Atlas Geophysics Report Number R2013036

Southern Wiso Basin Gravity Survey

Geoscience Australia

Attention: Mr Phill Wynne

Report completed by:

atlas GEOPHYSICS

LR Mathews

T 08 6278 2898
F 08 6278 1595
PO BOX 1049
MORLEY WA 6943
AUSTRALIA

info@atlasgeo.com.au

ABN 68 123 110 243

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1.0 Company Overview

Atlas Geophysics Pty Ltd is an Australian company based in Morley, Western Australia, whose mission is to provide the highest quality geophysical resource data to the mining, petroleum and exploration industry in a safe and timely manner. Through experience, innovation and excellence, the company will exceed its client's expectations and will continually develop its technologies and methodologies to maintain its reputation for being the best in the business.

The company specialises in the acquisition, processing and interpretation of potential field datasets, with particular emphasis on gravity. The director of the company, Leon Mathews B.Sc. Hons (Geophysics), has over 15 years experience in the field of gravity and brings to the company, a young, vibrant and motivated approach to project management. Strategically, through development and research, the company aims to expand into other geophysical acquisition markets that encompass methods such as electrical, electromagnetic, induced polarisation and reflection seismic. The company also has interests in developing an airborne platform capable of acquiring high quality magnetic and radiometric data so it can offer its clients a complete airborne and ground geophysical solution.

Atlas Geophysics Pty Ltd is committed to the values and principles of Health, Safety and Environment. To this end, the company aims to prevent injuries and occupational illness to its employees and minimise any adverse environmental impact its activities may have.

2.0 Project Brief

Atlas Geophysics project P2013036 required the acquisition and processing of **3,857** new regional gravity stations on behalf of Geoscience Australia (GA), funded by the Northern Territory Geological Survey (NTGS). The gravity survey, referred to as the "Southern Wiso Basin Gravity Survey" was assigned GA project number 201380.

The survey area covered a large area over the Tanami Dessert, west of Tennant Creek in the Northern Territory. Survey operations were based out of Lajamanu Aboriginal Community for the western section and for the east, a remote camp just west of an old exploration site/camp known as Explorer 108.

Atlas Geophysics Pty Ltd completed the acquisition of the dataset using helicopter-borne gravity methods. A single helicopter crew was used for the duration of the project.

The survey commenced on 11th July 2013 with survey cessation on 18th August 2013.

2.1 Location and Access

The gravity survey spanned an area approximately 420km x 290km (Figure 1) and covered all or parts of the following 1:250,000 map sheets:

- Winnecke Creek
- Tanami East
- Mount Solitaire
- Bonney Well
- South Lake Woods
- Green Swamp Well
- Lander River
- Barrow Creek

For the most part, the terrain was very flat and open, almost featureless. Sand dune systems dominated in the south, with dune heights varying from 2m to 15m. Vegetation was mainly Spinifex and other low lying scrub, some of which had been burnt out in bush-fires.

As most of the area covered Aboriginal Land, access was restricted to helicopter only. The single east-west road in the north connecting Tennant Creek to Lajamanu was not used for refuelling so this required careful planning to ensure the refuels and pilot changeovers were conducted only at the logistics bases.

The small Aboriginal Community of Lajamanu provided the first base of operations and this was accessed via the Tanami Road or by the Lajamanu-Top Springs Road. The Tanami Road was in very poor condition and the crew found the road to Top Springs to be much more trafficable.

Explorer 108, the second base of operations, was accessed using drilling and exploration tracks west from Tennant Creek. Access is good, with 80 kph possible for most of the journey.

2.2 Survey Configuration

Gravity acquisition was conducted using a square grid configuration with stations spaced at 4000m.

A number of stations were offset from their planned station location where culturally sensitive areas existed or helicopter landing was deemed risky e.g. Stuart Highway, large dunes etc. No stations were omitted from the survey.

Appendix A contains a station location plot of the acquired gravity stations.

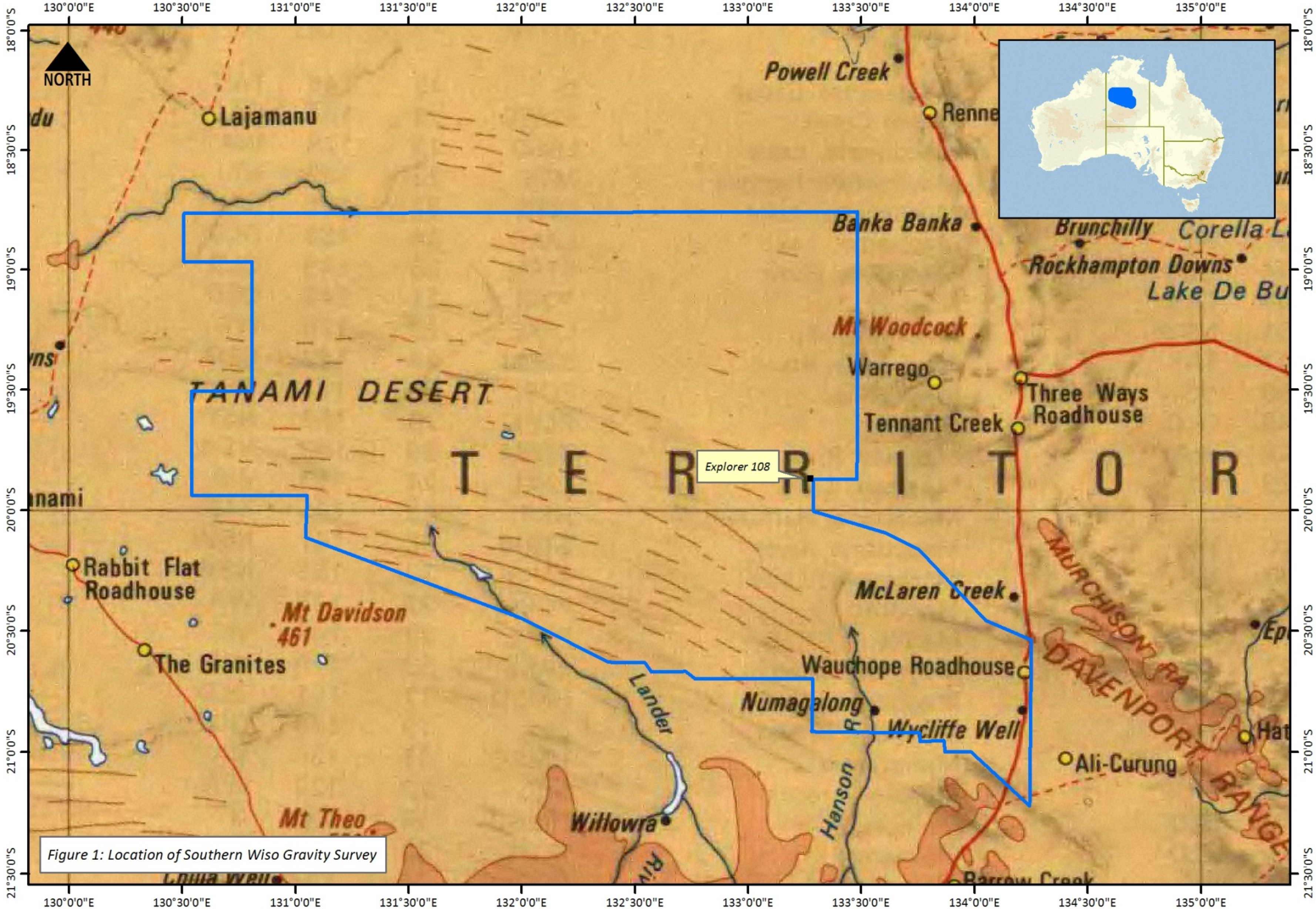


Figure 1: Location of Southern Wiso Gravity Survey

3.0 Personnel and Subcontractors

Atlas Geophysics Pty Ltd engages only fit, motivated and safe working professionals to conduct its gravity operations. Acquisition staff members are from a range of backgrounds, usually from the geoscience or geotechnical fields, and all are trained in senior first aid, bush survival, and advanced four wheel driving. Overseeing the acquisition and processing is the company's team of geophysicists and data processors – a team with a combined total of over 20 years experience in the acquisition, processing and quality analysis of gravity data.

3.1 Project Supervision

Supervising the project from Perth Operations was director Leon Mathews. Leon has been involved in the acquisition, processing and interpretation of potential field data for over 15 years and has directly overseen the acquisition and processing of over 1,000,000 gravity stations.

Leon was responsible for project supervision, as well as for conducting the processing and quality analysis of the gravity data on a daily basis.

All final data processing, QA, reporting and delivery was performed by Leon Mathews.

3.2 Acquisition/Other Personnel

Other personnel participating in field acquisition of the gravity data on this project were:

Chris Rea	*Supervising Geophysical Technician*
Tom Wood	Geophysical Technician
Barry Thompson	Pilot
Tony Neame	Pilot
Ryan Watson	Pilot

3.3 Subcontractors

Victorian based helicopter operations company, Great Ocean Road Helicopters Pty Ltd, were chosen to supply the helicopters, pilots and engineering support for the duration of this project.

4.0 Equipment and Instrumentation

4.1 Glonass/GPS Receiver Equipment

Leading edge dual-frequency GPS technologies from Leica Geosystems such as the GPS1200 have been utilised on the project to allow for post-processed kinematic (PPK) centimetre level accuracy 3D positions. System specifications for the receivers utilised can be found in the attached brochures (Figures 2-4). The GPS1200 system is equipped with future proof GNSS technology which is capable of tracking all available GNSS signals including the currently available GLONASS. These new generation receivers, in conjunction with full GNSS tracking and processing, offer a new level of unmatched solution accuracy and reliability, especially when compared to existing conventional L1, L2 GPS technologies.

The use of Glonass technology in addition to GPS provides very significant advantages:

- Increased satellite signal observations
- Markedly increased spatial distribution of visible satellites
- Reduced Horizontal and Vertical Dilution of Precision (DOP) factors
- Improved post-processed-kinematic (PPK) performance
- Decreased occupation times means faster acquisition

Eight Leica GPS1200 geodetic grade receivers were utilised to conduct the survey. Two receivers were used as a post-processed kinematic (PPK) rover in the helicopter, with the other receivers used as base stations for logging static data on multiple control stations.

On the helicopter, the GPS/Glonass antennas were mounted on the tail-boom of the aircraft and a fixed aluminium bracket at the front of the aircraft, with the receivers mounted on a custom mount inside the cabin.

Navigation between gravity stations was facilitated by a Garmin 296 GPS receiver operating in autonomous mode.

4.2 Gravity Instrumentation

Complementing the company's GNSS/GPS technologies is the latest in gravity instrumentation from Scintrex Ltd, the Scintrex CG-5 (Figure 5). The CG-5 digital automated gravity meter offers all of the features of the low noise industry standard CG-3M micro-gravity unit, but is smaller and lighter. It also offers improved noise rejection. By constantly monitoring tilt sensors electronically, the CG-5 automatically compensates for errors in gravity meter tilt. Due to a low mass and the excellent elastic properties of fused quartz, tares are virtually eliminated.

The CG-5 can be transported over very rough terrain, on quad bikes, foot, vehicle or helicopter without taring or drifting. In terms of repeatability, the CG-5 outperforms all existing gravity meter technologies, with a factory quoted repeatability of better than 0.005 mGal.

Table 1 below lists the gravity meters used on the project.

Gravity Meter Type	Gravity Meter Code	Gravity Meter Serial Number
Scintrex CG5	A1	40240
Scintrex CG5	A2	40241

Table 1: Gravity meters used on the project

4.3 Other Equipment

The company utilised the following additional equipment to fully support the operations:

- Two HP Laptop computers for data download and processing
- Three Iridium satellite phones for long distance communications and scheduled calls
- Personal Protective Equipment for all personnel
- Batteries, battery chargers, solar cells, UPS System
- Survey consumables
- Tools, engineering and maintenance equipment for vehicle servicing
- First aid and survival kits
- Tyres and recovery equipment
- Two satellite tracking and communication devices.

Leica GPS1200
Fast, accurate, rugged and reliable

SmartTrack+

GNSS technology
GPS1200's SmartTrack+ measurement engine now utilizes two global navigation satellite systems increasing the number of tracked satellites. The new SmartTrack+ measurement engine tracks all available GNSS signals (L2C and GLONASS). More satellites means higher productivity, accuracy and reliability. SmartTrack+ acquires satellites within seconds, is ideal in urban canyons and obstructed areas where other receivers often fail. GPS1200 with SmartTrack+ is designed to support the future signals GPS L5 and Galileo.

SmartCheck+
Continuously checking provides the highest possible reliability. A unique, built-in integrity monitoring system checks all results immediately. SmartCheck+ now processes GPS and GLONASS measurements simultaneously for centimeter-accuracy, 20 Hz RTK at 30 km and more. Initialize within seconds and survey in obstructed areas with a GX1230/ATX1230 (GPS only) sensor or increase productivity with a GX1230 GG/ATX1230 GG (GPS and GLONASS).

GLONASS
For many years the GLONASS system was not reliable enough in terms of satellite availability and system performance. With recent launches and commitment from the Russian government, reliability and availability are significantly improved. Under normal conditions there are 2 to 5 additional satellites compared to a GPS only constellation – and even more satellites will be available over the next two years. Now is the time to invest in hybrid GNSS technology.

"The GLONASS system should be created before 2008, as it was originally planned ... We have the possibility. Let us see what can be done in 2006 – 2007"

(Russian President Vladimir Putin December 26th 2005).

Exceptionally rugged
Don't worry about how your crews handle GPS1200. It's built to MIL specs to withstand the roughest use. With its strong, precision-machined magnesium housing, GPS1200 stands up to drops and falls and the jolts and vibrations of machines.

Immune to bad weather
Designed for temperatures from –40° C to +65° C (storage +80° C). GPS1200 shrugs off arctic cold and blistering heat. Fully waterproof – withstands immersion to 1 m – sand and dustproof, it operates perfectly in any conditions from tropical rainfall to desert sandstorms. GPS1200 just keeps on working.

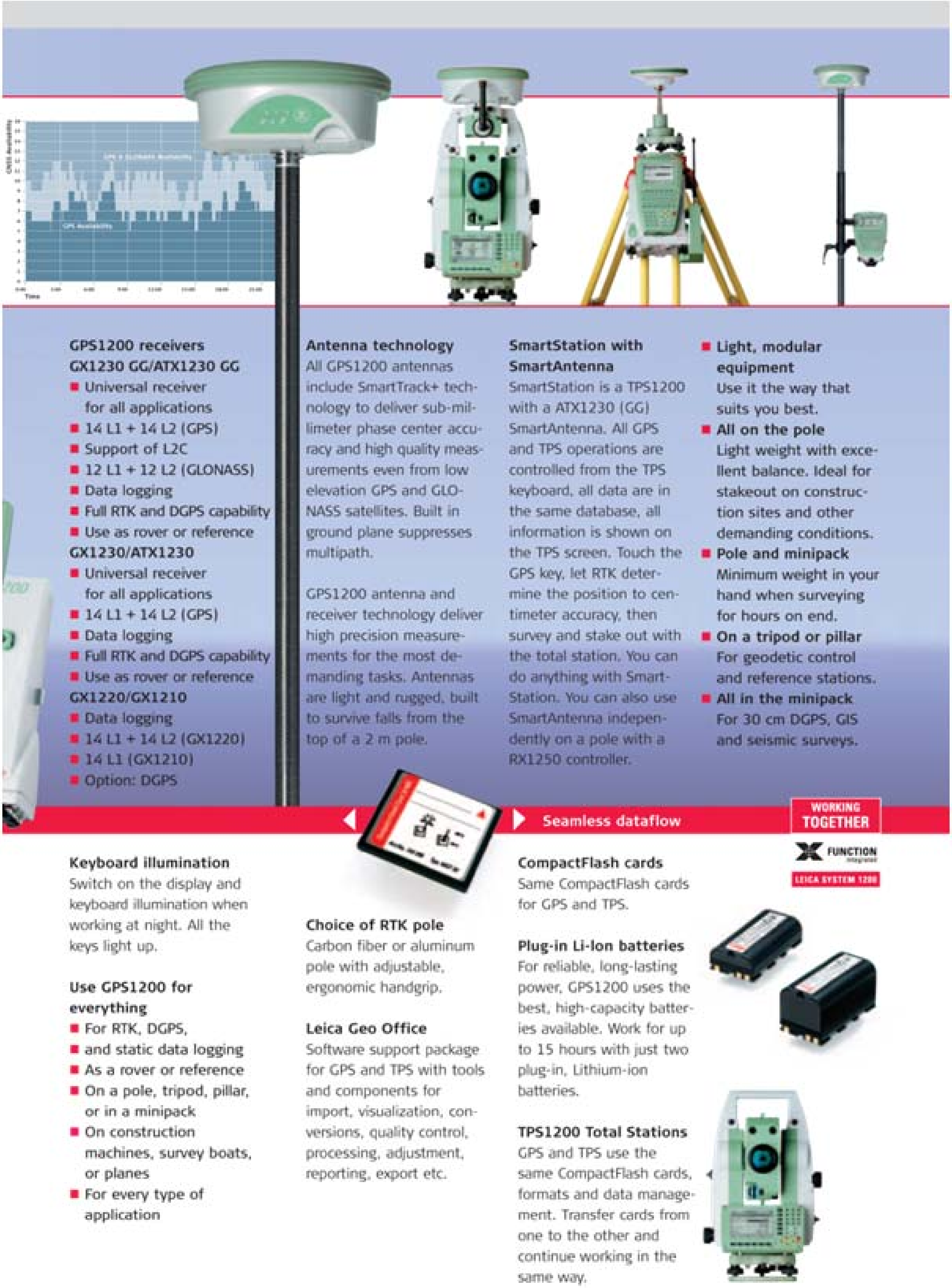
High contrast touch screen
The high quality 1/4 VGA (11 lines by 32 characters) with optional colour option (RX1250) touch screen guarantees perfect clarity and contrast. Whether in fading light or bright sunshine, you can always read the display perfectly. Operate using the touch screen or the QWERTY keyboard, which-ever you prefer.

With or without controller
Connect the controller to the receiver when you need to input information and make full use of the on-board functions and programs.

RTK/DGPS communication
Radio modems, GSM, GPRS and CDMA modules fit in waterproof housings attached to the receiver. Attach either one or two devices for RTK/DGPS reference and rover applications.

With *Bluetooth*® Wireless-Technology built in to the RX1250 controller complete cable free operation and connectivity to compatible wireless products is available.

Figure 2: Leica GPS1200 product brochure



GPS1200 receivers
GX1230 GG/ATX1230 GG
- Universal receiver for all applications
- 14 L1 + 14 L2 (GPS)
- Support of L2C
- 12 L1 + 12 L2 (GLONASS)
- Data logging
- Full RTK and DGPS capability
- Use as rover or reference

GX1230/ATX1230
- Universal receiver for all applications
- 14 L1 + 14 L2 (GPS)
- Data logging
- Full RTK and DGPS capability
- Use as rover or reference

GX1220/GX1210
- Data logging
- 14 L1 + 14 L2 (GX1220)
- 14 L1 (GX1210)
- Option: DGPS

Antenna technology
All GPS1200 antennas include SmartTrack+ technology to deliver sub-millimeter phase center accuracy and high quality measurements even from low elevation GPS and GLONASS satellites. Built in ground plane suppresses multipath.

GPS1200 antenna and receiver technology deliver high precision measurements for the most demanding tasks. Antennas are light and rugged, built to survive falls from the top of a 2 m pole.

SmartStation with SmartAntenna
SmartStation is a TPS1200 with a ATX1230 (GG) SmartAntenna. All GPS and TPS operations are controlled from the TPS keyboard, all data are in the same database, all information is shown on the TPS screen. Touch the GPS key, let RTK determine the position to centimeter accuracy, then survey and stake out with the total station. You can do anything with SmartStation. You can also use SmartAntenna independently on a pole with a RX1250 controller.

- **Light, modular equipment**
  Use it the way that suits you best.
- **All on the pole**
  Light weight with excellent balance. Ideal for stakeout on construction sites and other demanding conditions.
- **Pole and minipack**
  Minimum weight in your hand when surveying for hours on end.
- **On a tripod or pillar**
  For geodetic control and reference stations.
- **All in the minipack**
  For 30 cm DGPS, GIS and seismic surveys.

Seamless dataflow

WORKING TOGETHER
X FUNCTION
LEICA SYSTEM 1200

Keyboard illumination
Switch on the display and keyboard illumination when working at night. All the keys light up.

Use GPS1200 for everything
- For RTK, DGPS,
- and static data logging
- As a rover or reference
- On a pole, tripod, pillar, or in a minipack
- On construction machines, survey boats, or planes
- For every type of application

Choice of RTK pole
Carbon fiber or aluminum pole with adjustable, ergonomic handgrip.

Leica Geo Office
Software support package for GPS and TPS with tools and components for import, visualization, conversions, quality control, processing, adjustment, reporting, export etc.

CompactFlash cards
Same CompactFlash cards for GPS and TPS.

Plug-in Li-Ion batteries
For reliable, long-lasting power, GPS1200 uses the best, high-capacity batteries available. Work for up to 15 hours with just two plug-in, Lithium-ion batteries.

TPS1200 Total Stations
GPS and TPS use the same CompactFlash cards, formats and data management. Transfer cards from one to the other and continue working in the same way.

Figure 3: Leica GPS1200 product brochure

Leica GPS1200
Technical specifications and system features

GPS1200 receivers	GX1230 receiver	GX1220 receiver	GX1210 receiver	ATX1230 SmartAntenna / RX1250
GPS technology	SmartTrack	SmartTrack	SmartTrack	SmartTrack
Type	Dual frequency	Dual frequency	Single frequency	Dual frequency
Channels	12 L1 + 12 L2 / WAAS / EGNOS	12 L1 + 12 L2 / WAAS / EGNOS	12 L1 / WAAS / EGNOS	12 L1 + 12 L2 / WAAS / EGNOS
RTK	Yes, SmartCheck	No	No	Yes, SmartCheck
DGPS + WAAS / EGNOS	Yes	Optional	Optional	Yes
Status indicators	3 LED indicators: for power, tracking, memory.			
Ports	1 power port, 3 serial ports, 1 controller port, 1 antenna port.			1 power/controller port, Bluetooth port
Supply voltage,	Nominal 12 VDC.			
Consumption	5.2 W receiver + controller + antenna			ATX1230: 2.4 W, RX1250 1.1 W
Event input and PPS	Optional:	Optional:	Optional:	
	1 PPS output port	1 PPS output port	1 PPS output port	
	2 event input ports	2 event input ports	2 event input ports	
Standard antenna	SmartTrack AX1202	SmartTrack AX1202	SmartTrack AX1201	SmartTrack ATX1230
Built in groundplane	Built in groundplane	Built in groundplane	Built in goundplane	Built in goundplane

The following apply to all receivers except where stated.

Power supply	Two Li-Ion 3.8Ah/7.2V plug into receiver. One Li-Ion 1.9Ah/7.2V plugs into ATX1230 and RX1250.
Plug-in Li-Ion batteries Same for GPS and TPS	Power receiver + controller + SmartTrack antenna for about 15 hours (for data logging).
	Power receiver + controller + SmartTrack antenna + low power radio modem or phone for about 10 hours (for RTK/DGPS).
	Power SmartAntenna + RX1250 controller for about 5 hours (for RTK/DGPS)
External power	External power input 10.5 V to 28 V.
Weights	Receiver 1.20 kg. Controller 0.48 kg (RX1210) and 0.75 kg (RX1250). SmartTrack antenna 0.44 kg. SmartAntenna 1.12 kg. Plug-in Li-Ion battery 0.09 kg (1.9Ah) and 0.19 kg (1.9Ah).
	Carbon fiber pole with SmartTrack antenna and RX1210 controller: 1.80 kg.
	All on pole: carbon fiber pole with SmartAntenna, RX1250 controller and plug-in batteries: 2.84 kg.

Temperature	Operation:	Receiver	−40°C to +65°C
ISO9022	Antennas		−40°C to +70°C
MIL-STD-810F	Controllers		−30°C to +65°C
	Storage:	Receiver	−40°C to +80°C
	Antennas		−55°C to +85°C
	Controllers		−40°C to +80°C
Humidity ISO9022, MIL-STD-810F	Receiver, antennas and controllers Up to 100% humidity.		
Protection against water, dust and sand IP67, MIL-STD-810F	Receiver, antennas and controllers: Waterpoof to 1m temporary submersion. Dust tight		
Shock/drop onto hard surface	Receiver: withstands 1m drop onto hard surface. Antennas: withstand 1.5m drop onto hard surface.		
Topple over on pole	Receiver, antennas and controllers: withstand fall if pole topples over.		
Vibrations ISO9022 MIL-STD-810F	Receiver, antennas and controllers: withstand vibrations on large construction machines. No loss of lock.		

Figure 4: Leica GPS1200 technical specifications

SPECIFICATIONS

Sensor Type
Fused Quartz using electrostatic nulling

Reading Resolution
1 microGal

Standard Field Repeatability
< 5 microGal

Operating Range
8,000 mGal without resetting

Residual Long-Term Drift (static)
Less than 0.02 mGal/day

Range of Automatic Tilt Compensation
± 200 arc sec

Tares
Typically less than 5 microGals for shocks up to 20 G.

Automated Corrections
Tide, Instrument Tilt, Temperature, Noisy Sample, Seismic Noise Filter.

Dimensions
31 cm (H) x 22 cm x 21 cm
12 in (H) x 8.5 in x 8 in

Weight (including batteries)
8 kg, (17.5 lbs.)

Battery Capacity
2 x 6Ah (10.8V) rechargeable Litium-Ion Smart Batteries. Full day operation in normal survey conditions with two fully charged batteries.

Power Consumption
4.5 Watts at 25°C

Standard Operating Temperature Range
-40°C to +45°C

Ambient Temperature Coefficient
0.2 microGal/°C (typical)

Pressure Coefficient
0.15 microGal/kPa (typical)

Magnetic Field Coefficient
1 microGal/Gauss (typical)

Memory
Flash Technology (data security)
Standard 12 MBytes

Digital Data Output
RS-232 C and USB interface
Is optimized for Win XP™

Analog Data Output
Strip-Chart Recorder

Display Screen
¼ VGA 320 x 240 pixels

Keypad
27 key alpha/numeric

Standard System
- CG-5 Console
- Tripod base
- 2 rechargeable batteries
- Battery Charger, 110/240 V
- External Power 110/240 V
- RS-232 and USB Cables
- Carrying Bag
- Data dump and utilities software
- Operating Manual (CD)
- Transit Case

GPS
Enables GPS station referencing from an external 12 channel smart GPS antenna being connected via the RS-232 port. Standard GPS accuracy: <15m DGPS (WAAS) < 3m. Client has the option to use other higher accuracy GPS receivers outputting NMEA data string through the serial port.

OPTIONS

High Temperature Option
For use in climates that may exceed the normal operating temperate of 45°C. Allows operating temperatures of up to 55°C. This option is intended to be used in climates above freezing and needs to be ordered at the time of purchase.

Battery Belt
Suggested for cold weather operation.

COMPLETE GRAVITY SOLUTIONS

Special Applications
Please contact LRS Scintrex or your local representative.

Training Programs
LRS Scintrex can provide training programs at our office in Canada or at your location.

Application Software
LRS Scintrex can provide software packages to support your data processing, interpretation and mapping needs.

An ISO 9001:2000 registered company

* All specifications are subject to change without notice.

SCINTREX
A DIVISION OF LRS

CANADA
Scintrex
222 Snidercroft Road
Concord, Ontario, Canada L4K 2K1
Telephone: +1 905 669 2280
Fax: +1 905 669 6403
e-mail: scintrex@scintrexltd.com
Website: www.scintrexltd.com

MICRO g LACOSTE
A DIVISION OF LRS

USA
Micro-g LaCoste
1401 Horizon Avenue
Lafayette, CO 80026
Telephone: +1 303 828 3499
Fax: +1 303 828 3288
e-mail: info@microglacoste.com
website: www.microglacoste.com

Figure 5: Scintrex CG-5 specifications

5.0 Vehicle and Helicopter Transportation

5.1 Helicopters

Two, Robinson R44 Raven I helicopters (call signs VH-WMA and VH-APM) were supplied to the project (Photo 1). One machine was used for survey and the other on standby in case of emergency or breakdown. The helicopters were serviced in accordance with CASA specifications with 100 hourly services carried out in Tennant Creek.

The helicopters were equipped with an EPIRB device, comprehensive first aid and survival kits. Communications were via VHF radio and Iridium satellite phone. Helicopter movements were tracked using a satellite tracking system.

Aviation fuel and oils were supplied ex Alice Springs and ex Tennant Creek.

5.2 Support Vehicles

Facilitating refuelling operations were two 4WD Toyota Landcruiser utilities and an Isuzu FTS750 truck. A Toyota 4WD Landcruiser utility was used for crew and pilot transport, helicopter refuels and crew changeovers. The vehicles were fitted with the following equipment:

- Iridium satellite phone
- Garmin navigation grade GPS receiver with moving map display
- Spare navigation grade GPS receiver with batteries
- First aid and survival kit
- Two spare tyres
- Recovery equipment for tyre repair
- Recovery equipment including winch for bogging, stranding.
- Comprehensive tool-kit
- 10L of drinking water
- Satellite tracking device

All vehicles used on the project were supplied, serviced and maintained by Atlas Geophysics. The field crew carried out daily pre-start checks on all vehicles and these have been documented in Atlas Geophysics pre-start log books.

Photo 1: Helicopter VH-YMA surveying near some (rare) outcrop

6.0 Camping / Accommodation

The crew were accommodated and messed at Lajamanu Community and Rover Explorer 108 camp using Atlas mobile exploration camps.

7.0 Communications, Internet and Scheduled Calls

The primary method of communication for the field crews was via Iridium satellite phones. The helicopter crew made scheduled calls to the field operations base at hourly intervals. In addition to scheduled calls, the position of the helicopter was reported to the operations base at 10 minute intervals using Omnitrack satellite tracking technology.

Internet connections for client contact and data server access were established using a Telstra Turbo Gateway NextG internet modem and a Broadband Global Area Network (BGAN) satellite internet network system for remote locations.

8.0 Survey Methodology

All gravity data were acquired using Atlas Geophysics Pty Ltd helicopter-borne techniques. These techniques, which involve concurrent GPS and gravity acquisition, allow for rapid acquisition of very high quality data.

8.1 Gravity and GPS Control Establishment

Two primary GPS and gravity control stations were established, each near to the logistical base (Table 2).

At each primary control station a permanent monument was erected to mark and witness the station. The monument consisted of a 40cm star picket driven into the ground with about 10cm protruding alongside a small square concrete slab set level in concrete. The star picket marked the position of the GPS control station and the concrete slab marked the position of the gravity control station. A steel star picket of 1.5m length was placed within 0.5m of each control point and carried an Atlas Geophysics Pty Ltd witness plaque numbered with a unique station number (Figure 6).

Control Station ID	Lat / Long / Ht (GDA94, GRS80)	Observed Gravity (AAGD07 $\mu m/s^2$)
201303600001 (GA 20138000001) *Lajamanu A/S*	-18 19 59.5696 130 38 03.8980 344.321	9784601.97
201303600002 (GA 20138000002) *Explorer 108*	-19 53 08.1178 133 17 29.3805 299.440	9785408.39

Table 2: Gravity and GPS control stations used to control the survey

The details of all primary control stations have been recorded on Atlas Geophysics Pty Ltd control station summary sheets. The sheets include the geodetic coordinates, observed gravity value, station description, locality sketch, locality map and a digital photo of the station. The sheets are contained in Appendix B.

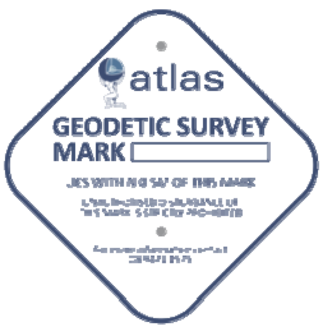


Figure 6: Atlas Geophysics Pty Ltd survey witness plaque

8.1.1 GPS Control

Primary GPS control was established for all control stations and this allowed all position and height information obtained from the gravity survey to be tied to the Geocentric Datum of Australia (GDA94), the Geodetic Reference System 1980 (GRS80) and Australian Height Datum (AHD).

Secondary GPS control was used to restrict kinematic baseline length. 10 separate remote, control stations were established in the field and all were marked with a 40cm steel rod driven into the ground with about 1cm protruding (not identified). In the field, whilst the survey was underway, temporary coordinates for these stations were established using static base-line processing to the primary control station over a minimum ten hour period.

Upon final processing, coordinates for all primary and secondary control stations were obtained using the 5 second static GPS data logged at each station whilst the gravity survey was underway. The static data has been submitted to Geoscience Australia's AUSPOS processing system to produce first-order geodetic coordinates accurate to better than 10mm for the x, y and z observables. Multiple days of static GPS data have been submitted to ensure accuracy and reliability of the solution.

Initial surveying was conducted using adopted control station coordinates since the AUSPOS system requires approximately two weeks before a Final Ephemeris Solution can be delivered. The adopted coordinates were derived from an autonomous GPS measurement at the primary control station giving an accuracy of better than 0.5m for x, y coordinates and better than 15m for the z coordinate. Once the final ephemeris solution for the control station coordinates was delivered by AUSPOS, all control and field GPS measurements had the necessary DC shift applied to give accurate, absolute positions for east, north and elevation. A listing of final coordinates for all control stations are contained in Appendix C.

8.1.2 Gravity Control

Primary gravity control was established at the same location as the primary GPS control stations. Once tied to the Australian Fundamental Gravity Network (AFGN), the gravity control stations allowed all field gravity observations to be tied to the Australian Absolute Gravity Datum 2007 (AAGD07).

An accurate observed or absolute gravity value for the control stations was established via "ABABA" ties with the project gravity meters to nearby AFGN stations. Table 3 summarises the control ties conducted and Appendix D contains the control tie data. Expected accuracy of the tie surveys would be better than 0.1 $\mu m/s^2$ (or 0.01 mGal).

Control Station ID	AFGN station tied to	Date of ties
201303600001 (GA 20138000001) *Lajamanu A/S*	1999929064 Tanami Airstrip Terminal	26/07/2013 27/07/2013
201303600002 (GA 20138000002) *Explorer 108*	1967930134 Tennant Creek Airstrip Terminal	02/08/2013 14/08/2013 16/08/2013

Table 3: Primary gravity and GPS control stations used to control the survey

8.2 GPS Data Acquisition, Processing and Quality Analysis

GPS-Glonass data were collected in static mode at each of the control stations and in kinematic mode with the helicopter using geodetic grade Leica GPS1200 receivers. Rigorous post-processing of the recorded kinematic data allowed for excellent GPS-Glonass ambiguity resolution and 3-D solution coordinate qualities better than 5cm for each of the gravity station locations. Atlas Geophysics QA procedures have ensured the final GPS-Glonass data have met and exceeded contract specifications.

8.2.1 GPS-Glonass Acquisition

Each GSL was positioned using navigation grade Garmin receivers fitted to custom mounts inside the cockpit of the helicopter. Accuracy of the positioning system was better than 5m and where practicable, the helicopter crew landed as close to the programmed station location as possible. Where it was too dangerous to land, stations were moved from the programmed coordinate.

For the kinematic helicopter operations, the GPS-Glonass sensors were mounted on a fixed aluminium bracket at the front of the aircraft (primary) and on the tail boom of the aircraft (secondary backup, with phase data logged by the receivers inside the cockpit. Data were logged at five second epochs onto Compact Flashcards (CF) for later downloading and processing. Static data were also concurrently logged at the primary and secondary GPS control stations to allow for later kinematic processing.

8.2.2 GPS-Glonass Processing

The acquired raw GPS-Glonass data were processed nightly using Novatel Waypoint Grafnav v8.40 post-processing software (Figure 7). GrafNav is a fully-featured kinematic and static GPS/Glonass post-processing package that uses Waypoint's robust GPS/Glonass processing carrier phase kinematic (CPK) filter engine. The software is capable of processing raw kinematic GPS/Glonass data from most GPS/GNSS receivers and allows the user to process the roving data from as many as eight separate control stations to achieve accuracies at the centimetre level. The software can automatically switch from static to kinematic processing and has a fixed static solution for static initialisation of short or medium baselines that are below 30km. Kinematic Ambiguity Resolution (KAR) allows the session to start in kinematic mode and can help fix otherwise unrecoverable cycle slips. Ionospheric processing and modelling is also included with the software and can help improve accuracy, especially over long baselines. Advantages of the Waypoint processing engine over other packages include:

Fast Processing – The Grafnav engine is one of the fastest on the market. For a single base station, a 2.40 Mhz PIII CPU can expect to process GPS data at 670 epochs/second. This means that a 4-hour 2 Hz data set will process one direction in 22 seconds. For two bases, processing takes 250 epochs/second or about 1 minute for the same 4-hour data set. For 4 bases, these times are 50 epochs/second or about 5 minutes.

Reliable OTF Processing – Waypoint's on-the-fly KAR algorithm has had years of development and testing. Various implementations and numerous options are available to control this powerful feature.

Multi-Base (MB) processing – With Version 8.40, GrafNav now supports true multiple control station processing where all of the baselines are incorporated into one sophisticated Kalman filter. This can spatially de-correlate some of the error sources while also allowing integer ambiguity determination using the closest base station. Satellite drop-outs at one base will also be compensated by the others. The two biggest advantages are improved overall accuracies and much less operator effort required to process and QC such data.

Accurate Static Processing – Three modes of static processing are implemented in the main processing kernel.

Dual Frequency Support – Full dual frequency GPS processing comes with the software. For ambiguity resolution, this entails wide/narrow lane solutions for KAR, fixed static and quick static. 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 initialisation 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. GrafNav also has the ability to combine these two solutions to obtain a globally optimum one.

GPS + GLONASS – The GrafNav kernel has the ability to also process GPS+GLONASS data. This is especially advantageous for applications in forested areas, where the additional satellite coverage can improve accuracies.

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.

High Dynamics – The GrafNav kernel can handle extremely high dynamics from missiles, rockets, dropped ordinances, and fast flying aircraft.

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

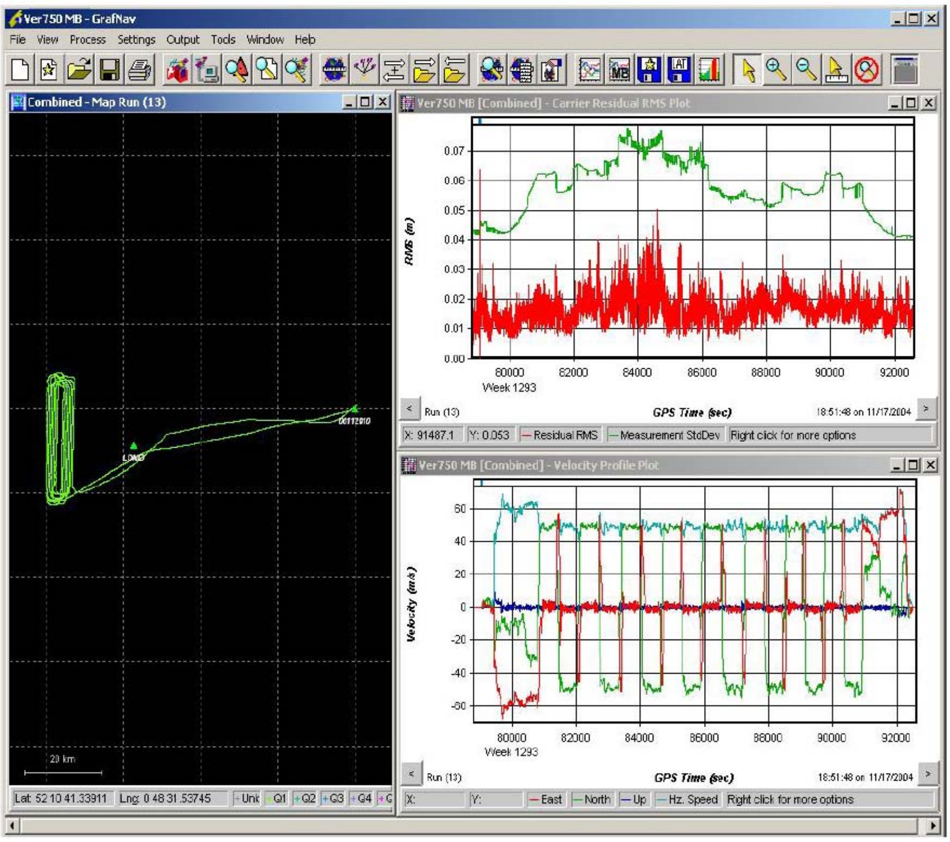


Figure 7: Waypoint Grafnav Processing Software

Once each epoch was processed to give a solution for the WGS84 position and elevation at ground level (i.e. corrected for sensor height), conversion between GPS-Glonass derived WGS84/GDA94 coordinates to Map Grid of Australia (MGA) coordinates was conducted within Waypoint. For most practical applications, where a horizontal accuracy of only a metre or greater is required, GDA94 coordinates can be considered the same as WGS84. MGA94 coordinates were obtained by projecting the GPS-derived WGS84 coordinates using a Universal Transverse Mercator (UTM) projection with zone (52 base) 53S (survey). For more information about WGS84, GDA94 and MGA94 coordinates, the reader is asked to visit the Geoscience Australia website http://www.ga.gov.au/earth-monitoring/geodesy/

Elevations above the Australian Height Datum (AHD) were modelled using Waypoint 8.40 software and 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/. To obtain AHD elevation, the modelled N value is subtracted from the GPS derived WGS84/GRS80 ellipsoidal height (Figure 8).

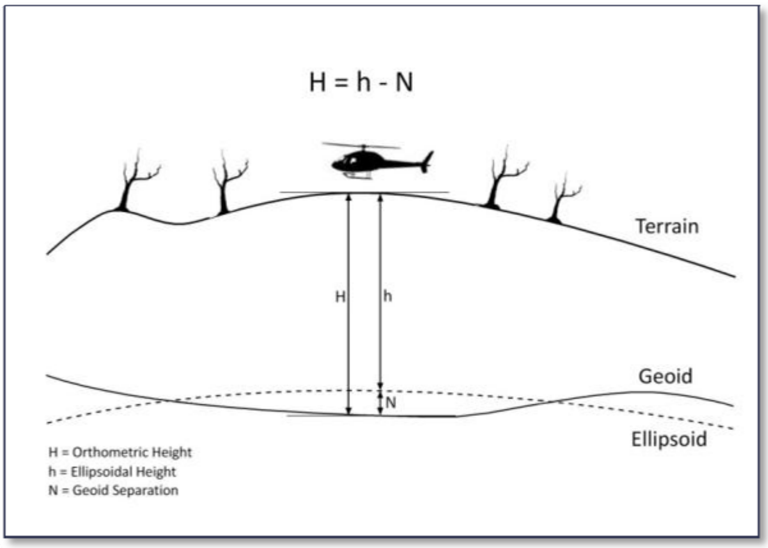


Figure 8: Geoid-Ellipsoid Separation

8.2.3 GPS/Glonass Quality Analysis

Rigorous quality analysis procedures were applied to the acquired GPS-Glonass data on a daily basis using Waypoint Grafnav's built in QA tools. Some of the tools used on this project include:

Combined Separation Plot: This plot shows the difference between the forward and reverse solutions (Figure 9). A perfect solution would have a separation of zero as this indicated the carrier phase ambiguities have been determined to be exactly the same value in both directions. A separation of better than 0.1m on a helicopter survey would indicate that the data is of high quality.

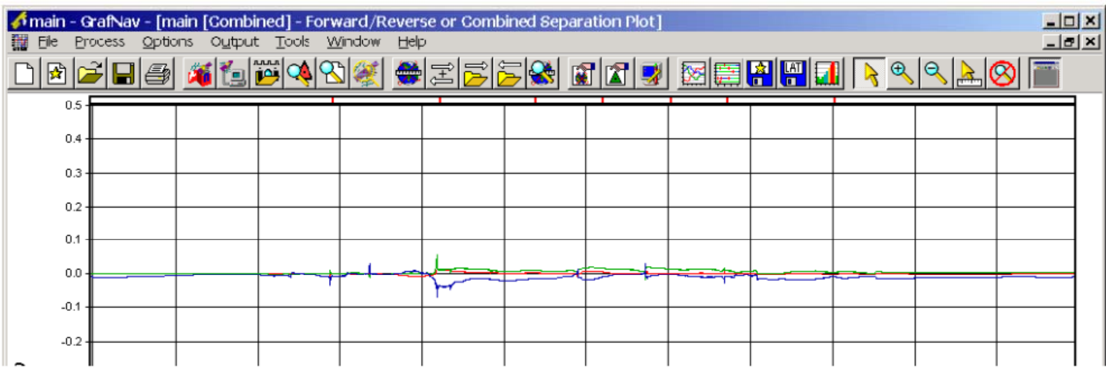


Figure 9: Combined Separation Plot

Float or Fixed Ambiguity Status Plot: This plot shows if the final solution is float or fixed (Figure 10). Fixed integer ambiguities generally have better accuracies (usually < 10cm accuracy). Ideally the plot should show fixed as this indicated an integer ambiguity fix on both forward and reverse directions.

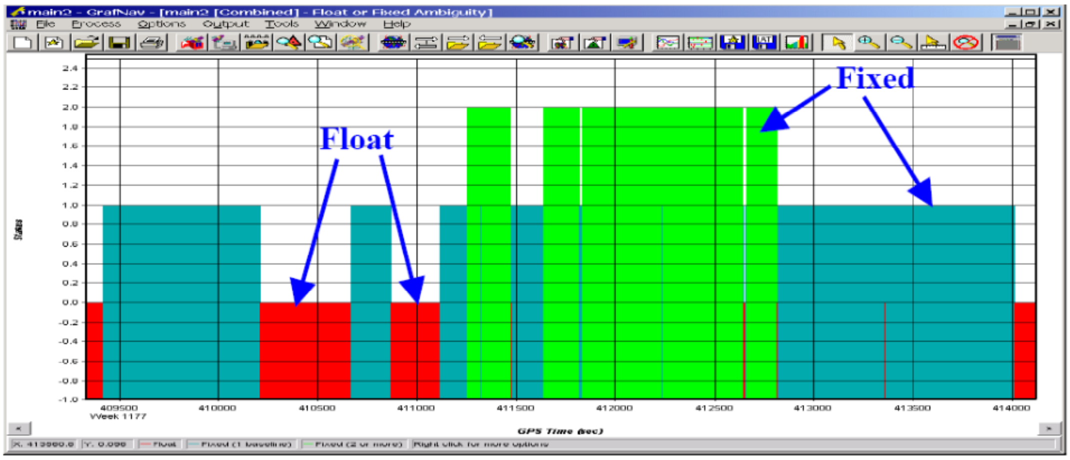


Figure 10: Float or Fixed Ambiguity Status Plot

Quality Factor Plot: This plot shows the quality of the final solution (Figure 11). There are five different quality factors plotted and these factors are also output in the Atlas Geophysics Pty Ltd GPS data file.

Quality 1 – Fixed Integer (Green)
Quality 2 – Stable Float (Aqua)
Quality 3 – Converging Float (Blue)
Quality 4 – DGPS or worse (Red)
Quality 5 – Single Point (Yellow)

Increasing quality factors indicate a worse solution. This is not a perfect indication, but it can be useful to isolate problems.

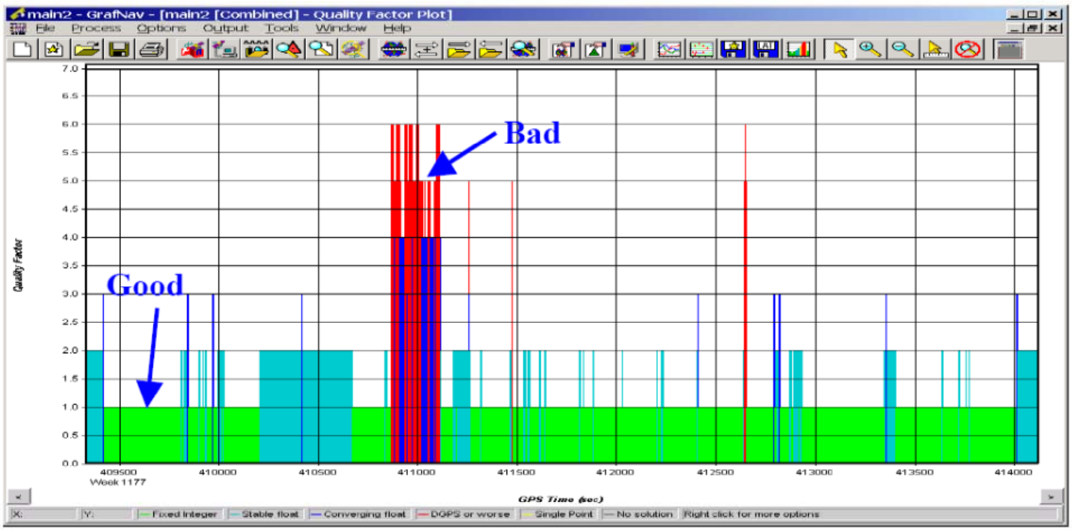


Figure 11: Quality factor plot

Complementing Waypoint GrafNav QA tools is the company's own in-house GPS quality analysis software. A module built into AGRIS (Atlas Geophysics Reduction and Information Software) allows the user to import the Waypoint output files and examine quality factors such as station repeatability between multiple control stations, coordinate velocity, dilution of precision, coordinate quality factor and standard error for each gravity station location. The procedure is carried out before merging the positional data with gravity data for final reduction to Bouguer Anomaly. Comprehensive statistics, repeatability analysis and histogram plotting are also performed.

QA procedures were applied to the GPS-Glonass data on a daily basis and any gravity stations not conforming to contract specifications were repeated by the company at no cost to the client.

8.3 Gravity Data Acquisition, Processing and Quality Analysis

Gravity data were gained using the company's rapid acquisition, high accuracy helicopter-borne techniques. The company's own in-house reduction and QA software was used to reduce the data on a daily basis to ensure quality and integrity. Final delivered data met and exceeded contract specifications.

8.3.1 Calibration of the Gravity Meter

The gravity meters used for survey on this project were calibrated pre and post survey on the Guildford Cemetery – Helena Valley Primary School calibration range (2010990117-2010990217) in Western Australia. The calibration process has validated the gravity meter's scale factor to ensure reduction of the survey data produces correct Observed Gravities from measured dial reading values. Table 4 summarises the results of the calibration ties and lists the resultant scale factor for the survey gravity meter. Appendix E contains the reduced data used to create the summary.

PRE SURVEY CALIBRATION RUN 13/06/14				
Meter Code	Meter SN	Calc 2010990217 AAGD07 ($\mu m/s^2$)	Diff ($\mu m/s^2$)	Scale
A1	40240	Not available		
A2	40241	9794483.84	0.01	0.999283

POST SURVEY CALIBRATION RUN 13/08/2012				
Meter Code	Meter SN	Calc 2010990217 AAGD07 ($\mu m/s^2$)	Diff ($\mu m/s^2$)	Scale
A1	40240	9794483.91	0.06	1.000000
A2	40241	9794483.92	0.07	0.999283

Table 4: Gravity meter scale factors

Weekly tilt-tests and cycles were conducted to ensure the meter's drift and tilt correction factors were valid. Gravity meter drift rates were monitored on a day to day basis using AGRIS software.

8.3.2 Acquisition of the Gravity Data

Gravity data were acquired concurrently with GPS-Glonass data using the Scintrex CG5 gravity meters. Data were acquired in a single shift of ten hours duration, with each shift consisting of a single loop controlled by observations at the gravity control stations. Each loop contained a minimum of two repeated readings so that an interlocking network of closed loops was formed. A total of **9.88%** repeats were acquired for quality control purposes. Repeat readings were evenly distributed on a time-basis throughout each of the gravity loops.

The gravity acquisition crew consisted of a single gravity operator and pilot. The pilot was responsible for safely navigating to each station, and once at the station, the operator disembarked from the helicopter and acquired the gravity data. The observation point was always situated in front of the aircraft, in the pilot's view. Under no circumstances were readings taken outside of the pilot's view as this can jeopardise the safety of the operator. As the helicopter always landed on flat ground, the error due to the gravity observation not being coincident with the GPS-Glonass observation is minimal. A small latitude based error of less than 0.05 $\mu m/s^2$ would apply, but this is not seen to be appreciable on a regional gravity survey, so is not corrected for.

At each station, the gravity operator took a minimum of two gravity readings of 15 second duration so that any seismic or wind noise could be detected. Control station readings were set to 60 second duration. Before taking the reading, the operator ensured that the instrument tilt-reading was restricted to less than 5 arc-seconds and after the reading, not higher than 20 arc-seconds. Tilt-testing prior to project commencement showed that the gravity meters performed well even at extreme tilts (better than 0.05 $\mu m/s^2$ at +150/-150 arc-seconds).

If two separate readings did not agree to better than 0.20 $\mu m/s^2$ (0.10 $\mu m/s^2$ for control station readings), then the operator continued taking readings until the tolerance between consecutive readings was achieved. At the conclusion of the gravity reading, the final data display on the gravity meter was analysed to ensure the instrument was performing to specification and that the station observation provided data conforming to the project specifications. The operator also checked that the temperature, standard deviation and rejection values were within required tolerance before recording the reading. At each station, the operator recorded the gravity data digitally in the gravity meter as well as in an Atlas Geophysics Pty Ltd field book so that instrument drift and reading repeatability could be analysed easily whilst in the field. Data recorded at each GSL was assigned a unique station code and station number.

Repeat stations were marked with a biodegradable flagging tape for subsequent reoccupation. When reoccupying stations, the pilot positioned the helicopter as close to the original landing spot as possible (usually better than 0.5m). A very small percentage of the repeat stations were positioned greater than 0.5m from the original location due to soft ground and/or windy conditions, but always on flat ground at the same level as the original observation. All repeat gravity observations were taken in exactly the same location, even if the helicopter landed slightly offset from the original position.

8.3.3 Processing of the Gravity Data

The acquired gravity data were processed using the company's in-house gravity pre-processing and reduction software, AGRIS. This software allows for full data pre-processing, reduction to Bouguer Anomaly, repeatability and statistical analysis, as well as full quality analysis of the output dataset.

The software is capable of downloading Scintrex CG3/CG5 and Lacoste Romberg gravity data. Once downloaded, the gravity data is analysed for consistency and preliminary QA is performed on the data to check that observations meet specification for standard deviation, reading rejection, temperature and tilt values. Once the data is verified, the software averages the multiple readings and performs a merge with the GPS data (which it has also previously verified) and performs a linear drift correction and earth tide correction. Calculation of Free Air and Bouguer Anomalies is then performed using the contract specified formulae.

The following corrections were applied to the dataset to produce Bouguer Anomaly values for each of the gravity stations. All formulae produce values in µm/s^2.

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

$$r_c = 10 \cdot (r \cdot S(r))$$

where,

r_c corrected reading in µm/s^2

r gravity meter reading in dial units

$S(r)$ scale factor (dial units/mGal)

Earth Tide Correction: The earth is subject to variations in gravity due to the gravitational attraction of the Sun and the Moon. These background variations can be corrected for using a predictive formula which utilises the gravity observation position and time of observation. The Scintrex CG5 gravity meter automatically calculates ETC but uses only an approximate position for the gravity observation so is not entirely accurate. For this reason, the Scintrex ETC is subtracted from the reading and a new correction calculated within AGRIS software. The full formula is listed in Appendix G.

$$r_t = r_c + g_{tide}$$

where,

r_t tide corrected reading in µm/s^2

r_c scale factor corrected reading in µm/s^2

g_{tide} Earth Tide Correction (ETC) in µm/s^2

Instrument Drift Correction: Since all gravity meters are mechanical they are all prone to instrument drift. Drift can be caused by mechanical stresses and strains in the spring mechanism as the meter is moved, knocked, reset, subjected to temperature extremes, subjected to vibration, unclamped etc. The most common cause of instrument drift is due to extension of the sensor spring with changes in temperature (obeying Hooke's law). To calculate and correct for daily instrument drift, the difference between the gravity control station readings (closure error) is used to assume the drift and a linear correction is applied.

$$ID = \frac{r_{cs2} - r_{cs1}}{t_{cs2} - t_{cs1}}$$

where,
ID Instrument Drift in µm/s² /hour
r_{cs2} control station 2nd reading in µm/s²
r_{cs1} control station 1st reading in µm/s²
t_{cs2} control station 2 time
t_{cs1} control station 1 time

Observed Gravity: The preceding corrections are applied to the raw gravity reading to calculate the earth's absolute gravitational attraction at each gravity station. The corrections produced Observed Gravities on the AAGD07 datum.

$$G_o = g_{cs1} + (r_t - r_{cs1}) - (t - t_{cs1}) \cdot ID$$

where,
G_o Observed Gravity in µm/s²
g_{cs1} control station 1 known observed gravity in µm/s²
r_t tide corrected reading in µm/s²
r_{cs1} control station 1 reading in µm/s²
t reading time
t_{cs1} control station 1 time
ID instrument drift in µm/s²/hour

Normal Gravity: The normal (or theoretical) gravity value at each gravity station is calculated based on the assumption that the Earth is a homogeneous ellipsoid. The closed form of the 1980 International Gravity Formula is used to approximate the theoretical gravity at each station location and essentially produce a latitude correction. Gravity values vary with latitude as the earth is not a perfect sphere and the polar radius is much smaller than the equatorial radius. The effect of centrifugal acceleration is also different at the poles versus the equator.

$$G_n = 9780326.7715((1 + 0.001931851353(sin^2 l)/(SQRT(1 - 0.0066943800229(sin^2 l)))$$

where,
G_n Theoretical Gravity in gravity units
l GDA94 latitude at the gravity station in decimal degrees

Atmospheric Correction: The gravity effect of the atmosphere above the ellipsoid can be calculated with an atmospheric model and is subtracted from the normal gravity.

$$AC = 8.74 - 0.00099 \cdot h + 0.0000000356 \cdot h^2$$

where,
AC Atmospheric Correction in gravity units
h elevation above the GRS80 ellipsoid in metres

Free Air Correction: Since the gravity field varies inversely with the square of distance, it is necessary to correct for elevation changes from the reference ellipsoid (GRS80). Gravitational attraction decreases as the elevation above the reference ellipsoid increases.

$$FAC = -(3.087691 - 0.004398\, sin^2 l) \cdot h + 7.2125 \cdot 10^{-7} \cdot h^2$$

where,
FAC Free Air Correction in gravity units
l GDA94 latitude at the gravity station in decimal degrees
h elevation above the GRS80 ellipsoid in metres

Bouguer Correction: If a gravity observation is made above the reference ellipsoid, the effect of rock material between the observation and the ellipsoid must be taken into account. The mass of rock makes a positive contribution to the gravity value. The correction is calculated using the closed form equation for the gravity effect of a spherical cap of radius 166.7km, based on a spherical Earth with a mean radius of 6,371.0087714km, height relative the ellipsoid and a rock density of 2.67 t/m^3.

$$BC = 2\pi G\rho((1 + \mu) \cdot h - \lambda R)$$

where,
BC Bouguer Correction in gravity units
G gravitational constant = $6.67428 \cdot 10^{-11} m^3 kg^{-1} s^{-2}$
ρ rock density (2.67 t/m^3)
h elevation above the GRS80 ellipsoid in metres
R $(R_o + h)$ the radius of the earth at the station
R_o mean radius of the earth = 6,371.0087714 km (on the GRS80 ellipsoid)
μ & λ are dimensionless coefficients defined by:

$$\mu = ((1/3) \cdot \eta^2 - \eta) \cdot$$

where,
η h/R

$$\lambda = (1/3)\{(d + f\delta + \delta^2)[(f - \delta)^2 + k]^{\frac{1}{2}} + p + m \cdot ln(n/(f - \delta + [(f - \delta)^2 + k]^{\frac{1}{2}})\}$$

where,
d $3 \cdot cos^2\alpha - 2$
f $cos\alpha$
k $sin^2\alpha$
p $-6 \cdot cos^2\alpha \cdot \sin(\alpha/2) + 4 \cdot sin^3(\alpha/2)$
δ (R_o/R)
m $-3 \cdot k \cdot f$
n $2 \cdot [sin\,(\alpha/2) - sin^2(\alpha/2)]$
α S/R_o with S = Bullard B Surface radius = 166.735 km

Terrain Correction: The terrain correction accounts for variations in gravity values caused by variations in topography near the observation point. The correction accounts for the attraction of material above the assumed spherical cap and for the over-correction made by the Bouguer correction when in valleys. The terrain correction is positive regardless of whether the local topography consists of a mountain or a valley. Section 8.3.4 contains a more in-depth discussion of the terrain correction process.

Free Air Anomaly: The free air anomaly is the difference between the observed gravity and normal gravity that has been computed for latitude and corrected for the elevation of the gravity station above or below the reference ellipsoid:

$$FAA = G_o - (G_n - AC) - FAC$$

where,
FAA Free Air Anomaly in gravity units
G_o Observed Gravity in gravity units
G_n Normal Gravity in gravity units
AC Atmospheric Correction in gravity units
FAC Free Air Correction in gravity units

Bouguer Anomaly: The Bouguer anomaly is computed from the free air anomaly above by removing the attraction of the spherical cap calculated by the Bouguer correction.

$$BA = FAA - BC$$

where,
BA Bouguer Anomaly in gravity units
FAA Free Air Anomaly in gravity units
BC Bouguer Correction in gravity units

Complete Bouguer Anomaly: This is obtained by adding the terrain correction to the Bouguer anomaly. The Complete Bouguer Anomaly is the most interpretable value derived from a gravity survey as changes in the anomaly can be directly attributed to lateral density contrasts within the geology below the observation point.

$$CBA = BA + TC$$

where,
CBA Complete Bouguer Anomaly in gravity units
BA Bouguer Anomaly in gravity units
TC Terrain Correction in gravity units

8.3.4 Terrain Corrections

Terrain corrections, which account for the variation in gravity due to topography proximal to the gravity station, were computed using a digital elevation model (DEM) and RASTERTC software from Geopotential. RASTERTC software permits the user to input a DEM in the form of a binary grid file, and gravity data in an ASCII file. From this information, the software is capable of calculating extremely accurate terrain corrections. For more detailed information regarding the software and algorithm, the reader is asked to visit the Geopotential website http://geopotential.com/docs/RasterTC/RasterTC.html

Elevation data were sourced from the [1 second SRTM Level 2 Derived Smoothed Digital Elevation Model (DEM-S) Version 1.0] which has an equivalent cell size of 30m. Data were extracted to provide a 30km buffer from the extents of the gravity survey.

A comparison against GPS heights recorded during the gravity survey revealed that the DEM data were sufficiently accurate to be used in regional terrain corrections. The average difference between GPS height and DEM heights was -2.71 m and the standard deviation of the differences was 1.89 m.

When executing the terrain correction, the following inputs were used with RASTERTC:

R_{MIN} = 30 m
R_{MED} = 250 m
R_{MAX} = 30000 m
Angle = 6 degrees

RMIN was selected to enable correction for topography near to the gravity station and coincided with the grid cell size of the SRTM DEM. RMAX was selected to allow for outer zone correction of severe topography at large distances from the gravity station. RMED was chosen so that the DEM would be sampled at an interval close to the grid cell size of the DEM when using the 6 degree integration angle.

The terrain correction software provides indicators for terrain correction quality and accuracy as part of its output (included on the data DVD as Appendix J). The output variables QFINNER and QFOUTER specify the quality factor for each correction made. If these factors have a value of 0, then the user can assume that the terrain correction proceeded successfully. If non-zero values are reported, then the value of the QF factor will provide an indication as to possible problems or inadequacies in the correction.

For the inner zone correction, an indicator of how well the terrain in the immediate vicinity of a gravity station is represented by the available elevation samples is obtained by examining the spatial distribution of the elevation samples. In the radial interval Rmin to Rmed, RASTERTC counts the number of samples falling within the 8 octants surrounding the station. If any of these octants are missing elevation samples, that fact is noted, and the tabulated quality factor simply notes how many of octants are missing samples (see Table 6).

For the outer zone correction, a result of 0 means that the correction proceeded successfully. If a portion of the outer-zone terrain is missing from the DEM supplied, the value of QF-Outer will reflect the per cent of terrain that was available (rounded to the nearest per cent). For example, if QF-Outer is 91, the implication is that 9% of the terrain in the outer zones was missing for some reason, and that the terrain correction calculated for that particular station is too small by some amount.

QF-Inner	Explanation of Error Code
0	Inner-zone terrain calculation OK
1	No elevation samples occur in 1 octant surrounding the gravity station
2	No elevation samples occur in 2 octants surrounding the gravity station
3	No elevation samples occur in 3 octants surrounding the gravity station
4	No elevation samples occur in 4 octants surrounding the gravity station
5	No elevation samples occur in 5 octants surrounding the gravity station
6	No elevation samples occur in 6 octants surrounding the gravity station
7	No elevation samples occur in 7 octants surrounding the gravity station
22	Duplicate elevation nodes encountered while calculating terrain gradients
23	All elevation nodes collinear or triangulation structure corrupted

Table 6: Terrain Correction Error Codes

8.3.5 Quality Analysis of the Processed Gravity data

Following reduction of the data to Bouguer Anomaly, repeatability and QA procedures were applied to both the positional and gravity observations using AGRIS software. AGRIS checks the following as part of its QA processing:

- Easting Observation Repeatability and Histogram
- Northing Observation Repeatability and Histogram
- Elevation Observation Repeatability and Histogram
- Gravity Observation Repeatability and Histogram
- Gravity SD, Tilt XY, Temperature, Rejection, Reading Variance
- Gravity meter drift / closure
- Gravity meter loop time, drift per hour
- GPS Dilution of Precision, Coordinate Quality Factor, Standard Error
- Variation of surveyed station location from programmed location

QA procedures were applied to the gravity data on a daily basis and any gravity stations not conforming to contract specifications were repeated by the company at no cost to the client.

8.3.6 Additional Processing, Gridding and Plotting

Complementing the QA procedures is additional daily gridding, imaging and plotting of the elevation and gravity data. Once processed to Bouguer Anomaly and assessed for QA, data are imported into Geosoft Oasis Montaj or ChrisDBF software for gridding at 1/5th the station spacing to produce ERMapper compatible grid files. Resultant grids are contoured, filtered and interpreted using ERMapper and ArcMap software to check that data is smoothly varying and that no spurious anomalies are present. A first vertical, tilt angle and horizontal derivative filter are routinely applied to the data as these filters allow for excellent noise recognition. Once identified, any spurious stations can be field checked by the helicopter crew the following day and repeated if required. During the course of the survey one anomalous station was field checked and found to be valid.

Plotting of the acquired stations on a daily basis allowed for identification of any missed stations which were then gained the following day.

9.0 Results

Despite a lack of vehicular access and often long ferries out from camp (especially from Lajamanu), the survey was completed with relative ease. Both man and machine performed excellently and the survey was completed ahead of schedule. There was one instance of downtime due to helicopter maintenance issues which forced the crew to abandon the day's survey early.

A total of **3,857** new gravity stations were gained during the survey.

Final data have been delivered to a technically excellent standard and are presented both digitally and hardcopy as Appendices to this report.

9.1 Survey Timing and Production Rates

The survey crew began gravity data acquisition on Thursday 11th July 2013 with survey cessation on Sunday 18th August 2013. The only downtime experienced was due to logistical base moves, remote GPS base establishment or minor helicopter maintenance. From the 27th July 2013 to 31st July 2013 the crew moved base camp from Lajamanu Community to Rover Explorer 108 camp. This required the crew to collect the refuel truck on the south western edge of the grid, pack up the Lajamanu camp, travel to Tennant Creek to refuel and resupply, then continue on to set up base at Rover Explorer 108 camp.

Due to the lack of access and long ferry times, acquisition out of Lajamanu was slower than it was out of Explorer 108. In the west, the crew averaged around 90-120 stations per day. After moving east to Explorer 108, production increased to around 140-160 stations per data. The helicopter crew also encountered strong winds over the flat desert on numerous days which did slow production.

A full production report can be found on the data DVD (Appendix J).

9.2 Data Formats

Final point located data for the project have been delivered in ASEG-GDF2 compliant format. Appendix I contains a listing of the definition and description files accompanying the final data.

Raw GPS-GNSS and gravity data in their respective native formats have been included on the data DVD as Appendix J. Table 7 overleaf summarises the deliverables.

Final Delivered Data	Format	Data DVD	Hardcopy
Gravity Database	Point located data ASEG-GDF2	•	
Raw Positional Data	AGRIS format, comma delimited	•	
Raw Gravity Data	Scintrex CG5 format	•	
Raw GPS-GNSS Data	Waypoint GPB Binary	•	
Gravity Control Data	Microsoft Excel Format	•	•
Calibration Data	Microsoft Excel Format	•	•
Repeat Data	Microsoft Excel Format	•	•
Terrain Corrections	RASTERTC output file	•	
Final Grids	ERMapper Grids .ers	•	
Final Images	Arcmap compatible TIFF	•	•
Acquisition Report	PDF .pdf	•	•

Table 7: Final Deliverables

9.3 Data Repeatability: All Observations

The repeatability of both the gravity and GPS data was excellent. In total, **381** gravity and GPS repeat stations were collected and analysed. As a percentage, this equates to **9.88%** of the total number of new gravity stations acquired. Repeat stations were acquired so that an even distribution between gravity loops was established and that all loops were interlocked.

Descriptive statistics pertaining to the repeatability are contained in Table 8 and Appendix F contains a tabulation of the actual repeat data for the entire survey.

The standard deviation of the gravity repeat deviations was **0.37 µm/s^2** and the standard deviation of the GPS derived elevation repeat deviations was **0.055m**. These statistics confirm that the data has met and exceeded contract specifications.

	Elevation Repeat (mGRS80)	Gravity Repeat (µm/s^2)
Mean	-0.010	0.01
Standard Error	0.003	0.02
Median	-0.005	0.02
Mode	0.026	0.22
Standard Deviation	0.055	0.37
Sample Variance	0.003	0.14
Kurtosis	0.787	-0.33
Skewness	-0.323	-0.11
Range	0.357	1.85
Minimum	-0.197	-0.93
Maximum	0.160	0.92
Sum	-3.705	2.94
Count	381	381

Table 8: Repeat Statistics

9.3.1 Repeatability Histograms

Histograms showing the distribution of repeat differences for both the GPS and gravity observations are shown in Figures 12 and 13.

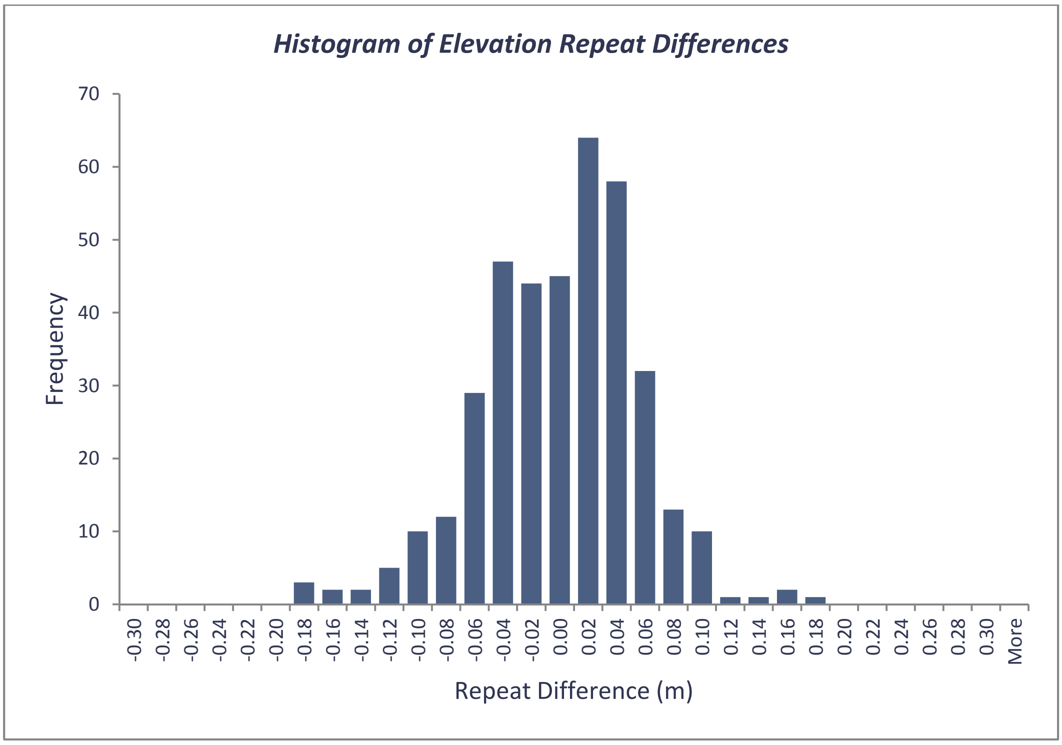


Figure 12: Histogram of GPS Repeat Differences

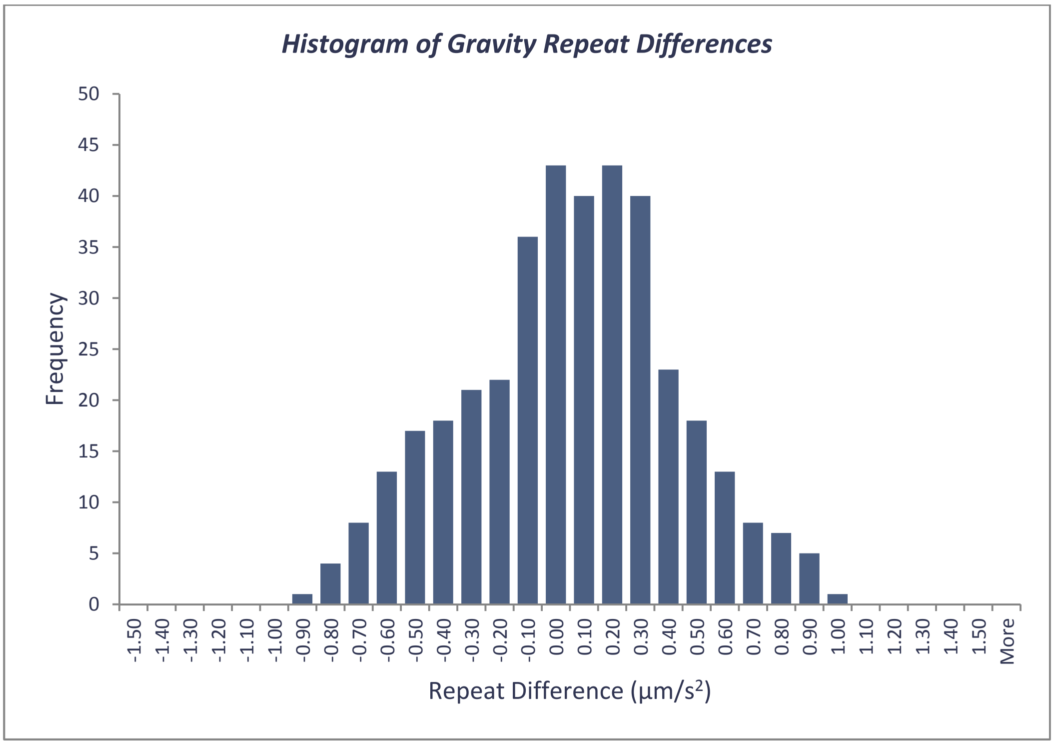


Figure 13: Histogram of Gravity Repeat Differences

9.4 Data Repeatability: Multiple Control Station Observations Only

The repeatability of gravity and GPS observations made with respect to multiple control stations was also analysed separately to the main database.

Descriptive statistics pertaining to the repeatability are contained in Table 9 and Appendix G contains a tabulation of the actual repeat data controlled from multiple control stations.

The standard deviation of the gravity repeat deviations was **0.55µm/s^2** and the standard deviation of the GPS derived elevation repeat deviations was **0.057m**. These statistics confirm that the data has met and exceeded contract specifications for data controlled from multiple control stations.

	Elevation Repeat (mGRS80)	Gravity Repeat (µm/s^2)
Mean	-0.021	-0.02
Standard Error	0.010	0.11
Median	-0.012	0.01
Mode	-0.037	-0.66
Standard Deviation	0.057	0.55
Sample Variance	0.003	0.30
Kurtosis	0.308	-1.35
Skewness	-0.404	0.16
Range	0.263	1.78
Minimum	-0.166	-0.86
Maximum	0.097	0.92
Sum	-0.748	-0.45
Count	35	23

Table 9: Repeat Statistics

9.4.1 Multiple Control Station Repeatability Histograms

Histograms showing the distribution of repeat differences for both the GPS and gravity observations from multiple control stations are shown in Figures 14 and 15.

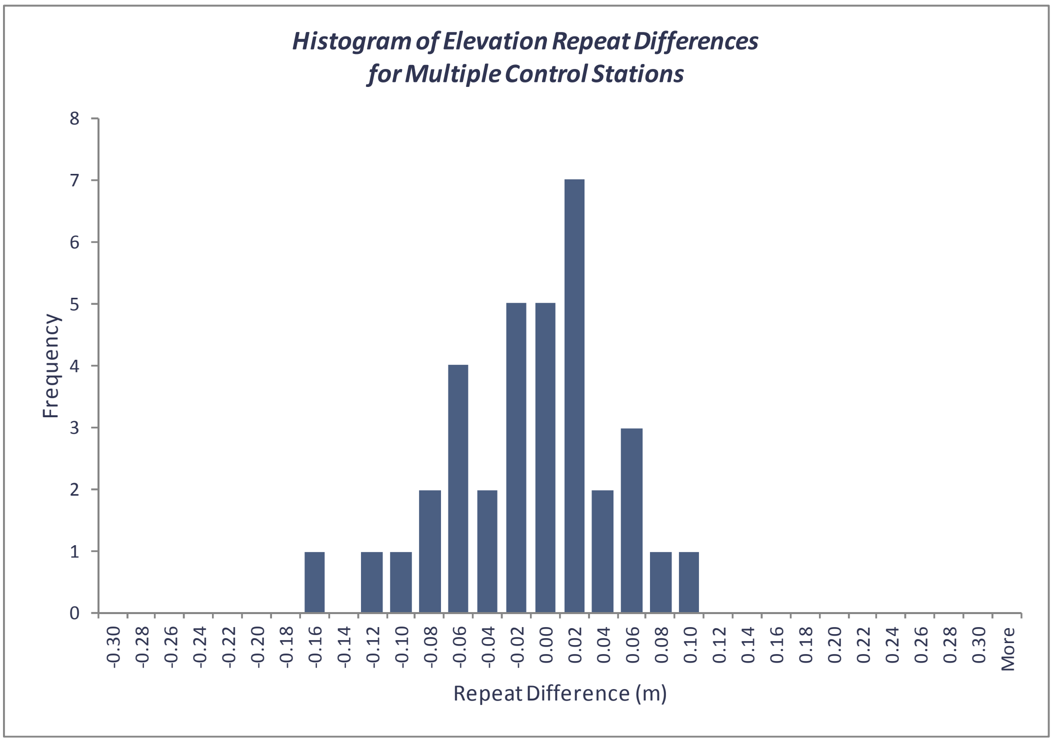


Figure 14: Histogram of GPS Repeat Differences

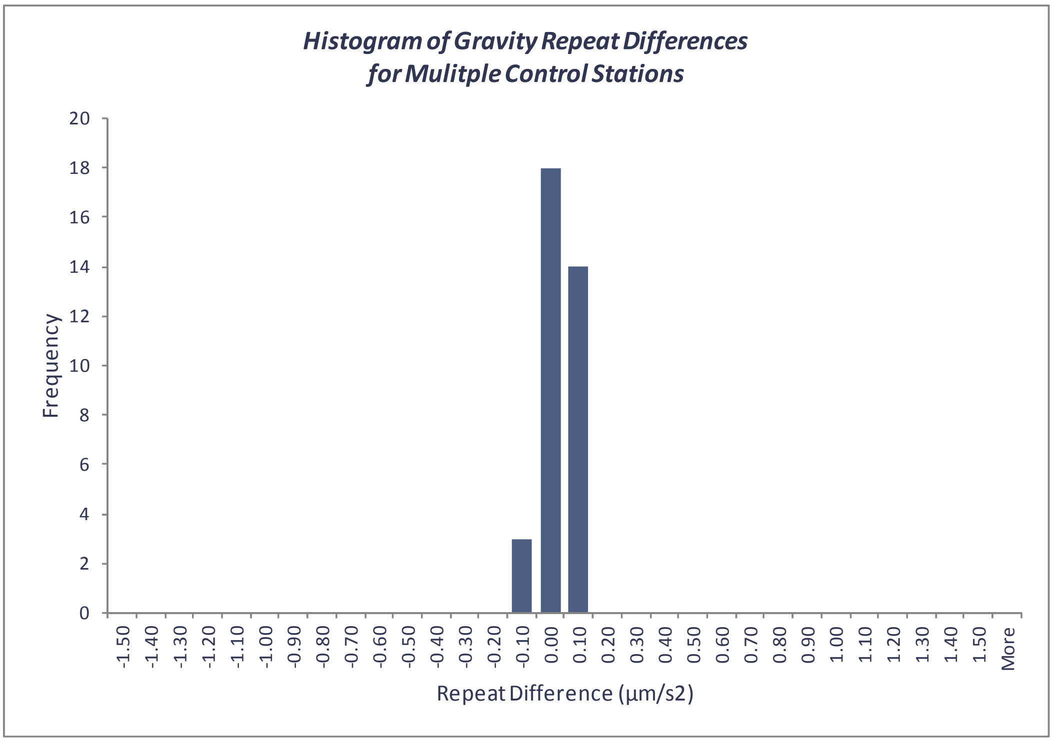


Figure 15: Histogram of Gravity Repeat Differences

9.5 Grids, Images and Plots

Final reduced data have been gridded using ChrisDBF software and a minimum curvature algorithm with multiple loops. All grids are provided in ERMapper compatible .ers format and are in units of µm/s^2 and m (GRS80).

Grids for GPS Derived Elevation (GRS80), Complete Spherical Cap Bouguer Anomaly (CSCBA267) and 1st vertical derivative of Complete Bouguer Anomaly (CBA267VD) were produced for this particular project. The grid cell size for all grids is 800m.

The grids produced have been imaged using Geosoft Oasis Montaj mapping and processing software. Five plots of these images have been included with this report to assist in data interpretation (Appendix A). The plots have been included digitally on the data DVD in Arcmap GIS compatible TIFF format.

Station Location Plot: The first plot displays the acquired gravity station locations overlayed on a 1:1 million topographic map of the area and surrounds. As evident on the plot, some stations have been moved off the original programmed co-ordinates due to terrain and safety considerations.

GPS Derived Elevation: This plot displays a pseudocoloured grid of the digital elevation data obtained from the gravity survey (GRS80). A histogram equalisation colour stretch has been applied when pseudocolouring and a sunshade from the north-east has been applied.

Complete Bouguer Anomaly 2.67 Contours: This plot displays a pseudocoloured grid of Complete Bouguer Anomaly calculated with a rock density of 2.67 t/m^3. A histogram equalisation stretch has been applied when pseudocolouring. Overlying the image data are contours created at an appropriate interval.

Complete Bouguer Anomaly 2.67 Sunshade: This plot displays a pseudocoloured grid of Complete Bouguer Anomaly calculated with a rock density of 2.67 t/m^3. A histogram equalisation stretch has been applied when pseudocolouring and a sunshade from the north-east has been applied.

Vertical Derivative Image: This plot displays a pseudocoloured grid of the first vertical derivative of Complete Bouguer Anomaly calculated with a rock density of 2.67 t/m^3. A histogram equalisation stretch has been applied when pseudocolouring and sunshading from the north-east has been applied. This image represents the rate of change of the Complete Bouguer Anomaly and is useful for detecting lineaments and body edges, especially where there are large regional gradients present.

10.0 Project Safety

There were no incidents or accidents to report during the project.

Weekly toolbox meetings were held to discuss project safety and address any staff member concerns. A Hazard Identification and Risk Assessment (HIRA) was carried out for all new tasks not covered under Atlas Geophysics Standard Operating Procedures (SOP's) or in the company's Health Safety and Environment (HSE) manual.

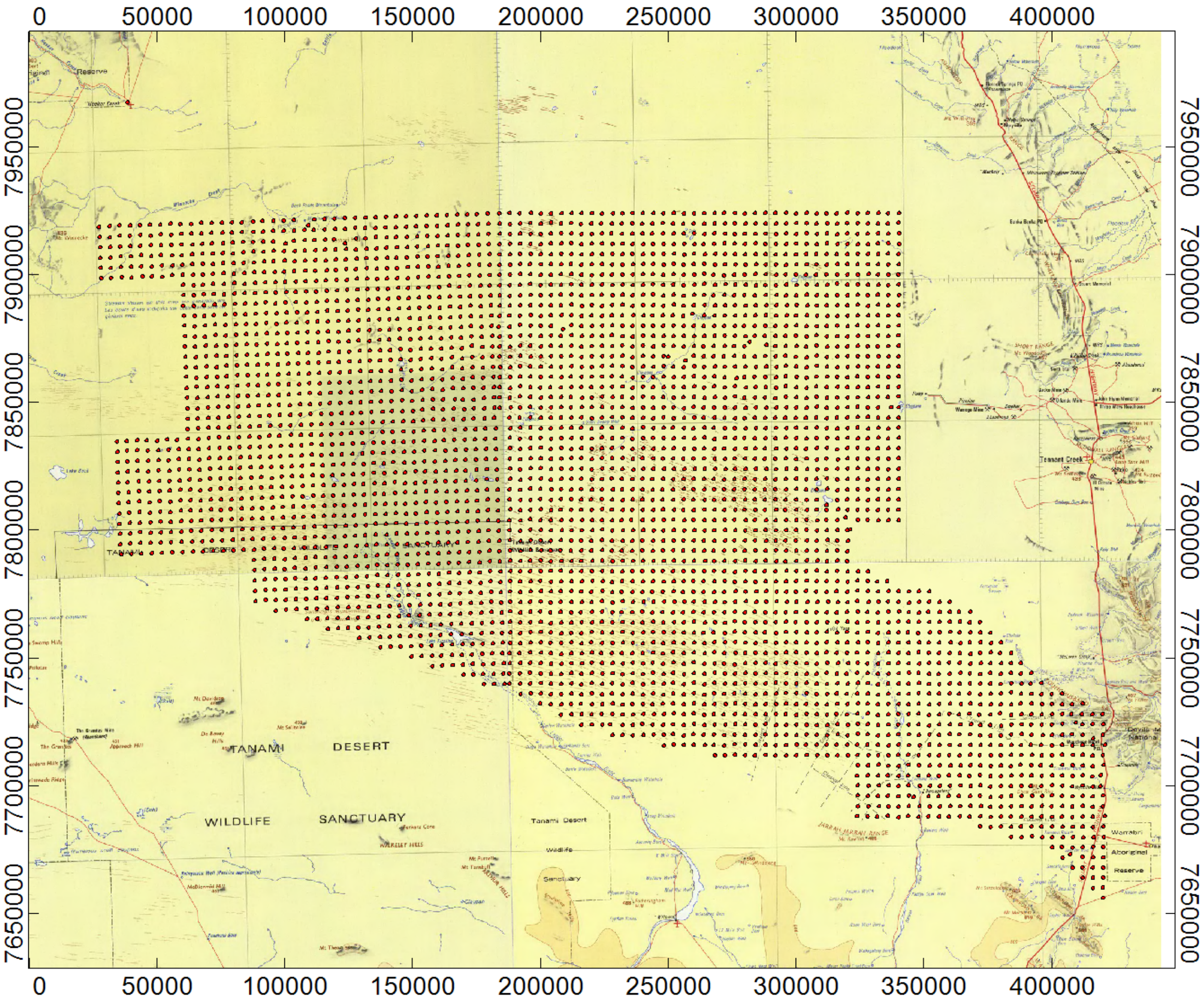
11.0 Conclusion

Atlas Geophysics Pty Ltd is confident that it has delivered high quality data to its client, to a high standard and in the safest way possible.

The company was pleased to be involved in the acquisition and processing of the gravity data collected on this project and look forward to working with Geoscience Australia again in the future.

Leon Mathews
Director

APPENDIX A
Plots and Images



Scale 1:2766500

50000 0 50000

(meters)

GDA94 / MGA zone 53

GEOSCIENCE AUSTRALIA

P2013036 GA SOUTHERN WISO BASIN GRAVITY SURVEY

Plot of Gained Gravity Stations

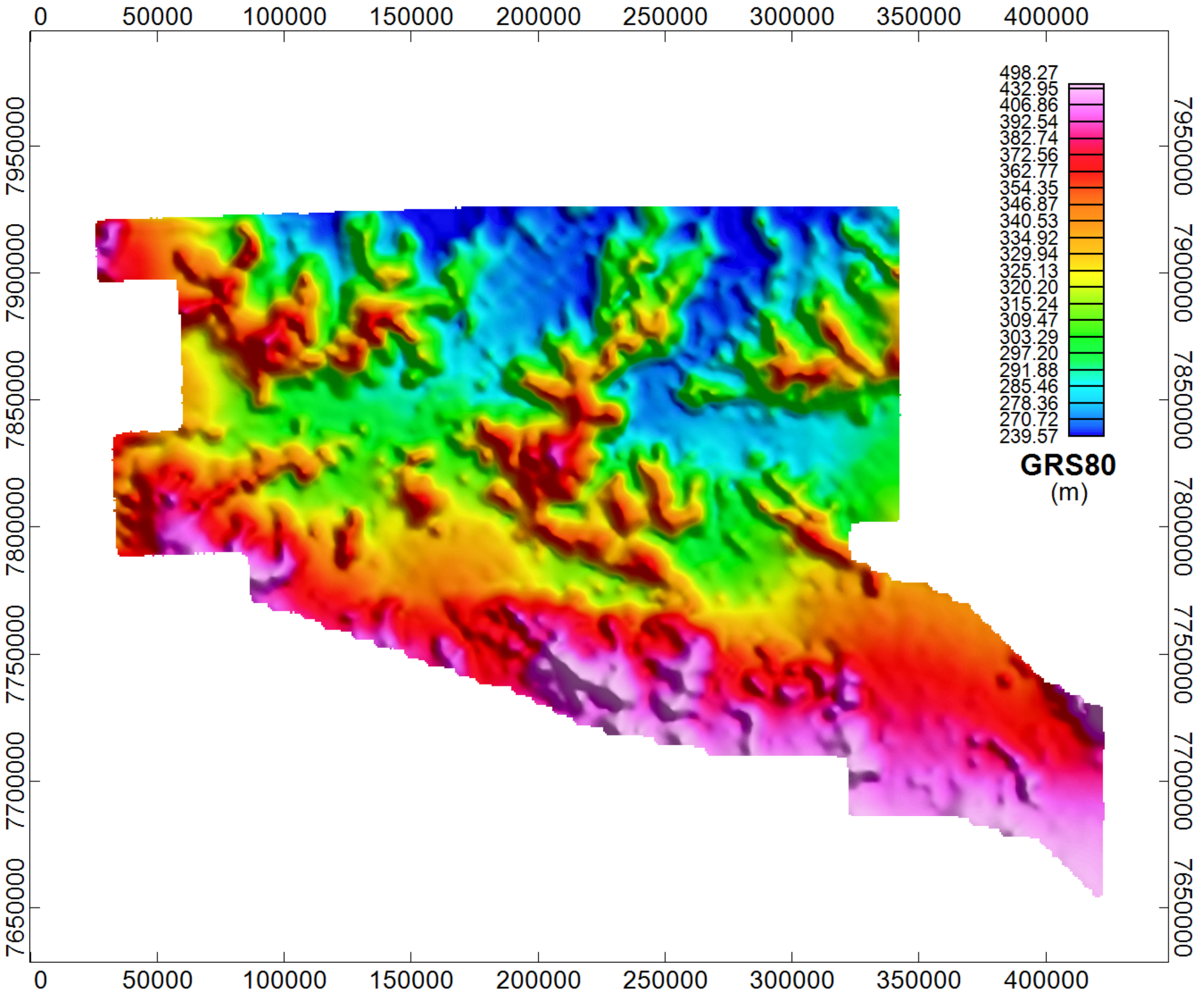
4km Square Grid Configuration

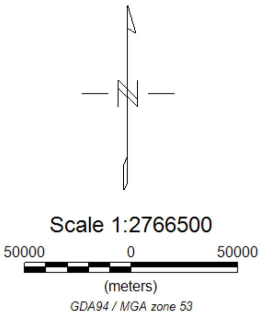
ATLAS GEOPHYSICS PTY LTD

FINAL DATA RELEASE

www.atlasgeo.com.au

drawn by : LRM





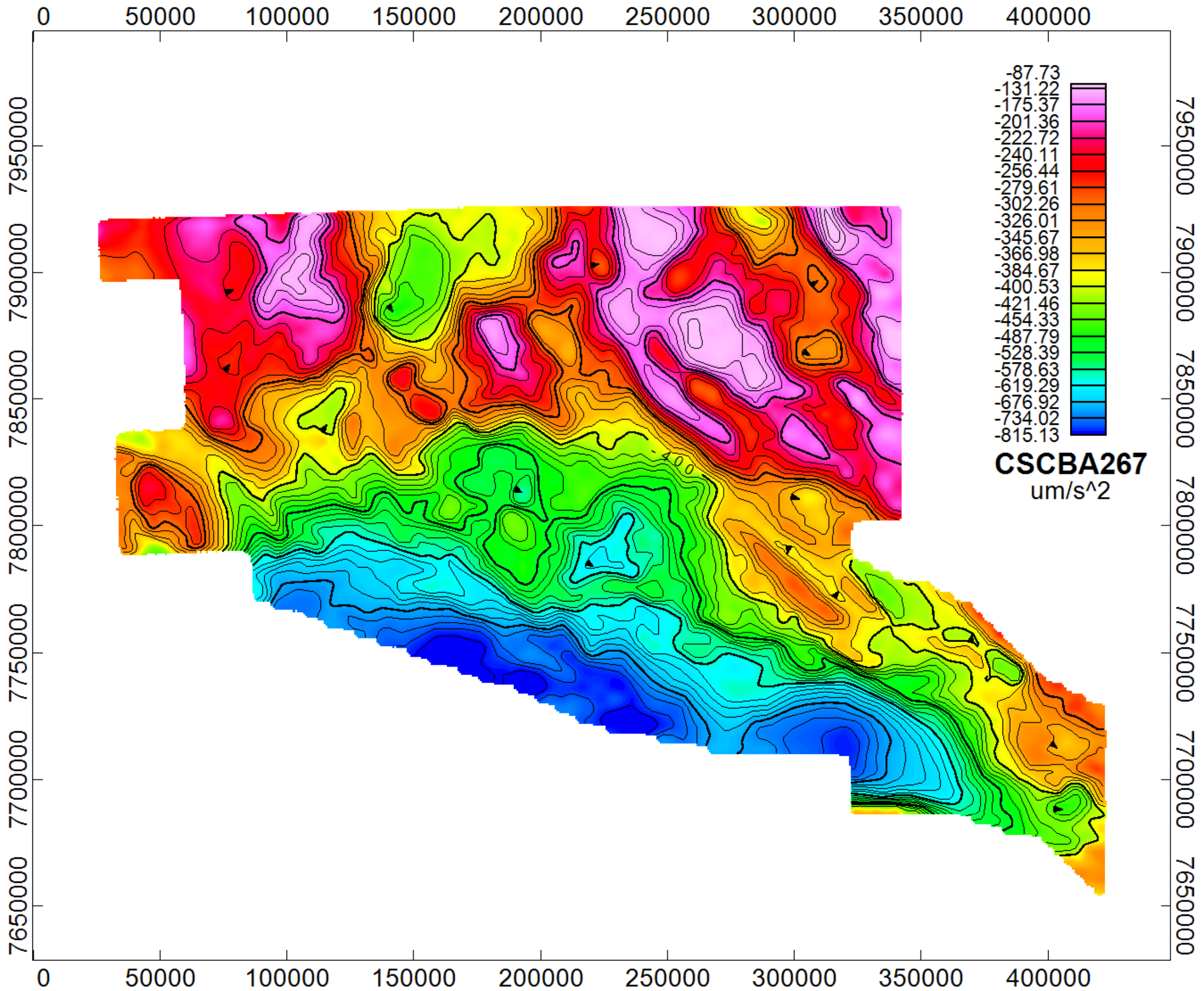
GEOSCIENCE AUSTRALIA

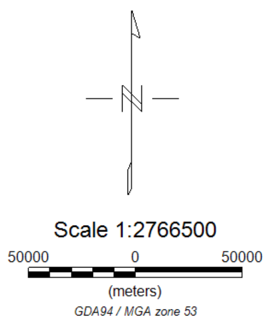
P2013036 GA SOUTHERN WISO BASIN GRAVITY SURVEY

Pseudocoloured Image of GPS Derived Elevation (GRS80)
Shade = NE, Contours = None, Histo =Equalised

ATLAS GEOPHYSICS PTY LTD
FINAL DATA RELEASE
www.atlasgeo.com.au

drawn by : LRM





GEOSCIENCE AUSTRALIA

P2013036 GA SOUTHERN WISO BASIN GRAVITY SURVEY

Pseudocoloured Image of Complete SC Bouguer Anomaly 2.67 t/m^3

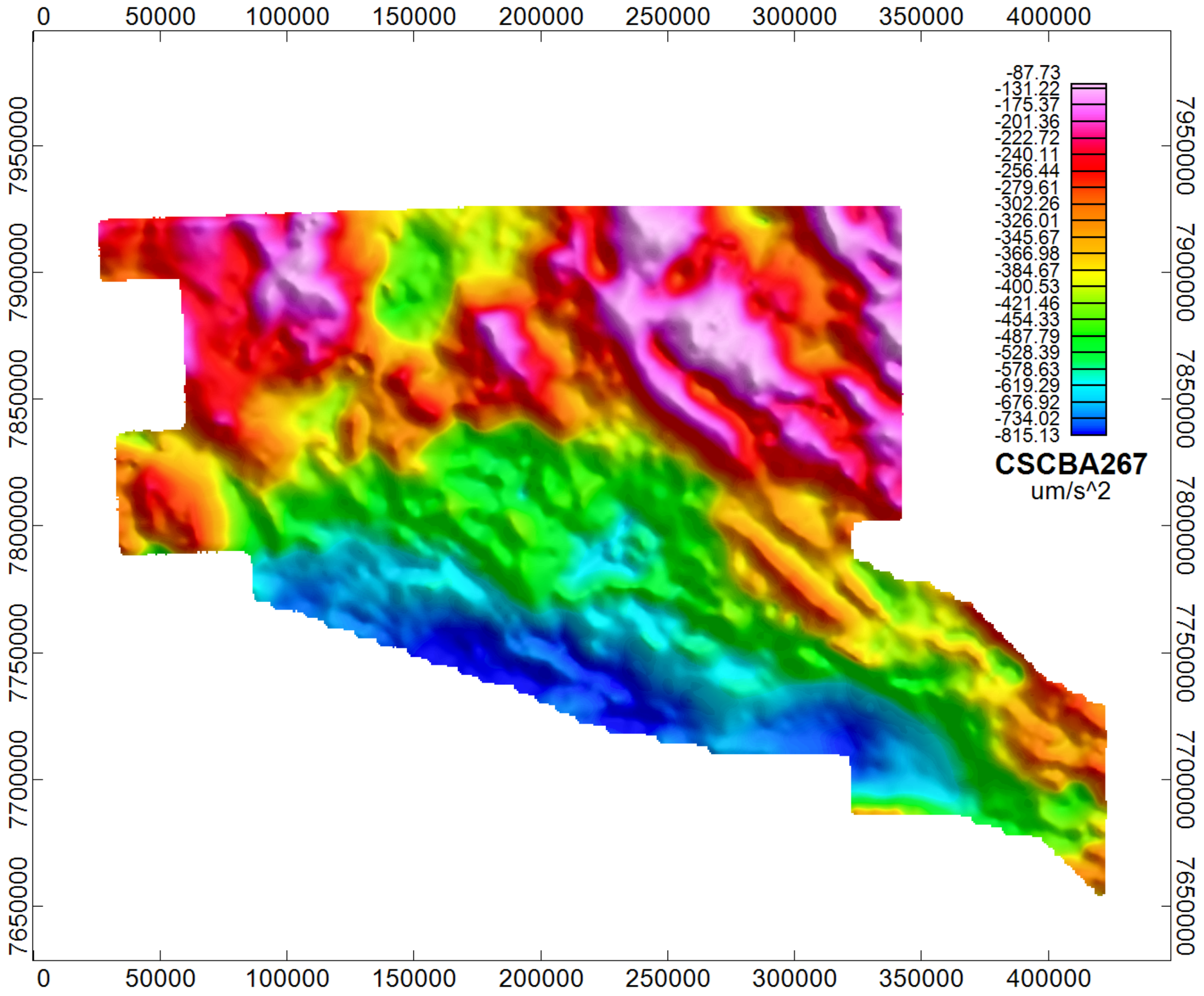
Shade = None, Contours = 20 um/s^2, Histo =Equalised

ATLAS GEOPHYSICS PTY LTD

FINAL DATA RELEASE

www.atlasgeo.com.au

drawn by : LRM



Scale 1:2766500

50000 0 50000

(meters)

GDA94 / MGA zone 53

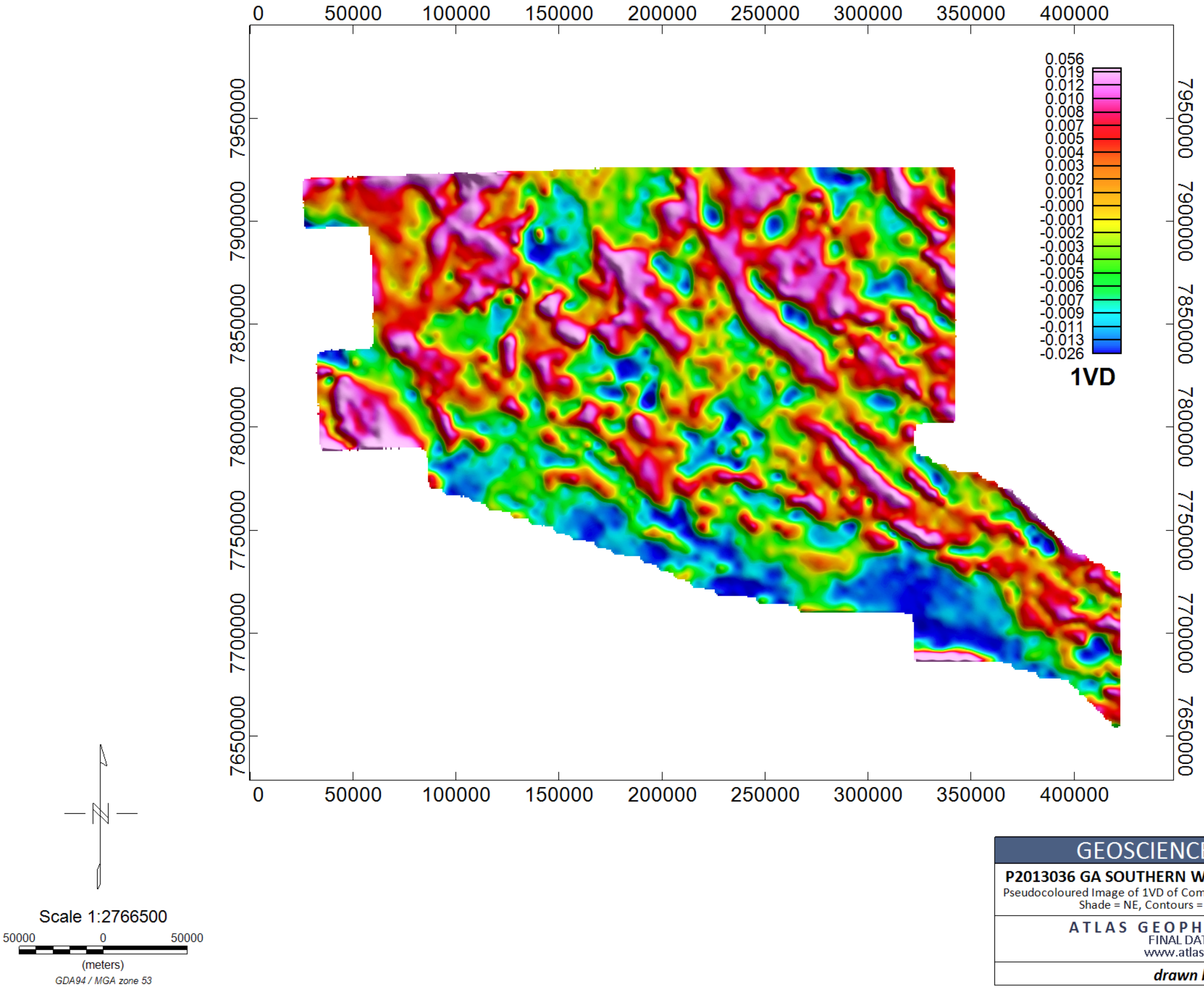
GEOSCIENCE AUSTRALIA

P2013036 GA SOUTHERN WISO BASIN GRAVITY SURVEY

Pseudocoloured Image of Complete SC Bouguer Anomaly 2.67 t/m^3
Shade = NE, Contours = None, Histo =Equalised

ATLAS GEOPHYSICS PTY LTD
FINAL DATA RELEASE
www.atlasgeo.com.au

drawn by : LRM



GEOSCIENCE AUSTRALIA

P2013036 GA SOUTHERN WISO BASIN GRAVITY SURVEY

Pseudocoloured Image of 1VD of Complete SC Bouguer Anomaly 2.67 t/m^3
Shade = NE, Contours = None, Histo =Equalised

ATLAS GEOPHYSICS PTY LTD
FINAL DATA RELEASE
www.atlasgeo.com.au

drawn by : LRM

APPENDIX B
Control Station Descriptions

201303600001 (GA 20138000001) – LAJAMANU A/S

GDA94/GRS80		MGA Z52		AMG Z52	
Latitude	-18 19 59.5696	*Easting*	672,714.609	*Easting*	672,581.397
Longitude	130 38 03.8980	*Northing*	7,972,173.342	*Northing*	7,972,007.727
Ellipsoidal Height	344.321	*Orthometric Height*	312.405	*Orthometric Height*	312.405

OBSERVED GRAVITY	
AAGD07 µm/s²	9784601.97

Occupation Method/Location Details

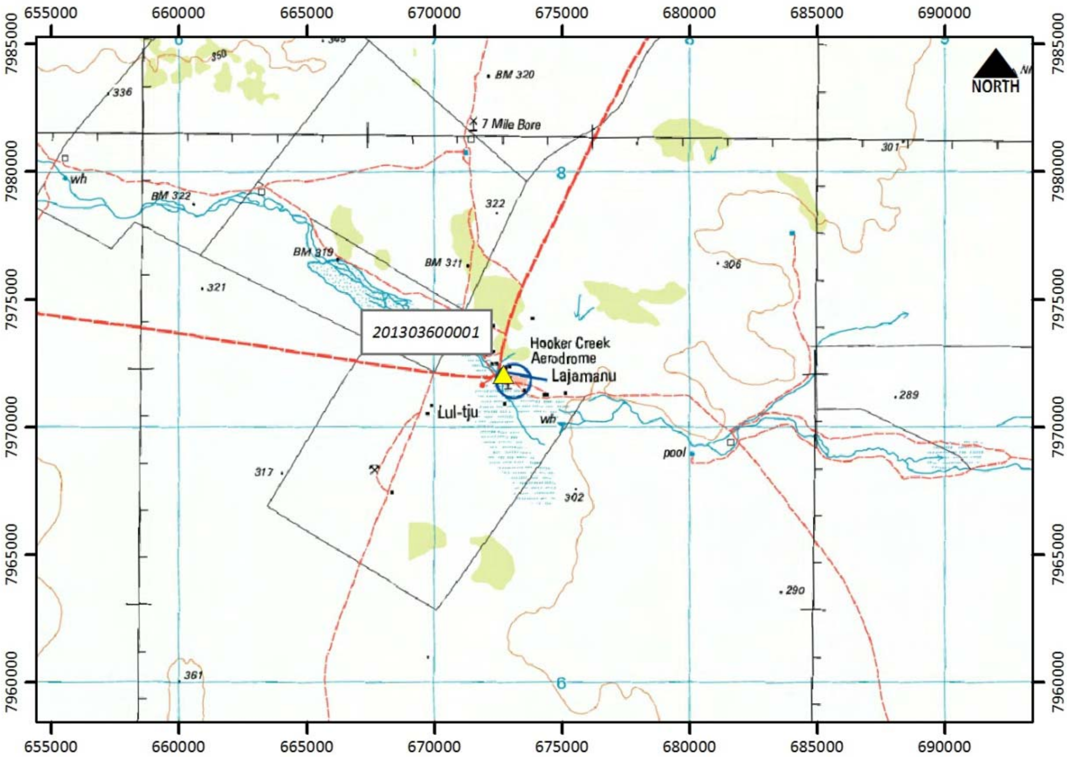
The GPS control point consists of a dumpy steel star picket driven into the ground to a height of 10cm above ground level. The gravity control point consists of a small concrete slab (30cm square) concreted into the ground, opposite the GPS control point. The control station is witnessed by an Atlas Geophysics survey plaque attached to a 1.5 metre steel picket placed within 0.5m of both control points.

Gravity Control was established by Atlas Geophysics via multiple ABA loops with two gravity meters to AFGN station 1999929064 Tanami Mine Airstrip Terminal. Expected accuracy would be better than 0.1 µm/s².

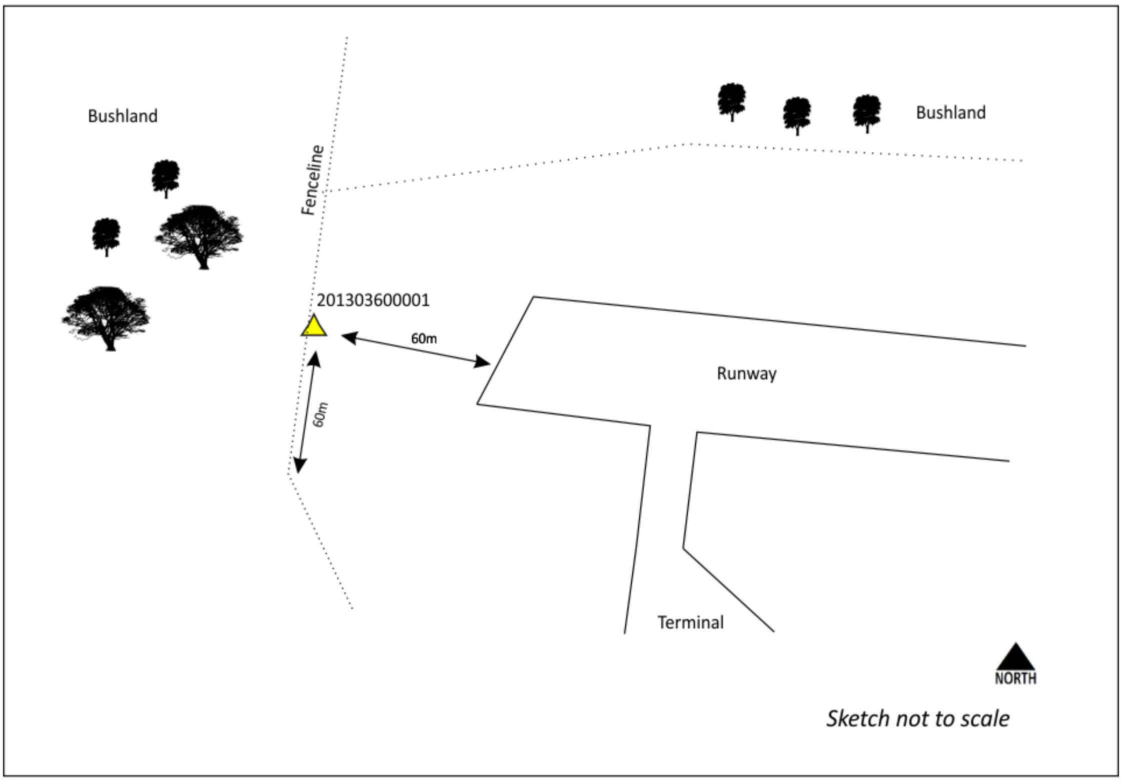
GPS Control was established using AUSPOS. Three separate +10 hour sessions were submitted to Geoscience Australia's online processing system, AUSPOS. Returned coordinates were accurate to better than 0.01m.

To locate the control station, first locate Lajamanu Airstrip. Enter the airfield and make your way to the western end of the airstrip. There is a boundary fence line 60m from the end of the airstrip. You will find the control station on the fence line.

Photograph of Control Station 201303600001



Location of Control Station 201303600001



Locality Sketch of Control Station 201303600001

201303600002 (GA 20138000002) – EXPLORER 108

GDA94/GRS80		MGA Z53		AMG Z53	
Latitude	-19 53 8.1178	*Easting*	321,132.120	*Easting*	321,002.753
Longitude	133 17 29.3805	*Northing*	7,800,272.119	*Northing*	7,800,101.585
Ellipsoidal Height	299.440	*Orthometric Height*	269.642	*Orthometric Height*	269.642

OBSERVED GRAVITY	
AAGD07 μm/s²	9785408.39

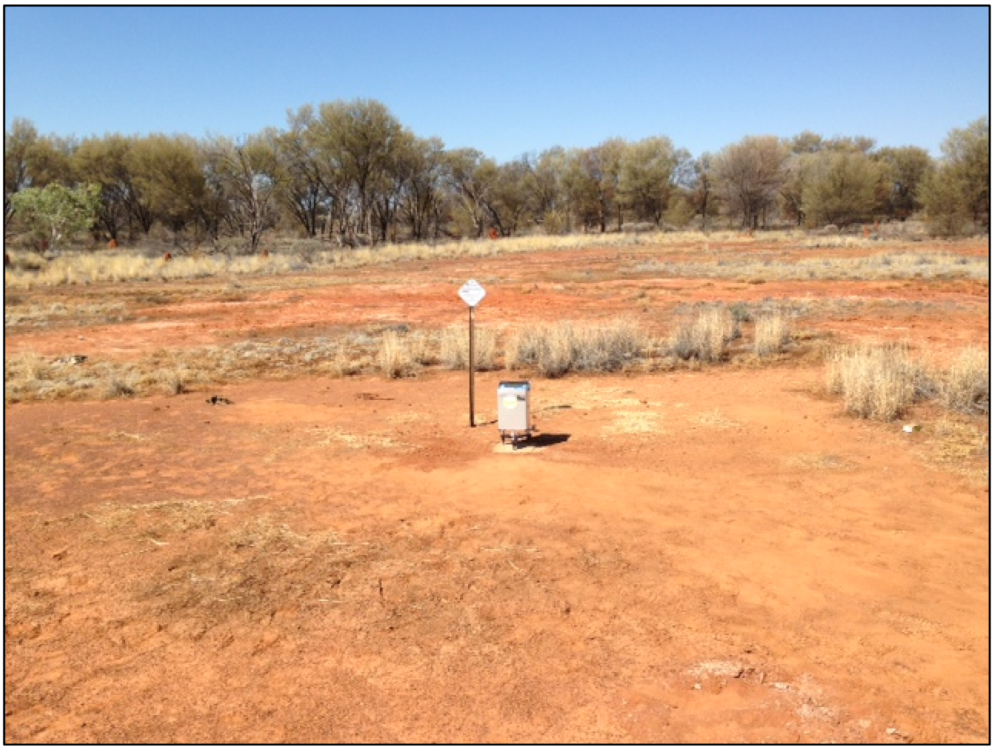
Occupation Method/Location Details

The GPS control point consists of a dumpy steel star picket driven into the ground to a height of 10cm above ground level. The gravity control point consists of a small concrete slab (30cm square) concreted into the ground, opposite the GPS control point. The control station is witnessed by an Atlas Geophysics survey plaque attached to a 1.5 metre steel picket placed within 0.5m of both control points.

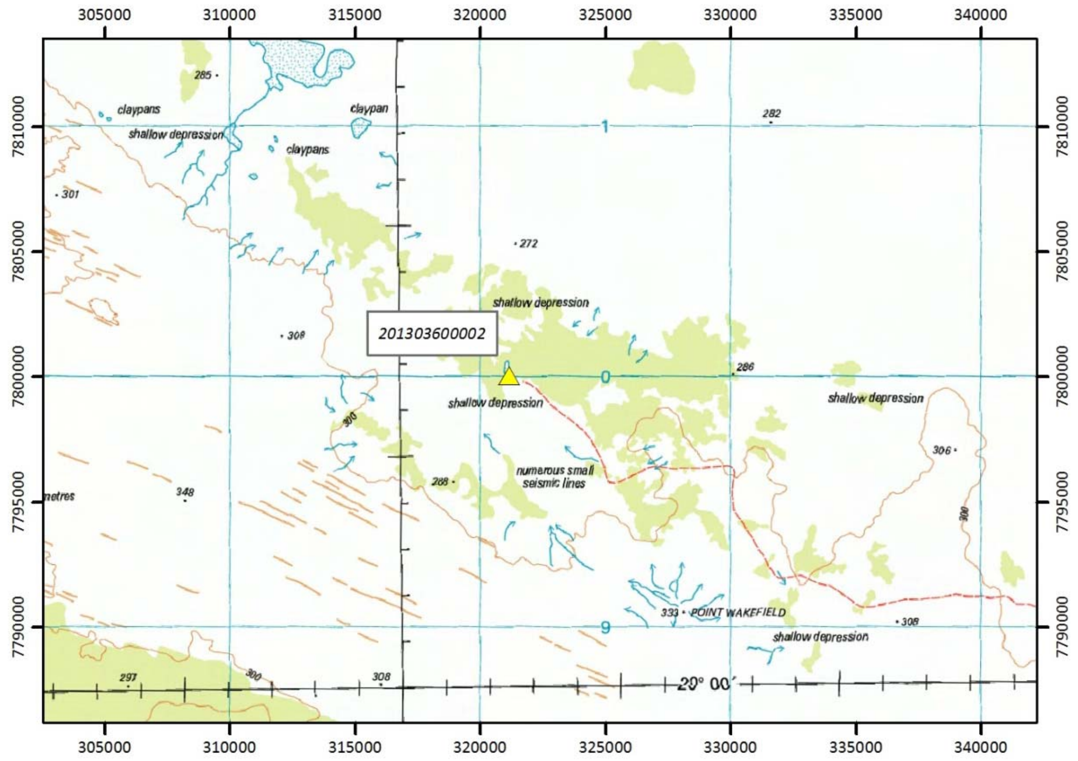
Gravity Control was established by Atlas Geophysics via multiple ABA loops with a single gravity meter to AFGN station 1967930134 Tennant Creek Airstrip terminal. Expected accuracy would be better than 0.1 μm/s^2.

GPS Control was established using AUSPOS. Three separate +10 hour sessions were submitted to Geoscience Australia's online processing system, AUSPOS. Returned coordinates were accurate to better than 0.01m.

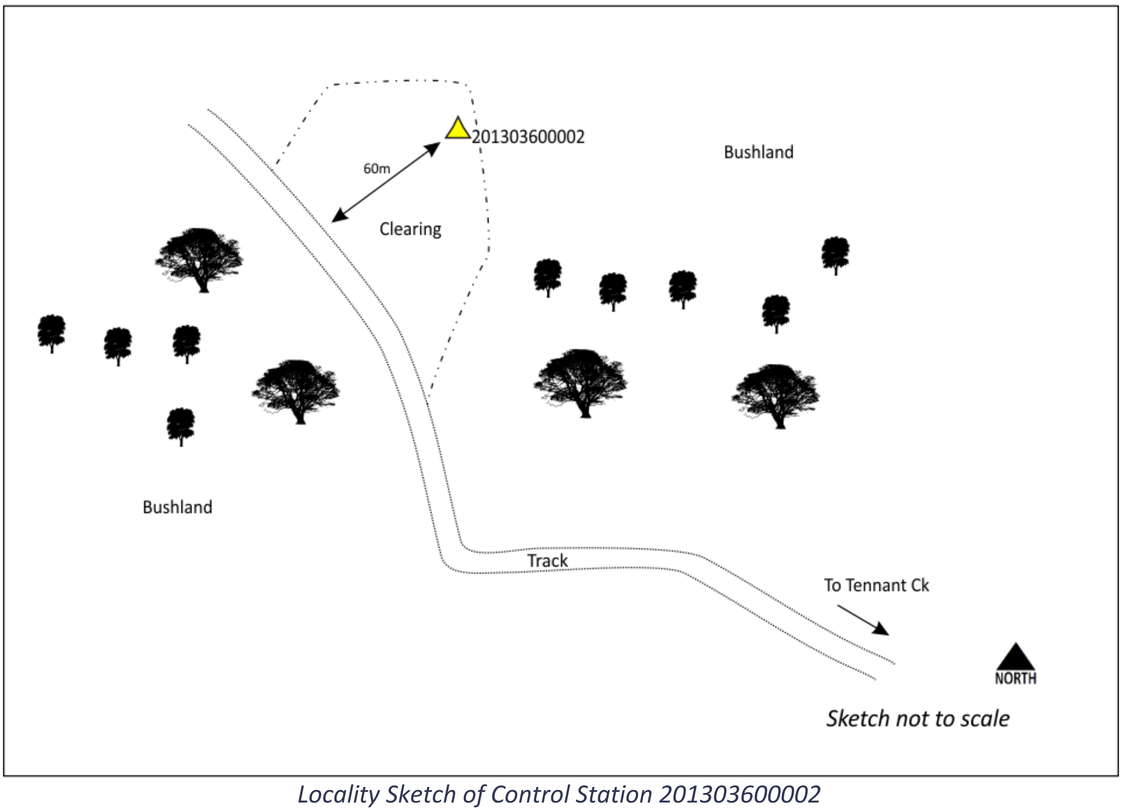
To locate the control station, from Tennant Creek take the Stuart Highway south for 6km. There will be a track heading west marked on the maps as Diamond Drill Hole Bore (abandoned) heading out to Kunayungku Outstation. Follow this track for 50km until you reach the outstation. There will be a track heading south from the outstation, follow it for 29km. At this point there will be a track heading west, take the track and follow it for 43km. There will be an old drill camp and the station is located in a clearing adjacent to an old drill hole, about 60m north-east of the track.



Photograph of Control Station 201303600002



Location of Control Station 201303600002



Locality Sketch of Control Station 201303600002

APPENDIX C
GPS Control Information

201303600001
0001 -18 19 59.56963 130 38 03.89794 344.322 312.406 GDA94
0001 -18 19 59.56960 130 38 03.89794 344.317 312.401 GDA94
0001 -18 19 59.56961 130 38 03.89797 344.323 312.407 GDA94

GDA94AVE
-18 19 59.5696
130 38 3.8980

-18.33321378
130.63441611

GRS80HT
344.321

AHDHT
312.405

N
31.916

MGA52
672714.609
7972173.342

AMG52
672581.397
7972007.727

201303600002
0002 -19 53 08.11781 133 17 29.38046 299.439 269.641 GDA94
0002 -19 53 08.11780 133 17 29.38048 299.436 269.638 GDA94
0002 -19 53 08.11783 133 17 29.38044 299.444 269.646 GDA94

GDA94AVE
-19 53 8.1178
133 17 29.3805

-19.88558828
133.29149458

GRS80HT
299.440

AHDHT
269.642

N
29.798

MGA53
321132.119
7800272.119

AMG53
321002.753
7800101.585

201303600100
1307 -19 05 35.58892 130 53 59.91835 354.921 325.843 GDA94
1307 -19 05 35.58892 130 53 59.91831 354.919 325.841 GDA94
1307 -19 05 35.58893 130 53 59.91831 354.925 325.847 GDA94

GDA94AVE
-19 5 35.5889
130 53 59.9183

-19.09321914
130.89997731

GRS80HT
354.922

AHDHT
325.844

N
29.078

MGA52
699889.779
7887773.610

AMG52
699756.533
7887607.851

201303600101
1307 -19 07 08.17877 131 42 01.32882 306.449 277.381 GDA94
1307 -19 07 08.17877 131 42 01.32884 306.443 277.375 GDA94
1307 -19 07 08.17878 131 42 01.32888 306.446 277.378 GDA94

GDA94AVE
-19 7 8.1788
131 42 1.3288

-19.11893856
131.70036911

GRS80HT
306.446

AHDHT
277.378

N
29.068

MGA52
784094.191
7883818.302

AMG52
783961.046
7883652.451

201303600102
1307 -19 46 32.59307 130 54 33.19578 359.670 333.439 GDA94
1307 -19 46 32.59301 130 54 33.19583 359.671 333.440 GDA94
1307 -19 46 32.59300 130 54 33.19580 359.665 333.434 GDA94

GDA94AVE
-19 46 32.5930
130 54 33.1958

-19.77572028
130.90922106

GRS80HT
359.669

AHDHT
333.438

N
26.231

MGA52
700024.572
7812209.323

AMG52
699891.259
7812043.478

201303600103
1307 -19 56 55.57249 131 40 36.89567 333.210 307.701 GDA94
1307 -19 56 55.57247 131 40 36.89569 333.219 307.710 GDA94
1307 -19 56 55.57244 131 40 36.89582 333.216 307.707 GDA94

GDA94AVE
-19 56 55.5725
131 40 36.8957

-19.94877014
131.67691547

GRS80HT
333.215

AHDHT
307.706

N
25.509

MGA52
780188.571
7791953.494

AMG52
780055.313
7791787.549

201303600104
1308 -19 07 11.90414 132 22 37.77025 308.922 278.335 GDA94
1308 -19 07 11.90418 132 22 37.77029 308.923 278.336 GDA94
1308 -19 07 11.90417 132 22 37.77028 308.919 278.332 GDA94

GDA94AVE
-19 7 11.9042
132 22 37.7703

-19.11997339
132.37715842

GRS80HT
308.921

AHDHT
278.334

N
30.587

MGA53
224068.439
7883827.964

AMG53
223938.700
7883657.604

201303600105
1308 -19 07 39.00935 133 05 50.39791 284.192 252.070 GDA94
1308 -19 07 39.00932 133 05 50.39792 284.188 252.066 GDA94
1308 -19 07 39.00932 133 05 50.39793 284.186 252.064 GDA94

GDA94AVE
-19 7 39.0093
133 5 50.3979

-19.12750258
133.09733275

GRS80HT
284.189

AHDHT
252.067

N
32.122

MGA53
299868.415
7883975.448

AMG53
299738.921
7883805.158

201303600106
1308 -19 48 07.03530 132 21 59.40155 325.472 298.161 GDA94
1308 -19 48 07.03541 132 21 59.40157 325.474 298.163 GDA94
1308 -19 48 07.03541 132 21 59.40150 325.474 298.163 GDA94

GDA94AVE
-19 48 7.0354
132 21 59.4015

-19.80195428
132.36650042

GRS80HT
325.473

AHDHT
298.162

N
27.311

MGA53
224103.934
7808285.143

AMG53
223974.275
7808114.546

201303600107
1308 -20 16 27.06028 132 21 28.57155 371.235 345.755 GDA94
1308 -20 16 27.06031 132 21 28.57158 371.232 345.752 GDA94
1308 -20 16 27.06028 132 21 28.57157 371.235 345.755 GDA94

GDA94AVE
-20 16 27.0603
132 21 28.5716

-20.27418342
132.35793656

GRS80HT
371.234

AHDHT
345.754

N
25.480

MGA53
224033.202
7755971.201

AMG53
223903.599
7755800.453

201303600108
1308 -20 32 06.16464 133 02 32.07965 381.997 355.405 GDA94
1308 -20 32 06.16467 133 02 32.07968 382.000 355.408 GDA94
1308 -20 32 06.16468 133 02 32.07968 382.003 355.411 GDA94

GDA94AVE
-20 32 6.1647
133 2 32.0797

-20.53504575
133.04224436

GRS80HT
382.000

AHDHT
355.408

N
26.592

MGA53
295879.204
7728085.108

AMG53
295749.823
7727914.354

201303600109
1308 -20 41 15.94357 133 50 51.80108 383.904 355.039 GDA94
1308 -20 41 15.94358 133 50 51.80109 383.896 355.031 GDA94
1308 -20 41 15.94359 133 50 51.80108 383.904 355.039 GDA94

GDA94AVE
-20 41 15.9436
133 50 51.8011

-20.68776211
133.84772253

GRS80HT
383.901

AHDHT
355.036

N
28.865

MGA53
379991.780
7711981.601

AMG53
379862.629
7711810.861

APPENDIX D
Gravity Control Processing and Information

201303600001 GRAVITY CONTROL TIES

1 = 201303600001 Lajamanu A/S
9064 = AFGN 1999929064 TANAMI A/S Terminal
Ties carried out by vehicle

METER A1

station	gda94_longitude_dd	gda94_latitude_dd	date_ddmmyyyy	time_hhmmss	dialrdng_mgal	etc_mgal	aagd07_mgal	metersn
1	130.634416	-18.333214	26/07/2013	07:04:09	1926.076	-0.027	980000.000	40240
1	130.634416	-18.333214	26/07/2013	07:05:15	1926.078	-0.028	980000.001	40240
9064	129.721100	-19.963200	26/07/2013	10:30:49	2015.948	-0.060	980089.800	40240
9064	129.721100	-19.963200	26/07/2013	10:31:54	2015.948	-0.059	980089.800	40240
1	130.634416	-18.333214	26/07/2013	13:15:41	1926.049	0.072	980000.000	40240
-1	130.634416	-18.333214	26/07/2013	13:16:46	1926.048	0.072	980000.000	40240

station	gda94_longitude_dd	gda94_latitude_dd	date_ddmmyyyy	time_hhmmss	dialrdng_mgal	etc_mgal	aagd07_mgal	metersn
1	130.634416	-18.333214	27/07/2013	09:32:23	1927.055	-0.069	980000.000	40240
1	130.634416	-18.333214	27/07/2013	09:33:29	1927.055	-0.069	980000.000	40240
9064	129.721100	-19.963200	27/07/2013	13:14:42	2016.786	0.033	980089.812	40240
9064	129.721100	-19.963200	27/07/2013	13:15:47	2016.788	0.034	980089.815	40240
1	130.634416	-18.333214	27/07/2013	16:10:14	1926.918	0.107	980000.001	40240
1	130.634416	-18.333214	27/07/2013	16:11:45	1926.917	0.107	980000.000	40240

METER A2

station	gda94_longitude_dd	gda94_latitude_dd	date_ddmmyyyy	time_hhmmss	dialrdng_mgal	etc_mgal	aagd07_mgal	metersn
1	130.634416	-18.333214	27/07/2013	10:37:54	3481.215	-0.059	980000.000	40241
1	130.634416	-18.333214	27/07/2013	10:39:00	3481.219	-0.059	980000.003	40241
9064	129.721100	-19.963200	27/07/2013	13:21:58	3571.182	0.038	980089.828	40241
9064	129.721100	-19.963200	27/07/2013	13:23:04	3571.184	0.039	980089.829	40241
1	130.634416	-18.333214	27/07/2013	15:58:49	3481.385	0.107	979999.999	40241
1	130.634416	-18.333214	27/07/2013	15:59:55	3481.387	0.107	980000.000	40241

AVG 9064	980089.814	
DIFF 9064_1	89.814	
KNOWN 9064	978550.011	
CALC 1	978460.197	mGal AAGD07
	9784601.97	**µm/s^2 AAGD07**

201303600002 GRAVITY CONTROL TIES

1 = 201303600001 Lajamanu A/S
134 = AFGN 1967930134 TENNANT CREEK A/S TERMINAL
Ties carried out by vehicle

METER A1

station	gda94_longitude_dd	gda94_latitude_dd	date_ddmmyyyy	time_hhmmss	dialrdng_mgal	etc_mgal	aagd07_mgal	metersn
2	133.291494	-19.885588	02/08/2013	13:22:39	2012.786	-0.022	980000.000	40240
2	133.291494	-19.885588	02/08/2013	13:23:45	2012.781	-0.022	979999.994	40240
134	134.184600	-19.641000	02/08/2013	15:54:59	1986.470	-0.045	979973.640	40240
134	134.184600	-19.641000	02/08/2013	15:56:05	1986.470	-0.045	979973.640	40240
2	133.291494	-19.885588	02/08/2013	18:56:51	2012.772	0.037	980000.000	40240
2	133.291494	-19.885588	02/08/2013	18:56:51	2012.772	0.037	980000.000	40240
2	133.291494	-19.885588	14/08/2013	07:22:49	2022.593	0.019	980000.000	40240
2	133.291494	-19.885588	14/08/2013	07:23:55	2022.593	0.018	979999.999	40240
134	134.184600	-19.641000	14/08/2013	11:39:46	1996.334	-0.043	979973.646	40240
134	134.184600	-19.641000	14/08/2013	11:40:52	1996.334	-0.043	979973.646	40240
2	133.291494	-19.885588	14/08/2013	16:59:47	2022.585	0.101	980000.000	40240
2	133.291494	-19.885588	14/08/2013	17:00:53	2022.585	0.101	980000.000	40240
2	133.291494	-19.885588	16/08/2013	07:17:28	2024.276	0.027	980000.000	40240
2	133.291494	-19.885588	16/08/2013	07:18:34	2024.275	0.027	979999.999	40240
134	134.184600	-19.641000	16/08/2013	10:24:03	1997.948	0.013	979973.648	40240
134	134.184600	-19.641000	16/08/2013	10:25:09	1997.949	0.013	979973.649	40240
2	133.291494	-19.885588	16/08/2013	13:52:33	2024.372	-0.048	980000.000	40240
2	133.291494	-19.885588	16/08/2013	13:53:39	2024.372	-0.048	980000.000	40240

AVG 134	979973.645	
DIFF 134 2	-26.355	
KNOWN 134	978514.484	
CALC 1	978540.839	mGal AAGD07
	9785408.39	**µm/s² AAGD07**

APPENDIX E
Gravity Meter Calibration Data

P2013036_GA_SOUTHERN_WISO_BASIN

PRE SURVEY CALIBRATION DATA

1 = 2010990117 CS1 Guildford Cemetery 9793899.63 µm/s^2 AAGD07

2 = 2010990217 CS2 Helena Valley Primary School **9794483.85 µm/s^2 AAGD07**

data in Gravity Units

STATION	MGAE	MGAN	DATE	TIME	OBSGAAD07_µm/s2	DRIFT_µm/s2	SERIAL
A2 METER							
1	420754.17	6464380.51	14/06/2013	09:48:08	9793899.63	-0.35	40241
1	420754.17	6464380.51	14/06/2013	09:49:14	9793899.63	-0.35	40241
2	417649.82	6460586.82	14/06/2013	10:20:31	9794483.82	-0.35	40241
2	417649.82	6460586.82	14/06/2013	10:21:37	9794483.83	-0.35	40241
1	420754.17	6464380.51	14/06/2013	10:47:17	9793899.64	-0.35	40241
1	420754.17	6464380.51	14/06/2013	10:48:23	9793899.63	-0.35	40241
1	420754.17	6464380.51	14/06/2013	10:48:23	9793899.63	-0.05	40241
2	417649.82	6460586.82	14/06/2013	11:12:39	9794483.85	-0.05	40241
2	417649.82	6460586.82	14/06/2013	11:13:45	9794483.86	-0.05	40241
1	420754.17	6464380.51	14/06/2013	11:38:02	9793899.64	-0.05	40241
1	420754.17	6464380.51	14/06/2013	11:39:08	9793899.63	-0.05	40241
				AVG2	**9794483.84**		

P2013036_GA_SOUTHERN_WISO_BASIN

POST SURVEY CALIBRATION DATA

1 = 2010990117 CS1 Guildford Cemetery 9793899.63 µm/s^2 AAGD07

2 = 2010990217 CS2 Helena Valley Primary School **9794483.85 µm/s^2 AAGD07**

data in Gravity Units

STATION	MGAE	MGAN	DATE	TIME	OBSGAAD07_µm/s2	DRIFT_µm/s2	SERIAL
A1 METER							
1	420754.17	6464380.51	04/10/2013	08:51:11	9793899.63	0.24	40240
1	420754.17	6464380.51	04/10/2013	08:52:17	9793899.66	0.24	40240
2	417649.82	6460586.82	04/10/2013	09:24:04	9794483.96	0.24	40240
2	417649.82	6460586.82	04/10/2013	09:25:10	9794483.95	0.24	40240
1	420754.17	6464380.51	04/10/2013	09:59:06	9793899.62	0.24	40240
1	420754.17	6464380.51	04/10/2013	10:00:12	9793899.63	0.24	40240
1	420754.17	6464380.51	04/10/2013	10:00:12	9793899.63	0.15	40240
2	417649.82	6460586.82	04/10/2013	10:32:34	9794483.91	0.15	40240
2	417649.82	6460586.82	04/10/2013	10:33:40	9794483.88	0.15	40240
1	420754.17	6464380.51	04/10/2013	11:13:41	9793899.62	0.15	40240
1	420754.17	6464380.51	04/10/2013	11:14:47	9793899.63	0.15	40240
1	420754.17	6464380.51	04/10/2013	11:14:47	9793899.63	0.09	40240
2	417649.82	6460586.82	04/10/2013	11:52:33	9794483.91	0.09	40240
2	417649.82	6460586.82	04/10/2013	11:53:39	9794483.87	0.09	40240
1	420754.17	6464380.51	04/10/2013	12:29:33	9793899.62	0.09	40240
1	420754.17	6464380.51	04/10/2013	12:30:39	9793899.63	0.09	40240
				AVG2	**9794483.91**		
A2 METER							
1	420754.17	6464380.51	05/09/2013	10:12:32	9793899.63	-0.42	40241
1	420754.17	6464380.51	05/09/2013	10:13:38	9793899.63	-0.42	40241
2	417649.82	6460586.82	05/09/2013	11:39:11	9794483.82	-0.42	40241
2	417649.82	6460586.82	05/09/2013	11:40:17	9794483.81	-0.42	40241
1	420754.17	6464380.51	05/09/2013	12:04:29	9793899.62	-0.42	40241
1	420754.17	6464380.51	05/09/2013	12:05:35	9793899.63	-0.42	40241
1	420754.17	6464380.51	05/09/2013	12:05:35	9793899.63	-0.23	40241
2	417649.82	6460586.82	05/09/2013	12:33:37	9794484.01	-0.23	40241
2	417649.82	6460586.82	05/09/2013	12:34:43	9794484.03	-0.23	40241
1	420754.17	6464380.51	05/09/2013	13:00:03	9793899.61	-0.23	40241
1	420754.17	6464380.51	05/09/2013	13:01:09	9793899.63	-0.23	40241
				AVG2	**9794483.92**		

APPENDIX F
Repeat Listing: All Observations

STATION	MGAEAST	MGANORTH	REPEAT_ERROR ELEVATION_M	REPEAT_ERROR GRAVITY_µm/s^2	DATE_DDMMYY	TIME_HHMMSS	METERSN
20138001001	31413.9	7918970.2	0.036	-0.07	11072013	174630	40240
20138001000	27233.3	7918628.3	-0.032	-0.07	11072013	175222	40240
20138001001	31414.5	7918970.7	-0.017	-0.24	12072013	090408	40240
20138001030	39293.2	7915170.2	-0.018	-0.45	12072013	091036	40240
20138001029	51532.1	7907670.8	-0.123	-0.05	12072013	091904	40240
20138001028	60024.3	7899888.9	-0.103	0.03	12072013	092602	40240
20138001002	68422.6	7883778.9	0.006	-0.30	12072013	093558	40240
20138001013	71191.8	7808132.7	-0.027	-0.43	12072013	110614	40240
20138001084	99510.0	7921132.6	-0.041	-0.13	12072013	182604	40240
20138001081	63314.2	7919775.2	0.057	-0.08	13072013	081848	40240
20138001082	75389.7	7920308.1	0.160	0.27	13072013	082734	40240
20138001083	87512.4	7920718.0	0.067	-0.36	13072013	083430	40240
20138001084	99510.2	7921132.4	0.048	-0.62	13072013	084124	40240
20138001107	111288.2	7917449.3	-0.069	0.39	13072013	084856	40240
20138001106	123475.3	7917815.9	-0.112	-0.32	13072013	085556	40240
20138001105	135367.3	7918206.0	-0.048	-0.21	13072013	090310	40240
20138001102	147386.2	7918710.0	-0.048	0.39	13072013	091032	40240
20138001099	159499.5	7919000.3	-0.038	0.17	13072013	091840	40240
20138001083	87512.2	7920718.1	0.011	0.39	13072013	142444	40240
20138001105	135367.4	7918205.8	0.017	0.43	13072013	144616	40240
20138001099	159499.7	7919000.1	0.000	0.14	13072013	145742	40240
20138001099	159499.5	7919000.2	0.003	0.02	13072013	174652	40240
20138001102	147386.2	7918709.7	0.017	0.20	13072013	175322	40240
20138001083	87512.3	7920718.1	0.023	0.28	14072013	073658	40240
20138001199	175990.4	7907754.5	-0.006	-0.04	14072013	084424	40240
20138001198	176015.2	7903886.8	-0.045	0.42	14072013	084802	40240
20138001189	176905.2	7875631.2	-0.039	0.00	14072013	091608	40240
20138001188	177205.8	7871666.3	0.016	-0.12	14072013	091950	40240
20138001064	152127.4	7790722.6	0.008	-0.02	14072013	102430	40240
20138001078	152811.0	7882713.3	-0.036	0.17	14072013	115020	40240
20138001083	87512.1	7920718.2	0.003	0.37	14072013	125318	40240
20138001084	99510.4	7921132.4	0.026	0.19	14072013	140232	40240
20138001211	115677.2	7913657.5	0.048	-0.58	14072013	141126	40240
20138001213	139806.8	7914520.1	-0.035	-0.71	14072013	142338	40240
20138001203	167612.9	7915476.2	-0.041	-0.28	14072013	144126	40240
20138001084	99510.1	7921132.4	0.039	0.23	14072013	174840	40240
20138001312	103599.7	7917216.7	-0.052	0.00	15072013	080756	40240
20138001311	107721.2	7913496.8	-0.042	0.09	15072013	081334	40240
20138001212	127825.7	7914086.3	-0.090	0.03	15072013	082702	40240
20138001215	159697.0	7915119.6	-0.064	0.76	15072013	084716	40240
20138001322	159846.3	7911356.5	0.019	-0.13	15072013	111156	40240
20138001000	27233.5	7918628.0	-0.027	-0.04	15072013	132854	40240
20138001001	31414.3	7918970.5	-0.013	0.12	15072013	181434	40240
20138001013	71191.7	7808132.4	0.009	0.08	16072013	165150	40240
20138001023	61871.8	7839530.1	0.024	-0.23	16072013	173010	40240
20138001024	61714.3	7851886.3	-0.012	-0.22	16072013	173652	40240
20138001027	60143.9	7887783.5	-0.015	0.21	16072013	175114	40240

STATION	MGAEAST	MGANORTH	REPEAT_ERROR ELEVATION_M	REPEAT_ERROR GRAVITY_µm/s^2	DATE_DDMMYY	TIME_HHMMSS	METERSN
20138001029	51532.0	7907670.7	-0.010	0.71	16072013	180054	40240
20138001315	71297.1	7920184.3	-0.093	-0.50	17072013	102242	40240
20138001316	79259.9	7920456.5	-0.102	-0.67	17072013	102844	40240
20138001083	87511.6	7920718.4	0.028	-0.03	17072013	103802	40240
20138001317	95497.1	7921044.7	-0.053	-0.45	17072013	104804	40240
20138001358	107813.1	7909367.8	-0.047	0.01	17072013	110608	40240
20138001319	119782.6	7909726.1	0.042	-0.40	17072013	111336	40240
20138001320	139710.2	7910535.3	0.036	-0.18	17072013	112338	40240
20138001232	178134.1	7843688.6	-0.049	-0.01	17072013	130411	40240
20138001078	152811.2	7882713.4	0.012	-0.09	17072013	144328	40240
20138001083	87512.6	7920718.4	0.031	0.15	17072013	170222	40240
20138001410	59625.4	7795449.0	0.042	0.28	18072013	081322	40240
20138001233	174318.3	7835494.1	0.012	0.11	18072013	113130	40240
20138001567	158290.9	7839063.9	-0.152	-0.26	18072013	114656	40240
20138001234	170699.0	7823271.0	0.008	-0.46	18072013	130159	40240
20138001081	63313.8	7919775.5	0.040	0.22	18072013	181850	40240
20138001081	63314.3	7919775.7	0.026	0.40	19072013	082634	40240
20138001525	67257.3	7920250.5	-0.021	0.11	19072013	083223	40240
20138001598	99900.2	7905438.9	0.008	0.17	19072013	091649	40240
20138001589	128125.0	7906175.7	-0.131	0.67	19072013	093916	40240
20138001588	131824.1	7906429.0	-0.111	0.84	19072013	094319	40240
20138001744	132162.4	7898416.7	0.067	-0.24	19072013	144355	40240
20138001743	132045.9	7902465.6	0.017	0.04	19072013	144804	40240
20138001594	111871.9	7905679.0	-0.059	-0.02	19072013	150726	40240
20138001595	107874.3	7905457.3	-0.066	-0.24	19072013	151131	40240
20138001080	108045.4	7901514.0	0.087	-0.28	19072013	151607	40240
20138001739	91946.4	7905138.2	-0.106	0.17	19072013	152408	40240
20138001737	87726.4	7909035.0	0.030	0.15	19072013	152847	40240
20138001735	83626.0	7912767.5	-0.033	-0.30	19072013	153313	40240
20138001733	79249.9	7916399.5	0.055	0.03	19072013	153753	40240
20138001081	63314.2	7919775.8	0.006	-0.36	19072013	155050	40240
20138001029	51531.8	7907671.0	0.071	-0.75	20072013	072750	40240
20138001028	60024.4	7899888.6	0.031	-0.17	20072013	073441	40240
20138001027	60143.4	7887783.2	0.004	0.19	20072013	074159	40240
20138001026	60908.9	7875871.0	-0.001	0.51	20072013	074848	40240
20138001025	61272.1	7863736.9	-0.010	0.08	20072013	075613	40240
20138001024	61714.2	7851886.3	-0.013	0.48	20072013	080600	40240
20138001023	61871.9	7839530.2	0.003	0.01	20072013	081713	40240
20138001022	66020.7	7839889.6	-0.060	0.25	20072013	082100	40240
20138001235	167040.8	7815273.5	0.084	-0.07	20072013	122816	40240
20138001236	163430.4	7803036.4	0.048	0.07	20072013	133240	40240
20138001237	159921.3	7795101.9	-0.044	0.27	20072013	142046	40240
20138001703	96378.9	7768534.0	0.024	0.27	20072013	164029	40240
20138001730	55171.4	7919894.5	-0.003	-0.06	21072013	082348	40240
20138001731	59029.9	7919750.4	0.036	-0.18	21072013	082743	40240
20138001732	71223.8	7916347.4	0.061	-0.42	21072013	084324	40240
20138001735	83626.7	7912767.6	0.002	0.00	21072013	090211	40240

STATION	MGAEAST	MGANORTH	REPEAT_ERROR ELEVATION_M	REPEAT_ERROR GRAVITY_µm/s^2	DATE_DDMMYY	TIME_HHMMSS	METERSN
20138001817	116351.7	7901661.2	-0.040	0.48	21072013	094110	40240
20138001079	128391.5	7894131.1	-0.069	-0.11	21072013	100132	40240
20138001036	72659.9	7880481.7	-0.123	-0.39	21072013	142355	40240
20138001002	68422.2	7883778.7	-0.186	0.18	21072013	142825	40240
20138001732	71223.5	7916347.2	-0.064	-0.15	21072013	151430	40240
20138001931	67363.6	7916059.8	-0.061	-0.12	21072013	152107	40240
20138001730	55171.4	7919894.4	0.078	-0.27	22072013	072350	40240
20138001930	59442.1	7915958.1	-0.042	0.32	22072013	073222	40240
20138002018	71320.5	7912216.3	0.065	0.13	22072013	074231	40240
20138001934	79541.9	7912509.8	-0.076	0.63	22072013	074754	40240
20138001936	83874.4	7904594.3	0.047	0.22	22072013	075606	40240
20138001938	88041.2	7900951.7	0.004	0.26	22072013	080026	40240
20138001939	99607.1	7901132.2	0.059	0.04	22072013	081104	40240
20138002025	51230.8	7919529.8	0.025	0.13	22072013	125614	40240
20138002027	63799.2	7911708.4	0.035	0.21	22072013	135933	40240
20138002032	108064.9	7897354.9	-0.086	-0.09	22072013	145024	40240
20138002033	115957.0	7897698.5	0.016	-0.33	22072013	145747	40240
20138002099	71758.8	7900283.8	-0.161	0.30	22072013	172910	40240
20138002100	63698.4	7907906.9	-0.043	0.08	22072013	174315	40240
20138002026	55490.4	7915514.4	0.087	-0.43	22072013	175931	40240
20138002025	51230.9	7919529.3	-0.034	-0.05	22072013	180711	40240
20138001027	60143.6	7887783.2	-0.022	-0.59	23072013	073446	40240
20138001026	60909.0	7875870.9	-0.037	-0.59	23072013	074502	40240
20138001025	61272.3	7863736.9	-0.037	0.48	23072013	075232	40240
20138001024	61714.5	7851886.2	-0.010	-0.15	23072013	075908	40240
20138001023	61871.6	7839530.2	-0.027	-0.33	23072013	080624	40240
20138001410	59625.2	7795448.9	-0.059	0.12	23072013	082502	40240
20138002171	144488.3	7774463.6	0.025	0.50	23072013	121244	40240
20138001703	96378.8	7768533.6	-0.024	-0.43	23072013	160455	40240
20138001013	71191.6	7808132.4	0.087	0.03	23072013	175859	40240
20138001050	74719.9	7824240.3	0.096	-0.43	23072013	180827	40240
20138002297	57783.4	7835323.0	-0.066	0.29	24072013	115115	40240
20138001046	73986.1	7840161.2	0.003	-0.16	24072013	115952	40240
20138001211	115676.9	7913657.5	-0.085	0.52	24072013	132814	40240
20138001733	79250.2	7916399.5	0.066	0.11	24072013	134139	40240
20138001930	59442.8	7915958.3	0.028	-0.20	24072013	135127	40240
20138002025	51230.3	7919529.7	-0.031	0.01	24072013	135718	40240
20138001731	59029.9	7919750.4	-0.048	-0.16	24072013	145940	40240
20138001931	67363.8	7916059.4	0.006	-0.11	24072013	150554	40240
20138002018	71320.7	7912216.3	-0.002	-0.14	24072013	151025	40240
20138001936	83874.9	7904594.0	-0.047	-0.09	24072013	151832	40240
20138001938	88040.7	7900951.7	-0.035	0.09	24072013	152251	40240
20138001036	72659.9	7880481.9	0.043	0.55	24072013	173917	40240
20138002290	51558.1	7911483.9	0.028	0.37	24072013	181621	40240
20138002025	51231.0	7919529.5	-0.045	-0.06	24072013	182146	40240
20138002402	131362.6	7806145.9	0.099	-0.30	25072013	115242	40241
20138001703	96378.8	7768533.9	0.013	0.32	25072013	150320	40241

STATION	MGAEAST	MGANORTH	REPEAT_ERROR ELEVATION_M	REPEAT_ERROR GRAVITY_µm/s^2	DATE_DDMMYY	TIME_HHMMSS	METERSN
20138001410	59625.3	7795448.8	-0.018	0.23	25072013	160242	40241
20138001013	71191.6	7808132.5	-0.068	0.00	25072013	161126	40241
20138001050	74719.7	7824240.0	-0.031	0.23	25072013	162536	40241
20138001046	73986.0	7840161.2	0.001	0.48	25072013	163238	40241
20138001043	73676.8	7852364.1	-0.001	0.19	25072013	163840	40241
20138001038	73054.7	7872120.3	0.034	0.15	25072013	164708	40241
20138001036	72660.1	7880481.9	0.043	-0.14	25072013	165152	40241
20138001078	152810.9	7882713.5	0.026	-0.01	25072013	175330	40241
20138001080	108045.7	7901514.2	-0.067	0.02	25072013	181908	40241
20138001598	99900.2	7905438.7	-0.060	-0.19	25072013	182418	40241
20138001733	79250.3	7916399.7	-0.096	-0.20	25072013	183350	40241
20138002294	64820.0	7871755.9	0.000	0.68	26072013	080140	40241
20138002295	65460.0	7856154.1	0.035	0.48	26072013	081536	40241
20138002296	65843.5	7843666.2	-0.020	-0.73	26072013	082628	40241
20138001064	152127.2	7790722.7	-0.039	0.24	26072013	102114	40241
20138001013	71191.3	7808132.8	0.018	0.36	26072013	111532	40241
20138002293	64353.3	7887711.0	0.018	0.28	26072013	115004	40241
20138001001	31414.4	7918970.4	-0.079	0.20	26072013	131544	40241
20138001030	39293.1	7915170.7	-0.063	0.02	26072013	140200	40241
20138001028	60024.1	7899888.8	0.016	0.22	26072013	150502	40241
20138002293	64353.2	7887711.3	-0.060	0.19	26072013	151530	40241
20138001002	68422.7	7883778.7	0.033	0.16	26072013	151942	40241
20138002600	319346.9	7804924.8	0.055	-0.33	01082013	150716	40241
20138002686	288045.2	7800004.9	-0.068	-0.18	02082013	072746	40241
20138002685	276191.0	7799947.6	-0.013	0.12	02082013	073446	40241
20138002684	264181.3	7799876.8	-0.008	0.05	02082013	074130	40241
20138002683	252081.5	7800014.0	0.001	0.22	02082013	074831	40241
20138002682	240147.3	7799990.3	0.001	0.43	02082013	075514	40241
20138002681	228040.1	7799901.3	-0.076	0.57	02082013	080302	40241
20138002637	224114.4	7808279.6	-0.049	0.63	02082013	080854	40241
20138002626	224065.1	7883815.2	-0.039	-0.13	02082013	091608	40241
20138002616	299868.3	7883954.3	-0.079	0.57	02082013	104120	40241
20138002615	299830.4	7843912.4	-0.024	0.36	02082013	111924	40241
20138002661	316074.0	7803935.4	0.040	-0.21	02082013	120826	40241
20138002666	259776.9	7767985.9	-0.086	0.14	02082013	135944	40241
20138002667	243748.7	7767778.6	-0.018	-0.09	02082013	141220	40241
20138002668	228096.3	7767928.0	-0.116	0.30	02082013	142630	40241
20138002669	224028.2	7755957.3	-0.094	0.20	02082013	144000	40241
20138001447	195889.5	7748168.6	0.003	0.92	02082013	160000	40241
20138001453	195950.6	7772052.0	0.006	0.50	02082013	162222	40241
20138001457	195978.5	7788111.7	-0.029	0.75	02082013	163912	40241
20138002681	228040.5	7799901.0	0.052	0.21	02082013	170918	40241
20138002682	240147.7	7799990.3	-0.030	-0.14	02082013	172114	40241
20138002683	252082.2	7800014.2	-0.044	-0.02	02082013	173114	40241
20138002684	264181.6	7799876.9	-0.021	0.12	02082013	174124	40241
20138002685	276190.9	7799947.8	0.016	0.04	02082013	175136	40241
20138002686	288045.0	7800004.8	0.037	0.19	02082013	180144	40241

STATION	MGAEAST	MGANORTH	REPEAT_ERROR ELEVATION_M	REPEAT_ERROR GRAVITY_µm/s^2	DATE_DDMMYY	TIME_HHMMSS	METERSN
20138001462	196001.5	7807985.2	0.044	-0.50	03082013	081836	40241
20138001464	195983.4	7816313.7	-0.012	-0.40	03082013	083300	40241
20138001469	196054.7	7836033.9	0.033	0.34	03082013	085340	40241
20138001132	191988.8	7864165.9	0.001	-0.66	03082013	091938	40241
20138001130	192094.1	7872274.9	-0.069	-0.54	03082013	092940	40241
20138001124	191895.7	7895958.0	-0.014	-0.18	03082013	095232	40241
20138001122	192025.2	7904134.1	0.049	-0.66	03082013	100314	40241
20138001119	191991.0	7915989.1	-0.009	-0.51	03082013	101628	40241
20138002681	228040.3	7799901.0	0.027	-0.57	03082013	124644	40241
20138002934	324128.4	7804052.1	0.063	0.39	03082013	182604	40241
20138002662	308009.6	7795835.5	-0.013	-0.25	04082013	071042	40241
20138002928	232174.4	7795823.4	-0.104	0.70	04082013	075220	40241
20138002637	224115.0	7808279.5	-0.043	0.81	04082013	080218	40241
20138002908	203787.5	7855844.1	0.021	-0.01	04082013	090608	40241
20138002907	207895.6	7855823.5	0.108	0.18	04082013	091044	40241
20138002906	208142.2	7859848.8	-0.019	0.27	04082013	093214	40241
20138002905	204055.9	7860041.2	-0.040	-0.58	04082013	093642	40241
20138002906	208142.3	7859848.5	-0.064	0.09	04082013	112910	40241
20138002907	207895.2	7855823.7	-0.079	0.28	04082013	113230	40241
20138003023	220021.1	7807969.5	0.035	0.28	04082013	122304	40241
20138002690	311982.2	7800007.8	0.015	-0.53	04082013	133012	40241
20138002934	324128.4	7804051.7	-0.041	0.53	04082013	135900	40241
20138002991	332151.2	7868001.5	-0.043	0.26	04082013	145452	40241
20138002990	327950.3	7868022.4	-0.024	0.03	04082013	145816	40241
20138002989	327942.8	7871943.4	0.038	-0.33	04082013	150134	40241
20138002988	331885.3	7871934.3	-0.036	0.20	04082013	150518	40241
20138002989	327943.7	7871944.6	-0.043	0.38	04082013	172122	40241
20138002988	331885.1	7871934.5	0.025	-0.18	04082013	172438	40241
20138002991	332151.4	7868001.4	-0.026	-0.32	04082013	172754	40241
20138002990	327950.4	7868022.6	0.043	-0.02	04082013	173128	40241
20138002752	311859.4	7807942.0	-0.005	-0.24	05082013	070914	40241
20138002749	300021.3	7808041.2	-0.052	-0.20	05082013	071538	40241
20138002637	224114.8	7808279.5	-0.005	-0.45	05082013	075914	40241
20138003023	220021.0	7807968.8	-0.047	-0.59	05082013	080546	40241
20138003039	212026.7	7856032.2	-0.055	0.05	05082013	084522	40241
20138002907	207895.6	7855823.4	-0.067	-0.17	05082013	085138	40241
20138002908	203787.6	7855844.0	0.000	0.09	05082013	085458	40241
20138002905	204055.7	7860041.0	0.043	0.31	05082013	085820	40241
20138002906	208141.9	7859848.6	0.026	-0.05	05082013	090204	40241
20138003042	211855.2	7860062.7	0.084	-0.15	05082013	090528	40241
20138003041	216041.5	7860004.7	0.018	-0.59	05082013	120628	40241
20138003042	211855.0	7860062.8	-0.073	-0.26	05082013	120952	40241
20138003039	212026.7	7856031.9	0.053	-0.25	05082013	121314	40241
20138003040	215841.5	7856030.3	-0.097	-0.42	05082013	121734	40241
20138003090	239955.2	7807968.9	0.078	-0.60	05082013	131202	40241
20138003096	324008.4	7807936.7	-0.021	-0.33	05082013	142410	40241
20138003151	324051.3	7868047.1	0.056	-0.74	05082013	151454	40241

STATION	MGAEAST	MGANORTH	REPEAT_ERROR ELEVATION_M	REPEAT_ERROR GRAVITY_µm/s^2	DATE_DDMMYY	TIME_HHMMSS	METERSN
20138002611	315926.3	7844038.3	-0.166	-0.86	05082013	175914	40241
20138002612	311924.6	7843842.8	0.028	-0.01	06082013	074026	40241
20138003296	296014.6	7903750.5	-0.097	-0.53	06082013	083513	40241
20138003295	295836.6	7907915.9	-0.088	-0.12	06082013	084142	40241
20138002626	224064.9	7883815.5	0.030	0.06	06082013	103356	40241
20138002710	227853.7	7884021.9	0.009	-0.20	06082013	112612	40241
20138003336	316036.6	7880045.9	0.007	-0.38	06082013	143006	40241
20138003335	316066.4	7868012.2	-0.063	-0.06	06082013	144052	40241
20138002612	311925.0	7843842.6	0.039	0.01	06082013	145708	40241
20138003332	311999.1	7820235.1	0.033	-0.64	06082013	151152	40241
20138002661	316074.2	7803934.8	-0.053	0.14	07082013	071308	40241
20138002752	311859.3	7807942.0	-0.026	0.36	07082013	071738	40241
20138003332	311998.9	7820235.0	-0.061	0.26	07082013	072412	40241
20138003092	268087.6	7808014.8	0.035	0.21	07082013	081610	40241
20138003091	255807.2	7807919.8	0.015	-0.70	07082013	082730	40241
20138002713	235968.7	7879963.3	-0.005	-0.02	07082013	095630	40241
20138003892	231894.1	7883999.0	-0.006	0.84	07082013	100030	40241
20138002710	227853.7	7884021.8	0.019	0.20	07082013	100338	40241
20138002626	224064.9	7883815.4	-0.015	0.82	07082013	100658	40241
20138002713	235968.8	7879963.2	0.033	-0.05	07082013	115106	40241
20138003977	231983.7	7832250.7	0.034	0.11	07082013	123330	40241
20138003332	311999.0	7820235.0	-0.049	0.74	07082013	135910	40241
20138002600	319347.1	7804924.8	-0.010	0.31	07082013	140654	40241
20138004050	304332.5	7823852.0	-0.044	0.68	08082013	071525	40241
20138002744	299986.7	7827740.9	-0.074	-0.13	08082013	072000	40241
20138004042	272131.1	7827906.6	0.024	0.33	08082013	074740	40241
20138004043	272363.9	7823912.9	-0.018	-0.37	08082013	075130	40241
20138004040	268299.7	7823979.4	-0.048	-0.86	08082013	075600	40241
20138004041	268121.8	7827962.6	-0.147	0.22	08082013	080004	40241
20138004050	304332.4	7823851.9	0.001	0.80	08082013	141344	40241
20138004152	296182.9	7831859.5	-0.052	0.51	08082013	141936	40241
20138004146	276048.0	7836083.5	-0.080	-0.71	08082013	143914	40241
20138004139	275918.3	7839839.5	-0.031	0.36	08082013	144328	40241
20138004138	276039.9	7843847.8	0.007	0.09	08082013	144648	40241
20138004137	271976.3	7843967.8	-0.047	0.05	08082013	145010	40241
20138002720	260043.5	7875915.0	-0.015	-0.82	08082013	152540	40241
20138002719	259878.5	7880012.6	-0.041	0.16	08082013	152906	40241
20138004153	308017.8	7815951.1	0.027	0.56	08082013	182222	40241
20138004153	308017.6	7815951.4	-0.040	-0.45	09082013	071034	40241
20138004216	308143.2	7827608.7	-0.057	-0.42	09082013	071716	40241
20138002614	303780.4	7843944.9	-0.042	-0.15	09082013	072554	40241
20138002733	304045.2	7875780.9	0.040	-0.76	09082013	075726	40241
20138002616	299868.1	7883954.7	0.032	-0.16	09082013	103032	40241
20138004202	308180.9	7883860.4	-0.059	0.22	09082013	103920	40241
20138002733	304045.5	7875780.8	0.008	-0.08	09082013	104732	40241
20138002614	303780.5	7843944.8	-0.004	0.49	09082013	140622	40241
20138004334	283977.3	7792097.8	-0.021	0.58	09082013	174716	40241

STATION	MGAEAST	MGANORTH	REPEAT_ERROR ELEVATION_M	REPEAT_ERROR GRAVITY_µm/s^2	DATE_DDMMYY	TIME_HHMMSS	METERSN
20138004333	296051.6	7791960.9	0.007	-0.19	09082013	180454	40241
20138002663	295762.7	7787772.8	-0.010	0.39	09082013	180818	40241
20138002690	311982.2	7800007.5	-0.012	0.36	09082013	182520	40241
20138004332	307985.3	7791968.2	0.020	-0.33	10082013	072750	40241
20138004384	304115.7	7791972.8	-0.029	-0.15	10082013	073130	40241
20138004382	300024.7	7787981.2	-0.036	0.31	10082013	073652	40241
20138004375	280135.6	7784087.7	-0.085	-0.30	10082013	075846	40241
20138004372	276047.1	7783670.0	0.041	0.22	10082013	080408	40241
20138004374	280114.8	7779950.7	-0.003	-0.17	10082013	123346	40241
20138002664	284022.4	7779844.3	-0.016	0.29	10082013	123704	40241
20138004332	307985.2	7791968.4	-0.030	0.39	10082013	130816	40241
20138004153	308017.5	7815951.3	-0.067	-0.82	10082013	133418	40241
20138004216	308142.8	7827608.2	0.056	0.24	10082013	134008	40241
20138002615	299830.4	7843912.5	0.056	-0.09	10082013	135724	40241
20138002626	224065.1	7883815.3	0.030	-0.13	10082013	163352	40241
20138002616	299868.4	7883954.1	0.060	0.00	10082013	172700	40241
20138002615	299830.3	7843912.4	-0.041	0.08	10082013	174540	40241
20138004332	307985.6	7791968.0	0.020	0.41	11082013	073758	40241
20138004472	300037.2	7780132.7	0.024	0.17	11082013	074526	40241
20138004469	296035.2	7779943.6	-0.038	0.19	11082013	074952	40241
20138002664	284022.5	7779844.0	-0.021	0.53	11082013	075710	40241
20138004374	280115.3	7779950.4	0.055	-0.11	11082013	080108	40241
20138004373	275930.9	7779786.8	0.023	0.06	11082013	080522	40241
20138002669	224028.2	7755956.9	0.006	0.22	11082013	094852	40241
20138002665	272041.3	7771822.9	-0.039	0.30	11082013	132646	40241
20138004469	296034.9	7779943.5	0.011	-0.74	11082013	134922	40241
20138004472	300037.0	7780132.7	-0.020	0.08	11082013	135236	40241
20138002755	319911.5	7787866.3	-0.124	0.16	11082013	144006	40241
20138002758	320070.1	7775922.7	-0.037	-0.16	11082013	144652	40241
20138002760	319808.1	7768056.8	-0.197	0.15	11082013	145214	40241
20138004676	324278.4	7783884.3	-0.023	0.21	12082013	073734	40241
20138004675	331983.1	7776056.9	-0.007	0.26	12082013	074336	40241
20138004674	340272.4	7768252.9	-0.063	0.49	12082013	074954	40241
20138004650	379986.6	7711966.3	0.031	-0.34	12082013	085556	40241
20138004674	340272.3	7768253.2	-0.115	-0.59	12082013	143146	40241
20138004676	324278.7	7783884.2	0.012	0.65	12082013	145306	40241
20138002754	320022.1	7791774.7	0.044	-0.17	12082013	145826	40241
20138004332	307985.4	7791968.1	-0.044	-0.11	13082013	073748	40241
20138004472	300037.2	7780132.9	-0.027	-0.45	13082013	074532	40241
20138004470	296068.5	7775990.9	-0.057	-0.93	13082013	074944	40241
20138002768	287917.6	7767868.7	-0.127	-0.66	13082013	075616	40241
20138002771	271947.8	7767914.5	-0.011	0.18	13082013	080404	40241
20138002666	259776.9	7767986.3	0.000	0.38	13082013	081108	40241
20138002667	243748.7	7767778.4	0.029	0.20	13082013	082012	40241
20138002666	259777.1	7767986.3	0.075	-0.52	13082013	120216	40241
20138002771	271947.8	7767914.3	0.009	0.63	13082013	121432	40241
20138002771	271947.8	7767914.5	0.039	0.57	13082013	140828	40241

STATION	MGAEAST	MGANORTH	REPEAT_ERROR ELEVATION_M	REPEAT_ERROR GRAVITY_µm/s^2	DATE_DDMMYY	TIME_HHMMSS	METERSN
20138002760	319808.0	7768057.5	0.074	-0.08	13082013	144911	40241
20138004676	324278.6	7783883.8	0.006	0.04	13082013	151314	40241
20138004676	324278.3	7783884.4	-0.032	0.19	14082013	072302	40241
20138004680	352311.9	7760080.4	0.009	0.02	14082013	074310	40241
20138004681	364058.9	7751897.8	-0.055	0.08	14082013	075124	40241
20138004918	396114.2	7731996.7	0.008	0.47	14082013	121019	40241
20138004683	380210.6	7747934.0	0.057	-0.32	14082013	123618	40241
20138004682	376015.9	7747919.0	-0.019	-0.09	14082013	124033	40241
20138004915	344038.6	7767948.3	-0.006	-0.05	14082013	133120	40241
20138004675	331983.2	7776057.0	-0.016	0.03	14082013	134742	40241
20138004676	324278.5	7783884.1	-0.044	-0.51	14082013	135408	40241
20138002755	319911.0	7787867.3	0.041	-0.64	14082013	140012	40241
20138004676	324278.6	7783883.9	0.009	-0.79	14082013	144443	40241
20138004777	332186.3	7772020.6	0.088	-0.61	14082013	145210	40241
20138002760	319808.1	7768057.7	0.144	0.23	14082013	182250	40241
20138002661	316074.3	7803934.9	0.029	0.48	15082013	071800	40241
20138002749	300020.7	7808042.1	0.025	-0.20	15082013	073130	40241
20138002637	224115.2	7808278.6	0.097	0.01	15082013	083108	40241
20138002669	224028.2	7755957.1	0.004	-0.38	15082013	091826	40241
20138004635	295866.9	7728068.3	0.037	0.17	15082013	103136	40241
20138002760	319808.6	7768057.7	0.099	-0.47	15082013	112130	40241
20138004675	331983.4	7776057.2	0.023	-0.27	15082013	121710	40241
20138004915	344038.5	7767948.0	-0.109	-0.43	15082013	122514	40241
20138004680	352312.0	7760080.5	0.007	-0.02	15082013	123204	40241
20138004681	364058.7	7751897.7	0.065	0.08	15082013	124106	40241
20138005112	391917.4	7727986.9	0.016	-0.68	15082013	155404	40241
20138004915	344038.2	7767948.8	0.120	-0.08	15082013	164856	40241
20138002755	319910.9	7787866.5	0.014	-0.12	15082013	170820	40241
20138004779	328028.4	7776173.3	-0.042	0.58	16082013	071022	40241
20138004915	344038.4	7767947.9	-0.077	-0.01	16082013	071928	40241
20138004680	352311.9	7760080.1	-0.037	-0.02	16082013	072548	40241
20138004681	364059.1	7751897.3	-0.012	0.06	16082013	073322	40241
20138004680	352312.0	7760080.1	0.026	-0.47	16082013	130229	40241
20138004777	332186.1	7772020.5	-0.021	0.75	16082013	132618	40241
20138002755	319911.3	7787866.8	0.048	-0.57	16082013	145226	40241
20138004779	328028.4	7776172.8	0.004	0.59	16082013	145926	40241
20138004674	340272.0	7768253.1	0.150	0.49	16082013	150710	40241
20138005108	315976.7	7784082.3	0.056	-0.25	17082013	071530	40241
20138004471	299845.6	7775967.4	-0.190	-0.70	17082013	072544	40241
20138005325	291982.9	7764032.9	0.038	0.29	17082013	110946	40241
20138002764	303861.9	7768015.6	0.014	-0.64	17082013	125259	40241
20138002758	320070.6	7775923.6	0.005	-0.38	17082013	130300	40241
20138002755	319910.8	7787867.3	-0.027	0.17	17082013	130948	40241
20138002755	319911.1	7787866.1	0.055	0.45	17082013	134430	40241
20138005108	315976.8	7784082.3	-0.012	0.44	17082013	134822	40241
20138005107	308062.9	7763998.0	-0.042	-0.04	17082013	135710	40241
20138002758	320070.2	7775923.0	-0.116	0.00	17082013	163852	40241

STATION	MGAEAST	MGANORTH	REPEAT_ERROR ELEVATION_M	REPEAT_ERROR GRAVITY_µm/s^2	DATE_DDMMYY	TIME_HHMMSS	METERSN
20138002755	319910.9	7787866.7	0.030	0.05	17082013	164526	40241
20138002755	319910.8	7787866.5	0.026	0.30	18082013	082504	40241
20138004779	328028.5	7776173.5	0.025	0.72	18082013	083316	40241
20138004650	379986.3	7711966.7	0.007	0.83	18082013	102902	40241
20138004635	295867.1	7728067.9	0.026	0.04	18082013	112916	40241

APPENDIX G
Repeat Listing: Multiple Control Station Observations

STATION	MGA94EAST	MGA94NORTH	REPEAT_ERROR ELEVATION_M	REPEAT_ERROR GRAVITY_µm/s^2	DATE_DDMMYY	TIME_HHMMSS	METERSN	GRVBASE	GPSBASE
20138001024	61714.311	7851886.127			11072013	165816	40240	20138000001	20138000100
20138001024	61714.261	7851886.283			16072013	173652	40240	20138000001	20138000100
20138001024	61714.204	7851886.337			20072013	080600	40240	20138000001	20138000100
20138001024	61714.531	7851886.209	-0.010		23072013	075908	40240	20138000001	20138000102
20138001025	61272.295	7863736.957			11072013	170538	40240	20138000001	20138000100
20138001025	61272.114	7863736.948			20072013	075613	40240	20138000001	20138000100
20138001025	61272.293	7863736.931	-0.037		23072013	075232	40240	20138000001	20138000102
20138001026	60908.827	7875870.879			11072013	171228	40240	20138000001	20138000100
20138001026	60908.858	7875871.038			20072013	074848	40240	20138000001	20138000100
20138001026	60908.982	7875870.914	-0.037		23072013	074502	40240	20138000001	20138000102
20138001027	60143.446	7887783.202			11072013	171926	40240	20138000001	20138000100
20138001027	60143.932	7887783.528			16072013	175114	40240	20138000001	20138000100
20138001027	60143.412	7887783.152			20072013	074159	40240	20138000001	20138000100
20138001027	60143.631	7887783.232	-0.022		23072013	073446	40240	20138000001	20138000102
20138001028	60024.073	7899888.709			11072013	172548	40240	20138000001	20138000100
20138001028	60024.261	7899888.875			12072013	092602	40240	20138000001	20138000100
20138001028	60024.353	7899888.587			20072013	073441	40240	20138000001	20138000100
20138001028	60024.122	7899888.826	0.016		26072013	150502	40241	20138000001	20138000001
20138001030	39292.756	7915170.663			11072013	174028	40240	20138000001	20138000100
20138001030	39293.181	7915170.214			12072013	091036	40240	20138000001	20138000100
20138001030	39293.073	7915170.745	-0.063		26072013	140200	40241	20138000001	20138000001
20138001080	108045.128	7901514.137			12072013	145412	40240	20138000001	20138000100
20138001080	108045.351	7901514.003			19072013	151607	40240	20138000001	20138000100
20138001080	108045.661	7901514.238	-0.067		25072013	181908	40241	20138000001	20138000001
20138001119	191991.068	7915988.999			13072013	100418	40240	20138000001	20138000101
20138001119	191990.984	7915989.067	-0.009	-0.51	03082013	101628	40241	20138000002	20138000104
20138001122	192025.173	7904134.159			13072013	101556	40240	20138000001	20138000101
20138001122	192025.196	7904134.100	0.049	-0.66	03082013	100314	40241	20138000002	20138000104
20138001124	191895.671	7895958.012			13072013	102622	40240	20138000001	20138000101
20138001124	191895.666	7895958.006	-0.014	-0.18	03082013	095232	40241	20138000002	20138000104
20138001130	192093.888	7872275.177			13072013	105052	40240	20138000001	20138000101

STATION	MGA94EAST	MGA94NORTH	REPEAT_ERROR ELEVATION_M	REPEAT_ERROR GRAVITY_µm/s^2	DATE_DDMMYY	TIME_HHMMSS	METERSN	GRVBASE	GPSBASE
20138001130	192094.128	7872274.877	-0.069	-0.54	03082013	092940	40241	20138000002	20138000104
20138001132	191988.516	7864166.188			13072013	110004	40240	20138000001	20138000101
20138001132	191988.805	7864165.947	0.001	-0.66	03082013	091938	40241	20138000002	20138000104
20138001447	195889.417	7748168.529			16072013	112830	40240	20138000001	20138000103
20138001447	195889.533	7748168.571	0.003	0.92	02082013	160000	40241	20138000002	20138000107
20138001453	195950.539	7772051.985			16072013	115224	40240	20138000001	20138000103
20138001453	195950.649	7772052.037	0.006	0.50	02082013	162222	40241	20138000002	20138000107
20138001457	195978.632	7788111.804			16072013	120844	40240	20138000001	20138000103
20138001457	195978.533	7788111.732	-0.029	0.75	02082013	163912	40241	20138000002	20138000106
20138001462	196001.438	7807985.419			16072013	122854	40240	20138000001	20138000103
20138001462	196001.473	7807985.201	0.044	-0.50	03082013	081836	40241	20138000002	20138000106
20138001464	195983.562	7816313.257			16072013	123654	40240	20138000001	20138000103
20138001464	195983.419	7816313.658	-0.012	-0.40	03082013	083300	40241	20138000002	20138000106
20138001469	196055.057	7836034.232			16072013	125506	40240	20138000001	20138000103
20138001469	196054.709	7836033.925	0.033	0.34	03082013	085340	40241	20138000002	20138000106
20138001598	99900.228	7905438.693			17072013	163458	40240	20138000001	20138000100
20138001598	99900.184	7905438.853	0.008		19072013	091649	40240	20138000001	20138000100
20138001598	99900.170	7905438.744	-0.060		25072013	182418	40241	20138000001	20138000001
20138001733	79250.093	7916399.578			19072013	084325	40240	20138000001	20138000100
20138001733	79249.916	7916399.534	0.055		19072013	153753	40240	20138000001	20138000100
20138001733	79250.204	7916399.495	0.066		24072013	134139	40240	20138000001	20138000100
20138001733	79250.261	7916399.679	-0.096		25072013	183350	40241	20138000001	20138000001
20138002290	51558.363	7911483.813			24072013	081356	40240	20138000001	20138000100
20138002290	51558.101	7911483.899	0.028	0.37	24072013	181621	40240	20138000001	20138000001
20138002611	315926.229	7844038.065			01082013	102446	40241	20138000002	20138000002
20138002611	315926.302	7844038.287	-0.166	-0.86	05082013	175914	40241	20138000002	20138000105
20138002637	224114.826	7808279.661			01082013	131734	40241	20138000002	20138000104
20138002637	224114.445	7808279.579	-0.049	0.63	02082013	080854	40241	20138000002	20138000106
20138002637	224114.976	7808279.468	-0.043	0.81	04082013	080218	40241	20138000002	20138000106

STATION	MGA94EAST	MGA94NORTH	REPEAT_ERROR ELEVATION_M	REPEAT_ERROR GRAVITY_µm/s^2	DATE_DDMMYY	TIME_HHMMSS	METERSN	GRVBASE	GPSBASE
20138002637	224114.759	7808279.481	-0.005	-0.45	05082013	075914	40241	20138000002	20138000106
20138002637	224115.207	7808278.550	0.097	0.01	15082013	083108	40241	20138000002	20138000107
20138002665	272040.549	7771823.214			01082013	160640	40241	20138000002	20138000002
20138002665	272041.266	7771822.862	-0.039	0.30	11082013	132646	40241	20138000002	20138000107
20138002668	228096.110	7767927.801			01082013	163008	40241	20138000002	20138000106
20138002668	228096.261	7767927.997	-0.116	0.30	02082013	142630	40241	20138000002	20138000107
20138002669	224027.765	7755957.428			01082013	164158	40241	20138000002	20138000106
20138002669	224028.168	7755957.288	-0.094	0.20	02082013	144000	40241	20138000002	20138000107
20138002669	224028.235	7755956.926	0.006	0.22	11082013	094852	40241	20138000002	20138000107
20138002669	224028.216	7755957.053	0.004	-0.38	15082013	091826	40241	20138000002	20138000108
20138002768	287917.422	7767868.968			02082013	133634	40241	20138000002	20138000002
20138002768	287917.606	7767868.675	-0.127	-0.66	13082013	075616	40241	20138000002	20138000108

APPENDIX H
Longman's Earth Tide Correction Formula

```
input dLat (latitude)
input dLon (longitude)
input dDate (date)
*Date broken down into year, month and date
input dTime (time)

array pClndr[12]={0,31,59,90,120,151,181,212,243,273,304,334}
lYr=year
lMo=month
lDa=day

ny=(lYr-1900)
days=(dTime/24.0+lDa-1+pClndr[lMo-1])
lLeap=(ny/4)
if(lLeap/2=ny and lMo<3)then lLeap=lLeap-1
lDay=(ny*365+lLeap+lDa+pClndr[lMo-1])
dcent = (ny*365.0+lLeap+days+0.5)/36525)
dhrs = (ny*365.0+lLeap+days+0.5)*24.0)
ds = (dcent*8399.7092 99+4.7200234 34+(dcent*dcent)*4.40696e-5)
dp=(dcent*71.01800936+5.835124713-(dcent*dcent)*1.80545e-4-dcent*2.1817e-
7*(dcent*dcent)
dh=(dcent*628.331950 9+4.88162792+(dcent*dcent)*5.27962e-6)
doln=(4.523588564-dcent*33.757153303+(dcent*dcent)*3.6749e-5)
dps=(dcent*0.030005264 16+4.908229461+(dcent*dcent)*7.902463e-6)
des=(0.01675104-dcent*4.18e-5-(dcent*dcent)*1.26e-7)
dsoln=(sin(doln))
dci=(0.91369-cos(doln)*0.03569)
dsi=(sqrt(1.0-(dci*dci))
dsn=(dsoln*0.08968/dsi)
dcn=(sqrt(1.0-(dsn*dsn))
dtit=(dsoln*0.39798/(dsi*cos(doln)*dcn+1.0dsoln*0.91739*dsn))
det=(atan(dtit)*2.0)
if (det<0.0)then det=det+6.2831852)

dolm1=(ds-doln+det+sin(ds-dp)*0.10979944)
dolm=(dolm1+sin((ds-dp)*2.0)*0.00376 7474+sin(ds-
dh*2.0+dp)*0.0154002+sin((ds-dh)*2.0)*0.00769395)
dha=((dTime*15.0-180)*0.0174532 92519 9+dLon/57.2957795 13)
dchi=(dha+dh-atan(dsn/dcn))
dal=(dLat/57.295779513)
dct=(sin(dal)*dsi*sin(dolm)+cos(dal)*((dci+1.0)*cos(dolm-dchi)+(1.0-
dci)*cos(dolm+dchi))/2.0)
dda=(cos(ds-dp)*0.14325+2.60144+cos((ds-dp)*2.0)*0.0078644+cos(ds-
dh*2.0+dp)*0.0200918+cos((ds-dh)*2.0)*0.0146006)
dr=(6.378388/sqrt((1.0-((cos(dal)*cos(dal))*0.00676902+1.0)
r_1=(dda)
r_2=(dct)
r_3=(dr)
r_4=(dda)
r_5=(dda*dda)
r_6=(dct)
dgm=(dr80.49049*dda*(r_1*r_1)*((r_2*r_2)*3.0-1.0)+(r_3*r_3)*7.4e-
4*(r_5*r_5)*dct*((r_6*r_6)*5.0-3.0))
dols=(dh+des*2.0*sin(dh-dps))
dchis=(dha+dh)
dds=((des*cos(dh-dps)+1.0)*0.668881/(1.0-(des*des)))
dcf=(sin(dal)*0.39798*sin(dols)+cos(dal)*(cos(dols-
```

APPENDIX I
Data Formats and Metadata

```
DEFN   ST=RECD,RT=COMM;RT:A4;COMMENTS:A76
DEFN 1 ST=RECD,RT=;PROJECT:F7.0:NULL=-9999.,UNIT=None,NAME=PROJECT
DEFN 2 ST=RECD,RT=;STATION:F12.0:NULL=-999999999.,UNIT=None,NAME=STATION
DEFN 3 ST=RECD,RT=;LATITUDE:F11.6:NULL=-99.999999,UNIT=Decimal Degrees,NAME=LATITUDE
DEFN 4 ST=RECD,RT=;LONGITUDE:F12.6:NULL=-999.999999,UNIT=Decimal Degrees,NAME=LONGITUDE
DEFN 5 ST=RECD,RT=;EASTING:F9.1:NULL=-99999.9,UNIT=metres,NAME=EASTING
DEFN 6 ST=RECD,RT=;NORTHING:F10.1:NULL=-999999.9,UNIT=metres,NAME=NORTHING
DEFN 7 ST=RECD,RT=;ELLIPSHTGRS80:F9.3:NULL=-999.999,UNIT=metres,NAME=ELLIPSHTGRS80
DEFN 8 ST=RECD,RT=;NAG09:F9.3:NULL=-999.999,UNIT=metres,NAME=NAG09
DEFN 9 ST=RECD,RT=;GRNDELEVATION:F9.3:NULL=-999.999,UNIT=metres,NAME=GRNDELEVATION
DEFN 10 ST=RECD,RT=;OBSGAAGD07:F12.2:NULL=-9999999.99,UNIT=µm/s^2,NAME=OBSGAAGD07
DEFN 11 ST=RECD,RT=;HTGM:F9.3:NULL=-999.999,UNIT=metres,NAME=HTGM
DEFN 12 ST=RECD,RT=;TCINNER:F7.2:NULL=-99.99,UNIT=µm/s^2,NAME=TCINNER
DEFN 13 ST=RECD,RT=;TCQFINNER:I4:NULL=-99,UNIT=None,NAME=TCQFINNER
DEFN 14 ST=RECD,RT=;TCOUTER:F7.2:NULL=-99.99,UNIT=µm/s^2,NAME=TCOUTER
DEFN 15 ST=RECD,RT=;TCQFOUTER:I4:NULL=-99,UNIT=None,NAME=TCQFOUTER
DEFN 16 ST=RECD,RT=;TCTOTAL:F7.2:NULL=-99.99,UNIT=µm/s^2,NAME=TCTOTAL
DEFN 17 ST=RECD,RT=;EFAA:F10.2:NULL=-99999.99,UNIT=µm/s^2,NAME=EFAA
DEFN 18 ST=RECD,RT=;SCBA267:F10.2:NULL=-99999.99,UNIT=µm/s^2,NAME=SCBA267
DEFN 29 ST=RECD,RT=;CSCBA267:F10.2:NULL=-99999.99,UNIT=µm/s^2,NAME=CSCBA267
DEFN 20 ST=RECD,RT=;HORIZDIST:F9.2:NULL=-9999.99,UNIT=metres,NAME=HORIZDIST
DEFN 21 ST=RECD,RT=;GRVBASE:F13.0:NULL=-9999999999.,UNIT=None,NAME=GRVBASE
DEFN 22 ST=RECD,RT=;GPSBASE:F13.0:NULL=-9999999999.,UNIT=None,NAME=GPSBASE
DEFN 23 ST=RECD,RT=;TIME:A9:,UNIT=None,NAME=TIME
DEFN 24 ST=RECD,RT=;DATE:A9:,UNIT=None,NAME=DATE
DEFN 25 ST=RECD,RT=;MGAZONE:F4.0:NULL=-9.,UNIT=None,NAME=MGAZONE
DEFN 26 ST=RECD,RT=;GMTYPESN:A30:,UNIT=None,NAME=GMTYPESN
DEFN 27 ST=RECD,RT=;STATIONDESC:F20.0:NULL=-99.,UNIT=None,NAME=STATIONDESC;END DEFN
DEFN 29 ST=RECD,RT=;COMMENTS:F20.0:NULL=-99.,NAME=COMMENTS;END DEFN
DEFN 1 ST=RECD,RT=PROJ; RT:A4
DEFN 2 ST=RECD,RT=PROJ; PROJNAME:A30: COMMENT=GDA94 / MGA zone 53
DEFN 3 ST=RECD,RT=PROJ; ELLPSNAM:A30: COMMENT=GRS 1980
DEFN 4 ST=RECD,RT=PROJ; MAJ_AXIS: D12.1: UNIT=m, COMMENT=6378137.000000
DEFN 5 ST=RECD,RT=PROJ; ECCENT: D12.9: COMMENT=298.257222
DEFN 6 ST=RECD,RT=PROJ; PRIMEMER: F10.1: UNIT=deg, COMMENT=0.000000
DEFN 7 ST=RECD,RT=PROJ; PROJMETH: A30: COMMENT=Transverse Mercator
DEFN 8 ST=RECD,RT=PROJ; PARAM1: D14.0: COMMENT=      0.000000
DEFN 9 ST=RECD,RT=PROJ; PARAM2: D14.0: COMMENT=    135.000000
DEFN 10 ST=RECD,RT=PROJ; PARAM3: D14.0: COMMENT=      0.999600
DEFN 11 ST=RECD,RT=PROJ; PARAM4: D14.0: COMMENT= 500000.000000
DEFN 12 ST=RECD,RT=PROJ; PARAM5: D14.0: COMMENT=10000000.00000
DEFN 13 ST=RECD,RT=PROJ; PARAM6: D14.0:
DEFN 14 ST=RECD,RT=PROJ; PARAM7: D14.0:
DEFN 15 ST=RECD,RT=PROJ; END DEFN
```

```
COMM ATLAS GEOPHYSICS PTY LTD ASEG-GDF2 FORMAT FILE
COMM WWW.ATLASGEO.COM.AU
COMM INFO@ATLASGEO.COM.AU
COMM
COMM ATLAS PROJECT NUMBER            P2013036
COMM GA PROJECT NUMBER               201380
COMM CLIENT                          GA
COMM PROJECT AREA                    SOUTHERN WISO BASIN
COMM START DATE                      11072013
COMM END DATE                        18082013
COMM PROCESSED BY                    LR MATHEWS
COMM
COMM VESSEL                          HELICOPTER ROBINSON R44
COMM OPERATORS                       GEOSCIENCE AUSTRALIA / NTGS
COMM OBSERVERS                       CR, TW
COMM
COMM MIN SPACING                     4000m
COMM MAX SPACING                     4000m
COMM LAYOUT                          CELL CENTRE
COMM
COMM GRAVITY STATIONS                3857
COMM
COMM GEODETIC DATUM                  GDA94
COMM PROJECTION                      MGA53
COMM HORIZ ACCURACY                  0.05 m
COMM
COMM VERTICAL DATUM                  GRS80
COMM VERTICAL ACCURACY               0.05 m
COMM
COMM GRAVITY DATUM                   AAGD07
COMM GRAVITY ACCURACY                0.4 µm/s^2
COMM
COMM GRAVITY INSTRUMENT              SCINTREX CG5
COMM GRAVITY SN                      40240,40241
COMM GPS INSTRUMENT                  LEICA GPS1200
COMM GPS METHOD                      PPK
COMM
COMM GPS BASE                        20138000001, 20138000002,20138000100-20138000109
COMM GRV BASE                        20138000001, 20138000002
COMM CTRL TIE STATION                1999929064, 1967930134
COMM
COMM PROCESSING
COMM DRIFT CORRECTION
COMM ETC CORRECTION                  LONGMAN
COMM NORMAL GRAVITY                  9780326.7715*((1+0.001931851353*(SIN(B3*(PI()/180)))^2)/(SQRT(1-0.0066943800229*(SIN(B3*(PI()/180)))^2)))
COMM ATMOSPHERIC CORRECTION          8.74-0.00099*F3+0.0000000356*F3^2
COMM FREE AIR CORRECTION             -(3.087691-0.004398*SIN(LAT)^2)*ELLIPSHT+0.00000072125*ELLIPSHT^2
COMM SCAP BOUGUER CORRECTION         2*PI*Gp((1+µ)*ELLIPSHT-LAMBDA*R) for p=2.67 t/m^3
COMM TERRAIN CORRECTION METHOD       RASTERTC
COMM
COMM SOFTWARE                        AGRIS(IN HOUSE), WAYPOINT840, CHRISDBF, ERMAPPER, RASTERTC
COMM
COMM
COMM DETAILED COLUMN DESCRIPTIONS
COMM COLUMN NAME                     COLUMN DESCRIPTION                                          UNITS
COMM
COMM PROJECT                         GA PROJECT NUMBER                                           NONE
COMM STATION                         GA STATION NUMBER                                           NONE
COMM LATITUDE                        COORDINATE LATITUDE GDA94                                   DECIMAL DEGREES
COMM LONGITUDE                       COORDINATE LONGITUDE GDA94                                  DECIMAL DEGREES
COMM EASTING                         COORDINATE EASTING MGA/GDA94                                M
COMM NORTHING                        COORDINATE NORTHING MGA/GDA94                               M
COMM ELLIPSHTGRS80                   COORDINATE ELEVATION ELLIPSOIDAL GRS80                      M
COMM NAG09                           GEOID ELLIPSOID SEPARATION AUSGEOID09                       M
COMM GRNDELEVATION                   GROUND LEVEL ELEVATION                                      M
COMM OBSGAAGD07GU                    OBSERVED GRAVITY AAGD07                                     µm/s^2
COMM HTGM                            STATION HEIGHT OF GRAVITY METER                             M
COMM TCINNER267                      INNER ZONE TERRAIN CORRECTION 2.67 t/m^3                    µm/s^2
COMM TCINNER230                      INNER ZONE TERRAIN CORRECTION 2.30 t/m^3                    µm/s^2
COMM TCQFINNER                       QUALITY FACTOR OF INNER ZONE TERRAIN CORRECTION             NONE
COMM TCOUTER267                      OUTER ZONE TERRAIN CORRECTION 2.67 t/m^3                    µm/s^2
COMM TCOUTER230                      OUTER ZONE TERRAIN CORRECTION 2.30 t/m^3                    µm/s^2
COMM TCQFOUTER                       QUALITY FACTOR OF OUTER ZONE TERRAIN CORRECTION             NONE
COMM TCTOTAL267                      TOTAL TERRAIN CORRECTION  2.67 t/m^3                        µm/s^2
COMM EFAA                            ELLIPSOIDAL FREE AIR ANOMALY                                µm/s^2
COMM SCBA267                         SPHERICAL CAP BOUGUER ANOMALY 2.67 t/m^3                    µm/s^2
COMM CSCBA267                        COMPLETE SPHERICAL CAP BOUGUER ANOMALY 2.67 t/m^3           µm/s^2
COMM HORIZDIST                       HORIZONTAL DISTANCE FROM PROGRAMMED STATION                 M
COMM GRVBASE                         GRAVITY BASE STATION REFERENCED TO                          NONE
COMM GPSBASE                         GPS BASE STATION REFERENCED TO                              NONE
COMM TIME                            TIME OF GRAVITY OBSERVATION                                 NONE
COMM DATE                            DATE OF GRAVITY OBSERVATION                                 NONE
COMM MGAZONE                         MGA ZONE NUMBER                                             NONE
COMM GMTYPESN                        GRAVITY METER TYPE SERIAL                                   NONE
COMM STATIONDESC                     STATION DESC                                                NONE
COMM COMMENTS                        COMMENTS                                                    NONE
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