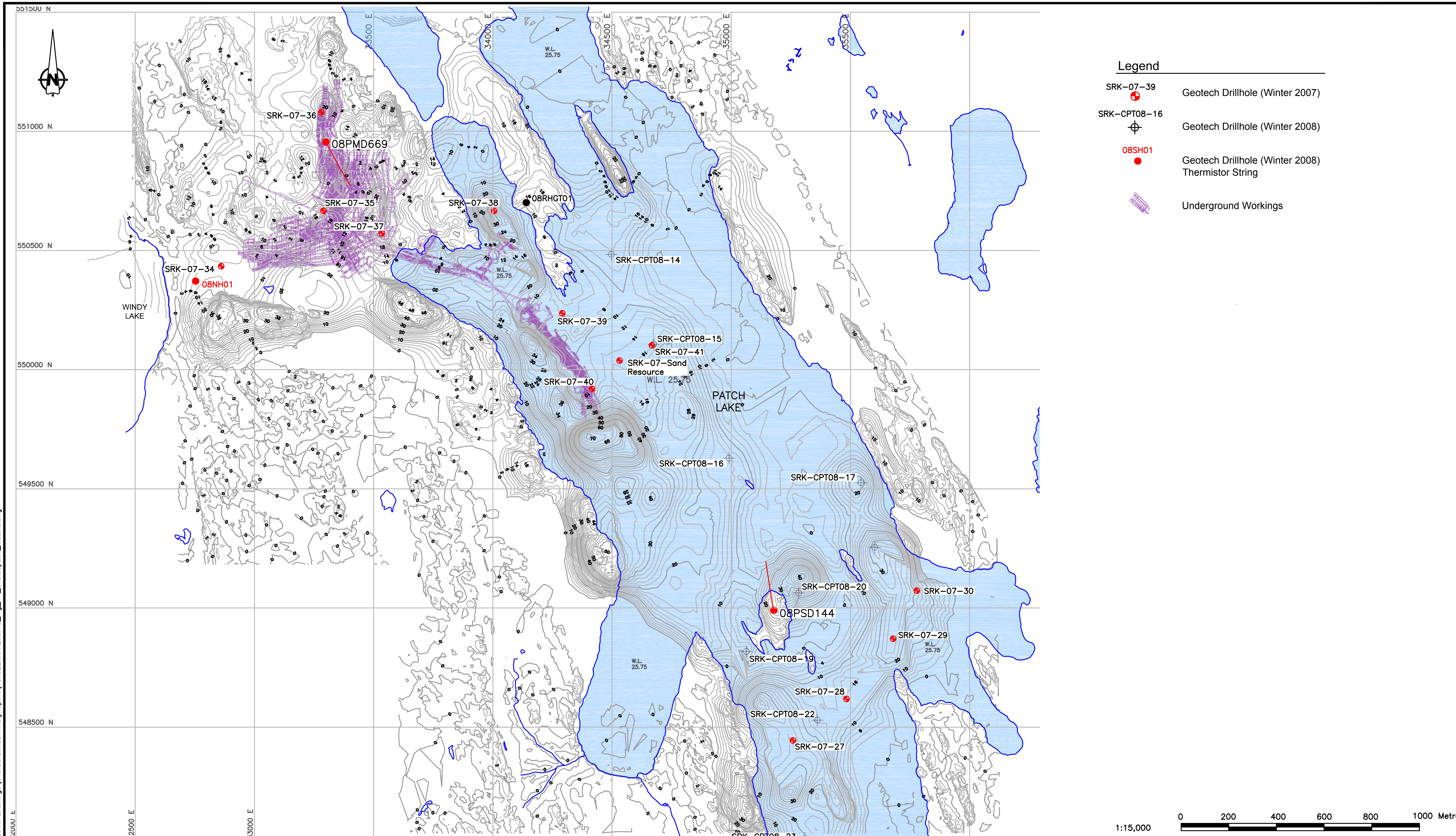


srk consulting

SRK JOB NO.: 1CT022.004

FILE NAME: 1CT022.004.200.10_Fig_11_OvbIsopach_Madrid.dwg

MAC RESOURCES

HOPE BAY PROJECT

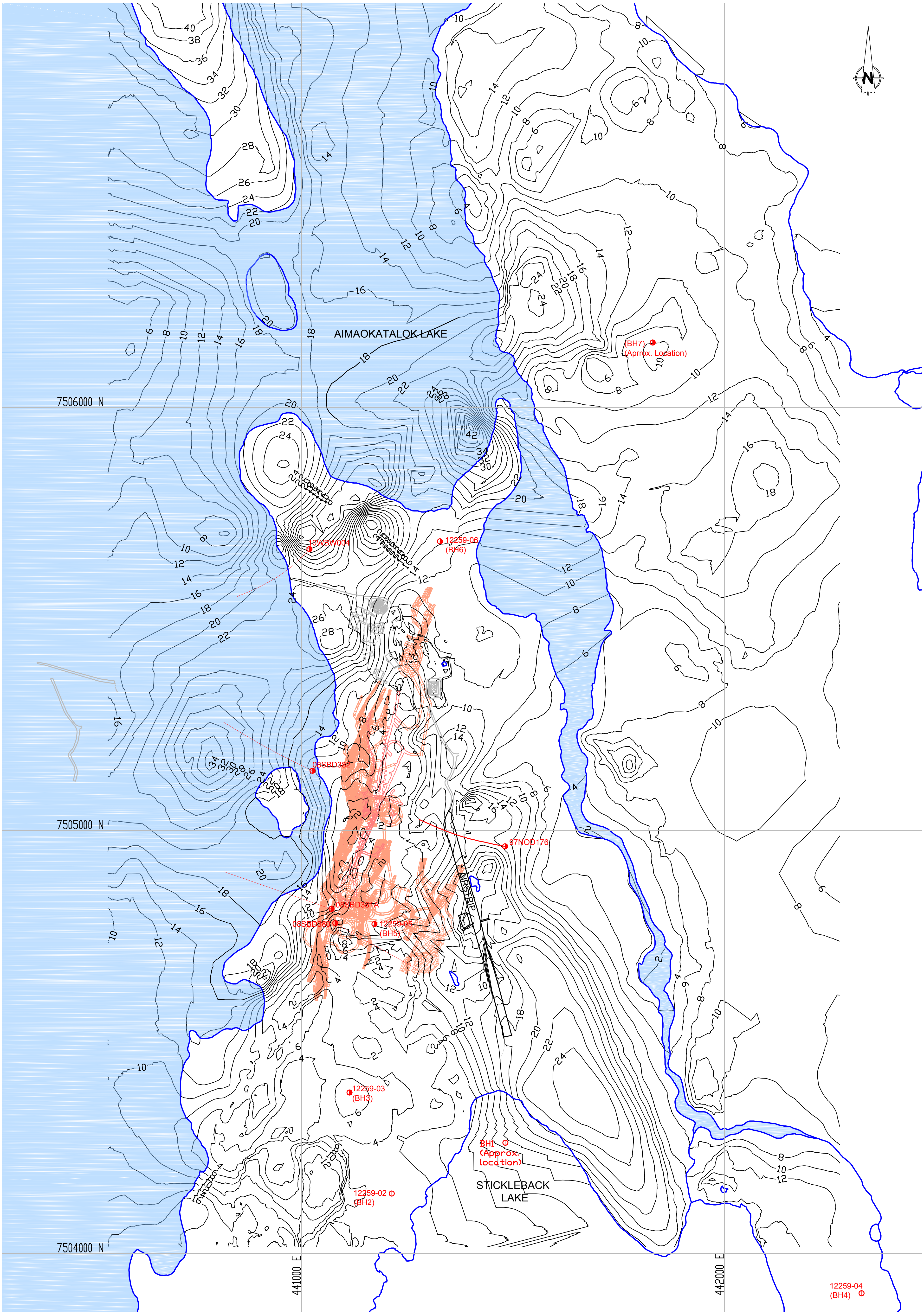
Overburden Summary Report

Overburden Isopach at the Madrid Mining Area

DATE:	APPROVED:	FIGURE:
July 2016	MMM	11

J:\01_SITES\Hope.Bay\!ACAD\2016 Drawings\OverburdenSummaryReport\1CT022.004.200.10_Fig_11_OvbIsopach_Madrid.dwg

J:\01_SITES\Hope.Bay\!ACAD\2016 Drawings\OverburdenSummaryReport\Boston_2mOVB_Isopach.dwg



LEGEND

12259-03 — Thermistor Installed

(BH1) — Thermistor Not Installed

08SBD380 — Angled Holes

28 — Ispoch 2m thickness Contour

Underground Workings

0 50 100 150 200 250

Scale in Metres

srk consulting

SRK JOB NO.: 1CT022.002

FILE NAME: Boston_2mOVB_Isopach.dwg

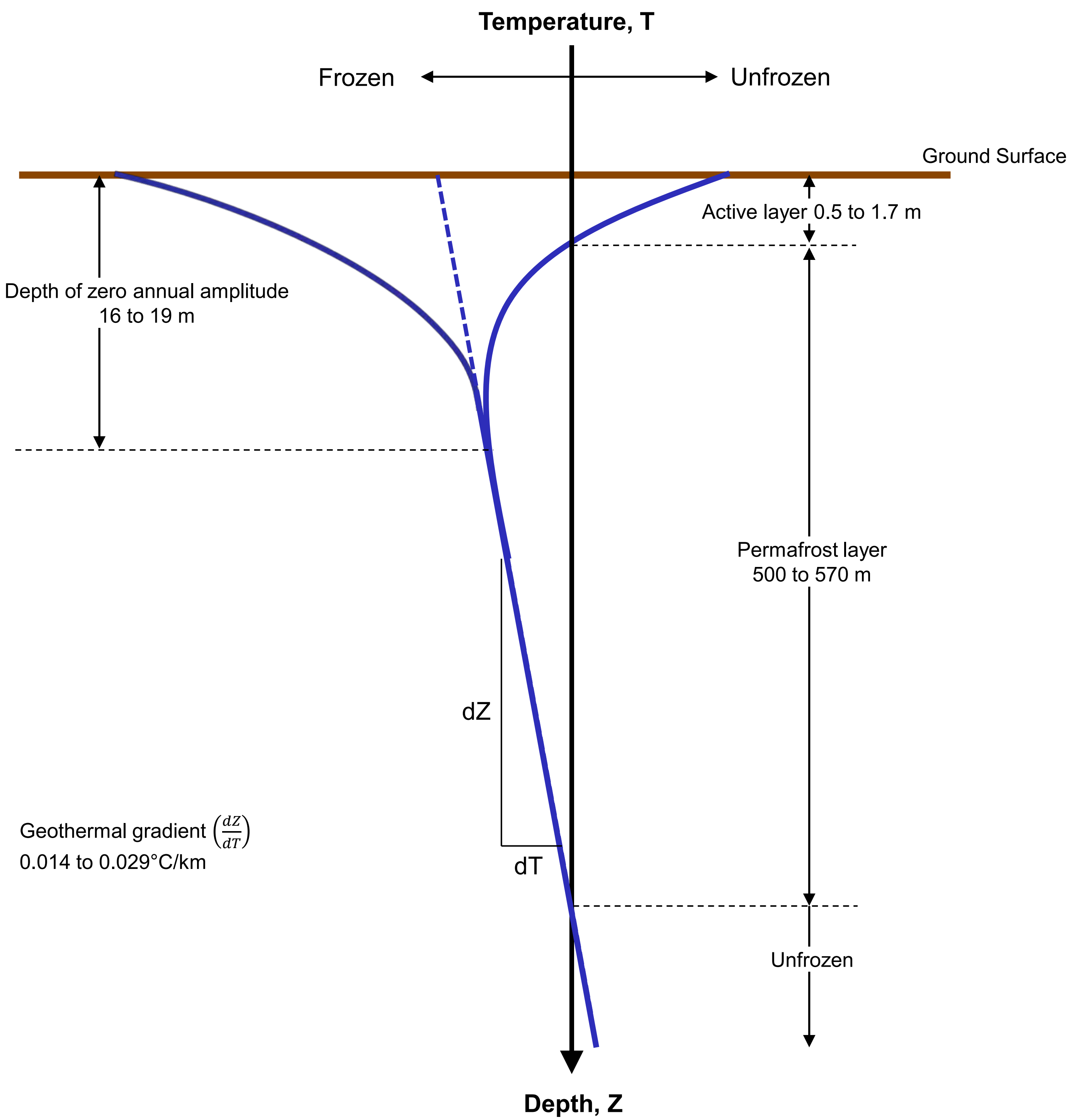
TMAC RESOURCES

HOPE BAY PROJECT

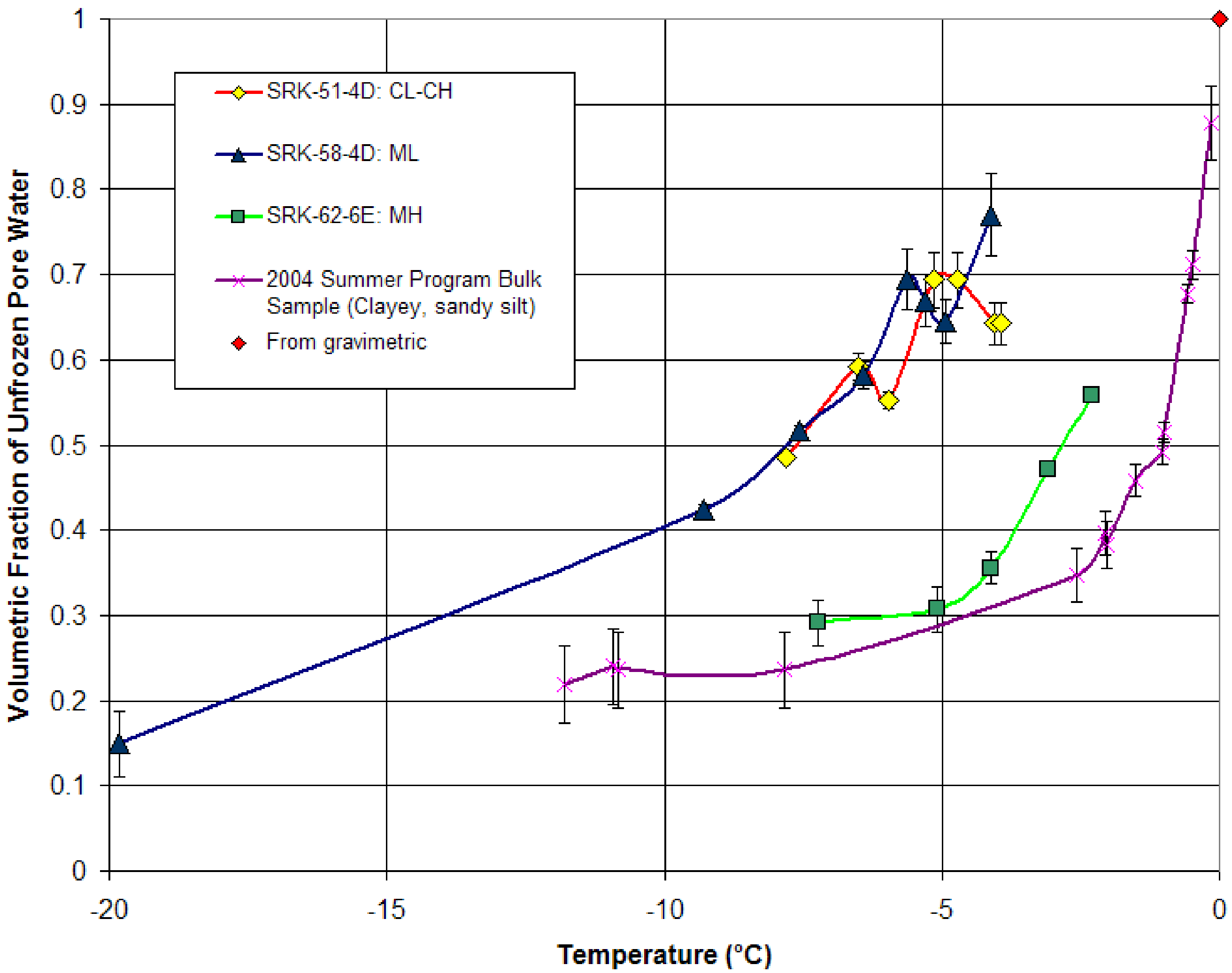
Overburden Summary Report

Overburden Isopach at the Boston Mining Area

DATE:	APPROVED:	FIGURE:
July 2016	MM	12



srk consulting	MAC RESOURCES	Overburden Summary Report **Ground Temperature and Permafrost Characteristics**
Job No: 1CT022.004 Filename: Fig10_PermafrosChar_1CT022.004_Rev01.pptx	Hope Bay Project	Date: July 2016 — Approved: MMM — Figure: **13**



Source: \\srk.ad\dfs\na\van\Projects\01_SITES\Hope.Bay\Old Miramar Jobs\1CM014.004_FEIS Submissions May 2005\Winter 2005 drilling\Report\Figures

srk consulting

MAC RESOURCES

Overburden Summary Report

Unfrozen Volumetric Water Content versus Temperature

Job No: 1CT022.004

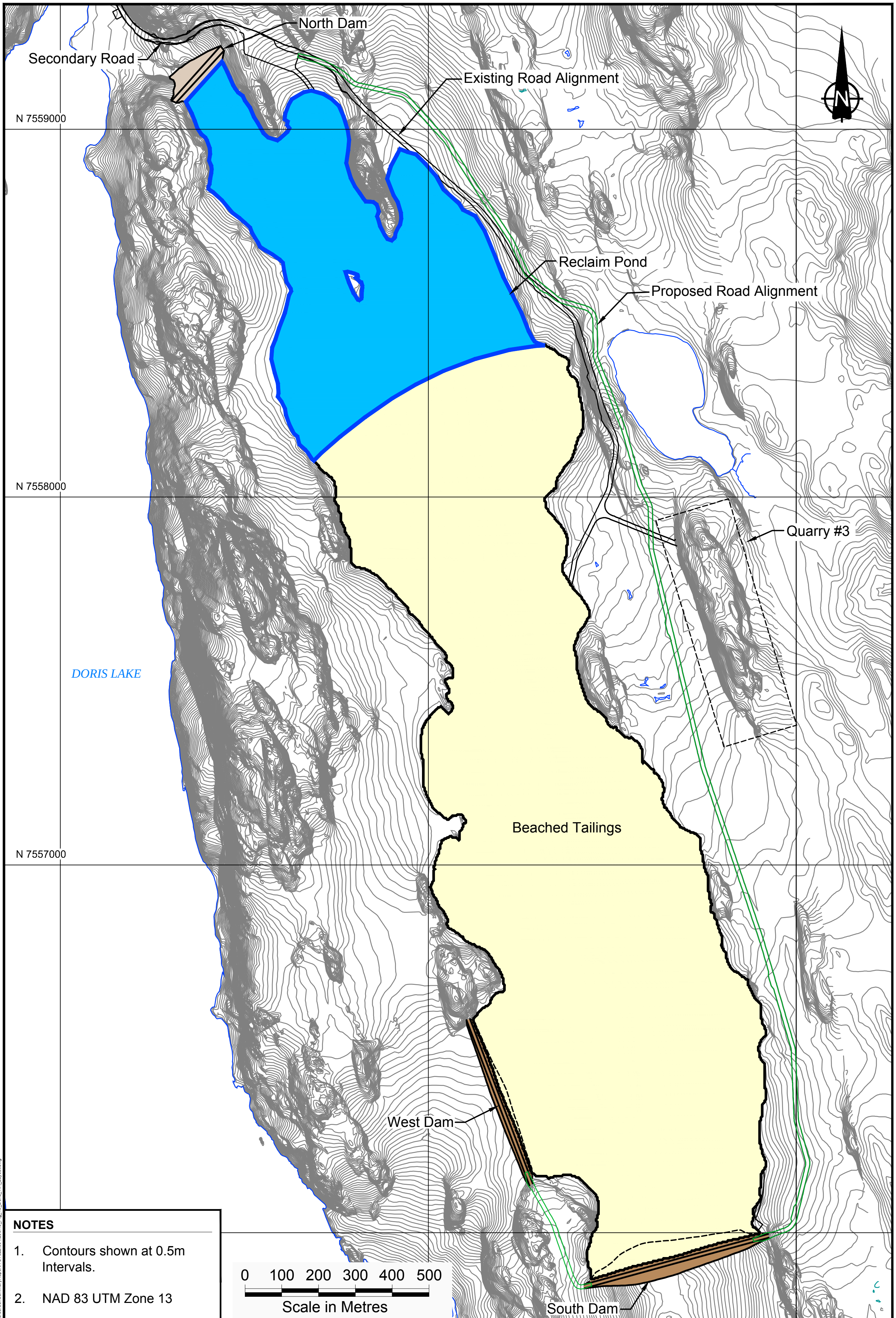
Filename: Fig13_UnfrozenWaterContent.pptx

Hope Bay Project

Date: July 2016

Approved: MMM

Figure: 14



NOTES

1. Contours shown at 0.5m Intervals.
2. NAD 83 UTM Zone 13

LEGEND

- Proposed Tailings Facility
- Proposed Dam/Dikes

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TMAC RESOURCES

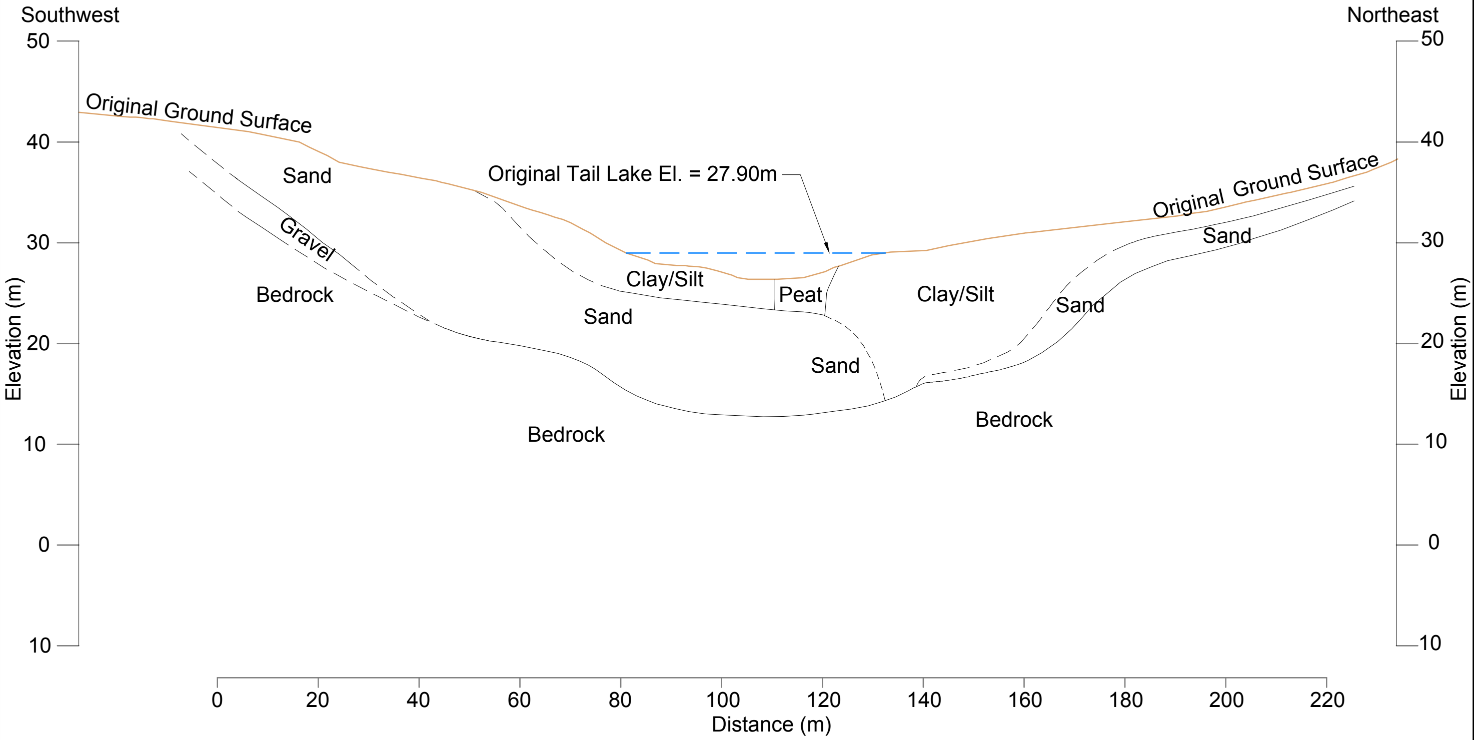
SRK JOB NO.:	1CT022.004.200.010
FILE NAME:	1CT022.004.200.10_Fig_15_Doris_TIA_Layout.dwg

HOPE BAY PROJECT

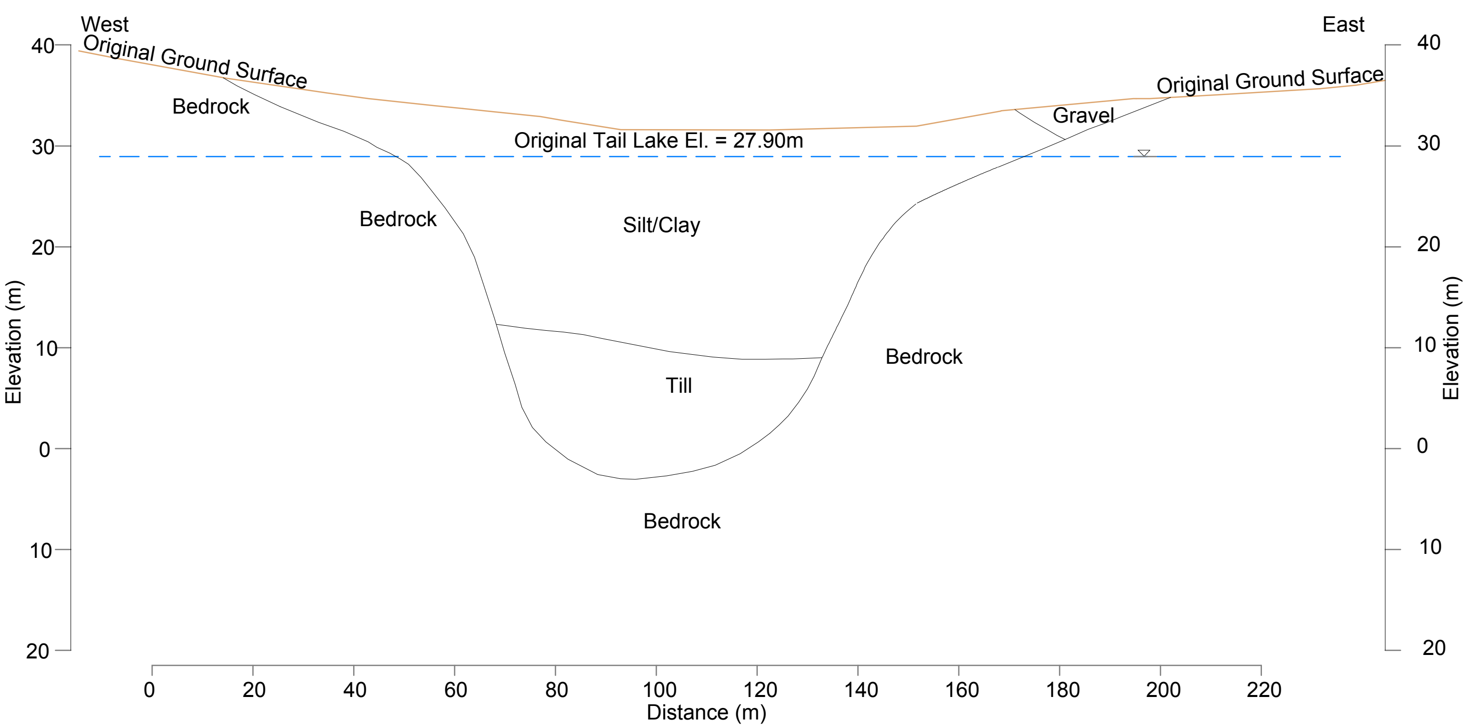
Overburden Summary Report

Doris TIA Layout

DATE:	APPROVED:	FIGURE:
July 2016	MMM	15



North Dam



South Dam

srk consulting

MAC RESOURCES

SRK JOB NO.: 1CT022.004

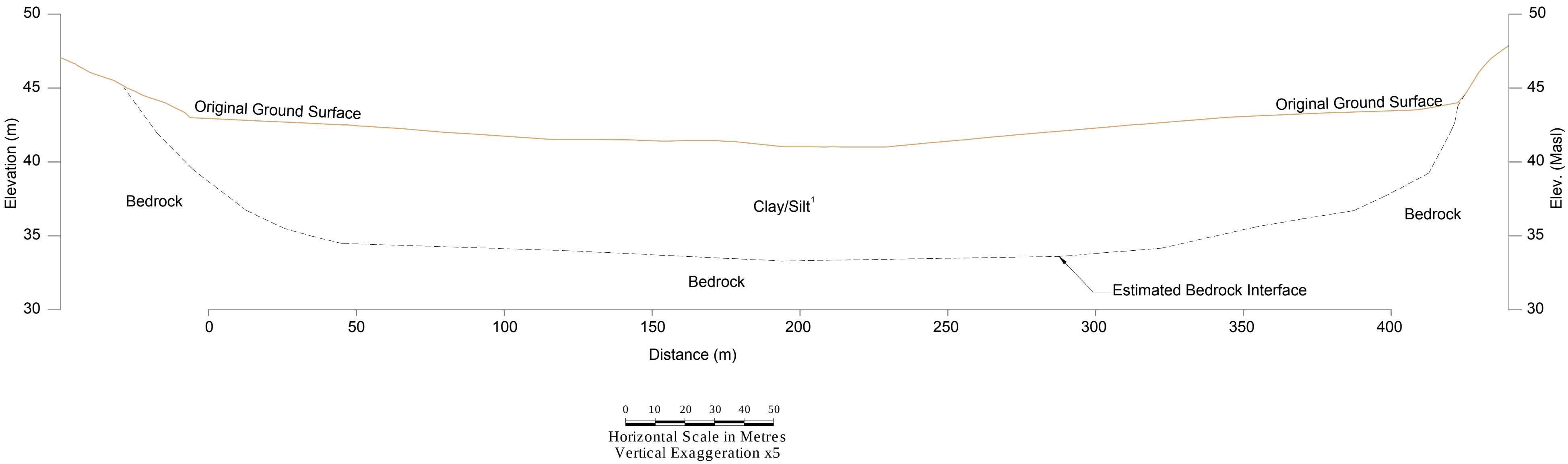
FILE NAME: 1CT022.004.200.10_Fig_16_OVB_Stratographic.dwg

HOPE BAY PROJECT

Overburden Summary Report

Interpreted Stratographic Profiles of the North and South Dams

DATE:	APPROVED:	FIGURE:
June 2016	MMM	16



NOTES

1. Stratigraphic profile based on a single borehole log. Bedrock contact and overburden material assumed.

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SRK JOB NO.: 1CT022.004

FILE NAME: 1CT022.004.200.10_Fig_17_OVB_Stratographic_WDam.dwg

TMAC RESOURCES

HOPE BAY PROJECT

Overburden Summary Report

Interpreted Stratographic Profile of the West Dam

DATE:	APPROVED:	FIGURE:
June 2016	MMM	17

Appendix A – Thermistor String Summary

SRK	Installation Date	Northing	Easting	Status	Area	Data Summary	Serial Number	Notes
SRK-11	Sep 2002	7559117.00	434347.00	Inactive	Doris	Sep 2002 - Jul 2010	00577-2	
SRK-13	Sep 2002	7559171.72	434383.32	Inactive	Doris	Sep 2002 - Aug 2003	00577-1	
SRK-14	Apr 2003	7559059.45	434291.66	Active	Doris	Apr 2003 - Sep 2015	690007	
SRK-15	Mar 2003	7559171.62	434383.00	Inactive	Doris	Apr 2003 - Oct 2008, Jul 2010	690012	
SRK-16	Sep 2002	7559092.00	434323.20	Inactive	Doris	Sep 2002 - Jul 2010	0577-3	
SRK-19	Apr 2003	7563211.92	432983.69	Inactive	Roberts Bay	Apr 2003 - Oct 2008	690006	
SRK-20	Apr 2003	7563129.78	432986.02	Inactive	Roberts Bay	Apr 2003 - Oct 2008	690009	
SRK-22	Apr 2003	7562026.69	432971.94	Active	Roberts Bay	Apr 2003 - Feb 2016	690003	
SRK-23	Apr 2003	7561665.77	432901.86	Inactive	Roberts Bay	Apr 2003 - Oct 2008	690008	
SRK-24	Apr 2003	7559493.64	432344.49	Active	Doris	Apr 2003 - Sep 2015	690001	
SRK-26	Apr 2003	7558819.91	433422.37	Inactive	Doris	Apr 2003 - Oct 2008	690002	
SRK-28	Apr 2003	7559046.27	433043.30	Inactive	Doris	Apr 2003 - Jul 2009	690011	
SRK-32	Apr 2003	7555914.51	435554.73	Inactive	Doris	Apr 2003 - Aug 2013	690010	
SRK-33	Apr 2003	7555930.36	435613.59	Active	Doris	Apr 2003 - Oct 2014	690005	
SRK-34A	Apr 2003	7555941.61	435640.69	Inactive	Doris	Apr 2003 - Oct 2008	690004	
SRK10-DCB2 Doris Bridge East	Jul 2011	7559478.35	434036.99	Active	Doris	Jul 2011 - Present	TS3017	Installed in bridge abutment.
SRK10-DCB1 Doris Bridge West	Jul 2011	7559475.15	434067.76	Active	Doris	Jul 2011 - Present	TS3016	Installed in bridge abutment.
SRK-35	Apr 2003	7559477.53	434035.64	Inactive	Doris	Apr 2003 - Nov 2010	690013	
SRK-37	Mar 2003	7559090.54	434328.97	Inactive	Doris	Apr 2003 - Jul 2010	690013	
SRK-38	Aug 2003	7558254.33	434525.84	Active	Doris	Aug 2003 - Sep 2015	TS0015	
SRK-39	Aug 2003	7556391.33	435164.13	Active	Doris	Aug 2003 - Oct 2014	TS0011	
SRK-40	Aug 2003	7558546.86	435492.39	Inactive	Doris	Aug 2003 - Oct 2008	TS0014	
SRK-41	Aug 2003	7559129.11	434358.55	Inactive	Doris	Aug 2003 - Oct 2010	TS0012	
SRK-42	Aug 2003	7559081.34	434402.62	Inactive	Doris	Aug 2003 - Jul 2010	TS0013	
SRK-43	Aug 2003	7555923.82	435584.52	Inactive	Doris	Aug 2003 - Oct 2008	TS0010	
SRK-50	Aug 2004	7559177.00	433807.00	Active	Doris	Aug 2004 - Nov 2014	TS1618	
SRK-51	Apr 2005	7559165.54	434390.70	Inactive	Doris	Apr 2005 - Jul 2010	TS2048	
SRK-52	Apr 2005	7559082.73	434316.33	Inactive	Doris	Apr 2005 - Jul 2010	TS2047	
SRK-53	Apr 2005	7556906.93	435184.24	Inactive	Doris	Apr 2005 - Aug 2013	TS1625	
SRK-54	Sep 2004	7556467.00	435632.00	Inactive	Doris	Sep 2004 - Jul 2010	TS1626	
SRK-55	Sep 2004	7557813.27	434935.95	Inactive	Doris	Sep 2004 - Sep 2004	TS1621	
SRK-56	Sep 2004	7558258.00	435334.00	Inactive	Doris	Sep 2004 - Oct 2005	TS1621	
SRK-57	Apr 2005	7557812.13	434937.72	Active	Doris	Apr 2005 - Oct 2014	TS1623	
SRK-58	Apr 2005	7557704.54	435284.89	Inactive	Doris	Apr 2005 - Aug 2012	TS1622	
SRK-62	Apr 2005	7558994.93	434500.74	Inactive	Doris	Apr 2005 - Jul 2010	TS2046	
SRK-JT1-09	Mar 2009	7563297.00	432534.00	Active	Roberts Bay Jetty	Mar 2009 - Present	TS2667	
SRK-JT2-09	Mar 2009	7563264.00	432550.00	Inactive	Roberts Bay Jetty	Mar 2009 - Nov 2011	TS2668	
SRK-JT2-12	May 2012	7563264.00	432550.00	Inactive	Roberts Bay Jetty	May 2012 - Sep 2012	TS3019	
08SBD380	Jul 2008	7504780.24	441079.71	Unknown	Boston	Jul 2008 - Aug 2010	VW8891/TS2717	
08SBD381A	Aug 2008	7504813.94	441070.40	Unknown	Boston	Aug 2008 - Sep 2009	VW8887/TS2713	
08SBD382	Aug 2008	7505140.53	441025.86	Unknown	Boston	Aug 2008 - Oct 2014	VW8888/TS2717	
08PMD669	Jul 2008	7550955.12	433300.23	Unknown	Madrid	Jul 2008 - Aug 2010	VW8847/TS2711	
08PSD144	Oct 2008	7548989.92	435177.97	Unknown	Madrid	Sep 2008 - Aug 2010	VW8890/TS2716	
08TDD632	Jun 2008	7559369.75	433915.20	Inactive	Doris	Jun 2008 - Jul 2010	VW8826/TS2706	
08TDD633	Jun 2008	7557646.05	433402.21	Inactive	Doris	No Data	VW8846/TS2710	
SRK-12-GTC-DH01	Apr 2012	7558917.20	433169.18	Active	Doris	Apr 2012 - Present	TS3260	Installed in pollution control pond berm.
SRK-12-GTC-DH02	Apr 2012	7558912.96	433225.25	Active	Doris	Apr 2012 - Present	TS3261	Installed in pollution control pond berm.
SRK-12-GTC-DH03	Apr 2012	7558930.81	433225.25	Active	Doris	Apr 2012 - Present	TS3262	Installed in pollution control pond berm.
SRK10-DWB1	Apr 2012	7555673.50	432703.40	Active	Madrid	Apr 2012 - Present	TS3021	Installed in bridge abutment.
SRK10-DWB2	Apr 2012	7555644.40	432708.20	Active	Madrid	Apr 2012 - Present	TS3025	Installed in bridge abutment.
SRK10-DWB3	Apr 2012	755615.00	432712.80	Active	Madrid	Apr 2012 - Present	TS3020	Installed in bridge abutment.
SRK10-DWB4	Apr 2012	7554860.30	432444.00	Active	Madrid	Apr 2012 - Present	TS3024	Installed in bridge abutment.
SRK10-DWB5	Apr 2012	7554831.30	732437.00	Active	Madrid	Apr 2012 - Present	TS3023	Installed in bridge abutment.
ND-HTS-040-31.5	Apr 2011	7559100.71	434324.01	Active	Doris	Aug 2012 - Present	TS3091	Installed in North Dam.
ND-HTS-040-33.5	Mar 2012	7559100.71	434324.01	Active	Doris	Aug 2012 - Oct 2013, May 2014 - Present	TS3102	Installed in North Dam.
ND-VTS-040-KT	Mar 2011	7559100.71	434324.01	Active	Doris	Aug 2012 - Present	TS3080	Installed in North Dam.
ND-VTS-060-DS	Feb 2011	7559115.28	434337.72	Active	Doris	Aug 2012 - Present	TS3086	Installed in North Dam.
ND-HTS-060-33.5	Mar 2012	7559115.28	434337.72	Active	Doris	Aug 2012 - Present	TS3099	Installed in North Dam.
ND-HTS-060-31.0	Feb 2012	7559115.28	434337.72	Active	Doris	Aug 2012 - Present	TS3096	Installed in North Dam.
ND-HTS-060-28.8	Apr 2011	7559115.28	434337.72	Active	Doris	Aug 2012 - Present	TS3092	Installed in North Dam.
ND-VTS-060-KT	Mar 2011	7559115.28	434337.72	Active	Doris	Aug 2012 - Present	TS3081	Installed in North Dam.
ND-VTS-060-US	Feb 2011	7559106.54	434346.46	Inactive	Doris	No Data	TS3085	Damaged during construction.
ND-VTS-085-DS	Feb 2011	7559133.96	434353.91	Active	Doris	Aug 2012 - Present	TS3088	Installed in North Dam.
ND-HTS-085-25.3	Apr 2011	7559133.96	434353.91	Active	Doris	Aug 2012 - Present	TS3093	Installed in North Dam.
ND-HTS-085-29.4	Feb 2012	7559133.96	434353.91	Active	Doris	Aug 2012 - Present	TS3097	Installed in North Dam.
ND-HTS-085-33.5	Mar 2012	7559133.96	434353.91	Inactive	Doris	No Data	TS3100	Damaged during construction.
ND-VTS-085-KT	Mar 2011	7559133.96	434353.91	Active	Doris	Aug 2012 - Present	TS3082	Installed in North Dam.
ND-VTS-085-US	Feb 2011	7559125.08	434363.23	Active	Doris	Aug 2012 - Present	TS3087	Installed in North Dam.
ND-VTS-130-DS	Feb 2011	7559167.23	434384.47	Active	Doris	Aug 2012 - Present	TS3090	Installed in North Dam.
ND-HTS-130-28.8	Apr 2011	7559167.23	434384.47	Active	Doris	Aug 2012 - Present	TS3094	Installed in North Dam.
ND-HTS-130-31.0	Feb 2012	7559167.23	434384.47	Active	Doris	Aug 2012 - Present	TS3098	Installed in North Dam.
ND-HTS-130-33.5	Mar 2012	7559167.23	434384.47	Active	Doris	Aug 2012 - Present	TS3101	Installed in North Dam.
ND-VTS-130-KT	Mar 2011	7559167.23	434384.47	Active	Doris	Aug 2012 - Present	TS3083	Installed in North Dam.
ND-VTS-130-US	Feb 2011	7559158.49	434393.93	Active	Doris	Aug 2012 - Present	TS3089	Installed in North Dam.
ND-HTS-175-32.5	Apr 2011	7559200.63	434414.72	Active	Doris	Aug 2012 - Present	TS3095	Installed in North Dam.
ND-HTS-175.33.5	Feb 2012	7559200.63	434414.72	Active	Doris	Aug 2012 - Present	TS3103	Installed in North Dam.
ND-VTS-175-KT	Mar 2011	7559200.63	434414.72	Active	Doris	Aug 2012 - Present	TS3084	Installed in North Dam.
12259-97-01 / DH#1	May 1997	7565767.60	431164.80	Inactive	Roberts Bay	Jun 1997, Apr 2003	1135	
12259-97-8 / DH#8	1997	7565625.00	431129.60	Inactive	Roberts Bay	No Data	1136	Damaged
12259-97-17 / DH#17	May 1997	7565519.50	431211.40	Inactive	Roberts Bay	Jun 1997	1134	
12259-03	May 1996	7504380.00	441113.00	Inactive	Boston	May 1996 - Sep 2001	1049	
12259-05	May 1996	7504778.00	441172.00	Inactive	Boston	May 1996 - Jun 1996	1050	
12259-96-06	May 1996	7505683.00	441327.00	Inactive	Boston	May 1996 - Sep 2001	1051	
97NOD176	Jun 1905	7504962.00	441481.00	Unknown	Boston	Oct 1997 - Sep 2001	1130	
TM00141	Jul 2014	7546691.1	435141.3	Active	Madrid	Apr 2015 - Jan 2016	TS3787	
TDD-242	May 2000	15549.98(1)	5067.82(1)	Inactive	Doris	Aug 2000 - Sep 2001	#2	
TDD-261	2000	15224.89(1)	4917.00(1)	Inactive	Doris	No Data	#1	
CX3(2)-13	1997	N/A	N/A	Inactive	Boston	No Data	N/A	Mentioned in Golder 2001. Drilled in Boston Underground, last face at 3935 m level cross cut.
DB#27-H	1997	N/A	N/A	Inactive	Boston	No Data	1142	Mentioned in Golder 2001. Drilled in Boston Underground, Drill bay #27.
DB#27-V	1997	N/A	N/A	Inactive	Boston	No Data	1142	Mentioned in Golder 2001. Drilled in Boston Underground, Drill bay #27.
DB#36	1997	N/A	N/A	Inactive	Boston	No Data	N/A	Mentioned in Golder 2001. Drilled in Boston Underground, Drill bay #36.

Notes:

(1) Local mine grid, conversion to UTM from this grid is unknown

(2) Coordinate system is UTM NAD83, Zone 13

Appendix B – Seismic Hazard Analysis

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Memo

To:	John Roberts, PEng, Vice President Environment	**Client:**	TMAC Resources Inc.
From:	Megan Miller, PEng	**Project No:**	1CT022.004
Reviewed By:	Maritz Rykaart, PhD, PEng	**Date:**	November 22, 2016
Subject:	Hope Bay Project: Horizontal Seismic Parameters for Pseudo-Static Modelling		

1 Introduction

The Hope Bay Project (the Project) is a gold mining and milling undertaking of TMAC Resources Inc. The Project is located 705 km northeast of Yellowknife and 153 km southwest of Cambridge Bay in Nunavut Territory, and is situated east of Bathurst Inlet. The Project comprises of three distinct areas of known mineralization plus extensive exploration potential and targets. The three areas that host mineral resources are Doris, Madrid, and Boston.

The Project consists of two phases; Phase 1 (Doris project), which is currently being carried out under an existing Water Licence, and Phase 2 which is in the environmental assessment stage. Phase 1 includes mining and infrastructure at Doris only, while Phase 2 includes mining and infrastructure at Madrid and Boston located approximately 10 and 60 km due south from Doris, respectively.

The Phase 2 project has several components that require slope stability analysis, including:

- North, South and West dams at the Doris Tailings Impoundment Area (TIA);
- Waste rock piles at Madrid North, Madrid South and Boston; and
- Dry stack tailings in the Boston Tailings Management Area (TMA).

All of these facilities will be founded on permafrost overburden of varying thickness. The overburden on site is comprised of ice rich marine clays and silts, with an active layer thickness of approximately 1 m (SRK, 2016a).

This memo presents the methodology for determining horizontal and vertical seismic parameters to be used in pseudo static slope stability analysis on the Project site. The values presented herein are site specific and dependant on foundation conditions, and embankment height.

2 Seismic Parameter Calculations

2.1 Site Ground Motions

Ground motions for the Boston and Madrid mining areas were obtained from the 2015 National Building Code of Canada seismic hazard calculator (NRC, 2016). Both mining areas are expected to have the same ground motions (Attachment 1), and are summarized in Table 2.1.

Ground motions for spectral periods of 0.05 s to 10.0 s and the peak ground acceleration (PGA) for the 1:10,000 year event were estimated by plotting the annual probability of exceedance and spectral acceleration (Sa(T)) values of the 1:476 and 1:4,275-year events on a log-log scale and extending the line to the annual probability of exceedance for the 1:10,000-year event, as outlined by NRC (2016). The extrapolated ground motions are a very rough estimation, which likely over estimates hazard, and a site specific hazard assessment is recommended (NRC, 2016). However, since the site is located in a low seismic zone, slope stability modelling with the extrapolated 1:10,000-year event can be used as a screening tool to determine if additional seismic analysis is required for the closure scenario.

The ground motions obtained from the seismic hazard calculator are for soils classified as Site Class C: very dense soil and soft rock. Ground motions for other material types are obtained by converting the Site Class C values to the average material type over the top 30 m of the soil profile using formulas and factors provided in Humar (2015) and NRCC (2015). Table 2.2 provides the properties used to define the different site classes.

Assuming thawed conditions, the overburden foundations under the specified infrastructure are Soft Soils (Site Class E) due to the natural moisture content (>40%), and undrained shear strength (11 to 25 kPa) expected in the marine silts and clays (Table 2.2). Even if other types of overburden or bedrock are present within the infrastructure foundations, these foundations would be classified as Soft Soils (Site Class E) because the marine clays and silts are likely more than 3 m thick (Table 2.2). Permafrost soils could likely be considered Site Class B or Site Class C (Table 2.2); however, since the Site Class E soils amplify ground accelerations using Site Class E for all analysis was adopted as a conservative approach.

Table 2.1: Site Class C Ground Motions for the Project

Spectral Period or Peak Parameter	Ground Accelerations (g)			
	1:100 year	1:476 year	1:1,000 year	1:2,475 year
Sa(0.05)	0.0034	0.012	0.021	0.042
Sa(0.1)	0.0056	0.019	0.031	0.059
Sa(0.2)	0.0069	0.021	0.032	0.056
Sa(0.3)	0.0065	0.019	0.029	0.047
Sa(0.5)	0.0051	0.017	0.025	0.038
Sa(1.0)	0.0026	0.0096	0.015	0.023
Sa(2.0)	0.0010	0.0041	0.0064	0.011
Sa(5.0)	0.0004	0.0009	0.0014	0.0023
Sa(10.0)	0.0003	0.0006	0.0008	0.0011
Peak Ground Acceleration (PGA)	0.0033	0.011	0.017	0.032

Source: NRCC 2016

Table 2.2: Site Classification for Seismic Site Response

<table>
<tr><th rowspan="2">Site Class</th><th rowspan="2">Ground Profile Name</th><th colspan="3">Average Properties for Top 30 m of Profile</th></tr>
<tr><th>Average Shear Wave Velocity, $\bar{V}_s$(m/s)</th><th>Average Standard Penetration Resistance, $\bar{N}_{60}$</th><th>Soil Undrained Shear Strength, s_u</th></tr>
<tr><td>A</td><td>Hard Rock(2)</td><td>$\bar{V}_s > 1{,}500$</td><td>N/A</td><td>N/A</td></tr>
<tr><td>B</td><td>Rock(2)</td><td>$760 < \bar{V}_s \le 1{,}500$</td><td>N/A</td><td>N/A</td></tr>
<tr><td>C</td><td>Very Dense Soil and Soft Rock</td><td>$360 < \bar{V}_s \le 760$</td><td>$\bar{N}_{60} > 50$</td><td>s_u > 100 kPa</td></tr>
<tr><td>D</td><td>Stiff Soil</td><td>$360 < \bar{V}_s \le 760$</td><td>$15 \le \bar{N}_{60} \le 50$</td><td>50 kPa < s_u ≤ 100 kPa</td></tr>
<tr><td rowspan="2">E</td><td rowspan="2">Soft Soil</td><td>$\bar{V}_s < 180$</td><td>$\bar{N}_{60}$<15</td><td>s_u < 50 kPa</td></tr>
<tr><td colspan="3">Any soil with more than 3 m of soil with the following characteristics:
1. Plasticity Index: PI ≥ 20
2. Moisture content: w ≥ 40%
3. Undrained shear strength: s_u < 25 kPa</td></tr>
<tr><td>F(1)</td><td>Other Soils</td><td colspan="3">Other soils include:
1. Liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils, and other soils susceptible to failure or collapse under seismic loading
2. Peat and/or highly organic clays greater than 3 m thickness
3. Highly plastic clays (PI>75) more than 8 m thick
4. Soft to medium stiff clays more than 30 m thick</td></tr>
</table>

Source: Adapted from National Building Code of Canada 2015 Table 4.1.8.4-A (NRCC 2015)

Notes:

(1) Site specific evaluation required.

(2) Site Classes A and B are not to be used if there is more than 3 m of softer materials between the rock and the underside of the footing or mat foundations. If more than 3 m of softer materials exist the Site Class is determined based on the average properties of the softer materials.

2.2 Horizontal Seismic Parameters

The horizontal seismic parameters were calculated from the site adjusted ground motions using the Limit Equilibrium Pseudo Static Stability Analysis method presented in Section 6.2.2 of the LRFD Seismic Analysis and Design of Transportation Geotechnical Features and Structural Foundations, Reference Manual (FHWA, 2011).

This analysis determines the horizontal seismic coefficient by reducing the site-adjusted PGA based on slope height and allowable deformation. The method assumes an allowable deformation of 1 to 2 inches (25 to 51 mm) for a seismic factor of safety (FOS) of 1.1. While a larger allowable deformation is unlikely to affect the stability of the waste rock piles, dry stack tailings and Doris TIA dams, this criteria is conservative.

As the horizontal seismic parameter is dependent on slope height, soil properties, and design earthquake it was calculated separately for each component. The horizontal seismic parameter values are provided in Section 3.

2.3 Vertical Seismic Parameters

For most earthquakes the horizontal acceleration component is much greater than the vertical acceleration component; therefore, the vertical seismic coefficient is commonly assumed to be zero (Seed and Whitman 1970; FHWA 2011 and Anderson *et al*., 2008).

3 Results

Table 3.1 presents the horizontal seismic coefficients for the Phase 2 infrastructure requiring stability analysis, assuming a FOS of 1.1. The vertical seismic coefficients are assumed to be negligible. The selection of the seismic event for each structure is based on Canadian Dam Association design guidelines (CDA, 2014) and the Mined Rock and Overburden Piles Investigation and Design Manual (Piteau, 1991). The selection of the appropriate seismic event from the design guidelines is described in the design documents of the infrastructure components (SRK 2016b, c, d, e and f).

Should analysis of other infrastructure be required, the horizontal seismic coefficients can be obtained from Table 3.1 assuming that the infrastructure is founded on a minimum of 3 m of marine silt and clay overburden (Site Class E).

Table 3.1: Horizontal Seismic Coefficients for Various Infrastructure at the Project

Structure	Critical Section Height (m)	Seismic Event	Horizontal Seismic Coefficient (g)
Operations			
North Dam	10	1:2,475	0.023
South Dam	15	1:2,475	0.021
West Dam	5	1:2,475	0.025
Madrid South Waste Rock Pile	20	1:476	0.0075
Madrid North Waste Rock Pile	20	1:476	0.0075
Boston Waste Rock Pile	25	1:476	0.0072
Boston TMA	25	1:2,475	0.018
Contact Water Pond Berms	2.5	1:476	0.0086
Closure			
South Dam	15	Halfway between 1:2,475 year and 1:10,000 year	0.036
West Dam	5	Halfway between 1:2,475 year and 1:10,000 year	0.043
Boston TMA	25	1:2,475	0.018

Source: \\srk.ad\dfs\na\van\Projects\01_SITES\Hope.Bay\1CT022.004_Phase 2 DEIS - Engineering Support\Task 210_Geotechnical_Overburden\Seismic Hazard Analysis\[HopeBay_SeismicCoefficentCalculation_1CT022.004_20160510_mmm.xlsm]Summary

Table 3.2: Horizontal Seismic Coefficient for the Project, Soil Class E

Dam / Embankment Height (m)	Seismic Coefficient (g)				
	1:100 year	1:476 year	1:1,000 year	1:2,475 year	1: 10,000 year
≤ 5	0.0026	0.0086	0.013	0.025	0.061
10	0.0024	0.0083	0.013	0.023	0.056
15	0.0023	0.0079	0.012	0.021	0.051
20	0.0021	0.0075	0.012	0.020	0.046
25	0.0020	0.0072	0.011	0.018	0.041
30	0.0018	0.0068	0.011	0.016	0.036
≥ 35	0.0018	0.0067	0.011	0.016	0.035

Source: \\srk.ad\dfs\na\van\Projects\01_SITES\Hope.Bay\1CT022.004_Phase 2 DEIS - Engineering Support\Task 210_Geotechnical_Overburden\Seismic Hazard Analysis\[HopeBay_SeismicCoefficentCalculation_1CT022.004_20160510_mmm.xlsm]Summary

4 References

Anderson, D. Martin, G. R., Lam, I., and Wang, J. N. 2008. Seismic Analysis and Design of Retaining Walls, Buried Structures, Slopes and Embankments. Prepared for the Transportation Research Board, Washington, D. C. NCHRP Report 611. 2008.

[CDA 2014] Canadian Dam Association. 2014. Technical Bulletin: Application of Dam Safety Guidelines to Mining Dams.

[FHWA] U.S. Department of Transportation Federal Highway Administration. 2011. LRFD Seismic Analysis and Design of Transportation Geotechnical Features and Structural Foundations, Reference Manual. NHI Course No. 130094. Publication No. FHWA-NHI-11-032. August 2011.

Humar, J. 2015. Background to some of the seismic design provisions of the 2015 national building code of Canada. Canadian Journal of Civil Engineering. 42:940-952. September 2, 2015.

[NRCC 2015] National Research Council of Canada, Canadian Commission on Building and Fire Codes. 2015. National Building Code of Canada. 2015.

[NRC] National Research Council of Canada. 2016. 2015 National Building Code of Canada Seismic hazard calculator .July 23, 2013. Available at: http://earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/index_2015-en.php (Accessed January 18, 2016).

[Piteau 1991] Piteau Associates Engineering Ltd. for British Columbia Mine Waste Rock Pile Research Committee. 1991. Mined Rock and Overburden Piles Investigation and Design Manual. Interim Guidelines. Prepared for the British Columbia Mine Dump Committee. May 1991.

Seed, B., and Whitman, V. 1970. Design for Earth Retaining Structures for Dynamic Loads. Presented in the 1970 Specialty Conference Lateral Stresses in the Ground and Design of Earth-Retaining Structures. Cornell University. June 22-24, 1970.

SRK Consulting (Canada) Inc. 2016a. Hope Bay Project, Geotechnical Design Parameters and Overburden Summary Report. Report prepared for TMAC Resources Inc. Project No.: 1CT022.004. 2016.

SRK Consulting (Canada) Inc. 2016b. Hope Bay Project, Doris Tailings Impoundment Area Phase 2 Design. Report prepared for TMAC Resources Inc. Project No.: 1CT022.004. 2016.

SRK Consulting (Canada) Inc. 2016c. Hope Bay Project, Boston Tailings Management Area Preliminary Design, Hope Bay, Nunavut, Canada. Report prepared for TMAC Resources Inc. Project No.: 1CT022.004. 2016.

SRK Consulting (Canada) Inc. 2016d. Hope Bay Project: Boston Surface Infrastructure. Memo prepared for TMAC Resources Inc. Project No.: 1CT022.004. 2016.

SRK Consulting (Canada) Inc. 2016e. Hope Bay Project: Madrid South Surface Infrastructure. Memo prepared for TMAC Resources Inc. Project No.: 1CT022.004. 2016.

SRK Consulting (Canada) Inc. 2016f. Hope Bay Project: Madrid North Surface Infrastructure. Memo prepared for TMAC Resources Inc. Project No.: 1CT022.004. 2016.

Attachment 1: 2015 National Building Code Seismic Hazard Calculation

2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

January 28, 2016

Site: 68.0642 N, 106.6069 W User File Reference: Hope Bay Project

Requested by: ,

National Building Code ground motions: 2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.05)	Sa(0.1)	**Sa(0.2)**	Sa(0.3)	**Sa(0.5)**	**Sa(1.0)**	**Sa(2.0)**	**Sa(5.0)**	**Sa(10.0)**	**PGA (g)**	**PGV (m/s)**
0.042	0.059	**0.056**	0.047	**0.038**	**0.023**	**0.011**	**0.0023**	**0.0011**	**0.032**	**0.027**

Notes. Spectral (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s. Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are specified in **bold** font. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. ***These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.***

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.0034	0.012	0.021
Sa(0.1)	0.0056	0.019	0.031
Sa(0.2)	0.0069	0.021	0.032
Sa(0.3)	0.0065	0.019	0.029
Sa(0.5)	0.0051	0.017	0.025
Sa(1.0)	0.0026	0.0096	0.015
Sa(2.0)	0.0010	0.0041	0.0064
Sa(5.0)	0.0004	0.0009	0.0014
Sa(10.0)	0.0003	0.0006	0.0008
PGA	0.0033	0.011	0.017
PGV	0.0028	0.011	0.017

References

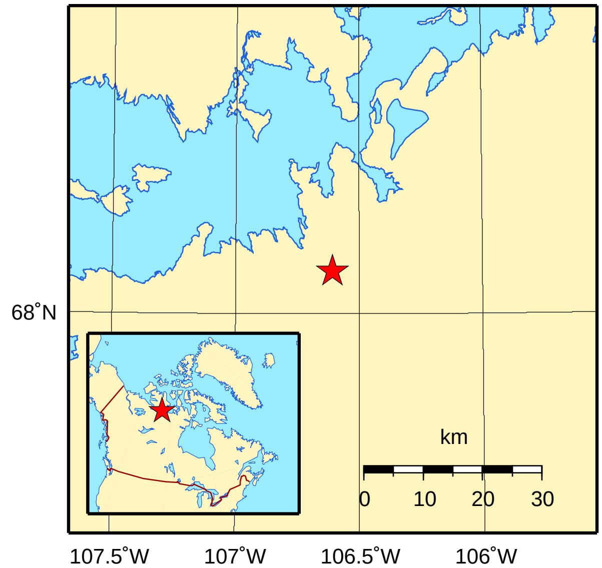
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

User's Guide - NBC 2015, Structural Commentaries NRCC no. xxxxxx (in preparation)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites *www.EarthquakesCanada.ca* and *www.nationalcodes.ca* for more information

Aussi disponible en français



2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

March 11, 2016

Site: 67.6578 N, 106.3849 W User File Reference: Boston Camp

Requested by: Megan Miller, SRK Consulting

National Building Code ground motions: 2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.05)	Sa(0.1)	**Sa(0.2)**	Sa(0.3)	**Sa(0.5)**	**Sa(1.0)**	**Sa(2.0)**	**Sa(5.0)**	**Sa(10.0)**	**PGA (g)**	**PGV (m/s)**
0.042	0.059	**0.056**	0.047	**0.038**	**0.023**	**0.011**	**0.0023**	**0.0011**	**0.032**	**0.027**

Notes. Spectral (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s. Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are specified in **bold** font. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. ***These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.***

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.0034	0.012	0.021
Sa(0.1)	0.0055	0.019	0.031
Sa(0.2)	0.0068	0.021	0.032
Sa(0.3)	0.0063	0.019	0.029
Sa(0.5)	0.0050	0.017	0.025
Sa(1.0)	0.0025	0.0094	0.015
Sa(2.0)	0.0010	0.0040	0.0063
Sa(5.0)	0.0004	0.0009	0.0013
Sa(10.0)	0.0003	0.0006	0.0008
PGA	0.0033	0.011	0.017
PGV	0.0028	0.010	0.017

References

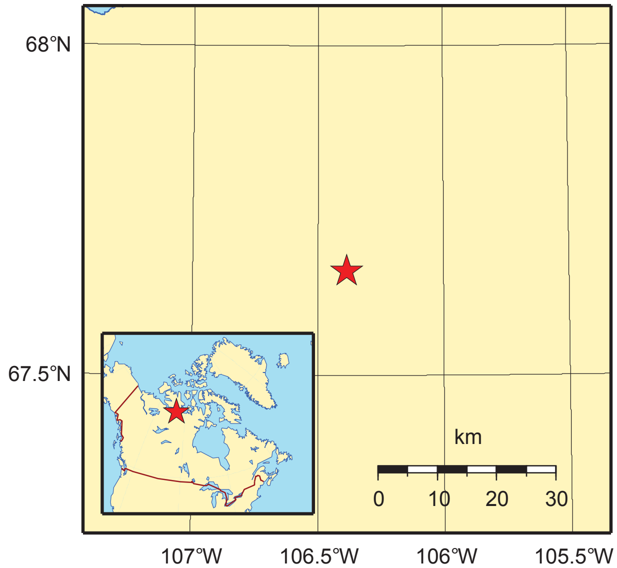
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

User's Guide - NBC 2015, Structural Commentaries NRCC no. xxxxxx (in preparation)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites *www.EarthquakesCanada.ca* and *www.nationalcodes.ca* for more information

Aussi disponible en français



Appendix C – Thermal Modelling to Support Run-of-Quarry Pad Design

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Memo

To:	John Roberts, PEng, Vice President Environment	**Client:**	TMAC Resources Inc.
From:	Christopher W. Stevens, PhD	**Project No:**	1CT022.004
Reviewed by:	Maritz Rykaart, PhD, PEng	**Date:**	November 22, 2016
Subject:	Hope Bay Project: Thermal Modelling to Support Run-of-Quarry Pad Design		

1 Introduction

The Hope Bay Project (the Project) is a gold mining and milling undertaking of TMAC Resources Inc. The Project is located 705 km northeast of Yellowknife and 153 km southwest of Cambridge Bay in Nunavut Territory, and is situated east of Bathurst Inlet. The Project comprises three distinct areas of known mineralization plus extensive exploration potential and targets. The three areas that host mineral resources are Doris, Madrid, and Boston.

The Project consists of two phases; Phase 1 (Doris project), which is currently being carried out under an existing Water Licence, and Phase 2 which is in the environmental assessment stage. Phase 1 includes mining and infrastructure at Doris only, while Phase 2 includes mining and infrastructure at Madrid and Boston located approximately 10 and 60 km due south from Doris respectively.

The Project site is located in the continuous permafrost region of Canada, and the overburden soils consist of marine clay, which in some areas are ice rich. These soils, if thawed, may not have sufficient bearing capacity to support important surface infrastructure such as roads or building foundations. Therefore, these structures must be founded on bedrock with the excavation of the overburden soils, or alternately the overburden soils must be kept frozen.

This memo presents thermal modelling carried out to estimate the minimum run-of-quarry (ROQ) (or geochemically suitable run-of-mine (ROM) waste rock) pad thickness required to ensure that the underlying overburden soils remain frozen. This includes consideration of heated buildings and a depressed freezing point as a result of pore water salinity.

The thermal modelling was performed for an operating design life of 20 years with consideration for climate change. At closure the ROQ pads will remain; however, since they no longer have to functionally perform as a structural foundation, thaw settlement and consolidation is acceptable.

2 Ground Conditions

2.1 Overburden

Laboratory and in-situ testing on disturbed and undisturbed geotechnical samples collected during previous drilling campaigns confirm that onshore overburden soils are comprised mainly of marine clays, silty clay and clayey silt, with pockets of moraine till underlying these deposits. Soils in the region are overlain by a thin veneer of hummocky organic soil (SRK 2016a). The marine clay (silty clay and clayey silt) is typically between 5 and 20 m thick, with variable pore water salinity typically between 37 and 47 parts per thousand (ppt.) (SRK 2016a). Ground ice is typically 10 to 30% by volume, but occasionally as high as 50%. Local till typically contains ice contents ranging from 5 to 25%.

The most prevalent rock type on site with surface exposure is mafic volcanics, predominantly basalt. In isolated locations there are small amounts of gabbro, felsic volcanic and granitoids.

2.2 Permafrost

Ground temperature measured at the Project site indicates an average permafrost temperature of −7.6°C, with a range from −5.6°C to −9.8°C (Figures 1 –4). These statistics are based on temperature measurements near the depth of zero annual amplitude from 37 baseline sites located in the Doris Mine, and the Madrid and Boston mining areas. The baseline ground temperature sites do not permit for separate assessment of permafrost temperatures at each of the three mining areas.

Average active layer thickness was calculated to average 1.0 m (range from 0.5 m to 1.4 m) for suitable measurements (Figures 1 and 2). The base of permafrost was calculated from 11 instrumented sites to average 398 mbgs, with a range from 78 mbgs to 570 mbgs depending on proximity to waterbodies (Figures 1 and 2). The geothermal gradient from deeper extents of permafrost was calculated to average 0.021°C m^{-1} (Figures 1 and 2).

3 Thermal Modelling

3.1 Approach

Thaw depth estimates were based on analytical and numerical models. Numerical simulation of conductive heat transfer under transient conditions was completed using the finite element model SVHeat version 6 developed by SoilVision Systems Ltd. and the FlexPDE Version 6.34 solver developed by PDE Solutions Inc. (SoilVision Systems 2004).

SVHeat one-dimensional (1D) model simulations were used to estimate thaw depth for areas not impacted by heated buildings (Section 4.1). Thaw depths beneath non-insulated buildings were based on a steady-state thermal model (Section 4.2). Further details of the steady state model can be found in Andersland and Ladanyi (2004). Thaw depths beneath insulated buildings were estimated using SVHeat two-dimensional (2D) model simulations (Section 4.3).

Multiple foundation temperatures (0°C, −1°C, and −2°C) were analyzed to assess the sensitivity of the results to changes in ROQ pad and/or insulation thickness. For design purposes, foundations were considered to be valid if the base of the pads remained colder than 0°C. Subsidence that occurs during normal operations would be considered manageable.

3.2 Model Inputs

3.2.1 Material Parameters

The material properties used in the thermal modelling are summarized in Table 1. Properties for the ROQ pads were taken from previous work performed by SRK at the Project site as described in SRK (2016a). Thermal properties for ridged polystyrene insulation were obtained from Andersland and Ladanyi (2004). The thermal properties for natural overburden clay were based on average soil properties and a freezing point depression of −2°C. An unfrozen water content curve for clay was included in the model with consideration for the freezing point depression in accordance with Banin and Anderson (1974). The thermal properties for peat represent measured values presented by Romanovsky and Osterkamp (2000).

Table 1: Material Thermal Properties

Material	Degree of Saturation (%)	Porosity	Thermal Conductivity, kJ/(m·day·°C)		Volumetric Heat Capacity, kJ/(m³·°C)	
			Unfrozen	Frozen	Unfrozen	Frozen
Run of Quarry	30	0.30	104	117	1,697	1,509
Polystyrene Insulation	0	-	3	3	38	38
Peat	100	0.65	48	138	2,600	2,200
Overburden Clay[1]	85	0.52	112	187	2,842	2,038

Notes:
1. Overburden clay includes a freezing point depression of −-2°C and unfrozen water content curve

3.2.2 Climate Boundary

A ground surface response curve was developed for the Project site, representing the ground temperature immediately below ground surface. The boundary condition was applied to the model as a sinusoidal function of temperature and time based on Equation 1 and the parameters shown in Table 2.

$$T = \max(nf * \left[MAAT + (C_A * t) + Amp * Sin\left(\frac{2\pi+(t+182.5)}{365}\right)\right], \text{nt} \left[MAAT + (C_A * t) + Amp * Sin\left(\frac{2\pi+(t+182.5)}{365}\right)\right] \quad \text{Eq.1}$$

Where:

- T *is the ground temperature measured in °C*
- nf *is the surface freezing n-factor*
- nt *is the surface thawing n-factor*
- $MAAT$ *is the mean annual air temperature measured in °C*
- Amp *is the air temperature amplitude measured in °C*
- C_A *is the air climate change factor in °C* d^{-1}
- t *is time measured in days*

Table 2: Model Climate Boundary Parameters

Thermal Model Parameter	Base Case	Sensitivity Values
Mean annual air temperature	−10.7°C	−10.7°C
Mean annual ground temperature[1]	−7.6°C	−7.6°C
Air temperature amplitude	21.0°C	21.0°C
Air climate change factor (C_A)	0.000203°C d^{-1}	0.000203°C d^{-1}
ROQ surface thawing n-factor (*nt*)	1.52	1.25^C and 2.01^w
ROQ surface freezing n-factor (*nf*)	0.86	1.02^C and 0.60^W
Geothermal gradient	0.021°C/m	0.021°C/m

Notes:
1. Mean annual air temperature for 2015 based on “R” analysis climate change projection for Doris Mining Area
2. Mean annual ground temperature based on average temperature near the depth of zero annual amplitude
3. Superscript C indicated cold case n-factor scenario and W indicates warm n-factors scenario

Mean annual air temperature (−10.7°C) is based on average “R” analysis values for the baseline period of 1979 to 2005 and adjusted to 2015 values based on climate change predictions (SRK 2016b). This mean annual air temperature is consistent with the average measured Doris air temperature in 2015 (−10.8°C) (ERM 2016).Amplitude is based on average “R” analysis values for the baseline period (SRK 2016b).

Seasonal n-factors are applied as multipliers of air temperature to estimate the ground surface temperature at the pad surface. The ROQ n-factors were based on average published values (Table 3). A ROQ freezing n-factor (*nf*) of 0.86 and thawing n-factor (*nt*) of 1.52 is considered reasonable base case conditions for the Project site.

Table 3: Published N-factors for Gravel Surfaces

Surface Type	Site	Source	*nt*	*nf*
Sand and Gravel	Fairbanks, Alaska	US Army Corps. (1950)	2.00	0.90
Gravel	Fairbanks, Alaska	US Army Corps. (1950)	1.99	0.76
Gravel	Fairbanks, Alaska	US Army Corps. (1950)	2.01	0.63
Gravel	Fairbanks, Alaska	Carlson and Kersten (1953)	1.40	0.60
Gravel	Chitina, Alaska	Esch (1973)	1.47	1.00
Gravel - Dark color	Fairbanks, Alaska	Berg and Aitken (1973)	1.40	-
Gravel	Fairbanks, Alaska	US Army (1972)	1.50	-
Gravel - Dark color	Fairbanks, Alaska	US Army (1972)	1.27	-
Gravel	Inuvik, NWT, Canada	Johnston (1982)	1.33	0.96
Gravel	Inuvik, NWT, Canada	Johnston (1982)	1.49	0.94
Gravel	Inuvik, NWT, Canada	Johnston (1982)	1.33	0.88
Gravel	Inuvik, NWT, Canada	Johnston (1982)	1.36	0.91
Gravel	Inuvik, NWT, Canada	Johnston (1982)	1.48	1.02

Surface Type	Site	Source	*nt*	*nf*
Gravel	North Slope, Alaska	Klene et al. (2001)	1.25	-
		Average	**1.52**	**0.86**
		Minimum	**1.25**	**0.60**
		Maximum	**2.01**	**1.02**
		Standard Deviation	**0.26**	**0.14**
		Count	**14**	**10**

Notes:
1. Thawing n-factor (nt) and freezing n-factor (nf)

A conservative geothermal gradient of 0.021°C m^{-1} was applied to the lower boundary of the model which is consistent with average conditions measured at the Project site.

Climate change is considered in Equation 1 using the air climate change factor. This factor allows for a daily increase in air temperature. Air temperature is projected to increase by 2.6°C (0.74°C per decade) at Doris and 2.0°C (0.58°C per decade) at Boston between the period of 1979-2005 and 2011-2040, respectively. The rate of change projected for Doris was adopted as a more conservative input parameter to the model. The air climate change factor applied to Equation 1 in the model was 0.000203°C d^{-1} which is equivalent to an increase of 0.74°C per decade.

4 Model Results

4.1 Thaw Penetration Depth

A transient 1D model was constructed in SVHeat to estimate thaw penetration depth for ROQ pads for areas not thermally impacted by heated buildings and other surface infrastructure. The model was based on the input parameters outlined Table 2 and a sinusoidal surface ground temperature with average n-factors applied. All model runs consisted of 0.10 m peat underlain by clay which extended to 10 m below the base of the ROQ pad (Figure 5).

The model simulations are relatively simplistic as they do not account for lateral heat flow. Heat transported by surface water and near surface groundwater is also not accounted for in the model and would be expected to alter thermal conditions within and beneath the pad. However, at this level of design, the simplistic 1D model simulations are deemed appropriate.

Figure 5 summarizes the depth of the 0°C, −1°C, and −2°C isotherm for different ROQ pad thicknesses. The depths are relative to the base of the pad. The model estimates a minimum pad thickness of 1.9 m would be required to maintain the 0°C isotherm at the base of the pad assuming average n-factors. A minimum pad thickness of 2.2 m and 2.7 m were estimated to maintain the −1°C and −2°C isotherms at the base of the pad, respectively. For general design purposes, it is estimated that a minimum pad thickness of 1.9 m would be required.

The increase in active layer thaw below the pad for the 0°C, −1°C, and −2°C isotherms over the 20-year design life is shown in Figures 6 through 8. Seasonal thaw is estimated to increase over time due to increasing surface temperature described by Equation 1.

Figure 9 shows the sensitivity of thaw depth to changes in surface n-factors. A Cold Case and Warm Case scenario was modelled using the literature n-factors. The Cold Case represents the minimum thawing n-factor and maximum freezing n-factors presented in Table 3. The Warm Case represents the maximum thawing and minimum freezing n-factors presented in Table 3. The estimated pad thickness required to maintain the 0°C isotherm within the pad is 1.4 m and 2.9 m for the Cold Case and Warm Case, respectively.

4.2 Heated Buildings with Non-Insulated Foundation

The following section estimates thaw depth for heated buildings with non-insulated foundations constructed over a ROQ pad surface. Thaw depth calculations presented in this section were based on a steady-state heat strip method. Buildings are assumed to be rectangular with the plotted widths equal to the smallest dimension. Analyses were completed for buildings with the smallest dimension (width) ranging from 0 to 20 m and for interior temperatures from 5 to 30°C. The steady-state model assumes average interior temperature throughout the entire year and average ground temperatures.

The steady-state thaw depth for a heated building with no foundation insulation to maintain 0°C, −1°C, and −2°C isotherms within the ROQ pad is shown in Figures 10 through 12. The steady-state thaw depths are in general agreement with SVHeat numerical model simulations. The results show a linear relationship between the required pad thickness (thaw depth) and the minimum building dimension for buildings less than 20 m wide. As the building width increases, this relationship becomes non-linear with resultant increase in the required pad thickness. This analysis indicates that an insulated foundation is required for most heated buildings to maintain a foundation temperature below 0°C.

4.3 Heated Buildings with Insulated Foundations

The thaw depth for heated buildings with insulated foundations was analyzed using 2D SVHeat models. The transient models were based on the following:

- Polystyrene board insulation applied on top of the ROQ pad with a width equal to the building (thermal properties shown in Table 1);
- Simulations based on insulation ranging from 0 m to 0.5 m thick;
- Minimum building dimension of 20 m;
- Internal building heat at 5°C, 10°C, 15°C, 20°C, 30°C; and
- A sinusoidal surface ground temperature surrounding the building based on Equation 1 (see Table 2 for base case input parameters).

The results of the analysis are provided in Figures 13 through 5. The figures show combinations of ROQ pad and insulation thicknesses required to maintain the 0°C, −1°C, and −2°C isotherms within the pad material for different interior building temperatures.

The model results indicate that increasing the insulation thickness from 0.1 m to 0.2 m for a building heated to 30°C and assuming a thawing point of 0°C will reduce the required pad thickness from 16.8 m to 12.5 m (i.e. 100 mm insulation is equivalent to 4.3 m of ROQ pad). A further increase in insulation thickness from 0.2 m to 0.3 m will reduce the ROQ pad thickness by an additional 2.7 m from 12.5 m to 9.8 m.

The following example is provided to estimate the ROQ pad and insulation thickness requirements for a heated building with a minimum dimension other than 20 m.

Example: 10 m wide building heated to a constant internal temperature of 5°C and a thaw temperature of 0°C.

Step 1: Select a desired insulation thickness (0.1 m).

Step 2: From Figure 13 (thaw temperature of 0°C), a 0.1 m insulation layer for a 20 m wide building is estimated to require a ROQ pad thickness of 2.5 m.

Step 3: From Figure 10, a 10 m wide building requires approximately 50% of the ROQ pad thickness compared to a 20 m wide building (3.7 m vs. 7.5 m).

Step 4: Therefore, for a 0.1 m insulation layer, approximately 1.25 m of ROQ pad is required (50% of 2.5 m).

5 Conclusion

The analysis presented, which only includes thermal conduction, suggest that a ROQ (or geochemically suitable waste rock) pad design thickness of at least 1.9 m is required to maintain the 0°C isotherm at the base of the pad for areas not thermally impacted by heated buildings and other surface infrastructure. This assumes a 20-year design life with allowance for climate change. A minimum pad thickness of 2.2 m and 2.7 m are estimated to maintain the −1°C and −2°C isotherms at the base of the pad, respectively under the same conditions. For typical design purposes, the 0°C isotherm should be maintained within the pad to limit any potential subsidence to a manageable level.

A greater pad thickness as well as possible foundation insulation would be required to maintain thaw penetration within the pad for areas thermally influenced by heated buildings. For large heated buildings, it is likely that additional preventative measures are required to prevent permafrost degradation. These may include:

- Building footings or piles which raise the building from the ground surface and allow for circulation of cold air;
- Placement of thermosyphons beneath the buildings; or
- Placement of metal pipe ducts in the pads beneath the buildings to provide air circulation.

The conservatism built into the thermal analysis presented in this memo has been discussed. However to put into context, it is worth considering the performance of the ROQ rock fill roads, airstrip and general building pads that currently exist at the Project site, both at the Doris and Boston mining areas.

Underground development rock was used in 1996 and 1997 to construct a rock fill pad at the Boston site, as well as an airstrip and an all-weather access road to link these facilities. Because the material is mine development rock, it is predominantly 150 mm minus size material. The pads and the airstrip is nominally 1 m thick, and the all-weather road is less than 0.5 m thick.

At the Doris site, significant infrastructure has been constructed including almost 20 km of all-weather road, a 1.5 km long airstrip and multiple very large construction pads and laydown areas. All of these facilities were constructed with ROQ material with a maximum rock fill size of 1 m. The roads, airstrip and various pads range in thickness from nominally 1 m to greater than 4 m; however, the predominant thickness is about 1 m. These facilities were constructed between 2007 and 2012, and consisted of both summer and winter construction.

Geotechnical inspections have been carried out annually at the Boston site since 2007 (SRK 2016c), and at the Doris site since 2009 (SRK 2016d). These inspections have confirmed that all pads, roads and airstrips have performed well and there have been no signs that suggest significant permafrost degradation has occurred, or are likely to start in the near term. Since many of these structures have thicknesses less than the recommended minimum design depth stated in this memo, it demonstrates that the calculated minimum design depths are conservative and that thinner pads can be constructed and evaluated using the observational approach over the life of the Project.

6 References

Andersland, O.B., and Ladanyi, B. 2004. Frozen Ground Engineering 2nd Edition. John Wiley and Sons, Inc. Hoboken, New Jersey.

Banin A, Anderson DM. 1974. Effects of Salt Concentration Changes During Freezing on the Unfrozen Water Content of Porous Materials. Water Resources Research 10: 124-128.

Berg, R.L., and Aitken, G.W. 1973. Some Passible Methods of Controlling Geocryological Conditions in Roadway Construction. Second International Conference on Permafrost. Yakutsk USSR. 581-586.

Carlson, H. and Kersten, M.S. 1953. Calculation of depths of freezing and thawing under pavements. Highw. Res. Board, Bull. No. 71, Discuss. by H.P. Aldrich and H.M. Paynter. 81-98.

ERM Group Inc. 2016. Daily 2012 to 2016, Doris and Boston, wind, temp; for SRK.xlsx. Excel sheet provided to SRK.

Esch, D.C. 1973. Control of Permafrost Degradation Beneath a Roadway by Subgrade Insulation. Second International Conference on Permafrost. Yakutsk USSR. 608-622.Johnston, G.H. 1982. Design and Performance of the Inuvik, N.W.T., Airstrip. Proceedings from the 4th Canadian Permafrost Conference. 577-585.

Klene, A.E., Nelson, F.E., Shiklomanov, N.I., and Hinkel, K.M. 2001. The N-factor in Natural Landscapes: Variability of Air and Soil-surface Temperatures, Kuparuk River Basin, Alaska, U.S.A. Arctic, Antarctic, and Alpine Research. 22: 140-148.

Romanovsky V.E., and Osterkamp, T.E. 2000. Effects of Unfrozen Water on Heat and Mass Transport Processes in the Active Layer and Permafrost. Permafrost and Periglacial Processes 11: 219-239.

SoilVision Systems, 2004. SVHeat Tutorial Manual, Theory Manual, Verification Manual. SoilVision Systems, Ltd. Saskatoon, Sask.

SRK Consulting (Canada) Inc. 2016a. Hope Bay Project, Geotechnical Design Parameters and Overburden Summary Report. Report prepared for TMAC Resources Inc. Project No.: 1CT022.004. 2016.

SRK Consulting (Canada) Inc. 2016b. Hope Bay Project, Climate Change Analysis. Report prepared for TMAC Resources Inc. Project No.: 1CT022.004. 2016.

SRK Consulting (Canada) Inc.2016c. Boston Advanced Exploration Project: 2015 Annual Geotechnical Inspection. Report prepared for TMAC Resources Inc. Project No.:1CT022.002. 2016.

SRK Consulting (Canada) Inc. 2016d. Doris North Project 2015 Annual Geotechnical Inspection. Report prepared for TMAC Resources Inc. Project No.:1CT022.002. 2016.

U.S. Army Corps of Engineering, 1950. Comprehensive Report Investigation of Military Construction in Arctic and Subarctic Regions 1945-1948.

U.S. Army. 1972. Meta Data Report. Farmers Loop Road Test Site. Fairbanks, Alaska.

Figures

Station ID	Northing	Easting	Location	Area	Data Exclusion and Limitations (See Notes)	ALT Average (m)	ALT Minimum (m)	ALT Maximum (m)	AL n	Geothermal Gradient (°C/m)	Base of Permafrost (mbgs)	Permafrost Temperature (°C)
SRK-11	7,559,117	434,347	North Dam	Doris Mining Area	1,4,5	<3.8	-	-	-	-	-	-7.9
SRK-13	7,559,172	434,383	North Dam	Doris Mining Area	6	-	-	-	-	-	-	-
SRK-14	7,559,059	434,292	Near North Dam	Doris Mining Area	1,5	1.3	1.0	1.4	11	-	-	-9
SRK-15	7,559,172	434,383	North Dam	Doris Mining Area	1,3,5	-	-	-	-	-	-	-8.1
SRK-16	7,559,092	434,323	North Dam	Doris Mining Area	1,4,5	<3.3	-	-	-	-	-	-9.8
SRK-19	7,563,212	432,984	Beach Laydown Area	Roberts Bay	1,4,5	<0.9	-	-	-	-	-	-7.6
SRK-20	7,563,130	432,986	Beach Laydown Area	Roberts Bay	1,5	0.9	0.7	1.1	4	-	-	-7.3
SRK-22	7,562,027	432,972	East of Doris Airstrip	Roberts Bay	1,4,5	<0.7	-	-	-	-	-	-7.7
SRK-23	7,561,666	432,902	South Apron Doris Airstrip	Roberts Bay	1,4,5	<0.9	-	-	-	-	-	-7.9
SRK-24	7,559,494	432,344	Near crusher at Q2	Doris Mining Area	1,4,5	<0.7	-	-	-	-	-	-7.3
SRK-26	7,558,820	433,422	Junction Doris Rd and Tail Lk Road	Doris Mining Area	1,4,5	<0.8	-	-	-	-	-	-8.8
SRK-28	7,559,046	433,043	Camp Pad	Doris Mining Area	1,4,5	<0.8	-	-	-	-	-	-8.1
SRK-32	7,555,915	435,555	South Dam Area	Doris Mining Area	1,5	1.1	0.9	1.4	7	-	-	-8.4
SRK-33	7,555,930	435,614	South Dam Area	Doris Mining Area	1,4,5	<0.7	-	-	-	-	-	-8.7
SRK-34A	7,555,942	435,641	South Dam Area	Doris Mining Area	1,4,5	<0.9	-	-	-	-	-	-8.1
SRK10-DCB2	7,559,478	434,037	Doris Creek Bridge Abutment East	Doris Mining Area	2	-	-	-	-	-	-	-
SRK10-DCB1	7,559,475	434,068	Doris Creek Bridge Abutment West	Doris Mining Area	2	-	-	-	-	-	-	-
SRK-35	7,559,478	434,036	Doris Creek - West	Doris Mining Area	1,5	0.5	0.5	0.5	2	-	-	-6.2
SRK-37	7,559,091	434,329	North Dam	Doris Mining Area	1,3,5	-	-	-	-	-	-	-8.2
SRK-38	7,558,254	434,526	Tail Lake West Side	Doris Mining Area	1,3,5	-	-	-	-	-	-	-8.1
SRK-39	7,556,391	435,164	Tail Lake West Side	Doris Mining Area	1,3,5	-	-	-	-	-	-	-7.7
SRK-40	7,558,547	435,492	Tail Lake East Side	Doris Mining Area	1,3,5	-	-	-	-	-	-	-8.7
SRK-41	7,559,129	434,359	North Dam Area	Doris Mining Area	1,3,5	-	-	-	-	-	-	-7.2
SRK-42	7,559,081	434,403	North Dam Area	Doris Mining Area	1,3,5	-	-	-	-	-	-	-8
SRK-43	7,555,924	435,585	South Dam Area	Doris Mining Area	1,3,5	-	-	-	-	-	-	-8.7
SRK-50	7,559,177	433,807	Doris Lake North End	Doris Mining Area	1,3	-	-	-	-	0.019	394	-5.6
SRK-51	7,559,166	434,391	North Dam Area	Doris Mining Area	1,5	0.7	0.6	0.7	3	-	-	-
SRK-52	7,559,083	434,316	North Dam Area	Doris Mining Area	1,5	0.7	0.7	0.8	3	-	-	-
SRK-53	7,556,907	435,184	Tail Lake West Side	Doris Mining Area	1,5	1.0	0.8	1.2	6	-	-	-6.6
SRK-54	7,556,467	435,632	Tail Lake East Side	Doris Mining Area	1,5	1.2	1.1	1.3	4	-	-	-6.9
SRK-55	7,557,813	434,936	Tail Lake West Side	Doris Mining Area	6	-	-	-	-	-	-	-
SRK-56	7,558,258	435,334	Tail Lake East Side	Doris Mining Area	6	-	-	-	-	-	-	-
SRK-57	7,557,812	434,938	Tail Lake West Side	Doris Mining Area	1,4,5	<3.3	-	-	-	-	-	-8.1
SRK-58	7,557,705	435,285	Tail Lake East Side	Doris Mining Area	1,5	1.0	0.9	1.1	2	-	-	-7
SRK-62	7,558,995	434,501	Tail Lake North End	Doris Mining Area	1,5	0.9	0.9	1.0	4	-	-	-
TM00141	7,546,691	435,141	Patch Lake	Madrid Mining Area	1,3,5	-	-	-	-	0.023	346	-
SRK-JT1-09	7,563,297	432,534	Jetty	Roberts Bay Jetty	2	-	-	-	-	-	-	-
SRK-JT2-09	7,563,264	432,550	Jetty	Roberts Bay Jetty	2	-	-	-	-	-	-	-
SRK-JT2-12	7,563,264	432,550	Jetty	Roberts Bay Jetty	2	-	-	-	-	-	-	-
08SBD380	7,504,780	441,080	South of Boston Camp	Boston Mining Area	1,3	-	-	-	-	0.017	565	-7.1
08SBD381A	7,504,814	441,070	South of Boston Camp	Boston Mining Area	1,3	-	-	-	-	0.029	281	-6.1
08SBD382	7,505,141	441,026	South of Boston Camp	Boston Mining Area	1,3	-	-	-	-	0.027	302	-6.2
08PMD669	7,550,955	433,300	Between Patch and Windy Lakes (N)	Madrid Mining Area	1,3	-	-	-	-	0.018	570	-7.6
08PSD144	7,548,990	435,178	Patch Lake Island	Madrid Mining Area	5,8	-	-	-	-	-	78	-
08TDD632	7,559,370	433,915	West Side Doris Lake N	Doris Mining Area	1	-	-	-	-	0.024	445	-6.7
08TDD633	7,557,646	433,402	West Side Doris Lake	Doris Mining Area	6	-	-	-	-	-	-	-
10WBW001	7,557,537	433,778	Beneath Doris Lake	Doris Mining Area	7	-	-	-	-	-	-	-
10WBW002	7,559,375	433,913	Doris Site	Doris Mining Area	1,3,5	-	-	-	-	0.014	511	-7.1
10WBW004	7,505,665	441,018	Boston Site	Doris Mining Area	1,3	-	-	-	-	0.018	326	-6.1
12259-97-01 / DH#1	7,565,768	431,165	Onshore West Side of Roberts Bay	Roberts Bay	6	-	-	-	-	-	-	-
12259-97-8 / DH#8	7,565,625	431,130	Onshore West Side of Roberts Bay	Roberts Bay	8	-	-	-	-	-	-	-
12259-97-17 / DH#17	7,565,520	431,211	Onshore West Side of Roberts Bay	Roberts Bay	8	-	-	-	-	-	-	-
12259-03	7,504,380	441,113	Boston Site	Boston Mining Area	1,5	0.9	0.8	0.9	2	-	-	-7.0
12259-05	7,504,778	441,172	Boston Site	Boston Mining Area	6	-	-	-	-	-	-	-
12259-96-06	7,505,683	441,327	Boston Site	Boston Mining Area	1,5	1.7	1.6	1.7	2	-	-	-7.8
97NOD176	7,504,962	441,481	Boston Site	Boston Mining Area	1,3,5	-	-	-	-	0.019	556	-9.0

Notes:

1. Statistics shown on Figure 2
2. See Notes on Figure 3

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TMAC RESOURCES

Job No: 1CT022.004

Filename: PermafrostCharacteristics.pptx

HOPE BAY PROJECT

Infrastructure Thermal Modeling

Permafrost Characteristics from Baseline Measurements

Date:	Approved:	Figure:
4/18/2016	cws	1

Station ID	Northing	Easting	Location	Area	Data Exclusion and Limitations (See Notes)	ALT Average (m)	ALT Minimum (m)	ALT Maximum (m)	AL n	Geothermal Gradient (°C/m)	Base of Permafrost (mbgs)	Permafrost Temperature (°C)
CX3(3)-13	-	-	Boston UG Workings	Boston Mining Area	6	-	-	-	-	-	-	-
TDD-242	-	-	-	Doris Mining Area	8	-	-	-	-	-	-	-
TDD-261	-	-	-	Doris Mining Area	6	-	-	-	-	-	-	-
DB#27-H	-	-	Boston UG Workings	Boston Mining Area	6	-	-	-	-	-	-	-
DB#27-V	-	-	Boston UG Workings	Boston Mining Area	6	-	-	-	-	-	-	-
DB#36	-	-	Boston UG Workings	Boston Mining Area	6	-	-	-	-	-	-	-
SRK-12-GTC-DH01	7,558,917	433,169	Pollution Control Pond	Doris Mining Area	2	-	-	-	-	-	-	-
SRK-12-GTC-DH02	7,558,913	433,225	Pollution Control Pond	Doris Mining Area	2	-	-	-	-	-	-	-
SRK-12-GTC-DH03	7,558,931	433,225	Pollution Control Pond	Doris Mining Area	2	-	-	-	-	-	-	-
SRK10-DWB1	7,555,674	432,703	Doris-Windy Road Bridge #2	Madrid Mining Area	2	-	-	-	-	-	-	-
SRK10-DWB2	7,555,644	432,708	Doris-Windy Road Bridge #2 / #3	Madrid Mining Area	2	-	-	-	-	-	-	-
SRK10-DWB3	7,556,150	432,713	Doris-Windy Road Bridge #3	Madrid Mining Area	2	-	-	-	-	-	-	-
SRK10-DWB4	7,554,860	432,444	Doris-Windy Road Bridge #4	Madrid Mining Area	2	-	-	-	-	-	-	-
SRK10-DWB5	7,554,831	732,437	Doris-Windy Road Bridge #4	Madrid Mining Area	2	-	-	-	-	-	-	-
ND-HTS-040-31.5	7,559,101	434,324	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-HTS-040-33.5	7,559,101	434,324	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-VTS-040-KT	7,559,101	434,324	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-VTS-060-DS	7,559,115	434,338	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-HTS-060-33.5	7,559,115	434,338	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-HTS-060-31.0	7,559,115	434,338	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-HTS-060-28.8	7,559,115	434,338	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-VTS-060-KT	7,559,115	434,338	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-VTS-060-US	7,559,107	434,346	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-VTS-085-DS	7,559,134	434,354	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-HTS-085-25.3	7,559,134	434,354	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-HTS-085-29.4	7,559,134	434,354	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-HTS-085-33.5	7,559,134	434,354	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-VTS-085-KT	7,559,134	434,354	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-VTS-085-US	7,559,125	434,363	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-VTS-130-DS	7,559,167	434,384	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-HTS-130-28.8	7,559,167	434,384	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-HTS-130-31.0	7,559,167	434,384	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-HTS-130-33.5	7,559,167	434,384	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-VTS-130-KT	7,559,167	434,384	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-VTS-130-US	7,559,158	434,394	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-HTS-175-32.5	7,559,201	434,415	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-HTS-175.33.5	7,559,201	434,415	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
ND-VTS-175-KT	7,559,201	434,415	North Dam	Doris Mining Area	2	-	-	-	-	-	-	-
					Average	**1.0**	**-**	**-**	**-**	**0.021**	**398**	**-7.6**
					Minimum	**-**	**0.5**	**-**	**-**	**0.014**	**78**	**-9.8**
					Maximum	**-**	**-**	**1.7**	**-**	**0.029**	**570**	**-5.6**
					n	**12**	**12**	**12**	**50**	**10**	**11**	**37**

Notes:

1. See Notes on Figure 3

srk consulting

TMAC RESOURCES

Job No: 1CT022.004

Filename: PermafrostCharacteristics.pptx

HOPE BAY PROJECT

Infrastructure Thermal Modeling

Permafrost Characteristics from Baseline Measurements

Date: 4/18/2016

Approved: cws

Figure: 2

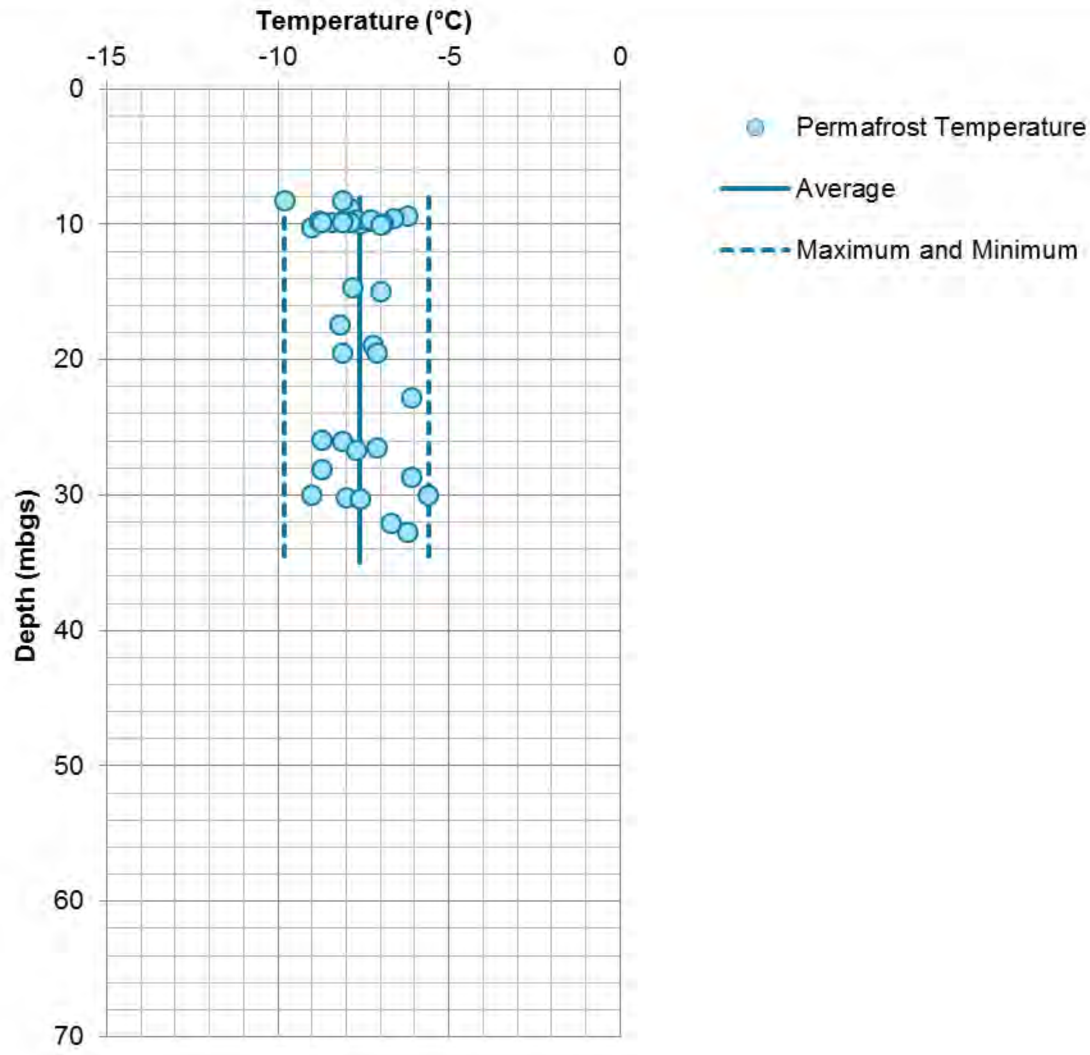
Notes:

Table Headings

1. Station ID – Thermistor cable identification
2. Northing and Easting – Universal Transverse Mercator coordinates for Stations (UTM NAD 83 Zone 13 N)
3. Location and Area provides descriptive location of the Station
4. Data Exclusion and Limitations index provided below
5. ALT Average – Average active layer thickness calculated for years with suitable data
6. ALT Minimum – Minimum active layer thickness calculated for years with suitable data
7. ALT Maximum – Maximum active layer thickness calculated for years with suitable data
8. AL n – Number of individual years with data suitable for active layer measurement
9. Geothermal Gradient – Calculated thermal gradient of deep permafrost for depths greater than 100 m
10. Base of Permafrost – Estimated bottom position of permafrost based on 0°C isotherm
11. Permafrost Temperature – Calculated between 8 and 33 m below ground surface based on data availability

Data Exclusion and Limitations Index

1. Baseline data used for permafrost characterization and statistics
2. Data excluded, monitoring site is not part of baseline monitoring
3. Measurement frequency, sensor position, and/or spacing not appropriate for estimation of active layer thickness
4. Active layer thickness constrained by upper sensor located within permafrost, value not included in statistics
5. Sensor position not appropriate for calculation of select permafrost characteristics
6. Insufficient data for analysis
7. Permafrost absent at instrumented site
8. Data in graphical form and not digital for exact calculation of temperature



Minimum Temperature	-9.8°C
Maximum Temperature	-5.6°C
Average Temperature	-7.6°C
Number of Stations	37

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TMAC RESOURCES

Infrastructure Thermal Modeling

Permafrost Temperature

Job No: 1CT022.004

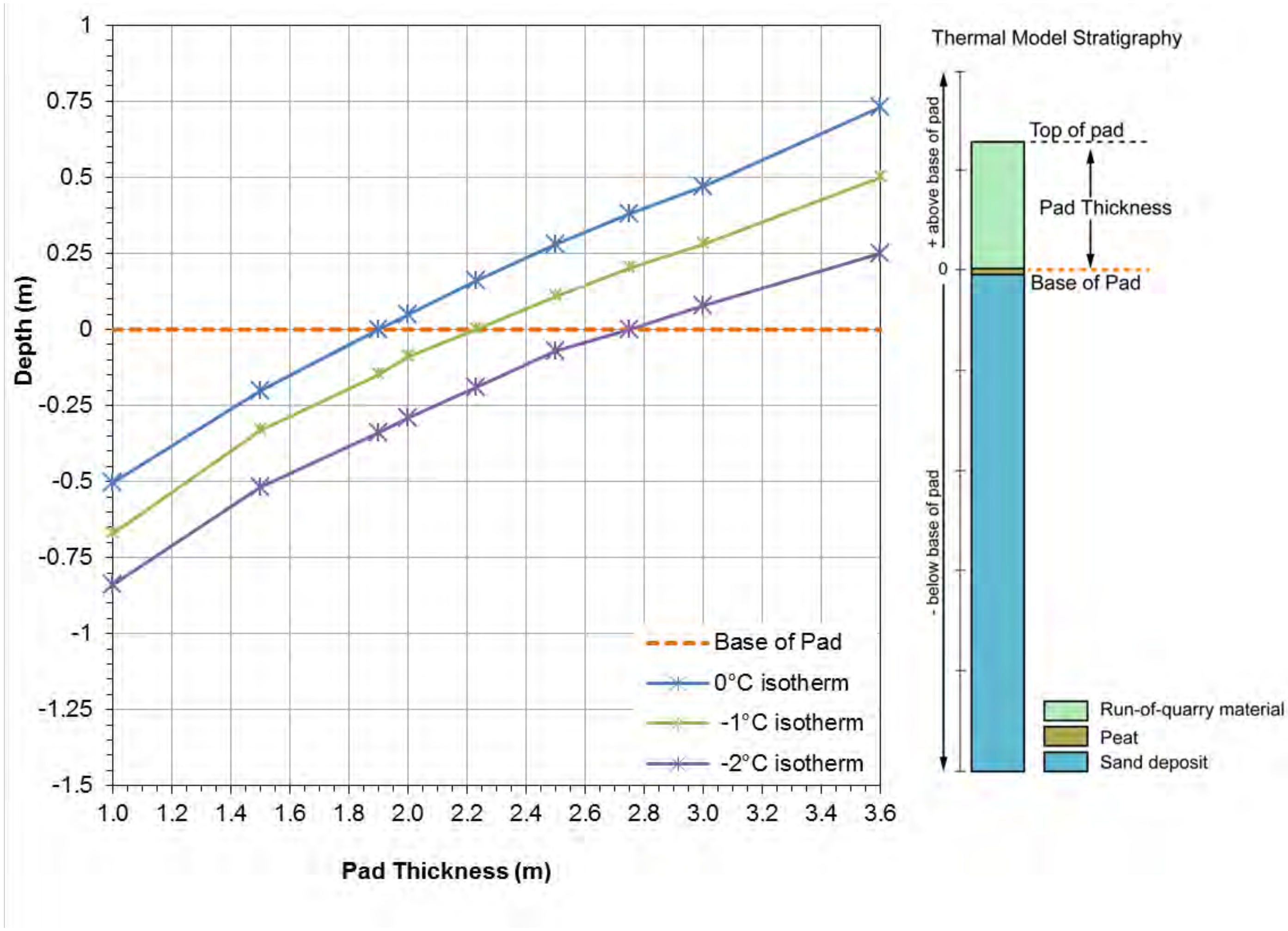
Filename: PermafrostTemperature_NearZeroAnnualAmp.pptx

HOPE BAY PROJECT

Date: 4/18/2016

Approved: cws

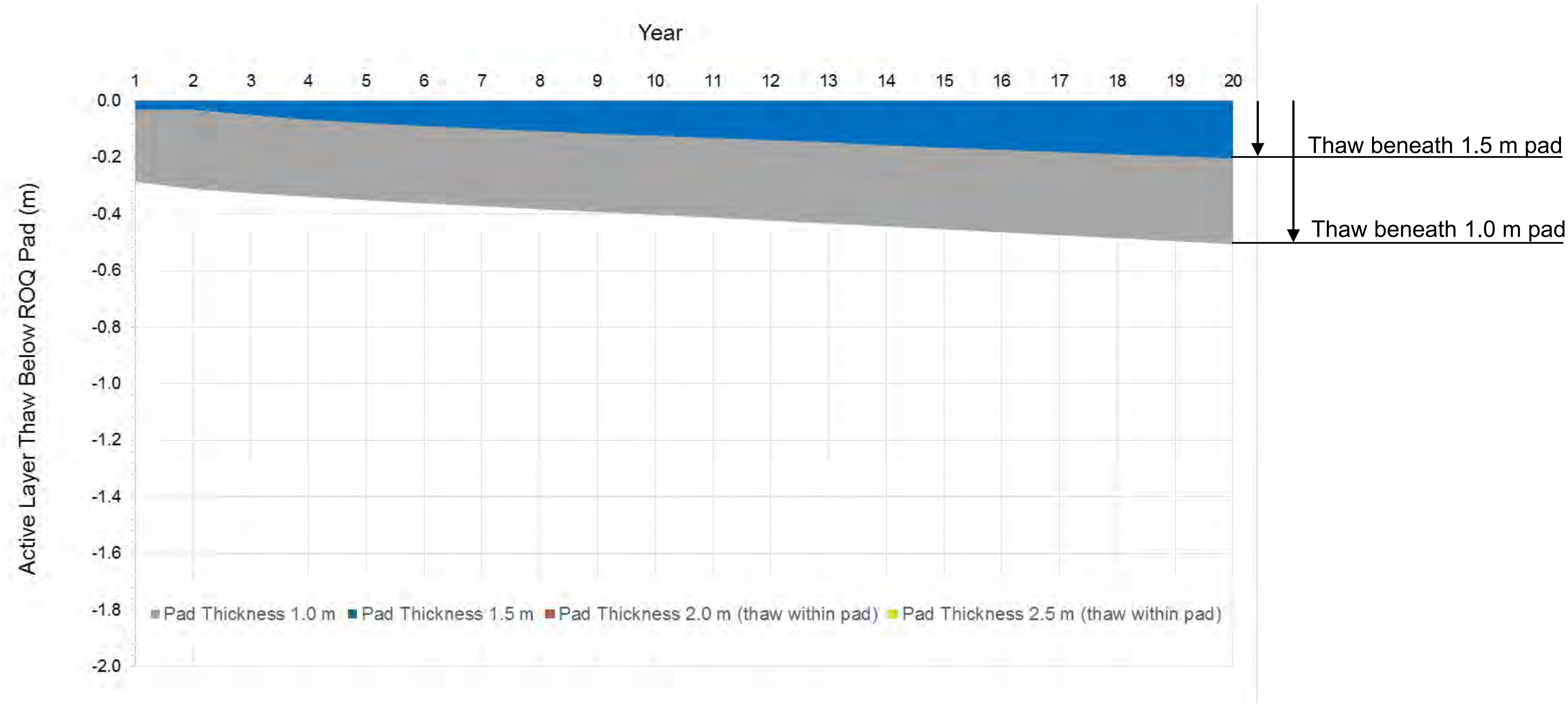
Figure: 4



Notes:

1. ROQ pad active layer for model year 20
2. Surface n-factors, nf 0.86, nt 1.52, average literature values
3. Active layer depth referenced from base of ROQ Pad

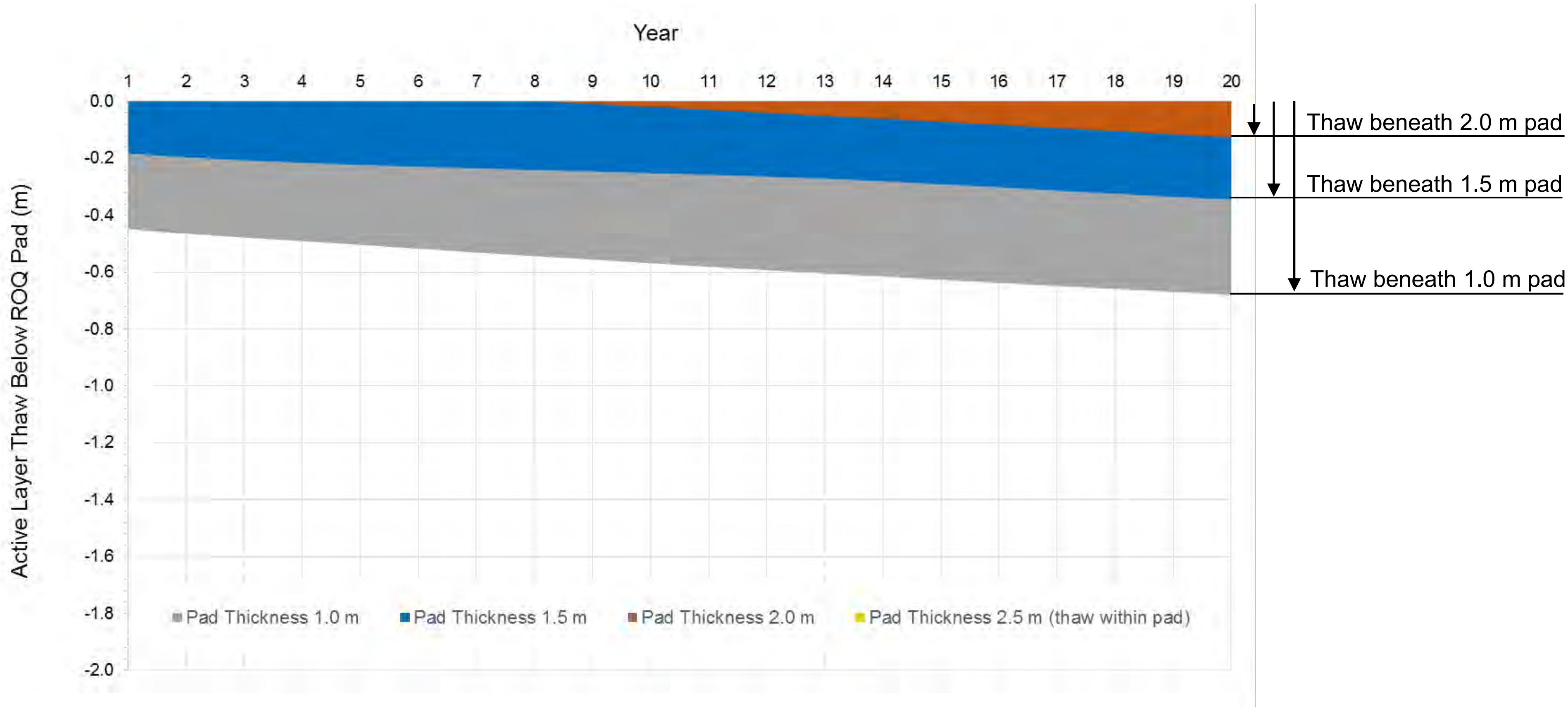
srk consulting	TMAC RESOURCES	Infrastructure Thermal Modeling **ROQ Pad Active Layer – Model Year 20**
Job No: 1CT022.004 Filename: ROQ_ActiveLayer_ModelYear20.pptx	HOPE BAY PROJECT	Date: 4/18/2016 Approved: cws Figure: 5



Notes:

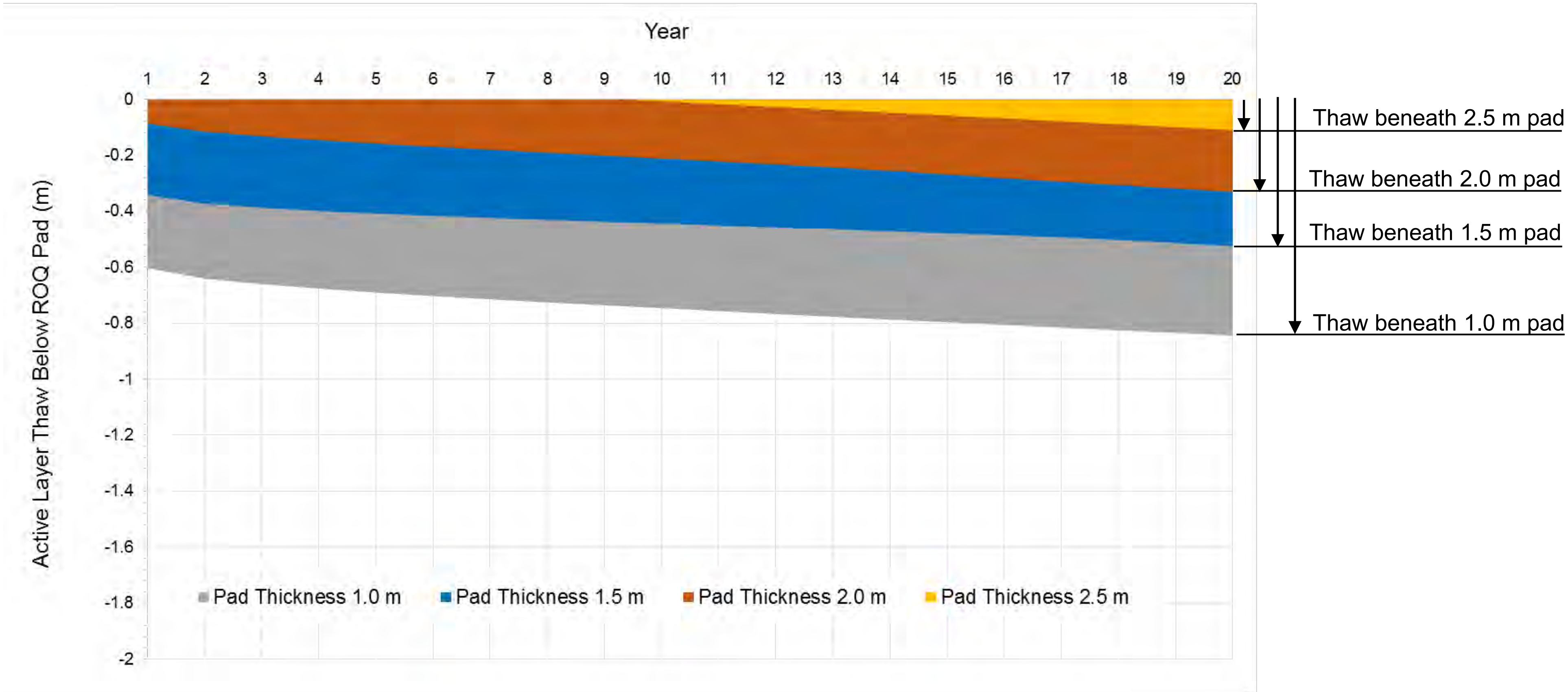
1. Active layer thaw below base of ROQ pad
2. Thaw based on 0°C isotherm for model year 1 to 20
3. Surface n-factors, nf 0.86, nt 1.52, average literature values
4. Thaw is above the base of the pad for a ROQ pad >1.9 m thick

srk consulting	TMAC RESOURCES	Infrastructure Thermal Modeling
		ROQ Pad Active Layer, 0°C Isotherm – Model Year 1 to 20
Job No: 1CT022.004 Filename: ROQ_ActiveLayer_ModelYear1to20.pptx	HOPE BAY PROJECT	Date: 4/18/2016 · Approved: cws · Figure: 6



Notes:
1. Active layer thaw below base of ROQ pad
2. Thaw based on -1°C isotherm for model year 1 to 20
3. Surface n-factors, nf 0.86, nt 1.52, average literature values
4. Thaw is above the base of the pad for ROQ pad >2.2 m thick

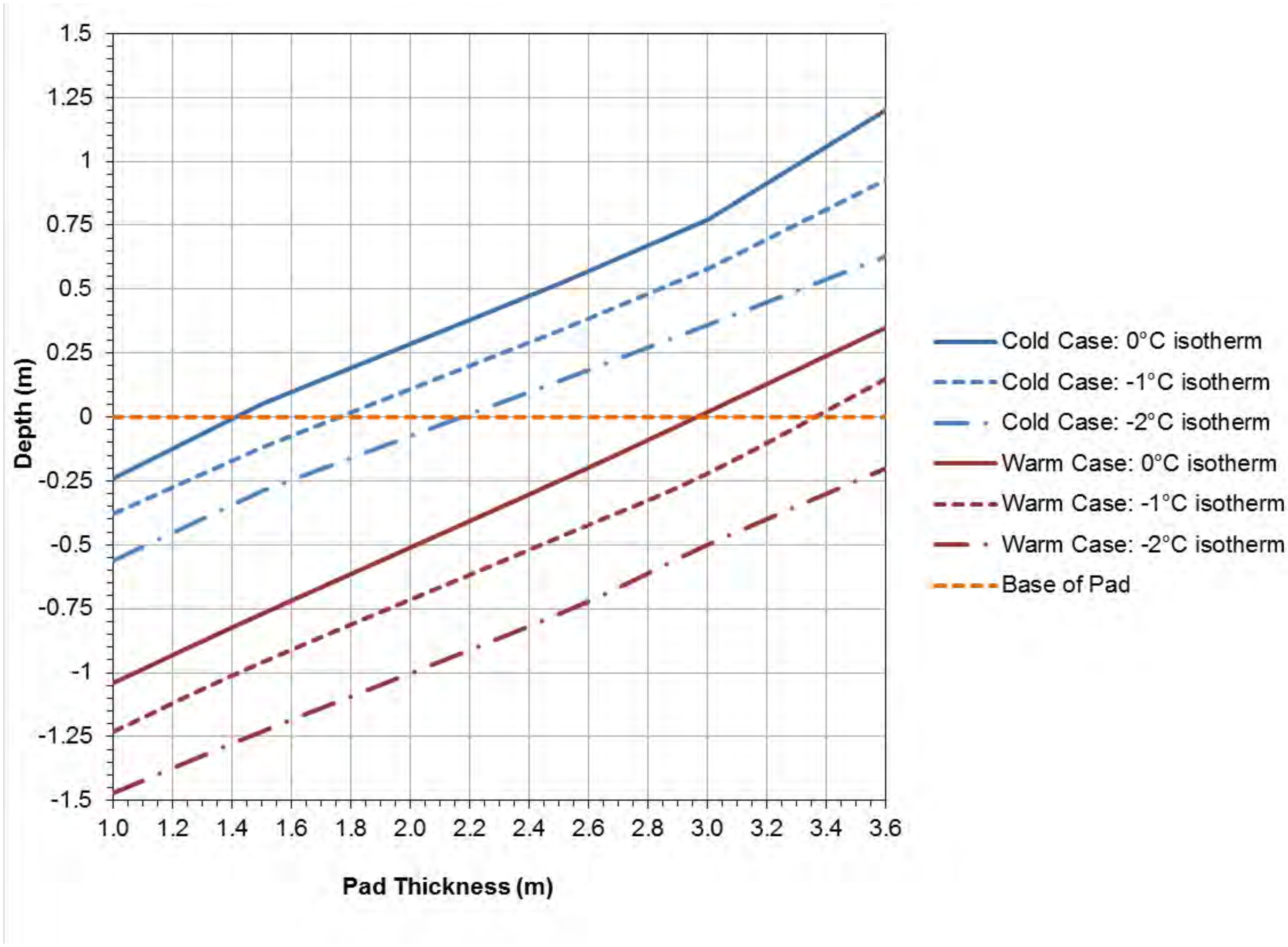
srk consulting	TMAC RESOURCES	Infrastructure Thermal Modeling **ROQ Pad Active Layer, -1°C Isotherm – Model Year 1 to 20**
Job No: 1CT022.004 Filename: ROQ_ActiveLayer_ModelYear1to20.pptx	HOPE BAY PROJECT	Date: 4/18/2016 · Approved: cws · Figure: 7



Notes:

1. Active layer thaw below base of ROQ pad
2. Thaw based on -2°C isotherm for model year 1 to 20
3. Surface n-factors, nf 0.86, nt 1.52, average literature values
4. Thaw is above the base of the pad for a ROQ pad >2.7 m thick

srk consulting	TMAC RESOURCES	Infrastructure Thermal Modeling
		ROQ Pad Active Layer, -2°C Isotherm – Model Year 1 to 20
Job No: 1CT022.004 Filename: ROQ_ActiveLayer_ModelYear1to20.pptx	HOPE BAY PROJECT	Date: 4/18/2016 · Approved: cws · Figure: 8



Notes:

1. ROQ pad active layer for model year 20
2. Cold Case n-factors, nf 1.02, nt 1.25, literature values
3. Warm Case n-factors, nf 0.6, nt 2.01, literature values
4. Active layer depth referenced from base of ROQ Pad

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