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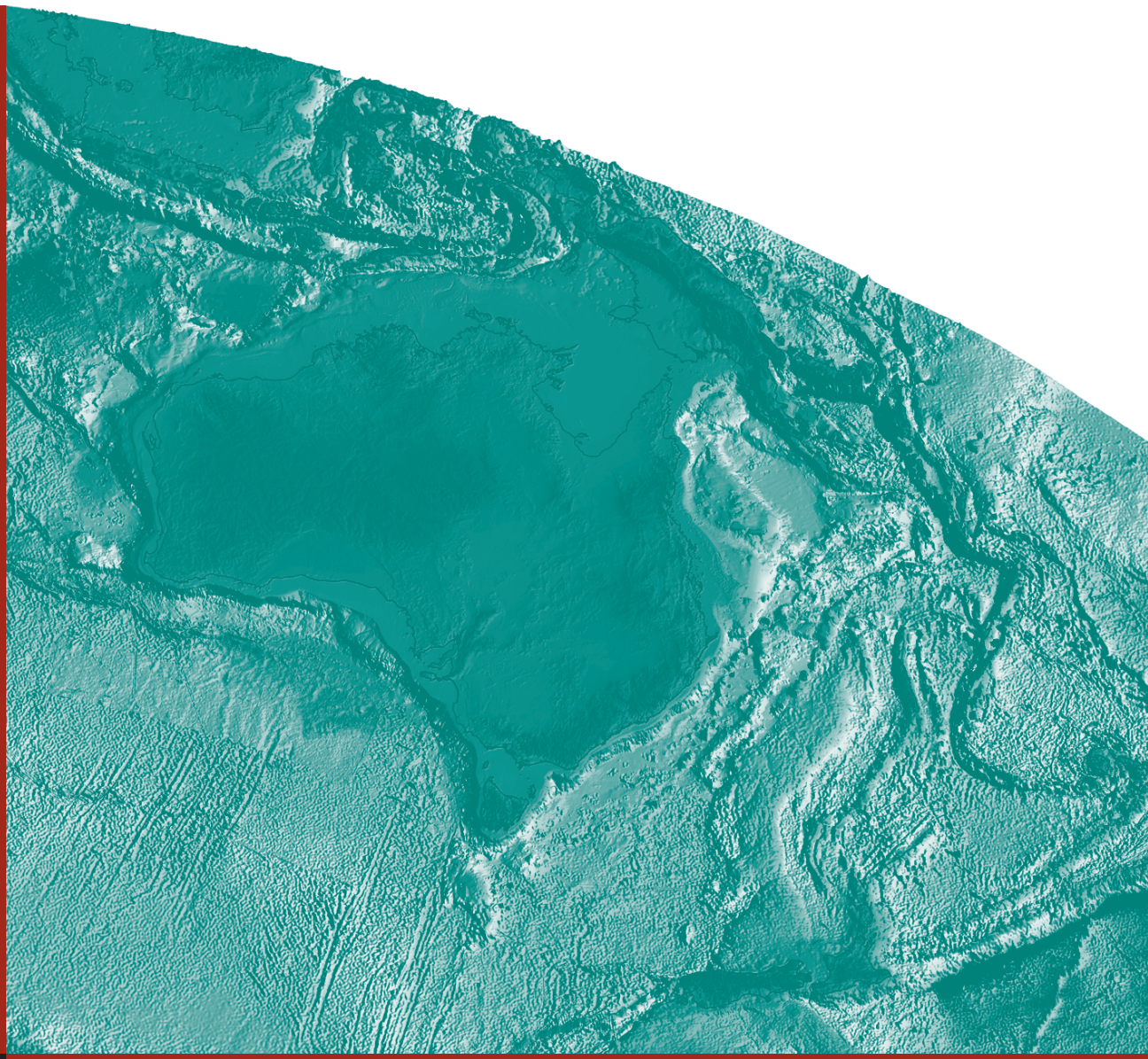

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by

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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
ITRF2008	International Terrestrial Reference Frame 2008

Introduction:

An application dated 29 August 2011 for verification of a reference standard of measurement under Regulation 12 of the National Measurement Regulations 1999 was received from the C.R. Kennedy Survey Solutions 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 C.R. Kennedy Survey Solutions during a 7-day period from 31 July to 6 August 2011 (day of year 212 to 218) for 18 stations (ACL2, ARUN, BCMT, BDRM, BLNA, CRKB, CRL_, CRNS, ENSH, GLAD, GYM2, HBAY, JEEB, MISA, PROS, SALT, TRNG and TWED) 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 eighteen C.R. Kennedy Survey Solutions stations spanning a 7-day period from 31 July to 6 August 2011 (day of year 212 to 218). Four character names of the stations are ACL2, ARUN, BCMT, BDRM, BLNA, CRKB, CRL_, CRNS, ENSH, GLAD, GYM2, HBAY, JEEB, MISA, PROS, SALT, TRNG and TWED. 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 summary file dated 29 August 2011 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 C.R. Kennedy Survey Solutions sites.

GPS Data Irregularities:

The GPS data set received on 29 August 2011 is regular.

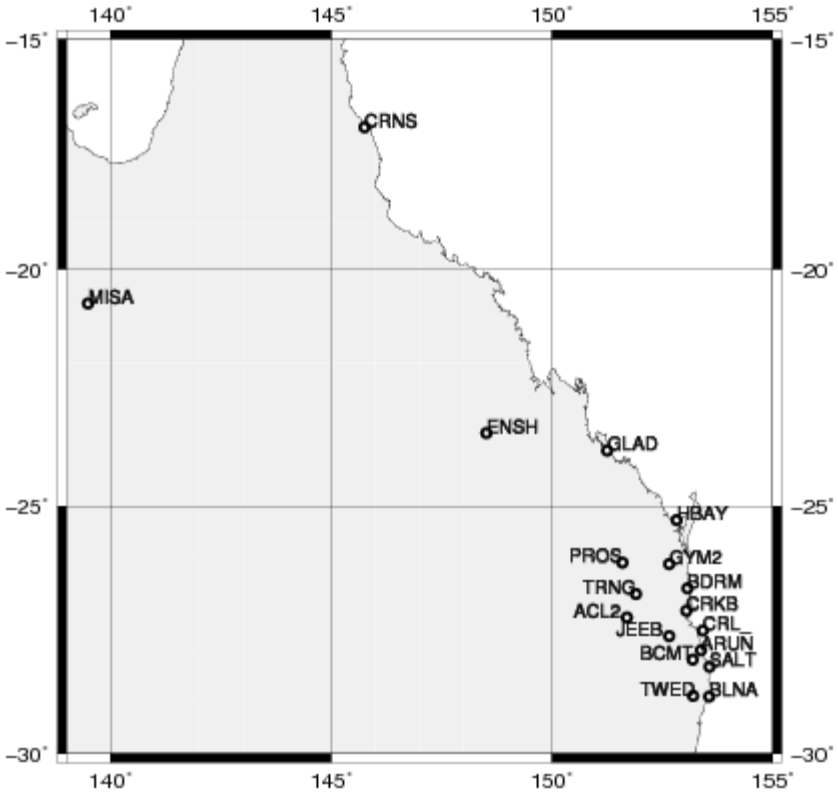

Figure 1: C.R. Kennedy Survey Solutions stations used in GPS data processing.

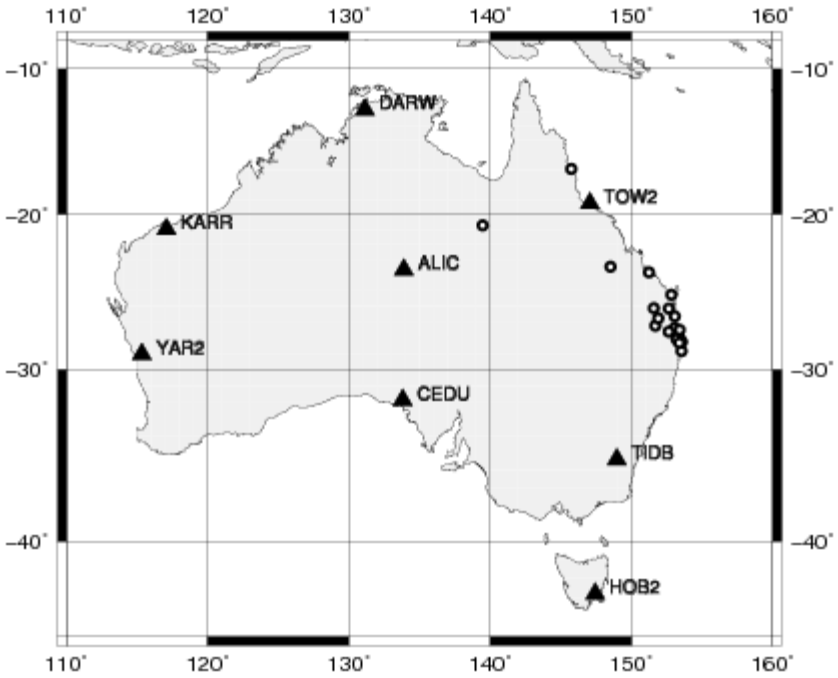

Figure 2: AFN (black triangles) stations used in GPS data processing.

Table 2: GPS receiver and antenna types for C.R. Kennedy Survey Solutions stations.

C.R. Kennedy Survey Solutions station	4-char. ID	GPS receiver type	GPS antenna serial number	IGS antenna type and dome type
SNA-Acland Coal	ACL2	LEICA GRX1200GGPRO	07160051	LEIAX1202GG NONE
SNA-Arundel	ARUN	LEICA GRX1200GGPRO	08150070	LEIAX1202GG NONE
SNA-Beechmont	BCMT	LEICA GRX1200GGPRO	08150053	LEIAX1202GG NONE
SNA-Buderim	BDRM	LEICA GRX1200+GNSS	06200165	LEIAX1202GG NONE
SNA-Ballina_SC	BLNA	LEICA GRX1200GGPRO	08220068	LEIAX1202GG NONE
SNA-Brisbane	CRKB	LEICA GRX1200GGPRO	07030026	LEIAX1202GG NONE
SNA-Con Rutile	CRL_	LEICA GRX1200GGPRO	08160083	LEIAX1202GG NONE
SNA-Cairns	CRNS	LEICA GRX1200+GNSS	010191058	LEIAS10 NONE
SNA-Ensham	ENSH	LEICA GRX1200+GNSS	09380073	LEIAX1203+GNSS NONE
SNA-Gladstone	GLAD	LEICA GRX1200+GNSS	09250131	LEIAX1203+GNSS NONE
SNA-Gympie2	GYM2	LEICA GRX1200GGPRO	08160098	LEIAX1202GG NONE
SNA-Hervey Bay	HBAY	LEICA GX1230GG	06200150	LEIAX1202GG NONE
SNA-Jeebropilly	JEEB	LEICA GRX1200+GNSS	09250099	LEIAX1203+GNSS NONE
SNA-Mt Isa	MISA	LEICA GRX1200GGPRO	08150065	LEIAX1202GG NONE
SNA-Proston	PROS	LEICA GRX1200+GNSS	09391055	LEIAS10 NONE
SNA-Salt KCliff	SALT	LEICA GRX1200GGPRO	08250003	LEIAX1202GG NONE
SNA-Tarong	TRNG	LEICA GRX1200GGPRO	06360003	LEIAX1202GG NONE
SNA-Tweed_SC	TWED	LEICA GRX1200+GNSS	07160038	LEIAX1202GG 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
AFN	ALIC	LEICA GRX1200GGPRO	09370001	LEIAR25.R3 NONE
AFN	CEDU	TRIMBLE NETR8	194	AOAD/M_T AUST
AFN	DARW	GRX1200GGPRO	CR13354	ASH700936D_M NONE
AFN	HOB2	LEICA GRX1200GGPRO	203	AOAD/M_T NONE
AFN	KARR	TRIMBLE NETR8	4938353444	TRM59800.00 NONE
AFN	TIDB	ASHTECH UZ-12	205	AOAD/M_T JPLA
AFN	TOW2	LEICA GRX1200GGPRO	326	AOAD/M_T AUST
AFN	YAR2	ASHTECH UZ-12	371	AOAD/M_T JPLA

Table 4: GPS antenna heights to ARP used in GPS processing.

C.R. Kennedy Survey Solutions station 4-char. ID	Domes number	Antenna height to ARP (M)	AFN site 4-char. ID	Domes number	Antenna height to ARP (M)
ACL2		0.0000	ALIC	50137M001	0.0015
ARUN		0.0000	CEDU	50138M001	0.0060
BCMT		0.0000	DARW	50134M001	0.0025
BDRM		0.0000	HOB2	50116M004	0.0000
BLNA		0.0000	KARR	50139M001	0.0010
CRKB		0.0000	TIDB	50103M108	0.0614
CRL_		0.0000	TOW2	50140M001	0.0035
CRNS		0.0000	YAR2	50107M004	0.0814
ENSH		0.0000			
GLAD		0.0000			
GYM2		0.0000			
HBAY		0.0000			
JEEB		0.0000			
MISA		0.0000			
PROS		0.0000			
SALT		0.0000			
TRNG		0.0000			
TWED		0.0000			

Method:

Analysis was undertaken following the procedures detailed in Geoscience Australia's GPS Analysis Manual for the Verification of Position Issue 1.9.

In summary, daily solutions of the C.R. Kennedy Survey Solutions 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 C.R. Kennedy Survey Solutions station and minimally constrained AFN (bold station names) station coordinates.

Station	East (mm)	North (mm)	Up (mm)	Station	East (mm)	North (mm)	Up (mm)
ALIC	0.9	0.6	1.8	ACL2	0.9	0.5	2.7
CEDU	1.0	0.9	3.5	ARUN	0.8	0.9	2.6
DARW	0.9	0.6	2.3	BCMT	1.0	0.6	3.5
HOB2	1.5	0.8	2.3	BDRM	0.5	0.7	2.2
KARR	0.7	0.4	1.4	BLNA	0.7	0.3	2.0
TIDB	1.4	0.9	3.0	CRKB	0.7	0.8	2.3
TOW2	0.6	0.9	4.8	CRL_	0.8	0.5	2.1
YAR2	0.9	1.8	5.9	CRNS	1.3	2.0	5.5
				ENSH	0.5	0.9	5.2
				GLAD	2.0	1.2	6.2
				GYM2	1.0	0.9	2.4
				HBAY	1.1	1.0	6.7
				JEEB	1.2	0.7	2.6
				MISA	0.9	0.5	2.7
				PROS	0.7	0.8	2.4
				SALT	0.4	0.6	3.0
				TRNG	1.0	0.9	6.6
				TWED	0.7	0.5	3.3

Table 6: Computed Geocentric Datum of Australia (GDA94) geodetic coordinates and their uncertainty for the C.R. Kennedy Survey Solutions 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 0.0315 m, 0.0315 m and 0.0544 m for east, north and vertical components respectively for all stations.

Station	Longitude (DMS east)			Latitude (DMS south)			Ellipsoidal height (M)
ACL2	151	41	58.62009	27	16	13.08155	509.4437
ARUN	153	22	26.49989	27	56	26.13528	60.6607
BCMT	153	11	37.05897	28	7	31.26375	586.7830
BDRM	153	4	9.00859	26	41	4.77841	182.2920
BLNA	153	33	41.56414	28	52	9.15527	51.3919
CRKB	153	2	49.72167	27	26	27.81280	56.0475
CRL_	153	25	17.44654	27	32	15.79347	157.9230
CRNS	145	45	29.92840	16	56	8.61636	72.0193
ENSH	148	31	12.89339	23	28	41.94310	243.6655
GLAD	151	15	15.91659	23	50	28.61209	84.9945
GYM2	152	39	36.15950	26	11	18.65465	120.4670
HBAY	152	49	35.60614	25	16	58.93631	66.8888
JEEB	152	39	29.49846	27	39	4.92934	108.7617
MISA	139	29	13.65528	20	44	11.60457	404.4740
PROS	151	35	47.40502	26	9	27.43574	402.4361
SALT	153	34	29.53906	28	16	18.24376	48.9671
TRNG	151	53	57.39722	26	47	43.55438	495.2974
TWED	153	24	0.91154	28	20	56.14440	80.6620

END OF REPORT