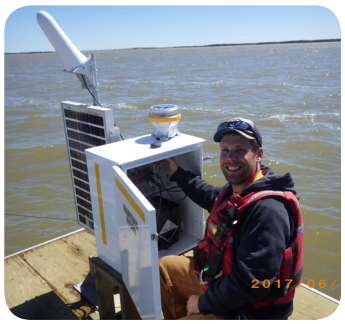
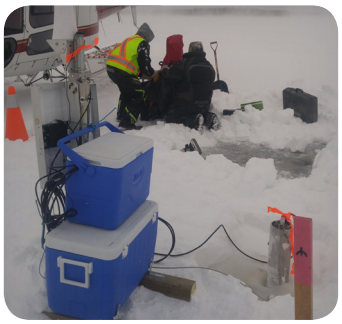
Keeyask Generation Project

Physical Environment Monitoring Plan

Physical Environment Monitoring Report

PEMP-2018-01





KEEYASK

Manitoba Sustainable Development Client File 5550.00
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2017 -2018

KEEYASK GENERATION PROJECT

PHYSICAL ENVIRONMENT MONITORING PLAN

REPORT #PEMP-2018-01

2017-2018 PHYSICAL ENVIRONMENT MONITORING REPORT: YEAR 4 CONSTRUCTION

Prepared by

Manitoba Hydro

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SUMMARY

Background

The Keeyask Generation Project (the Project) involves the construction and operation of the Keeyask Generating Station (GS) at Gull Rapids on the Nelson River. In order to obtain a Manitoba Environment Act licence to construct the GS and before construction began in July 2014, the Keeyask Hydropower Limited Partnership (KHLP) prepared a plan to monitor the effects of the Project on the physical environment. Monitoring results will help the KHLP, government regulators, members of local First Nation communities, and the general public understand how GS construction and operation affects the physical environment. Monitoring will help determine if the actual effects are consistent with predicted effects reported in the Project's environmental impact statement.

The Keeyask Physical Environment Monitoring Plan (PEMP) discusses planned monitoring during construction of the Project, which includes monitoring of water and ice regimes, shoreline erosion, sedimentation, debris and emission of greenhouse gases from the future reservoir. This report describes the physical environment monitoring activities and results for the 2017/18 monitoring period.

Water and Ice Regime

The water and ice monitoring parameters include water levels, water depth, water velocity, and ice cover; although velocity and depth monitoring is planned for after the reservoir is filled. After receiving approval for the Project in the summer of 2014, six automated, continuous water level gauges were installed on the Nelson River between Clark Lake and Gull Rapids to monitor water levels during the construction of the Project.

The river discharge between April 2017 and March 2018 was above the historical average (post Lake Winnipeg Regulation / Churchill River Diversion, September 1977 to March 2018) most of the time, ranging from a low of approximately 3,200 m^3/s (113,010 cfs) in October 2017 to a peak of almost 6,600 m^3/s (233,080 cfs) in May 2017. Flows were very high in the first half of the year, and were at record levels from early March to early June. Flows reduced through the summer and have been closer to average since about mid-September. Although the Project does not affect the amount of water flowing in the Nelson River, knowing the flow helps to understand whether or not water level changes upstream of the Project are due to changes in flow or because of Project construction.

Construction activities that have influenced the water conditions in Gull Lake and at Gull Rapids include river diversion measures implemented to divert water from construction areas. Construction of the North Channel Rock Groin near the head of Gull Rapids diverted most of the flow to the south channel of Gull Rapids and caused an increase in upstream water levels. The observed water level increases due to the North Channel Rock Groin were consistent with what was predicted.

Ice Extends into Trees

Ice monitoring is done using satellite imagery and photographs taken along the length of the study area during monthly field trips. The 2017/18 winter saw the earliest ice cover formation on Gull Lake since construction started, about 2 weeks earlier than the previous two winters with the ice boom in place. The leading ice front reached about 5 to 6 kms upstream of Birthday Rapids by the end of January, remaining there until mid-April, similar to the previous winter.

Shoreline Erosion and Reservoir Expansion

The largest changes in shoreline erosion rates were predicted to occur within the Gull Lake area of the reservoir during the initial impoundment and in the first year of operation. The rate of reservoir expansion due to erosion is predicted to decrease over time after the reservoir is impounded.

A review of aerial and satellite imagery near the entrance to Stephens Lake suggests that erosion rates have reduced in this area. This was first detected by lower winter turbidity results in Stephens Lake than had been seen in the past.

Sedimentation

Sedimentation monitoring includes studying how sediment is carried (called sediment transport) in the water and where it is deposited. It involves collecting water samples to measure the amount of sediment suspended in the water (done in a laboratory), using electronic devices that continuously measure turbidity (i.e., the murkiness of the water) over time and by taking readings with a hand-held meter when visiting monitoring sites. Sediment traps are used to collect sediment from the water over time to monitor the potential for sediment to settle out

(deposit) near areas of potentially important sturgeon habitat. Turbidity monitoring is done using a turbidity probe that has an optical sensor that is placed into the water and measures its murkiness.

Between Clark Lake and the Kettle GS, continuous turbidity probes were installed at five locations in summer and three locations in winter. In addition, water samples were obtained on roughly a monthly basis at 10 different locations, with up to 25 separate positions being sampled: i.e., some sites had more than one sampling position across the width of the river. More than 530 water samples were obtained and more than 1300 turbidity measurements were collected. As observed in previous years, results from summer monitoring in 2017/18 do not suggest any apparent effects of the Project on sediment transport.

In winter, it was observed that there was a decrease in turbidity and sediment transport downstream of the Project due to reduced erosion from ice processes. The EIS included the prediction that the Project would “significantly reduce erosion potential” downstream of the Project after construction, which would result in lower turbidity downstream. Changes were not anticipated during the construction period as some increases in water level due to ice were still expected to cause erosion at the entrance to Stephens Lake. The reduction was also observed downstream of the Stephens Lake in the Limestone GS forebay.

Winter Sedimentation Monitoring

A sediment trap generally consists of five open-ended plastic tubes standing vertically in a metal frame that sits on the lakebed. Sediment settling out of the water enters an opening in the tube

and accumulates in a sample jar at the bottom of the tube until the trap is recovered and the sediment samples are sent to a laboratory for grain size analyses. In 2017, a sediment trap was placed at the entrance to Stephens Lake. Originally, a sediment trap was to also be placed at the upstream end of Gull Lake. However, a sediment trap was not placed at this site in 2016 and 2017 because of adverse conditions that previously resulted in losing monitoring equipment at this location.

Five tube sediment trap used in PEMP deposition monitoring

Monitoring found sediment collected at a greater rate in the trap at the Stephens Lake site for the 2016/2017 winter monitoring period compared with the previous two winters. Very high flows were experienced in the spring which likely explains higher accumulation rates seen in 2016/17. Higher flows would increase water velocities and increase the erosion potential and the river's ability to transport sediment.

Continuous turbidity monitoring equipment – electronics cabinet and solar panel on a catamaran below which a turbidity sensor is suspended in the water

Debris

Manitoba Hydro operates waterway management programs on various water bodies to monitor and remove debris. A boat patrol (2 person crew in a boat) operated in the Project area from Clark Lake to Gull Rapids to identify debris such as floating logs and branches that need to be removed if they pose a safety hazard to navigation. Patrols also marked reefs and engaged with waterway users.

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1.0 INTRODUCTION

Construction of the Keeyask Generation Project (the Project), a 695 megawatt hydroelectric generating station (GS) and associated facilities, began in July 2014. The Project is located at Gull Rapids on the lower Nelson River in northern Manitoba where Gull Lake flows into Stephens Lake, 35 km upstream of the existing Kettle GS.

The *Keeyask Generation Project: Response to EIS Guidelines* (EIS), completed in June 2012, provides a summary of predicted effects and planned mitigation for the Project (KHLP 2012a). Technical supporting information for the physical environment and a summary of proposed monitoring and follow-up programs are provided in the *Keeyask Generation Project Environmental Impact Statement: Physical Environment Supporting Volume* (PESV; KHLP 2012b). As part of the licensing process for the Project, the Keeyask Physical Environment Monitoring Plan (PEMP) was developed detailing the monitoring activities for various components of the physical environment. The PEMP was finalized in 2015 following regulatory review and approval (KHLP 2015a).

This report generally describes the physical environment monitoring performed from April 2017 to March 2018, the fourth year of construction monitoring. When information is not available the information will be reported in the next monitoring year.

The physical environment is defined as the physical and chemical make-up of an ecosystem and describes the area where things live and includes the air, water and land within the ecosystem. Monitoring and follow-up activities focus on effects to key components of the physical environment to:

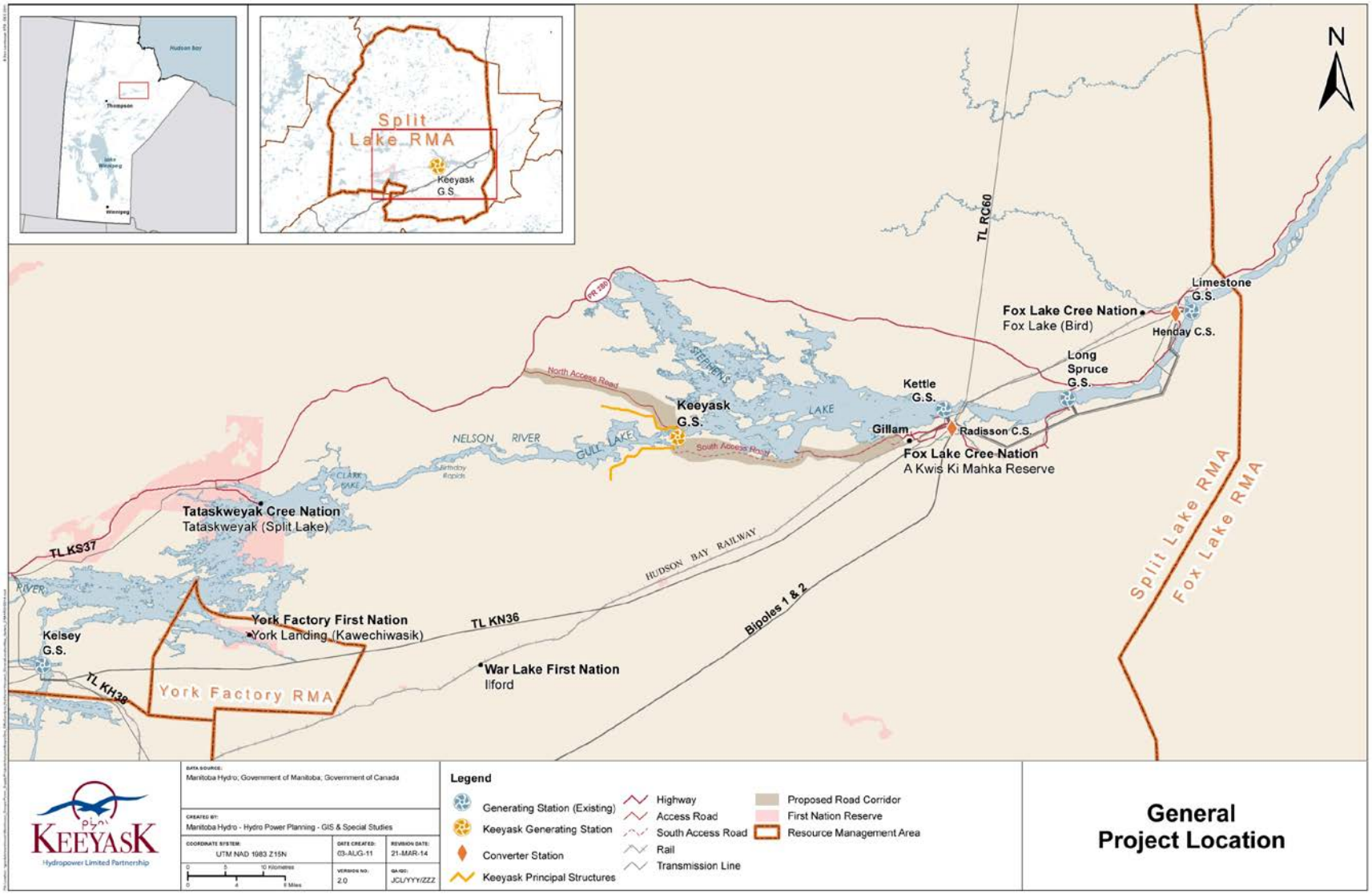
- Determine if EIS predictions of Project effects on the physical environment are correct and to identify unanticipated effects.
- Support other monitoring programs (e.g., aquatic and terrestrial) that will monitor Project effects and determine the effectiveness of mitigation and offsetting measures.

The environmental components that will be monitored under the PEMP include the following although, according to the plan, some components are not scheduled for monitoring each year while others may only occur during operation:

- surface water (level/depth) and ice-regimes,
- shoreline erosion and reservoir expansion,
- sedimentation (related to water quality, sediment transport and deposition),
- greenhouse gas,
- woody debris,
- surface water temperature and dissolved oxygen (related to water quality and aquatic habitat), and

- total dissolved gas pressure.

In 2017/18, physical environment monitoring included surface water and ice regime, sedimentation, dissolved oxygen, and woody debris monitoring. Monitoring for surface water temperature, shoreline erosion and reservoir expansion, and total dissolved gas pressure will begin after the reservoir is impounded. The PEMP provides a schedule of the physical environment monitoring activities planned during the construction and operation periods of the Project. The study area generally extends from Clark Lake into Stephens Lake near the Kettle Generating Station as shown on Map 1 (detailed site maps are provided in Appendix A).



Map 1: General Project location and study area

2.0 SURFACE WATER AND ICE REGIMES

The water regime and ice parameters include water levels, water depth, river and lake-bottom elevation, water velocity, and ice cover. The largest changes to water and ice regimes are expected to occur once the reservoir has been impounded and include increases in water levels, reduction of velocities and development of a smoother ice cover. During the construction period, water levels are expected to increase from the construction of cofferdams used to isolate construction areas and an ice cover is expected to develop earlier from the installation of an ice boom.

The objectives of the water and ice regime monitoring include:

- determining water level regime and verifying expected changes in water levels resulting from the Project;
- confirming that there are no unanticipated Project effects on Split Lake water levels;
- determining water depth/bottom elevation and velocity information to support monitoring being performed under the Aquatic Effects Monitoring Plan (AEMP; KHLP 2015b);
- measuring ice conditions to support understanding of winter water levels, which may be affected by ice processes; and
- confirming that future ice conditions during operation are consistent with predicted effects reported in the EIS.

2.1 NELSON RIVER FLOW CONDITIONS

River discharge (flow) is reported as the outflow from Split Lake and is not affected by the Keeyask Project. Small streams that flow into the monitoring area between Clark Lake and Gull Rapids typically contribute less than 3% of the total flow (KHLP 2012b) and are not included in the total flow. River flows are directly correlated to water levels under open water conditions (i.e. high flow volumes result in high water levels). In winter, the levels are also influenced by ice conditions so the relationship between flow and water level is not consistent between summer and winter months. Flows are calculated based on Split Lake water levels using an updated open-water rating curve developed in 2017 that includes a methodology for adjusting the calculated flow for winter conditions. The historical daily flow records have been analyzed to characterize flow conditions since September 1, 1977 and represent regulated flow conditions since Lake Winnipeg Regulation and Churchill River Diversion began operating.

Flows in the Nelson River have been greater than the historical daily median flows during most of the reporting period from April 2017 to March 2018 (Figure 1). The flow has ranged from approximately 3,200 m^3/s (113,010 cfs) in October 2017 to almost 6,600 m^3/s (233,080 cfs) in May 2017. Flows were high in the first half of 2017, exceeding the 95th percentile flow over most

of the period from January through late June. In fact, record high flows occurred from about early March to early June as a result of high runoff in the Nelson River system. The peak flow of of almost 6,600 m^3/s in May was much larger than the previous May high flow of about 5,300 m^3/s in 1985 and 2005. The 2017 high flow was close to historical high flows of 6,500-6,600 m^3/s observed in the high flow years of 2005 (early Aug. and late Sep) and 2011 (late Aug.). After the spring peak, flows in 2017 steadily dropped to a little below median flow by early October and have generally been between the 25th and 75th percentile flows since then.

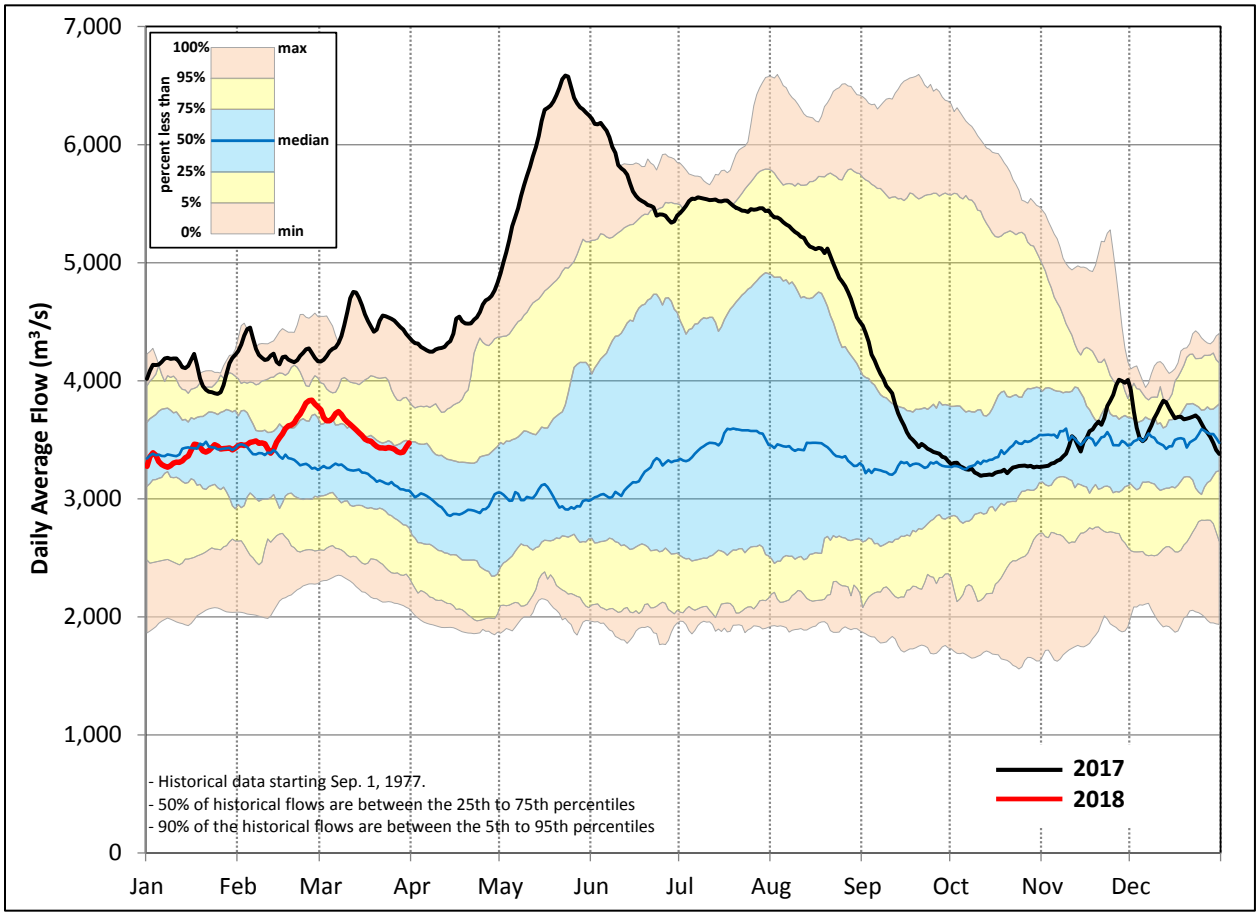


Figure 1: Split Lake 2016/2017 daily average outflow and historical statistics

2.2 OBSERVED WATER LEVELS – SUMMER AND WINTER

Water levels have been monitored at six sites from Clark Lake to Gull Rapids (Table 1, Map 2). A typical water level gauge is shown in Photo 1. The two Clark Lake sites have been monitored regularly since 2003, while the Gull Lake gauge was installed at the start of construction in mid July 2014. The other three sites were installed after construction started, once the necessary permits and heritage surveys were complete, which were applied for and done after the Environment Act licence was received in early July 2014. The original gauge at the upstream end of Gull Lake (05UF749) was wrecked by ice and was discontinued in May 2016. The gauge

was relocated about 3 km upstream to the mouth of Portage Creek. The new site (05UF587) began operation in September 2016. In addition to data from the PEMP gauges, data was also obtained from the existing Split Lake gauge at the community of Split Lake.

At the beginning of April 2017, the start of the current reporting period, water levels were starting to drop from their winter peak (Figure 2). Levels began to rise in April due to rising flows that peaked at near historic high levels in late May. Water levels rose to high levels on Gull, Clark and Split lakes in association with these high flows, water levels on Gull Lake reached within 2.5 m (8 ft) of the future Keeyask reservoir full supply level (159m).

At the site below Birthday Rapids, however, the water level initially increased as flows increased, but around mid-May, these levels began to drop sharply even as flows continued to increase for about another ten days: water level dropped almost 2 meters while flows increased by almost 700 m^3/s. Over that period, in association with the rising flow, levels continued to rise at the upstream sites below Clark Lake and on Clark and Split lakes. The fact that levels continued to rise at upstream sites, while there was a sharp drop in level below Birthday Rapids, shows that the high levels (about 162.3 m ASL) below the rapids were not creating a backwater effect on the upstream sites. Had there been a backwater effect, then levels at the upstream sites would have been expected to decline as levels below Birthday Rapids dropped. Levels began to drop below Birthday Rapids in spite of rising flows because ice that had accumulated below the rapids over winter began to break up so there was less constriction of the flow.

By the end of May the ice was largely gone and water levels returned to open-water conditions where levels are only dependent upon flow without any ice effects. During the open water period up to the time ice began to form in November, the water levels vary directly with flow changes (Figure 2). As reported in previous annual reports, the North Channel Rock Groin continues to raise open upstream water levels as compared with pre-Project levels, with greatest effects near the Rock Groin and diminishing effects upstream (Map 3). The effect on level diminishes further upstream such that there is no impact on levels at, and upstream of the monitoring site below Gull Rapids (Map 3). The observed effect is consistent with predicted effects within the range of model accuracy.

In early November, flows began to gradually increase, causing levels to rise (Figure 2). At the same time, air temperatures dropped and ice began to form behind the ice booms and on the lakes and rivers, which also caused levels to rise. On Clark and Split lakes, ice causes levels to rise about 0.7 m higher than open water levels under similar flow conditions.

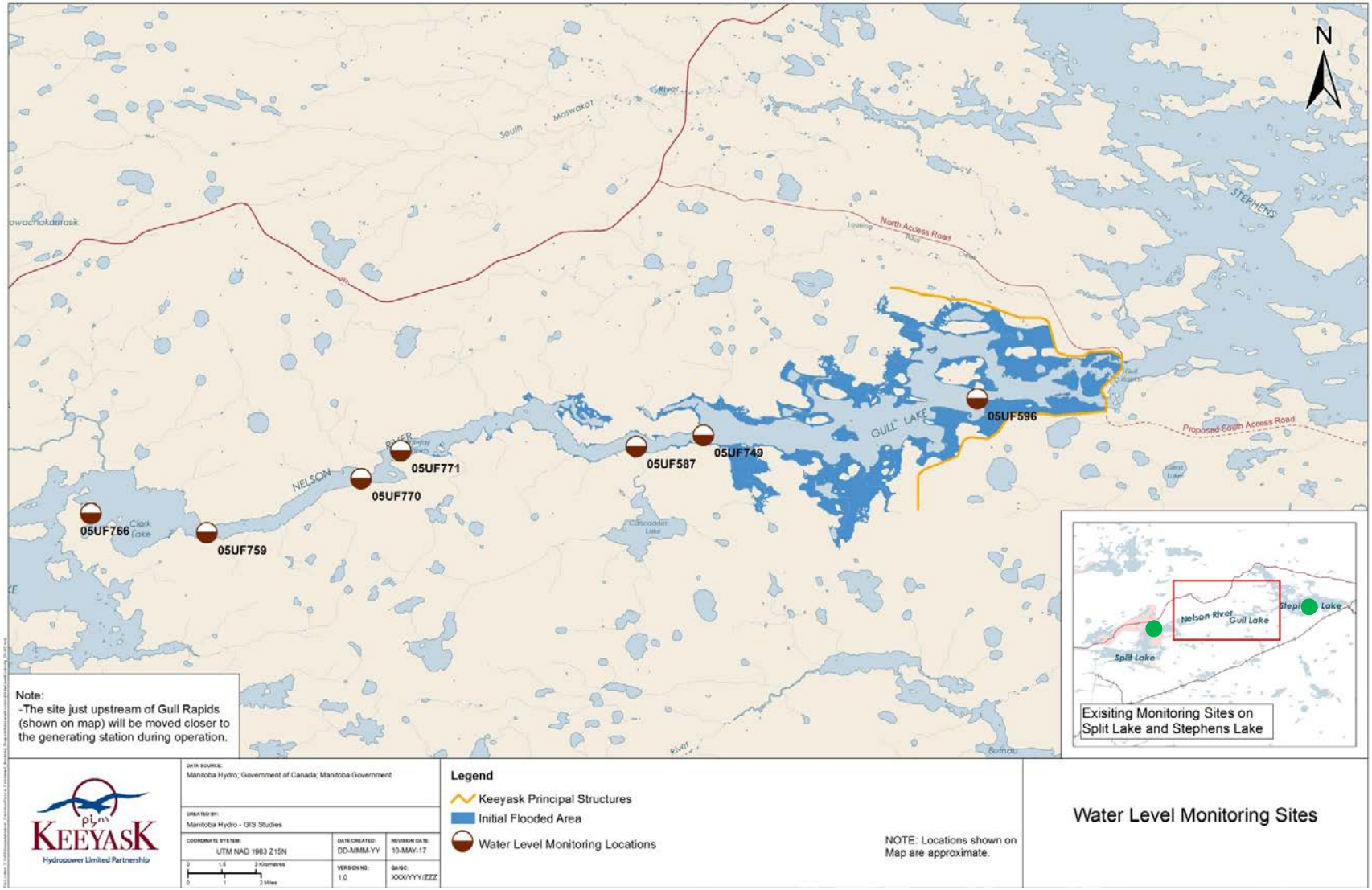
As in previous years, water levels at the site upstream of Gull Lake and the sites below and above Birthday Rapids show large increases in water level due to ice effects. Levels increase a maximum of about 4-5 m at these sites. These peak levels are not sustained for the winter: for example, at the site upstream of Gull Lake, the levels drop about 2 m through December after peaking near the end of November. Levels at the site below Clark Lake showed an increase in early January due to ice progression upstream of Birthday Rapids, which began in early January. Levels at this site continued to rise for several days even as levels below Birthday

Rapids dropped, suggesting that elevated levels due to ice at this site did not create a backwater effect on the site below Clark Lake.

Table 1: List of water level monitoring sites

Site ID	Name	Record	Notes
05UF766	Clark Lake	Oct. 2003 - present	4 km above outlet
05UF759	downstream of Clark Lake	Dec. 2003 - present	1.9 km below outlet
05UF770	upstream of Birthday Rapids	Oct. 2014 - present	1.1 km above rapids
05UF771	downstream of Birthday Rapids	Oct. 2014 - present	2.1 km below rapids
05UF749	upstream of Gull Lake	Oct. 2014 - May 2016	0.26 km above lake
05UF587	upstream of Gull Lake	Sep. 2016 - present	3.0 km above lake
05UF596	Gull Lake	Jul. 2014 - present	7 km above Gull Rapids
05UF701	Split Lake at Split Lake Community	Oct. 1997 - present	existing site

Photo 1: Water level gauging station in winter



Map 2: PEMP water level monitoring sites

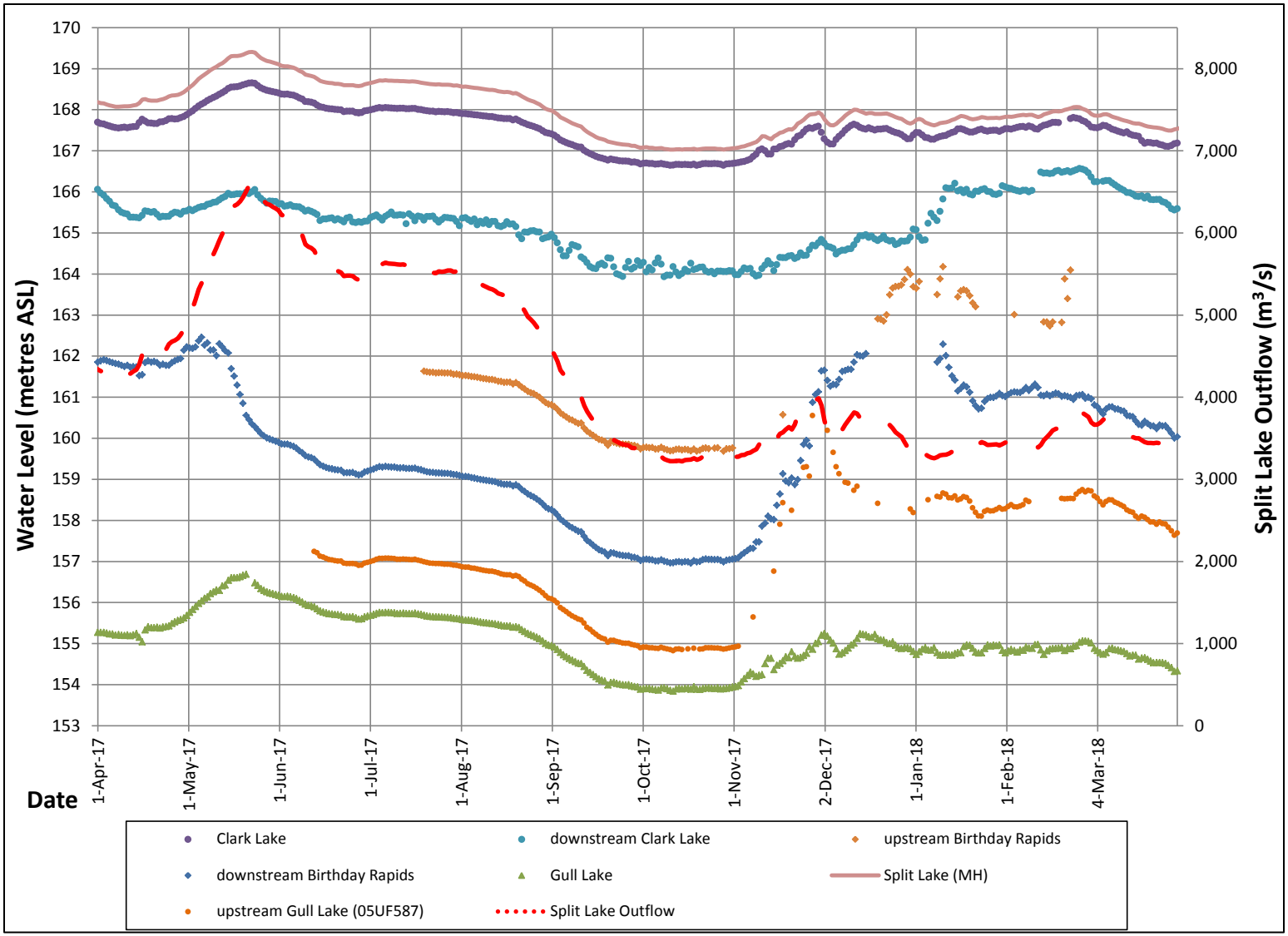
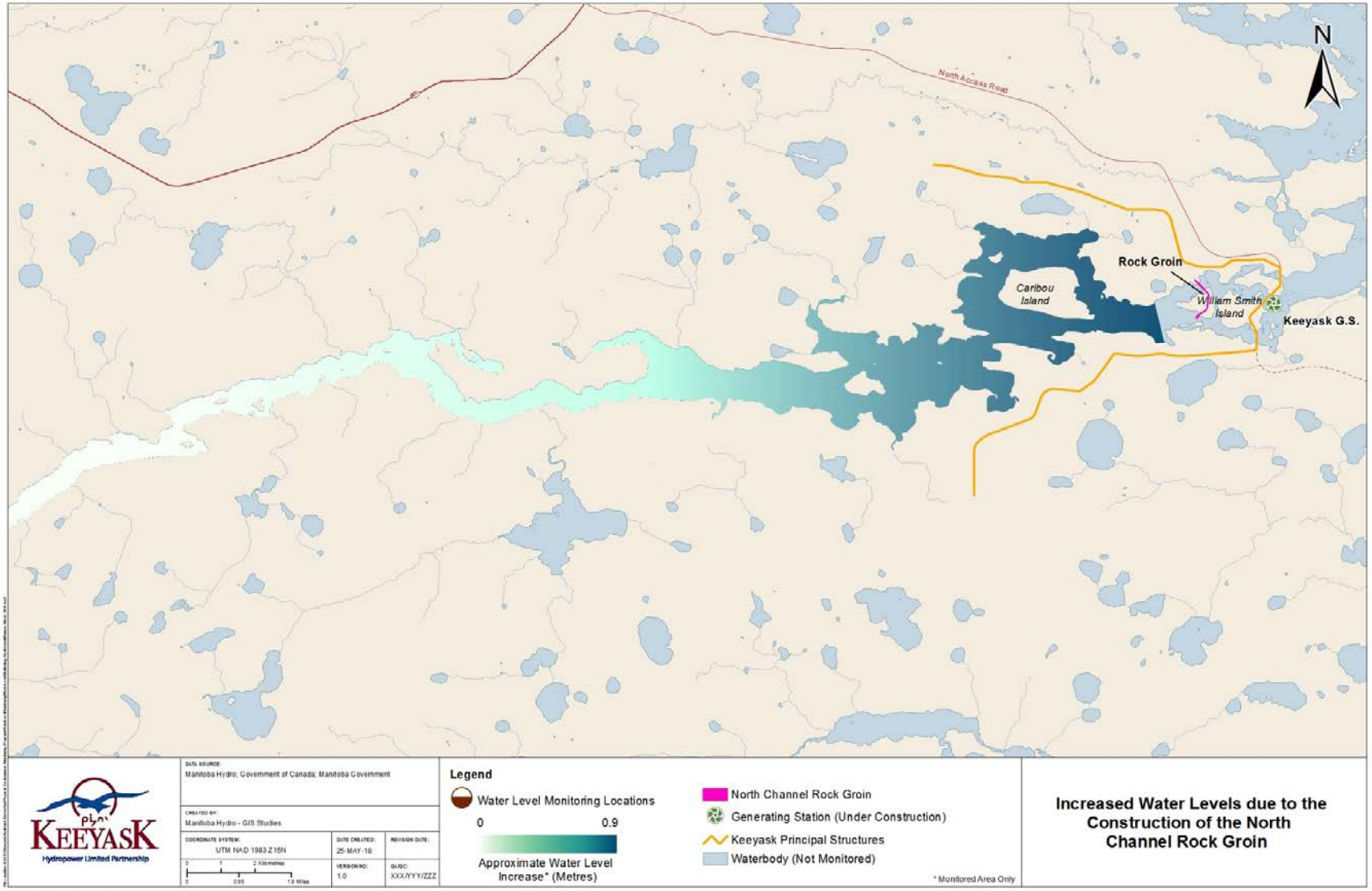


Figure 2: Observed water levels at PEMP monitoring sites in 2017/2018



NOTE: Locations shown on map are approximate.

Map 3: Approximate 2016 water level increases due to the North Channel Rock Groin (open water conditions)

2.3 CLARK LAKE AND SPLIT LAKE WATER LEVELS

Split Lake water level data from the existing Split Lake Community gauging station (Site ID: 05UF701) were obtained and plotted along with the levels for the PEMP site on Clark Lake (Figure 3). The levels on these two lakes show the same pattern of variation, differing by about 0.25-0.75 m with an average difference of approximately 0.5 m. During open water periods, both sites show a clear correlation to variations in flow and generally during winter as well. There is no impact on these levels due to the Project during the open water period. As noted above, the observed winter staging of up to about 0.7 m on Split Lake is typical for this lake. The PESV noted that winter staging on Split Lake in the pre-Project environment could range from 0.3 m to 1.2 m, and averaged about 0.6 m (KHLP 2012b, Section 4.3).

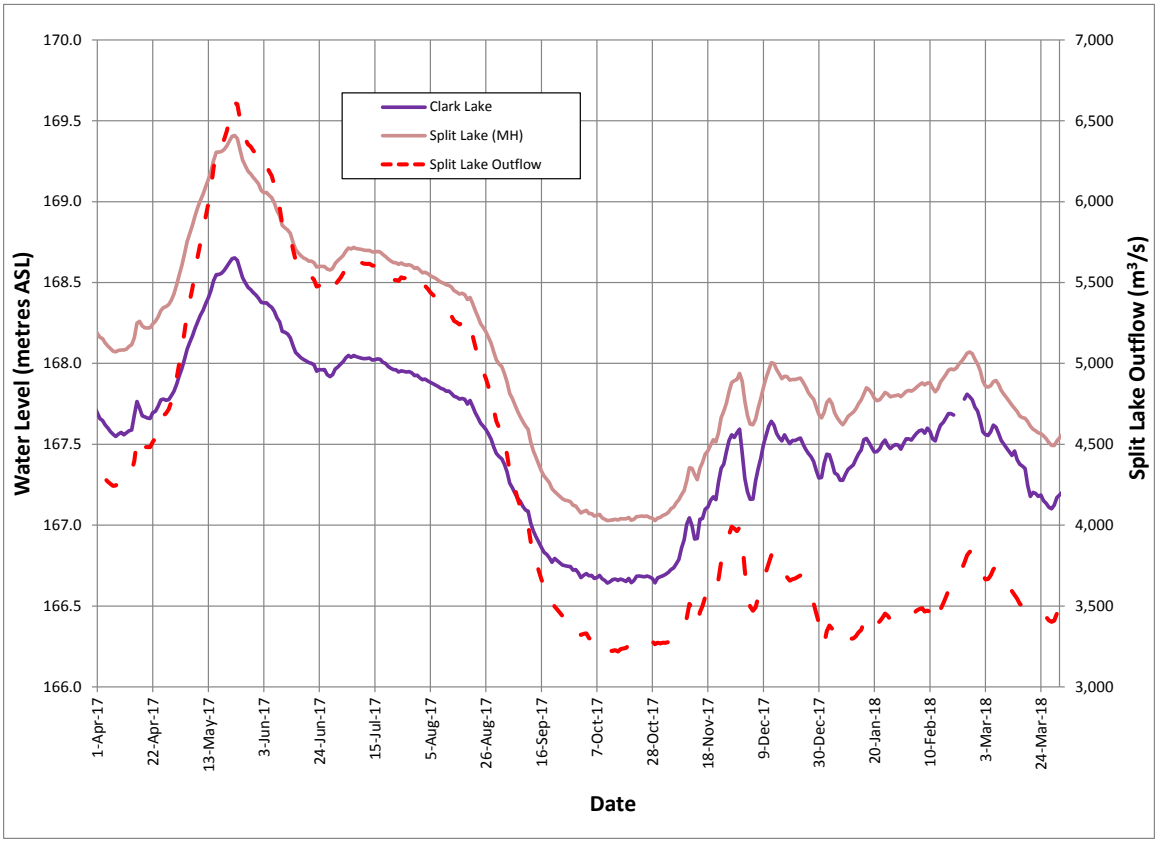


Figure 3: Observed water levels at Clark Lake and Split Lake in 2016/2017

2.4 ICE REGIME

The PESV (KHLP 2012b, Section 4) discusses ice processes and the pre-Project ice regime in the vicinity of the Project. In the pre-Project environment, a complete ice cover formed most years (approximately 2 out of 3 years) on Gull Lake and the Nelson River up to Birthday Rapids, although the timing and extent varied with flow and climate conditions. A combination of higher

flow and/or warmer conditions could prevent an ice bridge from forming in some years so that open water persisted in the central channel from the exit of Split Lake to the entrance of Stephens Lake. In contrast, with early cold temperatures and lower flows the ice front cover could advance upstream of Birthday Rapids. In years when bridging occurred, the date when it formed ranged from as early as November at lower flows to as late as January at higher flows.

The approximate dates for freeze up and breakup on Gull Lake since the start of construction are shown in Table 2. The 2017/18 winter saw the earliest ice cover formation on Gull Lake, about 2 weeks earlier than the previous two winters with the ice boom in place.

Table 2: Ice Dates and Cover

Year	Initial Freeze-up on Gull Lake	Ice Cover Advancement	Gull Lake Ice Break-up
2014/15	Jan 23, 2015 Nov 9, 2014*	foot of Birthday Rapids	May 13-15, 2015
2015/16	Nov 20, 2015	about 4 km upstream of Birthday Rapids	May 4-9, 2016
2016/17	Nov 19, 2016	about 6 km upstream of Birthday Rapids	May 22-24, 2017
2017/18	Nov 4, 2017	about 6 km upstream of Birthday Rapids	May 19-20, 2017

*Ice formation start date before ice boom failed

In 2017, average daytime temperatures dropped to below freezing in late October and ice formed upstream of the ice booms on November 4 as seen in Photo 2 and Photo 3 which were taken before and after ice developed. Figure 4 shows satellite images of the ice cover as it advances upstream during the winter. By November 10, the leading edge of the ice front was at the upstream end of Gull Lake. The ice front continued to advance upstream reaching Birthday Rapids by early January. The leading edge of the ice front reached about 5 to 6 km upstream of Birthday Rapids (Photo 4) by the end of January, remaining there till mid-April, similar to the previous winter. Gull Lake became predominately ice free around the same date as last winter.

Photo 2: Ice Boom A on east side of Caribou Island (Nov. 2 & 5, 2017)

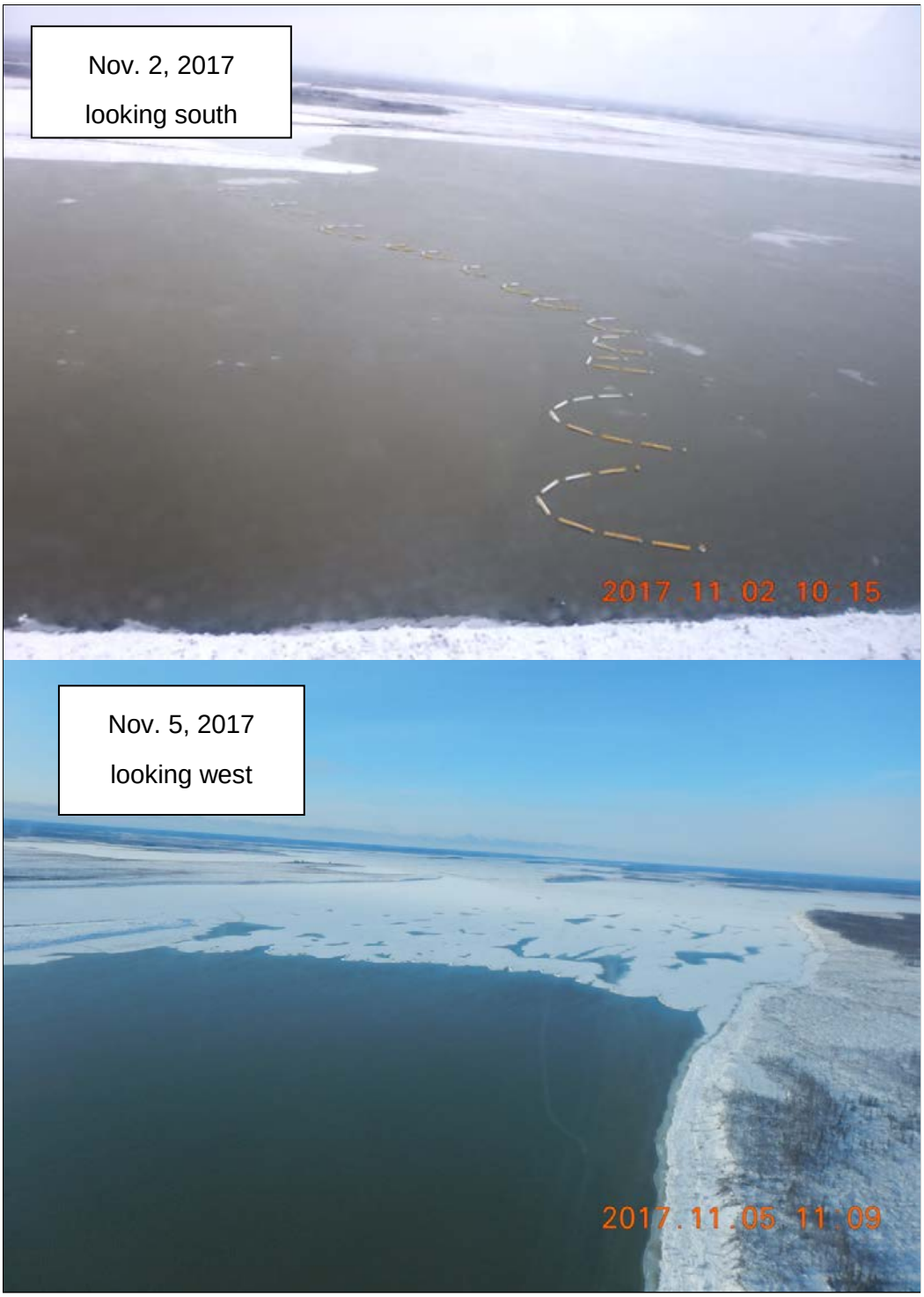


Photo 3: Ice Boom B on south side of Caribou Island (Nov. 2 & 5, 2017)

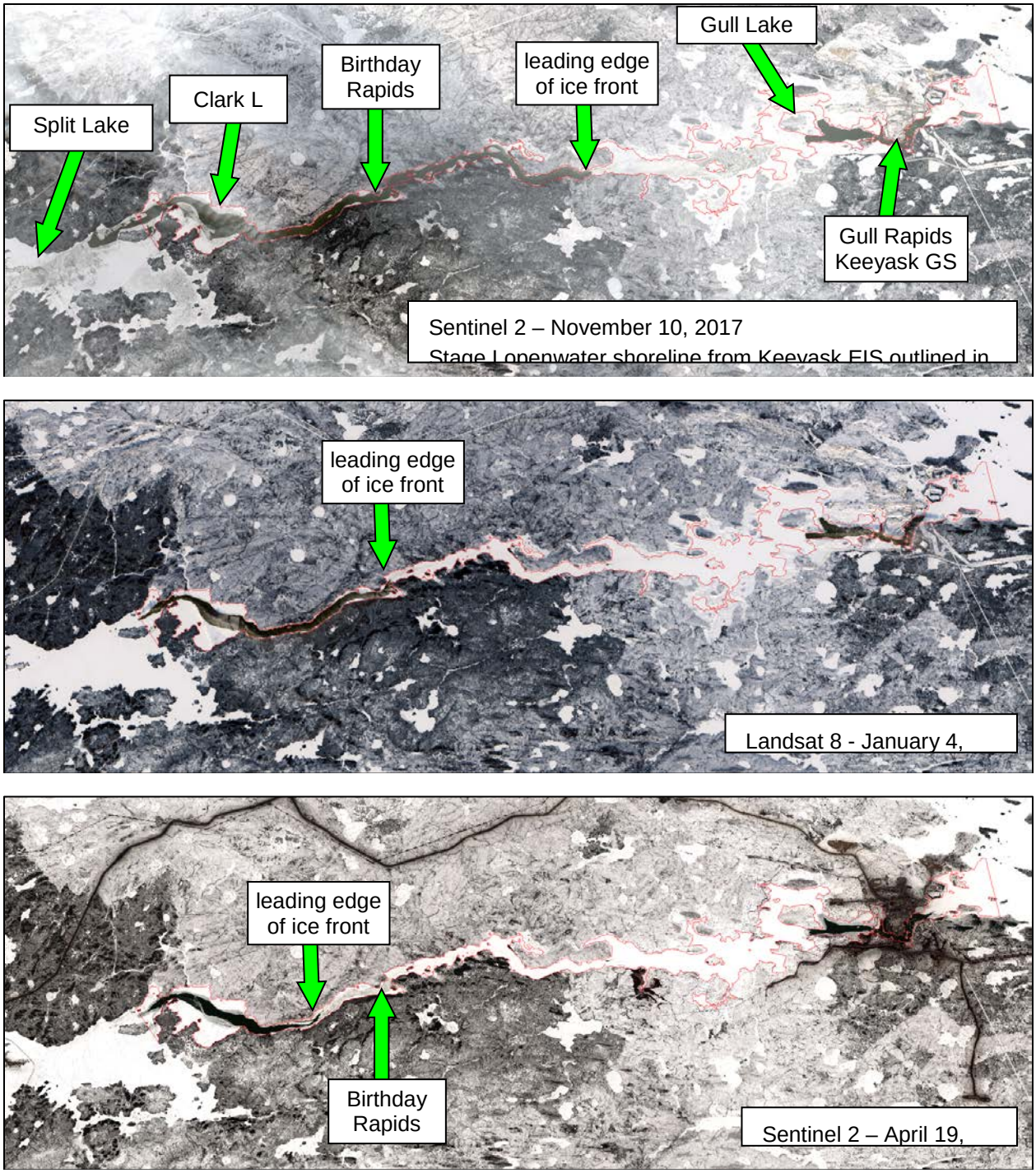


Figure 4: Ice Cover Observations from Satellite Images

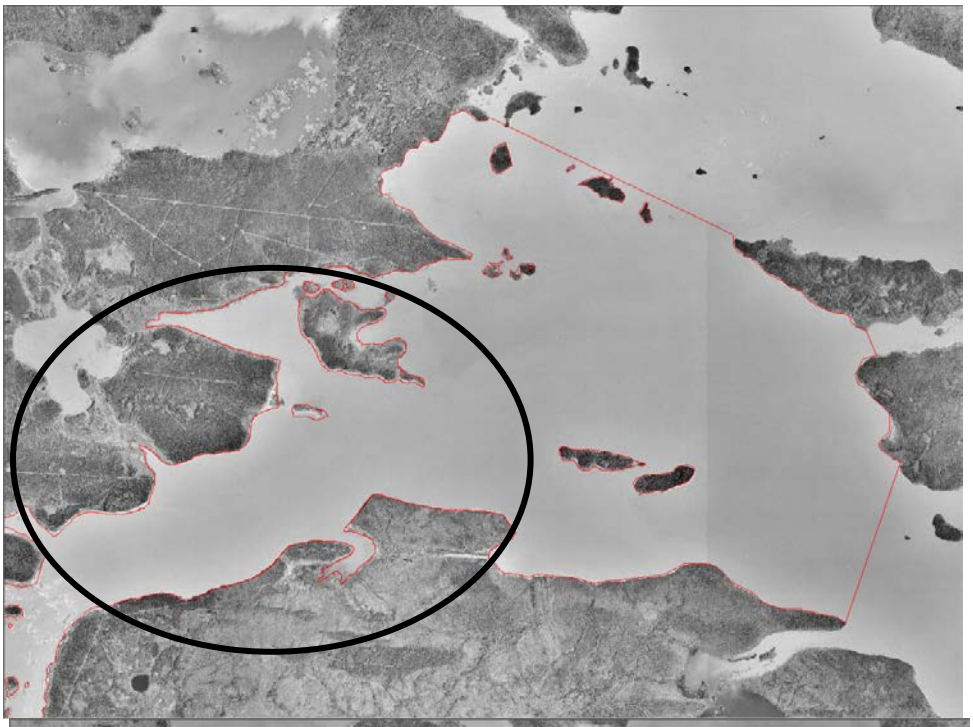
Photo 4: Leading edge of ice cover upstream of Birthday Rapids

3.0 SHORELINE EROSION

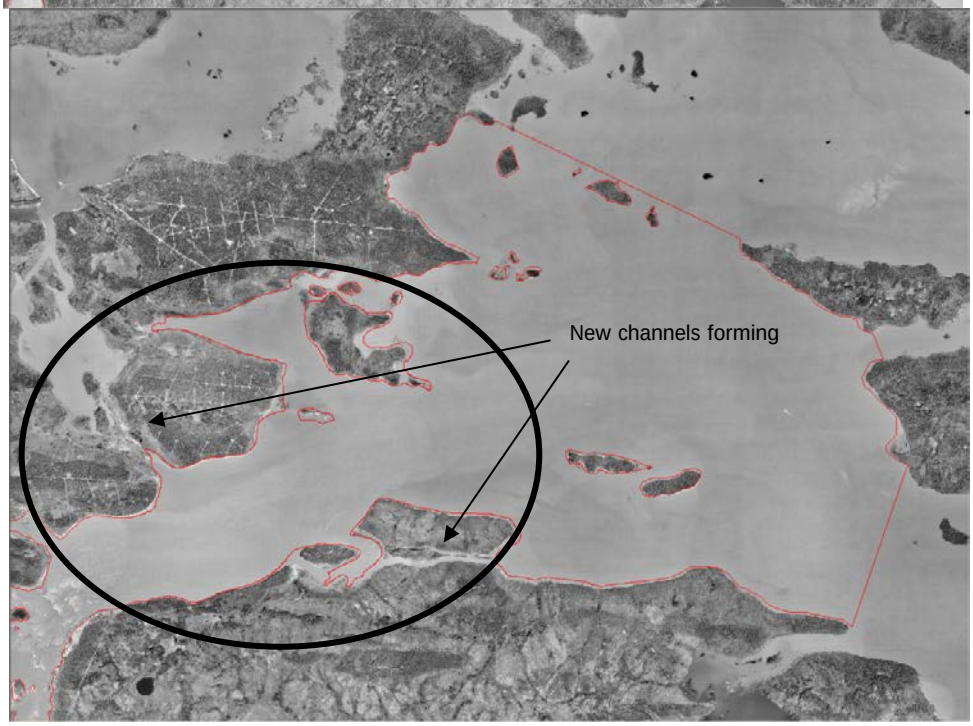
Shoreline erosion monitoring during construction consists of mapping the shoreline position (edge of peat for peat shorelines, top-of-bluff for mineral banks) prior to full impoundment of the reservoir. In 2014, high-resolution satellite imagery was collected at the start of the construction period. It is planned to collect similar satellite imagery in the future immediately before the creation of the reservoir. The shorelines at the start and end of construction will be compared to see if any substantive shoreline erosion occurred during construction. Images collected after impoundment will be used to determine the actual extent of flooding and reservoir expansion over time.

Sedimentation monitoring observations indicate that turbidity levels are lower in winter (See Section 4) and it is concluded that less erosion is occurring near the entrance to Stephens Lake as a result of the ice boom creating a stable ice cover upstream of the Project and in the Gull Rapids area. Imagery collected pre-construction and during construction (Figure 5) was reviewed to see if there was evidence of reduced erosion on Stephen Lake.

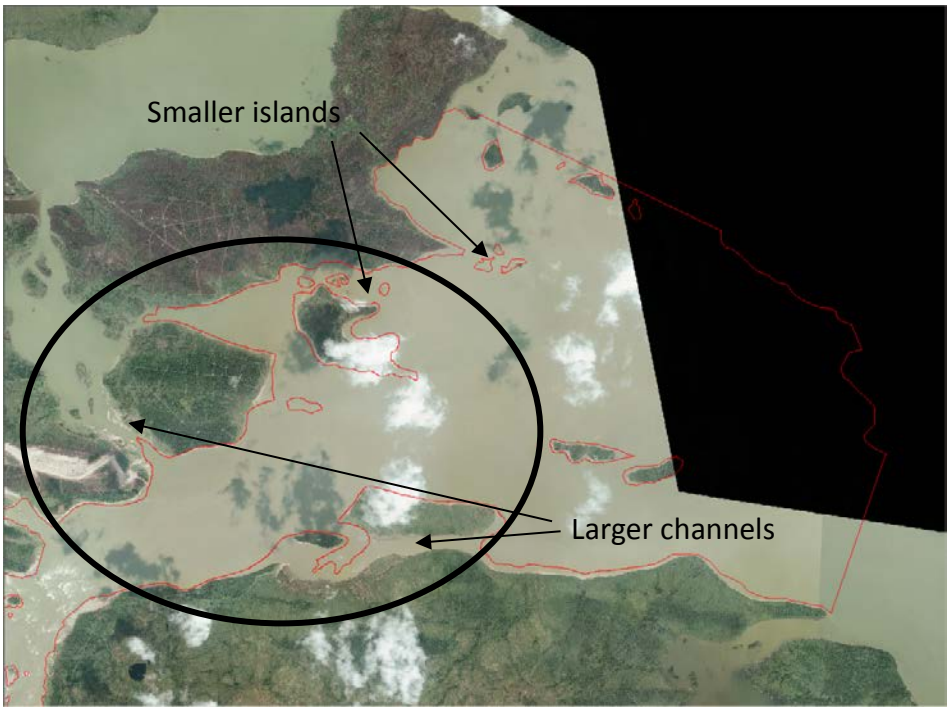
While the assessment is qualitative, large scale changes are seen between the 1999, 2006 and 2014 images (see circled area in photos below). The shoreline receded in many places, as observed by changes from the original shoreline shown in red. There are locations where new channels formed creating new islands, or smaller island disappearing entirely. Changes to the shorelines appear to have been minimal between the 2014 and 2017 images suggesting erosion rates have decreased, with changes to the land where construction activities have taken place. Work will continue on monitoring the shorelines and changes to erosion rates.



1999

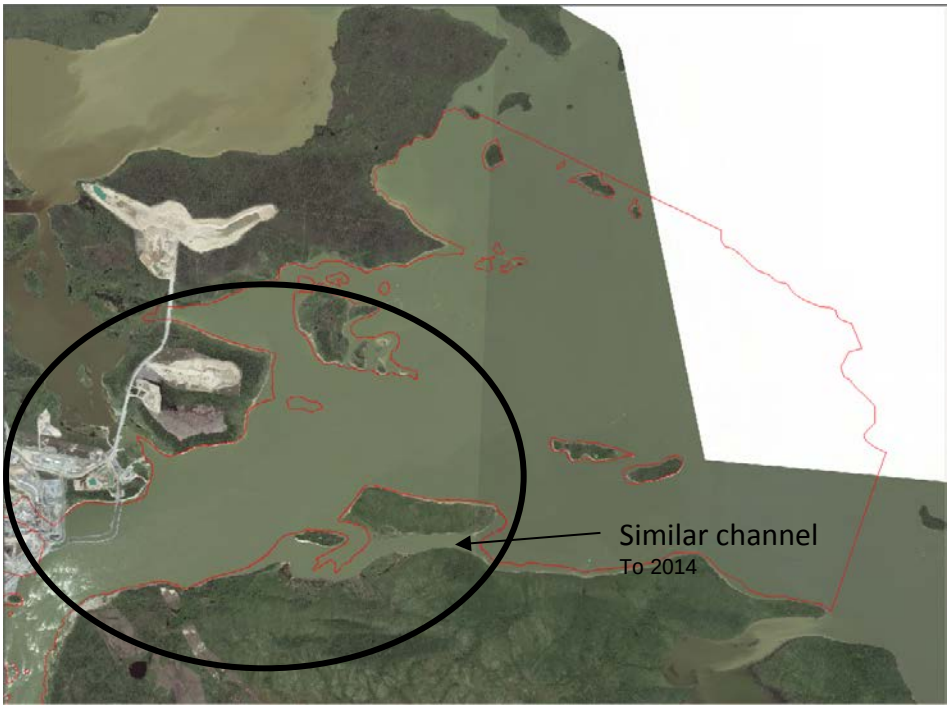


2006



2014

Image taken just prior to in-stream construction work starting



2017

Little change from 2014

Figure 5: Aerial and Satellite Imagery

4.0 SEDIMENTATION

Sedimentation monitoring includes monitoring the transport and deposition of sediment, the objectives of the sedimentation monitoring include:

- confirming sediment transport and deposition predictions; and
- supporting water quality and aquatic habitat monitoring components of the AEMP (KHLP 2015b).

The largest overall effects of the Project on sedimentation are predicted to occur after impoundment of the reservoir with the highest total sediment loading predicted to occur in the first year after impoundment. During the construction period prior to reservoir impoundment the PEMP sedimentation monitoring is generally done to collect data that will support conclusions of the effects of the Project on sediment transport and deposition after impoundment. Sediment monitoring under the *Sediment Management Plan for In-stream Construction* (SMP) (KHLP 2014) is designed to specifically monitor sediment releases due to in-stream construction activities. A separate annual report discusses the results of monitoring performed in the implementation of the SMP (Manitoba Hydro 2018).

Sediment transport monitoring is done through the collection of discrete water samples, continuous turbidity monitoring and sediment traps at locations shown in Map 5 (detailed site maps are provided in Appendix A). Discrete sampling involves the collection of water samples and in-situ measurements by field personnel at certain times (e.g., monthly) while continuous turbidity monitoring involves the installation of automated equipment that remains in place to take readings much more frequently. The continuous turbidity sites are periodically visited for maintenance checks; typically at the same time that discrete monitoring is performed. Sediment loading is estimated from the continuous turbidity data.

4.1 WINTER 2016-2017

In each annual report the winter sedimentation data is reported from the previous winter (i.e. one year delay) to allow time after the end of the field season for all data to be reviewed and analyzed before reporting. This report presents the 2016-17 winter sedimentation data.

4.1.1 CONTINUOUS AND DISCRETE TSS AND TURBIDITY

Monitoring in 2016-17 was conducted at three sites (Table 3). The equipment was installed after suitable ice conditions developed at the sites and removed before ice break up.

Table 3: 2016-2017 Winter Monitoring Locations

Site ID	Dates
K-Tu-06 (Clark Lake)	26-Jan-17 to 10-Apr-17
SMP-01 (Gull Lake)	12-Jan-17 to 15-Apr-17
SMP-03L (Stephens Lake)	19-Feb-17 to 08-May-17

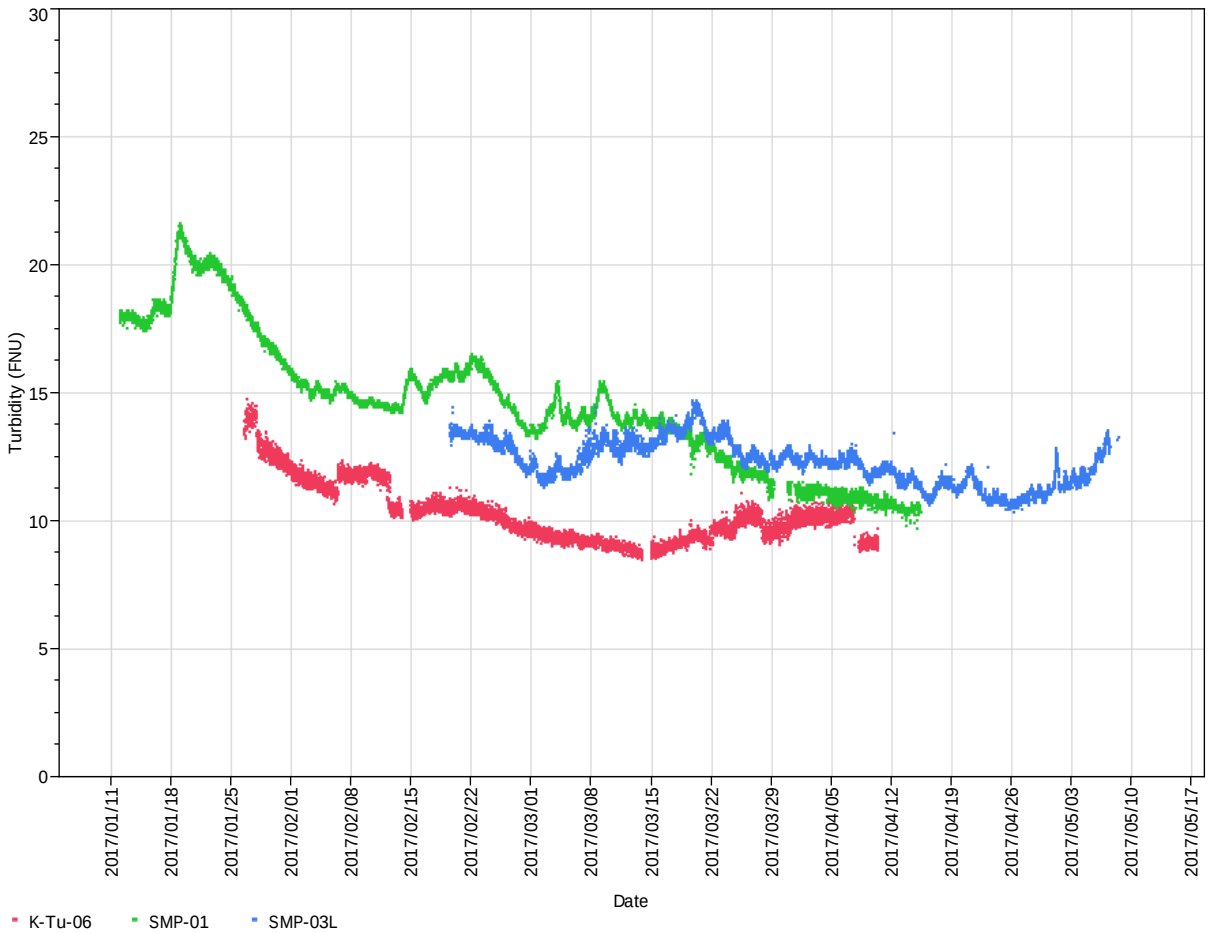


Figure 6: 2016-2017 Winter Continuous Turbidity

Turbidity levels were relatively consistent throughout the winter, with highest levels observed in late January followed by a decreasing trend over the winter; this pattern is commonly seen throughout a winter. In the 2016-17, the turbidity in Gull Lake (SMP-01) was higher than Clark Lake (K-Tu-06) for most of the winter period (Figure 6). Although previously there were short periods of times when Gull Lake was higher it has typically been lower than Clark Lake. However, the turbidity levels were observed to be generally equal or lower than pre-construction conditions (Figure 7). An increase in turbidity suggests a net increase in sediment (i.e. that some erosion of the shoreline or river bed was occurring) between Clark and Gull Lake monitoring sites. A review of river discharge and water levels showed that due to the ice conditions in 2016-17 the water levels were lower for the same or higher discharge rates than in

previous years. Having higher flows with lower levels would result in higher velocities in 2016-17 than in 2015-16 and would result in an increased erosion potential. It is likely that this is one of the reasons for the higher turbidity at Gull Lake in 2016-17.

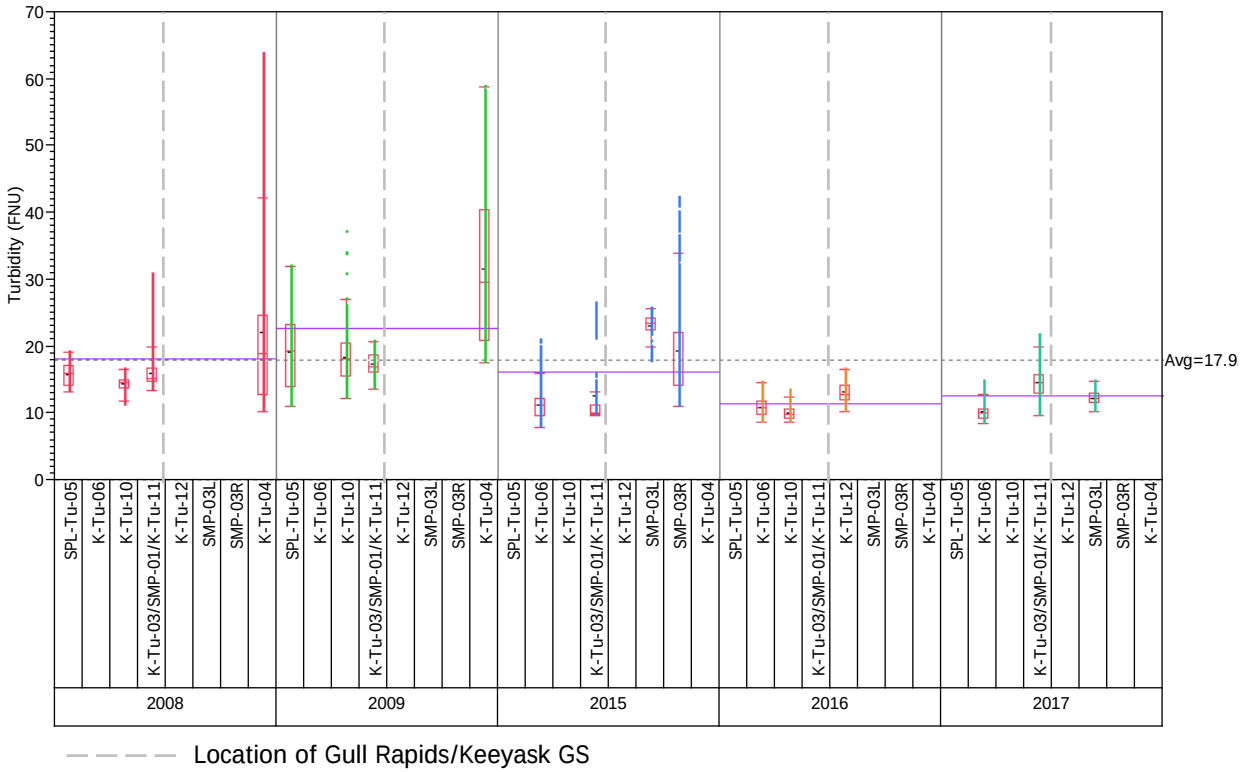


Figure 7: Summary of Winter Continuous Turbidity

As reported in 2015-16, the turbidity downstream of the Project in Stephens Lake (SMP-03) was similar to upstream levels in Gull Lake (Figure 7) in 2016-17. During pre-construction winter monitoring (2007-08 shown in Figure 8 and 2008-09) and in 2014-15 when the ice boom failed, it was observed that turbidity/sediment levels could be much higher in Stephens Lake (K-Tu-04) that in Gull Lake (K-Tu-10 and K-Tu-11), particularly early in the monitoring season. The higher levels in Stephens Lake likely resulted from ice accumulation at the entrance to Stephens Lake, which redirected flows and increased flow velocities causing erosion and increased sediment in the water. These elevated levels were also observed further downstream in the Limestone forebay prior to construction (Figure 9).

The EIS included the prediction that the Project will “significantly reduce erosion potential” downstream of the Project after construction which would result in lower turbidity downstream. Changes were not anticipated during the construction period as some increases in water level due to ice were still expected to cause erosion at the entrance to Stephens Lake. The earlier than expected reduction is likely due to the upstream ice boom creating a more stable upstream ice cover and reduction in the Stephens Lake ice dam and the cofferdams reducing the potential

erosion of shorelines. A review of aerial and satellite imagery that supports the reduction is discussed in Section 3.

The lower turbidity was also observed downstream of Stephens Lake in the Limestone GS reservoir as shown in Figure 10 (CAMP, pending). While reduced erosion that may lead to decreases in downstream TSS during the ice-cover season was predicted, the Physical Environment Support Volumes did not explicitly say that the effect of lower TSS would extend downstream, although it would be expected. Under open water conditions, however, effects on TSS are not expected to extend past Stephens Lake.

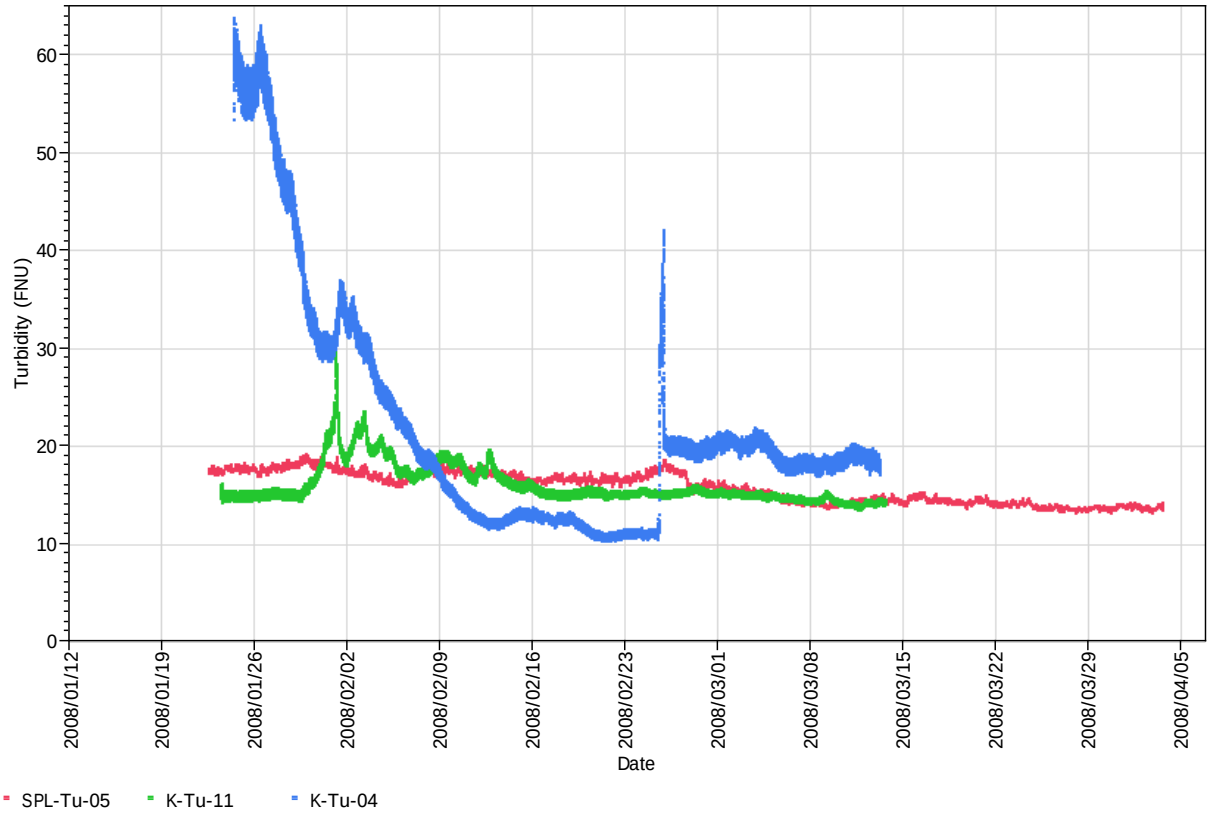


Figure 8: 2007-08 Winter Continuous Turbidity (Pre-construction)

Discrete TSS and Turbidity (Figure 11) data show consistent results with the continuous data. With the ice boom working to produce a stable ice cover upstream of the Project the downstream TSS and turbidity has dropped.

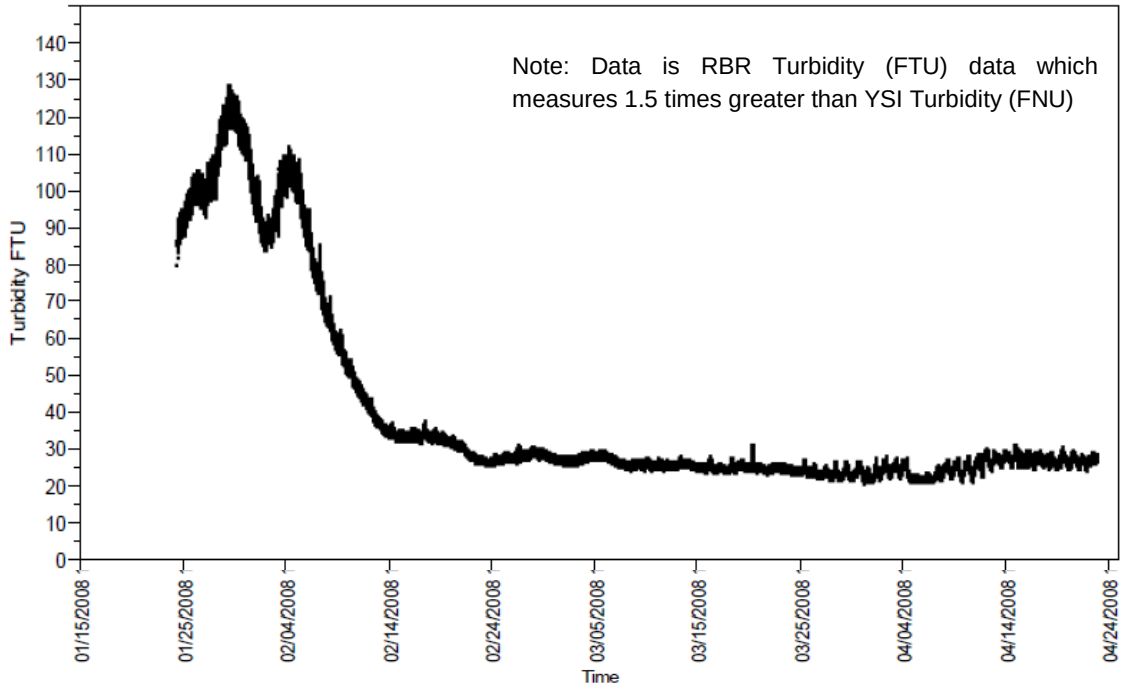


Figure 9: 2007-08 Limestone Forebay Turbidity

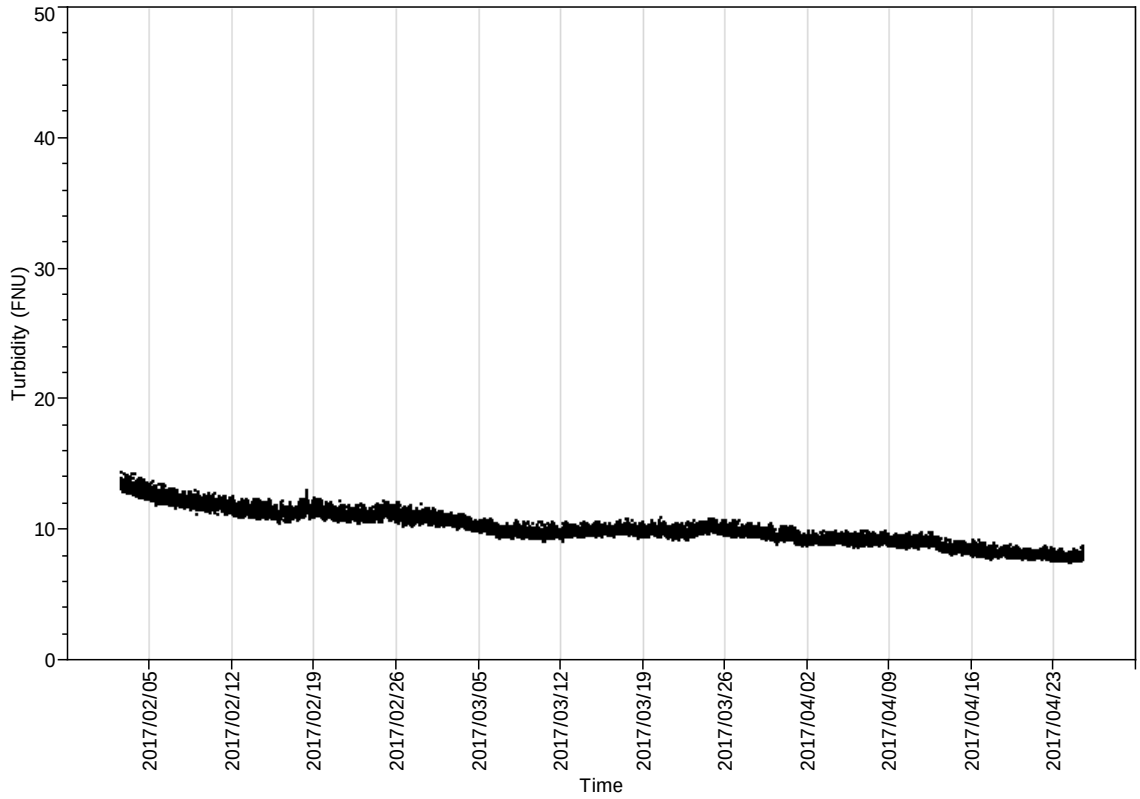


Figure 10: 2016-17 Limestone Forebay Turbidity

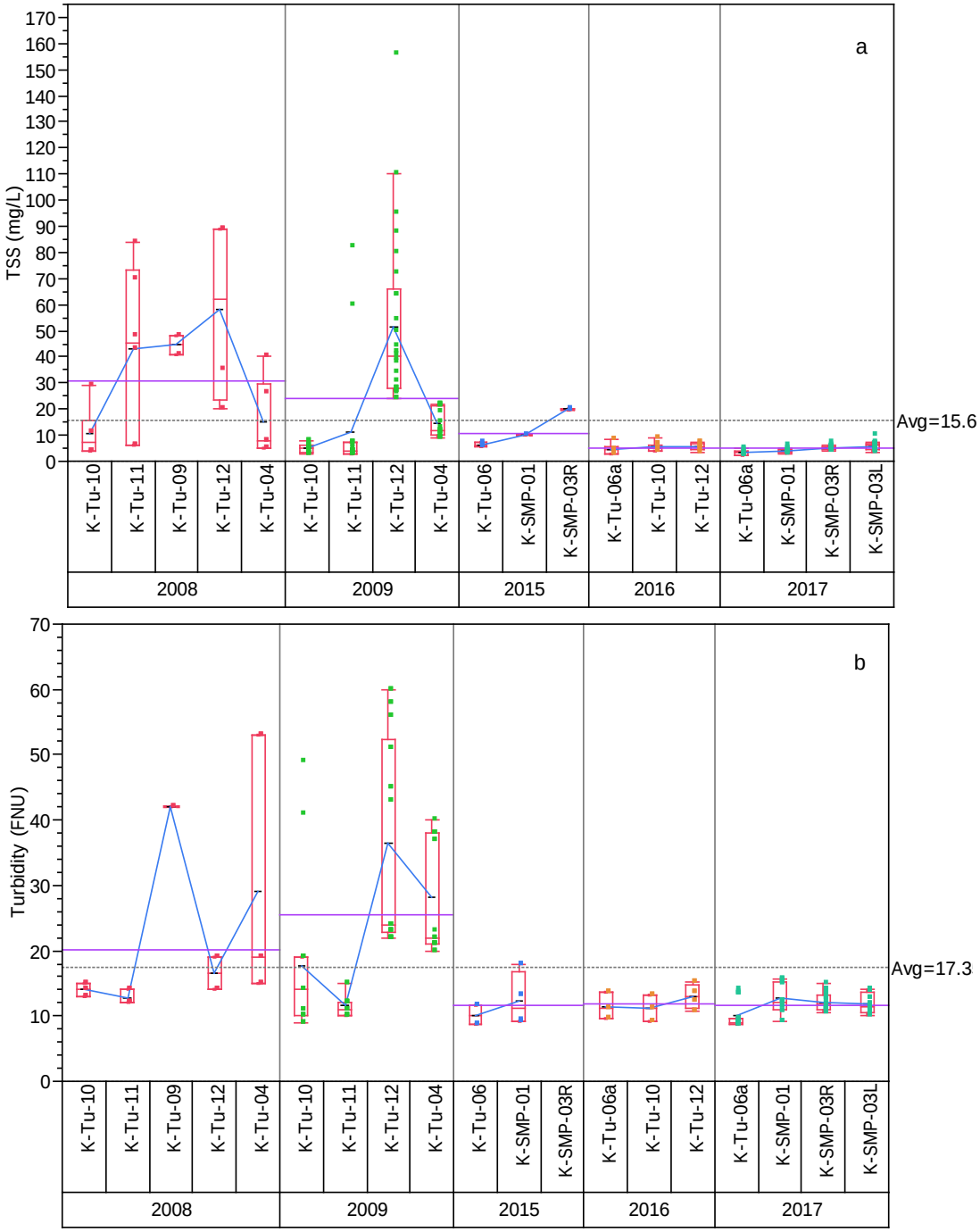


Figure 11: Summary of Winter Discrete TSS (a) and Turbidity (b)

4.1.2 ESTIMATED SUSPENDED SEDIMENT LOAD

The winter suspended sediment loads (Figure 12) are estimated based on the average daily turbidity and Keeyask Inflow discharge. Turbidity is converted to TSS concentrations using a Turbidity-TSS relationship developed for the SMP.

The estimated sediment load at the upstream end of the study area (measured at SPL-Tu-05 on Split Lake and K-Tu-06 Clark Lake) indicates that the winter average was higher during the two pre-construction years (3010 and 3760 Tonnes/day respectively) than the three winters monitored since construction started (1980, 1880 and 1960 Tonnes/day).

As noted above, during the 2015-16 and 2016-17 winters a downstream reduction in turbidity has resulted in a reduced sediment load entering Stephens Lake from the pre-construction period and in 2014-15 when the ice boom failed. It is estimated that approximately 80,000 Tonnes were eroded between the Gull Lake site (K-Tu-03) and Stephens Lake site (K-Tu-04) over a 2 ½ week period in 2007-2008 when the higher turbidity was observed.

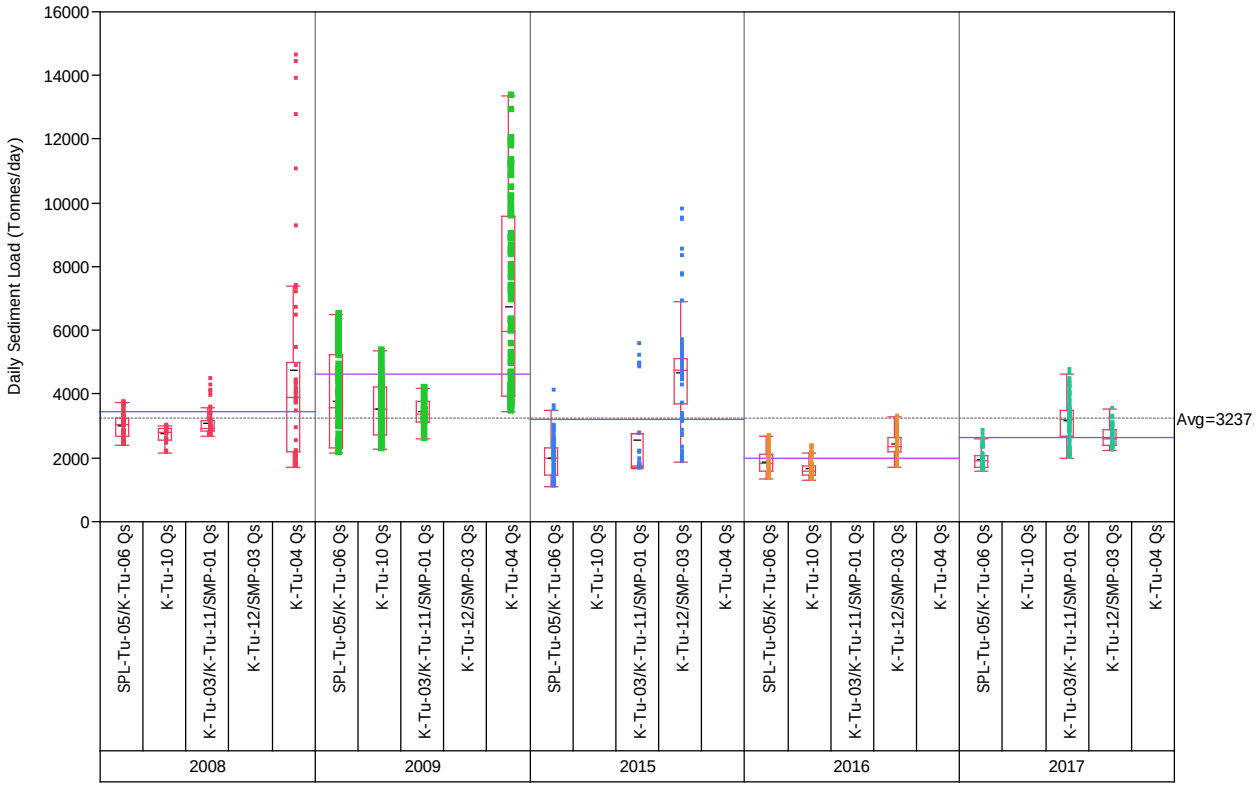


Figure 12: Summary of Winter Daily Suspended Sediment Load

4.2 SUMMER 2017

The summer monitoring period extends from the time ice has melted and equipment can be safely placed in the water (typically in June) until equipment can be safely removed before winter conditions and freeze up starts (typically late September/October).

4.2.1 CONTINUOUS TURBIDITY

The five continuous turbidity sites monitored in summer 2017 and the dates for which records are available are shown in Table 4 (location maps in Appendix 1). In 2017, the monitoring equipment at K-Tu-05 was moved to a location about 3.9 km upstream due to adverse site conditions. The previous year the catamaran carrying a solar panel and monitoring equipment at the K-Tu-05 location flipped over due to waves during a storm event.

The continuous turbidity monitoring stations consist of either a catamaran equipped for satellite data transmission (Photo 6) or a stand-alone buoy system requiring manual downloading of data. Both systems are equipped with an YSI multi-parameter sonde (6600 or EXO2 series) suspended two metres below the surface of the water.

Table 4: 2017 Summer Monitoring Locations

Site ID / Location	Dates
K-Tu-06 (Clark Lake)	14-Jun-17 to 19-Sep-17
*K-Tu-13 (Nelson River)	15-Jun-17 to 19-Sep-17
K-Tu-03 / SMP-01 (Gull Lake)	19-Jun-17 to 21-Sep-17
K-Tu-02 / SMP-02L	25-Jun-17 to 19-Sep-17
K-Tu-04 (Stephens Lake)	18-Jun-17 to 17-Sep-17

*K-Tu-05 relocated to K-Tu-13

The data collected at each of the monitoring sites was reviewed to identify and remove poor quality data that may result due to factors such as algae growth and vegetation on probes, dead batteries, and equipment malfunction. The continuous data (Figure 13) were also compared with the discrete readings (Figure 15) obtained on each maintenance site visit and adjustments made for any sensor drift. Data from K-Tu-03/SMP-01 was reduced by 1.8 FNU and data at K-Tu-02/SMP-02L was reduced by 3.5 FNU to match the data collected at other PEMP sites.

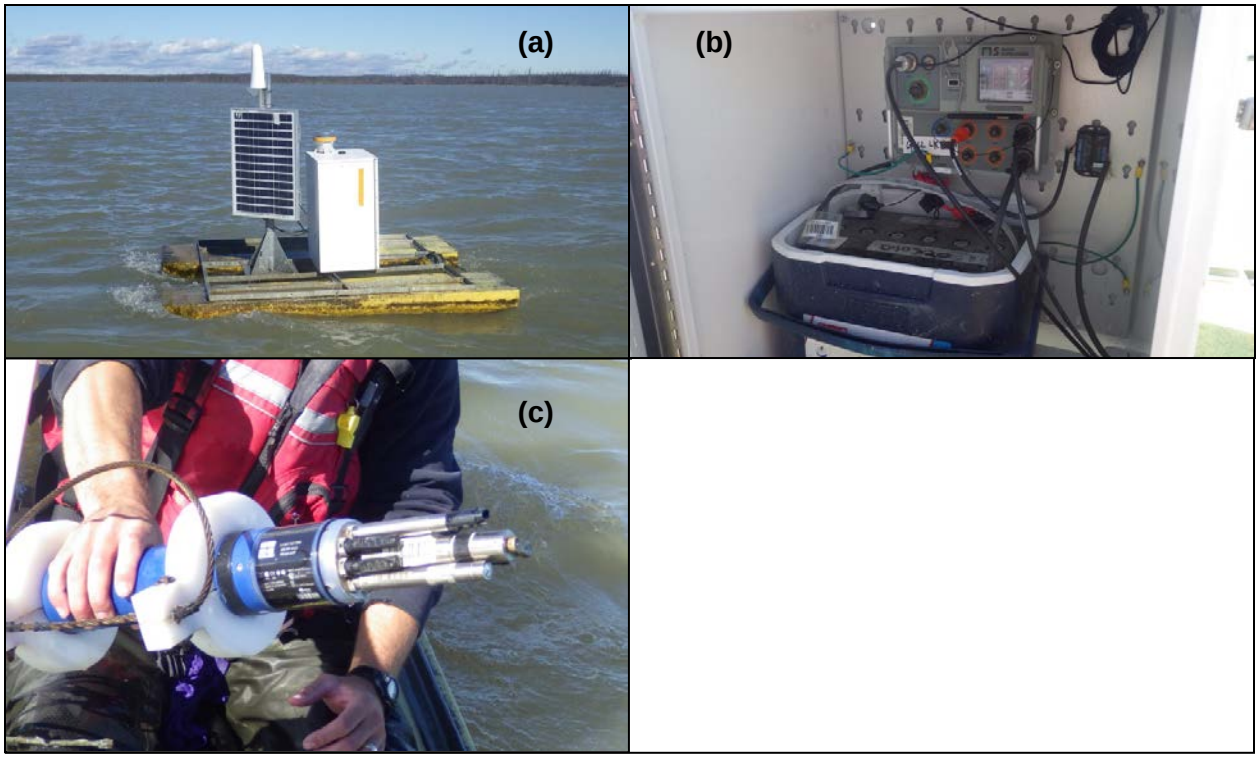


Photo 5: Continuous turbidity monitoring site: (a) catamaran with solar panel, transmitter and electronics cabinet, (b) electronics in cabinet, (c) probe with turbidity sensor installed

The turbidity at each of the sites follows a similar pattern (Figure 13) throughout the monitoring period, with an increase observed in late June dropping in late July before increasing again early September. The Nelson River discharge is highest early in the season and drops throughout the monitoring period, the turbidity levels do not follow the discharge pattern through the summer season. The observed spikes are observed at the site located upstream of any changes in water levels due to the Project (K-Tu-06) and are not caused by the Project. As observed in other years, the increases in turbidity are typically occurring during/after high wind/storm events either upstream or over the monitoring area. The wind speed shown in Figure 13 is taken from the Environment Canada Station at Gillam.

The average summer turbidity (Figure 14) was lower in 2017 than in 2016 and below the overall recorded summer average (24.4 FNU) that includes three pre-construction years and four construction years. The highest summer average to date was in 2008 before construction started. Differences between the sites are similar to observations seen in other years and no discernable changes resulting from the Project are evident.

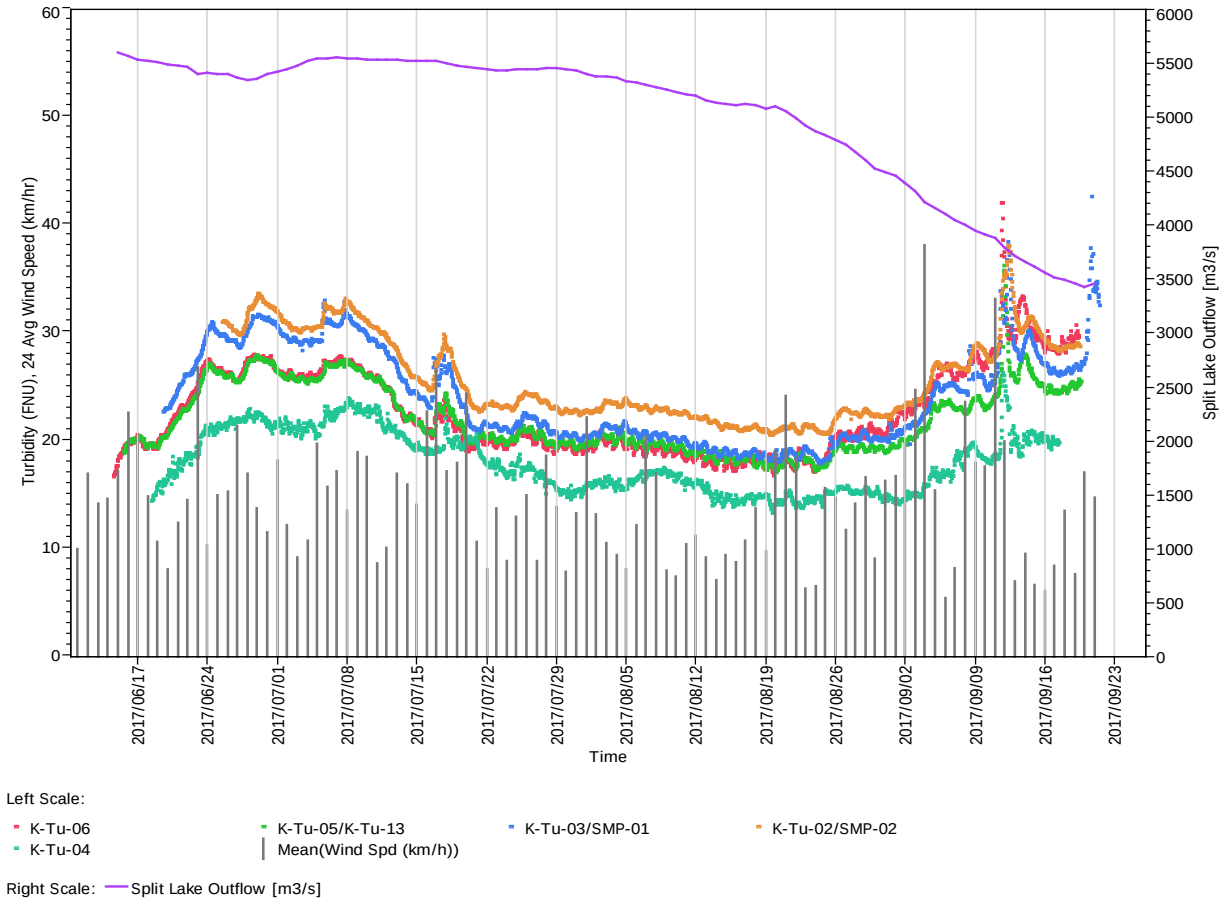


Figure 13: 2017 Summer Continuous Turbidity, Daily Discharge and 24-hr Wind Speed

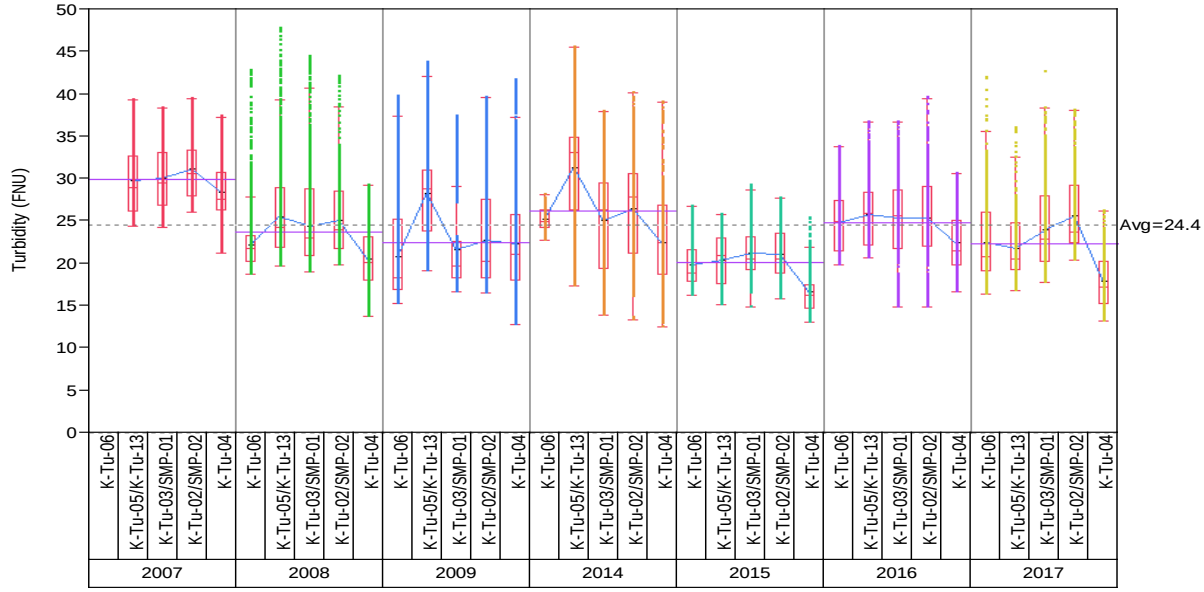


Figure 14: Summary of Summer Continuous Turbidity

4.2.2 DISCRETE TOTAL SUSPENDED SEDIMENT AND TURBIDITY

During the summer period, discrete water samples were taken for total suspended sediment (TSS) testing and in-situ turbidity (Tu) readings at both the discrete monitoring sites and at the continuous turbidity sites (see maps in Appendix A). Discrete sampling was performed four times at each site, typically coinciding with the scheduled maintenance visits at the continuous turbidity sites. The discrete readings are used to verify the continuous readings, confirm readings throughout the entire depth of the site and correlate turbidity and TSS.

The TSS results (Figure 15) range between 6 and 28 mg/L with round 4 in late September having the highest TSS. The fourth round of sampling occurred from 09/17/2017 to 09/21/2017 which coincided with a period of higher turbidity (Figure 13).

Figure 16 and Figure 17 shows the site, year and overall average of summer turbidity and TSS data collected during the pre-construction and construction periods to date under the sedimentation monitoring program. In 2017, the average TSS across the monitoring area was 1.5 mg/L above and the average turbidity was 3.5 FNU below the long term averages. The average inflow (site K-S-09, Clark Lake) TSS was 0.3 mg/L higher and the average inflow turbidity 2.9 FNU lower than the long term average at that site. Comparing pre-construction and during construction data shows there has been little change in summer averages between the inflow site (K-S-09) and the site just downstream of the Project (K-S-07). At K-S-09 the pre-construction average TSS was 15.0 mg/L and turbidity was 25.8 FNU and during construction the average TSS has been 15.9 mg/L and turbidity has been 24.2 FNU. At the site immediately downstream of the Project site (K-S-07) the pre-construction average TSS was 14.8 mg/L and turbidity was 25.6 FNU and during construction the average TSS has been 15.9 mg/L and turbidity has been 23.8 FNU.

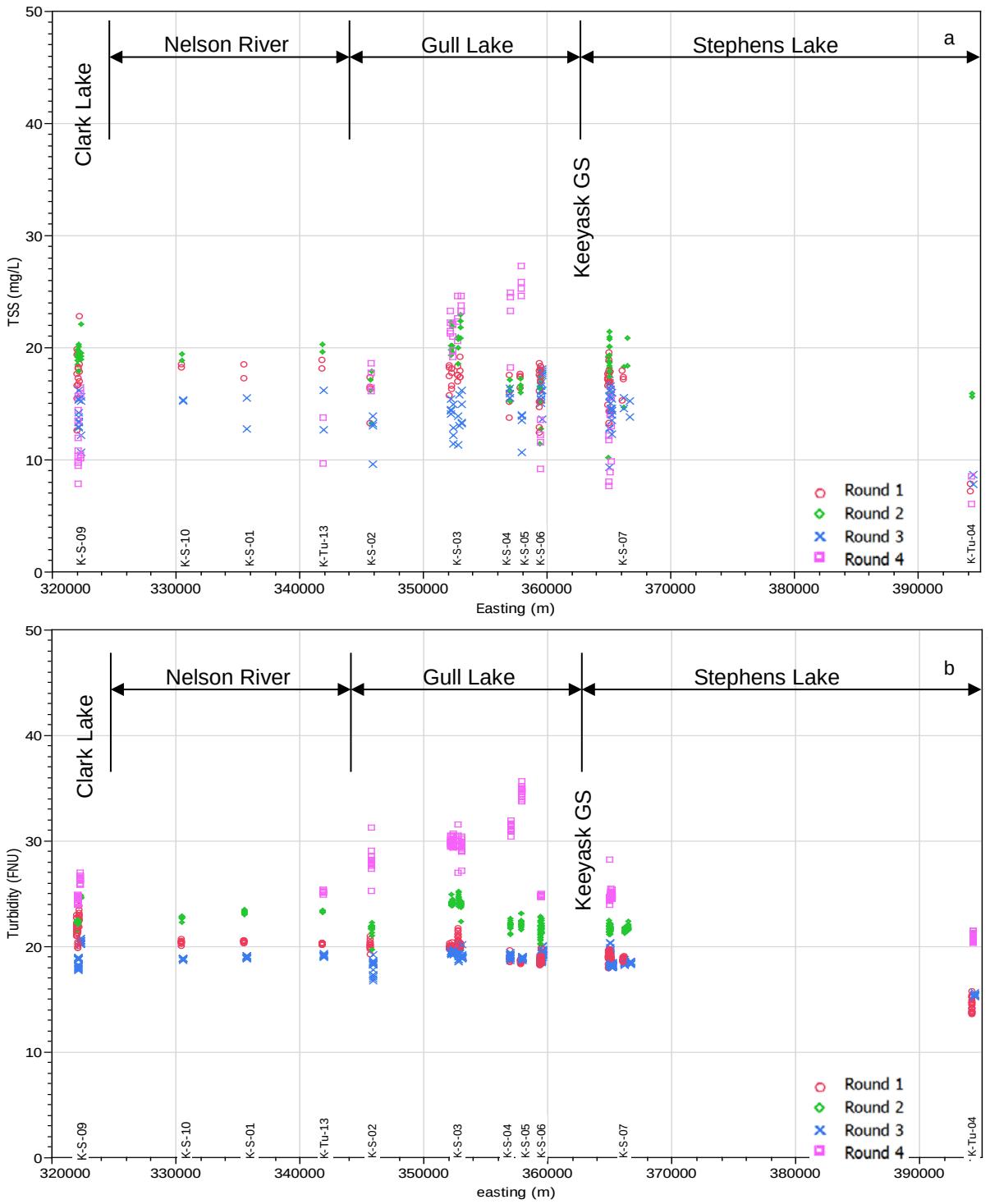


Figure 15: 2017 Summer Discrete TSS (a) and Turbidity (b)

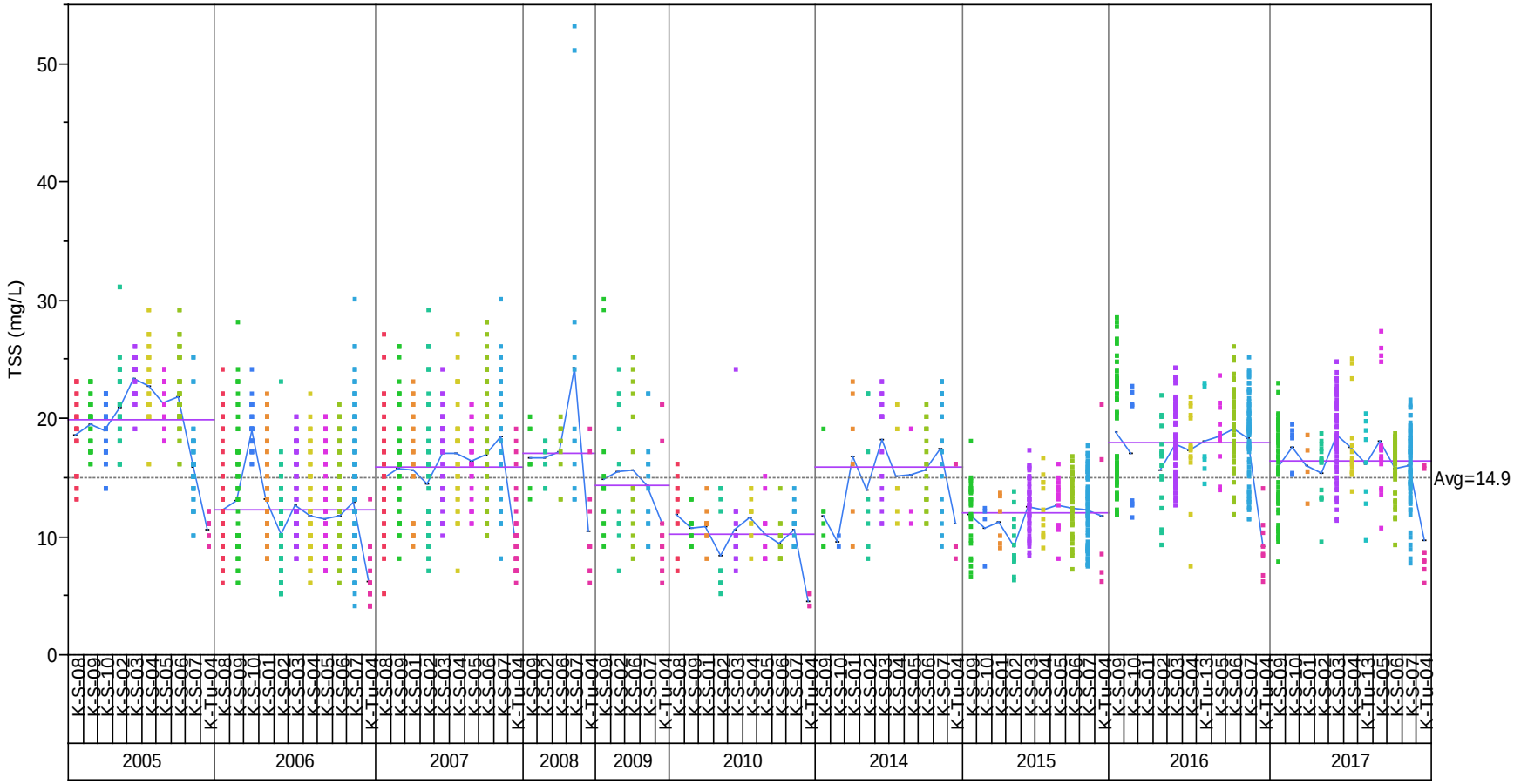


Figure 16: Summary of Summer Discrete TSS

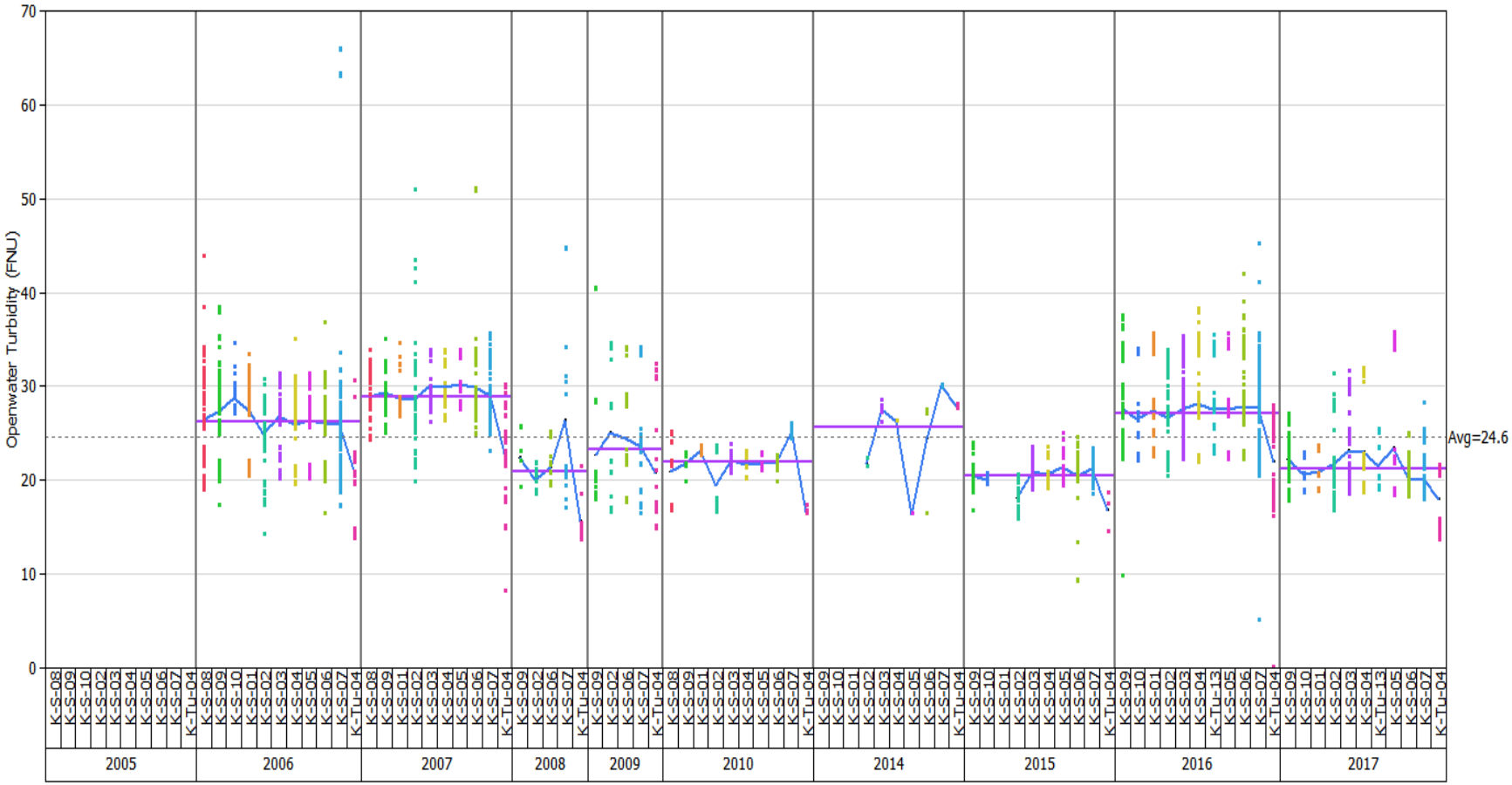


Figure 17: Summary of Summer Discrete Turbidity

4.2.3 ESTIMATED SUSPENDED SEDIMENT LOAD

The summer suspended sediment loads (Figure 18) are estimated based on the average daily turbidity and Keeyask inflow discharge. Turbidity is converted to TSS concentrations using a Turbidity-TSS relationship developed for the SMP.

The 2017 average summer suspended sediment load was close to the long term average (6,566 Tonnes/day), with the last three years all being near or below the long term average. As seen pre-construction in 2007 and 2009 there was an increase in sediment load through Gull Rapids/Keeyask GS construction area (K-Tu-03) to Stephens Lake (K-Tu-02) with a drop in suspended sediment load through Stephens Lake (K-Tu-02 to K-Tu-04).

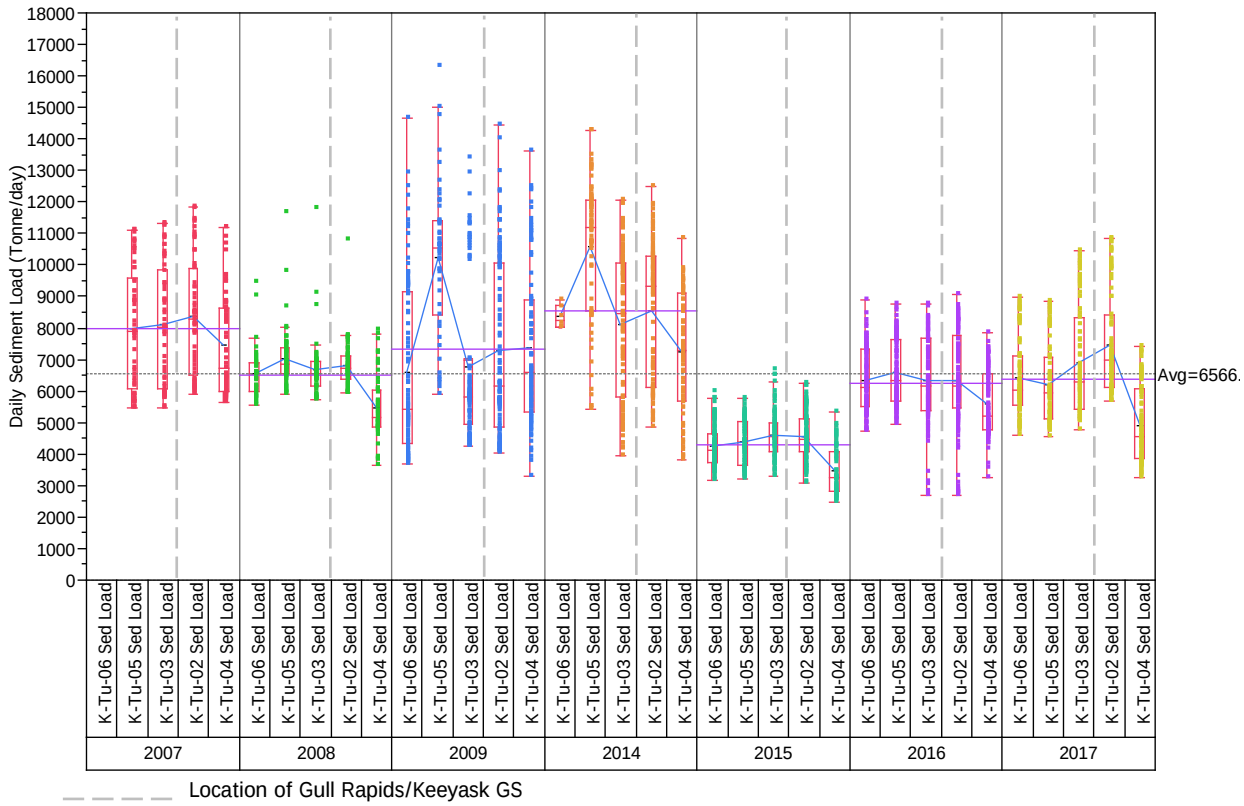


Figure 18: Summary of Summer Daily Sediment Load

4.2.4 DEPOSITION

A 5-tube sediment trap (Photo 7) was installed in Stephens Lake to monitor the sediment accumulation rate over the 2016/17 winter and 2017 summer periods. Due to a technical problem no sediment sample was retrieved during the 2017 summer period. Results from the 2016/17 winter monitoring are shown in Table 5.

The 2016/17 winter period had the highest accumulation rate to date (Table 6) during construction; 1.4 to 2.2 times higher than recorded the previous two winters. Note that this monitoring was not done during pre-construction monitoring periods. The accumulation rates do not correlate to the Winter Suspended Sediment Loading (Figure 12); however, the sediment loading does not cover entire period including the period of freeze up and break up. The winter/spring of 2016/17 saw very high flows in spring which likely explains the higher accumulation rates seen that winter. The sediment collected was primarily comprised of material in the fine sand and smaller grain size ranges with some medium sand (Figure 19).

Photo 6: 5-Tube sediment trap used at site K-ST-02

Table 5: Sediment Trap Monitoring Results for Site K-ST-02 (Stephens Lake)

Sample	flow 1	flow 2	flow 3	settle 1	settle 2	Average
Placed	October 15 2016					
Removed	June 17 2017					
# of Days	245					
Total Dry Mass (g)	391	418	385	328	515*	407
Accumulation Rate ($g/m^2/day$)	216	231	213	181	285*	225
Sand	75	84	78	76	78	78
Silt	21	13	18	20	18	18
Clay	4	3	4	4	4	4

*Sample jar overfilled

Table 6: Average Sediment Trap Accumulation Rates for Site K-ST-02 (Stephens Lake)

Monitoring Period	Average Accumulate Rate (g/m2/day)	Number of Days
Winter 2014-15	100	277
Summer 2015	173	72
Winter 2015-16	157	309
Summer 2016	120	68
Winter 2016-2017	225	245
Summer 2017	na	na

na – not available

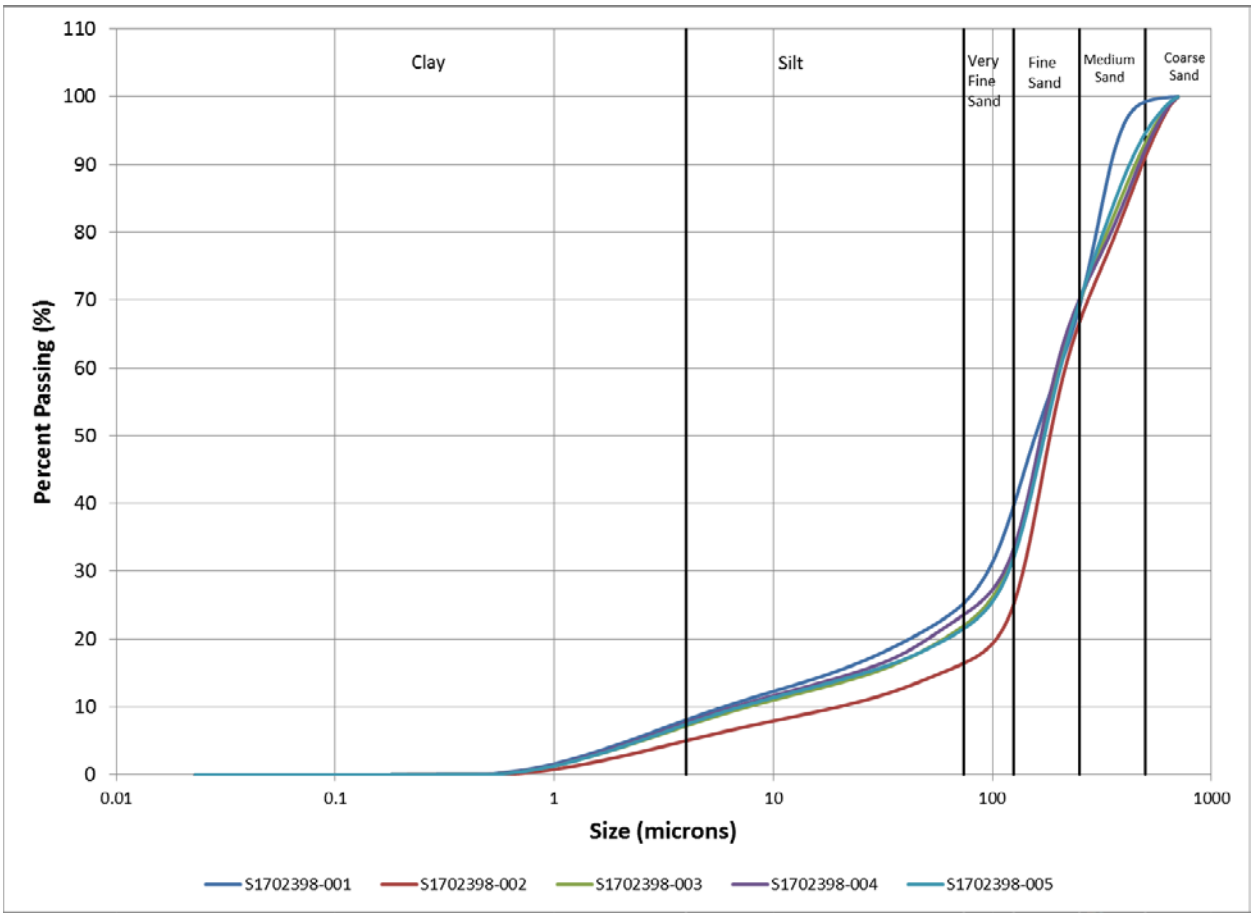
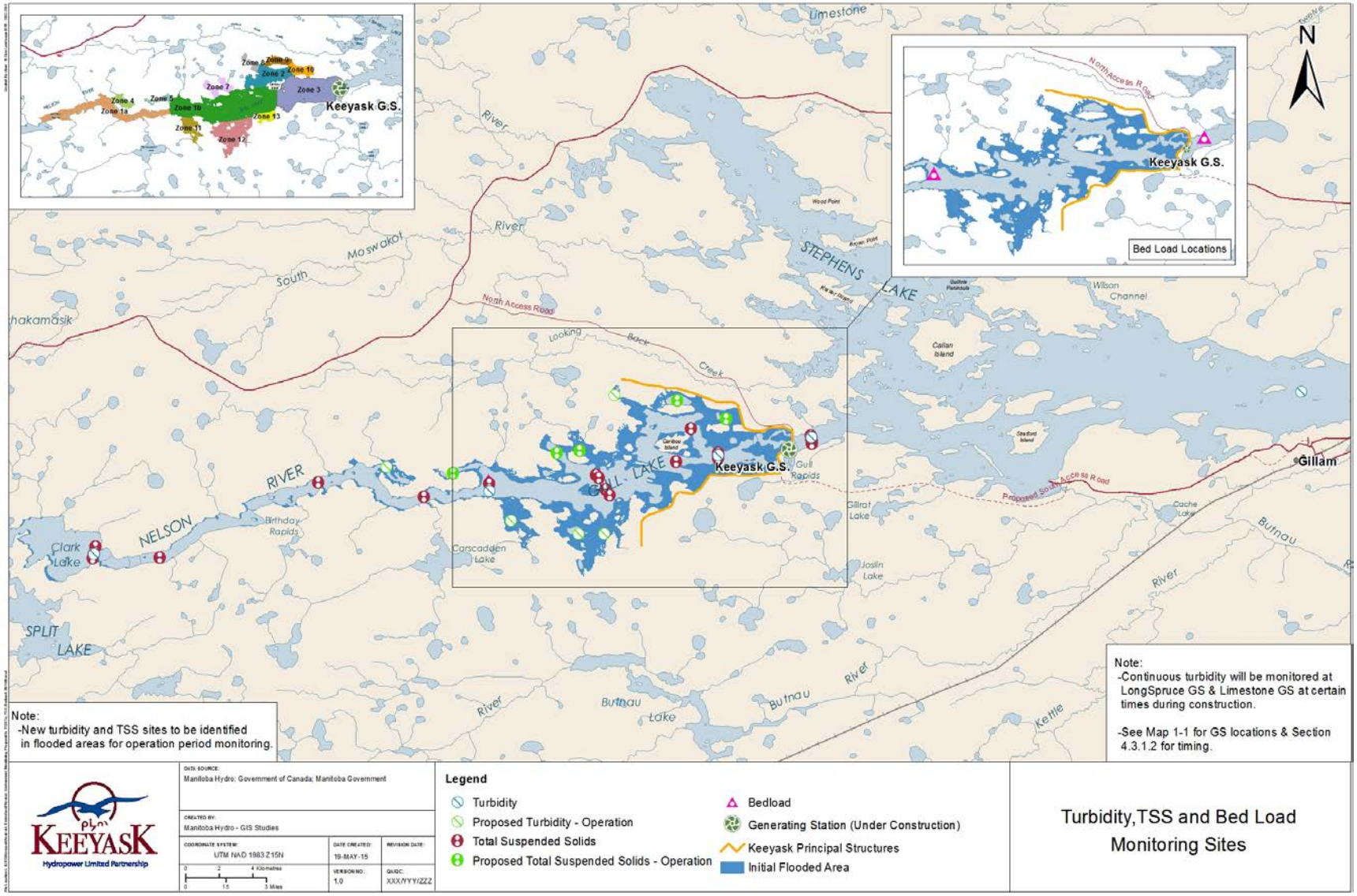


Figure 19: Sediment Trap Grain Size Distributions



Map 4: Turbidity, total suspended solids and bed load monitoring sites

5.0 ORGANIC CARBON

Organic carbon in the water is not expected to be affected by construction prior to impoundment of the reservoir. However, it is being measured during the construction period to provide baseline information. When the reservoir is filled, it will flood organic material such as peat and vegetation that may add organic carbon to the water in both dissolved and particulate forms.

Discrete water samples were obtained at up to 11 sites once a month from June to September, with sampling being done the second or third week of the month. These water samples were tested to measure the concentrations of Dissolved Organic Carbon (DOC) and Total Organic Carbon (TOC). These results are used to calculate the amount of Particulate Organic Carbon (POC), since POC is equal to TOC minus DOC. Up to 23 separate test locations were sampled each month because some sites have multiple test locations across the width of the river (e.g., site K-S-03 has sampling locations a, b, c, and d across the river). The monitoring results did not indicate any trends in organic carbon across the river width at any of the sampling sites (e.g., results didn't show one side to be higher than the other). For this reason, where a site has more than one sample location, the results for each month have been summarized by simply averaging the concentrations obtained at each location to produce a site average concentration. In the chart, some results do not show anything for POC.

There are cases where the laboratory result for TOC was less than the result for DOC, which produces in a negative value for POC. Where this occurs, only the DOC is plotted and is assumed to represent the TOC for the site (i.e., assumes no POC). Although DOC cannot technically be greater than TOC, this can occur in the test results because both parameters have a measurement accuracy of approximately +/-1 mg/l. Within the monitoring area TOC and DOC are typically nearly equal so the DOC test result can end up larger than the TOC value within the range of testing accuracy.

From all the results, the site averaged TOC ranged from about 8-10 mg/L and was predominantly comprised of DOC as site averaged POC was typically 0.5 mg/l or less in those cases where TOC was greater than DOC (Figure 20). In each month the site average TOC concentrations vary by 1 mg/L or less across the sites and over the season it only varies over a range of about 2 mg/l. The total organic carbon concentrations measured in summer 2017 are of a similar magnitude and overall range as in 2016. Observations in 2017 are consistent with those reported in the Keeyask EIS for the pre-construction period (KHLP 2012c, Appendix 2H) and, as before, show organic carbon is present primarily in dissolved form.

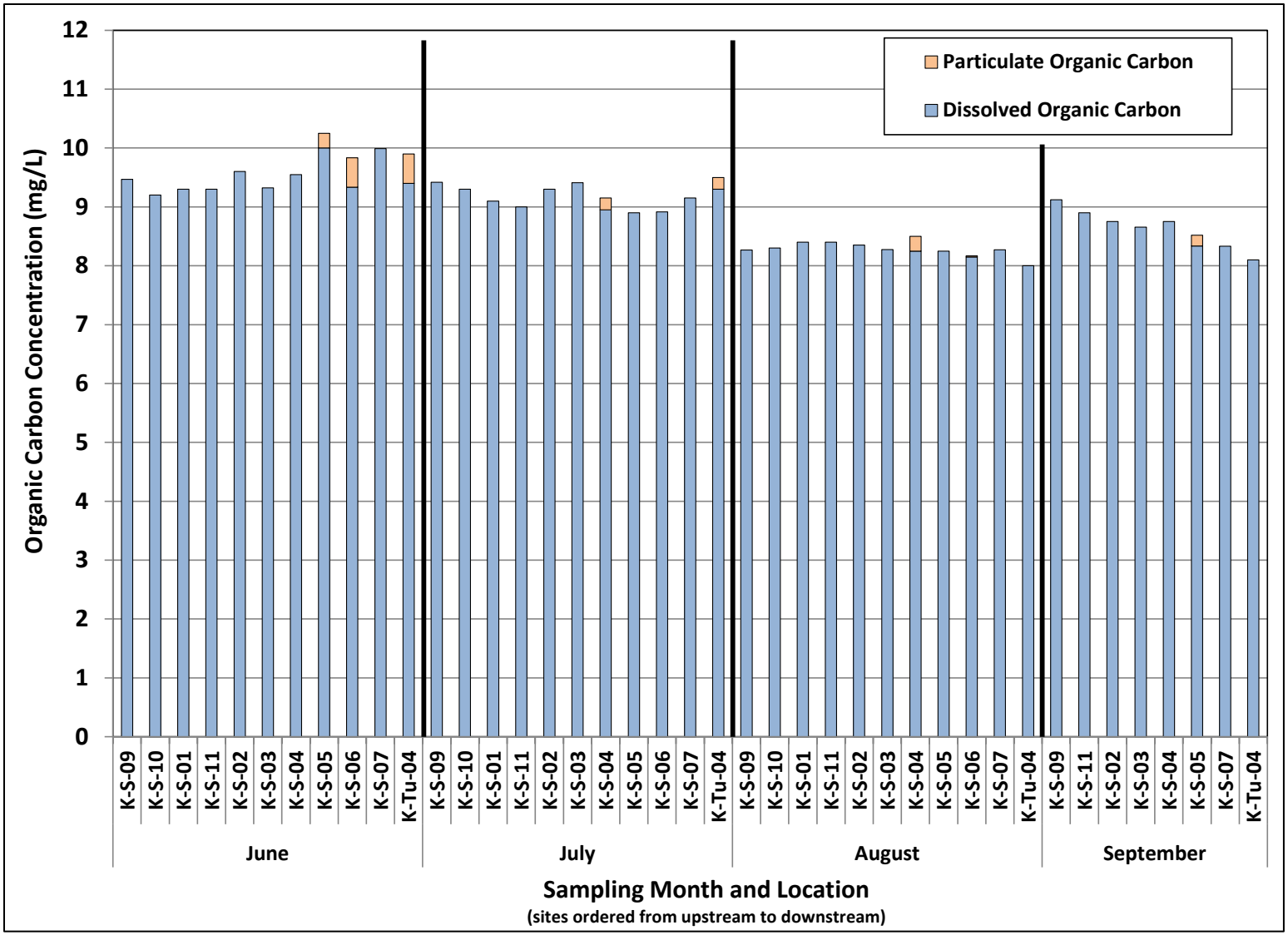


Figure 20: Summary of particulate, dissolved and total organic carbon

6.0 DISSOLVED OXYGEN

The in-situ monitoring performed during site visits included measuring the water temperature and dissolved oxygen (DO) concentration at the sites. Based on the water temperature, the DO saturation concentration can be calculated using a standard formula (USEPA 1985). Saturation concentration is the equilibrium DO concentration that the water will preferentially attain for a given water temperature. Water at low temperatures can hold more DO and thus has a higher saturation concentration than water at high temperatures. The degree of saturation, or percent saturation, is calculated as the actual DO concentration in the water divided by the saturation concentration. When the actual DO concentration equals the saturation concentration it is referred to as being “saturated”, whereas water with a DO greater than the saturation level is “super saturated”. The amount of oxygen dissolved in the water will attempt to balance out at the saturation concentration (i.e., 100% saturation) by exchanging oxygen with the atmosphere.

Pre-construction monitoring found that DO concentrations were typically at or near saturation concentration in the physical environment monitoring area. During construction, prior to reservoir impoundment, the Project is not anticipated to affect DO (KHLP 2012b, Section 9). As observed in 2015 and 2016, the monitoring results from summer 2017 confirmed this. DO concentrations ranged from a low of 8.3 mg/L in August to a high of 10.5 mg/L in June (Figure 21). The lowest DO concentrations occurred in August when water temperatures were warmest at about 21ºC, while the highest concentrations were observed in June when water temperatures were low at about 13-15ºC (Figure 22). In each month, the DO concentration varied over a small range of about 0.5 mg/l between the highest and lowest readings across all sites, consistent with expectations from pre-Project studies that DO would remain steady through the monitoring area. The highest concentrations in each month typically occurred at site K-S-07 below Gull Rapids, which may be anticipated as turbulent flow through the rapids adds oxygen to the water. There is no apparent effect of construction on in-stream DO concentrations.

Overall, the saturation levels varied from a low of about 92% to a super saturated high of 102% (Figure 21), the same as observed in 2016. The average saturation level at the monitoring sites over the entire summer varied from about 93% to 97%. The lowest levels of saturation occurred in September for most sites while June was generally the highest. In each month, the highest levels of saturation typically occur at site K-S-07 just below Gull Rapids (Figure 21). While DO concentrations showed little variation across sites, the degree of saturation tended to decline downstream (except through Gull Rapids) because temperatures tended to cool slightly, about 0.5-1.5 ºC, moving downstream from Split Lake (Figure 22).

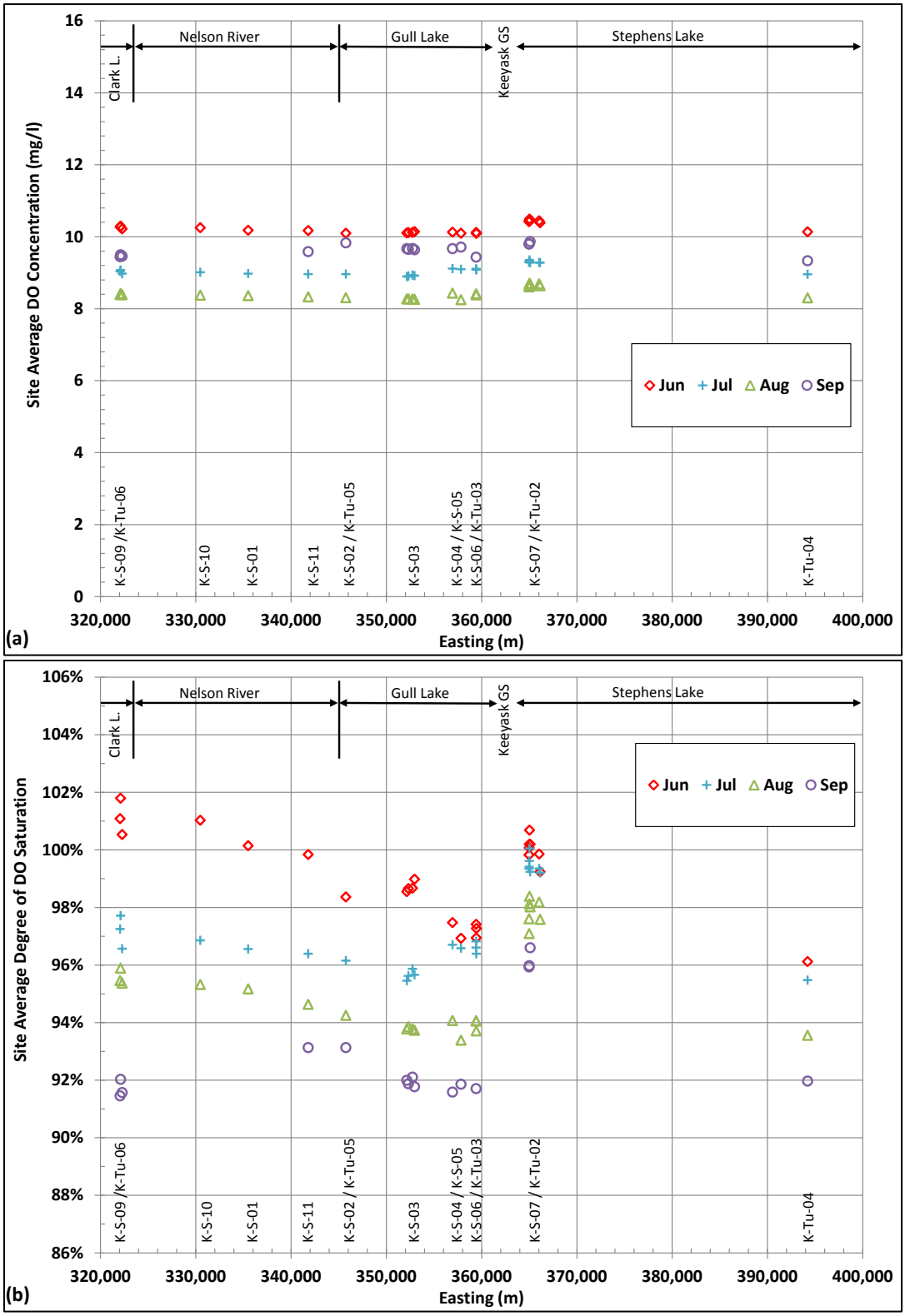


Figure 21: Summer 2017 discrete monitoring results: (a) dissolved oxygen concentration (b) degree of saturation

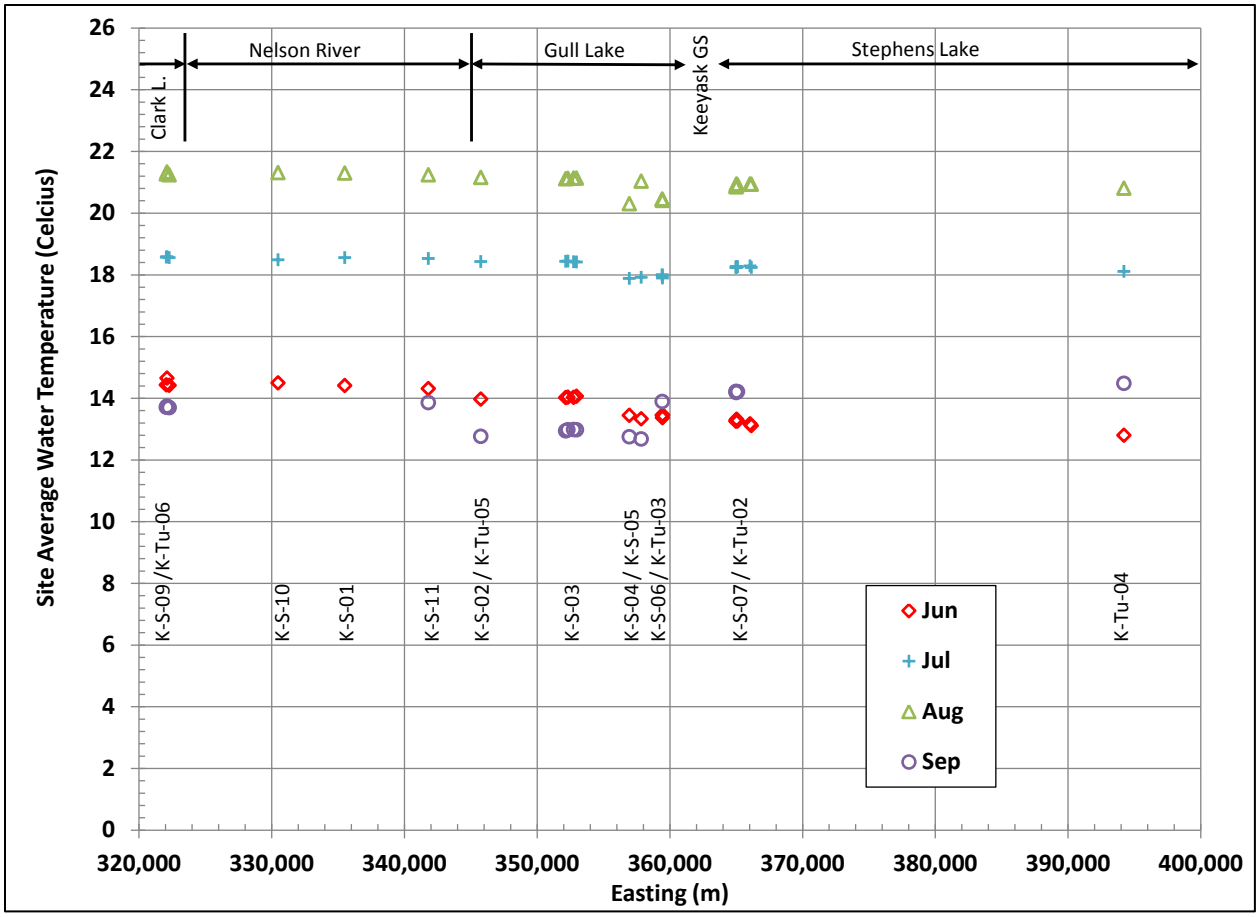


Figure 22: Summer 2017 discrete monitoring results: water temperature

7.0 DEBRIS

As part of the Project, in accordance with the Joint Keeyask Development Agreement (TCN et.al. 2009), a waterways management program was implemented in 2015 for the Project area from Clark Lake to Gull Rapids. A component of this program is the operation of a two-person boat patrol to identify and remove floating woody debris that may pose a safety hazard to navigation. Based out of the Split Lake community, the boat patrol was staffed by members of Tataskweyak Cree Nation and operated regularly in the Project area during the open water season, weather conditions permitting. Prior to 2015, this area was only visited about once each week (20% of the time) by the boat patrol that also operated on Split Lake and the amount of debris collected in the Clark to Gull Lake area was estimated to be 20% of the total amount of debris collected by the work crew.

The data from 2017 was not available at the time of reporting and will be included in next year's report.

Table 7: Debris Removed from the Keeyask Area

Year	Small (<1 m)	Large (> 1m)			
		New	Old	Beaver	Total
2003	3	4	7	0	11
2004	36	1	140	0	141
2005	2	6	103	0	109
2006	11	1	65	0	66
2007	0	3	81	0	84
2008	1	0	49	1	49
2012	0	1	30	1	32
2014	2	1	59	0	60
2015	4	0	6	0	10
2016	3	1	2	0	6
2017	Not available at the time of reporting				

8.0 LITERATURE CITED

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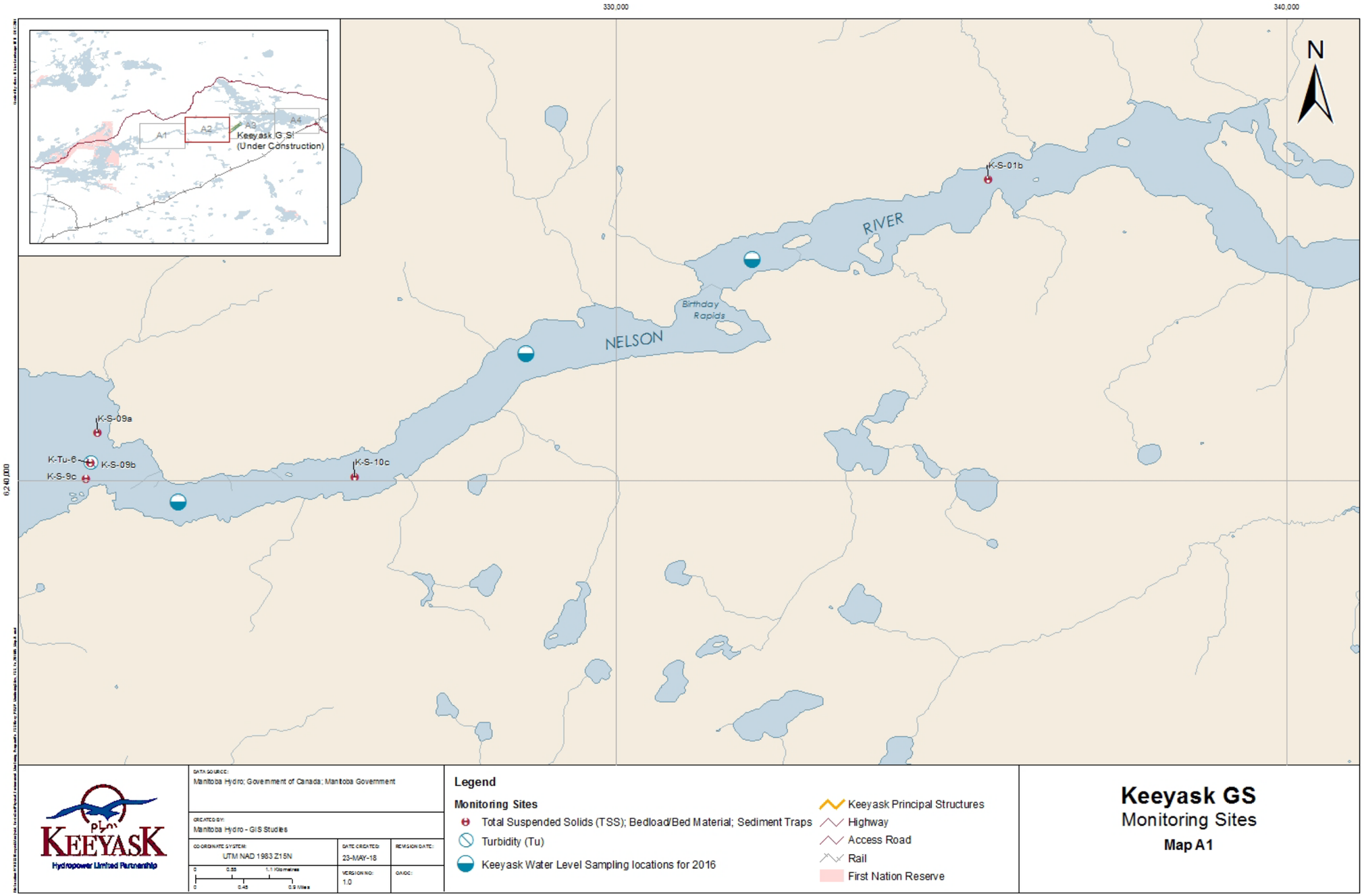
APPENDIX 1:
DETAILED MAPS OF TURBIDITY AND TSS MONITORING SITES


330,000
340,000
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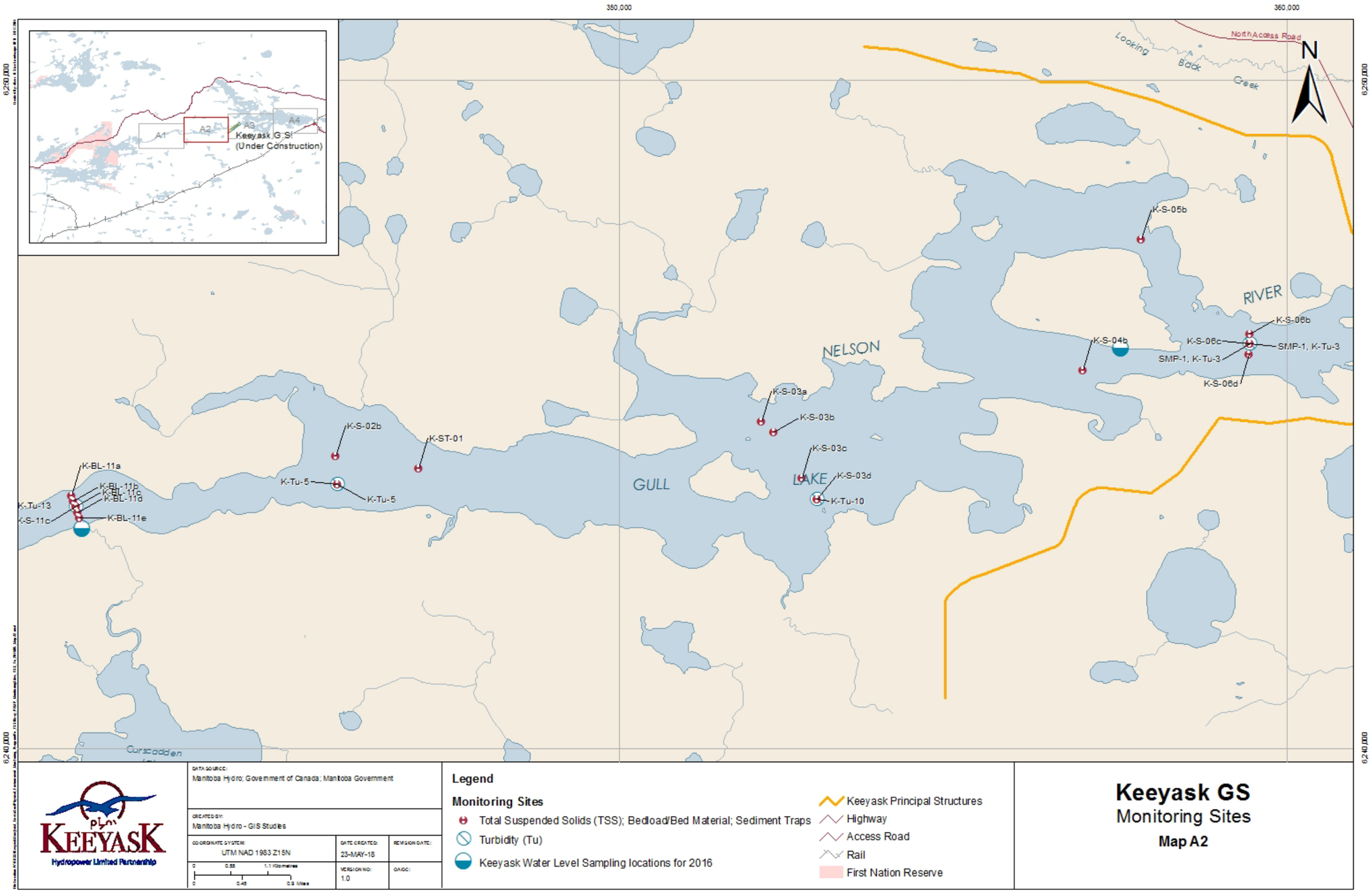
N
A1
A2
A3
A4
Keeyask G.S.
(Under Construction)
K-S-01b
RIVER
Birthday Rapids
NELSON
K-S-09a
K-Tu-6
K-S-09b
K-S-9c
K-S-10c
KEEYASK
Hydropower Limited Partnership
DATA SOURCE:
Manitoba Hydro; Government of Canada; Manitoba Government
CREATED BY:
Manitoba Hydro - GIS Studies
COORDINATE SYSTEM:
UTM NAD 1983 Z15N
DATE CREATED:
23-MAY-18
REVISION DATE:
VERSION NO:
1.0
CHKD:
Legend
Monitoring Sites
Total Suspended Solids (TSS); Bedload/Bed Material; Sediment Traps
Turbidity (Tu)
Keeyask Water Level Sampling locations for 2016
Keeyask Principal Structures
Highway
Access Road
Rail
First Nation Reserve
Keeyask GS
Monitoring Sites
Map A1


350,000
360,000
6,250,000
6,240,000
A1
A2
A3
A4
Keeyask GS
(Under Construction)
North Access Road
Looking Back Creek
N
RIVER
NELSON
GULL
LAKE
Curscadden
K-S-05b
K-S-06b
K-S-06c
K-S-06d
K-S-04b
SMP-1, K-Tu-3
K-S-03a
K-S-03b
K-S-03c
K-S-03d
K-Tu-10
K-S-02b
K-ST-01
K-Tu-5
K-BL-11a
K-BL-11b
K-BL-11c
K-BL-11d
K-BL-11e
K-Tu-13
K-S-11c
DATA SOURCE:
Manitoba Hydro; Government of Canada; Manitoba Government
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23-MAY-18
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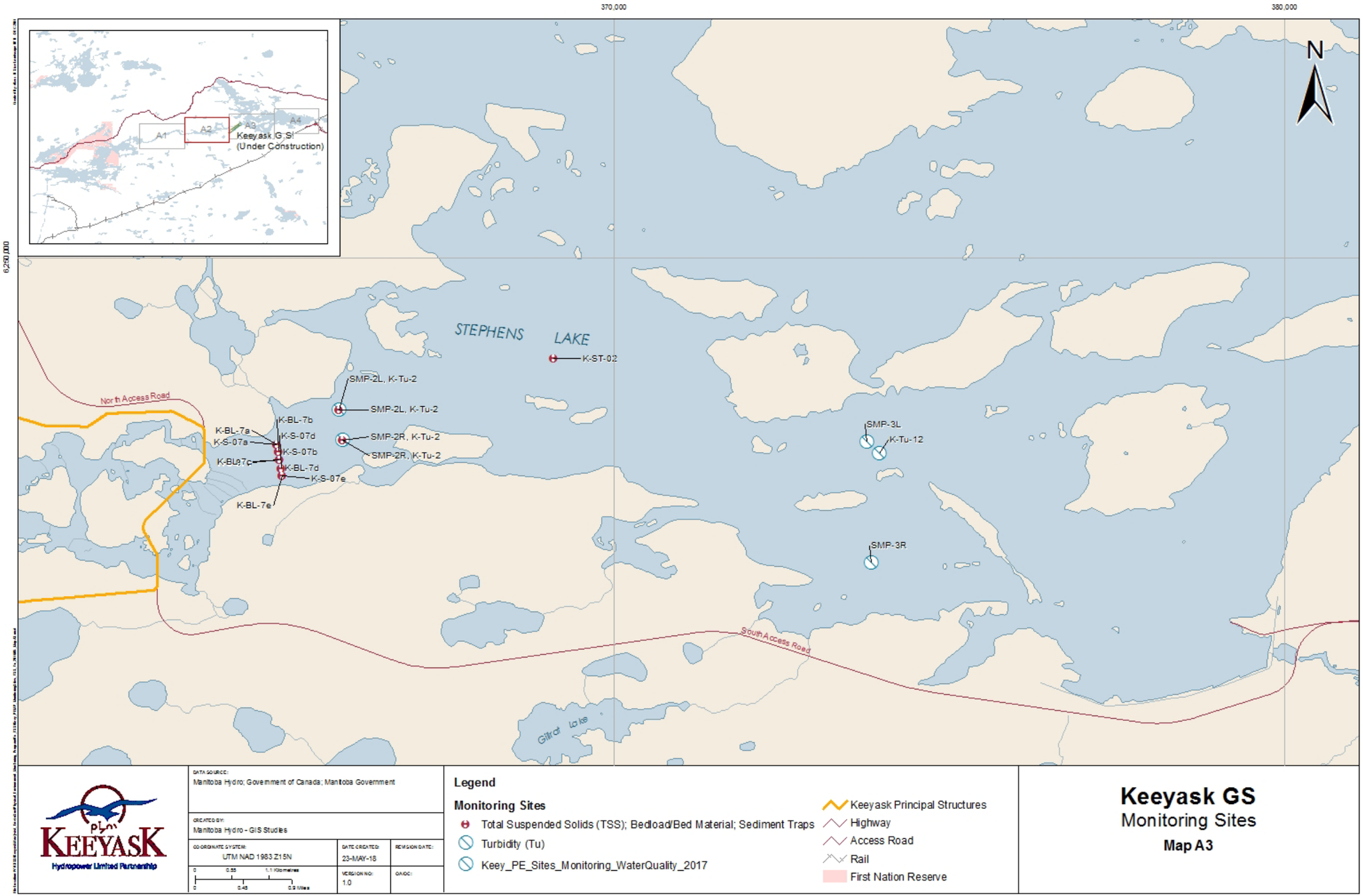
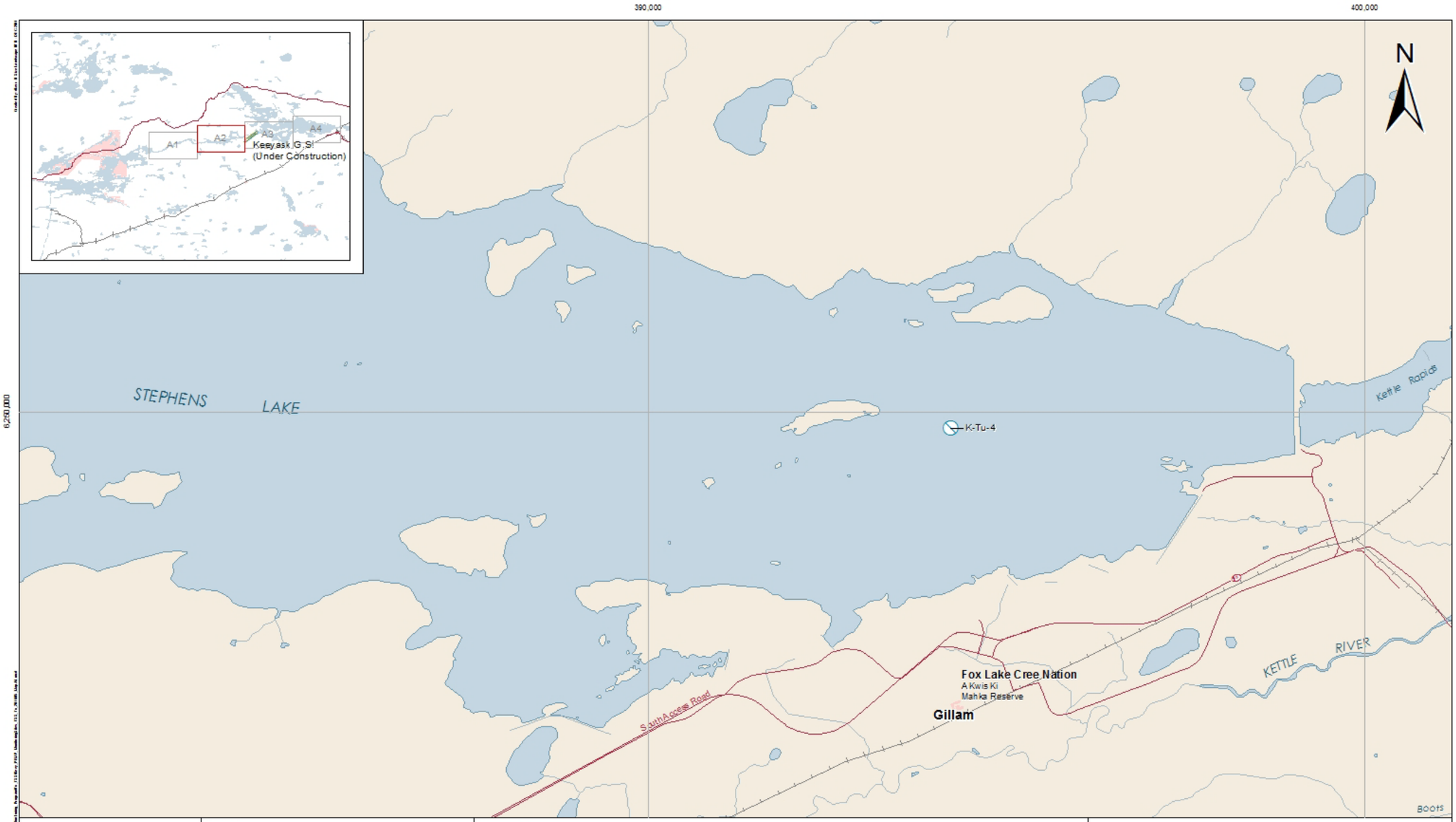
VERSION NO:
1.0
DWG:
KEEYASK
Hydropower Limited Partnership
Legend
Monitoring Sites
Total Suspended Solids (TSS); Bedload/Bed Material; Sediment Traps
Turbidity (Tu)
Keeyask Water Level Sampling locations for 2016
Keeyask Principal Structures
Highway
Access Road
Rail
First Nation Reserve
Keeyask GS
Monitoring Sites
Map A2


370,000
380,000
6,290,000
N
A1
A2
A3
A4
Keeyask G.S.
(Under Construction)
STEPHENS LAKE
K-ST-02
SMP-2L, K-Tu-2
SMP-2L, K-Tu-2
SMP-2R, K-Tu-2
SMP-2R, K-Tu-2
SMP-3L
K-Tu-12
SMP-3R
North Access Road
South Access Road
K-BL-7a
K-S-07a
K-BL-7b
K-S-07d
K-S-07b
K-BL-7c
K-BL-7d
K-S-07e
K-BL-7e
Gillrod Lake
DATA SOURCE:
Manitoba Hydro; Government of Canada; Manitoba Government
CREATED BY:
Manitoba Hydro - GIS Studies
COORDINATE SYSTEM:
UTM NAD 1983 Z15N
DATE CREATED:
23-MAY-18
REVISION DATE:
VERSION NO:
1.0
DWG:
0 0.55 1.1 Kilometers
0 0.45 0.9 Miles
Legend
Monitoring Sites
Total Suspended Solids (TSS); Bedload/Bed Material; Sediment Traps
Turbidity (Tu)
Keey_PE_Sites_Monitoring_WaterQuality_2017
Keeyask Principal Structures
Highway
Access Road
Rail
First Nation Reserve
Keeyask GS
Monitoring Sites
Map A3



KEEYASK Hydropower Limited Partnership

DATA SOURCE: Manitoba Hydro; Government of Canada; Manitoba Government

CREATED BY: Manitoba Hydro - GIS Studies

COORDINATE SYSTEM: UTM NAD 1983 Z15N

DATE CREATED: 23-MAY-18

REVISION DATE:

0 0.55 1.1 Kilometres

0 0.45 0.9 Miles

VERSION NO: 1.0

CHKD:

Legend

Monitoring Sites

- Total Suspended Solids (TSS); Bedload/Bed Material; Sediment Traps
- Turbidity (Tu)
- Keeyask Water Level Sampling locations for 2016
- Keeyask Principal Structures
- Highway
- Access Road
- Rail
- First Nation Reserve

Keeyask GS
Monitoring Sites
Map A4