Real-Time Water Quality 2013 Annual Report

Voisey's Bay Network

June 13 to
November 7, 2013

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) 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 2013 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. Leona Hyde has 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	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; Upper Reid Brook (Outlet from 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, 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 2013 when ice conditions permitted. This annual deployment report illustrates, discusses and summarizes water quality related events from June 13 to November 7. 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 2013 deployment season are summarized in Table 1.

Table 1: Installation and removal dates for 2013 deployment periods

Installation	Removal	Deployment
June 13	July 15	33 days
July 16	August 24	38 days
August 25	September 26	30 days
September 27	November 5/6/7	41-43 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 deployed from June 13 to November 7, 2013 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, June 13– November 7, 2013

			Instrument #	Temperature	pH	Specific Conductivity	Dissolved Oxygen	Turbidity
Upper Reid Brook	Jun 13, 2013	Deployment	62884	Excellent	Good	Excellent	Excellent	Excellent
	July 15, 2013	Removal	62884	Good	Good	Excellent	Good	Excellent
	July 16, 2013	Deployment	62884	Fair	Good	Excellent	Fair	Excellent
	Aug 24, 2013	Removal	62884	Excellent	Marginal	Excellent	n/a	n/a
	Aug 25, 2013	Deployment	62884	Excellent	Excellent	Excellent	n/a	Excellent
	Sep 26, 2013	Removal	62884	Marginal	Good	Excellent	n/a	n/a
	Sep 27, 2013	Deployment	62884	Good	Fair	Excellent	n/a	n/a
	Nov 6, 2013	Removal	62884	Poor	Poor	Excellent	n/a	n/a
Camp Pond Brook	Jun 13, 2013	Deployment	62885	Excellent	Marginal	Excellent	Excellent	Excellent
	July 15, 2013	Removal	62885	Excellent	Fair	Excellent	Good	Excellent
	July 16, 2013	Deployment	62885	Excellent	Poor	Excellent	Excellent	Excellent
	Aug 24, 2013	Removal	62885	Excellent	Good	Excellent	n/a	n/a
	Aug 25, 2013	Deployment	62885	Excellent	Good	Good	n/a	Excellent
	Sep 26, 2013	Removal	62885	Excellent	Good	Good	n/a	n/a
	Sep 27, 2013	Deployment	62885	Excellent	Good	Excellent	n/a	n/a
	Nov , 2013	Removal	62885	Excellent	Poor	Good	n/a	n/a
Lower Reid Brook	Jun 13, 2013	Deployment	62887	Excellent	Fair	Excellent	Good	Excellent
	July 15, 2013	Removal	62887	Excellent	Excellent	Excellent	Excellent	Excellent
	July 16, 2013	Deployment	62887	Excellent	Fair	Excellent	Excellent	Excellent
	Aug 24, 2013	Removal	62887	Excellent	Excellent	Excellent	n/a	n/a
	Aug 25, 2013	Deployment	62887	Excellent	Fair	Excellent	n/a	Excellent
	Sep 26, 2013	Removal	62887	Excellent	Excellent	Good	n/a	n/a
	Sep 27, 2013	Deployment	62887	Excellent	Marginal	Excellent	n/a	n/a
	Nov 5, 2013	Removal	62887	Excellent	Poor	Good	n/a	n/a
Tributary to Lower Reid Brook	Jun 13, 2013	Deployment	62886	Excellent	Excellent	Excellent	Fair	Excellent
	July 15, 2013	Removal	62886	Excellent	Excellent	Excellent	Excellent	Excellent
	July 16, 2013	Deployment	62886	Excellent	Poor	Excellent	Excellent	Excellent
	Aug 24, 2013	Removal	62886	Excellent	Poor	Excellent	n/a	n/a
	Aug 25, 2013	Deployment	62886	Good	Excellent	Good	n/a	Excellent
	Sep 26, 2013	Removal	62886	Good	Fair	Good	n/a	n/a
	Sep 27, 2013	Deployment	62886	Excellent	Fair	Excellent	n/a	n/a
	Nov 5, 2013	Removal	62886	Excellent	Poor	Excellent	n/a	n/a

Data Interpretation

- The following graphs and discussion illustrate significant water quality-related events from June 13 to November 7 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.

Upper Reid Brook (Outlet from Reid Pond)

- Water temperature ranged from 1.10 °C to 17.83°C during the 2013 deployment season, with a median value of 8.26°C (Figure 1).
- Water temperatures are increasing throughout June and July before reaching a seasonal high in early August. Water temperature begins to decrease in late August and continues decreasing into September and October.

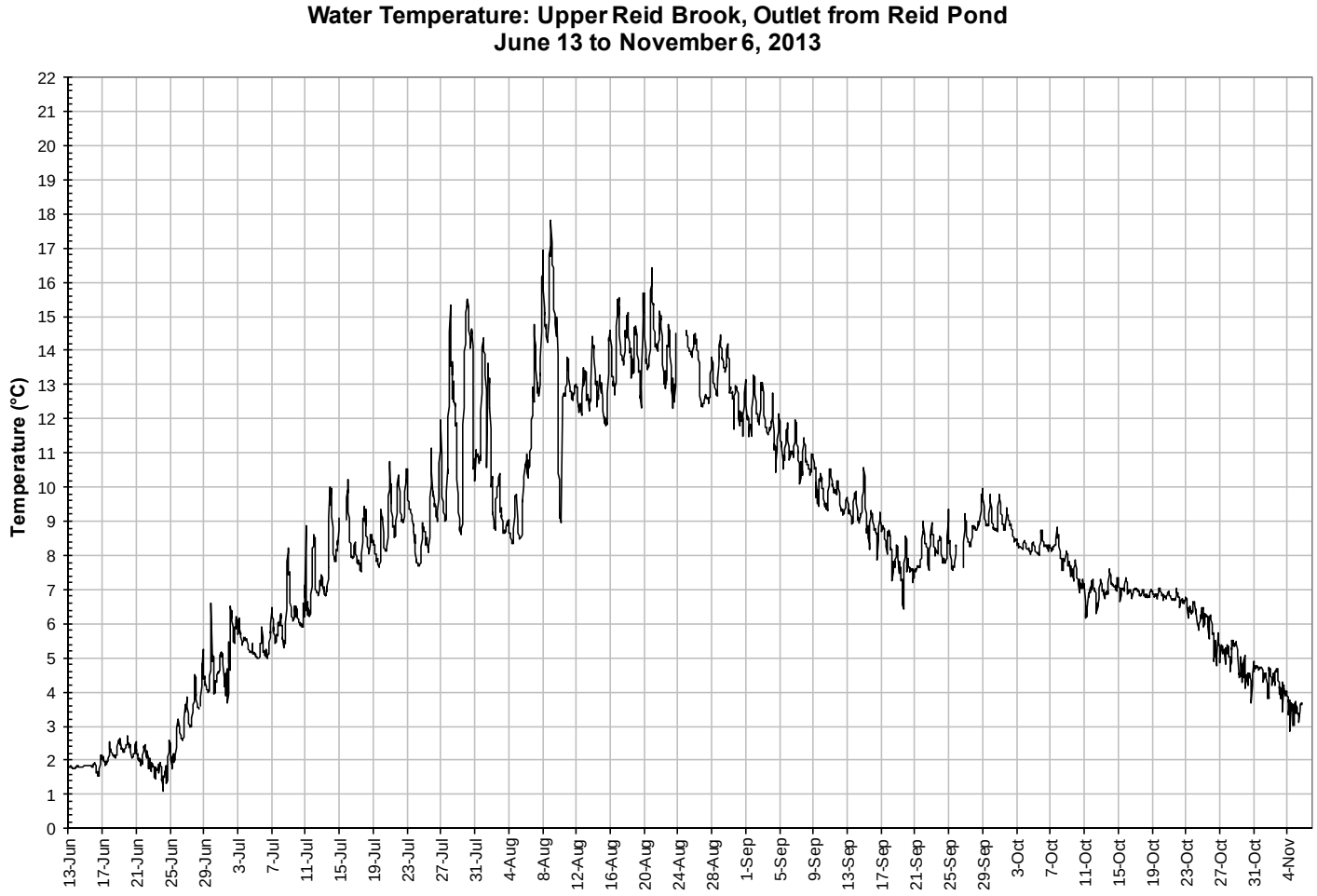

Figure 1: Water temperature at Upper Reid Brook

- 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.

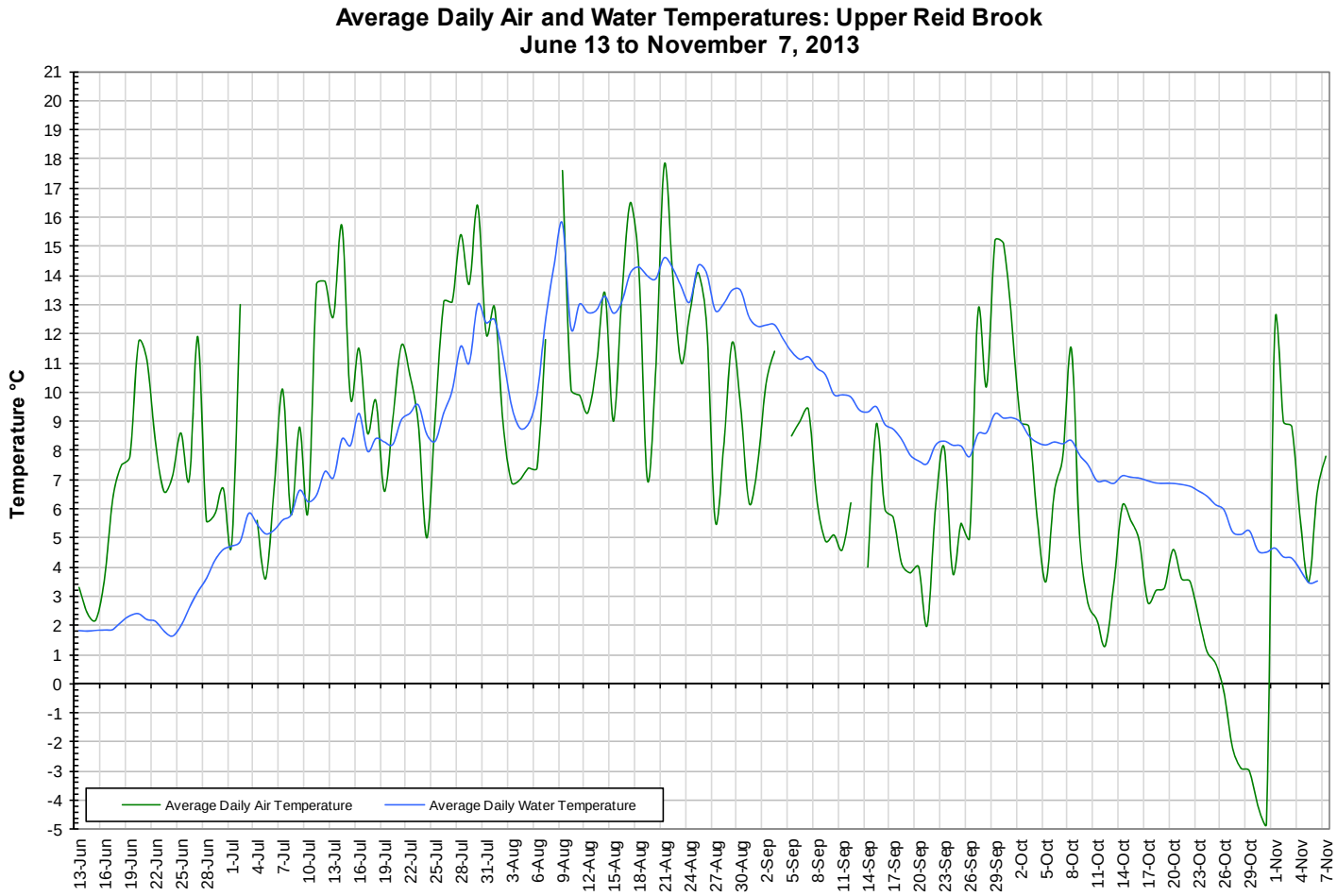

Figure 2: Average daily air and water temperatures at Upper Reid Brook

(weather data recorded at Nain)

- pH ranges between 6.35 and 7.16 pH units throughout the 2013 deployment season, with a median value of 6.86 pH units (Figure 3).
- pH values at this station are increasing slightly in the early summer.
- Most of the pH values throughout the season are within the range recommended by the CCME Guideline for the Protection of Aquatic Life (>6.5 and <9.0 pH units). At the beginning of the season, pH values are just below the minimum guideline. During the third deployment period when values are fluctuating during low water level conditions, the pH level does drop below the minimum guideline for a period up to one day. Guidelines are indicated in blue on Figure 3.

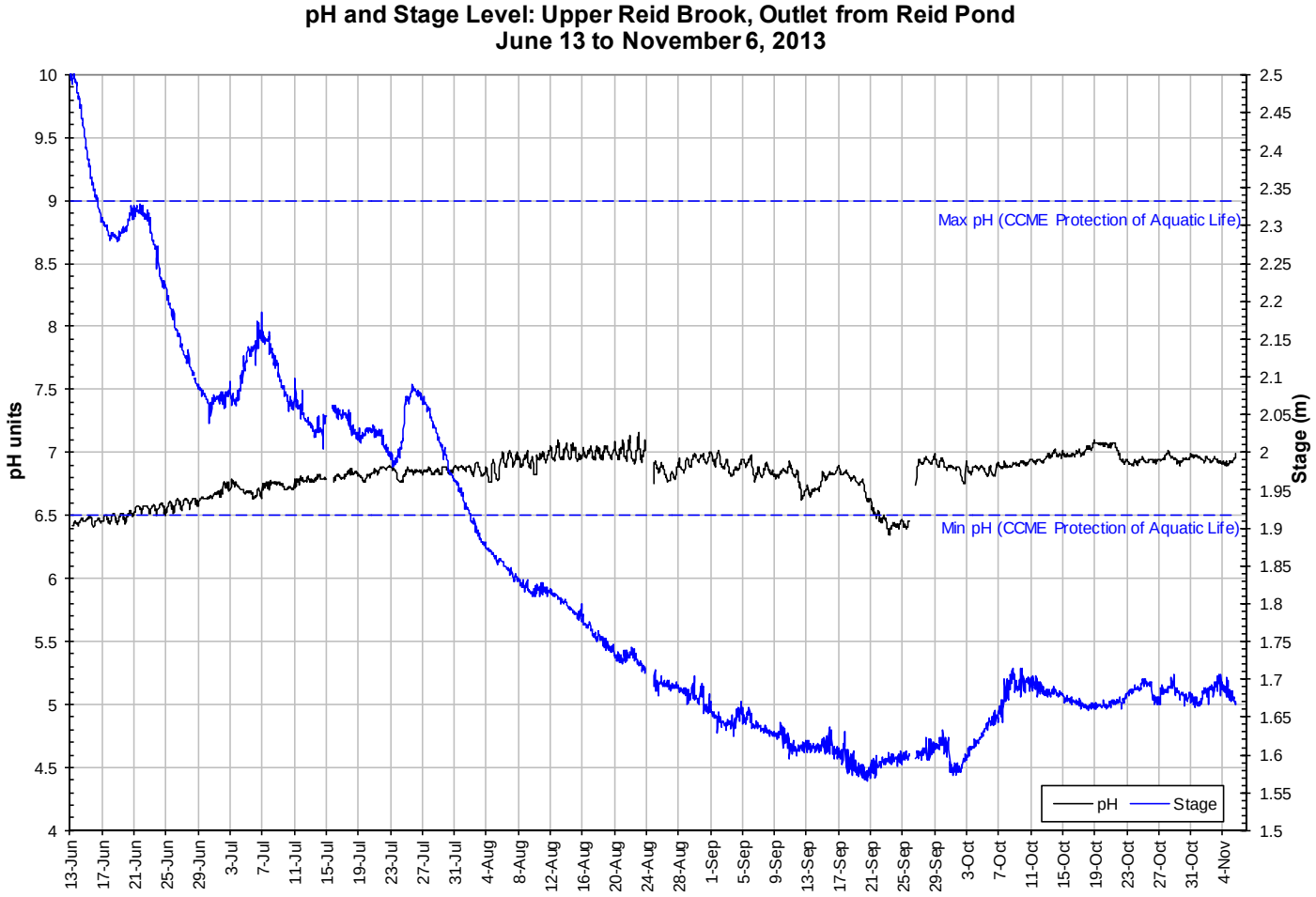

Figure 3: pH and stage level at Upper Reid Brook

- Specific conductivity ranges from 9.4µS/cm to 12.6µS/cm during the deployment season, with a median value of 11.7µS/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, a stable lake environment.

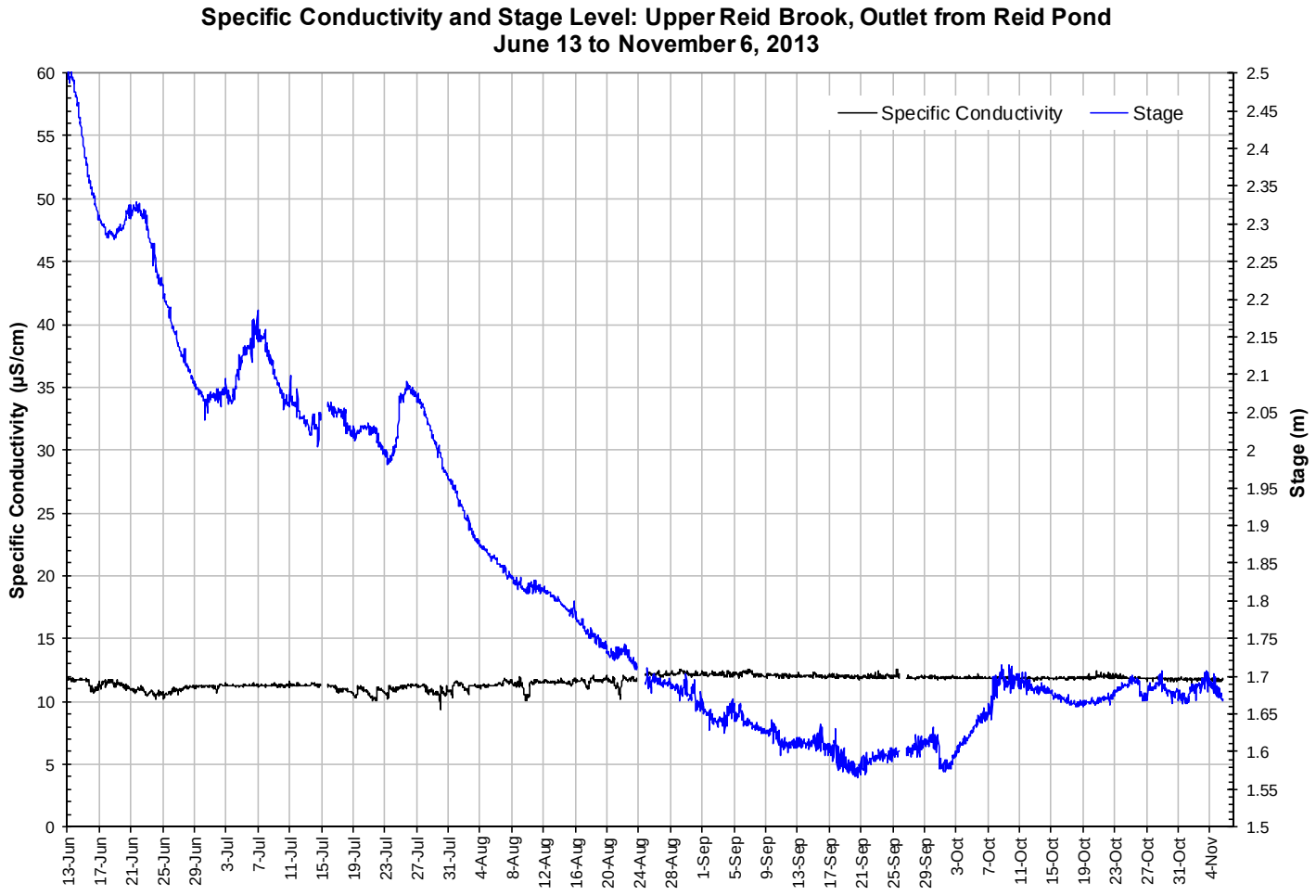

Figure 4: Specific conductivity and stage level at Upper Reid Brook

- Dissolved oxygen content ranges between 9.67mg/l and 12.65mg/l throughout the 2013 deployment season, with a median value of 11.35mg/l. The saturation of dissolved oxygen ranges from 87.3% to 110.7%, with a median value of 96.0% (Figure 5).
- Dissolved oxygen content shows a typical seasonal fluctuation in 2013, and is inversely proportional to the changes in water temperature (Figure 1). 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.

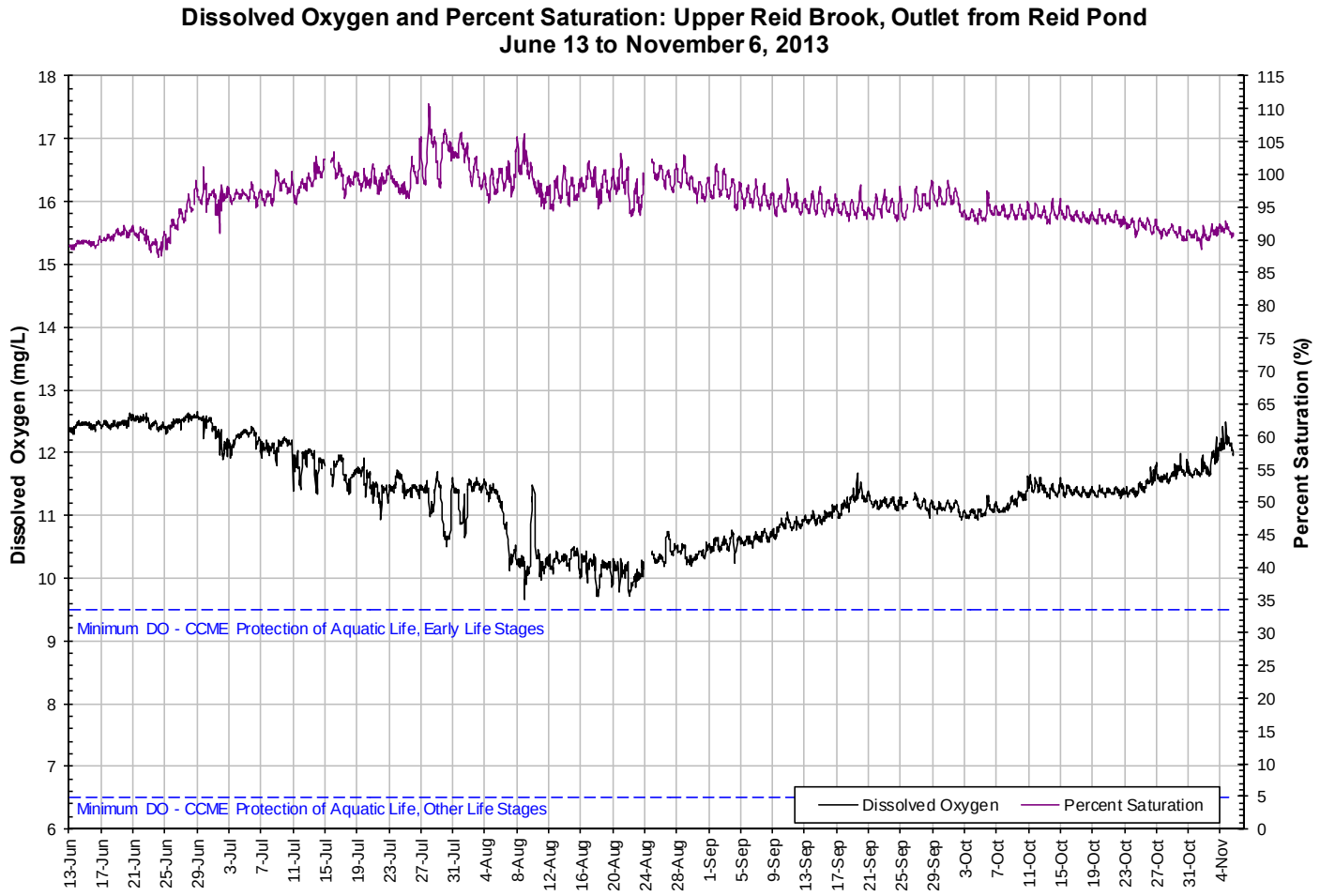

Figure 5: Dissolved oxygen and percent saturation at Upper Reid Brook

- Turbidity generally remains at 0NTU for the entirety of the 2013 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 2685NTU) for one hour periods. These are not considered water quality events as they are isolated and infrequent occurrences.

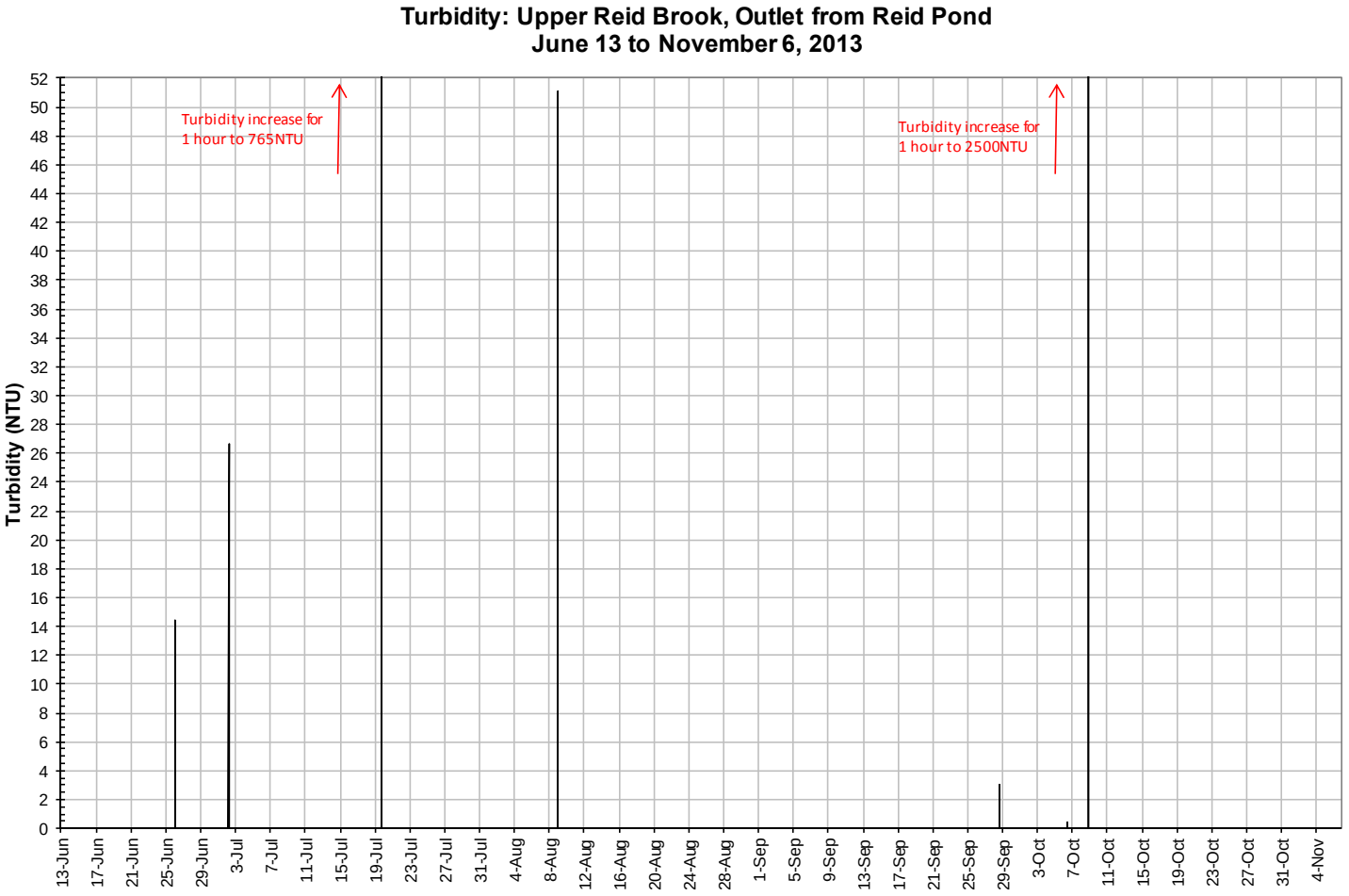

Figure 6: Turbidity at Upper Reid Brook

- Stage and precipitation are graphed below to show the relationship between rainfall and water level (Figure 7).
- Stage is decreasing for almost the entire deployment season with minimal increases. Stage levels decrease from a seasonal high of 2.51m to a seasonal low of 1.57m in early October, a difference of 0.94m. Stage levels increase slightly in the last month of the deployment season.
- Precipitation events are frequent (>50% of the days) and generally low in magnitude throughout the deployment season.

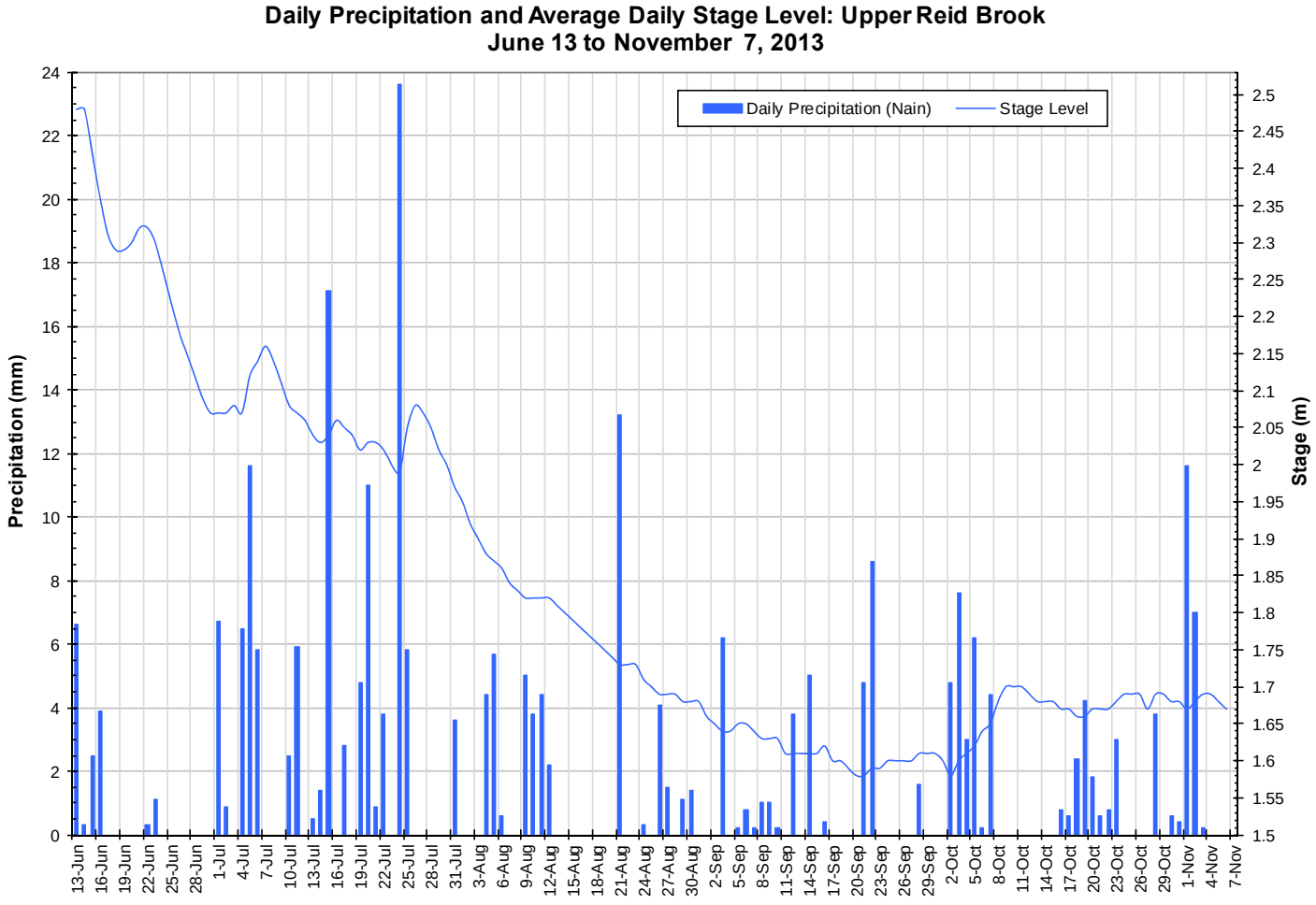

Figure 7: Daily precipitation and average daily stage level at Upper Reid Brook (weather data recorded at Nain)

Camp Pond Brook below Camp Pond

- Water temperature ranged from 0.03°C to 21.06°C during the deployment season, with a median value of 10.48°C (Figure 8).
- Water temperatures are increasing in the latter half of June and throughout July before peaking on July 29. Water temperature begins to decrease in August and continues decreasing throughout September and October.

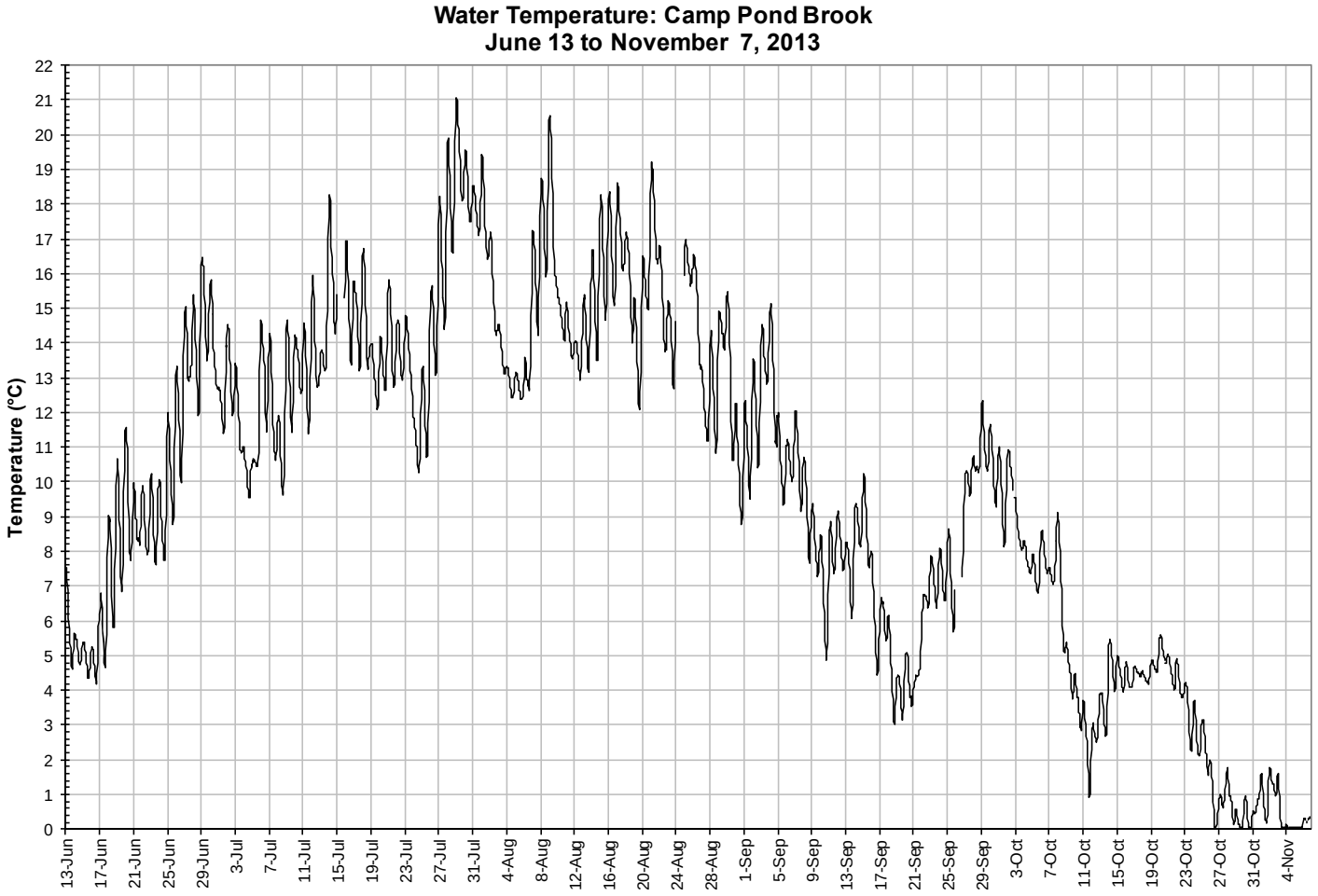

Figure 8: Water temperature at Camp Pond Brook

- 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.

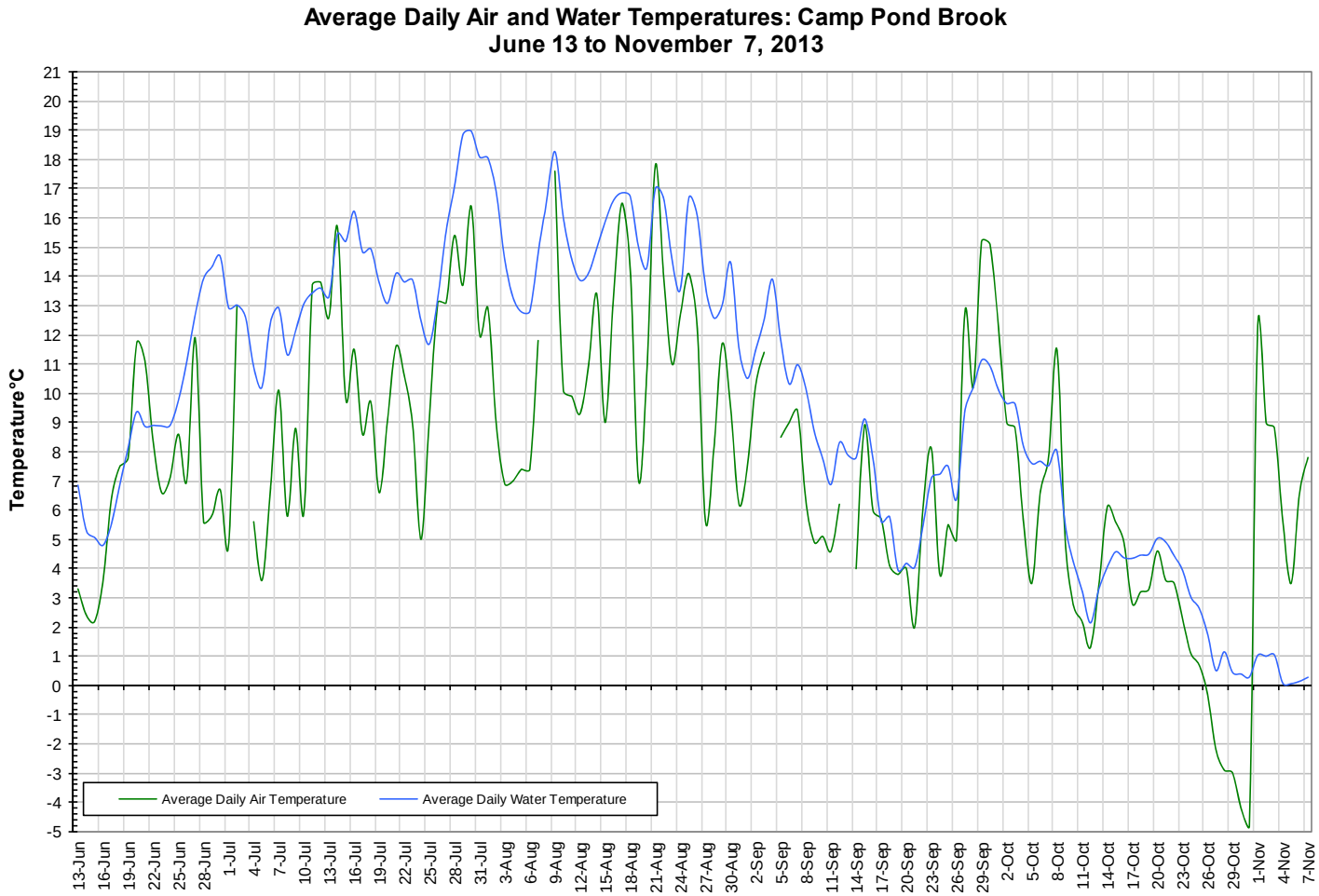

Figure 9: Average daily air and water temperatures at Camp Pond Brook

(weather data recorded at Nain)

- pH ranged between 6.20 and 7.21 pH units throughout the deployment season, with a median value of 6.95 pH units (Figure 10).
- Stage is included on Figure 10 to show the relationship between water level and pH. pH values increase slightly throughout the deployment season as stage decreases for almost the entire season.
- 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). In the beginning of and throughout the first deployment period, pH values are just below suggested guideline. Guidelines are indicated in blue on Figure 10

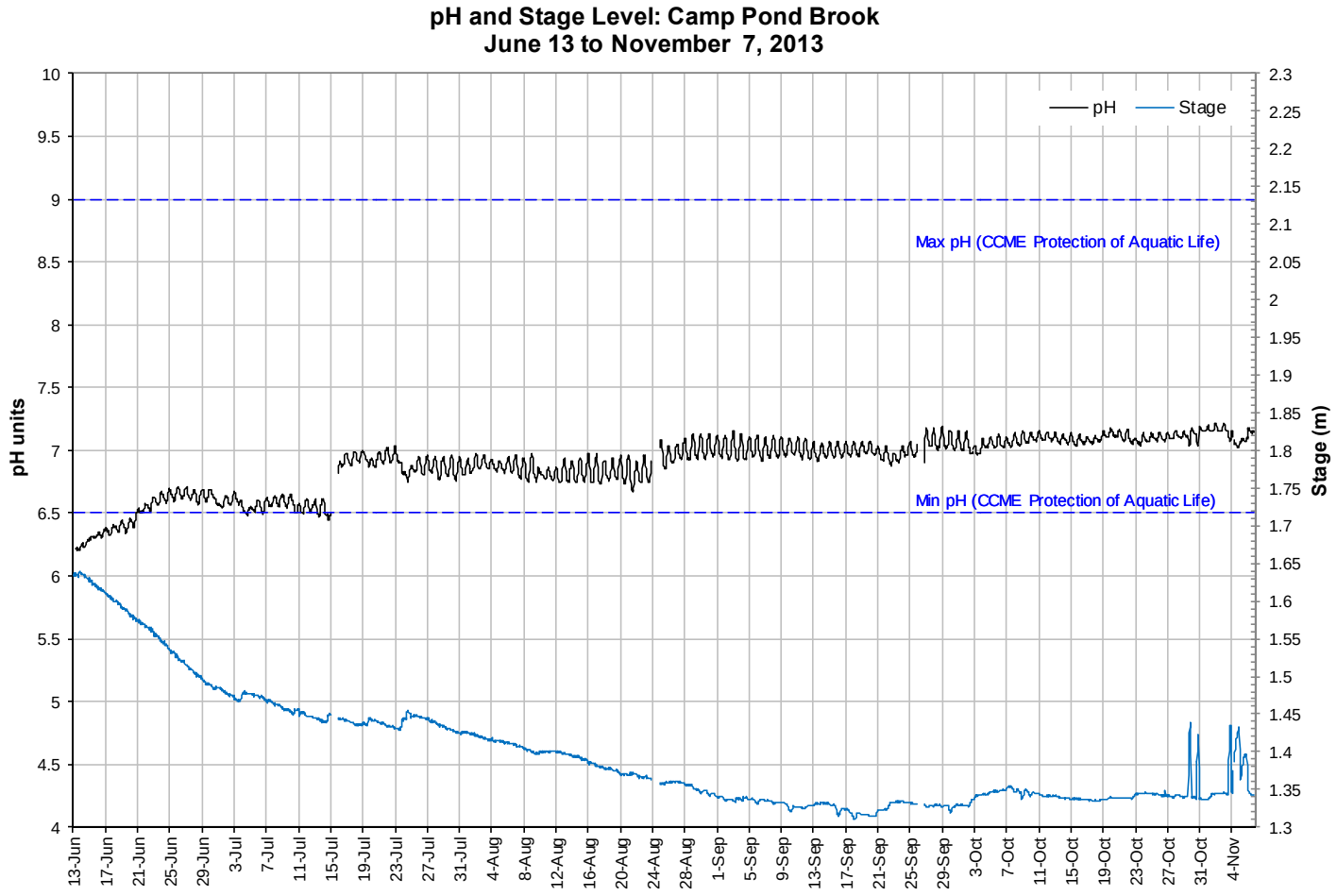

Figure 10: pH and stage level at Camp Pond Brook

- Specific conductivity ranged between 14.9µS/cm and 47.5µS/cm throughout the deployment season, with a median value of 36.3µS/cm (Figure 11).
- Stage is included in Figure 11 to illustrate the inverse relationship between conductivity and water level. Generally, stage decreases throughout the deployment season, and specific conductivity is increasing. Typically, as stage decreases, specific conductivity generally increases due to the increased concentration of dissolved solids in the water column. Inversely, as stage increases, specific conductivity decreases as the concentration of dissolved solids is diluted.
- Even near the end of the last deployment period, specific conductivity drops significantly as the sudden increases in stage level. It is unknown what caused these events to occur.

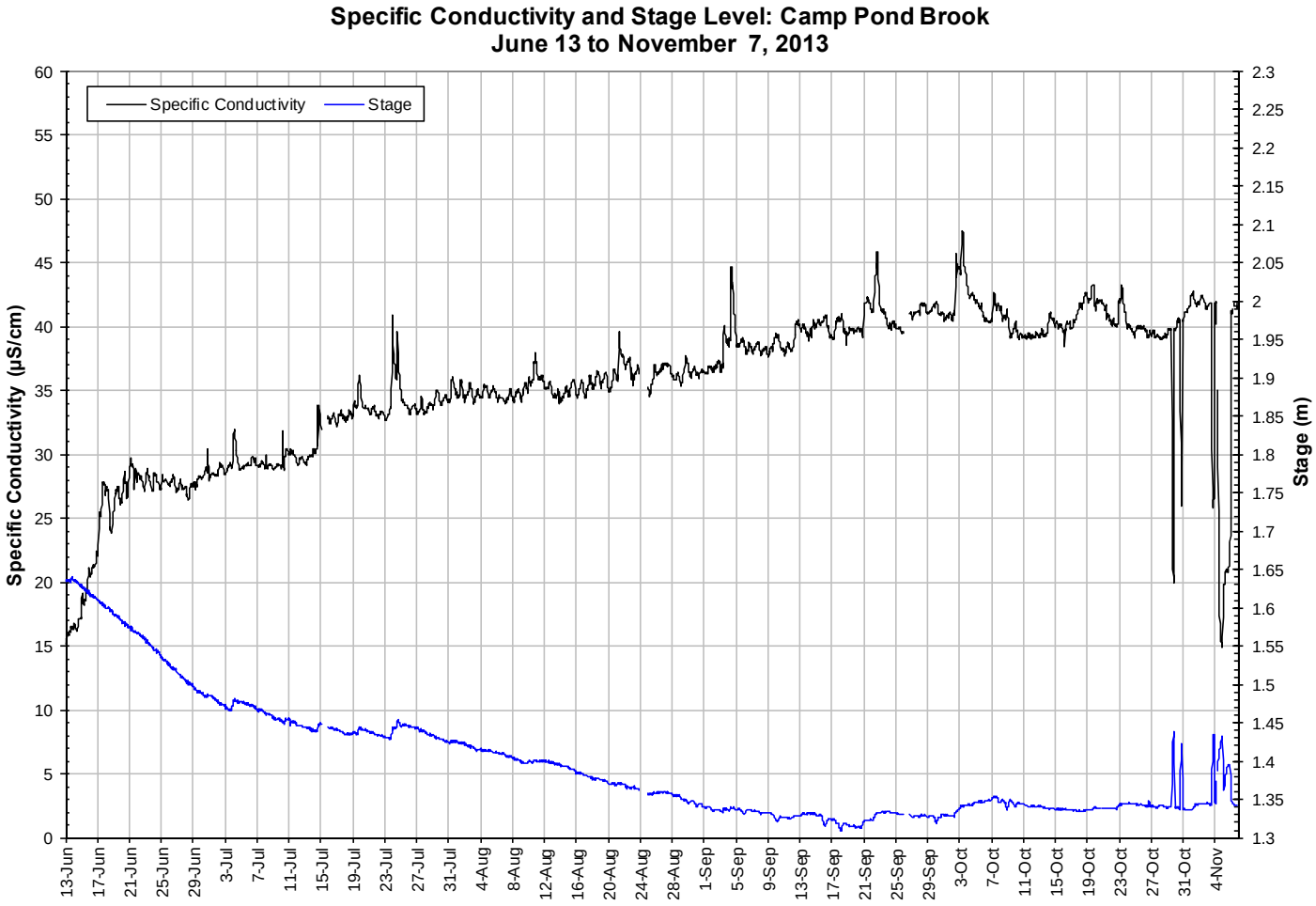

Figure 11: Specific conductivity and stage level at Camp Pond Brook

- Dissolved oxygen content ranges between 8.47mg/l and 13.72mg/l, with a median value of 10.40mg/l. The saturation of dissolved oxygen ranges from 85.6% to 101.1%, with a median value of 92.9% (Figure 12).
- Dissolved oxygen content shows a typical seasonal trend, inverse to water temperature. Dissolved oxygen content is decreasing throughout June and July reaching a seasonal low in mid 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). Most values were above the CCME Guideline for the Protection of Aquatic Life at Early Life Stages (9.5mg/l). During most of July and August, dissolved oxygen content is just slightly below this guideline. The guidelines are indicated in blue on Figure 12.

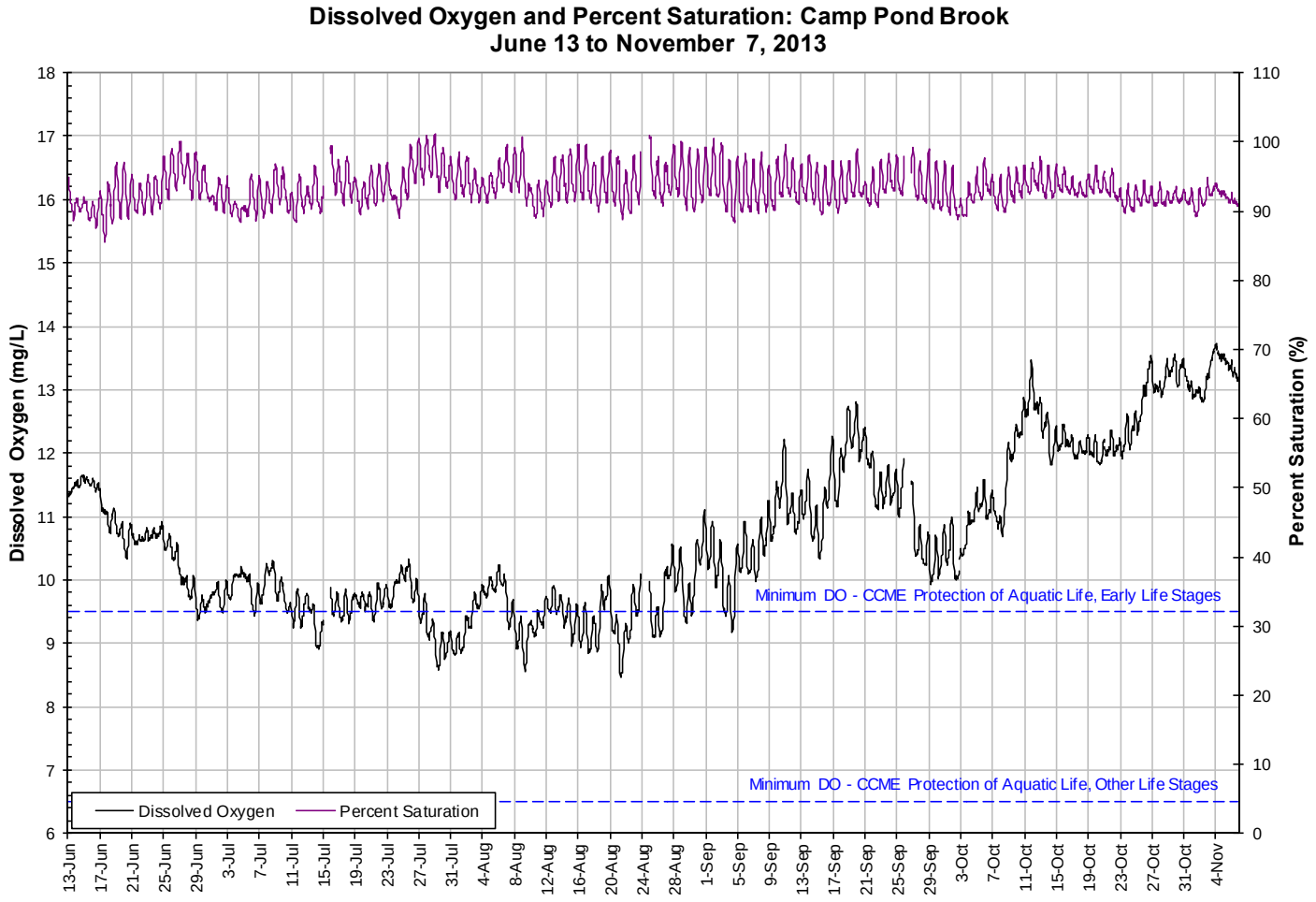

Figure 12: Dissolved oxygen and percent saturation at Camp Pond Brook

- Turbidity ranges between 0NTU and 61NTU during the 2013 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 four deployment periods from June 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. Most events are low in magnitude and short in duration.

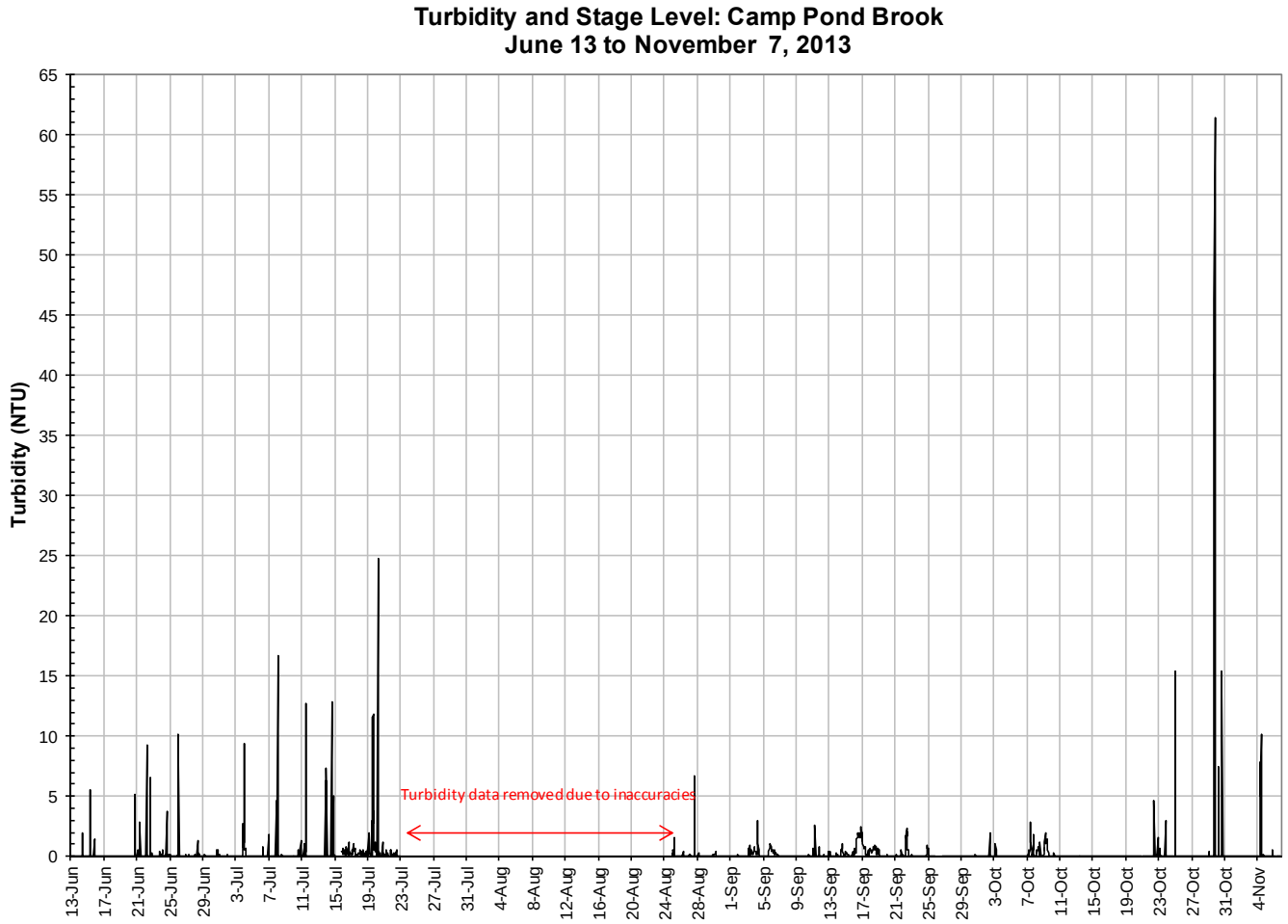

Figure 13: Turbidity at Camp Pond Brook

- Stage and precipitation are graphed below to show the relationship between rainfall and water level (Figure 14).
- 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 (>50% of the days) and moderate in magnitude throughout the deployment season.

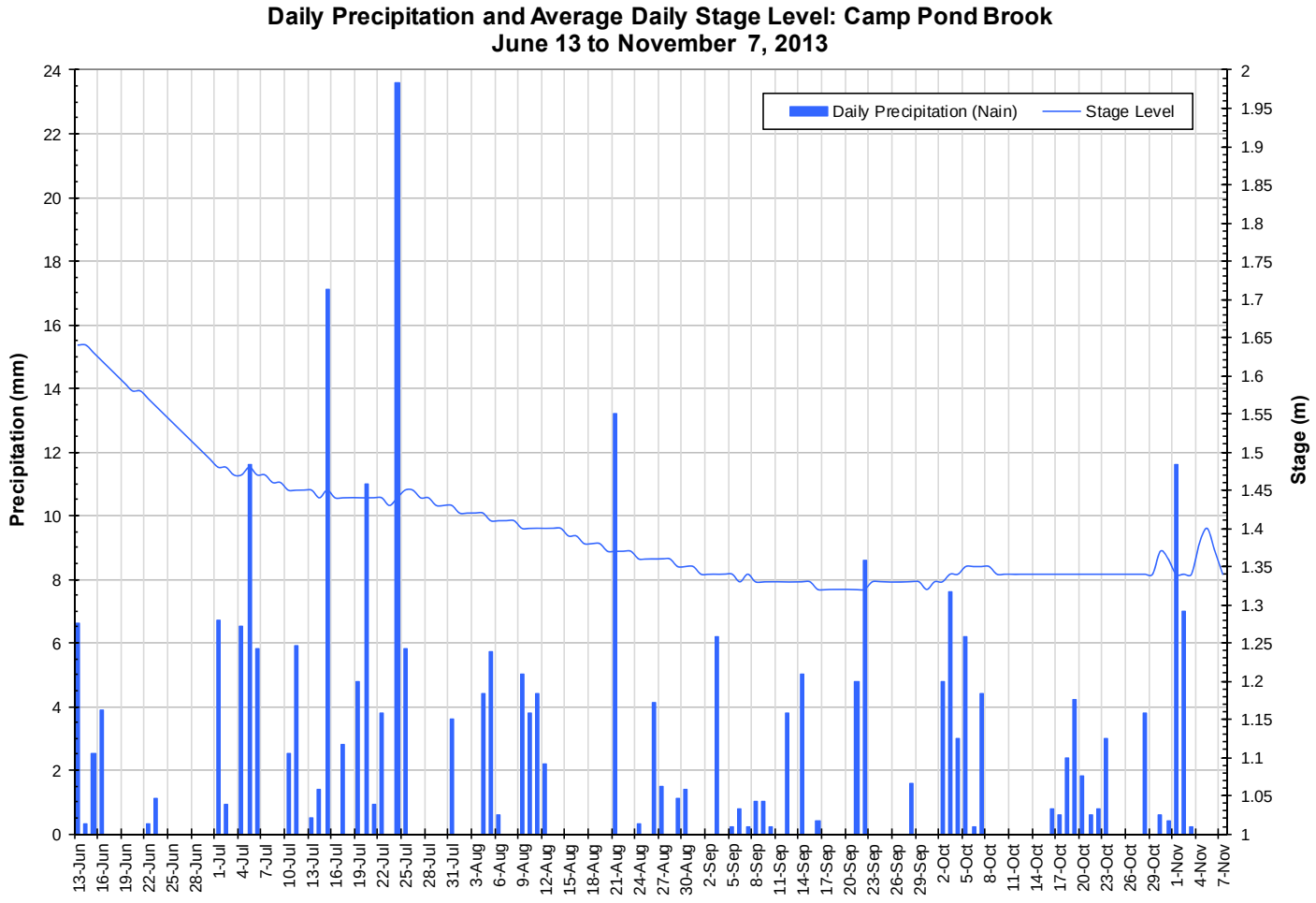

Figure 14: Daily precipitation and stage level at Camp Pond Brook

Tributary to Lower Reid Brook

- Water temperature ranged from 0.00°C to 16.40°C during the deployment season, with a median value of 7.90°C (Figure 15).
- Water temperatures are increasing during the first and second deployment before reaching a seasonal high in early August. Water temperature then begins to decrease throughout the late summer and fall period.

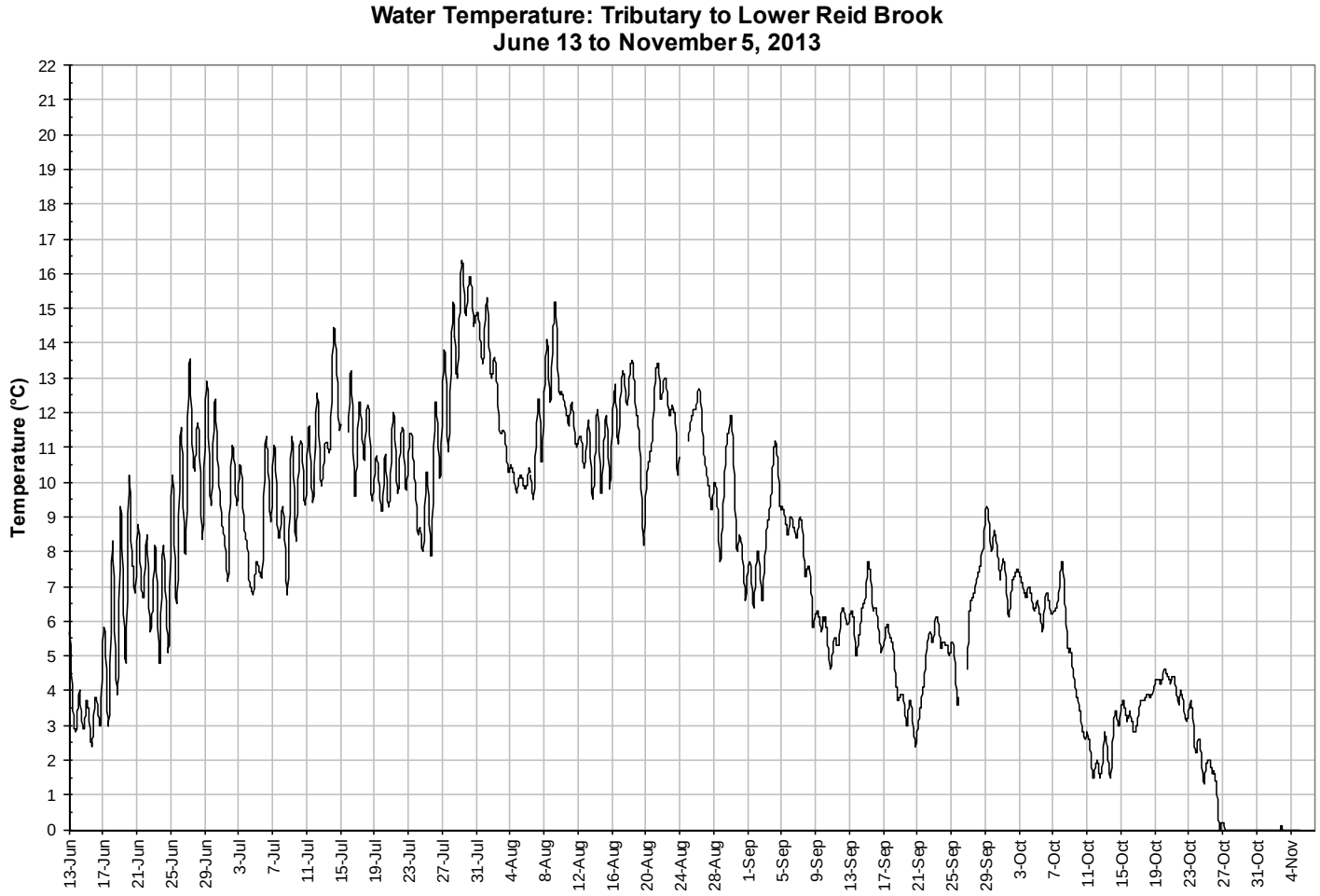

Figure 15: Water temperature at Tributary to Lower Reid Brook

- 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.

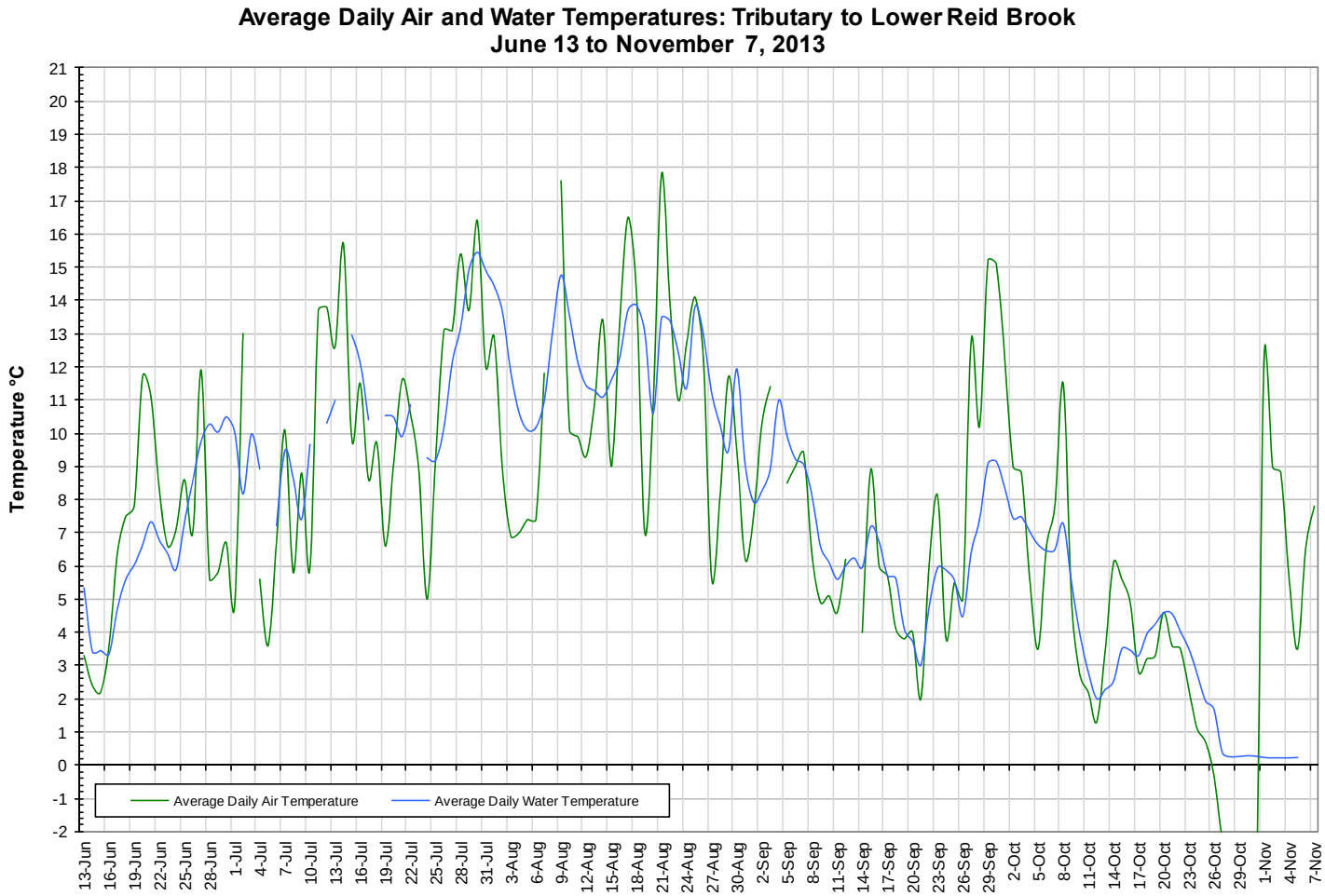

Figure 16: Average daily air and water temperatures at Tributary to Lower Reid Brook (weather data recorded at Nain)

- pH ranges between 6.46 and 7.21 pH units throughout the deployment season, with a median value of 6.88 pH units (Figure 17).
- Stage is included on Figure 10 to show the relationship between water level and pH. pH values fluctuate throughout the deployment season 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 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.

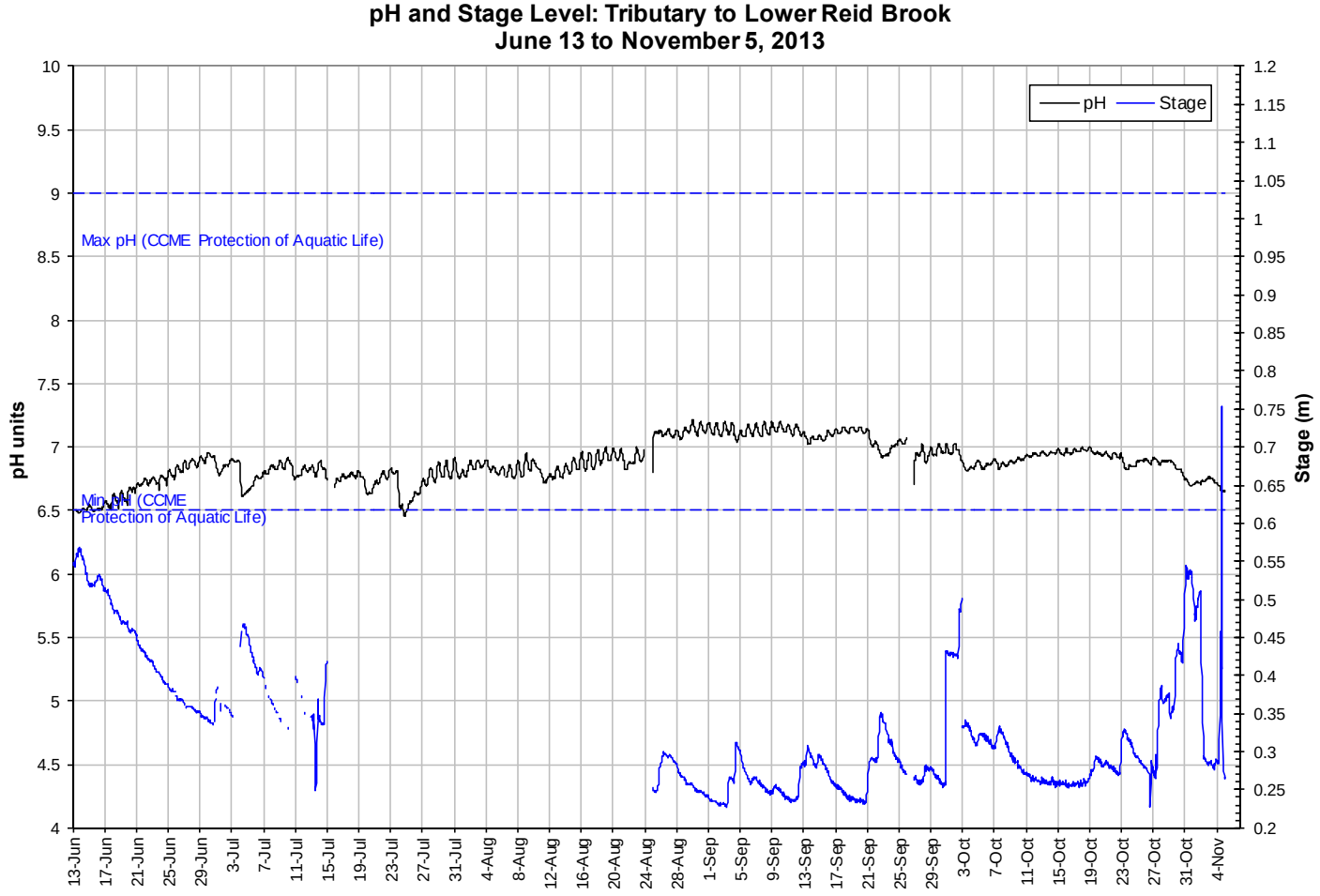

Figure 17: pH and stage level at Tributary to Lower Reid Brook

- Specific conductivity ranges between 16.0µS/cm and 56.6µS/cm throughout the deployment season, with a median value of 38.1µS/cm (Figure 18).
- Stage is included in Figure 18 to illustrate the inverse relationship between conductivity and water level. Generally, stage is decreasing throughout 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 general trend corresponds with the decreasing stage level and the short decreases in specific conductivity correlate with the intermittent increases in stage level. The relationship between stage levels and specific conductivity levels is typically very clear at this station throughout the entire deployment season.

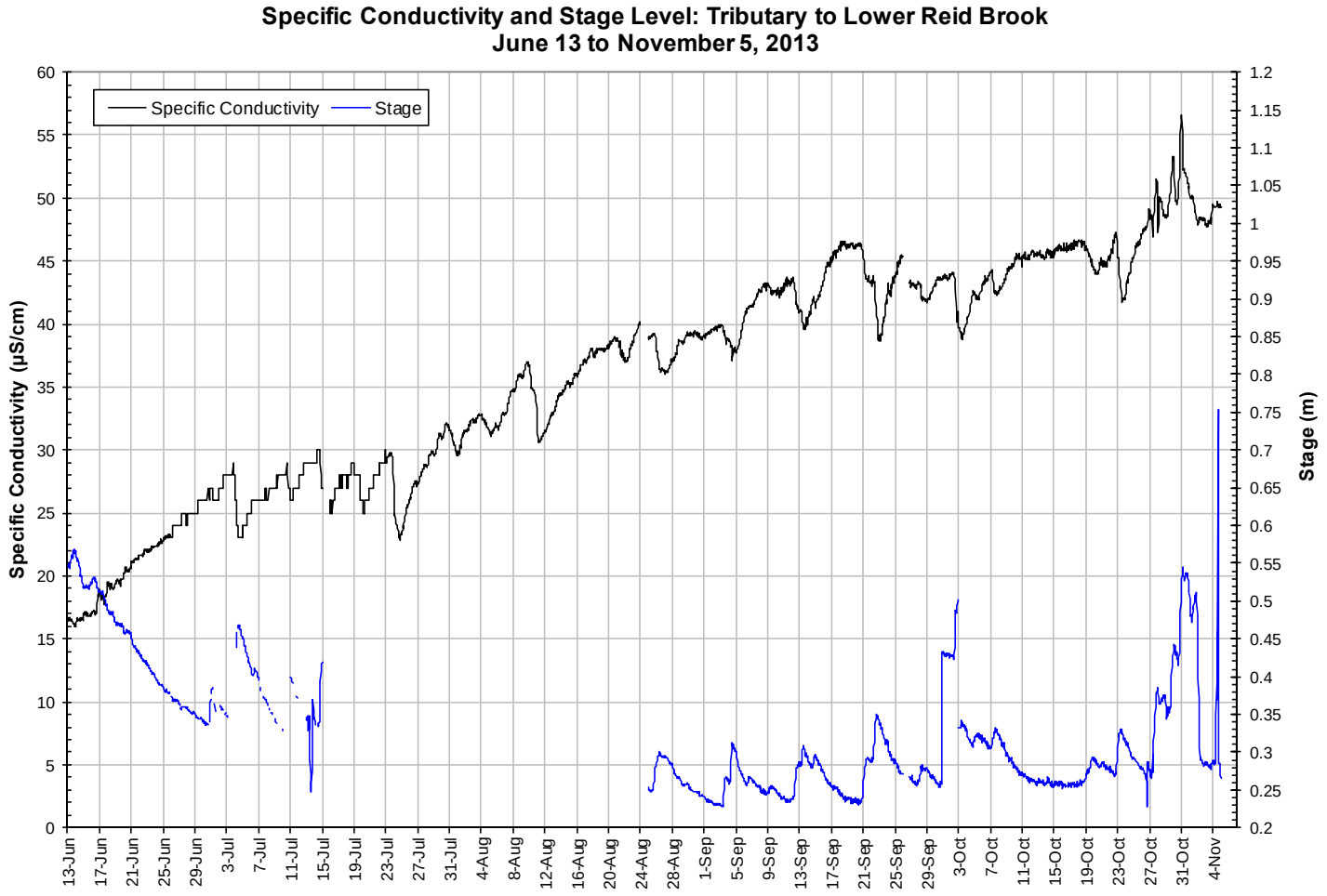

Figure 18: Specific conductivity and stage level at Tributary to Lower Reid Brook

- Dissolved oxygen content ranges between 9.26mg/l and 13.96mg/l, with a median value of 11.32mg/l. The saturation of dissolved oxygen ranges from 89.8% to 99.5%, with a median value of 95.3% (Figure 19).
- Dissolved oxygen content shows a typical seasonal trend, inverse to water temperature. Values are decreasing in the early summer months of June and July while water temperatures are increasing. Dissolved oxygen reaches a seasonal low in late 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 only 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.

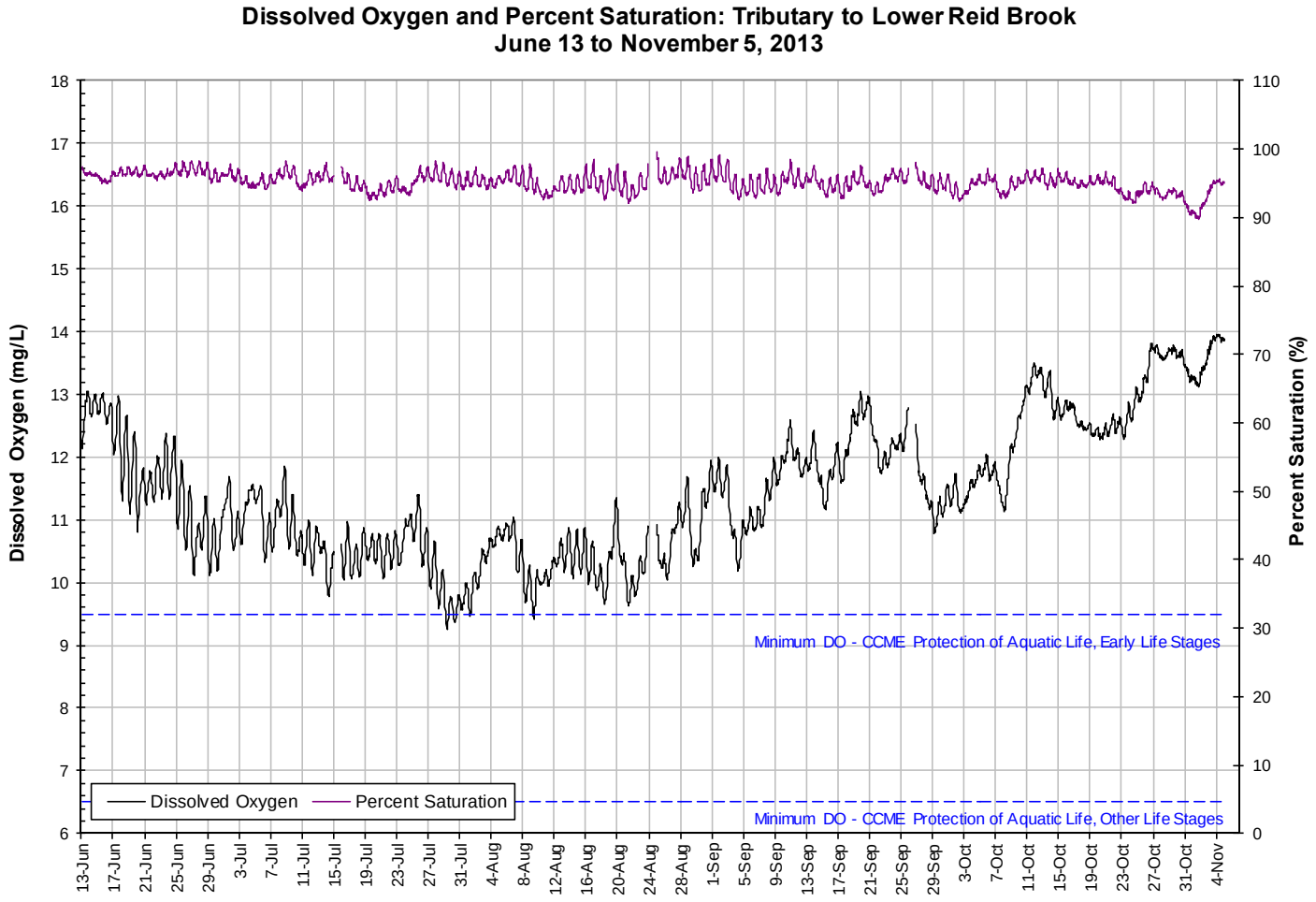

Figure 19: Dissolved oxygen and percent saturation at Tributary to Lower Reid Brook

- Turbidity ranges between 0NTU and 69NTU during the 2013 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 four deployment periods from June 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. Events are generally low in magnitude and short in duration.

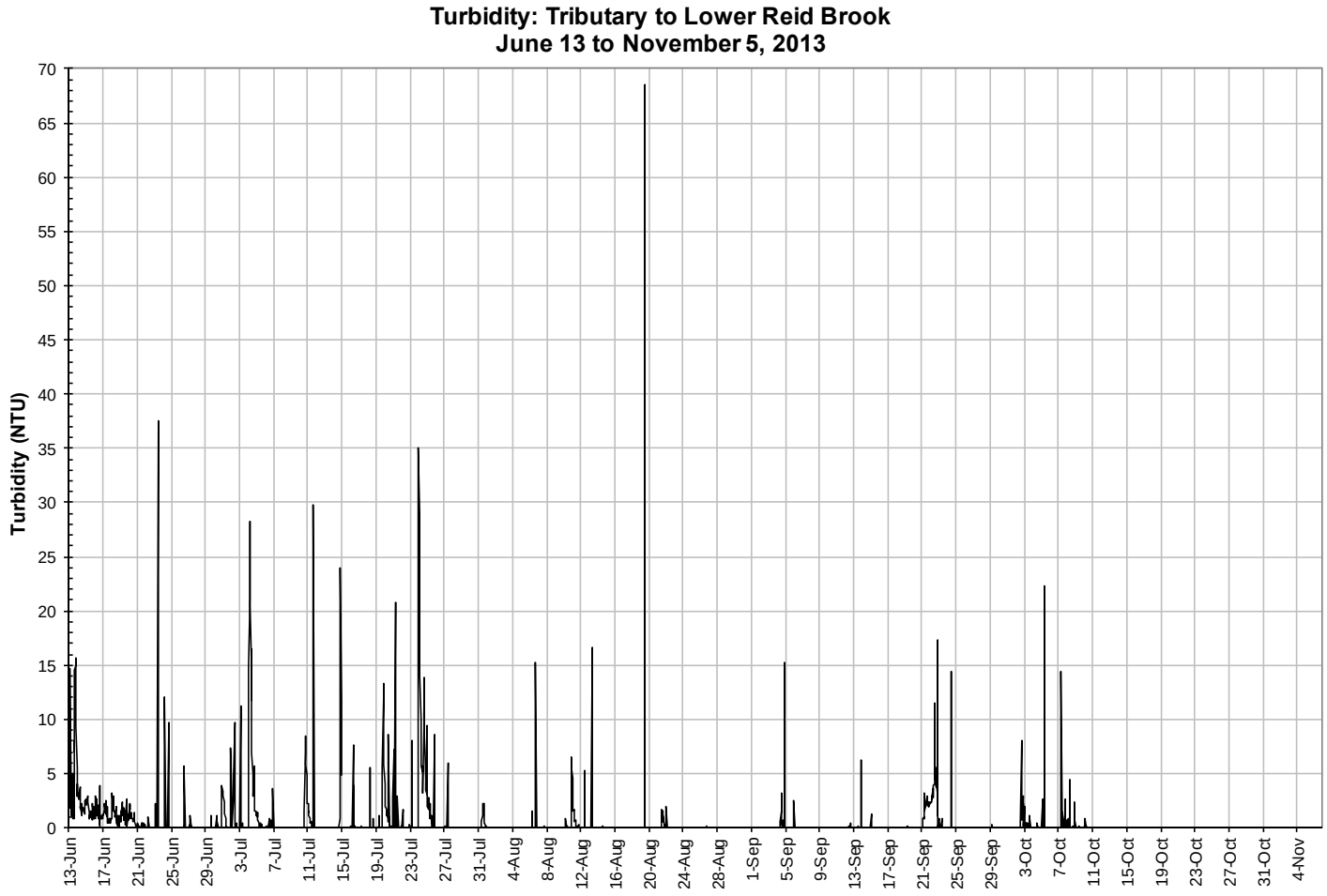

Figure 20: Turbidity at Tributary to Lower Reid Brook

- Stage and precipitation are graphed below to show the relationship between rainfall and water level (Figure 21).
- Stage levels are typically decreasing throughout the first deployment period and increase again before the start of the second deployment. Stage ranges between 0.23m and 0.75m, a difference of 0.52m.
- Precipitation events are frequent (>50% of the days) and moderate in magnitude throughout the deployment season.

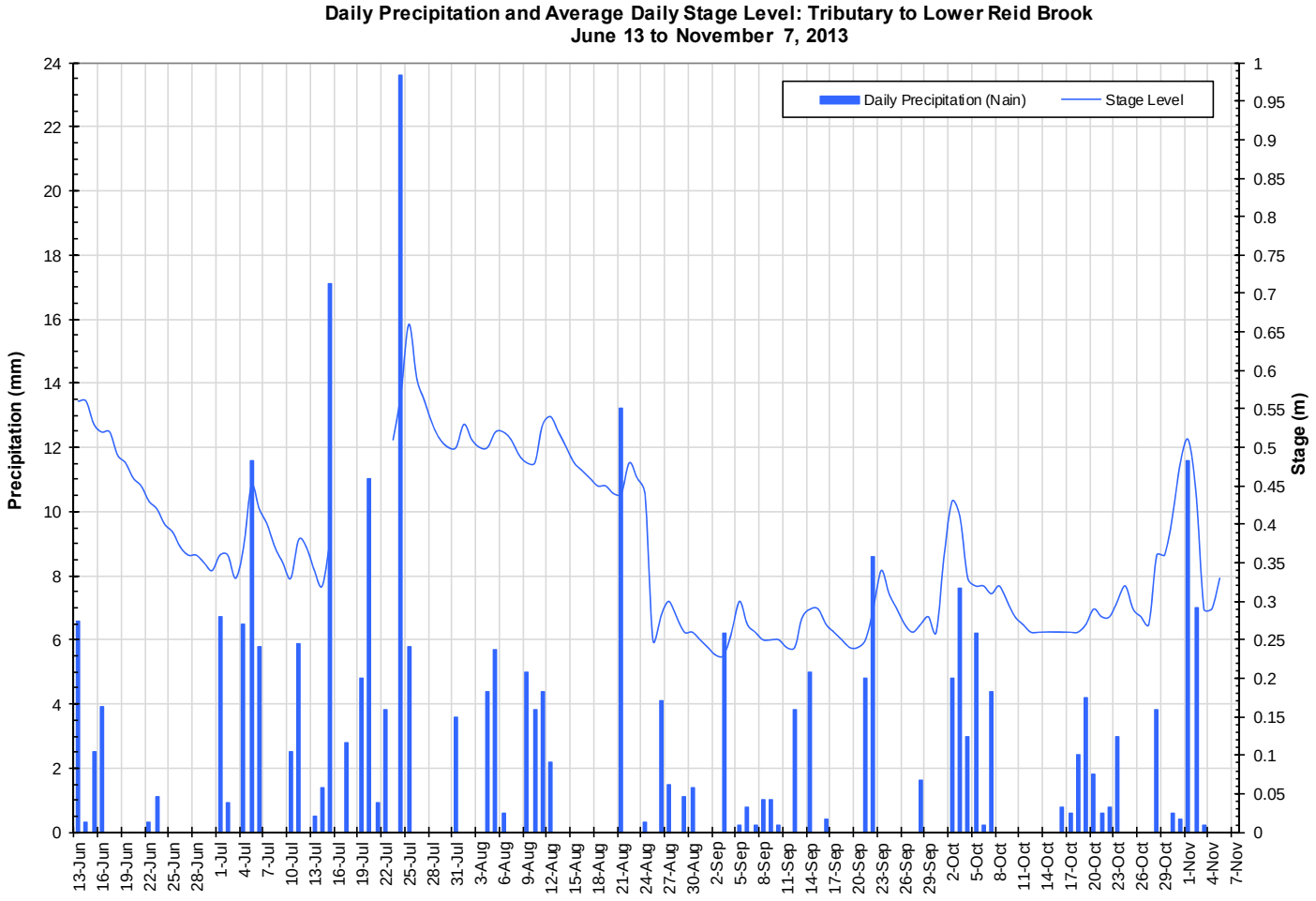

Figure 21: Average daily stage level and daily precipitation at Tributary to Lower Reid Brook

Lower Reid Brook

- Water temperature ranged from 0.19°C to 16.68°C during the deployment season, with a median value of 8.12°C (Figure 22).
- Water temperatures are increasing in the latter half of June and throughout July. Water temperature peaks in early August. Water temperature then begins to decrease throughout August and continues decreasing into September and October.

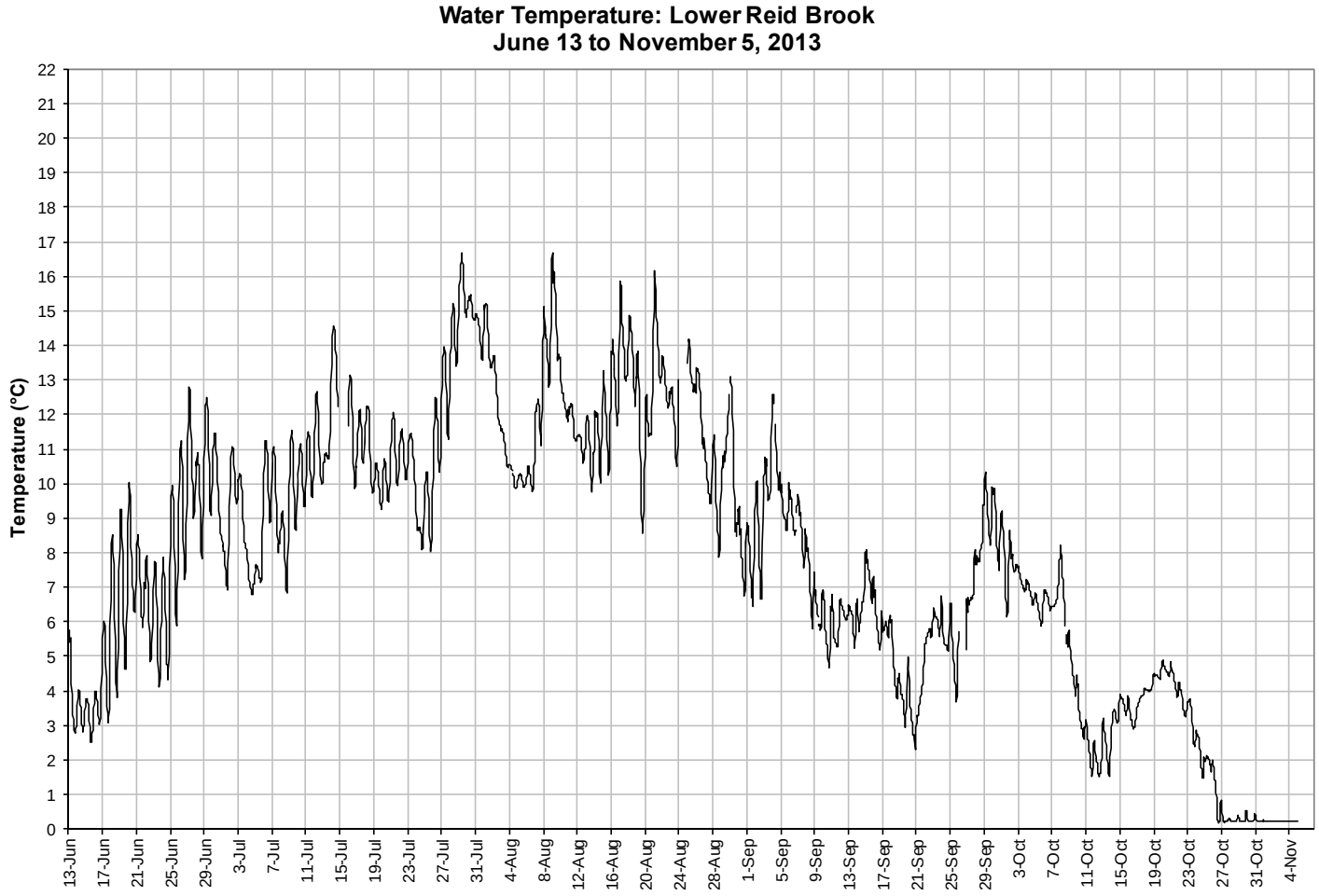

Figure 22: Water temperature at Lower Reid Brook

- 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.

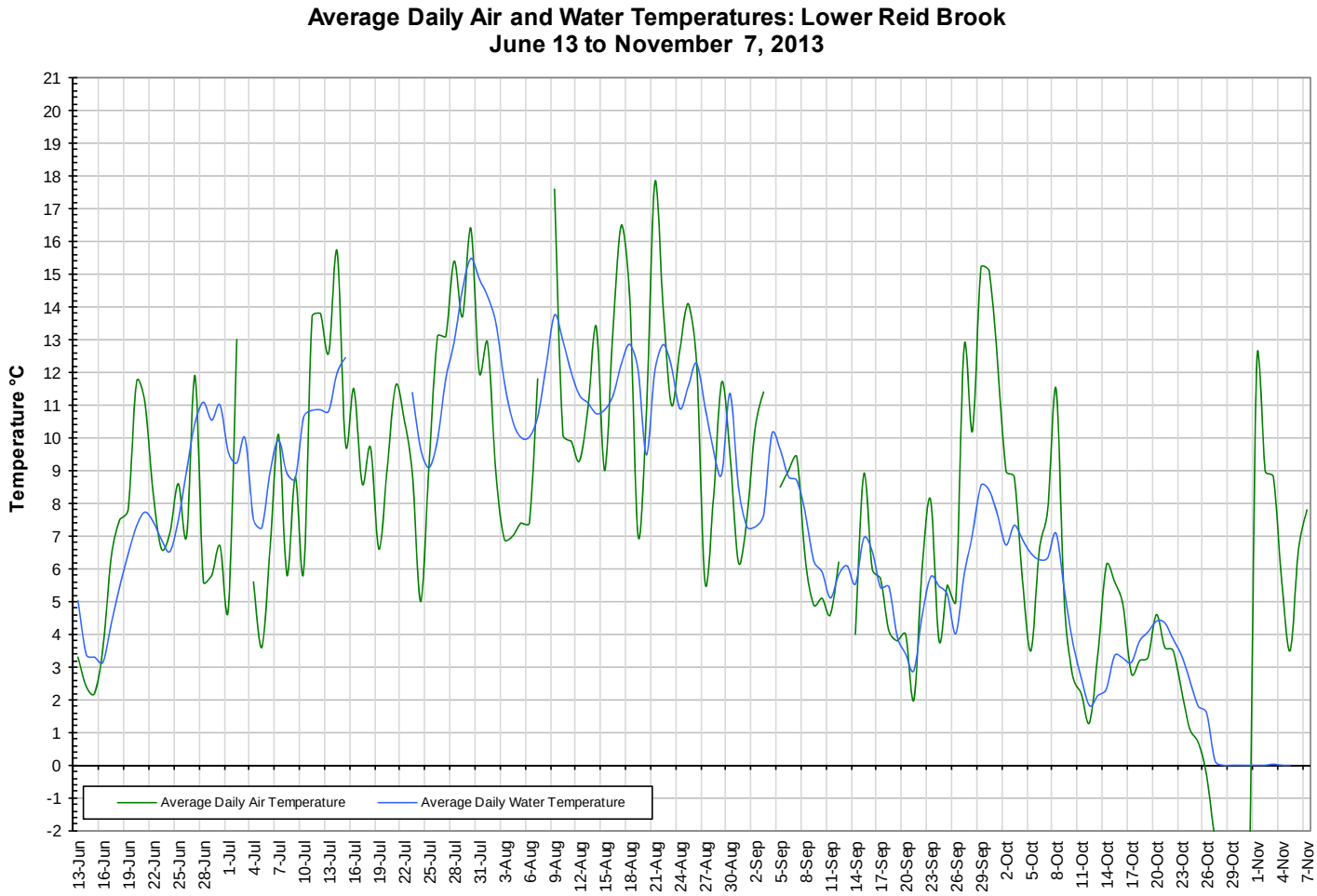

Figure 23: Average daily air and water temperatures at Lower Reid Brook

(weather data recorded at Nain)

- pH ranges between 5.69 and 7.25 pH units during the deployment season, with a median value of 6.86 pH units (Figure 24).
- 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 24. During the second deployment period, pH values appear to be decreasing to a low as 5.69 pH units. This is unusual for this station. When a new instrument is deployed in late August, pH values are reported within a normal range indicating that is likely an instrument error that caused the decrease and irregular data in the second deployment period.
- Stage is included on Figure 24 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 increases as stage decreases. This trend is experienced throughout the different deployment periods.

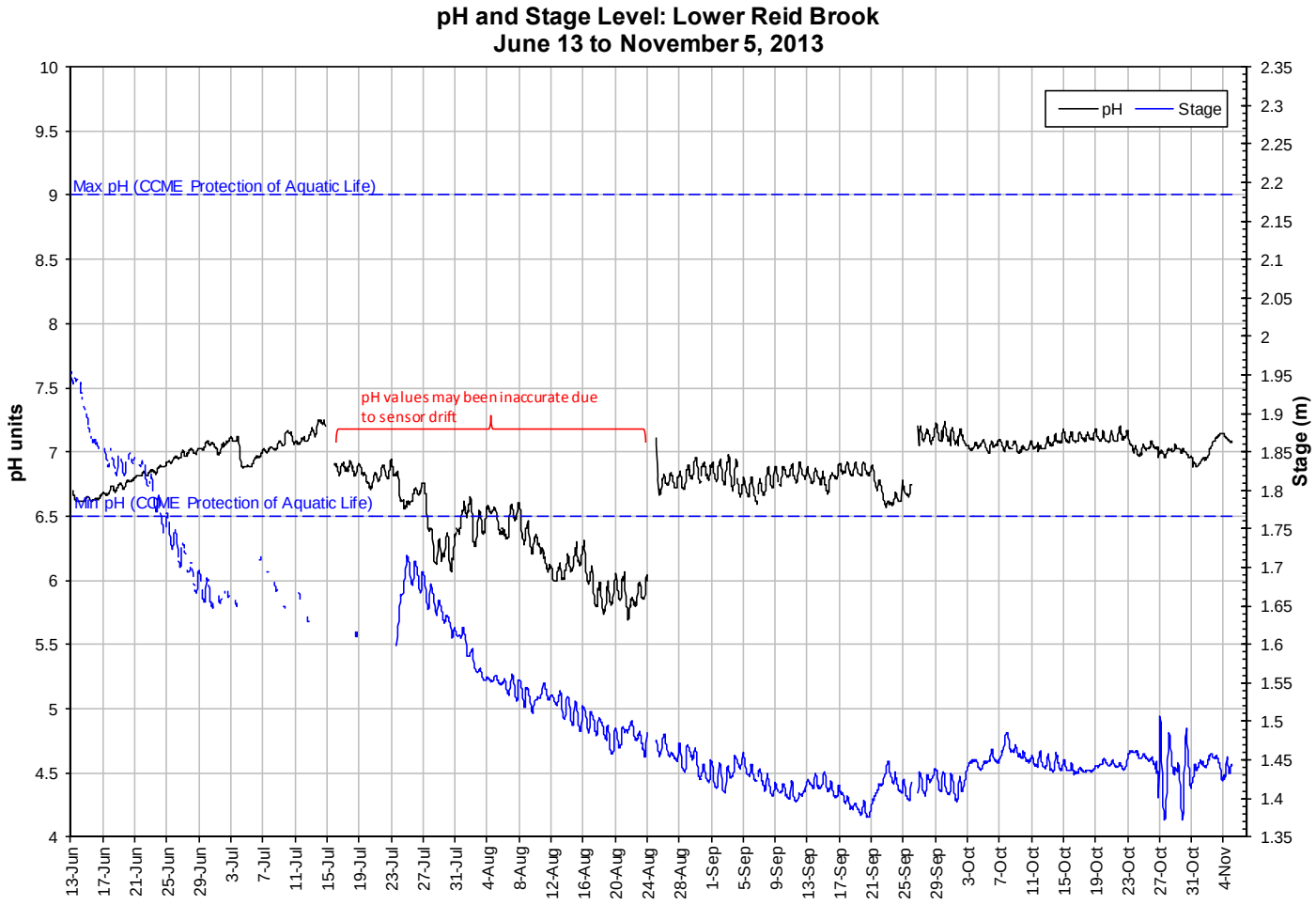

Figure 24: pH and stage level at Lower Reid Brook

- Specific conductivity ranges between 13.9µS/cm and 52.5µS/cm during the deployment season, with a median value of 34.6µS/cm (Figure 25).
- Stage is included in Figure 25 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 values generally increase throughout the entire deployment season. The relationship between stage levels and specific conductivity levels is very clear at this station throughout the entire deployment season.

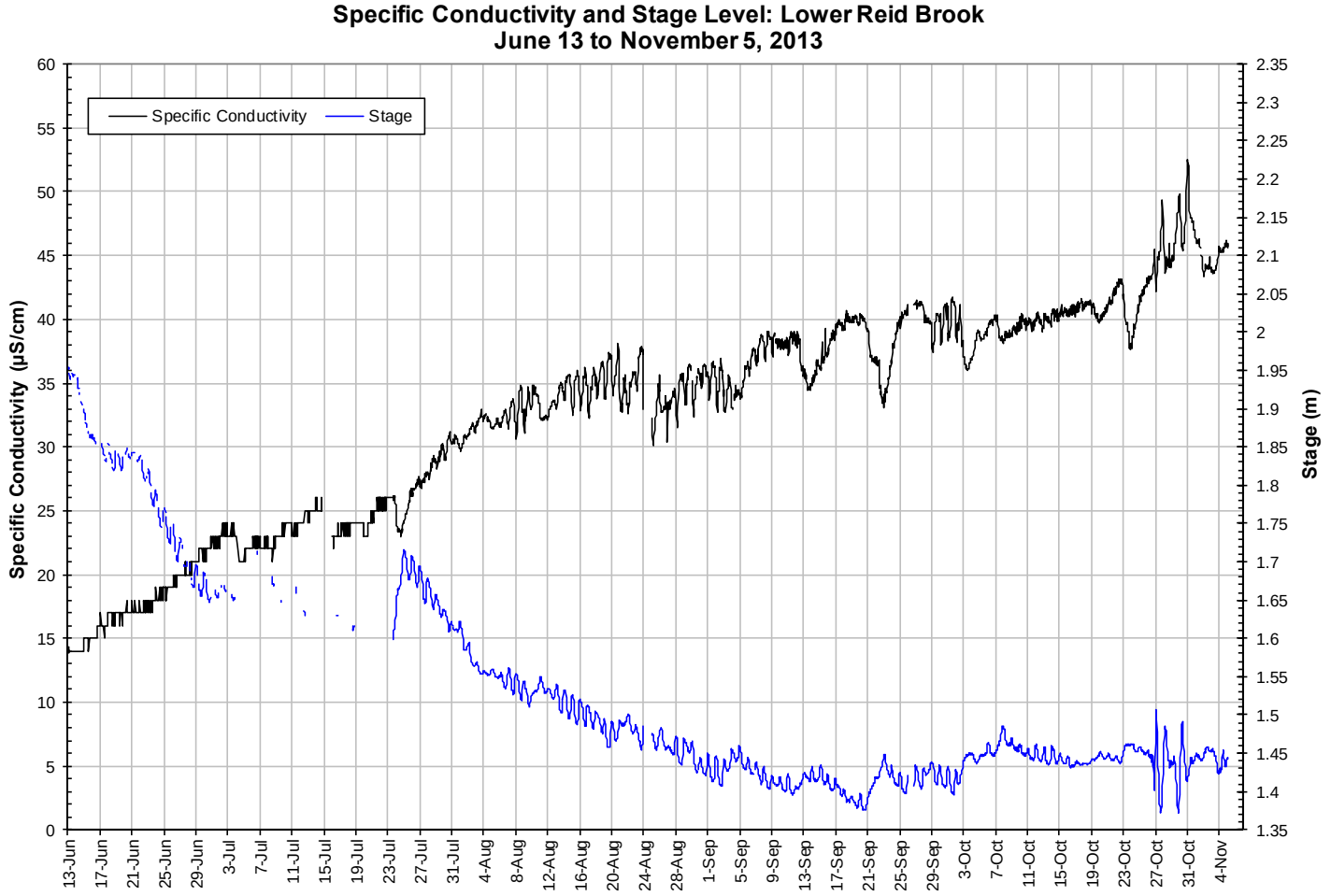

Figure 25: Specific conductivity and stage level at Lower Reid Brook

- Dissolved oxygen content ranges between 9.43mg/l and 13.89mg/l, with a median value of 11.46mg/l. The saturation of dissolved oxygen ranges from 89.7% to 105.1%, with a median value of 96.7% (Figure 26).
- Dissolved oxygen content shows a typical seasonal trend, inverse to water temperature. Values are decreasing 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 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 one occasion, during the period of warmest air and water conditions, dissolved oxygen content dropped to just below the suggested guideline. The guidelines are indicated in blue on Figure 26.

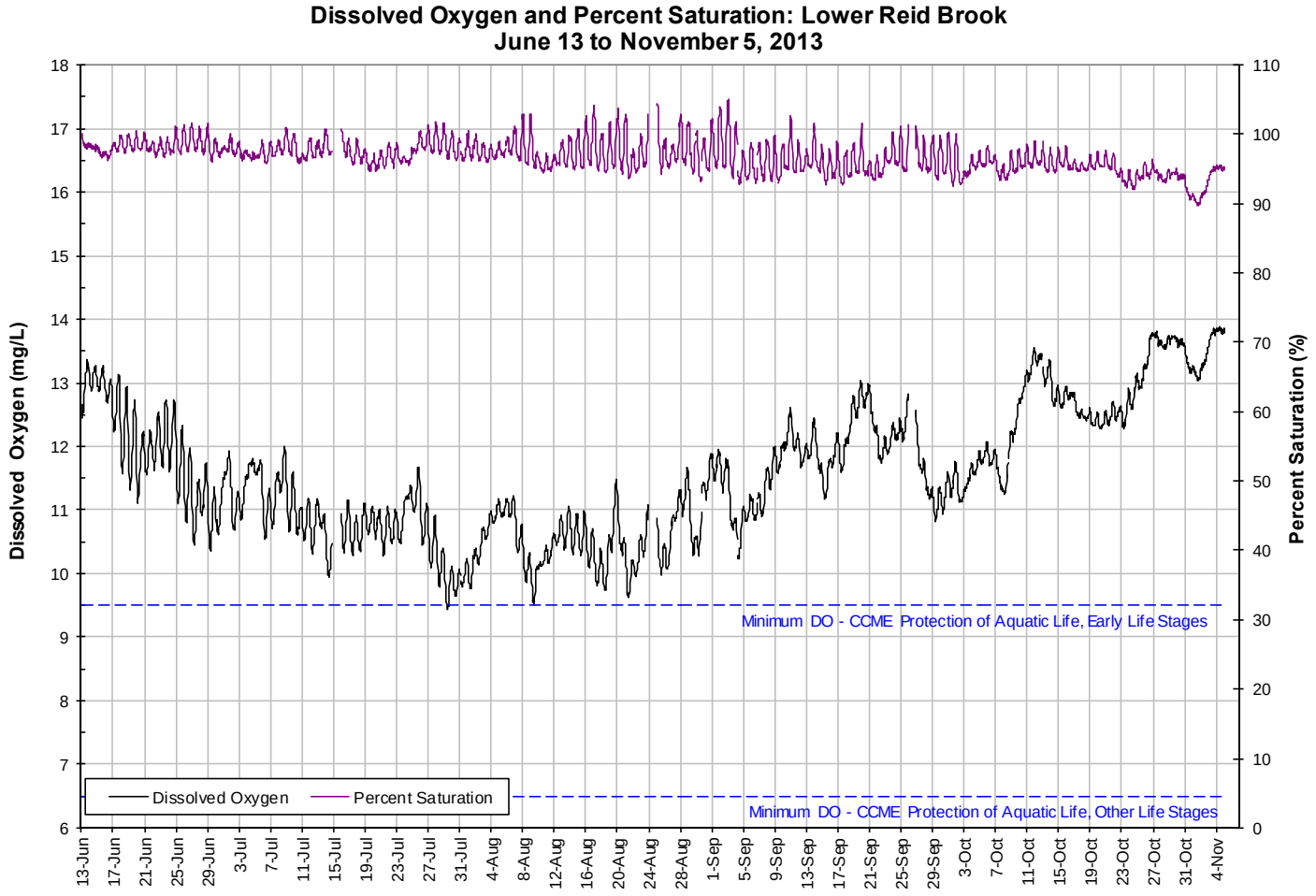

Figure 26: Dissolved oxygen and percent saturation at Lower Reid Brook

- Turbidity ranges between 0NTU and 259NTU during the 2013 deployment season (Figure 27). 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 four deployment periods from June 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. Turbidity events are generally low in magnitude and short in duration.

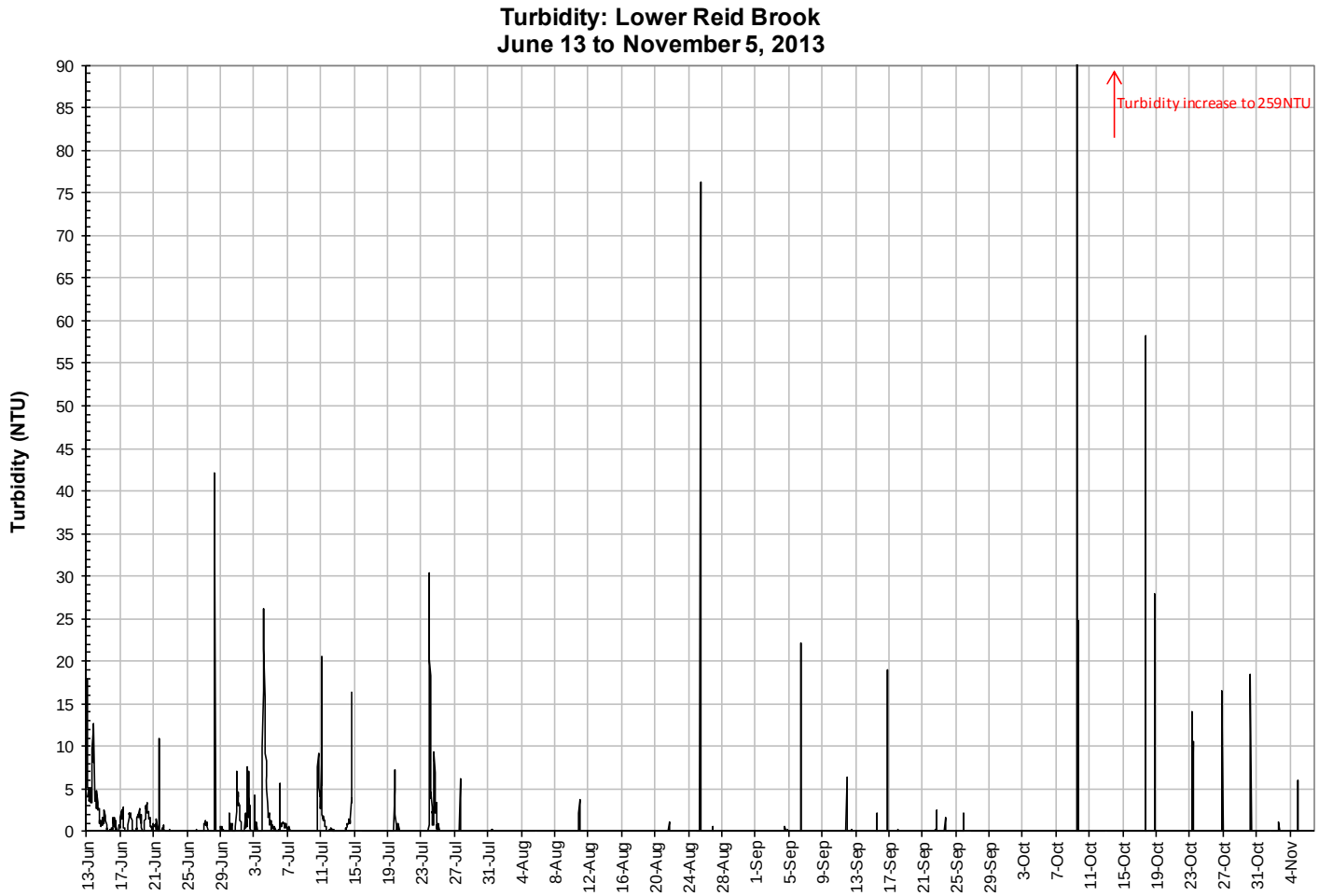

Figure 27: Turbidity at Lower Reid Brook

- Stage and precipitation are graphed below to show the relationship between rainfall and water level (Figure 28).
- Stage levels decreasing through much of the deployment period. Stage levels range between 1.37m and 1.95m, a difference of 0.58m.
- Precipitation events are frequent (>50% of the days) and moderate in magnitude throughout the deployment season.

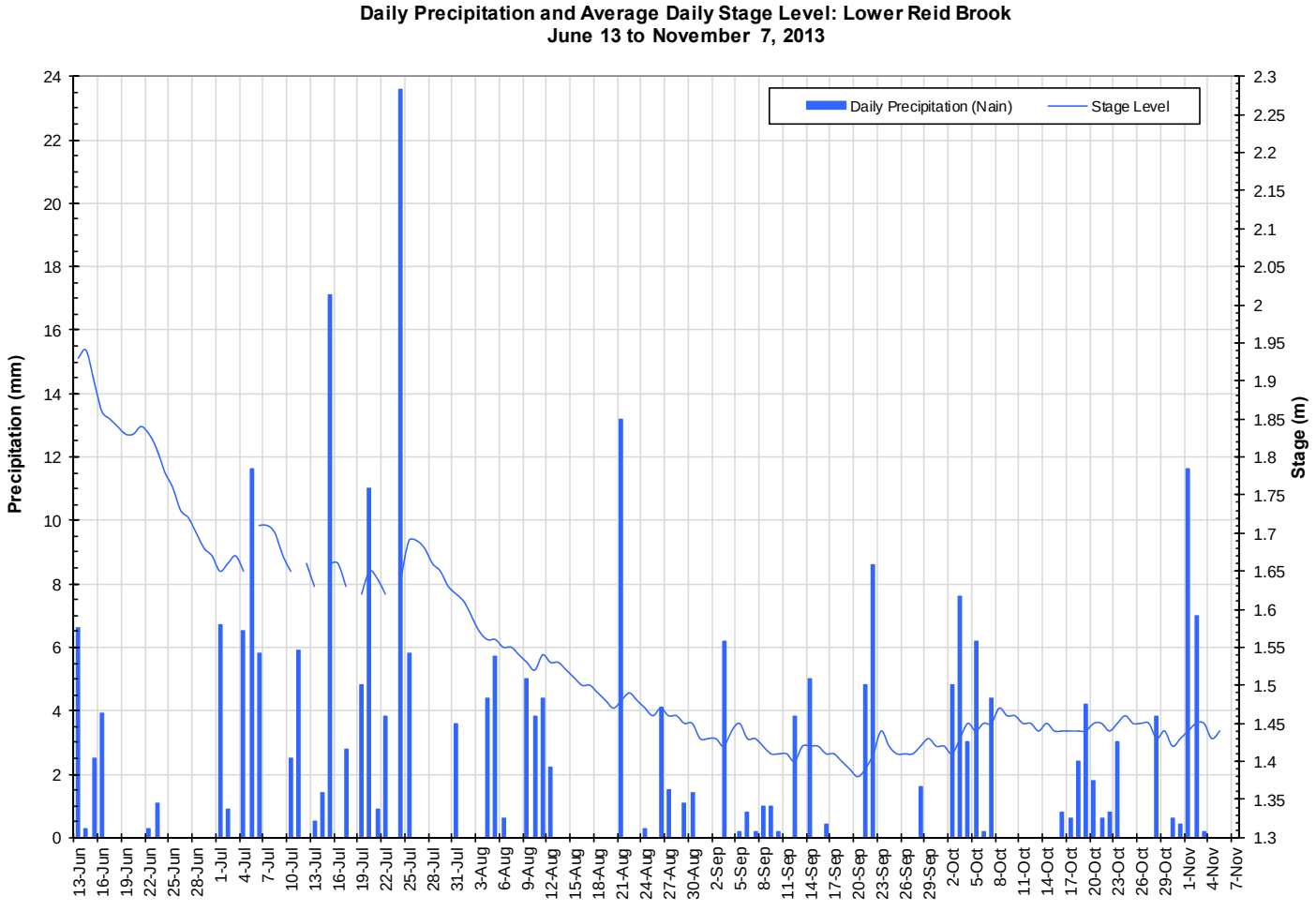

Figure 28: Daily precipitation and average daily stage level at Lower Reid Brook (weather data recorded at Nain)

Multi-Station Comparison

- This section of the annual report focuses on how the stations compared to one another throughout the 2013 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 decrease throughout August until the end of the deployment season in early November.
- Camp Pond Brook recorded the highest temperature in the network at 21.06°C. Camp Pond also had the highest median value for temperature at 10.48°C. Lower Reid Brook and Tributary to Lower Reid Brook have very similar water temperatures throughout the season.

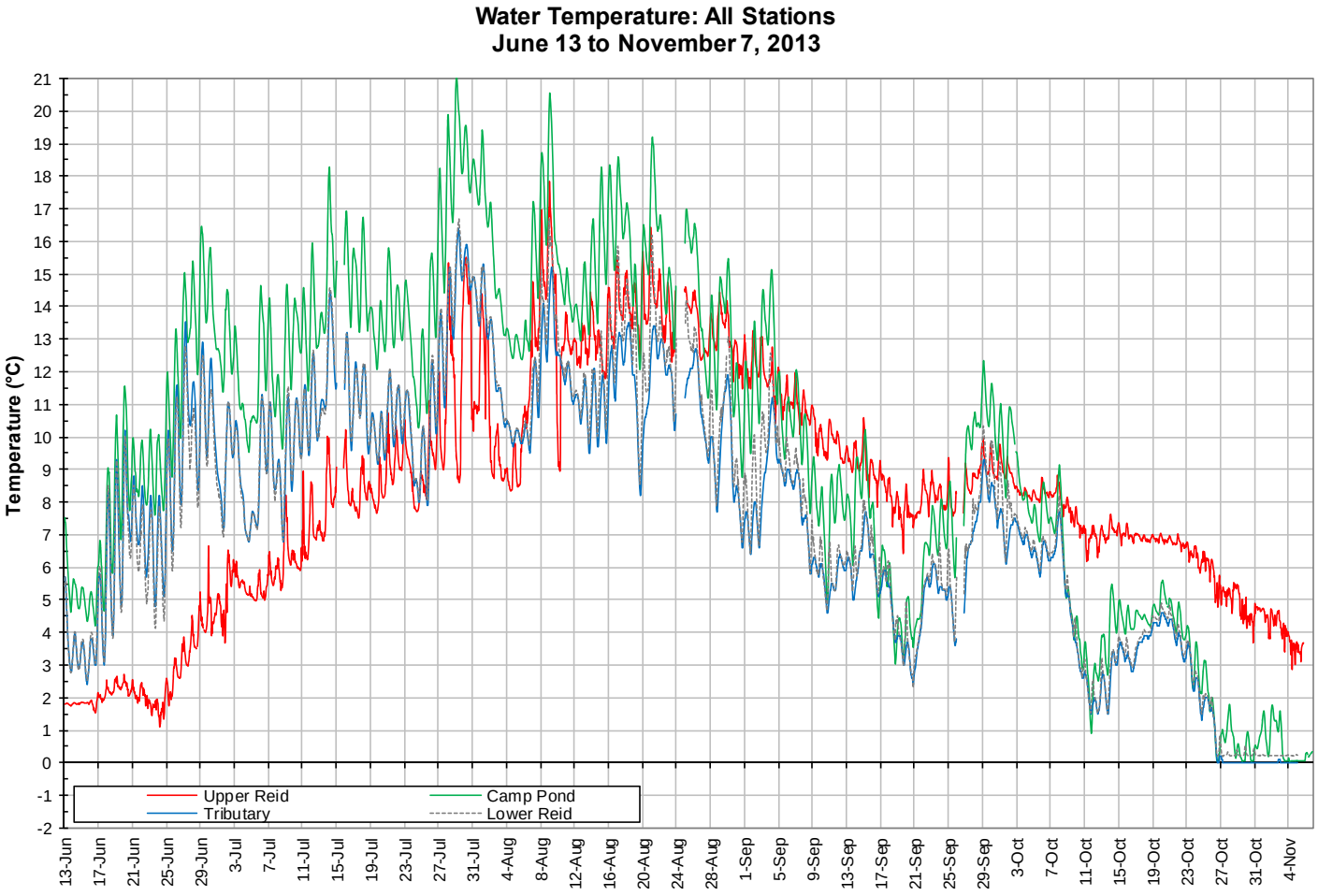

Figure 29: Water temperature at all stations

Temperature (°C)	Upper Reid	Camp Pond	Tributary	Lower Reid
Median	8.26	10.48	7.90	8.12
Max	17.83	21.06	16.40	16.68
Min	1.10	0.03	0.00	0.19

pH

- pH values are also comparable throughout the network of stations with median values between 6.86 and 6.95 pH units (Figure 30).
- With the exception of the irregular data at Lower Reid Brook in the second deployment period, pH values are relatively similar and stable throughout the entire network. There are several occasions when decreases in pH are occurring at all stations in the network simultaneously.

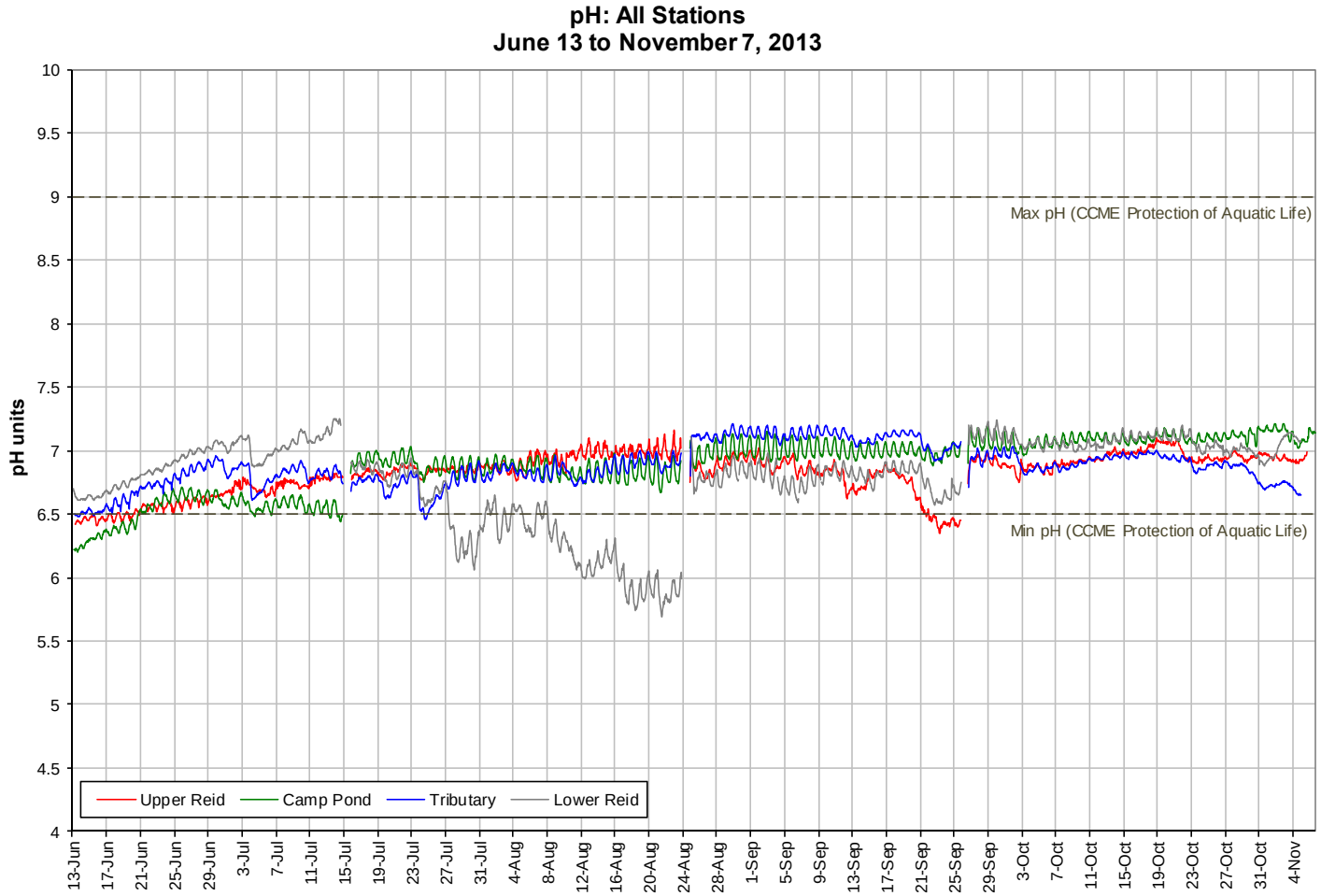

Figure 30: pH at all stations

pH (units)	Upper Reid	Camp Pond	Tributary	Lower Reid
Median	6.86	6.95	6.88	6.86
Max	7.16	7.21	7.21	7.25
Min	6.35	6.20	6.46	5.69

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 11.7µS/cm. At the stations on Camp Pond Brook, tributary to lower Reid and Lower Reid Brook, median values for specific conductivity are 36.3 µS/cm, 38.1 µS/cm and 34.6 µS/cm, respectively.
- 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 entire deployment season at the three stations. At these stations specific conductivity values fluctuate in response to changing stage levels and rainfall events. At the stations on tributary to Lower Reid and Lower Reid Brook, as stage increases, specific conductivity decreases caused by the dilution of major ions in the water column. Vice versa, as stage levels decrease, specific conductivity increases due to the increase in concentration of major ions.
- 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.

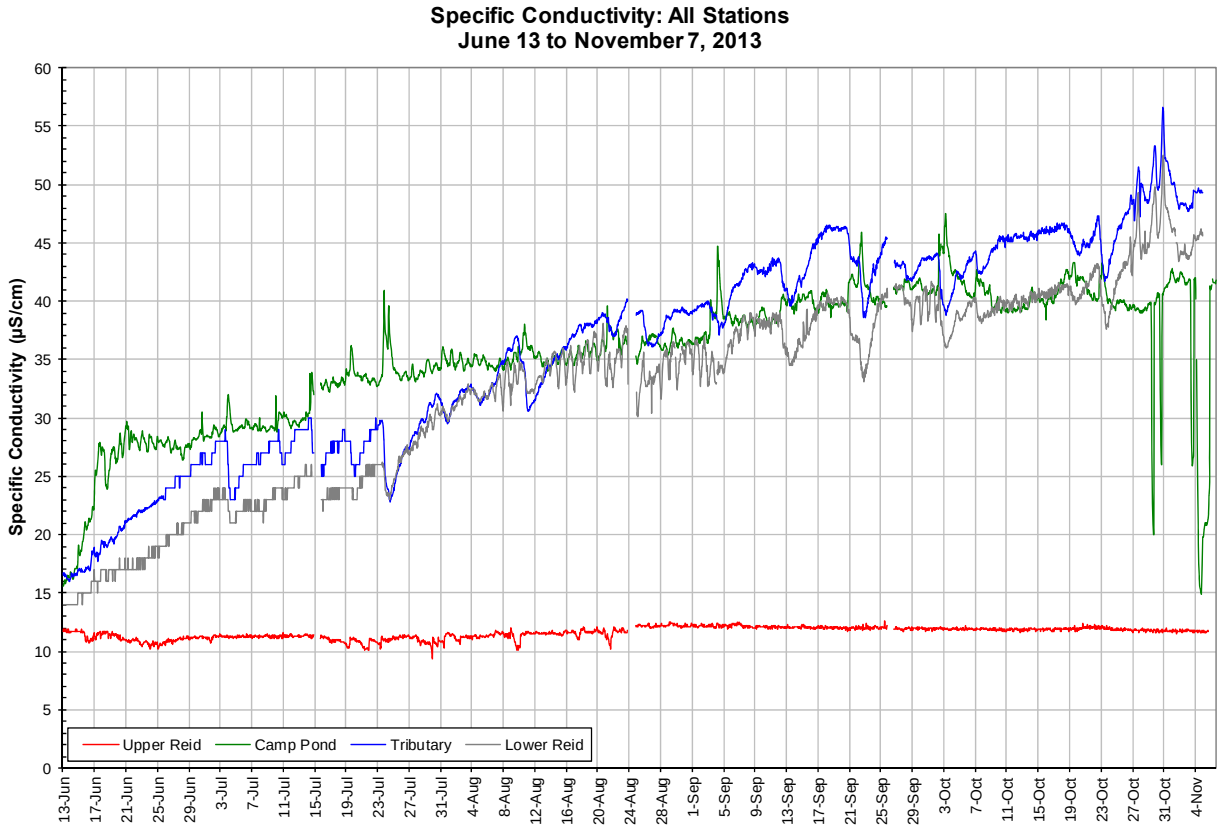

Figure 31: Specific conductivity at all stations

Specific Conductivity (µS/cm)	Upper Reid	Camp Pond	Tributary	Lower Reid
Median	11.7	36.3	38.1	34.6
Max	12.6	47.5	56.6	52.5
Min	9.4	14.9	16.0	13.9

Dissolved Oxygen and Percent Saturation

- Dissolved oxygen content had a median value between 10.40mg/l and 11.46mg/l throughout the network during the 2013 deployment season. Dissolved oxygen content showed a typical 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, and Lower Reid Brook were just below this guideline. At Camp Pond Brook, during the months of July and August, there are numerous occasions when dissolved oxygen content is below the guideline. The guidelines are indicated in on Figure 32.

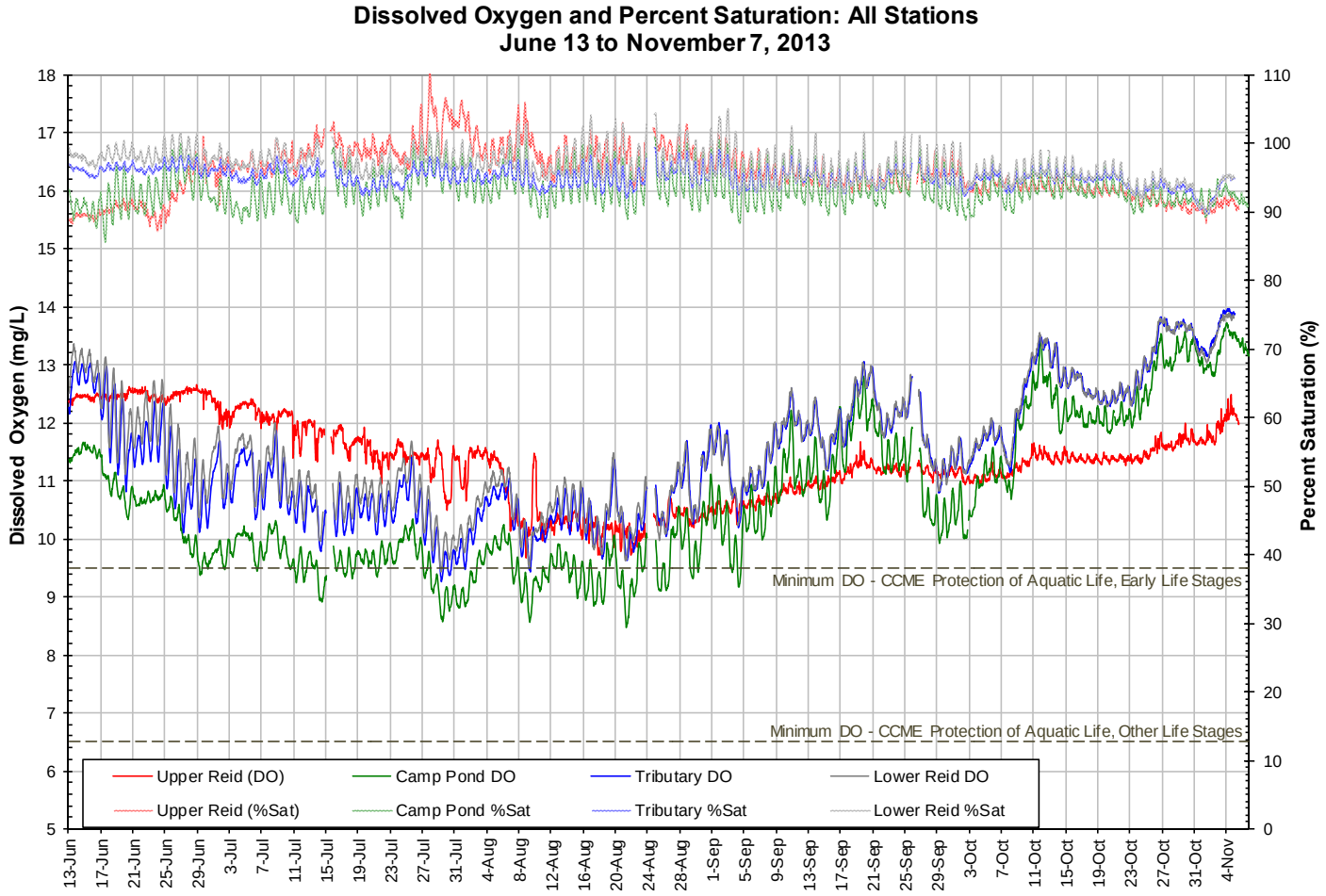

Figure 32: Dissolved oxygen and percent saturation at all stations

	Dissolved Oxygen (mg/l)				Percent Saturation			
	Upper Reid	Camp Pond	Tributary	Lower Reid	Upper Reid	Camp Pond	Tributary	Lower Reid
Median	11.35	10.40	11.32	11.46	96.0	92.9	95.3	96.7
Max	12.65	13.72	13.96	13.89	110.7	101.1	99.5	105.1
Min	9.67	8.47	9.26	9.43	87.3	85.6	89.8	89.7

Turbidity

- Turbidity values vary somewhat across the network throughout the 2013 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 Camp Pond Brook, Tributary to Lower Reid Brook and Lower Reid Brook show similar turbidity trends. Background levels are 0NTU at all 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. Turbidity data at Camp Pond Brook between July 23 and August 24 has been removed due to inaccuracies.

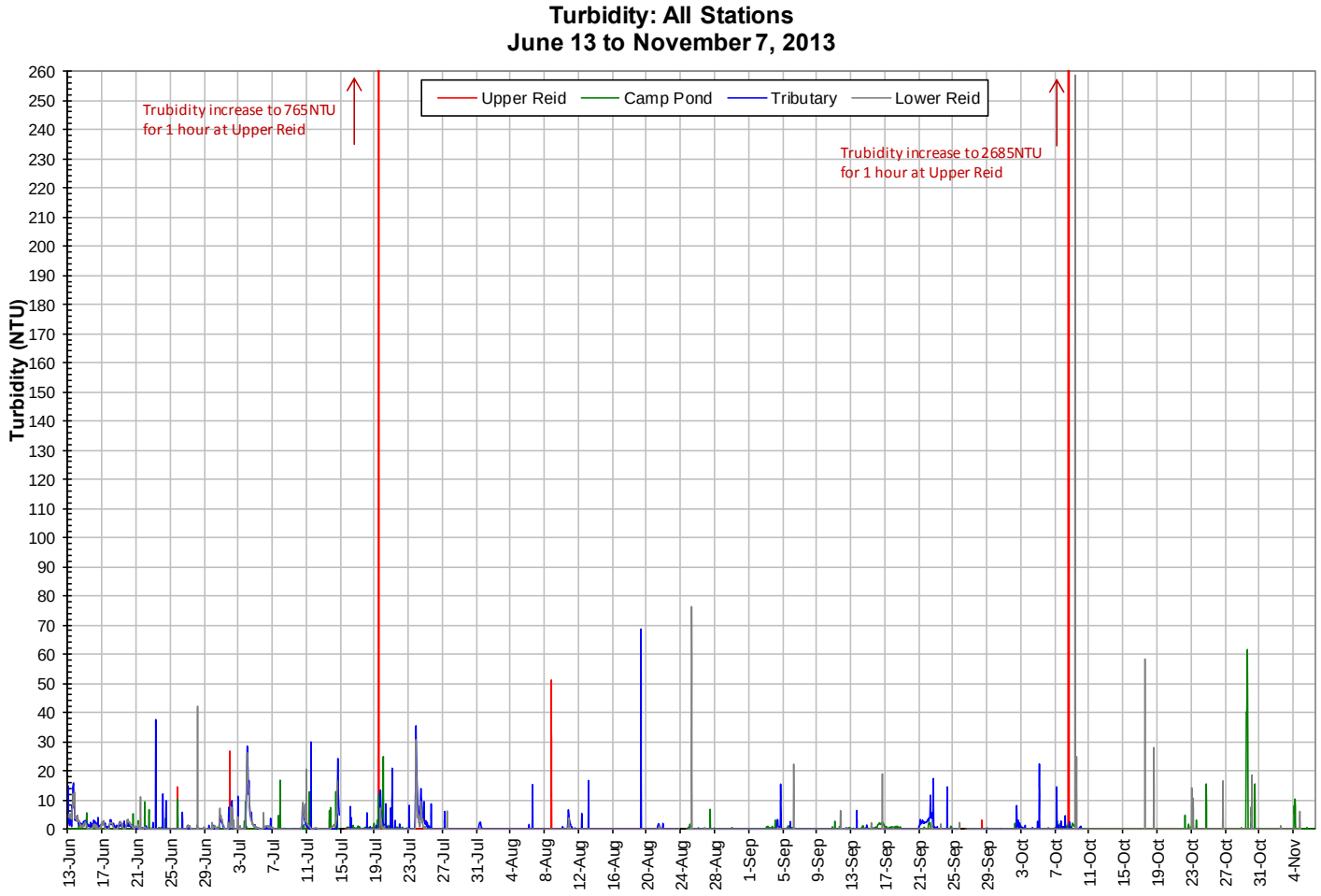

Figure 33: Turbidity at all stations

Turbidity (NTU)	Upper Reid	Camp Pond	Tributary	Lower Reid
Median	0	0	0	0
Max	2685	61	68.6	258.7
Min	0	0	0	0

Stage

- Stage levels are very similar throughout the season at all stations in the network, decreasing throughout the deployment season. 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.
- All stations reached a seasonal low water level in mid-September.

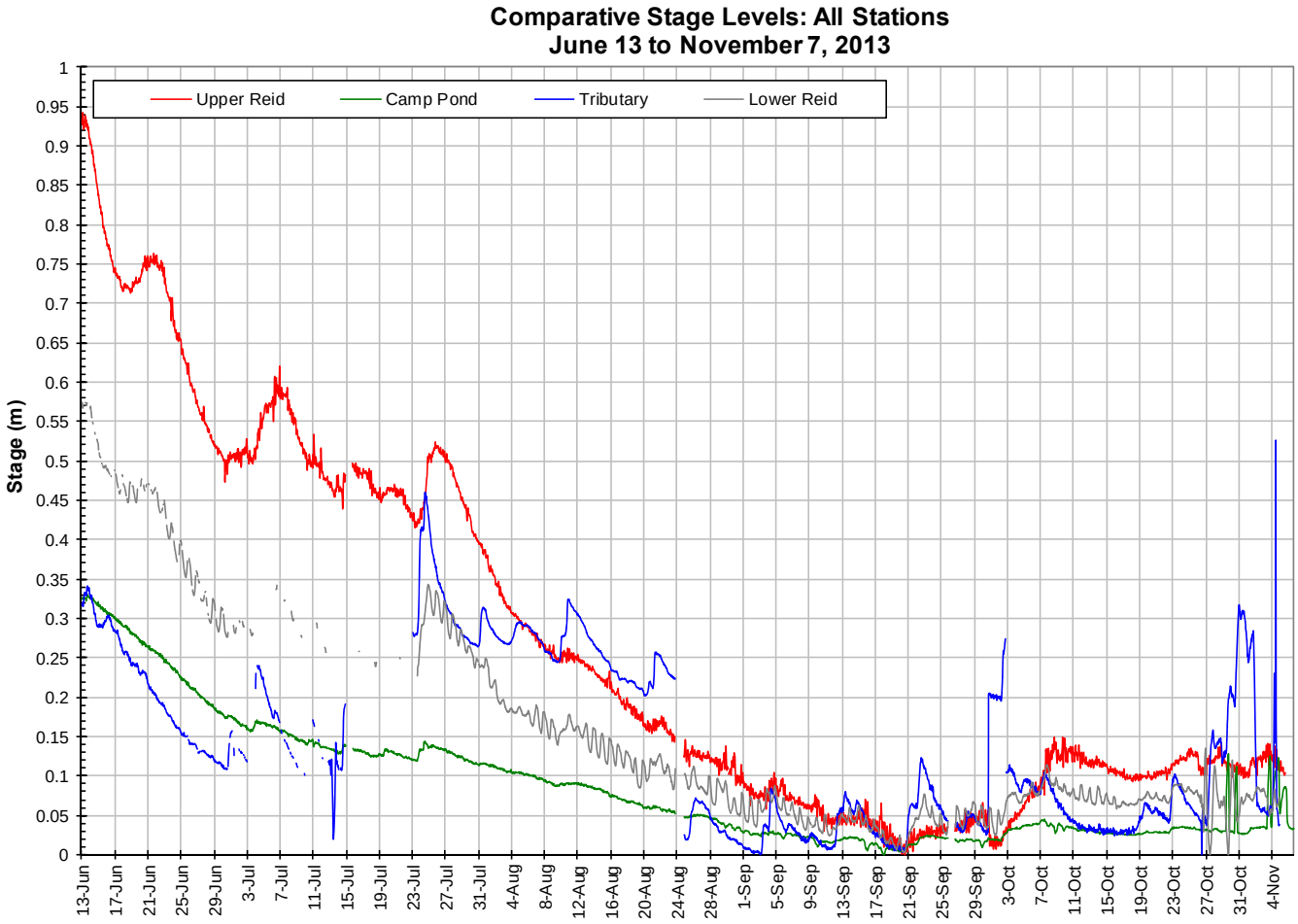

Figure 34: Stage levels at all stations

Stage (m)	Upper Reid	Camp Pond	Tributary	Lower Reid
Max	2.508	1.640	0.754	1.953
Min	1.566	1.310	0.228	1.372
Difference	0.942	0.330	0.526	0.581

Conclusions

- Instruments at water quality monitoring stations in the Voisey's Bay Network were deployed during four deployment periods from June 13 to November 7, 2013.
- 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 decreased throughout the season which caused general increasing trends in specific conductivity and pH except for at the station on 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 Tributary to Lower Reid and Lower Reid Brook, data transmission is intermittent throughout June and July. Environment Canada was onsite in late July to rectify the situation and uninterrupted data transmissions resumed for the remainder of the water quality monitoring season. 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.
    - With respect to quality of data and data removed from the data set due to sensor failures, disruptions were minimal in the 2013 deployment season. In one case, turbidity data at the station on Camp Pond Brook between July 23 and August 24 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 RTWQ 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 2014 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 2014 when ice conditions permit.
- In the 2014 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.

- 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 RTWQ.
- ENVC will work with Vale Environment staff to reassess the network design (station location) and plan for any necessary or desired changes in 2014 or in future seasons.
- Vale Voisey's Bay will receive monthly reports outlining the events that occurred in the previous deployment period and a 2014 annual report summarizing the events of the deployment season.
- ENVC staff is currently undertaking 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. The report will be completed by April 2014.
- 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 RTWQ data and grab sample data to estimate a variety of additional water quality parameters (*i.e.* TSS, major ions *etc.*).

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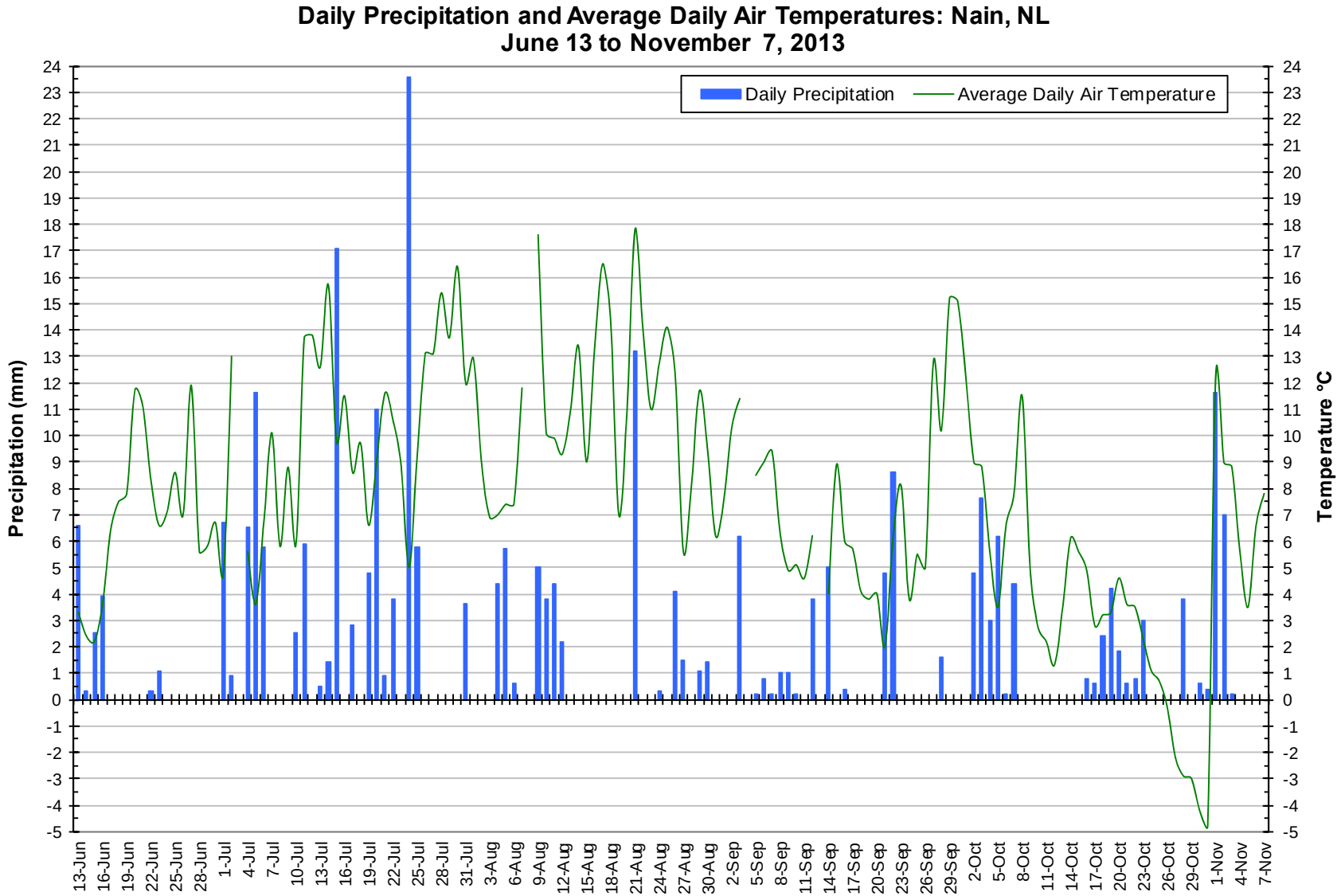
Appendix 1


Daily Precipitation and Average Daily Air Temperatures: Nain, NL
June 13 to November 7, 2013
Daily Precipitation
Average Daily Air Temperature
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