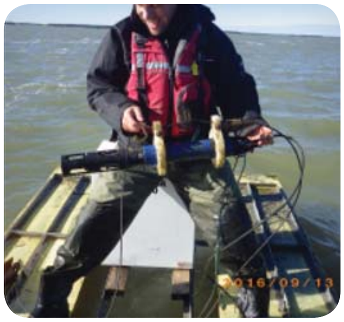
Keeyask Generation Project

Physical Environment Monitoring Plan

Physical Environment Monitoring Report

PEMP-2017-01



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2016 - 2017

KEEYASK GENERATION PROJECT

PHYSICAL ENVIRONMENT MONITORING PLAN

REPORT #PEMP-2017-01

2016-2017 PHYSICAL ENVIRONMENT MONITORING REPORT: YEAR 3 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 2016/2017 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 2016 and March 2017 was above the historical average most of the time, ranging from approximately 3,200 m^3/s (113,010 cfs) in May 2016 to 4,850 m^3/s (171,280 cfs) in January 2017. While river discharge was near the historical average in spring 2016, it was high for most of the last half of 2016 (above the historical 75th percentile flow) and was near or set record high flows from January to March 2017. 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 the Project.

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. As observed in previous years, the water level in Gull Lake at Caribou Island (7 km upstream) increased due to the rock groin, and in 2016 were about 0.9 m (3 feet) higher because of the rock groin. The amount of water level change due to this groin diminishes in the upstream direction and causes no change in water levels at Birthday Rapids or locations further upstream. The observed water level increases due to the North Channel Rock Groin were consistent with what was predicted.

Ice accumulation below Birthday Rapids and ice pans being transported from upstream.

A complete ice cover began forming on Gull Lake in early December, growing in an upstream direction until it progressed to the base of Birthday Rapids by early January. Water levels rose on Gull Lake and upstream to Birthday Rapids as the ice cover developed. Ice pans (small ice sheets) continued to move downstream from Clark Lake to Birthday Rapids and much of it would have been swept under the ice cover at Birthday Rapids. The ongoing accumulation of ice under the existing ice cove would gradually block the flow channel causing water levels to rise gradually. By early March, the gradual increase in levels reduced flow velocities in Birthday Rapids, which allowed the ice cover to progress upstream until the cover eventually reached about 6 km upstream of the rapids. This is about 2 km further upstream of the rapids than the ice cover reached in 2015. This is consistent with pre-Project observations that in years when the ice cover progressed through Birthday Rapids it would likely stop about 5 km upstream of the rapids.

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.

High resolution satellite imagery was collected to mark the location of the shoreline/top of bank at the start of the construction period. It is planned to collect satellite imagery in future years after the creation of the reservoir to monitor the location of the shoreline/top of bank in order to measure erosion and reservoir expansion over time.

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 individual turbidity readings 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 600 water samples were obtained and more than 750 on-site measurements were collected. As observed in previous monitoring during construction, results from the turbidity and suspended sediment monitoring in 2016/2017 do not suggest any apparent effects of the Project on sediment transport during the reporting period.

Botwing device (yellow) with mounted probe for turbidity sampling and hose for collection of water samples for laboratory testing

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 2016, 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 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 2015/2016 over-winter monitoring period compared with the previous winter (2014/2015) and compared with summer 2016. The sediment was also coarser, with a greater amount of sand being present. This may be due to the development of a very thick ice cover at the entrance to Stephens Lake, which constricts the flow. This flow constriction causes water levels to rise below Gull Rapids and may redirect flow along erodible shorelines, which may be source of the sand collected in winter 2015/2016. The sediment collected in summer was finer, being predominantly comprised of silt with some clay and little sand. Bottom material was sampled in 2015 and found mainly cobble at both the Gull Lake and Stephens Lake deposition monitoring sites. This indicates that while finer sediment is present in the water, it is not being deposited in the deposition monitoring areas but is instead being transported downstream.

Continuous turbidity monitoring equipment being prepared for deployment – electronics cabinet and solar panel on a catamaran below which a turbidity sensor will be 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. In total, 6 pieces of debris were removed and 7 reefs were marked.

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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 Effects 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 describes the physical environment monitoring performed from April 2016 to March 2017, third year of construction monitoring, which was completed in accordance with the PEMP.

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:

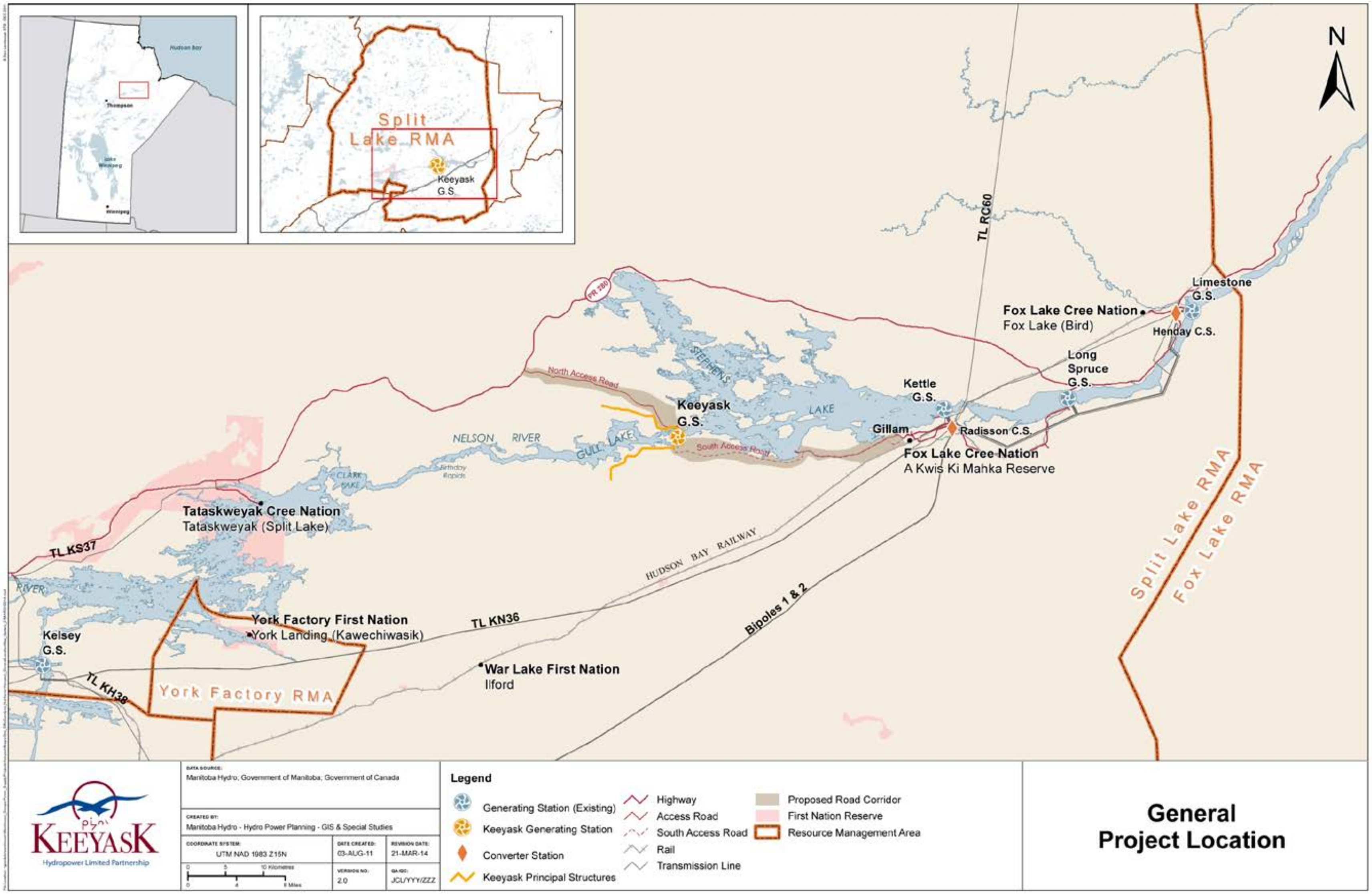
- Determine if EIS predictions of Project effects on the physical environment are correct and to identify unanticipated effects.
- Support other monitoring programs (e.g., aquatic and terrestrial) that will monitor Project effects and determine the effectiveness of mitigation and offsetting measures.

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 2016/2017, 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 represented by 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 Lake 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.

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 the current reporting period from April 2016 to March 2017. They have ranged from approximately 3,200 m^3/s (113,010 cfs) in May 2016 to 4,850 m^3/s (171,280 cfs) in January 2017. Flows were close to the median in spring 2016 but climbed through summer and by early August were above the 75th percentile flow. The flows remained above the 75th percentile flow until dipping close to the median in early December, which was followed by a rise in flow during the rest of the month. Since January 1, 2017, the flow has exceeded 4,000 m^3/s (141,260 cfs). On 58 of the 90 days from January 1 to March 31, about two-thirds of the time, the flow has exceeded the previous historical high flow and set a new high flow record.

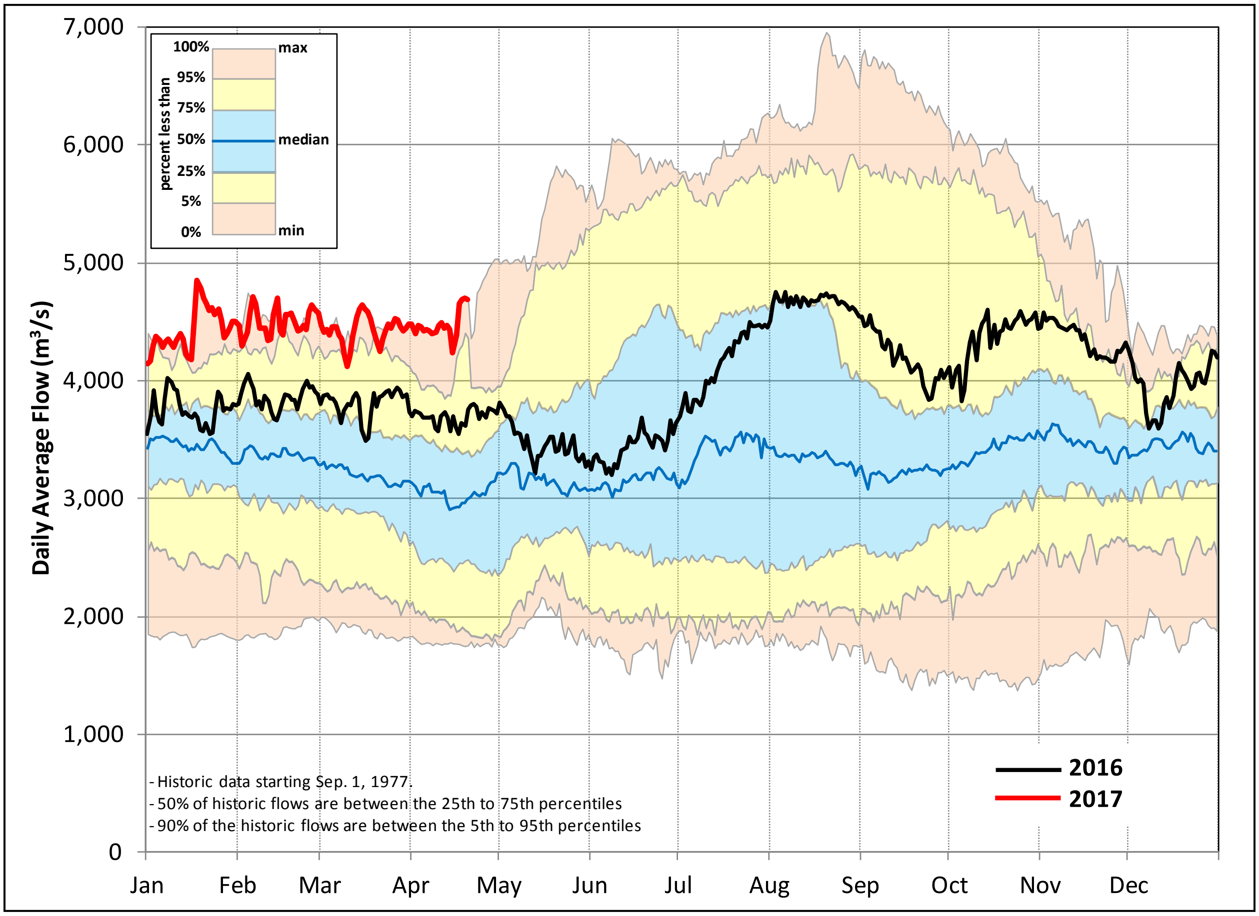


Figure 1: **Split Lake 2016/2017 daily average outflow and historical statistics**

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 2016, the start of the current reporting period, water levels were starting to drop from their winter peak (Figure 2). By the end of April the ice was starting to break up and about the first week of May the levels had returned to open-water conditions where levels are only dependent upon flow without any ice effects. During the open water period up to late November / early December, 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.

At the beginning of November, flows and water levels were steady in the study area as open water conditions prevailed (Figure 3). About November 19, air temperatures dropped and ice began to form behind the ice booms causing levels to rise at the site above Gull Lake. Levels dropped when temperatures increased, but by December 1, the levels were gradually increasing. About December 5, air temperatures dropped and an ice cover formed rapidly upstream on Gull Lake, causing a more rapid water level increase up to Birthday Rapids. On Clark and Split lakes, water level increases associated with ice growth also began about November 20 and ice effects persisted from then through the winter season.

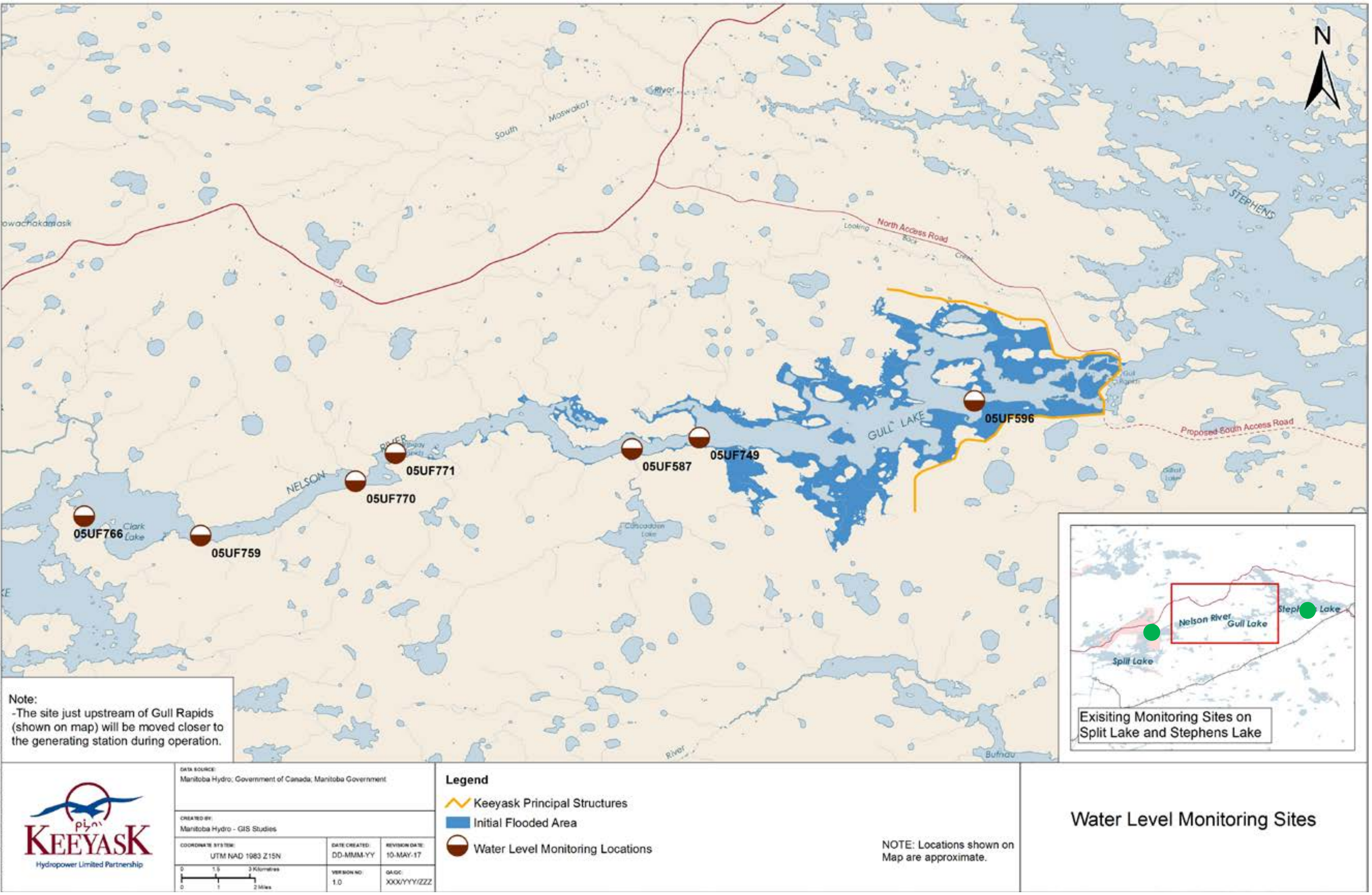
Levels increased 5-6 m at the sites upstream of Gull Lake and below Birthday Rapids. Erratic data was observed at the site upstream of Gull Lake (05UF587), which was likely due to ice effects on the equipment. A site visit in January 2017 found different levels of suspended ice (i.e., layers of ice frozen into the trees) at this gauge site, with ice right up to the base of the main equipment platform and ice on equipment and cabling below the platform (Photo 2). Water levels at the site above Birthday Rapids rose about 2.5 m in December and steadily rose through the winter, likely due to growth of shore ice and accumulation of ice at Birthday Rapids. Up to March, winter staging (i.e., an increase in water level not associated with an increase in flow) of about 1.3 m occurred below Clark Lake, about 0.8 m on Clark Lake, and about 0.7 m on Split Lake. The staging on Split Lake is typical of winter increases seen before construction (KHLP 2012b, Sec. 4.3.1.3).

Additional staging occurred at the sites upstream of Birthday Rapids in conjunction with a winter storm in early March. Favourable conditions existed such that on March 4 a snowfall appears to have caused the ice front to progress through Birthday Rapids and levels at the site upstream of Birthday Rapids rose sharply in response. Levels at the site below Clark Lake and on Clark and Split lakes began to increase on March 7, coincident with a winter storm. Levels gradually increased until March 12, rising about 1 m below Clark Lake and about 0.3 m on Clark and Split lakes. The initial sharp rise at the site below Clark Lake may be due to influence from the advancing ice front. It is not apparent if the advancing ice front affected levels on Clark and Split lakes since the increases on both were similar to increases observed under different conditions (e.g., late January to early February 2017), which was not associated with any increases between Clark Lake and Birthday Rapids.

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**

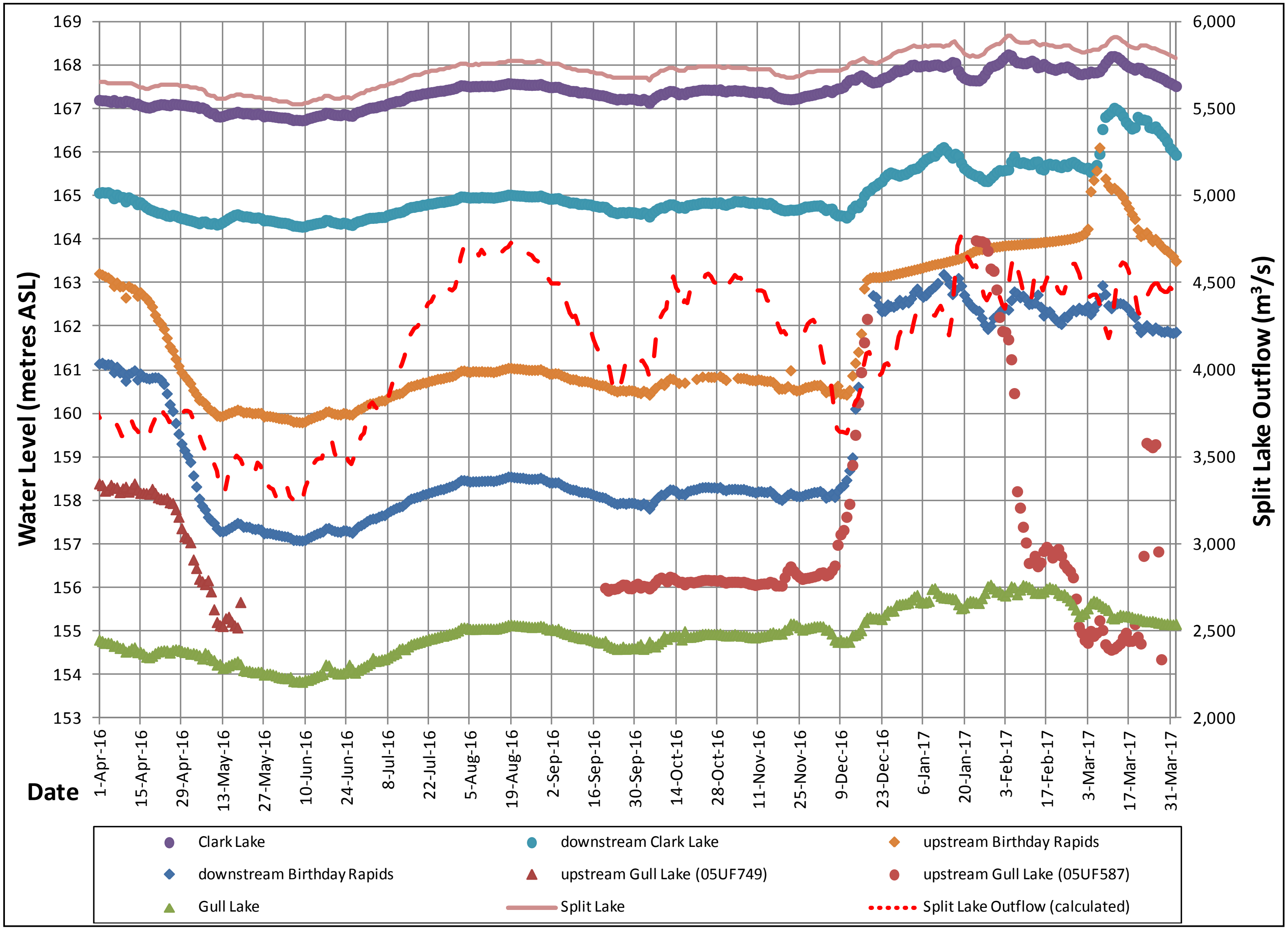
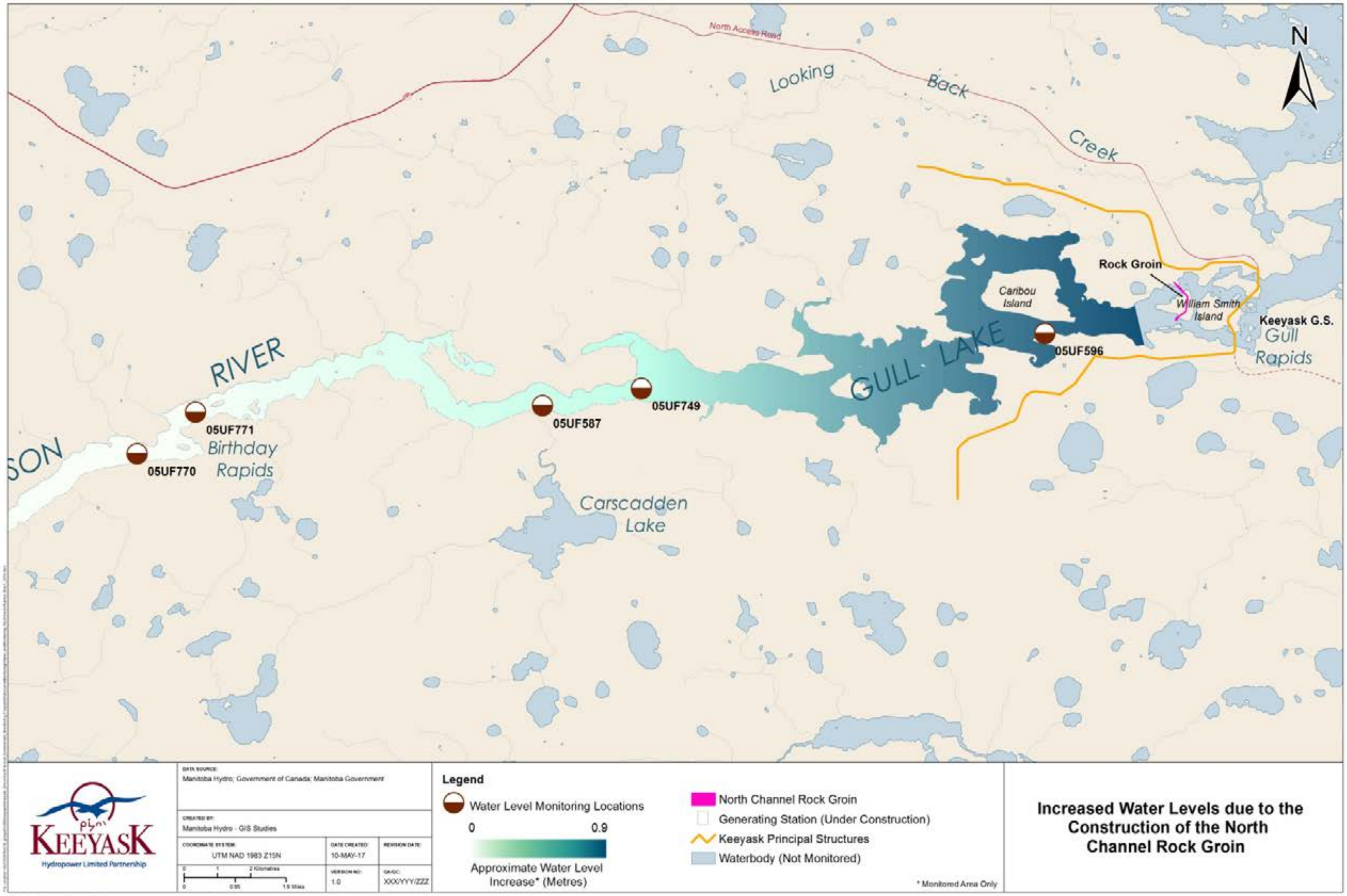


Figure 2: **Observed water levels at PEMP monitoring sites in 2016/2017**



NOTE: Locations shown on map are approximate.

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

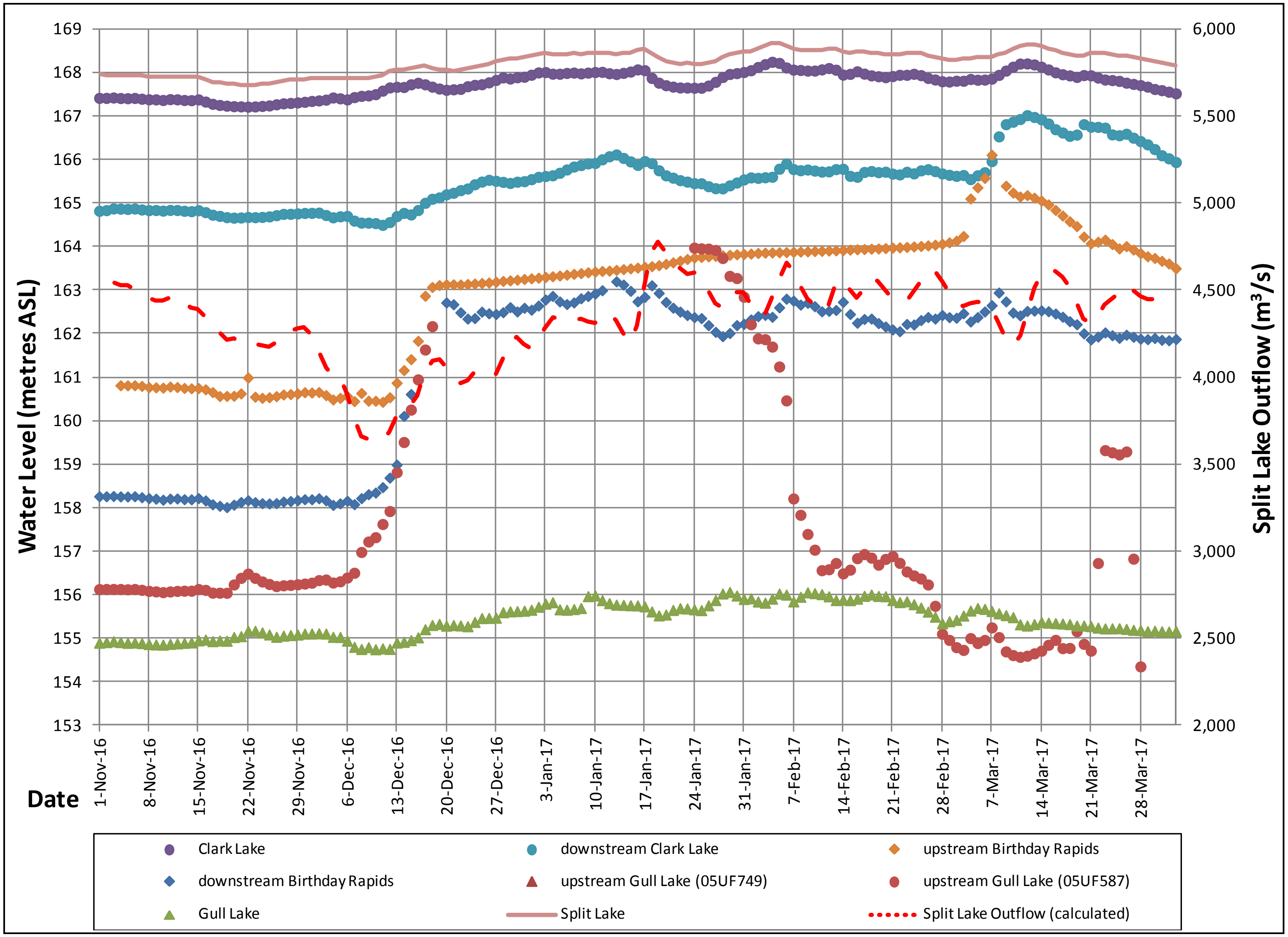


Figure 3: **Observed water levels, November 2016 to April 2017**

Photo 2: **Suspended ice at water level gauge 05UF587 upstream of Gull Lake with a summer image for reference**

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 4). The levels on these two lakes show the same pattern of variation, differing by about 0.3-0.6 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 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). The increase of about 0.3 m on Split Lake during the snowstorm in early March was coincident with increases observed at the site below Clark Lake and above Birthday Rapids. While the increases above Birthday Rapids and below Clark Lake were due to the ice front moving through Birthday Rapids, it is not clear that the increase on Clark and Split lakes were associated with the ice front progression. As noted above, the rise observed on Clark and Split lakes is similar to increases previously observed, such as the water level rise about a month earlier in late January to early February, which were associated with local ice conditions in Clark and Split lakes.

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 forms most years (approximately 2 out of 3 years) on Gull Lake and the Nelson River up to Birthday Rapids, although the timing and extent varies with flow and climate conditions. A combination of higher flow and/or warmer conditions may prevent a bridge from forming in some years so that open water may persist in the central channel from the exit of Split Lake to the entrance of Stephens Lake. In years when bridging does occur, the date when it occurs may be as early as November at lower flows to as late as January at higher flows.

In 2016, open water conditions persisted until about November 19 when air temperatures dropped sharply and ice formation increased, as evidenced by increasing water levels at gauge sites above Gull Lake and on Clark and Split lakes. Little ice was present at the ice booms on November 18, but ice had begun to accumulate on the 19th and water levels increased (Photo 3). Levels subsequently dropped on Gull Lake when temperatures increased, but by December 1, the Gull Lake levels were gradually increasing. About December 6, the temperatures dropped and levels began a sharper rise as the upstream ice cover progression increased. While ice had accumulated at Ice Boom B south of Caribou Island on November 19 (Photo 4) the ice had moved away from it in the following days. By December 3, the ice had bridged across the river just upstream of the boom, leaving open water between the boom and the ice bridge (Photo 4). This open water gap gradually iced over until it closed up by about mid January.

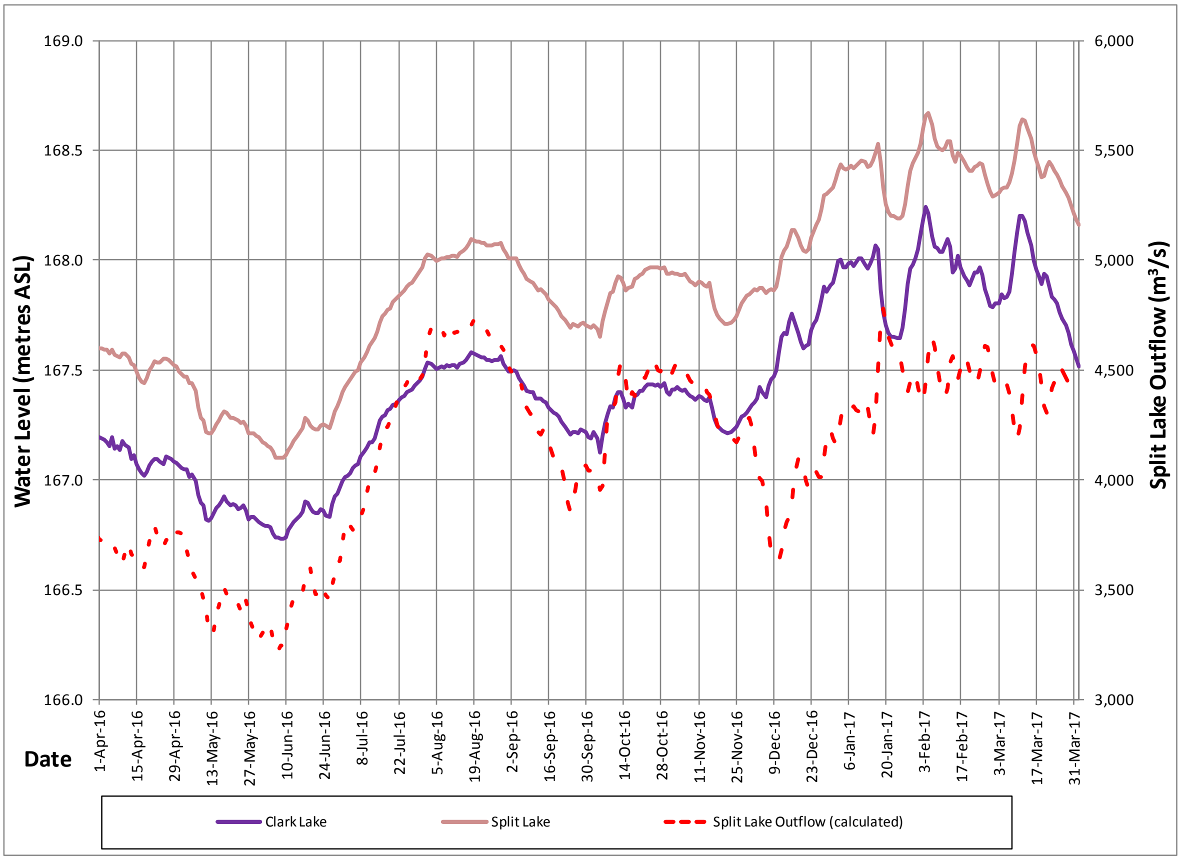
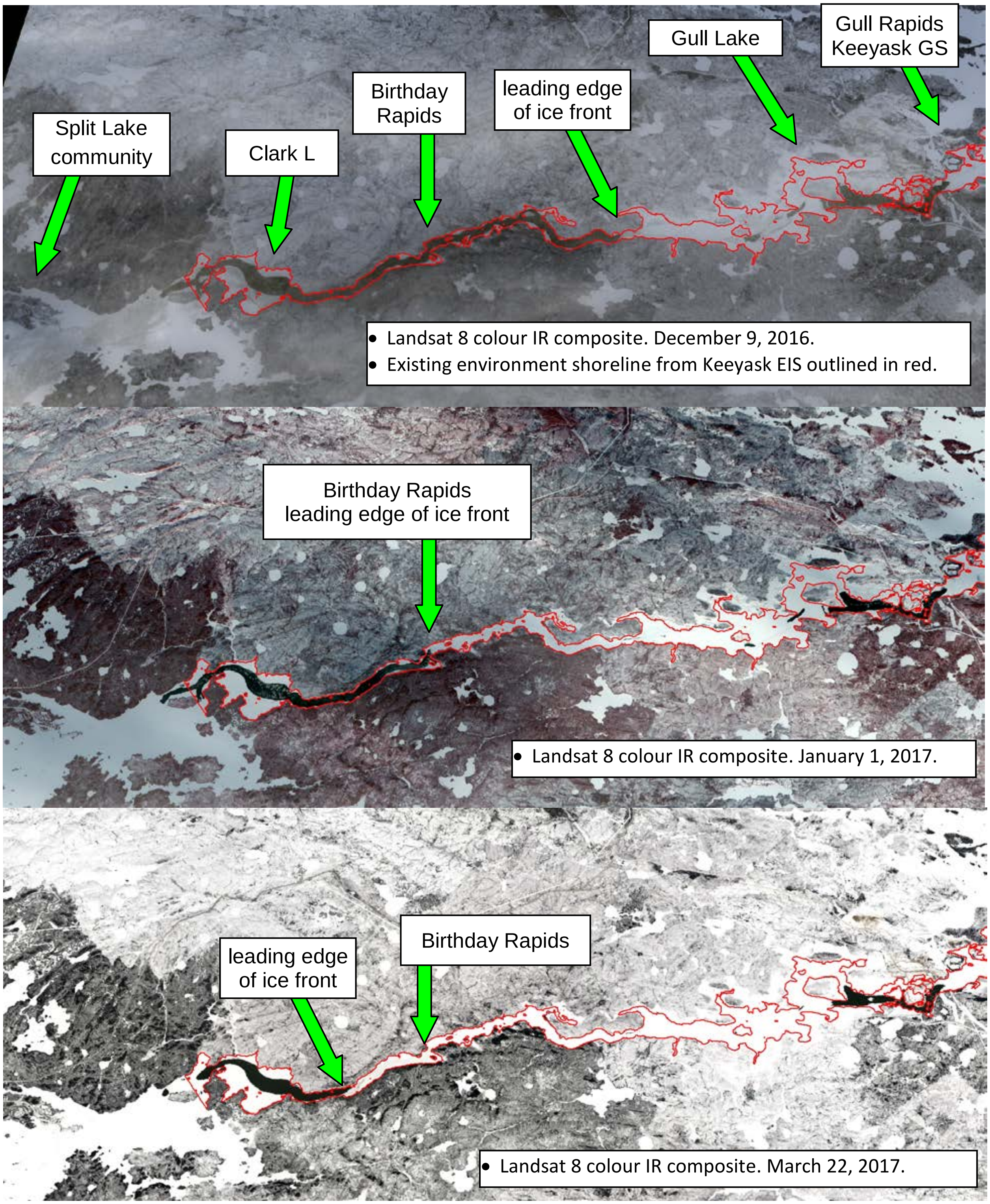


Figure 4: Observed water levels at Clark Lake and Split Lake in 2016/2017

There are no cloud free satellite images available during the period of initial freeze-up from about November 19 to December 6. A Landsat 8 image from December 9 shows that by that date the ice front had progressed to about 1 km upstream of Gull Lake (Figure 5). The ice front gradually progressed upstream and the next available satellite image on Jan 1, 2017, shows the ice front stalled at the base of Birthday Rapids (Figure 5). As noted above, the ice front progressed through Birthday Rapids about March 4. By the time of the next available satellite image on March 22, the ice front had progressed about 6 km upstream of Birthday Rapids (Figure 5). As noted in the 2015/2016 annual PEMP report (Manitoba Hydro 2016), the ice front also progressed through Birthday Rapids in March 2016 and progressed to at least 4 km upstream. The Keeyask EIS had also noted that in the pre-Project environment if the ice front progressed through Birthday Rapids, it would typically stall about 5 km upstream (KHLP 2012b). By the time of the next satellite image on March 31, 2017, the ice front had begun to recede downstream and continued to recede in subsequent images. Like the ice cover that forms in the river channel below Birthday Rapids, the upstream cover formed as ice piled up at the leading edge, pushing and shoving as more accumulated, resulting in a rough, jumbled ice surface (Photo 5, Photo 6).

Photo 3: **Ice Boom A on east side of Caribou Island (Nov. 18, 19, 2016)**

Photo 4: Ice Boom B on south side of Caribou Island (Nov. 19 & Dec. 3, 2016)



- Landsat 8 colour IR composite. December 9, 2016.
- Existing environment shoreline from Keeyask EIS outlined in red.
- Landsat 8 colour IR composite. January 1, 2017.
- Landsat 8 colour IR composite. March 22, 2017.

Figure 5: Ice Conditions – December 9, 2016; January 1, 2017; March 22, 2017

Photo 5: **Leading edge of ice cover upstream of Birthday Rapids (March 18, 2017)**

Photo 6: **Ice cover at Birthday Rapids (March 18, 2017)**

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 the start of construction and before 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 (SMP) for In-stream Construction (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 2017).

Sediment transport monitoring was done through collection of discrete water samples and continuous turbidity monitoring 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.

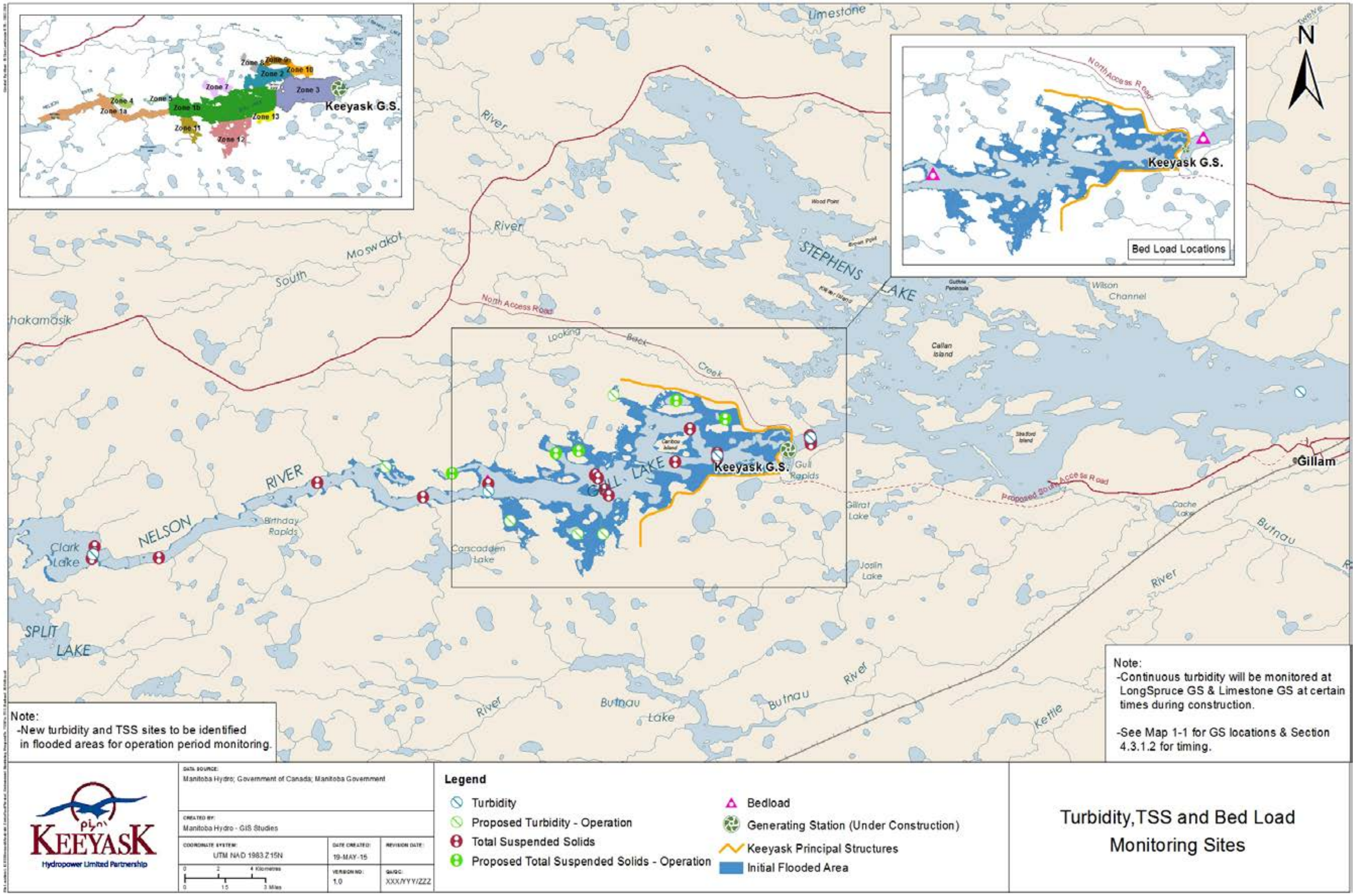
4.1 WINTER 2015-2016

Monitoring conducted in winter 2015/2016 was not presented in the 2015-2016 PEMP report (Manitoba Hydro 2016) because removal of equipment at the end of winter season does not allow time for the data to be reviewed before the reporting deadline. Continuous turbidity probes were deployed at three locations in January 2015: K-Tu-06 in Clark Lake; K-Tu-10 in Gull Lake; and K-Tu-12 in Stephens Lake (location maps in Appendix 1). The K-Tu-12 site is adjacent to the SMP-03 site that is monitored for the Keeyask SMP. It is further downstream from Gull Rapids than the K-Tu-02 site at the entrance to Stephens Lake, which is monitored during the summer. K-Tu-12 was monitored because adverse ice conditions (thick ice, slush under ice) prevented a probe from being placed closer to K-Tu-02.

Winter monitoring involves the use of the summer monitoring platforms placed on the ice (Photo 7). An aluminum pipe is placed through the ice and the turbidity probe is suspended in the pipe so that the sensor Projects out of the tube below the bottom of the ice. Winter monitoring faces unique difficulties due to factors such as slush below the ice and freezing of equipment.

Photo 7: Winter installation of continuous turbidity monitoring site

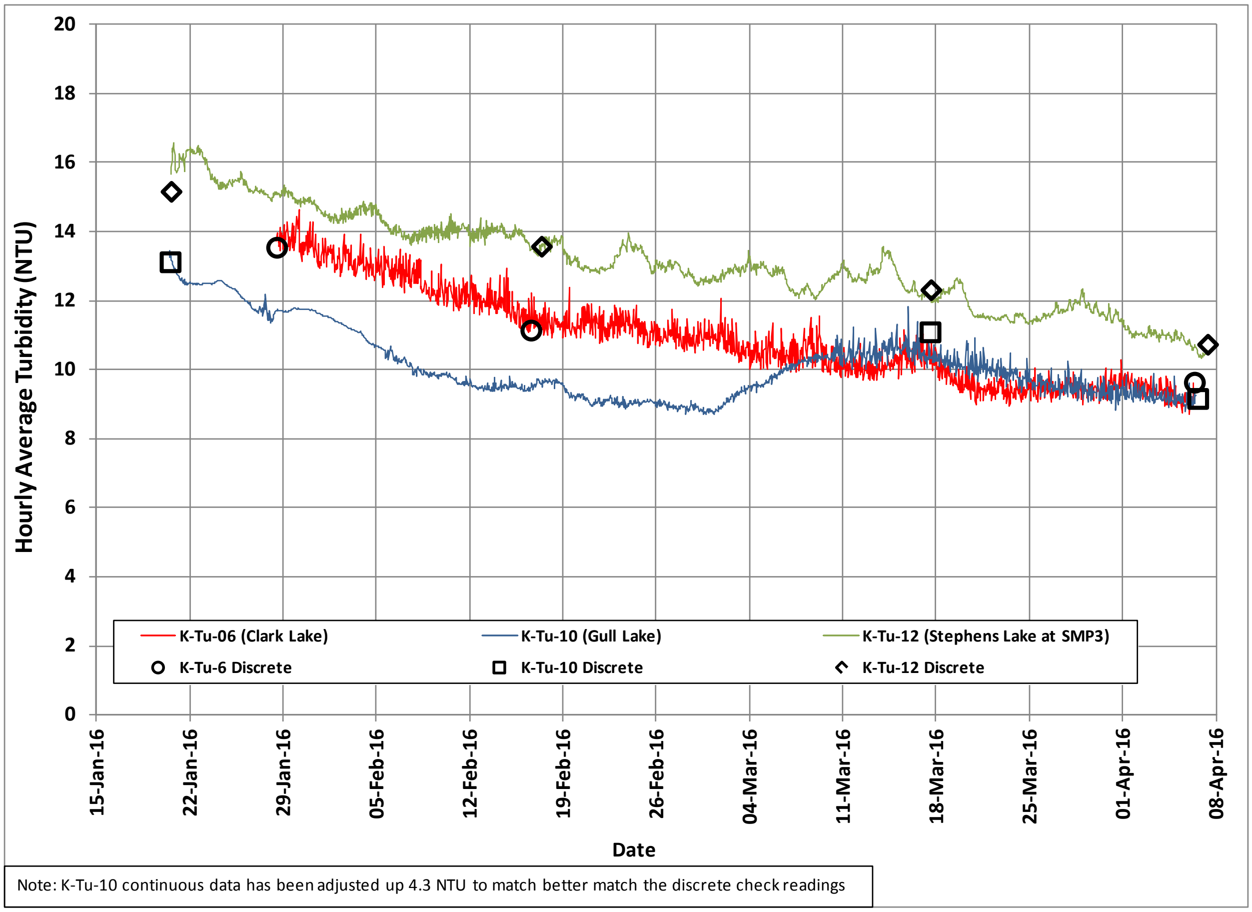
Figure 6 shows turbidity data collected in the January to April period. On three visits to site K-Tu-10 the discrete turbidity readings obtained using a separate check probe were consistently greater than the value from the continuous probe. The continuous probe likely had a low bias, therefore the continuous values were adjusted up by 4.3 NTU to better align with the discrete check readings. Turbidity generally declined at all three sites by about 4-6 NTU during the monitoring period. Turbidity was highest at K-Tu-12 in Stephens Lake, although K-Tu-06 was only lower by about 1 NTU over the whole period, as was K-Tu-10 over about the last month. A difference of 1 NTU is not particularly large. Turbidity at K-Tu-10 in Gull Lake was lower than at K-Tu-06 and K-Tu-12 by 2-3 NTU over about the first 5 weeks of monitoring before rising at the start of March. Though it cannot be confirmed, this may be due in part to additional water level staging at and upstream of Birthday Rapids at about the same time, as noted in Section 2.2. Conditions observed at K-Tu-06 are much the same as observed the previous winter (2014/2015) while results for site K-Tu-10 in Gull Lake are similar to the short period of data from Gull Lake in winter 2014/2015. Results at K-Tu-12 are much lower than observed the previous year, possibly due to less interference from ice and differences in under-ice erosion conditions.



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

Table 2: January – April discrete monitoring results

Site ID	Date	Turbidity (NTU)	TSS (mg/L)
K-Tu-10	20-Jan-16	13.1	7.8
K-Tu-12	20-Jan-16	15.2	7.3
K-Tu-06	28-Jan-16	13.6	6.5
K-Tu-06	16-Feb-16	11.2	2.7
K-Tu-12	17-Feb-16	13.6	4.4
K-Tu-10	17-Mar-16	11.1	4.3
K-Tu-12	17-Mar-16	12.3	4.8
K-Tu-06	06-Apr-16	9.6	4.4
K-Tu-10	06-Apr-16	9.2	5.0
K-Tu-12	07-Apr-16	10.7	5.5



Note: K-Tu-10 continuous data has been adjusted up 4.3 NTU to match better match the discrete check readings

Figure 6: Winter 2015/2016 continuous and discrete turbidity

As with the continuous turbidity, the discrete turbidity values showed a decline from the start to the end of the monitoring period (Table 2). Discrete TSS concentrations were higher in January but, except for a low value of 2.7 mg/L, only varied over a small range from 4.3 mg/L to 5.5 mg/L from February to April, a negligible difference of 1.2 mg/L. These TSS concentrations are similar to those observed in winter 2014/2015. Low TSS concentrations were observed in winter on Gull Lake prior to construction (2008, 2009), however some higher values of up about 40-80 mg/L were also measured in the pre-Project sampling (KGS Acres 2011). Below Gull Rapids, the pre-construction TSS concentrations were higher than observed in 2015/2016, having varied from about 20 mg/L to a maximum of 156 mg/L. The past higher TSS levels may result from ice accumulation at the entrance to Stephens Lake, which can redirect flows and increase flow velocities over erodible bottom material causing sediment to be suspended in the water. During construction, the upstream ice-boom reduces the accumulation of ice at the entrance to Stephens Lake, which may reduce the effects on TSS due to under-ice flow re-direction.

4.2 SUMMER 2016

4.2.1 BEDLOAD

Bedload monitoring was performed in both 2014 and 2015. However, in both years the monitoring attempts were not successful in being able to collect sufficient samples for laboratory testing. This was consistent with pre-Project monitoring which found that bedload sampling efforts typically returned no usable samples. Sampling across a wide range of flows has consistently indicated that bedload is negligible. The PEMP stated that if sampling efforts were unable to obtain adequate samples in the first two years of construction then the bedload monitoring would no longer be performed during construction. Therefore, bedload monitoring was not performed in 2016. Sampling will be attempted again during operation.

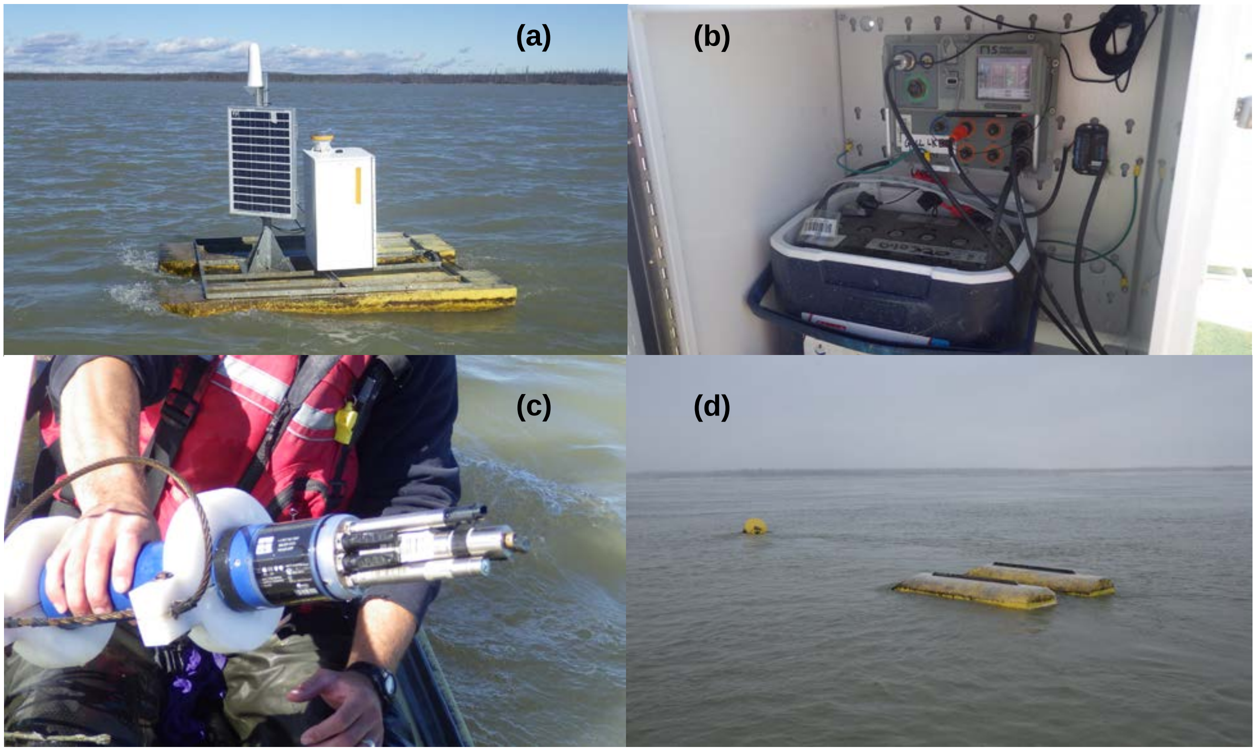
4.2.2 CONTINUOUS TURBIDITY

The five continuous turbidity sites monitored in summer 2016 and the dates for which records are available are (location maps in Appendix 1):

- K-Tu-06, Clark Lake, June 27 to October 18
- K-Tu-05, entrance of Gull Lake, June 27 to October 16
- K-Tu-03, head of Gull Rapids, June 11 to October 14
- K-Tu-02, entrance of Stephens Lake, June 7 to October 13
- K-Tu-04, near Kettle GS, June 24 to October 14

The continuous turbidity monitoring sites consist of a set of equipment and electronics that are placed at the monitoring sites through the summer (Photo 8). Anchored at each site is a catamaran on which is a solar panel, a transmitter and an electronics cabinet (Photo 8a). The cabinet houses a battery and electronic equipment to record the measurements collected by the turbidity sensor, which is mounted in the turbidity probe that is suspended below the catamaran (Photo 8b, c). Daily, the data are transmitted via satellite to Manitoba Hydro where it is stored in a database, which helps ensure data is not lost in case of an unexpected event that could cause data loss. For example, at the end of the season the catamaran at site K-Tu-05 was flipped by large waves, which compromised some equipment (Photo 8d).

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. A wiper on the turbidity probe cleans the sensor before each reading, which helps to reduce the potential effect of algae growth on sensor. The continuous data were also compared with the discrete readings obtained on each maintenance site visit. This comparison found that the continuous data at sites K-Tu-03 and K-Tu-02 were consistently slightly higher than the readings obtained from the handheld probe used for discrete readings. The handheld unit is considered more accurate because it is not left exposed in the environment and is more frequently maintained. For this reason, the K-Tu-03 and K-Tu-02 records were adjusted downward by 3.2 NTU and 2.8 NTU respectively. The K-Tu-03 continuous data also showed an abrupt 2.5 NTU downward shift at 6 pm on September 21 so that the remainder of the data after the shift was likely too low. To correct this, all the data after that time were adjusted upwards by 2.5 NTU.



Notes: (a) catamaran with solar panel, transmitter and electronics cabinet, (b) electronics in cabinet, (c) probe with turbidity sensor installed, (d) overturned catamaran at K-Tu-05

Photo 8: Continuous turbidity monitoring site

in the environment and is more frequently maintained. For this reason, the K-Tu-03 and K-Tu-02 records were adjusted downward by 3.2 NTU and 2.8 NTU respectively. The K-Tu-03 continuous data also showed an abrupt 2.5 NTU downward shift at 6 pm on September 21 so that the remainder of the data after the shift was likely too low. To correct this, all the data after that time were adjusted upwards by 2.5 NTU.

The data sets resulting from the quality review process were analyzed to calculate the hourly average turbidity at each of the five monitoring sites (Figure 7). For the four monitoring sites from Clark Lake to the entrance of Stephens Lake (K-Tu-06, K-Tu-05, K-Tu-03, and K-Tu-02) the patterns of turbidity variation are much the same at each site. Site K-Tu-06 in Clark Lake, however, has somewhat less pronounced peaks than the other three sites in this reach. Although turbidity tends to be lower at K-Tu-06 upstream and higher at K-Tu-02 downstream, the turbidity levels are generally within about 1-3 NTU of each other at these four sites, which is a relatively minor range of deviation. Overall, the turbidity at these four sites varies from about 20-33 NTU during the monitoring period. Somewhat higher values occur from mid-June to mid-August (approx. 25-33 NTU) with somewhat lower values from mid-August through September (approx. 20-25 NTU). At the start of October turbidity levels spike at these four sites due to high wind conditions and in October, aside from the peak, turbidity generally rises from about 20 NTU to 33 NTU.

Site K-Tu-04, which is in Stephens Lake about 30 km downstream of site K-Tu-02, typically has lower turbidity than the other four sites (Figure 7). It displays variations similar to those at the sites upstream but there are differences as well, such as larger declines in late June and mid July, and a less pronounced but more extended peak in early October. While the sediment from upstream is transported past site K-Tu-04, the turbidity may be lower as sediment settles out as flow passes through the lake. Also, spikes seen upstream due to storm or wind events may be less pronounced but more spread out in time because the upstream peak is attenuated as flow passes through the lake. Site K-Tu-04 may also differ from the other sites due to processes strictly within Stephens Lake that would not affect upstream locations (e.g., erosion of Stephens Lake shorelines). Overall, the 2016 turbidity levels appear to be a bit higher than observed in summer 2015 and more similar to the levels observed in 2014.

Consistent with pre-Project conditions, the continuous turbidity data do not suggest a strong correlation between river flow and turbidity level. While flow gradually increases through June and July, the observed turbidity shows a range of variation independent of flow changes. Notably, a large increase occurs at sites K-Tu-03 and K-Tu-02 in mid-June that is not associated with a large change in flow. Similarly, the rapid turbidity spike noted at the beginning of October is not obviously connected to a rapid change in flow. From late August through September, when flow declines from about 4,700 m^3/s to 3,800 m^3/s, turbidity remains relatively steady at all five sites.

Variations in turbidity show more of a response to wind conditions. Using Environment Canada hourly wind data from the Gillam Airport (Meteorological Service of Canada ID# 5061022) the 48-hour moving average wind speed was calculated for summer 2016 and plotted along with the continuous turbidity data (Figure 8). A 48-hour moving average was used to smooth out short peaks and troughs in wind conditions that are less likely to produce the larger wave conditions that can cause sediment to enter the water from shorelines and from stirring up sediment in shallow areas. Various peaks in the average wind directly correspond with turbidity increases. Most notable are the turbidity peaks around June 19 and the large spike at the beginning of October, which corresponds with the largest peak in the 48-hour average wind plot (Figure 8). The 48-hour average wind speed remains elevated above 15 km/h after the early October peak, which may be the cause of increasing turbidity level through October. The increase through October may also be due in part to sediment that entered the water further upstream during the high wind period that has a delayed effect in the Keeyask area due to transport time from an upstream area.

It should be noted that similar wind peaks do not necessarily create the same magnitude of effects on turbidity. For example, the two wind peaks around September 21 and 28 are similar in magnitude to the wind peak around June 19, but the September winds do not create a similar increase in turbidity (Figure 8). The response of turbidity to wind will depend on a number of factors such as: magnitude and duration of higher winds creating the peak; wind direction; and local wind variability since conditions at Gillam Airport may not be completely representative of what occurred further away in the Gull Lake or Split Lake areas.

4.2.3 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. In total, 10 different locations were monitored with a total of 25 individual sites being sampled since some locations have two or more sites being monitored across the width of the river. Additionally, some discrete monitoring sites (sites with K-S prefix) and continuous turbidity sites (sites with K-Tu prefix) are in the same location. Specifically, the sites visited were: K-S-01b; K-S-02b; K-S-03 (a, b, c, d); K-S-04b; K-S-05b; K-S-06 (b, c, d); K-S-07 (a, b, c, d, e); K-S-09 (a, b, c); K-S-10c; K-S-11c; K-Tu-02; and K-Tu-03, K-Tu-04; K-Tu-05; and K-Tu-06.

The average laboratory TSS and in-situ turbidity values for each site visit were calculated for each of the 25 individual sites that were monitored. Since the PEMP monitoring area has a predominantly east-west alignment, the results were plotted based on the easting component of each site’s UTM co-ordinate by using the easting values as the horizontal axis (Figure 9). Thus, the plotted results show the TSS and Tu variations in an upstream to downstream direction (from left to right) while also indicating the relative distance between the different monitoring sites: the difference in easting value between two sites is an estimate of the distance between the sites in meters.

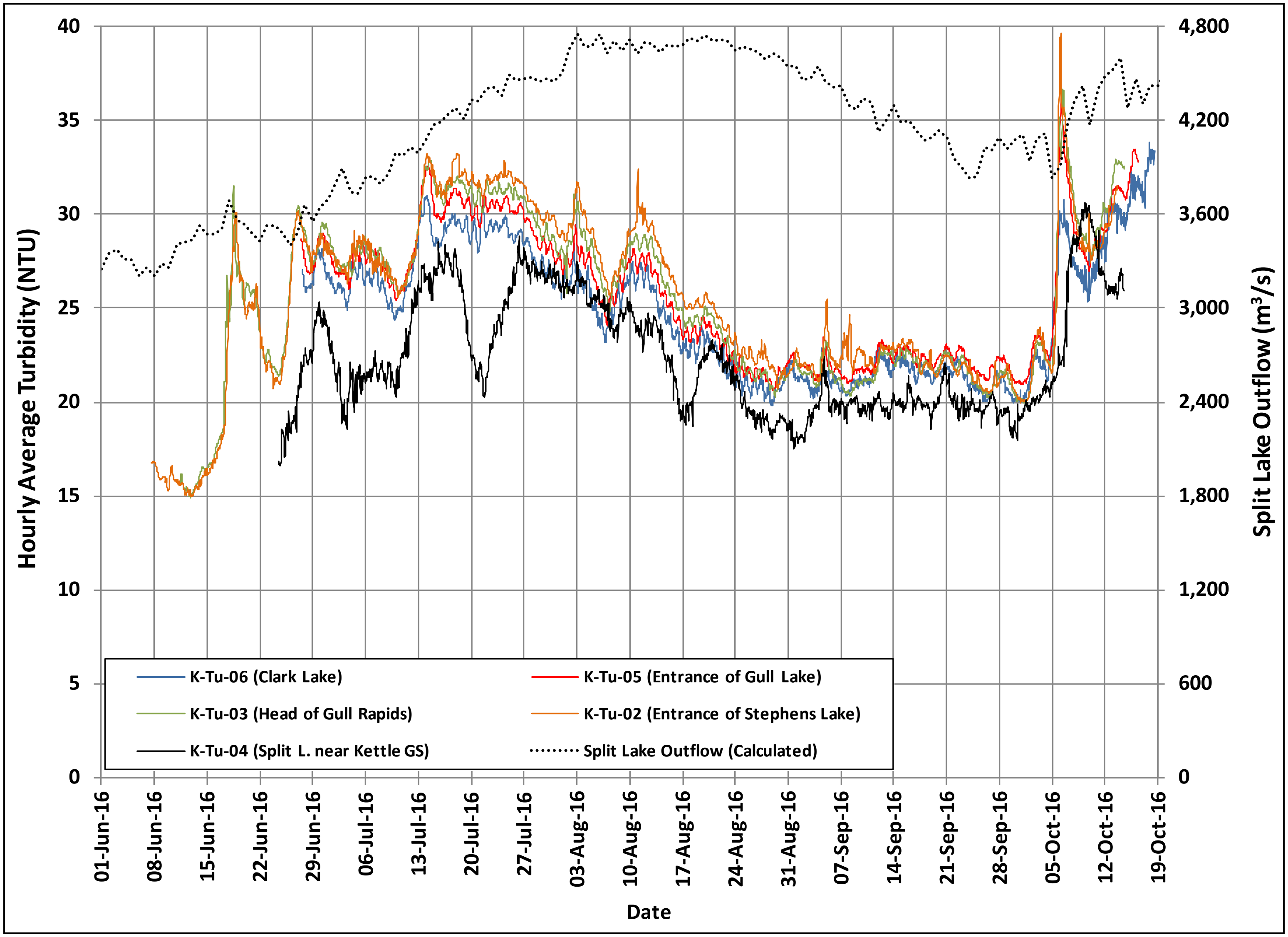


Figure 7: **Summer 2016 continuous turbidity and flow**

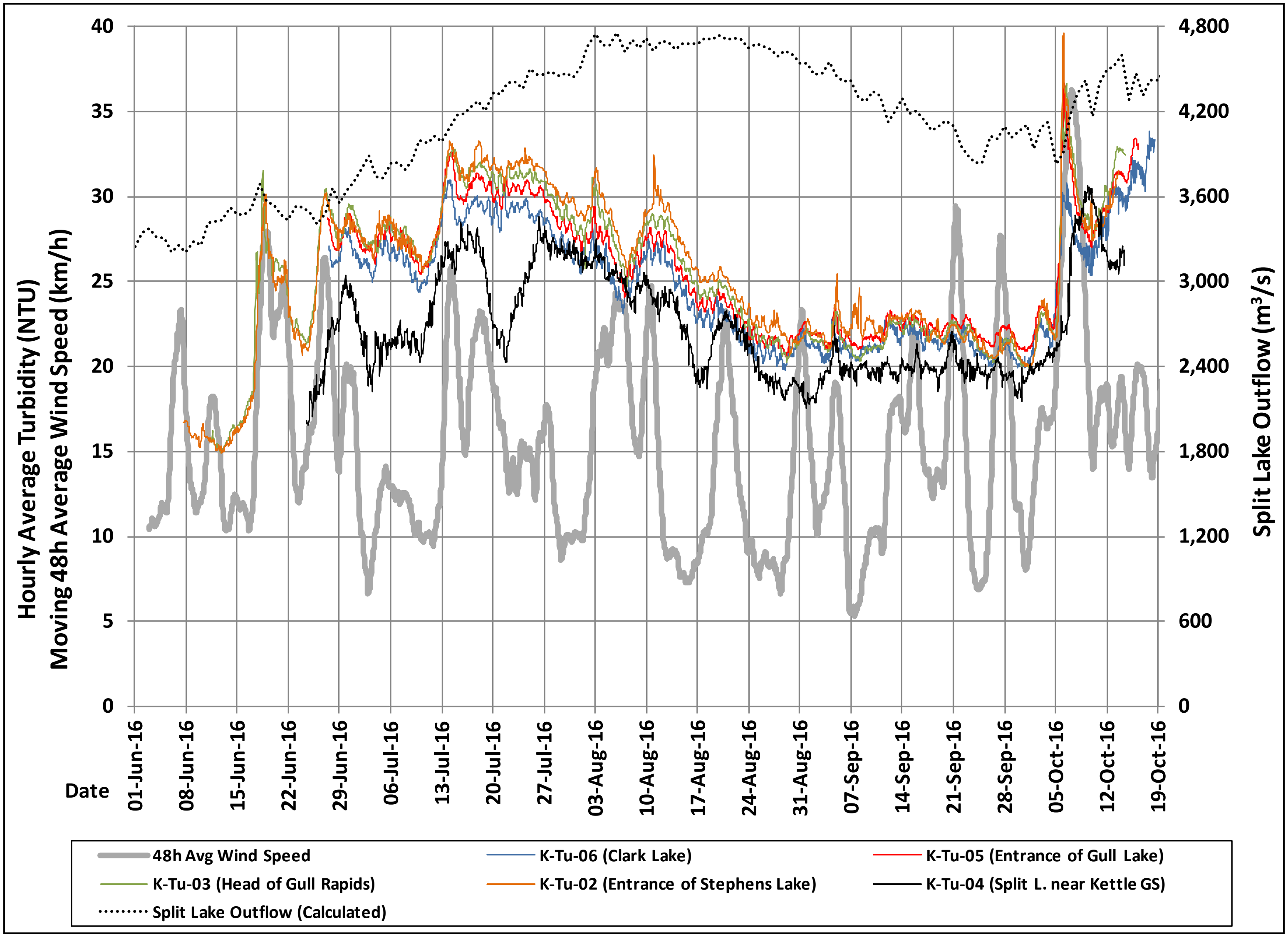


Figure 8: **Summer 2016 continuous turbidity and flow with moving 48-hour average wind speed**

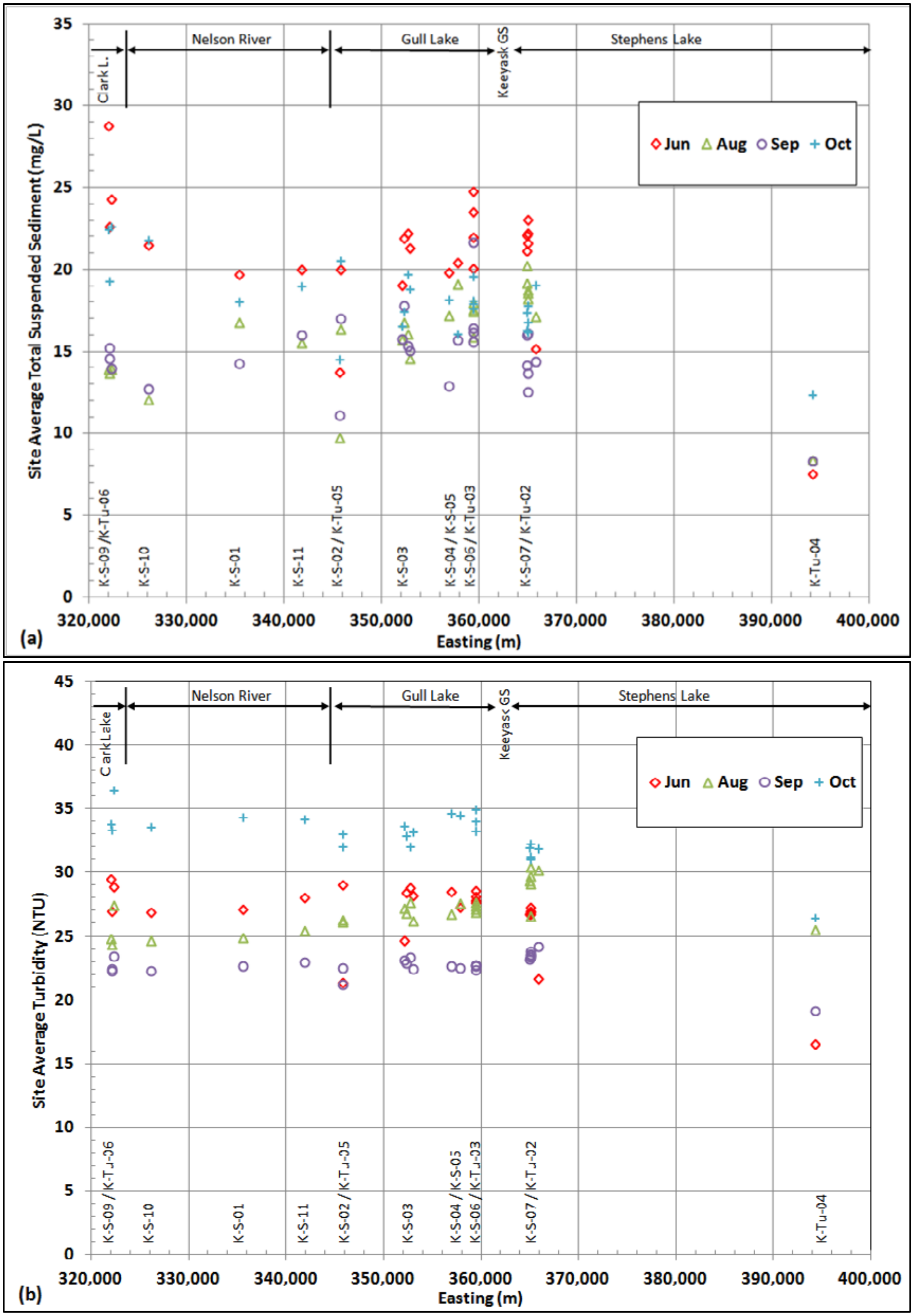


Figure 9: Summer 2016 discrete monitoring results: (a) TSS (b) turbidity

Overall, the results show that among all sites and months, the TSS concentrations predominantly ranged from about 13 to 23 mg/L. Only a few observations fell outside this range, with the highest value of 29 mg/L recorded at site K-S-09 in Clark Lake while the three lowest values of 7.5, 8.3, and 8.4 mg/L were recorded at K-Tu-04, just upstream of the Kettle GS. That the lowest TSS values occurred at site K-Tu-04 is not surprising considering the generally lower turbidity levels observed at this site through the continuous turbidity monitoring (Figure 7). The 2016 values were generally somewhat higher than TSS observed in 2015 and were similar to conditions observed in 2014. The 2016 TSS values are within the typical pre-Project TSS range of about 5-30 mg/L reported in the Keeyask EIS (KHLP 2012b).

Higher TSS concentrations were generally observed at each site in June while low values occurred in September. The lowest TSS levels were always observed at site K-Tu-04 near the Kettle GS. This is consistent with pre-Project studies that found TSS declines through Stephens Lake as sediment tends to deposit as flow passes through the lake (KHLP 2012b). Otherwise, there were no clearly consistent trends in TSS from upstream to downstream in the discrete data (Figure 9). In June, concentrations were high upstream at Clark Lake (K-S-09 / K-Tu-06) but were lower near Birthday Rapids (K-S-10) and generally increased to the entrance of Stephens Lake (K-S-07 / K-Tu-02). TSS in August generally increased from Clark Lake to the entrance of Stephens Lake. In September and October, there was no apparent trend from the site below Birthday Rapids (K-S-01) to the entrance of Stephens Lake.

The in-situ turbidity measurements predominantly lie within a range from about 20 to 35 NTU (Figure 9), which is higher than observed in 2015 when values primarily ranged from about 16-24 NTU. In 2016, the highest value of about 36 NTU was observed at site K-S-09 in Clark Lake while the two lowest values of 17 and 19 NTU were recorded at K-Tu-04, just upstream of the Kettle GS. The highest turbidity values for each site occurred in October, with the next highest levels generally occurring in June. This is consistent with the continuous turbidity results (Figure 7) but is different than the discrete TSS results which had generally higher TSS in June followed by October. As with TSS, the lowest discrete turbidity levels were generally observed in September. Overall, the trends in discrete turbidity results are generally consistent with what was observed from the continuous turbidity data. The difference in turbidity from upstream to downstream of the Keeyask GS site in Gull Rapids was not consistent: downstream values were about 1-2 NTU higher on average in August and September, but 1-2 NTU lower on average in June and October. These differences are considered small because deviations of a few NTU may even be observed at a single location over a short period of time (e.g., within an hour). The results do not suggest any notable effect on turbidity due to construction.

4.2.4 DEPOSITION AND SUBSTRATE

Deposition monitoring is being performed to provide understanding of pre-impoundment data on the potential for deposition after the reservoir is impounded. The sediment trap data provides information on the type of sediment being transported that could potentially settle in an area.

This, coupled with substrate sampling in the area, provides information whether the trapped sediment is deposited in the area or remains in suspension.

The PEMP (KHLP 2015a), proposed performing deposition monitoring at two locations, K-ST-01 and K-ST-02 (Map 4) *"if possible (e.g., water velocity not too high)"*. A sediment trap had been placed at site K-ST-01 over winter 2014/2015 and in summer 2015. In spring and fall of 2015, work crews were unable to recover the trap at K-ST-01. Rather than risk repeatedly losing equipment at this site due to the challenges posed by high flow velocities, it was decided to discontinue the placement of a sediment trap at site K-ST-01.

A sediment trap was deployed at the K-ST-02 site in Stephens Lake on October 2, 2015, and was recovered 309 days later on August 6, 2016 to obtain sediment samples collected in the trap (referred to as the winter period). It was redeployed on August 6 and recovered 68 days later on October 13, 2016 (referred to as the open water period), after which it was again redeployed to be in place until summer 2017. The trap consists of five 10-cm diameter tubes (Photo 9) that have jars at the bottom in which sediment is deposited. The two outer tubes (settling tubes) have open tops to better catch vertically settling sediment while the three middle tubes (flow tubes) have closed tops with a dozen 18 mm holes drilled around their circumference to catch sediment being advected horizontally with the flow.

Photo 9: 5-Tube sediment trap used at site K-ST-02

Deposition rates over the 68 days of deployment in the 2016 open water period ranged from 105-140 g/m^2/d, although this was just for the settling tubes while the flow tubes were more consistent at 114-125 g/m^2/d (Table 3). Over the longer winter period, sediment deposited more consistently between the tubes, ranging from 144-190 g/m^2/d (Table 3). Over the longer winter period the sediment deposition was about 30% higher than the open water period.

The sediment collected over the winter was much coarser than the sediment collected in the open water period. The winter samples were comprised of 41%-54% sand, 32%-41% silt and 14%-18% clay. The percentages were relatively consistent between the flow and settling tubes.

Table 3: Sediment Trap Monitoring Results for Site K-ST-02

Sample	**flow 1**	**flow 2**	**flow 3**	**settle 1**	**settle 2**	**Average**
Placed	Oct. 2, 2015					
Removed	Aug. 6, 2016					
# of Days	309					
Total Dry Mass (g)	434.7	330.2	345.4	359.7	327.7	359.5
Deposition Rate (g/m^2/day)	190	145	151	158	144	157
Sand	42%	41%	47%	54%	46%	
Silt	41%	41%	38%	32%	38%	
Clay	17%	18%	16%	14%	16%	
Sample	**flow 1**	**flow 2**	**flow 3**	**settle 1**	**settle 2**	**Average**
Placed	Aug. 6, 2016					
Removed	Oct. 13, 2015					
# of Days	68					
Total Dry Mass (g)	59.2	62.3	57.1	52.9	70.4	60.1
Deposition (g/cm^2)	0.80	0.84	0.77	0.72	0.95	0.81
Deposition Rate (g/m^2/day)	118	124	114	105	140	120
Sand	5%	5%	6%	10%	8%	
Silt	70%	70%	68%	67%	68%	
Clay	25%	25%	26%	23%	24%	
			Total Average Deposition (kg/m^2)			*57*
			Total Average Deposition (g/cm^2)			*6*
			Average Deposition Rate (g/m^2/day)			*151*

The open water period sediment was predominantly silt, which comprised 67%-70% of the sediment while about 23%-25% was clay and 5%-10% was sand. In general, the settling tubes collected a larger proportion of sand than the flow tubes. The greater rate of sediment collection in winter and the greater proportion of sand in winter may result from ice effects at the entrance to the Stephens Lake. As noted in the Keeyask EIS (KHLP 2012b) accumulation of ice below Gull Rapids causes water levels to rise in this area, which may cause flows to be redirected along erodible shorelines. This may introduce more sand into the flow than in summer when water levels are lower and shorelines may be less exposed to a high flow velocities that can transport the sand downstream. The degree to which flows may be redirected along shorelines will vary from year to year depending on the amount of water level increase that occurs due to ice accumulation and whether or not flows are redirected along erodible material.

The 2015/2016 winter deposition rates were about 60% greater than the 2014/2015 period (Manitoba Hydro 2016) and the sediment was much coarser. In the 2014/2015 period less than 10% of the sediment was comprised of sand. The difference in the amount of sediment collected in the two sampling periods may be due in part to the use of a different piece of equipment in winter 2014/2015 (*i.e.*, 3 open ended tubes of half the diameter) and variations in upstream ice effects. For the 2016 open water period, the deposition rate was about 30% lower than observed in open water monitoring in 2015 (Manitoba Hydro 2016), however it was similar in that most of the sediment was comprised of silt and clay with little sand. Sediment deposition was not monitored prior to construction. Results from the construction period will be used to identify if conditions change once the Project begins operation.

Substrate sampling was not performed in 2016 because sampling in 2015 found the bottom to be comprised of large cobble type material at both K-ST-01 and K-ST-02. As noted in the 2015/2016 PEMP annual report, based on the presence of a cobble bottom at site K-ST-02 it is apparent that fine material captured by the sediment trap is not being deposited and accumulated on the lake bed in this area (Manitoba Hydro 2016).

Photo 10: **Coarse substrate material at site K-ST-02 in 2015**

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.

During discrete sampling in August, September and October, water samples were collected for laboratory testing to measure Dissolved Organic Carbon (DOC) and Total Organic Carbon (TOC). These results are used to calculate the amount of Particulate Organic Carbon (POC), since POC concentration will be equal to TOC minus DOC. The first round of organic carbon sampling occurred in the first week of August, the second in mid-September, and the third in mid-October. Because the monitoring results did not indicate any particular trends at any of the sampling locations, the results have been summarized by simply averaging the results obtained at each location in each round of sampling. In the chart, some results do not show anything for POC. These 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).

From all the results, the TOC ranged from about 7.5-9.5 mg/L, which was predominantly DOC as the POC component was typically comprised less than 1 mg/L of the TOC. Within each test period, most of the TOC concentrations were within less than 1 mg/L of each other. While concentrations in August and September are similar, the levels in October are somewhat lower. Lower values in October are likely due to reduced biological activity as water temperatures cooled from about 13-15ºC in mid-September to about 3-5ºC in mid-October. The TOC and DOC concentrations measured in summer 2016 vary over a wider range than observed in 2015. However, most of the values in August and September fall in the range of 8-9 mg/L, similar to values observe in August and September 2015, and much the same as those reported in the Keeyask EIS for the pre-construction (KHLP 2012c, Appendix 2H).

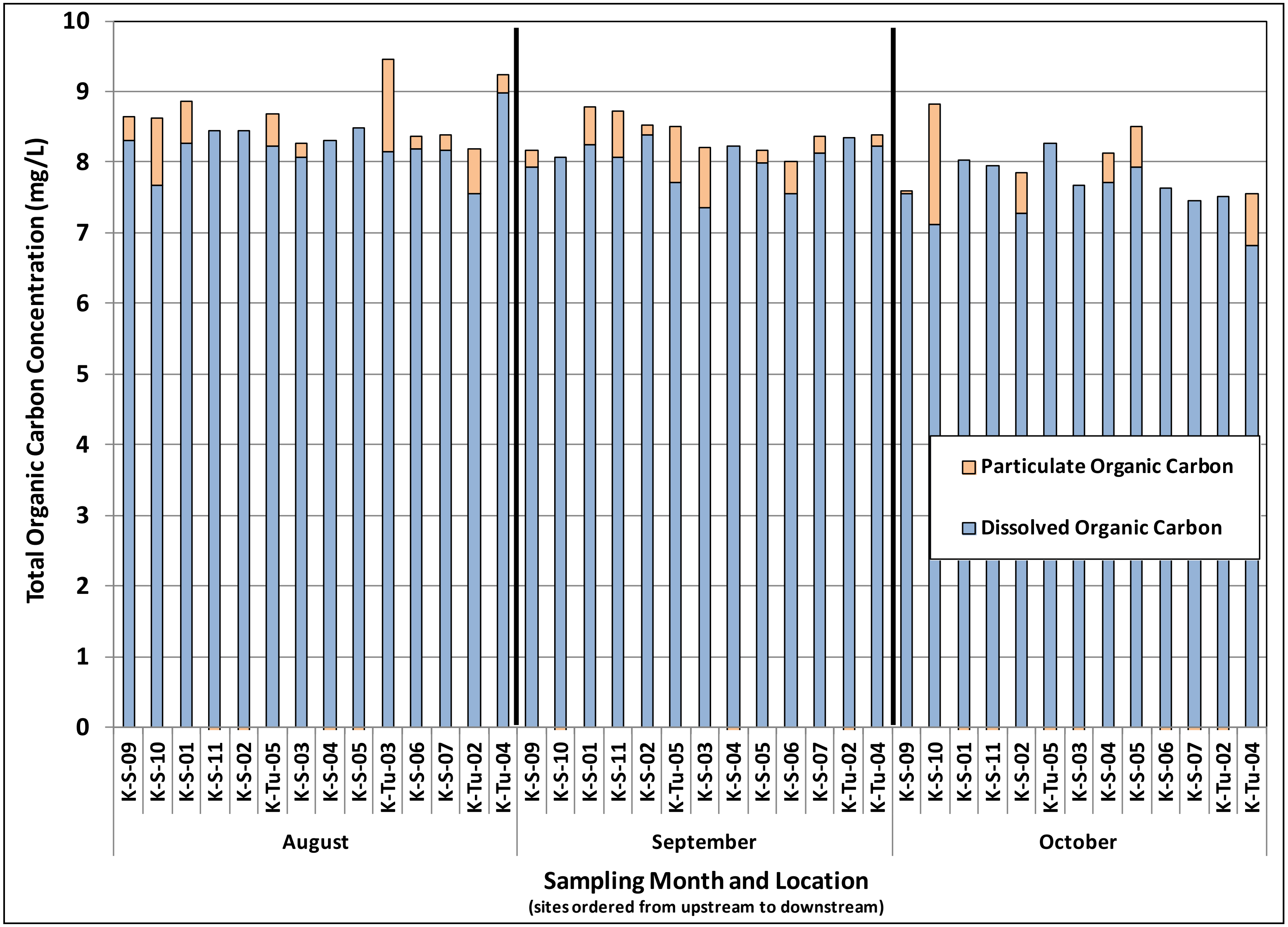


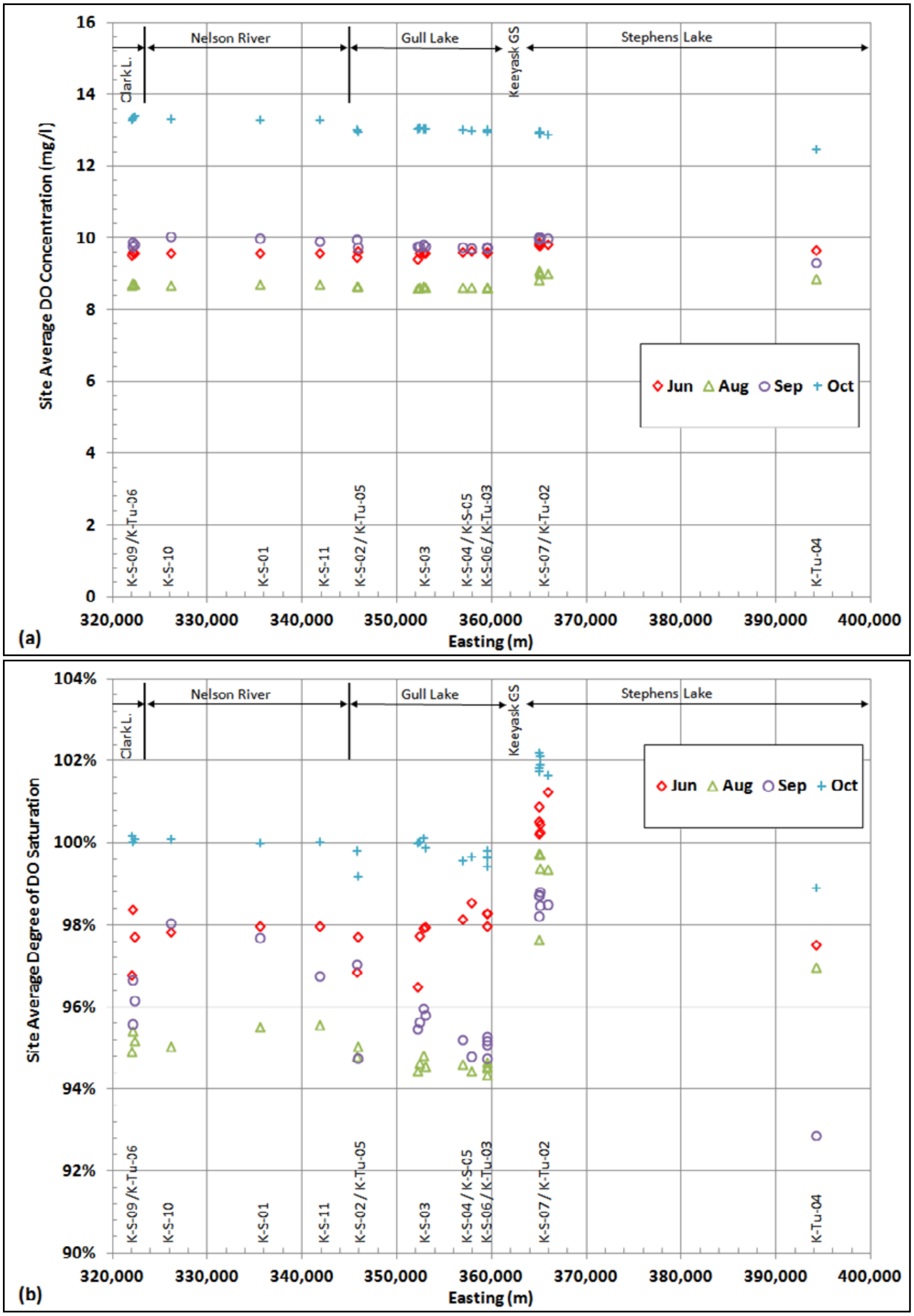
Figure 10: Summary of particulate, dissolved and total organic carbon

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 PEMP monitoring area. During construction, prior to reservoir impoundment, the Project is not anticipated to affect DO (KHLP 2012b, Section 9). As observed in 2015, the monitoring results from summer 2016 confirmed this. DO concentrations ranged from a low of 9.1 mg/L in August to a high of 13.4 mg/L in October (Figure 11). As expected, the lowest DO concentrations occurred in August when water temperatures were warmest at about 19ºC while the highest DO concentrations were observed in October when water temperatures were lowest at about 3-6ºC.

Overall, the saturation levels varied from a low of about 92% to a super saturated high of 102% (Figure 11). The average saturation level at the monitoring sites over the entire summer varied from about 96% to 100%. The lowest levels of saturation occurred in August for most sites. This is likely due to increased biological activity (e.g., algae growth), which consumes DO from the water, reducing the DO concentration below the saturation concentration. The highest levels of saturation occur in October when water temperatures are colder and there is less biological activity. In each month, the highest levels of saturation and most of the observed cases of super saturation occur at sites K-S-07 and K-Tu-02 just below Gull Rapids (Figure 11). This may be anticipated as turbulent flow through Gull Rapids adds oxygen to the water, sometimes beyond the point of saturation.



Notes: (a) dissolved oxygen concentration (b) degree of saturation

Figure 11: Summer 2016 discrete monitoring results

7.0 DEBRIS

As part of the Keeyask Project, in accordance with the Joint Keeyask Development Agreement (TCN et.al. 2009), a waterways management program was implemented in 2016 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.

Woody debris removed by the boat patrol was classified by size as either large or small, and by type as either new (green woody material), old or beaver (showing signs of beaver activity). In 2016, the boat patrol travelled approximately 4,200 km in the Project area and recorded the removal of 6 pieces of debris (Table 2), less than the amount in 2015. The boat patrol also marked 7 reefs and engaged with several waterway users.

Table 4: 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

8.0 LITERATURE CITED

Keeyask Hydropower Limited Partnership (KHLP). 2012a. Keeyask Generation Project: Response to EIS Guidelines. June 2012. Winnipeg, Manitoba.

Keeyask Hydropower Limited Partnership (KHLP). 2012b. Keeyask Generation Project: Physical Environment Supporting Volume. June 2012. Winnipeg, Manitoba

Keeyask Hydropower Limited Partnership (KHLP). 2012c. Keeyask Generation Project: Aquatic Environment Supporting Volume. June 2012. Winnipeg, Manitoba

Keeyask Hydropower Limited Partnership (KHLP). 2015a. Keeyask Generation Project: Physical Environment Monitoring Plan. October 2015. Winnipeg, Manitoba.

Keeyask Hydropower Limited Partnership (KHLP). 2015b. Keeyask Generation Project: Aquatic Effects Monitoring Plan. June 2015. Winnipeg, Manitoba.

Keeyask Hydropower Limited Partnership (KHLP). 2014. Keeyask Generation Project: Sediment Management Plan for In-stream Construction. July 2014. Winnipeg, Manitoba.

KGS Acres Ltd. 2011. Keeyask Generating Station, Stage IV Studies: Existing Environment Sedimentation (Memorandum GN9.2.3, Mb Hydro File No. 00195-11100-0154_03). June 2011. Winnipeg, Manitoba.

Manitoba Hydro. 2016. 2015–2016 Physical Environment Monitoring Report: Year 2 Construction. June 2016. Winnipeg, Manitoba.

Manitoba Hydro. 2017. Sediment Management Plan for In-Stream Construction Annual Report April 2016 – March 2017. June 2017. Winnipeg, Manitoba.

TCN, WLFN, YFFN, FLCN and the Manitoba Hydro-Electric Board. 2009. Joint Keeyask Development Agreement. May 2009. Winnipeg, Manitoba.

United States Environmental Protection Agency (USEPA), 1985. Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling. Second Edition. Environmental Research Laboratory, Office of Research and Development. June 1985. Athens, GA. EPA/600/3-85/040

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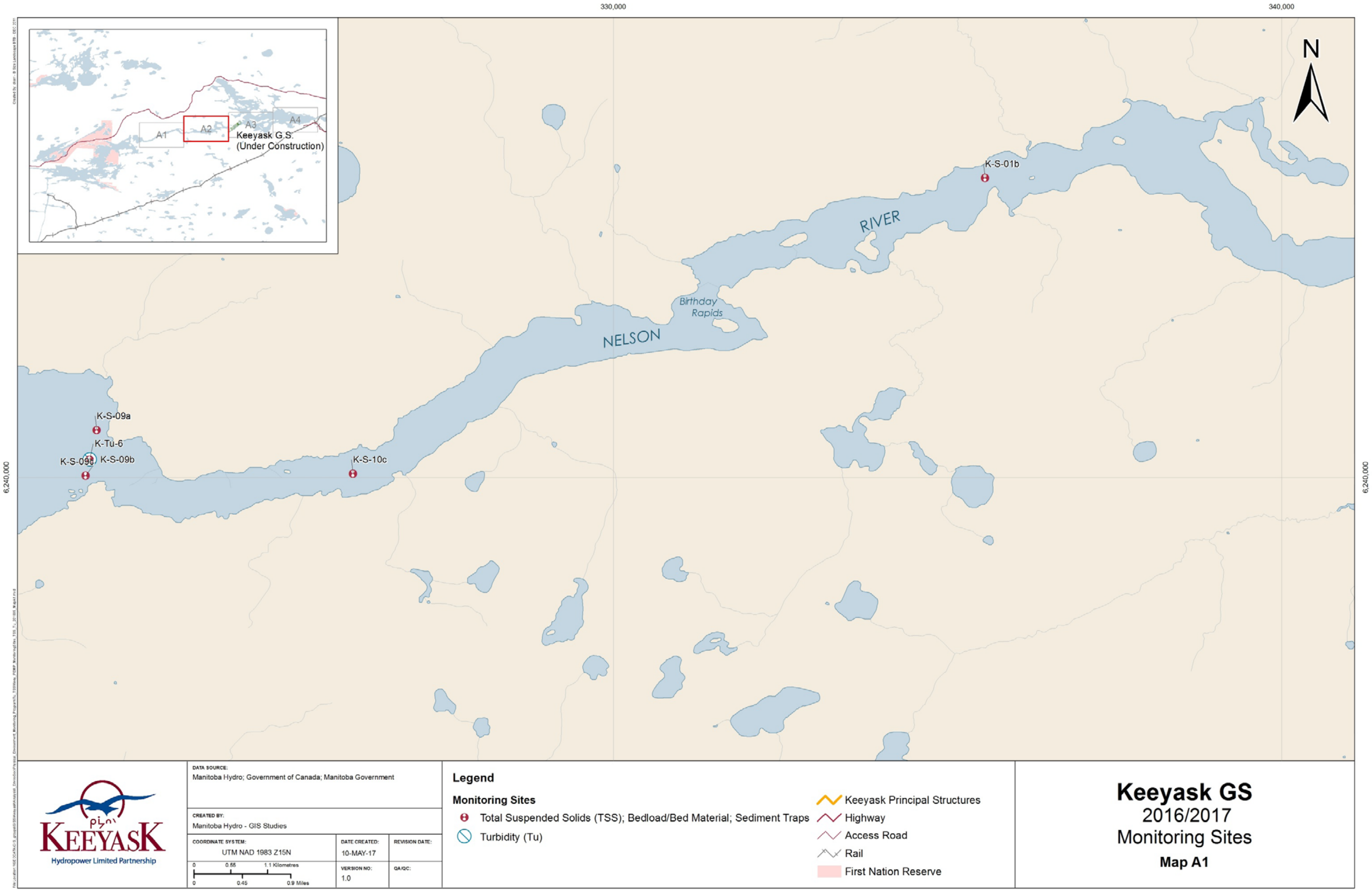
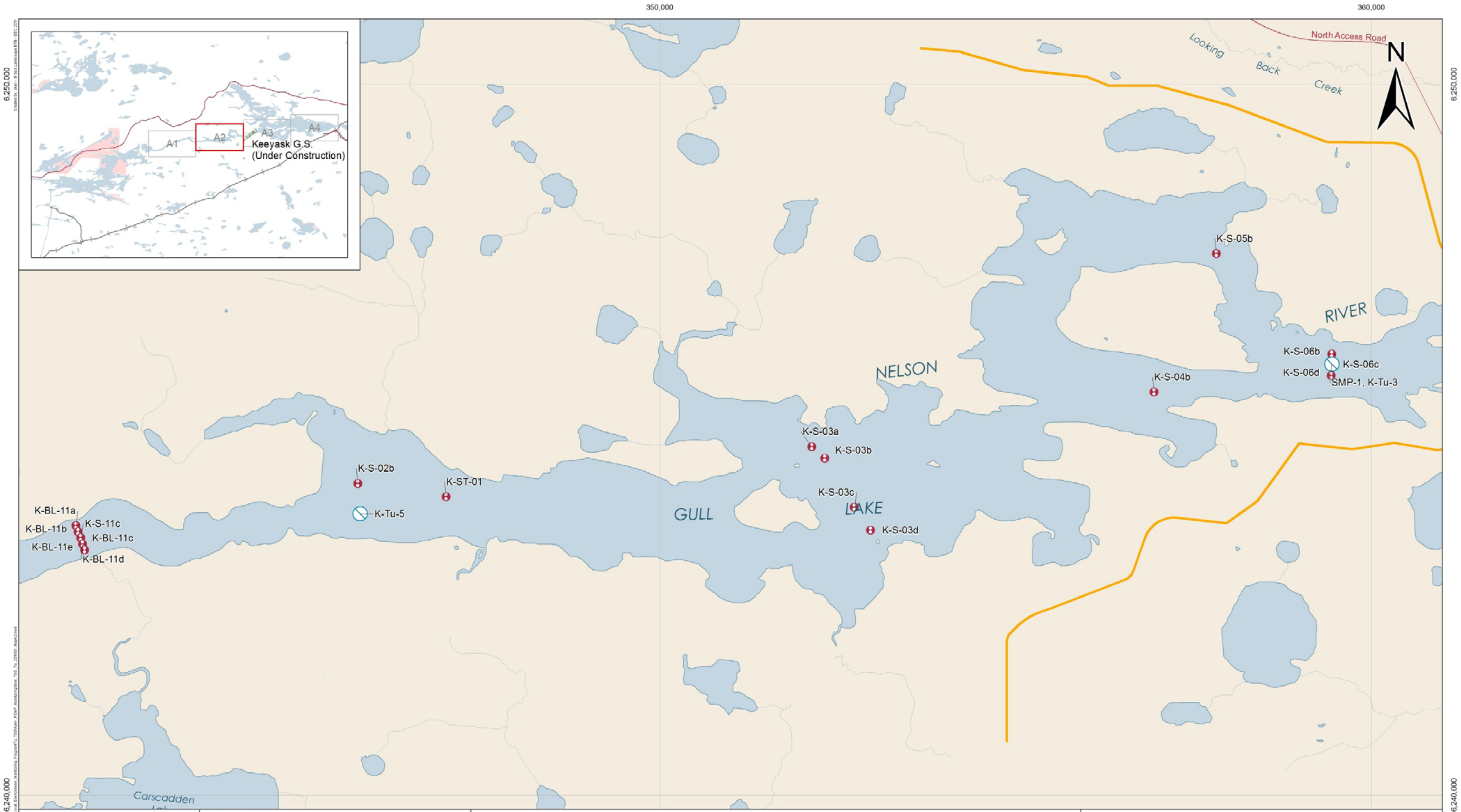
APPENDIX 1:

DETAILED MAPS OF TURBIDITY & TSS MONITORING SITES


330,000
340,000
6,240,000
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-09c
K-S-09b
K-S-10c
DATA SOURCE:
Manitoba Hydro; Government of Canada; Manitoba Government
CREATED BY:
Manitoba Hydro - GIS Studies
COORDINATE SYSTEM:
UTM NAD 1983 Z15N
DATE CREATED:
10-MAY-17
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 Principal Structures
Highway
Access Road
Rail
First Nation Reserve
Keeyask GS
2016/2017
Monitoring Sites
Map A1



KEEYASK
Hydropower Limited Partnership

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

CREATED BY:
Manitoba Hydro - GIS Studies

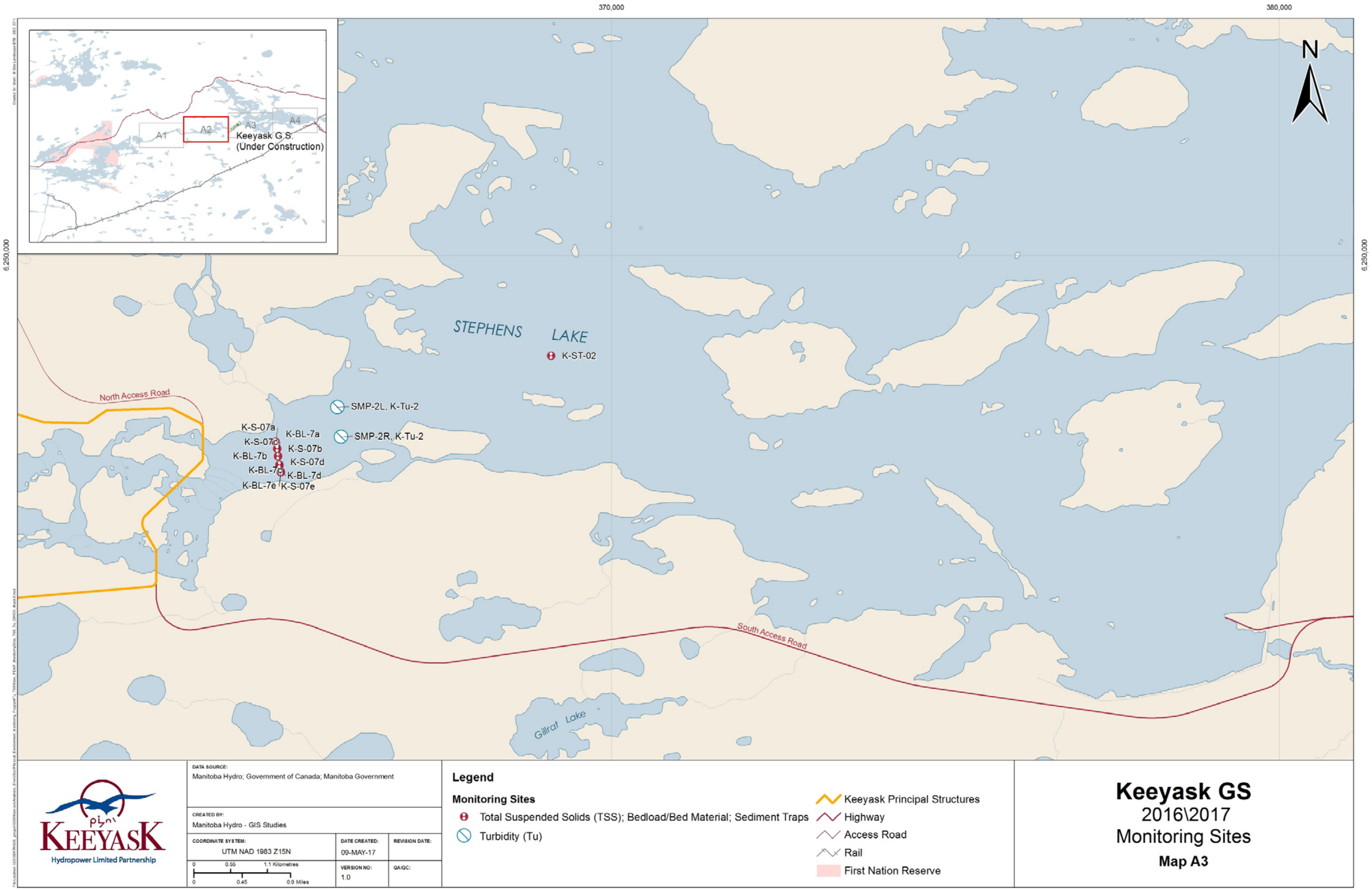
COORDINATE SYSTEM:	DATE CREATED:	REVISION DATE:
UTM NAD 1983 Z15N	09-MAY-17	
0 0.55 1.1 Kilometres 0 0.45 0.9 Miles	VERSION NO: 1.0	QA/QC:

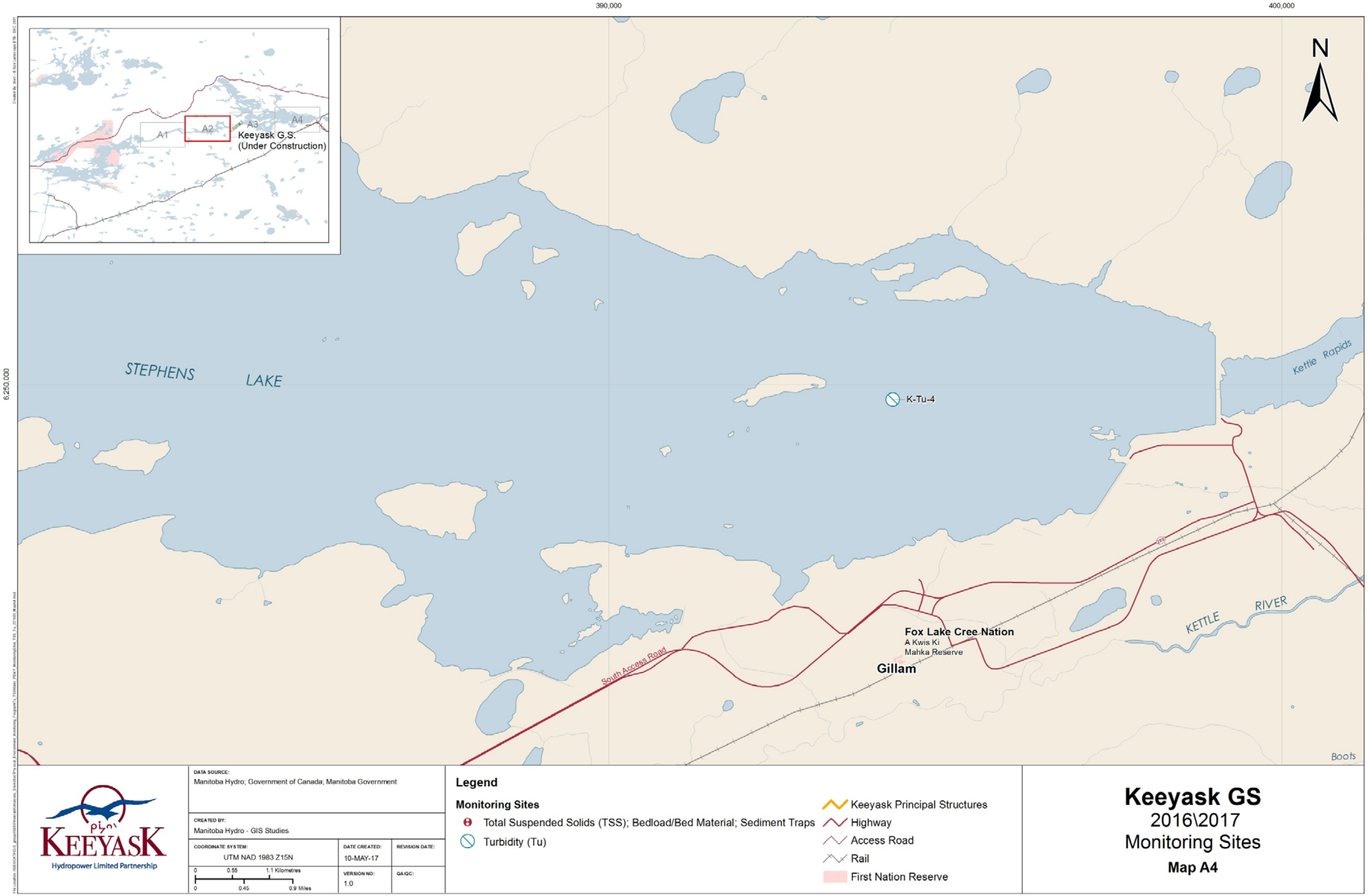
Legend

Monitoring Sites

●	Total Suspended Solids (TSS); Bedload/Bed Material; Sediment Traps
⃠	Turbidity (Tu)
	Keeyask Principal Structures
	Highway
	Access Road
	Rail
🟥	First Nation Reserve

Keeyask GS
2016\2017
Monitoring Sites
Map A2


370,000
380,000
6,250,000
6,250,000
N
A1
A2
A3
A4
Keeyask G.S.
(Under Construction)
STEPHENS LAKE
K-ST-02
SMP-2L, K-Tu-2
SMP-2R, K-Tu-2
K-S-07a
K-S-07c
K-BL-7b
K-BL-7c
K-BL-7e
K-BL-7a
K-S-07b
K-S-07d
K-BL-7d
K-S-07e
North Access Road
South Access Road
Gillrat Lake
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:
09-MAY-17
REVISION DATE:
VERSION NO:
1.0
QA/QC:
0 0.55 1.1 Kilometres
0 0.45 0.9 Miles
Legend
Monitoring Sites
Total Suspended Solids (TSS); Bedload/Bed Material; Sediment Traps
Turbidity (Tu)
Keeyask Principal Structures
Highway
Access Road
Rail
First Nation Reserve
Keeyask GS
2016\2017
Monitoring Sites
Map A3


390,000
400,000
6,250,000
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
280
Boots
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:
10-MAY-17
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 Principal Structures
Highway
Access Road
Rail
First Nation Reserve
Keeyask GS
2016\2017
Monitoring Sites
Map A4