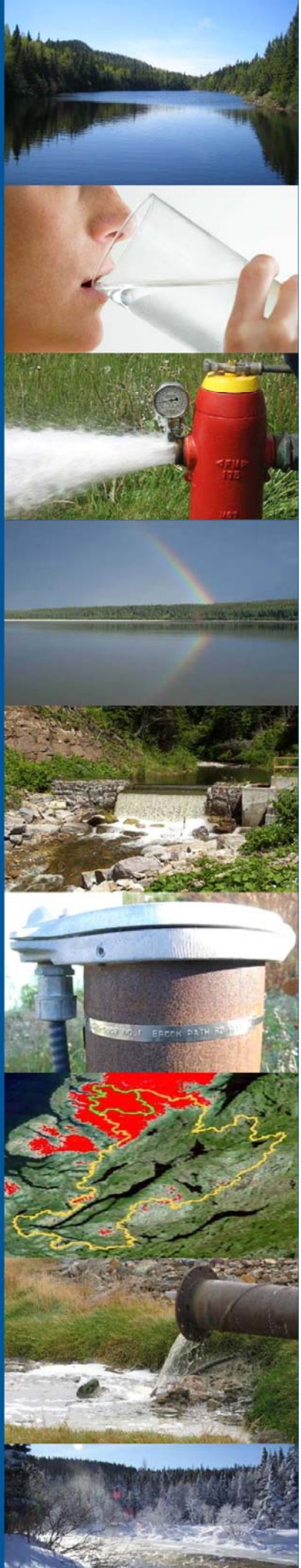

Real Time Water Quality Report

City of St. John's
Outer Cove Brook Network

Annual Deployment Report 2014

January 1 to December 31, 2014

Newfoundland Labrador

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

Prepared By:

Tara Clinton
Environmental Scientist
Water Resources Management Division
Department of Environment & Conservation
4th Floor, Confederation Building, West Block
PO Box 8700, St. John's NL A1B 4J6
Ph. No.: (709) 729 - 5925
Fax No.: (709) 729 - 0320
taraclinton@gov.nl.ca

Acknowledgements

The Real-Time Water Quality monitoring network at Outer Cove Brook in St. John's NL, is fully funded by the City of St. John's. The network's success is dependent on a joint partnership between the City of St. John's, Environment Canada (EC), and the Newfoundland and Labrador Department of Environment and Conservation (ENVC). Managers and program leads from each organization, namely Renee Paterson (ENVC), Howie Wills (EC), and David Wadden (City of St. John's), are committed to the operation of this network and ensuring it continually provides meaningful and accurate water quality and quantity data.

Staff of Environment Canada (Water Survey Canada) under the management of Howie Wills, play an essential role in the data logging/communication aspect of the network and maintains all water quantity monitoring equipment. EC-WSC staff visits the sites regularly to ensure the data logging and data transmitting equipment are working properly. Environment Canada also play the lead role in dealing with stage and flow issues. The quantity data is raw data that is transmitted via satellite and published online on ENVC Real-Time Stations website. Quantity data has not been corrected for backwater effect. Water Survey of Canada is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

ENVC is responsible for maintenance of the real-time water quality monitoring equipment, as well as recording and managing the water quality data. Tara Clinton, under the supervision of Renee Paterson, is ENVC's main contact for the real-time water quality monitoring operations at Outer Cove Brook, and was responsible for maintaining and calibrating water quality instruments, as well as grooming, analyzing and reporting on water quality data recorded at the stations during 2014.

All individuals from each agency are committed to maintaining and improving the Outer Cove Brook real-time monitoring network, and ensuring that it continues to provide meaningful, reliable and accurate water quality and quantity data.

Introduction

The Newfoundland and Labrador Department of Environment and Conservation (ENVC), in partnership with the City of St. John's and Environment Canada (EC), established two real-time water quality and quantity monitoring stations in April 2012 at Outer Cove Brook in the east end of St. John's, NL.

The official names of each of the stations are Outer Cove Brook below Airport (NF02ZM0364) and Outer Cove Brook at Clovelly Golf Course (NF02ZM0365). Their locations in relation to each other and surrounding land uses are shown in Figure 1.

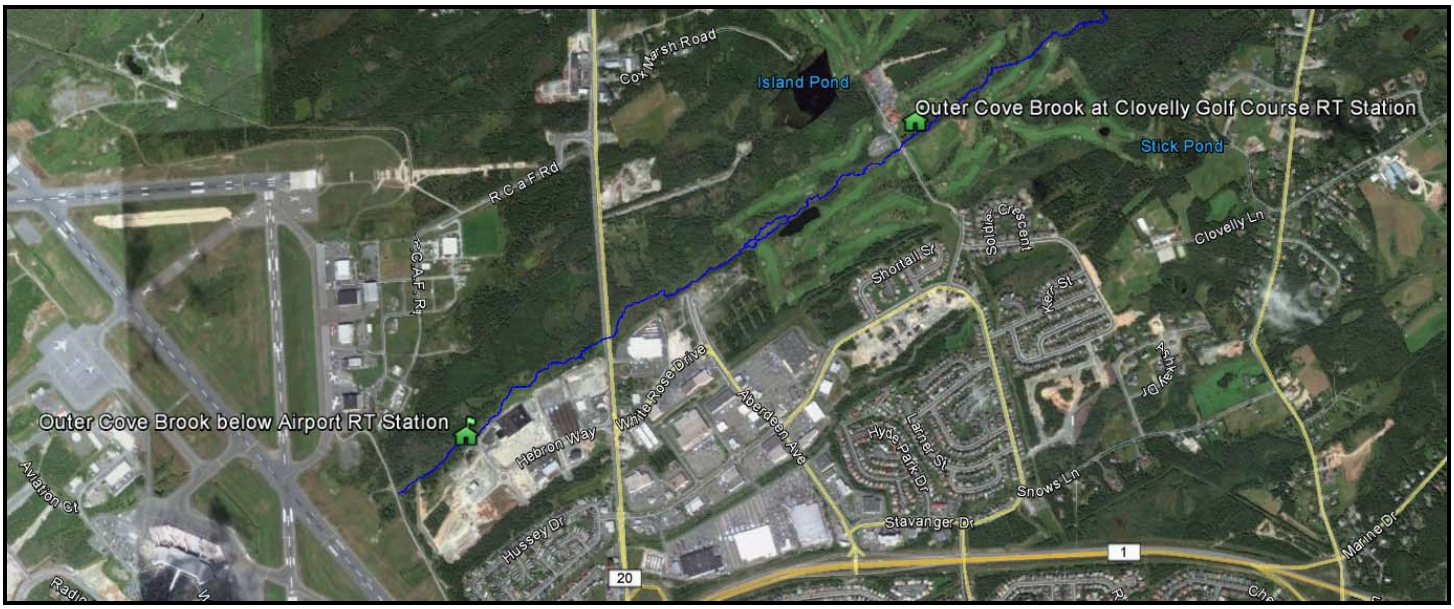

Figure 1: Locations of Outer Cove Brook Real-Time Water Quality and Quantity Monitoring Stations.

The Outer Cove Brook network was established in response to increased commercial development in the Torbay Road North Commercial Development Area. A significant portion of the land surrounding Outer Cove Brook is currently being developed into commercial establishments. One station is located upstream of the developments, while the other station is downstream.

An agreement was signed between the City of St. John's and ENVC for the establishment of a real-time monitoring network for Outer Cove Brook. Under this agreement, the City of St. John's is responsible for providing funding for the installation of two real-time water quality and quantity monitoring stations, including associated maintenance and equipment costs.

ENVC is responsible for the maintenance and calibration of water quality monitoring instruments, including initial setup of the station, and will continually retrieve, groom, analyze and report on the water quality data recorded at each of the stations. Real-time graphs of the water quality data will be published online, and will be monitored daily. The City of St. John's staff will be notified of any issues so that mitigative measures can be taken.

EC is responsible for the maintenance of the station's water quantity monitoring, datalogging and communications equipment. They are to ensure that the equipment is operating properly and transmitting the data efficiently. EC also plays the lead role in addressing all issues with stage and flow.

Site Descriptions

The headwaters of Outer Cove Brook originate in a boggy area of Airport Heights, just east of Windsor Lake (Figure 2). The brook flows beneath Portugal Cove Road, north toward St. John's International Airport, where it is partially channeled beneath the runways before emerging in a forested area on the eastern perimeter of the airport. The Outer Cove Brook below Airport station is approximately 400m downstream of the airport's perimeter. At this station, the river is surrounded by tall grasses and marshland, with mature conifer forests (see Figure 3a). The sonde is located in a deep section of the well-defined channel.

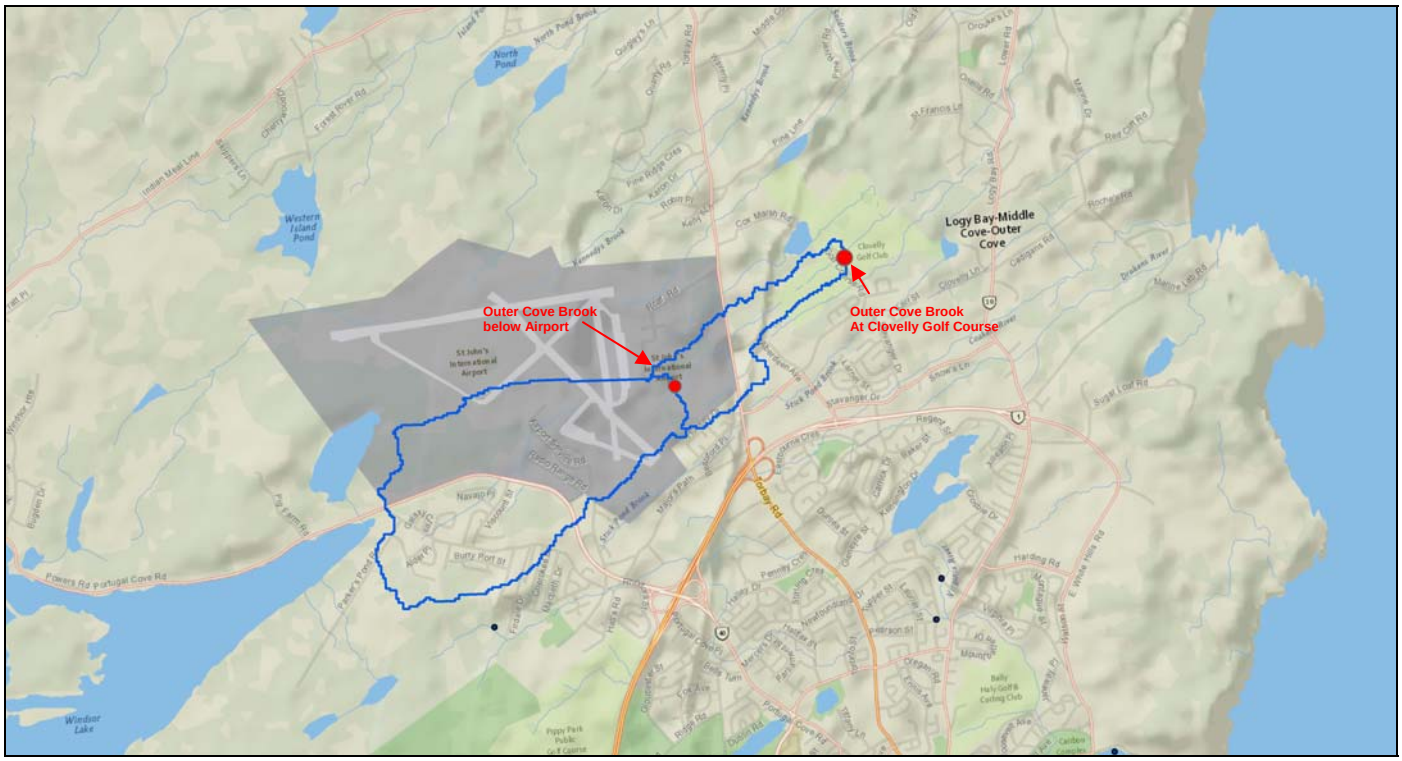

Figure 2: Map of the Outer Cove Brook Real-Time Water Quality/Quantity Monitoring Stations Watersheds

Outer Cove Brook then flows through the new Torbay Road North Commercial Development Area before passing beneath Torbay Road. The brook continues flowing north-east through marshlands surrounded by forest, bordering along the Abderdeen Extension development area, before entering and flowing through a buffer zone within Clovelly Golf Course. The second real-time station, Outer Cove Brook at Clovelly Golf Course, is located in a patch of trees on the eastern side of Golf Course Road adjacent to the clubhouse. The station sits in a marshy area which is heavily saturated during high flows and surrounded by tall grasses and some conifers (Figure 3b). The sonde typically sits in a deep, defined channel upstream of the braided portion of the river.

Downstream of the real-time stations, Outer Cove Brook meanders through the buffer zone in Clovelly Golf Course before entering a heavily forested area, where it continues northeastward to Savage Creek and is joined by Stick Pond Brook before crossing Outer Cove Road and flowing through the valley to its outlet in the Atlantic Ocean at Outer Cove Beach.

Figure 3: (a) Outer Cove Brook below Airport

(b) Outer Cove Brook at Clovelly Golf Course

Station Setup

Water quality parameters are measured at each station using a Hydrolab DataSonde instrument (Figure 4).

Model DS5 © 2005 Hach Company

Figure 4: Hydrolab DataSonde used for monitoring water quality parameters.

Six water parameters are measured at each station, including five water quality parameters (water temperature, dissolved oxygen, pH, turbidity and specific conductivity), and one water quantity parameter (stage). An additional water quality parameter, total dissolved solids (TDS) is calculated from this specific conductivity and water temperature (Appendix II).

Water quality and quantity data are recorded on a quarter-hourly basis (every 15 minutes) at both stations.

All data is viewable and downloadable online through ENVC's Automatic Data Retrieval System (ADRS) located here: http://www.env.gov.nl.ca/wrmd/ADRS/v6/Graphs_List.asp

Quality Assurance and Quality Control

To ensure accurate data collection, water quality instruments are subjected to quality assurance procedures, in order to mitigate any errors caused by biofouling and/or sensor drift. Quality assurance procedures include: (i) a thorough cleaning of the instrument, (ii) replacement of any small sensor parts that are damaged or unsuitable for reuse, and (iii) the calibration of the sensors using standard solutions. Quality assurance procedures are carried out every 30-40 days, before the start of a new deployment period.

Deployment periods for 2014 are summarized in Table 1.

Table 1: Water quality instrument deployment start and end dates for 2014 at Outer Cove Brook Stations

	Deployment	Removal
Outer Cove Brook Network	December 19, 2013	January 21, 2014
	January 21, 2014	February 21, 2014
	February 21, 2014	April 8, 2014
	April 8, 2014	May 14, 2014
	May 14, 2014	June 16, 2014
	June 17, 2014	August 22, 2014
	August 22, 2014	September 30, 2014
	September 30 2014	November 3, 2014
	November 3, 2014	December 31, 2014

As part of the quality control procedures, instrument performance is tested at the start and end of its deployment period (Appendix I).

Instruments are assigned a performance ranking (i.e. poor, marginal, fair, good, excellent) for each water quality parameter measured (Appendix I). Appendix I has the details on the instrument performance rankings of each of the instrument sensors deployed at Outer Cove Brook. The main issues which led to poor or marginal performance rankings were the presence of algae or biofouling on the field sonde at removal, and calibration issues with the QA/QC sonde.

For more detailed analyses of a particular time period, date or deployment period, please refer to the individual deployment reports: http://www.env.gov.nl.ca/env/waterres/rti/rtwq/csdr/index.html

Data Interpretation

Performance issues and data records were interpreted for each station during the deployment period for the following parameters:

- Water Temperature (^{o}C)
- pH (pH units)
- Specific Conductivity (uS/cm)
- Total Dissolved Solids (g/L)
- Dissolved Oxygen (mg/L)
- Dissolved Oxygen (%Sat)
- Turbidity (NTU)
- Stage (m)
- Streamflow (m^3/s)

A description of each parameter is provided in Appendix II.

The following parameter analyses cover the entire deployment period from January 1 to December 31, 2014. These interpretations aim to point out seasonal and overall trends and major issues affecting the parameters.

Any gaps in data are the result of transmission loss, or periods where the instrument was removed from the water.

With the exception of water quantity data (stage), all data used in the preparation of the graphs and subsequent discussion below adhere to the stringent QA/QC protocol. Water Survey of Canada is responsible for QA/QC of water quantity data. Corrected stage and streamflow data can be obtained upon request from Water Survey of Canada. Streamflow data was not included in this annual report. The data can be obtained from Water Survey of Canada should it be required. Streamflow is a calculated value that Water Survey of Canada model once one to two years of Stage data is collected.

Outer Cove Brook below Airport

Stage

Stage values are based on a vertical reference that is unique to each station, thus absolute values of stage are not comparable between stations, but relative changes in stage are.

Figure 5 displays stage values recorded every 15 minutes at Outer Cove Brook below Airport from January 1 to December 31, 2014. These values are provisional. Quality assured and quality controlled stage values are available through EC (http://www.ec.gc.ca/rhc-wsc/default.asp).

Stage values ranged from 0.813 m to 1.403 m. The highest stage value was recorded on March 27th, 2014 the increase came after several days of precipitation. Fluctuations in stage correspond to precipitation events as increased runoff into the river increases the river's volume, raising the stage level (Appendix VI).

This stream is naturally flashy under the influence of precipitation. Across the year of data there are frequent although not lengthy high stage periods. Due to transmission issues there is a loss in stage data from the middle of January to the middle of February during this deployment year.

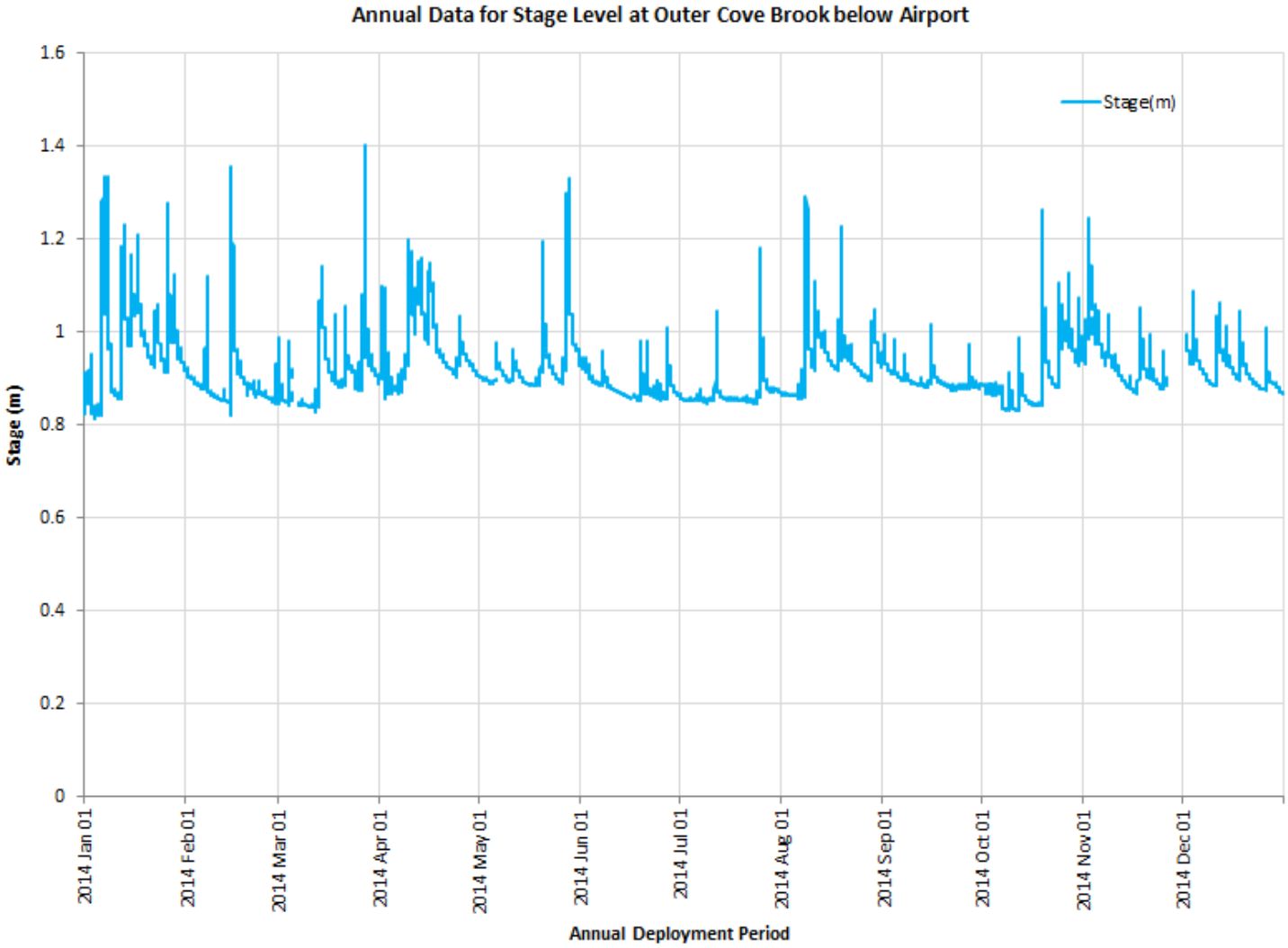

Figure 5: Stage (m) values recorded at Outer Cove Brook below Airport from January 1 to December 31, 2014.

Averaged daily data for Stage and total Precipitation

Precipitation data was collected by the St. John's International Airport Weather station. The data recorded is an average of the rainfall accumulation over the period of that day (Figure 6).

During this deployment year, the highest averaged daily precipitation recorded was 71.6mm on May 27th, 2014. There is a corresponding increase in Stage level during that rainfall event.

The stage data charted below is the average daily value to compare with the total precipitation for the time frame.

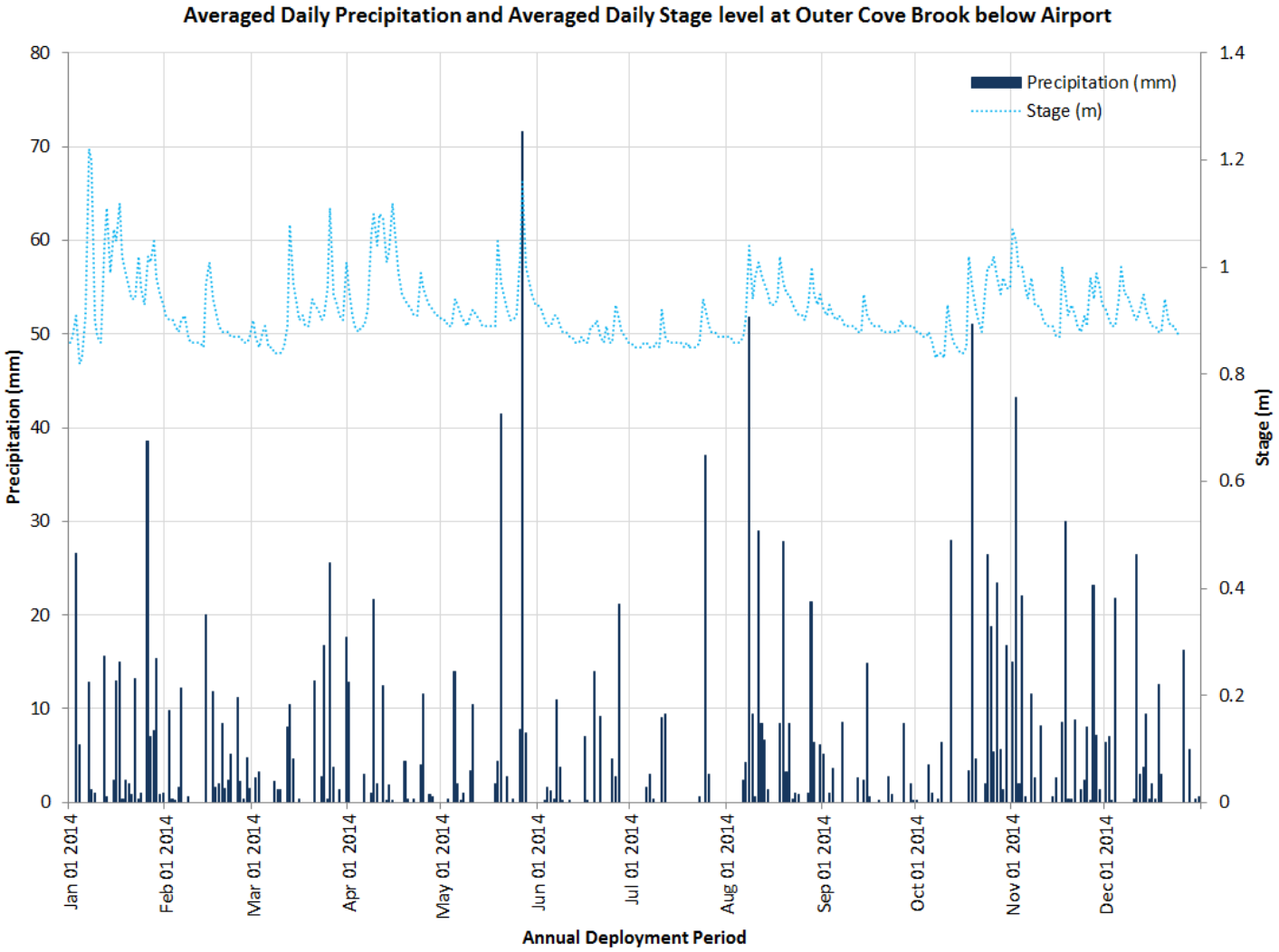

Figure 6: Precipitation recorded at St. John's International Airport Weather Station and Stage (m) values recorded at Outer Cove Brook below Airport

Water Temperature

Water temperature at Outer Cove Brook below Airport displays large diurnal variations, shown in Figure 7, typical of shallow water streams and ponds as they are highly influenced by diurnal variations in ambient air temperatures. Water temperatures start to increase from April to July. The highest temperatures recorded are in July which is the peak of the summer climate.

As the air temperatures decrease (Figure 7) the water temperatures also start to decrease. As the deployment year ends the water temperatures are recording some of the lowest for the year.

Water temperatures ranged from a minimum of -0.1°C to a maximum of 21.9°C, with a median of 7°C at the Outer Cove Brook below Airport.

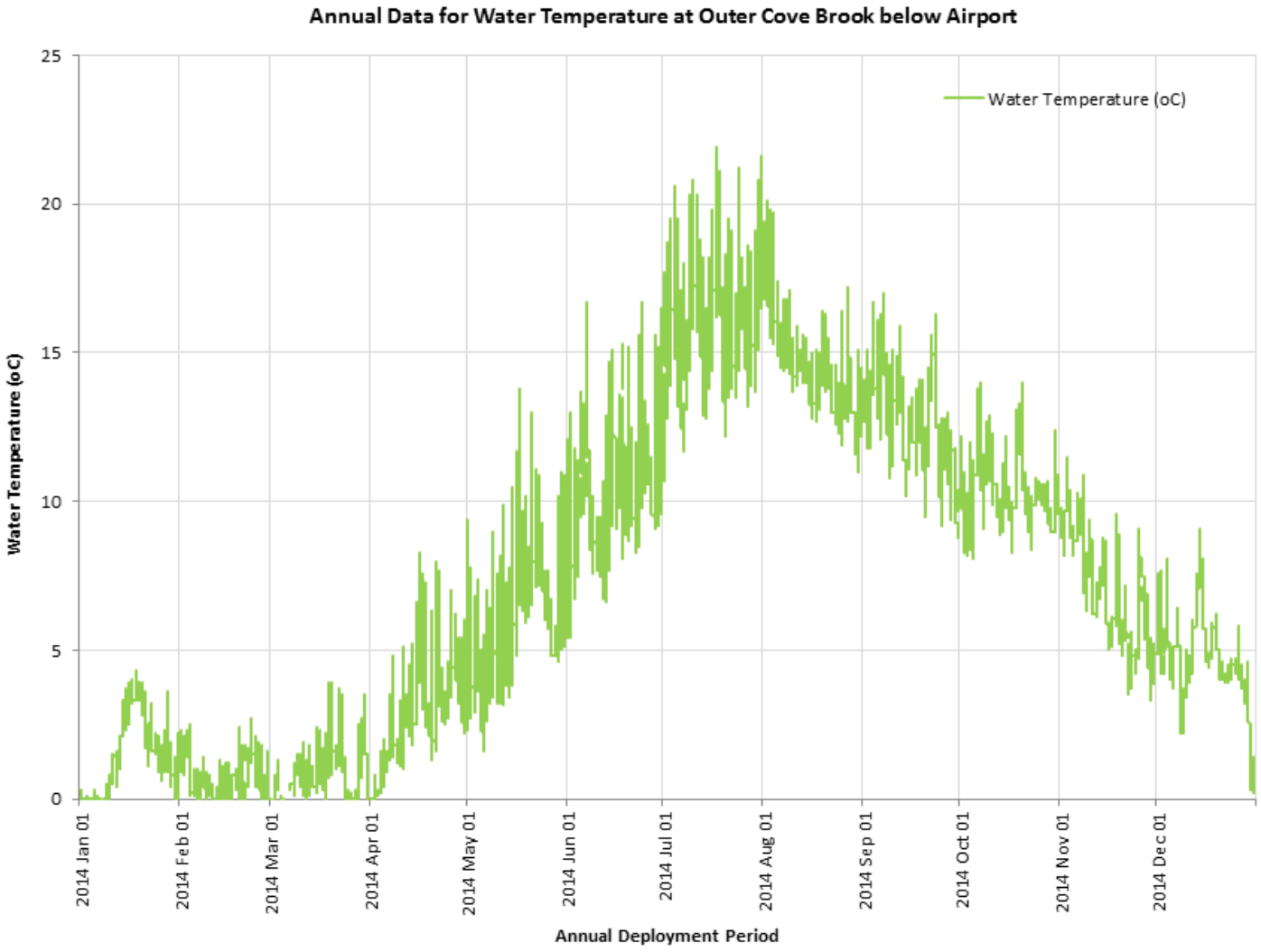

Figure 7: Water temperature (°C) values recorded at Outer Cove Brook below Airport

Water temperature values show a close relationship with air temperatures (Figure 8). Increases and decreases in air temperatures are reflected in water temperature. Air temperatures fluctuate on a larger scale than water temperature.

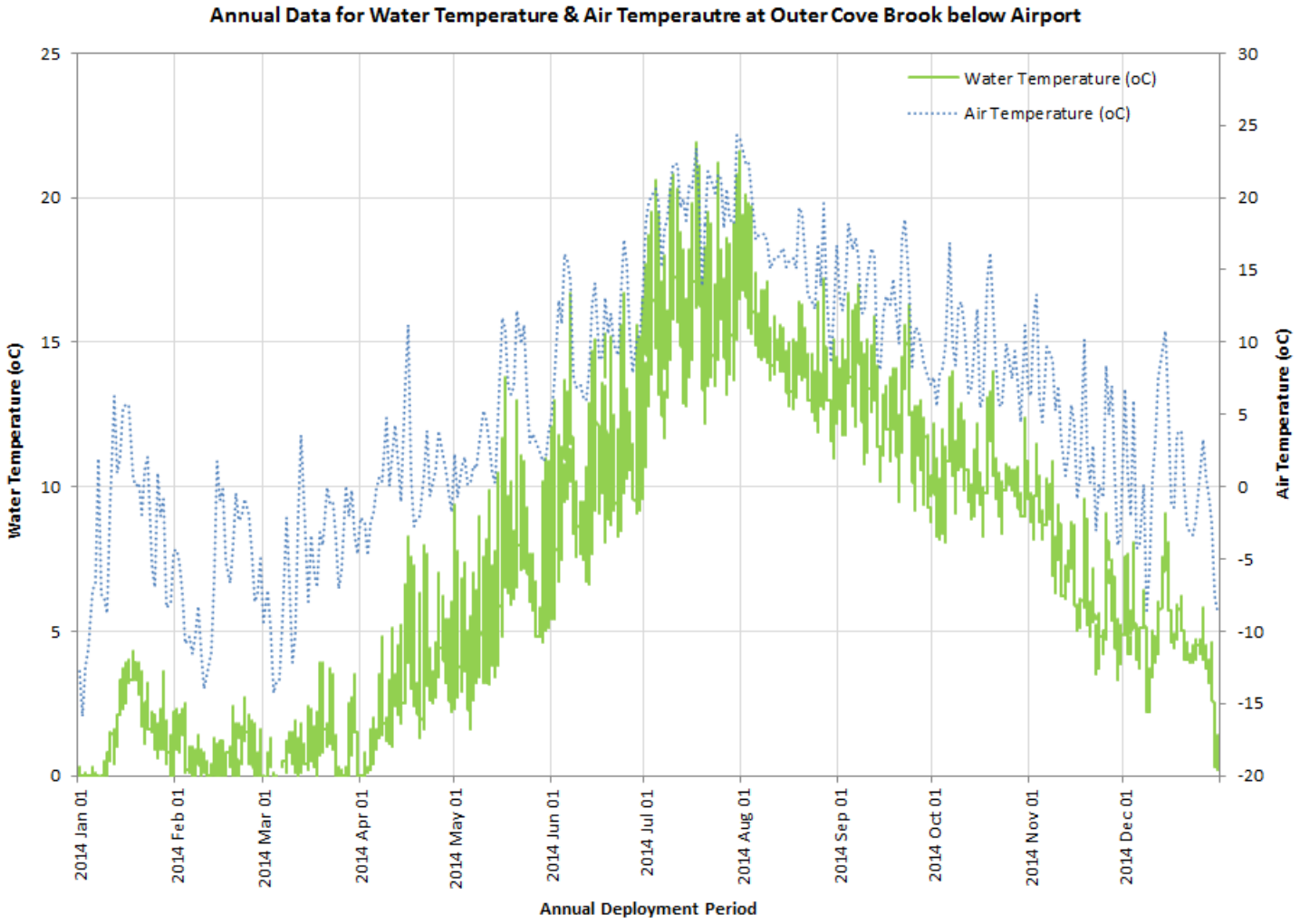

Figure 8: Averaged Air Temperature (°C) from St. John's International Airport & Water temperature (°C) values recorded at Outer Cove Brook below Airport

pH

During the deployment year Outer Cove Brook below Airport had pH values that ranged between a minimum of 5.84 and a maximum of 7.61 pH units, with a median value of 6.57 pH units. The CCME guidelines for the protection of freshwater aquatic life provide a basis by which to judge the overall health of a river system, (the guidelines are indicated in red). At this station, pH values do fall closer to the minimum guideline of 6.5, as shown in Figure 9.

The visible increases in pH values can be explained by corresponding precipitation events. The most noticeable events are the peaks in pH in June to the middle of August and August to September (circled in red). As stage level settles down the pH values increase. The reduced stage levels allow for the pH levels to become more alkaline until the next flush of water or runoff through the brook. This is likely the case for the high pH levels that start in the middle of August through to September.

It should be noted that during the months of December through to April there is a recurrent growth of slime-like aquatic vegetation that coats everything that is in the water (Appendix IV). The die off of this substance starts when the water temperatures start to increase at the end of May and into June. The die off can affect the pH levels for a short span of time.

The pH increase on July 4th was during a noted turbidity event, the increased sediment and material in the brook increased the alkalinity of the water for a short span of time.

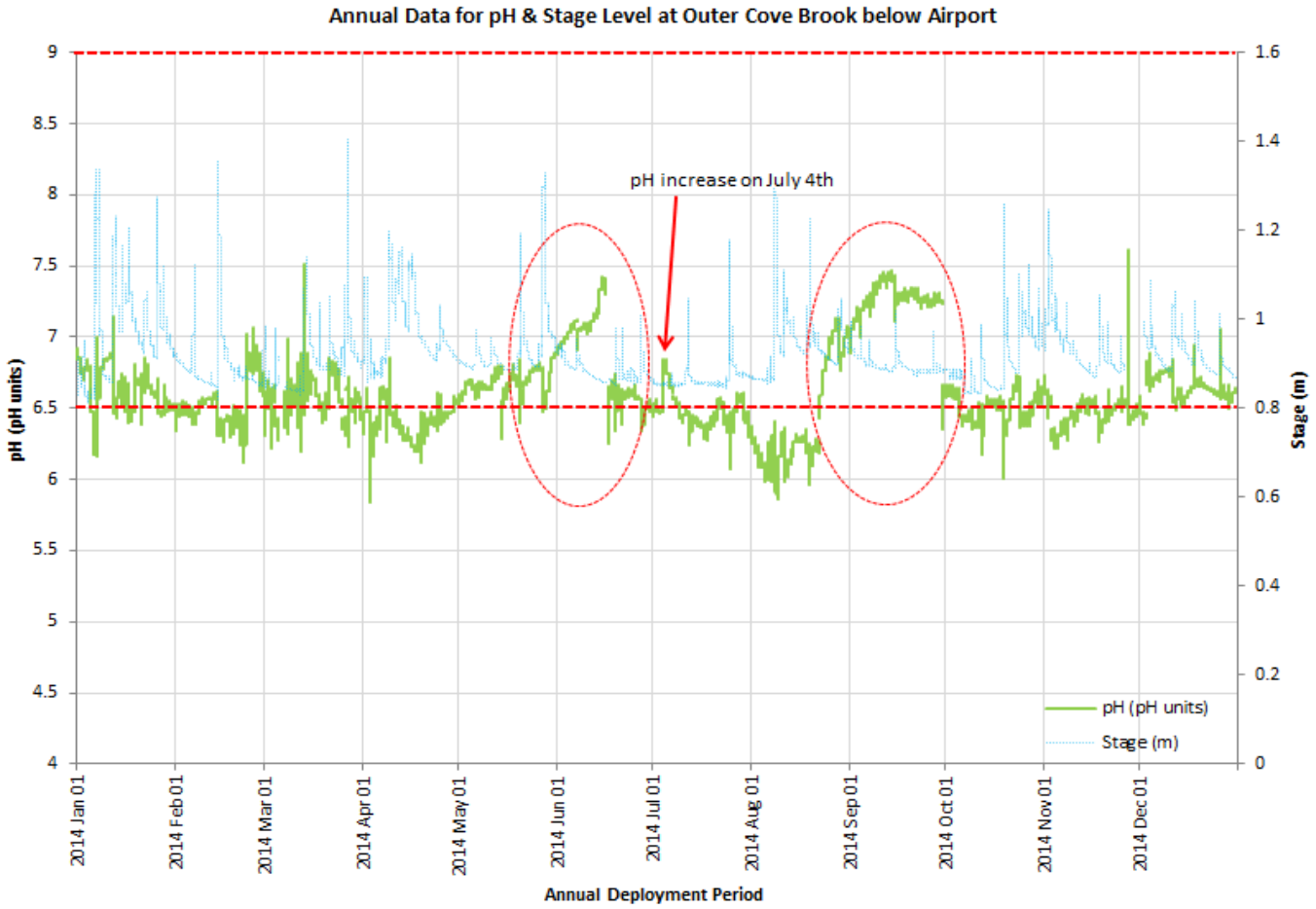

Figure 9: pH (pH units) values recorded at Outer Cove Brook below Airport

Specific Conductance and Total Dissolved Solids (TDS)

Specific conductivity ranged from 64.9 µS/cm to 2912 µS/cm, with a median value of 500 µS/cm. Total dissolved solids (TDS) ranged between 0.0416 and 1.86 g/L, with a median value of 0.32 g/L.

The maximum values for both parameters were reached early in March. Cold temperatures and snow throughout February followed by intermittent rainfall (Appendix VI) in March, washed road salts into the river system, leading to large increases in both Specific Conductivity and Total Dissolved Solids.

A seasonal trend in relation to stage is evident for specific conductivity and TDS in Figure 10. Cold, snowy winter months are marked by spikes in conductivity and TDS with stage increases as salts used on roadways and runways are washed, carried or blown in the brook during winter storms. Spring, summer and fall rainfalls increase stage level; however TDS and conductivity decrease due to dilution of solids in the brook from the added freshwater.

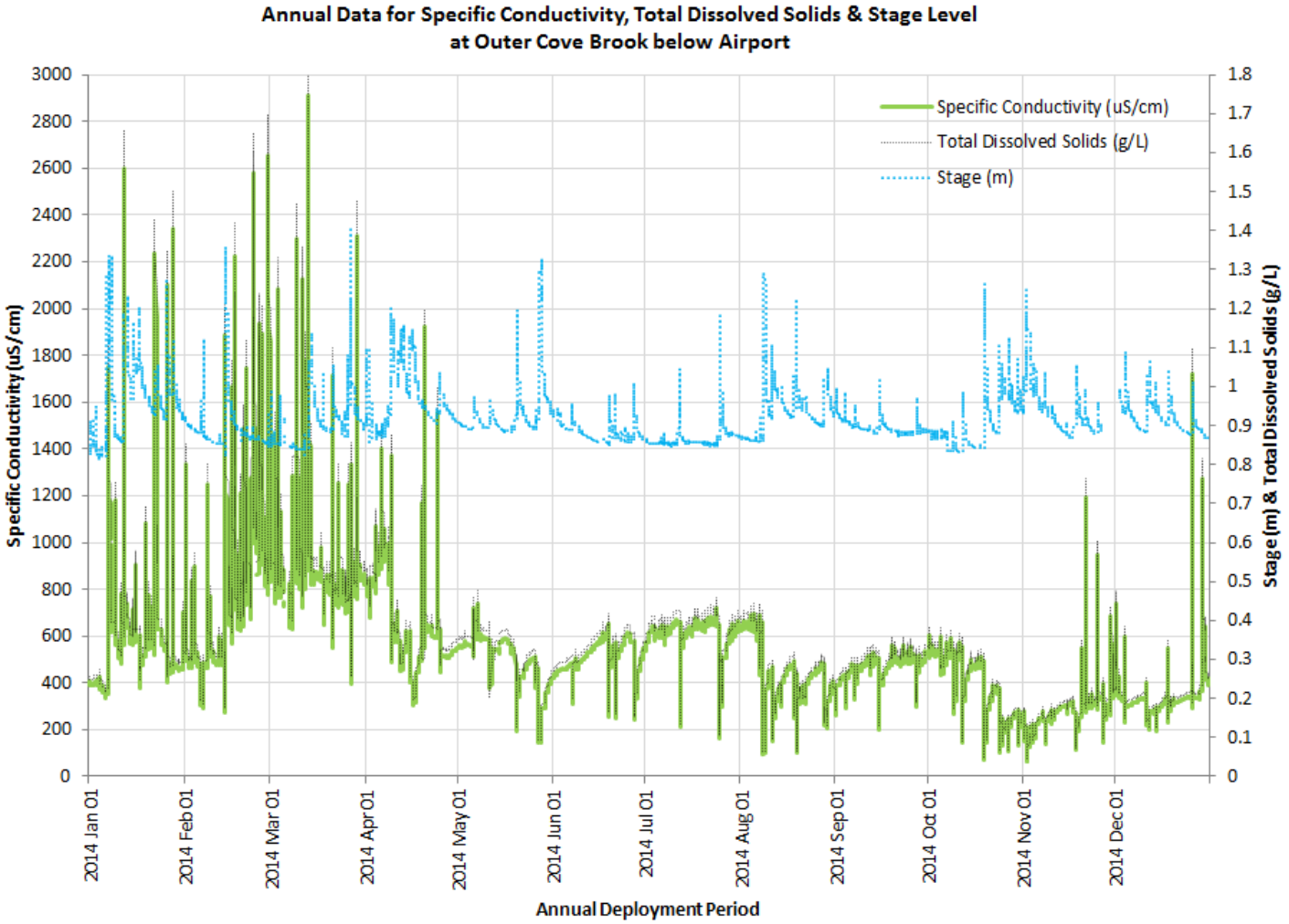

Figure 10: Specific conductivity (µS/cm), total dissolved solids (g/L) and stage level (m) values recorded at Outer Cove Brook below Airport.

Dissolved Oxygen

The Dissolved Oxygen % sat values ranged from 7.5 %Sat to 93.9 %Sat, with a median of 83.2 %Sat. Dissolved Oxygen (mg/L) measured 0.75mg/L to 12.71mg/L, with a median of 9.94mg/L. For most of the deployment year the DO mg/L values sit just above or within the minimum DO guideline for the protection of early life stages. However during the warmer months in the year the dissolved oxygen content drops below both guidelines. The water is warmer during this period and cannot hold the same amount of oxygen as the cooler months (Figure 11).

It was identified in April and again in May that the annual growth of the slime-like aquatic substance had returned to this brook. The substance completely coats anything in the water body, including the instrument and its protective casing. The fouling created issues with the data that the sensors were recording; the sensors have trouble taking an accurate reading through the substance (Appendix IV). An example of this is the low dissolved oxygen readings in May to mid-June. During die-off of the substance there is an excessive amount of oxygen being used in the brook and this is captured in the data with the lower dissolved oxygen readings from mid-June through to August.

The large DO (mg/L) dip in August (circled in red) corresponds with a high precipitation event. At this time turbidity increased and pH decreased during the same event.

Despite the high variations in dissolved oxygen, the data still captures the natural inverse fluctuations in dissolved oxygen (mg/L) between night and day and seasonal differences.

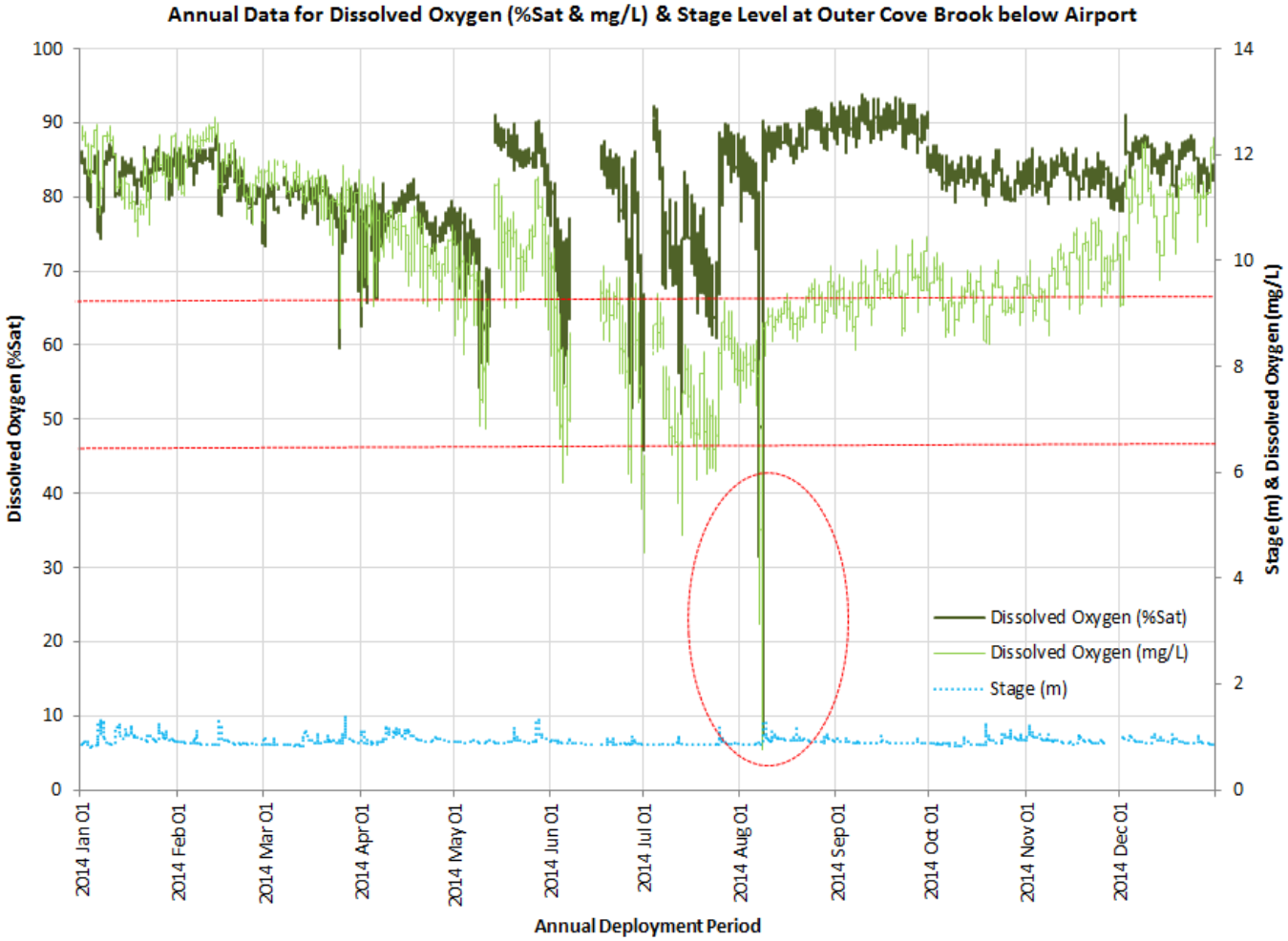

Figure 11: Dissolved oxygen (% Sat & mg/L) and water temperature (°C) values recorded at Outer Cove Brook below Airport.

Turbidity

During this deployment year the turbidity values ranged from 0 NTU to 1777 NTU, with a median of 0.7 NTU. The maximum value of 1777 NTU was recorded on June 1st, 2014 directly after an increase in stage level at the end of May 2014.

Generally, turbidity events coincide with rises in stage, as shown in Figure 12, which correspond with precipitation events. However there are other events that can cause increases in turbidity. The slime-like substance that grows in the brook influences the turbidity levels. Both the turbidity and dissolved oxygen data displayed indicates interference (Appendix IV).

On July 4th, 2014 there were documented turbidity events occurring at Outer Cove Brook below Airport (highlight by red arrow). A WRMD staff member visited the site and photographed the turbidity event (Appendix V). The turbidity was linked to the land clearing and construction occurring approximately 15 meters upstream from the station. The turbidity data displays a peak on July 4th with no peak in stage level.

On October 22nd, 2014 WRMD staff captured another turbidity event while visiting the brook. This event was captured with photographs (Appendix V) however the WRMD staff were unable to determine the cause of the event.

On November 3rd during a routine trip to the station, a turbidity event was captured (Appendix V). Due to heavy rainfall there were high flows which caused the streams to be more turbid than usual. This is represented on the chart in Figure 12 and in pictures in Appendix V.

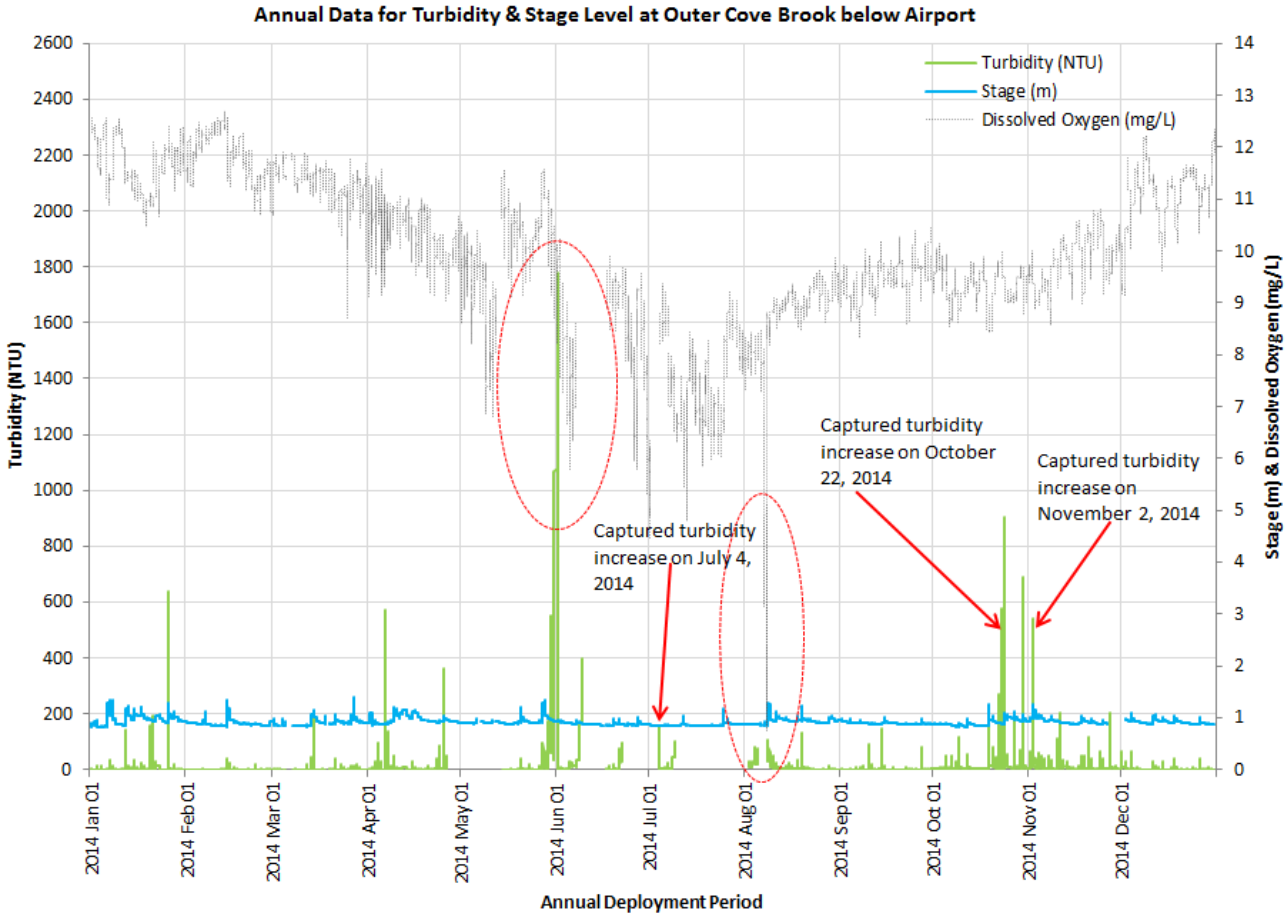

Figure 12: Turbidity (NTU) and stage level (m) values recorded at Outer Cove Brook below Airport.

Conclusions

During the 2014 deployment year, Outer Cove Brook below Airport displayed characteristics typical of other St. John's urban streams. Naturally this stream is very flashy and greatly influenced by snow melt, spring runoff and precipitation throughout the year; therefore there is a lot of variation in the water parameters data. Stage level captured the influences of precipitation and runoff events that occurred over the year.

During the months of January to early May there is a heavy growth of slime-like substance present in the brook. This substance coats the instrument and anything in the water during the time frame. It has caused some issues with the actual data due to the fouling of the sensor and it also impacted the water parameters (i.e. pH, dissolved oxygen content and turbidity) during the growth and die-off periods of the slime-like substance (Appendix V).

The brooks water temperatures are diurnal and also influenced by the surrounding air temperatures in relation to the season. The shallow urban streams and brooks respond faster to air temperatures which are clearly seen in the variability of the data.

Outer Cove Brook below Airport had a median pH value of 6.57 which was inside the normal range for stream water. Over the deployment there was several incidents' where pH increased (alkalinity increased) it is unclear what events caused the change in the pH levels. Although the pH median is within the normal range for stream water there is a lot of movement in the pH levels. The movement may be a result of a flashy urban brook influenced by the changing urban areas around it and the lifecycle of the slime-like substance.

Outer Cove Brook below Airport displays two different reactions in specific conductivity. During the winter thaw and high runoff seasons in March and April the conductivity levels increase with the higher stage levels likely a result of salt runoff from the surrounding urban areas and the airport. Into the summer and fall seasons (June through to early November) the conductivity levels drop with high stage levels. The decrease in conductivity during those times was likely a result of periods of rainfall diluting the suspended substances in the brooks.

The Dissolved Oxygen median for this deployment year was 9.94mg/L. As the warmer temperatures started in June the dissolved oxygen levels in the brook were extremely low. It was during this time that the slime-like algae growing in the brook had started to die off, in turn decreasing the dissolved oxygen levels.

Turbidity median for 2014 was 0.7 NTU which was lower than the 2013 median of 1.7 NTU. Majority of the turbidity increases corresponded with the precipitation events that can influence the amount of suspended sediments in the water column. There is also evidence that turbidity increases were a result of clearing and earth movement upstream from the real-time station.

Outer Cove Brook at Clovelly Golf Course
Stage

Stage values are based on a vertical reference that is unique to each station, thus absolute values of stage are not comparable between stations, but relative changes in stage are.

Figure 13 displays stage values recorded at Outer Cove Brook at Clovelly Golf Course from January 1 to December 31, 2014. These values are provisional. Quality assured and quality controlled stage values are available through EC (http://www.ec.gc.ca/rhc-wsc/default.asp).

Stage values ranged from 0.497m to 1.263m over the 2014 deployment year. Fluctuations in stage correspond to precipitation events as increased runoff into the river increases the river's volume, raising the stage level (Appendix VI).

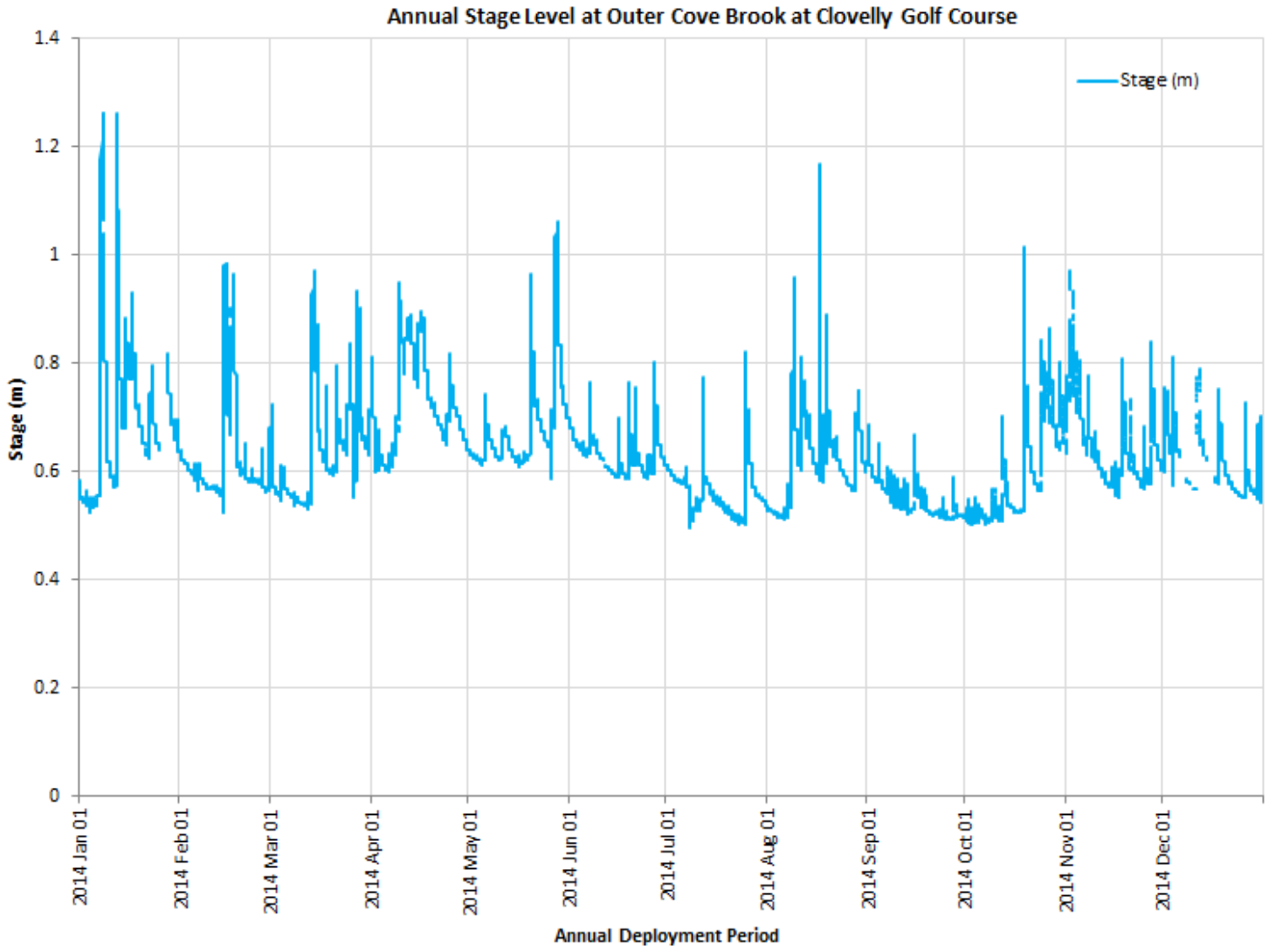

Figure 13: Stage (m) values recorded at Outer Cove Brook at Clovelly Golf Course.

Temperature

Water temperature at this station displays large diurnal variations, shown in Figure 14, typical of shallow water streams and ponds as they are highly influenced by diurnal variations in ambient air temperatures. The largest daily fluctuations are noticeable early June through to August 2014.

During this deployment period the water temperatures ranged from a minimum of -0.01 to 23.76°C, with a median of 6.985°C which was lower than 2013 median of 8.6°C in water temperature.

Seasonal temperature trends are obvious in Figure 14 as temperatures increase throughout spring and into the summer months, peaking in July, before gradually decreasing again throughout fall as winter approaches.

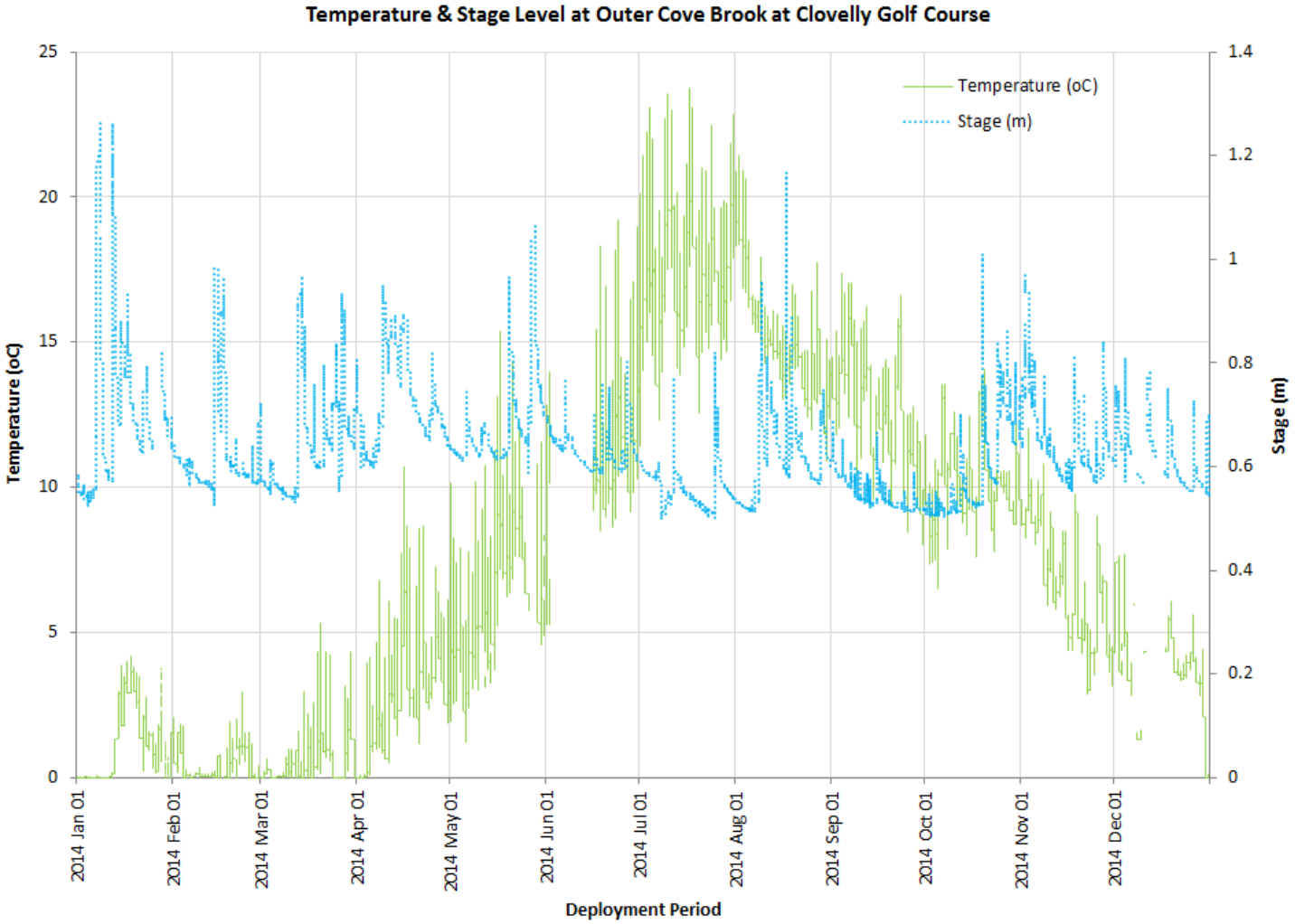

Figure 14: Water temperature (°C) values recorded at Outer Cove Brook at Clovelly Golf Course

Water temperature values show a close relationship with air temperatures (Figure 15). Increases and decreases in air temperatures are reflected in water temperature. Air temperatures fluctuate on a larger scale than water temperature.

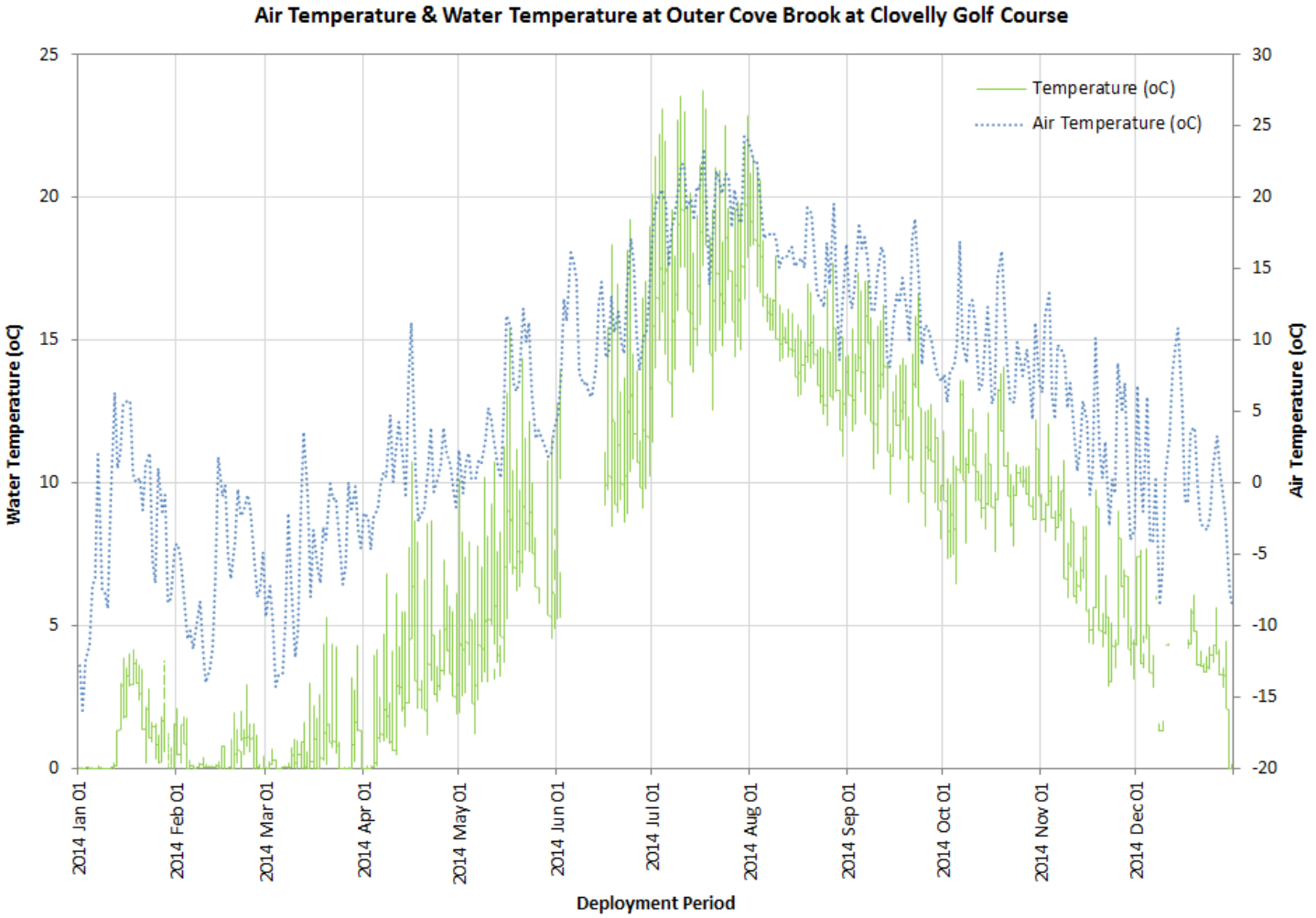

Figure 15: Averaged Air Temperature (°C) from St. John's International Airport & Water temperature (°C) values recorded at Outer Cove Brook at Clovelly Golf Course

pH

pH values ranged between 5.77 and 7.23 pH units, with a median of 6.48 pH units. The maximum value at Clovelly was within the same deployment period June that pH was increasing at the before Airport Station, indicating that something was affecting the water quality in the brook for a short period of time.

The CCME guidelines for the protection of freshwater aquatic life provide a basis by which to judge the overall health of a river system. At this station, pH values float around the minimum guideline of 6.5, as shown in Figure 16. Naturally, all streams and brooks are different. In the case of Outer Cove Brook at Clovelly Golf Course, pH is generally within the normal range for stream water in St. John's.

There are visible drops in pH values throughout the year; the decreases are corresponding to precipitation events. This is a natural occurrence between precipitation and pH levels (Figure 16).

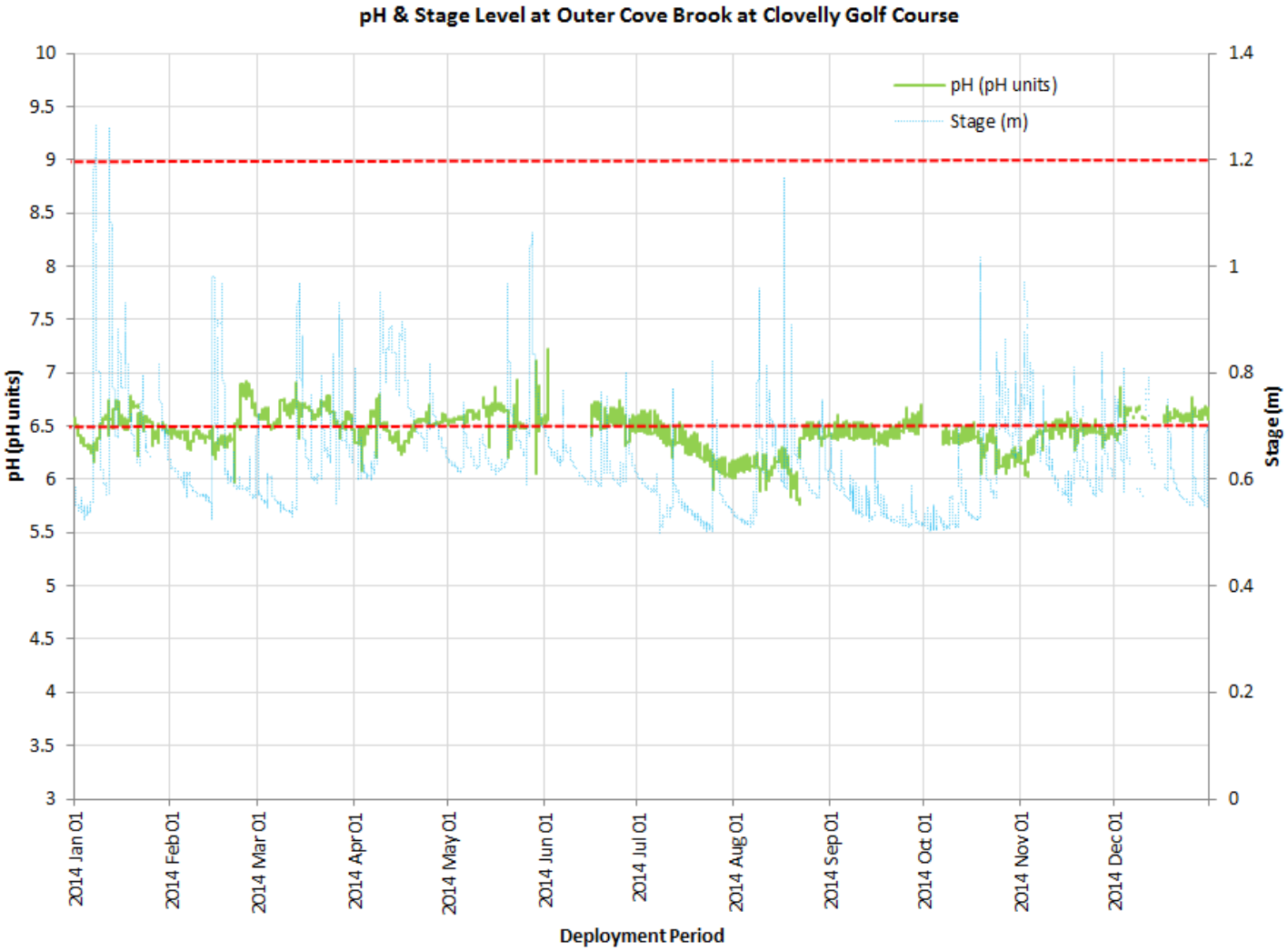

Figure 16: pH (pH units) values recorded at Outer Cove Brook at Clovelly Golf Course.

Specific Conductance and TDS

During the deployment year the specific conductivity ranged from 127.8 to 4541 uS/cm, with a median of 532 uS/cm. Total dissolved solids (TDS) ranged between 0.0818 g/L and 2.91 g/L, with a median of 0.341 g/L.

The maximum values for both parameters were reached on February 25th. Cold temperatures and snow throughout February was followed by intermittent rainfall for several days, this washed salts used on roadways during freezing temperatures (Figure 15) into the river system, resulting in the high conductivity values during that time.

A seasonal trend in relation to stage is evident for specific conductivity and TDS in Figure 17. Cold, snowy winter months are marked by spikes in conductivity and TDS with stage increases as salts used on roadways and runways are washed, carried or blown in the brook during winter storms. Spring, summer and fall rainfalls cause increases in stage with drops in TDS and conductivity due to dilution of solids in the brook from the added freshwater.

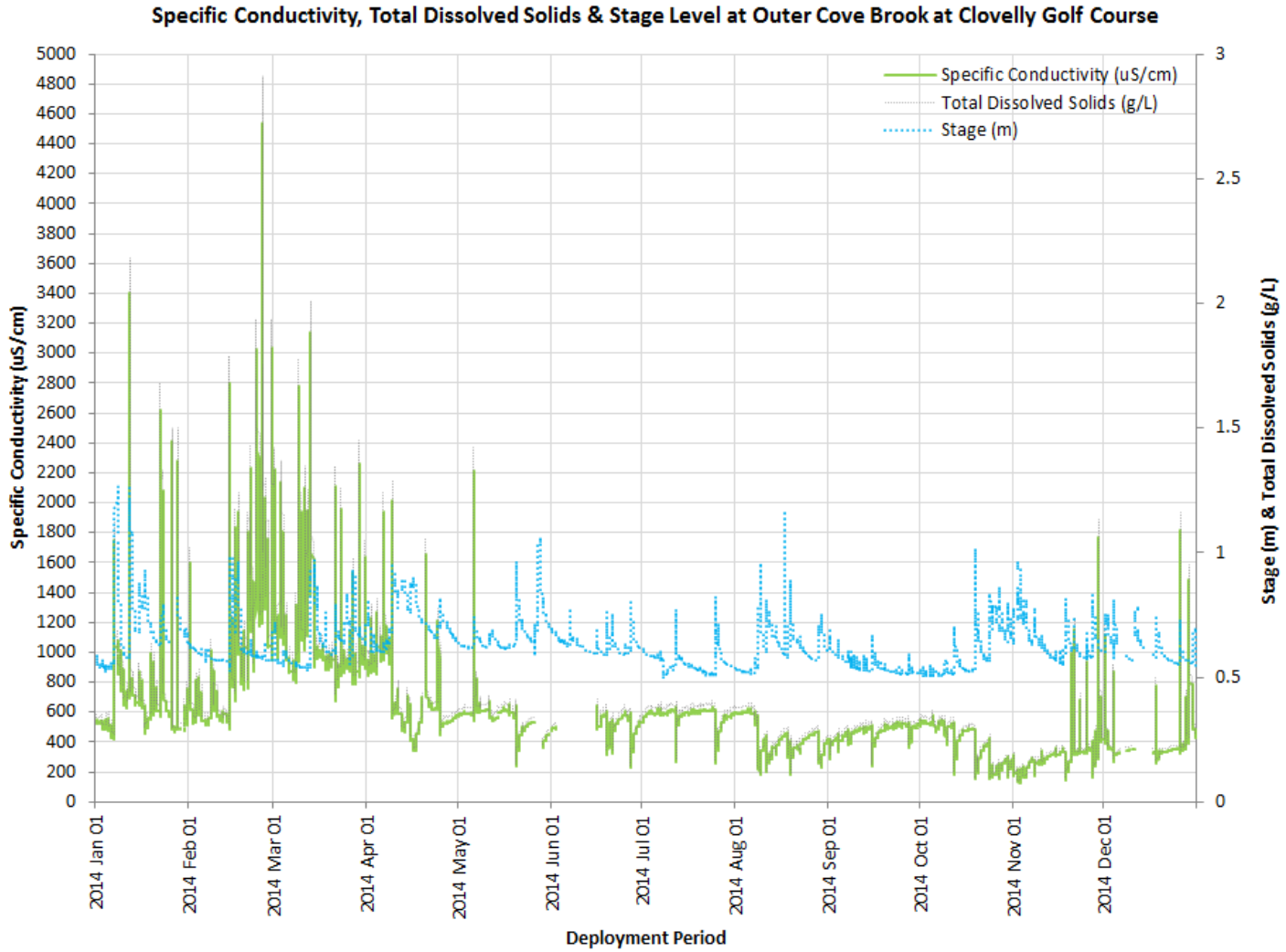

Figure 17: Specific conductivity (µS/cm), total dissolved solids (g/L) and stage level (m) values recorded at Outer Cove Brook at Clovelly Golf Course

Dissolved Oxygen

The instrument measures percent saturation directly, then calculates dissolved oxygen (mg/L) using the percent saturation and water temperature values.

The Dissolved Oxygen % sat values ranged from 57.1 to 101.8 %sat, with a median of 78.9 %sat. Dissolved Oxygen (mg/L) measured 5.62 mg/L to 12.98 mg/L, with a median of 9.82 mg/L. The DO mg/L values are above the minimum DO guideline for the protection of early life stages during winter, spring and fall months, but dip below this minimum value during the warmer summer months.

Dissolved oxygen (% sat) remained relatively constant throughout the seasons. Figure 18 demonstrates the natural inverse relationship that exists between dissolved oxygen (mg/L) and water temperature. Some of the lower dissolved oxygen (mg/L) levels early in the deployment season may be a result of the die-off of the slime-like algae that is present in the brook during these times.

The large fluctuations in DO during summer are due to the presence of large amounts of algae and vegetation around this station. During the day, the plants are photosynthesizing, producing oxygen, but cease this process as night due to the absence of sunlight, causing the depletion of oxygen in the water at night.

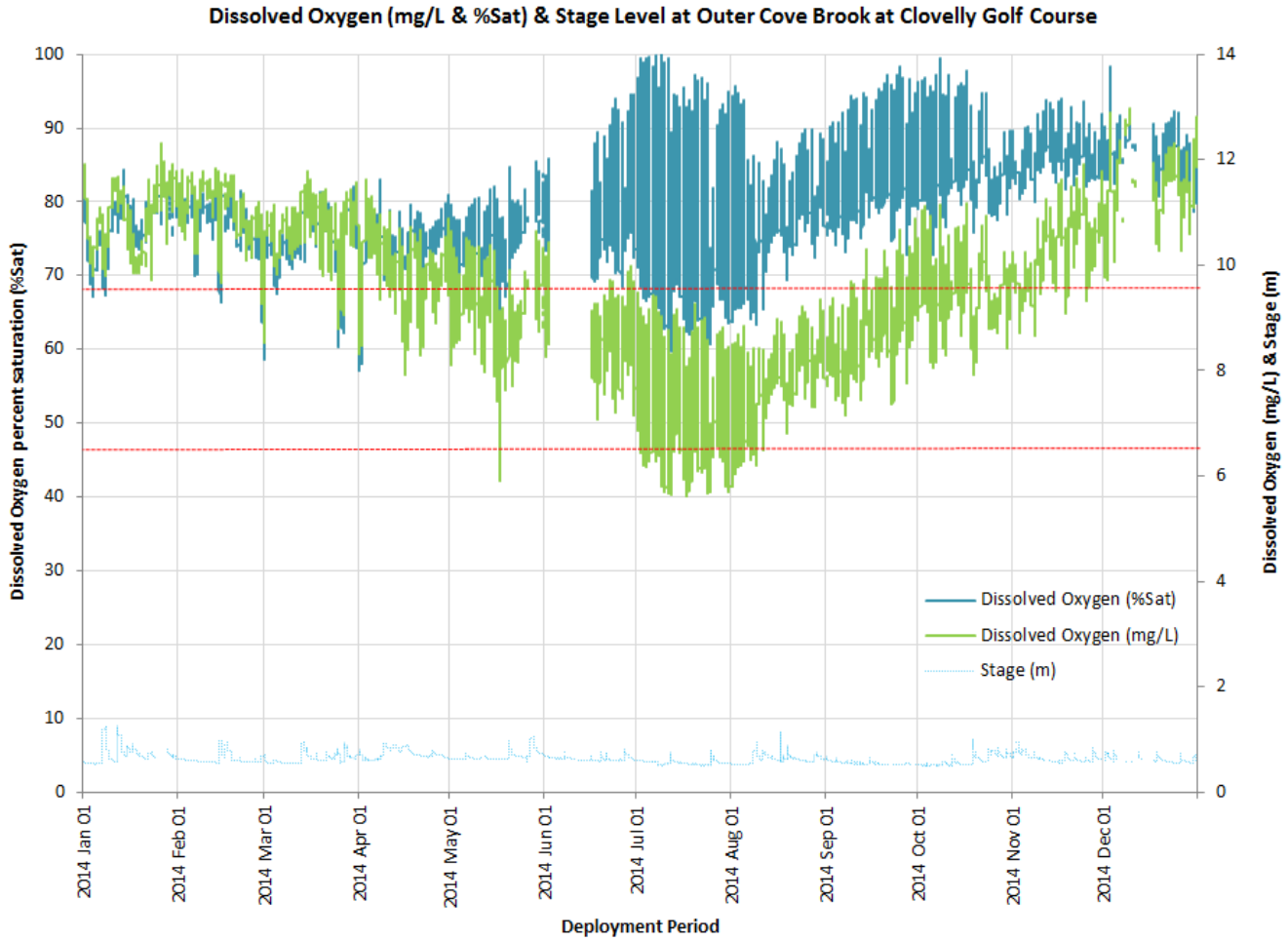

Figure 18: Dissolved oxygen (% Sat & mg/L) and water temperature (°C) values recorded at Outer Cove Brook at Clovelly Golf Course.

Turbidity

For 2014 deployment year the turbidity values ranged from 0 NTU to 270.7 NTU, with a median of 1.9 NTU. Generally, turbidity events coincide with rises in stage, as shown in Figure 19. In turn these events correspond to precipitation during the deployment periods (Appendix VI).

During routine field work for the station a turbidity event was captured. On November 3rd, high flows due to heavy rainfall in the previous 2 days caused the streams to be more turbid than usual. This is represented on the chart in Figure 19 and in pictures in Appendix V.

Short-term turbidity sensor interference events were recorded throughout the year. This interference is due to biofouling, leaf debris, and strands of algae which are abundant in Outer Cove Brook at Clovelly Golf Course. For these reasons, data was removed for several time periods as this data is inaccurate and should not be used for statistical analysis.

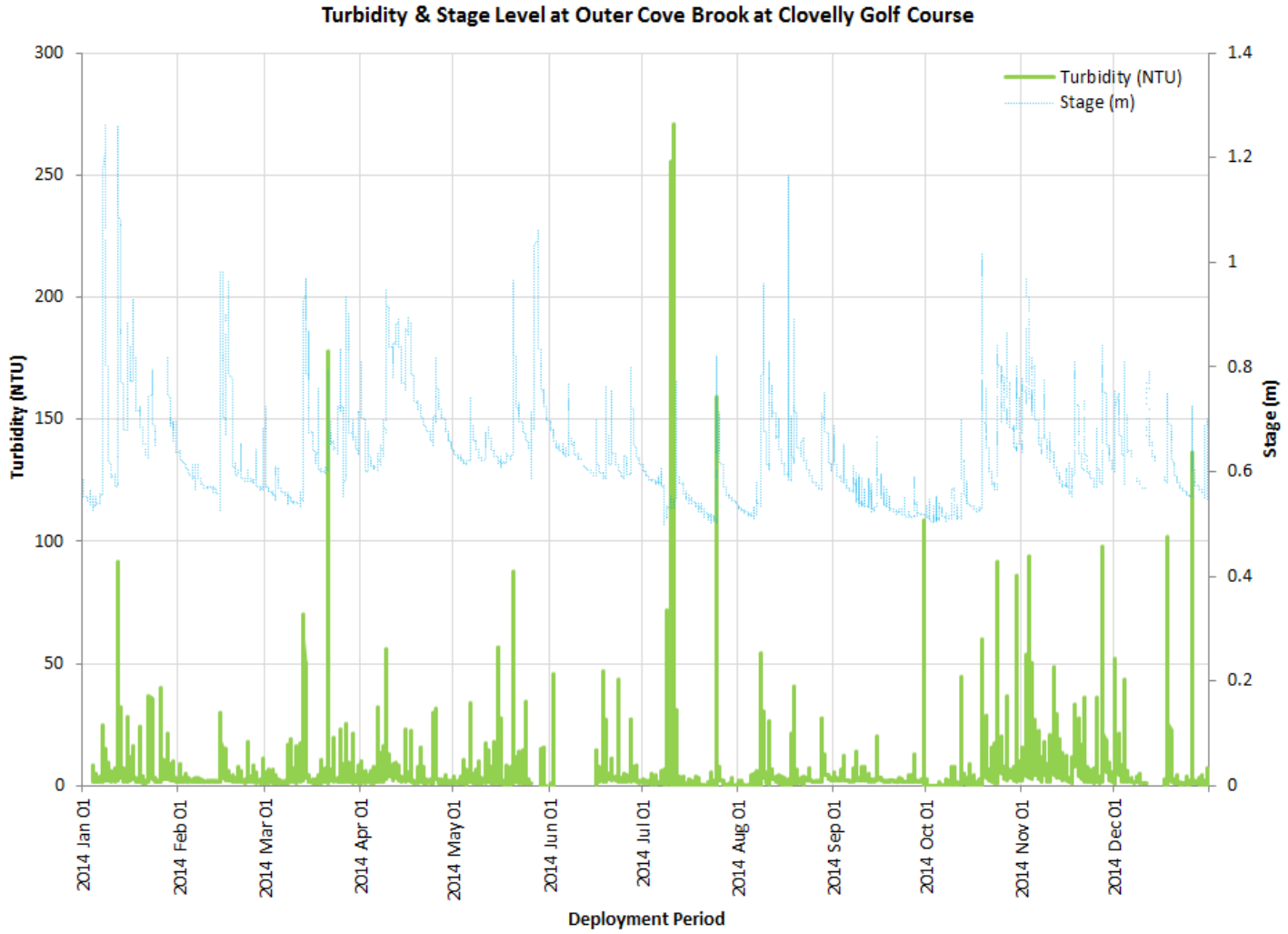

Figure 19: Turbidity (NTU) and stage level (m) values recorded at Outer Cove Brook at Clovelly Golf Course

Conclusions

During the 2014 deployment year Outer Cove Brook at Clovelly Golf Course displayed characteristics similar to that of Outer Cove Brook below Airport. The Clovelly Golf Course stream is also greatly influenced by snow melt, spring runoff and precipitation throughout the year; therefore there is a lot of variation in the water parameters data. Stage level captures the influences of precipitation and runoff events that occurred over the year.

During the months of January to early May there is evidence of the heavy slime-like substance at Clovelly (that is present in the Outer Cove Brook below Airport). While the incident of the substance is not as bad as the Airport Station, there is still a coating of it on the instrument and on the streambed. It has caused some issues with the actual data due to the fouling of the sensor and it has also changed the water parameters during the growth and die-off periods of the algae.

The Clovelly Station water temperatures are diurnal and also influenced by the surrounding air temperatures in relation to the season. The shallow urban streams and brooks respond faster to air temperatures and this can be seen in the variability of the water temperature data. This stream is braided and can get very shallow before it deepens where the instrument is located.

Outer Cove Brook at Clovelly Golf Course had a median pH value of 6.48 which was inside the normal range for stream water. The pH data displayed general events in relation to stage increase and rainfall.

Outer Cove Brook at Clovelly Golf Course displays two different reactions in specific conductivity. During the spring thaw and high runoff seasons in March and April the conductivity levels increase with the higher stage levels likely a result of salt runoff from the surrounding urban areas and the airport. Into the summer and fall seasons (June through to early November) the conductivity levels drop with high stage levels. The decrease in conductivity during those times was likely a result of periods of rainfall diluting the suspended substances in the brooks.

The Dissolved Oxygen median for this deployment year was 9.82mg/L. As the warmer temperatures started in June the dissolved oxygen levels in the brook started to dip under the CCME guideline for the protection of cold water other life cycles (6.5mg/L). This is a normal response of dissolved oxygen with warmer temperatures.

The turbidity increases corresponded with the precipitation events that can influence the amount of suspended sediments in the water column. Outer Cove Brook at Clovelly Golf Course had large amounts of aquatic vegetation growing in the brook that can cause interference for the turbidity sensor.

Outer Cove Brook Network

The instruments were deployment all year round at both stations. On December 16th and 17th at Outer Cove brook at Clovelly Golf Course there was maintenance completed on the field cable and the station was offline for several days.

Variations in stage are attributed to precipitation events. Both stations displayed a trend of decreasing stage values from spring to summer as spring thaw ends, lowest stage levels in the summer, followed by increased stage levels throughout fall due to numerous precipitation events (Appendix VI).

Water temperature trends over the year fluctuate diurnally, dependent on the ambient air temperature, warming as summer approaches, peaking in August, and falling as winter approaches. As precipitation increases the stage level it may decrease water temperatures. Outer Cove Brook at Clovelly Golf Course had the highest maximum in water temperature for the deployment year. However the median for water temperature for both Outer Cove Brook stations was almost the same, indicating that overall water temperature remains consistent across the brook (See Table 2).

pH median values at both stations hover around the CCME guideline minimum pH value of 6.5, naturally decreasing with stage increases. Newfoundland waters are naturally acidic and the medians are within the normal range for stream water in St. John's. Outer Cove Brook below Airport had the maximum pH at 7.61 pH units, although both stations had similar medians in pH for the deployment year (See Table 2).

Over the deployment year the fluctuations in specific conductivity are influenced by precipitation events, drops in conductivity after rainfalls due to dilution, and increasing with snowfall and low ambient air temperatures due to the addition of salts from nearby roadways. Clovelly station had a higher minimum and maximum but the medians for both stations were very similar (See Table 2).

Dissolved Oxygen values at both stations fall below the CCME recommended minimum guideline for DO of 6.5 mg/L during the summer months, when the warmer water can hold less oxygen. This is likely due to the increase in plant production in the river system during these warm months, depleting the water of its oxygen. Dissolved oxygen levels were lowest at Outer Cove Brook below Airport; the low values were recorded during the same time the die-off was occurring of the slime-like substance (Appendix IV). However the medians for dissolved oxygen at both stations are close in value (See Table 2).

Table 2: Minimum, Maximum and median values for each parameter measured at the Outer Cove Brook stations during the 2014 deployment season

	Water Temperature (oC)		pH(pH units)		Specific Conductivity (uS/cm)		Dissolved Oxygen (mg/L)		Turbidity (NTU)	
	Airport	Clovelly	Airport	Clovelly	Airport	Clovelly	Airport	Clovelly	Airport	Clovelly
Min	-0.1	-0.1	5.84	5.77	64.9	127.8	0.75	5.62	0	0
Max	21.9	23.76	7.61	7.23	2912	4541	12.71	12.98	1777	270.7
Median	7	6.985	6.57	6.48	500	532	9.94	9.82	0.7	1.9

Both stations were influenced by the presence of biofouling slime (Appendix IV). During the beginning of each deployment year there is a high growth of slime for several months that affects the sensors performance. At the Clovelly station there is a large amount of aquatic vegetation present all year round and the vegetation does have the potential to interfere with the sensors. For the most part over the deployment year the increases in turbidity corresponded with stage increases. At Outer Cove Brook below Airport there were several turbidity events captured during July, October and November 2014 these events were linked to land clearing occurring up stream (Appendix V). While the Airport station does have the larger turbidity maximum there is no significant difference between the medians of the two Outer Cove Stations.

APPENDIX I
Sensor Performance Rankings for Deployment Periods

Station	Date	Action	Comparison Ranking				
			Temperature	pH	Specific Conductivity	Dissolved Oxygen	Turbidity
Airport	Dec 19 2013	Deployment	Good	Fair	Excellent	Fair	Fair
	Jan 21 2014	Removal	Excellent	Excellent	Excellent	Fair	Excellent
Clovelly	Dec 19 2013	Deployment	Good	Good	Excellent	Good	Good
	Jan 21 2014	Removal	Excellent	Fair	Excellent	Fair	Excellent
Airport	Jan 21 2014	Deployment	Excellent	Excellent	Excellent	Fair	Excellent
	Feb 21 2014	Removal	Excellent	Poor	Excellent	Marginal	Excellent
Clovelly	Jan 21 2014	Deployment	Excellent	Excellent	Excellent	Excellent	Excellent
	Feb 21 2014	Removal	Excellent	Poor	Excellent	Good	Good
Airport	Feb 21 2014	Deployment	Excellent	Good	Excellent	Fair	Excellent
	April 8 2014	Removal	Excellent	Marginal	Excellent	Poor	Excellent
Clovelly	Feb 21 2014	Deployment	Excellent	Good	Excellent	Excellent	Excellent
	April 8 2014	Removal	Excellent	Good	Excellent	Good	Excellent
Airport	April 8 2014	Deployment	Good	Good	Good	Poor	Excellent
	May 14 2014	Removal	Fair	Good	Excellent	Poor	Poor
Clovelly	April 8 2014	Deployment	Good	Excellent	Good	Good	Good
	May 14 2014	Removal	Excellent	Excellent	Good	Marginal	Excellent
Airport	May 14 2014	Deployment	Excellent	Fair	Good	Excellent	Excellent
	June 16 2014	Removal	Good	Marginal	Good	Poor	Poor
Clovelly	May 14 2014	Deployment	Excellent	Good	Good	Fair	Good
	June 16 2014	Removal	Good	Good	Good	Excellent	Excellent
Airport	June 16 2014	Deployment	Fair	Excellent	Excellent	Fair	Excellent
	August 22 2014	Removal	Excellent	Excellent	Excellent	Excellent	Fair
Clovelly	June 16 2014	Deployment	Good	Good	Marginal	Excellent	Excellent
	August 22 2014	Removal	Excellent	Excellent	Good	Excellent	Excellent
Airport	August 22 2014	Deployment	Excellent	Excellent	Excellent	Excellent	Fair
	Sept 30 2014	Removal	Excellent	Fair	Good	Excellent	Excellent
Clovelly	August 22 2014	Deployment	Excellent	Excellent	Excellent	Excellent	Excellent
	Sept 30 2014	Removal	Excellent	Excellent	Excellent	Excellent	Excellent
Airport	Sept 30 2014	Deployment	Excellent	Good	Excellent	Excellent	Good
	Nov 3 2014	Removal	Good	Good	Good	Fair	Good
Clovelly	Sept 30 2014	Deployment	Excellent	Excellent	Excellent	Fair	Excellent
	Nov 3 2014	Removal	Excellent	Poor	Good	Excellent	Poor
Airport	Nov 3 2014	Deployment	Excellent	Good	Excellent	Fair	Marginal
	Dec 30 2014	Removal	Excellent	Excellent	Excellent	Excellent	Excellent
Clovelly	Nov 3 2014	Deployment	Excellent	Excellent	Excellent	Excellent	Poor
	Dec 30 2014	Removal	Excellent	Excellent	Excellent	Excellent	Excellent

Table3: Rankings of the Outer Cove Brook instruments over the 2014 deployment year

APPENDIX II
Water Parameter Description

Dissolved Oxygen

The amount of Dissolved Oxygen (DO) (mg/l) in the water is vital to aquatic organisms for their survival. The concentration of DO is affected by such things as water temperature, water depth and flow (e.g., aeration by rapids, riffles etc.), consumption by aerobic organisms, consumption by inorganic chemical reactions, consumption by plants during darkness, and production by plants during the daylight (Allan 2010).

pH

pH is the measure of hydrogen ion activity and affects: (i) the availability of nutrients to aquatic life; (ii) the concentration of biochemical substances dissolved in water; (iii) the efficiency of hemoglobin in the blood of vertebrates; and (iv) the toxicity of pollutants. Changes in pH can be attributed to industrial effluence, saline inflows or aquatic organisms involved in the photosynthetic cycling of CO_2 (Allan 2010).

Specific conductivity

Specific conductivity (µS/cm) is a measure of water's ability to conduct electricity, with values normalized to a water temperature of 25ºC. Specific conductance indicates the concentration of dissolved solids (such as salts) in the water, which can affect the growth and reproduction of aquatic life. Specific conductivity is affected by rainfall events, the composition of inflowing tributaries and their associated geology, saline inflow (e.g., road salt), agricultural run-off and industrial inputs (Allan 2010; Swanson and Baldwin 1965).

Stage

Stage (m) is the elevation of the water surface and is often used as a surrogate for the more difficult to measure flow.

Temperature

Essential to the measurement of most water quality parameters, temperature (^{o}C) controls most processes and dynamics of limnology. Water temperature is influenced by such things as ambient air temperature, solar radiation, meteorological events, industrial effluence, wastewater, inflowing tributaries, as well as water body size and depth (Allan 2010; Hach 2006).

Total Dissolved Solids

Total Dissolved Solids (TDS) (g/l) is a measure of alkaline salts dissolved in water or in fine suspension and can affect the growth and reproduction of aquatic life. It is affected by rainfall events, the composition of inflowing tributaries and their associated geology, saline inflow (e.g., road salt), agricultural run-off and industrial inputs (Allan 2010; Swanson and Baldwin 1965).

Turbidity

Turbidity (NTU) is a measure of the translucence of water and indicates the amount of suspended material in the water. Turbidity is caused by any substance that makes water cloudy (e.g., soil erosion, micro-organisms, vegetation, chemicals, etc.) and can correspond to precipitation events, high stage, and floating debris near the sensor (Allan 2010; Hach 2006; Swanson and Baldwin 1965).

APPENDIX III
References

References

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Canadian Council of Ministers of the Environment. 2007. Canadian water quality guidelines for the protection of aquatic life: Summary table. Updated December, 2007. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg. (Website: http://ceqg-rcqe.ccme.ca/download/en/222/)

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Swanson, H.A., and Baldwin, H.L., 1965. A Primer on Water Quality, U.S. Geological Survey. Online: http://ga.water.usgs.gov/edu/characteristics.html (accessed August 24, 2010)

Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51 p. + 8 attachments; accessed April 10, 2006, at *http://pubs.water.usgs.gov/tm1d3*

APPENDIX IV
Pictures of Slime-like substance at the Outer Cove Brook Stations

Slime at Outer Cove Brook below Airport
April 8th, 2014

Figure 21: Slime on Airport Instrument after 1 month deployment in April 2014.

Figure 22: Slime on Airport Instrument after 1 month deployment in April 2014.

Slime at Outer Cove Brook below Airport
May 13th, 2014

Figure 23: Slime on Airport Instrument after 1 month deployment in May 2014.

Figure 24: Slime on Airport Instrument after 1 month deployment in May 2014.

Figure 25: Slime on Airport Instrument after 1 month deployment in May 2014.

Figure 26: Slime on Airport instrument's protective casing in May 2014.

Figure 27: Slime on Airport instrument's sensor cage in May 2014.

Figure 28: Slime on the sensors of Airport station instrument after 1 month deployment in May 2014.

Slime at Outer Cove Brook at Clovelly Golf Course
May 13th, 2014

Figure 29: Slime in the brook at Clovelly Station in May 2014.

Figure 30: lime on the sensors of Clovelly station instrument after 1 month deployment in May 2014.

APPENDIX V
Turbidity at Outer Cove Brook Stations

Turbidity at Outer Cove Brook below Airport
July 4th, 2014

Figure 31: Turbidity in Airport brook on July 4th, 2014

Figure 32: Looking Downstream from Airport Station on July 4th, 2014

Figure 33: Looking Upstream from Airport Station on July 4th, 2014

Turbidity at Outer Cove Brook below Airport
July 4th, 2014

Figure 34: Walking toward Airport boundary (July 4th 2014)

Figure 35: Location of sediment runoff (July 4th 2014)

Figure 36 Looking downstream toward Station (July 4th 2014)

Figure 37: Land Clearing (July 4th 2014)

Turbidity at Outer Cove Brook below Airport Station
October 22nd, 2014

Figure 38: Turbidity occurring at Outer Cove Brook below Airport October 22, 2014.

Figure 39: Turbidity occurring at Outer Cove Brook below Airport October 22, 2014 (looking upstream).

Figure 40: Turbidity occurring at Outer Cove Brook below Airport October 22, 2014 (looking downstream).

Turbidity at Outer Cove Brook Stations
November 3rd, 2014

Figure 41: Turbidity occurring at Outer Cove Brook below Airport November 3, 2014.

Figure 42: Turbidity occurring at Outer Cove Brook below Airport November 3, 2014.

Figure 43: Turbidity occurring at Outer Cove Brook below Airport (Looking downstream from station) November 3, 2014.

Figure 44: Sediment on the instrument deployed at Outer Cove Brook below Airport November 3, 2014.

Figure 45: Turbidity occurring at Outer Cove Brook at Clovelly (Looking downstream from station) November 3, 2014.

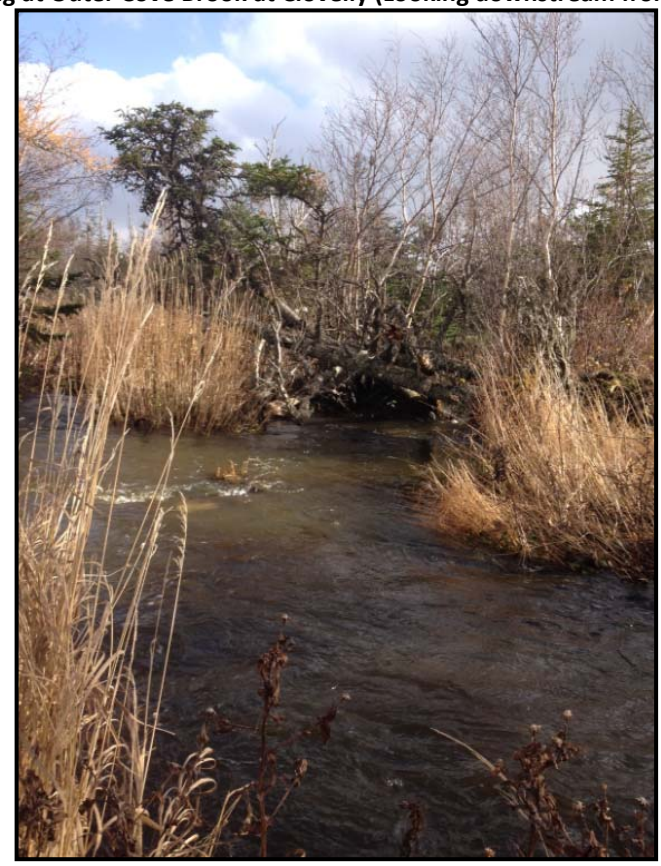
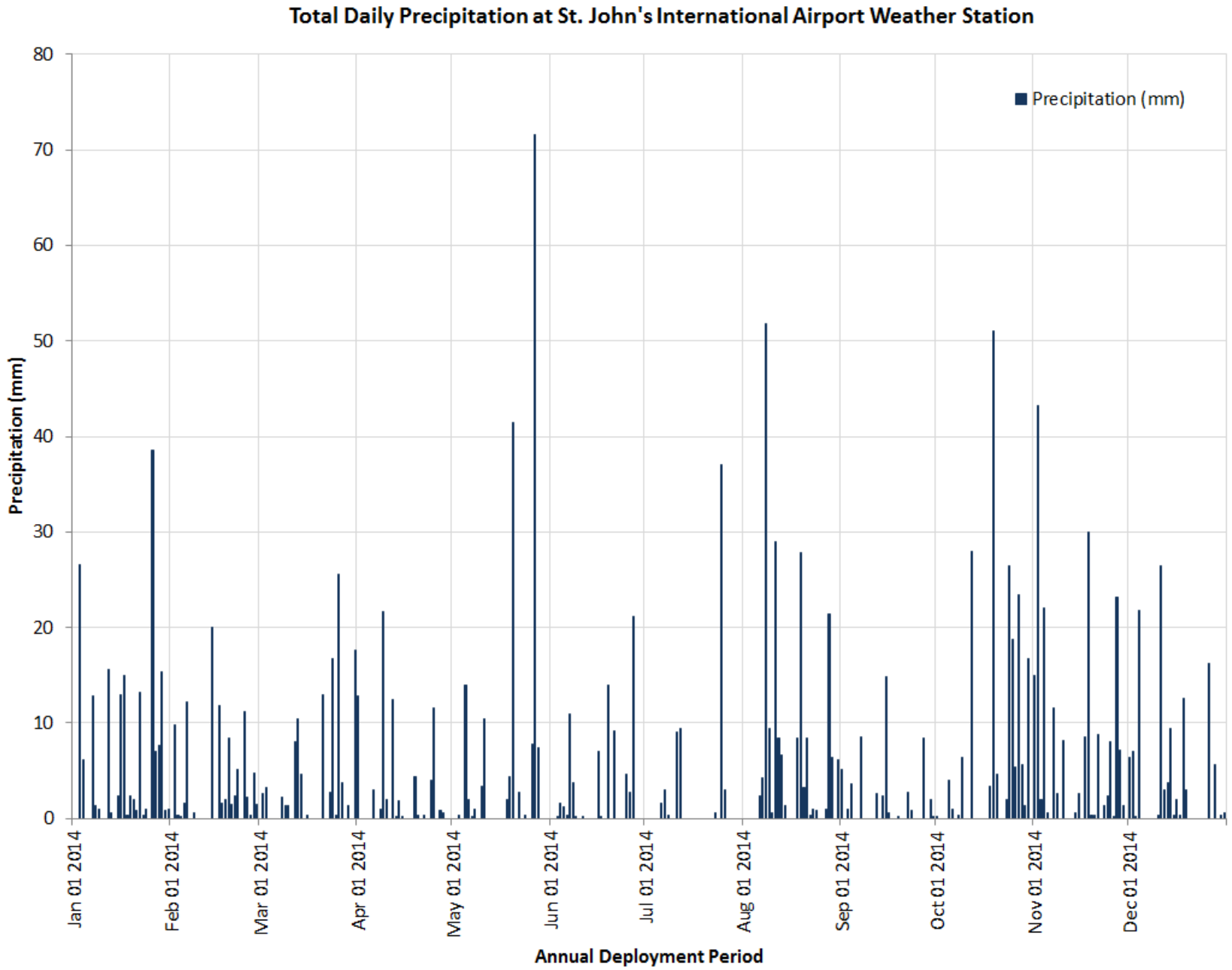


Figure 46: Turbidity occurring at Outer Cove Brook at Clovelly (Looking downstream) November 3, 2014.

Figure 47: Sediment on the instrument deployed at Outer Cove Brook at Clovelly Golf Course November 3, 2014.

APPENDIX VI
Precipitation Data from St. John's International Airport Weather Station


Total Daily Precipitation at St. John's International Airport Weather Station
Precipitation (mm)
Precipitation (mm)
80
70
60
50
40
30
20
10
0
Jan 01 2014
Feb 01 2014
Mar 01 2014
Apr 01 2014
May 01 2014
Jun 01 2014
Jul 01 2014
Aug 01 2014
Sep 01 2014
Oct 01 2014
Nov 01 2014
Dec 01 2014
Annual Deployment Period