Appendix 34

Meadowbank EEM Cycle 4 Interpretive Report

ENVIRONMENTAL EFFECTS MONITORING: CYCLE 4, MEADOWBANK MINE INTERPRETIVE REPORT

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Submitted To:

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EXECUTIVE SUMMARY

Introduction

Agnico Eagle Mines Ltd: Meadowbank Division began discharging treated effluent during 2009 and was subsequently required, under the Metal Mining Effluent Regulations (MMER), to monitor effects of that effluent on fish and fish habitat. This is the mine's Fourth EEM Interpretive Report, and it is submitted to Environment Canada on behalf of Agnico Eagle Mines Limited, Val-d'Or, Québec. Although this is the Cycle 4 EEM study at Meadowbank site, it is the first study for which Second Portage Lake has been the exposure site; during the first two EEM cycles the main discharge was to Third Portage North, while during the third EEM cycle the main discharge was to Wally Lake. This report documents the results of the mine's Cycle 4 EEM biological monitoring study, as well as the sub-lethal toxicity testing carried out on the Meadowbank Division effluent since the drafting of the Cycle 3 Interpretive Report.

Benthic Invertebrate Community Survey

This 2020 survey of benthic invertebrates compared a near-field exposure area in Second Portage Lake (SP-NF), with reference-area data from Innuguguayalik Lake (INUG) and Pipedream Lake (PDL). Samples were also collected from a far-field sampling area in Second Portage Lake (SP-FF) that is outside of the 1% effluent mixing zone. This is the fourth invertebrate community survey for the Meadowbank Mine under the MDMER (previously MMER), but the first undertaken in SP-NF (under MDMER) because discharge to the previous exposure areas (Third Portage North Lake [TPN] and Wally Lake [WAL]) has ceased. Benthos have been sampled from SP-FF and INUG since 2006, while PDL has been sampled since 2009 as part of the mine's Core Receiving Environmental Monitoring Program (CREMP). Samples collected in 2020 from SP-NF were the first collected for this exposure area. The Cycle 4 EEM benthic invertebrate survey employed the same sampling methods as the CREMP program so that a before-after-control-impact (BACI) design could be used for assessing data. Benthic invertebrates were collected in August 2020. Effects assessment involved use of baseline period data dating back to 2006, and testing of BACI and trend-over-time variations.

Some of the observed variations in core indices (total density, family richness, evenness, scores on NMDS axes 1 and axis 2) were related to variations in sample depth and in substrate total organic carbon and grain size. Testing for spatio-temporal variations, therefore, was carried out on residuals of the core indices, after taking into account the variations related to underlying physical variables. Reference-condition models were used to adjust benthic community indices to a more common set of conditions in terms of sample depth and substrate (grain size and TOC).

There were a number of spatial and temporal variations that were significant and that were consistent with operational influences. Most of the significant variations were small with effect sizes < ± 2 SDs from the reference area mean. However, significant differences in total density exceeded the critical effect size of ± 2 SD from the reference area mean, as well as background variability. Total densities at SP-NF where higher in 2020 than in the reference lakes, in SP-FF in 2014 to 2020, and in SP-FF in 2020.

The benthic community of SP-NF, however, was very similar to what is observed in the reference lakes, and in SP-FF during baseline periods. The nearfield exposure area contained 11 genera of chironomid in 2020, similar to what has been observed in the other lakes including the dominant genera *Micropsectra*, *Stichtochironomus*, *Tanytarsus*, and *Procladius*. There were no oligochaete worms in the benthos of SP-

NF in 2020, a group that typically increases in numbers when conditions degrade. The benthos of SP-NF also contained the caddisfly *Grensia*, which has been historically observed in SP (in low relative densities), and a species that is generally restricted to the cold, clear waters of the far north. In summary, the benthic community in SP-NF does not indicate degraded conditions and contained an assemblage of organisms that are typical for these Arctic systems.

Each of the three sampling areas had relatively low hardness with concentrations of metals and nutrients that are well below CCME water quality guidelines, and near detection limits. There were some increased levels of cations (Ca, Mg, K) in SP, reflecting the slightly higher hardness, but the changes are trivial relative to the concentrations that would be required in order to elicit a toxicity response.

Sub-Lethal Toxicity

Cycle 4 effluent samples produced no effect on survival of exposed fathead minnows. Measurable growth impairment in fathead minnows was observed in one of seven samples, with an IC25 estimate of 4.27%. One sample had a measured effect on survival of *Ceriodaphnia dubia*, with an LC50 of 91.0%. Measurable reproductive inhibition of *Ceriodaphnia dubia* was observed in three samples and with IC25 estimates of 80.8%, 62.2%, and 39.7%. Final effluent samples did not impair growth in any of the *Pseudokirchneriella subcapitata* tests during cycle 4. Inhibitory effects for *Lemna minor* were observed during one test where IC25 estimates for frond growth (dry weight) and frond number were 88.3% and 82.2%, respectively.

Fish Population Survey

A fish study is required if the 1% effluent plume extends 250 m or more from the discharge point. CORMIX modeling indicated that there is no scenario in which the 1% effluent plume extends to or beyond 250 m from the point of discharge. A fish study was, therefore, not required.

Mercury and Selenium in Fish Flesh

The mercury concentration and the selenium concentration in the effluent have consistently been less than the concentrations that would require a fish tissue study; therefore, a study respecting fish tissue mercury or fish tissue selenium was not required.

Future EEM Schedule

This Cycle 4 EEM study was the first EEM study for which Second Portage Lake was the exposure area. In 2020, the only effluent stream was via a diffuser into Second Portage Lake. If this continues to be the case, this outfall will be the subject on the Cycle 5 EEM biological study. Agnico will continue to monitor the volume and quality of the mine effluents. These data will be used to determine the effluent that will be the focus of the Cycle 5 EEM field study. The next EEM cycle should, therefore, be completed within 36 months of this submission in 2023, with the interpretive report submitted by July 1st, 2024.

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1.0 INTRODUCTION

1.1 Meadowbank Mine

The Meadowbank Mine (65°N, 96°W) is one of Canada's most northerly operating mines, located approximately 75 km north of the Hamlet of Baker Lake, Kivalliq District, Nunavut (Figure 1). Mine construction began in 2008 under Nunavut Water Board Type A License 2AM-MEA0815 (now 2AM-MEA1530) and Fisheries and Oceans Canada Authorization for Works or Undertaking Affecting Fish Habitat NU-03-0191.3 and NU-03-0191.4. Mine construction activities for the Goose Pit and Portage Pit included the isolation of portions of two lakes using dikes, with the dewatering of these impoundments into adjacent lakes starting in 2009. On December 31, 2009, Environment Canada notified Agnico that the Meadowbank Mine is subject to the Metal Mining Effluent Regulations (MMER). Mining activities were formally underway in March 2010. Since October 2019, mining operations have ceased at Meadowbank, but the Meadowbank milling and processing facilities, along with the storage of tailings, continue to operate with ore mined and transported from the Whale Tail Pit which is located approximately 50 km north of the Meadowbank site.

1.2 Regulatory Background

The MDMER, under the Fisheries Act, imposes liquid effluent limits for pH, cyanide, metals, and suspended solids, and prohibits the discharge of a liquid effluent that is acutely lethal to fish. The MDMER also requires mines to conduct Environmental Effects Monitoring (EEM) studies of fish, fish habitat and the use of fisheries resources in aquatic receiving environments. Under the MDMER, Agnico Eagle Mines Limited (Agnico) is required to conduct aquatic monitoring studies on the potential effects of the Meadowbank Division Mine's final liquid effluent on Second Portage Lake.

Schedule 5, Parts 1 and 2, of the MDMER requires each operating mine to conduct an EEM program consisting of the following components:

- **Effluent characterization and water quality monitoring** studies including sublethal toxicity testing; and,

- **Biological monitoring studies** consisting of a study design, field studies, data assessment and reporting.

Agnico conducted its Cycle 1 Biological Monitoring Study in August 2011, collecting fish and benthos from the exposure area in Third Portage Lake North (TPN) (Figure 2) and from two reference areas, one each in Innuguguayalik Lake (INUG) and Pipedream Lake (PDL) (Figure 2). The results of that first study were reported to Environment Canada in June 2012 (Azimuth, 2012). The Cycle 2 Biological Monitoring Study was conducted in August 2014, using the same exposure and reference areas. The results of the second study were reported to Environment Canada in June 2015 (C. Portt and Associates and Kilgour & Associates Ltd., 2015). The Cycle 3 Biological Monitoring Study was conducted in August 2017, using the same reference areas as the previous two cycles, but with Wally Lake as the exposure area. The results of the third study were reported to Environment Canada in June 2018 (C. Portt and Associates and Kilgour & Associates Ltd., 2018). A study design for a proposed Cycle 4 EEM Study, with the exposure area in Second

Portage Lake, was submitted to Environment Canada in February, 2020 (C. Portt and Associates, and Kilgour & Associates Ltd., 2020). The Technical Advisory Panel (TAP) reviewed the study design and provided comments to Agnico Meadowbank Division. These comments were addressed by Agnico, and the Meadowbank Cycle 4 EEM study design was accepted by Environment Canada on June 15, 2020 (Appendix 1). This report describes the results of the Fourth Biological Study undertaken August 21-26, 2020, pursuant to Agnico's requirement under the MDMER.

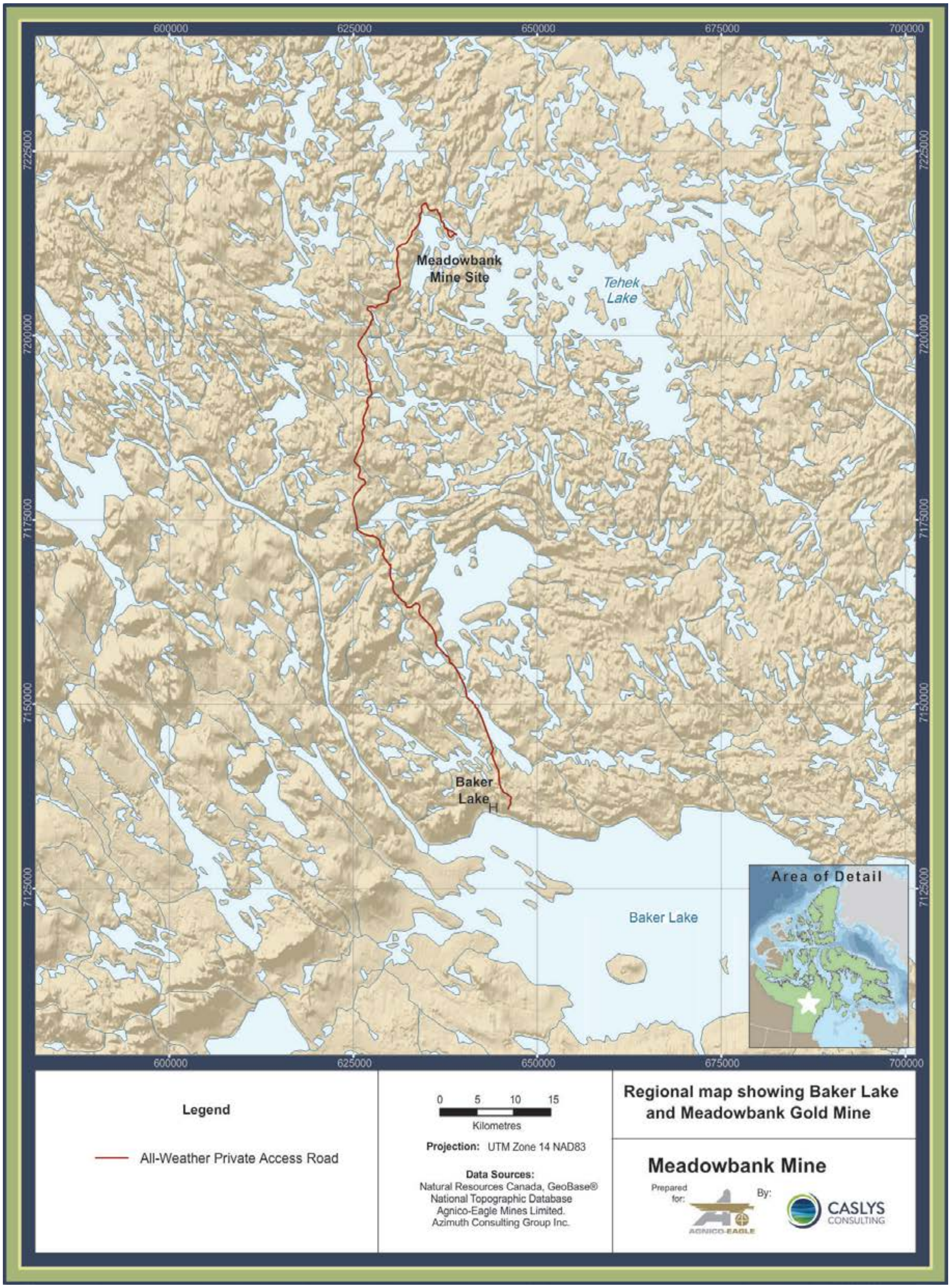

Figure 1. Location of Meadowbank Mine.

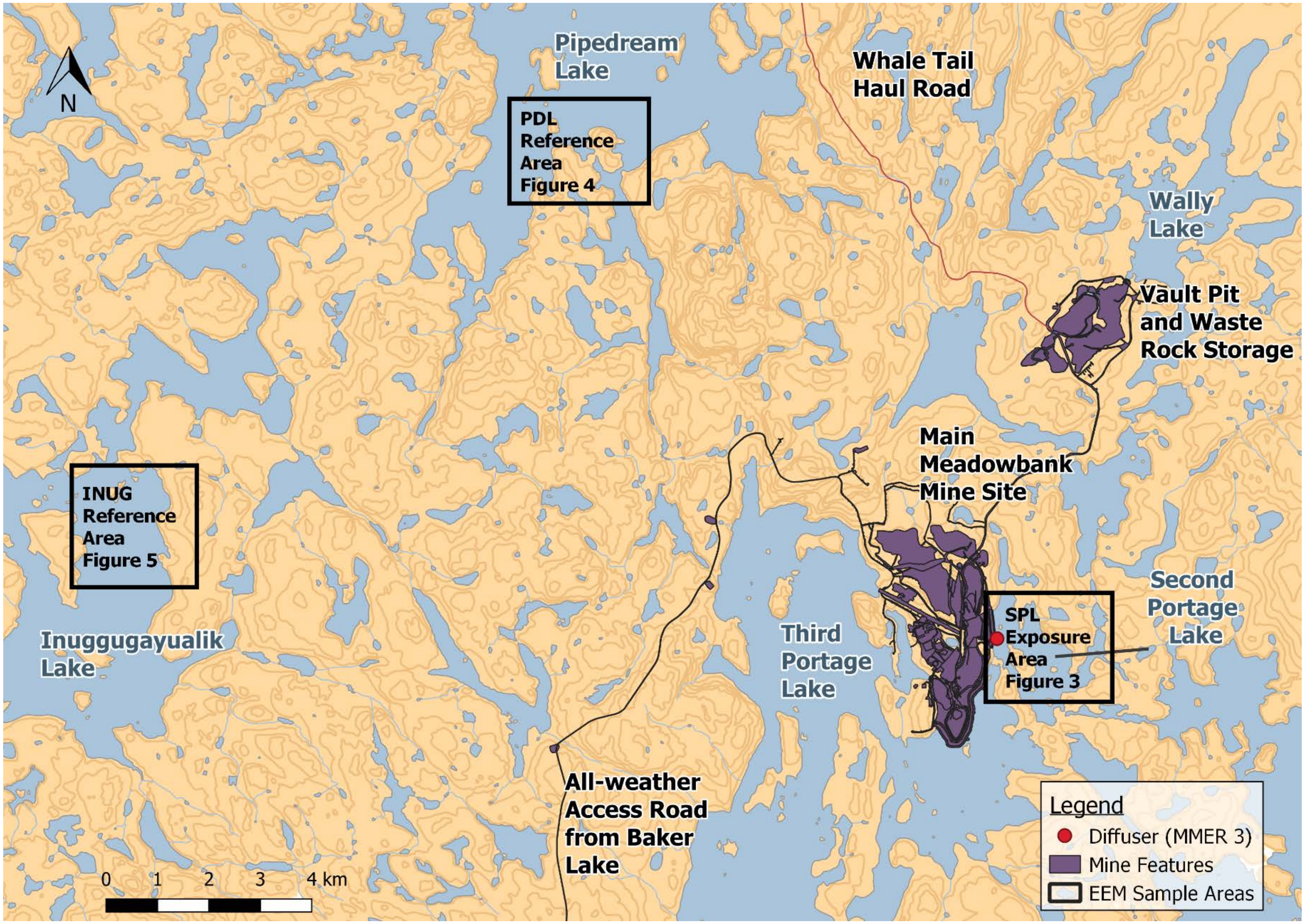

Figure 2. Map of the study area.

Table 1. Concordance table identifying the sections of this report that address specific MDMER reporting requirements.

MDMER Requirement	Where Found in the Document
12(a) description of any deviation from the study design that occurred while the biological monitoring studies were being conducted and any impact that the deviation had on the studies.	Section 2.3
12(b) the latitude and longitude of sampling areas in degrees, minutes and seconds and a description of the sampling areas sufficient to identify the location of the sampling areas.	Digital data submission and Section 4.
12(c) the dates and times when the samples were collected.	Section 4
12(d) the sample sizes.	Section 4
12(e)(ii) in the case of the study respecting the benthic invertebrate community, the mean, median, standard deviation, standard error, minimum and maximum values for effect indicators of the total benthic invertebrate density, evenness index, taxa richness and, if the study is conducted in an area where it is possible to sample sediment, total organic carbon content of sediment and particle size distribution of sediment	Section 4
12(f) in the case of the study respecting the benthic invertebrate community, a calculation of the similarity index effect indicator	Section 4
12(h) determination as to whether there is a statistically significant difference between the sampling areas, with statistical comparisons made separately and independently for each effect indicator	Section 4
12(i) a statistical analysis of the results of calculations that indicates the probability of correctly detecting an effect of a pre-defined size and the degree of confidence that can be placed in the calculations.	Section 4
12(j) for an effect indicator with an assigned critical effect size, a comparison on the magnitude of the effect to its critical effect size.	Section 4
12(k) any supporting data, including raw data for the information provided under (e) to (j)	Section 4, Appendix 3
12(l) a description of any quality assurance or quality control measures that were implemented, and the data related to the implementation of those measures.	Section 4 for description Appendix 2 for water quality data Appendix 4 for invertebrate data
12(m)(ii) based on the information referred to in paragraphs (e) to (k), the identification of an effect on the benthic invertebrate community	Section 4
12(n) for an effect indicator with an assigned critical effect size, a statement as to whether the absolute value of the magnitude of the effect is greater than the absolute value of the critical effect size.	Section 4
15(b) a summary of the results of effluent characterization, sublethal toxicity testing and water quality monitoring after the day on which the previous interpretive report was required to be submitted.	Section 2 for effluent characterization and water quality, Section 6 for sublethal toxicity testing
12(p) a description of how the conclusions will impact the study design for subsequent biological monitoring studies	Section 4.4.1
12(q) the month in which the next biological monitoring studies will start, if any biological monitoring studies are required.	Executive Summary Section 7
12(r) the date when the next interpretive report is required to be submitted	Executive Summary Section 7

2.0 STUDY DESIGN UPDATE

2.1 Mining and Wastewater Management Overview

No changes in the wastewater treatment system occurred between the submission of the Study Design and the Cycle 4 field work in August 2020.

As described in the EEM Cycle 4 Study Design (C. Portt and Associates, Kilgour & Associates Ltd., 2020), Agnico presently has only one (1) active effluent. This discharge occurs near the East Dike, where water that seeps through the dike from Second Portage Lake is collected and pumped via a diffuser back into Second Portage Lake. This non-contact water has not required water treatment to date. Approximately 144,000 m^3 in 2014 and 163,000 m^3 in 2015, were discharged intermittently. During 2016 this discharge was almost continuous, totaling approximately 180,000 m^3. Discharge was intermittent again during 2017 through 2020, totaling approximately 100,000 m^3 in 2017, 141,000 m^3 in 2018, 33,000 m^3 in 2019, and 90,000 m^3 in 2020. Daily discharge volumes from 2018 to 2020 are provided in Table 2. Effluent was discharged periodically in 2020 from January to June and October to December, and therefore was not discharged during the Cycle 4 EEM field investigations, conducted from August 21 to August 26, 2020. Agnico advised Environment and Climate Change Canada that this would be the case, via email on August 19, 2020. Effluent mixing in the Second Portage Lake receiving environment is discussed in Section 2.2.

The mine has been in reduced frequency for testing relating to the concentration of arsenic, copper, cyanide, lead, nickel, and zinc since September 19, 2016, because the final discharge point effluent was less than 10% of the value set out in column 2 [maximum authorized monthly mean concentration] of Schedule 4 for 12 consecutive months. The mine has also been in reduced frequency of testing for Radium 226 since March 29, 2016, because that substance’s concentration in the effluent was less than 0.037 Bq/L in 10 consecutive weeks of tests conducted under section 12 between December 1, 2015, and February 1, 2016. Effluent chemistry results from 2018 to 2020 are presented in Table 3. There have been no exceedances of the MDMER effluent discharge limits for deleterious substances at the Meadowbank Mine up to October 2020. The mine has been in reduced frequency of testing for acute lethality since September 19, 2016, because the effluent was determined not to be acutely lethal for the 12-month period between August 2015 and July 2016. Toxicity test results for sublethal endpoints are discussed in Section 6.0. Receiving environment water quality results for SP are presented in Table 4. Reference area water quality monitoring results for Third Portage Lake South are presented in Table 5.

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Table 2. Meadowbank Division effluent volume (m^3) from East Dike seepage to Second Portage Lake via outfall MMER-3 from 2018 to 2020.

Date	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18
1	616	509	587	429	612	932	0	0	465	401	382	366
2	537	349	605	420	620	914	0	0	462	403	381	365
3	537	356	611	377	615	809	0	0	454	400	381	356
4	537	339	599	233	584	0	0	0	458	399	381	364
5	537	341	515	414	625	0	0	0	481	397	381	363
6	537	473	604	647	624	0	0	0	474	396	380	358
7	537	574	613	620	622	0	0	0	479	395	380	362
8	678	495	606	620	613	0	0	0	474	390	376	357
9	617	531	608	591	624	0	0	0	469	388	380	360
10	611	565	618	590	630	0	0	0	468	393	379	359
11	651	594	618	596	621	0	0	0	467	393	378	358
12	620	554	617	570	631	0	0	0	464	387	378	349
13	616	488	621	608	633	0	0	0	461	391	377	357
14	615	454	625	616	630	0	0	0	450	391	376	349
15	607	335	619	611	620	0	0	0	451	390	376	355
16	633	558	626	609	623	0	0	0	448	390	376	355
17	612	501	598	599	627	0	0	0	444	389	375	346
18	536	413	612	574	627	0	0	0	435	388	367	354
19	527	521	612	590	628	0	0	0	438	388	374	354
20	593	415	603	600	617	0	0	0	436	383	374	352
21	544	370	515	611	608	0	0	254	433	389	372	352
22	607	596	602	616	607	0	0	501	431	387	372	346
23	496	603	614	615	595	0	0	500	428	387	371	350
24	360	601	619	617	594	0	0	496	425	386	366	350
25	345	594	615	616	597	0	0	491	422	385	368	349
26	380	604	615	611	572	0	0	485	412	380	368	349
27	420	604	625	619	607	0	0	480	415	385	361	345
28	499	600	610	617	618	0	0	470	413	384	367	348
29	513		601	613	622	0	0	472	410	383	366	348
30	343		562	614	623	0	0	468	408	379	365	347
31	380		498		611		0	467		383		347
Total	**16,638**	**13,937**	**18,592**	**17,062**	**19,078**	**2,654**	**0**	**5,084**	**13,372**	**12,078**	**11,226**	**10,968**

Table 2. (continued)

Date	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19
1	347	0	0	0	0	0	0	0	0	0	0	381
2	347	0	0	0	0	0	0	0	0	0	0	404
3	345	0	0	0	0	0	0	0	0	0	0	415
4	344	0	0	0	0	0	0	0	0	0	0	410
5	339	0	0	0	0	0	0	0	0	0	0	412
6	342	0	0	0	0	0	0	0	0	0	0	415
7	342	0	0	0	0	0	0	0	0	0	0	420
8	341	0	0	0	0	0	0	0	0	0	0	412
9	340	0	0	0	0	0	0	0	0	0	0	421
10	339	0	140	0	0	0	0	0	0	0	0	428
11	340	0	302	0	0	0	0	0	0	0	0	416
12	339	0	308	0	0	0	0	0	0	0	0	420
13	339	0	309	0	0	0	0	0	0	0	448	416
14	69	0	310	0	0	0	0	0	0	0	432	417
15	0	0	307	0	0	0	0	0	0	0	432	402
16	0	0	307	0	0	0	0	0	0	0	416	407
17	0	0	312	0	0	0	0	0	0	0	421	395
18	0	0	313	0	0	0	0	0	0	0	423	398
19	0	0	313	0	0	0	0	0	0	0	395	405
20	54	0	310	0	0	0	0	0	0	0	393	396
21	393	0	311	0	0	0	0	0	0	0	395	370
22	655	0	315	0	0	0	0	0	0	0	401	404
23	518	0	316	0	0	0	0	0	0	0	390	419
24	361	0	311	0	0	0	0	0	0	0	389	390
25	162	0	317	0	0	0	0	0	0	0	380	367
26	0	0	320	0	0	0	0	0	0	0	390	422
27	0	0	315	0	0	0	0	0	0	0	381	448
28	0	0	321	0	0	0	0	0	0	0	382	461
29	0		321	0	0	0	0	0	0	0	390	468
30	0		215	0	0	0	0	0	0	0	381	458
31	0		0		0		0	0		0		441
Total	**6,657**	**0**	**6,294**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**7,239**	**12,837**

Table 2. (continued)

Date	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20
1	460	436	444	294	437	472	0	0	0	0	319	306
2	468	446	446	353	450	423	0	0	0	0	328	316
3	464	444	464	450	445	437	0	0	0	0	331	309
4	464	419	441	468	454	444	0	0	0	0	326	277
5	471	421	463	438	440	263	0	0	0	0	326	301
6	427	392	479	586	408	0	0	0	0	0	325	284
7	409	398	436	493	429	0	0	0	0	0	321	310
8	436	363	431	441	430	0	0	0	0	0	279	305
9	501	342	359	516	450	0	0	0	0	0	301	303
10	443	341	474	457	457	0	0	0	0	0	300	275
11	490	414	497	411	472	0	0	0	0	0	297	300
12	466	551	481	188	475	0	0	0	0	0	265	300
13	412	462	455	315	464	0	0	0	0	0	201	305
14	473	475	462	460	483	0	0	0	0	0	273	300
15	522	440	450	242	473	0	0	0	0	0	233	291
16	462	434	476	239	480	0	0	0	0	0	279	292
17	462	470	478	407	438	0	0	0	0	0	290	293
18	468	395	463	394	500	0	0	0	0	0	275	282
19	463	394	443	405	503	0	0	0	0	0	276	285
20	461	472	436	478	496	0	0	0	0	0	276	270
21	429	490	474	460	502	0	0	0	0	0	281	245
22	374	486	476	441	500	0	0	0	0	0	268	294
23	353	457	489	457	501	0	0	0	0	320	285	284
24	339	429	506	433	497	0	0	0	0	321	249	289
25	340	473	447	402	503	0	0	0	0	319	254	283
26	336	468	431	429	487	0	0	0	0	324	263	296
27	365	436	452	499	504	0	0	0	0	324	249	290
28	389	355	447	473	498	0	0	0	0	337	285	281
29	416	436	442	441	483	0	0	0	0	329	205	295
30	420		360	480	496	0	0	0	0	328	240	292
31	426		349		475		0	0		324		300
Total	**13,410**	**12,537**	**13,949**	**12,548**	**14,632**	**2,039**	**0**	**0**	**0**	**2,927**	**8,401**	**9,053**

Table 3. Chemical and physical parameters for final effluent (outfall MMER-3) to Second Portage Lake from 2018-2020.

Date (dd-mm-yyyy)	06-02-2018	10-09-2018	15-10-2018	19-11-2018	07-01-2019	18-03-2019	18-11-2019
Parameter							
Alkalinity (mg $CaCO_3$/L)	28	28	26	28	29	39	22
Aluminum (mg/L)	0.042	0.031	<0.005	0.037	0.027	0.031	0.023
Ammonia nitrogen (NH3-NH4) (mg N/L)	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.13
Cadmium (mg/L)	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
Hardness (mg $CaCO_3$/L)	22	40	21	26	27	36	28
Iron (mg/L)	0.08	0.02	<0.01	0.04	0.02	0.04	0.02
Mercury (mg/L) (max allowance of 0.10µg/L)	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Molybdenum (mg/L)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Nitrate (mg N/L)	0.07	0.27	0.04	0.06	0.04	<0.01	0.04
Selenium (mg/L)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Chloride (mg/L)	-	-	-	-	0.9	1.5	0.8
Chromium (mg/L)	-	-	-	-	0.0006	<0.0006	0.0006
Cobalt (mg/L)	-	-	-	-	<0.0005	<0.0005	<0.0005
Sulphate (mg/L)	-	-	-	-	7.9	12.4	7.6
Thallium (mg/L)	-	-	-	-	<0.0002	<0.0002	<0.0002
Uranium (mg/L)	-	-	-	-	<0.001	<0.001	<0.001
Phosphorus (mg/L)	-	-	-	-	0.01	<0.01	<0.01
Manganese (mg/L)	-	-	-	-	<0.0005	0.0009	0.0007
Conductivity (µs/cm)	87.5	108.9	70.9	76.2	93.9	87	78.5
Temperature (°C)	0.5	8.9	3.8	4.1	7.2	4.5	6.5

Table 3. (continued).

Date (dd-mm-yyyy)	25-11-2019	23-12-2019	28-12-2019	06-01-2020	10-02-2020	27-04-2020	26-10-2020
Parameter							
Alkalinity (mg $CaCO_3$/L)	23	28	30	52	47	27	55
Aluminum (mg/L)	0.02	0.039	0.023	0.034	0.023	0.023	0.018
Ammonia nitrogen (NH3-NH4) (mg N/L)	<0.01	0.01	0.01	0.08	0.02	0.01	0.02
Cadmium (mg/L)	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
Hardness (mg $CaCO_3$/L)	29	30	35	31	26	31	30
Iron (mg/L)	0.07	0.02	0.02	0.11	<0.01	0.03	0.01
Mercury (mg/L) (max allowance of 0.10µg/L)	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.00002
Molybdenum (mg/L)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Nitrate (mg N/L)	0.06	0.04	<0.01	0.09	0.07	0.08	0.06
Selenium (mg/L)	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.0005
Chloride (mg/L)	0.8	0.8	0.9	1	1.9	1	0.98
Chromium (mg/L)	<0.0006	0.0007	0.0024	0.0006	0.0019	0.0008	<0.0006
Cobalt (mg/L)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Sulphate (mg/L)	9.7	7.1	6	7.3	2.3	7.2	6.8
Thallium (mg/L)	<0.0002	<0.0002	<0.0002	<0.0008	<0.0002	<0.0002	<0.0002
Uranium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Phosphorus (mg/L)	0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
Manganese (mg/L)	<0.0005	0.001	<0.0005	<0.0005	0.0013	0.0017	<0.0005
Conductivity (µs/cm)	82.5	78.9	78.3	73.2	77.8	87.2	64
Temperature (°C)	7.7	8.4	7.3	5.1	2.3	1.8	7.2

Table 4. Chemical and physical parameters for the MMER-3 exposure area at Second Portage Lake from 2018-2020.

Parameter	CCME (2020) Guideline[1]	2018			
		5-Feb	13-May	10-Sep	18-Nov
SP (Exposure Area)					
Alkalinity (mg $CaCO_3$/L)	NG	15	18	14	16
Aluminium-Total (mg/L)[2]	0.100 - 0.100	<0.005	0.012	< 0.005	< 0.005
Ammonia-Total (mg/L)[2,3]	1.2 - 19	< 0.01	0.03	< 0.01	< 0.01
Arsenic-Total (mg/L)	0.005	< 0.0005	0.0021	< 0.0005	< 0.0005
Cadmium-Total (mg/L)[4]	0.00004	< 0.00002	< 0.00002	< 0.00002	< 0.00002
Copper-Total (mg/L)[4]	0.002 - 0.002	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Cyanide-Total (mg/L)	0.005	<0.001	<0.001	<0.001	<0.001
Dissolved oxygen-Field (mg/L)	6.5 - 9.5	14.18	17.78	11.86	15.36
Hardness (mg $CaCO_3$/L)	NG	16	18	13	15
Iron-Total (mg/L)	0.3	< 0.01	< 0.01	< 0.01	< 0.01
Lead-Total (mg/L)[4]	0.001 - 0.001	< 0.0003	< 0.0003	< 0.0003	< 0.0003
Mercury-Total (mg/L)	0.000026	< 0.00001	< 0.00001	< 0.00001	< 0.00001
Molybdenum-Total (mg/L)	0.073	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Nickel-Total (mg/L)[4]	0.025 - 0.025	0.0025	0.0007	< 0.0005	< 0.0005
Nitrate-Total (mg N/L)	13.0	0.01	< 0.01	< 0.01	< 0.01
pH-Field	6.5 - 9.0	7.05	7.01	7.12	7.65
Radium-226 (Bq/L)	NG	-	-	-	-
Selenium-Total (mg/l)	0.001	<0.001	<0.001	<0.0005	<0.0005
Temperature-Field (^oC)	NG	0.35	0.57	8.8	1.49
Total suspended solid (mg/L)	5 - 25	2	24	< 1	< 1
Zinc-Total (mg/L)	NG	<0.001	<0.001	<0.001	<0.001
Conductivity (µs/cm)	NG	46.6	58.3	48.5	41.9

Notes: NG = no guideline; 1 CCME (Canadian Council of Ministers of the Environment) Canadian Water Quality Guidelines for the Protection of Aquatic Life, 2020; 2 Guideline is pH dependent; 3 Guideline is temperature dependent; 4 Guideline is hardness dependent; 5 Guideline is relative to background values; Shaded values exceed the CCME guideline

Table 4. (Continued)

Parameter	CCME (2020) Guideline[1]	2019 6-Jan	2019 12-Mar	2019 14-Nov	2019 15-Dec
SP (Exposure Area)					
Alkalinity (mg $CaCO_3$/L)	NG	17	22	12	19
Aluminium-Total (mg/L)[2]	0.100 - 0.100	<0.005	<0.005	<0.005	<0.005
Ammonia-Total (mg/L)[2,3]	1.2 - 19	<0.01	<0.01	0.02	0.02
Arsenic-Total (mg/L)	0.005	<0.0005	<0.0005	0.0016	0.0006
Cadmium-Total (mg/L)[4]	0.00004	<0.00002	<0.00002	<0.00002	<0.00002
Chloride-Total (mg/L)	120	0.9	1.3	0.9	0.9
Chromium-Total (mg/L)	NG	0.0008	<0.0006	<0.0006	<0.0006
Cobalt-Total (mg/L)	NG	<0.0005	<0.0005	<0.0005	<0.0005
Copper-Total (mg/L)[4]	0.002 - 0.002	<0.0005	<0.0005	0.0008	0.0007
Cyanide-Total (mg/L)	0.005	<0.001	<0.001	0.001	0.001
Dissolved oxygen-Field (mg/L)	6.5 - 9.5	15.96	17.54	16.23	15.53
Hardness (mg $CaCO_3$/L)	NG	16	16	17	15
Iron-Total (mg/L)	0.3	<0.01	<0.01	0.04	0.05
Lead-Total (mg/L)[4]	0.001 - 0.001	<0.0003	<0.0003	<0.0003	<0.0003
Manganese-Total (mg/L)[2,4]	0.210 - 0.250	<0.0005	0.0006	0.0009	<0.0005
Mercury-Total (mg/L)	0.000026	<0.00001	<0.00001	<0.00001	<0.00001
Molybdenum-Total (mg/L)	0.073	<0.0005	<0.0005	<0.0005	<0.0005
Nickel-Total (mg/L)[4]	0.025 - 0.025	<0.0005	<0.0005	0.0006	0.0018
Nitrate-Total (mg N/L)	13.0	<0.01	<0.01	0.05	<0.01
Phosphorus-Total (mg/L)	NG	<0.01	<0.01	<0.01	0.01
pH-Field	6.5 - 9.0	7.83	8.04	7.21	6.76
Radium-226 (Bq/L)	NG	-	-	<0.002	<0.002
Selenium-Total (mg/l)	0.001	<0.0005	<0.0005	<0.0005	<0.0005
Sulphate-Total (mg/L)	NG	6.7	6.8	6.7	7.1
Temperature-Field (^oC)	NG	1.55	1.39	1.2	1.25
Thalium-Total (mg/L)	0.0008	<0.0002	<0.0002	<0.0002	<0.0002
Total suspended solid (mg/L)[5]	5 - 25	6	1	3	<1
Uranium-Total (mg/L)	0.015	<0.001	<0.001	<0.001	<0.001
Zinc-Total (mg/L)	NG	<0.001	<0.001	0.001	<0.001
Conductivity (µs/cm)	NG	20.9	51.3	37.6	40.3

Notes: NG = no guideline; 1 CCME (Canadian Council of Ministers of the Environment) Canadian Water Quality Guidelines for the Protection of Aquatic Life, 2020; 2 Guideline is pH dependent; 3 Guideline is temperature dependent; 4 Guideline is hardness dependent; 5 Guideline is relative to background values; Shaded values exceed the CCME guideline.

Table 4. (Continued)

Parameter	CCME (2020) Guideline[1]	2020 21-Jan	22-Mar	10-May	15-Nov
SP (Exposure Area)					
Alkalinity (mg $CaCO_3$/L)	NG	29	48	19	49
Aluminium-Total (mg/L)[2]	0.100 - 0.100	<0.006	<0.006	<0.006	<0.006
Ammonia-Total (mg/L)[2,3]	1.2 - 19	0.02	<0.01	<0.01	<0.01
Arsenic-Total (mg/L)	0.005	<0.0005	<0.0005	<0.0005	<0.0005
Cadmium-Total (mg/L)[4]	0.00004	<0.00002	<0.00002	<0.00002	<0.00002
Chloride-Total (mg/L)	120	0.9	1	1.1	0.9
Chromium-Total (mg/L)	NG	<0.0005	0.0016	<0.0006	<0.0006
Cobalt-Total (mg/L)	NG	<0.0005	<0.0005	<0.0005	<0.0005
Copper-Total (mg/L)[4]	0.002 - 0.002	0.0007	0.0007	0.0007	<0.0005
Cyanide-Total (mg/L)	0.005	<0.001	<0.001	<0.001	<0.001
Dissolved oxygen-Field (mg/L)	6.5 - 9.5	16.76	18.25	17.11	16.17
Hardness (mg $CaCO_3$/L)	NG	22	15	17	16
Iron-Total (mg/L)	0.3	0.02	<0.01	<0.01	<0.01
Lead-Total (mg/L)[4]	0.001 - 0.001	<0.0003	<0.0003	<0.0003	<0.0003
Manganese-Total (mg/L)[2,4]	0.210 - 0.250	0.0011	0.0007	0.0007	0.0007
Mercury-Total (mg/L)	0.000026	<0.00001	<0.00001	<0.00001	<0.00001
Molybdenum-Total (mg/L)	0.073	<0.0005	<0.0005	<0.0005	<0.0005
Nickel-Total (mg/L)[4]	0.025 - 0.025	0.0023	<0.0005	0.0007	<0.0005
Nitrate-Total (mg N/L)	13.0	<0.01	<0.01	0.03	<0.01
Phosphorus-Total (mg/L)	NG	<0.01	0.01	<0.01	<0.04
pH-Field	6.5 - 9.0	7.02	6.77	6.68	7.04
Radium-226 (Bq/L)	NG	<0.002	-	-	-
Selenium-Total (mg/l)	0.001	<0.001	<0.001	<0.001	<0.0005
Sulphate-Total (mg/L)	NG	6.9	5.1	6.6	4.6
Temperature-Field (^oC)	NG	0.93	1.06	0.92	0.41
Thalium-Total (mg/L)	0.0008	<0.0008	<0.0002	<0.0002	<0.0002
Total suspended solid (mg/L)[5]	5 - 25	1	3	<1	<1
Uranium-Total (mg/L)	0.015	<0.001	<0.001	<0.001	<0.001
Zinc-Total (mg/L)	NG	0.003	0.003	0.134	<0.001
Conductivity (µs/cm)	NG	41.6	42.4	46.6	36.7

Notes: NG = no guideline; 1 CCME (Canadian Council of Ministers of the Environment) Canadian Water Quality Guidelines for the Protection of Aquatic Life, 2020; 2 Guideline is pH dependent; 3 Guideline is temperature dependent; 4 Guideline is hardness dependent; 5 Guideline is relative to background values; Shaded values exceed the CCME guideline

Table 5. Chemical and physical parameters for the MMER-3 reference area at Third Portage Lake South from 2018-2020.

Parameter	CCME (2020) Guideline[1]	2018			
		5-Feb	13-May	11-Sep	18-Nov
TPS (Reference Area)					
Alkalinity (mg $CaCO_3$/L)	NG	10	9	9	11
Aluminium-Total (mg/L)[2]	0.100 - 0.100	<0.005	0.032	< 0.005	< 0.005
Ammonia-Total (mg/L)[2,3]	1.3 - 19	0.03	0.04	< 0.01	< 0.01
Arsenic-Total (mg/L)	0.005	< 0.0005	0.001	< 0.0005	< 0.0005
Cadmium-Total (mg/L)[4]	0.00004	< 0.00002	0.00002	< 0.00002	< 0.00002
Copper-Total (mg/L)[4]	0.002 - 0.002	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Cyanide-Total (mg/L)	0.005	<0.001	<0.001	<0.001	<0.001
Dissolved oxygen-Field (mg/L)	6.5 - 9.5	14.76	14.58	11.70	17.26
Hardness (mg $CaCO_3$/L)	NG	12	8	7	8
Iron-Total (mg/L)	0.3	< 0.01	< 0.01	< 0.01	< 0.01
Lead-Total (mg/L)[4]	0.001 - 0.001	< 0.0003	< 0.0003	< 0.0003	< 0.0003
Mercury-Total (mg/L)	0.000026	< 0.00001	< 0.00001	< 0.00001	< 0.00001
Molybdenum-Total (mg/L)	0.073	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Nickel-Total (mg/L)[4]	0.025 - 0.025	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Nitrate-Total (mg N/L)	13.0	0.03	0.01	0.02	0.01
pH-Field	6.5 - 9.0	7.16	7.11	7.20	6.76
Radium-226 (Bq/L)	NG	-	-	-	-
Selenium-Total (mg/l)	0.001	<0.0005	<0.0005	<0.0005	<0.0005
Temperature-Field (^oC)	NG	0.2	1.2	8.5	0.5
Total suspended solid (mg/L)	5 - 25	1	1	1	1
Zinc-Total (mg/L)	NG	<0.001	0.002	<0.001	<0.001
Conductivity (µs/cm)	NG	34.5	68.8	31.4	28.7

Notes: NG = no guideline; 1 CCME (Canadian Council of Ministers of the Environment) Canadian Water Quality Guidelines for the Protection of Aquatic Life, 2020; 2 Guideline is pH dependent; 3 Guideline is temperature dependent; 4 Guideline is hardness dependent; 5 Guideline is relative to background values; Shaded values exceed the CCME guideline

Table 5. (Continued)

Parameter	CCME (2020) Guideline[1]	2019 6-Jan	2019 12-Mar	2019 13-Nov	2019 15-Dec
TPS (Reference Area)					
Alkalinity (mg $CaCO_3$/L)	NG	12	16	9	16
Aluminium-Total (mg/L)[2]	0.100 - 0.100	<0.005	<0.005	<0.005	<0.005
Ammonia-Total (mg/L)[2,3]	6 - 19	0.01	<0.01	0.02	0.02
Arsenic-Total (mg/L)	0.005	<0.0005	<0.0005	0.0023	0.0011
Cadmium-Total (mg/L)[4]	0.00004	<0.00002	<0.00002	<0.00002	<0.00002
Chloride-Total (mg/L)	120	0.7	1	0.8	0.7
Chromium-Total (mg/L)	NG	<0.0006	<0.0006	<0.0006	0.0009
Cobalt-Total (mg/L)	NG	<0.0005	<0.0005	<0.0005	<0.0005
Copper-Total (mg/L)[4]	0.002 - 0.002	<0.0005	<0.0005	<0.0005	<0.0005
Cyanide-Total (mg/L)	0.005	<0.001	<0.001	<0.001	<0.001
Dissolved oxygen-Field (mg/L)	6.5 - 9.5	17.89	19.12	15.98	16.79
Hardness (mg $CaCO_3$/L)	NG	9	10	11	10
Iron-Total (mg/L)	0.3	<0.01	<0.01	0.02	0.08
Lead-Total (mg/L)[4]	0.001 - 0.001	<0.0003	<0.0003	<0.0003	<0.0003
Manganese-Total (mg/L)[2,4]	0.230 - 0.260	<0.0005	<0.0005	0.0007	<0.0005
Mercury-Total (mg/L)	0.000026	<0.00001	<0.00001	<0.00001	<0.00001
Molybdenum-Total (mg/L)	0.073	<0.0005	<0.0005	<0.0005	<0.0005
Nickel-Total (mg/L)[4]	0.025 - 0.025	<0.0005	<0.0005	0.0006	<0.0005
Nitrate-Total (mg N/L)	13.0	<0.01	<0.01	<0.01	<0.01
Phosphorus-Total (mg/L)	NG	<0.01	<0.01	<0.01	<0.01
pH-Field	6.5 - 9.0	7.35	6.82	7.28	7.45
Radium-226 (Bq/L)	NG	-	-	<0.002	0.005
Selenium-Total (mg/l)	0.001	<0.0005	<0.0005	<0.0005	<0.0005
Sulphate-Total (mg/L)	NG	6.1	7.8	4.9	4.5
Temperature-Field (°C)	NG	0.53	0.61	0.78	0.82
Thalium-Total (mg/L)	0.0008	<0.0002	<0.0002	<0.0002	<0.0002
Total suspended solid (mg/L)[5]	5 - 25	16	<1	<1	1
Uranium-Total (mg/L)	0.015	<0.001	<0.001	<0.001	<0.001
Zinc-Total (mg/L)	NG	<0.001	<0.001	0.001	<0.001
Conductivity (µs/cm)	NG	15.3	36.7	27.4	30.9

Notes: NG = no guideline; 1 CCME (Canadian Council of Ministers of the Environment) Canadian Water Quality Guidelines for the Protection of Aquatic Life, 2020; 2 Guideline is pH dependent; 3 Guideline is temperature dependent; 4 Guideline is hardness dependent; 5 Guideline is relative to background values; Shaded values exceed the CCME guideline

Table 5. (Continued)

Parameter	CCME (2020) Guideline[1]	2020			
		21-Jan	22-Mar	10-May	15-Nov
TPS (Reference Area)					
Alkalinity (mg $CaCO_3$/L)	NG	47	49	9	31
Aluminium-Total (mg/L)[2]	0.100 - 0.100	<0.006	<0.006	<0.006	<0.005
Ammonia-Total (mg/L)[2,3]	6 - 19	<0.01	<0.01	0.01	<0.005
Arsenic-Total (mg/L)	0.005	<0.0005	<0.0005	<0.0005	<0.0005
Cadmium-Total (mg/L)[4]	0.00004	<0.00002	0.00003	<0.00002	<0.00002
Chloride-Total (mg/L)	120	0.9	1	0.9	0.8
Chromium-Total (mg/L)	NG	<0.0006	<0.0006	0.001	<0.0006
Cobalt-Total (mg/L)	NG	<0.0005	0.0005	<0.0005	<0.0005
Copper-Total (mg/L)[4]	0.002 - 0.002	<0.0005	0.0007	<0.0005	<0.0005
Cyanide-Total (mg/L)	0.005	<0.001	<0.001	<0.001	<0.001
Dissolved oxygen-Field (mg/L)	6.5 - 9.5	19.56	19.49	16.76	15.00
Hardness (mg $CaCO_3$/L)	NG	13	13	10	10
Iron-Total (mg/L)	0.3	<0.01	0.03	<0.01	<0.01
Lead-Total (mg/L)[4]	0.001 - 0.001	<0.0003	<0.0003	<0.0003	<0.00017
Manganese-Total (mg/L)[2,4]	0.230 - 0.260	0.001	0.0006	<0.0005	0.0011
Mercury-Total (mg/L)	0.000026	<0.00001	<0.00001	<0.00001	<0.00001
Molybdenum-Total (mg/L)	0.073	<0.0005	<0.0005	<0.0005	0.0006
Nickel-Total (mg/L)[4]	0.025 - 0.025	0.0006	<0.0005	<0.0005	<0.0005
Nitrate-Total (mg N/L)	13.0	<0.01	<0.01	0.03	<0.01
Phosphorus-Total (mg/L)	NG	<0.01	<0.01	<0.01	0.04
pH-Field	6.5 - 9.0	7.31	7.07	6.85	6.84
Radium-226 (Bq/L)	NG	0.007	<0.002	0.01	<0.002
Selenium-Total (mg/l)	0.001	<0.001	<0.001	<0.001	<0.0005
Sulphate-Total (mg/L)	NG	7.4	5.7	5.7	3.6
Temperature-Field (^oC)	NG	0.74	1.01	1.05	0.5
Thalium-Total (mg/L)	0.0008	<0.0008	<0.0002	<0.0002	<0.0002
Total suspended solid (mg/L)[5]	5 - 25	1	5	<1	<1
Uranium-Total (mg/L)	0.015	<0.001	<0.001	<0.001	<0.001
Zinc-Total (mg/L)	NG	0.002	<0.001	<0.001	<0.001
Conductivity (µs/cm)	NG	33.5	32.7	32.4	26.8

Notes: NG = no guideline; 1 CCME (Canadian Council of Ministers of the Environment) Canadian Water Quality Guidelines for the Protection of Aquatic Life, 2020; 2 Guideline is pH dependent; 3 Guideline is temperature dependent; 4 Guideline is hardness dependent; 5 Guideline is relative to background values; Shaded values exceed the CCME guideline

2.2 Effluent Mixing in the Receiving Environment

As indicated previously, with the cession of discharge to Wally Lake on October 9, 2017, the East Dike discharge to Second Portage Lake (MMER-3) is the only final discharge at the Meadowbank site and is the subject of the EEM Cycle 4 study. The diffuser location is shown in Figure 3. When discharge to Second Portage Lake first began, in 2014, during the winter period a diffuser was suspended down through a hole in the ice at the same location as the summer diffuser. In recent years the ‘summer’ diffuser has been used throughout the year.

Discharge is from a single orifice diffuser, oriented to discharge vertically upward, located approximately 45 m from shore and anchored on the bottom at a water depth of approximately 5 m. The diffuser was designed and built to be capable of discharging effluent at the rate of 12 L/sec which equals a discharge volume of 1037 m^3/day. The actual rate of discharge has always been less; the maximum recorded rate is 935 m^3/day.

Effluent mixing and the plume extent were modelled for Second Portage Lake by W.F. Baird & Associates Coastal Engineers Ltd. (Baird, 2020), and detailed methods and results were provided in the Cycle 4 study design document (C. Portt and Associates, and Kilgour & Associates Ltd., 2020). The plume extent was modelled for both summer (ice-free) and winter (ice-covered) conditions. Initial model runs were made using the design flow, which provides a theoretical worst-case scenario. Both summer and winter model runs were conducted for three plume buoyancy scenarios (negative, neutral, positive). For the summer scenario wind conditions were also varied (near stagnant, low, median, and high). For the winter scenarios ice thickness was varied (negligible, 0.5 m, 1 m, and 2 m). The results of the initial model runs were used to determine the scenario that would result in the largest plume under both summer and winter conditions (Figure 3). The plume extent was then modelled at minimum, maximum and mean flow rates for the scenario that would result in the largest plume under both summer and winter conditions and for the ‘typical’ summer and winter conditions. Key results of the plume modeling include:

- For all scenarios, at the design flow, which is the theoretical maximum, the effluent concentration 250 m from the outfall is less than 1%.
- For winter scenarios (ice cover present) the plume is predicted to be largest if the effluent is negatively buoyant and the ice thickness is two meters. The maximum extent of the 1% plume under this scenario, at the maximum reported winter flow rate, is 86 m. In other words, the 1% plume is predicted to not reach to or beyond 100 m when there is ice cover.
- For summer conditions, at the design flow, the 1% plume extends beyond 100 m for a number of scenarios.
- Under what are considered typical summer conditions, which are a neutrally buoyant plume and median wind, at the mean summer effluent discharge rate the maximum predicted extent of the 1% plume is 84 m. Under the same conditions, at the minimum discharge rate the 1% plume extends 162 m. The plume is larger at lower discharge rates due to the lower velocity of the effluent jet as it exits the diffuser.

- The largest plume extent under summer conditions is predicted for a negatively buoyant plume and low wind condition. At the mean summer discharge rate, under these conditions the 1% plume only extends for 18 m. At the maximum reported summer discharge rate, however, under these conditions the 1% plume extends for 220 m.

- The plume will attach to the shoreline for all cases.

Effluent was not being discharged during benthic invertebrate sample collection from August 21 to 26, 2020 (Table 2), and therefore delineation of the effluent plume could not be completed at that time.

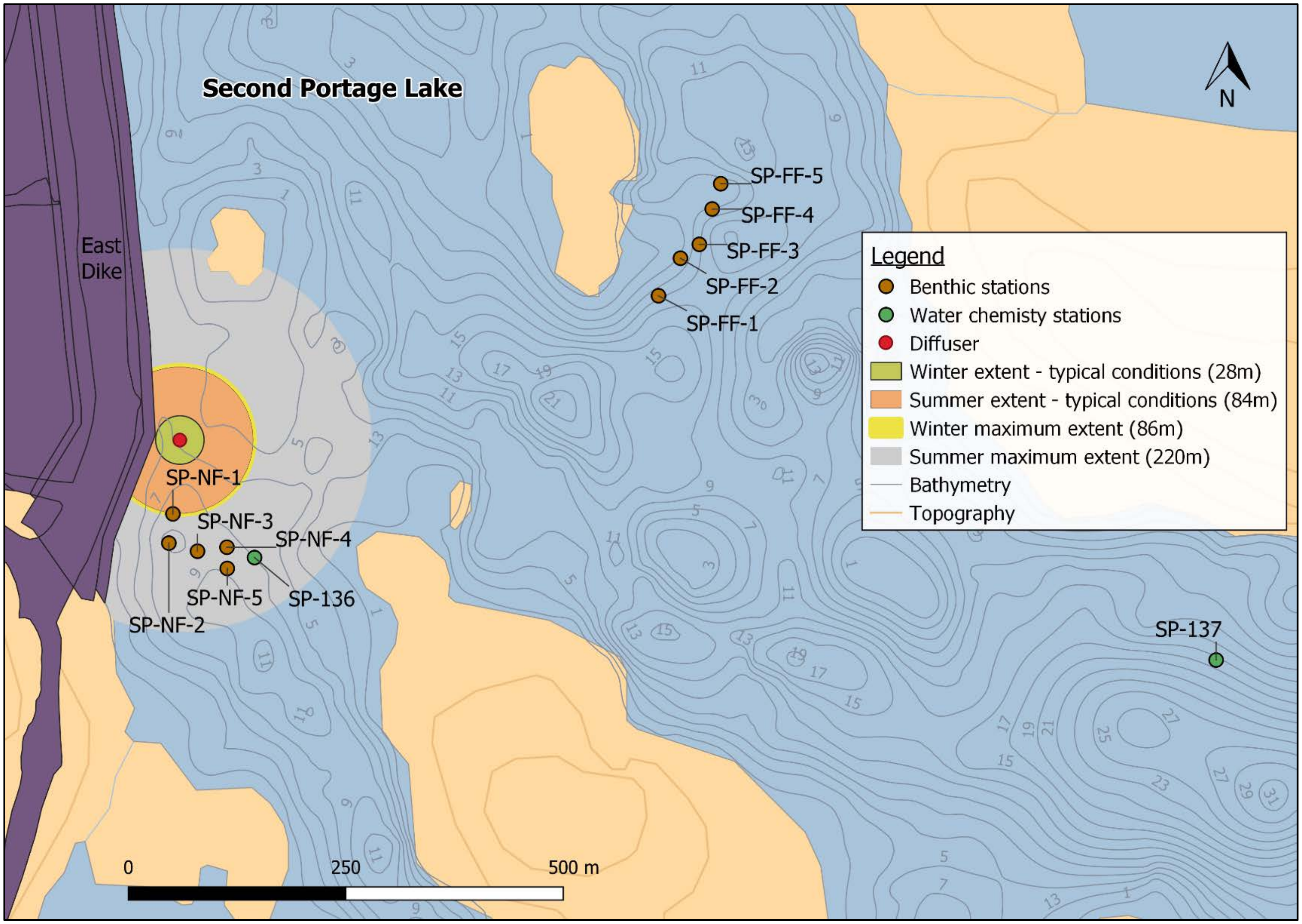

Figure 3. Second Portage Lake (SP) exposure area, including the diffuser (discharge point), and nearfield (NF) and farfield (FF) benthic and water quality stations. Modeled plume extents are shown for typical conditions and worst-case conditions at the maximum measured discharge rate for the period February 18, 2017, through December 31, 2019

2.3 Overview of Study Design Changes

There were no changes to design of the executed field program. The Cycle 4 EEM benthic invertebrate community study utilized the same two reference areas (PDL and INUG) that have been used in previous EEM studies and two exposure areas (nearfield and farfield) in Second Portage Lake, testing multiple hypotheses to evaluate potential effluent-related effects.

3.0 FISH POPULATION STUDY

The MDMER requires that a study respecting fish population is required, if the highest concentration of effluent in the exposure area, during a period in which there are deposits, is greater than 1% at any location that is 250 m or greater from a point at which the effluent enters the area from a final discharge point. CORMIX modeling indicated that there are no scenarios when the 1% effluent plume extends to or beyond 250 m from the point of discharge (Section 2.2, Figure 3). A fish study was, therefore, not required based on the 1% plume extent.

4.0 BENTHIC INVERTEBRATE COMMUNITY SURVEY

4.1 Introduction

This Cycle 4 EEM benthic invertebrate community study uses a before-after-control-impact (BACI) study design to assess benthic communities from two exposure areas in SP (Figure 3) and two reference areas, one in INUG (Figure 4), and one in PDL (Figure 5). The two exposure areas are: (1) a nearfield sampling area (SP-NF) within a 220 m radius of the effluent discharge point and (2) a farfield sampling area (SP-FF), where benthic collections have traditionally occurred (Figure 3). The farfield exposure area has the potential to control for historical influences of dike construction and ongoing influences of East dike operation. The study includes data collected in 2020 as well as data collected in previous years as part of the Core Receiving Environment Monitoring Program (CREMP).

Five sampling stations were nested within each sampling area. Sampling depths were targeted to be 7 to 8 m, with sampling stations minimally 20 m apart to ensure a minimum of statistical independence among stations.

Sample collection and processing followed the methodology used by the CREMP. Two sub-samples of the benthic community were collected from each sampling station and composited. However, at the suggestion of Environment and Climate Change Canada (ECCC), three grabs were collected from one station at SP-NF and kept separate for sorting and identification in order to support estimation of within-area variance and precision of core indices of composition, and to evaluate the precision provided by the two-grab samples in this EEM program.

Variability in core indices of composition among stations was used to judge the significance of variations among areas. Stations were therefore the unit of replication.

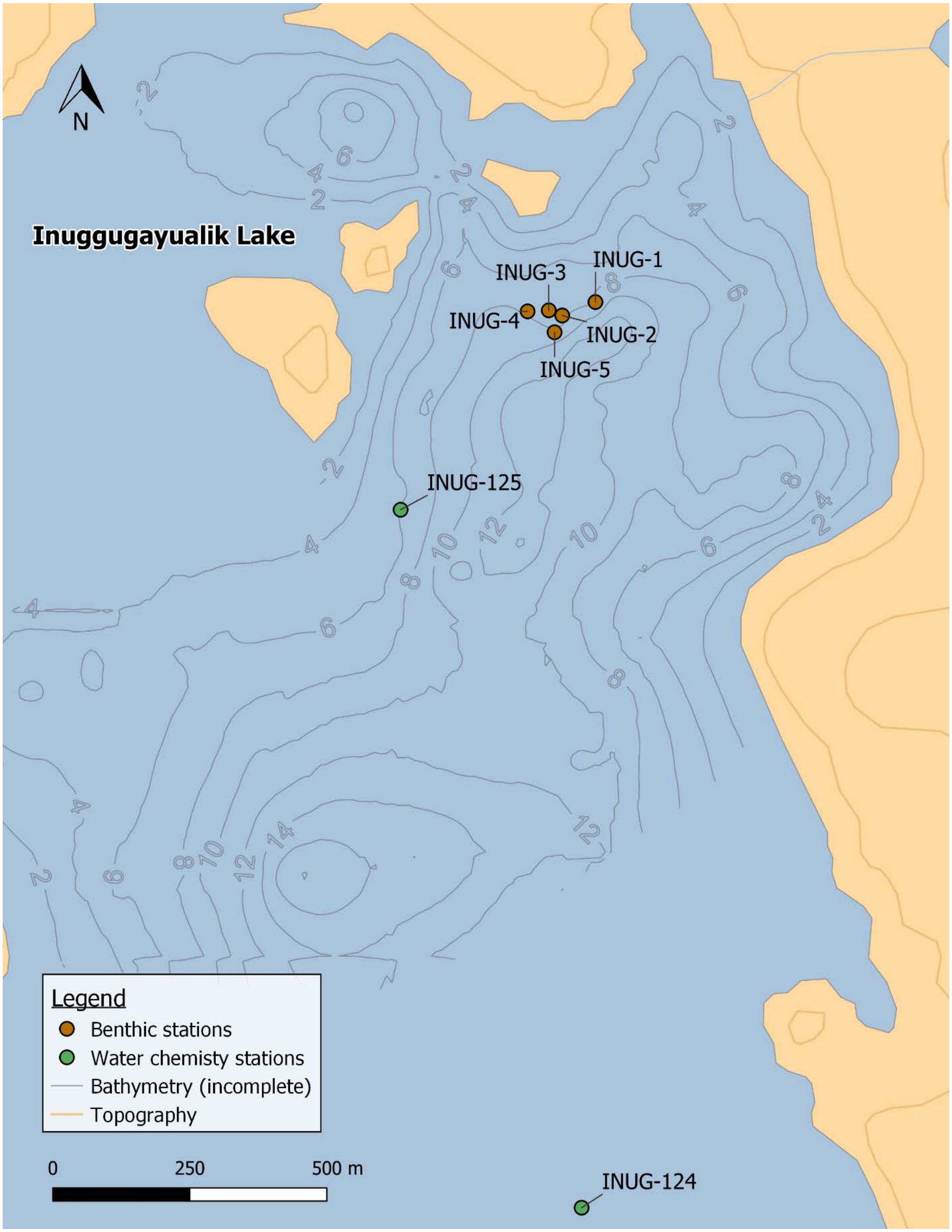

Figure 4. Inuggugayualik Lake (INUG) reference area

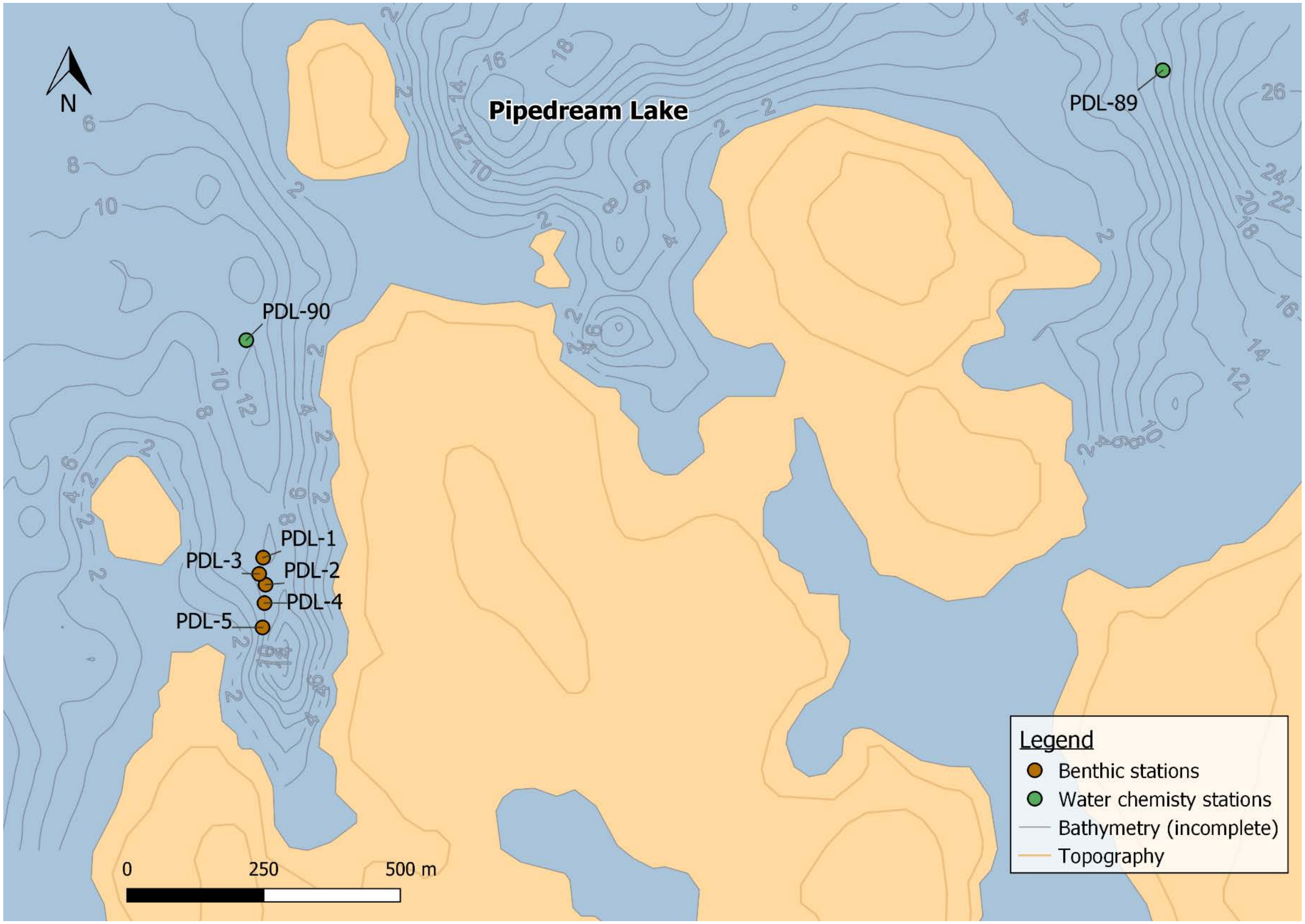

Figure 5. Pipedream Lake (PDL) reference area.

4.2 Materials and Methods

4.2.1 Benthic Sample Collection

Benthic invertebrates were collected on August 21 (INUG; reference area), August 22 (PDL; reference area) and August 26 (SP-NF, and SP-FF; exposure areas), 2020, with five sampling stations nested within each of these areas (Table 6). Water depth at the point of sampling was determined using an electronic sonar device. Samples were collected from a boat using a cleaned, stainless steel petite Ponar (0.023 m^2). Samples were washed/sieved on site using a 500-µm Nitex bag, transferred to a 1-L plastic bottle, and preserved with 10% buffered formalin. Sample sediments were always sieved down such that the residue (sediments and animals) amounted to less than around 100 ml of material. Duplicate samples (< ~200 ml), per station, were combined in the field. Triplicates from SP-NF station 1 were kept separate in the field for individual analysis by the taxonomist. Sample containers were packed in coolers/plastic totes and transported to Zaranko Environmental Assessment Services (ZEAS), who provided taxonomic services for these and all previous CREMP and EEM benthic invertebrate samples collected since 2006.

Table 6. Benthos sampling locations, Meadowbank Mine 2020

Area	Station	Latitude (dd mm ss)	Longitude (dd mm ss)	Zone	Easting (m)	Northing (m)
INUG	1	65° 3'7.82"N	96°23'22.19"W	14 W	622835	7216807
	2	65° 3'7.13"N	96°23'26.93"W	14 W	622774	7216783
	3	65° 3'7.45"N	96°23'28.81"W	14 W	622749	7216792
	4	65° 3'7.44"N	96°23'31.72"W	14 W	622711	7216790
	5	65° 3'6.15"N	96°23'28.10"W	14 W	622760	7216752
PDL	1	65° 6'18.25"N	96°13'1.36"W	14 W	630686	7223044
	2	65° 6'16.63"N	96°13'1.22"W	14 W	630690	7222994
	3	65° 6'17.29"N	96°13'2.00"W	14 W	630679	7223014
	4	65° 6'15.57"N	96°13'1.49"W	14 W	630688	7222961
	5	65° 6'14.12"N	96°13'1.87"W	14 W	630685	7222916
SP-NF	1	65° 1'8.06"N	96° 2'23.55"W	14 W	639451	7213828
	2	65° 1'7.01"N	96° 2'24.05"W	14 W	639446	7213795
	3	65° 1'6.64"N	96° 2'21.57"W	14 W	639479	7213785
	4	65° 1'6.75"N	96° 2'18.96"W	14 W	639513	7213790
	5	65° 1'5.97"N	96° 2'18.97"W	14 W	639514	7213766
SP-FF	1	65° 1'15.32"N	96° 1'40.08"W	14 W	640009	7214079
	2	65° 1'16.66"N	96° 1'37.94"W	14 W	640035	7214122
	3	65° 1'17.15"N	96° 1'36.28"W	14 W	640056	7214138
	4	65° 1'18.42"N	96° 1'34.99"W	14 W	640071	7214178
	5	65° 1'19.34"N	96° 1'34.13"W	14 W	640081	7214207

4.2.2 Supporting Environmental Variables

4.2.2.1 Water

Water samples were collected the same day that benthic samples were collected. Water was collected from two randomly selected locations situated near the benthos sampling areas (Table 7). Water depth at the point of sampling was determined using an electronic sonar device. The lakes were not thermally or chemically (determined by specific conductance) stratified, so water was collected from 3 m below surface. Samples in the past have all similarly been collected from 3 m below surface. The analytes and their detection limits, determined in water by ALS Environmental Ltd., Burnaby, British Columbia, are provided in Table 8.

Specific conductance (µS/cm), pH, dissolved oxygen (mg/L) and temperature (°C) were determined at the time of benthic invertebrate sample collection with a YSI Professional Plus. Meter calibration was undertaken daily following the methods in the user manual. Parameter resolution and accuracy were as follows:

- Specific conductance; resolution: 1 µS/cm, accuracy: the greater of ±1% of reading or 1 µS/cm.
- pH; resolution: 0.01 units, accuracy: ±0.2 units.
- Dissolved oxygen; resolution: 0.1 mg/L, accuracy: the greater of ±2% of reading or 0.2 mg/L.

- Temperature; resolution: 0.1°C, accuracy: ±0.2°C.

These parameters were measured at 1 m intervals from surface to 1 m off bottom, in each sampling area, to document the level of stratification at the time of benthic invertebrate sampling.

Table 7. Locations of water chemistry profiles and samples, Meadowbank Mine 2020

Area	Water Sample	Depth (m)	Latitude (dd mm ss)	Longitude (dd mm ss)	Zone	Easting (m)	Northing (m)
INUG	INUG-124	5.7	65° 2'56.10"N	96°23'50.59"W	14 W	622478	7216428
	INUG-125	9.2	65° 2'14.58"N	96°23'29.39"W	14 W	622809	7215155
PDL	PDL-89	12.2	65° 6'31.13"N	96°13'2.39"W	14 W	630655	7223442
	PDL-90	16.1	65° 6'44.67"N	96°10'52.31"W	14 W	632332	7223936
SP-NF	SP-136	6.8	65° 1'6.31"N	96° 2'16.56"W	14 W	639545	7213778
SP-FF	SP-137	17.5	65° 1'0.82"N	96° 0'52.61"W	14 W	640651	7213660

Table 8. Water quality parameters and associated detection limits, Meadowbank Mine 2020

Parameter	Detection Limit	Units
Conductivity	2	µS/cm
Hardness	0.5	mg/L
pH	0.1	-
Total Suspended Solids	1	mg/L
Total Dissolved Solids	3	mg/L
Turbidity	0.1	NTU
Alkalinity	1	mg/L
Ammonia	0.005	mg/L
Bromide	0.05	mg/L
Chloride	0.1	mg/L
Fluoride	0.02	mg/L
Nitrate	0.005	mg/L
Nitrite	0.001	mg/L
Total Kjeldahl Nitrogen	0.05	mg/L
Ortho Phosphate	0.001	mg/L
Total Phosphorus	0.002	mg/L
Silicate	0.5	mg/L
Sulfate	0.3	mg/L
Total Cyanide	0.001	mg/L
Free Cyanide	0.001	mg/L
Dissolved Organic Carbon	0.5	mg/L
Total Organic Carbon	0.5	mg/L
Aluminum	0.003	mg/L
Antimony	0.0001	mg/L
Arsenic	0.0001	mg/L
Barium	0.00005	mg/L
Beryllium	0.0001	mg/L

Parameter	Detection Limit	Units
Bismuth	0.00005	mg/L
Boron	0.01	mg/L
Cadmium	0.000005	mg/L
Calcium	0.05	mg/L
Chromium[4]	0.0001	mg/L
Cobalt	0.0001	mg/L
Copper	0.0005	mg/L
Iron	0.01	mg/L
Lead	0.00005	mg/L
Lithium	0.001	mg/L
Magnesium	0.1	mg/L
Manganese	0.0001	mg/L
Mercury	0.000005	mg/L
Molybdenum	0.00005	mg/L
Nickel	0.0005	mg/L
Phosphorus	0.05	mg/L
Potassium	0.1	mg/L
Selenium	0.00005	mg/L
Silicon	0.1	mg/L
Silver	0.00001	mg/L
Sodium	0.05	mg/L
Strontium	0.0002	mg/L
Sulfur	0.5	mg/L
Thallium	0.00001	mg/L
Tin	0.0001	mg/L
Titanium	0.0003	mg/L
Uranium	0.00001	mg/L
Vanadium	0.0005	mg/L
Zinc	0.003	mg/L

4.2.2.2 Sediment

Sediment samples were collected from each benthic invertebrate sampling station and analyzed for:

- Total organic carbon (%); and,
- Sediment particle size (% gravel, sand, silt, clay), per the Wentworth Classification.

Detection limits for sediment quality measures are provided in Table 9 below.

Table 9. Sediment measures and associated detection limits, Meadowbank Mine 2020

Parameter	Detection Limit	Units
% Gravel (> 2 mm)	1	%
% Sand (2 mm to 0.063 mm)	1	%
% Silt (0.063 mm to 4 μm)	1	%
% Clay (<4 μm)	1	%
Total Organic Carbon	0.1	%

Grain size data were used to compute an overall summary variable describing mean particle size (GMP).

$$GMP = \left[{d_g}^{w_g}\right] * \left[{d_{sa}}^{w_{sa}}\right] * \left[{d_{si}}^{w_{si}}\right] * \left[{d_c}^{w_c}\right]$$

where, d is the midpoint diameter of particles retained by a given sieve for gravel (g), sand (sa), silt (si) and clay (c), and w is the decimal fraction by weight of particles retained by a given sieve.

4.2.3 Data Analysis

4.2.3.1 Data

The data utilized in this interpretive report include all prior annually collected benthic community samples from INUG, PDL, SP-NF and SP-FF from 2006 to 2020. Benthic community samples were collected from SP-NF in 2020 only. There were always five sample stations per area per year as per Agnico's CREMP sampling design, with the exception of 2006 when only three stations were sampled in INUG and at SP-FF. PDL was not sampled in 2006, 2007 or 2008. In total, there were 211 two-grab benthos samples in the data set per Table 10 below.

Table 10. Summary of number of benthos stations per sample area, by year, Meadowbank Mine

Exposure Period	Year	Area				Grand Total
		INUG	PDL	SP-NF	SP-FF	
Baseline Period 1	2006	3			3	6
	2007	5			5	10
	2008	5			5	10
Baseline Period 2	2009	5	5		5	15
	2010	5	5		5	15
	2011	5	5		5	15
	2012	5	5		5	15
	2013	5	5		5	15
Exposure Period	2014	5	5		5	15
	2015	5	5		5	15
	2016	5	5		5	15
	2017	5	5		5	15
	2018	5	5		5	15
	2019	5	5		5	15
	2020	5	5	5	5	20
	Grand Total	73	60	5	73	211

4.2.3.2 Descriptors of Benthic Community Composition

Benthos counts were provided in an Excel spreadsheet. Organisms were identified to lowest practical level. The data were ‘rolled up’ to the level of Family for the analyses in this EEM Interpretive Report. Acarina were identified to genus only in 2017, and not in other years (only identified to Acarina in previous years). The 2017 genera were rolled up to Acarina to be consistent with the level of identification in previous years.

For each sample, the following descriptors of community composition and indices were calculated, as per the federal guidance for metal mining EEM (Environment Canada, 2012):

- Total density (total number of animals per m^2);
- Taxon Richness (number of Families),
- Evenness (E), where,

$$E = 1/\sum(p_i)^2/S;$$

- Bray-Curtis (BC) Distance Index, where,

$$BC = \frac{\sum |y_{i1} - y_{i2}|}{\sum (y_{i1} - y_{i2})}$$

Where, y_{i1} = density of family *i* in sample 1, y_{i2} = density of family *i* in sample 2.

Bray-Curtis distances were computed between all pairs of the n=211 samples. Densities were log transformed to provide reasonable NMDS scores. The Bray-Curtis distance matrix was used as the input distance matrix for an NMDS-based ordination carried out in SYSTAT. Two NMDS axes were produced by the ordination. Pearson correlations between raw taxa (family) densities and sample scores on each of the NMDS axes were computed. A scatterplot of taxa correlations was produced in order to illustrate the relationship between taxa densities and NMDS axis scores. Scatterplots of NMDS sample scores, by year, were produced in order to illustrate variations in benthic community composition among sample areas, over time.

4.2.3.3 Testing for Effluent Related Effects

To determine if variations in benthic community structure are associated with mine effluent, a combination of graphical and hypothesis testing procedures (Analysis of Variance, ANOVA) were used. Classical ANOVA was used to test for changes in differences in average values of compositional indices between reference and exposure areas.

The full complement of baseline and exposure period data (see Table 10) were used in an analysis of variance with Planned Linear Orthogonal Contrasts (or PLOC; see Hoke et al., 1990; Environment Canada and Department of Fisheries and Oceans, 1995). PLOC can test very specific hypotheses that are likely to be of interest. Hypotheses 1, 2a, 2b, 3a and 3b were the tested contrasts as illustrated in Table 11 below.

With this EEM program, sampling areas represent three levels of exposure: (1) reference; (2) nearfield; and (3) farfield. There are also three time periods to consider: (1) Baseline Period 1 which was before the East dike was constructed (i.e., 2006 and 2007); (2) Baseline Period 2 which was after the East dike, and before effluent exposure in SP (i.e., 2008 to 2013); and (3) Effluent Exposure Period in SP (i.e., 2014 to present). The nearfield sampling area has been influenced by dike construction/operation in addition to effluent release. The farfield sampling area was influenced by dike construction (Azimuth, 2011). The farfield sampling area is outside the 1% mixing zone and so is much less likely to have been influenced by mine effluent. Comparison of the nearfield and farfield sampling areas has the potential to identify mine-effluent effects, with the caveat that differences between nearfield and farfield sampling areas may also be natural; there are no data in the nearfield sampling area prior to effluent exposure.

<u>ANOVA 1</u> tested the hypothesis that there are no differences in indices of benthic community composition between SP-NF and the two reference lakes in 2020 (H01). This is the conventional EEM ANOVA. Data from all other baseline periods were used to put observed differences, if significant, into context of: (1) natural variations (i.e., as observed in the reference lakes and in SP during baseline 1); or, (2) dike related influences (i.e., as observed in SP during baseline 2). Acceptance of the null hypothesis, i.e., no significant differences, would support a conclusion that there are no effluent-related effects. Rejection of the null hypothesis, i.e., of no differences, would suggest the potential for effluent related effects, prompting ANOVA 2.

<u>ANOVA 2</u> tested the simple hypothesis that there are no significant differences in indices of benthic community composition between the nearfield exposure area and the farfield exposure area during the exposure period. This hypothesis 2a (H02a) was tested using effluent exposure period data from 2014 through 2020 in the farfield exposure area with contrast to the nearfield exposure-area data; hypothesis 2b (H02b) of this test used only the farfield effluent exposure period data from 2020 as a contrast to the nearfield data. No significant difference in either version of the test would support a conclusion that the reference-exposure difference from ANOVA 1 was potentially a function of the dike, and not effluent. A significant difference in both tests would suggest an effluent-related effect or would imply that the nearfield and farfield areas had natural differences in index values, prompting ANOVA 3.

<u>ANOVA 3</u> tested the hypothesis that indices of benthic community composition in the farfield exposure area were the same during the baseline period as during the effluent exposure period. Hypothesis 3a (H03a) of this test used the effluent exposure period data from 2014 to 2020 as a contrast to the baseline period data of 2006 and 2007. Hypothesis 3b (H03b) of this test used the data only from 2020 as a contrast to the baseline period data. If the hypothesis is accepted in both versions of the test, then differences between the nearfield and exposure area benthos can be concluded to have been related to effluent exposure.

For these ANOVAs, the variation among stations was used to judge the significance of the contrasts. The mean squared error term (MSE) was estimated through an omnibus ANOVA that incorporates data from all sample areas and years. Doing that ensures the most robust estimate of among station variability (i.e., among station SD), and therefore the most robust evaluation of the hypotheses.

Table 11. Linear contrasts (and associated coefficients) that were used to analyze the 2020 benthic community data from SP, INUG and PDL (Meadowbank Mine)

Year	Exposure Period	ANOVA 1				ANOVA 2a				ANOVA 2b			
		Nearfield vs Reference in 2020 (evaluate reference vs combined effects of berm and effluent)				Nearfield vs Farfield in 2020 (evaluate effluent vs effects of berm)				Nearfield vs Farfield in 2020 (evaluate effluent vs effects of berm)			
		Reference		Nearfield	Farfield	Reference		Nearfield	Farfield	Reference		Nearfield	Farfield
		INUG	PDL	Second Portage		INUG	PDL	Second Portage		INUG	PDL	Second Portage	
2006	Baseline Period 1 (before the berm)		no data	no data			no data	no data			no data	no data	
2007													
2008	Baseline Period 2 (before effluent exposure)												
2009													
2010													
2011													
2012													
2013													
2014	Exposure Period								0.143				
2015									0.143				
2016									0.143				
2017									0.143				
2018									0.143				
2019									0.143				
2020		0.5	0.5	-1.0	0			-1	0.143			1	-1
Power		0.963				0.992				0.892			

Year	Exposure Period		ANOVA 3a				ANOVA 3b			
			Farfield baseline vs Farfield exposure				Farfield baseline vs Farfield exposure			
			Reference		Nearfield	Farfield	Reference		Nearfield	Farfield
			INUG	PDL	Second Portage		INUG	PDL	Second Portage	
2006	Baseline Period 1 (before the berm)			no data	no data	0.5		no data	no data	0.5
2007						0.5				0.5
2008	Baseline Period 2 (before effluent exposure)									
2009										
2010										
2011										
2012										
2013										
2014	Exposure Period					-0.143				
2015						-0.143				
2016						-0.143				
2017						-0.143				
2018						-0.143				
2019						-0.143				
2020						-0.143				-1
Power			0.999				0.963			

Table Notes: Statistical power (probability of detecting an effect when the effect size is ±2x reference area standard deviation) is also provided for each contrast.

4.2.3.4 Assessment of Covariable Effects

Prior to running ANOVAs, we examined the associations between benthos and potential modifying factors (i.e., depth, substrate texture, sediment TOC) using backwards, stepwise, multiple regression. For indices that were significantly influenced by a modifying factor, we standardized the data using general linear models based on reference data, with application of the models to exposure data (per Bailey et al., 1998; Kilgour et al., 2018). Standardized benthic indices (i.e., standardized to a common depth, grain size, and/or TOC, as appropriate) were then the inputs to the ANOVAs.

4.2.3.5 Assessment of Bray-Curtis Distances

We used Mantel tests to test the hypotheses listed in Table 11, and using the methods described by Borcard and Legendre (2013). Mantel tests were completed in *R* Software. As there is no simple way in a Mantel test to partial-out the effects of covariables such as depth, grain size and/or TOC, the Bray-Curtis distances were used to compute NMDS axis scores which were modelled in a similar fashion as the other core and supporting indices of composition.

4.2.3.6 Comparison to Reference Normal Ranges

Variations tested by HO1, HO2a,b and HO3a,b were put into context using normal ranges computed from reference data. Normal ranges are conventionally thought of as the range of data that captures 95% of observations (from a reference condition), and are approximated by

$$95\%\, region = \bar{x} \pm 2SD$$

Where, $\bar{x}$ is the reference data mean, and SD is the standard deviation of the reference data (Kilgour et al., 1998; 2017). The value "2" is rounded up from the standard normal deviate of 1.96 for the 97.5th percentile for a normal distribution. In EEMs, the SD term is normally that for replicates (typically 5) within the reference sampling area (typically only 1 area). Here, we desired to estimate the normal range of reference data for the two reference lakes INUG and PDL (considered 'randomly' chosen from a statistical perspective). There were also multiple years of data from each lake (15 years in INUG and 12 years in PDL), with years also considered 'random'. Within each year and lake there were generally 5 replicate benthic samples (there were only three samples in INUG in 2006) again, with replicate samples considered 'random'. The calculation of SD for cases like this when there are nested random effects (i.e., replicates within areas within times) is somewhat more involved if it is to be done with accuracy. Here, we used the Parametric Bootstrap Method as described by Smith (2002). [Note: the study design had indicated we would use the Bagui Method as described by Smith, 2002, but we found that the Bootstrap Method more accurately determined the limits of the normal ranges via a simulation experiment (B. Kilgour, unpublished data)].

The Parametric Bootstrap Method involves the following general steps (from Smith, 2002):

1. Compute the following variance terms from an analysis of variance of the reference data from INUG and PDL with the following source terms: Year, Lake, Error;
    a. Variance among replicates (i.e., error);
    b. Variance among years;
    c. Variance among lakes.
2. Use the variance terms to set up a simulation exercise (here with 100 'runs') that draws random samples for INUG and PDL given the observed variance terms.
3. For each 'run', do the following
    a. compute variance components for 'lake' (S_L^2), 'year' (S_Y^2), and sample or 'error' (S_E^2);
    b. compute the standard deviation of replicates, (S_x^2) considering sample, year, and lake terms, as $S_x = \sqrt{S_L^2 + S_Y^2 + S_E^2}$;

   c. compute estimated tolerance limits for the reference data as $tolerance\ limits = \bar{x} \pm kSD_x$, where k is a tolerance factor for the 97.5th percentile with *n*-1 degrees of freedom (and where *n* is the total sample size across lakes and years).

4. From the 100 simulated upper tolerance limits, compute the 95th percentile as the bound for the upper end of reference data; and,

5. From the 100 simulated lower tolerance limits, compute the 5th percentile of as the bound for the lower end of reference data.

The calculations of normal ranges were applied to 'residuals' of the core indices of composition, since (and as is shown later) variations in the core indices varied significantly with underlying co-variables (total organic carbon, water depth, grain size). The limits as calculated represent the range within which it can be anticipated with 95% likelihood that a new reference sample (from either lake or any time period) would likely occur (Smith, 2002).

4.2.3.7 Presentation of Basic Statistics

Sample area means, medians, standard deviations, standard errors, minimum and maximum values for densities, family richness, and evenness were computed for 2020 data. The mean, median, SD, SE, minimum and maximum BC distances within reference (INUG and PDL), SP-NF and SP-FF were calculated using only 2020 data, in addition to statistics for BC distances between SP-NF and reference (INUG and PDL), between SP-NF and INUG, between SP-NF and PDL and between SP-NF and SP-FF.

The general equation for effect sizes that applied to all hypotheses, was the following:

$$ES_{HO} = \frac{\sum c_i \bar{x}_i}{SD_x}$$

Where;

- c_i are the contrast coefficients indicated in Table 11 for each lake x time combination (*i*) ;
- $\bar{x}_i$ are the lake x time means; and,
- SD_x is as defined above.

We did not compute an effect size for the Mantel tests on Bray-Curtis distances since there is no guidance on how to do so and further no guidance on how to interpret the relevance of the Mantel correlation (Environment Canada, 2012; Borcard and Legendre, 2013).

4.2.3.8 Statistical Power

The ability to detect an effect depends on sample size; where the study relies on a contrast of reference versus exposure locations, sample sizes refer to the number of replicate stations within both reference and exposure areas. Environment Canada (2012) has deemed that effects that exceed two times the standard deviation of reference-station values (i.e., $\pm 2SD_r$) will require further investigation. Therefore, it is necessary to calculate the probability that a difference of $\pm$ $2SD_r$ could be detected with a certain number of stations in both control and impact sampling areas.

In this study, power for each of the contrasts was computed in PASS 2020 v20.0.1, following Desu and Raghavarao (1990), Fleiss (1986) and Kirk (1982), with the critical effect size (CES) being 2SD_r in magnitude, and with SD_r being the equivalent of the SD_E described earlier.

4.2.3.9 Precision

Statistical power is a function of the underlying true effect size (or correlation) and number of replicate samples. In this EEM study, stations were considered the unit of replication, so it was the number of replicate stations within each area that was of critical importance in determining the power of the study. An additional factor indirectly influencing the power of a study is the degree of precision with which descriptors of community composition have been estimated. In benthic ecology, it is generally recommended that descriptors of community composition be estimated to within ± 20% of the actual (true) value (Elliott, 1977), which is what is stated in Environment Canada's (2012) guidance document.

The precision (*P*) of within-station estimates can be estimated as:

$$P = \frac{S}{\sqrt{n}\bar{x}}$$

where *s* is the within-station standard deviation, n is the number of replicate (field) sub-samples, and $\bar{x}$ is the estimated mean of the community descriptor. This equation can be re-arranged to solve for the number of replicate samples required to achieve the desired precision (*P*) of 0.2 (i.e., 20%):

$$n = \frac{S^2}{P^2\bar{x}^2}$$

The standard deviation can be estimated for each station separately, resulting in an estimated number of samples required to achieve the desired precision for the next study.

4.3 Results

4.3.1 Supporting Environmental Variables

4.3.1.1 General Limnology

Profiles of each lake indicated that they were similar in terms of dissolved oxygen and temperature (Figure 6). Dissolved oxygen was between 9 and 10 mg/L from surface to 1 m off bottom in each lake. There was no indication of a dissolved oxygen depression near the sediments in any of the three lakes. Temperature profiles in all three lakes were similar in that temperatures were homogeneous from surface to bottom, with only 1°C difference between SP (12°C) and both INUG (13°C) and PDL (11°C). Specific conductivity profiles in all three lakes were also homogeneous from surface to bottom, with the highest conductivity at SP-FF (36.7 µS/cm), followed by SP-NF (35.7 µS/cm), PDL (23.4 µS/cm) and INUG (16.3 µS/cm).

The three benthos sampling areas were similar in terms of depth (Figure 7). The benthic stations in each lake were of similar depth, averaging 8.2 m in INUG, 7.8 m in PDL, 8.0 m at SP-NF and 8.1 m at SP-FF. Water depths for stations in 2020 were also similar to previous years (Figure 7).

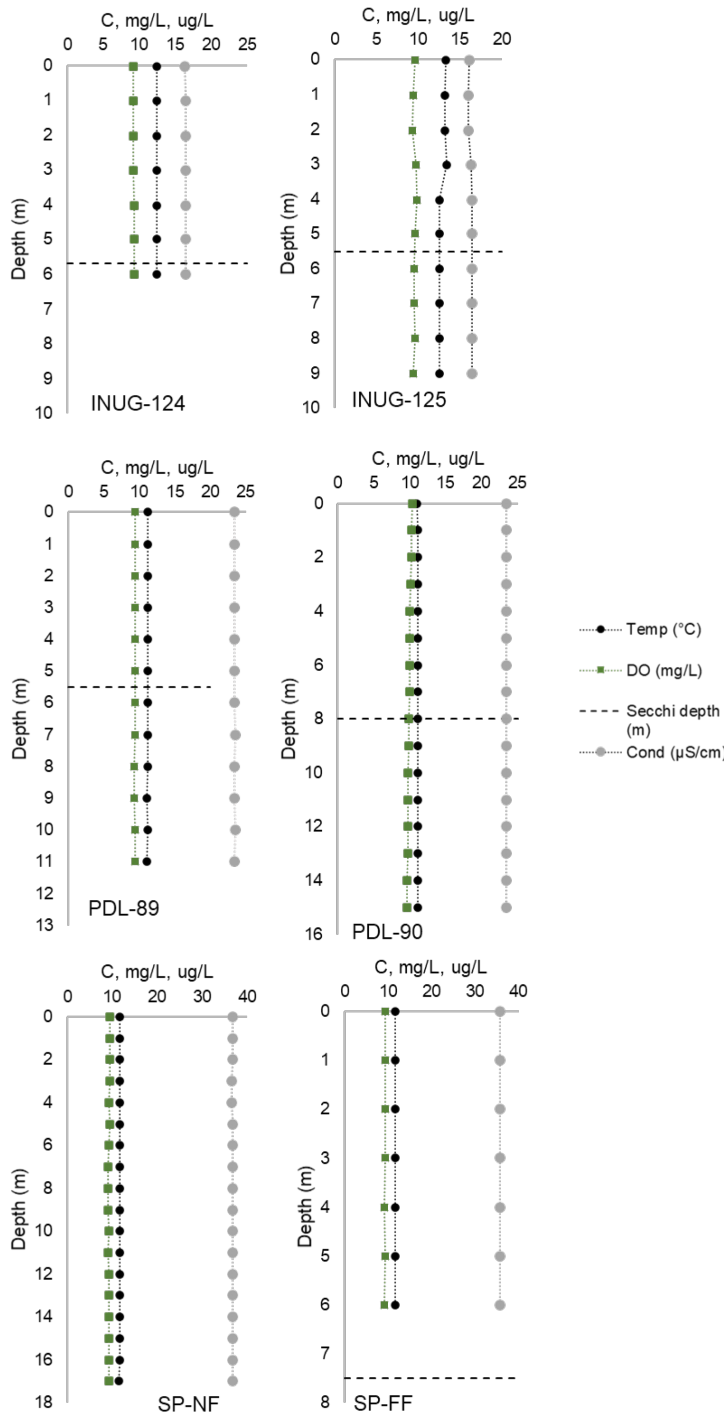

Figure 6. Depth profiles for water temperature, dissolved oxygen (DO) and conductivity, in each of the three benthos sampling areas, INUG, PDL, SP-NF and SP-FF.

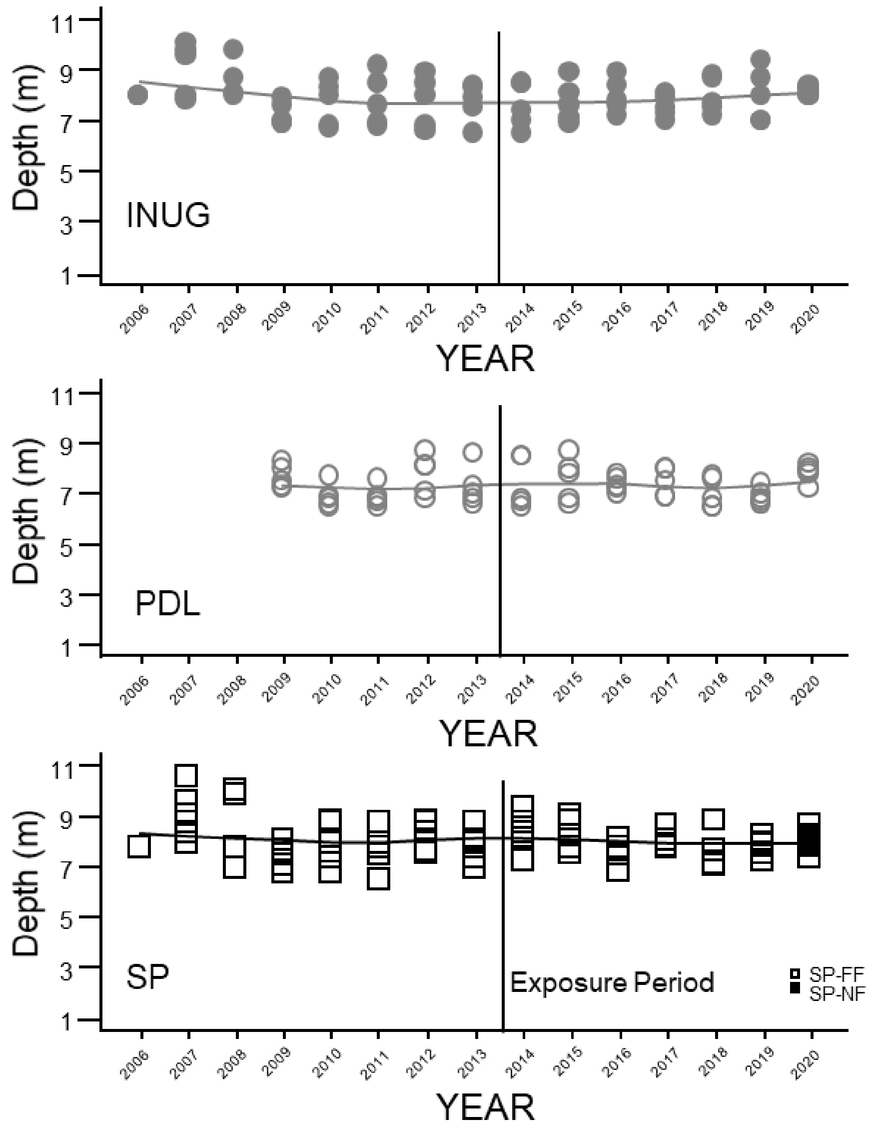

Figure 7. Water depth among years for INUG, PDL and SP, Meadowbank Mine

Figure Note: the line illustrates Locally Weighted Scatterplot Smoothing (LOWESS)-smoothed variations in annual averages.

4.3.1.2 Laboratory Water Chemistry

Detailed chemistry results for the benthos sampling areas are provided in Table 12. QA/QC for analytical chemistry is provided in Appendix 2. All RPD values were ≤ 20%.

The waters from the two control lakes were very ‘soft’, with hardness values of around 5.7 and 9.3 mg/L at INUG and PDL, respectively. Hardness at SP was higher, at around 13.9 mg/L. Total ammonia concentrations were around 0.017 mg/L in SP, similar to concentrations at INUG (0.007 mg/L) and PDL (0.015 mg/L). Chloride concentrations in SP were around 0.78 mg/L, similar to INUG (0.83 mg/L) and PDL (0.68 mg/L), but very low relative to the water quality guideline of 120 mg/L. Orthophosphate and total dissolved phosphorus were at non-detectable concentrations in all three lakes. Sulphate concentrations were higher in SP (5.1 mg/L) relative to the control lakes INUG (0.99 mg/L) and PDL (1.88 mg/L).

Measured concentrations of total metals never exceeded CCME guidelines for the protection of aquatic life (Table 12). Many of the metals were at or near non-detectable concentrations in all three lakes, including Sb, Be, Bi, B, Cd, Cr, Co, Cu, Pb, Li, Hg, Mo, Ni, P, Se, Ag, S, Tl, Sn, Ti, V and Zn. Concentrations of some metals were modestly higher in SP than in the reference lakes, including As, Ba, Fe, Mg, Mo, K, Si and Sr.

Concentrations of the cations Ca, K and Na were higher in SP than the two reference lakes, reflecting the higher hardness in SP. Sulfur was at non-detectable concentration in INUG and PDL (i.e., < 0.5 mg/L), and was about 3x the detection limit in SP (1.5 mg/L). Silicon concentrations exceeded the detection limit of 0.05 mg/L in all lakes.

Table 12. Detailed water quality for the benthos monitoring areas, Meadowbank Mine 2020

Variable	Units	CCME	INUG-124	INUG-125	PDL-89	PDL-90	SP-136	SP-137
Physical Tests								
Conductivity	µS/cm		15.7	15.6	22.5	22.7	35.4	35.8
Hardness (as $CACO_3$)	mg/L		5.5	5.8	9.4	9.3	13.9	13.9
pH (Laboratory)			6.78	6.80	7.00	7.00	7.12	7.16
Total Suspended Solids	mg/L		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Dissolved Solids	mg/L		13.2	9.4	15.8	15.4	22.2	22.4
Turbidity	NTU		0.19	0.16	0.14	0.12	0.15	0.14
Anions and Nutrients								
Alkalinity, Total	mg/L		5.1	5.2	7.7	8.1	9.9	10.4
Ammonia, Total (as N)	mg/L	equation[1]	0.0052	0.0087	<0.0050	0.0261	0.0296	<0.0050
Bromide (Br)	mg/L		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chloride (Cl)	mg/L	120	0.82	0.84	0.68	0.68	0.78	0.78
Fluoride (F)	mg/L	0.12	0.068	0.066	0.043	0.037	0.07	0.068
Nitrate (as N)	mg/L	3	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Nitrite (as N)	mg/L	0.06	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Total Kjeldahl Nitrogen	mg/L		0.120	0.100	0.100	0.096	0.140	0.133
Orthophosphate-Dissolved (as P)	mg/L		<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Phosphorus (P)-Total Dissolved	mg/L		<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Phosphorus (P)-Total	mg/L	0.004	0.0027	<0.0020	<0.0020	<0.0020	<0.0020	0.0032
Silicate (as SiO_2)	mg/L		<0.50	<0.50	<0.50	<0.50	0.5	0.55
Sulfate (SO_4)	mg/L		1.00	0.98	1.88	1.88	5.05	5.05
Cyanides								
Cyanide, Total	mg/L		<0.0010			<0.0010		<0.0010
Cyanide, Free	mg/L	0.005	<0.0010			<0.0010		<0.0010
Organic / Inorganic Carbon								
Dissolved Organic Carbon	mg/L		2.15	1.97	1.91	1.88	1.59	1.74
Total Organic Carbon	mg/L		2.04	2.34	1.71	1.83	1.68	1.78
Plant Pigments								
Chlorophyll-*a*	µg/L		0.390	0.404	0.262	0.284	0.482	0.448

Variable	Units	CCME	INUG-124	INUG-125	PDL-89	PDL-90	SP-136	SP-137
Total Metals								
Aluminum (Al)-Total	mg/L	equation	0.0060	0.0051	0.0040	0.0040	0.0055	0.0057
Antimony (Sb)-Total	mg/L		<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Arsenic (As)-Total	mg/L	0.005	0.00010	0.00012	0.00016	0.00016	0.00032	0.00028
Barium (Ba)-Total	mg/L		0.00159	0.00156	0.00179	0.00177	0.00242	0.00233
Beryllium (Be)-Total	mg/L		<0.000100	<0.000100	<0.000100	<0.000100	<0.000100	<0.000100
Bismuth (Bit)-Total	mg/L		<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Boron (Bo)-Total	mg/L	1.5	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium (Cd)-Total	mg/L	equation	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Calcium (Ca)-Total	mg/L		1.10	1.04	2.21	2.21	3.46	3.56
Chromium (Cr)-Total	mg/L	0.001	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Cobalt (Co)-Total	mg/L		<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Copper (Cu)-Total	mg/L	equation	<0.00050	<0.00050	<0.00050	<0.00050	0.00057	0.00059
Iron (Fe)-Total	mg/L	0.3	0.010	<0.010	<0.010	<0.010	0.018	0.018
Lead (Pb)-Total	mg/L	equation	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Lithium (Li)-Total	mg/L		<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Magnesium (Mg)-Total	mg/L		0.628	0.622	0.733	0.722	1.140	1.100
Manganese (Mn)-Total	mg/L		0.00189	0.00152	0.00108	0.00103	0.00170	0.00156
Mercury (Hg)-Total	mg/L	0.000026	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Molybdenum (Mo)-Total	mg/L	0.073	<0.000050	<0.000050	0.000053	<0.000050	0.000151	0.000152
Nickel (Ni)-Total	mg/L	equation	<0.00050	<0.00050	<0.00050	0.00055	<0.00050	<0.00050
Phosphorus (P)-Total	mg/L		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Potassium (K)-Total	mg/L		0.354	0.344	0.328	0.334	0.519	0.478
Selenium (Se)-Total	mg/L	0.001	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Silicon (Si)-Total	mg/L		0.16	0.14	0.15	0.14	0.24	0.26
Silver (Ag)-Total	mg/L	0.0001	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Sodium (Na)-Total	mg/L		0.529	0.534	0.478	0.472	0.897	0.800
Strontium (Sr)-Total	mg/L		0.0066	0.00621	0.0099	0.0101	0.0169	0.0186
Sulfur (S)-Total	mg/L		<0.50	<0.50	<0.50	<0.50	1.53	1.46
Thallium (Tl)-Total	mg/L	0.0008	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Tin (Sn)-Total	mg/L		<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010

Variable	Units	CCME	INUG-124	INUG-125	PDL-89	PDL-90	SP-136	SP-137
Titanium (Ti)-Total	mg/L		<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
Uranium (U)-Total	mg/L	0.015	0.000057	0.000059	0.000027	0.000028	0.000056	0.000052
Vanadium (V)-Total	mg/L		<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Zinc (Zn)-Total	mg/L	0.03	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030

[1]"equation" means that CCME guidelines (or thresholds) are calculated based on an equation which is either pH or hardness dependent. The ammonia and aluminum guidelines vary with pH, while the cadmium, copper, lead, manganese, nickel and zinc guidelines vary with hardness.
< indicates below detection limits.

4.3.1.3 Sediment Character

Grain size analysis and summary statistics collected from all the reference and exposure areas are provided in Table 13 and Table 14. Grain size of sediments collected from all lakes were similar in that they were dominated by silt material (between 69 and 84% in INUG, between 67 and 78% in PDL, between 65 and 70% in SP-NF and between 80 and 84% in SP-FF). Moderate amounts of clay (12 to 30%) and sand (1 to 19%) materials were also present in all lakes, with negligible gravel materials (<1 to 2.6%). The geometric mean particle (GMP) size of sediment for stations in 2020 were similar to what was observed in previous years (Figure 8).

Total organic carbon (TOC) in sediments, ranged between 1.3% and 4.6% in 2020 (Table 13). TOC for stations in 2020 were similar to what was observed in previous years (Figure 9).

Table 13. Variations in sample depth, TOC, sand, silt and clay, Meadowbank Mine 2020

Area	Station	Depth (m)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	TOC (%)
INUG (2020)	1	8.2	<1.0	1.9	83.6	14.5	3.8
	2	8.0	<1.0	3.6	81.2	15.2	3.9
	3	8.0	<1.0	19.3	68.7	12.0	4.0
	4	8.4	<1.0	4.3	79.6	16.1	4.0
	5	8.3	<1.0	3.5	79.4	17.1	3.8
PDL (2020)	1	8.2	<1.0	5.7	77.7	16.6	1.9
	2	7.9	<1.0	7.1	75.7	17.2	1.7
	3	7.2	<1.0	6.7	76.8	16.5	2.3
	4	7.8	<1.0	6.7	75.9	17.4	2.7
	5	8.0	2.6	8.4	67.4	21.6	1.3
SP-NF (2020)	1	8.7	<1.0	3.0	65.1	31.9	3.5
	2	7.4	<1.0	1.8	69.6	28.6	3.7
	3	8.1	<1.0	1.6	69.9	28.5	3.7
	4	8.1	<1.0	1.4	68.0	29.8	3.9
	5	8.3	<1.0	1.6	70.5	27.9	4.3
SP-FF (2020)	1	7.9	<1.0	2.2	84.0	13.8	2.9
	2	8.3	<1.0	1.7	82.1	16.2	3.1
	3	8.2	<1.0	2.7	83.4	13.9	3.4
	4	7.9	<1.0	1.8	82.8	15.4	4.6
	5	7.9	<1.0	3.4	80.4	16.2	4.4

Table 14 Summary statistics of sediment grain size and TOC of benthic invertebrate stations at the reference and exposure lakes, Meadowbank Mine 2020

Area	Metric	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	GMP (mm)	TOC (%)
INUG (2020)	Min	<1.0	1.9	68.7	12.0	0.024	3.77
	Max	<1.0	19.3	83.6	17.1	0.047	4.03
	Median	<1.0	3.6	79.6	15.2	0.025	3.90
	Mean	<1.0	6.5	78.5	15.0	0.029	3.90
	SD	0.0	7.2	5.7	1.9	0.010	0.11
	SE	0.0	3.2	2.6	0.9	0.004	0.05
PDL (2020)	Min	<1.0	5.7	67.4	16.5	0.026	1.33
	Max	2.6	8.4	77.7	21.6	0.027	2.66
	Median	<1.0	6.7	75.9	17.2	0.027	1.94
	Mean	1.3	6.9	74.7	17.9	0.027	1.99
	SD	0.7	1.0	4.2	2.1	0.001	0.51
	SE	0.3	0.4	1.9	1.0	<0.001	0.23
SP-NF (2020)	Min	<1.0	1.7	80.4	13.8	0.023	2.89
	Max	<1.0	3.4	84.0	16.2	0.025	4.58
	Median	<1.0	2.2	82.8	15.4	0.024	3.38
	Mean	<1.0	2.4	82.5	15.1	0.024	3.67
	SD	0.0	0.7	1.4	1.2	0.001	0.78
	SE	0.0	0.3	0.6	0.5	<0.001	0.35
SP-FF (2020)	Min	<1.0	1.4	65.1	27.9	0.015	3.54
	Max	<1.0	3.0	70.5	31.9	0.016	4.27
	Median	<1.0	1.6	69.6	28.6	0.016	3.70
	Mean	<1.0	1.9	68.6	29.3	0.016	3.81
	SD	0.0	0.6	2.2	1.6	<0.001	0.29
	SE	0.0	0.3	1.0	0.7	<0.001	0.13

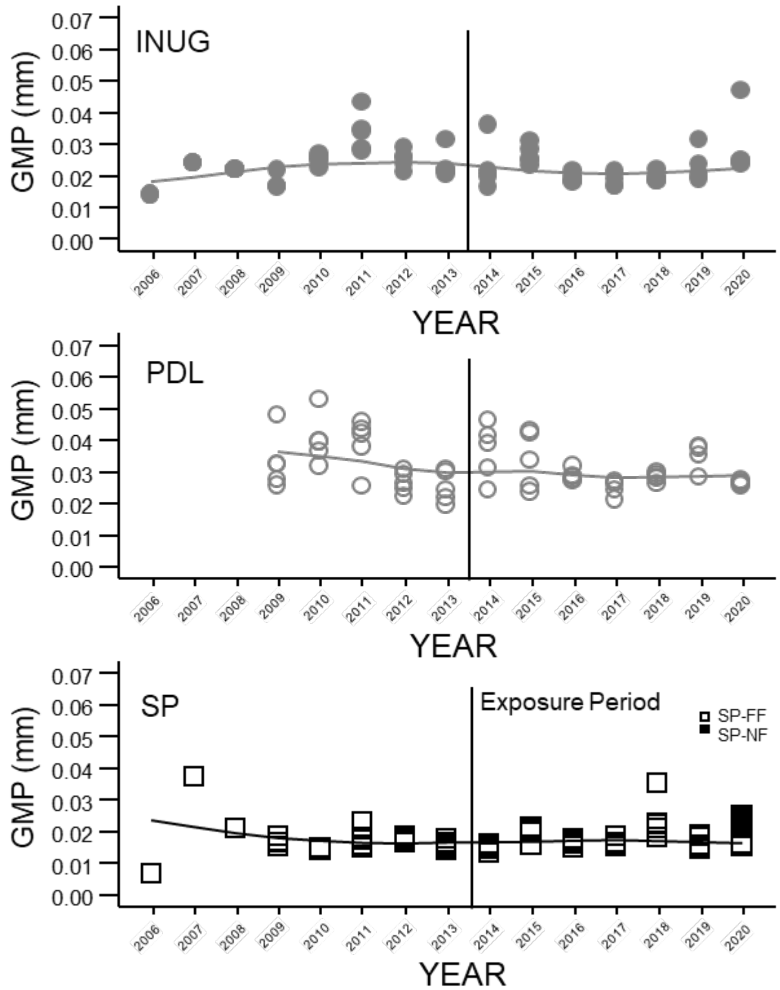

Figure 8. Geometric mean particle size (GMP) of sediment among years for INUG, PDL and SP, Meadowbank Mine

Figure Note: the line illustrates LOWESS-smoothed variations in annual averages.

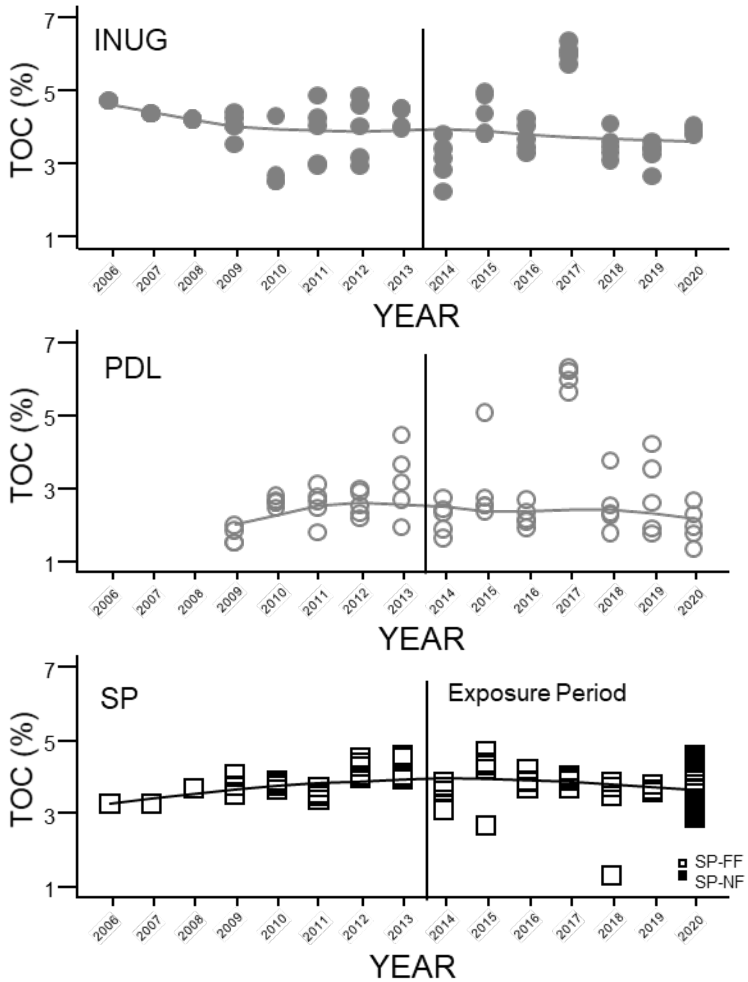

Figure 9. Total organic carbon (TOC) in sediment among years for INUG, PDL and SP, Meadowbank Mine

Figure Note: the line illustrates LOWESS-smoothed variations in annual averages.

4.3.2 Invertebrate Community Composition

4.3.2.1 General Description

Relative densities of benthos families in each of the lakes from the start of CREMP monitoring through to and including this 2020 survey are presented in Table 15, Table 16 and Table 17. Required statistics for each of the core indices of composition are provided in Table 18 (Total density, Family Richness, Evenness) and Table 19 (Bray-Curtis distances).

Benthic communities of the three study areas were generally similar in 2020, and similar to what had been described in previous years. The benthos of SP-NF and SP-FF were numerically dominated by non-biting midges (Chironomidae, 73% and 62%, respectively) and freshwater clams (Pisidiidae, 15% and 19%, respectively). The benthos of INUG and PDL were also numerically dominated by Chironomidae (76% and 59%, respectively) and Pisidiidae (16% and 26%, respectively). The Pisidiidae clams in SP-NF and SP-FF were of the genus *Pisidium*, like they have been in PDL. Pisidiidae in INUG have included both *Pisidium* and *Sphaerium nitidum*. Ostracoda accounted for 4% of total numbers of benthos collected from SP-NF, 6% of benthos from SP-FF, 2% of benthos from INUG and 7% of benthos from PDL. Naididae, Lumbriculidae and Arachnida each accounted for 2% of total benthos from SP-NF in 2020, while Nematoda, Harpacticoida and Limnephilidae each accounted for ≤ 1%.

There were 11 chironomid genera in the SP-NF stations in 2020, and 12 chironomid genera in the SP-FF stations. The following chironomid genera were numerically dominant not only in SP, but also in INUG and PDL: *Micropsectra*, *Stichtochironomus*, *Tanytarsus*, and *Procladius*. All of these genera are common and widely distributed in the Holarctic.

Quality assurance for the laboratory sorting of invertebrate samples is provided in Appendix 4. Sorting always produced > 95% of individuals in the samples and was therefore acceptable.

Variations in total densities and indices of composition (richness, evenness, diversity) over time and within sample areas are illustrated in Figure 10 through Figure 13. Total densities in SP-NF and SP-FF in 2020 varied between about 3,000 and 7,200 individuals per m^2 and between 1,300 and 2,600 individuals per m^2, respectively. The range of values at SP-FF was well within the range of values that was historically reported for that sample area, which have ranged from approximately 200 to 5,000 individuals per m^2. In 2020, densities in INUG varied between about 1,700 and 3,200 individuals per m^2, and densities in PDL varied between about 600 and 1,700 individuals per m^2. Total densities in INUG and PDL were also consistent with the range of values historically reported, which have been between about 300 and 6,000 individuals per m^2 in INUG and PDL.

In 2020, benthic samples from SP-NF produced between 7 and 9 families per sample, while samples from SP-FF produced between 5 and 8 families per sample (i.e., per pair of Ponar grabs; see Figure 11). The range of values at SP-FF was well within the range of values that was historically reported for that sample area, which have ranged from 2 to 8. Family richness in INUG varied between 5 and 9 families, and family richness in PDL varied between 4 and 6 families. Richness in INUG and PDL were also consistent with the range of values historically reported.

Evenness values in 2020 in SP-NF varied between 0.19 and 0.28 in 2020, while evenness values in SP-FF varied between 0.33 and 0.44. The range of values at SP-FF was well within the range of values that was historically reported for that sample area and were similar to values in 2020 at INUG (0.2 to 0.3) and PDL (0.3 to 0.6) (Figure 12). Evenness in INUG and PDL were also consistent with the range of values historically reported.

The results of the NMDS ordination are illustrated in Figure 14 (taxa correlations with axis scores) and Figure 15 (sample scores). Ostracoda densities were most strongly and positively associated with Axis 1 scores: samples with higher Axis 1 scores had higher numbers of Ostracoda. Acarina densities were most strongly negatively associated with Axis 2 scores, while Nemata and Limnephilidae densities were most strongly positively associated with Axis 2 scores: Samples with larger Axis 2 scores had higher densities of Limnephilidae and Nemata, and lower densities of Acarina. Figure 15 illustrates the variations over time in axis scores. Benthic community data from SP-NF in 2020 produced similar axis 1 and axis 2 scores to INUG, but lower axis 1 scores than SP-FF and lower axis 2 scores than PDL. The SP-NF scores reflected high relative densities of Chironomidae and Pisidiidae, i.e., taxa centered in Figure 14.

Table 15. Relative densities (%) of benthos taxa (families or higher level) and average of indices by year for INUG, Meadowbank Mine

Taxon	INUG														
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Nematoda	3	2	5	2	1	3	2	5	3	6	2	2	3	2	1
Platyhelminthes		3	<1	1	1		2	3			1	1	1	<1	1
Enchytraeidae								1							
Naididae	1	2	1	1	1	<1	1	2	1	<1	1	<1	1		1
Lumbriculidae	3	3	<1	3	3	5	3	2	1	2	<1	1	2	1	<1
Arachnida	5	5	2	3	4	2	4	1	1	1	1	2	3	2	2
Harpacticoida															<1
Ostracoda	7	<1	6	9	9	4	5	6	1	4	1	2	2	1	2
Notostraca		1	<1	<1		2	1				1				
Apataniidae												<1			
Limnephilidae				<1	2			<1	1	<1		<1		<1	
Chironomidae	47	57	71	50	37	41	45	57	60	63	70	66	46	67	76
Empididae	1		<1												
Pisidiidae	33	27	15	31	43	42	37	22	32	24	23	26	42	27	16
Indices															
Total Density	841	1,043	2,143	1,339	704	1,096	1,152	2,470	752	1,917	2,335	1,904	1,565	1,543	2,191
Family Richness	5.3	5.8	6.4	6.2	5.0	5.8	6.2	8.0	3.8	5.4	6.4	6.4	6.2	4.4	6.2
Family Diversity	0.63	0.56	0.54	0.63	0.61	0.64	0.64	0.58	0.53	0.54	0.45	0.51	0.57	0.47	0.39
Family Evenness	0.57	0.43	0.38	0.46	0.53	0.48	0.50	0.31	0.58	0.41	0.32	0.33	0.38	0.49	0.28

Table 16. Relative densities (%) of benthos taxa (families or higher level) and average of indices by year for PDL, Meadowbank Mine

Taxon	PDL											
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Nematoda	1	3	2	3	5	9	4	3	4	6	4	5
Platyhelminthes	<1								1			
Enchytraeidae												
Naididae	5	3	4		4	6	1	1	2	4	6	
Lumbriculidae	1	1	2	1	1	2	1	1	3	2	1	2
Arachnida	2	1	4	2	1	2	1	1	1	1	<1	1
Harpacticoida												
Ostracoda	9	8	3	2	7		11	3	13	12	13	7
Notostraca							<1			1	<1	
Apataniidae												
Limnephilidae	1	1	1	2	2		2	1	1	1	1	1
Chironomidae	60	54	54	64	57	52	59	65	52	41	56	59
Empididae												
Pisidiidae	20	28	31	26	23	29	20	26	24	34	19	26
Indices												
Total Density	1,930	1,013	991	1,026	1,513	548	1,391	1,530	970	826	1,257	1,143
Family Richness	6.2	5.2	5.2	4.4	6.2	4.4	6.0	5.4	6.4	5.4	5.6	5.2
Family Diversity	0.60	0.59	0.58	0.48	0.61	0.57	0.59	0.51	0.63	0.66	0.61	0.52
Family Evenness	0.42	0.49	0.48	0.46	0.42	0.57	0.41	0.42	0.44	0.57	0.49	0.42

Table 17. Relative densities (%) of benthos taxa (families or higher level) and average of indices by year for SP (FF and NF), Meadowbank Mine

Taxon	SP-FF															SP-NF
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2020
Nematoda	15	8	13	1	7	4	5	1	3	4	2	2	5	9	5	1
Platyhelminthes		<1										<1	<1			
Enchytraeidae																
Naididae		3		5	1	1	2	1	<1	1	2	<1	1	2	2	2
Lumbriculidae	1	3			1	1	2	<1	<1	<1	1	1	1	<1	2	2
Arachnida	10	11	3	7	7	8	4	2	3	3	6	4	5	5	5	2
Harpacticoida			1													<1
Ostracoda	5	2	18	10	11	10	10	8	6	8	6	9	13	16	6	4
Notostraca																
Apataniidae																
Limnephilidae	1		1			1	1	<1	<1		1					<1
Chironomidae	33	42	41	45	31	37	52	76	73	57	51	53	36	38	62	73
Empididae										<1						
Pisidiidae	36	31	22	33	42	39	23	11	14	27	33	30	38	29	19	15
Indices																
Total density	775	1,013	600	870	313	678	1,409	2,748	3,222	2,196	1,565	2,326	1,604	1,161	1,874	5,735
Family Richness	4.7	5.8	4.8	4.8	4.4	5.2	6.4	6.2	6.0	6.0	6.2	5.8	5.8	5.6	6.4	8.0
Family Diversity	0.66	0.68	0.70	0.65	0.65	0.66	0.64	0.41	0.45	0.58	0.62	0.58	0.67	0.71	0.56	0.45
Family Evenness	0.65	0.56	0.71	0.63	0.74	0.59	0.45	0.28	0.32	0.41	0.44	0.44	0.54	0.63	0.37	0.23

Table 18. Mean, median, minimum, maximum, standard deviation (SD) and standard error (SE) for core indices of benthic community composition for INUG, PDL and SP in 2020

Area	Metric	Total Density	Family Richness	Family Evenness
INUG (2020)	Min	1,717	5.0	0.18
	Max	3,196	9.0	0.33
	Median	1,891	6.0	0.29
	Mean	2,191	6.2	0.28
	SD	628	1.6	0.06
	SE	281	0.7	0.03
PDL (2020)	Min	565.2	4.0	0.34
	Max	1,761	6.0	0.58
	Median	1,087	6.0	0.40
	Mean	1,143	5.2	0.42
	SD	462	1.1	0.10
	SE	207	0.5	0.04
SP-NF (2020)	Min	3,022	7.0	0.19
	Max	7,217	8.0	0.31
	Median	6,022	8.0	0.23
	Mean	5,730	7.8	0.24
	SD	1,640	0.4	0.04
	SE	733	0.2	0.02
SP-FF (2020)	Min	1,326	5.0	0.33
	Max	2,587	7.0	0.44
	Median	1,652	6.0	0.37
	Mean	1,870	6.2	0.38
	SD	504	0.8	0.05
	SE	226	0.4	0.02

Table 19. Mean, median, minimum, maximum, standard deviation (SD) and standard error (SE) for Bray-Curtis distances for INUG, PDL and SP in 2020

Metric	Within Reference (INUG and PDL)	Within Exposure (SP-NF)	Within Exposure (SP-FF)	Between Reference and Exposure (SP-NF vs INUG/PDL)	Between SP-NF and INUG	Between SP-NF and PDL	Between SP-NF and SP-FF
Count	20	10	10	50	25	25	25
Minimum	0.05	0.03	0.05	0.13	0.13	0.14	0.07
Maximum	0.43	0.14	0.28	0.44	0.36	0.44	0.27
Median	0.20	0.10	0.13	0.25	0.20	0.30	0.15
Mean	0.21	0.10	0.15	0.26	0.22	0.29	0.16
SD	0.10	0.03	0.08	0.08	0.07	0.08	0.06
SE	0.02	0.01	0.03	0.01	0.01	0.02	0.01

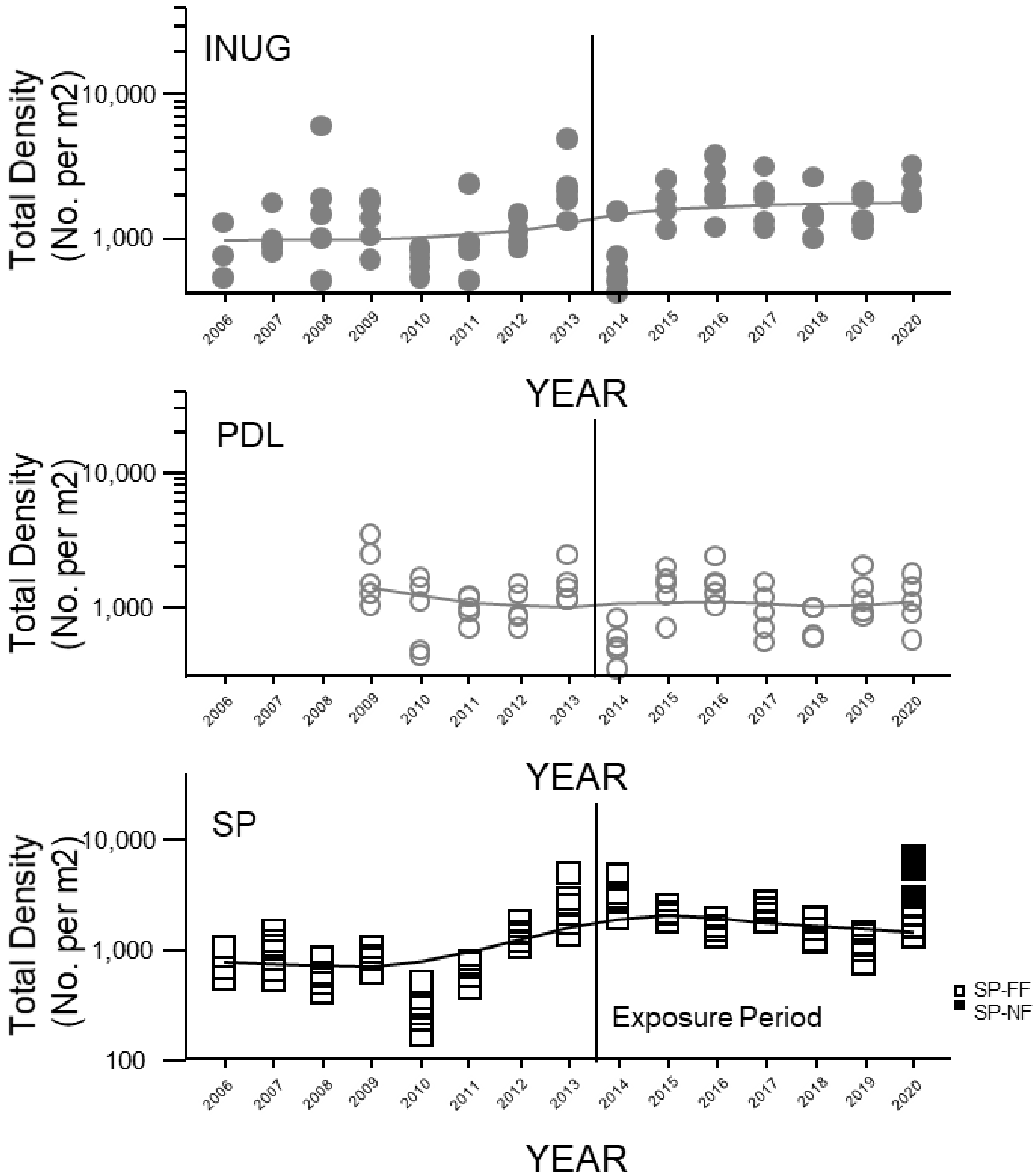

Figure 10. Number of organisms per m^2 among years for INUG, PDL and SP, Meadowbank Mine

Figure Note: the line illustrates LOWESS-smoothed annual averages.

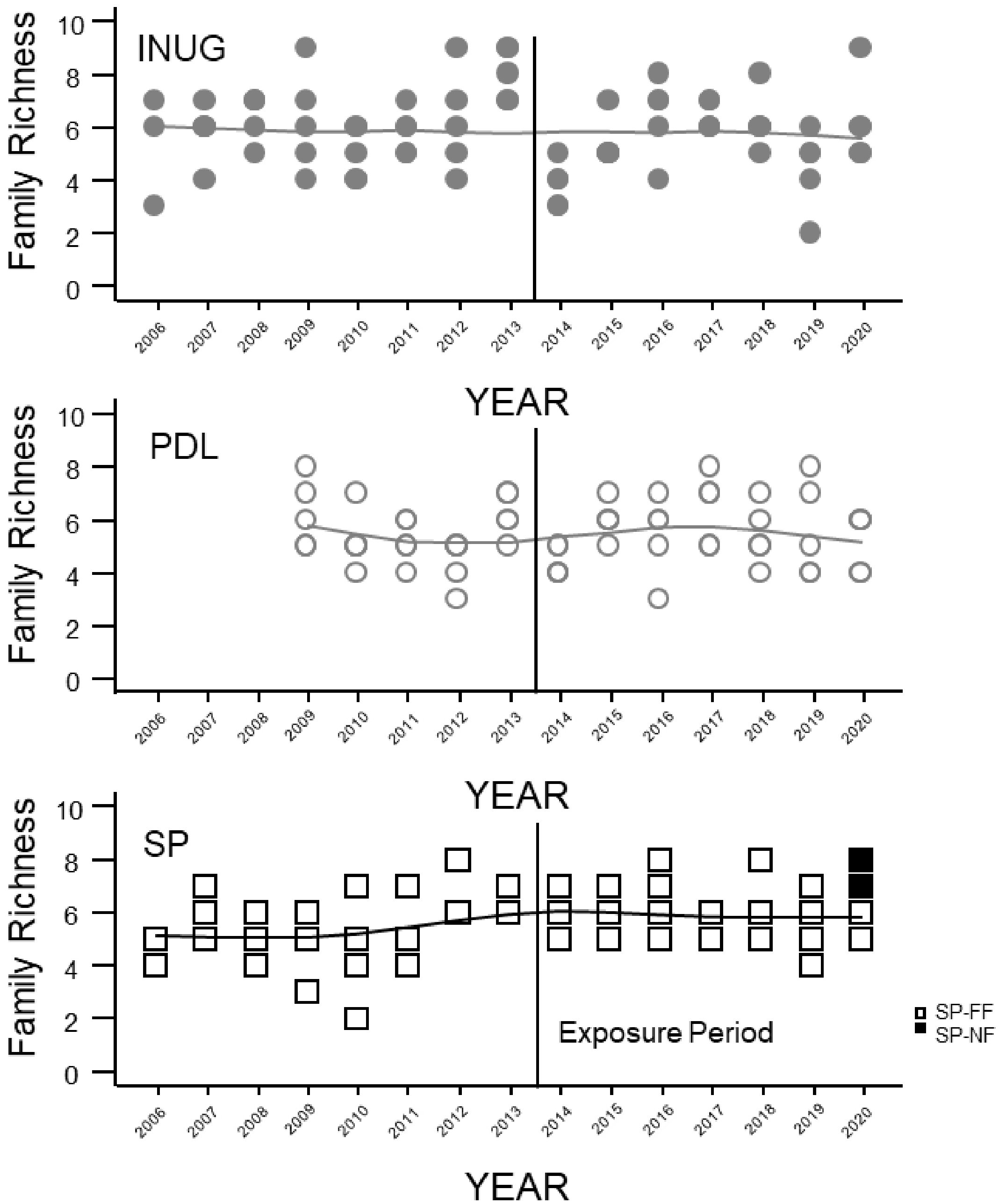

Figure 11. Taxa richness (number of families) among years for INUG, PDL and SP, Meadowbank Mine

Figure Note: the line illustrates LOWESS-smoothed annual averages.

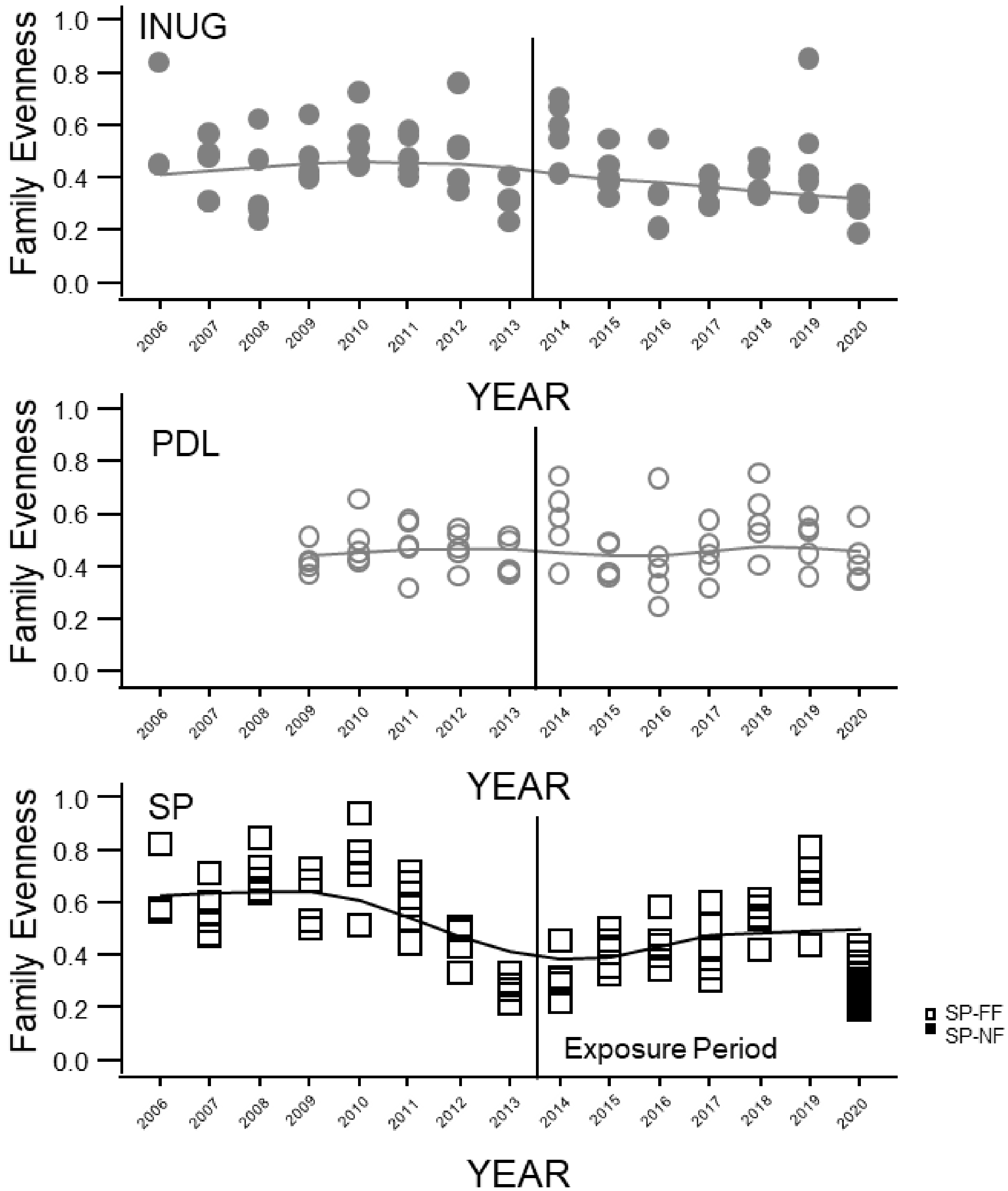

Figure 12. Family evenness among years for INUG, PDL and SP, Meadowbank Mine

Figure Note: the line illustrates LOWESS-smoothed variations in annual averages.

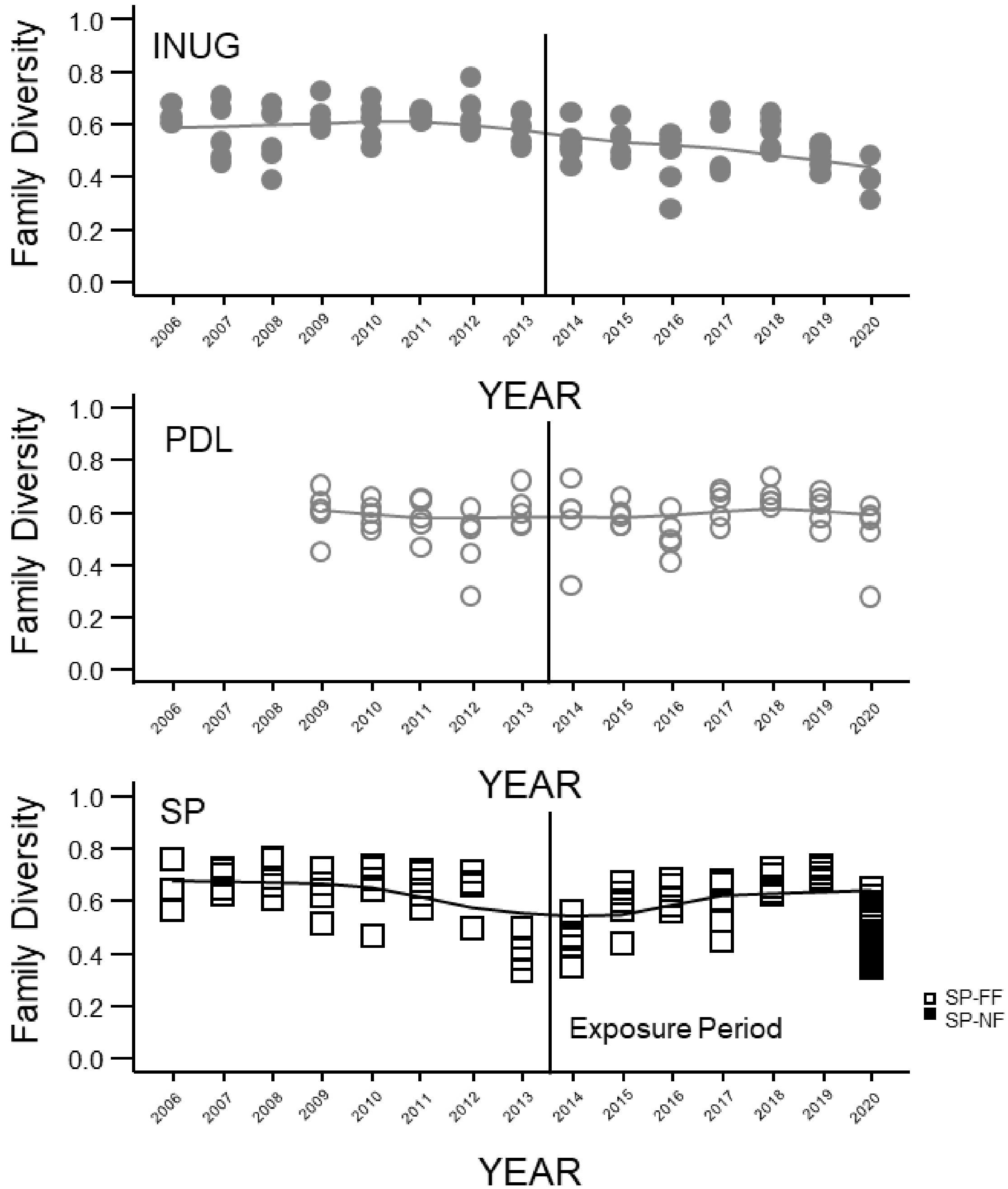

Figure 13. Family diversity among years for INUG, PDL and SP, Meadowbank Mine

Figure Note: the line illustrates LOWESS-smoothed variations in annual averages.

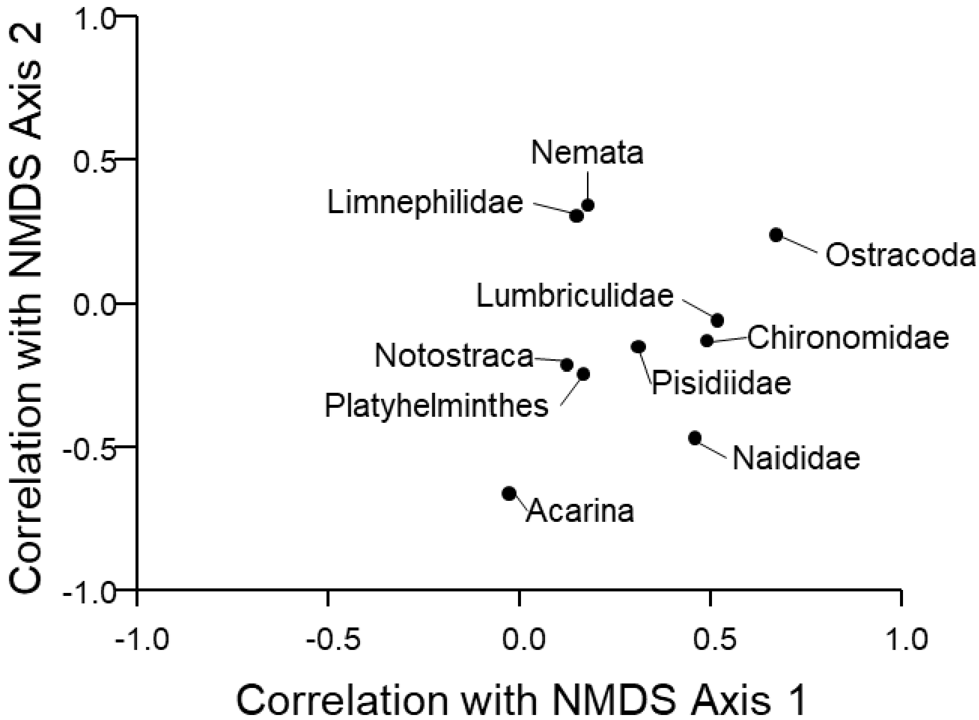

Figure 14. Scatter plot of axis 1 and 2 scores and associated taxa scores for Non-Metric Multidimensional Scaling (NMDS) analysis, Meadowbank Mine

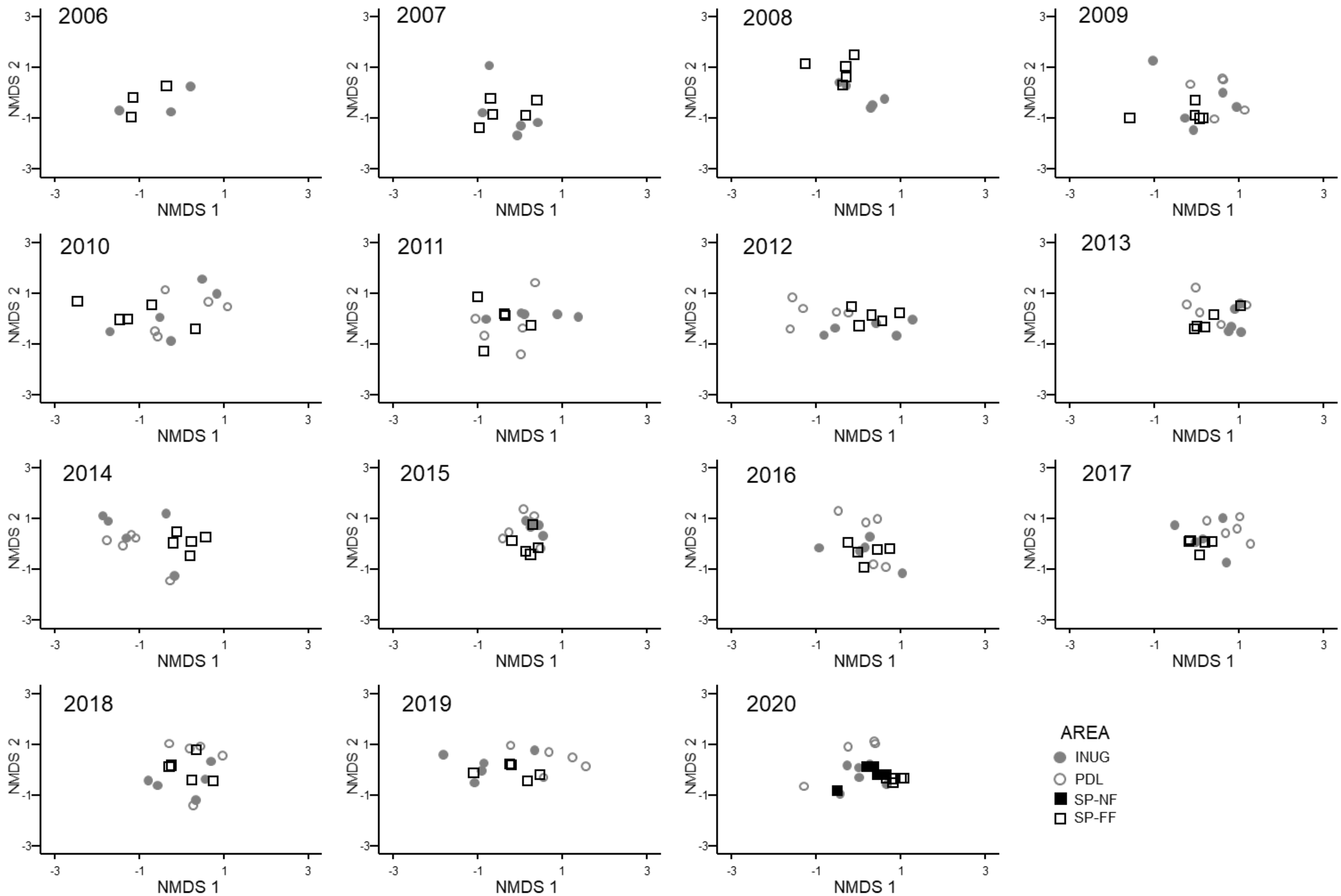

Figure 15. Scatterplots of NMDS axis scores for benthos community samples from INUG, PDL and SP by year, Meadowbank Mine

4.3.2.2 Controlling Variation in Benthic Indices

Backward, stepwise multiple regression was used to identify variables that explained variation in indices of benthic community composition in INUG, PDL and in SP-FF (baseline period). The results of the stepwise regressions are provided in Table 20 (ANOVA table) and Table 21 (reference models) below.

TOC explained significant amounts of variation in all of the core indices of benthic community composition, with the exception of NMDS axis 1 scores. The coefficients in Table 21 can be used to infer the nature of the association between indices and predictors. TOC had a positive coefficient (slope) for total densities and family richness, indicating that they increased in relation to TOC. TOC had a negative coefficient with evenness and NMDS axis 2 scores, indicating that they decreased in relation to TOC. Geometric mean particle size (GMP) explained significant amounts of variation for family richness (positive), evenness (negative) and NMDS axis 1 (positive). Depth explained significant amounts of variation for NMDS axis 1 (positive) and diversity (negative).

Table 20. ANOVA table for multiple regression models developed for each of the core and supporting indices of benthic community composition, Meadowbank Mine 2020

Index of Composition	Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
Core Variables						
Log of Density	Regression	0.333	1	0.333	6.62	**0.011**
	Residual	7.002	139	0.050		
Log of Family Richness	Regression	0.144	2	0.072	6.23	**0.003**
	Residual	1.592	138	0.012		
Evenness	Regression	0.225	2	0.113	6.75	**0.002**
	Residual	2.301	138	0.017		
NMDS Axis 1	Regression	5.596	2	2.798	4.85	**0.009**
	Residual	79.571	138	0.577		
NMDS Axis 2	Regression	1.624	1	1.624	2.96	**0.087**
	Residual	76.220	139	0.548		
Supporting Variable						
Diversity	Regression	0.061	1	0.061	6.14	**0.014**
	Residual	1.371	139	0.010		

Table Notes Values in bold represent *p*-Values that are statistically significant at $p < 0.10$

Table 21. Multiple regression model parameter estimates and percent of variation explained for each of the core and supporting indices of benthic community composition, Meadowbank Mine 2020

Index of Composition	Model Parameter Estimates				
	Constant	Log of Depth	Log of TOC	Log of Geo Mean	Model R^2
Core Variables					
Log of Density	2.93		0.29		0.04
Log of Family Richness	0.83		0.20	0.12	0.07
Evenness	0.39		-0.25	-0.12	0.08
NMDS Axis 1	3.59	0.05		0.08	0.05
NMDS Axis 2	0.34		-0.63		0.01
Supporting Variable					
Diversity	0.94	-0.41			0.04

4.3.2.3 Hypothesis Tests

This analysis focuses on the assessment of spatio-temporal variations in residuals of the core and supporting indices of benthic community composition after taking into account the variations related to depth, TOC and particle size (Table 21). Detailed results for the ANOVAs and computed effect sizes are provided in Table 22. Scatterplots of variations in residuals of core indices of composition are illustrated in Figure 16 to Figure 21. In addition to illustrating the individual residuals, the graphs also illustrate the normal range of variation for residuals based on the range observed for the reference data (i.e., data from INUG, PDL and the baseline period for SP-FF).

ANOVA 1 (H01) tested for differences in benthic communities between reference (INUG, PDL) and near-field exposure (SP-NF) in 2020. There were significant differences in four core indices of composition: density residuals ($p < 0.001$), richness residuals ($p = 0.003$), evenness residuals ($p = 0.087$) and NMDS axis 1 scores ($p < 0.001$, Table 22). Density residuals and richness residuals were significantly higher in SP-NF than in the reference lakes, as were NMDS axis 1 residuals. Evenness residuals and NMDS axis 2 residuals were significantly lower in SP-NF than in the reference lakes. Observed variations were relatively large for densities (2.35 SD), exceeding the CES of ±2SD. Observed variations were, however, relatively small for richness (+1.19 SD) and evenness (-1.22 SD), not exceeding the CES of ±2SD. There is no CES of Bray-Curtis distance, or the summary metrics of NMDS. The observed effect size for NMDS axis 1 scores (i.e., +1.08) were, however, smaller than the generic CES of ±2SD. There was no significant difference in the NMDS axis 2 residuals and diversity residuals for H01, and no further ANOVAs were computed for these indices.

ANOVA 2 (H02a,b) tested for differences in benthic communities between the nearfield exposure (SP-NF) and farfield exposure (SP-FF) areas during the effluent exposure period (H02a: 2014 to 2020, H02b: 2020 only). Density residuals for SP-NF in 2020 were higher than those for SP-FF from 2014-2020 ($p < 0.001$, ES = 2.10 SD) and from 2020 only ($p < 0.001$, ES = 2.17 SD). Richness residuals for SP-NF were higher in 2020 than for SP-FF from 2014-2020 ($p = 0.003$, ES = 1.02 SD) and 2020 only ($p = 0.076$, ES = 0.79 SD). Evenness residuals for SP-NF were lower in 2020 than for SP-FF from 2014-2020 ($p < 0.001$, ES = -1.22 SD) and from 2020 ($p = 0.016$, ES = -0.80 SD). NMDS Axis 1 scores for SP-NF in 2020 were higher than those for SP-FF from 2014-2020 (p = 0.003, ES = 0.74 SD), and in 2020 only (p = 0.080, ES = 0.56 SD). Observed variations in densities were relatively large (i.e., > 2SD), while observed variations for richness, evenness and NMDS axis 1 scores were small (i.e., < 2SD).

ANOVA 3 (H03a,b) tested for differences in benthic communities in the farfield exposure area (SP-FF) between the baseline period (2006-2007) and effluent exposure period (H03a: 2014-2020, H03b: 2020). There were significant differences in density residuals (p < 0.001, ES = 1.47 SD, p < 0.001, ES = 1.41 SD, respectively), evenness residuals (p < 0.001, ES = -0.79 SD and p < 0.001, ES = -1.21 SD, respectively) and NMDS axis 1 scores (p = 0.001, ES = 0.74 SD and p = 0.003, ES = 0.91 SD, respectively). Density residuals and NMDS axis 1 scores were higher in the exposure period than the baseline period, although observed variations were small in all cases, never exceeding the CES of ±2SD. Evenness residuals were lower in the exposure period than the baseline period, although observed variations were small, not exceeding the CES of ±2SD.

Detailed results for the Mantel tests are provided in Table 23. Results of the Mantel tests determined there were significant differences in Bray-Curtis distances based on all possible pairs between reference (INUG and PDL) and nearfield exposure (SP-NF) in 2020 (Mantel r = 0.279, p = 0.019, (Table 23). The Mantel tests for H02 and H02b suggested that Bray-Curtis distances varied significantly between nearfield and farfield exposure areas (Mantel r = 0.224 and 0.266, p = 0.016 and 0.020). The Mantel tests for H03b also suggested that Bray-Curtis distances varied in the farfield area from the baseline period (2006 and 2007) to the exposure period (2014 to 2020; Mantel r = 0.433, p = 0.001), although H03b suggested that Bray-Curtis distances in the farfield exposure area did not vary between the baseline period and 2020 (Mantel r = 0.025, p = 0.385).

The ANOVAs are one way to examine the variations in core indices. Normal ranges of reference data (station-level observations) provide another means of examining the significance of variations. The average for density residuals for SP-NF fell just outside (above) the normal ranges of reference data in 2020 (Figure 16) indicating effects that exceed the normal range. However, the average of residuals for family richness, evenness, NMDS axis 1 and 2 scores and diversity in 2020 for SP-NF typically fell within normal ranges for reference data (Figure 17 to Figure 21) indicate effects that are within the normal range.

Table 22. Results of the analysis of variance (ANOVA) for the five specified hypotheses, for core and supporting indices of benthic community composition at INUD, PDL and SP, Meadowbank Mine 2020

Index of Composition	Test	*SS*	*df*	*MSE*	*F* ratio	*p*-Value	Difference	Effect Size (SDs)
Log of Density Residuals	Omnibus	2.666	11	0.242	14.930	**<0.001**		
	HO1	0.931	1	0.931	57.339	**<0.001**	0.53	2.35
	HO2a	0.978	1	0.978	60.223	**<0.001**	0.47	2.10
	HO2b	0.593	1	0.593	36.496	**<0.001**	0.49	2.17
	HO3a	0.673	1	0.673	41.472	**<0.001**	0.33	1.47
	HO3b	0.300	1	0.300	18.460	**<0.001**	0.32	1.41
	Error	0.747	46	0.016				
Log of Richness Residuals	Omnibus	0.091	11	0.008	1.478	0.173		
	HO1	0.056	1	0.056	9.981	**0.003**	0.13	1.19
	HO2a	0.054	1	0.054	9.598	**0.003**	0.11	1.02
	HO2b	0.018	1	0.018	3.293	**0.076**	0.09	0.79
	HO3a	0.009	1	0.009	1.611	0.211	0.04	0.35
	HO3b	0.012	1	0.012	2.164	0.148	0.06	0.58
	Error	0.253	45	0.006				
Family Evenness Residuals	Omnibus	0.896	11	0.081	10.017	**<0.001**		
	HO1	0.025	1	0.025	3.051	**0.087**	-0.09	-0.49
	HO2a	0.206	1	0.206	25.271	**<0.001**	-0.22	-1.22
	HO2b	0.050	1	0.050	6.195	**0.016**	-0.14	-0.80
	HO3a	0.121	1	0.121	14.888	**<0.001**	-0.14	-0.79
	HO3b	0.138	1	0.138	17.018	**<0.001**	-0.21	-1.21
	Error	0.374	46	0.008				
NMDS Axis 1 Residuals	Omnibus	6.814	11	0.619	3.144	**0.003**		
	HO1	3.073	1	3.073	15.595	**<0.001**	0.96	1.08
	HO2a	1.889	1	1.889	9.587	**0.003**	0.66	0.74
	HO2b	0.633	1	0.633	3.211	**0.080**	0.50	0.56
	HO3a	2.660	1	2.660	13.502	**0.001**	0.66	0.74
	HO3b	1.987	1	1.987	10.085	**0.003**	0.81	0.91
	Error	8.867	45	0.197				
NMDS Axis 2 Residuals	Omnibus	4.248	11	0.386	2.058	**0.044**		
	HO1	0.481	1	0.481	2.562	0.116	-0.38	-0.45
	Error	8.631	46	0.188				
Family Diversity Residuals	Omnibus	0.550	11	0.050	7.947	**<0.001**		
	HO1	0.000	1	0.000	0.002	0.961	0.00	-0.02
	Error	0.290	46	0.006				

Table Notes: shading indicates contrasts that were significant and with effect sizes > ±2 SDs

Table 23. Results from the Mantel tests testing for spatial and temporal variations in Bray- Curtis distances, Meadowbank EEM

Test	Hypothesis	Mantel *r*	*p-value*
HO1	Reference (INUG & PDL) vs. Exposure (SP-NF)	0.279	**0.019**
HO2a	Farfield (SP-FF, 2014-2020) vs. Nearfield (SP-NF, 2020)	0.224	**0.016**
HO2b	Farfield (SP-FF, 2020) vs. Nearfield (SP-NF, 2020)	0.266	**0.020**
HO3a	Farfield Baseline (2006-2007) vs. Farfield Exposure (2014-2020)	0.433	**0.001**
HO3b	Farfield Baseline (2006-2007) vs. Farfield Exposure (2020)	0.025	0.385

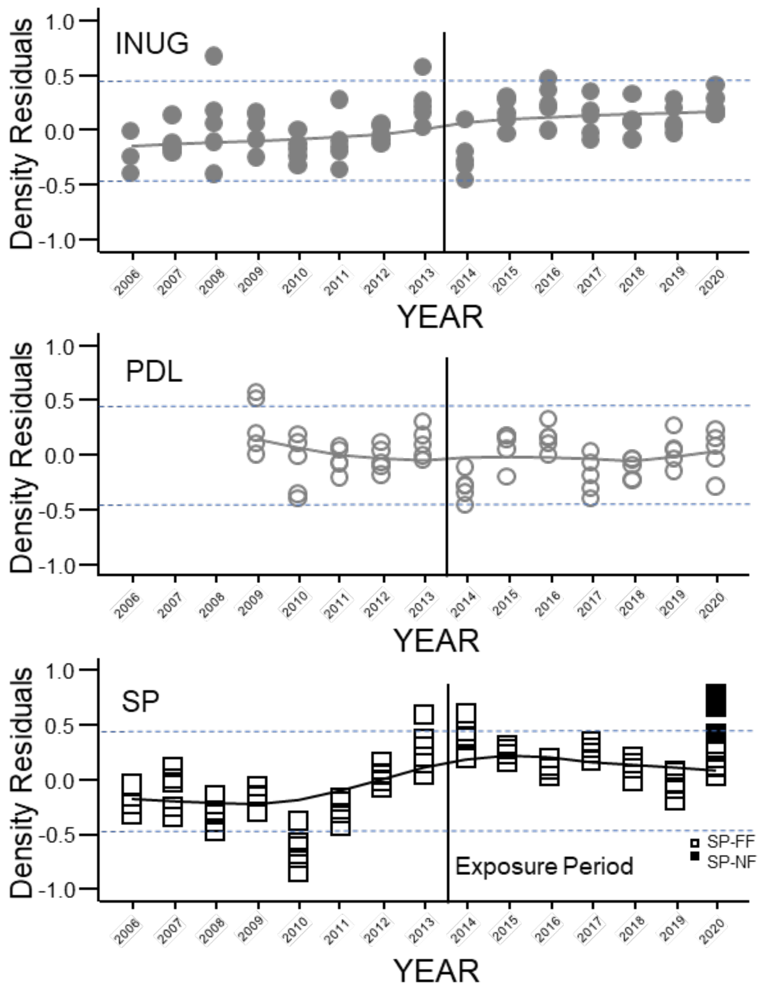

Figure 16. Residuals of total densities, among years for INUG, PDL and SP, Meadowbank Mine

Figure Note: the solid line illustrates LOWESS-smoothed variations in annual averages, while the dashed lines illustrate normal ranges of variation under reference conditions.

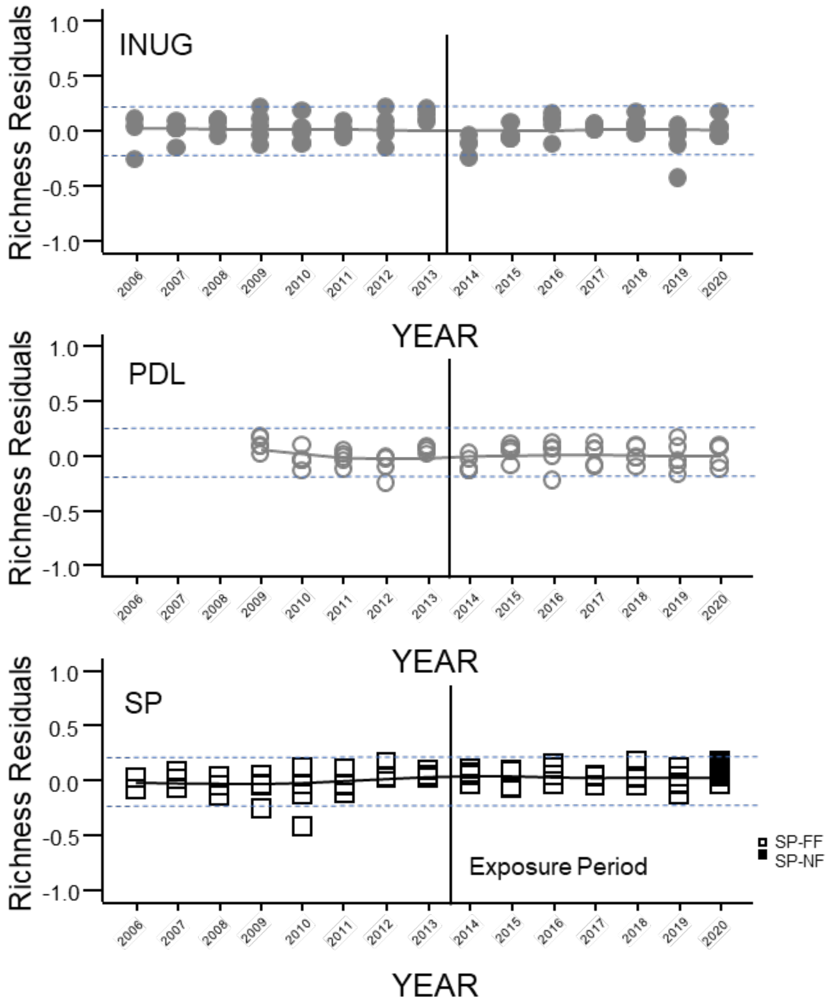

Figure 17. Residuals of family richness, among years for INUG, PDL and SP, Meadowbank Mine

Figure Note: the solid line illustrates LOWESS-smoothed variations in annual averages, while the dashed lines illustrate normal ranges of variation under reference conditions.

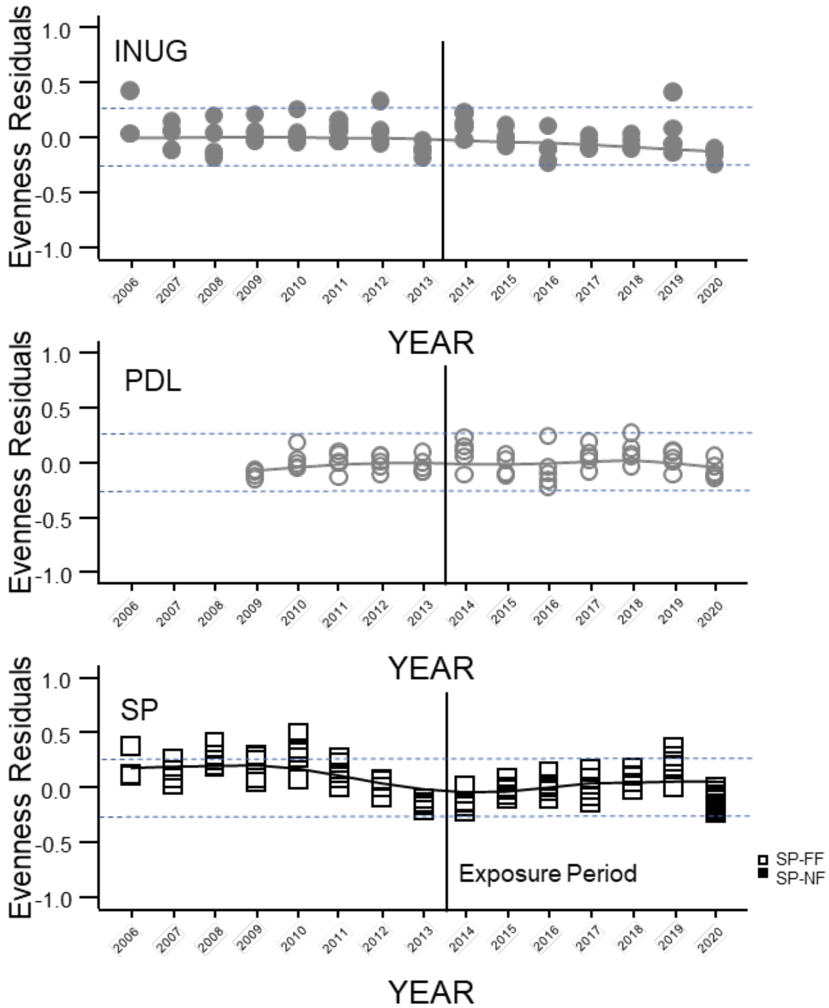

Figure 18. Residuals of evenness, among years for INUG, PDL and SP, Meadowbank Mine

Figure Note: the solid line illustrates LOWESS-smoothed variations in annual averages, while the dashed lines illustrate normal ranges of variation under reference conditions.

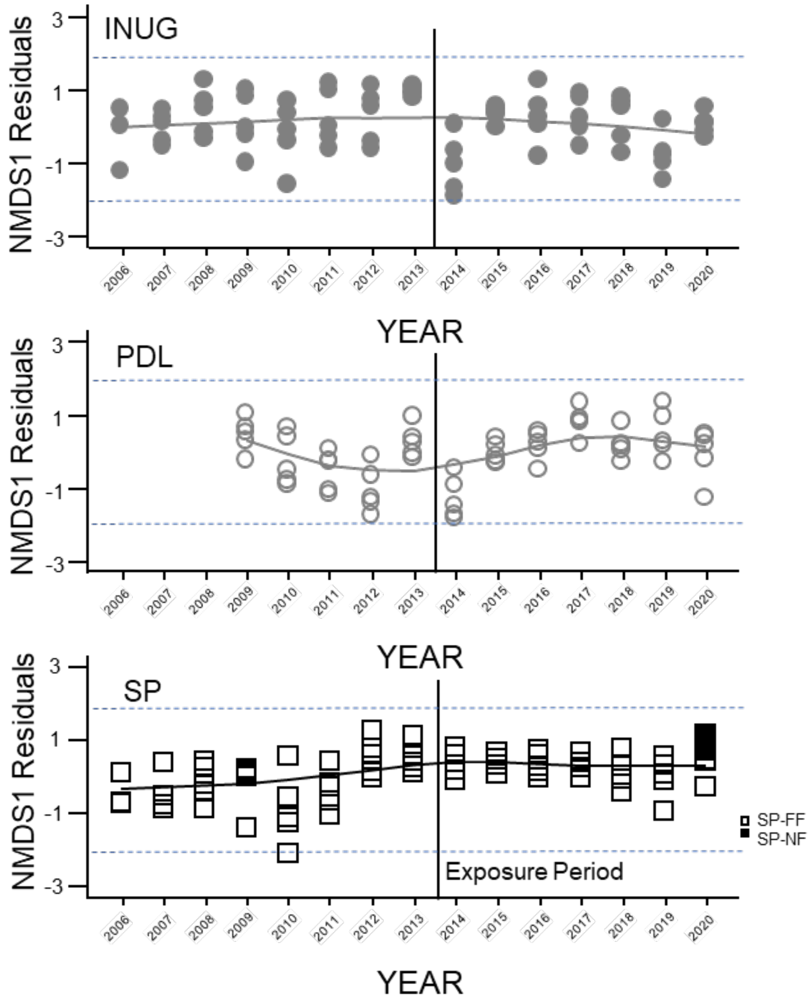

Figure 19. Residuals of NMDS Axis 1 Scores, among years for INUG, PDL and SP, Meadowbank Mine

Figure Note: the solid line illustrates LOWESS-smoothed variations in annual averages, while the dashed lines illustrate normal ranges of variation under reference conditions.

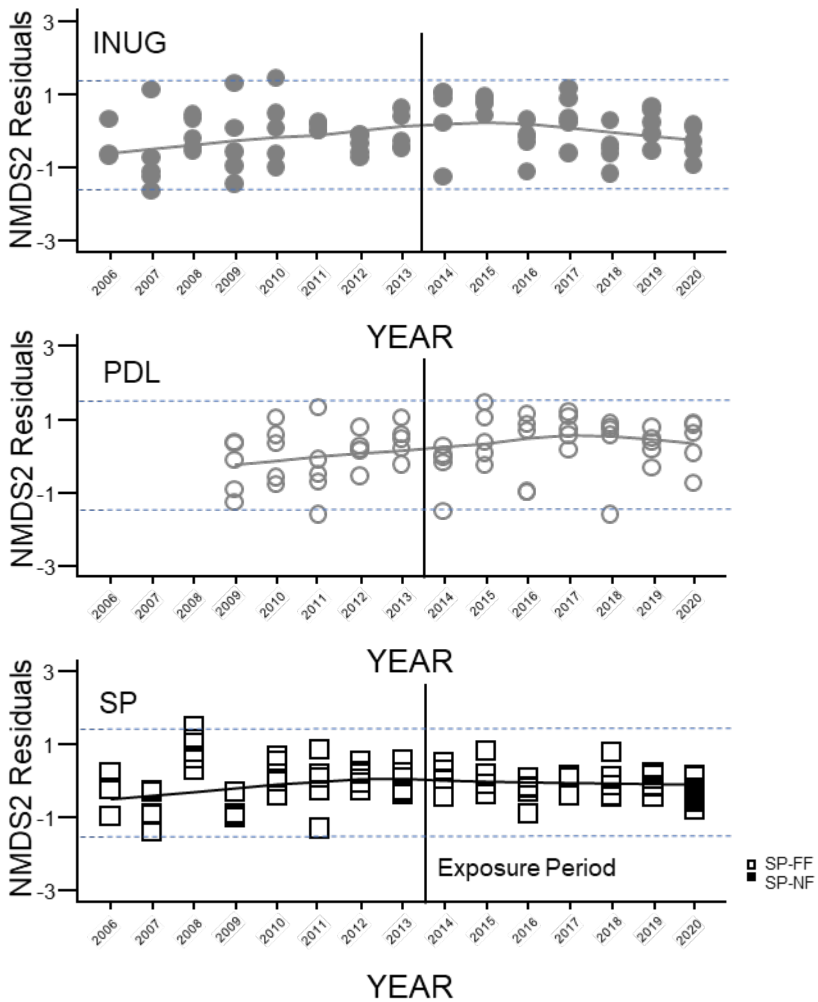

Figure 20. Residuals of NMDS Axis 2 Scores, among years for INUG, PDL and SP, Meadowbank Mine

Figure Note: the solid line illustrates LOWESS-smoothed variations in annual averages, while the dashed lines illustrate normal ranges of variation under reference conditions.

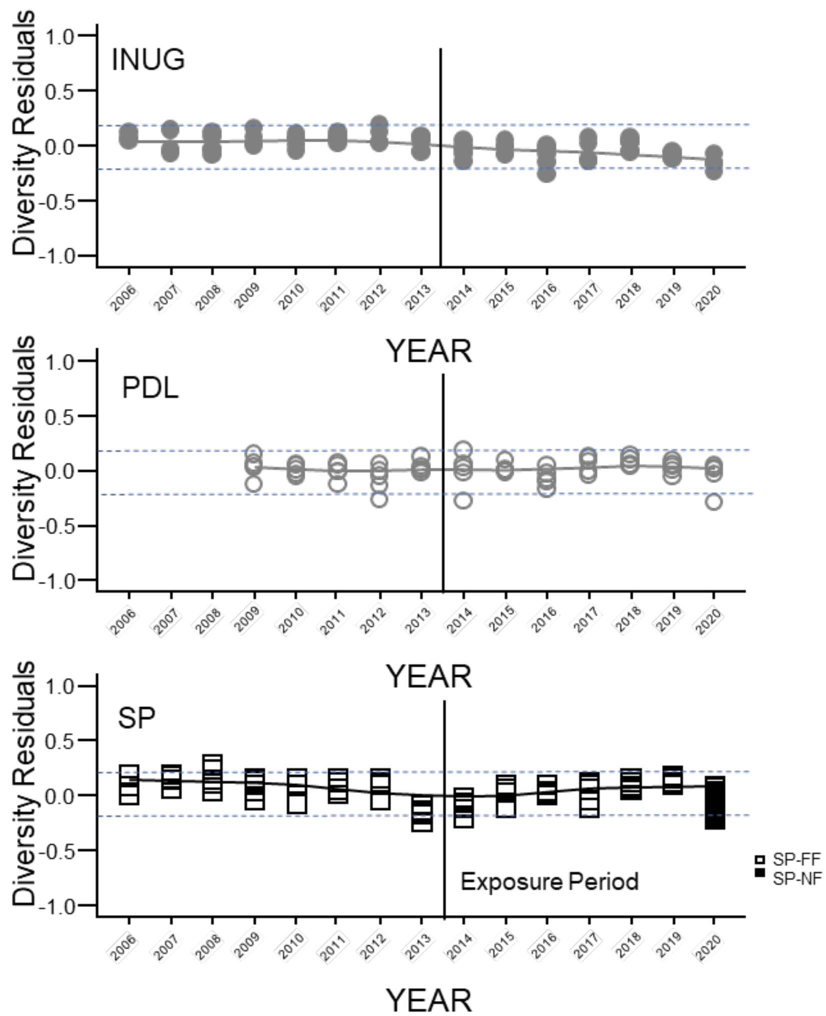

Figure 21. Residuals of diversity, among years for INUG, PDL and SP, Meadowbank Mine

Figure Note: the solid line illustrates LOWESS-smoothed variations in annual averages, while the dashed lines illustrate normal ranges of variation under reference conditions.

4.3.2.4 Precision

Estimated sample sizes required to obtain a precision of 0.2 (station values estimated to within ± 20% of their true values) are provided in Table 24 below. Precision estimates vary depending on the mean, with smaller means generally requiring a larger number of samples to get the estimates within 20% of the mean value. That said, total densities, family richness, and family diversity can be estimated to within 20% of the observed true means in SP-FF with single Ponar grabs. Having two grabs from those lakes will produce estimates for those variables that are even more precise than required. Two Ponar grabs were not sufficient to produce estimates within 20% of the true values for family evenness at SP-FF. Family evenness is a core variable.

Table 24. Sample sizes required to produce estimates of core and supporting indices of benthic invertebrate community composition that are within ±20% of the true values at a 'station' level

Core or Supporting	Variable	Dispersion	S	S^2	mean	Sample Size	
						n	Rounded Up
Core	log Density	0.2	0.21	0.045	3.65	0.08	<1
	log Richness	0.2	0.12	0.014	0.77	0.59	1
	Family Evenness	0.2	0.12	0.014	0.37	2.61	3
Supporting	Family Diversity	0.2	0.05	0.002	0.51	0.23	<1

Table Notes: S = standard deviation; S^2 = variance; $\bar{x}$ = station mean; N=estimated number of samples required.

4.4 Discussion

The benthic community of SP-NF in 2020 was diverse and consisted largely of chironomids and pisidiid fingernail clams. In terms of family compositions, the community of SP-NF was, further, very similar to what has been described from INUG, from PDL and from SP-FF. The benthos of SP-NF is therefore consistent with what is observed in reference lakes in the area, or for reference periods for SP-NF. The benthos of SP-NF is somewhat unique relative INUG and PDL, reflecting natural differences in sediment character.

Some of the observed variations in core indices of composition were related to variations in sampling depth and substrate total organic carbon and grain size. Testing for spatio-temporal variations, therefore, were carried out on residuals of the core indices, after taking into account the variations related to underlying physical variables.

Variations in residuals of indices of benthic community composition were assessed using specific contrasts designed to develop a burden of evidence that treated mine effluent was (or was not) causing effects on the benthic community of SP-NF. Some effluent-related null hypotheses were rejected, indicating differences that may be evidence of effluent-related effects. Effect sizes were, however, generally small and the benthic community of SP-NF contained a typical Artic assemblage. Any effluent-related effects, if present, were therefore subtle.

ANOVA 1 (H01) tested for differences in benthic communities between reference (INUG, PDL) and near-field exposure (SP-NF) in 2020. There were significant differences in four core indices of composition: total density, richness, evenness and NMDS axis 1 scores. Rejection of that null hypothesis for these indices was consistent with effluent related effects or naturally occurring differences. Effect sizes, however, only exceeded the CES of ± 2 SD for density. Densities in SP-NF was high relative to INUG and PDL in 2020.

ANOVA 2 tested for differences in benthic communities between the nearfield exposure (SP-NF) and farfield exposure (SP-FF) areas during the effluent exposure period (H02a: 2014 to 2020, H02b: 2020 only). There were significant differences in total density, richness, evenness and NMDS axis 1 scores for both H02a and b. Rejection of the null hypotheses for these indices suggests effluent related effects or implies that the nearfield and farfield areas have natural differences in index values. Again, effect sizes only exceeded the CES of ± 2 SD for total density.

ANOVA 3 tested for differences in benthic communities in the farfield exposure area (SP-FF) between the baseline period (2006-2007) and effluent exposure period (H03a: 2014-2020, H03b: 2020). There were significant differences in total density, evenness and NMDS axis 1 scores for both H03a and H03b. These differences are apparent in Figure 16 through Figure 21 and estimates of effect size (Table 22), particularly for total densities. Total densities were modestly higher in SP-FF during the effluent exposure period (2014 to 2020, and 2020 only) compared to the baseline period (2006/2007). That increase in numbers is potentially consistent with an effluent-related enhancement. That increase is also consistent with what visually appears to be a natural temporal oscillation in densities with higher densities in 2013 and 2014 and lower densities before and after in the farfield sampling area (SP-FF). Assuming the higher densities are an effluent-related phenomenon, the even-higher densities in the nearfield area (SP-NF) in 2020 could be consistent with an effluent-related enhancement. The higher densities of benthos in SP-NF may also be natural, potentially reflecting proximity to the dyke which would ameliorate fetch and related phenomena (Kilgour et al., 2000).

Despite the generally higher numbers of benthic organisms in the nearfield sampling area, the composition of benthic community at SP-NF was very similar to what has been observed in the reference lakes, and in SP-FF during baseline periods. NMDS axis scores in 2020 for SP-NF, for example, were within the range of values from SP-FF in the baseline period of 2006/2007 (Figure 15) indicating no difference from a baseline condition. Further, the benthic taxa collected from SP-NF are indicative of high-water quality. SP-NF benthos contained 11 genera of chironomid in 2020, similar to what had been observed in the other lakes including the dominant forms *Micropsectra*, *Stichtochironomus*, *Tanytarsus*, and *Procladius*. There were no oligochaete worms in the benthos of SP-NF in 2020, a group that typically increases in numbers when conditions degrade (Brinkhurst, 1980). The benthos of SP-NF in 2020 also contained the caddisfly *Grensia*, which has been historically observed in SP (in low relative densities), and a species that is generally restricted to the cold, clear waters of the far north (Harris and Lawrence, 1978). In summary, the benthic community in SP-NF does not indicate degraded conditions and contained an assemblage of organisms that are typical for these Arctic systems.

Each of the three sampling areas has relatively low hardness with concentrations of metals and nutrients that are well below CCME water quality guidelines, and near detection limits. There has been some elevation of cations (Ca, Mg, K) in SP, reflecting the slightly higher hardness in SP, but the changes are trivial relative to the concentrations that would be required in order to elicit a toxicity response (Mount *et al*., 1997).

4.4.1 Recommendations for Next Cycle

If the final discharge point in Second Portage Lake continues to be the only location where effluent is discharged, it is recommended the next (5th) EEM biological study utilize the same study design.

5.0 FISH TISSUE SURVEY

Mercury and selenium concentrations in the effluent were both consistently less than the concentrations that would require a fish tissue study; therefore, a study respecting fish tissue mercury or fish tissue selenium was not required.

6.0 SUBLETHAL TOXICITY TESTING

6.1 Introduction

Sub-lethal toxicity testing must be carried out two times per year for the first three years on the final discharge point that has potentially the most adverse environmental impact on the environment. After three years, the tests are to be conducted once per quarter on the species whose results produced the lowest geometric mean concentration having an effect (i.e., the species that is determined to be most affected by effluent). Since 2018, East Dike Seepage discharge has been the only one discharge to the receiving environment. In accordance with Subsection 6 (3) of the MDMER, *Ceriodaphnia dubia* is considered to be the species that is most effected by the effluent and sublethal toxicity testing is to be conducted quarterly on this species. However, all four species are still being tested. A summary of the results of the toxicological tests carried out on Meadowbank Mine effluent are presented here.

6.2 Materials and Methods

Laboratory testing of Meadowbank Mine final effluent was undertaken using four different tests: Fathead Minnow (*Pimephales promelas*) 7-Day Survival and Growth Test (EPS 1/RM/22, 2nd ed., Environment Canada, 2011), *Ceriodaphnia dubia* Survival and Reproduction Test (EPS 1/RM/21, Environment Canada, 2007a), the *Pseudokirchneriella subcapitata* 72-hour Growth Inhibition Test (EPS 1/RM/25, Environment Canada, 2007b), and the growth inhibition test with *Lemna minor* (EPS 1/RM/37, Environment Canada, 2007c). All four test protocols were run on final effluent samples at times of normal mine operation.

6.3 Results

The suite of four sublethal tests, outlined above, were completed on final effluent twice annually in 2018 and 2019, and on three occasions in 2020. Results of these tests are presented in Table 25

The LC50 to fathead minnows was greater than 100% in all seven lethality tests conducted from 2018 through 2020. Fathead growth inhibition was observed in one test conducted during this period. IC25 estimates for this test was 4.27%. This test was anomalous; mortality was 100% in one of three replicates at the 50% concentration and was 0% and 10% in the other two replicates. At 100% effluent concentration mortality in the three replicates was 0%, 10%, and 60%.

There was no lethality in six of seven tests conducted with *Ceriodaphnia dubia* during Cycle 4. One test result had an LC50 of 91.0%. Measurable reproductive inhibition was observed in three samples tested and IC25 estimates for these were 80.8%, 62.0%, and 39.7%.

No growth inhibition was observed in *Pseudokirchneriella subcapitata* exposed to effluent samples during cycle 4. Inhibitory effects for *Lemna minor* were observed in one test where IC25 estimates for frond growth (dry weight) and frond number were 88.3% and 82.2%, respectively.

Table 25. Sublethal toxicity data for 2018, 2019 and 2020.

Sample Collection Date	Test Species and Endpoint						
	Pimephales promelas		*Ceriodaphnia dubia*		*Pseudokirchneriella subcapitata*	*Lemna minor*	
	LC50	Growth IC25	LC50	Reproduction IC25	Growth IC25	Frond growth (dry wt.) IC25	Frond No. IC25
10-09-2018	>100%	>100%	>100%	>100%	>90.9%	>97%	>97%
19-11-2018	>100%	>100%	>100%	80.8%	>90.9%	>97%	>97%
18-03-2019	>100%	>100%	>100%	>100%	>90.9%	>97%	97%
25-11-2019	>100%	>100%	>100%	>100%	>90.9%	88.3%	82.2%
06-01-2020	>100%	>100%	>100%	62.2%	>90.9%	>97%	>97%
27-04-2020	>100%	>100%	91.0	39.7	>90.9%	>97%	>97%
26-10-2020	>100%	4.27%	>100%	>100%	>90.9%	>97%	>97%

Table Notes: Values represent percent effluent required to cause the effect; LC50 = concentration causing 50% mortality; IC25 = concentration causing 25% reduction in the sub-lethal endpoint, either growth, reproduction, frond number or frond weight.

6.4 Discussion

The EEM guidance document suggests that mines estimate the potential extent of the 25% effects zone in the receiving environment where the IC25 is less than 30% effluent concentration. The results of one anomalous test, discussed in the preceding section, indicated an IC25 of 4.27%. Based on the plume modelling study conducted for the study design (Baird, 2020), under the worst-case scenario (summer conditions, negatively buoyant effluent, low wind), the maximum effluent concentration at 100 m from the diffuser would be 3.0%. The distance from the diffuser at which a concentration of 4.27% would be attained is therefore less than 100 m.

7.0 SUMMARY AND CONCLUSIONS

This is the fourth invertebrate community survey for the Meadowbank Mine under the MMER/MDMER, but the first undertaken in SP-NF (under MDMER) because discharges to the previous exposure areas (Third Portage North Lake and Wally Lake (WAL)) have ceased. This 2020 survey of benthic invertebrates compared a near-field exposure area in Second Portage Lake (SP-NF), with reference-area data from Innuguguayalik Lake (INUG) and Pipedream Lake (PDL). Samples were also collected from a far-field sampling area in Second Portage Lake (SP-FF) that is outside of the 1% effluent mixing zone. Benthos have been sampled from SP-FF and INUG since 2006, while PDL has been sampled since 2009 as part of the mines Core Receiving Environmental Monitoring Program (CREMP). Samples collected in 2020 from SP-NF were the first collected for this exposure area.

The Cycle 4 EEM benthic invertebrate survey employed the same sampling methods as the CREMP program so that a before-after-control-impact (BACI) design could be used. There were a number of spatial and temporal variations that were significant and that were consistent with operational influences, but could also be due to natural variation. Most of the significant variations were small with effect sizes < ± 2 SDs. However, significant differences in densities exceeded the CES ± 2 SD, and variations exceeded background variability (i.e., the normal range of variation of reference data, INUG and PDL). Total densities at SP-NF where higher in 2020 than in reference lakes, than in SP-FF in 2014 to 2020, and than SP-FF in 2020.

Cycle 4 effluent samples produced no effect on survival of exposed fathead minnows. Measurable growth impairment in fathead minnows was observed in one of seven samples, with an IC25 estimate of 4.27%. One sample had a measured effect on survival of *Ceriodaphnia dubia*, with an LC50 of 91.0%. Measurable reproductive inhibition of *Ceriodaphnia dubia* was observed in three samples and with IC25 estimates of 80.8%, 62.2%, and 39.7%. Final effluent samples did not impair growth in any of the *Pseudokirchneriella subcapitata* tests during cycle 4. Inhibitory effects for *Lemna minor* were observed during one test where IC25 estimates for frond growth (dry weight) and frond number were 88.3% and 82.2%, respectively.

This Cycle 4 EEM study was the first EEM study for which Second Portage Lake was the exposure area. The next EEM cycle should, therefore, be completed within 36 months of the date when this submission was due, which is July 1st, 2024. Agnico will continue to monitor the volume and quality of the mine effluents. These data will be used to determine the requirements of the Cycle 5 EEM field study.

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Appendix 1 Correspondence with Environment Canada

Prairie and Northern Region
Environmental Protection Operations Directorate
Environment and Climate Change Canada
9250 – 49th Street NW
Edmonton, AB T6B 1K5

File #: MM3102

June 15, 2020

via email to: marie-pier.marcil@agnicoeagle.com

Marie-Pier Marcil
Senior Compliance Technician
Agnico Eagle Mines Ltd. - Meadowbank Division
10 200, route de preissac
Rouyn-Noranda, Québec J0Y1C0

Dear Marie-Pier Marcil:

Subject: Meadowbank Mine 4th EEM Study Design

Environment and Climate Change Canada (ECCC) has reviewed your "Environmental Effects Monitoring: Agnico Eagle Mines Ltd. – Meadowbank Division – Cycle 4 Study Design", submitted March 2, 2020 and the addendum submitted June 1, 2020. Our review took into account requirements of the *Metal and Diamond Mining Effluent Regulations* (MDMER) of the *Fisheries Act*, information in the EEM Technical Guidance Document as well as generally accepted standards of good scientific practice. This review is not a substitute for reading the MDMER and does not in any way supersede or modify the *Fisheries Act* or the MDMER. In the event of an inconsistency between this review and the Act and/or the MDMER, the Act and the Regulations prevail.

ECCC has completed the review and has no further comments at this time.

ECCC would appreciate receiving a final schedule for the biological monitoring, sent to Jennifer Froese at 780-722-6359 or at jennifer.froese@canada.ca at least two weeks prior to the commencement of field activities. As required under the MDMER, biological monitoring studies must be conducted in accordance with the study design. If it becomes impossible to follow the study design because of unusual circumstances, the mine must inform the Minister of the Environment (c/o Regional Director at ec.drrpn-rdpnr.ec@canada.ca) of those circumstances, without delay, and how the study will be conducted.

ECCC anticipates receiving the 4th interpretive report no later than July 1, 2021. Regulated facilities are required to submit EEM reports and biological monitoring data to the Environmental Effects Monitoring Electronic Reporting system (EEMER) at https://ec.ss.ec.gc.ca/.

If you have any questions or concerns about the EEM program or if you wish to discuss the study design, please contact Regional Coordinator Jennifer Froese at 780-722-6359 or at jennifer.froese@canada.ca. For questions regarding EEMER, please contact ec.esee-eem.ec@canada.ca.

Sincerely,

Margaret
Margaret Fairbairn
A/ Regional Director

cc:	Cristina Ruiu	Environment and Climate Change Canada, Regina
	Erik Allen	Environment and Climate Change Canada, Edmonton
	Jennifer Froese	Environment and Climate Change Canada, Edmonton
	Curtis Didham	Environment and Climate Change Canada, Iqaluit
	Derek Donald	Nunavut Water Board
	Karén Kharatyan	Nunavut Water Board
	Assol Kubeisinova	Nunavut Water Board
	Godwin Okonkwo	Crown-Indigenous Relations and Northern Affairs Canada
	David Zhong	Crown-Indigenous Relations and Northern Affairs Canada
	Meadowbank Environment Supervisor	Agnico Eagle Mines Ltd.

Appendix 2 Water Chemistry Quality Assurance

Table 2-1. Field duplicate, equipment blank, and travel blank for the 2020 CREMP water quality program.

Parameter	Duplicates				Blanks	
	SP-137	SP-137-DUP	RPD (%)		Travel Blank	Equipment Blank
Physical Tests						
Conductivity (µS/cm)	35.8	36.3	1.4		<2.0	<2.0
Hardness (as $CaCO_3$), Dissolved (mg/L)	13.9	14.6	4.9		<0.60	<0.60
Hardness (as $CaCO_3$), from total Ca/Mg (mg/L)	13.4	14.3	6.5		<0.60	<0.60
pH (lab)	7.16	7.11	0.7		5.72	5.45
Total Dissolved Solids (mg/L)	22.4	23	2.6		<3.0	<3.0
Total Dissolved Solids (mg/L), calculated	20.8	21.6	3.8		<1.0	1
Total Suspended Solids (mg/L)	<1.0	<1.0	0.0		<1.0	<1.0
Turbidity (NTU)	0.14	0.14	0.0		<0.10	<0.10
Anions and Nutrients (mg/L)						
Alkalinity, Hydroxide (as $CaCO_3$)	<1.0	<1.0	0.0		<1.0	<1.0
Alkalinity, Carbonate (as $CaC0_3$)	<1.0	<1.0	0.0		<1.0	<1.0
Alkalinity, Bicarbonate (as $CaCO_3$)	10.4	11.2	7.4		<1.0	<1.0
Alkalinity, Total (as $CaCO_3$)	10.4	11.2	7.4		<1.0	<1.0
Total Kjeldahl Nitrogen	0.133	0.111	18.0		<0.050	<0.050
Ammonia, Total (as N)	<0.0050	<0.0050	0.0		<0.0050	0.0204
Bromide	<0.050	<0.050	0.0		<0.050	<0.050
Chloride	0.78	0.83	6.2		<0.10	<0.10
Fluoride	0.068	0.066	3.0		<0.020	<0.020
Nitrate (as N)	<0.0050	<0.0050	0.0		<0.0050	<0.0050
Nitrite (as N)	<0.0010	<0.0010	0.0		<0.0010	<0.0010
Phosphate, ortho-, dissolved (as P)	<0.0010	<0.0010	0.0		<0.0010	<0.0010
Phosphorus, Total	0.0032	0.0029	9.8		<0.0020	<0.0020
Phosphorus, Total Dissolved	<0.0020	<0.0020	0.0		<0.0020	<0.0020
Silicate (as SIO_2)	0.55	0.53	3.7		<0.50	<0.50
Sulfate (as SO_4)	5.05	5.07	0.4		<0.30	<0.30
Cyanides (mg/L)						
Free Cyanide	<0.0010	<0.0010	0.0			
Total Cyanide	<0.0010	<0.0010	0.0			
Organic/Inorganic Carbon (mg/L)						
Dissolved Organic Carbon	1.74	1.73	0.6		<0.50	0.65
Total Organic Carbon	1.78	1.83	2.8		0.54	<0.50
Plant Pigments (µg/L)						
Chlorophyll-a	0.448	0.438	0.0			
Total Metals (mg/L)						
Aluminum	0.0057	0.0054	5.4		<0.0030	<0.0030
Antimony	<0.00010	<0.00010	0.0		<0.00010	<0.00010
Arsenic	0.00028	0.00033	16.4		<0.00010	<0.00010
Barium	0.00233	0.00251	7.4		<0.00010	<0.00010
Beryllium	<0.000100	<0.000100	0.0		<0.000100	<0.000100
Bismuth	<0.000050	<0.000050	0.0		<0.000050	<0.000050
Boron	<0.010	<0.010	0.0		<0.010	<0.010
Cadmium	<0.0000050	<0.0000050	0.0		<0.0000050	<0.0000050
Calcium	3.56	3.73	4.7		<0.050	<0.050
Cesium	<0.000010	<0.000010	0.0		<0.000010	<0.000010

Parameter	Duplicates				Blanks	
	SP-137	SP-137-DUP	RPD (%)		Travel Blank	Equipment Blank
Chromium	<0.00010	<0.00010	0.0		<0.00010	<0.00010
Cobalt	<0.00010	<0.00010	0.0		<0.00010	<0.00010
Copper	0.00059	0.00064	8.1		<0.00050	<0.00050
Iron	0.018	0.017	5.7		<0.010	<0.010
Lead	<0.000050	<0.000050	0.0		<0.000050	0.000069
Lithium	<0.0010	<0.0010	0.0		<0.0010	<0.0010
Magnesium	1.1	1.22	10.3		<0.0050	<0.0050
Manganese	0.00156	0.00168	7.4		<0.00010	<0.00010
Mercury	<0.0000050	<0.0000050	0.0		<0.0000050	<0.0000050
Molybdenum	0.000152	0.000153	0.7		<0.000050	<0.000050
Nickel	<0.00050	<0.00050	0.0		<0.00050	<0.00050
Phosphorus	<0.050	<0.050	0.0		<0.050	<0.050
Potassium	0.478	0.524	9.2		<0.050	<0.050
Rubidium	0.00085	0.00096	12.2		<0.00020	<0.00020
Selenium	<0.000050	<0.000050	0.0		<0.000050	<0.000050
Silicon	0.26	0.28	7.4		<0.10	<0.10
Silver	<0.000010	<0.000010	0.0		<0.000010	<0.000010
Sodium	0.8	0.874	8.8		<0.050	<0.050
Strontium	0.0186	0.0191	2.7		<0.00020	<0.00020
Sulfur	1.46	1.74	17.5		<0.50	<0.50
Tellurium	<0.00020	<0.00020	0.0		<0.00020	<0.00020
Thallium	<0.000010	<0.000010	0.0		<0.000010	<0.000010
Thorium	<0.00010	<0.00010	0.0		<0.00010	<0.00010
Tin	<0.00010	<0.00010	0.0		<0.00010	<0.00010
Titanium	<0.00030	<0.00030	0.0		<0.00030	<0.00030
Tungsten	<0.00010	<0.00010	0.0		<0.00010	<0.00010
Uranium	0.000052	0.000051	1.9		<0.000010	<0.000010
Vanadium	<0.00050	<0.00050	0.0		<0.00050	<0.00050
Zinc	<0.0030	<0.0030	0.0		<0.0030	<0.0030
Zirconium	<0.00020	<0.00020	0.0		<0.00020	<0.00020

Appendix 3 Benthic Community Data

Table 3-1. Count data for benthic samples collected on August 21 (INUG), 22 (PDL) and 26 (SP-NF and SP-FF), 2020.

TAXONOMY	INUG					PDL					SP-FF					SP-NF*					
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1.1	1.2	2	3	4	5
ROUNDWORMS																					
P. Nemata	1	1	1	-	2	6	4	1	-	1	5	7	5	1	2	-	1	5	1	2	1
FLATWORMS																					
P. Platyhelminthes																					
Cl. Turbellaria																					
indeterminate	-	-	3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ANNELIDS																					
P. Annelida																					
WORMS																					
S.F. Tubificinae																					
immatures with hair chaetae	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	12	5	2	3	-
S.F. Rhyacodrilinae																					
Rhyacodrilus coccineus	-	1	2	-	-	-	-	-	-	-	1	-	4	-	-	-	1	-	-	1	3
F. Lumbriculidae																					
Lumbriculus	1	-	1	-	-	1	2	2	-	-	1	2	3	-	2	2	3	12	4	1	4
ARTHROPODS																					
P. Arthropoda																					
MITES																					
Cl. Arachnida																					
O. Acarina																					
F. Acalyptonotidae																					
Acalyptonotus	-	-	-	-	-	-	-	1	-	-	1	3	-	1	-	-	-	3	2	1	-
F. Hygrobatidae																					
Hygrobates	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	1
F. Lebertiidae																					
Lebertia	-	2	-	-	1	-	-	-	1	-	2	-	-	2	-	-	-	-	-	-	2
F. Oxidae																					
Oxus	2	1	2	2	1	-	-	-	1	-	1	3	1	1	4	-	2	7	4	3	6
HARPACTICOIDS																					
O. Harpacticoida	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-
SEED SHRIMPS																					
Cl. Ostracoda	1	3	2	3	2	3	2	9	1	3	9	7	8	-	3	2	1	7	20	11	11
SPRINGTAILS																					
O. Collembola	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-
INSECTS																					
Cl. Insecta																					
CADDISFLIES																					
O. Trichoptera																					
F. Limnephilidae																					
Grensia praeterita	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	2	-	1

Table 3-1. (Continued)

TAXONOMY	INUG					PDL					SP-FF					SP-NF*					
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1.1**	**1.2**	**2**	**3**	**4**	**5**
TRUE FLIES																					
O. Diptera																					
MIDGES																					
F. Chironomidae																					
chironomid pupae	-	-	-	**1**	-	-	**1**	-	-	-	-	-	-	**1**	-	-	-	**1**	-	-	-
S.F. Chironominae																					
Corynocera ambigua	2	1	7	8	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Micropsectra	11	6	21	37	27	-	-	1	1	-	12	52	27	17	17	14	102	46	165	176	176
Microtendipes	4	8	9	14	3	-	-	-	-	-	-	-	-	-	-	1	1	4	6	3	6
Paracladopelma	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	3	-	-
Paratanytarsus	1	4	5	6	4	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Stempellinella	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stictochironomus	10	15	48	6	8	25	12	17	13	11	2	4	1	8	4	5	10	9	15	12	7
Tanytarsus	20	9	11	9	8	-	1	1	-	-	4	4	-	3	6	10	1	5	11	-	21
S.F. Diamesinae																					
Protanypus	-	1	-	2	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	1
S.F. Orthocladiinae																					
Abiskomyia	1	3	-	1	2	1	2	3	-	1	6	6	2	1	5	1	2	4	2	3	-
Heterotrissocladius	4	-	1	-	1	6	3	1	-	1	2	2	1	1	1	-	-	-	-	-	-
Mesocricotopus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Paracladius	-	-	-	-	-	-	-	-	-	-	1	-	4	-	1	-	-	-	-	-	-
Psectrocladius	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Zalutschia	-	1	-	-	2	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-
Orthocladiinae *Genus "Greenland"*	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S.F. Prodiamesinae																					
Monodiamesa	1	3	1	1	3	-	-	-	1	-	1	1	3	1	3	3	1	4	4	3	3
S.F. Tanypodinae																					
Procladius	5	4	7	6	7	10	5	14	7	10	14	13	11	5	15	13	10	11	31	18	35
Thienemannimyia complex	-	-	3	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-
MOLLUSCS																					
P. Mollusca																					
CLAMS																					
Cl. Bivalvia																					
F. Sphaeriidae																					
Pisidium/Cyclocalyx	-	5	4	4	1	-	-	1	-	-	7	9	17	9	4	18	15	11	54	30	16
Pisidium (Cyclocalyx/Neopisidium)	13	10	16	9	11	11	7	27	1	22	4	6	11	6	8	5	17	3	5	10	17
Sphaerium nitidum	1	2	2	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL NUMBER OF ORGANISMS	79	80	147	111	87	65	41	81	26	50	75	119	100	61	76	76	182	140	332	277	312
TOTAL NUMBER OF TAXA **	17	19	20	16	18	10	11	13	8	8	19	14	16	16	15	12	18	18	18	15	18

* Grabs for SF-NF-1 were processed separately as 1.1 and 1.2

** Bold entries excluded from taxa count

Appendix 4 Benthic Community Data Quality Assurance

Table 4-1. Percent recovery of benthic Macroinvertebrates from samples collected from benthic samples (2020).

Station	Number of Organisms Recovered (initial sort)	Number of Organisms in Re-sort	Percent Recovery
INUG-4	110	111	99.1%
SP-NF-1.2	179	182	98.4%
SP-FF-02	118	119	99.2%
		Average % Recovery	98.9%

QA/QC notes

Pupae were not counted toward total number of taxa unless they were the sole representative of their taxa group.

Immatures were not counted toward total number of taxa unless they were the sole representative of their taxa group. The exceptions to this rule are immature tubificidae with and without hairs. Immature oligocheates are counted as taxa as the probability of the immature being a unique taxa is high.

Indeterminates are unique taxa that could not be identified further for whatever reason, e.g., (small, damaged).