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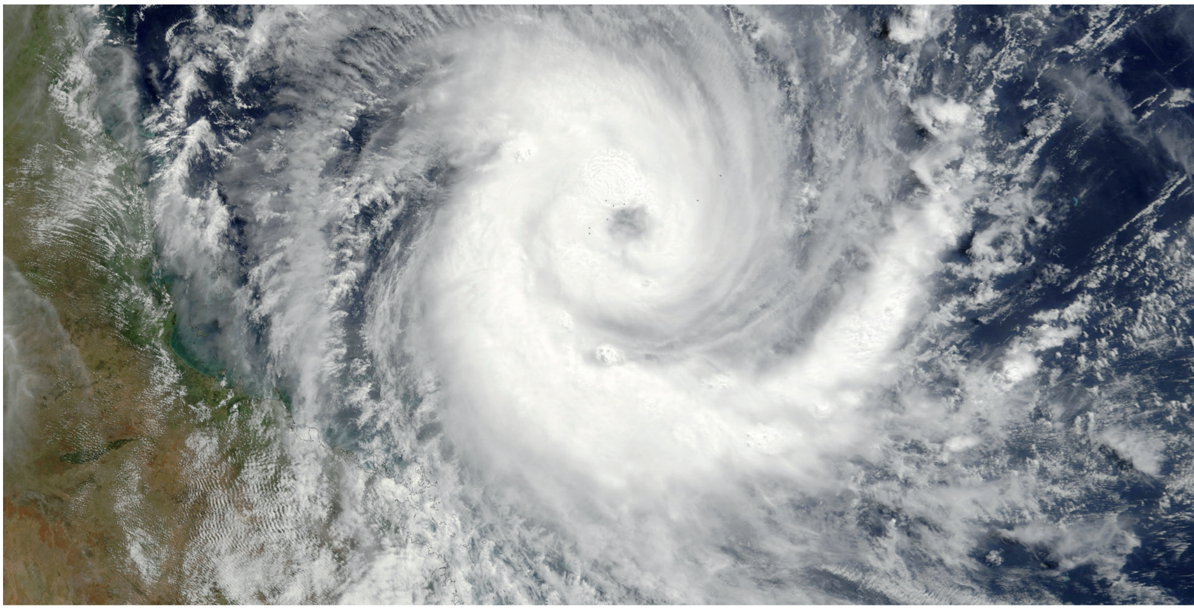

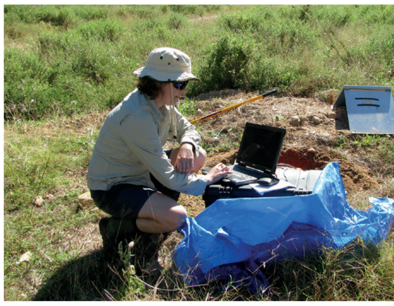

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Determination of GDA94 coordinates for nine stations of Ultimate Positioning Group Pty Ltd using the May and July 2012 GPS data sets

M. Jia, J. Dawson

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Contents

Introduction: **5**

Measurand: **5**

Measurand Traceability: **5**

Measurand Uncertainty: **5**

GPS Data: **6**

GPS Data Irregularities: **6**

Method: **9**

Results: **10**

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Expiry of this Report:

5 years after authorisation date.

Abbreviations:

AFN	Australian Fiducial Network
ARGN	Australian Regional GNSS Network
CORS	Continuously Operating Reference Stations
GDA94	Geocentric Datum Australia 1994
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRS80	Geodetic Reference System 1980
IGS	International GNSS Service
ITRF	International Terrestrial Reference Frame
ITRF92	International Terrestrial Reference Frame 1992
ITRF2008	International Terrestrial Reference Frame 2008

Introduction:

An application dated 20 September 2012 for verification of a reference standard of measurement under Regulation 12 of the National Measurement Regulations 1999 was received from the Ultimate Positioning Group Pty Ltd for verification of GDA94 position on their owned or managed station monuments. This report documents the processing and analysis of GPS data observed by the Ultimate Positioning Group Pty Ltd during three 7-day periods from 6 to 12 May 2012 (day of year 127 to 133) for the station STHE, from 13 to 19 May 2012 (day of year 134 to 140) for the station DELO and from 22 to 28 July (day of year 204 to 210) for seven stations BTYP, BURN, CAMP, DEVO, LAUN, RANE and SCOT, to satisfy the position verification requirements.

Measurand:

Station position, at the time of measurement and stated instrumentation, of a GPS monument with respect to the Geocentric Datum of Australia (GDA94) referred to the GRS80 ellipsoid being in the ITRF92 reference frame at the epoch 1994.0.

Measurand Traceability:

Measurement traceability was ensured by comparing the computed solution against the recognised value standard for position of the Australian Fiducial Network stations. Additionally, the computed solution was checked against the ITRF based solutions computed by the IGS and the individual global analysis centres of the IGS. The validity and traceability of the entire GPS system was ensured via its link to the global Satellite Laser Ranging (SLR) and Very Long Baseline Interferometry (VLBI) observing networks through the ITRF. The validity and traceability of our internal computation processes were ensured by undertaking standard benchmark analysis prior to this analysis.

Measurand Uncertainty:

Position uncertainties were calculated in accordance with the principles of the ISO Guide to the Expression of Uncertainty in Measurement (1995), with an interval estimated to have a confidence level of 95% at the time of verification. The combined standard uncertainty was converted to an expanded uncertainty using a coverage factor, *k*, of 2.

Type A uncertainty sources were evaluated by adopting an *a priori* sigma of **0.001** metre for the precision (1 sigma) of the L1-frequency, one-way, phase observation, at zenith. The corresponding uncertainties of all parameters were determined, by standard error propagation theory, in the least-squares estimation process used in the GPS analysis. Since the formal (internal) precision estimates of GPS solutions are well known to be optimistic, a factor of **10** (i.e. variance scale factor of 100) was subsequently applied to the variance-covariance matrix of the computed GDA94 coordinates.

Type B uncertainty sources, which in practice contribute to position uncertainty, cannot be estimated from the statistical analysis of short-period (i.e. 7-day) observations; these include environmental effects, such as long-period station loading (deformation) processes. Table 1 shows the major **Type B** uncertainty sources for GPS analysis.

Table 1. Type B uncertainty sources (95% C.L.) for position, determined from GPS, and the total uncertainty, assuming the normal distribution of the uncertainty sources, high degrees of freedom and a coverage factor, *k*, of 2.

Uncertainty Source	Position Uncertainty Horizontal (mm)	Position Uncertainty Vertical (mm)
Satellite orbits	5	10
Station deformation	5	15
Antenna phase centre	3	3
Monument stability	5	10
Reference Frame (ITRF)	3	5
Reference Frame (GDA94)	30	50
Total	**32**	**54**

GPS Data:

GPS RINEX data was supplied by the Ultimate Positioning Group Pty Ltd spanning a 7-day period from 6 to 12 May 2012 (day of year 127 to 133) for the station STHE, from 13 to 19 May 2012 (day of year 134 to 140) for the station DELO and from 22 to 28 July (day of year 204 to 210) for seven stations BTYP, BURN, CAMP, DEVO, LAUN, RANE and SCOT. Four character names of the stations are BTYP, BURN, CAMP, DELO, DEVO, LAUN, RANE, SCOT and STHE. Figure 1 shows the distribution of these stations. Table 2 lists the GPS receiver and antenna type at each site. The GPS receiver and antenna types, and GPS antenna heights to the Antenna Reference Point (ARP) as supplied in the amended station files dated 20 September 2012 submitted with the application for verification of position have been adopted for the GPS data processing. The ARP is the reference point as defined by IGS and the RINEX specifications.

Figure 2 shows the AFN network sites used in the GPS data processing. Table 3 lists the GPS receiver and antenna type used in the GPS data processing for each of the AFN network sites. Table 4 lists the GPS antenna heights used in the GPS data processing for the AFN and the Ultimate Positioning Group Pty Ltd sites.

GPS Data Irregularities:

The GPS data set received on 20 September 2012 is regular.

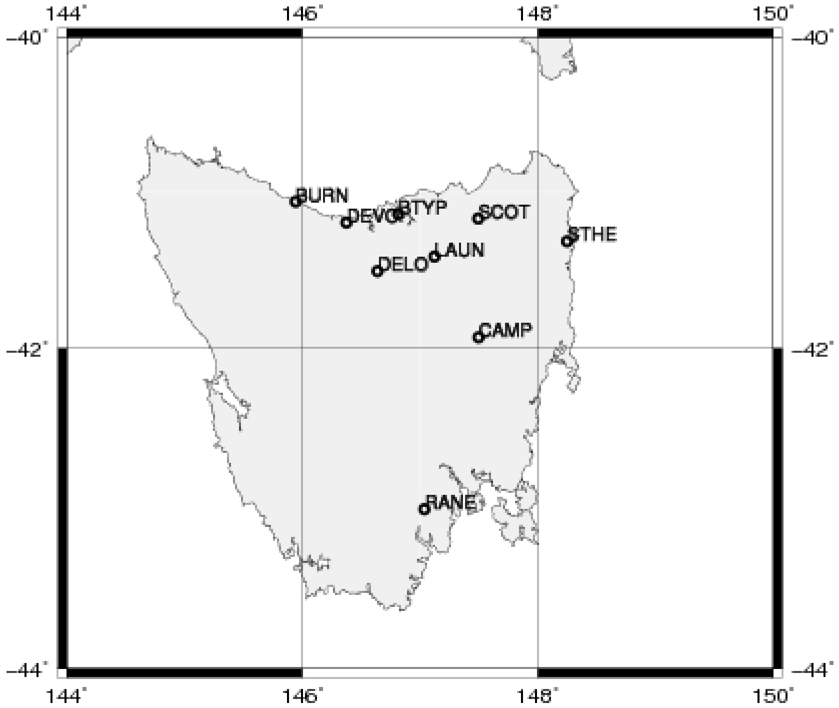

Figure 1: Ultimate Positioning Group Pty Ltd stations used in GPS data processing.

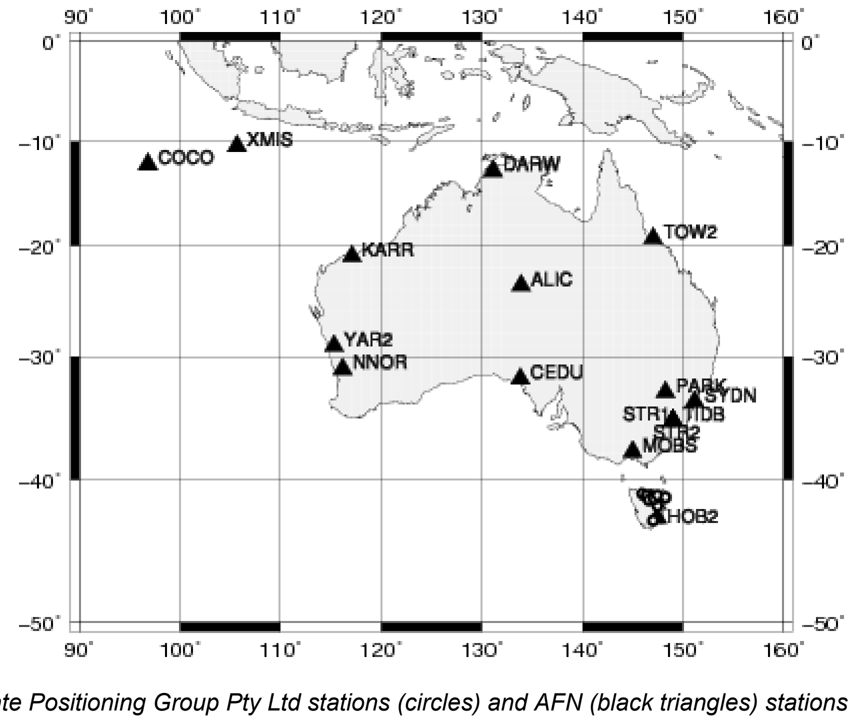

Figure 2: Ultimate Positioning Group Pty Ltd stations (circles) and AFN (black triangles) stations used in GPS data processing.

Table 2: GPS receiver and antenna types for stations of the Ultimate Positioning Group Pty Ltd.

Station name	4-char. ID	GPS receiver type	GPS antenna serial number	IGS antenna type and dome type
TP-Beauty	BTYP	TRIMBLE NETR9	1441107621	TRM57971.00 NONE
TP-Burnie	BURN	TRIMBLE NETR9	1441101273	TRM57971.00 NONE
TP-Campbell	CAMP	TRIMBLE NETR9	1441116098	TRM57971.00 NONE
TP-Deloraine	DELO	TRIMBLE NETR9	1441101019	TRM57971.00 NONE
TP-Devonport	DEVO	TRIMBLE NETR9	1441101095	TRM57971.00 NONE
TP-Launceston1	LAUN	TRIMBLE NETR9	1441101006	TRM57971.00 NONE
TP-Ranelagh	RANE	TRIMBLE NETR9	30767862	TRM57971.00 NONE
TP-Scottsdale	SCOT	TRIMBLE NETR9	1441116372	TRM57971.00 NONE
TP-St Helens	STHE	TRIMBLE NETR9	1441122384	TRM57971.00 NONE

Table 3: GPS receiver and antenna types for the AFN sites. The dome type at CEDU is AUST for DELO and STHE certificate data processing, and is NONE for other site certificate data processing.

GPS Network	4-char. ID	GPS receiver type	GPS antenna serial number	IGS antenna type and dome type
AFN	ALIC	LEICA GRX1200GGPRO	09370001	LEIAR25.R3 NONE
AFN	CEDU	TRIMBLE NETR8	194	AOAD/M_T AUST
AFN	CEDU	TRIMBLE NETR8	194	AOAD/M_T NONE
AFN	COCO	TRIMBLE NETR8	202	AOAD/M_T NONE
AFN	DARW	LEICA GRX1200GGPRO	CR13354	ASH700936D_M NONE
AFN	HOB2	LEICA GRX1200GGPRO	203	AOAD/M_T NONE
AFN	KARR	TRIMBLE NETR8	4938353444	TRM59800.00 NONE
AFN	MOBS	LEICA GRX1200GGPRO	CR20020709	ASH701945C_M NONE
AFN	NNOR	ASHTECH Z-XII3	CR620021402	ASH701945C_M NONE
AFN	PARK	JPS E_GGD	CR620011902	ASH701945C_M NONE
AFN	STR1	LEICA GRX1200GGPRO	CR620023911	ASH701945C_M NONE
AFN	STR2	TRIMBLE NETR8	4844A59851	TRM59800.00 NONE
AFN	SYDN	JPS E_GGD	CR519994908	ASH701945C_M NONE
AFN	TIDB	ASHTECH UZ-12	205	AOAD/M_T JPLA
AFN	TOW2	LEICA GRX1200GGPRO	09310016	LEIAR25.R3 NONE
AFN	XMIS	LEICA GRX1200GGPRO	CR6200503003	ASH701945C_M NONE
AFN	YAR2	ASHTECH UZ-12	371	AOAD/M_T JPLA

Table 4: GPS antenna heights to ARP used in GPS processing for Ultimate Positioning Group Pty Ltd stations and minimally constrained AFN (bold station names) stations.

Station 4-char. ID	number	to ARP (m)	Station 4-char. ID	Domes number	to ARP (m)
BTYP	NONE	0.0000	**HOB2**	50116M004	0.0000
BURN	NONE	0.0000	**KARR**	50139M001	0.0010
CAMP	NONE	0.0000	**MOBS**	50182M001	0.0000
DELO	NONE	0.0000	**NNOR**	50181M001	0.0655
DEVO	NONE	0.0000	**PARK**	50108M001	0.0000
LAUN	NONE	0.0000	**STR1**	50119M002	0.0040
RANE	NONE	0.0000	**STR2**	50119M001	0.0015
SCOT	NONE	0.0000	**SYDN**	50124M003	0.0300
STHE	NONE	0.0000	**TIDB**	50103M108	0.0614
ALIC	50137M001	0.0015	**TOW2**	50140M001	0.0033
CEDU	50138M001	0.0060	**XMIS**	50183M001	0.0000
COCO	50127M001	0.0040	**YAR2**	50107M004	0.0814
DARW	50134M001	0.0025			

Method:

Analysis was undertaken following the procedures detailed in Geoscience Australia's GPS Analysis Manual for the Verification of Position Issue 1.13.

In summary, daily solutions of the Ultimate Positioning Group Pty Ltd stations and AFN/ARGN/IGS/other site data were processed using Bernese GPS Processing Software version 5.0. The Bernese GPS Software conforms to the IERS2003 conventions. IGS final GPS satellite ephemerides and earth orientation parameters were used in the computations. The double difference carrier phase observables at 30-second epoch intervals were used for GPS data processing. Other measurement modelling and parameter estimation included:

- Receiver clock corrections.
- Absolute antenna elevation-dependent phase centre variation corrections.
- Solid earth tide displacements.
- Ocean loading displacements.
- Elevation cutoff of 10° for all observations.
- QIF integer ambiguity resolution strategy.
- Elevation dependent observation weighting.
- Troposphere zenith delays estimated at 1-hour intervals for all stations.
- Minimum constraint condition for daily network solution in terms of the ITRF2008 using subset of the IGS08 reference stations.

This solution was transformed to GDA94 using the transformation approach detailed in: ITRF to GDA94 coordinate transformation, John Dawson and Alex Woods, *Journal of Applied Geodesy* **4** (2010), no. 4, pp. 189-199, available online at www.reference-global.com/loi/jag.

Results:

Table 5 lists the Root Mean Square (RMS) of the daily station coordinate values. Table 6 lists the station coordinates resulting from the combination of the daily ITRF solutions and their subsequent transformation to GDA94.

Table 5: Root Mean Square (RMS) of daily Ultimate Positioning Group Pty Ltd station and minimally constrained AFN (bold station names) station coordinates.

Station	North (mm)	Eas (mm)	Up (mm)	Station	North (mm)	East (mm)	Up (mm)
Data set 1 (day of year 127 to 133)							
STHE	1.4	1.1	6.1	**PARK**	0.7	0.6	1.7
ALIC	0.7	0.6	2.2	**STR1**	0.7	1.8	4.1
CEDU	0.4	0.9	5.4	**STR2**	0.8	1.8	4.7
COCO	2.1	1.4	4.3	**SYDN**	1.3	0.7	2.6
DARW	1.0	1.5	2.8	**TIDB**	1.9	0.9	2.6
HOB2	1.8	3.4	6.4	**TOW2**	1.6	1.0	4.7
KARR	1.7	1.2	6.9	**XMIS**	2.2	2.3	5.0
MOBS	0.8	0.9	3.0	**YAR2**	0.6	0.8	3.7
NNOR	1.2	0.8	2.4				
Data set 2 (day of year 134 to 140)							
DELO	1.0	0.4	3.8	**PARK**	0.3	0.3	1.4
ALIC	0.7	0.3	2.3	**STR1**	0.4	0.6	2.8
CEDU	0.7	0.5	3.4	**STR2**	0.6	0.5	2.6
COCO	2.5	2.4	3.2	**SYDN**	0.4	0.5	2.1
DARW	0.6	0.6	2.5	**TIDB**	0.4	0.5	3.3
HOB2	1.4	1.3	3.4	**TOW2**	0.7	0.6	2.1
KARR	0.9	0.4	2.2	**XMIS**	1.8	1.7	6.0
MOBS	1.7	1.1	2.9	**YAR2**	0.4	0.7	2.7
NNOR	0.6	0.5	1.9				
Data set 3 (day of year 204 to 210)							
BTYP	0.9	0.7	3.8	**KARR**	0.6	0.5	2.6
BURN	0.8	1.0	3.6	**MOBS**	1.0	0.9	2.1
CAMP	0.6	0.4	3.7	**NNOR**	0.4	0.3	1.3
DEVO	1.1	0.9	3.7	**PARK**	3.0	1.3	1.1

LAUN	0.9	0.7	4.4	**STR1**	0.7	0.6	2.8
RANE	0.6	0.7	2.6	**STR2**	0.8	0.6	3.6
SCOT	0.8	0.8	2.2	**SYDN**	0.7	0.7	3.5
ALIC	0.7	0.4	1.5	**TIDB**	0.7	1.1	2.9
CEDU	0.7	0.8	1.4	**TOW2**	1.0	0.5	3.3
COCO	0.6	0.7	4.4	**XMIS**	1.4	1.3	3.9
DARW	0.6	0.7	2.9	**YAR2**	0.5	0.1	1.0
HOB2	0.9	1.3	1.5				

Table 6: Computed Geocentric Datum of Australia (GDA94) geodetic coordinates and their uncertainty for the Ultimate Positioning Group Pty Ltd stations. The uncertainties are calculated in accordance with the principles of the ISO Guide to the Expression of Uncertainty in Measurement (1995), with an interval estimated to have a confidence level of 95% at the time of verification. The combined standard uncertainty was converted to an expanded uncertainty using a coverage factor, k, of 2. The uncertainties are 0.032 m, 0.032 m and 0.054 m for east, north and vertical components respectively for all stations.

Station	**Longitude (DMS east)**			**Latitude (DMS south)**			**Ellipsoidal height (M)**
BTYP	146	48	56.55566	41	8	42.44326	10.1014
BURN	145	56	39.10712	41	3	55.90579	12.1702
CAMP	147	29	59.67609	41	55	54.39895	194.1339
DELO	146	38	22.21448	41	30	43.46399	321.381
DEVO	146	22	25.95557	41	11	57.50371	81.7498
LAUN	147	7	30.99132	41	25	7.20159	12.0335
RANE	147	2	13.7746	43	0	46.04374	24.4457
SCOT	147	29	47.27433	41	10	26.42838	235.0162
STHE	148	14	59.57185	41	19	14.81649	12.0221