Real-Time Water Quality 2012 Annual Report

Voisey's Bay Network

July 19 to November 4, 2012

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) as well as Environment Canada (EC) to ensure the protection of ambient water resources in Voisey's Bay, Labrador.

Vale Environment staff Erin Cullen, Dennis Martin, and Matt Hynes are acknowledged for their hard work during the 2012 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 ENVC have been integral in ensuring the smooth operation of such a technologically advanced network. Grace de Beer plays the lead role in coordinating and liaising between the major agencies involved, thus, ensuring open communication lines at all times. In addition, Grace is responsible for the data management/reporting, troubleshooting, along with ensuring the quality assurance/quality control measures are satisfactory. Paul Neary and Leona Hyde have 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.

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(M)	Real-time Water Quality (Monitoring)
WRMD	Water Resources Management Division
%Sat	Percent Saturation

Introduction

- The RTWQM 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 RTWQM network consists of four water quality monitoring stations; Upper Reid Brook (Outlet from Reid Pond), Tributary to Lower Reid Brook, Lower Reid Brook below Tributary and Camp Pond Brook below Camp Pond. 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, ENVC 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.
- Continuous monitoring recommenced in summer 2012 when ice conditions permitted. The deployment season start was delayed until July due to the late arrival of new equipment. This annual deployment report illustrates, discusses and summarizes water quality related events from July 19 to November 4. During this time, four visits were made to each of the four RTWQM 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 2012 deployment season are summarized in Table 1.

Table 1: Installation and removal dates for 2012 deployment periods

Installation	Removal	Deployment Period
July 19	August 15	27 days
August 15	September 24	30 days
September 26	November 4	39 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 deployed from July 19 to November 4, 2012 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, July 19– November 4, 2012

Station	Date	Activity	Instrument #	Temperature	pH	Specific Conductivity	Dissolved Oxygen	Turbidity
Upper Reid Brook	Jul 19, 2012	Deployment	62884	Excellent	Excellent	Excellent	Excellent	Excellent
Upper Reid Brook	Aug 15, 2012	Removal	62884	Excellent	Good	Excellent	Good	Excellent
Upper Reid Brook	Aug 15, 2012	Deployment	62884	Excellent	n/a	Excellent	Excellent	Excellent
Upper Reid Brook	Sep 24, 2012	Removal	62884	Excellent	Good	Excellent	Excellent	Excellent
Upper Reid Brook	Sep 26, 2012	Deployment	62884	Excellent	Good	Excellent	Excellent	Excellent
Upper Reid Brook	Nov 4, 2012	Removal	62884	Excellent	Good	Excellent	n/a	n/a
Tributary to Lower Reid Brook	Jul 19, 2012	Deployment	62886	Excellent	Excellent	Excellent	Excellent	Excellent
Tributary to Lower Reid Brook	Aug 15, 2012	Removal	62886	Excellent	Excellent	Excellent	Good	Excellent
Tributary to Lower Reid Brook	Aug 15, 2012	Deployment	62886	Excellent	n/a	Excellent	Excellent	Excellent
Tributary to Lower Reid Brook	Sep 24, 2012	Removal	62886	Excellent	Excellent	Good	Good	Excellent
Tributary to Lower Reid Brook	Sep 26, 2012	Deployment	62886	Excellent	Fair	Good	Excellent	Excellent
Tributary to Lower Reid Brook	Nov 4, 2012	Removal	62886	Excellent	Good	Good	n/a	n/a
Lower Reid Brook	Jul 19, 2012	Deployment	62887	Excellent	Excellent	Excellent	Excellent	Excellent
Lower Reid Brook	Aug 15, 2012	Removal	62887	Good	Good	Excellent	Excellent	Excellent
Lower Reid Brook	Aug 15, 2012	Deployment	62887	Excellent	n/a	Excellent	Excellent	Excellent
Lower Reid Brook	Sep 24, 2012	Removal	62887	Excellent	Excellent	Good	Good	Excellent
Lower Reid Brook	Sep 26, 2012	Deployment	62887	Excellent	Fair	Good	Excellent	Excellent
Lower Reid Brook	Nov 4, 2012	Removal	62887	Excellent	Excellent	Excellent	n/a	n/a
Camp Pond Brook	Jul 19, 2012	Deployment	62885	Excellent	Excellent	Excellent	Excellent	Excellent
Camp Pond Brook	Aug 15, 2012	Removal	62885	Excellent	Good	Excellent	Excellent	Excellent
Camp Pond Brook	Aug 15, 2012	Deployment	62885	Excellent	n/a	Excellent	Excellent	Excellent
Camp Pond Brook	Sep 24, 2012	Removal	62885	Good	Good	Excellent	n/a	Poor
Camp Pond Brook	Sep 26, 2012	Deployment	62885	Excellent	Fair	Good	Excellent	Excellent
Camp Pond Brook	Nov 4, 2012	Removal	62885	Excellent	Excellent	Good	n/a	n/a

Data Interpretation

- The following graphs and discussion illustrate significant water quality-related events from July 19 to November 4 in the Voisey's Bay RTWQM 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.

Upper Reid Brook (Outlet from Reid Pond)

- Water temperature ranged from 4.3 °C to 18.1°C during the 2012 deployment season, averaging 11.0°C (Figure 1).
- Water temperatures are at or near seasonal highs shortly after the first deployment. Water temperature peaks in mid-August at 18.1°C. Due to the late deployment start, the water temperature warming trends in the spring months are not captured. Water temperature begins to decrease in late August and continues decreasing into September and October.

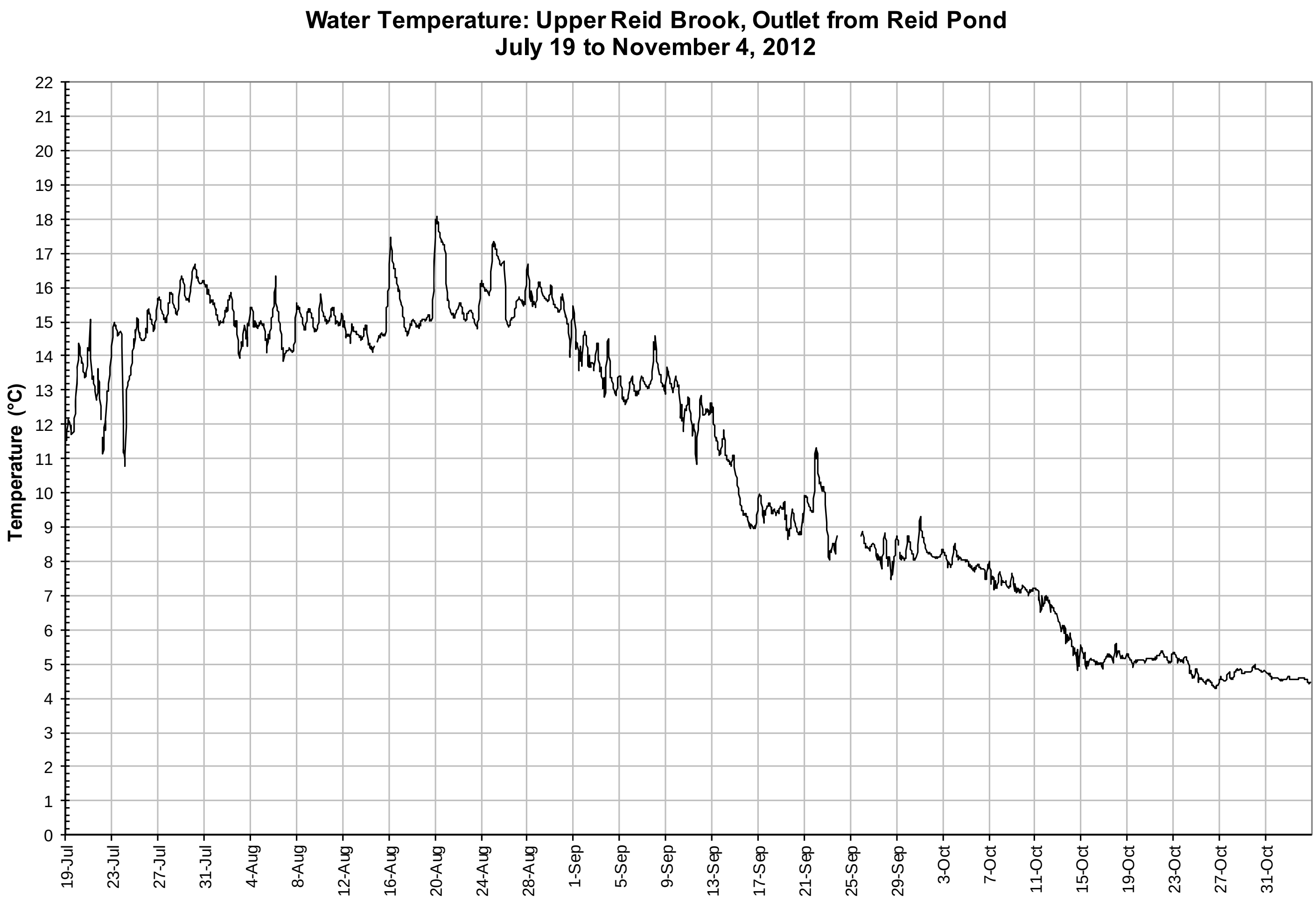

Figure 1: Water temperature at Upper Reid Brook

- 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.

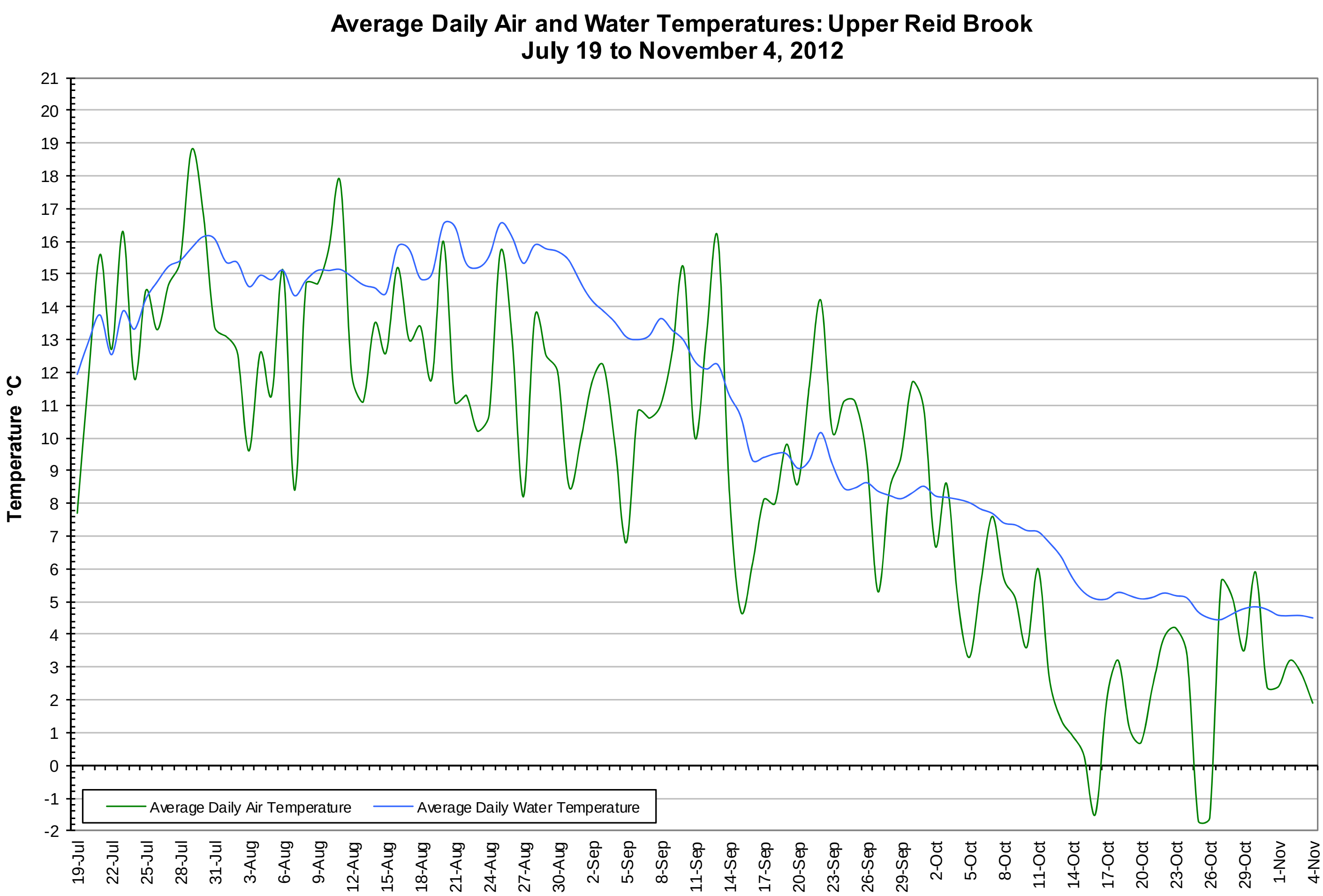

Figure 2: Average daily air and water temperatures at Upper Reid Brook

(weather data recorded at Nain)

- pH ranged between 6.73 and 7.28 pH units throughout the 2012 deployment season, averaging 7.02 pH units (Figure 3).
- pH values at this station are very stable as is expected due to the station's location at the outflow from Reid Pond, a stable lake environment. Regardless of changes in stage, pH values remain stable throughout the entire season.
- All of the pH values are within the range recommended by the CCME Guideline for the Protection of Aquatic Life (>6.5 and <9.0 pH units). Guidelines are indicated in blue on Figure 3.

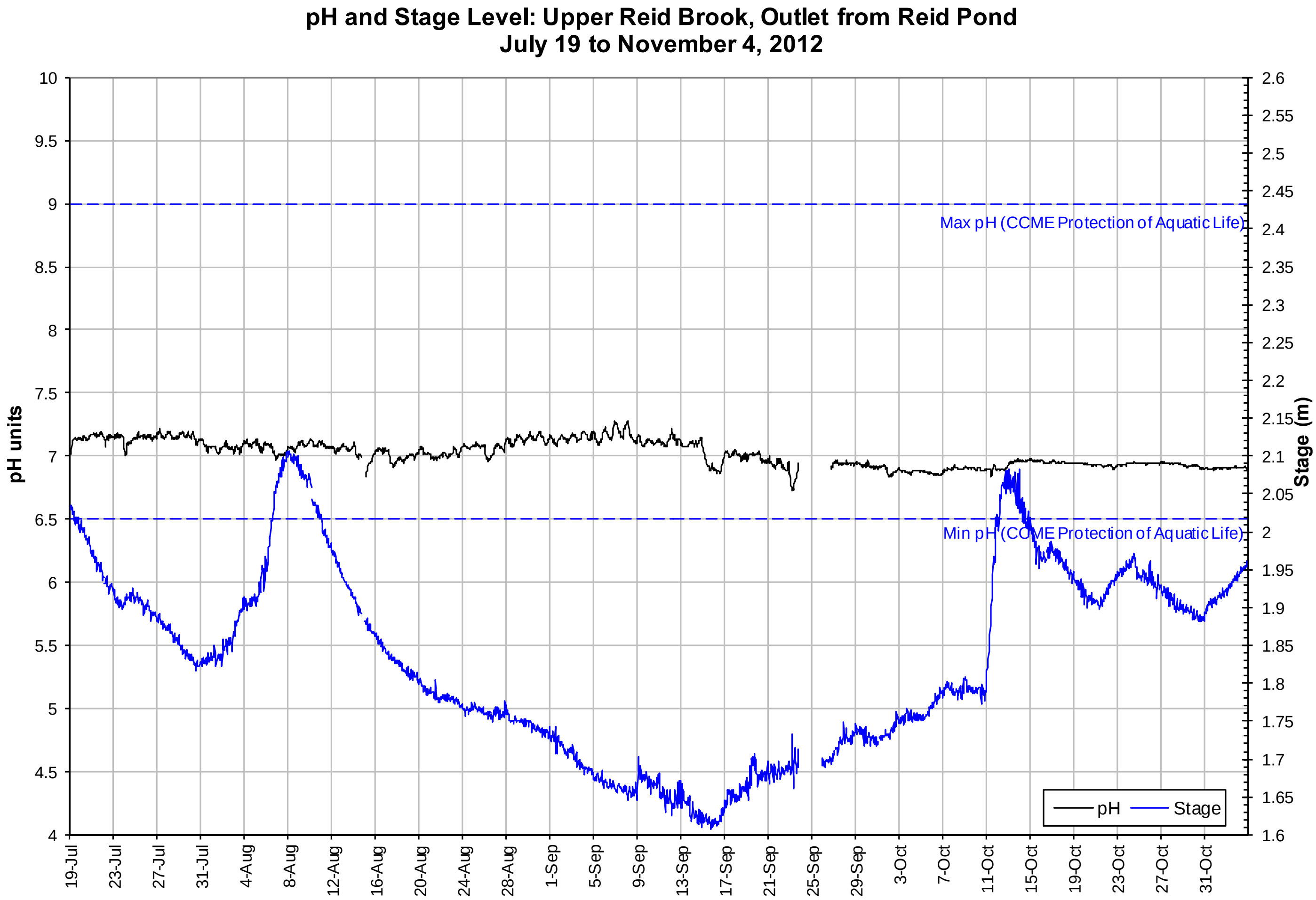

Figure 3: pH and stage level at Upper Reid Brook

- Specific conductivity ranged from 8.8µS/cm to 12.2µS/cm during the deployment season, averaging 10.5µS/cm (Figure 4).
- Specific conductivity is very low and extremely stable throughout the deployment season with minimal fluctuation regardless of the changing water level. This trend is expected as the flow from this station is directly from Reid Pond, stable lake environment.
- There is a clear distinction between each of the three deployment periods due to the recalibration of the instrument at the end of each period. Even though these differences appear large they are minimal increases/decreases (±2 µS/cm). Despite these differences the trends captured by the sensors throughout the deployment period are correct. These trends indicate that specific conductivity values are extremely stable.

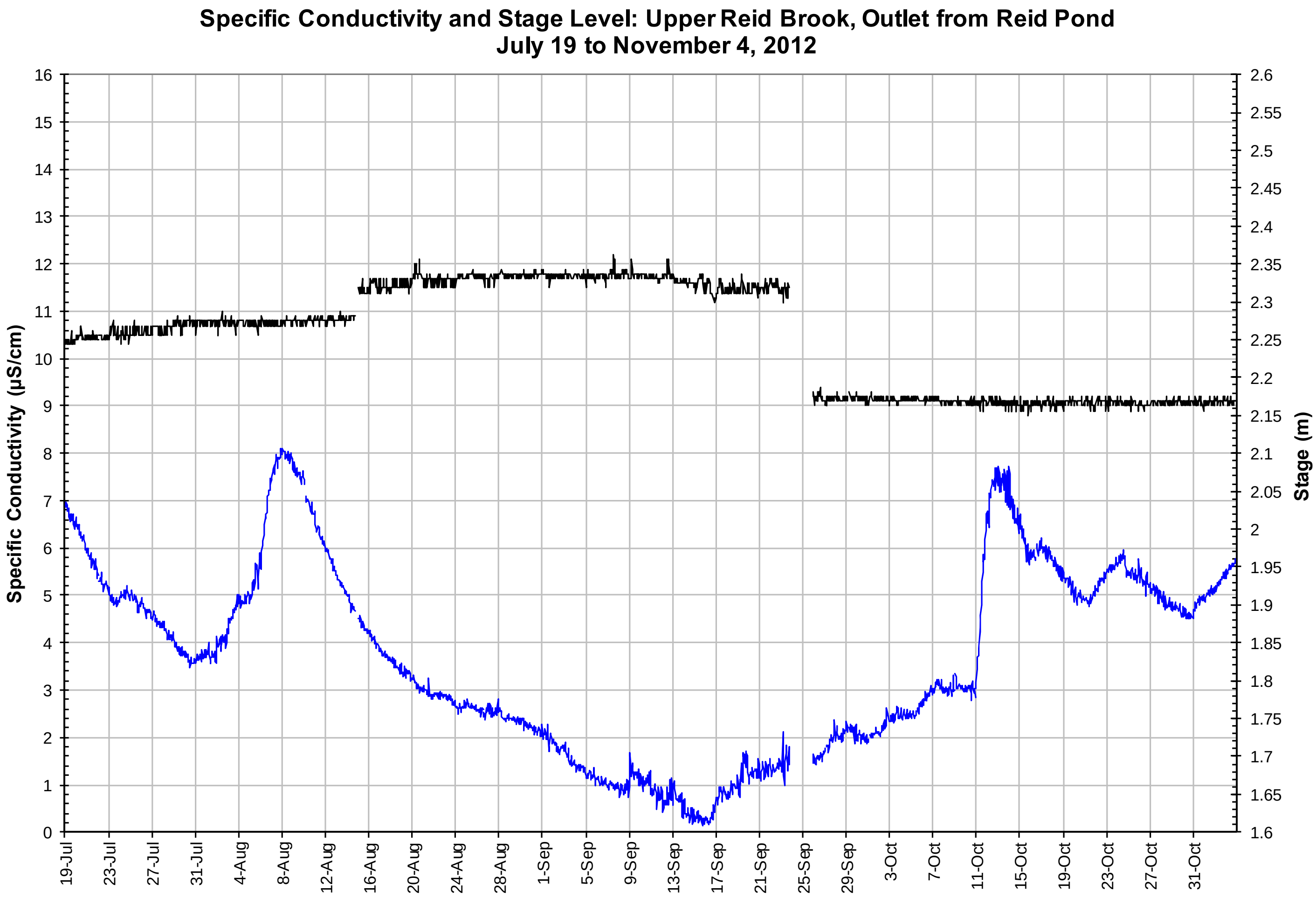

Figure 4: Specific conductivity and stage level at Upper Reid Brook

- Dissolved oxygen content ranged between 9.67mg/l and 12.31mg/l throughout the 2012 deployment season. The saturation of dissolved oxygen ranged from 92.7% to 104.9% (Figure 5).
- Dissolved oxygen content shows a typical seasonal fluctuation in 2012. Because of the late deployment start in 2012, the decreasing trend normally observed in the spring and early summer season is not captured. Dissolved oxygen values are low and consistent through the warmest part of the season and begin to increase in mid to late August as water and air temperatures begin to cool.
- 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 blue on Figure 5. The average dissolved oxygen value was 10.82mg/l.

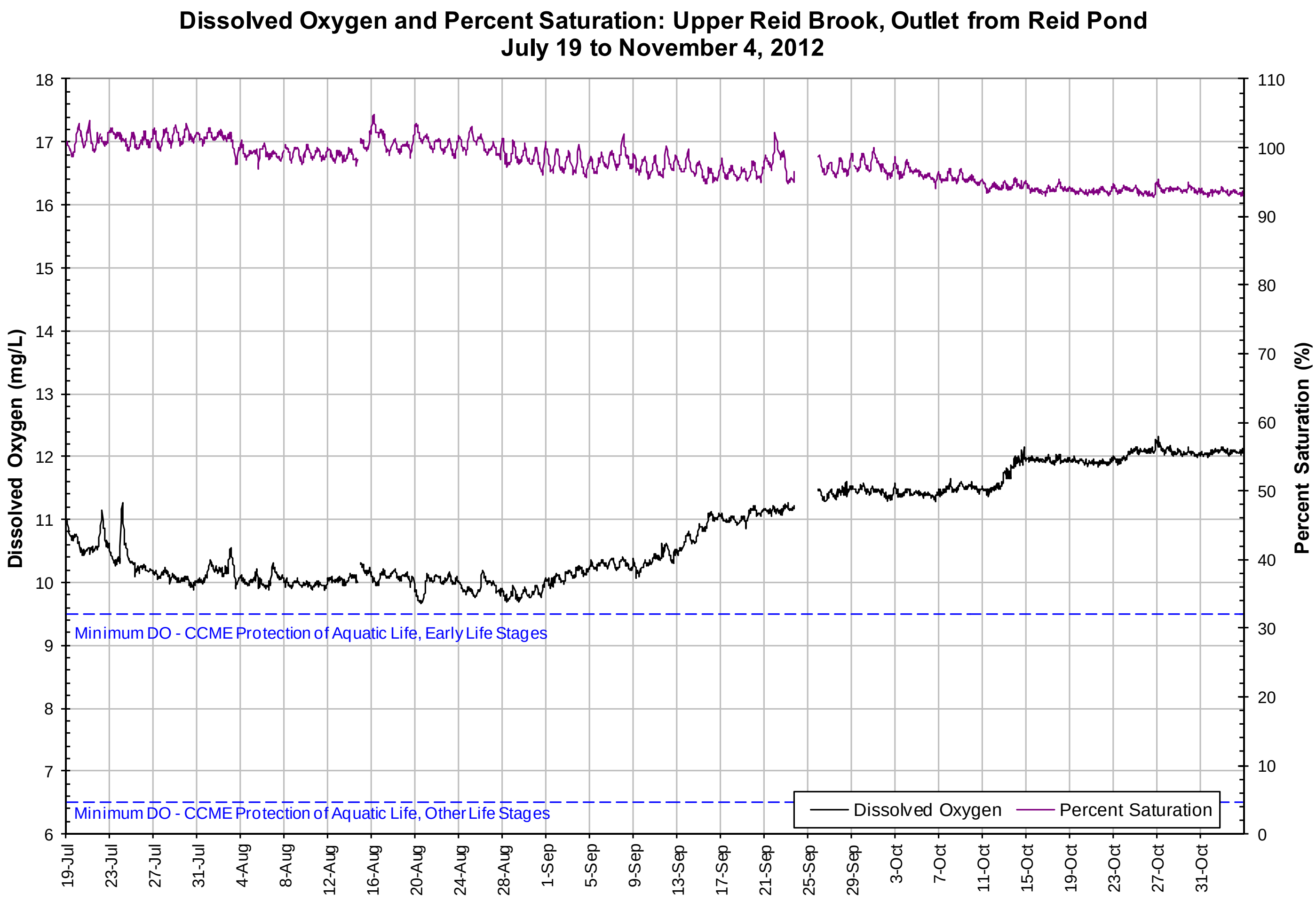

Figure 5: Dissolved oxygen and percent saturation at Upper Reid Brook

- Turbidity generally remains at 0NTU for the entirety of the 2012 deployment season (Figure 6). A median value of 0NTU indicates there is no natural background turbidity value at this station.
- There are a couple of instances where turbidity increases (to as high as 37.7NTU) for very short periods of time (1-3 hours). These are not considered water quality events as they are isolated and infrequent occurrences.

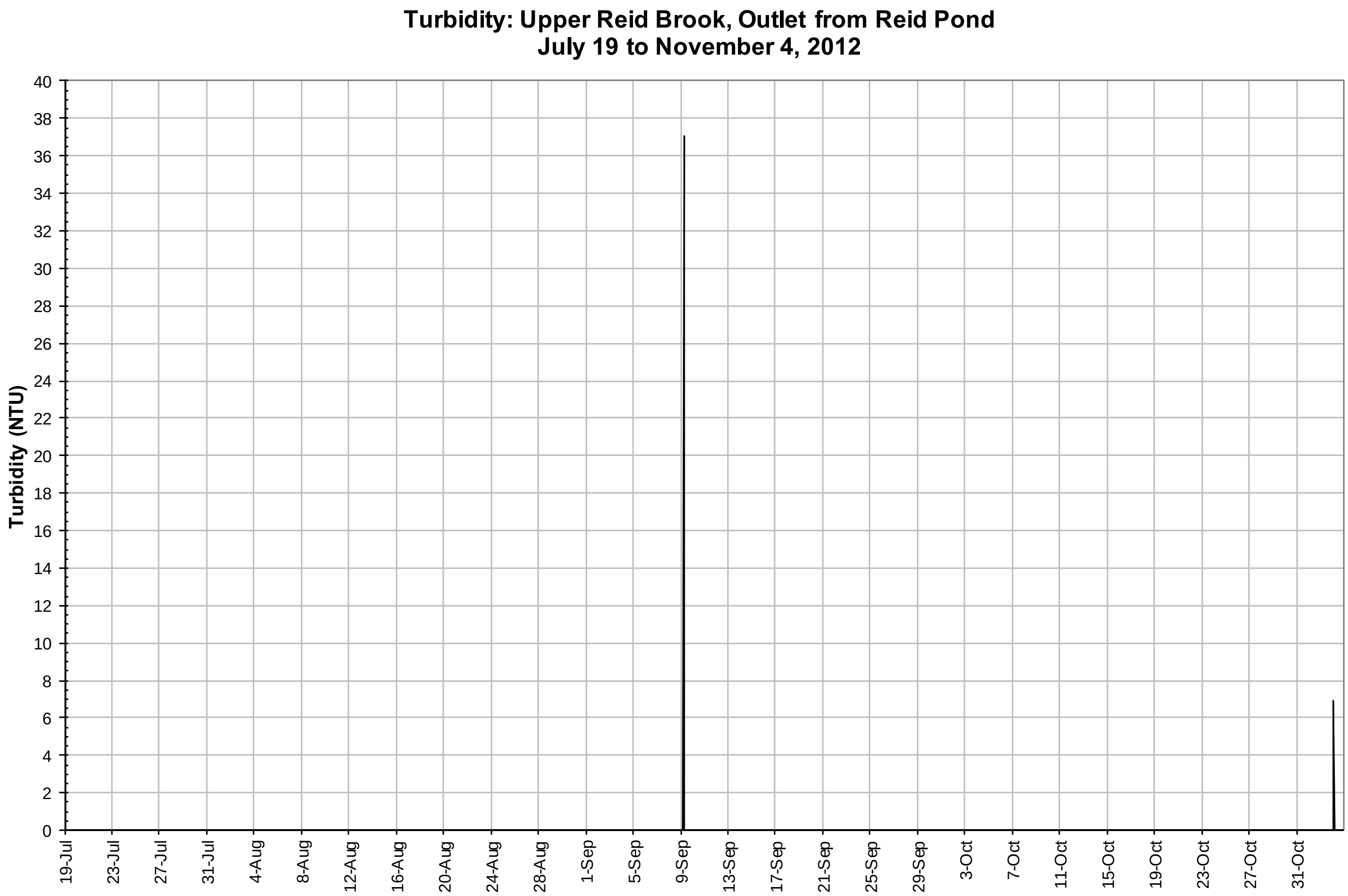

Figure 6: Turbidity at Upper Reid Brook

- Stage and precipitation are graphed below to show the relationship between rainfall and water level (Figure 7).
- Stage is increasing and decreasing at the beginning of the deployment season. Stage levels decrease from a seasonal high of 2.11m to a seasonal low of 1.61m through the month of August and beginning of September. Stage levels increase again from mid-September until mid-October.
- Precipitation events are frequent and moderate in magnitude throughout the deployment season.

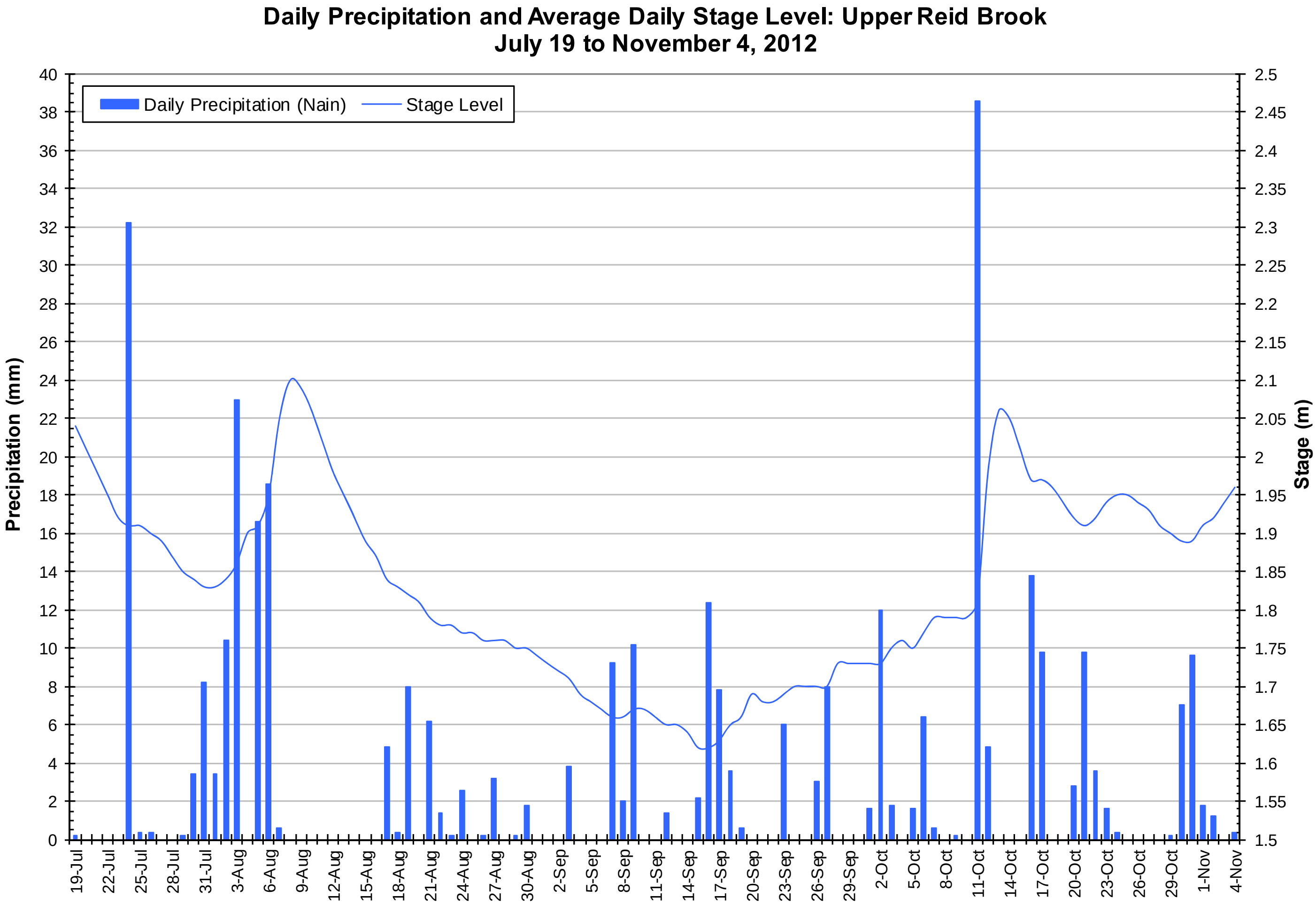

Figure 7: Daily precipitation and average daily stage level at Upper Reid Brook

(weather data recorded at Nain)

Tributary to Lower Reid Brook

- Water temperature ranged from 0.1 °C to 16.3°C during the deployment season, averaging 8.9°C (Figure 8).
- Water temperatures are at or near seasonal highs shortly after the first deployment. Water temperature peaks in mid-August at 16.3°C. Due to the late deployment start, the water temperature warming trends in the spring months are not captured. Water temperature begins to decrease in late August and continues decreasing into September and October.

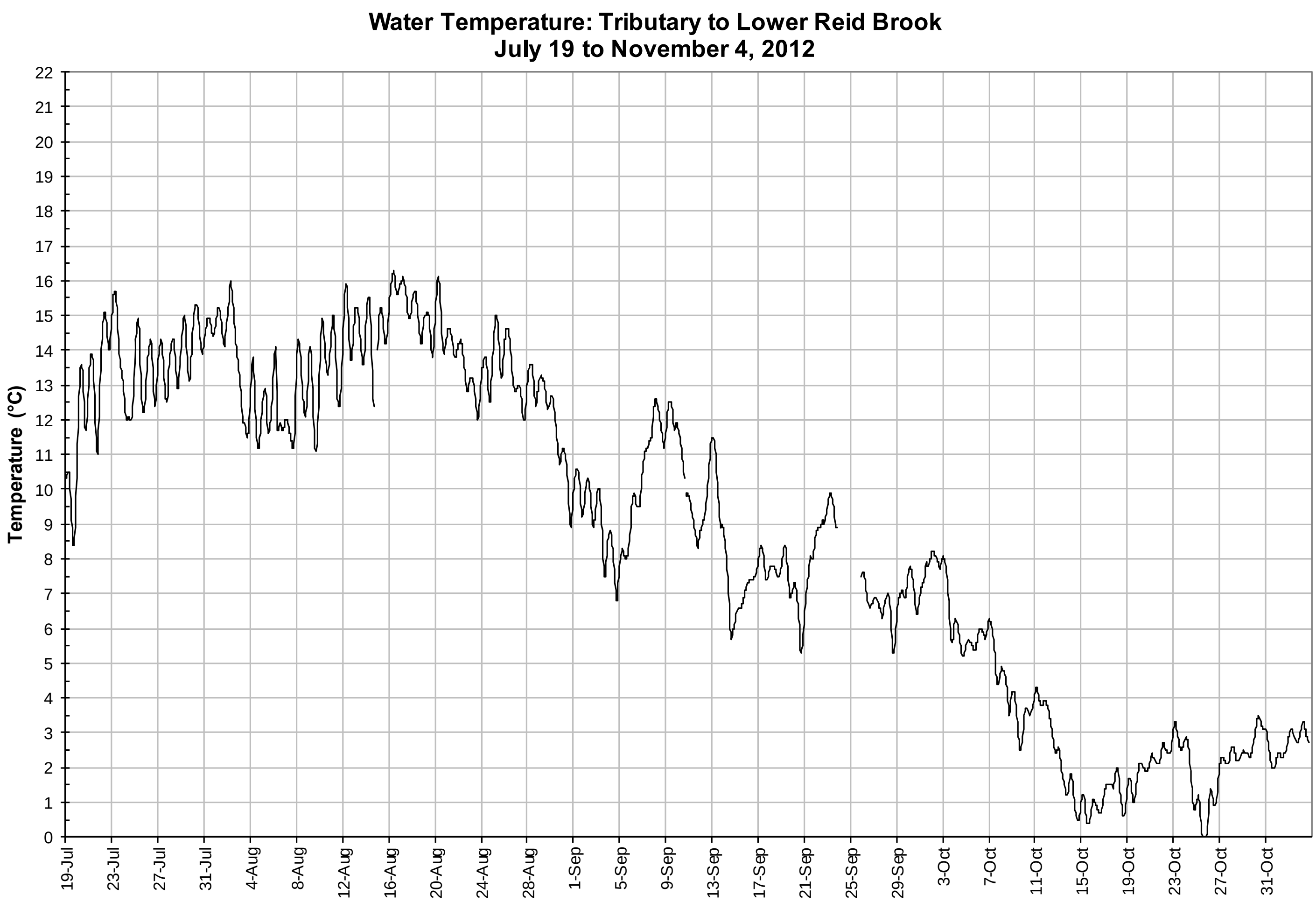

Figure 8: Water temperature at Tributary to Lower Reid Brook

- 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.

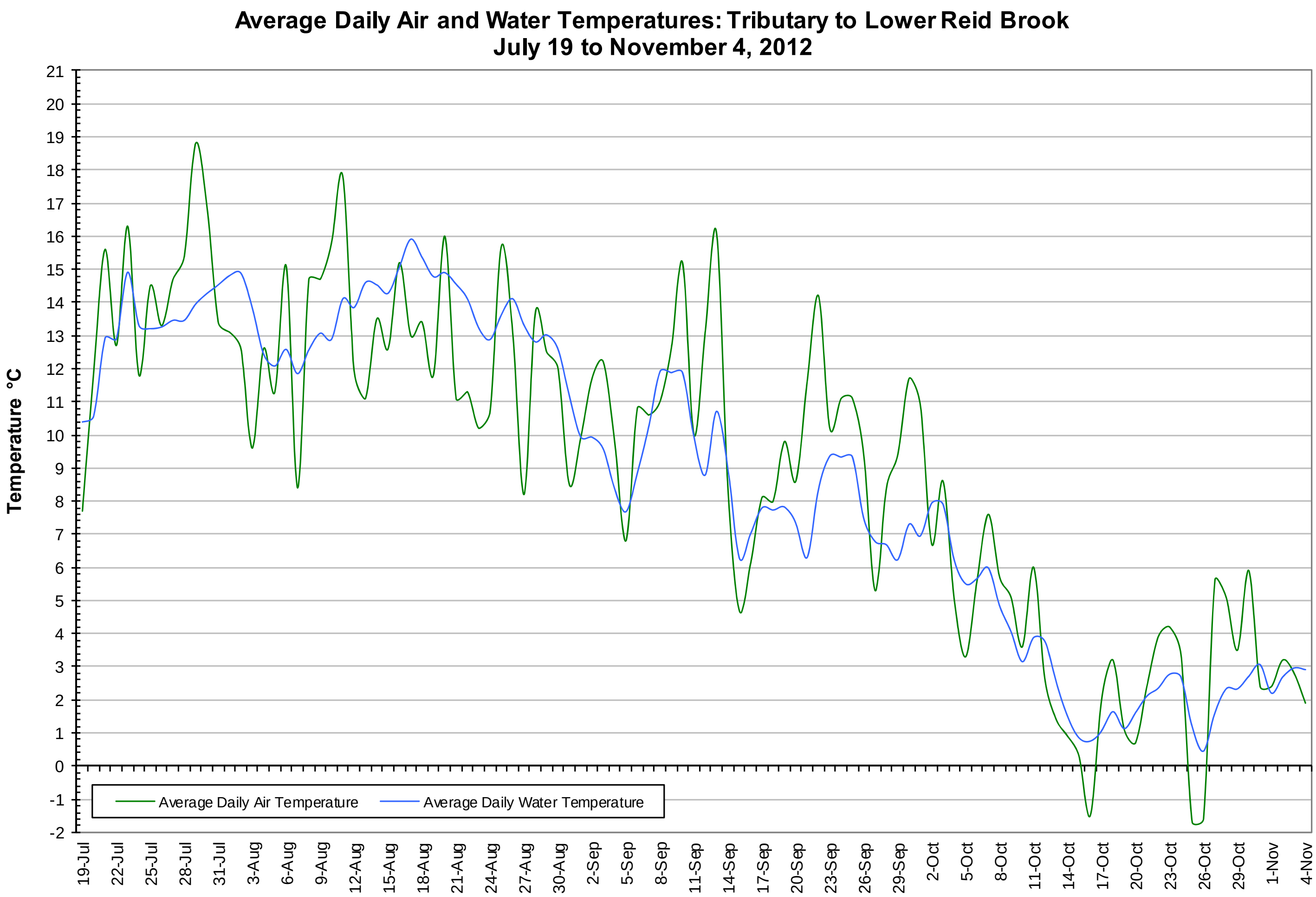

Figure 9: Average daily air and water temperatures at Tributary to Lower Reid Brook

(weather data recorded at Nain)

- pH ranged between 6.06 and 7.17 pH units throughout the deployment season, averaging 6.82 pH units (Figure 10).
- Stage is included on Figure 10 to show the relationship between water level and pH. pH values fluctuate throughout the deployment period with changing water levels. On a number of occasions, pH decreases as stage increases. This trend is experienced throughout the different deployment periods.
- Most values are 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 blue on Figure 10. On some occasions, pH values drop to just below suggested guideline values most often during periods of peak flow. pH values generally increase again in the hours and days following during which time stage levels are decreasing.

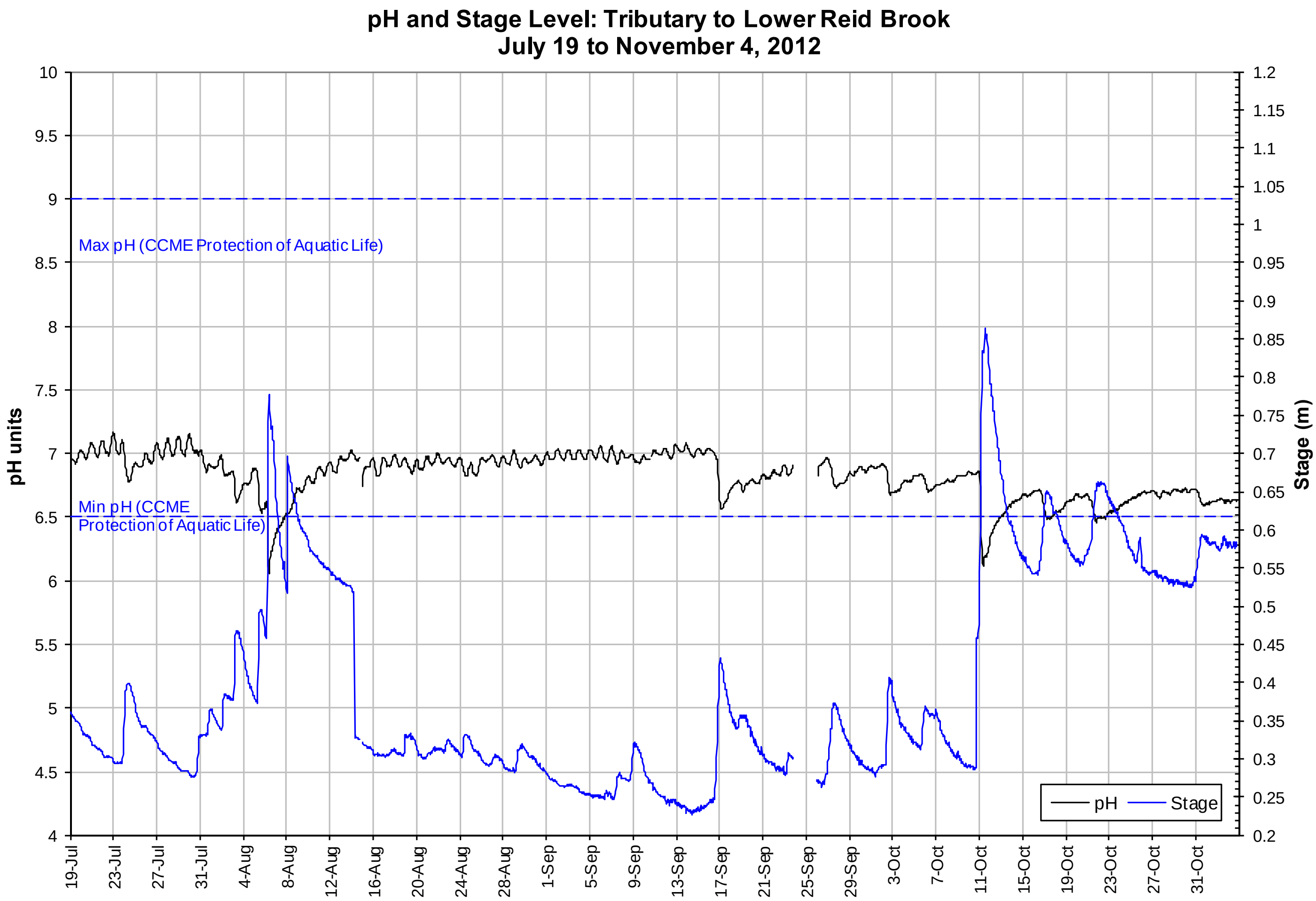

Figure 10: pH and stage level at Tributary to Lower Reid Brook

- Specific conductivity ranged between 17.8µS/cm and 41.4µS/cm throughout the deployment season, averaging 31.7µS/cm (Figure 11).
- Stage is included in Figure 11 to illustrate the inverse relationship between conductivity and water level. Generally, stage fluctuates throughout the deployment season. 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 and decreasing at the beginning of the first deployment period as stage levels also increase and decrease. Specific conductivity values generally increase throughout the month of August during a long period of time when stage levels are low. The relationship between stage levels and specific conductivity levels is very clear at this station throughout the entire deployment season.

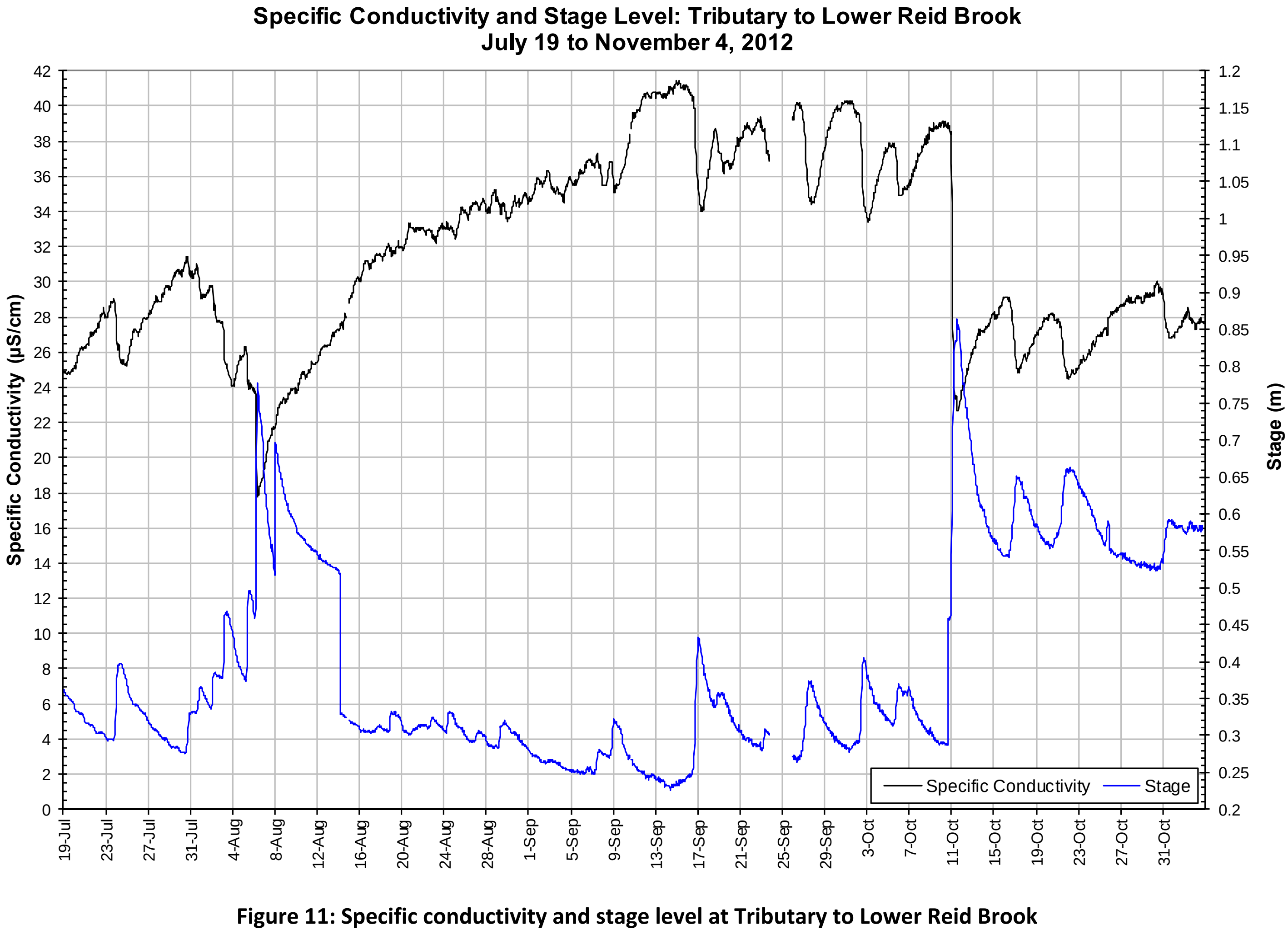

Figure 11: Specific conductivity and stage level at Tributary to Lower Reid Brook

- Dissolved oxygen content ranged between 9.35mg/l and 14.3mg/l, averaging 11.26mg/l. The saturation of dissolved oxygen ranged from 92.1% to 99.1%, averaging 95.9% (Figure 12).
- Dissolved oxygen content shows a typical seasonal trend, inverse to water temperature. Values are stable and low following the late deployment in mid-July. As water temperatures decrease in the late summer and early fall, dissolved oxygen content begins to increase.
- All values were above the minimum CCME Guideline for the Protection of Cold Water Biota at Other Life Stages (6.5mg/l). Almost all values were above the CCME Guideline for the Protection of Aquatic Life at Early Life Stages (9.5mg/l). On a few occasions, during periods of warm air and water conditions, dissolved oxygen contents dropped to just below the suggested guideline. The guidelines are indicated in blue on Figure 12.

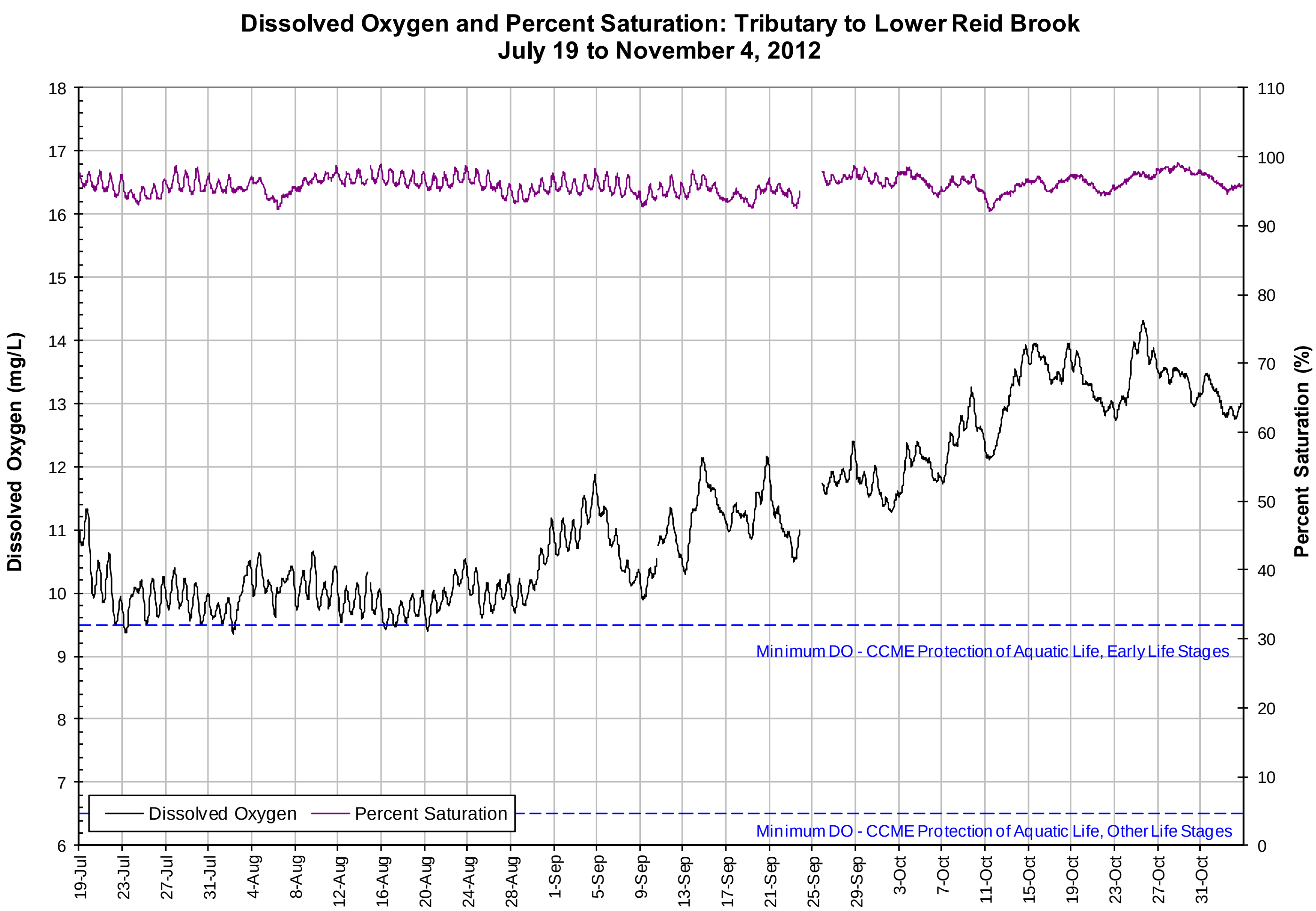

Figure 12: Dissolved oxygen and percent saturation at Tributary to Lower Reid Brook

- Turbidity ranges between 0NTU and 161NTU during the 2012 deployment season (Figure 13). A median value of 0NTU indicates there is no natural background turbidity value at this station.
- There are a number of turbidity events throughout the three deployment periods from July to November. Many of these increases correspond with rainfall events as indicated in the monthly deployment reports. Turbidity trends are similar throughout the deployment season.

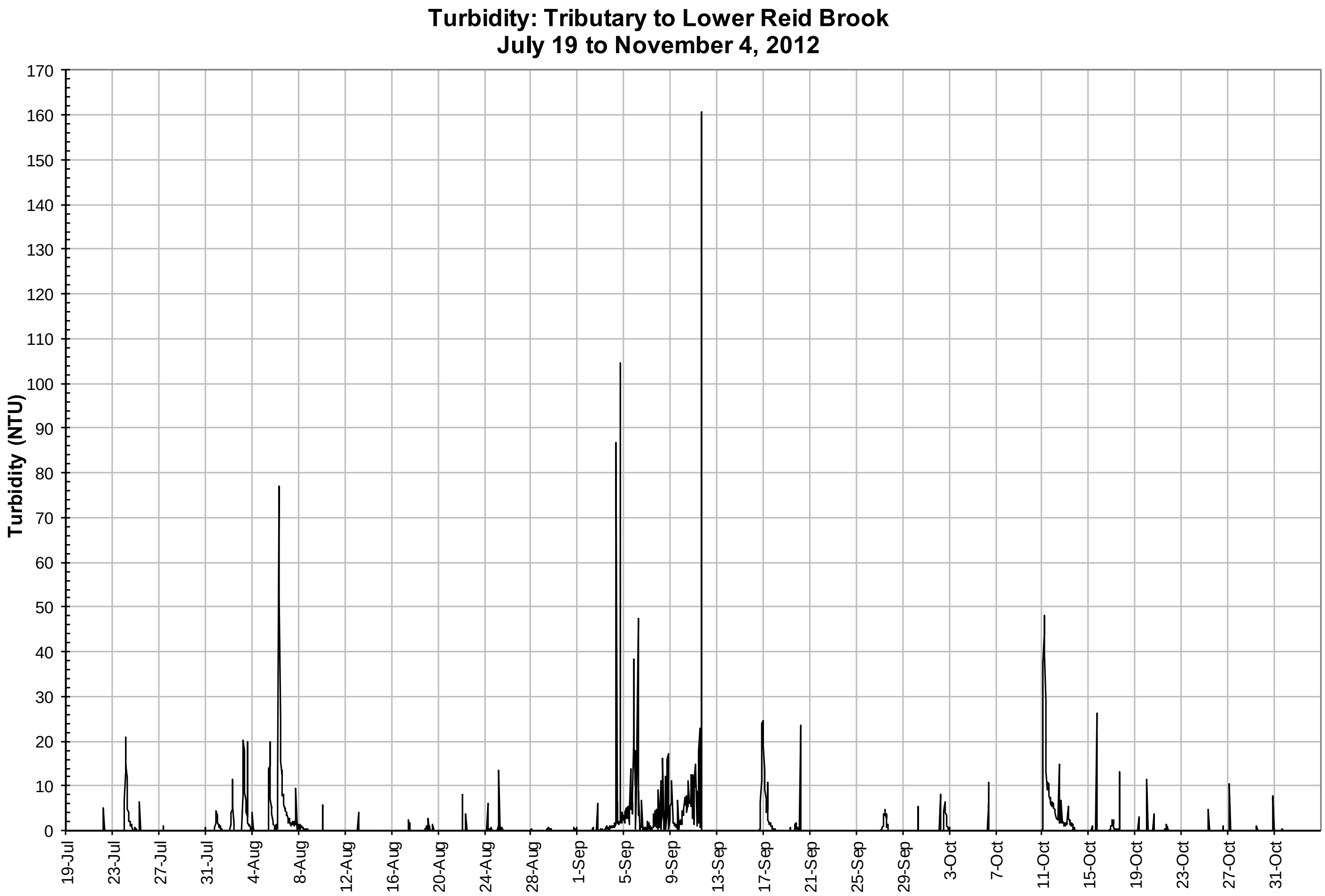

Figure 13: Turbidity at Tributary to Lower Reid Brook

- Stage and precipitation are graphed below to show the relationship between rainfall and water level (Figure 14).
- Stage levels are stable at the time of deployment in mid-July. Water levels increase sharply at the beginning of August following several days of precipitation. Stage levels then decrease sharply and remain low through the majority of the deployment season until increasing again in mid-October following another significant rainfall event.
- Precipitation events are frequent and moderate in magnitude throughout the deployment season.

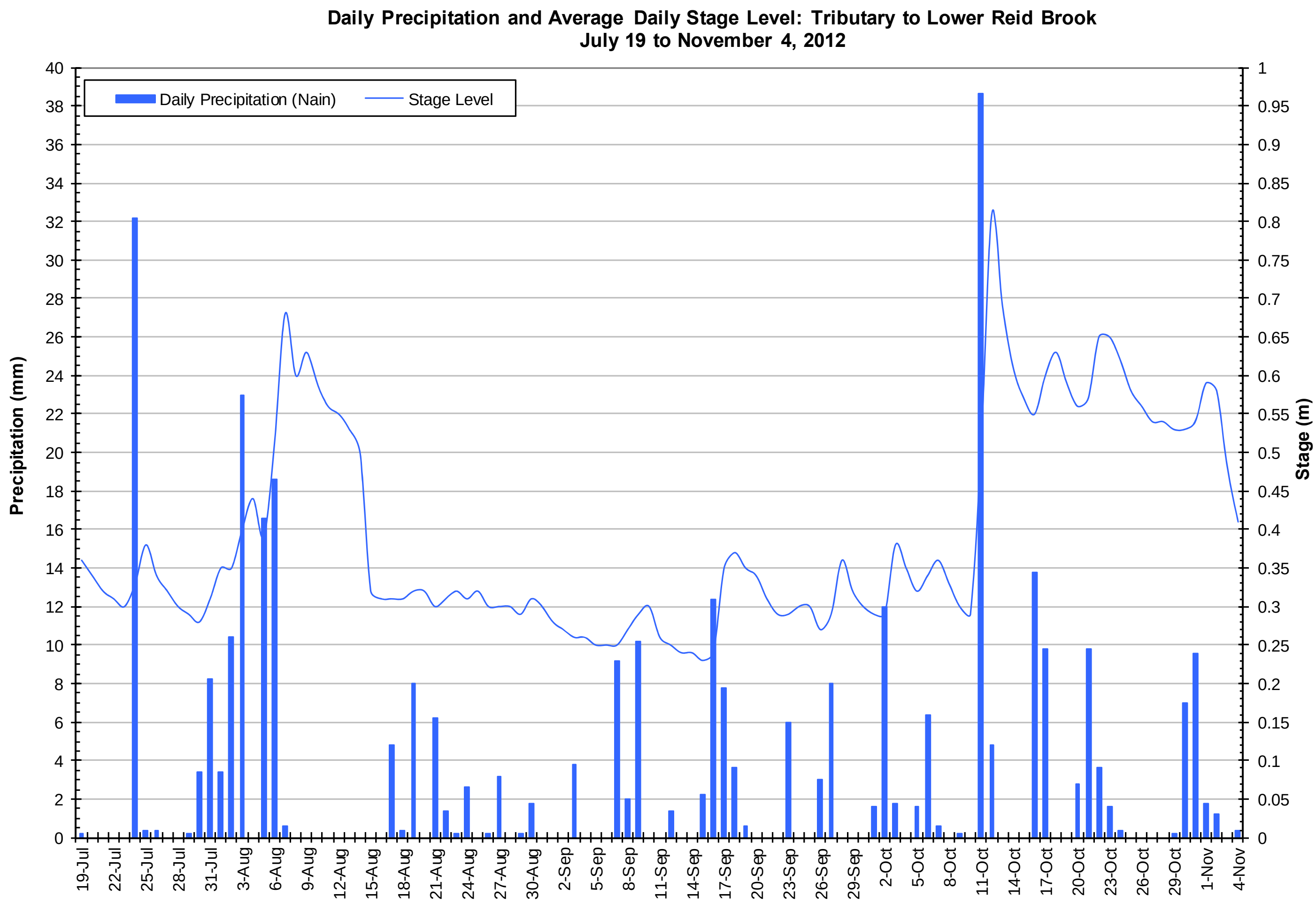

Figure 14: Average Daily Stage and Daily Precipitation at Tributary to Lower Reid Brook

Lower Reid Brook

- Water temperature ranged from 0.04 °C to 16.8°C during the deployment season, averaging 9.2°C (Figure 15).
- Water temperatures are at or near seasonal highs shortly after the first deployment. Water temperature peaks in late August at 16.8°C. Due to the late deployment start, the water temperature warming trends in the spring months are not captured. Water temperature begins to decrease in late August and continues decreasing into September and October.

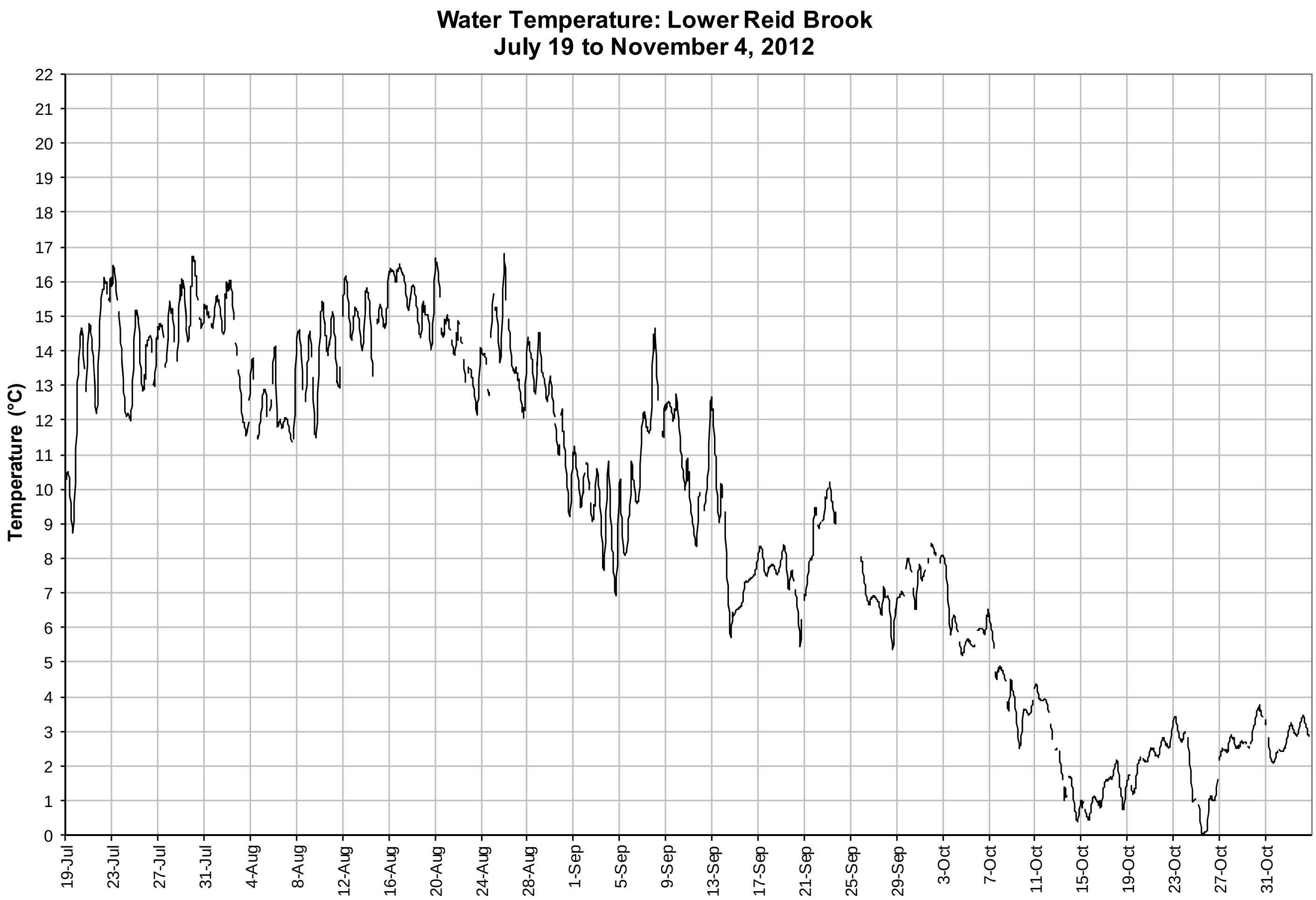

Figure 15: Water temperature at Lower Reid Brook

- 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.

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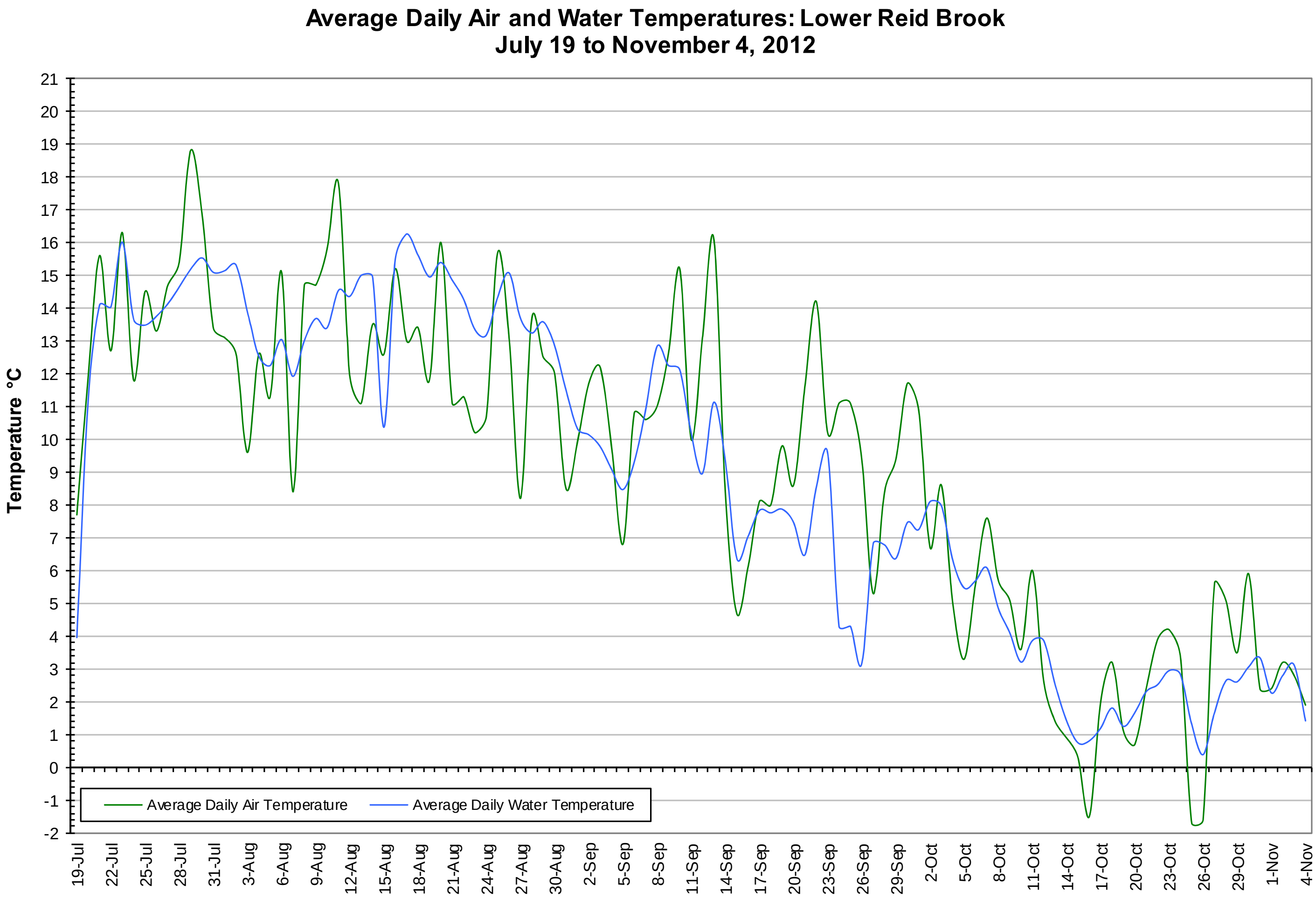


Figure 16: Average daily air and water temperatures at Lower Reid Brook

(weather data recorded at Nain)

- pH ranged between 6.21 and 7.49 pH units during the deployment season, averaging 6.99 pH units (Figure 17).
- Most values are 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 blue on Figure 17. On some occasions, pH values drop to just below suggested guideline values most often during periods of peak flow. pH values generally increase again in the hours and days following during which time stage levels are decreasing.
- Stage is included on Figure 17 to show the relationship between water level and pH. pH values fluctuate throughout the deployment period with changing water levels. On a number of occasions, pH decreases as stage increases. This trend is experienced throughout the different deployment periods.

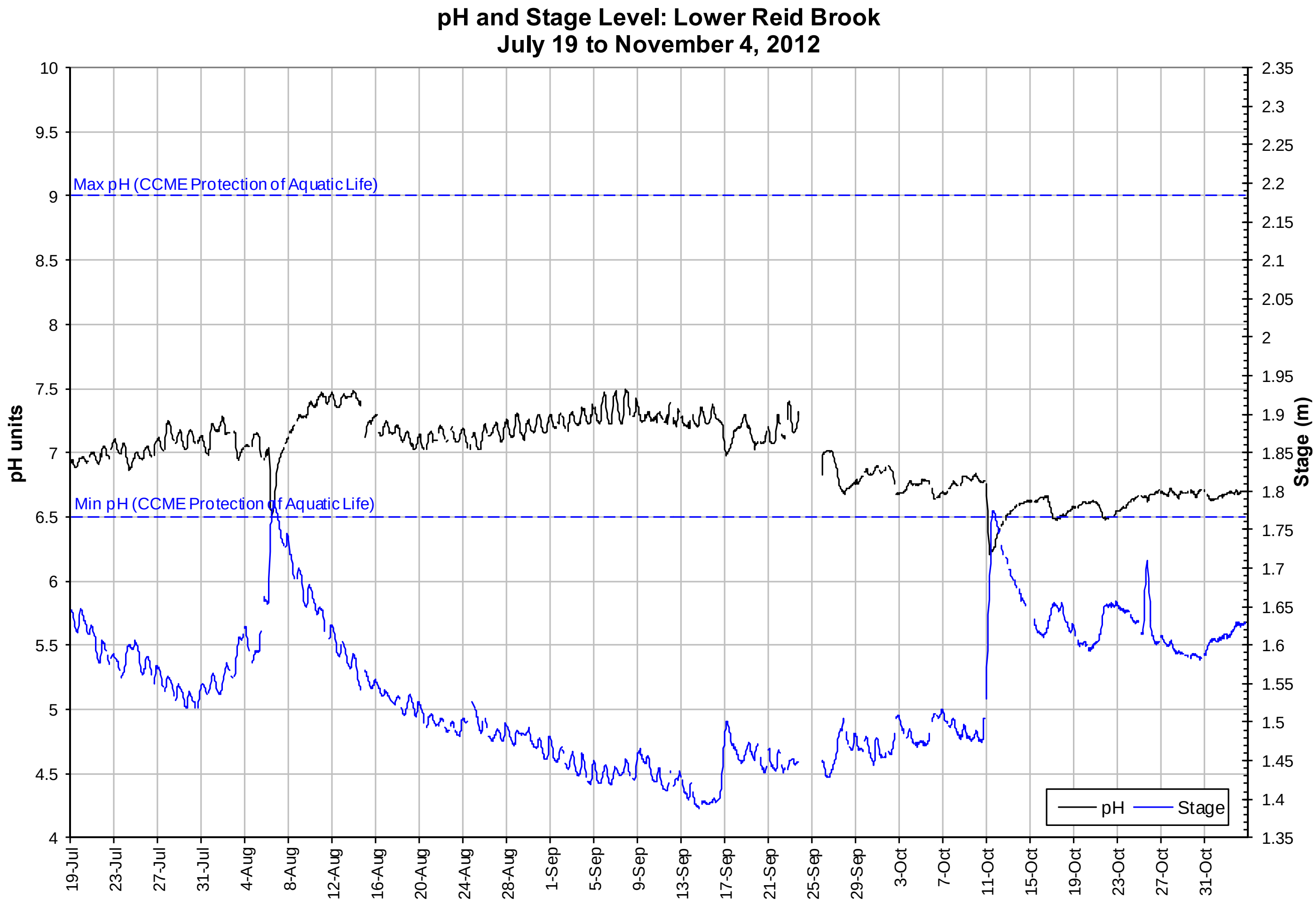


Figure 17: pH and stage level at Lower Reid Brook

- Specific conductivity ranged between 18.0µS/cm and 40.1µS/cm during the deployment season, averaging 30.3µS/cm (Figure 18).
- Stage is included in Figure 18 to illustrate the inverse relationship between conductivity and water level. Generally, stage fluctuates throughout the deployment season. 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 decreasing and increasing at the beginning of the first deployment period as stage levels increase and decrease. Specific conductivity values generally increase throughout the month of August during a long period of time when stage levels are low. The relationship between stage levels and specific conductivity levels is very clear at this station throughout the entire deployment season.

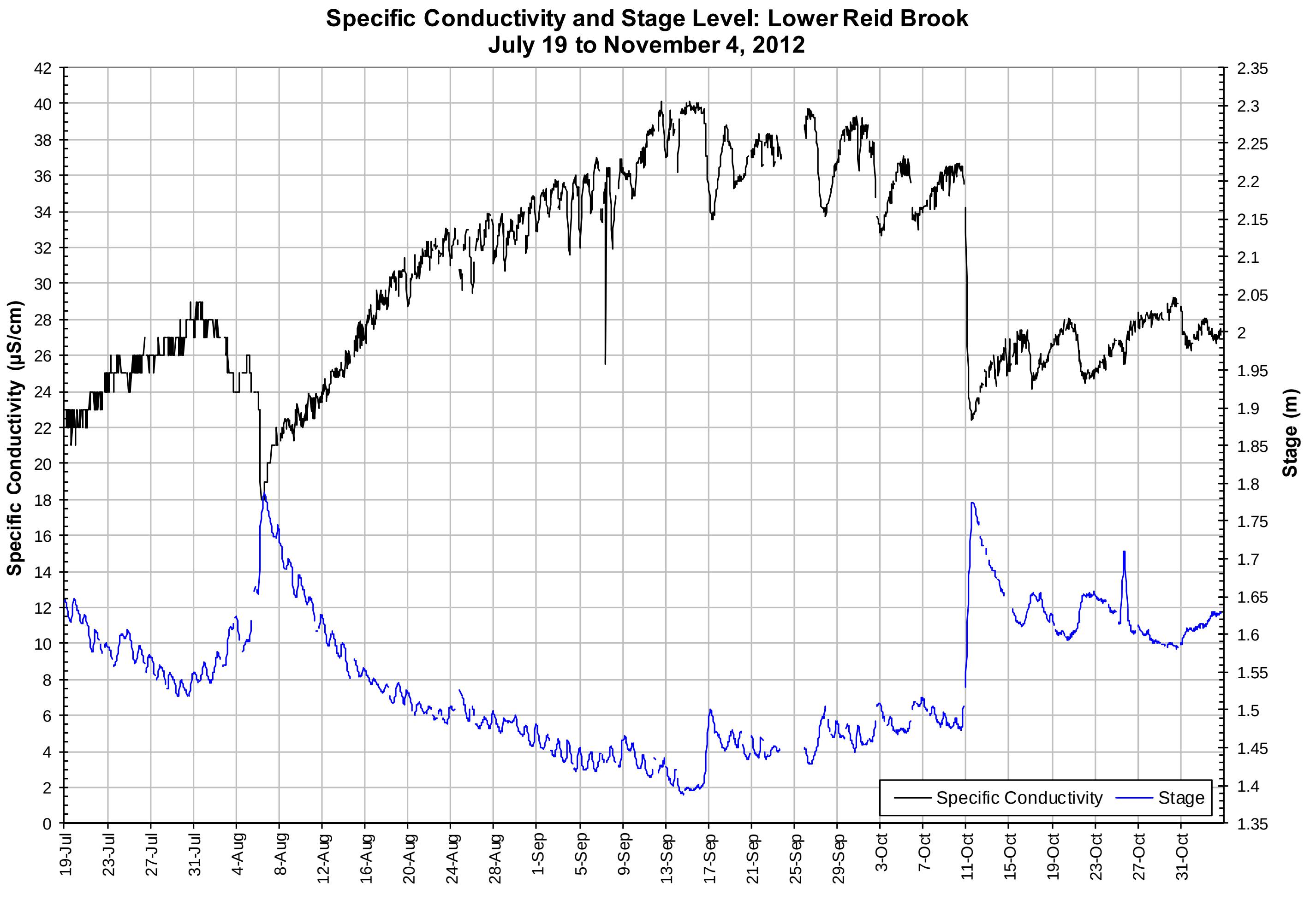


Figure 18: Specific conductivity and stage level at Lower Reid Brook

- Dissolved oxygen content ranged between 9.36mg/l and 14.5mg/l, averaging 11.35mg/l. The saturation of dissolved oxygen ranged from 89.9% to 102.9%, averaging 97.4% (Figure 19).
- Dissolved oxygen content shows a typical seasonal trend, inverse to water temperature. Values are stable and low following the late deployment in mid-July. As water temperatures decrease in the late summer and early fall, dissolved oxygen content begins to increase.
- All values were above the minimum CCME Guideline for the Protection of Cold Water Biota at Other Life Stages (6.5mg/l). Almost all values were above the CCME Guideline for the Protection of Aquatic Life at Early Life Stages (9.5mg/l). On a few occasions, during periods of warm air and water conditions, dissolved oxygen contents dropped to just below the suggested guideline. The guidelines are indicated in blue on Figure 19.

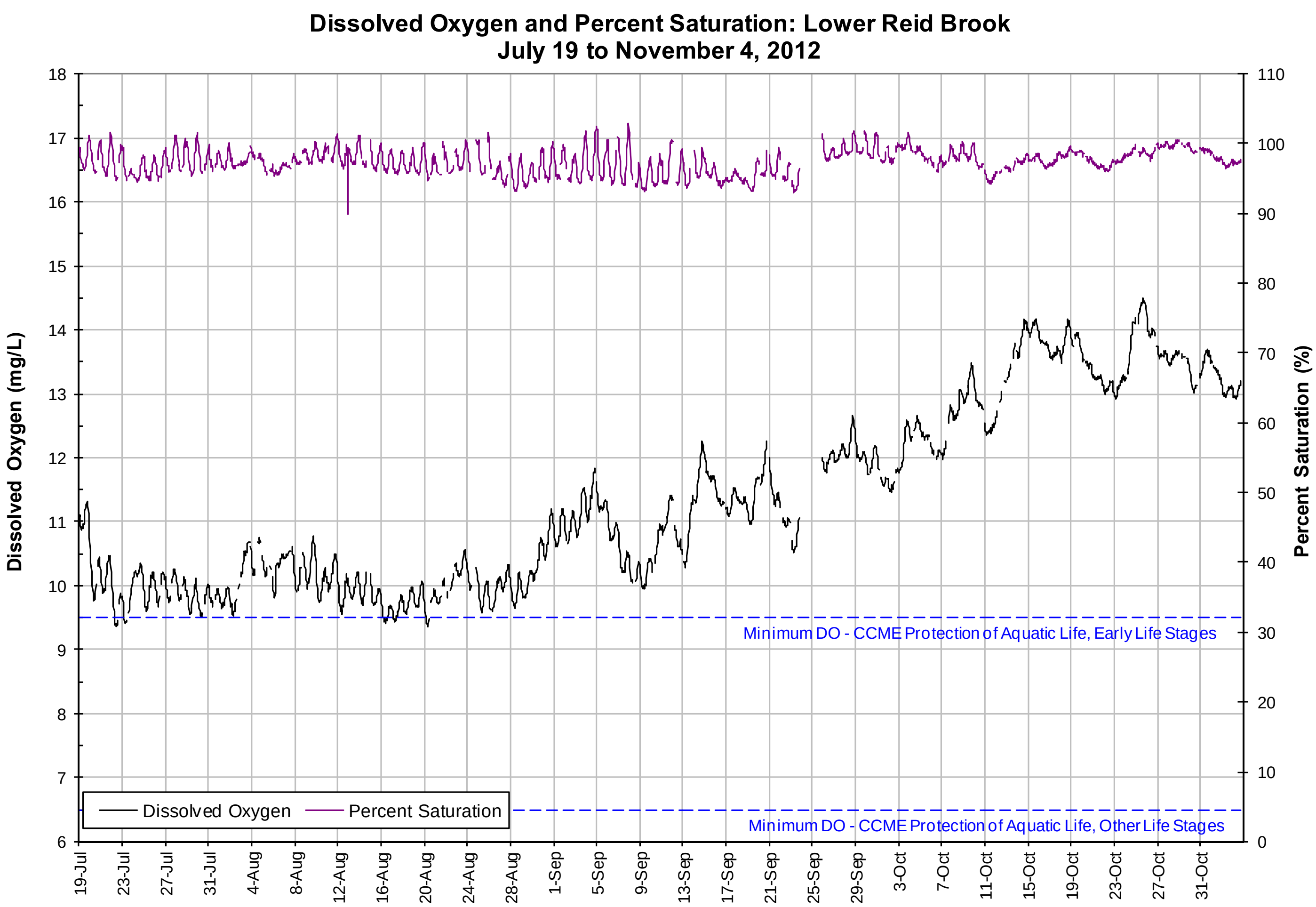


Figure 19: Dissolved oxygen and percent saturation at Lower Reid Brook

- Turbidity ranges between 0NTU and 81.9NTU during the 2012 deployment season (Figure 20). A median value of 0NTU indicates there is no natural background turbidity value at this station.
- There are a number of turbidity events throughout the three deployment periods from July to November, none of which last in excess of 24 hours. Many of these increases correspond with rainfall events as indicated in the monthly deployment reports. Turbidity trends are similar throughout the deployment season.

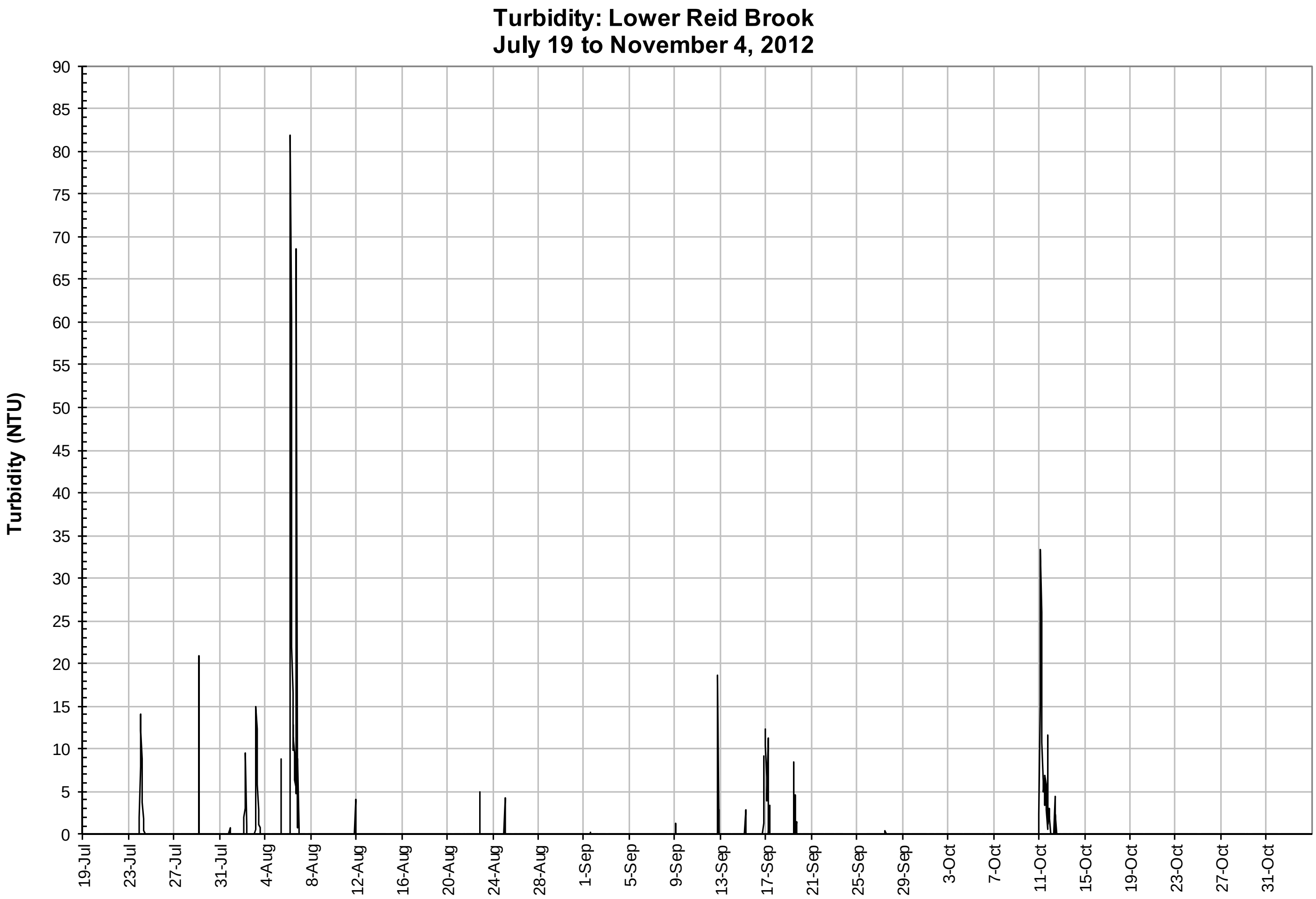


Figure 20: Turbidity at Lower Reid Brook

- Stage and precipitation are graphed below to show the relationship between rainfall and water level (Figure 21).
- Stage levels are decreasing slightly at the time of deployment in mid-July. Water levels increase sharply at the beginning of August following several days of precipitation. Stage levels then decrease sharply and remain low through the majority of the deployment season until increasing again in mid-October following another significant rainfall event.
- Precipitation events are frequent and moderate in magnitude throughout the deployment season.

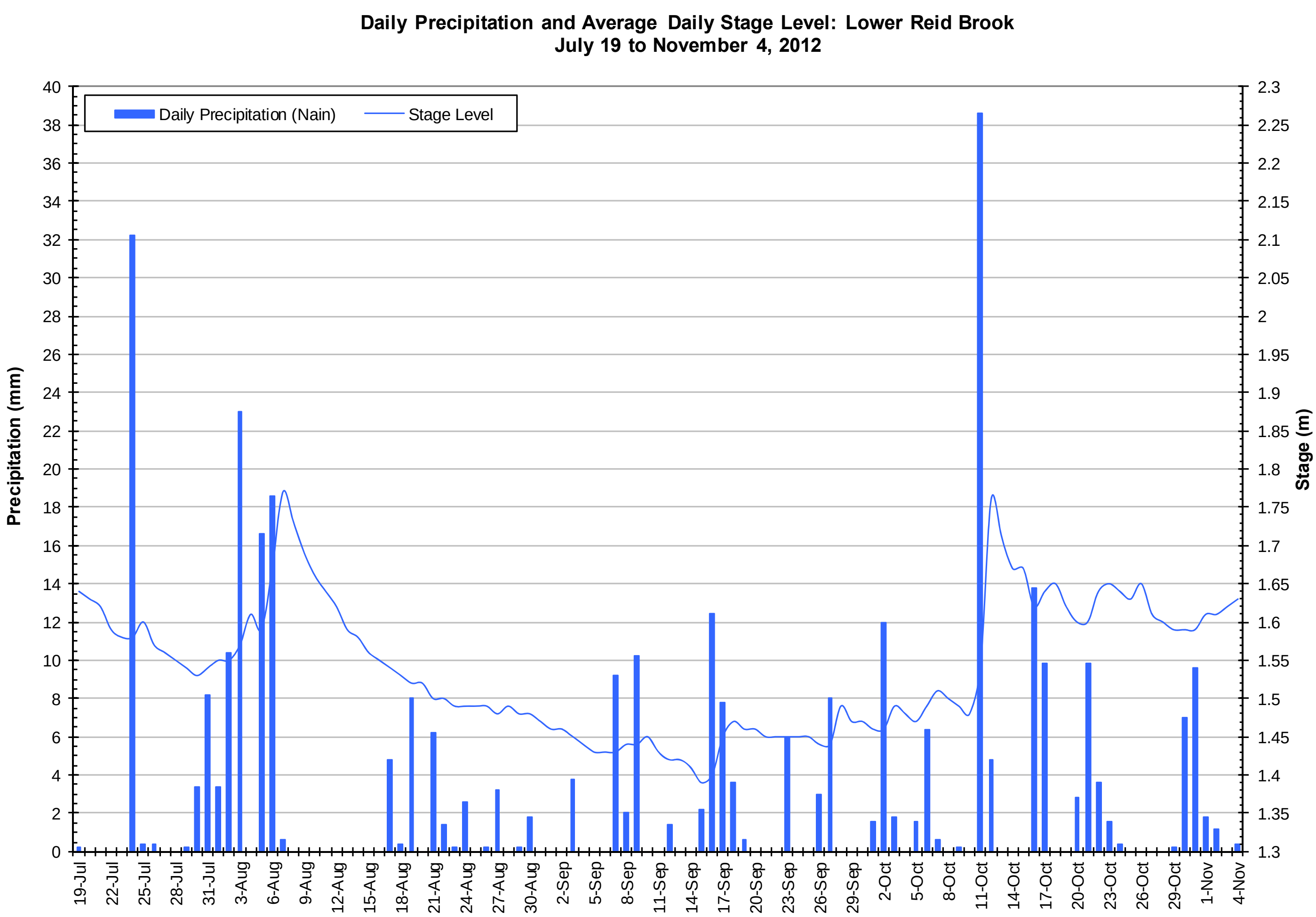


Figure 21: Daily precipitation and average daily stage level at Lower Reid Brook

(weather data recorded at Nain)

Camp Pond Brook

- Water temperature ranged from 0.1 °C to 20.7°C during the deployment season, averaging 10.9°C (Figure 22).
- Water temperatures are at or near seasonal highs shortly after the first deployment. Water temperature peaks in mid-August at 20.7°C. Due to the late deployment start, the water temperature warming trends in the spring months are not captured. Water temperature begins to decrease in late August and continues decreasing into September and October.

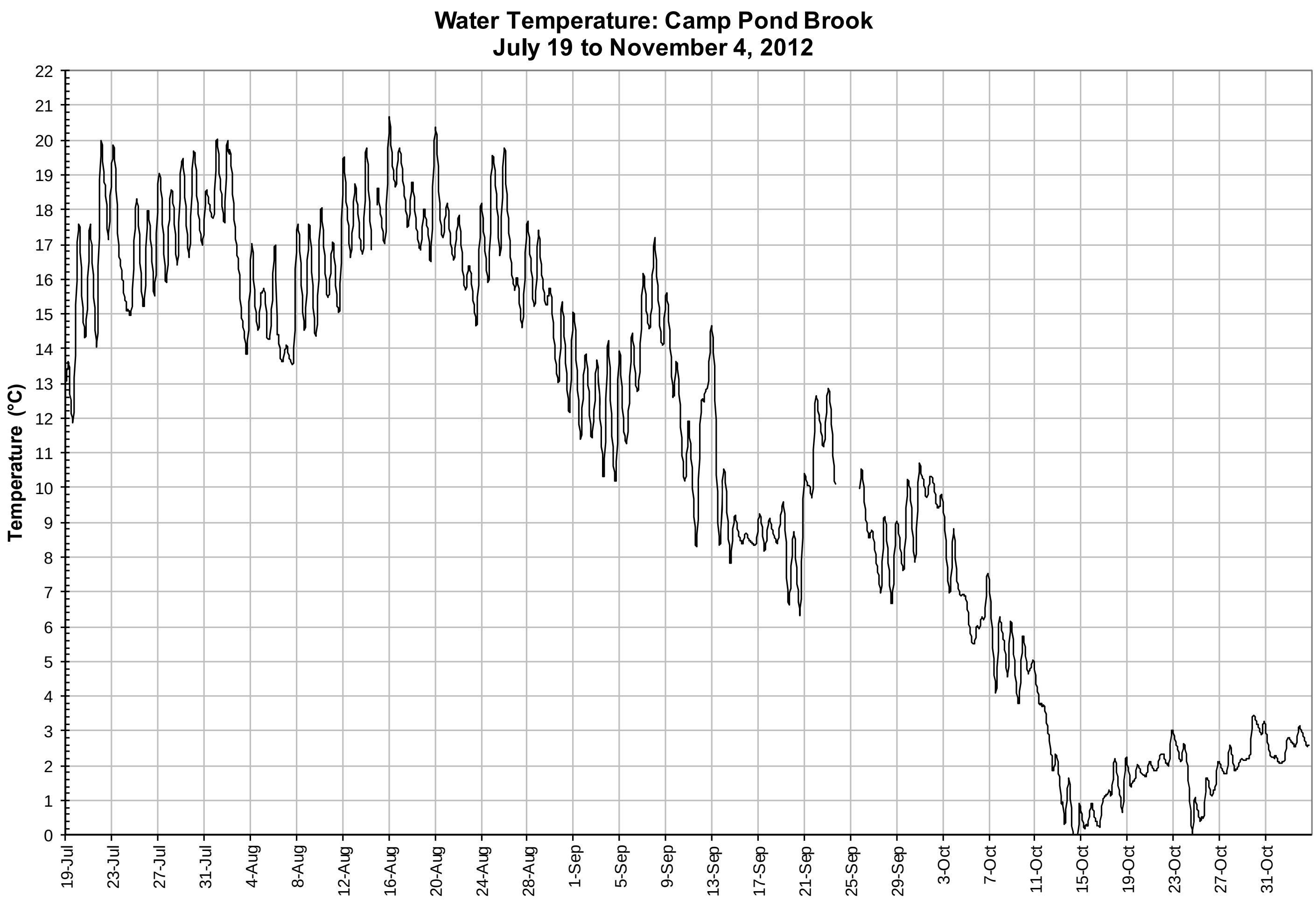


Figure 22: Water temperature at Camp Pond Brook

- 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.
- A large part of the data for stage is missing due to a transmission error at the station. Stage appears to be fluctuating at the beginning and the end of the deployment season. Based on the patterns in stage levels at the surrounding stations, it can be assumed the stage levels fluctuated similarly to station on Tributary to Lower Reid Brook and Lower Reid Brook.

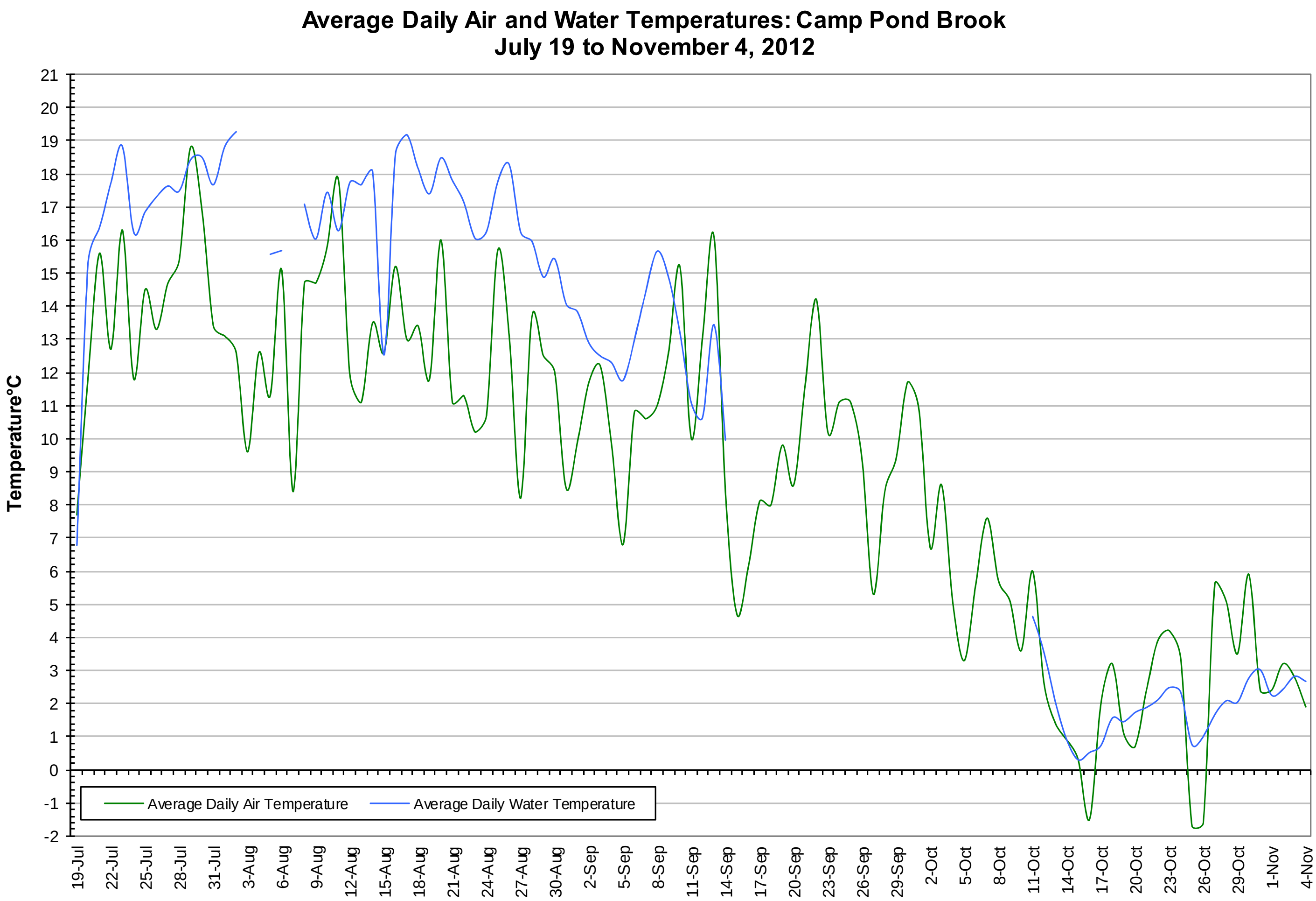


Figure 23: Average daily air and water temperatures at Camp Pond Brook

(weather data recorded at Nain)

- pH ranged between 6.75 and 7.44 pH units during the deployment season, averaging 7.14 pH units (Figure 24).
- pH values are generally stable with daily fluctuations throughout the deployment season.
- Stage is included on Figure 24 to show the relationship between water level and pH. A large part of the data for stage is missing due to a transmission error at the station. There is no significant relationship between water level and pH at this station during this time period.
- All values are 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 blue on Figure 24.

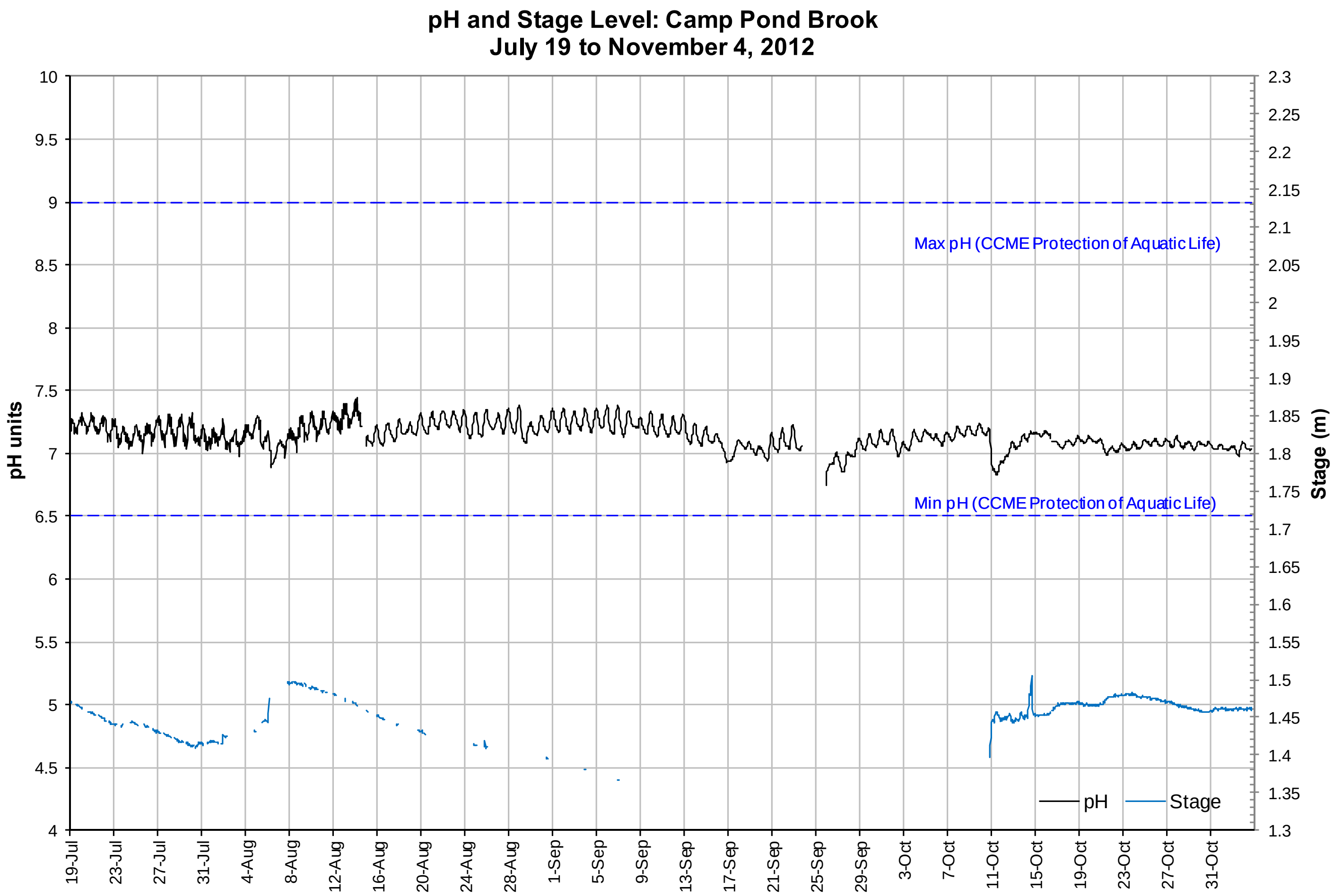


Figure 24: pH and stage level at Camp Pond Brook

- Specific conductivity ranged from 30.0µS/cm to 59.2µS/cm during the deployment season, averaging 35.4µS/cm (Figure 25).
- Stage is included in Figure 25 to illustrate the inverse relationship between conductivity and water level. A large part of the data for stage is missing due to a transmission error at the station. Stage appears to be fluctuating at the beginning and the end of the deployment season. Based on the patterns in stage levels at the surrounding stations, it can be assumed the stage levels fluctuated similarly to station on Tributary to Lower Reid Brook and Lower Reid Brook.
- Typically, stage level increases cause decreases in the specific conductivity of the water by diluting the concentrations of dissolved solids present in the water column. However, at this station, historic trends show an increase in specific conductivity when stage increases.
- Specific conductivity is increasing and decreasing at the beginning of the first deployment period as stage levels decrease and increase. Specific conductivity values are increasing slightly throughout the month of August during a long period of time when stage data is unavailable. There are a number of sharp spikes in specific conductivity, many of which correspond to rainfall events throughout the season.

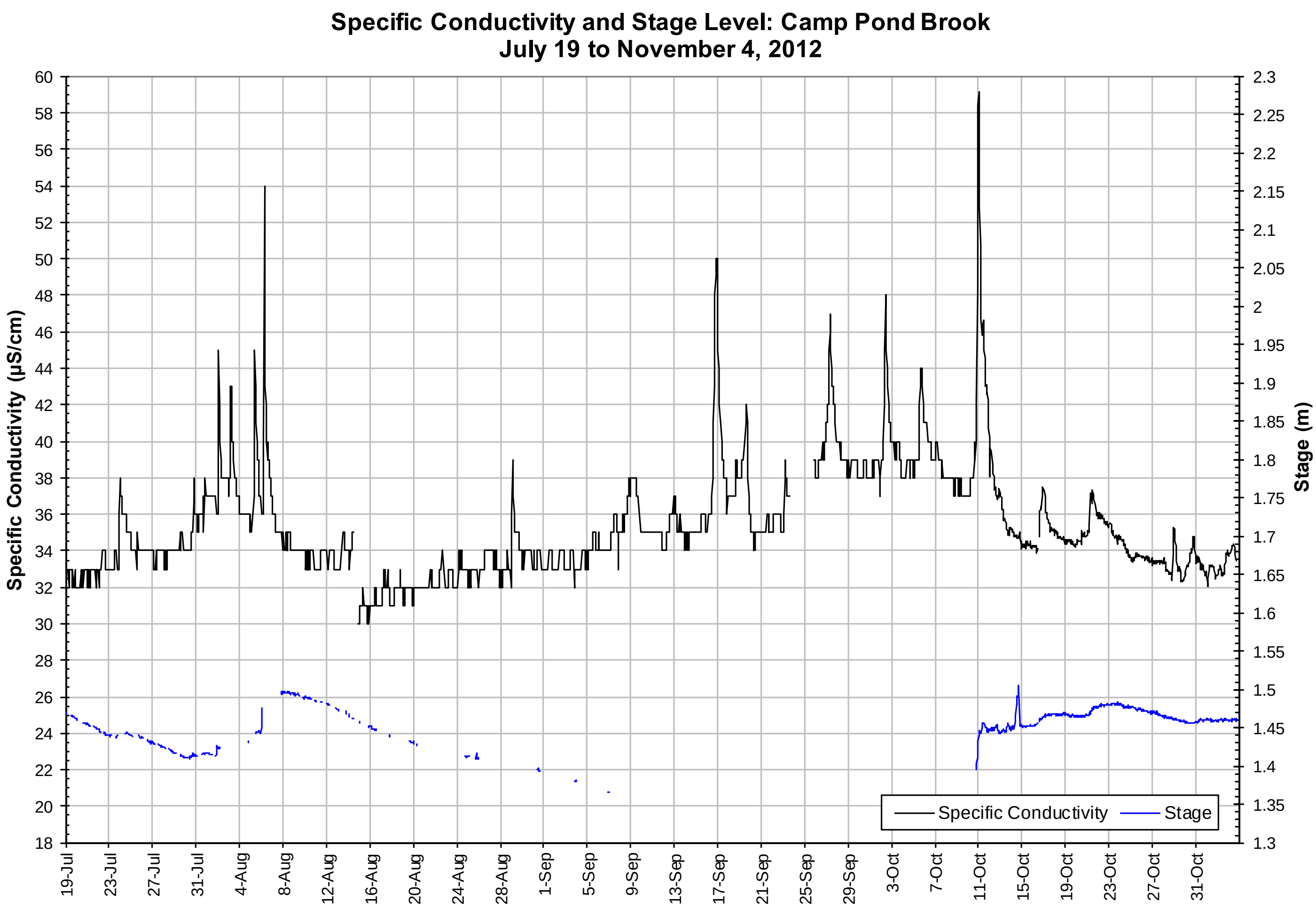


Figure 25: Specific conductivity and stage level at Camp Pond Brook

- Dissolved oxygen content ranged between 8.61mg/l and 14.01mg/l, averaging 10.64mg/l. The saturation of dissolved oxygen ranged from 89.0% to 101.7%, averaging 95.4% (Figure 26).
- Dissolved oxygen content shows a typical seasonal trend, inverse to water temperature. Values are stable and low following the late deployment in mid-July. As water temperatures decrease in the late summer and early fall, dissolved oxygen content begins to increase.
- All values were above the minimum CCME Guideline for the Protection of Cold Water Biota at Other Life Stages (6.5mg/l). Most values were above the CCME Guideline for the Protection of Aquatic Life at Early Life Stages (9.5mg/l). During the first deployment period, during the warmest period of air and water conditions, dissolved oxygen contents dropped to just below the suggested guideline. The guidelines are indicated in blue on Figure 26.

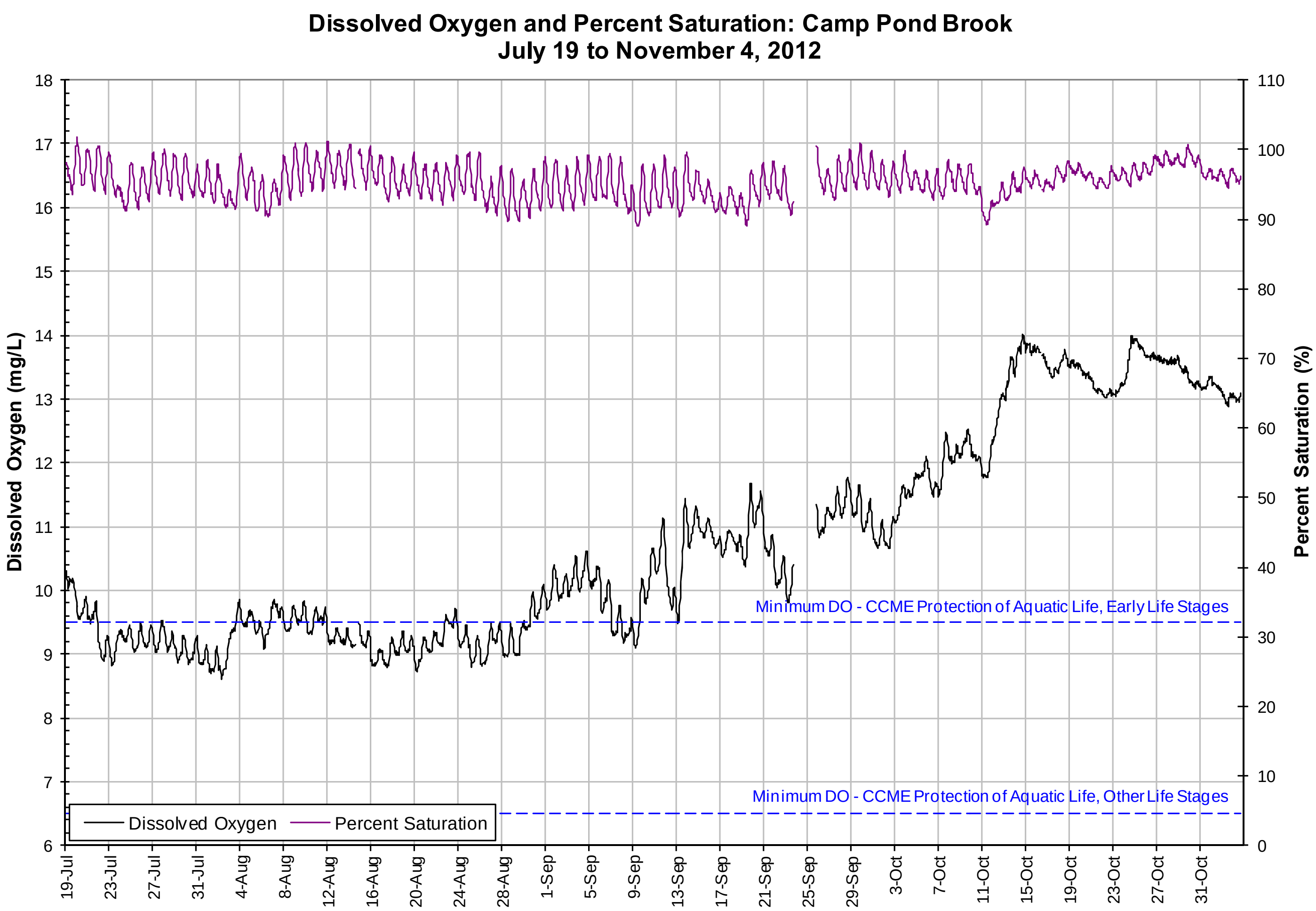


Figure 26: Dissolved oxygen and percent saturation at Camp Pond Brook

- Turbidity generally ranged between 0NTU to 123NTU (Figure 27). A median value of 0NTU indicates there is no consistent natural background turbidity value at this station.
- For the first two deployment periods, turbidity trends are similar to those experiences in the past at this station and comparable to other streams in the network. Background values are clearly at 0NTU with a number of turbidity increases that are short lived, to a maximum of 132NTU.
- In the third and final deployment period beginning September 26, the turbidity sensor appears to may have been affected by sand or gravel. Turbidity values are consistently increasing with no return to background levels. This trend is unexpected and an indication that the sensor is not functioning properly due to an outside influence. This data is subject to error and has been removed from the data set.

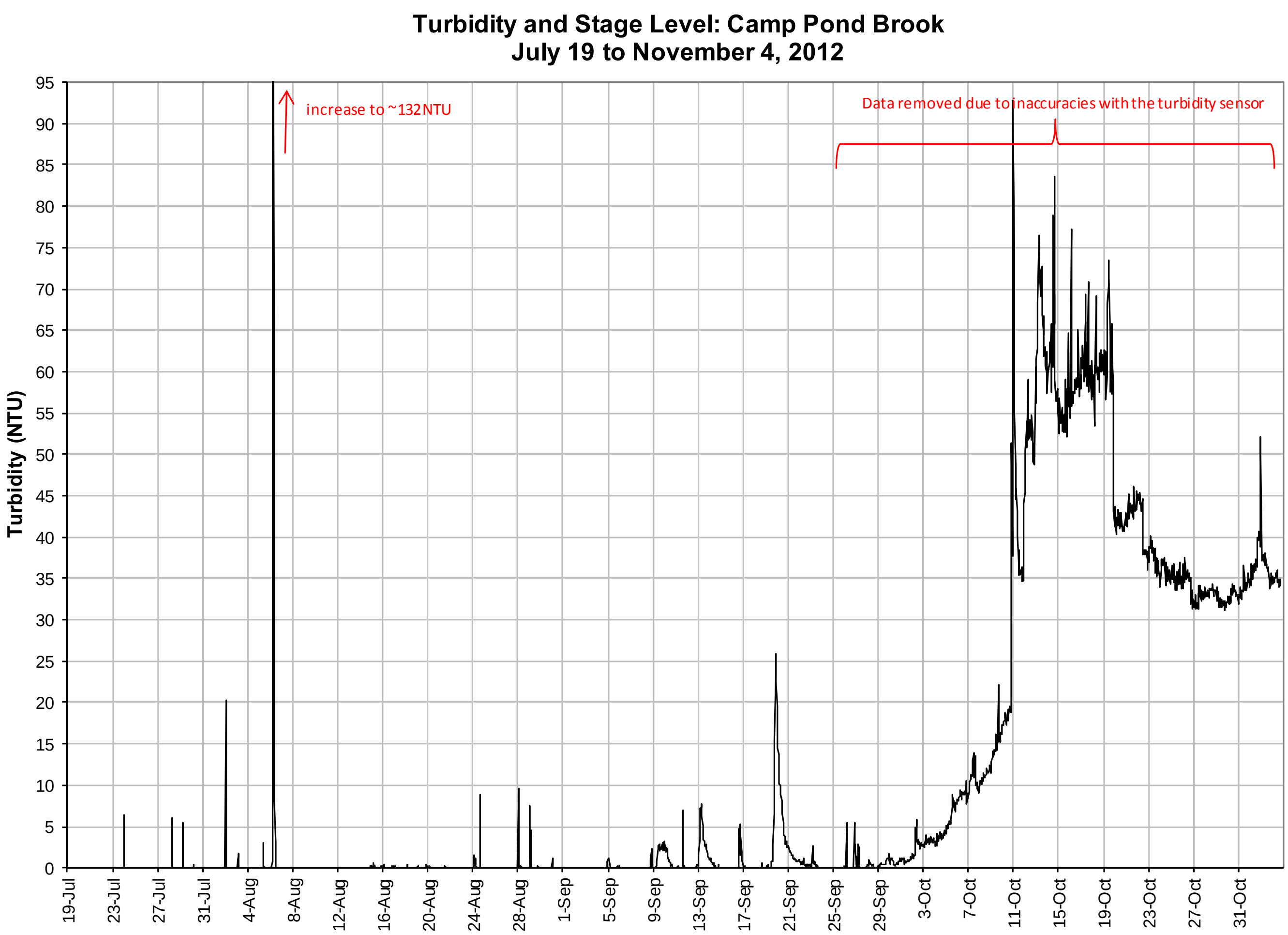


Figure 27: Turbidity and stage level at Camp Pond Brook

- Stage and precipitation are graphed below to show the relationship between rainfall and water level (Figure 28).
- Stage levels are decreasing slightly at the time of deployment in mid-July. Water levels increase at the beginning of August following several days of precipitation. Stage levels are unavailable during the middle of the deployment season due to a transmission error at this station. In the middle of the last deployment period, transmission resumes and stage levels appear to have stabilized for the remainder of the month.
- Precipitation events are frequent and moderate in magnitude throughout the deployment season.

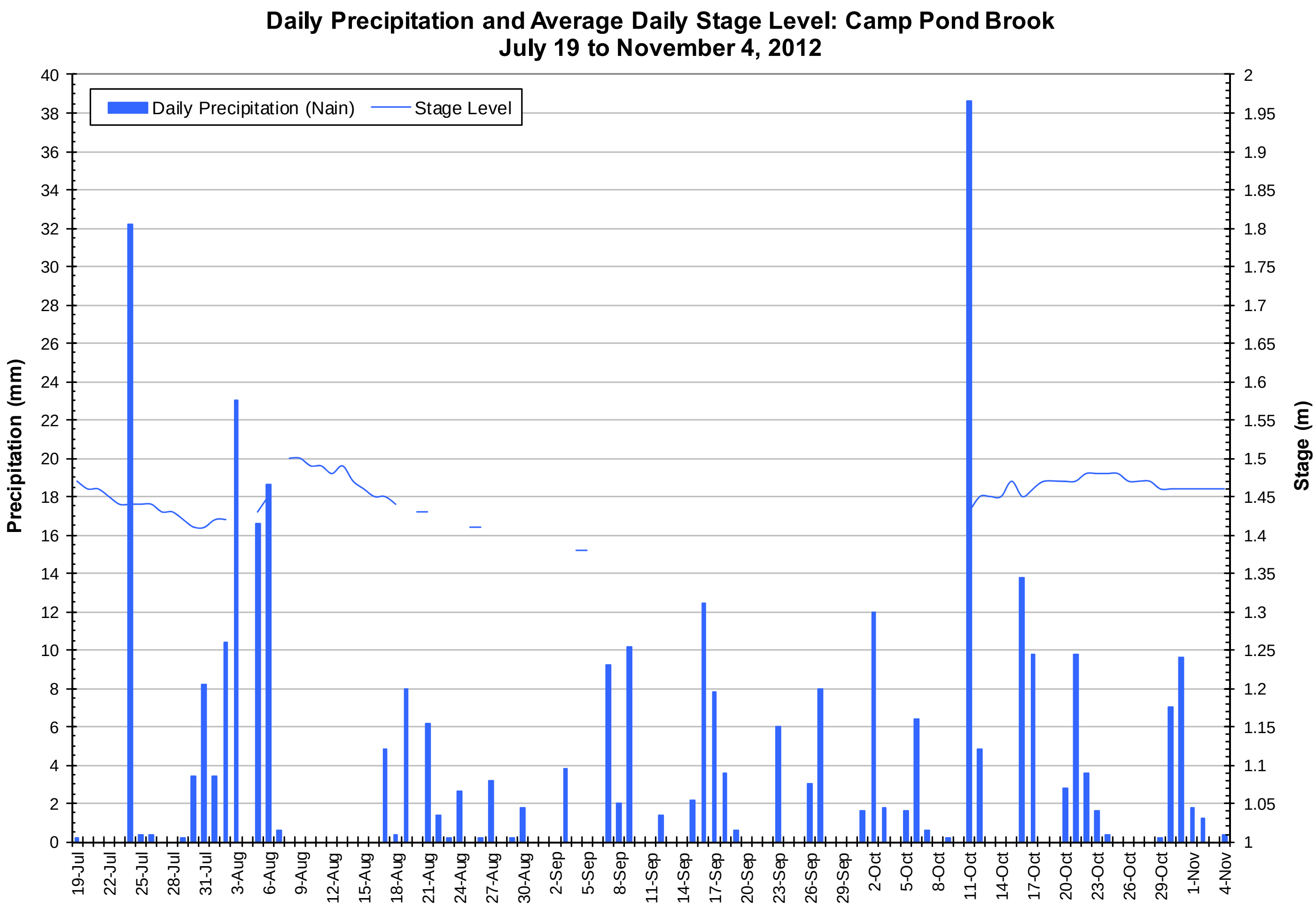


Figure 28: Daily precipitation and average daily stage level at Camp Pond Brook

(weather data recorded at Nain)

Multi-Station Comparison

- This section of the annual report focuses on how the stations compared to one another throughout the 2012 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 at or near season highs at the time of deployment in mid-July. Water temperatures peak at all stations in early to mid-August. Water temperatures then decrease throughout August until the end of the deployment season in late October.
- Camp Pond Brook recorded the highest temperature in the network at 20.7°C. However, on average, the station at Upper Reid Brook is the warmest of the four stations in the network. Lower Reid Brook and Tributary to Lower Reid Brook have very similar water temperatures throughout the season.

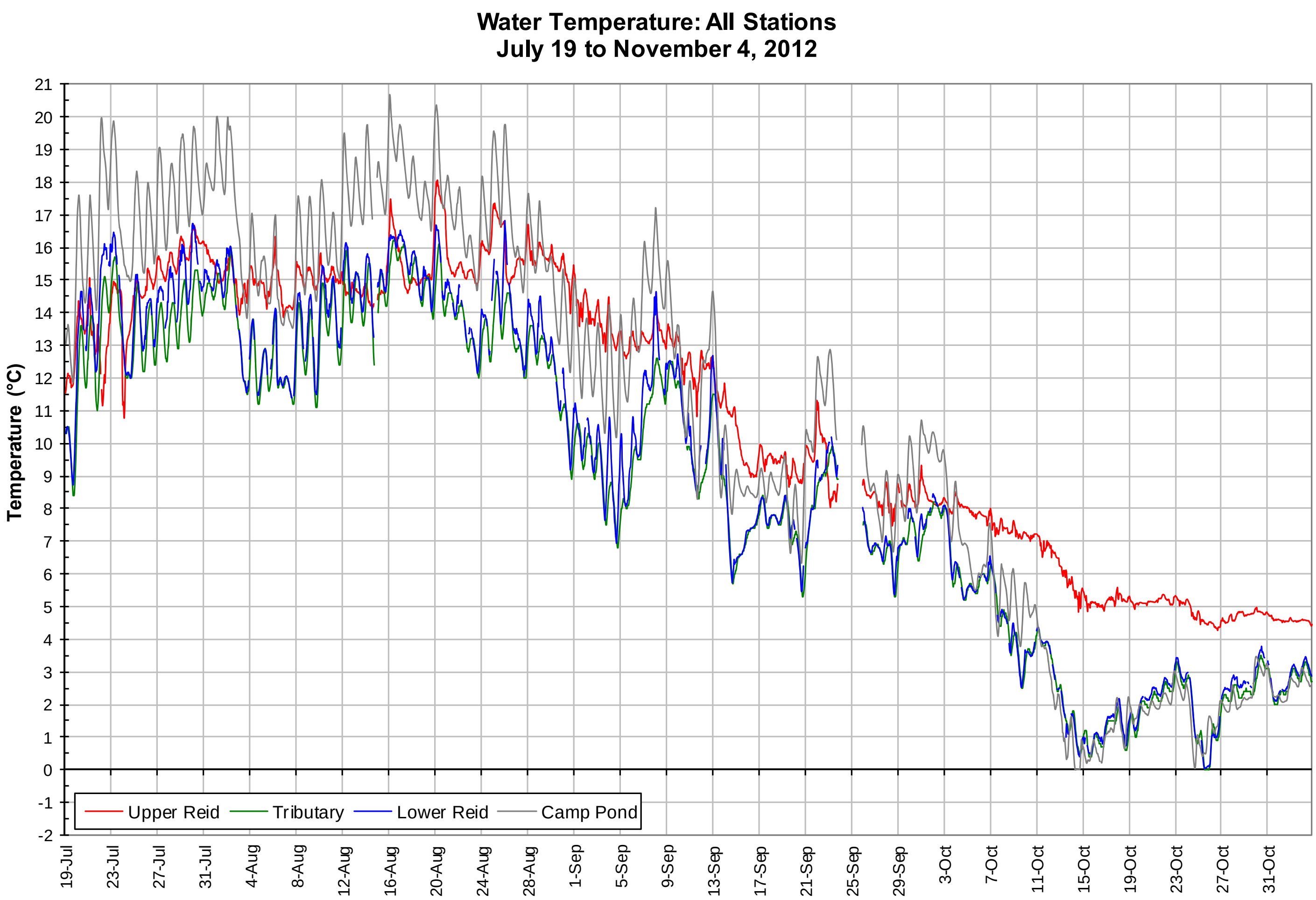


Figure 29: Water temperature at all stations

Temperature (°C)	Upper Reid	Tributary	Lower Reid	Camp Pond
Average	11.04	8.87	9.2	10.9
Max	18.06	16.3	16.81	20.67
Min	4.27	0	0.04	0

pH

- pH values are also comparable throughout the network of stations averaging between 6.21and 6.92 pH units (Figure 30).
- pH is the most stable and consistent at the station at Upper Reid Brook. pH values at the three stations lower in the network fluctuate more on a daily basis and in response to changing stage levels. Values at the station at Tributary to Lower Reid Brook and Lower Reid Brook are very similar and their fluctuations during sharp stage level increases following rainfall events are very clear. Large fluctuations at the station on Camp Pond Brook are less frequent but still do occur a few times throughout the season.

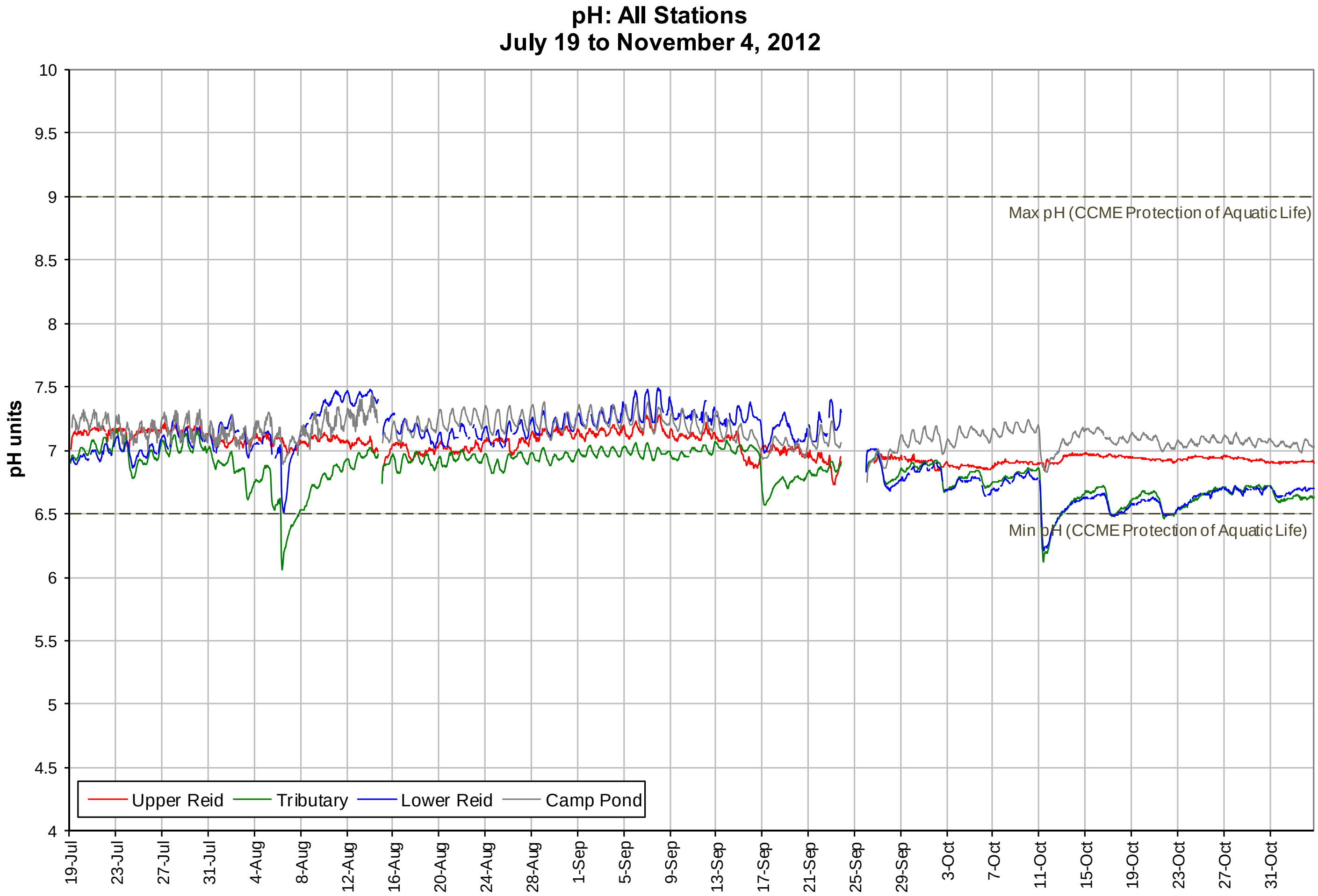


Figure 30: pH at all stations

pH (units)	Upper Reid	Tributary	Lower Reid	Camp Pond
Average	7.02	6.82	6.99	7.14
Max	7.28	7.17	7.49	7.44
Min	6.73	6.06	6.21	6.75

Specific Conductivity

- Specific conductivity trends vary throughout the network. At the station at Upper Reid Brook, specific conductivity levels are low and stable ranging only a few micro Siemens throughout the season.
- At the stations on Tributary to Lower Reid Brook and Lower Reid Brook, specific conductivity values (similar to pH values) fluctuate greatly in response to changing stage levels and rainfall events. At these stations, as stage increases, specific conductivity decreases caused by the dilution of major ions in the water column. Vice versa, as stage levels increase, specific conductivity increases due to the increase in concentration of major ions.
- Finally at the station on Camp Pond Brook, specific conductivity does not follow a typical inverse relationship with stage level increase during precipitation events. Instead, when water levels increase, there is typically an increase in specific conductivity. Although this relationship 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.

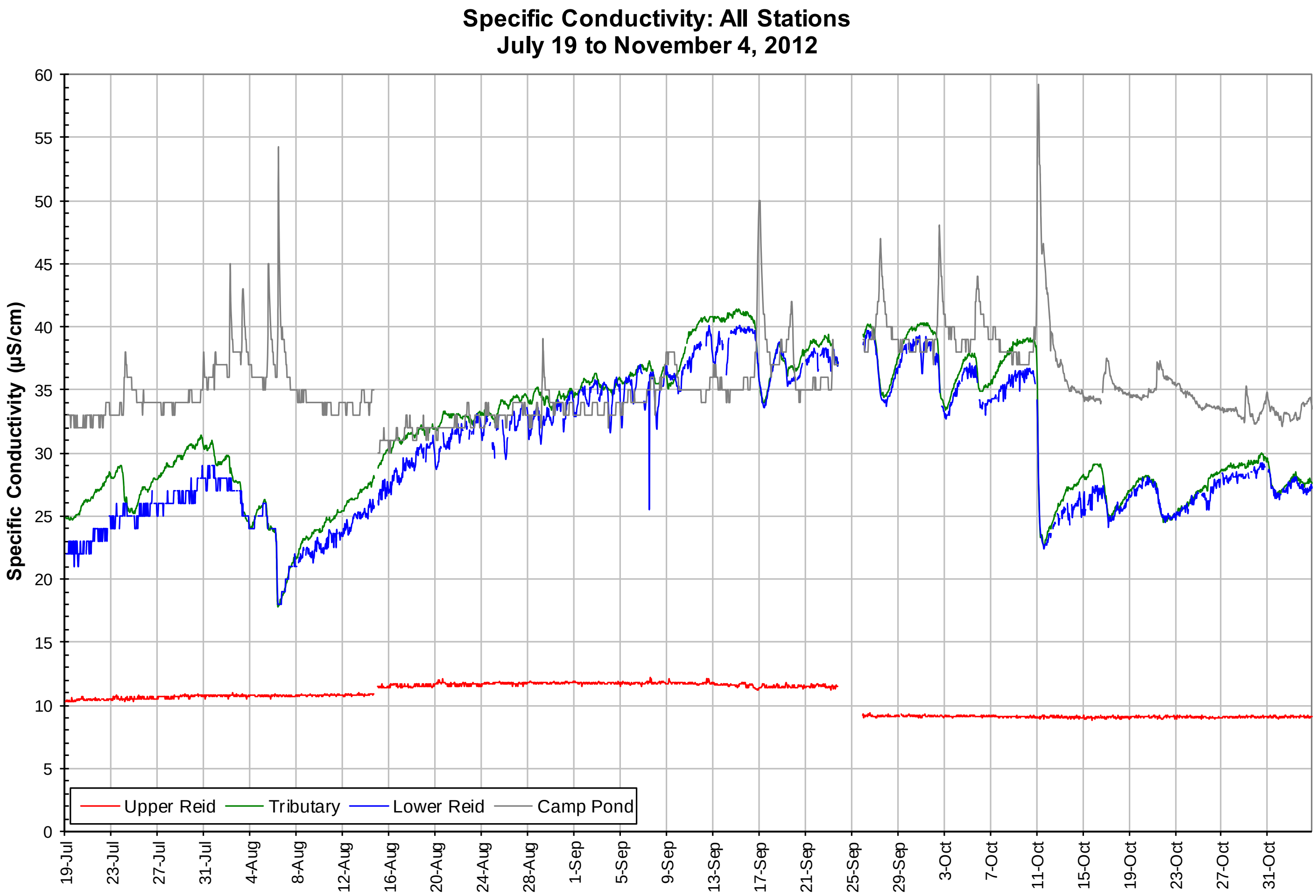


Figure 31: Specific conductivity at all stations

Specific Conductivity (µS/cm)	Upper Reid	Tributary	Lower Reid	Camp Pond
Average	10.5	31.7	30.3	35.4
Max	12.2	41.4	40.1	59.2
Min	8.8	17.8	18.0	30

Dissolved Oxygen and Percent Saturation

- Dissolved oxygen content averaged between 10.74mg/l and 11.35mg/l throughout the network during the 2012 deployment season. Dissolved oxygen content showed a typically inverse relationship with water temperature at all stations. Values are most stable at the station at Upper Reid Brook and shows 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) while most values at stations on Tributary to Lower Reid Brook, Lower Reid Brook and Camp Pond Brook were just below this guideline during the first deployment period. The guidelines are indicated in blue on Figure 32.

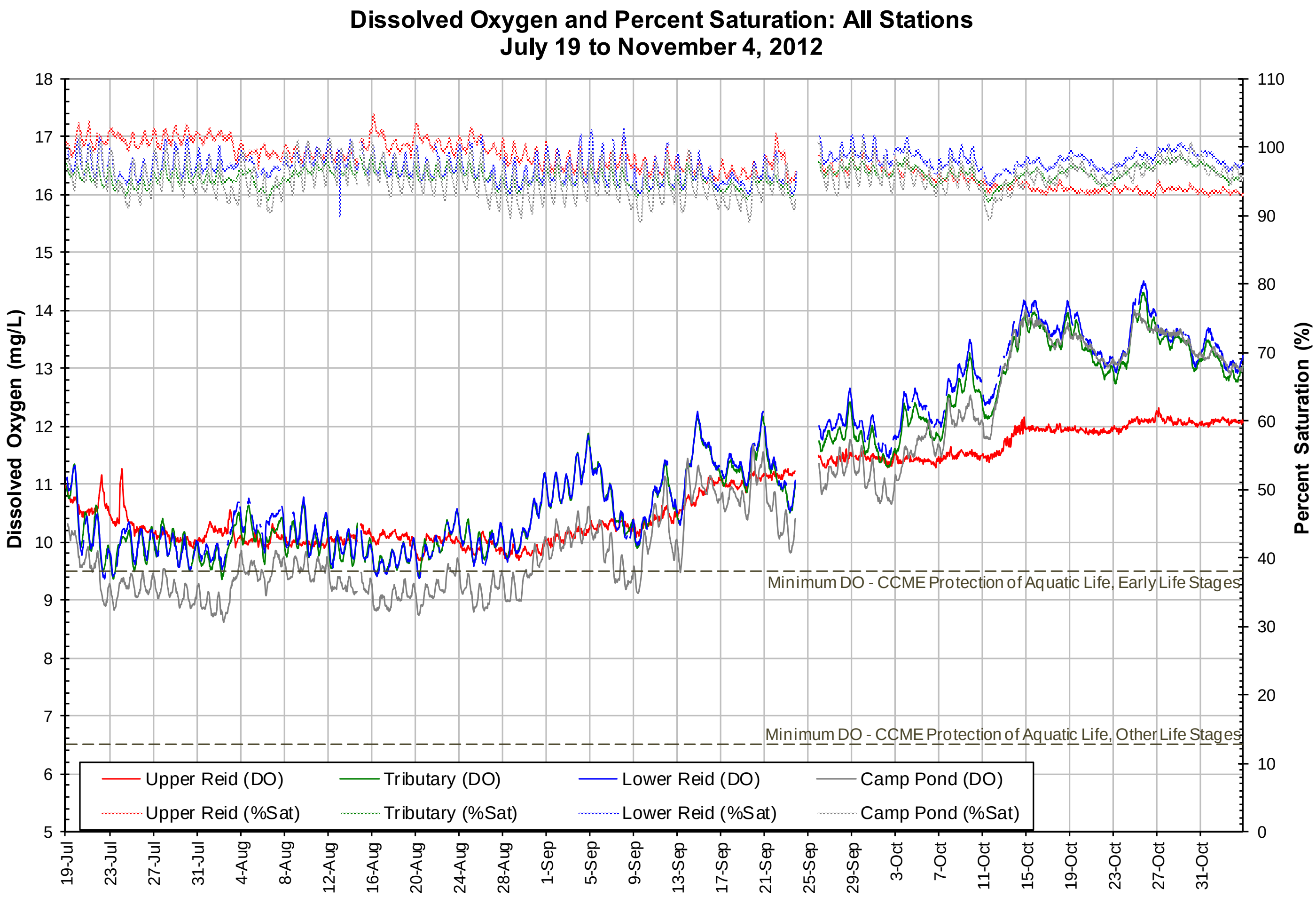


Figure 32: Dissolved oxygen and percent saturation at all stations

	Dissolved Oxygen (mg/l)				Percent Saturation			
	Upper Reid	Tributary	Lower Reid	Camp Pond	Upper Reid	Tributary	Lower Reid	Camp Pond
Average	10.82	11.26	11.35	10.74	97.7	95.9	97.4	95.4
Max	12.31	14.3	14.5	14.01	104.9	99.1	102.9	101.7
Min	9.67	9.35	9.36	8.61	92.7	92.1	89.9	89.0

Turbidity

- Turbidity values vary somewhat across the network throughout the 2012 season. However, median values at all station are 0NTU indicating there is no background turbidity at any of the stations in the network.
- There is little to no turbidity at the station at Upper Reid Brook. This station is extremely clean and clear and not impacted in any way. Stations at Tributary to Lower Reid Brook and Lower Reid Brook show similar turbidity trends. Background levels are 0NTU at both stations and there are a number of short lived, relatively low magnitude events occurring throughout the deployment season. Turbidity generally increases during or just following rainfall events and returns to baseline values (0NTU) in a matter of hours, sometimes days after the event. This is also the pattern captured at the station on Camp Pond Brook for the first two deployment periods. In the final deployment period at Camp Pond Brook, something appears to affect the sensor to the point of failure. Turbidity values continue to increase without ever returning to baseline conditions. This trend is not noted at any other station in the network. This data is subject to error and have been removed from the data set.

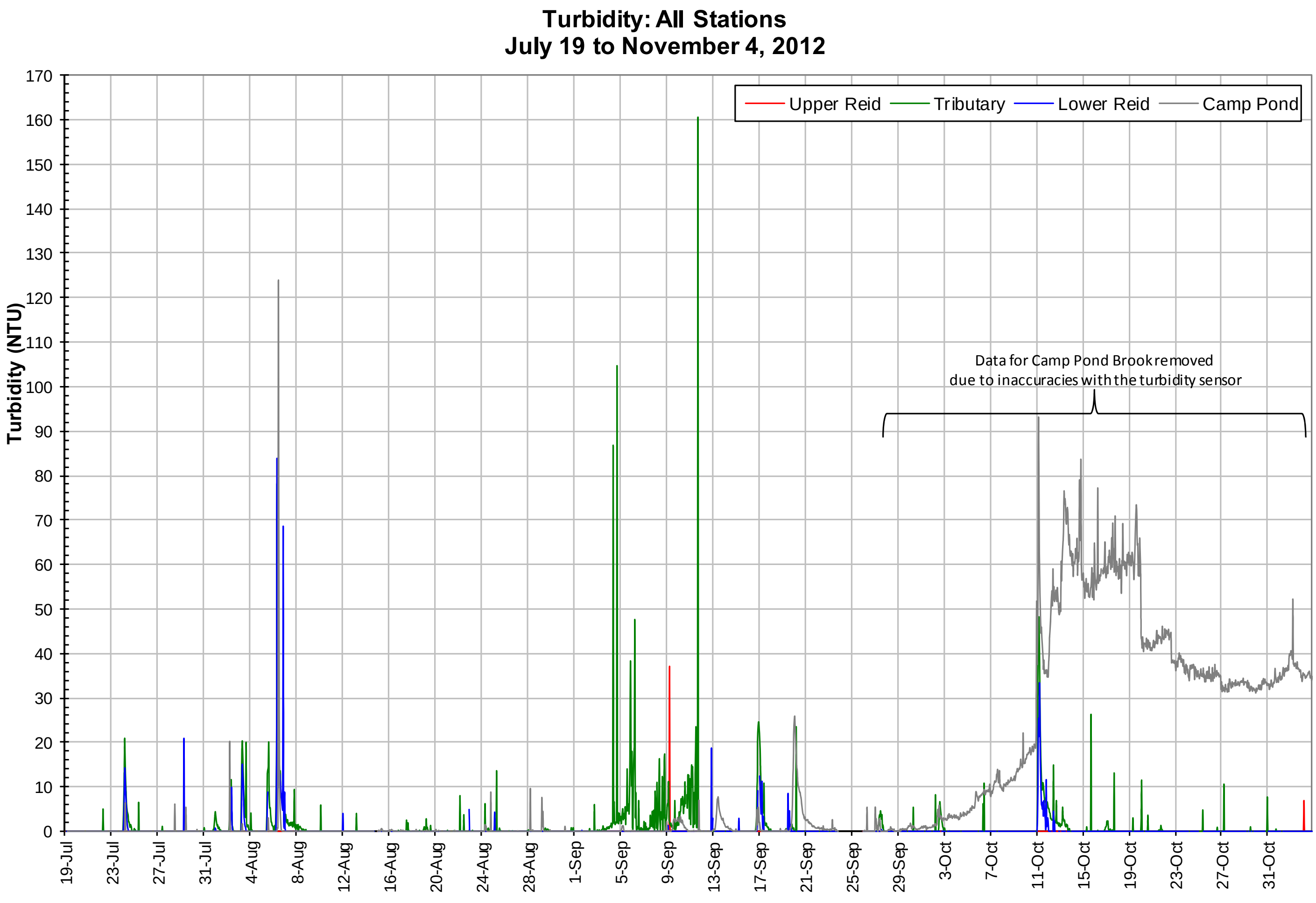


Figure 33: Turbidity at all stations

Turbidity (NTU)	Upper Reid	Tributary	Lower Reid	Camp Pond
Average	0	1.2	0.4	0.5
Max	37.1	161	81.9	123
Min	0	0	0	0
Median	0	0	0	0

Stage

- Stage levels are very similar throughout the season at all stations in the network. Rainfall events have a large effect on the streams in this network and therefore significant increases are noticed almost immediately during and following a rainfall event in the area. These increases are somewhat less significant at the station on Camp Pond Brook.
- Stage levels also decrease fairly quickly following a precipitation event. All stations reached a seasonal low in mid-September.

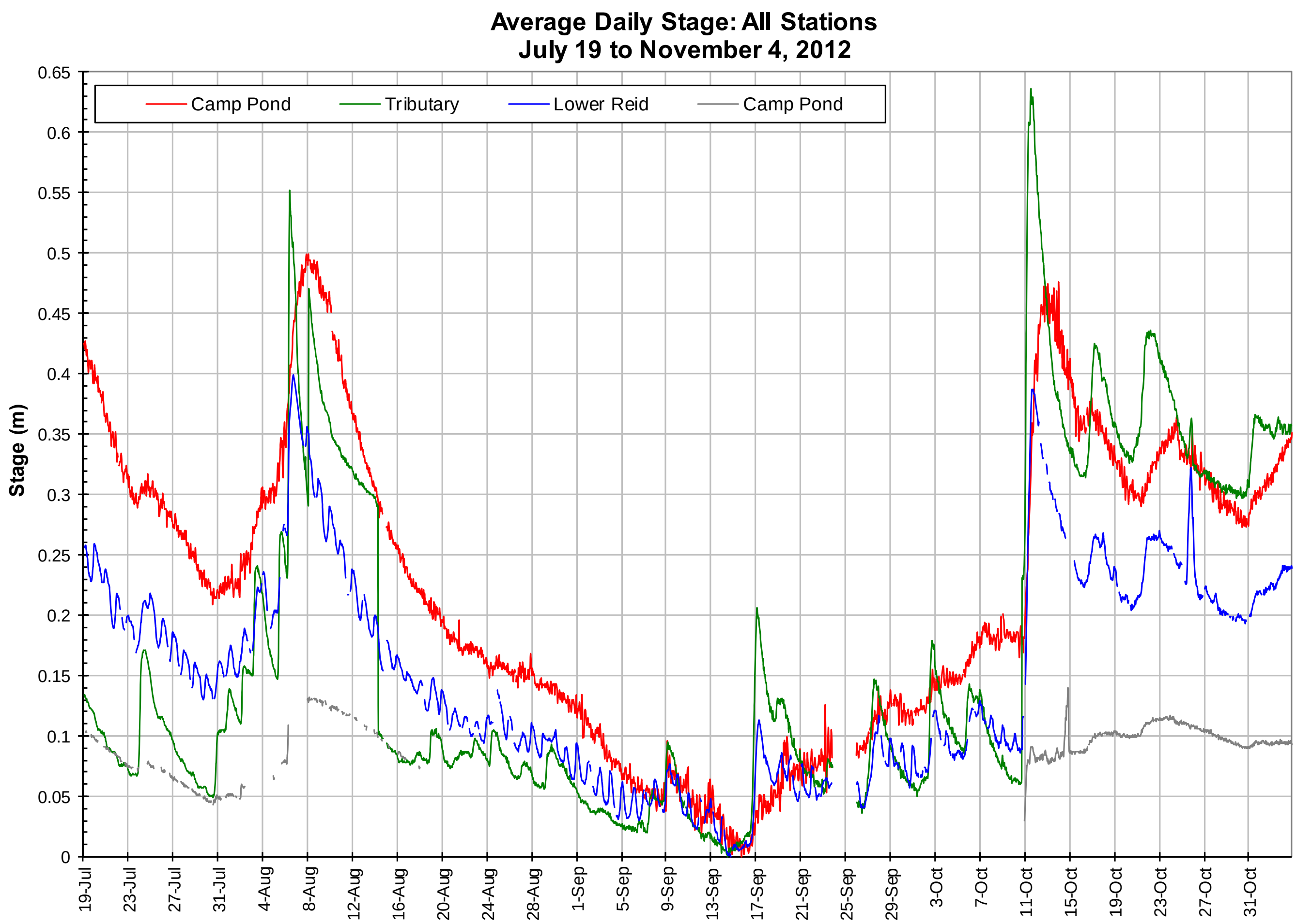


Figure 34: Stage levels at all stations

Conclusions

- Instruments at water quality monitoring stations in the Voisey's Bay Network were deployed during three deployment periods from July 19 to November 4, 2012. The deployment season was late starting due the delay in receiving new equipment required for the deployment season.
- The new instruments purchased prior to the 2012 season resulted in a substantial increase in the quality and quantity of data collected. Instruments and sensors were reliable, simple to calibrate, and increased the data integrity immensely compared to recent years.
- In most cases, weather related events or increase/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 fluctuated throughout the season having a large impact on pH, and specific conductivity at all stations with the exception of Upper Reid Brook. The Upper Reid Brook station is extremely stable and consistently has stable pH values and low stable specific conductivity values. Turbidity values showed a median value of 0NTU at all stations indicating there is no natural background turbidity in the network. Most turbidity events 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 and ENVC staff. This has provided good quality data with limited drift. The effects of bio fouling rarely impact the instruments due to the cold pristine nature of the river and the regular maintenance each month.
- The instruments performed well for much of the deployment season with limited disruptions to data collection.
    - At Camp Pond Brook and Lower Reid Brook, data transmission is intermittent throughout the entire deployment season. Environment Canada is aware of this issue and has been onsite a number of times to try and rectify the situation however the station continues to experience erratic communication. Data recorded by the instrument's internal log file has in large part been used to fill the data gaps resulting from the intermittent transmissions.
    - A similar transmission error occurred at the station on Upper Reid Brook from October 11-12. Data transmission resumed automatically following this short disruption. Again, the instrument's internal log file was able to supplement data lost during the transmission error.
    - With respect to quality of data and data removed from the data set due to sensor failures, disruptions were minimal in the 2012 deployment season. In one case, turbidity data at the station on Camp Pond Brook during the last deployment period was removed due to inaccuracies with increasing turbidity values and trends not typically experienced. The instrument and/or sensor may have been affected by sand or gravel causing the inaccurate values.

Path Forward

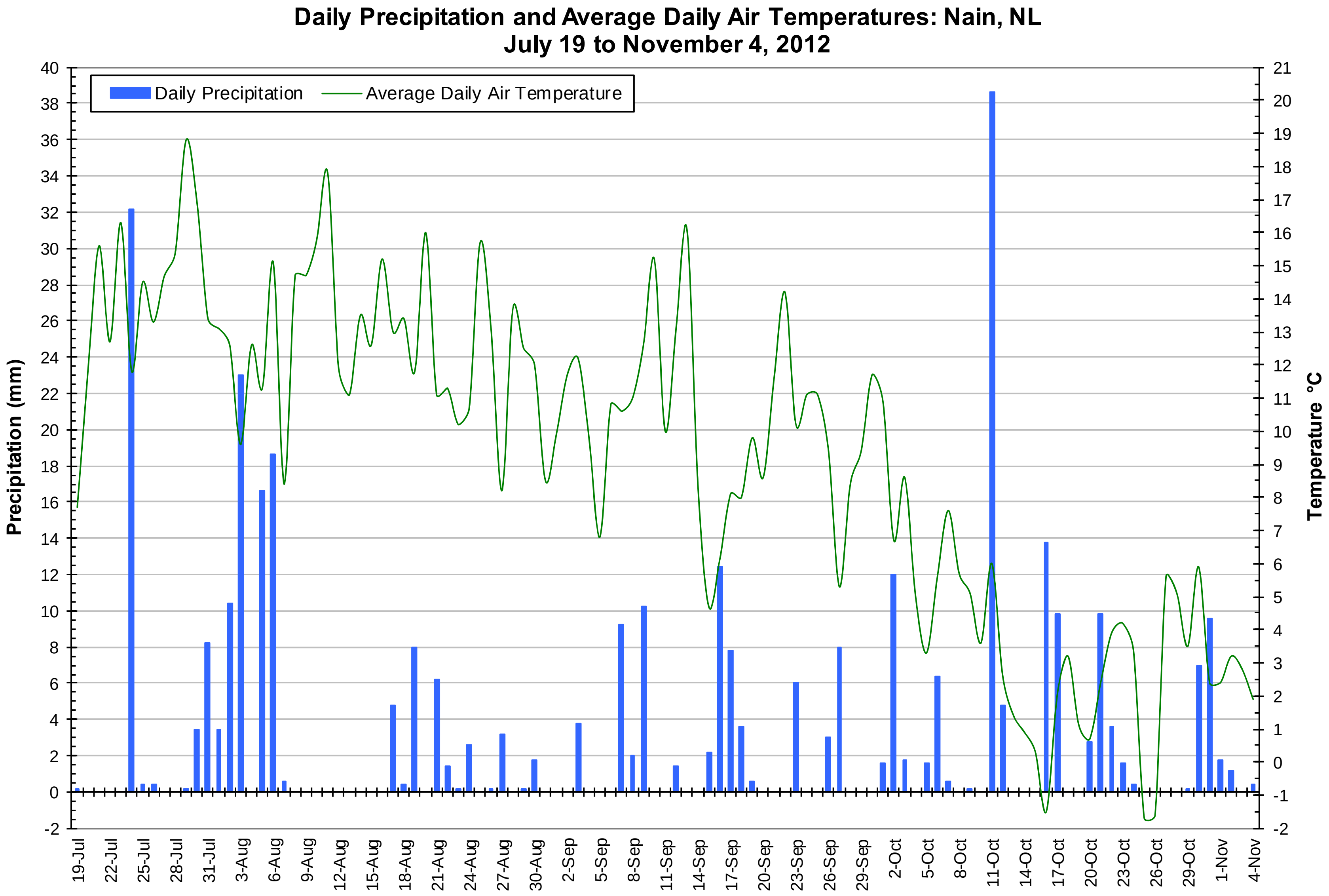
The success of these four stations is built largely by the individuals working at maintaining and monitoring the Voisey's Bay RTWQM network. This network has been improving since 2003 and continues to advance annually in background knowledge and awareness of the rivers behaviours. This is essential for identifying the difference between natural and unnatural events. As this agreement progresses into the 2013 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.

- Deployments will recommence in the spring 2013 when ice conditions permit.

- In the 2013 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 staff will perform regular site visits to ensure water quantity instrumentation is correctly calibrated and providing accurate measurements.
- An email alerting system will be established for the Voisey's Bay stations to catch emeging water quality issues at the start of the 2013 deployment season.
- ENVC 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 made to adapt to each site, ensuring secure and suitable conditions for RTWQM.
- ENVC will work with Vale Environment staff to reassess the network design (station location) and plan for any necessary or desired changes in 2013 or in future seasons.
- Vale Voisey's Bay will receive monthly reports outlining the events that occurred in the previous deployment period and a 2013 annual report summarizing the events of the deployment season.
- ENVC staff will outline and produce a comprehensive report on the RT network at Voisey's Bay featuring the network data from the past 10 years. ENVC staff will consult with Vale Environment staff on the direction and content of this report.
- Open communication lines will continue to be maintained between ENVC, EC and Vale Voisey's Bay employees involved with the agreement in order to respond to emerging issues on a proactive basis.
- Continue to work on Automatic Data Retrieval System to incorporate new capabilities.
- Creation of value added products using the RTWQ data, remote sensing and water quality indices.
- ENVC will begin development of models using RTWQM data and grab sample data to estimate a variety of additional water quality parameters (*i.e.* TSS, major ions *etc*.).

Prepared by:
Grace de Beer – Environmental Scientist
Department of Environment and Conservation
Water Resources Management Division
Phone: (709) 896-5542
Fax: (709) 896-9566
Email: gracedebeer@gov.nl.ca

Appendix 1


Daily Precipitation and Average Daily Air Temperatures: Nain, NL
July 19 to November 4, 2012
Daily Precipitation
Average Daily Air Temperature
Precipitation (mm)
Temperature °C
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