Keeyask Generation Project

Physical Environment Monitoring Plan

Physical Environment Monitoring Report

PEMP-2019-01

KEEYASK

Manitoba Sustainable Development Client File 5550.00
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2018 - 2019

KEEYASK GENERATION PROJECT

PHYSICAL ENVIRONMENT MONITORING PLAN

REPORT #PEMP-2019-01

2018-2019 PHYSICAL ENVIRONMENT MONITORING REPORT: YEAR 5 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 2018/19 monitoring period.

Water and Ice Regime

The water and ice monitoring parameters include water levels, water depth, water velocity, and ice cover; velocity and depth monitoring are planned to occur after the reservoir is created. 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 seasonal flows during the 2018/19 monitoring year were the lowest since the start of construction. Flows were near the historical median value much of the time near 3300 m^2/s except in fall when flows fell to levels seen less than 25% of the time.

In August 2018, the spillway came into operation and by mid-August rock had been pushed across the south channel and all water was passing through the spillway. The river closure did not affect water levels at any of the water level gauges.

Nelson River Being Closed-off with Spillway in Operation

Ice monitoring is done using satellite imagery and photographs taken along the length of the study area during monthly field trips. The 2018/19 winter saw the early ice cover formation on Gull Lake in early November similar to the previous year; about 2 weeks earlier than the first two winters with the ice boom in place. Once again the leading ice front reached about 6 km upstream of Birthday Rapids by the end of January, remaining there until mid-April, similar to the previous winter.

Sedimentation

Sedimentation monitoring includes studying how sediment is carried (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.

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.

In early August, an increase in turbidity was observed downstream of the Project in Stephens Lake during spillway commissioning over about 5 days. The increase was expected and was lower than had been predicted. Outside of the spillway commissioning period, the average summer turbidity was the second lowest observed during the eight years of monitoring, including three years of pre-construction monitoring, and no discernable changes resulting from the Project were evident.

In winter, the results continue to show 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 2017/18 winter and 2018 summer suspended sediment load was the lowest observed during monitoring both pre-construction and during construction to date.

Winter Sedimentation Monitoring on Clark Lake

In the spring of 2018, two sediment traps were installed in Stephens Lake, reconfigured to allow for easier field handling of the equipment. 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 since 2016 because of adverse conditions that previously resulted in losing monitoring equipment at this location. Traps installed over the 2017/18 winter could not be retrieved in the spring and are assumed lost.

The 2018 summer period had the lowest accumulation rate to date during construction. While the 2015 average sediment load was similar to 2018, the sediment rate in 2015 was over three times higher. While inconclusive, it is suspected that the results were lower due to sampling equipment issues.

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. The amount of floating debris reported in 2018 was 10 pieces which is similar to amounts recorded in 2015 and 2016.

Reservoir Greenhouse Gas

The purpose of Keeyask reservoir greenhouse gas monitoring program is to enable the comparison of aquatic greenhouse gas (GHG) concentrations and emissions before and after reservoir creation.

Reservoir GHG monitoring was conducted annually prior to construction of the Project from 2009 to 2013 and during the first year of construction in 2014.

The amount of carbon exchanged between the oceans, atmosphere, land, and living things is known as the carbon dioxide flux. The flux results recorded in 2018 are similar to those of other ecosystems similar to the Keeyask area and previous monitoring results.

The pre-construction and construction period GHG monitoring results will be compiled and the plan is to report the entire pre-flooding information in next year's monitoring report. This will enable the comparison of pre and post flood GHG measurements to determine the impact of impoundment.

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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 2018 to March 2019, the fifth year of construction monitoring. When information is not available the information will be reported in the following year's monitoring report.

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:

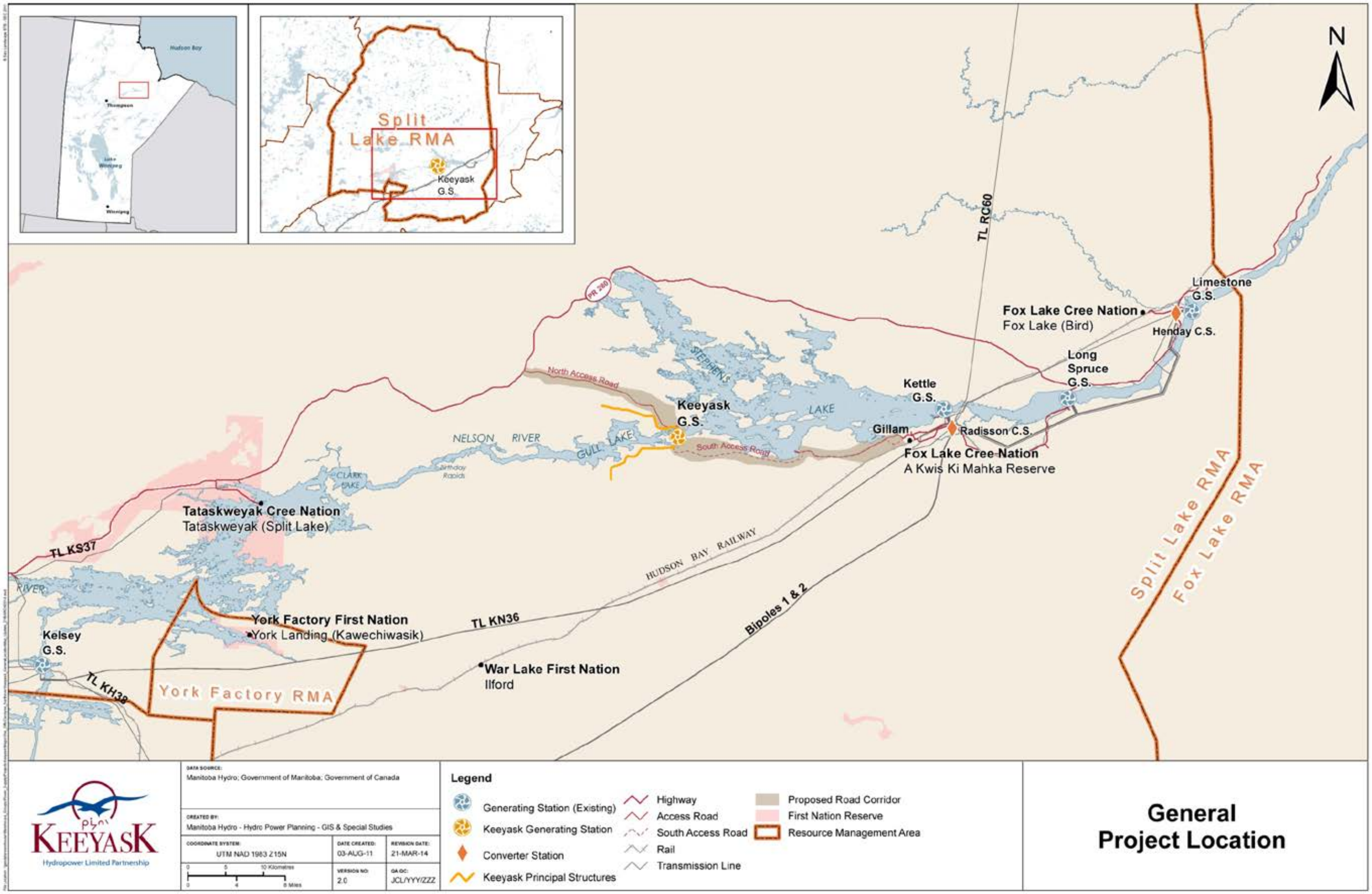
- Determine if EIS predictions of Project effects on the physical environment are correct and to identify unanticipated effects.
- Support other monitoring programs (e.g., aquatic and terrestrial) that will monitor Project effects and determine the effectiveness of mitigation and offsetting measures.

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 2018/19, physical environment monitoring included surface water and ice regime, sedimentation, dissolved oxygen, greenhouse gases, 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 which 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. Annual seasonal flows are summarized in Table 1; the summer flows are taken as May through October and winter flows from November through April.

The seasonal flows during the 2018/19 monitoring year were on average the lowest since the start of construction. Since the record high flow in the spring of 2017 the flows have reduced to near average or below average for much of the time (Figure 1).

Table 1: Annual Seasonal Discharges

Year / Season	Minimum (m^3/s)	Mean (m^3/s)	Maximum (m^3/s)
2014 Summer	5099	5518	5793
2014/15 Winter	3372	3825	5043
2015 Summer	3456	3744	4264
2015/16 Winter	3461	3712	3921
2016 Summer	3247	4072	4753
2016/17 Winter	3651	4202	4815
2017 Summer	3215	4888	6585
2017/18 Winter	2873	3472	3992
2018 Summer	2616	3095	3572
2018/19 Winter	2985	3313	3641

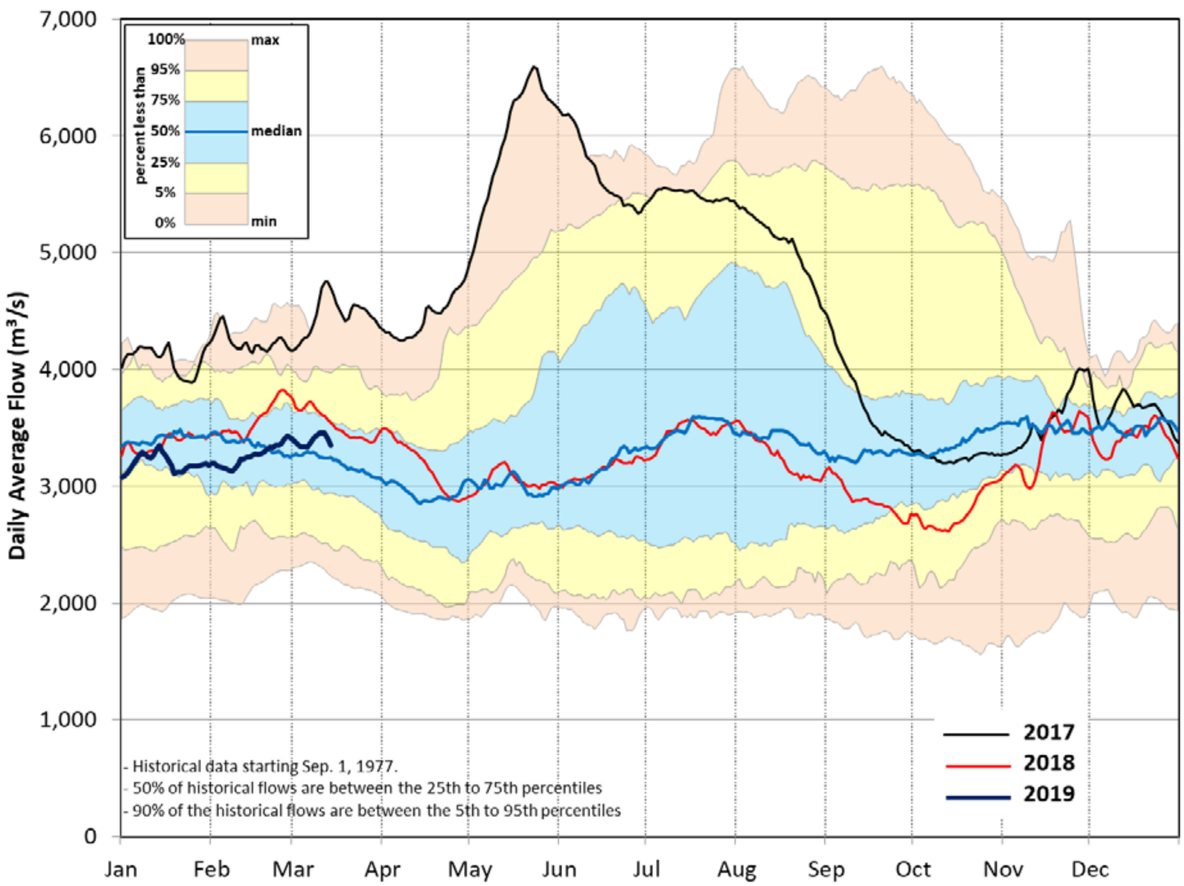


Figure 1: Split Lake 2018/2019 daily average outflow and historical statistics

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.

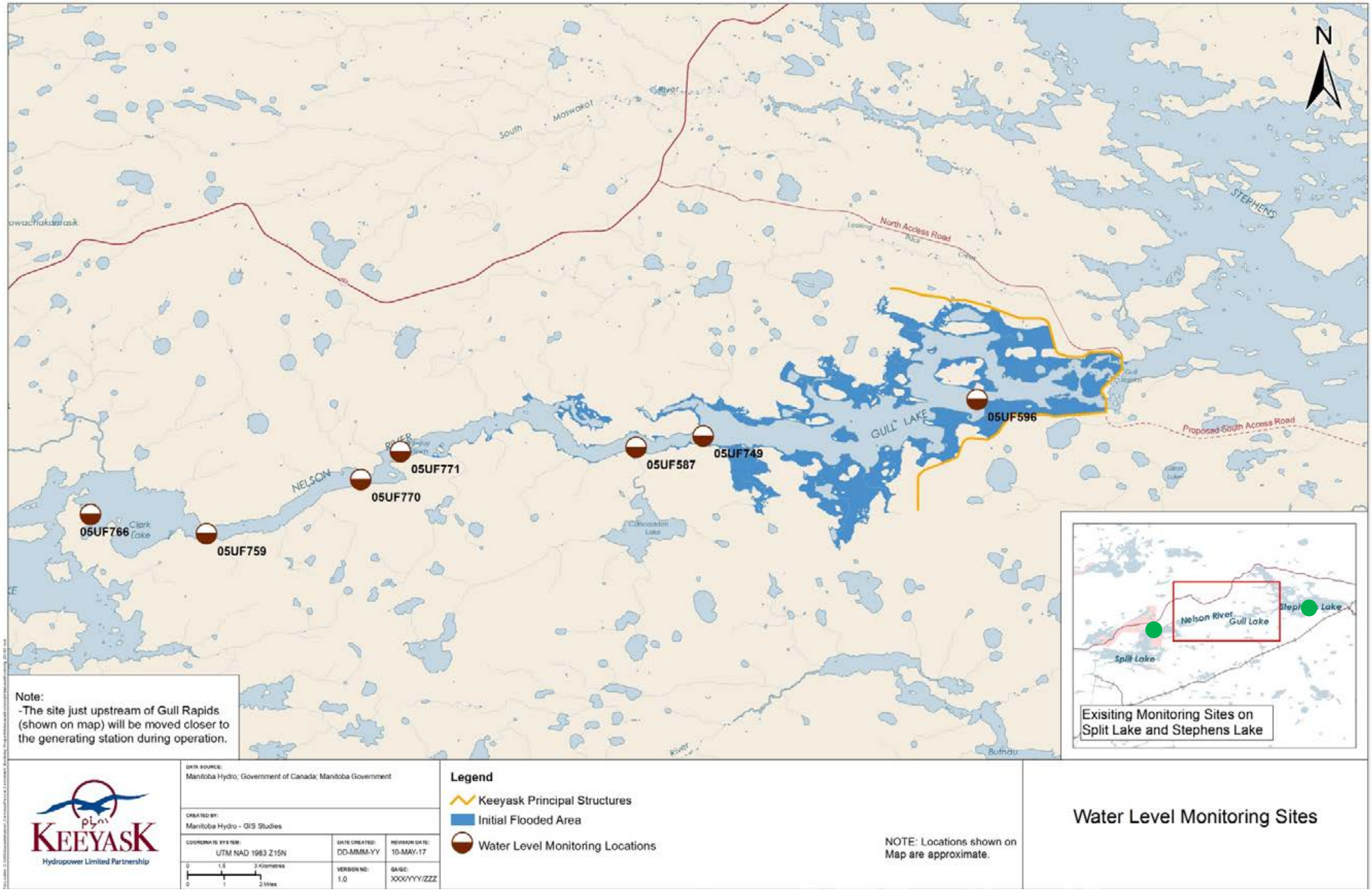
Water levels during the 2018/19 monitoring period saw little variation as the river discharge only saw small changes throughout the period. The drop in water levels in April/May 2018 and the 4 to 5 m increase in water level upstream of Gull Lake and smaller increases elsewhere in November 2018 are the result of ice process which is an annual occurrence.

No changes in water levels were observed at the monitoring stations due to 2018/19 construction activities. Map 3 shows the approximate water level increases due to the North Channel Rock Groin (open water conditions) that occurred in 2016.

Table 2: 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

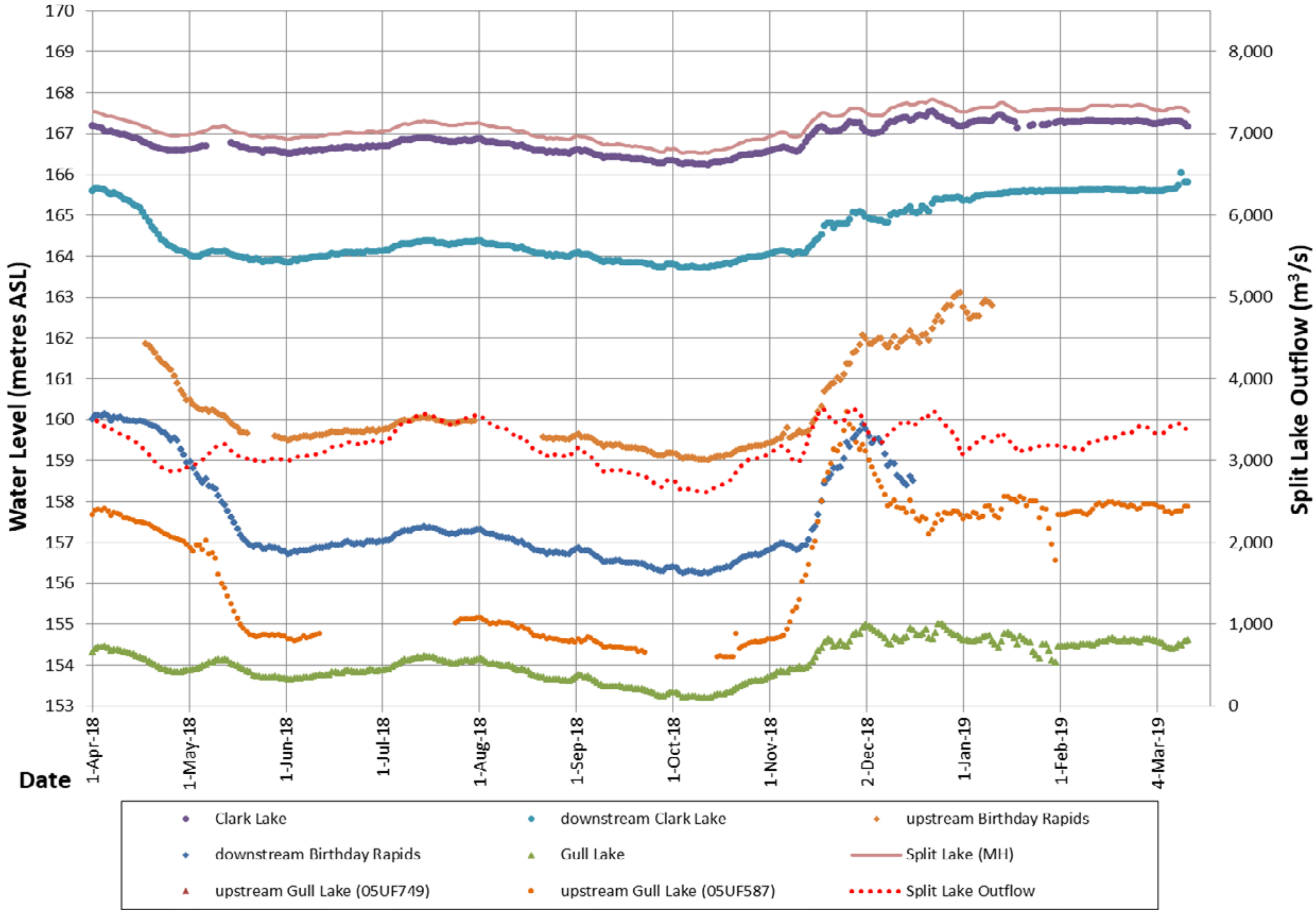
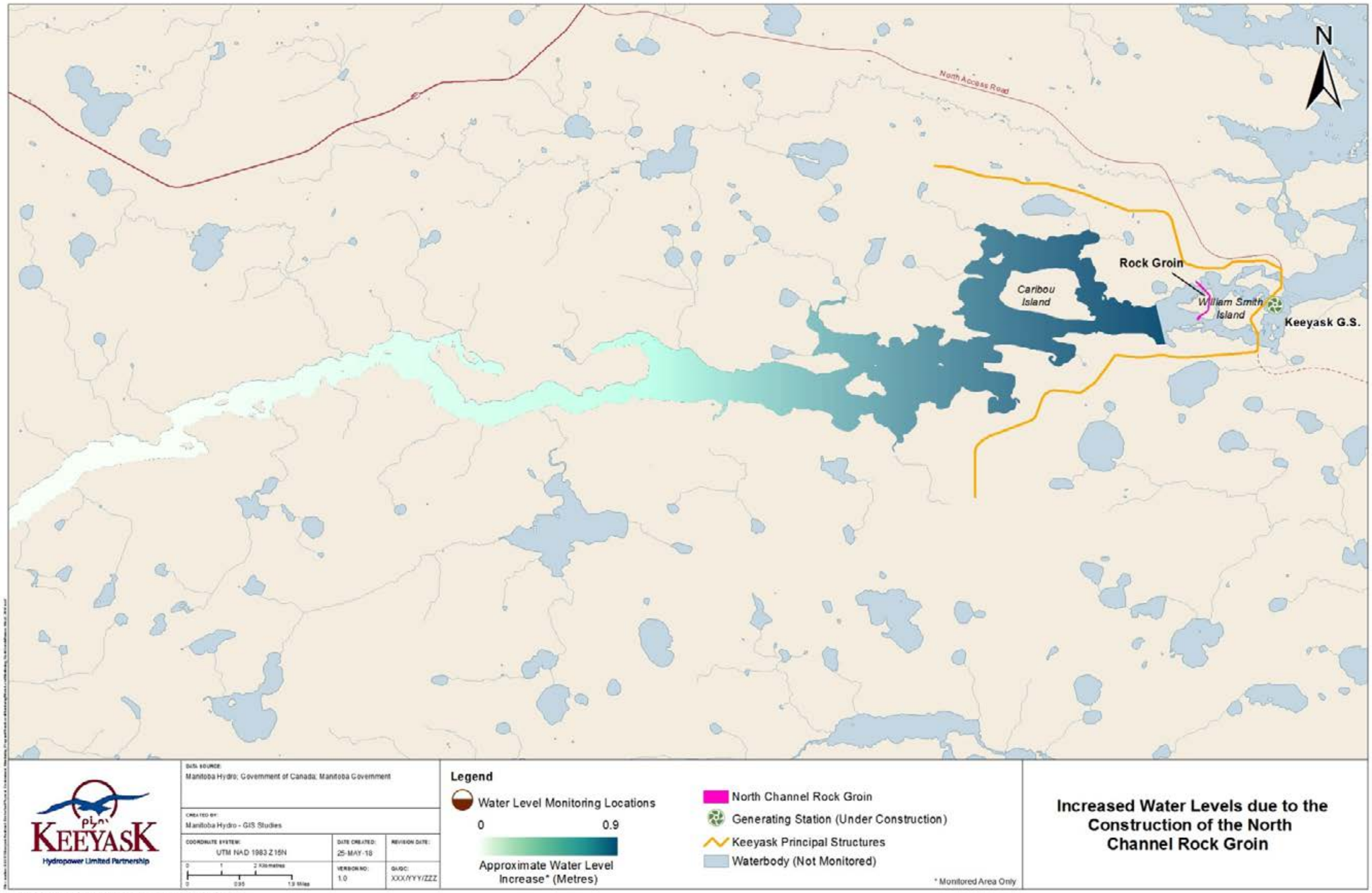


Figure 2: Observed water levels at PEMP monitoring sites in 2018/2019



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.

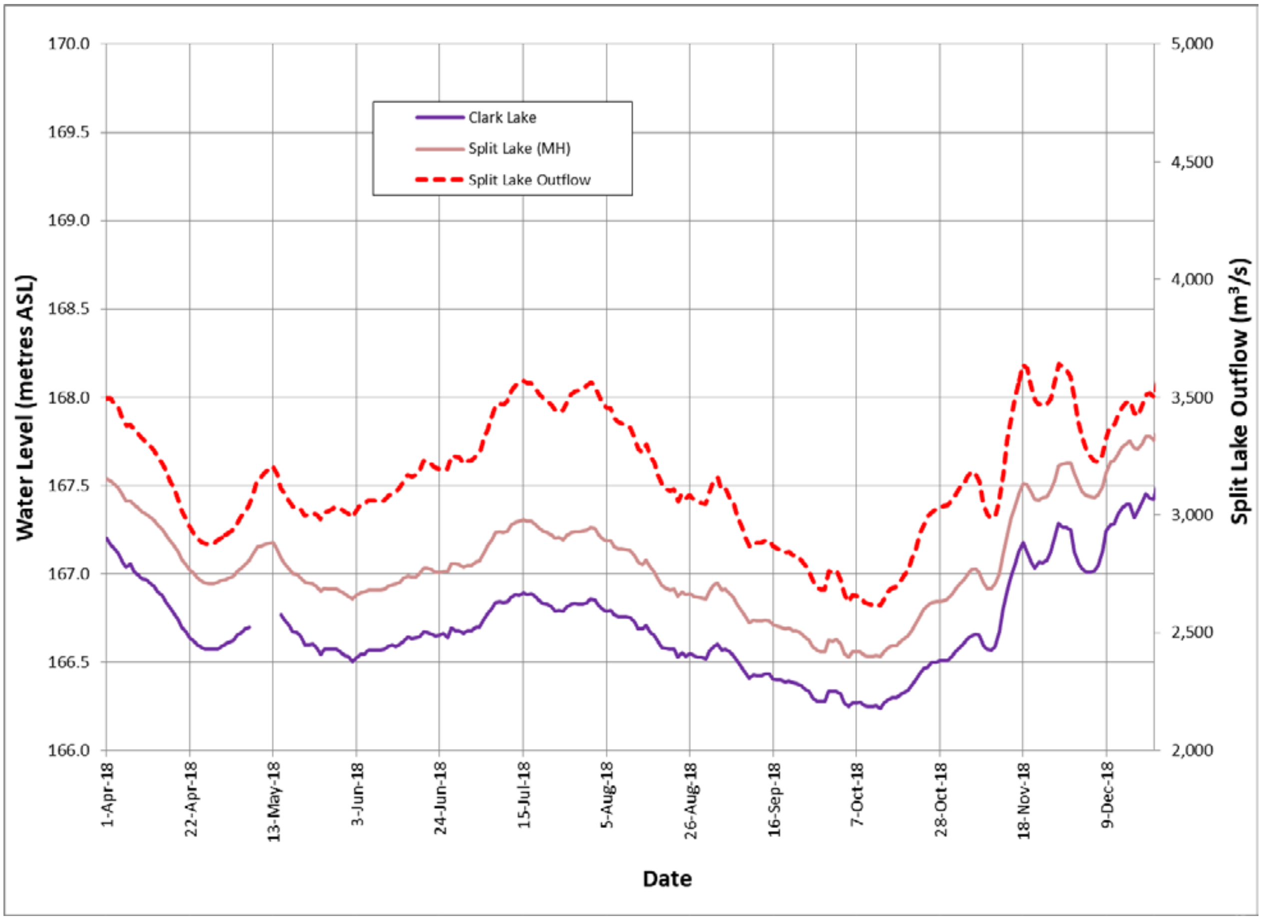


Figure 3: Observed water levels at Clark Lake and Split Lake in 2018/2019

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 2018/19 winter saw the same early ice cover as the previous year, the earliest since construction started.

Table 3: 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, 2018
2018/19	Nov 4-6, 2018	about 6 km upstream of Birthday Rapids	May 13-15 2019

*Ice formation start date before ice boom failed

In 2018, temperatures saw a rapid decrease in early November around the time ice formed upstream of the ice booms as seen in Photo 2 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 14, 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 late December. The leading edge of the ice front reached about 6 km upstream of Birthday Rapids by late January, remaining there till mid-April, similar to the previous winter. Gull Lake became predominately ice free around May 13-15 about a week earlier than the last two years.

Photo 2: Ice Boom A on east side of Caribou Island (Nov. 1 & 5, 2018)

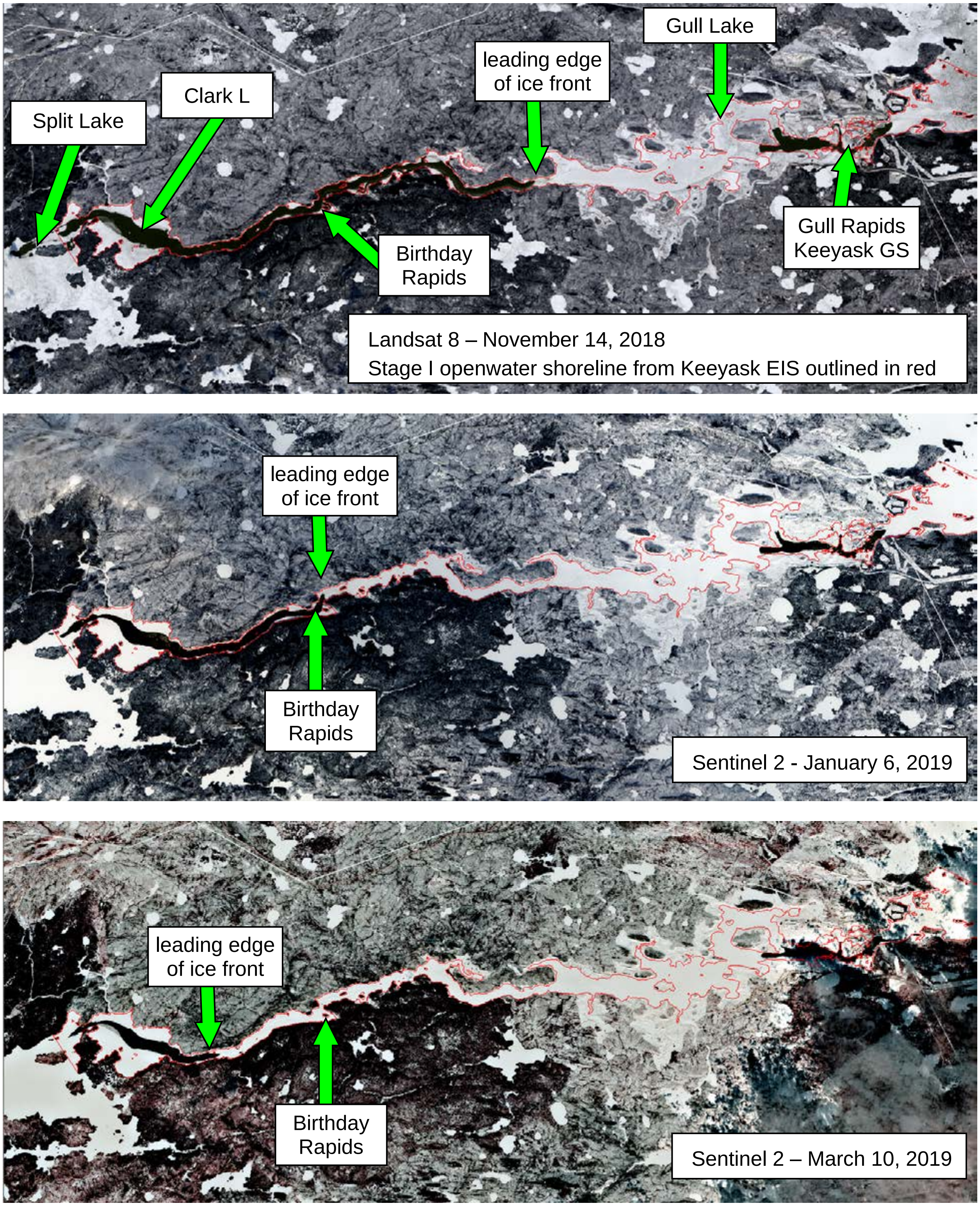


Figure 4: Ice Cover Observations from Satellite Images

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.

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 2019).

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 2017-2018

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 2017-18 winter sedimentation data.

4.1.1 CONTINUOUS AND DISCRETE TSS AND TURBIDITY

Monitoring in 2017-18 was conducted at three sites (Table 3). Each year the equipment is installed after suitable ice conditions develop at the sites and removed before ice break up.

Table 4: 2017-2018 Winter Monitoring Locations

Site ID	Dates
K-Tu-06 (Clark Lake)	30-Jan-2018 to 18-Apr-2018
SMP-01 (Gull Lake)	18-Jan-2018 to 22-Apr-2018
SMP-03L (Stephens Lake)	19-Jan-2018 to 30-Apr-2018

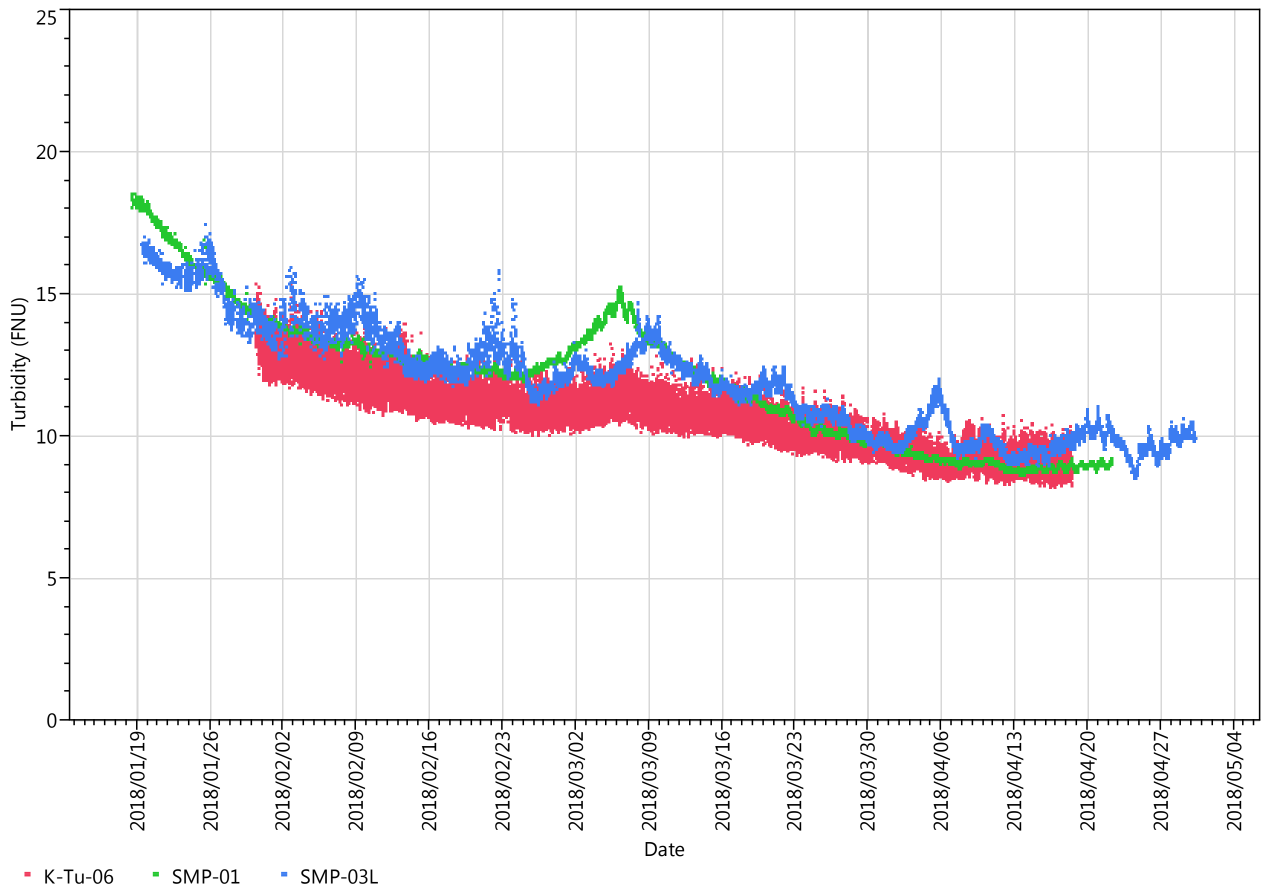


Figure 5: 2017-2018 Winter Continuous Turbidity

Turbidity levels dropped slightly over the course of the winter, with highest levels observed in late January followed by a decreasing trend over the winter; this pattern is commonly seen in winter.

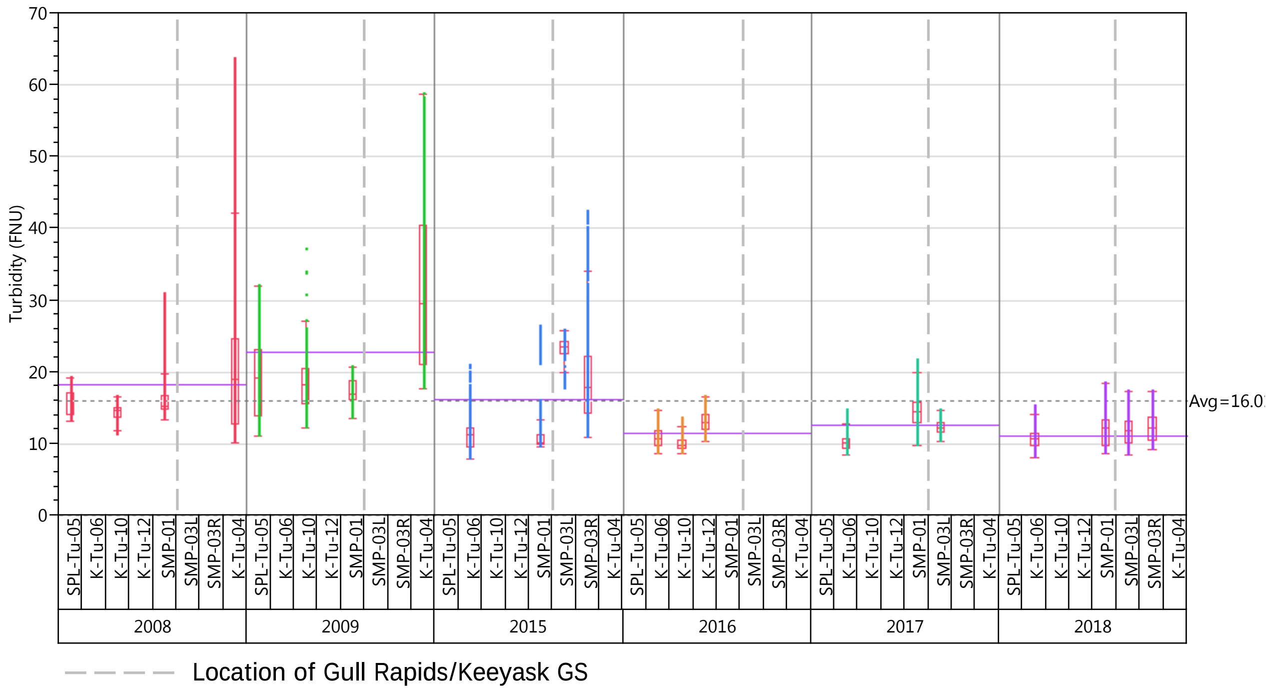


Figure 6: Summary of Winter Continuous Turbidity

Results from the 2017-18 winter monitoring show similar results to the past 2 winters with a reduction in turbidity levels in Stephens Lake from pre-construction conditions. 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..

Discrete TSS and Turbidity (Figure 7) 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.

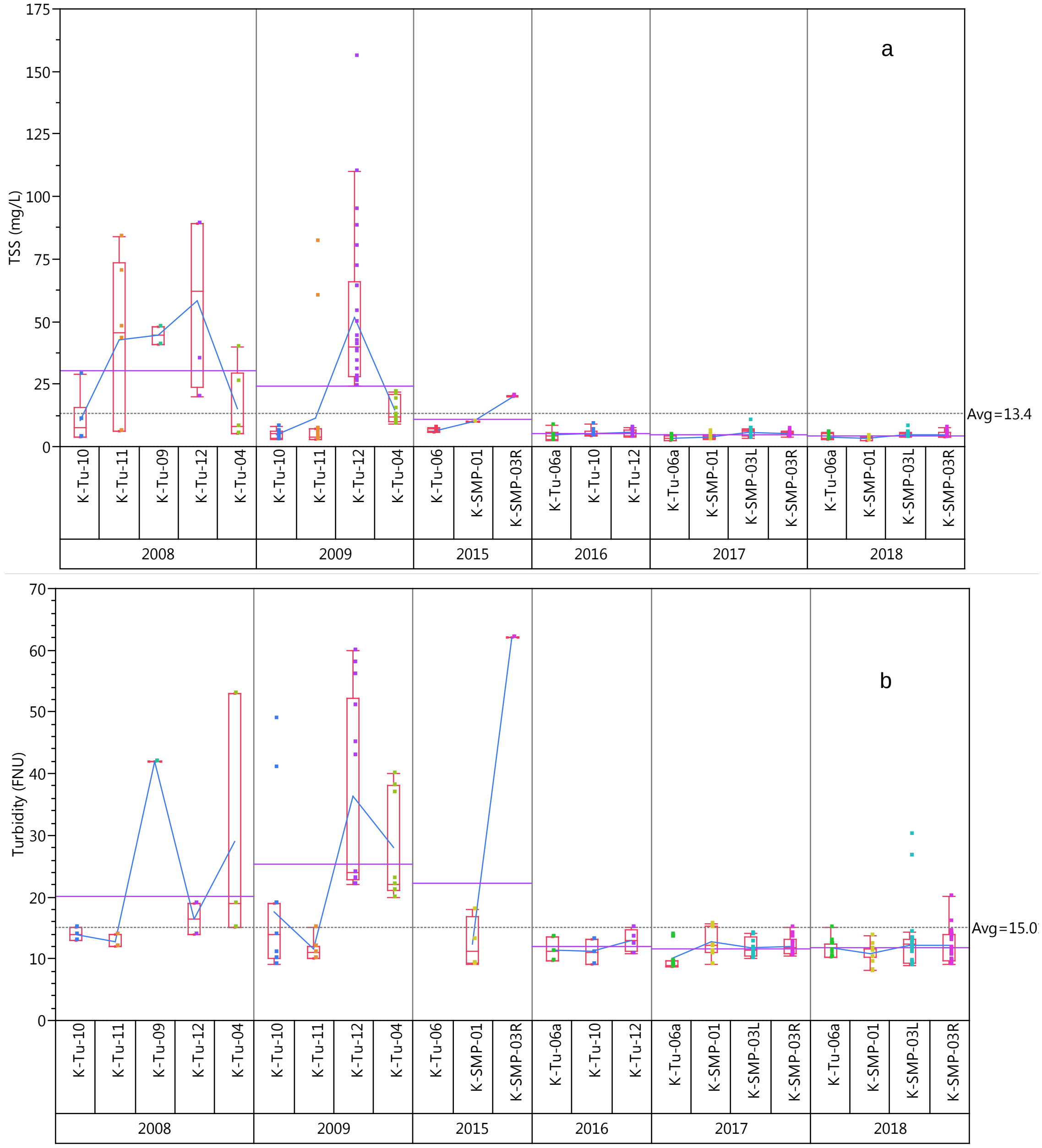


Figure 7: Summary of Winter Discrete TSS (a) and Turbidity (b)

4.1.2 ESTIMATED SUSPENDED SEDIMENT LOAD

The winter suspended sediment loads (Figure 8) 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 than the four winters monitored since construction started.

As noted above, 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.

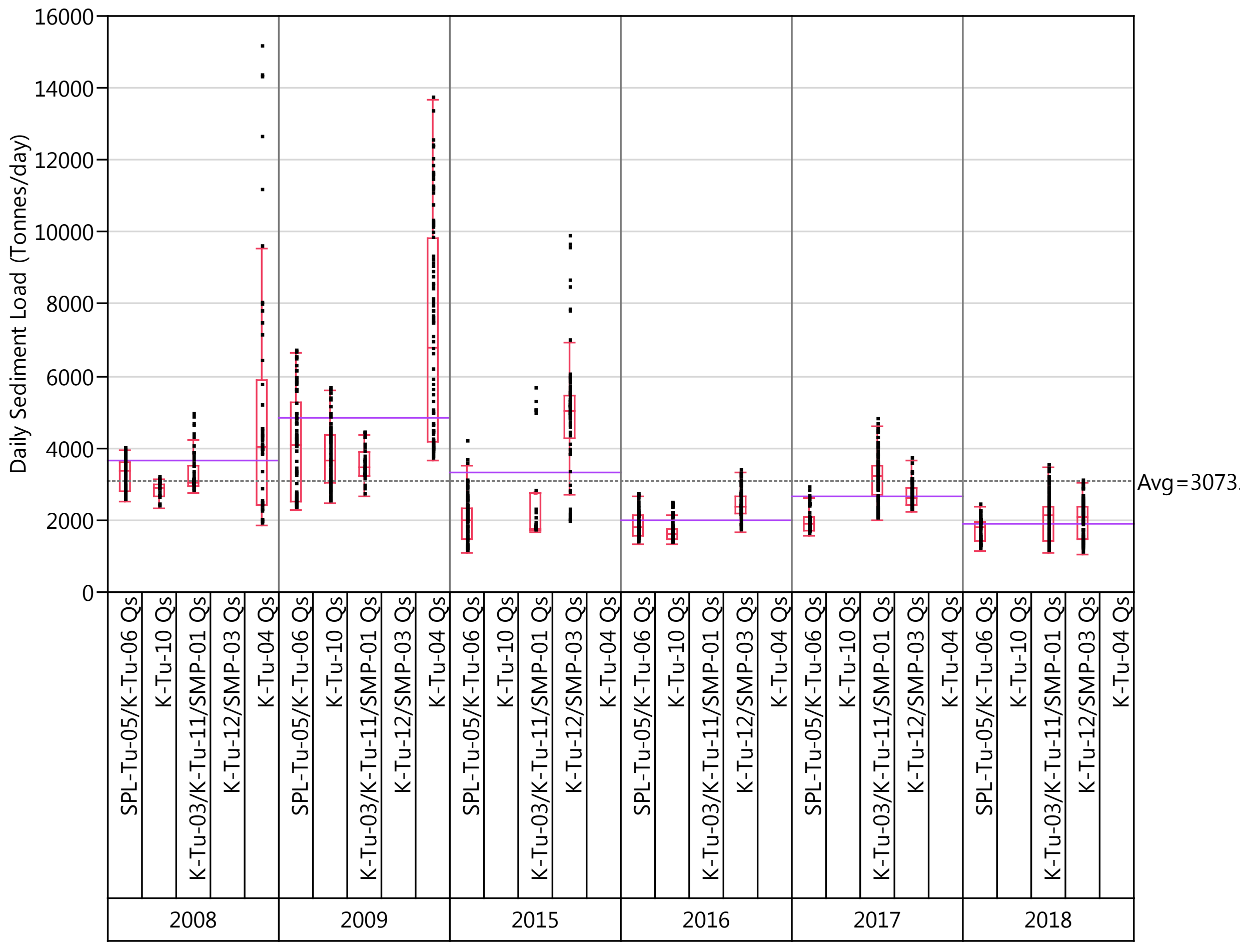


Figure 8: Summary of Winter Daily Suspended Sediment Load

4.2 SUMMER 2018

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 2018 and the dates for which records are available are shown in Table 4 (location maps in Appendix 1).

The continuous turbidity monitoring stations consist of either a catamaran equipped for satellite data transmission (Photo 3) 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 5: 2018 Summer Monitoring Locations

Site ID / Location	Dates
K-Tu-06 (Clark Lake)	2018/06/24 to 2018/09/19
*K-Tu-13 (Nelson River)	2018/06/24 to 2018/09/19
K-Tu-03 / SMP-01 (Gull Lake)	2018/06/09 to 2018/09/15
K-Tu-02 / SMP-02 (Stephens Lake Entrance)	2018/06/09 to 2018/10/01
K-Tu-04 (Stephens Lake)	2018/06/23 to 2018/09/18

*K-Tu-05 relocated to K-Tu-13 in 2017

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 9) were also compared with the discrete readings (Figure 12) obtained on each maintenance site visit and adjustments made for any sensor drift. For the PEMP report, the turbidity recorded at SMP-02L (left side of entrance channel) and SMP-02R (right side of entrance channel) were averaged to represent the average turbidity entering Stephens Lake. Data from K-Tu-03/SMP-01 and K-Tu-02/SMP-02L/SMP-02R was reduced by 6.5 FNU to match the data collected at other PEMP sites.

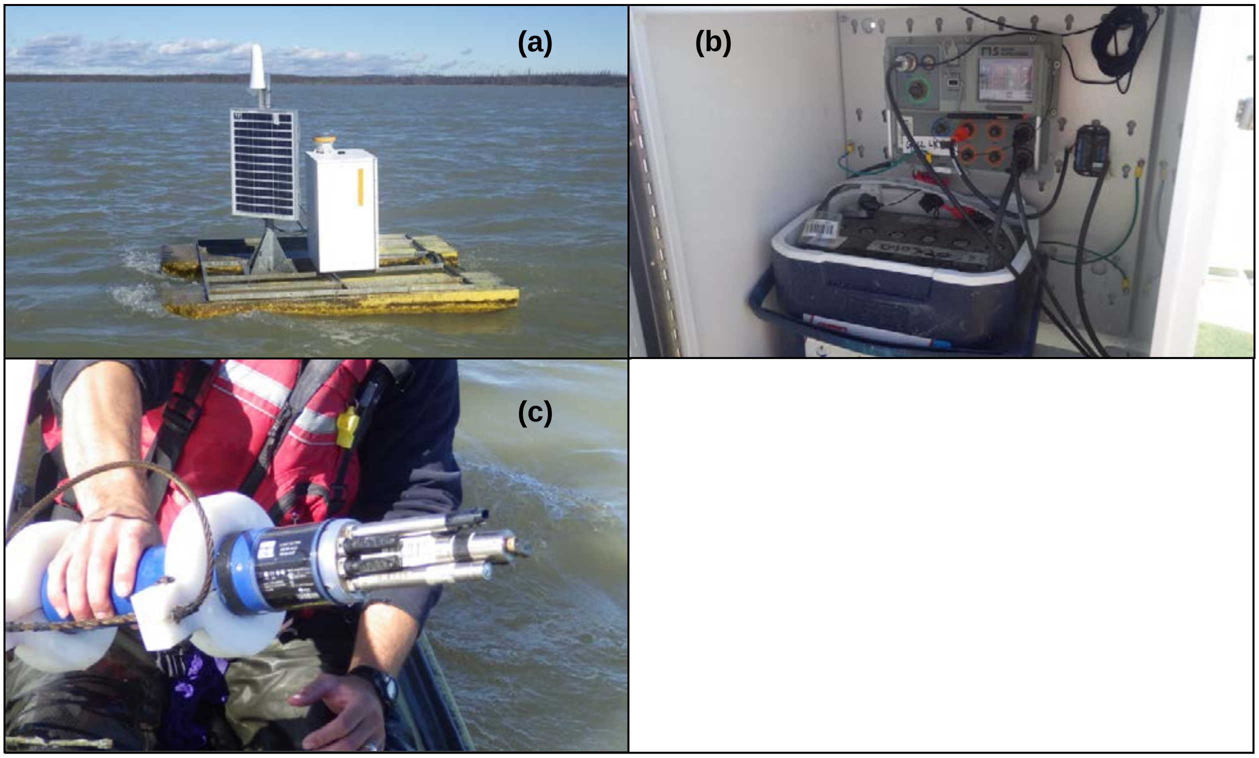


Photo 3: Continuous turbidity monitoring site: (a) catamaran with solar panel, transmitter and electronics cabinet, (b) electronics in cabinet, (c) probe with turbidity sensor installed

The turbidity at each of the sites follows a similar pattern (Figure 9) throughout the monitoring period, with an increase observed in late June and a drop through the month of July. In early August, an increase in turbidity downstream of the Project in Stephens Lake was observed at site K-Tu-02/SMP-02 during spillway commissioning, which took place from Aug 3-7. The spatial extent of the increase was observed in a Sentinel 2 satellite image captured on August 4, 2019, shown in false colour in Figure 10. The wind speed shown in Figure 9 is taken from the Environment Canada Station at Gillam.

The average summer turbidity (Figure 11) was the second lowest observed during the eight years of monitoring. Differences between the sites are similar to observations seen in other years and no discernable changes resulting from the Project are evident aside from the noted effects during spillway commissioning.

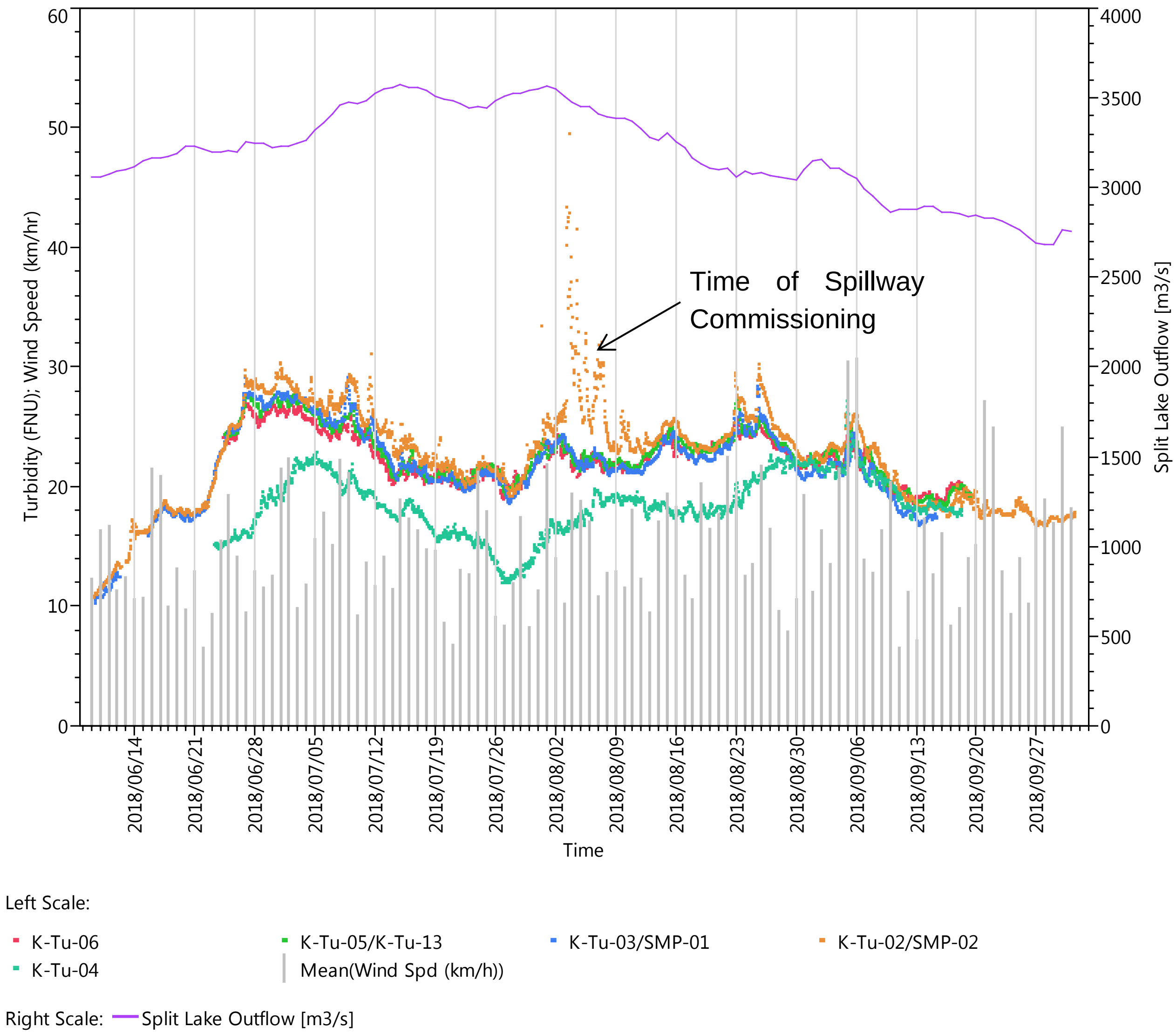


Figure 9: 2018 Summer Continuous Turbidity, Daily Discharge and 24-hr Wind Speed

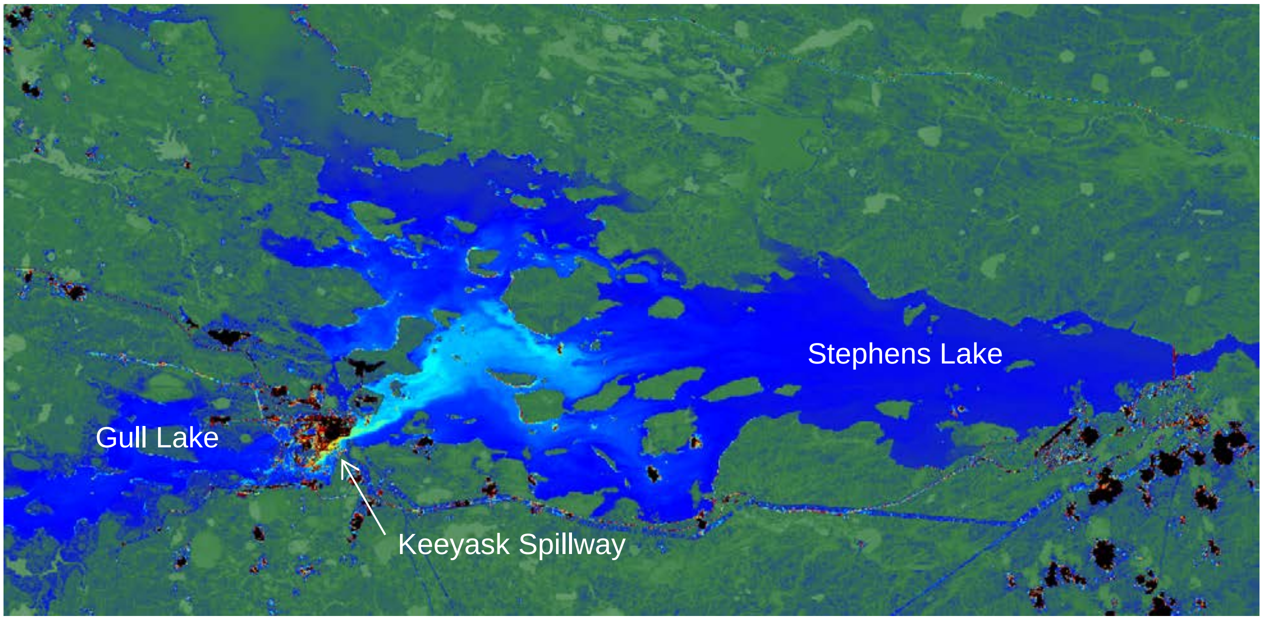


Figure 10: August 4, 2018 Sentinel 2 satellite false colour image showing extents of sediment plume during spillway commissioning

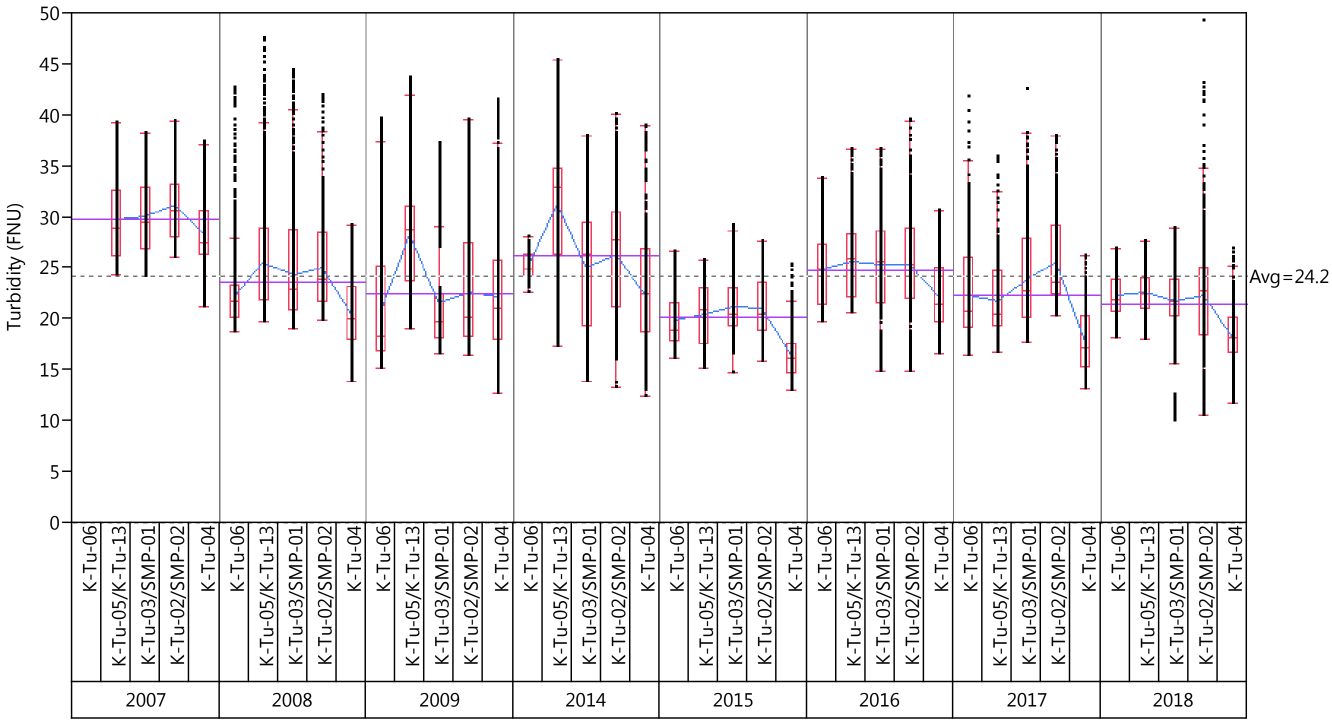


Figure 11: Summary of Summer Continuous Turbidity

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 monthly maintenance visits at the continuous turbidity sites between June and September. 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 2018 TSS results (Figure 12) ranged between 4 and 21 mg/L. The PEMP discrete measurements did not capture the spillway commissioning which was a period of higher TSS and turbidity downstream of the Project in Stephen Lake. Sedimentation monitoring during the spillway commissioning are detailed in the Sediment Management Plan for In-Stream Construction Annual Report April 2018 – March 2019 (Manitoba Hydro, 2019) and can be seen in the continuous turbidity data (Section 4.2.1)

Figure 13 and Figure 14 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 2018 the average annual TSS and turbidity across all sites was lower than the average since the pre-construction and during construction periods. The average TSS and turbidity during construction remains very close to the averages during the pre-construction years.

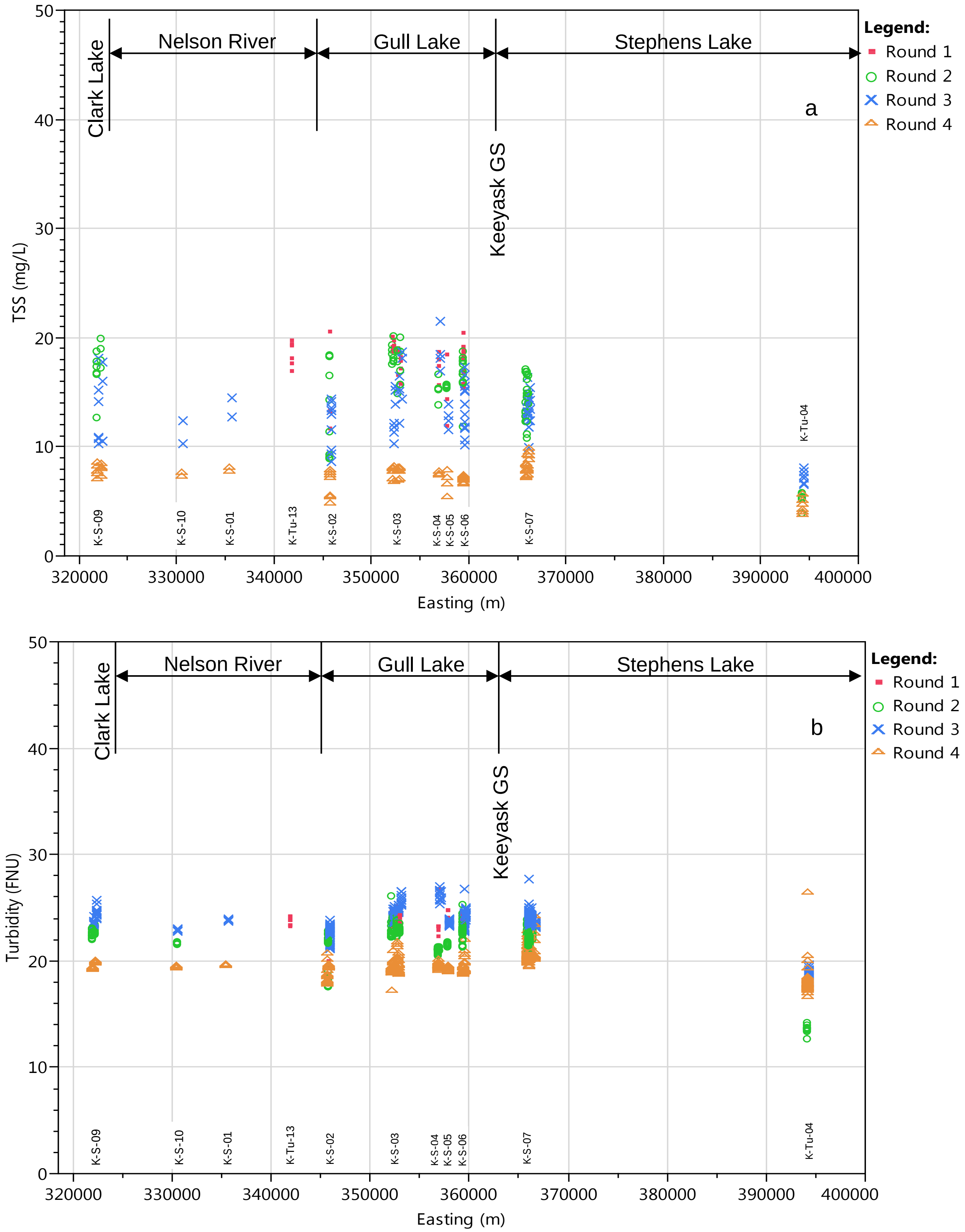
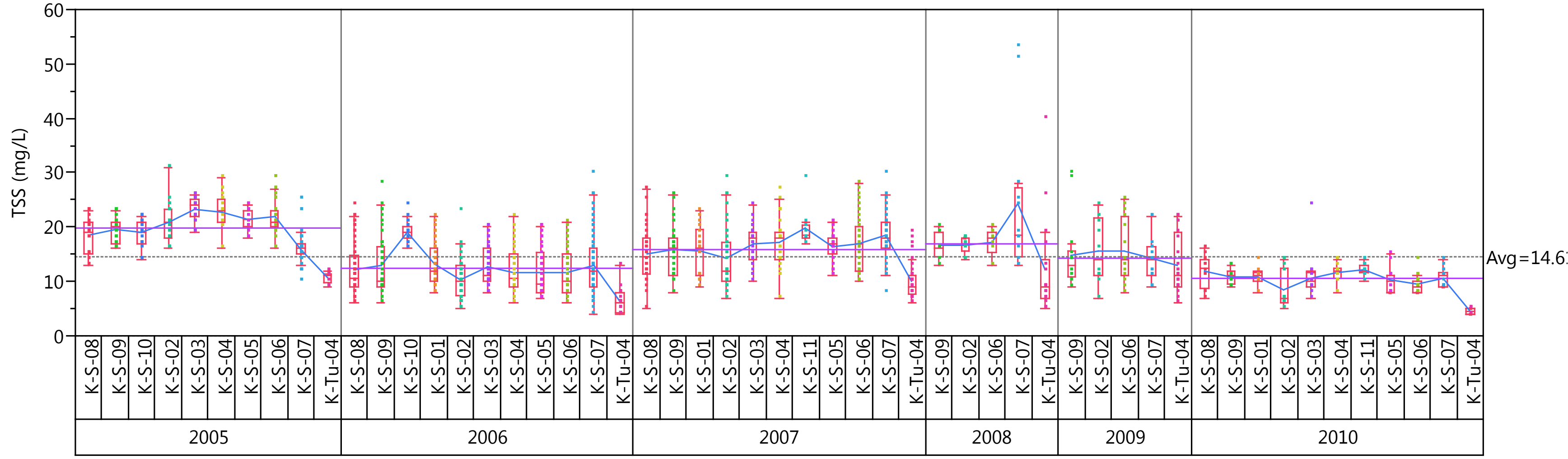


Figure 12: 2018 Summer Discrete TSS (a) and Turbidity (b)

Pre-Construction Period



During Construction Period

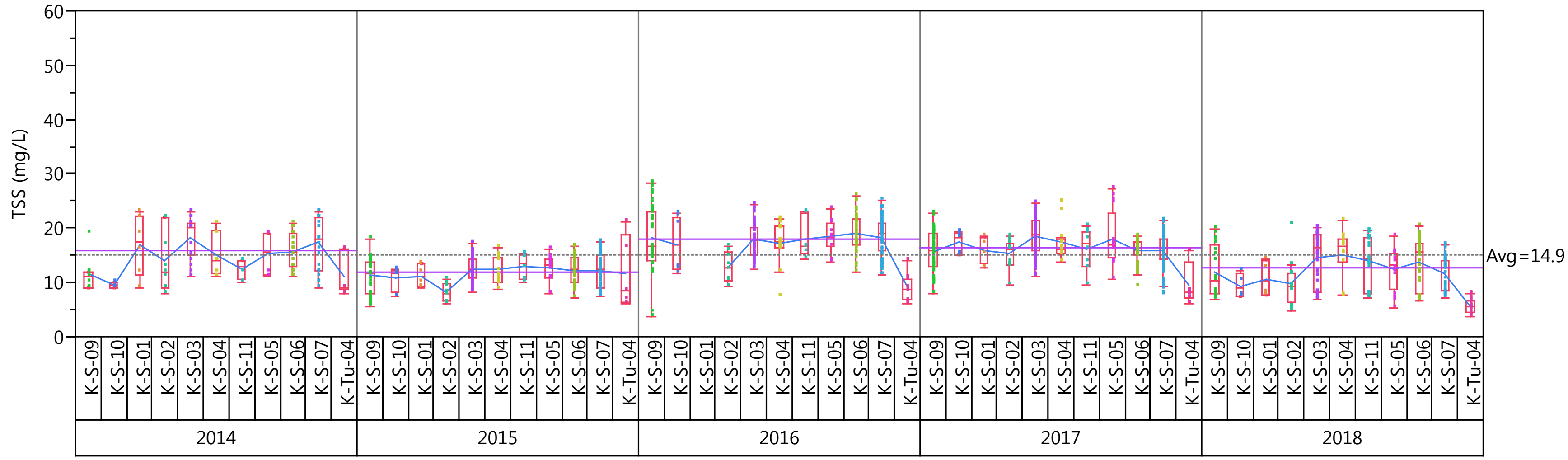


Figure 13: Summary of Summer Discrete TSS

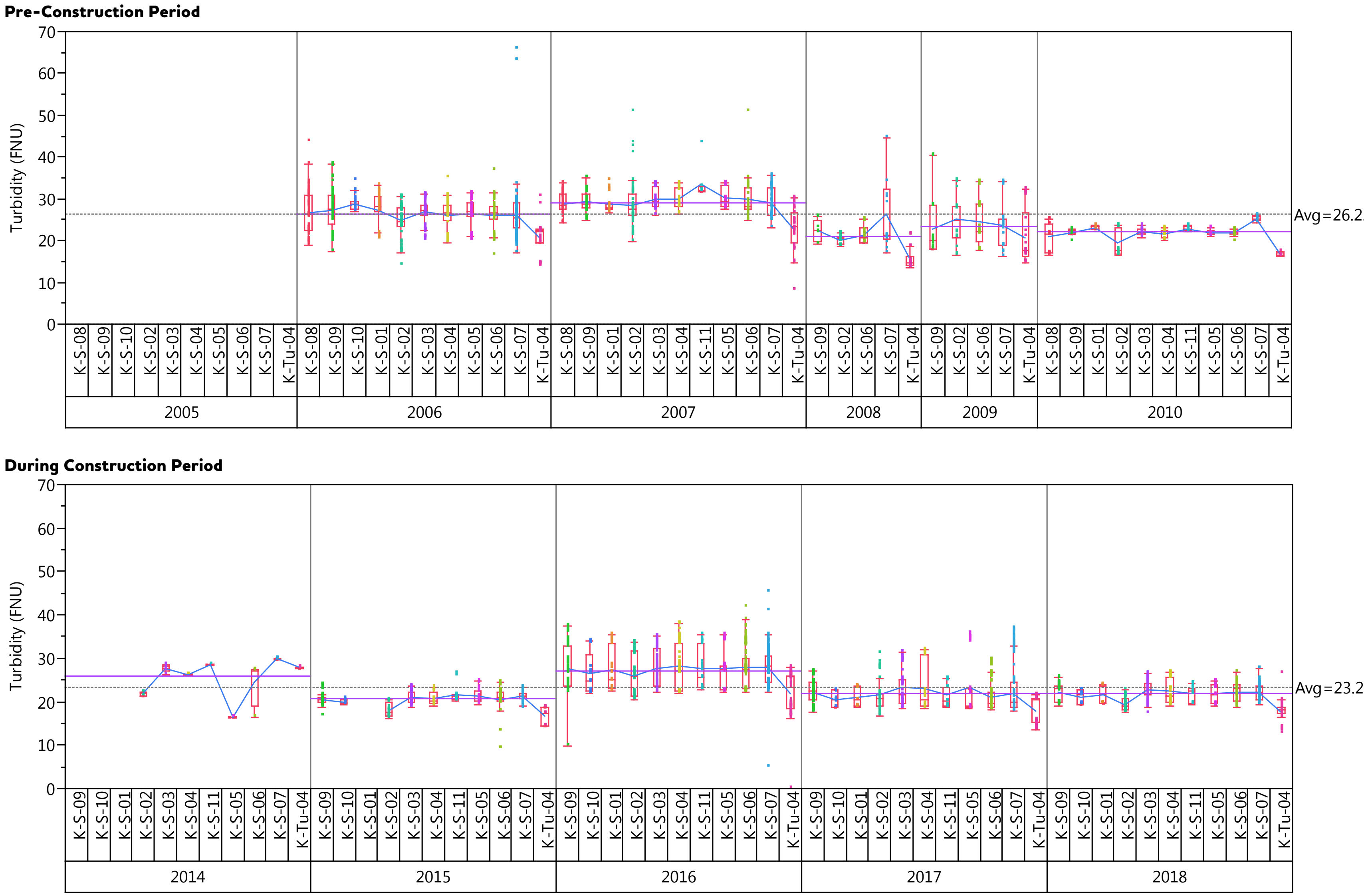


Figure 14: Summary of Summer Discrete Turbidity

4.2.3 ESTIMATED SUSPENDED SEDIMENT LOAD

The summer suspended sediment loads (Figure 15) 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 Sediment Monitoring Program.

The 2018 average summer suspended sediment load was the lowest recorded during the years of pre-construction and during construction monitoring to date. This is likely attributed to the lower flows observed in 2018. As seen in other years, there was a drop in suspended sediment load through Stephens Lake (K-Tu-02 to K-Tu-04).

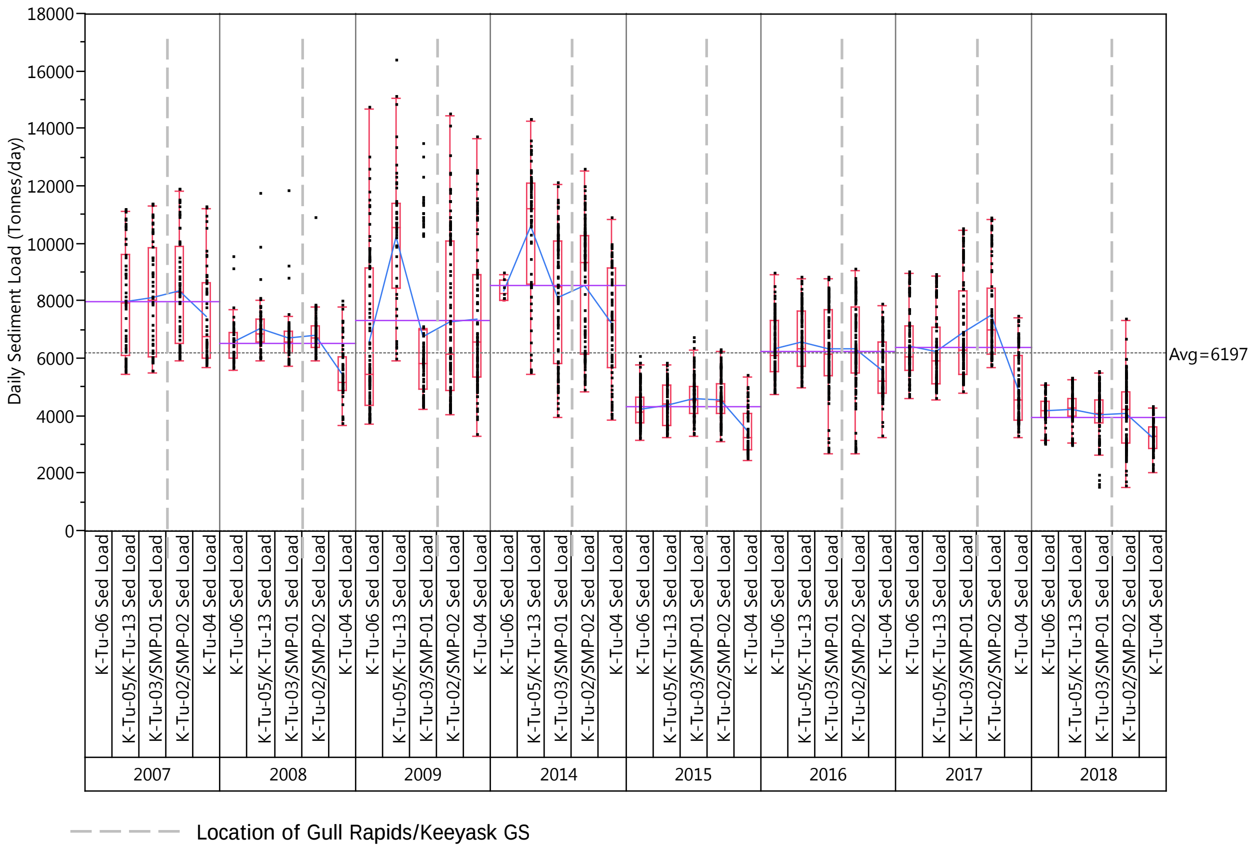


Figure 15: Summary of Summer Daily Sediment Load

4.2.4 DEPOSITION

A 5-tube sediment trap (Photo 7) was installed in Stephens Lake to monitor the sediment accumulation rate over the 2017/18 winter and two modified traps were installed for the 2018 summer period. The modified traps were constructed to have only two tubes so that the trap would be easier and safer to install and retrieve equipment by field crews. One tube is a settling trap that is open at the top and the second tube is a flow through trap that has hole in the side to allow water and sediment to flow into it.

The sediment trap installed over the 2017/18 winter could not be found in the spring and is considered unrecoverable. Only one of the two summer traps was retrieved in the fall on 2018 and the other trap is presumed missing. Results from the 2017/18 summer monitoring are shown in Table 5.

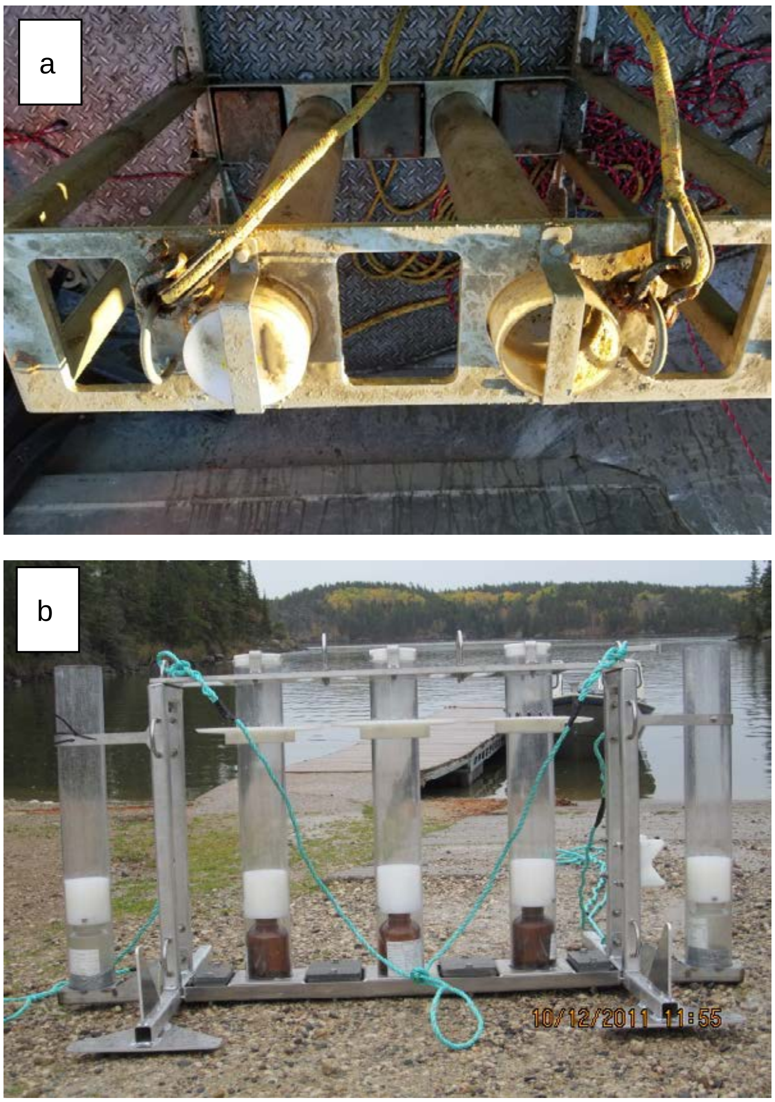


Photo 4: Sediment Traps (a) 2 Tube Design (b) 5-Tube Design

The 2018 summer period had the lowest accumulation rate to date (Table 6) during construction; about 28% to 40% the rate recorded in previous summers. Note that this monitoring was not done during pre-construction monitoring periods. The accumulation rates do not correlate to the Summer Suspended Sediment Loading (Figure 15). While the 2015 average sediment load was similar to 2018, the sediment rate in 2015 was over three times higher. It is inconclusive whether the sediment rates were affected by the design modification or environmental conditions. Photos from the end of the season showed that the settling trap was partially covered by a strap used to hold the tube in place and the flow through trap was missing the flow deflector plate. The sediment collected was primarily comprised of silt (Figure 16) which is similar to the 2015 results.

Table 6: Sediment Trap Monitoring Results for Site K-ST-02 (Stephens Lake)

Sample	Flow 1	Settle 1	Average
Placed	July 5 2018		
Removed	October 10 2018		
# of Days	97		
Total Dry Mass (g)	30.4	39.4	34.9
Accumulation Rate ($g/m^2/day$)	42	55	49
Sand	8	8	8
Silt	69	69	69
Clay	23	23	23

Table 7: Average Sediment Trap Accumulation Rates for Site K-ST-02 (Stephens Lake)

Monitoring Period	Average Accumulate Rate ($g/m^2/day$)	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
Winter 2017-2018	na	na
Summer 2018	49	97

na – not available

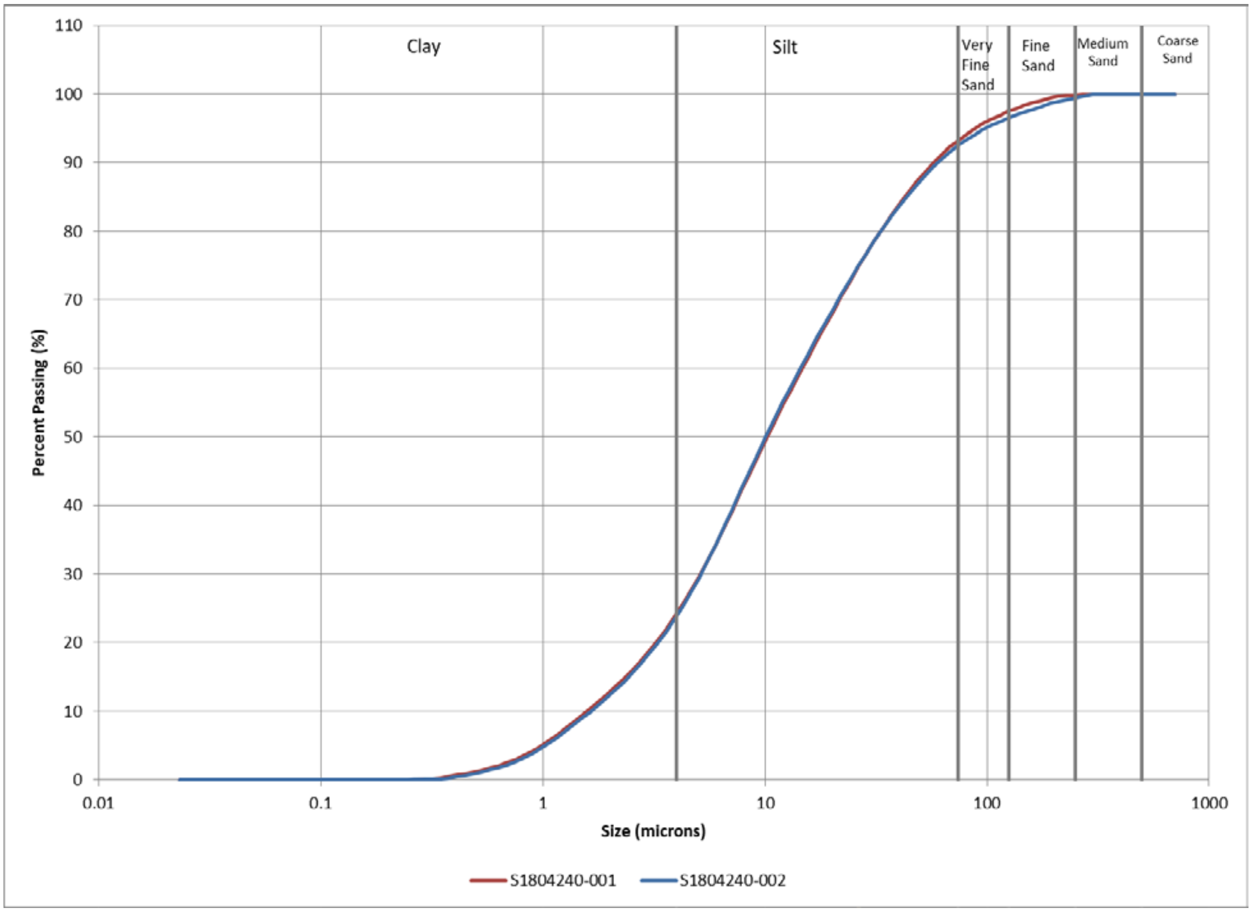
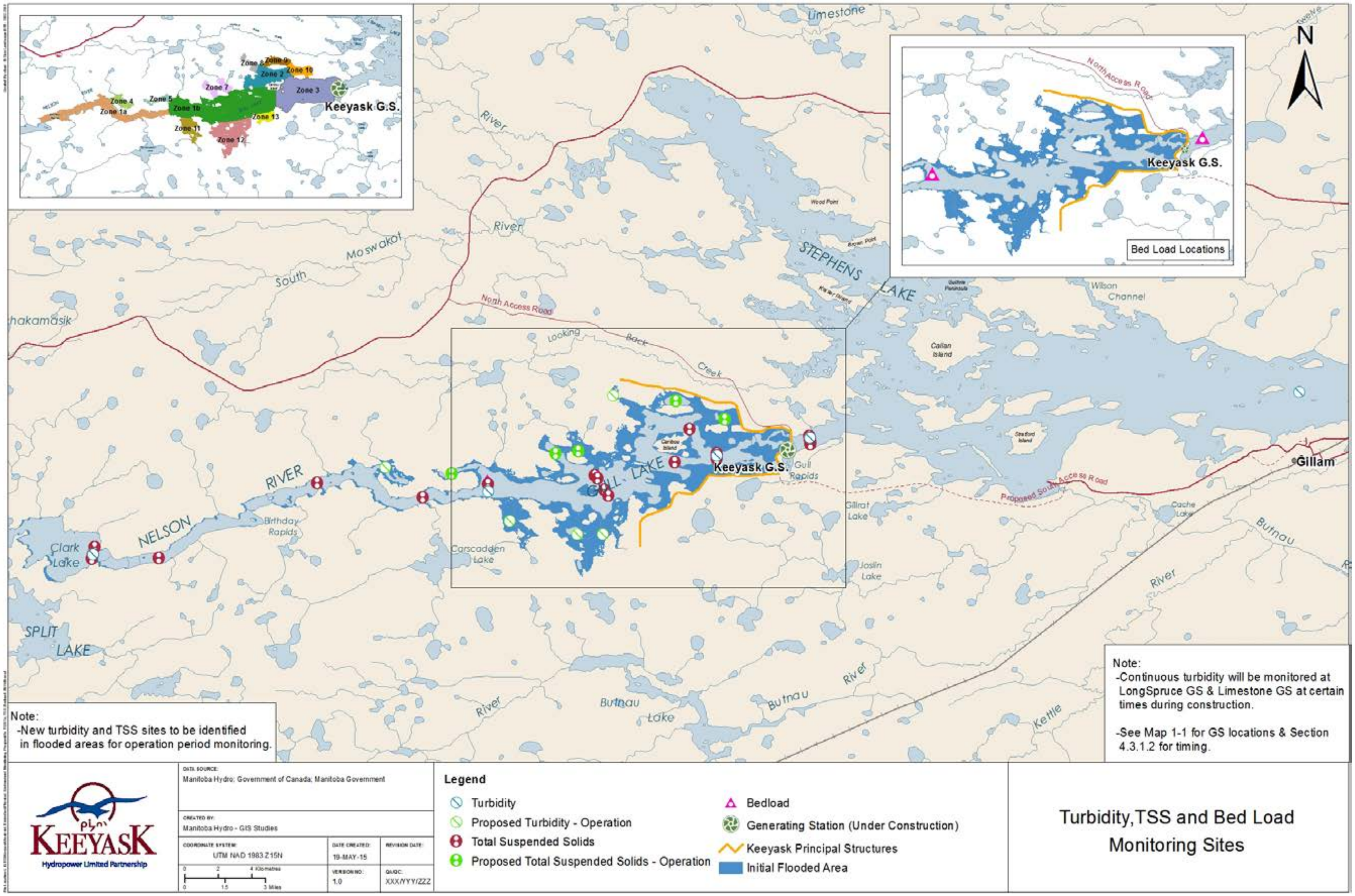


Figure 16: Sediment Trap Grain Size Distributions from 2018 Summer



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 9 sites once a month from June to September, sites vary in the number of points collected across the river. 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. The results for each month have been summarized by averaging the concentrations obtained at each location to produce a river section 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 17). 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 2018 are of a similar magnitude and overall range as in 2016 and 2017. The observations 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.

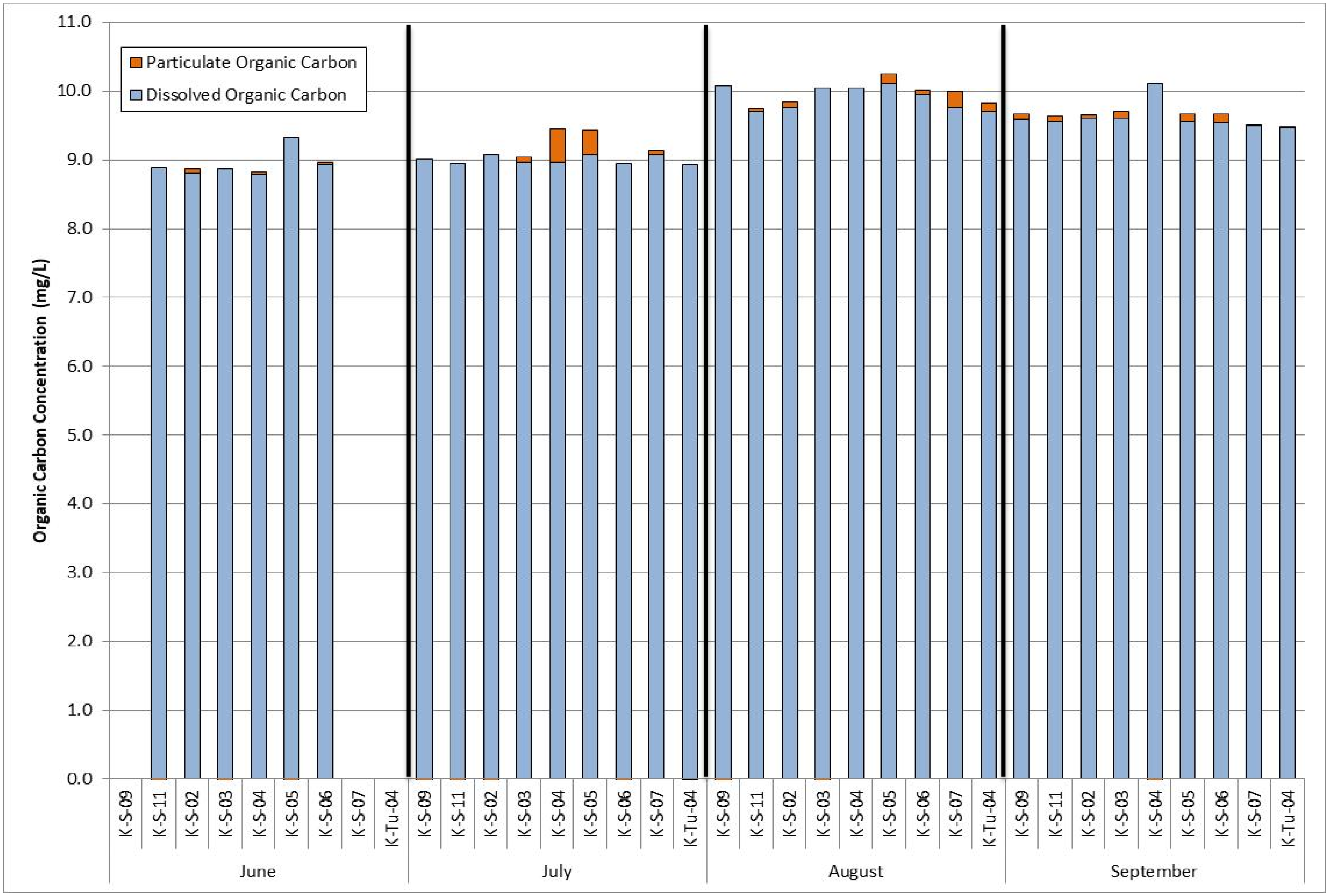


Figure 17: Summary of particulate, dissolved and total organic carbon

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. During construction, prior to reservoir impoundment, the Project is not anticipated to affect DO (KHLP 2012b, Section 9). As observed in since 2015, the monitoring results from summer 2018 confirmed this. DO concentrations ranged from a low of 8.8 mg/L in August to a high of 13.5 mg/L in September (Figure 18).

Overall, the saturation levels (Figure 18) varied from a low of about 91% to a super saturated high at one site of 119% in September when water temperature was at 9.6^{0}C. The very high super saturated DO (>110%) occurs in the top 2 m of the water column at one site with deeper readings around 98%. While these readings are an anomaly there does not appear to be any reason to suspect the data.

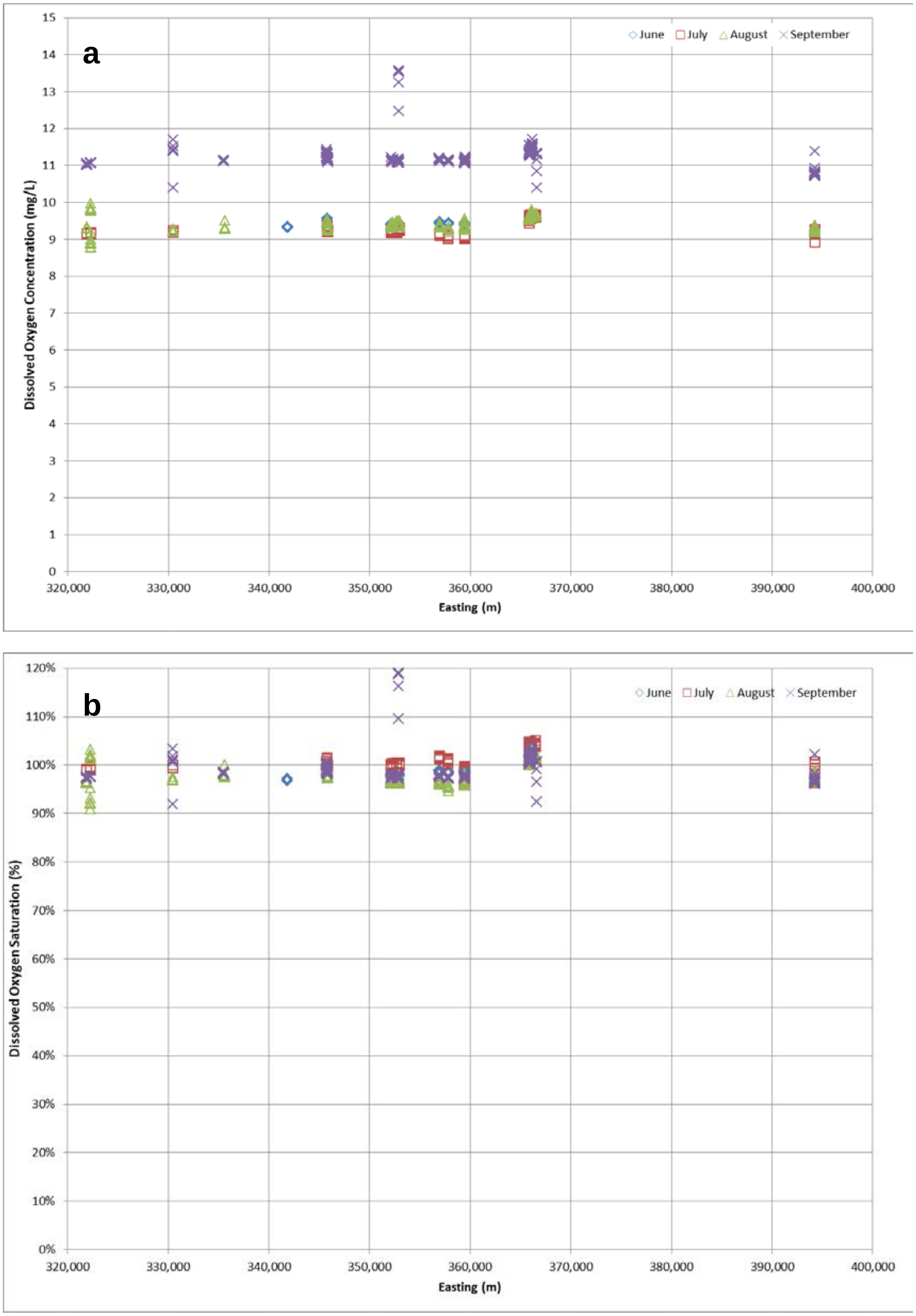


Figure 18: Summer 2018 discrete monitoring results: (a) dissolved oxygen concentration (b) degree of saturation

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 boat patrol to identify and remove floating woody debris (Photo 5) that may pose a safety hazard to navigation. Prior to 2015, this area was only visited about once each week (20% of the time) 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.

Starting in 2018 a new data collection program was initiated allowing for tracking of the location of floating debris and accounting for debris in the Keeyask area. Results of the debris monitoring program are shown in Table 7.

Table 8: 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				
2018	5	0	4	1	10

Photo 5: Large floating debris is removed from the water by the boat patrol team

8.0 RESERVOIR GREENHOUSE GAS

The purpose of Keeyask reservoir greenhouse gas monitoring program is to enable the comparison of aquatic greenhouse gas (GHG) concentrations and emissions before and after flooding and reservoir creation.

Studies have shown that GHG emissions from hydroelectric reservoirs in boreal ecosystems increase shortly after flooding (Teodoru et al. 2012). The size and duration of the change in GHG emissions ("reservoir effect") is influenced by many factors including reservoir size, type and amount of biomass flooded, location, water residence time, temperature, etc. (Demarty and Tremblay 2017; Goldenfum 2012). The Keeyask Physical Environment Supporting Volume (KHLP 2012b) predicted that carbon dioxide (CO_2) emissions would approach background levels by approximately 10 years after impoundment and that methane (CH_4) emissions would remain elevated throughout the 100 year life of the Keeyask Generation Project. These predictions were based on IPCC (2006) guidance at that time. Since then, reservoir GHG science has continued to evolve (Delsontro et al. 2018, Prairie et al 2018). Studies have focussed on GHG processes and emission pathways, and how GHG emissions may relate to reservoir characteristics and location. Similarly, the methods used to study GHGs at the future Keeyask reservoir have evolved and are described in this report.

8.1 PRE-PROJECT AND YEAR 1 CONSTRUCTION PERIOD

As reported in detail in the Keeyask 2014–2015 Physical Environment Monitoring Report: Year 1 Construction report (Manitoba Hydro 2015), measurement of aquatic GHG concentrations was conducted upstream, within and downstream of the planned Keeyask reservoir.

GHG concentrations were measured by discrete sampling (point-in-time measurements) and by continuous monitoring. Discrete sampling was conducted during the open water season and under the winter ice at various locations throughout the waterway to determine if aquatic GHG concentrations vary within the waterway. Continuous monitoring of CO_2 and CH_4 concentrations was conducted during the open water season at fixed locations to record seasonal and annual trends in aquatic GHG concentrations.

Reservoir GHG monitoring was conducted during the pre-Project period of 2009-2013 and during Year 1 of the Construction Period in 2014. The report concluded that in 2014, construction activities did not affect GHG aquatic concentrations or emissions. The data collected in 2014 along with data collected in the pre-Project period from 2009-2013 will provide suitable baseline data to compare against post-impoundment GHG concentrations and emissions.

8.2 2018 RESERVOIR GHG MONITORING

The 2018 reporting year marks the second year of monitoring since construction started devoted to the understanding of GHG exchange dynamics of the future Keeyask reservoir. Project details and summary results are described by Papakyriakou et al. (2019). The over-all project objective is to acquire pre- and post-flood information on rates, variability and controls of GHG exchange. Ultimately the information will be used to determine the net impact of the Keeyask Hydropower Project on reservoir GHG emissions.

During the baseline period and Year 1 of the Construction Period, GHG measurement methods followed industry best practices (i.e. UNESCO/International Hydropower Association (2010) guidance) and kept current as technology improved. The primary focus of those monitoring events were on measuring dissolved GHGs in water and their release to the atmosphere (“diffusive emissions”).

Through testing of monitoring methodologies, additional measurement methods have been included to address additional post flooding GHG emission pathways that are anticipated to result from impounding a variety of affected ecosystems. This is particularly the case for flooded peatlands, floating peat islands, and backbays and associated wetlands that will be connected to the resulting reservoir. The additional GHG pathways of interest include: (1) emissions that may emanate directly from partially submerged/floating peat and (2) from methane bubbles originating in the flooded sediments. Both emission pathways may occur at rates that are heterogeneous in time as space and therefore are difficult to characterize.

Eddy covariance (EC) monitoring has been added to the suite of measurement techniques. The EC method measures GHG concentrations in the air, along with wind direction. This enables calculations of GHG emissions from a wide zone of influence and includes emissions released from water surfaces, bubble emissions as well as emissions originating from unflooded, partially submerged and floating peat.

The EC method is proven technology for environmental and industrial emission measurements, is recognized by the UNESCO/IHA (2010) guidance for reservoir GHG measurement, but to date, has not been widely used for measuring aquatic GHG emissions from boreal hydroelectric reservoirs.

8.2.1 METHODS

In 2018, an Eddy covariance (EC) system was deployed on the southern bank of the Nelson River at 56.329166°N, 95.324554°W, approximately 7 km upstream of the Keeyask Generating Project (Figure 19). The system measured air-water exchange of greenhouse gases in an area that will become flooded after reservoir impoundment.

Sensors installed on a 4 m tall tripod at the site allowed the application of the eddy covariance technique for the measurement of CO_2 and CH_4 fluxes from the Nelson River channel and surrounding peatland extending over a period between May and September 2018 (Figure 20, Figure 21).

In addition to conducting EC monitoring, Nelson River water was sampled from shore at roughly monthly intervals from June to September 2018. The measured concentrations of dissolved CO_2 and CH_4 were used to calculate CO_2 and CH_4 diffusive fluxes from the water surface to the atmosphere. This approach is similar to that used during the baseline and first year of construction monitoring. Coupling EC monitoring with measurements of water quality, including variables that described the water's chemistry, improves our understanding of the drivers of GHG flux, and allows comparison with other similar aquatic environments.

Figure 19: Location of 2018 eddy covariance system and water sampling site on the Nelson River, upstream of the Keeyask Generation Project

Figure 20: Illustration of 2018 eddy covariance monitoring system.

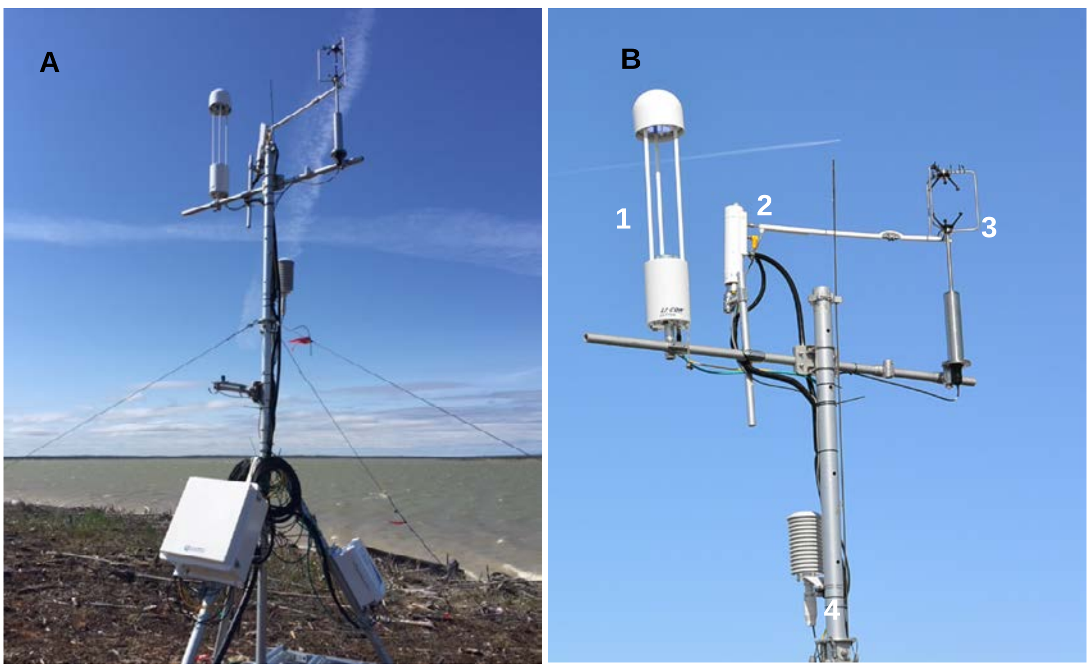


Figure 21: (A) Micrometeorological tower at Keeyask greenhouse gas monitoring site on the bank of the Nelson River. (B) Eddy covariance instrumentation on the tower including: (1) LI-7700 – CH4 Analyzer (2) LI-7200 – CO2/H2O Analyzer (3) Sonic Anemometer (4) Temperature/Relative Humidity Probe.

8.2.2 RESULTS

CARBON FLUX

- The average CO_2 flux over the river (north wind) on average showed a small outgassing of CO_2, approximately 0.47 μmol/m^2/s. Fifty percent of the flux measurements were between 0.27 and 0.61 μmol/m^2/s. The magnitude of the flux in μmol/m^2/s is equivalent to on average 40.61 mmol/m^2/d, or 487.70 mg C/m^2/d.
- The boreal peatland to the south of the river, which had been cleared in 2017, released CO_2 at a higher rate, averaging approximately 1.3 μmol/m^2/s. Fifty percent of the measurements were between 0.8 and 1.8 μmol/m^2/s. The magnitude of the average flux in μmol/m^2/s is equivalent to on average 117.50 mmol/m^2/d, or 1411.22 mg C/m^2/d.
- CO_2 outgassing increased slightly throughout the summer from the Nelson River and decreased in fall.
- An increase was seen in seasonal CO_2 outgassing from the cleared peatland at a larger rate than from the channel, and decreased with temperature cooling in September.
- CO_2 fluxes were almost exclusively emissions from both the Nelson River and the cleared peatland and were well in line with previous monitoring results.
- Little diurnal trends were observed in CO_2 fluxes for the Nelson River.
- CO_2 fluxes from the cleared peatland had diurnal trends that differed throughout the measurement period.

METHANE FLUX

- The methane flux was very close to zero, with median and average daily fluxes below the detection limit of the eddy covariance system for CH_4, which is approximately ± 0.005 μmol/m^2/s. Consequently, we are not able to differentiate these fluxes from zero.
- The Nelson River was supersaturated in CH_4 in all aquatic samples. CH_4 concentration was lower in June and largest in September
- Bulk CH_4 fluxes confirm small diffusive emissions into the atmosphere from the water.

8.2.3 SUMMARY OF 2018 RESERVOIR GHG MONITORING

Broadly speaking, the flux results from 2018 agree with other published literature of similar ecosystems and previous monitoring results. CO_2 flux estimates were either slightly larger than other large rivers in boreal regions (i.e., between 0.1 – 0.2 μmol/m^2/s) or within a similar range.

On average, a small flux uptake of CO_2 on the order of 0.52 μmol/m^2/s was observed during the 2017 field campaign associated with the river. The fact that the river toggled from taking in on average small amounts of CO_2 in 2017 to releasing small amounts of CO_2 in 2018 demonstrates variability in the system, and the need for continued monitoring to better understand the tendency of the river as a small sink or source of CO_2, and under what conditions.

On average the observed 2018 rate of CO_2 outgas from the cleared peatland in 2018 (1.3 μmol/m^2/s) was almost twice as large as observed in 2017 (approximately 0.7 μmol/m^2/s).

The eddy covariance estimate of the average CH_4 flux was close to zero and within noise of the measurement system. This is consistent with observations from 2017. The bulk flux estimates in 2018, based on CH_4 concentrations in the Nelson River water confirm the low level outgas of CH_4 by diffusion.

In most cases, CH_4 fluxes are likely similar to other large boreal rivers (<0.005 μmol/m^2/s) although some examples exist from other aquatic systems where large CH_4 fluxes occur (0.01-0.03 μmol/m^2/s).

It is anticipated that Pre-Project and Construction Period GHG monitoring results will be compiled and reported in next year's monitoring report. These data will enable the comparison of pre and post flood GHG measurements to determine the net impact of impoundment.

8.3 MONITORING PLANS FOR 2019

Monitoring plans for 2019 includes the following:

- Continue EC measurements of GHG exchange for the main Nelson River channel to further characterize the nature of the CO2 and CH4 emission or uptake characteristics from the pre-flood Nelson River.
- Install a second EC measurement system devoted to a future backbay. Backbays may disproportionately contribute to GHG emissions after impoundment.
- Conduct continuous measurement of dissolved near water surface GHG concentrations (CO2 and CH4) using submersible probes co-located in the main river channel and a backbay location.

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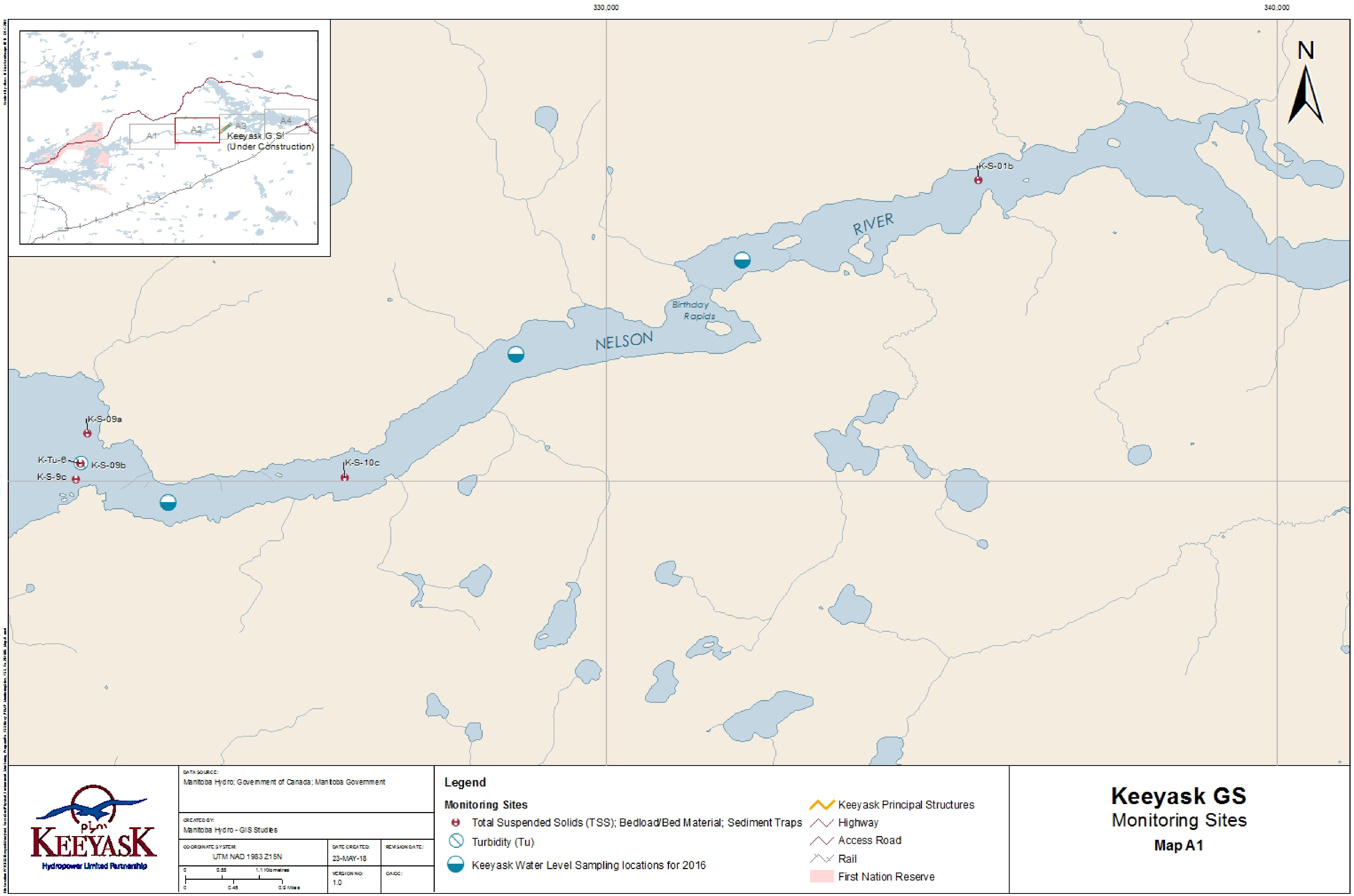
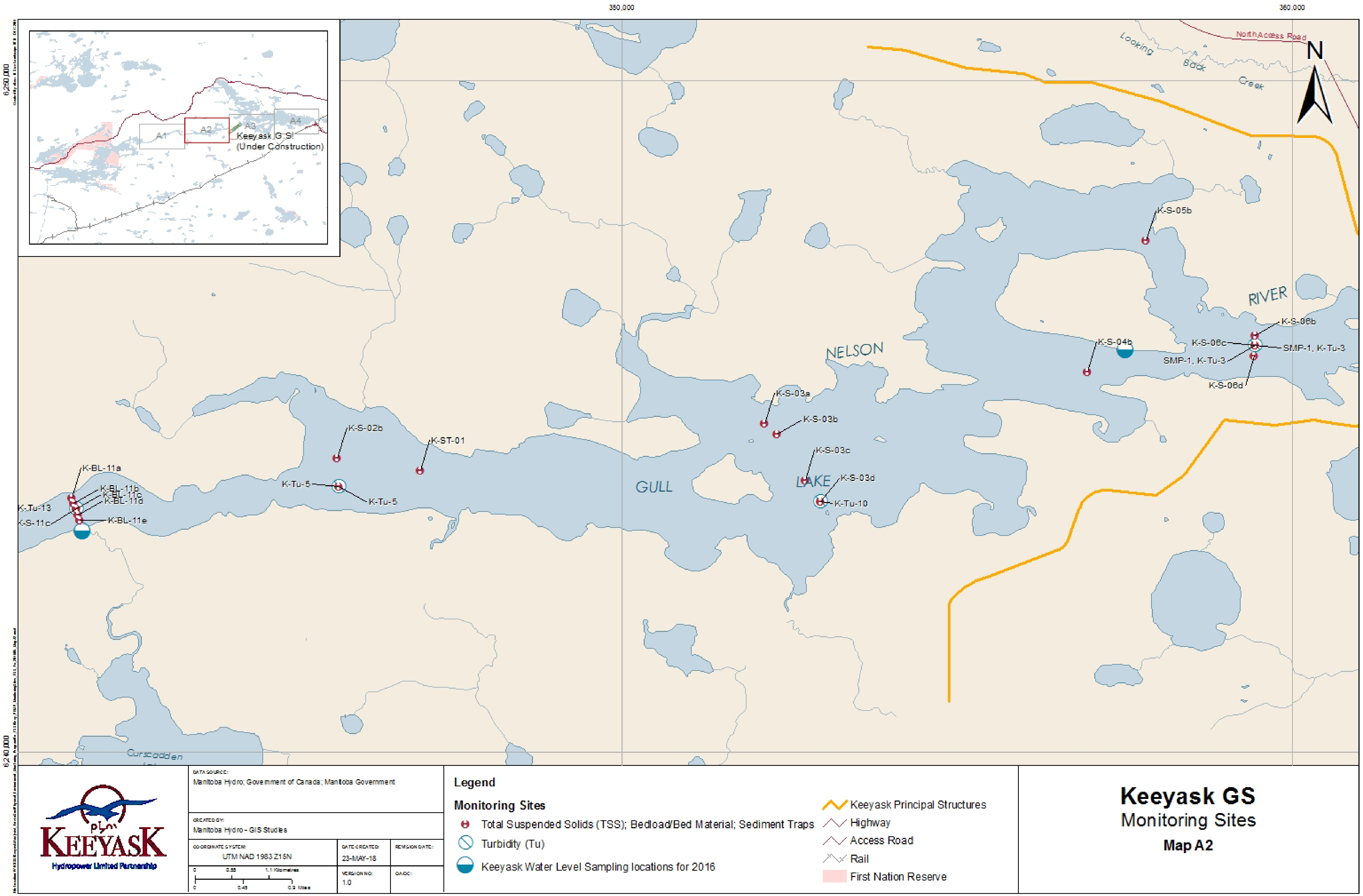
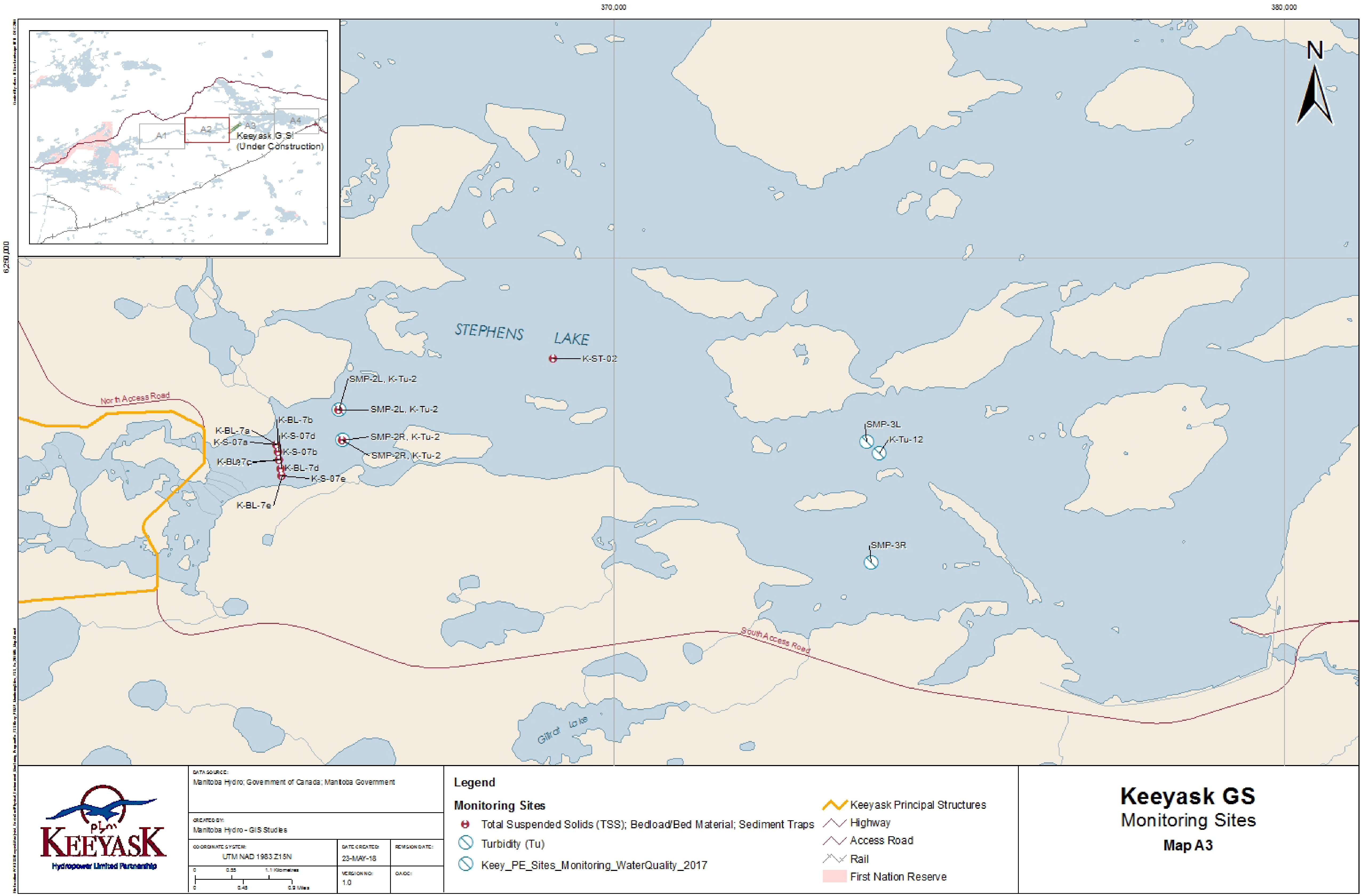
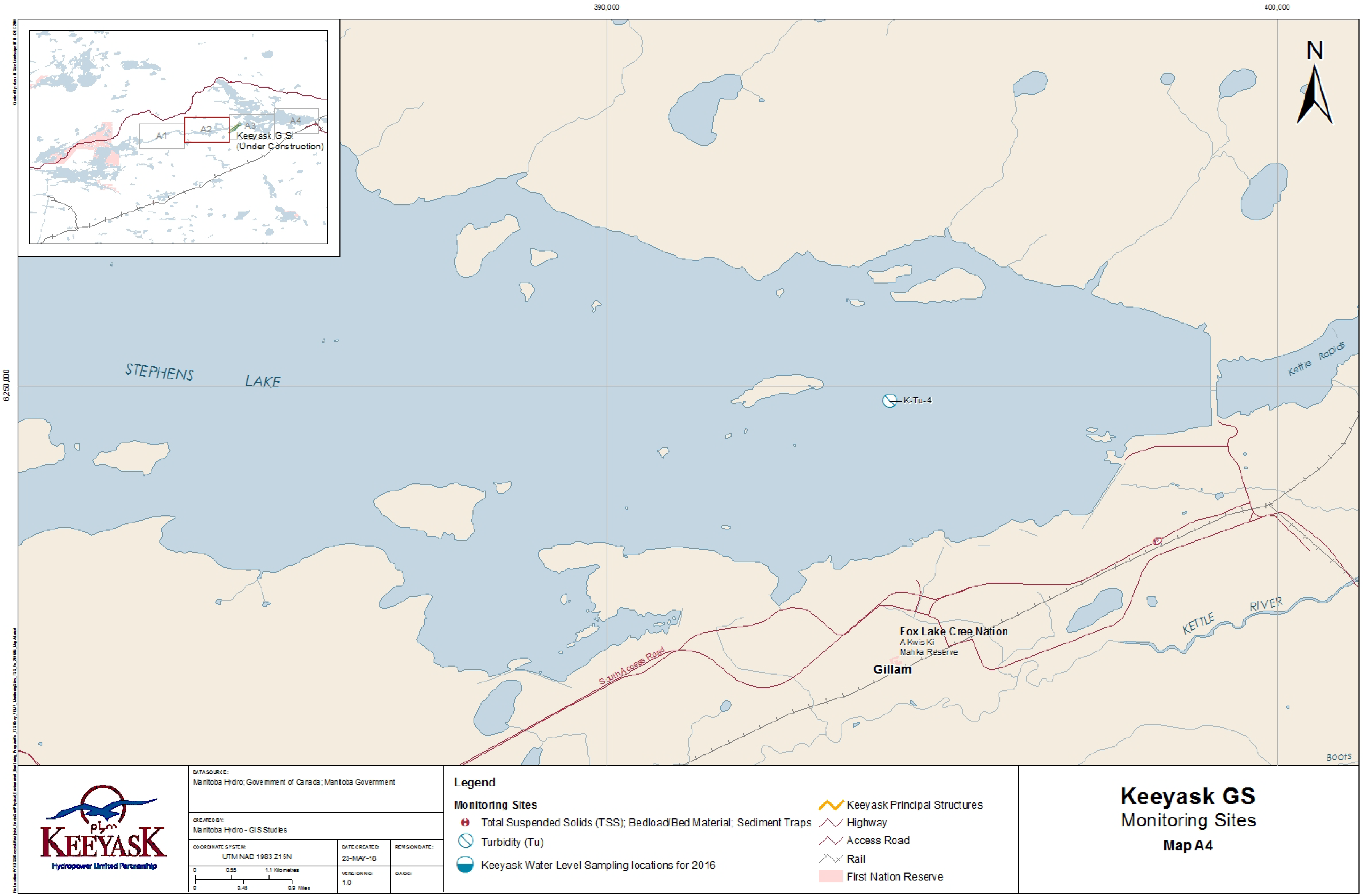
APPENDIX 1: DETAILED MAPS OF TURBIDITY AND TSS MONITORING SITES


330,000
340,000
6,240,000
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
Manitoba Hydro; Government of Canada; Manitoba Government
Manitoba Hydro - GIS Studies
UTM NAD 1983 Z15N
23-MAY-18
1.0
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 A1



350,000
360,000
6,250,000
6,240,000
A1
A2
A3
A4
Keeyask G.S.
(Under Construction)
N
North Access Road
Looking
Back
Creek
NELSON
RIVER
GULL
LAKE
Curscadden
K-S-05b
K-S-06b
K-S-06c
SMP-1, K-Tu-3
SMP-1, K-Tu-3
K-S-06d
K-S-04b
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-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
CREATED BY:
Manitoba Hydro - GIS Studies
COORDINATE SYSTEM:
UTM NAD 1983 Z15N
DATE CREATED:
23-MAY-18
REVISION DATE:
VERSION NO:
1.0
QA/QC:
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
6,250,000
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
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
SMP-3L
K-Tu-12
SMP-3R
North Access Road
South Access Road
Gilbert 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
QA/QC:
1.1 Kilometres
0.9 Miles
KEEYASK
Hydropower Limited Partnership
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


390,000
400,000
6,250,000
N
A1
A2
A3
A4
Keeyask G.S.
(Under Construction)
STEPHENS
LAKE
K-Tu-4
Kettle Rapids
KETTLE
RIVER
Fox Lake Cree Nation
A Kwis Ki
Mahka Reserve
Gillam
South Access Road
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
QA/QC:
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