Real-Time Water Quality Deployment Report

Voisey's Bay Network

September 9 to October 9, 2018

Newfoundland Labrador

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 monitors 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 of Reid Pond; Camp Pond Brook below Camp Pond; Tributary to Reid Brook; and Reid Brook below Tributary.

On September 9th, 2018, Vale Environment and Water Resources Management 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 and Water Resources Management Staff on October 9th, 2018. This was the third and final deployment for the 2018 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 alongside the field instrument. Values for temperature, pH, conductivity, dissolved oxygen and turbidity are compared between the two instruments**.** Based on the degree of difference between parameters recorded by the field instrument and 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

	Rank				
Parameter	**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	September 9	Deployment	Excellent	Marginal	Excellent	Excellent	Excellent
	October 9	Removal	Excellent	Excellent	Excellent	Good	Good
Camp Pond Brook	September 9	Deployment	Excellent	Marginal	Good	Excellent	Poor
	October 9	Removal	Excellent	Fair	Fair	Excellent	Poor
Reid Brook below Tributary	September 9	Deployment	Excellent	Fair	Excellent	Excellent	Excellent
	October 9	Removal	Excellent	Poor	Good	Good	Excellent
Tributary to Reid Brook	September 9	Deployment	Excellent	Good	Good	Excellent	Poor
	October 9	Removal	Excellent	Fair	Poor	Excellent	Poor

Reid Brook at Outlet of Reid Pond

- At deployment, temperature, conductivity, dissolved oxygen, and turbidity were all 'excellent', while pH was 'marginal'. The discrepancy in pH values may be attributable to the instrument not having sufficient time to acclimate, or to the QA/QC instrument not being placed close enough to the field sonde.
- At removal, all parameters ranked as either 'excellent' or 'good'.

Camp Pond Brook below Camp Pond

- At deployment, temperature and dissolved oxygen ranked as 'excellent', conductivity was 'good', pH was 'marginal', and turbidity was 'poor'.
- At removal, temperature and dissolved oxygen were 'excellent', pH and conductivity were 'fair', and turbidity was 'poor'. The 'poor' ranking for turbidity at both deployment and removal may be indicative of a calibration error with the field sonde. This is supported by similar and much lower turbidity levels reported by the QA/QC sonde and grab sample.

Reid Brook below Tributary

- At deployment, pH was 'fair', while all other parameters ranked as 'excellent'.
- At removal, temperature and turbidity were 'excellent', conductivity and dissolved oxygen were 'good', and pH was poor. This discrepancy may be attributable to the QA/QC instrument not having sufficient time to acclimate or not being placed close enough to the field sonde.

Tributary to Reid Brook

- At deployment, temperature and dissolved oxygen were 'excellent', pH and conductivity were 'good', while turbidity was 'poor'.
- At removal, temperature and dissolved oxygen were 'excellent', pH was 'fair', while both conductivity and turbidity ranked as 'poor'. The 'poor' ranking for turbidity at both deployment and removal is indicative of a calibration error with the field sonde, and this data has been removed from the dataset.

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 September 9th to October 9th, 2018 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.

Re

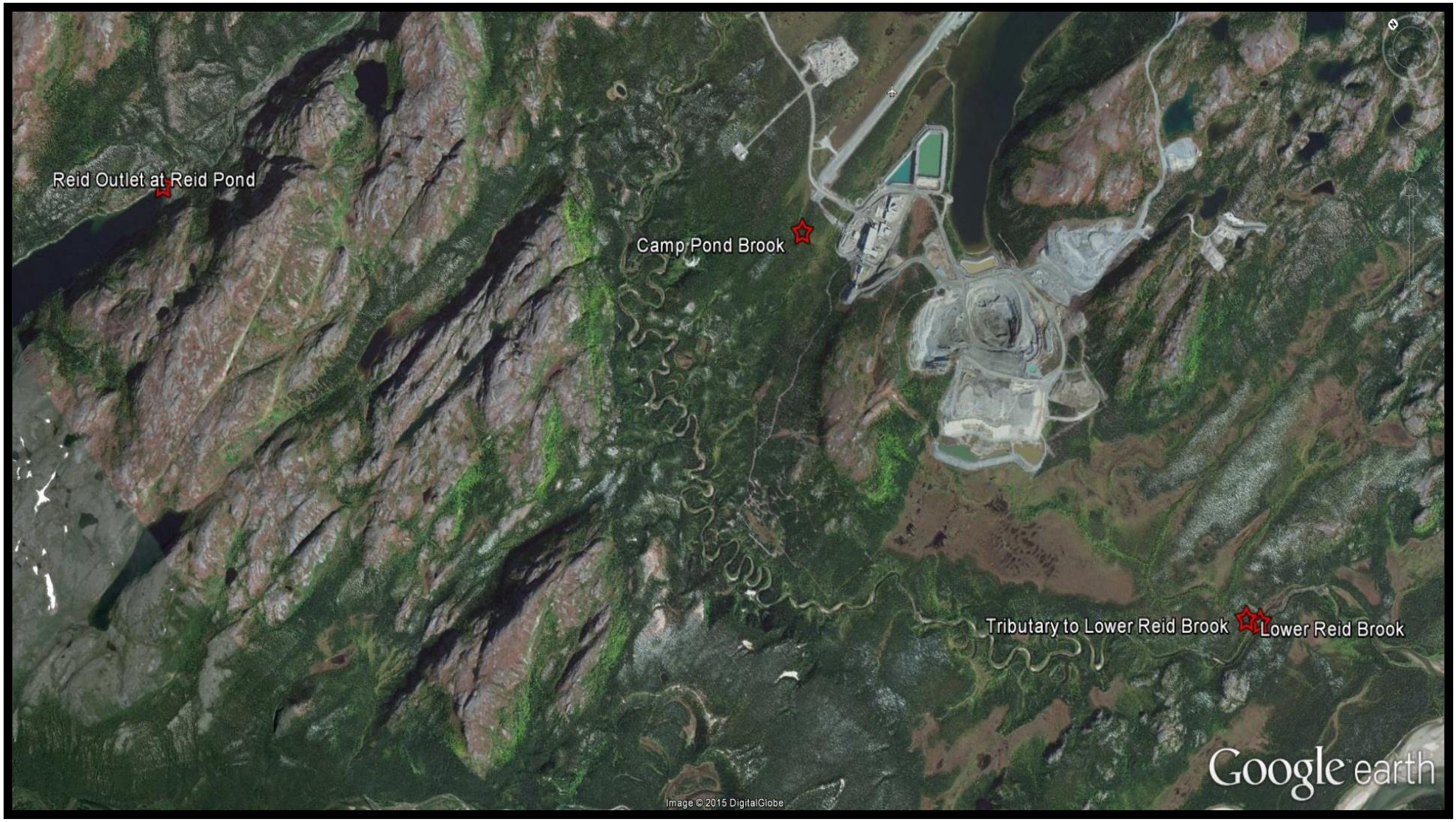

Figure 1: Voisey's Bay Network Station Locations

Re

Reid Brook at Outlet of Reid Pond

Water Temperature

Over the deployment period, water temperature ranged from 4.91°C to 10.75°C, with a median value of 7.57°C (Figure 2). Water temperature increased slightly during the first few days of deployment, corresponding closely to warmer air temperatures; however, from September 13th onward, water temperatures decreased steadily. This is to be expected as ambient air temperatures were also decreasing during this time (Figure 2). 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.

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.

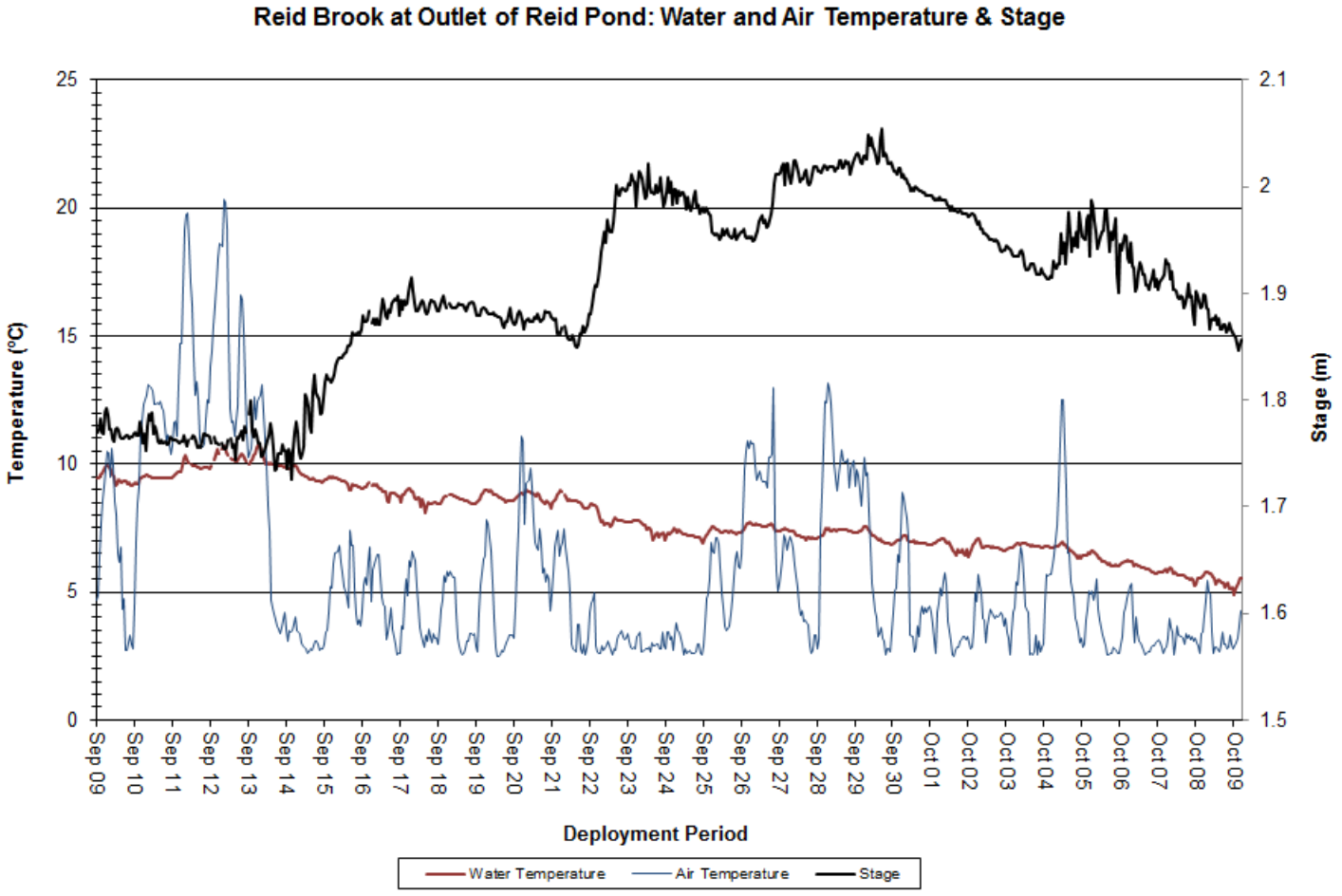

Figure 2: Water and Air Temperature & Stage at Reid Brook at Outlet of Reid Pond

pH

Over the deployment period, pH values ranged from 6.75 pH units to 7.51 pH units, with a median value of 7.06 pH units (Figure 3).

pH levels were quite consistent and remained within the CCME's Guidelines for the Protection of Aquatic Life for the duration 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.

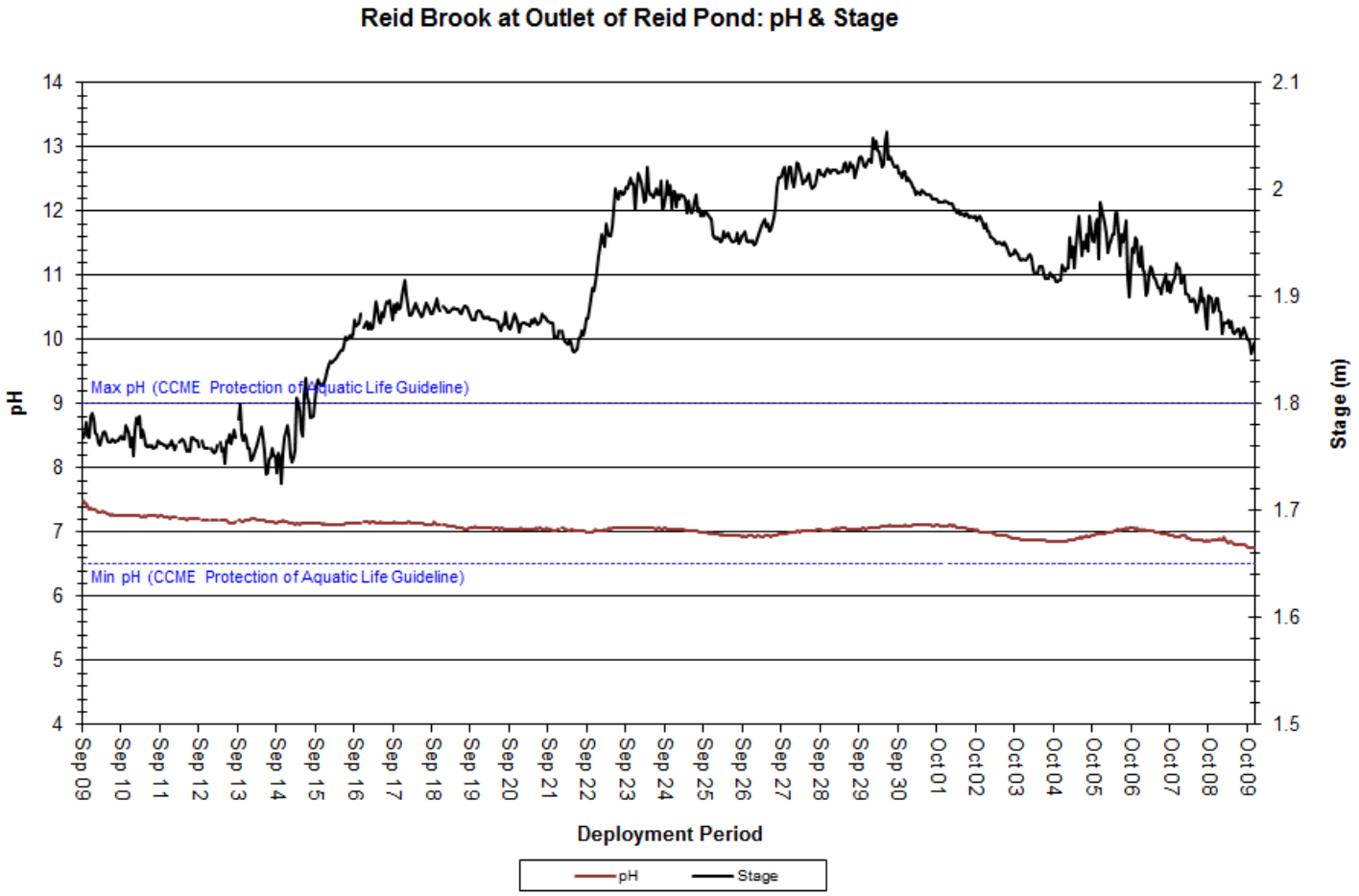

Figure 3: pH & Stage at Reid Brook at Outlet of Reid Pond

Specific Conductivity

Over the deployment period, specific conductivity levels ranged from 11.3µS/cm to 16.9µS/cm, with a median value of 12.5µS/cm (Figure 4). Conductivity at Reid Brook remained relatively 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.

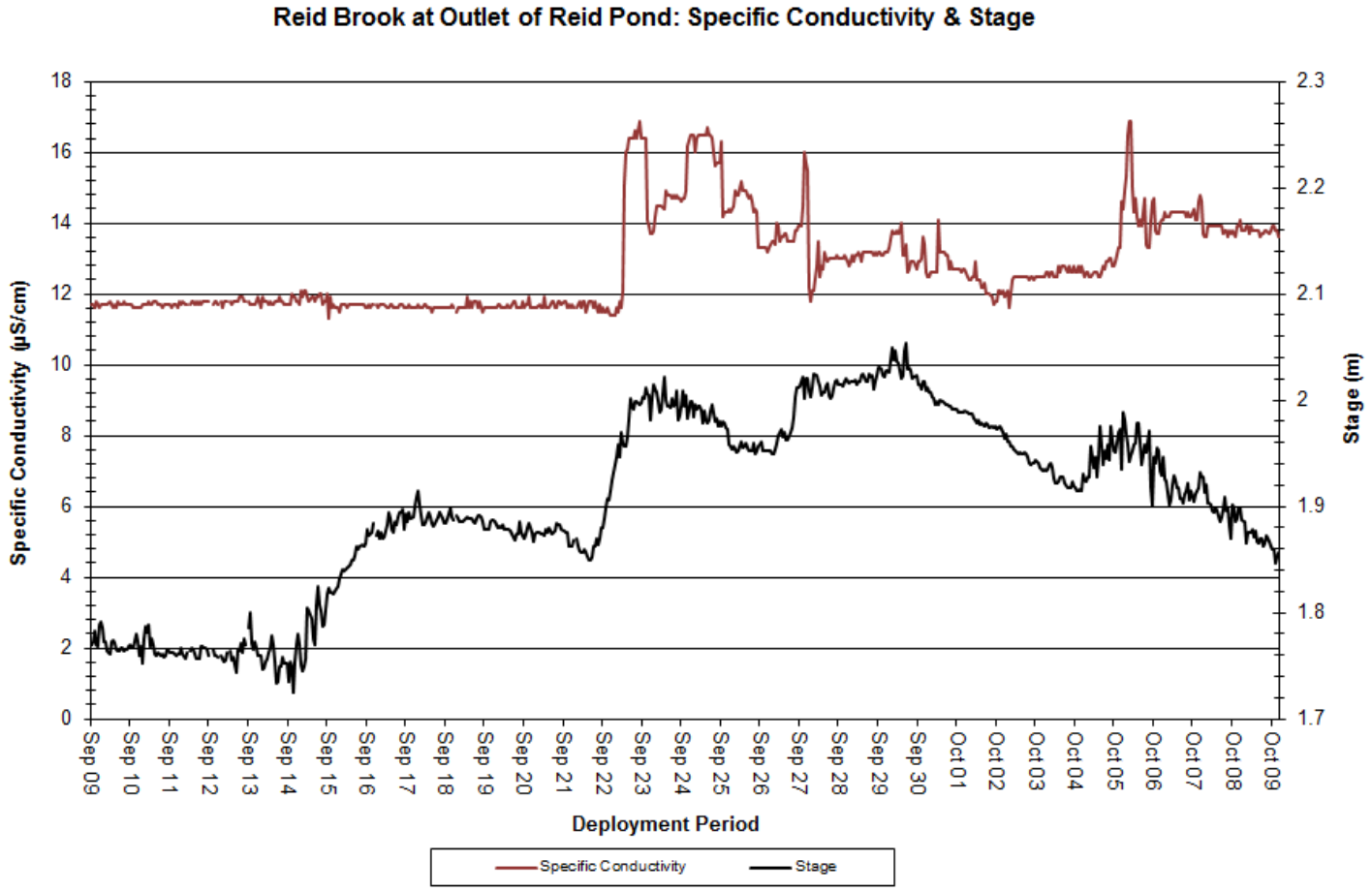

Figure 4: Specific Conductivity & Stage at Reid Brook at Outlet of Reid Pond

Dissolved Oxygen

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.

Over the deployment period, dissolved oxygen concentrations ranged from 10.72mg/L to 11.81mg/L, with a median value of 11.17mg/L. Percent saturation levels for dissolved oxygen ranged from 91.6% saturation to 98.8% saturation, with a median value of 93.6% saturation (Figure 5).

Dissolved oxygen concentration remained above the CCME's Guideline for the Protection of Early Life Stages (9.5 mg/L) for the duration of deployment. As ambient air temperatures decreased, there was a natural decrease in water temperature, which in turn resulted in a slight increase in dissolved oxygen concentration over the course of deployment (Figure 5).

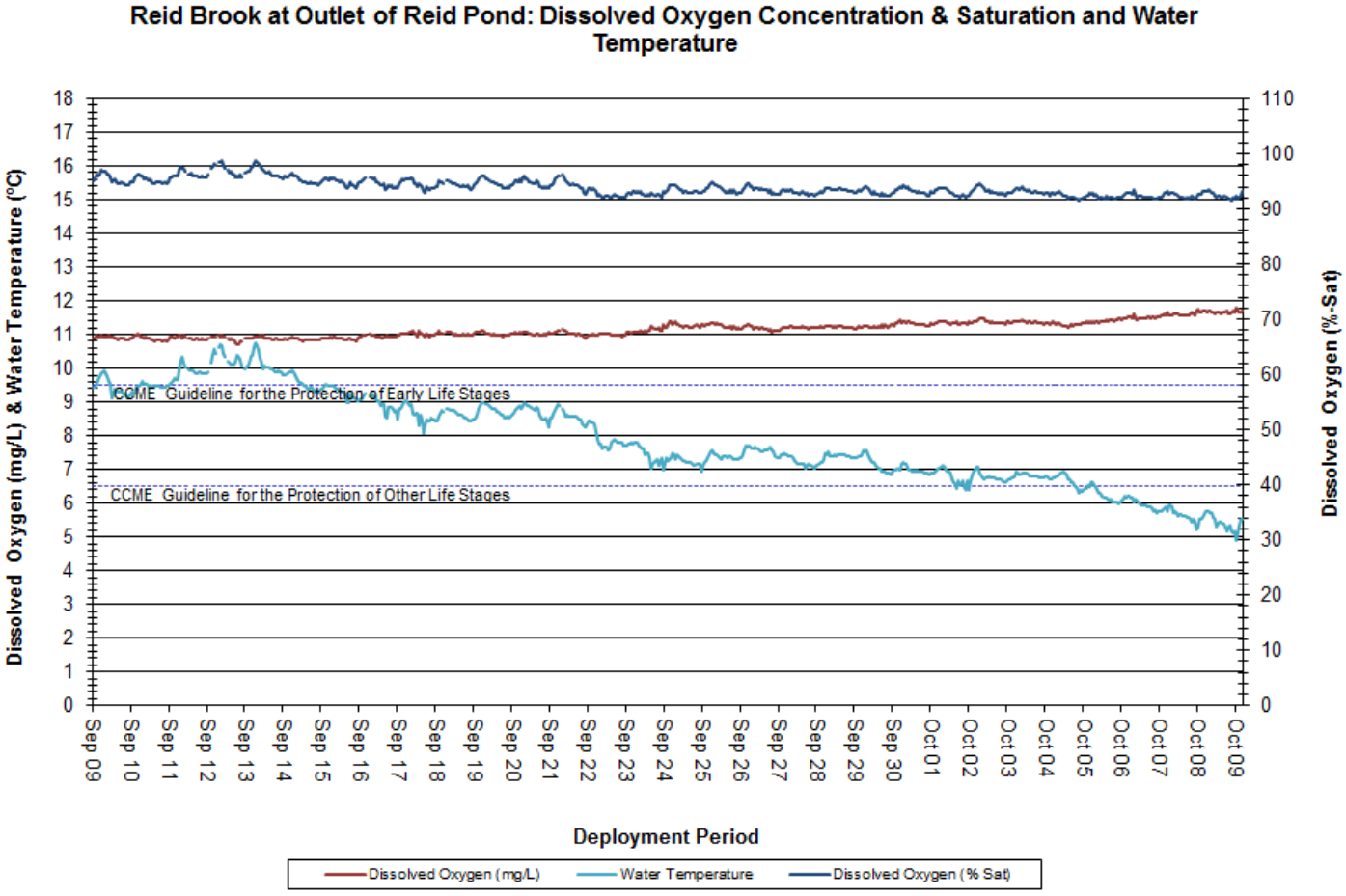

Figure 5: Dissolved Oxygen Concentration and Saturation & Water Temperature at Reid Brook at Outlet of Reid Pond

Turbidity

Over the deployment period, turbidity levels ranged from 1.3NTU to 11.7NTU, with a median value of 1.8NTU (Figure 6). A median value of 1.8NTU indicates that there was a small amount of natural 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 levels observed during deployment were very stable with only slight increases, which were often associated with precipitation events (Figure 6).

Turbidity values can also increase when there is a decrease in water level, which causes natural material in the water body to become concentrated.

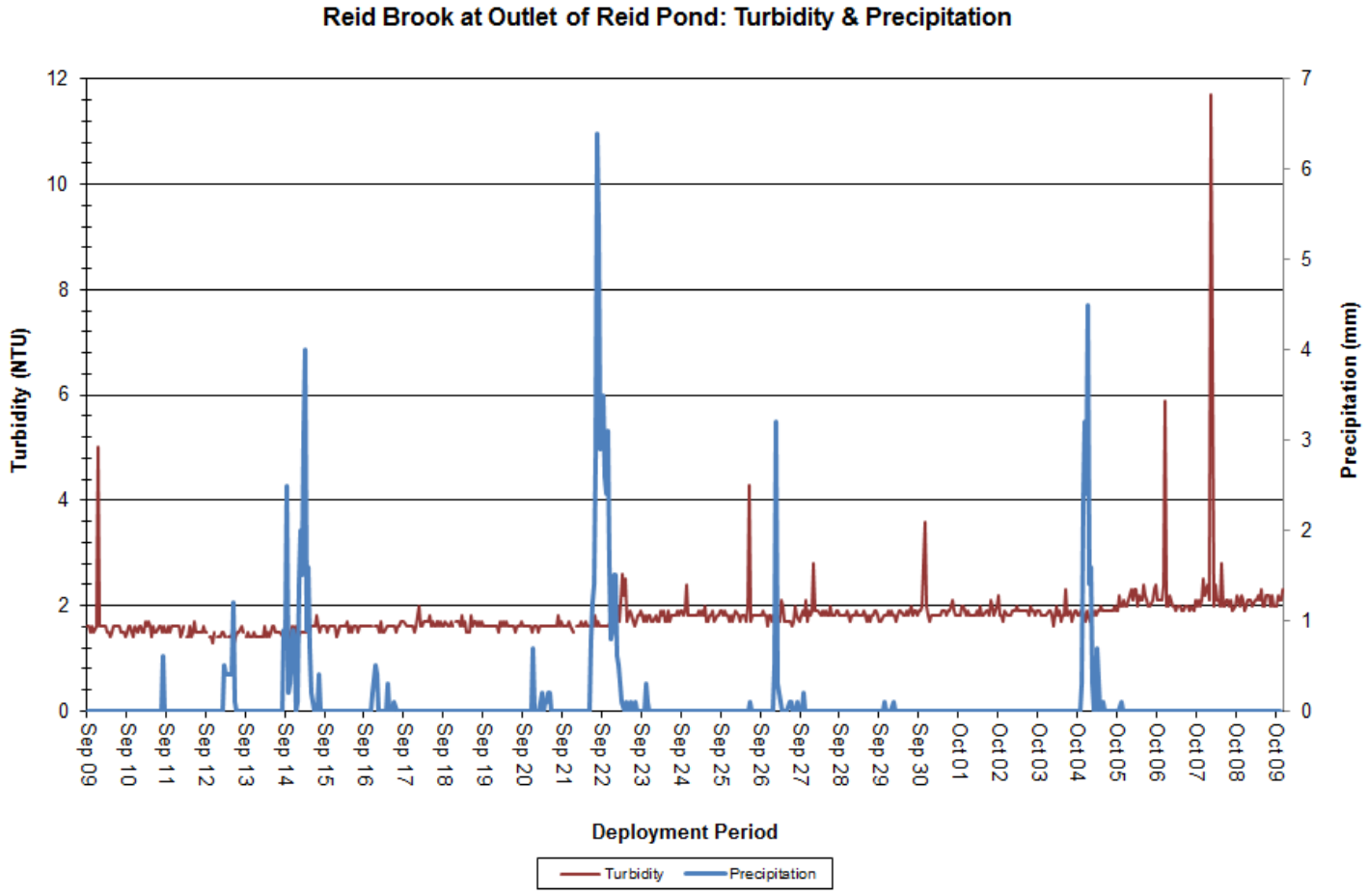

Figure 6: Turbidity & Precipitation at Reid Brook at Outlet of Reid Pond

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). Both stage and flow 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 and flow.

Over the deployment period, stage ranged from 1.73m to 2.05m, with a median value of 1.91m. Flow values ranged from 1.05m^3/s to 3.99m^3/s, with a median value of 2.39m^3/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.

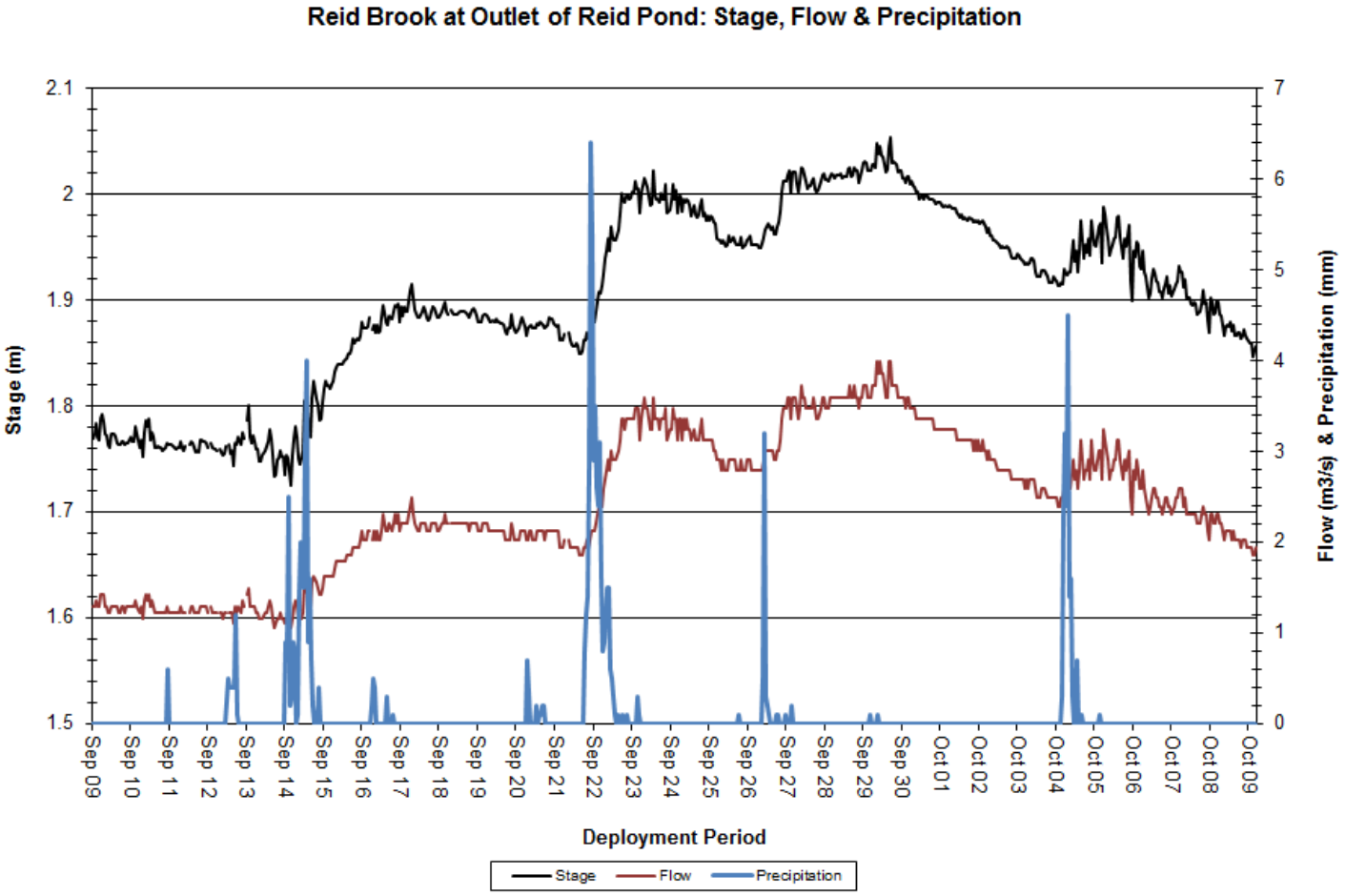

Figure 7: Stage, Flow & Precipitation at Reid Brook at Outlet of Reid Pond

Camp Pond Brook below Camp Pond

Water Temperature

Over the deployment period, water temperature ranged from 1.18°C to 13.07°C, with a median value of 6.24°C (Figure 8).

Water temperature at this station displays diurnal variations. There was a slight increase in water temperature at the start of deployment, followed by a gradual decrease over the remainder of the deployment period. This is to be expected as air temperatures showed a very similar trend (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.

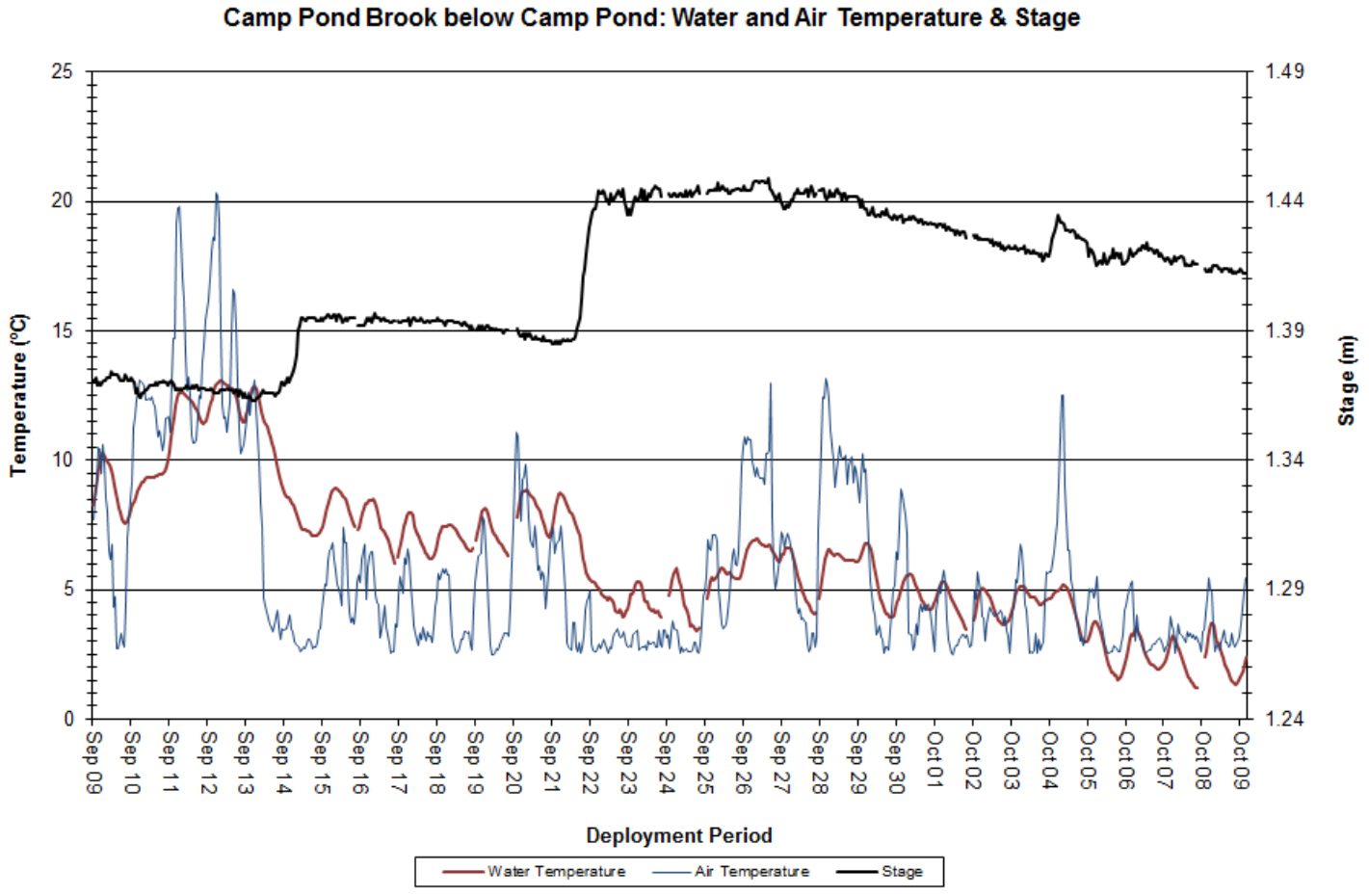

Figure 8: Water and Air Temperature & Stage at Camp Pond Brook below Camp Pond

pH

Over the deployment period, pH values ranged from 6.70 pH units to 7.07 pH units, with a median value of 6.95 pH units (Figure 9).

pH levels were quite consistent for the duration of deployment. pH levels remained within the CCME's Guidelines for Protection of Aquatic Life for the duration of deployment (Figure 13).

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 was particularly evident on September 22nd when a significant increase in stage caused a corresponding decrease in pH.

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.

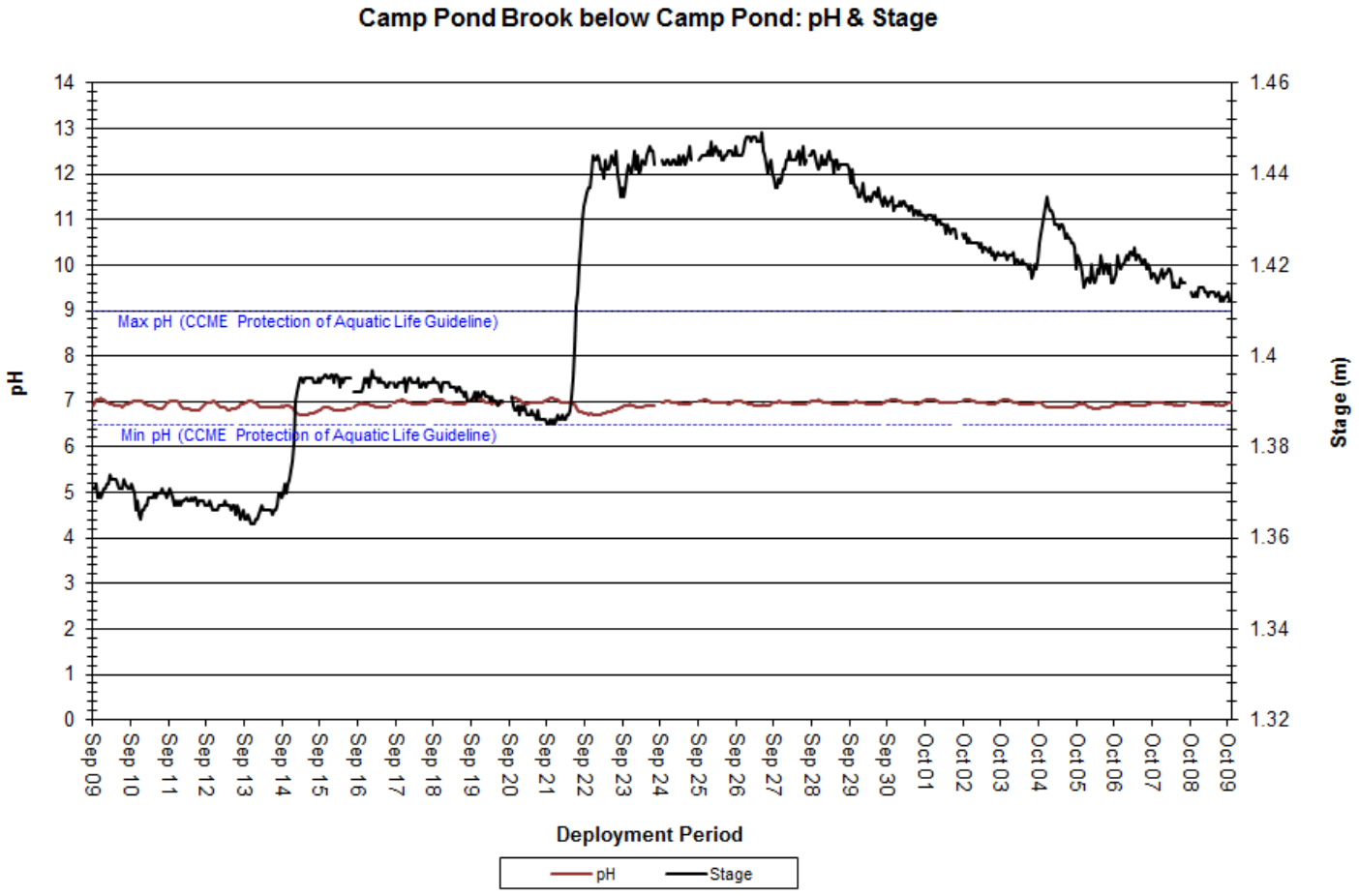

Figure 9: pH & Stage at Camp Pond Brook below Camp Pond

Specific Conductivity

Over the deployment period, specific conductivity ranged from 35.0µS/cm to 56.5µS/cm, with a median value of 38.4µS/cm (Figure 10).

Over the course of deployment, conductivity levels were relatively stable with a few temporary spikes. Significant increases in conductivity occurred on September 15th, September 22nd, and October 4th. These increases all correlate closely with both increases in stage (Figure 10) and precipitation events (Figure 13).

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.

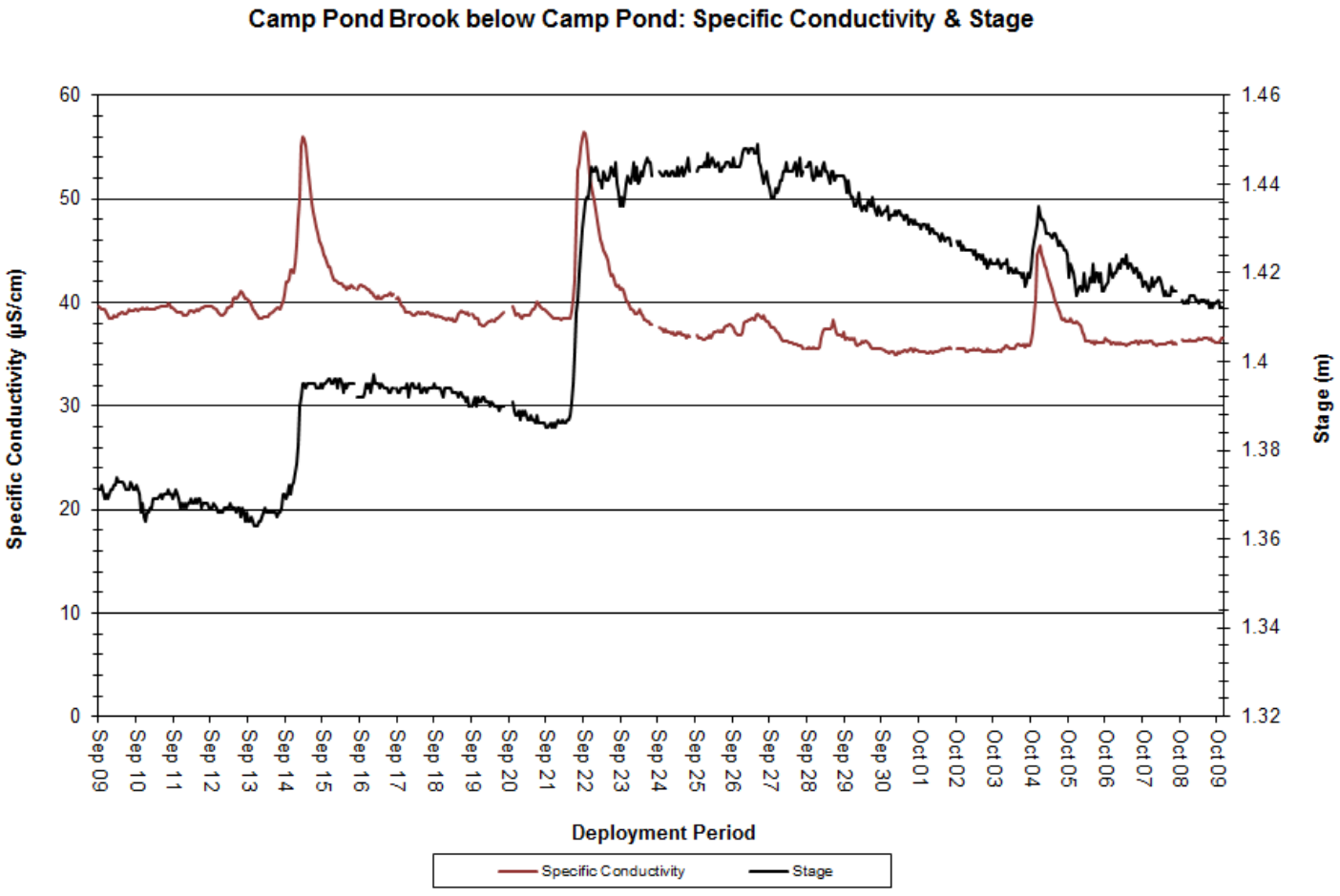

Figure 10: Specific Conductivity & Stage at Camp Pond Brook below Camp Pond

Dissolved Oxygen

Over the deployment period, dissolved oxygen concentration ranged from 10.06mg/L to 13.48mg/L, with a median value of 11.86mg/L. Saturation of dissolved oxygen ranged from 90.3% saturation to 101.4% saturation, with a median of 95.9% (Figure 11).

Dissolved oxygen concentrations remained above the CCME's Guideline for the Protection of Early Life Stages for the duration of deployment (Figure 11). Dissolved oxygen concentration increased steadily over the course of deployment; this is to be expected as water temperatures decreased. 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.

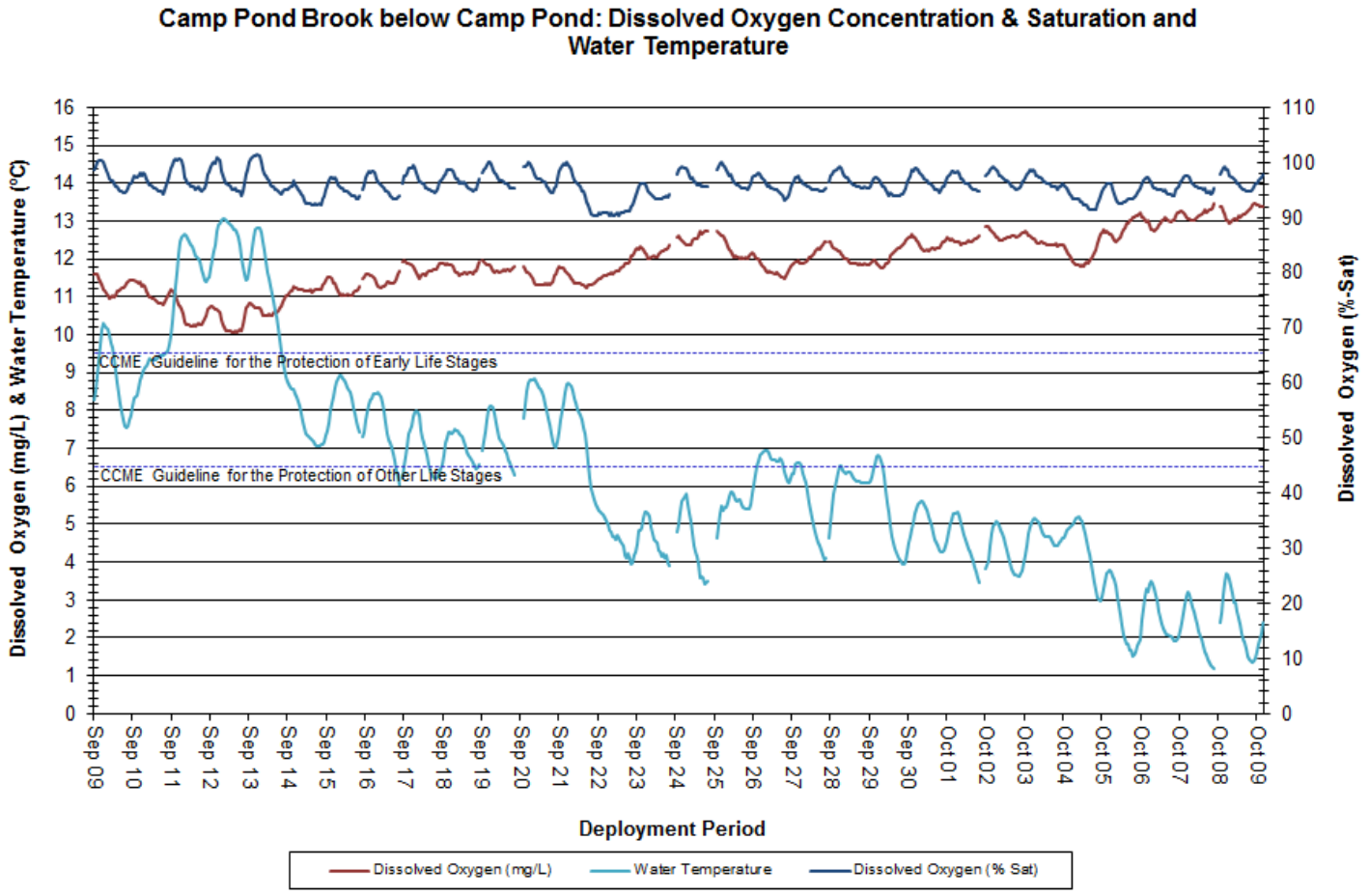

Figure 11: Dissolved Oxygen & Water Temperature at Camp Pond Brook below Camp Pond

Turbidity

Over the deployment period, turbidity ranged from 2.3NTU to 95.2NTU, with a median value of 16.0NTU (Figure 12). A median value of 16.0NTU indicates there was quite a bit of natural background turbidity at this station. While a low level of background turbidity is expected at this station, a median value of 16.0NTU is higher than expected and likely indicative of a minor calibration error. Turbidity data has not been removed from the dataset since the observed changes in turbidity levels are still important indicators of water quality events.

Spikes in turbidity levels observed throughout the deployment period correlate closely with precipitation events (Figure 12). This is to be expected since precipitation and subsequent runoff can increase the amount of suspended materials in the water column.

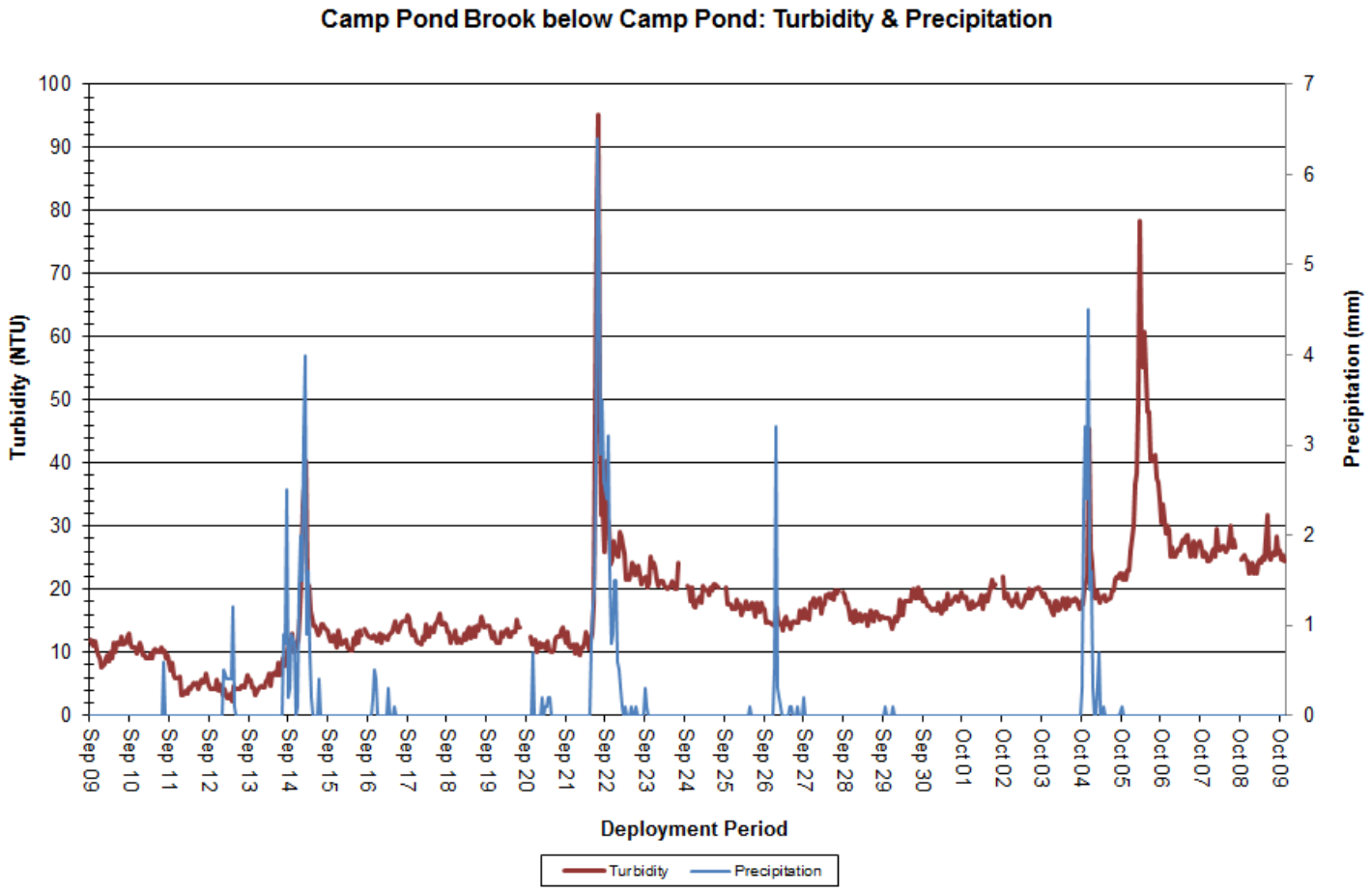

Figure 12: Turbidity & Precipitation at Camp Pond Brook below Camp Pond

Stage, Flow and Precipitation

Over the deployment period, stage values ranged from 1.36m to 1.45m, with a median value of 1.42m. Stream flow values ranged from 0.30m^3/s to 0.70m^3/s, with a median value of 0.56m^3/s. Precipitation data was obtained from the Voisey's Bay airstrip weather station (Figure 13).

Increases in stage and flow are often associated with rainfall events; this was particularly evident on September 15th, September 22nd, and October 4th (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.

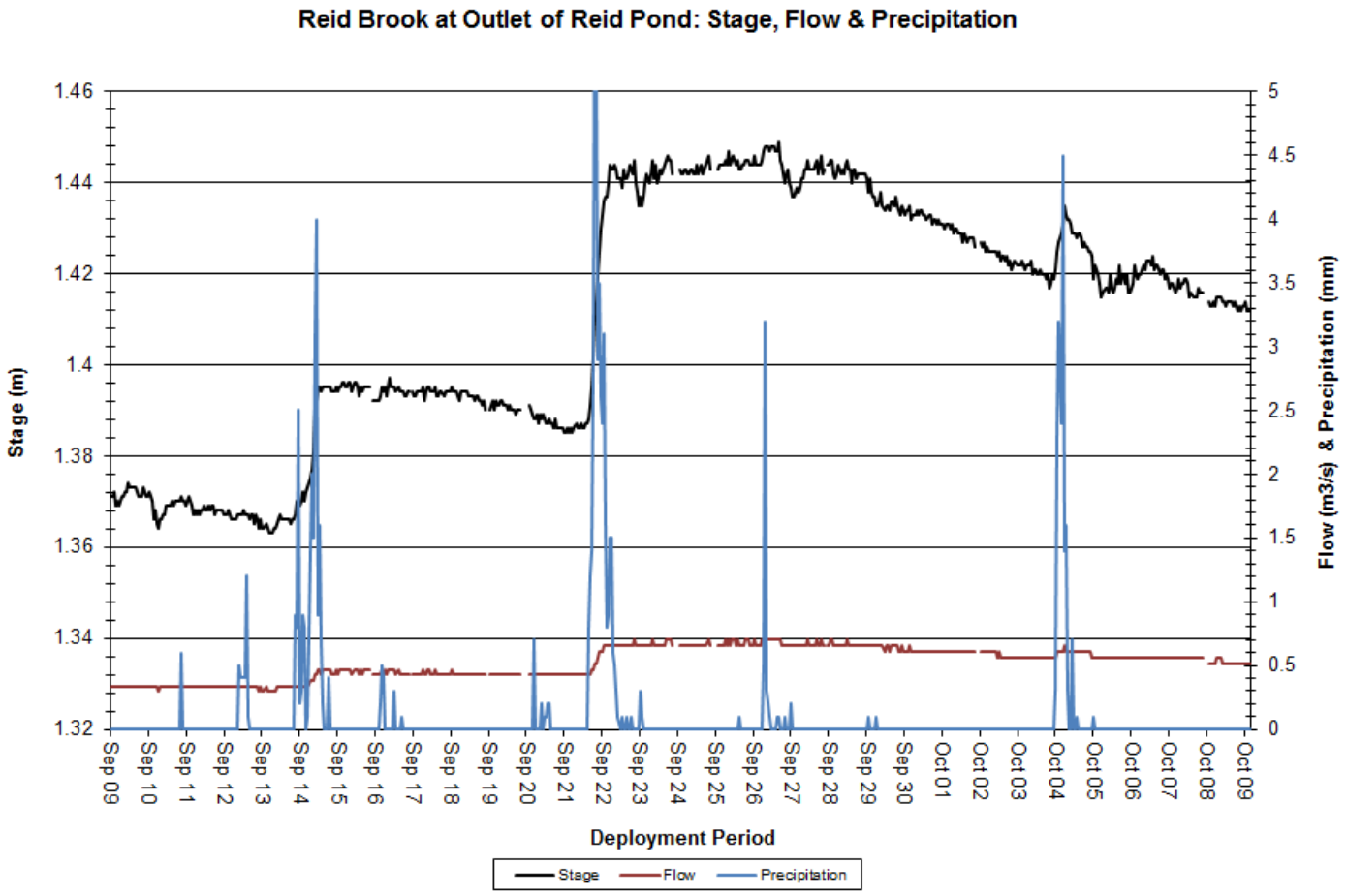

Figure 13: Stage, Flow & Precipitation at Camp Pond Brook below Camp Pond

Reid Brook below Tributary

Water Temperature

Over the deployment period, water temperature ranged from 1.86°C to 11.46°C, with a median value of 5.52°C (Figure 14).

Water temperature at this station displays diurnal variations. Water temperature increased slightly at the beginning of deployment and then decreased steadily for the remainder of the deployment period. This is to be expected as air temperatures also decreased (Figure 14). Air temperature data was obtained from the Voisey's Bay airstrip weather station.

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.

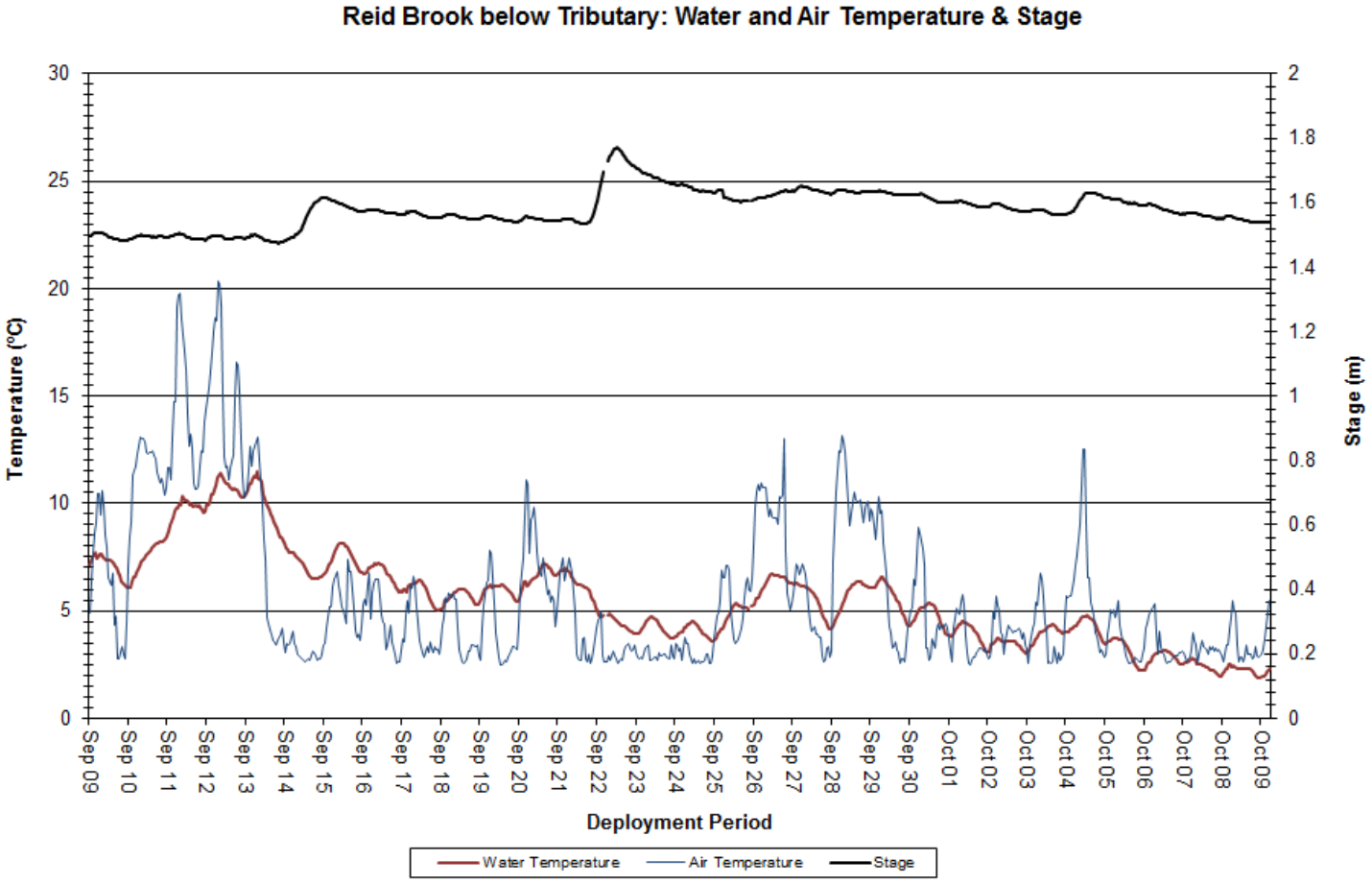

Figure 14: Water and Air Temperature & Stage at Reid Brook below Tributary

pH

Over the deployment period, pH ranged from 7.16 pH units to 7.84 pH units, with a median value of 7.69 (Figure 15).

pH remained within the CCME's Guidelines for the Protection of Aquatic Life for the duration of deployment. Decreases in pH levels observed on September 15th, September 22nd and October 4th were closely associated with increased stage levels (Figure 15) and rainfall events (Figure 19).

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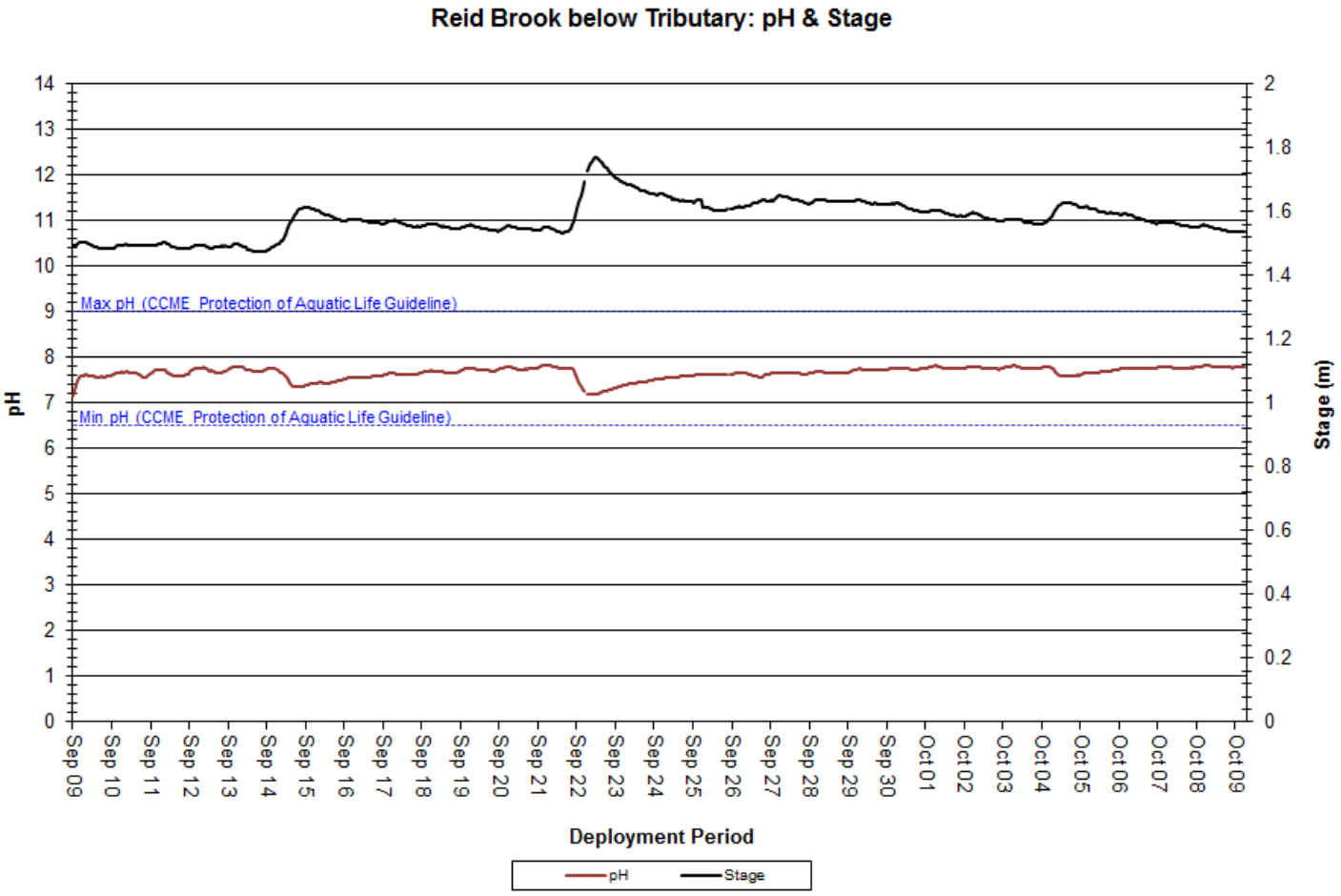

Figure 15: pH & Stage at Reid Brook below Tributary

Specific Conductivity

Over the deployment period, specific conductivity ranged from 23.5µS/cm to 36.1µS/cm, with a median value of 30.8µS/cm (Figure 16).

Stage and specific conductivity exhibit an inverse relationship in the graph below: as one parameter increases, the other decreases. As water levels decrease, suspended materials in the water body become more concentrated, in turn increasing specific conductivity (Figure 16).

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.

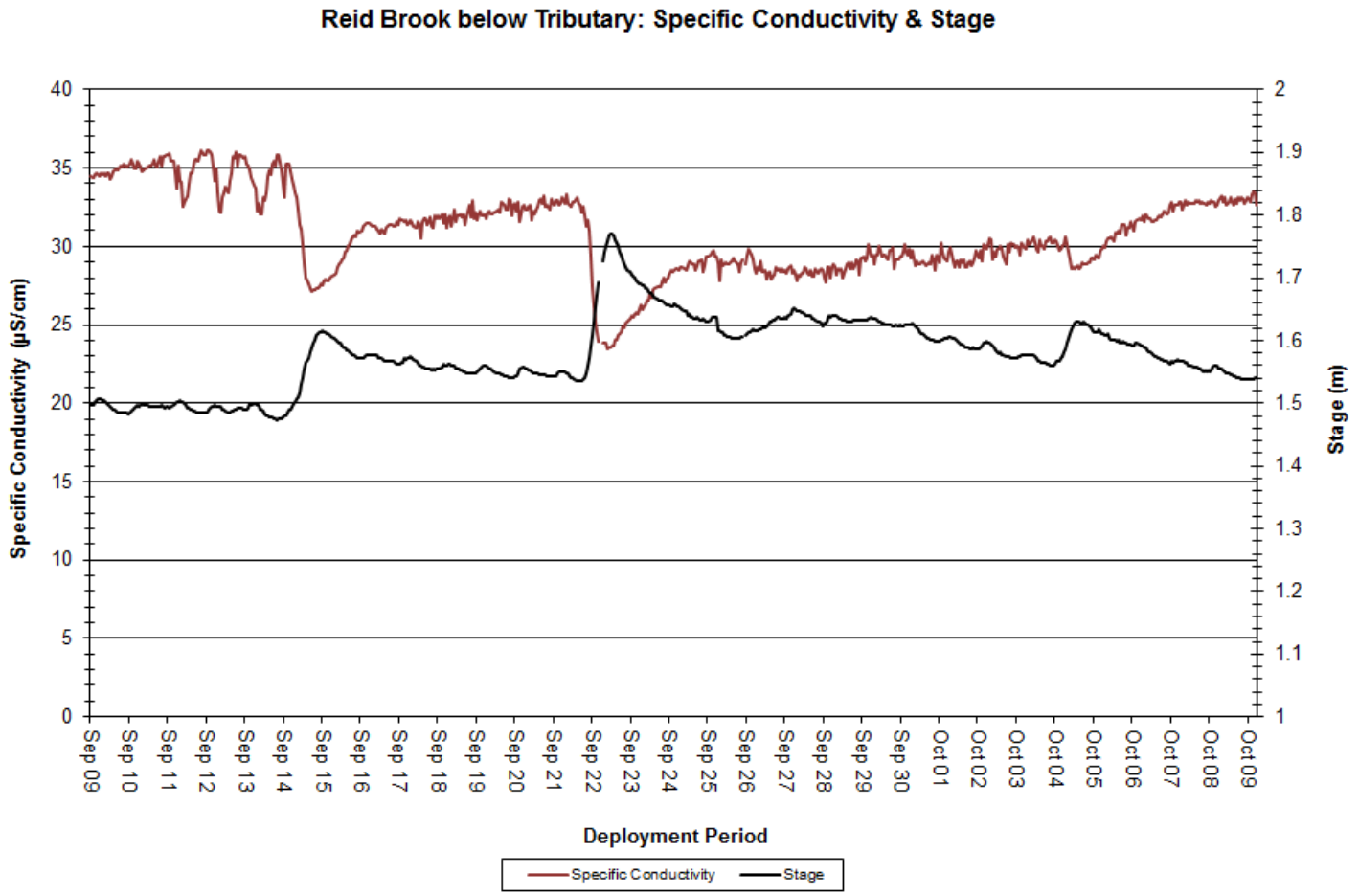

Figure 16: Specific Conductivity & Stage at Reid Brook below Tributary

Dissolved Oxygen

Over the deployment period, dissolved oxygen concentration ranged from 10.52mg/L to 13.22mg/L, with a median value of 12.00mg/L. Saturation of dissolved oxygen ranged from 91.4% saturation to 100.2% saturation, with a median value of 95.3% (Figure 17).

Dissolved oxygen concentration remained above the CCME's Guideline for the Protection of Early Life Stages (9.5mg/L) for the duration of deployment. Increasing dissolved oxygen concentrations correlated closely with decreasing water temperatures, which is to be expected as these parameters generally exhibit an inverse relationship.

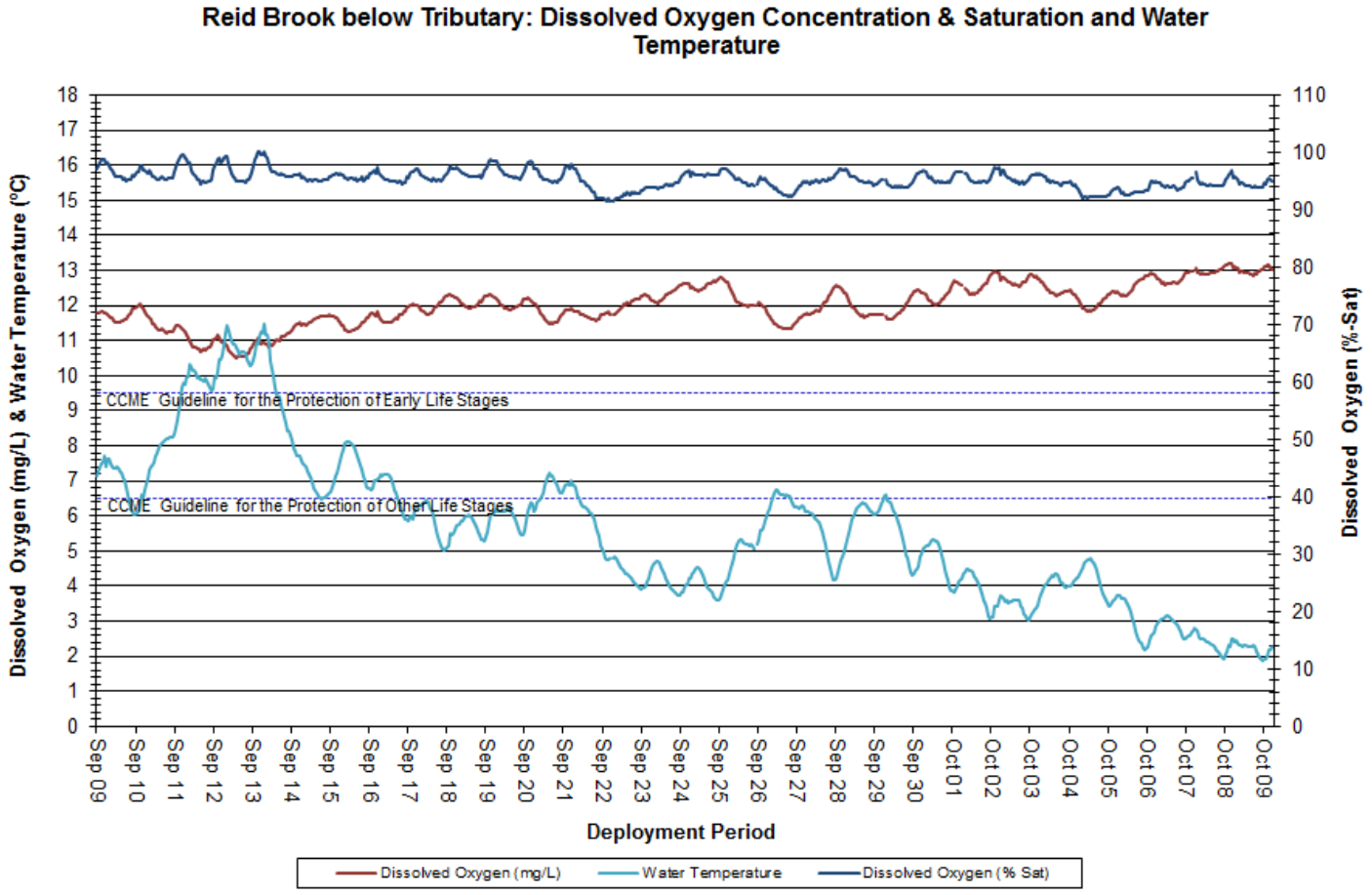

Figure 17: Dissolved Oxygen & Water Temperature at Reid Brook below Tributary

Turbidity

Over the deployment period, turbidity ranged from 0.0 NTU to 19.2 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.

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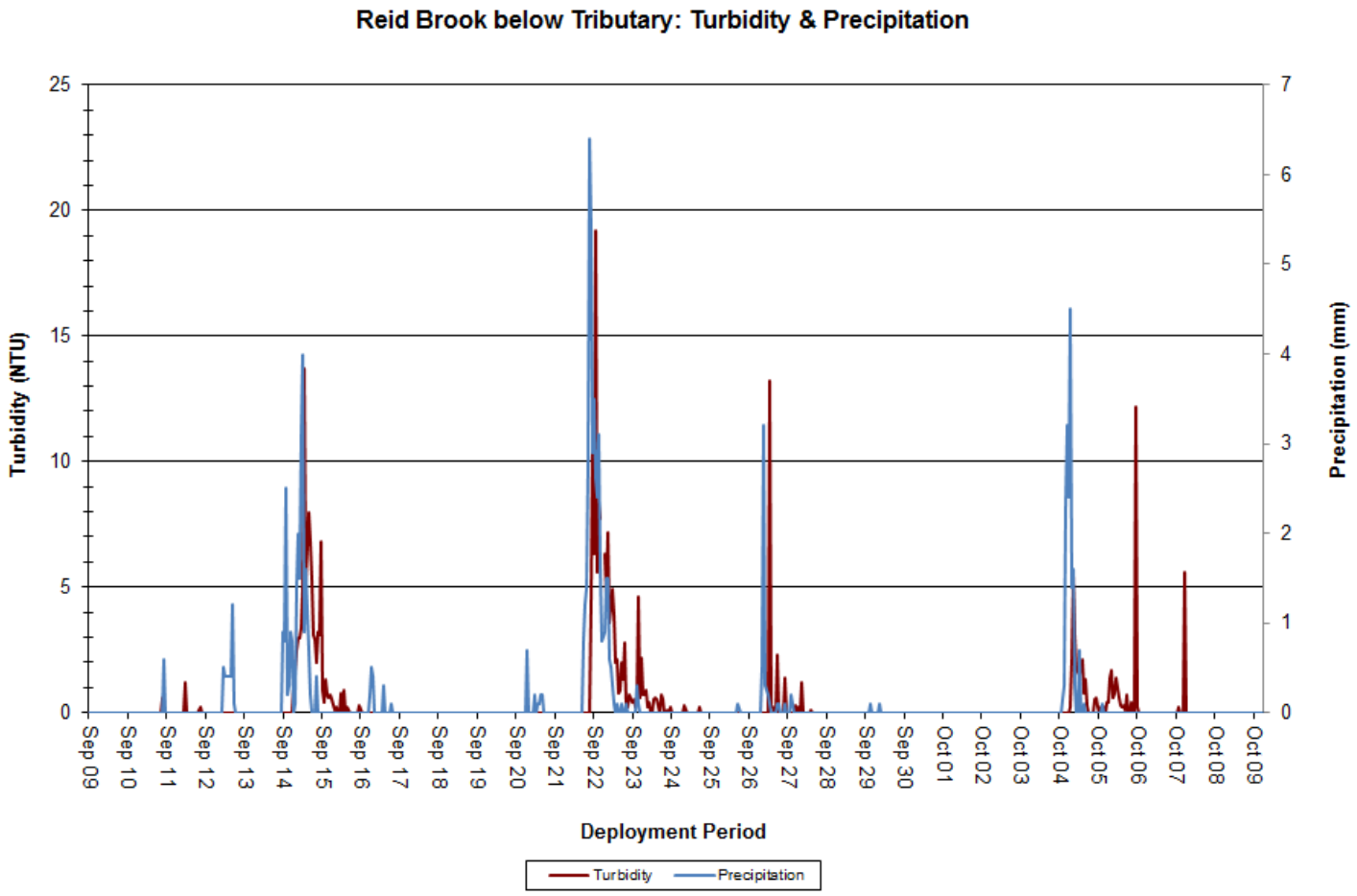

Figure 18: Turbidity & Precipitation at Reid Brook below Tributary

Stage, Flow and Precipitation

Over the deployment period, stage values ranged from 1.47m to 1.77m, with a median value of 1.58m. Flow ranged from 1.98m^3/s to 10.85m^3/s, with a median value of 3.95m^3/s. Precipitation data was obtained from the Voisey's Bay airstrip weather station (Figure 19).

Stage, flow and precipitation are graphed below to show the relationship between rainfall and water level. It is evident that many peaks in stage and flow are closely linked to precipitation events.

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.

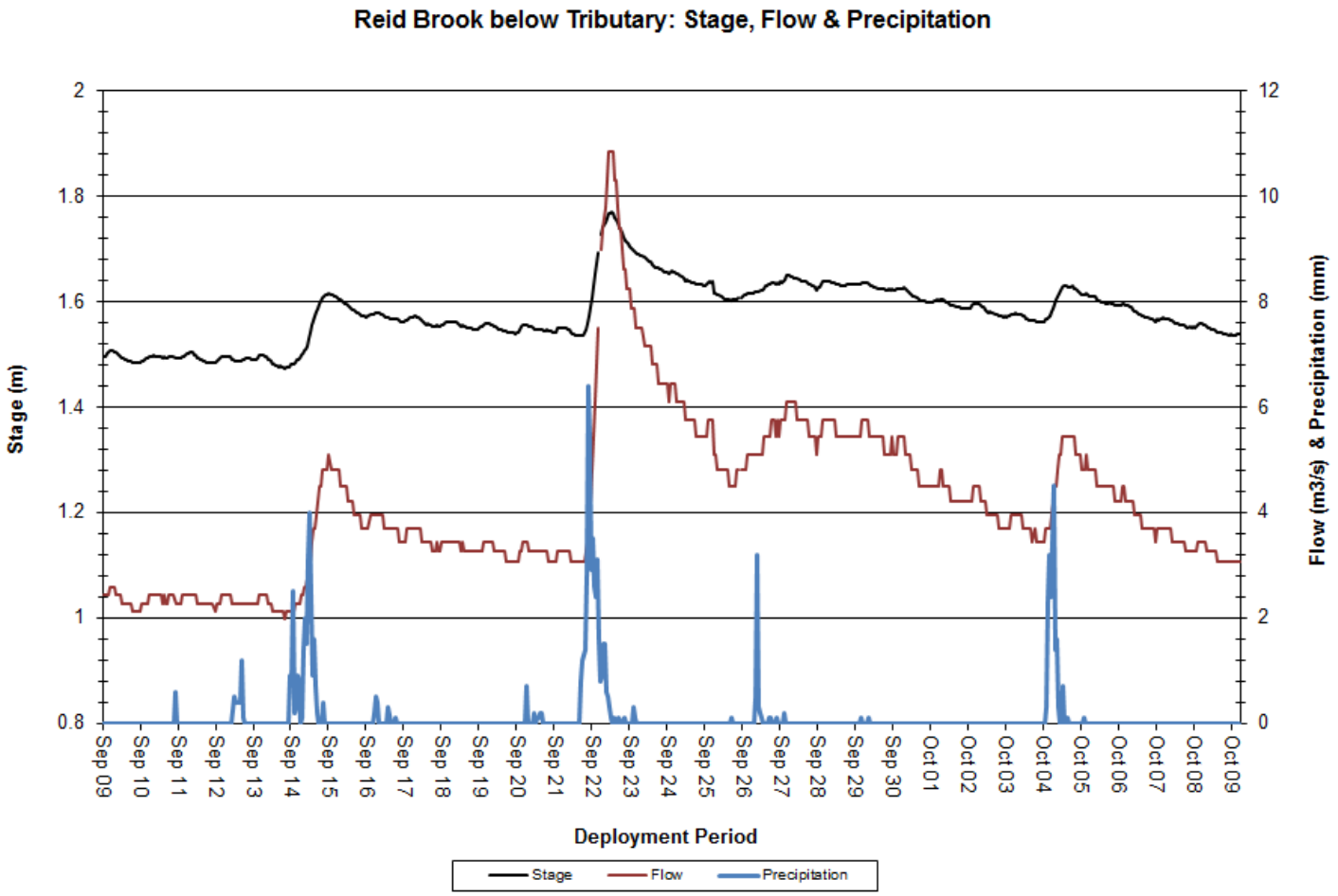

Figure 19: Stage, Flow & Precipitation at Reid Brook below Tributary

Tributary to Reid Brook

Water Temperature

Over the deployment period, water temperature ranged from 1.70°C to 10.50°C, with a median value of 5.30°C (Figure 20). 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 decreased gradually over the course of deployment and correlated closely with ambient air temperatures.

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.

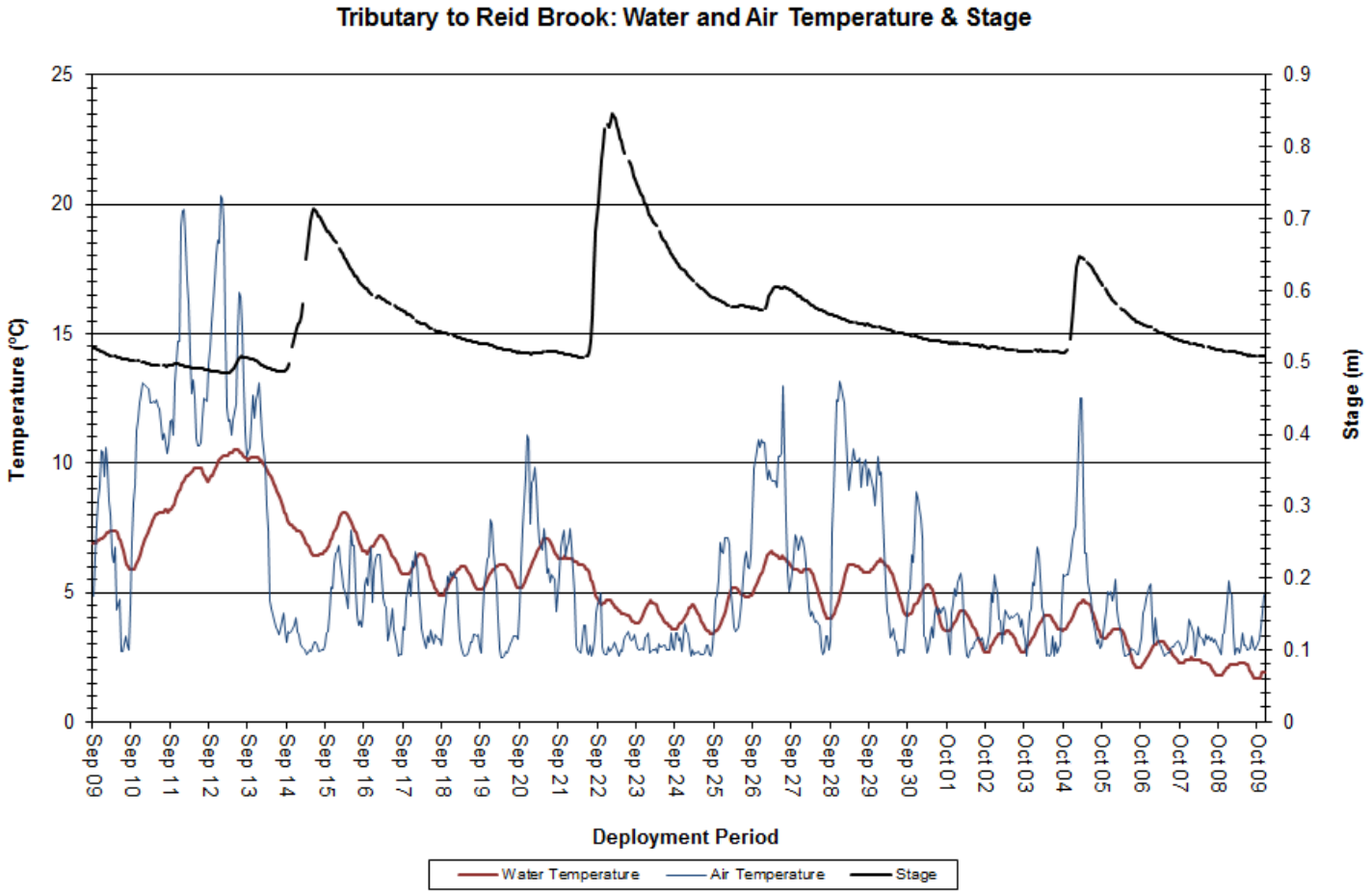

Figure 20: Water and Air Temperature & Stage at Tributary to Reid Brook

pH

Over the deployment period, pH ranged from 6.22 pH units to 7.01 pH units, with a median value of 6.78 (Figure 21).

Stage increases often indicate a rainfall event; rainfall will cause pH values to decrease for a short period of time (Figure 21). Increases in stage and associated decreases in pH were particularly evident on September 15th, September 22nd and October 4th.

pH levels remained within the CCME's Guidelines for the Protection of Aquatic Life for the majority of deployment, with two exceptions on September 15th and September 22nd associated with rainfall events and subsequent increased 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.

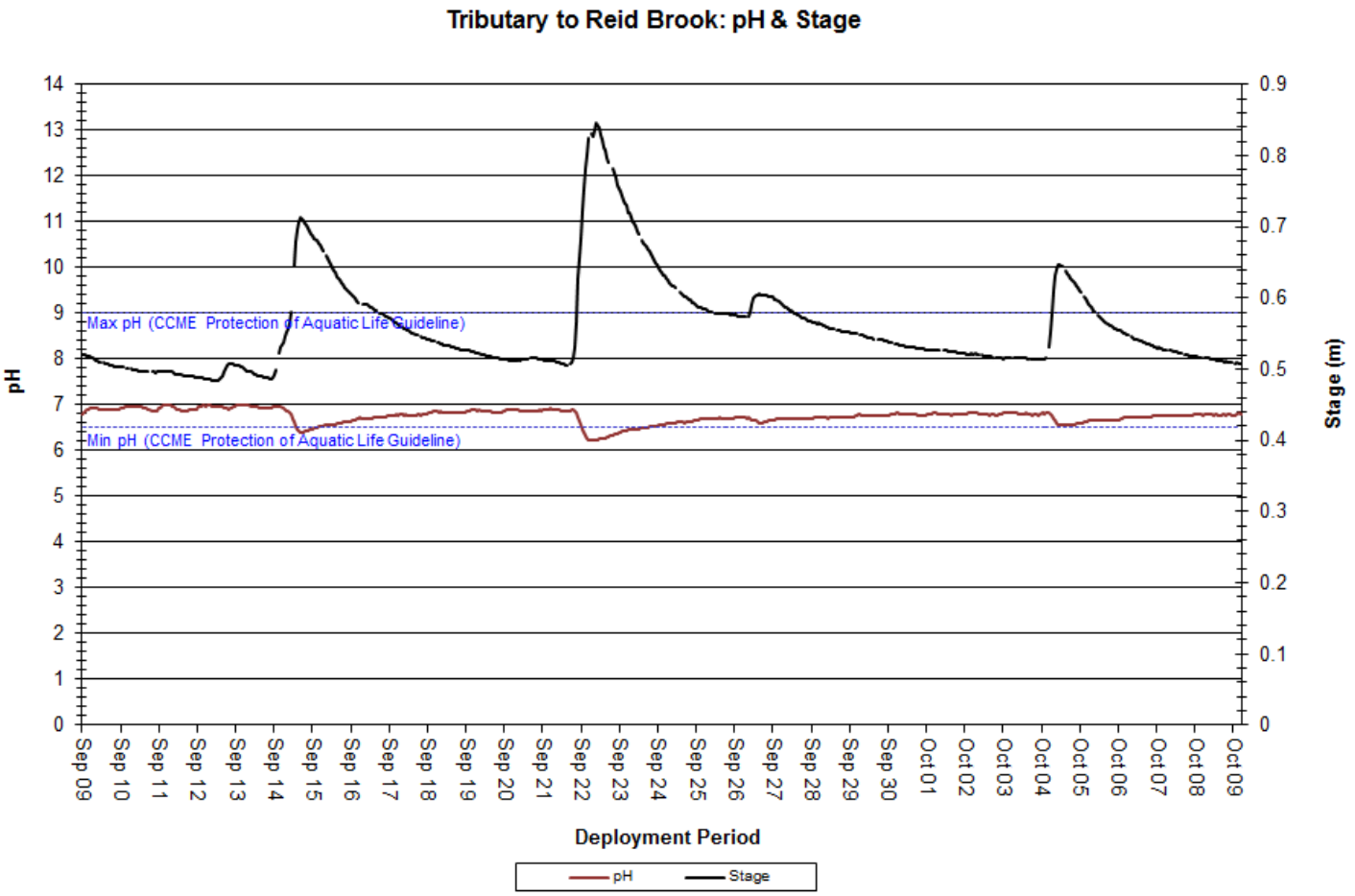

Figure 21: pH & Stage at Tributary to Reid Brook

Specific Conductivity

Over the deployment period, specific conductivity ranged from 17.6µS/cm to 28.4µS/cm, with a median value of 25.0µS/cm (Figure 22).

Specific conductance and stage generally exhibit an inverse relationship: as one parameter increases, the other decreases. An increased amount of water in the river system dilutes solids causing a decrease in conductivity, and vice versa. Rainfall events over the course of deployment (Figure 24) likely influenced the observed decrease in specific conductivity on the same dates.

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.

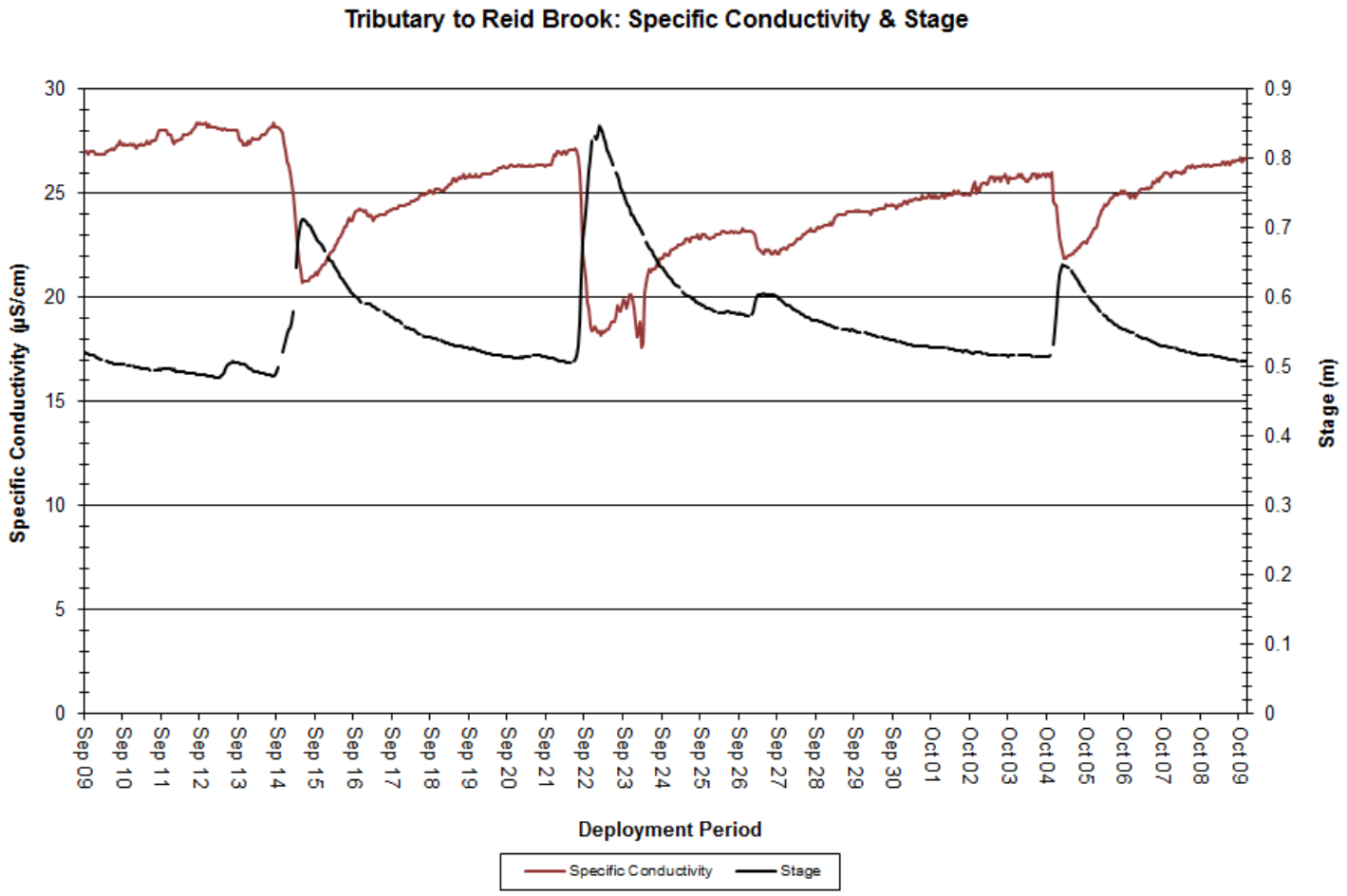

Figure 22: Specific Conductivity & Stage at Tributary to Reid Brook

Dissolved Oxygen

Over the deployment period, dissolved oxygen concentration ranged from 10.65mg/L to 13.26mg/L, with a median value of 12.06mg/L. The saturation of dissolved oxygen ranged from 90.9% saturation to 98.8% saturation, with a median value of 95.5% (Figure 23).

Dissolved oxygen levels remained above the CCME's Guideline for the Protection of Early Life Stages for the duration of deployment. Dissolved oxygen concentration gradually increased over the course of deployment, which is to be expected as water temperature decreased over the same period.

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.

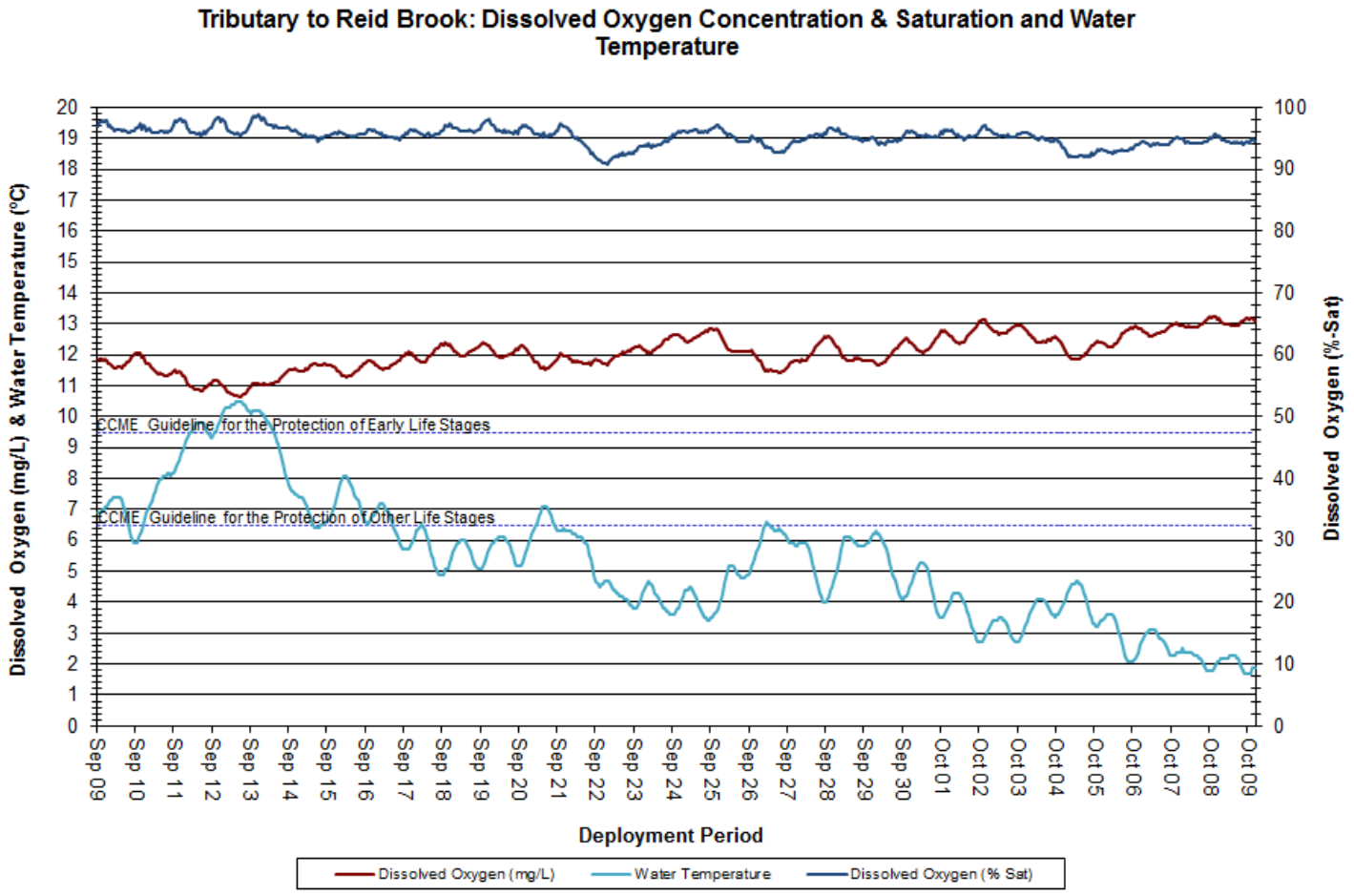

Figure 23: Dissolved Oxygen & Water Temperature at Tributary to Reid Brook

Turbidity

Over the deployment period, turbidity remained constant at 100.0 NTU with no fluctuations whatsoever. This is indicative of a serious calibration error during preparation of the field sonde and therefore all turbidity data has been removed from the dataset.

Stage, Flow and Precipitation

Over the deployment period, stage ranged from 0.49m to 0.85m, with a median value of 0.54m. Flow ranged from 0.17m^3/s to 1.79m^3/s, with a median value of 0.25m^3/s. Precipitation data was obtained from the Voisey's Bay airstrip weather station (Figure 24).

Stage, flow and precipitation are graphed below to show the relationship between rainfall and water level. It is evident that the peaks in stage and flow data are closely related to precipitation.

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.

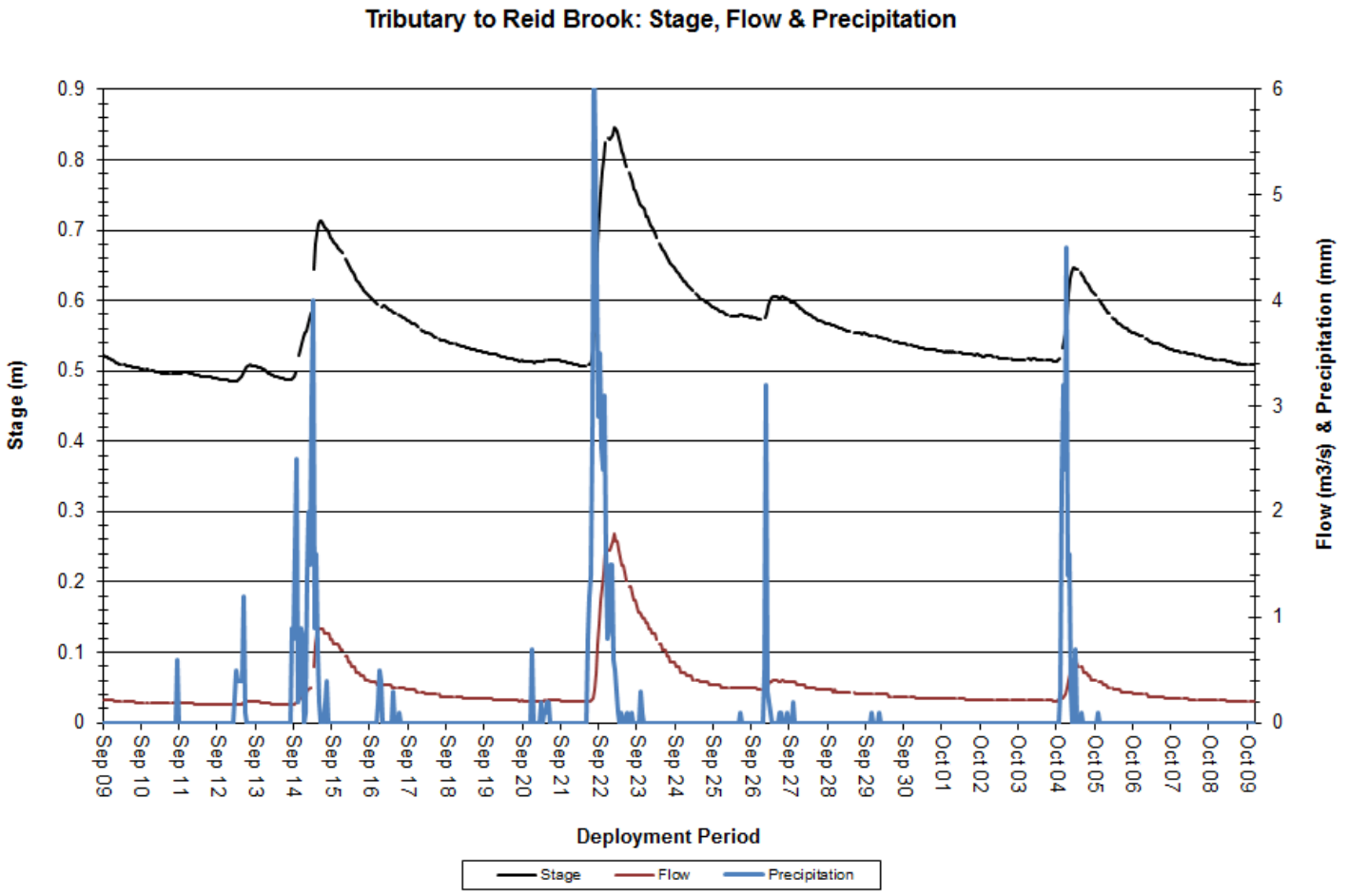

Figure 24: Stage, Flow & Precipitation at Tributary to Reid Brook

Conclusions

Water temperatures across all stations ranged from a minimum of 1.18°C to a maximum of 13.07°C, both at Camp Pond Brook below Camp Pond. Overall, water temperature was decreasing 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.

pH values across all stations ranged from a minimum of 6.22pH units at Tributary to Reid Brook to a maximum of 7.84pH units at Reid Brook below Tributary. pH values at all stations were relatively consistent and remained within the CCME's Guidelines for the Protection of Aquatic Life for the majority of deployment.

Specific conductivity across all stations ranged from a minimum of 11.3µS/cm Reid Brook at Outlet of Reid Pond to a maximum of 56.5µS/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 38.4µS/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 10.06mg/L to a maximum of 13.48mg/L, both at Camp Pond Brook below Camp Pond. Dissolved oxygen gradually increased over the deployment period and varied diurnally as water temperature is greatly affected by ambient air temperature. Dissolved oxygen levels remained above the CCME's Guideline for the Protection of Early Life Stages at all stations for the duration of deployment.

Turbidity levels across all stations ranged from a minimum of 0.0 NTU at Reid Brook below Tributary to a maximum of 95.2 NTU at Camp Pond Brook below Camp Pond. Turbidity levels showed natural increases and decreases corresponding to changes in stage and precipitation events. Turbidity data from Tributary to Reid Brook was removed due to a calibration error.

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 very accurate and no data was removed.

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.

APPENDIX A: Comparison Graphs

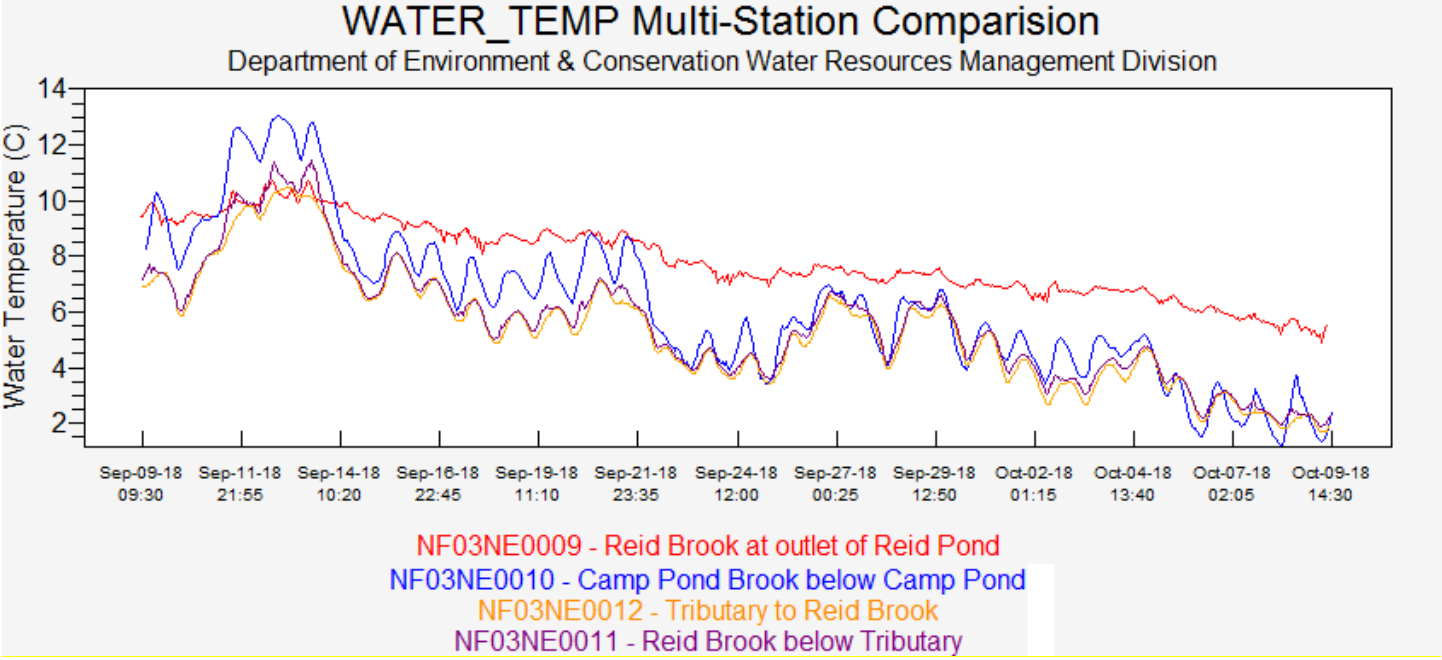

Figure A1: Comparison of Water Temperature (^{0}C) between all Real-Time Stations in Voisey's Bay.

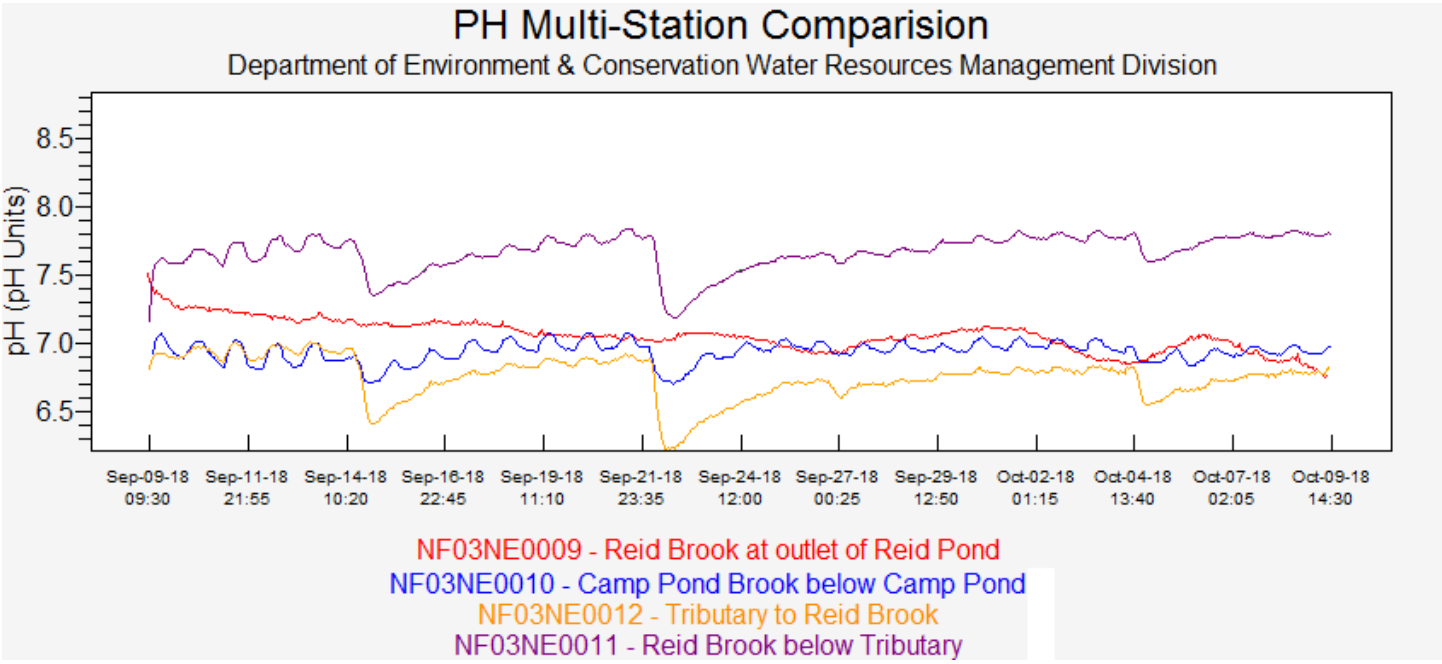

Figure A2: Comparison of pH between all Real-Time Stations in Voisey's Bay.

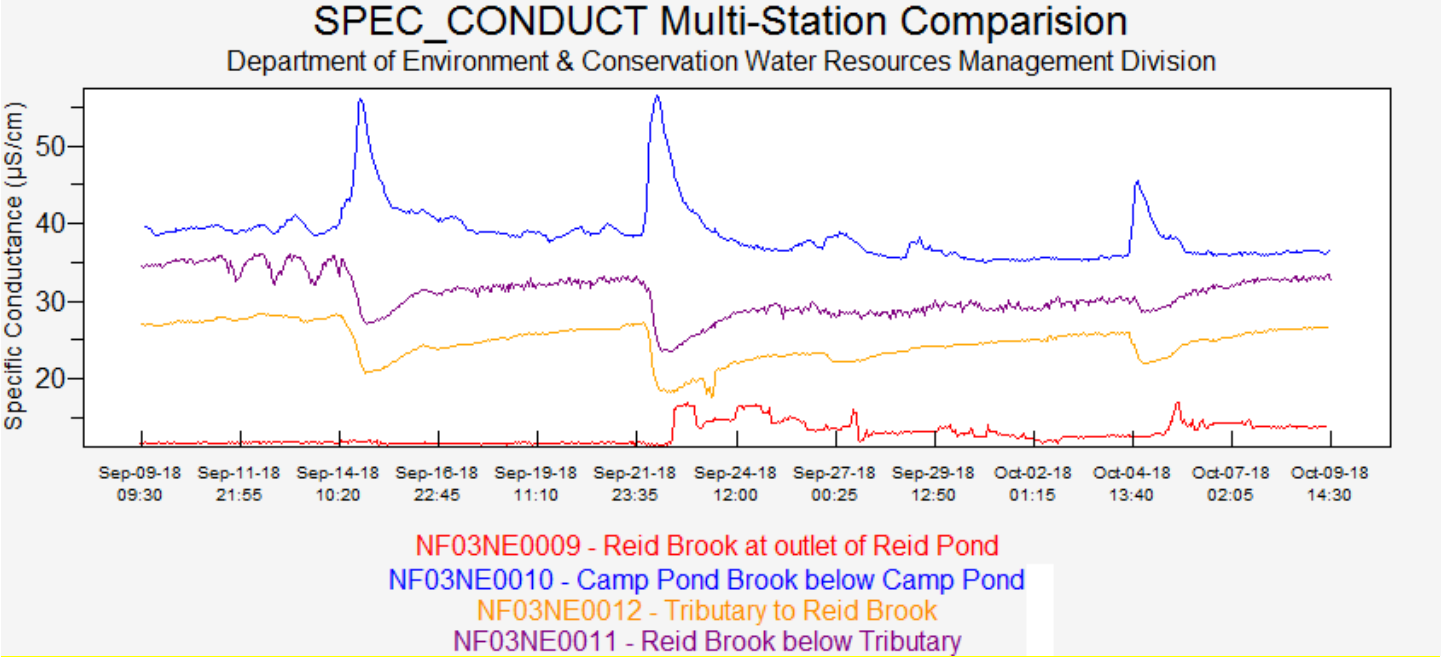

Figure A3: Comparison of Specific Conductivity (µS/cm) between all Real-Time Stations in Voisey's Bay.

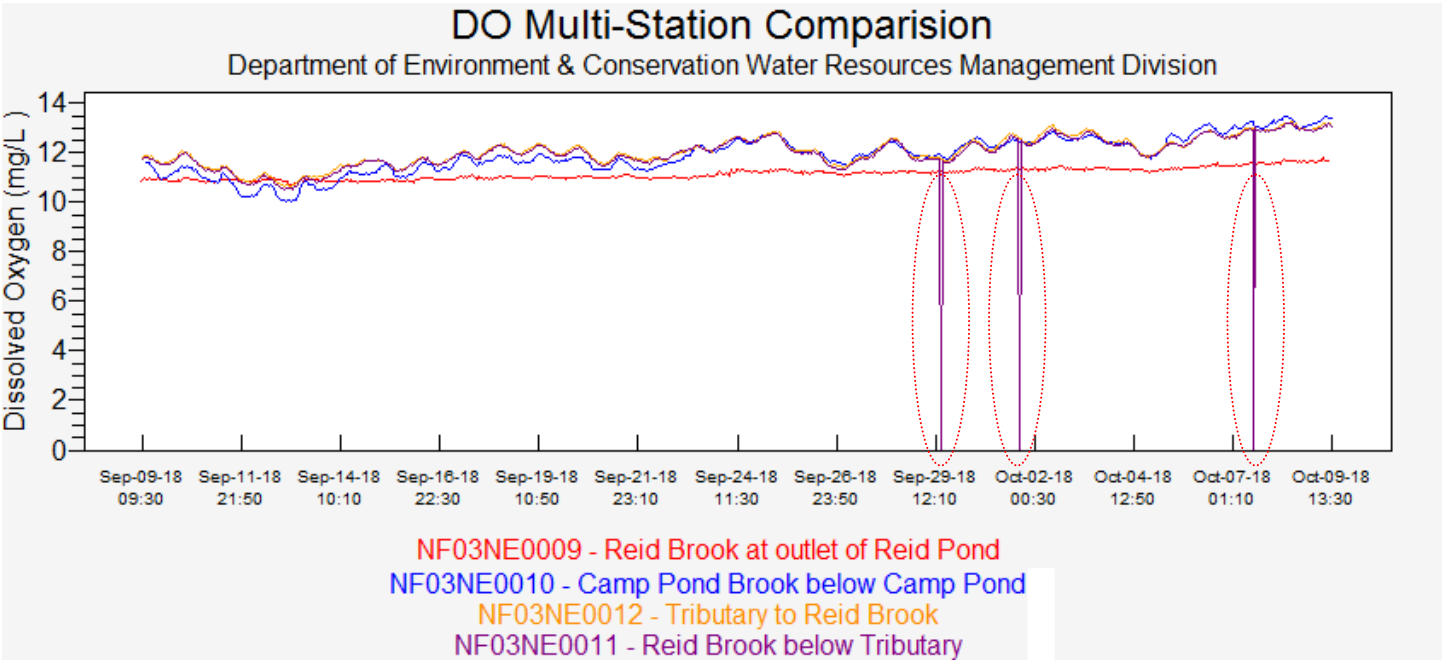

Figure A4: Comparison of Dissolved Oxygen (mg/L) between all Real-Time Stations in Voisey's Bay. Circled data points for Reid Brook below Tributary have been removed from analysis for QA/QC purposes.

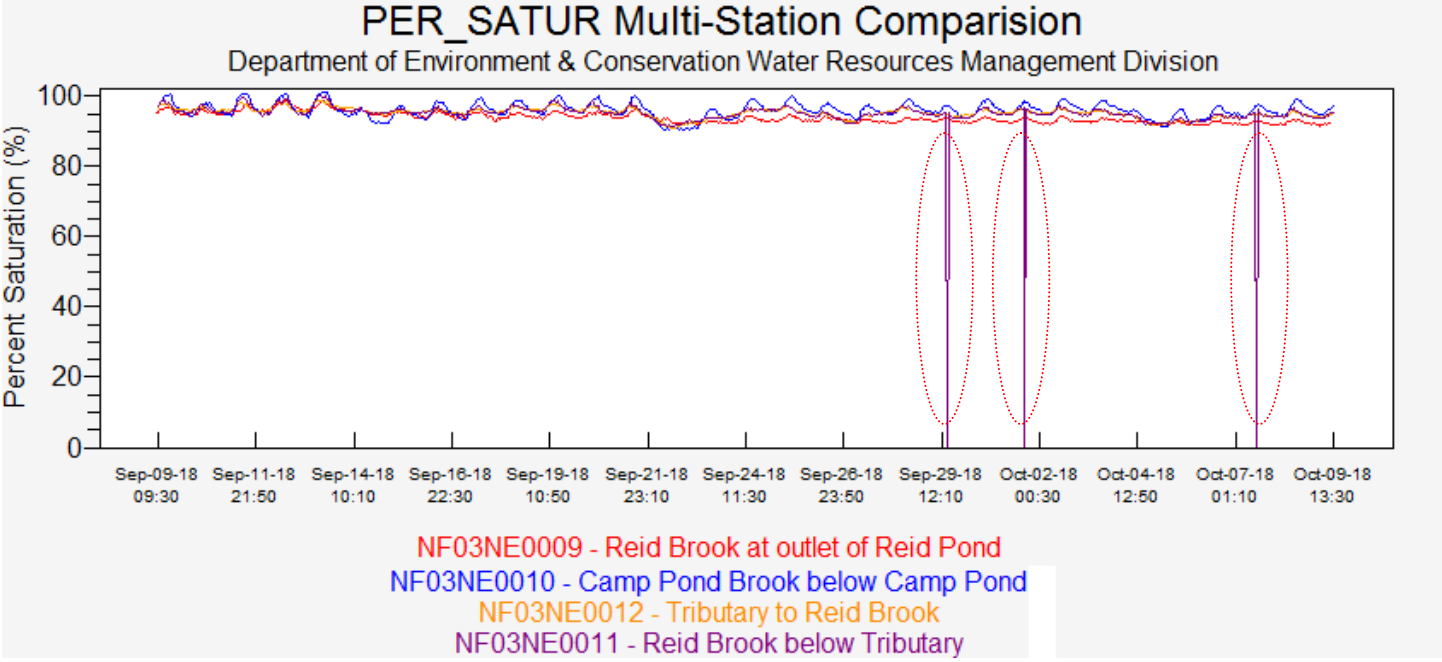

Figure A5: Comparison of Dissolved Oxygen (% Sat) between all Real-Time Stations in Voisey's Bay. Circled data points for Reid Brook below Tributary have been removed from analysis for QA/QC purposes.

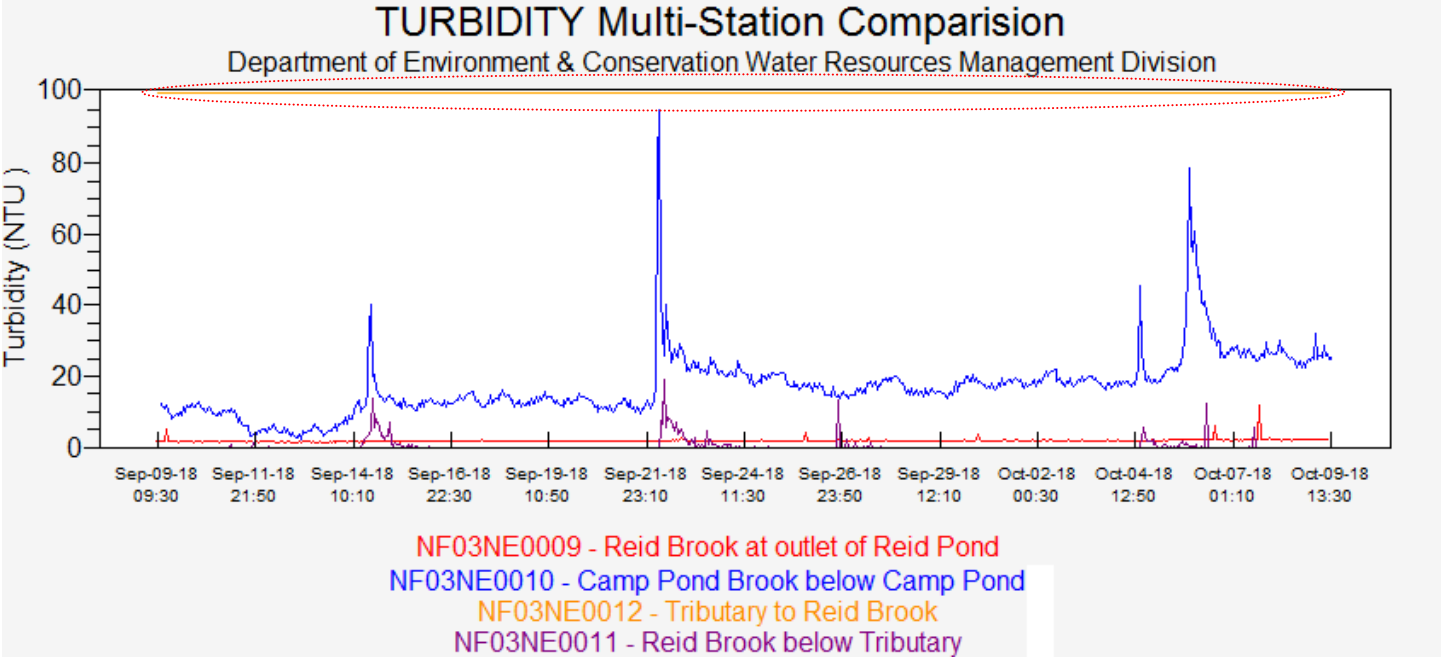

Figure A6: Comparison of Turbidity (NTU) between all Real-Time Stations in Voisey's Bay. There may have been a minor error during calibration that resulted in the higher-than-expected background turbidity level observed at Camp Pond Brook below Camp Pond. Circled data for Tributary to Reid Brook has been removed from analysis for QA/QC purposes due to a serious calibration error.

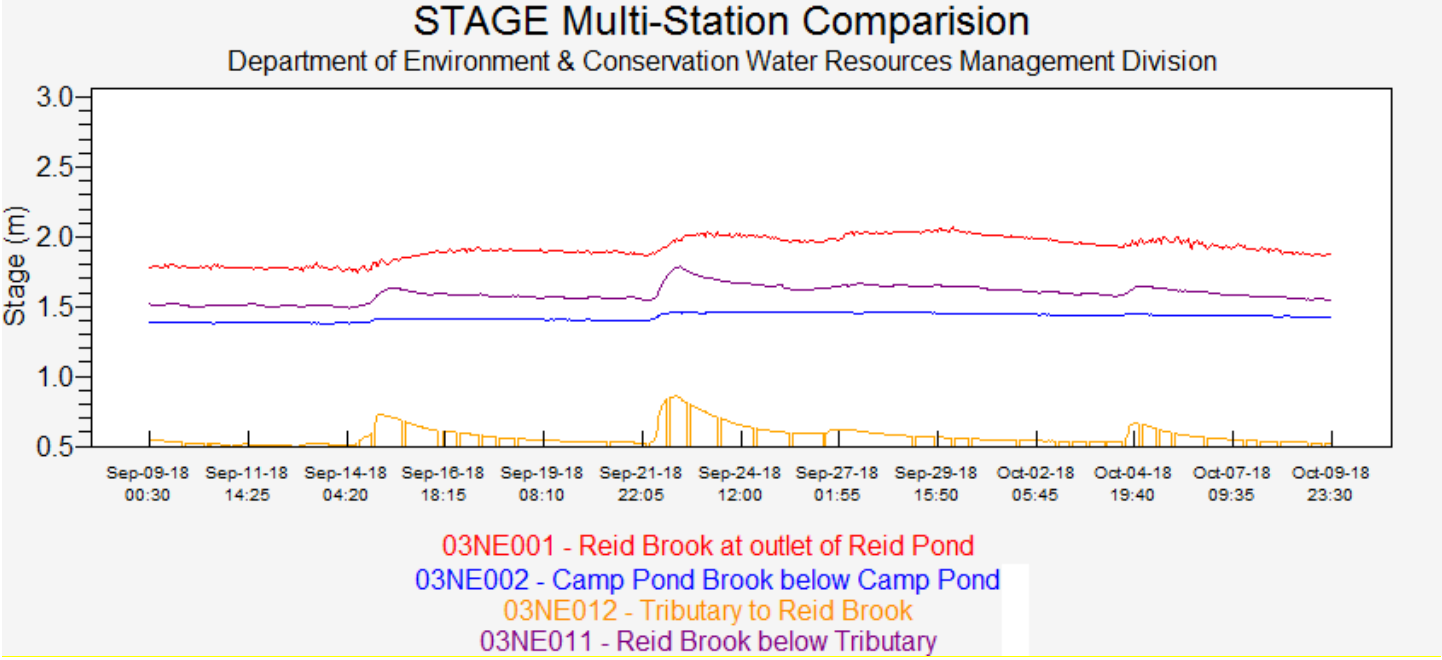

Figure A7: Comparison of Stage (m) between all Real-Time Stations in Voisey's Bay. Please note that stage data is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data.

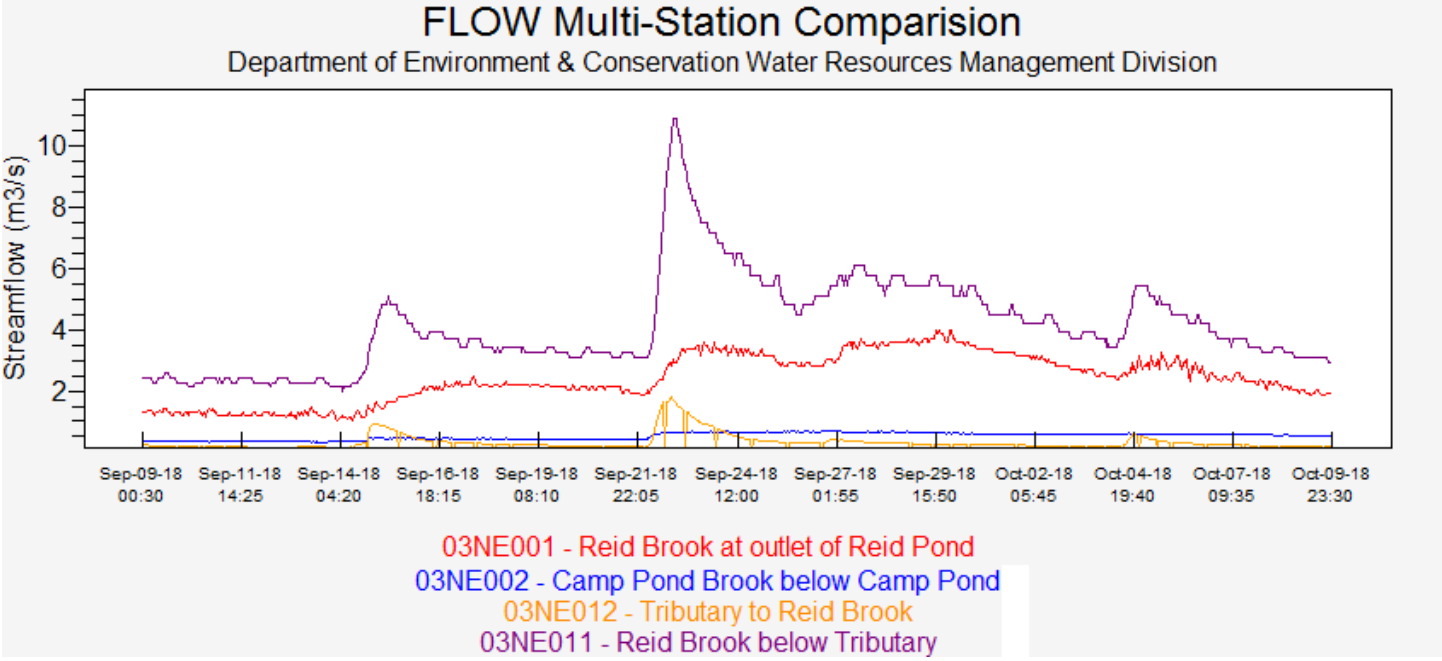

Figure A8: Comparison of Flow (m^3/s) between all Real-Time Stations in Voisey's Bay. Please note that flow data is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data.

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 CO_2 (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

REPORT OF ANALYSIS

Lab Report Number: **1816604**

Cient:	Department of Environment	**COC Number:**	835681
Attention:	Ms. Tara Clinton	**Date Reported:**	2018-09-21
Client Project:		**Date Submitted:**	2018-09-13
Purchase Order:	2180014302	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date
1387165	WS-S-0000 Reid Brook below Reid Pond	2018-1868-00-SI-SP	2018-09-09

Sample comment:

Holding time for turbidity analysis was exceeded for entire report.

Report comment:

ANALYTE	UNIT	MRL	RESULT
Alkalinity as CaCO3	mg/L	5	<5
Bromide	mg/L	0.25	<0.25
Chloride	mg/L	1	<1
Colour	TCU	2	9
Conductivity	uS/cm	5	14
Dissolved Organic Carbon	mg/L	0.5	1.0
Fluoride	mg/L	0.10	<0.10
Hardness as CaCO3	mg/L	1	2
N-NH3 (Ammonia)	mg/L	0.02	0.14
N-NO2 (Nitrite)	mg/L	0.10	<0.10
N-NO3 (Nitrate)	mg/L	0.10	<0.10
pH		1.00	6.65
Sulphate	mg/L	1	<1
Total Dissolved Solids (COND - CALC)	mg/L	1	9
Total Kjeldahl Nitrogen	mg/L	0.1	<0.1
Total Organic Carbon	mg/L	0.5	1.3
Turbidity	NTU	0.1	0.4
Aluminum	mg/L	0.01	0.04

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: 

Sarah Horner

REPORT OF ANALYSIS

Lab Report Number: **1816604**

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Attention:	Ms. Tara Clinton	**Date Reported:**	2018-09-21
Client Project:		**Date Submitted:**	2018-09-13
Purchase Order:	2180014302	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1387165	WS-S-0000 Reid Brook below Reid Pond	2018-1868-00-SI-SP	2018-09-09	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 turbidity analysis was exceeded for entire report.

Report comment:

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Client Project:		**Date Submitted:**	2018-09-13
Purchase Order:	2180014302	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1387165	WS-S-0000	2018-1868-00-SI-SP	2018-09-09	Uranium	mg/L	0.001	<0.001
	Reid Brook below Reid Pond			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 turbidity analysis was exceeded for entire report.

Report comment:

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Client Project:		**Date Submitted:**	2018-09-13
Purchase Order:	2180014302	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1387168	WS-S-0000	2018-1871-00-SI-SP	2018-09-09	Alkalinity as CaCO3	mg/L	5	13
	Camp Pond Brook Below Camp Pond			Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	3
Sample comment:				Colour	TCU	2	22
				Conductivity	uS/cm	5	54
				Dissolved Organic Carbon	mg/L	0.5	2.9
Report comment:				Fluoride	mg/L	0.10	0.10
				Hardness as CaCO3	mg/L	1	14
				N-NH3 (Ammonia)	mg/L	0.02	0.09
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	7.46
				Sulphate	mg/L	1	6
				Total Dissolved Solids (COND - CALC)	mg/L	1	35
				Total Kjeldahl Nitrogen	mg/L	0.1	<0.1
				Total Organic Carbon	mg/L	0.5	3.2
				Turbidity	NTU	0.1	2.4
				Aluminum	mg/L	0.01	0.06

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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Sarah Horner

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Purchase Order:	2180014302	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1387168	WS-S-0000	2018-1871-00-SI-SP	2018-09-09	Antimony	mg/L	0.0005	<0.0005
	Camp Pond Brook Below Camp Pond			Arsenic	mg/L	0.001	<0.001
				Barium	mg/L	0.01	<0.01
Sample comment:				Boron	mg/L	0.01	<0.01
				Calcium	mg/L	1	4
				Cadmium	mg/L	0.0001	<0.0001
Report comment:				Chromium	mg/L	0.001	<0.001
				Copper	mg/L	0.001	0.003
				Iron	mg/L	0.03	0.13
				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	0.033
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	2
				Strontium	mg/L	0.001	0.021

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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Client Project:		**Date Submitted:**	2018-09-13
Purchase Order:	2180014302	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1387168	WS-S-0000	2018-1871-00-SI-SP	2018-09-09	Uranium	mg/L	0.001	<0.001
	Camp Pond Brook Below Camp Pond			Zinc	mg/L	0.01	<0.01
				Phosphorus	mg/L	0.002	0.004
Sample comment:				Total Suspended Solids	mg/L	2	3

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: Sarah Horner

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Attention:	Ms. Tara Clinton	**Date Reported:**	2018-09-21
Client Project:		**Date Submitted:**	2018-09-13
Purchase Order:	2180014302	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1387167	WS-S-0000 Redi Brook Below Tributary	2018-1870-00-SI-SP	2018-09-09	Alkalinity as CaCO3	mg/L	5	8
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	2
				Colour	TCU	2	49
				Conductivity	uS/cm	5	37
				Dissolved Organic Carbon	mg/L	0.5	4.9
				Fluoride	mg/L	0.10	0.13
				Hardness as CaCO3	mg/L	1	7
				N-NH3 (Ammonia)	mg/L	0.02	0.10
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	6.96
				Sulphate	mg/L	1	3
				Total Dissolved Solids (COND - CALC)	mg/L	1	24
				Total Kjeldahl Nitrogen	mg/L	0.1	<0.1
				Total Organic Carbon	mg/L	0.5	5.0
				Turbidity	NTU	0.1	1.5
				Aluminum	mg/L	0.01	0.09

Sample comment:

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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APPROVAL: 

Sarah Horner

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Purchase Order:	2180014302	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1387167	WS-S-0000	2018-1870-00-SI-SP	2018-09-09	Antimony	mg/L	0.0005	<0.0005
	Redi Brook Below Tributary			Arsenic	mg/L	0.001	<0.001
				Barium	mg/L	0.01	<0.01
Sample comment:				Boron	mg/L	0.01	<0.01
				Calcium	mg/L	1	3
				Cadmium	mg/L	0.0001	<0.0001
Report comment:				Chromium	mg/L	0.001	<0.001
				Copper	mg/L	0.001	0.001
				Iron	mg/L	0.03	0.38
				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	0.008
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	2
				Strontium	mg/L	0.001	0.017

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

APPROVAL: Sarah Horner

REPORT OF ANALYSIS

Lab Report Number: **1816604**

Cient:	Department of Environment	**COC Number:**	835681
Attention:	Ms. Tara Clinton	**Date Reported:**	2018-09-21
Client Project:		**Date Submitted:**	2018-09-13
Purchase Order:	2180014302	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1387167	WS-S-0000	2018-1870-00-SI-SP	2018-09-09	Uranium	mg/L	0.001	<0.001
	Redi Brook Below Tributary			Zinc	mg/L	0.01	<0.01
				Phosphorus	mg/L	0.002	0.003
Sample comment:				Total Suspended Solids	mg/L	2	2

Report comment:

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LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1387166	WS-S-0000 Tributary to Reid Brook	2018-1869-00-SI-SP	2018-09-09	Alkalinity as CaCO3	mg/L	5	9
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	2
Sample comment:				Colour	TCU	2	48
				Conductivity	uS/cm	5	37
				Dissolved Organic Carbon	mg/L	0.5	4.9
Report comment:				Fluoride	mg/L	0.10	0.13
				Hardness as CaCO3	mg/L	1	7
				N-NH3 (Ammonia)	mg/L	0.02	0.10
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	6.96
				Sulphate	mg/L	1	3
				Total Dissolved Solids (COND - CALC)	mg/L	1	24
				Total Kjeldahl Nitrogen	mg/L	0.1	0.1
				Total Organic Carbon	mg/L	0.5	5.1
				Turbidity	NTU	0.1	2.5
				Aluminum	mg/L	0.01	0.12

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APPROVAL: 

Sarah Horner

REPORT OF ANALYSIS

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Purchase Order:	2180014302	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1387166	WS-S-0000 Tributary to Reid Brook	2018-1869-00-SI-SP	2018-09-09	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	0.001
				Iron	mg/L	0.03	0.54
				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	0.008
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	2
				Strontium	mg/L	0.001	0.018

Sample comment:

Report comment:

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LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1387166	WS-S-0000	2018-1869-00-SI-SP	2018-09-09	Uranium	mg/L	0.001	<0.001
	Tributary to Reid Brook			Zinc	mg/L	0.01	<0.01
				Phosphorus	mg/L	0.002	0.010
Sample comment:				Total Suspended Solids	mg/L	2	<2

Report comment:

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APPROVAL: 

Sarah Horner

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