Keeyask Generation Project

Aquatic Effects Monitoring Plan

Deep Water Substrate Composition Report

AEMP-2022-17

KEEYASK

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KEEYASK GENERATION PROJECT

AQUATIC EFFECTS MONITORING PLAN

REPORT #AEMP-2022-17

DEEP WATER SUBSTRATE COMPOSITION OF THE KEEYASK STUDY AREA, 2021

Prepared for

Manitoba Hydro

By

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SUMMARY

Background

The Keeyask Hydropower Limited Partnership (KHLP) was required to prepare a plan to monitor the effects of construction and operation of the Keeyask Generating Station (GS) on the environment. Besides measuring the accuracy of the predictions made and actual effects of the GS on the environment, monitoring results will provide information on how construction and operation of the GS will affect the environment and if more needs to be done to reduce harmful effects.

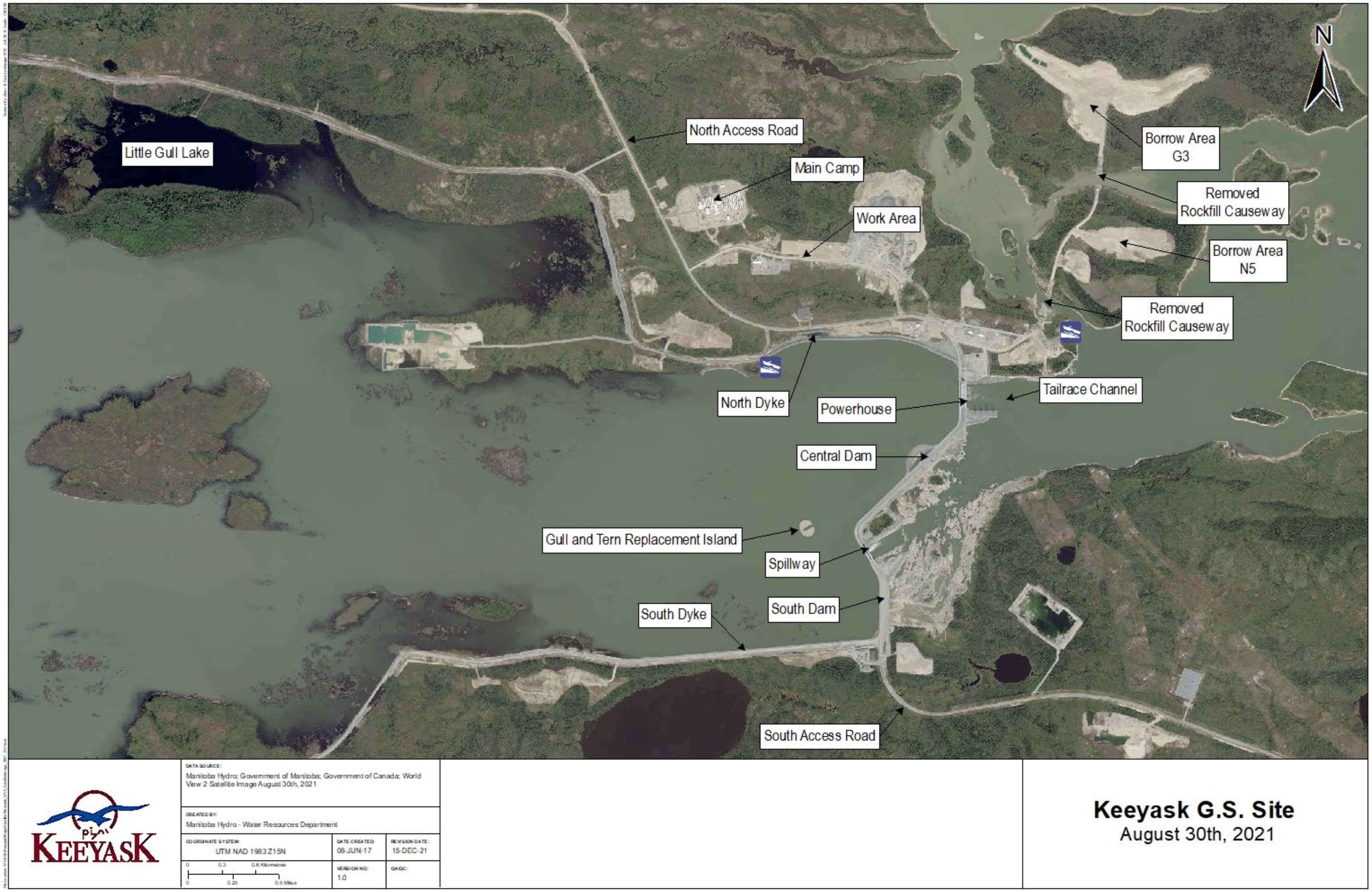
Construction of the Keeyask GS began in mid-July 2014 and instream work was completed in 2020. The reservoir was impounded with water levels being raised to full supply level between August 31 and September 5, 2020. Commissioning of the powerhouse turbines was initiated after impoundment and five of seven units were in-service by fall 2021. During commissioning and as units came into service, substantial flows continued through the spillway until the summer of 2021 when more flow was going through the powerhouse than spillway. By mid-September the spillway was closed and barely used in the fall.

Aquatic habitat provides the environment in which aquatic organisms live. The monitoring of aquatic habitat after construction of the generating station is an important part of the overall plan to monitor the impacts of construction and operation of the Keeyask GS on aquatic life including fish. Some habitats are especially important for fish species to complete their life cycles, such as places to spawn and places to eat. Some of these habitats were lost or changed with construction of the generating station and reservoir impoundment.

Deep water, offshore areas provide important feeding and rearing habitat for many fish species including Walleye (pickerel), Lake Whitefish, and Lake Sturgeon. Substrate types (what the bottom is made of) in these offshore habitats are often important because fish species seek out these areas. For example, juvenile Lake Sturgeon are found more in deep areas with sand or gravel substrates rather than with fine silty substrates.

Impoundment of the Keeyask reservoir in fall 2020 flooded areas upstream of the GS and changed many types of habitat including deep offshore areas. Flooding caused changes in water velocities and flow patterns. This can then cause changes in substrate type (for example, when water velocity slows in an area, it causes fine materials to be deposited where there used to be rock). It is expected that changes in flows upstream and downstream of the Keeyask GS will cause shifts in the types of substrates found in deep water areas.

This report presents the results of deep water substrate composition monitoring in the Keeyask reservoir in the first summer after flooding.



Map illustrating instream structures at the Keeyask Generating Station site, August 2021.

Silty (left) and sandy (right) substrates (river bottom) sampled in the Keeyask reservoir.

Why is the study being done?

Substrate type monitoring in deep water habitats is being done to answer five questions:

How will substrate composition change over time in deep water in the Keeyask reservoir and downstream of the Keeyask GS (including in the area of existing young-of-the-year *Lake Sturgeon habitat in Stephens Lake)?*

This question is important because some fish species, including young-of-the-year (fish that are less than one year of age) Lake Sturgeon, have substrates that they prefer for feeding and spawning. It is important that a variety of substrate types are available for fish to use upstream and downstream of the Keeyask GS.

How many years into the operation period will it take for substrate boundaries to form?

This question is important because substrate composition can take time to change. Slower water velocities in some areas of the reservoir and downstream of Keeyask GS can make fine substrates like silt settle out over top of pre-existing coarse materials. It is predicted that it will take at least three years to detect new substrate boundaries (or areas where different types of sediments are found) in the Keeyask study area, but this change may happen faster or slower than we think.

Will fines (sand/gravel) deposit below the Birthday Rapids area in slow lotic habitat (i.e., will new young-of-the-year *Lake Sturgeon habitat form in the reservoir)?*

Changes in water velocity and erosion upstream and downstream of the GS will change where different substrates (like silt, sand, and gravel) settle out. Before impoundment of the Keeyask GS, the area downstream of Birthday Rapids had very fast water and anything but the largest substrates (like boulders) would get washed away. Flooding of the reservoir caused the area downstream of Birthday Rapids to become wider and slower flowing. Because of this, it is possible that sand and gravel may now be deposited here. These substrates are preferred by young-of-the-year Lake Sturgeon, so this area may become new rearing habitat.

Will fines (sand/gravel) deposit near the entrance to present day Gull Lake (i.e., will new young-of-the-year *Lake Sturgeon habitat form in the reservoir)?*

Like Birthday Rapids, the area at the entrance to Gull Lake had very fast water and large substrates before impoundment. Flooding of the reservoir caused this area to become wider and slower flowing, and it is possible that sand and gravel may now be deposited here. These substrates are preferred by young-of-the-year Lake Sturgeon, so this area may become new rearing habitat.

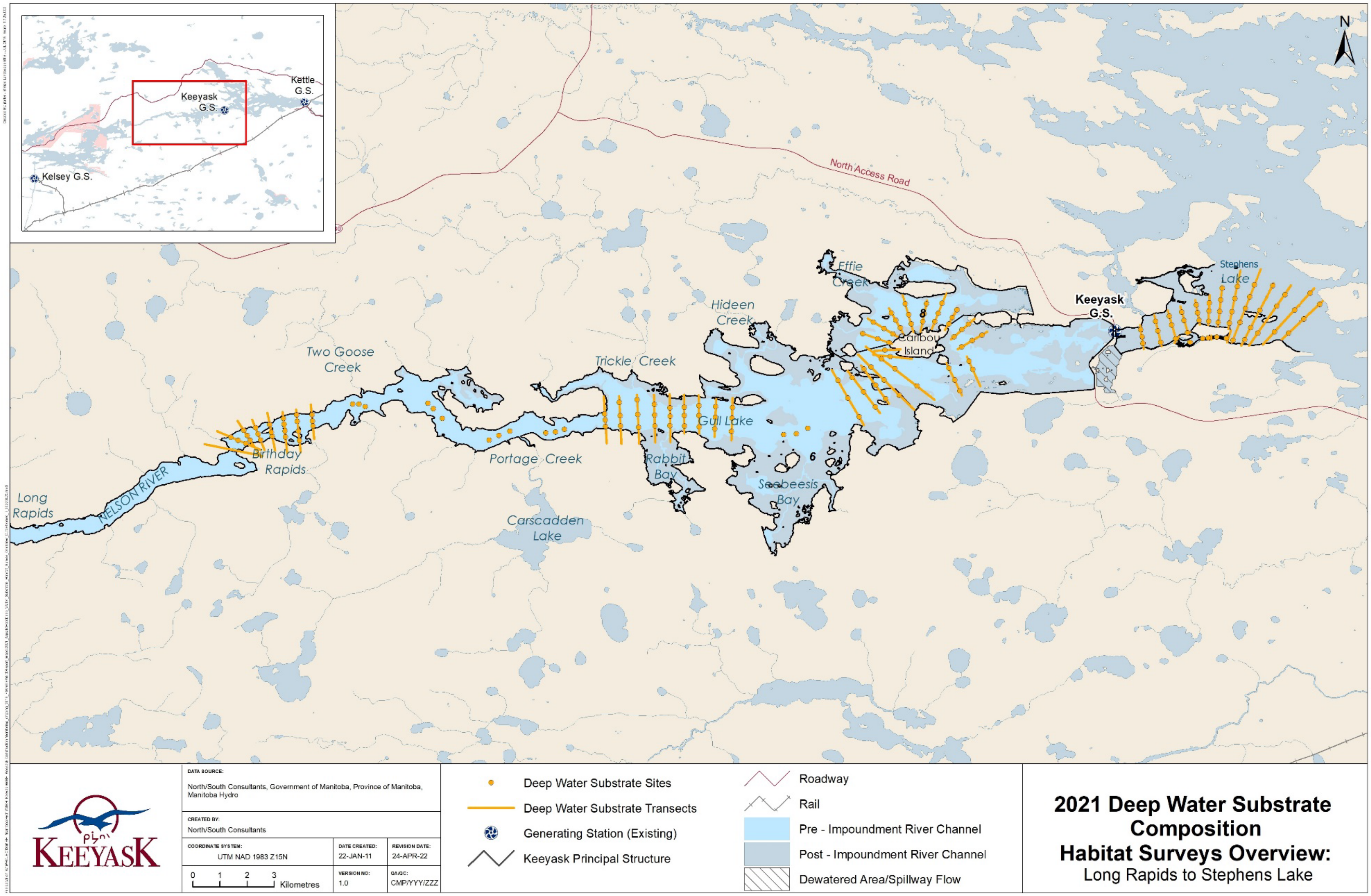
How precise were the post-Project models that predicted the long-term deep water substrate distribution?

This question is important because we do not fully understand how substrates will deposit throughout the whole Keeyask area and where substrates will change or stay the same. Fish prefer some types of substrates over others and knowing what substrates are there will help determine what types of fish will use these areas.

What was done?

Substrate composition (what the bottom is made of) was monitored in 2021 in five general areas including four upstream of the Keeyask GS and one downstream. These included areas downstream of Birthday Rapids, fast-flowing areas of the reservoir, downstream of the Gull Lake entrance, around Caribou Island, and in the upstream portion of Stephens Lake (see study area map below).

Substrate composition (what the bottom is made of) information was collected and measurements of how deep and fast the water is were taken at each area. Substrate type was identified in each area by using a Ponar dredge (to grab a sample of the bottom), a sounding line (to hear or feel if the bottom is rocky or soft), and a sonar (to make a picture of the bottom). A few Ponar grab samples were also sent to the lab to confirm classifications done in the field.



Map illustrating sites surveyed for deep water substrate composition, August 2021.

Ponar sampler (left) used to grab samples of substrate and acoustic monitor (right) used to map substrate types.

What was found?

Substrates (what the bottom is made of) near Birthday Rapids, the area between Birthday Rapids and Gull Lake, and the entrance to Gull Lake were generally hard and rocky. They were made up largely of bedrock, boulder, and cobble with small areas of gravel. No smaller substrates were found.

The area around Caribou Island had more of a mix of substrates ranging from hard rock to soft mud. An area of sand was present in the middle of the channel to the west and north of Caribou Island, surrounded by mud (i.e., silt and clay) in off-channel areas. Upstream and downstream of this sandy area the channel is generally rocky. Some silt was deposited near the downstream end of the sand.

Substrate within the upper portion of Stephens Lake varied and were generally hard with areas of bedrock and boulder closer to the Keeyask GS. A single site consisting largely of sand was identified about 4.5 km downstream of the GS. Farther downstream sites largely consisted of a mix of silt, sand, and clay. Organic material (loose, broken-down plant matter) was found at some sites starting about 5.5 km downstream of the GS.

What does it mean?

It is still too early to see in there are any changes to deep water substrates upstream and downstream of the Keeyask GS as the result of the Project.

What will be done next?

The program will be repeated in 2022. Substrate data will be collected in the same areas and the same sites to see if anything has changed.

ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

The Keeyask Generation Project (the Project) is a 695-megawatt (MW) hydroelectric generating station at Gull Rapids on the lower Nelson River in northern Manitoba. The Project is located approximately 725 kilometres (km) northeast of Winnipeg, 35 km upstream of the existing Kettle Generating Station, where Gull Lake flows into Stephens Lake, 60 km east of the community of Split Lake, 180 km east-northeast of Thompson and 30 km west of Gillam (Map 1). Construction of the Project began in July 2014.

The *Keeyask Generation Project: Response to EIS Guidelines*, completed in June 2012, provides a summary of predicted effects and planned mitigation for the Project. Technical supporting information for the aquatic environment, including a description of the environmental setting, effects and mitigation, and a summary of proposed monitoring and follow-up programs, is provided in the *Keeyask Generation Project Environmental Impact Statement: Aquatic Environment Supporting Volume* (AE SV). As part of the licensing process for the Project, an *Aquatic Effects Monitoring Plan* (AEMP) was developed detailing the monitoring activities of various components of the aquatic environment for the construction and operation phases of the Project.

Aquatic habitat provides the environment in which aquatic biota live, as defined by water depth, velocity, substratum, and structure (including non-living and living (rooted plants) components). Aquatic habitat monitoring programs occur within the area of direct effect between the outlet of Clark Lake and approximately 7 km downstream of the GS. These programs were designed to record changes over time in aquatic habitat that was altered by the Project, document the evolution of flooded terrestrial habitat into productive aquatic areas, and to assess conditions on structures constructed to offset habitat loss. A specific monitoring program was designed to assess the effects of the Project on deep water substrate type.

Data collected in deep water areas (greater than 3 m) will be used to monitor changes in substrate composition both upstream and downstream of the Keeyask GS. Changes to the distribution of the substrate in deep water is indicative of an alteration to the hydraulics and the ability of the river to transport materials along the bed. The evolution of substrate composition in deep water within the newly formed reservoir depends mostly on the pattern of water velocities that develop within the reservoir, and how the processes of erosion, transport, and deposition in the river channel maintain or alter the existing substrate. Potential effects on aquatic habitat downstream of the GS include the deposition of fine sediments over existing cobble and gravel substrate in the channel area and the existing sand lens in upper Stephens Lake.

Impoundment of the Keeyask reservoir was completed on September 5, 2020. Sampling in the Keeyask reservoir in 2021 represented the first year of sampling under operating conditions (water levels and flows). Monitoring in Stephens Lake, however, represented a transition between construction and operation as a considerable portion of the flow was still being passed through the spillway in spring and early summer when only a few units were in-service. Later in the summer and early fall, as additional units became operational, the entire flow of the river was flowing through the powerhouse.

The key questions identified in the AEMP for this monitoring component are:

- *How will substrate composition change over time in deep water in the Keeyask reservoir and downstream of the GS (including in the area of existing young-of-the-year [YOY] Lake Sturgeon habitat in Stephens Lake)?*
- *How many years into the operation period will it take for substrate boundaries to form?*
- *Will fines (sand/gravel) deposit below the Birthday Rapids area in slow lotic habitat (i.e., will new YOY Lake Sturgeon habitat form in the reservoir)?*
- *Will fines (sand/gravel) deposit in the area near the entrance to present day Gull Lake (i.e., will new YOY Lake Sturgeon habitat form in the reservoir)?*
- *How precise were the post-Project models that predicted the long-term deep water substrate distributions?*

This report provides results collected August 2021, nearly one year following impoundment. It should be noted, as YOY Lake Sturgeon also used deep water habitats, a subset of the transects for the deep water habitat study are included in the sensitive habitat study (Larter and Hrenchuk 2022). Surveys will be repeated in 2022 and 2023 using the same measures to describe changes to substrate composition as the Keeyask reservoir ages and operation of the GS continues.

2.0 STUDY SETTING

The study area encompasses an approximately 50 km long reach of the Nelson River from Long Rapids to the upper portion of Stephens Lake (Map 1). This section of river offers a diversity of physical habitat conditions, including a variety of substrate types, and variable water depths (range 0–30 m) and velocities.

Clark Lake is located immediately downstream of Split Lake, and approximately 42 km upstream of the Keeyask GS (formerly Gull Rapids) (Map 1). Downstream from the outlet of Clark Lake, the Nelson River narrows and water velocity increases for a 3 km stretch, known as Long Rapids. For the next 7 km, the river widens, and water velocity decreases. The area between Clark Lake and the Keeyask GS is considered the Keeyask reservoir.

Birthday Rapids is located approximately 10 km downstream of Clark Lake and 30 km upstream of Gull Rapids/the Keeyask GS and marks the upstream end of major water level changes as a result of impoundment by the Keeyask GS. The drop in elevation from the upstream to downstream side of Birthday Rapids was approximately 2 m prior to impoundment but is now a nearly level, albeit fast-flowing section of river. The 14 km reach of the Nelson River between Birthday Rapids and Gull Lake was characterized as a large and somewhat uniform channel with medium to high water velocities and a few large bays. This area is now within the Keeyask reservoir, though flooding was limited to mainly shoreline areas.

Prior to impoundment, Gull Lake was a widening of the Nelson River, with moderate to low water velocity beginning approximately 20 km upstream of Gull Rapids/the Keeyask GS. Water levels on Gull Lake increased by several metres following impoundment and flooding along the shoreline and small tributaries entering this reach was extensive. Although this area is now a portion of the Keeyask reservoir, it is referred to herein as Gull Lake.

Just below the Keeyask GS, the Nelson River enters Stephens Lake. Stephens Lake was formed in 1971 by construction of the Kettle GS. Construction of the Keeyask GS has altered the flow distribution immediately downstream of the station. Kettle GS is located approximately 40 km downstream of the Keeyask GS.

2.1 FLOWS, WATER LEVELS, AND KEEYASK OPERATIONS

From October 2020 to mid-June 2021 the calculated Split Lake outflow varied about the median flow of about 3,300 m^3/s, ranging between about 3,000 m^3/s and 3,900 m^3/s. From mid-June to mid-August, the flows steadily decreased from about 3,700 m^3/s to about 2,000 m^3/s, which is approximately the 5^{th} percentile low flow. Low flow conditions persisted from summer into winter, with flows dropping to a low of about 1,800 m^3/s at the end of November 2021. These are the lowest flows that have occurred during Keeyask construction. It is not since 2005 that flows this low have occurred on the Nelson River.

Water levels on Gull Lake have been held steady between about 158.8–159 m since reservoir impoundment in September 2020. Upstream of Gull Lake at gauges below and above Birthday Rapids the levels were about 0.5 m and 2 m higher than on Gull Lake, a smaller difference than would have occurred prior to the project. Upstream levels increased about 3–4 m at these sites in winter due to ice effects as in previous years. Due to low flows in summer 2021 the water surface was relatively flat from Gull Lake to the gauge just upstream of Birthday Rapids, with a difference of only about 0.8–0.9 m between the two.

Keeyask is transitioning from a construction project to an operating station (Map 2). In 2021, the work at site has been focused on bringing units into service. By the end of April 2021, prior to the start of aquatic monitoring, Unit 1 and Unit 2 were in service. Throughout the open–water period more units were being tested and brought into service one at a time. As units came into service, the distribution of flow between the spillway and powerhouse has gradually shifted, as summarized in the table below. By the end of October 2021 five units were fully in service.

Discharges from the spillway and powerhouse are not measured but have been estimated based on performance design curves. For reference it is noted that the design discharge capacity of the powerhouse is 4,000 m^3/s, giving each turbine unit a discharge capacity of approximately 570 m^3/s.

The Table below outlines Keeyask GS operation, including powerhouse and spillway flows, in 2021.

Time 2021	Powerhouse Units	Spillway Gate Operation	Powerhouse (m^3/s)	Spillway	Keeyask Total
			Discharge (m^3/s)		
end Apr – end Jun	Unit 2 online Unit 3 testing	Gates 1, 2, 3, 5, 7 in use until mid–Jun. Gates 1, 3, 5, 7 primarily mid to end Jun.	Steady at about 1,100 varying down to 600 on a few intermittent days and up to 1,650 during 2 weeks of U3 testing	Generally 2,200–2,800 except during U3 testing it varied from about 1,400–2,400	Generally 3,400–3,900 except during Unit 3 testing it varied from 2,600–3,600
end Jun – mid Sep	Unit 3 online Unit 5 testing	Generally, Gates 1,3, 5, 7 until mid Jul. Gates 3, 5, 7 until end of Jul. Various gates used in Aug. Gates 1 and 7 used in September until closure of all gates on Sep 11.	About 1,650, but reduced to 1,100 for 2 weeks with a unit shut down and varying up to 2,100 during 2 weeks of U5 testing	From end Jun to mid Aug Nelson R inflow declined from about 3,600 to about 1,800–2,200 and has remained steady around 2,000–2,200 m^3/s since then – corresponding spillway discharge gradually declined from about 2,400 to 0 by mid-September when U5 came into service although daily variations of +/- 200–400 or more in a few instances occurred during this time	Total Keeyask discharge declined from about 3,600 to an average of about 2,000–2,200 corresponding to the decrease in Nelson R inflow, and daily variation of about +/- 200-400 depending on spillway and powerhouse operations
Mid Sep – end Oct	Unit 5 online Unit 4 testing Unit 4 online Oct 25	Various gates used very sporadically. First reopening on Sep 28.	Average discharge about 2,000-2200 with typical daily variation from 1,600-2,200 and a maximum variation between 1,000-2,800 depending on unit operations an U4 testing	No spillway flow except for a few intermittent days of up to 1,000	Same as powerhouse

3.0 METHODS

Substrate surveys were conducted between August 14 and August 23, 2021 from Birthday Rapids to Stephens Lake (Map 3).

3.1 BOTTOM TYPE VALIDATION

Bottom type validation or substrate sampling was used to both observe and record substrate characteristics at discrete locations and validate the acoustic bottom typing data. Substrate grab samples were collected using either a petite Ponar (0.023 m^2 surface area) or standard Ponar (0.052 m^2 surface area) dredge sampler. Primary, secondary, and tertiary substrate types were identified at each validation site and classified according to a modified Wentworth sediment size classification, an estimate of the relative substrate composition of the sample was recorded (Table 1; Wentworth 1922). At several sites where fine or organic substrates were encountered, the grab samples were preserved for particle size analysis (PSA) and organic content analysis, conducted at ALS Laboratories. At locations where the Ponar could not be used (e.g., in areas of high currents or rock bottom) a weighted sounding line was dragged across the substrate to differentiate between rock versus fine hard-packed substrates. Side-scan images collected using a Lowrance® Elite FS were also used during data processing to verify *in situ* substrate classification.

3.2 ACOUSTIC IMAGING SURVEYS

A Lowrance® Elite FS sonar/GPS echosounder was used to collect general depth and bottom composition data as well as sidescan acoustic imagery at sensitive habitat areas. Sidescan sonar image data have been shown to be effective in interpreting and mapping the substrate classes of benthic environments (Lucieer 2008; Kaeser et al. 2013; Fakiris et al. 2019). The system included a TotalScan™ transducer (83/200 kHz traditional sonar beams, as well as 455/800 kHz sidescan/down scan beams). Data were collected using a 50 m swath. Positions of the substrate validation locations were imported into SonarWiz 7 software and viewed with the high-resolution imagery as a backdrop. Sidescan image mosaics of each of the survey areas were produced with the software. The raw image data and georeferenced image mosaics will be used in future analyses to potentially detect substrate boundary differences in future years of monitoring.

A DSP Inc. 3DSS-IDX-450 combined sidescan sonar and multibeam echosounder (MBES) was used to create substrate maps at each of the deep water habitat areas. This system was used to provide higher resolution imagery. Data were collected using a 100 m swath. The echosounder was coupled to a Septentrio dual antenna GNSS receiver to provide precise positions.

The substrate validation data and georeferenced acoustic image mosaics were imported into ArcGIS 10.8 mapping software. Substrate validation data were classed and symbolized according to their basic (rock, sand, mud, organics) substrate classification. The 8-bit georeferenced acoustic image mosaics were displayed with a bronze color palette (0-256), with light colours representing hard surfaces (*e.g.*, rock features) and dark representing soft (*e.g.*, mud bottom). Satellite imagery representative of the reservoir in 2021 were used as background map layers for context.

4.0 RESULTS

4.1 DOWNSTREAM OF BIRTHDAY RAPIDS

The area extending approximately 3 km downstream of Birthday Rapids was surveyed and 23 pre-selected bottom type validation sites were sampled within the reach (Map 4). Due to high water velocities, a weighted sounding line was used at 22 sites, while a standard Ponar was used at one (Table 2). Hard bedrock, cobble, and gravel substrates were observed at each site. Transect 1, located where the Nelson River narrows at Birthday Rapids, was not sampled due to high water velocities. Sidescan imagery from a single longitudinal transect down the middle of the river indicated the substrate along the transect to be predominantly bedrock.

Substrate mapping derived from analysis of acoustic sidescan image data indicated the area was dominated by rock substrates (Table 1; Figure 1). The majority of sites consisted of cobble and boulder, and bedrock was identified at five sites within the southern portion of the sample area (Table 2). Gravel and cobble substrate was identified at seven sites distributed throughout the reach and one area of gravel was identified near small islands located in Transect 7 (site DST1-5; Map 4). No smaller substrate types were identified.

4.2 LOTIC CHANNELS IN THE KEEYASK RESERVOIR

Four distinct areas were surveyed within the area of the Keeyask reservoir between Birthday Rapids and Gull Lake (Map 5). Twelve pre-selected bottom type validation sites were sampled across the four areas. Due to high water velocities and hard substrates, a weighted sounding line was used in each (Table 3). Bedrock was observed at each site. Substrate mapping derived from analysis of sidescan image data indicated rock substrates throughout the reach, each consisting largely of boulder, cobble, and bedrock (Table 3; Figure 2).

One additional area was surveyed within the lotic channel downstream of the Gull Lake entrance (Map 6). Three pre-selected bottom type validation sites were sampled using a weighted sounding line, and bedrock was observed at each site. Substrate mapping derived from analysis of sidescan image data indicated the area was largely composed of cobble and boulder but also contained small amounts of gravel (Table 3). No smaller substrate types were identified.

4.3 GULL LAKE ENTRANCE

The area extending approximately 4.5 km downstream of the Gull Lake entrance was surveyed and 27 pre-selected bottom type validation sites were sampled within the reach (Map 7). Due to high water velocities, sidescan imagery was used to confirm substrate type. The survey reach downstream of the Gull Lake entrance consisted largely of rock substrates. The majority of sites consisted of a mix of cobble, gravel, boulder, and bedrock (Table 4; Figure 3). No smaller substrate types were identified.

4.4 KEEYASK RESERVOIR NEAR CARIBOU ISLAND

The area of the Keeyask reservoir surrounding Caribou Island was surveyed and 49 pre-selected bottom type validation sites were sampled within the reach (Map 8). A petite Ponar was used to confirm substrate type at 39 sites, a weighted sounding line at eight sites, sidescan sonar image at one, and a sample was not collected at one site (Table 5).

Both substrate collection and mapping using sidescan sonar indicated that substrate types varied throughout the reach, ranging from areas of cobble and boulder to areas of clay and silt (Table 5; Figure 4). Organic matter consisting of flooded terrestrial matter was found at six sites, located at the extreme edges of transects (Map 8; Photo 1). Areas where sand was the dominant substrate were found in five sites located within the middle of the channel to the west and north of Caribou Island at Transects 7–13 (Map 8; Photo 2). PSA was conducted at one of these sites (DST3-33) which indicated a high fraction of sand (96.9%) followed by silt and clay (Table 5). This area was bordered on the upstream and downstream sides by areas of rock and by areas of mud near the edges of each transect. Silt deposition was evident at 24 sites overlying silty sand and clay substrates, largely beginning near the downstream end of the sandy area at Transect 12.

4.5 STEPHENS LAKE

The area extending from approximately 1.0–7.5 km downstream of the Keeyask GS was surveyed and 49 pre-selected bottom type validation sites were sampled within the reach (Map 9). A petite Ponar was used to confirm substrate types at 34 sites, a weighted sounding line at one site, and a sidescan sonar image at the remaining 14 sites (Table 6).

Both substrate collection and mapping using sidescan sonar indicated that substrate types varied throughout the reach, ranging from areas of cobble and boulder to areas of clay and silt (Table 6; Figure 5). Sites within the main river channel located closer to the GS (i.e., Transects 1–7) were identified as hard and rocky consisting largely of bedrock. Substrate mapping derived from analysis of sidescan image data indicated the area to be dominated by a mix of boulder, cobble, and bedrock with some gravel located in areas farther from the GS (beginning in Transect 4).

An area of predominantly sand was identified in Transect 8, approximately 4.5 km downstream of the GS (DST4-22). Downstream of this area, substrates become largely soft silt and clay. Silt deposition was evident at 17 sites, largely extending downstream from Transect 9. Organic matter was present at five of these sites, comprised of detritus and loose, broken-down plant matter.

5.0 DISCUSSION

The primary objective of the deep water habitat monitoring is to monitor changes in substrate composition in deep water areas (greater than 3 m) both upstream and downstream of the Keeyask GS. Changes to the distribution of the substrate in deep water is indicative of alteration to the hydraulics and the ability of the river to transport materials along the bed. The evolution of substrate composition in deep water within the newly formed reservoir depends mostly on the pattern of water velocities that develop within the reservoir, and how the processes of erosion, transport, and deposition in the river channel maintain or alter the existing substrate. Substrate data were collected from five general areas in August 2021 including: i) downstream of Birthday Rapids; ii) lotic channels within the Keeyask reservoir; iii) downstream of the entrance to Gull Lake; iv) the portion of the Keeyask reservoir surrounding Caribou Island; and v) the upper portion of Stephens Lake.

Substrates within the upper reaches of the Keeyask reservoir (i.e., between Birthday Rapids and the entrance to Gull Lake) were generally hard, largely consisting of bedrock, boulder, and cobble with some areas of gravel present. No smaller substrates were present. Substrate type varied more within the lower portion of the Keeyask reservoir (*i.e.*, the area around Caribou Island). An area of sand was present within the middle of the channel to the west and north of Caribou Island, surrounded by mud (*i.e.*, silt and clay) in off-channel areas. Upstream and downstream of this sandy area, the main position of the channel is generally rocky. Some silt deposition was evident towards the downstream end of the sandy area.

Substrate also varied within the upper end of Stephens Lake. Substrates were generally hard closer to the GS, dominated by a mix of boulder, cobble, and bedrock with some gravel located in areas farther from the GS. Two sites consisting largely of sand was identified, one of which was located approximately 4.5 km downstream of the GS, and one approximately 7.5 km downstream. Farther downstream sites largely consisted of a mix of silt, sand, and clay. Organic material (detritus and loose, broken-down plant matter) was observed at five sites towards the downstream end of the study reach.

Data were collected during the first open-water period following impoundment of the Keeyask reservoir. Because of this, it is too soon to make inferences about changes to substrate types caused by the Project. Surveys will be repeated annually for the first three years after impoundment using the same measures to describe changes to substrate composition as the Keeyask reservoir ages and as operation of the GS continues.

6.0 SUMMARY AND CONCLUSIONS

- Substrate data were collected from five general areas in August 2021:
  - Downstream of Birthday Rapids substrates were hard, consisting of bedrock, boulder, and cobble with some areas of gravel present. No small substrates were present.
  - The lotic channel of the Keeyask reservoir (i.e., the area between Birthday Rapids and Gull Lake) consisted of a mix of cobble, gravel, boulder, and bedrock substrates. No small substrates were present.
  - Downstream of the entrance to Gull Lake substrates consisted of a mix of cobble, gravel, boulder, and bedrock. No small substrates were present.
  - The portion of the Keeyask reservoir surrounding Caribou Island consisted of a mix of substrate types ranging from hard to soft. An area of sand was present within the middle of the channel to the east and north of Caribou Island, surrounded by mud (*i.e.*, silt and clay) in off-channel areas. Upstream and downstream of this sandy area the channel was generally rocky. Some silt deposition was evident towards the downstream end of the sandy area.
  - Substrate within the upper portion of Stephens Lake varied and were generally hard closer to the GS, dominated a mix of boulder, cobble, and bedrock with some gravel located in areas. Two sites consisting largely of sand were identified approximately 4.5 km downstream of the GS and farther downstream approximately 7.5 km from the GS. Farther downstream sites largely consisted of a mix of silt, sand, and clay. Organic material (detritus and loose, broken-down plant matter) was observed at five sites towards the downstream end of the study reach.
- As 2021 represents the first year of deep water monitoring data, it is too early to make conclusions regarding changes to substrate composition as a result of the Project. This study will be repeated in 2022.

7.0 LITERATURE CITED

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TABLES

Table 1: Modified Wentworth scale of material size used to classify substrate *in situ* (after Wentworth 1922).

Size Range	Wentworth Class	General Class	Basic Class
-	-	Bedrock	Rock
>256 mm	Boulder	Boulder	
64–256 mm	Cobble	Cobble	
32–64 mm	Very coarse gravel	Gravel	
16–32 mm	Coarse gravel		
8–16 mm	Medium gravel		
4–8 mm	Fine gravel		
2–4 mm	Very fine gravel		
1–2 mm	Very coarse sand	Sand	Sand
0.5–1 mm	Coarse sand		
0.25–0.5 mm	Medium sand		
125–250 µm	Fine sand		
62.5–125 µm	Very fine sand		
3.9–62.5 µm	Silt	Silt	Mud
0.98–3.9 µm	Clay	Clay	
-	-	Organic	Organic

Table 2: Locations and results of field bottom type validation sampling and post-survey class verification in the area downstream of Birthday Rapids, 2021.

Site ID	Transect ID	Method	Date	UTM Easting	UTM Northing	Depth (m)	Compaction	Estimated Substrate Composition						Basic Class	Class Verification[1]
								Substrate 1	%	Substrate 2	%	Substrate 3	%		
DST1-1	8	weighted sounding line	8/14/2021	334384	6243720	3	hard	cobble	-	-	-	-	-	rock	cobble/boulder
DST1-2	8	weighted sounding line	8/14/2021	334364	6243902	9.5	hard	cobble	-	-	-	-	-	rock	cobble/boulder
DST1-3	8	weighted sounding line	8/14/2021	334348	6244132	10.5	hard	gravel	-	-	-	-	-	rock	gravel/cobble
DST1-4	7	standard Ponar	8/14/2021	333888	6243184	4.6	hard	gravel	-	-	-	-	-	rock	gravel/cobble
DST1-5	7	weighted sounding line	8/14/2021	333844	6243525	4.6	hard	gravel	-	-	-	-	-	rock	gravel
DST1-6	7	weighted sounding line	8/14/2021	333803	6243889	3.1	hard	bedrock	-	-	-	-	-	rock	cobble/boulder
DST1-7	7	weighted sounding line	8/14/2021	333780	6244135	3.5	hard	cobble	-	-	-	-	-	rock	cobble/boulder
DST1-8	6	weighted sounding line	8/14/2021	333365	6243315	5.3	hard	cobble	-	-	-	-	-	rock	cobble/gravel/boulder
DST1-9	6	weighted sounding line	8/14/2021	333342	6243538	5.2	hard	bedrock	-	-	-	-	-	rock	boulder/bedrock
DST1-10	6	weighted sounding line	8/14/2021	333316	6243782	4.3	hard	cobble	-	-	-	-	-	rock	boulder/cobble
DST1-11	6	weighted sounding line	8/14/2021	333293	6243989	4	hard	cobble	-	-	-	-	-	rock	cobble/large gravel
DST1-12	5	weighted sounding line	8/14/2021	332878	6243338	4.2	hard	cobble	-	-	-	-	-	rock	bedrock/boulder
DST1-13	5	weighted sounding line	8/14/2021	332847	6243484	3.3	hard	bedrock	-	-	-	-	-	rock	bedrock
DST1-14	5	weighted sounding line	8/14/2021	332788	6243771	3.9	hard	cobble	-	-	-	-	-	rock	cobble/boulder
DST1-15	4	weighted sounding line	8/14/2021	332452	6243197	6.3	hard	cobble	-	-	-	-	-	rock	cobble/boulder
DST1-16	4	weighted sounding line	8/14/2021	332357	6243423	2.2	hard	bedrock	-	-	-	-	-	rock	boulder/bedrock
DST1-17	4	weighted sounding line	8/14/2021	332260	6243659	2	hard	cobble	-	-	-	-	-	rock	cobble/gravel
DST1-18	3	weighted sounding line	8/14/2021	332078	6243187	4.4	hard	cobble	-	-	-	-	-	rock	cobble/gravel
DST1-19	3	weighted sounding line	8/14/2021	331960	6243366	7	hard	bedrock	-	-	-	-	-	rock	boulder/bedrock
DST1-20	3	weighted sounding line	8/14/2021	331829	6243559	7.1	hard	cobble	-	-	-	-	-	rock	cobble/boulder
DST1-21	2	weighted sounding line	8/14/2021	331901	6243074	5.5	hard	bedrock	-	-	-	-	-	rock	cobble/boulder
DST1-22	2	weighted sounding line	8/14/2021	331616	6243194	7.2	hard	bedrock	-	-	-	-	-	rock	boulder/cobble
DST1-23	2	weighted sounding line	8/14/2021	331360	6243305	5.8	hard	gravel	-	-	-	-	-	rock	gravel/cobble

1 – Class verified with digital images and sidescan imagery post-survey.

Table 3: Locations and results of field bottom type validation sampling and post-survey class verification in the lotic portion of the Keeyask reservoir between Birthday Rapids and Gull Lake, 2021.

Site ID	Transect ID	Method	Date	UTM Easting	UTM Northing	Depth (m)	Compaction	Estimated Substrate Composition						Basic Class	Class Verification[1]
								Substrate 1	%	Substrate 2	%	Substrate 3	%		
RSC-1	-	weighted sounding line	16-Aug-21	335842	6244523	11.4	Hard	bedrock	100	-	-	-	-	rock	boulder/cobble
RSC-2	-	weighted sounding line	16-Aug-21	336073	6244523	10	Hard	bedrock	100	-	-	-	-	rock	boulder/cobble
RSC-3	-	weighted sounding line	16-Aug-21	336305	6244424	3.4	Hard	bedrock	100	-	-	-	-	rock	boulder/cobble/bedrock
RSC-4	-	weighted sounding line	16-Aug-21	338620	6244556	11.3	Hard	bedrock	100	-	-	-	-	rock	boulder/cobble/bedrock
RSC-5	-	weighted sounding line	16-Aug-21	338818	6244357	11.5	Hard	bedrock	100	-	-	-	-	rock	bedrock
RSC-6	-	weighted sounding line	16-Aug-21	339149	6243994	8.8	Hard	bedrock	100	-	-	-	-	rock	boulder/cobble/bedrock
RSC-7	-	weighted sounding line	16-Aug-21	340869	6243200	9.5	Hard	bedrock	100	-	-	-	-	rock	boulder/cobble/bedrock
RSC-8	-	weighted sounding line	16-Aug-21	341232	6243365	7.1	Hard	bedrock	100	-	-	-	-	rock	cobble/boulder/bedrock
RSC-9	-	weighted sounding line	16-Aug-21	341629	6243532	11.4	Hard	bedrock	100	-	-	-	-	rock	boulder/cobble/bedrock
RSC-10	-	weighted sounding line	16-Aug-21	642952	6243465	10	Hard	bedrock	100	-	-	-	-	rock	boulder/bedrock
RSC-11	-	weighted sounding line	16-Aug-21	343316	6243498	11.6	Hard	bedrock	100	-	-	-	-	rock	boulder/cobble
RSC-12	-	weighted sounding line	16-Aug-21	343647	6243597	13.3	Hard	bedrock	100	-	-	-	-	rock	boulder/cobble
RSC-13	-	weighted sounding line	16-Aug-21	351717	6243398	20	Hard	bedrock	100	-	-	-	-	rock	cobble/gravel/boulder
RSC-14	-	weighted sounding line	16-Aug-21	352180	6243431	19	Hard	bedrock	100	-	-	-	-	rock	cobble/boulder/gravel
RSC-15	-	weighted sounding line	16-Aug-21	352610	6243630	17	Hard	bedrock	100	-	-	-	-	rock	cobble/boulder/gravel

1 – Class verified with digital images and sidescan imagery post-survey.

Table 4: Locations and results of field bottom type validation sampling and post-survey class verification in Keeyask reservoir downstream of the entrance to Gull Lake, 2021.

Site ID	Transect ID	Method	Date	UTM Easting	UTM Northing	Depth (m)	Compaction	Estimated Substrate Composition						Basic Class	Class Verification[1]
								Substrate 1	%	Substrate 2	%	Substrate 3	%		
DST2-1	9	sidescan image	23/Aug/21	349796	6243522	9	hard	bedrock	100	-	-	-	-	rock	cobble/gravel/boulder
DST2-2	9	sidescan image	23/Aug/21	349817	6244004	15	hard	bedrock	100	-	-	-	-	rock	gravel/cobble/boulder
DST2-3	9	sidescan image	23/Aug/21	349838	6244400	11	hard	bedrock	100	-	-	-	-	rock	cobble/gravel/boulder
DST2-4	8	sidescan image	23/Aug/21	349182	6243617	9	hard	bedrock	100	-	-	-	-	rock	bedrock/boulder/cobble
DST2-5	8	sidescan image	23/Aug/21	349198	6244035	16	hard	bedrock	100	-	-	-	-	rock	cobble/gravel/boulder
DST2-6	8	sidescan image	23/Aug/21	349217	6244432	16	hard	bedrock	100	-	-	-	-	rock	cobble/gravel/boulder
DST2-7	7	sidescan image	23/Aug/21	348605	6243686	11	hard	bedrock	100	-	-	-	-	rock	gravel/cobble/boulder
DST2-8	7	sidescan image	23/Aug/21	348595	6244104	14	hard	bedrock	100	-	-	-	-	rock	boulder/cobble/bedrock
DST2-9	7	sidescan image	23/Aug/21	348595	6244475	12	hard	bedrock	100	-	-	-	-	rock	gravel/cobble/boulder
DST2-10	6	sidescan image	23/Aug/21	348065	6243718	13	hard	bedrock	100	-	-	-	-	rock	gravel/cobble/boulder
DST2-11	6	sidescan image	23/Aug/21	348060	6244099	15	hard	bedrock	100	-	-	-	-	rock	boulder/cobble/gravel
DST2-12	6	sidescan image	23/Aug/21	348060	6244411	8	hard	bedrock	100	-	-	-	-	rock	cobble/gravel/boulder
DST2-13	5	sidescan image	23/Aug/21	347531	6243734	12	hard	bedrock	100	-	-	-	-	rock	gravel/cobble/boulder
DST2-14	5	sidescan image	23/Aug/21	347536	6244083	21	hard	bedrock	100	-	-	-	-	rock	gravel/bedrock
DST2-15	5	sidescan image	23/Aug/21	347531	6244385	7	hard	bedrock	100	-	-	-	-	rock	gravel/cobble
DST2-16	4	sidescan image	23/Aug/21	346975	6243718	10	hard	bedrock	100	-	-	-	-	rock	gravel/cobble/boulder
DST2-17	4	sidescan image	23/Aug/21	346965	6244125	13	hard	bedrock	100	-	-	-	-	rock	gravel/boulder/bedrock
DST2-18	4	sidescan image	23/Aug/21	346954	6244512	16	hard	bedrock	100	-	-	-	-	rock	cobble/gravel/boulder
DST2-19	3	sidescan image	23/Aug/21	346377	6244512	8	hard	bedrock	100	-	-	-	-	rock	gravel/cobble
DST2-20	3	sidescan image	23/Aug/21	346346	6244146	15	hard	bedrock	100	-	-	-	-	rock	gravel/cobble/boulder
DST2-21	3	sidescan image	23/Aug/21	346325	6244681	10	hard	bedrock	100	-	-	-	-	rock	cobble/gravel
DST2-22	2	sidescan image	23/Aug/21	345705	6243723	11	hard	bedrock	100	-	-	-	-	rock	gravel/bedrock
DST2-23	2	sidescan image	23/Aug/21	345700	6244099	14	hard	bedrock	100	-	-	-	-	rock	gravel/cobble/bedrock
DST2-24	2	sidescan image	23/Aug/21	345668	6244586	10	hard	bedrock	100	-	-	-	-	rock	gravel/cobble

Table 4: Locations and results of field bottom type validation sampling and post-survey class verification in Keeyask reservoir downstream of the entrance to Gull Lake, 2021 (continued).

Site ID	Transect ID	Method	Date	UTM Easting	UTM Northing	Depth (m)	Compaction	Estimated Substrate Composition						Basic Class	Class Verification[1]
								Substrate 1	%	Substrate 2	%	Substrate 3	%		
DST2-25	1	sidescan image	23/Aug/21	345160	6243697	8	hard	bedrock	100	-	-	-	-	rock	gravel/cobble/bedrock
DST2-26	1	sidescan image	23/Aug/21	345150	6243945	14	hard	bedrock	100	-	-	-	-	rock	boulder/cobble/bedrock
DST2-27	1	sidescan image	23/Aug/21	345129	6244168	10	hard	bedrock	100	-	-	-	-	rock	gravel/cobble/boulder

1 – Class verified with digital images and sidescan imagery post-survey.

Table 5: Locations and results of field bottom type validation sampling and post-survey class verification in Keeyask reservoir in the vicinity of Caribou Island, 2021.

Site ID	Transect ID	Method	Date	UTM Easting	UTM Northing	Depth (m)	Compaction	Estimated Substrate Composition						Basic Class	Silt Deposition Evident	Class Verification[1]
								Substrate[1]	%	Substrate[2]	%	Substrate[3]	%			
DST3-1	18	weighted sounding line	19/Aug/21	358677	6245800	12.1	Hard	boulder	100	-	-	-	-	rock	no	cobble/boulder
DST3-2	18	weighted sounding line	19/Aug/21	358544	6246102	9.6	Hard	boulder	100	-	-	-	-	rock	no	boulder/cobble
DST3-3	17	petite Ponar	19/Aug/21	358200	6245012	2.0	-	organics	100	-	-	-	-	organics	no	organics/flooded terrestrial
DST3-4	17	petite Ponar	19/Aug/21	358015	6245414	2.7	-	organics	-	-	-	-	-	organics	no	organics/flooded terrestrial
DST3-5	17	weighted sounding line	19/Aug/21	357798	6245848	18.2	Hard	boulder	100	-	-	-	-	boulder	no	cobble/boulder/bedrock
DST3-6	16	weighted sounding line	19/Aug/21	358269	6246631	9.0	hard	boulder	100	-	-	-	-	rock	no	cobble/gravel/boulder
DST3-7	16	petite Ponar	19/Aug/21	358655	6246864	6.6	medium	clay	95	silt	5	-	-	mud	yes	clay/silt
DST3-8	16	petite Ponar	19/Aug/21	359015	6247060	2.5	soft	organics	100	-	-	-	-	organic	no	organics/flooded terrestrial
DST3-9	15	weighted sounding line	19/Aug/21	357989	6247001	6.0	hard	boulder	100	-	-	-	-	rock	no	boulder/bedrock/cobble
DST3-10	15	petite Ponar	19/Aug/21	358280	6247261	11.2	hard	cobble	40	boulder	30	gravel	30	rock	no	cobble/boulder/gravel
DST3-11	15	petite Ponar	19/Aug/21	358523	6247462	3.2	soft	organic	100	-	-	-	-	organic	no	organics/flooded terrestrial
DST3-12	14	petite Ponar	19/Aug/21	357798	6247478	11.4	hard	boulder	100	-	-	-	-	rock	no	boulder/bedrock/cobble
DST3-13	14	petite Ponar	19/Aug/21	357931	6247710	6.7	hard	gravel	100	-	-	-	-	rock	no	gravel/cobble
DST3-14	14	petite Ponar	19/Aug/21	358100	6247991	3.5	soft	organics	100	-	-	-	-	organic	no	organics/flooded terrestrial
DST3-15	13	petite Ponar	19/Aug/21	357280	6247557	7.8	medium	clay	80	sand	10	silt	10	mud	yes	clay/sand/silt
DST3-16	13	petite Ponar	19/Aug/21	357412	6247864	10.7	hard	sand	95	silt	5	-	-	sand	yes	sand/silt
DST3-17	13	petite Ponar	19/Aug/21	357550	6248240	7.4	medium	clay	95	silt	5	-	-	mud	yes	clay/silt
DST3-18	12	petite Ponar	19/Aug/21	356835	6247557	6.3	medium	clay	95	silt	5	-	-	mud	yes	clay/silt/sand
DST3-19	12	petite Ponar	19/Aug/21	356893	6247848	6.9	medium	clay	95	silt	5			mud	yes	silt/sand/clay
DST3-20	12	petite Ponar	19/Aug/21	356973	6248213	16.2	medium	clay	95	silt	5			mud	yes	silt/clay/sand
DST3-21	11	petite Ponar	19/Aug/21	356412	6247472	6.8	medium	clay	95	silt	5			mud	yes	clay/silt/sand
DST3-22	11	petite Ponar	19/Aug/21	356317	6247816	8.2	medium	sand	95	silt	5			sand	yes	sand/silt
DST3-23	11	petite Ponar	19/Aug/21	356195	6248218	10.3	medium	clay	95	silt	5			mud	yes	clay/silt
DST3-24	10	petite Ponar	19/Aug/21	356010	6247329	2.1	-	organics	100	-	-	-	-	organic	no	organics/flooded terrestrial
DST3-25	10	petite Ponar	19/Aug/21	355840	6247610	13.7	hard	sand	100	-	-	-	-	sand	yes	sand/silt
DST3-26	10	petite Ponar	19/Aug/21	355682	6247880	6.5	soft	clay	70	silt	15	gravel	15	mud	yes	clay/silt/gravel
DST3-27	9	petite Ponar	19/Aug/21	355740	6247107	6.5	medium	clay	80	sand	10	silt	10	mud	yes	clay/sand/silt
DST3-28	9	petite Ponar	19/Aug/21	355412	6247303	13.0	medium	sand	100	-	-	-	-	sand	no	sand
DST3-29	9	petite Ponar	19/Aug/21	355015	6247541	6.5	medium	clay	70	sand	15	silt	15	mud	yes	clay/silt/sand
DST3-30	8	petite Ponar	19/Aug/21	355602	6246784	6.2	medium	clay	70	sand	20	silt	10	mud	yes	clay/sand/silt
DST3-31	8	petite Ponar	19/Aug/21	355179	6246927	10.5	hard	gravel	100	-	-	-	-	rock	no	gravel
DST3-32	8	petite Ponar	19/Aug/21	354628	6247112	6.9	medium	clay	70	silt	30	-	-	mud	yes	clay/silt
DST3-33	7	petite Ponar	19/Aug/21	355438	6246509	13.1	hard	sand	100	-	-	-	-	sand	no	sand/gravel
DST3-34	6	no sample	19/Aug/21	355639	6246271	13.9	-	-	-	-	-	-	-	rock	no	gravel/cobble
DST3-35	5	petite Ponar	19/Aug/21	355311	6246181	10.6	Moderate	clay	95	silt	5	-	-	mud	yes	clay/silt
DST3-36	5	petite Ponar	19/Aug/21	355809	6245821	14.8	-	cobble	100	-	-	-	-	rock	no	cobble
DST3-37	5	petite Ponar	19/Aug/21	356629	6245186	7.3	Moderate	clay	95	silt	5	-	-	mud	yes	clay/silt

Table 5: Locations and results of field bottom type validation sampling and post-survey class verification in Keeyask reservoir in the vicinity of Caribou Island, 2021 (continued).

Site ID	Transect ID	Method	Date	UTM Easting	UTM Northing	Depth (m)	Compaction	Estimated Substrate Composition						Basic Class	Silt Deposition Evident	Class Verification[1]
								Substrate[1]	%	Substrate[2]	%	Substrate[3]	%			
DST3-38	4	petite Ponar	19/Aug/21	354930	6245885	8.0	Hard	clay	95	silt	5	-	-	mud	yes	clay/silt/sand
DST3-39	4	sidescan sonar	19/Aug/21	355412	6245409	18.3	Hard	boulder	100	-	-	-	-	rock	no	cobble/boulder/gravel
DST3-40	4	petite Ponar	19/Aug/21	355967	6244853	2.5	soft	organic	100	-	-	-	-	organic	yes	organics/silt
DST3-41	3	petite Ponar	19/Aug/21	355470	6244721	6.5	Hard	clay	95	silt	5	-	-	mud	yes	clay/silt
DST3-42	3	weighted sounding line	19/Aug/21	355099	6245218	7.3	Hard	boulder	100	-	-	-	-	rock	no	boulder/cobble
DST3-43	3	petite Ponar	19/Aug/21	354666	6245811	7.8	Hard	clay	95	silt	5	-	-	mud	yes	clay/silt
DST3-44	2	petite Ponar	19/Aug/21	355094	6244414	5.2	Hard	clay	95	silt	5	-	-	mud	yes	clay/silt
DST3-45	2	weighted sounding line	19/Aug/21	354655	6244980	19.5	Hard	boulder	100	-	-	-	-	rock	no	gravel/cobble/boulder
DST3-46	2	petite Ponar	19/Aug/21	354242	6245498	2.0	-	organic	100	-	-	-	-	organic	no	organics/trace silt
DST3-47	1	petite Ponar	19/Aug/21	354496	6244059	7.0	Hard	boulder	100	-	-	-	-	rock	no	cobble/boulder
DST3-48	1	weighted sounding line	19/Aug/21	354078	6244747	13.0	Hard	boulder	100	-	-	-	-	rock	no	gravel/cobble
DST3-49	1	petite Ponar	19/Aug/21	353713	6245398	7.5	Hard	clay	95	silt	5	-	-	mud	yes	clay/silt

1 – Class verified with digital images and sidescan imagery post-survey.

Table 6: Locations and results of field bottom type validation sampling and post-survey class verification in the upper portion of Stephens Lake, 2021.

Site ID	Transect ID	Method	Date	UTM Easting	UTM Northing	Depth (m)	Compaction	Estimated Substrate Composition						Basic Class	Silt Deposition Evident	Class Verification[1]
								Substrate[1]	%	Substrate[2]	%	Substrate[3]	%			
DST4-1	13	Petite Ponar	20/Aug/21	370314	6247135	16.5	soft	clay	95	silt	5	-	-	mud	yes	silt/clay/organics
DST4-2	13	Petite Ponar	20/Aug/21	370870	6247650	20.2	medium	clay	95	silt	5	-	-	mud	yes	clay/silt
DST4-3	13	Petite Ponar	20/Aug/21	371455	6248199	1.5	hard	clay	95	silt	5	-	-	mud	yes	clay/silt/sand
DST4-4	12	Petite Ponar	20/Aug/21	369795	6247184	15.6	soft	silt	90	clay	5	organics	5	mud	yes	silt/clay/organics
DST4-5	12	Petite Ponar	20/Aug/21	370536	6247988	15.0	soft	organics	60	silt	40	-	-	organics	yes	silt/organics
DST4-6	12	Petite Ponar	20/Aug/21	371108	6248613	1.8	soft	sand	95	silt	5	-	-	sand	yes	sand/silt
DST4-7	11	Petite Ponar	20/Aug/21	369176	6247138	15.0	soft	clay	50	organics	40	sand	10	mud	yes	silt/organics
DST4-8	11	Petite Ponar	20/Aug/21	369881	6248133	18.2	soft	silt		clay		organics		mud	yes	silt/clay/organics
DST4-9	11	Petite Ponar	20/Aug/21	370182	6248560	15.6	soft	clay	50	silt	40	organics	10	mud	yes	silt/clay/organics
DST4-10	10	sidescan image	20/Aug/21	368693	6246893	14.4	hard	cobble	50	gravel	30	boulder	20	rock	no	cobble/gravel/boulder
DST4-11	10	Petite Ponar	20/Aug/21	368918	6247340	13.8	soft	clay	60	silt	40	-	-	mud	yes	silt/clay
DST4-12	10	Petite Ponar	20/Aug/21	369256	6247975	12.6	soft	clay	90	silt	10	-	-	mud	yes	clay/silt
DST4-13	10	Petite Ponar	20/Aug/21	369729	6248884	15.5	hard	cobble	50	boulder	40	silt	10	rock	yes	cobble/boulder/silt
DST4-14	9	Petite Ponar	20/Aug/21	368273	6246873	13.6	hard	cobble	50	gravel	30	boulder	20	rock	no	cobble/gravel/boulder
DST4-15	9	Petite Ponar	20/Aug/21	368525	6247525	14.6	hard	cobble		boulder		silt		rock	yes	cobble/boulder/silt
DST4-16	9	sidescan image	20/Aug/21	368723	6248047	12.0	hard	cobble	50	gravel	40	boulder	10	rock	no	cobble/gravel/boulder
DST4-17	9	Petite Ponar	20/Aug/21	368885	6248474	16.4	soft	silt	50	sand	40	clay	10	mud	yes	silt/sand/clay
DST4-18	9	Petite Ponar	20/Aug/21	369054	6248911	15.0	soft	silt	50	sand	30	clay	20	mud	yes	silt/sand/clay
DST4-19	18	Petite Ponar	20/Aug/21	368015	6246949	9.0	hard	cobble	50	gravel	30	boulder	20	rock	no	cobble/gravel/boulder
DST4-20	8	Petite Ponar	20/Aug/21	368134	6247492	13.5	hard	gravel	50	cobble	30	boulder	20	rock	no	gravel/cobble/boulder
DST4-21	8	Petite Ponar	20/Aug/21	368227	6247915	15.6	hard	gravel	50	cobble	30	boulder	20	rock	no	gravel/cobble/boulder
DST4-22	8	Petite Ponar	20/Aug/21	368330	6248405	7.3	medium	sand	100	-	-	-	-	sand	no	sand
DST4-23	8	Petite Ponar	20/Aug/21	368432	6248854	13.6	medium	gravel	70	silt	20	clay	10	rock	yes	gravel/silt/clay
DST4-24	17	Petite Ponar	20/Aug/21	367671	6246992	6.6	hard	cobble	60	gravel	30	boulder	10	rock	no	cobble/gravel/boulder
DST4-25	7	Petite Ponar	20/Aug/21	367724	6247528	14.0	hard	gravel	60	cobble	30	boulder	20	rock	no	gravel/cobble/boulder
DST4-26	7	Petite Ponar	20/Aug/21	367774	6247932	13.2	hard	boulder	50	cobble	30	gravel	20	rock	no	boulder/cobble/gravel
DST4-27	7	Petite Ponar	20/Aug/21	367810	6248355	12.7	hard	gravel	70	sand	30	-	-	rock	no	gravel/sand
DST4-28	7	Petite Ponar	20/Aug/21	367863	6248785	14.2	soft	organics	90	silt	10	-	-	organics	yes	organics/silt
DST4-29	6	Petite Ponar	20/Aug/21	367344	6246959	8.7	hard	gravel	100	-	-	-	-	rock	no	gravel/cobble/boulder
DST4-30	6	Petite Ponar	20/Aug/21	367367	6247571	13.0	hard	gravel	100	-	-	-	-	rock	no	gravel/cobble/boulder
DST4-31	6	Petite Ponar	20/Aug/21	367380	6247948	12.5	hard	bedrock	100	-	-	-	-	rock	no	bedrock/boulder
DST4-32	6	weighted sounding line	20/Aug/21	367394	6248249	11.6	hard	gravel	100	-	-	-	-	rock	no	gravel/cobble
DST4-33	5	Petite Ponar	20/Aug/21	367146	6246939	6.3	Hard	bedrock	100	-	-	-	-	rock	no	cobble/boulder
DST4-34	5	sidescan image	20/Aug/21	367017	6247604	13.6	Hard	bedrock	100	-	-	-	-	rock	no	boulder/cobble
DST4-35	5	sidescan image	20/Aug/21	366960	6247889	12.2	Hard	bedrock	100	-	-	-	-	rock	no	gravel/cobble/boulder
DST4-36	5	Petite Ponar	20/Aug/21	366911	6248170	11.9	Hard	bedrock	100	-	-	-	-	rock	no	gravel/cobble/boulder

Table 6: Locations and results of field bottom type validation sampling and post-survey class verification in the upper portion of Stephens Lake, 2021 (continued).

Site ID	Transect ID	Method	Date	UTM Easting	UTM Northing	Depth (m)	Compaction	Estimated Substrate Composition						Basic Class	Silt Deposition Evident	Class Verification[1]
								Substrate[1]	%	Substrate[2]	%	Substrate[3]	%			
DST4-37	4	Petite Ponar	20/Aug/21	366683	6246797	6.2	medium	clay	100	-	-	-	-	mud	no	clay/silt/sand
DST4-38	4	Petite Ponar	20/Aug/21	366590	6247144	3.2	Hard	bedrock	100	-	-	-	-	rock	no	boulder/cobble/gravel
DST4-39	4	sidescan image	20/Aug/21	366463	6247603	18.2	Hard	bedrock	100	-	-	-	-	rock	no	cobble/gravel/boulder
DST4-40	4	sidescan image	20/Aug/21	366378	6247905	13.3	Hard	bedrock	100	-	-	-	-	rock	no	gravel/cobble/boulder
DST4-41	3	Petite Ponar	20/Aug/21	366157	6246923	5.7	Hard	bedrock	100	-	-	-	-	rock	no	boulder/cobble
DST4-42	3	sidescan image	20/Aug/21	366008	6247430	13.4	Hard	bedrock	100	-	-	-	-	rock	no	boulder/cobble/bedrock
DST4-43	3	sidescan image	20/Aug/21	365919	6247756	13.4	Hard	bedrock	100	-	-	-	-	rock	no	cobble/boulder/bedrock
DST4-44	2	sidescan image	20/Aug/21	365601	6246801	8.0	Hard	bedrock	100	-	-	-	-	rock	no	boulder/cobble/bedrock
DST4-45	2	sidescan image	20/Aug/21	365497	6247226	9.9	Hard	bedrock	100	-	-	-	-	rock	no	boulder/cobble
DST4-46	2	sidescan image	20/Aug/21	365416	6247574	9.9	Hard	bedrock	100	-	-	-	-	rock	no	boulder/cobble/bedrock
DST4-47	1	sidescan image	20/Aug/21	364950	6246754	6.5	Hard	bedrock	100	-	-	-	-	rock	no	boulder/cobble/bedrock
DST4-48	1	sidescan image	20/Aug/21	364913	6246996	5.3	Hard	bedrock	100	-	-	-	-	rock	no	boulder/cobble/bedrock
DST4-49	1	sidescan image	20/Aug/21	364867	6247260	3.0	Hard	bedrock	100	-	-	-	-	rock	no	boulder/cobble/bedrock

1 – Class verified with digital images and sidescan imagery post-survey.

Table 7: Results of particle size analysis (conducted at ALS Laboratories) from samples collected at selected sites in the Keeyask reservoir near Caribou Island and upper Stephens Lake, 2021.

Area Name	Field Site No.	Inorganic Carbon (%)	$CaCO_3$ Equivalent	Total Carbon by Combustion (%)	Total Organic Carbon (%)	% Sand (2.0-0.05 mm)	% Silt (0.05-2 µm)	% Clay (<2 µm)	Texture
Caribou Island	DST3-17	2.06	17.2	4.08	2.02	22.6	67.9	9.5	silt loam
Caribou Island	DST3-32	2.09	17.4	4.28	2.19	4.7	84.2	11.1	silt
Caribou Island	DST3-33	2.15	17.9	2.46	<0.49	96.9	1.9	1.2	sand
Caribou Island	DST3-37	1.94	16.2	4.10	2.16	58.7	35.9	5.4	sandy loam
Stephens Lake	DST4-4	1.7	14.2	4.53	2.83	54.4	38.3	7.3	sandy loam
Stephens Lake	DST4-17	1.67	13.9	4.13	2.46	66.4	26.5	7.1	sandy loam
Stephens Lake	DST4-18	1.91	15.9	4.44	2.53	46.5	44.9	8.6	loam

FIGURES

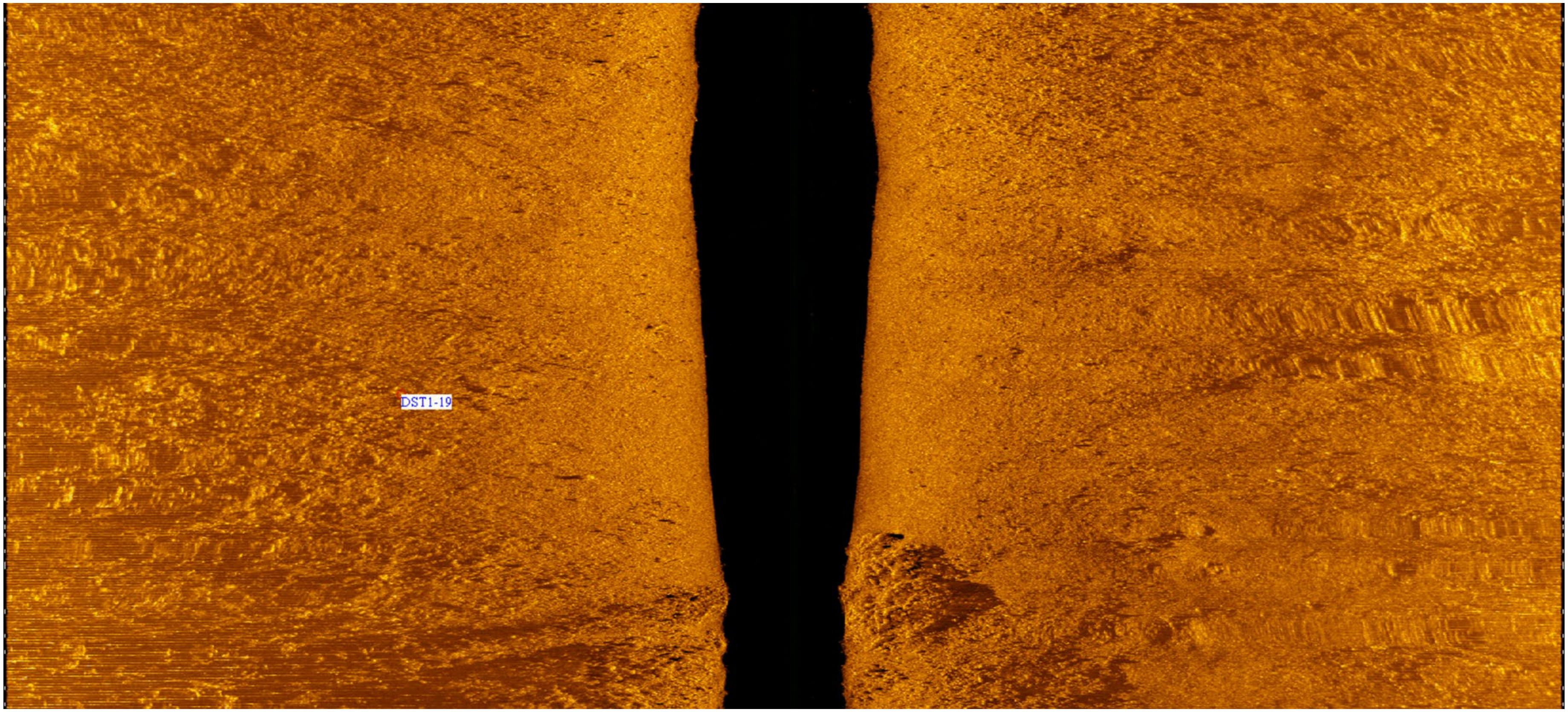


Figure 1: Detailed high-resolution sidescan 'waterfall' image showing predominantly boulder and bedrock substrate at site DST1-19 in the area of the Keeyask reservoir downstream of Birthday Rapids, 2021.

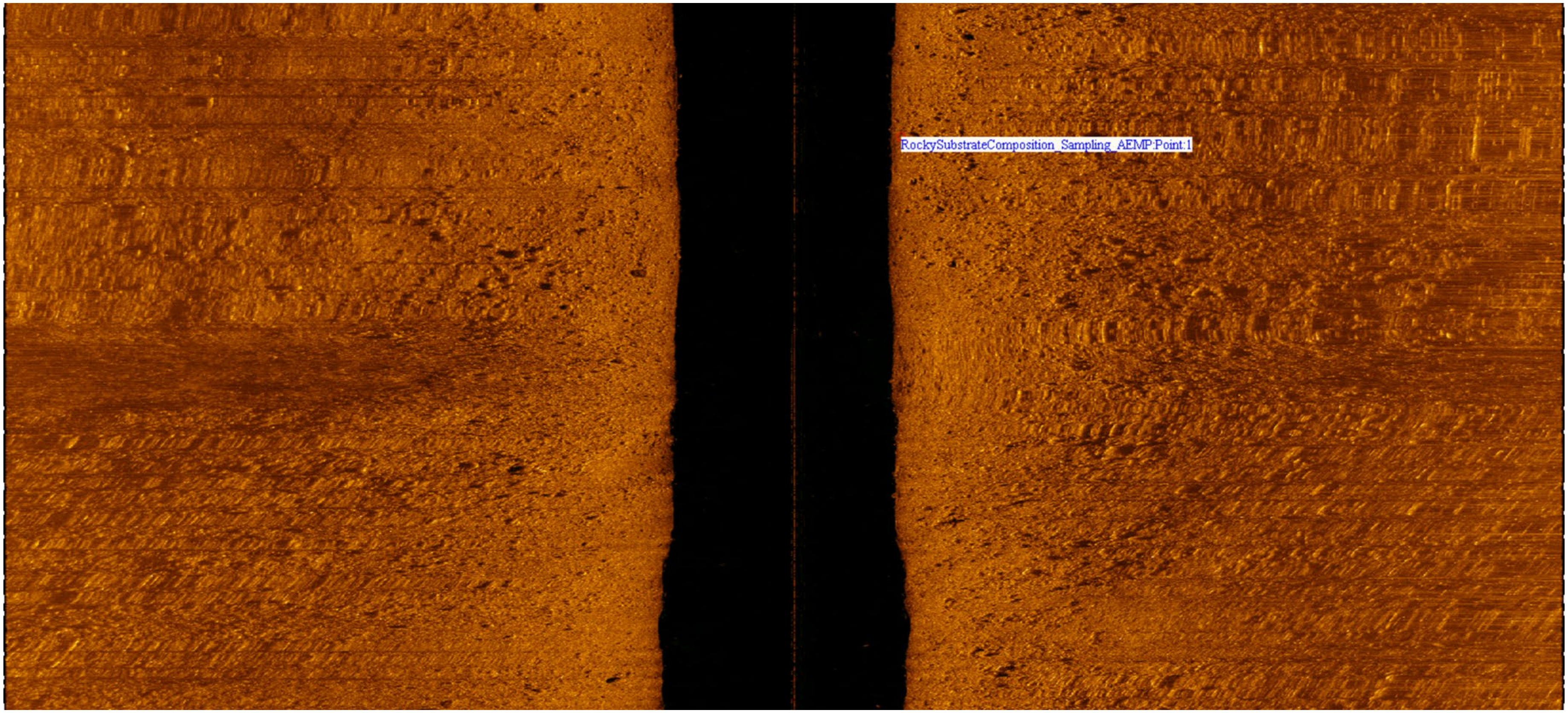


Figure 2: Detailed high-resolution sidescan 'waterfall' image showing predominantly boulder and cobble substrate at site RSC-1 in the area of the Keeyask reservoir between Birthday Rapids and the entrance to Gull Lake, 2021.

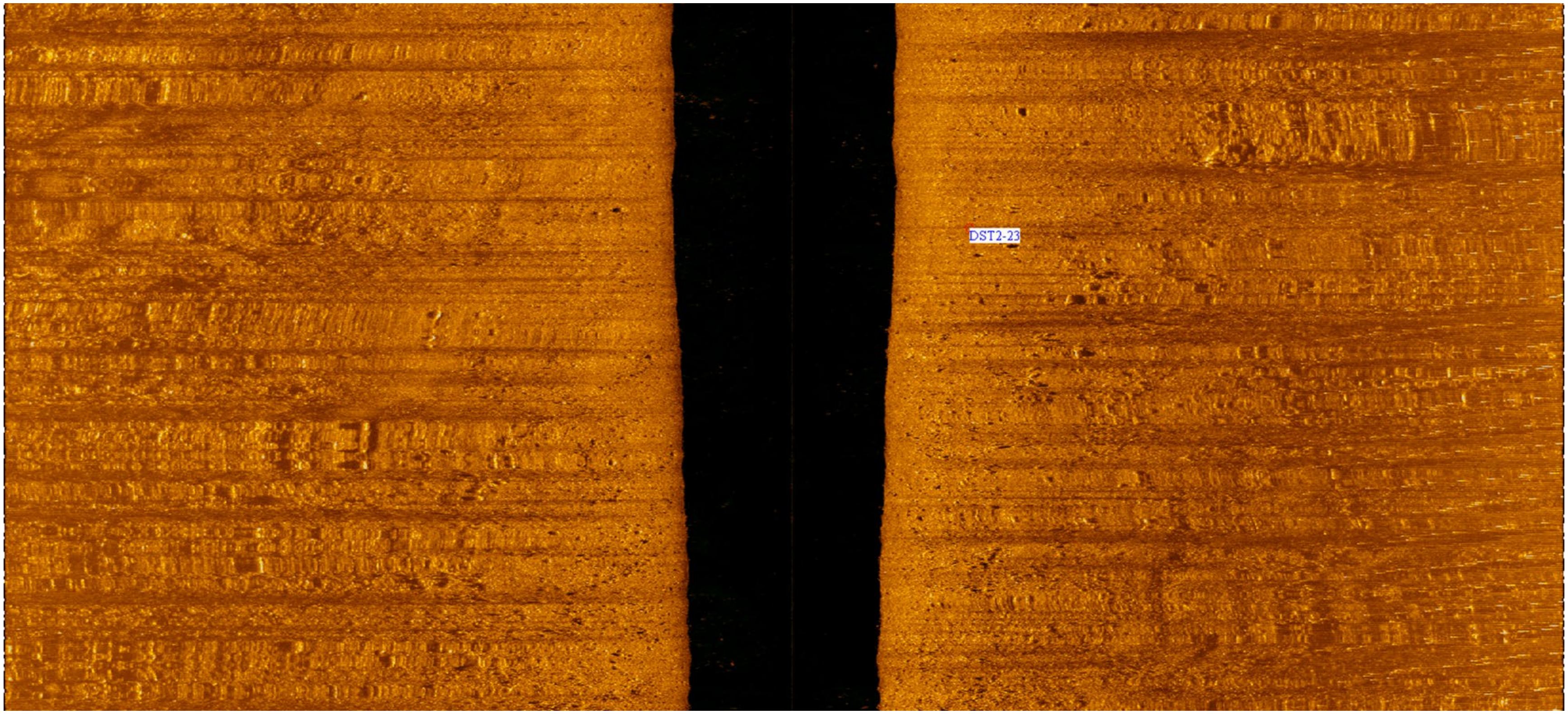


Figure 3: **Detailed high-resolution sidescan 'waterfall' image showing predominantly boulder and cobble substrate at site DST2-23 in the area of the Keeyask reservoir downstream of the entrance to Gull Lake, 2021.**

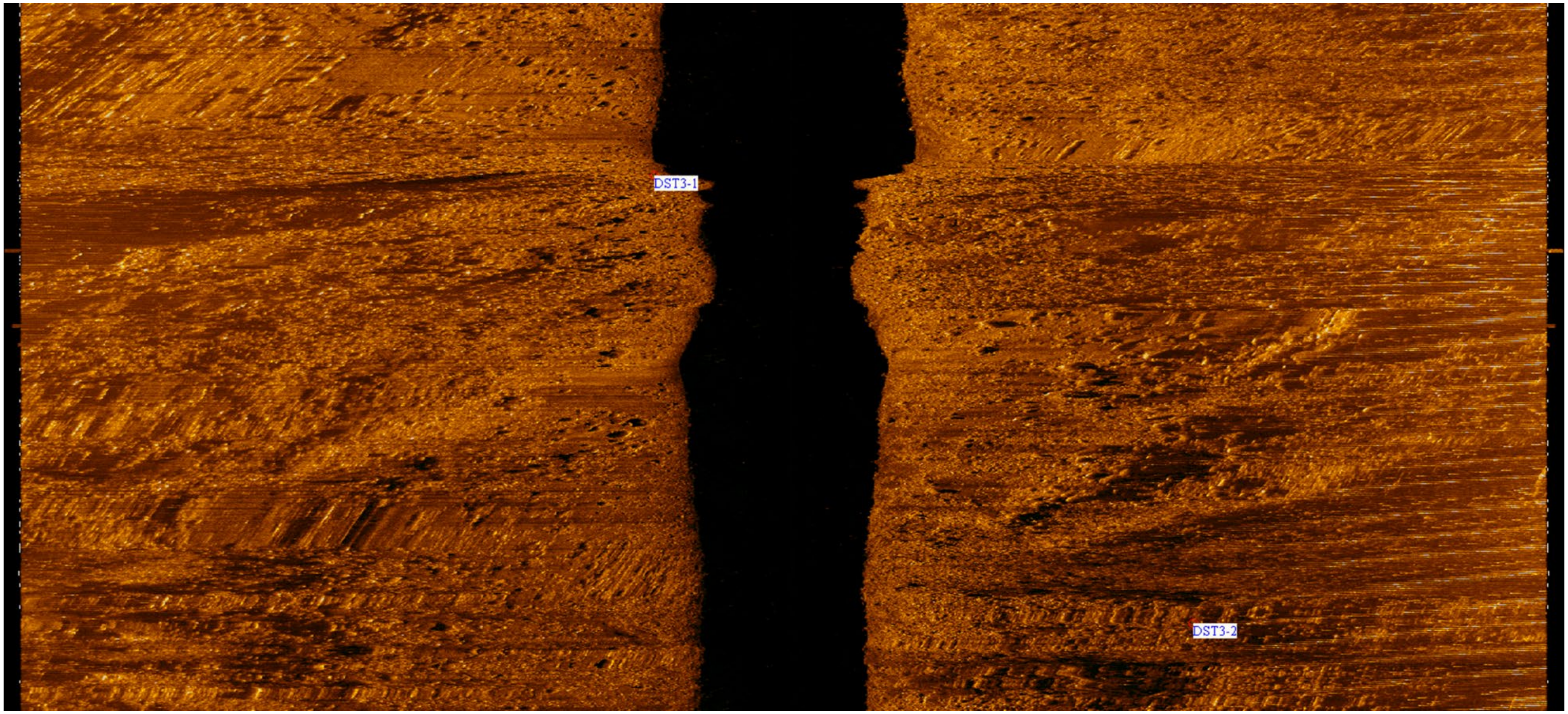


Figure 4: Detailed high-resolution sidescan 'waterfall' image showing predominantly boulder and cobble substrate at sites DST3-1 and DST3-2 in the area of the Keeyask reservoir surrounding Caribou Island, 2021.

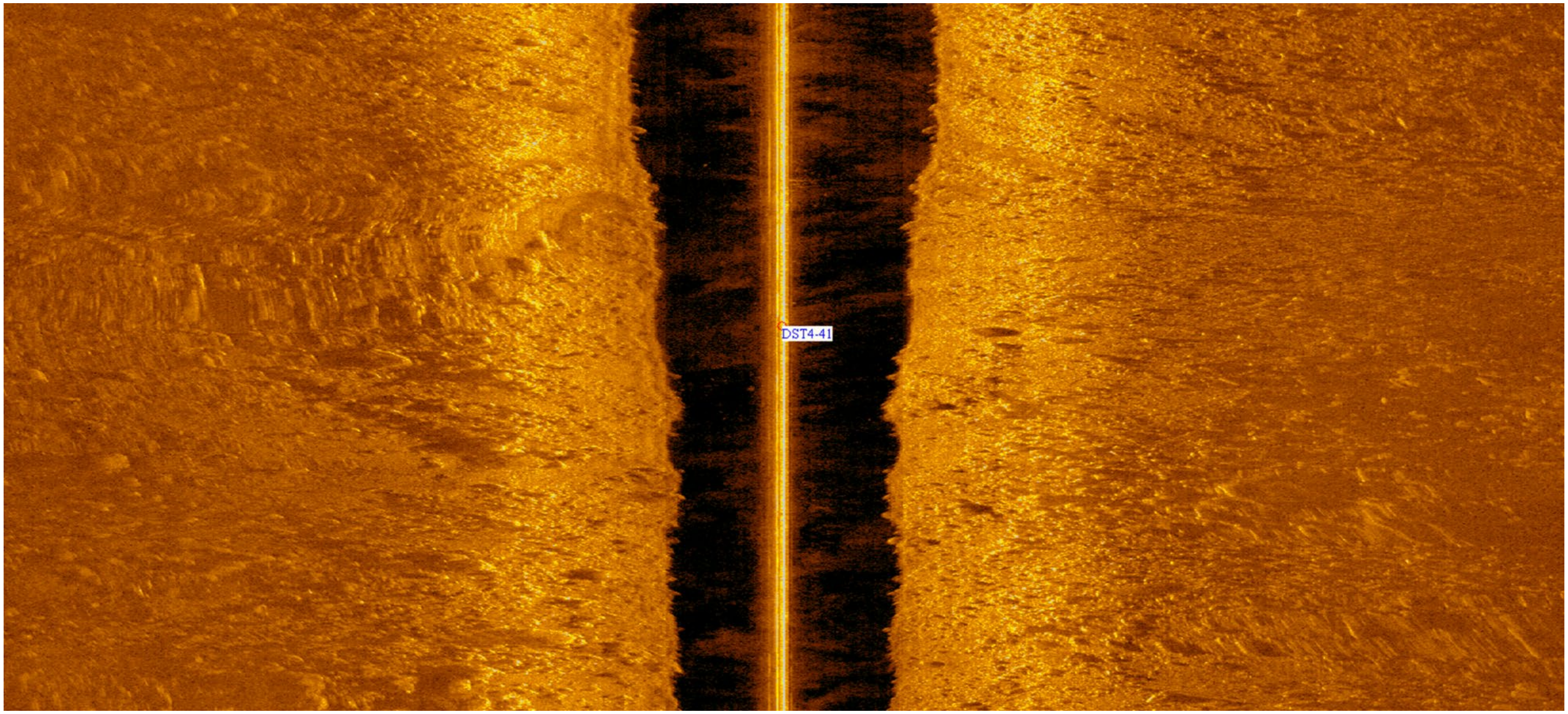
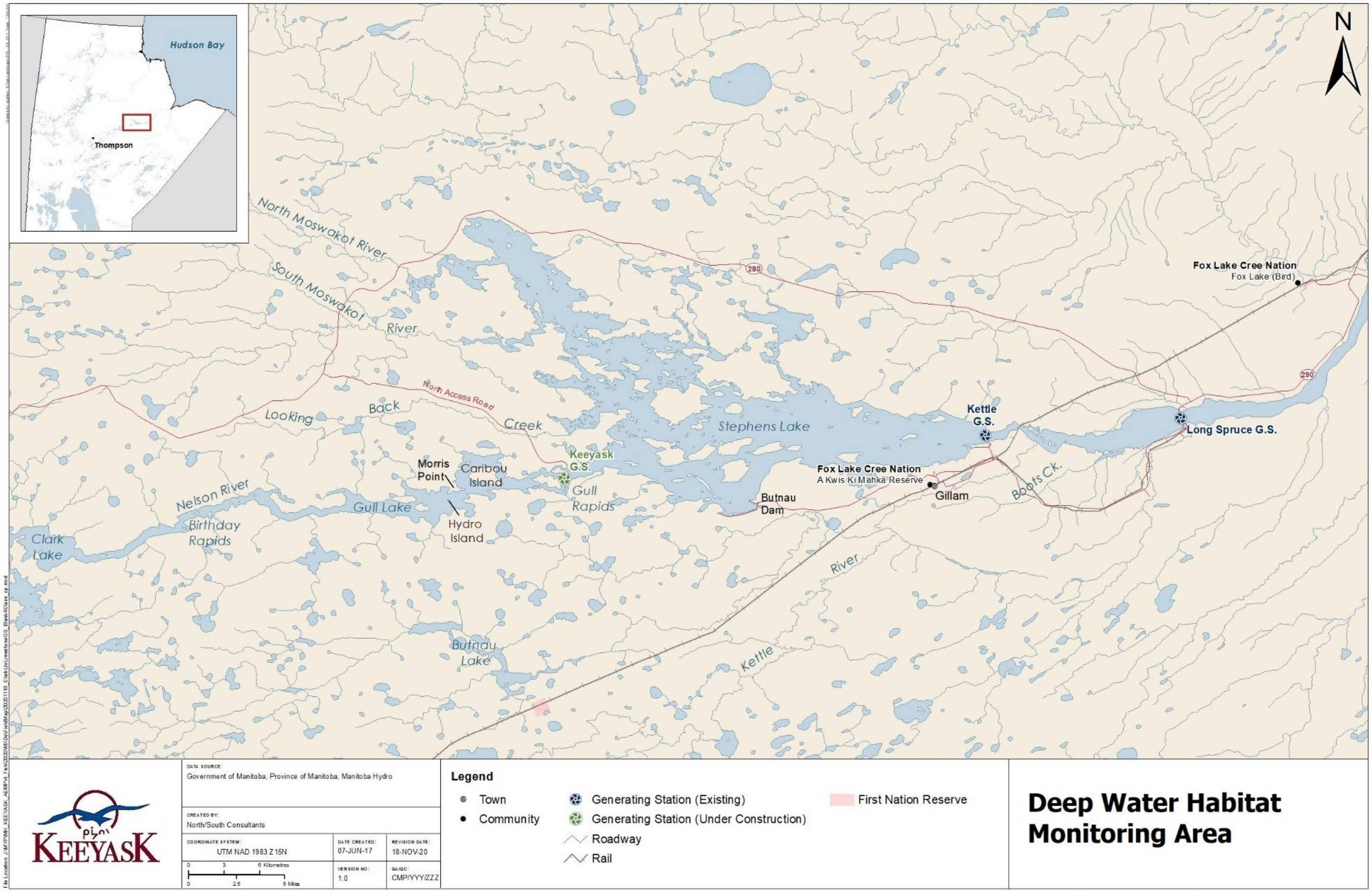
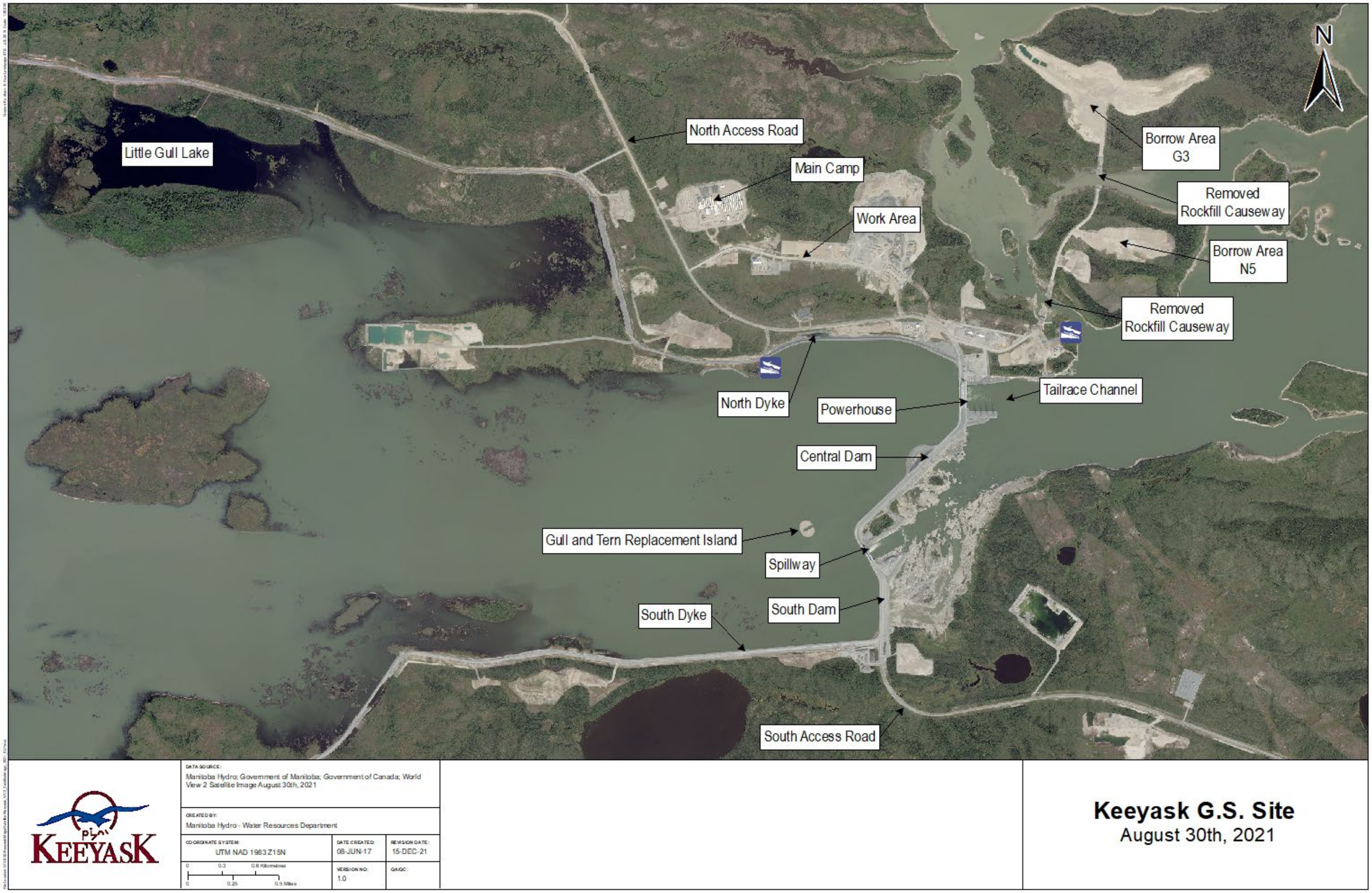


Figure 5: Detailed high-resolution sidescan 'waterfall' image showing predominantly boulder and cobble substrate at site DST4-41 in the upstream portion of Stephens Lake, 2021.

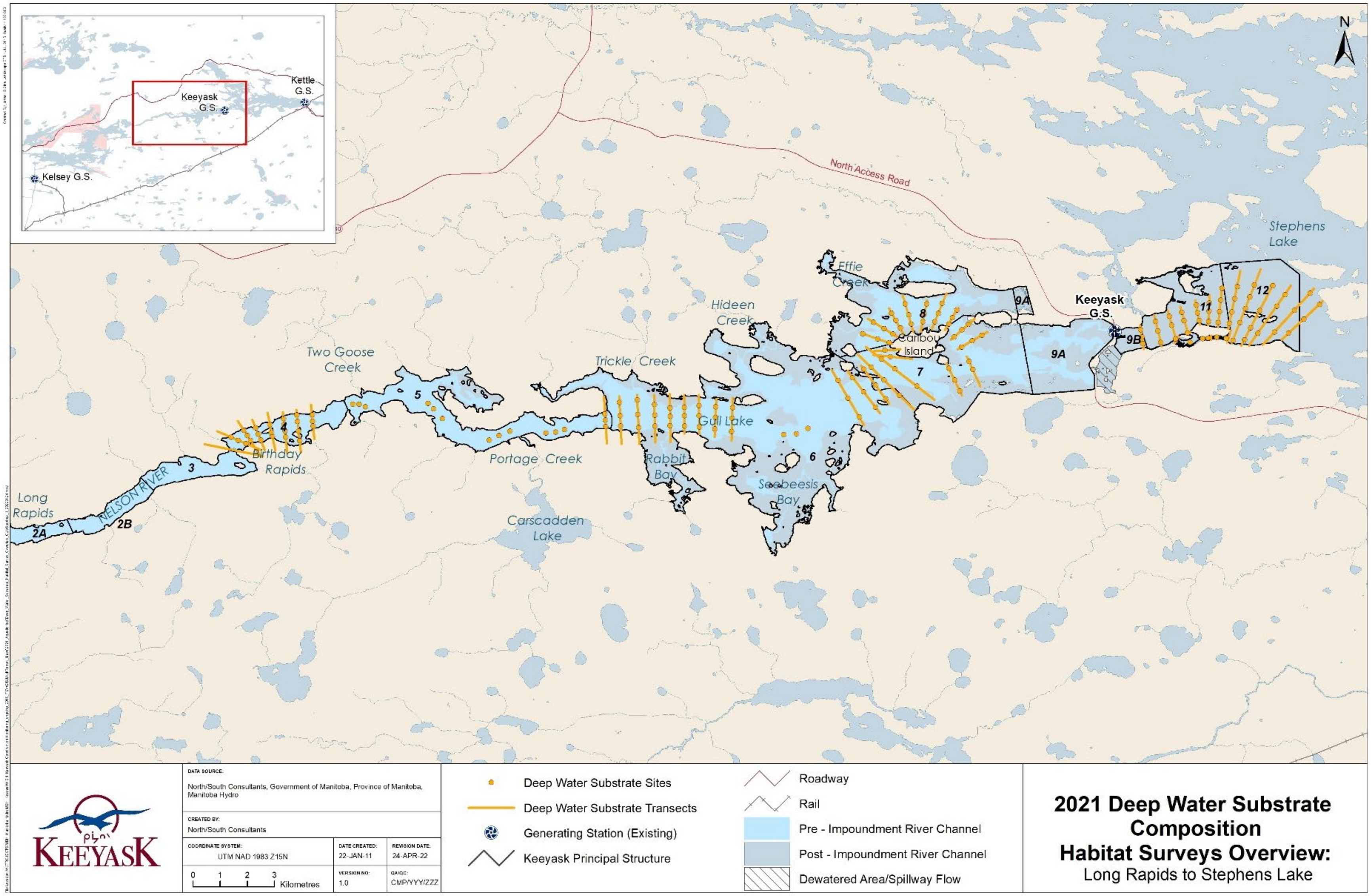
MAPS



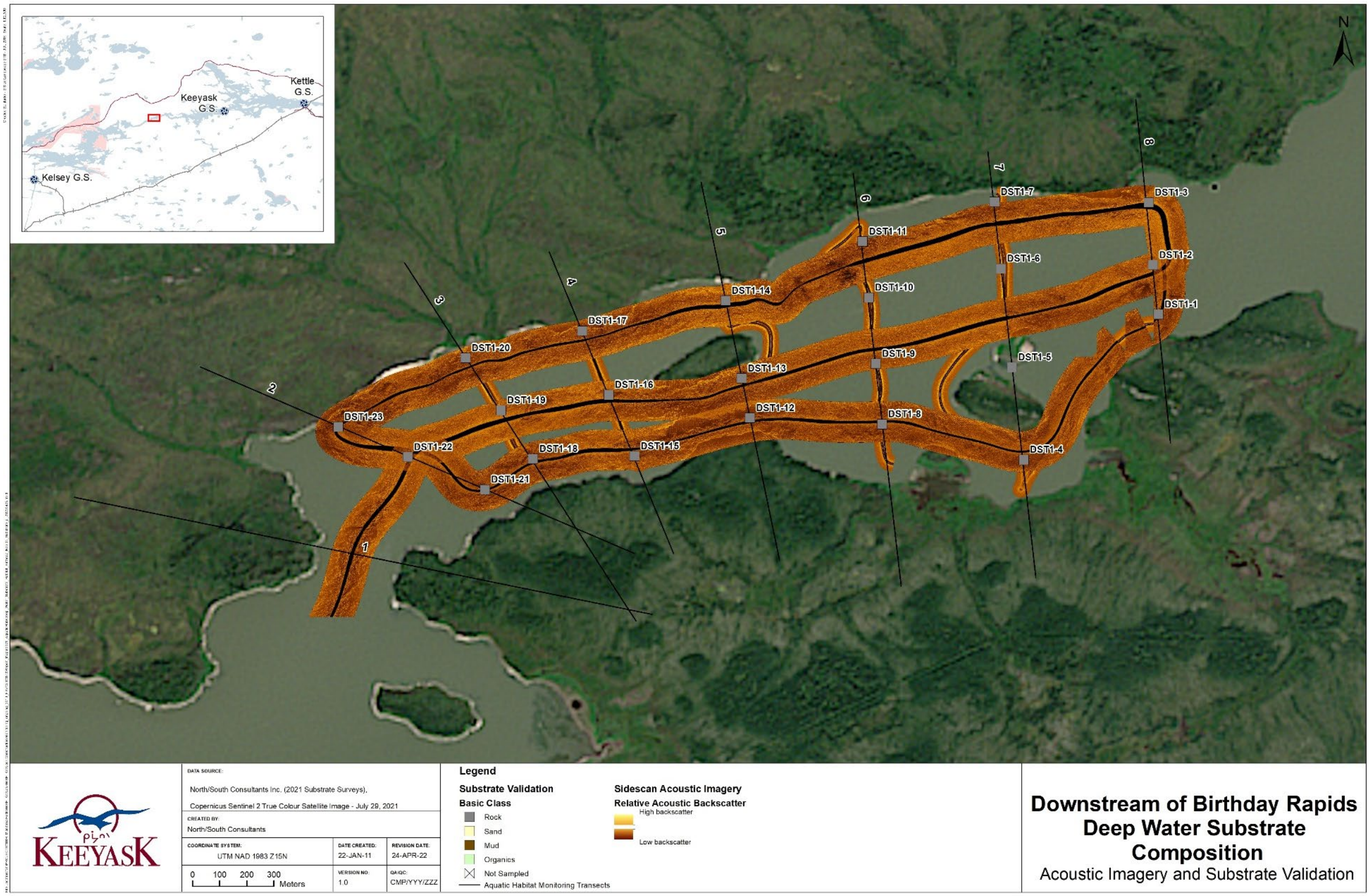
Map 1: Map of the Keeyask Study Area showing the Upper Split Lake Area, the Nelson River from Clark Lake to the Keeyask GS (referred to herein as the Keeyask reservoir), and Stephens Lake.



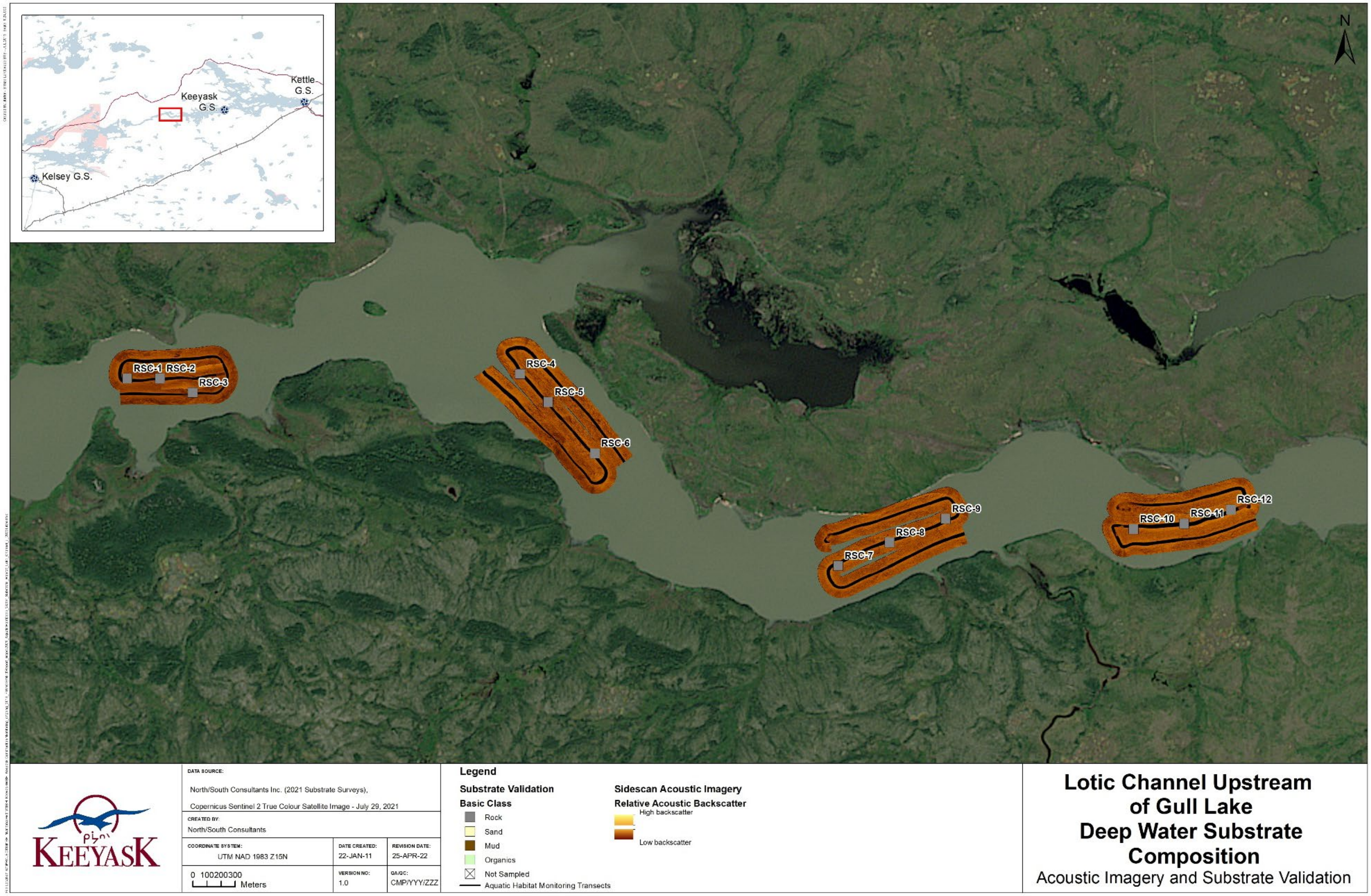
Map 2: Map illustrating instream structures at the Keeyask Generating Station site after reservoir flooding, August 2021.



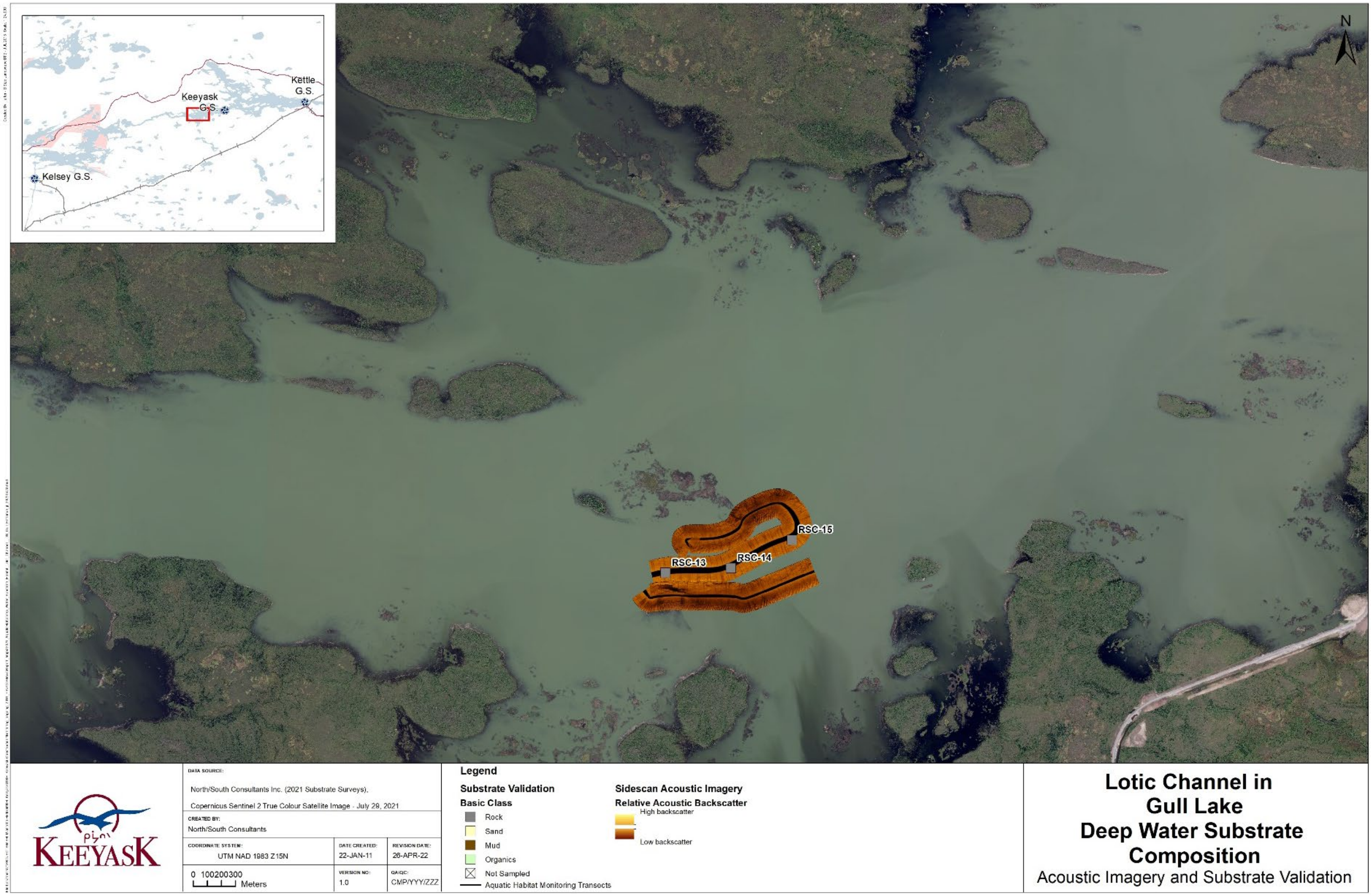
Map 3: **Map illustrating the locations of the pre-selected deep water substrate composition sampling sites and transects for the Keeyask study area (aquatic habitat reach boundaries indicated in black outline).**



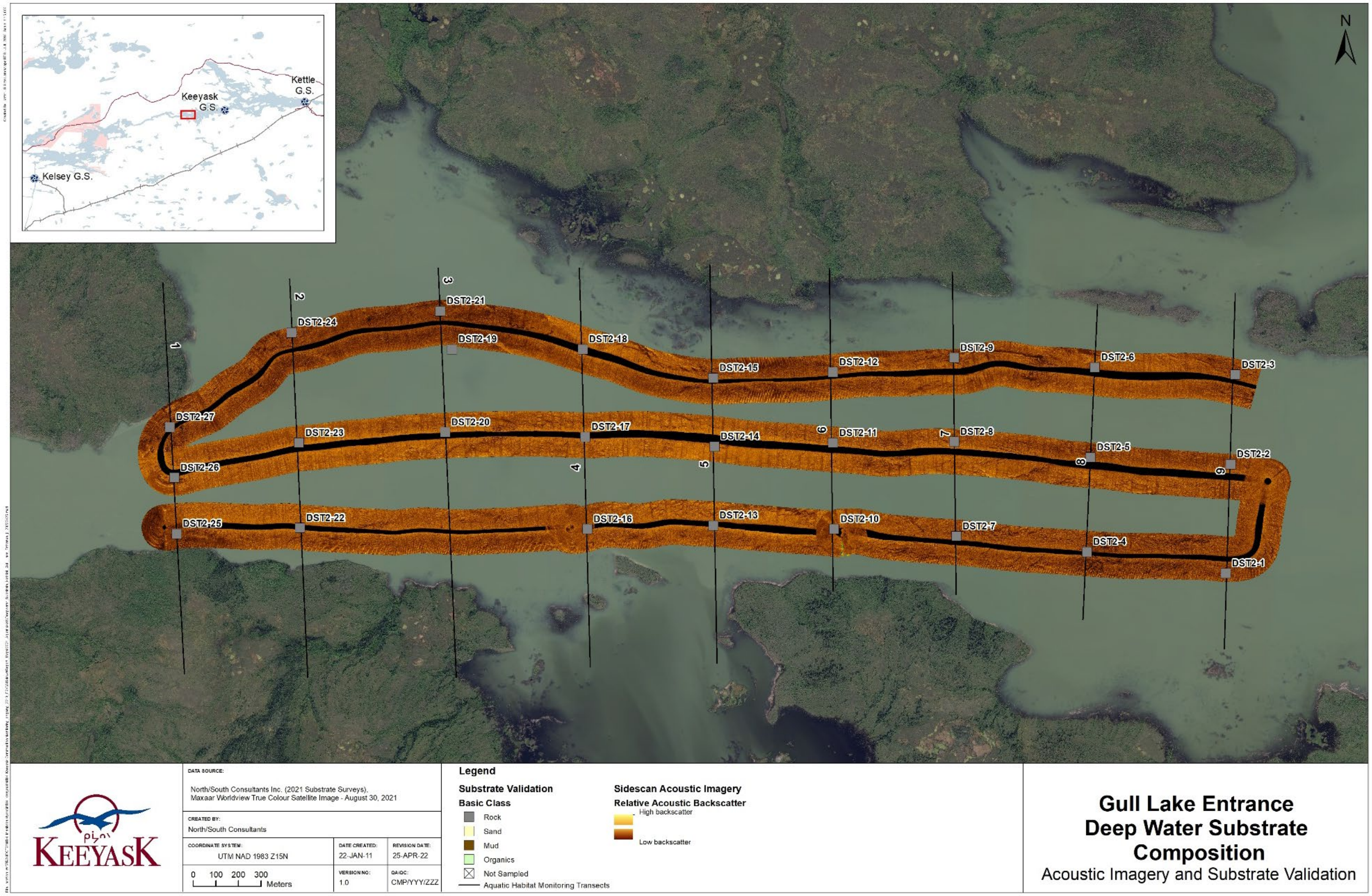
Map 4: **Map illustrating the results of substrate composition sampling sites and acoustic imaging for the area of the Keeyask reservoir downstream of Birthday Rapids, 2021.**



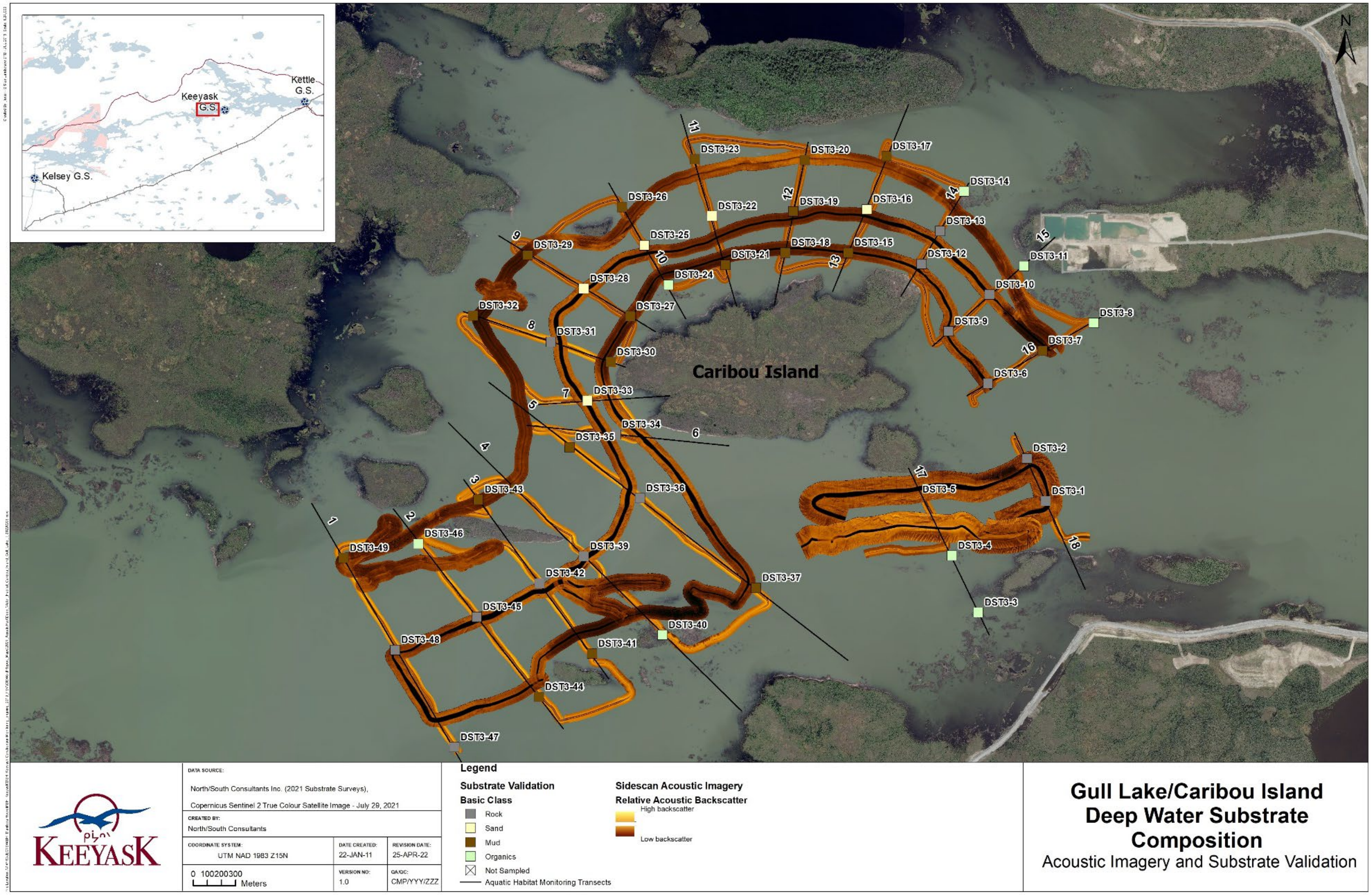
Map 5: **Map illustrating the results of substrate composition sampling sites and acoustic imaging for the area of the Keeyask reservoir between Birthday Rapids and the entrance to Gull Lake, 2021.**



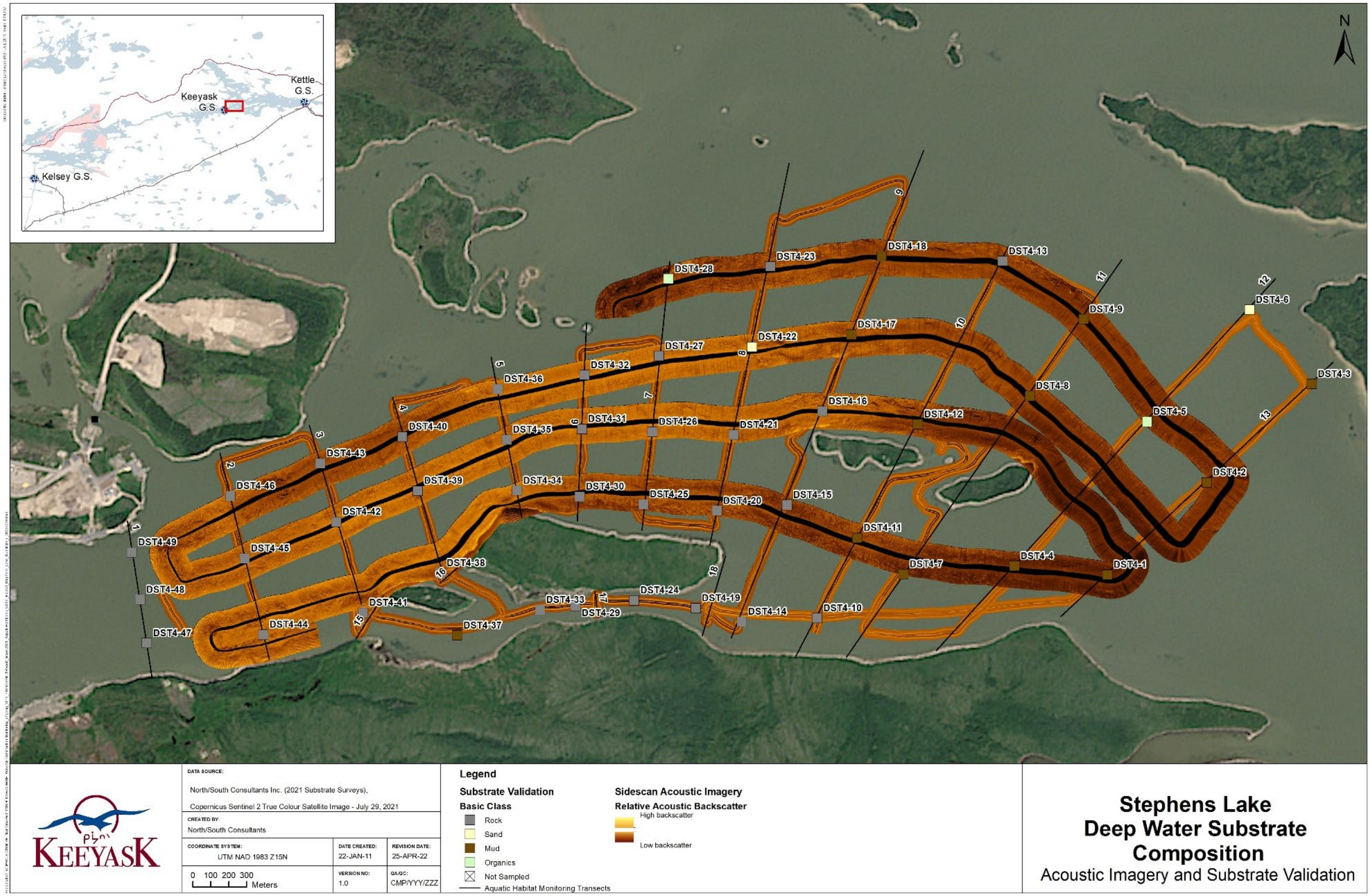
Map 6: **Map illustrating the results of substrate composition sampling sites and acoustic imaging for the area of the Keeyask reservoir in the lotic channel downstream of the entrance to Gull Lake, 2021.**



Map 7: **Map illustrating the results of substrate composition sampling sites and acoustic imaging for the area of the Keeyask reservoir downstream of the entrance to Gull Lake, 2021.**



Map 8: **Map illustrating the results of substrate composition sampling sites and acoustic imaging for the area of the Keeyask reservoir surrounding Caribou Island, 2021.**



Map 9: **Map illustrating the results of substrate composition sampling sites and acoustic imaging for the upstream portion of Stephens Lake, 2021.**

PHOTOS

Photo 1: Substrate collected at site DST3-3 in the area of the Keeyask reservoir surrounding Caribou Island showing organic matter.

Photo 2: Substrate collected at site DST3-33 in the area of the Keeyask reservoir surrounding Caribou Island showing sand.