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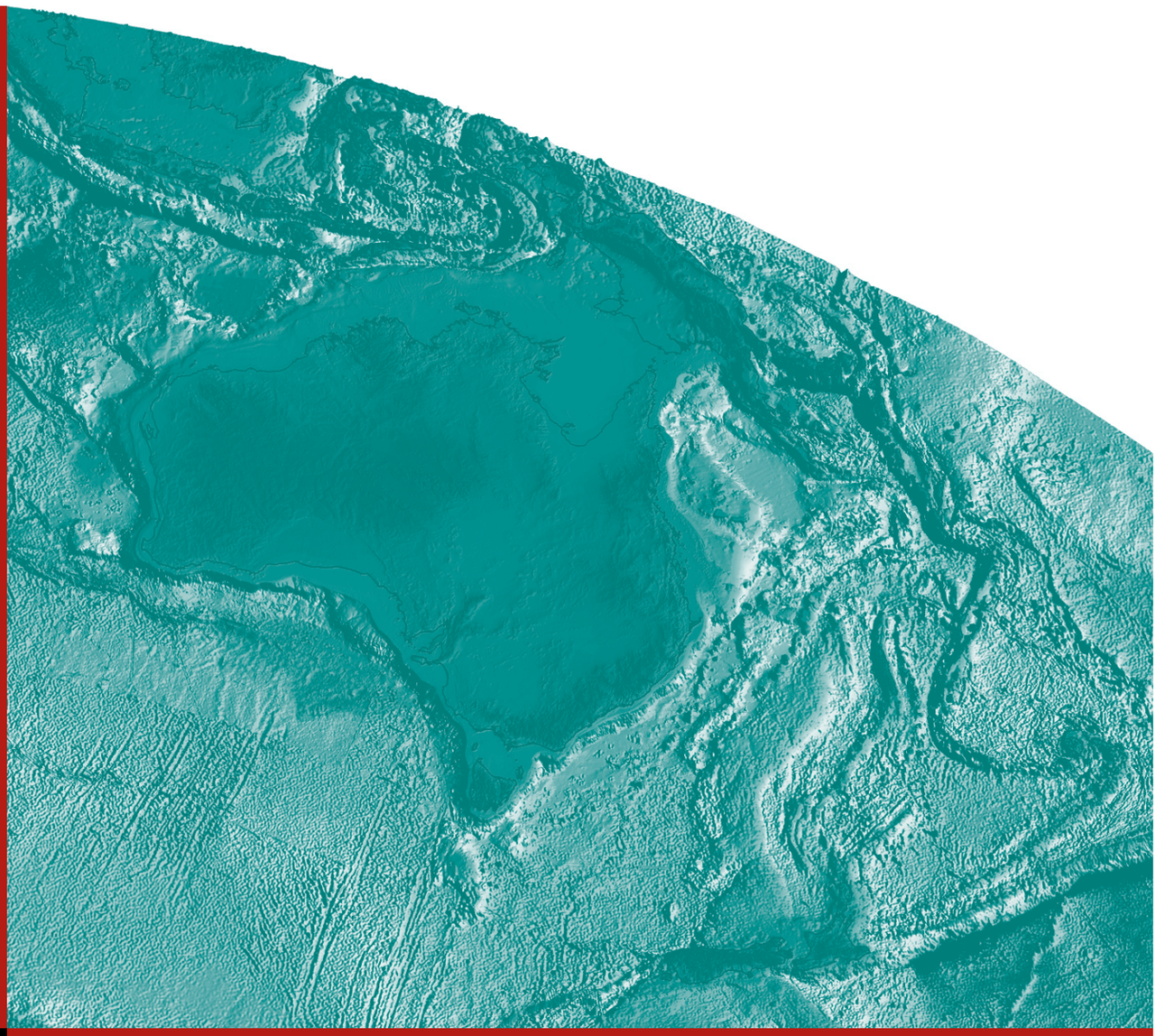

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by

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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
ITRF2005	International Terrestrial Reference Frame 2005

Introduction:

An application dated 13th October 2010 for verification of a reference standard of measurement under Regulation 12 of the National Measurement Regulations 1999 was received from the Western Australian Land Information Authority for verification of GDA94 position on their GPS Network Perth monuments. This report documents the processing and analysis of GPS data observed by the GPS Network Perth CORS stations during a 7-day period from 01 August to 07 August 2010 (day of year 213 to 219) for two stations (COLL and MDAH), and from 15th August to 21st August 2010 (day of year 227 to 233) for eleven stations (BALI, BINN, BUSS, CUND, DWEL, KDAL, MIDL, ROTT, STRG, TORK, and WHIY) 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 for thirteen GPS Network Perth CORS stations spanning a 7-day period from 01st August to 07th August 2010 (day of year 213 to 219) for two stations (COLL and MDAH), and from 15th August to 21st August 2010 (day of year 227 to 233) for eleven stations (BALI, BINN, BUSS, CUND, DWEL, KDAL, MIDL, ROTT, STRG, TORK, and WHIY). Figure 1 shows the distribution of these stations. Table 2 lists the GPS receiver and antenna type at each site. An antenna height of 0.000m to the Antenna Reference Point (ARP) has been adopted for all GPS Network Perth CORS stations. The ARP is the reference point as defined by IGS and the RINEX specifications.

Figure 2 shows the extended regional network of IGS, ARGN and AFN network sites where data available 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 IGS, ARGN and AFN network sites. Table 4 lists the GPS antenna heights used in the GPS data processing for all sites.

GPS Data Irregularities:

No irregularities were identified in the GPS data supplied in RINEX format from the GPS Network Perth CORS stations, except that the one-week data were put in one RINEX file for each site, and RINEX heads did not follow the standard format.

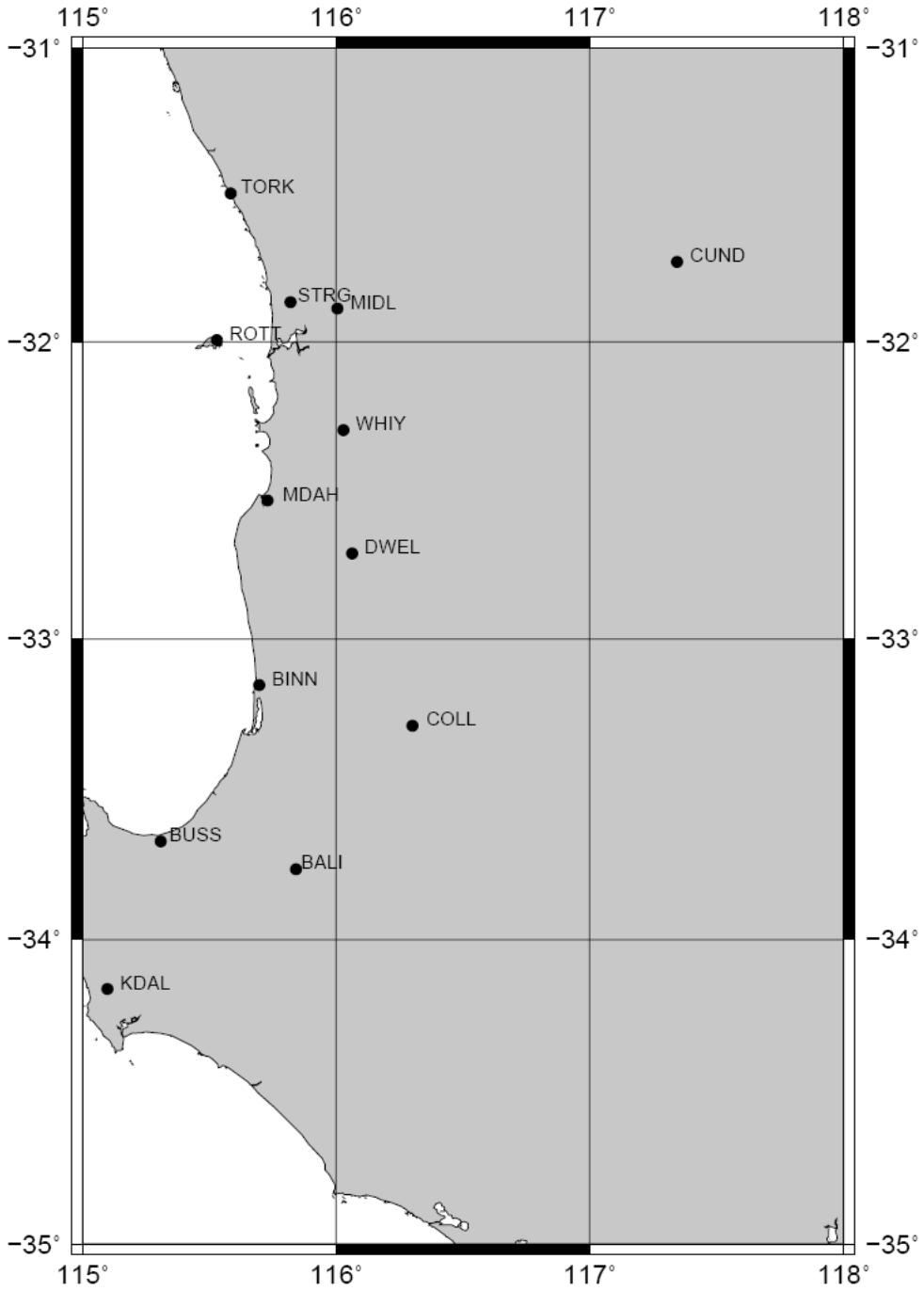

Figure 1: Distribution of GPS Network Perth CORS stations.

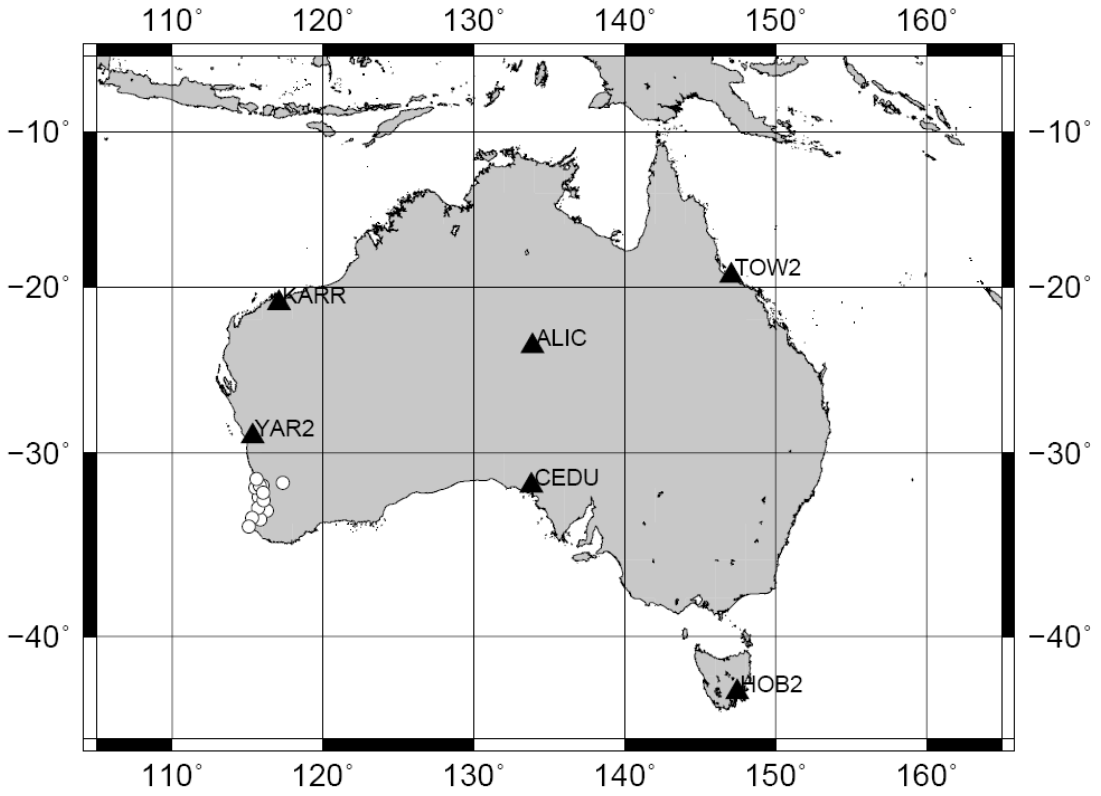

Figure 2: AFN/ARGN/IGS stations (black triangles) and GPS Network Perth CORS stations (circles) used in GPS data processing.

Table 2: Receiver and antenna types for CORS stations of GPS Network Perth.

GPS Network Perth base station	4-char. ID	GPS receiver type	GPS antenna SERIAL NUMBER	IGS antenna type AND DOME TYPE
Balingup	BALI	TRIMBLE NETR5	30973154	TRM55971.00 NONE
Binningup	BINN	TRIMBLE NETR5	30318060	TRM55971.00 NONE
Busselton	BUSS	TRIMBLE NETR5	30966303	TRM55971.00 NONE
Collie	COLL	TRIMBLE NETR5	30975474	TRM55971.00 NONE
Cunderdin	CUND	TRIMBLE NETR5	23534390	TRM55971.00 NONE
Dwellingup	DWEL	TRIMBLE NETR5	30337696	TRM55971.00 NONE
Karridale	KDAL	TRIMBLE NETR5	30966384	TRM55971.00 NONE
Mandurah	MDAH	TRIMBLE NETR5	23534323	TRM55971.00 NONE
Midland	MIDL	TRIMBLE NETR5	23534341	TRM55971.00 NONE
Rottnest	ROTT	TRIMBLE NETR5	23534347	TRM55971.00 NONE
Stirling	STRG	TRIMBLE NETR5	1440921100	TRM55971.00 NONE
Two Rocks	TORK	TRIMBLE NETR5	23534334	TRM55971.00 NONE
Whitby	WHIY	TRIMBLE NETR5	30765368	TRM55971.00 NONE

Table 3: GPS receiver and antenna types for the AFN sites.

GPS Network	4-char. ID	GPS receiver type	GPS antenna SERIAL NUMBER	IGS antenna type AND DOME TYPE
IGS, ARGN,AFN	ALIC	LEICA GRX1200GGPRO	318	AOAD/M_T NONE
IGS, ARGN,AFN	CEDU	ASHTECH UZ-12	194	AOAD/M_T AUST
IGS, ARGN,AFN	HOB2	LEICA GRX1200GGPRO	203	AOAD/M_T NONE
IGS, ARGN,AFN	KARR	ASHTECH UZ-12	320	AOAD/M_T AUST
IGS, ARGN,AFN	TOW2	LEICA GRX1200GGPRO	326	AOAD/M_T AUST
IGS, ARGN,AFN	YAR2	ASHTECH UZ-12	371	AOAD/M_T JPLA

Table 4: GPS antenna heights to ARP used in GPS processing and site DOMES numbers.

Site 4-char. ID	DOMES number	ANTENNA HEIGHT TO ARP (M)	site 4-char. ID	DOMES number	ANTENNA HEIGHT TO ARP (M)
BALI	59994M001	0.0000	STRG	AUM000100	0.0000
BINN	AUM000091	0.0000	TORK	AUM000089	0.0000
BUSS	59993M001	0.0000	WHIY	AUM000090	0.0000
COLL	59992M001	0.0000	**ALIC**	**50137M001**	**0.0070**
CUND	59991M001	0.0000	**CEDU**	**50138M001**	**0.0060**
DWEL	AUM000092	0.0000	**HOB2**	**50116M004**	**0.0000**
KDAL	59989M001	0.0000	**KARR**	**50139M001**	**0.0020**
MDAH	AUM000093	0.0000	**TOW2**	**50140M001**	**0.0035**
MIDL	59990M001	0.0000	**YAR2**	**50107M004**	**0.0814**
ROTT	AUM000088	0.0000			

Method:

Analysis was undertaken following the procedures detailed in Geoscience Australia's GPS Analysis Manual for the Verification of Position Issue 1.6.

In summary, daily solutions of the GPS Network Perth 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 ITRF2005 using subset of the IGS05 reference stations.

Daily solutions were combined to provide a weekly solution. This solution was transformed to GDA94 using a seven parameter transformation.

Results:

Table 5 lists the Root Mean Square (RMS) of the daily station coordinate values. Table 6 lists the GDA94 station coordinates resulting from the combination together with the position recognised-value standard GDA94 coordinates held fixed in the adjustment.

Table 5: Root Mean Square (RMS) of daily GPS Network Perth and minimally constrained AFN/ARGN/IGS (bold station names) station coordinates.

Station	North (mm)	East (mm)	Up (mm)	Station	North (mm)	East (mm)	Up (mm)
ALIC	1.1	0.4	3.2	CUND	0.6	1.2	3.7
CEDU	1.3	1.1	5.6	DWEL	1.0	1.4	3.3
HOB2	0.8	1.5	3.2	KDAL	1.1	2.0	5.0
KARR	0.6	1.4	2.1	MDAH	1.0	1.5	5.6
TOW2	1.3	0.9	5.6	MIDL	1.2	1.7	5.7
YAR2	1.0	1.4	6.0	ROTT	2.4	3.4	5.8
BALI	0.7	1.7	4.0	STRG	0.9	1.4	4.9
BINN	0.9	1.4	3.9	TORK	1.5	1.8	5.7
BUSS	0.9	1.9	4.1	WHIY	0.8	1.2	4.1
COLL	0.8	1.2	3.7				

Table 6: Computed Geocentric Datum of Australia (GDA94) geodetic coordinates and their uncertainty for the GPS Network Perth CORS 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.

Station	Longitude (DMS east) Std (M)			Latitude (DMS south) Std (M)			Ellipsoidal height (M) Std (M)
BALI	115	50	33.19266 0.0315	33	46	0.09737 0.0315	177.4694 0.0544
BINN	115	41	51.06098 0.0315	33	9	11.51281 0.0315	-23.7261 0.0544
BUSS	115	18	31.75479 0.0315	33	40	27.71880 0.0315	-26.2433 0.0544
COLL	116	18	1.74088 0.0315	33	17	23.01289 0.0315	207.9608 0.0544
CUND	117	20	40.19584 0.0315	31	43	42.72732 0.0315	282.7021 0.0544
DWEL	116	3	45.13491 0.0315	32	42	48.81548 0.0315	233.8830 0.0544
KDAL	115	5	54.79191 0.0315	34	9	48.44247 0.0315	44.3265 0.0544
MDAH	115	43	45.18941 0.0315	32	32	7.14197 0.0315	-18.2030 0.0544
MIDL	116	0	19.61778 0.0315	31	53	11.47340 0.0315	-6.7624 0.0544
ROTT	115	31	44.40519 0.0315	31	59	40.08251 0.0315	-13.9375 0.0544
STRG	115	49	9.51501 0.0315	31	51	58.34156 0.0315	0.0622 0.0544
TORK	115	35	3.5735 0.0315	31	29	44.54338 0.0315	-11.6901 0.0544
WHIY	116	1	41.03486 0.0315	32	17	51.12818 0.0315	200.4301 0.0544

END OF REPORT