Real-Time Water Quality Deployment Report

Voisey's Bay Network

June 17 to August 4, 2018

Newfoundland Labrador

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

Contents

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

On June 17, 2018, 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 August 4, 2018. This was the first 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	June 17	Deployment	Good	**Poor**	Excellent	Excellent	Excellent
	August 4	Removal	Excellent	Good	Excellent	Excellent	Excellent
Camp Pond Brook	June 17	Deployment	Excellent	Fair	Good	Excellent	Good
	August 4	Removal	Excellent	Marginal	Marginal	Excellent	**Poor**
Reid Brook below Tributary	June 17	Deployment	Excellent	**Poor**	Excellent	Good	Excellent
	August 4	Removal	Excellent	Good	Excellent	Excellent	Excellent
Tributary to Reid Brook	June 17	Deployment	Excellent	Good	Excellent	Excellent	**Poor**
	August 4	Removal	Excellent	Excellent	Excellent	Excellent	**Poor**

Reid Brook at Outlet of Reid Pond

- At deployment, conductivity, dissolved oxygen and turbidity all ranked as 'excellent'. Temperature ranked as 'good', while pH ranked as 'poor'. 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 in close enough proximity to the field sonde.
- At removal, temperature, conductivity, dissolved oxygen and turbidity all ranked as 'excellent', while pH ranked as 'good'.

Camp Pond Brook below Camp Pond

- At deployment, temperature and dissolved oxygen were 'excellent', conductivity and turbidity were 'good', while pH was 'fair'. The discrepancy between pH values is likely due to the instrument having insufficient time to acclimate, as evidenced by a sharp increase in pH values over the first few hours of deployment (see Figure 9).
- At removal, temperature and dissolved oxygen ranked as 'excellent', pH and conductivity were 'marginal', while turbidity was 'poor'. The discrepancy in turbidity values may be attributed to sediment build-up around the instrument following rainfall events.

Reid Brook below Tributary

- At deployment, temperature, conductivity and turbidity all ranked as 'excellent', dissolved oxygen was 'good', while pH was poor. The discrepancy between pH values is likely attributable to the instrument not having sufficient time to acclimate.
- At removal, water quality parameters all ranked as either 'Excellent' or 'Good'.

Tributary to Reid Brook

- At deployment, temperature, conductivity and dissolved oxygen all ranked as 'excellent', pH was 'good', while turbidity was 'poor'.
- At removal, all water quality parameters were 'excellent', with the exception of turbidity, which was 'poor'. The ranking of 'poor' at both deployment and removal is likely due to a calibration error with the field sonde.

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 17th to August 4th, 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.

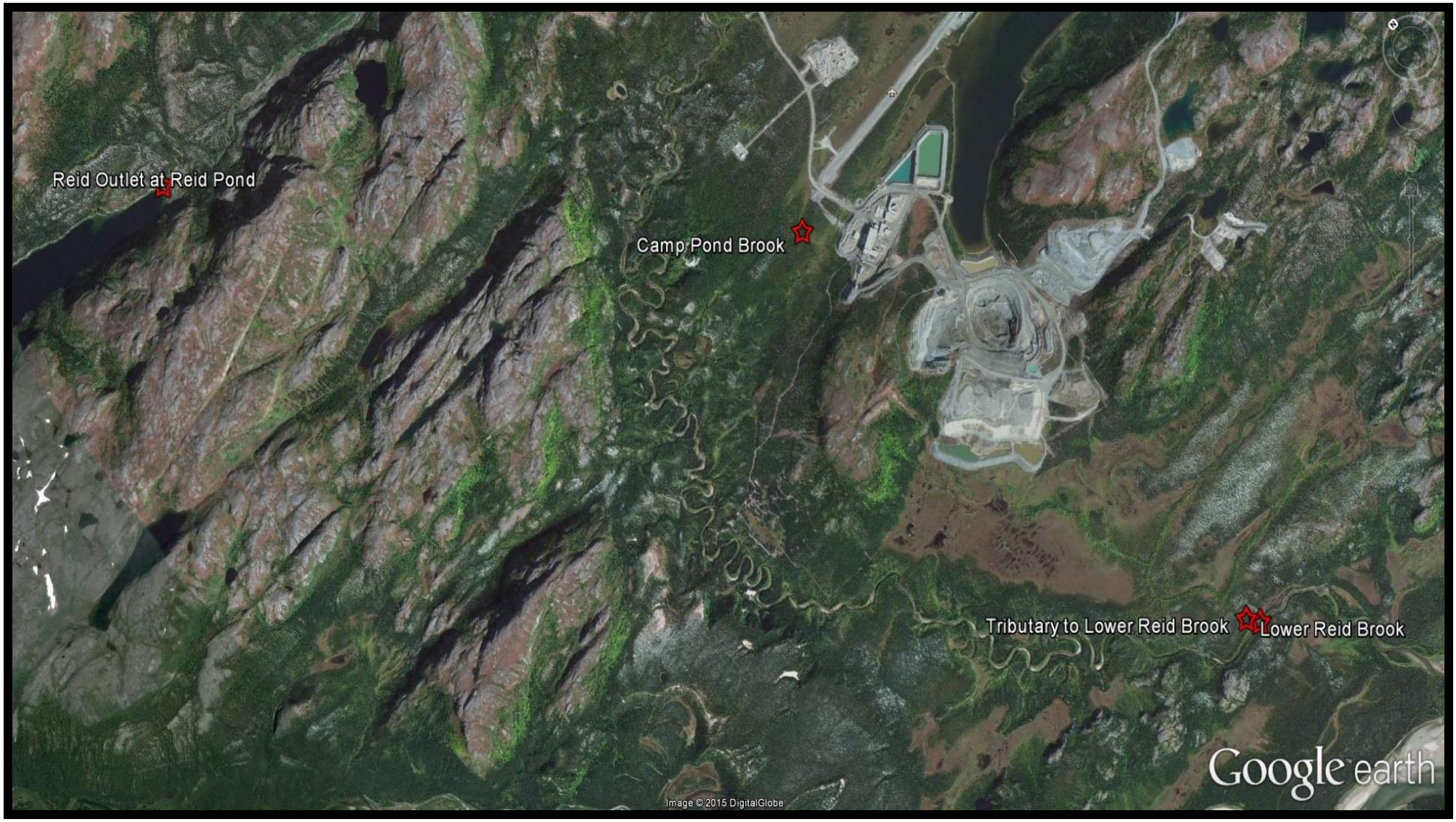

Figure 1: Voisey's Bay Network Station Locations

Reid Brook at Outlet of Reid Pond

Water Temperature

Over the deployment period, water temperature ranged from 1.37°C to 14.64°C, with a median value of 5.73°C (Figure 2). The very stable water temperature at the beginning of deployment can be attributed to Reid Pond still being covered with ice. From July 3rd onwards, temperature started to increase more rapidly, which is to be expected as air temperatures started to warm into the summer months (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.

Noticeable increases in water temperature occurred on July 14th, July 23rd and August 3rd (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.

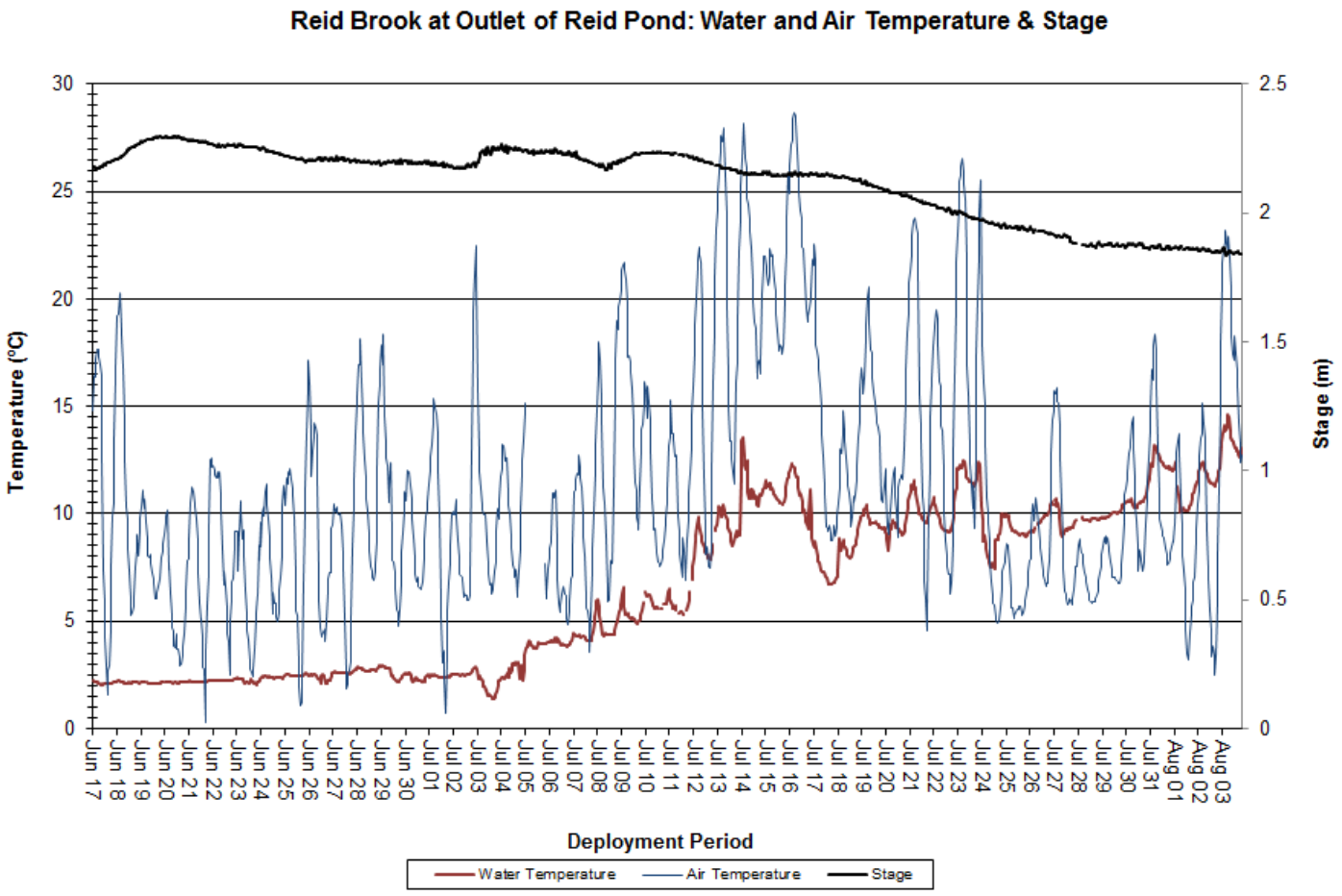

Figure 2: Water and Air Temperature & Stage at Reid Brook at Outlet of Reid Pond

pH

Over the deployment period, pH values ranged from 6.36 pH units to 8.04 pH units, with a median value of 6.76 pH units (Figure 3).

pH levels decreased steadily for the first two weeks of deployment, after which they remained quite consistent for the remainder of the deployment period. pH data for this site remained within the CCME's Guidelines for the Protection of Aquatic Life for the majority of deployment, falling slightly below the guidelines near the end 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.

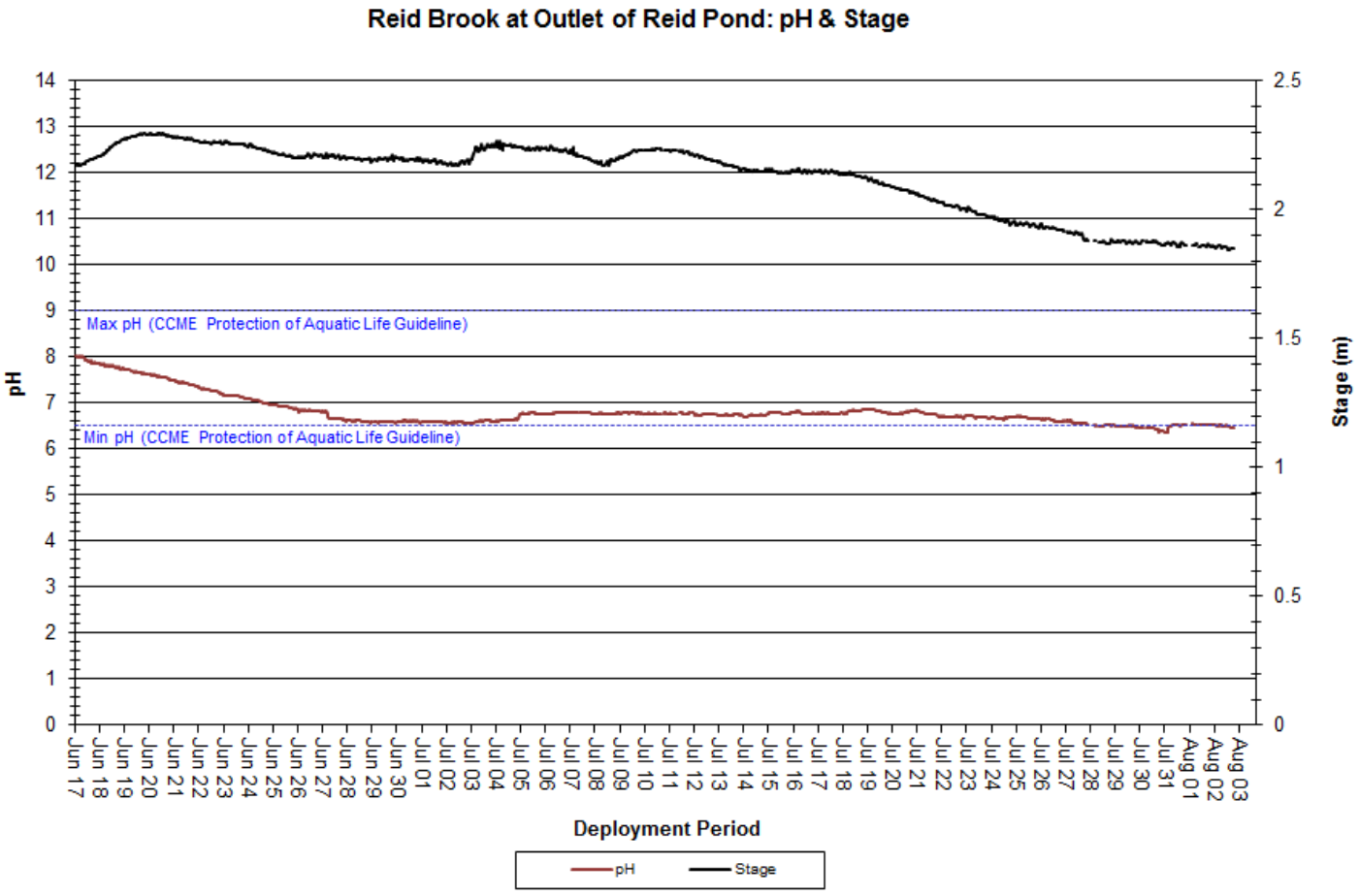

Figure 3: pH & Stage at Reid Brook at Outlet of Reid Pond

Specific Conductivity

Over the deployment period, specific conductivity levels ranged from 9.1µS/cm to 11.9µS/cm, with a median value of 11.4µS/cm. Conductivity at Reid Brook remains 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.

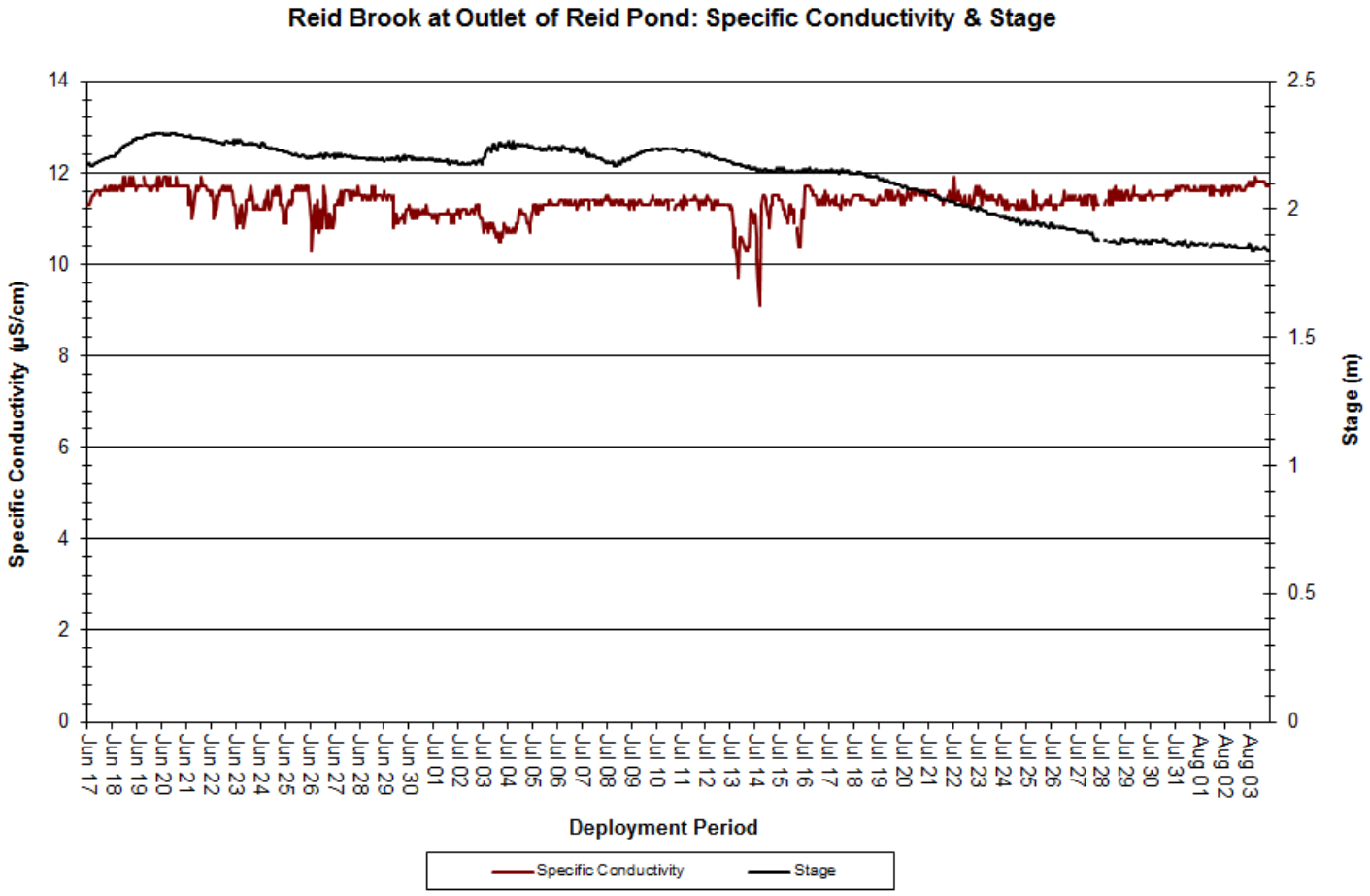

Figure 4: Specific Conductivity & Stage at Reid Brook at Outlet of Reid Pond

Dissolved Oxygen

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 concentration levels ranged from 10.31mg/L to 12.92mg/L, with a median value of 12.09mg/L. Percent saturation levels for dissolved oxygen ranged from 86.6% saturation to 110.4% saturation, with a median value of 97.3% saturation (Figure 5).

Dissolved oxygen concentration values remained above the CCME's Guideline for the Protection of Early Life Stages (9.5 mg/L) for the duration of deployment. As spring changed to summer, there was a natural increase in water temperature, which in turn resulted in a slight decrease in dissolved oxygen concentrations (Figure 5).

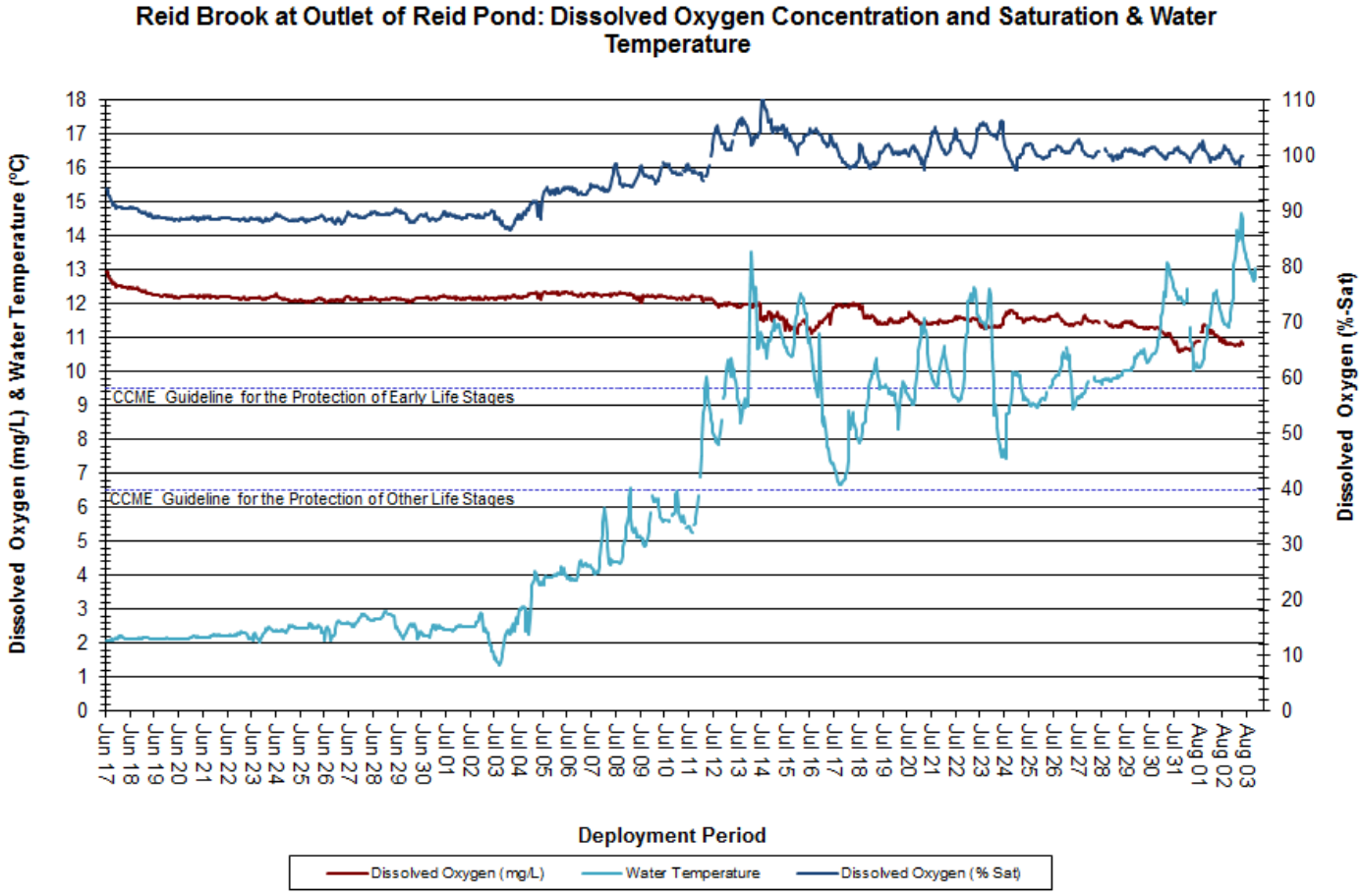

Figure 5: Dissolved Oxygen Concentration and Saturation & Water Temperature at Reid Brook at Outlet of Reid Pond

Turbidity

Over the deployment period, turbidity levels ranged from 1.2NTU to 196.4NTU, with a median value of 2.3NTU (Figure 6). A median value of 2.3NTU 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. Many of the increases in turbidity levels observed during deployment are associated with precipitation events and turbidity levels returned to background levels fairly quickly following the precipitation event (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.

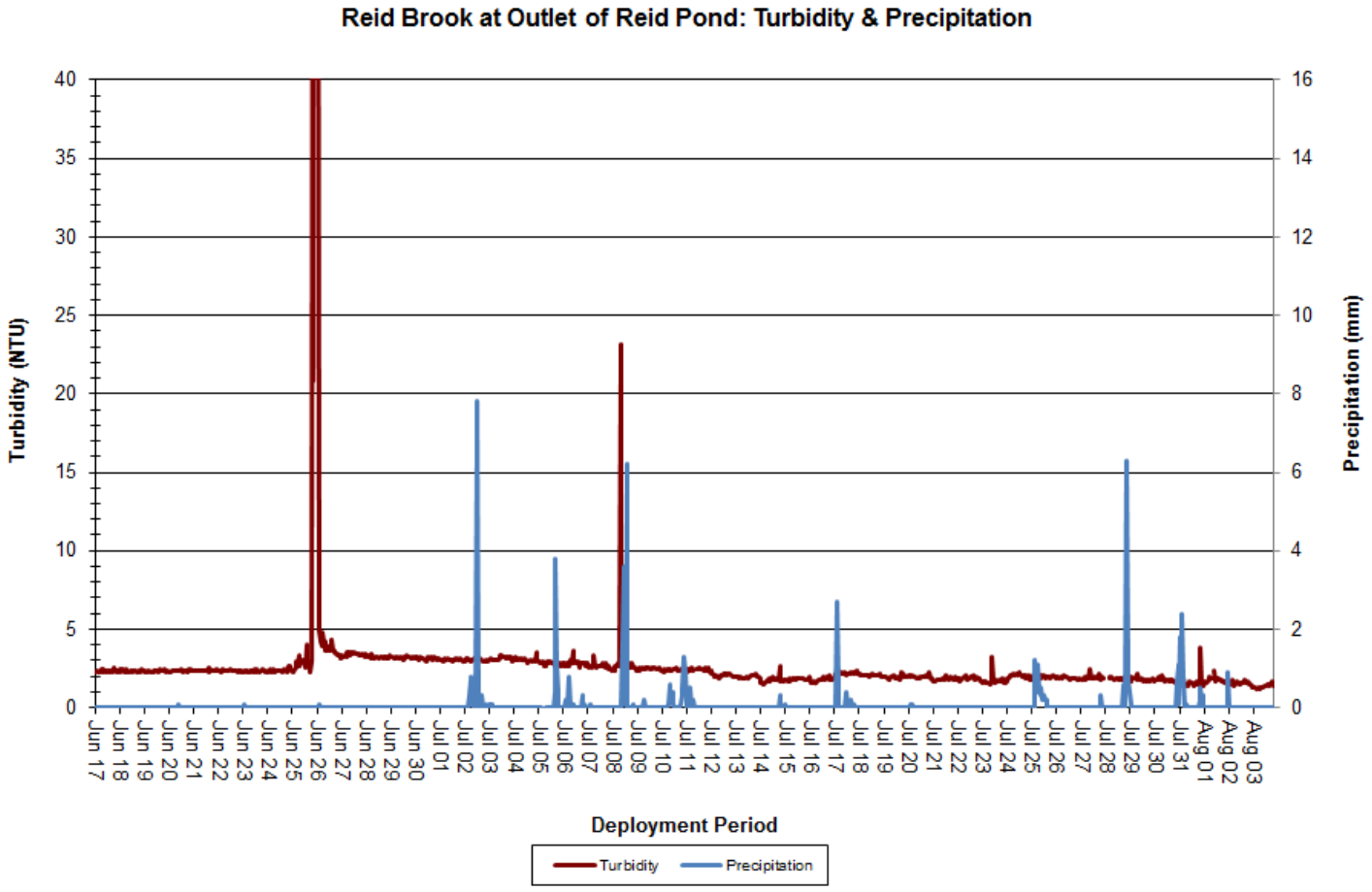

Figure 6: Turbidity & Precipitation at Reid Brook at Outlet of Reid Pond

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). 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 1.84m to 2.30m, with a median value of 2.19m. Flow values ranged from 1.78m^3/s to 8.31m^3/s, with a median value of 6.15m^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.

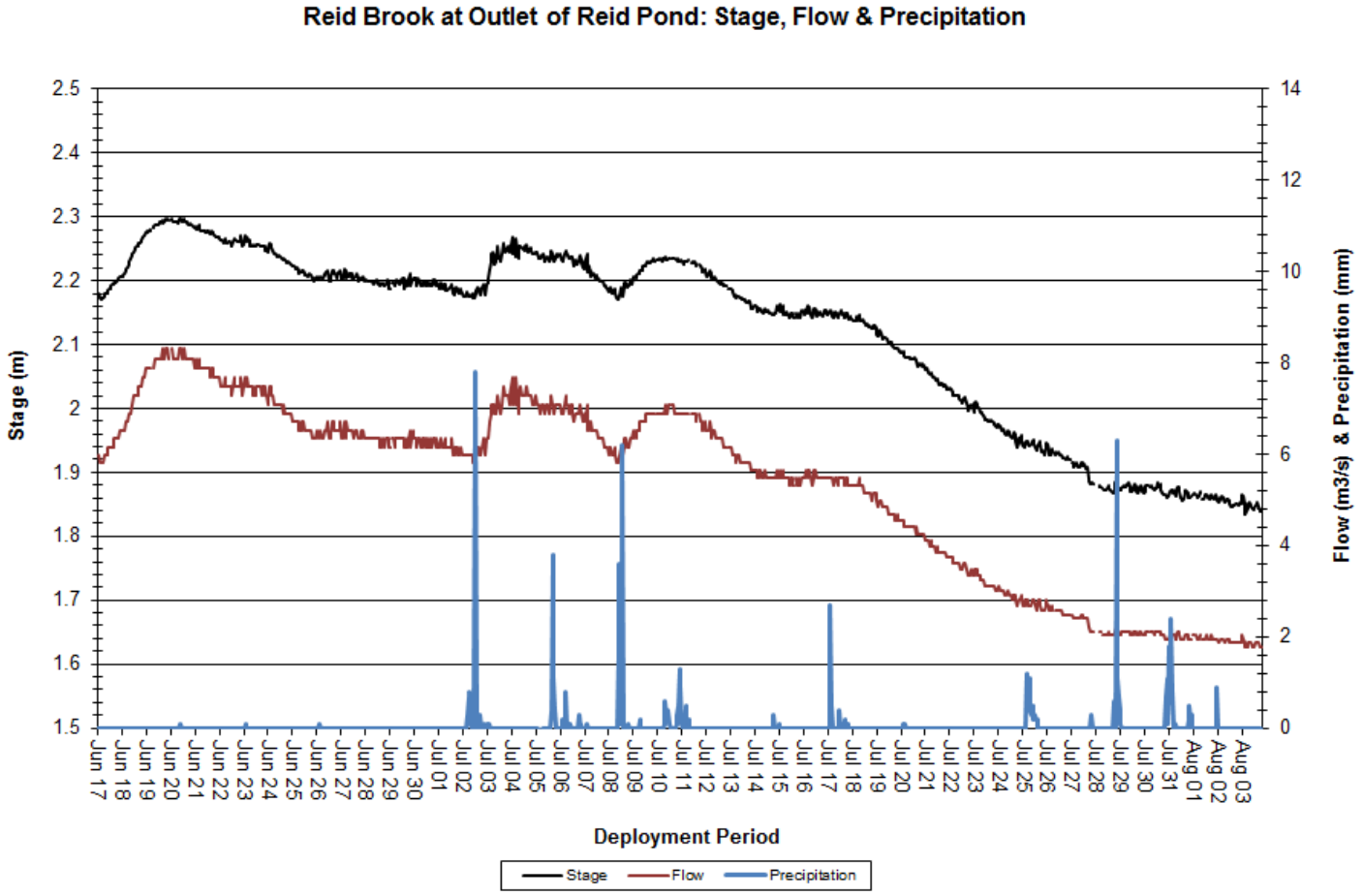

Figure 7: Stage, Flow & Precipitation at Reid Brook at Outlet of Reid Pond

Camp Pond Brook below Camp Pond

Water Temperature

Over the deployment period, water temperature ranged from 3.90°C to 20.79°C, with a median value of 13.07°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.

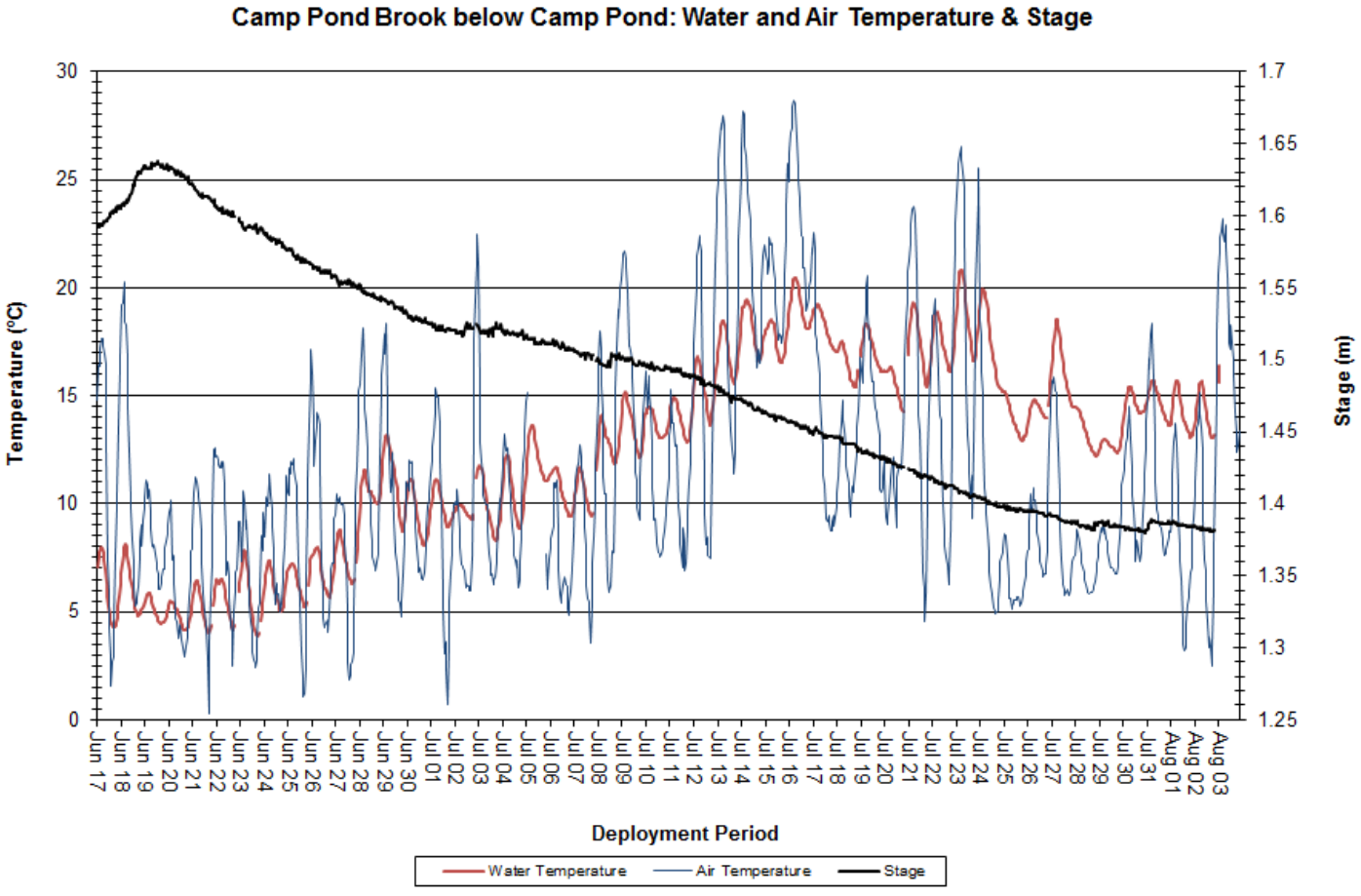

Figure 8: Water and Air Temperature & Stage at Camp Pond Brook below Camp Pond

pH

Over the deployment period, pH values ranged from 5.68 pH units to 7.46 pH units, with a median value of 7.18 pH units (Figure 9).

pH levels increased steadily for the first two weeks of deployment, after which levels remained consistent for the remainder of deployment. pH levels remained within the CCME's Guidelines for Protection of Aquatic Life for the majority of deployment.

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.

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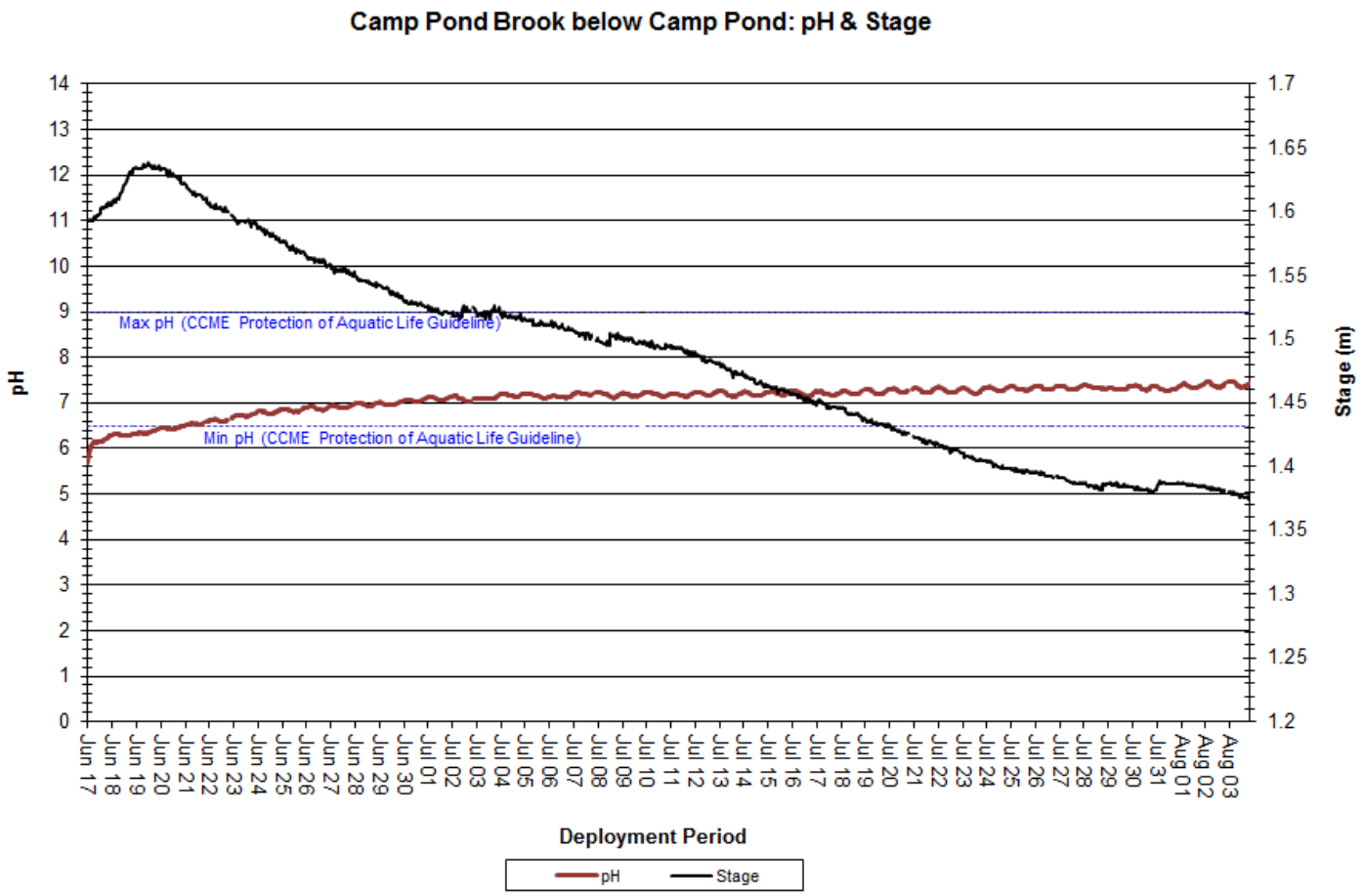

Figure 9: pH & Stage at Camp Pond Brook below Camp Pond

Specific Conductivity

Over the deployment period, specific conductivity ranged from 16.4µS/cm to 33.7µS/cm, with a median value of 26.5µS/cm (Figure 10).

Conductivity levels increased quickly at the beginning of the deployment period, which is likely attributable to snow melt and subsequent runoff entering Camp Pond Brook.

Over the remainder of the deployment period, conductivity levels slowly increased while stage decreased. This is a common association, since a decrease in water level serves to concentrate suspended materials in the water column, in turn increasing specific conductivity (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.

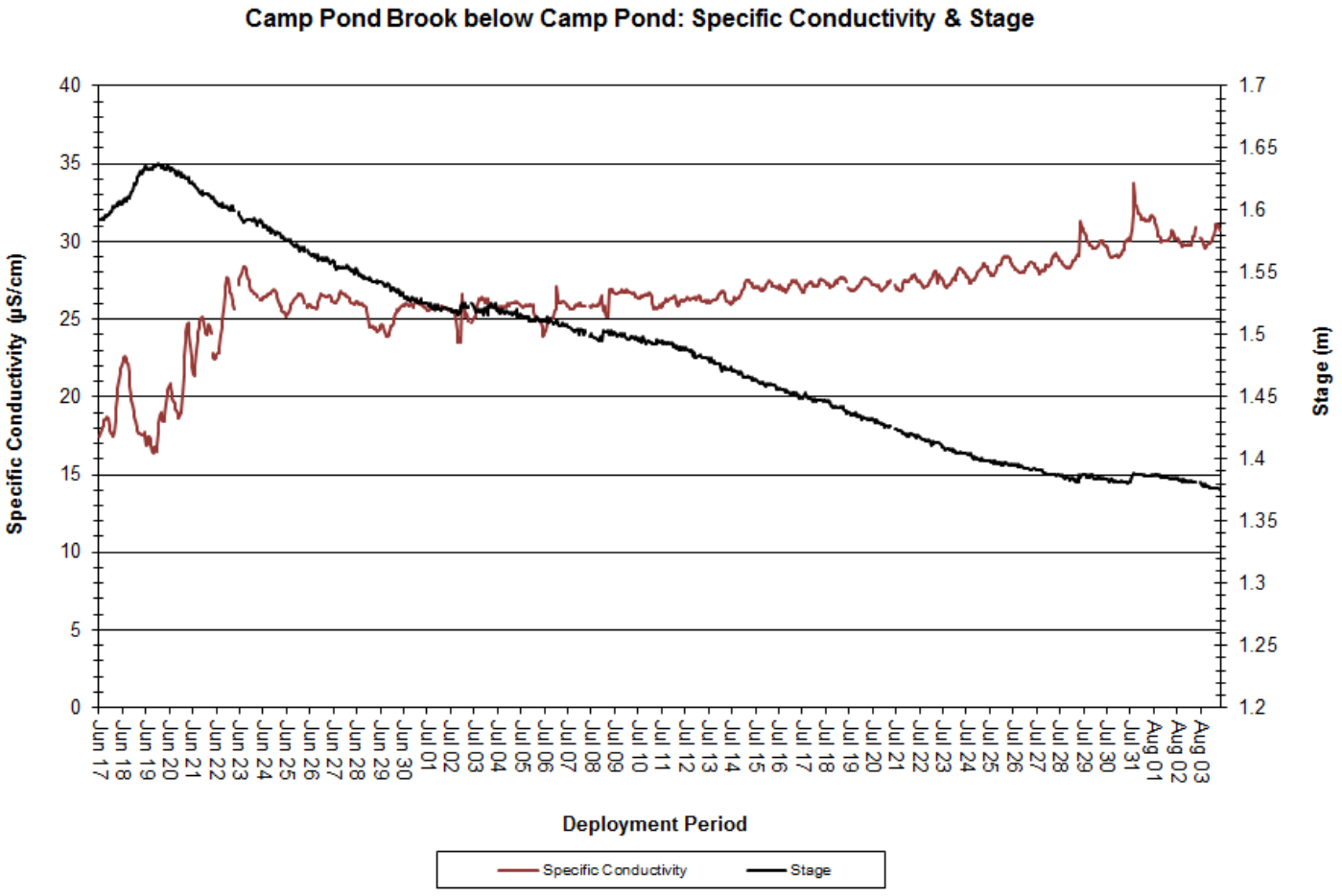

Figure 10: Specific Conductivity & Stage at Camp Pond Brook below Camp Pond

Dissolved Oxygen

Over the deployment period, dissolved oxygen concentration ranged from 8.56mg/L to 12.07mg/L, with a median value of 9.97mg/L. Saturation of dissolved oxygen ranged from 84.4% saturation to 101.9% saturation, with a median value of 94.5% (Figure 11).

Dissolved oxygen concentrations started to occasionally dip below the CCME's Guideline for the Protection of Early Life Stages from July 13 through to the end of the deployment period. These occurrences corresponded closely with warmer water temperatures during the same period (Figure 11). This is expected as water temperature directly influences the level of dissolved oxygen present in the water column; as water temperatures increase, dissolved oxygen concentrations decrease.

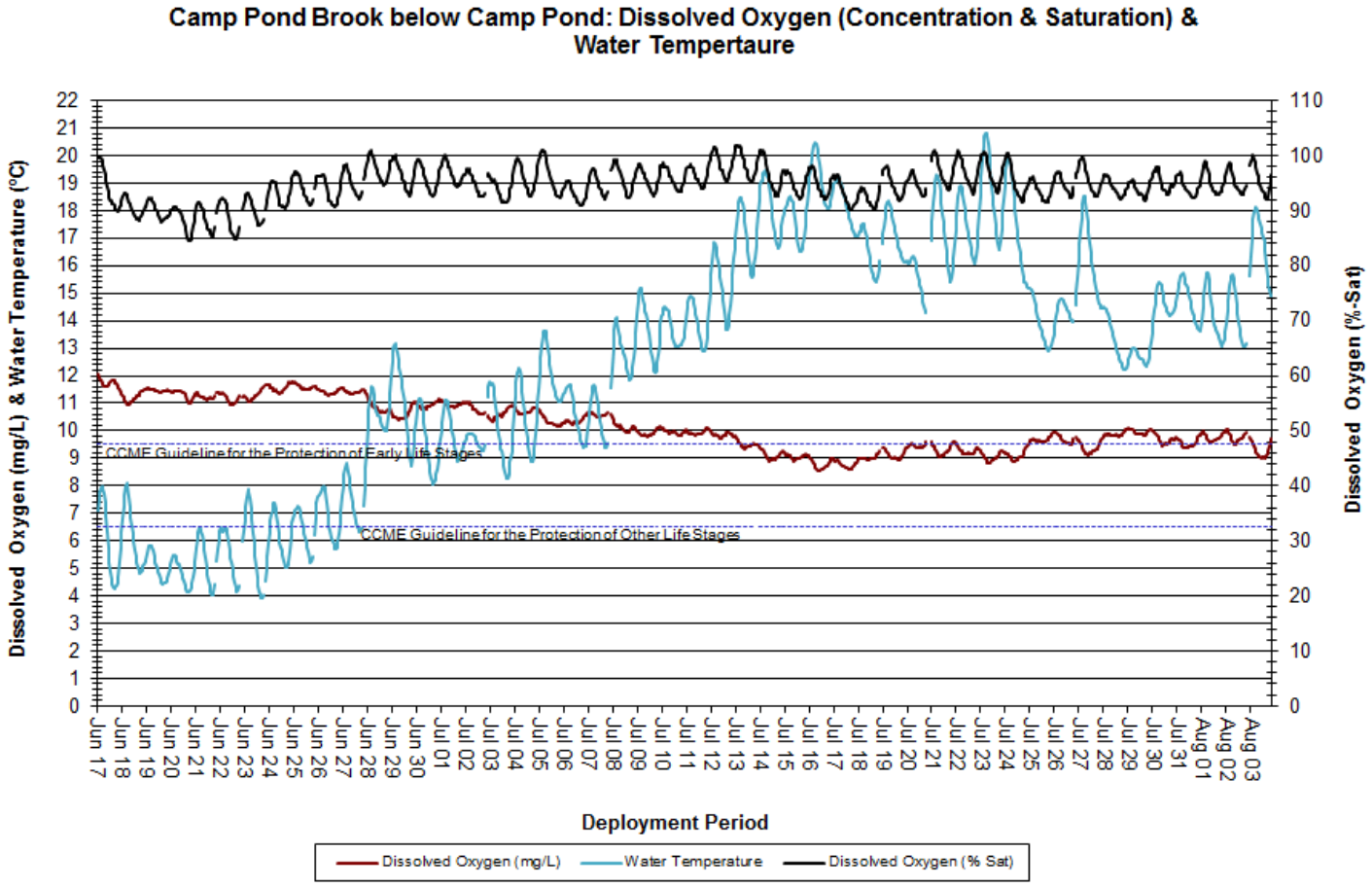

Figure 11: Dissolved Oxygen & Water Temperature at Camp Pond Brook below Camp Pond

Turbidity

Over the deployment period, turbidity ranged from 0.0NTU to 124.0NTU, with a median value of 0.0NTU (Figure 12). A median value of 0.0NTU indicates there was very little natural background turbidity at this station.

The higher turbidity levels observed at the beginning of the deployment period are likely attributable to snow melt and subsequent runoff entering Camp Pond Brook. Smaller turbidity peaks observed from June 29th onwards correlate closely with rainfall events (Figure 12).

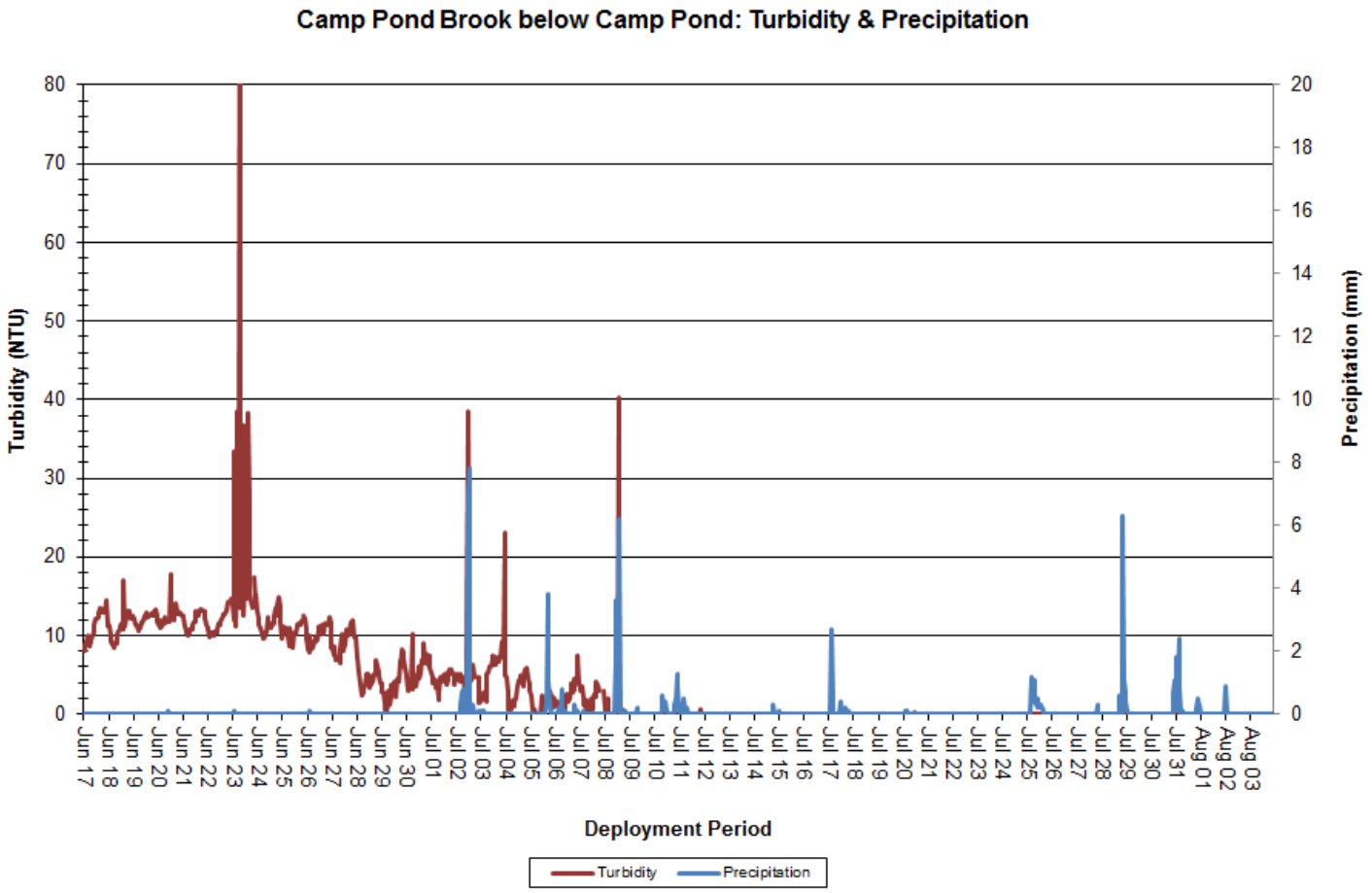

Figure 12: Turbidity & Precipitation at Camp Pond Brook below Camp Pond

Stage, Flow and Precipitation

Over the deployment period, stage values ranged from 1.38m to 1.64m, with a median value of 1.49m. Stream flow values ranged from 0.38m^3/s to 2.14m^3/s, with a median value of 0.88m^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, which were particularly evident on July 2nd, July 9th, and July 29th (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.

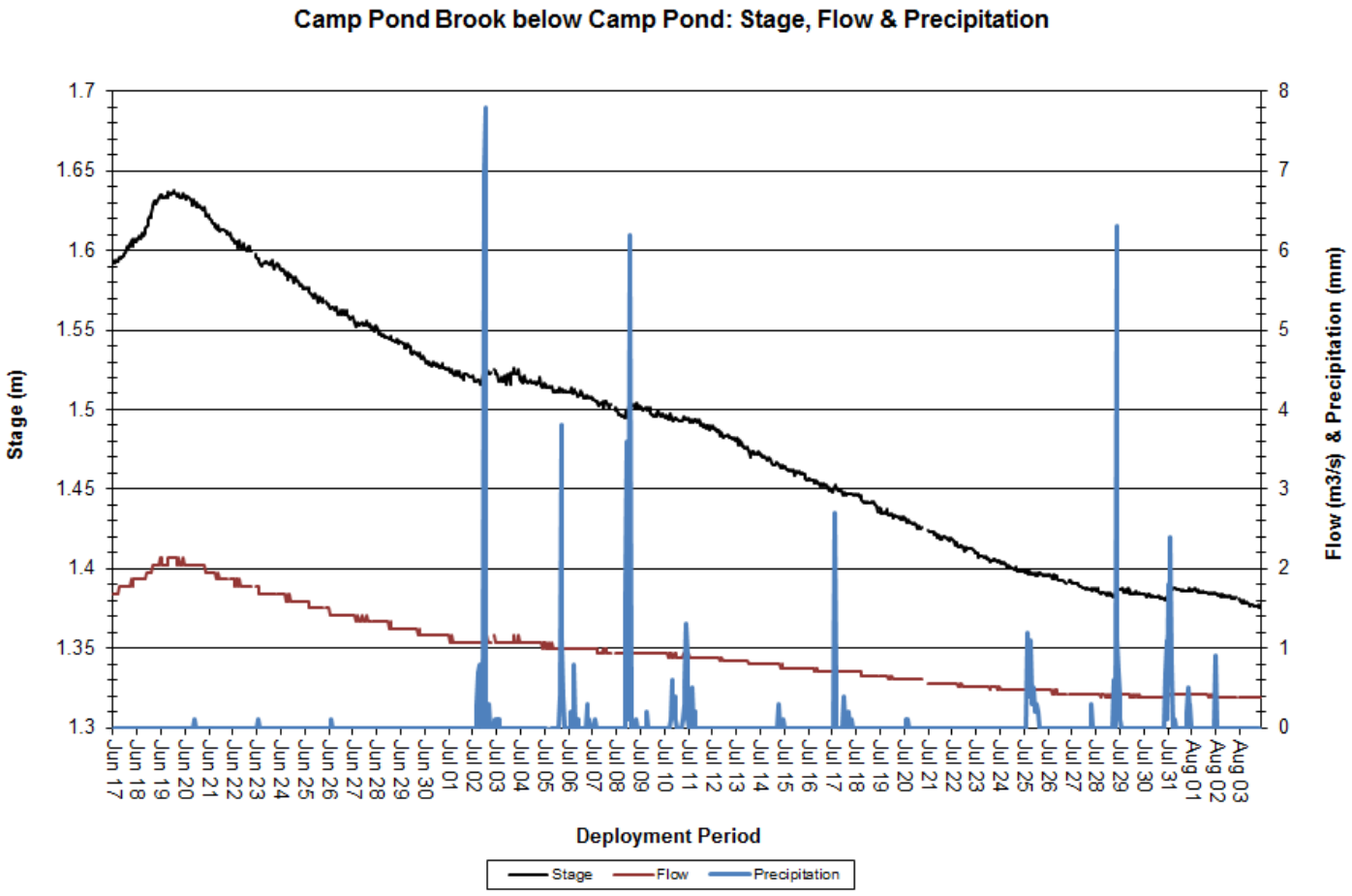

Figure 13: Stage, Flow & Precipitation at Camp Pond Brook below Camp Pond

Reid Brook below Tributary

Water Temperature

Over the deployment period, water temperature ranged from 3.04°C to 17.33°C, with a median value of 10.21°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.

Figure 13 also displays the relationship between stage and water temperature. As stage steadily decreased over the deployment period, water temperature generally increased.

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.

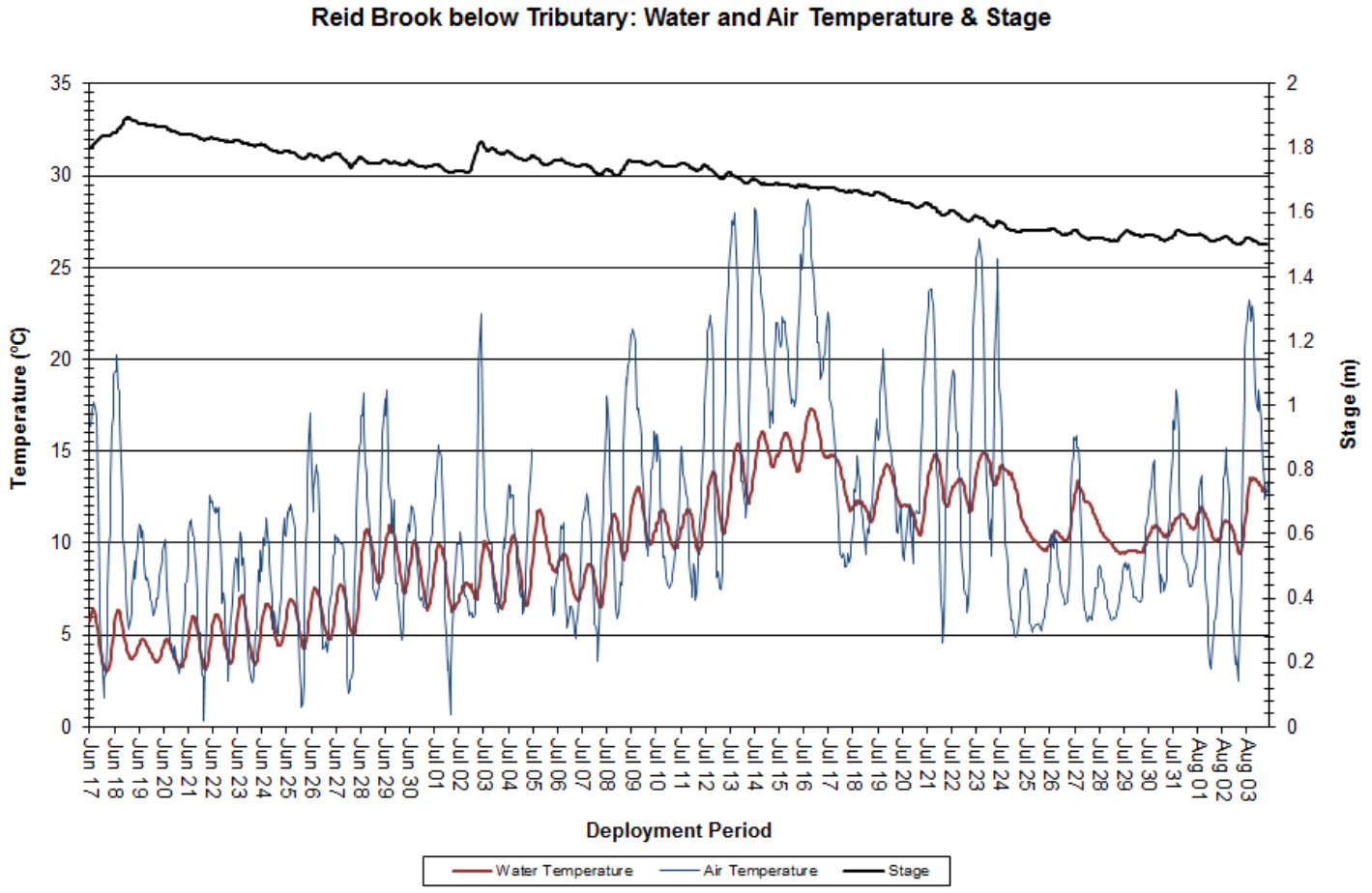

Figure 14: Water and Air Temperature & Stage at Reid Brook below Tributary

pH

Over the deployment period, pH ranged from 5.31 pH units to 6.47 pH units, with a median value of 6.23 (Figure 15).

pH remained below the CCME's Minimum Guideline for the Protection of Aquatic Life for the duration of deployment.

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.

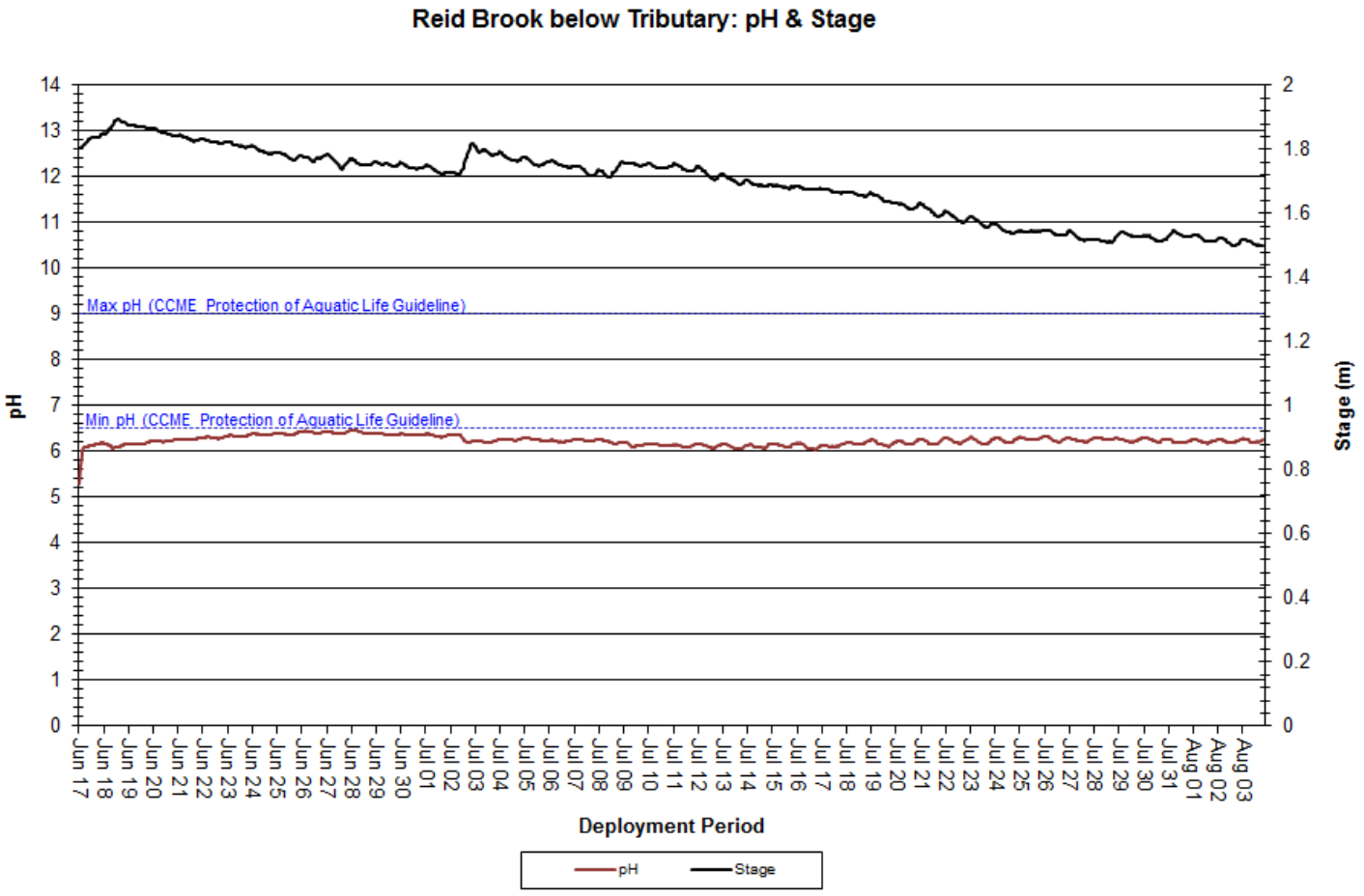

Figure 15: pH & Stage at Reid Brook below Tributary

Specific Conductivity

Over the deployment period, specific conductivity ranged from 14.3µS/cm to 31.7µS/cm, with a median value of 21.7µS/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 decreased over the course of deployment, suspended materials in the water body became 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.

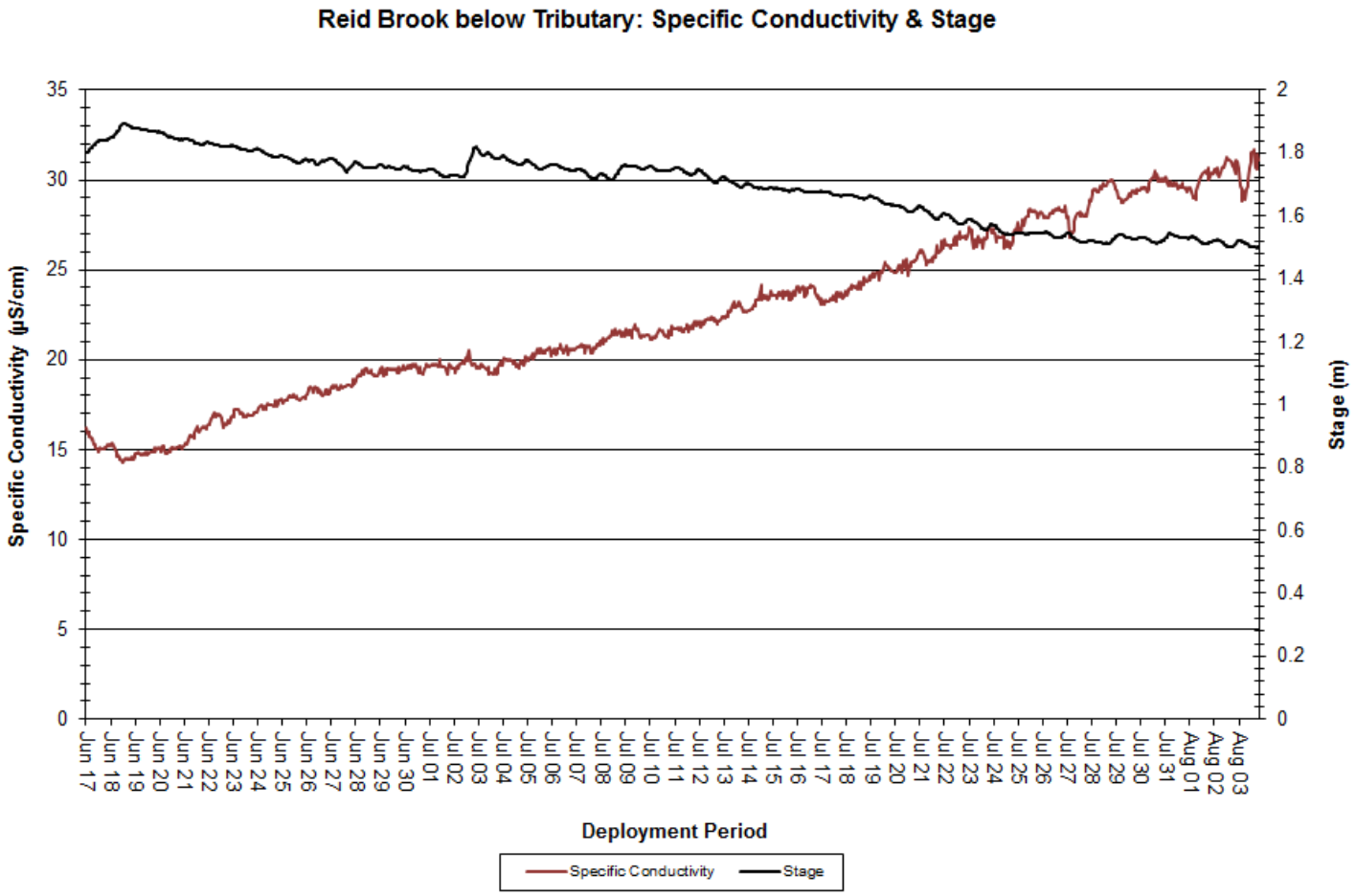

Figure 16: Specific Conductivity & Stage at Reid Brook below Tributary

Dissolved Oxygen

Over the deployment period, dissolved oxygen concentration ranged from 9.19mg/L to 12.73mg/L, with a median value of 10.82mg/L. The saturation of dissolved oxygen ranged from 93.3% saturation to 101.6% saturation, with a median value of 95.9% (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, with the exception of a short period on July 16th. This event correlated closely with a spike in water temperature, which is to be expected; as water temperature increases, dissolved oxygen concentration decreases. Dissolved oxygen concentration was fairly consistent over the course of deployment, with fluctuations closely connected to changes in water temperature.

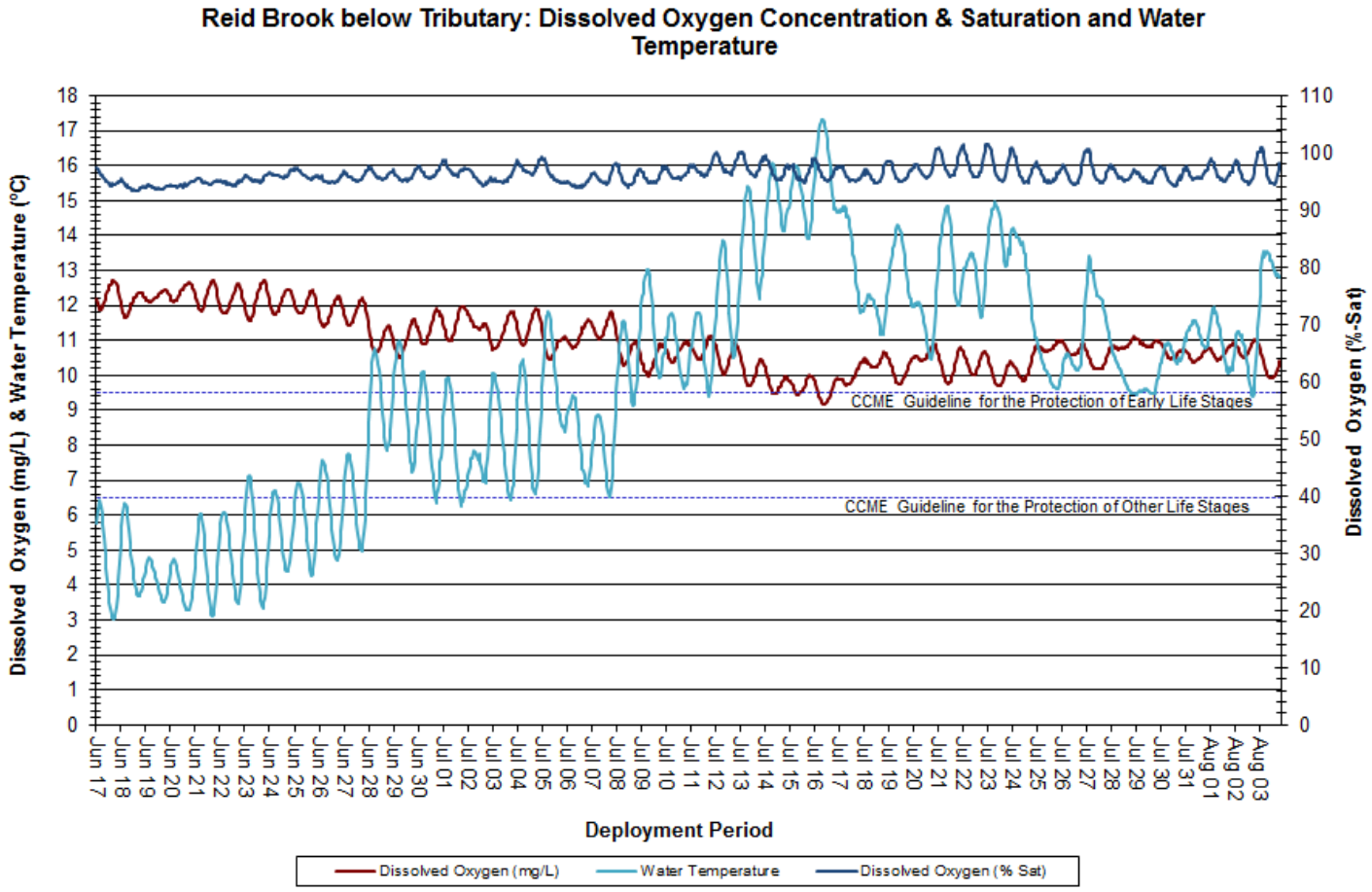

Figure 17: Dissolved Oxygen & Water Temperature at Reid Brook below Tributary

Turbidity

Over the deployment period, turbidity ranged from 0.0 NTU to 12.1 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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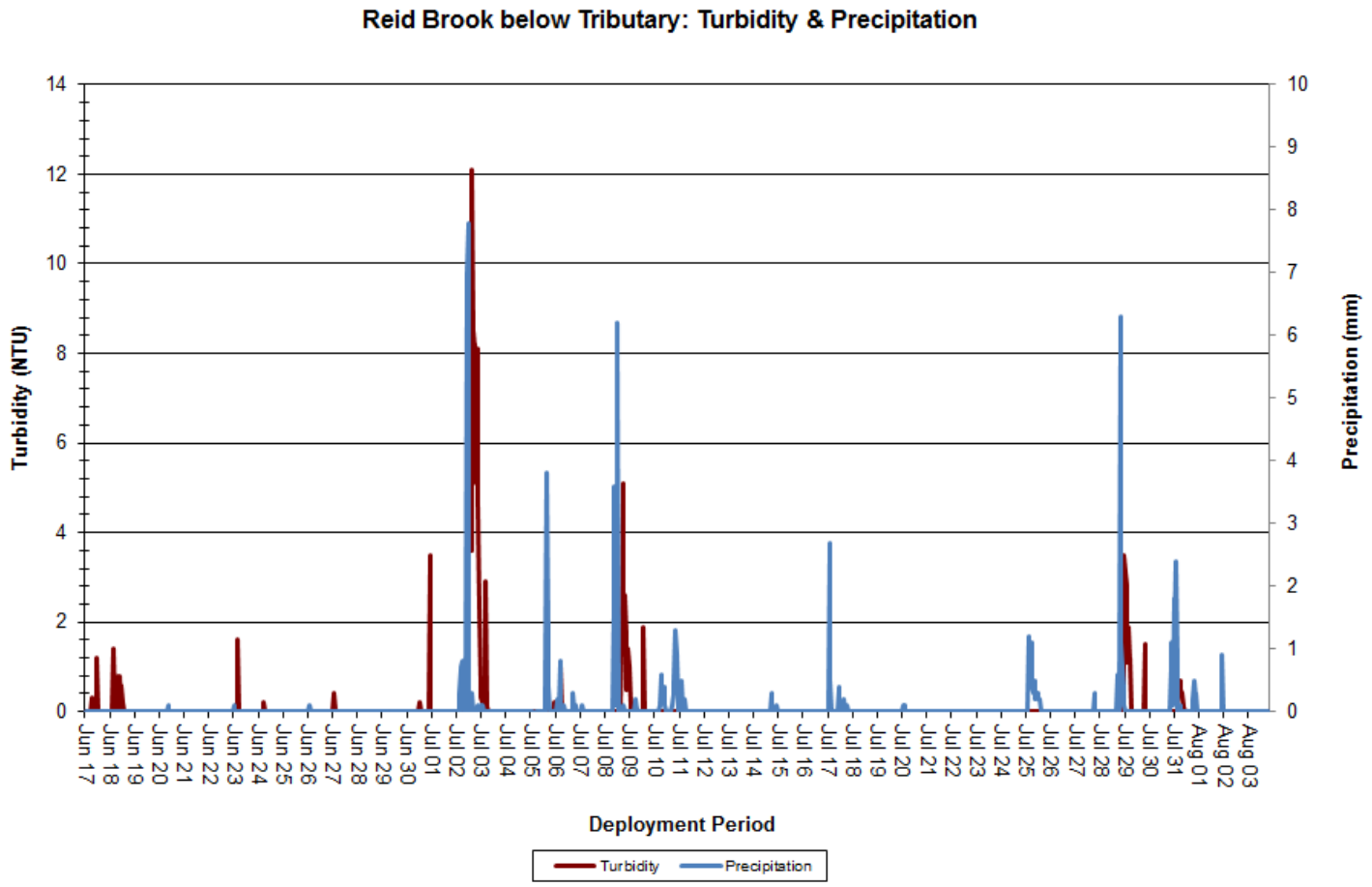

Figure 18: Turbidity & Precipitation at Reid Brook below Tributary

Stage, Flow and Precipitation

Stage, flow and precipitation are graphed below to show the relationship between rainfall and water level. It is evident that many peaks in stage (m) and flow (m^3/s) are closely linked to precipitation events.

Over the deployment period, stage values ranged from 1.50m to 1.90m, with a median value of 1.73m. Flow ranged from 2.43m^3/s to 16.83m^3/s, with a median value of 9.00m^3/s. Precipitation data was obtained from the Voisey's Bay airstrip weather station (Figure 19)

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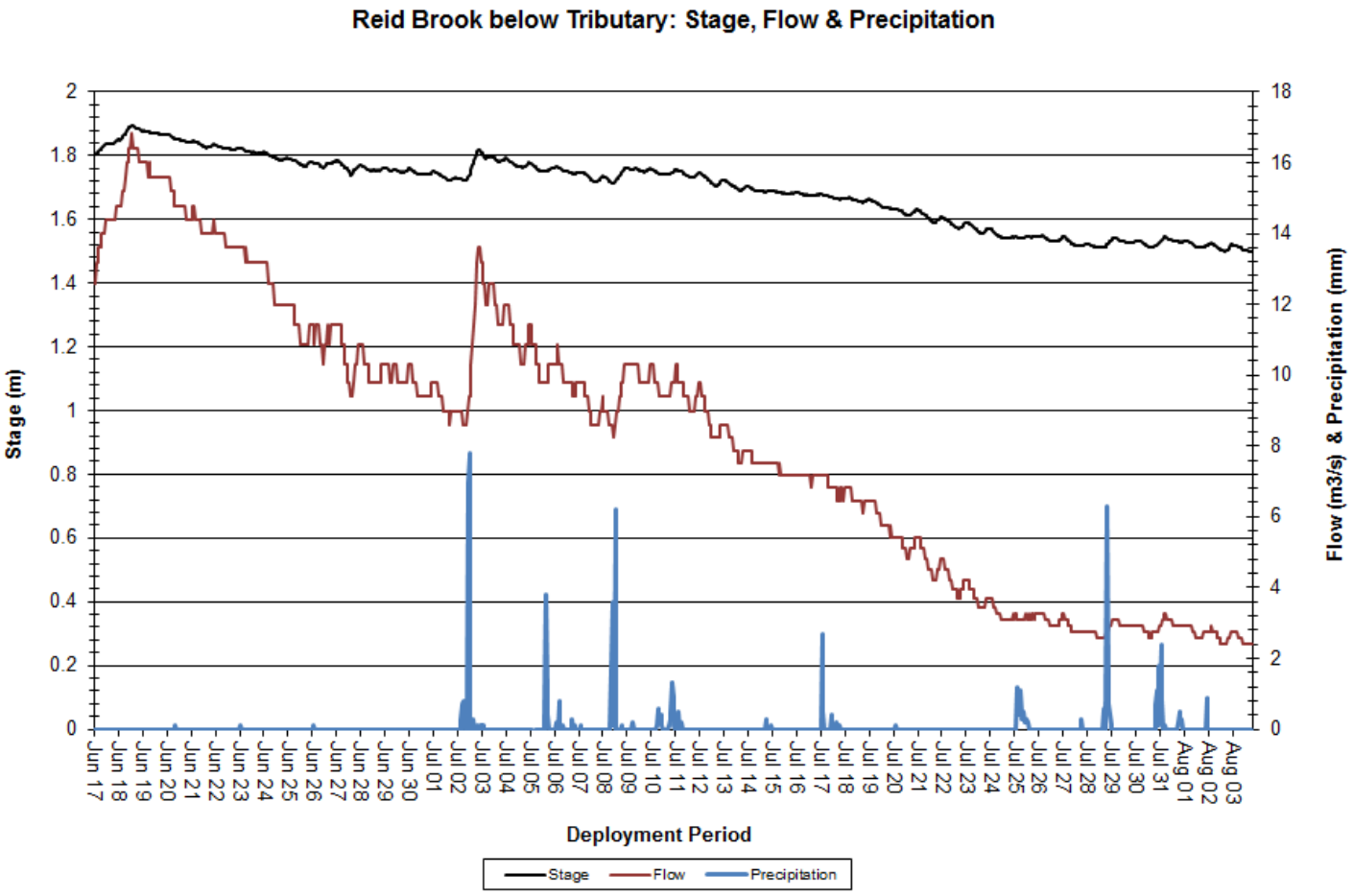

Figure 19: Stage, Flow & Precipitation at Reid Brook below Tributary

Tributary to Reid Brook

Water Temperature

Over the deployment period, water temperature ranged from 2.90°C to 17.40°C, with a median value of 10.30°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 increased gradually over the course of deployment with the change from spring to summer, and correlated closely with ambient air temperatures.

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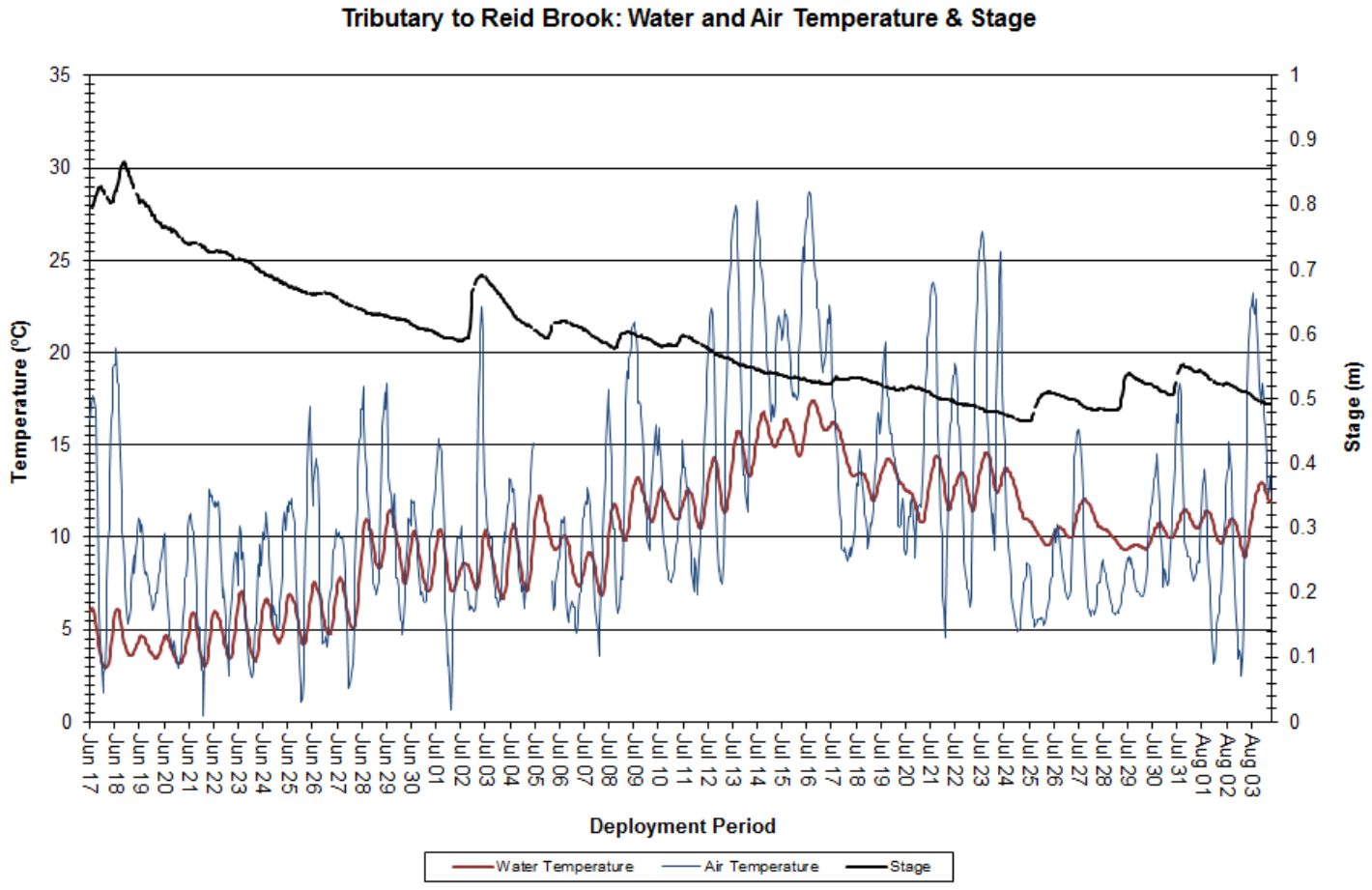


Figure 20: Water and Air Temperature & Stage at Tributary to Reid Brook

pH

Over the deployment period, pH ranged from 6.15 pH units to 6.97 pH units, with a median value of 6.70 (Figure 21).

Stage increases often indicate a rainfall event; rainfall will cause pH values to decrease for a short period of time (Figure 21). This is evidenced by an obvious increase in stage and associated decrease in pH on July 2nd.

At the beginning of deployment, pH values slowly but steadily increased. pH levels reached the CCME's Minimum Guideline for the Protection of Aquatic Life around June 26th, and remained within the acceptable range for the remainder 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.

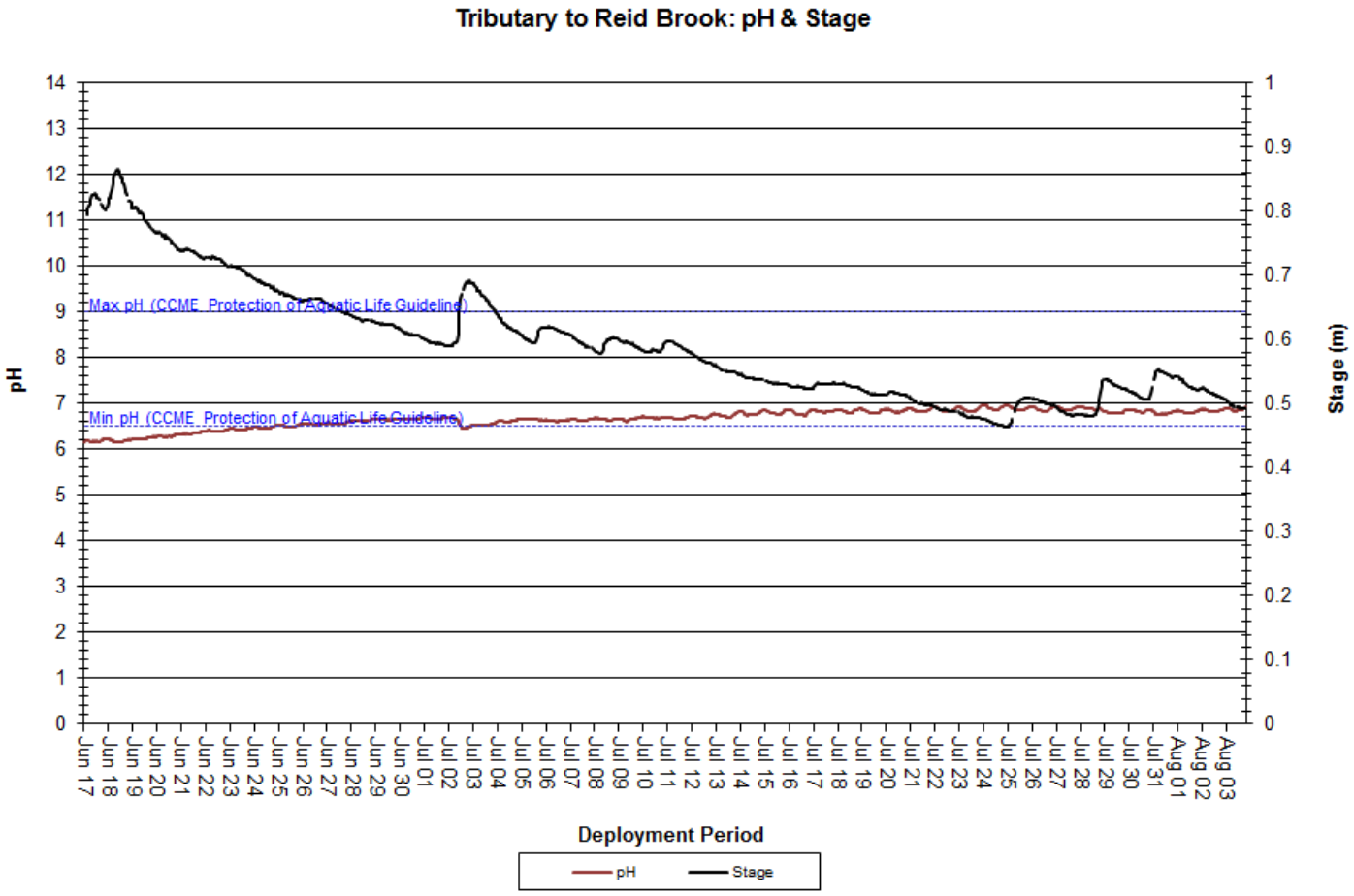


Figure 21: pH & Stage at Tributary to Reid Brook

Specific Conductivity

Over the deployment period, specific conductivity ranged from 14.0µS/cm to 34.5µS/cm, with a median value of 24.7µS/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.

There was also a gradual increase in conductivity across the deployment period. This is to be expected; as air temperatures increased and evaporation occured in the brook, dissolved particulate matter became more concentrated.

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.

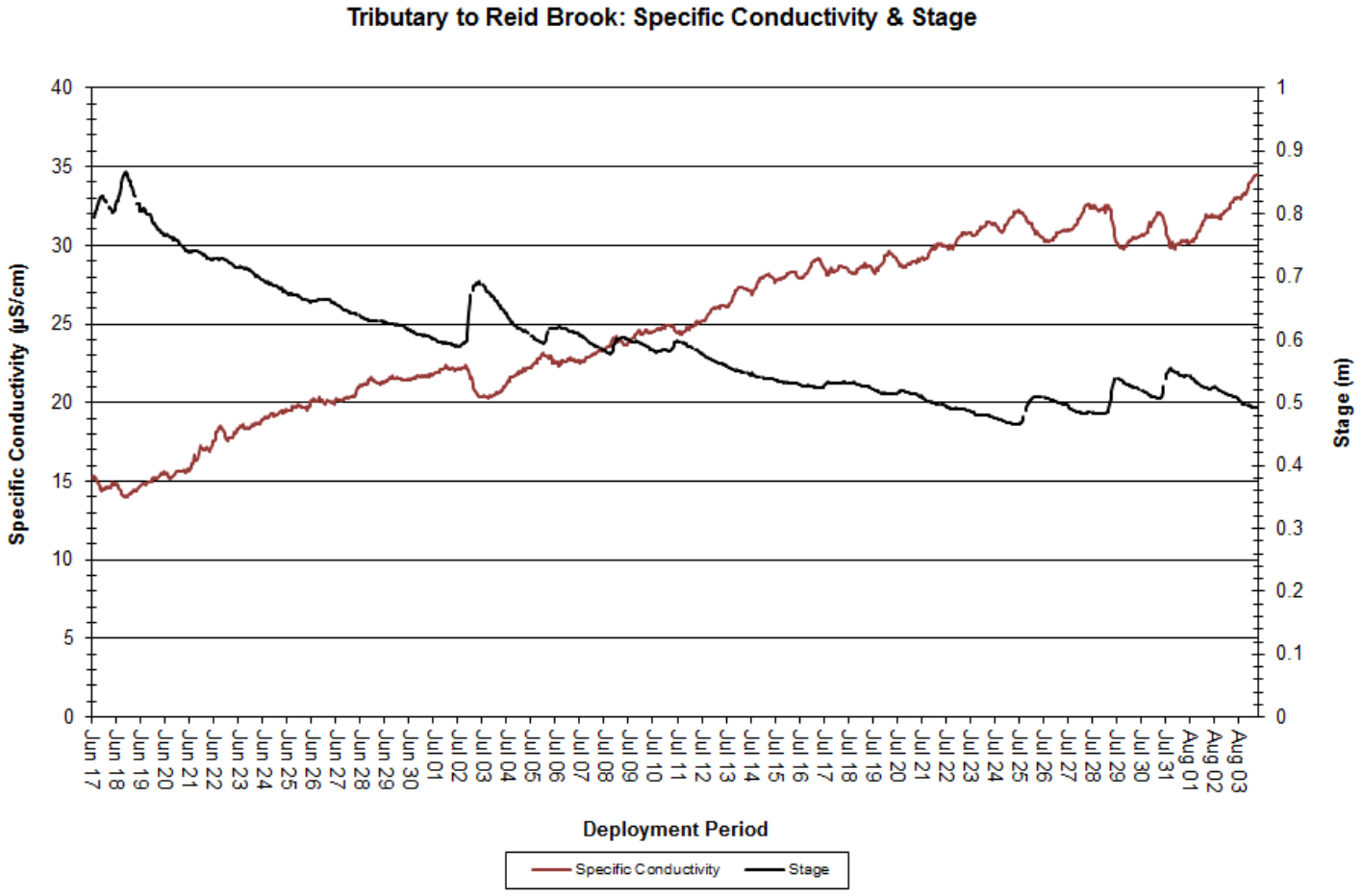


Figure 22: Specific Conductivity & Stage at Tributary to Reid Brook

Dissolved Oxygen

Over the deployment period, dissolved oxygen concentration ranged from 9.05mg/L to 12.53mg/L, with a median value of 10.60mg/L. The saturation of dissolved oxygen ranged from 91.4% saturation to 98.9% saturation, with a median value of 94.3% (Figure 23).

Dissolved oxygen levels remained above the CCME's Guidelines for the Protection of Early/Other Life Stages for the majority of deployment, with the exception of a short period in mid-July. This decrease in dissolved oxygen corresponded closely to a period of increased water temperature.

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.

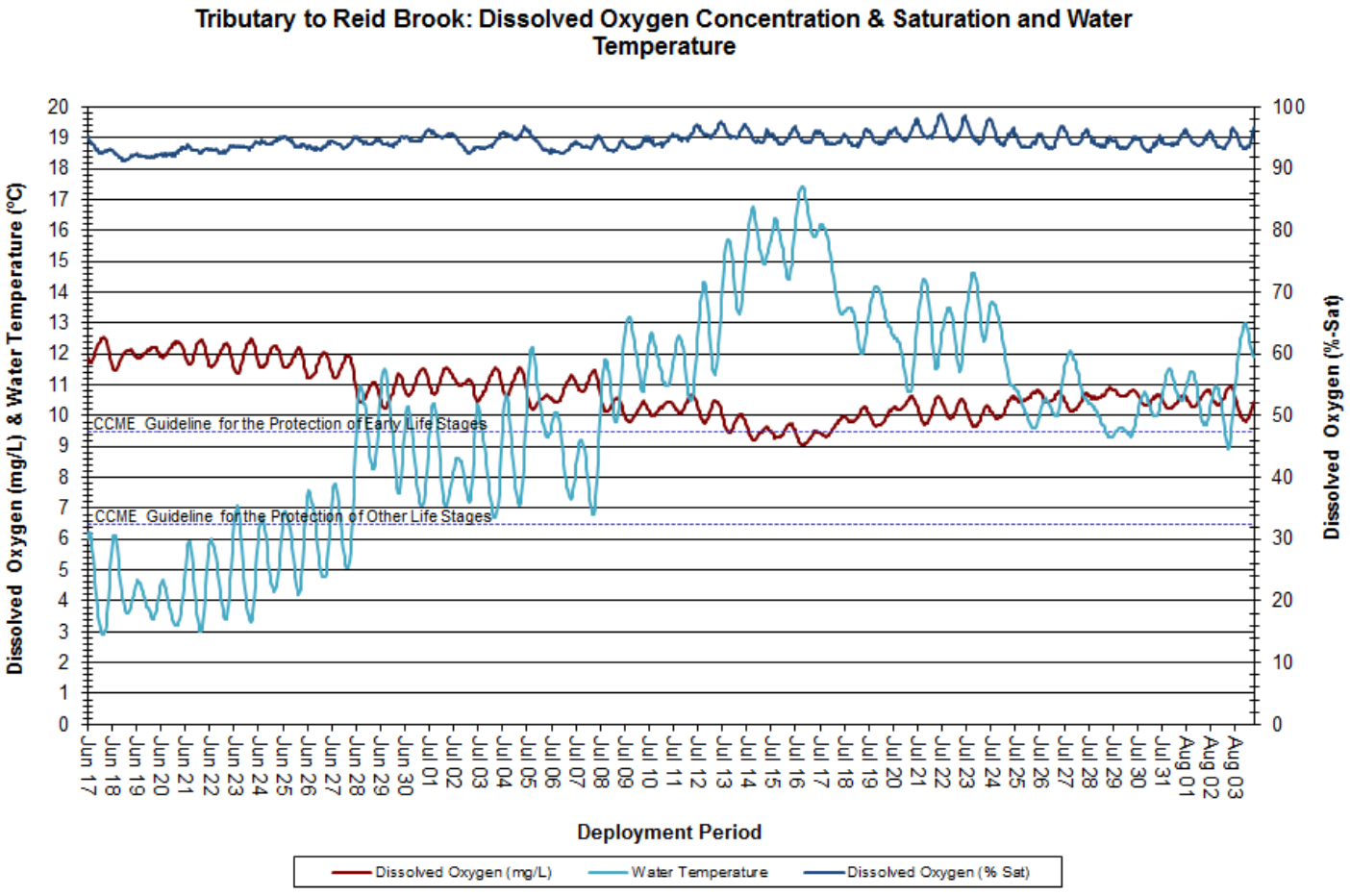


Figure 23: Dissolved Oxygen & Water Temperature at Tributary to Reid Brook

Turbidity

Over the deployment period, turbidity ranged from 16.6 NTU to 31.4 NTU, with a median value of 16.9 NTU (Figure 24). A median value of 16.9 NTU indicates that there was quite a bit of natural background turbidity at this station; however, this is an unusually high turbidity level for this station. Considering the graphed data below, an error was likely made during calibration that resulted in this higher-than-expected background turbidity level.

There were a number of turbidity events at this station, with many of the larger turbidity events correlating with rainfall events (Figure 24). 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.

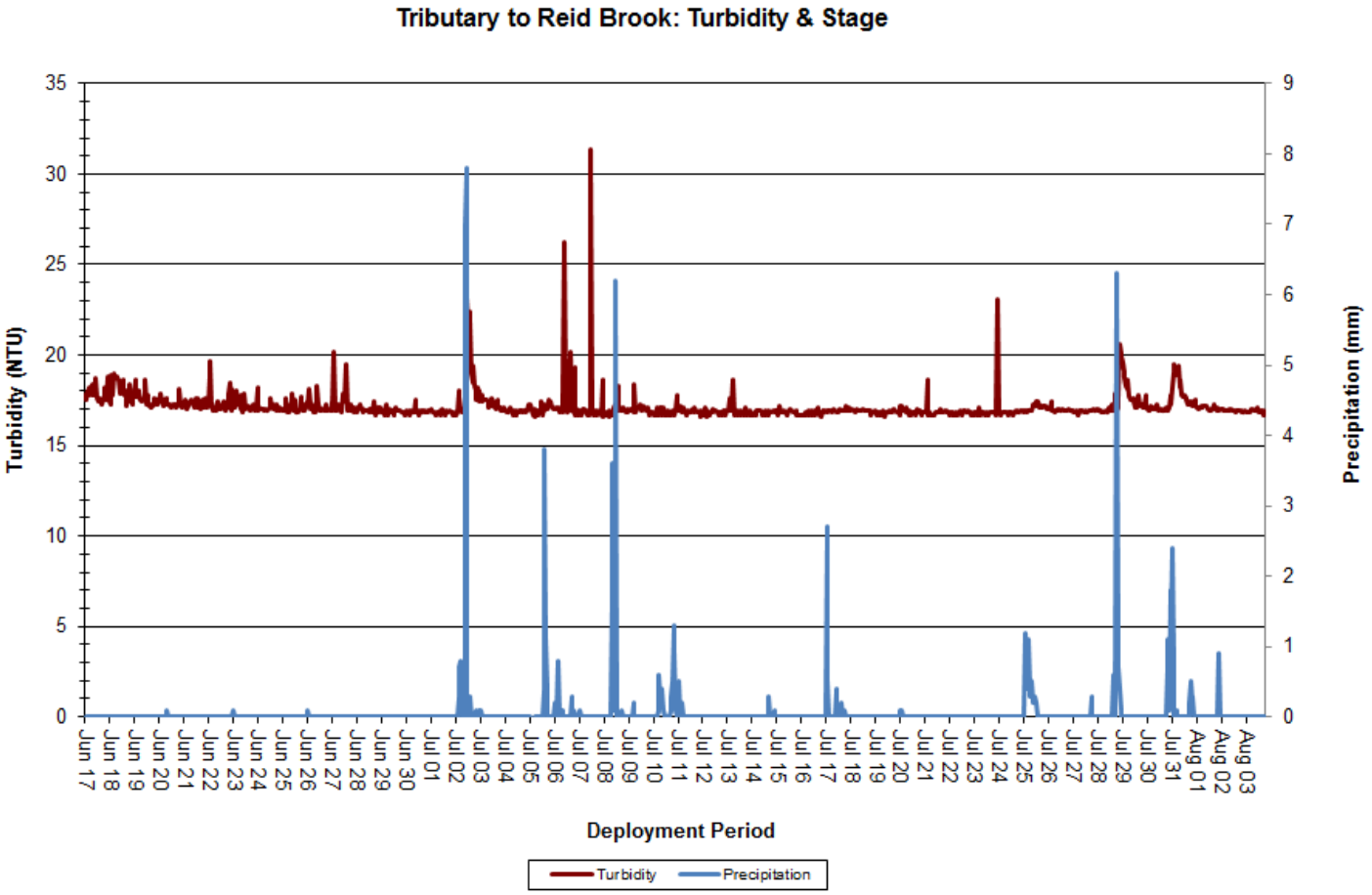


Figure 24: Turbidity & Stage at Tributary to Reid Brook

Stage, Flow and Precipitation

Over the deployment period, stage ranged from 0.47m to 0.87m, with a median value of 0.59m. Flow ranged from 0.14m^3/s to 1.96m^3/s, with a median value of 0.36m^3/s. Precipitation data was obtained from the Voisey's Bay airstrip weather station (Figure 25).

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.

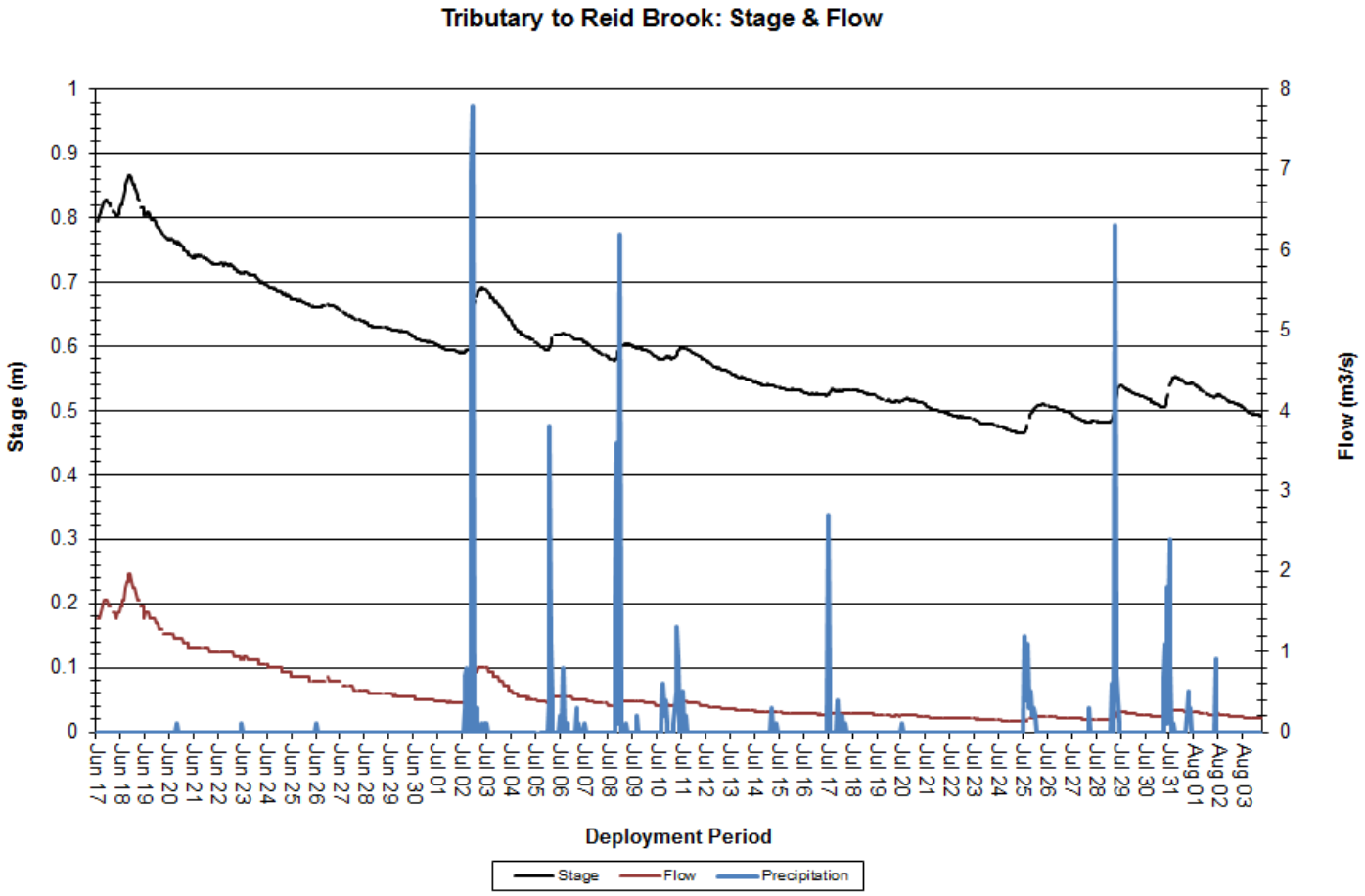


Figure 25: Stage, Flow & Precipitation at Tributary to Reid Brook

Conclusions

Water temperatures across all stations ranged from a minimum of 1.37°C at Reid Brook at Outlet of Reid Pond to a maximum of 20.79°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.

pH values across all stations ranged from a minimum of 5.31pH units at Reid Brook below Tributary to a maximum of 8.04pH units at Reid Brook at Outlet of Reid Pond. pH values at all stations were relatively consistent.

Specific conductivity across all stations ranged from a minimum of 9.1µS/cm at Reid Brook at Outlet of Reid Pond to a maximum of 34.5µS/cm at Tributary to Reid Brook. 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 26.5µS/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 8.56mg/L at Camp Pond Brook below Camp Pond to a maximum of 12.92mg/L at Reid Brook at Outlet of Reid Pond. Dissolved oxygen is generally lower 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 Guideline for the Protection of Early Life Stages at the Reid Brook at Outlet of Reid Pond station. At the other stations, dissolved oxygen levels remained above the CCME's guidelines for the majority of deployment, with exceptions correlating closely with higher water temperatures.

Turbidity levels across all stations ranged from a minimum of 0.0 NTU at two stations to a maximum of 196.4NTU at Reid Brook at Outlet of Reid Pond. Turbidity levels showed natural increases and decreases corresponding to stage and 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 very accurate, with two exceptions: air temperature data was removed from July 5 at 14:00 through July 6 at 7:00 due to inaccurate readings of -50°C; and precipitation data was removed from July 5 at 16:00 and 17:00 due to inaccurate readings that did not correspond to any water quality events.

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

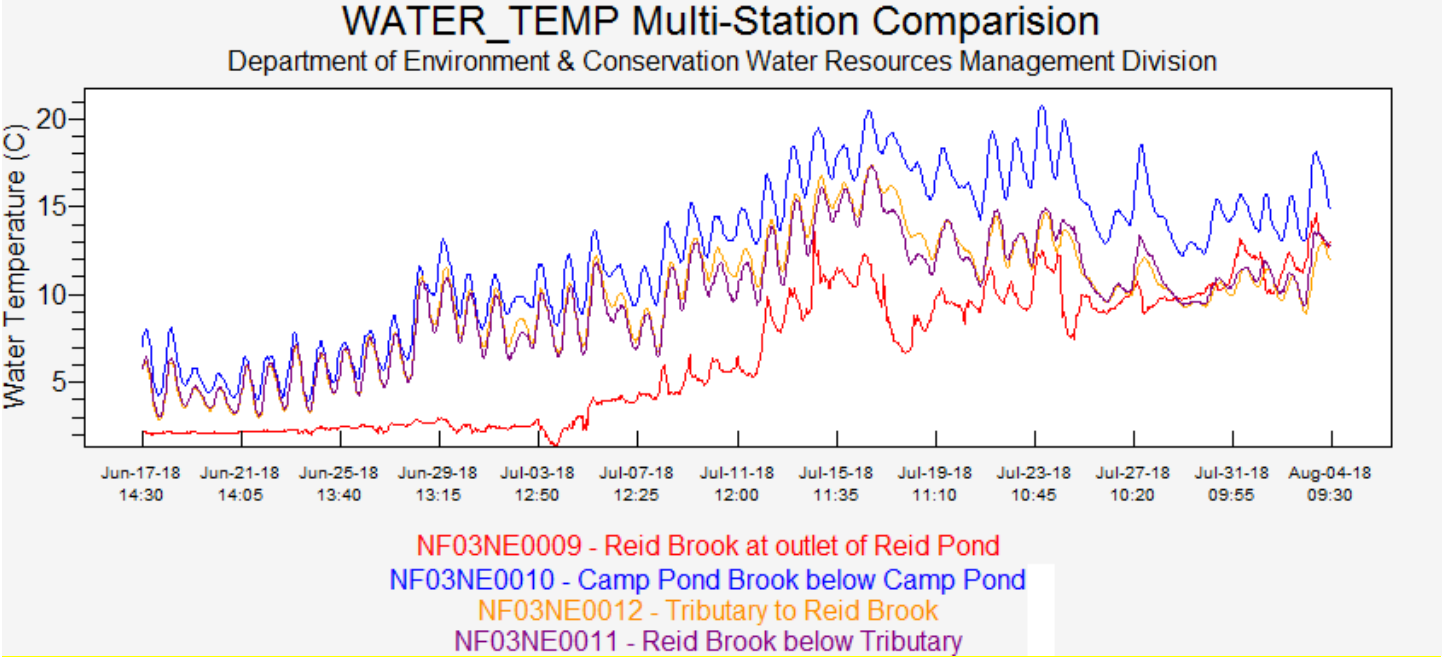


Figure A1: Comparison of Water Temperature (^{0}C) between all Real-Time Stations in Voisey's Bay.

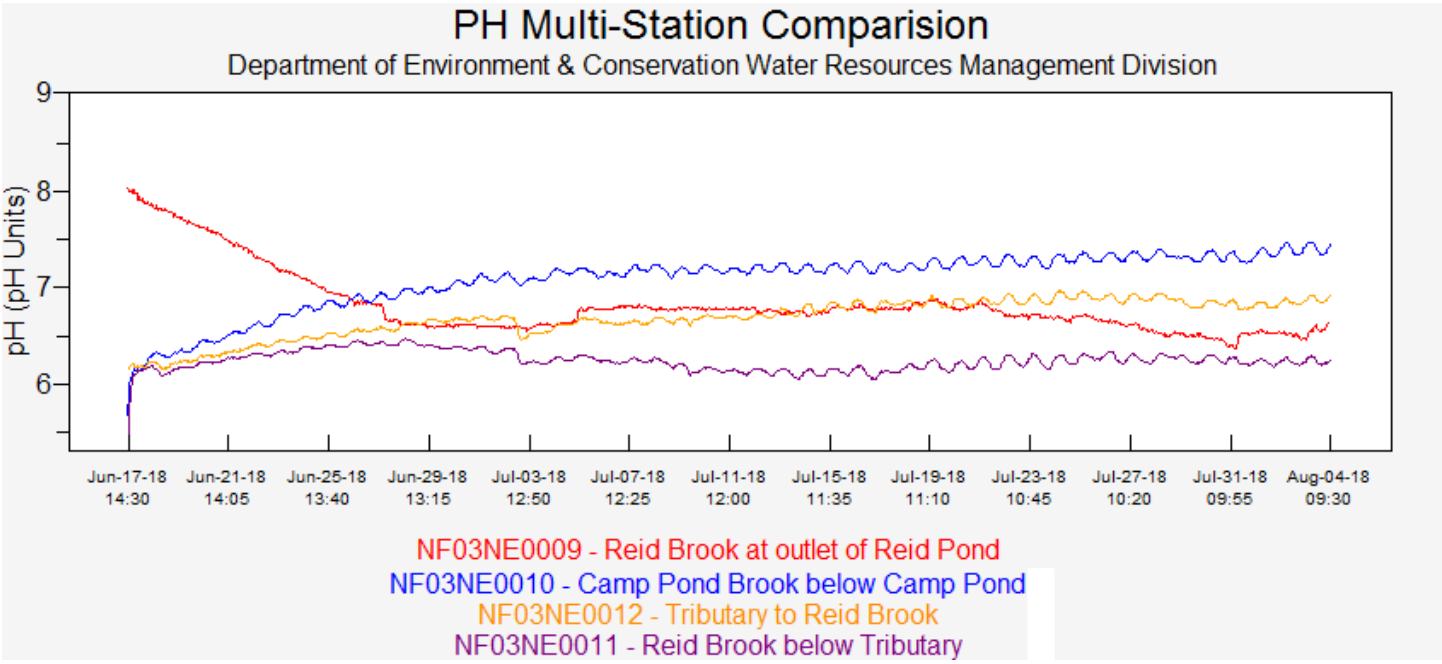


Figure A2: Comparison of pH between all Real-Time Stations in Voisey's Bay.

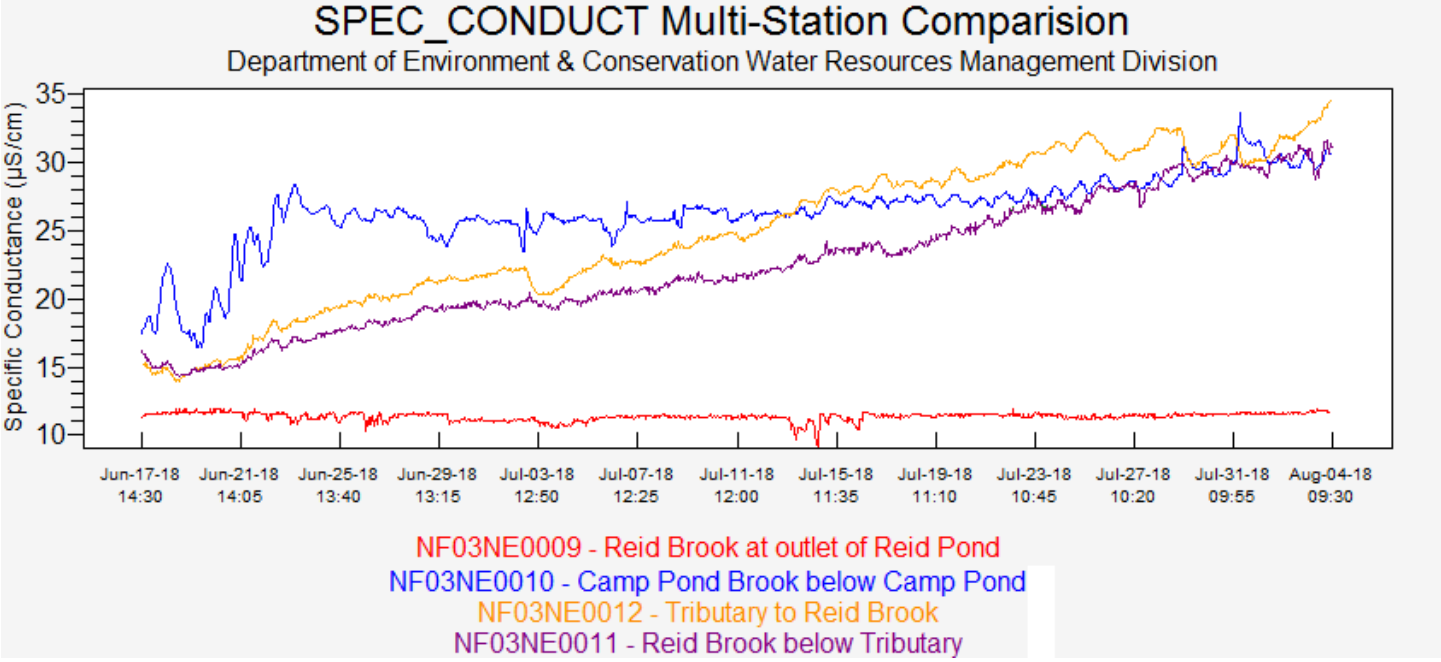


Figure A3: Comparison of Specific Conductivity (µS/cm) between all Real-Time Stations in Voisey's Bay.

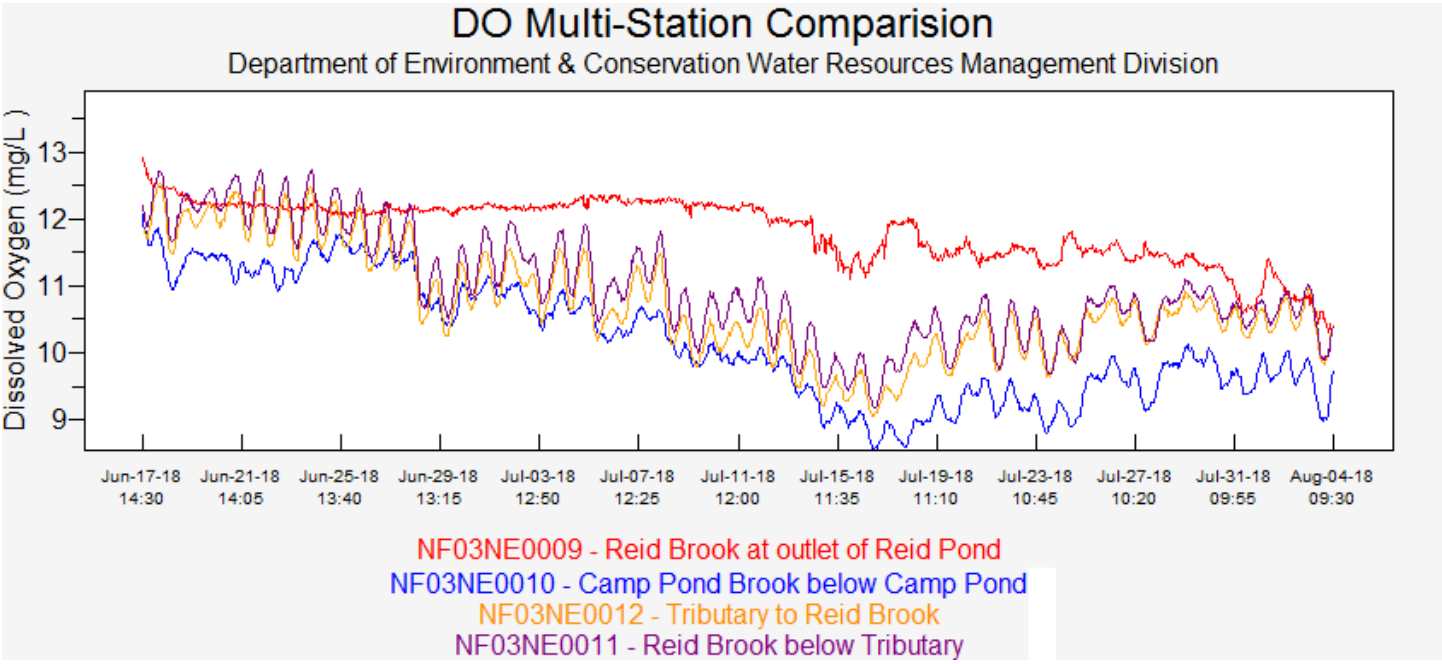


Figure A4: Comparison of Dissolved Oxygen (mg/L) between all Real-Time Stations in Voisey's Bay.

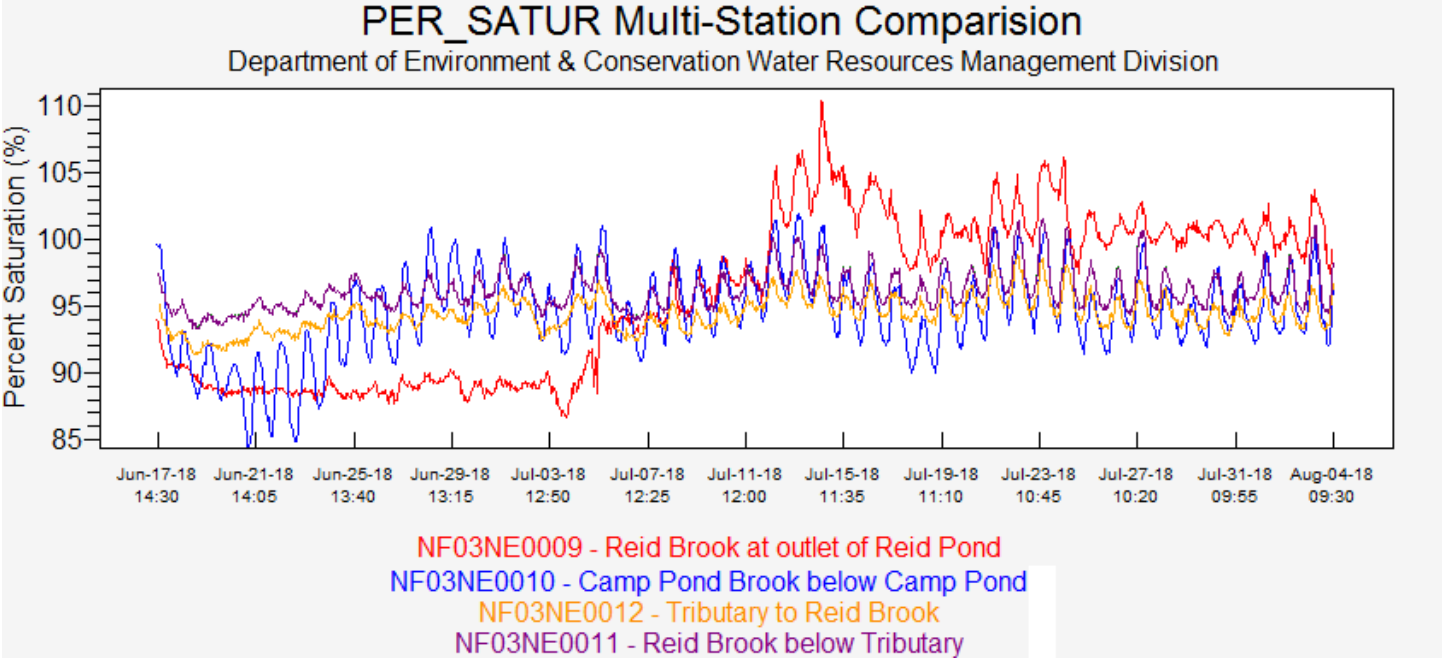


Figure A5: Comparison of Dissolved Oxygen (% Sat) between all Real-Time Stations in Voisey's Bay.

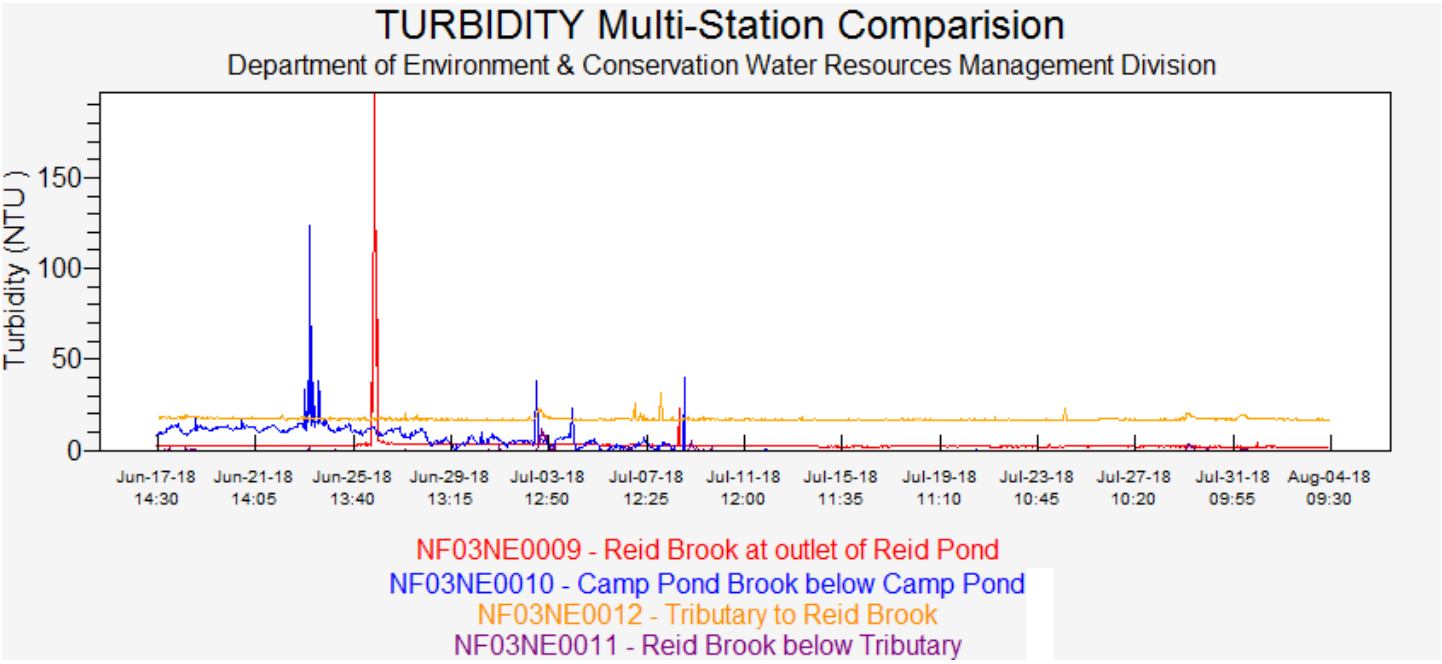


Figure A6: Comparison of Turbidity (NTU) between all Real-Time Stations in Voisey's Bay. There may have been an error during calibration that resulted in the higher-than-expected background turbidity level observed at Tributary to Reid Brook.

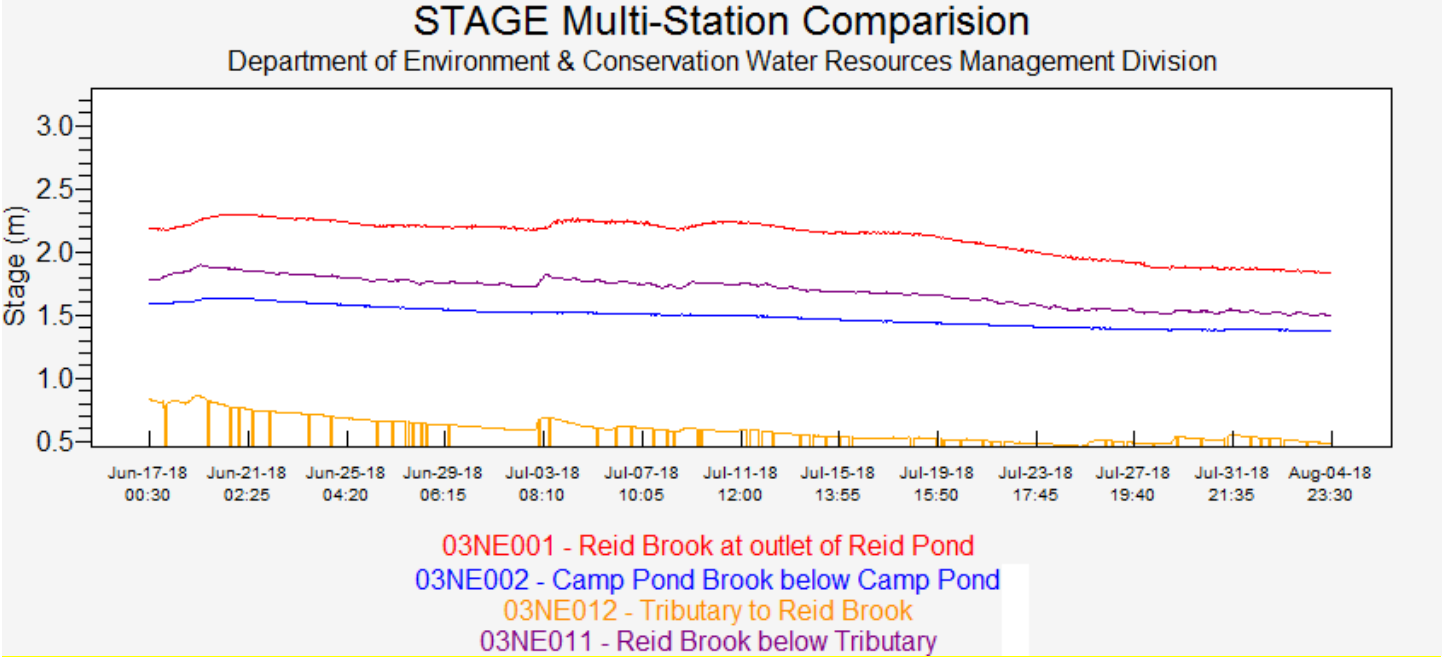


Figure A7: Comparison of Stage (m) between all Real-Time Stations in Voisey's Bay. Please note that stage data is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data.

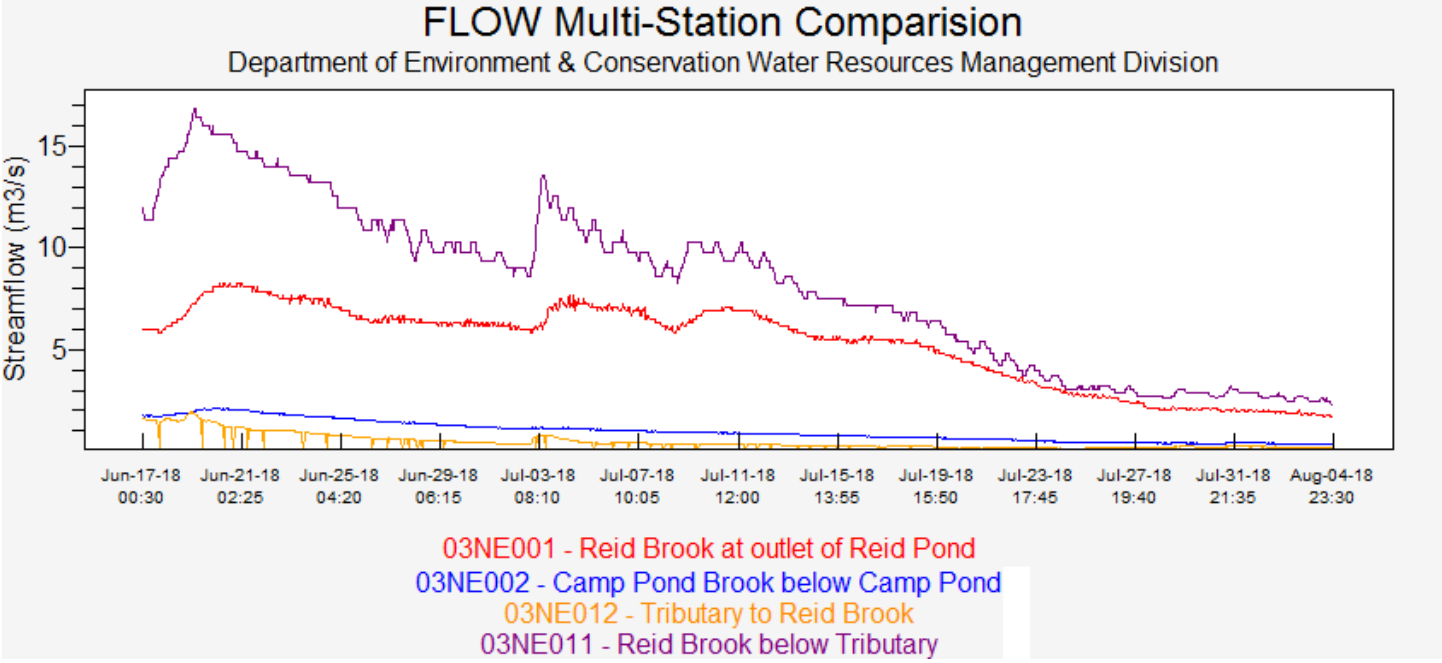


Figure A8: Comparison of Flow (m^3/s) between all Real-Time Stations in Voisey's Bay. Please note that flow data is raw data. It has not been corrected for backwater effect. WSC is responsible for QA/QC of water quantity data.

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: **1810302**

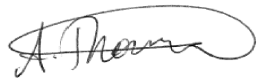
Cient:	Department of Environment	**COC Number:**	832715
Attention:	Ms. Tara Clinton	**Date Reported:**	2018-07-03
Client Project:		**Date Submitted:**	2018-06-21
Purchase Order:	2180014302	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1367177	WS-S-0000 Reid Brook below Reid Pond	2018-1855-00-SI-SP	2018-06-17	Alkalinity as CaCO3	mg/L	5	<5
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	<1
				Colour	TCU	2	15
				Conductivity	uS/cm	5	13
				Dissolved Organic Carbon	mg/L	1.0	2.9
				Fluoride	mg/L	0.10	<0.10
				Hardness as CaCO3	mg/L	1	2
				N-NH3 (Ammonia)	mg/L	0.05	<0.05
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	6.51
				Sulphate	mg/L	1	<1
				Total Dissolved Solids (COND - CALC)	mg/L	1	8
				Total Kjeldahl Nitrogen	mg/L	0.1	0.2
				Total Organic Carbon	mg/L	1.0	3.3
				Turbidity	NTU	0.1	1.2
				Aluminum	mg/L	0.01	0.07

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.
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

REPORT OF ANALYSIS

Lab Report Number: **1810302**

Cient:	Department of Environment	**COC Number:**	832715
Attention:	Ms. Tara Clinton	**Date Reported:**	2018-07-03
Client Project:		**Date Submitted:**	2018-06-21
Purchase Order:	2180014302	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1367177	WS-S-0000	2018-1855-00-SI-SP	2018-06-17	Antimony	mg/L	0.0005	<0.0005
	Reid Brook below Reid 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	1
				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	0.03
				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	0.004

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: A. Thomas

Addrine Thomas

REPORT OF ANALYSIS

Lab Report Number: **1810302**

Cient:	Department of Environment	**COC Number:**	832715
Attention:	Ms. Tara Clinton	**Date Reported:**	2018-07-03
Client Project:		**Date Submitted:**	2018-06-21
Purchase Order:	2180014302	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1367177	WS-S-0000	2018-1855-00-SI-SP	2018-06-17	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
Sample comment:				Total Suspended Solids	mg/L	2	<2

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: A. Thomas

Addrine Thomas

REPORT OF ANALYSIS

Lab Report Number: **1810302**

Cient:	Department of Environment	**COC Number:**	832715
Attention:	Ms. Tara Clinton	**Date Reported:**	2018-07-03
Client Project:		**Date Submitted:**	2018-06-21
Purchase Order:	2180014302	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date
1367180	WS-S-0000 Camp Pond Brook below Camp Pond	2018-1858-00-SI-SP	2018-06-17

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	2
Colour	TCU	2	38
Conductivity	uS/cm	5	22
Dissolved Organic Carbon	mg/L	1.0	5.2
Fluoride	mg/L	0.10	<0.10
Hardness as CaCO3	mg/L	1	5
N-NH3 (Ammonia)	mg/L	0.05	<0.05
N-NO2 (Nitrite)	mg/L	0.10	<0.10
N-NO3 (Nitrate)	mg/L	0.10	<0.10
pH		1.00	6.57
Sulphate	mg/L	1	2
Total Dissolved Solids (COND - CALC)	mg/L	1	14
Total Kjeldahl Nitrogen	mg/L	0.1	0.1
Total Organic Carbon	mg/L	1.0	6.4
Turbidity	NTU	0.1	1.2
Aluminum	mg/L	0.01	0.11

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

REPORT OF ANALYSIS

Lab Report Number: **1810302**

Cient:	Department of Environment	**COC Number:**	832715
Attention:	Ms. Tara Clinton	**Date Reported:**	2018-07-03
Client Project:		**Date Submitted:**	2018-06-21
Purchase Order:	2180014302	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1367180	WS-S-0000	2018-1858-00-SI-SP	2018-06-17	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
				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	0.002
				Iron	mg/L	0.03	0.22
				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	0.010
				Potassium	mg/L	1	<1
				Selenium	mg/L	0.001	<0.001
				Sodium	mg/L	2	<2
				Strontium	mg/L	0.001	0.009

Sample comment:

Holding time for turbidity analysis was exceeded for entire report.

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: A. Thomas

Addrine Thomas

REPORT OF ANALYSIS

Lab Report Number: **1810302**

Cient:	Department of Environment	**COC Number:**	832715
Attention:	Ms. Tara Clinton	**Date Reported:**	2018-07-03
Client Project:		**Date Submitted:**	2018-06-21
Purchase Order:	2180014302	**Sample Matrix:**	Water

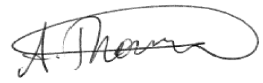
LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1367180	WS-S-0000	2018-1858-00-SI-SP	2018-06-17	Uranium	mg/L	0.001	<0.001
	Camp Pond Brook below Camp Pond			Zinc	mg/L	0.01	<0.01
				Phosphorus	mg/L	0.002	0.007
				Total Suspended Solids	mg/L	2	<2

Sample comment:

Holding time for turbidity analysis was exceeded for entire report.

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

REPORT OF ANALYSIS

Lab Report Number: 1810302

Cient:	Department of Environment	**COC Number:**	832715
Attention:	Ms. Tara Clinton	**Date Reported:**	2018-07-03
Client Project:		**Date Submitted:**	2018-06-21
Purchase Order:	2180014302	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date
1367179	WS-S-0000 Reid Brook to Tributary	2018-1857-00-SI-SP	2018-06-17

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	49
Conductivity	uS/cm	5	21
Dissolved Organic Carbon	mg/L	1.0	6.3
Fluoride	mg/L	0.10	<0.10
Hardness as CaCO3	mg/L	1	2
N-NH3 (Ammonia)	mg/L	0.05	<0.05
N-NO2 (Nitrite)	mg/L	0.10	<0.10
N-NO3 (Nitrate)	mg/L	0.10	<0.10
pH		1.00	6.72
Sulphate	mg/L	1	2
Total Dissolved Solids (COND - CALC)	mg/L	1	14
Total Kjeldahl Nitrogen	mg/L	0.1	0.1
Total Organic Carbon	mg/L	1.0	6.6
Turbidity	NTU	0.1	0.8
Aluminum	mg/L	0.01	0.13

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

REPORT OF ANALYSIS

Lab Report Number: 1810302

Cient:	Department of Environment	**COC Number:**	832715
Attention:	Ms. Tara Clinton	**Date Reported:**	2018-07-03
Client Project:		**Date Submitted:**	2018-06-21
Purchase Order:	2180014302	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1367179	WS-S-0000 Reid Brook to Tributary	2018-1857-00-SI-SP	2018-06-17	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	0.28
				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	0.008

Sample comment:

Holding time for turbidity analysis was exceeded for entire report.

Report comment:

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APPROVAL: A. Thomas

Addrine Thomas

REPORT OF ANALYSIS

Lab Report Number: **1810302**

Cient:	Department of Environment	**COC Number:**	832715
Attention:	Ms. Tara Clinton	**Date Reported:**	2018-07-03
Client Project:		**Date Submitted:**	2018-06-21
Purchase Order:	2180014302	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1367179	WS-S-0000	2018-1857-00-SI-SP	2018-06-17	Uranium	mg/L	0.001	<0.001
	Reid Brook to Tributary			Zinc	mg/L	0.01	<0.01
				Phosphorus	mg/L	0.002	0.008
Sample comment:				Total Suspended Solids	mg/L	2	4

Holding time for turbidity analysis was exceeded for entire report.

Report comment:

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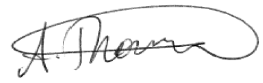
APPROVAL: 

Addrine Thomas

REPORT OF ANALYSIS

Lab Report Number: **1810302**

Cient:	Department of Environment	**COC Number:**	832715
Attention:	Ms. Tara Clinton	**Date Reported:**	2018-07-03
Client Project:		**Date Submitted:**	2018-06-21
Purchase Order:	2180014302	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
1367178	WS-S-0000 Tributary to Reid Brook	2018-1856-00-SI-SP	2018-06-17	Alkalinity as CaCO3	mg/L	5	<5
				Bromide	mg/L	0.25	<0.25
				Chloride	mg/L	1	1
				Colour	TCU	2	53
				Conductivity	uS/cm	5	17
				Dissolved Organic Carbon	mg/L	1.0	6.0
				Fluoride	mg/L	0.10	<0.10
				Hardness as CaCO3	mg/L	1	2
				N-NH3 (Ammonia)	mg/L	0.05	<0.05
				N-NO2 (Nitrite)	mg/L	0.10	<0.10
				N-NO3 (Nitrate)	mg/L	0.10	<0.10
				pH		1.00	6.45
				Sulphate	mg/L	1	1
				Total Dissolved Solids (COND - CALC)	mg/L	1	11
				Total Kjeldahl Nitrogen	mg/L	0.1	0.2
				Total Organic Carbon	mg/L	1.0	6.7
				Turbidity	NTU	0.1	1.4
				Aluminum	mg/L	0.01	0.13

Sample comment:

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Report comment:

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APPROVAL: A. Thomas

Addrine Thomas

REPORT OF ANALYSIS

Lab Report Number: **1810302**

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Attention:	Ms. Tara Clinton	**Date Reported:**	2018-07-03
Client Project:		**Date Submitted:**	2018-06-21
Purchase Order:	2180014302	**Sample Matrix:**	Water

LAB ID	Supply / Description	Client Sample ID	Sample Date	ANALYTE	UNIT	MRL	RESULT
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				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	0.30
				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	0.008

Sample comment:

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Report comment:

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APPROVAL: A. Thomas

Addrine Thomas

REPORT OF ANALYSIS

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				Phosphorus	mg/L	0.002	0.008
				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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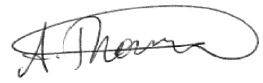
APPROVAL: 

Addrine Thomas

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