Baffinland Iron Mines Corporation
Mary River Expansion Project

Northern Railway – Instrumentation Monitoring Program

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Date	**Rev.**	**Status**	**Prepared By**	**Checked By**	**Approved By**	**Approved By**
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To: [Hatch Ltd.] [***confirm entity***] (together with its affiliates, the "Consultant")

Re: Draft Report for [***insert description of report***] (and together with any subsequent revisions thereof, the "**Report**") dated [***insert date***] prepared by the Consultant for [***insert name of client***] (the "**Client**"), in respect of the [***insert description of project***].

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Dated: October 29, 2019

[INSERT NAME OF REPORT RECIPIENT]

By: ____

Name:

Title:

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1. Introduction

Hatch has been retained by Baffinland Iron Mines Ltd. (BIM) to assist on the design and construction of the railway connecting Milne Port and the main Mary River mine site.

The Northern Railway which stretches between the Mary River mine-site and Milne Port comprises of construction of railway embankments through cuts and fills and four (4) major bridge crossings. Long term foundation monitoring for the earthworks is recommended in various geotechnical design reports to verify the long-term structural behavior and its operation and maintenance issues. Short term monitoring is also recommended to verify the design assumptions, and to be carried out during construction.

The Instrumentation Monitoring Program for the Northern Railway is developed to implement such monitoring program, which addresses the installation, data acquisition and processing and reporting plan for the instrumentation.

2. Instrumentation and Monitoring

2.1 Purpose

A surveillance and monitoring program complete with monitoring of key parameters with the use of civil instrumentation is required to control the ground movement and settlement for the proposed Northern Railway.

The requirements for Northern Railway instrumentation along the alignment were evaluated with the criteria intended to:

- Verify design assumptions and construction methods.
- Monitor performance during construction.
- Monitor responses during commissioning of railway foundation.
- Monitor long-term post construction performance.
- Provide evidence demonstrating proper design and construction should future issues arise.
- Provide Quality Control, Safety, and Legal Protection.

2.2 Instrumentation Design Approach

The general approach to develop a geotechnical instrumentation program specific to the Northern Railway construction and operation as indicated in Section 2.1 is to ensure adequate instrumentation to monitor and confirm the performance of the railway foundation. The specifications for the supply, installation and monitoring for geotechnical instrumentation have been prepared by Hatch as part of the construction work activities.

The geotechnical instrumentation design is based on the 20 steps systematic approach as defined in the “Geotechnical Instrumentation for Monitoring Field Performance” [Ref. 1]. The procedure is summarized by the following steps:

- Steps 1 through 5 assists in identifying the requirements for instrumentation including the construction, operation, potential failure mechanisms and design assumptions of the Project.
- Steps 6 and 7 predict the anticipated magnitudes of change and devising remedial actions in the event of hazard levels have been partially addressed to confirm equipment types and their operating ranges/sensitivities, as well as defining the monitoring locations. Completion of these steps will be subject to the as-built/installed instrumentation and can be fully developed after final design and installation for inclusion in the post-installation surveillance and monitoring manual.
- Step 8 highlights the need to assign tasks for the development of the instrumentation program.
- Steps 9 and 10 provide considerations for the selection of instruments and their locations.
- Steps 11 and 12 focus on factors that influence measured data and on ensuring accuracy has been partly addressed in design and defined in the installation details. However, some issues will be related to the actual installation and will be confirmed after construction.
- Step 13 refers to the specific purpose of each proposed instrument. This step is required to design the instrumentation system for the railway line.
- Step 14 discusses the preparation of a budget for construction and long-term costs. Final estimated costs for procurement and installation can be determined once the scope and number of instruments is confirmed as part of the design process.
- Steps 15 and 16 refer to procurement specifications and installation planning which requires finalization once the instrument types and number are confirmed, and responsibilities for installation are identified.
- Steps 17 and 18 are associated with the post-installation surveillance and monitoring manual. This can be developed after the final design and installation.
- Steps 19 and 20 discuss finalization of the contractual arrangements and preparation of the final program budget.

3. Instrumentation Selection

In general, instrumentation which will be used to monitor the earthworks and railway foundation will consist mainly of temperature and movement gauges.

Thermistors will be used to determine the soil temperature profile in order to observe the permafrost conditions as a result of the railway construction and operation.

Movement gauges will detect movements or measure deformation and settlements, and will include deep-seated benchmarks/benchmarks (monuments), survey points, survey targets, settlement plates and inclinometers.

- Deep-seated benchmarks/benchmarks (monuments) serve as the permanent elevation reference which provides precise vertical datum of mean sea level. It also serves to provide coordinates/locations as control points along the railway alignment.
- Survey points (survey rods) are designed to establish points for monitoring vertical and horizontal deformation at or near ground surface.
- Survey targets are used for monitoring vertical and horizontal deformation at or near ground surface on the specified structures.
- Settlement plates are designed to monitor the ground settlement at fill placement areas.
- Inclinometers are designed to monitor horizontal deformation of the ground.

The instrument functions and details are explained below:

3.1 Thermistor Strings

To collect Mean Annual Ground Temperature (MAGT) measurements for design, thermistor strings installed in soils will provide temperature measurements, and establish the depth of the annual thaw and active freeze-thaw zone obtained through ground temperature profiling on a regular basis. The sensors are also known as thermistor beads and are connected with strings where the data will be collected into an electronic readout instrument or a data logger.

A thermistor string comprises of several individual thermal sensors encapsulated in a rugged, direct burial, multiconductor cable for multiple measurements in a single borehole. Thermistor strings can be manufactured according to the design requirements for overall length, number of sensors and accuracy. Thermistor strings are typically used for profiling temperatures in boreholes, glaciers and permafrost.

Thermistor beads are semiconductors behaving as thermal resistors, that is, resistors with a high (usually negative) temperature coefficient of resistance. They are made from a mixture of metal oxides encased in epoxy or glass. The beads are small in size and extremely robust with a high degree of stability over a long-life span. For remote unattended applications, thermistors can be connected to dataloggers to provide automatic data collection at pre-determined intervals and data transmission via wireless methods. For these applications, connectors can be attached to the thermistor strings to facilitate rapid connection. A typical thermistor string is shown in Figure 3-1:

Table 3-1: Thermistor String (inset shows a close-up of an encapsulated sensor)

Thermistor strings will be installed under cut and fill slopes at ice rich, weak or susceptible areas along the railway alignment; under and downstream of selected culverts, attached to the bridge piers and under the abutments. As such, the thermistor strings can be installed horizontally, vertically or with an angle.

3.2 Benchmark Monuments/Deep-seated Benchmarks

Generally, benchmarks will be installed every 10 kilometres, to control the ground elevation change along the railway alignment. The distances between each benchmark depend on the necessity for local survey work to make references to established monuments with known coordinates and elevation. At areas where the bedrock outcrops are present, benchmark markers will be installed on the sound rock surface by drilling a hole at least 7 cm deep into the bedrock and cementing a shorter rod into the hole. A typical metal benchmark marker is shown in Figure 3-2.

At the areas covered by overburden, deep-seated benchmarks/benchmarks can be installed with the rod extending to at least 90 cm into the bedrock, where practical. In areas where bedrock is relatively deep, benchmarks may have to be anchored deep into the ground to ensure minimal movements and influences from frost heave, settlements, etc. A typical deep-seated benchmark is shown in Figure 3-3.

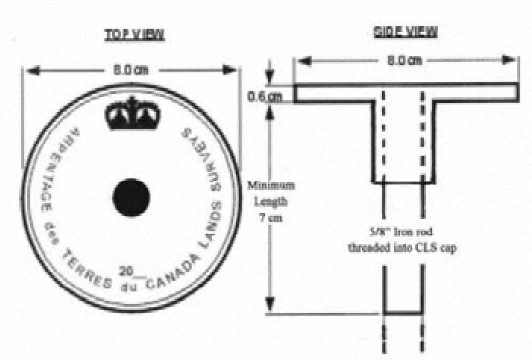


Figure 3-2: Benchmark Marker

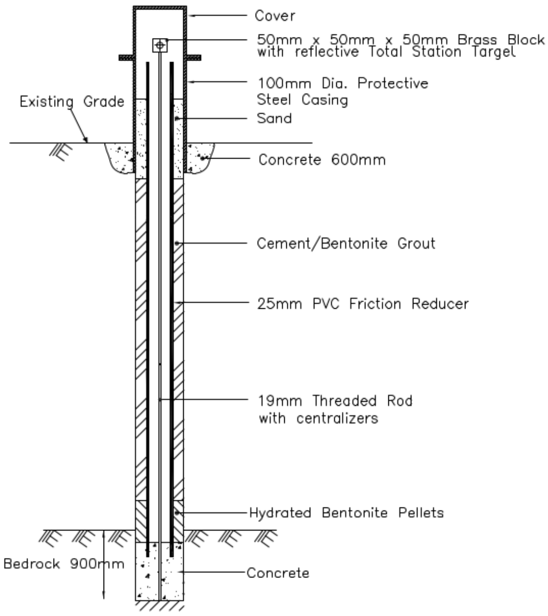


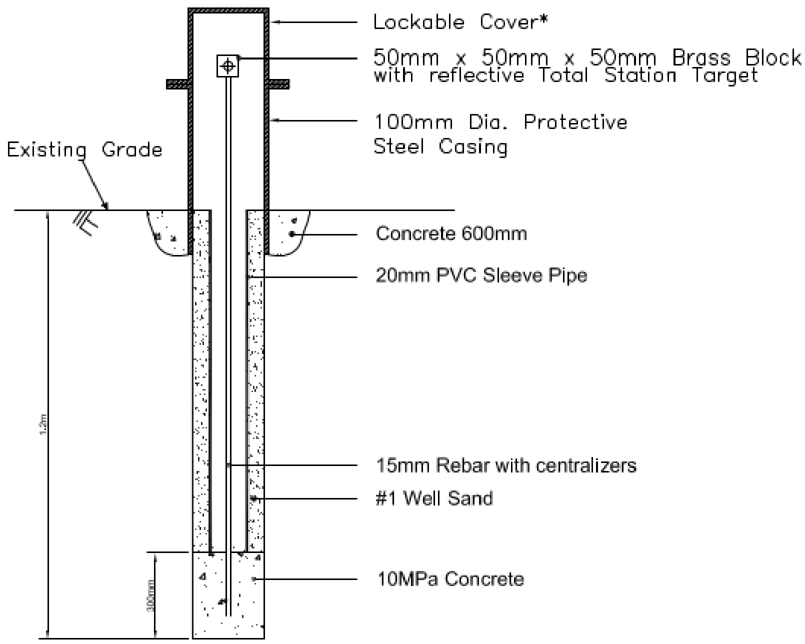
Figure 3-3: Deep-Seated Benchmark

3.3 Survey Points

Survey points or survey markers are pieces of monument or stakes which are embedded into the ground (native soils or top of the fills), so that they can be used as permanent markers where field survey work for the ground between the points can be made. The installation for survey points can be elaborate to ensure that these points do not move over time and will be tied back to a permanent benchmark prior to the field survey work. Elaborate installation for a survey point may include provisions to minimize frost heave and settlement of the surrounding fills. This can be made by extending the monument below the frost depth and/or the use of an outer casing to reduce movement of the monument. Alternatively, simple wooden stakes may be utilized, but will require tying into a permanent benchmark to establish exact position of the points.

The ground measurement by surveying instrument will be made between the survey points, and the ground elevation profile will be established and compared to previous observation periods to identify any ground movement in the area. Movement of the area may indicate settlement, compaction of fills, failure of a slope, etc. However, the survey results obtained from the ground between the survey points (with correction made from the tie-in to a permanent benchmark) could not provide information about foundation settlement, as measurements are made at ground surface. For this purpose, a settlement plate will be used instead.

Readings for the survey points shall be accurate to ±0.5 mm. A typical survey point for the railway alignment can be used in Figure 3-4:



^Note: * typically a metal casing with a cap and a lock system

Figure 3-4: Survey Point

3.4 Survey Targets

Survey targets are small targets (typically made of reflective, tough and UV resistant materials) which can be attached to a structure surface such as a concrete wall, steel beam, steel piles, etc. It can be in the form of steel screws or plates which can be welded or attached securely to steel structures or anchored securely into concrete wall. The survey target has an “X” target or marker for surveying purpose to determine their coordinates in space (x, y and z coordinates).

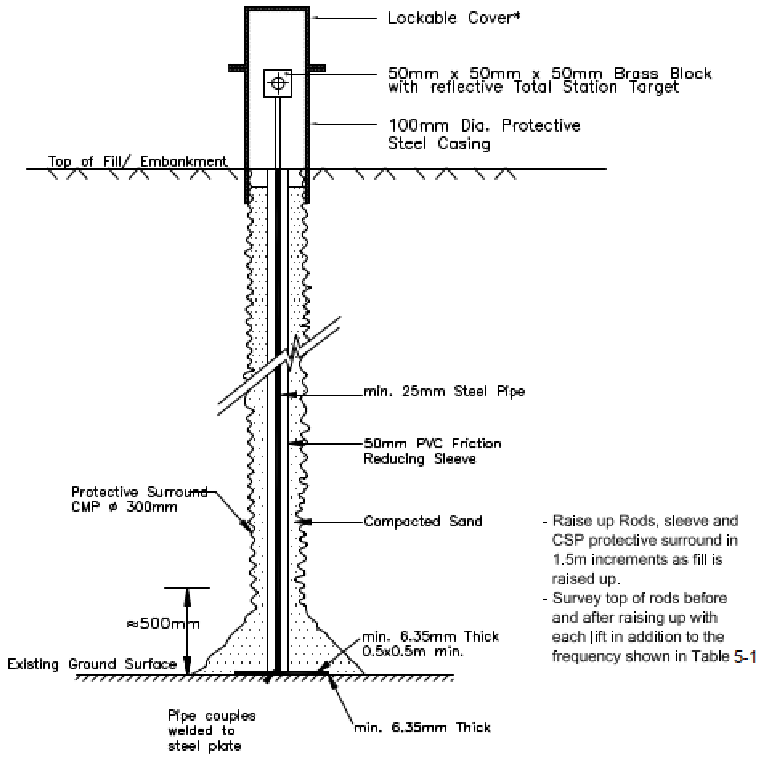
Survey targets will be attached to various concrete or steel structures including on non-pile areas such as top of rail ties, culverts; on pile caps for the railway bridges, in structure areas such as steel tie-beams, concrete caps, etc.

3.5 Settlement Plates

The settlement plate system consists of a base plate, a reference rod (riser pipe), the couplings for the rod, and the pipe cap at the top. The settlement plates should be installed on the existing ground surface prior to the placement of the fills or backfills, to monitor the ground surface settlements as a result of fill loads.

The plate should be placed on a flat surface and the elevation of the ground at that location is surveyed prior to placement of the fills to establish the baseline readings, and the extensions to the rod (riser pipe) are added until it reaches the final height of the fill.

A typical settlement plate for the fills can be installed as shown in Figure 3-5.



Note: * typically a metal casing with a cap and a lock system

Figure 3-5: Settlement Plate

In high railway embankment areas, such as those where the height of the embankment exceeds 3 to 5 m, the extensions applied to the vertical rod of the settlement plates will result a very slender instrument which may be subjected to lateral forces. In such areas, a different instrument to monitor settlement may need to be used. There is a settlement sensor that can be placed at the base of the embankment, but it will need to have an elaborate setting, not practical and costly (such as Roctest's SSG vibrating wire soil settlement gauge or equivalent).

Alternatively, settlement of the embankment may have to be measured at the crest of the embankment by placing survey targets on top of grades, or steel rail component. The settlement measurements at these points needs to be reset for additional fill layers during any re-ballasting work. Furthermore, such measurement will not only show the ultimate settlement at the foundation level of the railway embankment, but also include any settlements within the embankment fill itself. However, continuing and excessive settlements which are measured on top of the grades may indicate foundation settlement, not just through the embankment fills and ballasts, and therefore may require further investigations.

3.6 Inclinometers

Inclinometer installation will be used to monitor the slope stability of the bridge abutments. The inclinometer reading is conducted within the inclinometer casing installed in drilled borehole. The inclinometer casing has four orthogonal grooves along the inner wall used to guide an inclinometer probe in order to survey the alignment of the inclinometer casing.

An inclinometer probe contains orthogonal sensors that measure the angle that the body of the probe makes with vertical (for vertical and inclined casings) or horizontal (for horizontal casings). Inclinometer probes also have sprung wheels to hold them in the center of the inclinometer casing as the survey is taking place. The details of the inclinometer casing and the probe is shown in Figure 3-6:

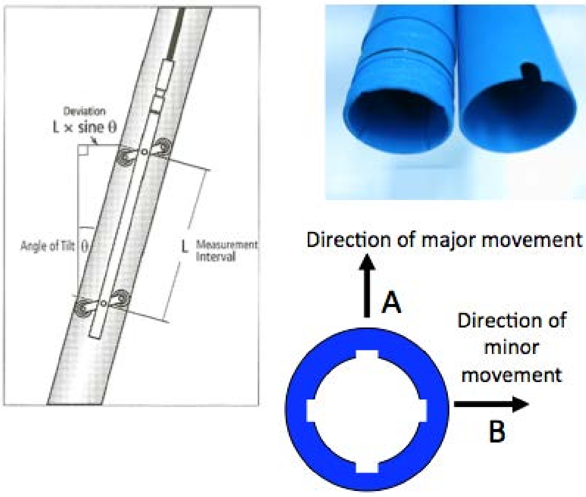


Figure 3-6: Details of Inclinometer Casing and Probe

Once the reading at specific depth is stabilized, the reading is accepted on the readout and registered, the readout unit will be turned off and data will be transferred to the computer. The probe is then moved to the next interval.

The technical specifications for Instrumentation and Monitoring are provided under a separate document [Ref. 2].

For horizontal deformation gauges, or deformation along slopes, recent development comes up with an instrument consisting of a cable with selective nodes containing sensors which can monitor deformation along the cable line. Such an instrument can be placed in a trench under a culvert to measure deformation of the culvert under the embankment load. Shape Accelerometer Arrays (SAA) or Micro Electro Mechanical System (MEMS) accelerometers can be used for this purpose.

4. Instrument Installation

The geotechnical instrumentation program for Northern Railway covers four areas: (a) Embankment Cuts, (b) Embankment Fills, (c) Culverts, and (d) Bridges.

4.1 General Considerations

The instrumentation for the railway embankment and culverts includes benchmark installation for control points along the alignment, selected survey points at the embankment cut and fill areas, survey targets installed on top of each of selected culverts, settlement plates for embankment fills, and thermistor strings located on selected areas.

The instrumentation at the bridges consists of thermistor strings, survey targets, settlement plates and inclinometers. For the piers and abutments, the temperature of the soils surrounding the piers and the abutments are critical to their performance, so the thermistor strings will be installed at the piers and abutments. The survey targets will be installed on top of bridge piers to identify any movements of the bridge foundations, and the inclinometers are used to monitor any lateral movements of the bridge abutments.

The installation sketches are attached in Appendix A of this Program.

4.2 Installation Schedule

To optimize the railway instrumentation program, thermistor strings and survey points are recommended to be installed in phases based on site conditions, with an aim to conduct intensive monitoring at sensitive areas.

Phase I instruments are designed to control the representative and critical site conditions, they should be installed prior to or during construction. An approximate location plan for Phase I instrumentation can be found in Appendix B.

Phase II instruments are a secondary monitoring system and will be added to sensitive areas identified by the readings of the Phase I instruments. Phase II instruments will be installed after Phase I instruments, and the number and the locations are subject to change based on the monitoring results from the Phase I instruments. Almost all changes to the site condition, i.e., change of temperatures, subsoil and structure deformation, settlement of fill and abutments, will be monitored and controlled after Phase I and Phase II installation.

Phase III instruments serve as a supplementary monitoring approach to be added at the areas where the significant change of temperature, and deformation are confirmed while the instruments are not sufficient to monitor the change, and/or the areas where the monitoring results are not reasonable or consistent over time.

As such, the Phase II and Phase III instruments may be installed in different orders or omitted depending on the monitoring results from previous phase(s) instruments. The instrument installation schedule for the railway monitoring is shown in Table 4-1.

Table 4-1: Instrument Installation Schedule

Instrument	Installation Schedule	
	Phase I	Phases II and III
Benchmark	Prior to or during construction	-
Thermistor String, horizontal	1. Prior to culvert installation 2. Prior to backfilling of embankment and abutment	1. After backfilling of embankment and abutment 2. After embankment excavation
Thermistor String, vertical	1. Together with pile driving for bridges 2. After abutment construction 3. After embankment excavation and backfilling 4. After culvert installation	1. After embankment excavation and backfilling 2. After culvert installation
Survey Point	Right after excavation, grading and backfilling	After construction of embankment

Instrument	Installation Schedule	
	Phase I	Phases II and III
Survey Target	1. Together with pile cap installation 2. After culvert installation	-
Settlement Plate	Prior to backfilling of embankment and abutment	-
Inclinometer	Right after abutment construction	-

The approximate location of Phase I instrumentation, excluding instrumentation for culverts and bridges, can be found in Appendix B. A table summarizing the approximate locations and phases of all instrumentation can be found in Appendix C, and the details of the phased instrument installation schedule are specified in Section 4.3.

It should be noted that the instrumentation schedule is based on available design drawings at current stage. Modifications will be required whenever the railway design changes in alignment layout, structure details, construction sequence and schedule, etc. They should be updated to reflect the design changes.

4.3 Installation

All the instruments should be installed at accessible locations and visible for surveying, the reading ends of the horizontal thermistor strings should be clearly marked/labeled and protected from damage. For instrumentation such as benchmarks, survey points, settlement points and inclinometers, the color of the protective casings should be bright and easily distinguishable from the surroundings.

Assigned areas for instrumentation should be prepared by cleaning the ground surface, and applying neat cement paste, grout or other materials as required.

Minimum clearances should be established from utilities and existing structures prior to installing instruments.

If necessary, protective measures, such as bollard installation may be required to keep the instrument from getting damaged from construction traffic.

4.3.1 Thermistor Strings

Thermistor strings will be installed horizontally and/or vertically at embankment cut and fill areas, culverts and bridges along the railway alignment. To protect the thermistor strings from damage due to construction, the thermistor strings should be threaded into 25 mm (1”) PVC pipe prior to installation.

Horizontal Thermistor Strings

Wherever possible and practical, horizontal thermistor strings will be laid along the cut and fill slopes, below the culverts and buried in the middle of a 600 mm sand cushion pad. The sand cushion pad should be compacted properly before the fill is placed.

For the horizontal thermistor strings within the rockfill, place one layer of geotextile 300 mm below the thermistor string/cable location, and follow the same procedure as mentioned above.

Minimum length of 20 m is required for the horizontal thermistor strings installed along the embankment. For the thermistor strings installed under the culverts and bridge abutments, the string lengths should cover the full lengths of the culverts and the abutments.

Care should be given when placing the rockfill and pouring concrete footings above the thermistor strings.

Vertical Thermistor Strings

Vertical thermistor strings will be installed in 15 m deep boreholes in vicinity of the culvert exit areas (downstream), attached to one of the vertical piles for each pile cap at the bridge sites, and in selected areas at the slope toes of the embankment where the excavation and backfilling thickness exceeds 3 m. The vertical thermistor strings may also be placed in other areas where horizontal thermistor strings cannot be placed.

For the vertical thermistor strings installed at the embankment areas and the culverts, the borehole drilling, and grouting should follow the instructions below:

- Drill borehole to 15 m – 20 m depths below existing ground surface.
- Prior to installing instrumentation, remove material adhering to inside of casing or augers, and cuttings.
- Install protection to exposed parts of instruments as shown in sketches/drawings.
- Thoroughly mix grout to uniform consistency.
- Thermistor strings should be coiled or snaked to ensure adequate slack in case of ground movement. Strings should be protected by burying or be placed in conduit in areas likely to be damaged by construction activity.

Prior to driving the piles, the 25 mm PVC pipe with a thermistor string threaded inside is attached to the full length on a selected pile installed in the middle of the pier. After the pile cap is installed, the thermistor string is fixed on the cap and the reading ends are extended to the bridges.

The thermistor strings are suggested to be installed in phases, based on the temperature change at different areas. The phased installation of the thermistor strings is summarized in Table 4-2, with the full details of the phased thermistor strings available in Appendix C.

Table 4-2: Summary of Phased Thermistor String Installation

Location	Direction	Phase I	Phase II	Phase III	Total
Embankment Excavation	Horizontal	10	5	13	28
Embankment Fill	Horizontal	31	29	67	127
Culvert base	Horizontal	38	-	-	38
Bridge abutment	Horizontal	8	-	-	8
	Subtotal	87	34	80	**201**

Location	Direction	Phase I	Phase II	Phase III	Total
Embankment Excavation	Vertical	4	7	0	11
Embankment Fill	Vertical	28	18	30	76
Culvert	Vertical	38	-	-	38
Pile cap of bridge	Vertical	19	-	-	19
	Subtotal	89	25	30	**144**

As mentioned in Section 4.2, installation of Phase II and Phase III thermistor strings may be in different orders or omitted depending on the monitoring results from previous phase(s) instruments.

4.3.2 *Benchmarks (Monuments)/Deep-seated Benchmarks*

A total of 11 benchmarks are suggested along the railway alignment, at approximately 10 km spacing. As specified in Section 3.3, at the areas where bedrock outcrops are present, the monuments will be installed on the sound outcrops visible along the railway alignment. At the areas covered by overburden, the benchmark rods should reach the bedrock and extend to at least 90 cm in the bedrock or anchored deep in overburden as indicated in Section 3.2.

4.3.3 *Survey Points*

Survey points will be intensively installed along the embankment, at the cutting and filling areas. The survey point installation is to be done in phases, the phased installation of the survey points is summarized in Table 4-3, with the full details of the phased survey points available in Appendix C.

Table 4-3: Summary of Phased Survey Point Installation

Location	Phase I	Phase II	Phase III	Total
Embankment Cuts (Excavations)	14	13	20	47
Embankment Fills	62	54	93	209
Subtotal	76	67	113	256

As mentioned in Section 4.2, installation of Phase I and Phase III survey points may be in different orders or omitted depending on the monitoring results from previous phase(s) instruments.

4.3.4 *Survey Targets*

Survey targets will be attached on top of selected culverts and pile caps. The target locations must be able to be accessed by the surveying activities.

4.3.5 *Settlement Plates*

Settlement plates tend to be a hindrance to the placement of fills. Settlement plates should be clearly and adequately marked in order to protect the riser pipes from construction traffic during placement of the fills.

Care is required around the riser pipes or rods, and extension to the riser pipes or rods is made as the fill is being placed. The riser pipes or rods should remain verticals and not get bent or damaged during the placement of the fills around it.

4.3.6 Inclinometers

Inclinometer casing is suited for installation in boreholes at the bridge abutments. It is compatible with all commercially available inclinometer probes, including RST's MEMS Digital Inclinometer Probe. RST manufactures Inclinometer casing with precision CNC technology.

15 m inclinometers are suggested to be installed at the abutments, the inclinometer layout is shown in Appendix A, Instrument Sketch.

4.4 Overall Instrumentation Program

The overall instrumentation is summarized in Table 4-4 below:

Table 4-4: Summary of Phased Survey Point Installation

Location	Bench Mark	Survey Point	Survey Target(1)	Settlement Plate	Thermistor String		Inclinometer(2)
					Horizontal	Vertical	
Embankment excavations	8	47	-	-	28	11	-
Embankment Fills	3	209	-	108	127	76	-
Culverts	-	-	38	-	38	38	-
Bridges	-	-	19	8	8	19	16
Total	11	256	57	116	201	144	16

Notes:

(1) To be installed on top of each culvert and pile cap.

(2) 2 for each bridge abutment.

(3) A detailed summary of all instrumentation can be found in Appendix C.

4.5 Earthworks Construction Schedule

Appendix D shows the earthworks construction schedule for the railway line, which is based on the construction schedule titled "Project Master Execution Schedule (Schedule 9A)" dated April 15, 2019. As shown in the location map, all earthworks will be carried out during the periods 2020, 2020-2021 and 2021. Based on this information, the instrumentation which will be installed during the earthworks in 2020 will provide observations during the first year of the two-year proposed construction periods. The initial readings from the instruments installed in 2020 will be used to provide modifications and changes, if required, to the instrumentation installed during the 2021 construction. A summary of the earthwork construction schedule, in both chainage and percent of railway constructed during each period, is shown in Table 4-5 below.

Table 4-5: Summary of Earthwork Construction Schedule

Earthwork Construction Period	Length of Rail (m)	Percent of Rail
2020	32214	29.4%
2020 & 2021 *	25000	22.8%
2021	52397	47.8%

Note: * These are railway sections which are constructed in 2020 but not completed until 2021.

4.6 Installation by Third Party for the Contractor

It is understood that the installation of the instrumentation may be carried out by a specialty contractor who is familiar with instrumentation installation for various civil works (third party). They will set up and initiate the installation of the instrument under direction from Hatch and will carry out calibrations and initial readings and interpretations. They are capable of making modifications, change the monitoring programming, etc., after discussion and approval from Hatch and BIM.

If installation of the instrumentation will be carried out by a third party, the following Sections 5 and 6 may need to be established initially with Hatch and BIM, prior to handing over the instrumentation monitoring program after installation.

5. Instrumentation Monitoring Plan

A monitoring program should be implemented prior to and during the construction to identify areas with excess settlement, movements, or change in permafrost conditions, etc. that would require remediation. It should be completed on a regular basis and provide information for the maintenance program. Remediation will consist of complete or partial removal of the affected fills, proof rolling of the native subgrade, and backfilling with compacted rockfill.

The rail track may need to be re-leveled and/or re-aligned periodically by railway technologies/ machines, where the settlement exceeds the tolerance in the design life.

As indicated in Section 4.5, the railway embankment which will be built in 2020, and/or started in 2020 and completed in 2021 can also be used as “test sections”, in which instrumentation placed in these sections will be used to determine additional instrumentation work which may or may not be required during the subsequent construction in 2021.

5.1 Data Acquisition

Instrumentation data acquisition consists of baseline readings and routine readings with specified reading frequencies described below. All collected reading data must have the capability to be transmitted remotely through Data Acquisition System (DAS).

5.1.1 Baseline Reading

Baseline reading is the initial reading taken prior to construction to provide a baseline against which all subsequent readings are compared to assess movement and changes in the areas.

Baseline readings of the instruments shall be carried out at least three (3) days after installation and represent acceptable baseline conditions. Baseline conditions will be used as the basis of subsequent reporting and interpretation of the movement, temperature and load level changes.

When there is an indication that diurnal or thermal/weather effects may influence the readings, this should be identified by taking readings at appropriate frequencies during the baseline readings period. Any external influences which affect the baseline data shall be identified and described in the weekly and installation reports.

5.1.2 Monitoring Frequency

Read and record data at frequencies which are indicated in Table 5-1, Monitoring Frequency.

Table 5-1: Monitoring Frequency

Instrument	Baseline Reading	During Construction	After Construction	End Date
Thermistor String, Horizontal	– Phase I: 3 times, one (1) week prior to filling – Phases II and III: A minimum of 3, right after installation	Daily throughout construction	Once a week until data stabilized, then TBD	TBD
Thermistor String, Vertical	3 times, right after installation	Daily throughout construction	Once a week until data stabilized, then TBD	TBD
Survey Point	– Phase I: 3 times, one (1) week prior to filling – Phases II and III: 3 times, right after installation	Weekly throughout construction	Once a month until data stabilized, then TBD	TBD
Survey Target	3 times, prior to girder and track installation	Weekly throughout construction	Once a month until data stabilized, then TBD	TBD
Settlement Plate	3 times, right after installation	Daily throughout filling	Once a week until data stabilized, then TBD	TBD
Inclinometer	3 times, right after installation	Daily throughout bridge construction	Once a week until data stabilized, then TBD	TBD

TBD – To Be Determined

Monitoring frequencies in Table 5-1 are a minimum requirement and may be modified, depending on location, construction progress and backfilling work. Scheduling and efficiency of temporary works, construction rates of movement and other activities affecting the ground, utilities or structures are subject to monitoring.

Whenever sets of data are measured, they shall be compared to previous sets of data. If anomalous readings are present which differ from the expected value, trend or rate of change, they shall be checked to ascertain whether the anomaly is due to measurement or reading error. Take additional immediate measurements when measured values indicated an excessive variability, as determined by BIM and Hatch.

Further readings at closer frequencies shall be taken immediately. If the readings remain persistently anomalous and are not due to error, an investigation shall be carried out to determine the cause, and the contingency or action plans shall be initiated.

5.2 Drone-Based Monitoring

Routine monitoring of the railway alignment can be supported by an Unmanned Aerial Vehicle (UAV)-based monitoring program, which enables the comprehensive surveying of railway infrastructure from a working height of 25 m, to a sub-5 mm accuracy at low maintenance and instrumentation costs.

A typical drone-based monitoring system consists of the drone(s), the Control Station (CS) and the communication link. The system can capture track condition and communicate with the control station at real time base. As such, the drone-based monitoring system will provide an early warning system to detect the significant ground movement events including natural hazards by means of communications between the drones and the remote-control centers using mobile terminals.

A properly equipped drone can monitor working conditions of the railway track, identify the damage of the culverts and bridges, significant dealignment of the railway track, embankment erosion and/or slumps, falling obstacles blocking the track, and temperature change along the alignment.

Frequent and automatic drone-based monitoring program can be enhanced by less frequent real-person monitoring to control the monitoring accuracy at a cost-effective base. More details about the drone-based monitoring program will be provided in a separate Program as required.

5.3 Review and Alert Level of Instruments

Review levels are the values of instrumentation readings at which BIM and Hatch jointly assess the necessity of altering method, or rate of sequence of construction. They are the response levels which encompass the temperature, movement, deformation, stress and strain change from the baseline readings.

Alert levels are values of instrumentation readings at which BIM and Hatch shall order construction operations to cease, take necessary and agreed upon measures to mitigate unacceptable loads, levels of movement and assure safety of Work. Alert level for each instrument represents maximum permissible ground movement due to activities associated with the construction, or the maximum load or stress which may be imposed on elements of temporary works system during construction.

Table 5-2: Review and Alert Levels for Instruments

Instrument	Location	Review Level	Alert Level
Thermistor String, Horizontal	Embankment Cuts and Fills	-2°C	2°C
	Culvert base	-2°C	-0°C
	Bridge abutment	-2°C	-0°C
Thermistor String, Vertical	Embankment Cuts and Fills	-5°C	-2°C
	Culvert Foundation	-5°C	-2°C

Instrument	Location	Review Level	Alert Level
	Bridge pier (pile cap)	-5°C	-2°C
Survey Point	Embankment Cuts and Fills	4 mm	8 mm
Survey Target	Culvert top	3 mm	5 mm
	Bridge pier (pile cap)	3 mm	5 mm
Settlement Plate	Embankment Fills	5 mm	8 mm
	Bridge abutment	4 mm	7 mm
Inclinometer	Bridge abutment	7 mm	10 mm

5.4 Response Actions

Respond immediately to data that exceeds performance criteria, including response review and alert level.

5.4.1 General Response Procedures

If Review Level is reached, Hatch will:

1. Meet with BIM to discuss response action(s) and develop an Alert-Level Response Plan of Action.
2. Implement reviewed and accepted Alert-Level Plan of Action.

Alert Levels are not to be exceeded. Activities may be suspended in affected areas with exception of those actions necessary to avoid exceeding Alter Level or to make the work safe and secure. If Alert Level is reached, Hatch will:

1. Meet with BIM to discuss response action(s) and develop an Alert-Level Response Plan of Action.
2. Install and monitor additional instruments.
3. Implement reviewed and accepted Alert-Level Response Plan of Action.

5.4.2 Response Plan for Review and Alert Levels

Response plan should include the follows:

- Names, telephone numbers and locations of persons responsible for implementation of contingency plans.
- Materials and equipment required to implement contingency plans.
- Location on Site of all required material and equipment to implement contingency plans.
- Step-by-step procedure for performing work involved in implementation of contingency plans.
- Specific actions related to the Response Level values for all instruments, including means of reducing or eliminating movements and rates of movements.

- Clear identification of objectives of contingency plans and methods to measure plan success.

5.5 Maintenance of Instruments and Equipment

Supply, fabricate and install protection to installed instrumentation, protect from damage during construction, and maintain exposed instrumentation components. Repair or replace damaged instruments.

Always calibrate instruments at the beginning and end of work and during the monitoring program to meet manufacturer's minimum calibration requirements. Damaged or non-functional instruments shall be replaced or repaired to ensure uninterrupted readings schedules.

5.5.1 Instrument Maintenance

Maintain instrumentation in accordance with manufacturer's recommendation through the duration of monitoring.

Should it become apparent that an instrument has been damaged/lost/moved due to the construction works, Hatch will notify BIM immediately and decide the installation of the replacement.

Replacement instrumentation must be correlated with previous readings.

5.5.2 Calibration

Calibration aims to program or set an instrument to measure accurate and precise data. Calibration is required for consistent data and shall be completed to ensure recorded information is applicable, correct and real. Calibration can take place in a laboratory or in the field.

Third Party Contractor specializing in instrumentation (GKM) will install and will take initial readings, perform calibration procedures and provide the results of all instrumentation calibration along with accuracy achieved and the respective confidence levels.

6. Data Storage and Interpretation

Data shall be collected in accordance with the schedule as presented in Hatch's Specification. Readings shall be taken in accordance with the equipment manufacturers' instruction manual.

6.1 Data Storage

For every single monitoring reading, the following records shall be made and stored on the instrumentation database:

- Type of instruments.
- Instrument reference.
- Date and time of reading.
- Person taking the reading or method of taking the reading.
- Identification and reference of read-out equipment used.

- Individual readings and average readings.
- Instrument calibration record/history.

In addition to the above, the following information should be recorded:

- Weather including temperatures.
- Nearby construction activity (if any).

The database system will be set up to store, manipulate and report the large volumes of data anticipated for the works. The system will be capable of continuous monitoring and rapidly updating graphical plots to facilitate real-time monitoring where required. The system will be capable of automatically notifying relevant personnel when re-set limits are exceeded.

All data is automatically backed-up daily to an off-site, internet accessible drive.

6.2 Data Interpretation

After the initial set-up, calibrations, and readings by third party, Hatch will be responsible for interpreting the monitoring data, and will respond immediately to data that exceeds performance criteria, including response levels defined in Section 5.3. This will be established until the field data stabilize and data can be handed over to BIM for the continuation of the instrumentation monitoring. Some of the instruments may need to be monitored as part of the operation and maintenance of the project.

During this period, end-of-day logs of major construction events, including a brief narrative describing the construction activities will be submitted, to allow for correlation between measured data and construction activities. The log is also to include detailed progress activities, observations of groundwater flow, instability and other unusual events, and a brief description of soil conditions encountered, and duration and cause of interruptions or delays to construction progress.

6.3 Instrumentation Reporting

Contractor(s) in charge of instrumentation installation and maintenance and monitoring should report to BIM periodically.

6.3.1 Instrumentation Installation Records

A complete installation record for each instrument should be provided by the Third-Party Contractor (GKM) upon completion of the installation. The installation record should include the installation date, elevation and coordinates, depth and structure of the instrument and material used for the installation, if any.

6.3.2 Instrumentation Monitoring Reports

As part of the instrumentation monitoring program, the Third-Party Contractor (GKM) should submit instrument monitoring reports during construction. GKM will be responsible for the initial installation and calibration and monitoring, but subsequent monitoring post construction may be contracted to another company or carry out in-house.

Series of progressive instrumentation monitoring reports should be prepared at a quarterly base during the railway construction, in which the monitoring results are summarized and interpreted, the suggestions and recommendations are provided on protection of the ground surface conditions.

Annual instrumentation monitoring reports will be prepared to provide and interpret the monitoring data, recommend the remediations of the railway operation, and/or suggest an enhanced monitoring program. The initial annual report will be completed by GKM, but subsequent reports can be reported by a separate Contractor.

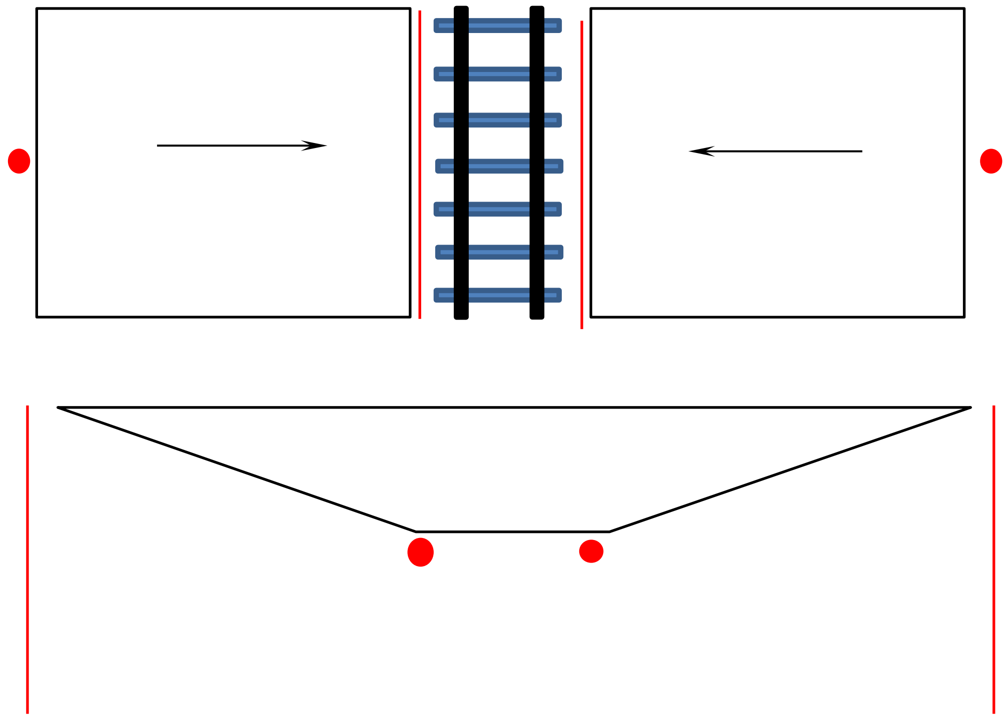
7. References

1. Dunnicliff, J. "Geotechnical Instrumentation for Monitoring Field Performance", 1993, Appendix A.
2. Hatch Ltd., "Baffinland Iron Mines Corporation – Mary River Expansion project – Standard Specification – Instrumentation and Monitoring", H353004-00000-221-078-0007 Rev 0, 5 July 2019.
3. Natural Resources of Canada, "Specifications and Recommendations for Control Surveys and Survey Markers", 1978.

Appendix A
Typical Instrumentation Sketches

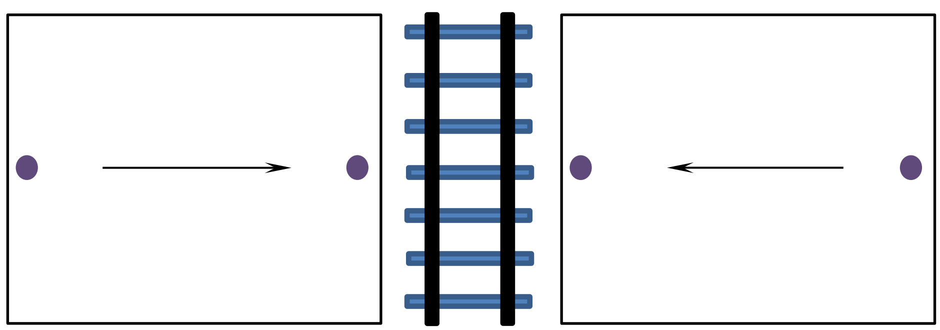
1. Typical Instrument Installations on Embankment Cuts/Excavations

1.1 Thermistor Strings



2 horizontal strings along toe base, 2 vertical strings (in BHs) at the crest of excavation/cut

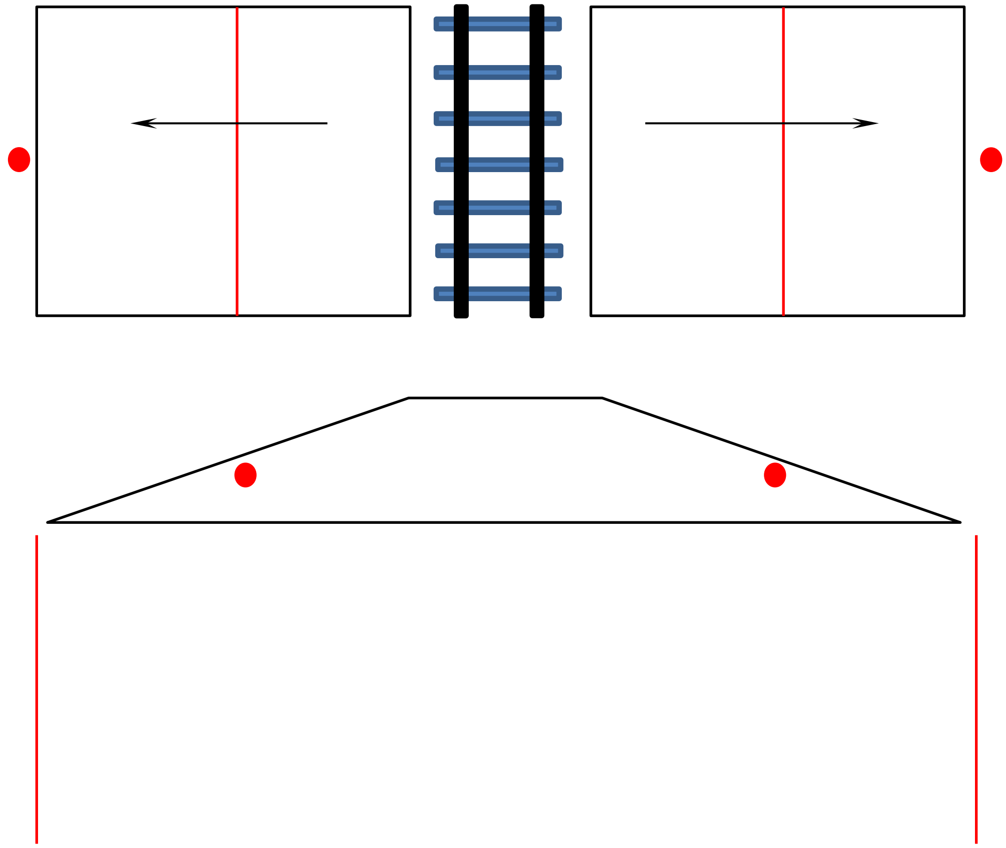
1.2 Survey Points



Survey points to be located at the crests and toes of excavation/cut. Locations to be determined.

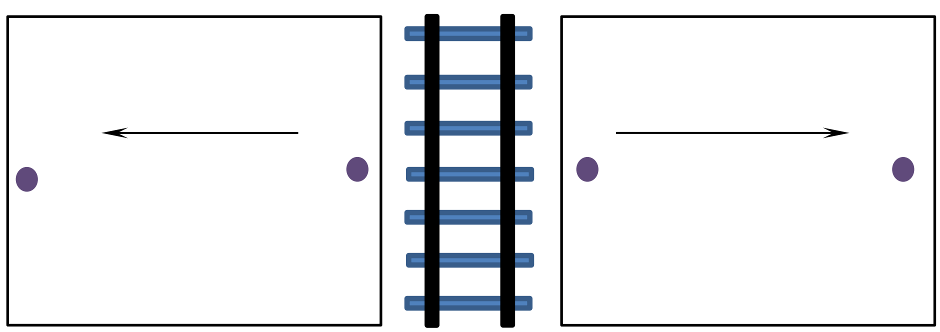
2. Typical Instrument Installation on Embankment Fills

2.1 Thermistor Strings



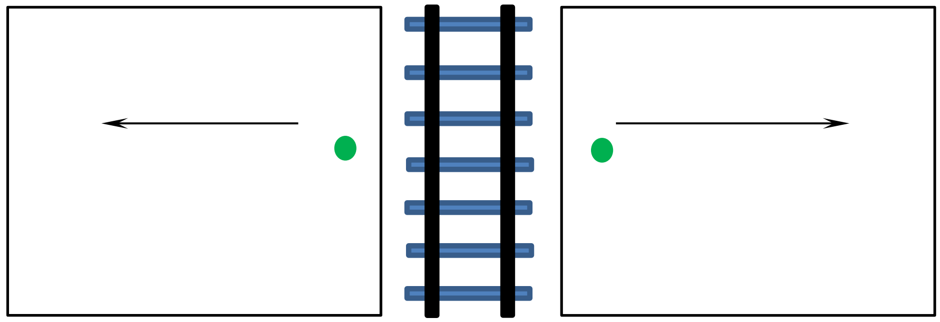
2 horizontal strings along slopes, 2 vertical strings (in BHs) at the crest of excavation/cut

2.2 Survey Points



Survey points to be located at the crests and toes of embankment fills. Locations to be determined.

2.3 Settlement Plates

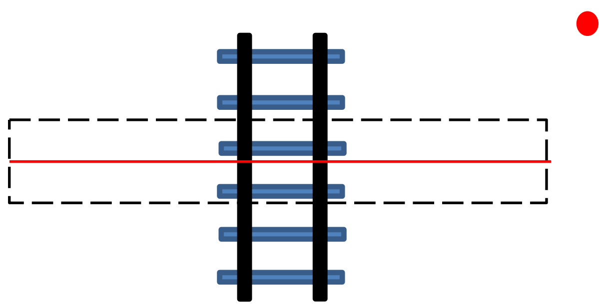


Settlement Plates to be located at the foundation. Locations to be determined (under the crest to observed highest loading)

3. Typical Instrumentations along Culverts

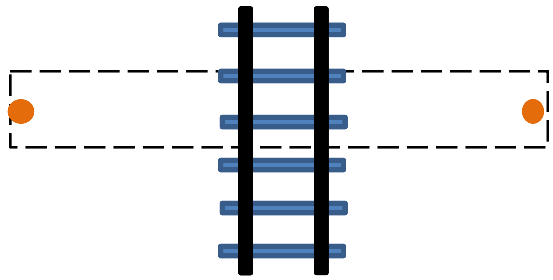
3.1 Thermistor Strings

1 thermistor string is installed horizontally below the culvert, and 1 vertical thermistor string is installed downstream of the creek, to a depth of 5 m – 8 m. For the case of multiple barrels at one culvert location, only one horizontal thermistor string will be placed under the selected culvert.



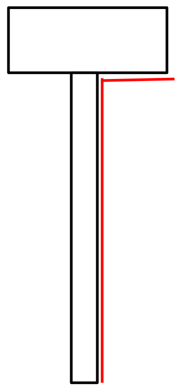
3.2 Survey Targets

2 survey targets are to be installed on top of each of selected culverts (upstream and downstream) . Survey targets will be installed in all barrels for the case of multiple barrels at one culvert location.



4. Typical Instrumentations at Bridge Sites

4.1 Vertical Thermistor Strings



Bridge #15+913

One for each Pier (6 strings)

Bridge #70+363

One for each Pier (7 strings)

Bridge #85+640

One for each Pier (3 strings)

Bridge #101+842

One for each Pier (3 strings)

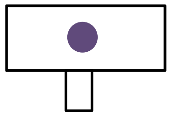
Vertical thermistor string will be threaded in the 25 mm PVC pipe, bond to a vertical pile on the outside of the pile casing and extended to the bottom of the pile, the reading end is placed on the bridge. A total of 19 vertical thermistor strings are planned for the 4 bridges.

Thermistor beads will be spaced at 1.5 m interval, including one at the bottom of the pile.

4.2 Horizontal Thermistor Strings

2 horizontal thermistor strings will be installed for each of the 4 bridge sites. Total 8 thermistor strings.

4.3 Survey Targets



One survey target will be installed on each pier, at end of pile cap facing downstream. A total of 19 survey targets are planned for the 4 bridges.

4.4 Settlement Plates

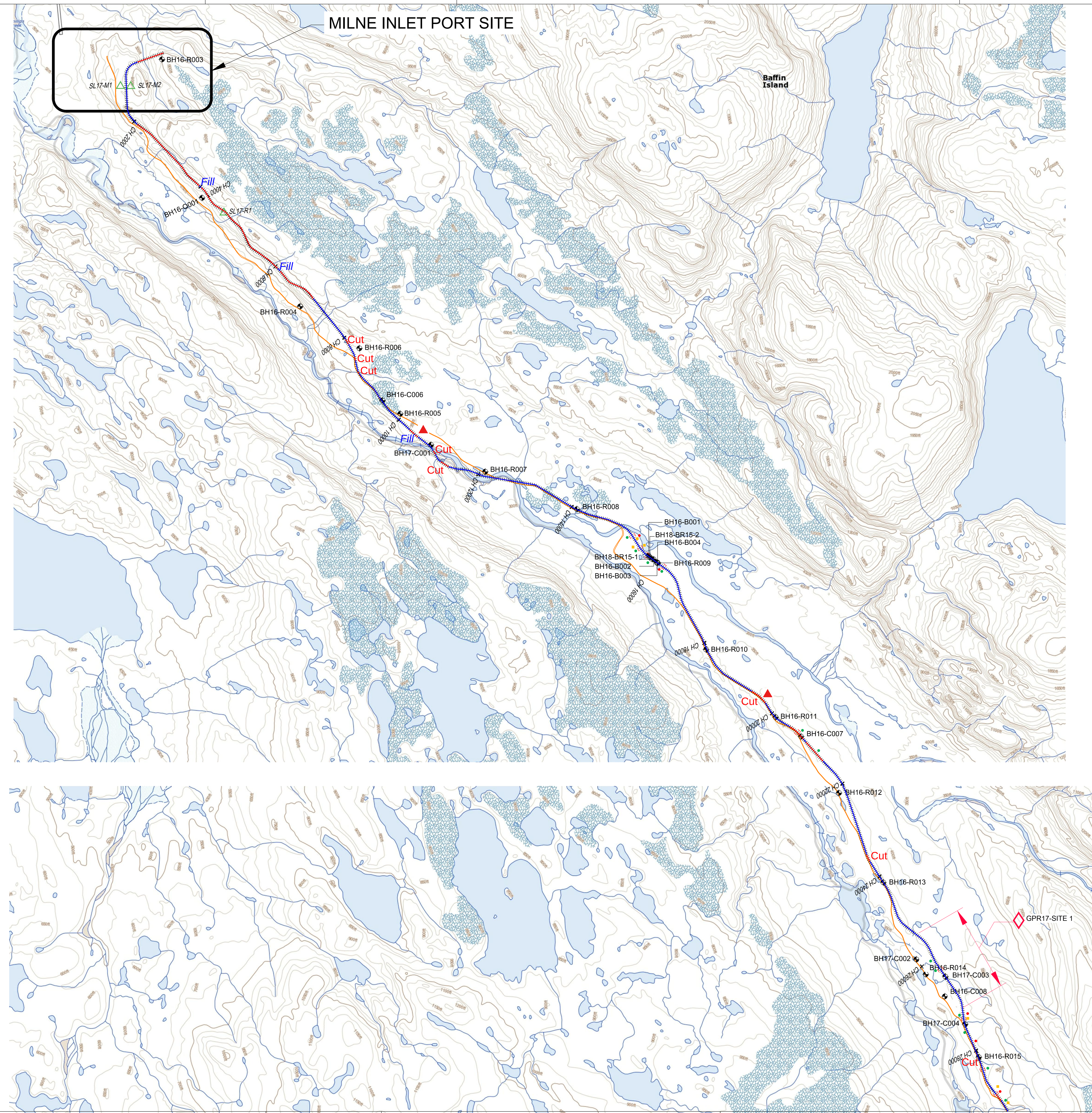
1 settlement plate is placed for each abutment as shown below. A total of 8 settlement plates are planned for the 4 bridges. Settlement plate to be placed at the foundation of each bridge abutment, and installed prior to abutment construction.

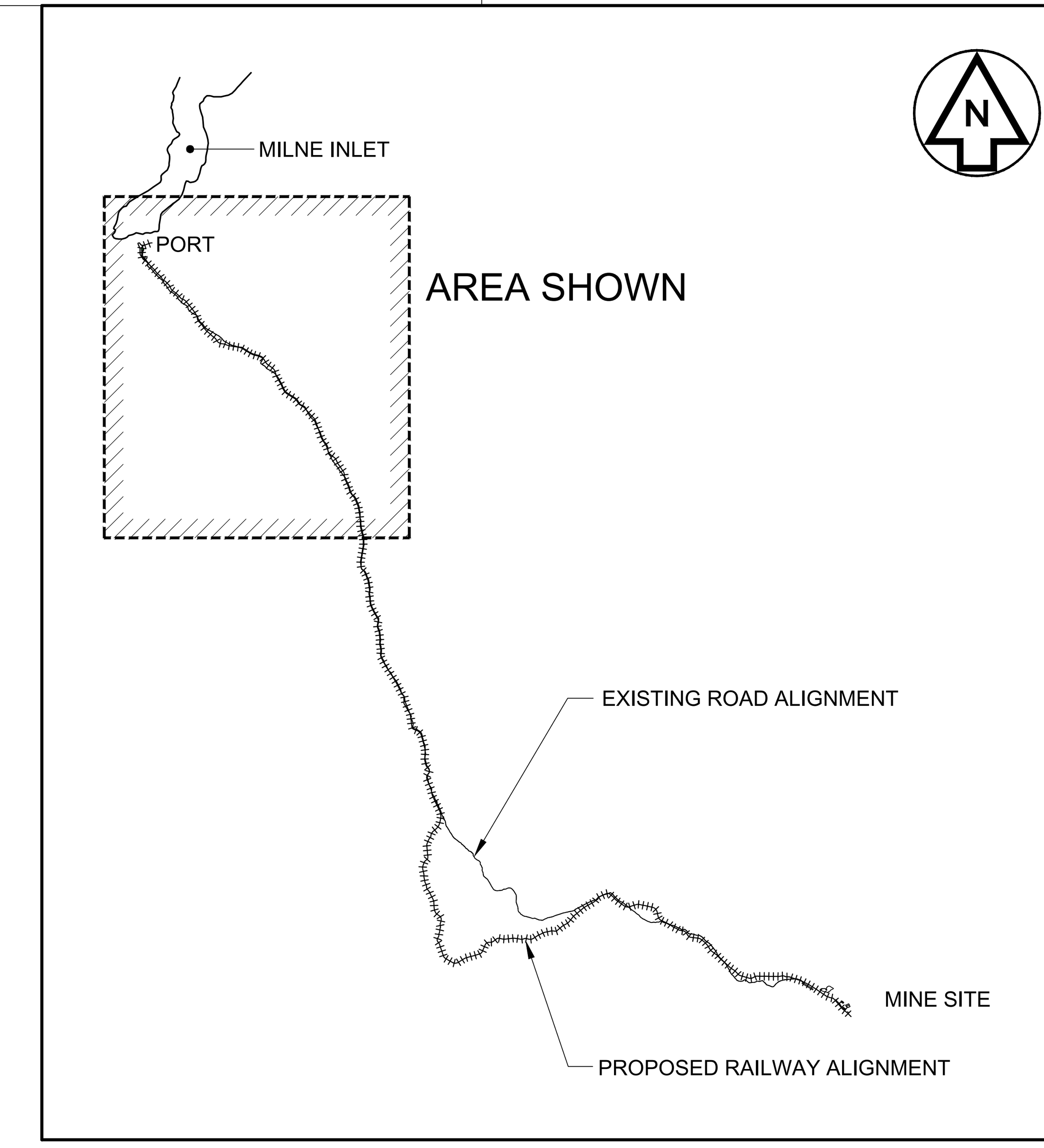
4.5 Inclinometers

Inclinometers to be placed to monitor any movement of the bridge abutments. 2 inclinometers per bridge sites, total 8 inclinometers. Additional inclinometers to be installed, if required.

Appendix B
Instrumentation Location Plan

H353004-10000-229-230-0005
DWG. No.





KEY PLAN

0 10 20 30 40 50 kilometres

SCALE 1:500 000

LEGEND

- AS-BUILT BOREHOLE LOCATION
- CHAINAGE POINT ALONG RAIL ALIGNMENT
- SEISMIC LINE LOCATION
- GROUND PENETRATING RADAR SURVEY (GPR) AREA
- PROPOSED RAILWAY
- EXISTING TOTE ROAD
- BENCHMARK
- SURVEY POINT
- SETTLEMENT PLATE
- HORIZONTAL THERMISTOR
- VERTICAL THERMISTOR
- Cut
- Fill

Notes:

1. Survey targets and all instrumentation at bridge and culvert locations are not shown in this plan. For all instrumentation see Appendix C.
2. Only phase 1 instrumentation is shown in this plan. For other phases see Appendix C.
3. The location of cuts, fills and instrumentation are approximate and are intended for visual representation.

0 1 2 3 4 5 KILOMETRES

SCALE 1:50 000 (B1 SHEET)

HATCH

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DRAWING No.	DRAWING TITLE
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No.	DESCRIPTION	BY	CHK'D	DATE
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REVISIONS

ROLE	NAME	SIGNATURE	DATE
DRAFTSPERSON	R PELAEZ	NR	10/08/2018
DESIGNER	M YANG	NR	20/08/2018
CHECKER	W HOYLE		20/08/2018
DESIGN COORD.	M YANG		20/08/2018
RESP. ENG.	H GHIABI		20/08/2018
LEAD DISC. ENG.	W HOYLE		20/08/2018
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BAFFINLAND IRON ORE MINES LP
MARY RIVER EXPANSION PROJECT

GEOTECHNICAL INVESTIGATIONS
LOCATION PLAN
SHEET 1 OF 4

SCALE 1:50,000 OR AS NOTED

DWG. No. H353004-10000-229-230-0005

REV A

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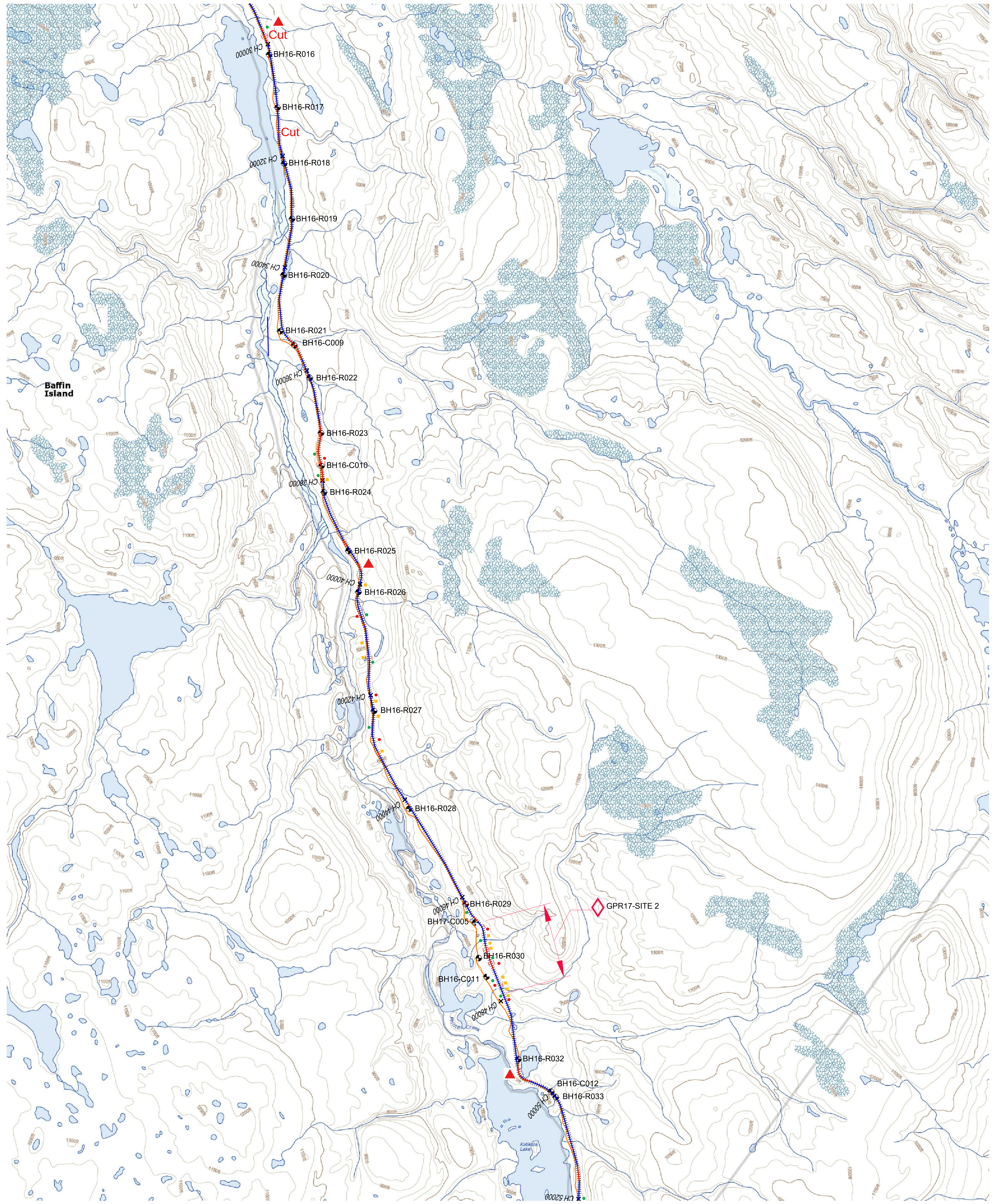

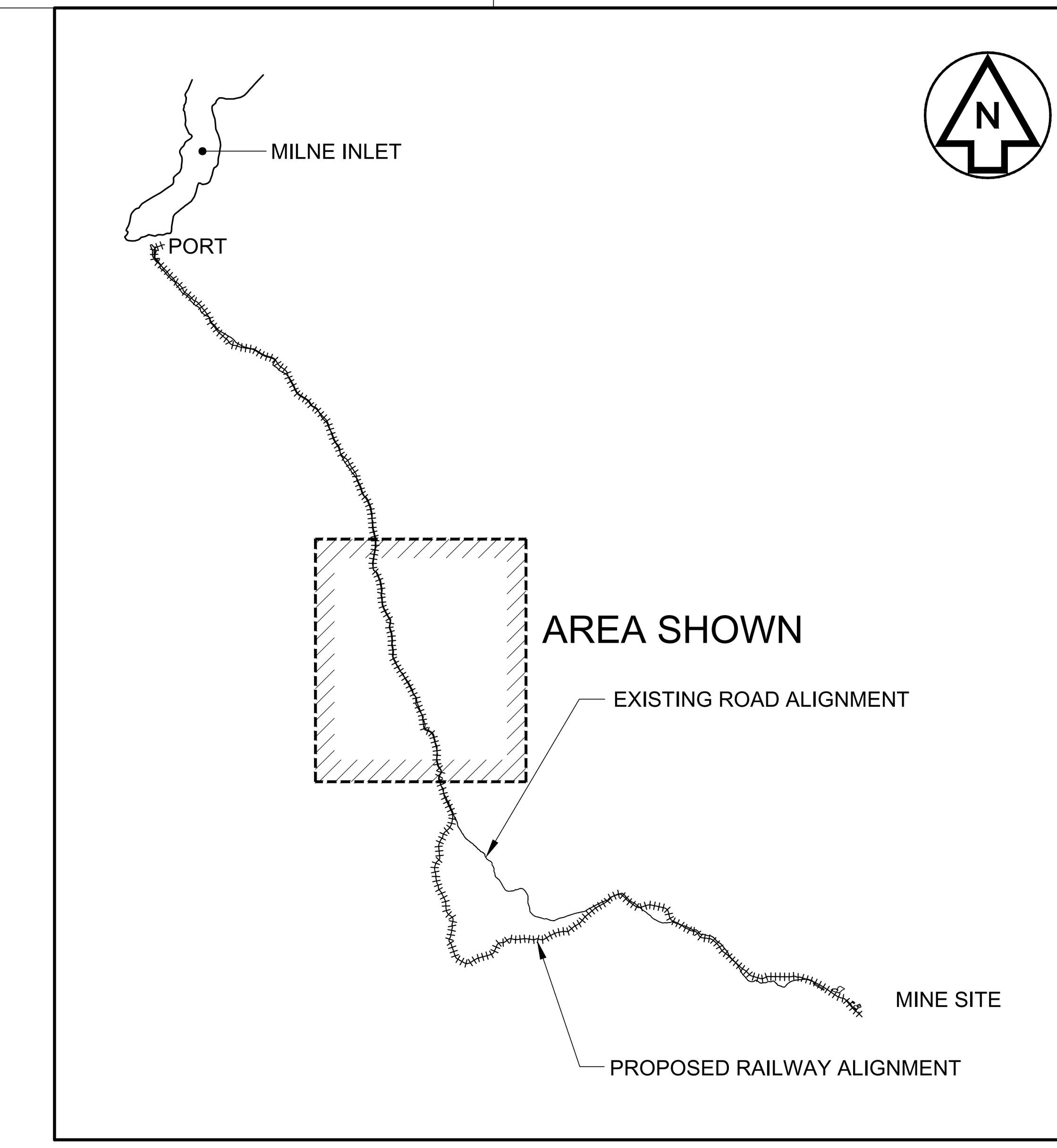

KEY PLAN

0 10 20 30 40 50 kilometres

SCALE 1:500 000

LEGEND

- AS-BUILT BOREHOLE LOCATION
- CHAINAGE POINT ALONG RAIL ALIGNMENT
- SEISMIC LINE LOCATION
- GROUND PENETRATING RADAR SURVEY (GPR) AREA
- PROPOSED RAILWAY
- EXISTING TOTE ROAD
- BENCHMARK
- SURVEY POINT
- SETTLEMENT PLATE
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0 1 2 3 4 5 KILOMETRES

SCALE 1:50 000 (B1 SHEET)

HATCH

Baffinland

ROLE	NAME	SIGNATURE	DATE
DRAFTSPERSON	R PELAEZ	NR	10/08/2018
DESIGNER	M YANG	NR	20/08/2018
CHECKER	W HOYLE		20/08/2018
DESIGN COORD.	M YANG		20/08/2018
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LEAD DISC. ENG.	W HOYLE		20/08/2018
ENG. MANAGER	F VAN BILJON		20/08/2018
PROJ. MANAGER	S PERRY		20/08/2018

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MARY RIVER EXPANSION PROJECT

GEOTECHNICAL INVESTIGATIONS
LOCATION PLAN
SHEET 2 OF 4

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REV A

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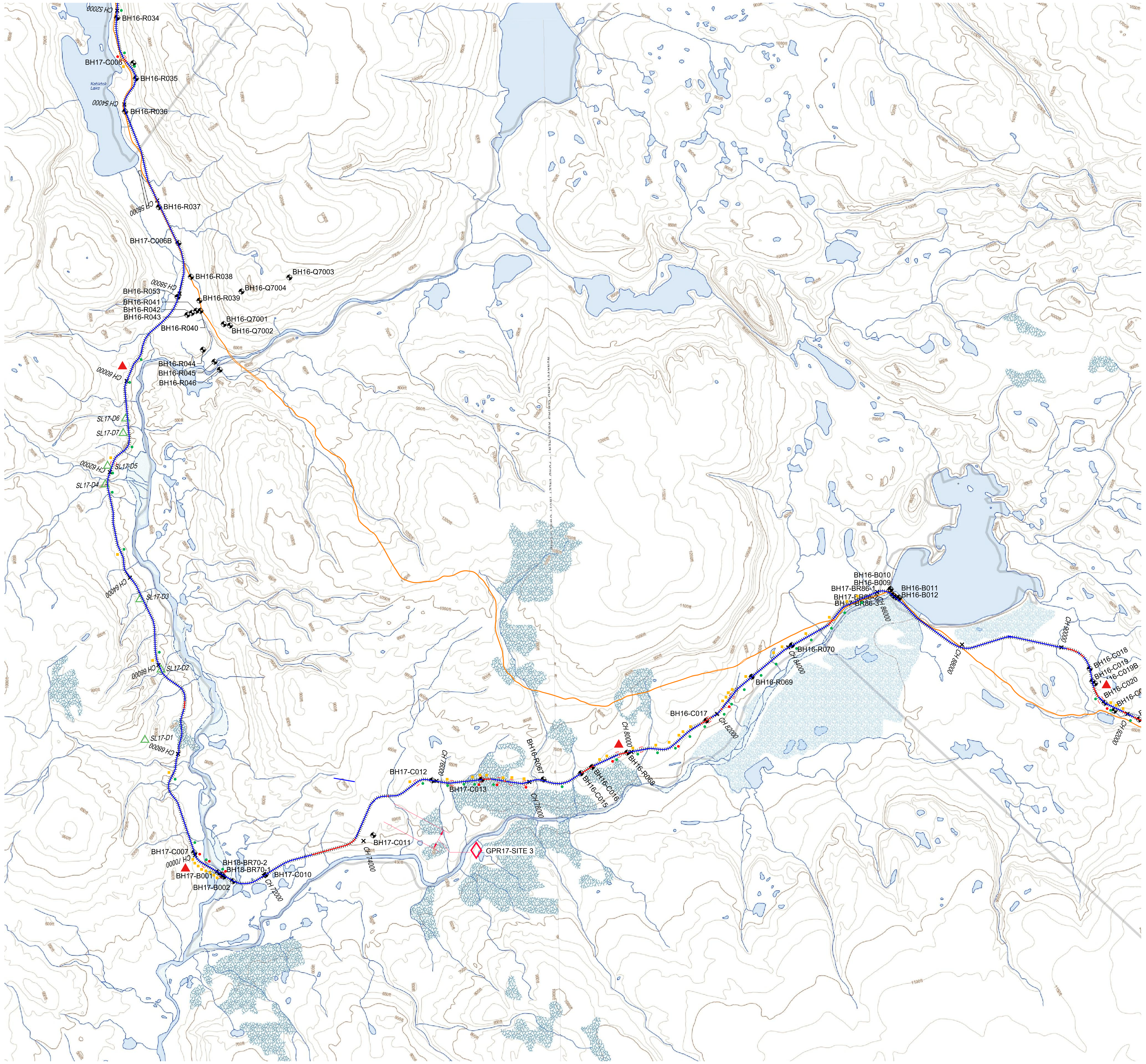

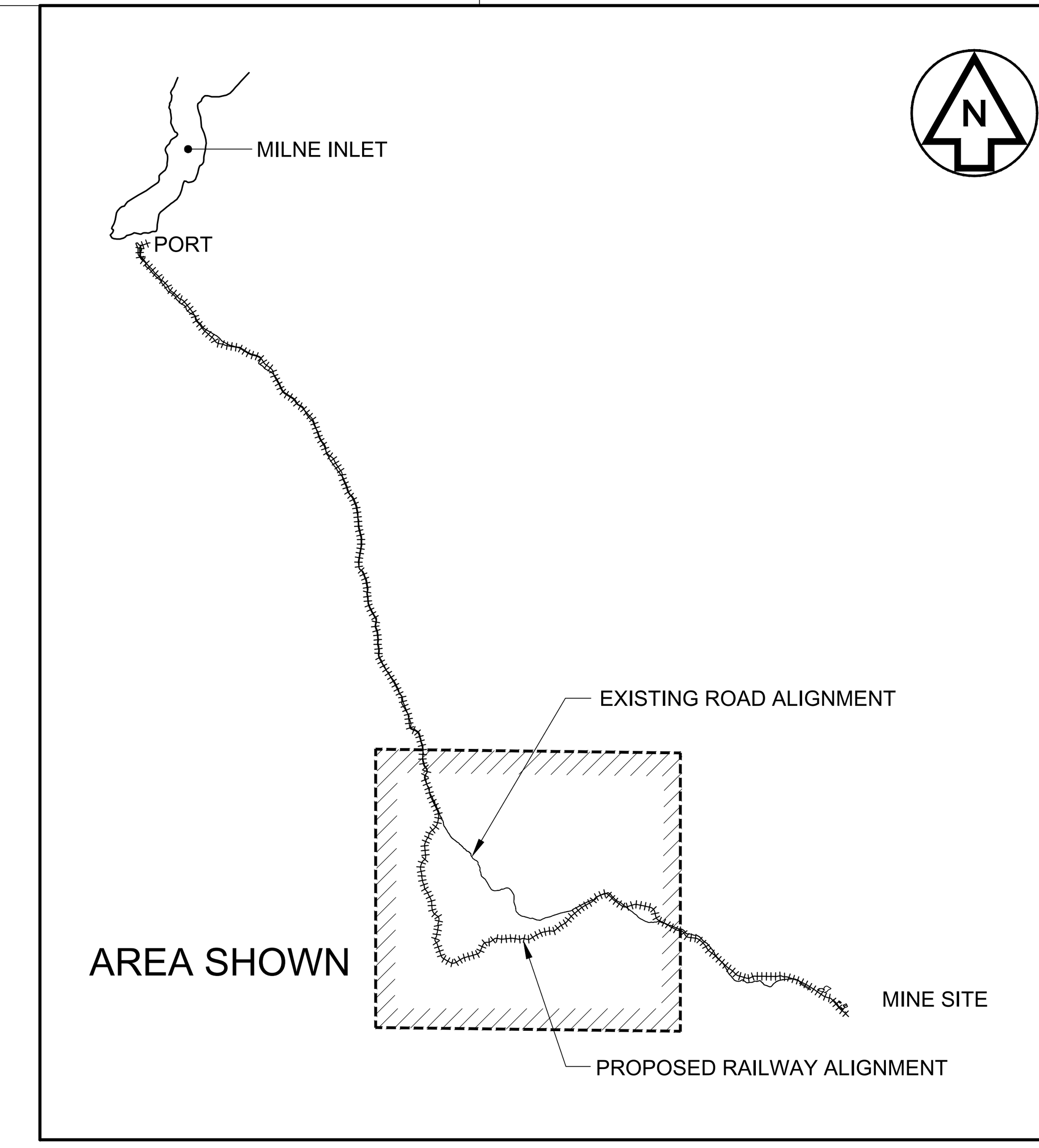

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0 10 20 30 40 50 kilometres

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- AS-BUILT BOREHOLE LOCATION
- CHAINAGE POINT ALONG RAIL ALIGNMENT
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0 1 2 3 4 5 KILOMETRES

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GEOTECHNICAL INVESTIGATIONS
LOCATION PLAN
SHEET 3 OF 4

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SHEET SIZE: D

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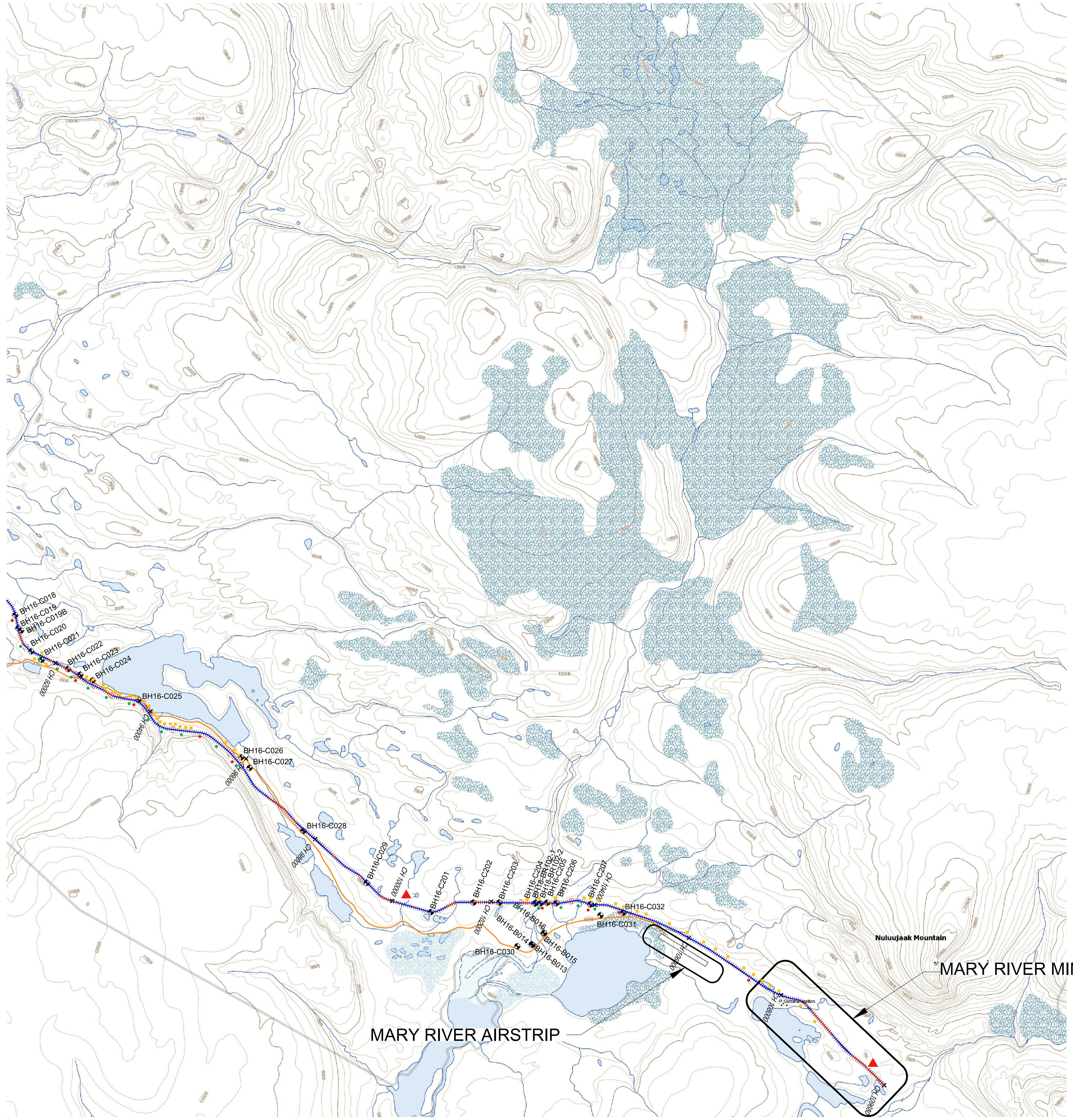

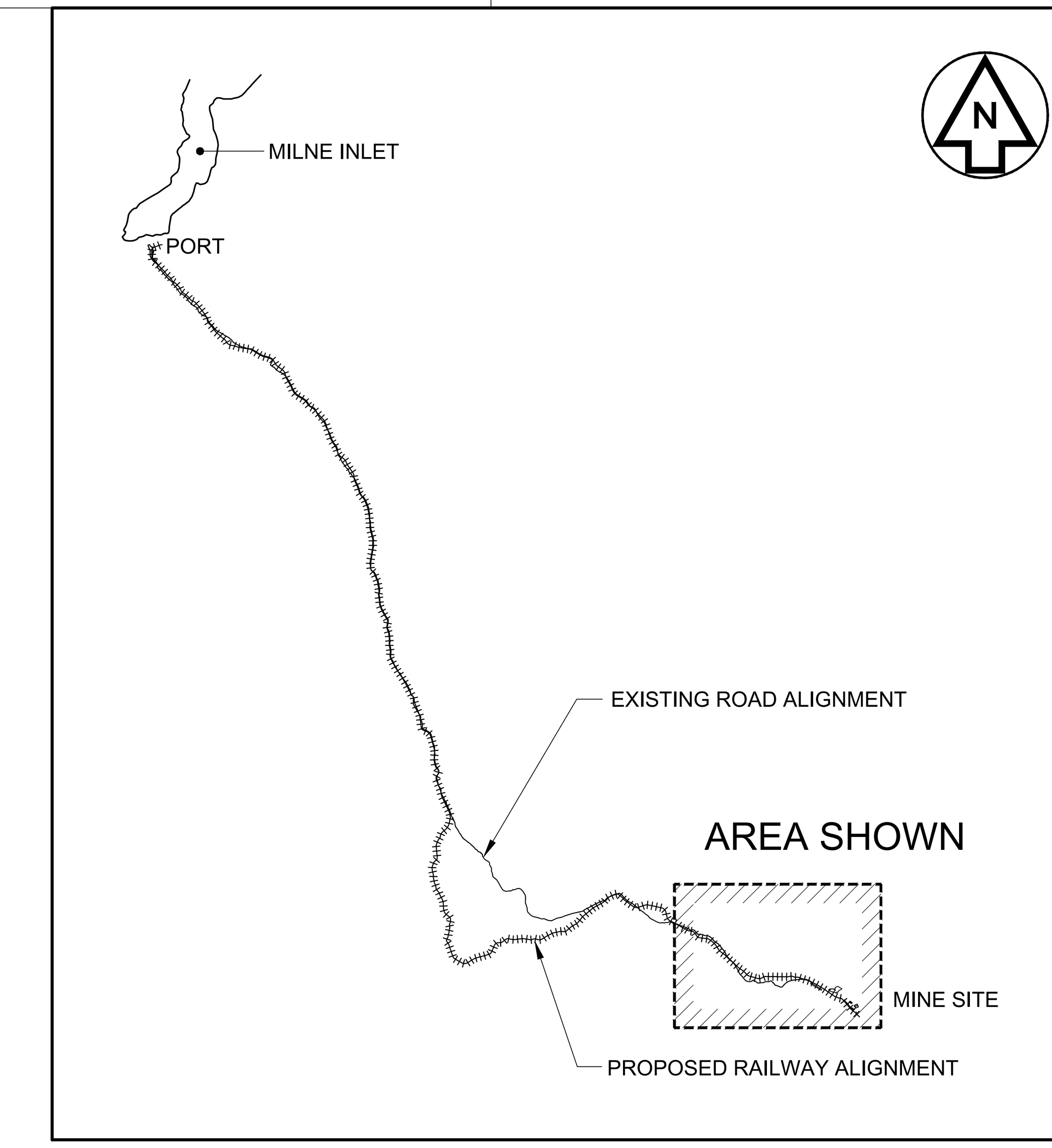

KEY PLAN

0 10 20 30 40 50 kilometres
SCALE 1:500 000

LEGEND

- AS-BUILT BOREHOLE LOCATION
- CHAINAGE POINT ALONG RAIL ALIGNMENT
- SEISMIC LINE LOCATION
- GROUND PENETRATING RADAR SURVEY (GPR) AREA
- PROPOSED RAILWAY (ALIGNMENT ADDED IN MARCH 2018)
- EXISTING TOTE ROAD
- BENCHMARK
- SURVEY POINT
- SETTLEMENT PLATE
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- VERTICAL THERMISTOR
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- Fill

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SCALE 1:50 000 (B1 SHEET)

HATCH

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GEOTECHNICAL INVESTIGATIONS
LOCATION PLAN
SHEET 4 OF 4

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Appendix C
Summary of Phased Instrument Installation

Legend

Colour Code	Feature or Phase
	Ice rich
	Phase 1
	Phase 2
	Phase 3

Benchmarks

Benchmarks (Every 10 km)				
Chainage Range (m)	**BM No**	**Cut/Fill**	**Relationship with Railway**	**Number of Benchmarks**
9+000 - 11+000	BM 1	Cut	E	1
19+000 - 21+000	BM 2	Cut	E	1
29+000 - 31+000	BM 3	Fill	E	1
39+000 - 41+000	BM 4	Cut	E	1
49+000 - 51+000	BM 5	Fill	*	1
59+000 - 61+000	BM 6	Cut	W	1
69+000 - 71+000	BM 7	Fill	W	1
79+000 - 81+000	BM 8	Cut	N	1
89+000 - 91+000	BM 9	Cut	N	1
99+000 - 101+000	BM 10	Cut	N	1
108+000 - 109+000	BM 11	Cut	N	1
			Total	**11**

Note: * means relationship of benchmark to be decided based on-site conditions

Rail Embankment Survey Points

Survey Points (Rail Embankments)					
Chainage Range	**Feature**	**Cut/Fill**	**Location**	**Relationship with Railway**	**Number**
15+200 – 16+250	Ice rich, highly susceptible	Fill	15+200	W	1
		Fill	15+300	W	1
		Fill	15+400	W	1
		Fill	15+500	W	1
		Fill	15+600	W	1
		Fill	15+700	W	1
		Fill	15+800	W	1
		Fill	15+900	W	1
		Fill	16+000	W	1
		Fill	16+100	W	1
		Fill	16+200	W	1
		Fill	16+300	W	1
			Subtotal	**12**	
20+510 – 21+000	Ice lens	Cut	20+520	E	1
		Cut	20+620	E	1
	Moderately susceptible	Cut	20+820	E	1
		Fill	21+020	E	1
			Subtotal	**4**	
25+980 – 26+250	High susceptible	Fill	26+000	W	1
		Fill	26+100	W	1
		Fill	26+200	W	1
			Subtotal	**3**	
27+200 – 27+360	High susceptible	Fill	27+200	W	1
		Fill	27+300	W	1
		Fill	27+400	W	1
27+360 – 30+000	Potentially susceptible	Fill	27+600	E	1
		Fill	27+800	E	1
		Cut	28+000	E	1
		Fill	28+200	E	1
		Fill	28+400	E	1
		Fill	28+600	E	1
		Fill	28+800	E	1
		Fill	29+000	E	1
		Fill	29+200	E	1
		Fill	29+400	E	1
		Fill	29+600	E	1
		Fill	29+800	E	1
		Fill	30+000	E	1

Survey Points (Rail Embankments)					
Chainage Range	**Feature**	**Cut/Fill**	**Location**	**Relationship with Railway**	**Number**
			Subtotal	**16**	
37+500 – 38+000	Ice rich, moderately susceptible	Cut	37+500	W	1
		Cut	37+600	W	1
		Cut	37+700	W	1
		Fill	37+800	W	1
		Cut	37+900	W	1
		Fill	38+000	W	1
			Subtotal	**6**	
40+440 – 43+000	Potentially susceptible	Fill	40+600	W	1
		Fill	40+800	W	1
		Fill	41+000	W	1
		Fill	41+200	W	1
		Fill	41+400	W	1
		Fill	42+000	W	1
		Fill	42+200	W	1
		Fill	42+400	W	1
		Fill	42+600	W	1
		Fill	42+800	W	1
		Fill	43+000	W	1
			Subtotal	**11**	
46+250 – 48+000	Ice rich, highly susceptible	Fill	46+300	W	1
		Fill	46+400	W	1
		Cut	46+500	W	1
		Fill	46+600	W	1
		Fill	46+700	W	1
		Fill	46+800	W	1
		Fill	46+900	W	1
		Fill	47+000	W	1
		Cut	47+100	E	1
		Cut	47+200	E	1
		Cut	47+300	E	1
		Cut	47+400	E	1
		Cut	47+500	E	1
		Fill	47+600	W	1
		Fill	47+700	W	1
		Fill	47+800	W	1
		Fill	47+900	W	1
		Fill	48+000	W	1
			Subtotal	**18**	
52+000 – 53+250	Potentially susceptible	Fill	52+000	E	1

Survey Points (Rail Embankments)					
Chainage Range	**Feature**	**Cut/Fill**	**Location**	**Relationship with Railway**	**Number**
		Fill	52+200	E	1
		Fill	52+400	E	1
	Ice rich, potentially susceptible	Cut	52+960	E	1
		Fill	53+100	E	1
		Fill	53+200	E	1
			Subtotal	**6**	
59+340 – 60+120	Potentially susceptible	Fill	59+400	E	1
		Cut	59+600	E	1
		Cut	59+800	E	1
		Fill	60+000	E	1
			Subtotal	**4**	
61+020 – 62+500	Moderately susceptible	Fill	61+400	E	1
		Fill	61+600	E	1
		Fill	61+800	E	1
		Fill	62+000	E	1
		Fill	62+200	E	1
		Fill	62+400	E	1
			Subtotal	**6**	
63+250 – 63+750	Moderately susceptible	Fill	63+250	E	1
		Fill	63+500	E	1
		Fill	63+750	E	1
			Subtotal	**3**	
65+750 – 66+000	Moderately susceptible	Fill	65+700	E	1
		Fill	65+800	E	1
		Fill	65+900	E	1
			Subtotal	**3**	
68+250 – 68+500	Moderately susceptible	Fill	68+300	E	1
		Fill	68+400	E	1
		Fill	68+500	E	1
			Subtotal	**3**	
69+760 – 70+000	Potentially susceptible	Fill	69+800	E	1
70+000 – 70+800	Ice rich, potentially susceptible,	Fill	70+000	E	1
		Fill	70+100	E	1
		Fill	70+200	E	1
		Fill	70+300	E	1
		Fill	70+400	E	1
		Fill	70+500	E	1
		Fill	70+600	E	1
		Fill	70+700	E	1
		Fill	70+800	E	1

Survey Points (Rail Embankments)					
Chainage Range	**Feature**	**Cut/Fill**	**Location**	**Relationship with Railway**	**Number**
70+800 – 71+000	Potentially susceptible	Fill	71+000	E	1
			Subtotal	**11**	
75+750 – 77+600	Highly susceptible	Fill	75+800	S	1
		Fill	75+900	S	1
		Fill	76+000	S	1
		Fill	76+100	S	1
		Fill	76+200	S	1
		Fill	76+300	S	1
		Fill	76+400	S	1
		Fill	76+500	S	1
		Fill	76+600	S	1
		Fill	76+700	S	1
		Fill	76+800	S	1
		Fill	76+900	S	1
		Cut	77+000	S	1
		Cut	77+100	S	1
		Fill	77+200	S	1
		Fill	77+300	S	1
		Cut	77+400	S	1
		Fill	77+500	S	1
		Fill	77+600	S	1
77+600 – 80+000	Potentially susceptible	Fill	77+800	S	1
		Fill	78+000	S	1
		Fill	78+200	S	1
		Fill	78+400	S	1
		Fill	78+600	S	1
		Fill	78+800	S	1
		Fill	79+000	S	1
		Cut	79+200	S	1
		Fill	79+400	S	1
		Fill	79+600	S	1
		Cut	79+800	S	1
		Fill	80+000	S	1
			Subtotal	**31**	
80+000 – 85+800	Ice rich, potentially susceptible	Fill	80+100	S	1
		Fill	80+200	S	1
		Fill	80+300	S	1
		Fill	80+400	S	1
		Fill	80+500	S	1
		Fill	80+600	S	1

Survey Points (Rail Embankments)					
Chainage Range	Feature	Cut/Fill	Location	Relationship with Railway	Number
		Fill	80+700	S	1
		Fill	80+800	S	1
		Fill	80+900	S	1
		Fill	81+000	S	1
		Cut	81+100	S	1
		Fill	81+200	S	1
		Fill	81+300	S	1
		Cut	81+400	S	1
		Fill	81+500	S	1
		Fill	81+600	S	1
		Cut	81+700	S	1
		Cut	81+800	S	1
		Cut	81+900	S	1
		Fill	82+000	S	1
		Cut	82+100	S	1
		Fill	82+200	S	1
		Fill	82+300	S	1
		Fill	82+400	S	1
		Fill	82+500	S	1
		Fill	82+600	S	1
	Ice rich, potentially susceptible	Fill	82+700	S	1
		Fill	82+800	S	1
		Fill	82+900	S	1
		Fill	83+000	S	1
		Fill	83+100	S	1
		Fill	83+200	S	1
		Fill	83+300	S	1
		Fill	83+400	S	1
		Fill	83+500	S	1
		Fill	83+600	S	1
		Fill	83+700	S	1
		Fill	83+800	S	1
		Fill	83+900	S	1
		Fill	84+000	S	1
		Fill	84+100	S	1
		Fill	84+200	S	1
		Fill	84+300	S	1
		Fill	84+400	S	1
		Fill	84+500	S	1
		Fill	84+600	S	1

Survey Points (Rail Embankments)					
Chainage Range	**Feature**	**Cut/Fill**	**Location**	**Relationship with Railway**	**Number**
		Fill	84+700	S	1
		Fill	84+800	S	1
	Ice rich, potentially susceptible	Cut	84+900	S	1
		Cut	85+000	S	1
		Cut	85+100	S	1
		Fill	85+200	S	1
		Fill	85+300	S	1
		Fill	85+400	S	1
		Fill	85+500	S	1
		Fill	85+600	S	1
		Fill	85+700	S	1
		Fill	85+800	S	1
			Subtotal	**58**	
91+250 – 95+100	Ice rich, highly susceptible	Cut	91+300	N	1
		Cut	91+400	N	1
		Cut	91+500	N	1
		Fill	91+600	N	1
		Fill	91+700	N	1
		Fill	91+800	N	1
		Fill	91+900	N	1
		Fill	92+000	N	1
		Fill	92+100	N	1
		Cut	92+200	N	1
		Fill	92+300	N	1
		Cut	92+400	N	1
		Cut	92+500	N	1
		Cut	92+600	N	1
		Cut	92+700	N	1
		Fill	92+800	N	1
		Fill	92+900	N	1
		Fill	93+000	N	1
		Fill	93+100	N	1
		Fill	93+200	N	1
		Cut	93+300	N	1
		Cut	93+400	N	1
		Cut	93+500	N	1
		Fill	93+600	N	1
		Fill	93+700	N	1
		Fill	93+800	N	1
		Fill	93+900	N	1

Survey Points (Rail Embankments)					
Chainage Range	Feature	Cut/Fill	Location	Relationship with Railway	Number
		Fill	94+000	N	1
		Fill	94+100	N	1
		Fill	94+200	N	1
		Fill	94+300	N	1
		Fill	94+400	N	1
		Fill	94+500	N	1
		Fill	94+600	N	1
		Fill	94+700	N	1
		Fill	94+800	N	1
		Fill	94+900	N	1
		Fill	95+000	N	1
		Fill	95+100	N	1
			Subtotal	**39**	
95+500 - 95+750	Ice rich, moderately susceptible	Fill	95+550	N	1
		Fill	95+650	N	1
		Fill	95+750	N	1
95+750 - 96+000	Ice rich, highly susceptible	Fill	95+800	N	1
		Fill	95+900	N	1
		Fill	96+000	N	1
			Subtotal	**6**	
102+520 - 103+260	Ice rich, highly susceptible	Fill	102+500	S	1
		Fill	102+600	S	1
		Fill	102+700	S	1
		Fill	102+800	S	1
		Fill	102+900	S	1
		Cut	103+000	S	1
		Cut	103+100	S	1
		Cut	103+200	S	1
103+260 - 103+780	Ice rich, non susceptible	Fill	103+300	S	1
		Fill	103+400	S	1
		Cut	103+500	S	1
		Cut	103+600	S	1
		Fill	103+700	S	1
103+780 - 104+000	Ice rich, highly susceptible	Fill	103+800	S	1
		Fill	103+900	S	1
		Fill	104+000	S	1
			Subtotal	**16**	
			Total	**256**	

Culvert Survey Targets

Survey Targets (2 per Culvert Barrel)			
Culvert ID	Subsurface	Number of Barrels	Number of Survey Targets
CV-103-1	Ice Rich	4	8
CV-104-3	Ice Rich	1	2
CV-93-3a	Ice Rich	1	2
CV-95-3	Ice Rich	1	2
CV-107-3	Ice Rich	1	2
CV-46-4	Ice Rich	4	8
CV-15-2	Ice Rich	1	2
CV-47-3*	Ice Rich	2	4
CV-15-3	Ice Rich	1	2
CV-92-3	Ice Rich	1	2
CV-81-2	Ice Rich	1	2
CV-82-4	Ice Rich	1	2
CV-80-2a	Ice Rich	1	2
CV-91-0	Ice Rich	1	2
CV-83-1	Ice Rich	1	2
CV-70-2	Ice Rich	3	6
CV-53-1a	Ice Rich	1	2
CV-71-1	Ice Rich	3	6
CV-108-2	Ice Rich	1	2
CV-53-1	Ice Rich	1	2
CV-84-1*	Ice Rich	2	4
CV-105-4	Ice Rich	1	2
CV-94-2	Ice Rich	1	2
CV-102-4	Ice Rich	1	2
CV-85-2	Ice Rich	1	2
CV-106-1a	Ice Rich	1	2
CV-4-1	Ice Poor	1	2
CV-5-3	Ice Poor	1	2
CV-6-3	Ice Poor	2	4
CV-1-9	Ice Poor	1	2
CV-62-1*	Ice Poor	4	8
CV-68-1	Ice Poor	3	6
CV-77-2*	Ice Poor	2	4
CV-58-6	Ice Poor	1	2
CV-60-3	Ice Poor	1	2
CV-38-3	Ice Poor	3	6
CV-29-2*	Ice Poor	3	6
CV-19-2	Ice Poor	1	2

Survey Targets (2 per Culvert Barrel)			
Culvert ID	Subsurface	Number of Barrels	Number of Survey Targets
CV-43-5	Ice Poor	1	2
CV-35-2*	Ice Poor	1	2
CV-51-2	Ice Poor	1	2
CV-39-1	Ice Poor	1	2
CV-47-1*	Ice Rich	2	4
CV-48-4*	Ice Poor	4	8
CV-58-4a*	Ice Poor	1	2
CV-86-2*	Ice Poor	6	12
CV-96-1*	Ice Poor	1	2
BG-14-1C*	Ice Poor	1	2
CV-104-5*	Ice Rich	1	2
CV-107-4*	Ice Rich	1	2
CV-186*	Ice Rich	1	2
Pedestrian Underpass at Mine*	Ice Rich	1	2
Total			**168**

Note: * denotes arch plate culverts.

Bridge Pier Survey Targets

Survey Targets (1 per Pier)		
Bridge	**Pier**	**Number of Survey Targets**
BR #15.913	Pier #1	1
	Pier #2	1
	Pier #3	1
	Pier #4	1
	Pier #5	1
	Pier #6	1
BR #70.363	Pier #1	1
	Pier #2	1
	Pier #3	1
	Pier #4	1
	Pier #5	1
	Pier #6	1
	Pier #7	1
BR #85.640	Pier #1	1
	Pier #2	1
	Pier #3	1
BR #101.842	Pier #1	1
	Pier #2	1
	Pier #3	1
	Total	**19**

Rail Embankment Settlement Plates

Settlement Plates (Embankment Fills)				
Chainage Range (m)	**Feature**	**Location (m)**	**Relationship with Railway**	**Number of Settlement Plates**
15+200 – 16+250	Ice rich, highly susceptible	15+300	E	1
		15+600	W	1
		15+900	W	1
		Subtotal	**3**	
27+200 – 27+360	High susceptible	27+300	E	1
27+360 – 30+000	Potentially susceptible	28+500	W	1
		28+800	E	1
		Subtotal	**3**	
37+500 – 38+000	Ice rich	38+000	W	1
		Subtotal	**1**	
40+440 – 43+000	Non and potentially susceptible	40+050	W	1
		41+100	W	1
		41+400	W	1
		42+100	W	1
		42+300	W	1
		42+800	W	1
		Subtotal	**6**	
46+250 – 48+000	Ice rich, highly susceptible	46+700	W	1
		46+800	E	1
		46+850	W	1
		47+600	E	1
		47+700	W	1
		47+800	E	1
		47+900	W	1
		Subtotal	**7**	
53+040 – 53+250	Ice rich	53+200	W	1
		Subtotal	**1**	
61+020 – 62+500	Moderately susceptible	61+800	W	1
		Subtotal	**1**	
63+250 – 63+750	Moderately susceptible	63+700	W	1
		Subtotal	**1**	
65+750 – 66+000	Moderately susceptible	65+900	E	1
		Subtotal	**1**	
68+250 – 68+500	Moderately susceptible	68+250	W	1
		Subtotal	**1**	
70+000 – 70+800	Ice rich, potentially susceptible	70+050	E	1
		70+150	W	1

Settlement Plates (Embankment Fills)				
Chainage Range (m)	**Feature**	**Location (m)**	**Relationship with Railway**	**Number of Settlement Plates**
		70+250	E	1
		70+350	W	1
		70+450	E	1
		70+550	W	1
		70+650	E	1
		70+750	W	1
		Subtotal	**8**	
75+750 – 77+600	Highly susceptible	75+750	S	1
		76+250	S	1
		76+750	S	1
		76+850	N	1
		76+950	S	1
		77+200	N	1
		77+550	S	1
77+600 – 80+000	Potentially susceptible	77+950	S	1
		79+350	N	1
		79+550	S	1
		Subtotal	**10**	
80+000 – 85+800	Ice rich, potentially susceptible	80+050	S	1
		80+500	N	1
		80+750	N	1
		81+150	S	1
		81+250	N	1
		81+450	S	1
		82+250	N	1
		82+350	S	1
		82+450	N	1
		82+550	S	1
		82+950	N	1
		83+750	S	1
		83+950	N	1
		84+350	S	1
		85+050	N	1
		85+450	S	1
		85+650	N	1
		Subtotal	**17**	
91+250 – 95+100	Ice rich, highly susceptible	91+650	N	1
		91+850	N	1
		91+950	S	1

Settlement Plates (Embankment Fills)				
Chainage Range (m)	**Feature**	**Location (m)**	**Relationship with Railway**	**Number of Settlement Plates**
		92+350	N	1
		92+450	S	1
		92+850	N	1
		92+950	S	1
		93+150	N	1
		93+250	S	1
		93+650	N	1
		93+750	S	1
		93+850	N	1
		93+950	S	1
		94+050	N	1
		94+150	S	1
		94+250	N	1
		94+450	N	1
		94+550	S	1
		94+650	N	1
		94+750	S	1
		94+850	N	1
		94+950	S	1
		Subtotal	**22**	
95+500 - 96+000	Ice rich, highly susceptible	95+550	N	1
		95+750	S	1
		95+850	N	1
		95+950	S	1
		Subtotal	**4**	
102+520 - 103+260	Ice rich, highly susceptible	102+650	S	1
		102+850	N	1
103+260 - 103+780	Ice rich, n susceptible	103+350	S	1
103+780 - 104+000	Ice rich, highly susceptible	103+850	N	1
		103+950	S	1
		104+050	N	1
		Subtotal	**6**	
104+000 - 109+530	Assume ice rich	104+450	S	1
		104+550	N	1
		104+750	S	1
		104+950	N	1
		105+550	N	1
		105+950	S	1
		106+250	N	1

Settlement Plates (Embankment Fills)				
Chainage Range (m)	**Feature**	**Location (m)**	**Relationship with Railway**	**Number of Settlement Plates**
		106+450	S	1
		106+650	N	1
	Assume ice rich	107+150	S	1
		107+350	N	1
		107+550	S	1
		107+750	N	1
		107+950	S	1
		108+250	N	1
		108+450	S	1
		Subtotal	**16**	
			Total	**108**

Bridge Abutment Settlement Plates

Settlement Plates (2 per Bridge)			
Bridge	**Feature**	**Area**	**Number of Settlement Plates**
Bridge #15.913	Ice rich, highly susceptible	Fill	2
Bridge #70.363	Ice rich, potentially susceptible	Fill	2
Bridge #85.640	Ice rich, potentially susceptible	Fill	2
Bridge #101.842	Ice poor, non-susceptible	Cut	2
		Total	8

Railway Embankment Horizontal Thermistor Strings

Horizontal Thermistor Strings (Rail Embankments)							
Chainage Range (m)	**Feature**	**Cut/Fill**	**From (m)**	**To (m)**	**Length (m)**	**Relationship with Railway**	**Number of Horizontal Thermistors**
15+200 – 16+250	Ice rich, highly susceptible	Fill	15+240	15+260	20	W	1
		Fill	15+340	15+360	20	E	1
		Fill	15+440	15+460	20	W	1
		Fill	15+540	15+560	20	E	1
		Fill	15+640	15+660	20	W	1
		Fill	15+740	15+760	20	E	1
		Fill	15+840	15+860	20	W	1
		Fill	15+940	15+960	20	E	1
		Fill	16+040	16+060	20	W	1
		Fill	16+140	16+160	20	E	1
				Subtotal	**200**		**10**
20+510 – 21+000	Ice lens	Cut	20+540	20+560	20	E	1
	Moderately susceptible	Cut	20+840	20+860	20	W	1
				Subtotal	**40**		**2**
25+980 – 26+250	High susceptible	Fill	26+040	26+060	20	W	1
		Fill	26+140	26+160	20	E	1
		Fill	26+240	26+260	20	W	1
				Subtotal	**60**		**3**
27+200 – 27+360	High susceptible	Fill	27+240	27+260	20	E	1
		Fill	27+340	27+360	20	W	1
		Fill	27+440	27+460	20	E	1
27+360 – 30+000	Potentially susceptible	Fill	27+600	27+620	20	W	1
		Fill	27+800	27+820	20	E	1
		Fill	28+000	28+020	20	W	1
		Cut	28+200	28+220	20	E	1
		Fill	28+400	28+420	20	E	1
		Fill	28+600	28+620	20	W	1
		Fill	28+800	28+820	20	E	1
		Fill	29+000	29+020	20	W	1
		Fill	29+200	29+220	20	E	1
		Fill	29+400	29+420	20	W	1
		Fill	29+600	29+620	20	E	1
		Fill	29+800	29+820	20	W	1
				Subtotal	**300**		**15**
		Cut	37+540	37+560	20	W	1

Horizontal Thermistor Strings (Rail Embankments)							
Chainage Range (m)	**Feature**	**Cut/Fill**	**From (m)**	**To (m)**	**Length (m)**	**Relationship with Railway**	**Number of Horizontal Thermistors**
37+500 – 38+000	Ice rich, moderately susceptible	Cut	37+640	37+660	20	E	1
		Fill	37+780	37+800	20	E	1
		Cut	37+840	37+860	20	W	1
				Subtotal	**80**		**4**
40+440 – 43+000	Potentially susceptible	Fill	40+600	40+620	20	W	1
		Fill	40+800	40+820	20	E	1
		Fill	41+360	41+380	20	W	1
		Fill	42+020	42+040	20	E	1
		Fill	42+220	42+240	20	W	1
		Fill	42+800	42+820	20	E	1
				Subtotal	**120**		**6**
46+250 – 48+000	Ice rich, highly susceptible	Fill	46+380	46+400	20	W	1
		Cut	46+520	46+540	20	E	1
		Fill	46+620	46+640	20	W	1
		Fill	46+720	46+740	20	E	1
		Fill	46+820	46+840	20	W	1
		Fill	46+920	46+940	20	E	1
		Cut	47+120	47+140	20	W	1
		Cut	47+220	47+240	20	E	1
		Cut	47+320	47+340	20	W	1
		Cut	47+420	47+440	20	E	1
		Fill	47+520	47+540	20	W	1
		Fill	47+620	47+640	20	E	1
		Fill	47+720	47+740	20	W	1
		Fill	47+820	47+840	20	E	1
		Fill	47+920	47+940	20	W	1
				Subtotal	**300**		**15**
52+000 – 53+250	Potentially susceptible	Fill	52+000	52+020	20	E	1
	Ice rich, potentially susceptible	Fill	53+020	53+040	20	W	1
		Fill	53+120	53+140	20	E	1
		Fill	53+220	53+240	20	W	1
				Subtotal	**80**		**4**
59+340 – 60+120	Potentially susceptible	Fill	59+400	59+420	20	E	1
		Cut	59+800	59+820	20	E	1
		Fill	60+000	60+020	20	E	1
				Subtotal	**60**		**3**
61+020 – 62+500	Moderately susceptible	Fill	61+520	61+540	20	W	1
		Fill	61+820	61+840	20	E	1

Horizontal Thermistor Strings (Rail Embankments)							
Chainage Range (m)	**Feature**	**Cut/Fill**	**From (m)**	**To (m)**	**Length (m)**	**Relationship with Railway**	**Number of Horizontal Thermistors**
		Fill	62+020	62+040	20	W	1
		Fill	62+220	62+240	20	E	1
		Fill	62+420	62+440	20	W	1
				Subtotal	**100**		**5**
63+250 – 63+750	Moderately susceptible	Fill	63+500	63+520	20	E	1
				Subtotal	**20**		**1**
65+750 – 66+000	Moderately susceptible	Fill	65+800		20	W	1
				Subtotal	**20**		**1**
68+250 – 68+500	Moderately susceptible	Fill	68+400		20	E	1
				Subtotal	**20**		**1**
69+760 – 70+000	Potentially susceptible	Fill	69+840	69+860	20	E	1
70+000 – 70+800	Ice rich, potentially susceptible,	Fill	70+040	70+060	20	W	1
		Fill	70+140	70+160	20	E	1
		Fill	70+240	70+260	20	W	1
		Fill	70+340	70+360	20	E	1
		Fill	70+440	70+460	20	W	1
		Fill	70+540	70+560	20	E	1
		Fill	70+640	70+660	20	W	1
		Fill	70+740	70+760	20	E	1
		Fill	70+840	70+860	20	W	1
70+800 – 71+000	Potentially susceptible	Fill	70+940	70+960	20	E	1
				Subtotal	**220**		**11**
75+750 – 77+600	Highly susceptible	Fill	75+840	75+860	20	S	1
		Fill	75+940	75+960	20	N	1
		Fill	76+040	76+060	20	S	1
		Fill	76+140	76+160	20	N	1
		Fill	76+240	76+260	20	S	1
		Fill	76+340	76+360	20	N	1
		Fill	76+440	76+460	20	S	1
		Fill	76+540	76+560	20	N	1
		Fill	76+640	76+660	20	S	1
		Fill	76+740	76+760	20	N	1
		Fill	76+840	76+860	20	S	1
		Fill	76+940	76+960	20	N	1
		Cut	77+040	77+060	20	S	1
		Cut	77+140	76+160	20	N	1

Horizontal Thermistor Strings (Rail Embankments)							
Chainage Range (m)	**Feature**	**Cut/Fill**	**From (m)**	**To (m)**	**Length (m)**	**Relationship with Railway**	**Number of Horizontal Thermistors**
		Fill	77+240	77+60	20	S	1
		Fill	77+340	77+360	20	N	1
		Cut	77+440	77+460	20	S	1
		Fill	77+540	76+560	20	N	1
		Fill	77+640	77+660	20	S	1
77+600 – 80+000	Potentially susceptible	Fill	77+940	77+960	20	N	1
		Fill	78+900	78+920	20	S	1
		Fill	79+400	79+420	20	N	1
		Fill	79+600	79+620	20	S	1
		Cut	79+800	79+820	20	N	1
		Fill	80+000	80+020	20	S	1
				Subtotal	**500**		**25**
80+000 – 85+800	Ice rich, potentially susceptible	Fill	80+140	80+160	20	S	1
		Fill	80+540	80+560	20	N	1
		Fill	81+440	81+460	20	S	1
		Cut	81+840	81+860	20	N	1
		Cut	82+140	82+160	20	S	1
		Fill	82+340	82+360	20	N	1
		Fill	82+440	82+460	20	S	1
		Fill	82+940	82+960	20	N	1
		Fill	83+740	83+760	20	S	1
		Fill	84+380	84+400	20	N	1
				Subtotal	**200**		**10**
91+250 – 95+100	Ice rich, highly susceptible	Cut	91+340	91+360	20	N	1
		Cut	91+440	91+460	20	S	1
		Fill	91+640	91+660	20	N	1
		Fill	91+840	91+860	20	S	1
		Fill	92+040	92+060	20	N	1
		Cut	92+240	92+260	20	S	1
		Fill	92+440	92+460	20	N	1
		Cut	92+640	92+660	20	S	1
		Fill	92+840	92+860	20	N	1
		Cut	93+340	93+360	20	S	1
		Cut	93+440	93+460	20	N	1
		Fill	93+740	93+760	20	S	1
		Fill	93+840	93+860	20	N	1
		Fill	93+940	93+960	20	S	1
		Fill	94+040	94+060	20	N	1
		Fill	94+140	94+160	20	S	1

Horizontal Thermistor Strings (Rail Embankments)							
Chainage Range (m)	**Feature**	**Cut/Fill**	**From (m)**	**To (m)**	**Length (m)**	**Relationship with Railway**	**Number of Horizontal Thermistors**
		Fill	94+240	94+260	20	N	1
		Fill	94+340	94+360	20	S	1
		Fill	94+440	94+460	20	N	1
		Fill	94+540	94+560	20	S	1
		Fill	94+640	94+660	20	N	1
		Fill	95+040	95+060	20	S	1
				Subtotal	**440**		**22**
95+500 - 95+750	Ice rich, m susceptible	Fill	95+600	95+620	20	N	1
95+750 - 96+000	Ice rich, highly susceptible	Fill	95+800	95+820	20	S	1
		Fill	95+900	95+920	20	N	1
				Subtotal	**60**		**3**
102+520-103+260	Ice rich, highly susceptible	Fill	102+540	102+560	20	S	1
		Fill	102+640	102+660	20	N	1
		Fill	102+740	102+760	20	S	1
		Fill	102+840	102+860	20	N	1
		Fill	102+940	102+960	20	S	1
		Cut	103+140	103+160	20	N	1
		Cut	103+240	103+260	20	S	1
103+260-103+780	Ice rich, non-susceptible	Fill	103+340	103+360	20	N	1
		Fill	103+440	103+460	20	S	1
		Cut	103+540	103+560	20	N	1
		Cut	103+640	103+660	20	S	1
		Fill	103+740	103+760	20	N	1
103+780-104+000	Ice rich, highly susceptible	Fill	103+840	103+860	20	S	1
		Fill	103+940	103+960	20	N	1
				Subtotal	**280**		**14**
				Total	**3100**		**155**

Bridge Abutment Horizontal Thermistor Strings

Horizontal Thermistor Strings (Bridge Abutments)				
Bridge	**Location (m)**	**Feature**	**Cut/Fill**	**Number of Horizontal Thermistors**
#1	15+913	Ice rich, highly susceptible	Fill	2
#2	70+363	Ice rich, potentially susceptible	Fill	2
#3	85+640	Ice rich, potentially susceptible	Fill	2
#4	101+842	Poor in ice	Cut	2
Subtotal				8

Culvert Horizontal Thermistor Strings

Horizontal Thermistor Strings (2 per Culvert Barrel)		
Culvert ID	Subsurface	Number of Horizontal Thermistors
CV-103-1	Ice Rich	2
CV-104-3	Ice Rich	2
CV-93-3a	Ice Rich	2
CV-95-3	Ice Rich	2
CV-107-3	Ice Rich	2
CV-46-4	Ice Rich	2
CV-15-2	Ice Rich	2
CV-47-3*	Ice Rich	2
CV-15-3	Ice Rich	2
CV-92-3	Ice Rich	2
CV-81-2	Ice Rich	2
CV-82-4	Ice Rich	2
CV-80-2a	Ice Rich	2
CV-91-0	Ice Rich	2
CV-83-1	Ice Rich	2
CV-70-2	Ice Rich	2
CV-53-1a	Ice Rich	2
CV-71-1	Ice Rich	2
CV-108-2	Ice Rich	2
CV-53-1	Ice Rich	2
CV-84-1*	Ice Rich	2
CV-105-4	Ice Rich	2
CV-94-2	Ice Rich	2
CV-102-4	Ice Rich	2
CV-85-2	Ice Rich	2
CV-106-1a	Ice Rich	2
CV-4-1	Ice Poor	2
CV-5-3	Ice Poor	2
CV-6-3	Ice Poor	2
CV-1-9	Ice Poor	2
CV-62-1*	Ice Poor	2
CV-68-1	Ice Poor	2
CV-77-2*	Ice Poor	2
CV-58-6	Ice Poor	2
CV-60-3	Ice Poor	2
CV-38-3	Ice Poor	2
CV-29-2*	Ice Poor	2
CV-19-2	Ice Poor	2

Horizontal Thermistor Strings (2 per Culvert Barrel)		
Culvert ID	Subsurface	Number of Horizontal Thermistors
CV-43-5	Ice Poor	2
CV-35-2*	Ice Poor	2
CV-51-2	Ice Poor	2
CV-39-1	Ice Poor	2
CV-47-1*	Ice Rich	2
CV-48-4*	Ice Poor	2
CV-58-4a*	Ice Poor	2
CV-86-2*	Ice Poor	2
CV-96-1*	Ice Poor	2
BG-14-1C*	Ice Poor	2
CV-104-5*	Ice Rich	2
CV-107-4*	Ice Rich	2
CV-186*	Ice Rich	2
Pedestrian Underpass at Mine*	Ice Rich	2
Total		104

Note: * denotes arch plate culverts.

Rail Embankment Vertical Thermistor Strings

Vertical Thermistor Strings (Rail Embankments)					
Chainage Range (m)	**Feature**	**Cut/Fill**	**Location (m)**	**Relationship with Railway**	**Number of Vertical Thermistors**
15+200 – 16+250	Ice rich, highly susceptible	Fill	15+300	W	1
		Fill	15+740	E	1
		Fill	16+100	E	1
			Subtotal	**3**	
20+510 – 21+000	Ice lens	Cut	20+600	E	1
			Subtotal	**1**	
27+200 – 27+360	High susceptible	Fill	27+300	W	1
27+360 – 30+000	Potentially susceptible	Fill	27+600	W	1
		Fill	27+900	E	1
		Fill	28+400	E	1
		Fill	28+800	E	1
			Subtotal	**5**	
37+500 – 38+000	Ice rich, m susceptible	Cut	37+700	W	1
			Subtotal	**1**	
40+440 – 43+000	Potentially susceptible	Fill	40+500	W	1
		Fill	41+300	W	1
		Fill	42+000	E	1
		Fill	42+200	W	1
		Fill	42+800	E	1
			Subtotal	**5**	
46+250 – 48+000	Ice rich, highly susceptible	Fill	46+600	W	1
		Fill	46+700	E	1
		Fill	46+800	W	1
		Cut	47+300	W	1
		Cut	47+400	E	1
		Fill	47+500	W	1
		Fill	47+600	E	1
		Fill	47+700	W	1
		Fill	47+900	E	1
		Fill	48+000	W	1
			Subtotal	**10**	
52+000 – 53+040	Potentially susceptible	Fill	52+000	E	1
53+040 - 53+250	Ice rich, potentially susceptible	Fill	53+100	W	1
		Fill	53+200	E	1
			Subtotal	**3**	
59+340 – 60+120	Potentially susceptible	Cut	59+600	E	1
			Subtotal	**1**	

Vertical Thermistor Strings (Rail Embankments)					
Chainage Range (m)	**Feature**	**Cut/Fill**	**Location (m)**	**Relationship with Railway**	**Number of Vertical Thermistors**
61+020 – 62+500	Moderately susceptible	Fill	61+800	W	1
			Subtotal	**1**	
63+250 – 63+750	Moderately susceptible	Fill	63+700	E	1
			Subtotal	**1**	
65+750 – 66+000	Moderately susceptible	Fill	66+000	W	1
			Subtotal	**1**	
68+250 – 68+500	Moderately susceptible	Fill	68+250	E	1
			Subtotal	**1**	
70+000 – 70+800	Ice rich, potentially susceptible,	Fill	70+000	W	1
		Fill	70+100	E	1
		Fill	70+200	W	1
		Fill	70+300	E	1
		Fill	70+400	W	1
		Fill	70+500	E	1
		Fill	70+600	W	1
		Fill	70+700	E	1
		Fill	70+800	W	1
			Subtotal	**9**	
75+750 – 77+600	Highly susceptible	Fill	75+800	S	1
		Fill	76+300	N	1
		Fill	76+700	S	1
		Fill	76+800	N	1
		Fill	76+900	S	1
		Cut	77+100	N	1
		Fill	77+200	S	1
77+600 – 80+000	Potentially susceptible	Fill	77+800	N	1
		Fill	77+960	S	1
		Fill	78+200	N	1
		Fill	79+500	S	1
		Cut	79+800	N	1
			Subtotal	**12**	
80+000 – 85+800	Ice rich, potentially susceptible	Fill	81+200	S	1
		Fill	81+500	N	1
		Cut	81+840	N	1
		Fill	82+340	N	1
		Fill	82+440	S	1
		Fill	83+740	S	1
		Fill	84+380	N	1
			Subtotal	**7**	

Vertical Thermistor Strings (Rail Embankments)					
Chainage Range (m)	**Feature**	**Cut/Fill**	**Location (m)**	**Relationship with Railway**	**Number of Vertical Thermistors**
91+250 – 95+100	Ice rich, highly susceptible	Cut	91+340	N	1
		Fill	91+640	N	1
		Fill	92+440	N	1
		Fill	92+840	N	1
		Cut	93+440	N	1
		Fill	93+740	S	1
		Fill	93+840	N	1
		Fill	93+940	S	1
		Fill	94+040	N	1
		Fill	94+140	S	1
		Fill	94+240	N	1
		Fill	94+440	N	1
		Fill	94+540	S	1
		Fill	965+040	S	1
			Subtotal	**14**	
95+750 - 96+000	Ice rich, highly susceptible	Fill	95+900	S	1
			Subtotal	**1**	
102+520 - 103+260	Ice rich, highly susceptible	Fill	102+840	N	1
		Cut	103+100	N	1
103+780 - 104+000	Ice rich, highly susceptible	Fill	103+900	S	1
104+000 - 109+530	Assumed ice rich	Fill	104+500	N	1
		Fill	104+900	S	1
		Fill	107+200	N	1
		Fill	107+400	S	1
		Fill	107+600	N	1
		Fill	107+800	S	1
		Fill	108+000	N	1
		Fill	108+200	S	1
			Subtotal	**11**	
			Total		**87**

Bridge Pier Vertical Thermistor Strings

Vertical Thermistor Strings (1 per Bridge Pier)					
Bridge	**Location (m)**	**Feature**	**North Abutment**	**South Abutment**	**Number of Vertical Thermistors**
#1	15+913	Ice rich, highly susceptible	Fill	Fill	6
#2	70+363	Ice rich, potentially susceptible	Fill	Fill	7
#3	85+640	Ice rich, potentially susceptible	Fill	Fill	3
#4	101+842	Poor in ice	Cut	Cut	3
Subtotal					19

Culvert Vertical Thermistor Strings

Vertical Thermistor Strings (1 per Culvert)		
Culvert ID	Subsurface	Number of Vertical Thermistors
CV-103-1	Ice Rich	1
CV-104-3	Ice Rich	1
CV-93-3a	Ice Rich	1
CV-95-3	Ice Rich	1
CV-107-3	Ice Rich	1
CV-46-4	Ice Rich	1
CV-15-2	Ice Rich	1
CV-47-3*	Ice Rich	1
CV-15-3	Ice Rich	1
CV-92-3	Ice Rich	1
CV-81-2	Ice Rich	1
CV-82-4	Ice Rich	1
CV-80-2a	Ice Rich	1
CV-91-0	Ice Rich	1
CV-83-1	Ice Rich	1
CV-70-2	Ice Rich	1
CV-53-1a	Ice Rich	1
CV-71-1	Ice Rich	1
CV-108-2	Ice Rich	1
CV-53-1	Ice Rich	1
CV-84-1*	Ice Rich	1
CV-105-4	Ice Rich	1
CV-94-2	Ice Rich	1
CV-102-4	Ice Rich	1
CV-85-2	Ice Rich	1
CV-106-1a	Ice Rich	1
CV-4-1	Ice Poor	1
CV-5-3	Ice Poor	1
CV-6-3	Ice Poor	1
CV-1-9	Ice Poor	1
CV-62-1*	Ice Poor	1
CV-68-1	Ice Poor	1
CV-77-2*	Ice Poor	1
CV-58-6	Ice Poor	1
CV-60-3	Ice Poor	1
CV-38-3	Ice Poor	1
CV-29-2*	Ice Poor	1
CV-19-2	Ice Poor	1

Vertical Thermistor Strings (1 per Culvert)		
Culvert ID	Subsurface	Number of Vertical Thermistors
CV-43-5	Ice Poor	1
CV-35-2*	Ice Poor	1
CV-51-2	Ice Poor	1
CV-39-1	Ice Poor	1
CV-47-1*	Ice Rich	1
CV-48-4*	Ice Poor	1
CV-58-4a*	Ice Poor	1
CV-86-2*	Ice Poor	1
CV-96-1*	Ice Poor	1
BG-14-1C*	Ice Poor	1
CV-104-5*	Ice Rich	1
CV-107-4*	Ice Rich	1
CV-186*	Ice Rich	1
Pedestrian Underpass at Mine*	Ice Rich	1
Total		**104**

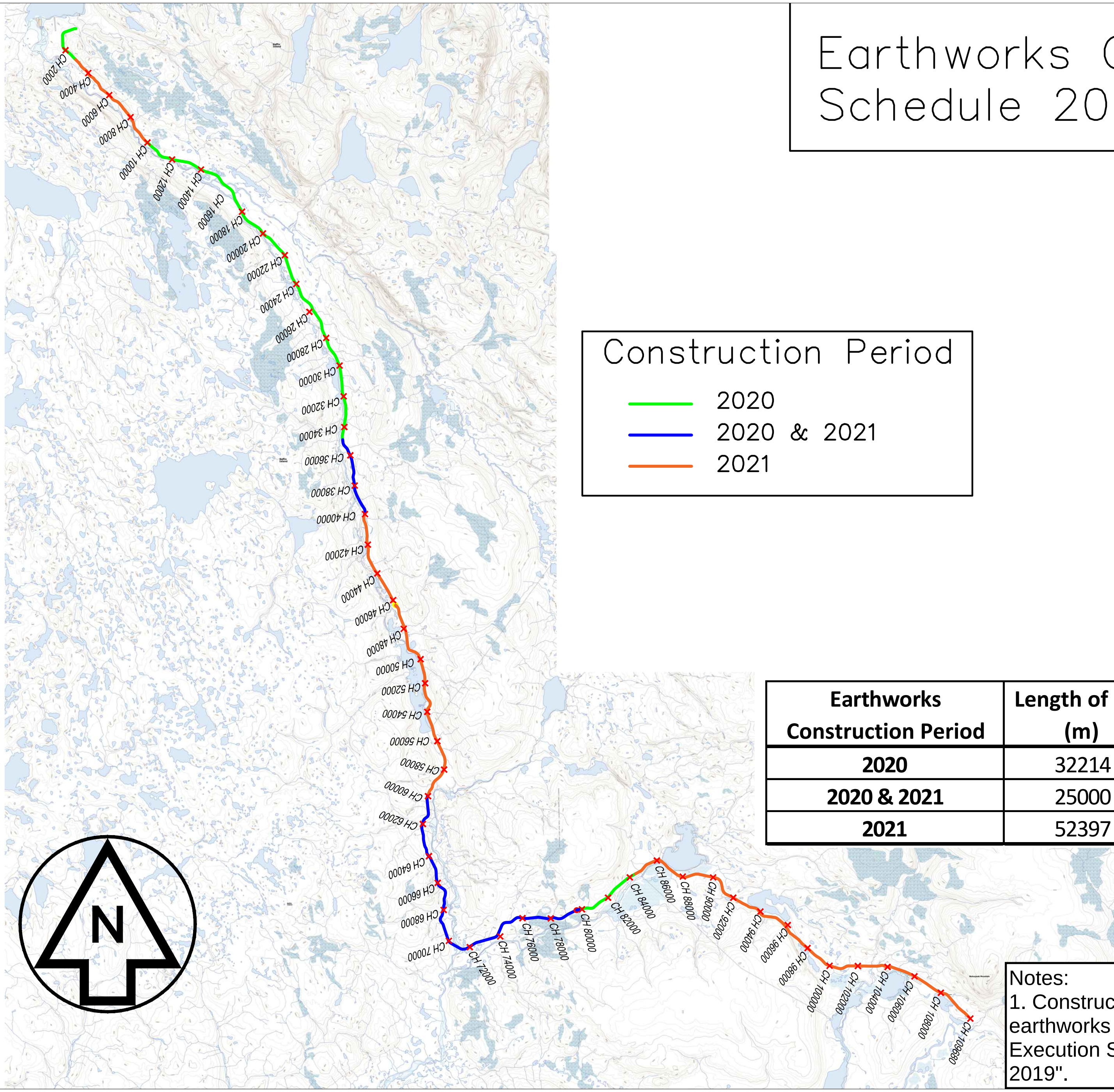
Note: * denotes arch plate culverts.

Bridge Inclinometers

Inclinometers (2 per Bridge)				
Bridge	**Location (m)**	**Feature**	**Cut/Fill**	**Number of Inclinometer**
#1	15+913	Ice rich, highly susceptible	Fill	2
#2	70+363	Ice rich, potentially susceptible	Fill	2
#3	85+640	Ice rich, potentially susceptible	Fill	2
#4	101+842	Poor in ice	Cut	2
Subtotal				8

Appendix D
Earthwork Construction Schedule
2020-2021

Earthworks Construction Schedule 2020–2021



Construction Period

- 2020
- 2020 & 2021
- 2021

Earthworks Construction Period	Length of Rail (m)	Percent of Rail
2020	32214	29.4%
2020 & 2021	25000	22.8%
2021	52397	47.8%

Notes:
1. Construction schedule breakdown for earthworks is based on "Project Master Execution Schedule 9A" dated "15-Apr-2019".