

---

To:	Karyn Lewis, Project Manager Lupin Project	From:	Alvin Tong, P.Eng.
	Mandalay Resources Corporation Suite 330, 76 Richmond Street Toronto, ON M5C 1P1		Stantec Consulting Ltd, 200-325 25 Street, Calgary, AB T2A 7H8
File:	Lupin Gold Project – 129500081	Date:	October 15, 2019

---

**Reference: 2AM-LUP1520 Technical Meeting Commitment Number 11 Response – Geophysical Survey Lupin Mine Tailings Containment Area Dams**

## INTRODUCTION

Lupin Mine Incorporated (LMI), a wholly owned subsidiary of Mandalay Resources Corporation is requesting the renewal and amendment of their existing Type “A” Water Licence No: 2AM-LUP1520, to allow for Final Closure and Reclamation of the Lupin Mine Project (Lupin). The Nunavut Water Board (NWB or Board) Water Licence Application No. 2AM-LUP1520 Technical Meeting was held June 6-7, 2019 in Kugluktuk, Nunavut. Appendix D of the June 18, 2018 Pre-Hearing Conference Decision Report outlines the agreed upon List of Commitments (Commitments). Stantec Consulting Ltd. (Stantec) was retained by LMI to support the responses to select commitments and this technical memo provides the responses to fulfill Commitment No. 11, shown below, which relates to conducting a geophysical survey along two selected Lupin Mine Tailings Containment Area (TCA) dams.

11	LMI	ECCC	One-time geophysical survey conducted along two selected dams to confirm the condition of frozen cores.	15-Oct-19	Technical Memo
----	-----	------	---	-----------	----------------

Two dams were selected by Stantec for the geophysical surveys; Dam 3D representing an internal TCA dam and Dam 4 representing an external TCA dam (Figure 1). Dam 3D and Dam 4 were specifically selected since they both have thermistors installed for calibration. Aurora Geosciences Ltd. completed the surveys and the methods, results and interpretation are included in the attached memorandum titled “Lupin Tailings Dams Geophysics Survey 2019”.

October 15, 2019  
Karyn Lewis, Project Manager Lupin Project  
Page 2 of 2

Reference: 2AM-LUP1520 Technical Meeting Commitment Number 10 Response

**Attachment:**

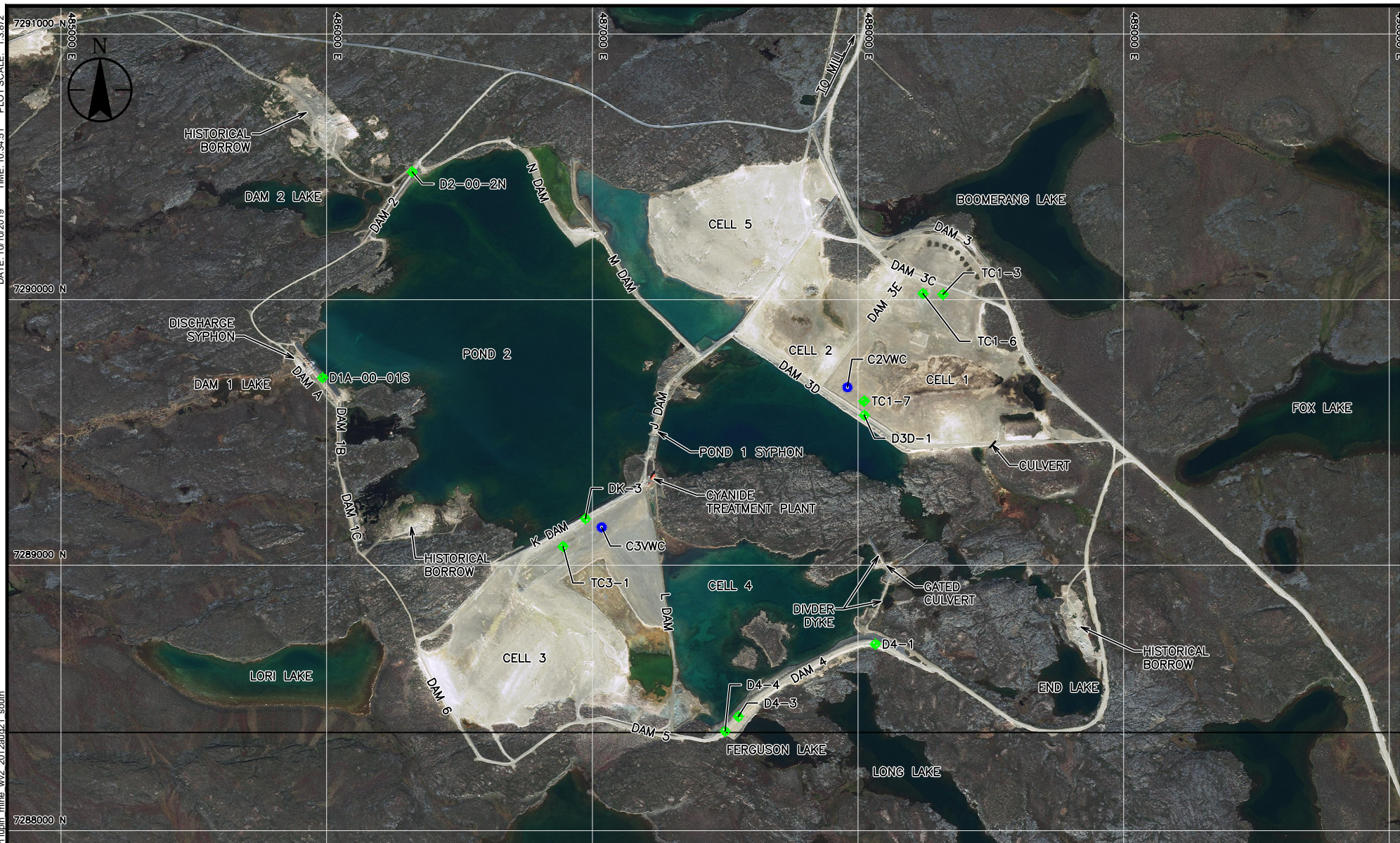
Aurora Geosciences Ltd. 2019. Lupin Tailings Dams Geophysics Survey 2019. Prepared for Stantec.

**Stantec Consulting Ltd**



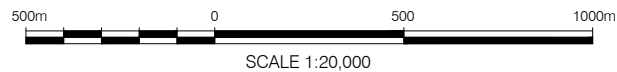
**Alvin Tong** P.Eng.  
Senior Geotechnical Engineer  
Phone: (604) 630-5833  
Alvin.Tong@Stantec.com





## LEGEND

- ACTIVELY MONITORED THERMISTOR
- VOLUMETRIC WATER CONTENT SENSOR STRINGS



SCALES INDICATED BASED ON AN 8.5"x11" PLOT CONFIGURATION

## LUPIN MINES INC.

### 2019 GEOPHYSICAL SURVEY

SCALE:	AS SHOWN
DATE:	2019-10-10
CO-ORD. SYS.:	UTM83-12
DRWN BY:	KM
DSGN BY:	--
REVD BY:	AT
APP'D BY:	SE

### TAILINGS CONTAINMENT AREA



PROJECT NO.:	FIG. NO.:	REV.:
129500083	1	A



## **Memorandum**

**To:** Stantec. Inc.  
Alvin Tong, P.Eng.; Sara Wilkins, P.Geol.

**Date:** October 15, 2019

**From:** Aurora Geosciences Ltd.  
Troy Unrau, P.Geo

**Re:** Lupin Tailings Dams Geophysics Survey 2019

This memorandum report describes Ground Penetrating Radar (GPR) and Electrical Resistivity Tomography (ERT) surveys conducted at Lupin Mine for Stantec (the Client) by Aurora Geosciences Ltd. (Aurora). Lupin Mine is a remote site located in the Kitikmeot region in Nunavut, Canada. The geophysical surveys described in this report were completed on tailings dams 3D and 4. The purpose of these surveys were identify thawed ice core sections along the dam where there is a potential for the tailings to seep through the dyke.

The survey was completed between August 22<sup>nd</sup> -25<sup>th</sup>, 2019 by a crew of three operators (Darrell Epp, William Onah, Hayden Playter). Operations were based out of Lupin main camp.

Two methods were used: GPR and ERT. These were completed using: a Sensors and Software Noggin 100MHz GPR and an ABEM TerrameterLS.

## **Method Backgrounds**

### ***Ground Penetrating Radar (GPR)***

GPR is a geophysical technique that uses electromagnetic radiation to profile subsurface layers. During operation, a pulse of electromagnetic radiation in the form of radio waves centered over a particular frequency is emitted from the instrument and a portion of the energy is reflected back to the surface by interfaces between materials with contrasting dielectric properties. Timing the arrivals of the reflected energy allows a pseudo depth section (radargram) to be constructed from data collected along a profile. The velocity at which the radar wave travels through the ground is used to determine the depths to the reflectors.

Large contrasts between dielectric properties of bedrock, water, ice and sediments can produce strong radar reflectors which make GPR a useful technique for mapping subsurface stratigraphy. See Table 1 for a list of dielectric electric properties observed in common geological materials. If two materials have similar dielectric properties, a weak reflection may be produced; if they have identical properties, no reflection will be produced.

Depth of investigation of the survey is generally dependent on a combination of the conductivity of the medium, the power of the instrument, and the frequency of the signal (Reynolds, 2017). Generally, higher conductivity corresponds to higher attenuation factors and higher frequency corresponds to a higher rate of attenuation; therefore higher conductivity and frequency result in reduced depth of investigation.

**Table 1 : Typical dielectric constant, electrical conductivity & resistivity, velocity and attenuation observed in common geologic materials (Annan, 2003)**

<i>MATERIAL</i>	<i>Dielectric Constant (k)</i>	<i>Electrical Conductivity (mS/m)</i>	<i>Electrical Resistivity (Ohm-m)</i>	<i>Velocity (m/ns)</i>	<i>Attenuation (dB/m)</i>
Air	1	0	$\infty$	0.30	0
Fresh Water	80	0.5	2000	0.033	2x10-3
Dry Sand	3 – 5	0.01	100,000	0.15	0.01
Saturated Sand	20 – 30	0.1 – 1.0	1,000 – 10,000	0.06	0.03 – 0.3
Clays	5 – 40	2 – 1000	1 – 500	0.06	1 – 300
Silts	5 – 30	1 – 100	100 – 1,000	0.07	1 – 100
Pure Ice	3 – 4	0.01	100,000	0.16	0.01
Granite	4 – 6	0.01 – 1	1 – 100,000	0.13	0.1 – 1

### ***Electrical Resistivity Tomography (ERT)***

The ERT method uses an array of up to 61 simultaneously connected electrodes to measure the electrical resistivity of the ground. Current is injected at two electrodes to cause electricity to flow in the ground. At some distance away, electrical potential (voltage) is measured to determine where the current is flowing in the ground. By alternating which electrodes are used to inject the current, and which electrodes are used to monitor the electrical potential, variations of the electrical properties of the ground can be mapped.

The depth and resolution depends on a number of factors, including: the array configuration used (which electrodes inject current, and which ones measure current), the electrode spacing, the electrical conductivity of the ground (conductive ground prevents measurement at depth), and the amount of current able to be injected into the ground. Using a 5 m electrode spacing produces a vertical model resolution of approximately 1.25 m and a horizontal model resolution of 2.5 m near the surface. This model resolution decreases with depth.

Additionally, the model is sensitive to conductors that are adjacent to the survey line as well as those below the survey line. This is due to the volume of averaging getting larger as electrodes get further apart. A deep anomaly in the model can be the result of a shallow anomaly adjacent to the survey line. Thus depth for ERT surveys should rather be interpreted as 'distance from the survey line'.

## Survey Location

The Lupin Mine is a remote site located north of Lac de Gras in Nunavut, Canada approximately 400 km northeast of Yellowknife and occupies 1:250,000 NTS map sheet 076E. Lupin is accessible year round by air and seasonally by the Tibbit to Contwoyto ice road that typically operates from February to the end of March.

The geophysical surveys described in this report were completed over the tailings dyke of dams 3D and 4 as labelled by the Client.

All coordinates described in this memo refer to UTM zone 12N, WGS84.

## Field Operations

The GPR survey was conducted along the same profile as the ERT survey, pin flags are used a reference on both dams.



**Figure 1. Operator performing the Ground Penetration Radar (GPR) cross profile on dam 4.**





**Figure 2. Electrical Resistivity Tomography setup on dam 3D.**

Prior to setting up the ERT system, GPS coordinates were obtained from sections along the dam so as to plan the survey profile according to specifications given by the client. In Dam 4, the profile was conducted along the center line of the dam while at Dam 3D, it was offset upstream along the dyke (Figure 2). Where electrical contact problems occurred due to a relatively resistive ground, fresh water mixed with salt (sodium or calcium chloride) was added to the electrode location. Failing this, the electrode would be disabled from the array and located at a suitable location. This survey was conducted using both dipole-dipole and gradient-plus configurations.

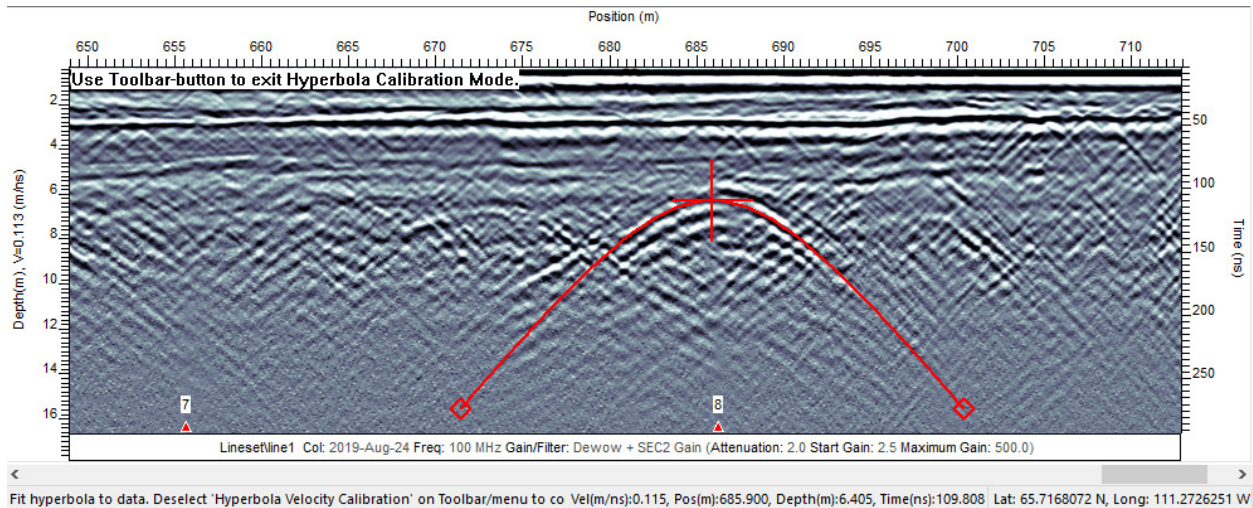
Furthermore, a short profile (2.5 m electrode spacing) was conducted perpendicular to the initial profile on Dam 4 over a conductive section (pseudo depth of around 10 m) in an attempt to verify whether the deep conductivity results were coming from below the dam or adjacent to it. Similarly, a high resolution survey was conducted on Dam 3D over an anomalous region using an electrode spacing 2.5 m.

## **GPR Processing**

GPR data requires a number of processes to be applied before it can be interpreted. These processes are described herein:

**Velocity calibration:** GPR data is recorded as a series of reflected radio waves. The time it takes for these reflections to arrive is noted in the raw GPR data. However, in order to convert these times into depth below the ground surface, an estimate for the radar velocity below the surface must be obtained. The simplest way to obtain this estimate is to look for hyperbolic reflectors. The best hyperbolic reflectors are single points that pass directly below the radar instrument. By fitting a theoretical hyperbola to these observed hyperbola, an estimate can be produced. Several hyperbola were fit at various spots in the data arriving at an estimate of 0.115 metres per nanosecond, plus or minus 0.005. An example of

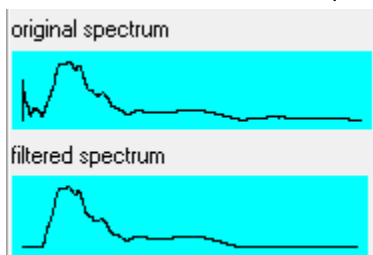
this curve fitting process is shown in Figure 3, where the GPR section crossed buried thermistor D4-4 on Dam 4.



**Figure 3: Hyperbola velocity calibration at thermistor D4-4 on Dam 4.**

The GPR data are processed using the commercially available ReflexW software package developed by Sandmeier Scientific Software. Geosoft software are used to present the results. The following general procedures are utilized in the order that they are described:

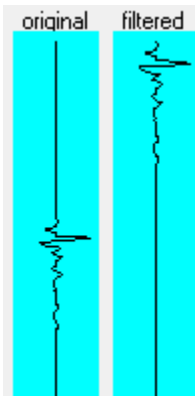
1. Butterworth Bandpass filter, from 40 to 400 MHz. This serves to remove low frequency antenna-to-antenna reverberations (dewow), and high frequency noise unrelated to the GPR survey signals.



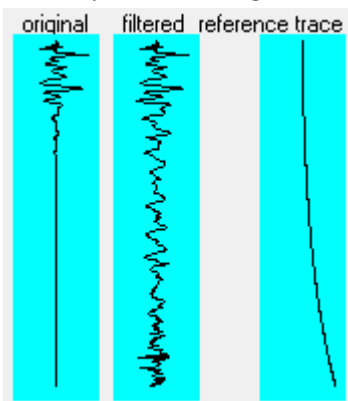
2. Background removal: Signals which persist on every trace, such as the direct airwave arrival, can be suppressed. The average of all traces is on a line subtracted from each trace on that line.



3. Set time-zero: Zero is set to be the first arrival of energy. The value used as an offset is inspected visually. Traces are moved upwards as required.



4. Time cut: The time window is trimmed to 300 ns as no coherent signal is visible beyond this point.
5. Gain function: The amplitude of reflected signals gets lower as depth increases. In order to make deep reflector easier to visually inspect and interpret, the gain is increased with depth. A gain function is applied, which increases the amplitudes of reflectors at depth exponentially. Note that this amplifies both signal and noise.



6. Horizontal Smoothing: To reduce the amount of speckle, a horizontal smoothing filter (running average) is applied across the profile. This replaces each trace with the average of the 10 nearest traces. This tends to improve clarity on horizontal features at the expense of vertical features. Noses of hyperbola are preserved while their limbs diminish. This also improves the signal to noise ratio by a factor of square root of 10.
7. The resulting data is exported as a SEG-Y file and imported into Geosoft Oasis Montaj for plotting as a cross section. Times are converted to depths using 0.115 m/ns, an estimate for subsurface velocity measured from hyperbola. A 10X vertical exaggeration is applied here, and a colour scheme to make the reflectors as prominent as possible is used.

## ERT Processing

ERT data was archived on a nightly basis. This archived data include: raw .DAT files from the instrument, and GPS waypoints of the start, cable junctions, thermistors near the line, and end point of the profile.

Nightly data processing included: inspecting the raw ERT data for quality and a field inversion of the data to produce field preliminary results. The resulting model was used to inform the next day's survey.

The final ERT data is processed using the commercially available RES2D software package developed by Geotomo Software, an industry standard for inversion of ERT data. Geosoft Oasis Montaj is used to present the results. The following general procedures are utilized in the order that they are described:

1. Manually merge the data from the different arrays (dipole-dipole and gradient+) converting to the generalized array format; remove negative values; and incorporate GPS positions to produce a single DAT file for each line surveyed.
2. Import the resulting DAT file into RES2D and inversion modelling using default parameters.
3. Export the inversion results to XYZ.
4. Import the relevant section of the XYZ into Geosoft Oasis Montaj.
5. Create a 3D voxel from the inversion results using inverse distance gridding.
6. Sample the 3D voxel along the locations of the existing GPR profiles, already loaded into Geosoft.

## Interpretation & Results

Nine section figures were generated in Geosoft Oasis Montaj. They are:

1. Section 1: Dam 3D Interpreted Electrical Resistivity and GPR Reflectors
2. Section 2: Dam 4 Interpreted Electrical Resistivity and GPR Reflectors
3. Section 3: Dam 4 Cross Line Interpreted Electrical Resistivity and GPR Reflectors
4. Section 4: Dam 3D GPR Reflectors
5. Section 5: Dam 4 GPR Reflectors
6. Section 6: Dam 4 Cross Line GPR Reflectors
7. Section 7: Dam 3D Electrical Resistivity
8. Section 8: Dam 4 Electrical Resistivity
9. Section 9: Dam 4 Cross Line Electrical Resistivity

Sections 4 through 9 are provided for clarity, should the busy colour schemes in Sections 1 through 3 cause problems. All sections provide UTM coordinates along the top of the profile, and depths below ground surface along the vertical axis. A vertical exaggeration factor of ten has been applied to all figures – which makes dipping features appear steeper than they are in reality.

The GPR data shows several distinct continuous reflectors which extend the entire length of the section. These reflectors have been interpreted, from top to bottom as: transition from dry to water saturated material; transition from wet to frozen material; top of bedrock. The top of bedrock reflector is quite weak in places and its interpretation is less confident than the other two layers. The strongest reflector is the interpreted wet to frozen interface – the top of the ice core in the Dam as present on the date of the survey.

### ***Dam 3D***

All three GPR reflectors are continuous, indicating no break or absence in the ice core of the dam.

The ERT data indicates a slightly conductive surface layer (yellows), beneath which lies more resistive material (blues, greens, whites) which is consistent with the ice core of the dam and underlying bedrock. Beyond 10 m depth, the model becomes conductive again, which is interpreted as conductive features adjacent to the dam.

A single anomalous area is interpreted in the data, both in the GPR data and the ERT data. This area stretches 120 m in length and is characterized by: the interpreted top of the ice core being deeper, several strong GPR reflectors which produced strong hyperbola (circled on Section 1), and conductivity anomalies associated with those strong GPR reflectors (reddish colour within circles on Section 1). While this area is considered anomalous, it does not indicate a failure of the ice core. Rather, it is likely that the top of the ice core is depressed at this location. It is possible that the circled spots indicate wet spots that have higher total dissolved salts, fractures, or buried metal objects (i.e.: old culverts, drill casing, rebar reinforced concrete, instrumentation, etc.).

#### ***Dam 4***

The top two GPR reflectors are continuous across the section, indicating no break or absence in the ice core of the dam. The bedrock reflector is discontinuous, owing to its depth – particularly on the western side of the dam.

The ERT is quite consistent across this section, showing a slightly conductive near surface region, and a more resistive region below that. The conductivity showing on this section below 10 m is interpreted to be related to the adjacent tailings pond. This interpretation is supported by the conductor disappearing at either end of the section, where the line extends past the pond.

Additionally, a short cross line was installed at dam 4 to support the interpretation that the conductivity feature at depths beyond 10 m was indeed being caused by the adjacent tailings pond. The cross line indicates that there is no conductive feature directly beneath the dam.

No anomalies on Dam 4 were identified in this data.

#### **Final Products**

The following products were delivered alongside this report, for archival purposes.

- Nine section figures in PDF format. Sections 1, 2, 4, 5, 7, and 8 will require a poster plotter to print at the correct scale. Sections 3, 6, and 9 will print on standard paper sizes.
- A zip file containing an ESRI ShapeFile and AutoCAD DXF outlining the anomalous region on Dam 3D, for use by Stantec when plotting their own maps.
- The raw data used to produce these sections. The Raw Data is quite large in size (several megabytes) and is difficult to email. It has been delivered independently from this report.

#### **Future Work**

As the chosen geophysical techniques were able to adequately detect the presence of the ice core within the dams, and independently identify regions of interest, we conclude that these methods can be used at this location in the future.



## References

Annan, A.P., 2003, Ground Penetrating Radar Principles, Procedures & Applications.

Reynolds, J.M., 1997, An Introduction to Applied and Environmental Geophysics.

Respectfully Submitted,

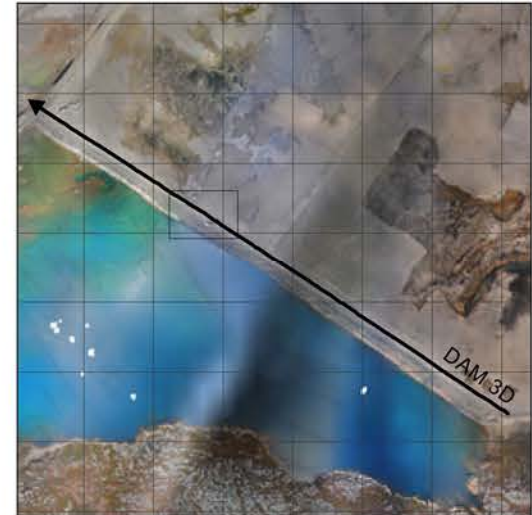
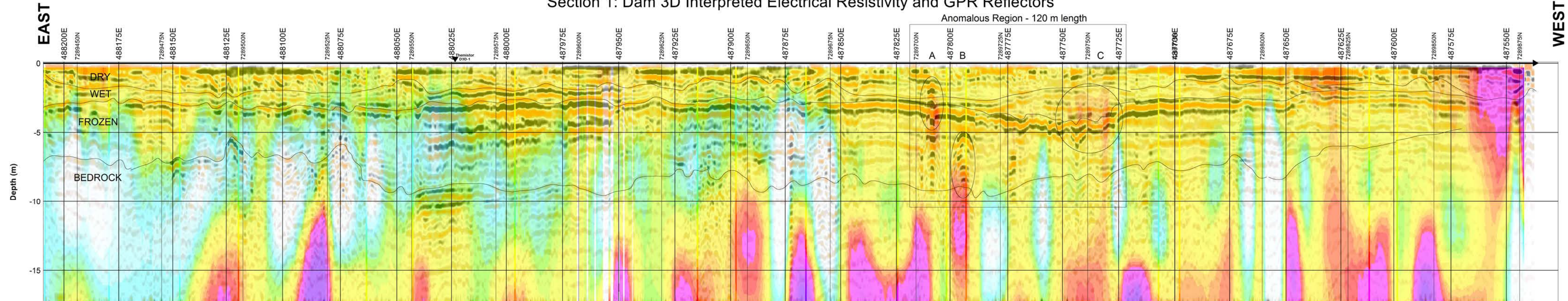


Troy Unrau, P.Geo. (NAPEG #1963)

Aurora Geosciences Ltd.

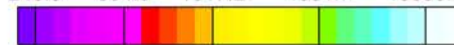


# Section 1: Dam 3D Interpreted Electrical Resistivity and GPR Reflectors



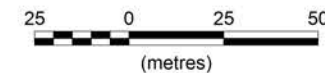
Section Trace Plan View

240.5 604.0 1517.2 4581.7 13836.6



**Resistivity**  
Ω-m

Scale 1:2000



Vertical Exaggeration: 10

**Lupin Tailings Dams**  
**Geophysics Survey 2019**

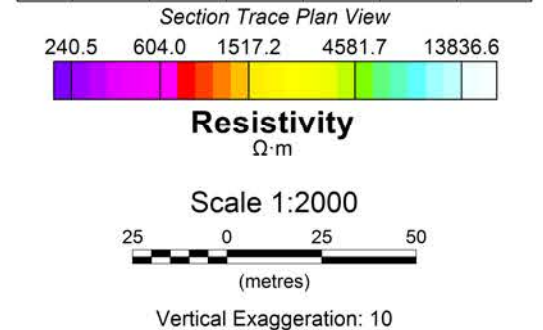
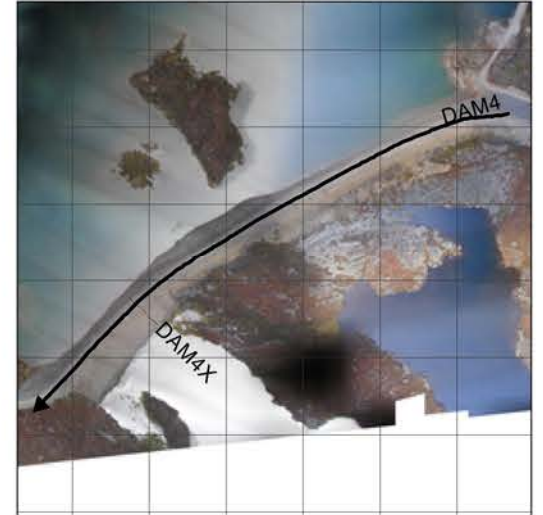
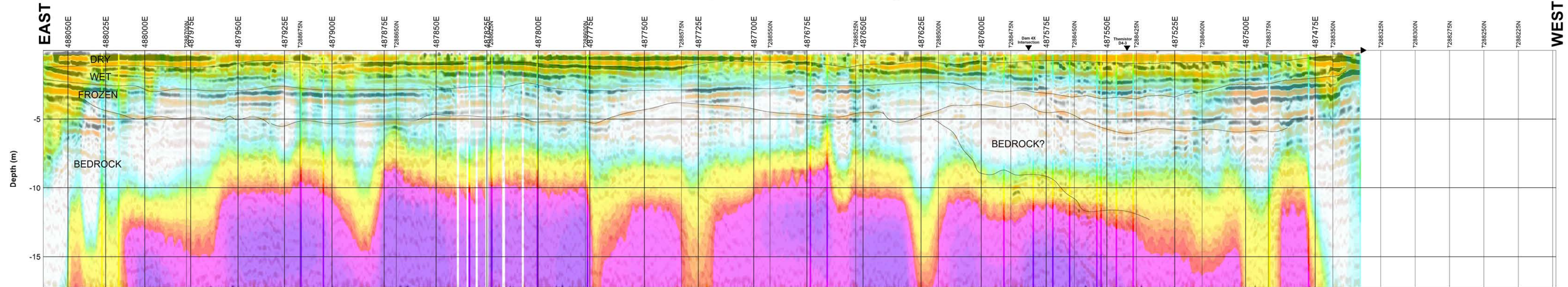
Aurora Geosciences Ltd.

Drawn by TU on 2019-09-25  
STN-19074-NT





## Section 2: Dam 4 Interpreted Electrical Resistivity and GPR Reflectors



**Lupin Tailings Dams  
Geophysics Survey 2019**

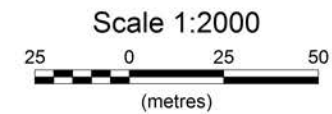
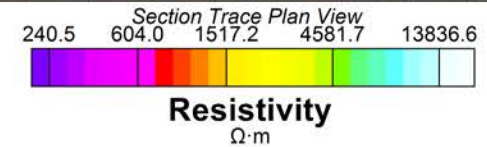
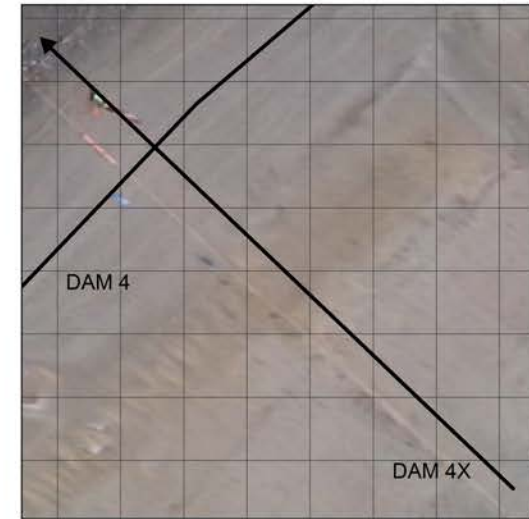
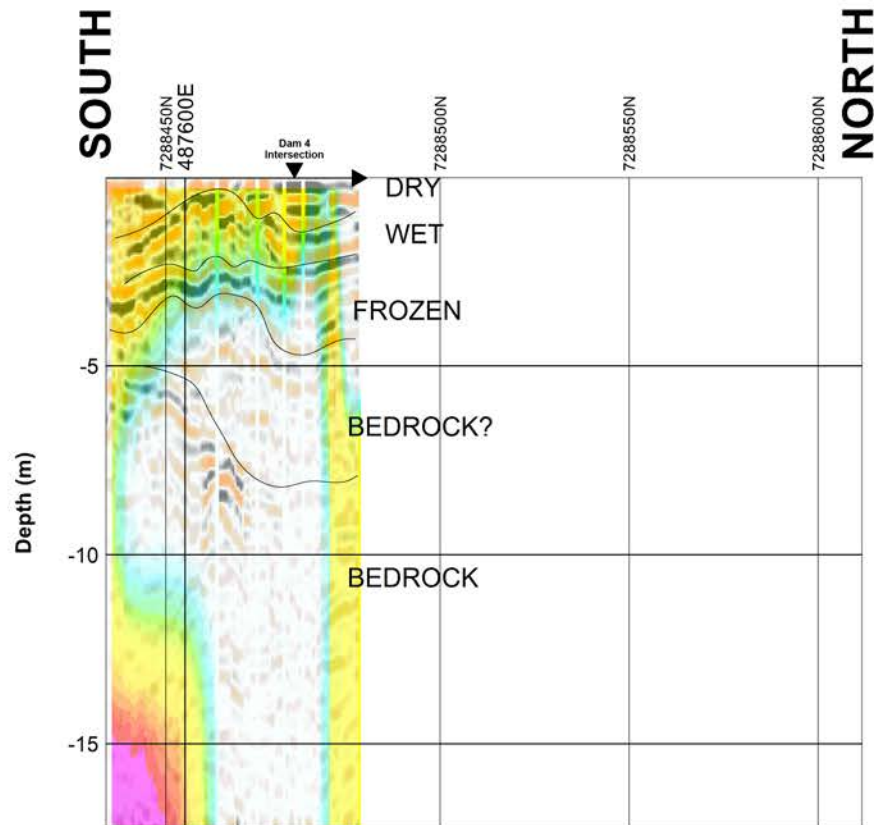
Aurora Geosciences Ltd.

Drawn by TU on 2019-09-25  
STN-19074-NT





### Section 3: Dam 4 Cross Line Interpreted Electrical Resistivity and GPR Reflectors



Vertical Exaggeration: 10

### Lupin Tailings Dams Geophysics Survey 2019

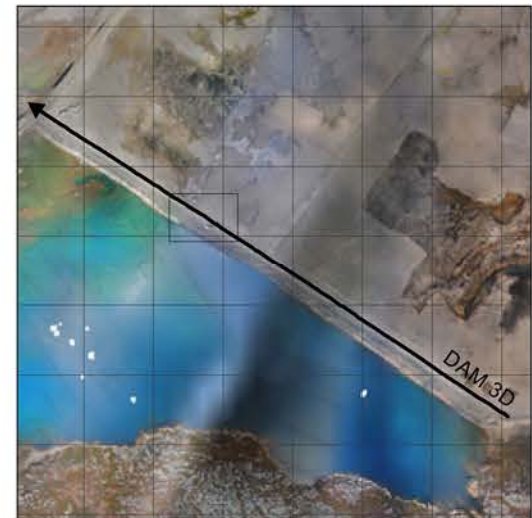
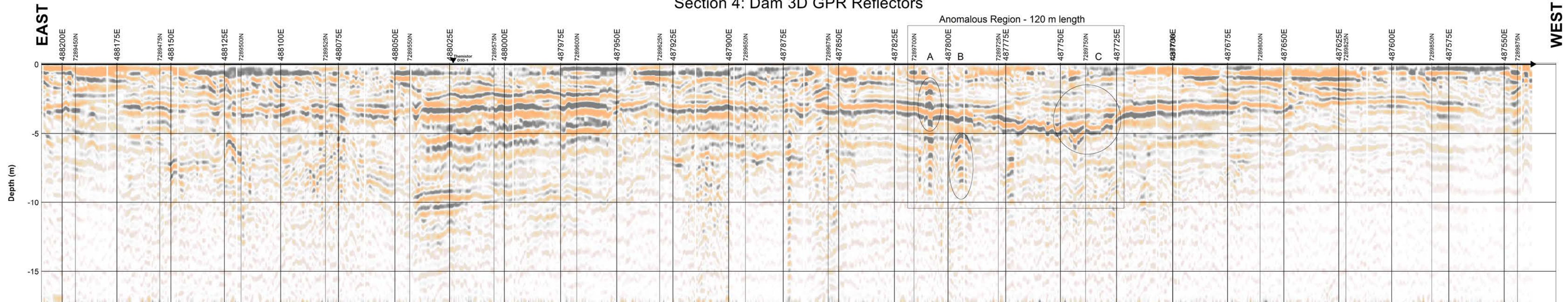
Aurora Geosciences Ltd.

Drawn by TU on 2019-09-25  
STN-19074-NT





# Section 4: Dam 3D GPR Reflectors



Section Trace Plan View

Scale 1:2000

25 0 25 50

(metres)

Vertical Exaggeration: 10

Lupin Tailings Dams  
Geophysics Survey 2019

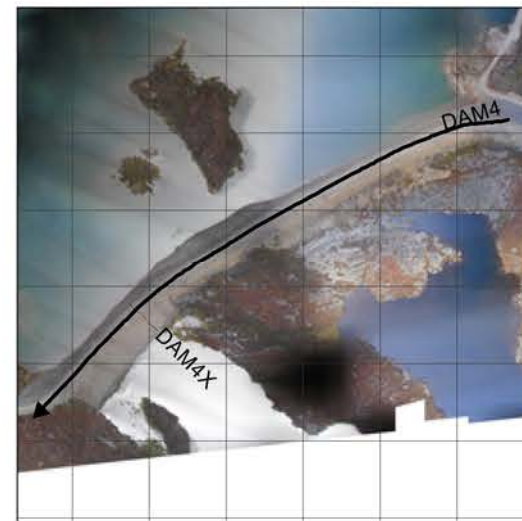
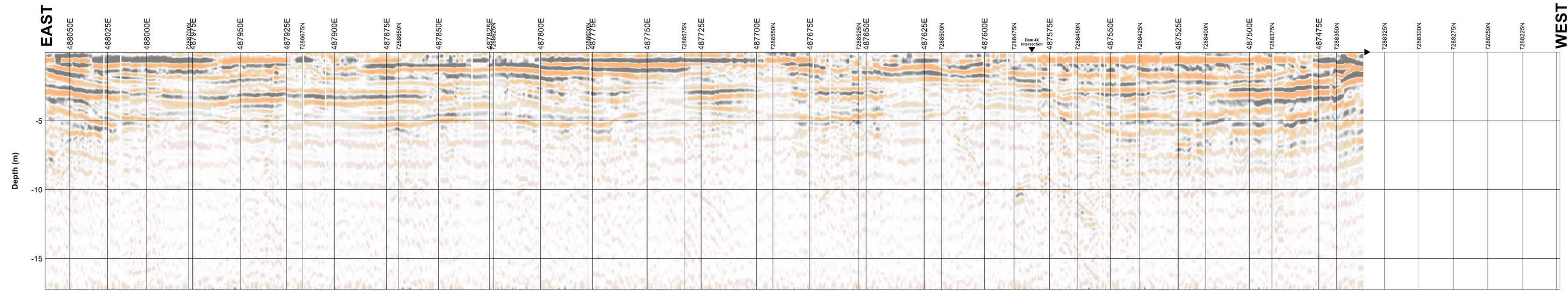
Aurora Geosciences Ltd.

Drawn by TU on 2019-09-25  
STN-19074-NT

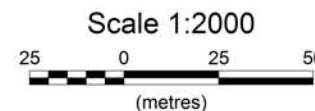




# Section 5: Dam 4 GPR Reflectors



Section Trace Plan View



Vertical Exaggeration: 10

Lupin Tailings Dams  
Geophysics Survey 2019

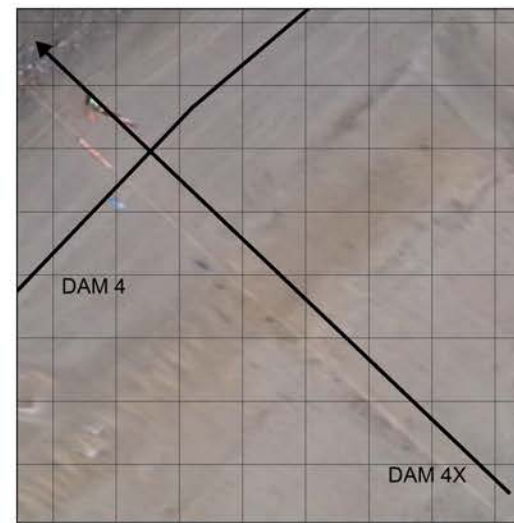
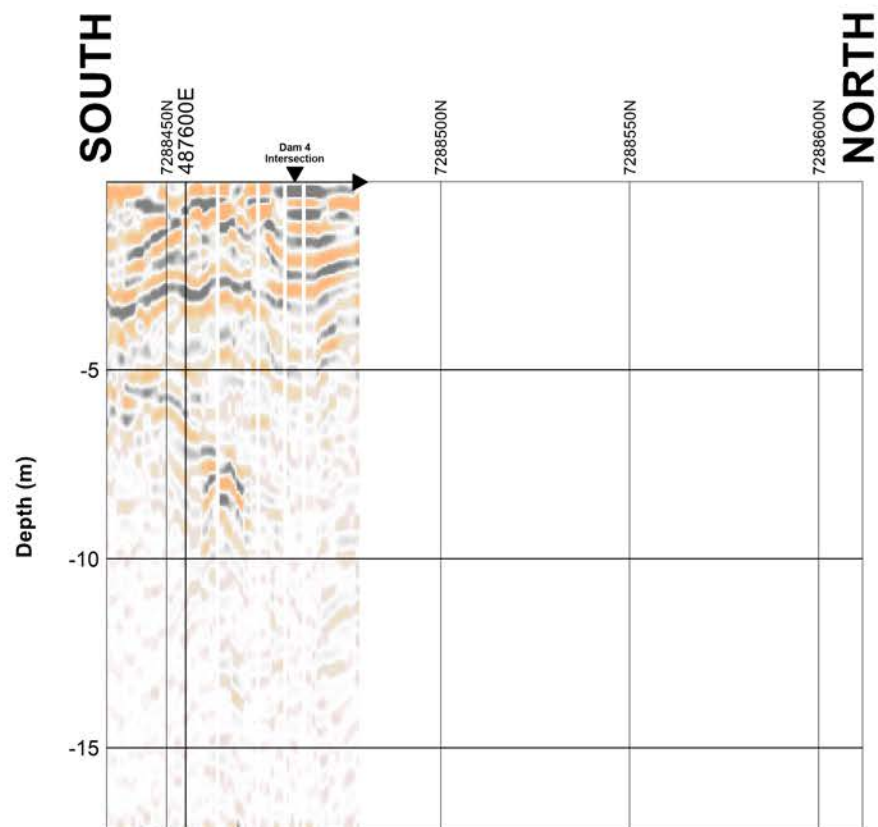
Aurora Geosciences Ltd.

Drawn by TU on 2019-09-25  
STN-19074-NT

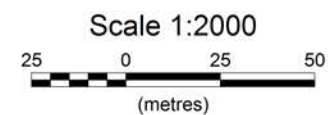




## Section 6: Dam 4 Cross Line GPR Reflectors



Section Trace Plan View



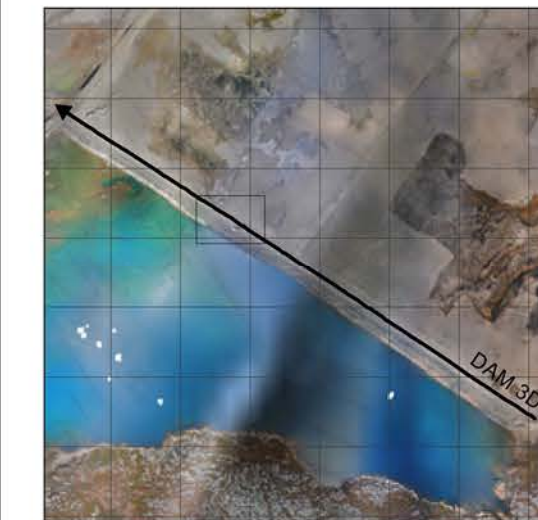
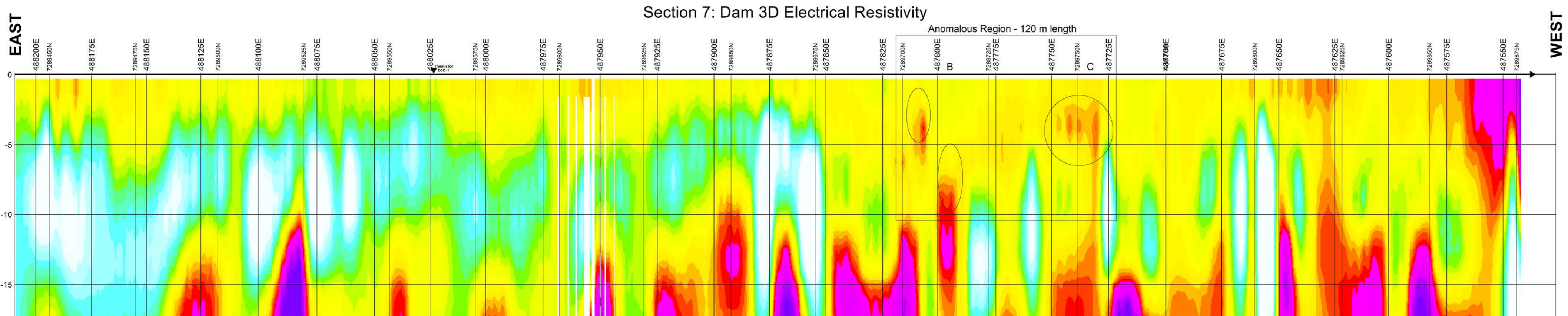
Vertical Exaggeration: 10

## Lupin Tailings Dams Geophysics Survey 2019

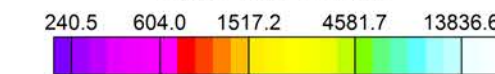
Aurora Geosciences Ltd.

Drawn by TU on 2019-09-25  
STN-19074-NT

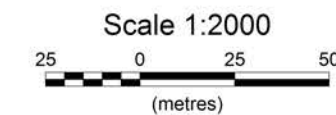




Section Trace Plan View



**Resistivity**  
Ω-m



Vertical Exaggeration: 10

**Lupin Tailings Dams  
Geophysics Survey 2019**

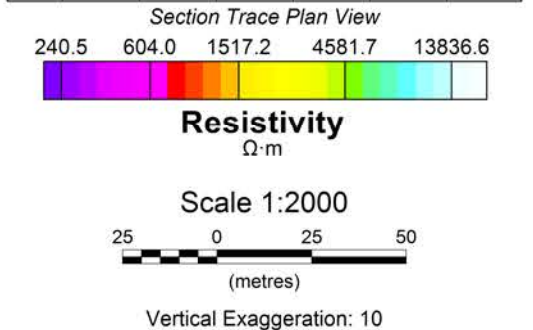
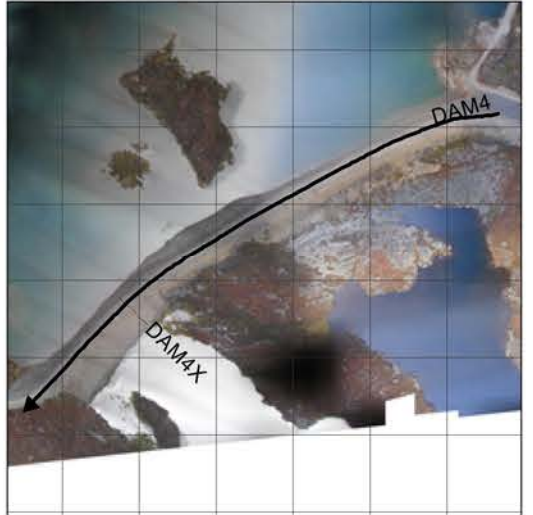
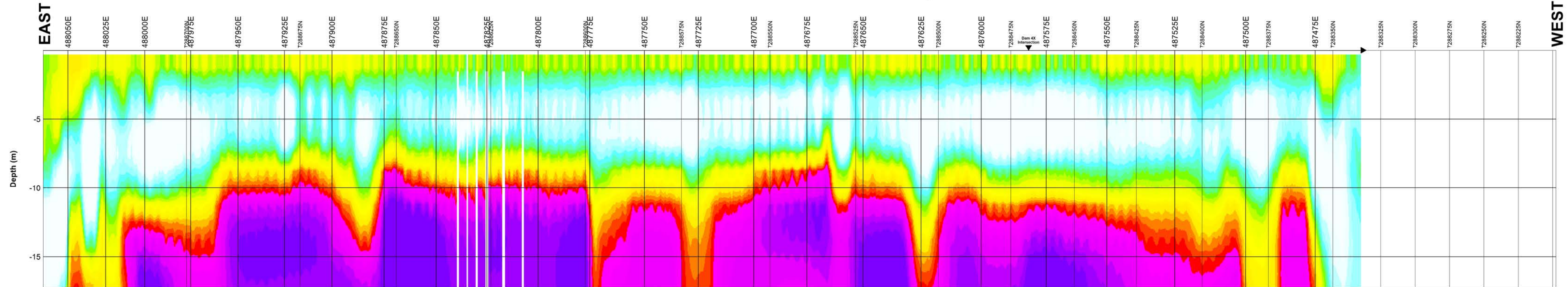
Aurora Geosciences Ltd.

Drawn by TU on 2019-09-25  
STN-19074-NT





# Section 8: Dam 4 Electrical Resistivity



**Lupin Tailings Dams  
Geophysics Survey 2019**

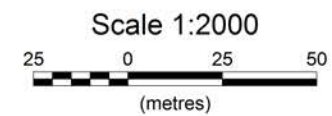
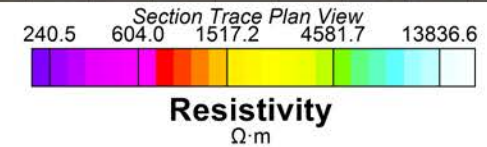
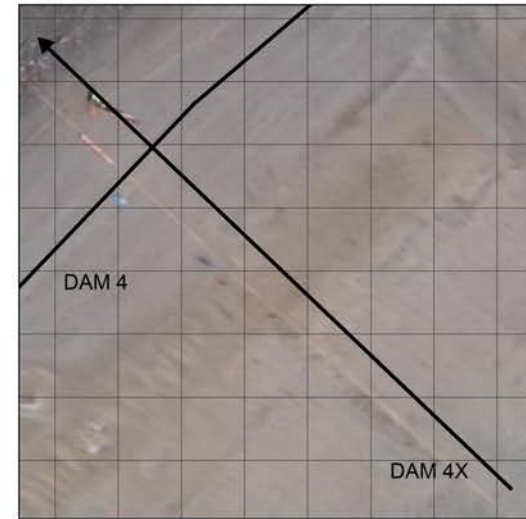
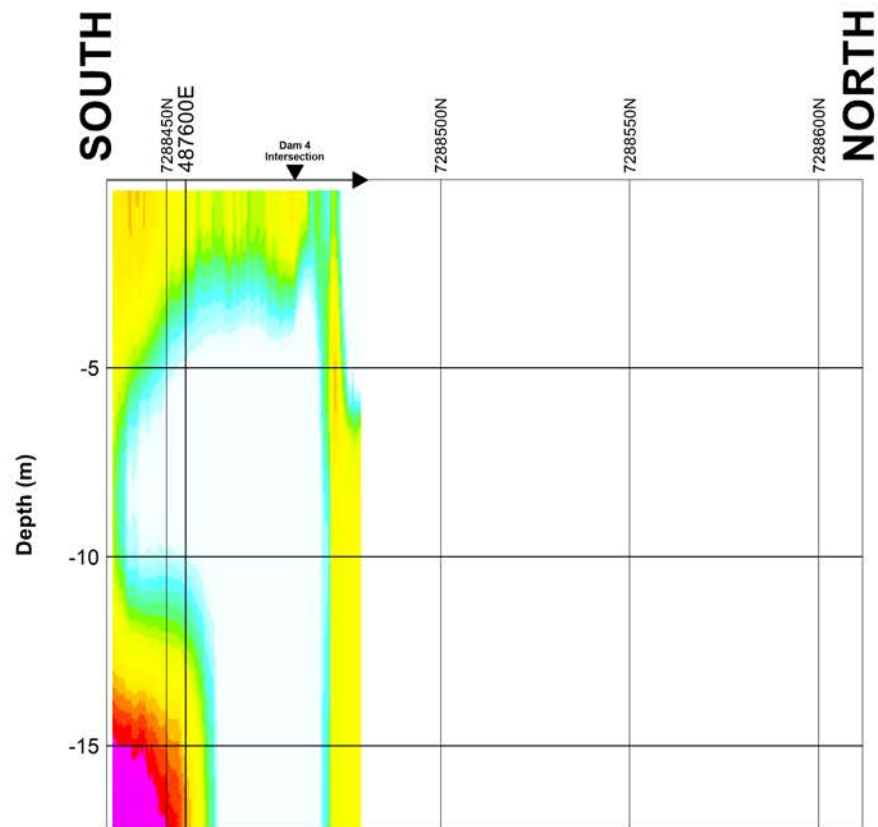
Aurora Geosciences Ltd.

Drawn by TU on 2019-09-25  
STN-19074-NT





## Section 9: Dam 4 Cross Line Electrical Resistivity



Vertical Exaggeration: 10

## Lupin Tailings Dams Geophysics Survey 2019

Aurora Geosciences Ltd.

Drawn by TU on 2019-09-25  
STN-19074-NT

