

Real-Time Water Quality Deployment Report

Voisey's Bay Network

June 10 to July 6, 2019



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

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Real Time Water Quality Monitoring

Staff with the Department of Municipal Affairs and Environment monitor the real-time web pages regularly.

This deployment report discusses water quality related events occurring at four stations in the Voisey's Bay Network: Reid Brook at Outlet to Reid Pond; Camp Pond Brook below Camp Pond; Tributary to Reid Brook; and Reid Brook below Tributary.

On June 10, 2019, Vale Environment staff deployed real-time water quality monitoring instruments at the four real-time stations in the Voisey's Bay network. Instruments were removed by Vale Environment Staff on July 6, 2019. This was the first deployment for the 2019 season.

Quality Assurance and Quality Control

As part of the Quality Assurance and Quality Control protocol (QA/QC), an assessment of the reliability of data recorded by an instrument is made at the beginning and end of the deployment period. This procedure is based on the approach used by the United States Geological Survey.

At deployment and removal, a QA/QC instrument is temporarily deployed adjacent to the field instrument. Values for temperature, pH, conductivity, dissolved oxygen and turbidity are compared between the two instruments. Based on the degree of difference between parameters recorded by the field instrument and QA/QC instrument at deployment and at removal, a qualitative statement is made about the data quality (Table 1).

Table 1: Ranking classifications for deployment and removal

Parameter	Rank				
	Excellent	Good	Fair	Marginal	Poor
Temperature (oC)	<=+/-0.2	>+/-0.2 to 0.5	>+/-0.5 to 0.8	>+/-0.8 to 1	<+/-1
pH (unit)	<=+/-0.2	>+/-0.2 to 0.5	>+/-0.5 to 0.8	>+/-0.8 to 1	>+/-1
Sp. Conductance (µS/cm)	<=+/-3	>+/-3 to 10	>+/-10 to 15	>+/-15 to 20	>+/-20
Sp. Conductance > 35 µS/cm (%)	<=+/-3	>+/-3 to 10	>+/-10 to 15	>+/-15 to 20	>+/-20
Dissolved Oxygen (mg/l) (% Sat)	<=+/-0.3	>+/-0.3 to 0.5	>+/-0.5 to 0.8	>+/-0.8 to 1	>+/-1
Turbidity <40 NTU (NTU)	<=+/-2	>+/-2 to 5	>+/-5 to 8	>+/-8 to 10	>+/-10
Turbidity > 40 NTU (%)	<=+/-5	>+/-5 to 10	>+/-10 to 15	>+/-15 to 20	>+/-20

It should be noted that the temperature sensor on any instrument is the most important. All other parameters can be broken down into three groups: temperature dependent; temperature compensated; and temperature independent. Because the temperature sensor is not isolated from the rest of the instrument, the entire instrument must be at the same temperature before the sensor will stabilize. The values may take some time to climb to the appropriate reading; if a reading is taken too soon it may not accurately portray the water body.

Deployment and removal comparison rankings for the Voisey's Bay Network stations are summarized in Table 2.

Table 2: Comparison rankings for Voisey's Bay Network stations

Station Voisey's Bay	Date	Action	Comparison Ranking				
			Temperature	pH	Conductivity	Dissolved Oxygen	Turbidity
Reid Brook at Outlet	June 10	Deployment	Excellent	Good	Excellent	Good	Excellent
	July 6	Removal	Excellent	Fair	Excellent	Fair	Excellent
Camp Pond Brook	June 10	Deployment	Excellent	Fair	Excellent	Excellent	Excellent
	July 6	Removal	Excellent	Good	Good	Excellent	Poor
Reid Brook below Tributary	June 10	Deployment	Excellent	Excellent	Excellent	Excellent	Excellent
	July 6	Removal	Excellent	Good	Excellent	Good	Excellent
Tributary to Reid Brook	June 10	Deployment	Excellent	Excellent	Excellent	Excellent	Excellent
	July 6	Removal	Excellent	Marginal	Excellent	Good	Good

Reid Brook at Outlet of Reid Pond

- At deployment, temperature, conductivity, and turbidity all ranked as 'excellent', while pH and dissolved oxygen were 'good'.
- At removal, temperature, conductivity, and turbidity all ranked as 'excellent', while pH and dissolved oxygen were 'fair'.

Camp Pond Brook below Camp Pond

- At deployment, temperature, conductivity, dissolved oxygen, and turbidity were all 'excellent', while pH was 'fair'.
- At removal, temperature and dissolved oxygen were 'excellent', while pH and conductivity were 'good'. Turbidity ranked as 'poor', which may be attributed to sediment build-up around the instrument.

Reid Brook below Tributary

- At deployment, all parameters ranked as 'excellent'.
- At removal, all parameters ranked as either 'excellent' or 'good'.

Tributary to Reid Brook

- At deployment, all parameters ranked as 'excellent'.
- At removal, temperature and conductivity were 'excellent', dissolved oxygen and turbidity were 'good', while pH was 'marginal'.

It is important to note that, in general, there are several conditions under which a less than ideal QA/QC ranking may be obtained. These include, but are not limited to: placement of the QA/QC sonde in relation to the field sonde; the amount of time each sonde is given to stabilize before readings are recorded; and deteriorating performance of one or more of the sensors.

Data Interpretation

The following graphs and discussion illustrate significant water quality-related events from June 10th to July 6th, 2019 in the Voisey's Bay Real-Time Water Quality Monitoring Network.

With the exception of water quantity data (stage and flow), all data used in the preparation of the graphs and subsequent discussion below adhere to stringent QA/QC protocol. Water Survey of Canada is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

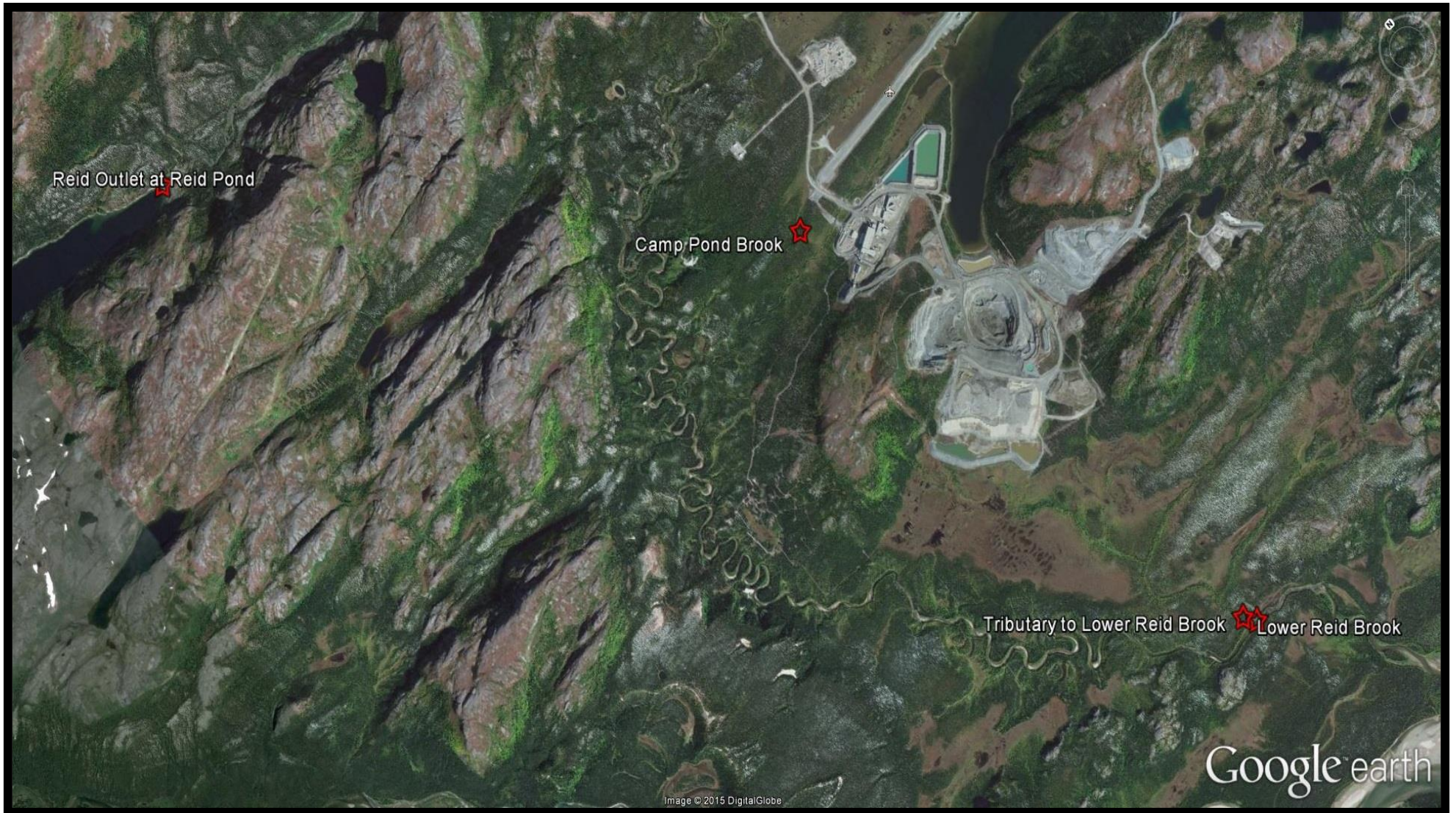


Figure 1: Voisey's Bay Network Station Locations

Reid Brook at Outlet of Reid Pond

Water Temperature

Over the deployment period, water temperature ranged from 2.49°C to 6.43°C, with a median value of 4.21°C (Figure 2). The very stable water temperature observed over the duration of deployment can be attributed to Reid Pond still being covered with ice. As evidenced in the graph below, air temperature fluctuates to a much greater extent each day compared to water temperature. Air temperature data was obtained from the Voisey's Bay airstrip weather station.

A noticeable increase in water temperature occurred on July 4th (Figure 2), which is likely a result of the warmer air temperatures occurring during the same time frame. This water body takes longer to acclimatize to changes in temperature as it has a much larger surface area compared to the brooks at the other RTWQ stations in this network.

Please note the stage data used below is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

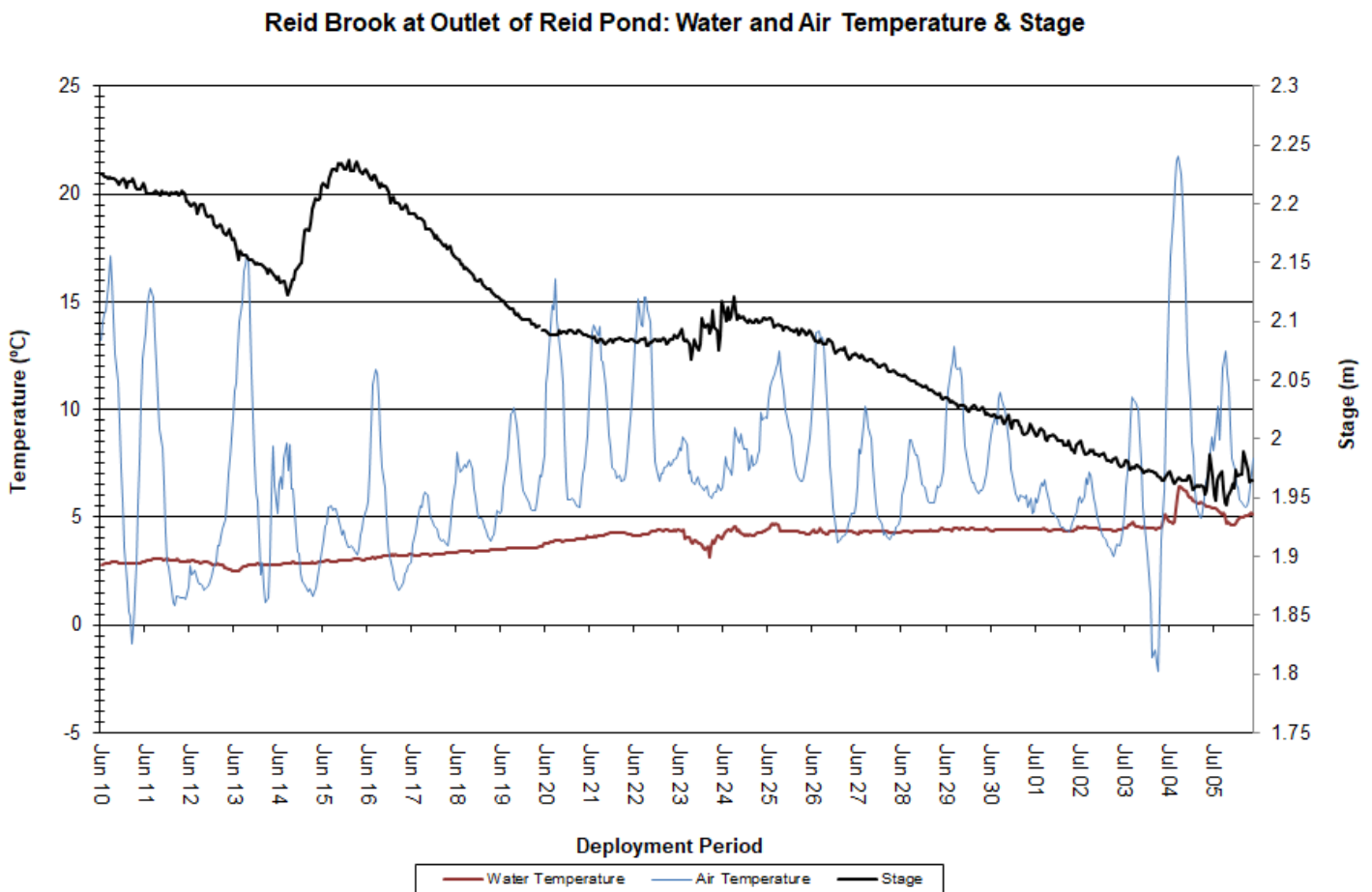


Figure 2: Water and Air Temperature & Stage at Reid Brook at Outlet of Reid Pond

pH

Over the deployment period, pH values ranged from 5.81 pH units to 6.77 pH units, with a median value of 6.54 pH units (Figure 3).

pH levels were within the CCME's Guidelines for the Protection of Aquatic Life for the first half of deployment, after which they fell below the minimum guideline for the remainder of the deployment period. This decreased pH level corresponded closely with decreasing stage levels.

Please note the stage data used below is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

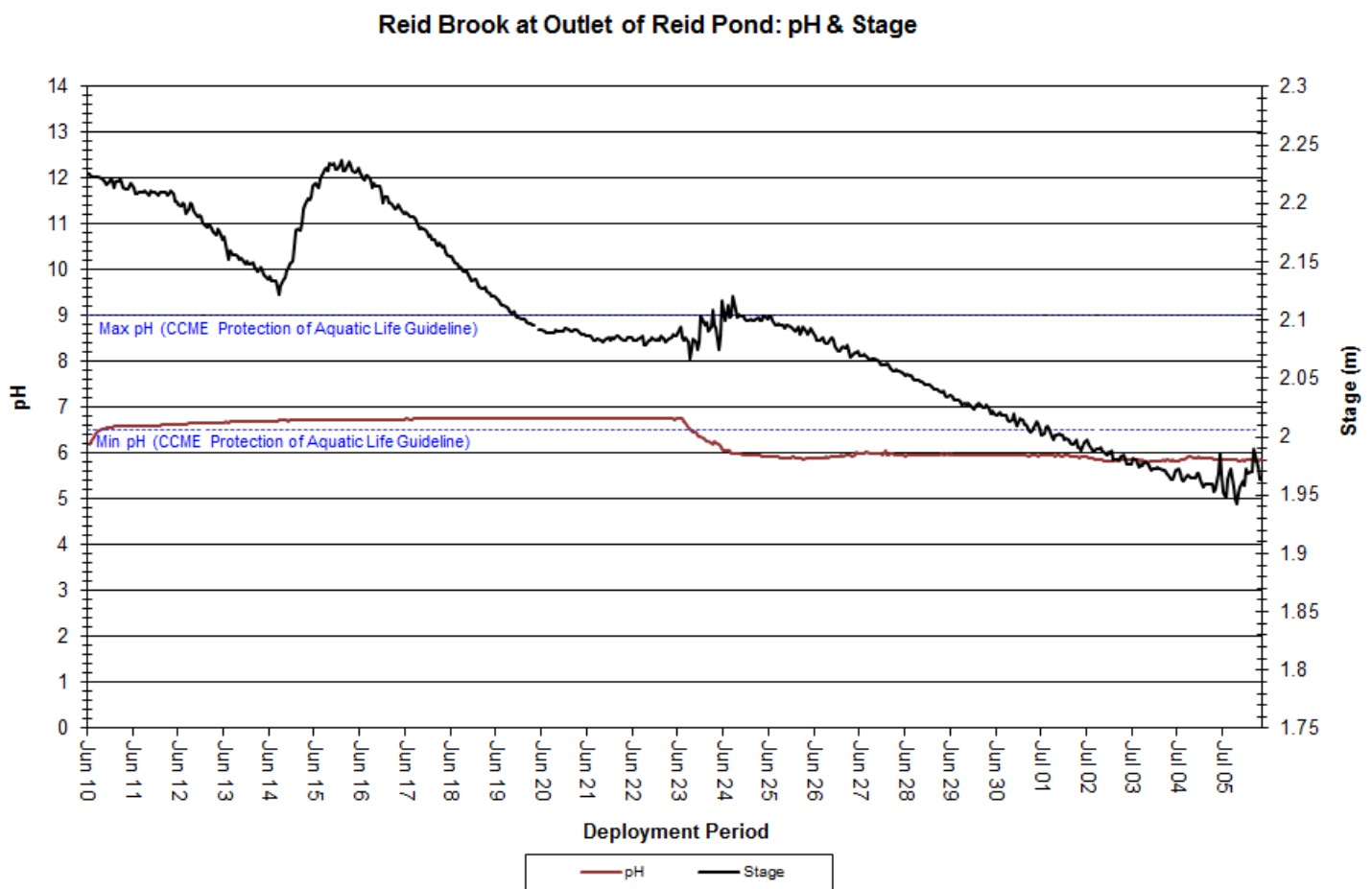


Figure 3: pH & Stage at Reid Brook at Outlet of Reid Pond

Specific Conductivity

Over the deployment period, specific conductivity levels ranged from 8.5 μ S/cm to 8.9 μ S/cm, with a median value of 8.8 μ S/cm. Conductivity at Reid Brook remained very stable. This is to be expected as this water body is pristine in nature and is far removed from any anthropogenic disturbances that could affect water quality.

The relationship between conductivity and stage level is generally inversed. When stage levels decrease, specific conductivity levels increase, as the decreased amount of water in the river system concentrates the solids that are present. Similarly, as stage levels rise, conductivity levels will dip in response. This relationship is not as evident at Reid Brook as it is at other stations in the Voisey's Bay network (Figure 4).

Please note the stage data used below is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

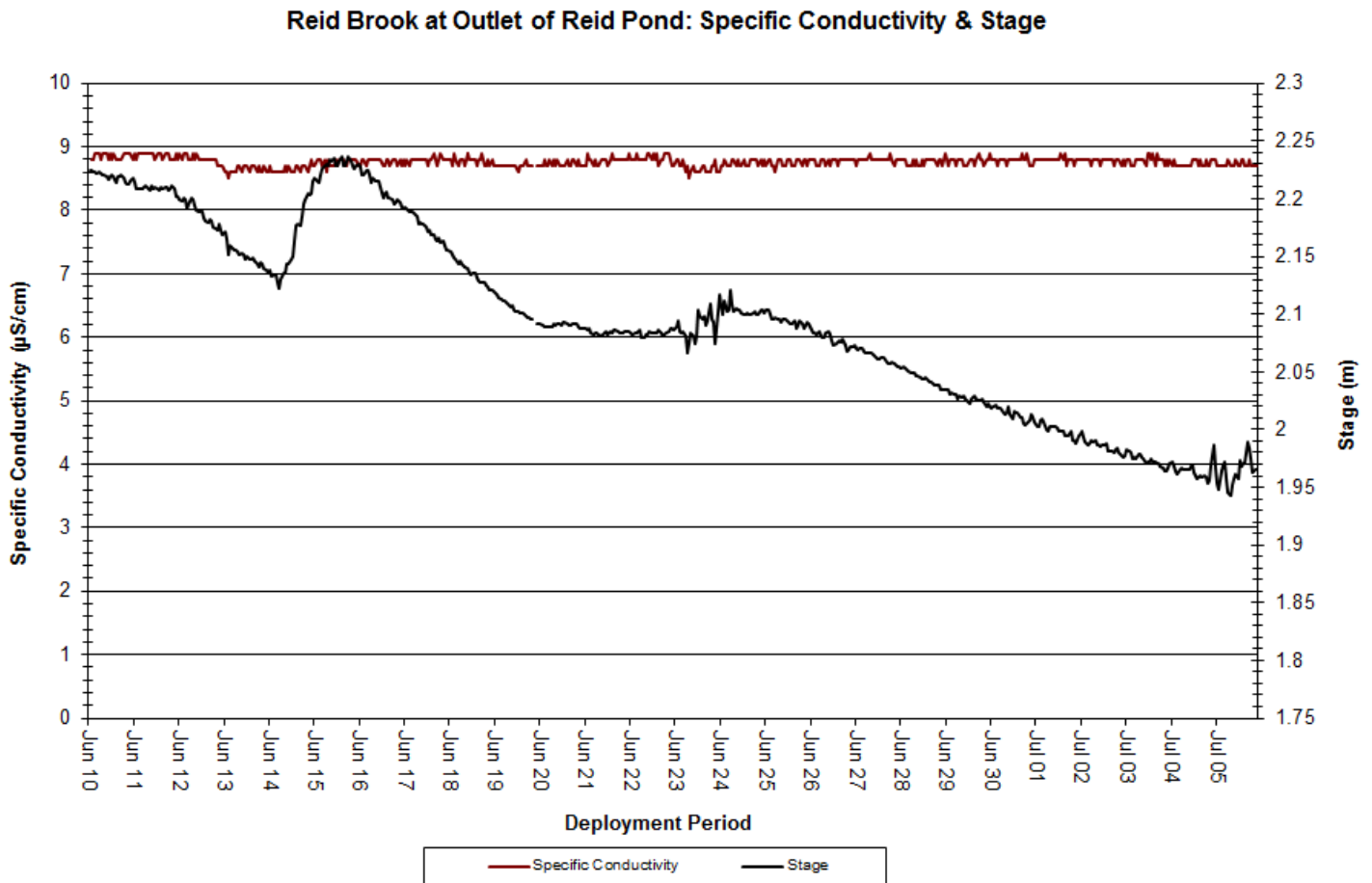


Figure 4: Specific Conductivity & Stage at Reid Brook at Outlet of Reid Pond

Dissolved Oxygen

Over the deployment period, dissolved oxygen concentration levels ranged from 12.14mg/L to 12.52mg/L, with a median value of 12.35mg/L. Percent saturation levels for dissolved oxygen ranged from 91.4% saturation to 100.3% saturation, with a median value of 95.9% saturation (Figure 5).

The water quality instrument measures dissolved oxygen concentration (mg/L) with a dissolved oxygen probe. The instrument then calculates percent saturation (% Sat) taking into account water temperature.

Dissolved oxygen concentration values remained above the CCME's Guidelines for the Protection of Early Life Stages (9.5 mg/L) and Other Life Stages (6.5 mg/L) for the duration of deployment. Very stable water temperatures in Reid Pond over the course of deployment resulted in very little fluctuation in dissolved oxygen concentrations over the same period (Figure 5).

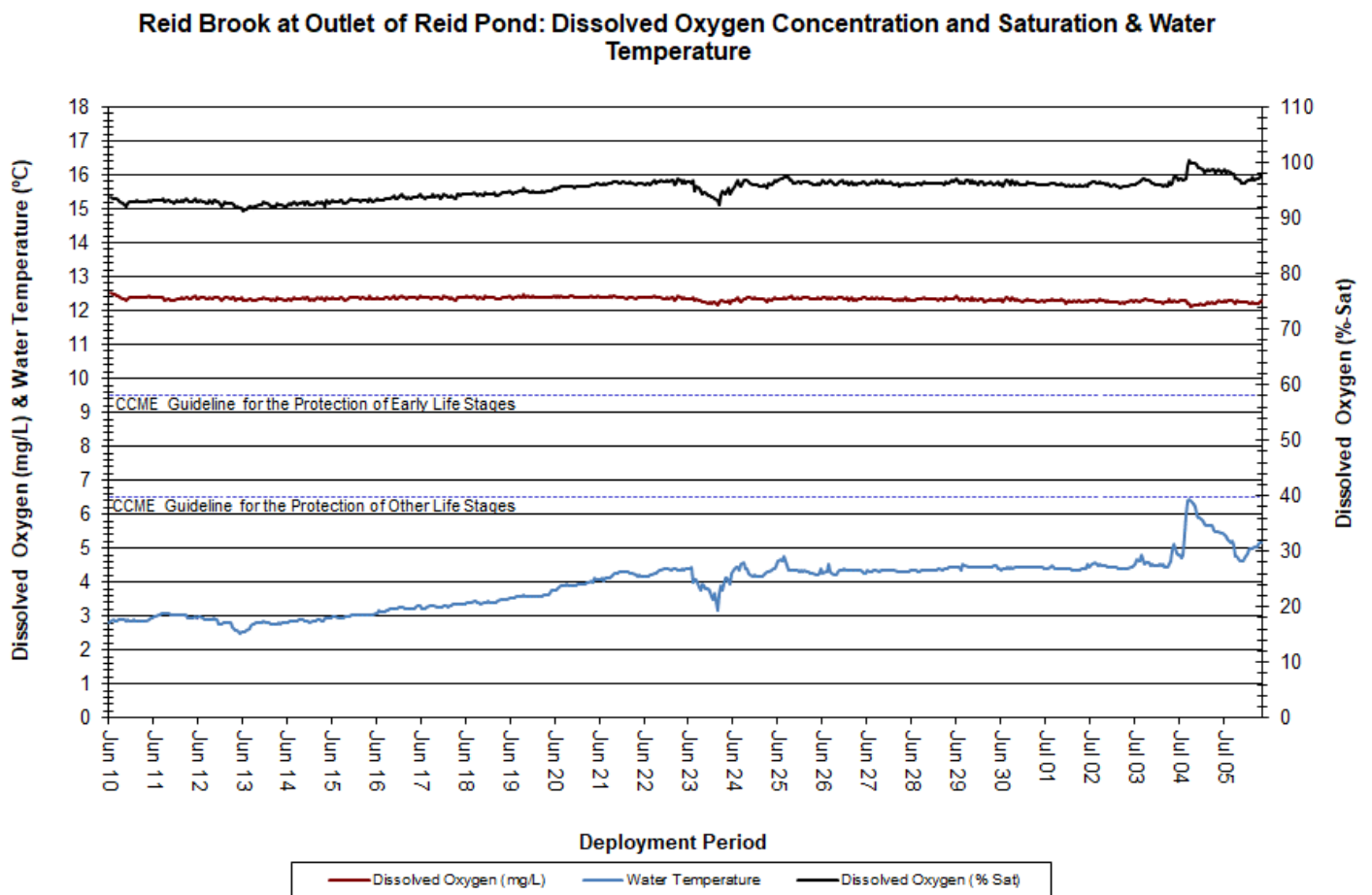


Figure 5: Dissolved Oxygen Concentration and Saturation & Water Temperature at Reid Brook at Outlet of Reid Pond

Turbidity

Over the deployment period, turbidity levels remained stable at 0.0NTU (Figure 6). This indicates that there was very little background turbidity at this station during deployment.

All water bodies have a natural level of turbidity. A significant increase in turbidity is of concern when monitoring water quality. Higher turbidity readings would normally be expected during heavy rainfall or runoff events. Generally, turbidity levels increase for a short period of time and then return to within a baseline range. Turbidity values can also increase when there is a decrease in water level, which causes natural material in the water body to become concentrated.

Despite several precipitation events, turbidity levels remained at 0 NTU for the duration of deployment (Figure 6). This is not unusual for this station as it is pristine in nature and far removed from anthropogenic influences that may affect water quality.

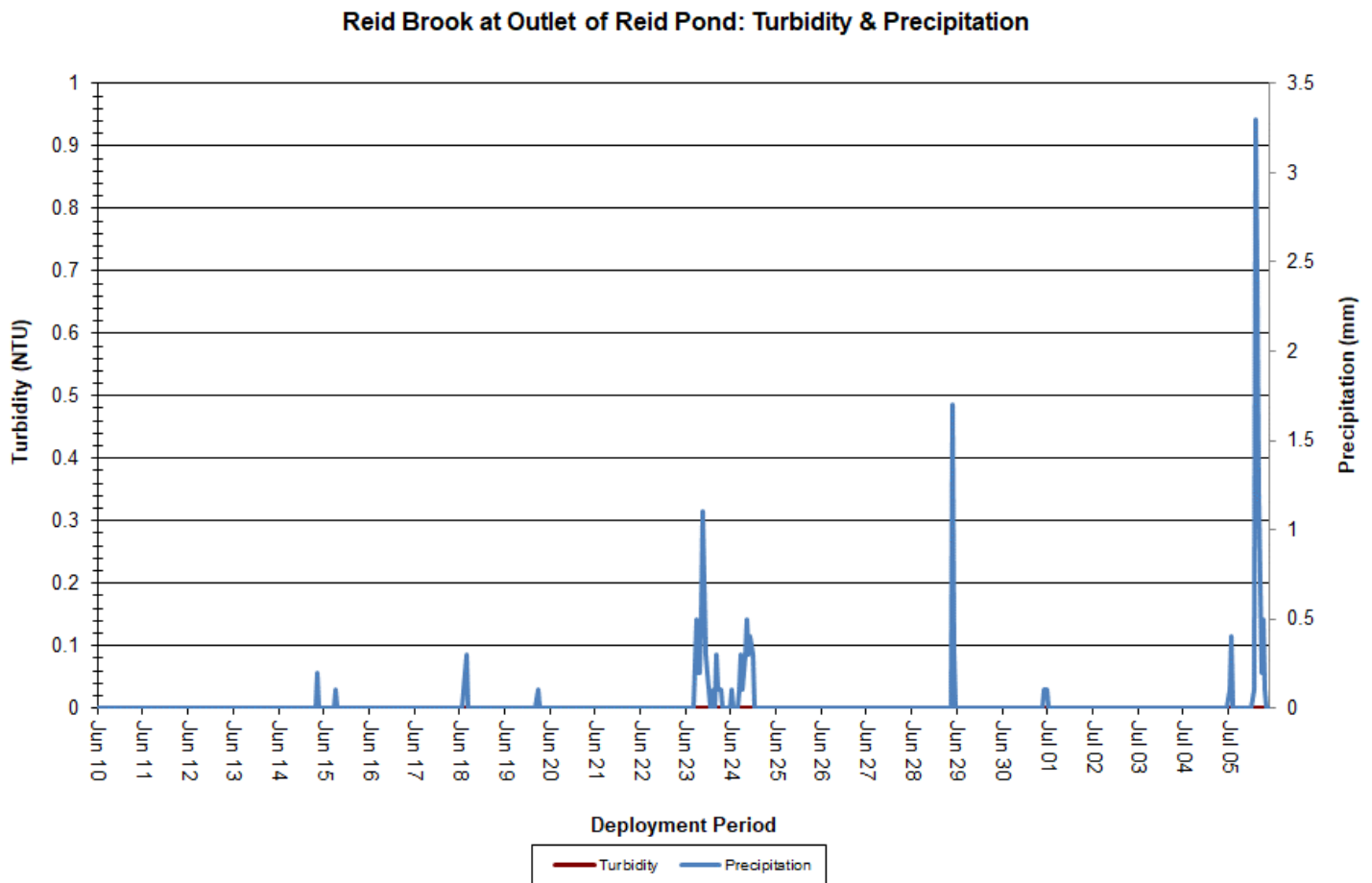


Figure 6: Turbidity & Precipitation at Reid Brook at Outlet of Reid Pond

Stage, Flow & Precipitation

Stage is an important parameter, as it provides an estimate of water level at a station and can explain some of the events that are occurring with other parameters (e.g. specific conductivity, DO, and turbidity). Stage will generally increase during rainfall events (Figure 7) and during any surrounding snow or ice melt; however, direct snowfall will not cause a significant increase in stage.

Over the deployment period, stage values ranged from 1.94m to 2.24m, with a median value of 2.09m. Flow values ranged from 2.69m³/s to 7.08m³/s, with a median value of 4.54m³/s. Precipitation data was obtained from the Voisey's Bay airstrip weather station (Figure 7).

Please note the stage and flow data used below is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

Reid Brook at Outlet of Reid Pond: Stage, Flow & Precipitation

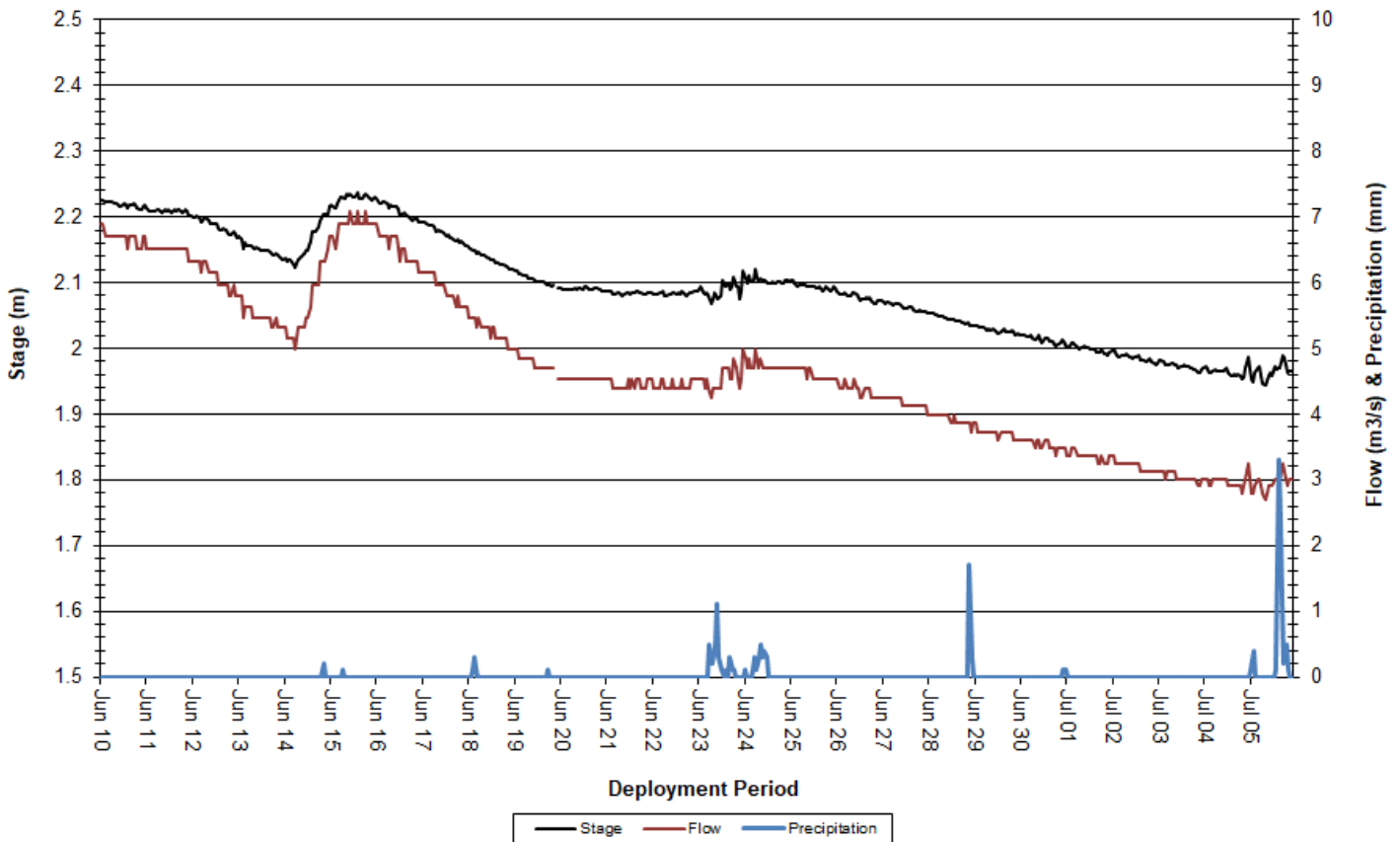


Figure 7: Stage, Flow & Precipitation at Reid Brook at Outlet of Reid Pond

Camp Pond Brook below Camp Pond

Water Temperature

Over the deployment period, water temperature ranged from 7.21°C to 16.09°C, with a median value of 10.75°C (Figure 8).

Water temperature at this station displays diurnal variations. There was a gradual increase in water temperature over the course of deployment. This is to be expected as air temperatures increased with the change from spring to summer (Figure 8). Air temperature data was obtained from the Voisey's Bay airstrip weather station.

Camp Pond Brook is sensitive to changes in ambient air temperature and fluctuates considerably depending on the weather and time of day. This station typically has the highest water temperatures and greatest fluctuations when compared to the other stations in the network.

Please note the stage data used below is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

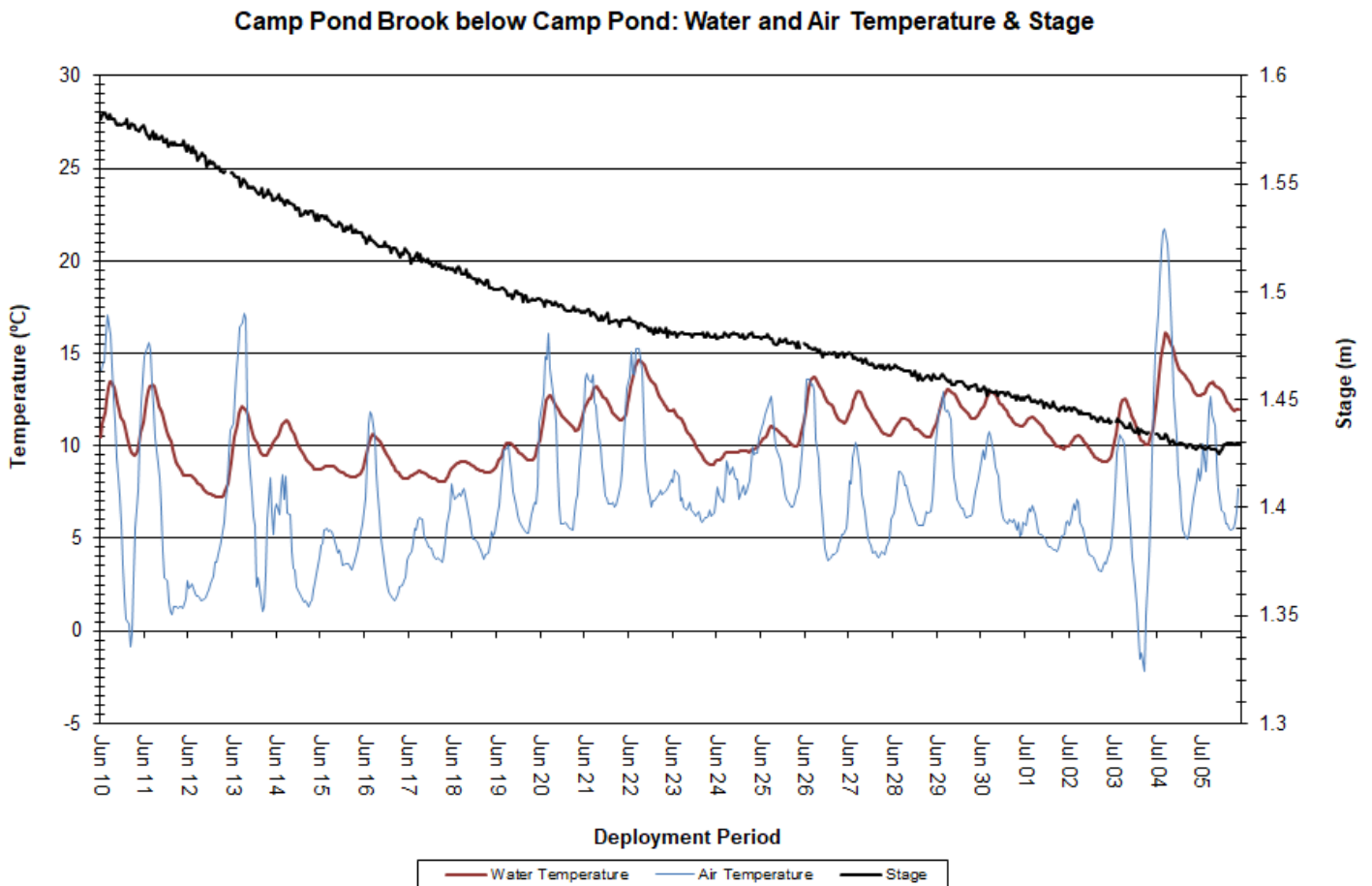


Figure 8: Water and Air Temperature & Stage at Camp Pond Brook below Camp Pond

pH

Over the deployment period, pH values ranged from 5.70 pH units to 6.59 pH units, with a median value of 6.38 pH units (Figure 9).

pH levels increased slowly over the course of deployment, but remained below the CCME's Guidelines for the Protection of Aquatic Life for the majority of the deployment period.

Natural events such as rainfall and snow melt will alter the pH of a brook for a period of time - pH levels will decrease slightly during and after high stage levels. This is a natural process and may have contributed to lower pH levels observed at the beginning of the deployment period.

Please note the stage data used below is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

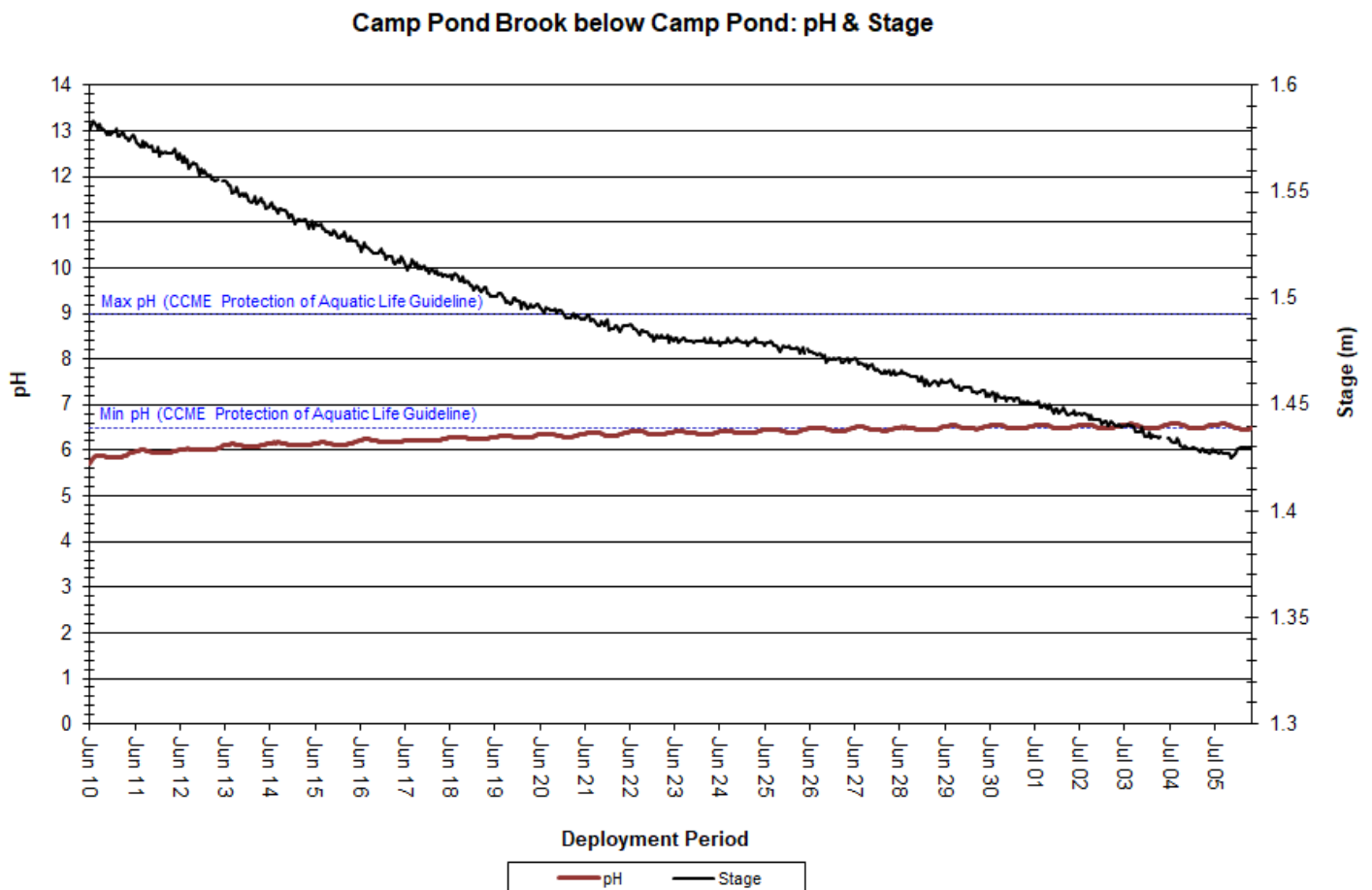


Figure 9: pH & Stage at Camp Pond Brook below Camp Pond

Specific Conductivity

Over the deployment period, specific conductivity ranged from 25.6 μ S/cm to 31.6 μ S/cm, with a median value of 28.3 μ S/cm (Figure 10).

Conductivity levels were variable but consistent across the deployment period as stage steadily decreased. A decrease in water level generally serves to concentrate suspended materials in the water column, in turn increasing specific conductivity; however, this association is not clearly visible in the graph below except towards the very end of deployment (Figure 10).

Please note the stage data used below is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

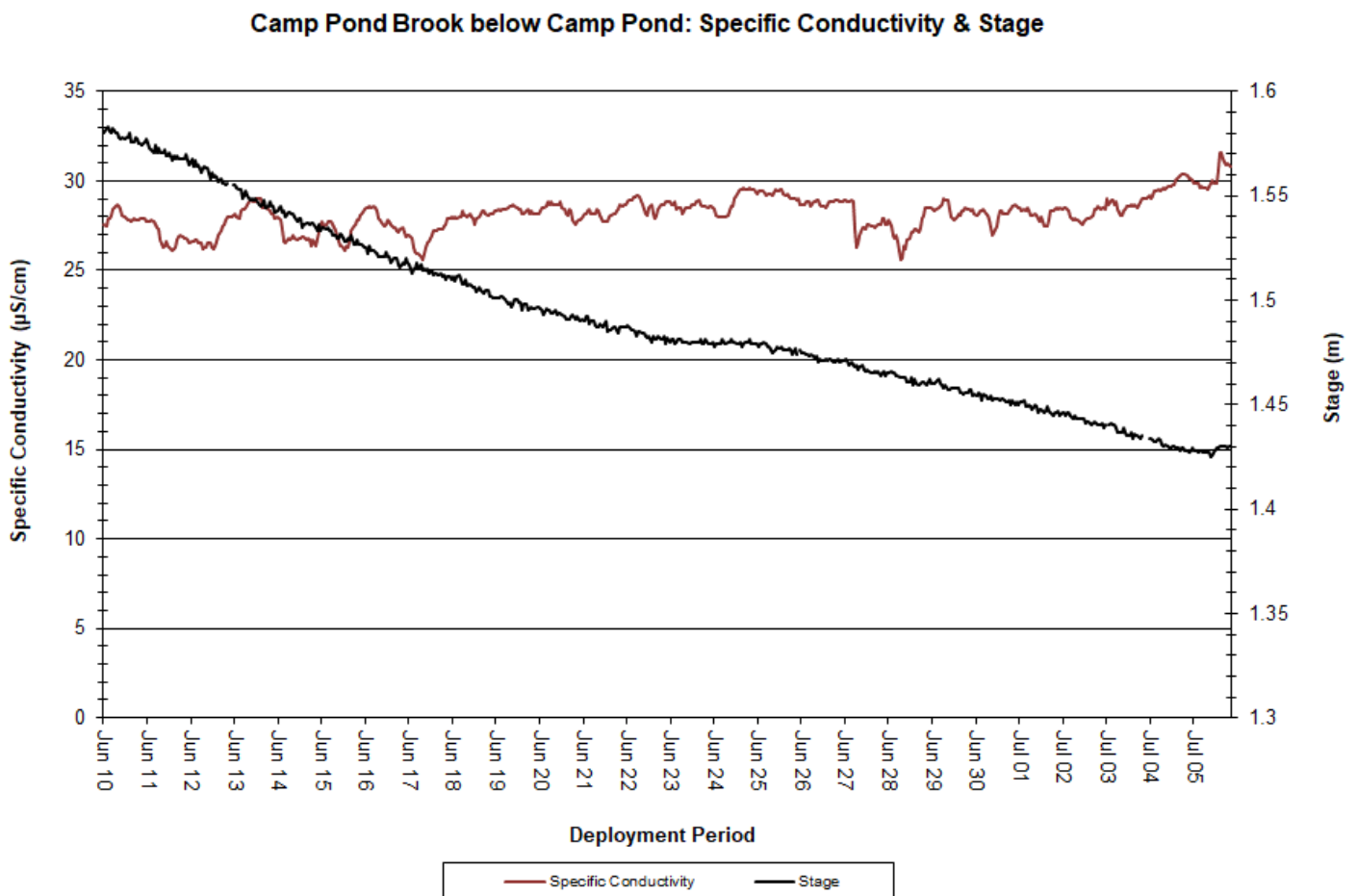


Figure 10: Specific Conductivity & Stage at Camp Pond Brook below Camp Pond

Dissolved Oxygen

Over the deployment period, dissolved oxygen concentration ranged from 9.68mg/L to 11.32mg/L, with a median value of 10.58mg/L. Saturation of dissolved oxygen ranged from 92.1% saturation to 104.4% saturation, with a median value of 96.3% (Figure 11).

Dissolved oxygen concentrations slowly decreased across the deployment period, while water temperature slowly increased. This observation is to be expected as water temperature directly influences the level of dissolved oxygen present in the water column; as water temperatures increase, dissolved oxygen concentrations decrease, and vice versa.

Dissolved oxygen concentrations remained above the CCME's Guideline for the Protection of Early Life Stages and Other Life Stages for the duration of the deployment period (Figure 11).

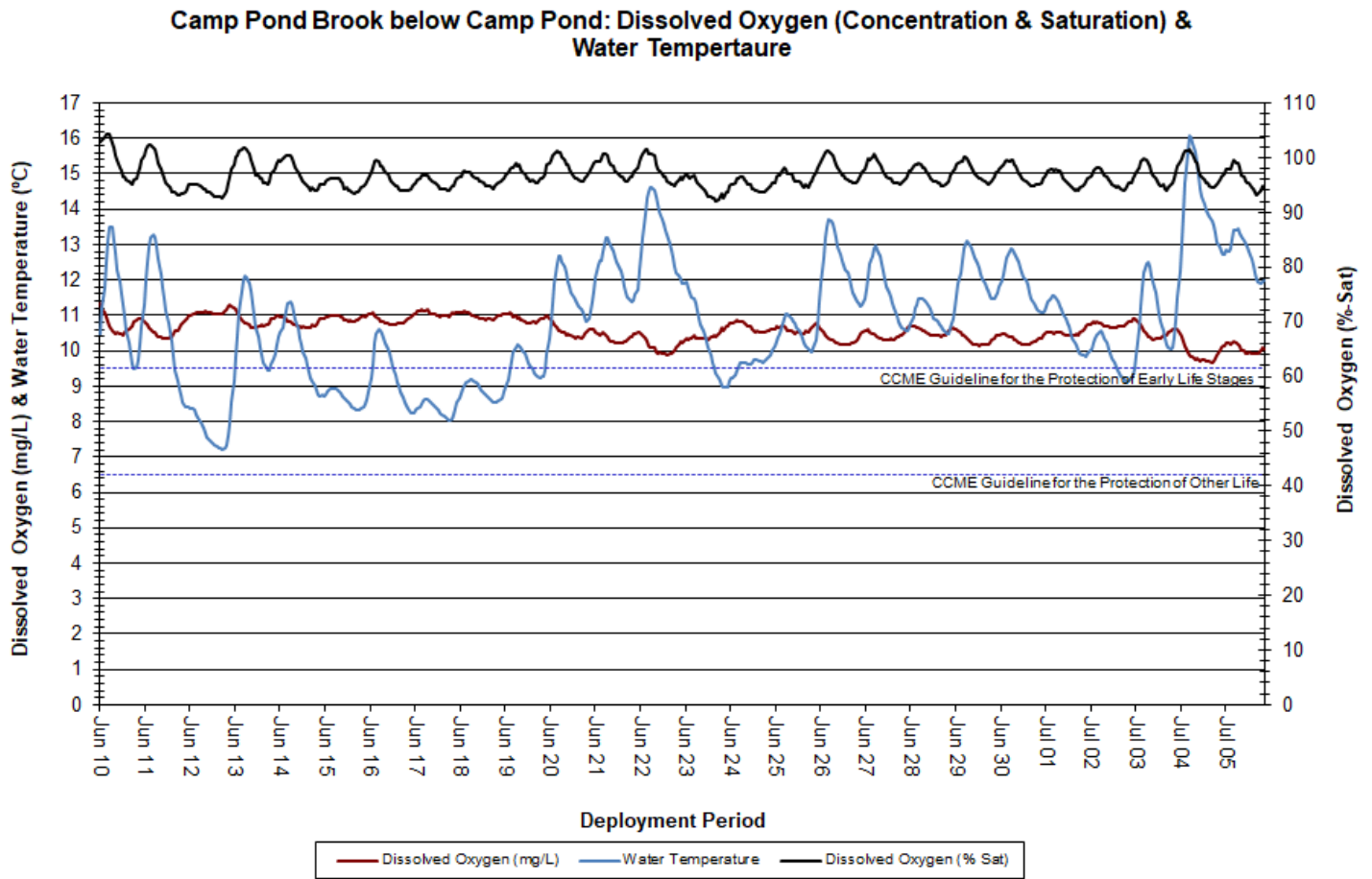


Figure 11: Dissolved Oxygen & Water Temperature at Camp Pond Brook below Camp Pond

Turbidity

Over the deployment period, turbidity ranged from 0.0NTU to 18.9NTU, with a median value of 9.8NTU (Figure 12). A median value of 9.8NTU indicates that there was quite a bit of natural background turbidity at this station.

Higher turbidity levels are commonly observed at this station and are likely attributable to snow melt and subsequent runoff entering Camp Pond Brook (Figure 12). Precipitation data was obtained from the Voisey's Bay airstrip weather station.

Camp Pond Brook below Camp Pond: Turbidity & Precipitation

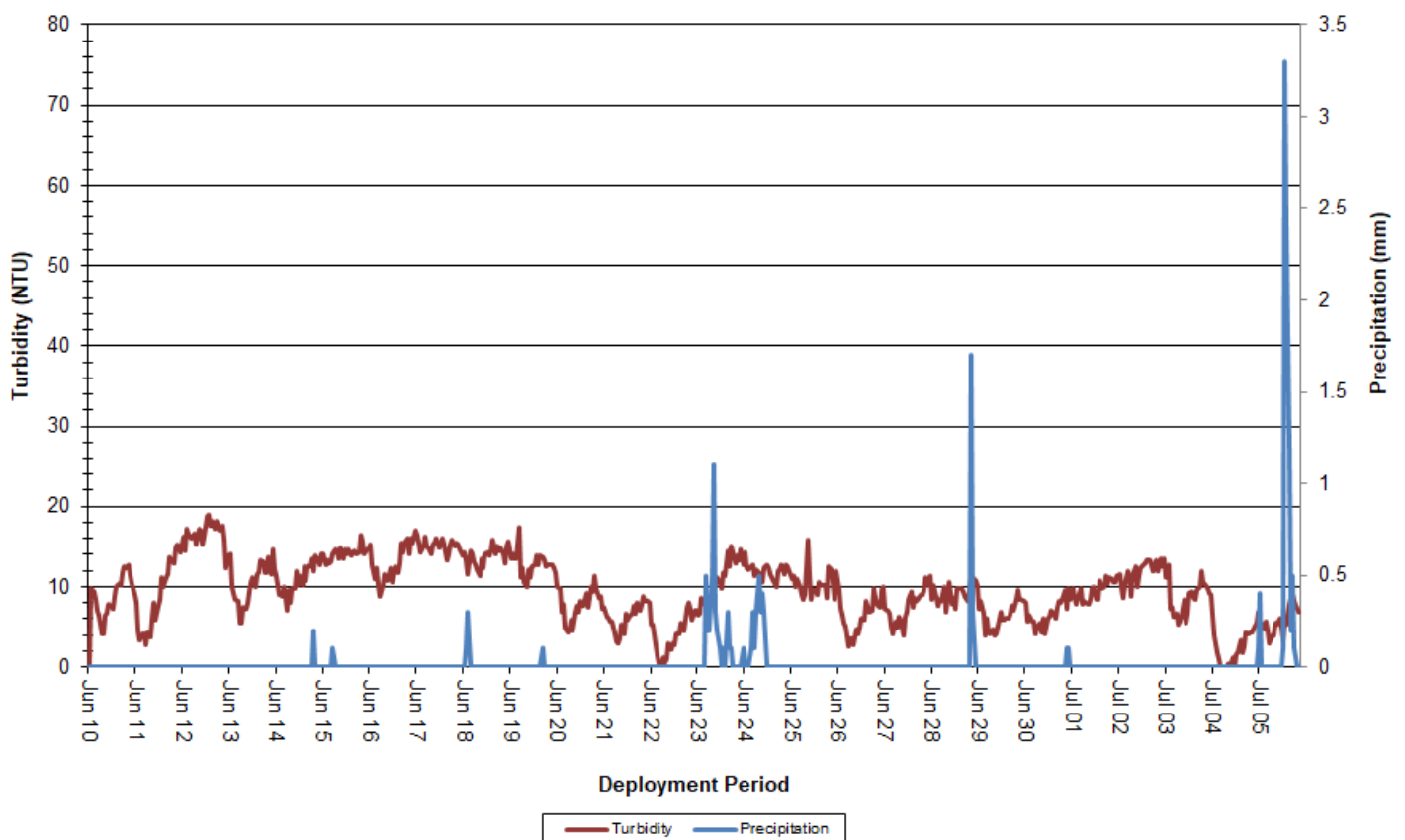


Figure 12: Turbidity & Precipitation at Camp Pond Brook below Camp Pond

Stage, Flow and Precipitation

Over the deployment period, stage values ranged from 1.43m to 1.58m, with a median value of 1.48m. Stream flow values ranged from 0.61m³/s to 1.59m³/s, with a median value of 0.84m³/s. Precipitation data was obtained from the Voisey's Bay airstrip weather station (Figure 13).

Stage decreased steadily across the deployment period. A slight increase in stage was observed on July 6th and can be attributed to the observed rainfall event (Figure 13).

Please note the stage and flow data used below is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request to WSC.

Camp Pond Brook below Camp Pond: Stage, Flow & Precipitation

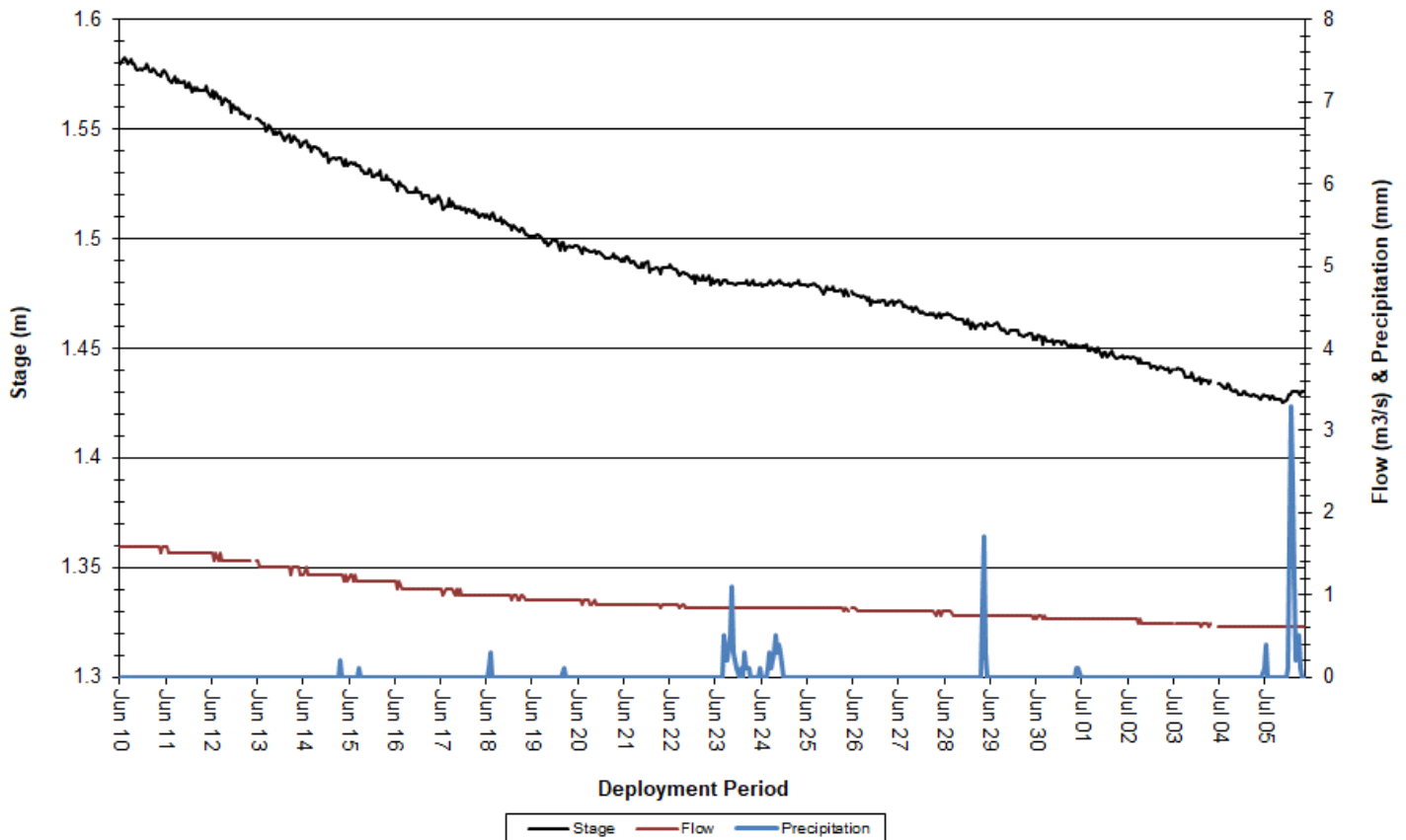


Figure 13: Stage, Flow & Precipitation at Camp Pond Brook below Camp Pond

Reid Brook below Tributary

Water Temperature

Over the deployment period, water temperature ranged from 5.59°C to 12.43°C, with a median value of 8.49°C (Figure 14).

Water temperature at this station displays diurnal variations, and there was a gradual increase in the water temperature throughout the deployment period as spring changed to summer. This is to be expected as air temperatures also increased (Figure 14). Air temperature data was obtained from the Voisey's Bay airstrip weather station.

Stage data is not available because there was an issue with the transmission of data from this station during deployment. All other data was obtained via the RTWQ instrument's internal log file.

Reid Brook below Tributary: Water and Air Temperature

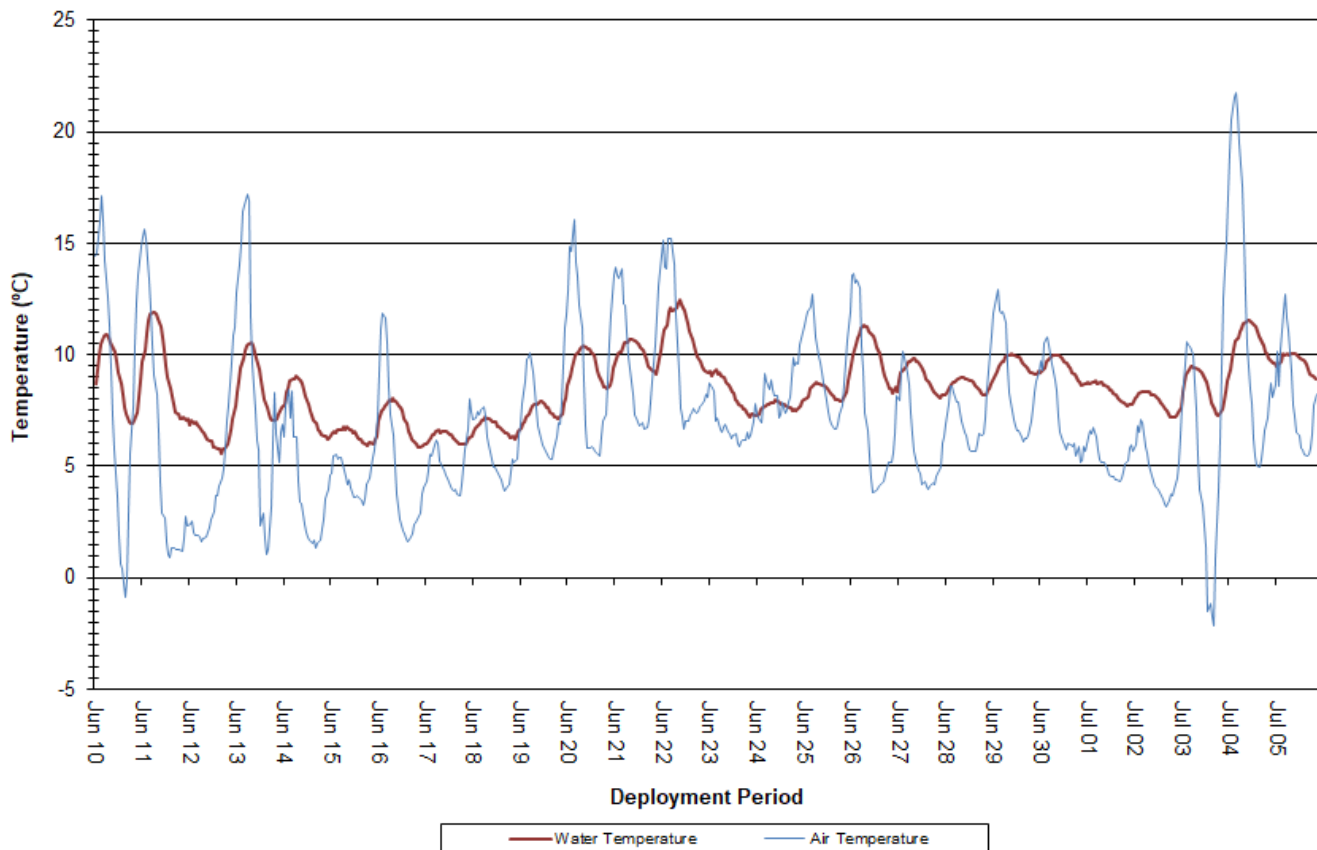


Figure 14: Water and Air Temperature at Reid Brook below Tributary

pH

Over the deployment period, pH ranged from 5.97 pH units to 6.91 pH units, with a median value of 6.74 (Figure 15).

pH was below the CCME's Minimum Guideline for the Protection of Aquatic Life at the very beginning of the deployment period, but increased quickly and remained within the CCME's guidelines from June 13th onwards.

Stage data is not available because there was an issue with the transmission of data from this station during deployment. All other data was obtained via the RTWQ instrument's internal log file.

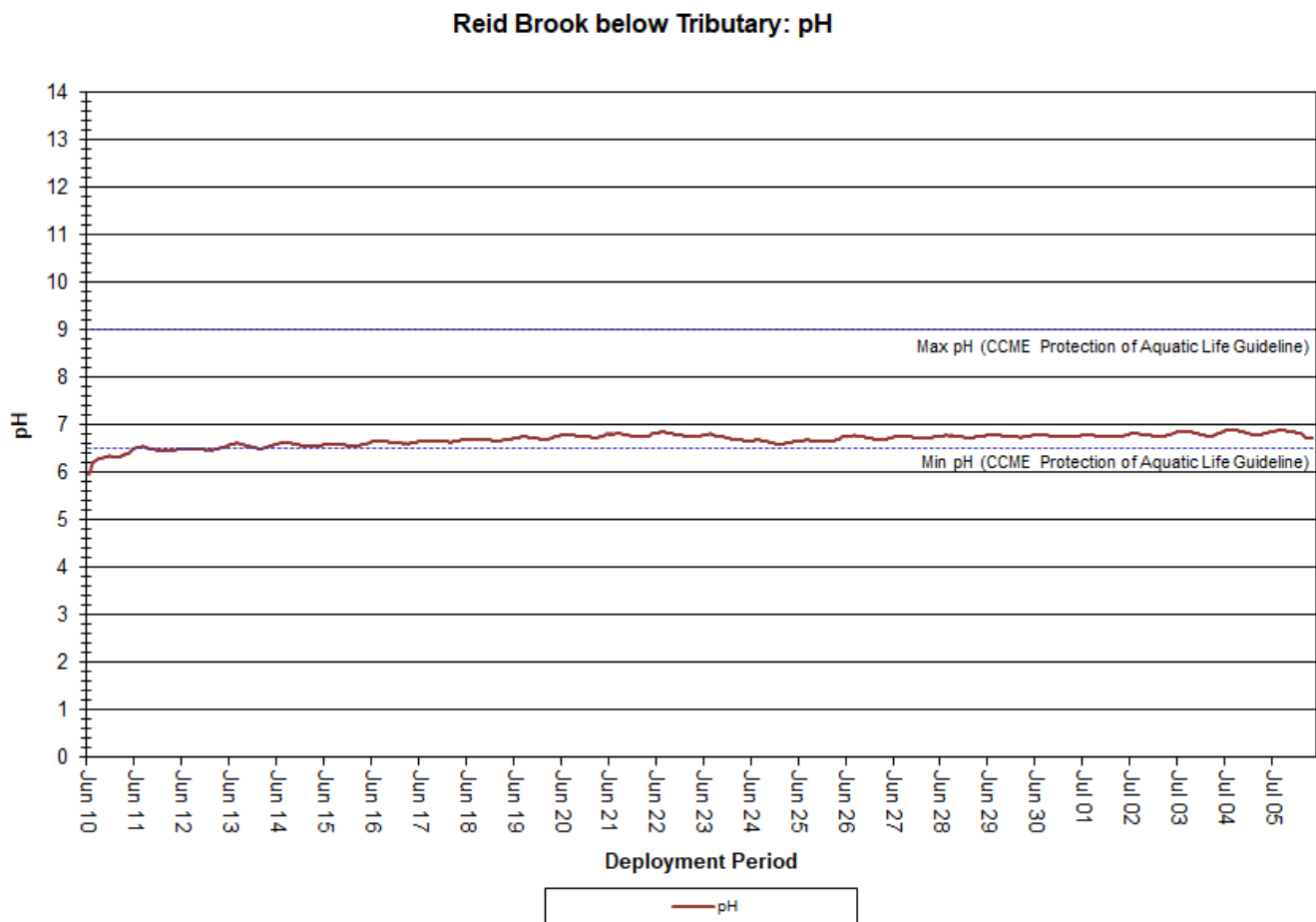


Figure 15: pH at Reid Brook below Tributary

Specific Conductivity

Over the deployment period, specific conductivity ranged from 20.0 μ S/cm to 28.0 μ S/cm, with a median value of 23.0 μ S/cm (Figure 16).

Specific conductivity steadily increased over the course of deployment (Figure 16).

Specific conductivity and stage generally exhibit an inverse relationship: as one parameter increases, the other decreases. Increasing specific conductivity levels are likely due to decreasing water levels, which is characteristic of this station at this time of year; however, due to an equipment failure we do not have stage data to verify this relationship.

Stage data is not available because there was an issue with the transmission of data from this station during deployment. All other data was obtained via the RTWQ instrument's internal log file.

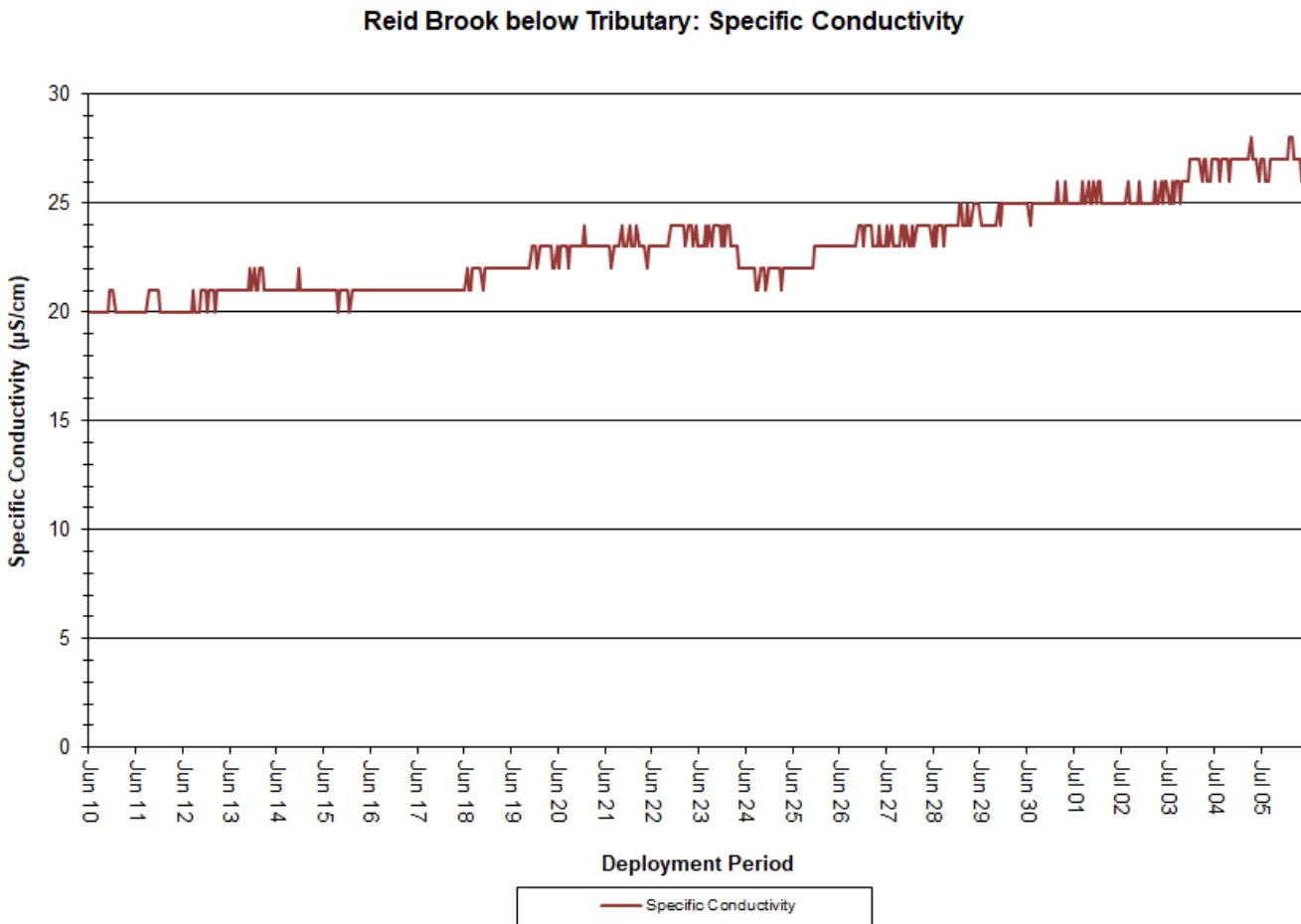


Figure 16: Specific Conductivity at Reid Brook below Tributary

Dissolved Oxygen

Over the deployment period, dissolved oxygen concentration ranged from 9.98mg/L to 11.88mg/L, with a median value of 11.14mg/L. The saturation of dissolved oxygen ranged from 93.8% saturation to 100.5% saturation, with a median value of 96.1% (Figure 17).

Dissolved oxygen concentrations remained above the CCME's Guidelines for the Protection of Early Life Stages (9.5mg/L) and Other Life Stages (6.5 mg/L) for the duration of deployment. Dissolved oxygen concentration was fairly consistent over the course of deployment, with fluctuations closely connected to changes in water temperature. This is to be expected as water temperature and dissolved oxygen concentration generally exhibit an inverse relationship.

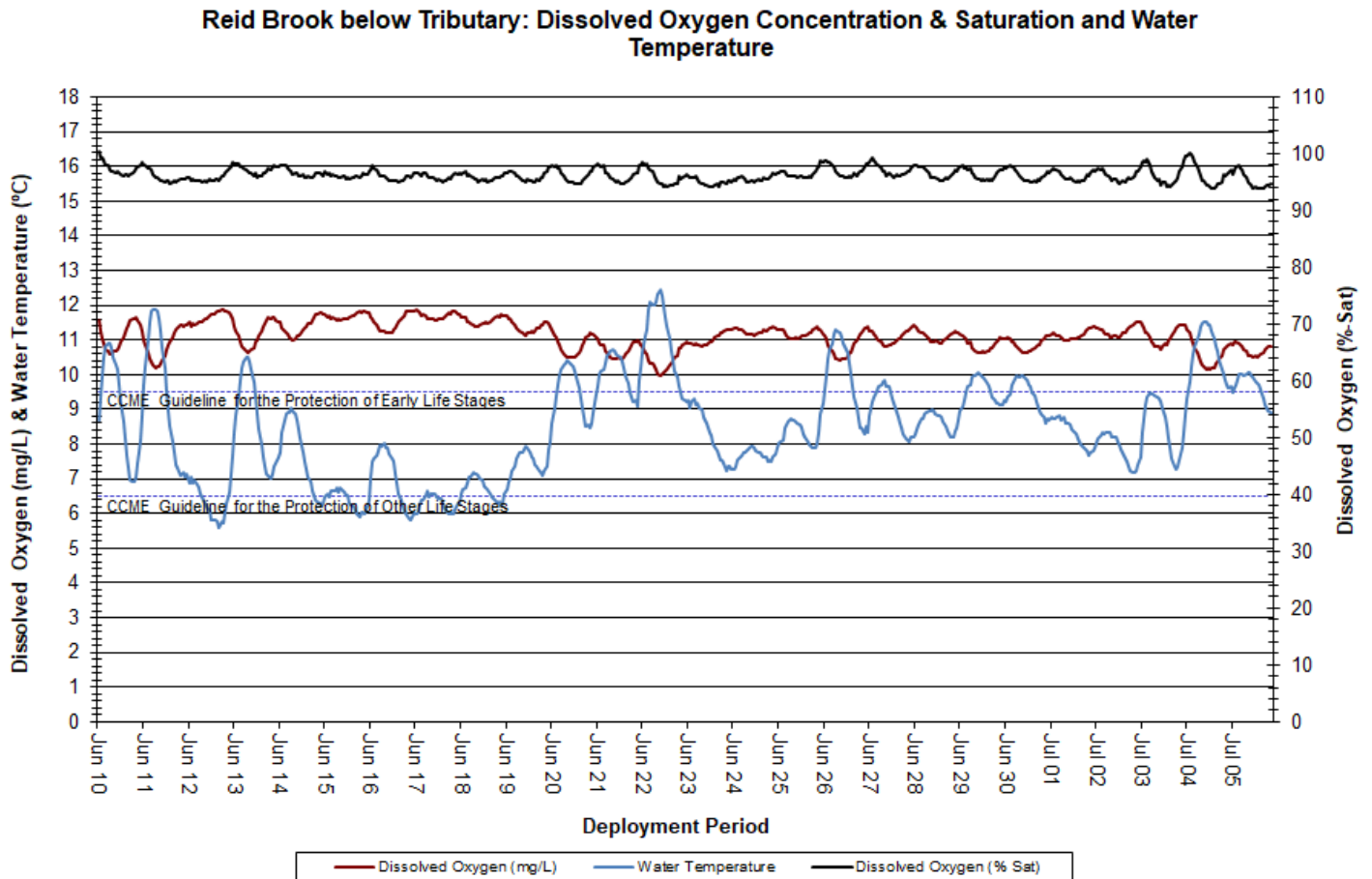


Figure 17: Dissolved Oxygen & Water Temperature at Reid Brook below Tributary

Turbidity

Over the deployment period, turbidity ranged from 0.0 NTU to 12.8 NTU, with a median value of 0.0 NTU (Figure 18). A median turbidity value of 0.0 NTU indicates that there was very little background turbidity at this station.

The majority of the turbidity events observed at this station closely correlated with rainfall events (Figure 18), which can cause mixing of solids in the water column. Precipitation data was obtained from the Voisey's Bay airstrip weather station.

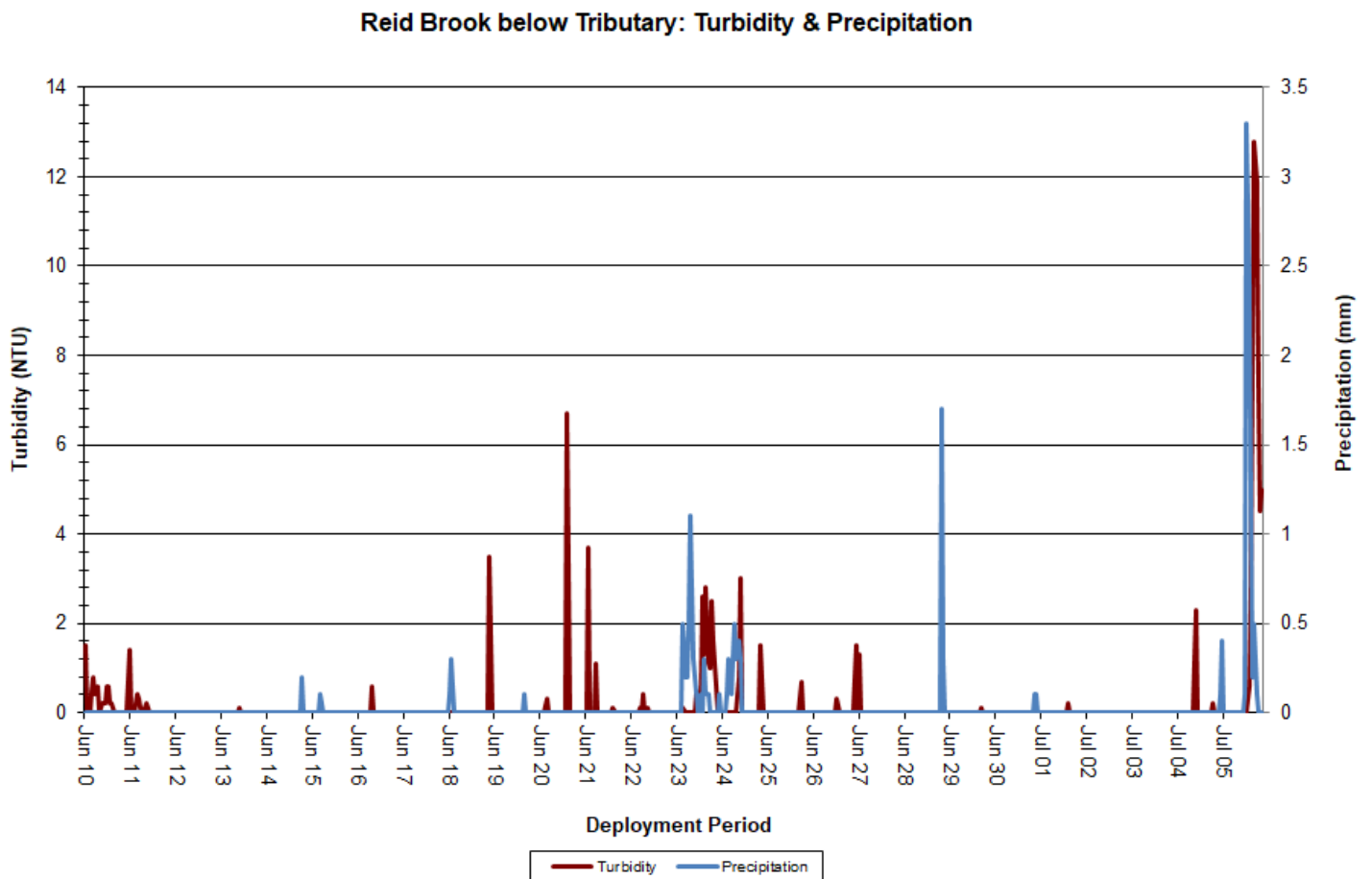


Figure 18: Turbidity & Precipitation at Reid Brook below Tributary

Stage and Flow

Stage and flow data are not available because there was an issue with the transmission of data from this station during deployment. All other data was obtained via the RTWQ instrument's internal log file.

Tributary to Reid Brook

Water Temperature

Over the deployment period, water temperature ranged from 6.12°C to 12.89°C, with a median value of 8.82°C (Figure 19). Streams and brooks are sensitive to changes in the ambient air temperature, thus water temperature will fluctuate considerably depending on the weather and the time of day. Air temperature fluctuates to a greater extent compared to water temperature. Air temperature data was obtained from the Voisey's Bay airstrip weather station.

Water temperature data displays a natural diurnal pattern. As expected, water temperatures increased gradually over the course of deployment with the change from spring to summer, and correlated closely with ambient air temperatures.

Stage data is not available because there was an issue with the transmission of data from this station during deployment. All other data was obtained via the RTWQ instrument's internal log file.

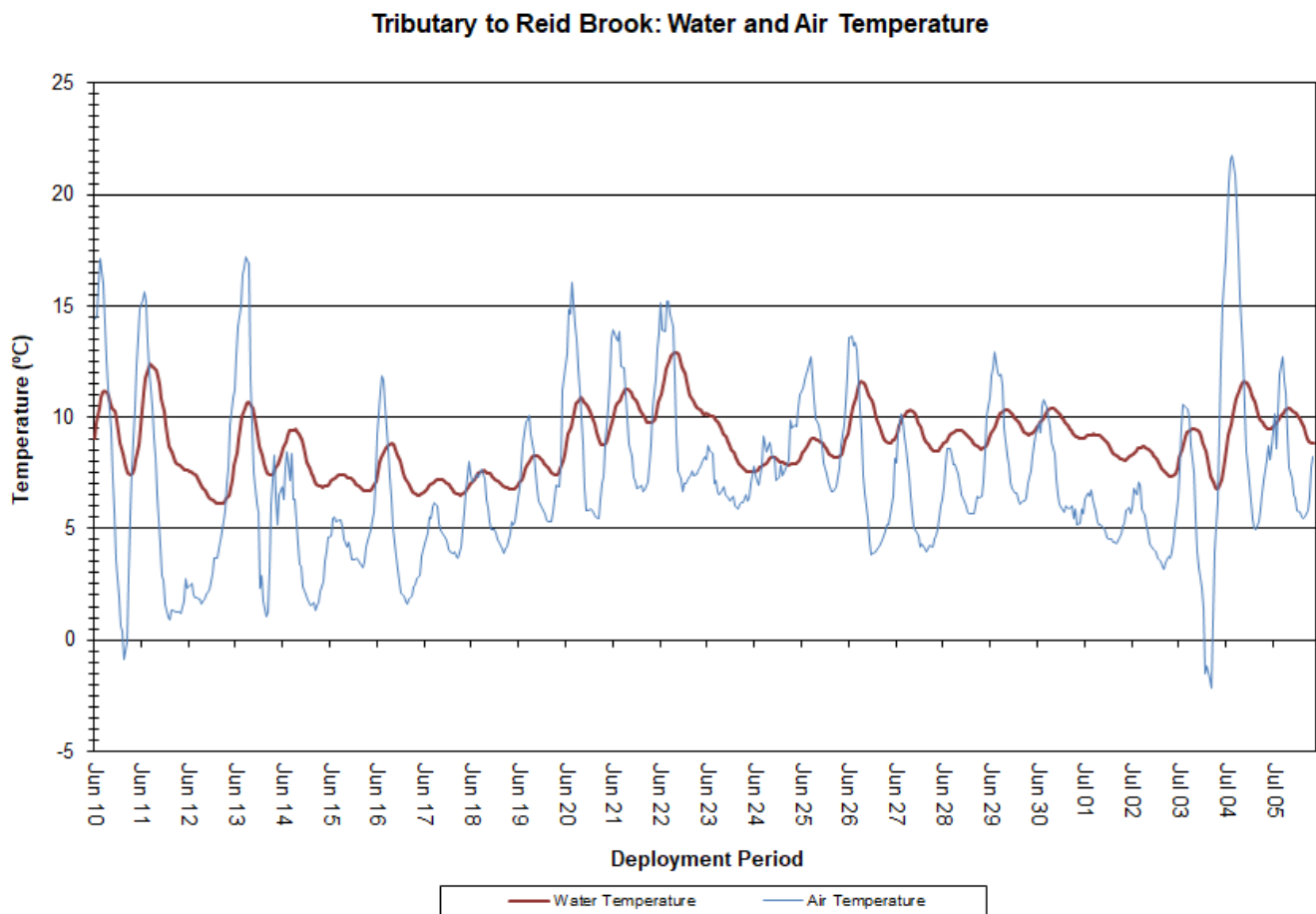


Figure 19: Water and Air Temperature at Tributary to Reid Brook

pH

Over the deployment period, pH ranged from 6.11 pH units to 7.11 pH units, with a median value of 6.79 (Figure 20).

pH values reached the CCME's Minimum Guideline for the Protection of Aquatic Life shortly after the start of deployment, and remained within the acceptable range for the remainder of the deployment period.

Stage data is not available because there was an issue with the transmission of data from this station during deployment. All other data was obtained via the RTWQ instrument's internal log file.

Tributary to Reid Brook: pH

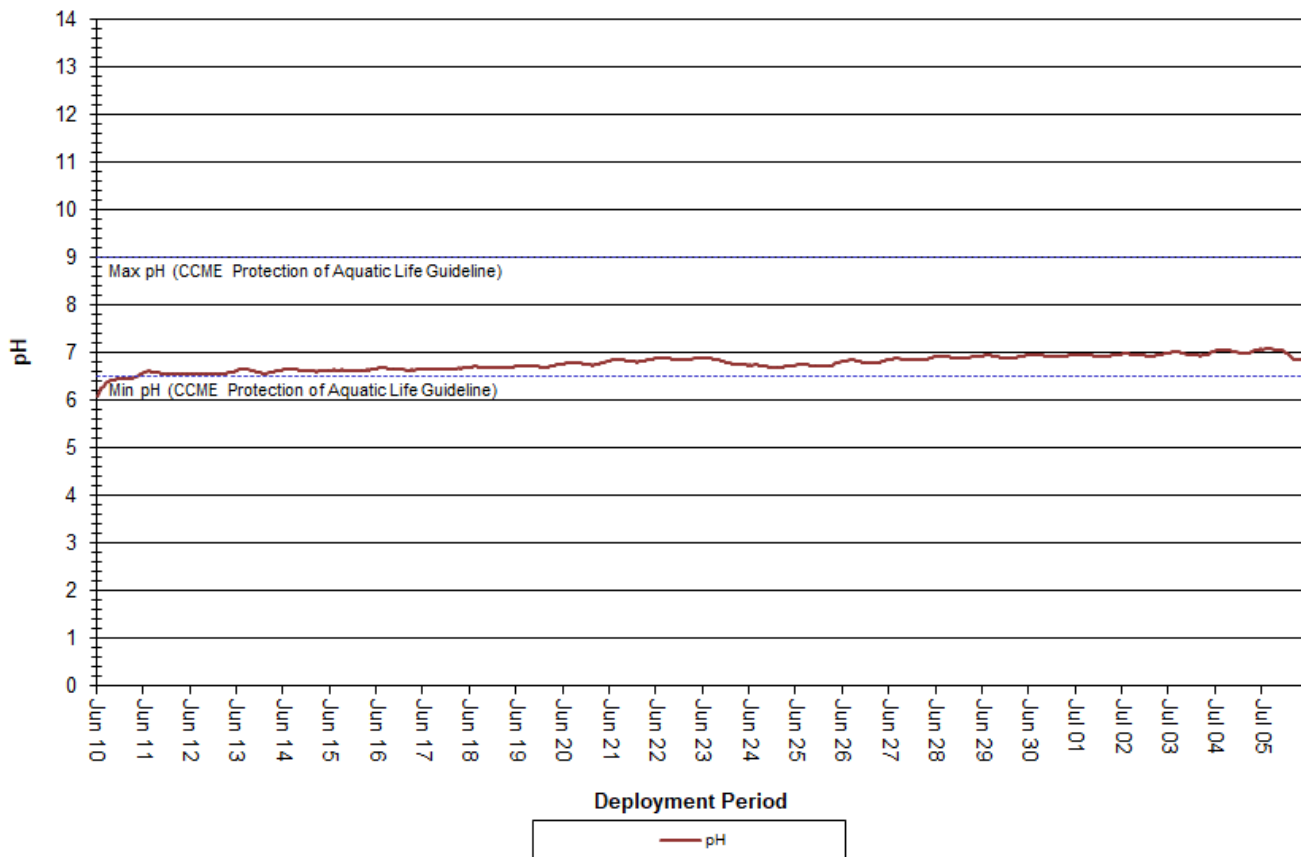


Figure 20: pH at Tributary to Reid Brook

Specific Conductivity

Over the deployment period, specific conductivity ranged from 20.0 μ S/cm to 29.0 μ S/cm, with a median value of 24.0 μ S/cm (Figure 21).

Specific conductivity and stage generally exhibit an inverse relationship: as one parameter increases, the other decreases. Increasing specific conductivity levels are likely due to decreasing water levels, which is characteristic of this station at this time of year; however, due to an equipment failure we do not have stage data to verify this relationship.

Stage data is not available because there was an issue with the transmission of data from this station during deployment. All other data was obtained via the RTWQ instrument's internal log file.

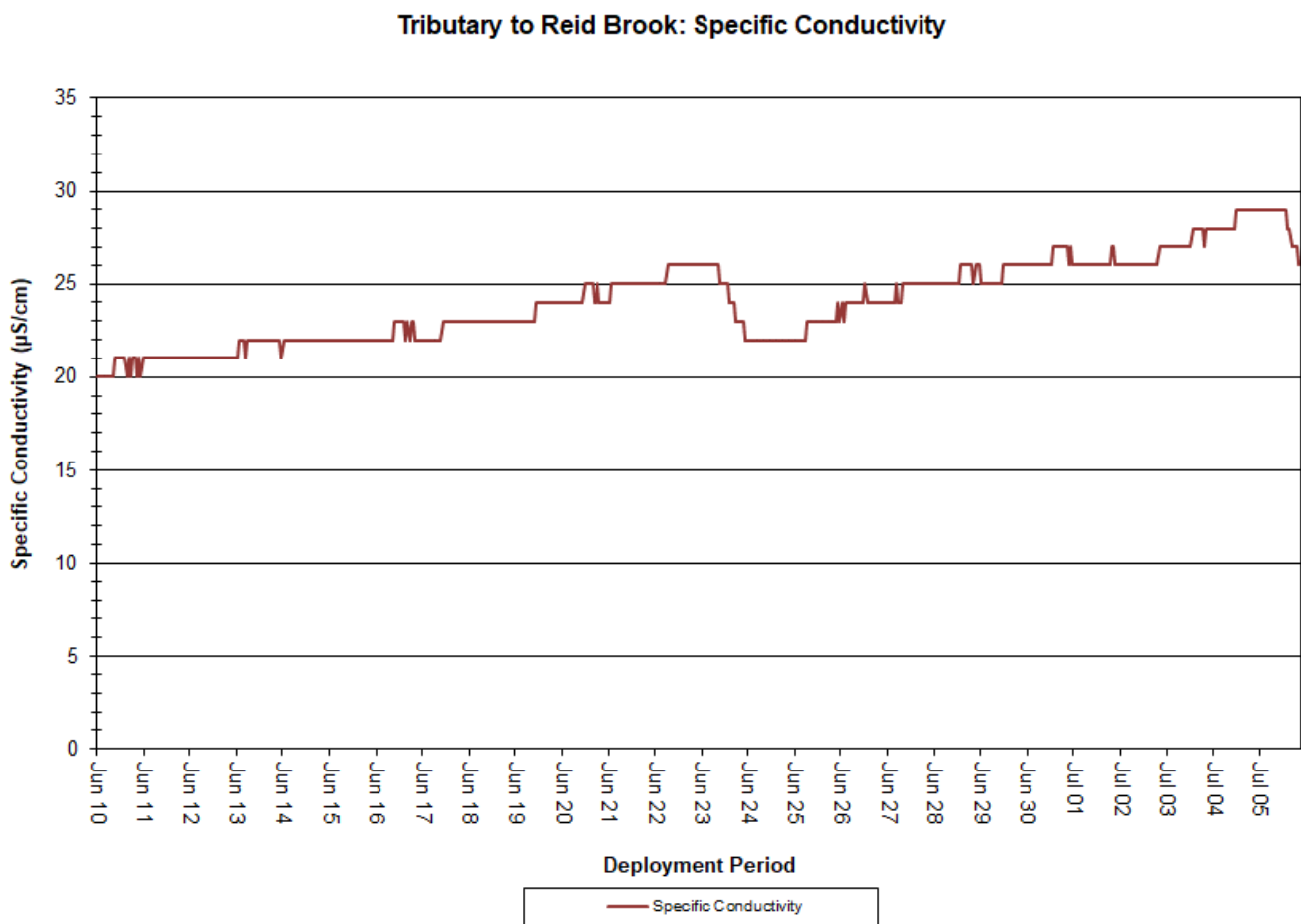


Figure 21: Specific Conductivity at Tributary to Reid Brook

Dissolved Oxygen

Over the deployment period, dissolved oxygen concentration ranged from 9.80mg/L to 11.74mg/L, with a median value of 10.99mg/L. The saturation of dissolved oxygen ranged from 93.3% saturation to 98.6% saturation, with a median value of 95.6% (Figure 22).

Dissolved oxygen levels remained above the CCME's Guidelines for the Protection of Early and Other Life Stages for the duration of deployment.

Dissolved oxygen concentration displays a diurnal pattern. During nightfall, dissolved oxygen levels are higher as cooler temperatures allow for more DO to be stored in the water column. During the day, dissolved oxygen levels are lower. This is a result of warmer water temperatures and photosynthesis by aquatic plants, which decrease dissolved oxygen levels in the water column.

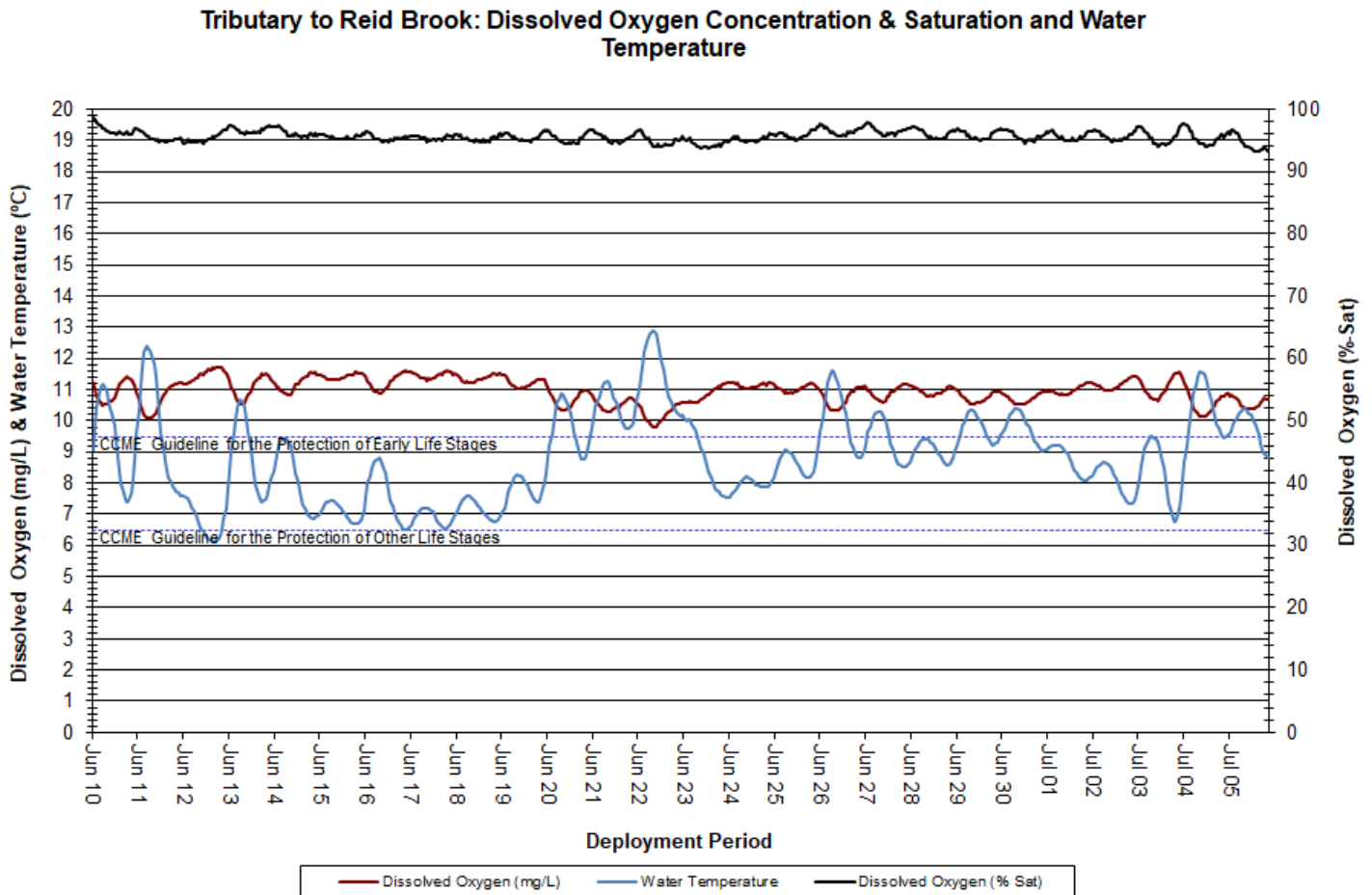


Figure 22: Dissolved Oxygen & Water Temperature at Tributary to Reid Brook

Turbidity

Over the deployment period, turbidity ranged from 2.5 NTU to 15.2 NTU, with a median value of 3.4 NTU (Figure 23). A median value of 3.4 NTU indicates that there was a small amount of natural background turbidity at this station.

There were a number of turbidity events at this station, with many of the larger turbidity events correlating with rainfall events (Figure 23). Rainfall generally causes an increase in water volume, which serves to stir up solid materials in the water column, in turn increasing turbidity. This site is particularly prone to variable turbidity, as it has a sandy-clay bottom that is easily disturbed by precipitation events.

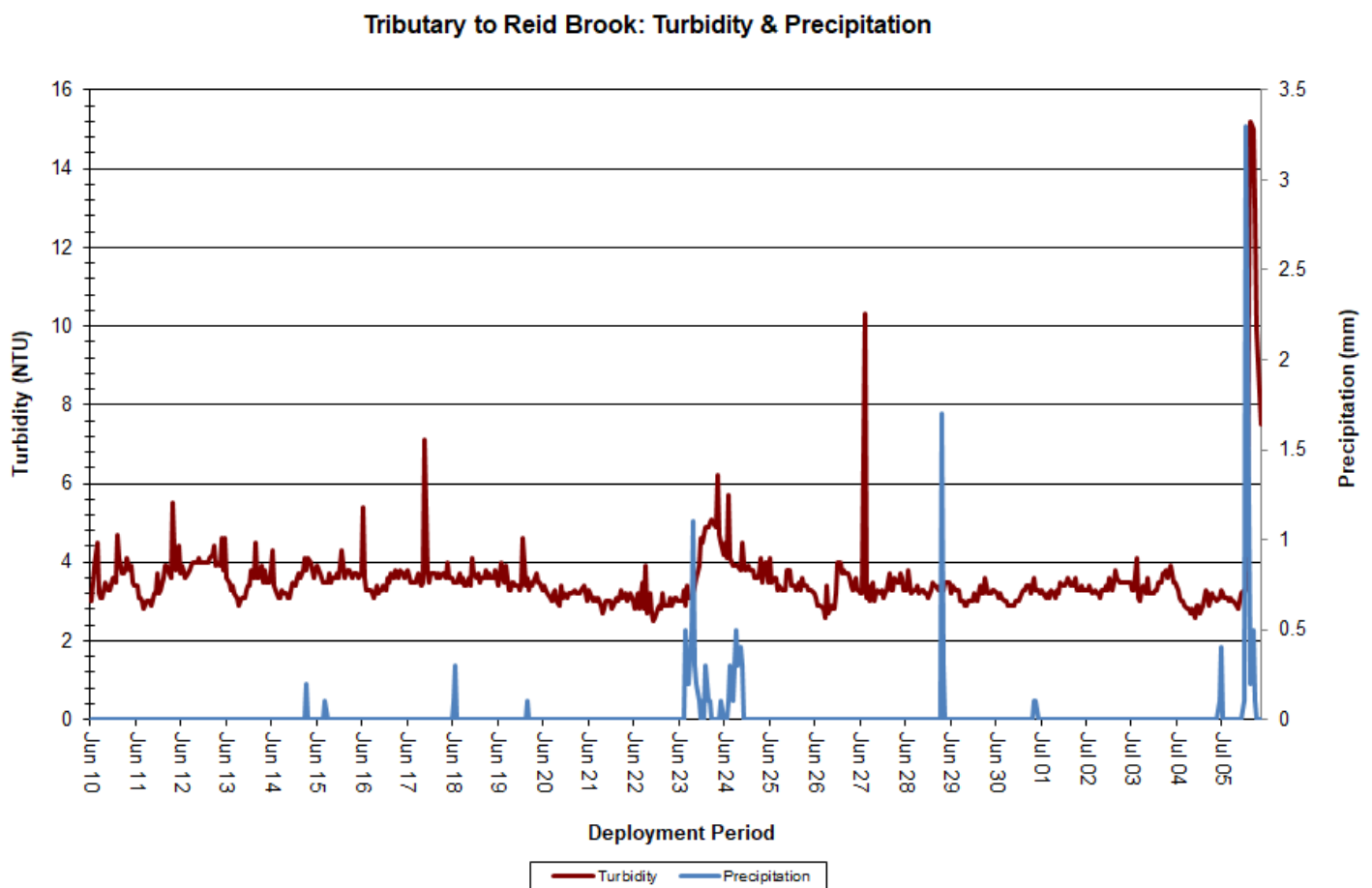


Figure 23: Turbidity & Precipitation at Tributary to Reid Brook

Stage and Flow

Stage and flow data are not available because there was an issue with the transmission of data from this station during deployment. All other data was obtained via the RTWQ instrument's internal log file.

Conclusions

Water temperatures across all stations ranged from a minimum of 2.49°C at Reid Brook at Outlet of Reid Pond to a maximum of 16.09°C at Camp Pond Brook below Camp Pond. Overall, water temperature was increasing across the network. Stations at Camp Pond Brook, Tributary to Reid Brook, and Reid Brook below Tributary are more sensitive to changes in ambient air temperatures as these sites are brooks with continuously moving water. In contrast, Reid Brook at Outlet of Reid Pond is a large pond with a high surface area and deeper, slower-moving water, and was ice-covered for the majority of this deployment period.

pH values across all stations ranged from a minimum of 5.70pH units at Camp Pond Brook below Camp Pond to a maximum of 7.11pH units at Tributary to Reid Brook. pH values at all stations were relatively consistent across the deployment period.

Specific conductivity across all stations ranged from a minimum of 8.5µS/cm at Reid Brook at Outlet of Reid Pond to a maximum of 31.6µS/cm at Camp Pond Brook below Camp Pond. Conductivity values at Reid Brook at Outlet of Reid Pond were the lowest across the network. Camp Pond Brook below Camp Pond had the highest median value at 28.3µS/cm, which is to be expected given the station's proximity to the Voisey's Bay mine site and increased potential for roadway runoff and other anthropogenic influences.

Dissolved oxygen levels across all stations ranged from a minimum of 9.68mg/L at Camp Pond Brook below Camp Pond to a maximum of 12.52mg/L at Reid Brook at Outlet of Reid Pond. Dissolved oxygen is generally higher at this time of year and varies diurnally as water temperature is greatly affected by ambient air temperature. Dissolved oxygen levels remained above the CCME's Guidelines for the Protection of Early and Other Life Stages at all stations for the duration of deployment.

Turbidity levels across all stations ranged from a minimum of 0.0 NTU at three stations to a maximum of 18.9NTU at Camp Pond Brook below Camp Pond. Turbidity levels showed natural increases and decreases generally corresponding to precipitation events.

Air temperature and precipitation data were obtained from the Voisey's Bay weather station, which is located at the airstrip. This data appears to be quite accurate and no modifications were made.

Overall, the changes in water quality parameters over the course of this deployment can be explained by natural events. Camp Pond Brook below Camp Pond does have the potential for anthropogenic influences as the site is the closest to the inhabited area. It is important to note that during a change (a decrease or increase) in water quality, change only occurs for a short period of time and then water quality parameters return to baseline.

References

- Canadian Council of Ministers of the Environment. (2014) "Canadian water quality guidelines for the protection of aquatic life" Canadian Council of Ministers of the Environment. Retrieved from: http://www.ccme.ca/en/resources/canadian_environmental_quality_guidelines/index.html
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- OTT Hydromet (2017) "Hydrolab" Retrieved from: <http://www.ott.com/en-us/products/water-quality-2/hydrolab-ds5x-multiparameter-data-sonde-855/>
- Mike Sader (2017) "Turbidity Measurement: A Simple, Effective Indicator of Water Quality Change". OTT Hydromet. Retrieved from <http://www.ott.com/en-us/products/download/turbidity-white-paper/>
- Swanson, H.A., and Baldwin, H.L., (1965) "A Primer on Water Quality" U.S. Geological Survey. Retrieved from: <http://ga.water.usgs.gov/edu/characteristics.html>

APPENDIX A: Comparison Graphs

Water Temperature at Real-Time Water Quality Monitoring Stations

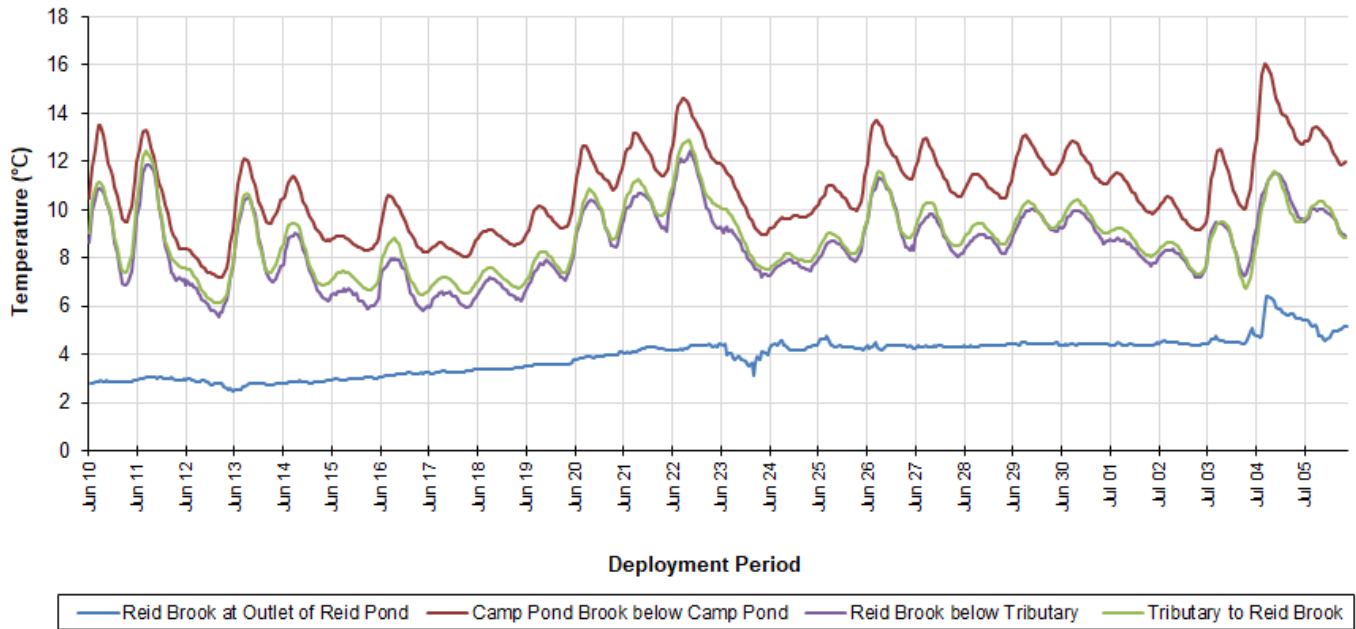


Figure A1: Comparison of Water Temperature (°C) between all Real-Time Stations in Voisey's Bay.

pH at Real-Time Water Quality Monitoring Stations

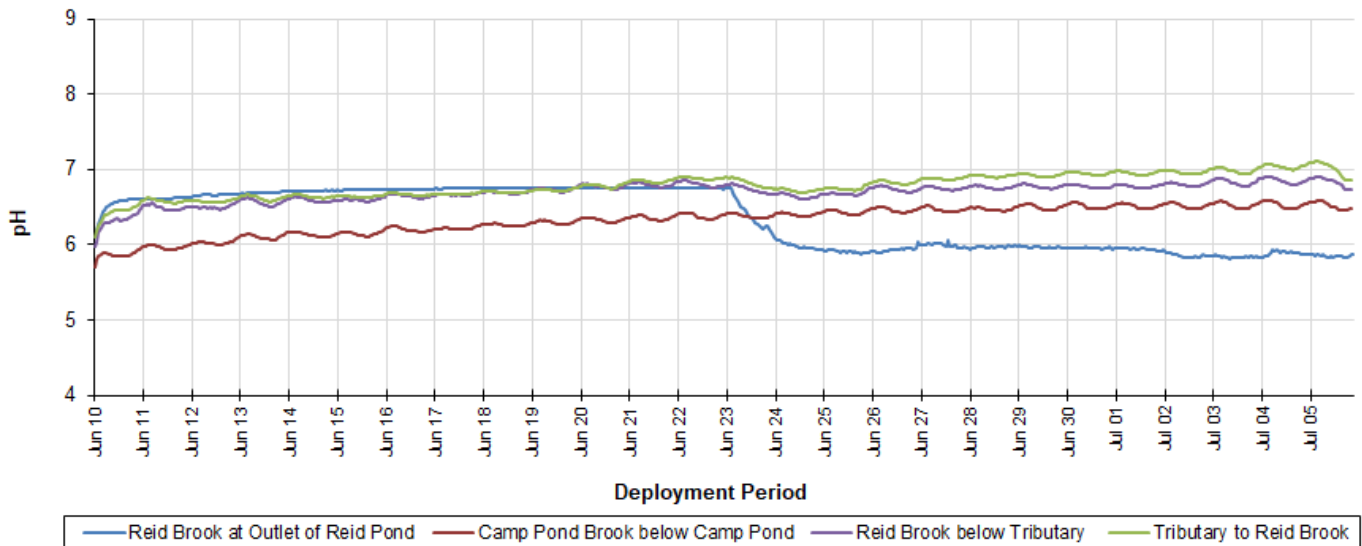


Figure A2: Comparison of pH between all Real-Time Stations in Voisey's Bay.

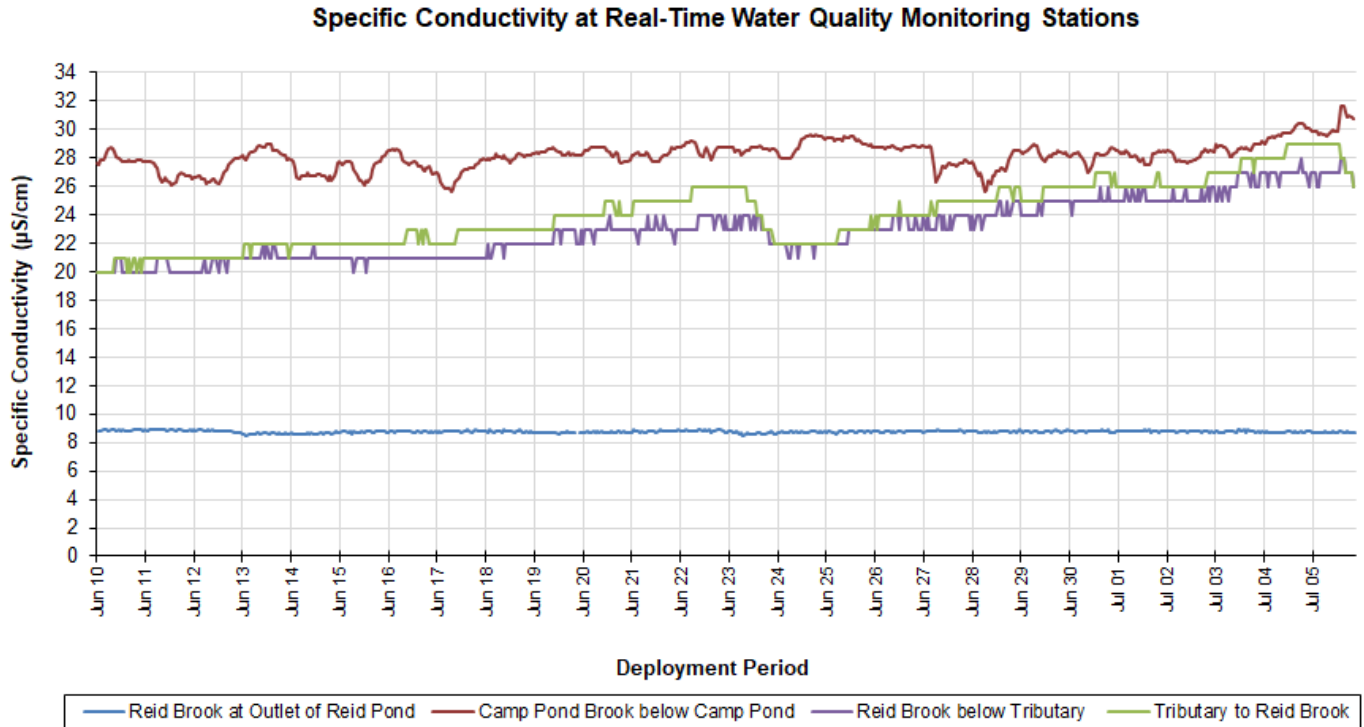


Figure A3: Comparison of Specific Conductivity ($\mu\text{S}/\text{cm}$) between all Real-Time Stations in Voisey's Bay.

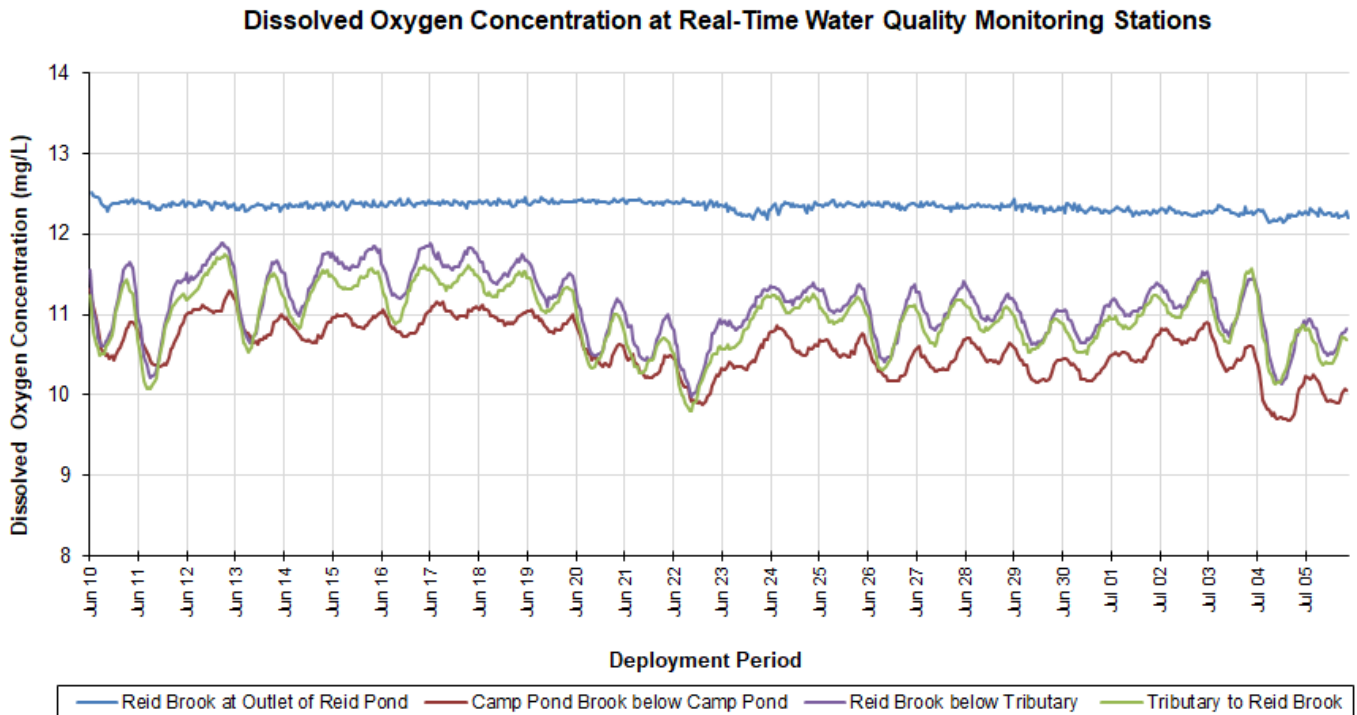


Figure A4: Comparison of Dissolved Oxygen (mg/L) between all Real-Time Stations in Voisey's Bay.

Dissolved Oxygen (% Saturation) at Real-Time Water Quality Monitoring Stations

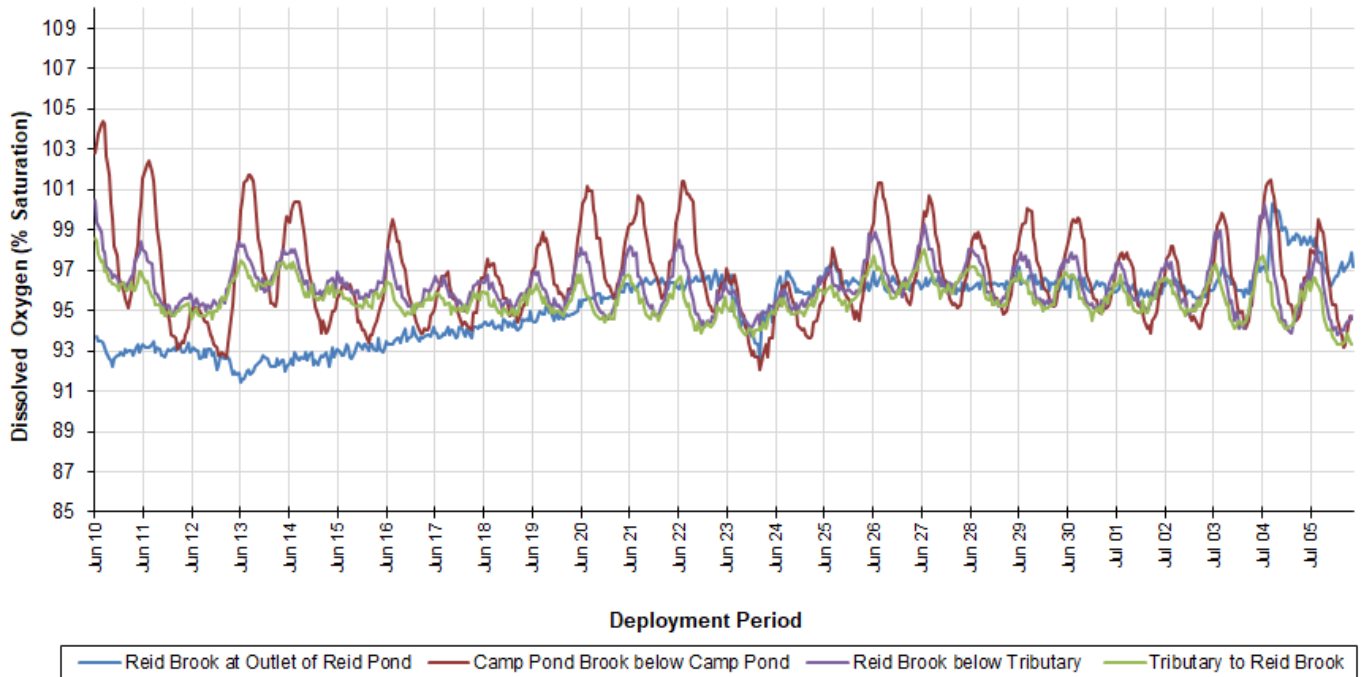


Figure A5: Comparison of Dissolved Oxygen (% Sat) between all Real-Time Stations in Voisey's Bay.

Turbidity at Real-Time Water Quality Monitoring Stations

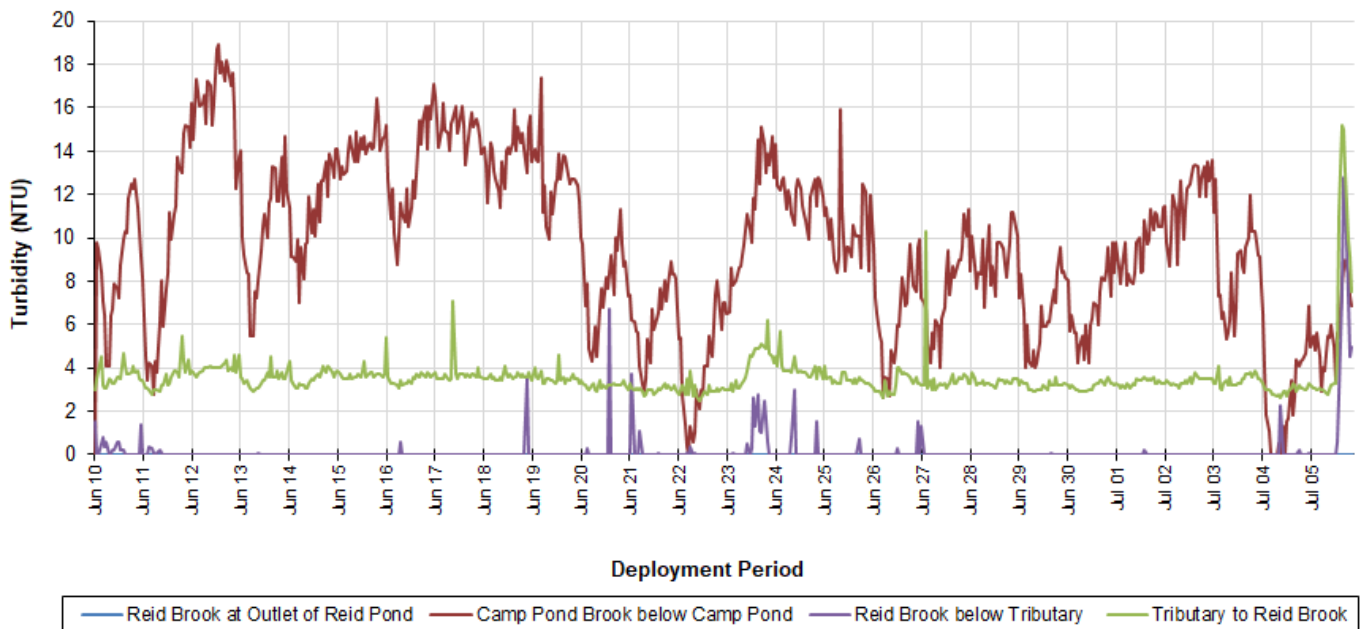


Figure A6: Comparison of Turbidity (NTU) between all Real-Time Stations in Voisey's Bay.

APPENDIX B: Water Parameter Description

Dissolved Oxygen: The amount of Dissolved Oxygen (DO) (mg/L or % saturation) in the water is vital to the survival of aquatic organisms. 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 (CCME 2014).

Flow: Flow (m³/s) is a measure of how quickly a volume of water is displaced in streams, rivers, and other channels.

pH: pH is the measure of hydrogen ion activity and affects: (i) the availability of nutrients to aquatic life; (ii) the concentration of biochemical substances dissolved in water; (iii) the efficiency of hemoglobin in the blood of vertebrates; and (iv) the toxicity of pollutants. Changes in pH can be attributed to industrial effluence, saline inflows or aquatic organisms involved in the photosynthetic cycling of CO₂ (CCME 2014).

Specific conductivity: Specific conductivity (μS/cm) is a measure of water's ability to conduct electricity, with values normalized to a water temperature of 25°C. 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 (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 (°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 (OTT Hydromet 2017).

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 (CCME 2014; 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 (Sadar, 2017).

APPENDIX C: Grab Sample Results

Client: Department of Environment

Attention: Ms. Leona Hyde

Client Project:

Purchase Order: 2180014303

COC Number: 844849

Date Reported: 2019-06-28

Date Submitted: 2019-06-17

Sample Matrix: Water

<u>LAB ID</u>	<u>Supply / Description</u>	<u>Client Sample ID</u>	<u>Sample Date</u>	<u>ANALYTE</u>	<u>UNIT</u>	<u>MRL</u>	<u>RESULT</u>
1433469	WS-S-0000 Redi Brook @ Outlet	2019-6400-00-SI-SP	2019-06-10	Alkalinity as CaCO3	mg/L	5	<5
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	<1
				Colour	TCU	2	10
				Conductivity	uS/cm	5	14
				Dissolved Organic Carbon	mg/L	0.5	1.9
				Fluoride	mg/L	0.10	<0.10
				Hardness as CaCO3	mg/L	1	2
				N-NH3 (Ammonia)	mg/L	0.010	<0.010
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	6.53
				Sulphate	mg/L	1	1
				Total Dissolved Solids (COND - CALC)	mg/L	1	9
				Total Kjeldahl Nitrogen	mg/L	0.15	<0.15
				Total Organic Carbon	mg/L	0.5	2.2
				Turbidity	NTU	0.1	0.5
				Aluminum	mg/L	0.01	0.05

Sample comment:

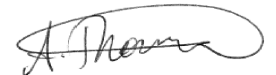
Holding time for N-NO2, N-NO3 analysis was exceeded.

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at <http://www.cala.ca/scopes/2602.pdf>.

Results relate only to the parameters tested on the samples submitted.

Methods references and/or additional QA/QC information available on request.



APPROVAL: _____

Addrine Thomas

Client: Department of Environment
Attention: Ms. Leona Hyde
Client Project:
Purchase Order: 2180014303

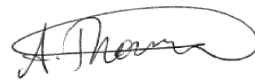
COC Number: 844849
Date Reported: 2019-06-28
Date Submitted: 2019-06-17
Sample Matrix: Water

<u>LAB ID</u>	<u>Supply / Description</u>	<u>Client Sample ID</u>	<u>Sample Date</u>	<u>ANALYTE</u>	<u>UNIT</u>	<u>MRL</u>	<u>RESULT</u>
1433469	WS-S-0000 Redi Brook @ Outlet	2019-6400-00-SI-SP	2019-06-10	Antimony	mg/L	0.0005	<0.0005
				Arsenic	mg/L	0.001	<0.001
				Barium	mg/L	0.01	<0.01
				Boron	mg/L	0.01	<0.01
				Calcium	mg/L	1	1
				Cadmium	mg/L	0.0001	<0.0001
				Chromium	mg/L	0.001	<0.001
				Copper	mg/L	0.001	<0.001
				Iron	mg/L	0.03	<0.03
				Lead	mg/L	0.001	<0.001
				Magnesium	mg/L	1	<1
				Manganese	mg/L	0.01	<0.01
				Mercury	mg/L	0.0001	<0.0001
				Nickel	mg/L	0.005	<0.005
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	<2
				Strontium	mg/L	0.001	0.005

Sample comment:
Holding time for N-NO2, N-NO3 analysis was exceeded.

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at <http://www.cala.ca/scopes/2602.pdf>.
Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

APPROVAL: 
Addrine Thomas

Client: Department of Environment

Attention: Ms. Leona Hyde

Client Project:

Purchase Order: 2180014303

COC Number: 844849

Date Reported: 2019-06-28

Date Submitted: 2019-06-17

Sample Matrix: Water

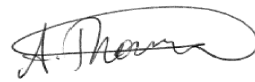
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1433469	WS-S-0000 Redi Brook @ Outlet	2019-6400-00-SI-SP	2019-06-10	Uranium	mg/L	0.001	<0.001
				Zinc	mg/L	0.01	<0.01
				Phosphorus	mg/L	0.002	<0.002
				Total Suspended Solids	mg/L	2	<2

Sample comment:

Holding time for N-NO₂, N-NO₃ analysis was exceeded.

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at <http://www.cala.ca/scopes/2602.pdf>.
 Results relate only to the parameters tested on the samples submitted.
 Methods references and/or additional QA/QC information available on request.

APPROVAL: 
 Addrine Thomas

Client: Department of Environment
Attention: Ms. Leona Hyde
Client Project:
Purchase Order: 2180014303

COC Number: 844849
Date Reported: 2019-06-28
Date Submitted: 2019-06-17
Sample Matrix: Water

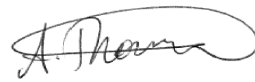
<u>LAB ID</u>	<u>Supply / Description</u>	<u>Client Sample ID</u>	<u>Sample Date</u>	<u>ANALYTE</u>	<u>UNIT</u>	<u>MRL</u>	<u>RESULT</u>
1433470	WS-S-0000 Camp Pond Brook	2019-6401-00-SI-SP	2019-06-10	Alkalinity as CaCO3	mg/L	5	7
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	2
				Colour	TCU	2	26
				Conductivity	uS/cm	5	33
				Dissolved Organic Carbon	mg/L	0.5	3.8
				Fluoride	mg/L	0.10	<0.10
				Hardness as CaCO3	mg/L	1	7
				N-NH3 (Ammonia)	mg/L	0.010	<0.010
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	6.88
				Sulphate	mg/L	1	3
				Total Dissolved Solids (COND - CALC)	mg/L	1	21
				Total Kjeldahl Nitrogen	mg/L	0.15	<0.15
				Total Organic Carbon	mg/L	0.5	3.6
				Turbidity	NTU	0.1	0.8
				Aluminum	mg/L	0.01	0.07

Sample comment:

Holding time for N-NO2, N-NO3 analysis was exceeded.

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at <http://www.cala.ca/scopes/2602.pdf>.
 Results relate only to the parameters tested on the samples submitted.
 Methods references and/or additional QA/QC information available on request.

APPROVAL: 
 Addrine Thomas

Client: Department of Environment
Attention: Ms. Leona Hyde
Client Project:
Purchase Order: 2180014303

COC Number: 844849
Date Reported: 2019-06-28
Date Submitted: 2019-06-17
Sample Matrix: Water

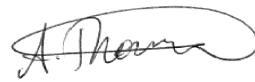
<u>LAB ID</u>	<u>Supply / Description</u>	<u>Client Sample ID</u>	<u>Sample Date</u>	<u>ANALYTE</u>	<u>UNIT</u>	<u>MRL</u>	<u>RESULT</u>
1433470	WS-S-0000 Camp Pond Brook	2019-6401-00-SI-SP	2019-06-10	Antimony	mg/L	0.0005	<0.0005
				Arsenic	mg/L	0.001	<0.001
				Barium	mg/L	0.01	<0.01
				Boron	mg/L	0.01	<0.01
				Calcium	mg/L	1	3
				Cadmium	mg/L	0.0001	<0.0001
				Chromium	mg/L	0.001	<0.001
				Copper	mg/L	0.001	0.003
				Iron	mg/L	0.03	0.19
				Lead	mg/L	0.001	<0.001
				Magnesium	mg/L	1	<1
				Manganese	mg/L	0.01	0.01
				Mercury	mg/L	0.0001	<0.0001
				Nickel	mg/L	0.005	0.024
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	<2
				Strontium	mg/L	0.001	0.015

Sample comment:

Holding time for N-NO2, N-NO3 analysis was exceeded.

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at <http://www.cala.ca/scopes/2602.pdf>.
 Results relate only to the parameters tested on the samples submitted.
 Methods references and/or additional QA/QC information available on request.

APPROVAL: 
 Addrine Thomas

Client: Department of Environment

Attention: Ms. Leona Hyde

Client Project:

Purchase Order: 2180014303

COC Number: 844849

Date Reported: 2019-06-28

Date Submitted: 2019-06-17

Sample Matrix: Water

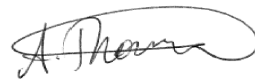
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1433470	WS-S-0000 Camp Pond Brook	2019-6401-00-SI-SP	2019-06-10	Uranium	mg/L	0.001	<0.001
				Zinc	mg/L	0.01	<0.01
				Phosphorus	mg/L	0.002	0.003
				Total Suspended Solids	mg/L	2	<2

Sample comment:

Holding time for N-NO₂, N-NO₃ analysis was exceeded.

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at <http://www.cala.ca/scopes/2602.pdf>.
 Results relate only to the parameters tested on the samples submitted.
 Methods references and/or additional QA/QC information available on request.

APPROVAL: 
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Client: Department of Environment
Attention: Ms. Leona Hyde
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Purchase Order: 2180014303

COC Number: 844849
Date Reported: 2019-06-28
Date Submitted: 2019-06-17
Sample Matrix: Water

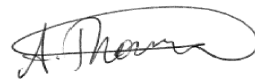
<u>LAB ID</u>	<u>Supply / Description</u>	<u>Client Sample ID</u>	<u>Sample Date</u>	<u>ANALYTE</u>	<u>UNIT</u>	<u>MRL</u>	<u>RESULT</u>
1433472	WS-S-0000 Reid Brook below Tributary	2019-6403-00-SI-SP	2019-06-10	Alkalinity as CaCO3	mg/L	5	<5
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	1
				Colour	TCU	2	43
				Conductivity	uS/cm	5	22
				Dissolved Organic Carbon	mg/L	0.5	5.2
				Fluoride	mg/L	0.10	<0.10
				Hardness as CaCO3	mg/L	1	5
				N-NH3 (Ammonia)	mg/L	0.010	<0.010
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	6.60
				Sulphate	mg/L	1	2
				Total Dissolved Solids (COND - CALC)	mg/L	1	14
				Total Kjeldahl Nitrogen	mg/L	0.15	0.16
				Total Organic Carbon	mg/L	0.5	5.2
				Turbidity	NTU	0.1	1.8
				Aluminum	mg/L	0.01	0.12

Sample comment:

Holding time for (Turbidity) analysis was exceeded for the entire report. Holding time for N-NO2, N-NO3 analysis was exceeded.

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at <http://www.cala.ca/scopes/2602.pdf>.
 Results relate only to the parameters tested on the samples submitted.
 Methods references and/or additional QA/QC information available on request.

APPROVAL: 
 Addrine Thomas

Client: Department of Environment
Attention: Ms. Leona Hyde
Client Project:
Purchase Order: 2180014303

COC Number: 844849
Date Reported: 2019-06-28
Date Submitted: 2019-06-17
Sample Matrix: Water

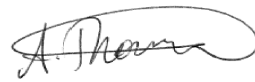
<u>LAB ID</u>	<u>Supply / Description</u>	<u>Client Sample ID</u>	<u>Sample Date</u>	<u>ANALYTE</u>	<u>UNIT</u>	<u>MRL</u>	<u>RESULT</u>
1433472	WS-S-0000 Reid Brook below Tributary	2019-6403-00-SI-SP	2019-06-10	Antimony	mg/L	0.0005	<0.0005
				Arsenic	mg/L	0.001	<0.001
				Barium	mg/L	0.01	<0.01
				Boron	mg/L	0.01	<0.01
				Calcium	mg/L	1	2
				Cadmium	mg/L	0.0001	<0.0001
				Chromium	mg/L	0.001	<0.001
				Copper	mg/L	0.001	0.001
				Iron	mg/L	0.03	0.28
				Lead	mg/L	0.001	<0.001
				Magnesium	mg/L	1	<1
				Manganese	mg/L	0.01	<0.01
				Mercury	mg/L	0.0001	<0.0001
				Nickel	mg/L	0.005	0.006
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	<2
				Strontium	mg/L	0.001	0.011

Sample comment:

Holding time for (Turbidity) analysis was exceeded for the entire report. Holding time for N-NO₂, N-NO₃ analysis was exceeded.

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at <http://www.cala.ca/scopes/2602.pdf>. Results relate only to the parameters tested on the samples submitted. Methods references and/or additional QA/QC information available on request.

APPROVAL: 
 Addrine Thomas

Client: Department of Environment

Attention: Ms. Leona Hyde

Client Project:

Purchase Order: 2180014303

COC Number: 844849

Date Reported: 2019-06-28

Date Submitted: 2019-06-17

Sample Matrix: Water

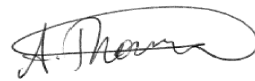
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1433472	WS-S-0000 Reid Brook below Tributary	2019-6403-00-SI-SP	2019-06-10	Uranium	mg/L	0.001	<0.001
				Zinc	mg/L	0.01	<0.01
				Phosphorus	mg/L	0.002	0.005
				Total Suspended Solids	mg/L	2	<2

Sample comment:

Holding time for (Turbidity) analysis was exceeded for the entire report. Holding time for N-NO₂, N-NO₃ analysis was exceeded.

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at <http://www.cala.ca/scopes/2602.pdf>.
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 Methods references and/or additional QA/QC information available on request.

APPROVAL: 
 Addrine Thomas

Client: Department of Environment
Attention: Ms. Leona Hyde
Client Project:
Purchase Order: 2180014303

COC Number: 844849
Date Reported: 2019-06-28
Date Submitted: 2019-06-17
Sample Matrix: Water

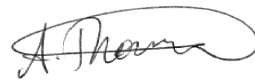
<u>LAB ID</u>	<u>Supply / Description</u>	<u>Client Sample ID</u>	<u>Sample Date</u>	<u>ANALYTE</u>	<u>UNIT</u>	<u>MRL</u>	<u>RESULT</u>
1433471	WS-S-0000 Tributary to Reid Brook	2019-6402-00-SI-SP	2019-06-10	Alkalinity as CaCO3	mg/L	5	<5
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	1
				Colour	TCU	2	45
				Conductivity	uS/cm	5	22
				Dissolved Organic Carbon	mg/L	0.5	5.5
				Fluoride	mg/L	0.10	<0.10
				Hardness as CaCO3	mg/L	1	5
				N-NH3 (Ammonia)	mg/L	0.010	<0.010
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	6.60
				Sulphate	mg/L	1	2
				Total Dissolved Solids (COND - CALC)	mg/L	1	14
				Total Kjeldahl Nitrogen	mg/L	0.15	<0.15
				Total Organic Carbon	mg/L	0.5	5.5
				Turbidity	NTU	0.1	1.1
				Aluminum	mg/L	0.01	0.12

Sample comment:

Holding time for N-NO2, N-NO3 analysis was exceeded.

Report comment:

Eurofins (Ottawa) is accredited for specific parameters by CALA. The scope can be viewed at <http://www.cala.ca/scopes/2602.pdf>.
 Results relate only to the parameters tested on the samples submitted.
 Methods references and/or additional QA/QC information available on request.

APPROVAL: 
 Addrine Thomas

Client: Department of Environment
Attention: Ms. Leona Hyde
Client Project:
Purchase Order: 2180014303

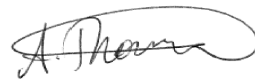
COC Number: 844849
Date Reported: 2019-06-28
Date Submitted: 2019-06-17
Sample Matrix: Water

<u>LAB ID</u>	<u>Supply / Description</u>	<u>Client Sample ID</u>	<u>Sample Date</u>	<u>ANALYTE</u>	<u>UNIT</u>	<u>MRL</u>	<u>RESULT</u>
1433471	WS-S-0000 Tributary to Reid Brook	2019-6402-00-SI-SP	2019-06-10	Antimony	mg/L	0.0005	<0.0005
				Arsenic	mg/L	0.001	<0.001
				Barium	mg/L	0.01	<0.01
				Boron	mg/L	0.01	<0.01
				Calcium	mg/L	1	2
				Cadmium	mg/L	0.0001	<0.0001
				Chromium	mg/L	0.001	<0.001
				Copper	mg/L	0.001	0.001
				Iron	mg/L	0.03	0.31
				Lead	mg/L	0.001	<0.001
				Magnesium	mg/L	1	<1
				Manganese	mg/L	0.01	<0.01
				Mercury	mg/L	0.0001	<0.0001
				Nickel	mg/L	0.005	0.006
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	<2
				Strontium	mg/L	0.001	0.011

Sample comment:
Holding time for N-NO2, N-NO3 analysis was exceeded.

Report comment:

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Methods references and/or additional QA/QC information available on request.

APPROVAL: 

Addrine Thomas

Client: Department of Environment
Attention: Ms. Leona Hyde
Client Project:
Purchase Order: 2180014303

COC Number: 844849
Date Reported: 2019-06-28
Date Submitted: 2019-06-17
Sample Matrix: Water

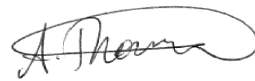
<u>LAB ID</u>	<u>Supply / Description</u>	<u>Client Sample ID</u>	<u>Sample Date</u>	<u>ANALYTE</u>	<u>UNIT</u>	<u>MRL</u>	<u>RESULT</u>
1433471	WS-S-0000 Tributary to Reid Brook	2019-6402-00-SI-SP	2019-06-10	Uranium	mg/L	0.001	<0.001
				Zinc	mg/L	0.01	<0.01
				Phosphorus	mg/L	0.002	0.005
				Total Suspended Solids	mg/L	2	2

Sample comment:

Holding time for N-NO₂, N-NO₃ analysis was exceeded.

Report comment:

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 Methods references and/or additional QA/QC information available on request.

APPROVAL: 
 Addrine Thomas