Appendix 26

Meadowbank 2019 Thermal Report

MEADOWBANK PROJECT

Thermal Report

Prepared by:
Agnico Eagle Mines Limited – Meadowbank Division

Version 1
March 2020

DOCUMENT CONTROL

Version	Date (YMD)	Section	Revision
1	2020-03-31	All	All

INTRODUCTION

To observe the freezeback of the Tailing Storage Facility (TSF) and the Rockfill Storage Facilities (RSF's) at the Meadowbank Mine Project, a series of subsurface thermistors have been installed at strategic locations.

The purposes of the TSF thermistors are to monitor the talik temperatures underneath the TSF as freezing progresses and to monitor the freezing of the tailings. The purpose of the thermistors in the RSF is to monitor the RSF temperature as freezing progresses. See Figure 1 for the locations of the thermistors installed. Appendix A of this Plan contains the updated data from each thermistor for 2019.

The thermistors are monitored periodically and as-needed, and this will continue throughout the operational period as well as during closure and post closure. The results collected are to be used to evaluate the predicted thermal response of the facilities with the actual thermal response. This will allow adjustments to the tailings deposition plan, the Waste Rock deposition plan and the final Closure Plan.

INSTRUMENT SPECIFICATIONS

Each thermistor installed as part of the thermal monitoring plan must comply with the general specifications presented in Table 1.

Table 1: Thermistor Specifications

Items	Specifications
Accuracy	1 degree Celsius
Thermistor temperature range	-40 to 40 degree Celsius
Method of cable termination	Amphenol connector and DAS direct connection
Cable termination enclosures	Weatherproof Animal resistant
Readout and data logger	Manual and DAS

THERMAL MONITORING OF THE TSF

The monitoring program objective for the TSF is to provide the data required to validate the predictions of freezeback within the tailings and support the cover design. The goals of the TSF North and South Cell cover systems and landforms are to ensure long-term landform stability, encourage TSF freeze-back into the surrounding permafrost, and maintain either subzero temperature or a high degree of saturation (>85%) in the tailings at all times. If it is determined by monitoring during operations that the tailings are freezing at lower rates than predicted, then mitigation procedures would be implemented.

An instrumentation plan for the TSF is planned to be developed to define the required instrumentation at closure once capping of the TSF is completed. The purpose of the performance monitoring system is to ensure that the cover performs as per its design intent.

The instruments installed in the North Cell TSF were done in locations where tailings deposition was not planned to resume. No instruments are currently installed within the tailings of the South Cell.

As the TSF is reaching its final elevation, thermistors will be installed from the final tailings surface, and directly into the underlying bedrock.

THERMAL PERFORMANCE OF THE TSF

The thermistors are indicating that freezeback is occurring within the North Cell TSF.

Instruments located near the pond of water of the North Cell are showing a portion of unfrozen tailings at depth with frozen tailings in surface (with a 4-5 m active layer) and a progression of the freezing front advancing at depth. This is represented by yellow dot on Figure 1 (NC-16-1, NC-16-2, NC17-3, NC-17-2, NC-17-6). Instruments located away from the water pond show that the tailings and its foundation are entirely frozen with an active depth of 4-5 m. This is represented by red, green and orange dot on Figure 1 (NC-17-1, NC17-4, NC-17-6, NC-17-7, NCIS-01 to NCIS-04).

Instruments installed in the capping or rockfill structure above taillings show that the active layer remained confined in the waste rock showing the effectiveness of the capping concept. This si represented by green and red dot on Figure 1 (NC-17-5, SWD-16-01).

The thermal prediction of the tailings freezeback made by Golder in 2008 indicated that for the more conservative scenario the entire tailings body would be completely frozen within a period of about 40 years after the end of operations with the freezing front advancing into the foundation beneath the tailings in the long term. The results are aligned with this modelling with most data showing a quicker freezeback than anticipated.

THERMAL MONITORING PLAN OF THE RSF

Thermistors are installed within the Portage RSF. No instruments are installed within the Vault RSF.

Additional thermistors are planned to be installed within the Portage and Vault RSF at closure. An instrumentation plan will be developed to define the required instrumentation at closure.

THERMAL PERFORMANCE OF THE RSF

In 2019 AEM initiated with O'Kane a mandate to review the thermal model of the Portage RSF with the objective of evaluating the accuracy of the thermal model by comparing the simulated results with field data collected from the thermistor data. This report is attached in Appendix B of this document.

The study done by O'Kane came to the following conclusion:

- Decreasing tends in active zone depth are recorded at most thermistor locations
- The thermal model predicted colder temperatures near surface compared to recorded near surface temperatures
- Temperature trends are becoming more consistent with simulated temperatures over time
- The observed active zone is generally thicker on the north slope compared to the south slope which is the opposite of the conceptual model.

The numerical modelling undertaken in 2016 tended to predict colder temperature than the thermistors during the observed period at all locations. However, the difference between the modelled and observed temperature is becoming less over time and the overall trend in the observed data is becoming more consistent with the model. The timing and amplitude of seasonal trends already show a good match between observed and modelled results, but the model results are shifted lower due to the predicted colder temperature. It is expected that the trend towards consistency will continue, further increasing confidence.

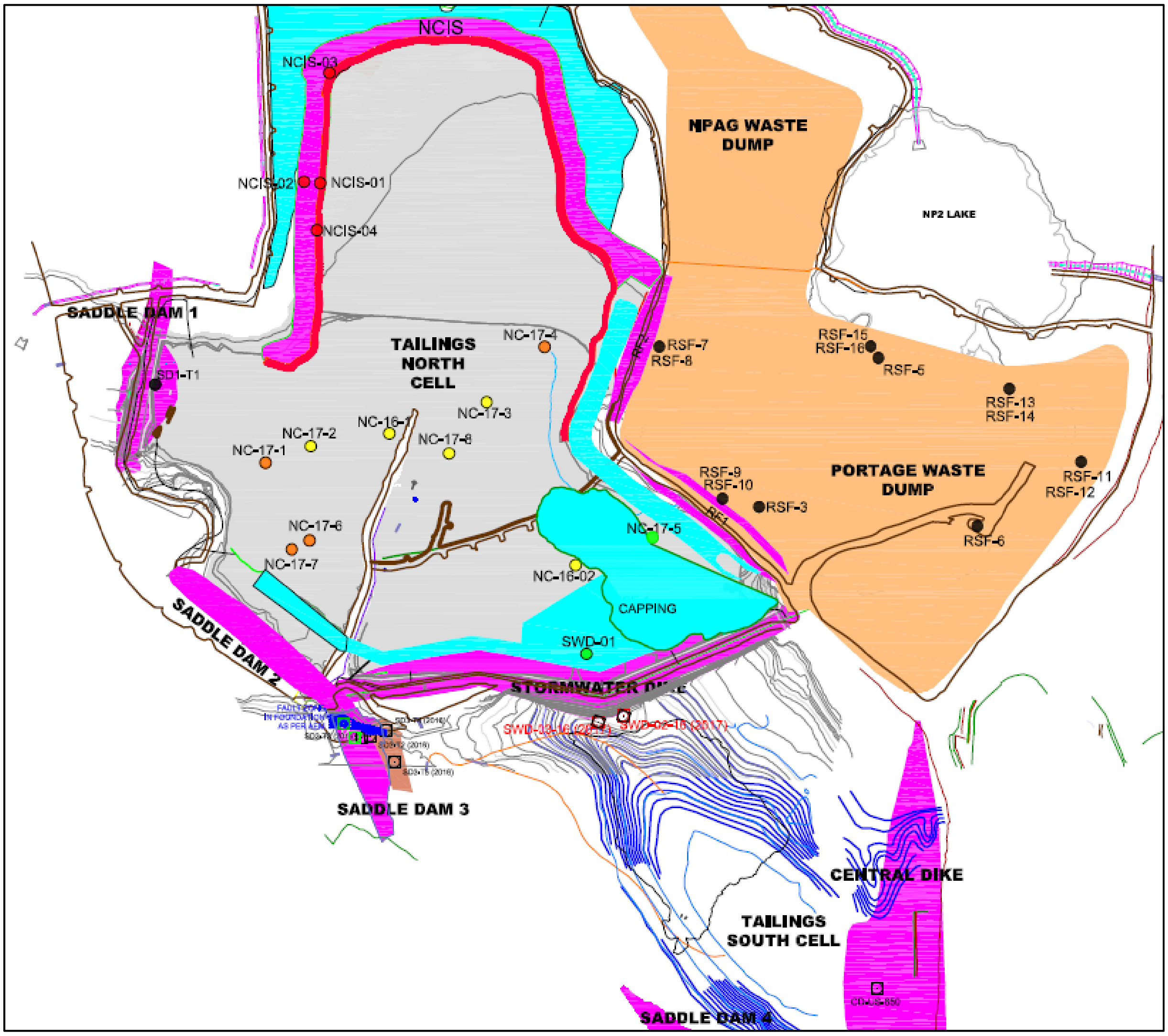
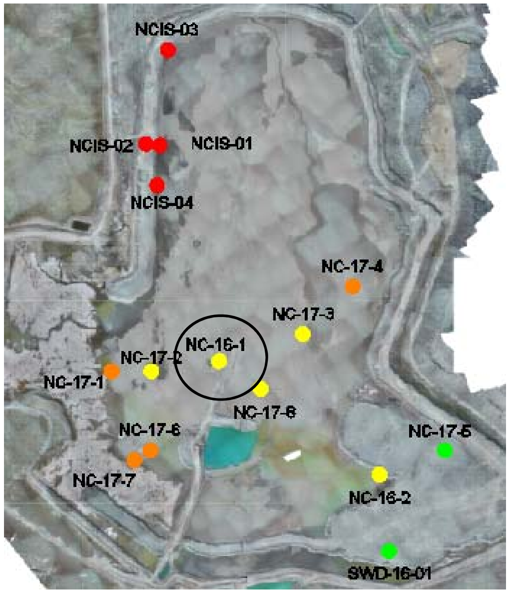


Figure 1: Thermistor Location in Portage RSF, TSF North Cell, and TSF South Cell

Name	Area	Easting (X)	Northing (Y)	Elevation (Z)	Azimuth	Dip	Installed	Active (Y) or (N)
NC-16-01	NC	637562.77	7215849.33	147.63	--	-90	2016	Y
NC-16-02	NC	637969.22	7215561.87	148.33	--	-90	2016	Y
NC-17-1	NC	637290.00	7215823.00	148.10	--	-90	2018	Y
NC-17-2	NC	637391.00	7215823.00	147.61	--	-90	2017	Y
NC-17-3	NC	637775.00	7215917.00	147.65	--	-90	2015	Y
NC-17-4	NC	637901.00	7216038.00	148.48	--	-90	2015	Y
NC-17-5	NC	638134.34	7215623.68	152.00	--	-90	2015	Y
NC-17-6	NC	637389.00	7215623.00	147.78	--	-90	2015	Y
NC-17-7	NC	637348.00	7215598.00	147.89	--	-90	2015	Y
NC-17-8	NC	637668.00	7215778.00	146.45	--	-90	2015	Y
NCIS-01	NC	637412.84	7216395.10	152.43	--	-90	2018	Y
NCIS-02	NC	637377.24	7216398.61	151.63	--	-90	2018	Y
NCIS-03	NC	637432.58	7216636.35	154.74	--	-90	2018	Y
NCIS-04	NC	637405.47	7216293.32	152.15	--	-90	2018	Y
SWD-01	NC	606778.00	7256254.00	162.00	--	-90	2014	Y
SD1-1	SD1	637030.50	7215957.68	150.00	--	Liner	2009	Y
SD2-1	SD2	637290.00	7215420.00	150.00	--	Liner	2012	Y
SD4-1	SD4	638253.95	7214479.72	144.00	--	Liner	2017	N
CD-US 0+650	CD	638626.00	7214639.00	126.40	--	Liner	2015	Y
RSF-3	RSF	607078.00	7256522.00	155.00	--	-90	2013	Y
RSF-5	RSF	638629.81	7216014.00	193.02	--	-90	2013	Y
RSF-6	RSF	638845.40	7215647.00	197.79	--	-90	2013	Y
RSF-7	RSF	638153.00	7216039.00	173.50	--	-55	2015	Y
RSF-8	RSF	638156.00	7216038.00	173.85	--	-70	2015	Y
RSF-9	RSF	638290.00	7215707.00	171.26	--	-55	2015	Y
RSF-10	RSF	638293.00	7215711.00	171.70	--	-70	2015	Y
RSF-11	RSF	639071.00	7215787.00	193.13	--	-55	2015	Y
RSF-12	RSF	639066.00	7215791.00	193.51	--	-70	2015	Y
RSF-13	RSF	638916.00	7215943.00	191.69	--	-55	2015	N
RSF-14	RSF	638917.00	7215939.00	191.81	--	-80	2015	N
RSF-15	RSF	638612.00	7216038.00	192.10	--	-55	2015	Y
RSF-16	RSF	638610.00	7216033.00	192.39	--	-70	2015	Y

NC-16-01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NCIS-01
NCIS-04
NC-17-4
NC-17-3
NC-16-1
NC-17-2
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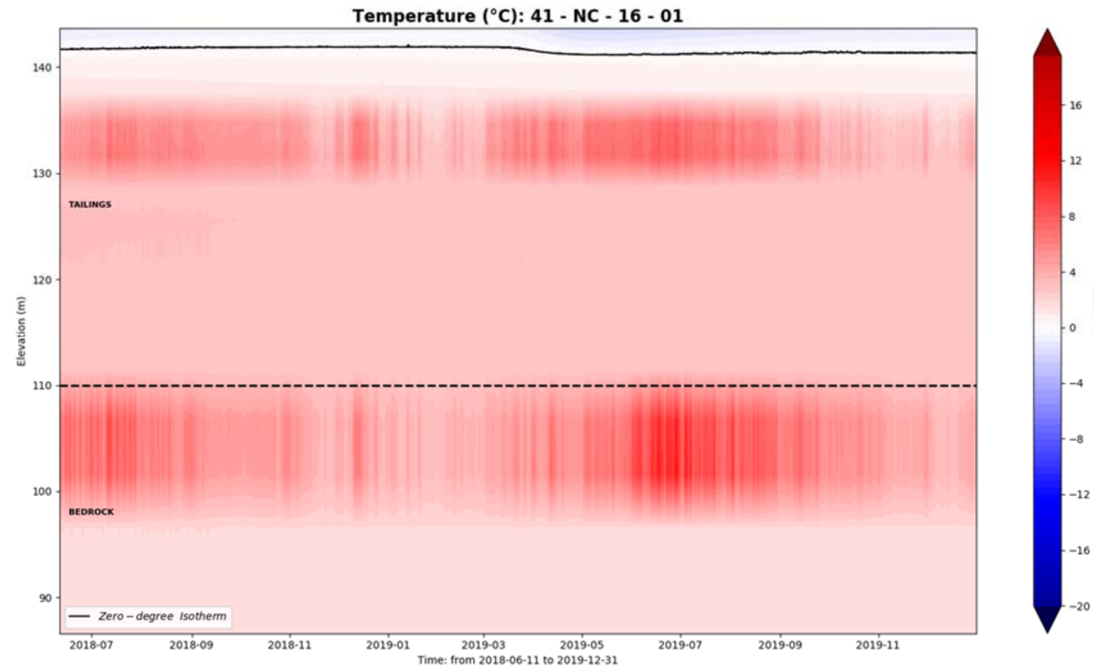
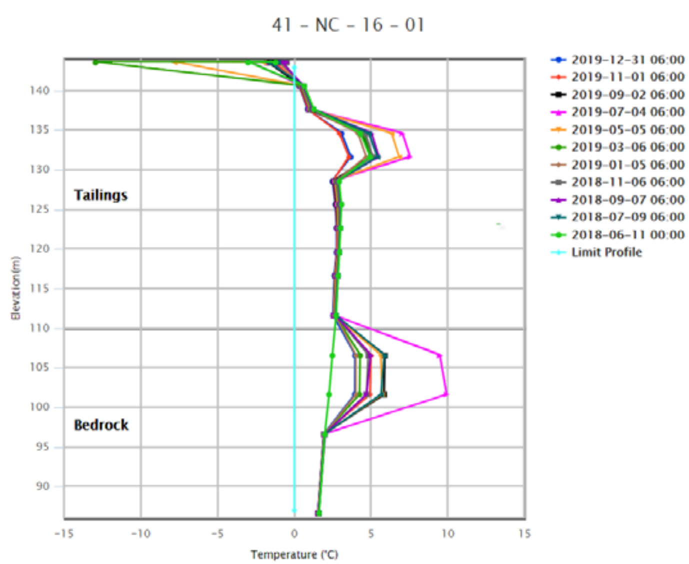
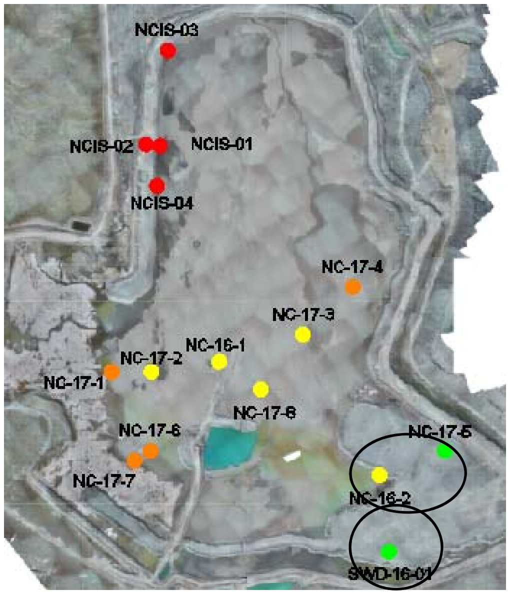
NC-17-8
NC-17-6
NC-17-5
NC-17-7
NC-16-2
SWD-16-01


Temperature (°C): 41 - NC - 16 - 01
TAILINGS
BEDROCK
Elevation (m)
Zero – degree Isotherm
Time: from 2018-06-11 to 2019-12-31
Temperature (°C)


41 – NC – 16 – 01
Tailings
Bedrock
Elevation(m)
Temperature (°C)
2019-12-31 06:00
2019-11-01 06:00
2019-09-02 06:00
2019-07-04 06:00
2019-05-05 06:00
2019-03-06 06:00
2019-01-05 06:00
2018-11-06 06:00
2018-09-07 06:00
2018-07-09 06:00
2018-06-11 00:00
Limit Profile

NC-16-02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NCIS-01
NCIS-04
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NC-17-3
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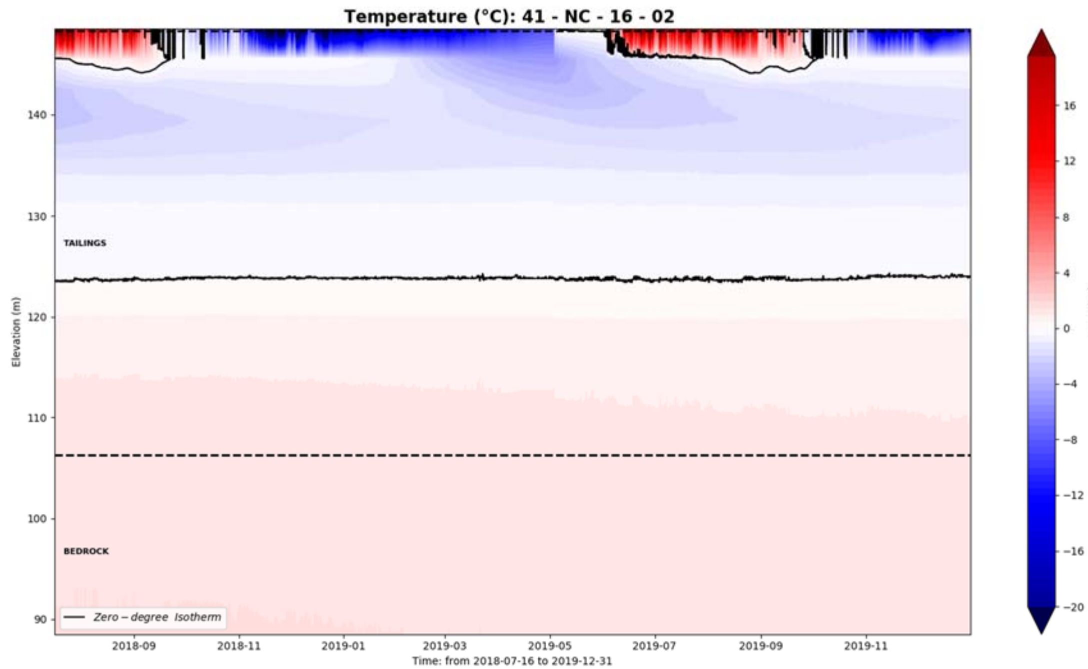
NC-16-2
SWD-16-01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Elevation (m)
TAILINGS
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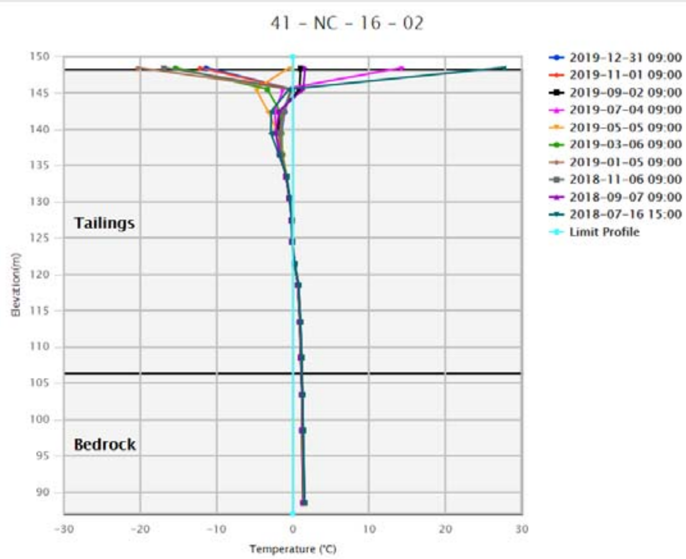
Zero – degree Isotherm
Time: from 2018-07-16 to 2019-12-31
Temperature (°C)


41 - NC - 16 - 02
Elevation(m)
Temperature (°C)
Tailings
Bedrock
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2019-11-01 09:00
2019-09-02 09:00
2019-07-04 09:00
2019-05-05 09:00
2019-03-06 09:00
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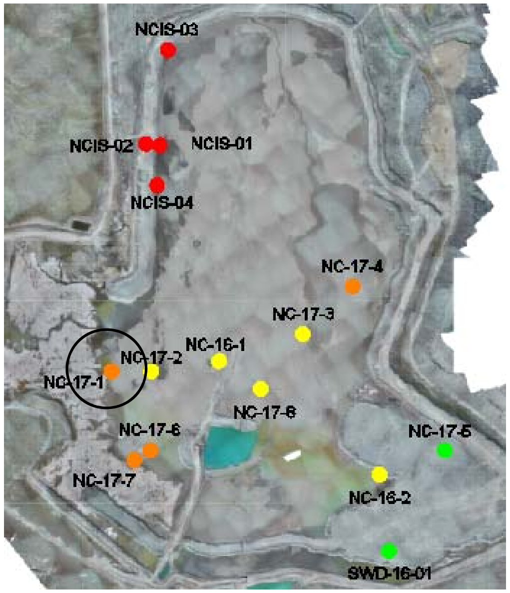

NCIS-03
NCIS-02
NCIS-01
NCIS-04
NC-17-4
NC-17-3
NC-16-1
NC-17-2
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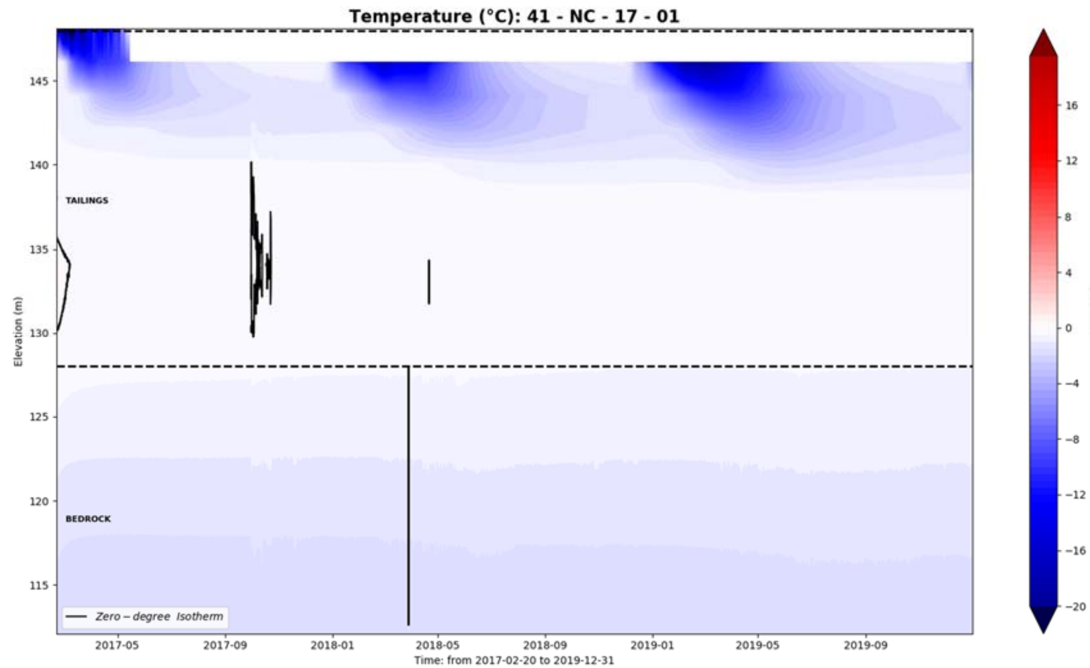
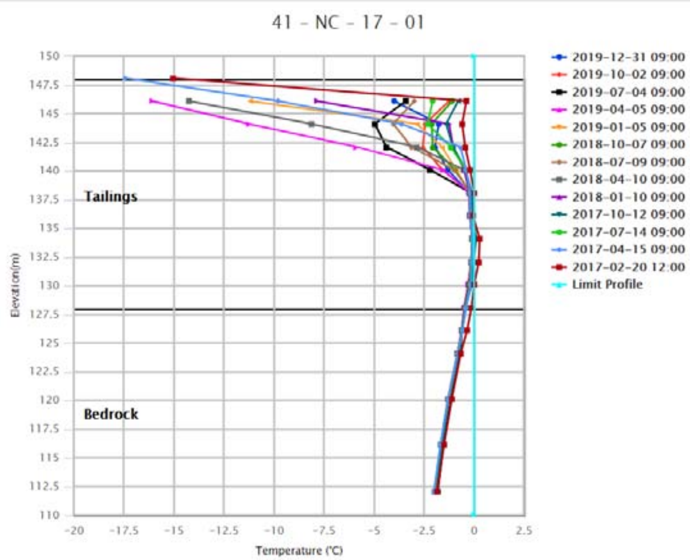
NC-16-2
SWD-16-01



Temperature (°C): 41 - NC - 17 - 01
Elevation (m)
TAILINGS
BEDROCK
Zero – degree Isotherm
Time: from 2017-02-20 to 2019-12-31
Temperature (°C)



41 - NC - 17 - 01
Tailings
Bedrock
Elevation(m)
Temperature (°C)
2019-12-31 09:00
2019-10-02 09:00
2019-07-04 09:00
2019-04-05 09:00
2019-01-05 09:00
2018-10-07 09:00
2018-07-09 09:00
2018-04-10 09:00
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2017-02-20 12:00
Limit Profile

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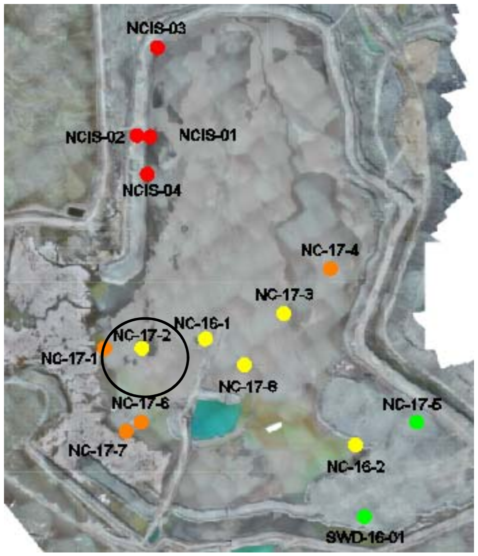
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NCIS-01
NCIS-04
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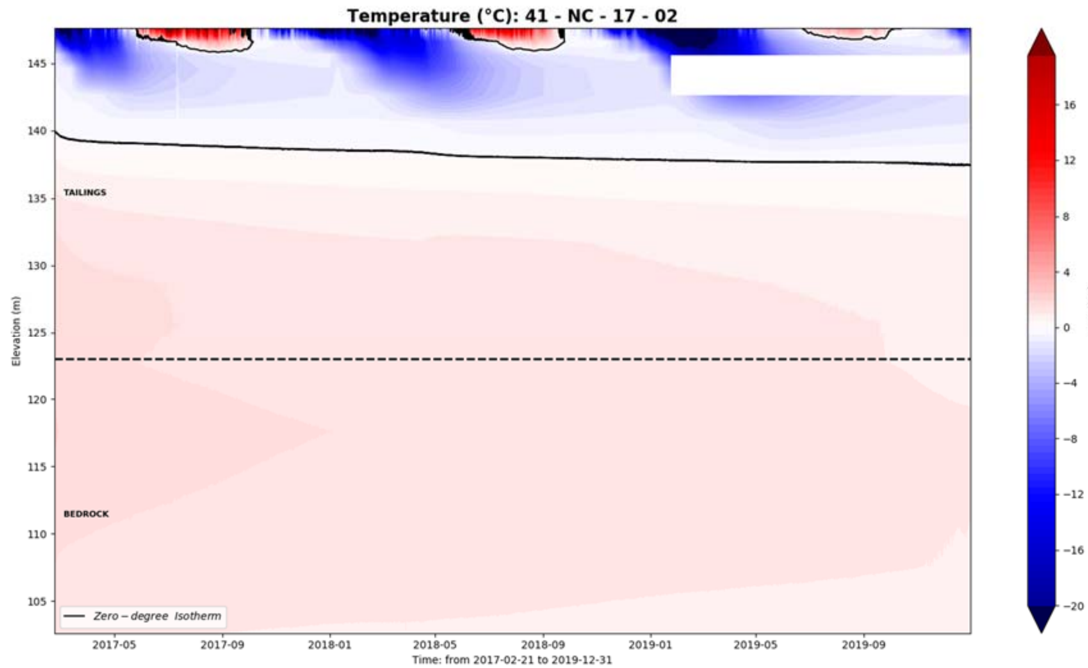
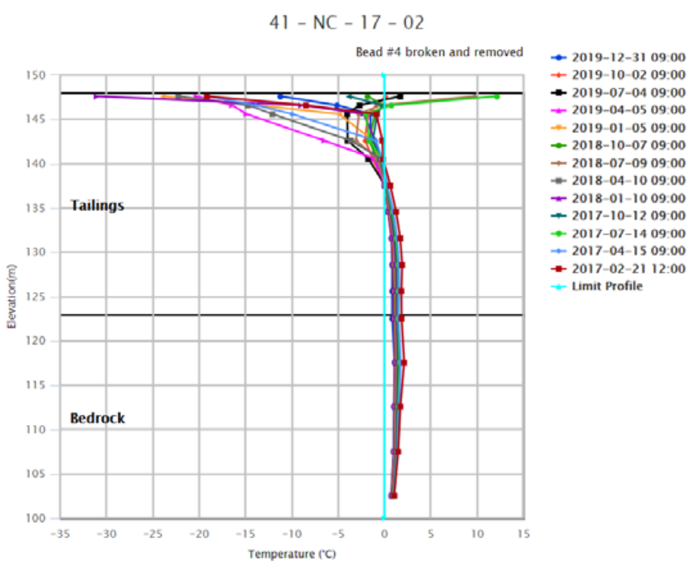

Temperature (°C): 41 - NC - 17 - 02
Elevation (m)
TAILINGS
BEDROCK
Zero – degree Isotherm
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
Time: from 2017-02-21 to 2019-12-31
Temperature (°C)


41 – NC – 17 – 02
Bead #4 broken and removed
Tailings
Bedrock
Elevation(m)
Temperature (°C)
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2019-07-04 09:00
2019-04-05 09:00
2019-01-05 09:00
2018-10-07 09:00
2018-07-09 09:00
2018-04-10 09:00
2018-01-10 09:00
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2017-04-15 09:00
2017-02-21 12:00
Limit Profile

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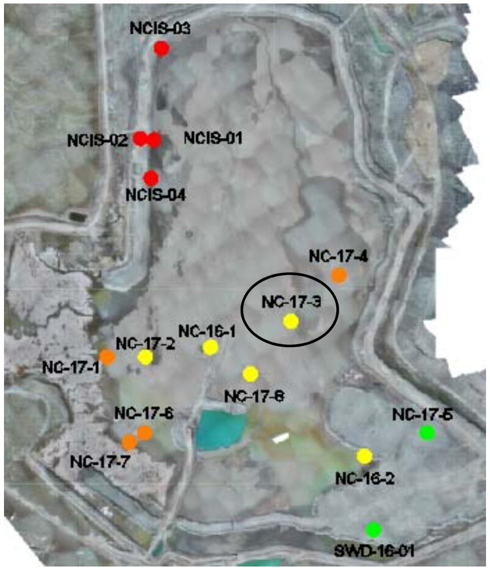
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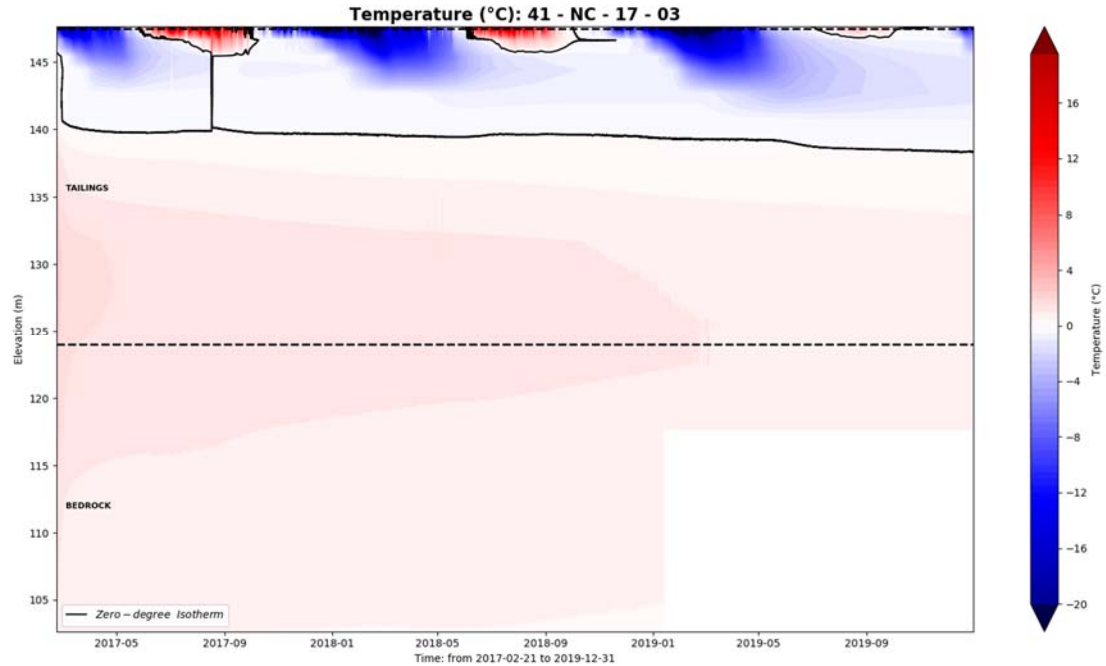
NC-16-2
SWD-16-01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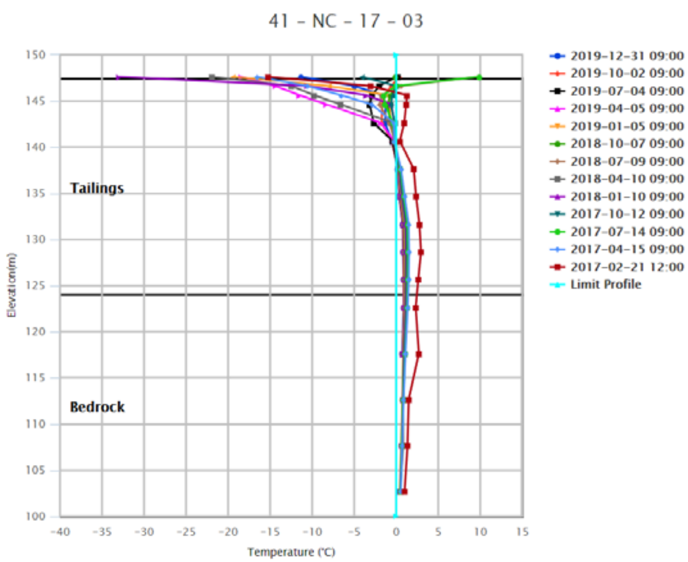
Elevation (m)
TAILINGS
BEDROCK
Zero – degree Isotherm
Time: from 2017-02-21 to 2019-12-31
Temperature (°C)


41 – NC – 17 – 03
Tailings
Bedrock
Elevation(m)
Temperature (°C)
2019-12-31 09:00
2019-10-02 09:00
2019-07-04 09:00
2019-04-05 09:00
2019-01-05 09:00
2018-10-07 09:00
2018-07-09 09:00
2018-04-10 09:00
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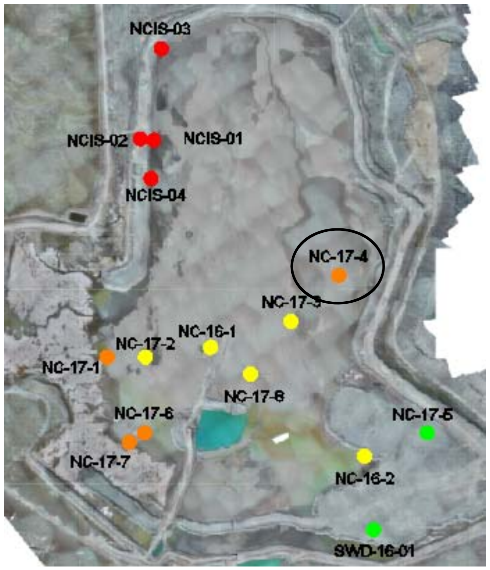
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NCIS-01
NCIS-04
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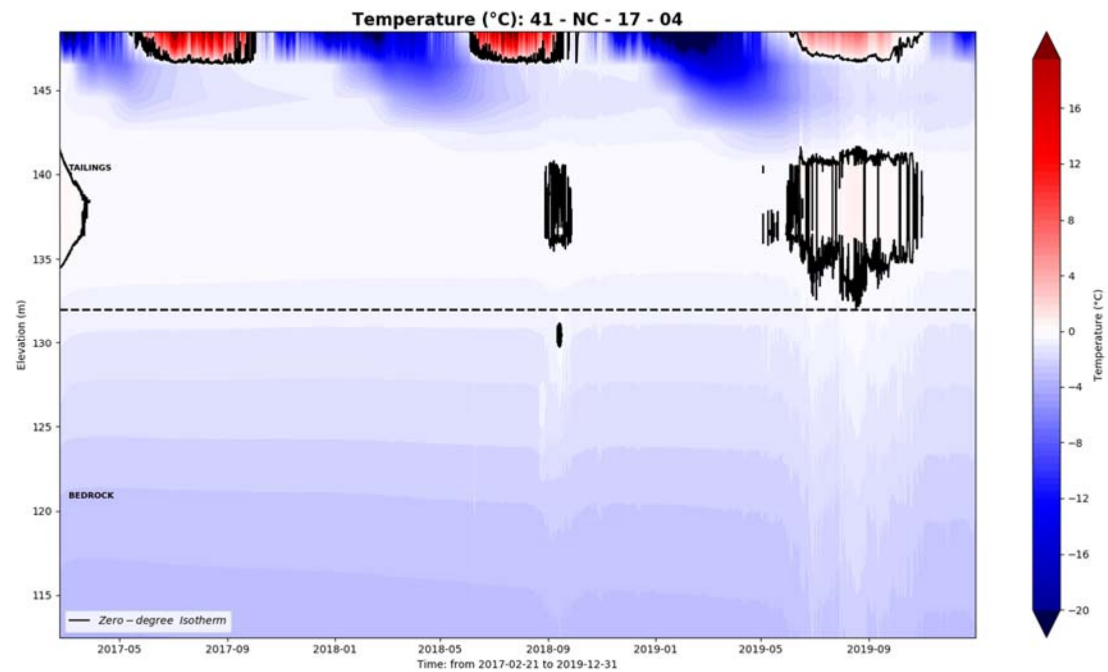
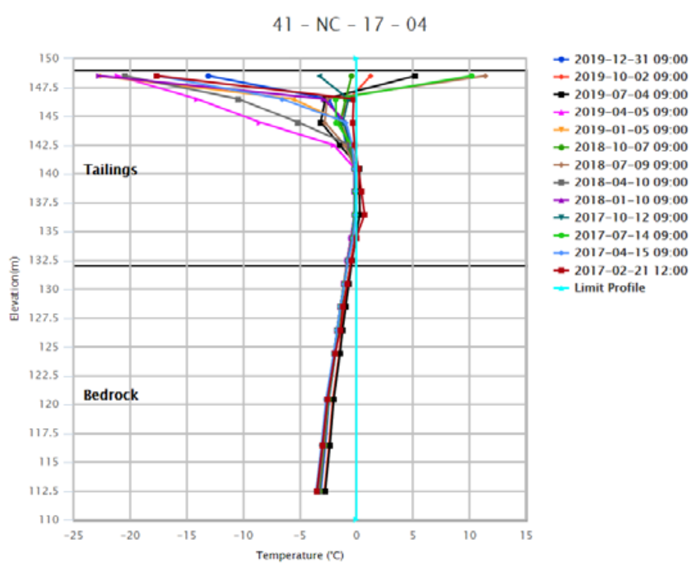
NC-16-2
SWD-16-01


Temperature (°C): 41 - NC - 17 - 04
TAILINGS
BEDROCK
Elevation (m)
Zero – degree Isotherm
Time: from 2017-02-21 to 2019-12-31
Temperature (°C)


41 – NC – 17 – 04
Tailings
Bedrock
Elevation(m)
Temperature (°C)
2019-12-31 09:00
2019-10-02 09:00
2019-07-04 09:00
2019-04-05 09:00
2019-01-05 09:00
2018-10-07 09:00
2018-07-09 09:00
2018-04-10 09:00
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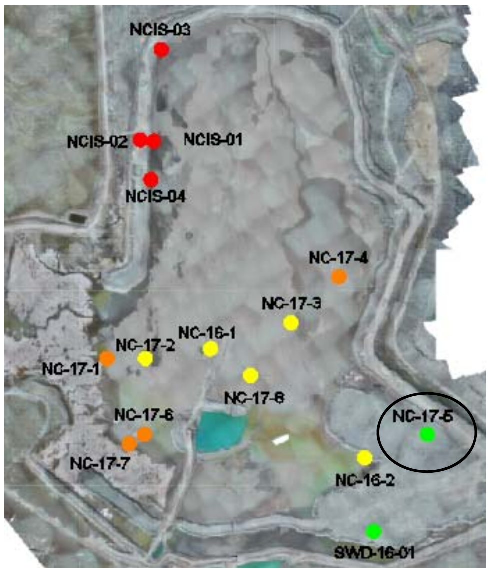
Limit Profile

NC-17-05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NCIS-02
NCIS-01
NCIS-04
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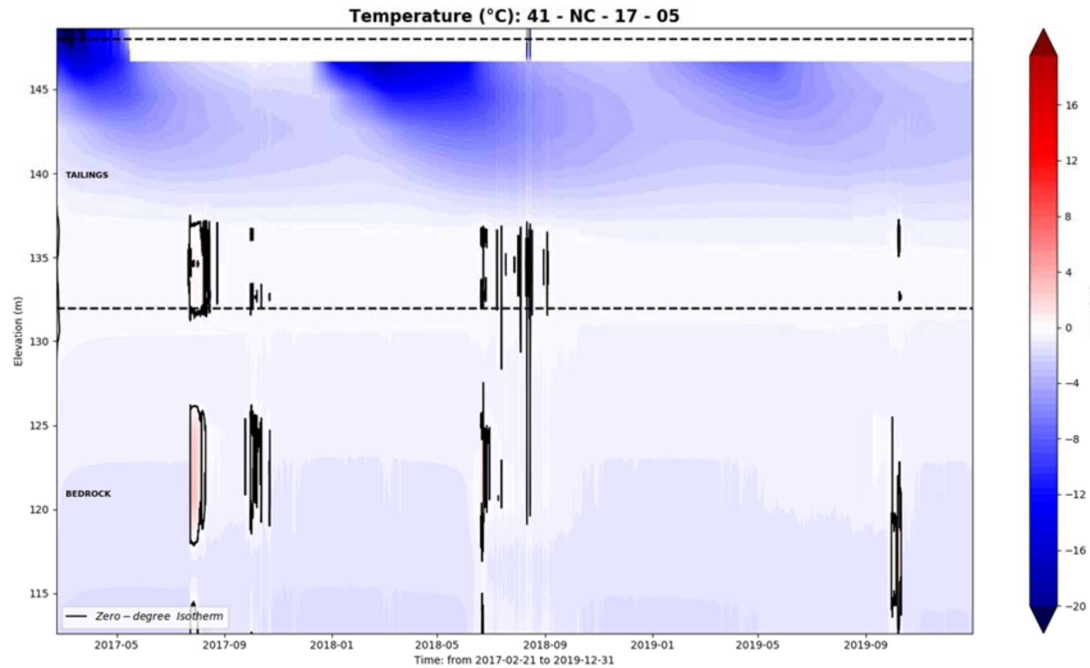
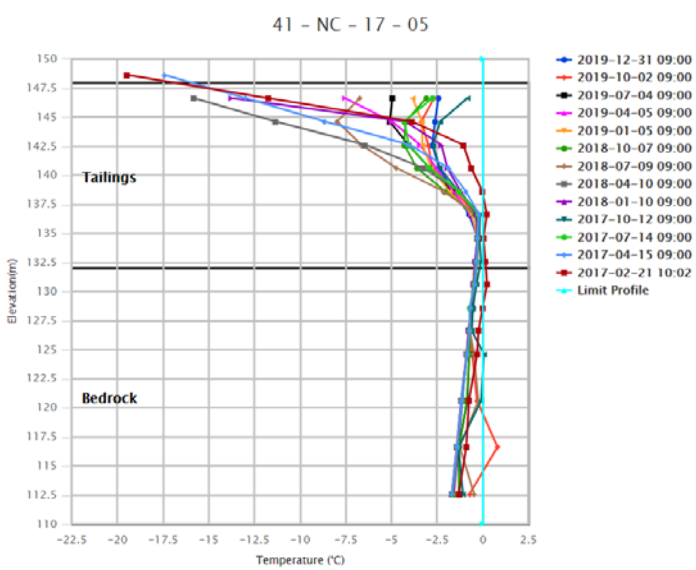

Temperature (°C): 41 - NC - 17 - 05
TAILINGS
BEDROCK
Elevation (m)
Zero – degree Isotherm
Time: from 2017-02-21 to 2019-12-31
Temperature (°C)


41 – NC – 17 – 05
Tailings
Bedrock
Elevation(m)
Temperature (°C)
2019-12-31 09:00
2019-10-02 09:00
2019-07-04 09:00
2019-04-05 09:00
2019-01-05 09:00
2018-10-07 09:00
2018-07-09 09:00
2018-04-10 09:00
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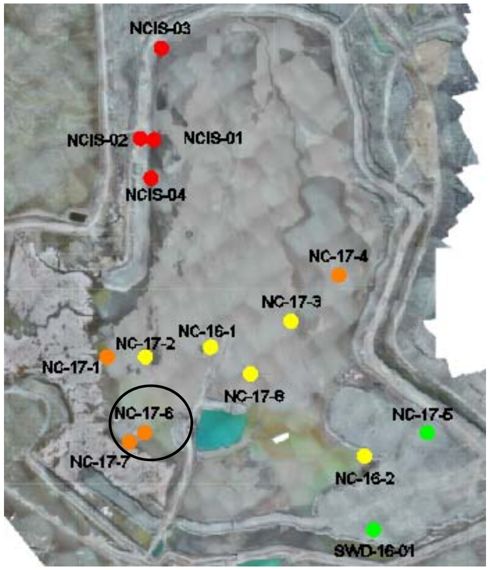
Limit Profile

NC-17-06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NCIS-02
NCIS-01
NCIS-04
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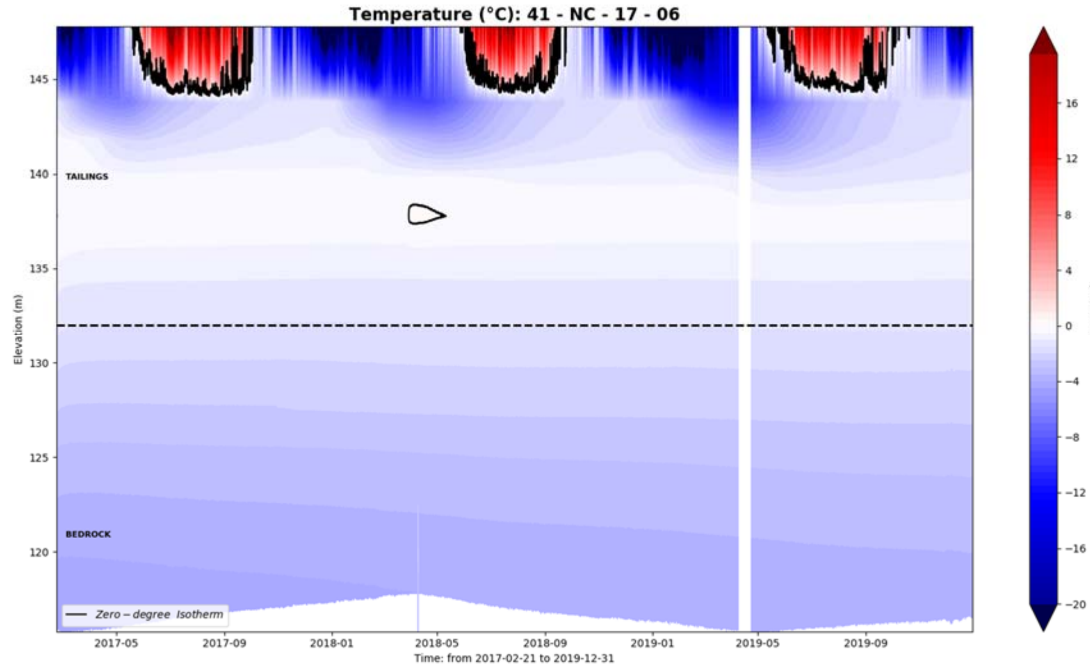
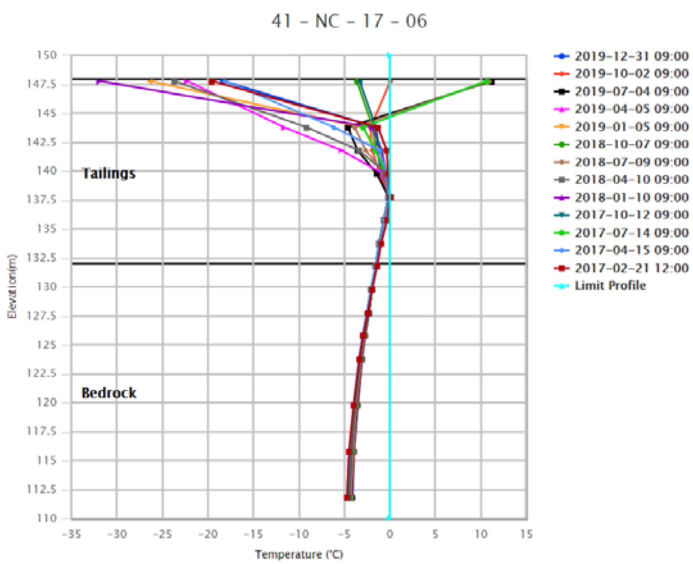

Temperature (°C): 41 - NC - 17 - 06
TAILINGS
BEDROCK
Zero – degree Isotherm
Elevation (m)
Time: from 2017-02-21 to 2019-12-31
Temperature (°C)


41 – NC – 17 – 06
Tailings
Bedrock
Elevation(m)
Temperature (°C)
2019-12-31 09:00
2019-10-02 09:00
2019-07-04 09:00
2019-04-05 09:00
2019-01-05 09:00
2018-10-07 09:00
2018-07-09 09:00
2018-04-10 09:00
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2017-04-15 09:00
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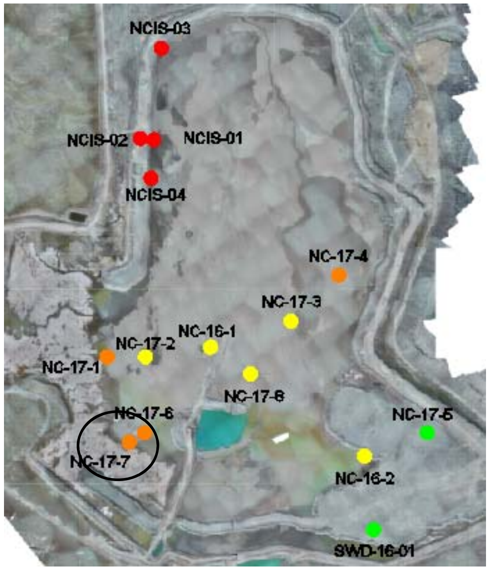
Limit Profile

NC-17-07


NCIS-03
NCIS-02
NCIS-01
NCIS-04
NC-17-4
NC-17-3
NC-16-1
NC-17-2
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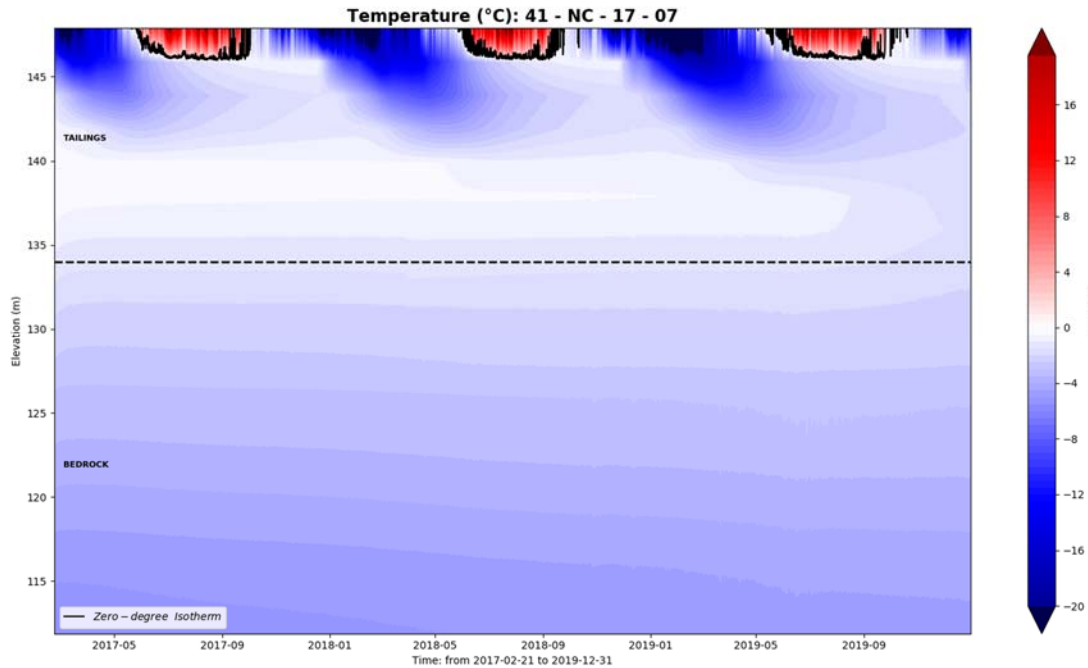
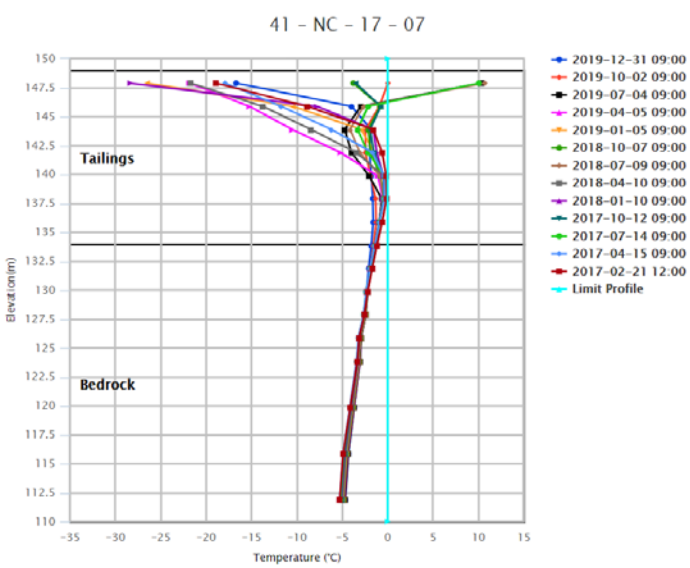
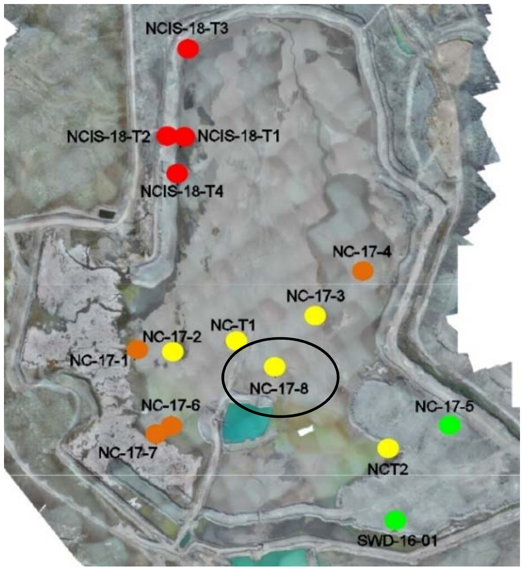
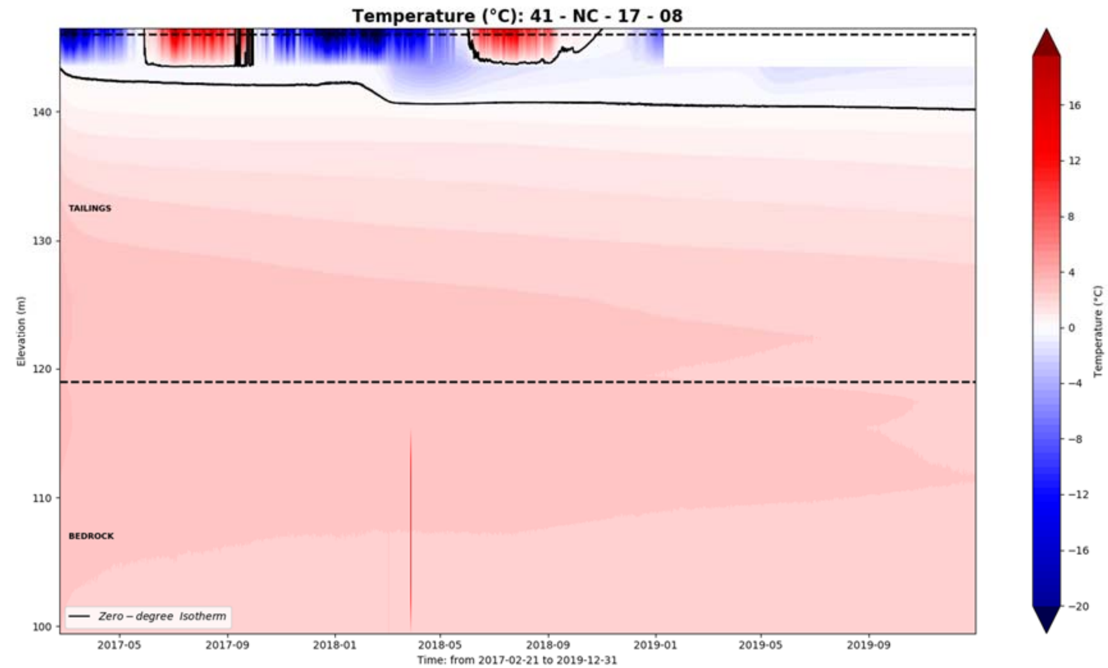
NC-17-8
NC-17-6
NC-17-5
NC-17-7
NC-16-2
SWD-16-01

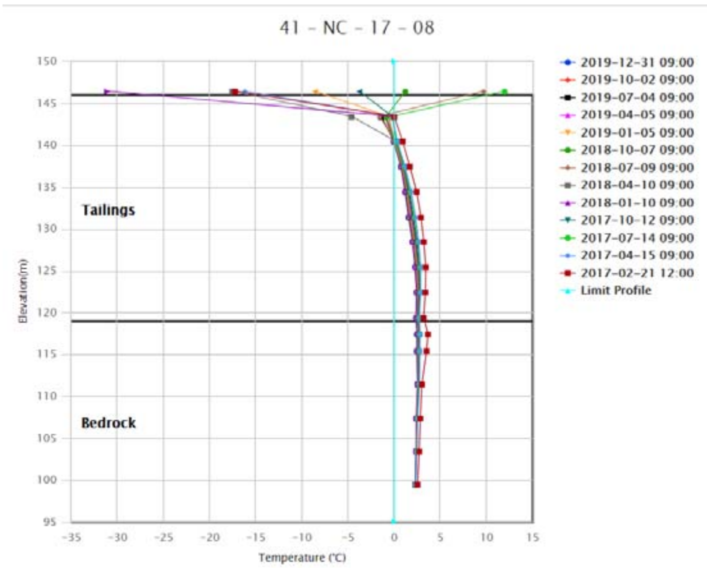

Temperature (°C): 41 - NC - 17 - 07
Elevation (m)
TAILINGS
BEDROCK
Zero – degree Isotherm
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
Time: from 2017-02-21 to 2019-12-31
Temperature (°C)


41 – NC – 17 – 07
Tailings
Bedrock
Elevation(m)
Temperature (°C)
2019-12-31 09:00
2019-10-02 09:00
2019-07-04 09:00
2019-04-05 09:00
2019-01-05 09:00
2018-10-07 09:00
2018-07-09 09:00
2018-04-10 09:00
2018-01-10 09:00
2017-10-12 09:00
2017-07-14 09:00
2017-04-15 09:00
2017-02-21 12:00
Limit Profile

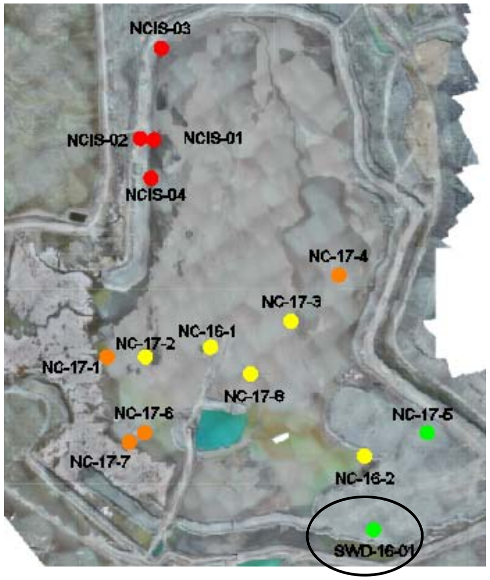
NC-17-08

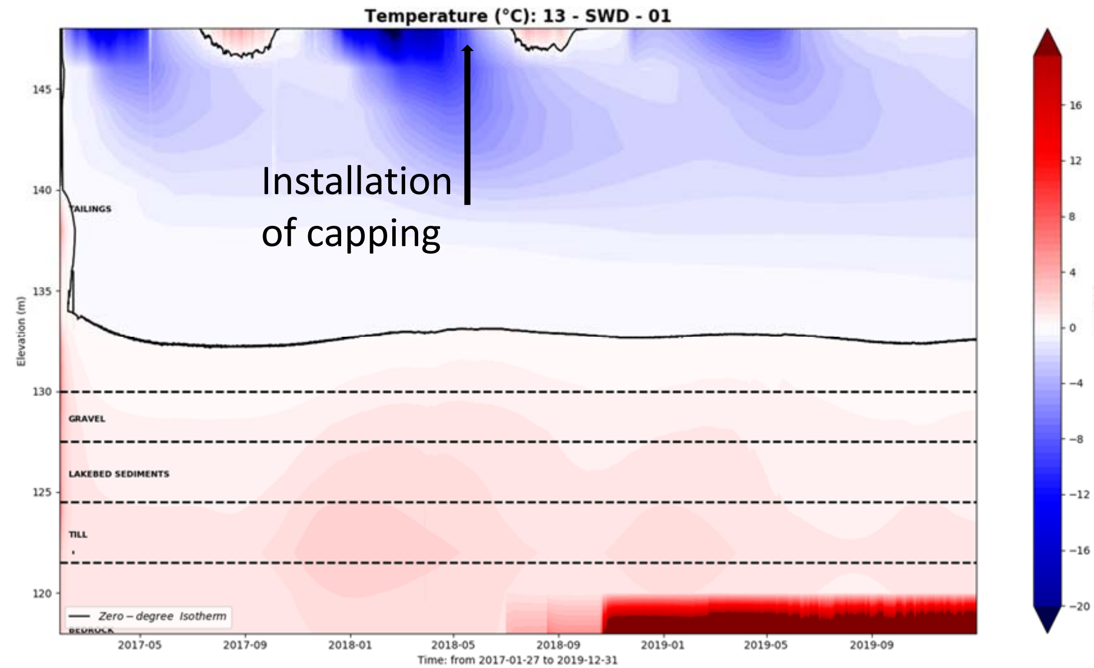

NCIS-18-T3
NCIS-18-T2
NCIS-18-T1
NCIS-18-T4
NC-17-4
NC-17-3
NC-T1
NC-17-2
NC-17-1
NC-17-8
NC-17-6
NC-17-5
NC-17-7
NCT2
SWD-16-01

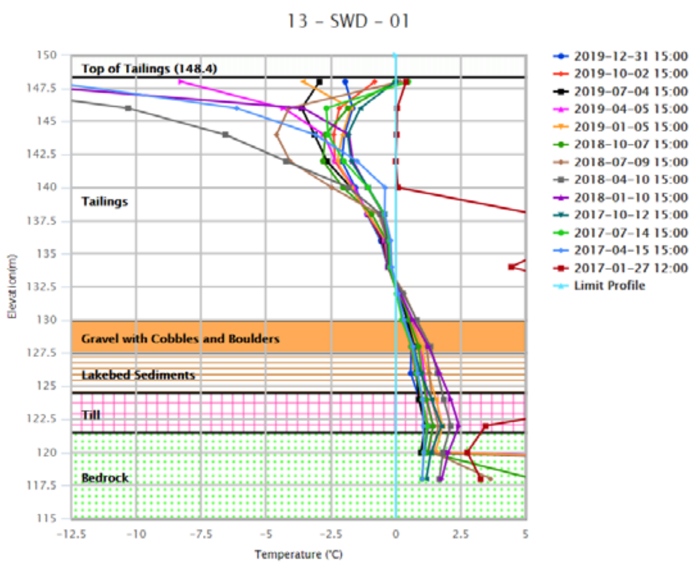

Temperature (°C): 41 - NC - 17 - 08
TAILINGS
BEDROCK
Elevation (m)
Zero – degree Isotherm
Time: from 2017-02-21 to 2019-12-31
Temperature (°C)


41 – NC – 17 – 08
Tailings
Bedrock
Elevation(m)
Temperature (°C)
2019-12-31 09:00
2019-10-02 09:00
2019-07-04 09:00
2019-04-05 09:00
2019-01-05 09:00
2018-10-07 09:00
2018-07-09 09:00
2018-04-10 09:00
2018-01-10 09:00
2017-10-12 09:00
2017-07-14 09:00
2017-04-15 09:00
2017-02-21 12:00
Limit Profile

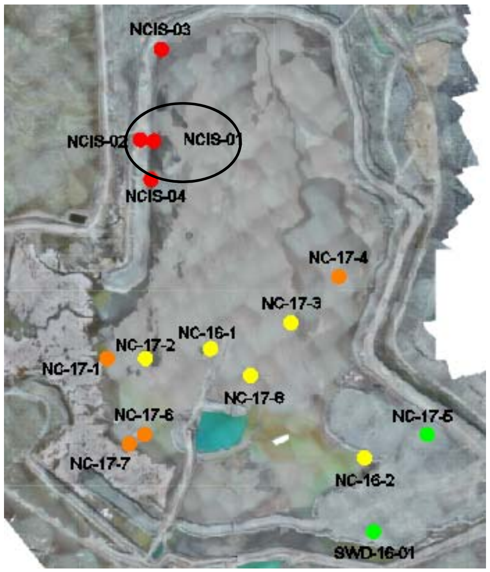
SWD-01


NCIS-03
NCIS-02
NCIS-01
NCIS-04
NC-17-4
NC-17-3
NC-16-1
NC-17-2
NC-17-1
NC-17-8
NC-17-6
NC-17-5
NC-17-7
NC-16-2
SWD-16-01

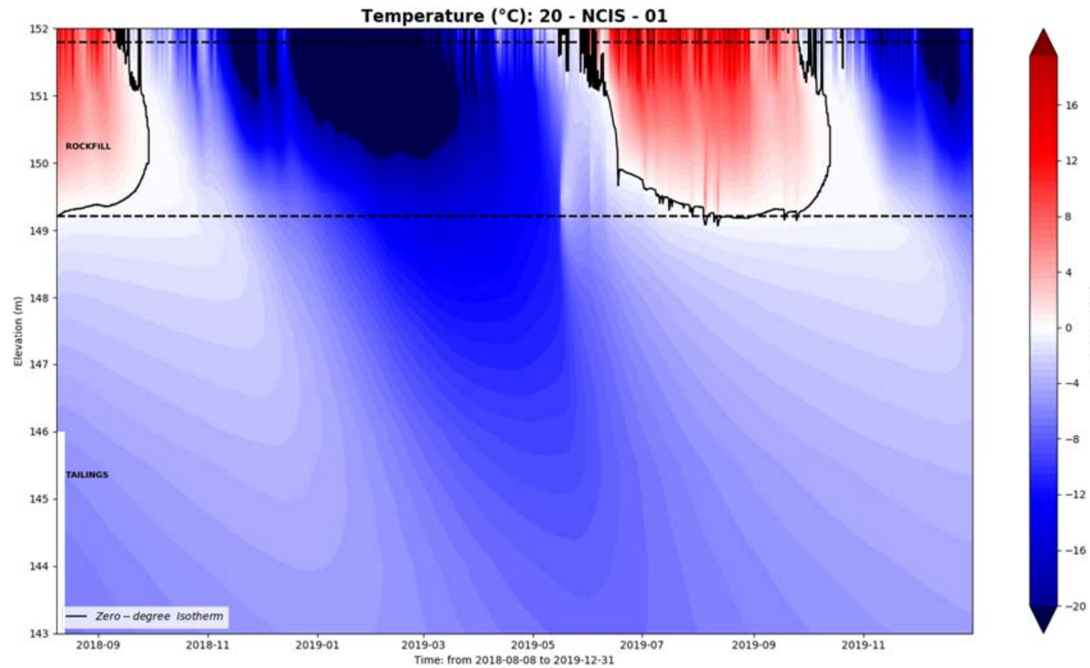

Temperature (°C): 13 - SWD - 01
Installation of capping
TAILINGS
GRAVEL
LAKEBED SEDIMENTS
TILL
BEDROCK
Zero – degree Isotherm
Elevation (m)
Temperature (°C)
Time: from 2017-01-27 to 2019-12-31


13 - SWD - 01
Top of Tailings (148.4)
Tailings
Gravel with Cobbles and Boulders
Lakebed Sediments
Till
Bedrock
Elevation(m)
Temperature (°C)
2019-12-31 15:00
2019-10-02 15:00
2019-07-04 15:00
2019-04-05 15:00
2019-01-05 15:00
2018-10-07 15:00
2018-07-09 15:00
2018-04-10 15:00
2018-01-10 15:00
2017-10-12 15:00
2017-07-14 15:00
2017-04-15 15:00
2017-01-27 12:00
Limit Profile

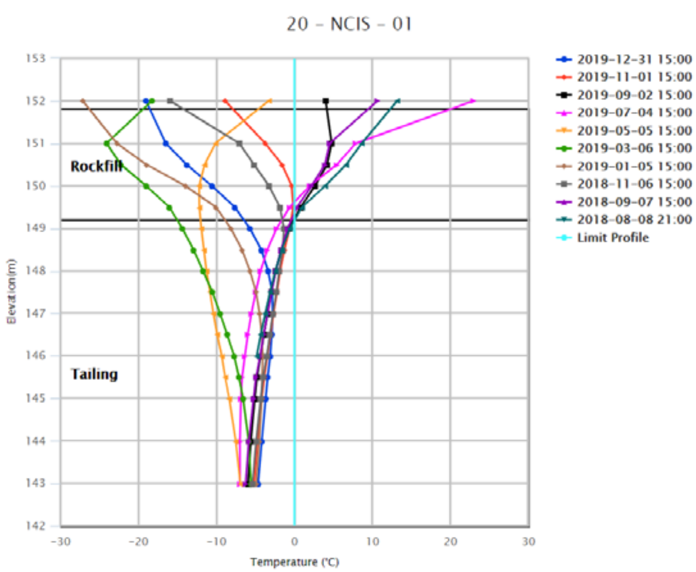
NCIS-01



NCIS-03
NCIS-02
NCIS-01
NCIS-04
NC-17-4
NC-17-3
NC-16-1
NC-17-2
NC-17-1
NC-17-8
NC-17-6
NC-17-5
NC-17-7
NC-16-2
SWD-16-01

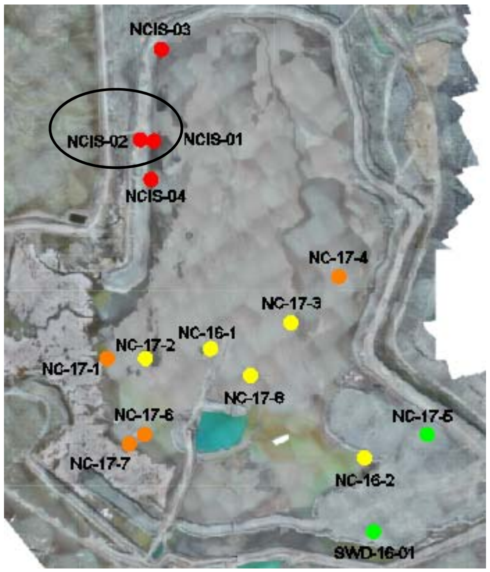


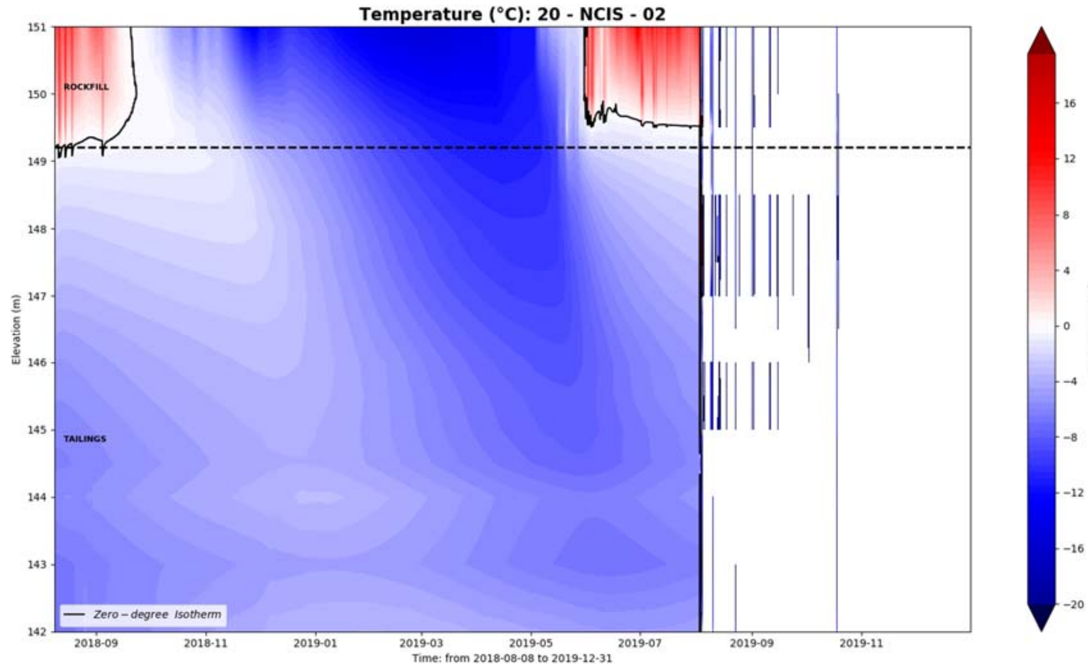
Temperature (°C): 20 - NCIS - 01
ROCKFILL
TAILINGS
Zero – degree Isotherm
Elevation (m)
Temperature (°C)
Time: from 2018-08-08 to 2019-12-31

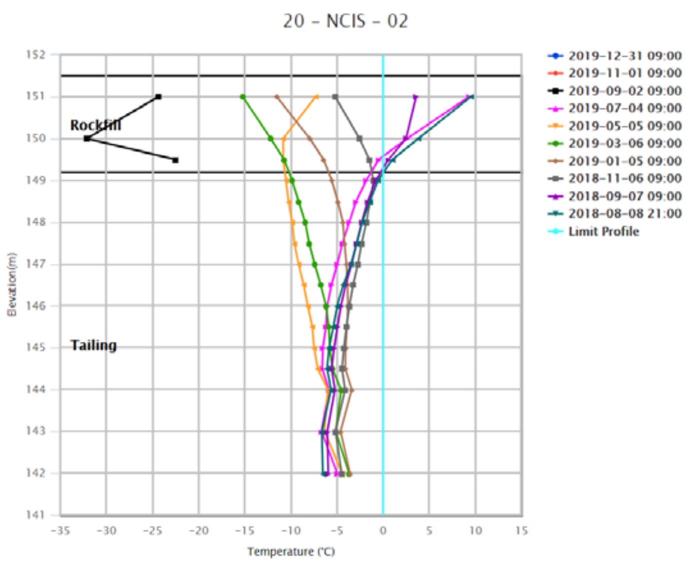


20 – NCIS – 01
Rockfill
Tailing
Elevation(m)
Temperature (°C)
2019-12-31 15:00
2019-11-01 15:00
2019-09-02 15:00
2019-07-04 15:00
2019-05-05 15:00
2019-03-06 15:00
2019-01-05 15:00
2018-11-06 15:00
2018-09-07 15:00
2018-08-08 21:00
Limit Profile

NCIS-02

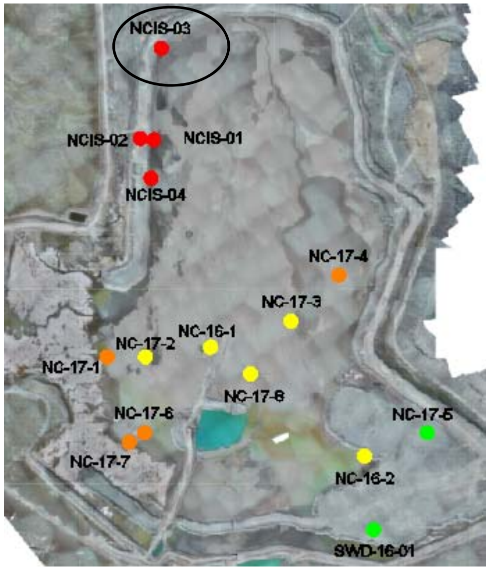


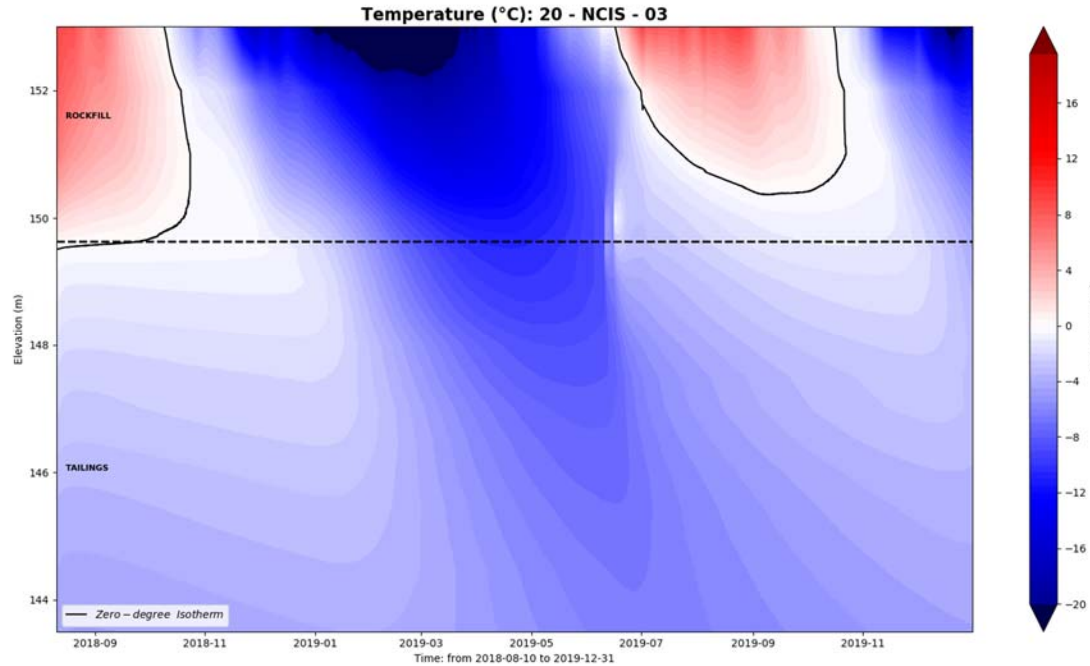


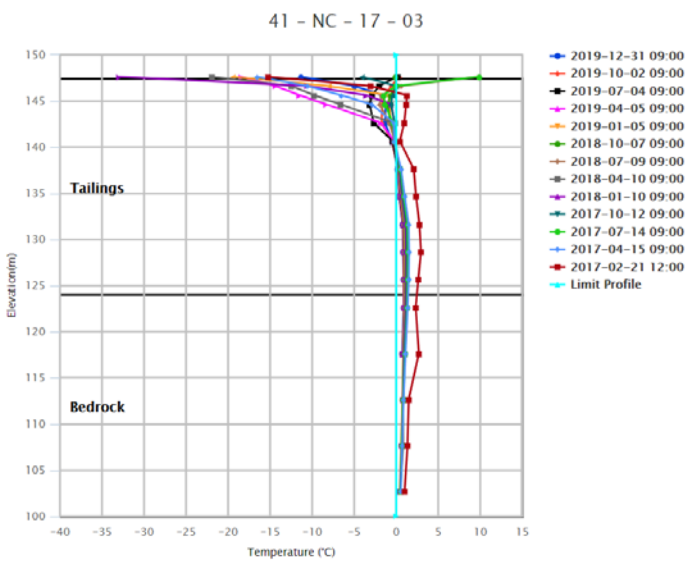


Instrument was damaged by wildlife and equipment.
Planned to fix in 2020.

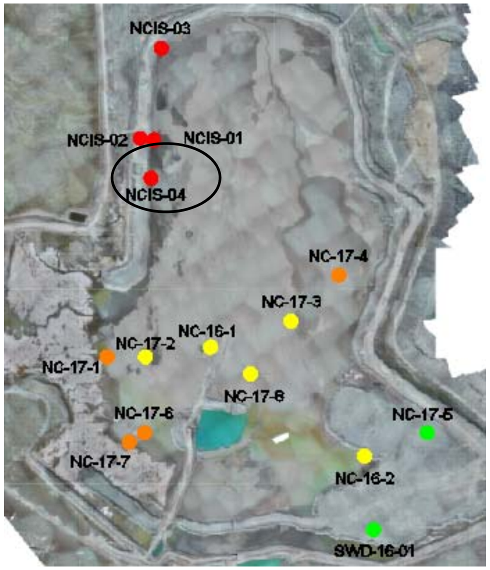
NCIS-03

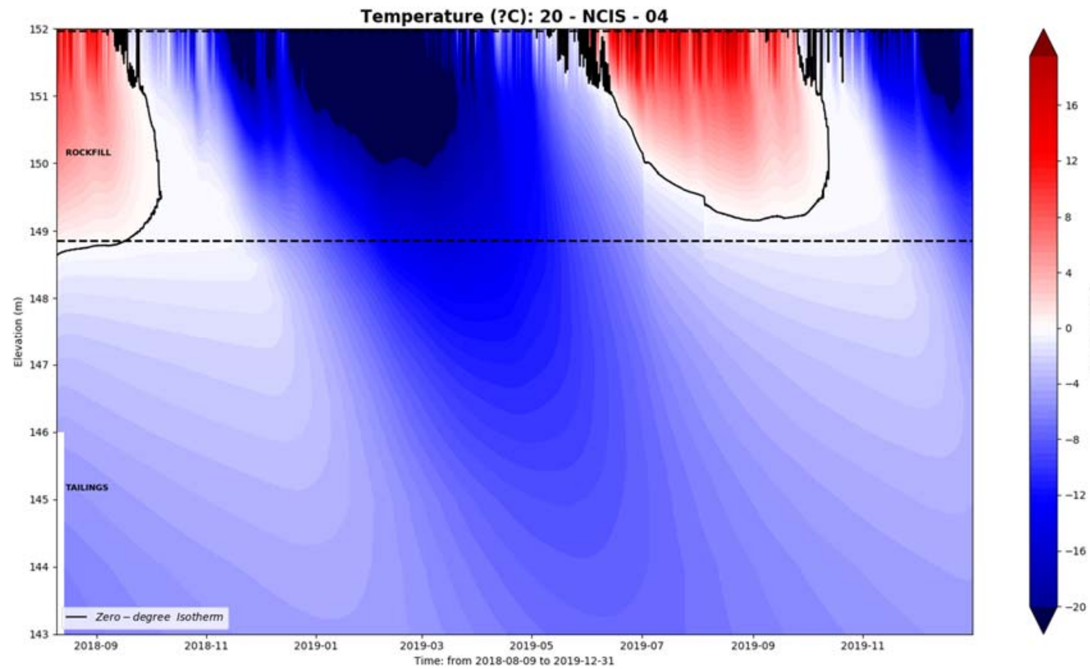

NCIS-03
NCIS-02
NCIS-01
NCIS-04
NC-17-4
NC-17-3
NC-16-1
NC-17-2
NC-17-1
NC-17-8
NC-17-6
NC-17-5
NC-17-7
NC-16-2
SWD-16-01

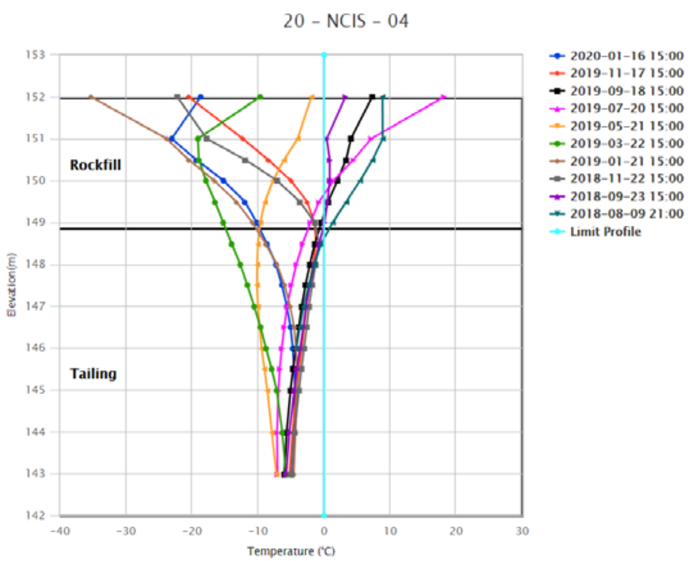

Temperature (°C): 20 - NCIS - 03
ROCKFILL
TAILINGS
Elevation (m)
Zero – degree Isotherm
Time: from 2018-08-10 to 2019-12-31
Temperature (°C)


41 – NC – 17 – 03
Tailings
Bedrock
Elevation(m)
Temperature (°C)
2019-12-31 09:00
2019-10-02 09:00
2019-07-04 09:00
2019-04-05 09:00
2019-01-05 09:00
2018-10-07 09:00
2018-07-09 09:00
2018-04-10 09:00
2018-01-10 09:00
2017-10-12 09:00
2017-07-14 09:00
2017-04-15 09:00
2017-02-21 12:00
Limit Profile

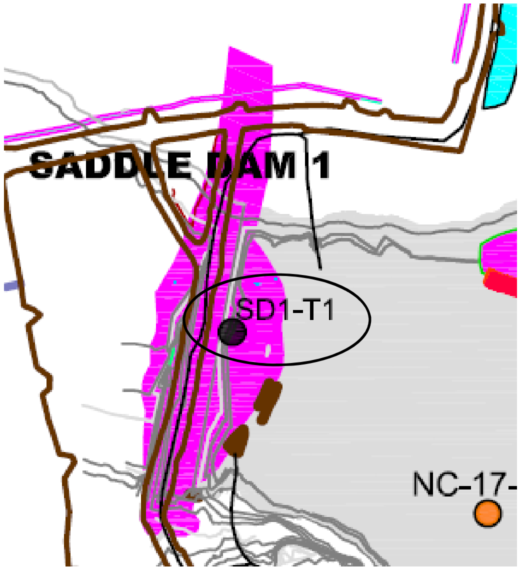
NCIS-04

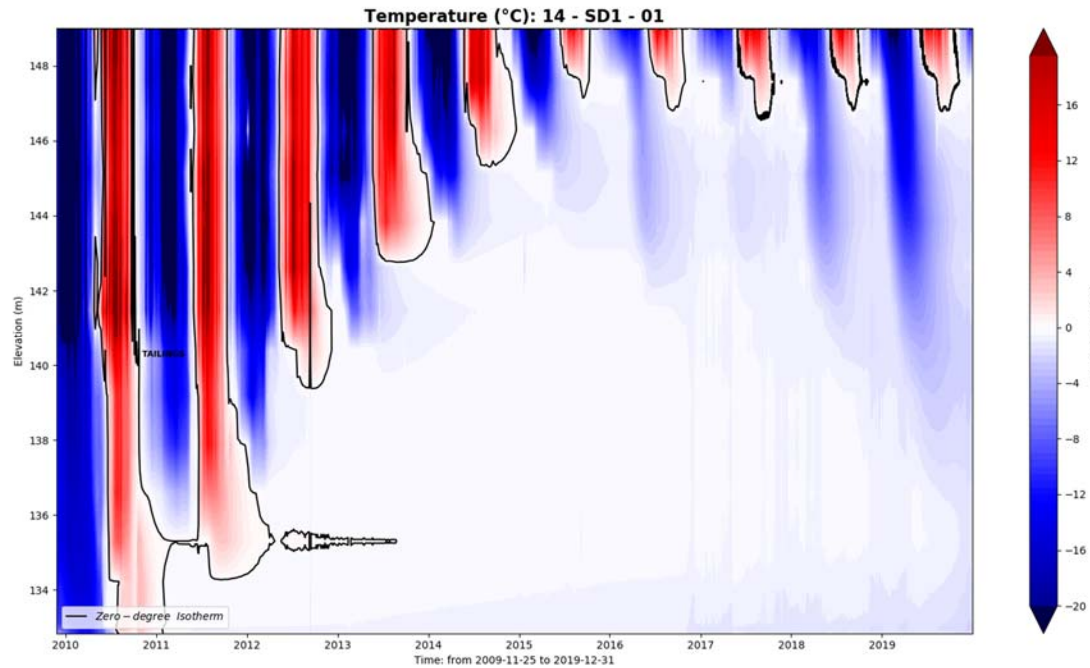

NCIS-03
NCIS-02
NCIS-01
NCIS-04
NC-17-4
NC-17-3
NC-16-1
NC-17-2
NC-17-1
NC-17-8
NC-17-6
NC-17-5
NC-17-7
NC-16-2
SWD-16-01

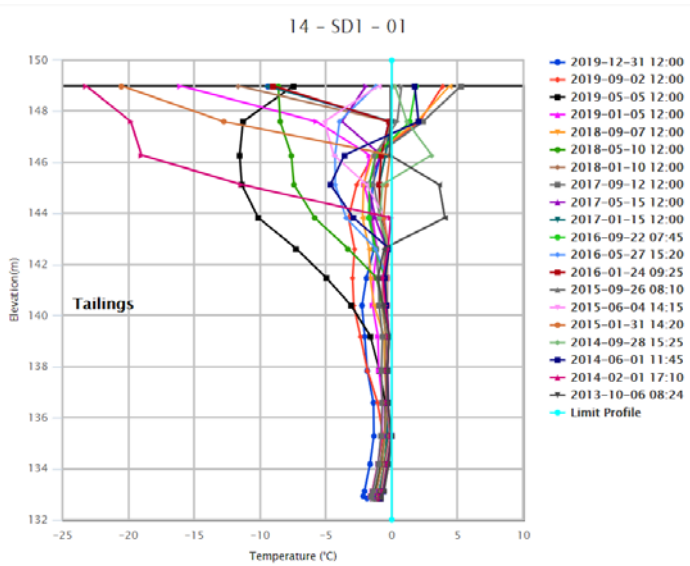

Temperature (?C): 20 - NCIS - 04
ROCKFILL
TAILINGS
Elevation (m)
Zero – degree Isotherm
Time: from 2018-08-09 to 2019-12-31
Temperature (?C)


20 – NCIS – 04
Rockfill
Tailing
Elevation(m)
Temperature (°C)
2020-01-16 15:00
2019-11-17 15:00
2019-09-18 15:00
2019-07-20 15:00
2019-05-21 15:00
2019-03-22 15:00
2019-01-21 15:00
2018-11-22 15:00
2018-09-23 15:00
2018-08-09 21:00
Limit Profile

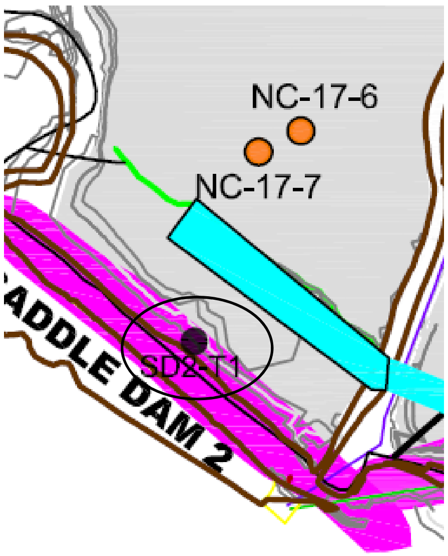
SD1-1

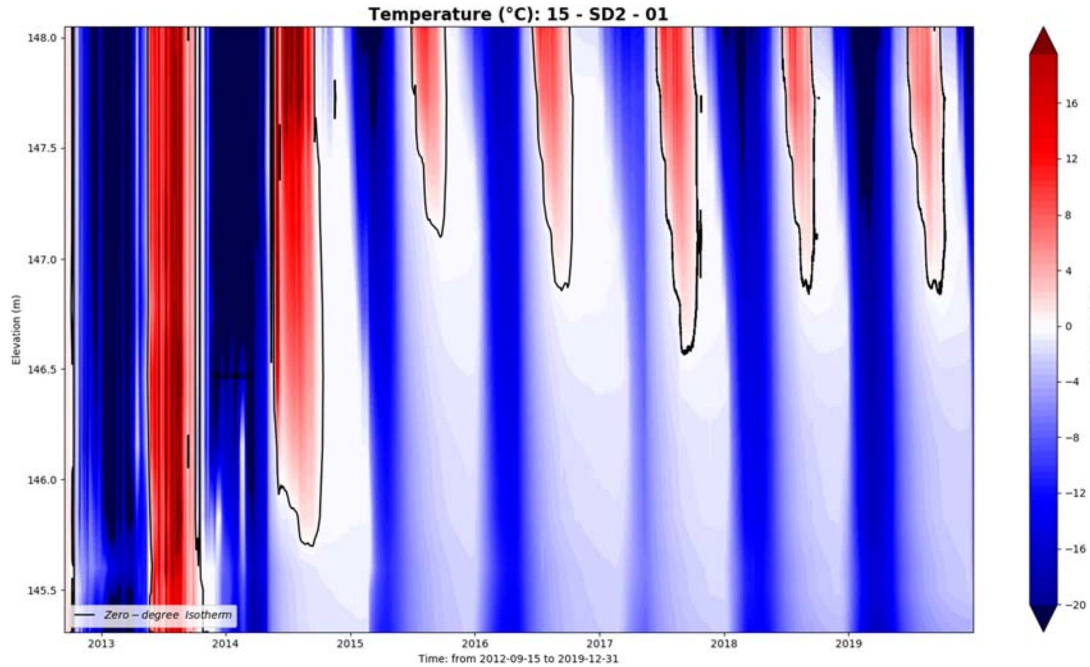

SADDLE DAM 1
SD1-T1
NC-17-

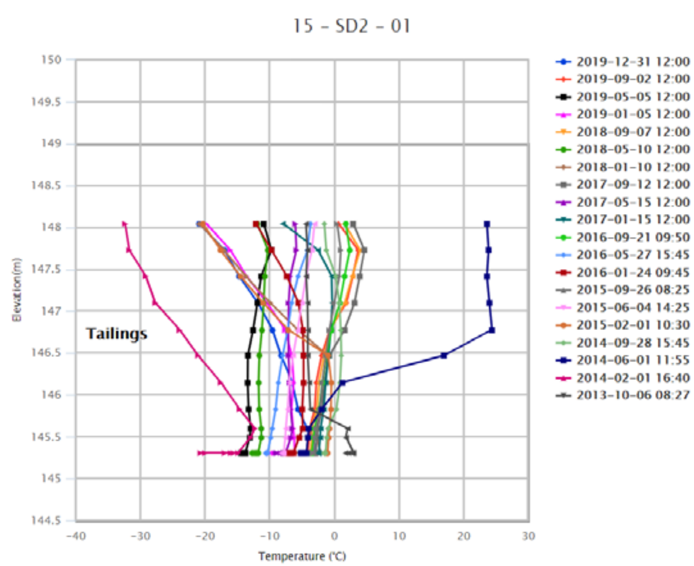

Temperature (°C): 14 - SD1 - 01
Elevation (m)
Zero – degree Isotherm
Time: from 2009-11-25 to 2019-12-31
Temperature (°C)


14 - SD1 - 01
Tailings
Elevation(m)
Temperature (°C)
2019-12-31 12:00
2019-09-02 12:00
2019-05-05 12:00
2019-01-05 12:00
2018-09-07 12:00
2018-05-10 12:00
2018-01-10 12:00
2017-09-12 12:00
2017-05-15 12:00
2017-01-15 12:00
2016-09-22 07:45
2016-05-27 15:20
2016-01-24 09:25
2015-09-26 08:10
2015-06-04 14:15
2015-01-31 14:20
2014-09-28 15:25
2014-06-01 11:45
2014-02-01 17:10
2013-10-06 08:24
Limit Profile

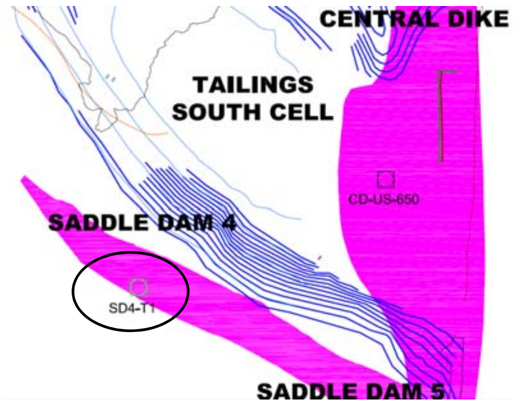
SD2-1

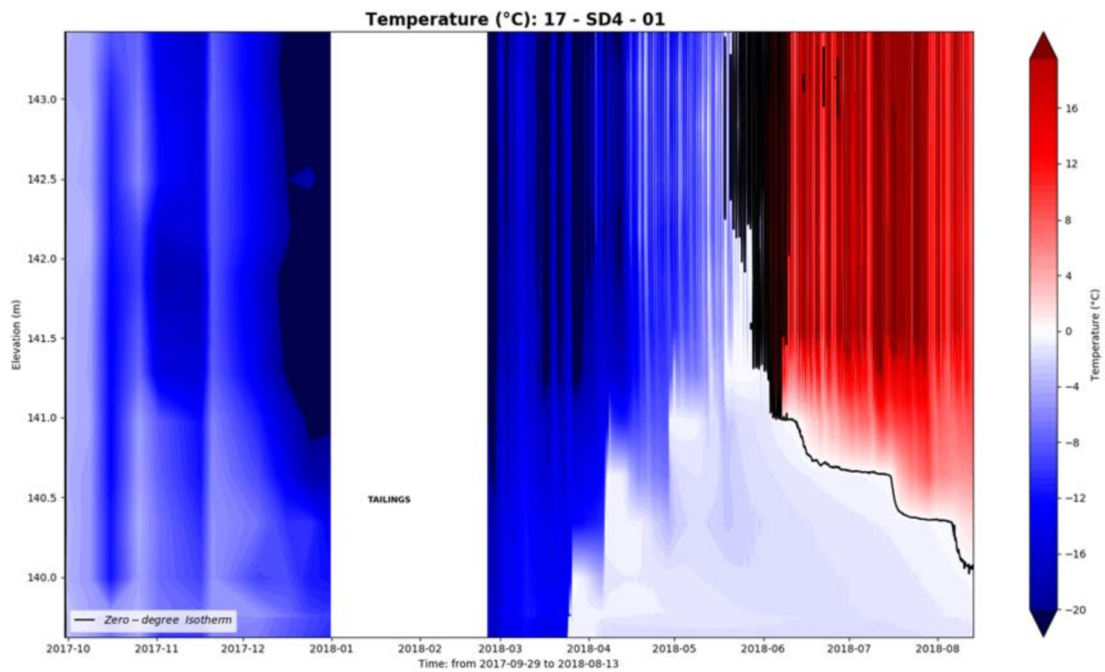

NC-17-6
NC-17-7
SD2-T1
ADDLE DAM 2

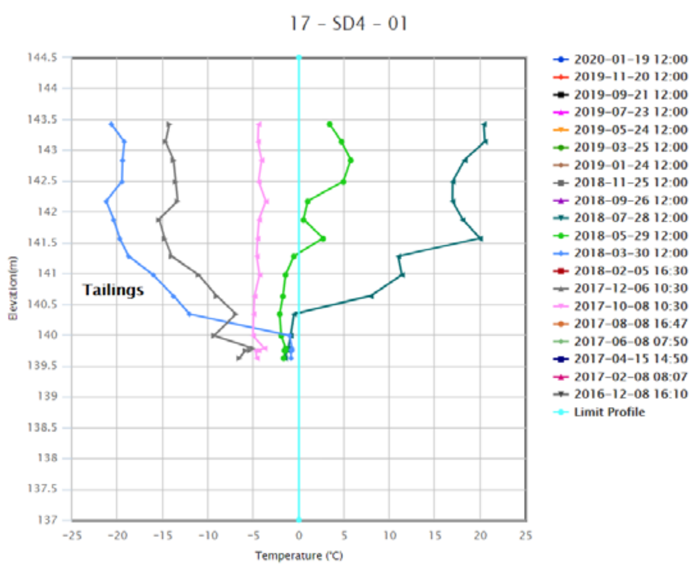

Temperature (°C): 15 - SD2 - 01
Elevation (m)
148.0
147.5
147.0
146.5
146.0
145.5
Zero – degree Isotherm
2013
2014
2015
2016
2017
2018
2019
Time: from 2012-09-15 to 2019-12-31
Temperature (°C)
16
12
8
4
0
−4
−8
−12
−16
−20


15 – SD2 – 01
Elevation(m)
150
149.5
149
148.5
148
147.5
147
146.5
146
145.5
145
144.5
Tailings
−40
−30
−20
−10
0
10
20
30
Temperature (°C)
2019-12-31 12:00
2019-09-02 12:00
2019-05-05 12:00
2019-01-05 12:00
2018-09-07 12:00
2018-05-10 12:00
2018-01-10 12:00
2017-09-12 12:00
2017-05-15 12:00
2017-01-15 12:00
2016-09-21 09:50
2016-05-27 15:45
2016-01-24 09:45
2015-09-26 08:25
2015-06-04 14:25
2015-02-01 10:30
2014-09-28 15:45
2014-06-01 11:55
2014-02-01 16:40
2013-10-06 08:27

SD4-1

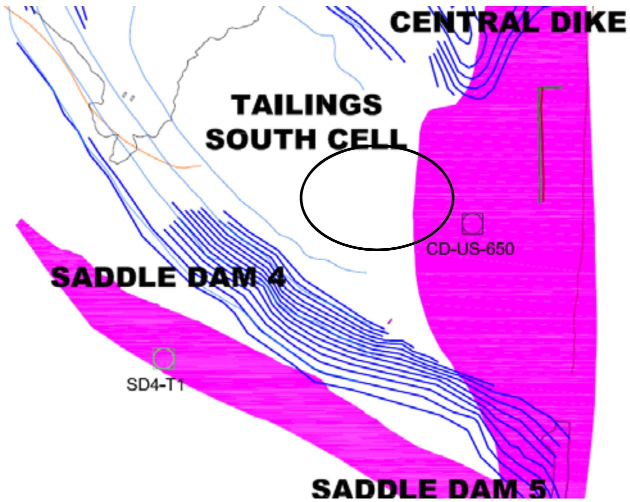


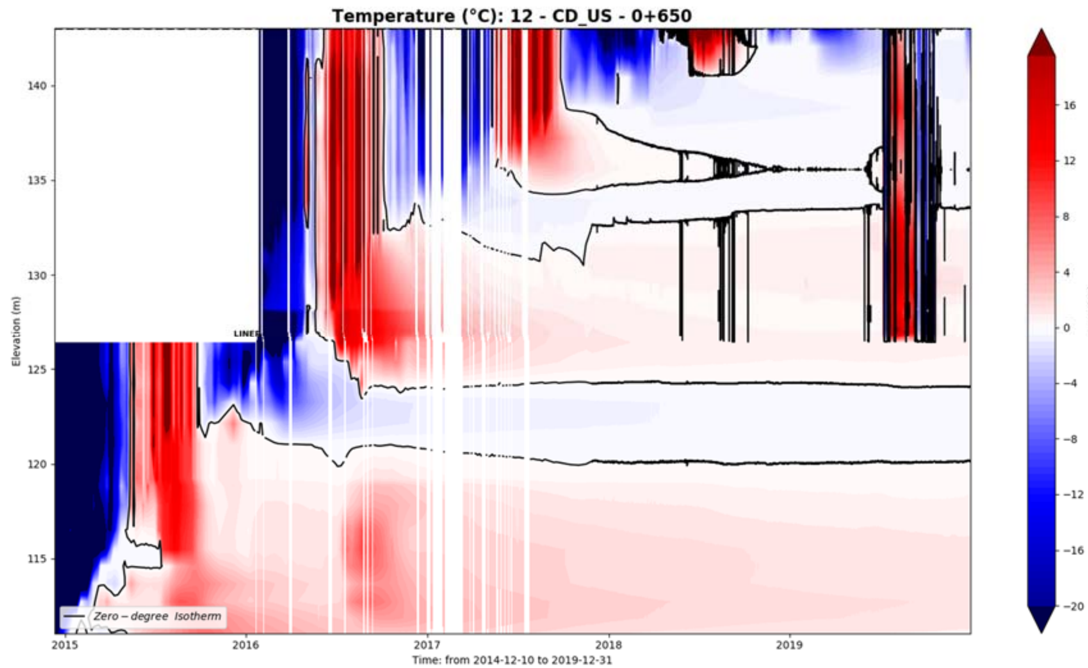


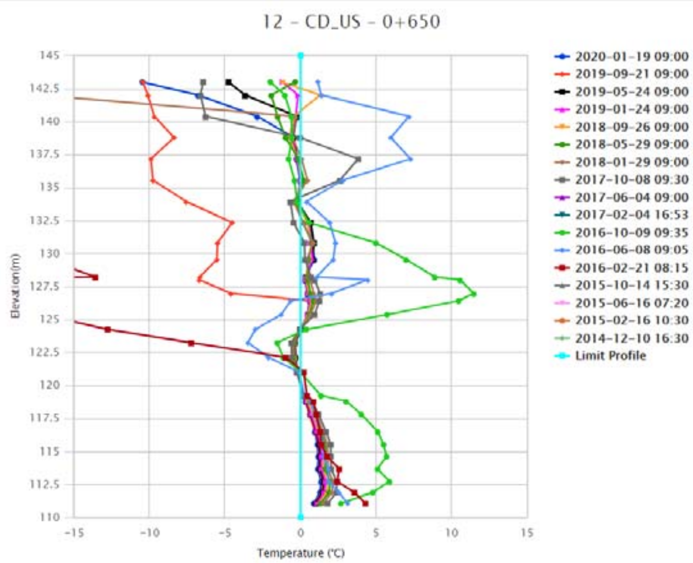


This instrument is broken and not sending anymore data.

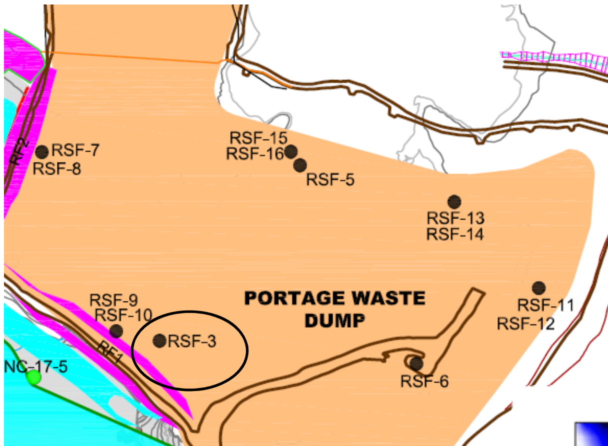
CD-US-0+650

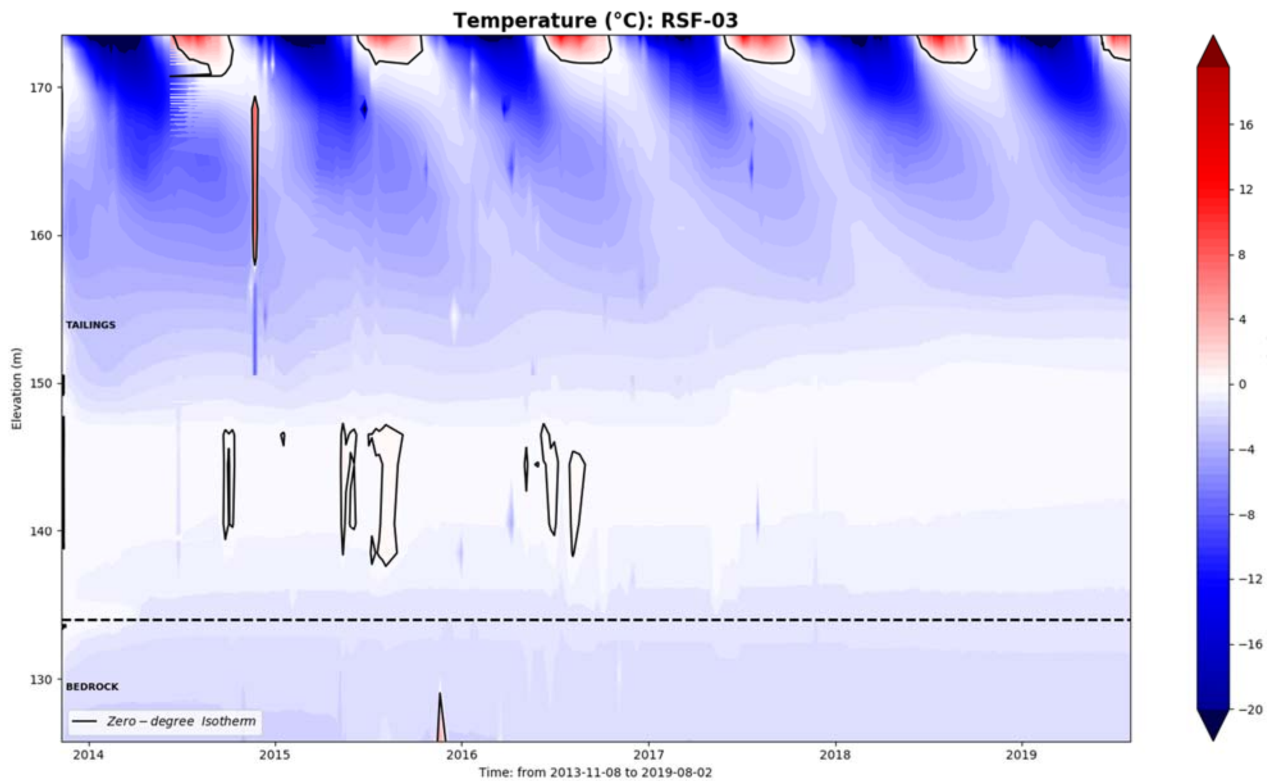

CENTRAL DIKE
TAILINGS SOUTH CELL
CD-US-650
SADDLE DAM 4
SD4-T1
SADDLE DAM 5


Temperature (°C): 12 - CD_US - 0+650
Elevation (m)
Zero – degree Isotherm
Time: from 2014-12-10 to 2019-12-31
Temperature (°C)

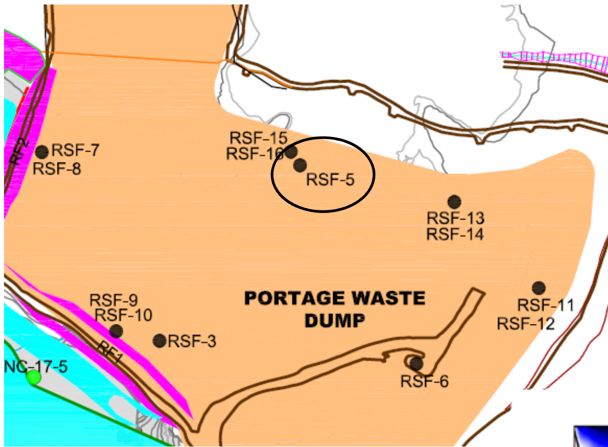

12 – CD_US – 0+650
Elevation(m)
Temperature (°C)
2020-01-19 09:00
2019-09-21 09:00
2019-05-24 09:00
2019-01-24 09:00
2018-09-26 09:00
2018-05-29 09:00
2018-01-29 09:00
2017-10-08 09:30
2017-06-04 09:00
2017-02-04 16:53
2016-10-09 09:35
2016-06-08 09:05
2016-02-21 08:15
2015-10-14 15:30
2015-06-16 07:20
2015-02-16 10:30
2014-12-10 16:30
Limit Profile

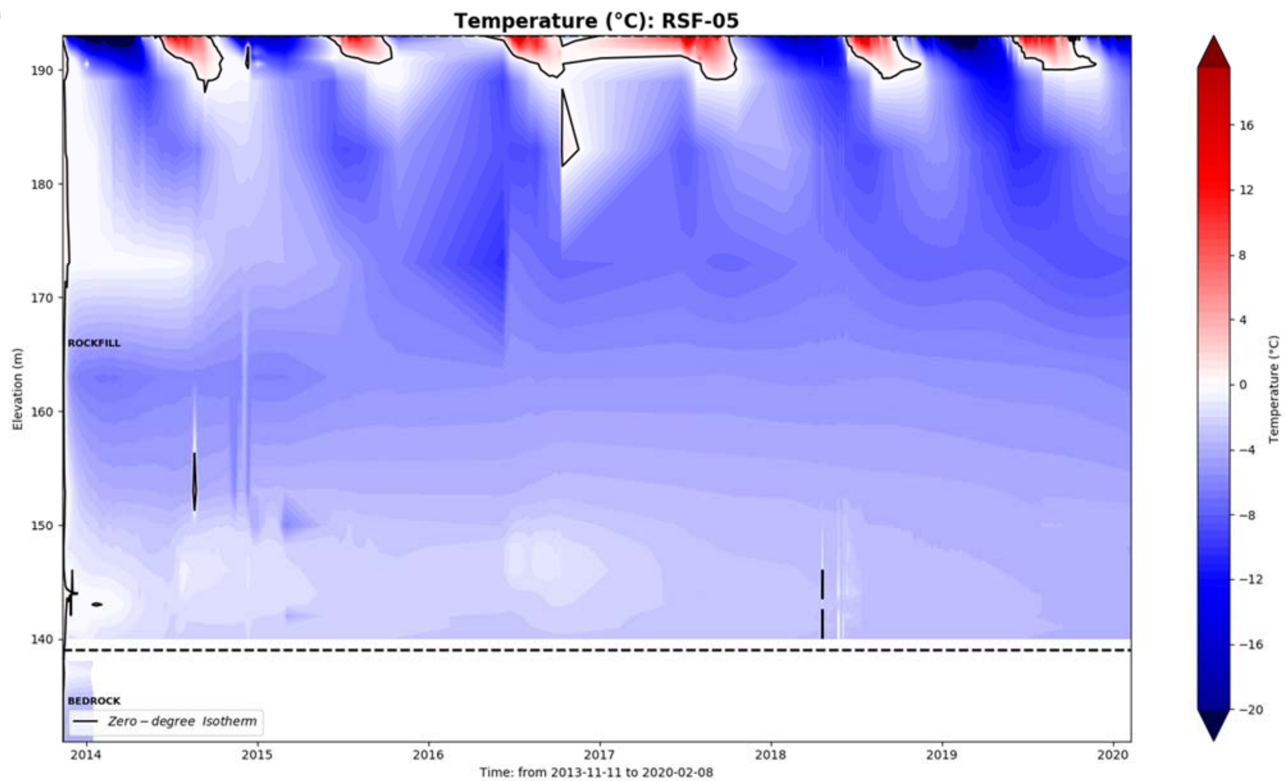
RSF-3


RSF-7
RSF-8
RSF-15
RSF-16
RSF-5
RSF-13
RSF-14
RSF-9
RSF-10
RSF-3
PORTAGE WASTE
DUMP
RSF-11
RSF-12
RSF-6
NC-17-5

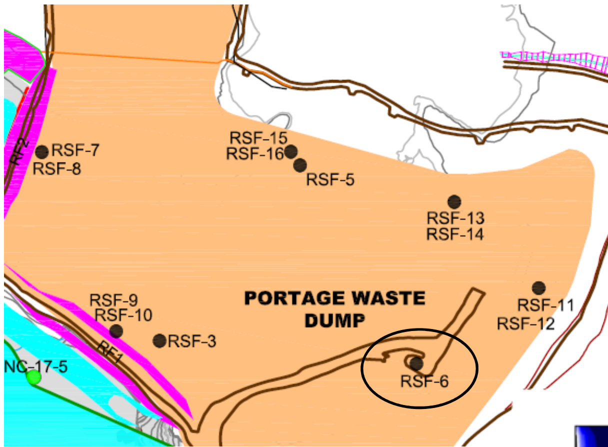

Temperature (°C): RSF-03
Elevation (m)
TAILINGS
BEDROCK
Zero – degree Isotherm
Time: from 2013-11-08 to 2019-08-02
Temperature (°C)

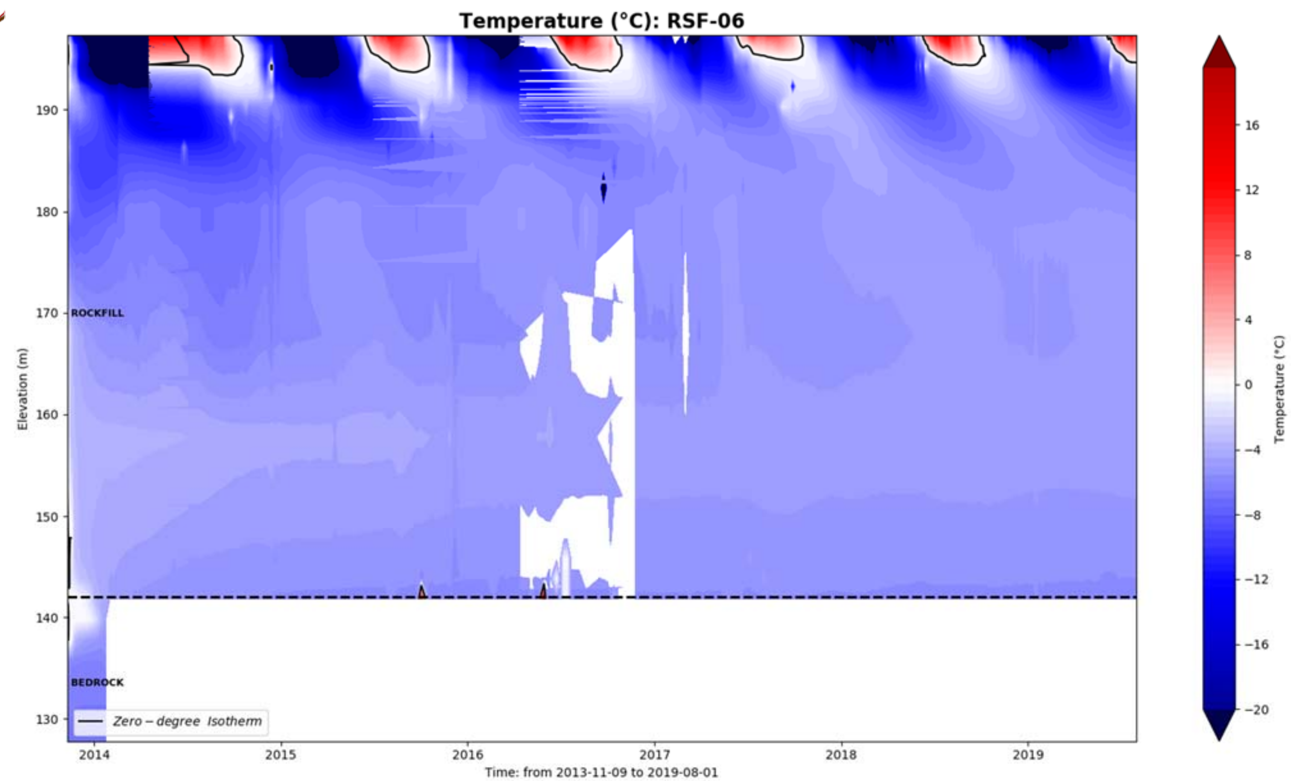
RSF-5


RSF-7
RSF-8
RSF-15
RSF-16
RSF-5
RSF-13
RSF-14
PORTAGE WASTE
DUMP
RSF-9
RSF-10
RSF-3
RSF-11
RSF-12
RSF-6
NC-17-5

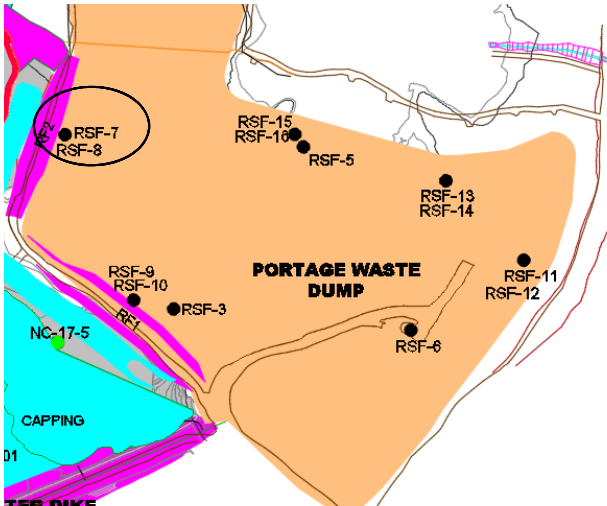

Temperature (°C): RSF-05
Elevation (m)
190
180
170
160
150
140
ROCKFILL
BEDROCK
Zero – degree Isotherm
2014
2015
2016
2017
2018
2019
2020
Time: from 2013-11-11 to 2020-02-08
Temperature (°C)
16
12
8
4
0
−4
−8
−12
−16
−20

RSF-6

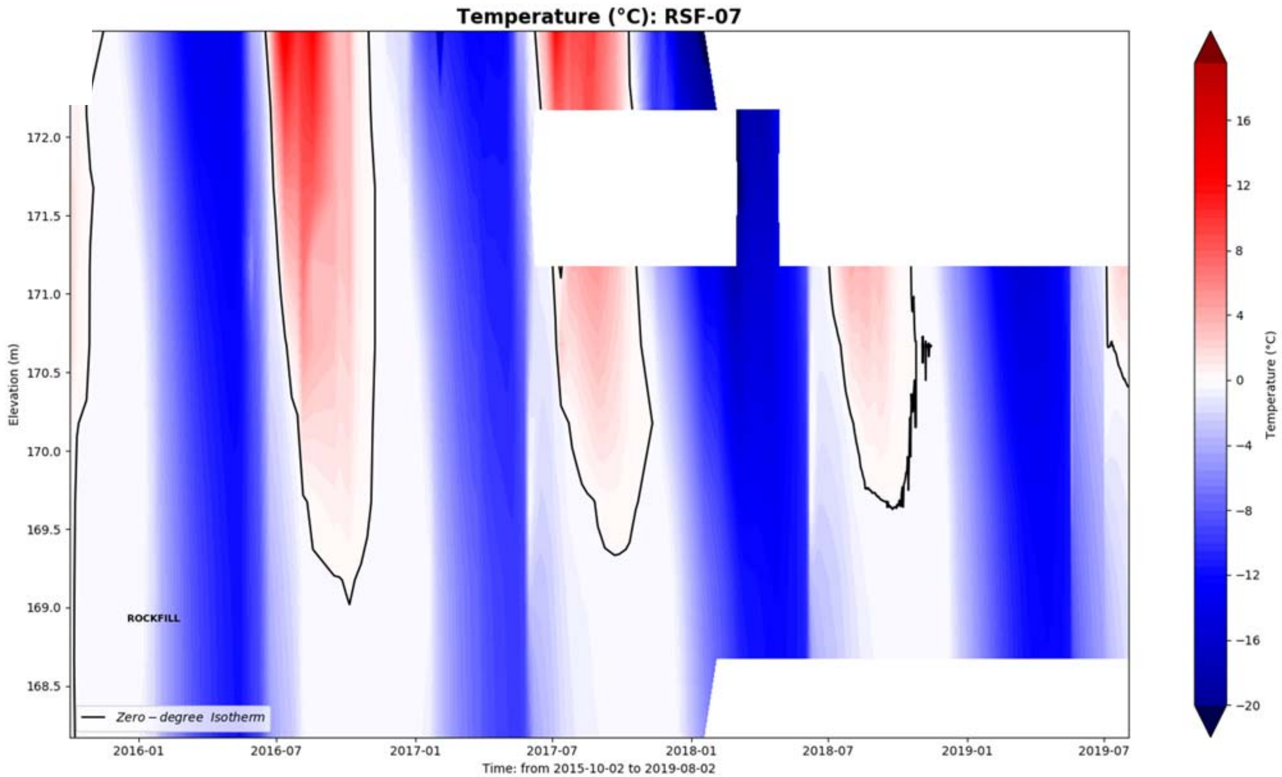

RSF-7
RSF-8
RSF-15
RSF-16
RSF-5
RSF-13
RSF-14
PORTAGE WASTE
DUMP
RSF-9
RSF-10
RSF-3
RSF-11
RSF-12
RSF-6
NC-17-5


Temperature (°C): RSF-06
Elevation (m)
ROCKFILL
BEDROCK
Zero – degree Isotherm
Time: from 2013-11-09 to 2019-08-01
Temperature (°C)

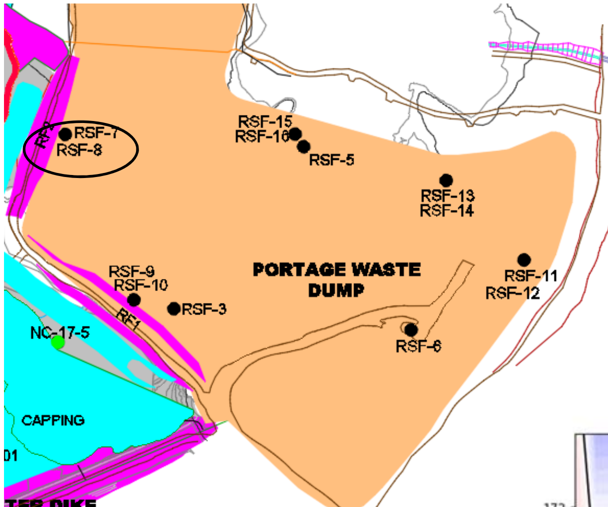
RSF-7 & RSF-8



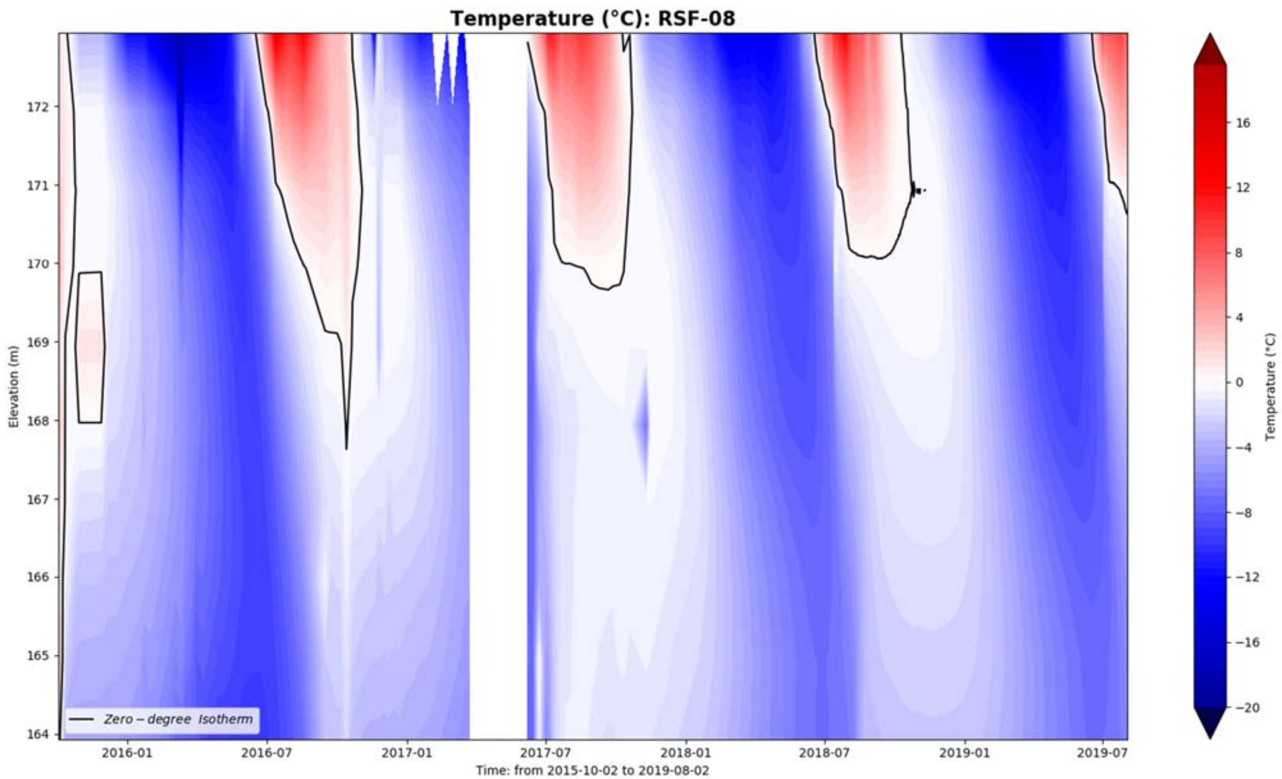
RSF-7 installed at a dip of -55°



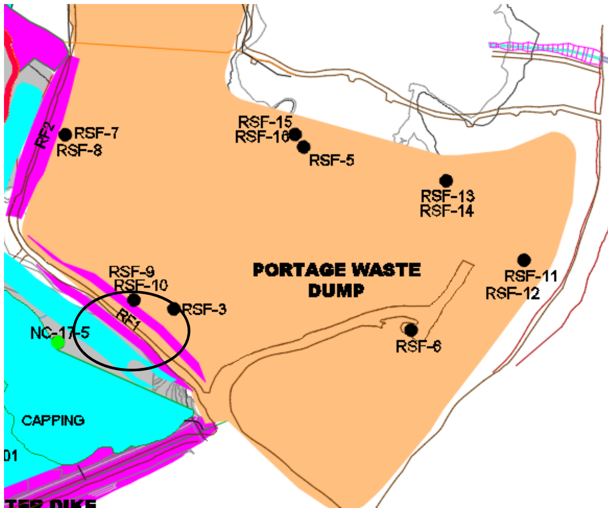
RSF-8



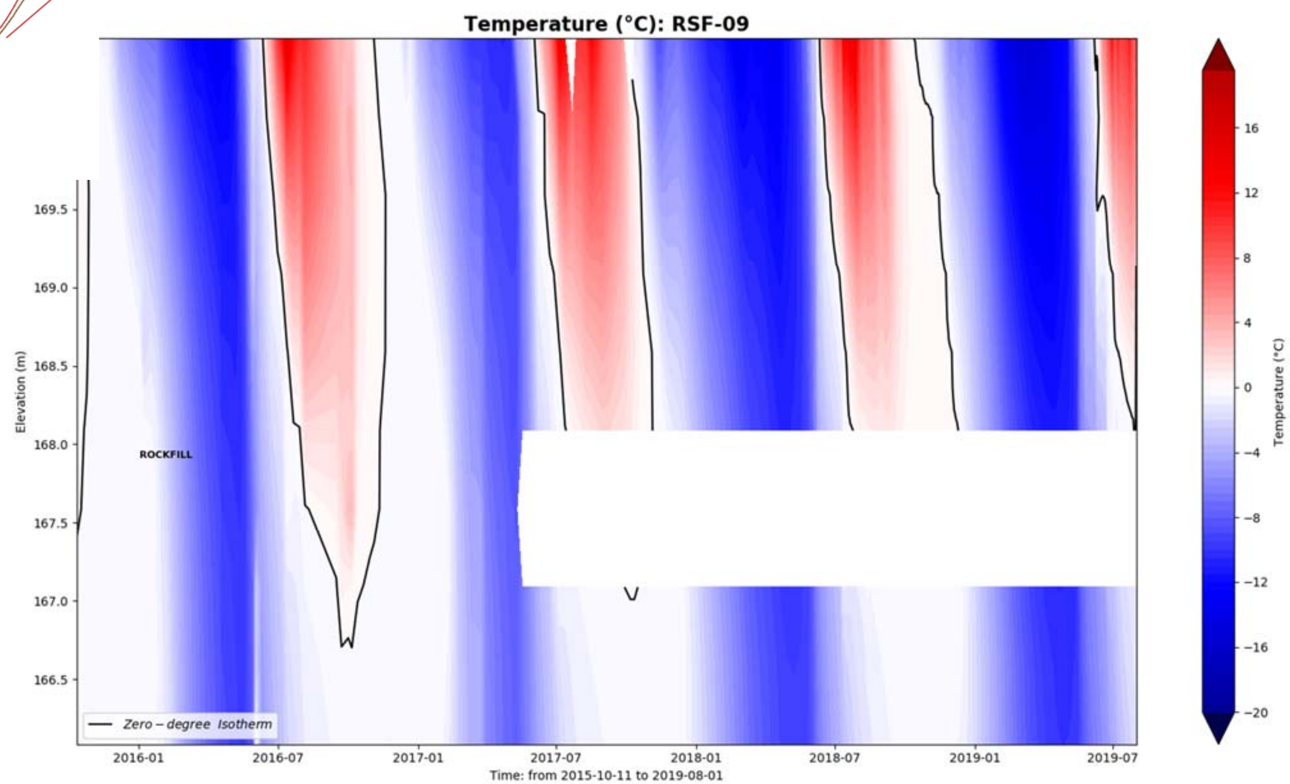
RSF-8 installed at a dip of -70°



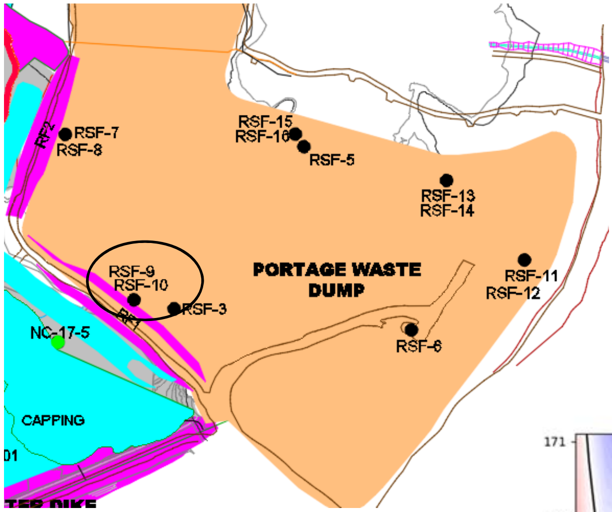
RSF-9



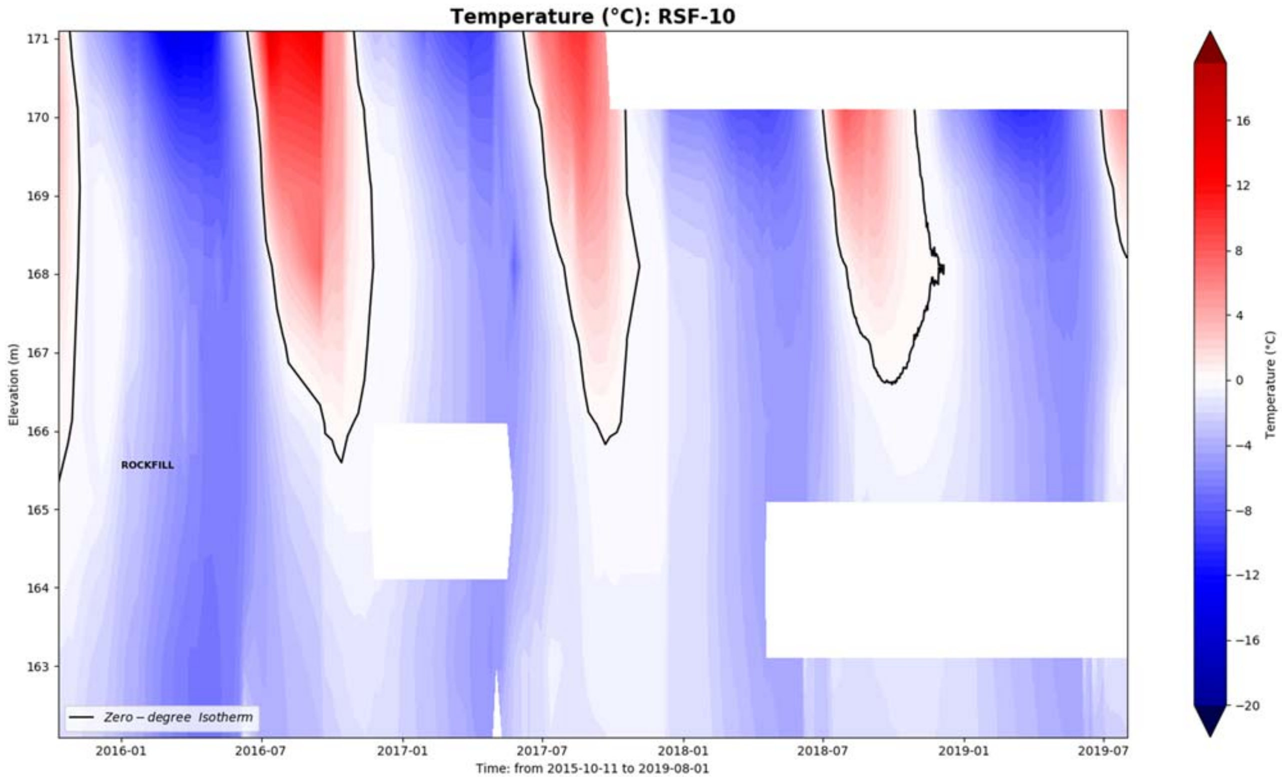
RSF-9 installed at a dip of -55°



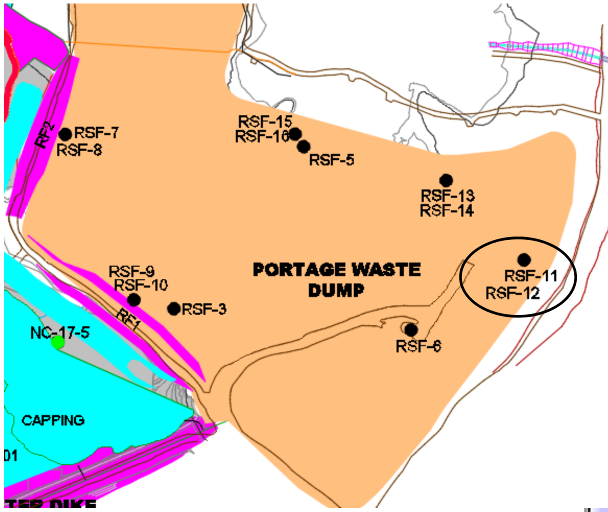
RSF-10



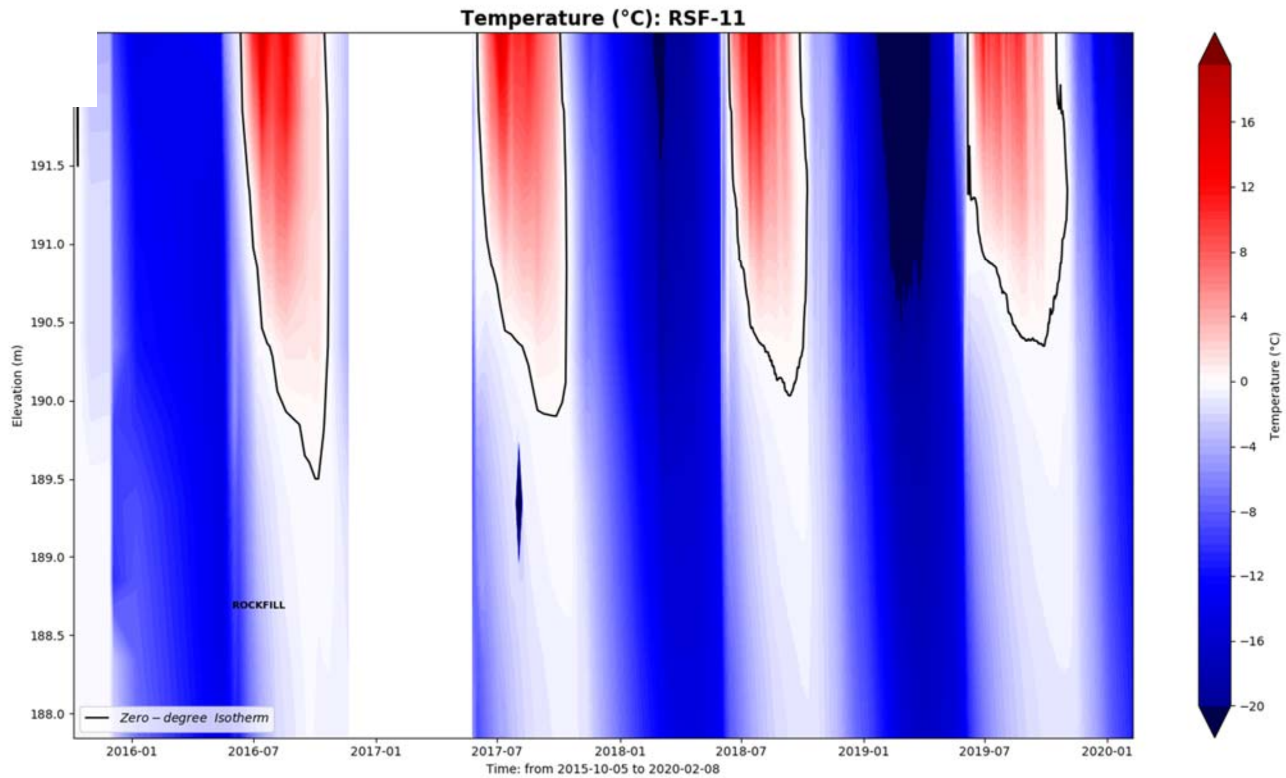
RSF-10 installed at a dip of -70°



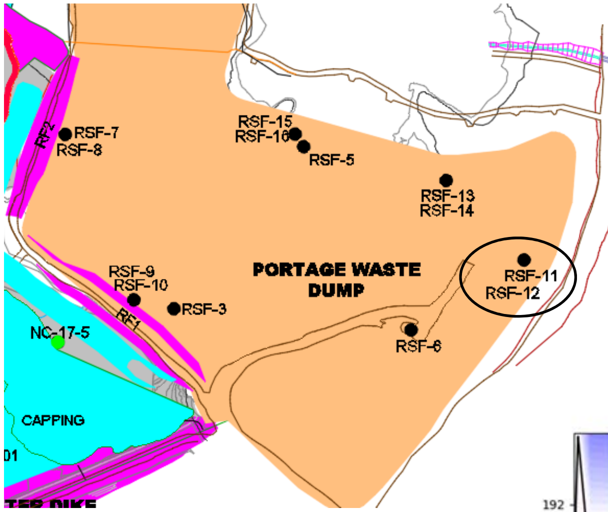
RSF-11



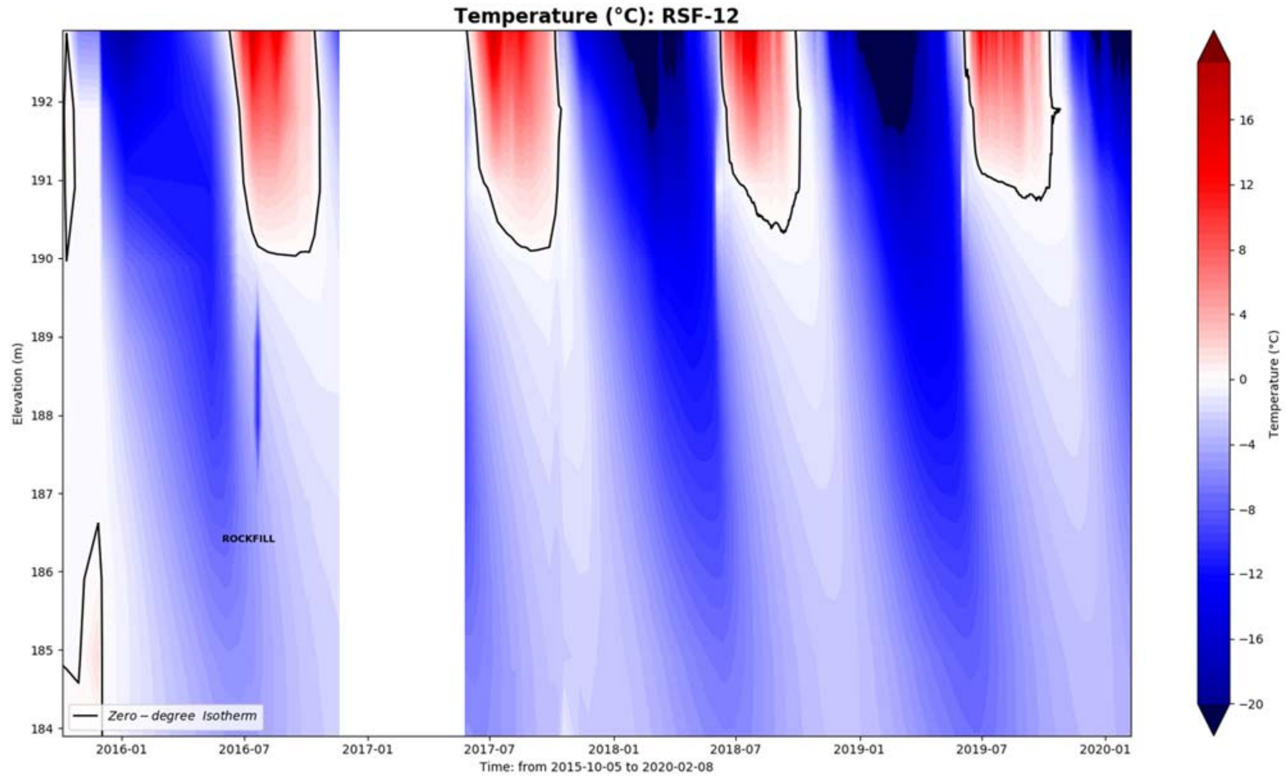
RSF-11 installed at a dip of -55°



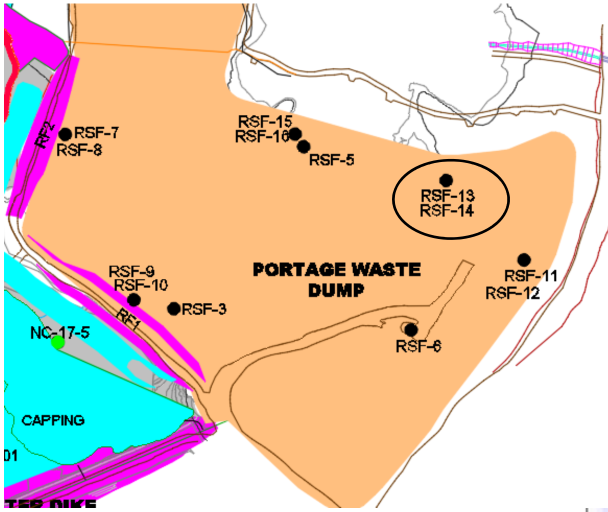
RSF-12



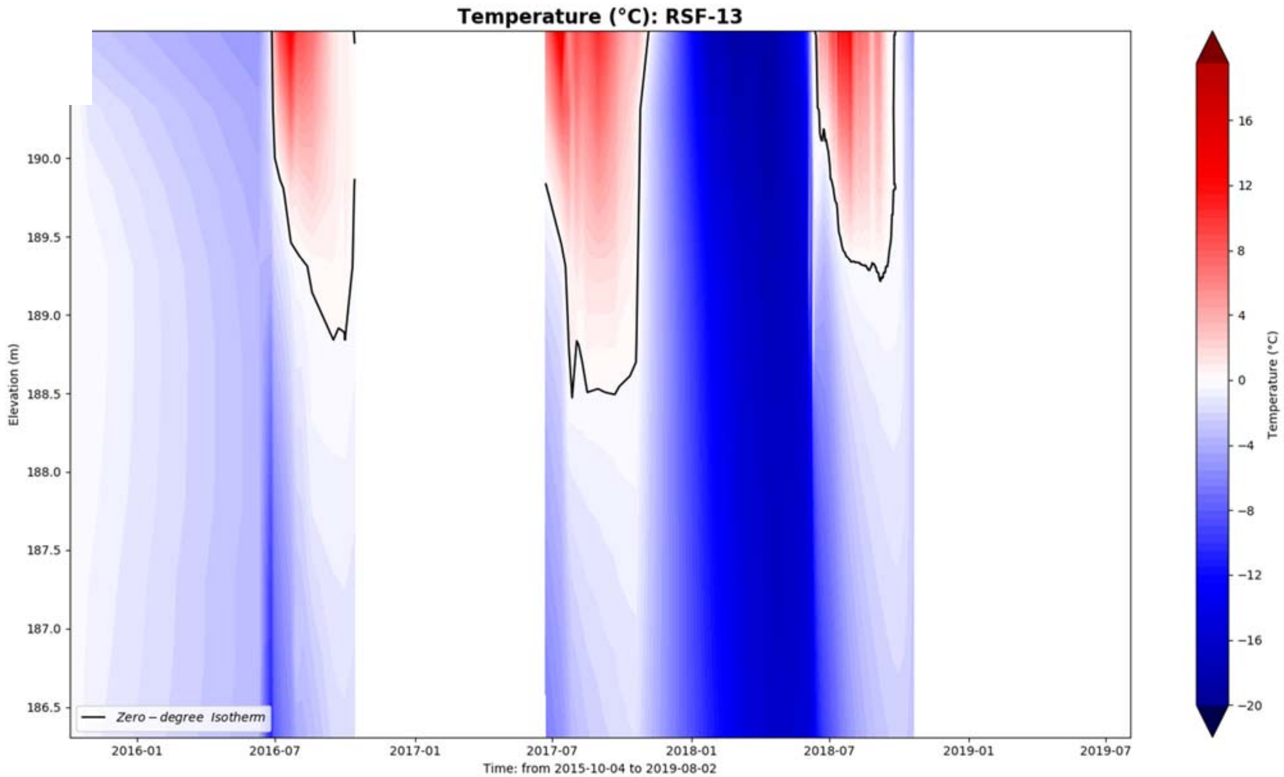
RSF-12 installed at a dip of -70°



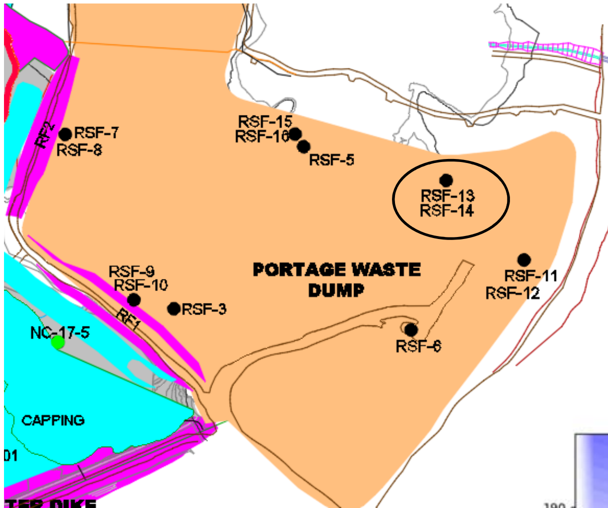
RSF-13



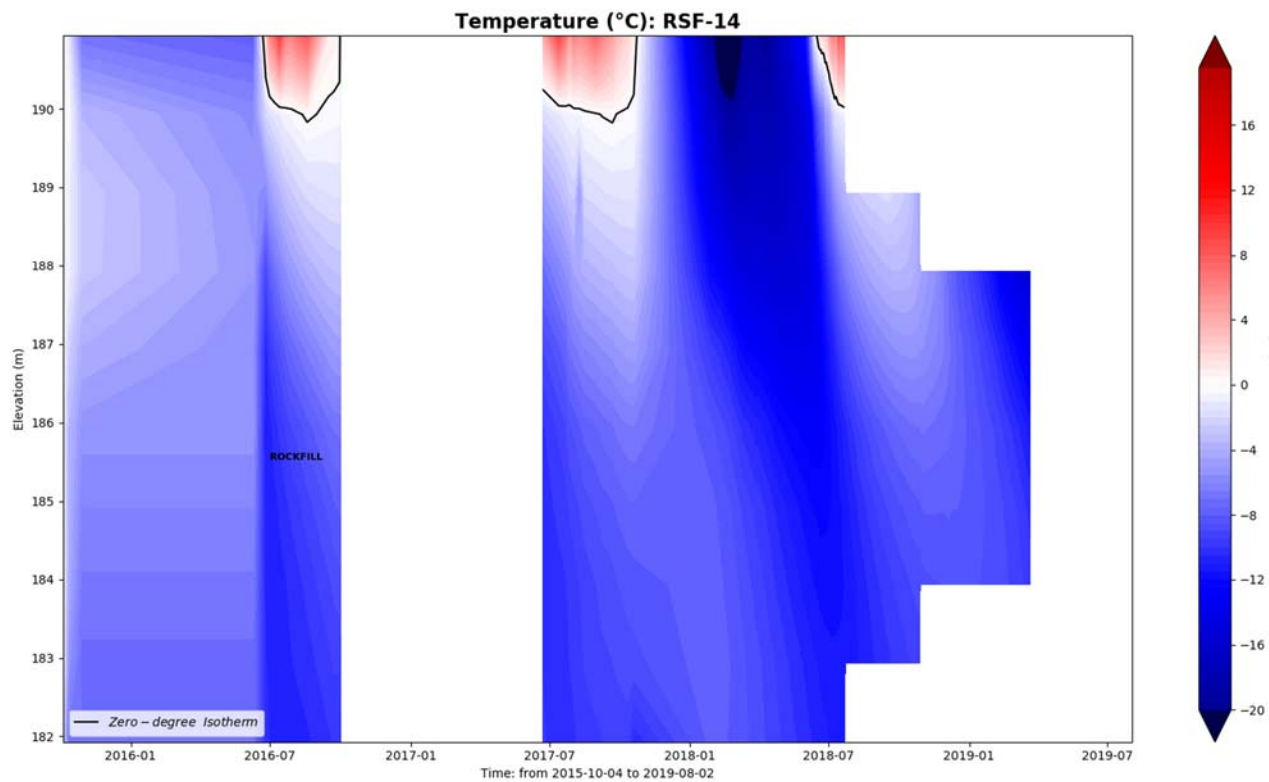
RSF-13 installed at a dip of -55°. No longer active as the cable was cut by wildlife. Planned to repair.



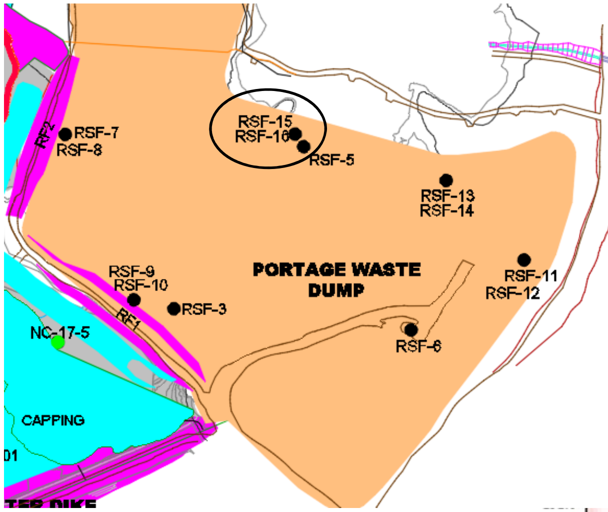
RSF-14



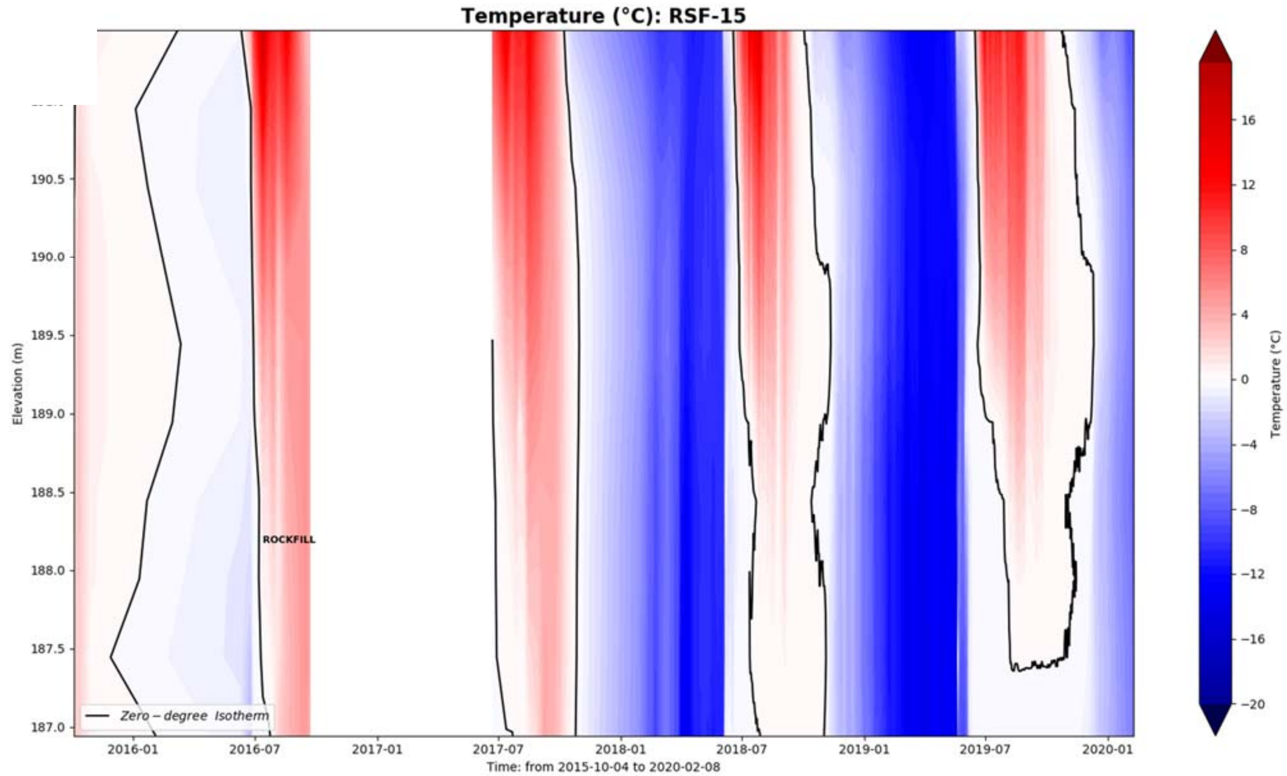
RSF-14 installed at a dip of -80°. No longer active as the cable was cut by wildlife.



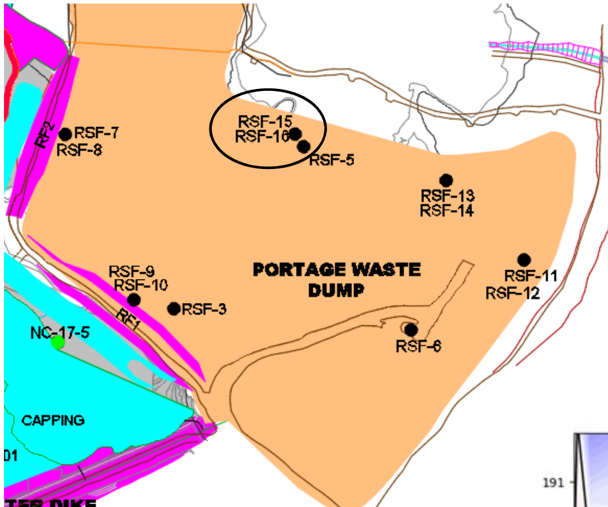
RSF-15



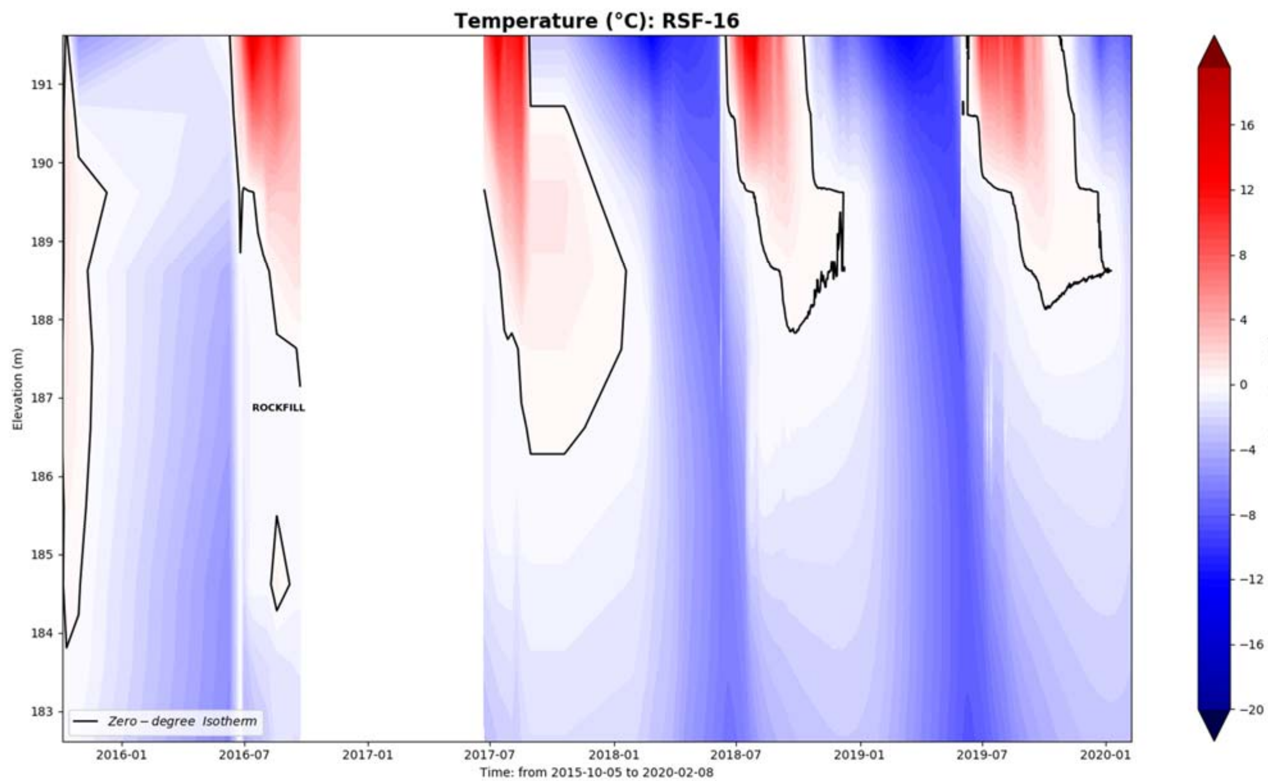
RSF-15 installed at a dip of -55°



RSF-16



RSF-16 installed at a dip of -70°



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November 1, 2019

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Re: Thermal Model Review of Meadowbank Portage Waste Rock Storage Facility

To comply with Crown-Indigenous Relations and Northern Affairs Canada's (CIRNACs) request following the 2017 annual report review, Agnico Eagle Mines Limited – Meadowbank Division (AEM) requested Okane complete a review of the thermal model of the Portage Rock Storage Facility (RSF) completed in 2016[1]. The objective of the proposed work is to evaluate the accuracy of the thermal model by comparing the simulated results with field data collected from thermistors installed in the Portage RSF, and in doing so, determine if the model is representative of the thermal conditions in the Portage RSF.

Scope of Work

The scope of work outlined by AEM comprises two main tasks:

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[1] O'Kane Consultants Inc. (Okane). 2016. Summary of Thermal Modelling of Portage RSF at Meadowbank Mine. Okane ref: 948-4. September.

- A comparison of the initial baseline model predictions versus actual data from available thermistors; and
- Identification of any data gaps for the thermal model update.

This memorandum summarizes review and summary of thermistor data and the 2016 numerical model, comparison of simulated versus measured data to assess the validity, accuracy, and predictive capabilities of the thermal model, and identification of data gaps and recommendations for addressing specific data gaps.

Background / Cover System Purpose

The primary purpose of the Portage RSF cover system is to maintain geochemical stability by insulating the potentially acid generating (PAG) waste material and limiting oxidation by maintaining frozen conditions within the PAG waste rock. The cover system also prevents runoff from contacting PAG waste rock material.

More than 80% of the Portage RSF has been progressively reclaimed (from 2011 to 2017) during operations with the placement of a 4 m non-potentially acid generating (NPAG) cover system on the RSF PAG slopes.[2] The Portage RSF is being used for operations, therefore, reclamation of the remaining RSF will be completed post-closure. Drilled thermistors were installed within the Portage RSF in 2013 and 2015 to measure *in situ* temperature and monitor permafrost aggradation. Temperature monitoring has indicated that freeze-back is occurring[3].

In 2016, numerical modelling was completed using recorded temperature data to simulate the seasonal active zone depth within the Portage RSF cover system and to confirm that the RSF will remain frozen for the next 150 years under agreed upon climate change scenarios. The active zone is the uppermost layer of material above permafrost that undergoes freeze-thaw cycles from atmospheric forcing. This layer thaws in the spring and summer and freezes in the fall and winter.

The main uncertainty for closure of Portage RSF is if the cover system thickness is adequate to insulate PAG materials to limit oxidation reactions and to ensure permafrost aggradation[4].

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[2] SNC Lavalin Inc. 2019. Meadowbank Interim Closure and Reclamation Plan (ICRP) - Update 2019 - Final Report. SNC file: 662987-5000-4EER-0001 Rev 00. May

[3] Agnico Eagle Mines Limited. 2018. Updated Waste Rock and Tailings Management Report and Plan - 2017. March 2018.

[4] Golder Associates Ltd., 2014. Interim Closure and Reclamation Plan. Report No. 13-1151-0131 to Agnico Eagle Mines Ltd. January 2014.

Thermistor Data Summary

Thermistor were installed in Portage RSF in 2013 and 2015 to measure internal thermal conditions in the Portage RSF. A plan view of the thermistor monitoring locations on the Portage RSF is provided in Figure **1**.

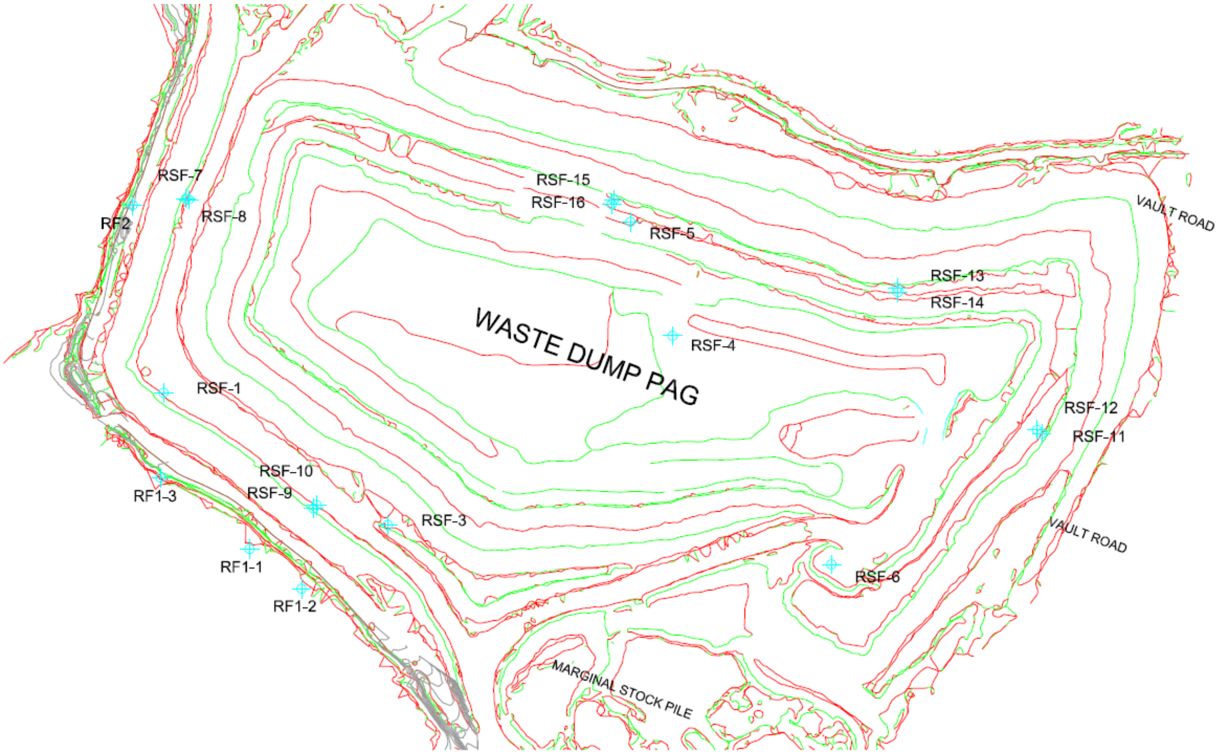

Figure 1: Plan view of thermistor string monitoring locations at Portage RSF

Table 1 provides a summary of the thermistor locations, measurement depth range, and approximate active zone depth for each year of monitoring based on the available data. The thermistors require time to equilibrate after installation, therefore, the first year of data after installation were omitted from estimates provided in Table 1. Grey shaded cells highlight thermistor stations that measured active zone depths greater than 4.0 m during the given monitoring year. The active zone depth (Table 1) was defined as the depth of the zero-degree isotherm (Appendix A) and interpolated based on the thermistor bead point measurements.

Table 1: Summary of Equilibrated Thermistor Data.

Thermistor Label	Measurement Depth Range (m)	Approximate Active Zone Depth (m)[1,2]					Thermistor Location on Portage RSF
		2014	2015	2016	2017	2018	

RF1-1	13 – 60	N/A	N/A	N/A	N/A	N/A	off SW Toe
RF1-2	0 – 15	N/A	4.25	3.5	2.2	0.5	off SW Toe
RF1-3	0 – 30	2.6	2.1	1.7	1.3	0.6	Toe of SW Slope
RF-2	12 – 60	N/A	N/A	N/A	N/A	N/A	Toe of W Slope
RSF-1	0 – 50	N/A	N/A	N/A	N/A	N/A	SW Mid-slope
RSF-3	0.5 – 46	3.2	2.4	2.3	2.3	2.3	SW Mid-slope
RSF-4	2.5 – 80	3.5	N/A	N/A	N/A	N/A	Plateau
RSF-5	0.5 – 63	4.5	2.9	4.25	4.3	4.2	N Mid-slope
RSF-6	0.5 – 70	4.5	4	3.75	2.9	3.4	S Slope Crest
RSF-7	0.7 – 4.5			3.7	3.5	3.2	W Mid-slope
RSF-8	0.8 – 9.3			4.5	3.9	3.5	W Mid-slope
RSF-9	0.5 – 4.3			3.7	3.5	<3.4	SW Mid-slope
RSF-10	0.6 – 9.2			5.8	5.6	4.9	SW Mid-slope
RSF-11	0.6 – 4.4			3.0	2.7	2.5	E Mid-slope
RSF-12	0.5 – 9.0			3.25	3.2	3	E Mid-slope
RSF-13	0.7 – 4.5			2.3	2.6	2.0	N Mid-slope
RSF-14	0.8 – 9.8			2.0	2.0	1.8	N Mid-slope
RSF-15	0.5 – 4.3			>4.3	>4.3	~4.3	N Mid-slope
RSF-16	0.7 – 9.2			5.3	5.9	4.3	N Mid-slope

[1] N/A - either no sensors installed near surface, station is no longer working, or no sensor installed at the depth required to confidently estimate active zone depth.
[2] Initial year of monitoring omitted to account for sensor equilibration.

In general, a decreasing trend in the active zone depth is recorded over time. For the last 3 years (2016 to 2018), RSF-5 (Figure **2**) measured an active zone depth between 4.2 m and 4.3 m (hovering near the 4.0 m cover system / waste rock interface).

The thermistor installed off the RSF south-west toe into bedrock (RF 1-2) has also shown a continuous decrease in measured active zone depth since 2014 (Figure 3). This decreasing trend seen in the active zone depth is independent of ambient air temperature trends (i.e. winter temperatures are not continually decreasing each year). Temperature plots for all thermistors are provided in Appendix A. White zones on the plots indicate periods of missing data.

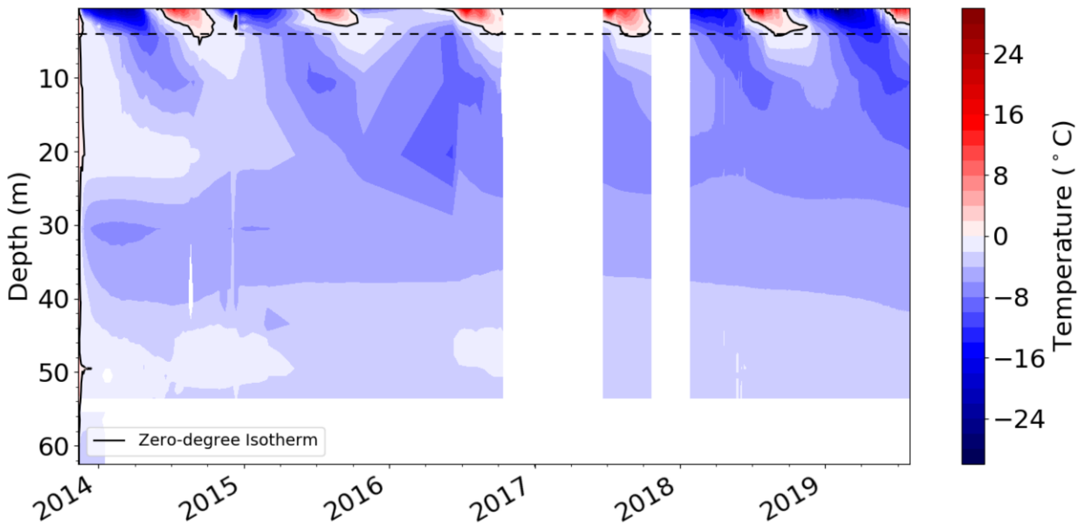

Figure 2: Thermistor RSF-5 temperature plot.

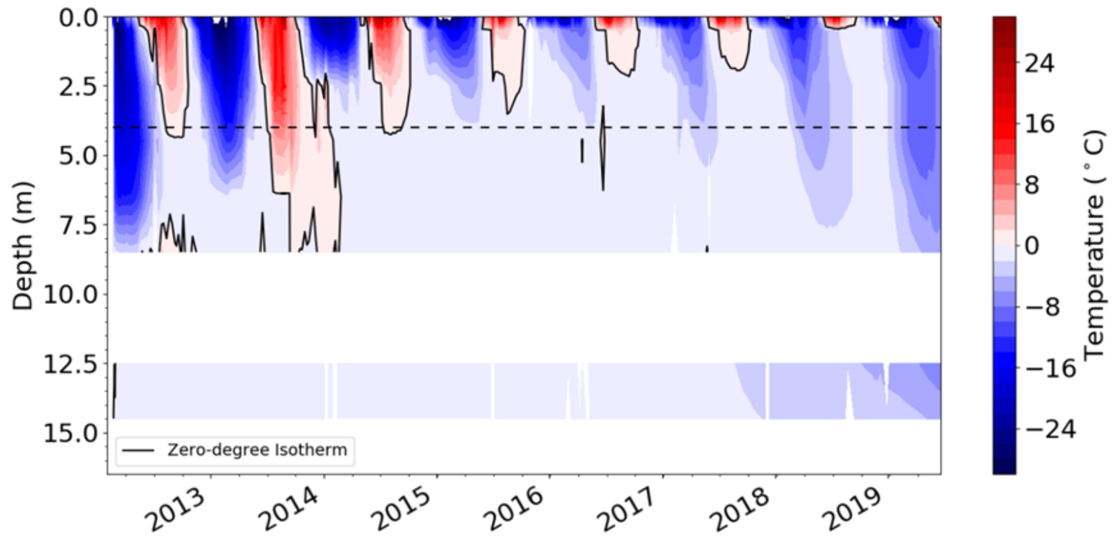

Figure 3: Thermistor RF1-2 temperature plot.

RSF-1, RSF-3, RSF-6, RSF-9, and RSF-10 were all installed on southern facing slopes of the RSF. In 2018, an active zone depth of approximately 4.9 m was measured by RSF-10. RSF-3, RSF-6 and RSF-9 all recorded an active zone depth less than 4.0 m in 2018. RSF-1 does not have any sensors installed between 3.7 m and 9.7 m to estimate an accurate active zone depth at this station, though the active zone has extended to a depth greater than 3.7 m since the beginning on monitoring.

RSF-5, RSF-13, RSF-14, RSF-15, and RSF-16 were all installed on the northern facing slope. In 2018 the maximum active zone depth measured by the northern slope installed thermistors was approximately 4.2 to 4.3 m at RSF-5, RSF-15, and RSF-16. RSF-13 and RSF-14 both measured active zone depths less than 2.0 m in 2018 and both show a decreasing trend in the active zone depth.

All thermistors installed on the west slope (RSF-7 and RSF-8) and east slope (RSF-11 and RSF-12) measured active zone depths less than 4.0 m in 2018. Only one thermistor (RSF-4) was installed on the plateau area of the Portage RSF which stopped recording data in 2015 therefore no comment can be made on trends in measured data for the plateau area of the Portage RSF.

Thermal Modelling Summary

OKC (2016) completed one-dimensional (1D) and two-dimensional (2D) soil-plant atmosphere (SPA), thermal and air flow modelling to assess the effectiveness of the Portage RSF cover system at maintaining the PAG waste rock below the freezing point under future climate conditions. The main objective of the numerical modelling exercise was to estimate the depth of the active zone (layer of materials undergoing freeze-thaw cycles from atmospheric forcing) within the Portage RSF and to confirm that the PAG waste rock will remain frozen for the next 150 years under agreed upon climate change scenarios (RCP 4.5 and RCP 6.0).

Some key assumptions made by Okane[5] in 2016 based on the Portage RSF thermal conceptual model for current and future climate scenarios were as follows:

- The RSF had not yet completely frozen back;
- The top 4 to 5 m of the RSF still thawed during the summer, but it was anticipated that this active layer would decrease in thickness once permafrost had fully formed within the RSF;
- Based on initial wind and solar radiation analyses, it was anticipated that the northwest corner and north slope of the RSF would have the coolest conditions and thinnest active zone. The next-coolest regions of the RSF would be the western slope, followed by the eastern slope. The south slope was anticipated to be the area with the highest potential for a thicker active layer.
- Additional rainfall and runoff predicted from climate change models, along with the anticipated rise in average annual temperature, are likely to increase the potential for a thicker active layer.

Thermistor strings RSF-3, RSF-4, RSF-5, and RSF-6 were used to calibrate a 1D model before selecting two 2D cross sections for calibration. Based on the conceptual model, it was

[5] O'Kane Consultants Inc. (Okane). 2016. Summary of Thermal Modelling of Portage RSF at Meadowbank Mine. Okane ref: 948-4. September.

expected that the south face of the Portage RSF would be most susceptible to thawing, while the northwest corner was expected to be the least susceptible. As a result, a north-south cross section and a northwest – southeast cross section were chosen for calibration.

Table 2 shows the simulated temperature results at 4 m depth on the south slope, north slope and plateau areas for the RCP 4.5 and RCP 6.0 climate scenarios while Table 3 shows the simulated maximum depth of the active zone. Given the climate change scenarios evaluated, the simulated active zone depth remained within the 4 m cover system for the RCP 4.5 climate change scenario and extended beyond the 4 m cover system for infrequent time periods using the RCP 6.0 climate change scenario. The active zone reached a maximum depth of 6.1 m in the plateau area, though, the unfrozen conditions were limited in time and area of the RSF, and the area refroze following the thawed period. The thawed portion of the PAG waste rock was above 0°C for ~2% of the 150-year modelled period, therefore, long-term impacts to the receiving environment were anticipated to be limited.

Table 2: Temperature results at 4 m depth for modelled 150-year climate change scenarios.

Climate Scenario	Maximum Model Predicted Temperature (°C)	Percent Time Temperature >0°C	Maximum Consecutive Days >0°C	Frequency >0°C
South Face RCP 4.5	-0.1	0%	0	0
North Face RCP 4.5	-1.1	0%	0	0
Plateau RCP 4.5	-0.2	0%	0	0
South Face RCP 6.0	0.1	<1%	99	1
North Face RCP 6.0	0.2	1%	173	2
Plateau RCP 6.0	0.5	2%	664	2

Source: Okane, 2016

Table 3: Maximum depth of active zone for 150-year future climate scenarios.

Scenario	Maximum Estimated Depth of Active Layer
South Face RCP 4.5	< 4.0 m
North Face RCP 4.5	<4.0 m
Plateau RCP 4.5	<4.0 m
South Face RCP 6.0	4.3 m
North Face RCP 6.0	4.9 m
Plateau Face RCP 6.0	6.1 m

Source: Okane, 2016

Comparison of Thermistor and Simulated Data

The primary purpose of comparing site measured data (climate and *in situ* temperature) to simulation inputs and temperature estimates is to assess the validity, accuracy, and predictive capabilities of the thermal model, and to provide recommendations to address any data gaps if needed.

Key Climate Parameters

For the thermal model to accurately predict the Portage RSF thermal conditions key parameters must be characterized. Climate data is a key parameter for thermal modelling of which precipitation (including snow depth), air temperature, and net radiation are driving factors for freeze-thaw effects simulated in the upper portion of the model. The site weather station is located on the south-west side of the air strip on the Meadowbank mine site (approximately 1.5 km southwest of Portage RSF). Although snow depth was considered by the numerical model, a snow depth comparison was not completed in this work since snow depth is not measured on the Portage RSF.

Climate Change

As part of the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (AR5), the IPCC adopted new Representative Concentration Pathways (RCPs) to replace the previous emission scenarios of the Special Report on Emission Scenarios (SRES) (IPCC, 2013)[6]. The four adopted RCPs differ from the SRES in that they represent greenhouse gas concentration trajectories, not emissions trajectories. The four scenarios (RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5) are named after the radiative target forcing level for 2100, which are

[6] IPCC. 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.). Cambridge University Press. Cambridge, United Kingdom and New York, NY, USA.

based on the forcing of greenhouse gases and other agents (van Vuuren et al. 2011)[7]. These values are relative to pre-industrial levels. RCP 4.5 and RCP 6.0 scenarios were chosen as the most reasonable climate change scenarios and used to create two, 150-year climate change databases. Figure 4 provides the concentration of all forcing agents (in parts per million (ppm) of CO_2-equivalence) for the four RCP scenarios.

Monthly results from two general circulation models (GCM) were used to provide estimates of climate conditions for Meadowbank over the next 150 years. The CanESM2/CGCM4 model developed by the Canadian Centre for Climate Modelling and Analysis (CCCma) was used to develop inputs for the Representative Concentration Pathways (RCP) 4.5 climate database (CCCma, 2014)[8]. A second GCM needed to be selected as the CCCma has not publicly released its results for the RCP6 scenario. Hence, the CESM1-CAM5 model, developed by the National Center for Atmospheric Research (NCAR), was selected to provide monthly estimates of climate conditions for the RCP 6.0 climate database (NCAR, 2014)[9]. Scaling from current measurement of precipitation and air temperature for the 150-year database were developed according to the GCM.

[7] Van Vuuren, D.P., Edmonds, J., Kainuma, M., Raihi, K., Thomson, A., Hibbard, K. Hurtt, G.C., Kram, T. Krey, V., Lamarque, J.F., et al. 2011. The representative concentration pathways: an overview. Climatic Change. Vol. 109.

[8] CCCma 2014. CanESM2 RCP4.5 Project. Canadian Centre for Climate Modelling and Analysis. Environment Canada. http://www.cccma.ec.gc.ca/

[9] NCAR (National Center for Atmospheric Research), 2014. CESM1-CAM5 model – RCP6. http://ncar.ucar.edu/budget-and-planning/2014-ncar-program-operating-plan/5141-community-earth-system-model

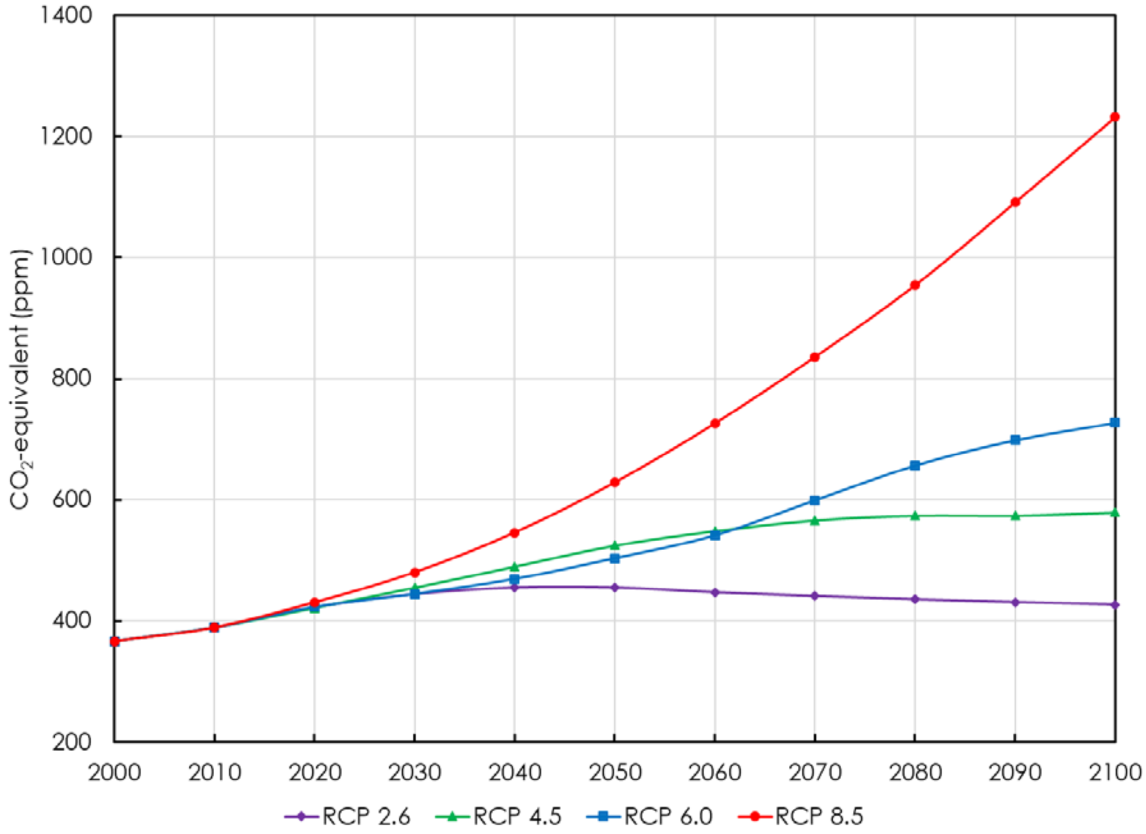

Figure 4: **All forcing agents' atmospheric CO_2-equivalent concentrations according to four RCP scenarios.**

Precipitation

The on-site weather station has been recording precipitation since January 2014. The thermal model used this data up to August 2015 as climate input. Daily precipitation was projected past this date under RCP 4.5 and RCP 6.0. Figure 5 provides 2018 recorded daily precipitation compared to projected daily precipitation under RCP 4.5 and RCP 6.0. Daily recorded precipitation compared to RCP 4.5 and RCP 6.0 projected daily precipitation for the period of January 2014 to August 2019 is provided in Appendix B. Figure 6 compares the observed cumulative precipitation starting August 2015 to the projected cumulative precipitation under the two climate change scenarios.

The projected daily precipitation tends to show larger precipitation events than were observed, especially during the summer of 2018. RCP 6.0 predicted a very large rainfall, approximately 84 mm/day, event during this time period, while observed rainfall was never more than 10 mm/day. Despite the larger precipitation events, the cumulative precipitation was relatively consistent between the observed and projected data over the period of interest. The RCP 6.0 projection overestimated cumulative precipitation by approximately 120 mm due to the large precipitation event in summer 2018. The RCP 4.5 projection underestimated cumulative precipitation by approximately 20 mm.

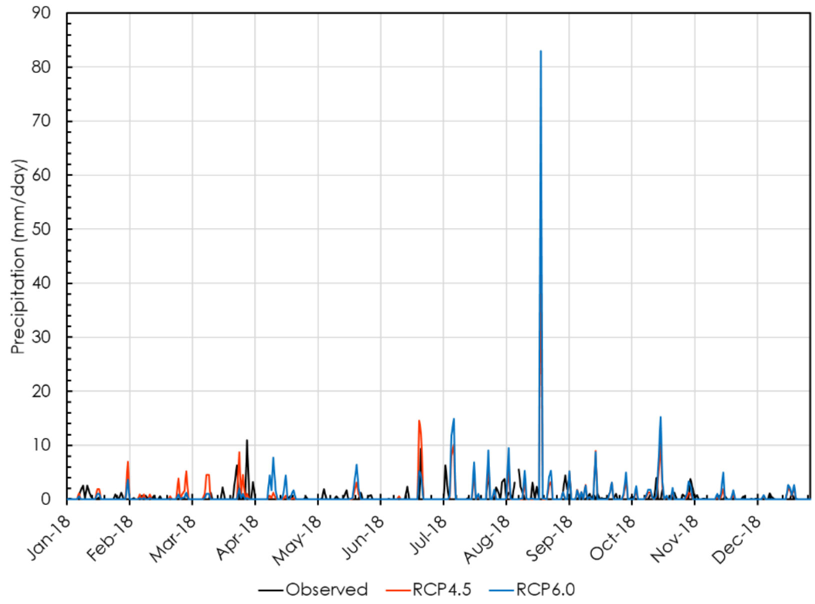

Figure 5: Comparison of 2018 daily precipitation recorded on site and the projected daily precipitation under RCP 4.5 and RCP 6.0.

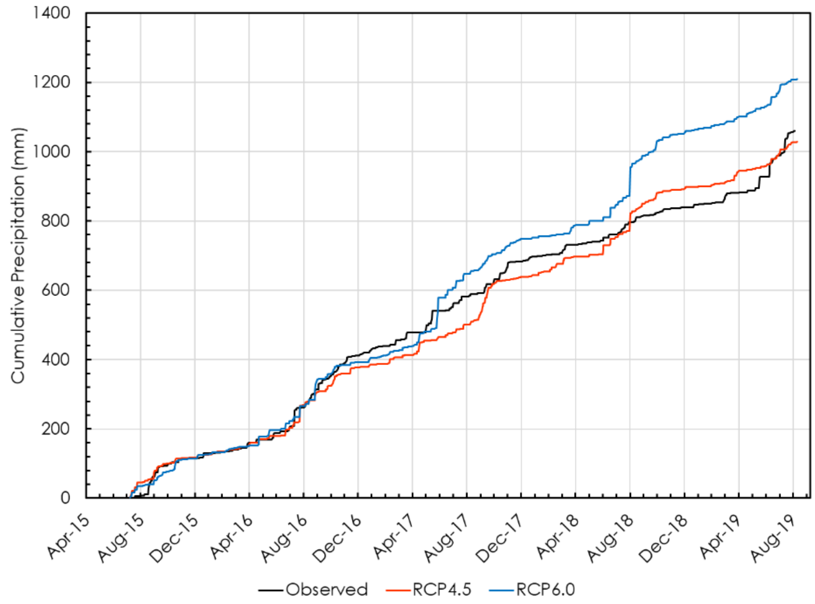

Figure 6: Comparison of cumulative total precipitation recorded on site and the projected cumulative total precipitation under RCP 4.5 and RCP 6.0 since August 2015.

Air Temperature

The air temperature is one of the main factors influencing the depth of the active zone and one of the key climate inputs of the thermal modelling program. This section discusses the comparison between observed air temperature and projected air temperature used in the numerical model.

The on-site weather station has been recording air temperature since 2013. The 2016 thermal model used the site data up to August 2015 as the model input for air temperature. Past this date, the air temperature was projected under two climate change scenarios, RCP4.5 and RCP 6.0. Figure 7 compares the 2018 observed maximum daily air temperature to the projected RCP 4.5 and RCP 6.0 temperatures, while Figure 8 compares the 2018 minimum daily air temperatures. Maximum and minimum temperature comparison plots for 2015 to 2019 are provided in Appendix B.

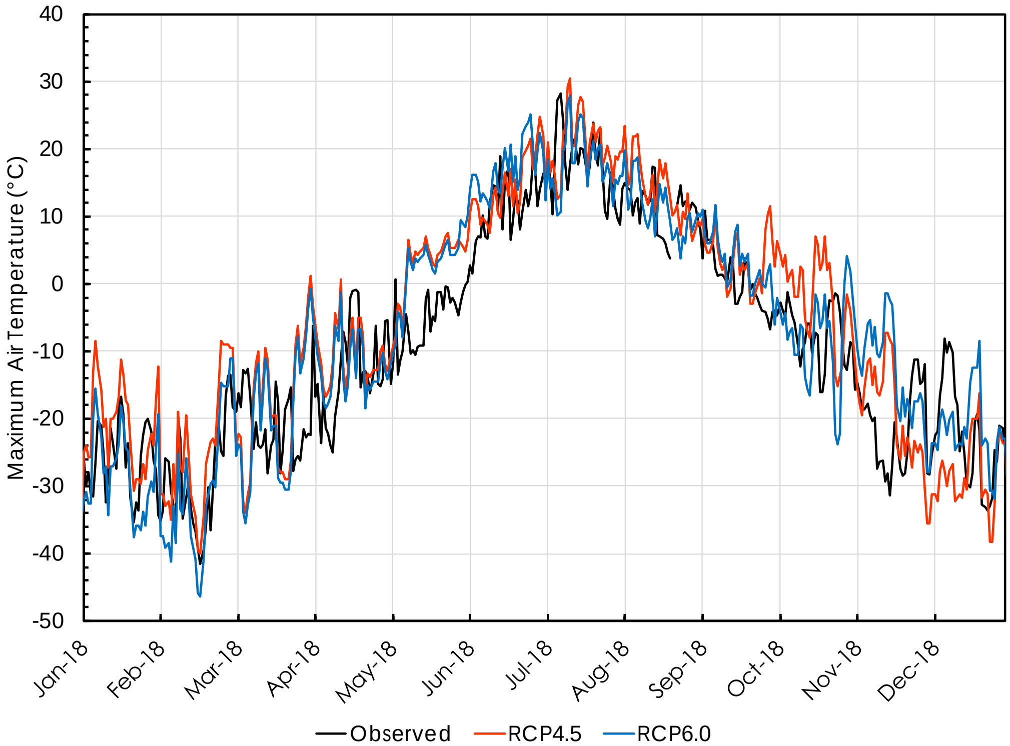

Figure 7: Comparison of 2018 observed maximum daily air temperature and projected maximum air temperature under RCP4.5 and RCP6.0 used in the 2016 thermal modelling.

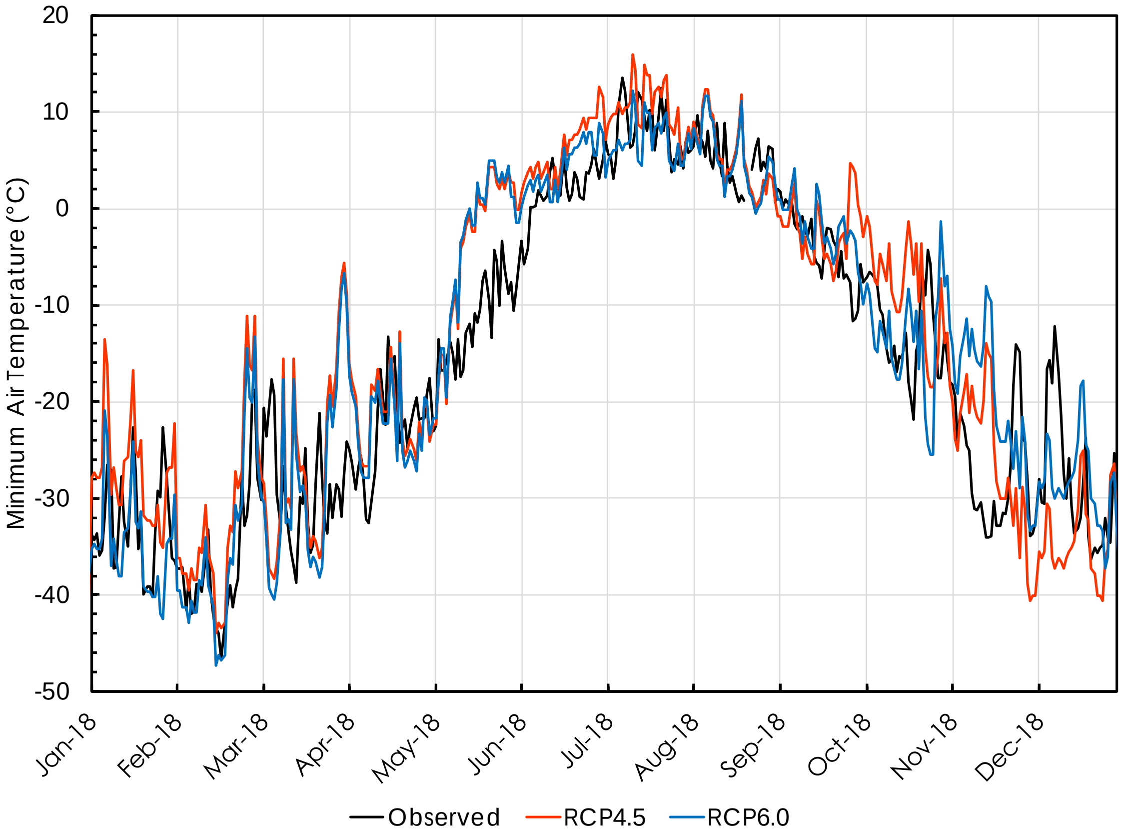

Figure 8: Comparison of 2018 observed minimum air temperature and projected minimum air temperature under RCP4.5 and RCP6.0 used in the 2016 thermal modelling.

The projected air temperatures under both climate change scenarios show a good overall fit to observed air temperatures. Both projections tend to overestimate extreme winter temperatures, while RCP 6.0 also tends to overestimate summer temperatures. Both projected climate scenarios overestimated May temperatures with the onset of thaw occurring earlier than recorded at site in May 2018. However, seasonal averages are consistent between all three datasets. The onset of freezing temperatures in the fall in both projected scenarios is consistent with observed temperatures.

Net Radiation

The thermal model used net radiation data that was directly measured at Meadowbank from January 2013 to August 2015. Past August 2015, net radiation was projected under the RCP4.5 and RCP 6.0 climate change scenarios. Net radiation data was then scaled in order to account for anticipated changes in daily net radiation due to slope aspect and angle.

Figure 9 shows site measured net radiation data and the RCP 4.5 plateau net radiation data used in the modelling program. Net radiation data used in the modelling program may have overestimated net radiation in the spring an summer, and underestimated net radiation during the summer and winter months (Figure 10). However, since net radiation is not measured directly on the Portage RSF slopes, net radiation data used for north and south facing slopes in the thermal modelling program cannot be validated.

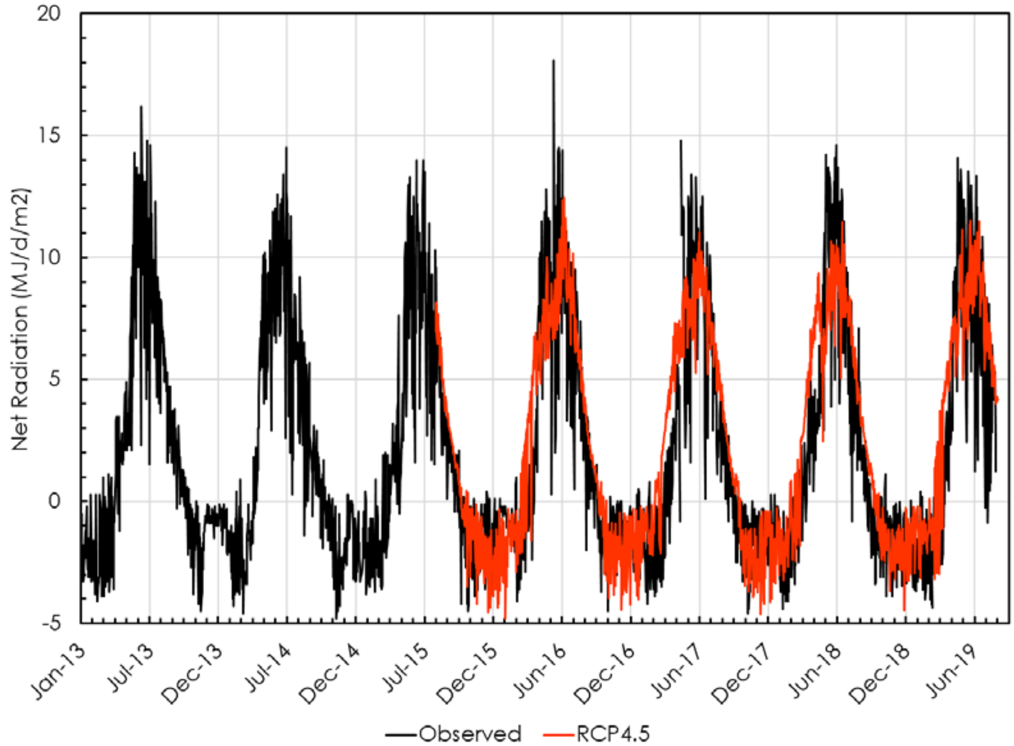

Figure 9: Comparison of the observed net radiation and the estimated net radiation under RCP4.5 used in the 2016 thermal modelling for plateau areas.

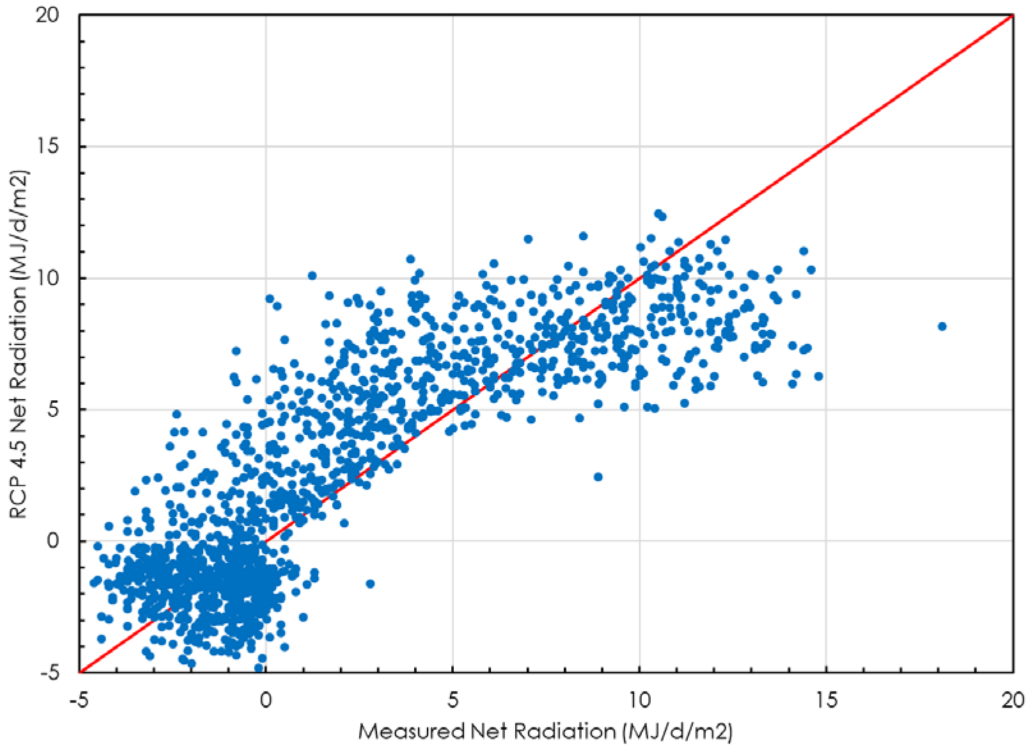

Figure 10: Comparison of the observed net radiation and the estimated net radiation under RCP4.5 used in the 2016 thermal modelling for plateau areas.

Freeze / Thaw Cycling Depth

Recorded temperature at a depth of approximately 4 m was compared to simulated thermal model temperatures to assess the accuracy of the thermal model. Recorded and simulated temperatures follow the same seasonal trends and have similar amplitudes of seasonal temperature fluctuations though recorded temperatures are generally higher than those simulated. Recorded temperatures indicate sensors are equilibrating during the initial years post-installation; therefore, analysis of recorded and simulated data will focus on 2017 and 2018.

Throughout the period of record, RCP 4.5 simulations have underestimated temperatures at a depth of 4 m, though the magnitude of seasonal temperature changes are similar to recorded data. RSF-3 recorded temperature at a depth of 4 m reached a maximum of approximately 0°C in the summer versus predicted maximum temperatures of approximately -4°C. RSF-3, shown in Figure 11, was used to calibrate the thermal model in 2016.

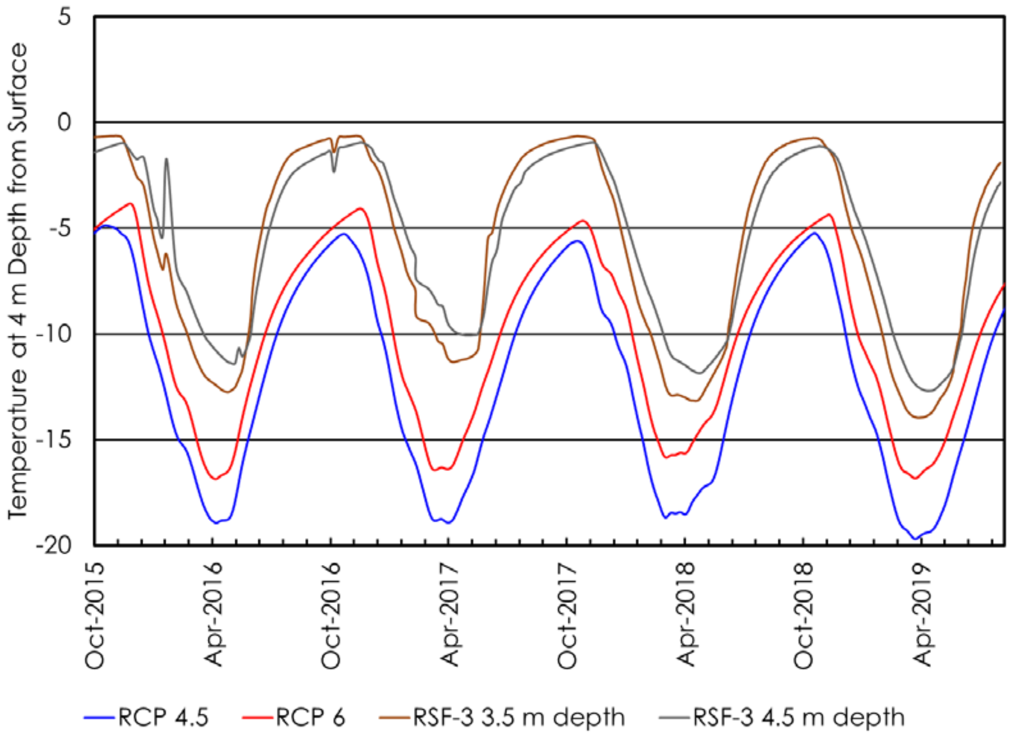

Figure 11: RSF-3 measured temperature at 3.5 m and 4.5 m depth compared to model predicted temperature at 4 m depth.

North-Facing Slope

Figure 12 shows the general trends in recorded and simulated temperatures at a depth of ~4 m on northern facing slope locations. RSF-13 and RSF-14 are located on the eastern portion of the north slope while RSF-15, RSF-16 and RSF-5 are located on the western portion of the north slope (Figure 1). Simulated temperatures show a good match to RSF-13 and RSF-14, with similar active zone depths and seasonal trends.

RSF-5, RSF-15, and RSF-16 were all installed in the same vicinity on the north facing slope. Simulated temperatures were lower than those recorded at RSF-5 though the match appears to be improving in 2018-19 in terms of the amplitude of seasonal temperature fluctuation observed. RSF-16 recorded temperature has less amplitude of seasonal temperature fluctuations compared to RSF-5 and simulated results. The lower amplitude of seasonal temperature fluctuation at RSF-16 could be due to the deeper installation depth but also could be due to variability in cover system and waste rock materials, and moisture conditions. The cause of sharp changes in RSF-15 recorded temperatures is unknown and could potentially indicate sensor error.

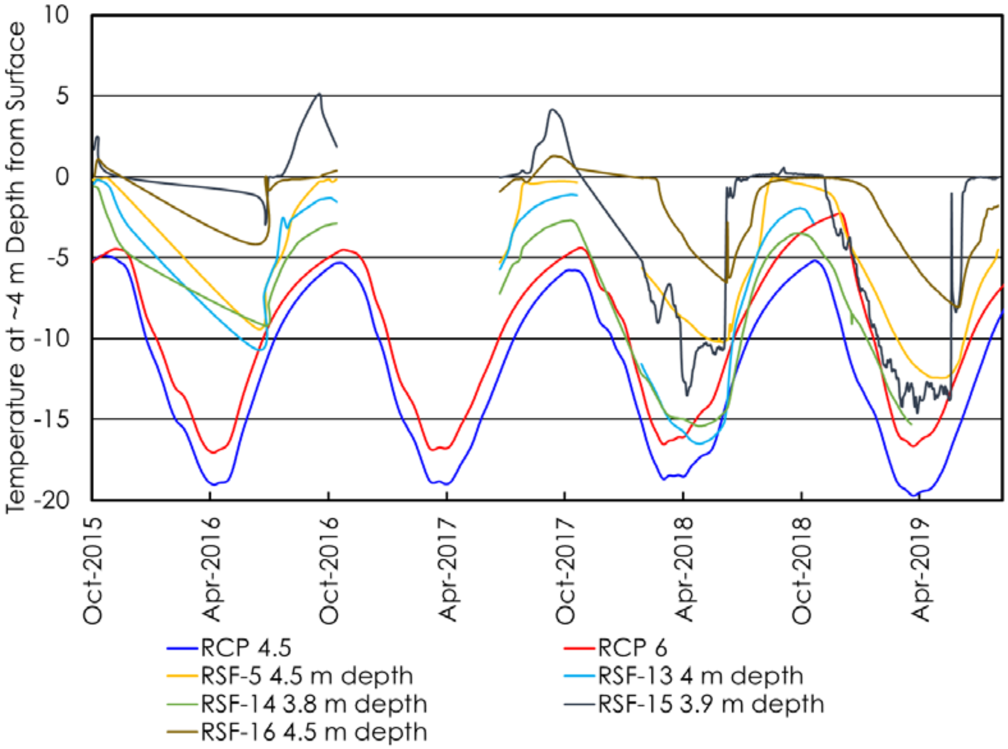

Figure 12: Simulated temperature at 4 m depth compared to thermistor recorded temperatures near 4 m depth at north facing slope locations.

South-Facing Slope

Figure 13 shows the general trends in recorded and simulated temperatures at a depth of ~4 m on southern facing slope locations. Thermistors on the southern facing slope of Portage RSF generally measure higher temperatures and show less seasonal variation in temperature (generally a 10-degree difference from maximum to minimum temperatures) than simulated by the model (Figure 13).

RSF-9 and RSF-10 were installed in the same vicinity but measured a 5-degree difference in winter low temperatures (-10°C compared to -5°C). As mentioned for the north slope, the range in recorded temperatures at similar depths and location could potentially be due to variability in material properties and moisture conditions. A degree of heterogeneity is to be expected in an engineered cover system. Understanding the expected range of heterogeneity and the measured impacts of heterogeneity on moisture and temperature conditions can provide valuable data by which to calibrate sensitivity models and develop technical specifications for construction. Sensitivity modelling and an adequate quality assurance program during construction can limit the impact of risks associated with inherent material heterogeneity.

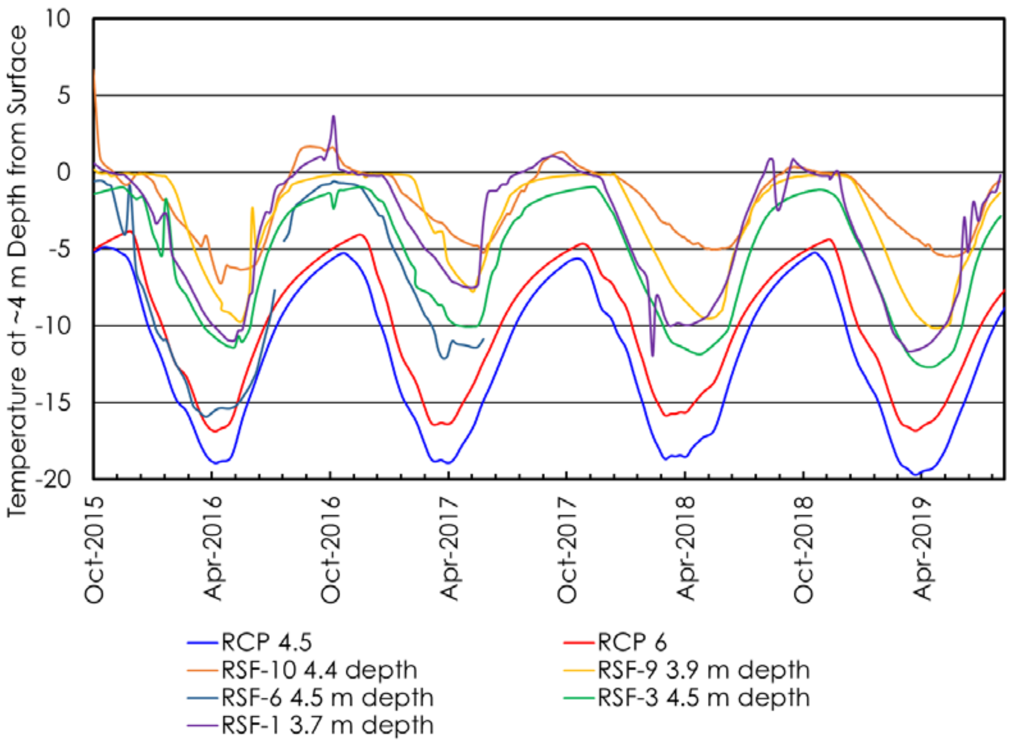

Figure 13: Simulated temperature at 4 m depth compared to thermistor recorded temperatures near 4 m depth at south facing slope locations.

Key Findings

The overall objective of completing a review and comparison of recorded and simulated *in situ* temperatures is to both verify the accuracy of the current thermal model and identify uncertainties and/or data gaps in the current monitoring plan. Key findings based on the review and comparison of the Portage RSF monitoring and modelling programs are presented in the form of overarching statements below.

Overarching Statements

1) Decreasing trends in the active zone depth are recorded at most thermistor locations.

2) The thermal model predicted colder temperatures near surface compared to recorded near surface temperatures.

3) Temperature trends are becoming more consistent with simulated temperatures over time.

4) The observed active zone is generally thicker on the north slope compared to the south slope. In the conceptual model, the south slope was anticipated to be the area with the highest potential for a thicker active layer.

5) Comparison of site recorded net radiation to model input net radiation shows that the model underestimated net radiation by approximately 10-15% in the summer months.

6) Snow depth is currently not recorded on the RSF.

Discussion

The numerical modelling undertaken in 2016 (Okane, 2016)[1] tended to predict colder soil temperatures than the thermistors during the observed period at all locations. However, the difference between the modelled and observed temperature is becoming less over time and the overall trend in the observed data is becoming more consistent with the model. The timing and amplitude of seasonal trends already show a good match between observed and modelled results, but the model results are shifted lower due to the predicted colder temperatures.

As the overall trend in the observed data is becoming more consistent with the results of the numerical model with time, the confidence in the numerical model as a predictor of future conditions is moderate to high. It is expected that the trend towards consistency will continue, further increasing confidence.

Closing

Please do not hesitate to contact me at 306-713-1568 or gallen@okc-sk.com should you have any questions or comments.

Appendix A
Thermistor Temperature Figures

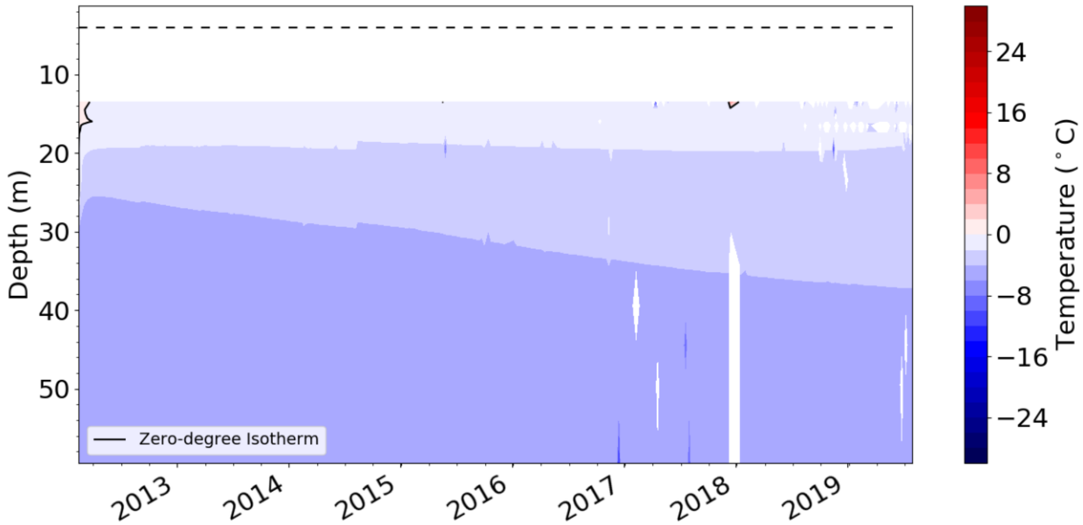

Figure 14: Thermistor RF1-1 temperature plot.

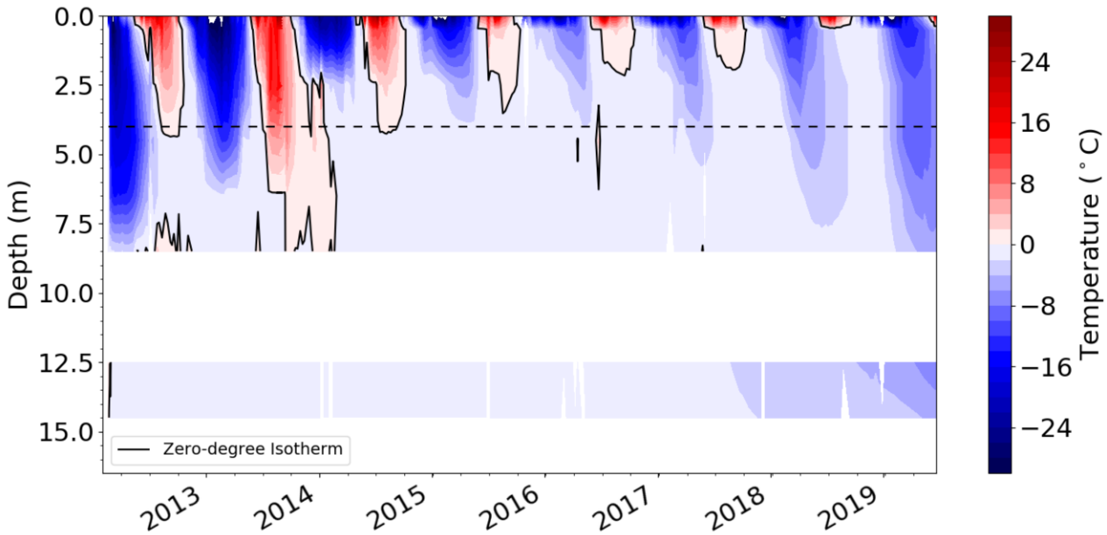

Figure 15: Thermistor RF1-2 temperature plot.

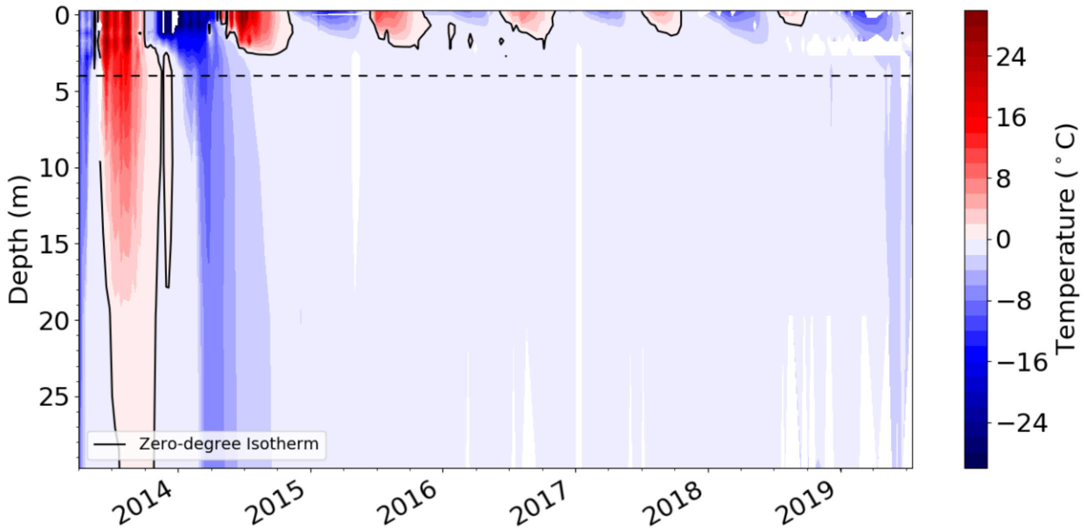

Figure 16: Thermistor RF1-3 temperature plot.

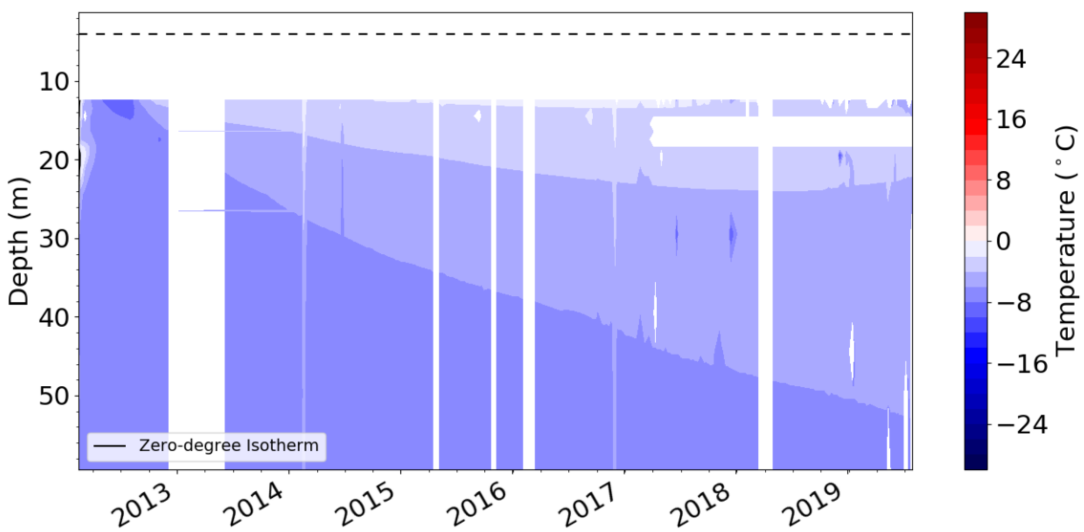

Figure 17: Thermistor RF-2 temperature plot.

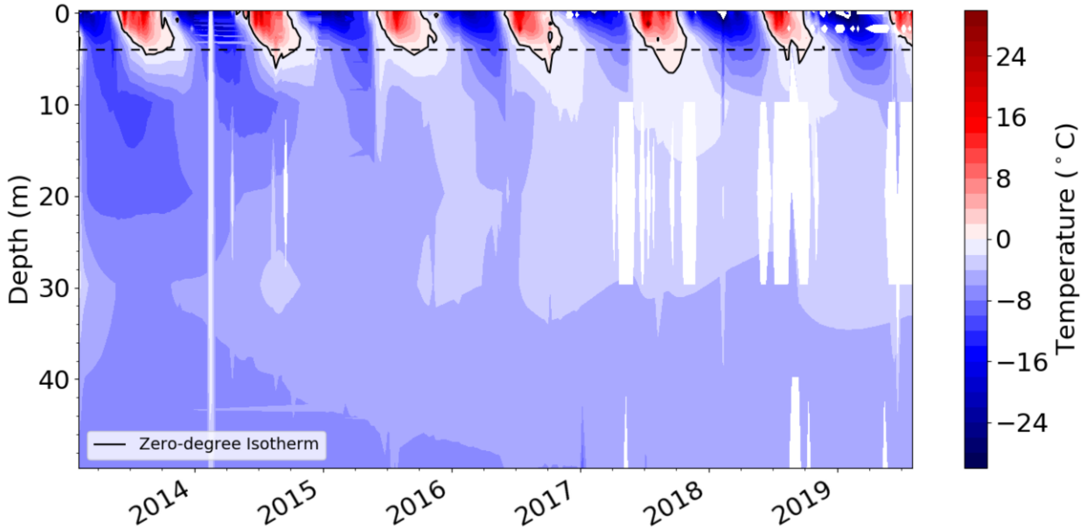

Figure 18: Thermistor RSF-1 temperature plot.

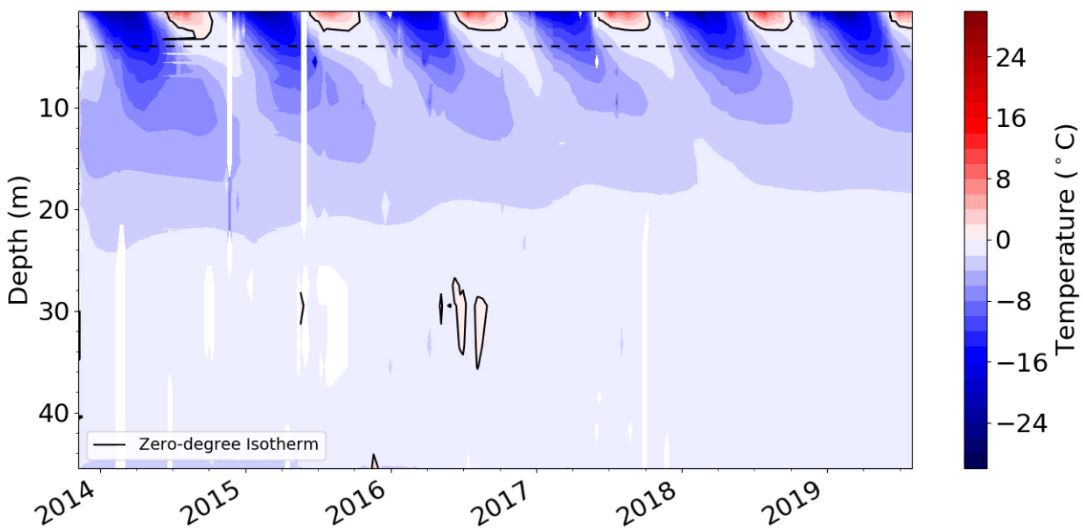

Figure 19: Thermistor RSF-3 temperature plot.

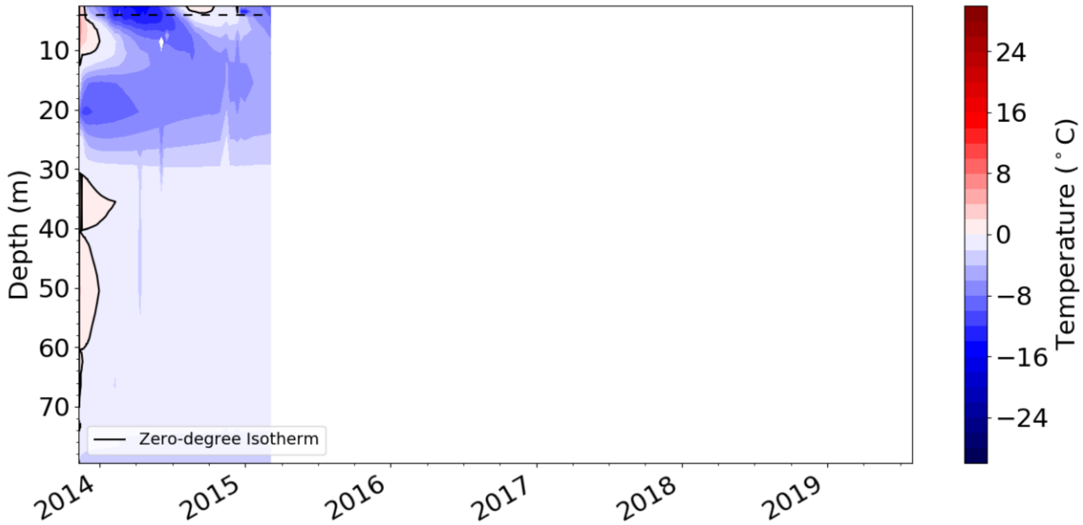

Figure 20: Thermistor RSF-4 temperature plot.

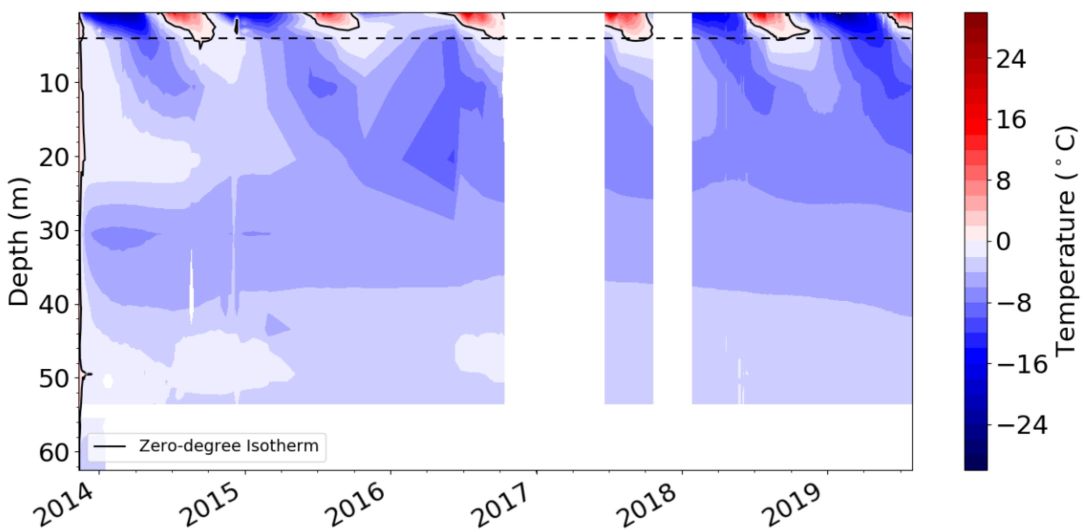

Figure 21: Thermistor RSF-5 temperature plot.

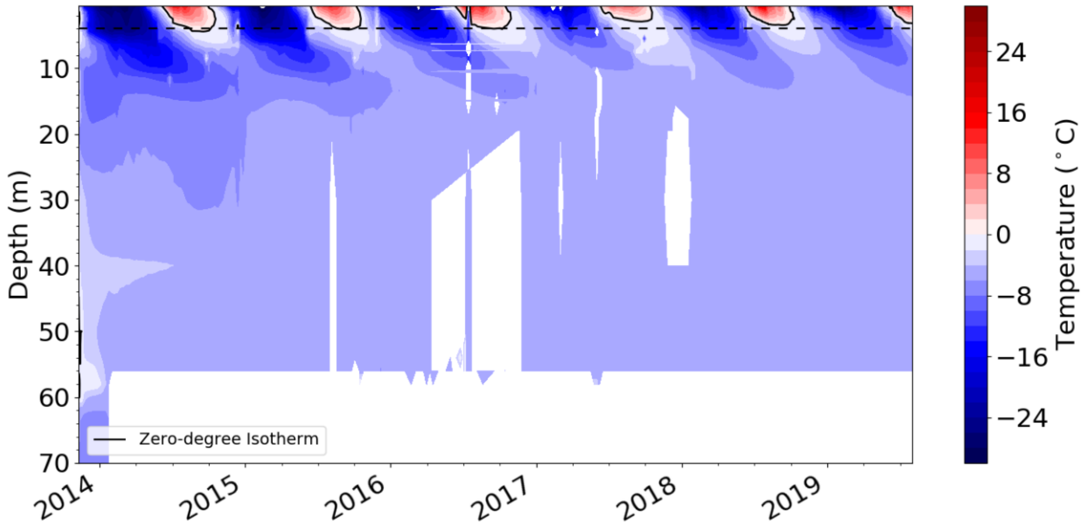

Figure 22: Thermistor RSF-6 temperature plot.

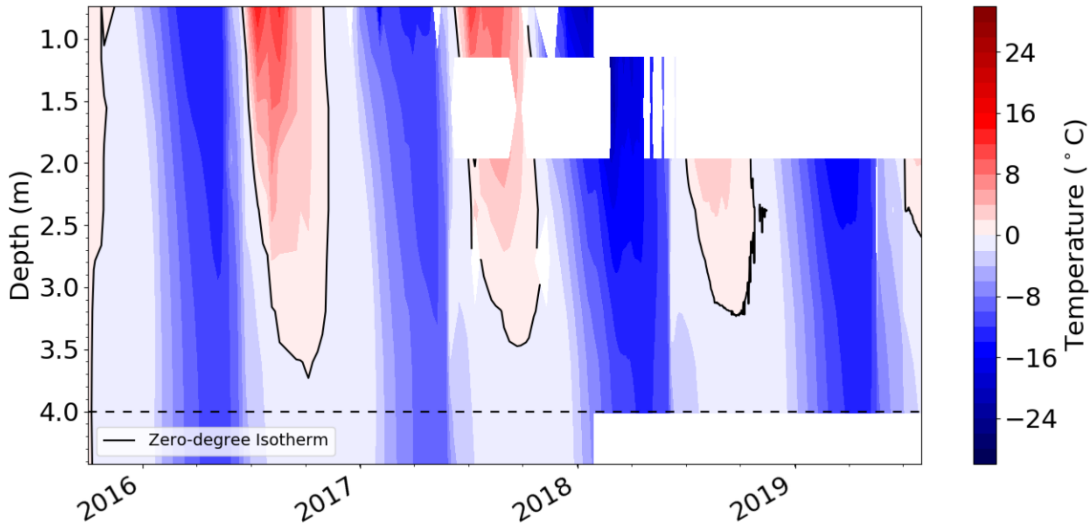

Figure 23: Thermistor RSF-7 temperature plot.

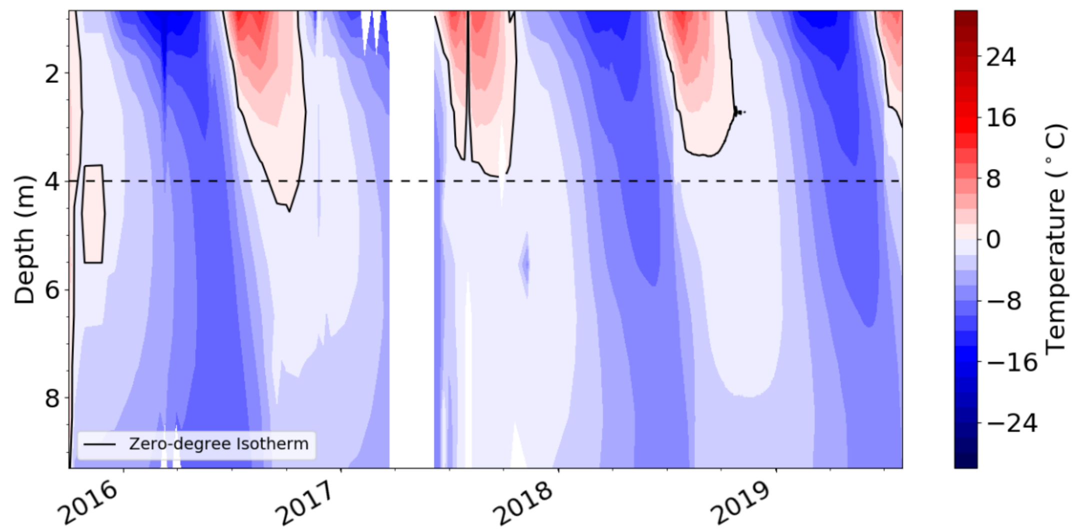

Figure 24: Thermistor RSF-8 temperature plot.

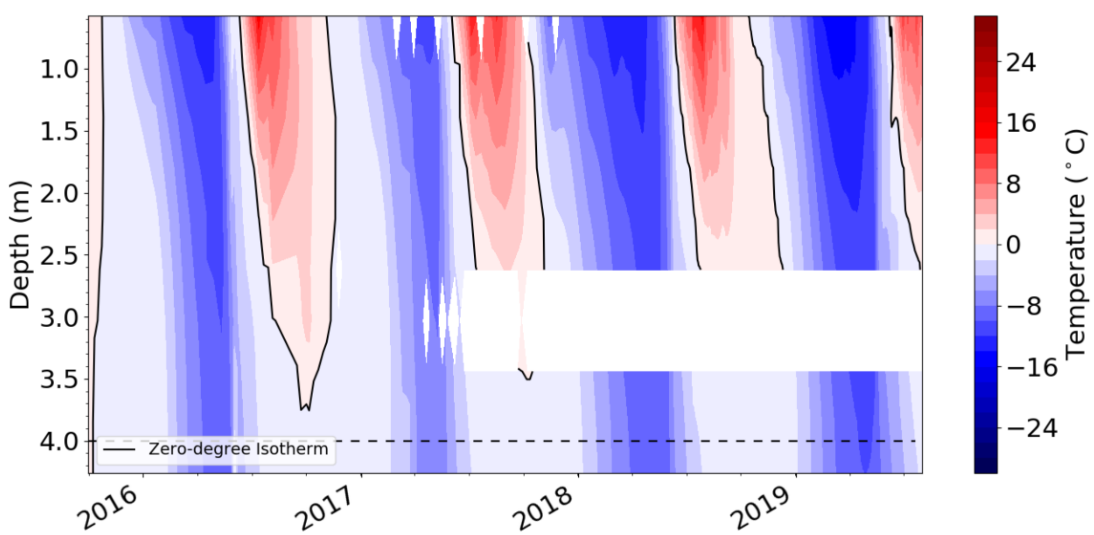

Figure 25: Thermistor RSF-9 temperature plot.

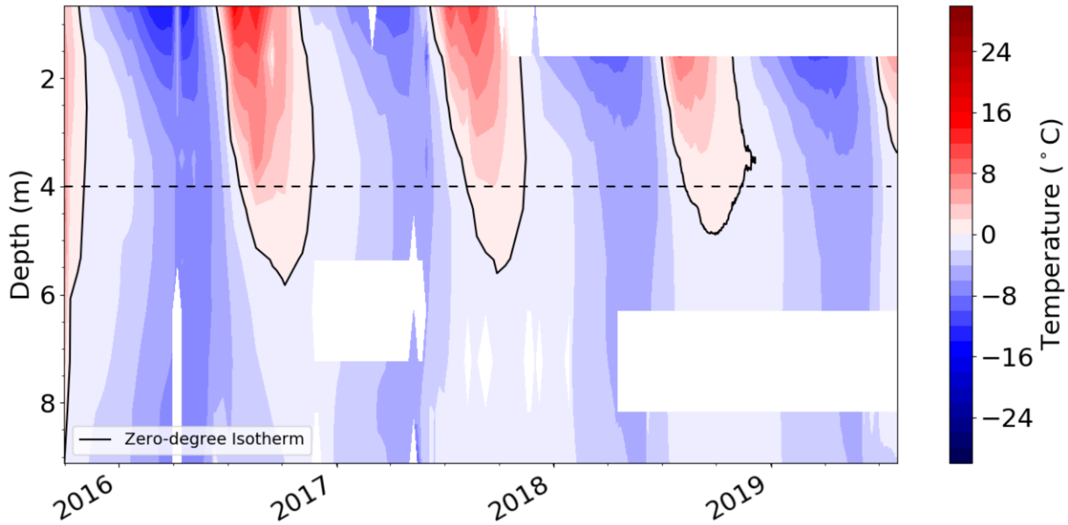

Figure 26: Thermistor RSF-10 temperature plot.

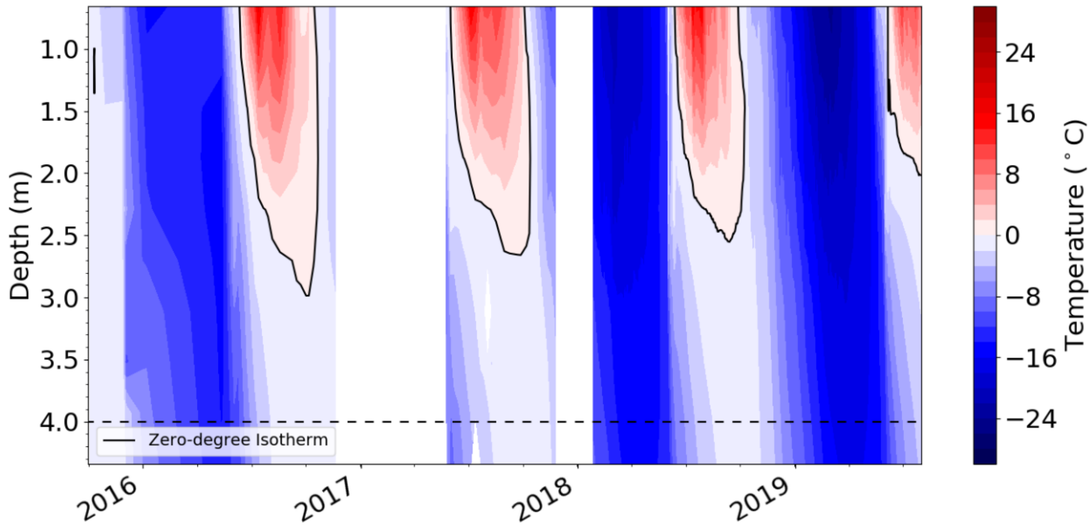

Figure 27: Thermistor RSF-11 temperature plot.

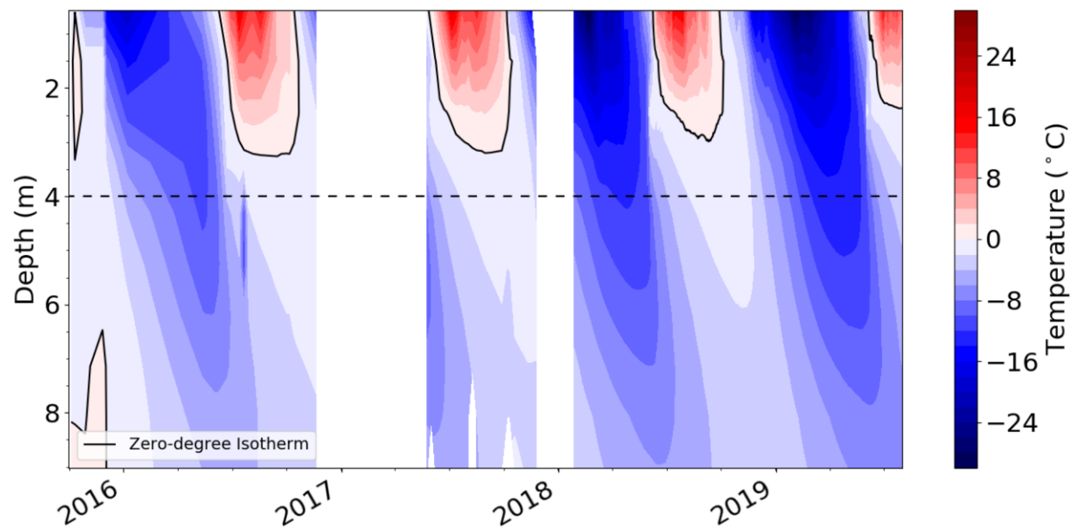

Figure 28: Thermistor RSF-12 temperature plot.

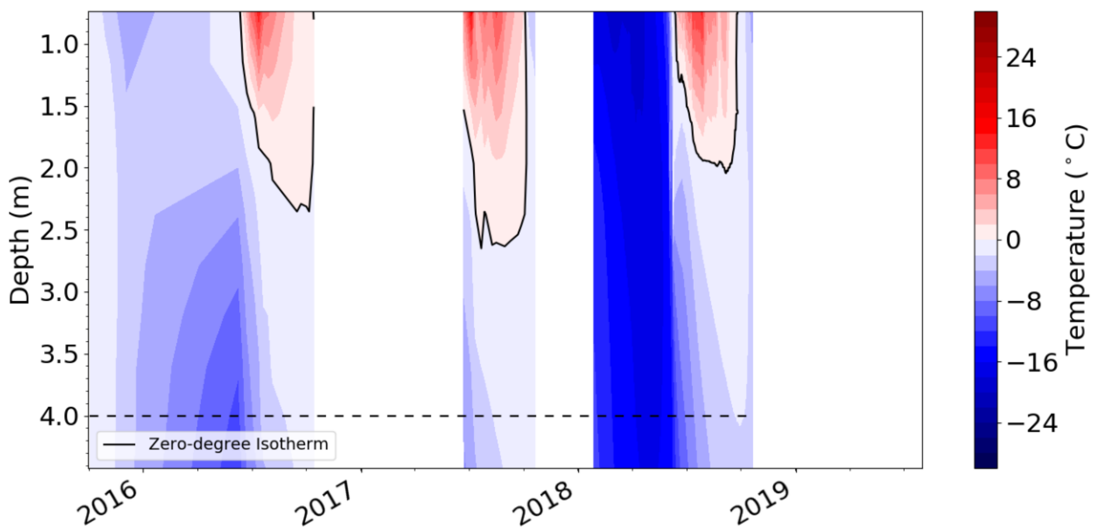

Figure 29: Thermistor RSF-13 temperature plot.

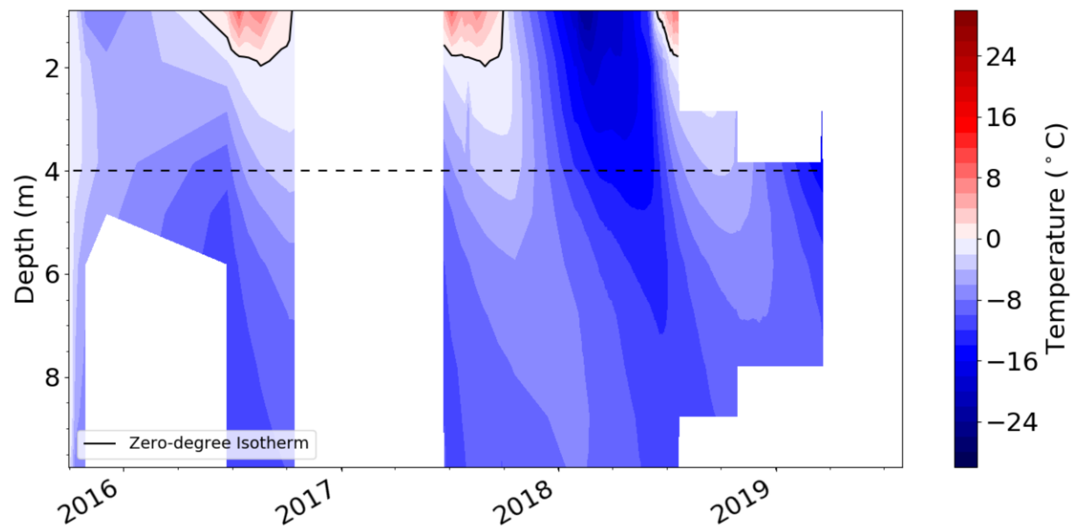

Figure 30: Thermistor RSF-14 temperature plot.

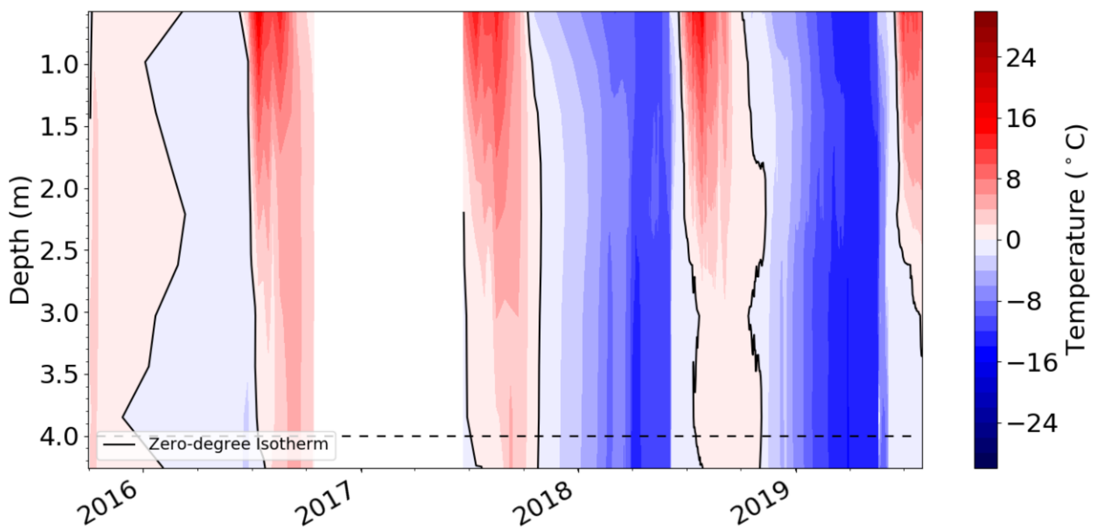

Figure 31: Thermistor RSF-15 temperature plot.

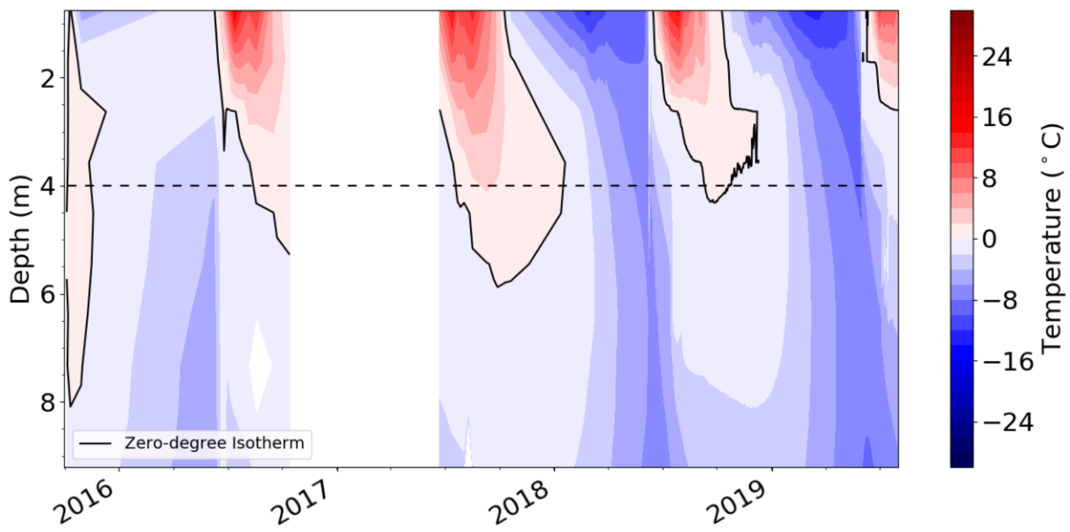

Figure 32: Thermistor RSF-16 temperature plot.

Appendix B
Climate Comparison Graphs

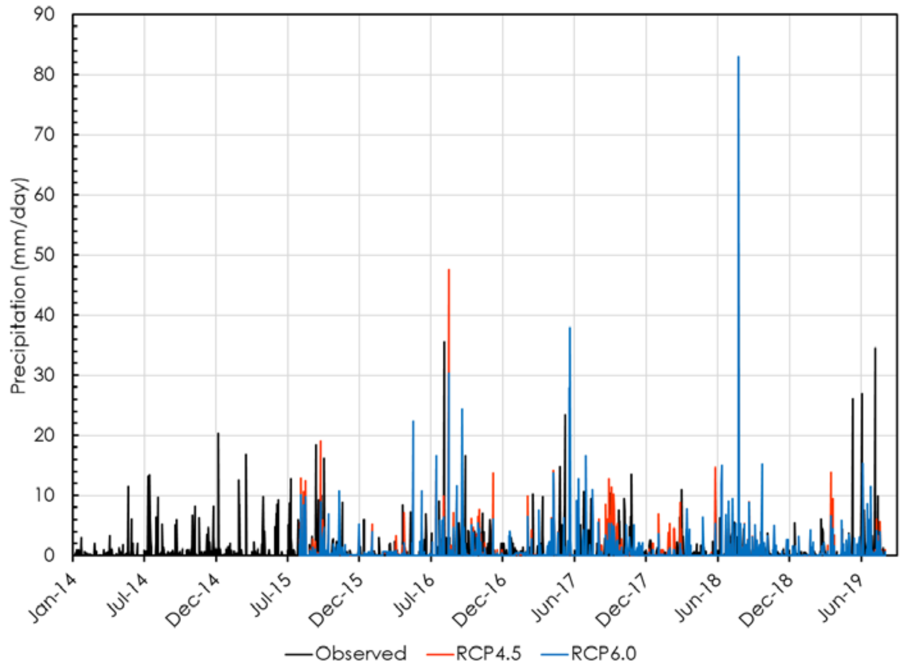

Figure 33: Comparison between the observed daily precipitation and the estimated daily precipitation under RCP 4.5 and RCP 6.0 used in the 2016 thermal modelling.

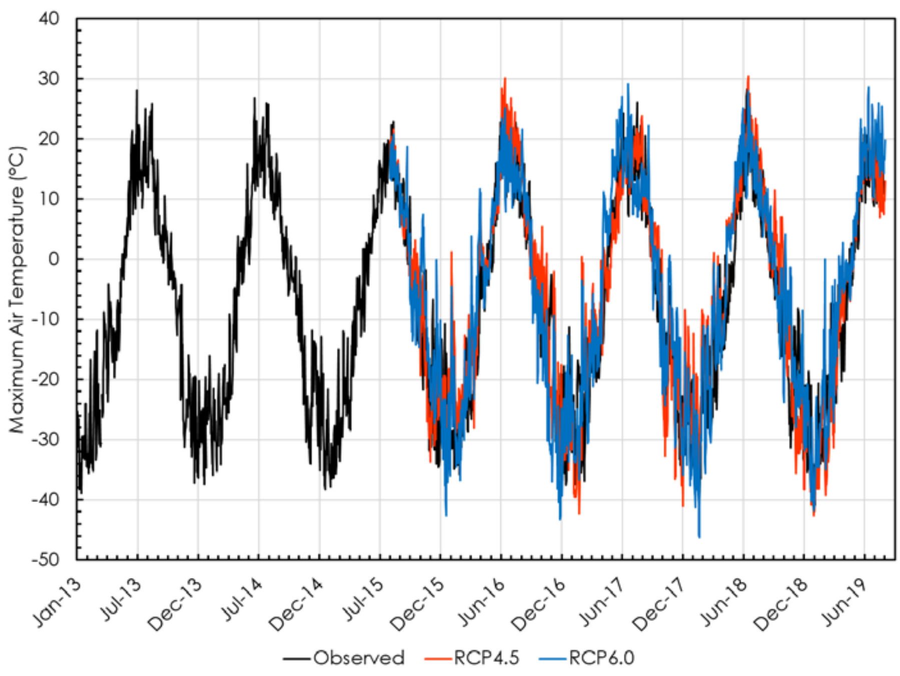

Figure 34: Comparison between the observed maximum daily air temperature and the estimated maximum air temperature under RCP 4.5 and RCP 6.0 used in the 2016 thermal modelling.

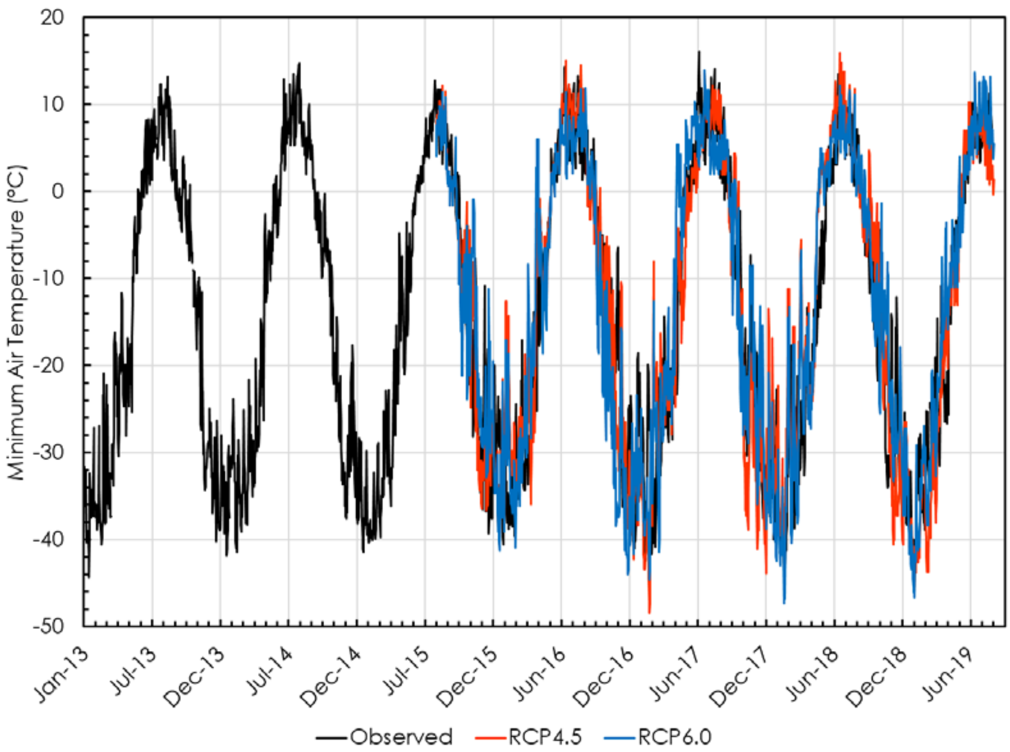

Figure 35: Comparison between the observed minimum daily air temperature and the estimated maximum air temperature under RCP 4.5 and RCP 6.0 used in the 2016 thermal modelling.

Appendix C
Simulated and Recorded Temperature Comparison Figures

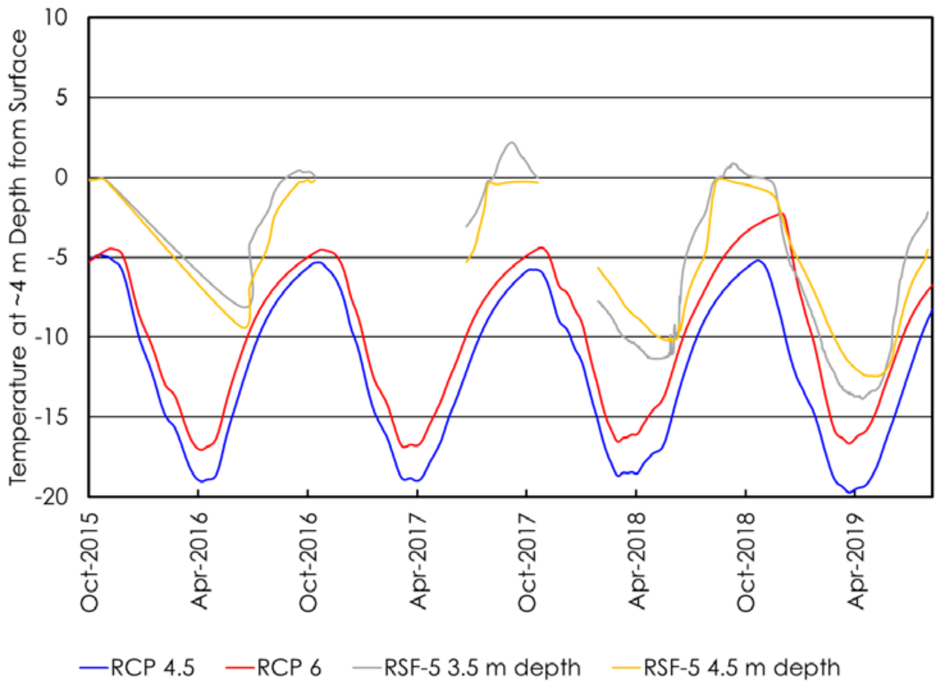

Figure 36: North slope simulated temperature at 4 m depth compared to RSF-5 recorded temperature at ~ 4 m depth.

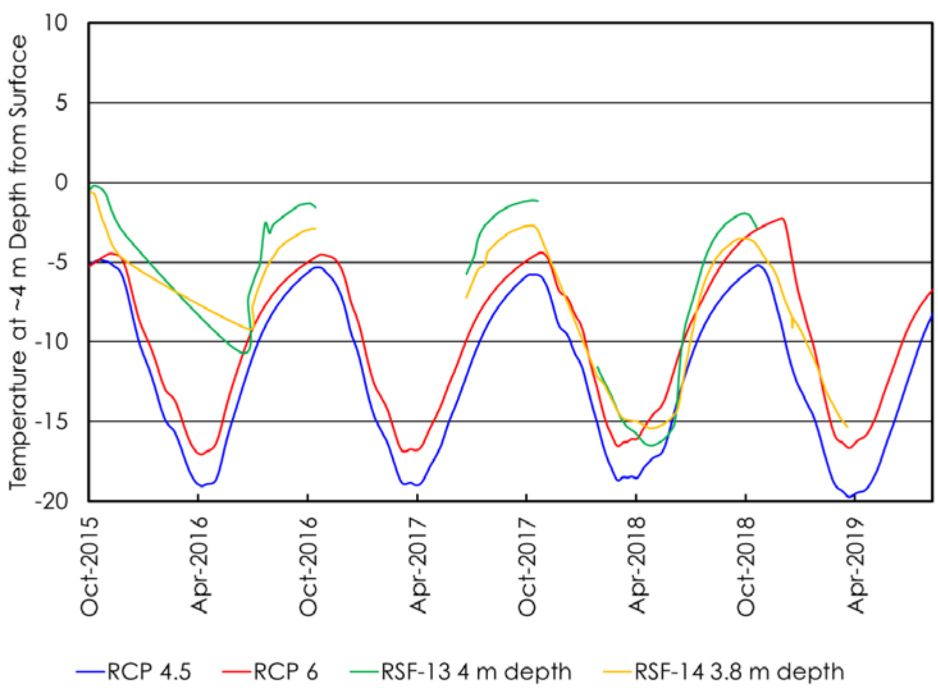

Figure 37: North slope simulated temperature at 4 m depth compared to RSF-13 and RSF-14 recorded temperature at ~ 4 m depth.

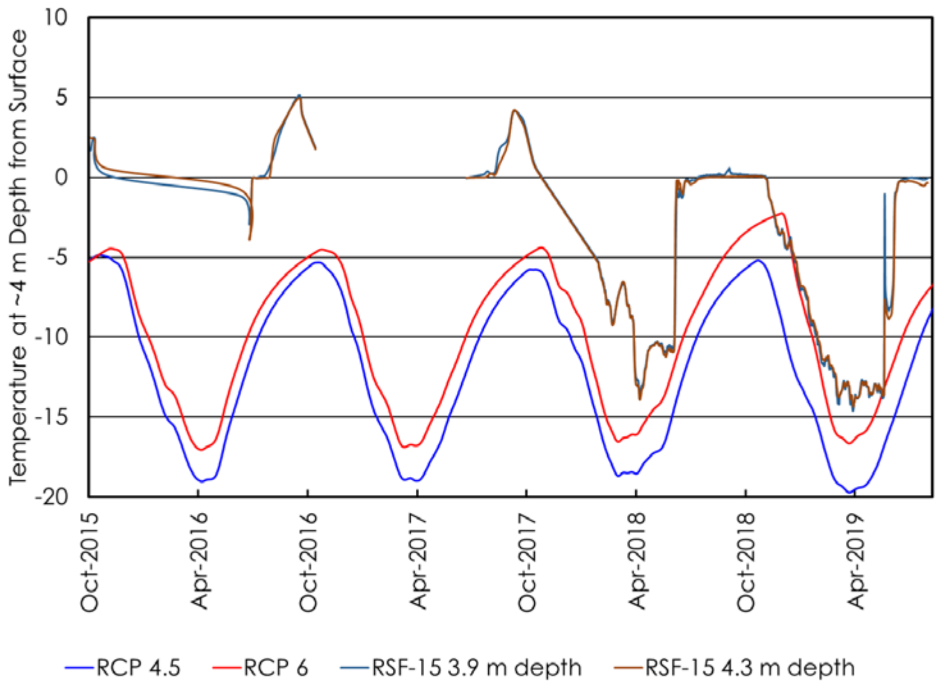

Figure 38: North slope simulated temperature at 4 m depth compared to RSF-15 recorded temperature at ~ 4 m depth.

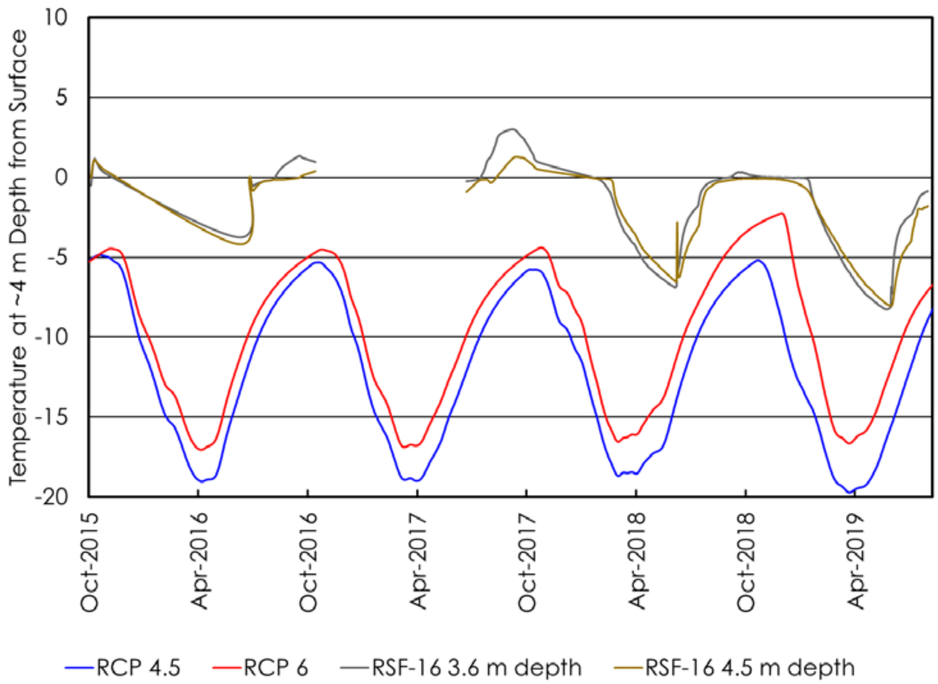

Figure 39: North slope simulated temperature at 4 m depth compared to RSF-16 recorded temperature at ~ 4 m depth.

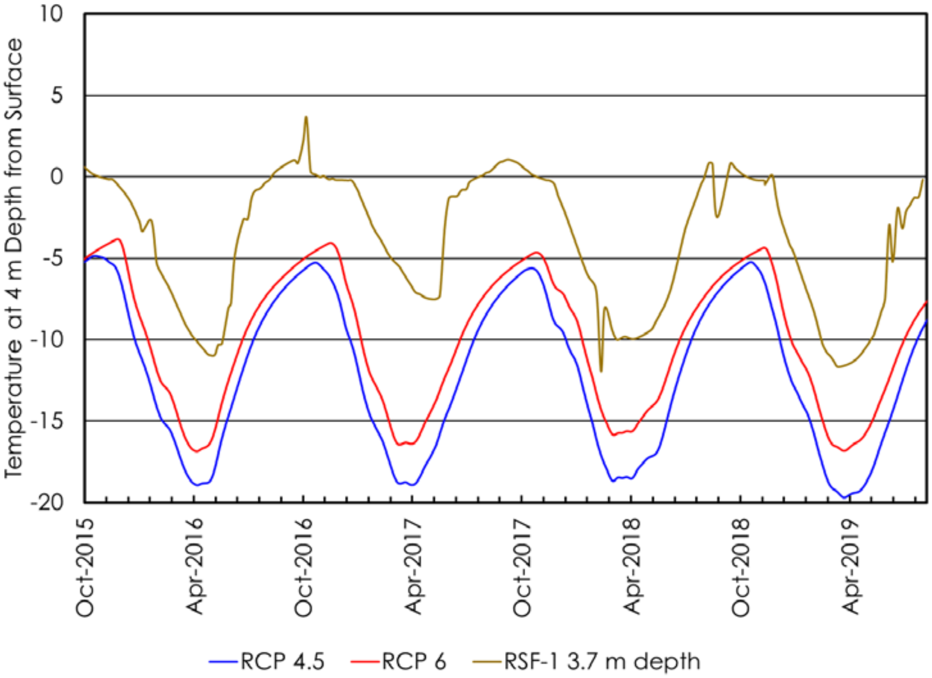

Figure 40: South slope simulated temperature at 4 m depth compared to RSF-1 recorded temperature at ~ 4 m depth.

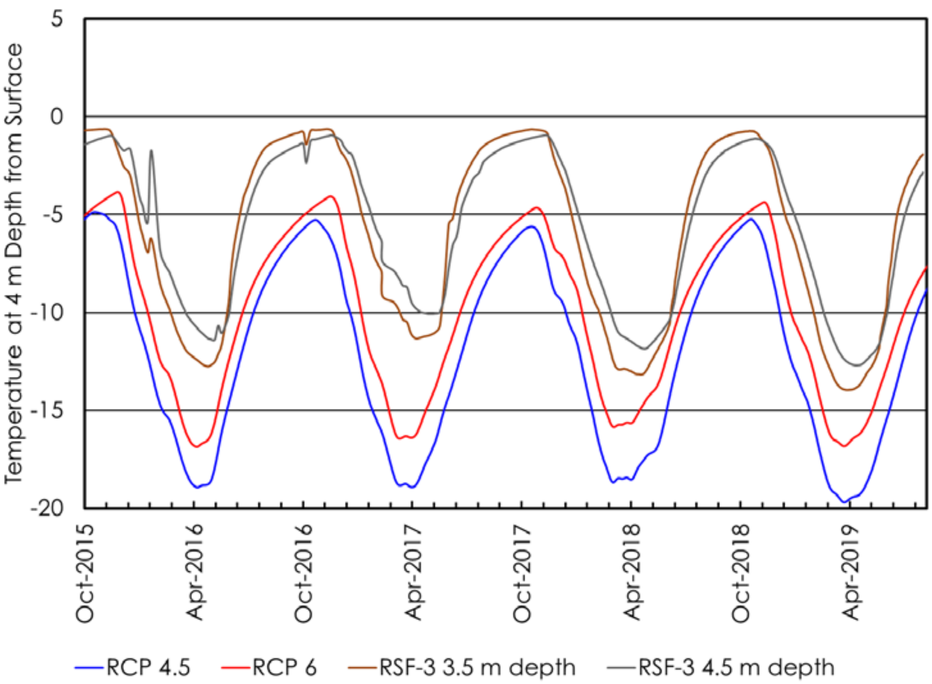

Figure 41: South slope simulated temperature at 4 m depth compared to RSF-3 recorded temperature at ~ 4 m depth.

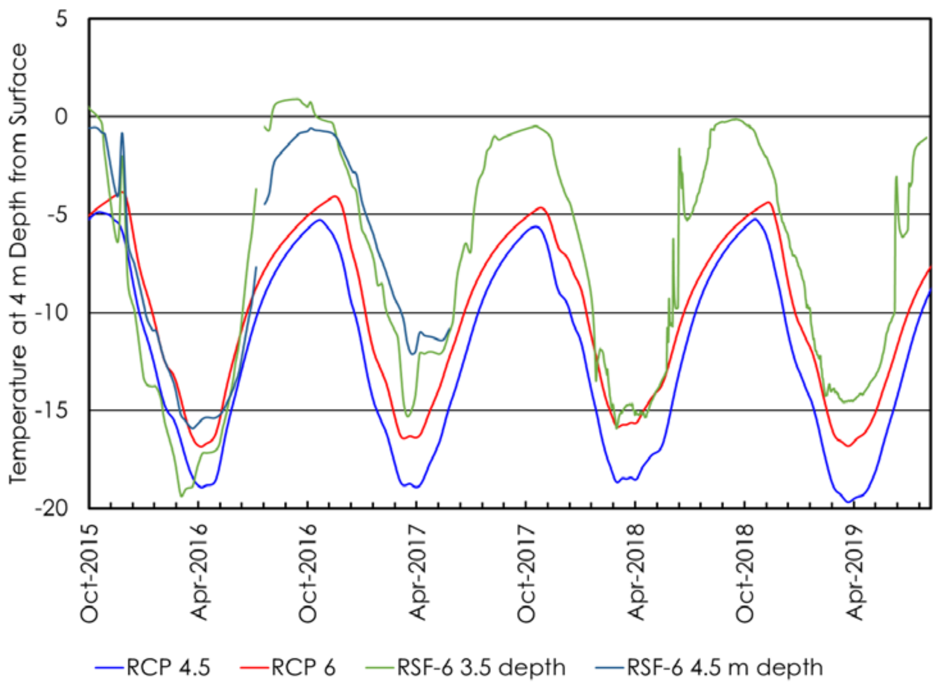

Figure 42: South slope simulated temperature at 4 m depth compared to RSF-6 recorded temperature at ~ 4 m depth.

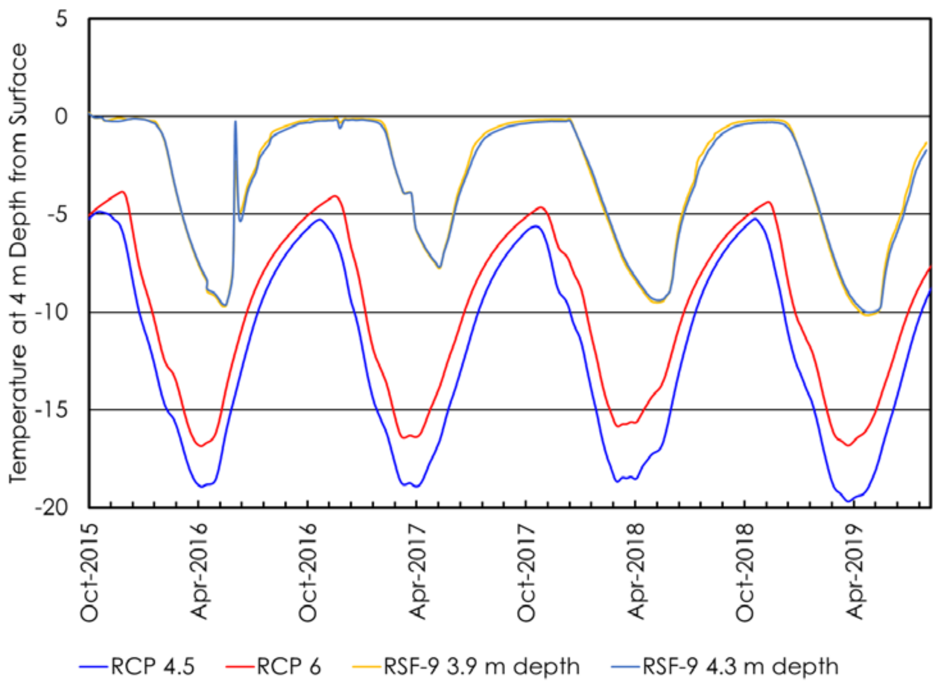

Figure 43: South slope simulated temperature at 4 m depth compared to RSF-9 recorded temperature at ~ 4 m depth.

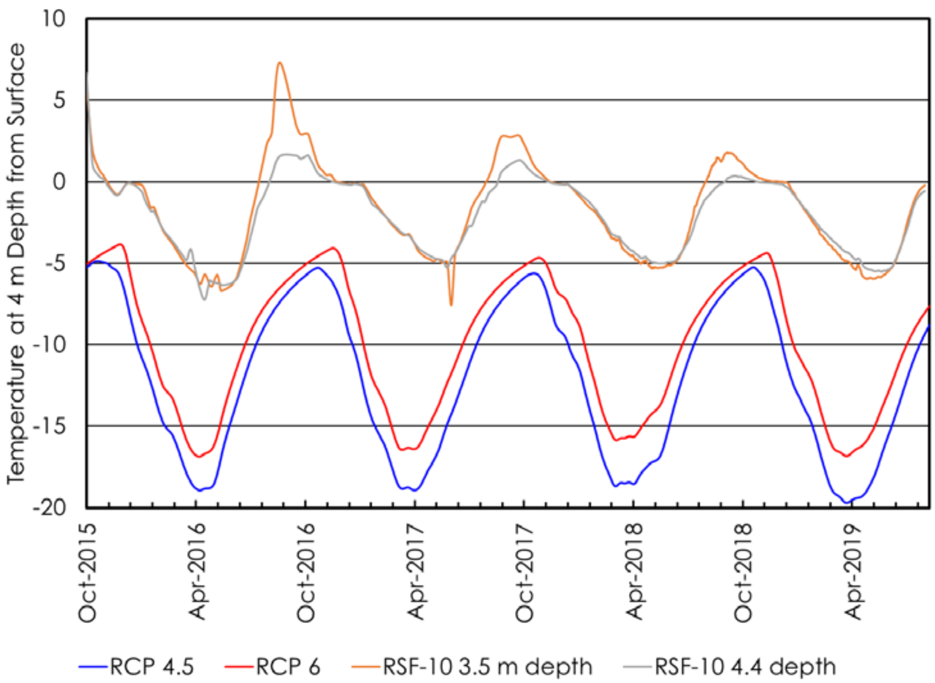

Figure 44: South slope simulated temperature at 4 m depth compared to RSF-10 recorded temperature at ~ 4 m depth.

Appendix D
2016 Portage WRSF Thermal Modelling

O'Kane Consultants
Integrated Mine Waste Management and Closure Services
Specialists in Geochemistry and Unsaturated Zone Hydrology

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Our ref: 948-4
September 28, 2016

Rebecca Cousineau
Geotechnical Supervisor
Agnico Eagle Mines
Agnico Eagle Mines Limited
MeadowBank Division
Baker Lake, Nunavut, Canada
X0C 0A0

Re: Summary of Thermal Modelling of Portage RSF at Meadowbank Mine

Agnico Eagle Mines (AEM) retained O'Kane Consultants Ltd. (OKC) to evaluate the expected thermal behaviour of the Portage Rock Storage Facility (RSF) at Meadowbank Mine site, considering climate change over the next 150 years. Currently, the Portage RSF has a 4 m non-potentially acid generating (NPAG) cover system encapsulating the potentially acid generating (PAG) waste rock. The purpose of the cover system is to ensure geochemical stability of the Portage RSF by insulating the PAG waste rock from direct interaction with atmospheric forces by keeping the waste rock frozen. OKC developed and employed a specific numerical modelling approach to assess the effectiveness of the Portage RSF cover system at maintaining the PAG waste rock below the freezing point under future climate conditions.

The main objective of the numerical modelling exercise is to estimate the depth of the active layer (layer of materials undergoing freeze-thaw cycles from atmospheric forcing) within the Portage RSF and to confirm that the PAG waste rock will remain frozen, and oxidation rates greatly decreased, for the next 150 years under agreed upon climate change scenarios. One-dimensional (1D) and two-dimensional (2D) soil-plant-atmosphere (SPA), thermal and air flow modelling were completed, primarily to determine internal temperatures. The following letter report starts with a summary of the conceptual model and key model results from the modelling programs followed by additional details of the SPA, airflow, and thermal/seepage modelling completed for this project.

Conceptual Model

The conceptual model of the Portage RSF was previously described by OKC (OKC, 2016[1]). Since its initial development, the conceptual model has been updated as part of the work conducted for this project. The following assumptions form the conceptual model for the thermal behaviour of the Portage RSF under current and future climate conditions. These assumptions are based on available documentation and monitoring data gathered since construction of the RSF.

- The RSF still has not completely frozen;

[1] 2016. O'Kane Consultants. Memo to Rebecca Cousineau Re: Agnico Eagle Mines Ltd. Meadowbank Mine Site - Conceptual Model for Thermal Modelling of the Portage RSF. June 2, 2016.

- The top 4 to 5 m of the RSF still thaw during the summer, but it is anticipated that this active layer (i.e. the depth at the surface of the RSF that does not form permafrost (stay below 0°C)) will decrease in thickness once permafrost has fully formed within the RSF;
- Based on initial wind and solar radiation analyses, it is anticipated that the northwest corner and north slope of the RSF will have the coolest conditions and thinnest active zone. The next-coolest regions of the RSF will be the western slope, followed by the eastern slope. The south slope is anticipated to be the area with the highest potential for a thicker active layer.
- Additional rainfall and runoff predicted from climate change models, along with the anticipated rise in average annual temperature, are likely to increase the potential for a thicker active layer.
- Thermal modelling of the RSF will assist in developing the expected seasonal active layer thickness under climate change conditions, as well as to determine if permafrost conditions within the RSF are sustainable under climate change conditions.

It had previously been stated that temperatures above freezing at depths of 5-15 m were measured along the southern slope. This was thought to be due to its direct sun exposure and increased net radiation. However, upon closer examination of the data, it was found that several of the thermistor string have not yet equilibrated to the surrounding temperatures of the RSF. This is thought to be due to the disturbance caused during installation. In the case of thermistors installed in November 2013 (RSF 3-6), the disturbance within the waste rock material generally lasted until approximately late May 2014. Several thermistor beads located within the bedrock have not yet reached equilibrium with the surrounding bedrock. Once the erroneous temperature data within the waste rock was removed from the data record, it was found that the previously observed active layer at RSF-4 was an artefact of thermistor installation. Due to the long lag time to equilibration, the remaining thermistors are only just beginning to provide reliable data and were therefore excluded from informing the conceptual model and numerical modelling. Table 1 provides updated active zone depths for the equilibrated thermistors since equilibration (approximately May, 2014).

Table 1: Summary of Equilibrated Thermistor Data

Thermistor Label	Apparent Active Zone Depth (m)
RSF-3	2.5
RSF-4	3.5
RSF-5	4.5
RSF-6	3.5

Numerical Modelling Program

Three components of the GeoStudio suite of programs were used in combination for this project: SEEP/W; TEMP/W; and AIR/W. GeoStudio Version 9 was used to conduct the modelling. A description of this modelling software can be found in OKC, 2016, appended to this report.

Model Calibration

A 1D model simulated with a combination of SEEP/W, TEMP/W, and AIR/W was calibrated to RSF-3, using a modelled cover system of 0.3 m of crushed NPAG waste, overlying the remaining 3.7 m NPAG material overlying PAG waste rock. This configuration was used to mimic the impacts of material placement (dozer and truck traffic) on near surface cover system material. This trafficked layer is found on the plateau area, bench crests, and inter-bench slopes. The cover system on the inter-bench slopes will likely have slightly different properties as it is not trafficked and would likely require the 0,3 m crushed NPAG layer used in modelling. As the thermistor strings used in calibration are exclusively located on the plateau or bench crests, the 0.3 m crushed NPAG layer was used in all modelling. A similar approach was used in previous cover system modelling (OKC, 2014[2]) at Meadowbank. GeoStudio Version 9 required the following material property inputs for each material:

- thermal conductivity vs. volumetric water content;
- volumetric specific heat capacity function;
- unfrozen volumetric water content vs. temperature;
- hydraulic conductivity function'
- water retention curve; and
- air conductivity function.

RSF-3 was chosen for material calibration. The location of the thermistors in shown in Figure 1. The 1D calibration model ran between January 1, 2013 and December 31, 2015 using site data as external boundary conditions. Once calibrated, the modelled temperature profile was shown to be an excellent match to the measured temperature data over the entire profile of RSF-3 between May 2014 and December 2015. Figure 2 compared the modelled and measured temperature data.

[2] 2014. O'Kane Consultants. Agnico Eagle Mines – Meadowbank Project – Summary of Modelling of Potential Cover Systems for the North Cell Tailings Storage Facility. December 20, 2014..

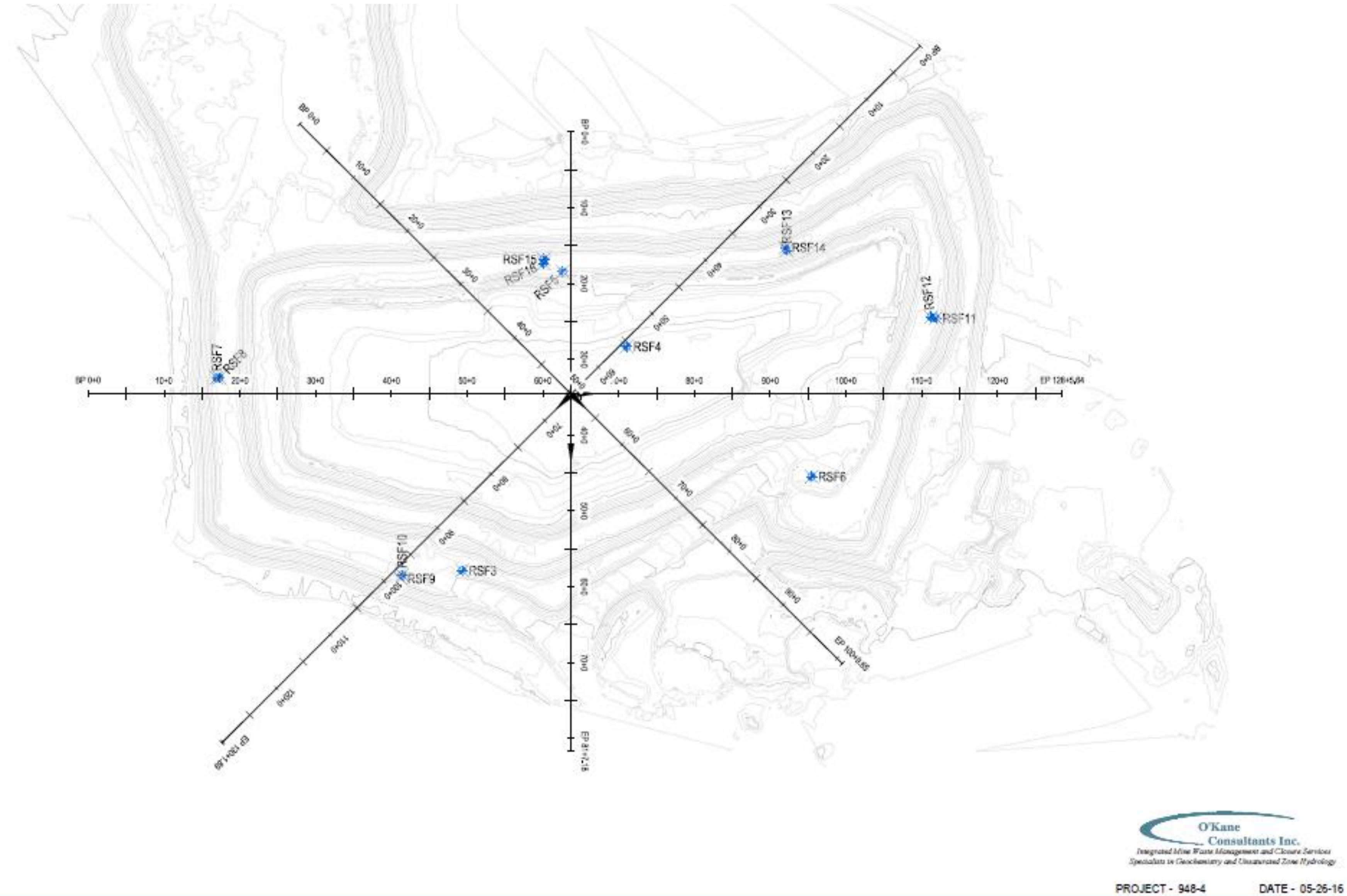

Figure 1: Plan view of thermistor strings at Portage RSF

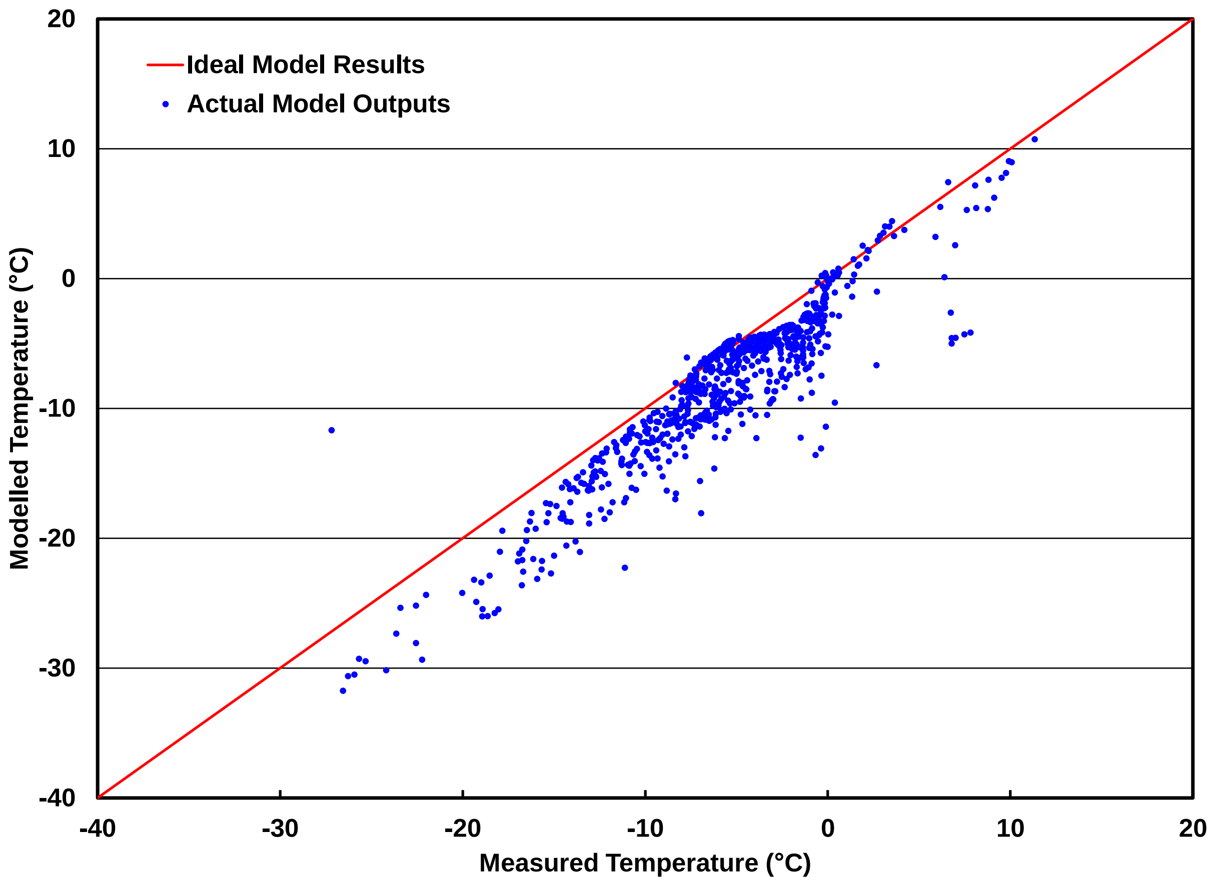

Figure 2: Comparison of measured and modelled temperature in 1D RSF-3 model.

Following 1D calibration, two 2D cross sections were selected for calibration. Based on the conceptual model, it was expected that the south face would be most susceptible to thawing, while the northwest corner was expected to be the least susceptible. As a result, a North-South cross section and a North West – South East cross section were chosen for calibration. The selected cross sections are shown in Figures 3 and 4 with the locations of the thermistors shown in each. Several of the thermistors shown in Figure 3 and 4 do not fall directly on the cross sections. The actual elevation of the thermistor beads was adjusted where necessary in order for the depth of the actual thermistor beads to be accurately represented in the model. As mentioned previously, following data validation, only thermistor strings RSF-3, RSF-4, RSF-5 and RSF-6 were used in calibration although all thermistor locations are shown in the cross sections.

The material properties developed in the 1D model were used as initial material properties in the 2D modelling. The material properties were once again adjusted in order to provide the best match between model-predicted temperatures and collected thermistor data. The same temperature record (January 1, 2013 to December 31, 2015) was used for calibration of the 2D models. The results of 2D comparison are shown in Figure 5 and 6.

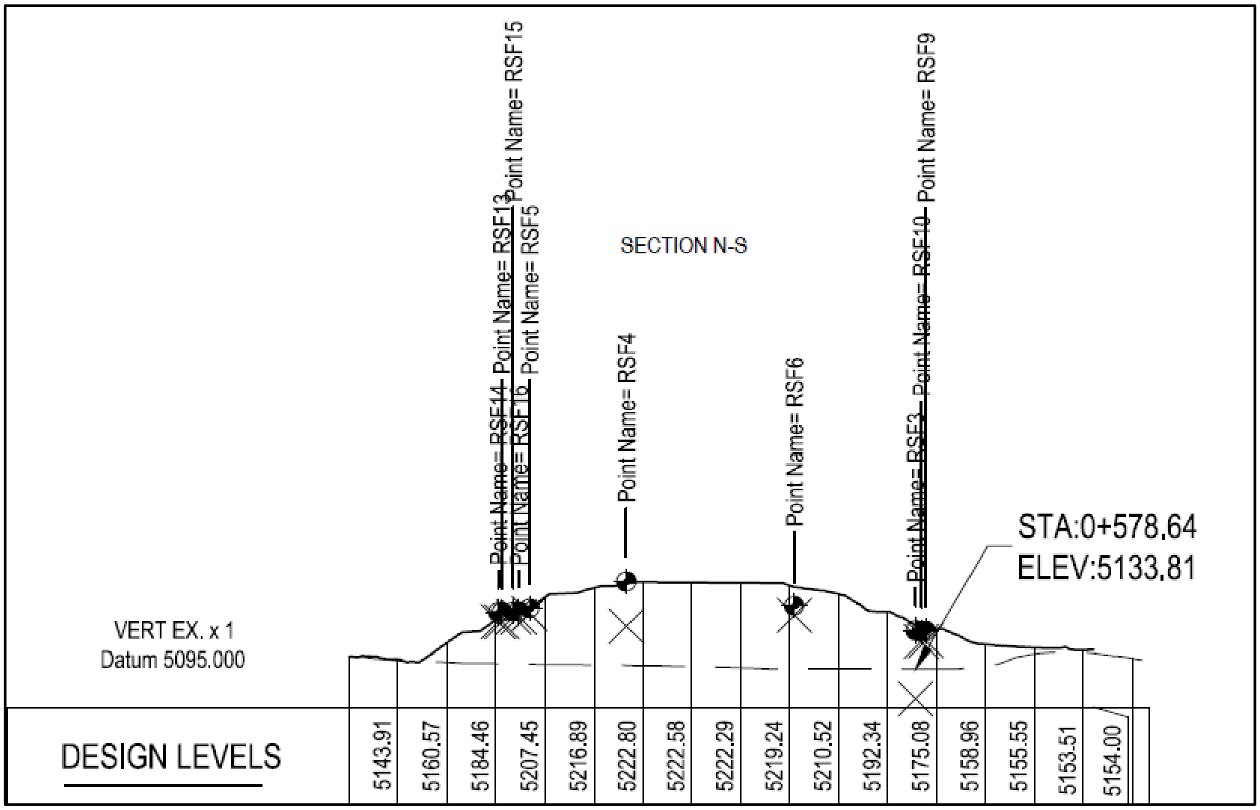

Figure 3: North-South cross section used in 2D modelling.

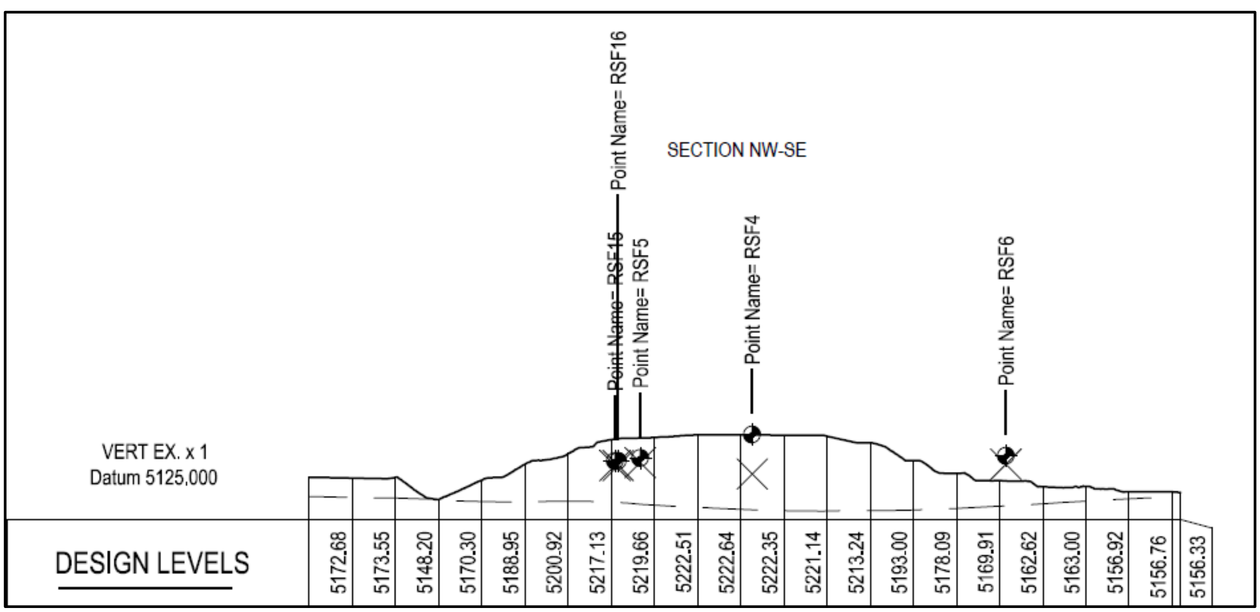

Figure 4: North West – South East cross section used in 2D modelling.

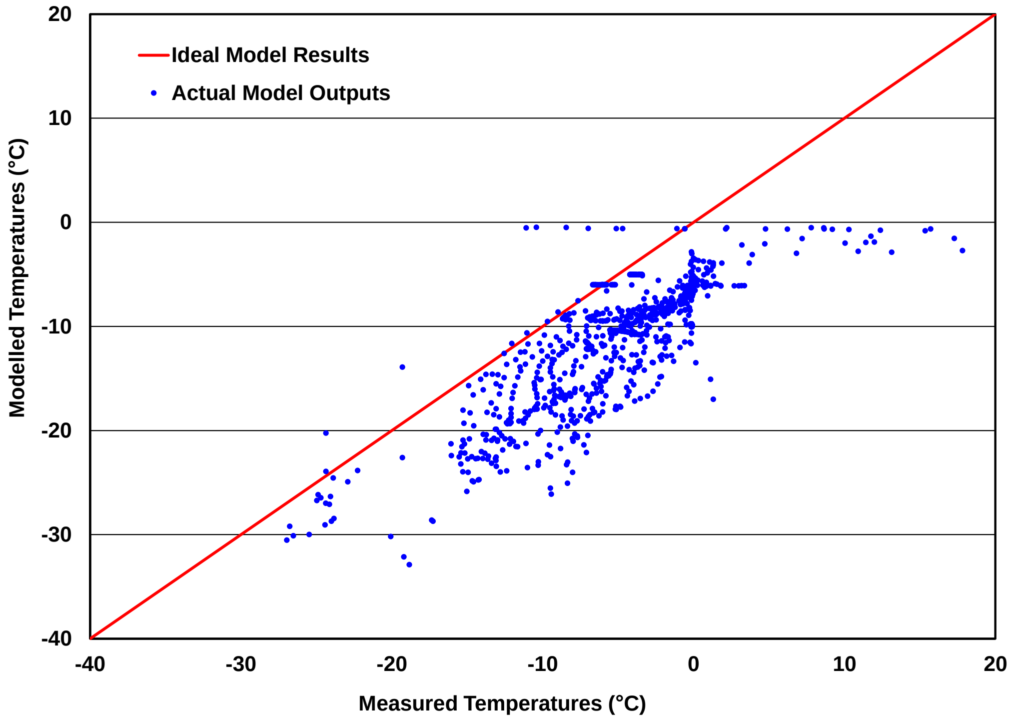

Figure 5: Comparison of measured and modelled temperature in 2D North-South cross section.

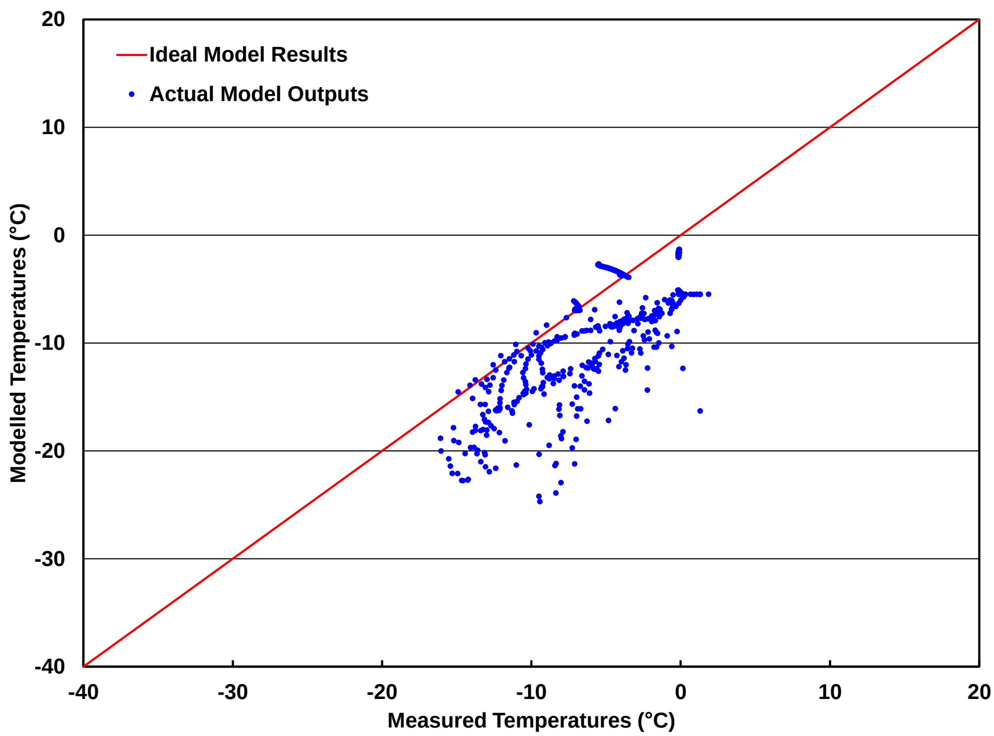

Figure 6: Comparison of measured and modelled temperature in 2D North West – South East cross section.

It is the experience of OKC that attempting to calibrate temporal and spatially variable processes such as heat flow within a RSF using point measurements can be extremely difficult. Calibration to spatially and temporally variable data can lead to unwarranted model complexity. For example, as the mean and variance of each individual data point (thermistor) changes over time so should the material within its general vicinity. However, changing material properties over time and both with depth and laterally would increase the complexity of a model without increasing the certainty in results. As a result, the 1D calibration was revisited to refine the model outputs in the vicinity of the cover system/waste rock interface as this area is of particular interest. The 1D model outputs were adjusted at approximately 4 m depth to provide the best match to maximum temperatures measured by the thermistors and account for the systematic error observed in model outputs. For example, the maximum temperature recorded (following QAQC of data) at RSF3 at 3.5 m depth was -0.1°C (Figure 7). Following calibration, the maximum temperature output by the model over the same time period was -1.3°C. An offset of 1.2°C was therefore added to model output values to correct for this bias. The same process found that at 4.5 m depth an offset of 1.8°C was required. The results of this model adjustment are shown in Figures 7 and 8. Based on this 4 m depth adjustment, a 1.5°C offset was included in all subsequent model outputs at 3.5 m to 4.5 m. This adjustment provided the best match in amplitude of temperature change, timing of temperature change and maximum modelled temperature.

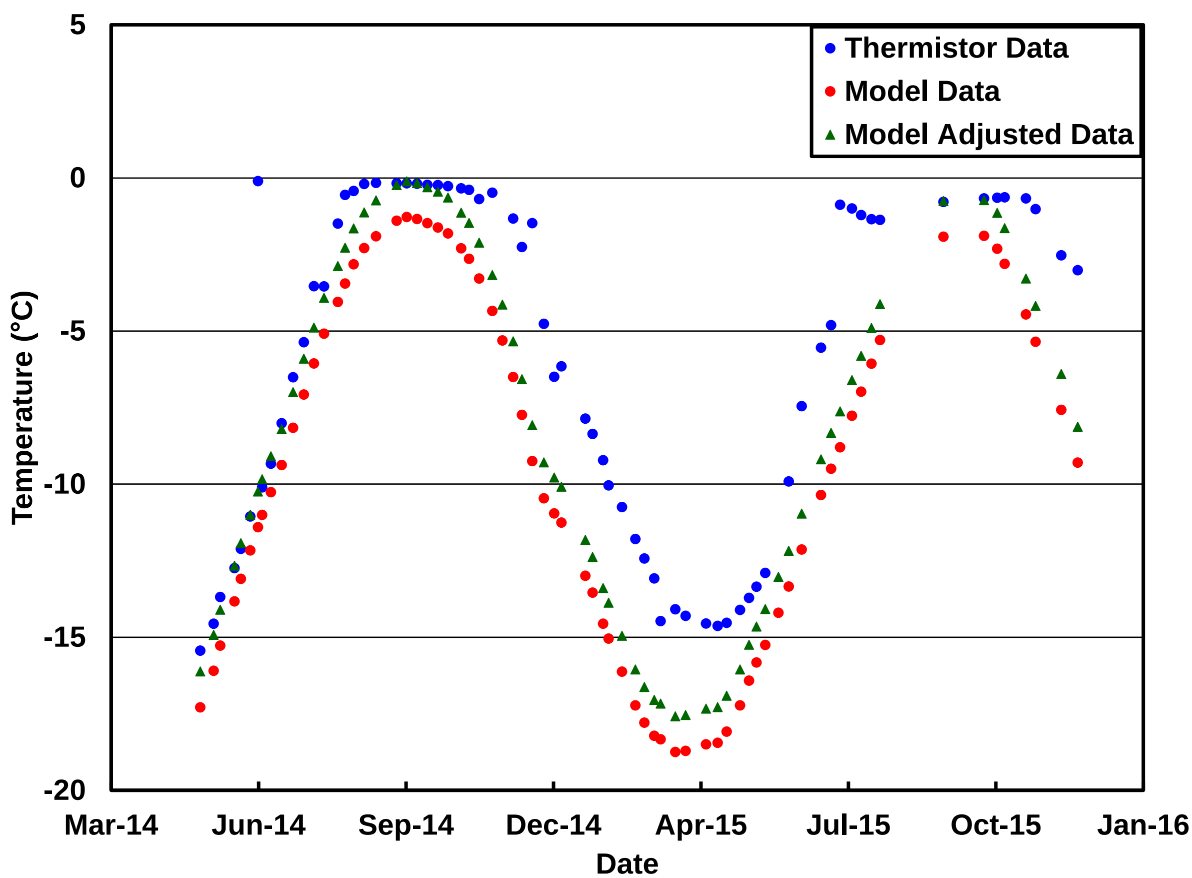

Figure 7: Adjusted model data for the 1D calibration model of RSF 3 at 3.5 m depth.

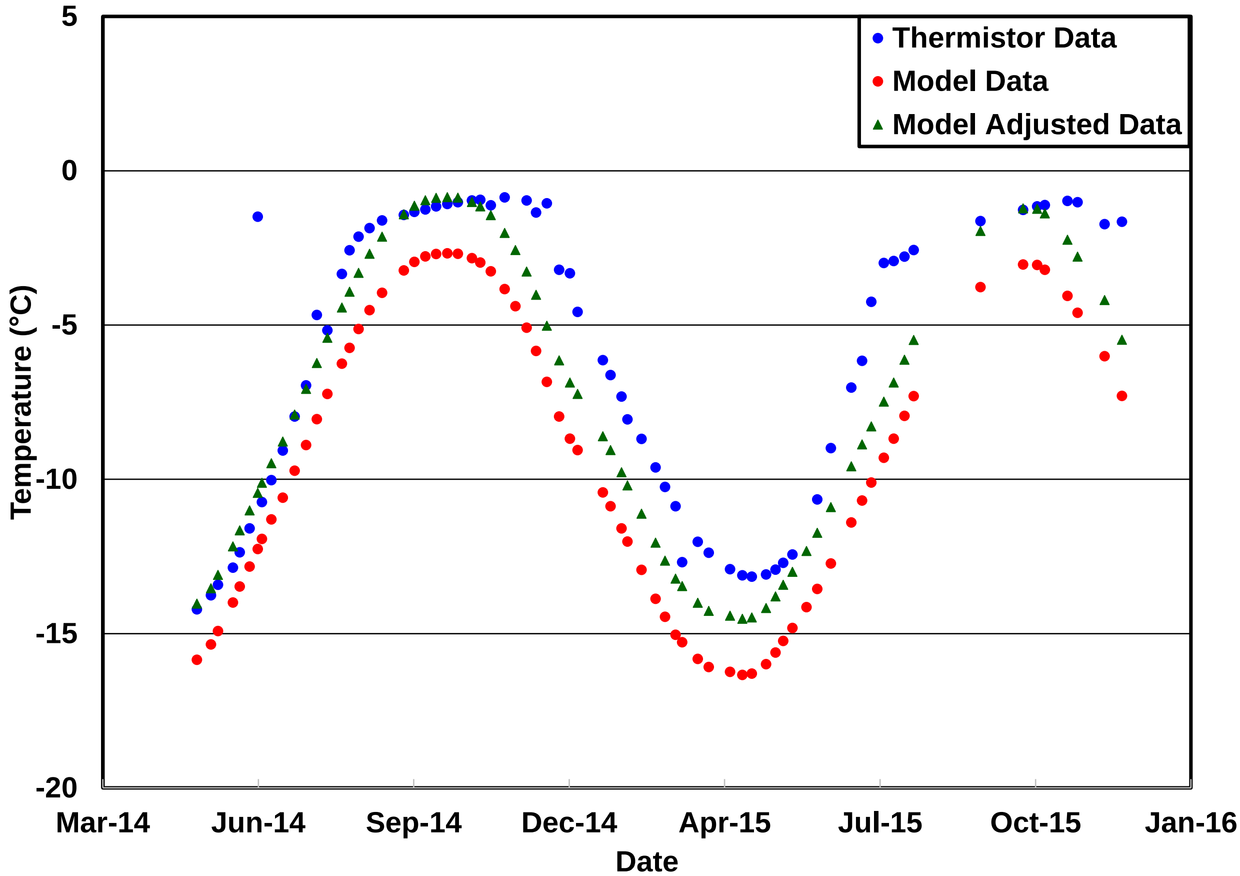

Figure 8: Adjusted model data for the 1D calibration model of RSF 3 at 4.5 m depth.

During 2D calibration, convective airflow was not observed. Lateral airflow in the model was constrained to the 0.3 m crushed soapstone layer. This is likely as a result of the lower air permeability of the calibrated NPAG/PAG waste rock. Therefore, The RSF can be reasonably approximated using a 1D analysis. In addition, the mesh size of the 2D models was also constrained by computability. Achieving reasonable mesh size in the 2D models results in models that were too large for the computational ability of GeoStudio. Smaller meshing provides more detailed results as the model interpolates values over smaller areas. Using 1D models allowed for a mesh size more than an order of magnitude smaller than the 2D models, providing increased reliability in results. As a result of the required level of detail computational requirements, further modelling of different slope aspects was completed using 1D sections.

Key Input Development

The 2D, 150 year, SEEP/W, TEMP/W, AIR/W, climate change model requires the following daily inputs:

- Air temperature;
- barometric pressure;
- wind speed;
- precipitation;

- relative humidity; and
- net radiation.

It is also optional to manually enter snow depth, although the model is capable of estimating this value based on temperature and precipitation inputs.

Monthly results from two general circulation models (GCM) were used to provide estimates of climate conditions for Meadowbank over the next 150 years. The CanESM2/CGCM4 model developed by the Canadian Centre for Climate Modelling and Analysis (CCCma) was used to develop inputs for the Representative Concentration Pathways (RCP) 4.5 climate database (CCCma, 2014)[3]. A second GCM needed to be selected as the CCCma has not publicly released its results for the RCP6 scenario. Hence, the CESM1-CAM5 model, developed by the National Center for Atmospheric Research (NCAR), was selected to provide monthly estimates of climate conditions for the RCP6 climate database (NCAR, 2014)[4]. Scaling from current measurement of precipitation and air temperature for the 150 year database were developed according to the GCM, while relative humidity data was not scaled.

It was identified that both slope aspect and angle were likely to cause a change in the thermal and water balance of the Portage RSF relative to a plateau area. In order to account for this, separate climate inputs for daily wind speed and daily net radiation were developed for each slope and aspect modelled. Daily wind speed was adjusted according to the methodology outlined in OKC, 2016[5].

Net radiation has been directly measured at Meadowbank since January, 2013. This data was scaled in order to account for changes in daily net radiation due to slope aspect and angle. Maximum scaling was assumed to be within ±90% of the measured net radiation data. Straker (2015)[6] proposed a simple methodology for determining the effect of slope aspect and angle at a given latitude and surface material (based on particle size distribution) on soil moisture regime in terms of available water storage capacity (AWSC). The AWSC for each slope angle and aspect was estimated using this proposed methodology. The increase or decrease in AWSC is based on changes in evaporative demand which were assumed to be exclusively caused by changes in net radiation. The original site net radiation data was then scaled in order to account for the change in estimated AWSC. Average measured daily net radiation at the site is approximately 1.7 MJ/m^2/day. Table 2 shows the results of this estimation.

[3] CCCma 2014. CanESM2 RCP4.5 Project. Canadian Centre for Climate Modelling and Analysis. Environment Canada. http://www.cccma.ec.gc.ca/

[4] NCAR (National Center for Atmospheric Research), 2014. CESM1-CAM5 model – RCP6. http://ncar.ucar.edu/budget-and-planning/2014-ncar-program-operating-plan/5141-community-earth-system-model

[5] 2016. O'Kane Consultants. Memo to Rebecca Cousineau Re: Agnico Eagle Mines Ltd. Meadowbank Mine Site - Conceptual Model for Thermal Modelling of the Portage RSF. June 2, 2016.

[6] Straker. L *et.al.* 2015. Mine reclamation and surface water balances: an ecohydrologic classification system for min-affected watersheds. Mine Closure 2015, Vancouver, Canada.

Table 2: Estimated net radiation scaling factors.

Slope Aspect	Slope Angle (deg)	Slope Aspect Adjustment (mm/cm)	Slope Angle Adjustment (mm/cm)	Adjusted AWSC (mm/cm)	Net Radiation Scaling Factor	Average Daily Net Radiation (MJ/ m^2/day)
Flat	0	0	0	0.35	0%	1.7
N	35	+0.23	+0.23	0.82	-80%	0.3
S	35	-0.23	-0.16	-0.04	+90%	3.2
NW	35	+0.12	+0.23	0.7	-45%	0.9
SE	35	-0.12	-0.15	0.08	+55%	2.6

Key Results

The North-South Portage RSF cross section (Figure 3) was modelled for the climate change thermal modelling using three separate 1D models. Each of these models included a 0.3 m crushed NPAG layer as discussed in "Model Calibration". It is important to note that simplifying assumption may not represent all areas of the slopes adequately, and that future modelling should examine both the effects of the trafficked plateau crests and non-trafficked sloped areas. Table 3 shows the maximum temperature reached at a depth of 4 m for each climate change scenario (including 1.5°C adjustment). The percent of time that material at 4 m depth is predicted to thaw, and the maximum consecutive days that the cover system / waste rock interface at 4 m depth will not be frozen are also provided in Table 3. Lastly, the number of times that the cover system thaws to a depth of 4 m over the 150 years modelled is provided. As described in *Model Calibration* an offset of 1.5 °C was noted between modelled and measured temperatures during calibration. Graphs of temperature at 4 m depth for all scenarios shown in Table 3 can be found in Appendix C.

Table 3: Temperature results at 4 m depth for modelled 150 year climate change scenarios.

Climate Scenario	Maximum Model Predicted Temperature (°C)	Percent Time Temperature > 0°C	Maximum Consecutive Days > 0°C (Days)	Frequency > 0°C
South Face RCP 4.5	-0.1	0%	0	0
North Face RCP 4.5	-1.1	0%	0	0
Plateau RCP 4.5	-0.2	0%	0	0
South Face RCP 6	0.1	<1%	99	1
North Face RCP 6	0.2	1%	173	2
Plateau RCP 6	0.5	2%	664	2

Based on the results it was found that the plateau under RCP 6 climate change conditions is most sensitive to climate warming. With the exception of the Plateau under RCP 6 conditions, the entire cover system is expected to re-freeze over winter every year. However, the modelling results showed 664 consecutive thawed days, including an entire winter season at the Plateau in RCP 6. The entire depth of the North Face and Plateau cover systems are expected to thaw twice over 150 years (as shown in Table 3). The maximum length of thaw is shown in Table 3, the shorter thawing events are expected to be 168 days and 266 days for the North Face and the Plateau, respectively.

Given the climate change scenarios evaluated, modelling predicts that the active layer will extend beyond the 4 m cover system currently in place for infrequent time periods under the RCP 6 climate change scenario. The maximum active layer depth over the entire period modelled was estimated from modelling and is shown in Table 4.

Table 4: Maximum depth of thaw under the RCP 6 scenario over the 150 years modelled.

Climate Scenario	Maximum Estimated Depth of Active Layer (m)
South Face RCP 4.5	< 4.0
North Face RCP 4.5	< 4.0
Plateau RCP 4.5	< 4.0
South Face RCP 6	4.3
North Face RCP 6	4.9
Plateau RCP 6	6.1

The modelling results indicate that under the more pessimistic climate change scenario (i.e. showing the greater temperature increase) RCP6, the current cover system in place will not prevent thawing of the upper portion of the PAG waste material. The active layer reaches a depth of 6.1m under the plateau area and a portion of this PAG material remains unfrozen for a period of 664 days. As the thawed conditions are limited in time, limited in area of the RSF where it occurs, and that the region is reintegrated into permafrost following the thawed period, long term impacts are likely to be limited. The time period during which the upper portion of the PAG waste material is above 0°C is limited to 2% of the 150-year timeframe modelled. It should also be noted that these thawed waste conditions do not occur under the RCP4.5 climate change conditions as modelled.

Please do not hesitate to contact me at 250-802-3999 or rshurniak@okc-sk.com should you have any questions or comments.

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Numerical Modelling Group Leader

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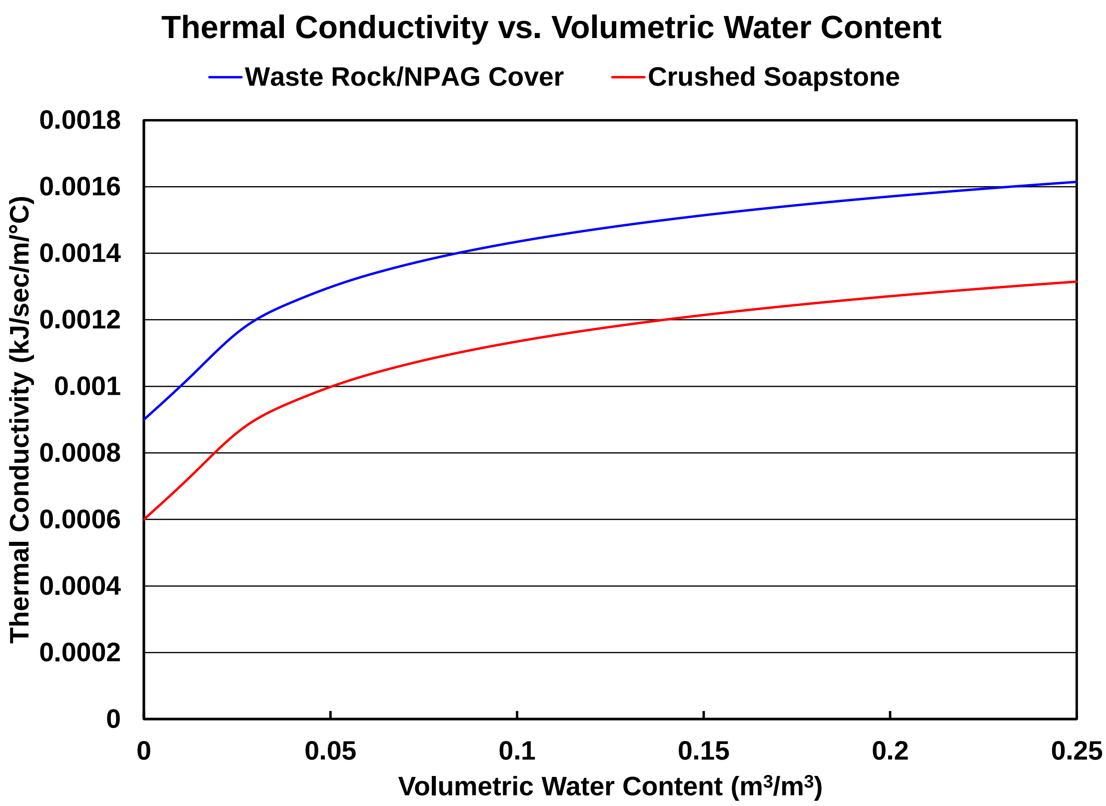
Appendix A: Memo to Rebecca Cousineau Re: Agnico Eagle Mines Ltd. Meadowbank Mine Site - Conceptual Model for Thermal Modelling of the Portage RSF. June 2, 2016

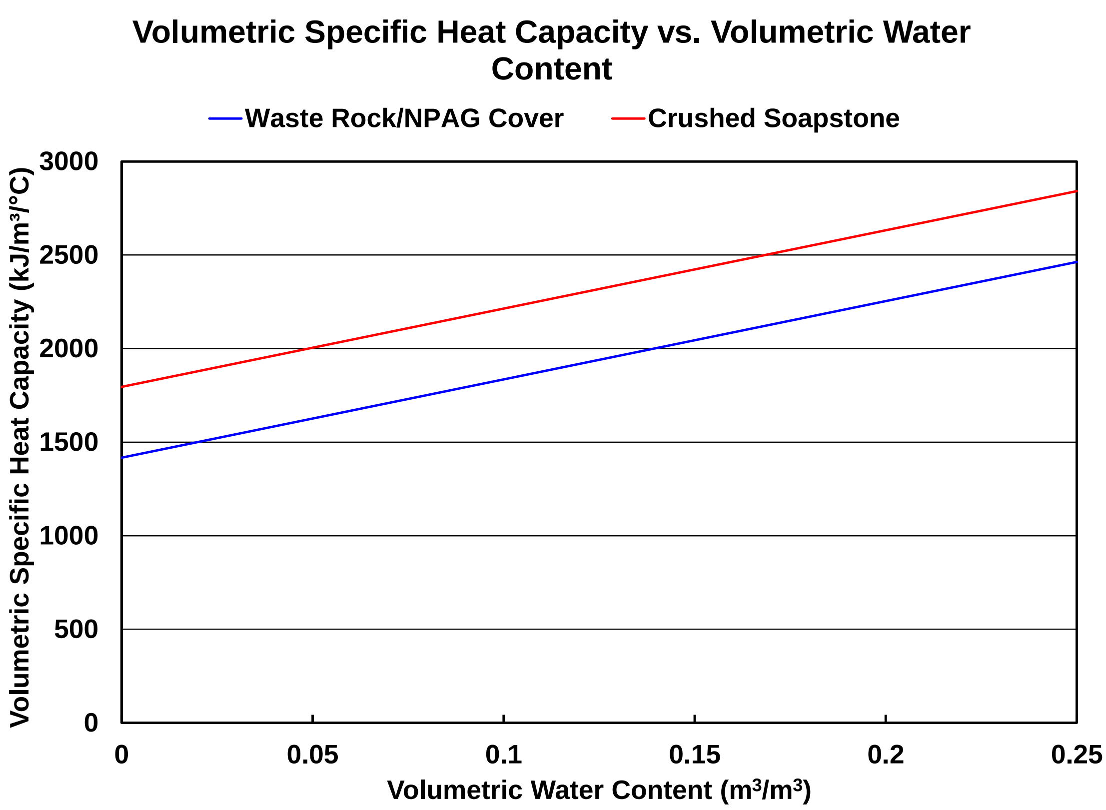
Appendix B: Calibrated Material Property Functions

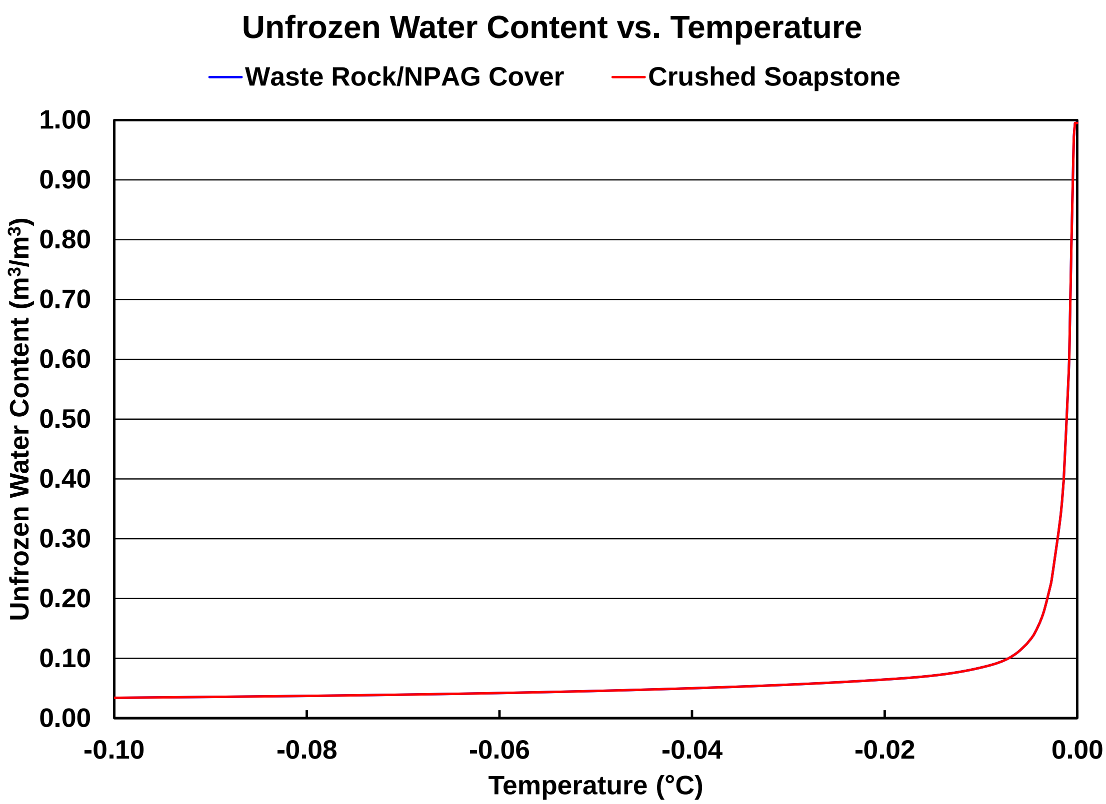
Appendix C: Key Result Graphs

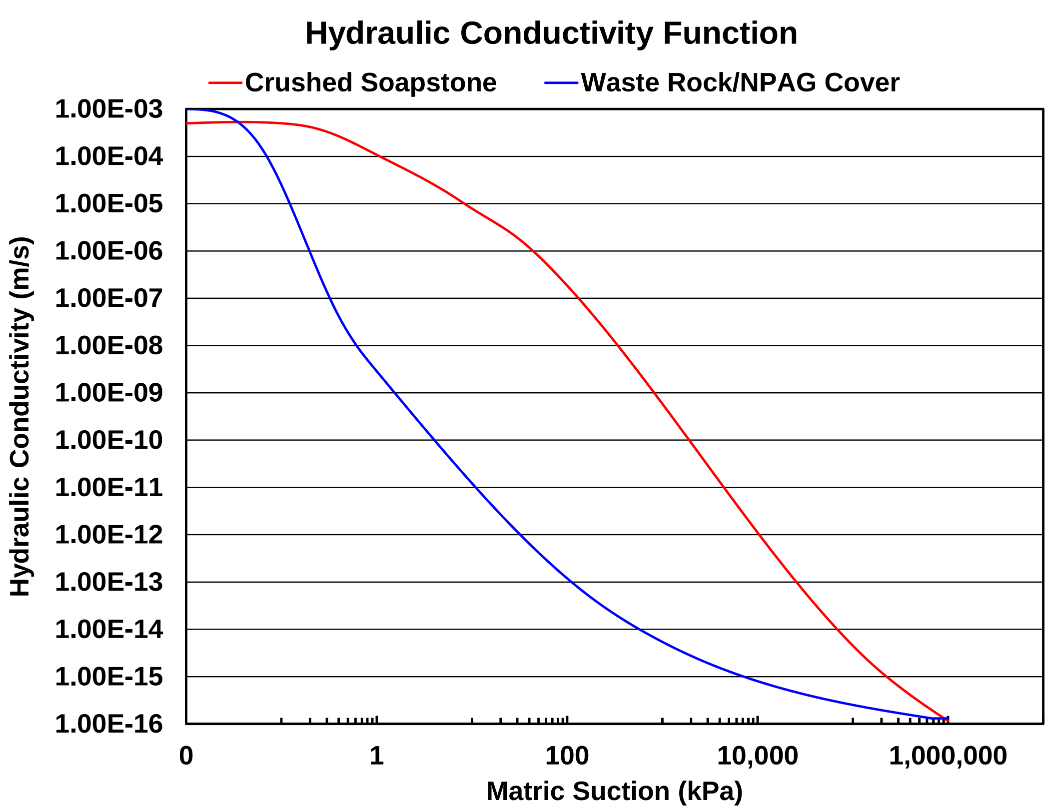
Appendix A

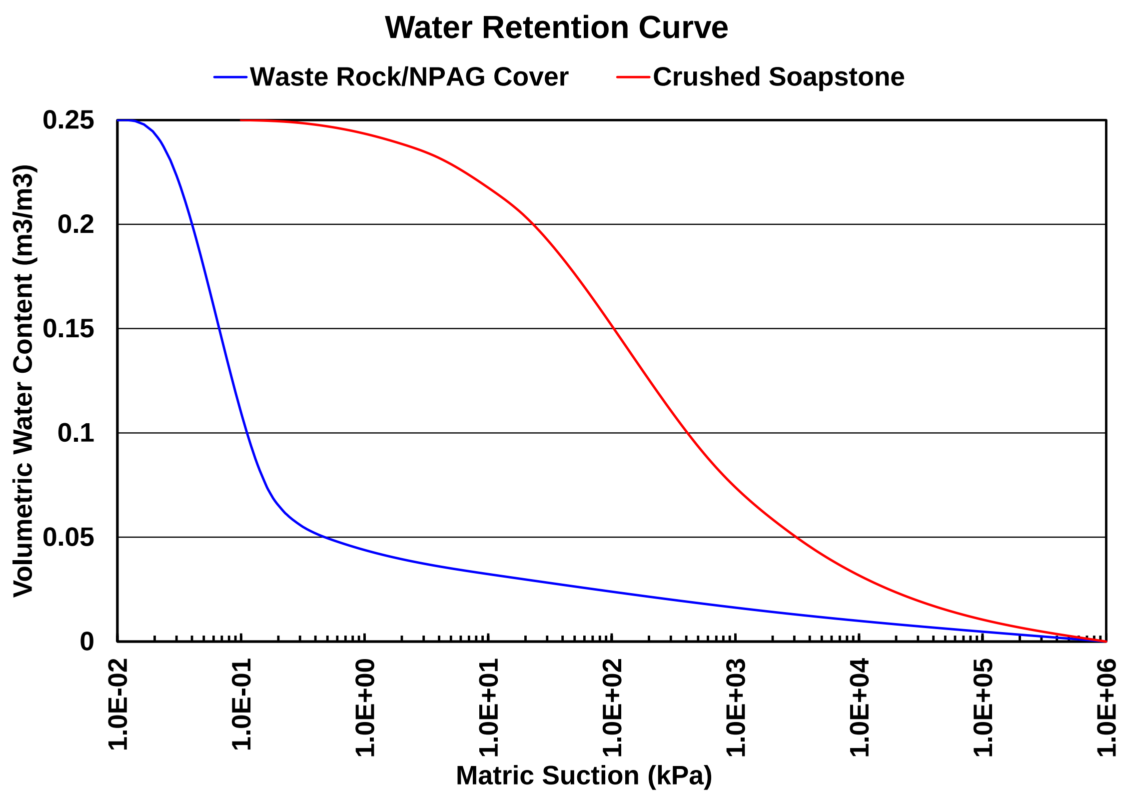
Appendix B

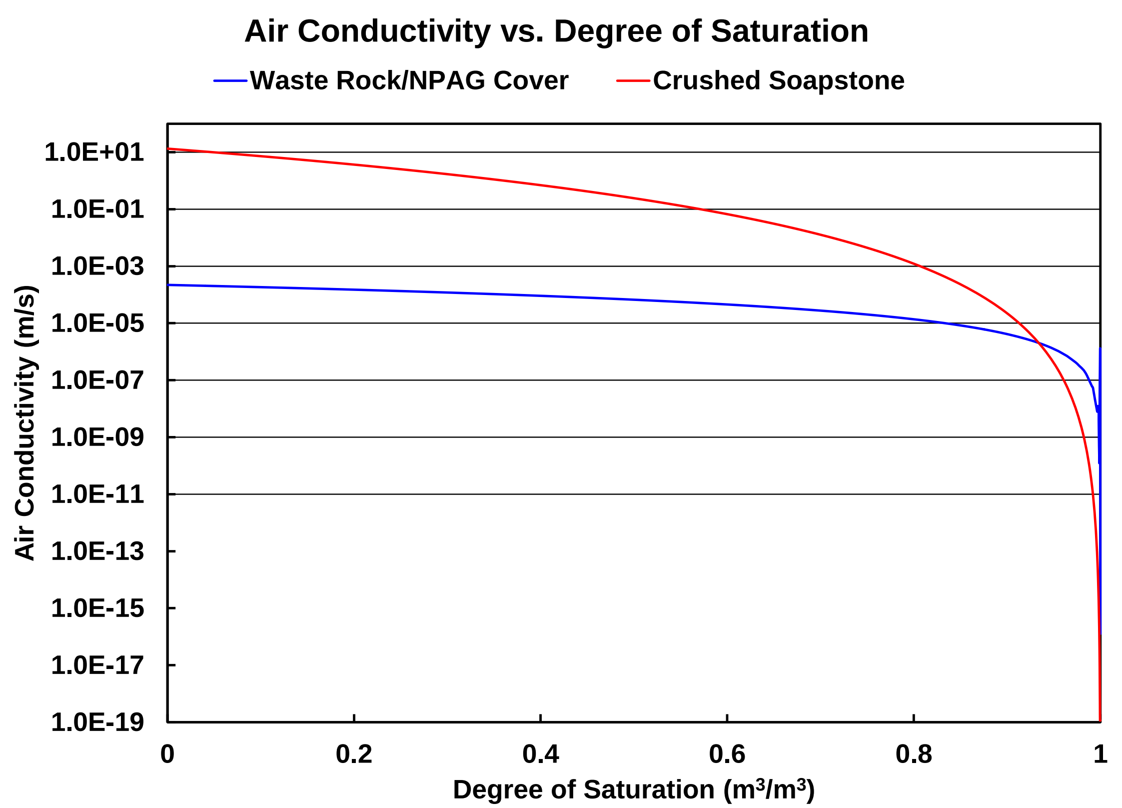

Thermal Conductivity vs. Volumetric Water Content
Waste Rock/NPAG Cover
Crushed Soapstone
Thermal Conductivity (kJ/sec/m/°C)
0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
0
0.05
0.1
0.15
0.2
0.25
Volumetric Water Content (m³/m³)


Volumetric Specific Heat Capacity vs. Volumetric Water Content
Waste Rock/NPAG Cover
Crushed Soapstone
Volumetric Specific Heat Capacity (kJ/m³/°C)
3000
2500
2000
1500
1000
500
0
0
0.05
0.1
0.15
0.2
0.25
Volumetric Water Content (m³/m³)

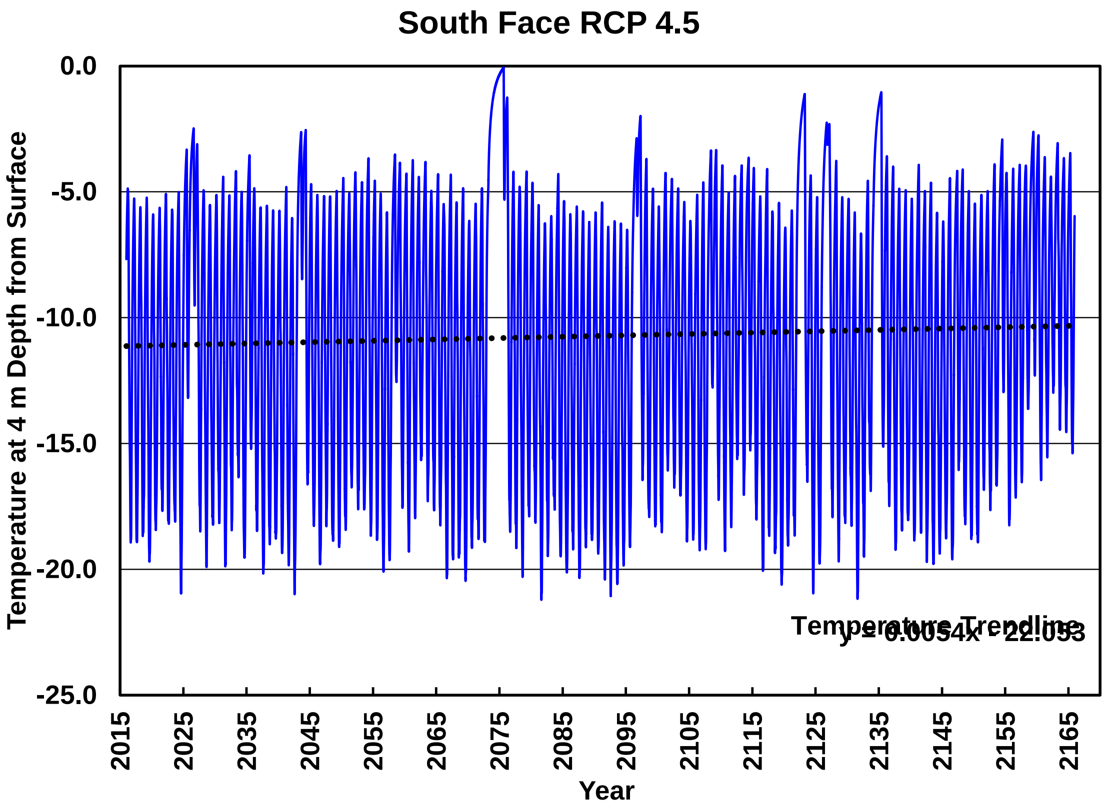

Unfrozen Water Content vs. Temperature
Waste Rock/NPAG Cover
Crushed Soapstone
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Unfrozen Water Content (m³/m³)
-0.10
-0.08
-0.06
-0.04
-0.02
0.00
Temperature (°C)

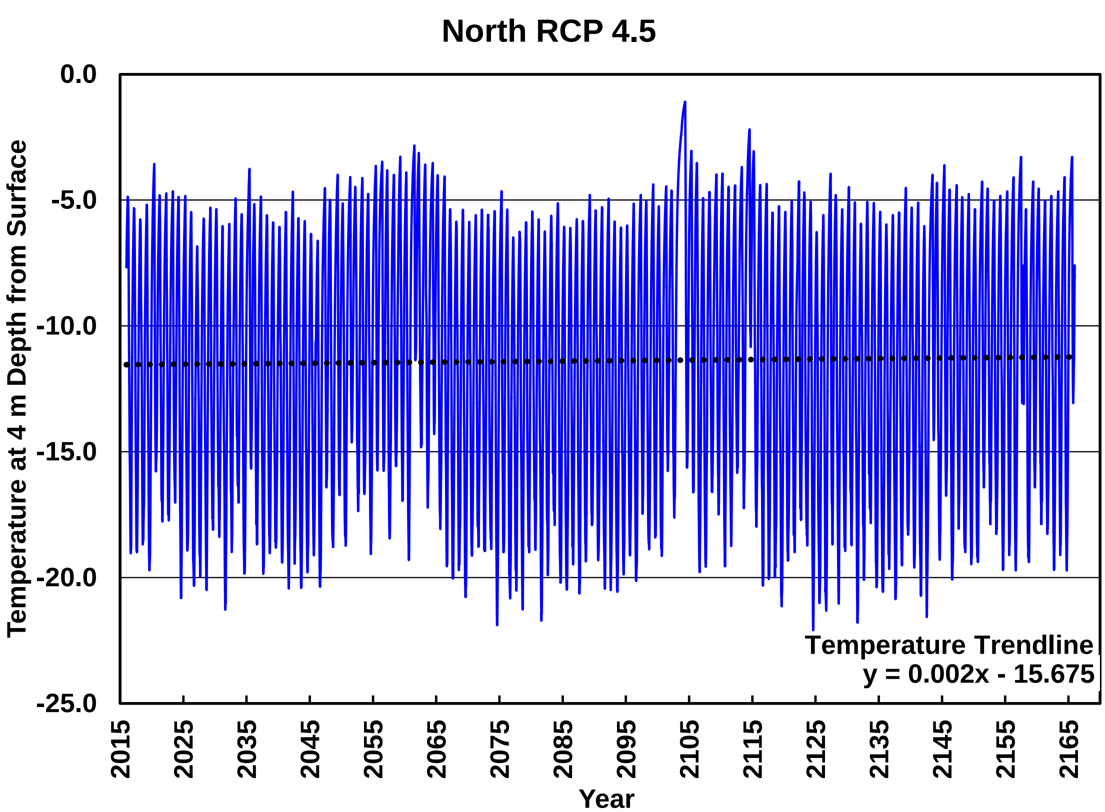

Hydraulic Conductivity Function
Crushed Soapstone
Waste Rock/NPAG Cover
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-07
1.00E-08
1.00E-09
1.00E-10
1.00E-11
1.00E-12
1.00E-13
1.00E-14
1.00E-15
1.00E-16
Hydraulic Conductivity (m/s)
0
1
100
10,000
1,000,000
Matric Suction (kPa)

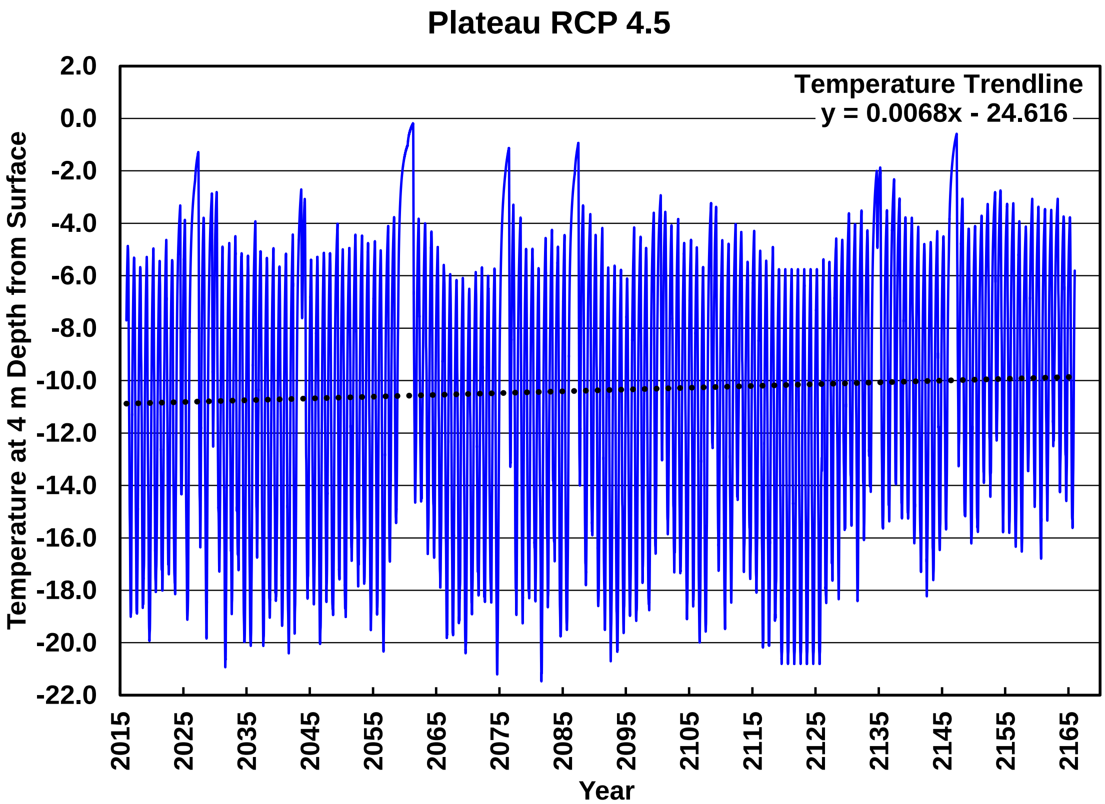

Water Retention Curve
Waste Rock/NPAG Cover
Crushed Soapstone
Volumetric Water Content (m3/m3)
0.25
0.2
0.15
0.1
0.05
0
1.0E-02
1.0E-01
1.0E+00
1.0E+01
1.0E+02
1.0E+03
1.0E+04
1.0E+05
1.0E+06
Matric Suction (kPa)

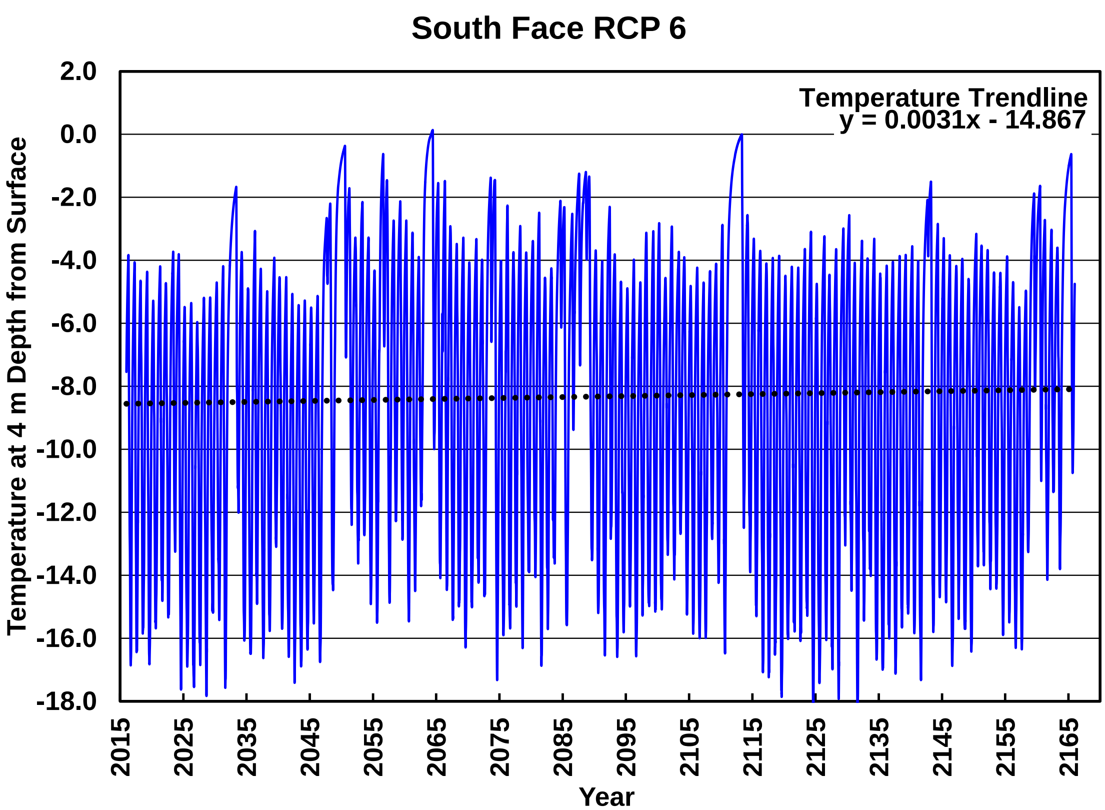

Air Conductivity vs. Degree of Saturation
Waste Rock/NPAG Cover
Crushed Soapstone
Air Conductivity (m/s)
1.0E+01
1.0E-01
1.0E-03
1.0E-05
1.0E-07
1.0E-09
1.0E-11
1.0E-13
1.0E-15
1.0E-17
1.0E-19
0
0.2
0.4
0.6
0.8
1
Degree of Saturation (m³/m³)

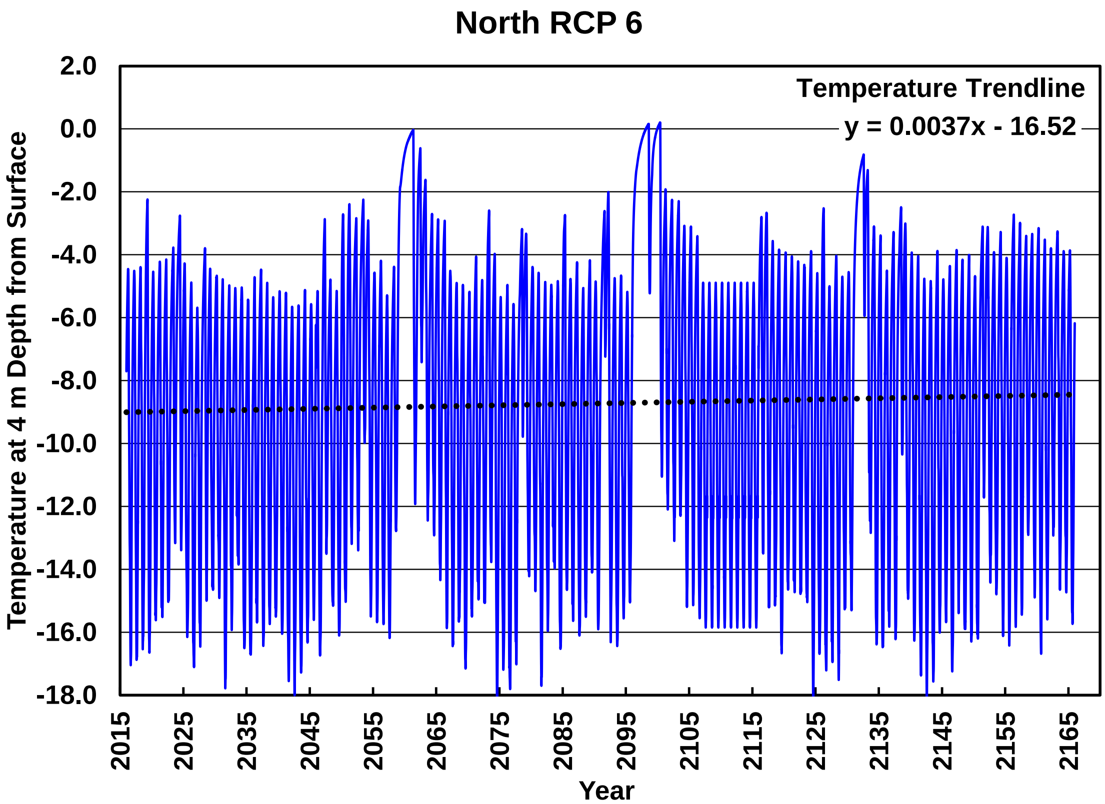
Appendix C


South Face RCP 4.5
Temperature at 4 m Depth from Surface
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
2015
2025
2035
2045
2055
2065
2075
2085
2095
2105
2115
2125
2135
2145
2155
2165
Year
Temperature Trendline
y = 0.0054x - 22.053


North RCP 4.5
Temperature at 4 m Depth from Surface
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
2015
2025
2035
2045
2055
2065
2075
2085
2095
2105
2115
2125
2135
2145
2155
2165
Year
Temperature Trendline
y = 0.002x - 15.675


Plateau RCP 4.5
Temperature Trendline
y = 0.0068x - 24.616
Temperature at 4 m Depth from Surface
Year
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
-14.0
-16.0
-18.0
-20.0
-22.0
2015
2025
2035
2045
2055
2065
2075
2085
2095
2105
2115
2125
2135
2145
2155
2165


South Face RCP 6
Temperature Trendline
y = 0.0031x - 14.867
Temperature at 4 m Depth from Surface
Year
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
-14.0
-16.0
-18.0
2015
2025
2035
2045
2055
2065
2075
2085
2095
2105
2115
2125
2135
2145
2155
2165


North RCP 6
Temperature Trendline
y = 0.0037x - 16.52
Temperature at 4 m Depth from Surface
Year
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
-14.0
-16.0
-18.0
2015
2025
2035
2045
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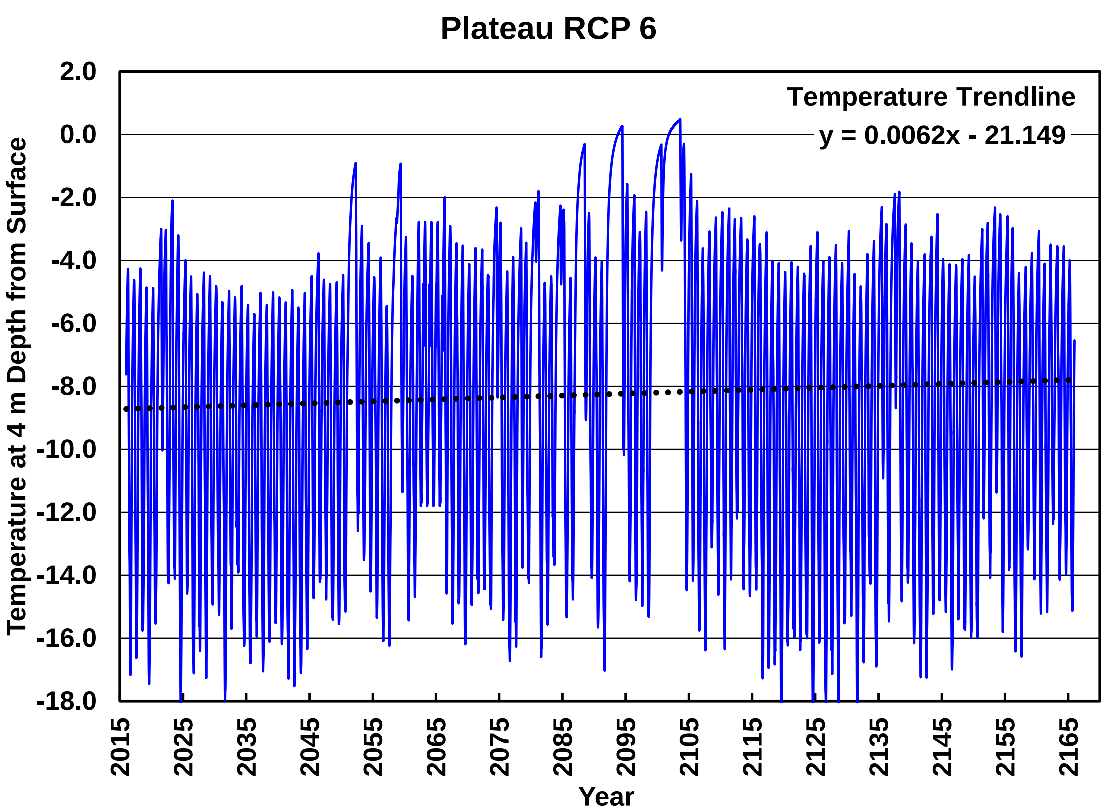
2135
2145
2155
2165


Plateau RCP 6
Temperature Trendline
y = 0.0062x - 21.149
Temperature at 4 m Depth from Surface
Year
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
-14.0
-16.0
-18.0
2015
2025
2035
2045
2055
2065
2075
2085
2095
2105
2115
2125
2135
2145
2155
2165