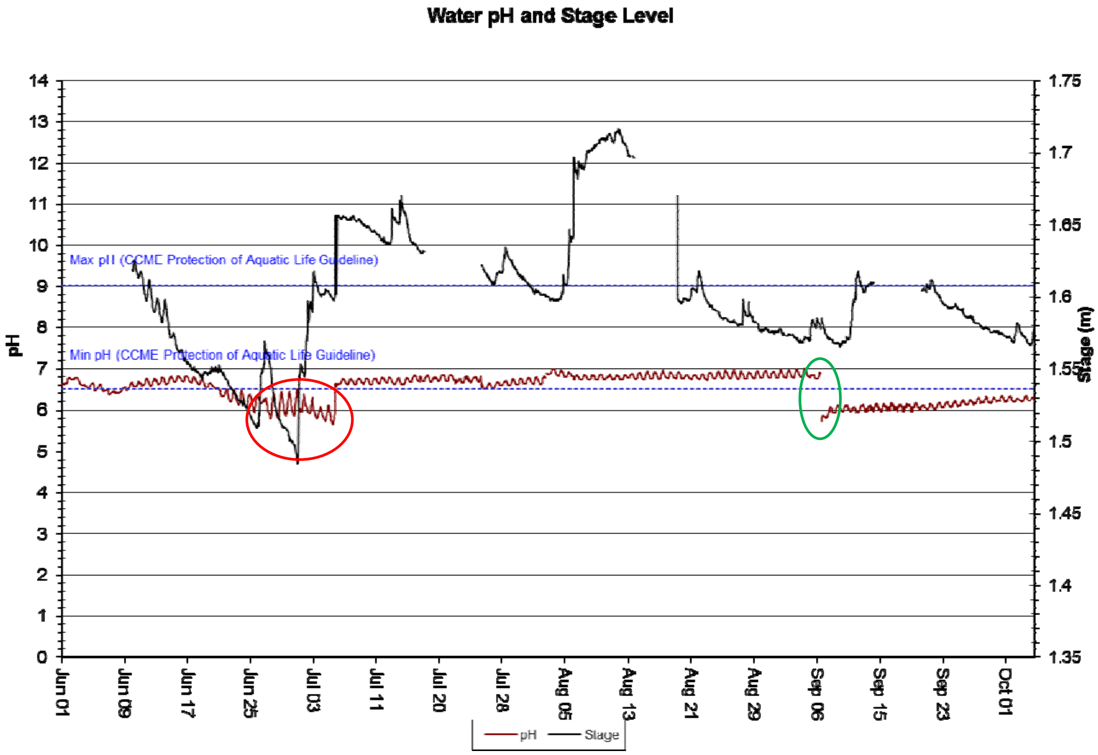

Figure 12. Joan Brook - pH Values – June 1, 2016 to October 4, 2016.

Specific Conductivity

- Specific Conductivity ranged from 10.0 µs/cm to 21.0 µs/cm at Elross Creek, from 2.5 µs/cm to 17.0 µs/cm at Goodream Creek, and from 3.0 µs/cm to 8.5 µs/cm at Joan Brook, from May 31st, 2016 to October 5th, 2016 (Figures 13, 14 & 15).
- Specific conductivity values at all three stations showed regular diurnal fluctuations which are related to diurnal temperature fluctuations.
- Specific conductivity is highly variable at all three stations with the highest degree of variation at Goodream Creek where fluctuations from low flow to high flow conditions seems to have a volatile impact on specific conductivity.

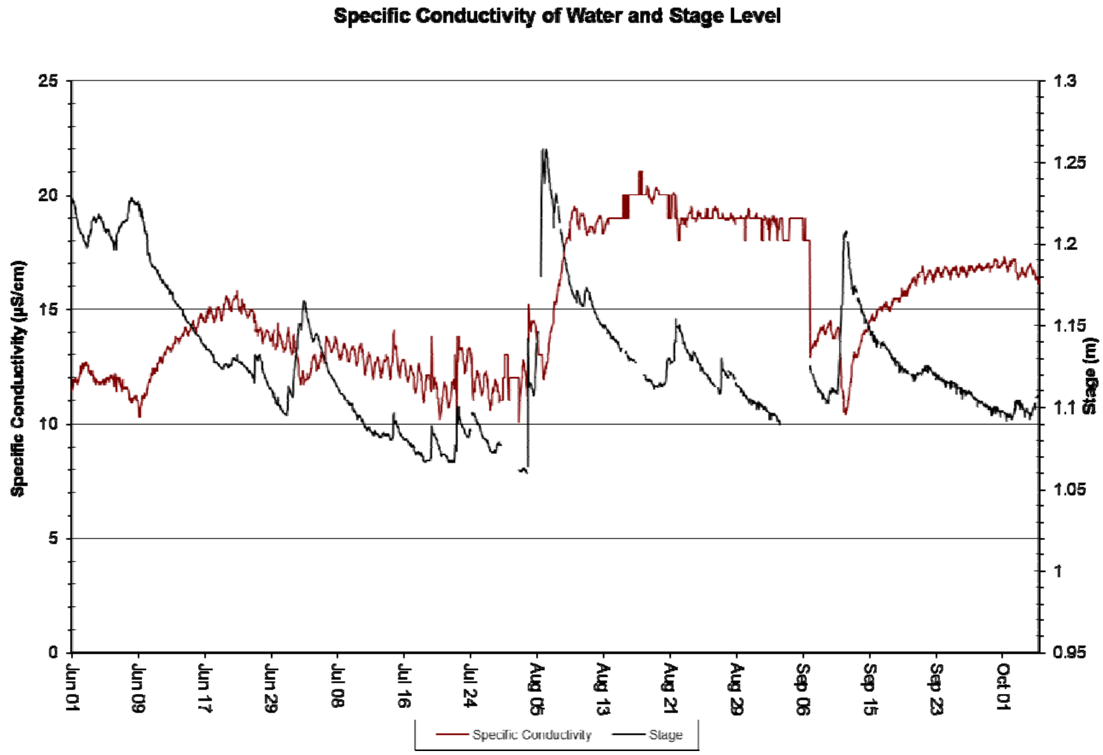

Figure 13. Elross Creek - Specific Conductivity (µS/cm) - June 1, 2016 to October 5, 2016.

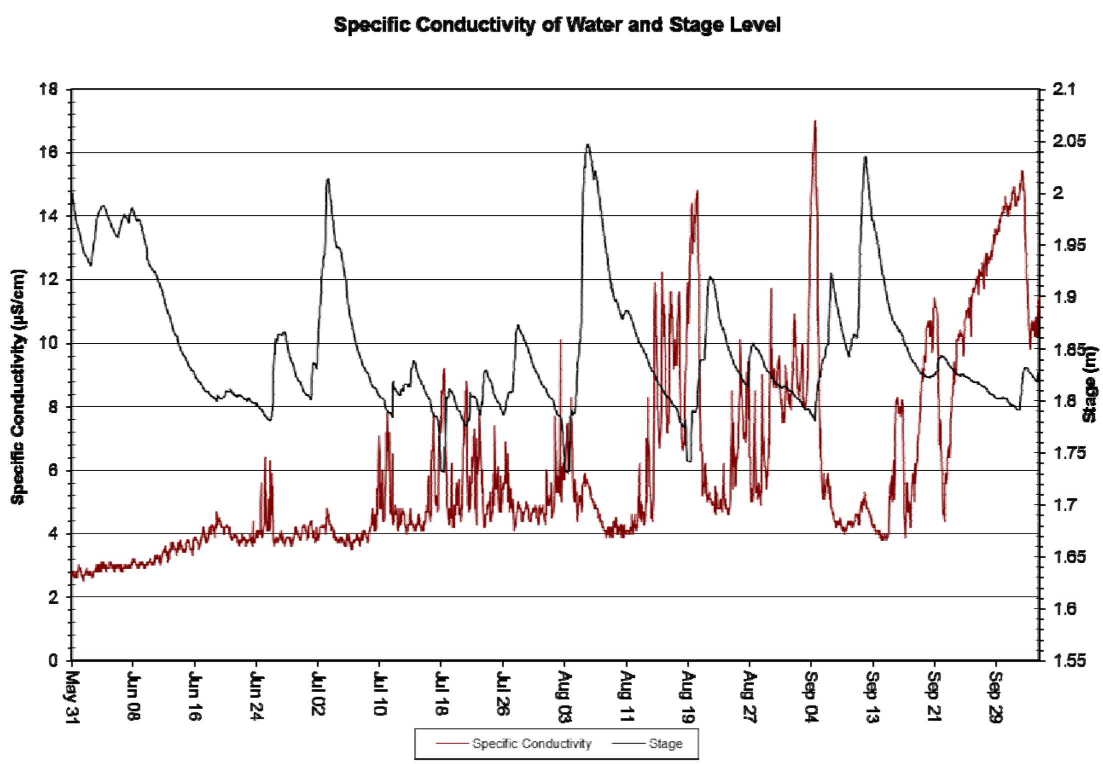

Figure 14. Goodream Creek - Specific Conductivity (µS/cm) -May 31, 2016 to October 4, 2016.

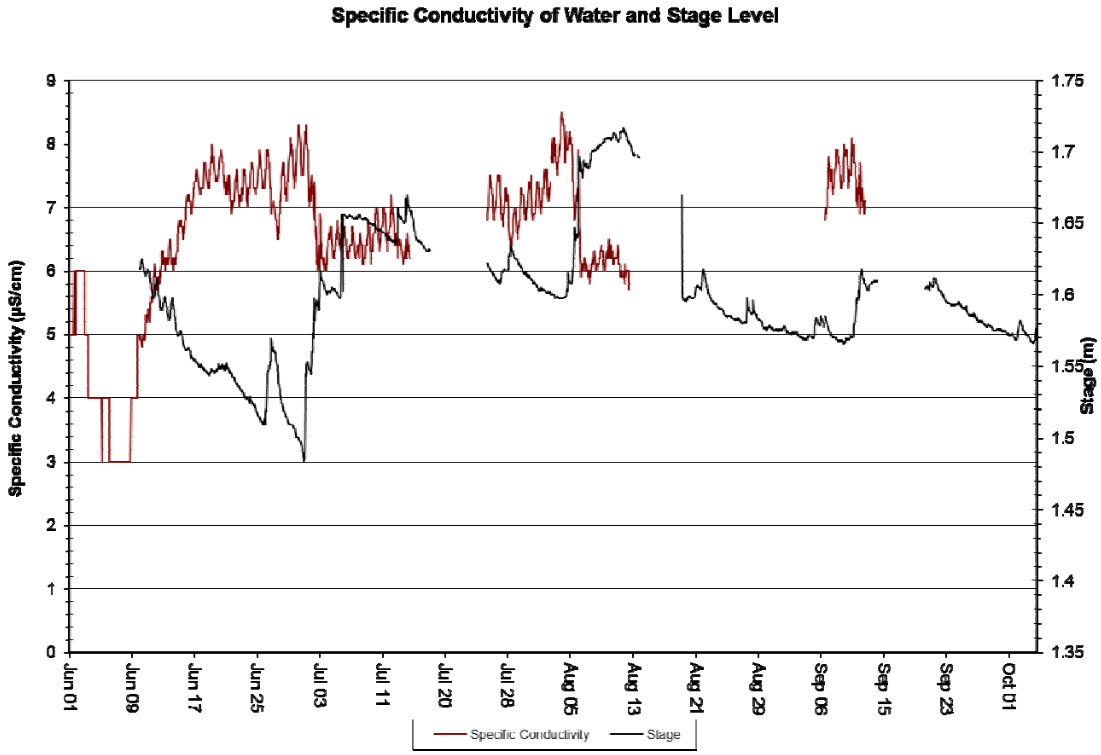

Figure 15. Joan Brook - Specific Conductivity (µS/cm) - June 1, 2016 to October 4, 2016

Dissolved Oxygen

- Dissolved Oxygen (DO) values ranged from 8.32 mg/l (83.5%) to 12.92 mg/l (99.5%) at Elross Creek, from 1.42 mg/l (14.3%) to 12.66 mg/l (106.0%) at Goodream Creek, and from 8.93 mg/l (90.3%) to 13.07 mg/l (102.9%) at Joan Brook, from May 31st, 2016 to October 5th, 2016 (Figures 16, 17 & 18).
- Oxygen levels at Goodream creek were heavily impacted by low flow conditions and on numerous occasions dipped well below the normal range (see inside red ovals, Figure 17) to levels dangerously low for fish and other aquatic species. It appears that these low oxygen values were caused naturally, by extremely low water levels due to a relatively dry year. When water levels are extremely low and there is little or no flowing water, oxygen becomes depleted.
- DO levels show diurnal variations at all three stations. These diurnal variations are related to diurnal fluctuations in temperature and photosynthetic cycling of CO_2 by aquatic organisms.
- Trends in DO corresponded well with the inverse of water temperature, since colder water has a greater potential to dissolve oxygen compared to warmer water. As a result DO is higher in the spring and fall when water temperatures are cooler.
- DO values at Elross Creek and Joan Brook fell below cold water minimum guidelines set for aquatic life during early life stages (9.5 mg/l), but were above minimum guidelines set for other life stages (6.5 mg/l), as determined by the Canadian Council of Ministers of the Environment (2007). Due to low flow at Goodream Creek, DO values fell below both the early life stages 9.5 (mg/l) and other life stages (6.5 mg/l) guidelines.

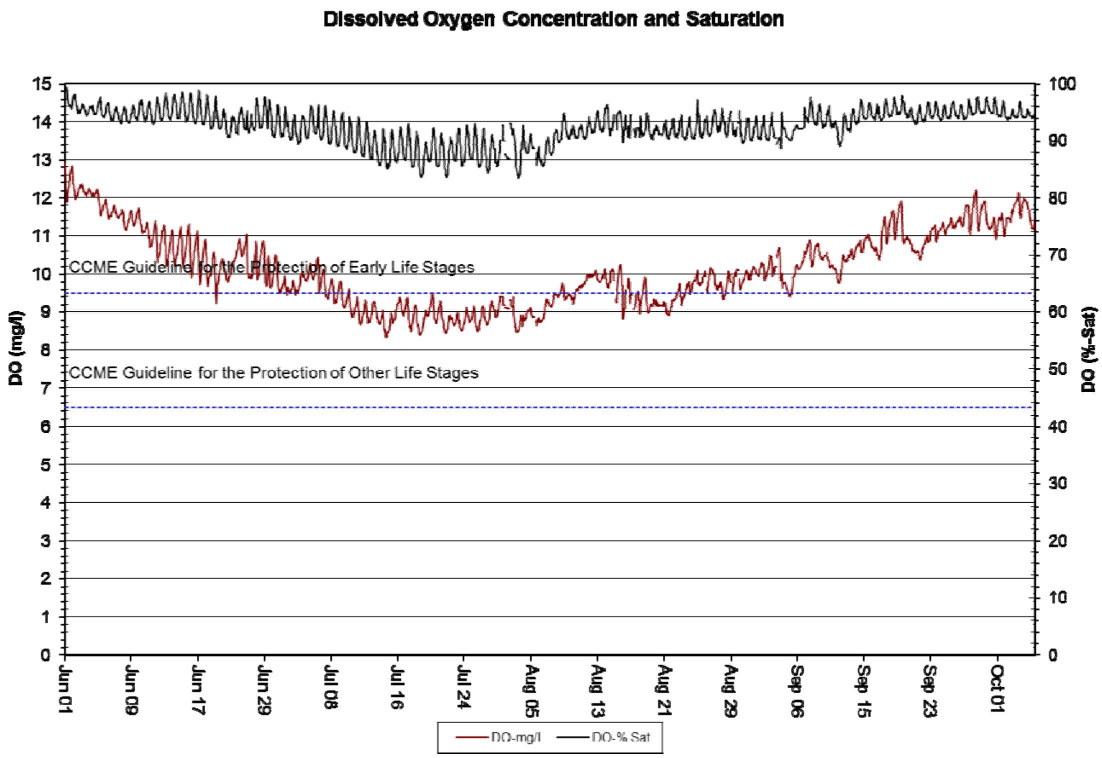

Figure 16. Elross Creek - Dissolved Oxygen (mg/l & %Saturation) – June 1, 2016 to October 5, 2016.

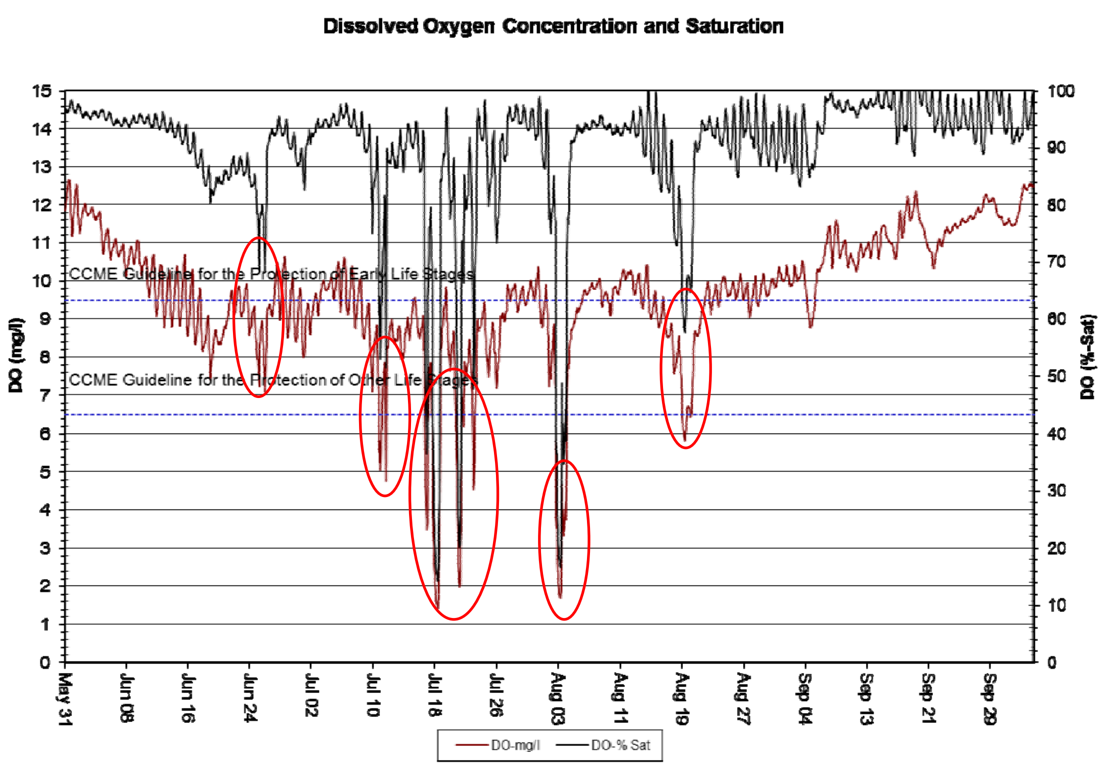

Figure 17. Goodream Creek - Dissolved Oxygen (mg/l) - May 31, 2016 to October 4, 2016.

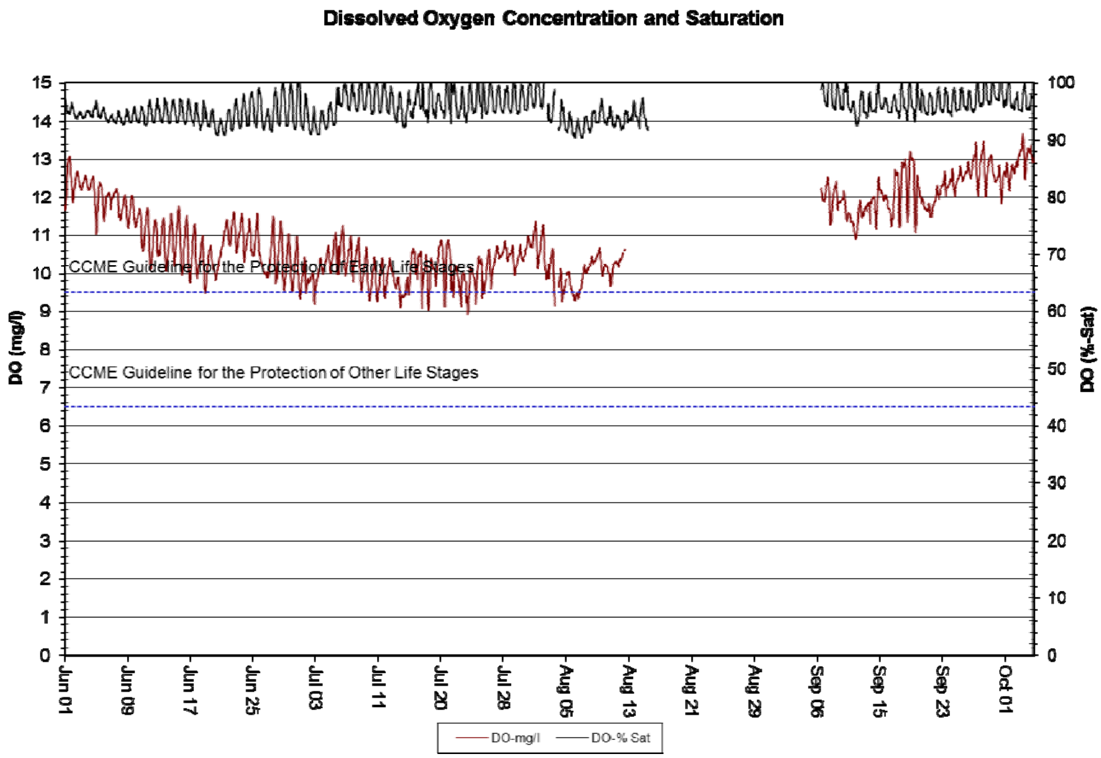

Figure 18. Joan Brook - Dissolved Oxygen (mg/l & % Saturation) - June 1, 2016 to October 4, 2016.

Turbidity

- Turbidity values ranged from 0.0 NTU to 1251.0 NTU at Elross Creek, from 0.0 NTU to 1674.0 NTU at Goodream Creek, and from 0.0 NTU to 1097.0 NTU, from May 31st, 2016 to October 5th, 2016 (Figures 19. 20 & 21).
- For all three stations significant spikes in turbidity correspond closely with significant increases in flow as indicated by stage height. For example, the most significant spike in stage height at all three stations is related to heavy rainfall from August 5th to 7th and for all three stations there is a corresponding spike in turbidity (see inside red ovals, Figures 19, 20 & 21).
- Turbidity is generally higher and subject to much greater fluctuations at Elross Creek than it is at Goodream Creek or Joan Brook. This difference is understandable given the fact that the Elross Creek watershed has significant disturbance from historical and ongoing mining activity, while the Goodream Creek watershed is relatively undisturbed and the Joan Brook watershed is in the early stages of development.

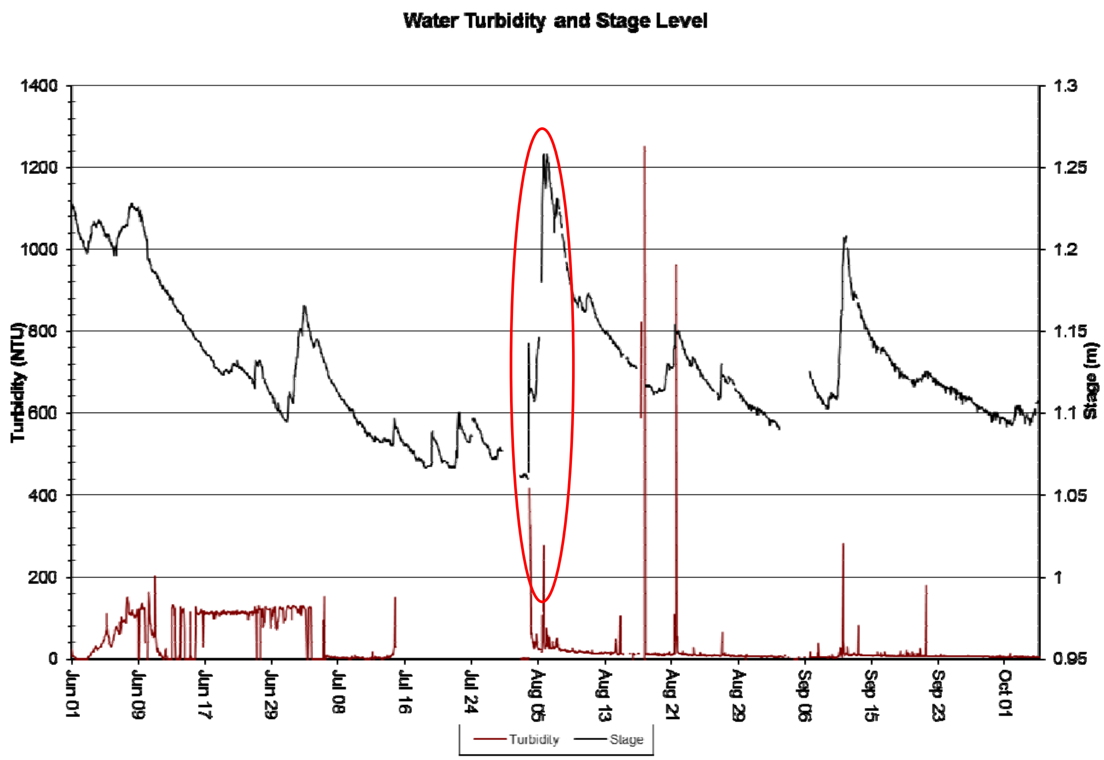

Figure 19. Elross Creek - Turbidity (NTU) values - June 1, 2016 to October 5, 2016.

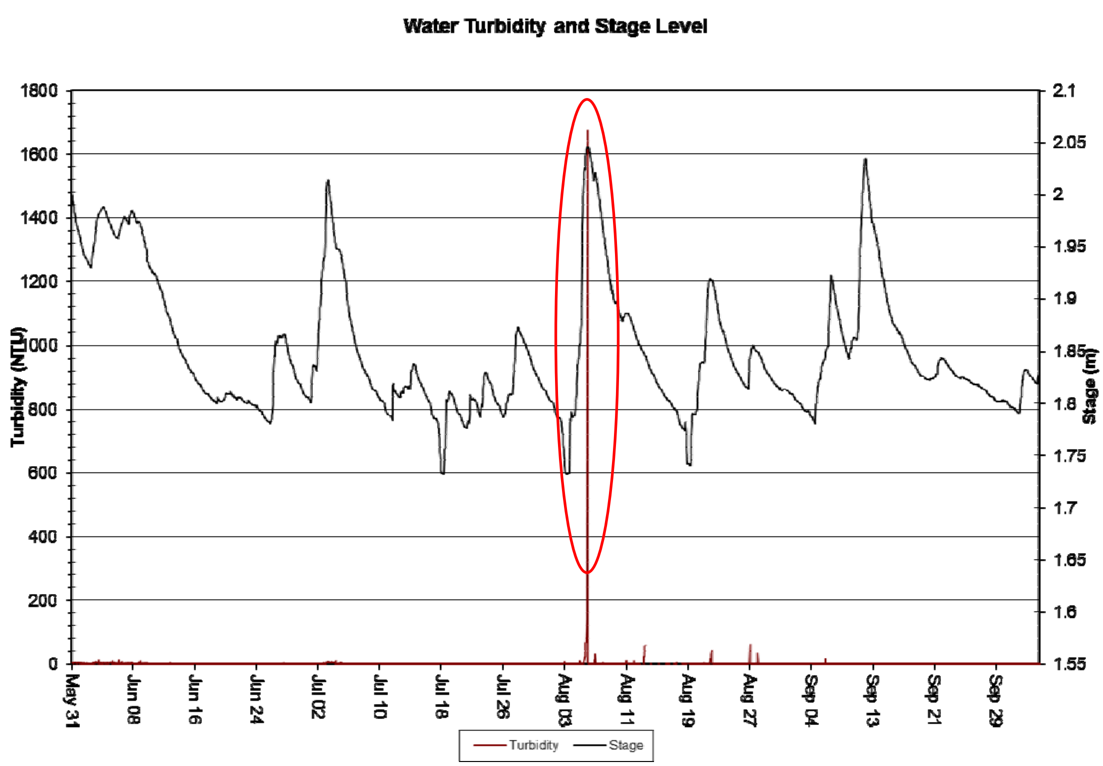

Figure 20. Goodream Creek - Turbidity (NTU) - May 31, 2016 to October 6

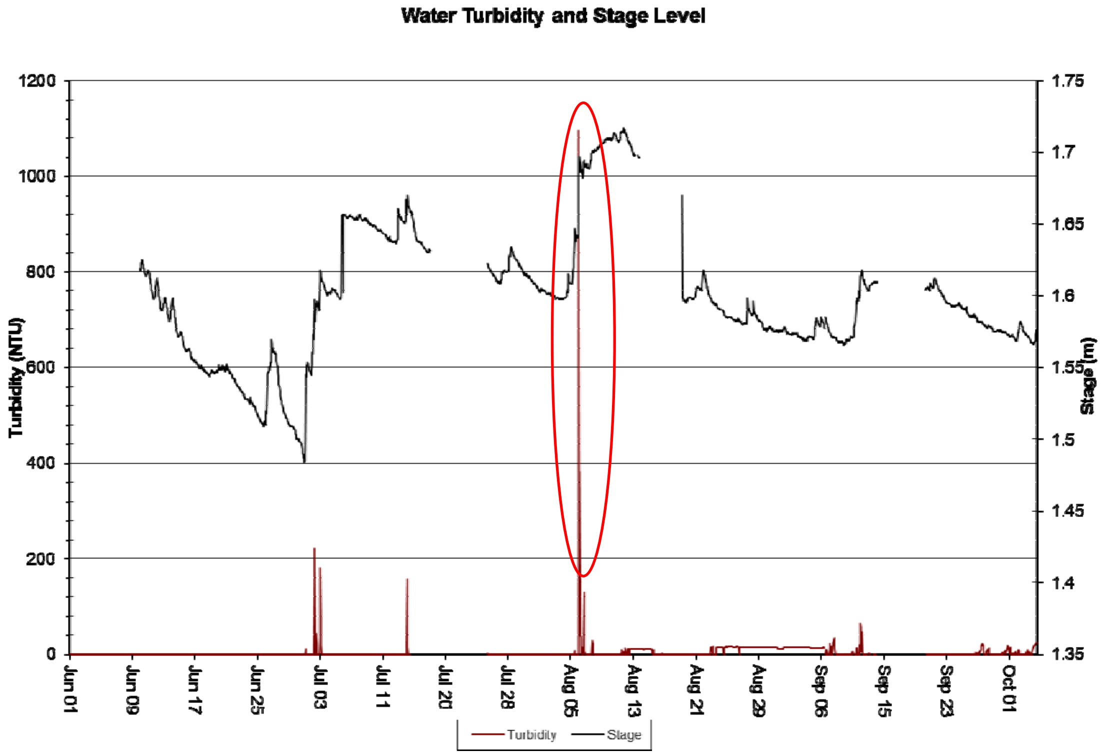

Figure 21. Joan Brook - Turbidity (NTU) - June 1, 2016 to October 4, 2016

Conclusions

- Water quality monitoring instruments were deployed at three stations near the Elross Lake and DSO4 Project 2B, Iron Ore Mine between May 31st, 2016 and October 5th, 2016. The stations are located on Elross Creek, Goodream Creek and Joan Brook.
- The water quality monitoring instruments were deployed for four consecutive deployment periods ranging from 27 to 36 days.
- The performance ratings of all instrument sensors ranged between marginal to excellent at the beginning of each of the four deployment periods, and poor and excellent at the end of the deployment periods. The marginal rating for turbidity at Elross creek was to due relatively high and highly variable turbidity at the time of deployment. At Goodream Creek the marginal rating was for a pH probe that was getting towards the end of its life and was very slow to stabilize in the extremely low specific conductivity water. The poor oxygen comparison at the end of the third deployment at Joan Brook was due to a malfunctioning oxygen sensor on the field instrument. The poor comparison for turbidity at the end of the last deployment at Joan Brook was most likely due to relatively high turbidity over the deployment period causing a buildup on the sensor which the wiper could not keep up with, and/or a malfunctioning wiper.
- It should be noted that extreme low flow conditions at Goodream Creek pushed the values of a number of parameters, including; oxygen, specific conductivity and pH, outside their normal range on several occasions.
- Variations in water quality/quantity values recorded at each station are summarized below:

- STAGE: Stage values ranged from 1.06 m to 1.26m at Elross Creek, from 1.73 m to 2.05 m at Goodream Creek, and from 1.48 m to 1.72 at Joan Brook from May 31st, 2016 to October 5th, 2016. Fluctuations in stage corresponded well with rainfall events. During three out of four deployment periods stage height at the Goodream Creek station was critically low and some water quality parameters were pushed outside their normal range.
- WATER TEMPERATURE: Water temperature ranged from 1.30˚C to 15.60˚C at Elross Creek, from 0.50˚C to 19.10˚C at Goodream Creek, and from 0.18˚C to 16.20˚C at Joan Brook from May 31st, 2016 to October 5th, 2016. Water temperatures at all three stations display large diurnal variations and seasonal water temperature trends corresponded very well with trends in air temperatures.

- pH: pH values ranged from 5.97 units to 7.20 units at Elross Creek, from 4.87 to 6.68 at Goodream Creek, and from 5.66 units to 7.00 units at Joan Brook, from May 31st, 2016 to October 5th, 2016. At Goodream Creek there were several periods when pH dipped below the normal range which was related to periods of extremely low flow. pH values show diurnal variations at all three stations which are related to diurnal fluctuations in temperature, oxygen and photosynthetic cycling of CO_2 by aquatic organisms.

- SPECIFIC CONDUCTIVITY: Specific Conductivity ranged from 10.0 µs/cm to 21.0 µs/cm at Elross Creek, from 2.5 µs/cm to 17.0 µs/cm at Goodream Creek, and from 3.0 µs/cm to 8.5 µs/cm at Joan Brook, from May 31st, 2016 to October 5th, 2016. Specific conductivity values at all three stations showed regular diurnal fluctuations which are related to diurnal temperature fluctuations.
- DISSOLVED OXYGEN: Dissolved Oxygen (DO) values ranged from 8.32 mg/l (83.5%) to 12.92 mg/l (99.5%) at Elross Creek, from 1.42 mg/l (14.3%) to 12.66 mg/l (106.0%) at Goodream Creek, and from 8.93 mg/l (90.3%) to 13.07 mg/l (102.9%) at Joan Brook, from May 31st, 2016 to October 5th, 2016. On several occasions at Goodream Creek oxygen levels dipped well below the normal range to levels dangerously low for fish and other aquatic species. It appears that these low oxygen values were caused naturally, by extremely low water levels due to a relatively dry year. DO levels show diurnal variations at both stations which are related to diurnal fluctuations in temperature and photosynthetic cycling of CO_2 by aquatic organisms. Trends in DO corresponded well with the inverse of water temperature and as a result, DO is higher in the spring and fall when water temperatures are cooler.
- TURBIDITY: Turbidity values ranged from 0.0 NTU to 1251.0 NTU at Elross Creek, from 0.0 NTU to 1674.0 NTU at Goodream Creek, and from 0.0 NTU to 1097.0 NTU, from May 31st, 2016 to October 5th, 2016. For all three stations significant spikes in turbidity correspond closely with significant increases in flow as indicated by stage height. Turbidity is generally higher and subject to much greater fluctuations at Elross Creek than it is at Goodream Creek and Joan Brook. This difference is understandable given the fact that the Elross Creek watershed has significant disturbance from historical and

ongoing mining activity, while the Goodream Creek watershed is relatively undisturbed and Joan brook is in the early stages of development.

Path Forward

- ECC staff will redeploy RTWQ instruments at Elross Creek, Goodream Creek and Joan Brook in the spring of 2017, when ice conditions allow. The field season will be broken down into four, month long deployment periods, and WRMD staff will perform regular site visits for calibration and maintenance of the instruments.
- ECC staff will continue to rely on input and assistance from TSMC staff in the operation and maintenance of all three TSMC Real Time Water Quality stations at Elross Creek, Goodream Creek and Joan Brook. Every effort will be made to coordinate in advance with TSMC staff for site visits during the 2017 field season. ECC staff are very appreciative of the field assistance provided by TSMC staff during the 2016 field season and are hoping to carry on with this arrangement again next year.
- If necessary, deployment techniques will be evaluated and adapted to each site, ensuring secure and suitable conditions for RTWQ monitoring.
- ECC staff will update TSMC staff on any changes to processes and procedures with handling, maintaining and calibrating the real-time instruments.
- ECCC staff will perform regular site visits to ensure water quantity instrumentation is correctly calibrated and providing accurate measurements.
- Parameter alerts will be set prior to the 2017 deployment season to notify ECC staff by email of any emerging water quality issues.
- TSMC will continue to be informed of data trends and any significant water quality events in the form of email and/or monthly deployment reports, when the deployment season begins. TSMC will also receive an annual report, summarizing the events of the deployment season.
- ECC has begun development of models using water quality monitoring data and grab sample data to estimate a variety of additional water quality parameters (e.g., TSS and major ions). This work will continue with a goal in implementing these models for RTWQ data collected.
- ECC will continue to work on its Automatic Data Retrieval System, to incorporate new capabilities in data management and data display.
- ECC will be active in creating new value added products using the RTWQ data and water quality indices.
- Open communication will continue to be maintained between ECC, ECCC and TSMC employees involved with the agreement, in order to respond to emerging issues on a proactive basis.

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APPENDIX A
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 start 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 start of the deployment period, a fully cleaned and calibrated QA/QC water quality instrument (i.e., QA/QC Sonde) is placed *in-situ* with the fully cleaned and calibrated Field Sonde. After Sonde readings have stabilized, which may take up to five minutes in some cases, water quality parameters, as measured by both Sondes, are recorded to a field sheet. Field Sonde performance for all parameters is rated based on differences recorded by the Field Sonde and QA/QC Sonde. If the readings from both Sondes are in close agreement, the QA/QC Sonde can be removed from the water. If the readings are not in close agreement, there will be attempts to reconcile the problem on site (e.g., removing air bubbles from sensors, etc.). If no fix is made, the Field Sonde may be removed for recalibration.
- At the end of the deployment period, a fully cleaned and calibrated QA/QC Sonde is once again deployed *in-situ* with the Field Sonde, which has already been deployment for 30-40 days. After Sonde readings have stabilized, water quality parameters, as measured by both Sondes, are recorded to a field sheet. Field Sonde performance for all parameters is rated based on differences recorded by the Field Sonde and QA/QC Sonde.
- Performance ratings are based on differences listed in the table below.

	Rating				
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 ≤ 35 (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)	≤ ±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 (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 B
Water Parameter Description

Dissolved Oxygen - The amount of Dissolved Oxygen (DO) (mg/l) 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).

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 (S/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 (^{o}C) 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).

APPENDIX C

Environment Canada Weather Data - Schefferville (May 31, 2016 to Oct.5, 2016)

Date/Time	Max Temp (°C)	Min Temp (°C)	Mean Temp (°C)	Heat Deg Days (°C)	Cool Deg Days (°C)	Total Precip (mm)
5/31/2016	3.3	-4.1	-0.4	18.4	0	1.2
6/1/2016	5.6	-4.8	0.4	17.6	0	0
6/2/2016	9.6	-5.3	2.2	15.8	0	0
6/3/2016	5.3	1.9	3.6	14.4	0	7.2
6/4/2016	6.1	3	4.6	13.4	0	0.9
6/5/2016	12.4	2.8	7.6	10.4	0	0.4
6/6/2016	9.3	4.3	6.8	11.2	0	2.8
6/7/2016	8.2	5.4	6.8	11.2	0	1.5
6/8/2016	11.3	5.1	8.2	9.8	0	5.7
6/9/2016	11	3.6	7.3	10.7	0	2.5
6/10/2016	14.4	5.5	10	8	0	0.2
6/11/2016	15.7	5.6	10.7	7.3	0	1.7
6/12/2016	18.8	4.2	11.5	6.5	0	0
6/13/2016	19.3	5.6	12.5	5.5	0	0
6/14/2016	17.3	5.2	11.3	6.7	0	0
6/15/2016	16.6	3.8	10.2	7.8	0	0
6/16/2016	18.8	1.6	10.2	7.8	0	0
6/17/2016	20.4	2.2	11.3	6.7	0	0.3
6/18/2016	25.7	3.9	14.8	3.2	0	0
6/19/2016	24.2	10	17.1	0.9	0	1.9
6/20/2016	17.8	9.4	13.6	4.4	0	4
6/21/2016	15.1	5.6	10.4	7.6	0	0.9
6/22/2016	9.6	3.9	6.8	11.2	0	1.4
6/23/2016	12.2	3.1	7.7	10.3	0	0
6/24/2016	13.4	4.4	8.9	9.1	0	0
6/25/2016	18.5	6.2	12.4	5.6	0	0
6/26/2016	19.2	4.8	12	6	0	12.4
6/27/2016	20.6	5	12.8	5.2	0	12.3
6/28/2016	13.4	2.7	8.1	9.9	0	0.6
6/29/2016	17	1.7	9.4	8.6	0	0.2
6/30/2016	17.2	4.1	10.7	7.3	0	0
7/1/2016	20.5	4.6	12.6	5.4	0	8.7
7/2/2016	18.9	10.2	14.6	3.4	0	20.7
7/3/2016	16.2	8.4	12.3	5.7	0	7.6

Date/Time	Max Temp (°C)	Min Temp (°C)	Mean Temp (°C)	Heat Deg Days (°C)	Cool Deg Days (°C)	Total Precip (mm)
7/5/2016	11.5	4.2	7.9	10.1	0	2.1
7/6/2016	16.1	3.7	9.9	8.1	0	0.3
7/7/2016	20	5.5	12.8	5.2	0	0
7/8/2016	22.5	7.6	15.1	2.9	0	0
7/9/2016	22.7	8.8	15.8	2.2	0	0
7/10/2016	23.7	10	16.9	1.1	0	0
7/11/2016	24.2	11.8	18	0	0	0.2
7/12/2016	23.4	9.7	16.6	1.4	0	0
7/13/2016	19.1	11.1	15.1	2.9	0	0.7
7/14/2016	26	15.4	20.7	0	2.7	10.8
7/15/2016	18.1	8	13.1	4.9	0	1.1
7/16/2016	20.6	8	14.3	3.7	0	0
7/17/2016	24.4	12.7	18.6	0	0.6	0
7/18/2016	24.6	10.5	17.6	0.4	0	0
7/19/2016	16.4	7.2	11.8	6.2	0	32.4
7/20/2016	19.5	6.7	13.1	4.9	0	0
7/21/2016	24.3	8.2	16.3	1.7	0	0
7/22/2016	20.6	14.3	17.5	0.5	0	0
7/23/2016	21.3	13.7	17.5	0.5	0	0
7/24/2016	19.4	12.8	16.1	1.9	0	1.1
7/25/2016	21.2	10.4	15.8	2.2	0	0
7/26/2016	15	9.2	12.1	5.9	0	0.4
7/27/2016	11.1	8.8	10	8	0	7.3
7/28/2016	13.3	8.7	11	7	0	15.7
7/29/2016	15.2	9.4	12.3	5.7	0	1.5
7/30/2016	15.8	8.9	12.4	5.6	0	0.3
7/31/2016	13	8.1	10.6	7.4	0	0
8/1/2016	18.2	6.8	12.5	5.5	0	0.2
8/2/2016	22.1	6.8	14.5	3.5	0	0
8/3/2016	24.8	7.6	16.2	1.8	0	0
8/4/2016	22.6	13	17.8	0.2	0	6
8/5/2016	16.3	12.6	14.5	3.5	0	17.2
8/6/2016	16	8.2	12.1	5.9	0	54.6
8/7/2016	9.2	6.8	8	10	0	10.7
8/8/2016	11.9	6.7	9.3	8.7	0	0
8/9/2016	18.6	7.8	13.2	4.8	0	0
8/10/2016	18.1	9.9	14	4	0	2

Date/Time	Max Temp (°C)	Min Temp (°C)	Mean Temp (°C)	Heat Deg Days (°C)	Cool Deg Days (°C)	Total Precip (mm)
8/11/2016	11.6	5.3	8.5	9.5	0	5.1
8/12/2016	8.8	4.2	6.5	11.5	0	0.4
8/13/2016	14.1	7.4	10.8	7.2	0	0.3
8/14/2016	16.2	5.3	10.8	7.2	0	0.2
8/15/2016	20.1	3.7	11.9	6.1	0	0.4
8/16/2016	21.6	6.8	14.2	3.8	0	0
8/17/2016	22.7	6.1	14.4	3.6	0	0
8/18/2016	19.7	7.6	13.7	4.3	0	0
8/19/2016	22.2	6.1	14.2	3.8	0	0.5
8/20/2016	17	12.9	15	3	0	1.5
8/21/2016	21.3	14.3	17.8	0.2	0	16.2
8/22/2016	16.7	9.4	13.1	4.9	0	5.7
8/23/2016	17.4	8.1	12.8	5.2	0	0.2
8/24/2016	14.2	5.8	10	8	0	2
8/25/2016	11.5	6	8.8	9.2	0	0
8/26/2016	14.6	4.2	9.4	8.6	0	0.2
8/27/2016	15.9	3.5	9.7	8.3	0	3.9
8/28/2016	19.5	8.5	14	4	0	0.4
8/29/2016	12.9	4.3	8.6	9.4	0	0
8/30/2016	14.1	5.4	9.8	8.2	0	0.3
8/31/2016	8.8	4.4	6.6	11.4	0	0
9/1/2016	10.5	3.5	7	11	0	0.8
9/3/2016	9.2	0.3	4.8	13.2	0	0.5
9/4/2016	21.4	1.1	11.3	6.7	0	0
9/5/2016	18.4	7.9	13.2	4.8	0	5.7
9/6/2016	7.9	5.2	6.6	11.4	0	6
9/7/2016	6.6	3.3	5	13	0	11
9/8/2016	11.8	1.4	6.6	11.4	0	0.2
9/9/2016	10.3	1.2	5.8	12.2	0	2.8
9/10/2016	15.9	5.8	10.9	7.1	0	3.6
9/11/2016	13.8	6.1	10	8	0	19.2
9/12/2016	10.8	4.5	7.7	10.3	0	2.5
9/13/2016	10.8	3.7	7.3	10.7	0	2.9
9/14/2016	10.8	0.7	5.8	12.2	0	0.7
9/15/2016	9	1.9	5.5	12.5	0	0.2
9/16/2016	14.7	-0.9	6.9	11.1	0	1
9/17/2016	6.1	-1.7	2.2	15.8	0	0.2

Date/Time	Max Temp (°C)	Min Temp (°C)	Mean Temp (°C)	Heat Deg Days (°C)	Cool Deg Days (°C)	Total Precip (mm)
9/18/2016	8.1	-2.4	2.9	15.1	0	0.7
9/19/2016		-3.4				
9/21/2016	12.9	6	9.5	8.5	0	1.7
9/22/2016	7.5	2.4	5	13	0	0
9/23/2016	6.4	1.6	4	14	0	0
9/24/2016	7.2	0.7	4	14	0	0
9/25/2016	5.3	1.7	3.5	14.5	0	0
9/26/2016	4.8	-1.9	1.5	16.5	0	0.4
9/27/2016	7.5	-3.2	2.2	15.8	0	0
9/28/2016	12	-1.3	5.4	12.6	0	0
9/29/2016		2.9				
9/30/2016	11	4.2	7.6	10.4	0	0
10/1/2016	11.2	0.3	5.8	12.2	0	0
10/2/2016	4.2	-1.1	1.6	16.4	0	6.3
10/3/2016		-1.2				
10/4/2016	9.3	1.4	5.4	12.6	0	3.5
10/5/2016		4.5				
10/6/2016	11.5	2.1	6.8	11.2	0	9.5
10/7/2016	7.8	3.1	5.5	12.5	0	3.8

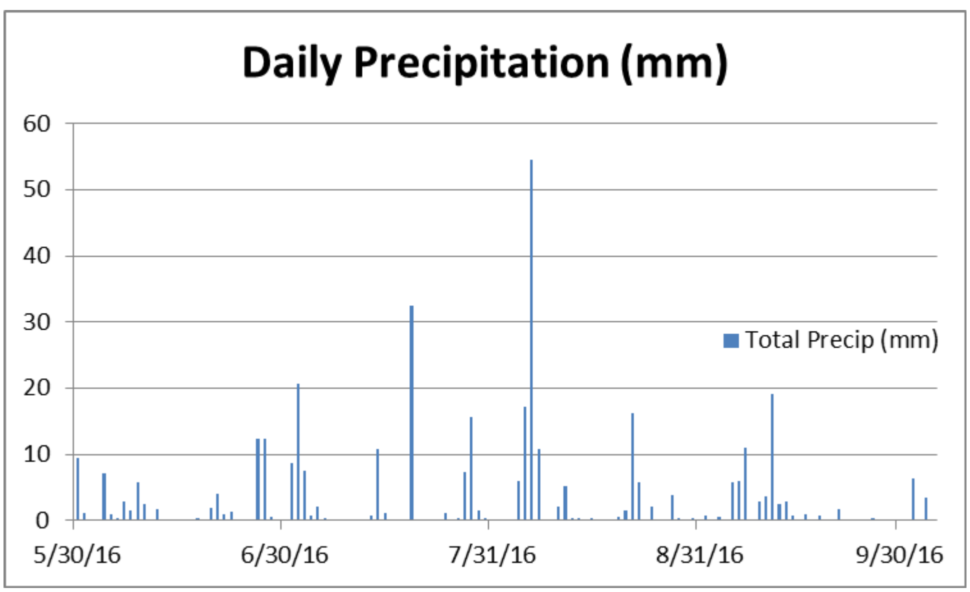

Figure 1. Daily precipitation recorded at the Schefferville Weather Station by ECCC from May 30, 2016 to October 5, 2016.

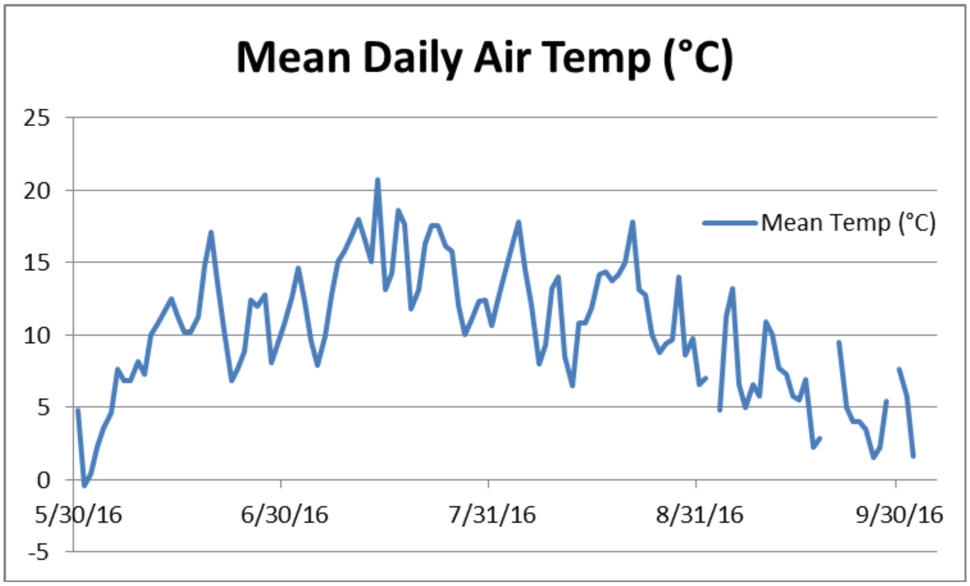

Figure 2. Daily mean temperature recorded at the Schefferville Weather Station by ECCC from May 31, 2016 to October 5, 2016.