Real-Time Water Quality 2020 Annual Report

Voisey's Bay Network

June 29 to October 26, 2020

Newfoundland Labrador

Government of Newfoundland & Labrador
Department of Environment, Climate Change and Municipalities
Water Resources Management Division

Contents

Acknowledgements

The Real-Time Water Quality Monitoring Network in Voisey's Bay is successful in tracking emerging water quality issues due to the hard work and diligence of certain individuals. The management and staff of Vale work in cooperation with the management and staff of the Department of Environment, Climate Change and Municipalities (ECCM) Water Resources Management Division (WRMD), as well as Environment and Climate Change Canada (ECCC), to ensure the protection of ambient water resources in Voisey's Bay, Labrador.

Vale Environmental Coordinators are acknowledged for their hard work during the 2020 deployment period, and ensuring the Real-Time Water Quality Monitoring Network is operating to the standards set by ECCM. It is only through their dedication to properly maintain and calibrate the equipment and perform acceptable quality control measures that the data can be viewed as reliable and accurate.

Various individuals from WRMD have been integral in ensuring the smooth operation of such a technologically advanced network. WRMD staff played a lead role in coordinating and liaising between the major agencies involved, thus, ensuring open communication lines at all times. In addition, WRMD is responsible for the data management/reporting, troubleshooting, along with ensuring the quality assurance/quality control measures are satisfactory. WRMD provides data to the general public on a near real-time basis through the departmental web page.

Environment and Climate Change Canada staff of the Meteorological Service of Canada: Water Survey Canada play an essential role in the data logging/communication aspect of the network. These individuals visit the site often to ensure the data logging equipment is operating properly and transmitting the data efficiently. Finally, they play the lead role in dealing with hydrological quantity and flow issues.

Staff with ECCM, ECCC, and Vale are fully committed to improving this network and ensuring it provides meaningful and accurate water quality/quantity data that can be used in the decision-making process. This network is only successful due to the cooperation of all three agencies involved.

Abbreviations

ECCC	Environment and Climate Change Canada
WSC	Water Survey of Canada
ECCM	Department of Environment, Climate Change and Municipalities
DO	Dissolved Oxygen
NL	Newfoundland and Labrador
QA/QC	Quality Assurance and Quality Control
RTWQ	Real-time Water Quality
WRMD	Water Resources Management Division
%Sat	Percent Saturation
PTE	Performance Testing and Evaluation

Introduction

The RTWQ network in Voisey's Bay was successfully established by ECCM and ECCC in cooperation with Vale in 2003 and further expanded in 2006. The objective of the network is to identify and track emerging water quality or quantity management issues and ensure protection of ambient water resources in and around the Voisey's Bay operations.

The RTWQ network consists of four water quality monitoring stations: Reid Brook at Outlet of Reid Pond, Camp Pond Brook below Camp Pond, Tributary to Reid Brook, and Reid Brook below Tributary. These stations measure water quality parameters including water temperature, pH, specific conductivity, dissolved oxygen, and turbidity. Two additional parameters, total dissolved solids and percent saturation are calculated from measured parameters.

These stations also record continuous stage level and streamflow rate data. These parameters are the responsibility of ECCC; however, if needed, WRMD staff reporting on water quality will have access to water quantity information to understand and explain water quality fluctuations.

Four new Hydrolab Datasonde 5X instruments were purchased in the spring 2012 season for this network, as well as a new Hydrolab Minisonde 5 for QA/QC measurements and an Archer handheld display unit.

This annual deployment report illustrates, discusses and summarizes water quality related events from June 29 to October 26, 2020. During this time, four visits were made to each of the four RTWQ sites. Instruments were deployed for approximately month-long intervals referred to as deployment periods.

Maintenance and Calibration

It is recommended that regular maintenance and calibration of the instruments take place on a monthly basis to ensure accurate data collection. This procedure is the responsibility of the Vale Environment staff and is performed approximately every 30 days.

Maintenance includes a thorough cleaning of the instrument and replacement of any small sensor parts that are damaged or unsuitable for reuse. Once the instrument is cleaned, Vale Environment staff members carefully calibrate each sensor attachment for pH, specific conductivity, dissolved oxygen and turbidity.

An extended deployment period (>30 days) can result in instrument sensor drift, which may result in skewed data. Instrument sensors will still work to capture any water quality event, although exact data values collected may be inaccurate. Installation and removal dates for each station in the 2020 deployment season are summarized in Table 1.

Table 1: Installation and removal dates for 2020 deployment periods

Installation	Removal	Deployment
June 29	August 7	39 days
August 8/9	September 8	30/31 days
September 11	October 26	45 days

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. The procedure is based on the approach used by the United States Geological Survey.

At deployment and removal, a QA/QC Instrument is temporarily deployed adjacent to the Field Instrument. Values for temperature, pH, conductivity, dissolved oxygen and turbidity are compared between the two instruments**.** Based on the degree of difference between parameters recorded by the Field Instrument and QA/QC Instrument at deployment and at removal, a qualitative statement is made on the data quality (Table 2).

Table 2: 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. As 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 3. For additional information and explanations of rankings including "N/A" rankings, please refer to the monthly deployment reports.

Table 3: Comparison Rankings for Voisey's Bay Network Stations for 2020 Deployment Season

Station	Date	Action	Temperature	pH	Specific Conductivity	Dissolved Oxygen	Turbidity
Reid Brook at Outlet of Reid Pond	June 29, 2020	Deployment	Excellent	Excellent	Excellent	Excellent	Excellent
	August 7, 2020	Removal	Good	Poor	Excellent	Excellent	Excellent
	August 9, 2020	Deployment	Fair	Good	Excellent	Excellent	Excellent
	September 8, 2020	Removal	Good	Fair	Excellent	Excellent	Excellent
	September 11, 2020	Deployment	Excellent	Fair	Excellent	Excellent	Excellent
	October 26, 2020	Removal	N/A	N/A	N/A	N/A	N/A
Camp Pond Brook below Camp Pond	June 29, 2020	Deployment	Excellent	Fair	Excellent	Excellent	Excellent
	August 7, 2020	Removal	Excellent	Good	Excellent	Excellent	Excellent
	August 8, 2020	Deployment	Excellent	Good	Excellent	Excellent	Excellent
	September 8, 2020	Removal	Excellent	Good	Excellent	Excellent	Excellent
	September 11, 2020	Deployment	Excellent	Poor	Excellent	Excellent	Excellent
	October 26, 2020	Removal	N/A	N/A	N/A	N/A	N/A
Reid Brook below Tributary	June 29, 2020	Deployment	Excellent	Poor	Excellent	Excellent	Poor
	August 7, 2020	Removal	Excellent	Excellent	Good	Excellent	Excellent
	August 9, 2020	Deployment	Excellent	Fair	Good	Excellent	Excellent
	September 8, 2020	Removal	Excellent	Excellent	Good	Excellent	Excellent
	September 11, 2020	Deployment	Excellent	Poor	Poor	Excellent	Excellent
	October 26, 2020	Removal	N/A	N/A	N/A	N/A	N/A
Tributary to Reid Brook	June 29, 2020	Deployment	Excellent	Marginal	Excellent	Excellent	Excellent
	August 7, 2020	Removal	Excellent	Excellent	Good	Excellent	Poor
	August 8, 2020	Deployment	Poor	Good	Excellent	Excellent	Excellent
	September 8, 2020	Removal	Excellent	Excellent	Good	Excellent	Excellent
	September 11, 2020	Deployment	Excellent	Poor	Good	Excellent	Good
	October 26, 2020	Removal	N/A	N/A	N/A	N/A	N/A

Data Interpretation

The following graphs and discussions illustrate significant water quality-related events from June 29 through October 26, 2020 in the Voisey's Bay RTWQ Network.

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

Initial deployment for 2020 was delayed compared to previous years due to the COVID-19 panademic which resulted in restrictions to travel and shipping delays.

During the first deployment period, turbidity readings at Tributary to Reid Brook remained constant at 100NTU for the duration of deployment. This is being attributed to a calibration error with the field sonde and the data is inaccurate.

During the third deployment period, specific conductivity readings at Reid Brook below Tributary were significantly higher than expected. This is being attributed to a calibration error with the field sonde.

All instruments were sent to the St. John's WRMD laboratory at the end of the season for yearly PTE. Any necessary repairs and replacement sensors will be addressed before the 2021 season.

Reid Brook at Outlet of Reid Pond

During the 2020 deployment season, water temperature ranged from 4.17°C to a maximum of 20.62°C (Figure 1). Water temperature values for 2020 were similar to data from the 2019 and 2018 deployment seasons (Table 4).

Temperatures steadily increased from initial deployment through mid-August, after which they started to decrease again through September and October (Figure 1).

Please note that the stage data on the graph 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.

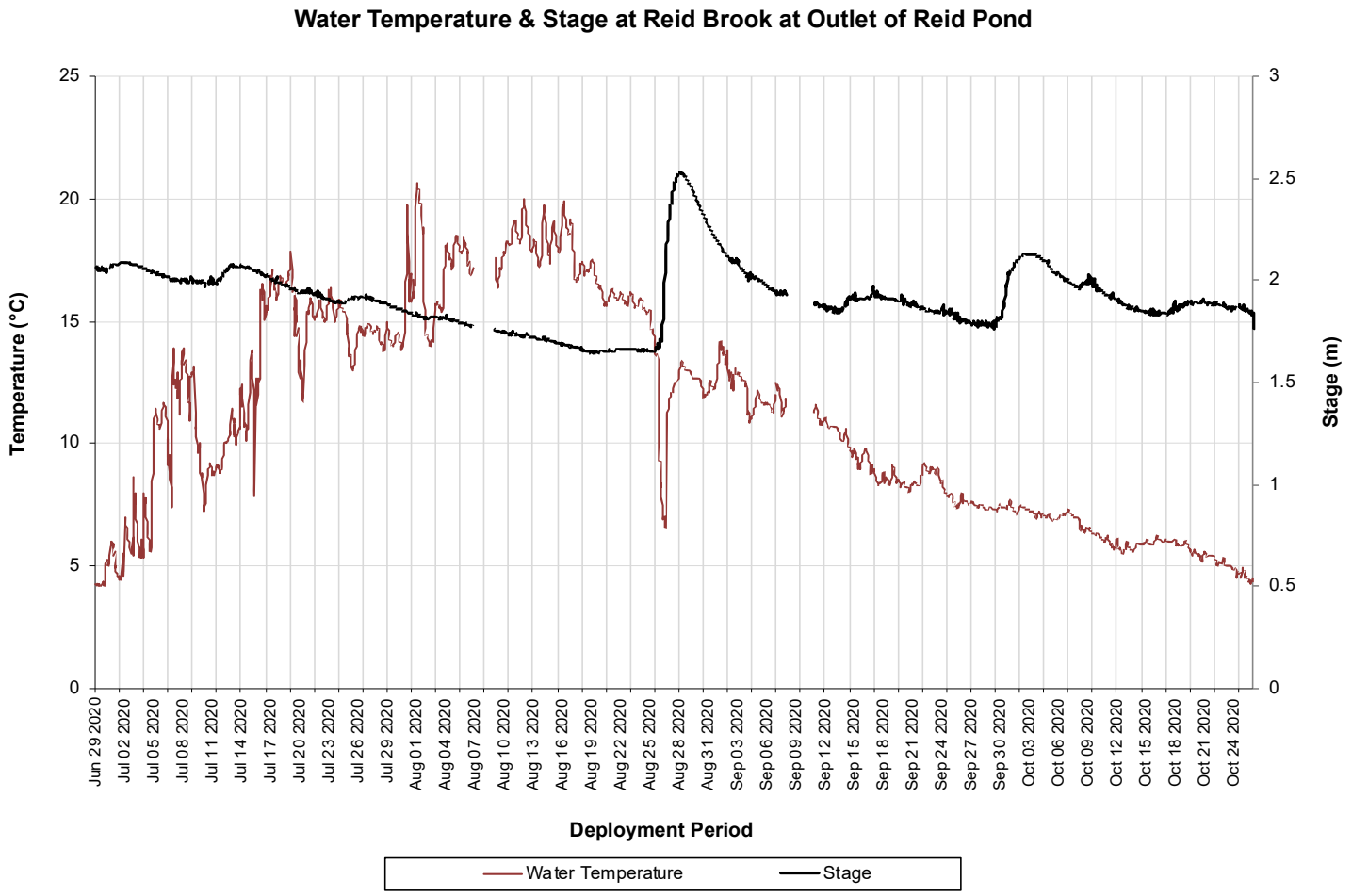

Figure 1: Water Temperature & Stage at Reid Brook at Outlet of Reid Pond

Table 4: Comparisons of Minimum, Maximum and Median from the past three deployment years

Water Temperature	2020	2019	2018
Min	4.17	2.49	1.37
Max	20.62	13.99	15.97
Median	10.93	8.90	9.34

Water temperatures maintains a close relationship with air temperature (Figure 2). Increases and decreases in air temperatures throughout 2020 were associated with similar changes in water temperature. Air temperatures fluctuate to a greater extent each day when compared to water temperatures. This location is also less susceptible to extreme temperature fluctuations as Reid Pond is a larger body of water. Air temperature data was obtained from the Voisey's Bay Weather Station located at the airstrip.

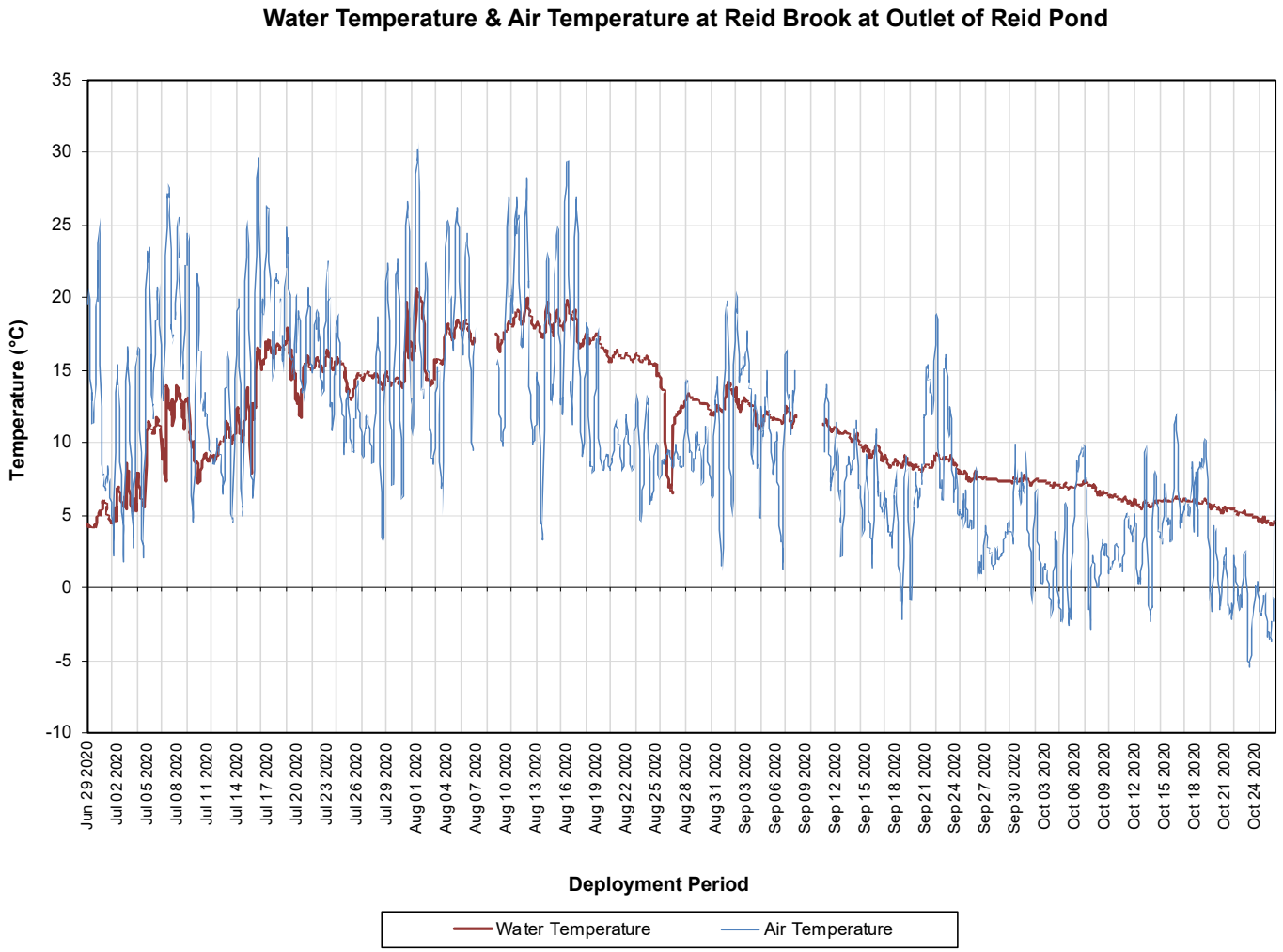

Figure 2: Water Temperature & Air Temperature at Reid Brook at Outlet of Reid Pond

During the 2020 deployment season, pH ranged from 4.59 pH units to a maximum of 8.91 pH units (Table 5). This station is at the outlet of a pond and so pH data has a wider range compared to that of a stream or brook. In a pond environment, water parameters take longer to change after an influence; ponds have a larger volume of water and in turn have a slower turnover rate compared to streams or brooks.

Figure 3 displays the relationship between pH and stage; generally when stage increases, pH decreases slightly. pH was below the CCME's Guidelines for the Protection of Aquatic Life for the majority of the deployment season, except for during the second deployment period from mid-August to early September.

Please note that the stage data on the graph 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.

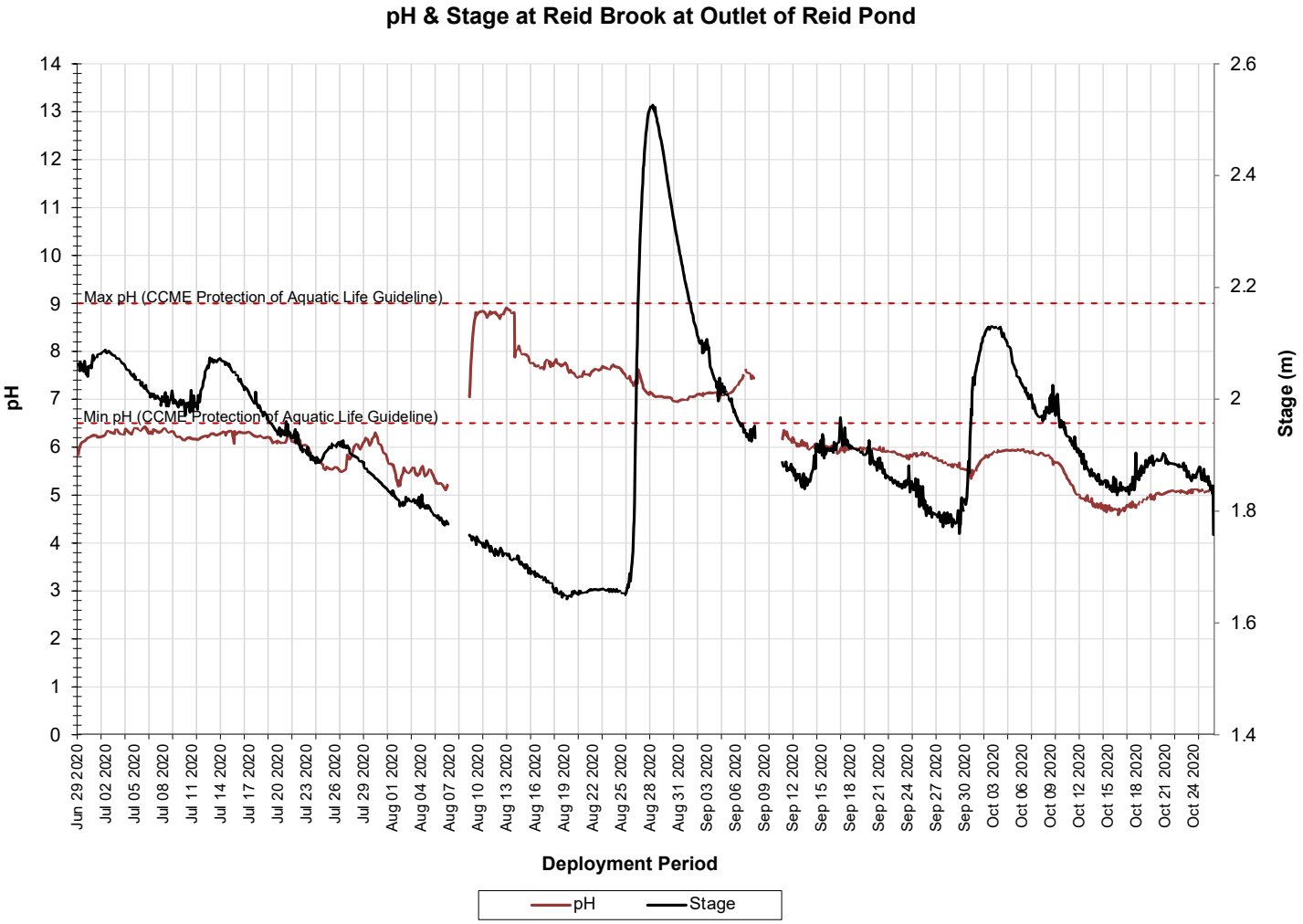

Figure 3: pH & Stage at Reid Brook at Outlet of Reid Pond

Table 5: Comparisons of Minimum, Maximum and Median from the past three deployment years

pH	2020	2019	2018
Min	4.59	5.21	6.36
Max	8.91	10.05	8.04
Median	6.06	6.86	6.96

During the 2020 deployment season, specific conductivity values ranged from 9.1µS/cm to a maximum of 29.7µS/cm. An overall conductivity median of 12.1µS/cm indicates that this station naturally has very low conductivity, and was similar to previous deployment seasons (Table 6).

Specific conductivity was low and stable throughout the majority of the deployment season with only minor fluctuations (Figure 4). This trend is to be expected at this station, since it is located at the outflow of the stable environment of Reid Pond. The variability in specific conductivity observed towards the very end of the deployment season is likely due to sediment build-up or natural debris around the sensor.

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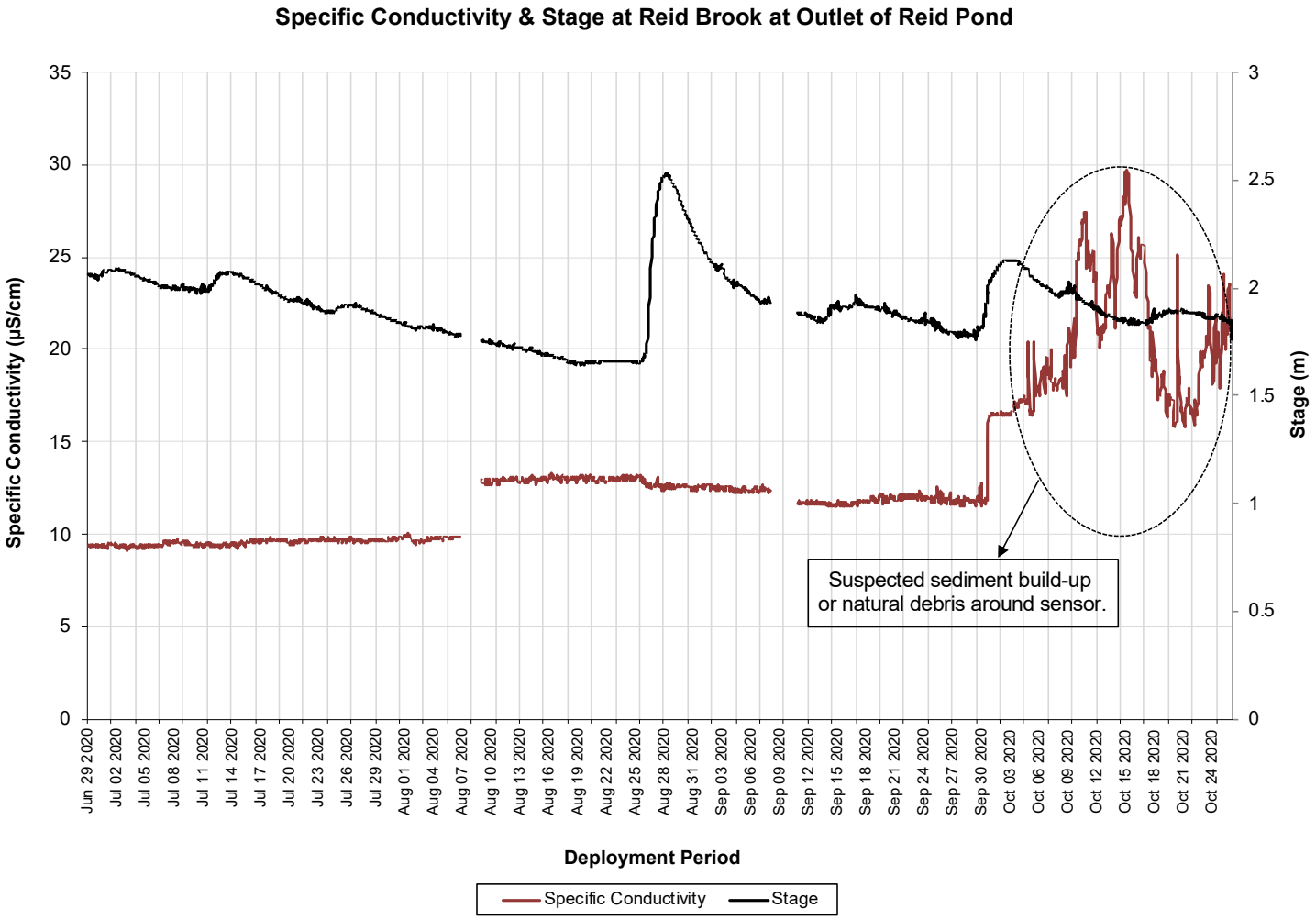

Figure 4: Specific Conductivity & Stage at Reid Brook at Outlet of Reid Pond

Table 6: Comparisons of Minimum, Maximum and Median from the past three deployment years

Specific Conductivity	2020	2019	2018
Min	9.1	8.5	9.1
Max	29.7	13.8	27.5
Median	12.1	11.6	11.8

During the 2020 deployment season, dissolved oxygen concentrations ranged from 9.36mg/L to a maximum of 12.81mg/L, with a median value of 11.04mg/L. Saturation of dissolved oxygen ranged from 83.6% to 110.6%, with a median value of 98.6% (Table 7).

Dissolved oxygen concentrations displayed typical seasonal fluctuations throughout the deployment season, and exhibited an inverse relationship with water temperature (Figure 5). Dissolved oxygen values were high at the beginning of deployment when water temperatures were low. Dissolved oxygen values decreased steadily until August, after which they began to increase again through the remainder of deployment as water temperatures decreased into the fall season.

Dissolved oxygen values remained above the CCME's Guideline for the Protection of Other Life Stages (6.5mg/L) and Early Life Stages (9.5mg/L) for the majority of the deployment season. Instances where dissolved oxygen levels dipped below the CCME's Guideline for the Protection of Early Life Stages correlated closely with warmest water temperatures and were infrequent.

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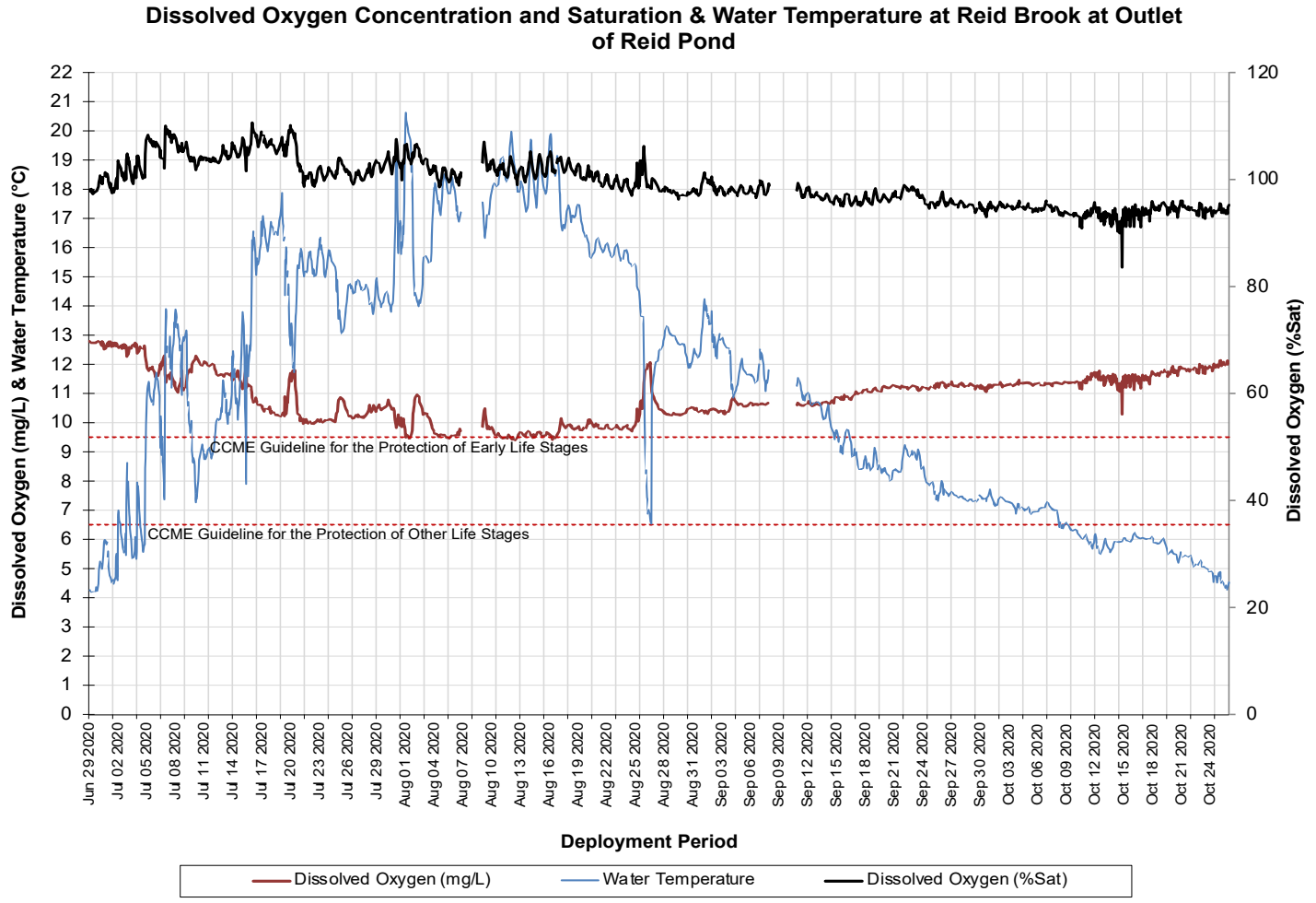

Figure 5: Dissolved Oxygen Concentration and Saturation & Water Temperature at Reid Brook at Outlet of Reid Pond

Table 7: Comparisons of Minimum, Maximum and Median from the past three deployment years

Dissolved Oxygen (mg/L)	2020	2019	2018
Min	9.36	10.37	9.63
Max	12.81	12.52	12.92
Median	11.04	11.00	11.23

Percent Saturation (%)	2020	2019	2018
Min	83.6	90.3	86.6
Max	110.6	106.7	110.4
Median	98.6	97.0	95.6

During the 2020 deployment season, turbidity values ranged from 0.0NTU to a maximum of 774.0NTU. A median value of 0.0NTU indicates that there is very little background turbidity at this station (Table 8).

There were only a few turbidity events at this station over the course of deployment (Figure 6). This is to be expected, as this site is pristine in nature and far removed from the Voisey's Bay mine site.

Turbidity levels can be influenced by precipitation and subsequent runoff. It is common to see levels increase during these events and it is important that the turbidity levels return to natural levels after such events.

Please note that the stage data on the graph 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.

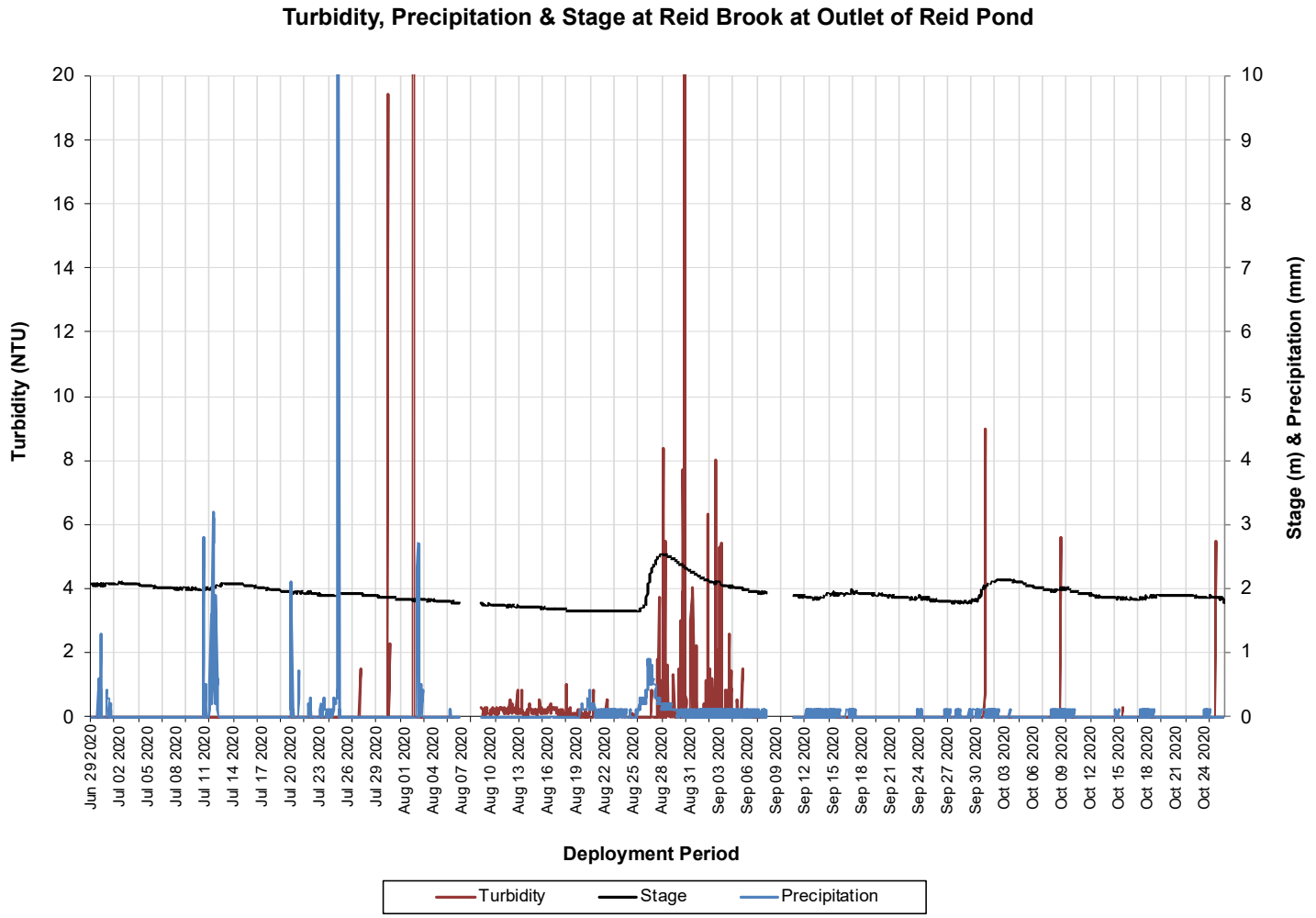

Figure 6: Turbidity & Stage at Reid Brook at Outlet of Reid Pond

Table 8: Comparisons of Minimum, Maximum and Median from the past three deployment years

Turbidity	2020	2019	2018
Min	0.0	0.0	0.7
Max	774.0	484.0	196.4
Median	0.0	0.0	1.8

Camp Pond Brook below Camp Pond

During the 2020 deployment season, water temperature ranged from 0.16°C to a maximum of 23.45°C. The median temperature of 13.00°C was slightly higher than those from the 2019 and 2018 deployment seasons (Table 9), but may be attributed to the late start to the deployment season due to the Covid-19 pandemic.

Water temperature was highest during early August (Figure 7). Water temperatures started to noticeably decrease from late August onwards as ambient air temperatures also decreased (Figure 8).

Please note that the stage data on the graph 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.

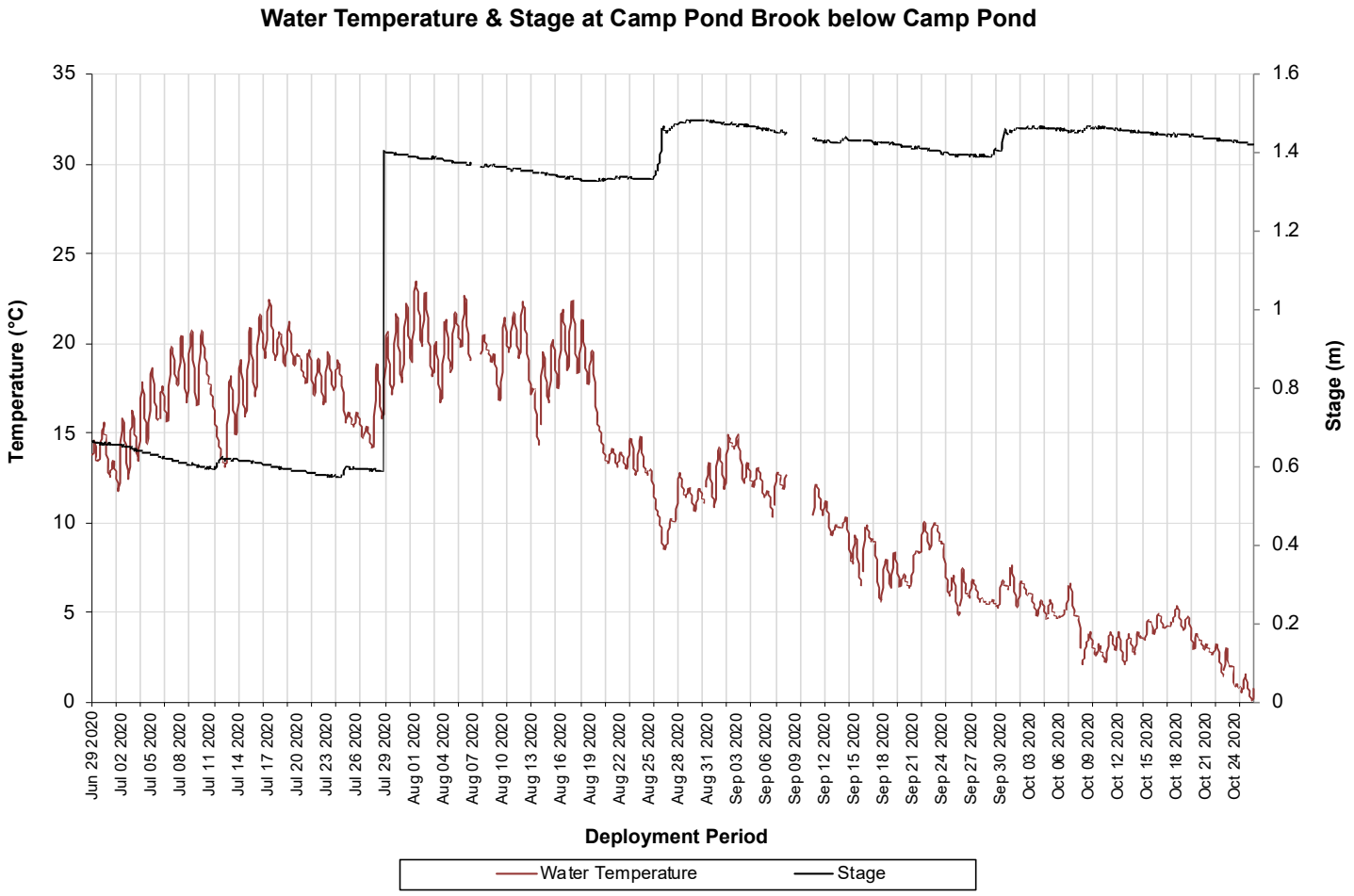

Figure 7: Water Temperature & Stage at Camp Pond Brook below Camp Pond

Table 9: Comparisons of Minimum, Maximum and Median from the past three deployment years

Water Temperature	2020	2019	2018
Min	0.16	2.99	1.18
Max	23.45	18.76	21.42
Median	13.00	11.22	11.34

Water temperature values showed a close relationship with ambient air temperatures (Figure 8); increases and decreases in air temperatures were reflected in similar changes in water temperatures. Air temperatures fluctuate to a greater extent than water temperatures. Air temperature data was obtained from the Voisey's Bay Weather Station located at the airstrip.

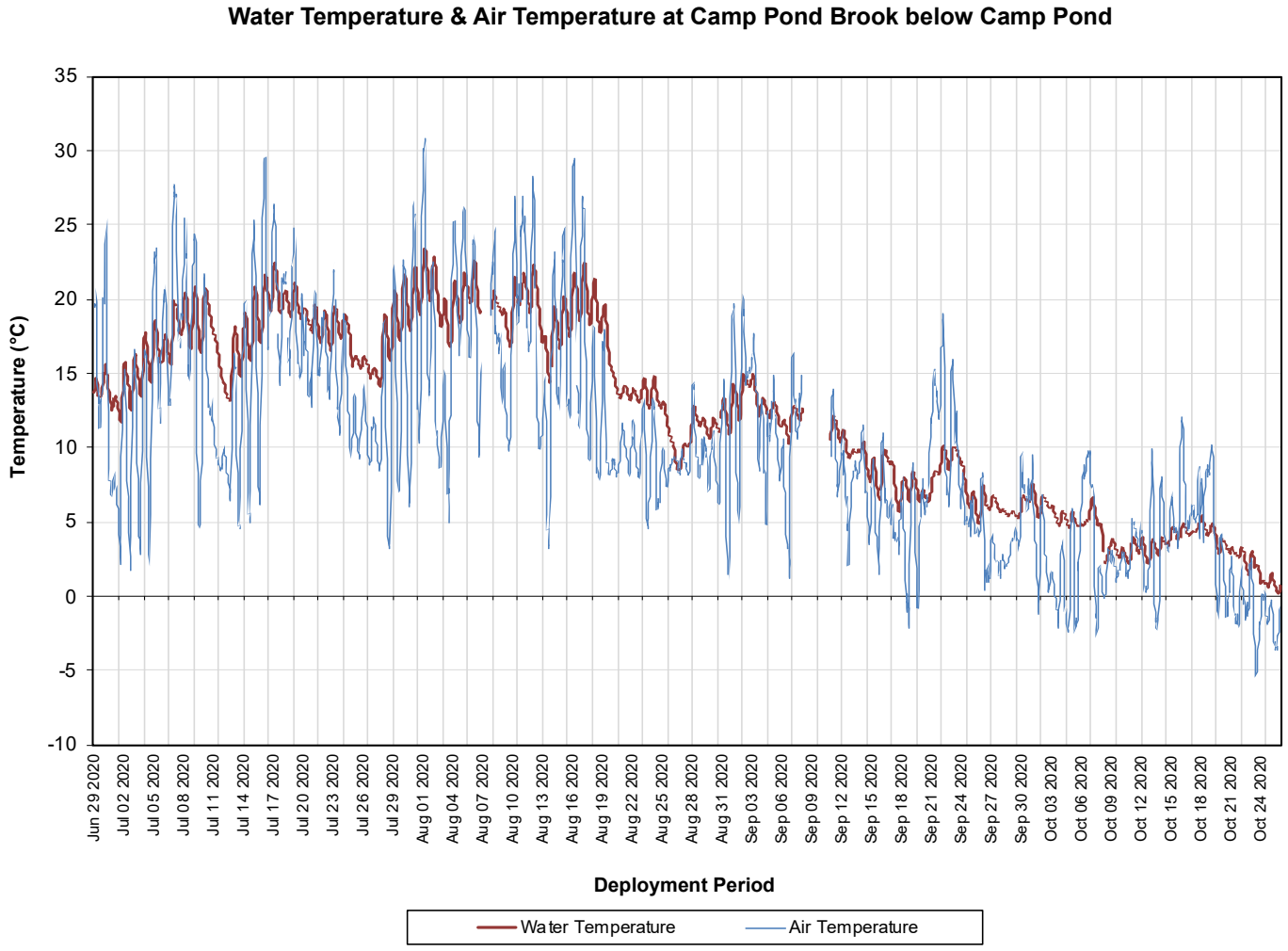

Figure 8: Water Temperature & Air Temperature at Camp Pond Brook below Camp Pond

During the 2020 deployment season, pH ranged from 6.35 pH units to a maximum of 7.11 pH units. The median value of 6.62 was similar to those from both 2019 (6.58) and 2018 (6.94) (Table 10).

Stage is included in the graph below to show the relationship between water level and pH values. Across the deployment season, pH data was reasonably stable. pH values were within the CCME's Guidelines for the Protection of Aquatic Life for the majority of the deployment season. Instances where pH values fell below the CCME's Minimum Guideline were often associated with increases in stage (Figure 9).

Please note that the stage data on the graph 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.

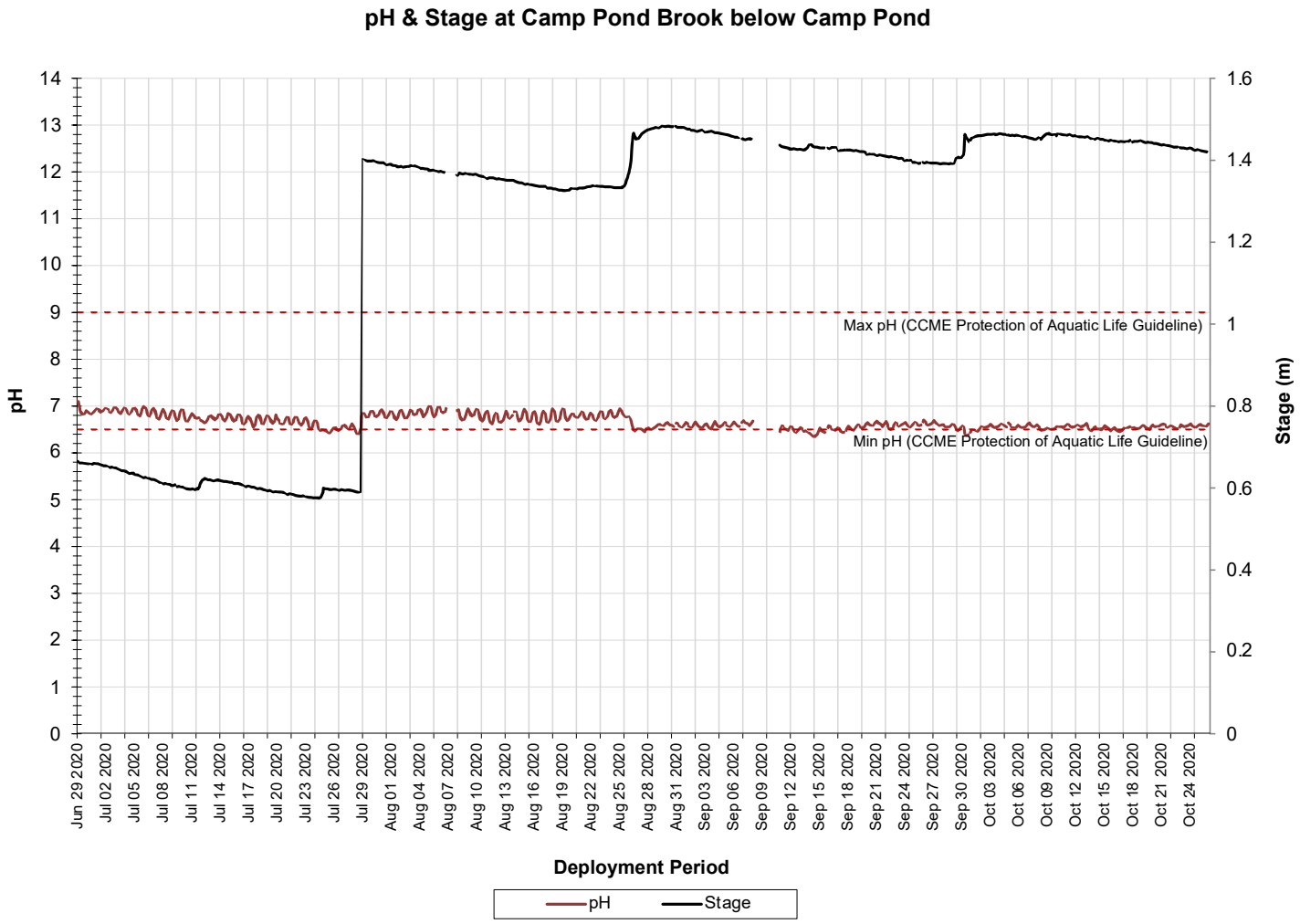

Figure 9: pH & Stage at Camp Pond Brook below Camp Pond

Table 10: Comparisons of Minimum, Maximum and Median from the past three deployment years

pH	2020	2019	2018
Min	6.35	5.70	5.68
Max	7.11	7.07	7.47
Median	6.62	6.58	6.94

During the 2020 deployment season, specific conductivity ranged from 26.4µS/cm to a maximum of 76.5µS/cm (Figure 10). The median value of 36.6µS/cm was very similar to those from 2019 (34.8µS/cm) and 2018 (35.9µS/cm) (Table 11).

Stage is included in the graph below to illustrate the relationship between conductivity and water level (Figure 10). In general, stage and conductivity exhibit an inverse relationship: when one parameter increases, the other decreases. In some instances, however, sharp increases in stage correlate with similar increases in conductivity, which is likely due to increased rainfall and runoff. This site is in close proximity to the mine site and so is heavily influenced by runoff factors that the other Voisey's Bay real-time stations do not experience.

Over the deployment season, conductivity levels in Camp Pond Brook increased steadily and then stabilized, while stage generally decreased. This relationship is to be expected as rainfall events, and subsequent bank runoff, generally decrease as the winter season approaches.

Please note that the stage data on the graph 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.

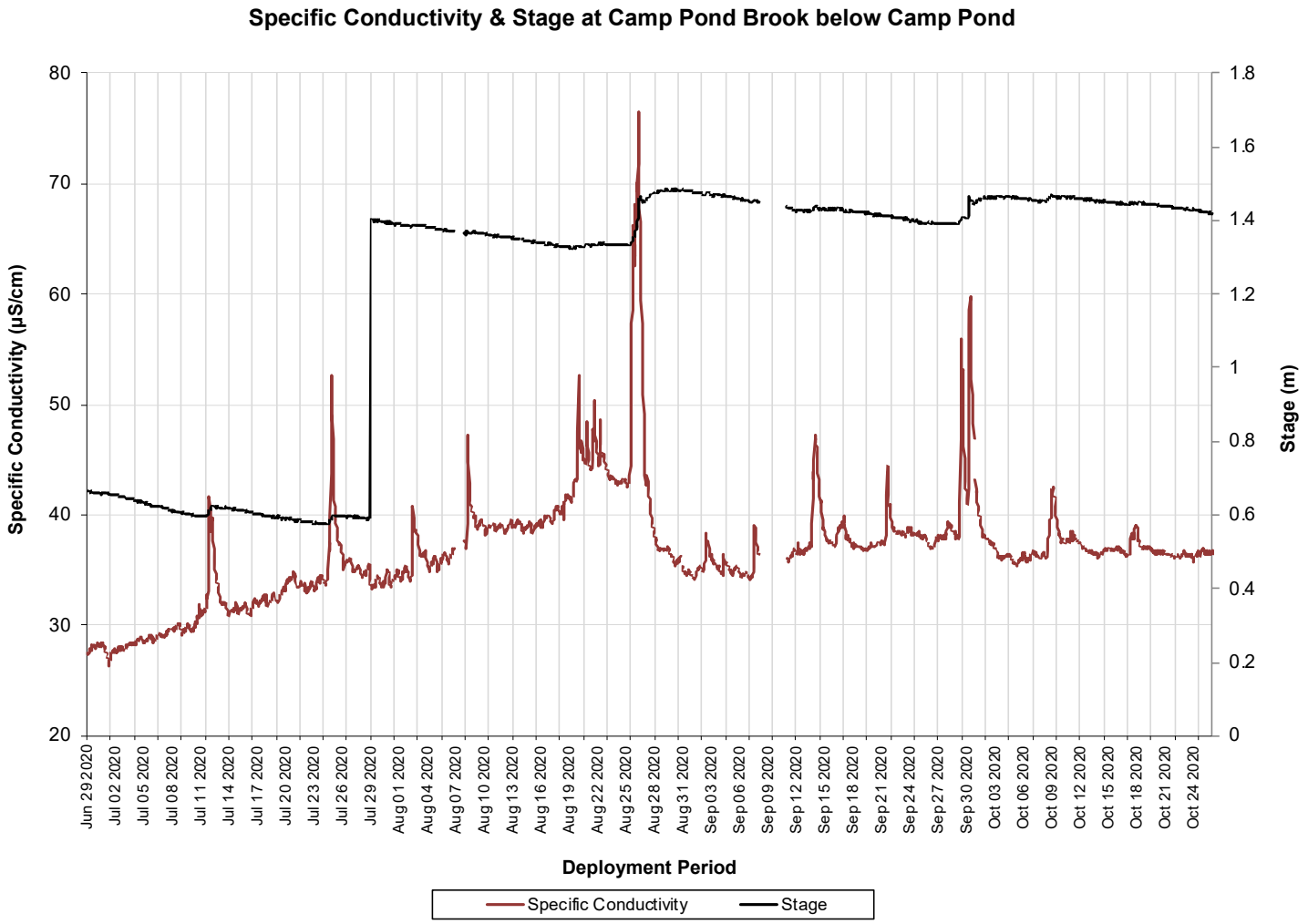

Figure 10: Specific Conductivity & Stage at Camp Pond Brook below Camp Pond

Table 11: Comparisons of Minimum, Maximum and Median from the past three deployment years

Specific Conductivity	2020	2019	2018
Min	26.4	25.6	16.4
Max	76.5	49.7	111
Median	36.6	34.8	35.9

During the 2020 deployment season, dissolved oxygen concentrations ranged from 7.90mg/L to a maximum of 13.58mg/L, with a median value of 10.04mg/L that was close to the 2019 median of 10.46mg/L. Saturation of dissolved oxygen ranged from 87.5% to 103.1%, with a median value of 94.8% (Table 12).

Dissolved oxygen concentrations exhibited typical seasonal trends, and were inversely related to water temperature. Dissolved oxygen concentrations were lowest throughout July and early August when water temperatures were warmest. As water temperatures decreased into late summer and fall, dissolved oxygen concentrations began to increase. Frequent fluctuations in dissolved oxygen levels are consistent with smaller daily changes in water temperature (Figure 11).

Dissolved oxygen concentrations dipped below the CCME's Guideline for the Protection of Early Life Stages (9.5mg/L) through July until mid-August. These dips are to be expected as they correspond closely with increased water temperatures during the same time frames. Dissolved oxygen concentrations remained above the CCME's Guideline for the Protection of Other Life Stages (6.5mg/L) for the duration of the deployment season.

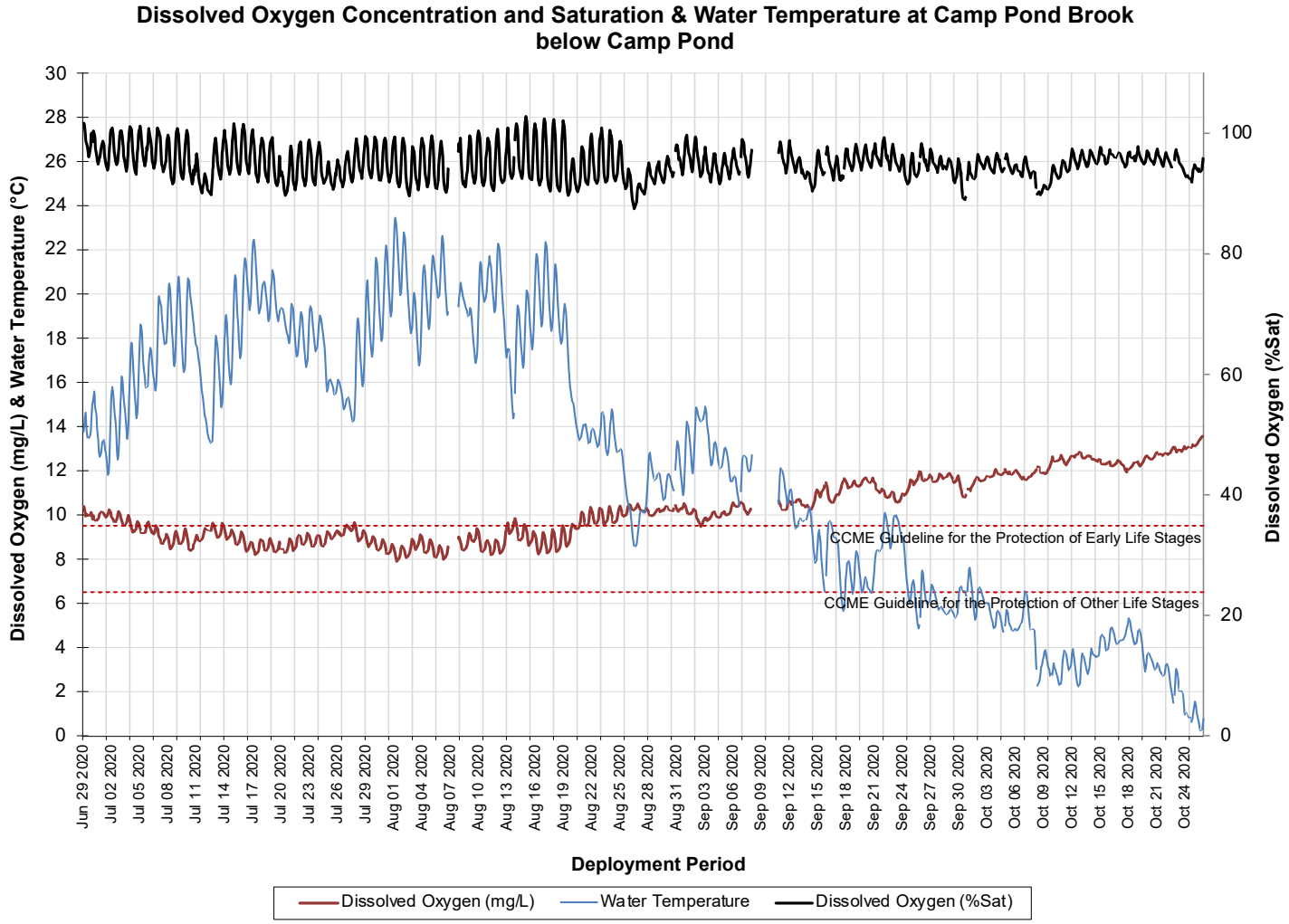

Figure 11: Dissolved Oxygen Concentration and Saturation & Water Temperature at Camp Pond Brook below Camp Pond

Table 12: Comparisons of Minimum, Maximum and Median from the past three deployment years

Dissolved Oxygen (mg/L)	2020	2019	2018
Min	7.90	9.00	8.27
Max	13.58	12.42	13.48
Median	10.04	10.46	10.38

Percent Saturation (%)	2020	2019	2018
Min	87.5	90.3	84.4
Max	103.1	104.4	102.2
Median	94.8	96.2	95.2

During the 2020 deployment season, turbidity values ranged from 0.0NTU to a maximum of 314.7NTU, with a median value of 0.8NTU (Figure 12). A median value of 0.8NTU indicates that there is a very small amount of natural background turbidity at this station. The median turbidity value for 2020 was between those from the 2019 (4.7) and 2018 (0.0) deployment seasons (Table 13).

There were a number of turbidity spikes throughout the deployment season, the majority of which corresponded with precipitation events and subsequent increases in stage.

Please note that the stage data on the graph 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.

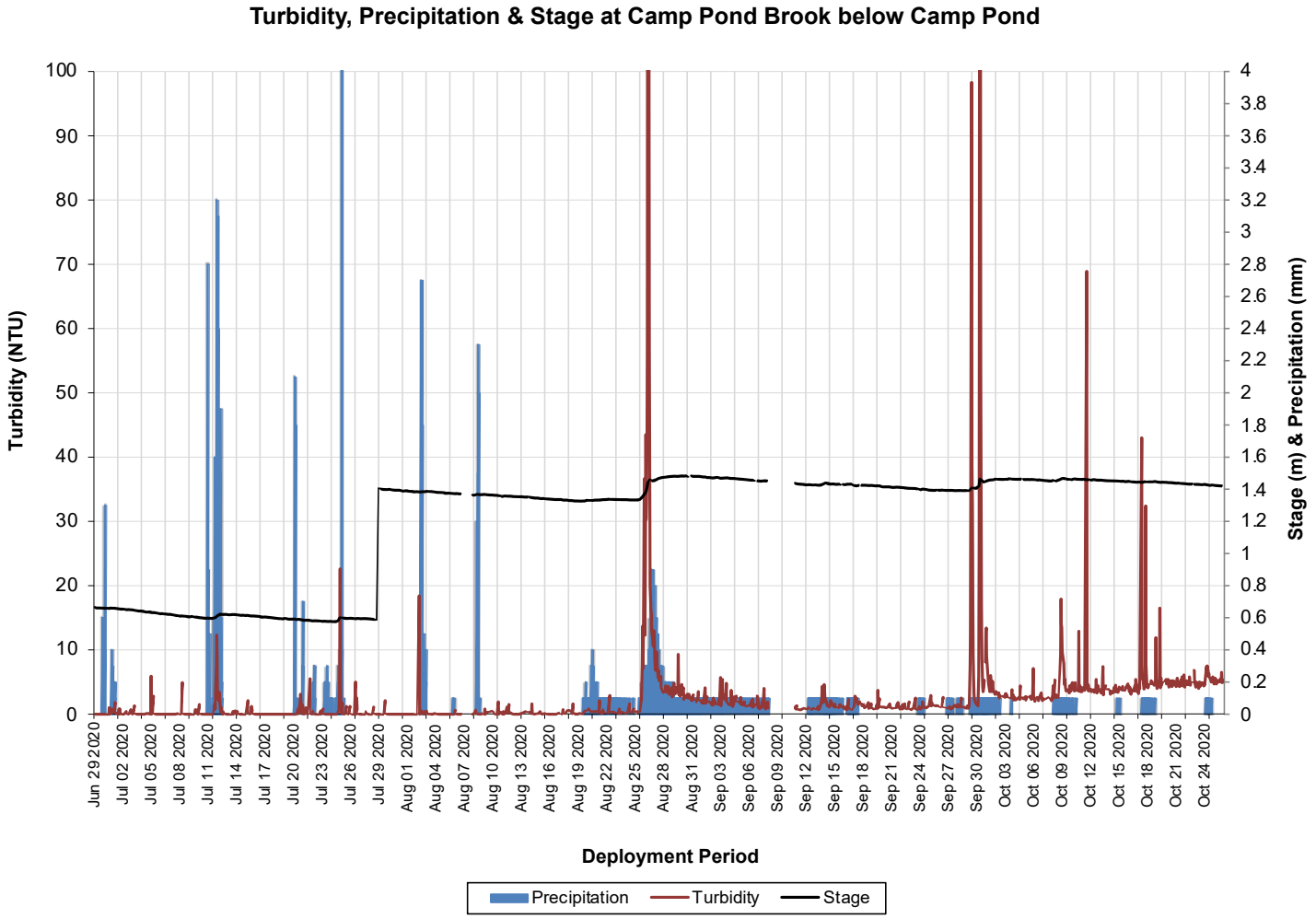

Figure 12: Turbidity & Stage at Camp Pond Brook below Camp Pond

Table 13: Comparisons of Minimum, Maximum and Median from the past three deployment years

Turbidity	2020	2019	2018
Min	0.0	0.0	0.0
Max	314.7	46.5	446
Median	0.8	4.7	0.0

Reid Brook below Tributary

During the 2020 deployment season, water temperature ranged from 0.2°C to a maximum of 20.1°C, with a median value of 10.7°C (Table 14). Water temperatures were highest through early to mid-August as air temperatures increased with the summer season. From late August onwards, water temperatures steadily declined as ambient air temperatures also declined (Figure 13 & 14).

Water temperatures have been very consistent at this station over recent years (Table 14).

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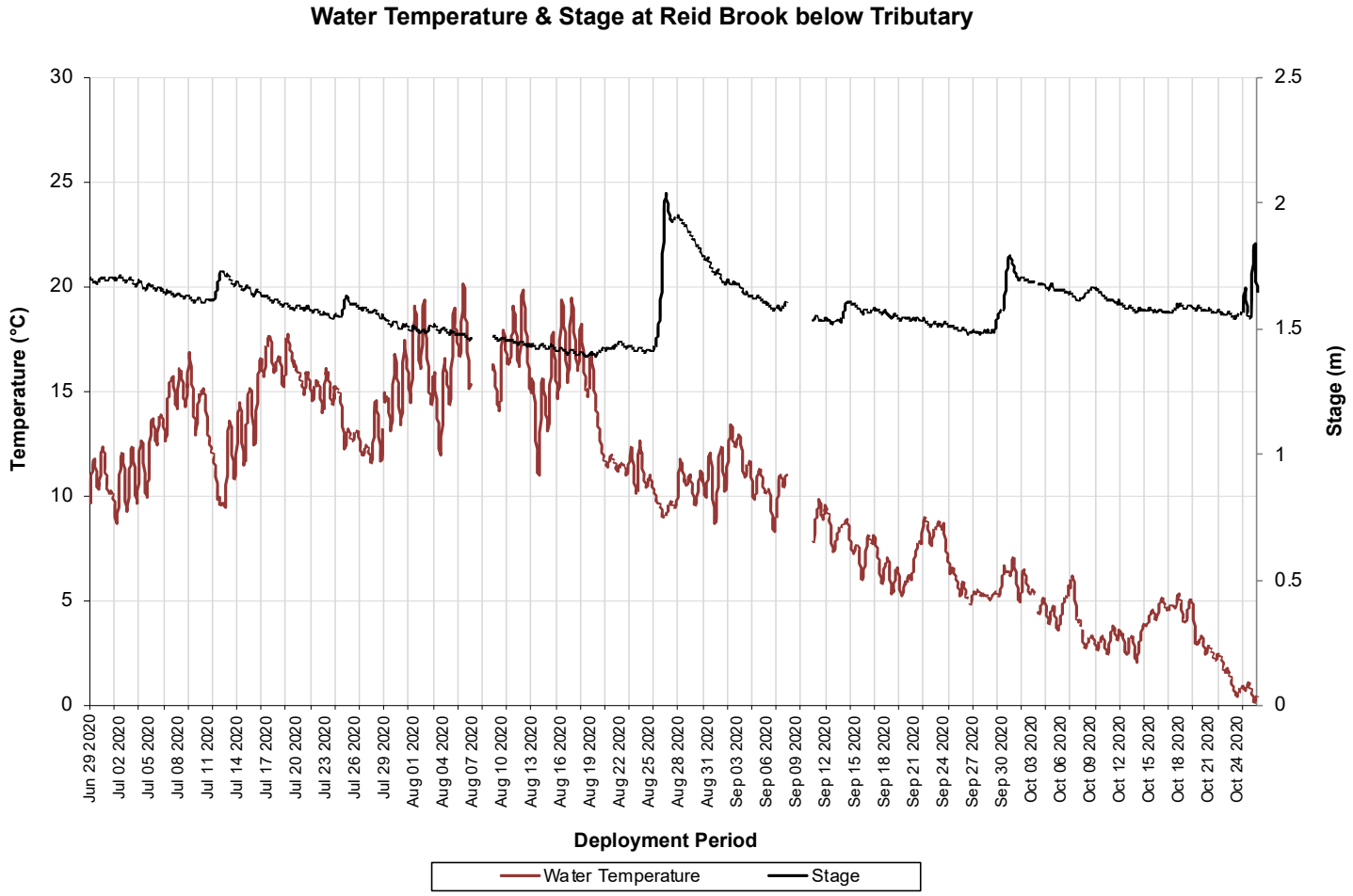

Figure 13: Water Temperature & Stage at Reid Brook below Tributary

Table 14: Comparisons of Minimum, Maximum and Median from the past three deployment years

Water Temperature	2020	2019	2018
Min	0.2	3.4	1.7
Max	20.1	15.2	17.4
Median	10.7	9.2	9.2

Water temperatures closely correlate with ambient air temperatures, with increases and decreases in ambient air temperatures being reflected in water temperatures (Figure 14). Air temperatures fluctuate to a greater extent each day as compared to water temperatures. Air temperature data was obtained from the Voisey's Bay Weather Station located at the Air Strip.

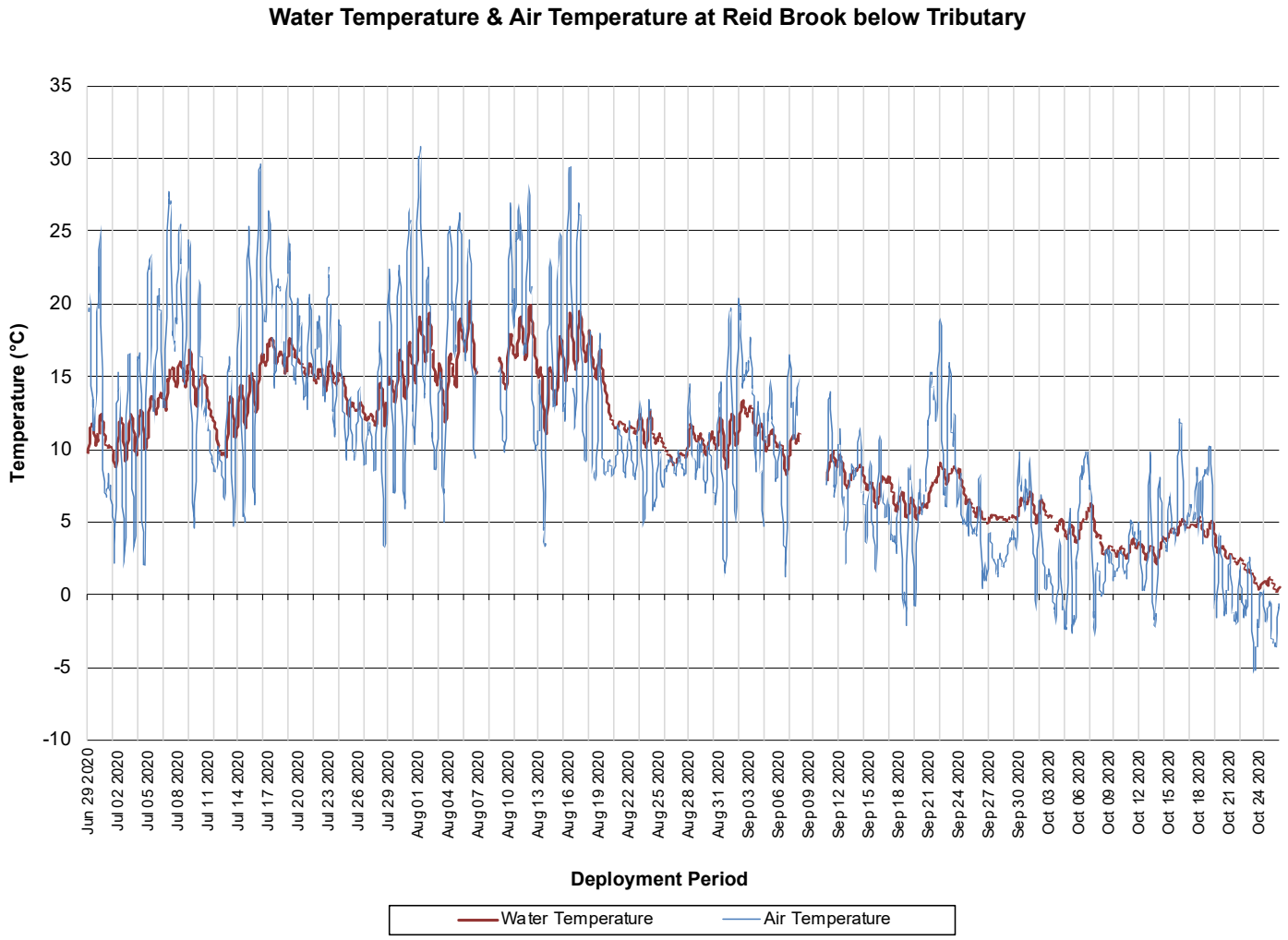

Figure 14: Water Temperature & Air Temperature at Reid Brook below Tributary

During the 2020 deployment season, pH ranged from 5.97 pH units to a maximum of 7.52 pH units, with a median value of 6.86 (Figure 15). pH data at this station has been consistent over recent years with median values of 6.72 in 2019 and 6.83 in 2018 (Table 15).

Stage data is included in Figure 15 to show how stage influences pH over time. In general, as stage decreases, pH increases and vice versa. This is a natural relationship and is expected in brooks.

pH values at this site were within the CCME's Guidelines for the Protection of Aquatic Life for the majority of the deployment season. Instances where pH values fell below the CCME's Minimum Guideline often correlated closely with increases in stage.

Please note that the stage data on the graph 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.

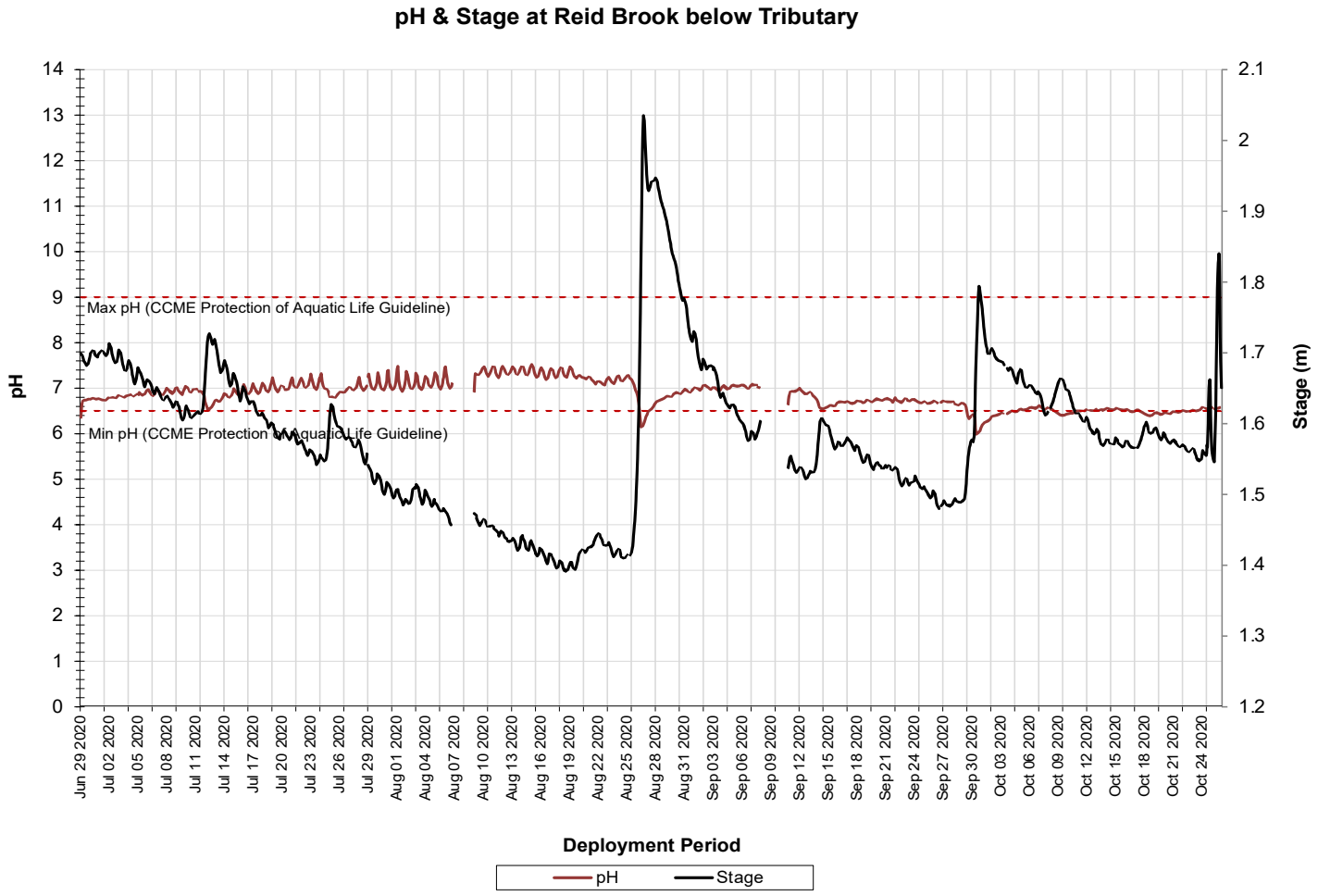

Figure 15: pH & Stage at Reid Brook below Tributary

Table 15: Comparisons of Minimum, Maximum and Median from the past three deployment years

pH	2020	2019	2018
Min	5.97	5.97	6.15
Max	7.52	7.71	7.28
Median	6.86	6.72	6.83

During the 2020 deployment season, specific conductivity levels ranged from 16.3µS/cm to a maximum of 247µS/cm, with a median value of 34.1µS/cm (Table 16). This median value is higher than those observed in previous years, which is partly influenced by higher conductivity levels during the last deployment period, which are being attributed to a calibration error with the field sonde (Figure 16).

Specific conductivity changes with water level fluctuationss: as stage increases, specific conductivity decreases. This is due to dilution of dissolved solids in the water column; as stage decreases, the concentration of dissolved solids increases, in turn increasing specific conductivity. This relationship is evident in the graph below.

Please note that the stage data on the graph 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.

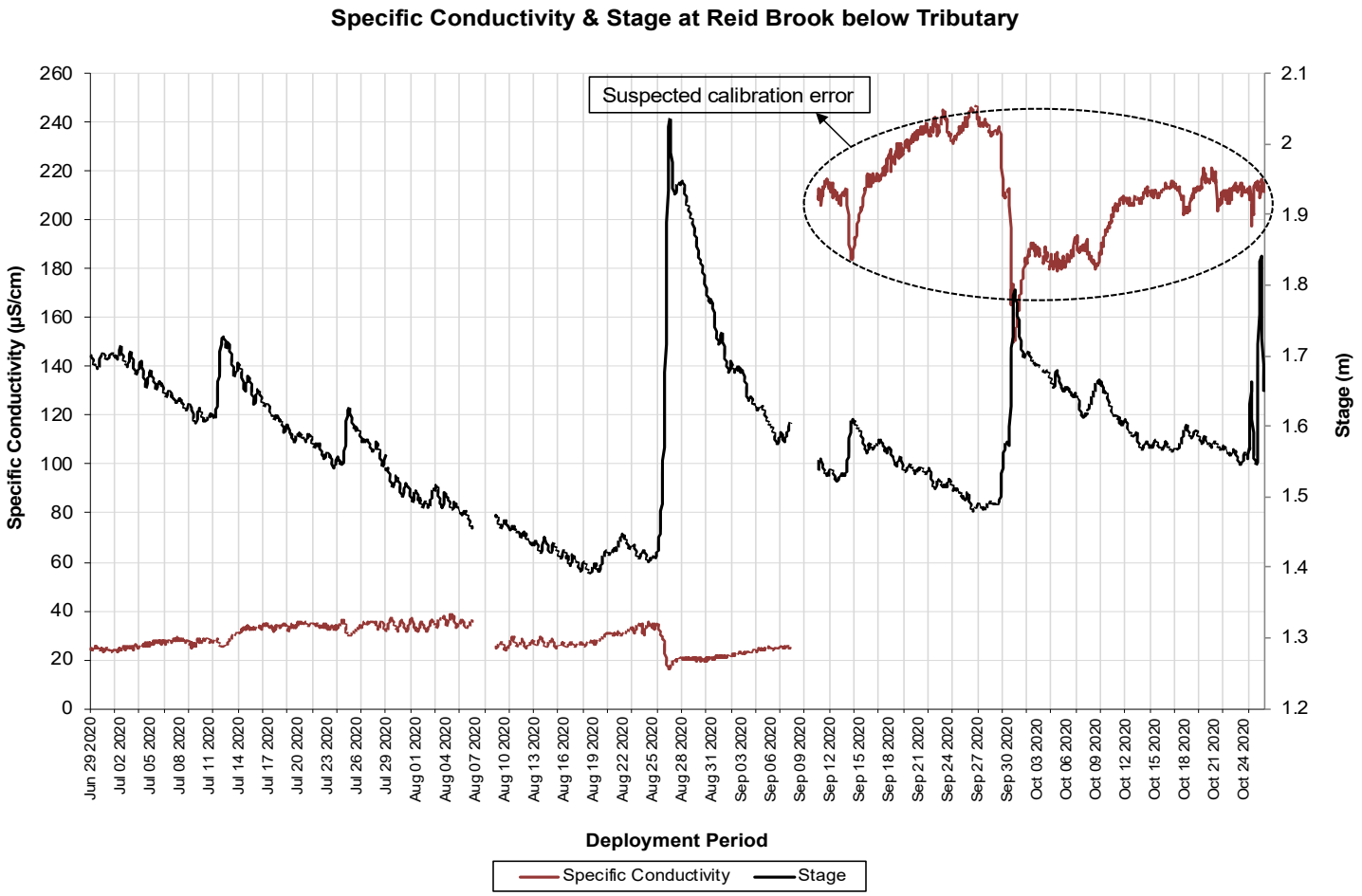

Figure 16: Specific Conductivity & Stage at Reid Brook below Tributary

Table 16: Comparisons of Minimum, Maximum and Median from the past three deployment years

Specific Conductivity	2020	2019	2018
Min	16.3	20.0	14
Max	247	42.3	40.3
Median	34.1*	30.7	27.8

*median higher than expected due to suspected calibration error

During the 2020 deployment season, dissolved oxygen concentrations ranged from 8.79mg/L to a maximum of 14.67mg/L, with a median value of 10.71mg/L. The saturation of dissolved oxygen ranged from 91.9% to 144.2%, with a median value of 96.1% (Figure 17). Dissolved oxygen values have been quite consistent at this site over recent years (Table 17).

Dissolved oxygen concentrations were lowest through early August when water temperatures were highest. Increases in water temperature result in less dissolved oxygen being present in a water body. As water temperatures started to decrease from late September onwards, dissolved oxygen concentrations started to increase.

Dissolved oxygen concentrations remained above the CCME's Guidelines for the Protection of Early Life Stages (9.5mg/L) and Other Life Stages (6.5mg/L) for the majority of the deployment season. Instances where dissolved oxygen levels fell below the CCME's Guideline for the Protection of Early Life Stages correlated closely with periods of warmer water temperatures.

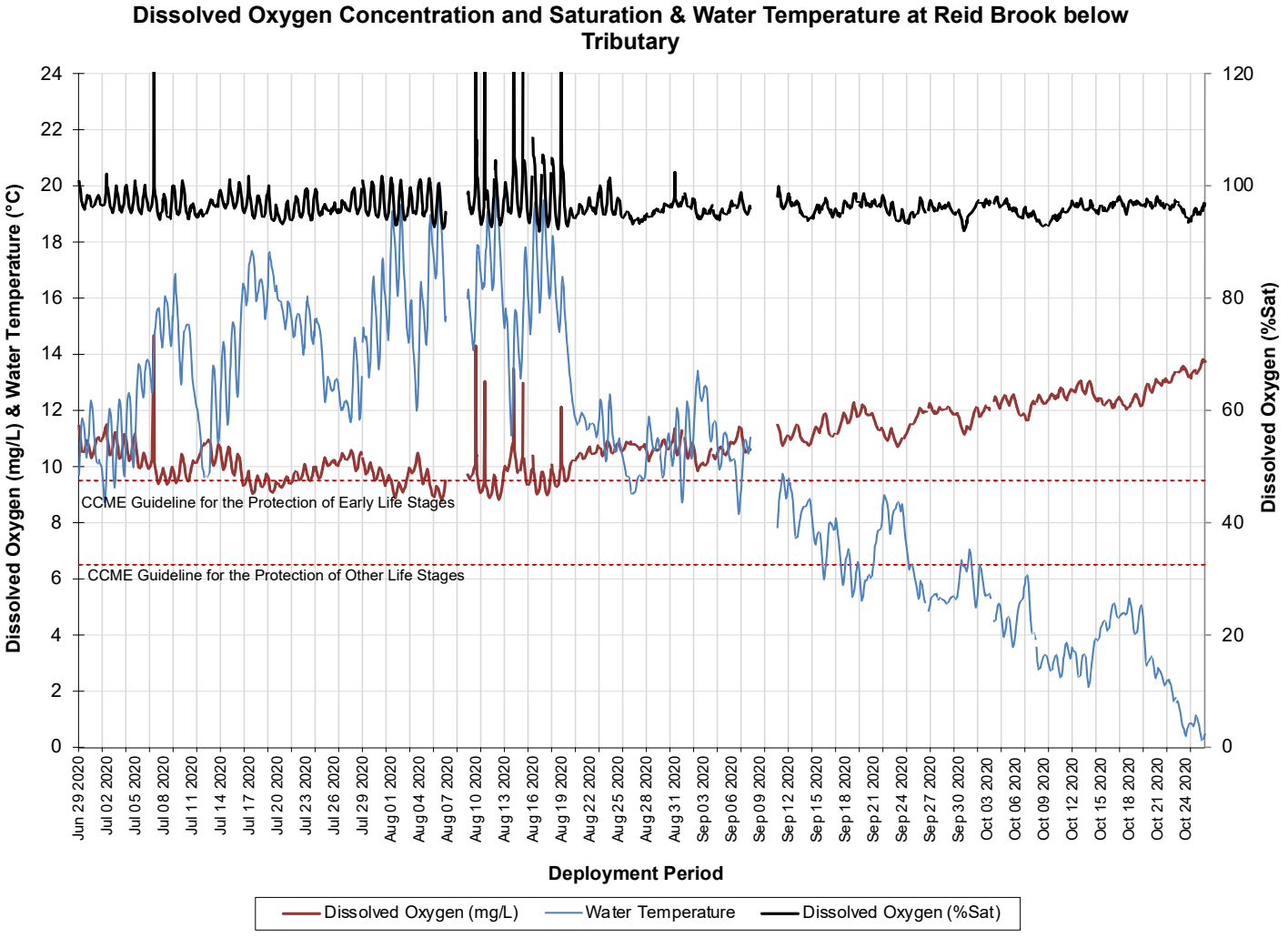

Figure 17: Dissolved Oxygen Concentration and Saturation & Water Temperature at Reid Brook below Tributary

Table 17: Comparisons of Minimum, Maximum and Median from the past three deployment years

Dissolved Oxygen (mg/L)	2020	2019	2018
Min	8.79	9.58	9.05
Max	14.67	12.68	13.26
Median	10.71	11.05	10.95

Percent Saturation (%)	2020	2019	2018
Min	91.9	91.7	90.9
Max	144.2	102.3	102.6
Median	96.1	97.0	94.8

During the 2020 deployment season, turbidity ranged from 0.0NTU to a maximum of 41.7NTU, with a median value of 0.0NTU (Figure 18). A median value of 0.0NTU indicates that there is a very low level of natural background turbidity at this station, and is consistent with past deployment seasons (Table 18).

Many of the turbidity increases at this site corresponded with rainfall events and subsequent runoff. Observed turbidity events were generally low in magnitude and short in duration. It is not uncommon to see turbidity fluctuate in a brook relating to environmental factors, such as changes in stage level and precipitation.

Please note that the stage data on the graph 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.

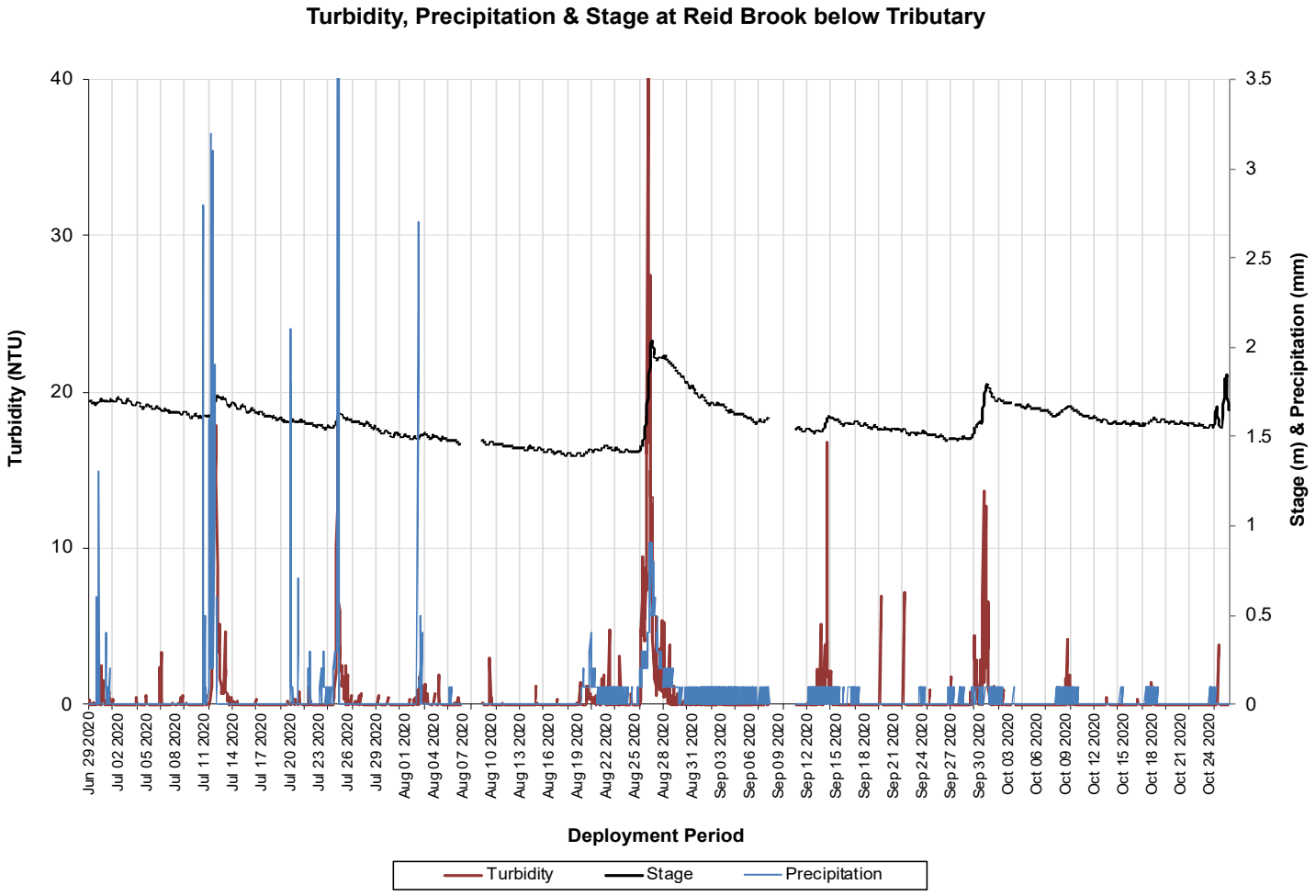

Figure 18: Turbidity, Precipitation & Stage at Reid Brook below Tributary

Table 18: Comparisons of Minimum, Maximum and Median from the past three deployment years

Turbidity	2020	2019	2018
Min	0.0	0.0	0.0
Max	41.7	1053	52.8
Median	0.0	0.0	16.8*

*median higher than expected due to suspected calibration error

Tributary to Reid Brook

During the 2020 deployment season, water temperature ranged from 0.2ºC to a maximum of 17.4ºC, with a median value of 10.6°C (Figure 19). Water temperature at this site has been quite consistent over recent years, with median values of 9.39°C in 2018 and 9.20°C in 2019 (Table 19).

Water temperatures were highest through mid-July and mid-August as air temperatures increased with the summer season (Figure 19 & 20). From the end of August onwards, water temperatures steadily declined as ambient air temperatures also declined (Figure 20).

Please note that the stage data on the graph 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.

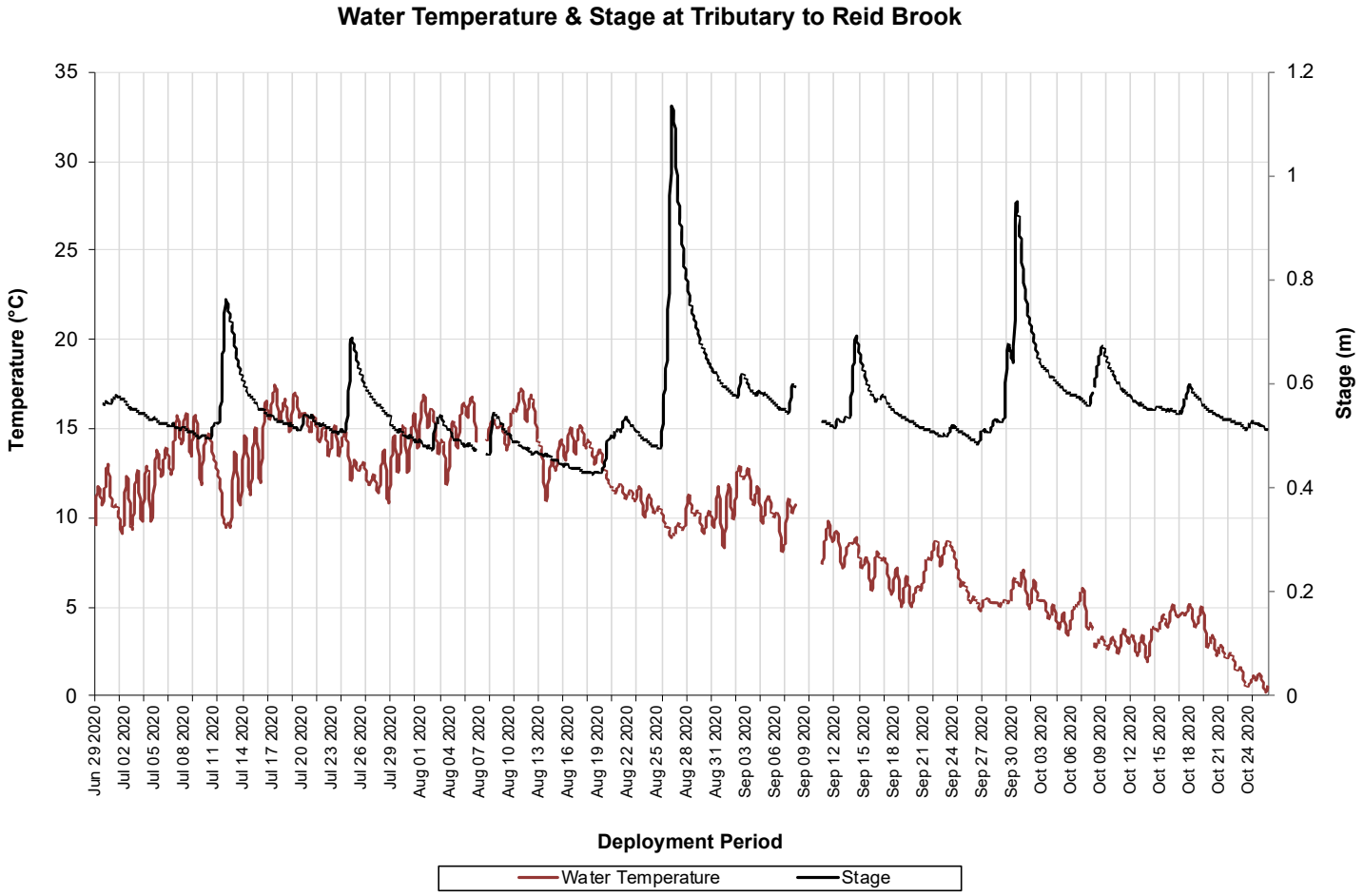

Figure 19: Water Temperature & Stage at Tributary to Reid Brook

Table 19: Comparisons of Minimum, Maximum and Median from the past three deployment years

Water Temperature	2020	2019	2018
Min	0.2	3.30	1.86
Max	17.4	15.10	18.02
Median	10.6	9.20	9.39

Water temperatures showed a close relationship with air temperatures (Figure 20). Fluctuations in air temperatures were reflected in water temperatures. Air temperatures fluctuate to a greater extent each day when compared with water temperatures.

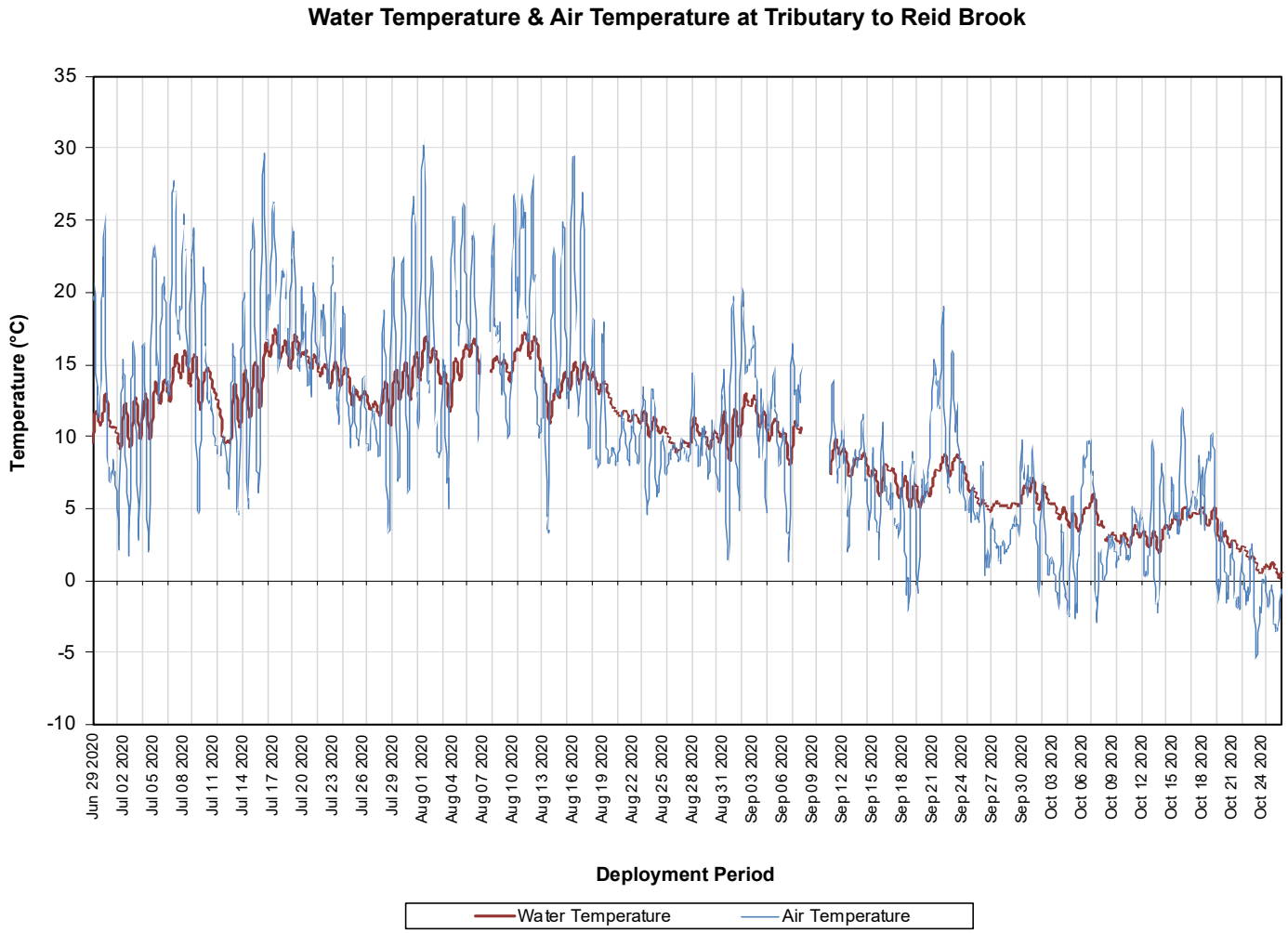

Figure 20: Water Temperature & Air Temperature at Tributary to Reid Brook

During the 2020 deployment season, pH data ranged from 5.95 to a maximum of 7.19 pH units, with a median value of 6.80 pH units (Table 20).

Stage data is included in Figure 21 to show how stage influences pH over time. In general, as stage decreases pH increases, and vice versa. Sharp increases in stage correlate closely with sharp decreases in pH.

pH values remained within the CCME's Guidelines for the Protection of Aquatic Life for the majority of the deployment season. Instances where pH values temporarily fell below the CCME's Minimum Guideline correlate closely with sharp increases in stage (Figure 21).

Please note that the stage data on the graph 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.

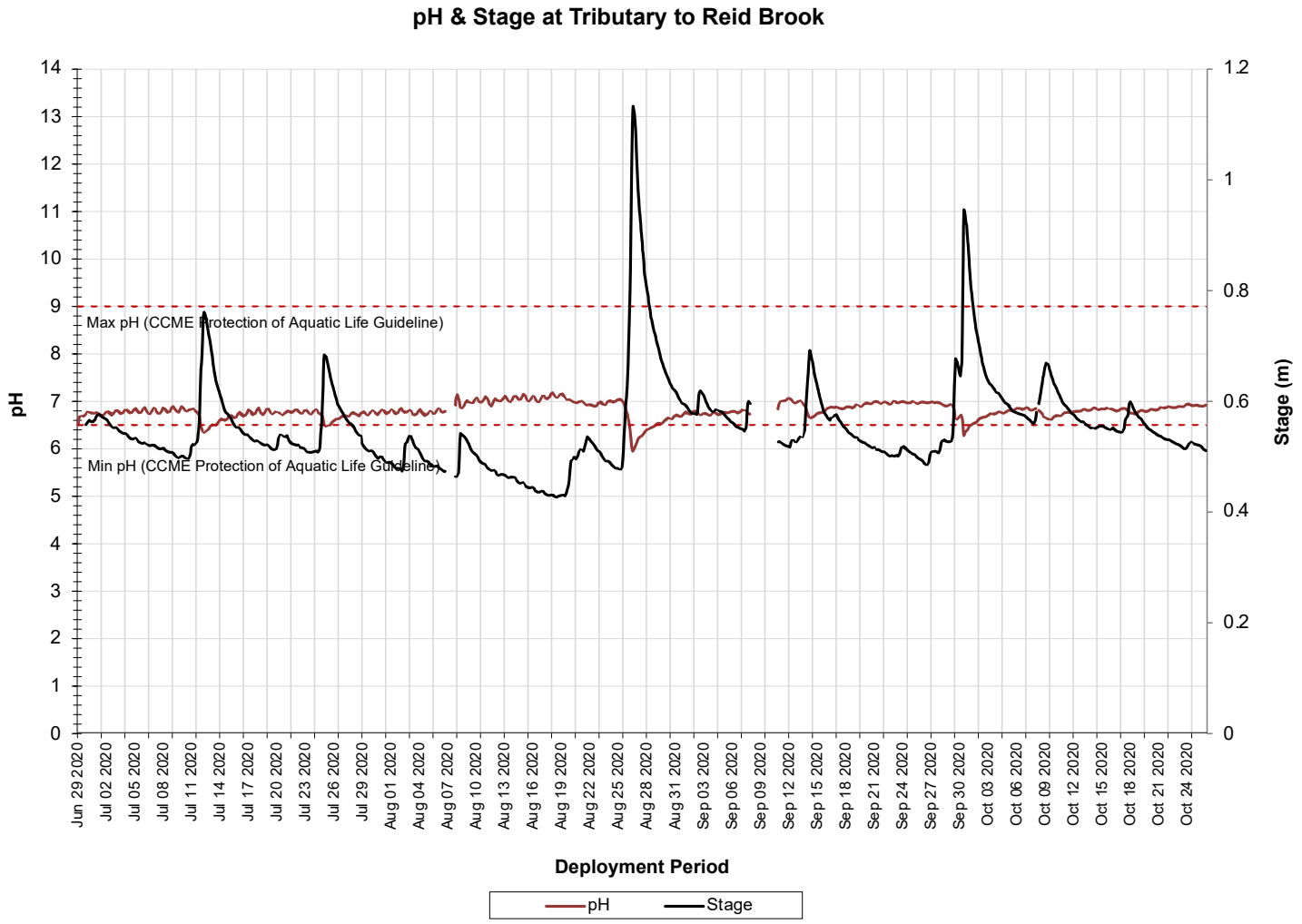

Figure 21: pH & Stage at Tributary to Reid Brook

Table 20: Comparisons of Minimum, Maximum and Median from the past three deployment years

pH	2020	2019	2018
Min	5.95	6.05	5.31
Max	7.19	7.11	7.84
Median	6.80	6.74	7.33

During the 2020 deployment season, specific conductivity ranged from 21.2µS/cm to a maximum of 47.4µS/cm, with a median value of 33.9µS/cm (Table 21).

Specific conductivity demonstrated a continuously increasing trend over the course of deployment, exhibiting a strong inverse relationship with stage. Increases in stage level dilute dissolved solids in the water column, in turn reducing specific conductivity. Inversely, as stage decreases specific conductivity increases as dissolved solids become more concentrated in the water column (Figure 22).

Please note that the stage data on the graph 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.

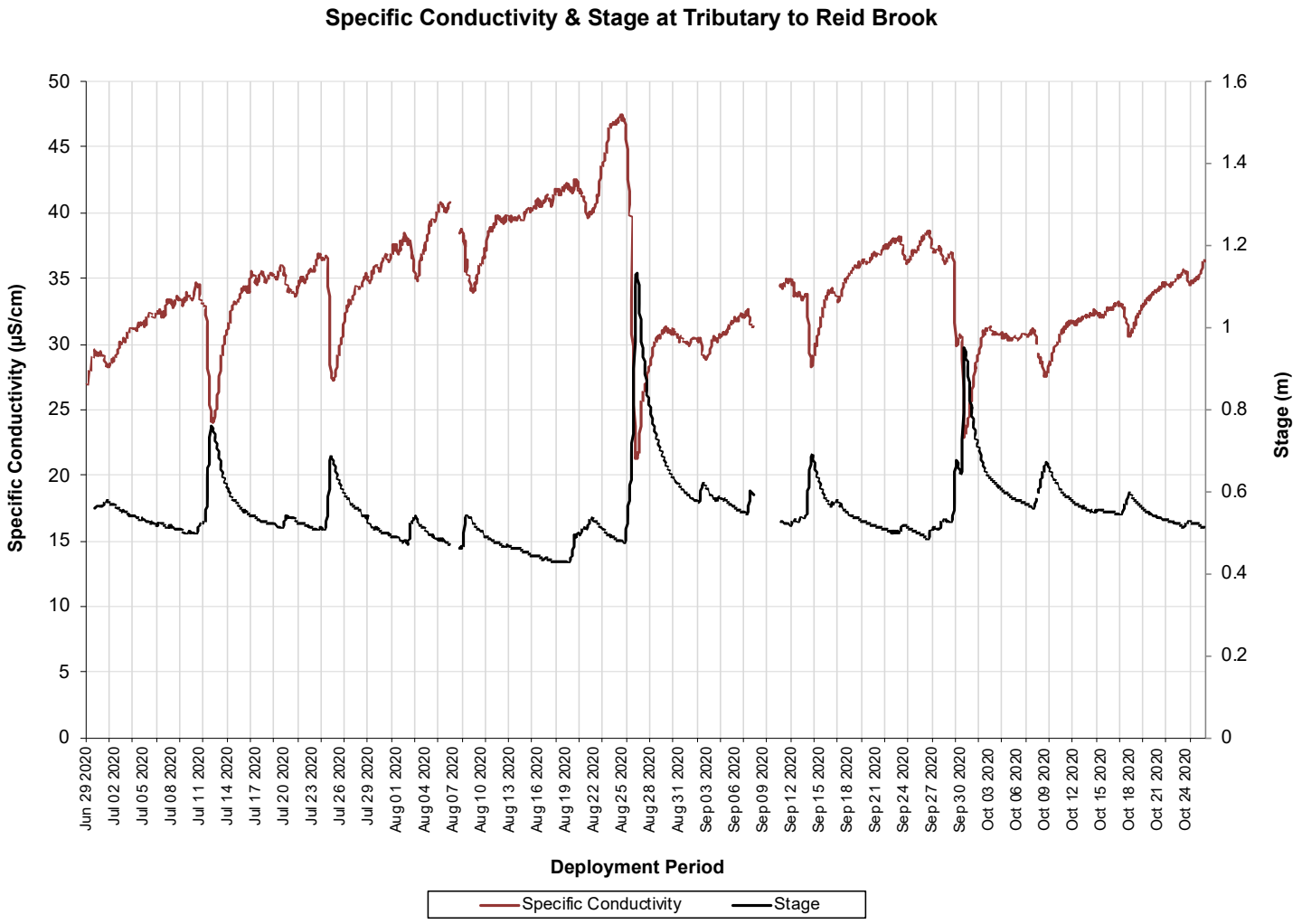

Figure 22: Specific Conductivity & Stage at Tributary to Reid Brook

Table 21: Comparisons of Minimum, Maximum and Median from the past three deployment years

Specific Conductivity	2020	2019	2018
Min	21.2	8.8	14.3
Max	47.4	41.1	38.1
Median	33.9	27.5	29.2

During the 2020 deployment season, dissolved oxygen concentration ranged from 9.10mg/L to a maximum of 13.77mg/L, with a median value of 10.73mg/L. Saturation of dissolved oxygen ranged from 90.1% to 101.1%, with a median value of 95.9% (Figure 23). Median values for both dissolved oxygen concentration and percent saturation were consistent with values from previous deployment seasons (Table 22).

Observed dissolved oxygen concentrations exhibited typical seasonal trends and were inversely related to water temperature. Dissolved oxygen concentrations were lowest through July and mid-August when water temperatures were warmest. Dissolved oxygen concentrations began to increase from late August onwards as water temperatures decreased (Figure 23).

Dissolved oxygen concentrations remained above the CCME's Guidelines for the Protection of Early Life Stages (9.5mg/L) for the majority of deployment; instances where dissolved oxygen levels fell below the guideline correlated closely with warmer water temperatures. Dissolved oxygen concentrations remained above the CCME's Guidelines for the Protection of Other Life Stages (6.5mg/L) for the full deployment season.

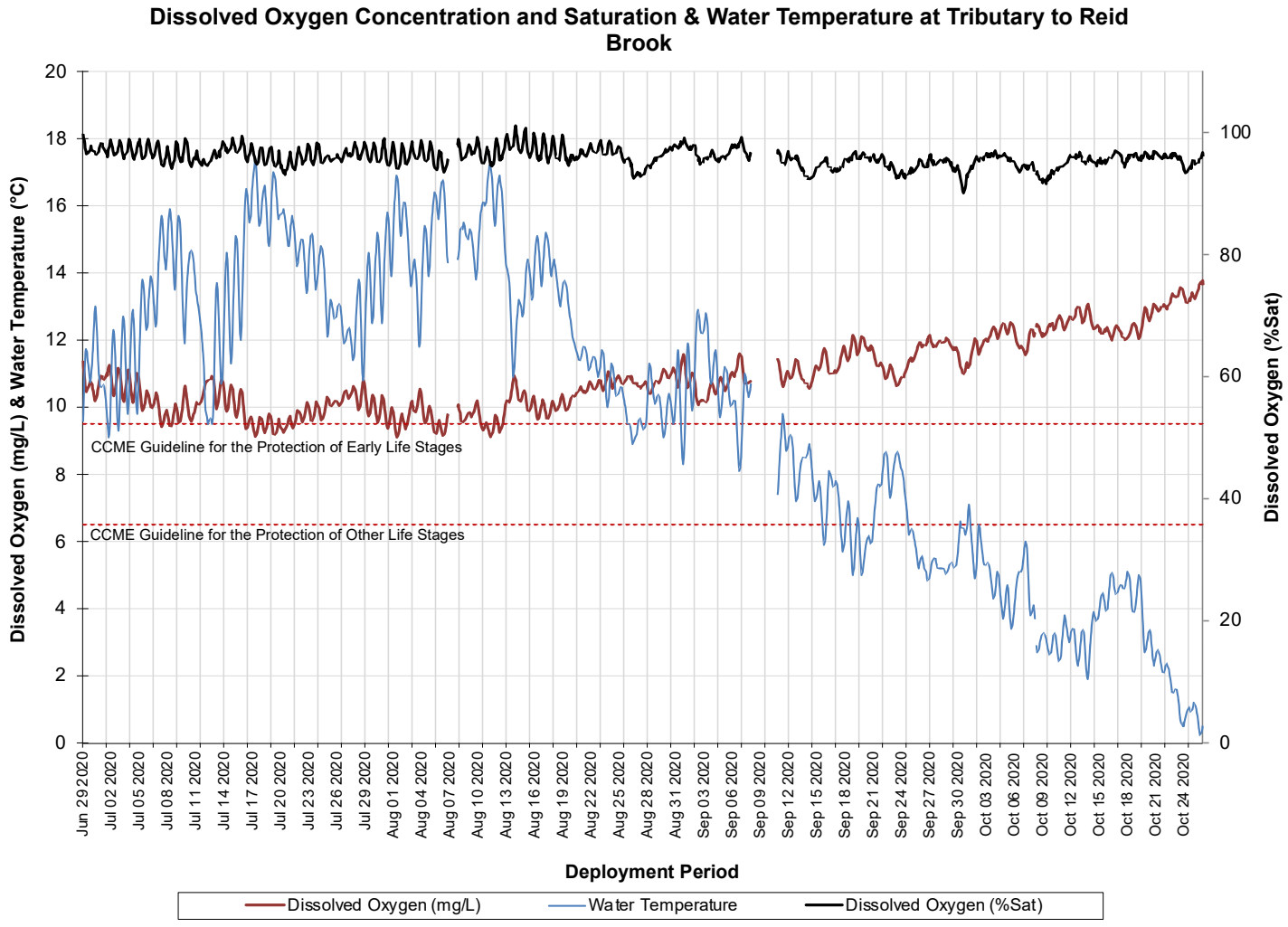

Figure 23: Dissolved Oxygen Concentration and Saturation & Water Temperature at Tributary to Reid Brook

Table 22: Comparisons of Minimum, Maximum and Median from the past three deployment years

Dissolved Oxygen (mg/L)	2020	2019	2018
Min	9.10	9.50	9.03
Max	13.77	12.73	13.22
Median	10.73	10.99	10.89

Percent Saturation (%)	2020	2019	2018
Min	90.1	92.2	91.4
Max	101.1	100.7	103.9
Median	95.9	96.5	95.6

During the 2020 deployment season, turbidity ranged from 2.1NTU to a maximum of 100NTU, with a median value of 4.5NTU (Table 23). This median is higher than expected at this station and is being slightly skewed by a suspected calibration error that affected turbidity values during the first deployment period.

Over the course of the deployment season, increases in turbidity generally corresponded with increases in stage and precipitation events. This is to be expected as increased precipitation and run-off may introduce natural organic matter into the water column. Turbidity levels quickly returned to background levels following stage increases and precipitation events (Figure 24).

Please note that the stage data on the graph 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.

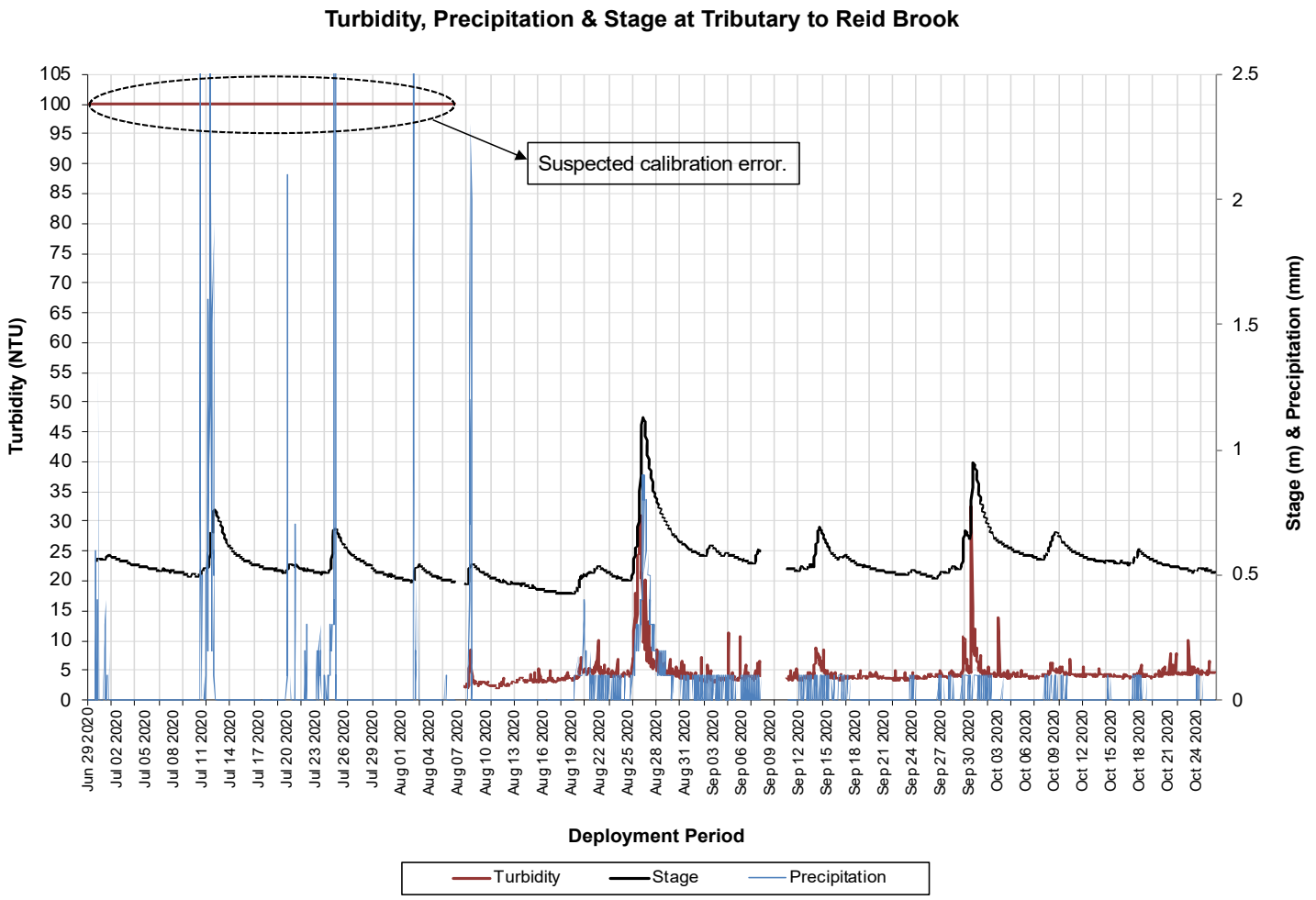

Figure 24: Turbidity, Precipitation & Stage at Tributary to Reid Brook

Table 23: Comparisons of Minimum, Maximum and Median from the past three deployment years

Turbidity	2020	2019	2018
Min	2.1	0.0	0.0
Max	100	1131.0	366.1
Median	4.5*	1.2	0.0

*median higher than expected due to suspected calibration error

Multi-Station Comparison

The following section of this report focuses on comparisons between the four stations in the Voisey's Bay real-time network.

Temperature

During the 2020 deployment season, water temperatures at all four real-time stations ranged from 0.16°C to a maximum of 23.45°C, both of which were recorded at Camp Pond Brook below Camp Pond.

Water temperature trends were similar at each of the four RTWQ stations, and closely resembled ambient air temperatures (Figure 25). Water temperatures at Camp Pond Brook below Camp Pond, Reid Brook below Tributary and Tributary to Reid Brook all followed a similar trend, peaking in late July. Reid Brook at Outlet of Reid Pond is generally slower to respond to changes in air temperatures since it is a larger volume of water and takes longer to acclimatize.

Tributary to Reid Brook and Reid Brook below Tributary had very similar water temperature data. This is to be expected as Tributary to Reid Brook flows directly into Reid Brook below Tributary. Both are fast flowing sites with similar environmental influences. Camp Pond Brook below Camp Pond exhibits more pronounced changes in water temperature compared to the other stations, recording the lowest and highest single temperatures in the network, as well as the highest median temperature of 13.00°C (Table 24).

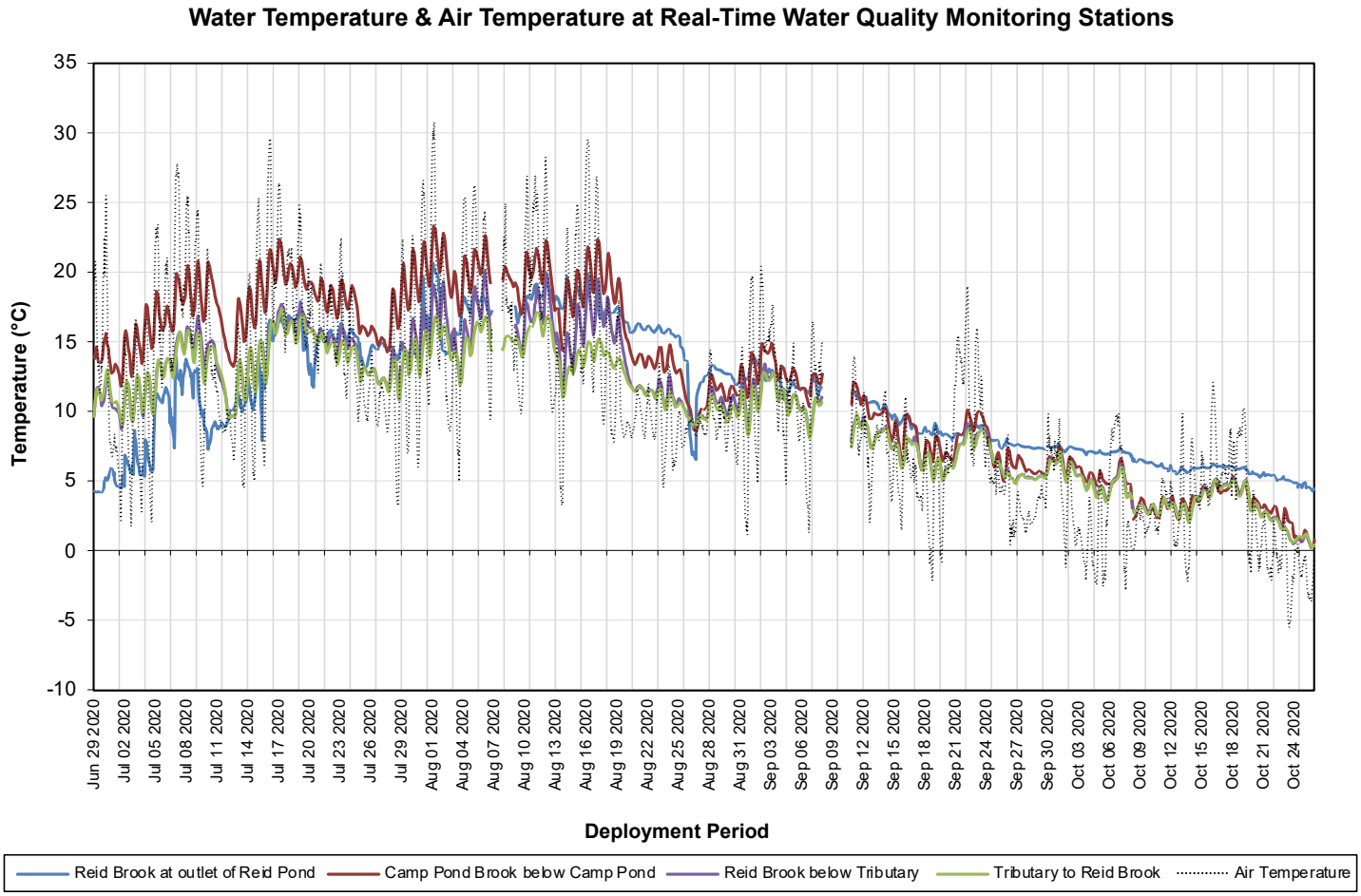

Figure 25: Water Temperature & Air Temperature at all RTWQ Stations

Table 24: Comparisons of Minimum, Maximum and Median from all RTWQ stations

Temperature (°C)	Reid Brook at Outlet of Reid Pond	Camp Pond Brook below Camp Pond	Reid Brook below Tributary	Tributary to Reid Brook
Min	4.17	0.16	0.17	0.20
Max	20.62	23.45	20.12	17.40
Median	10.93	13.00	10.71	10.60

pH

During the 2020 deployment season, median pH values at all four real-time stations ranged from 6.06 pH units at Reid Brook at Outlet of Reid Pond to 6.86 pH units at Reid Brook below Tributary (Table 25).

pH data for all stations followed a similar trend. The Reid Brook at Outlet of Reid Pond station is at the outlet of a pond and has different factors influencing pH as compared to the other sites, and tends to exhibit a wider range of pH values. Camp Pond Brook below Camp Pond, Reid Brook below Tributary, and Tributary to Reid Brook all showed similar pH movements across the deployment season (Figure 26).

There were several events where pH fell below the CCME's Minimum Guideline for the Protection of Aquatic Life. When compared to precipitation data (Figure 26), there is an evident change in pH levels during higher and longer precipitation events, specifically at Camp Pond Brook below Camp Pond, Reid Brook below Tributary, and Tributary to Reid Brook. Many of the fluctuations in the pH data across the real-time stations corresponded closely with precipitation events. This relationship is much less evident at Reid Brook at Outlet of Reid Pond.

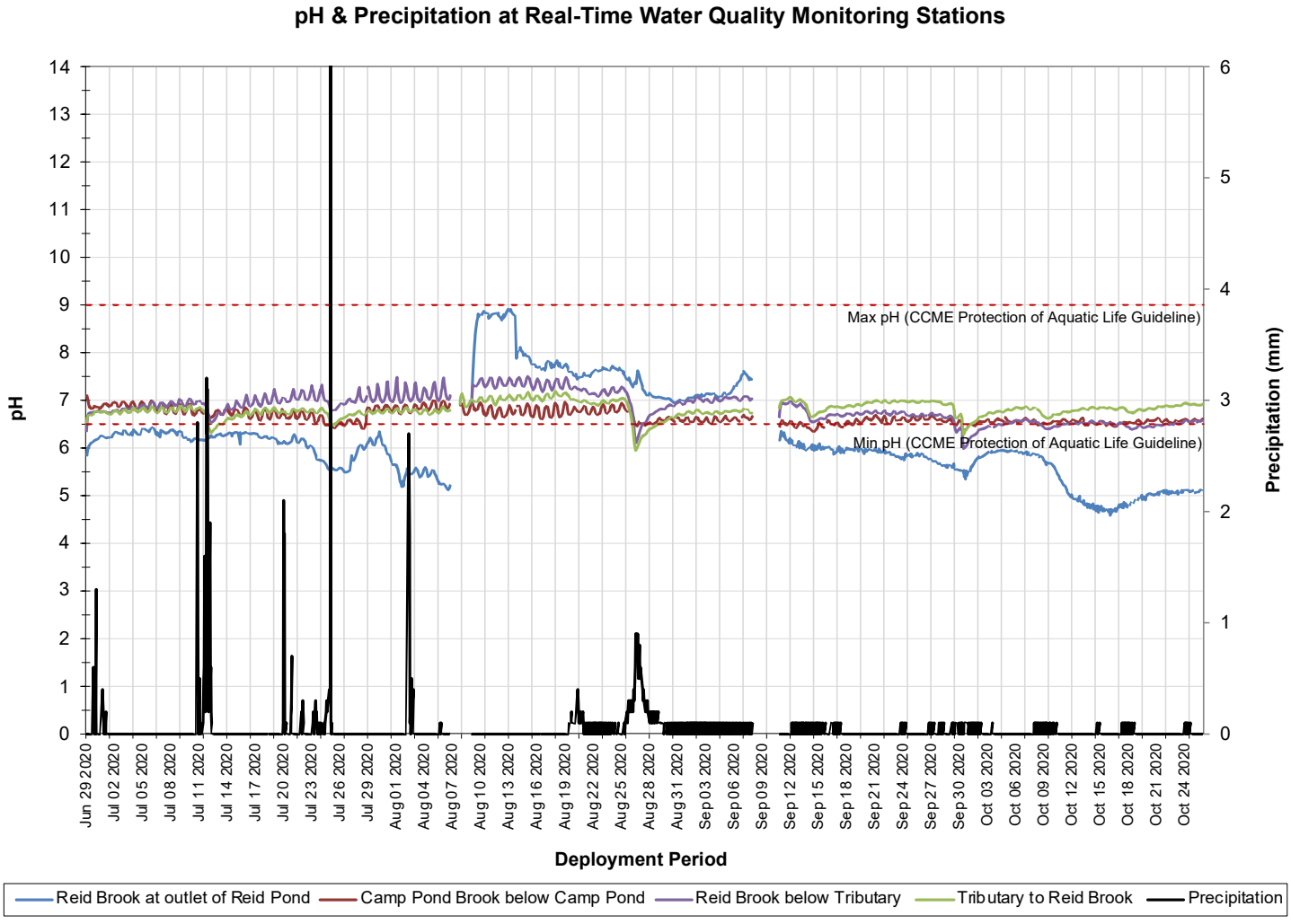

Figure 26: pH & Precipitation at all RTWQ Stations

Table 25: Comparisons of Minimum, Maximum and Median from the four real-time stations

pH (units)	Reid Brook at Outlet of Reid Pond	Camp Pond Brook below Camp Pond	Reid Brook below Tributary	Tributary to Reid Brook
Min	4.59	6.35	5.97	5.95
Max	8.91	7.11	7.52	7.19
Median	6.06	6.62	6.86	6.80

Specific Conductivity

During the 2020 deployment season, specific conductivity medians ranged from 12.1µS/cm at Reid Brook at Outlet of Reid Pond to a maximum of 36.6µS/cm at Camp Pond Brook below Camp Pond (Table 26).

Reid Brook at Outlet of Reid Pond maintained a stable specific conductivity level across most of the deployment season. Stable conductivity levels are to be expected at this station since it is located in an established pond environment. Reid Brook below Tributary and Tributary to Reid Brook had similar conductivity levels and followed a similar trend. Camp Pond Brook below Camp Pond displayed greater and more fluctuating specific conductivity levels. This trend is typical of this station, as it is located closer to the Voisey's Bay mine site than the other stations and is therefore more susceptible to anthropogenic influences (Figure 27).

Reid Brook below Tributary, Tributary to Reid Brook and Camp Pond Brook below Camp Pond all generally displayed increasing conductivity levels across the deployment season. This is to be expected as stage levels decrease and suspended solids become more concentrated in the water column. As Reid Brook at Outlet of Reid Pond is a more stable water quality environment, conductivity data remained quite consistent, with the exception of the very end of the deployment season.

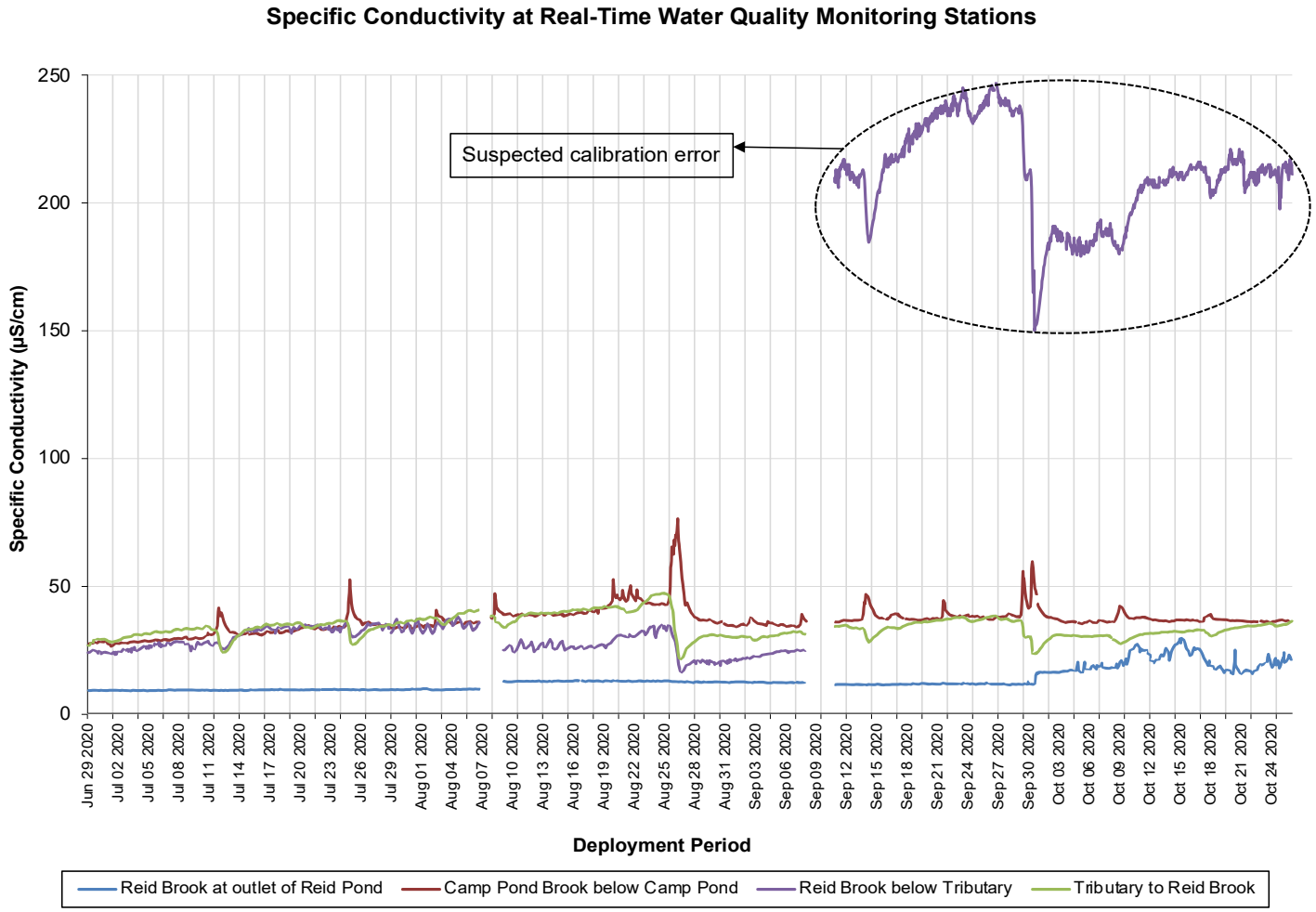

Figure 27: Specific Conductivity at all RTWQ Stations

Table 26: Comparisons of Minimum, Maximum and Median from the four real-time stations

Specific Conductivity	Reid Brook at Outlet of Reid Pond	Camp Pond Brook below Camp Pond	Reid Brook below Tributary	Tributary to Reid Brook
Min	9.1	26.4	16.3	21.2
Max	29.7	76.5	247 *	47.4
Median	12.1	36.6	34.1	33.9

*data influenced by suspected calibration error

Dissolved Oxygen Concentration and Saturation of Dissolved Oxygen

During the 2020 deployment season, dissolved oxygen concentration medians ranged from 10.04mg/L at Camp Pond Brook below Camp Pond to a maximum of 11.04mg/L at Reid Brook at Outlet of Reid Pond (Table 27). Dissolved oxygen concentrations displayed a typical inverse relationship with both water and ambient air temperatures at all stations (Figure 28a). Dissolved oxygen levels were most stable at Reid Brook at Outlet of Reid Pond, whereas there was greater fluctuation at the other three stations.

During the warmer periods through July and August, dissolved oxygen levels at all stations fell, at least occasionally, below the CCME's Guideline for the Protection of Early Life Stages (9.5mg/L). Dissolved oxygen concentrations rose above the CCME's Guidelines for the Protection of Early Life Stages at all stations from late August onwards as water temperatures decreased. Dissolved oxygen concentrations remained above the CCME's Guideline for the Protection of Other Life Stages for the duration of deployment at all stations (Figure 28a).

The observed changes in dissolved oxygen levels are not unusual and are to be expected during warmer temperatures. As air temperatures decreased into the cooler fall season, dissolved oxygen levels began to steadily increase.

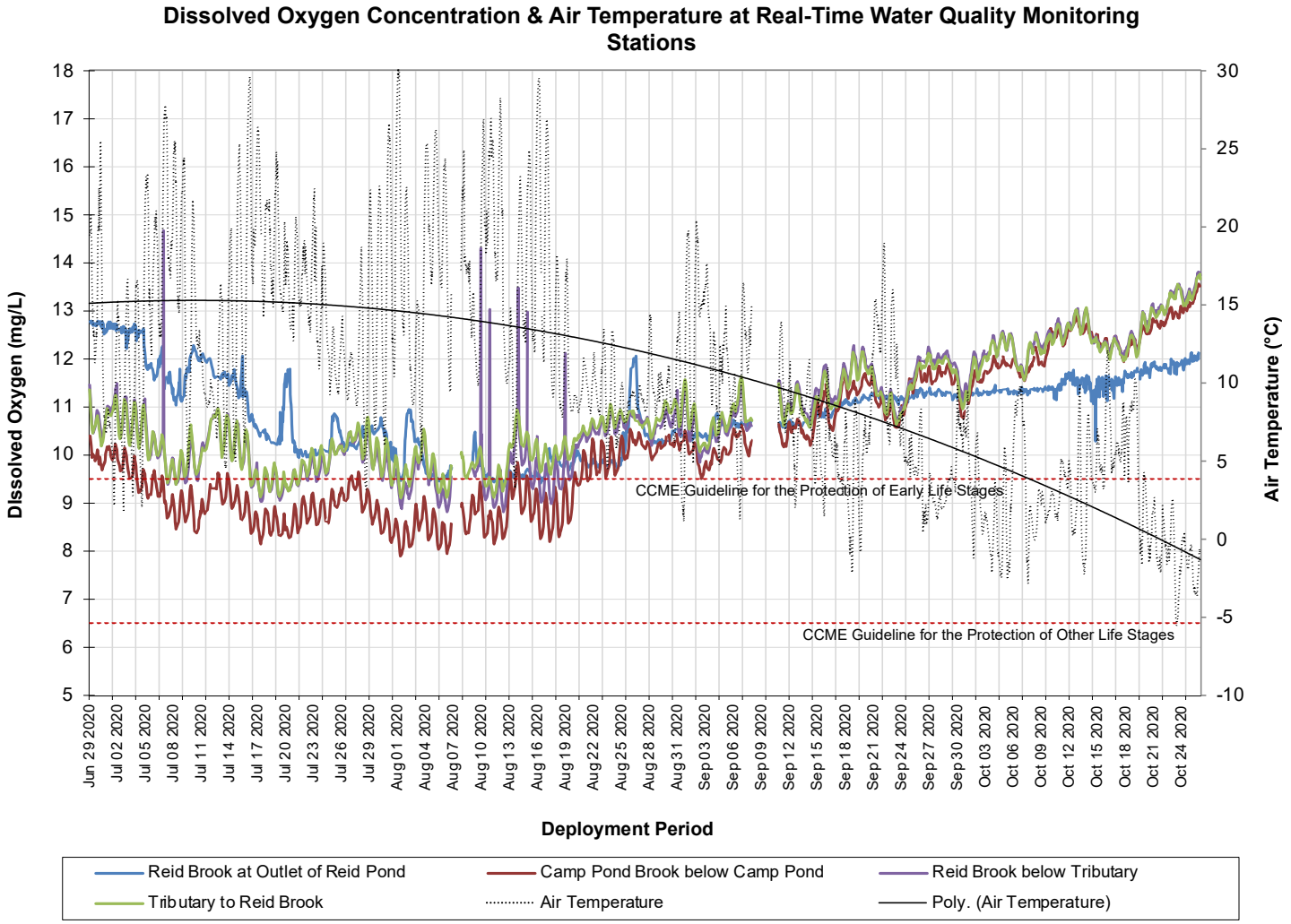

Figure 28a: Dissolved Oxygen Concentration & Air Temperature at all RTWQ Stations

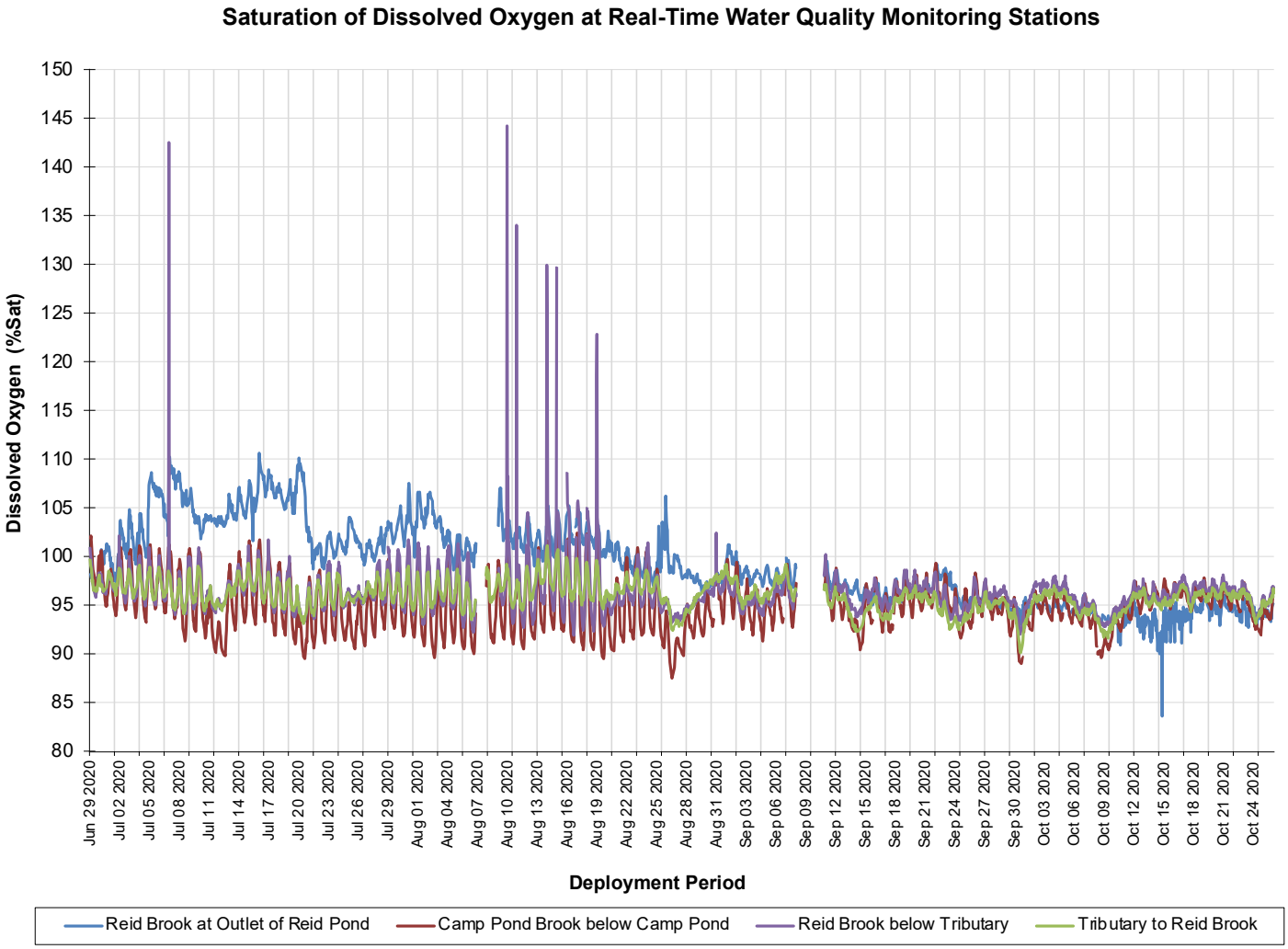

Figure 28b: Saturation of Dissolved Oxygen at all RTWQ Stations

Table 27: Comparisons of Minimum, Maximum and Median from the four real-time stations

	Dissolved Oxygen (mg/L)				Dissolved Oxygen (% Saturation)			
	Reid Brook at Outlet of Reid Pond	Camp Pond Brook below Camp Pond	Reid Brook below Tributary	Tributary to Reid Brook	Reid Brook at Outlet of Reid Pond	Camp Pond Brook below Camp Pond	Reid Brook below Tributary	Tributary to Reid Brook
Min	9.36	7.90	8.79	9.10	83.6	87.5	91.9	90.1
Max	12.81	13.58	14.67	13.77	110.6	103.1	144.2	101.1
Median	11.04	10.04	10.71	10.73	98.6	94.8	96.1	95.9

Turbidity

During the 2020 deployment season, turbidity ranged from 0.0NTU at two stations to a maximum of 774NTU at Reid Brook at Outlet of Reid Pond (Table 28). It is not unusual to see significant variability in turbidity data, as this parameter is influenced by many factors (e.g. precipitation, runoff from surrounding environments, high water flow (bubbles) and debris, such as leaf litter). Median turbidity values at all stations indicate that there is very little background turbidity at these stations, which is to be expected (Figure 29b).

Figure 29a displays all turbidity data for the four real-time stations, as well as precipitation data. In contrast, Figure 29b displays turbidity data on a scale of 100NTU. The use of a smaller scale allows for more accurate comparison of turbidity events between the different stations, and clearly shows the relationship between precipitation events and increased turbidity levels.

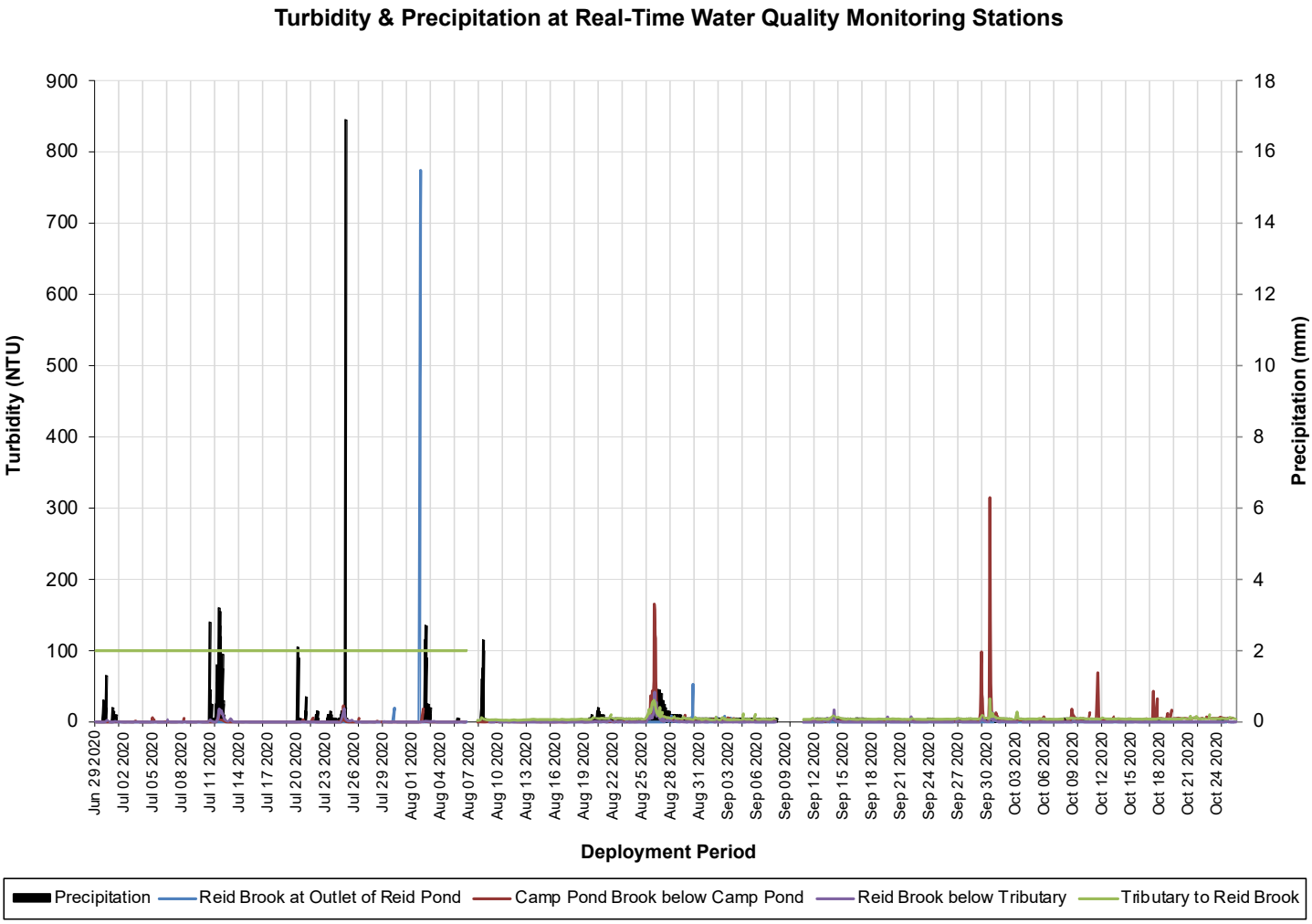

Figure 29a: Turbidity & Precipitation at all RTWQ Stations

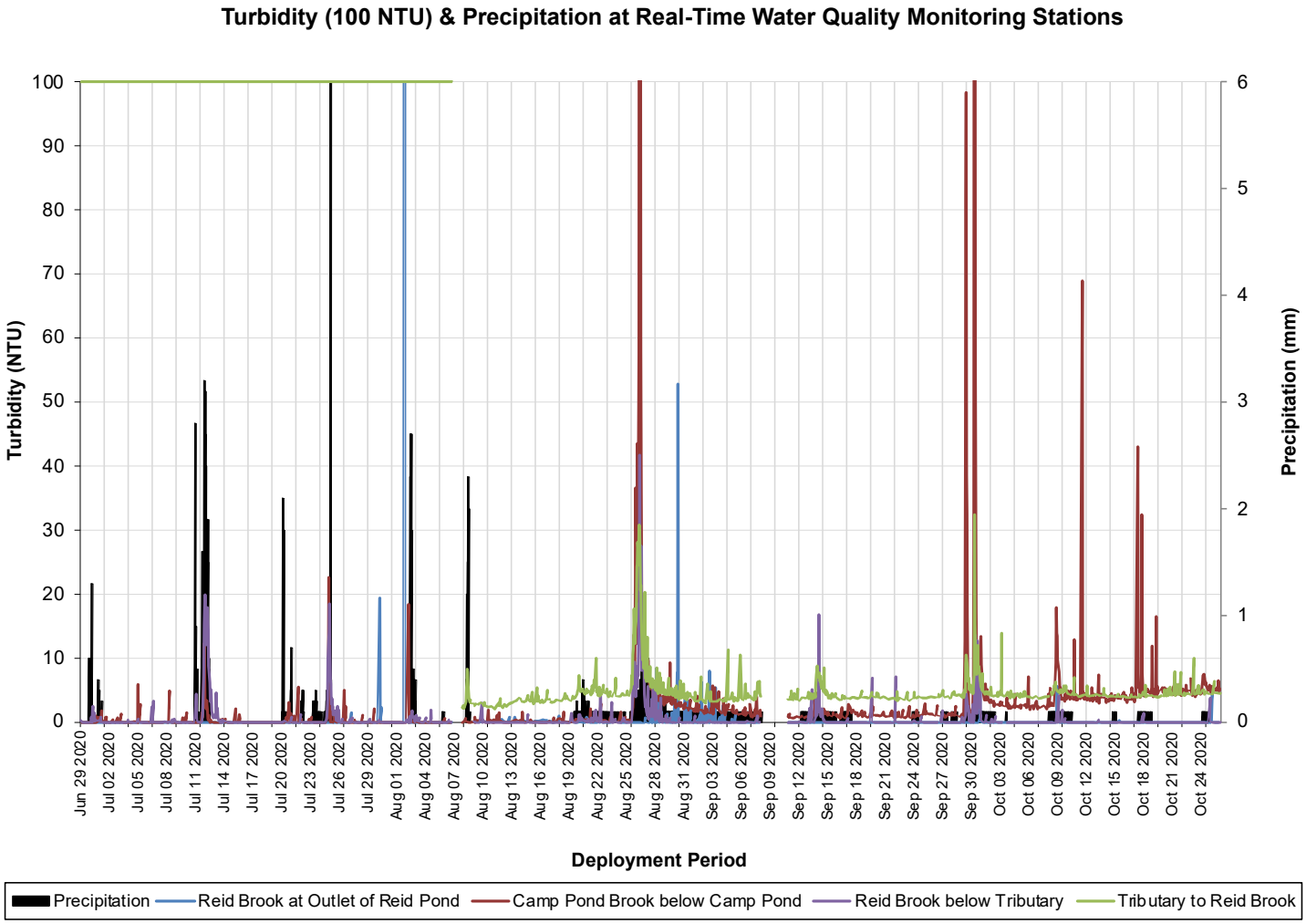

Figure 29b: Turbidity & Precipitation at all RTWQ Stations (graphed to 100 NTU)

Table 28: Comparisons of Minimum, Maximum and Median from the four real-time stations

Turbidity (NTU)	Reid Brook at Outlet of Reid Pond	Camp Pond Brook below Camp Pond	Reid Brook below Tributary	Tributary to Reid Brook
Min	0.0	0.0	0.0	2.1
Max	774	314.7	41.7	100
Median	0.0	0.8	0	4.5

Stage

During the 2020 deployment season, stage levels were variable but generally decreasing over the course of deployment at all stations. Camp Pond Brook below Camp Pond exhibited the least variation in stage level, but did react to high precipitation events (Figure 30).

There is an obvious relationship between precipitation and stage. Tributary to Reid Brook, Reid Brook below Tributary, and Reid Brook at Outlet of Reid Pond had very obvious responses to precipitation events. Precipitation events had slightly less influence at Camp Pond Brook below Camp Pond as this station is in close proximity to the lake, but the relationship is still evident (Figure 30).

Please be advised that WSC is responsible for the QA/QC of water quantity data. Corrected data can be obtained upon request. Stage data is included in this report to highlight the relationship with water quality parameters.

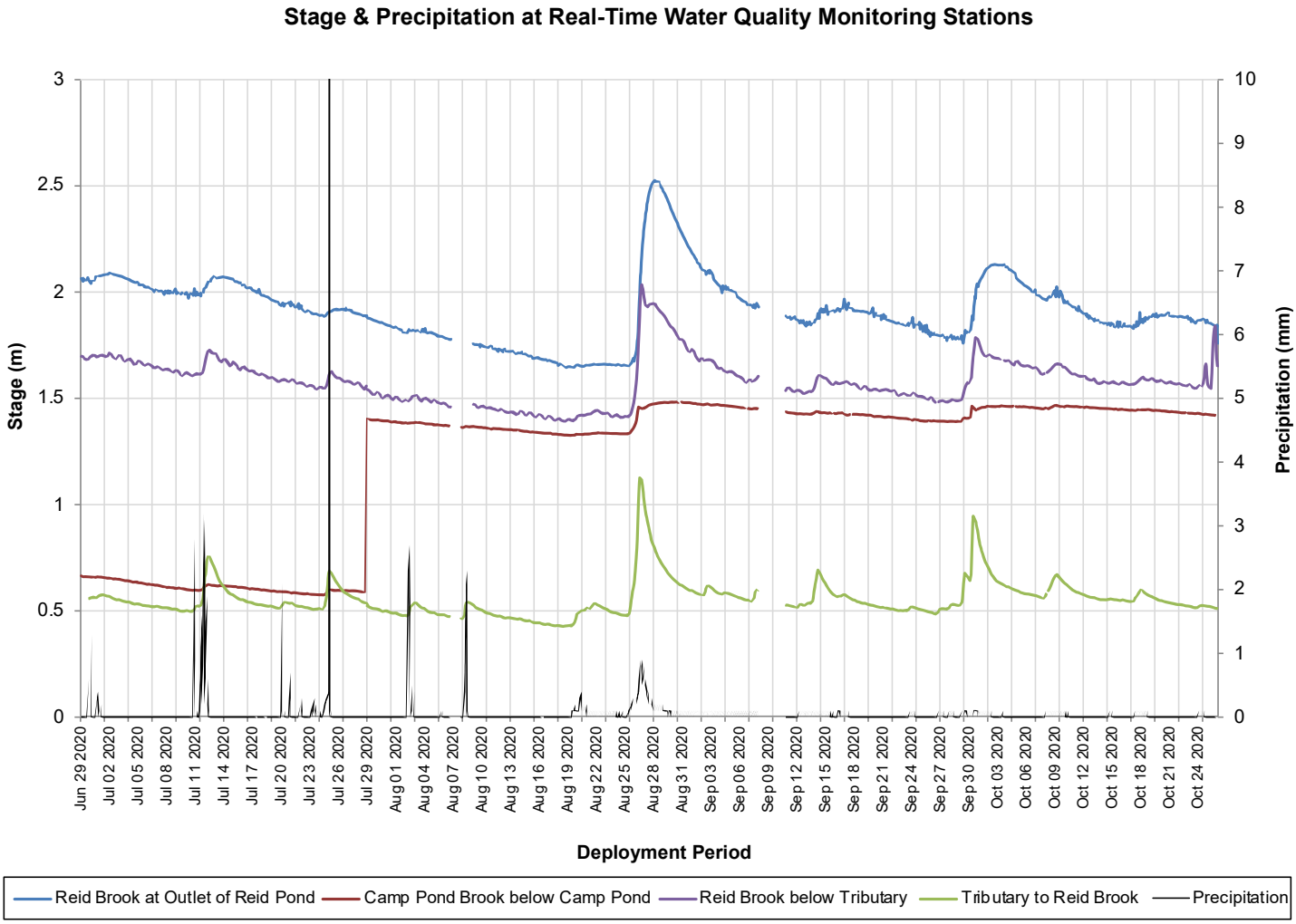

Figure 30: Stage & Precipitation at all RTWQ Stations

Table 29: Comparisons of Minimum, Maximum and Median from the four real-time stations

Stage (m)	Reid Brook at Outlet of Reid Pond	Camp Pond Brook below Camp Pond	Reid Brook below Tributary	Tributary to Reid Brook
Min	1.643	0.575	1.391	0.427
Max	2.526	1.484	2.036	1.133
Median	1.901	1.393	1.577	0.536
Difference (Max-Min)	0.883	0.909	0.645	0.706

Conclusions

The 2020 deployment season ran from June 29th until October 26th, and consisted of three deployment periods.

The majority of water quality events at the four RTWQ stations can be explained by precipitation events, spring thaw influences, and/or changes in air temperature as the seasons moved from spring to summer to fall.

Water temperature and dissolved oxygen were directly influenced by typical seasonal trends, increasing or decreasing with warming or cooling air temperatures. pH levels were generally maintained throughout deployment, except during high stage events or precipitation events when pH values decreased for a short period of time.

Three RTWQ stations had specific conductivity levels that increased across the deployment season; Reid Brook at Outlet of Reid Pond was the exception with relatively stable conductivity levels, which are attributed to the stable pond environment nearby.

Turbidity data showed significant variation across the network; however, the majority of turbidity increases were associated with precipitation events occurring at the same time. Observed turbidity events were short in duration and turbidity readings typically returned to background levels.

Path Forward

The success of the real-time water monitoring network is largely due to environmental staff maintaining and monitoring the Voisey's Bay RTWQ network. This network has been improving since 2003 and continues to advance annually in background knowledge and awareness of the area's characteristics. Data collected within this network is essential for identifying the difference between natural and anthropogenic events. As this agreement progresses into the 2021 deployment period for the Voisey's Bay stations, the following is a list of planned activities to be carried out. This list also includes some multi-year activities planned in the previous year that are still in progress.

- Staff from Vale will be responsible for monthly maintenance and calibration (as was the case in the past). WRMD staff will perform regular site visits to audit and assist in the maintenance and calibration procedures from time to time. WSC staff will perform regular site visits to ensure water quantity instrumentation is functioning correctly, calibrated and providing accurate measurements.
- WRMD staff will update Voisey's Bay staff on any changes to processes and procedures with handling, maintaining and calibrating the RTWQ instruments.
- If necessary, changes or improvements to deployment techniques will be adapted to each specific site, ensuring secure and suitable conditions for RTWQ.
- WRMD will work with Vale Environment staff to reassess the network design (station location) and plan for any necessary or desired changes in 2021 or in future seasons.
- Open communication lines will continue to be maintained between WRMD, ECCC and Vale employees involved with the agreement in order to respond to emerging issues on a proactive basis.
- Vale will receive deployment reports outlining the events that occurred in the previous deployment period and a 2021 annual report summarizing the events of the entire deployment season.
- WRMD will continue to work on Automatic Data Retrieval System to incorporate new capabilities when applicable.
- WRMD will continue to work on the creation of value added products using the RTWQ data, remote sensing and water quality indices.
- WRMD will begin development of models using RTWQ data and grab sample data to estimate a variety of additional water quality parameters (*i.e.* TSS, major ions *etc*.).
- 2021 deployments will recommence in the Spring.

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