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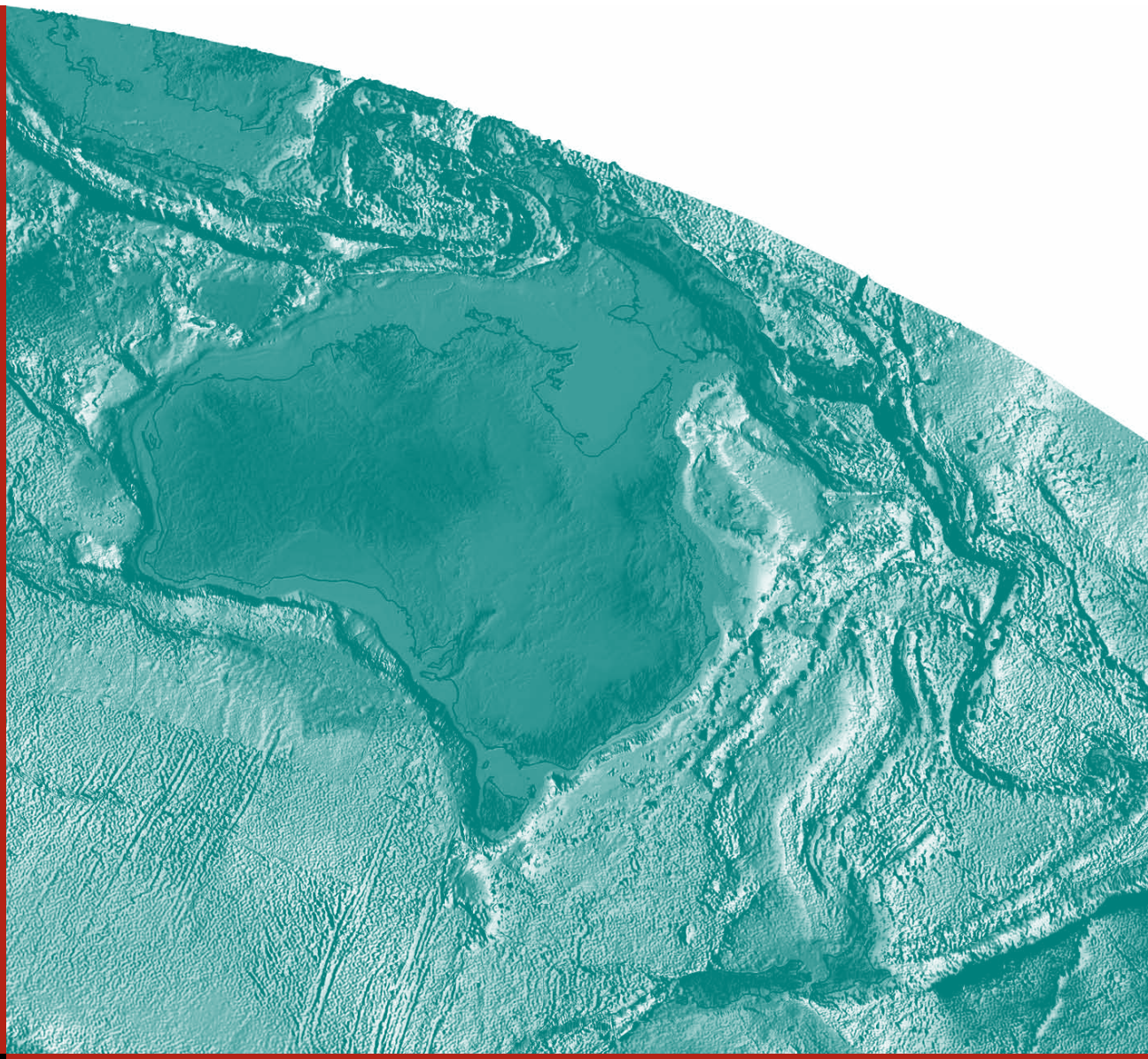

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by

M. Jia and J. Dawson

Australian Government
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Name of NATA approved facility:

Geoscience Australia – National Geospatial Reference Systems
Corner Jerrabomberra Ave and Hindmarsh Drive
Symonston ACT 2609 Australia
Telephone: (02) 6249 9111 Facsimile: (02) 6249 9969
Email: geodesy@ga.gov.au

Client Detail:

Mr Ryan Ruddick
National Geospatial Reference Systems
Earth Monitoring Group
Geospatial and Earth Monitoring Division
Geoscience Australia
Telephone: (02) 6249 9426 Facsimile: (02) 6249 9969
Email: ryan.ruddick@ga.gov.au
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Expiry of this Report:

5 years after authorisation date.

Abbreviations:

AFN	Australian Fiducial Network
ARGN	Australian Regional GPS Network.
CORS	Continuously Operating Reference Station
GDA94	Geocentric Datum Australia 1994
GNSS	Global Satellite Navigation 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 10 May 2010 for verification of a reference standard of measurement under Regulation 12 of the National Measurement Regulations 1999 was received from the project of National Geospatial Reference Systems, Geoscience Australia, for verification of GDA94 position on their ARGN and AuScope station monuments. This report documents the processing and analysis of GPS data observed by the ARGN and AuScope stations during a 7-day period from 28 March to 3 April 2010 (day of year 87 to 93) 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 system at the epoch 1994.

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 uncertainties 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 49 ARGN and AuScope stations spanning a 7-day period from 28 March to 3 April 2010 (day of year 87 to 93). Four character names of 49 stations are ALBY ALIC ANDA BBOO BNDY BUR2 BURA CEDU COCO COOB DARM DARW DODA ESPA HIL1 HOB2 HYDN JAB2 KALG KARR KAT1 KAT2 KELN KUNU LARR LIAW LORA LORD MOBS NORF NORS PARK RAVN RHPT SA45 SPBY STR1 STR2 SYDN TID1 TOW2 WAGN WARA XMIS YAR2 YAR3 YARR YEEL YELO. Data from the non-GA station TIDB, was also used in the analysis. Figure 1 shows the distribution of these stations. Table 2 lists the GPS receiver and antenna types at each site. The GPS receiver and antenna types, and GPS antenna heights to the Antenna Reference Point (ARP) as supplied in the amended log files dated 13 May 2010 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. Table 3 lists the GPS antenna heights used in the GPS data processing for all sites.

GPS Data Irregularities:

The receiver and antenna types in the RINEX header of the station COOB were not correct in the first data supply dated 10 May 2010 and the corrected data were resupplied on 13 May 2010.

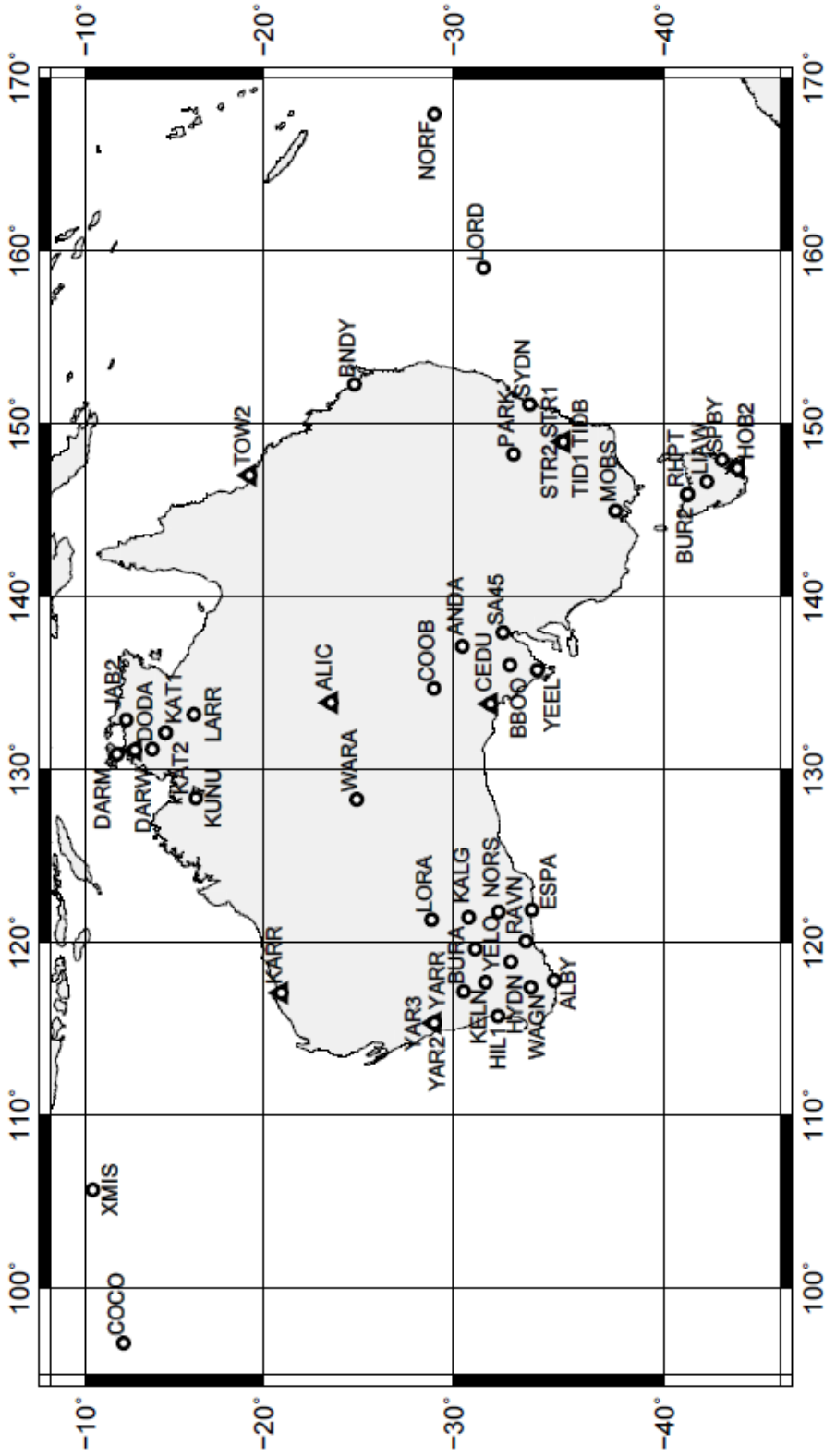

Figure 1: AFN (black triangles), ARGN and AuScope (circles) stations used in GPS data processing. All AFN stations are part of ARGN stations.

Table 2: AFN (bold station names), ARGN and AuScope receiver and antenna types.

AFN, ARGN and AuScope station	4-char. ID	GPS network	GPS receiver type	GPS antenna SN	IGS antenna and dome type
Albany	ALBY	AuScope	LEICA GRX1200GGPRO	200527	LEIAT504GG NONE
Alice Springs	ALIC	IGS, AFN, ARGN	LEICA GRX1200GGPRO	318	AOAD/M_T NONE
Andamooka	ANDA	AuScope	LEICA GRX1200GGPRO	200531	LEIAT504GG SCIS
Buckleboo	BBOO	AuScope	LEICA GRX1200GGPRO	200547	LEIAT504GG SCIS
Bundaberg	BNDY	ARGN	TRIMBLE NETR5	200538006	ASH701945E_M NONE
Burnie	BUR2	ARGN	LEICA GRX1200GGPRO	103322	LEIAT504 SCIS
Burakin	BURA	AuScope	LEICA GRX1200GGPRO	200552	LEIAT504GG SCIS
Ceduna	CEDU	IGS, AFN, ARGN	ASHTECH UZ-12	192	AOAD/M_T AUST
Cocos	COCO	IGS, ARGN	TRIMBLE NETR5	202	AOAD/M_T NONE
Coober Pedy	COOB	AuScope	LEICA GRX1200+GNSS	09480010	LEIAR25.R3 LEIT
Darwin Airport	DARM	IGS, ARGN	LEICA GRX1200PRO	42022	ASH701945C_M NONE
Darwin	DARW	IGS, AFN, ARGN	LEICA GRX1200GGPRO	13354	ASH700936D_M NONE
Douglas Daly	DODA	AuScope	LEICA GRX1200GGPRO	200536	LEIAT504GG NONE
Esperance	ESPA	AuScope	LEICA GRX1200GGPRO	200533	LEIAT504GG SCIS
Hillarys	HIL1	ARGN	LEICA GRX1200PRO	5200404028	ASH701945C_M NONE
Hobart	HOB2	IGS, AFN, ARGN	LEICA GRX1200GGPRO	203	AOAD/M_T NONE
Hyden	HYDN	AuScope	LEICA GRX1200GGPRO	200534	LEIAT504GG SCIS
Jabiru	JAB2	IGS, ARGN	LEICA GRX1200GGPRO	103313	LEIAT504 NONE
Kalgoorlie	KALG	AuScope	LEICA GRX1200GGPRO	200526	LEIAT504GG SCIS
Karratha	KARR	IGS, AFN, ARGN	ASHTECH UZ-12	320	AOAD/M_T AUST
Katherine	KAT1	AuScope	LEICA GRX1200+GNSS	09310015	LEIAR25.R3 LEIT
Katherine	KAT2	ARGN	TRIMBLE NETR8	4938353446	TRM59800.00 NONE
Kellerberrin	KELN	AuScope	LEICA GRX1200GGPRO	200548	LEIAT504GG SCIS
Kununurra	KUNU	AuScope	LEICA GRX1200GGPRO	200539	LEIAT504GG SCIS
Larrimah	LARR	AuScope	LEICA GRX1200GGPRO	200535	LEIAT504GG NONE
Liawenee	LIAW	AuScope	LEICA GRX1200GGPRO	200538	LEIAT504GG SCIS
Leonora	LORA	AuScope	LEICA GRX1200GGPRO	200542	LEIAT504GG SCIS
Lord Howe Island	LORD	ARGN	LEICA GRX1200GGPRO	200702	LEIAT504GG NONE
Melbourne Observatory	MOBS	IGS, ARGN	LEICA GRX1200GGPRO	20020709	ASH701945C_M NONE
Norfolk Island	NORF	ARGN	LEICA GRX1200GGPRO	200696	LEIAT504GG SCIS
Norseman	NORS	AuScope	LEICA GRX1200GGPRO	200546	LEIAT504GG SCIS
Australian Telescope National Facility	PARK	IGS, ARGN	JPS E_GGD	620011902	ASH701945C_M NONE
Ravensthorpe	RAVN	AuScope	LEICA GRX1200GGPRO	200716	LEIAT504GG SCIS
Round Hill Point Light House	RHPT	ARGN	LEICA GRX1200GGPRO	103316	LEIAT504 NONE

Table 2 continued

Saltia	SA45	AuScope	LEICA GRX1200GGPRO	200551	LEIAT504GG	SCIS
Spring Bay	SPBY	AuScope	LEICA GRX1200GGPRO	200549	LEIAT504GG	SCIS
Stromlo	STR1	IGS, ARGN	LEICA GRX1200GGPRO	620023911	ASH701945C_M	NONE
Stromlo	STR2	IGS, ARGN	TRIMBLE NETR5	2170236	TPSCR3_GGD	CONE
National Measurement Institute	SYDN	IGS, ARGN	JPS E_GGD	519994908	ASH701945C_M	NONE
Tidbinbilla	TID1	IGS, ARGN	TRIMBLE NETR8	205	AOAD/M_T	JPLA
Tidbinbilla	TIDB	IGS, AFN, ARGN	ASHTECH Z-XII3	205	AOAD/M_T	JPLA
Townsville	TOW2	IGS, AFN, ARGN	LEICA GRX1200GGPRO	326	AOAD/M_T	AUST
Wagin	WAGN	AuScope	LEICA GRX1200+GNSS	09330050	LEIAR25.R3	LEIT
Warakurna	WARA	AuScope	LEICA GRX1200GGPRO	200677	LEIAT504GG	SCIS
Christmas Island	XMIS	IGS, ARGN	LEICA GRX1200GGPRO	6200503003	ASH701945C_M	NONE
Yaragadee	YAR2	IGS, AFN, ARGN	ASHTECH UZ-12	371	AOAD/M_T	JPLA
Yaragadee	YAR3	IGS, ARGN	LEICA GRX1200GGPRO	08360001	LEIAR25	NONE
Yaragadee	YARR	IGS, ARGN	LEICA GRX1200PRO	103314	LEIAT504	NONE
Yeelanna	YEEL	AuScope	LEICA GRX1200GGPRO	200532	LEIAT504GG	SCIS
Yellowdine	YELO	AuScope	LEICA GRX1200GGPRO	200523	LEIAT504GG	SCIS

Table 3: AFN (bold station names), ARGN and AuScope 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)
ALBY	50191M001	0.0000	LIAW	50192M001	0.0000
ALIC	50137M001	0.0070	LORA	59999M001	0.0000
ANDA	59971M001	0.0000	LORD	59998M001	0.0000
BBOO	59997M001	0.0000	MOBS	50182M001	0.0000
BNDY	50185M001	0.0000	NORF	50189M001	0.0000
BUR2	50144M003	0.0005	NORS	50194M001	0.0000
BURA	50193M001	0.0000	PARK	50108M001	0.0000
CEDU	50138M001	0.0060	RAVN	59967M001	0.0000
COCO	50127M001	0.0040	RHPT	50187M001	0.0000
COOB	59970M001	0.0000	SA45	59987M001	0.0305
DARM	50184M001	0.0035	SPBY	50162M004	0.0005
DARW	50134M001	0.0025	STR1	50119M002	0.0040
DODA	59985M001	0.0000	STR2	50119M001	0.0310
ESPA	50177M002	0.0000	SYDN	50124M003	0.0300
HIL1	50141S001	0.0000	TID1	50103M108	0.0614
HOB2	50116M004	0.0000	**TIDB**	50103M108	0.0614
HYDN	50195M001	0.0000	**TOW2**	50140M001	0.0035
JAB2	50136M002	0.0000	WAGN	59966M001	0.0040
KALG	50188M001	0.0000	WARA	50198M001	0.0000
KARR	50139M001	0.0020	XMIS	50183M001	0.0000
KAT1	59968M001	0.0000	**YAR2**	50107M004	0.0814
KAT2	59968M002	0.0000	YAR3	50107M008	0.0040
KELN	50197M001	0.0000	YARR	50107M006	0.0045
KUNU	59995M001	0.0000	YEEL	59996M001	0.0000
LARR	59984M001	0.0000	YELO	50199M001	0.0000

Method:

Analysis was undertaken following the procedures detailed in the Geoscience Australia, GPS Analysis Manual for the Verification of Position Issue 1.5.

In summary, daily solutions of the ARGN and AuScope, and AFN/ARGN/IGS site data were processed using the 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 L3 ionosphere free carrier phase observable at 30-second epoch intervals was used for the 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 4 lists the Root Mean Square (RMS) of the daily station coordinate values. Table 5 lists the GDA94 station coordinates resulting from the combination.

Table 4: Root Mean Square (RMS) of daily AFN (bold station names), ARGN and AuScope, and minimally constrained AFN/ARGN/IGS station coordinates.

Station	East (mm)	North (mm)	Up (mm)	Station	East (mm)	North (mm)	Up (mm)
ALBY	1.7	2.0	2.1	LIAW	0.6	0.6	2.5
ALIC	0.5	0.7	4.5	LORA	0.8	0.9	5.0
ANDA	0.6	0.6	5.1	LORD	1.7	2.1	3.4
BBOO	0.5	0.6	5.5	MOBS	0.8	0.7	2.6
BNDY	1.5	1.2	3.1	NORF	1.0	2.7	4.0
BUR2	1.2	1.2	2.8	NORS	1.3	1.6	4.9
BURA	0.8	0.7	2.0	PARK	1.2	0.9	3.9
CEDU	0.6	0.6	4.4	RAVN	1.6	0.9	3.1
COCO	2.2	3.7	6.0	RHPT	0.7	0.7	2.6
COOB	0.7	0.7	5.4	SA45	0.4	0.7	4.7
DARM	1.1	0.8	8.4	SPBY	0.9	1.0	3.4
DARW	1.5	1.4	1.8	STR1	0.3	0.4	2.4
DODA	1.4	1.1	4.2	STR2	0.7	0.6	1.0
ESPA	0.8	0.5	3.4	SYDN	1.2	1.1	5.1
HIL1	0.7	1.0	2.5	TID1	0.9	1.0	2.5
HOB2	1.1	0.6	3.9	**TIDB**	1.0	0.9	2.6
HYDN	0.8	1.1	2.2	**TOW2**	1.8	0.8	7.9
JAB2	1.3	1.3	7.6	WAGN	0.9	1.1	5.9
KALG	0.5	0.9	4.4	WARA	0.6	0.7	4.4
KARR	1.5	1.3	5.1	XMIS	1.9	2.3	1.9
KAT1	1.4	1.0	3.0	**YAR2**	1.0	1.0	2.5
KAT2	1.3	0.9	4.6	YAR3	1.1	1.1	2.0
KELN	0.7	0.9	1.8	YARR	1.0	1.0	2.0
KUNU	0.7	1.1	6.6	YEEL	0.5	0.7	7.6
LARR	1.3	0.7	4.7	YELO	0.8	1.8	2.8

Table 5: Computed Geocentric Datum of Australia (GDA94) geodetic coordinates and their uncertainty for ARGN and AuScope 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)			Latitude (DMS south)			Ellipsoidal height (M)
			Std (M)			Std (M)	Std (M)
ALBY	117	48	36.64954 0.0315	34	57	0.84504 0.0315	36.7212 0.0544
ALIC	133	53	7.84800 0.0315	23	40	12.44591 0.0315	603.3398 0.0544
ANDA	137	9	36.34836 0.0315	30	27	11.86835 0.0315	101.4723 0.0544
BBOO	136	3	31.20743 0.0315	32	48	37.28610 0.0315	288.7313 0.0544
BNDY	152	19	15.60726 0.0315	24	54	29.62392 0.0315	80.1112 0.0544
BUR2	145	54	53.45476 0.0315	41	3	0.26106 0.0315	3.9015 0.0544
BURA	117	10	28.69094 0.0315	30	31	31.90374 0.0315	327.9809 0.0544
CEDU	133	48	35.37574 0.0315	31	52	0.01660 0.0315	144.8155 0.0544
COCO	96	50	2.27371 0.0315	12	11	18.06741 0.0315	-35.2366 0.0544
COOB	134	43	21.25276 0.0315	29	2	4.99196 0.0315	230.3856 0.0544
DARM	130	53	29.35749 0.0315	12	25	26.46080 0.0315	83.1480 0.0544
DARW	131	7	57.84786 0.0315	12	50	37.35841 0.0315	125.2018 0.0544
DODA	131	11	12.56033 0.0315	13	50	4.50761 0.0315	90.6163 0.0544
ESPA	121	53	39.54892 0.0315	33	52	27.57626 0.0315	32.5289 0.0544
HIL1	115	44	18.87911 0.0315	31	49	31.90480 0.0315	-27.1909 0.0544
HOB2	147	26	19.43584 0.0315	42	48	16.98537 0.0315	41.1338 0.0544
HYDN	118	53	30.73624 0.0315	32	26	57.80232 0.0315	300.1481 0.0544
JAB2	132	53	40.30949 0.0315	12	39	36.56590 0.0315	82.6254 0.0544
KALG	121	27	33.30198 0.0315	30	47	3.83834 0.0315	338.0935 0.0544
KARR	117	5	49.87270 0.0315	20	58	53.16984 0.0315	109.2226 0.0544
KAT1	132	9	11.76523 0.0315	14	22	33.63335 0.0315	184.3853 0.0544
KAT2	132	9	9.00221 0.0315	14	22	30.29289 0.0315	184.3233 0.0544
KELN	117	42	9.46539 0.0315	31	37	20.37930 0.0315	253.1338 0.0544
KUNU	128	45	45.42588 0.0315	15	40	37.09199 0.0315	91.9841 0.0544
LARR	133	12	45.90845 0.0315	15	34	23.39672 0.0315	229.4247 0.0544
LIAW	146	40	23.08325 0.0315	41	54	8.17797 0.0315	1054.3466 0.0544
LORA	121	20	14.17224 0.0315	28	54	22.48169 0.0315	431.2571 0.0544
LORD	159	3	40.31116 0.0315	31	31	11.61087 0.0315	71.5013 0.0544
MOBS	144	58	31.20672 0.0315	37	49	45.89883 0.0315	40.6696 0.0544

Table 5 continued.

NORF	167	56	19.78743 0.0315	29	2	36.06677 0.0315	159.1147 0.0544
NORS	121	47	14.04382 0.0315	32	15	36.10212 0.0315	461.2628 0.0544
PARK	148	15	52.58910 0.0315	32	59	55.58176 0.0315	397.4411 0.0544
RAVN	120	4	15.17419 0.0315	33	35	48.31706 0.0315	205.8089 0.0544
RHPT	145	57	42.61942 0.0315	41	3	54.48437 0.0315	25.9603 0.0544
SA45	137	56	3.56715 0.0315	32	28	13.07668 0.0315	201.9758 0.0544
SPBY	147	55	51.04999 0.0315	42	32	47.20575 0.0315	1.1602 0.0544
STR1	149	0	36.17982 0.0315	35	18	55.93946 0.0315	800.0258 0.0544
STR2	149	0	36.54767 0.0315	35	18	58.19897 0.0315	802.5667 0.0544
SYDN	151	9	1.35698 0.0315	33	46	51.18413 0.0315	85.6755 0.0544
TID1	148	58	47.98450 0.0315	35	23	57.15605 0.0315	665.4245 0.0544
TOW2	147	3	20.46549 0.0315	19	16	9.42804 0.0315	88.2182 0.0544
WAGN	117	24	36.32656 0.0315	33	19	59.06144 0.0315	289.0260 0.0544
WARA	128	17	46.20594 0.0315	25	2	13.95620 0.0315	587.2555 0.0544
XMIS	105	41	18.58063 0.0315	10	26	59.89870 0.0315	261.5833 0.0544
YAR2	115	20	49.09997 0.0315	29	2	47.61688 0.0315	241.3618 0.0544
YAR3	115	20	49.72796 0.0315	29	2	47.40388 0.0315	242.5280 0.0544
YARR	115	20	49.08940 0.0315	29	2	47.74256 0.0315	241.4278 0.0544
YEEL	135	47	3.74893 0.0315	34	8	38.97280 0.0315	169.8065 0.0544
YELO	119	38	44.85700 0.0315	31	17	26.52180 0.0315	347.2285 0.0544

END OF REPORT