# VALE INCO – Voisey's Bay

# Real Time Water Quality Monitoring Network

# 2009 Annual Report

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Prepared by: Grace Gillis
Environmental Scientist
Water Resources Management Division
Department of Environment and Conservation
Newfoundland and Labrador
(T) 709 – 896 – 5542
(F) 709 – 896 – 4330
(E) gracegillis@gov.nl.ca

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# Acknowledgements

The Real-Time Water Quality Monitoring Network in Voisey's Bay is successful in tracking emerging water quality issues due to the hard work and diligence of certain individuals. The management and staff of Vale Inco 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 Voisey's Bay, Labrador.

The Vale Inco Environmental Coordinators on-site, Perry Blanchard and Paul Hounsell, work to ensure the Real-Time Water Quality Monitoring Network is operating to the standards set by ENVC. It is only through their dedication to properly maintain and calibrate the equipment and perform acceptable quality control measures that the data can be viewed as reliable and accurate.

Various individuals from ENVC have been integral in ensuring the smooth operation of such a technologically advanced network. Renée Paterson plays the lead role in coordinating and liaising between the major agencies involved, thus, ensuring open communication lines at all times. In addition, Renée is responsible for the data management/reporting, troubleshooting, along with ensuring the quality assurance/quality control measures are satisfactory. Paul Neary, Leona Hyde and Amir Ali Khan have worked on the communication aspects of the network ensuring the data is being provided to the general public on a near real-time basis through the departmental web page.

EC staff of the Meteorological Service of Canada: Water Survey Canada (Perry Pretty, Bill Mullins, Brent Ruth, Roger Ellsworth, Dwayne Akerman and Mike Ludwicki) play an essential role in the data logging/communication aspect of the network. These individuals visit the site often 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 ENVA (Renée Paterson) and EC (Howie Wills) 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. This network is only successful due to the cooperation of all three agencies involved.

# Introduction

The Real-Time Water Quality Monitoring Network began in Voisey's Bay during the summer of 2003 with the establishment of three surface water stations (**Reid Brook at Outlet of Reid Pond– NF03NE0009**; **Camp Pond Brook below Camp Pond– NF03NE0010**; **Lower Reid Brook below Tributary – NF03NE0011**). These three stations have been operational (for summer/fall months) on an annual basis since 2003 and act as an early warning system to capture water quality related events. The three above-noted surface water stations have been providing valuable water quality information.

An additional surface water station (**Tributary to Lower Reid Brook – NF03NE0012)** was installed in 2006. This station is located in fairly close proximity to the ovoid and thus it was chosen in particular to capture any water quality events that may result from the actual open-pit mining activities.

A groundwater monitoring station was also established in 2006 at Headwater Pond (**Well below tailings Dam – NF03NE0008**) however has not been operational since 2007. The instrument has not been installed in 2008 or 2009 due to complications with the location of the well and damage that occurred over the 2007 winter months. An alternative set-up for this station will be considered in the winter of 2010 for the next deployment year. All five real-time water quality stations can be seen in **Figure 1**.

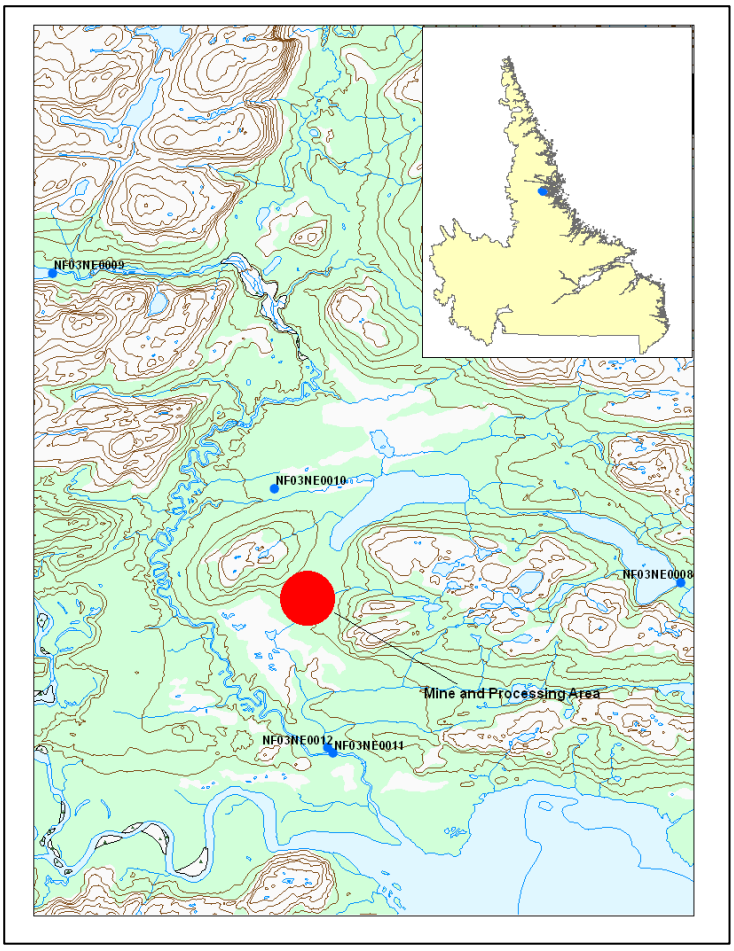


**Figure 1: Map of 5 RTWQ Monitoring stations at Voisey's Bay**

# Maintenance and Calibration

It is recommended that regular maintenance and calibration take place on a monthly basis to ensure accurate data collection. This procedure is the responsibility of the Vale Inco staff and is performed preferably every 30 days. An extended deployment period (>30 days) can result in instrument sensor drift which may result in skewed data. The Datasonde sensors will still work to capture any water quality event even though the exact data values collected may be inaccurate.

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. On an annual basis, all RTWQ instrumentation is sent to the manufacturer for performance evaluation testing and any necessary repairs.

The water quality instruments were removed for the winter months in the fall of 2008. Instruments were sent to ENVC in St. John's. ENVC staff was responsible for sending the instruments to the manufacturer. The instruments were returned to ENVC for a departmental check before being returned to Vale Inco staff in Voisey's Bay.

On June 19-20, 2009, instruments were successfully deployed at the Upper Reid Brook, Camp Pond Brook, Lower Reid Brook and Tributary to Reid Brook stations. In August 2009, Vale Inco staff removed all instruments for cleaning and calibration, instruments were returned to the water within 2-3 days. In September, RTWQ Program Coordinator, Renee Paterson, visited the four RTWQ sites in accompaniment with Vale Inco Staff to ensure all procedures and protocols were being adhered to. All instruments were removed for cleaning and calibration and returned to the water within 3 days. Finally, in the end of October, all four instruments were removed for the winter season and stations secured for the winter months. A summary of the deployment periods during the 2009 season are in **Table 1**. It is important to note that some deployment periods were longer than thirty days due to such issues as availability of helicopters to get to remote locations; allowing for additional monitoring time before winter removal; etc.

**Table 1: Summary of deployment periods at Voisey's Bay RTWQ Network in 2009.**

| Station | Installation | Removal | Days |
|---|---|---|---|
| Upper Reid Brook NF03NE0009 | 19-Jun-09 | 6-Aug-09 | 48 |
| | 8-Aug-09 | 12-Sep-09 | 35 |
| | 15-Sep-09 | 27-Oct-09 | 42 |
| Camp Pond Brook NF03NE0010 | 20-Jun-09 | 5-Aug-09 | 46 |
| | 8-Aug-09 | 12-Sep-09 | 35 |
| | 15-Sep-09 | 27-Oct-09 | 42 |
| Lower Reid Brook NF03NE0011 | 19-Jun-09 | 6-Aug-09 | 48 |
| | 6-Aug-09 | 12-Sep-09 | 37 |
| | 15-Sep-09 | 27-Oct-09 | 42 |
| Tributary to Reid Brook NF03NE0012 | 19-Jun-09 | 6-Aug-09 | 48 |
| | 8-Aug-09 | 12-Sep-09 | 35 |
| | 15-Sep-09 | 27-Oct-09 | 42 |

# Quality Assurance and Quality Control

Quality Assurance and Quality Control is a very important component of the RTWQM program and is regarded as an essential procedure to be preformed attentively by staff during installation and removal. These measures have been put in place to ensure that the instruments are collecting accurate data. There are 2 main components to the QA/QC measures performed by staff.

i) Data from the water quality monitoring instrument in-situ (Datasonde) are compared to data from the QA/QC Datasonde at the time of deployment after maintenance/calibration procedures have been performed; data must fall within a specified range and are ranked from excellent to poor (**Table 2**).
ii) Water grab samples are taken from each station at the time of redeployment and sent to a CALA certified laboratory for analysis. The results are then compared to those of the water quality monitoring instrument in-situ (Datasonde) and must fall within a specified range to receive a ranking (**Table 2**). Only three readings available from the lab for comparison – pH; conductivity; turbidity.

**Table 2: Comparison Ranking Table.** Differences between parameter values from in-situ field instrument and QA/QC instrument or laboratory results from grab samples are ranked from excellent to poor.

| Parameters | Excellent | Good | Fair | Marginal | Poor |
|---|---|---|---|---|---|
| **Temperature ($^{O}$C)** | ≤±0.2 | ≥±0.2 to 0.5 | ≥±0.5 to 0.8 | ≥±0.8 to 1.0 | ≥±1.0 |
| **pH (unit)** | ≤±0.2 | ≥±0.2 to 0.5 | ≥±0.5 to 0.8 | ≥±0.8 to 1.0 | ≥±1.0 |
| **Dissolved Oxygen (mg/L)** | ≤±0.3 | ≥±0.3 to 0.5 | ≥±0.5 to 0.8 | ≥±0.8 to 1.0 | ≥±1.0 |
| **Conductance**<br>**<35µS/cm (µS/cm)**<br>**>35µS/cm (%)** | ≤±3<br>≤±3 | ≥±3 to 10<br>≥±3 to 10 | ≥±10 to 15<br>≥±10 to 15 | ≥15 to 20<br>≥15 to 20 | ≥±20<br>≥±20 |
| **Turbidity**<br>**<40 NTU (NTU)**<br>**>40 NTU (%)** | ≤±2<br>≤±5 | ≥±2 to 5<br>≥±5 to 10 | ≥±5 to 8<br>≥±10 to 15 | ≥8 to 10<br>≥15 to 20 | ≥±10<br>≥±20 |

QA/QC data comparisons by instrument and laboratory analysis for each station are summarized in Tables 3-6.

**Table 3: QAQC comparison rankings for Reid Brook at Outlet of Reid Pond**

| Reid Brook at Outlet of Reid Pond | | QAQC Sonde | Field Sonde | Laboratory Analysis | Sonde Comparison Ranking | Field-Laboratory Comparison | Comments |
|---|---|---|---|---|---|---|---|
| **19-Jun-09 (installation)** | Temp (°C) | 1.64 | 1.73 | - | Excellent | - | |
| | pH (units) | 5.89 | 6.11 | 6.4 | Good | Good | |
| | Conductivity (µS/cm) | 8.4 | 9.5 | 13 | Excellent | Good | |
| | Dissolved Oxygen (mg/L) | 13.02 | 13.52 | - | Good | - | |
| | Turbidity (NTU) | - | 0.4 | 0.2 | - | Excellent | |
| **6-Aug-09 (removal)** | Temp (°C) | 13.57 | 13.63 | - | Excellent | - | |
| | pH (units) | 6.76 | 7.07 | - | Good | - | |
| | Conductivity (µS/cm) | 10.6 | 9.6 | - | Excellent | - | |
| | Dissolved Oxygen (mg/L) | 9.82 | 9.85 | - | Excellent | - | |
| | Turbidity (NTU) | - | 0.3 | - | | - | |
| **8-Aug-09 (installation)** | Temp (°C) | N/A | 12.73 | - | N/A | - | No QAQC readings taken at installation. Grab samples taken at removal. |
| | pH (units) | N/A | 6.89 | N/A | N/A | N/A | |
| | Conductivity (µS/cm) | N/A | 9.699 | N/A | N/A | N/A | |
| | Dissolved Oxygen (mg/L) | N/A | 10.8 | - | N/A | - | |
| | Turbidity (NTU) | - | 0.1 | N/A | - | N/A | |
| **12-Sep-09 (removal)** | Temp (°C) | 8.78 | 8.92 | - | Excellent | - | |
| | pH (units) | 7.08 | 6.93 | - | Excellent | - | |
| | Conductivity (µS/cm) | 9.7 | 9.5 | - | Excellent | - | |
| | Dissolved Oxygen (mg/L) | 11.13 | 11.1 | - | Excellent | - | |
| | Turbidity (NTU) | - | 0 | - | - | - | |
| **15-Sep-09 (installation)** | Temp (°C) | 7.76 | 7.91 | - | Excellent | - | |
| | pH (units) | 6.66 | 7.44 | 6.6 | Fair | Fair | |
| | Conductivity (µS/cm) | 9.1 | 9.1 | 14 | Excellent | Good | |
| | Dissolved Oxygen (mg/L) | 11.42 | 10.92 | - | Good | - | |
| | Turbidity (NTU) | - | N/A | 0.6 | - | N/A | No field sonde turbidity reading |
| **27-Oct-09 (removal)** | Temp (°C) | 2.86 | 3.3 | - | Good | - | |
| | pH (units) | 6.07 | 7.38 | - | Poor | - | |
| | Conductivity (µS/cm) | 10.3 | 9 | - | Excellent | - | |
| | Dissolved Oxygen (mg/L) | 12.92 | 12.35 | - | Fair | - | |
| | Turbidity (NTU) | - | N/A | - | - | - | |

**Table 4: QAQC comparison rankings for Camp Pond Brook**

| Camp Pond Brook | | QAQC Sonde | Field Sonde | Laboratory Analysis | Sonde Comparison Ranking | Field-Laboratory Comparison | Comments |
|---|---|---|---|---|---|---|---|
| **20-Jun-09 (installation)** | Temp (°C) | 6.22 | 6.53 | - | Good | - | |
| | pH (units) | 6.11 | 6.55 | 6.6 | Good | Excellent | |
| | Conductivity (µS/cm) | 20.1 | 24.1 | 27 | Good | Excellent | |
| | Dissolved Oxygen (mg/L) | 12.11 | 11.44 | - | Fair | - | |
| | Turbidity (NTU) | - | 4.3 | 0.5 | - | Good | |
| **5-Aug-09 (removal)** | Temp (°C) | 16.03 | 15.95 | - | Excellent | - | |
| | pH (units) | 6.89 | 6.93 | - | Excellent | - | |
| | Conductivity (µS/cm) | 32.5 | 35.4 | - | Excellent | - | |
| | Dissolved Oxygen (mg/L) | 9.15 | 1.7 | - | Poor | - | |
| | Turbidity (NTU) | - | | - | - | - | |
| **8-Aug-09 (installation)** | Temp (°C) | N/A | 12.69 | - | N/A | - | No QAQC readings taken at installation. Grab samples taken at removal. |
| | pH (units) | N/A | 6.99 | N/A | N/A | N/A | |
| | Conductivity (µS/cm) | N/A | 25.3 | N/A | N/A | N/A | |
| | Dissolved Oxygen (mg/L) | N/A | 9.87 | - | N/A | - | |
| | Turbidity (NTU) | - | 2.4 | N/A | - | N/A | |
| **12-Sep-09 (removal)** | Temp (°C) | 10.41 | 10.4 | - | Excellent | - | |
| | pH (units) | 7.18 | 7.25 | - | Excellent | - | |
| | Conductivity (µS/cm) | 30.5 | 26.3 | - | Good | - | |
| | Dissolved Oxygen (mg/L) | 10.93 | 10.57 | - | Good | - | |
| | Turbidity (NTU) | - | 1.7 | - | - | - | |
| **15-Sep-09 (installation)** | Temp (°C) | 5.11 | 5.25 | - | Excellent | - | |
| | pH (units) | 6.96 | 6.69 | 6.8 | Good | Excellent | |
| | Conductivity (µS/cm) | 30.3 | 36.3 | 17 | Good | Marginal | |
| | Dissolved Oxygen (mg/L) | 11.77 | 11.89 | - | Excellent | - | |
| | Turbidity (NTU) | - | N/A | 0.7 | - | N/A | No field sonde turbidity reading |
| **27-Oct-09 (removal)** | Temp (°C) | -0.24 | -0.15 | - | Excellent | - | |
| | pH (units) | 6.57 | 7.29 | - | Fair | - | |
| | Conductivity (µS/cm) | 33.6 | 38.1 | - | Good | - | |
| | Dissolved Oxygen (mg/L) | 14.02 | 13.09 | - | Marginal | - | |
| | Turbidity (NTU) | - | N/A | - | - | - | No field sonde turbidity reading |

**Table 5: QAQC comparison rankings for Lower Reid Brook**

| Lower Reid Brook | | QAQC Sonde | Field Sonde | Laboratory Analysis | Sonde Comparison Ranking | Field-Laboratory Comparison | Comments |
|---|---|---|---|---|---|---|---|
| **19-Jun-09 (installation)** | Temp (°C) | 6.53 | 6.6 | - | Excellent | - | |
| | pH (units) | 6.24 | 6.19 | 6.6 | Excellent | Good | |
| | Conductivity (µS/cm) | 12.4 | 15 | 17 | Excellent | Excellent | |
| | Dissolved Oxygen (mg/L) | 12.05 | 12.32 | - | Excellent | - | |
| | Turbidity (NTU) | - | 8.3 | 0.7 | - | Marginal | |
| **6-Aug-09 (removal)** | Temp (°C) | 13.64 | 13.6 | - | Excellent | - | |
| | pH (units) | 7.08 | 6.93 | - | Excellent | - | |
| | Conductivity (µS/cm) | 28.7 | 32 | - | Good | - | |
| | Dissolved Oxygen (mg/L) | 9.78 | 8.51 | - | Poor | - | |
| | Turbidity (NTU) | - | 6.6 | - | - | - | |
| **8-Aug-09 (installation)** | Temp (°C) | N/A | 11.43 | - | N/A | - | No QAQC readings taken at installation. Grab samples taken at removal. |
| | pH (units) | N/A | 6.76 | N/A | N/A | N/A | |
| | Conductivity (µS/cm) | N/A | 24 | N/A | N/A | N/A | |
| | Dissolved Oxygen (mg/L) | N/A | 10.62 | - | N/A | - | |
| | Turbidity (NTU) | - | 0 | N/A | - | N/A | |
| **12-Sep-09 (removal)** | Temp (°C) | 10.28 | 10.5 | - | Good | - | |
| | pH (units) | 7.24 | 7.33 | - | Excellent | - | |
| | Conductivity (µS/cm) | 28.9 | 31 | - | Excellent | - | |
| | Dissolved Oxygen (mg/L) | 11.25 | 10.25 | - | Marginal | - | |
| | Turbidity (NTU) | - | 0 | - | - | - | |
| **15-Sep-09 (installation)** | Temp (°C) | 4.78 | 4.85 | - | Excellent | - | |
| | pH (units) | 6.8 | 7.22 | 7 | Good | Good | |
| | Conductivity (µS/cm) | 28.4 | 30 | 13 | Excellent | Marginal | |
| | Dissolved Oxygen (mg/L) | 12.2 | 12.45 | - | Excellent | - | |
| | Turbidity (NTU) | - | 2.5 | 0.7 | - | Excellent | |
| **27-Oct-09 (removal)** | Temp (°C) | -0.17 | -0.03 | - | Excellent | - | |
| | pH (units) | 5.46 | 7.46 | - | Poor | - | |
| | Conductivity (µS/cm) | 41.1 | 40 | - | Excellent | - | |
| | Dissolved Oxygen (mg/L) | 13.87 | 12.98 | - | Marginal | - | |
| | Turbidity (NTU) | - | 9.5 | - | - | - | |

**Table 6: QAQC comparison rankings for Tributary to Lower Reid Brook**

| Tributary to Lower Reid Brook | | QAQC Sonde | Field Sonde | Laboratory Analysis | Sonde Comparison Ranking | Field-Laboratory Comparison | Comments |
|---|---|---|---|---|---|---|---|
| **19-Jun-09 (installation)** | Temp (°C) | 7.1 | 7.4 | - | Good | - | |
| | pH (units) | 6.19 | 6.4 | 6.61 | Excellent | Good | |
| | Conductivity (µS/cm) | 13.1 | 17 | 18 | Excellent | Excellent | |
| | Dissolved Oxygen (mg/L) | 11.58 | 12.11 | - | Fair | - | |
| | Turbidity (NTU) | - | 0 | 0.6 | - | Excellent | |
| **6-Aug-09 (removal)** | Temp (°C) | 13.53 | 13.7 | - | Good | - | |
| | pH (units) | 6.92 | 6.91 | - | Excellent | - | |
| | Conductivity (µS/cm) | 29.3 | 31.5 | - | Excellent | - | |
| | Dissolved Oxygen (mg/L) | 9.68 | 10.28 | - | Fair | - | |
| | Turbidity (NTU) | - | 0 | - | - | - | |
| **8-Aug-09 (installation)** | Temp (°C) | N/A | 11.3 | - | N/A | - | |
| | pH (units) | N/A | 6.94 | N/A | N/A | N/A | No QAQC readings taken at installation. Grab samples taken at removal. |
| | Conductivity (µS/cm) | N/A | 31.7 | N/A | N/A | N/A | |
| | Dissolved Oxygen (mg/L) | N/A | 10.83 | - | N/A | - | |
| | Turbidity (NTU) | - | 0 | N/A | - | N/A | |
| **12-Sep-09 (removal)** | Temp (°C) | 8 | 8 | - | Excellent | - | |
| | pH (units) | 7 | 7.1 | - | Excellent | - | |
| | Conductivity (µS/cm) | 30.7 | 36.3 | - | Good | - | |
| | Dissolved Oxygen (mg/L) | 11.56 | 11.99 | - | Good | - | |
| | Turbidity (NTU) | - | 0 | - | - | - | |
| **15-Sep-09 (installation)** | Temp (°C) | 4.96 | 5 | - | Excellent | - | |
| | pH (units) | 6.26 | 6.39 | 7.05 | Excellent | Good | |
| | Conductivity (µS/cm) | 27.8 | 35.8 | 38 | Good | Excellent | |
| | Dissolved Oxygen (mg/L) | 12.16 | 12.05 | - | Excellent | - | |
| | Turbidity (NTU) | - | 0 | 1.2 | - | Excellent | |
| **27-Oct-09 (removal)** | Temp (°C) | -0.24 | -0.1 | - | Excellent | - | |
| | pH (units) | 6.22 | 7.04 | - | Marginal | - | |
| | Conductivity (µS/cm) | 33.8 | 46.7 | - | Fair | - | |
| | Dissolved Oxygen (mg/L) | 13.48 | 13.82 | - | Good | - | |
| | Turbidity (NTU) | - | 0 | - | - | - | |

# Data Interpretation

## *Reid Brook at Outlet of Reid Pond (Upper Reid Brook) – NF03NE0009*

- This station is located on Reid Brook at the outlet of Reid Brook Pond and is most often referred to as "Upper Reid Brook".
- This is a control station with relatively pristine waters, unaffected by the mining activities at Voisey's Bay.

### Temperature

- Temperature rises throughout the early summer and peaks in early August at around 16°C (**Figure 2**). Water temperature is highly variable throughout the day and night during the early summer, sometimes fluctuating up to 6° C in a 12 hour period.
- Water temperature is closely related to air temperature. Air temperature data for Nain, NL is available in **Appendix 1**.
- Temperature ranges between 1.72°C and 16.08°C between June and October 2009. Monthly averages, maximums and minimums are summarized in **Table 7**.

**Table 7: Summary statistics for water temperature at Upper Reid Brook**

| Temperature (°C) | July | August | September | October | June to October |
|---|---|---|---|---|---|
| Average | 7.10 | 10.83 | 8.60 | 5.95 | 7.62 |
| Maximum | 16.08 | 15.88 | 10.62 | 8.54 | 16.08 |
| Minimum | 3.11 | 7.68 | 6.93 | 2.91 | 1.72 |

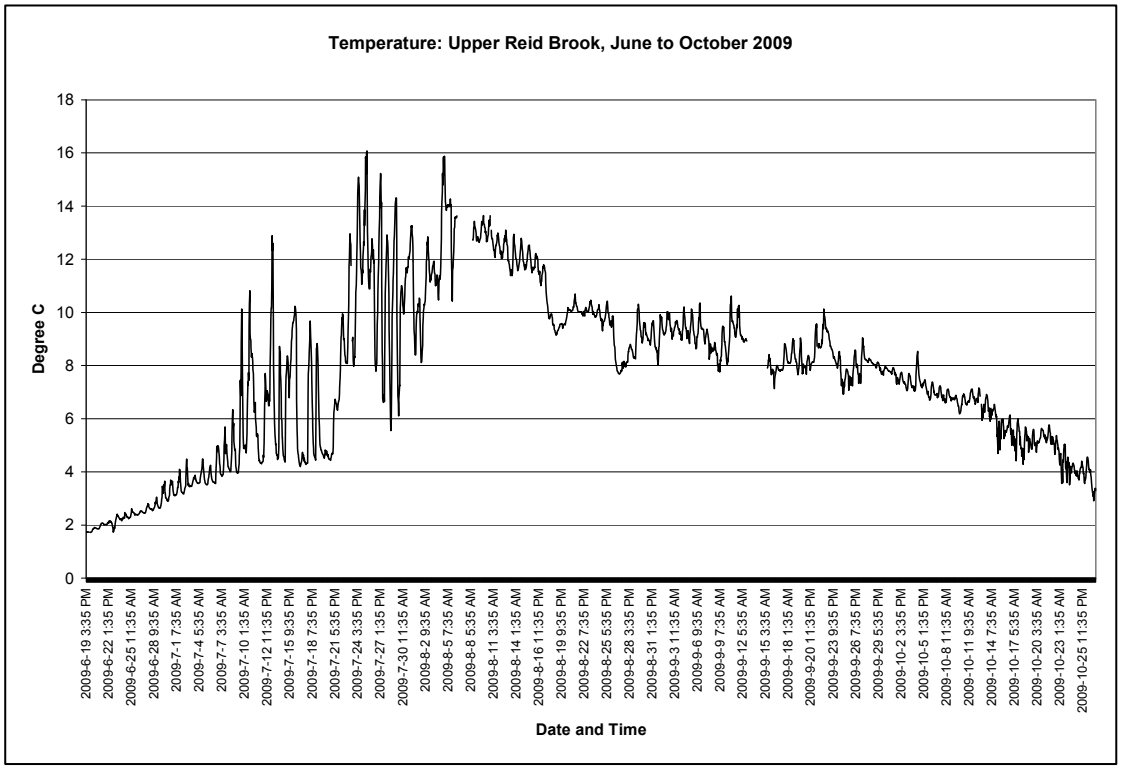


**Figure 2: Water Temperature for Upper Reid Brook, June to October 2009.**

## pH

- pH is stable for most of the deployment season, however, there is significant fluctuation between mid July to early August (**Figure 3**). This can likely be attributed to sensor instability.
- pH ranges between 5.75 and 7.83 units throughout the deployment season. Monthly averages, maximums and minimums are summarized in **Table 8**.
- Ninety three percent of time, pH measurements are within the CCME Guidelines for the Protection of Aquatic Life (>6.5 and <9.0).

**Table 8: Summary statistics for pH at Upper Reid Brook**

| pH | July | August | September | October | June to October |
|---|---|---|---|---|---|
| Average | 6.68 | 6.84 | 7.16 | 7.59 | 7.00 |
| Maximum | 7.17 | 7.25 | 7.80 | 7.83 | 7.83 |
| Minimum | 5.75 | 5.87 | 6.68 | 7.32 | 5.75 |

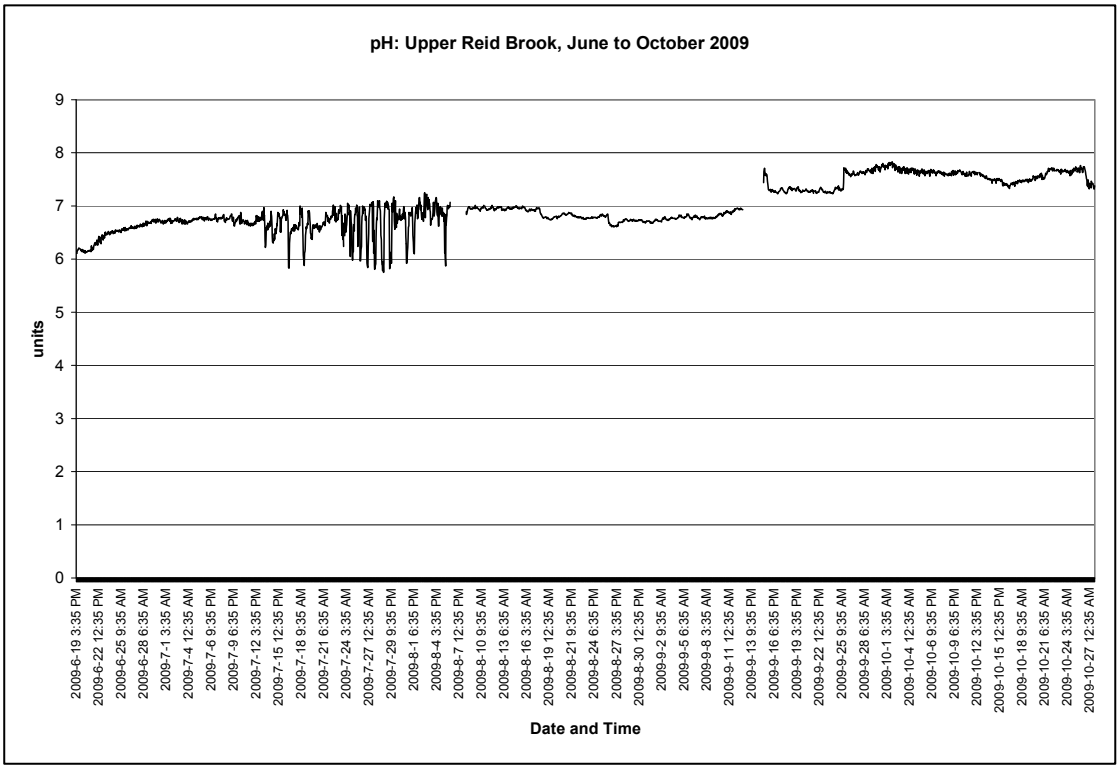


**Figure 3: pH for Upper Reid Brook, June to October 2009.**

## Specific Conductivity

- Specific conductivity fluctuates daily throughout the deployment season and remains relatively stable at low levels (**Figure 4**). This trend is expected as this station is a background station with no impacts from mining affecting the water quality.
- Specific conductivity ranges between 8.60µS/cm and 10.00µS/cm. Monthly averages, maximums and minimums are summarized in **Table 9**.

**Table 9: Summary statistics for specific conductivity at Upper Reid Brook**

| Specific Conductivity (µS/cm) | July | August | September | October | June to October |
|---|---|---|---|---|---|
| Average | 9.35 | 9.55 | 9.34 | 9.01 | 9.33 |
| Maximum | 9.90 | 10.00 | 9.90 | 9.80 | 10.00 |
| Minimum | 8.60 | 9.00 | 8.80 | 8.70 | 8.60 |

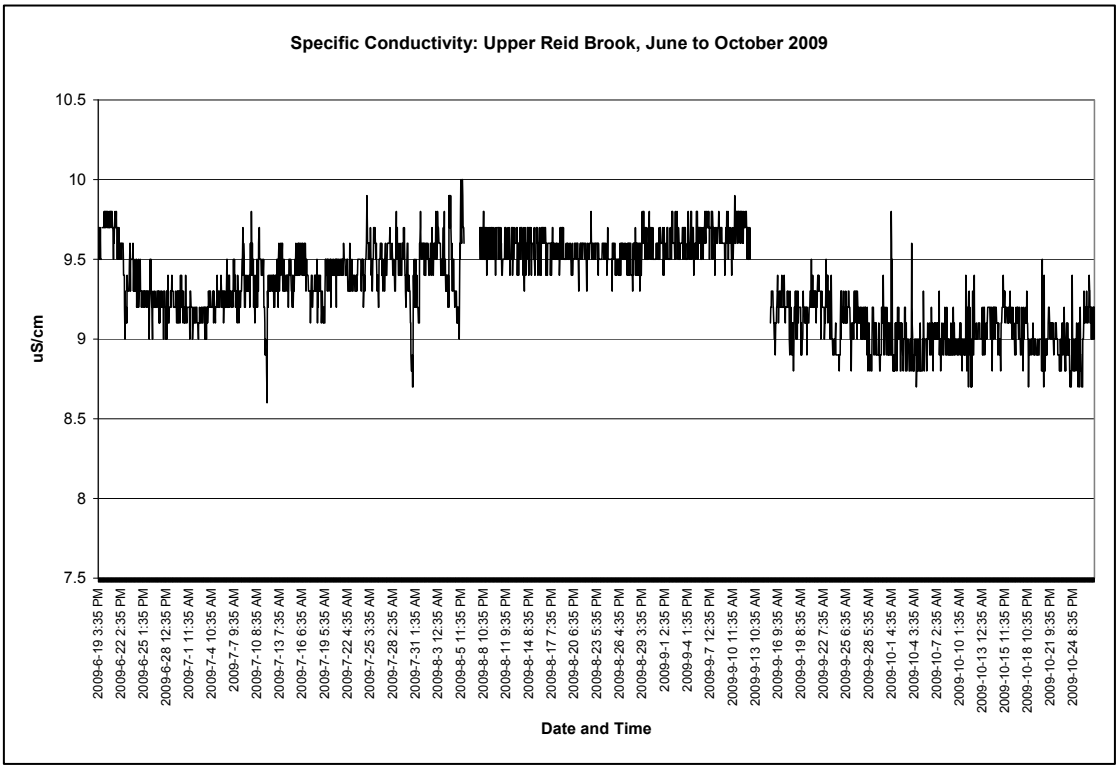


**Figure 4: Specific Conductivity for Upper Reid Brook, June to October 2009.**

## Dissolved Oxygen and Percent Saturation

- Dissolved oxygen concentrations decrease slightly at the beginning of the deployment season during early summer (**Figure 5**). This trend is expected as dissolved oxygen content is inversely related to water temperature. During this time water temperature is rising and dissolved oxygen content is decreasing.
- Dissolved oxygen content appears to fluctuate considerable between mid July and early August. This is a cause of sensor instability. Similarly, during the last 5 weeks of the deployment from mid September to late October, dissolved oxygen content varies considerably. The cause of the sensor malfunction is unknown and will be addressed before redeployment in 2010.
- Percent saturation is a function of dissolved oxygen and water temperature. Percent saturation values show a similar trend as dissolved oxygen content.
- Dissolved oxygen content ranges between 8.71mg/L and 13.52mg/L. Less than 1% of the time measurements are below the recommended guideline for dissolved oxygen content (>9.00mg/L) for cold water bodies as stated by the CCME Guidelines for the Protection of Aquatic Life. Monthly averages, maximums and minimums for dissolved oxygen and percent saturation are summarized in **Table 10**.

**Table 10: Summary statistics for dissolved oxygen and percent saturation at Upper Reid Brook**

| **Dissolved Oxygen (mg/L) and Percent Saturation (%)** | July | | August | | September | | October | | June to October | |
|---|---|---|---|---|---|---|---|---|---|---|
| | DO | %Sat | DO | %Sat | DO | %Sat | DO | %Sat | DO | %Sat |
| Average | 12.23 | 100.61 | 10.81 | 97.54 | 10.62 | 91.12 | 10.19 | 81.65 | 11.19 | 93.37 |
| Maximum | 13.06 | 108.90 | 12.13 | 103.20 | 11.51 | 98.99 | 12.68 | 95.59 | 13.52 | 108.90 |
| Minimum | 10.36 | 96.40 | 9.66 | 93.50 | 8.71 | 73.59 | 8.78 | 73.40 | 8.71 | 73.40 |

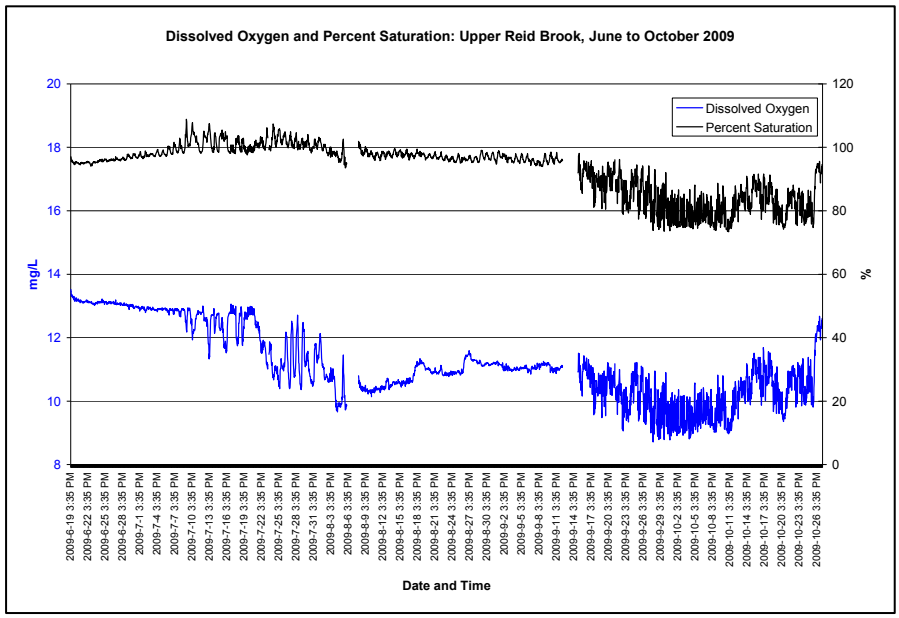


**Figure 5: Dissolved Oxygen and Percent Saturation for Upper Reid Brook, June to October 2009.**

## Turbidity

- Turbidity is most often 0NTU at this station (**Figure 6**). This is expected as the brook is pristine.
- Turbidity values however, do become apparent near the end of the deployment season during October. An event lasting over three weeks saw turbidity values averaging below 5NTU and spiking once to 25.6NTU. It is unknown what caused this turbidity event to occur as precipitation data for this time period does not tend to correspond with the increase in values. The instrument will be sent for performance testing evaluation in winter 2010 as this may be a result of sensor malfunction.
- Turbidity averages under 1NTU for the entire deployment season. Monthly averages, maximums and minimums are summarized in **Table 11**.

**Table 11: Summary statistics for turbidity at Upper Reid Brook**

| Turbidity (NTU) | July | August | September | October | June to October |
|---|---|---|---|---|---|
| Average | 0.0 | 0.0 | 0.3 | 3.2 | 0.8 |
| Maximum | 4.6 | 2.1 | 12.8 | 25.6 | 25.6 |
| Minimum | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

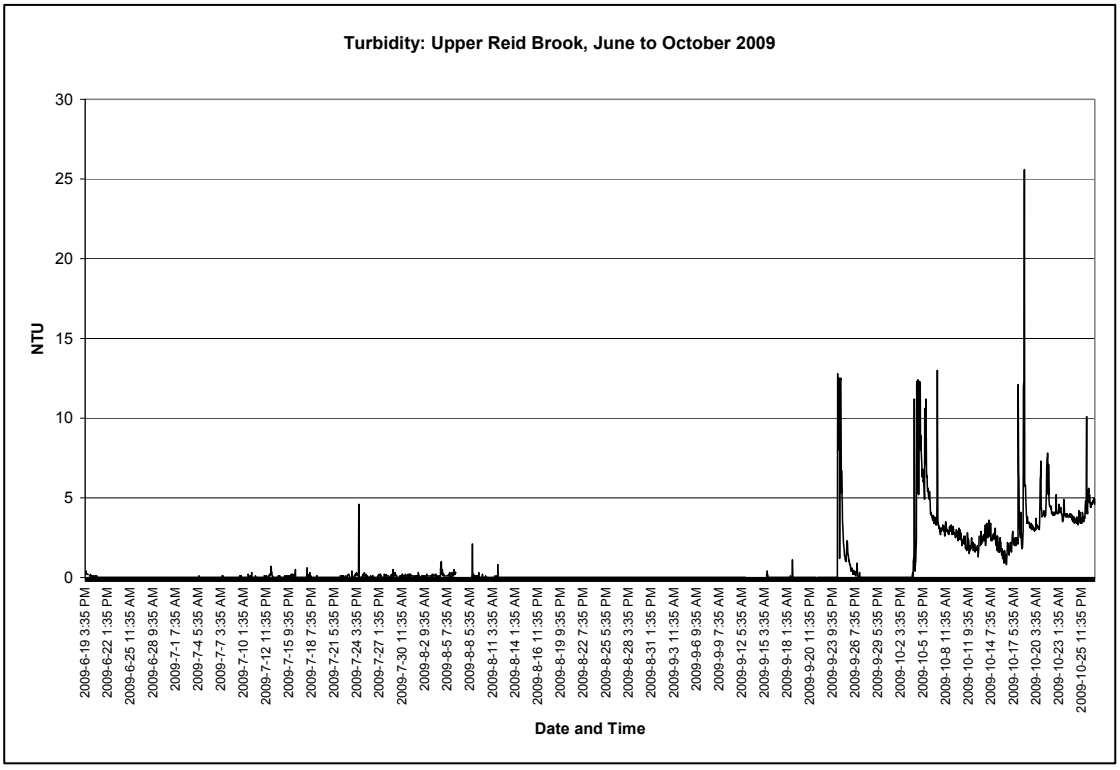


**Figure 6: Turbidity for Upper Reid Brook, June to October 2009.**

## Stage and Flow

- Stage levels decrease throughout the early summer and remain low through the end of the deployment season (**Figure 7**).
- Flow patterns are similar, with flow rates as high as 15.5$m^3$/s in the early summer when the instrument was first deployed. Flow rates are generally under 3$m^3$/s for the majority of the deployment season.
- Stage increases are most often directly related to precipitation events (**Appendix 1**). There is a considerable increase in stage in mid August that is directly related to a rainfall event.
- Monthly average, maximums and minimums for stage and flow are summarized in **Table 12**.

**Table 12: Summary statistics for stage and flow at Upper Reid Brook**

| Stage (m) and Flow (m3/s) | July | | August | | September | | October | | June to October | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Stage | Flow | Stage | Flow | Stage | Flow | Stage | Flow | Stage | Flow |
| Average | 2.028 | 3.884 | 1.889 | 2.185 | 1.662 | 0.738 | 1.597 | 0.452 | 1.853 | 2.615 |
| Maximum | 2.237 | 7.420 | 1.985 | 3.180 | 1.830 | 1.660 | 1.648 | 0.629 | 2.565 | 15.500 |
| Minimum | 1.869 | 1.980 | 1.797 | 1.420 | 1.567 | 0.366 | 1.571 | 0.377 | 1.567 | 0.366 |

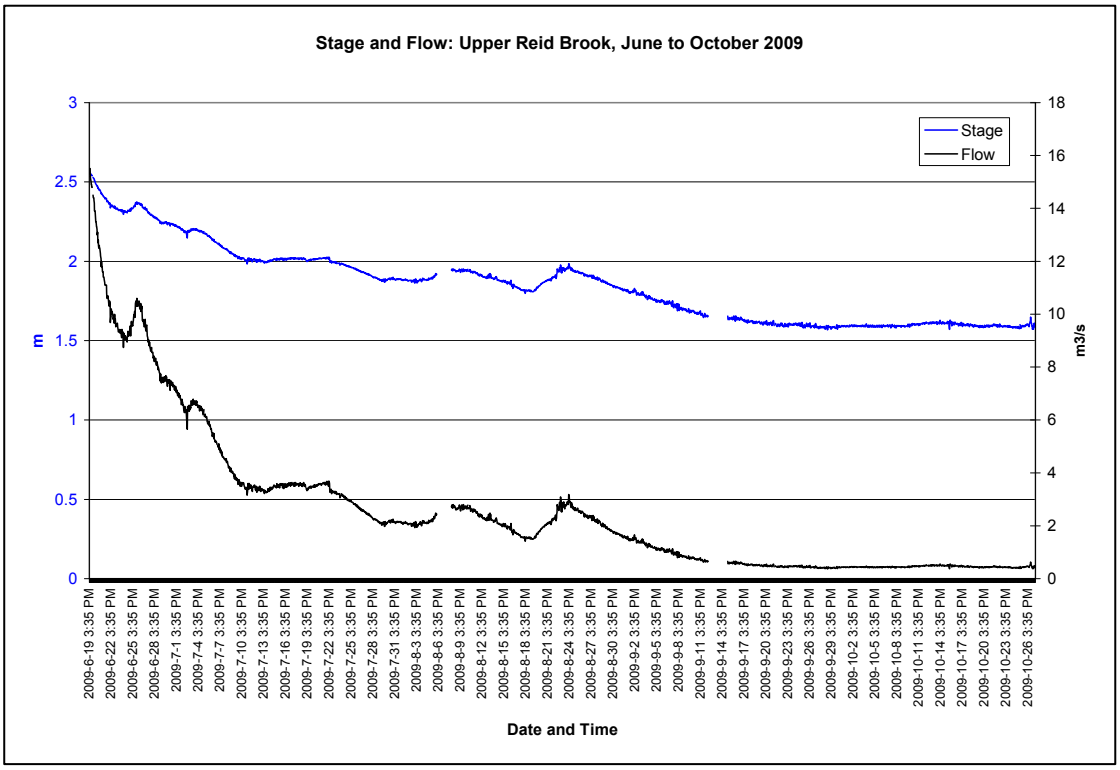


**Figure 7: Stage for Upper Reid Brook, June to October 2009.**

## *Camp Pond Brook below Camp Pond - NF03NE0010*

- This station is located on Camp Pond Brook below Camp Pond.
- The Camp Pond Brook site was chosen to capture any emerging water quality events due to the nearby development of the mine/mill site.

## Temperature

- Temperature fluctuates considerably throughout the entire deployment season (**Figure 8**). A general increasing trend can be identified in the first month of the deployment before a general decreasing trend takes over for the remainder of the deployment season.
- Water temperature is closely related to air temperature. Air temperature data for Nain, NL is available in **Appendix 1**.
- Temperature ranges between -0.24°C and 21.98°C between June and October 2009. Monthly averages, maximums and minimums are summarized in **Table 13**.

**Table 13: Summary statistics for water temperature at Camp Pond Brook**

| Temperature (C°) | July | August | September | October | June to October |
|---|---|---|---|---|---|
| Average | 14.87 | 12.41 | 9.18 | 2.70 | 10.13 |
| Maximum | 21.98 | 18.67 | 13.90 | 7.10 | 21.98 |
| Minimum | 9.76 | 7.65 | 4.48 | -0.24 | -0.24 |

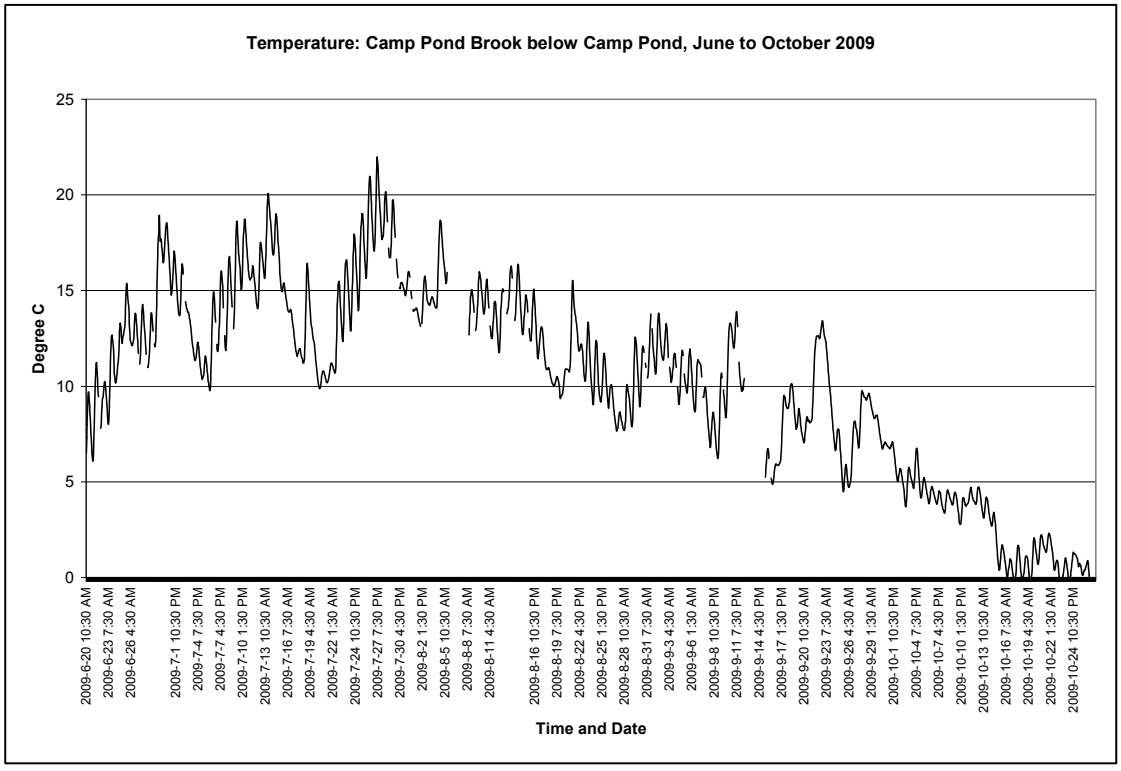


**Figure 8: Water Temperature for Camp Pond Brook, June to October 2009.**

## pH

- pH fluctuates diurnally and shows a general increasing trend throughout the deployment season (**Figure 9**).
- pH ranges between 6.51 and 7.47 units. All pH measurements are within the CCME Guideline for the Protection of Aquatic Life (>6.5 and <9.0).
- Monthly averages, maximums and minimums are summarized in **Table 14**.

**Table 14: Summary statistics for pH at Camp Pond Brook**

| pH | July | August | September | October | June to October |
|---|---|---|---|---|---|
| Average | 6.94 | 7.05 | 7.24 | 7.31 | 7.10 |
| Maximum | 7.08 | 7.25 | 7.47 | 7.42 | 7.47 |
| Minimum | 6.78 | 6.80 | 6.69 | 7.22 | 6.51 |

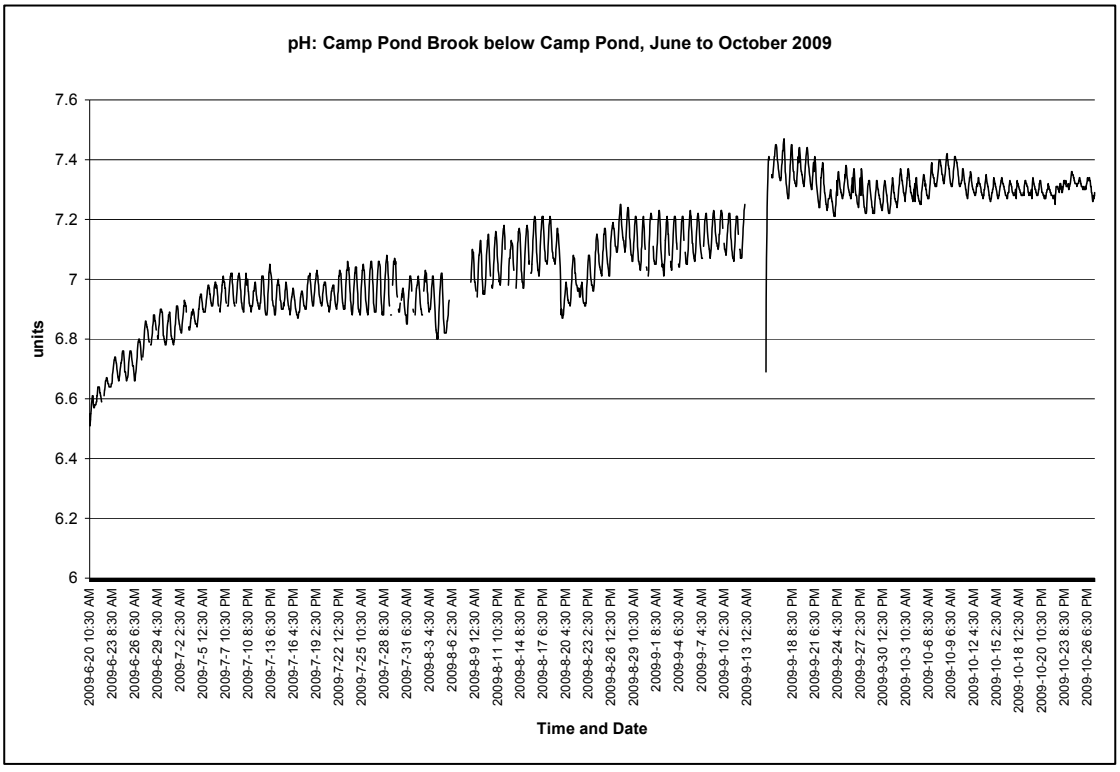


**Figure 9: pH for Camp Pond Brook, June to October 2009.**

## Specific Conductivity

- Specific conductivity appears to increase throughout the first deployment period of the season (**Figure 10**). This is not likely due to sensor drift as the comparison values at installation and removal for conductivity were both ranked excellent. When the instrument is removed and then replaced, conductivity values are slightly lower. Unfortunately there are no QAQC values for ranking at installation in August.
- Specific Conductivity values tend to fluctuate and correspond well with rainfall events (**Appendix 1**).
- Monthly averages, maximums and minimums are summarized in **Table 15**.

**Table 15: Summary statistics for specific conductivity at Camp Pond Brook**

| Specific Conductivity (µS/cm) | July | August | September | October | June to October |
|---|---|---|---|---|---|
| Average | 29.79 | 27.08 | 31.98 | 37.12 | 30.88 |
| Maximum | 34.80 | 51.70 | 41.60 | 40.40 | 51.70 |
| Minimum | 25.70 | 24.10 | 24.40 | 29.70 | 20.10 |

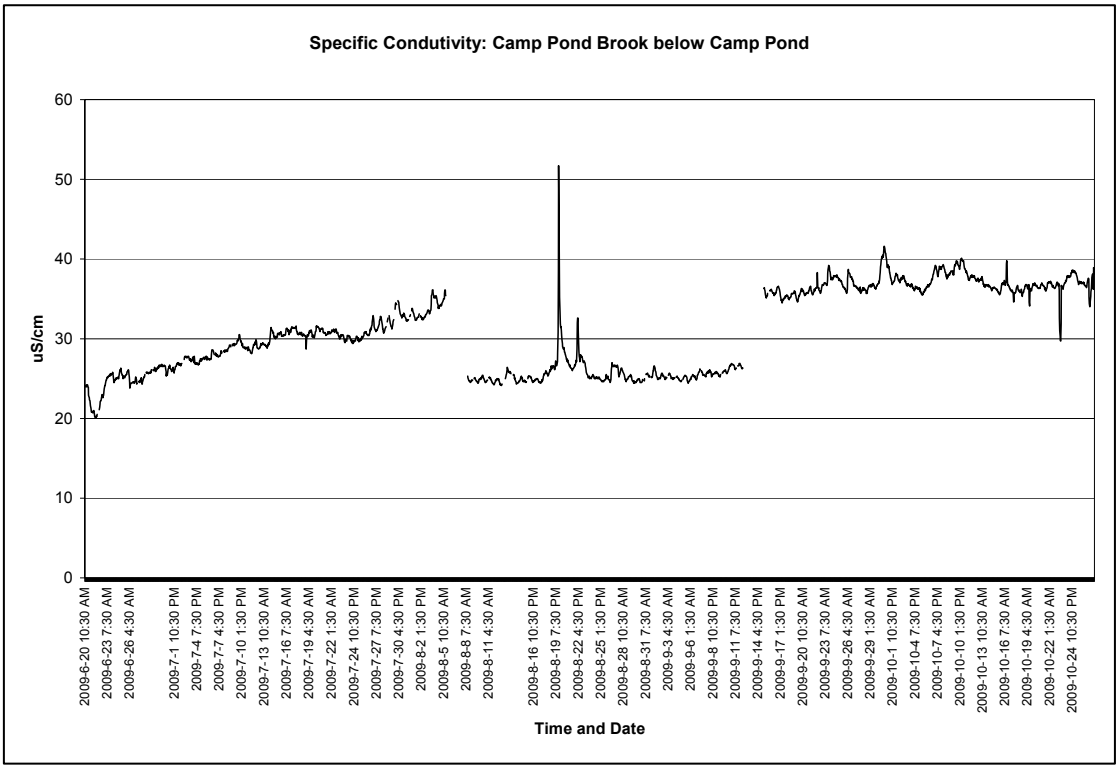


**Figure 10: Specific conductivity for Camp Pond Brook, June to October 2009.**

## Dissolved Oxygen and Percent Saturation

- Dissolved oxygen concentrations decrease slightly at the beginning of the deployment season during early summer (**Figure 11**). This trend is expected as dissolved oxygen content is inversely related to water temperature. During this time water temperature is rising and dissolved oxygen content is decreasing.
- Percent saturation is a function of dissolved oxygen and water temperature. Percent saturation values show a similar trend as dissolved oxygen content.
- Dissolved oxygen content ranges between 7.04mg/L and 13.21mg/L. Seventy-five percent the time, measurements are within the recommended guideline for dissolved oxygen content (>9.00mg/L) for cold water bodies as stated by the CCME Guidelines for the Protection of Aquatic Life.
- Monthly averages, maximums and minimums for dissolved oxygen and percent saturation are summarized in **Table 16**.

**Table 16: Summary statistics for dissolved oxygen and percent saturation at Camp Pond Brook**

| Dissolved Oxygen (mg/L) and Percent Saturation (%) | July | | August | | September | | October | | June to October | |
|---|---|---|---|---|---|---|---|---|---|---|
| | DO | %Sat | DO | %Sat | DO | %Sat | DO | %Sat | DO | %Sat |
| Average | 8.48 | 83.55 | 9.34 | 87.23 | 10.22 | 88.53 | 11.78 | 86.51 | 9.89 | 86.62 |
| Maximum | 10.13 | 92.80 | 10.63 | 94.00 | 11.89 | 96.00 | 13.21 | 91.10 | 13.21 | 96.00 |
| Minimum | 7.16 | 75.10 | 7.04 | 74.00 | 8.93 | 81.80 | 9.93 | 81.00 | 7.04 | 74.00 |

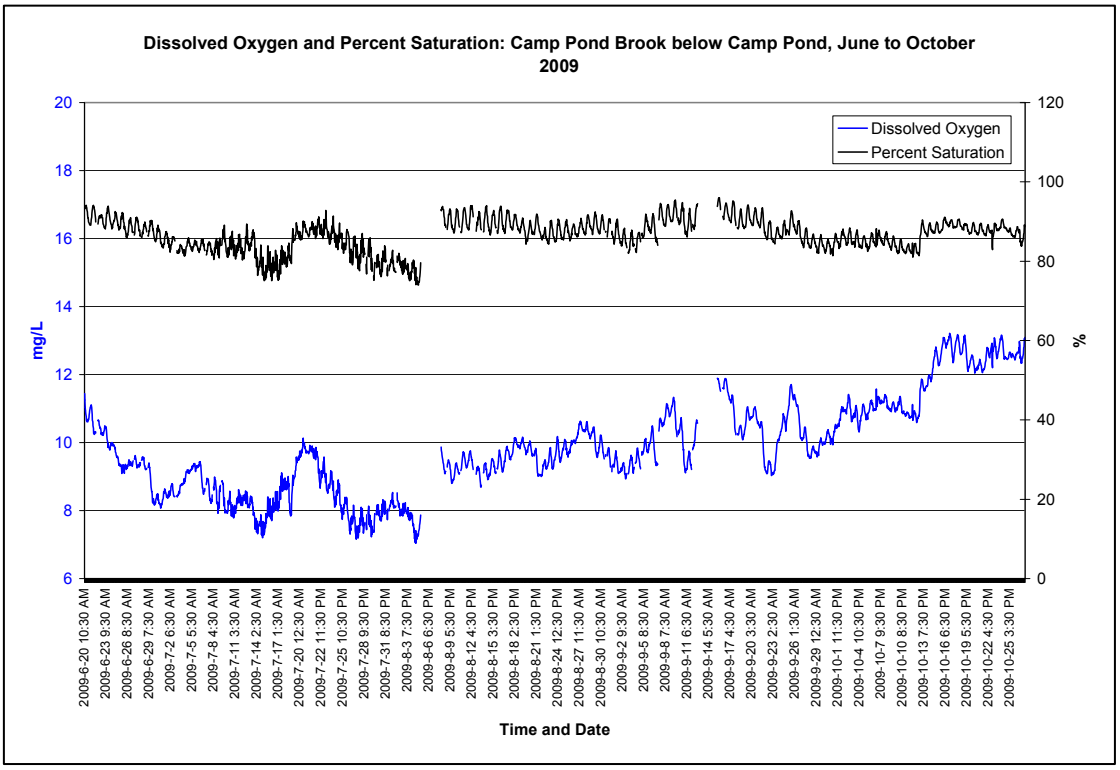


**Figure 11: Dissolved oxygen and percent saturation for Camp Pond Brook, June to October 2009.**

## Turbidity

- Turbidity values at this station are consistently above 0NTU, and have a background value of around 3-5NTU (**Figure 12**).
- There are a number of increases that occur throughout the deployment season (up to 166.9NTU, which is not shown on Figure 12). Many of these increases do not last longer than 1-2 hours. These increases are often related back to precipitation events as recorded by Environment Canada in Nain. NL (**Appendix 1**).
- Monthly averages, maximums and minimums are summarized in **Table 17**.

**Table 17: Summary statistics for turbidity at Camp Pond Brook**

| Turbidity (NTU) | July | August | September | October | June to October |
|---|---|---|---|---|---|
| Average | 2.6 | 2.5 | 1.6 | 1.2 | 2.1 |
| Maximum | 166.9 | 63.4 | 39.2 | 17.1 | 166.9 |
| Minimum | 1.1 | 1.0 | 0.1 | 0.5 | 0.1 |

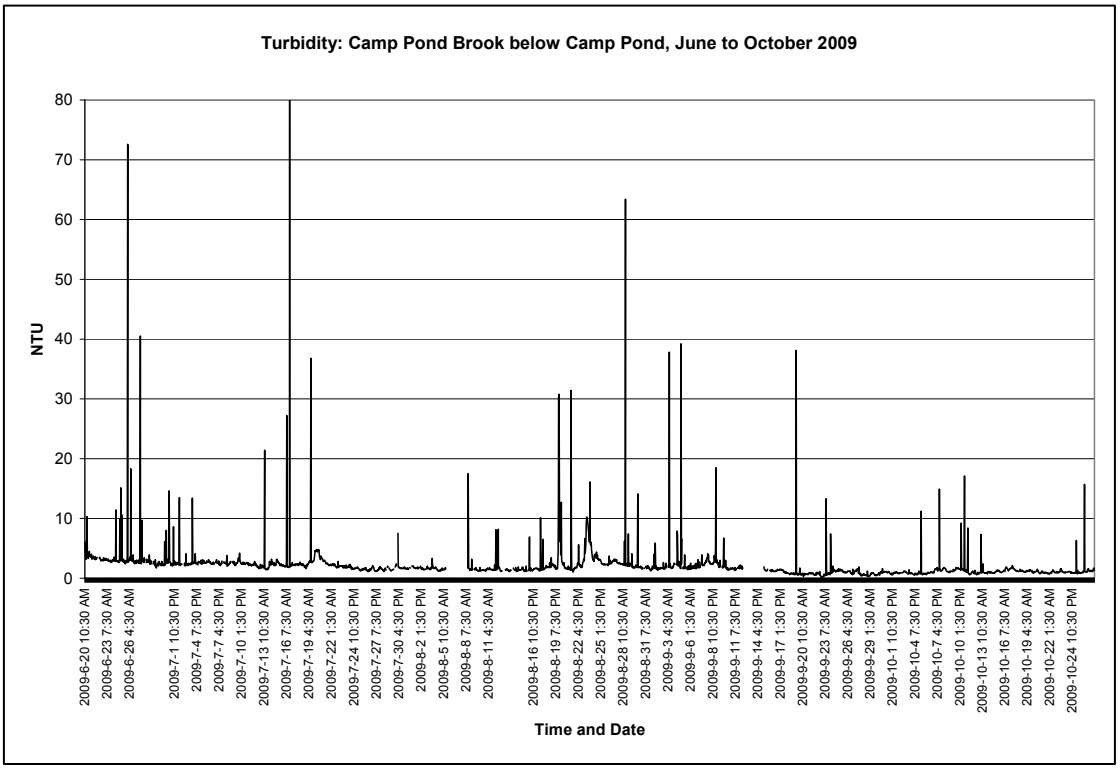


**Figure 12: Turbidity for Camp Pond Brook, June to October 2009.**

## Stage and Flow

- Stage and flow decrease significantly in the first month of the deployment season before leveling off and remaining low for the remainder of the deployment (**Figure 13**).
- Stage increases are most often directly related to precipitation events (**Appendix 1**). There is a considerable increase in stage in mid August that is directly related to a rainfall event. Additionally, stage and flow fluctuate, peaking intermittently at the very end of the deployment. These increases are not related to rainfall events as they were not recorded by the control station in the area and only last for 1 hour at a time unlike natural gradual increases/decreases in stage during rainfall events. These events may in fact be caused by 'slush spikes' which are fluctuation events that occur on raw data when freezing is taking place.
- Monthly average, maximums and minimums for stage and flow are summarized in **Table 18**.

**Table 18: Summary statistics for stage and flow at Camp Pond Brook**

| Stage (m) and Flow (m3/s) | July | | August | | September | | October | | June to October | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Stage | Flow | Stage | Flow | Stage | Flow | Stage | Flow | Stage | Flow |
| Average | 1.438 | 0.514 | 1.393 | 0.309 | 1.349 | 0.160 | 1.322 | 0.083 | 1.393 | 0.363 |
| Maximum | 1.517 | 0.963 | 1.420 | 0.419 | 1.402 | 0.343 | 1.398 | 0.327 | 1.642 | 1.970 |
| Minimum | 1.393 | 0.308 | 1.361 | 0.192 | 1.324 | 0.085 | 1.293 | 0.038 | 1.293 | 0.038 |

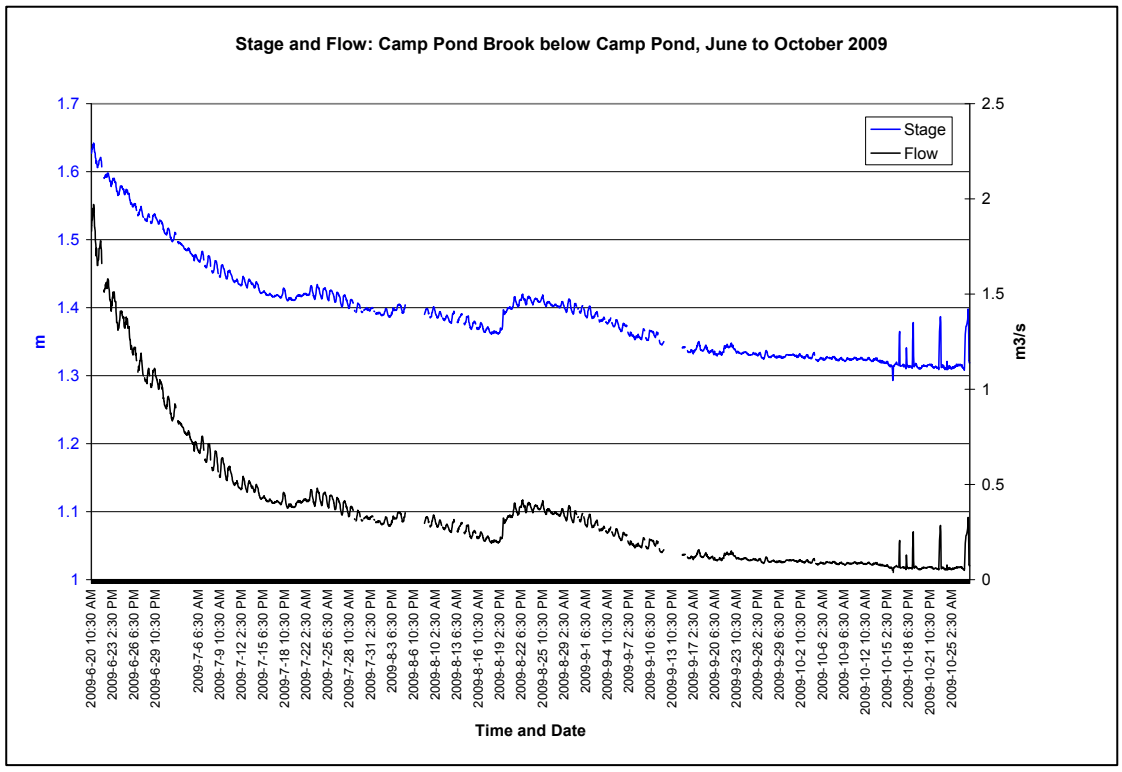


**Figure 13: Stage and flow for Camp Pond Brook, June to October 2009.**

## *Lower Reid Brook below Tributary - NF03NE0011*

- This station is located on Lower Reid Brook below an unnamed tributary.
- The Lower Reid Brook site was chosen as a downstream location that could be used to determine if water quality events from the upstream development area were still having an impact downstream just before the stream runs into the ocean.

## Temperature

- Temperature fluctuates considerably throughout the entire deployment season (**Figure 14**). A general increasing trend can be identified in the first month of the deployment before a general decreasing trend takes over for the remainder of the deployment season.
- Water temperature is closely related to air temperature. Air temperature data for Nain, NL is available in **Appendix 1**.
- Temperature ranges between -0.24°C and 15.41°C between June and October 2009. Monthly averages, maximums and minimums are summarized in **Table 19**.

**Table 19: Summary statistics for water temperature at Lower Reid Brook**

| **Temperature (C°)** | July | August | September | October | June to October |
|---|---|---|---|---|---|
| Average | 11.06 | 10.50 | 7.58 | 2.10 | 7.94 |
| Maximum | 15.41 | 15.14 | 12.28 | 6.19 | 15.41 |
| Minimum | 6.41 | 6.33 | 3.62 | -0.24 | -0.24 |

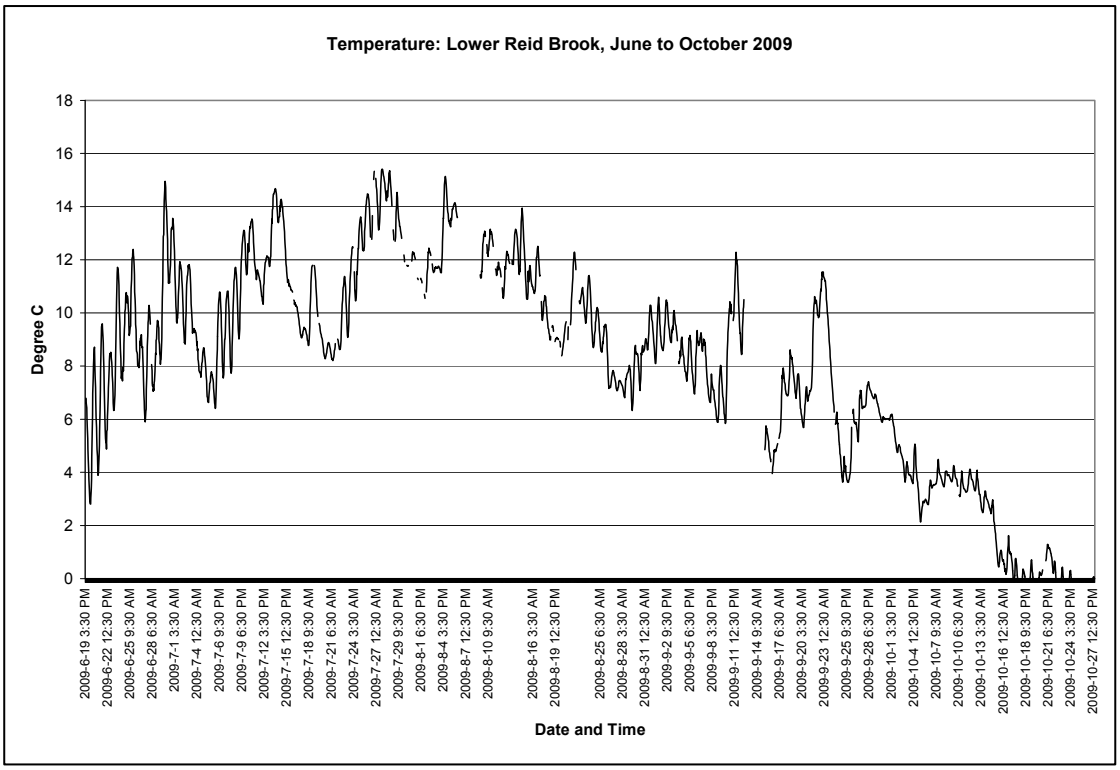


**Figure 14: Water temperature for Lower Reid Brook, June to October 2009.**

## pH

- pH rises slightly at this station throughout the deployment season (**Figure 15**).
- pH ranges between 6.51 and 8.04 units. All values are within the CCME Guidelines for the Protection of Aquatic Life (>6.5 and <9.0).
- Monthly averages, maximums and minimums are summarized in **Table 20**.

**Table 20: Summary statistics for pH at Lower Reid Brook**

| pH | July | August | September | October | June to October |
|---|---|---|---|---|---|
| Average | 6.94 | 7.01 | 7.51 | 7.53 | 7.20 |
| Maximum | 7.04 | 7.22 | 8.04 | 7.59 | 8.04 |
| Minimum | 6.83 | 6.74 | 7.07 | 7.40 | 6.51 |

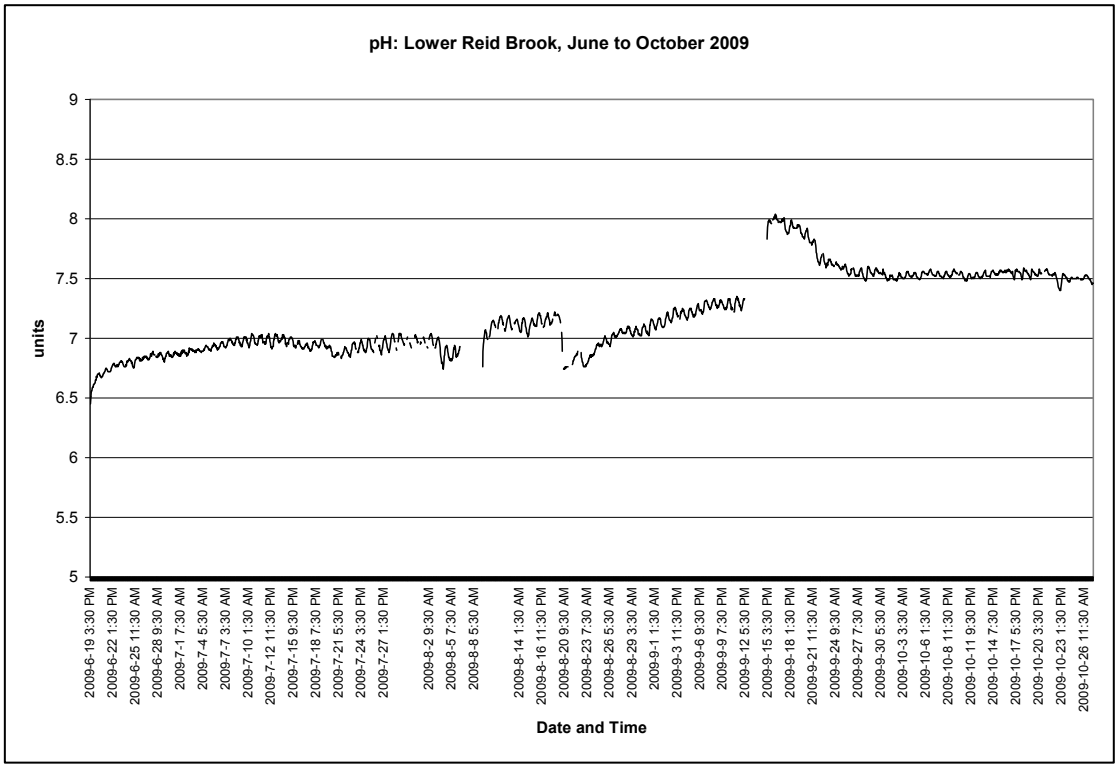


**Figure 15: pH for Lower Reid Brook, June to October 2009.**

## Specific Conductivity

- Specific conductivity rises continuously throughout the deployment season (**Figure 16**).
- Specific conductivity values tend to fluctuate and correspond well with rainfall events (**Appendix 1**).
- Monthly averages, maximums and minimums are summarized in **Table 21**.

**Table 21: Summary statistics for specific conductivity at Lower Reid Brook**

| Specific Conductivity (µS/cm) | July | August | September | October | June to October |
|---|---|---|---|---|---|
| Average | 24.02 | 27.45 | 31.72 | 35.78 | 28.34 |
| Maximum | 31.00 | 32.00 | 34.00 | 42.00 | 42.00 |
| Minimum | 17.00 | 24.00 | 29.00 | 32.00 | 14.00 |

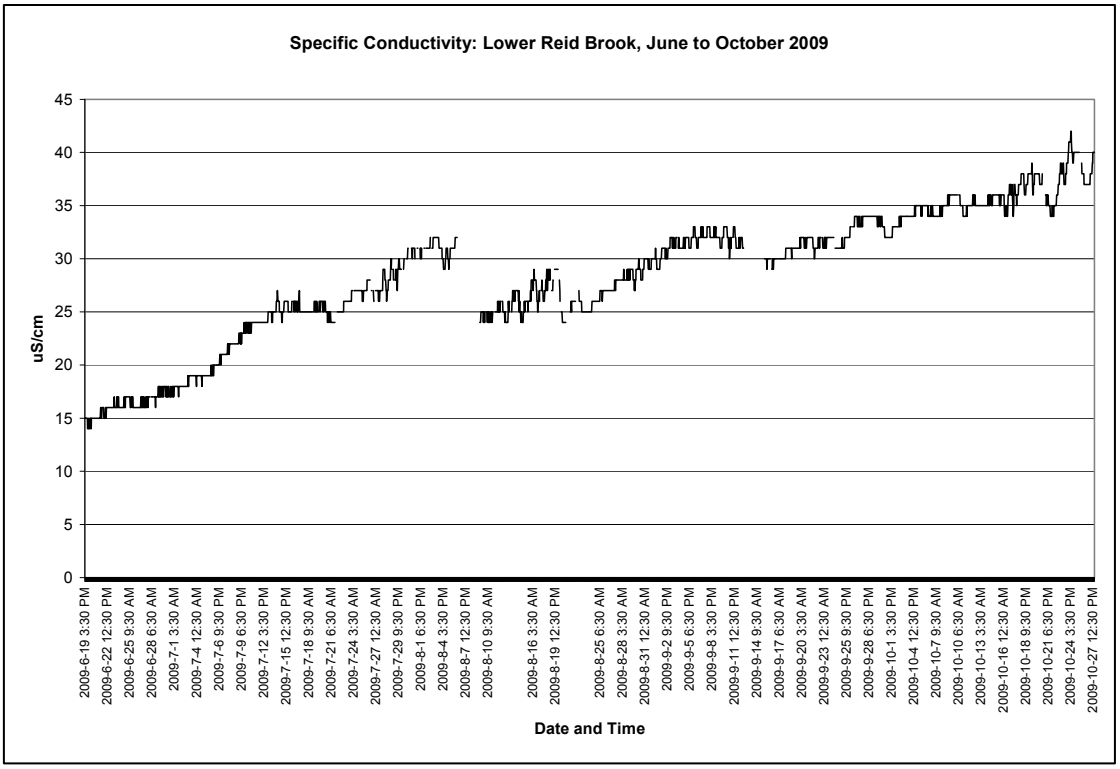


**Figure 16: Specific conductivity for Lower Reid Brook, June to October 2009.**

## Dissolved Oxygen and Percent Saturation

- Dissolved oxygen content fluctuates throughout the deployment season (**Figure 17**).
- Water temperature and dissolved oxygen content are inversely related. A general decreasing trend is noticeable during the first month of the deployment which water temperatures are rising. Dissolved oxygen tends to increase slightly throughout the later half of the deployment as water temperature cools.
- Percent saturation is a function of water temperature and dissolved oxygen content and remains relatively stable throughout the 2009 deployment season.
- Monthly averages, maximums and minimums for dissolved oxygen and percent saturation are summarized in **Table 22**.

**Table 22: Summary statistics for dissolved oxygen and percent saturation at Lower Reid Brook**

| Dissolved Oxygen (mg/L) and Percent Saturation (%) | July | | August | | September | | October | | June to October | |
|---|---|---|---|---|---|---|---|---|---|---|
| | DO | %Sat | DO | %Sat | DO | %Sat | DO | %Sat | DO | %Sat |
| Average | 9.69 | 87.73 | 9.94 | 88.93 | 10.61 | 88.49 | 12.24 | 88.49 | 10.64 | 88.93 |
| Maximum | 11.22 | 94.10 | 11.15 | 97.30 | 12.45 | 98.20 | 13.27 | 92.40 | 13.28 | 100.50 |
| Minimum | 8.11 | 79.70 | 7.98 | 77.70 | 8.88 | 81.00 | 10.74 | 85.60 | 7.98 | 77.70 |

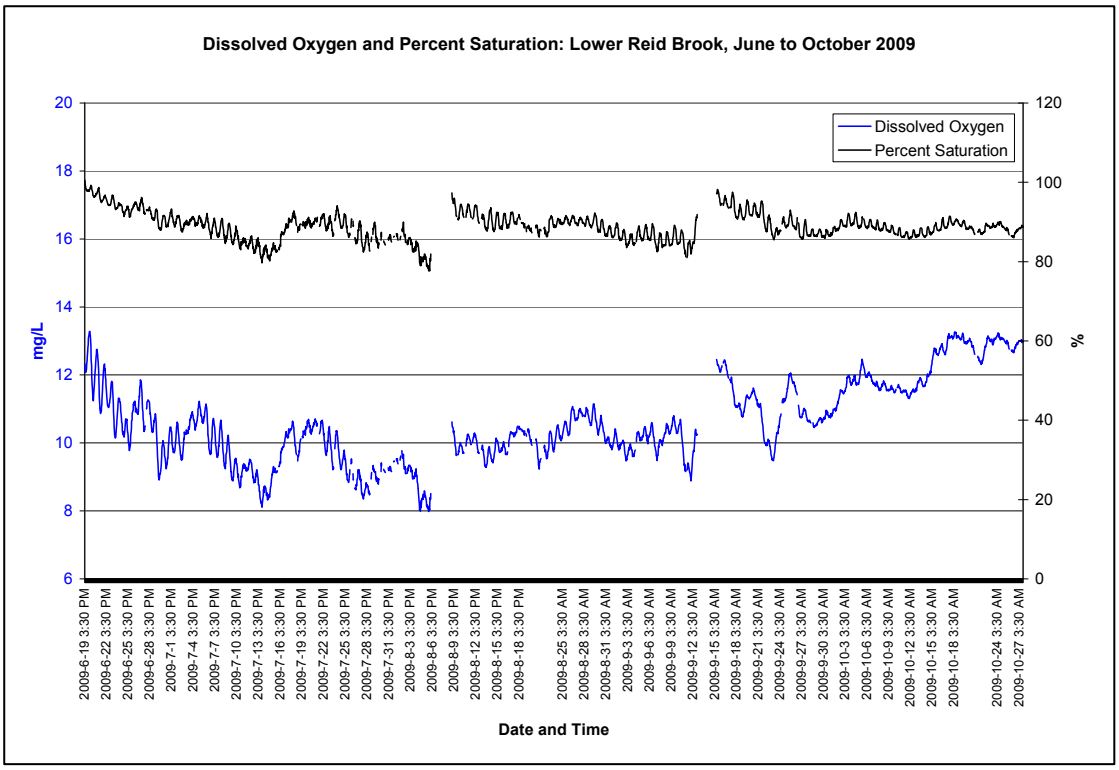


**Figure 17: Dissolved oxygen and percent saturation for Lower Reid Brook, June to October 2009.**

## Turbidity

- This station has a background turbidity level of about 3NTU (**Figure 18**). There are a couple of events which peak above 10NTU and one event which reaches nearly 40NTU. These increases can be related to rainfall events as recorded by Environment Canada in Nain, NL (**Appendix 1**).
- Monthly averages, maximums and minimums are summarized in **Table 23**.

**Table 23: Summary statistics for turbidity at Lower Reid Brook**

| Turbidity (NTU) | July | August | September | October | June to October |
|---|---|---|---|---|---|
| Average | 3.3 | 1.1 | 1.2 | 4.0 | 2.6 |
| Maximum | 13.9 | 38.9 | 6.5 | 14.6 | 38.9 |
| Minimum | 1.9 | 0.0 | 0.0 | 1.9 | 0.0 |

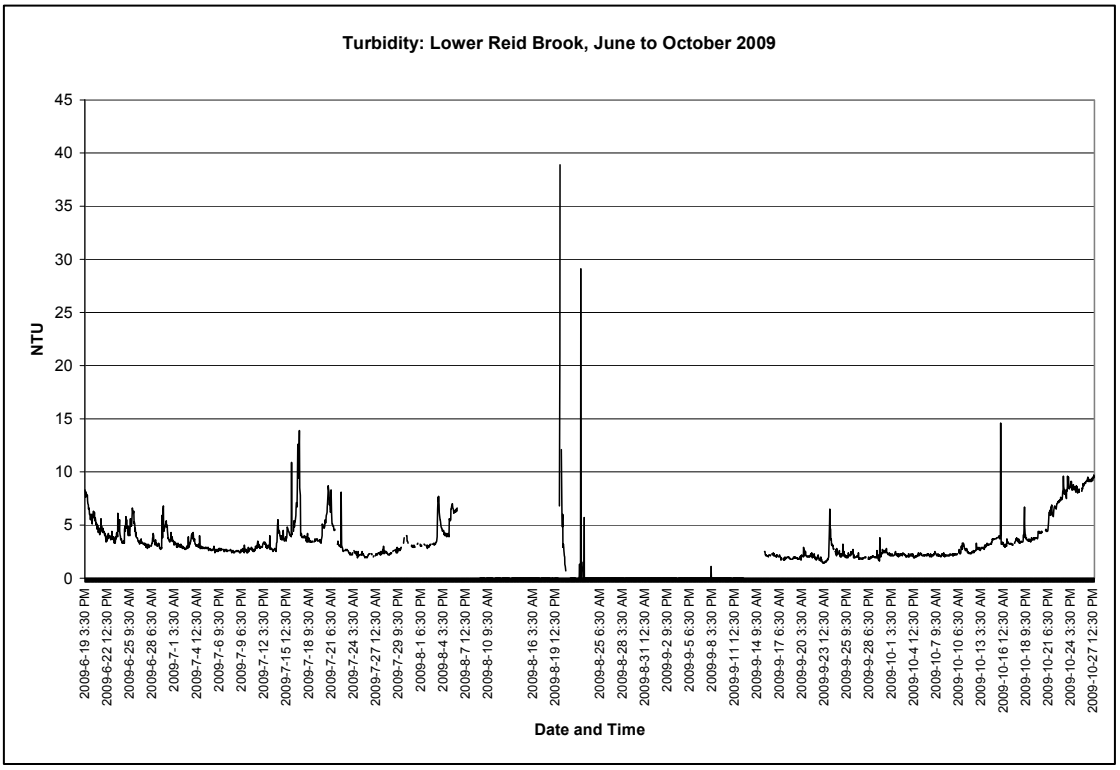


**Figure 18: Turbidity for Lower Reid Brook, June to October 2009.**

## Stage and Flow

- Stage and flow rate decrease considerably through the first month of deployment and remain low for the remainder of the deployment season (**Figure 19**).
- Stage increases are most often directly related to precipitation events (**Appendix 1**). There is a considerable increase in stage in mid August that is directly related to a rainfall event. Additionally, stage and flow fluctuate, peaking intermittently at the very end of the deployment. These increases are not related to rainfall events as they were not recorded by the control station in the area and only last for 1 hour at a time unlike natural gradual increases/decreases in stage during rainfall events. These events may in fact be caused by 'slush spikes' which are fluctuation events that occur on raw data when freezing is taking place.
- Monthly average, maximums and minimums for stage and flow are summarized in **Table 24**.

**Table 24: Summary statistics for stage at Lower Reid Brook**

| Stage (m) and Flow (m3/s) | July | | August | | September | | October | | June to October | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Stage | Flow | Stage | Flow | Stage | Flow | Stage | Flow | Stage | Flow |
| Average | 1.635 | 5.965 | 1.551 | 3.301 | 1.432 | 1.139 | 1.405 | 0.779 | 1.540 | 4.353 |
| Maximum | 1.766 | 11.400 | 1.629 | 5.570 | 1.515 | 2.420 | 1.502 | 2.150 | 1.995 | 22.900 |
| Minimum | 1.537 | 2.910 | 1.495 | 2.010 | 1.384 | 0.620 | 1.301 | 0.620 | 1.301 | 0.620 |

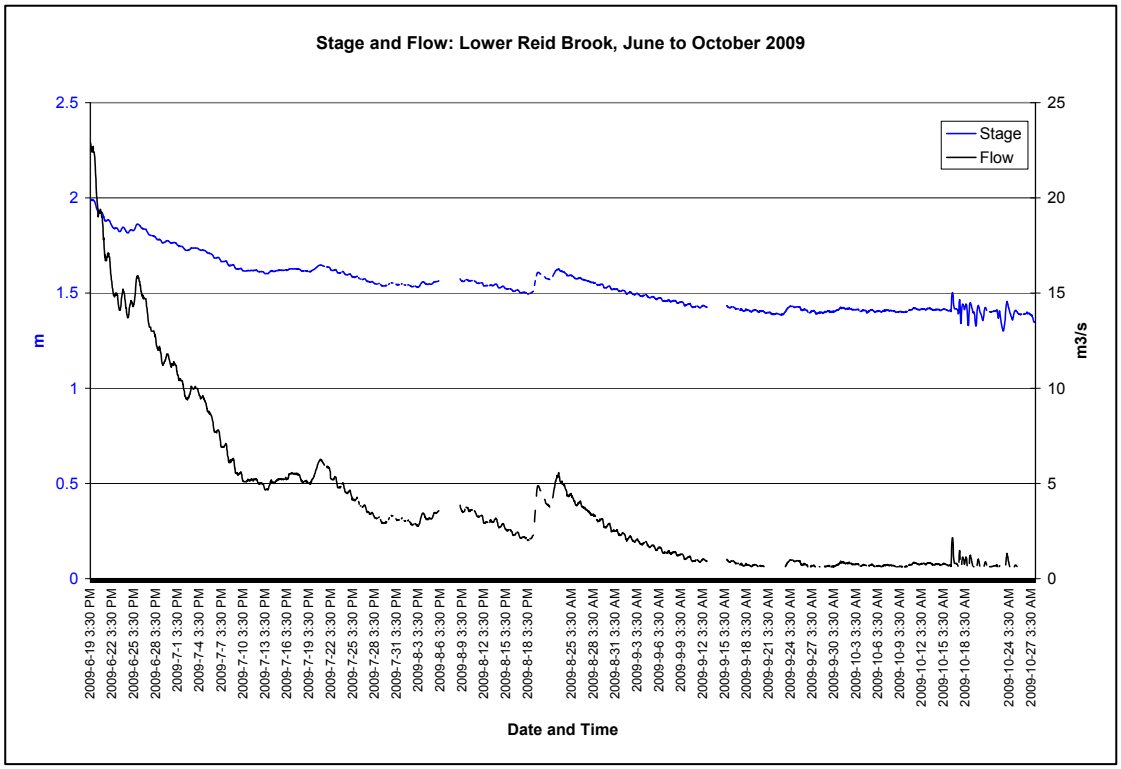


**Figure 19: Stage for Lower Reid Brook, June to October 2009.**

## *Tributary to Reid Brook - NF03NE0012*

- This station is located on an unnamed tributary flowing into Reid Brook.
- The Tributary to Lower Reid Brook station is located in fairly close proximity to the ovoid and thus it was chosen in particular to capture any water quality events that may result from the actual open-pit mining activities.

### Temperature

- Temperature fluctuates considerably throughout the entire deployment season (**Figure 20**). A general increasing trend can be identified in the first month of the deployment before a general decreasing trend resumes for the remainder of the deployment season.
- Water temperature is closely related to air temperature. Air temperature data for Nain, NL is available in **Appendix 1**.
- Temperature ranges between -0.10°C and 16.30°C between June and October 2009. Monthly averages, maximums and minimums are summarized in **Table 25**.

**Table 25: Summary statistics for water temperature at Tributary to Lower Reid Brook**

| Temperature (C°) | July | August | September | October | June to October |
|---|---|---|---|---|---|
| Average | 11.41 | 10.40 | 7.31 | 2.16 | 8.12 |
| Maximum | 15.20 | 15.00 | 10.70 | 6.20 | 16.30 |
| Minimum | 7.21 | 6.30 | 3.70 | -0.10 | -0.10 |

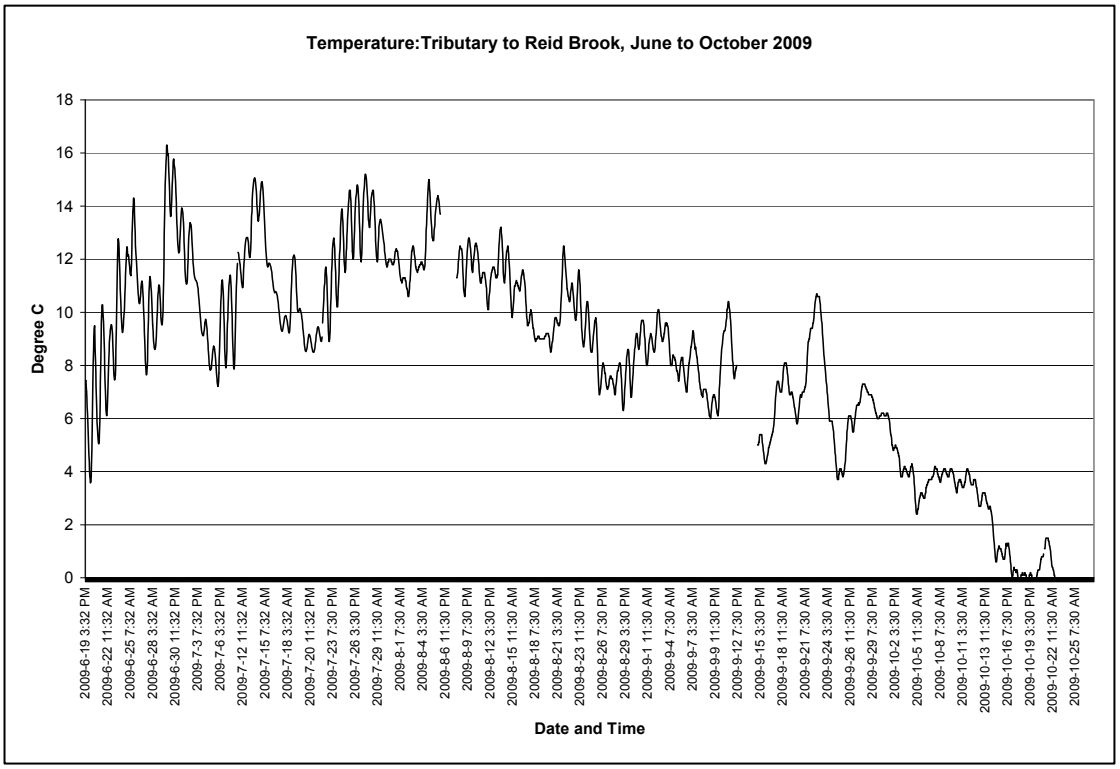


**Figure 20: Water temperature for Tributary to Lower Reid Brook, June to October 2009.**

## pH

- pH rises slightly throughout the beginning of the deployment season (**Figure 21**).
- There is a significant decrease in pH at this station in mid August that corresponds with a rainfall event (**Appendix 1**).
- pH ranges between 6.51 and 7.21 units. All values are within the CCME Guidelines for the Protection of Aquatic Life (>6.5 and <9.0).
- Monthly averages, maximums and minimums for pH are summarized in **Table 26**.

**Table 26: Summary statistics for pH at Tributary to Lower Reid Brook**

| pH | July | August | September | October | June to October |
|---|---|---|---|---|---|
| Average | 6.88 | 6.91 | 7.07 | 7.08 | 6.96 |
| Maximum | 7.08 | 7.12 | 7.21 | 7.12 | 7.21 |
| Minimum | 6.74 | 6.52 | 6.81 | 7.01 | 6.51 |

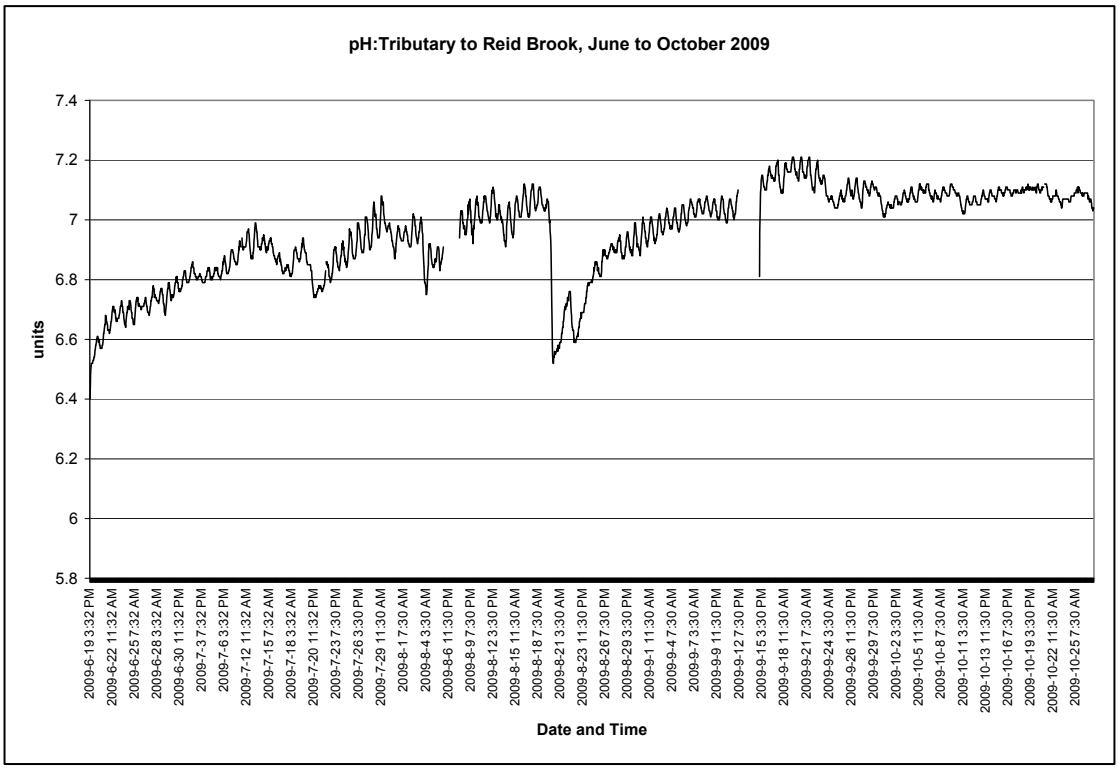


**Figure 21: pH for Tributary to Lower Reid Brook, June to October 2009.**

## Specific Conductivity

- Specific conductivity increases throughout the deployment season (**Figure 21**).
- Specific Conductivity values tend to fluctuate and correspond well with rainfall events (**Appendix 1**).
- Monthly averages, maximums and minimums are summarized in **Table 27**.

**Table 27: Summary statistics for specific conductivity at Tributary to Lower Reid Brook**

| Specific Conductivity (µS/cm) | July | August | September | October | June to October |
|---|---|---|---|---|---|
| Average | 28.07 | 30.95 | 35.83 | 41.73 | 32.70 |
| Maximum | 33.40 | 35.10 | 39.20 | 49.50 | 49.50 |
| Minimum | 22.70 | 25.00 | 31.20 | 36.70 | 17.00 |

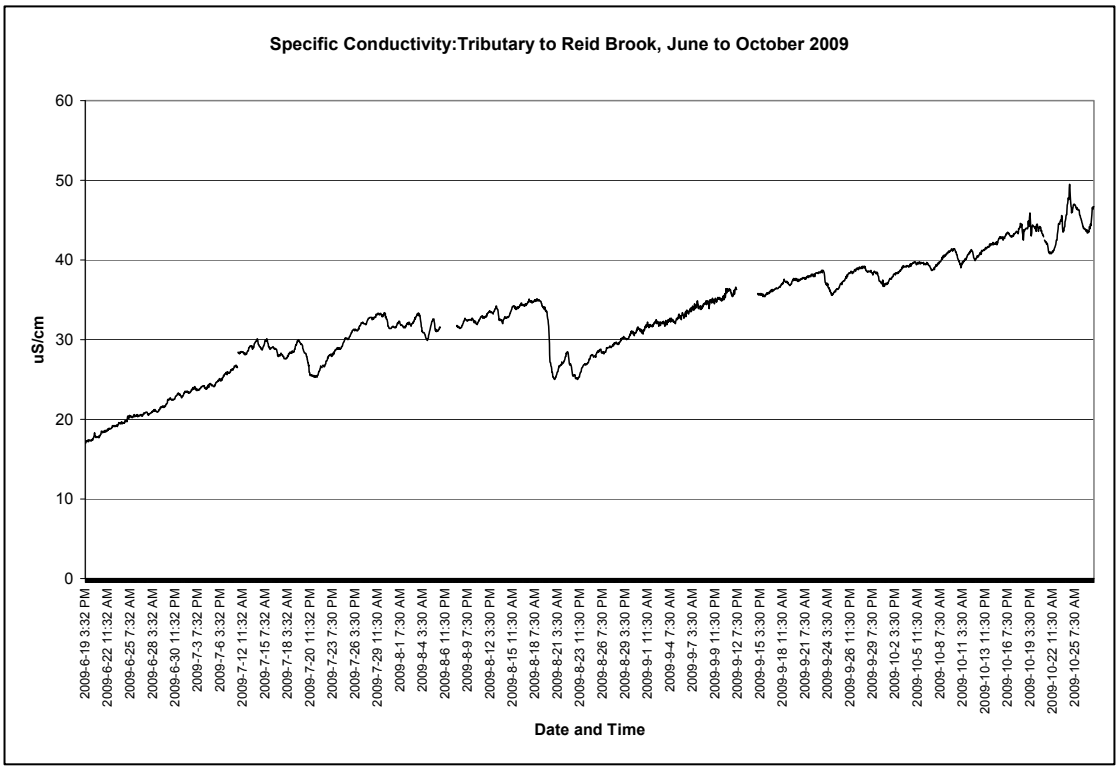


**Figure 22: Specific conductivity for Tributary to Lower Reid Brook, June to October 2009**.

## Dissolved Oxygen and Percent Saturation

- Dissolved oxygen content fluctuates throughout the deployment season (**Figure 23**).
- Water temperature and dissolved oxygen content are inversely related. Even though water temperature is increasing throughout the beginning of the deployment season and decreasing in the latter half, dissolved oxygen connect tends to remain stable from June to October.
- Percent saturation is a function of water temperature and dissolved oxygen content decreases slightly throughout the 2009 deployment season.
- Monthly averages, maximums and minimums for dissolved oxygen and percent saturation are summarized in **Table 22**.

**Table 28: Summary statistics for dissolved oxygen and percent saturation at Tributary to Lower Reid Brook**

| **Dissolved Oxygen (mg/L) and Percent Saturation (%)** | July | | August | | September | | October | | June to October | |
|---|---|---|---|---|---|---|---|---|---|---|
| | DO | %Sat | DO | %Sat | DO | %Sat | DO | %Sat | DO | %Sat |
| Average | 11.08 | 101.27 | 11.05 | 98.72 | 11.55 | 95.80 | 13.05 | 94.60 | 11.64 | 97.97 |
| Maximum | 12.30 | 104.00 | 12.36 | 103.20 | 12.65 | 101.20 | 14.06 | 96.90 | 14.06 | 104.00 |
| Minimum | 10.01 | 99.10 | 10.04 | 96.20 | 10.25 | 91.90 | 11.60 | 92.60 | 9.88 | 91.90 |

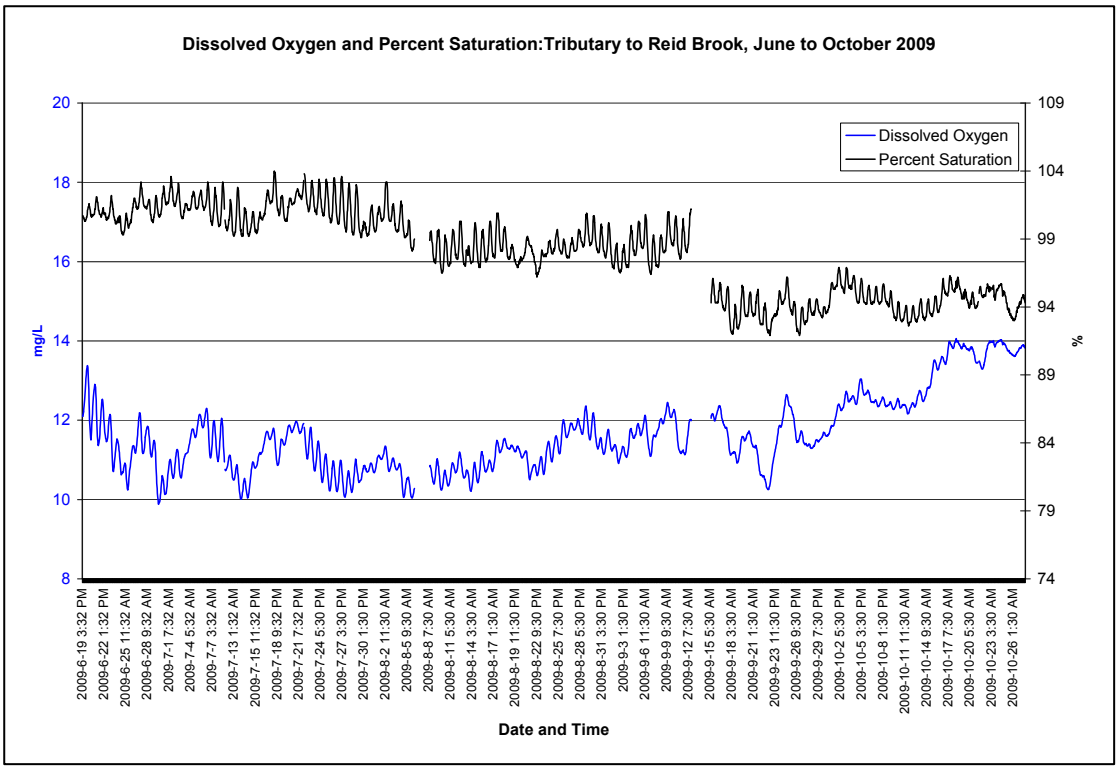


**Figure 23: Dissolved oxygen and percent saturation for Lower Reid Brook, June to October 2009.**

## Turbidity

- There are several short turbidity increases throughout the deployment season at this station (**Figure 24**).
- Even though increased turbidity readings tend to be frequent, only 6% of the readings recorded are above 1NTU. Generally this station is reporting a turbidity value of 0NTU. No value is sustained for any length of time.
- Some of these increases are likely attributed to precipitation events as recorded by Environment Canada in Nain, NL (**Appendix 1**).
- Monthly averages, maximums and minimums are summarized in **Table 29**.

**Table 29: Summary statistics for turbidity at Tributary to Lower Reid Brook**

| Turbidity (NTU) | July | August | September | October | June to October |
|---|---|---|---|---|---|
| Average | 0.5 | 0.8 | 0.4 | 0.3 | 0.5 |
| Maximum | 230.7 | 48.6 | 42.4 | 46.9 | 230.7 |
| Minimum | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

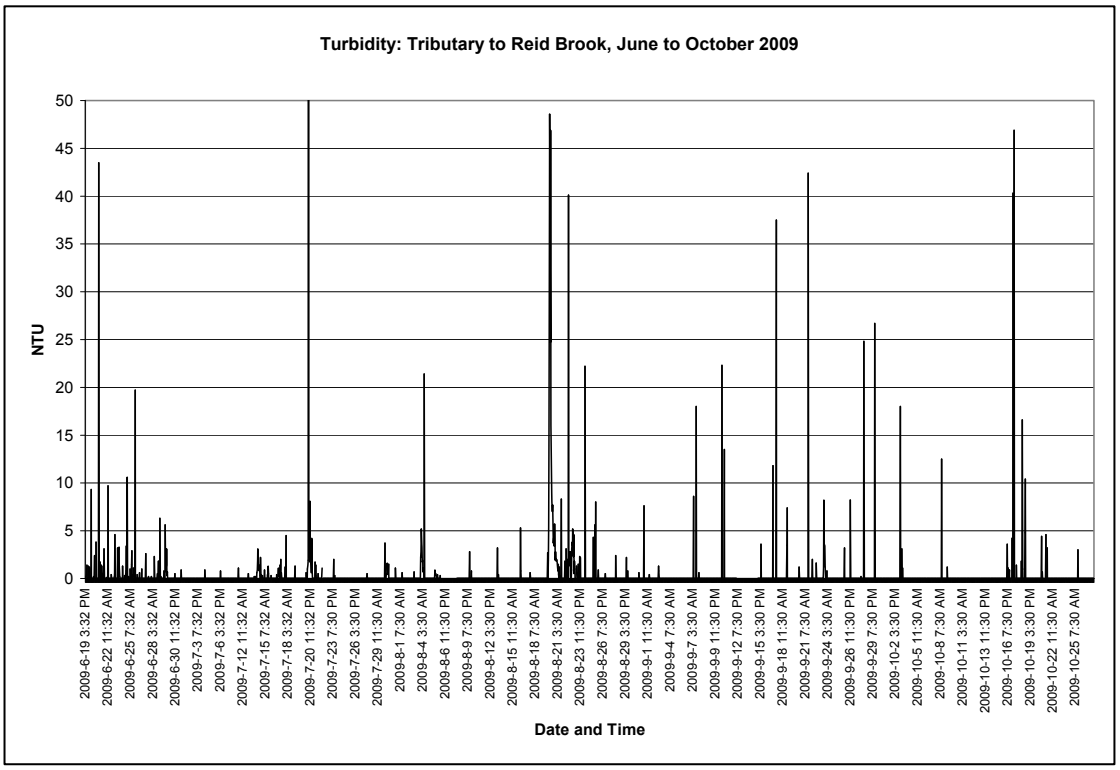


**Figure 24: Stage for Tributary to Lower Reid Brook, June to October 2009.**

## Stage

- Stage fluctuates at this station but does not tend to decrease significantly in the early summer months as other stations display clearly (**Figure 25**).
- Stage increases significantly for a short period of time in mid-August corresponding with a significant rainfall (**Appendix 1**).
- Flow rate is not calculated for this station.
- Monthly averages, maximums and minimums for stage and are summarized in **Table 30**.

**Table 30: Summary statistics for stage at Tributary to Lower Reid Brook**

| **Stage (m)** | July | August | September | October | June to October |
|---|---|---|---|---|---|
| Average | 0.473 | 0.485 | 0.391 | 0.427 | 0.456 |
| Maximum | 0.535 | 0.643 | 0.470 | 0.555 | 0.659 |
| Minimum | 0.423 | 0.413 | 0.342 | 0.376 | 0.342 |

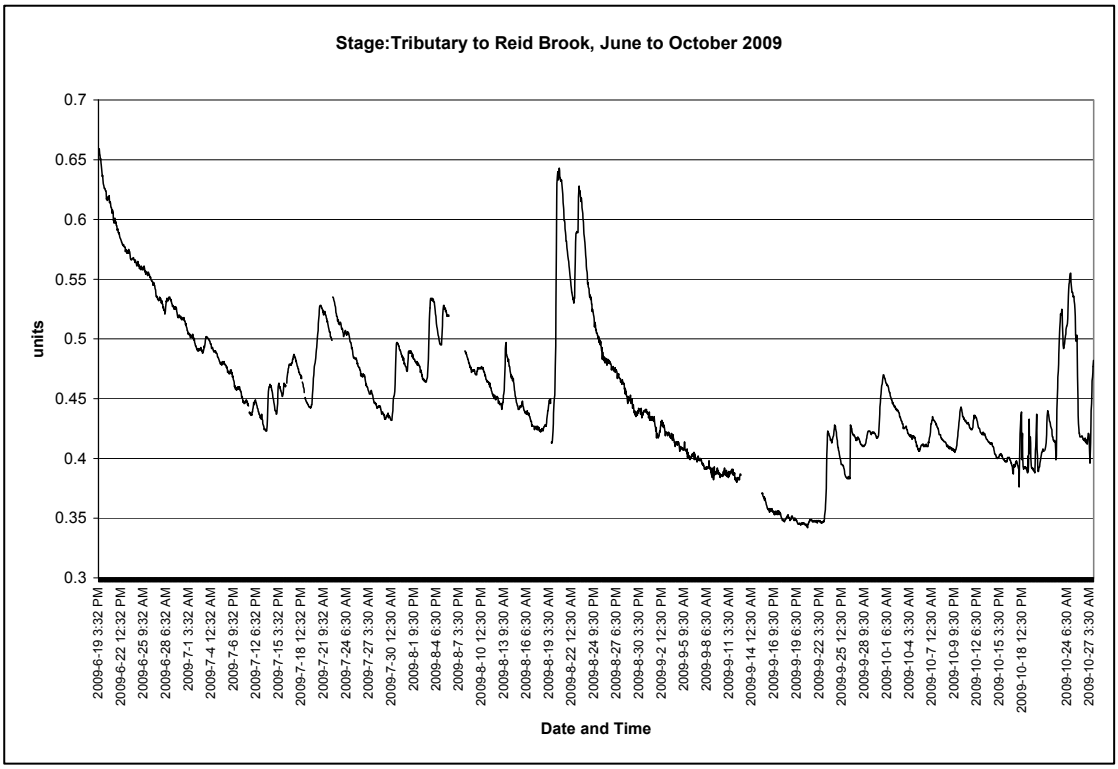


**Figure 25: Stage for Tributary to Lower Reid Brook, June to October 2009.**

## *Station Comparison*

- In the previous section, each station is discussed individually however it is important to relate the stations to one another and understand some of the parameters trends that occur throughout the RTWQ network. This section will briefly overview the five major parameters as they relate to one another across the network at the Voisey's Bay site.

### Temperature

- All sites follow a typical warming period in the early summer and cooling period in the later summer and fall months (**Figure 26**).
- Temperature fluctuates diurnally across all sites.
- Upper Reid brook tends to be the coolest at the beginning of the deployment season however remains the warmest at the end of the season. This is likely due to lake effect warming and cooling as this station is just below the outlet from Reid Pond.
- Camp Pond Brook is on average the warmest of the four sites.

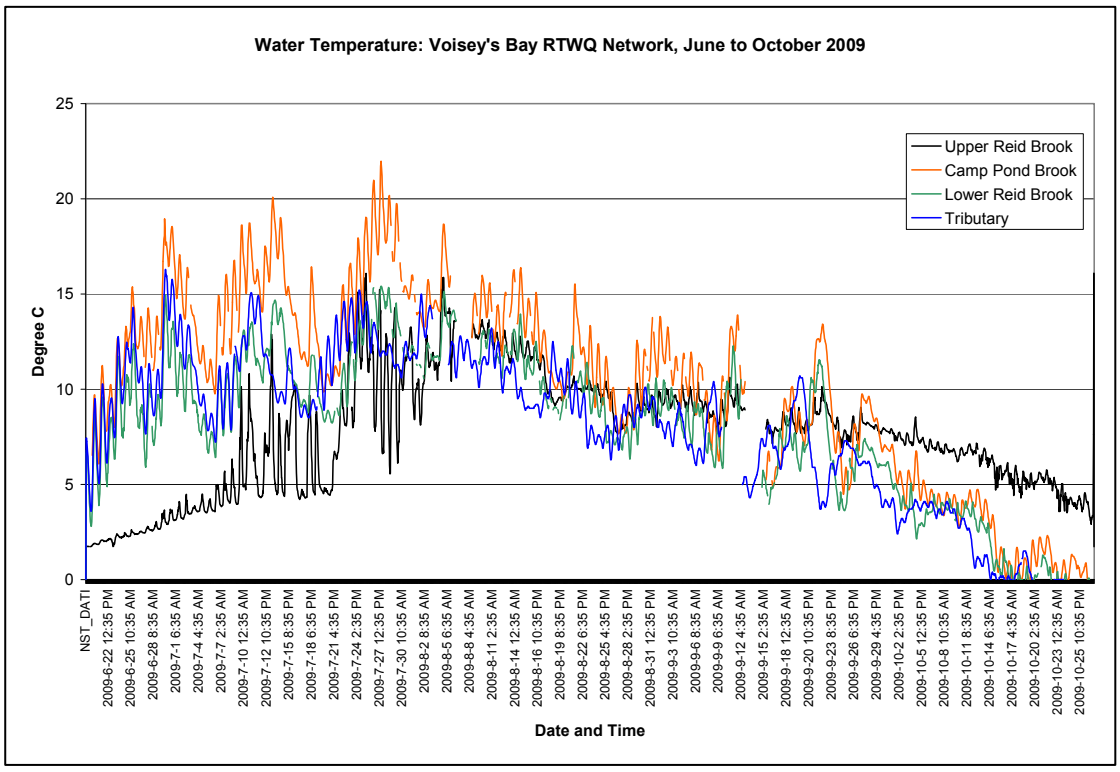


**Figure 26: Water temperature for Voisey's Bay RTWQ Network, June to October 2009.**

## pH

- pH tends to follow a similar pattern at each station (**Figure 27**).
- The highly variable data at Upper Reid Brook between mid July and early August is erroneous due to sensor malfunction.
- Upper Reid Brook tends to have a lower pH than the other sites, however, at the end of the deployment season, the pH at Upper Reid Brook is slightly elevated and not relating to the other three sites clearly (circled in purple).
- pH in at all sites is affected by the rainfall event occurring in mid August (circled in red).

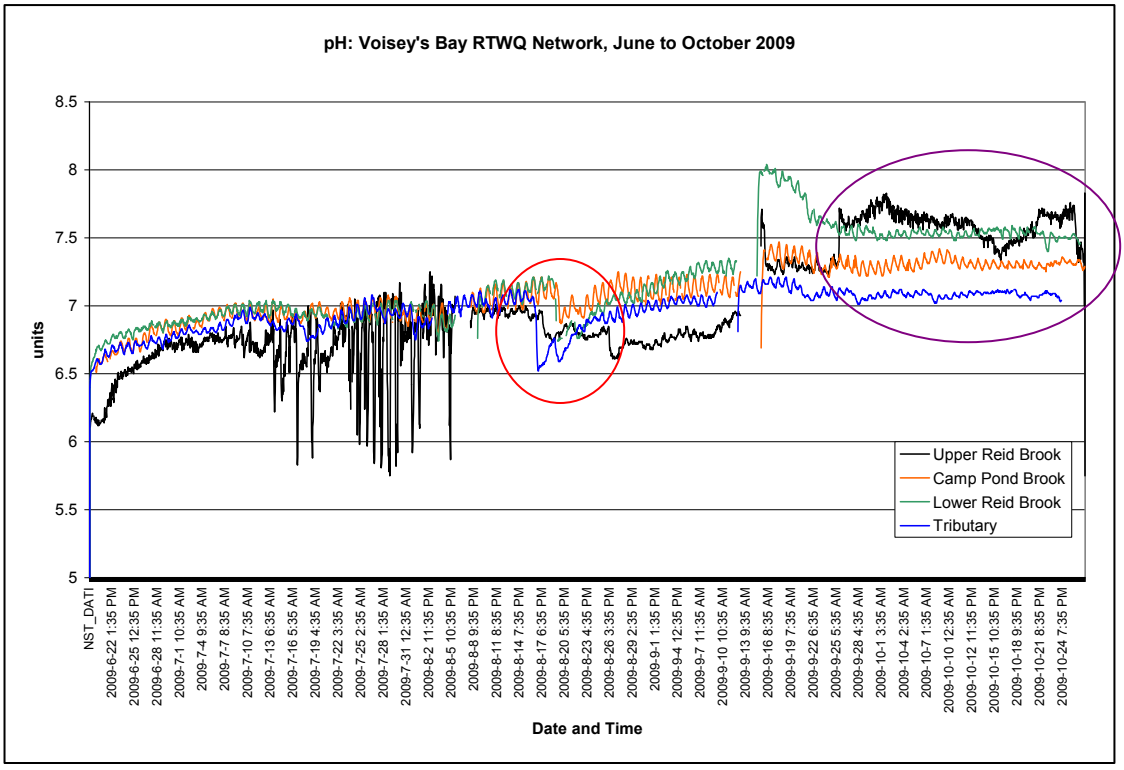


**Figure 27: pH for Voisey's Bay RTWQ Network, June to October 2009.**

## Specific Conductivity

- Specific conductivity is unaffected by mining operations and remains low at Upper Reid Brook. The difference between this station and the impacted stations downstream is very clear (**Figure 28**).
- Lower Reid Brook appears to have the lowest conductivity out of the three impacted stations.
- During the rainfall event in Mid August, specific conductivity peaks to over 50uS/cm at Camp Pond Brook while Lower Reid Brook and the station in the tributary remain relatively unaffected (circled in red).

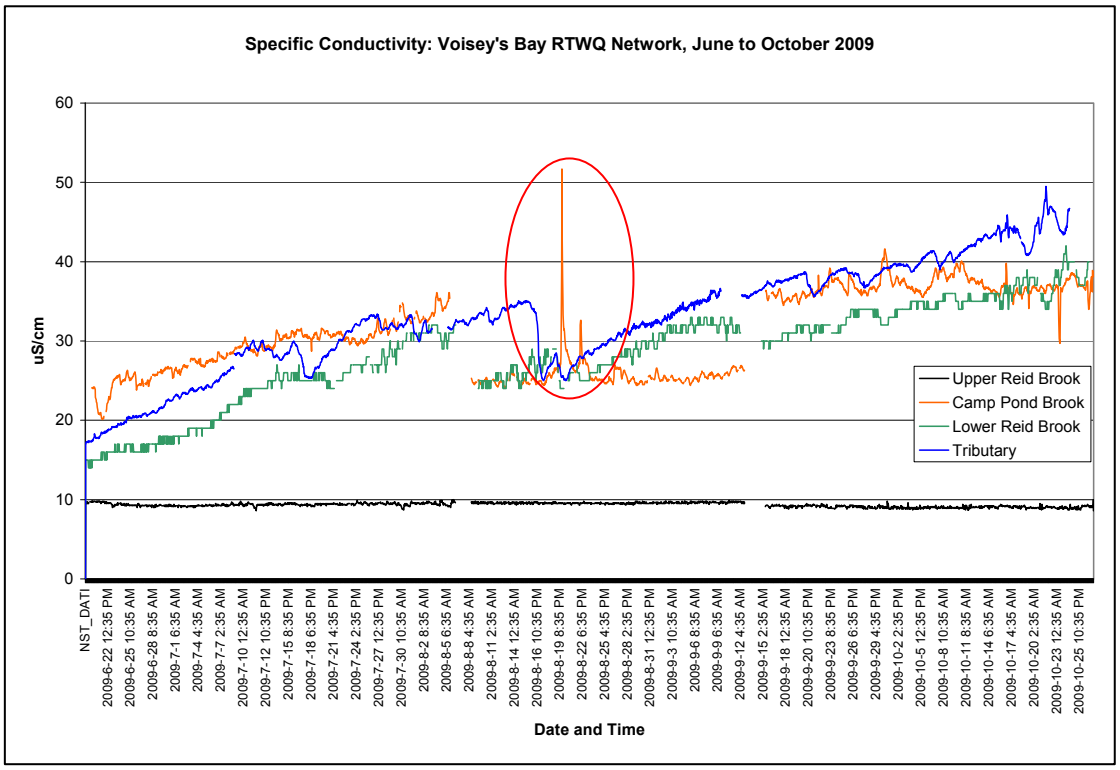


**Figure 28: Specific conductivity for Voisey's Bay RTWQ Network, June to October 2009.**

## Dissolved Oxygen

- Dissolved oxygen tends to follow a similar pattern at each station (**Figure 29**).
- Upper Reid Brook tends to have higher dissolved oxygen content at the beginning of the deployment period and lower concentration at the end of the deployment season. This trend is expected as this station also reports being coolest in the early summer and warmest later in the fall due to lake effect warming and cooling.
- Camp Pond Brook on average has the lowest dissolved oxygen content. Similarly, this trend is expected as it is also the warmest of the four sites.

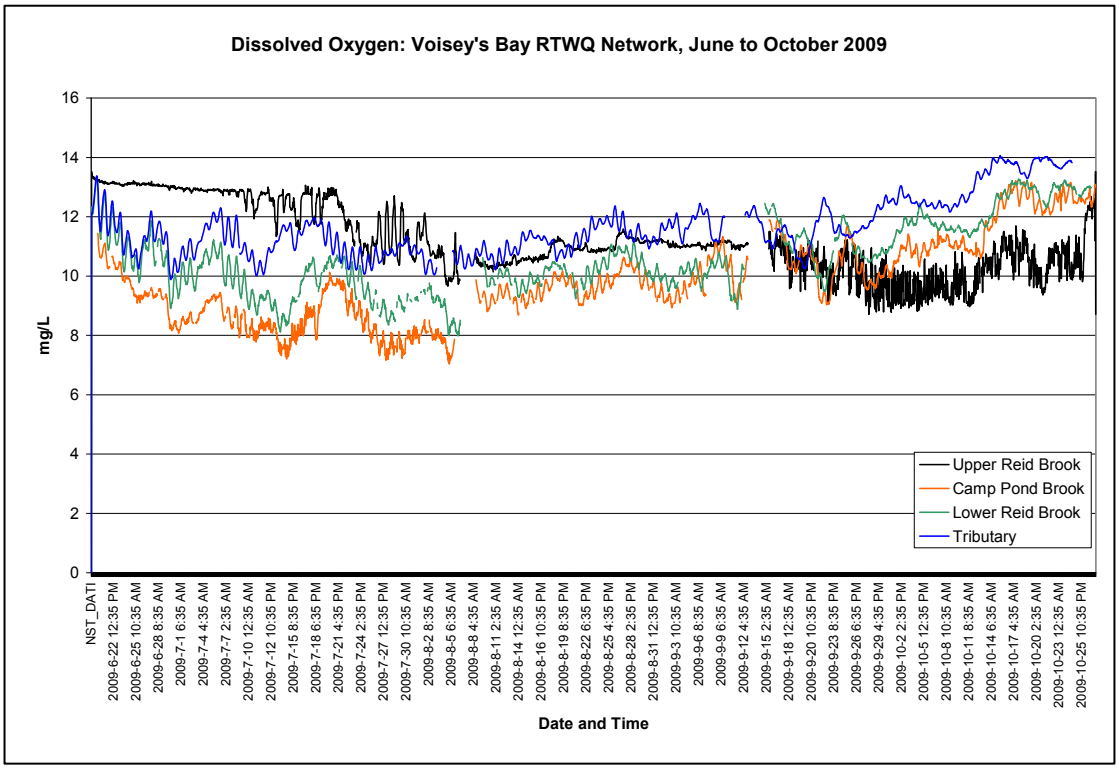


**Figure 29: Dissolved oxygen for Voisey's Bay RTWQ Network, June to October 2009.**

## Turbidity

- Turbidity is variable across the four sites (**Figure 30**).
- Camp Pond Brook and Lower Reid Brook tend to have background turbidity levels less than 5NTU while Upper Reid Brook and the tributary to Lower Reid Brook have no background turbidity levels. Each station experiences several short turbidity increases that are most often related back to precipitation events.

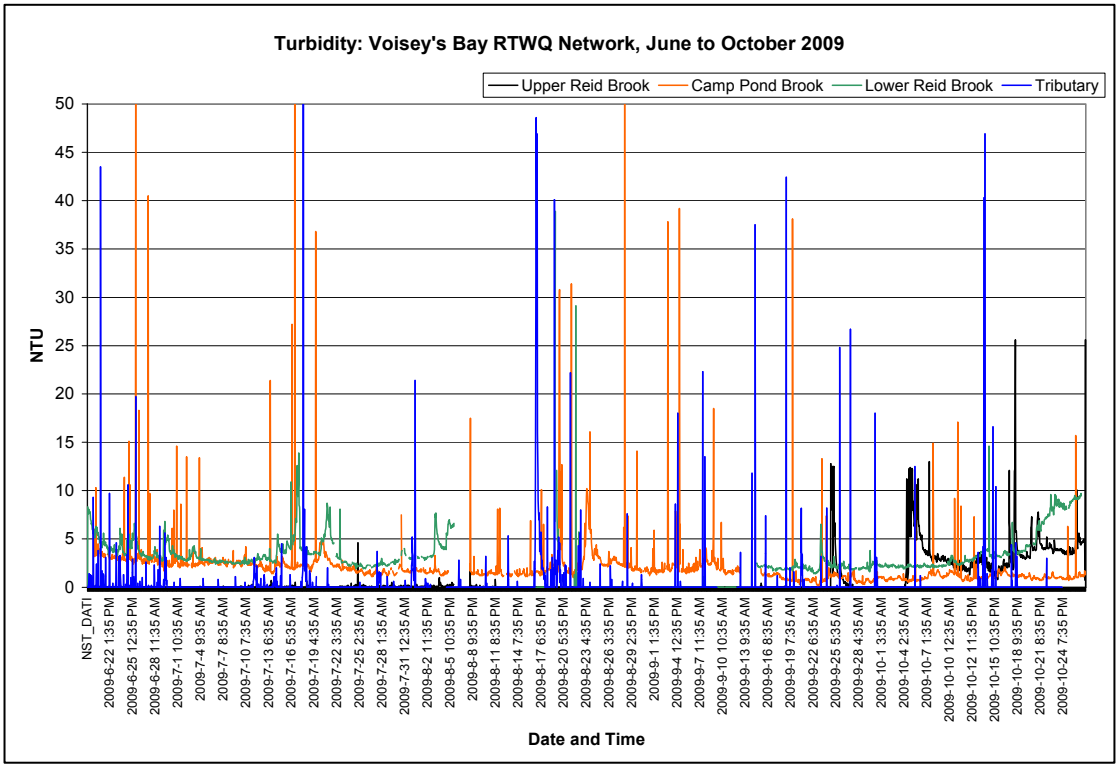


**Figure 30: Turbidity for Voisey's Bay RTWQ Network, June to October 2009.**

## Stage

- Stage tends to follow a similar pattern at each station (**Figure 31**).
- At all stations stage decreases in the beginning of the deployment period during June and the beginning of July before leveling off for the remainder of the deployment season. This pattern is most noticeable at stations on Upper and Lower Reid Brook and less noticeable at stations on Camp Pond Brook and the Tributary to Lower Reid Brook.
- There is significant rainfall event in mid August which increases stage level at all four stations (circled in purple).
- Near the end of the deployment period, stage increases in short bursts at the three impacted stations (circled in red). These increases did not occur at the control station on Upper Reid Brook. These events may in fact be caused by 'slush spikes' which are fluctuation events that occur on raw data when freezing is taking place.

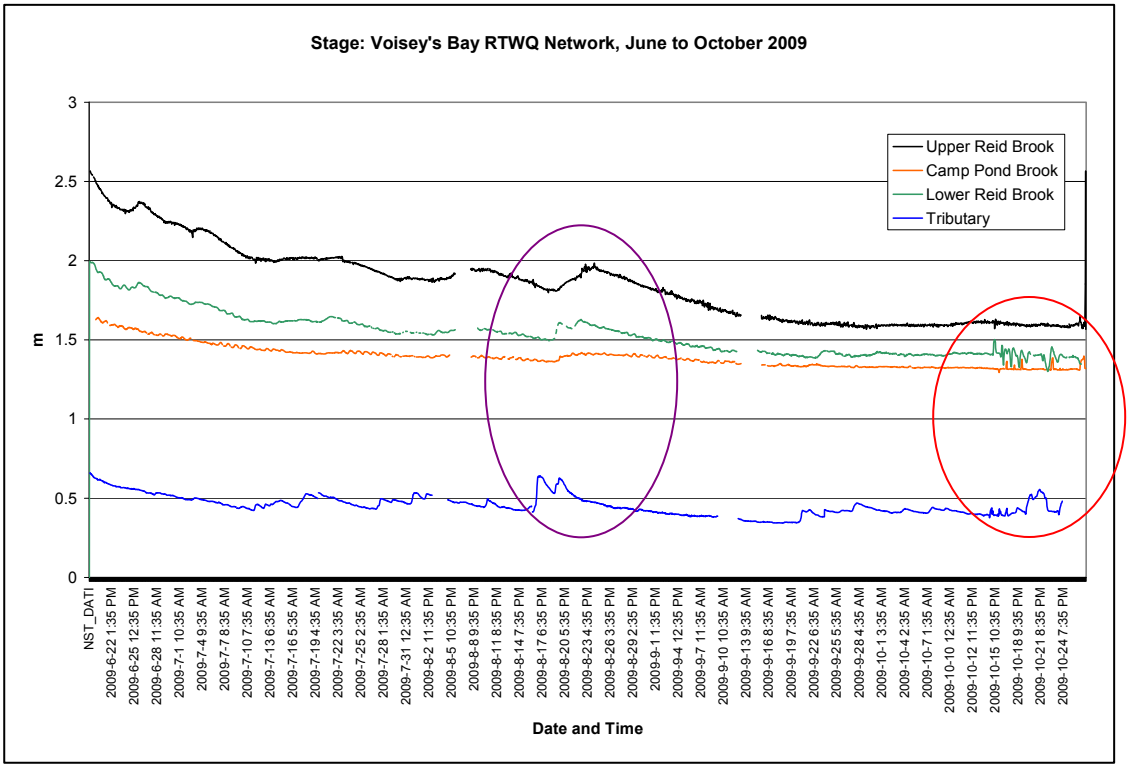


**Figure 31: Stage for Voisey's Bay RTWQ Network, June to October 2009.**

# Conclusions

- The Voisey's Bay RTWQ monitoring network was successful in continuing to observe and catch any emerging water quality issues that may have arisen due to mining operations in the area.
- The majority of increases/decreases in water quality parameters can usually be attributed to precipitation events.
- Upper Reid Brook continues to be a pristine area that can effectively be used as a control station that provides reliable natural background water quality data for comparison purposes.
- The water quality of Camp Pond Brook, Lower Reid Brook and the Tributary to Lower Reid Brook has not indicated any significant problems with the mining operations.

# Path Forward

For the 2010 season, improvements on procedures and protocols followed by staff in the field, laboratory and office have been implemented. Vale Inco environmental staff will be informed in detail of these new procedures prior to the start of the deployment season in 2010. The new procedures and protocols will be outlined in the RTWQ manual which will also be available to Vale Inco environment staff before instruments are deployed in 2010. These improvements include:

- In–field cleaning to evaluate possible bio-fouling drift error
- Immediate laboratory calibration to evaluate calibration drift error following deployment
- Implementation of USGS data correction procedures combining bio-fouling and calibration drift errors to accurately correct data if required.

In order for a program to be successful, it is essential to continually evaluate and move forward. Environmental Scientist, Grace Gillis (Goose Bay office) will be responsible communications between Vale Inco and ENVC in the upcoming deployment season, including site visits 1-2 times per deployment season and preparation of monthly and annual reports.

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.

- Shipment of instruments for servicing work during the winter months
- Testing/preparation of instruments in St. John's office prior to spring deployment to ensure all instruments are functioning properly
- Spring site visitation to install all instruments and continue to standardize all data logger programming
- Continued monitoring of water quality from late spring to late fall 2010
- Analysis in the form of monthly deployment reports; annual report will be prepared at end of 2010 calendar year
- Continued direct communication between ENVC and Vale Inco staff to respond to emerging issues on a proactive basis
- Continued site visitation and training by ENVC staff throughout the summer and fall

- Plans are underway to relocate the groundwater monitoring station to avoid by snow/ice; reinstallation to take place in spring 2010
- Continued work on Automatic Data Retrieval System to incorporate new capabilities
- Continued transfer of data from DOEC to Vale Inco staff through the departmental web page
- Provide on-line statistical analysis of data; work on extrapolation of other water quality parameters using regression analysis
- Creation of value added products using the real-time water quality data, remote sensing and water quality indices

# Contacts

**Grace Gillis**
Environmental Scientist
Water Resources Management Division
Department of Environment and Conservation
PH: (709) 896-5542
FX: (709) 896-4340
Email: gracegillis@gov.nl.ca

**Renee Paterson**
Real Time Water Quality Monitoring Coordinator
Senior Environmental Scientist
Water Resources Management Division
Department of Environment and Conservation
PH: (709) 729-1159
FX: (709) 729-0320
Email: reneepaterson@gov.nl.ca

**Howie Wills**
Area Manager
Water Survey of Canada
Environment Canada
PH: (709) 772-4844
FX: (709) 772-5097
Email: howie.wills@ec.gc.ca

# Appendix 1 – Weather Data

Source: Environment Canada, National Climate Data and Information Archive

**Table 1.1: Weather Data for Nain, NL, June 19 to October 27, 2009**

| June to October , 2009 | | | | | | |
|---|---|---|---|---|---|---|
| | Max Temp°C | Min Temp°C | Mean Temp°C | Total Rain | Total Snow | Total Precip |
| 19-Jun | 13.3 | 3.6 | 8.5 | T | 0 | T |
| 20-Jun | 12 | -0.2 | 5.9 | 0 | 0 | 0 |
| 21-Jun | 10.4 | -0.5 | 5 | 0 | 0 | 0 |
| 22-Jun | 14.8 | -1.3 | 6.8 | 0.4 | 0 | 0.4 |
| 23-Jun | 13.4 | 4.9 | 9.2 | 0 | 0 | 0 |
| 24-Jun | 24.3 | 2.3 | 13.3 | T | 0 | T |
| 25-Jun | 21.1 | 3.8 | 12.5 | 8 | 0 | 8 |
| 26-Jun | 9.2 | 0.7 | 5 | 0 | 0 | 0 |
| 27-Jun | 10.3 | -6.2 | 2.1 | 0.6 | 0 | 0.6 |
| 28-Jun | 7.8 | 2.2 | 5 | 5 | 0 | 5 |
| 29-Jun | 23.1 | 4.7 | 13.9 | 0 | 0 | 0 |
| 30-Jun | 11.8 | 4.2 | 8 | 0 | 0 | 0 |
| 1-Jul | 9.4 | 2.7 | 6.1 | T | 0 | T |
| 2-Jul | 10.8 | 3 | 6.9 | 24 | 0 | 24 |
| 3-Jul | 7.7 | 1.9 | 4.8 | 1.2 | 0 | 1.2 |
| 4-Jul | 7.9 | 2.2 | 5.1 | 0.4 | 0 | 0.4 |
| 5-Jul | 6.2 | 1.1 | 3.7 | 0 | 0 | 0 |
| 6-Jul | 12.7 | 2.7 | 7.7 | 0 | 0 | 0 |
| 7-Jul | 12.9 | 1.4 | 7.2 | 0 | 0 | 0 |
| 8-Jul | 14.1 | 2.4 | 8.3 | 0 | 0 | 0 |
| 9-Jul | 16.7 | 4.5 | 10.6 | 0 | 0 | 0 |
| 10-Jul | 15.9 | 5.9 | 10.9 | 1.6 | 0 | 1.6 |
| 11-Jul | 9 | 5.7 | 7.4 | 6.4 | 0 | 6.4 |
| 12-Jul | 10.8 | 3.7 | 7.3 | 1.8 | 0 | 1.8 |
| 13-Jul | 22.9 | 7.2 | 15.1 | 3.6 | 0 | 3.6 |
| 14-Jul | 13.8 | 4.2 | 9 | 14.1 | 0 | 14.1 |
| 15-Jul | 11.7 | 5.5 | 8.6 | 4.6 | 0 | 4.6 |
| 16-Jul | 8.5 | 5.5 | 7 | 7.2 | 0 | 7.2 |
| 17-Jul | 9.1 | 5.5 | 7.3 | 3.6 | 0 | 3.6 |
| 18-Jul | 12.8 | 5.9 | 9.4 | 0 | 0 | 0 |
| 19-Jul | 9.9 | 1.7 | 5.8 | 5 | 0 | 5 |
| 20-Jul | 7.5 | 5.3 | 6.4 | 10.8 | 0 | 10.8 |
| 21-Jul | 8.4 | 3 | 5.7 | 3.6 | 0 | 3.6 |
| 22-Jul | 13.9 | 4.4 | 9.2 | 0 | 0 | 0 |
| 23-Jul | 19.3 | 4.4 | 11.9 | 0.8 | 0 | 0.8 |
| 24-Jul | 21.6 | 6.5 | 14.1 | 0 | 0 | 0 |
| 25-Jul | 19.8 | 5.7 | 12.8 | 0 | 0 | 0 |
| 26-Jul | 19 | 6.4 | 12.7 | 0 | 0 | 0 |
| 27-Jul | 20.8 | 5.7 | 13.3 | 0 | 0 | 0 |
| 28-Jul | 16.3 | 6.9 | 11.6 | 0 | 0 | 0 |
| 29-Jul | 11.8 | 6.1 | 9 | 6 | 0 | 6 |
| 30-Jul | 10.3 | 4.2 | 7.3 | 13 | 0 | 13 |
| 31-Jul | 13 | 7.6 | 10.3 | 0.8 | 0 | 0.8 |
| 1-Aug | 10.7 | 4 | 7.4 | 2.2 | 0 | 2.2 |
| 2-Aug | 11.8 | 6.7 | 9.3 | 2 | 0 | 2 |
| 3-Aug | 13.7 | 7.5 | 10.6 | 9 | 0 | 9 |
| 4-Aug | 24.6 | 7.8 | 16.2 | 0.8 | 0 | 0.8 |
| 5-Aug | 18.6 | 9.7 | 14.2 | 7.8 | 0 | 7.8 |
| 6-Aug | 20.2 | 10.1 | 15.2 | 1 | 0 | 1 |
| 7-Aug | 14.1 | 9.7 | 11.9 | 4.6 | 0 | 4.6 |
| 8-Aug | 15.2 | 6.9 | 11.1 | 0 | 0 | 0 |
| 9-Aug | 20.9 | 5.5 | 13.2 | 2.6 | 0 | 2.6 |
| 10-Aug | 17.2 | 7.9 | 12.6 | 2 | 0 | 2 |
| 11-Aug | 14.1 | 8.5 | 11.3 | 0.8 | 0 | 0.8 |
| 12-Aug | 17.1 | 7.4 | 12.3 | 0 | 0 | 0 |
| 13-Aug | 22.9 | 8 | 15.5 | 6.4 | 0 | 6.4 |
| 14-Aug | 17.8 | 8.2 | 13 | 0 | 0 | 0 |
| 15-Aug | 15.7 | 5.8 | 10.8 | 1 | 0 | 1 |
| 16-Aug | 15.9 | 4.8 | 10.4 | 2.2 | 0 | 2.2 |
| 17-Aug | 15.9 | 3.7 | 9.8 | T | 0 | T |
| 18-Aug | 8.5 | 4.9 | 6.7 | 6.4 | 0 | 6.4 |
| 19-Aug | 7.2 | 3 | 5.1 | 22.8 | 0 | 22.8 |
| 20-Aug | 7.9 | 5.8 | 6.9 | 9.4 | 0 | 9.4 |
| 21-Aug | 13.3 | 6 | 9.7 | 0 | 0 | 0 |
| 22-Aug | 14.6 | 5.6 | 10.1 | 11 | 0 | 11 |
| 23-Aug | 16.7 | 9 | 12.9 | 0 | 0 | 0 |
| 24-Aug | 13.4 | 6.3 | 9.9 | 0 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 25-Aug | 13.2 | 5.2 | 9.2 | T | 0 | T |
| 26-Aug | 7.4 | 1.2 | 4.3 | 0 | 0 | 0 |
| 27-Aug | 9 | 0.1 | 4.6 | 0.2 | 0 | 0.2 |
| 28-Aug | 9.1 | 2.2 | 5.7 | T | 0 | T |
| 29-Aug | 14.6 | 1.4 | 8 | 0 | 0 | 0 |
| 30-Aug | 16.6 | 3.2 | 9.9 | 0.4 | 0 | 0.4 |
| 31-Aug | 13.2 | 3.8 | 8.5 | 0.4 | 0 | 0.4 |
| 1-Sep | 15.5 | 2.5 | 9 | 0 | 0 | 0 |
| 2-Sep | 17.3 | 7 | 12.2 | 0.6 | 0 | 0.6 |
| 3-Sep | 14.8 | 3.5 | 9.2 | 0.2 | 0 | 0.2 |
| 4-Sep | 13.9 | 1.1 | 7.5 | 0 | 0 | 0 |
| 5-Sep | 13.7 | 6 | 9.9 | 0 | 0 | 0 |
| 6-Sep | 17.3 | 4.1 | 10.7 | 0.2 | 0 | 0.2 |
| 7-Sep | 9.9 | 4.2 | 7.1 | 1.6 | 0 | 1.6 |
| 8-Sep | 10.8 | 4.6 | 7.7 | 0.4 | 0 | 0.4 |
| 9-Sep | 14.7 | 3.6 | 9.2 | 0.6 | 0 | 0.6 |
| 10-Sep | 24 | 4.7 | 14.4 | T | 0 | T |
| 11-Sep | 18.1 | 2.6 | 10.4 | 0 | 0 | 0 |
| 12-Sep | 6.2 | 1.1 | 3.7 | 1 | 0 | 1 |
| 13-Sep | 7.7 | 1.8 | 4.8 | 0 | T | T |
| 14-Sep | 4.7 | 0.9 | 2.8 | 2.4 | T | 2.4 |
| 15-Sep | 5.8 | 0.7 | 3.3 | 0 | 0 | 0 |
| 16-Sep | 9.9 | 0.7 | 5.3 | 0.2 | 0 | 0.2 |
| 17-Sep | 16.8 | 7.5 | 12.2 | 0.8 | 0 | 0.8 |
| 18-Sep | 16.8 | 4.1 | 10.5 | 0.4 | 0 | 0.4 |
| 19-Sep | 7.7 | 2.9 | 5.3 | 1.2 | 0 | 1.2 |
| 20-Sep | 12.9 | 4.3 | 8.6 | 0.2 | 0 | 0.2 |
| 21-Sep | 21.6 | 7.7 | 14.7 | 2 | 0 | 2 |
| 22-Sep | 21.8 | 6.3 | 14.1 | 0.8 | 0 | 0.8 |
| 23-Sep | 6.3 | 1.1 | 3.7 | 9.2 | 0.4 | 9.6 |
| 24-Sep | 5.6 | -0.7 | 2.5 | 0 | 2.4 | 2.4 |
| 25-Sep | 5.7 | -0.7 | 2.5 | 0 | 0 | 0 |
| 26-Sep | 13.5 | 0.5 | 7 | 4 | 0 | 4 |
| 27-Sep | 15.3 | 4 | 9.7 | T | 0 | T |
| 28-Sep | 8 | 5 | 6.5 | 1.4 | 0 | 1.4 |
| 29-Sep | 7.4 | 4.2 | 5.8 | 1.8 | 0 | 1.8 |
| 30-Sep | 6.7 | 3.2 | 5 | 6.4 | 0 | 6.4 |
| 1-Oct | 6.9 | 2.1 | 4.5 | 0.4 | 0 | 0.4 |
| 2-Oct | 5.3 | -0.8 | 2.3 | T | 0 | T |
| 3-Oct | 7.2 | -1.6 | 2.8 | 0 | 0 | 0 |
| 4-Oct | 9.5 | -0.8 | 4.4 | 0 | 0 | 0 |
| 5-Oct | 3.7 | 0.4 | 2.1 | 0.2 | T | 0.2 |
| 6-Oct | 4.3 | 1 | 2.7 | 2 | 0.4 | 2.4 |
| 7-Oct | 5.8 | 2.4 | 4.1 | 0 | 0 | 0 |
| 8-Oct | 7 | 1 | 4 | 1.6 | T | 1.6 |
| 9-Oct | 5.7 | 1.7 | 3.7 | 1.4 | 0 | 1.4 |
| 10-Oct | 11.8 | -0.9 | 5.5 | 1 | T | 1 |
| 11-Oct | 5.1 | 1.6 | 3.4 | 7.2 | 0 | 7.2 |
| 12-Oct | 7.4 | 0.6 | 4 | 0.8 | 0 | 0.8 |
| 13-Oct | 6.6 | 0.1 | 3.4 | 0 | 0 | 0 |
| 14-Oct | 3.6 | -1.7 | 1 | 0 | 0 | 0 |
| 15-Oct | 3.8 | -2 | 0.9 | T | T | T |
| 16-Oct | 4.7 | -2.5 | 1.1 | 0 | 0 | 0 |
| 17-Oct | 4.7 | -2.9 | 0.9 | 0 | 0 | 0 |
| 18-Oct | 3.5 | -1.5 | 1 | 0 | 0 | 0 |
| 19-Oct | 8.1 | -4.7 | 1.7 | 0 | 0 | 0 |
| 20-Oct | 4.4 | -0.6 | 1.9 | 3 | 2.6 | 5.6 |
| 21-Oct | 2.6 | -0.5 | 1.1 | 0.2 | 3.6 | 3.8 |
| 22-Oct | -0.3 | -5 | -2.7 | 0 | T | T |
| 23-Oct | 2.2 | -8.2 | -3 | 0 | T | T |
| 24-Oct | 1 | -8.2 | -3.6 | 0 | 0 | 0 |
| 25-Oct | 1 | -1.4 | -0.2 | 0 | 8.2 | 8.2 |
| 26-Oct | 2.9 | -1.9 | 0.5 | 0 | 1.4 | 1.4 |
| 27-Oct | -0.6 | -6.1 | -3.4 | 0 | 0 | 0 |

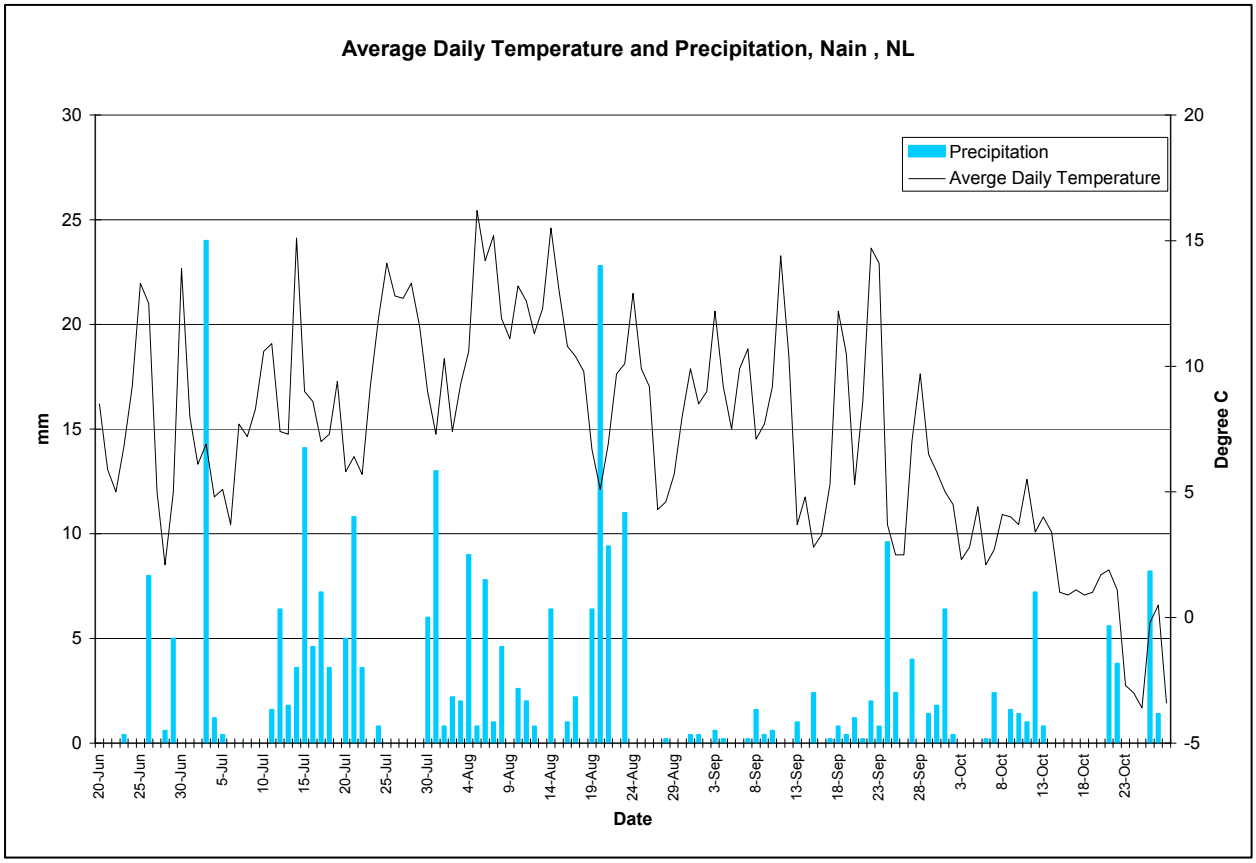


**Figure 1.1: Average daily air temperature and precipitation for Nain, NL.**