Real-Time Water Quality 2014 Annual Report

Voisey's Bay Network

June 12 to November 5, 2014

Newfoundland Labrador

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

Real-Time Water Quality Deployment Report

Voisey's Bay Network

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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 and Conservation (ENVC) Water Resources Management Division as well as Environment Canada (EC) to ensure the protection of ambient water resources in Voisey's Bay, Labrador.

Vale Environmental Coordinators are acknowledged for their hard work during the 2014 deployment period, and ensuring the Real-Time Water Quality Monitoring Network is operating to the standards set by ENVC. It is only through their dedication to properly maintain and calibrate the equipment and perform acceptable quality control measures that the data can be viewed as reliable and accurate.

Various individuals from WRMD have been integral in ensuring the smooth operation of such a technologically advanced network. WRMD staff in Goose Bay play the 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 worked on the communication aspects of the network ensuring the data is being provided to the general public on a near real-time basis through the departmental web page. Due to staff change over Tara Clinton was responsible for the Voisey's Bay stations over the 2014 deployment season.

Environment Canada staff of the Meteorological Service of Canada: Water Survey Canada (Perry Pretty, Brent Ruth, Roger Ellsworth, Dwayne Ackerman and Mike Ludwicki) play an essential role in the data logging/communication aspect of the network. These individuals visit the site often to ensure the data logging equipment is operating properly and transmitting the data efficiently. Finally, they play the lead role in dealing with hydrological quantity and flow issues.

The managers ENVC (Renée Paterson), EC (Howie Wills) and Vale (Perry Blanchard) 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

EC	Environment Canada
ENVC	Department of Environment and Conservation
DO	Dissolved Oxygen
NL	Newfoundland and Labrador
QAQC	Quality Assurance and Quality Control
RTWQ	Real-time Water Quality
WRMD	Water Resources Management Division
%Sat	Percent Saturation

Introduction

The RTWQ network in Voisey's Bay was successfully established by ENVC and EC 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 Lower Reid Brook, and Lower 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 flow rate data. These parameters are the responsibility of EC, 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 spring 2012 season for this network as well as a new Hydrolab Minisonde 5 for QAQC measurements and an Archer handheld display unit.

This annual deployment report illustrates, discusses and summarizes water quality related events from June 12 to November 5, 2014. During this time, four visits were made to each of the four RTWQ sites. Instruments were deployed for three, 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 preferably 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 carefully calibrates 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. The instrument sensors will still work to capture any water quality event even though the exact data values collected may be inaccurate. Installation and removal dates for each station in the 2014 deployment season are summarized in Table 1.

Table 1: Installation and removal dates for 2014 deployment periods

Installation	Removal	Deployment
June 12	July 15	33 days
July 16	August 20	36 days
August 20	September 23	35 days
September 24	November 5	43 days

Quality Assurance and Quality Control

As part of the Quality Assurance and Quality Control protocol (QAQC), 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 QAQC Instrument is temporarily deployed along side 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 QAQC 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 dependant, 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 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

	Date	Schedule	Instrument #	Temperature	pH	Specific Conductivity	Dissolved Oxygen	Turbidity
Upper Reid Brook	Jun 12, 2013	Deployment	62884	Fair	Fair	Good	Excellent	Excellent
	July 15, 2013	Removal	62884	-	-	-	-	-
	July 16, 2013	Deployment	62884	Good	Excellent	Excellent	Excellent	Excellent
	Aug 20, 2013	Removal	62884	-	-	-	-	-
	Aug 20, 2013	Deployment	62884	-	-	-	-	-
	Sep 23, 2013	Removal	62884	Excellent	Good	Excellent	Good	Excellent
	Sep 24, 2013	Deployment	62884	Excellent	Good	Excellent	Good	Excellent
	Nov 5, 2013	Removal	62884	Excellent	Excellent	Good	Excellent	Excellent
Camp Pond Brook	Jun 12, 2013	Deployment	62885	Excellent	Good	Fair	Good	Excellent
	July 15, 2013	Removal	62885	-	-	-	-	-
	July 16, 2013	Deployment	62885	Excellent	Excellent	Excellent	Excellent	Excellent
	Aug 20, 2013	Removal	62885	Excellent	Excellent	Excellent	Excellent	Excellent
	Aug 20, 2013	Deployment	62885	Excellent	Good	Excellent	Excellent	Excellent
	Sep 23, 2013	Removal	62885	Excellent	Excellent	Excellent	Fair	Excellent
	Sep 24, 2013	Deployment	62885	Excellent	Fair	Excellent	Excellent	Excellent
	Nov 5 , 2013	Removal	62885	Excellent	Excellent	Fair	Fair	Excellent
Lower Reid Brook	Jun 12, 2013	Deployment	62887	Good	Good	Good	Good	Excellent
	July 15, 2013	Removal	62887	-	-	-	-	-
	July 16, 2013	Deployment	62887	Fair	Excellent	Excellent	Good	Excellent
	Aug 20, 2013	Removal	62887	Excellent	Excellent	Excellent	Excellent	Excellent
	Aug 20, 2013	Deployment	62887	Excellent	Excellent	Excellent	Excellent	Excellent
	Sep 23, 2013	Removal	62887	Excellent	Good	Excellent	Fair	Good
	Sep 24, 2013	Deployment	62887	Excellent	Fair	Excellent	Fair	Excellent
	Nov 5, 2013	Removal	62887	Excellent	Excellent	Marginal	Fair	Excellent
Tributary to Lower Reid Brook	Jun 13, 2013	Deployment	62886	Excellent	Excellent	Good	Fair	Fair
	July 15, 2013	Removal	62886	-	-	-	-	-
	July 16, 2013	Deployment	62886	Fair	Excellent	Excellent	Good	Excellent
	Aug 20, 2013	Removal	62886	Excellent	Excellent	Excellent	Excellent	Excellent
	Aug 20, 2013	Deployment	62886	Excellent	Excellent	Excellent	Excellent	Excellent
	Sep 23, 2013	Removal	62886	Excellent	Fair	Excellent	Excellent	Good
	Sep 24, 2013	Deployment	62886	Excellent	Marginal	Excellent	Excellent	Good
	Nov 5, 2013	Removal	62886	Excellent	Good	Fair	Good	Excellent

Data Interpretation

The following graphs and discussion illustrate significant water quality-related events from June 12 to November 5, 2014 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 QAQC protocol. Water Survey of Canada is responsible for QAQC of water quantity data. Corrected data can be obtained upon request to Water Survey of Canada.

During this deployment year there were several transmission issues with the data. Reid Brook at Outlet of Reid Pond was offline for almost 2 months of deployment. Due to a transmission issue no data was being sent real-time, therefore the data graphed in this report was collected via the internal log file. Reid Brook also had a pH sensor fail during the second deployment period. The pH data was removed from this time frame as it was inaccurate and therefore there is a large gap in the data. Camp Pond Brook below Camp Pond had transmissions issues during the last deployment period and thus stage and streamflow was unable to be recorded; therefore there is no stage data from October 17th onwards at this station.

Reid Brook at Outlet of Reid Pond

During this deployment season the water temperature ranged within a minimum of 2.21°C to a maximum of 19.25°C. The water temperature minimum and maximum values for 2014 were slightly higher than that of 2013 deployment season. However the median for 2014 at 7.90 °C was slightly lower than 2013 which was 8.26 °C for the deployment season (Figure 1).

Water temperatures start to steadily increase on the onset of June. By the end of July and throughout August the water temperatures were at the highest. As the Fall season started the water temperatures had already started to decrease. This is depicted below in Figure 1.

There are several independent increases and decreases in water temperature unfortunately due to stage and streamflow data not being transmitted from July 22nd through to October 6th, it is difficult to determine whether the acute changes in water temperature were a result of rainfall during those times.

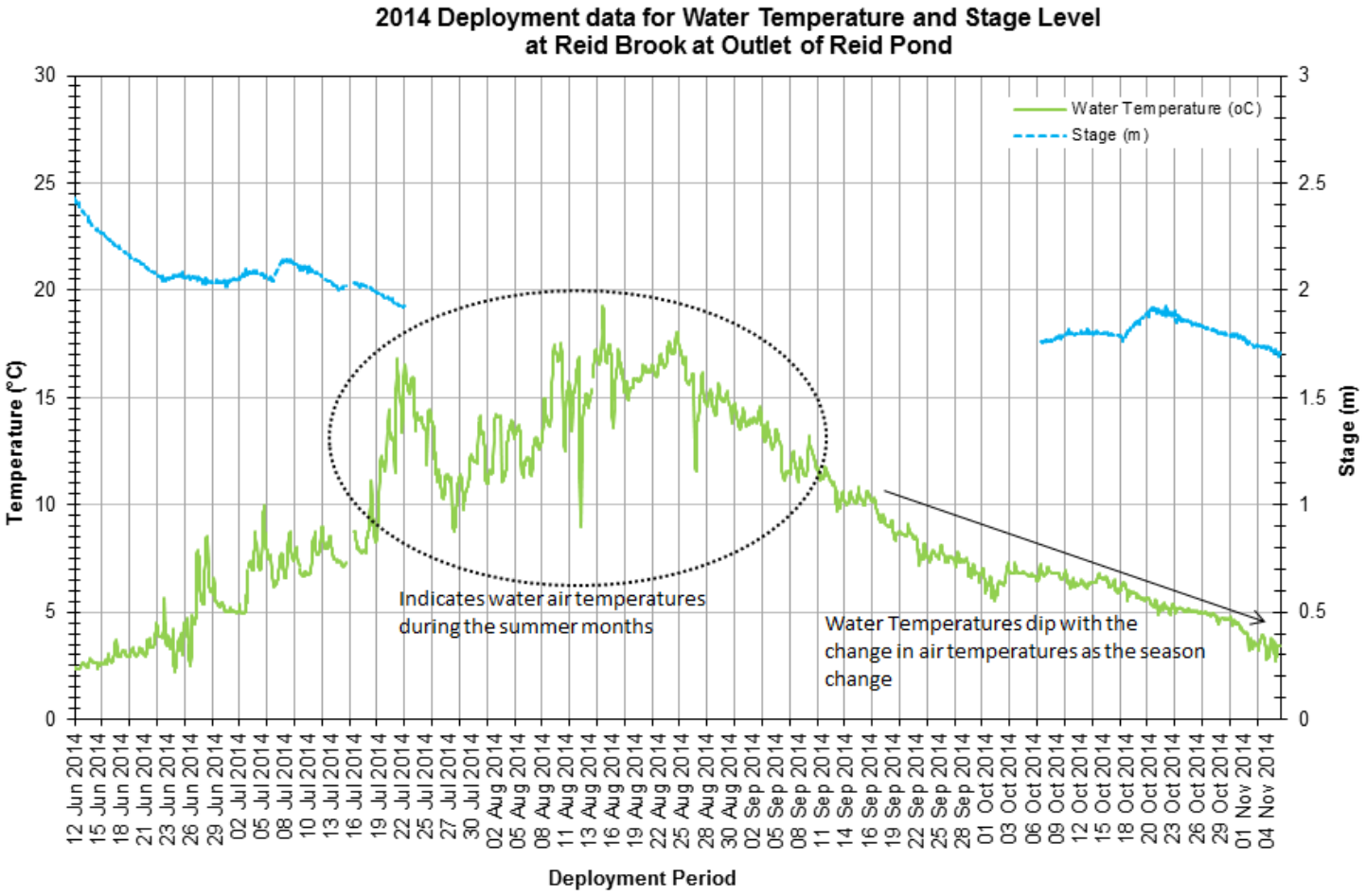

Figure 1: Water temperature at Reid Brook below Reid Pond

Water temperature values show a close relationship with air temperatures (Figure 2). Increases and decreases in air temperatures are reflected in water temperatures. Air temperatures clearly fluctuate at a greater scale each day when compared with water temperatures.

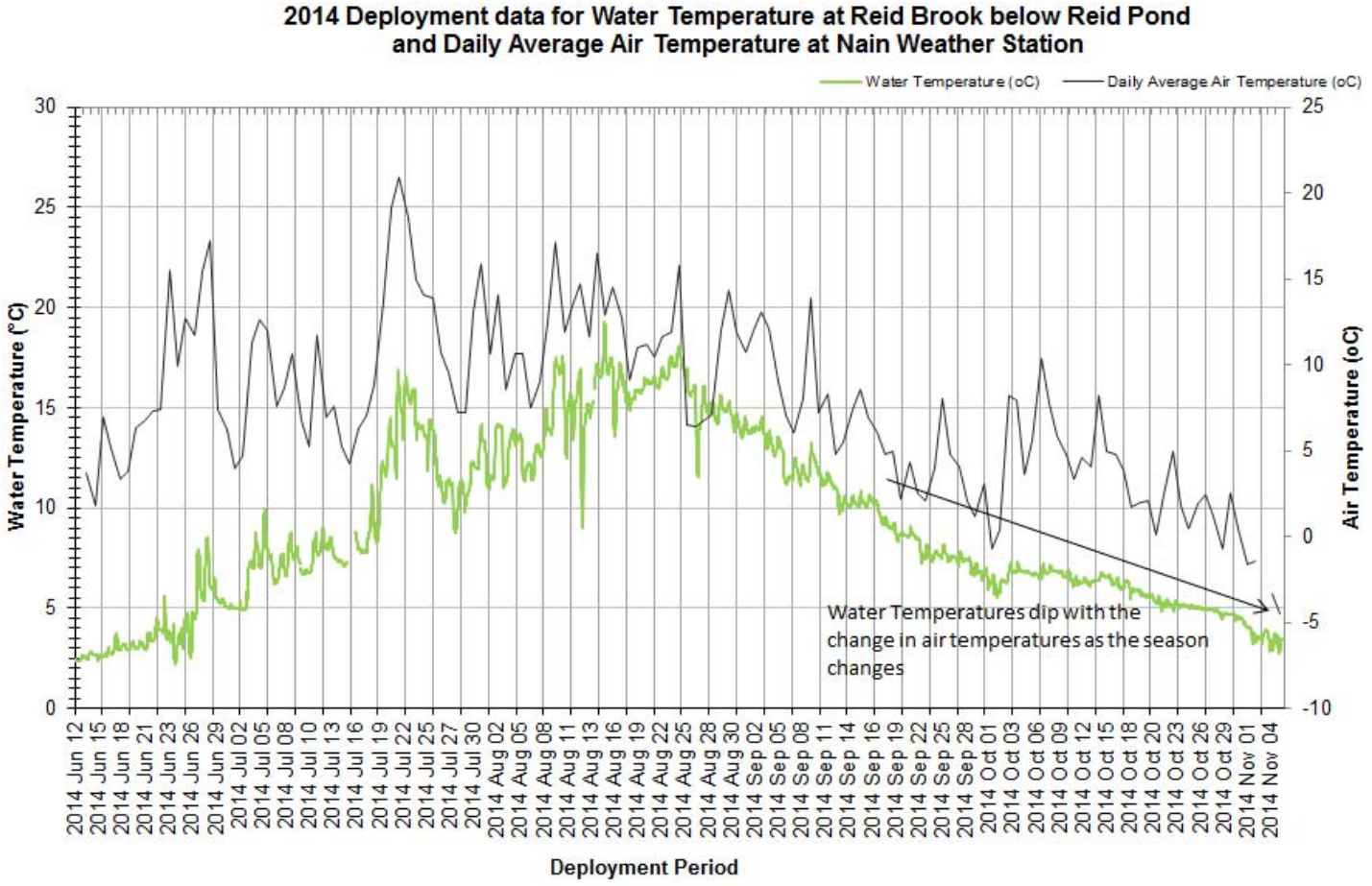

Figure 2: Average daily air temperatures from a weather station in Nain and hourly water temperatures at Reid Brook below Reid Pond

During this deployment season the pH data ranged between a minimum of 5.38 pH units and a maximum of 8.96 pH units. This deployment season had the pH sensor malfunction during a monthly deployment. Therefore the incorrect values were removed from the data set and there is a gap in the pH data from July 22nd, 2014 through to August 20th, 2014.

There is more movement in the pH values during the summer months. On August 22nd the pH data dipped to 5.38 pH units and then the levels climbed up to 7.42 pH units were it stabilized for a while before peaking on August 25th to 8.25 pH units. It is unclear why the pH data fluctuated. A similar occurrence is evident on September 15th – 16th, as the pH values climbed to a high of 8.96 pH units. It is unclear what may have influenced these values.

pH values at this station increased slightly throughout summer, then as the Fall season approached the pH levels started to dip again toward the end of the deployment season.

At the beginning of the season the pH values were just below the minimum guideline. During the third deployment period the pH levels were fluctuating, likely in response to the change in stage levels. As the forth deployment period started the pH levels dropped below the minimum guideline for a day at a time.

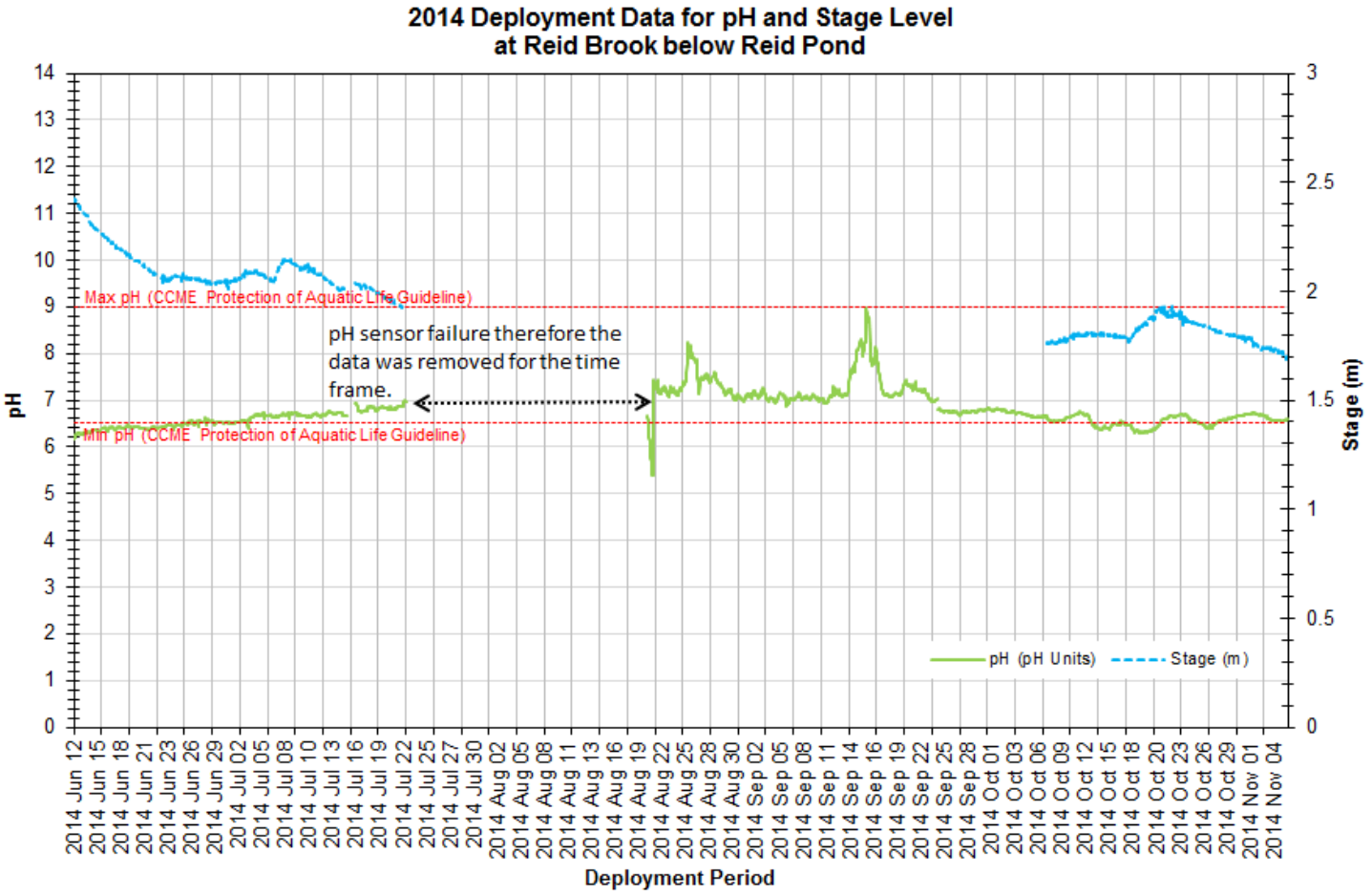

Figure 3: pH and Stage Level at Reid Brook below Reid Pond

This deployment season had specific conductivity values ranging from a minimum of 9.7µS/cm to a maximum of 13.0µS/cm. The overall conductivity median of 11.7µS/cm (Figure 4) indicated that this station naturally has really low conductivity.

Specific conductivity was very low and stable throughout the deployment season with very minimal fluctuation regardless of the changing water level. This trend is to be expected as this station is on a pond and the water flow for this station is directly from Reid Pond, which is a stable lake environment.

The higher conductivity levels in the third and fourth deployment period are likely a result of lower stage level at that time of the year. The difference in the data display on the graph is a result of the internal log file being used for the third and fourth deployment periods. The internal log file does not record as long a number as the datalogger therefore the data is rounded slightly and when graphed doesn't have the same data display as transmitted data.

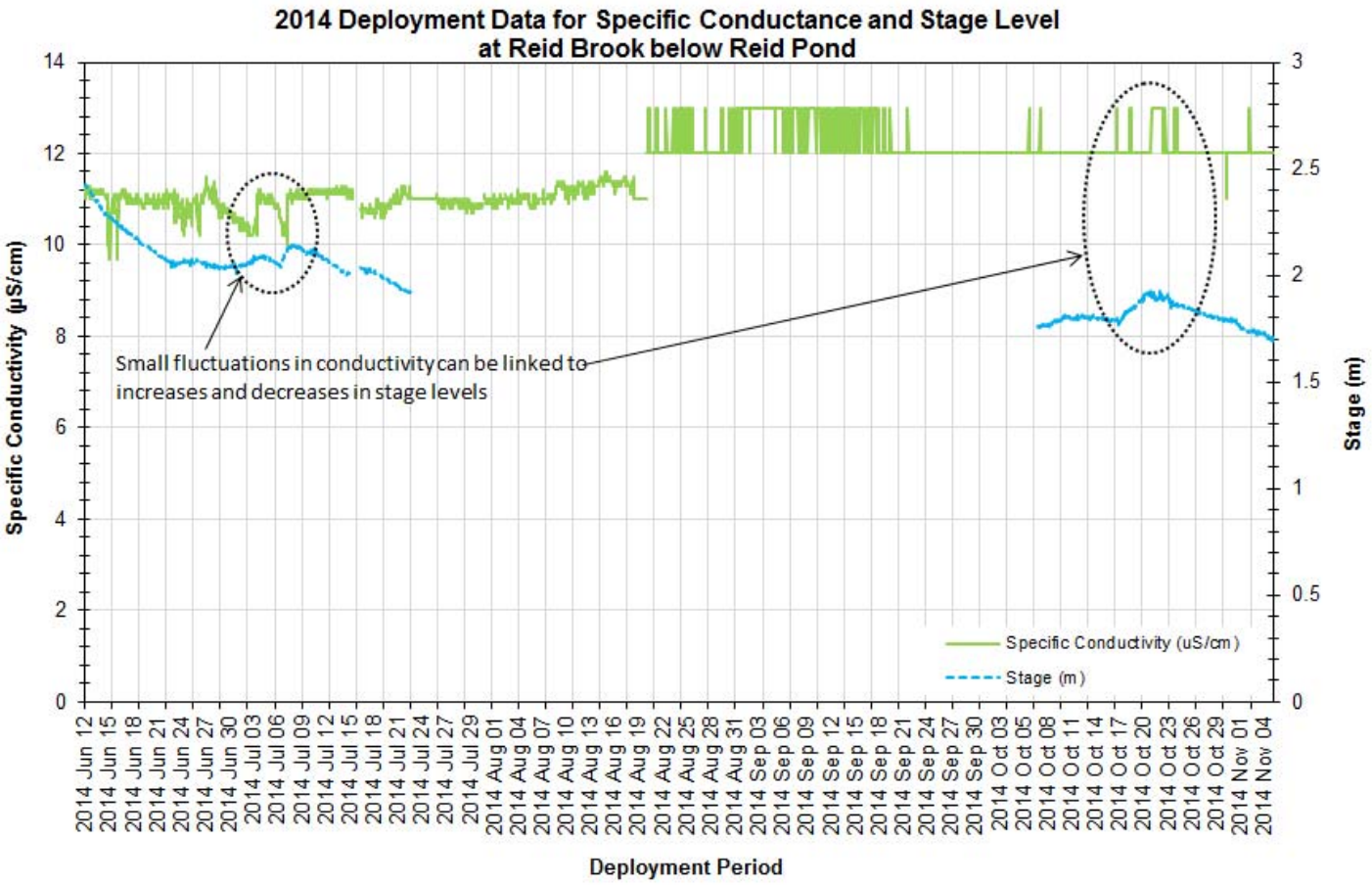

Figure 4: Specific conductivity and stage level at Reid Brook below Reid Pond

During this deployment season the dissolved oxygen content ranged between a minimum of 9.54mg/l and a maximum of 12.82mg/l. The overall dataset had a median value of 11.66mg/l. The saturation of dissolved oxygen ranged from 88.5% to 114.6%, with a median value of 97.2% (Figure 5).

Dissolved oxygen content shows a typical seasonal fluctuation in 2014, and is inversely proportional to the changes in water and air temperature (Figure 2). Dissolved oxygen values were low and consistent through the warmest part of the season and began to increase in mid to late September as water and air temperatures began to cool with the change to Fall season.

All values were above both the minimum CCME Guideline for the Protection of Cold Water Biota at Other Life Stages (6.5mg/l) and Early Life Stages (9.5mg/l) during the deployment season. The guidelines are indicated in red on Figure 5.

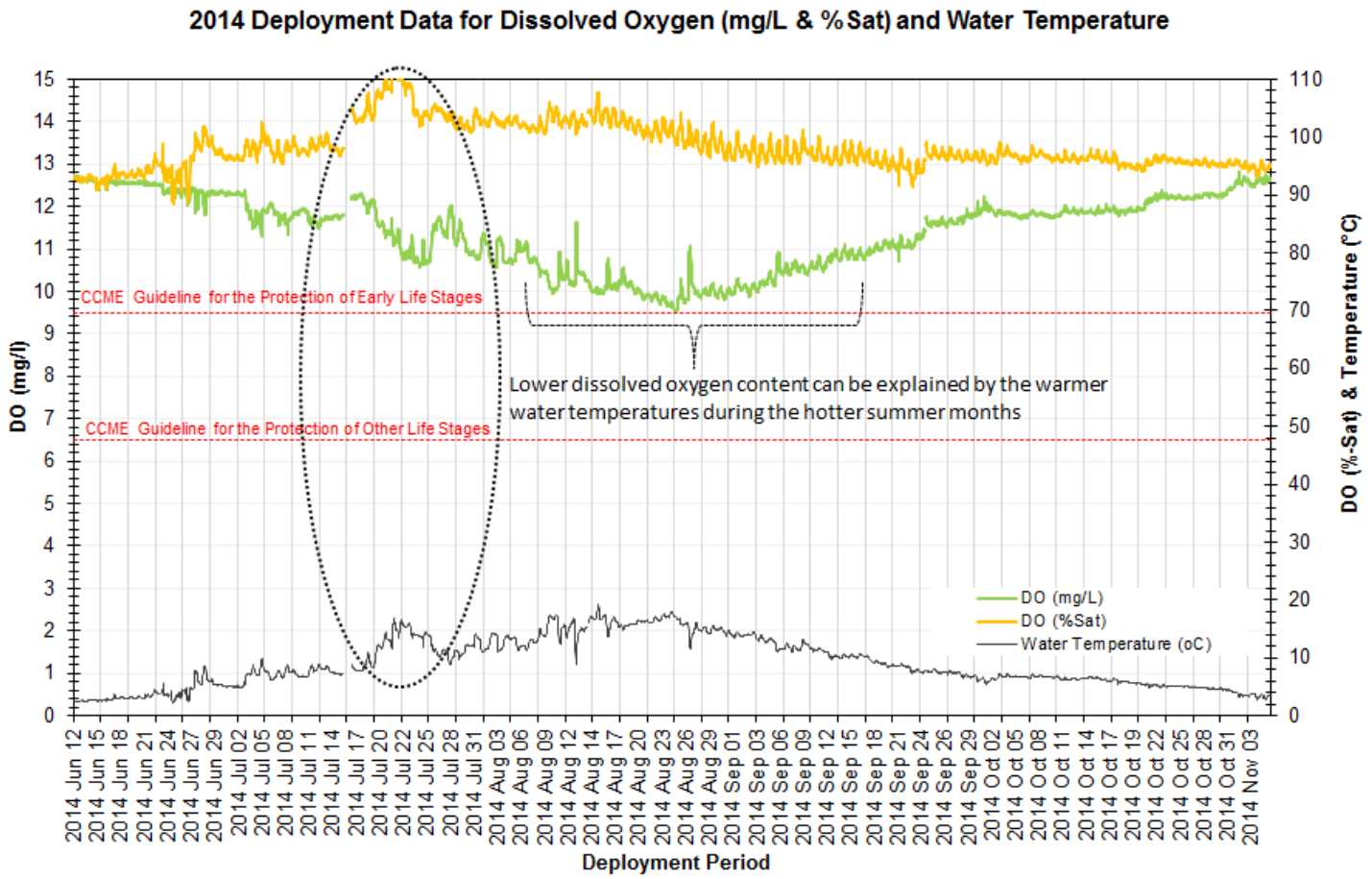

Figure 5: Dissolved oxygen and percent saturation at Reid Brook below Reid Pond

Turbidity values during this deployment period ranged between a minimum of 0.0NTU and a maximum of 49.3NTU. The median for the turbidity data remained a 0.0NTU, this indicates that there is no natural background turbidity at this station.

Outside of the one high reading of 49.3NTU in the first deployment period the rest of the turbidity peaks are below 14NTU and most are just hourly peaks (Figure 6). This station remains stable during this deployment season with no large changes in the turbidity dataset.

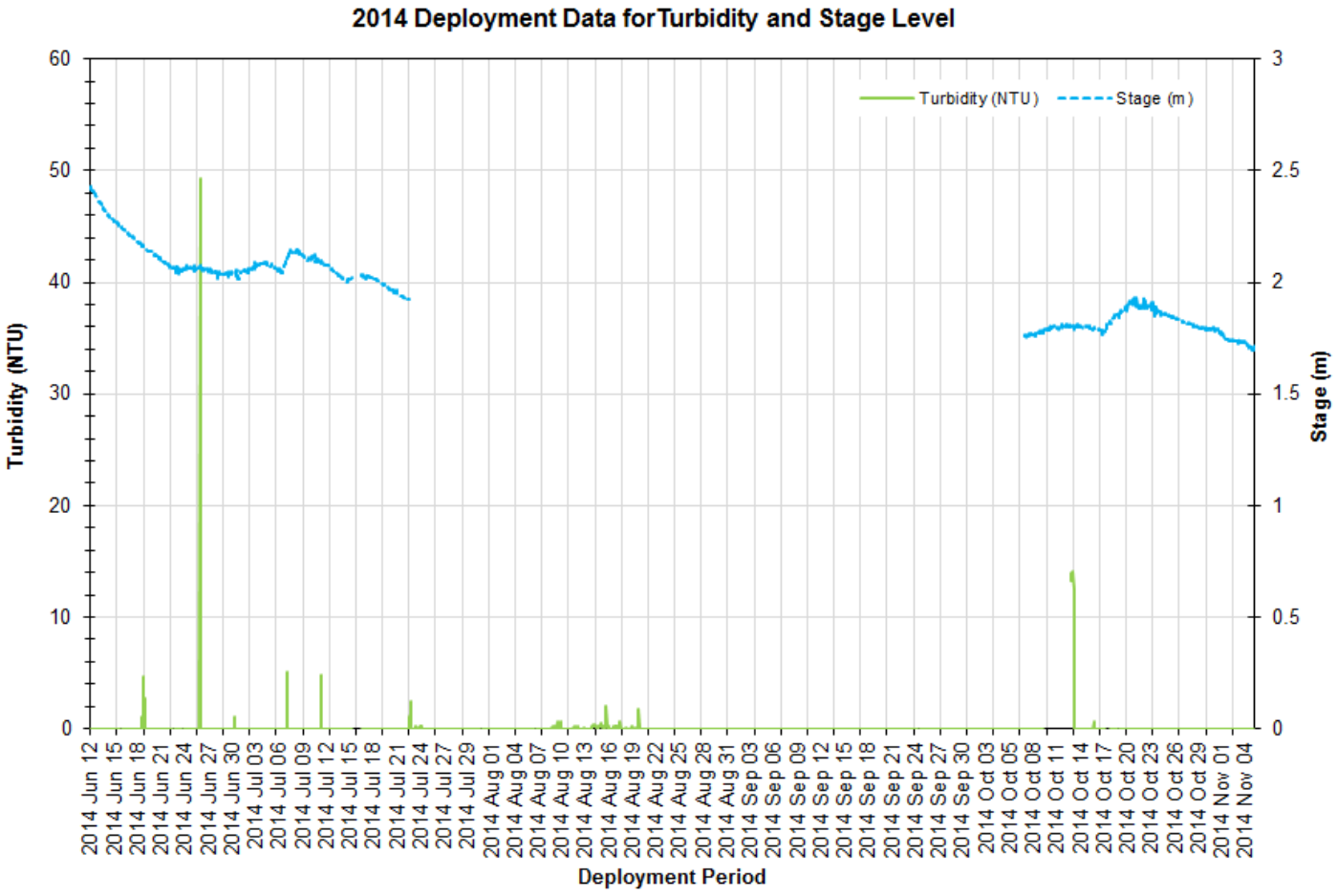

Figure 6: Turbidity and Stage data at Reid Brook below Reid Pond

During this deployment season there was an ongoing issue with data transmission for the stage and streamflow data. Unfortunately the water quality instrument was unable to log water quantity data internally. Therefore there is a large gap in the data set from July 22nd through to October 6th, 2014.

To provide an overview of the external factors that can influence water quality and quantity parameters precipitation was included in the graph below (Figure 7).

The stage and streamflow data that was collected indicated that both parameters are decreasing for most of the deployment season with minimal spikes. At the beginning of deployment the spring thaw has increased the flow of water into the brooks and as the deployment period continues that large flush of spring runoff is decreasing with warmer temperatures. The increases that were recorded for stage and streamflow link with precipitation events at the same time frame.

This deployment season had frequent rainfall. The rainfall events occurred about ~50% of the deployment period. Precipitation over the deployment had a minimum of 0.0mm to a maximum of 33.7mm on September 22, 2014.

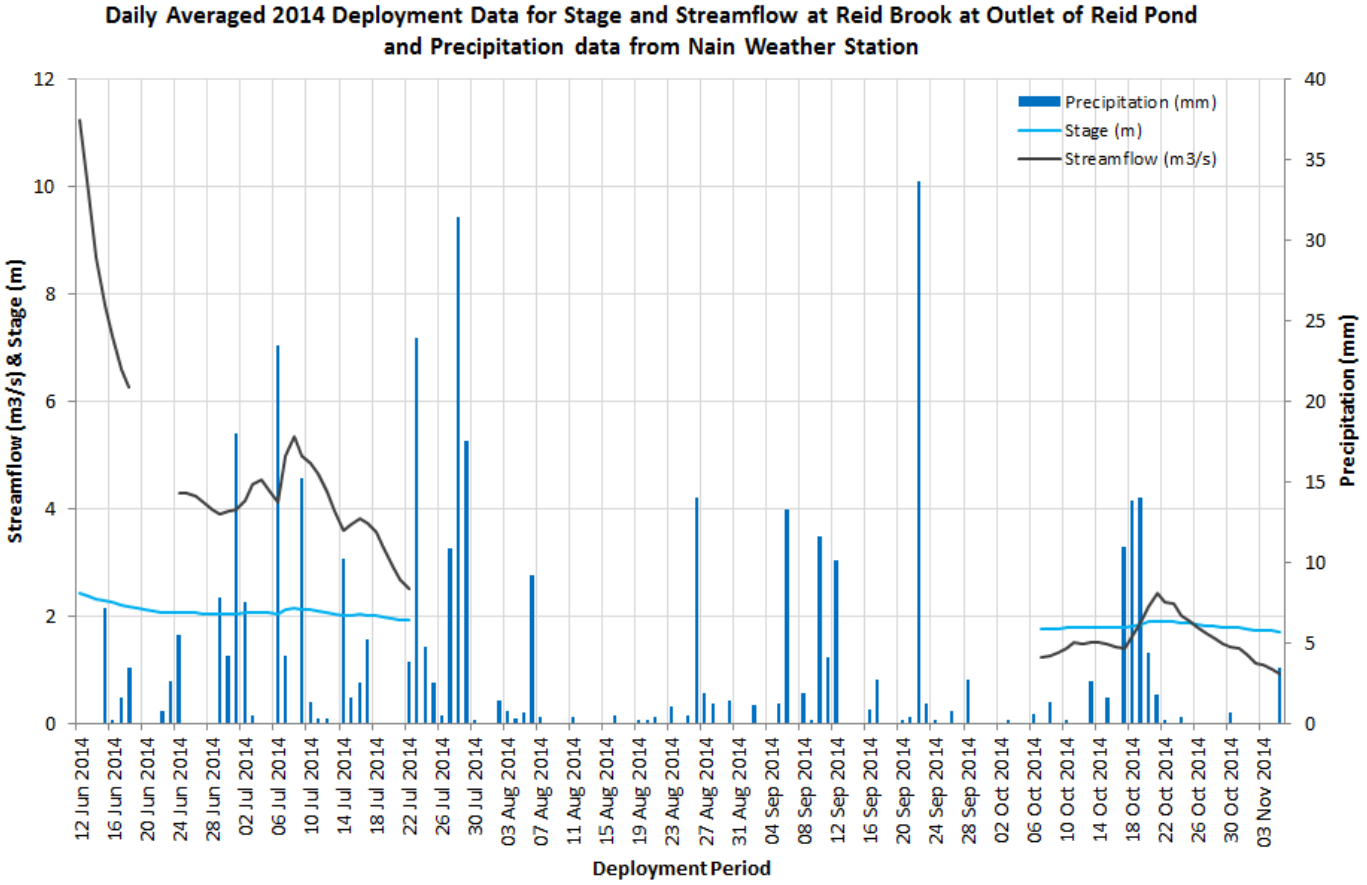

Figure 7: Daily Precipitation and Average daily Stage and Streamflow at Reid Brook at Outlet of Reid Pond (Weather data recorded at Nain)

Camp Pond Brook below Camp Pond

During this deployment season the water temperature values at Camp Pond Brook ranged from a minimum of 0.39°C to a maximum of 22.9°C (Figure 8). With the highest temperatures occurring in the warmer summer period.

Overall the water temperature increased at the beginning of the first deployment period and peaked during the second and third deployment. At the end of August the water temperatures steadily decline as the air temperatures change with the winter season approaching.

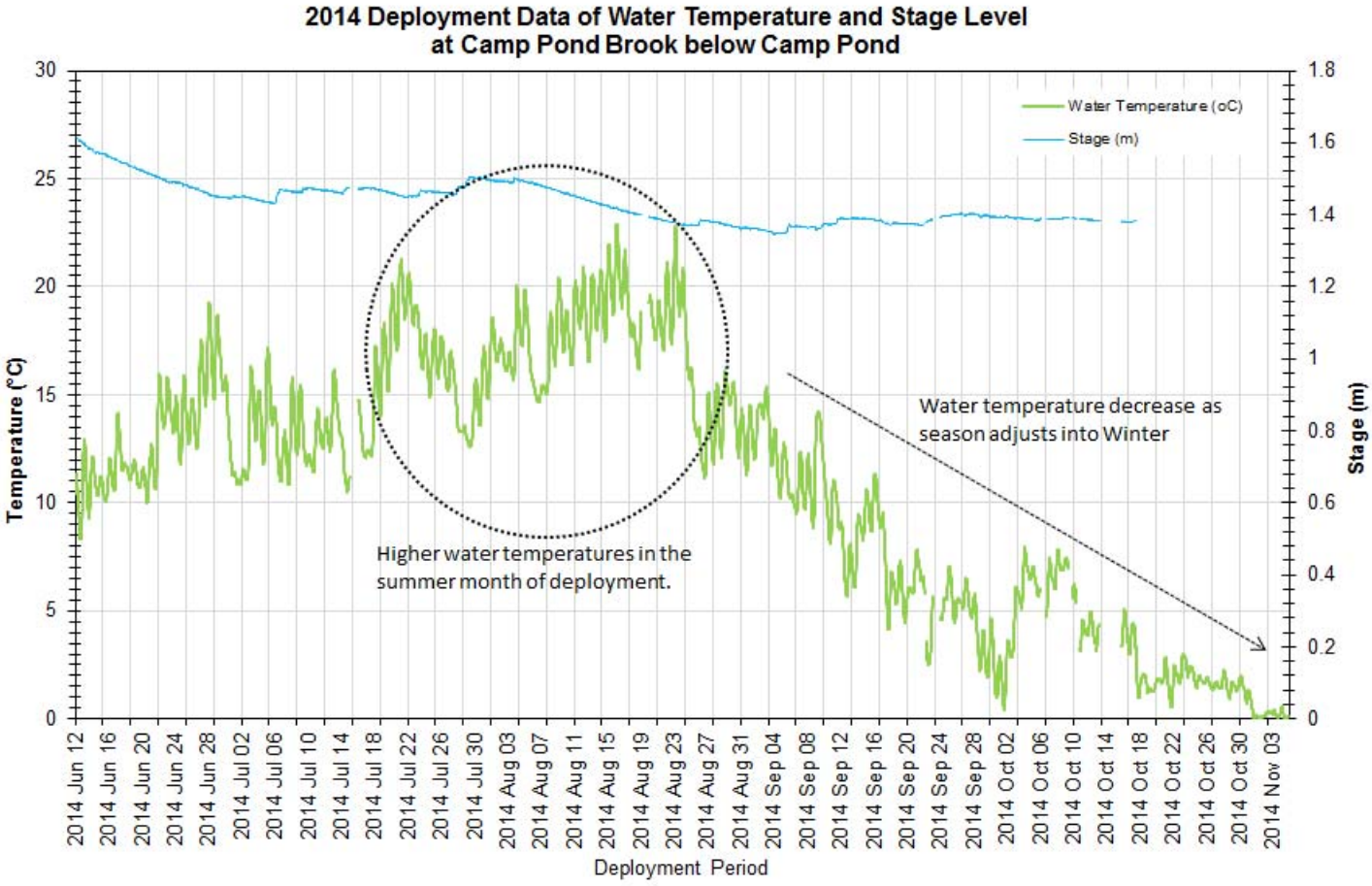

Figure 8: Water temperature and Stage Level at Camp Pond Brook below Camp Pond

Water temperature values show a close relationship with air temperatures (Figure 9). Increases and decreases in air temperatures are reflected in water temperatures. Air temperatures clearly fluctuate at a greater scale each day when compared with water temperatures.

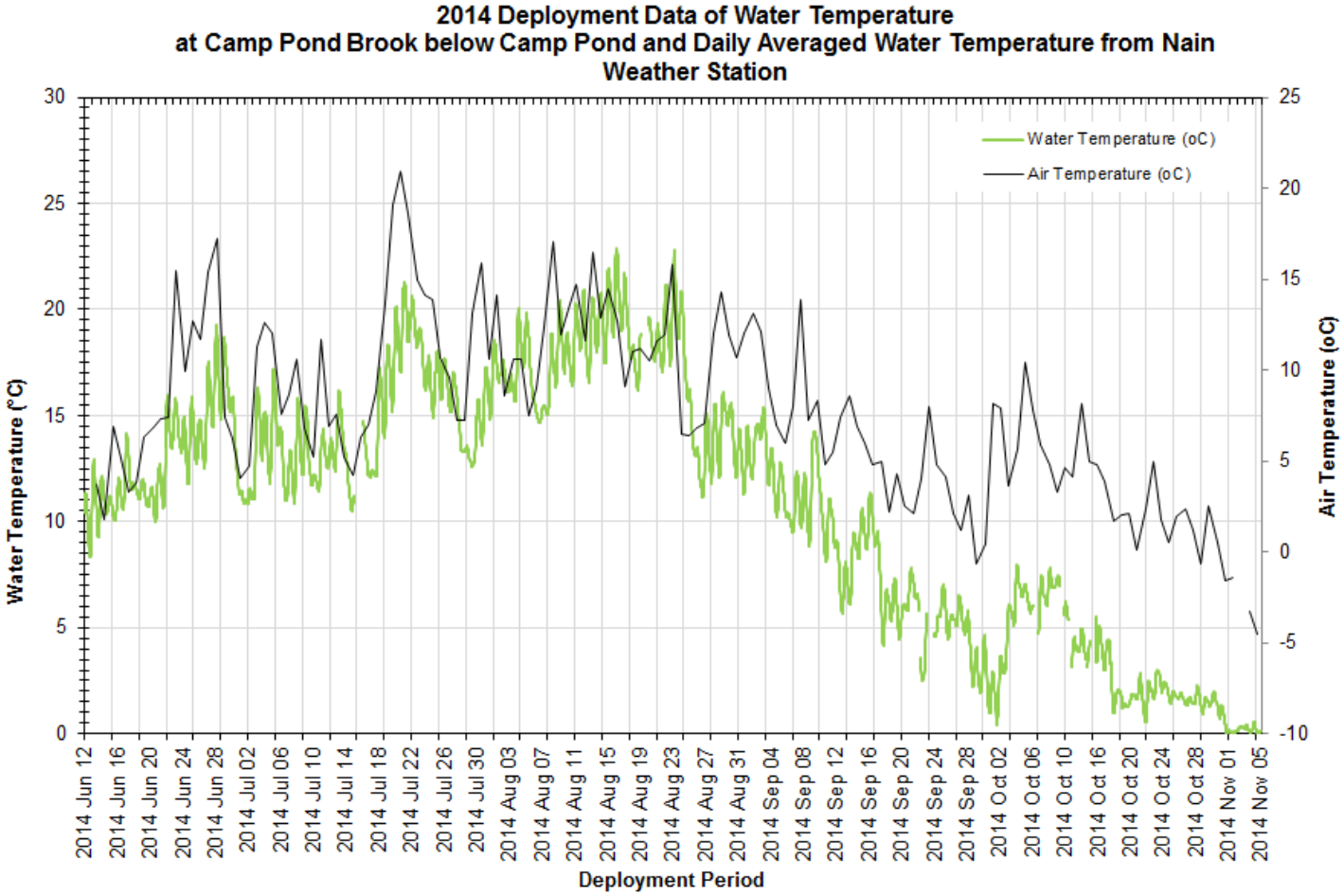

Figure 9: Average daily air and water temperatures at Camp Pond Brook below Camp Pond (Weather data recorded at Nain)

During this deployment season the pH data ranged between a minimum of 6.40 and a maximum of 7.08 pH units throughout the deployment season (Figure 10). The data for 2014 had a slightly lower median value of 6.85 pH units when compared with the median value of 6.95 pH units in 2013.

Stage is included on Figure 10 to show the relationship between water level and pH. The pH data is reasonably stable, except for a small dip on September 22nd and 23rd where the values drop below the minimum guideline for a short span of time. Majority of the events in this deployment season can be linked to precipitation during the same time frames.

Most of the pH data is within the recommended range that's suggested by the CCME Guidelines for the Protection of Aquatic Life (>6.5 and <9.0 pH units). Guidelines are indicated in red on Figure 10.

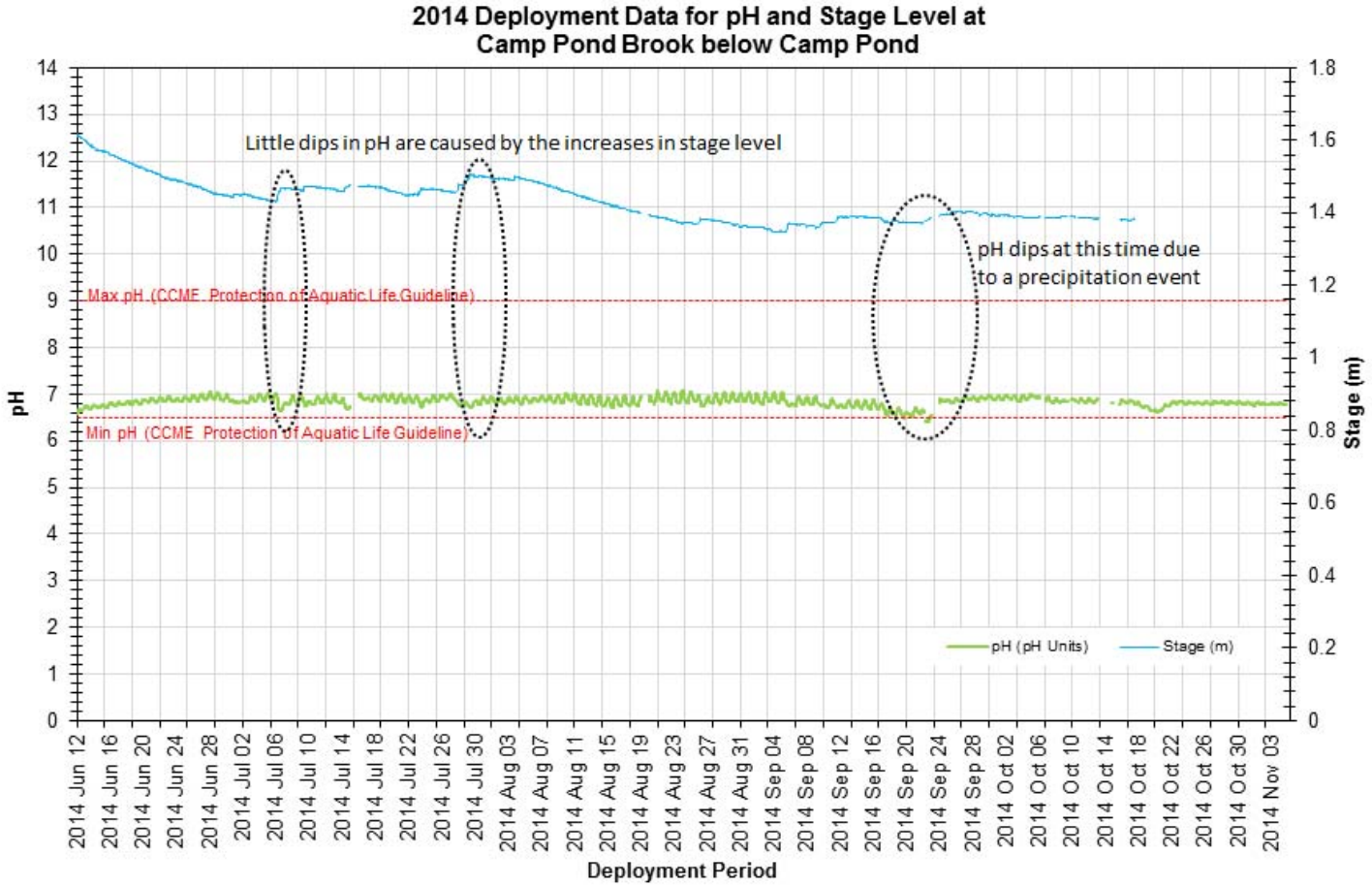

Figure 10: pH and Stage Level at Camp Pond Brook below Camp Pond

This deployment season had specific conductivity data within a minimum of 27.8µS/cm and a maximum of 56.7µS/cm (Figure 11). This deployment season had a slightly lower conductivity median of 35.8µS/cm when compared with the 2013 conductivity median of 36.3µS/cm.

Stage is included in Figure 11 to illustrate the comparable relationship between conductivity and water level. At this station when stage levels are high the conductivity level also increases. This is generally not the case at other stations, however due to the proximity of this brook to roadways and the mine site this brook is heavily influenced by runoff factors that the other Voisey's Bay real-time stations do not exhibit.

Over the entire deployment season the conductivity level in the brook increased slightly, while the stage level decreased. This relationship is to be expected as the incidents of rainfall and bank runoff start to decrease as the winter season approaches.

Near the end of the last deployment period on November 1st and November 5th, the specific conductivity spiked for a period of time and then the values dipped on two separate occasions; it is unknown what caused these events to occur.

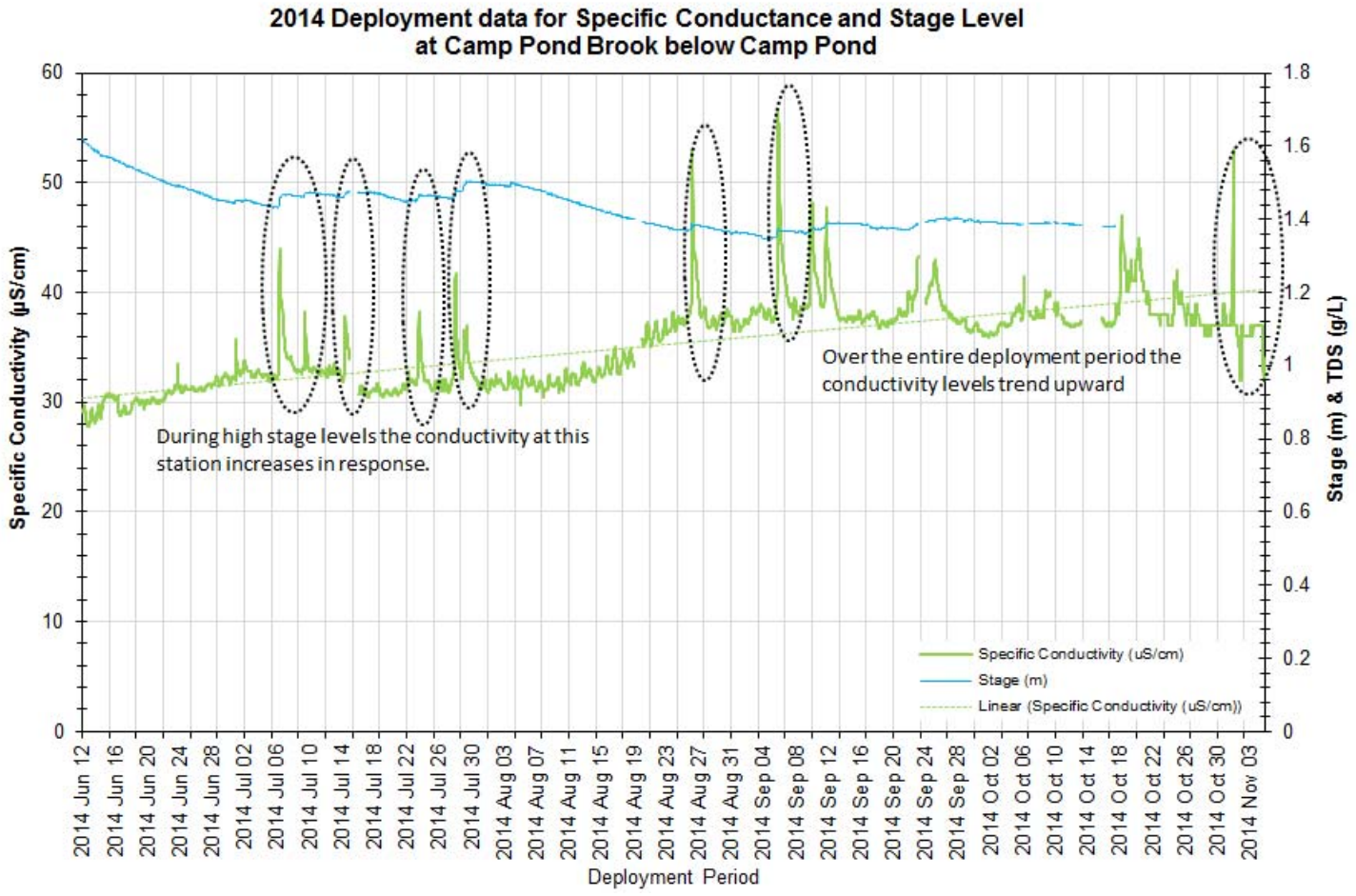

Figure 11: Specific conductivity and Stage Level at Camp Pond Brook below Camp Pond

This deployment season at Camp Pond Brook had dissolved oxygen ranges between a minimum of 8.08mg/l and a maximum of 13.67mg/l, with a slightly lower median value of 9.87mg/L than the 2013 median of 10.40mg/l. The saturation of dissolved oxygen ranged from a minimum of 86.7% to 102.8%, with a median value of 94.2% (Figure 12).

Dissolved oxygen content showed a typical seasonal trend, inverse to water temperature. Dissolved oxygen content is decreasing throughout June and July reaching a seasonal low toward the end of August when water temperatures are the warmest. As water temperatures decrease in the late summer and early fall, dissolved oxygen content begins to increase. There are fluctuations that are concurrent with the changes in water temperature.

All values were above the minimum CCME Guideline for the Protection of Cold Water Biota at Other Life Stages (6.5mg/l). There were some dips below the CCME Guideline for the Protection of Aquatic Life at Early Life Stages (9.5mg/l) however the dips correspond with water temperature lows during those same time frames. The guidelines are indicated in red on Figure 12.

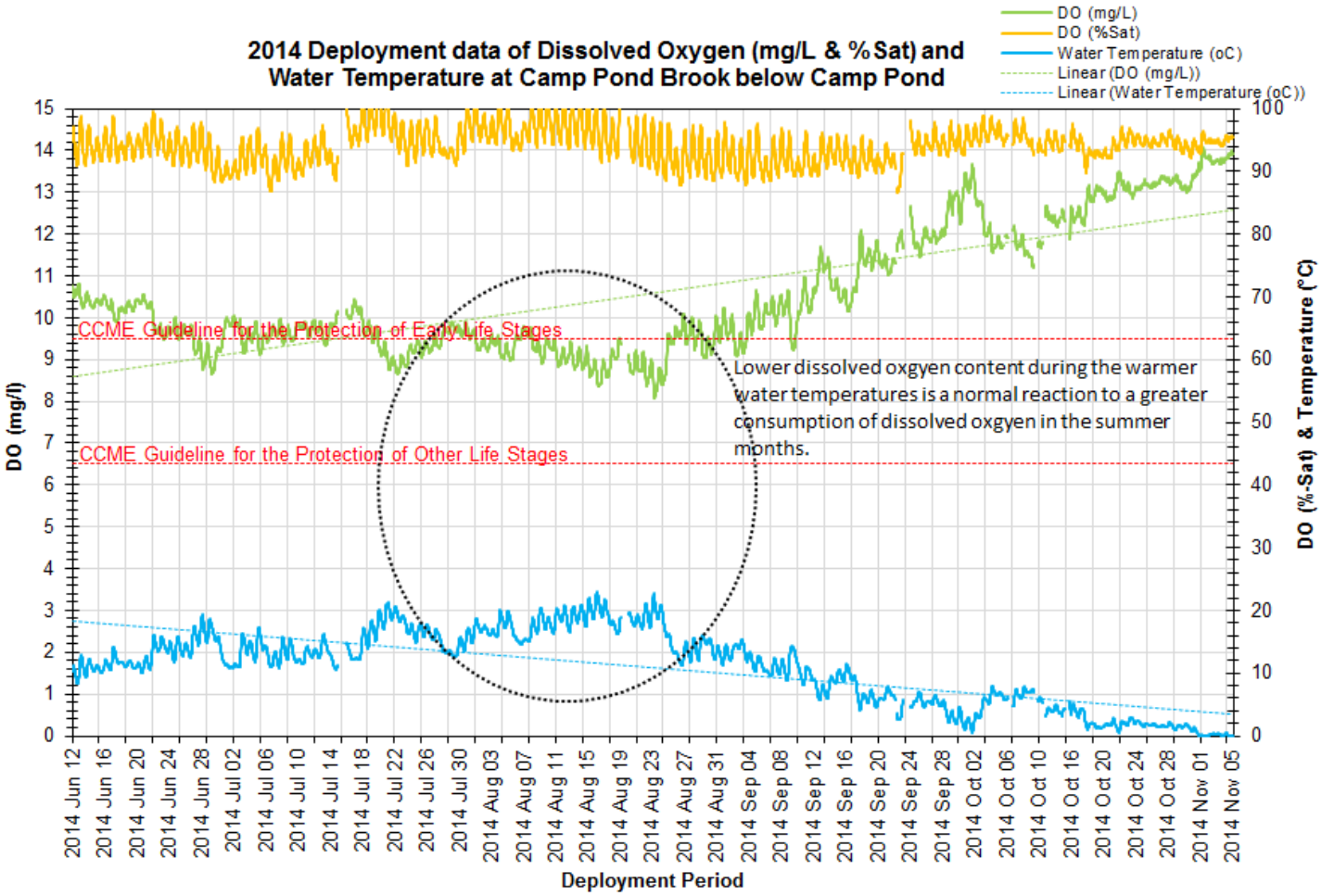

Figure 12: Dissolved Oxygen and Water Temperature at Camp Pond Brook below Camp Pond

Camp Pond Brook below Camp Pond had turbidity values that ranged between a minimum of 0.0NTU and a maximum of 117.0NTU during the 2014 deployment season (Figure 13). A median value of 0.3NTU indicates there is very little or no natural background turbidity occurring at this station.

While there are a number of turbidity spikes throughout the four deployment periods from June to November 2014, the majority of these increases correspond with rainfall events. Turbidity events are similar throughout the deployment season. Most events are low in magnitude and short in duration.

The largest turbidity event that occurred on October 20th of 117.0NTU was directly after two days of recorded precipitation which likely increased the suspended matter in the brook.

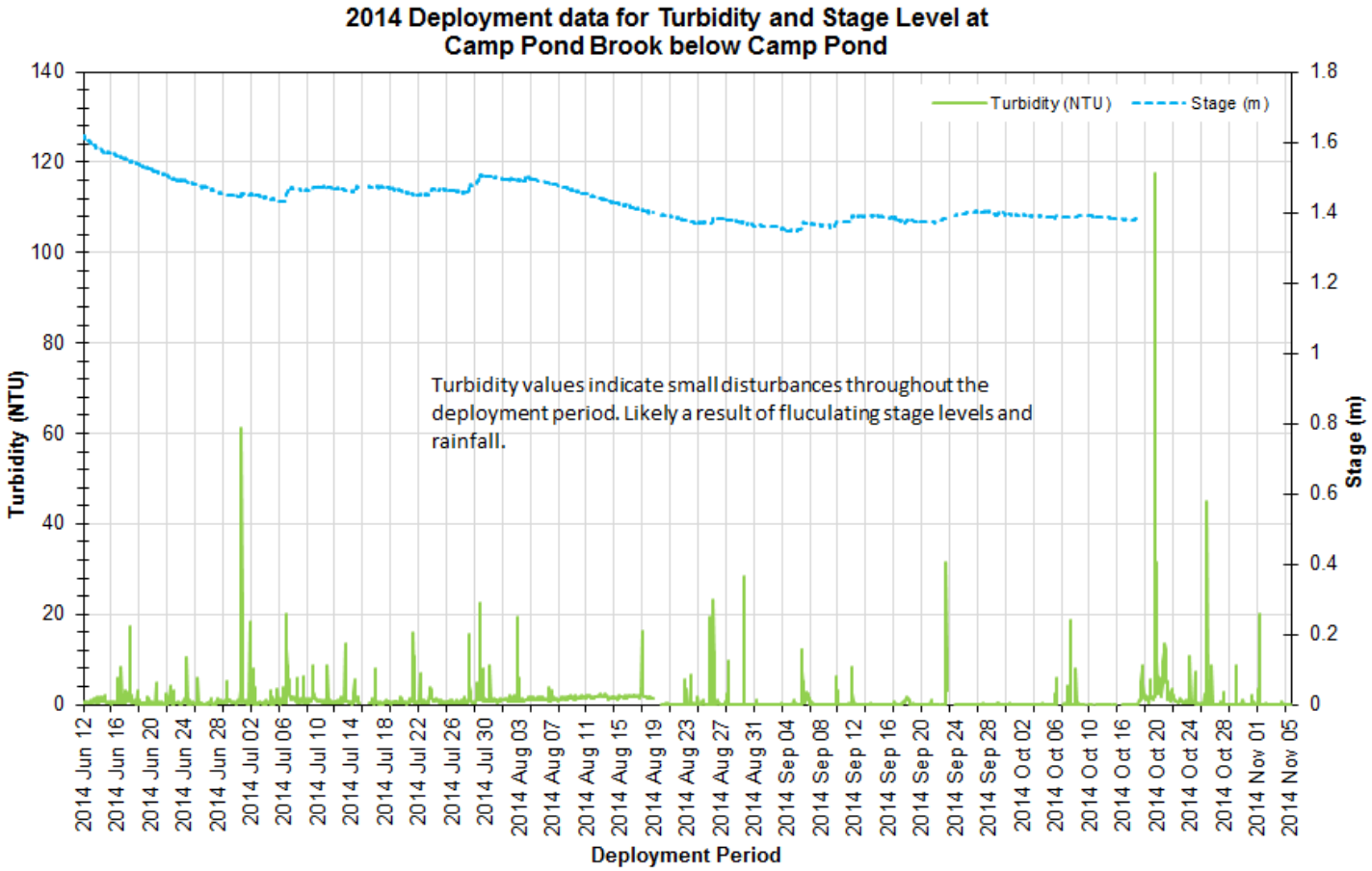

Figure 13: Turbidity and Stage Level at Camp Pond Brook below Camp Pond

Camp Pond Brook below Camp Pond had transmission issues at different times throughout this deployment season. Therefore there is missing data throughout the deployment. However for this deployment season stage levels ranged within a daily average minimum of 1.35m to a daily average maximum of 1.62 m at Camp Pond. The streamflow data ranged between a daily average minimum of 0.19 m^3/s and a daily average maximum of 1.80m^3/s at Camp Pond (Figure 14).

Precipitation was graphed with stage and streamflow to indicate how external factors such as rainfall, can influence the change in water bodies. The precipitation data was received from the weather station in Nain. The precipitation data had an average low of 0.0mm and an average high of 33.7mm on September 22nd, 2014.

Stage levels are decreasing steadily throughout most of the deployment season. Water levels stabilize around the beginning of September and there are a couple of increases captured at the end of the final deployment period. Stage ranges between 1.31m and 1.64m, a difference of 0.33m.

Precipitation events are frequent, occurring on 76 days of the 147 day deployment period. Although mostly moderate in scale the precipitation still influences changes in the brook.

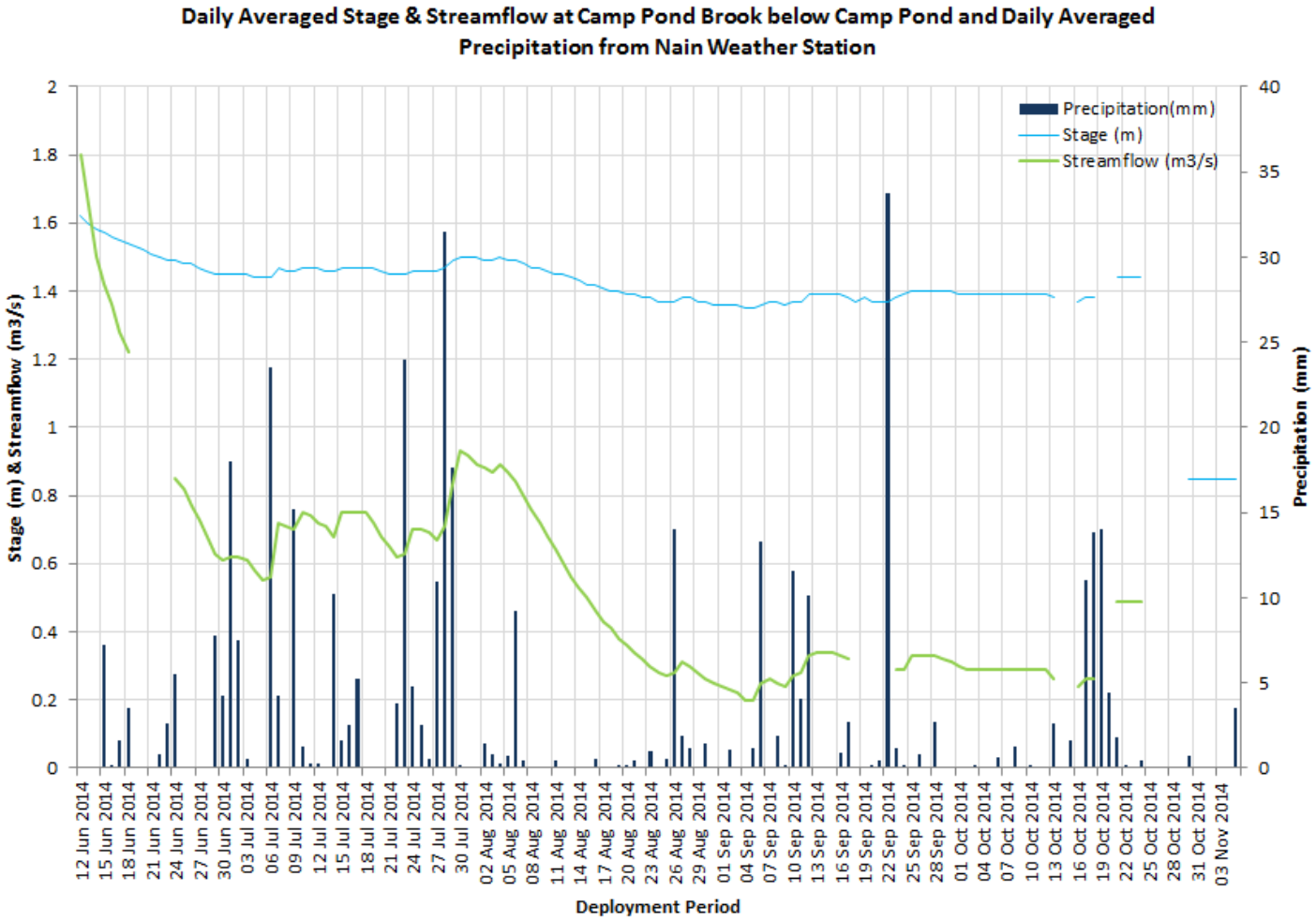

Figure 14: Daily precipitation and daily Stage and Streamflow at Camp Pond Brook below Camp Pond

Tributary to Lower Reid Brook

During this deployment season the water temperatures ranged between a minimum of 0.10°C to a maximum of 18.30°C at Tributary to Lower Reid Brook (Figure 15). The water temperatures were highest from early July to the end of August as the air temperatures increased with summer. From the end of August onwards the water temperatures made a steady decline as the ambient air temperatures adjusted to the fall and winter seasons approaching.

This station had an overall water temperature median value of 9.30°C which was slightly higher than 2013 water temperature median of 7.90°C (Figure 15).

During the higher stage levels the water temperature decreases in response, this is evident throughout the whole deployment period; however some examples are July 2nd, July 22nd and August 7th.

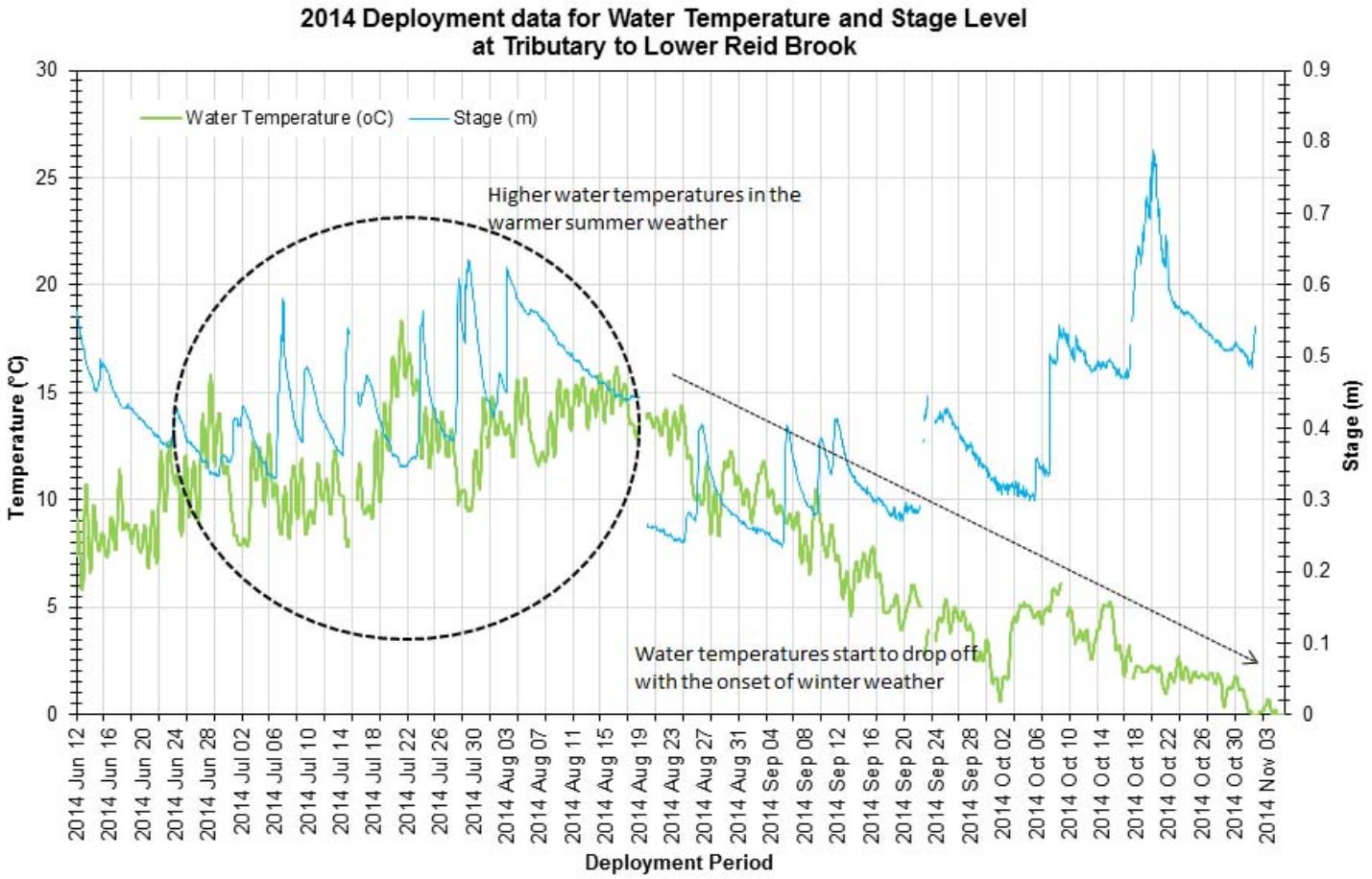

Figure 15: Water temperature and Stage Level at Tributary to Lower Reid Brook

Water temperature values show a close relationship with air temperatures (Figure 16). Increases and decreases in air temperatures are reflected in water temperatures. Air temperatures clearly fluctuate at a greater scale each day when compared with water temperatures.

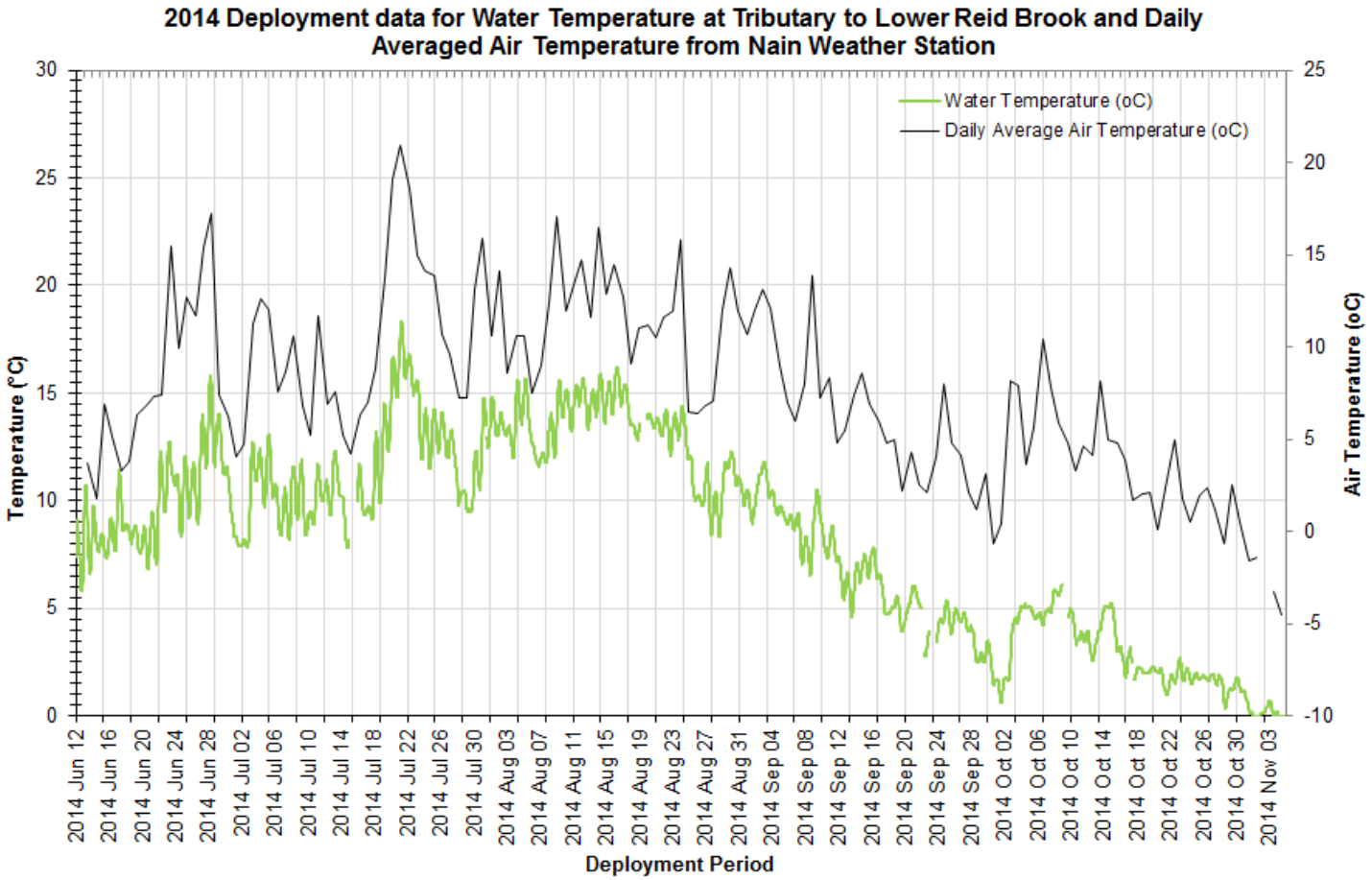

Figure 16: Average daily Air Temperatures from Weather Station in Nain and average daily Water Temperatures at Tributary to Lower Reid Brook

The pH data at Tributary to Lower Reid Brook ranged between a minimum of 6.06 pH units and a maximum of 7.10 pH units throughout the deployment season. This data had a median of 6.69 pH units (Figure 17).

Stage is included on Figure 17 to show the relationship between water level and pH. pH values fluctuated throughout the deployment season corresponding with the changing water levels. On a number of occasions, pH decreases as stage increased. This trend is experienced throughout the different deployment periods.

pH values during this deployment season are mostly found along the minimum CCME Guideline for the Protection of Aquatic Life. The guidelines are indicated in red on Figure 17. On several occasions, the pH values drop under the suggested guideline however most of these events are during periods of high stage levels.

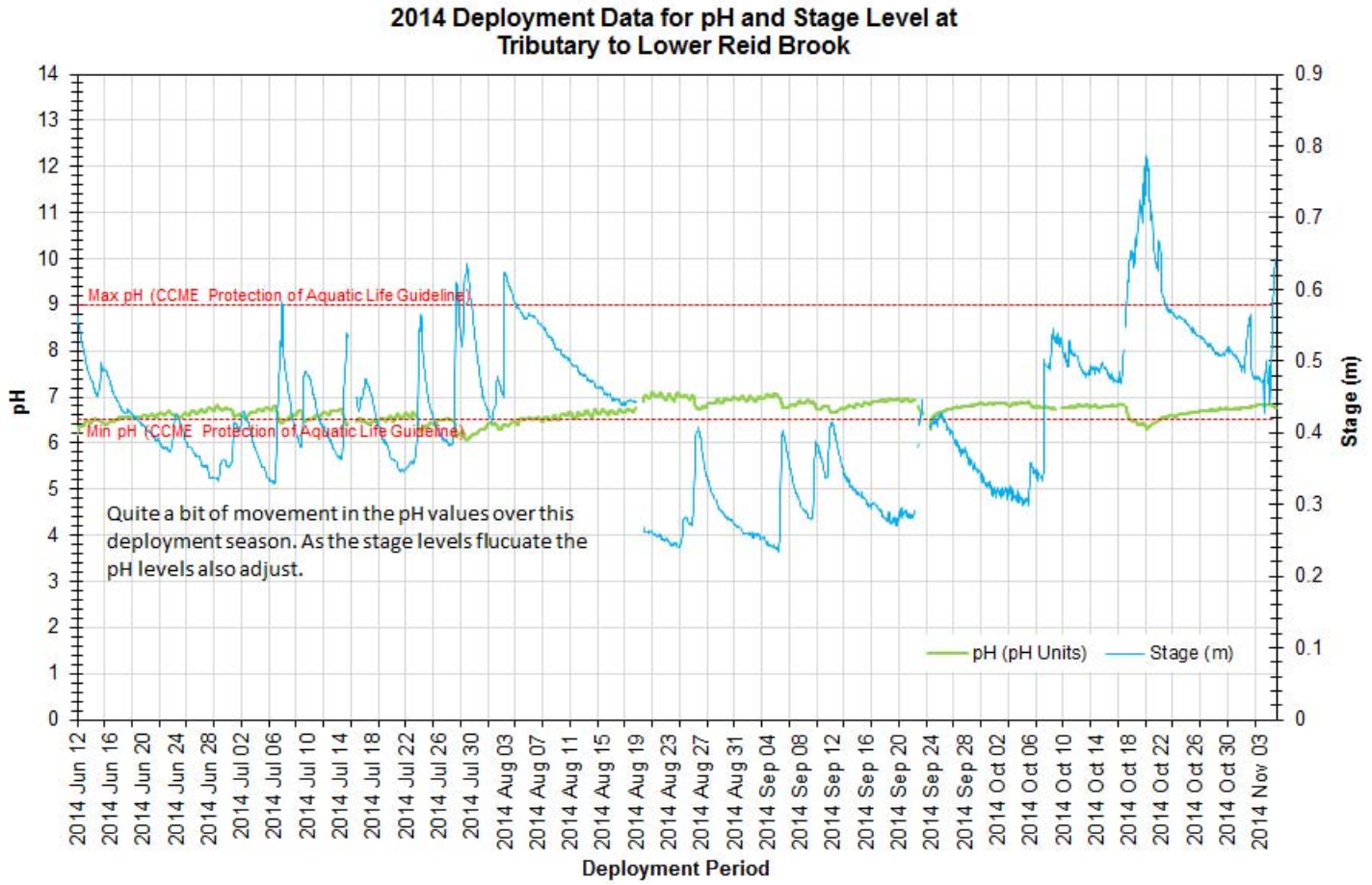

Figure 17: pH and stage level at Tributary to Lower Reid Brook

The specific conductivity levels at Tributary to Lower Reid Brook ranged between a minimum of 18.4µS/cm to a maximum amount of 42.6µS/cm during the deployment season. This deployment period data had a median value of 32.2µS/cm (Figure 18).

Stage is included in Figure 18 to illustrate the inverse relationship between conductivity and water level. Generally, the stage was decreasing during the deployment season with periodic short increases. Specific conductivity changes with the varying water level. As stage increases, specific conductivity generally decreases due to the dilution of dissolved solids in the water column. Inversely, as stage decreases, specific conductivity increases as the concentration of dissolved solids increases.

Specific conductivity is increasing throughout the entire deployment season with periodic short decreases. The increase is illustrated by the trend line. The general trend corresponds with the decreasing stage level. The relationship between stage levels and specific conductivity levels is typically very evident at this station.

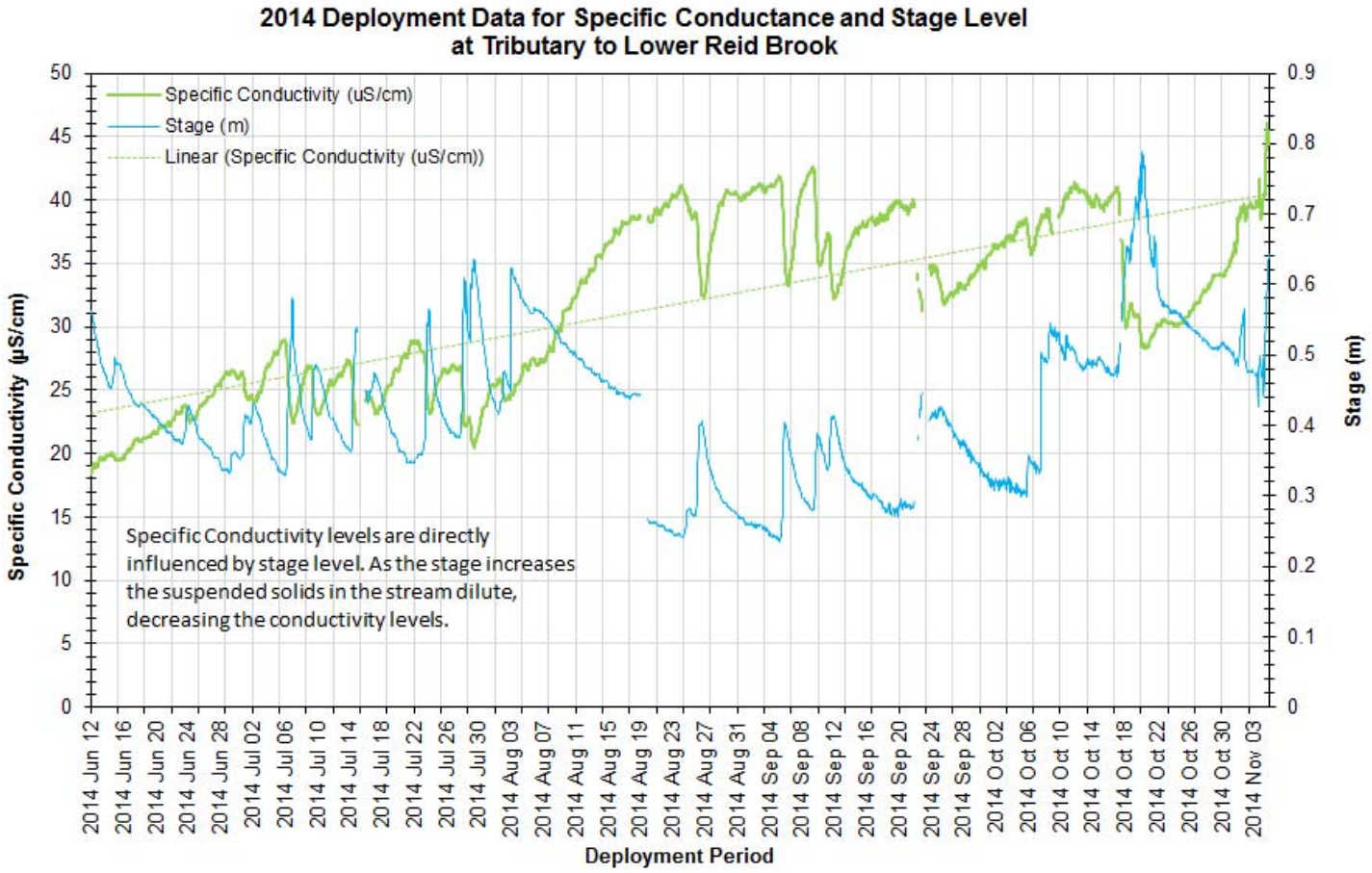

Figure 18: Specific conductivity and stage level at Tributary to Lower Reid Brook

This deployment season had dissolved oxygen content that ranged between a minimum of 8.99mg/l and a maximum of 14.12mg/l, with a median value of 10.88mg/l. The saturation of dissolved oxygen ranged from 91.5% to 100.9%, with a median value of 95.8% (Figure 19).

Dissolved oxygen content showed a typical seasonal trend, inverse to water temperature. Values are lower in the early summer months of June and July while water temperatures are increasing. Dissolved oxygen reaches a seasonal low on July 22nd, 2014.

As water temperatures decrease in the late summer and early fall, dissolved oxygen content begins to increase.

The majority of dissolved oxygen values were above the CCME Guideline for the Early Life Stages (9.5mg/l). There are several days during the deployment period that the dissolved oxygen content dips below the Guideline for the Early Life Stages (9.5mg/L). These events occurred during periods of warm air and warm water temperatures. The guidelines are indicated in red on Figure 19.

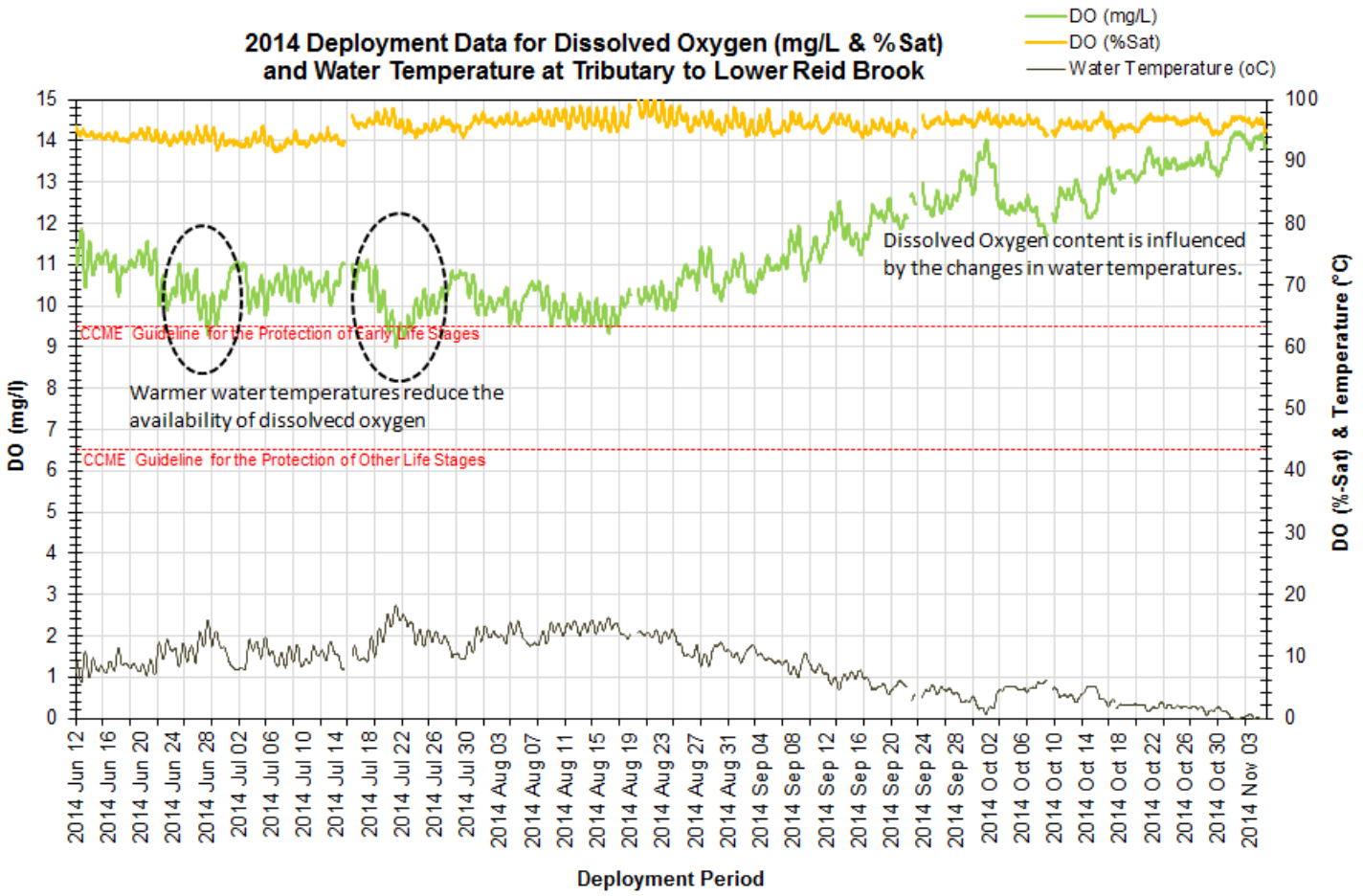

Figure 19: Dissolved oxygen (mg/l & %Sat) and Water Temperature at Tributary to Lower Reid Brook

Tributary to Lower Reid Brook station had turbidity data that ranged within a minimum of 0.0NTU to a maximum of 125.3NTU during the 2014 deployment season (Figure 20). This data had a median value of 0.0NTU, the low turbidity median indicated that there is little to no natural background turbidity at this station.

There were a number of turbidity events throughout the four deployment periods from June to November. Many of the increases corresponded with rainfall events as indicated in the monthly deployment reports. Turbidity events were similar throughout the deployment season. The events that were captured were generally low in magnitude and short in duration.

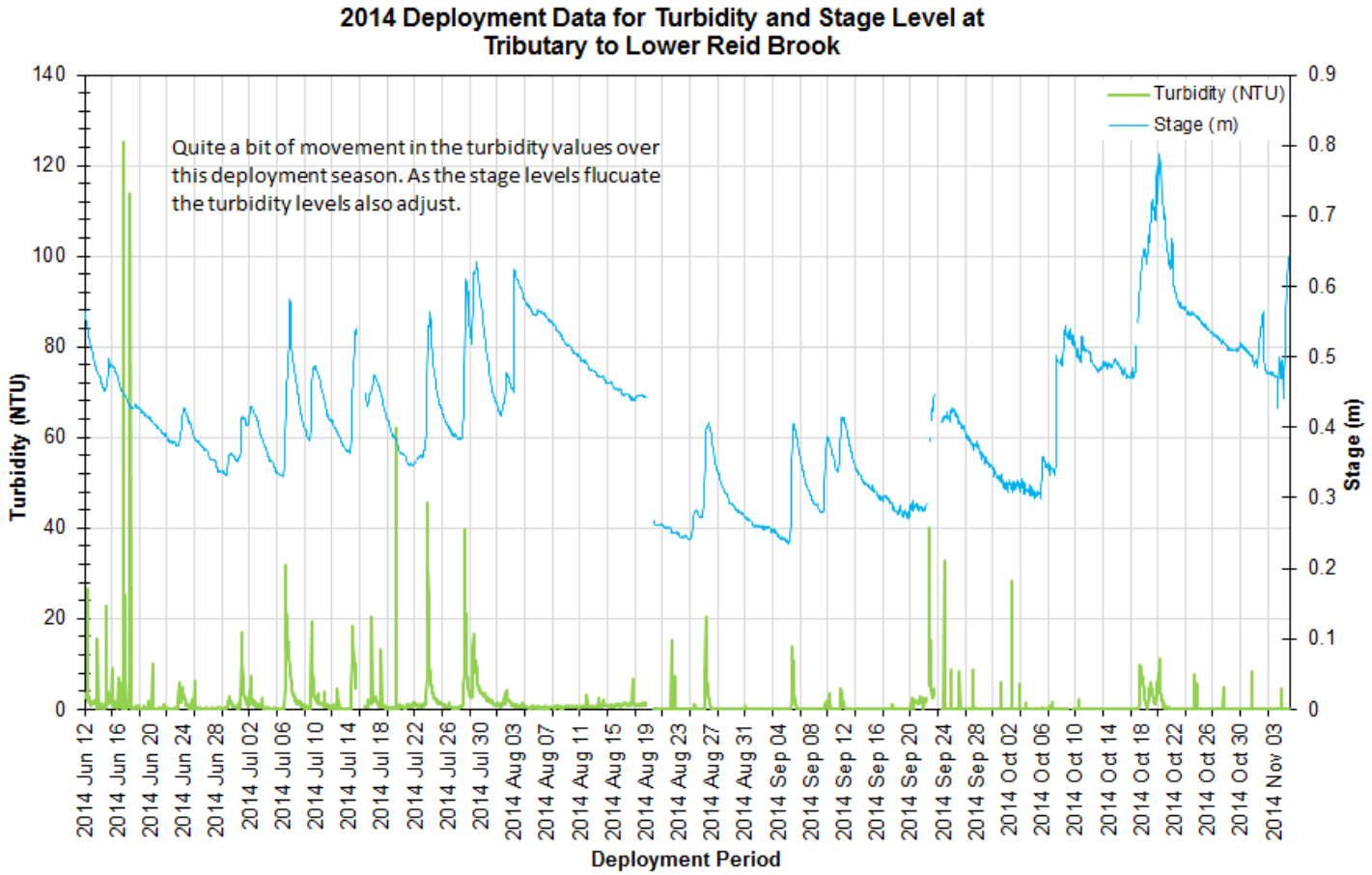

Figure 20: Turbidity and Stage level at Tributary to Lower Reid Brook

During the deployment season Tributary to Lower Reid Brook was influenced by external factors such as snow melt, spring runoff and rainfall. Figure 21 displays the daily averaged data for stage and streamflow at Tributary to Lower Reid Brook, as well as the precipitation amounts recorded at the Nain Weather Station (Appendix 1).

Stage and streamflow levels corresponded with the precipitation data. Typically after several days of rainfall there was an increase in both stage and streamflow at Tributary to Lower Reid Brook. The hourly stage data ranged between a minimum of 0.23m to a maximum of 0.79m. The hourly streamflow data ranged between a minimum of 0.03m^3/s to a maximum of 0.61m^3/s.

Precipitation events were frequent, occurring on 76 days of the 147 day deployment period. The highest precipitation recorded was September 22nd with 33.7mm of daily average rainfall recorded.

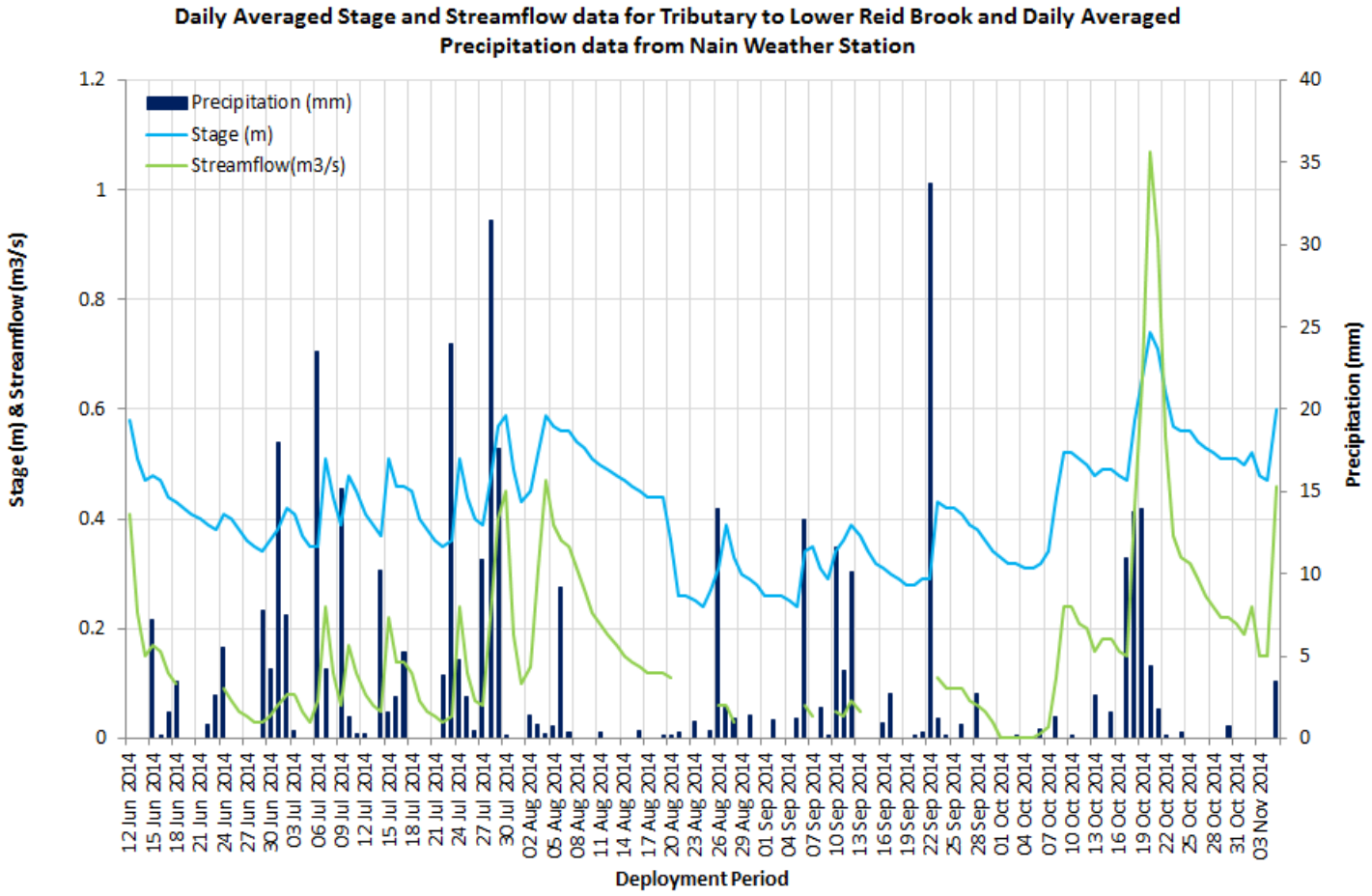

Figure 21: Average daily Stage and Streamflow level at Tributary to Lower Reid Brook and daily precipitation recorded at Nain Weather Station.

Lower Reid Brook below Tributary

During the deployment season the water temperature ranged between a minimum of 0.15°C to a maximum of 19.44°C, this station had a median of 9.39°C which was slightly highly than 2013 deployment season with a median 8.12°C (Figure 22).

During the July and August months the water temperature for Lower Reid brook displayed the highest temperatures for the deployment season. When the summer period (July and August) ended the water temperatures started to decline almost immediately as the climate changed for Fall and Winter seasons.

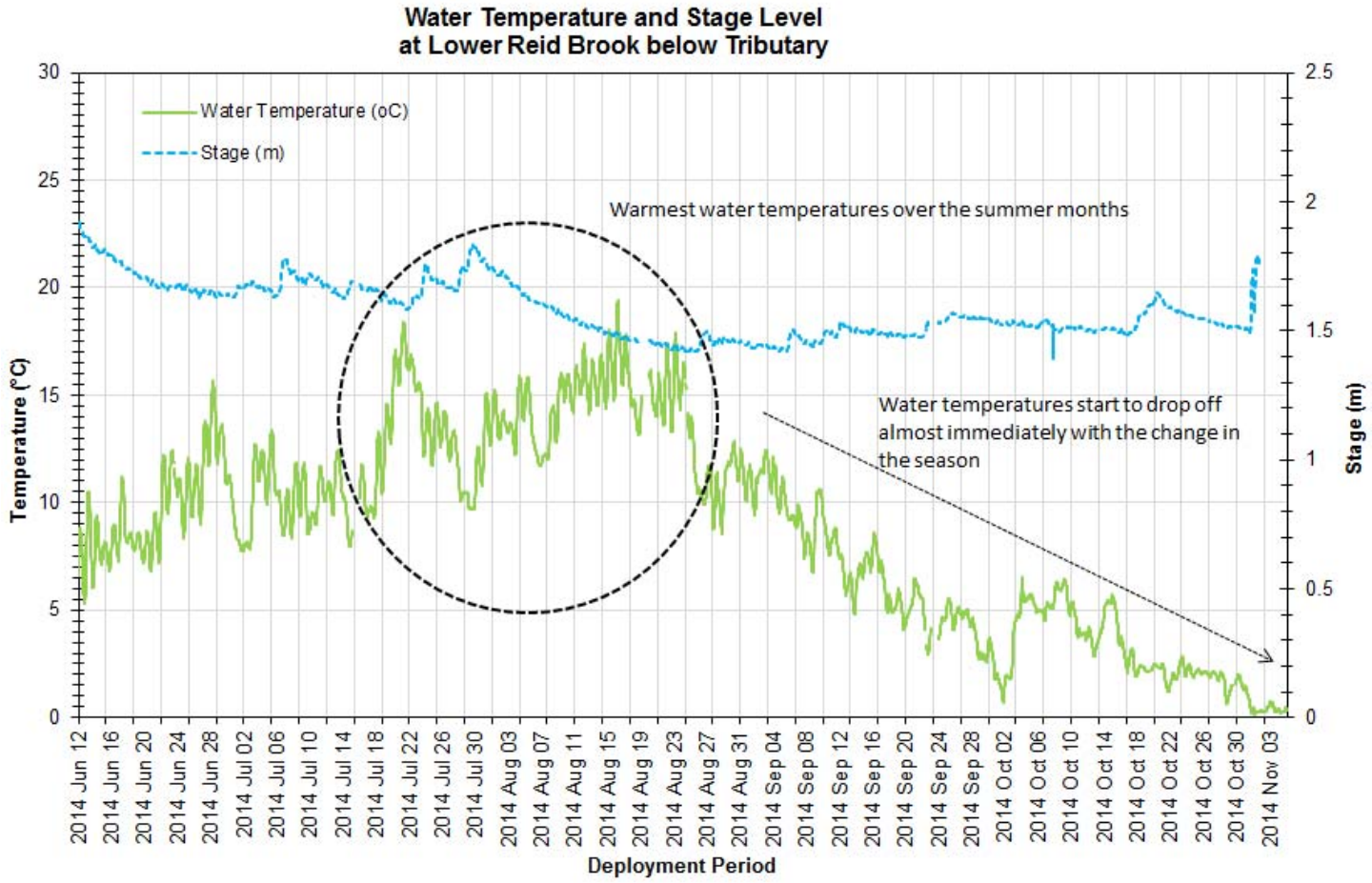

Figure 22: Water temperature at Lower Reid Brook below Tributary

Water temperature values show a close relationship with air temperatures (Figure 23). Increases and decreases in air temperatures are reflected in water temperatures. Air temperatures clearly fluctuate at a greater scale each day when compared with water temperatures.

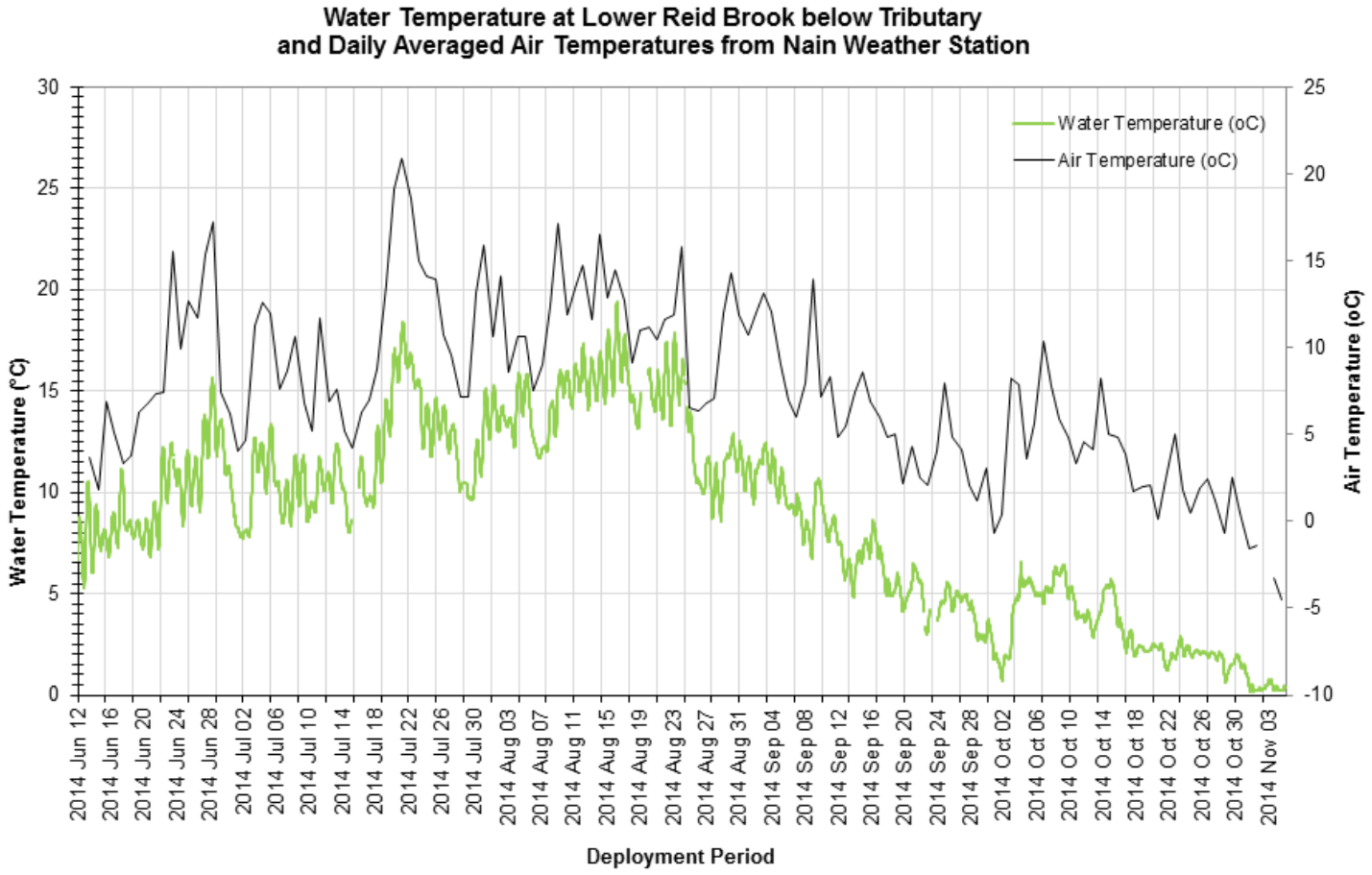

Figure 23: Water temperatures at Lower Reid Brook below Tributary and Average Daily Air Temperatures at Nain Weather Station

At Lower Reid Brook below Tributary the pH data during the deployment season ranged between a minimum of 6.07 to a maximum of 7.42 pH units during the deployment season, with a median value of 6.77 pH units (Figure 24).

Most of the values were within the recommended range for pH as suggested by the CCME Guidelines for the Protection of Aquatic Life (>6.5 and <9.0 pH units). Guidelines are indicated in red on Figure 24. There were several days that pH dipped below the minimum guideline, this seemed to occur during higher stage levels and after several days the pH levels climbed back within the CCME guideline.

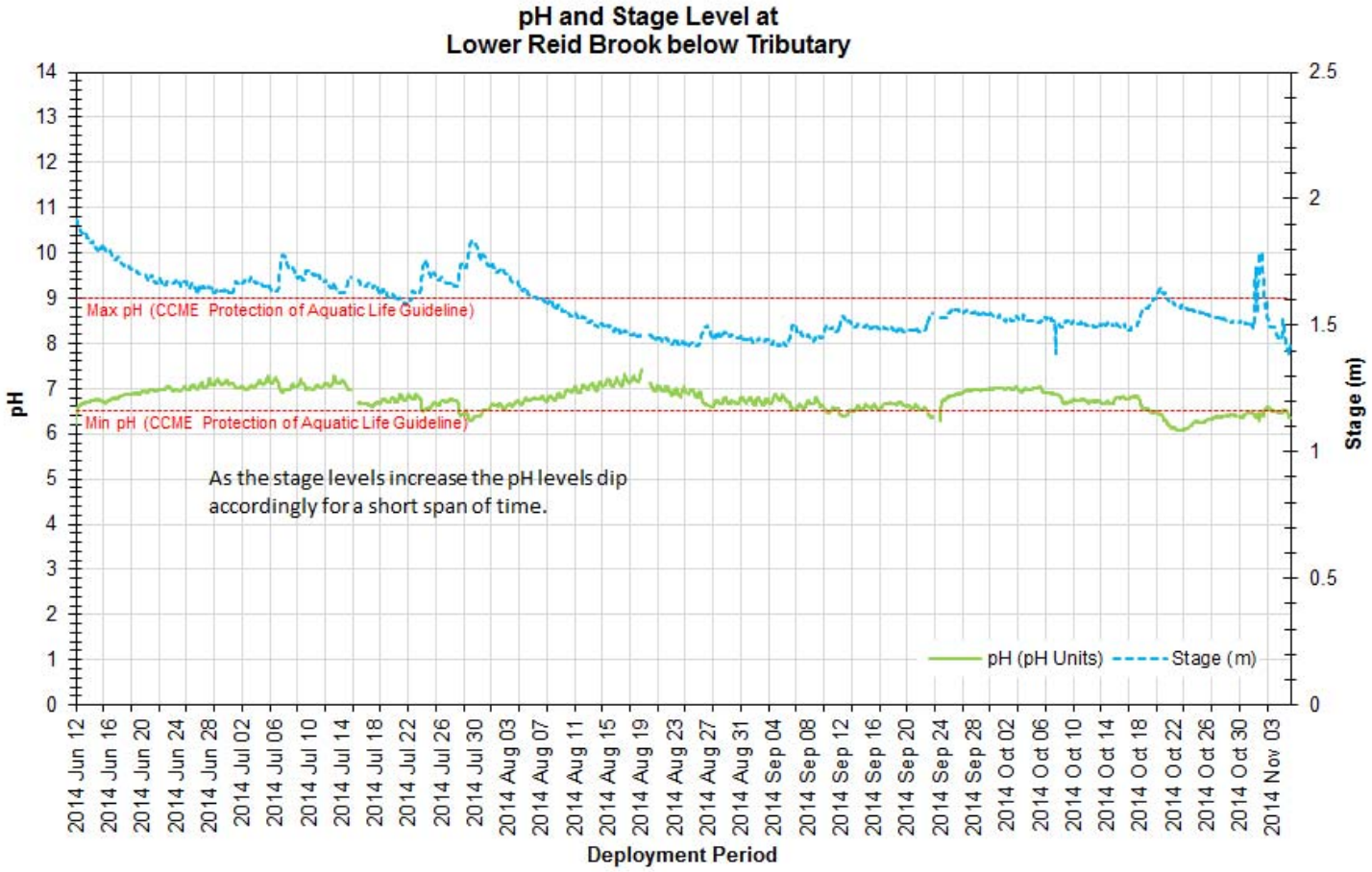

Figure 24: pH and stage level at Lower Reid Brook below Tributary

The specific conductivity data ranged between a minimum of 15.1µS/cm to a maximum of 41.5µS/cm during the deployment season. The specific conductivity data had a median of 31.7µS/cm which was just slightly lower than 2013 deployment season which had a median value of 34.6µS/cm (Figure 25).

Stage was included in Figure 25 to illustrate the inverse relationship between conductivity and water level. Generally, stage fluctuates throughout the deployment season. Specific conductivity levels do change with the varying water level. As the stage level increased, specific conductivity generally decreased due to the dilution of dissolved solids in the water column. Inversely, as stage decreased, specific conductivity increased as the concentration of dissolved solids rises.

Specific conductivity values generally increase throughout the entire deployment season. The relationship between stage level and specific conductivity values was evident throughout the entire deployment season.

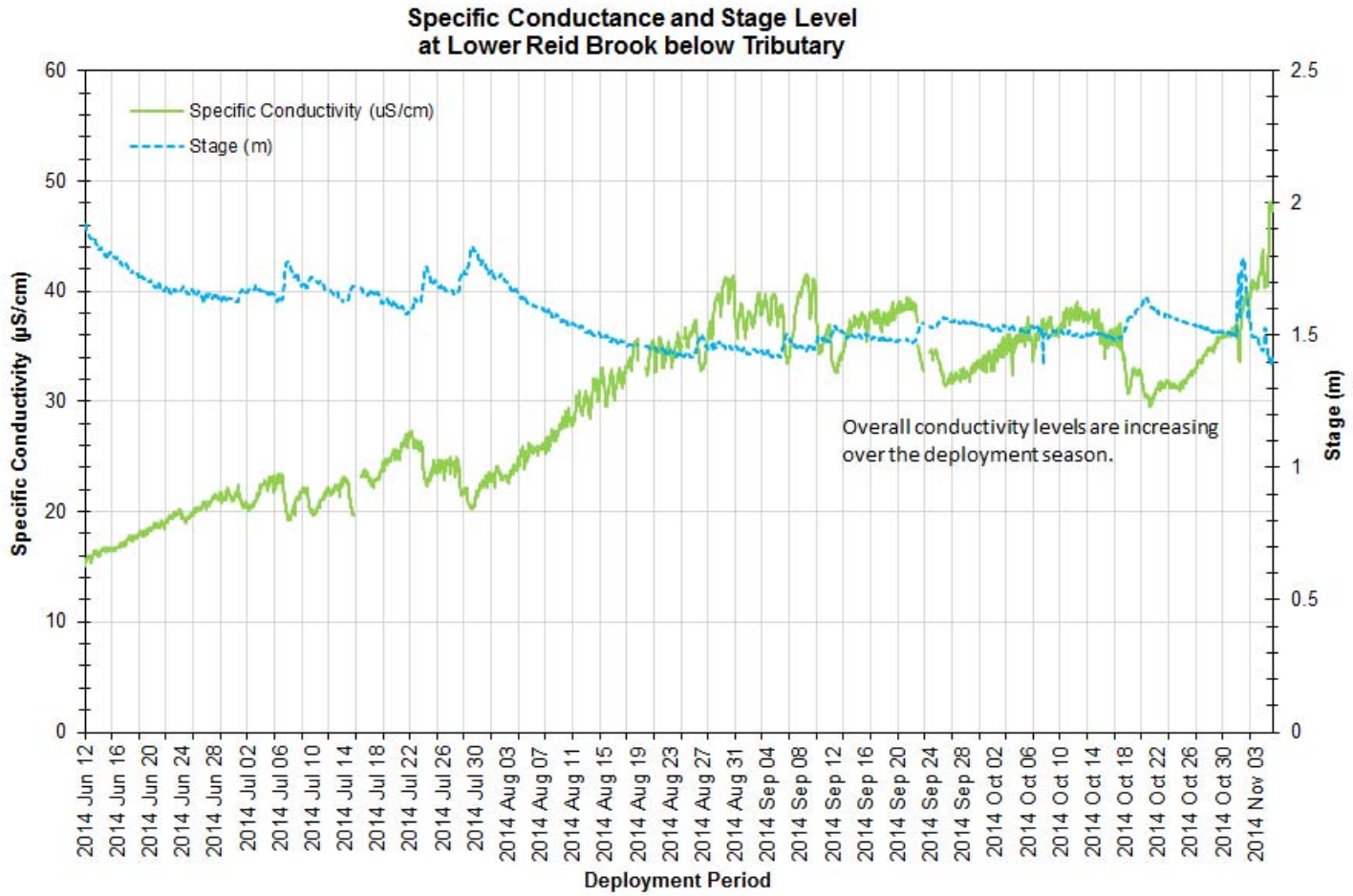

Figure 25: Specific conductivity and stage level at Lower Reid Brook below Tributary

The dissolved oxygen content at Lower Reid Brook below Tributary ranged between 8.91mg/l to 13.93mg/l, with a median value of 10.70mg/l during this deployment season. The saturation of dissolved oxygen ranged within 89.7% to 104.6%, with a median value of 94.8% (Figure 26).

Dissolved oxygen content indicated a typical seasonal trend, inverse to water temperature. Dissolved oxygen content was lower throughout the latter half of June and the month of July reaching a seasonal low in late July. As water temperatures decrease in the late summer and early fall, dissolved oxygen content begins to increase.

All the dissolved oxygen concentration values were above the minimum CCME Guideline for the Protection of Other Life Stages (6.5mg/l). During warmer temperature the dissolved oxygen did drop below the Guideline for the Protection of Early Life Stages (9.5mg/L) however after a couple of days the values increased to above the guideline (Figure 26).

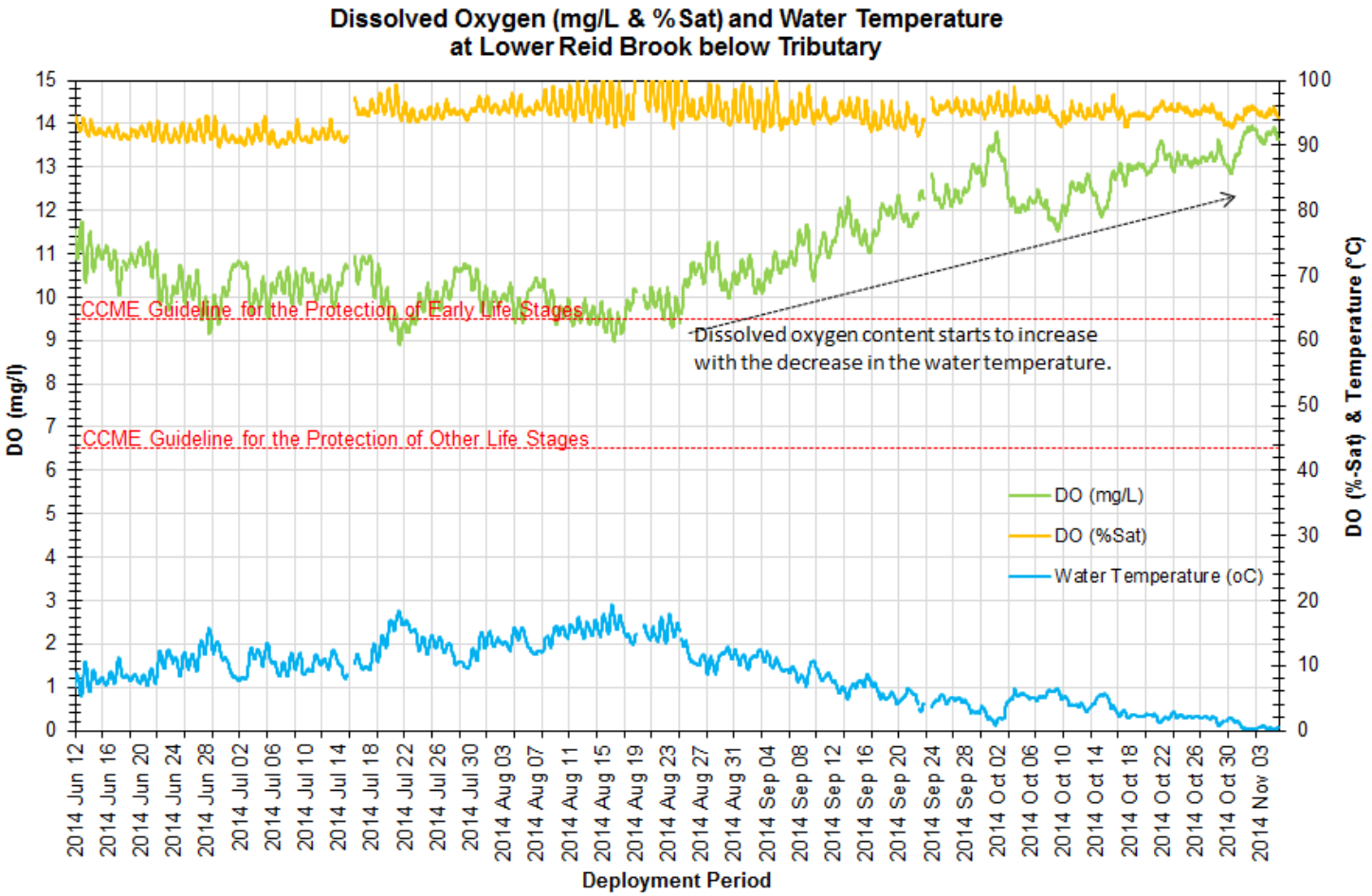

Figure 26: Dissolved Oxygen (mg/L & % Sat) and Water Temperature at Lower Reid Brook below Tributary

The turbidity data at Lower Reid Brook below Tributary ranged between a minimum of 0.0NTU and a maximum of 48.1NTU during the 2014 deployment season (Figure 27). This data set had a median value of 0.0NTU which indicated that there was little to no natural turbidity present at this station.

There are a number of turbidity events throughout the four deployment periods from June to November. Many of these increases corresponded with rainfall events as indicated in the monthly deployment reports.

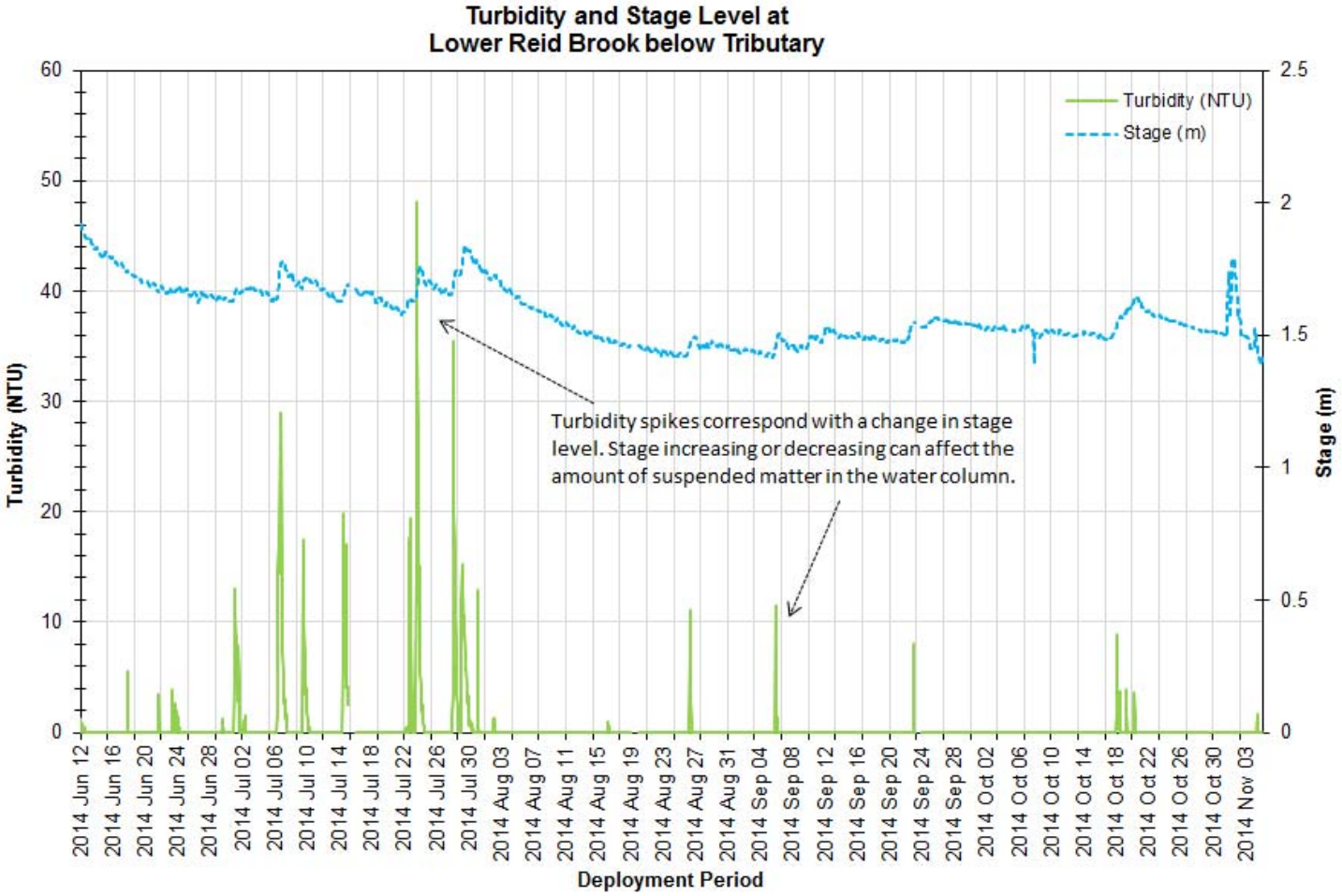

Figure 27: Turbidity and Stage Level at Lower Reid Brook below Tributary

The stage, streamflow and precipitation data are graphed below to show the relationship between rainfall and water level (Figure 28) in a brook. The changes of the water column during or after rainfall can explain some of the events that were evident on the previous water parameter graphs (Appendix 1).

During the deployment season the stage levels remained reasonably consistent. The stage levels during this deployment period ranged within a minimum of 1.39m to a maximum of 1.92m. The streamflow hourly data ranged between 0.83m^3/s to 18.30m^3/s.

Of the 147 days of deployment there were 79 days with some level of precipitation, approximately >50% of the deployment period had rainfall. Precipitation ranged from a daily average minimum of 0.0mm to a daily average maximum of 33.7mm which was recorded on September 22, 2015.

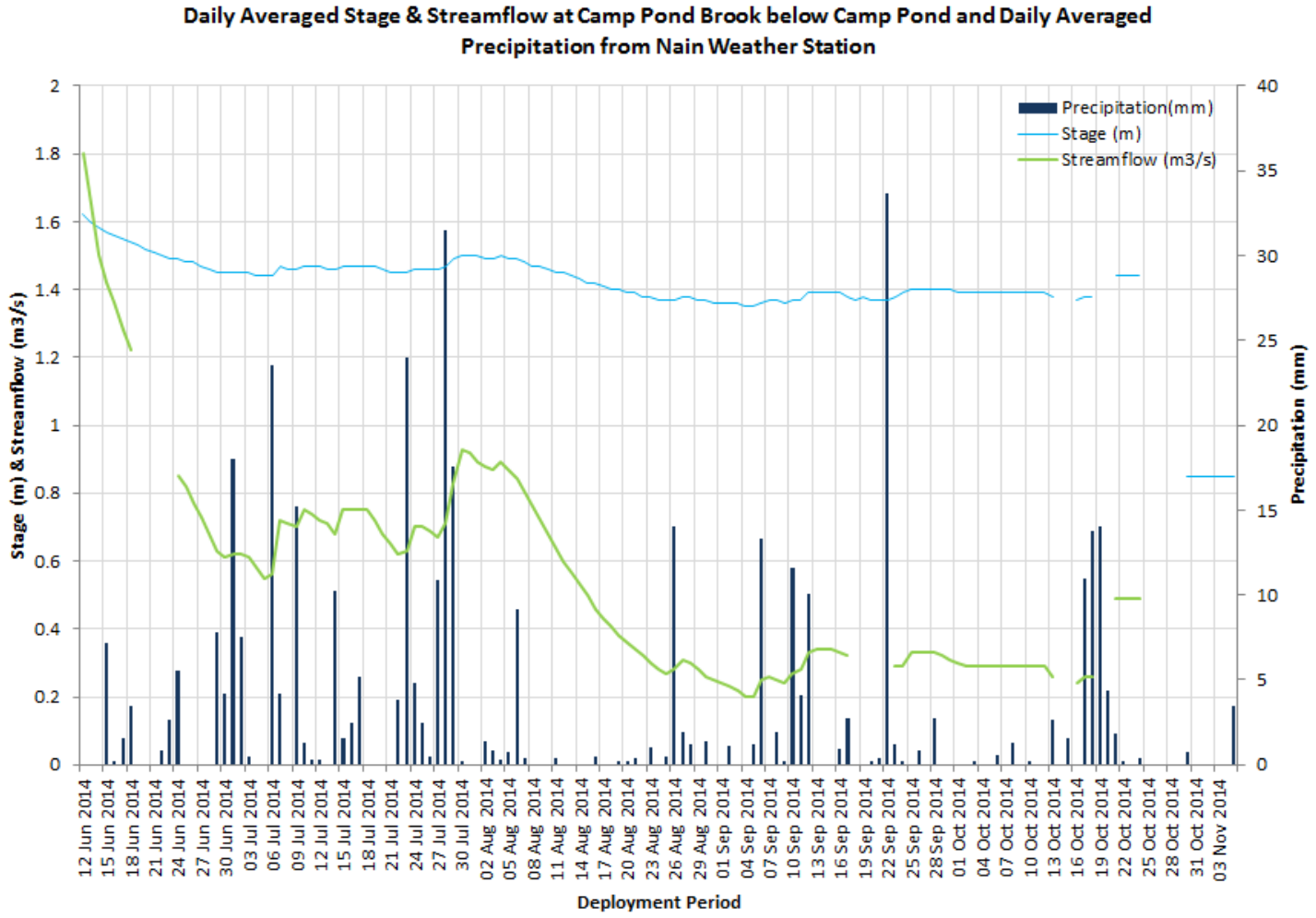

Figure 28: Stage and Streamflow level at Lower Reid Brook below Tributary and Precipitation data from the Nain Weather Station.

Multi-Station Comparison

This section of the 2014 annual report focuses on the real-time stations compared against each other during the entire deployment season.

Temperature

Water temperature trends at each of the four stations are comparable with one another (Figure 29). There is clear seasonal trend at all stations with water temperatures. Water temperatures peak at all stations in late July or early August. Water temperatures then start to decrease at the end of August. The deployment season had a steady decline in water temperatures until the end of the deployment season in early November.

For the 2014 deployment season Camp Pond Brook recorded the highest temperature in the network at 22.90°C. Camp Pond also had the highest median value for temperature at 12.34°C. Lower Reid Brook and Tributary to Lower Reid Brook have very similar water temperatures throughout the season. Reid Brook at outlet of Reid Pond had the lowest (coldest) median at 7.90°C. Reid Brook at Outlet of Reid Pond is a pond and it takes a lot longer to warm up during the summer and cool down into the winter than flowing streams or brooks.

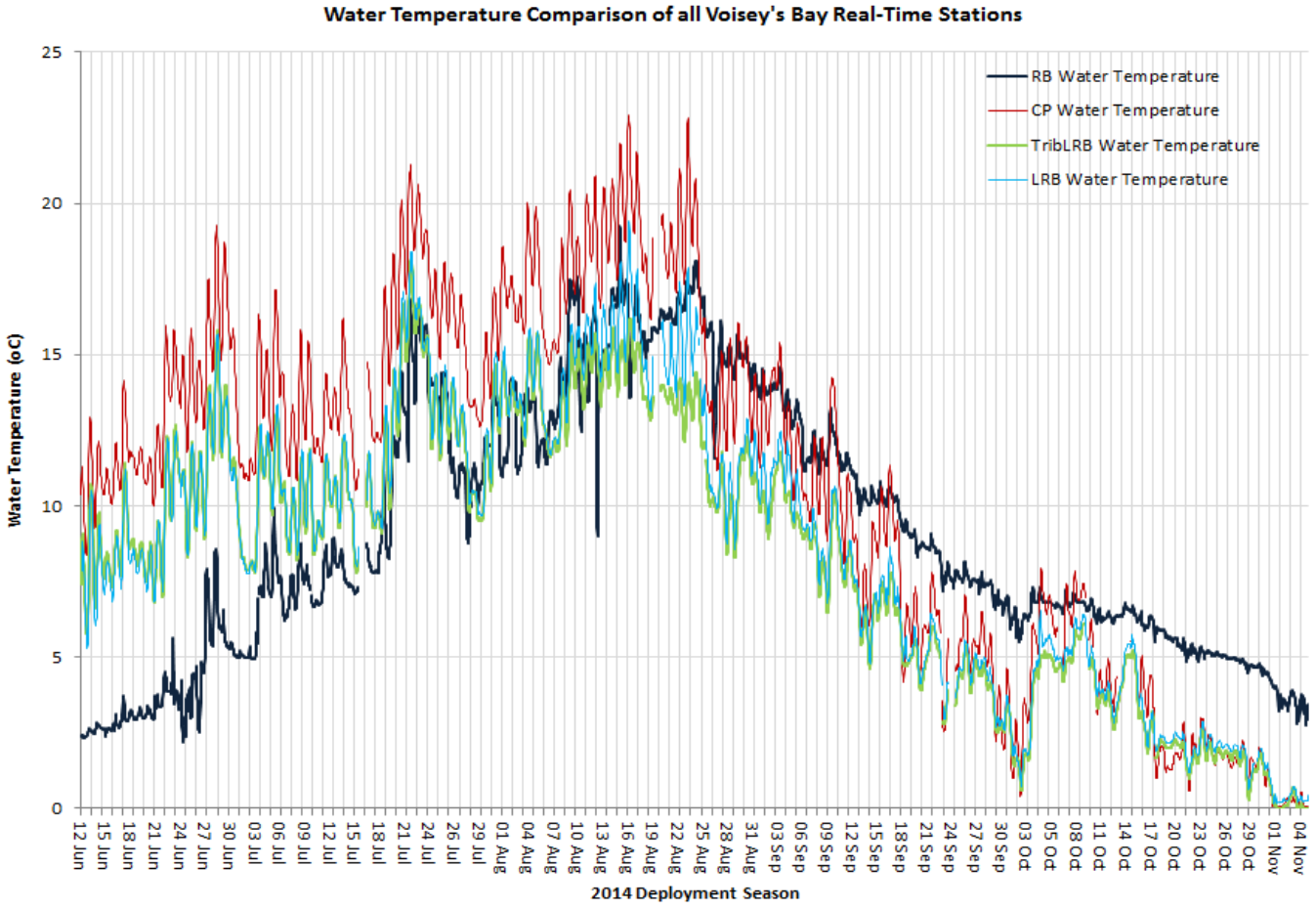

Figure 29: Water temperature at all stations

Temperature (°C)	Reid Brook	Camp Pond	Tributary	Lower Reid
Median	7.90	12.34	9.30	9.39
Max	19.25	22.90	18.30	19.44
Min	2.21	0.39	0.10	0.15

pH

During the 2014 deployment period the pH medians of the Real-Time stations were within 6.69 to 6.85 pH units (Figure 30). The majority of the pH data collected was within this range.

Reid Brook at Outlet of Reid Pond had several distinct differences in the pH data from the other stations. Reid Brook had an extremely low reading on August 22nd and then extremely high readings on August 28th and September 16th. It was not determined what the causes of the unusual readings were at the time.

The other stations maintain reasonably steady pH values throughout the deployment season. The fluctuations in the data are represented in all the pH values.

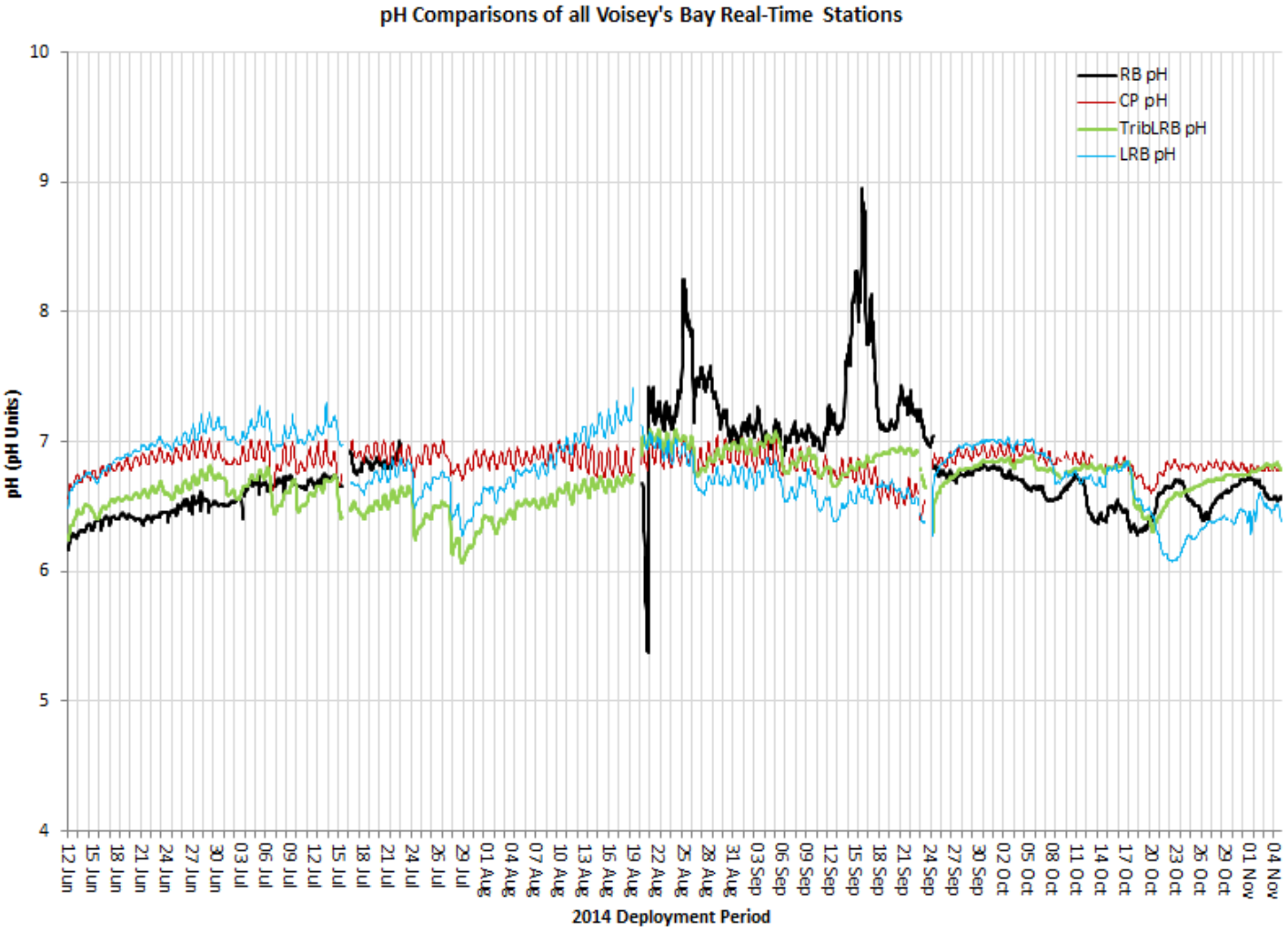

Figure 30: pH at all stations

pH (units)	Reid Brook	Camp Pond	Tributary	Lower Reid
Median	6.78	6.85	6.69	6.77
Max	8.96	7.08	7.10	7.42
Min	5.38	6.40	6.07	6.07

Specific Conductivity

Specific conductivity trends vary throughout the network. At the station at Upper Reid Brook, specific conductivity levels are low and stable with a median value of 12.0µS/cm. Specific conductivity at Upper Reid Brook is stable throughout the entire deployment season as this station is located at the outlet from Reid pond, a stable lake environment. Downstream in the network, specific conductivity is increasing steadily throughout the deployment season at the remaining three stations.

At the stations on Camp Pond Brook, Tributary to lower Reid and Lower Reid Brook, median values for specific conductivity are 35.5 µS/cm, 32.2 µS/cm and 31.7 µS/cm, respectively. At these stations specific conductivity values fluctuate in response to changing stage levels and rainfall events. Generally at Tributary to Lower Reid and Lower Reid Brook, as stage increases, specific conductivity decreases. This is caused by the dilution of major ions in the water column from the rainfall. Vice versa, as stage levels decrease, specific conductivity increases due to the increase in concentration of major ions.

At Camp Pond Brook below Camp Pond station the specific conductivity does not follow a typical inverse relationship with stage level increase during precipitation events. Instead, when water levels increase, there is an increase in specific conductivity. Although this association is not typically expected, this is the relationship most often seen at this station. Specific conductivity is also on average higher at this station than at the other stations in the network.

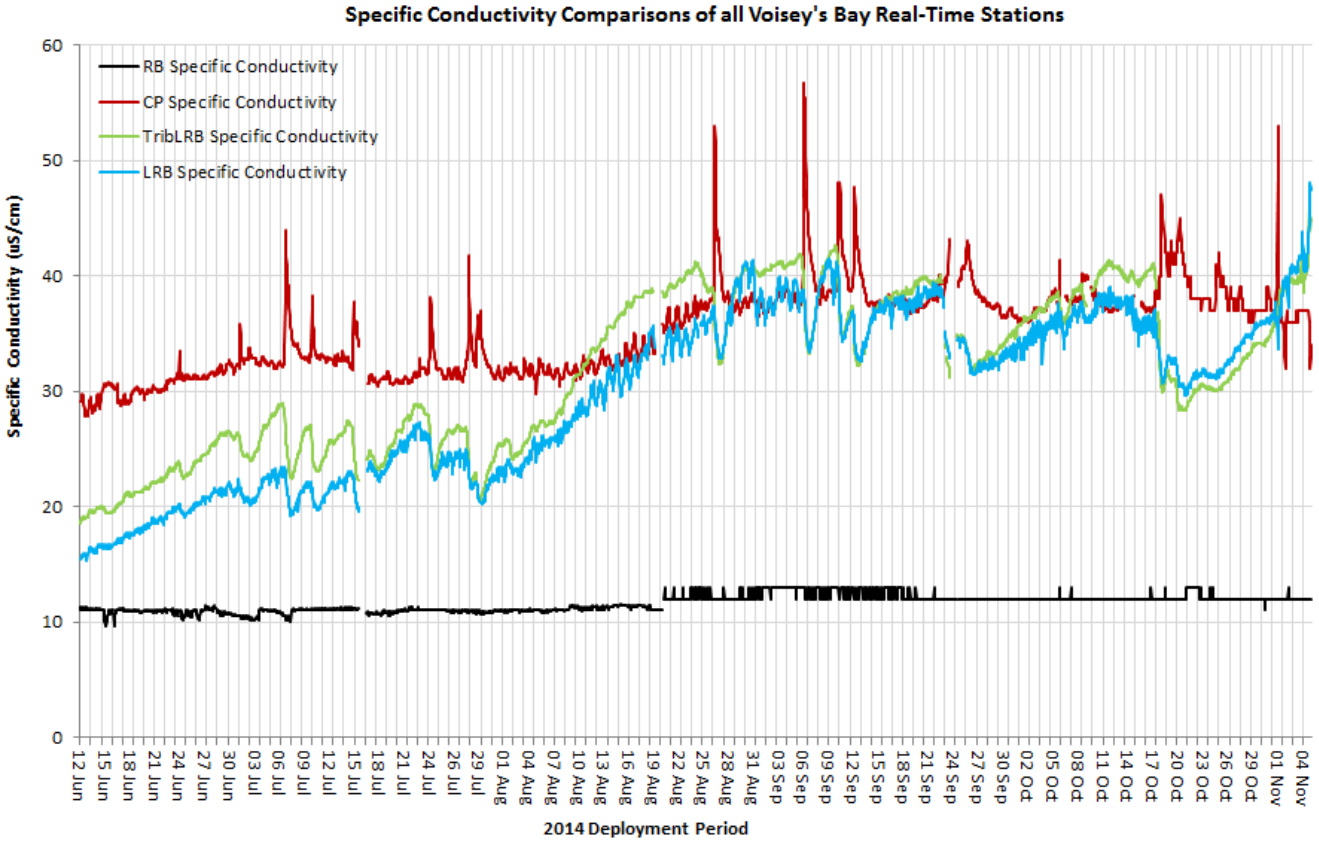

Figure 31: Specific conductivity at all stations

Specific Conductivity	Reid Brook	Camp Pond	Tributary	Lower Reid
Median	12.0	35.5	32.2	31.7
Max	13.0	56.7	42.6	41.5
Min	9.7	27.8	18.4	15.1

Dissolved Oxygen and Percent Saturation

The dissolved oxygen content this deployment season had median values between 9.86mg/l and 11.66mg/l throughout the network. Dissolved oxygen content showed a typical inverse relationship with water temperature at all stations. DO values are most stable at the station at Reid Brook below Reid Pond and showed greater fluctuation at stations further downstream where water temperatures also fluctuate more.

All values at all stations were above the minimum CCME Guideline for the Protection of Cold Water Biota at Other Life Stages (6.5mg/l). All values at the station at Upper Reid Brook were above the CCME Guideline for the Protection of Aquatic Life at Early Life Stages (9.5mg/l). During the warmer temperatures DO content does dip below the CCME Guideline for Early Life Stages for Tributary to Lower Reid Brook, Lower Reid Brook below Tributary and at Camp Pond Brook below Camp Pond stations. The warmer water temperatures are during the months of July and August which is also when the larger decreases in DO content occur. The guidelines are indicated in on Figure 32.

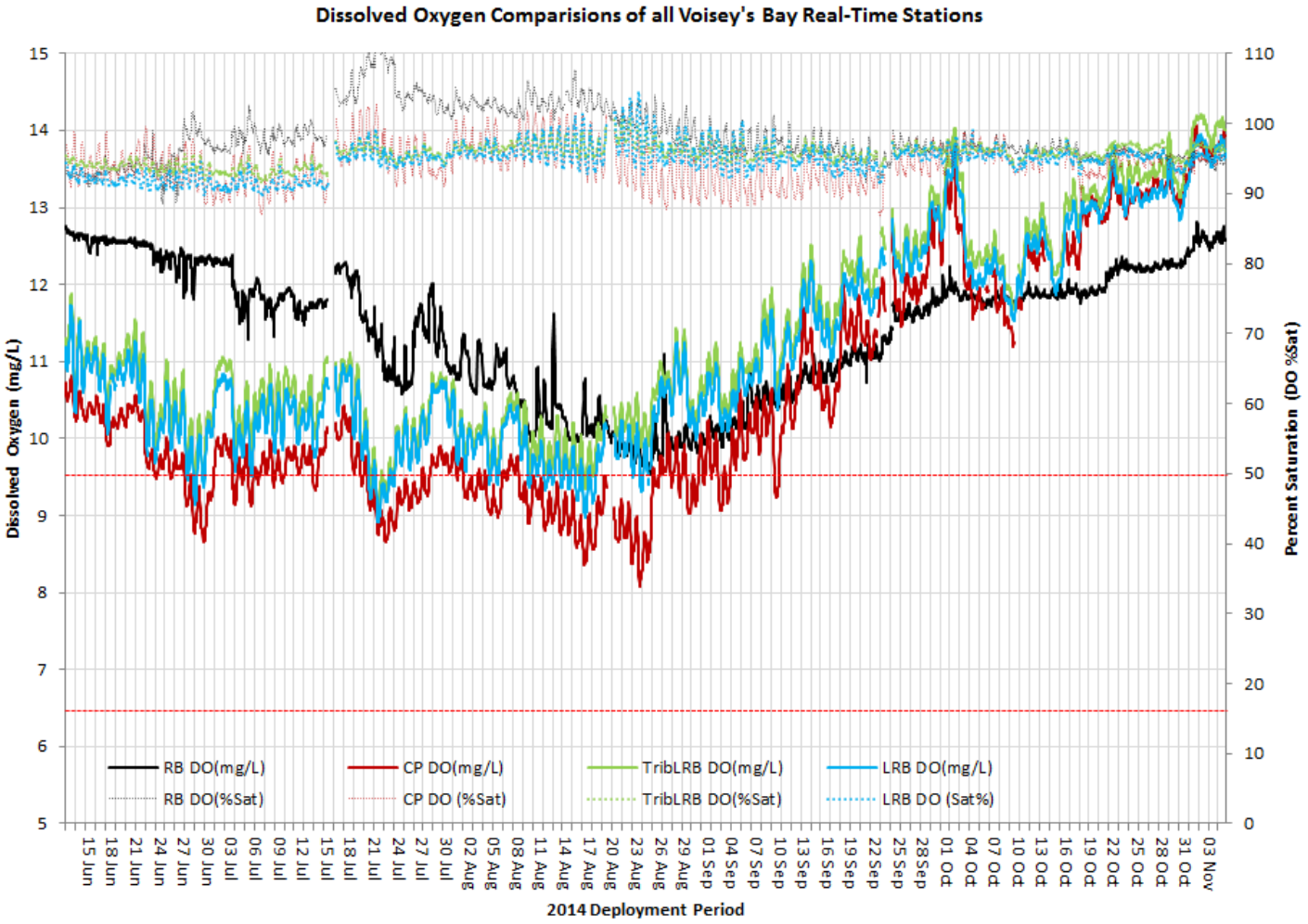

Figure 32: Dissolved oxygen and percent saturation at all stations

	Dissolved Oxygen (mg/l)				Percent Saturation			
	Reid Brook	Camp Pond	Tributary	Lower Reid	Reid Brook	Camp Pond	Tributary	Lower Reid
Median	11.66	9.86	10.88	10.70	97.2	94.2	95.8	94.8
Max	12.82	13.67	14.12	13.93	114.5	102.8	100.9	104.6
Min	9.54	8.08	8.99	8.91	88.5	86.7	91.5	89.7

Turbidity

Turbidity values vary somewhat across the network throughout the 2014 season. Median values at all real-time stations range only between 0.0NTU to 0.3NTU indicating there is no background turbidity at any of the stations.

During this deployment season there is little to no turbidity at the Reid Brook below Reid Pond. Reid Brook below Reid Pond remains very much in its natural state and is not impacted in any way.

Camp Pond Brook below Camp Pond, Tributary to Lower Reid Brook and Lower Reid Brook below Tributary can be influenced from anthropogenic sources. Although majority of the turbidity values are 0.0NTU, during rainfall or runoff events there are a number of short lived, relatively low magnitude events occurring. The turbidity levels did increase during rainfall events however the levels settle back to baseline values (0NTU) in a matter of hours, sometimes days after the event.

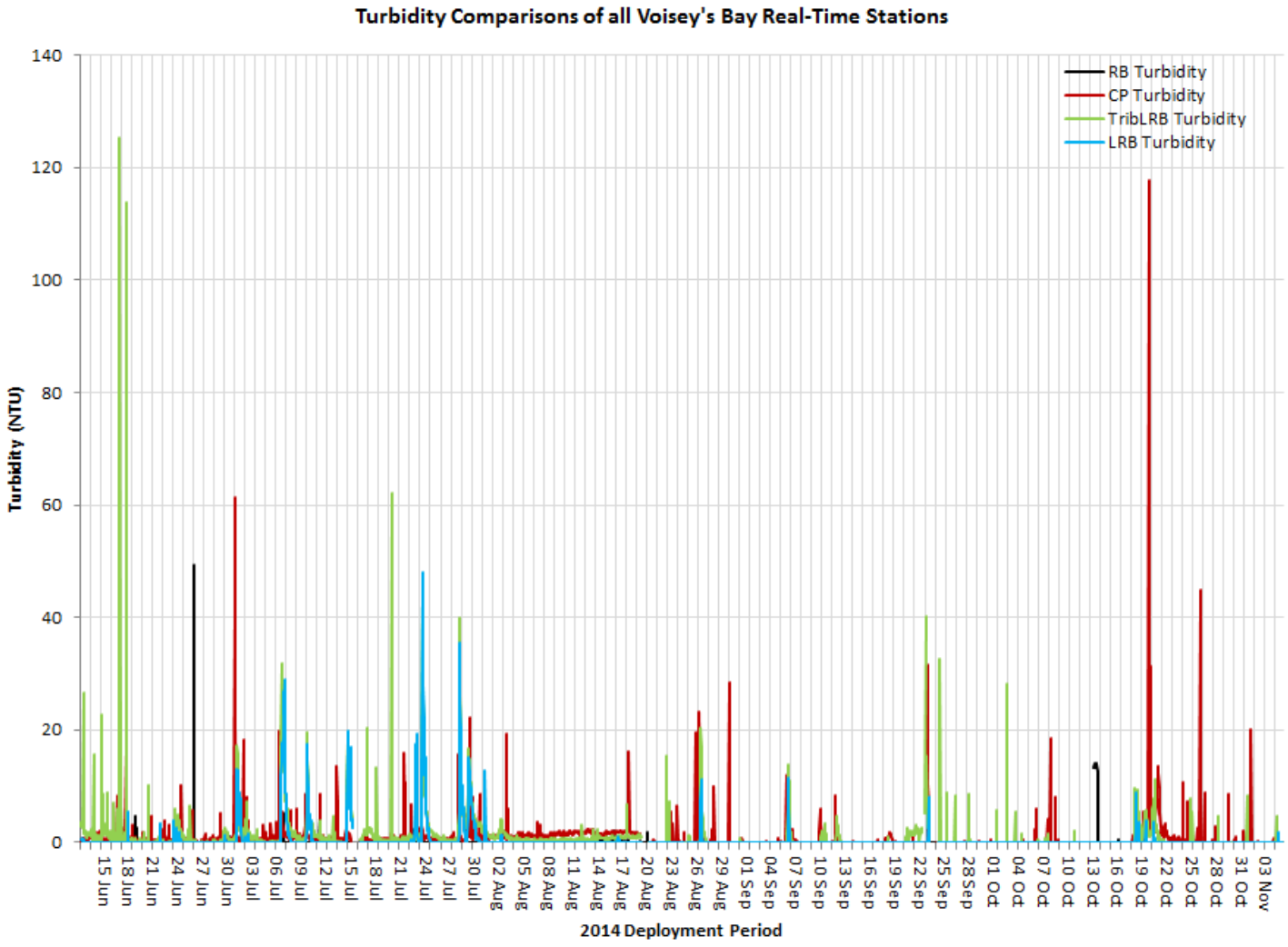

Figure 33: Turbidity at all stations

Turbidity (NTU)	Reid Brook	Camp Pond	Tributary	Lower Reid
Median	0.0	0.3	0.0	0.0
Max	49.3	117.7	125.3	48.1
Min	0.0	0.0	0.0	0.0

Stage

The beginning of deployment season has higher stage levels as it is capturing the end of the spring thaw. Throughout the deployment the stage levels remain reasonably constant for each station. Peaks in the stage level can be linked to rainfall events or runoff from surrounding environment (Appendix 1).

Rainfall events have a large effect on the streams in the real-time network. Significant increases in stage level are noticed almost immediately following a rainfall event in the area. The influences of precipitation events are not as evident at Camp Pond Brook below Camp Pond and the stage increases are somewhat less significant at this station.

The greatest difference in stage level of the deployment season was Tributary to Lower Reid Brook with a difference of 0.56m between its highest stage and lowest stage.

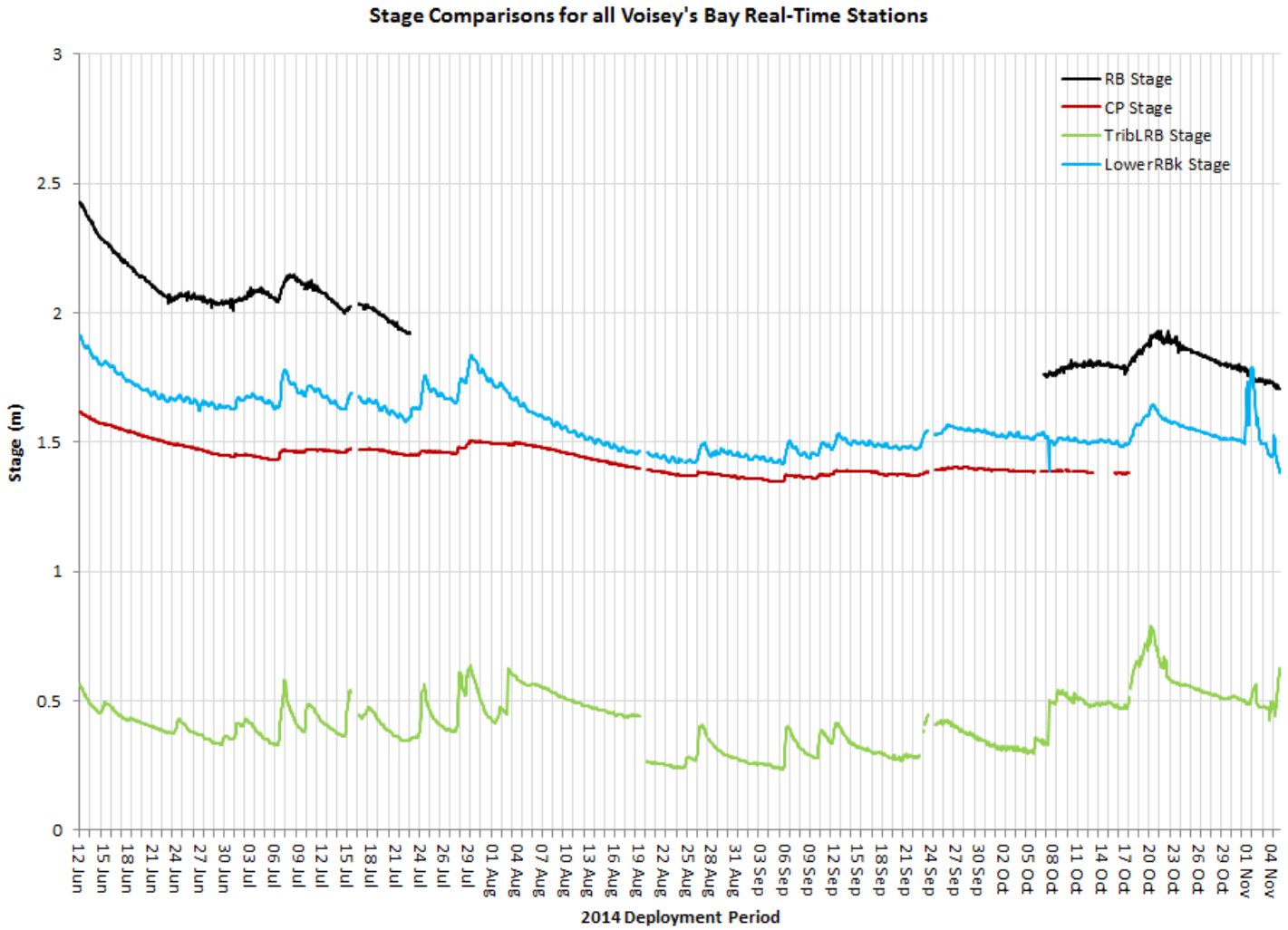

Figure 34: Stage levels at all stations

Stage (m)	Reid Brook	Camp Pond	Tributary	Lower Reid
Max	2.43	1.62	0.79	1.92
Min	1.92	1.35	0.23	1.39
Difference	**0.51**	**0.27**	**0.56**	**0.53**

Conclusions

Instruments at water quality monitoring stations in the Voisey's Bay Network were deployed during four deployment periods from June 12 to November 5, 2014.

In most cases, weather related events or increases/decreases in water level could be used to explain the fluctuations. Water temperature and dissolved oxygen showed typical seasonal trends, increasing or decreasing with warming and cooling air temperatures. Stage levels decreased throughout the season which caused general increasing trends in specific conductivity and pH except for at the Reid Brook below Reid Pond station. The Reid Brook below Reid Pond station is extremely constant. This station has steady pH values and unwavering specific conductivity values. Across all stations turbidity values showed a median within 0.0NTU to 0.3NTU indicating there is naturally no background turbidity in this network of brooks. When turbidity events did occur most were short lived, relatively low in magnitude and similar throughout the season.

Regular visits on a near 30 day deployment schedule have been adhered to in cooperation with Vale Environmental Staff and WRMD staff. This has provided good quality data with limited drift. The effects of bio fouling rarely impact the instruments due to the regular maintenance, cooler water temperatures and pristine nature of the rivers.

Reid Brook below Reid Pond had a pH failure during the second deployment period. The pH probe failed and the data was inaccurate and removed from the dataset. Therefore there is pH data missing from July 22nd through to August 20th 2014. This station also had a transmission issue; no data was transmitted real-time from July 22nd through to October 8th, 2014. The data displayed in this report for that time frame was obtained from the internally logged data file. All other station's instruments performed well for the deployment season with limited or no disruptions to data collection.

Path Forward

The success of these four stations is largely due to the 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 rivers behaviours. The data collected is essential for identifying the difference between natural and irregular events. As this agreement progresses into the 2015 deployment period for the Voisey's Bay stations, the following is a list of planned activities to be carried out in the upcoming year. The list also includes some multi-year activities planned in the previous year that are still in progress.

- In the 2015 deployment season, staff from Vale will be responsible for monthly maintenance and calibration (as was the case in the past). ENVC staff will perform regular site visits to audit and assist in the maintenance and calibration procedures from time to time. EC Water Survey of Canada 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 2015 or in future seasons.
- Open communication lines will continue to be maintained between WRMD, EC and Vale Voisey's Bay employees involved with the agreement in order to respond to emerging issues on a proactive basis.
- Vale will receive 30 day deployment reports outlining the events that occurred in the previous deployment period and a 2015 annual report summarizing the events of the entire deployment season.

- WRMD staff is currently undertaking a comprehensive report on the RT network at Voisey's Bay featuring the network data from the past 10 years. WRMD staff will consult with Vale Environment staff on the direction and content of this report. The report will be completed by March 2015.
- 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*.).
- 2015 deployments will recommence in the Spring as soon as the ice conditions in the brooks permit.
- WRMD is organizing a maintenance and calibration training session available for all industry partners to attend. The details and content of the training session will be communicated with VALE closer to the scheduled timeframe.

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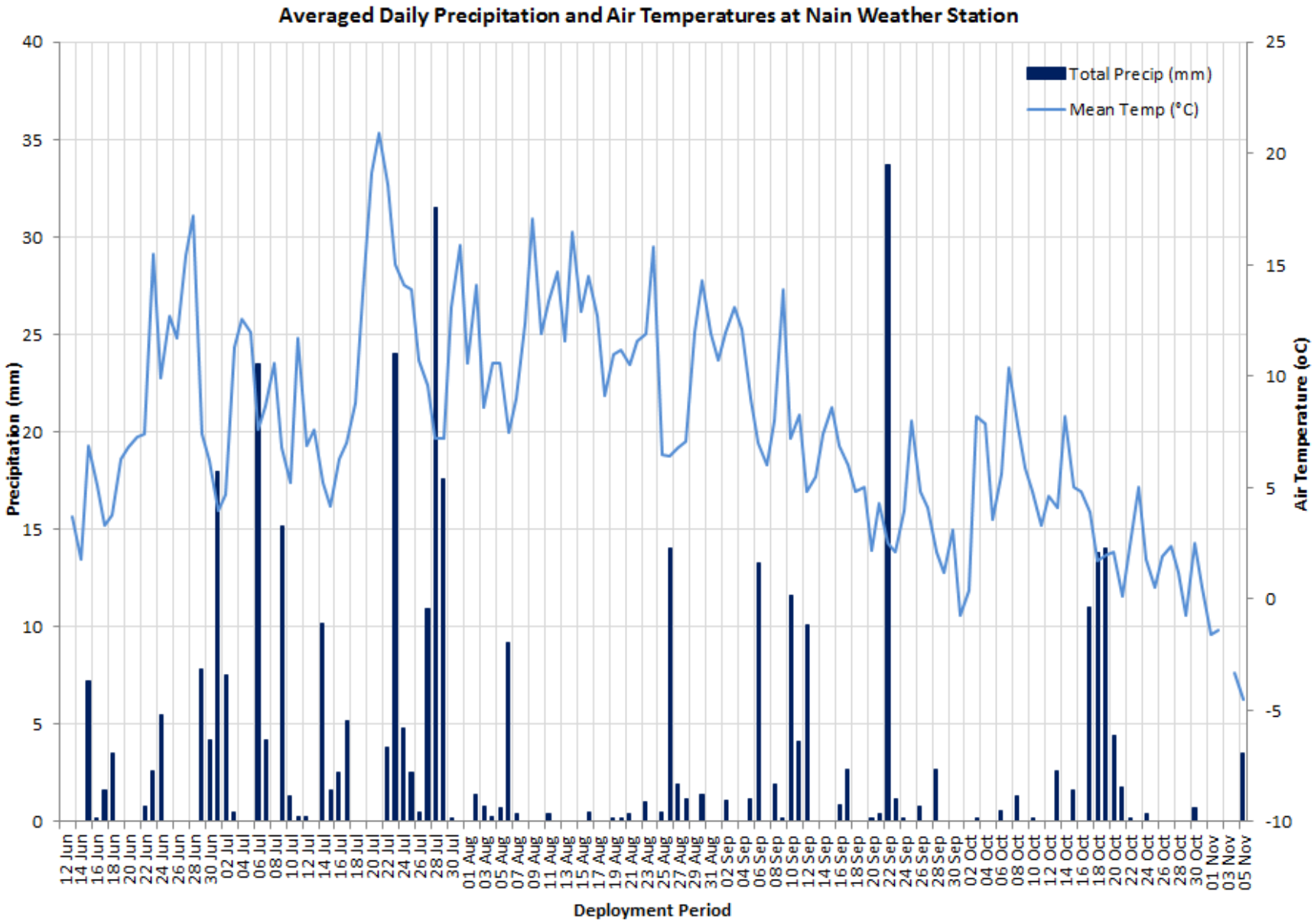
Appendix 1


Averaged Daily Precipitation and Air Temperatures at Nain Weather Station
Total Precip (mm)
Mean Temp (°C)
Precipitation (mm)
Air Temperature (oC)
Deployment Period