Teck Duck Pond Operations Real-Time Water Quality Monitoring Network Annual Report 2013

2014-02-11

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

Acknowledgements

The Real-Time Water Quality Monitoring Network at Teck Duck Pond Operations is successful in tracking emerging water quality issues due to the hard work and diligence of individuals from three different organizations. The management and staff of Teck Duck Pond Operations 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 the vicinity of the mine and mill.

At Teck Duck Pond Operations several staff members including General Manager Larry Bartlett have assisted in ensuring that the real-time system is operating such that data are reliable and accurate. Boyd Gulliford, Jill Kelly, Carol-Ann Hayden, and Robert Vaters have provided valuable assistance with the stations and feedback from time to time.

Various individuals from the Department of Environment and Conservation under the direction of Haseen Khan have been integral in ensuring the smooth operation of such a technologically advanced network. Renée Paterson and Robert Wight played the lead roles in coordinating and liaising between the major agencies involved, thus, ensuring open lines of communication at all times. Robert Wight was responsible for the data management/reporting, troubleshooting, along with ensuring the quality assurance/quality control measures are satisfactory. Throughout the year, Robert travelled to Teck Duck Pond Operations sometimes twice monthly to maintain and service the equipment and troubleshoot any technical problems as they arose. Paul Neary and Leona Hyde have worked on the communication aspects of the network ensuring the data is being provided to the general public on a near real-time basis through the departmental web page.

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. Brent Ruth, Roger Ellsworth, Perry Pretty, Dwayne Ackerman, Taylor Krupa and Mike Ludwicki visit the site several times throughout the year to ensure the data logging equipment is operating properly and transmitting the data efficiently. They play the lead role in dealing with hydrological quantity and flow issues.

All individuals from each agency are fully committed to maintaining and 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 open communication and high level of cooperation of all three agencies involved.

Section 1.0 Introduction

The Real-Time Water Quality Monitoring Network at Teck Duck Pond Operations began in 2006 when the property was being developed by Aur Resources Inc. This network forms part of a larger network of government run and government-industry partnership run real-time water quality stations throughout the Province. **Figure 1** depicts the Real-Time Water Quality Monitoring Network at Teck Duck Pond Operations in relation to the others on the island portion of the Province.

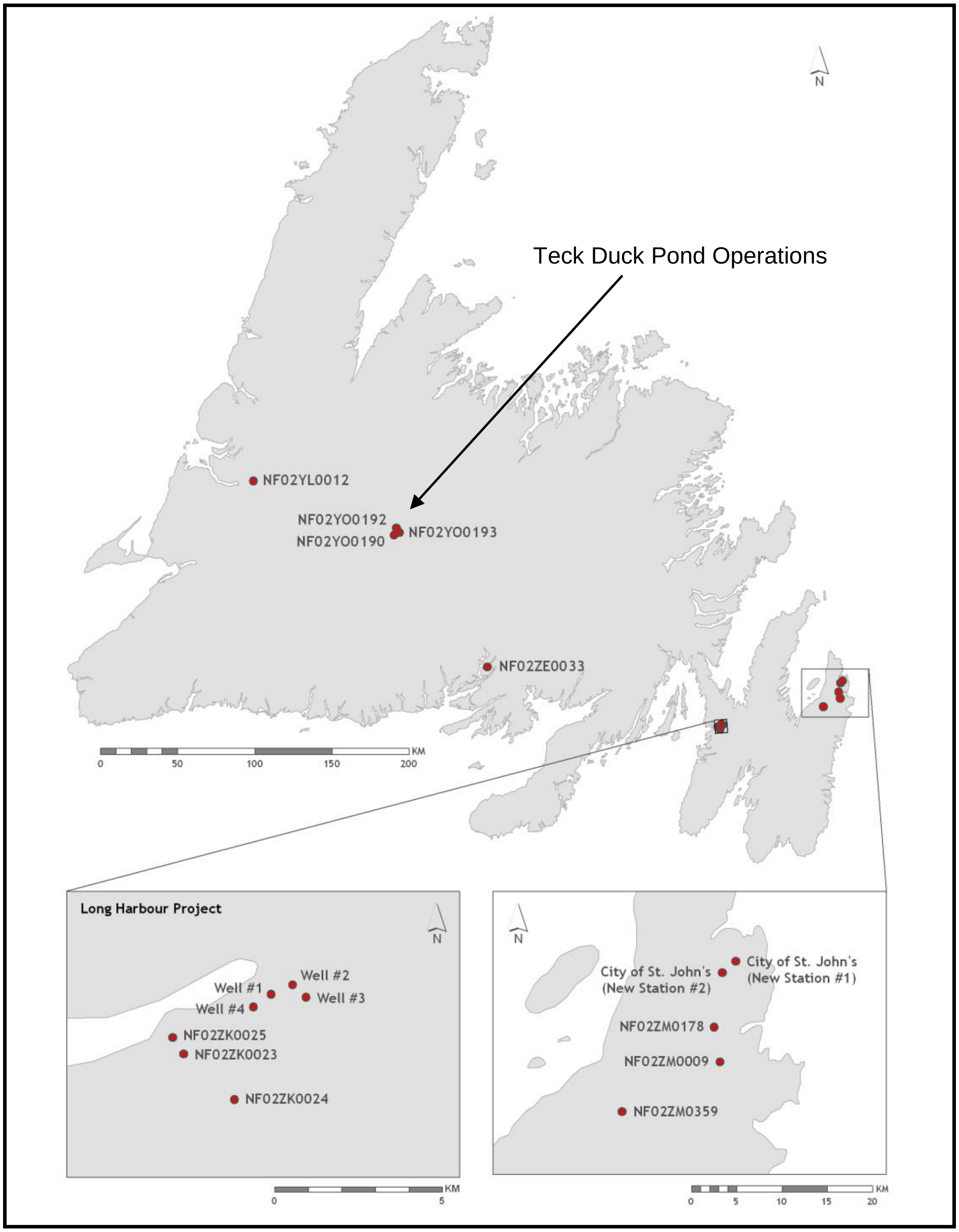

Figure 1: Real-Time Water Quality Monitoring Stations, Newfoundland

Three permanent stations (**Figure 2**) are established at Teck Duck Pond Operations; two in surface water streams and one in a ground water monitoring well:

- **Tributary to Gills Pond Brook Station (NF02YO0190**) is located 1700 m downstream of the final release point for the site's Tailings Management Area / Polishing Pond. This station is located such that any impacts from normal mine/mill discharge on receiving waters can be measured. This station has been fully operational since May 10, 2006 during the mine/mill construction phase.

- **East Pond Brook Station (NF02YO0192)** is located several kilometers downstream of the Tailings Management Area. This station is located such that any surface water impacts from the Tailing Management Area via seepage through Dam A may be measured. This station has been fully operational since September 7, 2006, during the mine/mill construction phase.

- **Monitoring Well After Tailings Dam Station (NF02YO0193)** is located approximately 100 meters below Tailings Dam A. This station is located such that any ground water impacts from the Tailing Management Area via seepage through Dam A may be measured. This station has also been fully operational since September 7, 2006.

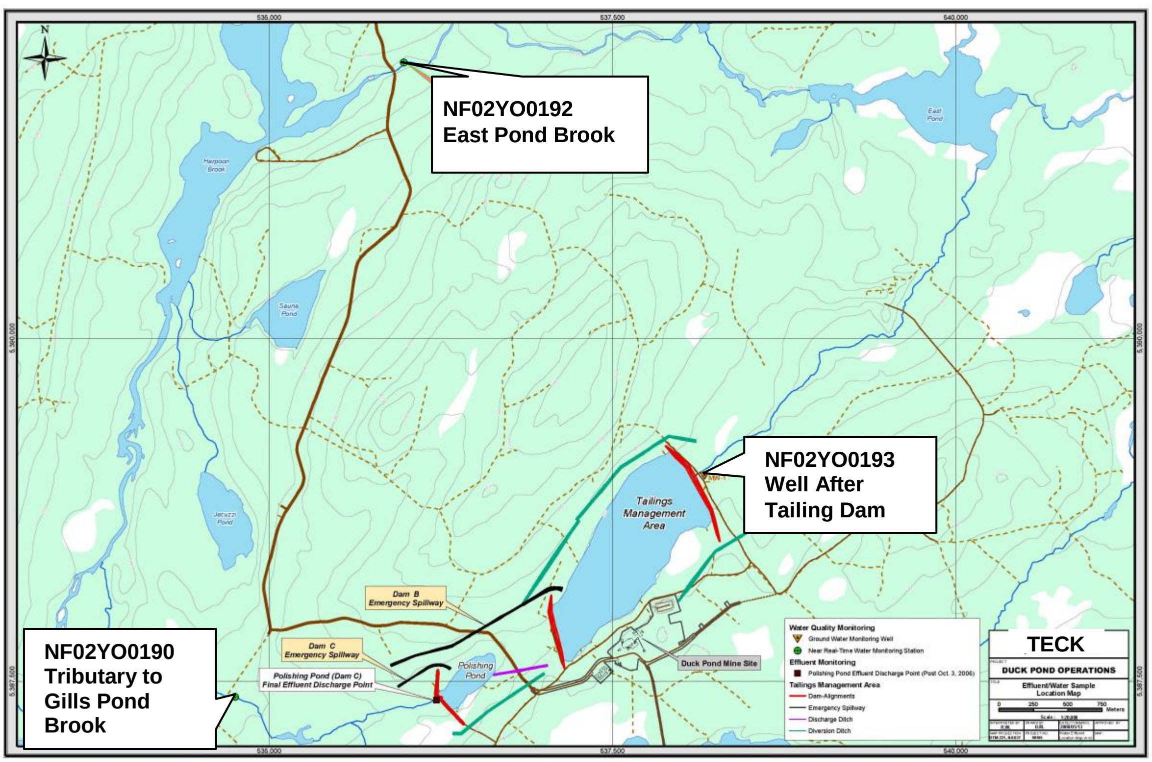

Figure 2: Real-Time Water Quality Monitoring Stations
Teck Duck Pond Operations

The two surface water stations (Tributary to Gills Pond Brook Station (NF02YO0190) and East Pond Brook Station (NF02YO0192)) are operated under a renewable cost-shared agreement with Teck Duck Pond Operations. The operation of the ground water station (Monitoring Well After Tailings Dam Station (NF02YO0193)) is funded solely under the Canada-Newfoundland and Labrador Water Quality Agreement.

The objective of operating these stations is to provide an early warning of any potential or emerging water quality issues such that mitigative measures can be employed to ensure that discharge from Teck Duck Pond Operations meets all regulatory requirements and has minimal impact on the receiving waters and other water in proximity to the site, which are the headwaters of the Exploits River.

It was initially intended to remove the instruments from the three stations during the winter months, as the instruments are prone to be damaged by freezing. Furthermore, initially, there was no discharge planned for the winter months. However, as the mine and mill have become operational, discharge from the site has been required outside the planned time frame of May through November. Accordingly, the instruments have been deployed continuously whenever possible throughout the year.

The instruments at Tributary to Gills Pond Brook Station (NF02YO0190) and East Pond Brook Station (NF02YO0192) were deployed nearly continuously throughout the year. During the winter months, they remained deployed for longer periods to minimize the risk of damage from freezing during deployment and removal. Up to this point in time no significant negative impacts on the instruments have been observed. During the remaining months, these instruments were changed out approximately monthly, to facilitate regular maintenance and calibration.

As Monitoring Well After Tailings Dam Station (NF02YO0193) freezes at surface, an instrument is deployed continuously over the winter months. Following regular servicing and calibration it was placed in the well on October 3, 2012, and remained deployed until May 14, 2013. However, typical of the past several winters, there were some data communication errors throughout parts of the colder months. This reoccurring problem continues to be investigated, with multiple system components being changed out from time to time. Past experience has indicated that this probe is very stable over the long term, thus deployments up to six months have been recommended by the vendor.

Presently, all instruments are **Hydrolab®** brand **DataSonde®** probes in the surface water stations and a **Quanta G®** probe in the ground water station. To allow for continuous monitoring without extended periods of missing data, and to augment the older fleet of instruments, Teck Duck Pond Operations has purchased two additional **DataSonde®** probes and one additional **Quanta G®** probe so that replacement units having the same technical specifications, are always available when one or all three instruments are out of service for an extended period of time. Portable **Hydrolab®** brand **MiniSonde®** probes having the same technical specifications are used for QA/QC purposes.

From time to time there are transmission errors resulting in a loss of data through our satellite-based communications system. For the surface water-based instruments (**DataSondes®**) we have the ability to log the water quality data internally, and augment any missing data, particularly for periods of more than a few hours. This feature is not available on the ground water-based **Quanta G®** instrument. Any significant periods of missing satellite-based data which are augmented with internally logged data are noted in specific Deployment Period reports.

Section 2.0 Maintenance and Calibration

All staff involved in the installation, deployment, maintenance and calibration of these probes have undergone training and certification by **Hydrolab®.** Maintenance and calibration of these probes are undertaken in controlled conditions at the laboratories of the Department of Environment and Conservation in Grand Falls – Windsor and/or St. John's. Maintenance and calibration procedures, specified by the equipment manufacturer are followed precisely, and all calibration values logged in a database. All replacement parts, reagents and calibration solutions used, meet the manufacturer's specifications.

It is recommended that regular maintenance and calibration of the **DataSonde®** instruments take place on a monthly basis in order to ensure the accuracy of the data. Particularly during the warmer months, the sensors are prone to fouling from the accumulation of biofilm and other organic matter in the streams. **Quanta G®** instruments are intended for longer term deployments, with less frequent maintenance and calibration, as they may not be as subject to fouling in the well where temperatures are colder and water chemistry more stable. **Table 1** details the dates the instruments were installed and removed for maintenance and calibration in 2013. It is important to note that during the winter months instruments remained deployed for periods longer than a month to minimize the risk of damage from freezing during installation and removal. It has also been demonstrated that during the winter months, due to the colder temperatures, there is less fouling of the sensors, thus allowing them to remain accurate for longer periods of time.

Tributary to Gills Pond Brook Station (NF02YO0190)			
Deployment Period			
Installation Date (yyyy-mm-dd)	Removal Date (yyyy-mm-dd)	Days Deployed	Remarks
2012-11-14	2013-05-10	176	Winter deployment
2013-05-10	2013-06-11	31	
2013-06-13	2013-07-22	39	
2013-07-24	2013-08-13	19	
2013-08-15	2013-10-08	53	
2013-10-08	2013-11-14	36	
2013-11-14			Ongoing winter deployment
East Pond Brook Station (NF02YO0192)			
Deployment Period			
Installation Date (yyyy-mm-dd)	Removal Date (yyyy-mm-dd)	Days Deployed	Remarks
2012-11-14	2013-05-10	176	Winter deployment
2013-05-10	2013-06-11	31	
2013-06-13	2013-06-17	4	
2013-06-17	2013-07-22	35	
2013-07-24	2013-08-13	19	
2013-08-13	2013-10-08	55	
2013-10-08	2013-11-14	36	
2013-11-14			Ongoing winter deployment
Monitoring Well After Tailings Dam Station (NF02YO0193)			
Deployment Period			
Installation Date (yyyy-mm-dd)	Removal Date (yyyy-mm-dd)	Days Deployed	Remarks
2012-10-03	2013-05-14	223	Winter deployment
2013-05-14	2013-08-13	91	
2013-08-13	2013-11-13	92	
2013-11-13			Ongoing winter deployment

Table 1: Maintenance and Calibration Schedule

Section 3.0 Discharge from Polishing Pond

Under Provincial and Federal regulatory measures, effluent from the mine's Tailings Management Area may be discharged (controlled release) through the Polishing Pond to receiving waters (Tributary to Gills Pond Brook) provided it meets stringent criteria. During 2013, there were seven separate Discharge Periods. The number of days discharging each month and the Average Daily Discharge are summarized in **Table 2.**

Month 2013	# of Days Discharging	Average Daily Discharge (m^3/day)
January	15	2,624
February	0	0
March	0	0
April	16	5,722
May	31	19,039
June	30	18,248
July	31	18,450
August	24	13,107
September	25	14,148
October	15	7,525
November	28	15,838
December	18	9,641

Table 2

- **Figure 3** illustrates the Total Daily Discharge from Polishing Pond in relation to the Average Daily Stage or Water Level in the receiving waters, Tributary to Gills Pond Brook. Increases in Stage above normal baseline levels are quite evident during discharge periods. The peaks during January, February and March are the result of the backwater effect due to in-stream icing conditions. Other peaks are the result of significant precipitation/runoff events. Please note that the stage illustrated on this graph is the Average Daily Stage, which is different then the hourly stage measurements illustrated and discussed in Section 4.1; some of the extreme high and low hourly values are normalized in the average. The stage data is raw data that is transmitted via satellite and published on our web page. It 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.

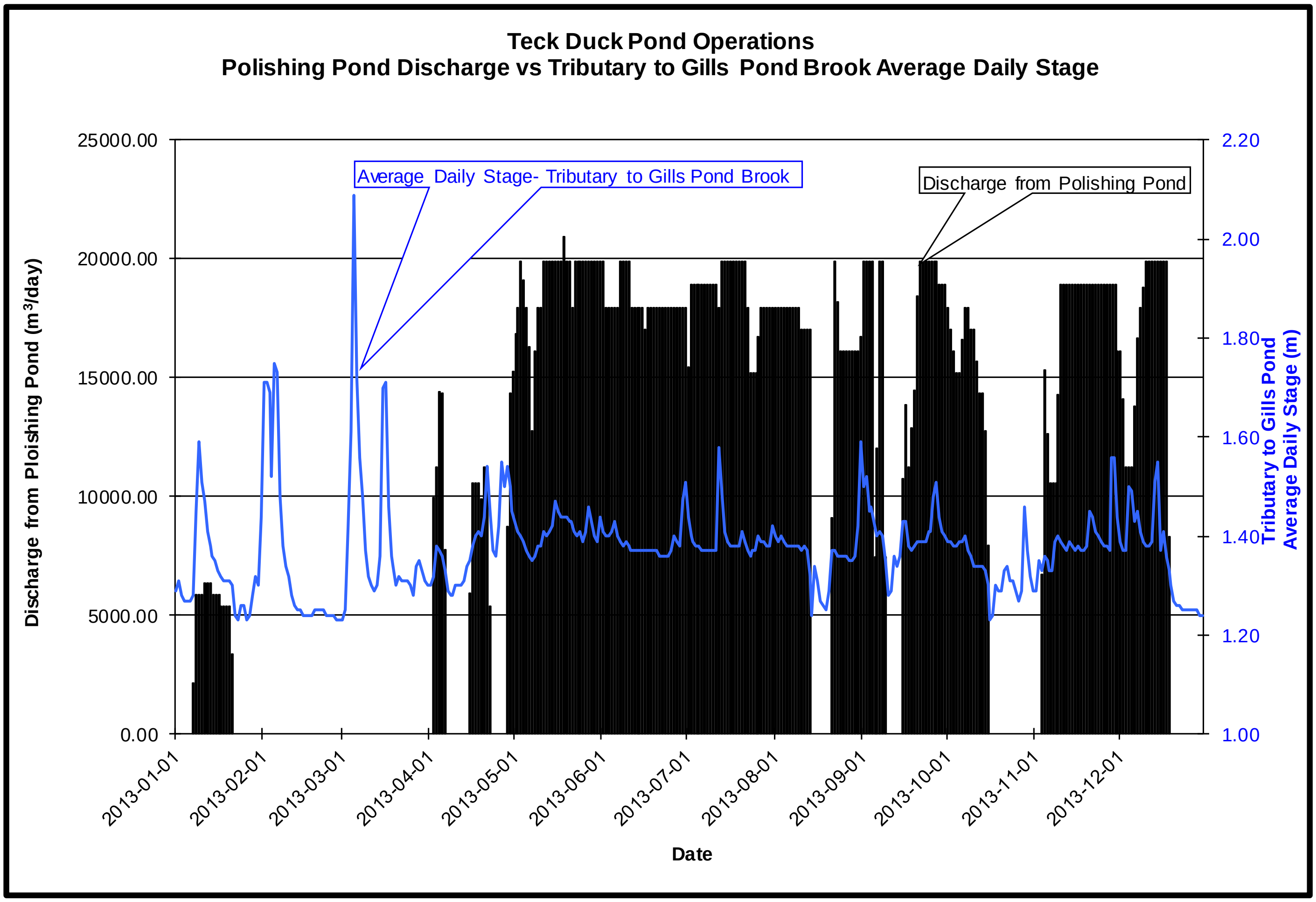

Figure 3

It is important to note, that while meeting the discharge criteria, the physical and chemical characteristics of the discharge water will be different from, and alter the physical and chemical properties in the receiving water. This will be evident in some of the parameters reviewed in Section 4.1.

Section 4.0 Data Interpretation

Section 4.1 Tributary to Gills Pond Brook Station (NF02YO0190)

Tributary to Gills Pond Brook Station is located 1700 m downstream of the final discharge point for the mine's Tailings Management Area - Polishing Pond. This station is located such that any impacts from the mine discharge on receiving waters can be measured.

The water temperature (**Figure 4**) ranged from a minimum of -0.45 °C to a maximum of 25.43 °C. In the winter months, under the cover of ice in the stream, temperatures were generally at or slightly below the freezing point. The highest temperatures were measured in June, July and August. The temperature profile for this stream is very similar to that of East Pond Brook (**Figure 10**). There are no obvious changes in temperature during discharge periods (**Figure 3**). Accordingly discharge from the Polishing Pond does not appear to have any significant impact on the water temperature at this station.

There is no recommended limit or range for water temperature.

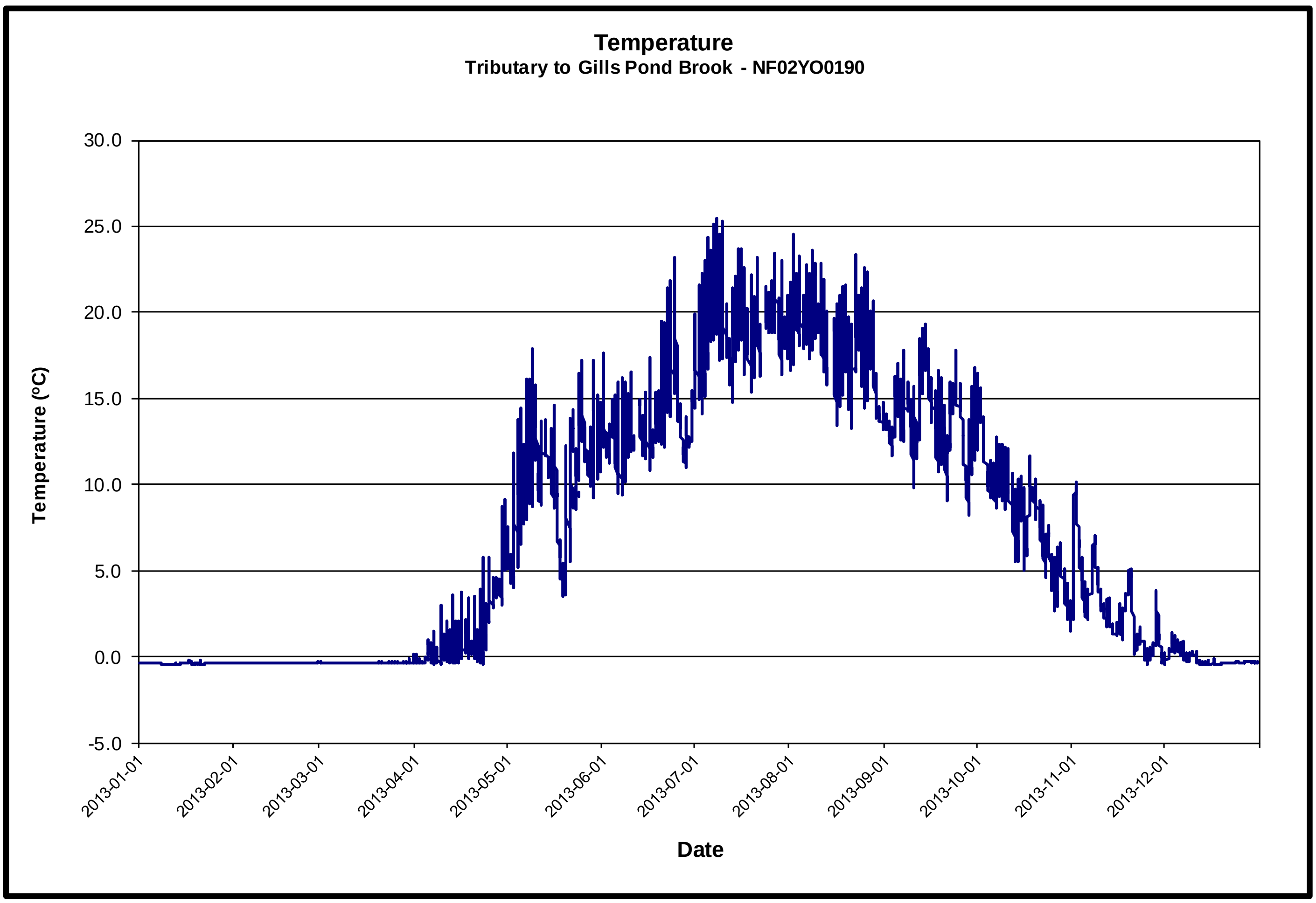

Figure 4

The pH (**Figure 5**) ranged from a minimum of 5.86 to a maximum of 7.67. The pH of this stream is naturally quite low, often being documented to be near or below the lower limit of the recommended range (6.5 – 9.0 – see colored lines on **Figure 5**) for the CCME *Canadian Water Quality Guidelines for the Protection of Aquatic Life* [(1)]. It should be noted however, that discharge from Polishing Pond often has a pH higher than the natural background pH of the receiving waters. Thus, when there is discharge from Polishing Pond (**Figure 3**), there is generally an increased pH in the stream at this station, which often brings the water within the pH range recommended by CCME. The pH profile throughout the year is similar to East Pond Brook (**Figure 11**), except for the influences of the discharge periods.

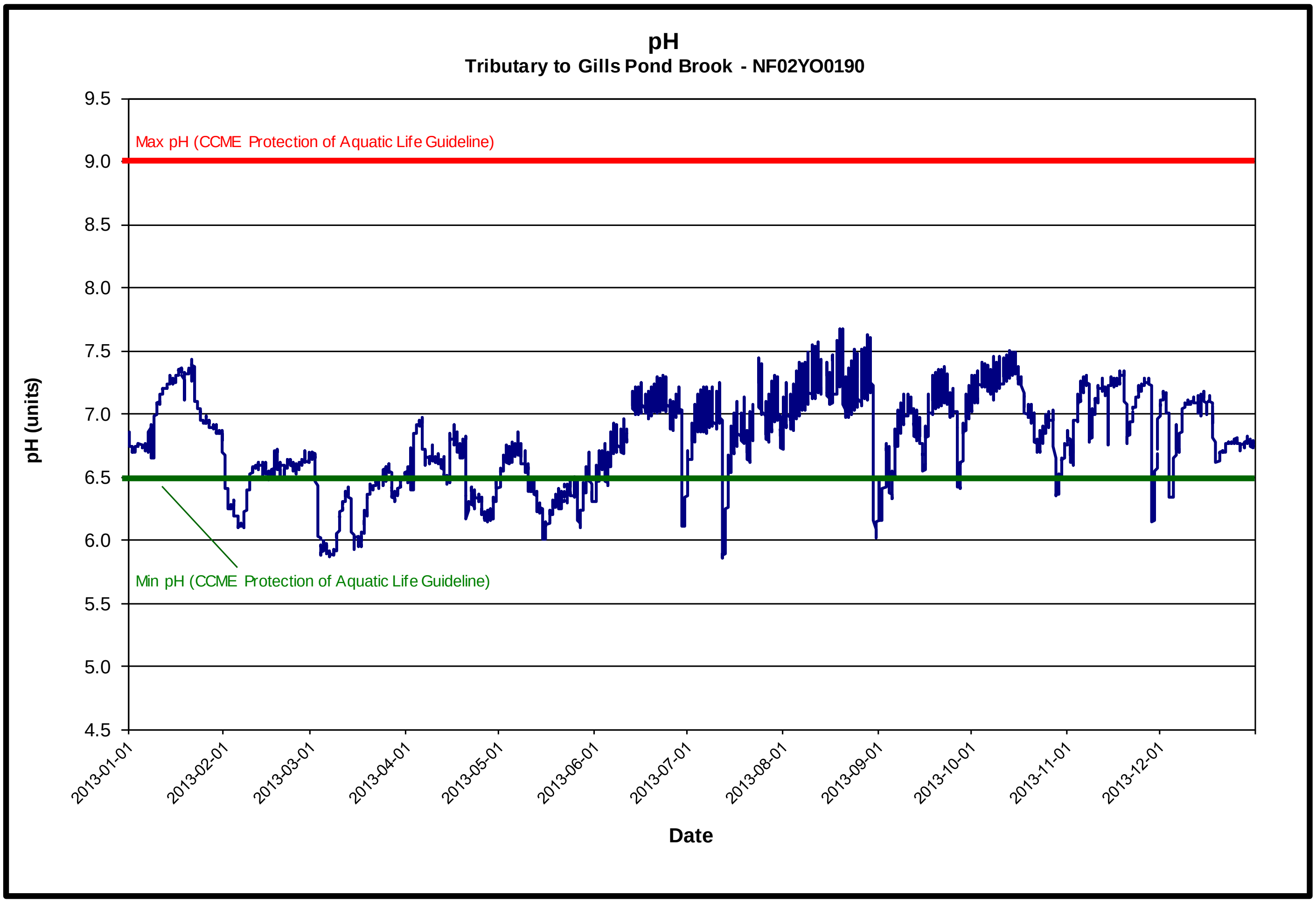

Figure 5

The specific conductivity (**Figure 6**) is affected by the amount of dissolved metals and salts in the water. Pristine waters in this part of the island generally have a specific conductance of less than 50 µS/cm. Outside the periods when there is discharge from Polishing Pond (**Table 2**), the specific conductivity in this stream would generally be quite low. During the past year, the minimum specific conductivity was measured to be 18.6 µS/cm. When there is discharge from the Polishing Pond, conductivity increases significantly, the highest value being measured to be 1288.0 µS/cm. The significant increases and decreases in specific conductivity correspond closely with the beginning and end of the discharge periods from polishing pond (**Figure 3**).

It is interesting to note, that specific conductivity dips, sometimes significantly, during increased stage following periods of snowmelt or rainfall. Snowmelt and rainfall contributions to the stream's discharge would generally have an extremely low (approaching zero) background specific conductively and would effectively 'dilute' water in stream. This is particularly more evident when there is discharge from the Polishing Pond.

There is no recommended limit or range for specific conductance, although it is a key indicator of the dissolved metals and salts in the discharge from Polishing Pond.

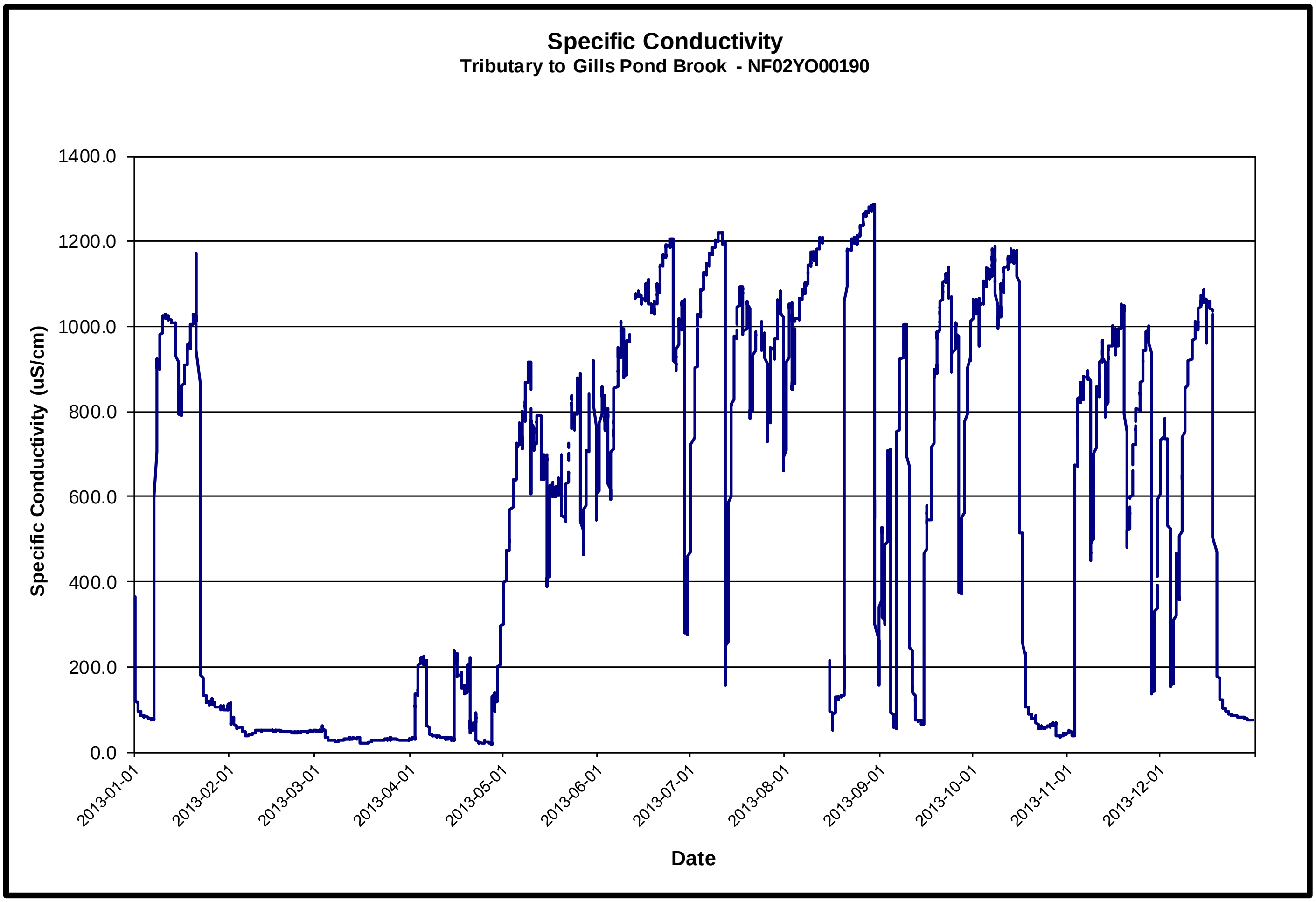

Figure 6

Dissolved oxygen (**Figure 7**) ranged from a minimum of 7.79 mg/L to a maximum of 13.75 mg/L. Generally, dissolved oxygen is inversely proportional to water temperature; this being evident in comparison to **Figure 4**.

There were four rapid and uncharacteristic drops in Dissolved Oxygen in the first part of the year (see red ellipse in the graph below). All four events correspond to extremely high water levels (see **Figure 9** below), which are caused by the backwater effect due to in-stream icing conditions. The first event occurs when there was discharge from the Polishing Pond, the remaining three events occur when there was no discharge from the Polishing Pond into Tributary to Gills Pond Brook. It is interesting to note that there was very little difference over the four events.

The CCME *Canadian Water Quality Guidelines for the Protection of Aquatic Life* [(1)] for dissolved oxygen establish two separate lower limits for cold water biota: other life stages – above 6.5 mg/L; and early life stages – above 9.5 mg/L. While dissolved oxygen consistently remained above 6.5 mg/L, in the warmer months, it did not remain above 9.5 mg/L, the recommended lower limit for early life stage cold water biota. This is a function of the inverse relationship to the warmer water temperatures. During the period when dissolved oxygen was below 9.5 mg/L, the percent saturation (DO % Sat) usually remained in the normal range between 80 % and 100 %, indicating that the water was fully saturated with oxygen. In fact, the dissolved oxygen in waters in East Pond Brook (**Figure 13**) has a very similar profile. There does not appear to be any appreciable change in dissolved oxygen resultant from discharge from Polishing Pond.

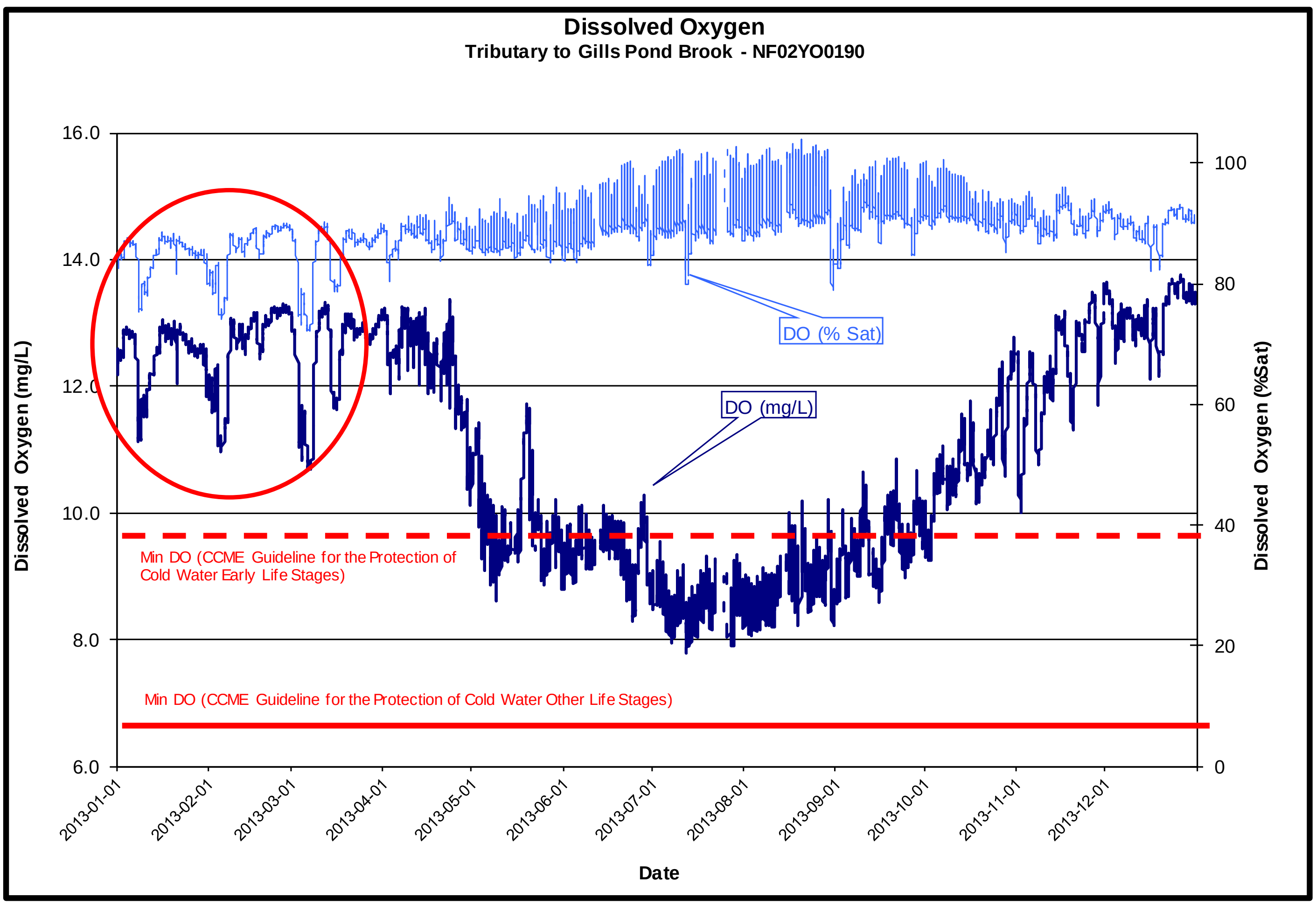

Figure 7

Turbidity (**Figure 8**) ranged from a minimum of 0.0 NTU to a maximum of 1295.0 NTU. On occasion on-line transmitted turbidity values were reported to be 3000 NTU. This number represents a system error in data transmission. Accordingly, these values have been removed and when appropriate, internally (**DataSonde®**) logged turbidity values substituted. During periods when there was no discharge from Polishing Pond, turbidity values were generally at or close to zero. The frequency and intensity of turbidity spikes was generally greater during periods of discharge from Polishing Pond (**Figure 3**). The highest spikes in late April, late August, and late November-early December, all occur when there was discharge from the Polishing Pond, and often when there was a change in the discharge rate. The extremely high peaks on August 24, 25, and 26, 2013 do not appear to correspond with changes in any other monitored parameter, nor any changes in East Pond Brook, nor do they appear to be associated with any weather or precipitation event.

It has also been documented in the *Real Time Water Quality Report Duck Pond Operations (Teck Cominco Limited) Deployment Period 2008-10-16 to 2008-11-12* (2) that at this location, air entrainment due to higher water velocities, and turbulent flow at higher stream discharges sometimes results in false-positive turbidity values. Accordingly, the on-line real time turbidity graph is annotated with the following comment: '*Turbidity values may be exaggerated due to air entrainment (turbulent flow)'.*

Since 2011 the sensor has been placed as far downstream of the plunge pool as possible to avoid the influences of turbulent water, and the introduction of air bubbles (air entrainment), which sometimes cause the false-positive readings. In fact, it has been demonstrated in *Real Time Water Quality Report, Duck Pond Operations (Teck Duck Pond Operations), Deployment Period 2011-08-10 to 2011-09-16*(3), that during periods of no discharge, the turbidity is seldom measured above zero. However, given the limitations of the site (i.e. a small pool in a small tributary, which is subject to high flows, introduced from the discharge from Polishing Pond) there is little else that can be done physically. We will continue to monitor the situation, and test and employ any further mitigative measures which may be beneficial.

From time to time, leaves, algae and other natural in-stream debris became caught on the turbidity sensor, causing interference and false-positive readings. Data for these periods has been removed. Any unusual turbidity measurements will continue to be investigated by staff of the Department of Environment and Conservation and/or Teck Duck Pond Operations.

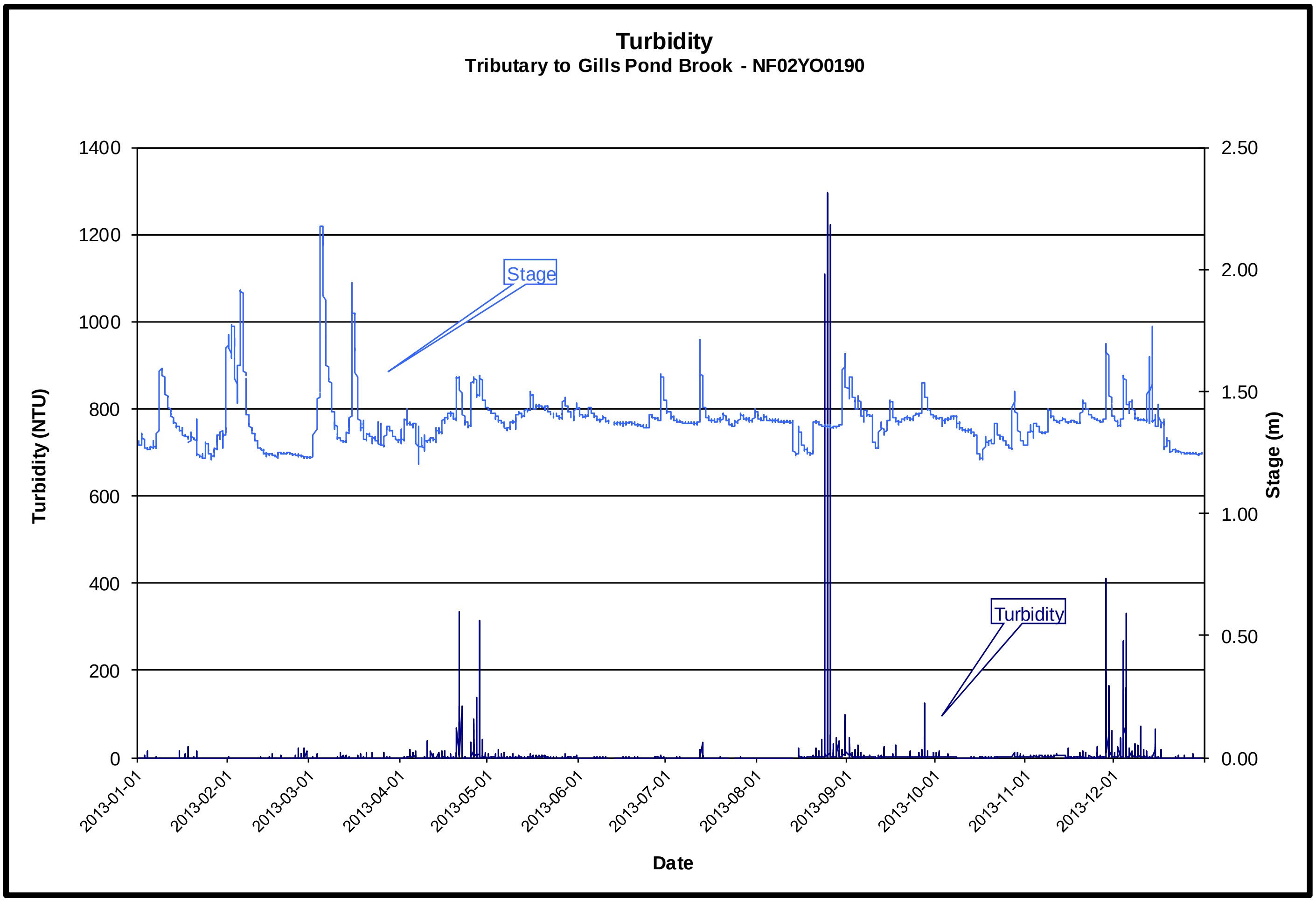
Turbidity
Tributary to Gills Pond Brook - NF02YO0190
Stage
Turbidity
Turbidity (NTU)
Stage (m)
Date
0
200
400
600
800
1000
1200
1400
0.00
0.50
1.00
1.50
2.00
2.50
2013-01-01
2013-02-01
2013-03-01
2013-04-01
2013-05-01
2013-06-01
2013-07-01
2013-08-01
2013-09-01
2013-10-01
2013-11-01
2013-12-01

Figure 8

The stage or water level (**Figure 9**) was recorded to be between 1.20 m and 2.18 m. The flow or discharge ranged from a minimum of 0.01 m^3/s to a maximum of 2.49 m^3/s. At this location, stage is referenced to an arbitrary bench mark. The highest stage was recorded in the winter, presumably due to the backwater effect from ice formation.

For the remainder of the year, however, stage and flow were within normal ranges, with the higher levels corresponding to periods of controlled release from Polishing Pond (**Figure 3**) and following snow melt and rainfall events.

The flow or discharge is calculated based upon a stage-discharge curve which is developed over time. There are periods during the year, when extreme high and low flows could not be calculated as they were outside the range of the existing curve.

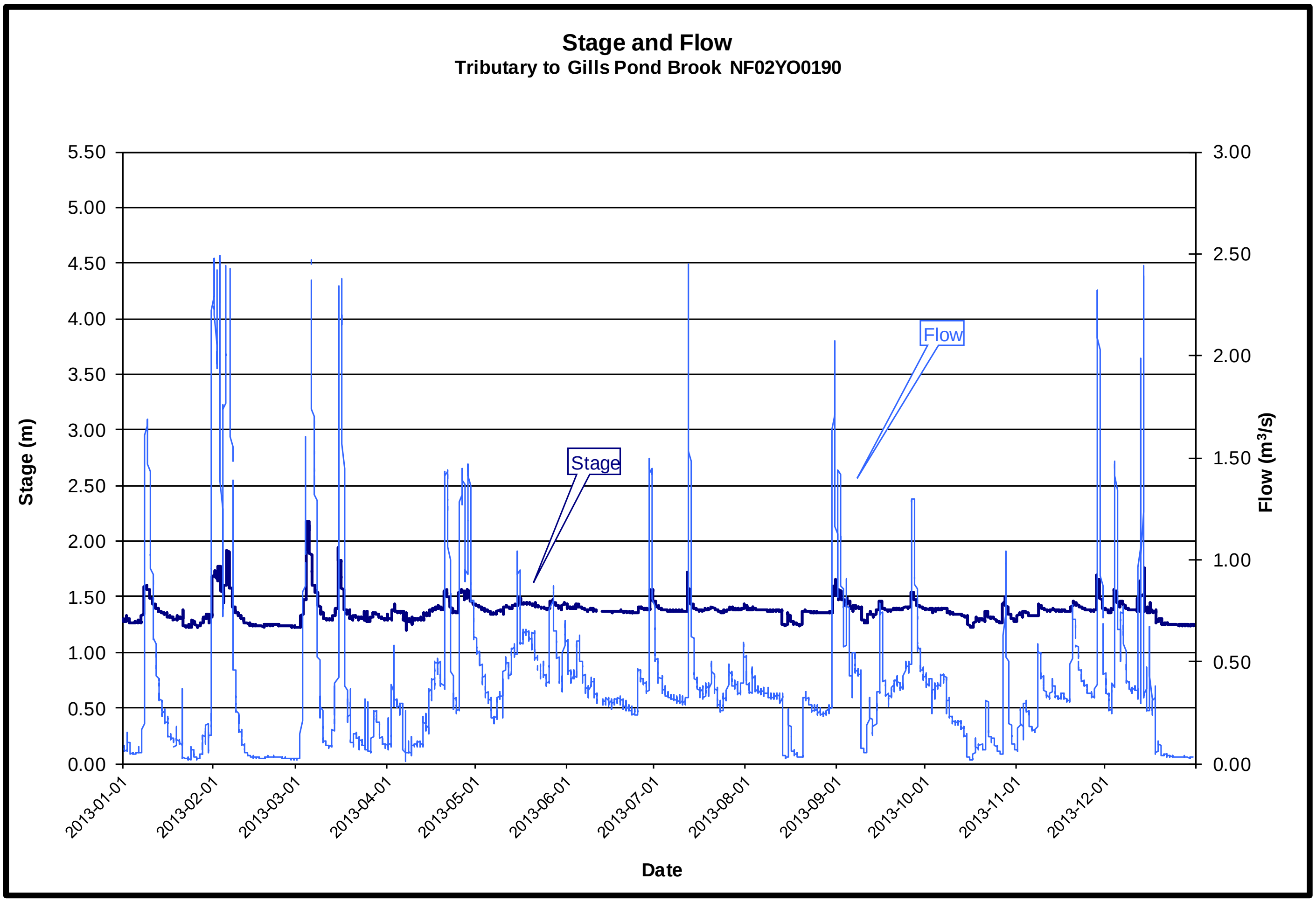

Figure 9

Section 4.2 East Pond Brook Station (NF02YO0192)

East Pond Brook Station is located several kilometres downstream of the Tailings Management Area. This station is located such that any surface water impacts from the Tailing Management Area via seepage through Dam A may be measured.

The water temperature (**Figure 10**) ranged from a minimum of 0.03 °C to a maximum of 26.05 °C. In the winter months, under the cover of ice in the stream, temperatures were generally at or slightly above the freezing point. The highest temperatures were measured in June through August. The temperature profile for this stream is very similar to that of Tributary to Gills Pond Brook (**Figure 4**).

There is no recommended limit or range for water temperature.

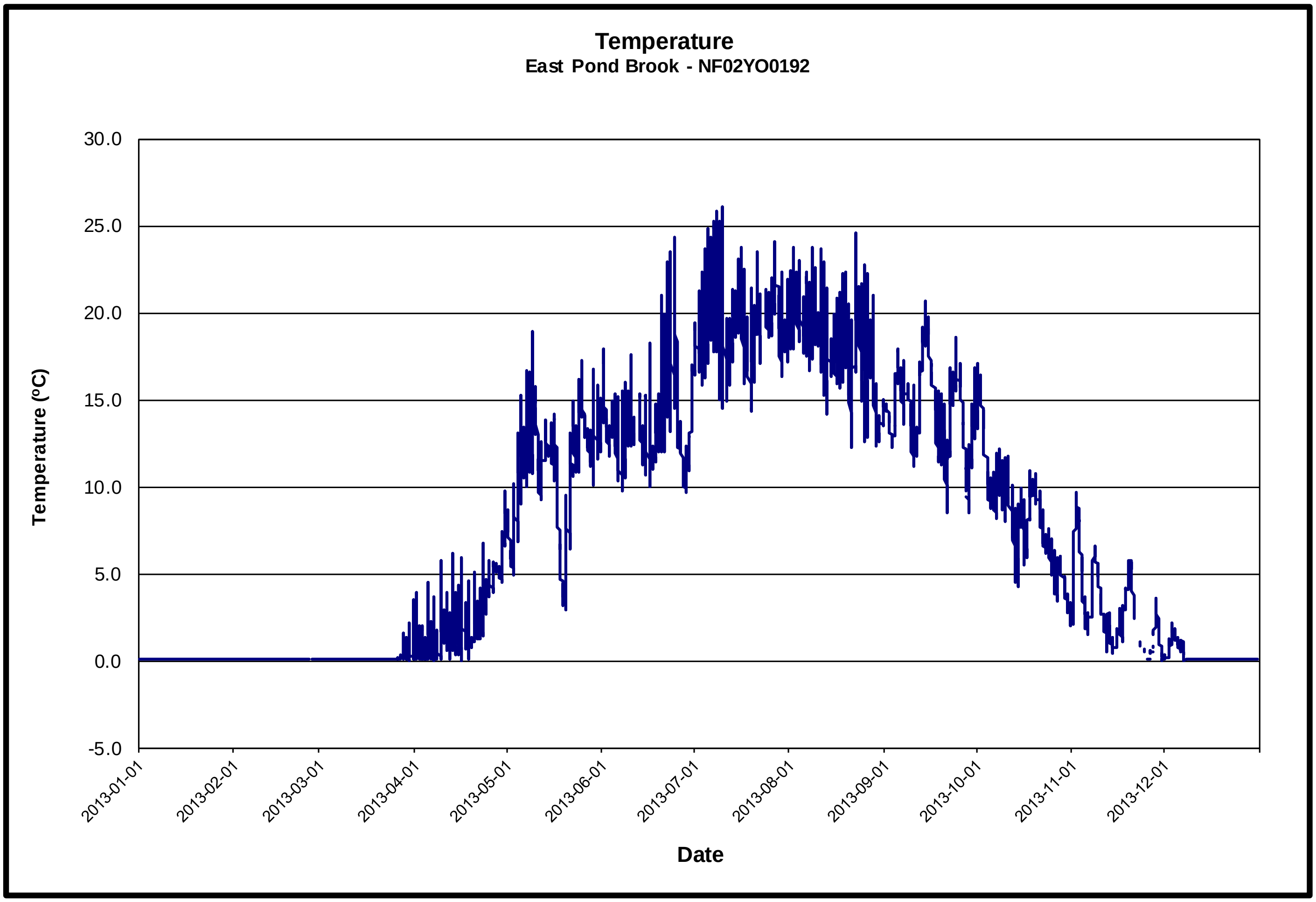

Figure 10

The pH (**Figure 11**) ranged from a minimum of 5.11 to a maximum of 7.23. The pH of this stream is naturally quite low, often being documented to be near or below the lower limit of the recommended range (6.5 – 9.0 – see colored lines on **Figure 11**) for the CCME *Canadian Water Quality Guidelines for the Protection of Aquatic Life* [(1)].

There is a period of missing pH data from August 18, 2013 through October 8, 2013, due to a malfunctioning pH sensor. A back-up instrument was not available due to it being sent out for repairs.

Variation in pH is influenced by a number of factors. For example, there is an inverse relationship with stage (**Figure 15**) which is influenced by snowmelt and precipitation, and a positive relationship with specific conductivity (**Figure 12**). All variations in pH appear to be due to natural influences.

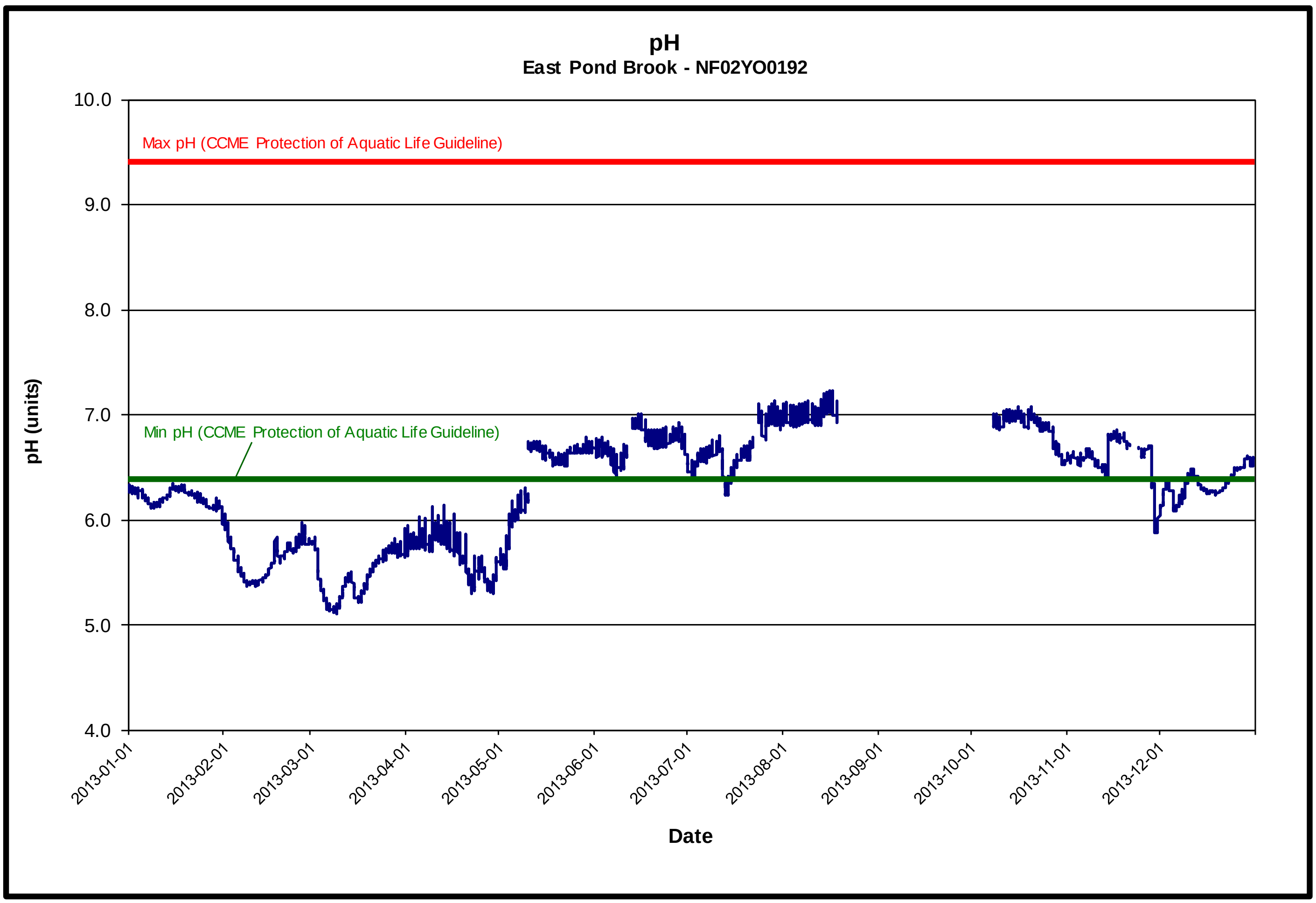

Figure 11

The specific conductivity (**Figure 12**) is affected by the amount of dissolved metals and salts in the water. Pristine waters in this part of the island generally have a specific conductance of less than 50 µS/cm.

During the past year, the specific conductivity ranged between 12.6 µS/cm and 45.0 µS/cm. There values are typical for this stream.

Specific conductivity shows a similar profile to pH (**Figure 11**).

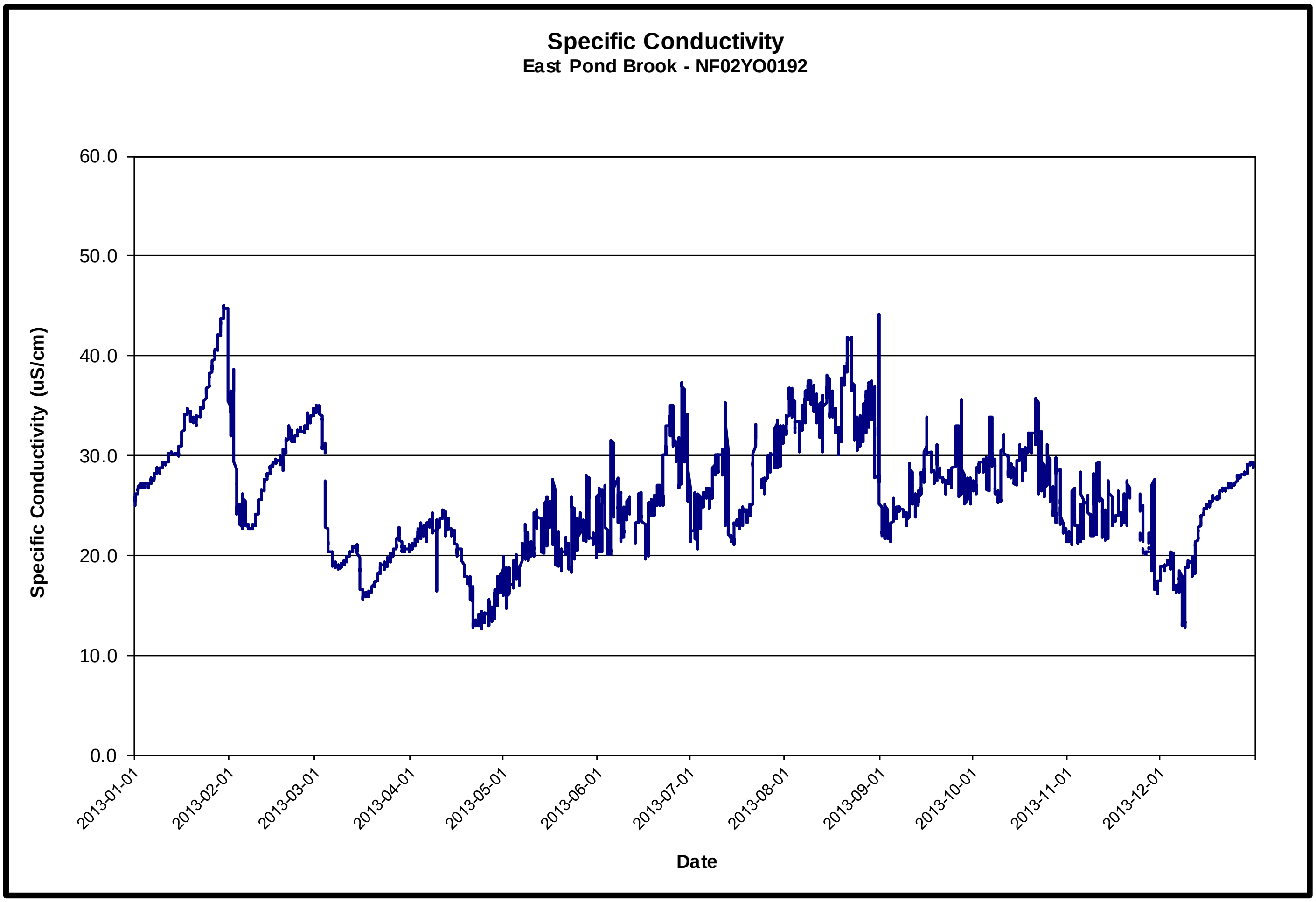

Figure 12

Dissolved oxygen (**Figure 13**) ranged from a minimum of 7.81 mg/L to a maximum of 14.03 mg/L. Generally, dissolved oxygen is inversely proportional to water temperature; this being evident in comparison to **Figure 10**.

The CCME *Canadian Water Quality Guidelines for the Protection of Aquatic Life* (1) for dissolved oxygen establish two separate lower limits for cold water biota: other life stages – above 6.5 mg/L; and early life stages – above 9.5 mg/L. While dissolved oxygen consistently remained above 6.5 mg/L, in the warmer months, it did not remain above 9.5 mg/L, the recommended lower limit for early life stage cold water biota. This is a natural function of the inverse relationship to the warmer water temperatures. During the period when dissolved oxygen was below 9.5 mg/L, the percent saturation (DO % Sat) remained in the normal range between 80 % and 100 %, indicating that the water was fully saturated with oxygen.

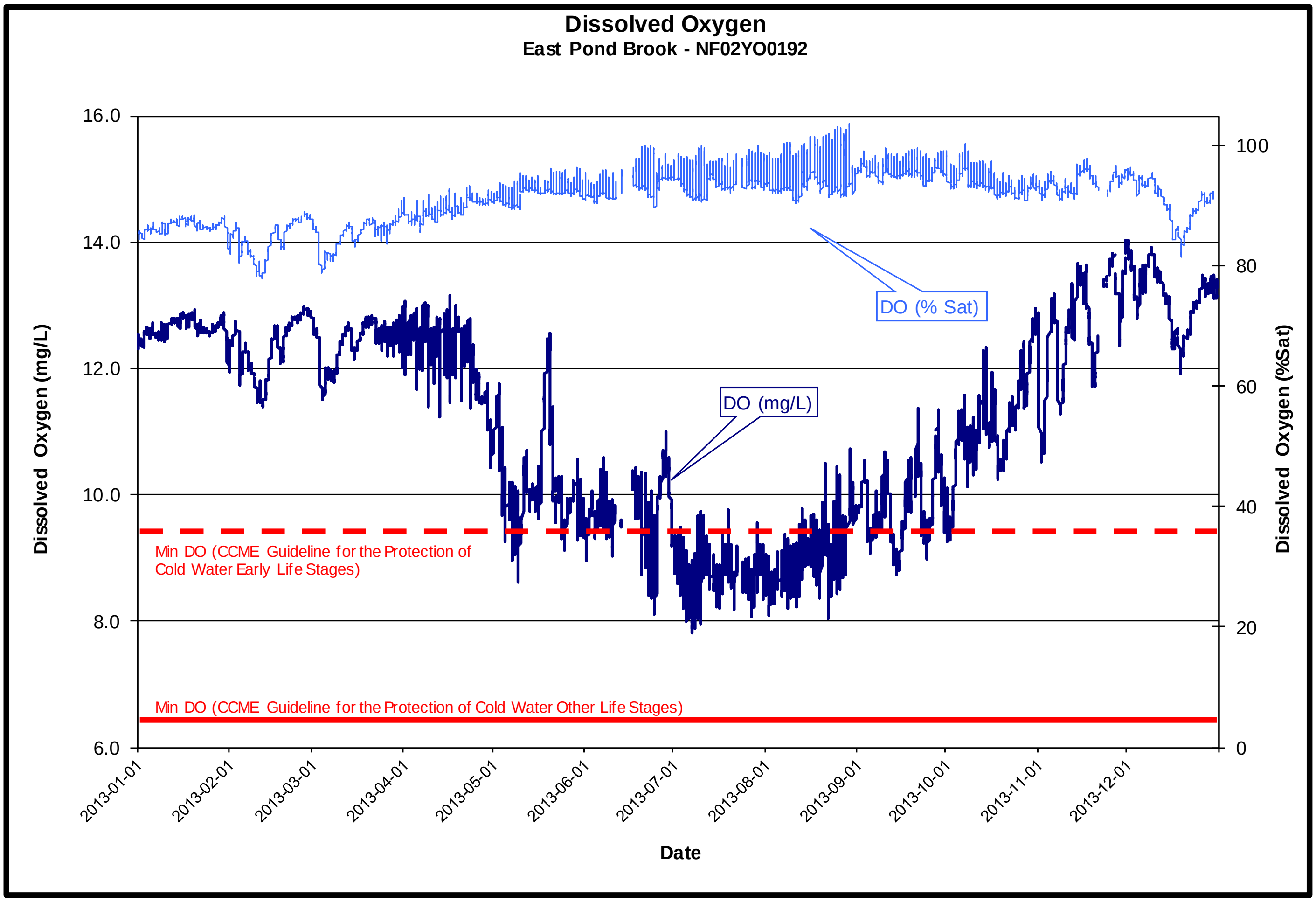

Figure 13

Turbidity (**Figure 14**) ranged from a minimum of 0.0 NTU to a maximum of 152.30 NTU. Generally, turbidity values in this stream are at or close to zero. The cause of the single turbidity peak on June 25, 2013 is unknown.

On occasion on-line transmitted turbidity values were reported to be 3000 NTU. This number represents a system error in data transmission. Accordingly, these values have been removed and when appropriate, internally (**DataSonde®**) logged turbidity values were substituted. There were also a couple of occasions when leafy debris was noted to have been caught in the sensor, resulting in false-positive data. Data for these periods have been removed form the data set.

Throughout the year, high turbidity was not visible in the stream nor documented in any water sample results.

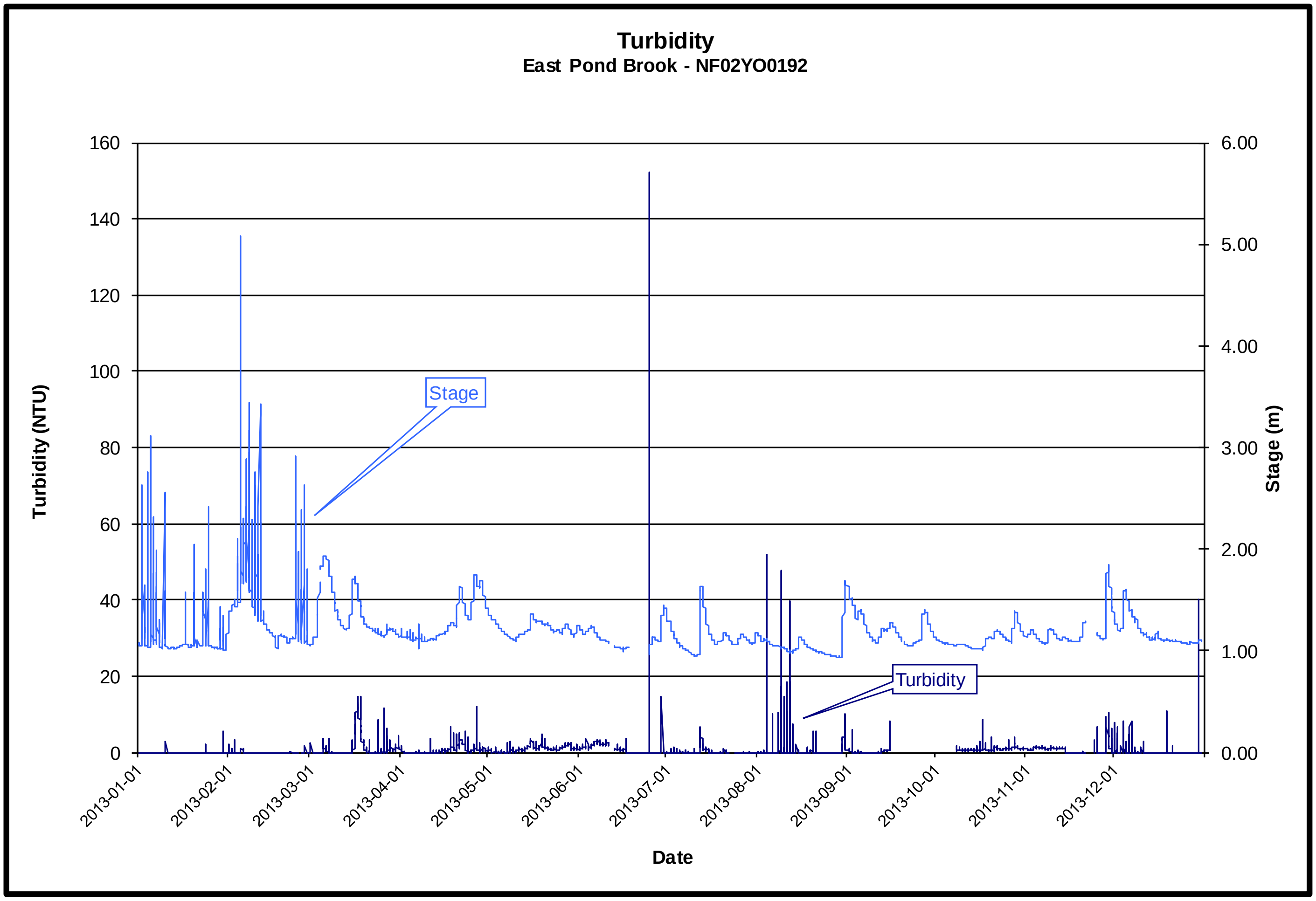

Figure 14

The stage or water level (**Figure 15**) was recorded to be between 0.93 m and 5.08 m. The flow or discharge ranged from a minimum of 0.20 m^3/s to a maximum of 13.50 m^3/s. At this location, stage is referenced to an arbitrary bench mark. Peaks in stage during the winter months are attributed to the backwater effect from ice formation.

For the remainder of the year, however, stage and flow were within normal ranges, with the higher levels following snow melt and rainfall events.

The flow or discharge is calculated based upon a stage-discharge curve which is developed over time. There are periods during the year, when extreme high and low flows could not be calculated as they were outside the range of the existing curve.

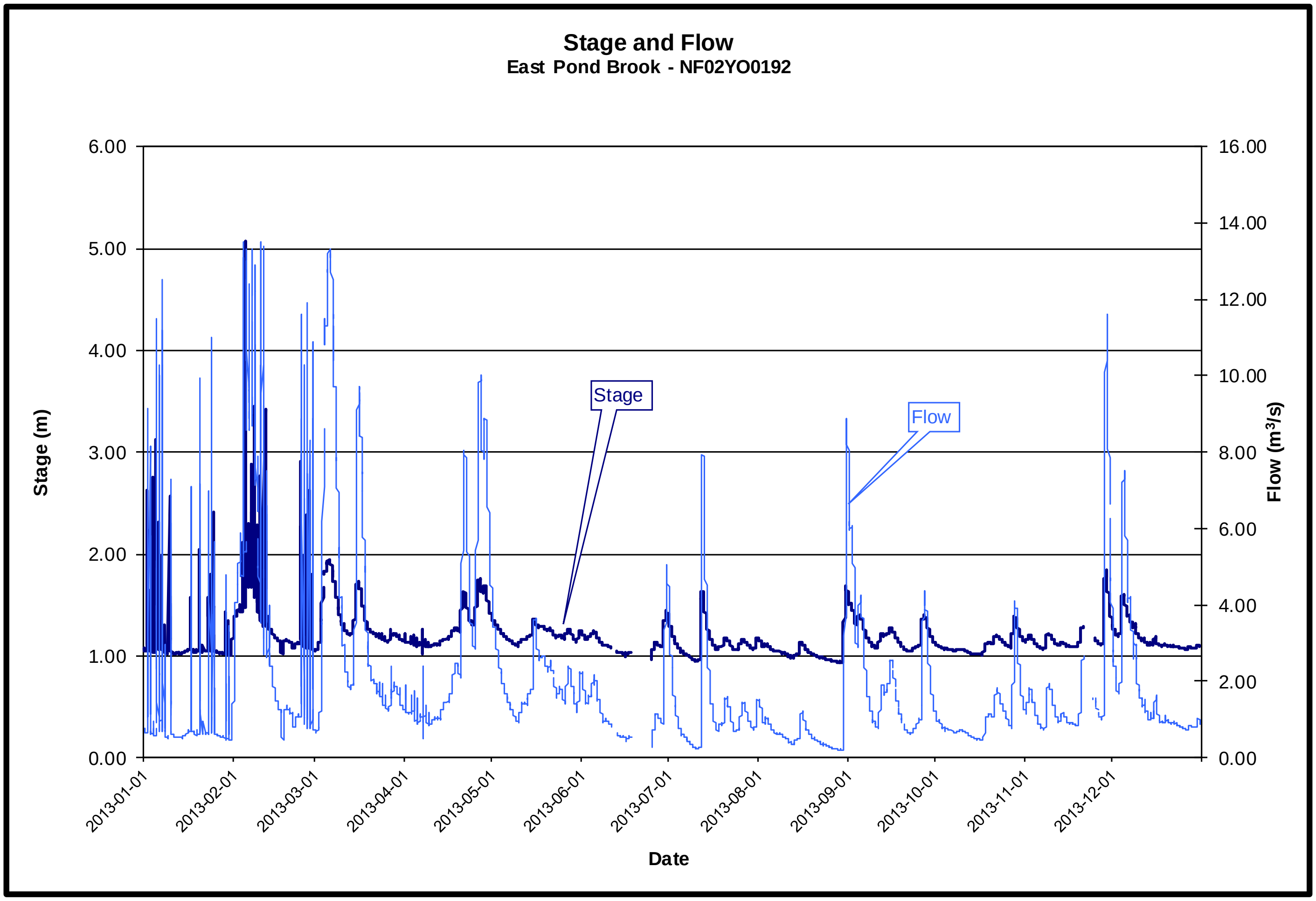

Figure 15

Section 4.3 Monitoring Well After Tailings Dam Station (NF02YO0193)

Monitoring Well After Tailings Dam Station is located near the toe of Tailings Dam A. This station is located such that any ground water impacts from the Tailing Management Area via seepage through Dam A may be measured.

Two artifacts in the data are evident. The large ellipse highlights a higher temperature from May 14, 2013 through August 13, 2013 of approximately 0.25 ^{o}C. Again from November 13, 2013 (small ellipse) through the end of the year the temperature is recorded as approximately 0.25 ^{o}C higher than the other deployment periods. It has been determined that the fixed factory temperature calibration on the **Quanta G®** probe (s/n 00653) used during these two deployment periods is approximately 0.25 ^{o}C higher than the fixed factory temperature calibration on the **Quanta G®** probe (s/n 00035) used for the other deployment periods. This variation is however, within the manufacturer's accuracy specification for these instruments (±0.20 ^{o}C x 2).

The small ellipse at the beginning of the last deployment period also highlights a rapid decrease in temperature over the first hour of deployment. This is in part, due to the disruption in the water column in the well during the replacement of the instrument.

Water temperature (**Figure 16**) ranged from a minimum of 5.20 ^{o}C to a maximum of 6.35 ^{o}C. Lower temperatures were recorded in the summer months, while the higher temperatures were recorded in winter months. While the temperature profile is very similar to previous years, it has been noted that despite the seasonal variation, the mean temperature in this well appears to be increasing slightly since 2008. This change and its potential implications will be subject to further analysis in collaboration with Pollution Prevention Division of ENVC.

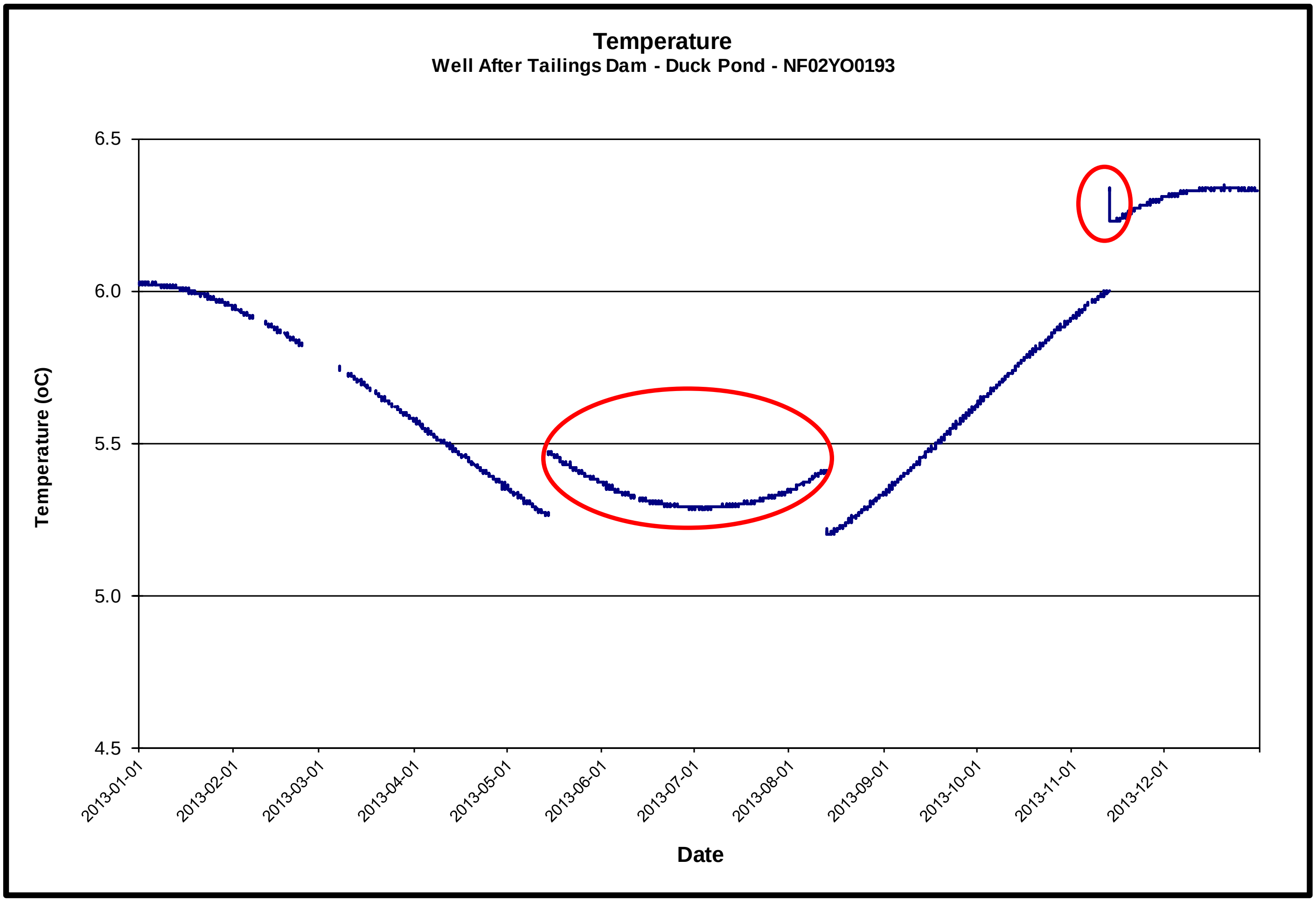
Temperature
Well After Tailings Dam - Duck Pond - NF02YO0193
6.5
6.0
5.5
5.0
4.5
Temperature (oC)
2013-01-01
2013-02-01
2013-03-01
2013-04-01
2013-05-01
2013-06-01
2013-07-01
2013-08-01
2013-09-01
2013-10-01
2013-11-01
2013-12-01
Date

Figure 16

The pH measurements for this well are depicted in **Figure 17**. Values ranged from a minimum of 7.60 to maximum of 8.85.

At the beginning of each deployment period, there is a significant increase in pH which essentially 'levels off' for the remainder of that period. This response in pH is typical of previous deployments. Prior to an investigation of this feature in 2011, it was believed that this is a function of the well being purged. However, it has been determined that the rapid change in pH at the beginning of each deployment is simply a function of the water in the small diameter well being displaced, as the instrument is deployed in the well(4), thus temporarily disturbing the relatively 'static' nature of the well. Accordingly, it has been decided to minimize the number of deployments of the instrument in this well, and maximize the length of the deployment periods (approximately 6 months). Furthermore, it has also been demonstrated that purging the well has no long term (i.e. less than 60 minutes) effect on the water quality, including pH, in the well(4). The effects of purging the well at the beginning of deployment, and during deployment continue to be monitored, as it is necessary to sample this well from time to time while the instrument is deployed. A draft Standardized Purging and Sampling Protocol (5) has been developed for this particular well.

pH levels appear to be typical based upon historical data.

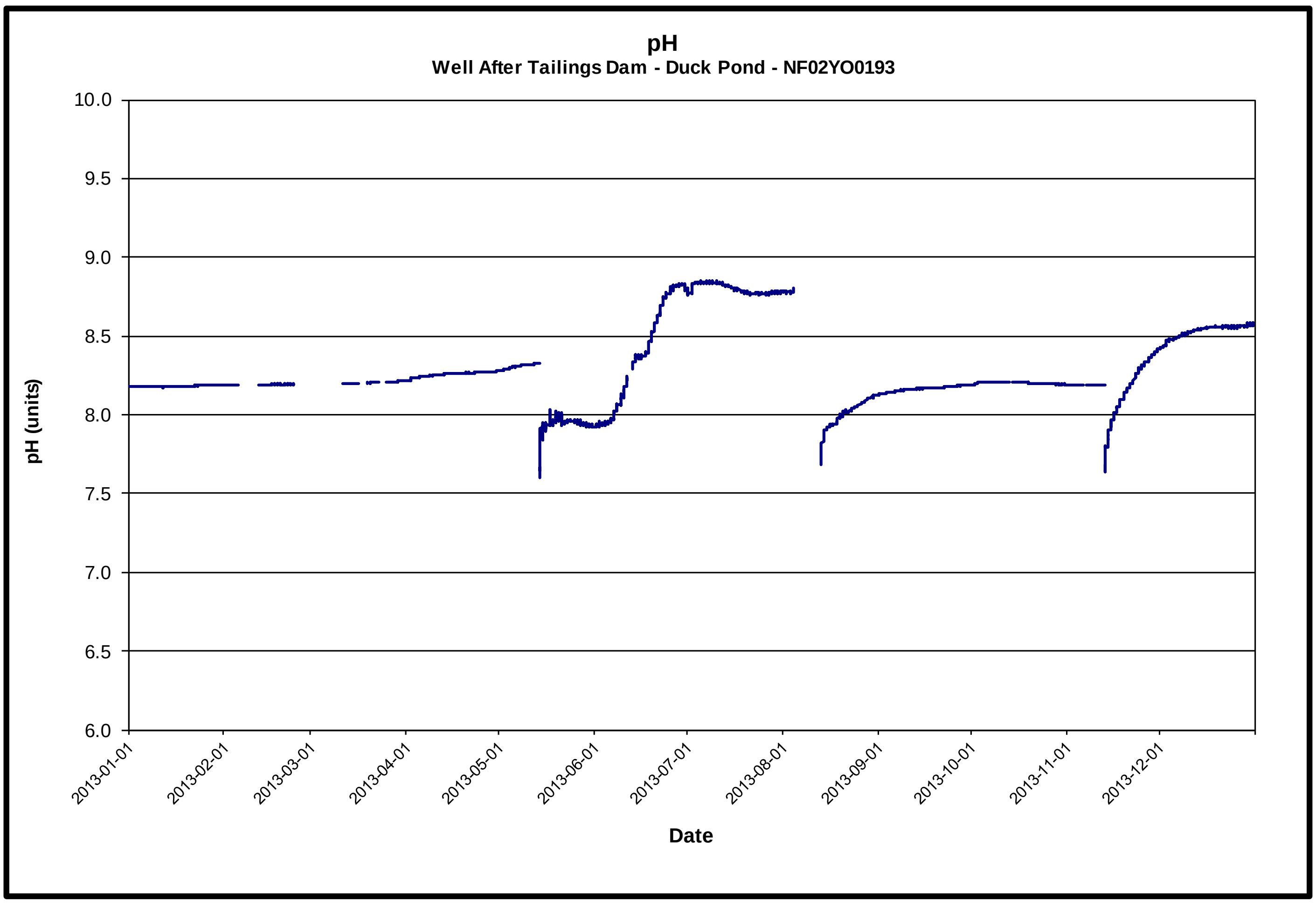

Figure 17

Specific conductivity in this well is higher than surrounding surface waters due to the highly mineralized nature of the material through which it is drilled. The well is also located such that it can be used to measures changes in ground water resultant from seepage from Tailing Dam A.

Specific conductance in this well (**Figure 18**) ranged from a minimum of 0.706 mS/cm to a maximum of 0.817 mS/cm. The range is higher than measured in previous years.

The continued rise in specific conductivity over this year follows a trend that has been apparent in previous years. This change and its potential implications will be subject to further analysis in collaboration with Pollution Prevention Division of ENVC.

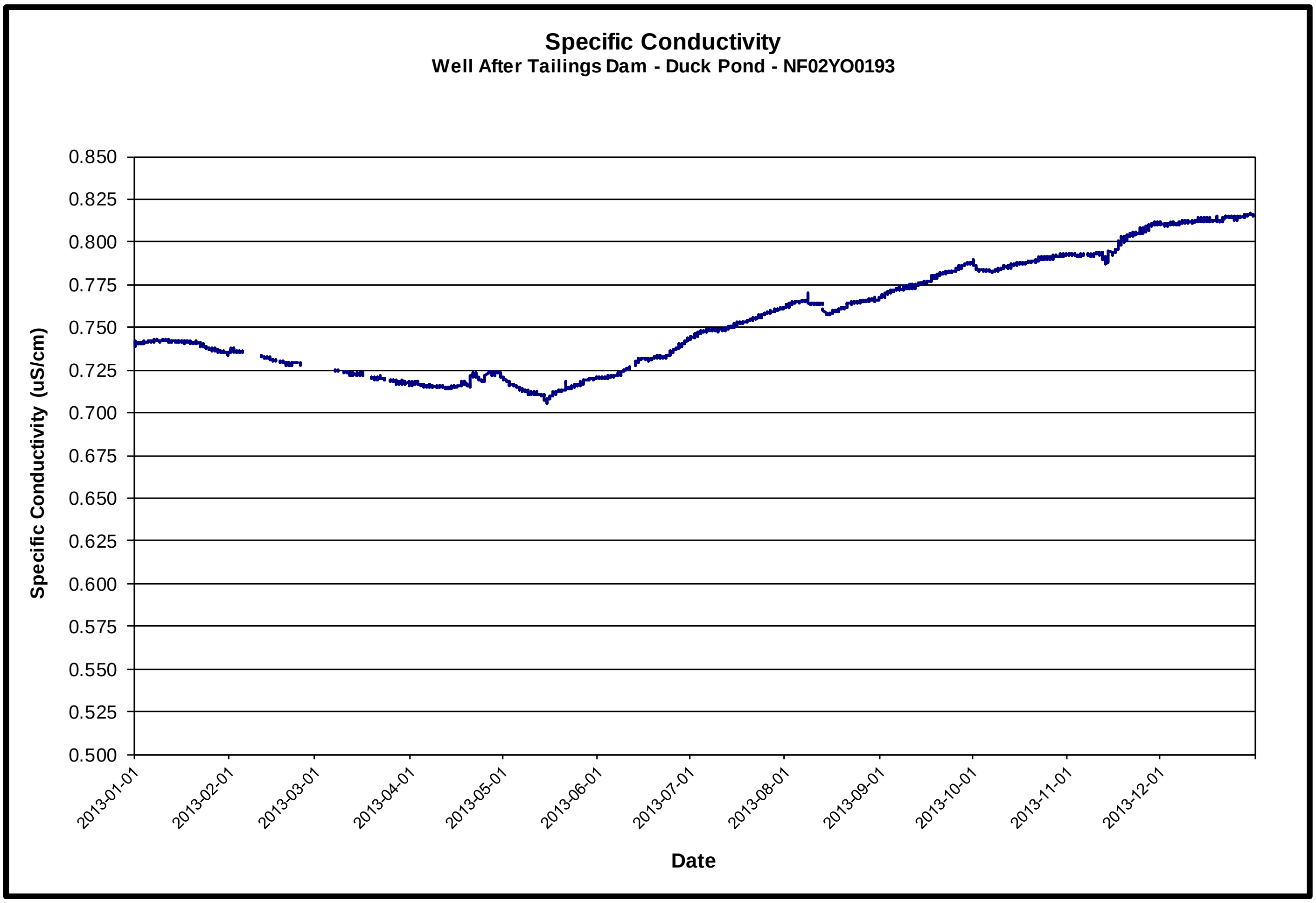

Figure 18

This shallow well is located in a glacial till, less than 100 meters from the toe of Tailings Dam A and less than 50 meters from a small stream (Trout Brook). The water elevation (**Figure 19**) in this well ranged between a minimum of 270.66 m and maximum of 271.06 m.

There is excellent agreement between recorded and measured water elevations throughout the year, with the maximum differential being measured to be 0.017 m. This indicates that the water elevation being logged is extremely accurate.

An analysis of the long term water elevation of this well [6], shows a significant correlation (Pearson Correlation Coefficient = 0.84) with the water level in the Tailings Management Area (TMA). Thus as water levels in the TMA rise and fall, so does the water elevation in this well, suggesting as we would expect, a hydraulic connection between the two. During particular seasons, a weak correlation (Pearson Correlation Coefficient = 0.19) exists between the long term water elevation in this well and the water level East Pond Brook, suggesting that, over shorter periods, changes in the well's water elevation may be influenced to some degree by the nearby stream.

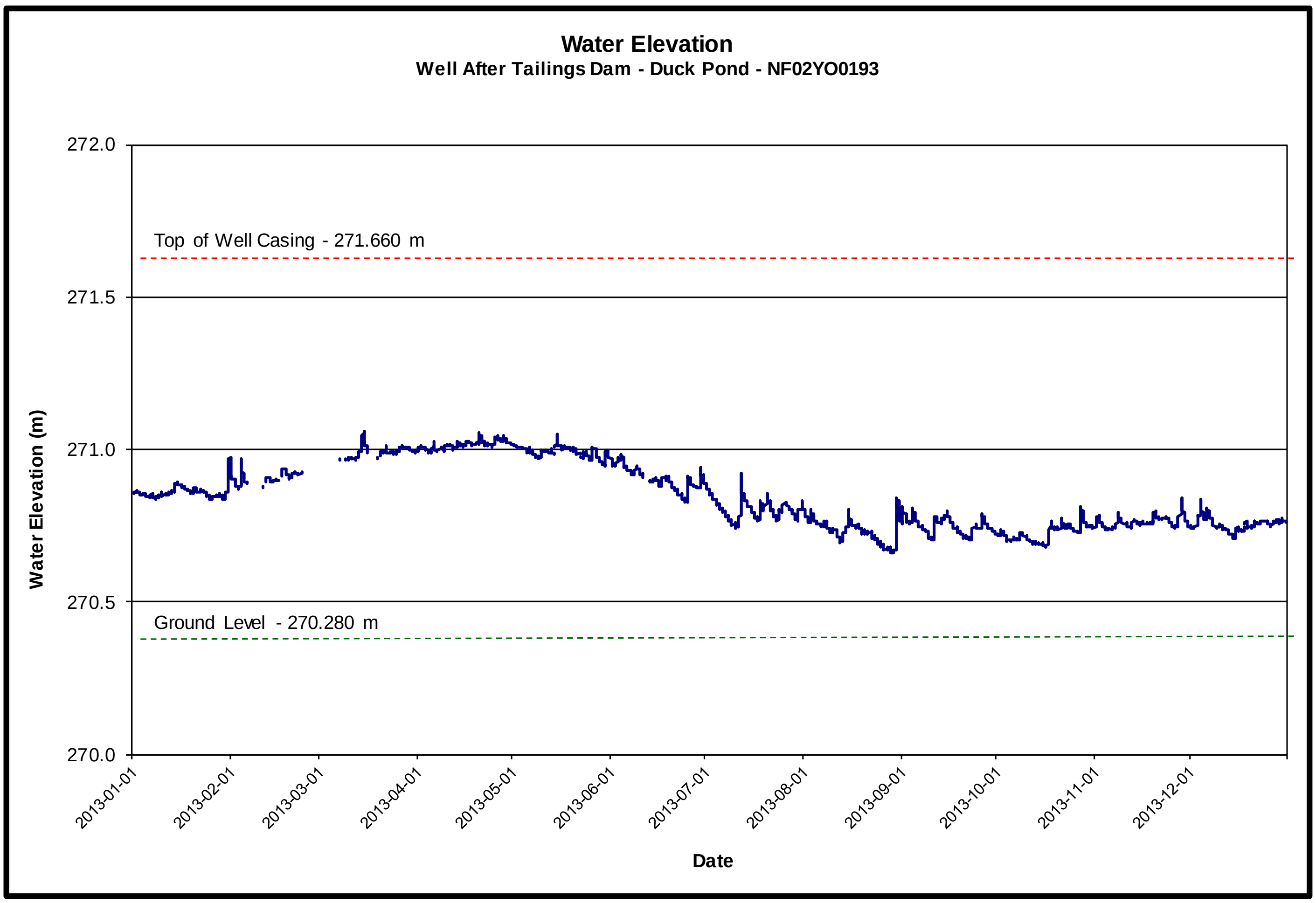

Figure 19

Section 5.0 Quality Assurance / Quality Control (QA/QC) Measures

- Quality Assurance/Quality Control (QA/QC) measures are a very important aspect of the Real-Time Water Quality Monitoring Network at Teck Duck Pond Operations. These measures are put in place to ensure that the instruments are reading data accurately, and the numbers that are reported are representative of the actual environmental conditions.

- As part of the QA/QC protocol, an assessment of the reliability of data recorded by an instrument is made at the beginning and end of the deployment period. The ranking system is based upon methodology developed by the U.S. Geological Survey [7], and uses the formulae in **Table 3** to qualify or rank the accuracy of the instruments.

	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

Table 3

- For the Surface Water Stations, upon deployment and removal, a QA/QC **MiniSonde®** is temporarily deployed along side the Field **DataSonde®**. Values for each recorded parameter are compared between the two instruments. Based upon the difference between the parameters recorded by the Field **DataSonde®** and QA/QC **MiniSonde®** a qualitative statement (Ranking) is usually made on the data.

- The ranking at the beginning of the deployment period is shown in **Table 4** for Tributary to Gill's Pond Brook and **Table 5** for East Pond Brook.

- Because the deployment set-up for Well After Tailings Dam (MW1) is different, comparison with another instrument is not possible. In this case, a grab sample is usually collected at the beginning and end of the deployment period, and the ranking is calculated for pH and Specific Conductance based upon live data and laboratory data. However, during this reporting period, there are a few examples when a grab sample could not be collected and thus no comparisons or rankings are possible. See **Table 6**.

- With the exception of water quantity data (Stage), all data used in the preparation of the graphs above and subsequent discussion below adhere to this stringent Quality Assurance and Quality Control (QA/QC) protocol. Water Survey of Canada is responsible for QA/QC of water quantity data. Corrected data can be obtained upon request.

Tributary to Gills Pond Brook Station (NF02YO0190)				
Parameter	**Installation Date (yyyy-mm-dd)**	**Ranking**	**Removal Date (yyyy-mm-dd)**	**Ranking**
Temp (°C)	2012-11-14	Good	2013-05-10	Good
pH (units)		Good		Excellent
Sp. Conductivity (uS/cm)		Excellent		Excellent
Dissolved Oxygen (mg/L)		Excellent		Excellent
Turbidity (NTU)		Excellent		Excellent
Temp (°C)	2013-05-10	Excellent	2013-06-11	Excellent
pH (units)		Good		Excellent
Sp. Conductivity (uS/cm)		Excellent		Excellent
Dissolved Oxygen (mg/L)		Excellent		Good
Turbidity (NTU)		Good		Excellent
Temp (°C)	2013-06-13	Excellent	2013-07-22	Excellent
pH (units)		Excellent		Excellent
Sp. Conductivity (uS/cm)		Excellent		Excellent
Dissolved Oxygen (mg/L)		Excellent		Excellent
Turbidity (NTU)		Excellent		Good
Temp (°C)	2013-07-24	Excellent	2013-08-13	Excellent
pH (units)		Excellent		Good
Sp. Conductivity (uS/cm)		Excellent		Excellent
Dissolved Oxygen (mg/L)		n/a		Excellent
Turbidity (NTU)		Excellent		Good
Temp (°C)	2013-08-15	Good	2013-10-08	Good
pH (units)		Excellent		Excellent
Sp. Conductivity (uS/cm)		Excellent		Excellent
Dissolved Oxygen (mg/L)		Excellent		Excellent
Turbidity (NTU)		Excellent		Excellent
Temp (°C)	2013-10-08	Excellent	2013-11-14	Excellent
pH (units)		Good		Good
Sp. Conductivity (uS/cm)		Excellent		Good
Dissolved Oxygen (mg/L)		Excellent		Good
Turbidity (NTU)		Excellent		Good
Temp (°C)	2013-11-14	Excellent	Ongoing	n/a
pH (units)		Good		n/a
Sp. Conductivity (uS/cm)		Good		n/a
Dissolved Oxygen (mg/L)		Good		n/a
Turbidity (NTU)		Good		n/a

Table 4

East Pond Brook Station (NF02YO0192)				
Parameter	**Installation Date (yyyy-mm-dd)**	**Ranking**	**Removal Date (yyyy-mm-dd)**	**Ranking**
Temp (°C)	2012-11-14	Excellent	2013-05-10	Excellent
pH (units)		Excellent		Good
Sp. Conductivity (uS/cm)		Excellent		Excellent
Dissolved Oxygen (mg/L)		Good		Good
Turbidity (NTU)		Excellent		Excellent
Temp (°C)	2013-05-10	Excellent	2013-06-11	Excellent
pH (units)		Excellent		Excellent
Sp. Conductivity (uS/cm)		Excellent		Excellent
Dissolved Oxygen (mg/L)		Excellent		Excellent
Turbidity (NTU)		Excellent		Good
Temp (°C)	2013-06-13	Excellent	2013-06-17	Excellent
pH (units)		Excellent		Good
Sp. Conductivity (uS/cm)		Good		Excellent
Dissolved Oxygen (mg/L)		Excellent		Excellent
Turbidity (NTU)		Excellent		Excellent
Temp (°C)	2013-06-17	Good	2013-07-22	Excellent
pH (units)		Good		Excellent
Sp. Conductivity (uS/cm)		Good		Excellent
Dissolved Oxygen (mg/L)		Excellent		Excellent
Turbidity (NTU)		Excellent		Excellent
Temp (°C)	2013-07-24	Good	2013-08-13	Good
pH (units)		Excellent		Fair
Sp. Conductivity (uS/cm)		Excellent		Good
Dissolved Oxygen (mg/L)		Excellent		Excellent
Turbidity (NTU)		Excellent		Excellent
Temp (°C)	2013-08-13	Excellent	2013-10-08	Excellent
pH (units)		Good		n/a
Sp. Conductivity (uS/cm)		Excellent		Excellent
Dissolved Oxygen (mg/L)		Excellent		Excellent
Turbidity (NTU)		Excellent		n/a
Temp (°C)	2013-10-08	Excellent	2013-11-14	Excellent
pH (units)		Excellent		Good
Sp. Conductivity (uS/cm)		Excellent		Excellent
Dissolved Oxygen (mg/L)		Excellent		Good
Turbidity (NTU)		Excellent		Excellent
Temp (°C)	2013-11-14	Excellent	Ongoing	n/a
pH (units)		Excellent		n/a
Sp. Conductivity (uS/cm)		Excellent		n/a
Dissolved Oxygen (mg/L)		Excellent		n/a
Turbidity (NTU)		Excellent		n/a

Table 5

Well After Tailings Dam (MW1) Station (NF02YO0193)				
Parameter	**Installation Date (yyyy-mm-dd)**	**Ranking**	**Removal Date (yyyy-mm-dd)**	**Ranking**
pH (units)	2012-10-03	Fair	2013-05-14	Excellent
Sp. Conductivity (uS/cm)		Excellent		Good
pH (units)	2013-05-14	Fair	2013-08-13	n/a
Sp. Conductivity (uS/cm)		Excellent		Excellent
pH (units)	2013-08-13	Fair	2013-11-13	Good
Sp. Conductivity (uS/cm)		Excellent		Excellent
pH (units)	2013-11-13	Poor	Ongoing	n/a
Sp. Conductivity (uS/cm)		Excellent		n/a

Table 6

For Tributary to Gills Pond Brook Station (NF02YO0190) the monitoring instruments performed extremely well. The *in situ* **DataSonde®** ranked 'Excellent' or 'Good' compared to a portable **MiniSonde®** results in 64 of 64 measurements.

For East Pond Brook Station (NF02YO0192) the monitoring instruments performed extremely well. The *in situ* **DataSonde®** ranked 'Excellent' or 'Good' compared to a portable **MiniSonde®** results in 72 of 73 measurements.

For East Pond Brook Station (NF02YO0192) there was one ranking of 'Fair' upon removal. It was noted that there was considerable fouling on the sensor.

For Well After Tailings Dam (MW1) Station (NF02YO0193), the monitoring instruments performed very well. The *in situ* **Quanta G®** ranked 'Excellent' or 'Good' compared to laboratory results in 9 of 13 measurements. A 'Fair' or 'Poor' ranking for pH is related to the depressed pH values at the beginning of each deployment period; for which there is no known remedy.

This confirms that the measurements recorded by each of these instruments and transmitted to our web site in real-time are very accurate. However, it is understood drift may increase over time, particularly in the warmer months when bio-fouling is more likely to occur. Accordingly, when conditions and accessibility permit, the instruments will continue to be maintained and calibrated at the intervals recommended by the manufacturer.

Maintenance and calibration are always undertaken by trained staff in accordance with protocols prescribed by the manufacturer. All replaceable parts, reagents and calibration solutions used meet the specifications of the manufacturer. All work is undertaken in a controlled laboratory environment.

In order to ensure long term accuracy for the instruments, they are returned to the vendor and/or our in-house factory-trained staff periodically (approximately every two years, or when problems or issues are observed) for Performance and Evaluation Testing (PET). At this time, sensors are replaced if required, and the instruments are maintained and calibrated to factory specifications.

Section 6.0 Conclusions

The Real-Time Water Quality Monitoring Network at Teck Duck Pond Operations has again this year proven to be quite useful. The data derived from this network has been used by Teck management and staff to monitor their performance. Government has reviewed the data daily to ensure that equipment is functioning properly, and that discharge from the site remains within the regulated discharge criteria. The public, who have access to this data through the web, have undoubtedly been diligent in monitoring the water quality data as well.

In the two surface water stations (Tributary to Gills Pond Brook and East Pond Brook), while changes to water quality have been observed throughout the year, no serious incidents has been identified which have raised any cause for concern. No mitigative measures have needed to be employed to address any problems or issues resultant from this monitoring.

The incidents of false-positive turbidity measurements at Tributary to Gills Pond Brook due to air entrainment have been minimized significantly. However, given the occasional elevation in turbidity at Tributary to Gill's Pond Brook periodically in 2013, diligence must be exercised to ensure that continued elevation in turbidity does not become, or become indicative of, a serious problem.

In Monitoring Well After Tailings Dam (MW1), some long term changes in temperature and specific conductance have been documented. The situation will continue to be monitored and reviewed from time to time in collaboration with Pollution Prevention Division of ENVC.

Continued operation of the Real-Time Water Quality Monitoring Network at Teck Duck Pond Operations is planned for the life of the operation, and throughout the planned closure, rehabilitative and subsequent monitoring phases.

Section 7.0 Path Forward

In order for this program to remain successful, it is essential to continually evaluate, improve and move forward. The following is a list of initiatives and activities to be carried out in the upcoming year:

1) The **DataSonde®** instruments owned by Teck Duck Pond Operations will be monitored closely to ensure their accuracy and reliability. Should any issues be identified, they will be returned to the vendor and/or Department of Environment and Conservation for factory servicing and calibration.

2) Currently, four **DataSonde®** instruments owned by Teck Duck Pond Operations are available for service in the surface water - based stations. Two older units, nearing their projected lifecycle of 5 to 10 years continue to be updated with some new sensor tips and software. Two new instruments have been put into regular service on a rotating basis.

3) Currently two **Quanta G®** instruments (one owned by Teck Duck Pond Operations and one owned by Department of Environment and Conservation) are deployed in Monitoring Well After Dam A on a rotating basis.

4) The false-positive turbidity measurements at Tributary to Gills Pond Brook Station (NF02YO0190) have been investigated for several years. Moving the instrument a little downstream further away from the plunge pool has minimized false-positive readings considerably. Given the limitations of the site, there is not much else that can be done. However, we will continue to monitor the situation, and test and employ any further mitigative measures which may be beneficial.

5) The Standardized Well Purging and Sampling Protocol for Monitoring Well After Tailings Dam A appears to be working well. Its use will continue by ENVC and Teck staff, with feedback and updates as necessary.

6) The pathways leading to the Real-Time Water Quality Monitoring stations were upgraded significantly in 2011. Some minor maintenance work may be needed in subsequent years.

7) In 2012 it was decided that no additional real-time water quality monitoring stations were needed in anticipation of the planned development of the Boundary Deposit. However, as the boundary development proceeds, and the entire operation moves toward end-of mine, the need for any additional stations will continue to be assessed. New stations can be considered if the need arises.

8) Work will continue to optimize sensor performance, data transmission, and information transfer. Any emerging issues will be addressed in a timely manner.

9) Work will continue to enhance and automate the data handling and reporting processes. ENVC is working on extrapolation of other water quality parameters using regression analysis.

10) An evaluation of the most recent Closure Plan for the site has been completed. Real time water quality monitoring is planned to continue throughout the completion of the life-of-mine, and the planned closure, rehabilitative and subsequent monitoring phases.

Section 8.0 References

1. *Canadian Water Quality Guidelines for the Protection of Aquatic Life,* Canadian Council of Environment Ministers, 1999, Update 7.1, December 2007.

2. *Real Time Water Quality Report, Duck Pond Operations (Teck Cominco Limited), Deployment Period 2008-10-16 to 2008-11-12*, Department of Environment and Conservation, 2009. http://www.env.gov.nl.ca/env/waterres/rti/rtwq/csdr/index.html#11

3. *Real Time Water Quality Report, Duck Pond Operations (Teck Duck Pond Operations), Deployment Period 2011-08-10 to 2011-09-16*, Department of Environment and Conservation, 2011. http://www.env.gov.nl.ca/env/waterres/rti/rtwq/csdr/index.html#11

4. *Accuracy and Precision in Real-Time Water Quality Monitoring* - *How good is my data?* , Proceedings of Real Time Water Quality Workshop, Department of Environment and Conservation, June 7, 2011. http://www.env.gov.nl.ca/env/waterres/rti/rtwq/workshops.html#2011

5. *Draft Standardized Purging and Sampling Protocol for MW1@ Teck Duck Pond Operations*, Department of Environment and Conservation, June 15, 2011.

6. Rahman, Shibly, Personal Communication and Internal E-mails, September 6, 2012.

7. *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,* U.S Geological Survey, 2006.