Real Time Water Quality Report

Tata Steel Minerals Canada
Elross Lake Network

Annual Deployment Report 2017

2017-06-07 to 2017-10-11

Government of Newfoundland & Labrador
Department of Municipal Affairs & Environment
Water Resources Management Division
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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 Municipal Affairs & Environment (MAE). 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 MAE and ECCC staff with fieldwork operations. TSMC employees who were helpful in this regard included Loic Didillon, Youness Elhariri, Jordan Gallant, 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.

MAE is responsible for recording and managing water quality data. Ian Bell, under the supervision of Renee Paterson, is MAE'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 three deployments during the 2017 field season. Instrument performance evaluation and repairs, during the winter of 2017, were conducted in-house by Tara Clinton.

Introduction

- An agreement was signed on April 18, 2011, between the Newfoundland & Labrador Department of Municipal Affairs & Environment (MAE) 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 Elross Creek, Goodream Creek and Joan Brook Stations

	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 2017.
- 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. MAE 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, MAE, 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.
- MAE 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 June 7, 2017 to October 11, 2017.

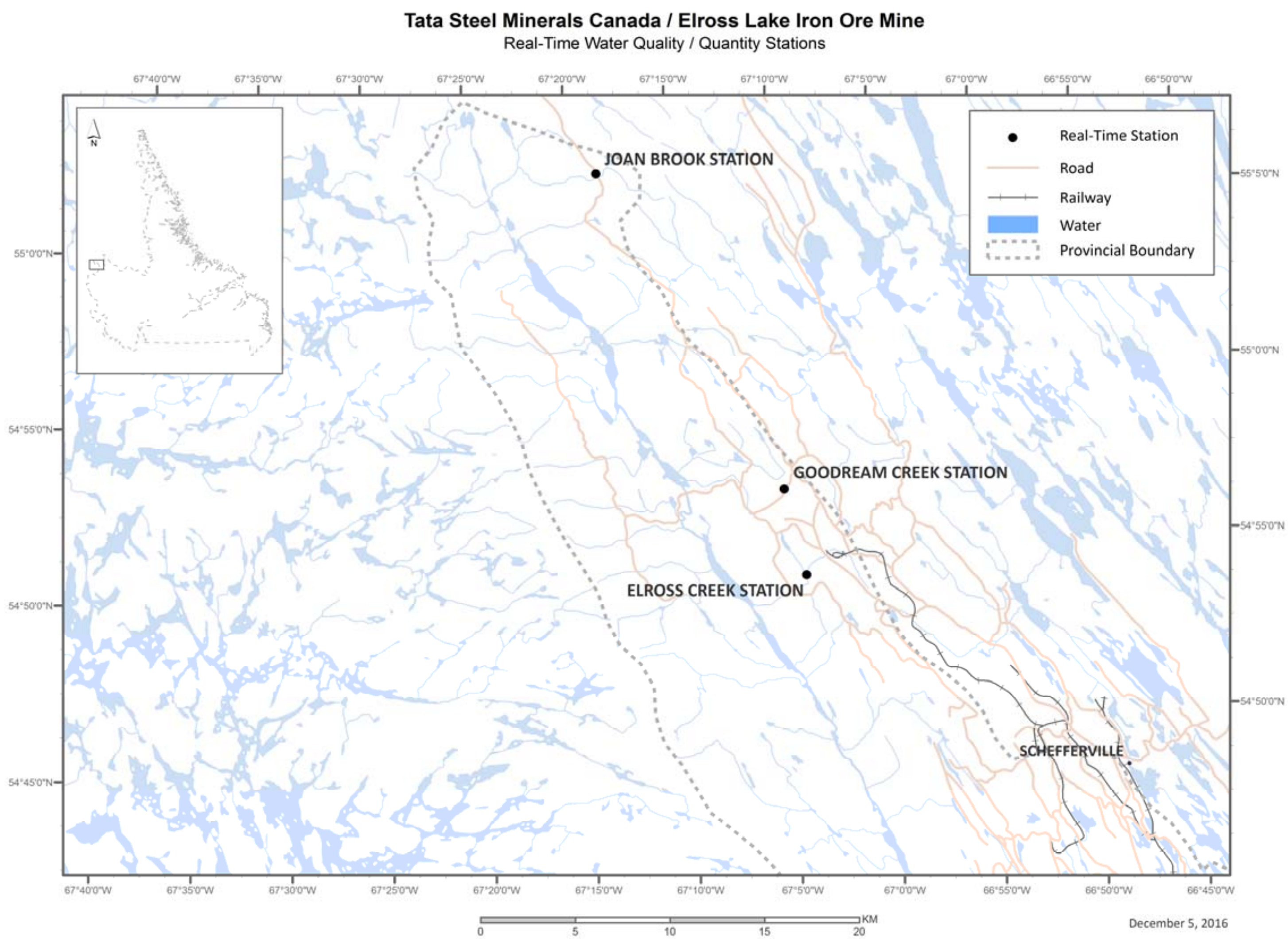

Figure 2. Map of real-time water quality/quantity stations in the vicinity of Elross Lake Iron Ore Mine in Western Labrador.

Quality Assurance & Quality Control

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

Model DS5 © 2005 Hach Company

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 2017 at Elross Creek, Goodream Creek and Joan Brook.

Station	Start date	End date	Duration (days)	Instrument
Elross Creek	2017-06-07	2017-07-11	34	66462
	2017-07-11	2017-08-09	29	49201
	2017-08-09	2017-09-05	27	49201
	2017-09-05	2017-10-11	36	62065
Goodream Creek	2017-06-07	2017-07-12	35	62065
	2017-07-12	2017-08-09	28	62069
	2017-08-09	2017-09-06	28	62069
	2017-09-06	2017-10-11	35	49201
Joan Brook	2017-06-07	2017-07-12	35	62069
	2017-07-12	2017-08-08	29	66462
	2017-08-09	2017-09-06	28	66462
	2017-09-06	2017-10-11	35	66462

- 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 2017. There were several "Poor" and "Marginal" ratings at the time when instruments were removed at the end of deployment periods. These poor and marginal rating may be caused by several factors, including: calibration drift over the deployment period, fouling of the probe with heavy siltation over the deployment, or technical issues with sensors or data transmission systems. While the instruments performed well at the time of installation it is not unusual for sensors to develop issues over the deployment period, particularly at sites where there is significant siltation related to mining activity.

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	2017-06-07	66462	Excellent	Good	Excellent	Excellent	Good
	End	2017-07-11		Poor	Fair	Good	Poor	Good
	Start	2017-07-11	49201	Excellent	Excellent	Excellent	Excellent	Excellent
	End	2017-08-09		Excellent	Excellent	Excellent	Excellent	Good
	Start	2017-08-09	49201	Excellent	Excellent	Excellent	Excellent	Excellent
	End	2017-09-05		Excellent	Fair	Excellent	Excellent	Marginal
	Start	2017-09-05	62065	Excellent	Excellent	Excellent	Excellent	Excellent
	End	2017-10-11		Excellent	Excellent	Fair	Good	Good
Goodream Creek	Start	2017-06-07	62065	Excellent	Good	Excellent	Fair	Excellent
	End	2017-07-12		Excellent	Good	Excellent	Good	Excellent
	Start	2017-07-12	62069	Excellent	Excellent	Excellent	Excellent	Excellent
	End	2017-08-09		Excellent	Marginal	Good	Poor	Excellent
	Start	2017-08-09	62069	Excellent	Good	Excellent	Excellent	Excellent
	End	2017-09-06		Good	Good	Good	Excellent	Excellent
	Start	2017-09-06	49201	Excellent	Good	Excellent	Excellent	Excellent
	End	2017-10-11		Poor	Poor	Excellent	Poor	Excellent
Joan Brook	Start	2017-06-07	62069	Excellent	Excellent	Excellent	Excellent	Excellent
	End	2017-07-12		Excellent	Good	Excellent	Fair	Excellent
	Start	2017-07-12	66462	Excellent	Excellent	Excellent	Excellent	Excellent
	End	2017-08-08		Excellent	Excellent	Excellent	Excellent	Excellent
	Start	2017-08-09	66462	Excellent	Fair	Excellent	Excellent	Excellent
	End	2017-09-06		Excellent	Good	Excellent	Excellent	Excellent
	Start	2017-09-06	66462	Excellent	Fair	Excellent	Excellent	Good
	End	2017-10-11		Excellent	Good	Good	Excellent	Excellent

- Bath tests conducted in the winter of 2017 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 2017 field season were relatively minor and within the range normally experienced under rigours field conditions.

Deployment Notes

- 2017 Operations at TSMC's DSO Project recommenced in March from DSO Area 3 and DSO Area 4. TSMC also started mining operations in Goodwood pit (Quebec) in July. 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 (IOCC) and at SFPPN (Pointe-Noire) for onward shipment to customers in Europe and China. The company was awarded the John T. Ryan Mine Safety Award from the Canadian Institute of Mining and Metallurgy (CIM) for two consecutive years. TSMC's operations will be limited in January and February and are planned to resume at the end of March, 2018.
- The 2017 field season at TSMC ran from June 7th, 2017 until October 11th, 2017, with four back-to-back deployment periods. There were no significant operational issues with any of the equipment deployed during the 2017 field season. It should be noted that during two 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 six parameters:

  (i.) Stage (m)
  (ii.) Temperature (^{o}C)
  (iii.) pH
  (iv.) Specific conductivity (µs/cm)
  (v.) Dissolved oxygen (mg/l)
  (vi.) 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 June 7th, 2017 to October 11th, 2017. At Goodream Creek there is also flow data. These values are provisional. A complete dataset of quality assured and quality controlled stage values should be available upon request through ECCC after March 2018 (http://www.ec.gc.ca/rhc-wsc/default.asp).
- Stage values ranged from 0.79 m to 1.25m at Elross Creek, from 1.74 m (flow 0.00 M^3/s) to 2.08 m (flow 0.33 M^3/s) at Goodream Creek, and from 1.48 m to 1.67 at Joan Brook from June 7th, 2017 to October 11th, 2017.
- At Elross Creek on around June 12th there is a sudden increase in stage height (see inside red oval) which was caused by an adjustment made by Water Survey of Canada staff while conducting routine maintenance at the site.
- Fluctuations in stage corresponded well with rainfall events (Climate data located in Appendix C). There are numerous occasions where this is the case, and a good example can be seen at all three stations around August 24th (see inside green ovals – Figures 4, 5 & 6) when a significant spike in stage height can be seen. This spike corresponds with a period of heavy rainfall (25.3 mm) on August 23rd.
- At Goodream Creek station there were times when stage height was very low and there was effectively zero flow. These low flow periods are natural occurrences at Goodream Creek during extended dry spells in the summer season. These low flow conditions tend to affect some of the water quality parameters, such as temperature, oxygen and specific conductivity, pushing them outside their normal range.
- 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.

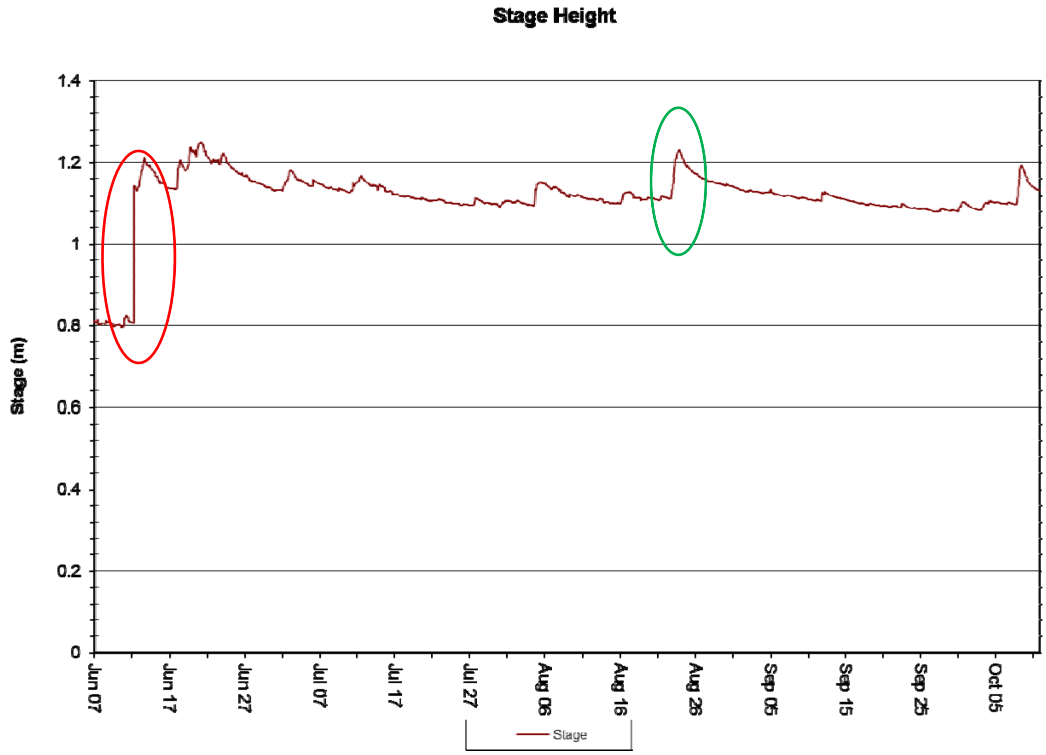

Figure 4. Elross Creek - Stage Height (m) - June 7, 2017 to October 11, 2017.

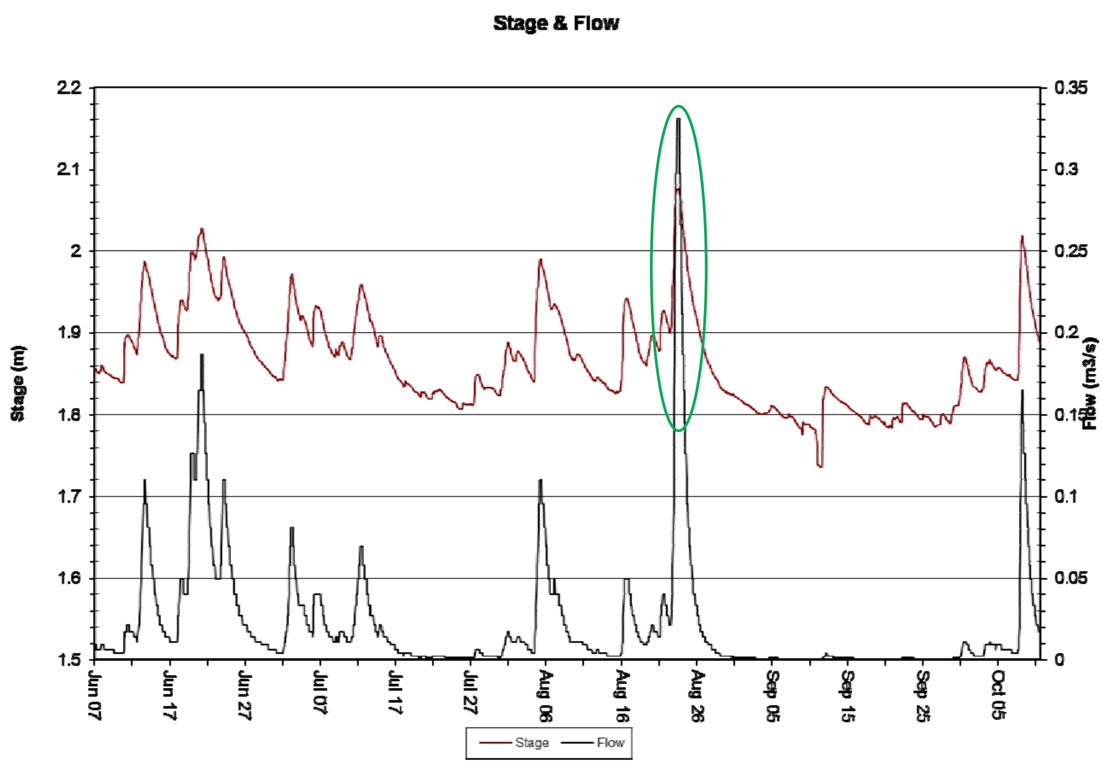

Figure 5. Goodream Creek Stage Height (m) and Flow (m3/s)- June 7 2017 to October 11, 2017

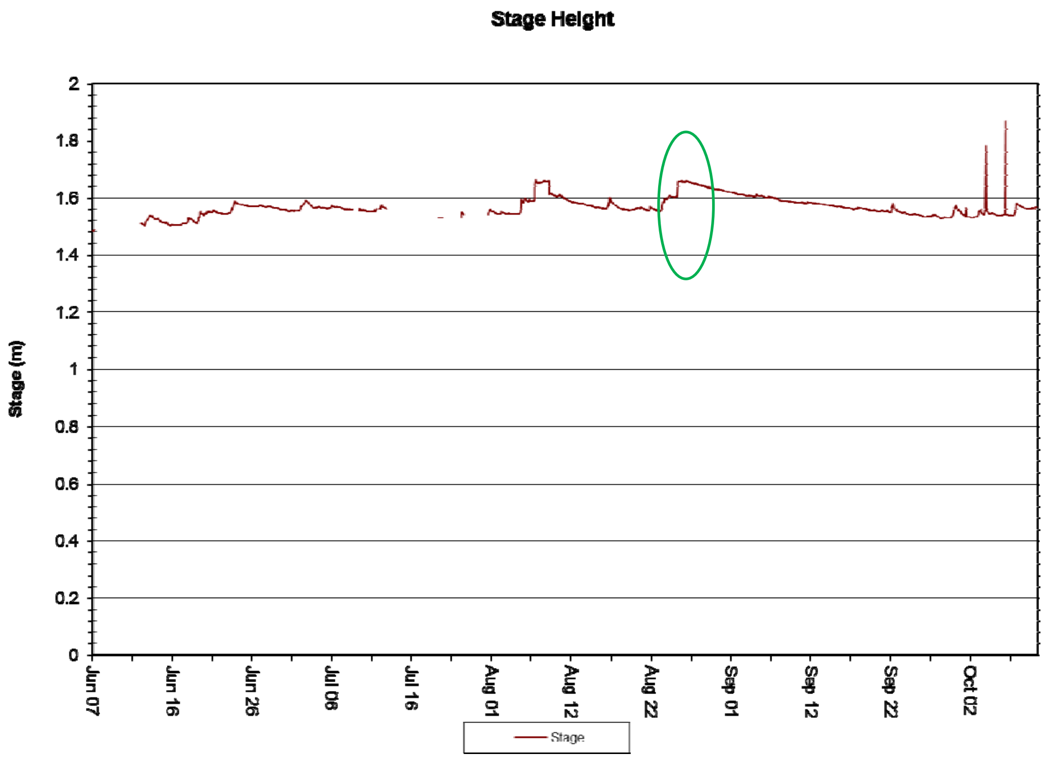

Figure 6. Joan Brook - Stage Height (m) - June 7, 2017 to October 11, 2017

Temperature

- Water temperature ranged from 1.40˚C to 14.20˚C at Elross Creek, from 0.20˚C to 17.70˚C at Goodream Creek, and from 0.10˚C to 14.20˚C at Joan Brook from June 7th, 2017 to October 11th, 2017 (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.

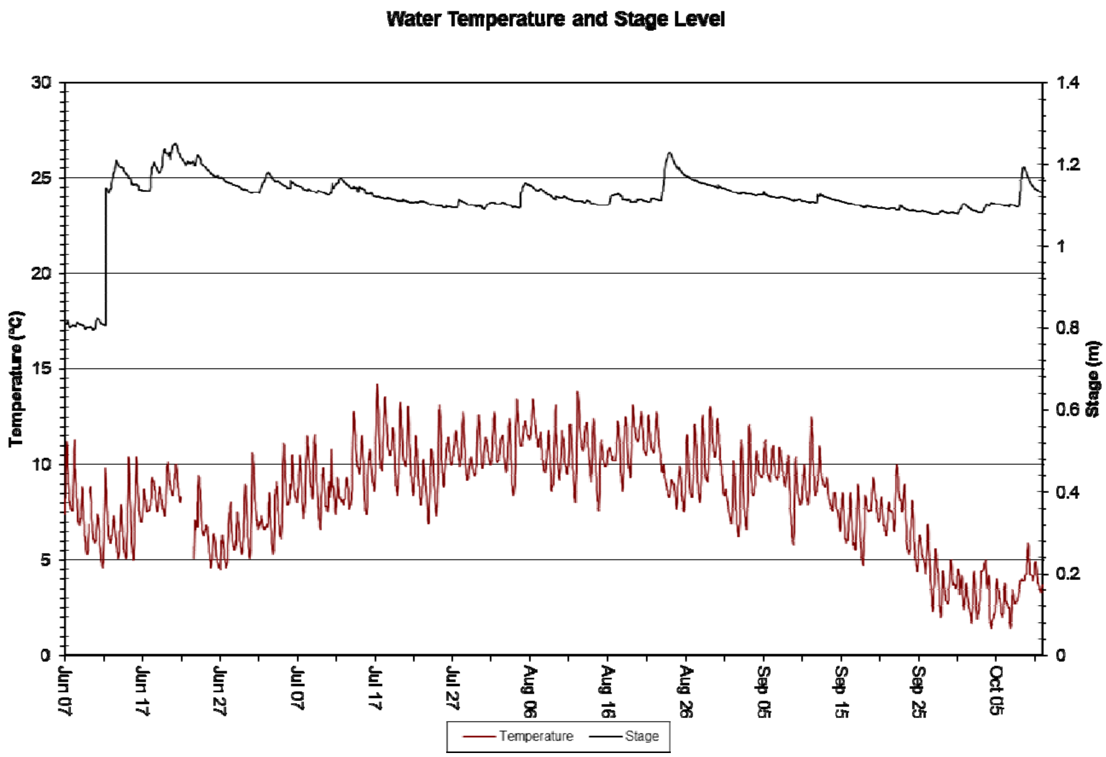

Figure 7. Elross Creek - Water Temperature (°C) - June 7, 2017 to October 11, 2017

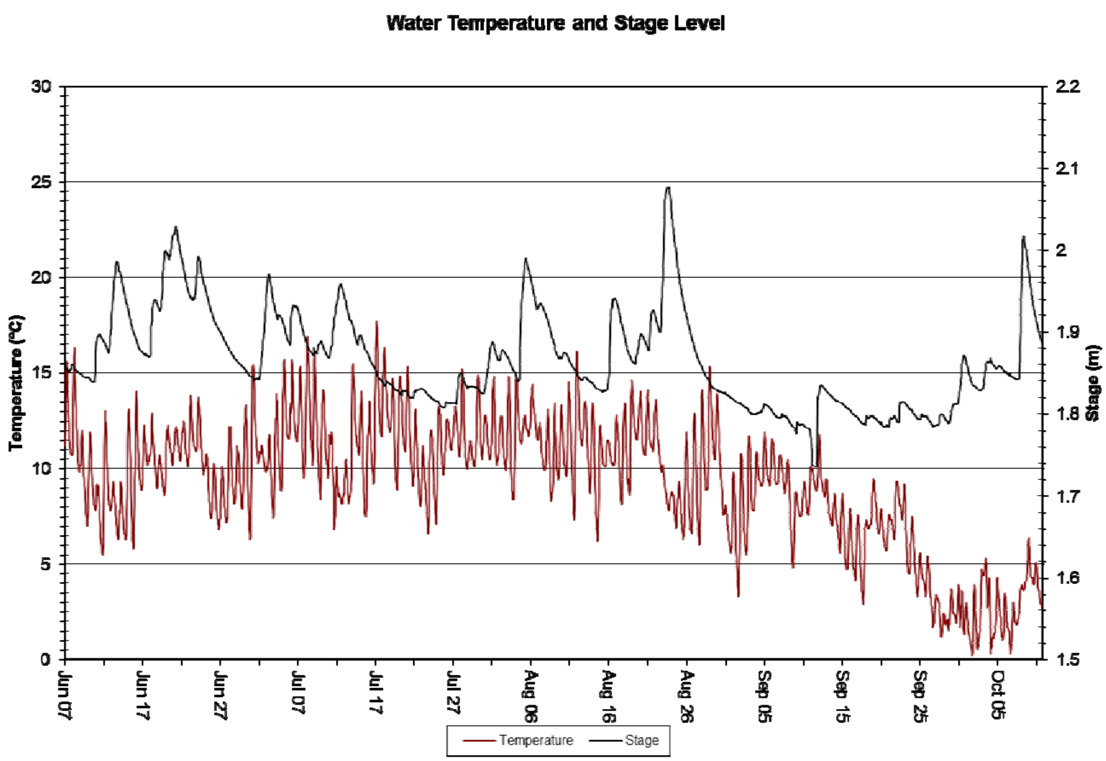

Figure 8. Goodream Creek - Water Temperature (°C) – June 7, 2017 to October 11, 2017

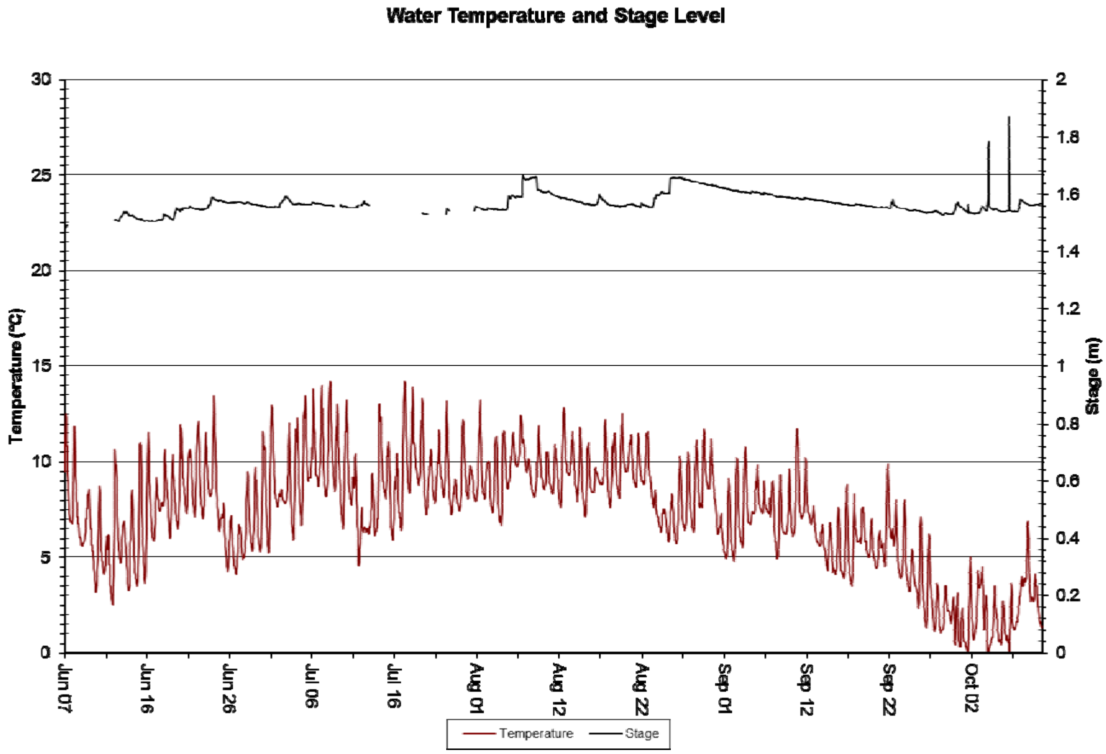

Figure 9. Joan Brook - Water Temperature (^{o}C) - June 7, 2017 to October 11, 2017

pH

- pH values ranged from 5.90 units to 6.90 units at Elross Creek, from 5.17 to 6.30 at Goodream Creek, and from 6.21 units to 6.90 units at Joan Brook, from June 7th, 2017 to October 11th, 2017 (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 (Figure 10) 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 takes a noticeable dip (see inside red ovals, Figure 10)
- At Goodream Creek pH is fairly variable (Figure 11) due to both low flow conditions and significant increases in flow. During periods with rapidly increasing flow, pH is affected and appears to make noticeable dips (see inside red ovals, Figure 11). During an extended period of extremely low flow conditions from around September 6th to September 12th it appears that pH is affected and a notable dip can be seen(see inside green oval, Figure 11)
- At Joan Brook pH is relatively stable (Figure 12) during the deployment period and does not seem to be significantly impacted by changes in flow.

- With a median value of 6.52 most pH values recorded at Elross Creek were at, or very near, 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 5.94 and all of the values were below the minimum pH guideline. At Joan Brook the median pH value was 6.73 and almost all 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.

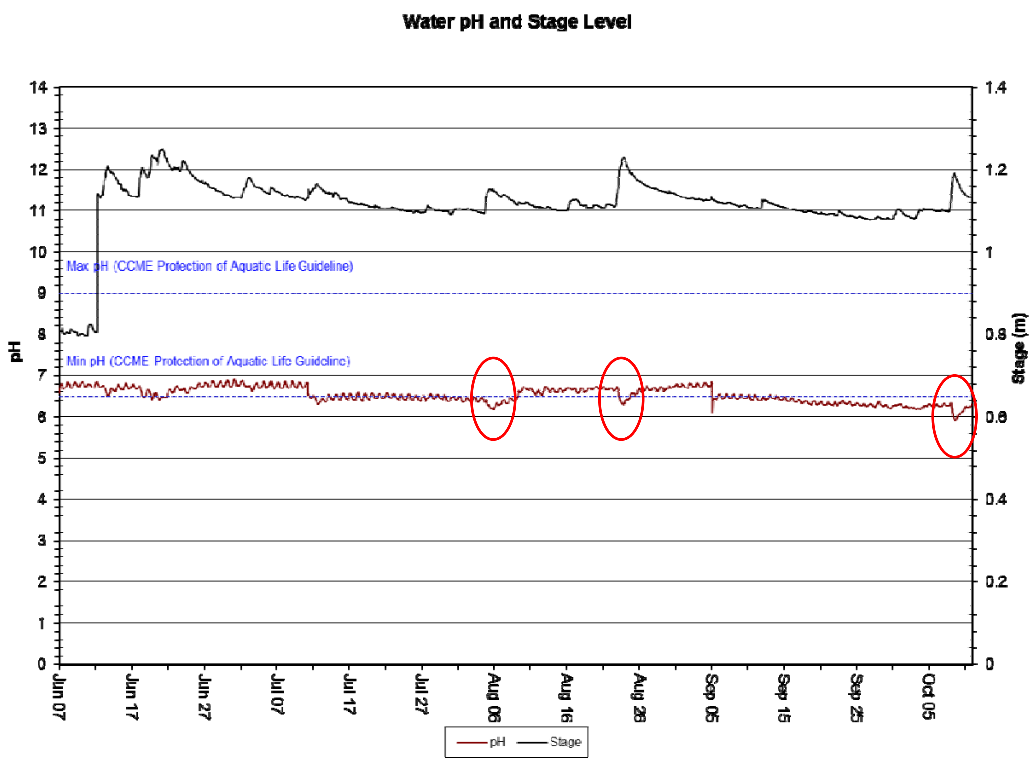

Figure 10. Elross Creek - pH Values - June 7, 2017 to October 11, 2017

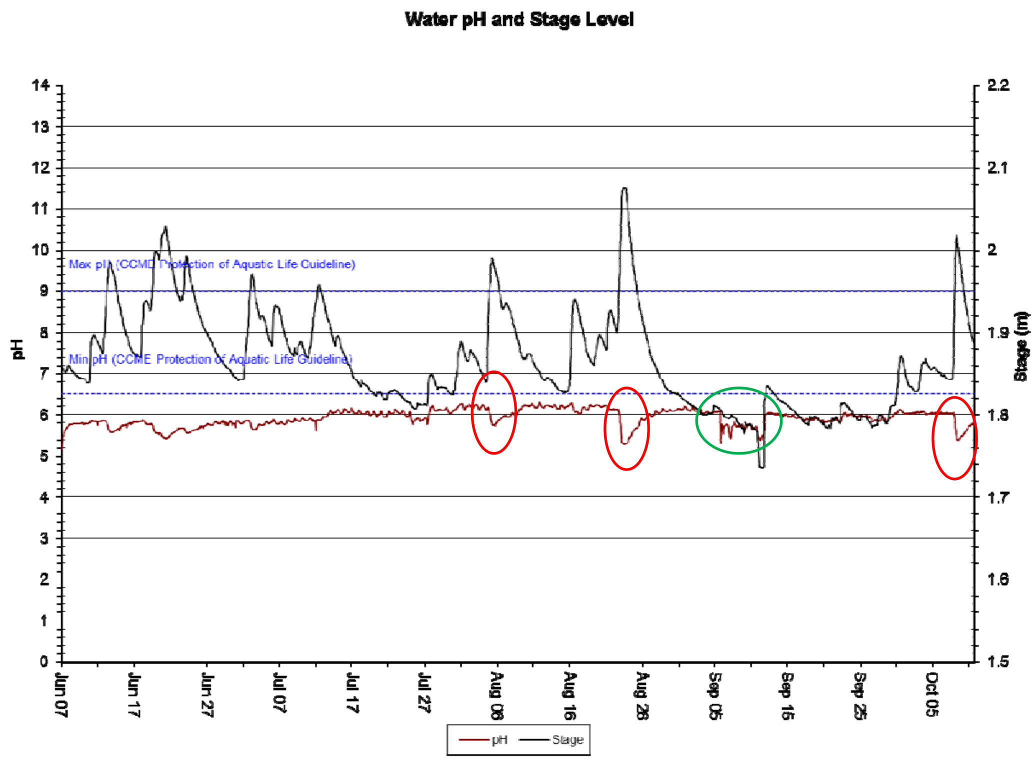

Figure 11. Goodream Creek - pH Values – June 7, 2017 to October 11, 2017

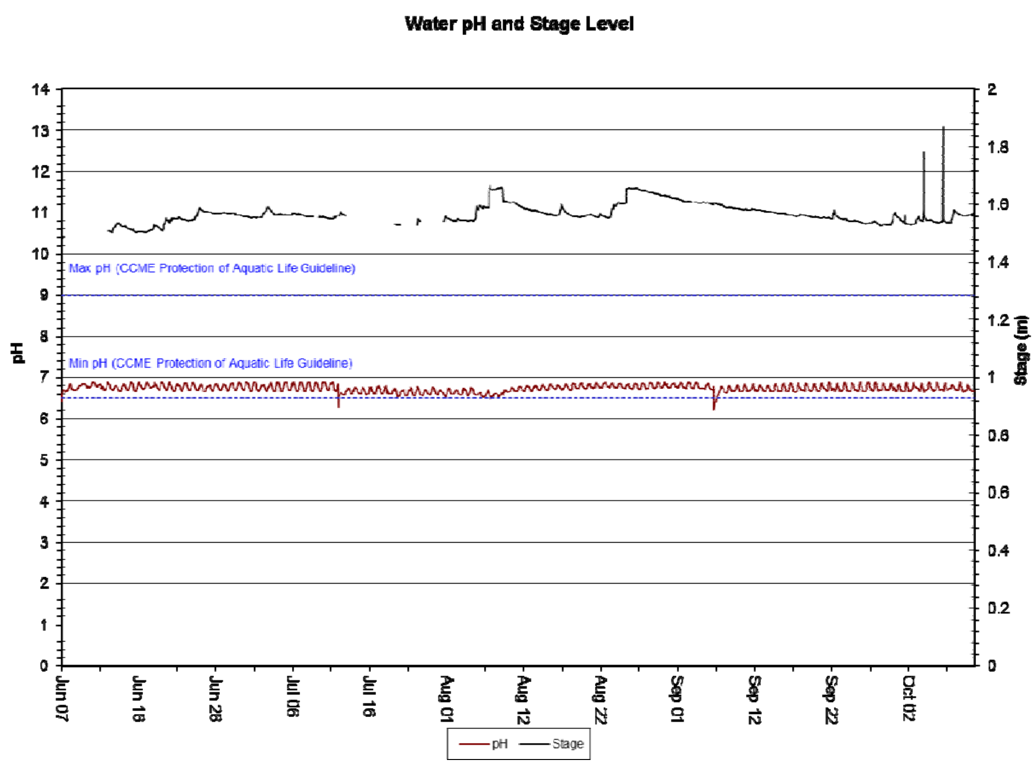

Figure 12. Joan Brook - pH Values – June 7, 2017 to October 11, 2017

Specific Conductivity

- Specific Conductivity ranged from 10.0 µs/cm to 21.2 µs/cm at Elross Creek, from 1.9 µs/cm to 9.7 µs/cm at Goodream Creek, and from 5.0 µs/cm to 9.3 µs/cm at Joan Brook, from June 7th, 2017 to October 11th, 2017 (Figures 13, 14 & 15).
- 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.
- Specific conductivity values at all three stations showed regular diurnal fluctuations which are related to diurnal temperature fluctuations.
- At Elross Creek it is possible to see dips in specific conductivity which correspond with significant spikes in stage height and corresponding flow (see inside red ovals, Figure 13).
- The step like graph for specific conductivity at Joan Brook for the first half of the deployment period is due to a programming issue with not enough decimal places being recorded. This programming issue was rectified by ECCC staff on around August 12th, 2017.

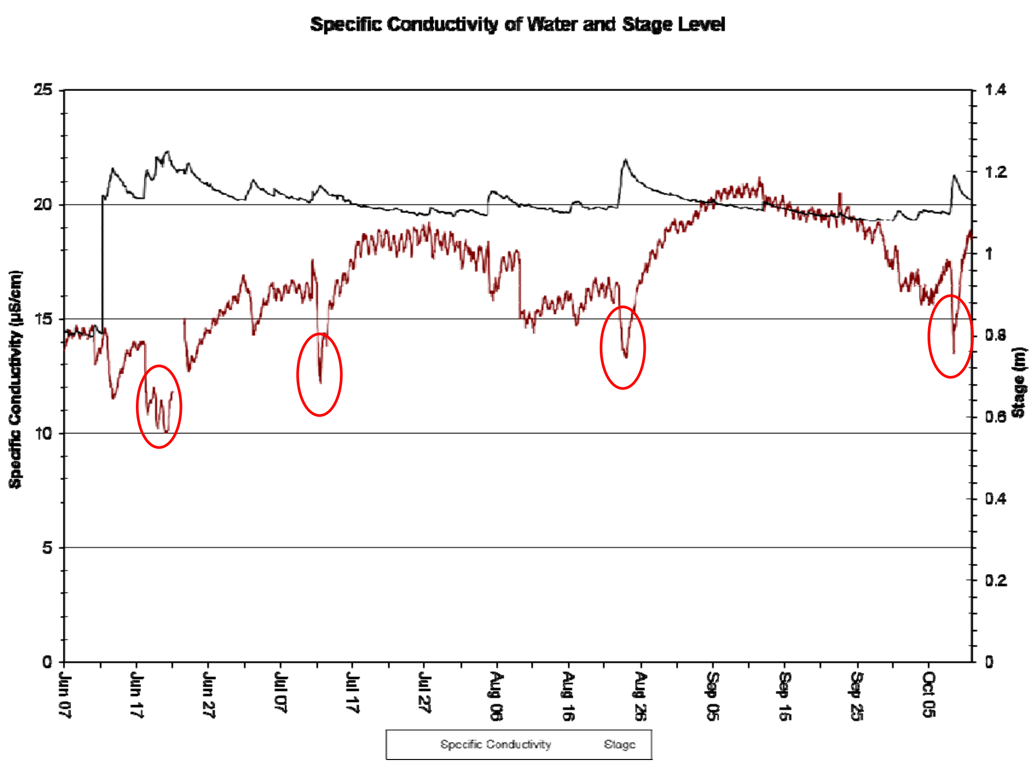

Figure 13. Elross Creek - Specific Conductivity (µS/cm) - June 7, 2017 to October 11, 2017

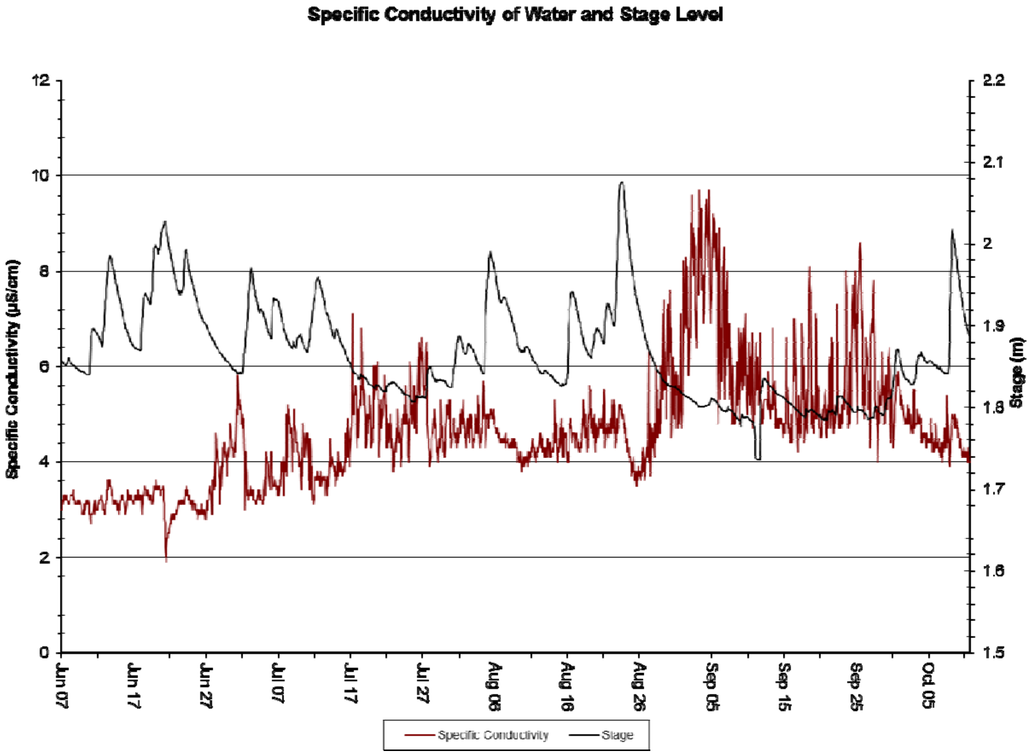

Figure 14. Goodream Creek - Specific Conductivity (µS/cm) –June 7, 2017 to October 11, 2017

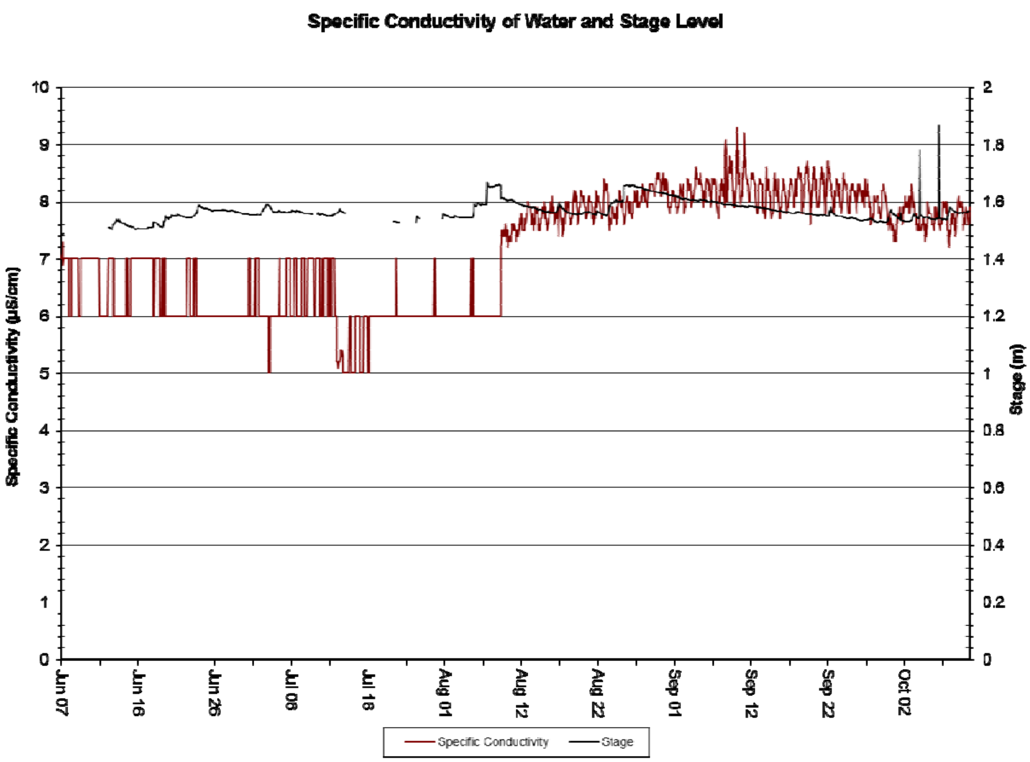

Figure 15. Joan Brook - Specific Conductivity (µS/cm) - June 7, 2017 to October 11, 2017

Dissolved Oxygen

- Dissolved Oxygen (DO) values ranged from 8.86 mg/l (88.2%) to 12.40 mg/l (102.9%) at Elross Creek, from 4.93 mg/l (46.6%) to 13.04 mg/l (107.9%) at Goodream Creek, and from 9.49 mg/l (88.0%) to 13.15 mg/l (102.8%) at Joan Brook, from June 7th, 2017 to October 11th, 2017 (Figures 16, 17 & 18).
- Oxygen levels at Goodream creek were impacted by low flow conditions and on two occasions dipped below the normal range (see inside red ovals, Figure 17). 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 generally higher in the spring and fall when water temperatures are cooler.
- DO values at Elross Creek 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). Do values at Joan Brook were at or above both guidelines. 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.

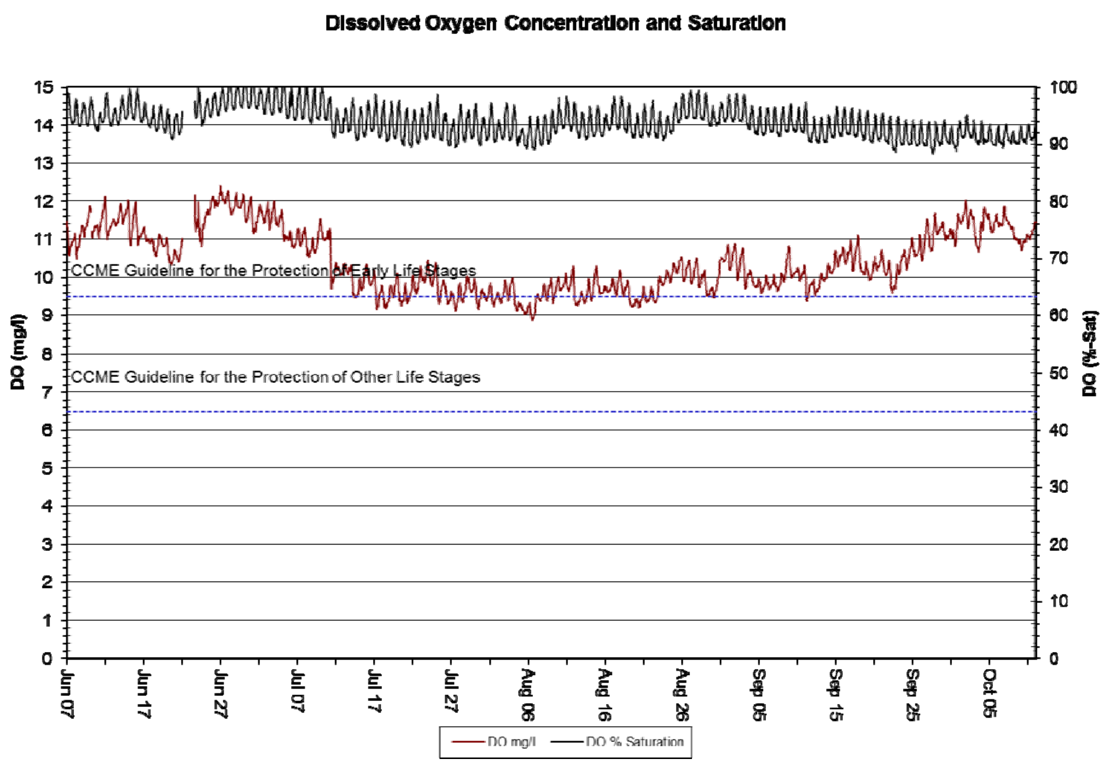

Figure 16. Elross Creek - Dissolved Oxygen (mg/l & %Saturation) – June 7, 2017 to October 11, 2017

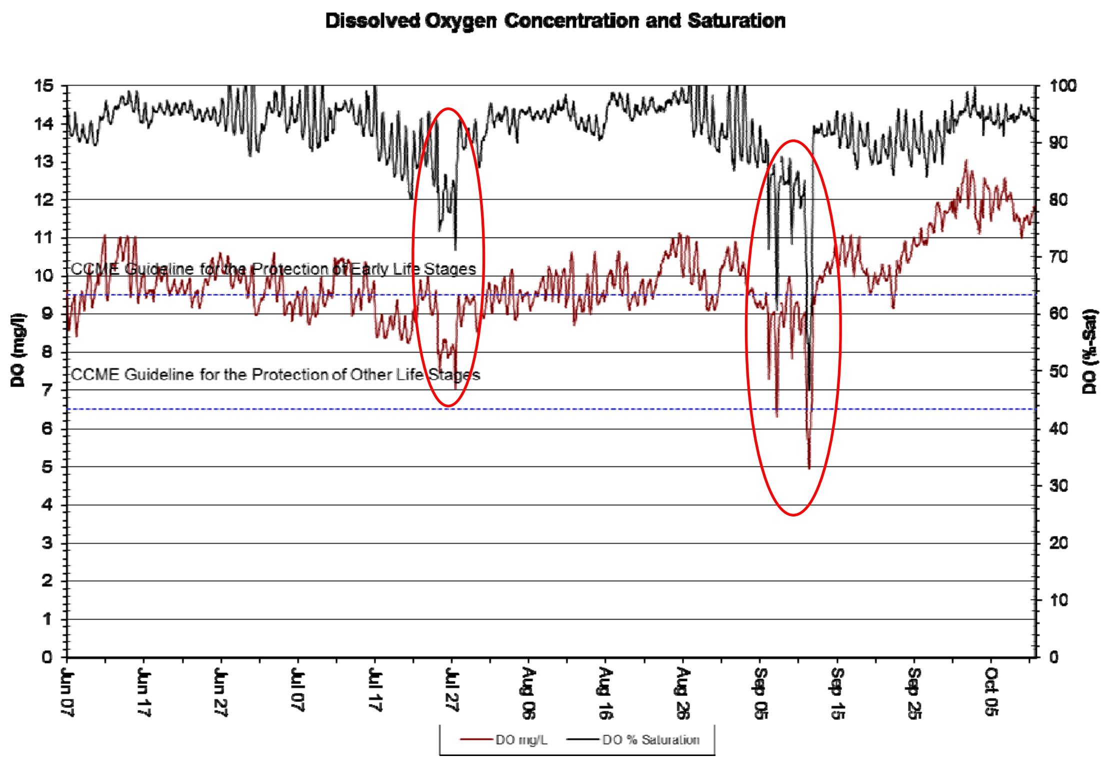

Figure 17. Goodream Creek - Dissolved Oxygen (mg/l & %Saturation) – June 7, 2017 to October 11, 2017

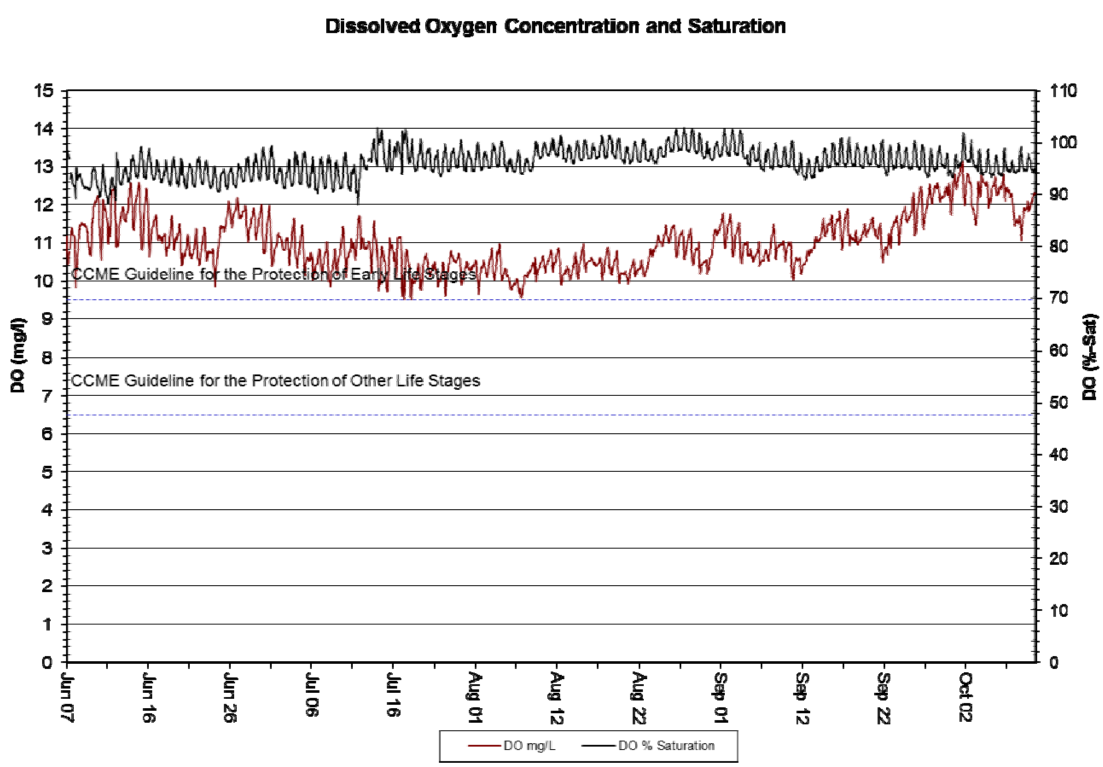

Figure 18. Joan Brook - Dissolved Oxygen (mg/l & % Saturation) - June 7, 2017 to October 11, 2017

Turbidity

- Turbidity values ranged from 0.0 NTU to 217.4 NTU at Elross Creek, from 0.0 NTU to 18.0 NTU at Goodream Creek, and from 0.0 NTU to 1328.0 NTU at Joan Brook, from June 7th, 2017 to October 11th, 2017 (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, a significant spike in stage height at all three stations at around August 24th has corresponding spikes in turbidity (see inside red ovals, Figures 19, 20 & 21).
- During the July deployment at Goodream Creek the turbidity values remained at 0.0 NTU for the entire deployment period which is an indication of either an issue with the turbidity sensor or with the calibration procedures. These data have been flagged as erroneous and removed from the dataset.
- Turbidity is generally higher and subject to much greater fluctuations at Elross Creek and Joan Brook then it is at Goodream Creek. This difference is understandable given the fact that the Elross Creek and Joan Brook watersheds have ongoing mining activity, while the Goodream Creek watershed is relatively undisturbed.

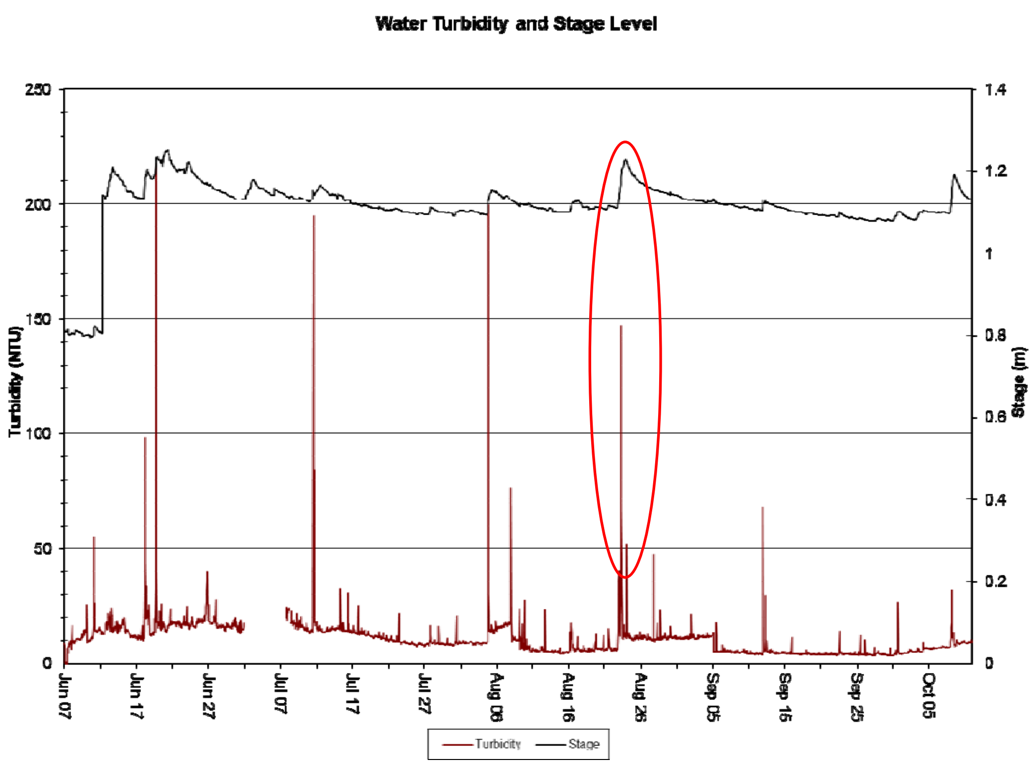

Figure 19. Elross Creek - Turbidity (NTU) - June 7, 2017 to October 11, 2017

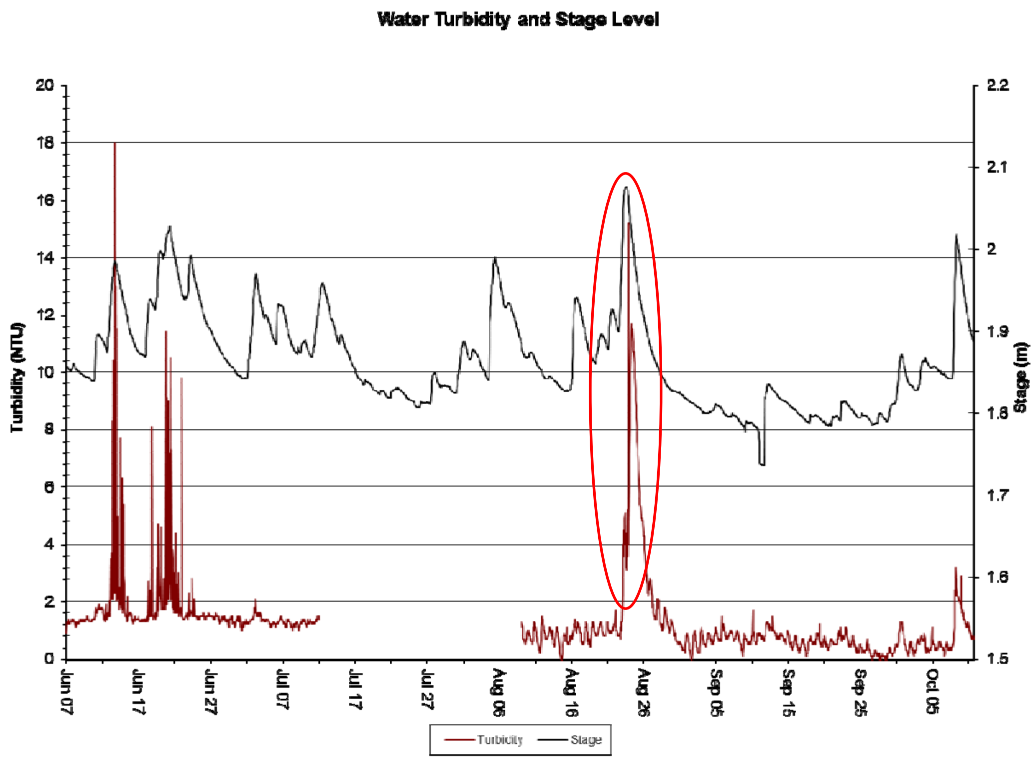

Figure 20. Goodream Creek - Turbidity (NTU) – June 7, 2017 to October 11, 2017

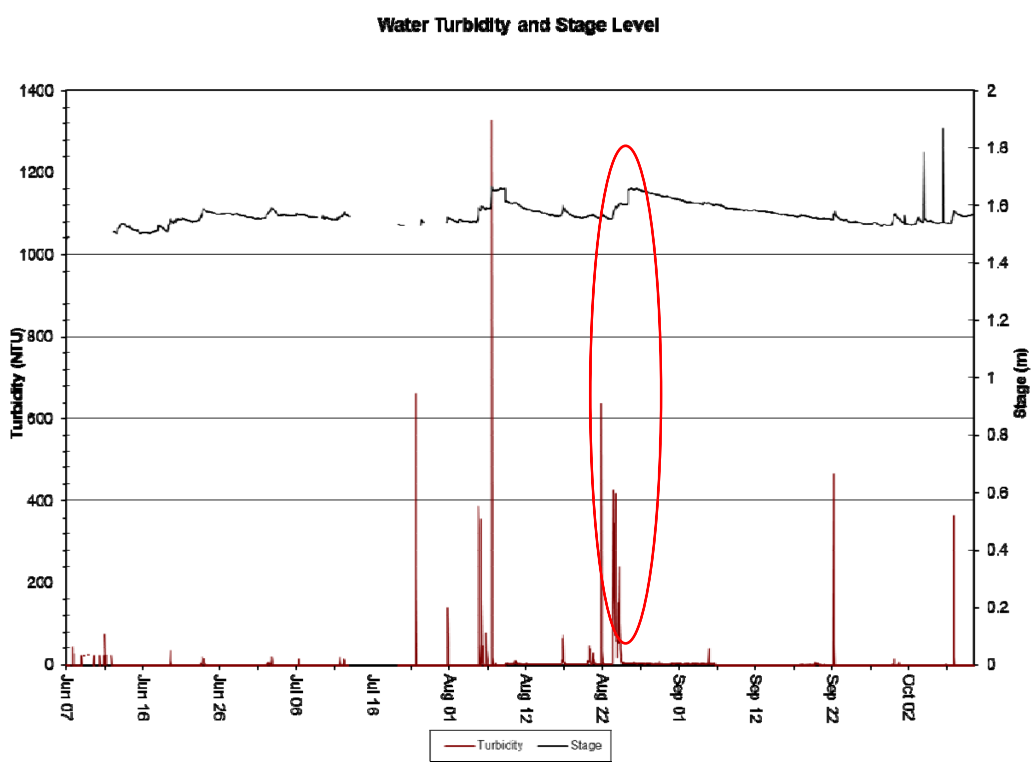

Figure 21. Joan Brook - Turbidity (NTU) - June 7, 2017 to October 11, 2017

Conclusions

- Water quality monitoring instruments were deployed at three stations near the Elross Lake and DSO4 Project 2B, Iron Ore Mine, between June 7th, 2017 and October 11th, 2017. 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 from marginal-to-excellent with the majority of rankings being "good" and "excellent" in 2017. There were several "Poor" and "Marginal" ratings at the time when instruments were removed at the end of deployment periods. These poor and marginal rating may be caused by several factors, including: calibration drift over the deployment period, fouling of the probe with heavy siltation over the deployment, or technical issues with sensors or data transmission systems. While the instruments performed well at the time of installation it is not unusual for sensors to develop issues over the deployment period, particularly at sites where there is significant siltation related to mining activity.
- It should be noted that 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 two occasions.
- Variations in water quality/quantity values recorded at each station are summarized below:

    - STAGE: Stage values ranged from 0.79 m to 1.25m at Elross Creek, from 1.74 m (flow 0.00 M^3/s) to 2.08 m (flow 0.33 M^3/s) at Goodream Creek, and from 1.48 m to 1.67 at Joan Brook from June 7th, 2017 to October 11th, 2017. Fluctuations in stage corresponded well with rainfall events. At Goodream Creek station there were times when stage height was very low and there was effectively zero flow. These low flow periods are natural occurrences at Goodream Creek during extended dry spells in the summer season. These low flow conditions tend to affect some of the water quality parameters, such as oxygen, pH and specific conductivity, pushing them outside their normal range.
    - WATER TEMPERATURE: Water temperature ranged from 1.40˚C to 14.20˚C at Elross Creek, from 0.20˚C to 17.70˚C at Goodream Creek, and from 0.10˚C to 14.20˚C at Joan Brook, from June 7th, 2017 to October 11th, 2017. 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 5.90 units to 6.90 units at Elross Creek, from 5.17 to 6.30 at Goodream Creek, and from 6.21 units to 6.90 units at Joan Brook, from June 7th, 2017 to October 11th, 2017. 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 21.2 µs/cm at Elross Creek, from 1.9 µs/cm to 9.7 µs/cm at Goodream Creek, and from 5.0 µs/cm to 9.3 µs/cm at Joan Brook, from June 7th, 2017 to October 11th, 2017. 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 8.86 mg/l (88.2%) to 12.40 mg/l (102.9%) at Elross Creek, from 4.93 mg/l (46.6%) to 13.04 mg/l (107.9%) at Goodream Creek, and from 9.49 mg/l (88.0%) to 13.15 mg/l (102.8%) at Joan Brook, from June 7th, 2017 to October 11th, 2017. On two occasions at Goodream Creek oxygen levels dipped 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 low water levels due to a relatively dry year. DO levels show diurnal variations at all three 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 217.4 NTU at Elross Creek, from 0.0 NTU to 18.0 NTU at Goodream Creek, and from 0.0 NTU to 1328.0 NTU at Joan Brook, from June 7th, 2017 to October 11th, 2017. 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 and Joan Brook then it is at Goodream Creek. This difference is understandable given the fact that the Elross Creek and Joan Brook watersheds have ongoing mining activity, while the Goodream Creek watershed is relatively is relatively undisturbed.

Path Forward

- MAE staff will redeploy RTWQ instruments at Elross Creek, Goodream Creek and Joan Brook in the spring of 2018, when ice conditions allow. The field season will be broken down into four, month long deployment periods, and MAE staff will perform regular site visits for calibration and maintenance of the instruments.
- MAE 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 2018 field season. MAE staff are very appreciative of the field assistance provided by TSMC staff during the 2017 field season and are hoping to carry on with this arrangement again next year.
- MAE staff will continue to work co-operatively with TSMC staff to co-ordinate the relocation of the Goodream Creek Station to a new monitoring location further downstream on Goodream Creek.
- If necessary, deployment techniques will be evaluated and adapted to each site, ensuring secure and suitable conditions for RTWQ monitoring.

- MAE 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 2018 deployment season to notify MAE 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.
- MAE 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.
- MAE will continue to work on its Automatic Data Retrieval System, to incorporate new capabilities in data management and data display.
- MAE 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 MAE, 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 (□S/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 (μS/cm) is a measure of water's ability to conduct electricity, with values normalized to a water temperature of 25ºC. Specific conductance indicates the concentration of dissolved solids (such as salts) in the water, which can affect the growth and reproduction of aquatic life. Specific conductivity is affected by rainfall events, the composition of inflowing tributaries and their associated geology, saline inflow (e.g., road salt), agricultural run-off and industrial inputs (Allan 2010; Swanson and Baldwin 1965).

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

Temperature - Essential to the measurement of most water quality parameters, temperature (^{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 (June 7, 2017 to Oct.11, 2017)

Date/Time	Max Temp (°C)	Min Temp (°C)	Mean Temp (°C)	Heat Deg Days (°C)	Cool Deg Days (°C)	Total Precip (mm)
6/7/2017	20.1	3.7	11.9	6.1	0	0
6/8/2017	18.7	8.6	13.7	4.3	0	1.4
6/9/2017	9.5	3	6.3	11.7	0	0
6/10/2017	10.9	1.6	6.3	11.7	0	0
6/11/2017	14.3	3.1	8.7	9.3	0	13.9
6/12/2017	12.8	1.4	7.1	10.9	0	0
6/13/2017	8.4	3	5.7	12.3	0	16.8
6/14/2017	8.7	2	5.4	12.6	0	0.3
6/15/2017	12.9	1	7	11	0	0
6/16/2017	16.6	0.2	8.4	9.6	0	0.9
6/17/2017	15.1	8.1	11.6	6.4	0	0
6/18/2017	16.7	8.9	12.8	5.2	0	14.3
6/19/2017	10.7	7	8.9	9.1	0	12.7
6/20/2017	14.8	6.8	10.8	7.2	0	5.3
6/21/2017	14	7.5	10.8	7.2	0	23.3
6/22/2017	9.7	6.9	8.3	9.7	0	2
6/23/2017	14.7	6.5	10.6	7.4	0	8.6
6/24/2017	17.9	5.9	11.9	6.1	0	13.7
6/25/2017	9.8	4	6.9	11.1	0	0.4
6/26/2017	9.3	3.5	6.4	11.6	0	0.8
6/27/2017	10.1	3	6.6	11.4	0	0
6/28/2017	14.9	4.9	9.9	8.1	0	0
6/29/2017	10.7	5.2	8	10	0	0.7
6/30/2017	16	5	10.5	7.5	0	0
7/1/2017	18.9	2.7	10.8	7.2	0	8.9
7/2/2017	11.3	8.9	10.1	7.9	0	9.3
7/3/2017	15.8	4.3	10.1	7.9	0	6.1
7/4/2017	18.1	3	10.6	7.4	0	1
7/5/2017	21.5	10.6	16.1	1.9	0	0
7/6/2017	19.6	13	16.3	1.7	0	7.5
7/7/2017	17.2	6.2	11.7	6.3	0	1.1
7/8/2017	20.7	5.8	13.3	4.7	0	1.5
7/9/2017	18.8	4.6	11.7	6.3	0	5.2
7/10/2017	16.6	3	9.8	8.2	0	0

Date/Time	Max Temp (°C)	Min Temp (°C)	Mean Temp (°C)	Heat Deg Days (°C)	Cool Deg Days (°C)	Total Precip (mm)
7/11/2017	14.1	3.1	8.6	9.4	0	6.4
7/12/2017	10.2	0.3	5.3	12.7	0	8
7/13/2017	13.6	7	10.3	7.7	0	0.3
7/14/2017	22	8.8	15.4	2.6	0	0.6
7/15/2017	17.5	3.8	10.7	7.3	0	3.4
7/16/2017	15.7	3.2	9.5	8.5	0	1.1
7/17/2017	23.5	12.1	17.8	0.2	0	0
7/18/2017	25.4	12.3	18.9	0	0.9	1.2
7/19/2017	14.6	4.1	9.4	8.6	0	0.2
7/20/2017	17.7	4.2	11	7	0	8.1
7/21/2017	14.5	6.4	10.5	7.5	0	0.2
7/22/2017	10.7	3.3	7	11	0	8
7/23/2017	8.7	3	5.9	12.1	0	1.9
7/24/2017	15.3	3	9.2	8.8	0	1.6
7/25/2017	21.6	4.8	13.2	4.8	0	1.2
7/26/2017	20.8	12	16.4	1.6	0	1.6
7/27/2017	17.7	10.7	14.2	3.8	0	6.8
7/28/2017	14.4	6.7	10.6	7.4	0	2.2
7/29/2017	10.3	6.8	8.6	9.4	0	1.7
7/30/2017	17.9	9	13.5	4.5	0	0
7/31/2017	16.1	9.5	12.8	5.2	0	24
8/1/2017	17.6	9.3	13.5	4.5	0	3.7
8/2/2017	15.7	9	12.4	5.6	0	3.3
8/3/2017	15.5	5.4	10.5	7.5	0	0
8/4/2017	19.3	4.8	12.1	5.9	0	4.9
8/5/2017	19.4	11.9	15.7	2.3	0	23.5
8/6/2017	19.7	12.2	16	2	0	1.9
8/7/2017	12.2	6.6	9.4	8.6	0	6.5
8/8/2017	14.6	4.7	9.7	8.3	0	0.2
8/9/2017	16.8	5	10.9	7.1	0	1.8
8/10/2017	13.1	8.4	10.8	7.2	0	4.2
8/11/2017	15.4	8	11.7	6.3	0	0
8/12/2017	20	4.6	12.3	5.7	0	0
8/13/2017	15.1	8.2	11.7	6.3	0	7.2
8/14/2017	14.4	5.2	9.8	8.2	0	0
8/15/2017	14.3	3.1	8.7	9.3	0	0.9
8/16/2017	12.1	9.8	11	7	0	11.1

Date/Time	Max Temp (°C)	Min Temp (°C)	Mean Temp (°C)	Heat Deg Days (°C)	Cool Deg Days (°C)	Total Precip (mm)
8/17/2017	17.4	7.2	12.3	5.7	0	0.5
8/18/2017	18.8	4.8	11.8	6.2	0	1
8/19/2017	19.6	9.4	14.5	3.5	0	2.4
8/20/2017	17.5	9.3	13.4	4.6	0	3.7
8/21/2017	14.9	10.1	12.5	5.5	0	6
8/22/2017	15.9	9.1	12.5	5.5	0	0.5
8/23/2017	9.1	4.3	6.7	11.3	0	25.3
8/24/2017	7.9	4	6	12	0	12
8/25/2017	12.2	1.4	6.8	11.2	0	0
8/26/2017	15.2	1.5	8.4	9.6	0	0.3
8/27/2017	17.8	6.3	12.1	5.9	0	0
8/28/2017	20.1	5	12.6	5.4	0	0
8/29/2017	21.6	11.1	16.4	1.6	0	0
8/30/2017	20.6	6	13.3	4.7	0	2.1
8/31/2017	6	2.2	4.1	13.9	0	0.4
9/1/2017	10.9	1.7	6.3	11.7	0	0.2
9/2/2017	16.7	0.6	8.7	9.3	0	1.3
9/3/2017	19.9	3.5	11.7	6.3	0	0.8
9/4/2017	14.1	8.4	11.3	6.7	0	1.3
9/5/2017	14.8	9.2	12	6	0	2.2
9/6/2017	14.3	7.3	10.8	7.2	0	0.2
9/7/2017	13.6	7.5	10.6	7.4	0	1.5
9/8/2017	11	0.7	5.9	12.1	0	0.5
9/9/2017	13.5	0.2	6.9	11.1	0	1.4
9/10/2017	15.1	5.6	10.4	7.6	0	0
9/11/2017	20.2	5.1	12.7	5.3	0	0
9/12/2017		9				
9/13/2017		7.8				
9/14/2017						
9/15/2017	8.2	1.7	5	13	0	0
9/16/2017	9.2	1.2	5.2	12.8	0	0
9/17/2017	11.6	-0.5	5.6	12.4	0	0
9/18/2017	13.4	-1.9	5.8	12.2	0	0.6
9/19/2017	13.5	7.9	10.7	7.3	0	0.2
9/20/2017	10.5	4.5	7.5	10.5	0	0
9/21/2017	10.6	3.9	7.3	10.7	0	0.5
9/22/2017	17.5	7.7	12.6	5.4	0	7.1

Date/Time	Max Temp (°C)	Min Temp (°C)	Mean Temp (°C)	Heat Deg Days (°C)	Cool Deg Days (°C)	Total Precip (mm)
9/23/2017	12.1	0.2	6.2	11.8	0	0.7
9/24/2017	11.1	0.8	6	12	0	0
9/25/2017	6	0	3	15	0	1.3
9/26/2017	8.1	-3.8	2.2	15.8	0	0.4
9/27/2017	5.2	-5.1	0.1	17.9	0	1.5
9/28/2017	0.9	-2.2	-0.7	18.7	0	6.5
9/29/2017	4.2	-1.9	1.2	16.8	0	0.5
9/30/2017	6.8	1.4	4.1	13.9	0	7.9
10/1/2017	2.3	-1.6	0.4	17.6	0	0.7
10/2/2017	6.5	-2	2.3	15.7	0	0
10/3/2017	10	0.2	5.1	12.9	0	7.2
10/4/2017	10.3	-2	4.2	13.8	0	6.8
10/5/2017	3	-2	0.5	17.5	0	0.9
10/6/2017	2.5	-1.3	0.6	17.4	0	2
10/7/2017	2.2	-1	0.6	17.4	0	3.1
10/8/2017	11.2	1.1	6.2	11.8	0	16.6
10/9/2017	13	1.9	7.5	10.5	0	0
10/10/2017	7.8	1.5	4.7	13.3	0	0.8
10/11/2017	3.5	-0.6	1.5	16.5	0	0.2

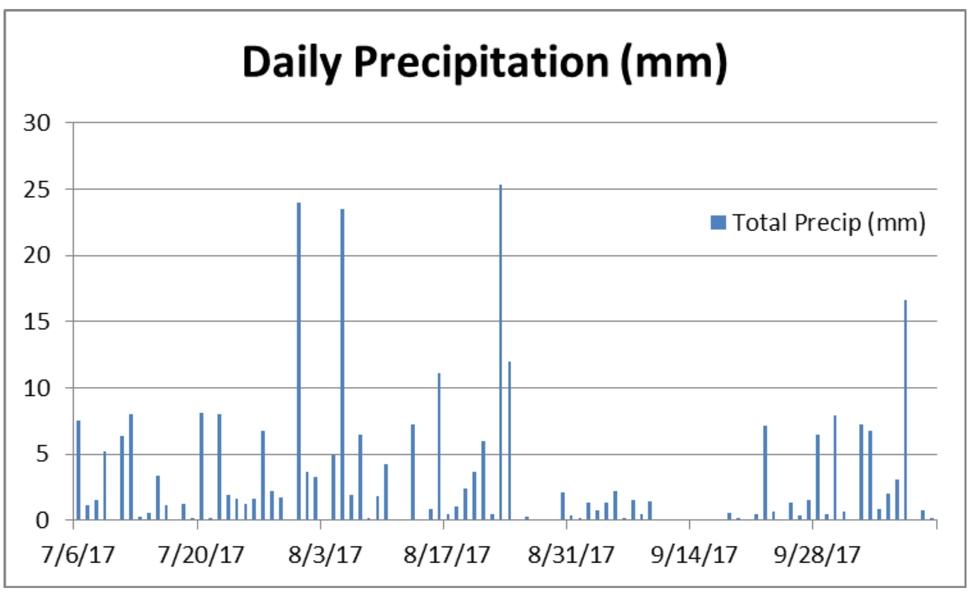

Figure 1. Daily precipitation recorded at the Schefferville Weather Station by ECCC from June 6, 2017 to October 11, 2017.

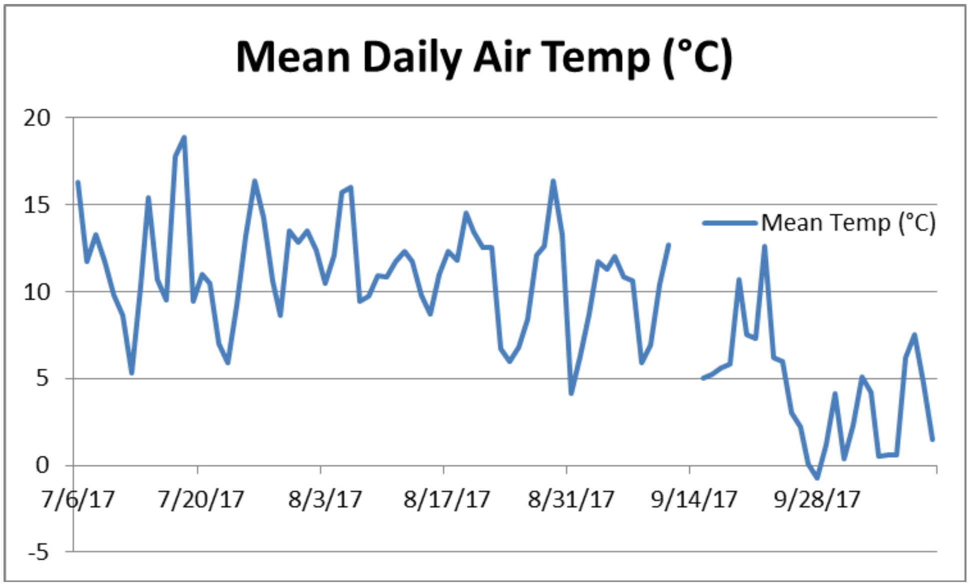

Figure 2. Daily mean temperature recorded at the Schefferville Weather Station by ECCC from June 6, 2017 to October 11, 2017.