



Sydney Opera House Traverse GDA2020

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1. Purpose / Background

The purpose of this survey is to provide survey control for the Sydney Opera House to enable the site to be moved onto the newly established GDA2020 datum.

The traverse has been designed and carried out to Class B standards as per the requirements set out in Surveyor-General's Direction No. 12 (SGD12) and associated documentation. It covers an approximate area of 250m² and consists of 13 stations. The traverse connects to the overarching Sydney Opera House GNSS Static survey for primary survey control – this has been previously submitted and approved for update in SCIMS.

This report covers the 3D GDA2020 adjustment of Sydney Opera House traverse. It is intended to update SCIMS with GDA2020 horizontal coordinates, ellipsoid heights, Class, Positional Uncertainty, and other relevant metadata as recommended at the conclusion of this report.

2. Fieldwork / Observations

Fieldwork was carried out on the 21st of May 2020 by DCS Spatial Services staff. Fieldwork specifications follow Class B standards, refer to the attached field notes and Survey Checklist for further detail.

A number of miscellaneous and eccentric survey marks were placed as part of the traverse and do not conform to the Regulation in terms of mark type and monumentation. These survey marks will be downgraded in Class to account.

3. Equipment

Table 1: Total station equipment details.

Designation	Make	Model	Serial Number
Total Station	Leica	TS16	xxxx xxxx

4. Network Design and Control Strategy

The survey is designed as a heavily braced closed loop traverse that extends around and through the Sydney Opera House. The longest and shortest line in the network is 172m and 27m respectively.

It was attempted to connect into each survey mark a minimum of 3x to ensure sufficient redundancy in the network. Similarly, it was attempted to set up on each survey mark with both the instrument and target. Where this was not feasible (e.g along the sea wall), triple radiations were observed to ensure sufficient redundancy. This will be further reflected in the Class assessment for each survey mark.

The traverse connects into the overarching **300213 Sydney Opera House GNSS Static GDA2020** network and adjoining **300174 Sydney CBD Traverse GDA2020** network for primary survey control. Additional survey control to the east of the traverse would have been ideal but was not feasible due to local site constraints. All survey control is of an equal or better Class and contains Positional Uncertainty, satisfying the control requirements for SGD12. Refer to **Figure 1** for further information.

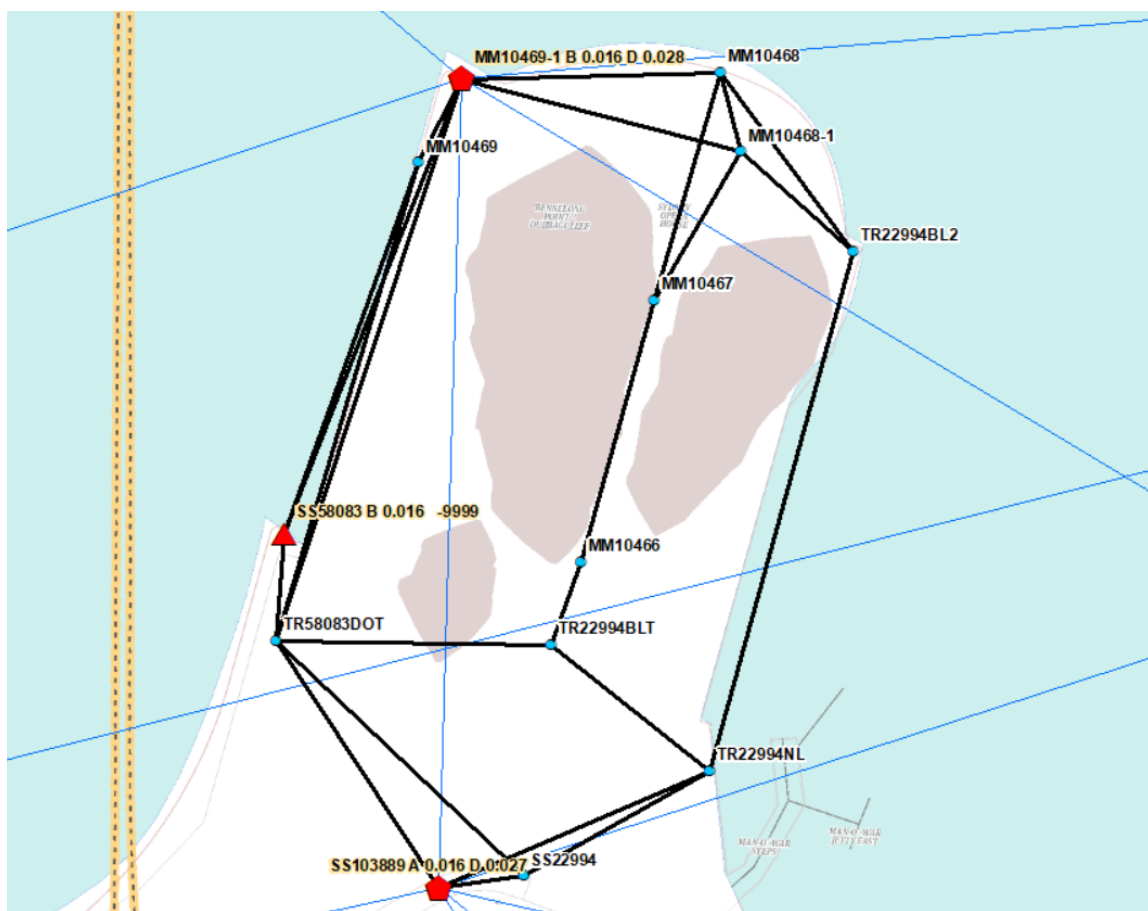


Figure 1: The Sydney Opera House traverse shown in black with the 300215 Sydney Opera House GNSS Static network overlaid in blue. 3D survey control marks (GDA2020 Hz + EHGT constraints) are shown via the red pentagons, 2D survey control marks (GDA2020 Hz only constraints) are shown via the red triangle, while survey marks to be adjusted are shown via the blue circles.

Overall, the network design and adopted control strategy is deemed fit-for-purpose and satisfies the requirements of a Class B survey.



Figure 2: MM10468 and SS22994 setup.

5. Processing and Reduction Strategy

Software: FB04
Version: V10.0.1

All observations and individual pointings were checked for gross errors and compliance with Class B tolerances (e.g. direction ranges and residuals).

In-house program FB04 was used to apply temperature and pressure corrections as well as prism constants to reduce distances to the ellipsoid. All angle and direction observations have been appropriately reduced to grand means in preparation for the least squares adjustment.

6. Adjustment Strategy and Options Used

Software: Microsearch Geolab 2001
Version: 2001.9.20.0

Table 2: Total station observation weightings applied to the overall adjustment for distance (EDIS), direction (DIR) and height difference (HDF) measurements. .

Component	Constant	PPM	Centering To (m)	Centering From (m)
EDIS	0.002 m	2	0.001	0.001
DIR	2 "		0.001	0.001
HDF	0.008 "	20	0.001	0.001

A 3D minimally constrained and fully constrained least squares adjustment has been run to determine Class, provisional coordinates, and Positional Uncertainty respectively. Applied observation weightings (input standard deviations) are listed in **Table 2**.

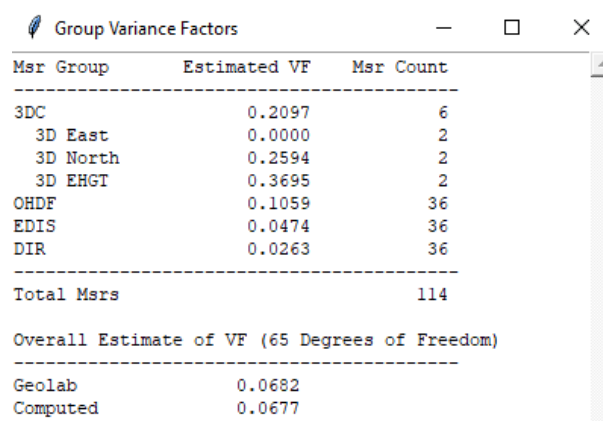
Adjustment constraints have been sourced from SCIMS and use the survey mark's corresponding GDA2020 horizontal and vertical (EHGT) positional uncertainty (HPU, VPU).

7. Minimally Constrained Adjustment

The intent of this survey is to award a **GDA2020 horizontal Class B** and **GDA2020 vertical (EHGT) Class D**.

A minimally constrained adjustment was run to validate the quality of the control survey and make a statistical determination of Class. **SS103889 (A 0.016 D 0.027)** and **MM10469-1(B 0.016 D 0.028)** were constrained in GDA2020 horizontal coordinates and ellipsoid height (3D) as sourced from SCIMS.

The initial variance factor (VF) from the adjustment was well below one, at 0.068, which fails the Chi-Square test (see **Figure 3**). The group VF for distance (EDIS) and direction (DIR) are quite small but overall balanced. The height difference group VF (OHDF) is slightly more elevated suggesting some tension in the height component of the traverse.



Msr Group	Estimated VF	Msr Count
3DC	0.2097	6
3D East	0.0000	2
3D North	0.2594	2
3D EHGT	0.3695	2
OHDF	0.1059	36
EDIS	0.0474	36
DIR	0.0263	36
Total Msrs		114
Overall Estimate of VF (65 Degrees of Freedom)		
Geolab	0.0682	
Computed	0.0677	

Figure 3: Minimally constrained variance factor results.

The minimally constrained adjustment indicated a normalised distribution of residuals with all values well below the critical factor of 3.5158.

The largest standardised residual occurred in the EHGT component of 3D constraint MM10469-1 (-0.007m res, -2.602 std res). The largest absolute residual in terms of size occurred in the direction (DIR) component of line TR58083DOT – SS58083 (2.5" res, std res 1.5, 31.47 m). The largest absolute residual in terms of ppm occurred in the height difference (HDF) component of line TR58083DOT – SS58083 (0.004m res, 2.294 std res, 31.47m line, 131.45ppm) which can be attributed to the short line and inherent noise in the measurement. Refer to the attached least square adjustment output files for further detail.

Overall, the variance factors and residuals suggest the survey fits together well validating the quality of observations and the adopted survey methodology. No changes have been made to the applied observation weightings to ensure realistic least square adjustment statistics commensurate with the achievable measurement precision of the survey.

The difference between adjusted coordinates to SCIMS was computed to check for any potential mark movement and to gain an idea of how datum behaves in the adjustment (see **Table 3**). SS56064, SS103889 and MM10469-1 showed small differences indicating good agreement in survey control.

Table 3. Minimally constrained adjustment coordinate differences compared to established SCIMS marks.

Survey Mark	Class / PU			GDA2020 SID:	GDA2020 EHGT SID:	Δ Easting	Δ Northing	Horizontal Shift	Δ EHGT
SS58083	B	0.016		300367	N/A	-0.002	0.002	0.003	No EHGT
SS103889	A	0.016	D 0.027	300367	300367	0.000	0.003	0.003	-0.006
MM10469-1	B	0.016	D 0.028	300367	300367	0.000	-0.003	0.003	0.007

A statistical assessment of horizontal and vertical Class has been made. Using the calculated relative error ellipses and distance between two survey marks, a corresponding **c** value has been calculated by rearranging the Class formula ($r = c(d+0.2)$). The calculated **c** value was then checked to see what Class it meets. All REEs have been converted from 2-sigma (95% CI) to 1-sigma (68% CI) as per SGD12 requirements.

Class has been assessed between every survey mark in the network, temporary stations have been ignored.

Table 4: GDA2020 horizontal and vertical Class assessment.

From	To	Major-Semi Axis		Vertical		Distance		Horizontal Class		Vertical Class	
		(95% CI)	(68% CI)	(95% CI)	(68% CI)	(m)	(km)	c	Class	c	Class
MM10468	SS103889	0.006	0.003	0.003	0.002	251.933	0.252	5.8	A	3.8	A
MM10468	SS22994	0.006	0.003	0.004	0.002	241.702	0.242	5.7	A	4.3	A
MM10469-1	SS103889	0.006	0.002	0.003	0.001	236.266	0.236	5.5	A	3.2	A
MM10469-1	SS22994	0.006	0.002	0.003	0.002	233.518	0.234	5.5	A	3.9	A
MM10468-1	SS103889	0.006	0.002	0.003	0.002	232.343	0.232	5.6	A	3.7	A
MM10468-1	SS22994	0.006	0.002	0.004	0.002	220.879	0.221	5.5	A	4.3	A
MM10469	SS103889	0.005	0.002	0.004	0.002	211.85	0.212	5.3	A	4.4	A
MM10469	SS22994	0.005	0.002	0.004	0.002	210.631	0.211	5.4	A	4.9	A
MM10468	SS58083	0.005	0.002	0.003	0.002	185.553	0.186	5.2	A	4.4	A
MM10467	SS103889	0.005	0.002	0.003	0.002	182.692	0.183	5.0	A	4.4	A
MM10468-1	SS58083	0.004	0.002	0.003	0.002	174.008	0.174	4.8	A	4.0	A
MM10467	SS22994	0.004	0.002	0.004	0.002	172.392	0.172	4.8	A	5.1	A
MM10466	MM10468	0.004	0.002	0.003	0.002	148.641	0.149	4.6	A	4.9	A
MM10466	MM10469-1	0.004	0.002	0.003	0.002	145.232	0.145	4.6	A	4.6	A
MM10469-1	SS58083	0.004	0.002	0.002	0.001	142.531	0.143	4.4	A	3.5	A
MM10466	MM10468-1	0.003	0.001	0.003	0.002	128.546	0.129	4.3	A	4.6	A
MM10467	SS58083	0.003	0.001	0.003	0.002	127.863	0.128	4.3	A	5.2	A
MM10466	MM10469	0.003	0.001	0.004	0.002	125.811	0.126	4.3	A	6.1	A
SS22994	SS58083	0.003	0.001	0.004	0.002	122.16	0.122	4.0	A	5.6	A
MM10469	SS58083	0.003	0.001	0.003	0.001	115.29	0.115	3.8	A	4.4	A
SS103889	SS58083	0.003	0.001	0.003	0.002	113.174	0.113	3.8	A	4.8	A
MM10466	SS103889	0.003	0.001	0.003	0.002	103.972	0.104	3.6	A	5.6	A
MM10468-1	MM10469	0.003	0.001	0.003	0.002	94.26	0.094	3.7	A	5.8	A
MM10466	SS22994	0.003	0.001	0.004	0.002	93.342	0.093	3.7	A	6.5	A
MM10468	MM10469	0.003	0.001	0.004	0.002	92.079	0.092	3.8	A	6.5	A
MM10466	SS58083	0.002	0.001	0.004	0.002	87.153	0.087	3.5	A	6.3	A
MM10467	MM10469-1	0.002	0.001	0.003	0.002	85.825	0.086	3.5	A	5.2	A
MM10468-1	MM10469-1	0.002	0.001	0.002	0.001	84.472	0.084	3.2	A	4.2	A

MM10467	MM10469	0.002	0.001	0.004	0.002	79.766	0.080	3.6	A	6.8	A
MM10466	MM10467	0.002	0.001	0.003	0.001	79.243	0.079	3.2	A	4.7	A
MM10468	MM10469-1	0.002	0.001	0.003	0.001	75.794	0.076	3.3	A	5.1	A
MM10467	MM10468	0.002	0.001	0.003	0.001	69.398	0.069	3.0	2A	5.2	A
MM10467	MM10468-1	0.001	0.001	0.002	0.001	50.293	0.050	2.4	2A	4.8	A
MM10469	MM10469-1	0.001	0.000	0.003	0.001	27.413	0.027	1.8	2A	6.2	A
SS103889	SS22994	0.001	0.000	0.003	0.001	25.71	0.026	1.8	2A	6.2	A
MM10468	MM10468-1	0.001	0.000	0.002	0.001	23.966	0.024	1.8	2A	5.4	A

Based on **Table 4**, the survey predominantly meets a statistical horizontal and vertical **Class A**, far surpassing the intended Class B allocation.

Based on the statistical results above and factoring in network design, survey practices adopted, equipment / instrumentation used, reduction techniques employed; as well as other considerations such as monument quality, survey intent, and current DCS Spatial Services business rules; the following recommendations are made:

- The survey is overall awarded **Class B** horizontally and **Class D** vertically (EGHT).
- **MM10468**, **MM10469** and **SS22994** were not directly set up on via the instrument and will be downgraded to horizontal and vertical **Class D** to compensate.
- **MM10468-1** has poor mark monumentation (bolt and nail in concrete) and will be downgraded to horizontal and vertical **Class E** to compensate.

8. Adjustment Constraints

All potential 3D and 2D constraints were applied in the fully constrained adjustment. No issues were found with survey control as detailed in the minimally constrained adjustment.

Table 5: GD2020 constraints from SCIMS applied in the fully constrained adjustment. Note SS58303 does not have EHGT in SCIMS and therefore will only be used as a 2D constraint.

Mark	Class / PU	Source	Easting	Northing	Zone	Ellipsoid Height	Constrained
MM10469-1	B 0.016 D 0.028	300367	6252357.769	334841.349	MGA 56	26.203	Yes
SS103889	A 0.016 D 0.027	300367	6252121.744	334848.613	MGA 56	33.329	Yes
SS58083	B 0.016	300367	6252222.226	334797.353	MGA 56	N/A	Yes

9. Fully Constrained Adjustment

For the fully constrained adjustment, the constraints listed in **Table 5** have been applied using the survey mark's corresponding SCIMS GDA2020 Positional Uncertainty expressed as a standard deviation (see **Section 6**).

The measurement input standard deviations applied in the minimally constrained adjustment and outlined in **Section 6** remain unchanged. Type B errors were introduced into the adjustment in order to appropriately calculate realistic positional uncertainties, as per DCS Spatial Services' policy.

The fully constrained adjustment returns an overall VF of 0.0678 with 0 flagged residuals. The observation group variance factors (EDIS, DIR, OHDF) follow the same trend as in the minimally constrained adjustment and are similar in size. The 3D and 2D constraint (3DC, 2DC) group variance factors are also small indicating a good agreement in survey control. It is noted that the 3DC North VF is slightly elevated compared to the East component which is a result of the network geometry and location of survey control (north – south).

Msr Group	Estimated VF	Msr Count
3DC	0.2225	6
3D East	0.0238	2
3D North	0.2789	2
3D EHGT	0.3648	2
2DC	0.0606	2
2D East	0.0803	1
2D North	0.0410	1
OHDF	0.1045	36
EDIS	0.0468	36
DIR	0.0268	36
Total Msrs		116
Overall Estimate of VF (67 Degrees of Freedom)		
Geolab	0.0678	
Computed	0.0678	
Note: 2DC Northing components cannot be computed reliably due to reporting errors in Geolab		

Figure 6: Fully constrained adjustment variance factor results.

There were no flagged residuals outside the critical value of 3.5204 and all residuals follow a normalised distribution. This further indicates a good fit amongst survey control and observations with appropriate input standard deviations applied. Refer to the attached least squares output files for further detail.

As a final check, the fully constrained adjusted coordinates were compared to their current SCIMS coordinates as a check for any gross errors (see **Table 6**). All survey marks to be upgraded move by less than 1.5m horizontally which is within GDA2020 transformation parameters. All 3 constraints show minor movement within their current SCIMS GDA2020 positional uncertainty, as expected.

Table 6: Fully constrained adjustment coordinate differences compared to SCIMS. Ellipsoid height has not been compared.

Survey Mark	Class & PU	GDA2020 SID:	GDA2020 EHGT SID:	Δ Easting	Δ Northing	Horizontal Shift
SS58083	B 0.016	300367	N/A	-0.001	0.001	0.001
SS22994	U	300006	N/A	-0.108	-0.443	0.456
MM10469	U	300006	N/A	0.118	0.769	0.778
MM10466	U	300006	N/A	0.034	1.353	1.353
MM10468	U	300006	N/A	-0.414	1.308	1.372
MM10467	U	300006	N/A	0.04	0.958	0.959
SS103889	A 0.016 D 0.027	300367	300367	0.001	0.002	0.002
MM10469-1	B 0.016 D 0.028	300367	300367	0.000	-0.003	0.003
MM10468-1	U	300006	N/A	0.204	1.085	1.104

No changes have been made based on the coordinate shifts seen in the fully constrained adjustment.

Analysing the calculated GDA2020 positional uncertainties in this adjustment, all survey marks proposed for upgrade achieved a HPU of less than 30mm and VPU of 40mm which is deemed fit-for-purpose.

Final recommendations are made at the conclusion of this report.

10. Recommendation

It is recommended that SCIMS is updated with the survey marks listed in **Table 7** including GDA2020 coordinates, ellipsoid height, Class and Positional Uncertainty.

Overall, it is recommended that the survey be awarded a GDA2020 **horizontal Class B** and **vertical (Ellipsoid Height) Class D** based on the results of this adjustment.

Specifically, it is recommended that **MM10468, MM10468-1, MM10469** and **SS22994** awarded **Class D** horizontally and **Class D** vertically.

Table 7: Final adjusted GDA2020 coordinates, Class and Positional Uncertainty. Note coordinates shown with a corresponding 'F' under 'HFIX' or 'VFIX' are adjustment constraints and are not proposed for update via this survey.

MARK	HFIX	EASTING	NORTHING	ZONE	HC	HPU	VFIX	HEIGHT	VC	VPU
MM10466		334884.423	6252219.085	56	B	0.017		26.231	D	0.033
MM10467		334901.417	6252296.480	56	B	0.018		26.238	D	0.033
MM10468		334916.870	6252364.131	56	D	0.022		26.277	D	0.033
MM10468-1		334924.196	6252341.314	56	E	0.021		26.195	E	0.031
MM10469		334830.340	6252332.669	56	D	0.019		26.27	D	0.033
MM10469-1	F	334841.349	6252357.769	56	B	0.016	F	26.203	D	0.028
SS103889	F	334848.613	6252121.744	56	A	0.016	F	33.329	D	0.027
SS22994		334873.108	6252126.442	56	D	0.02		27.11	D	0.033
SS58083	F	334797.353	6252222.226	56	B	0.016		24.258	D	0.031

11. Appendix

Indicate which appendices have been attached to this report and provide relevant file names.

Yes	N/A	Appendices
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Appendix A: <i>SGD12 Survey Checklist.pdf</i>
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Appendix B: <i>Photos</i>
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Appendix C: <i>Field notes, log sheets, session diagrams</i>
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Appendix D: <i>Instrument calibration certificate(s)</i>
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Appendix E: <i>Native instrument raw data files</i>
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Appendix F: <i>Spatial Services format specific raw data file(s)</i>
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Appendix G: <i>Processing / reduction files</i>
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Appendix H: <i>Network diagrams, plans</i>
<input checked="" type="checkbox"/>	<input type="checkbox"/>	Appendix I: <i>Least squares adjustment input file(s) – minimally + fully constrained</i>



Appendix J:

Least squares adjustment output file(s) – minimally + fully constrained



Appendix K:

Provisional coordinates, heights, Class and Positional Uncertainty

Outline any additional attachments:

Not applicable.

12. Submission Statement

I, **John Surveyor**, of **DCS Spatial Services**, present the survey outlined in this report as meeting the requirements of a horizontal Class **B** and vertical Class **D** control survey as per *Surveyor-General's Direction No. 12*.

I understand that the inclusion of these results in SCIMS and their final Class and uncertainty classification is at the sole discretion of DCS Spatial Services.

A signed checklist, as per the requirements of *Surveyor-General's Direction No. 12* is attached (Appendix A).

Signed: *Include signature here*

Dated: *Include date of signature here*

End of Report

DCS Spatial Services use only

Analysis by DCS Spatial Services:

Comments by DCS Spatial Services Senior Surveyor or nominated representative:

Approved for SCIMS update:

Transaction Number:

SCIMS Updated: