

# AXIS CONSULTANTS

## 2013 NORTHERN TERRITORY GRAVITY SURVEYS PROCESSING AND LOGISTICS REPORT

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## 1. INTRODUCTION

During October and November 2013, Daishsat Geodetic Surveyors carried out three precision gravity surveys for Axis Consultants (part of the Gutnick Group) with a total of 1,878 new gravity stations surveyed in the Northern Territory.

Gravity data was acquired using Scintrex CG-5 gravity meters. Position and level data were obtained using Leica SR530 and GX1230 geodetic-grade DGPS systems to produce precise Post-Processed locations and elevations. Gravity and GPS data were acquired using Daishsat ATV and foot-borne methods.

Gravity data was reduced using standard reductions on the ISOGAL84 gravity network. GPS data were reduced to MGA coordinates with levels expressed as meters above the Australian Height Datum (AHD).

## 2. SURVEY OVERVIEW

Top End Mining's EL26206 survey was located ~200km northeast of Katherine. This survey was completed first with 560 new stations acquired using All-Terrain Vehicle's over an area of 7.5km<sup>2</sup>. The survey comprised of a central semi-detailed grid of 320 gravity stations acquired at 100m x 100m station spacing's and was extended to the northwest and southeast by 240 stations acquired at 100m x 200m stations spacing's.

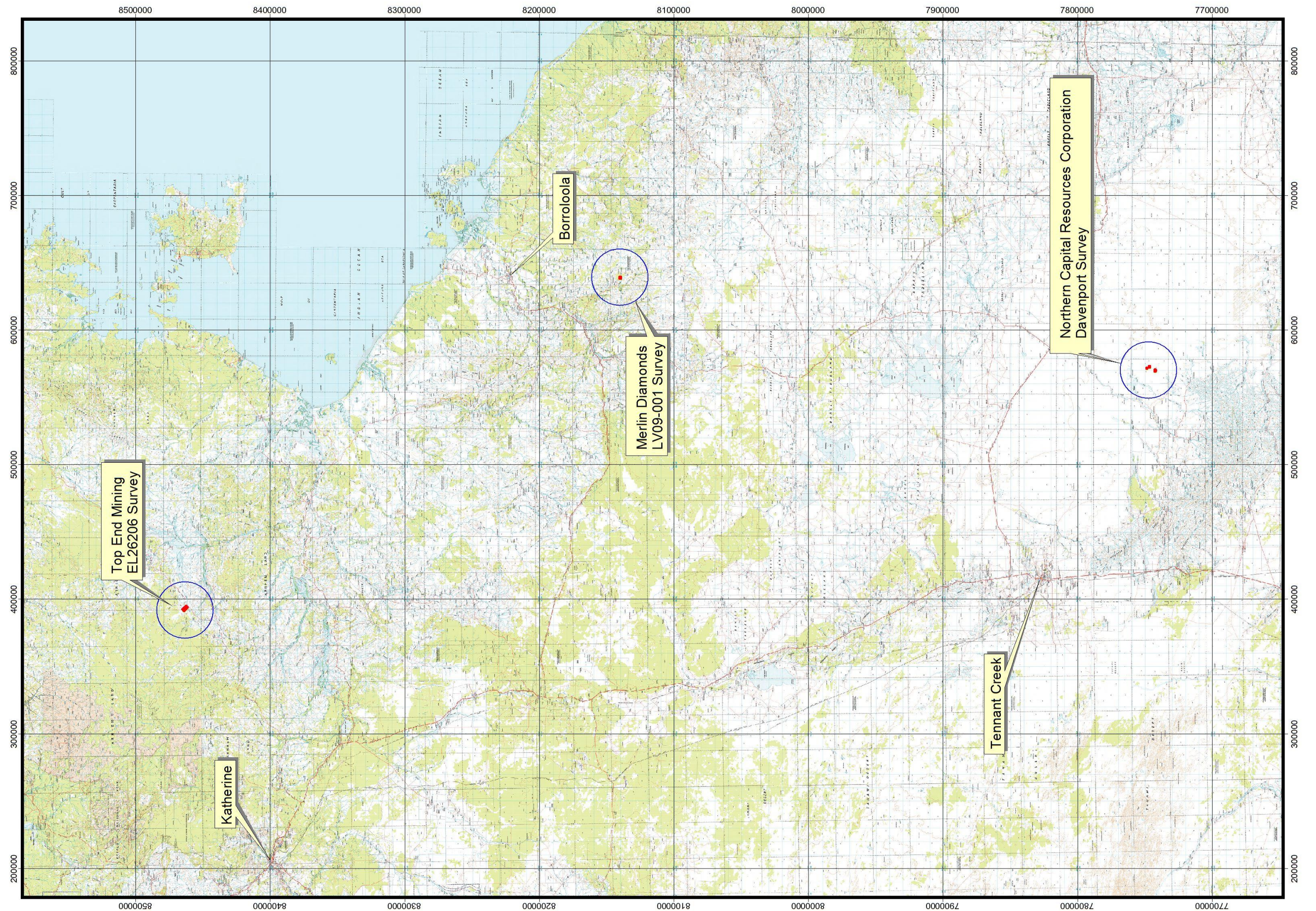
Merlin Diamonds LV09-001 survey was located adjacent to the Merlin Diamond Mine ~100km south of Borrooloola. The survey was completed after the EL26206 survey with 240 new stations acquired using All-Terrain Vehicle's over an area of 2.1km<sup>2</sup>. Semi-detailed gravity data was acquired at 100m x 100m station spacing's.

Northern Capital Resources Corporation's Davenport survey was located 180km southeast of Tennant Creek. The survey was completed last after the completion of the LV09-009 survey with 1,081 stations acquired using All-Terrain Vehicle's over three grids – Area 1, Area 2 & Area 3 – covering a total area of 3.4km<sup>2</sup>. Each grid comprised of a detailed gravity grid with stations acquired at 50m x 50m surrounded by a semi-detailed gravity grid with stations acquired at 50m x 100m.

The terrain encountered throughout the survey areas was extremely tough for gravity surveying with the survey crews having to negotiate through thick vegetation, tall trees, large rock-strewn gullies, rocky outcrops and burn-out scrubland. Due to the rough terrain many stations had to be offset from their proposed locations.

FIGURE 1 shows the location of the survey grids, APPENDIX A contains station plots of the survey grids, and specifications for the surveys are contained in APPENDIX C.





**Figure 1 – Survey Locations**



### 3. PERSONNEL AND EQUIPMENT

#### 3.1 Personnel

Gravity data acquisition was carried out by Daishsat field surveyors Peter Rose and Josh Jordan. Peter is one of Daishsat's most senior field surveyors and was the designated project supervisor who was responsible for daily management of the job.

Final data reduction, image processing and inspection were performed by the company geophysicist, Grant Coopes.

#### 3.2 Survey equipment

Surveying equipment utilised on this survey included:

- Scintrex CG-5 Gravity meters
- Leica System GX1230 & SR530 dual frequency GPS receivers
- Garmin vehicle-mounted GPS receivers for navigation
- Notebooks for data processing and backup
- Various chargers, surveying equipment and batteries

#### 3.3 Vehicles

Due to the location of the survey and the type of terrain to be encountered, Toyota Landcruiser 4WD vehicles and Daishsat ATV's (DATV's) were used on the survey. The Landcruiser's were used for transport to and from site and the DATV's were used for data acquisition.

To maintain the high Daishsat safety record, the Landcruiser was custom fitted with a range of safety equipment including:

- Omnitrack GPS tracking / communications system
- Dual fuel tanks
- Spare tires, tubes and tyre repair kit
- Satellite phone and UHF Radio
- Self-recovery equipment including, on board winch, snatch straps and rope
- Tools and spares to enable field repairs as necessary
- Survival kit with EPIRB emergency locator beacon

The DATV used was equipped with the following survey and safety equipment:

- 10L jerry can of spare fuel
- UHF communications
- GPS receiver for surveying and navigation
- Personal First Aid Kit
- Self-recovery equipment including winch, snatch straps and rope
- Tyre repair kit
- Tools and spares to enable field repairs as necessary

### 3.4 Accommodation

To minimize daily travel times and maximise production the crews stayed within close proximity to the survey areas wherever possible. For the EL26206 survey the crew set up a base camp ~700m east of the survey grid; for the LV09-001 survey the crew were accommodated at the Merlin Mine Camp; and for the Davenport survey the crew set up a base camp centrally located to each of the grids.

### 3.5 Communications

The survey crews were equipped with hand-held Iridium satellite phones, vehicle-mounted UHF radios and the “Omnitrack” satellite-based tracking and communication system was used on all vehicles to enable asset monitoring via a web interface. Scheduled communication and data exchanges with the Perth and Murray Bridge offices were ongoing for the duration of the job.



**Photos 1-2 – Heavily customised Daishsat ATV (DATV) used for gravity acquisition**

## 4. GPS SURVEYING AND PROCESSING

### 4.1 Set out of the grids

This was done concurrently with the gravity data acquisition using the Leica GX1230 GPS operating in post-processing mode. Where possible, the readings were taken as close to the ideal coordinates as possible using a Garmin GPS to navigate to the stations. At each station, the station number, position and RL were recorded digitally by the GPS crew. At the repeat stations, a washer tied to pink flagging, marked with the station number, was used for identification. At each station, the station number, position and RL were recorded digitally by the GPS crew.

### 4.2 Survey datum and control

The gravity surveying, and hence any gravity reductions, used the Australian Height Datum (AHD) as the reference datum. A new GPS base station was established at each of the survey areas for positional control. Base 1068 was established at the base camp for the EL26202 survey; Base 1069 was established within the survey grid for the LV09-001 survey; and Base 1392 was established at the base camp for the Davenport survey.

Co-ordinates for all of these base stations were calculated using three days' worth of static data, and connections to ITRF stations using Geoscience Australia's online GPS processing system, AUSPOS. For more information on this system, please visit <http://www.ga.gov.au/earth-monitoring/geodesy/auspos-online-gps-processing-service.html>. Details for this GPS base can be found in Appendix D.

### 4.3 Processing of the position and level data

The logged GPS data was recorded on removable CF cards, which were downloaded onto the laptops daily. The data was then processed using Novatel's Waypoint post-processing suite.

Waypoint combines the processing components, GrafNav and GrafNet, in a complete package. GrafNav processes data for one baseline (e.g. one base and one remote). GrafNav is normally used for kinematic data which it is extremely well suited for. It can also process single static baselines. Receiver types can be mixed and matched via the use of a common format. This component of Waypoint was used for processing the kinematic data acquired each day.

GrafNav and GrafNet share the same processing engine that has been under continuous development since its original inception by Waypoint in 1992. The core of this robust engine is its carrier phase kinematic (CPK) Kalman filter. Some of the major advantages of Waypoint's kernel are:

Fast processing - The GrafNav kernel is one of the fastest on the market. It will process ~0.8 epochs per MHz per second on a Pentium II.

Robust Kalman filter - From experience with processing GPS data from fast jets and NASA sounding rockets, the processing kernel has become extremely robust. Efforts have been made to account for all of the various data error possibilities given the different types of GPS receivers that GrafNav/GrafNet can handle.

Reliable OTF - Waypoint's on-the-fly (OTF) algorithm, called Kinematic Ambiguity Resolution (KAR), has had years of development and stresses reliability. Variations are implemented for both single and dual frequencies, and numerous options are available to control this powerful feature.

Accurate Static Processing - Three modes of static processing are implemented in the processing kernel. Fixed static is the most accurate. A quick static solution is also available as an alternative, while the float and iono-free float solution is useful for long baselines.

Dual Frequency - Full dual frequency support comes with GrafNav / GrafNet. For ambiguity resolution, this entails wide/narrow lane solutions for KAR, fixed static and quick static. Ionospheric processing is very important with the peak of the ionosphere's cycle occurring in 2000. The GrafNav kernel implements two ionospheric processing modes including the iono-free and relative models. The relative model is especially useful for airborne applications where initialization is near the base station, and this method is much less susceptible to L2 phase cycle slips.

Forward and Reverse - Processing can be performed in both the forward and reverse directions. Both GrafNav and GrafNet also have the ability to combine these two solutions to obtain a globally optimum one.

Velocity Determination - Since the GrafNav kernel includes the L1 Doppler measurement in its Kalman filter, velocity determination is very accurate. In addition to this, a considerable amount of code has been added specifically for the detection and removal of Doppler errors.

Long Baseline - Because precise ephemeris and dual frequency processing is supported; long baselines accuracies can be as good as 0.1 PPM.

For more information about Waypoint processing software, and in particular, GrafNav, please visit [http://www.waypnt.com/grafnav\\_d.html](http://www.waypnt.com/grafnav_d.html).

Grid coordinates were obtained by projecting the GPS-derived WGS84 coordinates using a UTM projection with zone 53 south. For more information about WGS84 please visit <http://www.ga.gov.au/geodesy/datums/>.

AHD heights were also calculated by Waypoint which utilises the latest geoid model for Australia, AUSGEOID09. Information about the geoid, and the modelling process used to extract separations (N values) can be found at <http://www.ga.gov.au/geodesy/ausgeoid/>.



## 5. GRAVITY ACQUISITION AND PROCESSING

### 5.1 Gravity data acquisition

Gravity observations were made simultaneously with the GPS observation. Two observations were made for each station so that any seismic or instrumental noise could be immediately detected. Each observation consisted of a 20-second or greater stacking time. The accepted tolerance between readings was limited to 0.030 of a dial reading to ensure accuracy. Vertical and horizontal levels were restricted to 10 arc seconds at all times.

At each station, the station number, time and two gravity readings (in dial units) were recorded in Daishsat carbon-copy gravity field books. The Scintrex CG-5 also automatically records the station, time and readings digitally to allow for downloading to computer.

### 5.2 Gravity base stations

Gravity base stations were used for the calculation of absolute gravity and daily drift determination during the surveys and were located coincident with GPS Bases 1068, 1069 and 1392. Base 1068 was tied to AFGN station 1980902318 located at the Katherine Airport; Base 1069 was tied to AFGN station 2013919810 located under the waiting shelter at the Borroloola Airport; and Base 1392 was tied to AFGN station 20139199934 located at the Tennant Creek Airport. Details for these bases can be found in Appendix D.

When in the field, a base station reading was taken in the morning before observing, and at evening after the last observation. When taking a base station reading, the observed gravity values were stacked over 120 seconds to ensure accuracy. Observations were repeated until the readings repeated to 0.010 of a dial reading or less.

### 5.3 Gravity data processing

Raw gravity data were processed on a daily basis to check for quality and integrity. This interim process produced a set of Bouguer Gravity values, which were contoured and imaged to provide a check for any anomalous readings that would need repeating. Geosoft GRAVRED software was used for the gravity reduction in the field. Other software used on this project includes ArcView, ChrisDBF, and Oasis Montaj.

The formulae used in the gravity reduction are listed below:

**Instrument scale factor:** This correction was used to correct a gravity reading (in dial units) to a relative milliGal value based on the meter calibration.

**Tidal correction:** This correction was used to correct for background variations due to changes in the relative position of the moon and sun. The Scintrex calculated ETC was removed and a new ETC calculated using Geosoft Formulae and the surveyed GPS latitude. The formula is too complex to list here.

**Instrument Drift:** Since gravity meters are mechanical, they are prone to drift (extension of the spring with heat, obeying Hooke's law). If two base readings are taken one can assume that the drift between the two readings is linear and can therefore be calculated. The drift and tidal corrected value is referred to as the *observed gravity*.

**Theoretical Gravity:** The theoretical value of gravity was calculated using the 1967 variant of the International Gravity Formula and used to latitude correct the observed gravity.

$$GT = 978031.856 \times (1 + 0.005278895 \times \sin^2 \phi + 0.000023462 \times \sin^4 \phi)$$

where  $\phi$  represents degrees of latitude

**Free-Air Correction:** Since gravity varies inversely with the square of distance, it is necessary to correct for changes in elevation between stations to reduce field readings to a datum surface (in this case, AHD).

$$FAC = 0.308596 \times h_{AHD}$$

**Bouguer Correction:** This correction accounts for the attraction of material between the station and datum plane that is ignored in the free-air calculation. A value of 2.67 gm/cc was used in the correction.

$$BC = 0.0419088 \times \rho \times h_{AHD}$$

where  $\rho$  = density (2.67 gm/cc)

**Free Air Gravity:** This is obtained by applying the free air correction (FAC) to the observed gravity reading.

$$FAG = G_{OBSG} - GT + FAC$$

**Bouguer Gravity:** This is obtained when all the preceding reductions or corrections have been applied to the observed gravity reading.

$$BG = G_{OBSG} - GT + FAC - BC$$

## 5.4 Gravity meter calibration and scale factor

The gravity meters used on the survey had previously been calibrated on the South Australian gravity calibration range. Derived scale factors from these calibrations are shown below:

Gravity Meters			
Meter	Model	Serial Number	Scale Factor
P	Scintrex CG-5	080540394	1.000683
Q	Scintrex CG-5	080640417	0.999423



## 6. RESULTS

Raw and processed GPS and gravity data are contained on CD-ROM as APPENDIX E.

Hardcopy plots of station locations and gridded data images are contained in APPENDIX A.

### 6.1 Stations Surveyed and Survey Progress

In total 1,878 new stations were acquired during the project and of these, 158 were revisited for survey quality control. Despite extremely tough terrain through some of the survey grids the survey crews were able to achieve an average production rate of ~120 stations per day per crew. A brief production summary for the survey is shown in Table 1 below.

EL26206 Survey		
Gravity Stations Acquired (Including Repeats)	<b>604</b>	Stations
New Gravity Station Repeats	<b>44</b>	7.9%
New Gravity Stations Acquired	<b>560</b>	Stations
LV09-0001 Survey		
Gravity Stations Acquired (Including Repeats)	<b>259</b>	Stations
New Gravity Station Repeats	<b>22</b>	9.3%
New Gravity Stations Acquired	<b>237</b>	Stations
Davenport Surveys		
Gravity Stations Acquired (Including Repeats)	<b>1,173</b>	Stations
New Gravity Station Repeats	<b>92</b>	8.5%
New Gravity Stations Acquired	<b>1,081</b>	Stations

**Table 1: Production Summary**

### 6.2 Data Repeatability

Analysis of the repeat data shows that measurement repeatability is excellent for both GPS and Gravity observations. An analysis of the survey data is included in APPENDIX B. Based on the repeat data, one can assume the following typical accuracies for the observables:

Z position observation: < 0.002 m

Gravity observation: < 0.001 mGals

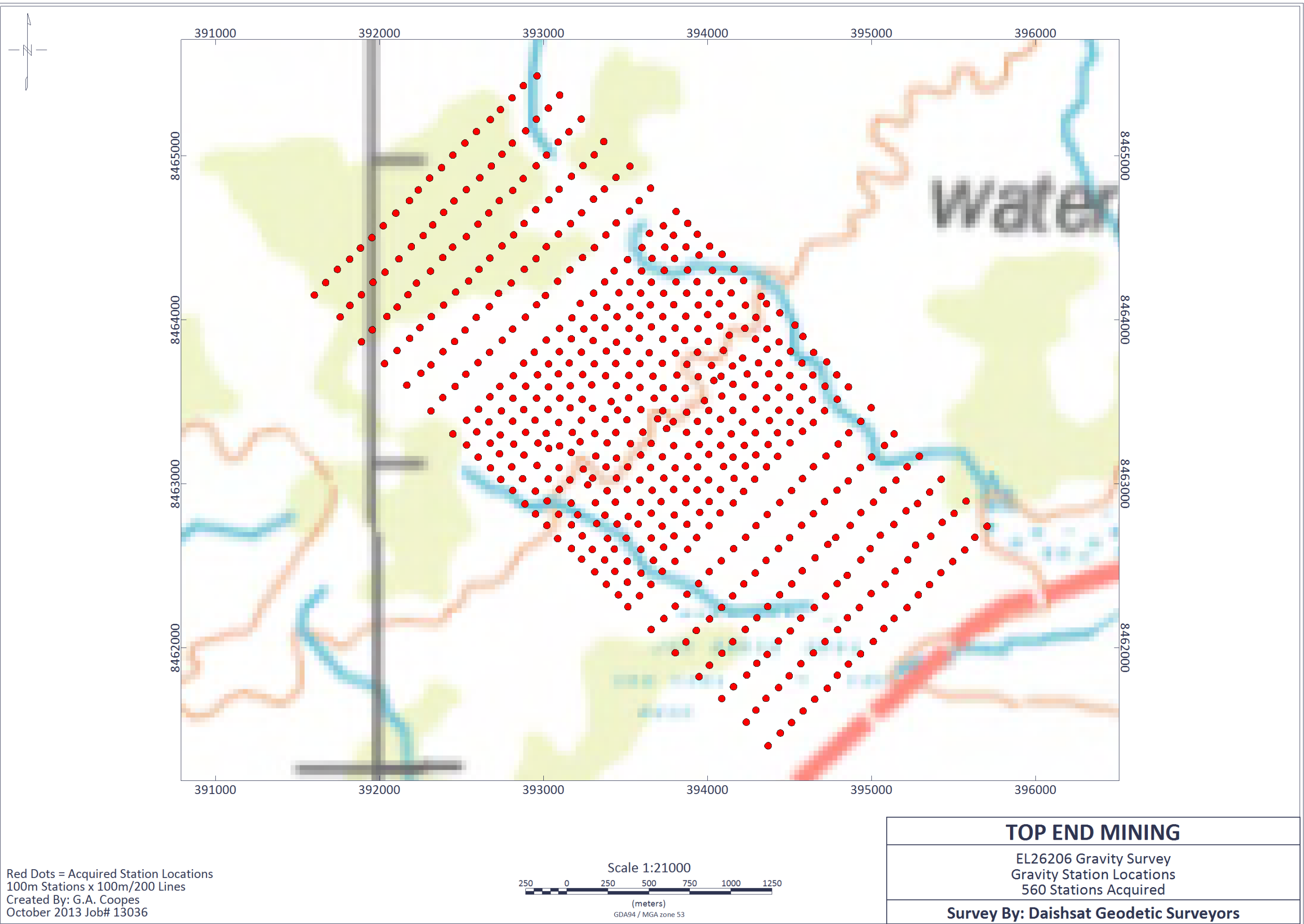


**Photos 3-5 – Survey Photos**

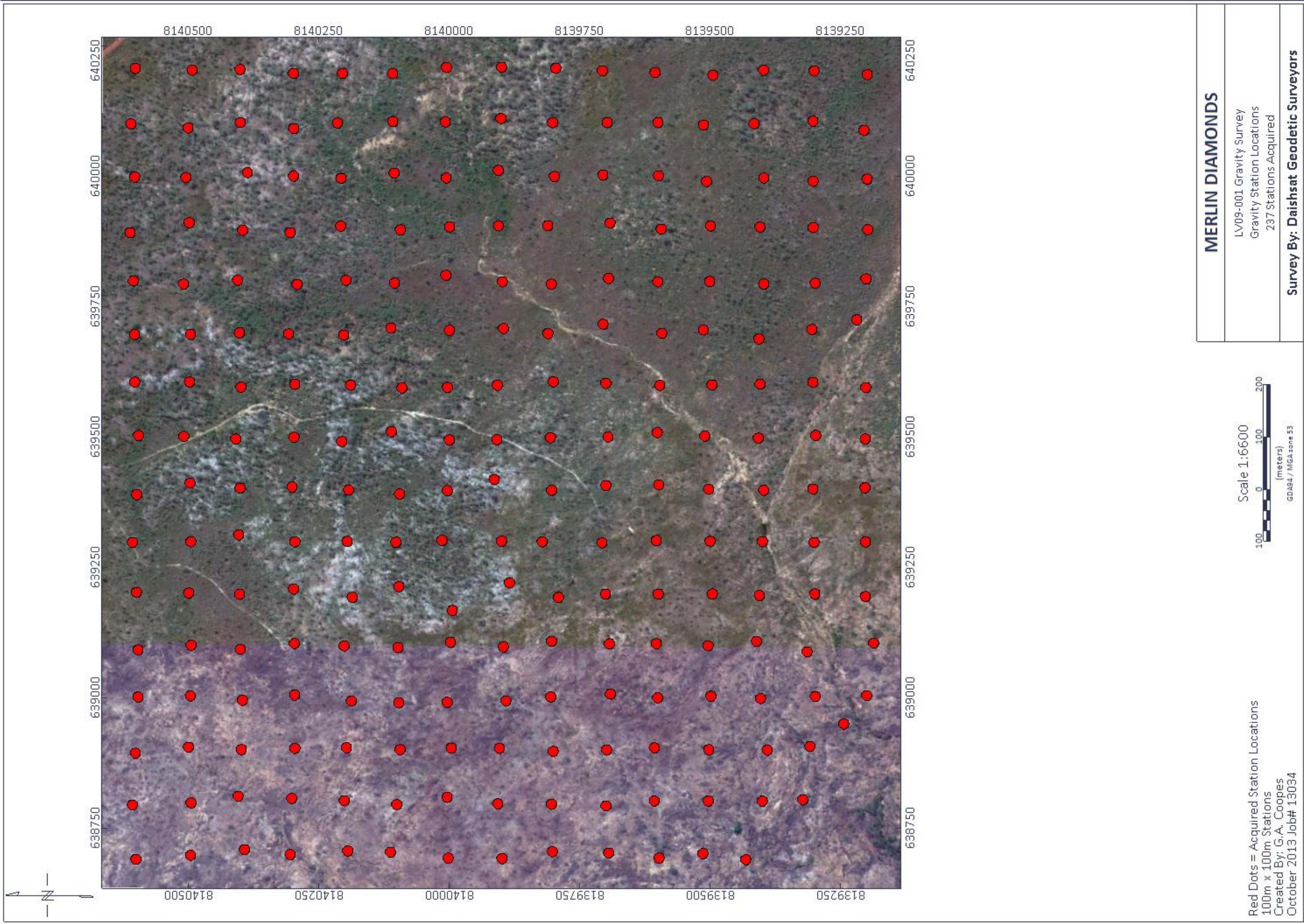


## **APPENDIX A**

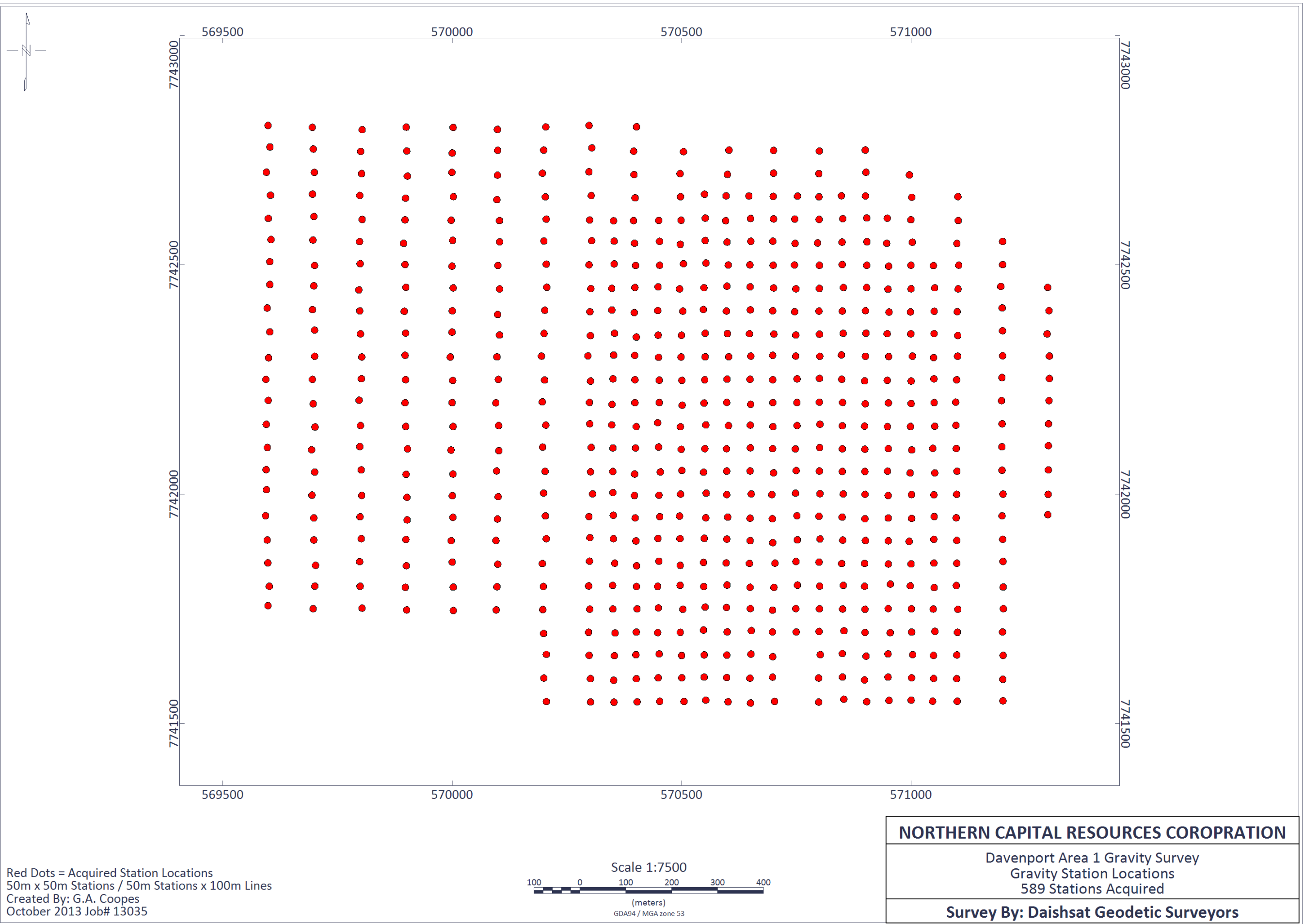
### **Station Location Plots**



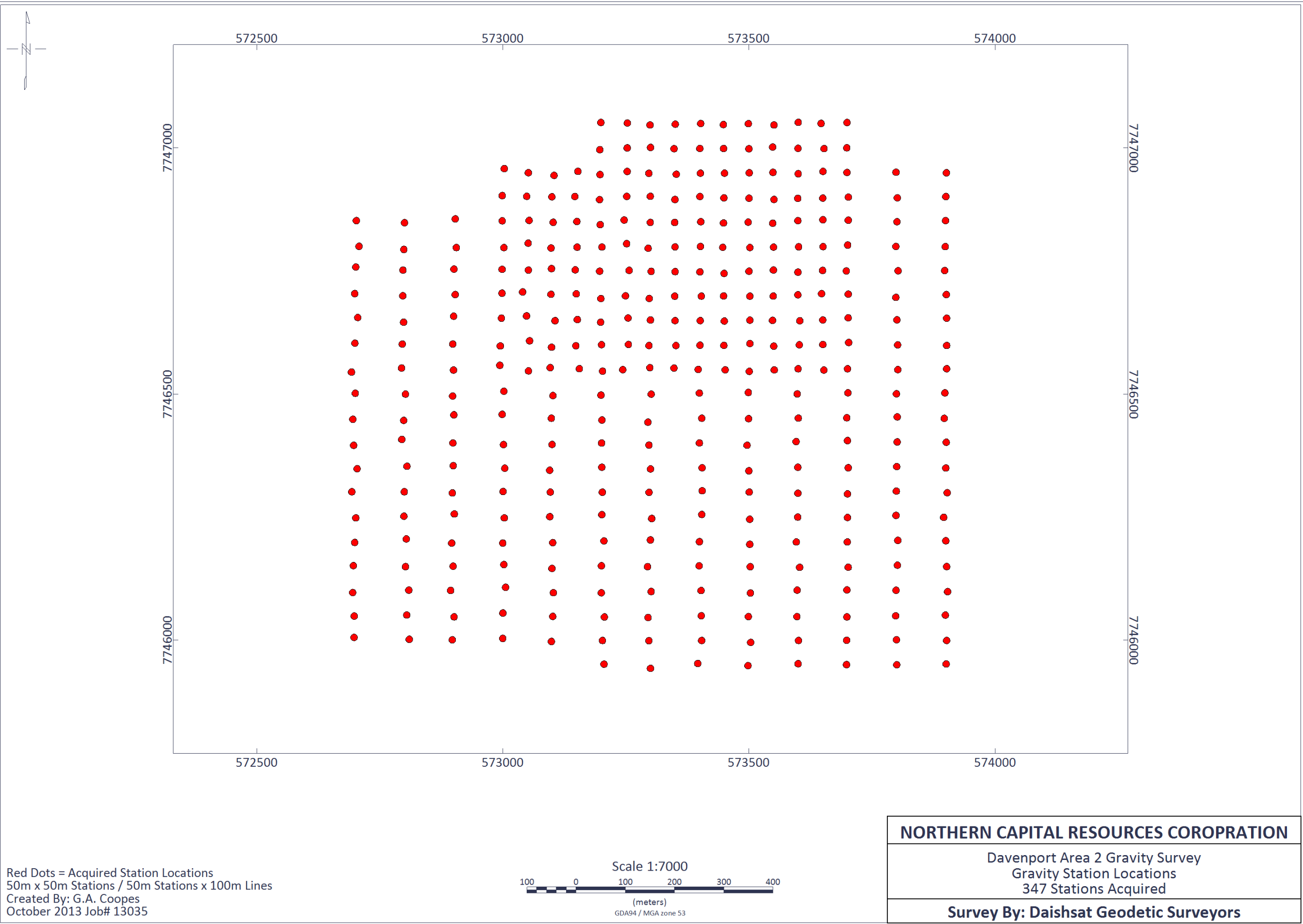


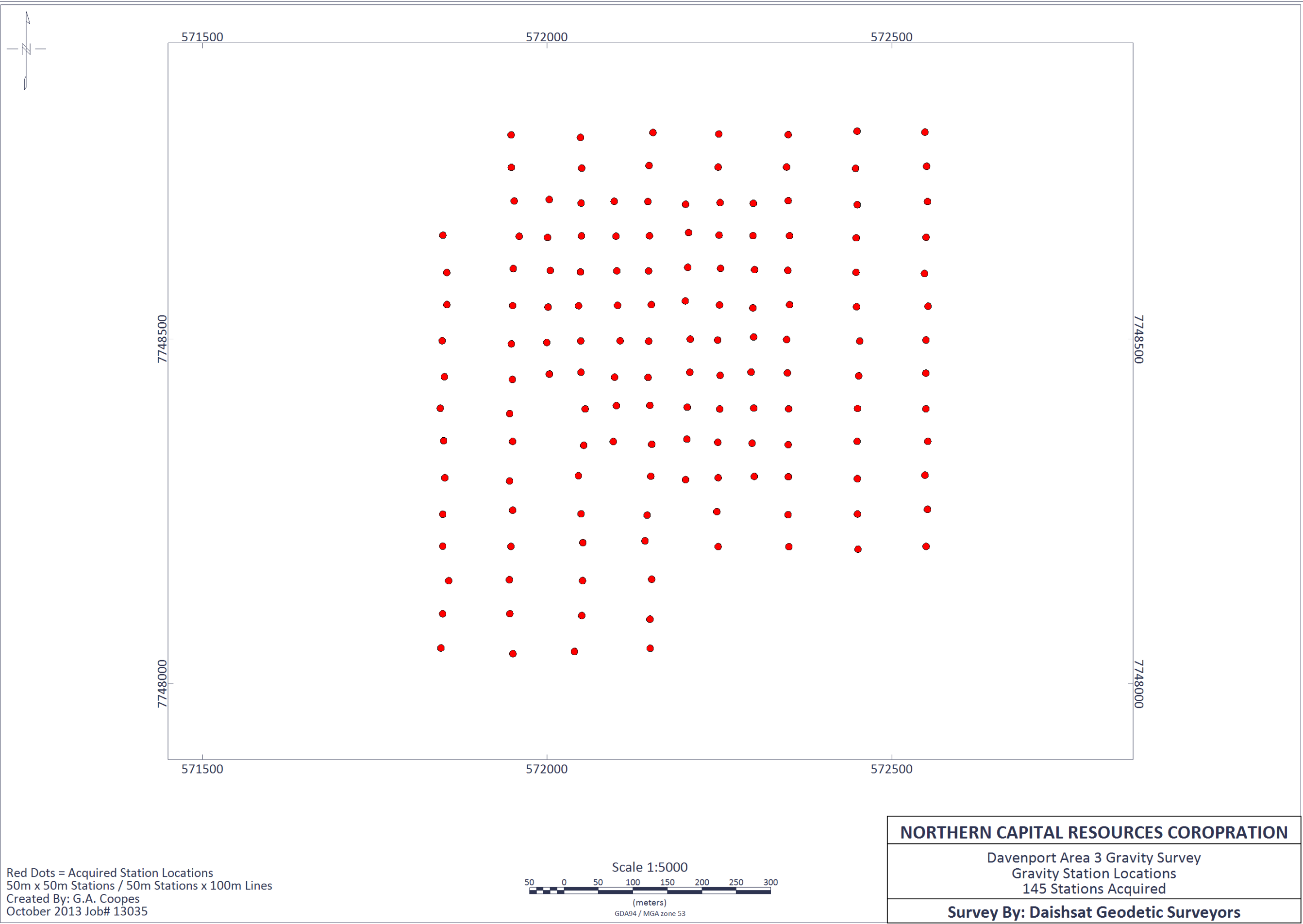










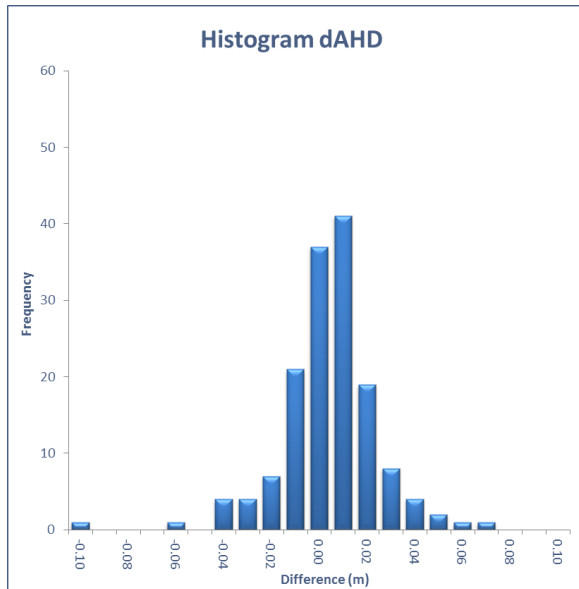




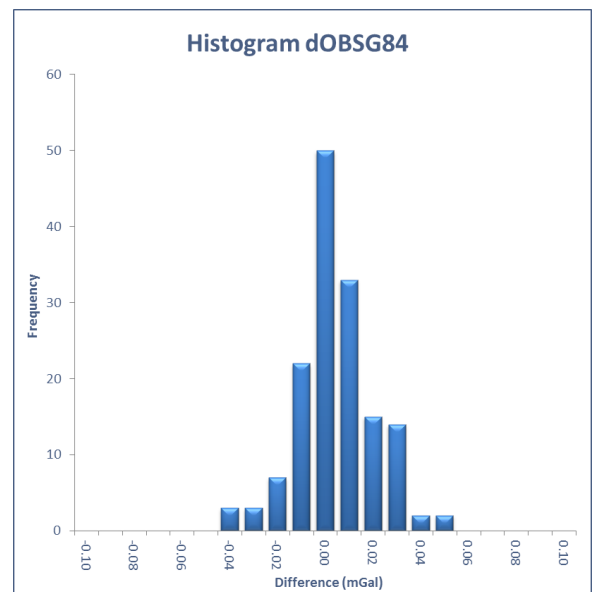
## APPENDIX B

### Repeat Tabulation and Analysis

Repeatability of AHD



Repeatability of OBSG84



### Summary Statistics

Summary Statistics		
Statistic	dAHD	dOBSG
Mean	0.000	0.000
Standard Error	0.002	0.001
Median	0.001	0.000
Mode	0.000	0.000
Standard Deviation	0.021	0.016
Sample Variance	0.000	0.000
Kurtosis	9.349	0.807
Skewness	-1.400	-0.031
Range	0.195	0.094
Minimum	-0.130	-0.048
Maximum	0.065	0.046
Sum	-0.071	0.022
Count	151	151

## APPENDIX C

### Survey Information

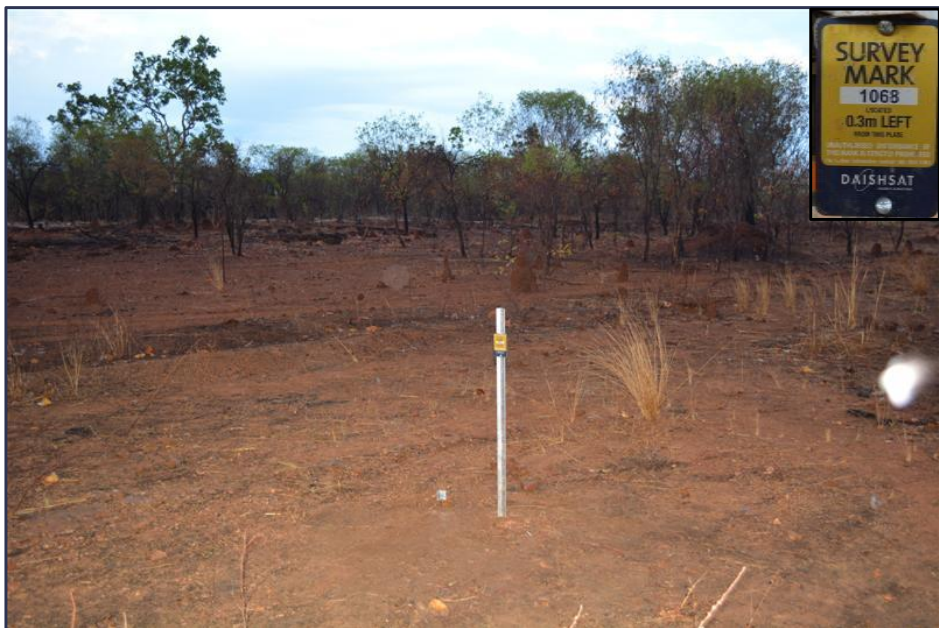
EL26206 Survey	
<b>Client</b>	TOP END MINING
<b>Operators</b>	Peter Rose / Josh Jordan
<b>Techniques Employed</b>	Post-Processed GPS / DATV Ground Gravity
<b>Station Spacing</b>	100m
<b>Line Spacing</b>	100m / 200m
<b>Gravity Meters</b>	Scintrex CG5: SN: 080640417
<b>GPS Units</b>	Leica SR530 (Base) & Leica GX1230 (Rover)
<b>Number of Points Surveyed</b>	604 Total (Includes 560 New and 44 Repeats)
<b>Gravity Base</b>	Daishsat Base: 1608
<b>GPS Base</b>	Daishsat Base: 1608
<b>Dates of Survey</b>	15 <sup>th</sup> to the 20 <sup>th</sup> of October, 2013

LV09-0001 Survey	
<b>Client</b>	MERLIN DIAMONDS
<b>Operators</b>	Peter Rose / Josh Jordan
<b>Techniques Employed</b>	Post-Processed GPS / DATV Ground Gravity
<b>Station Spacing</b>	100m
<b>Line Spacing</b>	100m
<b>Gravity Meters</b>	Scintrex CG5: SN: 080540394; SN: 080640417
<b>GPS Units</b>	Leica SR530 (Base) & Leica GX1230 (2 x Rovers)
<b>Number of Points Surveyed</b>	259 Total (Includes 237 New and 22 Repeats)
<b>Gravity Base</b>	Daishsat Base: 1069
<b>GPS Base</b>	Daishsat Base: 1069
<b>Dates of Survey</b>	22 <sup>nd</sup> and 23 <sup>rd</sup> of October, 2013

Davenport Surveys	
<b>Client</b>	NORTHERN CAPITAL RESOURCES CORPORATION
<b>Operators</b>	Peter Rose / Josh Jordan
<b>Techniques Employed</b>	Post-Processed GPS / DATV Ground Gravity
<b>Station Spacing</b>	50m
<b>Line Spacing</b>	50m / 100m
<b>Gravity Meters</b>	Scintrex CG5: SN: 080540394; SN: 080640417
<b>GPS Units</b>	Leica SR530 (Base) & Leica GX1230 (2 x Rovers)
<b>Number of Points Surveyed</b>	1,173 Total (Includes 1,081 New and 92 Repeats)
<b>Gravity Base</b>	Daishsat Base: 1392
<b>GPS Base</b>	Daishsat Base: 1392
<b>Dates of Survey</b>	27 <sup>th</sup> of October to the 1 <sup>st</sup> of November, 2013




**APPENDIX D**  
**Base Station Information**

GPS/Gravity Base 1068 - EL26026			
FINAL AUSPOS CO-ORDINATES			
MGA94 / AHD		GDA94 / WGS84	
EASTING (m)	396397.895	LATITUDE (DMS)	13° 54' 13.67958" S
NORTHING (m)	8462704.568	LONGITUDE (DMS)	134° 02' 27.87637" E
ZONE (UTM, South)	53	ELL HT (m)	196.774
ORTHO HT (AHD, m)	143.999		
N (AUSGEOID09, m)	52.775		
GRAVITY AND CONTROL DETAILS			
OBSERVED GRAVITY		CONTROL DETAILS	
978314.593 ISO GAL84 (mGal)		GPS – Daishsat using a multiple static sessions and the AUSPOS online GPS Processing system. Expected accuracy of station coordinates better than 0.005m.	
978314.515 AAGD07 (mGal)		Gravity – Daishsat using multiple ABA ties to AFGN station 1980902318 located at the Katherine Airport. Expected accuracy better than 0.010 mGal	
MISCELLANEOUS DETAILS			
Est. Date: 13/10/2013	Established By: Peter Rose		Survey: 13036
DESCRIPTION AND ACCESS			
This base station consists of a small star picket protruding from the ground and is witnessed by a Daishsat survey plaque, placed on a large star picket ~ 0.3m to the right. The base is located approximately 200km northeast of Katherine and can be accessed by travelling east from Katherine along the Central Arnhem Road for 201.5 km then turn off the road and travel north cross country for ~200m to the base.			
<div></div>			
Field Photo Of Base			

GPS/Gravity Base 1069 - Merlin Mine			
FINAL AUSPOS CO-ORDINATES			
MGA94 / AHD		GDA94 / WGS84	
EASTING (m)	639321.699	LATITUDE (DMS)	16° 49' 19.35083" S
NORTHING (m)	8139671.277	LONGITUDE (DMS)	136° 18' 27.21460" E
ZONE (UTM, South)	53	ELL HT (m)	211.257
ORTHO HT (AHD, m)	164.841		
N (AUSGEOID09, m)	46.416		
GRAVITY AND CONTROL DETAILS			
OBSERVED GRAVITY		CONTROL DETAILS	
978430.572 ISO GAL84 (mGal)		GPS – Daishsat using a multiple static sessions and the AUSPOS online GPS Processing system. Expected accuracy of station coordinates better than 0.005m.	
978430.494 AAGD07 (mGal)		Gravity – Daishsat using multiple ABA ties to AFGN station 2013919810 located under the waiting shelter at the Borroloola Airport. Expected accuracy better than 0.010 mGal	
MISCELLANEOUS DETAILS			
Est. Date: 22/10/2013	Established By: Peter Rose		Survey: 13034
DESCRIPTION AND ACCESS			
<p>This base station consists of a small star picket protruding from the ground and is witnessed by a Daishsat survey plaque, placed on a large star picket ~ 0.3m to the right. The base is located approximately 100km south of Borroloola in a clearing adjacent to an old drill pad near the Merlin Diamond Mine. The base can be accessed by travelling north from along the road adjacent to the mine site office and pass through a security gate, at 2.2km leave the main track and follow two wheel track on the left heading west, at 2.5km take left hand fork, at 2.9km take left hand fork and at 4.0km the base is reached.</p>			
<div></div>			
Field Photo Of Base			



GPS/Gravity Base 1392 - Davenport			
FINAL AUSPOS CO-ORDINATES			
MGA94 / AHD		GDA94 / WGS84	
EASTING (m)	571524.458	LATITUDE (DMS)	20° 23' 40.80151" S
NORTHING (m)	7744694.749	LONGITUDE (DMS)	135° 41' 07.68552" E
ZONE (UTM, South)	53	ELL HT (m)	304.908
ORTHO HT (AHD, m)	271.789		
N (AUSGEOID09, m)	33.119		
GRAVITY AND CONTROL DETAILS			
OBSERVED GRAVITY		CONTROL DETAILS	
978560.549 ISOGAL84 (mGal)		GPS – Daishsat using a multiple static sessions and the AUSPOS online GPS Processing system. Expected accuracy of station coordinates better than 0.005m.	
978560.471 AAGD07 (mGal)		Gravity – Daishsat using multiple ABA ties to AFGN station 20139199934 located at the Tennant Creek Airport. Expected accuracy better than 0.010 mGal	
MISCELLANEOUS DETAILS			
Est. Date: 27/10/2013	Established By: Peter Rose		Survey: 13035
DESCRIPTION AND ACCESS			
<p>This base station consists of a small star picket protruding from the ground and is witnessed by a Daishsat survey plaque, placed on a large star picket ~ 0.3m to the right. The base is located approximately 180km southeast of Tennant Creek in the middle of crown lands with no distinguishing features and can be accessed by heading east off the Stuart Highway along the main track to Kurundi station 80km south of Tennant Creek. At 49.6km pass Kurundi Station and continue north, at 54.2km the main track turns to the east, and at 116.1km reach a T-junction and take the track to the right heading south. At 129.3km pass through a gate and continue south, at 130.5km take the right-hand turn towards Canteen Creek, at 169.5km leave the track after crossing a grid and travel north on the western side of the fence, at 183.5km pass through a gate on the left and travel east on the south side of a broken old fence which disappears and head northeast cross country reaching the base at 204.5km.</p>			
<div></div>			
Field Photo Of Base			

## **APPENDIX E**

### **Data CD-ROM**

(Attached to back cover)