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# Mary River Project Lake Sedimentation Monitoring: 2019 to 2020

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# Mary River Project Lake Sedimentation Monitoring: 2019 to 2020

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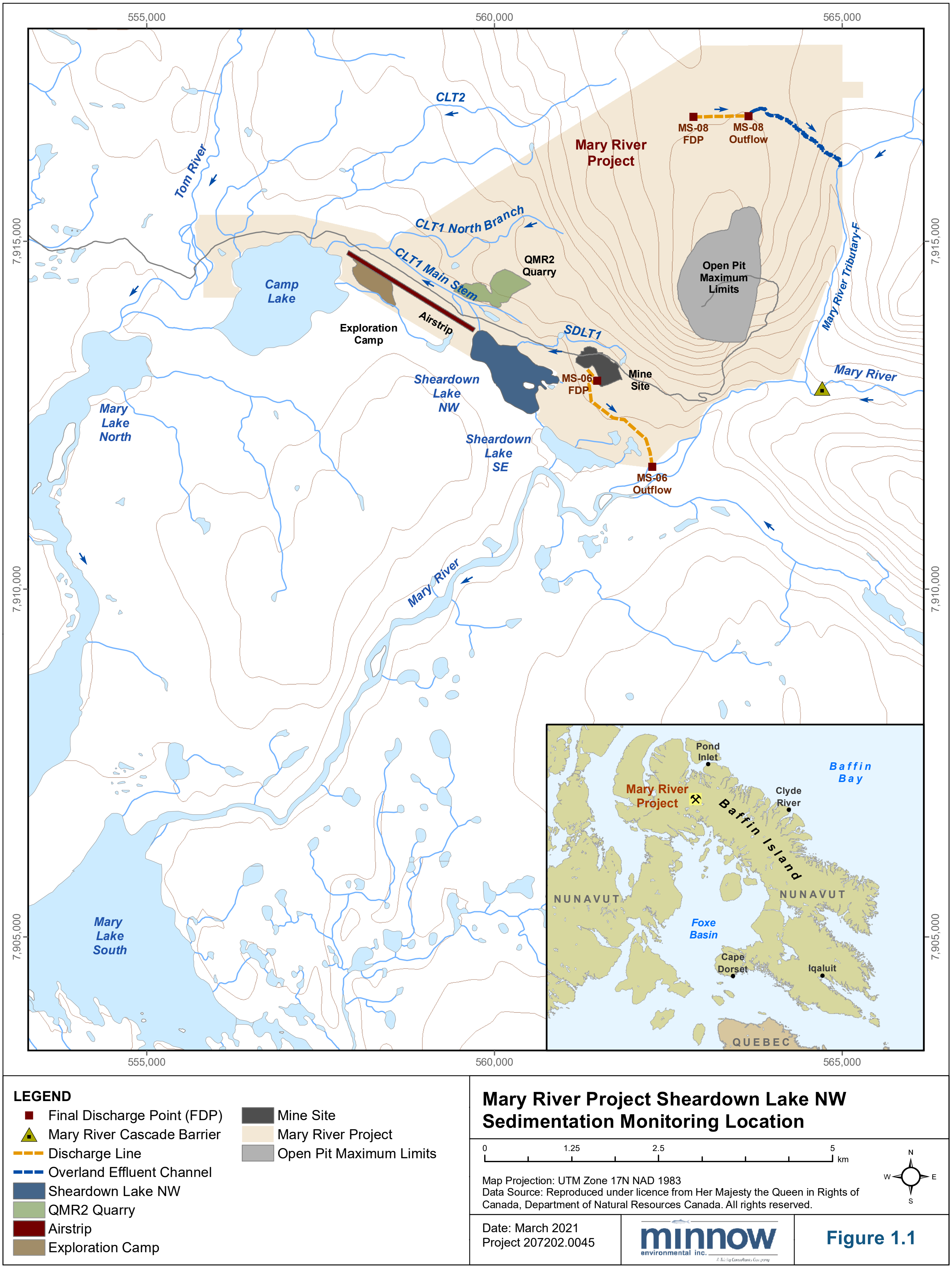
# 1 INTRODUCTION

The Mary River Project (the Project), owned and operated by Baffinland Iron Mines Corporation (Baffinland), is a high-grade iron ore mining operation located in the Qikiqtani Region of northern Baffin Island, Nunavut (Figure 1.1). Commercial open pit mining, including pit bench development, ore haulage, and ore stockpiling, as well as the crushing and screening of high-grade iron ore, commenced at the Project Mine Site in 2015. The Project has the potential to result in increased sedimentation in mine area waterbodies from fugitive dust deposition and surface runoff/erosion from the mine site, as well as from increased biological productivity (e.g., eutrophication due to treated sewage discharge). In aquatic environments, these deposits may lead to physical habitat alteration (e.g., changes in substrate composition) and/or chemical alteration (e.g., changes in metal, nutrient, and/or organic content concentrations) that, in turn, could alter biotic assemblages and lead to adverse ecological effects (e.g., physical smothering of organisms residing in existing substrate, direct response of organisms to changes in substrate chemistry).

To better understand rates of sediment deposition associated with the Project and the potential implications of this sediment deposition on aquatic biota, Lake Sedimentation Monitoring was included as a special investigation component of the mine Aquatic Effects Monitoring Plan (AEMP; Baffinland 2015; NSC 2014a). The primary issue of concern regarding greater sedimentation in lakes related to the Project is the potential effects to arctic charr (*Salvelinus alpinus*) populations, which can possibly be affected by:

- Changes in benthic invertebrate community structure and/or density due to habitat alteration that, in turn, alter the arctic charr food base;
- Loss of arctic charr spawning habitat resulting from accumulation of fine material on, and/or greater embeddedness of, substrate used by arctic charr for spawning; and,
- Accumulation of fine material on substrate used by arctic charr for spawning that, in turn, could limit the amount of oxygen available in arctic charr spawning beds during the overwinter incubation period resulting in reduced egg hatching success and/or reduced larvae survival following hatch (Berry et al. 2003).

The Lake Sedimentation Monitoring study is a year-round sampling program that was designed to track sedimentation rate (i.e., total dry weight of deposited sediment) at Sheardown Lake NW separately over ice-cover and open-water periods (Baffinland 2015; NSC 2014a,b, 2015; Minnow 2016, 2017, 2018, 2019, 2020). Sheardown Lake NW is expected to receive the highest amounts of sediment inputs through dust deposits and site runoff compared to other waterbodies near the Project, and therefore this lake has served as the focus for the monitoring of




## Mary River Project Sheardown Lake NW Sedimentation Monitoring Location

Map Projection: UTM Zone 17N NAD 1983
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**Figure 1.1**

Document Path: S:\Projects\197202\197202.0032 - Baffinland 2019 CREMP and EEM SD\4 - GIS\Lake Sedimentation Report\19-32 Fig 1.1 Location.mxd lake sedimentation (Figure 1.1; NSC 2014b). Sedimentation monitoring was initiated at Sheardown Lake NW in 2013, with data collected from fall 2013 to fall 2014 serving as baseline for one full ice-cover period and one full open-water period. These baseline data, in turn, were intended to be used as the basis for the annual evaluation of potential effects of Project operations on lake sedimentation (Minnow 2016, 2017, 2018, 2019, 2020). This report presents the results of the 2019 to 2020 Lake Sedimentation Monitoring study, including the evaluation of potential Project-related influences on sedimentation at Sheardown Lake NW in the sixth year following the commencement of commercial mine operation in 2015.

# 2 METHODS

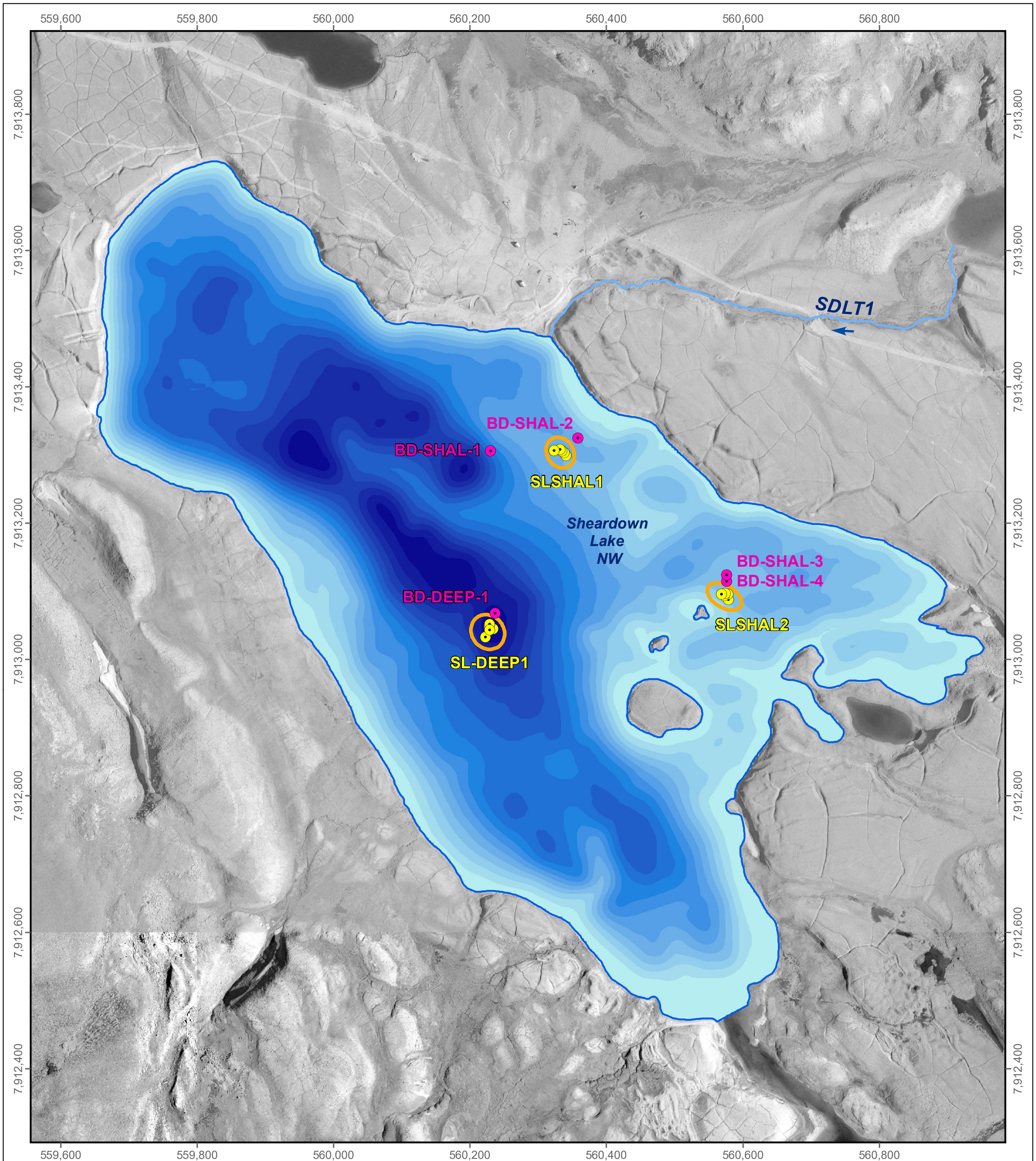
## 2.1 Overview

Sheardown Lake NW sedimentation studies have been used to estimate sedimentation rate and sediment accumulation over ice-cover and open-water periods in association with the Project (Baffinland 2015; NSC 2014a,b, 2015; Minnow 2016, 2017, 2018, 2019, 2020). The monitoring of sedimentation rate ($mg/cm^{-2} \cdot day^{-1}$) has been conducted using consistent monitoring station locations, sampling equipment, and approach since 2013 (Minnow 2020). Under the original study design, the methods specified did not provide sufficient sample volume to derive reliable estimates of sediment accumulation (i.e., deposit thickness) at Sheardown Lake NW. *In lieu* of sufficient sample volumes to determine sedimentation accumulation, dry bulk density (DBD) data from similar sedimentation studies conducted at Canadian Shield lakes in northern Ontario (Minnow Environmental Inc. unpublished data) or from a tributary to Sheardown Lake (referred to as SDLT1) were used to estimate the amount of sediment accumulation at Sheardown Lake NW in studies conducted prior to 2018 (Minnow 2016, 2017, 2018). Beginning with the 2017 to 2018 study, the Sheardown Lake NW sedimentation study design was modified to include methods for direct collection of DBD information from deposited sediment as the basis for allowing improved estimates of sediment accumulation (Minnow 2019, 2020). The methodology provided below reflects the updated study design for station locations, field and laboratory methods to evaluate sedimentation rate and sediment accumulation, and data analysis.

## 2.2 Station Locations

Sedimentation for the 2019 to 2020 study was monitored at the same three stations established at Sheardown Lake NW in 2013 (Figure 2.1; Table 2.1). The initial selection of station locations in 2013 accounted for dominant benthic habitat types present in the lake as well as habitat considered important for supporting the resident arctic charr population. These considerations resulted in the establishment of Shallow Depositional, Shallow Hard-Bottom, and Deep Profundal stations for Sheardown Lake NW sedimentation monitoring based on the following rationale:

1. Shallow Depositional Station (SHAL1): Silt-loam represents the dominant substrate type in Sheardown Lake NW, and therefore increased sedimentation on habitat characterized by this substrate has the greatest potential to affect overall lake benthic invertebrate density and/or community structure. In turn, benthic invertebrate community changes in habitat of this type have a high potential to affect the arctic charr population of Sheardown Lake. Silt substrate in the lake littoral zone was targeted for placement of this station to represent a potentially high sediment deposition habitat. Because this station is located near the outlet from SDLT1, information acquired from this station also serves to




**LEGEND**

- Dry Bulk Density Replicate Site
- Sedimentation Rate Replicate Site
- Sedimentation Monitoring Station

**Bathymetry (m)**

0- 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16 - 18
18 - 20
20 - 22
22 - 24
24 - 26
26 - 28
28 - 30

## Sheardown Lake NW Lake Sedimentation Monitoring Locations, 2019 to 2020

0 125 250 500 Meters

N W E S

Map Projection: UTM Zone 17N NAD 1983
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**Figure 2.1**

Document Path: S:\Projects\197202\197202.0032 - Baffinland 2019 CREMP and EEM SD\4 - GIS\Lake Sedimentation Report\19-32 Fig 2.1 Sheardown Lake Bathymetry.mxd

**Table 2.1: Sedimentation Rate and Dry Bulk Density Trap Replicate Station Coordinates, Habitat Information, and Deployment and Retrieval Information, Sheardown Lake NW Sedimentation Monitoring Study, 2019 to 2020**

| Station | Station Replicate | Location (UTM; Zone 17W) | | Station Depth (m) | Substrate | Ice - Cover Period (2019 to 2020) | | | Open-Water Period (2020) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Easting | Northing | | | Date Deployed | Date Retrieved | Set Duration (days) | Date Deployed | Date Retrieved | Set Duration (days) |
| Shallow 1 (SL SHAL1) | SL-SHAL-1A | 560341 | 7913299 | 10.2 | silt | 10-Sep-19 | 18-Jul-20 | 312 | 18-Jul-20 | 4-Sep-20 | 48 |
| | SL-SHAL-1B | 560338 | 7913303 | 10.0 | silt | 10-Sep-19 | 18-Jul-20 | 312 | 18-Jul-20 | 4-Sep-20 | 48 |
| | SL-SHAL-1C | 560335 | 7913306 | 9.6 | silt | 10-Sep-19 | 19-Jul-20 | 313 | 19-Jul-20 | 4-Sep-20 | 47 |
| | SL-SHAL-1D | 560332 | 7913308 | 10.6 | silt | 10-Sep-19 | 16-Jul-20 | 310 | 16-Jul-20 | 4-Sep-20 | 50 |
| | SL-SHAL-1E | 560323 | 7913307 | 10.3 | silt | 10-Sep-19 | 18-Jul-20 | 312 | 18-Jul-20 | 4-Sep-20 | 48 |
| Shallow 2 (SL SHAL2) | SL-SHAL-2A | 560579 | 7913088 | 6.8 | cobble | 9-Sep-19 | 18-Jul-20 | 313 | 18-Jul-20 | 5-Sep-20 | 49 |
| | SL-SHAL-2B | 560578 | 7913096 | 6.7 | cobble | 10-Sep-19 | 16-Jul-20 | 310 | 16-Jul-20 | 5-Sep-20 | 51 |
| | SL-SHAL-2C | 560573 | 7913094 | 6.5 | cobble | 9-Sep-19 | 16-Jul-20 | 311 | 16-Jul-20 | 5-Sep-20 | 51 |
| | SL-SHAL-2D | 560574 | 7913097 | 6.9 | cobble | 10-Sep-19 | 16-Jul-20 | 310 | 16-Jul-20 | 5-Sep-20 | 51 |
| | SL-SHAL-2E | 560569 | 7913096 | 6.9 | cobble | 10-Sep-19 | 16-Jul-20 | 310 | 16-Jul-20 | 5-Sep-20 | 51 |
| Deep 1 (SL DEEP1) | SL-DEEP-1A | 560234 | 7913045 | 30.0 | silt | 11-Sep-19 | 14-Jul-20 | 307 | 14-Jul-20 | 5-Sep-20 | 53 |
| | SL-DEEP-1B | 560228 | 7913049 | 28.9 | silt | 11-Sep-19 | 14-Jul-20 | 307 | 14-Jul-20 | 4-Sep-20 | 52 |
| | SL-DEEP-1C | 560223 | 7913033 | 27.0 | silt | 11-Sep-19 | 14-Jul-20 | 307 | 14-Jul-20 | 4-Sep-20 | 52 |
| | SL-DEEP-1D | 560229 | 7913052 | 28.3 | silt | 11-Sep-19 | 18-Jul-20 | 311 | 18-Jul-20 | 4-Sep-20 | 48 |
| | SL-DEEP-1E | 560229 | 7913044 | 28.9 | silt | 11-Sep-19 | 14-Jul-20 | 307 | 14-Jul-20 | 4-Sep-20 | 52 |
| Dry Bulk Density | BD-SHAL-1 | 560230 | 7913306 | nc | silt | 10-Sep-19 | 18-Jul-20 | 312 | 18-Jul-20 | 4-Sep-20 | 48 |
| | BD-SHAL-2 | 560358 | 7913325 | nc | silt | 10-Sep-19 | 18-Jul-20 | 312 | 18-Jul-20 | 4-Sep-20 | 48 |
| | BD-SHAL-3 | 560576 | 7913115 | nc | silt | 9-Sep-19 | 18-Jul-20 | 313 | 18-Jul-20 | 4-Sep-20 | 48 |
| | BD-SHAL-4 | 560576 | 7913124 | nc | silt | 10-Sep-19 | 18-Jul-20 | 312 | 18-Jul-20 | 4-Sep-20 | 48 |
| | BD-DEEP-1 | 560237 | 7913068 | nc | silt | 11-Sep-19 | 18-Jul-20 | 311 | 18-Jul-20 | 4-Sep-20 | 48 |

Notes: "na" indicates not applicable (no sediment traps deployed). "nc" indicates data not collected. "nr" indicates sediment trap not retrieved.

2. evaluate the extent to which sediment releases from key lake tributaries affect sedimentation at Sheardown Lake NW.
3. Shallow Hard-Bottom Station (SHAL2): Increased sedimentation at hard-bottom areas could reduce the amount of habitat available to arctic charr for spawning and/or reduce arctic charr within-year egg hatch/reproductive success. Therefore, this station was established on coarse substrate (i.e., gravel, cobble) in the lake littoral zone at an area considered to provide suitable spawning habitat for arctic charr.
4. Deep Profundal Station (DEEP1): Because the profundal area is the ultimate depositional zone within lakes, the highest sediment deposition rate can be expected to occur at the deepest point within the main basin of a lake. This station was established on silt substrate within the profundal zone of the main lake basin (approximately 30 m deep) to provide an estimate of maximum sedimentation for Sheardown Lake NW.

## 2.3 Field and Laboratory Methods

### 2.3.1 Sedimentation Rate

Lake sedimentation rate was monitored at Sheardown Lake NW for the 2019 to 2020 ice-cover and 2020 open-water periods using sediment traps constructed of the same materials and dimensions as those employed since the initial study in 2013. Specifically, each sediment trap was constructed of three 50 cm long, 5 cm inside diameter polyvinyl chloride (PVC) pipes (i.e., 58.9 $cm^2$ surface area) sealed at the bottom and clamped together to create a single trap unit. The sediment trap was designed to provide an aspect ratio of approximately 10:1, which meets the ≥ 5:1 aspect ratio generally recommended for cylindrical sediment traps to effectively monitor sediment deposition (Mudroch and MacKnight 1994). Each sediment trap unit was secured to a float-anchor system designed to maintain the trap in an upright position on the lake bottom for the duration of each deployment period. Under this system, the mouth of the sediment trap unit was situated approximately 1.5 m above the substrate.

Sedimentation was assessed separately for applicable ice-cover and open-water periods at Sheardown Lake NW. The seasonal timing of the ice breakup and freeze-up period at Sheardown Lake NW generally corresponds to mid-July and mid-September, respectively. For the 2019 to 2020 ice-cover period, five sediment traps were deployed at each of the Sheardown Lake NW stations from September 9$^{th}$ to 11$^{th}$, 2019 (Table 2.1). Sediment traps deployed over the ice-cover period were individually fitted with a marker buoy and lowered to the bottom such that the marker buoy was submerged approximately 2 to 3 m below the water surface to attempt to avoid entrapment of the buoy by ice during winter. Sediment traps for the 2019 to 2020 ice-cover period were retrieved from July 14$^{th}$ to 18$^{th}$, 2020 (307- to 313-day duration; Table 2.1). Because marker buoys were submerged, a grappling tool was required to secure the marker buoy and retrieve the sediment trap at the time of collection. Open-water period sediment traps were deployed as sediment traps became available in July 2020, and were retrieved on September 4th and 5th, 2020 (47- to 53-day duration; Table 2.1). For the open-water period, traps were lowered to the lake floor on individual lines fitted with a surface marker buoy so that they could be seen from the lake surface. Supporting information collected at the time of deployment of each sediment trap included Global Positioning System (GPS) coordinates and water depth.

Sediment trap retrieval involved pulling the entire unit to the surface very slowly to prevent sediment re-suspension in, and/or sediment loss from, each sediment trap. The entire contents of the trap, including all water and deposited sediment, were transferred into a 20 L plastic container pre-labelled with station identification and collection date information. Ambient water was used to rinse all sediment from each sediment trap, applied as a pressurized spray when appropriate. Upon complete removal of all material within the sediment trap, the sediment traps were redeployed at approximately the same locations of retrieval. Following collection of all sediment from individual traps, the sample containers were sealed and stored upright in a dark location until submission to the analytical laboratory. The lake sedimentation samples were shipped to ALS Canada Ltd. (ALS; Waterloo, ON) for analysis of sediment total dry weight. At the laboratory, the sedimentation samples were filtered through a pre-weighed 0.70 µm glass fiber filter. The filter apparatus and container were rinsed three times to ensure complete removal of all sediment. The filter and residual sample material were dried at 105°C for two hours, allowed to cool for one hour, and then weighed to the nearest milligram using an appropriate electronic balance with draft shield. As in previous studies, low sample volumes were encountered for each sediment trap replicate, and each station, for the 2019 to 2020 ice-cover period and 2020 open-water period samples, precluding any additional analysis of the sedimentation material (e.g., sediment metal concentrations, DBD).

### 2.3.2 Sediment Accumulation (Dry Bulk Density)

Sediment DBD information, collected to allow estimation of the amount of sediment accumulation for separate ice-cover and open-water periods, was collected for the 2019 to 2020 ice-cover period and 2020 open-water period using sediment traps of differing dimensions to those used for the collection of sedimentation rate data. The DBD sediment traps were constructed of a single 75 cm long, 15.2 cm inside diameter acrylonitrile-butadiene-styrene (ABS) pipe (182 cm$^2$ surface area) that was capped at the bottom end.[1] Each DBD sediment trap was secured to a float-anchor system designed to maintain the trap in an upright position on the

[1] The resulting DBD sediment traps had an aspect ratio of 5:1, meeting the recommended aspect ratio for cylindrical sediment traps to effectively monitor sediment deposition (Mudroch and MacKnight 1994).

lake bottom for the duration of the deployment period. The mouth of the DBD sediment trap was designed to sit approximately 1.5 m above the substrate, mirroring the same distance above bottom that the mouth of sediment traps used to monitor sedimentation rate were situated.

Five DBD sediment traps were deployed in Sheardown Lake NW for the ice-cover period and the open-water period (Table 2.1; Figure 2.1). For the 2019 to 2020 ice-cover period, the DBD sediment traps were deployed from September 9$^{th}$ to 11$^{th}$, 2019 and retrieved on July 18$^{th}$, 2020 (311- to 313-day duration; Table 2.1). Similar to sediment traps deployed for sedimentation rate determination, DBD sediment traps deployed over the ice-cover period were individually fitted with a marker buoy that was submerged approximately 2 to 3 m below the water surface so as to avoid entrapment of the buoy by ice during winter, and required use of a grappling tool for trap retrieval. Open-water period DBD sediment traps were deployed and retrieved on July 18$^{th}$ and September 4$^{th}$, 2020, respectively (48-day duration; Table 2.1). For the open-water period, the DBD sediment traps were lowered to the lake floor on individual lines fitted with a surface marker buoy so that they could be seen from the lake surface. At the time of deployment, GPS coordinates were taken at each DBD sediment trap location.

The retrieval process involved pulling each DBD sediment trap to the surface very slowly to prevent sediment re-suspension in, and/or sediment loss from, each trap. The entire contents of the trap, including all water and deposited sediment, was transferred into a 4 L plastic container pre-labelled with the replicate identification code. The removal of residual material in each DBD sediment trap was accomplished using a plastic spatula and/or a pressurized stream of water. The DBD samples were transported to an on-site laboratory and left undisturbed for a period of approximately 48 hours to allow the sediment to settle. After 48 hours, the overlying water was siphoned and/or pipetted from the sediment and the sediment was then transferred into a 50 mL glass collection jar. To ensure sufficient sample volume for DBD analysis, sediment was composited to create a single sample from the two replicate DBD sediment traps at each shallow station. Sufficient sample volume required for DBD analysis was acquired from the single replicate DBD sediment trap deployed at the deep station (BD-DEEP-1) during each sampling event. Following collection of all sediment, the sample containers were sealed and stored cool in an upright position until submission to the Saskatchewan Research Council (SRC; Saskatoon, SK). At SRC, the analysis of DBD was conducted using the pycnometer method.

## 2.4 Data Analysis

Sedimentation (deposition) rate was calculated for each replicate sediment trap using the equation (Kemp et al. 1974):

$$Sedimentation\ rate\ (mg/cm^{-2}day^{-1}) = \frac{dry\ weight\ (mg)}{total\ area\ (cm^{2})} \div deployment\ time\ period\ (day)$$

The sedimentation rate information was evaluated statistically as follows: 1) spatial comparisons among the three stations for separate ice-cover and open-water periods; 2) comparisons between the ice-cover and open-water periods at each station; and, 3) temporal comparisons at each station among years of mine operation and baseline separately for ice-cover and open-water periods. For the statistical analysis, raw data were assessed for normality and homogeneity of variance and log-transformed as necessary to meet test assumptions prior to conducting Student's t-tests, Analysis-of-Variance (ANOVA), and *post hoc* tests, where appropriate. In instances where normality could not be achieved through data transformation, non-parametric Mann-Whitney U-test statistics were used for pair-wise comparisons, and Kruskal-Wallis H-tests were used for multiple group (i.e., station or year) comparisons using rank transformed data. Similarly, in instances in which normal data exhibited unequal variance despite log transformation, Student's t-tests assuming unequal variance were used for pair-wise comparisons. For multiple station or year comparisons, Tukey's Honestly Significant Difference (HSD) *post hoc* tests were conducted for pair-wise comparisons. All statistical comparisons were conducted using R programming (R Foundation for Statistical Computing, Vienna, Austria).

Estimation of the uncompacted thickness (mm) of sediment accumulation was calculated separately for each of the ice-cover and open-water periods using the equation:

$$Accumulation\ thickness\ (mm/period^{-1}) = \frac{Sedimentation\ rate\ (mg/mm^{-2}period^{-1})}{Dry\ bulk\ density\ (mg/mm^{-3})}$$

Sedimentation DBD results were used to separately estimate sediment accumulation at Sheardown Lake NW shallow and deep stations for each of the 2019 to 2020 ice-cover and 2020 open-water periods. The sediment accumulation information was evaluated statistically between littoral and profundal habitat separately for the ice-cover and open-water periods, and between the ice-cover and open-water periods separately for each habitat type, using the same statistical methods described above that were used for comparing sedimentation rates.

Baffinland has recently proposed sediment accumulation thresholds to guide management response decisions as part of a Trigger, Action, Response Plan (TARP) under an upcoming, currently draft version, of the Mary River Project AEMP (Baffinland 2021). The proposed thresholds include a low action response threshold of 0.15 mm sediment deposition based on the upper range of natural sedimentation rate of 50 mg/cm$^2$/year converted to a sediment thickness using the DBD of deposited sediment at Sheardown Lake, a moderate action response threshold of 0.54 mm sediment deposition based on the sediment accumulation predicted in the Final Environmental Impact Statement (FEIS; Volume 7, Section 3.4.2.3) for the Project, and a high action response threshold of 1 mm sediment deposition based on the threshold presented in the FEIS for the Project. The latter was adopted from, and supported by, Morgan et al. (1983), Fudge and Bodaly (1984), and Berry et al. (2011) as the sediment accumulation thickness over the egg incubation period at which adverse effects on fish egg survival may occur. On Baffin Island, arctic charr spawning occurs in autumn (September and October) and although egg hatch occurs in early April, larval emergence generally does not occur until ice breakup in mid-July (Scott and Crossman 1998). Because this egg incubation and larval swim-up period mirrors the ice-cover period used in this study, accumulation thickness for the ice-cover period was used to evaluate the potential effects of depositing sediment on arctic charr egg survival at Sheardown Lake NW. Sediment accumulation from the 2019 to 2020 ice-cover period was compared to the low, moderate, and high action response thresholds proposed under in the Baffinland (2021) draft AEMP to identify potential effects to arctic charr egg incubation associated with sediment deposits at the Project and to guide management decisions in accordance with the TARP framework proposed therein.

# 3 RESULTS

## 3.1 Sedimentation Rates

### 3.1.1 2019 to 2020 Ice-Cover and Open-Water Periods

Within Sheardown Lake NW, sedimentation rates were lower at the littoral stations (i.e., SHAL1 and SHAL2) than at the profundal station (i.e., main basin Station DEEP1) for both the 2019 to 2020 ice-cover and 2020 open-water periods, although only the difference between SHAL2 and DEEP1 was significant (Figure 3.1; Appendix Tables A.1 to A.4). The occurrence of highest sedimentation rate at the deepest area of Sheardown Lake NW was consistent with normal lake deposition patterns (see Wetzel 2001) and all previous sedimentation studies (Minnow 2020; Figure 3.1). Sedimentation rates at the two shallow littoral stations (Stations SHAL1 and SHAL2) did not differ significantly from each other for the ice-cover period or open-water period (Appendix Table A.4), suggesting relatively uniform sedimentation between depositional habitat located close to the SDLT1 outlet (SHAL1) and habitat characterized by hard-bottomed substrate potentially used for arctic charr spawning (SHAL2).

Sedimentation rates were significantly higher during the open-water period compared to the ice-cover period at all Sheardown Lake NW sedimentation monitoring stations (Appendix Table A.5). Sedimentation rates ranged from 1.9 to 2.6 times greater during the open-water period than during the ice-cover period, potentially reflecting greater sediment input from surface runoff and/or naturally greater amounts of settling autochthonous material (e.g., settling/decay of plankton) generated during the open-water period. Nevertheless, on average, approximately 74% of the total sediment deposited at the Sheardown Lake NW stations from September 2019 to September 2020 occurred over the ice-cover period, reflecting the much longer time of ice-cover compared to open-water through a typical year in the arctic.

Annual sedimentation extrapolated from the 2019 to 2020 Sheardown Lake NW data indicated approximately 24.4 and 25.0 mg/cm$^2$/year of sediment deposition at the SHAL1 and SHAL2 littoral stations, respectively, and 28.2 mg/cm$^2$/year of sediment deposition at the DEEP1 profundal station. These annual rates were within the range of those observed at other Canadian arctic lakes (e.g., 7 to 50 mg/cm$^2$/year; Lockhart et al. 1998) and were much lower than at proglacial lakes in south-east Greenland (e.g., mean of 790 mg/cm$^2$/year; Hasholt et al. 2000). Therefore, the annual sedimentation rate at Sheardown Lake NW over the study period was within a range that is typical for Canadian arctic lakes.

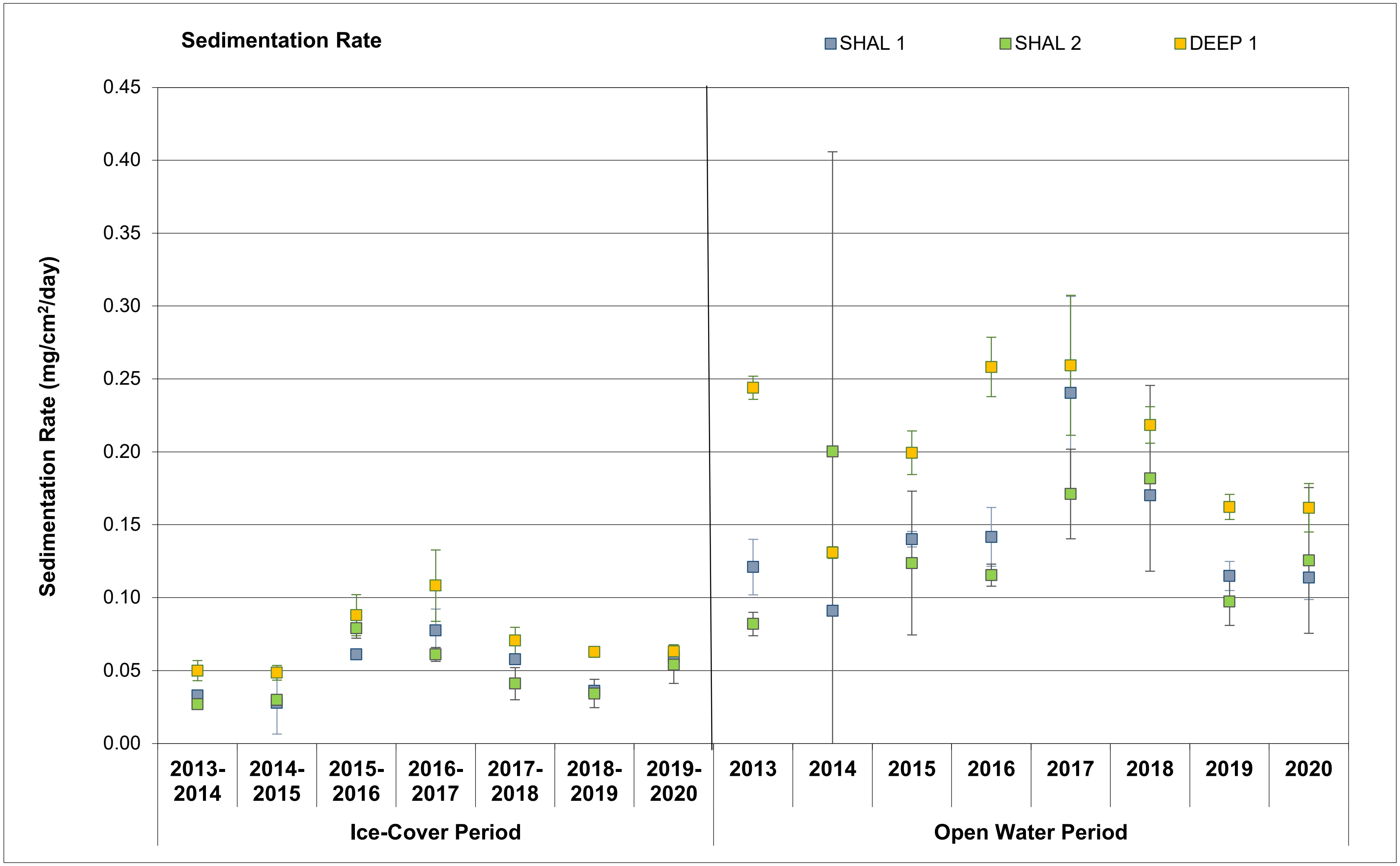


**Figure 3.1: Sedimentation Rates During Ice-Cover and Open-Water Periods at Sheardown Lake NW over Mine Baseline (2013 to 2014) and Operational (2015 to 2020) Phases, Sheardown Lake NW Sedimentation Monitoring Study**

### 3.1.2 Temporal Comparisons

Ice-cover period sedimentation rates at littoral stations SHAL1 and SHAL2 were significantly greater for the 2019 to 2020 ice-cover period than during the mine baseline (2013 to 2014), but were within the range the rates shown since 2014 and were not indicative of any upwards trend over time (Figure 3.1; Appendix Tables A.6 and A.7). Sedimentation rates at Station DEEP1 did not differ significantly between the 2019 to 2020 ice-cover period and baseline ice-cover period, with rates over the 2019 to 2020 ice-cover period at this station within the lower range of those observed since 2014 (Figure 3.1; Appendix Table A.8).

Open-water period sedimentation rates at all littoral (SHAL1, SHAL2) and profundal (DEEP1) stations of Sheardown Lake NW in 2020 were within the range of baseline conditions shown in 2013 and 2014, which was in line with previous results at each respective station for years of mine operation from 2015 to 2019 (Figure 3.1).[2] Although higher sedimentation rates were indicated at Station SHAL1 in 2017 and 2018 compared to baseline, the average sedimentation rate shown in 2020 at this station was comparable to that shown in the baseline studies for the open-water period (Figure 3.1). Overall, sedimentation rates over the 2020 open-water period were within the natural range of baseline conditions at all Sheardown Lake NW stations.

Annual sedimentation rates at Sheardown Lake NW shallow littoral stations were higher for the 2019 to 2020 period (24.4 to 25.0 mg/cm$^2$/year) than total annual rates shown for 2013 to 2014 baseline monitoring (13.9 to 16.5 mg/cm$^2$/year; from NSC 2014a) and for 2014 to 2015 monitoring (15.2 to 15.5 mg/cm$^2$/year) conducted at the onset of commercial mine operations (Figure 3.2).[3] The annual sedimentation rate at profundal Station DEEP1 was lower for 2019 to 2020 (28.2 mg/cm$^2$/year) than in all previous years of mine operation beginning in 2015 (range from 29.1 to 45.0 mg/cm$^2$/year), indicating lower mine-related input of sediment to deeper portion of the lake more recently (Figure 3.2). Nevertheless, the annualized sedimentation rate at Station DEEP1 remained higher for 2019 to 2020 than during baseline (21.2 mg/cm$^2$/year) and near start-up of commercial mine operations (24.5 mg/cm$^2$/year; Figure 3.2). Overall, the temporal data indicated higher total annual sedimentation rates at all Sheardown Lake NW stations since commercial production commenced in 2015, but there was no indication of an increasing trend in annual sedimentation rates over time at any of the littoral or profundal monitoring stations within the lake.

[2] Temporal statistical analysis of open-water period sedimentation rates was not able to include 2013 baseline data as the replicate data for this year were not reported. The results of temporal statistical analysis for open-water periods from the 2014 baseline and 2015 to 2020 mine operational years are provided herein (Appendix Tables A.6 to A.8).

[3] Annual sedimentation data calculated as the sum of the September to July ice-cover period data and July to September open-water period data.

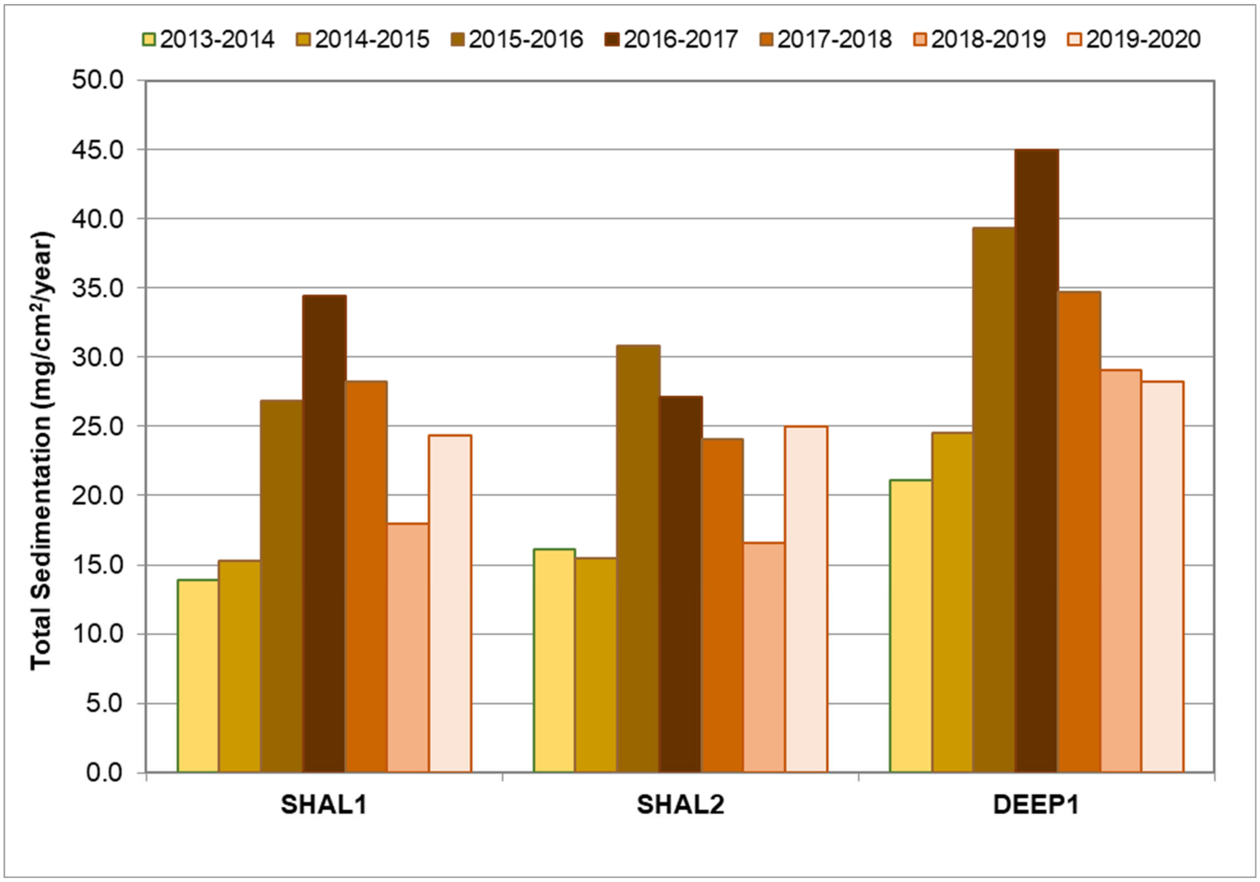


**Figure 3.2: Temporal Comparison of Total Annual Sedimentation Rates at Sheardown Lake NW, 2013 to 2020**

Note: Annual sedimentation data calculated as the sum of the September to July ice-cover period data and July to September open-water period data.

## 3.2 Sediment Accumulation Estimate

### 3.2.1 2019 to 2020 Ice-Cover and Open-Water Periods

The dry bulk density (DBD) of sedimentation material collected at Sheardown Lake NW at the end of the ice-cover and open-water periods in 2020 ranged from 2.22 to 3.03 g/cm$^3$, and was comparable to the DBD of samples collected in 2018 and 2019 (Appendix Table A.9).[4] Similar sediment DBD was indicated between the littoral and profundal stations for the 2019 to

[4] The DBD values used to derive sediment accumulation (thickness) previously were lower (i.e., 0.197 g/cm$^3$ based on data from sediment traps set at Canadian Shield lakes in Northern Ontario, and 1.284 g/cm$^3$ based on sediment collected in-stream and along the shoreline of a tributary to Sheardown Lake NW) than bulk density information for sedimentation material collected directly from Sheardown Lake in 2018, 2019, and 2020. The derivation of sediment accumulation estimates using site-specific DBD information provides more reliable estimates than those derived using the methods presented in past studies. For this reason, the sediment accumulation estimates provided from 2018 to 2019 (Minnow 2019, 2020) and herein supersede all estimates presented in previous reports.

2020 period, suggesting that the source of sedimentation material was similar between shallow and deep stations within the lake.

Sediment accumulation estimates derived for the combined 2019 to 2020 ice-cover and 2020 open-water periods ranged from 0.08 mm/year at littoral Station SHAL1 to 0.11 mm/year at profundal Station DEEP1 (Figure 3.3).[5] Within Sheardown Lake NW, less sediment accumulation occurred at the littoral stations (i.e., SHAL1 and SHAL2) than the profundal station (i.e., DEEP1) from 2019 to 2020, but only the difference over the open-water period was significant (Appendix Table A.11). The occurrence of highest sediment accumulation at the deepest area of the lake was consistent with normal lake deposition patterns (see Wetzel 2001). Total sediment accumulation at littoral and profundal stations was significantly higher over the ice-cover period than over the open-water period (Appendix Table A.13), reflecting the much longer duration of the ice-cover period (i.e., mean of 310 versus 50 days; Table 2.1). The sediment accumulation thicknesses estimated at all Sheardown Lake NW stations for the September 2019 to September 2020 period were comparable to annual sediment accumulation reported at profundal depths of an Alaskan arctic lake (0.16 ± 0.08 mm/year; Cornwell 1985), but were otherwise low compared to other arctic lakes. For instance, annual sediment accumulation ranged from 0.27 ± 0.12 to 1.2 ± 0.32 mm/year (average of 0.54 mm/year) among seven arctic lakes in western Greenland (Sobek et al. 2014), which was in line with annual sediment accumulation reported globally for lakes located north of approximately 65° latitude with maximum depths greater than 10 m (range from 0.3 to 1.5 mm/year; see Brothers et al. 2008).

The sediment accumulation thickness estimated for the 2019 to 2020 arctic charr egg incubation/larval pre-emergence period (i.e., approximately mid-September to mid-July; Scott and Crossman 1998) at Sheardown Lake NW varied from 0.061 ± 0.009 mm at the littoral silt-bottomed station (i.e., SHAL1) to 0.063 ± 0.007 mm at the littoral hard-bottomed station (i.e., SHAL2), the values of which between stations was not significant (Figure 3.3; Appendix Table A.11). Therefore, 2019 to 2020 sediment accumulation over the duration of the expected arctic charr egg incubation period was less than half of the (draft) TARP low action response threshold of 0.15 mm, and well below the 1 mm sediment thickness reported to influence egg hatch/larval pre-emergence success (Figure 3.3). Accordingly, no adverse effects to arctic charr reproductive success were likely at Sheardown Lake NW as a result of sedimentation/sediment accumulation over the 2019 to 2020 incubation period, and no further management response was triggered based on these results.

[5] Annual sedimentation accumulation estimates reflected the sum of the September to July ice-cover period data (2019 to 2020) and July to September (2020) open-water period data.

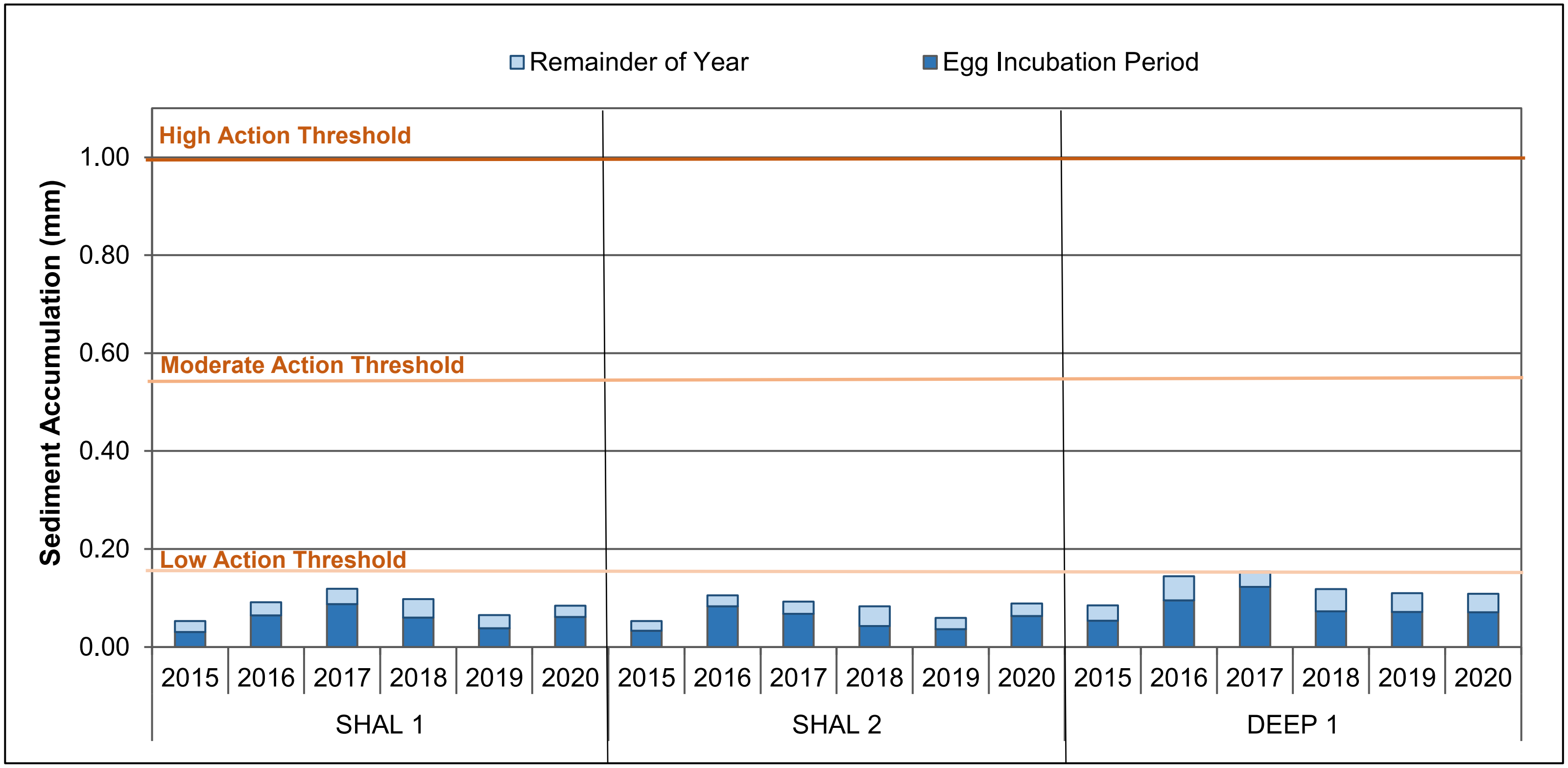


**Figure 3.3: Sediment Accumulation Estimates for Arctic Charr Egg Incubation Period and the Total Year, 2015 to 2020**

### 3.2.2 Temporal Comparisons

Sediment accumulation at Sheardown Lake NW over the ice-cover period was significantly higher for 2019 to 2020 than for 2018 to 2019 at the shallow littoral stations (SHAL1 and SHAL2), but no significant differences in sediment accumulation were indicated over the ice-cover period between years at the profundal station (DEEP1; Appendix Table A.13). In addition, no significant differences in sediment accumulation over the open-water period occurred between 2019 and 2020 for any of the shallow littoral stations or profundal stations (Appendix Table A.13). Sediment accumulation estimates have been derived using simultaneous collection of DBD and sedimentation rate data only since the 2018 to 2019 ice-cover period, and therefore evaluation of temporal changes was limited only to the past two years.

# 4 CONCLUSIONS

Lake Sedimentation Monitoring has been included as a special investigation component of the Project AEMP since 2013. The objective of this monitoring is to track sedimentation and evaluate the potential for adverse influences on resident arctic charr populations due to sedimentation at a representative lake (Sheardown Lake NW) within the immediate area of mine influence. The principal conclusions of the 2019 to 2020 lake sedimentation monitoring study are:

- Sheardown Lake NW sedimentation rates at shallow littoral stations over the ice-cover period were significantly higher from 2019 to 2020 than during baseline, but no increasing trend in sedimentation rate was indicated since commercial mine operations commenced in 2015. In addition, sedimentation rates at profundal areas during the 2019 to 2020 ice-cover period, and at littoral and profundal areas during the 2020 open-water period, did not differ significantly from rates during baseline. Overall, despite annual sedimentation rates higher for the 2019 to 2020 period than rates during the 2013 to 2014 baseline period, no increasing trend in sedimentation rates was indicated between 2015 and 2020 at Sheardown Lake NW.
- Annual sediment accumulation estimates for Sheardown Lake NW for the 2019 to 2020 combined ice-cover and open-water periods were within the lower range of annual estimates for arctic lakes of comparable size and/or depth. The sediment accumulation thickness estimated for the 2019 to 2020 arctic charr egg incubation/larval pre-emergence period at Sheardown Lake NW was below the draft TARP low action threshold of 0.15 mm, and approximately one tenth of the threshold level of 1 mm of sediment deposition purported to affect incubation success, for the arctic charr egg incubation period. Overall, these results indicated no effects on arctic charr reproductive success were likely at Sheardown Lake NW as the result of sedimentation rates/accumulation over the 2019 to 2020 egg incubation/larval pre-emergence period and, based on these results, no further management response was triggered for future studies.

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# APPENDIX A

# SUPPORTING SEDIMENTATION INFORMATION

**Table A.1: Sedimentation and Sediment Accumulation Data for the 2019 to 2020 Ice-Cover Period at Sheardown Lake NW**

| Station | Station Replicate | Original Set Location (UTM; Zone 17W) | | Station Depth (m) | Date Deployed | Date Retrieved | Set Duration (days) | Total Dry Weight (g) | Sedimentation Rate ($mg/cm^2/day$) | Sediment Accumulation (mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Easting | Northing | | | | | | | |
| Shallow 1 (SL SHAL1) | SL-SHAL-1A | 560341 | 7913299 | 10.2 | 10-Sep-19 | 18-Jul-20 | 312 | 1.061 | 0.058 | 0.059 |
| | SL-SHAL-1B | 560338 | 7913303 | 10.0 | 10-Sep-19 | 18-Jul-20 | 312 | 1.036 | 0.056 | 0.058 |
| | SL-SHAL-1C | 560335 | 7913306 | 9.6 | 10-Sep-19 | 19-Jul-20 | 313 | 1.047 | 0.057 | 0.059 |
| | SL-SHAL-1D | 560332 | 7913308 | 10.6 | 10-Sep-19 | 16-Jul-20 | 310 | 0.964 | 0.053 | 0.054 |
| | SL-SHAL-1E | 560323 | 7913307 | 10.3 | 10-Sep-19 | 18-Jul-20 | 312 | 1.357 | 0.074 | 0.076 |
| | | | | | | **Average** | **312** | **1.093** | **0.060** | **0.061** |
| | | | | | | **Standard Deviation** | **1.1** | **0.152** | **0.008** | **0.009** |
| Shallow 2 (SL SHAL2) | SL-SHAL-2A | 560579 | 7913088 | 6.8 | 9-Sep-19 | 18-Jul-20 | 313 | 0.915 | 0.050 | 0.053 |
| | SL-SHAL-2B | 560578 | 7913096 | 6.7 | 10-Sep-19 | 16-Jul-20 | 310 | 1.155 | 0.063 | 0.067 |
| | SL-SHAL-2C | 560573 | 7913094 | 6.5 | 9-Sep-19 | 16-Jul-20 | 311 | 1.231 | 0.067 | 0.072 |
| | SL-SHAL-2D | 560574 | 7913097 | 6.9 | 10-Sep-19 | 16-Jul-20 | 310 | 1.007 | 0.055 | 0.059 |
| | SL-SHAL-2E | 560569 | 7913096 | 6.9 | 10-Sep-19 | 16-Jul-20 | 310 | 1.101 | 0.060 | 0.064 |
| | | | | | | **Average** | **311** | **1.082** | **0.059** | **0.063** |
| | | | | | | **Standard Deviation** | **1.3** | **0.124** | **0.007** | **0.007** |
| Deep 1 (SL DEEP1) | SL-DEEP-1A | 560234 | 7913045 | 30.0 | 11-Sep-19 | 14-Jul-20 | 307 | 1.179 | 0.065 | 0.073 |
| | SL-DEEP-1B | 560228 | 7913049 | 28.9 | 11-Sep-19 | 14-Jul-20 | 307 | 1.102 | 0.061 | 0.068 |
| | SL-DEEP-1C | 560223 | 7913033 | 27.0 | 11-Sep-19 | 14-Jul-20 | 307 | 1.131 | 0.063 | 0.070 |
| | SL-DEEP-1D | 560229 | 7913052 | 28.3 | 11-Sep-19 | 18-Jul-20 | 311 | 1.277 | 0.070 | 0.079 |
| | SL-DEEP-1E | 560229 | 7913044 | 28.9 | 11-Sep-19 | 14-Jul-20 | 307 | 1.040 | 0.058 | 0.064 |
| | | | | | | **Average** | **308** | **1.146** | **0.063** | **0.071** |
| | | | | | | **Standard Deviation** | **1.8** | **0.089** | **0.005** | **0.006** |

**Table A.2: Sedimentation and Sediment Accumulation Data for the 2019 Open-Water Period at Sheardown Lake NW**

| Station | Station Replicate | Original Set Location (UTM; Zone 17W) | | Station Depth (m) | Date Deployed | Date Retrieved | Set Duration (days) | Total Dry Weight (g) | Sedimentation Rate ($mg/cm^2/day$) | Sediment Accumulation (mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Easting | Northing | | | | | | | |
| **Shallow 1 (SL SHAL1)** | SL-SHAL-1A | 560341 | 7913299 | 10.2 | 18-Jul-20 | 4-Sep-20 | 48 | 0.280 | 0.099 | 0.020 |
| | SL-SHAL-1B | 560338 | 7913303 | 10.0 | 18-Jul-20 | 4-Sep-20 | 48 | 0.312 | 0.110 | 0.022 |
| | SL-SHAL-1C | 560335 | 7913306 | 9.6 | 19-Jul-20 | 4-Sep-20 | 47 | 0.283 | 0.102 | 0.020 |
| | SL-SHAL-1D | 560332 | 7913308 | 10.6 | 16-Jul-20 | 4-Sep-20 | 50 | 0.399 | 0.135 | 0.029 |
| | SL-SHAL-1E | 560323 | 7913307 | 10.3 | 18-Jul-20 | 4-Sep-20 | 48 | 0.344 | 0.122 | 0.025 |
| | | | | | | **Average** | **48** | **0.324** | **0.114** | **0.023** |
| | | | | | | **Standard Deviation** | **1.1** | **0.049** | **0.015** | **0.004** |
| **Shallow 2 (SL SHAL2)** | SL-SHAL-2A | 560579 | 7913088 | 6.8 | 18-Jul-20 | 5-Sep-20 | 49 | 0.295 | 0.102 | 0.020 |
| | SL-SHAL-2B | 560578 | 7913096 | 6.7 | 16-Jul-20 | 5-Sep-20 | 51 | 0.253 | 0.084 | 0.017 |
| | SL-SHAL-2C | 560573 | 7913094 | 6.5 | 16-Jul-20 | 5-Sep-20 | 51 | 0.363 | 0.121 | 0.025 |
| | SL-SHAL-2D | 560574 | 7913097 | 6.9 | 16-Jul-20 | 5-Sep-20 | 51 | 0.327 | 0.109 | 0.023 |
| | SL-SHAL-2E | 560569 | 7913096 | 6.9 | 16-Jul-20 | 5-Sep-20 | 51 | 0.636 | 0.212 | 0.044 |
| | | | | | | **Average** | **51** | **0.375** | **0.125** | **0.026** |
| | | | | | | **Standard Deviation** | **0.9** | **0.152** | **0.050** | **0.010** |
| **Deep 1 (SL DEEP1)** | SL-DEEP-1A | 560234 | 7913045 | 30.0 | 14-Jul-20 | 5-Sep-20 | 53 | 0.535 | 0.171 | 0.041 |
| | SL-DEEP-1B | 560228 | 7913049 | 28.9 | 14-Jul-20 | 4-Sep-20 | 52 | 0.550 | 0.180 | 0.042 |
| | SL-DEEP-1C | 560223 | 7913033 | 27.0 | 14-Jul-20 | 4-Sep-20 | 52 | 0.486 | 0.159 | 0.037 |
| | SL-DEEP-1D | 560229 | 7913052 | 28.3 | 18-Jul-20 | 4-Sep-20 | 48 | 0.383 | 0.136 | 0.029 |
| | SL-DEEP-1E | 560229 | 7913044 | 28.9 | 14-Jul-20 | 4-Sep-20 | 52 | 0.500 | 0.163 | 0.038 |
| | | | | | | **Average** | **51** | **0.491** | **0.162** | **0.038** |
| | | | | | | **Standard Deviation** | **1.9** | **0.065** | **0.017** | **0.005** |

**Table A.3: Sedimentation (mg/cm$^{-2}$·day$^{-1}$) Summary Statistics for Sheardown Lake NW, Lake Sedimentation Monitoring Study, 2019 to 2020**

| Study Period | Station | Sample Size | Mean | Standard Deviation | Standard Error | Minimum | Median | Maximum |
|---|---|---|---|---|---|---|---|---|
| Ice-Cover 2019 to 2020 | SHAL 1 | 5 | 0.060 | 0.008 | 0.004 | 0.053 | 0.057 | 0.074 |
| | SHAL 2 | 5 | 0.059 | 0.007 | 0.003 | 0.050 | 0.060 | 0.067 |
| | DEEP1 | 5 | 0.063 | 0.005 | 0.002 | 0.058 | 0.063 | 0.070 |
| Open-Water 2020 | SHAL 1 | 5 | 0.114 | 0.015 | 0.007 | 0.099 | 0.110 | 0.135 |
| | SHAL 2 | 5 | 0.125 | 0.050 | 0.022 | 0.084 | 0.109 | 0.212 |
| | DEEP1 | 5 | 0.162 | 0.017 | 0.007 | 0.136 | 0.163 | 0.180 |

**Table A.4: Statistical Comparison of Sedimentation Rate among Sheardown Lake NW Stations for Ice-Cover and Open-Water Periods, Lake Sedimentation Monitoring Study, 2019 to 2020**

| Study Period | Overall 3-group Comparison | | | | Pair-wise comparisons | | | |
|---|---|---|---|---|---|---|---|---|
| | Statistical Test[a] | Transform-ation | Significant Difference Among Areas? | p-value | (I) Area | (J) Area | Significant Difference Between Areas? | p-value |
| Ice-Cover 2019 to 2020 | ANOVA | none | NO | 0.586 | SHAL1 | SHAL2 | NO | 0.995 |
| | | | | | SHAL1 | DEEP1 | NO | 0.673 |
| | | | | | SHAL2 | DEEP1 | NO | 0.615 |
| Open-Water 2020 | ANOVA | log10 | YES | 0.057 | SHAL1 | SHAL2 | NO | 0.928 |
| | | | | | SHAL1 | DEEP1 | YES | 0.065 |
| | | | | | SHAL2 | DEEP1 | NO | 0.122 |

Shading indicates significant difference between study areas based on ANOVA p-value less than 0.1.

[a] Statistical tests include Analysis of Variance (ANOVA) followed by post hoc Tukey's HSD tests or Kruskal-Wallis (K-W) multiple group test followed by Mann-Whitney (M-W) pair-wise tests.

**Table A.5: Statistical Comparison of Sedimentation ($mg/cm^2/day$) Between the 2019 to 2020 Ice-Cover and 2020 Open-Water Periods at Sheardown Lake NW**

| Station | Statistical Test Results | | | | Summary Statistics | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Statistical Test[a] | Transform-ation | Significant Difference Between Areas? | *p*-value | Period | N | Mean | Standard Deviation | Standard Error | Minimum | Median | Maximum |
| SHAL1 | tequal | log10 | YES | 0.001 | Ice-Cover 2019 to 2020 | 5 | 0.060 | 0.008 | 0.004 | 0.053 | 0.057 | 0.074 |
| | | | | | Open-Water 2020 | 5 | 0.114 | 0.015 | 0.007 | 0.099 | 0.110 | 0.135 |
| SHAL2 | tequal | log10 | YES | 0.003 | Ice-Cover 2019 to 2020 | 5 | 0.059 | 0.007 | 0.003 | 0.050 | 0.060 | 0.067 |
| | | | | | Open-Water 2020 | 5 | 0.125 | 0.050 | 0.022 | 0.084 | 0.109 | 0.212 |
| DEEP1 | tequal | log10 | YES | 0.001 | Ice-Cover 2019 to 2020 | 5 | 0.063 | 0.005 | 0.002 | 0.058 | 0.063 | 0.070 |
| | | | | | Open-Water 2020 | 5 | 0.162 | 0.017 | 0.007 | 0.136 | 0.163 | 0.180 |

Shading indicates significant difference between seasonal periods based on p-value less than 0.10.

[a] Statistical tests include t-test assuming equal variance (tequal), t-test assuming unequal variance (tunequal), or Mann-Whitney U-test (M-W).

**Table A.6: Statistical Comparison of Sedimentation Rates Between Mine Baseline (2013 to 2014) and Operational (2015 to 2020) Phases at Sheardown Lake NW Shallow Station 1 (SHAL1) during Ice-Cover and Open-Water Periods, Lake Sedimentation Monitoring Study, 2013 to 2020**

| Seasonal Period | Overall 6-group Comparison | | | | Pair-wise, *post-hoc* comparisons | | | |
|---|---|---|---|---|---|---|---|---|
| | Statistical Test[a] | Transform-ation | Significant Difference Among Areas? | p-value | Deployment Period | Mean Rate | Standard Deviation | Temporal Difference[b] |
| **Ice-Cover** | K-W | rank | YES | 0.004 | 2013 - 2014 | 0.033 | 0.002 | a |
| | | | | | 2014 - 2015 | 0.028 | 0.021 | a |
| | | | | | 2015 - 2016 | 0.061 | 0.003 | b |
| | | | | | 2016 - 2017 | 0.078 | 0.015 | b |
| | | | | | 2017 - 2018 | 0.058 | 0.000 | abc |
| | | | | | 2018 - 2019 | 0.036 | 0.003 | ac |
| | | | | | 2019 - 2020 | 0.060 | 0.008 | bc |
| **Open-Water** | K-W | rank | YES | 0.001 | 2014 | 0.091 | 0.003 | a |
| | | | | | 2015 | 0.140 | 0.005 | bc |
| | | | | | 2016 | 0.142 | 0.020 | bc |
| | | | | | 2017 | 0.240 | 0.066 | c |
| | | | | | 2018 | 0.170 | 0.000 | bc |
| | | | | | 2019 | 0.115 | 0.010 | ac |
| | | | | | 2020 | 0.114 | 0.015 | ac |

[a] Statistical tests include analysis of variance (ANOVA; followed by Tukey's Honestly Significant Difference post-hoc tests) and Kruskal Wallis H-test (K-W; followed by Mann-Whitney U-test pair-wise comparisons).

[b] Deployment periods denoted by the same letter do not differ significantly.

**Table A.7: Statistical Comparison of Sedimentation Rates Between Mine Baseline (2013 to 2014) and Operational (2015 to 2020) Phases at Sheardown Lake NW Shallow Station 2 (SHAL2) during Ice-Cover and Open-Water Periods, Lake Sedimentation Monitoring Study, 2013 to 2020**

| Seasonal Period | Overall 6-group Comparison | | | | Pair-wise, *post-hoc* comparisons | | | |
|---|---|---|---|---|---|---|---|---|
| | Statistical Test[a] | Transform-ation | Significant Difference Among Areas? | p-value | Deployment Period | Mean Rate | Standard Deviation | Temporal Difference[b] |
| **Ice-Cover** | ANOVA | none | YES | 0.001 | 2013 - 2014 | 0.027 | 0.001 | a |
| | | | | | 2014 - 2015 | 0.030 | 0.002 | a |
| | | | | | 2015 - 2016 | 0.079 | 0.007 | b |
| | | | | | 2016 - 2017 | 0.061 | 0.005 | c |
| | | | | | 2017 - 2018 | 0.041 | 0.011 | a |
| | | | | | 2018 - 2019 | 0.034 | 0.010 | a |
| | | | | | 2019 - 2020 | 0.054 | 0.013 | c |
| **Open-Water** | K-W | rank | NO | 0.102 | 2014 | 0.200 | 0.206 | a |
| | | | | | 2015 | 0.124 | 0.049 | a |
| | | | | | 2016 | 0.116 | 0.008 | a |
| | | | | | 2017 | 0.171 | 0.031 | a |
| | | | | | 2018 | 0.182 | 0.064 | a |
| | | | | | 2019 | 0.097 | 0.016 | a |
| | | | | | 2020 | 0.125 | 0.050 | a |

[a] Statistical tests include analysis of variance (ANOVA; followed by Tukey's Honestly Significant Difference post-hoc tests) and Kruskal Wallis H-test (K-W; followed by Mann-Whitney U-test pair-wise comparisons).

[b] Deployment periods denoted by the same letter do not differ significantly.

**Table A.8: Statistical Comparison of Sedimentation Rates Between Mine Baseline (2013 to 2014) and Operational (2015 to 2020) Phases at Sheardown Lake NW Deep Station 1 (DEEP1) during Ice-Cover and Open-Water Periods, Lake Sedimentation Monitoring Study, 2013 to 2020**

| Seasonal Period | Overall 6-group Comparison | | | | Pair-wise, *post-hoc* comparisons | | | |
|---|---|---|---|---|---|---|---|---|
| | Statistical Test[a] | Transform-ation | Significant Difference Among Areas? | p-value | Deployment Period | Mean Rate | Standard Deviation | Temporal Difference[b] |
| **Ice-Cover** | ANOVA | log10 | YES | 0.001 | 2013 - 2014 | 0.050 | 0.007 | ab |
| | | | | | 2014 - 2015 | 0.049 | 0.005 | b |
| | | | | | 2015 - 2016 | 0.088 | 0.014 | cd |
| | | | | | 2016 - 2017 | 0.108 | 0.024 | c |
| | | | | | 2017 - 2018 | 0.071 | 0.009 | de |
| | | | | | 2018 - 2019 | 0.063 | 0.004 | ae |
| | | | | | 2019 - 2020 | 0.063 | 0.005 | ae |
| **Open-Water** | ANOVA | log10 | YES | 0.001 | 2014 | 0.131 | 0.004 | a |
| | | | | | 2015 | 0.199 | 0.015 | b |
| | | | | | 2016 | 0.258 | 0.020 | c |
| | | | | | 2017 | 0.259 | 0.048 | c |
| | | | | | 2018 | 0.218 | 0.013 | bc |
| | | | | | 2019 | 0.162 | 0.009 | d |
| | | | | | 2020 | 0.162 | 0.017 | d |

[a] Statistical tests include analysis of variance (ANOVA; followed by Tukey's Honestly Significant Difference post-hoc tests) and Kruskal Wallis H-test (K-W; followed by Mann-Whitney U-test pair-wise comparisons).

[b] Deployment periods denoted by the same letter do not differ significantly.

**Table A.9: Dry Bulk Density of Sedimentation Samples Collected at Sheardown Lake NW Since 2018**

| Period | Sample Identification | Collection Date | Density ($g/cm^3$) |
|---|---|---|---|
| Open-Water 2018 | SDNW DBD | September 21, 2018 | 2.94 |
| Ice-Cover 2018 to 2019 | BD-SHAL-A | August 12, 2019 | 2.76 |
| | BD-SHAL-B | August 12, 2019 | 2.76 |
| | BD-Deep | August 12, 2019 | 2.88 |
| Open-Water 2019 | BD-SHAL | October 1, 2019 | 2.53 |
| | BD-DEEP | October 1, 2019 | 2.59 |
| Ice-Cover 2019 to 2020 | BD-SHAL-A | July 18, 2020 | 3.03 |
| | BD-SHAL-B | July 18, 2020 | 2.91 |
| | BD-Deep | July 14, 2020 | 2.75 |
| Open-Water 2020 | BD-SHAL-A | September 4, 2020 | 2.37 |
| | BD-SHAL-B | September 5, 2020 | 2.46 |
| | BD-Deep | September 5, 2020 | 2.22 |

**Table A.10**: **Sediment Accumulation (mm) Summary Statistics for Sheardown Lake NW, Lake Sedimentation Monitoring Study, 2019 to 2020**

| Study Period | Station | Sample Size | Mean | Standard Deviation | Standard Error | Minimum | Median | Maximum |
|---|---|---|---|---|---|---|---|---|
| Ice-Cover 2019 to 2020 | SHAL 1 | 5 | 0.061 | 0.009 | 0.004 | 0.054 | 0.059 | 0.076 |
| | SHAL 2 | 5 | 0.063 | 0.007 | 0.003 | 0.053 | 0.064 | 0.072 |
| | DEEP1 | 5 | 0.071 | 0.006 | 0.002 | 0.064 | 0.070 | 0.079 |
| Open-Water 2020 | SHAL 1 | 5 | 0.023 | 0.004 | 0.002 | 0.020 | 0.022 | 0.029 |
| | SHAL 2 | 5 | 0.026 | 0.010 | 0.005 | 0.017 | 0.023 | 0.044 |
| | DEEP1 | 5 | 0.038 | 0.005 | 0.002 | 0.029 | 0.038 | 0.042 |

**Table A.11: Statistical Comparison of Sediment Accumulation (mm) among Sheardown Lake NW Stations for Ice-Cover and Open-Water Periods, Lake Sedimentation Monitoring Study, 2019 to 2020**

| Study Period | Overall 3-group Comparison | | | | Pair-wise comparisons | | | |
|---|---|---|---|---|---|---|---|---|
| | Statistical Test[a] | Transform-ation | Significant Difference Among Areas? | p-value | (I) Area | (J) Area | Significant Difference Between Areas? | p-value |
| Ice-Cover 2019 to 2020 | ANOVA | none | NO | 0.122 | SHAL1 | SHAL2 | NO | 0.913 |
| | | | | | SHAL1 | DEEP1 | NO | 0.128 |
| | | | | | SHAL2 | DEEP1 | NO | 0.243 |
| Open-Water 2020 | ANOVA | none | YES | 0.015 | SHAL1 | SHAL2 | NO | 0.821 |
| | | | | | SHAL1 | DEEP1 | YES | 0.017 |
| | | | | | SHAL2 | DEEP1 | YES | 0.051 |

Shading indicates significant difference between study areas based on ANOVA p-value less than 0.1.

[a] Statistical tests include Analysis of Variance (ANOVA) followed by post hoc Tukey's HSD tests or Kruskal-Wallis (K-W) multiple group test followed by Mann-Whitney (M-W) pair-wise tests.

**Table A.12: Statistical Comparison of Sediment Accumulation (mm) Between the 2019 to 2020 Ice-Cover and 2020 Open-Water Periods at Sheardown Lake NW**

| Station | Statistical Test Results | | | | Summary Statistics | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Statistical Test[a] | Transform-ation | Significant Difference Between Areas? | *p*-value | Period | N | Mean | Standard Deviation | Standard Error | Minimum | Median | Maximum |
| SHAL1 | tequal | log10 | YES | 0.001 | Ice-Cover 2019 to 2020 | 5 | 0.061 | 0.009 | 0.004 | 0.054 | 0.059 | 0.076 |
| | | | | | Open-Water 2020 | 5 | 0.023 | 0.004 | 0.002 | 0.020 | 0.022 | 0.029 |
| SHAL2 | tequal | log10 | YES | 0.001 | Ice-Cover 2019 to 2020 | 5 | 0.063 | 0.007 | 0.003 | 0.053 | 0.064 | 0.072 |
| | | | | | Open-Water 2020 | 5 | 0.026 | 0.010 | 0.005 | 0.017 | 0.023 | 0.044 |
| DEEP1 | tequal | log10 | YES | 0.001 | Ice-Cover 2019 to 2020 | 5 | 0.071 | 0.006 | 0.002 | 0.064 | 0.070 | 0.079 |
| | | | | | Open-Water 2020 | 5 | 0.038 | 0.005 | 0.002 | 0.029 | 0.038 | 0.042 |

Shading indicates significant difference between seasonal periods based on p-value less than 0.10.

[a] Statistical tests include t-test assuming equal variance (tequal), t-test assuming unequal variance (tunequal), or Mann-Whitney U-test (M-W).

**Table A.13: Statistical Comparison of Sediment Accumulation at Sheardown Lake NW Stations Among Years for Separate Ice-Cover and Open-Water Periods, 2018 to 2020**

| Station | Seasonal Period | Overall 6-group Comparison | | | | Pair-wise, *post-hoc* comparisons | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Statistical Test[a] | Transform-ation | Significant Difference Among Areas? | p-value | Deployment Period | Mean (mm) | Standard Deviation | Temporal Difference[b] |
| SHAL1 | Ice-Cover | tequal | none | YES | 0.001 | 2018 - 2019 | 0.038 | 0.003 | a |
| | | | | | | 2019 - 2020 | 0.061 | 0.009 | b |
| | Open-Water | tequal | none | NO | 0.143 | 2019 | 0.026 | 0.003 | a |
| | | | | | | 2020 | 0.023 | 0.004 | a |
| SHAL2 | Ice-Cover | tequal | none | YES | 0.001 | 2018 - 2019 | 0.036 | 0.010 | a |
| | | | | | | 2019 - 2020 | 0.063 | 0.007 | b |
| | Open-Water | tequal | log10 | NO | 0.683 | 2019 | 0.023 | 0.004 | a |
| | | | | | | 2020 | 0.026 | 0.010 | a |
| DEEP1 | Ice-Cover | tequal | none | NO | 0.816 | 2018 - 2019 | 0.072 | 0.005 | a |
| | | | | | | 2019 - 2020 | 0.071 | 0.006 | a |
| | Open-Water | tequal | none | NO | 0.789 | 2019 | 0.038 | 0.003 | a |
| | | | | | | 2020 | 0.038 | 0.005 | a |

[a] Statistical tests include t-test assuming equal variance (tequal), t-test assuming unequal variance (tunequal), or Mann-Whitney U-test (M-W).

[b] Deployment periods denoted by the same letter do not differ significantly based on tests conducted for each individual station.