INFILL GRAVITY SURVEY OF NORTH WESTERN TASMANIA

For MINERAL RESOURCES TASMANIA

BY Integrated Mapping Technologies Pty Ltd

Reg Court
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Contents

FIGURES IN TEXT

TABLES IN TEXT

APPENDICES AT REAR

1 INTRODUCTION

Integrated Mapping Technologies Pty Ltd (IMT) has conducted a regional gravity survey over an area in North Western Tasmania for Mineral Resources Tasmania (MRT). The location of the survey is defined in Figure 1 hereto. The objective of the survey was the densification of gravity observations to improve the resolution of geological models of the region.

In the course of conducting the work, IMT established a 2nd Order gravity base Station at Britton Swamp, near Smithton in the North West. Routine gravity observations were made relative to the existing fundamental gravity network, incorporating the new base station, at intervals of approximately one kilometer along roads and tracks (including farm tracks). Stations were located and leveled to a high level of precision and accuracy using GPS surveying techniques and the AUSPOS Space Geodesy service of Geoscience Australia.

All new gravity stations have been terrain corrected by Dr David Leaman of Leaman Geophysics Pty Ltd in Tasmania.

A total of 1 new gravity base station and 220 new gravity stations were observed in the course of the North Western survey. The precision of observations can be summarized as:

GPS Survey Observations:-	20mm +/- 1ppm
Gravity Observations:-	+/-0.01mgals

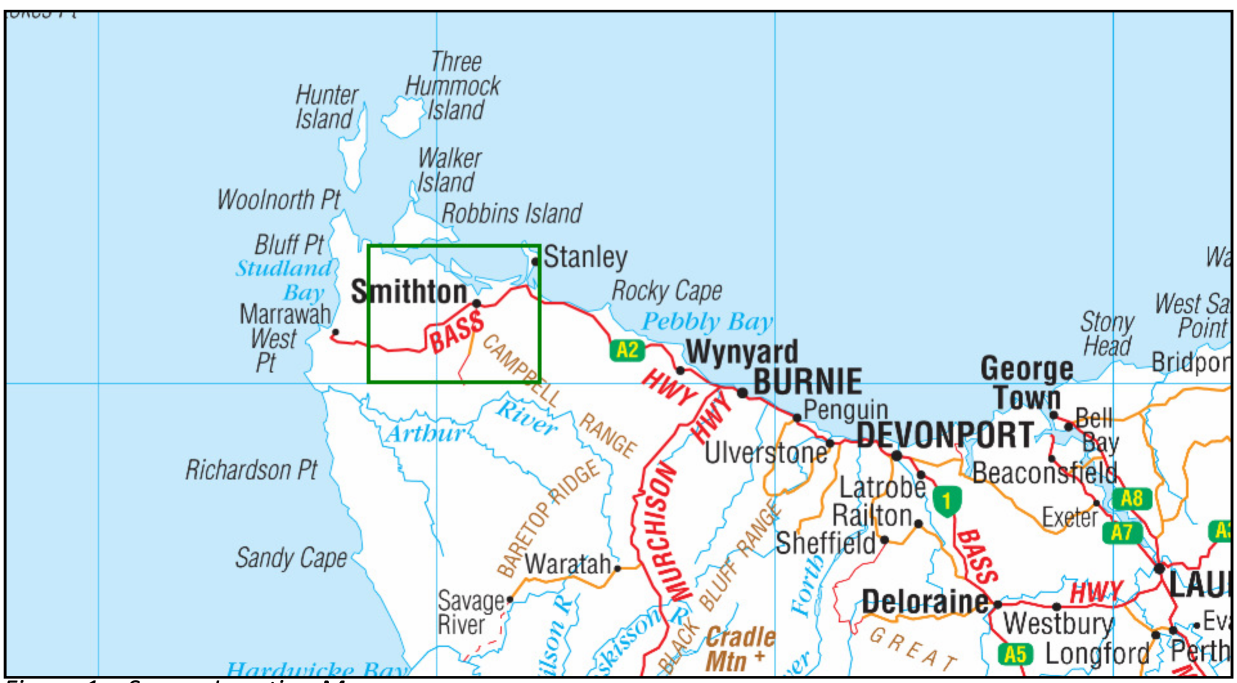

Figure 1 – Survey Location Map

2 INSTRUMENTATION & EQUIPMENT

2.1 SURVEYING INSTRUMENTS

- 2 x Sokkia GSR2700 ISX Dual Frequency GPS/GLONASS geodetic RTK receivers with 72 universal GNSS channels, high performance RTK algorithms enabling +40km RTK baselines, in-built RTK radio communications and “Bluetooth” wireless technology.
- Survey Controller - Allegro CX with “Bluetooth” wireless technology.
- Base Radio Repeater - Satel Satteline 3AS Epic 10W Base Radio for long range RTK operations.
- A range of tribrachs, tripods, bipods and vehicle GPS antennae mounting system mounting system.
- Solar panel for charging GPS base station battery.

2.2 GRAVITY METER

LaCoste & Romberg Model G Land Gravity Meter Serial Number G517. Gravity observations were recorded on the Allegro CX survey data recorder.

2.3 FIELD COMPUTING SYSTEM

- Panasonic “Tuff Book” CF19 Mk1 computer with:-
    - Intel Pentium dual coreU2400 1.6Ghz CPU
    - 10.4” XGA daylight readable touch screen convertible to tablet mode
    - 1.5GB DDR2 SDRAM
    - Shock mounted 80GB SATA HDD
    - Serial Port, SD card slot, express card slot, Firewire Port, 2xUSB 2.0ports, internal modem, 802.11 a+b+g WLAN and integrated “bluetooth”
    - vehicle dashboard mounting
- Cannon BJC4550 A3 printer/plotter
- 120GB external HDD back-up system
- External DVD Writer

3 SOFTWARE

3.1 SURVEYING & NAVIGATION

- Sokkia SPECTRUM Versions 3.75 & 4.00 GPS post processing, analysis and network adjustment package.
- NOVATEL Convert4 package to convert GPS & GLONASS data to Rinex Format in AUSPOS compatible format.
- Carlson SurvCE Version 2 data collector software
- Carlson Field 2007 Standalone (used in this case to display GIS data for navigation and landowner database.

3.2 GRAVITY

The gravity reduction software utilized by IMT was a package of programs developed by Surtec Geosurveys Pty Ltd. Specific programs used in data reductions are listed and described below:-

GRAVRED: This program takes a field gravity file (output from GRAVIN) and computes observed gravity and normal gravity by applying corrections for instrument factor then tide and then drift against known bases (in separate file) to give observed gravity. Latitude corrections are then computed from AMG coordinates converted to UTM to give normal gravity.

The program can be used on local grids (with skewed azimuth) or with AMG co-ordinates. A local or ISOGAL84 gravity datum can be used.

Tide corrections for each gravity station are computed within the gravred program using an upgraded variation of the BMR's program ERTIDE1. Tide corrections are applied before drift corrections.

After application of tide corrections, the data is scanned for base stations (defined by co-ordinate in a base station file) or repeat stations which are then flagged (unless disabled for the purposes of testing repeatability). Each base is then examined and assigned a value that is a linear interpolation of known drift on either side of it. Each of these is then assigned a weight that is the inverse of the product of the time to the adjacent known values. For each base station, the weights are summed and a weighted average of assigned values calculated. The base with the most weight is then given the true value of the weighted average and is flagged as another known station. This process is repeated until all the repeated stations are assigned values.

These stations are then used to correct the rest of the data.

Latitude corrections are computed (in this case) using the formula:

Latitude correction = $978031.8(1 + 0.0053024\sin^2 q - 0.0000059\sin^2 2q)$
(where q = latitude)

Dependant on input data and requirements, the following outputs are written to separate files

nnnn.CHK	A formatted file of raw gravity observations.
nnnn.COR	A file listing station number, co-ordinate, elevation, tide, drift and latitude corrections with observed gravity.
nnnn.ABS	A file listing XY co-ordinates and observed gravity.
nnnn.UTM	A file listing principal facts.
nnnn.RED	A file listing station number, co-ordinate, elevation, Terrain corrections (output from separate program) and normal gravity - input to BOUGUER for Bouguer reductions.
BOUGUER:	This program follows GRAVRED (and TERRAIN) and calculates the free air and Bouguer effects. Provision is made for calculating the density which gives the flattest final gravity including terrain effects.

The formula used for free air and Bouguer corrections is as defined in BMR publication No. 261 by Wellman, Barlow and Murray, 1985 (Gravity Base Station Network Values, Australia)

3.3 OTHER SOFTWARE

- SURFER Version 8
- TEXTPAD Version 5
- MICROSOFT Office EXCEL 2007
- MICROSOFT Office WORD 2007
- TEXTPAD Version 5

4 METHODOLOGY

4.1 PROJECT ESTABLISHMENT

On award of contract, MRT provided IMT with a GIS compatible regional database of topography, hydrography, infrastructure, the Cadastre and planned gravity station locations for the project area.

Before commencing fieldwork, the regional data base was imported to the "Carlson Standalone" software on the field computer system. The software was configured to provide IMT field personnel with "real time" navigation and visualization of existing gravity stations and cadastral data. MRT produced and delivered hardcopy 1:25,000 scale topographic maps and a range of Forestry Maps for use in the daily planning of fieldwork.

4.2 GRAVITY METER CALIBRATION

Prior to commencement of the survey, and on completion, the calibration of the gravity meter was tested on the Canberra Gravity Range by ABABA tie using station 6491.0304 (UNI CS1) and 7691.0204 at Mt Ainslie. The actual interval for this range is 54.75mGals. The interval determined before the survey was 54.75mGals and on completion of the survey was 54.73mGals. The meter displayed slightly more drift in the second calibration test. Results of the calibration tests are included in Appendix 1 hereto.

4.3 GRAVITY CONTROL NETWORK

Gravity base station observations were made as an ABABA tie between the new base located at Britton Swamp and the Fundamental Gravity Base Station (FGBS) located at Smithton A/S Terminal (6491.9142) using a single LaCoste and Romberg gravity meter (serial number 517).

The observation of ABABA tie was corrected for instrument factor, then tide then drift to derive 3 changes in gravity for the interval. These 3 changes in gravity was then summed and averaged to derive an adopted value for the new base. Instrument Factors for the gravity meter are listed in Appendix Two and the reduction of the ABABA tie is listed in Appendix Three.

4.3.1 Secondary Gravity Bases

All routine gravity observations were made relative to base stations described above. No secondary base stations were established in the course of the survey.

4.3.2 Base Station Values

Table 1 hereunder lists the adopted values of the new gravity base station. Recovery information for the new gravity base station is set out hereunder as APPENDIX 4.

Table 1. **NEW GRAVITY BASE STATION**						03- 2008
Pt No	***AGD66 E***	***AGD66 N***	***AHD71***	***Mark Details***	***Location***	***Obs Gravity***
9100	328,796.38	5,464,154.14	44.577	SPM6596	Pokes Hill	980,277.07

4.4 SURVEY CONTROL

All new gravity stations were coordinated and leveled from newly established marks whose position was determined with the AUSPOS Space Geodesy absolute positioning technique using logged GPS reference station observations. One of the 2 new stations, 1083, was located close by the existing 4th Order trig heighted trigonometric station ST 1083 at Pokes Hill Eccentric RM2.

AUSPOS processing reports are attached hereto as Appendix 5.

No control traversing or network adjustment was attempted or was necessary.

New stations were established where there were no available existing survey marks of acceptable Class and Order. They were positioned such that base lines to gravity stations were generally kept under 10kms in length although some were up to 27kms long. Also, bases were positioned where possible to provide a clear unimpeded view of the sky and if possible a high position to improve line of sight radio coverage for Real Time Kinematic (RTK) survey procedures.

4.4.1 AUSPOS Processing.

Where a GPS base station was placed at a new mark, data were downloaded to computer after the first full days observation from the new reference station. Reference station data were converted to RINEX format using the NOVATEL program Convert4. In the process of this conversion, data was de-sampled to 30 second epochs and all GLONASS data was stripped out.

RINEX data was subsequently Emailed to GA and was processed quickly with results generally being received within a couple of hours of dispatch. The processing report was examined to evaluate the estimated coordinate precision, the Root Mean Square error and the percentage of data deleted before accepting or rejecting the AUSPOS determination of station coordinate and elevation.

AUSPOS Processing Reports are herewith as Appendix 5.

4.4.2 Survey Control Summary

Table2 below summarizes the survey control used to coordinate and level new gravity stations. The coordinates and elevations of both stations were determined using AUSPOS positioning. The Coordinate and elevation for Stn ST1083, RM2 was the average of 4 determinations.

Table 2 **SURVEY CONTROL SUMMARY** Mar-08

Pt No	*AGD66 E*	*AGD66 N*	*AHDTas83*	*Mark*	*XY Class*	*XY Order*	*Z Class*	*Z Order*	*Location*
8100	327,825.65	5,464,508.06	89.590	60cm SIP	GPS				Rainbow Hill
1083	341,965.57	5,472,853.98	80.435	ST1083 RM2	GPS				Pokes Hill

4.5 ROUTINE OPERATIONS

4.5.1 Access & Landowner Contact

Access permits were provided by MRT for Tasmanian National Parks and State Forestry areas. In the course of conducting the survey, it was also necessary to access private land. Where this was required, IMT personnel were required to contact the landowner and seek permission to enter. The process involved in identifying landowners was:-

- Plan the work several days in advance and identify land parcels to which access was required.
- Contact MRT and request identification of relevant landowners from an internal MRT database (the "List"). Information was generally provided within 24 hours.
- The landowner was then contacted by phone and asked to give permission for access.

Where permission was denied, the planned station was abandoned.

4.5.2 Overview

The field crew mobilized to the project area in North West Tasmania on the 6th of February, 2008. On the 7th February, the crew set up a new second order gravity base station (9100) at Britton Swamp adjuacent to the existing survey mark SPM6596 by establishing an ABABA tie between the new base and the FGBS at Smithton Aerodrome. The crew then commenced routine observations which continued until the 16th February at which time the crew demobilized.

Fieldwork was conducted by Senior IMT technician Richard Duggan and trainee technician Chris Jackson. Operations were based from hotels and motels and were conducted using a Toyota Landcruiser trayback 4WD fitted with an on-board computer based navigation and GIS for transport.

4.5.3 Typical Daily Routine

The typical daily routine of the field crew under ideal conditions may be summarized as:-

- The crew would depart their operations base and move to the gravity base station from which they planned working from for the day.
- At the base station, the operator would check the adjustment of the gravity meter, then read and record 2 gravity observations at intervals of around 5 minutes.
- The crew would then drive to the planned location for the GPS reference station (if not coincident with the gravity base), set the base receiver up and switch it on to record 1 second epochs of data in Kinematic survey mode. If a new base was being set up. A recovery sketch would be made and photos of the location would be taken.
- The Gravity operator would then commence observation of routine stations within a radius of generally less than 10km (but up to 27km) of the GPS reference station.
- The length of GPS observations was determined by the distance from the Reference Station, the number of observable satellites and satellite geometry.
- Navigation to planned stations was by means of the GPS survey system, an onboard computer and a GIS data base of the regions topography, cadastre and existing gravity stations.

- After approximately 1.5 hours of routine observation, the operator would move to the last repeat station observed the previous day (RptA)and re-observe gravity (RptB) then resume routine operations. In nearly all repeat gravity observations, only an autonomous GPS fix was attempted so as to minimize time lost in the repeat observation process.
- After a further period of approximately 1.5hrs gravity observation, a gravity station was marked for repeat observation in the next loop and gravity was observed (rpt A).
- After a further 1.5hrs of observation, the operator returned to the base station he was operating from (or an alternative) and observed gravity to close the gravity loop then had a short break for lunch.
- After lunch, observation of the next gravity loop was commenced and routine observations were conducted for 1.5 hours followed by return to the last repeat station observed in the morning loop (rpt A) at which a repeat gravity observation was made (RptB).
- Routine observations were then conducted for a further 1.5 hours at which time a station was marked as a repeat station for re-observation of gravity in the first loop of the following day (RptA).
- Routine gravity observations were then made for a further 1.5hrs followed by a return to the GPS Reference Station which was then shut down and packed up.
- If not coincident with the GPS Base, the crew next travelled to the Gravity base in use and twice observed gravity to close the second loop of the day.
- Operators then returned to base to download and process data.
- As processing was being carried out by one operator, the other operator was generally engaged in planning access routes for work over the next few days, in contacting landowners regarding permission to access their land and identifying land parcels for which contact details were required.

Note 1:
The repeat observation procedure ensures, as far as it is practically possible, that each gravity loop is tied to both the last and next loop providing a rigorous test of repeatability. The process also provides opportunities to recover data within a loop in the event of a tare in the gravity data.

Note 2:
GPS observations were made in kinematic mode (with continuous recording of data between stations) but processed as Static observations. - this strategy allowed us to achieve a higher level of precision with short occupation times and facilitated several different processing strategies in the event of poor data.

Note 3:
The recently released (April 08) Version 4.00 of the SPECTRUM GPS post processing software has created opportunities to re-process GPS data and potentially recover some of the abandoned stations.

4.5.4 Data Processing On Site

For a number of reasons (see 4.5.2 above), it was not feasible to do any more than basic processing of gravity data on site to test drift levels and check for the presence of tares in the data.

The onsite processing stream was therefore limited to:-

- Downloading of GPS receivers to computer
- Downloading of the Allegro data logger on which RTK observations and gravity observations were stored.
- Formatting and processing of gravity data using "autonomous' GPS coordinates and elevations to check for excessive drift and/or tares.
- Copying of files to disk for posting to Sydney Office.

5 DATA PROCESSING IN SYDNEY

5.1 GENERAL

Data was dispatched twice weekly by Express Post. As data was received, it was downloaded to individual day directories; each with sub directories for paperwork, gravity data, GPS data and GPS Processing. Data logged at new GPS reference stations was identified and processed to RINEX Format using the Novatel CONVERT4 software then dispatched to GA for determination of a station coordinate and elevation using the AUSPOS Space Geodesy service (see section 4.4)

5.2 ROUTINE SURVEY DATA PROCESSING

Once the results of AUSPOS processing were received, a SPECTRUM "Project" was created in the relevant "day" directory. GPS Data were imported to the project. Vectors from the reference station to each gravity observation were developed then checked and edited. After fixing the coordinates and elevation of the reference station (AUSPOS coordinates and height), GPS vectors were processed and adjusted to derive coordinates and elevations for each gravity station.

A processing summary was automatically generated for checking and was subsequently saved and printed. The summary detailed, on a vector by vector basis, the type of processing solution achieved, the length of the vector, the percentage of GPS data used, the Ratio, Root Mean Square (RMS) error and the Standard Deviation (SD).

This summary information was examined and, where solution type or statistics indicated a poor solution for a vector, a range of evaluations were carried out to see whether there may be an alternative processing strategy available for individual problem vectors. Evaluations included:-

- Number of satellites
- Raw satellite data
- Vector residuals
- Frequency and timing of cycle slips etc

Depending on the evaluation of each problem vector, processing parameters were varied in an attempt to achieve a FIXED solution for each vector and/or improve each solution achieved. Some of the processing parameter variations included start and end time of observation, varying the elevation mask and in some cases, switching off specific satellites.

Once GPS processing solutions had been optimized, a summary solution file listing point number, AMG Zone 55 – AGD66 easting and Northing and AHD (Tas) 1983 orthometric heght was exported to the "day" directory as a *.CSV file.

It should be noted that where stations achieved an RTK "FIXED" solution, the data was manually adjusted by an XYZ Block shift within an EXCEL Spreadsheet when daily data was being merged into blocks (see below). This was because there was insufficient data to process the raw data through SPECTRUM.

5.3 ROUTINE GRAVITY DATA PROCESSING

A summary raw gravity data file was compiled as an EXCEL spreadsheet. To this, processed and adjusted survey data were merged with gravity observations. The compiled file listed gravity observations and adjusted station coordinates and elevations, adjustment calculations for RTK survey observations, repeat gravity observations, the type of survey observation/solution achieved for each station, the location of the GPS reference station and gravity base station and any modifications made to data after it was received in Sydney (corrections). This file is appended hereto as Appendix 6.

Block gravity observations were next exported from the summary spreadsheet in a space delimited file ready for processing in the Surtec gravity reduction program GRAVRED.

Before processing, however, coordinates used on *gravity only* repeat observations were varied by a few centimeters to ensure they were not treated as secondary base stations as Surtec gravity reduction software recognises base stations by co-ordinate. If repeat observations have the same coordinate, they are treated as being secondary bases.

Merged gravity and survey observations were then corrected for instrument factor, then tide and then drift against adopted base station values using the program GRAVRED which output files of corrections applied and observed gravity (.COR), normal gravity (.RED) and a listing of observed gravity values with geographic coordinates (.UTM). Repeat gravity and GPS observations were noted then averaged in the RED files.

RED files were then shipped to Dr Leaman for the computation of Terrain Corrections.

5.4 REPEAT GRAVITY OBSERVATIONS

A total of 186 observations were made at repeated gravity stations A listing of repeat gravity station observations is appended hereto as Appendix 7. Observed gravity values for each repeat station are listed along with the average value of each repeat station and the deviation of each repeat. The Standard Deviation of repeat observations was computed to be 0.020mGals.

5.5 COMPILATION OF DATA IN MRT FORMAT

Once final terrain corrections were received, a space delimited TXT file was compiled listing Station Number, Easting and Northing (AMGZ55, AGD66 in meters), Orthometric Height (AHD 1983 Tas. In meters), Observed Gravity (ISOGAL65 in mGals) and Terrain Correction computed at a density of 2.67g/cc in mGals.

6 ESTIMATED PRECISION & ACCURACY

6.1 PRECISION OF OBSERVATIONS

The precision of observations can be summarized as:

GPS Survey Observations:-	20mm +/- 1ppm
Gravity Observations:-	+/-0.01mgals

6.2 ESTIMATED ACCURACY OF CONTROL NETWORKS

- Based on an examination of miscloses and error distribution in closed gravity control loops, the estimated accuracy of gravity base stations is +/-0.01mgals.
- Based on an examination of repeated processing of GPS Base Station data using the AUSPOS Space Geodesy Processing Service, the estimated accuracy of GPS Reference Stations is +/-15mm in coordinate and +/-30mm in elevation

6.3 ESTIMATED ACCURACY OF ROUTINE OBSERVATIONS

- Based on the standard deviation of repeated gravity observations, the estimated accuracy of routine gravity stations is +/-0.012mGals.
- No meaningful attempt was made to obtain repeat determinations of gravity station coordinates and elevations because of time constraints. The accuracy of all static survey observations was estimated and reported in summary form by the processing software. In general terms, the accuracy of FIXED 3D solutions is better than 10mm and of FLOAT solutions is better than 250mm.

7 DATA DISK

A data disc has been prepared and is inserted at the rear of this report. The contents of the disc are summarized below:

TABLE 3:
COMPUTER FILES ON DISK

DIRECTORY	FILE NAME	CONTENTS
00_Data_MRT_Format	MRT_NWTAS_07-08_Comp@267	Text file listing ISOGAL65 Observed Gravity in mGals and Terrain Corrected Gravity using a density of 2.67g/cc
Compilations	NWcomp.XLS	Compilation of Gravity Observations and survey sol'n
02_AUSPOS	7 *.PDF Files – 8100A&B 1083A-E	7 AUSPOS Processing Reports: File No = Stn No
03_Base_Network_Obs	Basecon.txt	Compilation of raw gravity observations - base connection
	Basecon.COR	Ins't factor, tide and drift corrections, obs'd gravity - base net
04_Report	Sub-Directory Appendices	Multiple Files
	Sub-Directory Recovery Sketches	Multiple Files