Pioneer Exploration Consultants Ltd.
675 Industrial Ave, Ottawa, On K1G 0Z1
info@pioneerexploration.ca
T. 1-306-715-6802

AIRBORNE LIDAR SURVEY REPORT

Pioneer Exploration Consultants Ltd.
675 Industrial Ave, Ottawa, On K1G 0Z1
info@pioneerexploration.ca
T. 1-306-715-6802

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Pioneer Exploration Consultants Ltd.
675 Industrial Ave, Ottawa, On K1G 0Z1
info@pioneerexploration.ca
T. 1-306-715-6802

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1. INTRODUCTION

The following report covers data acquisition, data processing, data delivery and instrument specifications involved in the completion of this project. This report does not include any geological interpretations of the dataset.

1.1 Project Overview

Date In	July 26, 2024
Date Out	August 13, 2024
Client	Baffinland Iron Mines
Survey Location	Baffin Island, Nunavut
Survey Area	1530 km²
Aircraft Model	Airbus Helicopters AS350 B2 C-GHVU
Aircraft Operator	Canadian Helicopters Ltd.
Takeoff & Landing Site	Mary River Aerodrome (YMV)
Data Collection	Jean-François Dionne, Michael Burns
Data Processing & QA/QC	Jean-François Dionne

1.2 Project Deliverables & Specifications

Deliverable	Format	Specification	Remarks
Point Cloud	LAS Ver. 1.4	Approx. 10-15 pts/m^2	Entire area
DTM	GeoTIFF	50cm Resolution	Entire area
Orthophoto	GeoTIFF	8-10 cm resolution	Entire area

Figure 1: Survey area location highlighted in red.

2. DATA ACQUISITION

2.1 Geodetic Parameters

Horizontal CRS	NAD83 (CSRS) / UTM zone 17N (EPSG 2958)
Vertical CRS	CGVD2013
Geoid	CGG2013a
EPOCH	2010.000

2.2 Reference Stations

Reference stations were established to provide high-precision GNSS corrections for trajectory post-processing. The table below lists the reference stations used for processing. Reference station data was corrected using Canadian Spatial Reference System Precise Point Positioning (CSRS-PPP) service, and the correction details can be found in Appendix 4.

2.3 Ground Control Points

Ground Control Points (GCPs) are precisely surveyed locations that improve the accuracy of airborne LiDAR and orthophoto datasets. They provide ground truth, serving as reference markers to validate and adjust the dataset to real-world measurements. GCPs help assess accuracy, identify discrepancies, and apply corrections, ensuring reliable, high-precision mapping and analysis.

Ground Control Points were used to ensure data accuracy, with the acquisition details and full list provided in Appendix 5.

2.4 Flight Planning & Execution

The table below lists the flights conducted for the survey including relevant details. Additional flight planning parameters and instrument setup information can be found in Appendix 1. Instrument settings for the LiDAR sensor can be found in Appendix 2, and for the integrated camera system in Appendix 3.

Table 1 Summary of Executed Flights for Survey Completion

Flight	Flight Start (YYYYMMDD-HHMMSS)	Reference Station
1	20240731-050306	Emlid Base 70
2	20240802-172136	Emlid Base 3 Stensby
3	20240803-123809	Emild Base 3 Stensby
4	20240804-121442	Emlid Base 70
5	20240805-123328	Emlid Base 70
6	20240806-124848	Emlid Base 70
7	20240806-164900	Emlid Base 70
8	20240807-122146	Emlid Base 6
9	20240807-161708	Emlid Base 6
10	20240808-122553	Emlid Base Port
11	20240808-162259	Emlid Base Port
12	20240808-200949	Emlid Base Port
13	20240809-122335	Emlid Base 6
14	20240809-162128	Emlid Base 6
15	20240810-122319	Emlid Heli Base
16	20240810-154627	Emlid Heli Base

The survey area was broken into 8 survey blocks to facilitate acquisition and processing. The figures below illustrate the flight trajectory recorded during the survey, providing a visual representation of the aircraft's path over the surveyed areas.

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Figure 2a: LiDAR Survey Block A flight line coverage.

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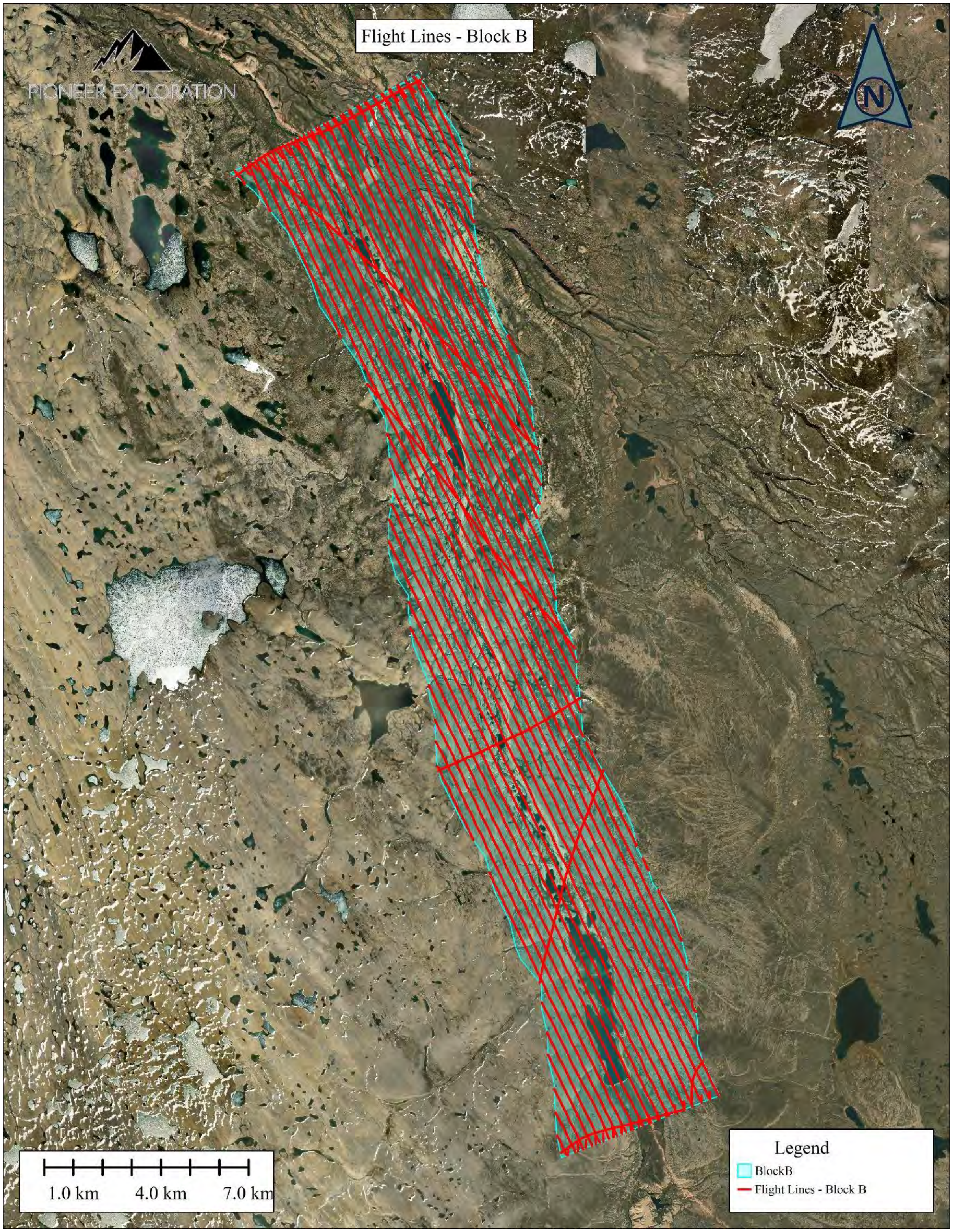

Figure 3b: LiDAR Survey Block B flight line coverage.

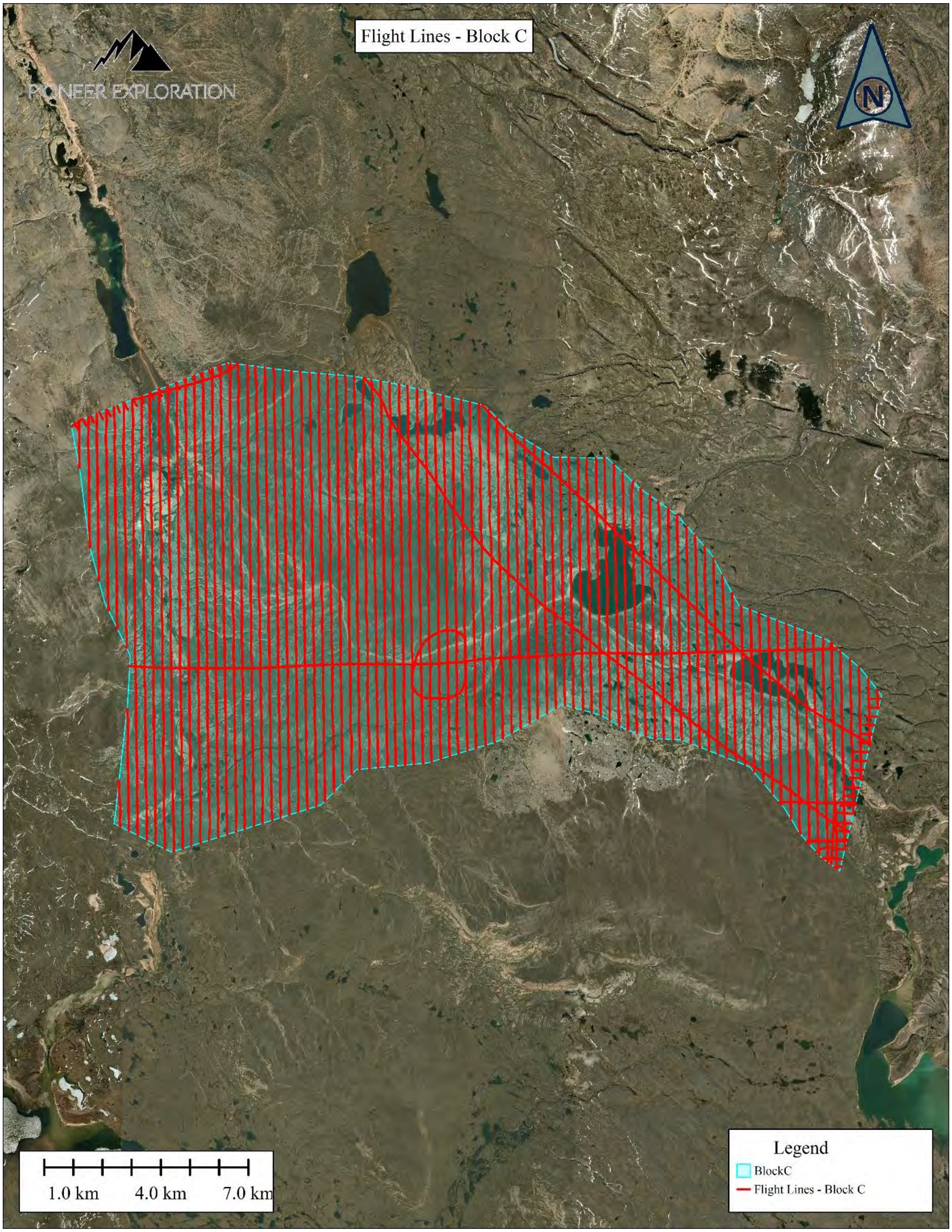

Figure 4c: LiDAR Survey Block C flight line coverage.

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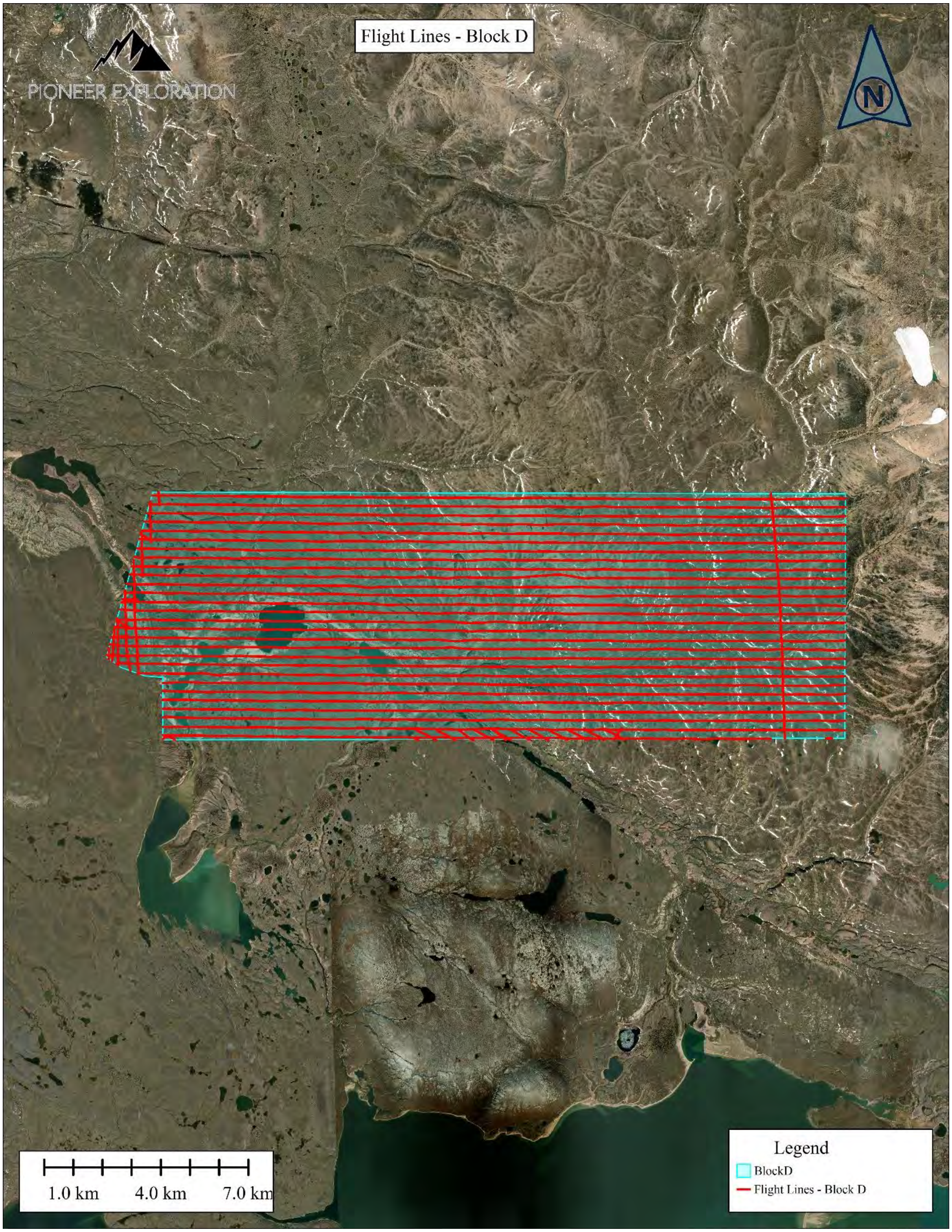

Figure 5d: LiDAR Survey Block D flight line coverage.

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Figure 6e: LiDAR Survey Block E flight line coverage.

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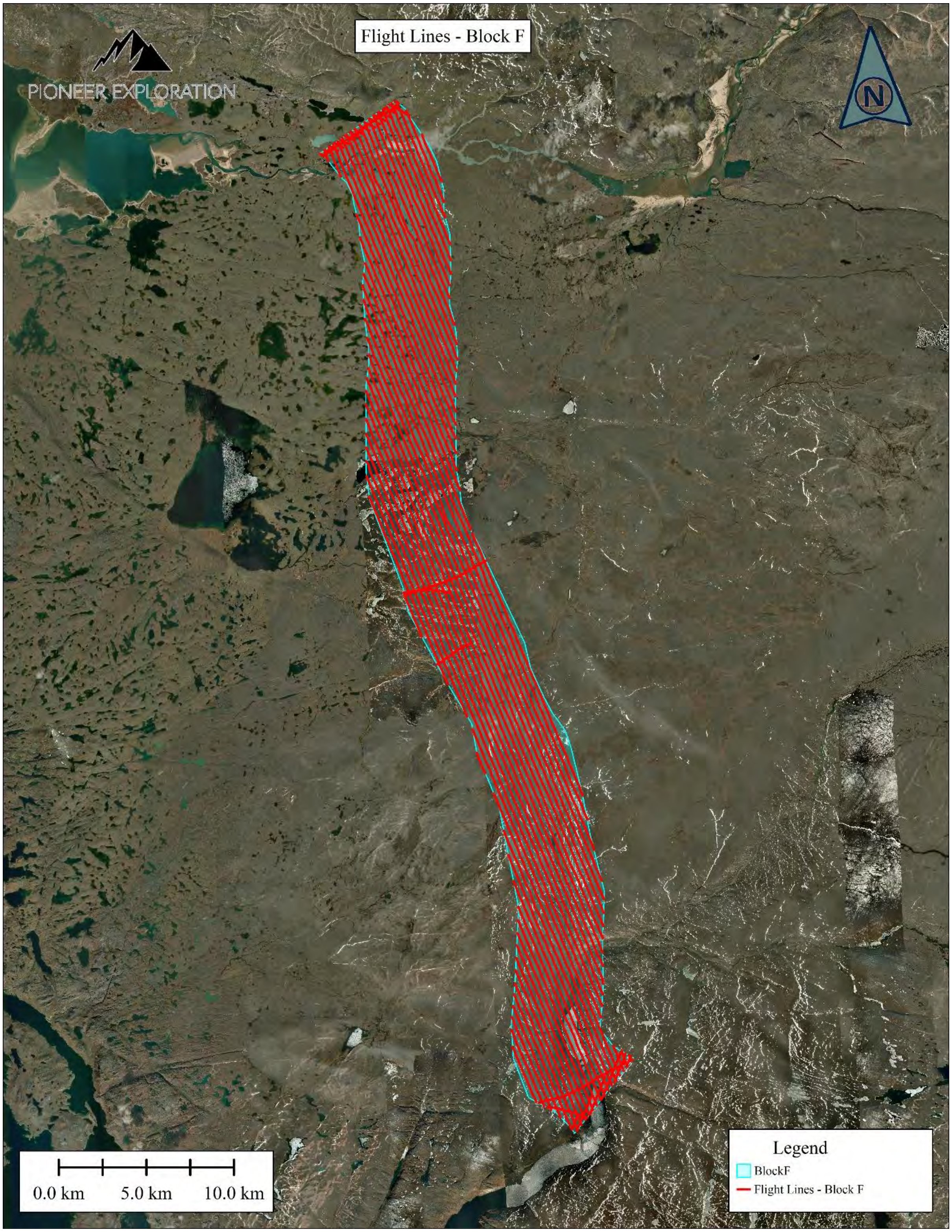

Figure 7f: LiDAR Survey Block F flight line coverage.

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Figure 8g: LiDAR Survey Block G flight line coverage.

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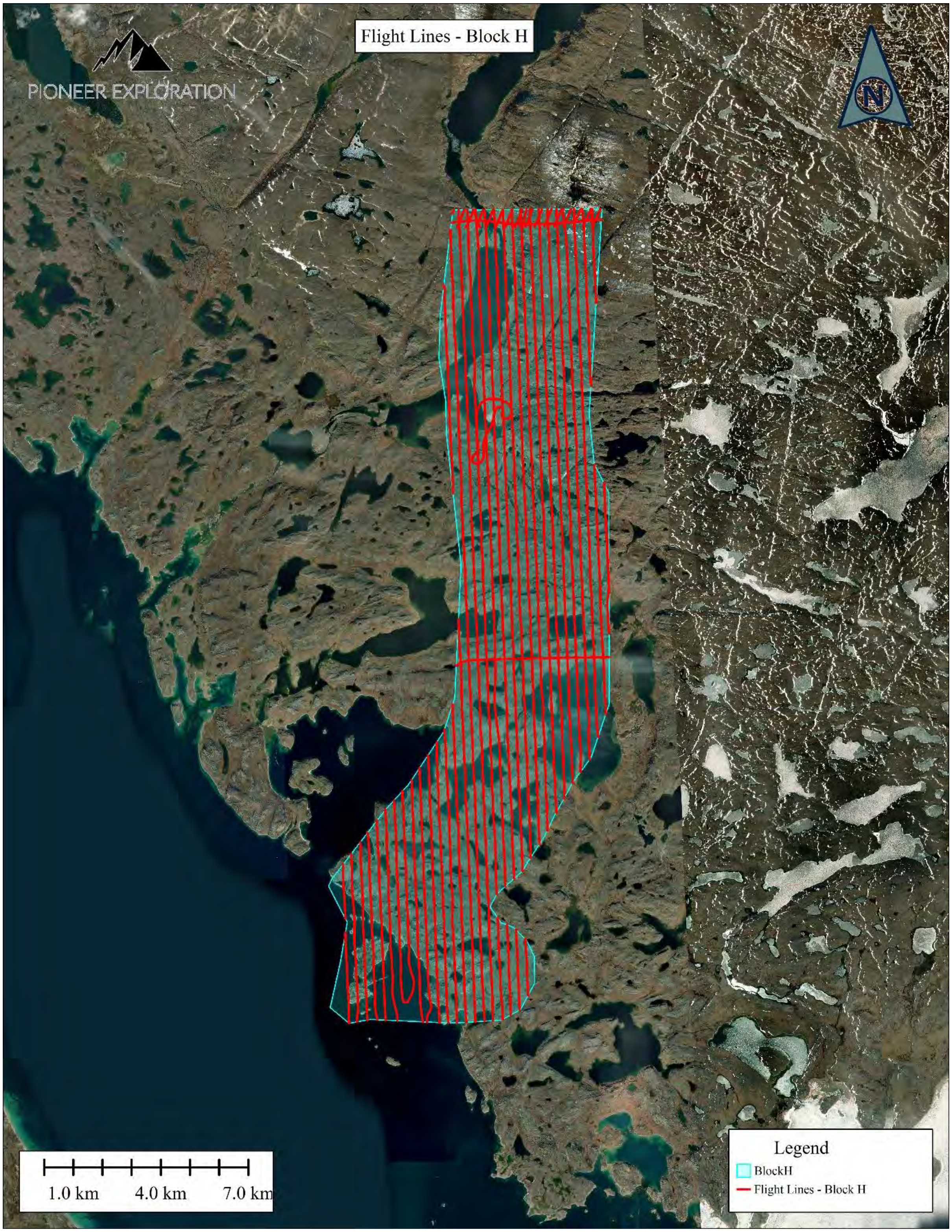

Figure 9h: LiDAR Survey Block H flight line coverage.

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675 Industrial Ave, Ottawa, On K1G 0Z1
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3. DATA PROCESSING

3.1 Trajectory Post-Processing

NovAtel's Inertial Explorer software is used in two stages to produce a post-processed and corrected flight trajectory.

In the GNSS processing stage, raw satellite data is collected from the base station and sensor receivers. Differential correction is applied to adjust for atmospheric delays, satellite geometry, and timing errors. This produces a refined position that is used to update sensor coordinates during calibration and data processing.

In the tightly coupled processing stage, inertial measurement unit (IMU) data is combined with GNSS data in a single estimation process. This integration of accelerometer and gyroscope measurements with satellite observations results in improved accuracy and robustness even when satellite signals are weak or obstructed.

3.2 Point Cloud Processing

Throughout the LiDAR processing workflow, error sources including sensor ranging, lever arms, atmospheric conditions, GNSS and IMU offsets, are analyzed and minimized. Vertical accuracy is mostly affected by GNSS and atmospheric factors, while horizontal accuracy is mostly dependant on GNSS, IMU and LiDAR lever arms.

Phoenix LiDAR Systems' Spatial Explorer software resolves Multiple Time Around (MTA) ambiguities in the raw LiDAR returns. The post-processed trajectory is imported and used to generate the point cloud using real-world corrected coordinates. A cloverleaf flight pattern enables boresight calibration to reduce misalignment between the LiDAR sensor and the IMU. When available, ground control points verify that initial accuracies fall within acceptable limits.

Bayes Map's Strip Align fine tunes the alignment of overlapping flight lines by adjusting common areas between adjacent strips. Ground control points are used for absolute correction and accuracy assessment, producing the final corrected point cloud solution.

Terrasolid's TerraScan software classifies points into the required deliverable categories. A scripted method removes outliers and noise, extracts bare-earth points with an iterative surface model, and classifies over-ground features such as low vegetation, high vegetation, and buildings.

Blue Marble Geographics' Global Mapper then uses the classified point cloud to produce Digital Elevation Models. The Triangulated Irregular Network method generates a Digital Terrain Model from bare-earth points and a Digital Surface Model from all points excluding noise. Global Mapper also creates contour lines and various topographic analyses when needed.

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4. RESULTS & QUALITY CONTROL

4.1 Trajectory Validation

The following table summarizes key trajectory validation metrics. See Appendix 6 for graphs and detailed analysis. Descriptions and values are sourced from Inertial Explorer Documentation.

Table 2 Summary of Trajectory Validation Metrics

Metric	Description	Unit	Acceptability Threshold	Pass
Forward/Reverse Separation (Fixed)	Difference between forward and reverse GNSS/IMU solutions where both have fixed integer ambiguities, indicating consistency	m	< ±0.30	Yes
Estimated Position Accuracy	Standard deviation of the east, north and up directions. Summary of error sources, including the float/fixed ambiguity status and satellite geometry.	m	XY: < 0.05 Z: < 0.10	Yes
PDOP (Position Dilution of Precision)	Unitless indicator of how favorable the satellite geometry is to 3D positioning accuracy	-	≤ 3.0	Yes
Estimated Attitude Accuracy	Standard deviation computed in the GNSS/IMU Kalman filter in terms of roll, pitch and heading	arcmin	< 0.60	Yes

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Appendix 1
Flight Planning Overview

RIEGL

RIPARAMETER 2.4.0

Time / Date:	13:35:30 / 12.04.2024											
Author:	M. Burns											
Project Name:	Baffinland 10-15ppm											
Project Information:	NONE											
Scanner Settings:												
Device Type:	VUX-240											
Meas. Prog.:	300 kHz											
PRR:	300	kHz										
Laser Power Level:	100	%										
Laser Program:	2											
Angular Step Width:	0.0350	deg										
Scan Rate:	117	lps										
FOV of Scanner:	75.0	deg										
FOV of Single Lidar Channel:	75.0	deg										
Flight Parameters:												
Height AGL:	488	m	1600	ft								
Height AMSL:	538	m	1765	ft								
Speed:	41.2	m/s	80.0	kn	148	km/h						
Scan Pattern:	Minimum Terrain Altitude:				Maximum Terrain Altitude:				Min. Terrain Altitude excl. Overlap:			
Point Distance:												
MIN:	0.298	m	0.977	ft	0.267	m	0.877	ft	0	m	0	ft
AVG:	0.349	m	1.15	ft	0.313	m	1.03	ft	0	m	0	ft
MAX:	0.473	m	1.55	ft	0.425	m	1.39	ft	0	m	0	ft
Footprint Diameter:												
MIN:	0.121	m	0.396	ft	0.108	m	0.355	ft	0	m	0	ft
AVG:	0.131	m	0.429	ft	0.117	m	0.385	ft	0	m	0	ft
MAX:	0.152	m	0.499	ft	0.136	m	0.448	ft	0	m	0	ft
Line Distance:	0.353	m	1.16	ft								
Swath Width:	748	m	2455	ft	671	m	2202	ft	0	m	0	ft
Lateral Strip Separation:	337	m	1105	ft								
Overlap Per Side:	412	m	1350	ft	335	m	1098	ft				
Sidelap Per Side:	55.0	%			49.8	%						
Point Density:												
MIN:	5.99	pts/m^2			6.68	pts/m^2			0	pts/m^2		
AVG:	8.12	pts/m^2			9.05	pts/m^2			0	pts/m^2		
MAX:	9.51	pts/m^2			10.6	pts/m^2			0	pts/m^2		
MTA Zones Used:												
MTA Zone Width:	500	m	1639	ft								
MTA Zone MIN:	1											
MTA Zone MAX:	2											
Productivity:												
Net Area Rate:	49.9	km^2/h										
Typ. Data Rate:	16.2	GB/h										
Max. Data Rate:	33.3	GB/h										
Laser Safety Information:							Reference:					
NOHD:	0	m	0	ft	0	%	437	m	1434	ft		
ENOHD:	0	m	0	ft	0	%	437	m	1434	ft		
Laser standard:	2014											
Auxiliary Limits:							Reference:					
Max. Meas. Range Used:	661	m	2170	ft	86.0	%	767	m	2516	ft		
Scan Rate Range Prod.:	77170	m*lps			51.0	%	150000	m*lps				
Terrain Altitude Variation:	50.2	m	165	ft								
MTA Zone List:												
MTA Zone 1:	0	-	500	m	0	-	1639	ft				
MTA Zone 2:	500	-	999	m	1639	-	3279	ft				

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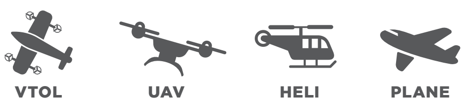
Appendix 2
Instrument Specification – LiDAR System

PHOENIX
LiDAR SYSTEMS

NEW PRODUCT



RANGER XL

The **Ranger XL** is a lightweight airborne laser scanner, especially designed for use on UAS and small manned aeroplanes or helicopters. With its wide field of view of 75 degrees and an extremely fast data acquisition rate of up to 1.8 MHz, the **Ranger XL** is perfectly suited for high point density corridor mapping applications such as power line, railway track and pipeline inspection.

FEATURES

- » Easily mountable to unmanned platforms (UAVs) and to helicopters, gyrocopters, and other small manned aircrafts.
- » Operating flight altitude up to 1,400 m / 4,600 ft
- » Scan speed up to 400 lines/second

QUICK SPECS

Absolute Accuracy
25-50 mm @ 350 m Range

PP Attitude Heading RMS Error
0.010° / 0.019° IMU options

Weight (including AIR NavBox)
5 kg / 11 lbs

Dimensions (with AIR NavBox)
348.5 x 164 x 189 mm

Laser Range
900 m @ 20% Reflectivity

Scan Rate
1800 kHz, up to 15 returns

APPLICATIONS

- » Utilities Mapping
- » Railway Track Mapping
- » Agriculture & Forestry Monitoring
- » Open Pit Mining Operations
- » General Mapping

PLATFORM

OVERALL DIMENSIONS (with AIR NavBox)	352 x 164 x 185 mm
OPERATING VOLTAGE	18 - 34 V DC
POWER CONSUMPTION	75 W
OPERATING TEMPERATURE	-10° - +40° C
WEIGHT (including Air NavBox)	4.4 kg / 11 lbs

LiDAR SENSOR

LASER PROPERTIES	1550 nm
RANGE MIN	5 m
MAX EFFECTIVE MEASUREMENT RATE	up to 1,500,000 meas./sec
HORIZONTAL FIELD OF VIEW	75°
ACCURACY	20 mm
PRECISION	15 mm
LASER BEAM DIVERGENCE	0.35 mrad
LASER BEAM FOOTPRINT (GAUSSIAN BEAM DEFINITION)	35 mm @ 100 m, 175 mm @ 500 m, 350 mm @ 1000 m
MAX MEASURING RANGE ρ 20% (ρ 60%)	900 m (1400 m)
SENSOR CLASSIFICATION	IP64 dust and splash-proof
WEIGHT	≤ 3.8 kg (without IMU/GNSS)
POWER CONSUMPTION	65 W