Technical Specifications for NSW Secondary Control Surveys

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Cover photograph shows a GNSS survey at TS2136 Gap at Fowlers Gap, Western NSW. Included in the photo is TS12278 Fowlers Gap Continuously Operating Reference Station (CORS).

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Definitions

In this document, the following terms have the meaning as indicated below.

the Act	Means the Surveying and Spatial Information Act 2002.
AHD	As defined in Clause 3 of the Act. AHD71 is the datum surface approximating mean sea level that was adopted by the National Mapping Council of Australia in May 1971.
AUSPOS	Geoscience Australia's free online GPS processing service.
Benchmark	Means any mark as defined in Clause 27 & Schedule 1 of the Regulation.
Calibration	As defined in *Surveyor-General's Direction No. 5 – Calibration of Electronic Distance Measuring (EDM) Equipment* (SGD5), calibration is the determination of instrument errors by comparing the value indicated by the measuring equipment with the known or true value. Consequently, corrections must be applied to all measurements made with the equipment in order to obtain 'true' measurements.
Class	As *Surveyor-General's Direction No. 12 - Control Surveys and SCIMS* (SGD12).
Constrained adjustment - fully	As defined in SGD12, means an adjustment which has a sufficient number of constrained survey control marks, identified in the control strategy (see SGD12), to propagate datum and uncertainty throughout the control survey.
Constrained adjustment - minimally	As defined in SGD12, means an adjustment which has the minimum number of constrained survey control marks to calculate all dimensions of the adjustment and assess Class.
Control survey	As defined in SGD12, a control survey is performed by making suitably accurate measurements between new or existing survey marks and referring them to identifiable survey control marks in an existing control network. In the context of this document, a control survey is taken to mean any survey that is carried out for the purpose of deriving coordinates, heights and related information of survey marks underpinning the State Control Survey Network for update of SCIMS.
GDA	Means the Geocentric Datum of Australia, as defined in Clause 3 of the Act.
GDA2020	Means the Means the Geocentric Datum of Australia 2020.
GNSS	Means Global Navigation Satellite System.
Local Uncertainty	As *Surveyor-General's Direction No. 12 - Control Surveys and SCIMS* (SGD12).
Positional Uncertainty	As *Surveyor-General's Direction No. 12 - Control Surveys and SCIMS* (SGD12).
Primary Control Survey	As defined in SGD12, a primary control survey is a survey that: • Is considered of State or National significance and serves to establish and propagate datum such as GDA2020 and AHD71. This includes, as an example, survey networks such as the Australian National Levelling Network (ANLN), CORSnet-NSW and the GDA Spine and Subspine network(s), and • Is identified as such by the Surveyor-General of NSW and/or Spatial Services.

the Regulation	Means the Surveying and Spatial Information Regulation 2017.
SCIMS	Means the information management system maintained by the Surveyor-General and known as the "Survey Control Information Management System", as defined in Clause 5 of the Regulation.
SCIMS Online	Is the web mapping tool that makes SCIMS data available to the public via the SIX Spatial Services Portal.
Secondary Control Survey	As defined in SGD12, a secondary control survey is a survey that: • Is not defined as a Primary Control Survey, • Predominately serves to refine/maintain the State Control Survey Network as well as propagate datum, • Is common for projects that require survey control to be densified from the Primary Control Survey to the site to establish datum, e.g. infrastructure projects, and • Is identified as such by the Surveyor-General of NSW and/or Spatial Services.
SGD12	Means the Surveyor-General's Direction No. 12 – Control Surveys and SCIMS.
SP1 v1.7	Means the Intergovernmental Committee on Surveying and Mapping (ICSM) publication 'Standards and Practices for Control Surveys (SP1), Version 1.7'.
SP1 v2.2	Means the Intergovernmental Committee on Surveying and Mapping (ICSM) publication 'Standard for the Australian Survey Control Network (SP1), Version 2.2'.
the State Adjustment	As defined in SGD12, the State Adjustment is a subset of the State control survey maintained by Spatial Services containing survey measurements used to determine coordinates, heights and qualities with respect to the national reference frames as prescribed in the Act.
State control survey	As defined in Clause 3 of the Act. Also known as the State Control Survey Network.
State Control Survey Network	Means the State control survey as defined in Clause 3 of the Act. A network of stations and survey measurements maintained by Spatial Services used to determine coordinates, heights and qualities with respect to the national reference frames.
Survey Mark	Means any mark as defined in Clause 27 & Schedules 1, 2, 3 or 4 of the Regulation.
Survey Control Mark	Means a survey mark that forms part of a control strategy that will be used to constrain a control survey and establish datum (GDA2020, AHD71, or both), see SGD12.
Surveyor-General	As defined in Clause 3 of the Act.
Verification	As defined in *Surveyor-General's Direction No. 5 – Calibration of Electronic Distance Measuring (EDM) Equipment* (SGD5), verification is a test to confirm that the accuracy attained by a measuring instrument is within allowable accuracy limits as defined in a specification or as required by legislation.
Uncertainty	As defined in SP1 v2.2, uncertainty in this document means doubt about the validity of a measurement or result of a measurement (e.g. a position). Uncertainty is an indication of how wrong a value may be and is used in this document to quantify the level of survey quality, expressed as a standard deviation in the International System of Units (SI) expanded to the 95% confidence level.

1. Introduction

This document has been developed by the Department of Customer Service - Spatial Services (hereafter referred to as Spatial Services) to provide the minimum equipment and observation specifications, and reduction or processing techniques required to allow a control survey to be included in the State Control Survey Network. It will assist surveyors in designing and undertaking a control survey to achieve a certain Class for update into the Survey Control Information Management System (SCIMS).

This document, the *Technical Specification for NSW Secondary Control Surveys*, is based on the Intergovernmental Committee of Survey and Mapping (ICSM) publication '*Standards and Practices for Control Surveys, version 1.7'* (SP1 v1.7) and has been updated to ensure that current best practice surveying techniques are adopted.

This document must be used in conjunction with *Surveyor-General's Direction No. 12 – Control Surveys and SCIMS* (SGD12) for secondary control surveys. It does not supersede SP1 v.1.7 (or SP1 v2.2), which remains the national guideline for control surveys.

2. Scope

The specifications detailed in this document apply only to secondary control survey techniques at the Class or Classes shown in **Table 1**.

Table 1: Approved survey techniques and applicable Class for secondary control surveys.

Survey Technique	Achievable Horizontal Class	Achievable Vertical Class	Applicable Conditions
Traversing	B, C, D	D	Measurement lines must be less than 1 km in length
Trigonometric Heighting	N/A	B, C	
Differential Levelling	N/A	LB, LC, LD	
GNSS Static	A, B, C, D	A, B, C, D	
GNSS RTK	D	D	
AUSPOS	D	D	

Surveys or survey techniques that are not included in **Table 1**, **must** instead adopt SP1 v1.7 and consult Spatial Services for update of SCIMS. Any additional specifications detailed in SGD12 **must** also be observed.

All updates or amendments to SP1 v1.7 are shown in **grey highlighted blue text** font.

3. Traversing Specifications

In order to update SCIMS, any control survey carried out in GDA2020 must be capable of delivering three-dimensional coordinates (easting, northing, MGA zone and ellipsoidal height). The following traversing specifications detail how to achieve a GDA2020 horizontal Class and to facilitate the derivation of approximate ellipsoidal heights at a vertical Class D. This requires traverse observations to record distance, horizontal and vertical angles, as well as instrument and target heights to the nearest millimetre at each station set-up.

For specifications on the measurement of accurate heights using a total station, refer to **Section 4**.

3.1. Equipment Specifications

Traverse equipment specifications are listed in **Table 2,** based on SP1 v1.7 Part B Clause 2.2 Table 11, 12 and 13, and Clause 2.3 Table 14 and 15.

Table 2: Traversing – Equipment specifications.

Class	B	C	D
Minimum EDM distance measuring accuracy [1]	**3 mm ± 3 ppm**	**5 mm ± 5 ppm**	**5 mm ± 5 ppm**
Minimum horizontal and vertical angle measuring accuracy [1]	**3”**	**5”**	**10”**
Reflectorless EDM allowed to measure to survey marks	**No**	**No**	**No**
Recommended use of Automatic Target Recognition (ATR)	**Yes**	**Yes**	**Yes**
National standard traceability of EDM	Yes	Yes	Yes
Instrument horizontal angle least count category: Highest High Medium	 1” 	 1” 	 1” 6”
Target prism and carrier [2]	**Circular prism**	**Circular prism**	**Recommend circular prism**
Tribrach	**Optical or laser plummet, Centring accuracy 1 mm.**	**Optical or laser plummet, Centring accuracy 1 mm.**	**Optional [3]**
Tripod [4]	**Yes**	**Yes**	**Recommended**

Notes:

1. Instruments must be capable of measuring to the indicated precisions to achieve a desired Class of survey. It is suggested to use the instrument specifications as a guide for determining appropriate input standard deviations for a least squares adjustment, see SGD12 for further information.
2. Where optional, it is recommended that circular prisms are used for targets when traversing. All prisms must be calibrated in relation to the instrument.

3. Bipods/ranging poles may be used for targets to achieve Class D but must be tested and adjusted before use. Tribrachs must be used when setting up on a trig pillar or spigot.
4. Tripods must be stable and of good quality.

3.2. Equipment Testing and Adjustment Procedures

Traverse equipment testing and adjustment specifications are listed in **Table 3**, based on SP1 v1.7 Part B Clause 2.2 Table 13 and Clause 2.3 Table 15.

Table 3: Traversing – Equipment testing and adjustment procedures.

Class	B	C	D
Instrument systematic errors [1]	Yes	Yes	Yes
Additive constant correction [2]	**Instruments and ancillary equipment must be calibrated and checked in accordance with the Regulation and as stipulated in Surveyor-General's Direction No. 5 (SGD5). Users must demonstrate legal traceability.**		
Cyclic error correction			
Frequency correction **(scale factor correction)**			
Barometer correction			
Thermometer correction			

Notes:

1. Instruments must be adjusted and corrected for all systematic errors in accordance with the instrument manual (e.g. automatic target recognition (ATR), dislevelment of the trunnion axis, collimation error, circle eccentricity, tilting axis error, compensator index errors, and vertical index error). The systematic instrument error corrections must be applied regularly, particularly after instrument service or calibration, or after long or rough periods of travel.
2. The additive constant must be determined for each target prism (reflector) type or model used.

3.3. Observation Procedures

Traverse observation procedure specifications are listed in **Table 4**, based on SP1 v1.7 Part B Clause 2.2 Table 11 and 12, Clause 2.3 Table 14 and 15, and Clause 2.5 Table 24.

Table 4: Traversing – Observation procedures.

Class	B	C	D
General			
Minimum number of **sets** [1]	**1**	1	1
Minimum number of rounds **(face left - face right)** per set [2]	6	**3**	**2**
Order of observations (face left – face right) [3]	**ABC – CBA**	**ABC – CBA**	**ABC – CBA**
Occupy all survey marks with both the instrument and target [4]	**Yes**	**Yes**	**Optional**
Height of instrument and target(s) accurately measured [5]	**Yes**	**Yes**	**Yes**
Observation correction: Refraction [6]	Minimise using appropriate procedures for prevailing conditions. **Do not apply refraction correction in the instrument settings.**		

Class	B	C	D
EDM			
Thermometer type	Mercury in glass, **or equivalent digital thermometer.**		
Thermometer graduation interval (least count)	< 1°C	< 1°C	< 1°C
Record temperature to	1°C	1°C	1°C
Record pressure to	3 hPa	3 hPa	3 hPa
Wet bulb readings or relative humidity readings [7]	**Estimate**	**Estimate**	**Estimate**
Atmospheric dial setting (where possible) [8]	**Optional**	Optional	Optional
Allow minimum warm-up time [9]	Yes, **if applicable.**	**Yes, if applicable.**	**Yes, if applicable.**
Collect meteorological observations (mets) at both ends of measured lines before and after measurements, **only if the difference in temperature and/or distance between instrument and target(s) is significant**	Yes	**At instrument station only.**	-
Horizontal and Vertical Angle Measurement			
Residuals from mean of any angle within each set: (i) should seldom exceed: (ii) should never exceed:	 3" 5"	 3" 6"	 5" 10"
Ranges from mean of any angle within each set: (i) should seldom exceed: (ii) should never exceed:	 6" 10"	 6" 12"	 10" 20"
(n-1) rounds are required to meet the range specifications, otherwise the user should re-observe set [10]			

Notes:

1. A 'set' is made up of multiple numbers of rounds.
2. A 'round' is comprised of a face-left and face-right pointing to each target where a distance, horizontal and vertical angle is measured in each face.
3. Target(s) should be observed in a face-left to face-right order i.e. if three targets (A, B & C) are being observed from a station, then targets A, B and C must be observed in face-left first, followed by observing targets C, B and A in face-right. Observing in this order from face-left to face-right constitutes one round.
4. Where indicated, all survey marks (including survey control marks) must be occupied by the instrument. Radiations are not permitted from another survey mark or traverse station, e.g. at the end of a traverse line.
5. The height of instrument and target must be accurately measured (to the nearest mm). A useful independent check is to take a second measurement using imperial units (inches) and to convert to metres. Users must **not** approximate height readings.

6. Users should be aware of the effect of atmospheric conditions on horizontal and vertical refraction and should not make observations during conditions which cause high refraction.
7. The relative humidity and source (e.g. Bureau of Meteorology) must be recorded in the field notes.
8. If users **choose not to** set the atmospheric dial setting to zero, they must ensure they have applied all necessary atmospheric corrections (e.g. first velocity correction) in the instrument. If users **choose to** set the atmospheric dial setting to zero, then users must apply atmospheric corrections (e.g. first velocity correction) in post processing. Users must show traceability and proof that relevant corrections have been applied to observations when submitting to Spatial Services.
9. If applicable, allow minimum instrument warm-up time as required by manufacturer specifications.
10. **(n-1)** rounds must meet the required *range* and *residuals* specification for a Class of survey or the entire set must be re-observed. For example, for a Class B traverse, 5 rounds (i.e. 6 - 1 rounds) must meet the required range (10") and residual (5") specifications.

3.4. Reduction Procedures

Traverse reduction procedure specifications are listed in **Table 5**, based on SP1 v1.7 Part B Clause 2.2 Table 13.

Table 5: Traversing – Reduction procedures.

Class	B	C	D
First velocity correction (atmospheric correction)	**Apply in post processing or in the instrument.** [1]		
Arc-to-chord correction (beam curvature correction)	**Apply in post processing.** [2]		
Second velocity correction (dip correction)			
Chord-to-chord correction (combined slope & mean sea level)			
Second chord-to-arc correction (geoidal chord to arc correction)			
Geoid-to-ellipsoid correction			

Notes:

1. It is recommended that the first velocity correction is applied in post processing if software permits. The details of the first velocity correction, including whether it is applied or not applied in the instrument, and the values applied (where relevant) must be recorded in field notes and raw data files.
2. Distances must be reduced to the ellipsoid. Users must refer to the GDA2020 Technical Manual for the appropriate geometric corrections and reduction techniques to apply and follow. All geometric corrections must be applied in post processing (not in the instrument) and if applicable. For example, the second velocity correction is negligible unless measured over long distances and so is generally considered not applicable.

4. Trigonometric Heighting Specifications

The following trigonometric heighting specifications must be applied in addition to the traversing specifications outlined in **Section 3** to achieve heights at the Class specified below. Any specifications listed in **Table 6**, based on SP1 v1.7 Part B Clause 2.5 Table 24, that are in conflict with **Section 3** take precedence.

Table 6: Trigonometric heighting specifications.

Class	B	C
Non-simultaneous reciprocal vertical angles [1]	Yes	**Yes**
Maximum observation distance	**300 m**	**600 m**
Height of instrument and target(s) accurately measured [2]	**Yes**	**Yes**
Minimum ground clearance	**0.3 m**	**0.3 m**

Notes:

1. Atmospheric refraction imposes one of the most severe accuracy limitations on trigonometrical heighting. However, the impact of atmospheric refraction can be reduced significantly using reciprocal vertical angle observations. The forward and reverse reciprocal vertical angle observations must be averaged to determine the height difference between survey marks.
2. The height of instrument and target must be accurately measured (to the nearest mm). A useful independent check is to take a second measurement using imperial units (inches) and to convert to metres. Users must **not** approximate height readings.

5. Differential Levelling Specifications

The following specifications apply to optical or digital levels for surveys of Class LB, LC or LD.

5.1. Equipment Specifications

Differential levelling equipment specifications are listed in **Table 7**, based on SP1 v1.7 Part B Clause 2.4 Table 16.

Table 7: Differential levelling – Equipment specifications.

Class	LB	LC	LD
Level-minimum requirements	0.4 mm/km optical or digital level.	1.0-1.5 mm/km optical or digital level.	1.5 mm/km or upward (i.e. less sensitive) optical or digital level.
Staff construction minimum requirements (analogue or bar-coded) [1]	Rigid invar	Folding staff of wood or fibreglass.	Telescopic staff of wood, fibreglass or aluminium.
Staff graduation interval (analogue staves)	5 mm or 10 mm	10 mm	10 mm
Tripod construction [2]	Rigid	Rigid **or telescopic**	Rigid or telescopic
Bubble attached to staff [3]	Yes	**Optional**	Optional
Solid, portable change points	Yes	Yes	**Yes**
Umbrella for level [4]	**Optional**	No	No
Use of support struts [5]	**Yes**	**Optional**	**Optional**

Notes:

1. Analogue refers to staves that have accepted metric or foot face patterns that have been developed over time for optical levels. Bar-coded refers to staff face patterns developed specifically for digital levels.
2. If using a telescopic tripod, users must ensure the tripod legs are set at equal lengths, locked, and are rigid and consistent throughout the level run.
3. If the bubble is not attached, it must be firmly held against the staff whilst reading height observations and subject to staff verticality checks daily.
4. Collimation error can change with fluctuations in temperature. It is therefore recommended that an umbrella be used to shade the level instrument if there are large variations in ambient temperature.
5. It is recommended that support structures are used if environmental conditions are windy or additional support is required to effectively level the staff. Note that if conditions are too windy, the level run **must** be abandoned until the weather calms.

5.2. Equipment Testing and Adjustment Procedures

Differential levelling equipment testing and adjustment specifications are listed in **Table 8**, based on SP1 v1.7 Part B Clause 2.4 Table 17.

Table 8: Differential levelling – Equipment testing and adjustment procedures.

Class	LB	LC	LD
System test prior to commencement (e.g. ISO, DIN or Princeton) [1]	**Optional**	Optional	Optional
Maximum standard error in the slope of the line of sight as determined by the system test	Optical level: 4”/2 mm run. Digital level: 0.8” accuracy setting.	Optical level: 10”/2 mm run. Digital level: 1.0” accuracy setting.	-
Vertical collimation check (e.g. two-peg test) Frequency: Maximum collimation error:	Daily 4” or 1.5 mm over 80 m.	Daily 10” or 4 mm over 80 m.	**Weekly** 10” or 4 mm over 80 m.
Level crosshair verticality check	Yes	Yes	Optional
Staff calibration frequency	**Minimum 2 years.** [2]	**Optional**	Optional
Staff bubble verticality check	**Daily**	**Daily**	**Daily**
Staff bubble verticality to be within	10’	10’	10’
Thermometers accurate to	1°C	1°C	**1°C**

Notes:

1. Refer to International Organisation of Standards (ISO) technical document ISO 17123-2 or German Institute for Standardisation (DIN) technical document DIN 18723-2 for further details.
2. Staff calibration may be extended to a maximum of 5-year intervals if the staff is well maintained. Calibrated invar staves should be stored and transported in secure casings to prevent damage and disturbance. If a staff has been disturbed, then it must be immediately calibrated before use.

5.3. Observation Procedures

Differential levelling observation procedure specifications are listed in **Table 9**, based on SP1 v1.7 Part B Clause 2.4 Table 18.

Table 9: Differential levelling – Observation procedures.

Class	LB	LC	LD
Instrument levelled by "unsystematic" method [1]	Yes	Yes	Optional
"Leap-frog" system of progression used [2]	Yes	Yes	Optional
Staff readings recorded to nearest:	0.1 mm For digital levels take the mean of five with an indicated standard deviation of 0.001 m or less.	1 mm For digital levels as for LB.	1 mm **For digital levels as for LB.**
Temperature recorded:	At **start and finish of both the forward and back section of the level run,** and at pronounced changes of temperature.	**-**	-
Maximum sight length [3]	60 m	80 m	100 m
Minimum ground clearance of line of sight	0.5 m	0.3 m	0.2 m
Back-sight and fore-sight lengths to be equal within [4]	2%	2%	5%
Observing times (LMT)	Any time, provided atmospheric conditions allow positive resolution of staff graduation.		
Two-way levelling [5]	Yes	Yes	Yes
Even number of instrument set-ups between **survey marks**	Yes	Yes	Optional
Minimum number of holding marks used for temporary suspension of levelling [6]	2	2	1
Minimum number of holding marks used for temporary suspension of levelling > 5 days	3 overlapping marks relevelled within: 2√d	3 2√d	1

Class	LB	LC	LD
Maximum allowable misclosure (mm) of forward and **back** level runs	8√d	12√d	18√d
Minimum number of **survey control marks** used to prove datum	3	3	2
Each survey mark to be independently occupied by staff minimum twice per level run (i.e. double levelled)	**Yes**	**Yes**	**Yes**
Maximum misclose (mm) on **survey control marks** [7]	8√d	12√d	18√d
	where d is the distance in kilometres between **survey control marks**		
Avoid spurs in network [8]	**Yes**	**Yes**	**Optional**
Approximate coordinates provided for unestablished survey marks	**Yes**	**Yes**	**Yes**
Observation method [9]	**BFFB**	**BF**	**BF**

Notes:

1. When centring automatic levels with circular bubbles, the "unsystematic" method of levelling the instrument must be used whereby the telescope is pointed in forward and back directions at alternate set-ups, i.e. always towards the same staff-person who will be "leap-frogging" each instrument set-up.
2. "Leap-frog" levelling involves the one staff remaining at a particular change point for both sightings. To avoid staff index error the same staff is used for the first back-sight and the last fore-sight of each level run. Note that the use of 1 staff forces you to use the leap-frog method.
3. Maximum sight length is determined from instrument set-up to staff.
4. Sum of back-sight (BS) and fore-sight (FS) distances to be within specified tolerances between survey marks. This may require the route of the level run to be pre-marked or additional consideration given in the planning stages.
5. In two-way levelling, users must adopt a sequence in observations similar to the following:

   SSM1, CP1, CP2, CP3, CP4, **SSM2**, CP5, CP6, **SSM3, SSM3**, CP7, CP8, **SSM2**, CP9, CP10, CP11, CP12, **SSM1**

   where CP stands for 'change point'. Note this is an example only; the number of required change points will depend on the conditions of the site.
6. Holding marks are temporary survey marks that are used as a starting point for a subsequent level run if it had previously been suspended. Holding marks must be firmly established and placed in a safe location free from disturbance, otherwise the level run may need to be restarted from the nearest survey control mark.
7. The user must check the misclose between survey control marks (also referred to as datum benchmarks) to ensure they meet the specified Class and establish AHD71 datum. For example, the allowable misclose for a Class LC levelling run that extends between two survey control marks on a 400 m line is approximately 7.6 mm. See SGD12 for further information.
8. A spur is a linear level run hanging from one junction point without any survey control marks at the extremity or without closing a loop.
9. **BF**: back-sight – fore-sight. **BFFB**: back-sight – fore-sight fore-sight – back-sight. Two-way levelling still needs to be carried out as specified, i.e. BFFB does not automatically equate to two-way levelling.

5.4. Reduction Procedures

Differential levelling reduction procedure specifications are listed in **Table 10**, based on SP1 v1.7 Part B Clause 2.4 Table 19.

Table 10: Differential levelling – Reduction procedures.

Class	LB	LC	LD
Apply orthometric correction [1]	Yes	**Optional**	**Optional**
Apply invar staff calibration corrections [2]	**Yes, if applicable.**	**N/A**	**N/A**

Notes:

1. Users are **not** required to apply the orthometric correction themselves as this will be done by Spatial Services. However, users must ensure that the appropriate information to enable the calculation of the orthometric correction is supplied to Spatial Services, i.e. approximate horizontal coordinates for all survey marks within a level run. Refer to Roelse et al. (1975) for the formal definition (note the formula used is a truncated version of Rapp, 1961).

2. Calibration corrections (scale factor and/or thermal expansion) of invar staff to be applied only if significant, considering temperature and elevation differences over the extent of the level run. Users should contact Spatial Services for further advice.

6. GNSS Specifications

The following specifications apply to the following Global Navigation Satellite System (GNSS) surveying techniques:

- **Post-Processed Static GNSS (GNSS Static)**
- **Real Time Kinematic GNSS (RTK) – Single-base RTK** and **Network RTK (NRTK)**
- **AUSPOS**

See SGD12 for definitions of the above and any additional requirements.

The following specifications have been compiled from ICSM publications SP1 v1.7, SP1 v2.2 and internal Spatial Services best practice guidelines for GNSS surveying.

6.1. GNSS Static

6.1.1. Equipment Specifications

GNSS Static equipment specifications are listed in **Table 11.**

Table 11: GNSS Static – Equipment specifications.

Class	A	B	C	D
Verify GNSS equipment annually [1]	Yes	Yes	Yes	Yes
Use Spatial Services GNSS log sheet [2]	Recommended			
GNSS antenna support [3]	Stable, good-quality tripod, tribrach and optical / laser plummet.			Recommended tripod, tribrach and optical / laser plummet; or bipod.
IGS antenna models applied [4]	Yes	Yes	Yes	Yes
Minimum epoch sampling rate	10 sec	10 sec	10 sec	10 sec
Multi-constellation GNSS capability	Yes	Yes	Optional	Optional
Minimum signal tracking capability	Dual-frequency	Dual-frequency	Dual-frequency	Dual-frequency
Minimum elevation mask angle [5]	10°	10°	10°	10°

Notes:

1. All GNSS equipment used for the purpose of a control survey must be verified annually to ensure legal traceability, see *Surveyor-General's Direction No. 9 – GNSS for Cadastral Surveys* (SGD9).
2. It is recommended to use the Spatial Services GNSS log sheet as it indicates the minimum details to be captured as part of a GNSS survey, see SGD12 Resource Pack.
3. Ranging poles without support are not permitted. Specifications may be waived for set-up on a trig pillar or equivalent. Bipods are to be checked for verticality before commencing survey.

4. International GNSS Service (IGS) antenna models (currently *igs14.atx*) can be accessed at https://files.igs.org/pub/station/general/.

5. The elevation mask angle should either be adjusted in real time or during post processing, depending on the station's sky view, in order to minimise the impacts of multipath and obstructions.

6.1.2. Observation Procedures

GNSS Static observation procedure specifications are listed in **Table 12**.

Table 12: GNSS Static – Observation procedures.

Class	A	B	C	D
Maximum achievable Class	Yes	Yes	Yes	Yes
Guide to minimum station spacing	1 km	0.5 km	-	-
Typical station spacing	1 – 10 km	0.5 – 1 km	0.2 km	-
Measure instrument height vertically to Antenna Reference Point (ARP) to the nearest mm [1]	Yes	Yes	Yes	Yes
Antenna orientated to true north within 5 degrees	If applicable [2]			
Minimum number of common satellites in one system (e.g. GPS) observed between stations	4+	4+	4+	4+
Recommended maximum GDOP [3]	3	3	3	3
Independent occupations per station: [4]				
at least 3x (% of total stations)	20%	10%	-	-
at least 2x (% of total stations)	100%	100%	100%	-
at least 1x (% of total stations)	100%	100%	100%	100%
Recommended survey geometry between adjacent stations: [5]				
Triangles (% of total stations)	Yes (70%)	Yes (60%)	Yes (50%)	-
Quadrilaterals (% of total stations)	Yes (30%)	Yes (40%)	Yes (50%)	-
Radiations	No	No	No	Yes
Trivial baselines allowed [6]	No	No	No	No
Minimum observation time per: [7]				
< 5 km baseline	20 min	20 min	20 min	20 min
> 5 km baseline	(2d +10) min	(2d +10) min	(2d +10) min	(2d +10) min
	where d is the distance in kilometres between stations			

Notes:

1. Refer to the instrument manual to determine where the Antenna Reference Point (ARP) is located. A useful independent check is to take a second measurement of the instrument height using imperial units (inches) and to convert to metres. Users must **not** approximate height readings. Instrument heights for re-occupation should change by at least 0.1 m unless set up on a trig pillar.
2. For older GNSS equipment without appropriate antenna models, it may be required to orientate antennas to true north. Refer to manufacturer's specifications.
3. Known as the Geometric Dilution of Precision, the GDOP is a useful metric in GNSS planning to understand the spread and relative position of GNSS satellites and how this will affect the quality of a position. A lower GDOP indicates a greater spread of GNSS satellite and higher precision of the position results.
4. Independent occupations per station may be back-to-back, but the antenna along with the supporting tripod (if applicable) are to be re-set for each occupation. As an example, to achieve Class A, 20% of stations within a control survey network must be independently occupied at least three times (3x) and 100% of all stations must be occupied at least two times (2x). Conversely, to achieve Class D, all stations in a control survey network must be occupied once with no trivial baselines.
5. This specification outlines the minimum network geometry requirements to be met when designing and observing a GNSS Static network. For example, for a Class A survey, 70% of all survey marks within the network should be connected to each other through triangular geometry, i.e. processing three baselines between three survey marks (with no trivial baselines). This will naturally be achieved with the minimum number of independent occupations required per station. Network design must be discussed with Spatial Services to ensure it is fit-for-purpose for the State Control Survey Network and update of SCIMS. See SGD12 for further details.
6. An independent baseline is a three-dimensional vector derived between two or more receivers logging data at the same time. However, in one session, observing with **n** receivers, only **(n – 1)** can be considered independent baselines providing no closed figure is created. All other baselines are considered trivial. See SGD12 for further information.
7. Observation times may need to be increased due to environmental conditions (e.g. tree cover) and equipment capabilities in order to satisfactorily resolve ambiguities. The **(2d+10)** minutes rule is a guide only.

6.1.3. Processing Specifications

GNSS Static processing specifications are listed in **Table 13**.

Table 13: GNSS Static – Processing specifications.

Class	A	B	C	D
GNSS processing software	Capability to generate a reliable variance-covariance matrix for each measurement.			
Final IGS satellite ephemerides [1]	Yes	Optional	Optional	Optional
Troposphere model applied (e.g. Hopfield or Saastamoinen)	Yes	Yes	Yes	Yes
Ionospheric model applied	Yes	Yes	Yes	Yes
Minimum distance for ionospheric free threshold [2]	15 km	15 km	-	-
Achieve ambiguity resolution	Yes	Yes	Yes	Yes
Clean baselines [3]	Yes	Yes	-	-

Notes:

1. IGS provides Final, Rapid and Ultra-Rapid orbits that vary in precision and latency. GNSS receivers will automatically record a broadcast orbit. For Class A, all baselines need to be processed using IGS Final Satellite Ephemerides data which can be accessed at https://www.igs.org/products#about. For lower Classes, users can opt to use Final, Rapid, Ultra-Rapid or broadcast orbits, but should ensure that the orbits used in the post processing of a control survey are consistent and communicated to Spatial Services.

2. Processed baseline solutions should consider the baseline length as well as the type of receiver used in order to counter the effects of ionospheric activity. As a guide, SP1 v1.7 recommends that for shorter baseline lengths of 10 – 15 km, 'L1 only' solutions are obtained, while dual-frequency ambiguity fixed L1 and L2 solutions in their ionosphere-free linear combinations are usually obtained for baseline lengths in excess of this and up to 50 km.

3. Processed baselines must be cleaned to remove any noisy satellite observation data and minimise processing residuals, ensuring that ambiguity resolution has been achieved. Processing techniques include cleaning GNSS observation data, 'windowing' observation sessions, adjusting elevation angles, removing specific satellites and/or entire GNSS constellations, and adjusting GNSS processing solution types. All processing decisions must be summarised in the required survey report when submitting data to Spatial Services. See SGD12 for more information.

6.2. RTK

6.2.1. Equipment Specifications

RTK equipment specifications are listed in **Table 14**.

Table 14: RTK – Equipment specifications.

RTK Technique	Single-base RTK	Network RTK
Verify GNSS equipment annually [1]	Yes	Yes
Use Spatial Services GNSS log sheet [2]	Recommended	Recommended
GNSS antenna support	Recommended stable, good-quality tripod, tribrach and optical / laser plummet, or high-quality stable bipod / ranging pole with support struts.	
IGS antenna models applied [3]	Yes	Yes
Minimum epoch sampling rate	1 sec	1 sec
Multi-constellation GNSS capability	Optional	Optional
Minimum signal tracking capability	Dual-frequency	Dual-frequency
Minimum elevation mask angle [4]	10°	10°

Notes:

1. All GNSS equipment used for the purpose of a control survey must be verified annually to ensure legal traceability, see *Surveyor-General's Direction No. 9 – GNSS for Cadastral Surveys* (SGD9).
2. It is recommended to use the Spatial Services GNSS log sheet as it indicates the minimum details to be captured as part of a GNSS survey, see SGD12 Resource Pack.
3. International GNSS Service (IGS) antenna models (currently *igs14.atx*) can be accessed at https://files.igs.org/pub/station/general/.
4. The elevation mask angle should either be adjusted in real time or during post processing, depending on the station's sky view, in order to minimise the impacts of multipath and obstructions.

6.2.2. Observation Procedures

RTK observation procedure specifications are listed in **Table 15**.

Table 15: RTK – Observation procedures.

RTK Technique	Single-base RTK	Network RTK
Maximum achievable Class	D	D
Recommended maximum GDOP	3	3
Minimum independent occupations per station [1]	2	2
Minimum time between independent occupations	30 min	30 min
Minimum observation time per occupation (at 1 second epoch sampling rate)	2 min	2 min

<table>
<tr><th>RTK Technique</th><th>Single-base RTK</th><th>Network RTK</th></tr>
<tr><td>Measure instrument height vertically to Antenna Reference Point (ARP) to the nearest mm [2]</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Maximum distance from CORS or base station [3]</td><td>20 km</td><td>N/A</td></tr>
<tr><td>Survey must connect into [4]</td><td colspan="2">• Minimum 3 x GDA2020 horizontal Class D or better survey marks with best available PU, and
• Minimum 3 x AHD71 vertical Class B / LD or better survey marks with best available PU.</td></tr>
<tr><td>Perform site validation [5]</td><td>Yes, daily.</td><td>Yes, daily.</td></tr>
<tr><td>Apply site transformation [6]</td><td>Yes, if significant.</td><td>Yes, if significant.</td></tr>
<tr><td>Maximum horizontal coordinate difference between independent occupations [7]</td><td>0.035 m</td><td>0.035 m</td></tr>
<tr><td>Maximum height difference between independent occupations [7]</td><td>0.065 m</td><td>0.065 m</td></tr>
</table>

Notes:

1. The number of independent occupations may need to be increased if the coordinate differences between multiple occupations exceed the desired Class of survey.
2. Refer to the instrument manual to determine where the Antenna Reference Point (ARP) is located. A useful independent check is to take a second measurement of the instrument height using imperial units (inches) and to convert to metres. Users must **not** approximate height readings. Instrument heights for re-occupation should change by at least 0.1 m unless set up on a trig pillar.
3. Rigorous testing has shown that the precision and accuracy of single-base RTK exponentially degrades once the user is more than 20 km away from a CORS or base station due to ionospheric impacts.
4. The minimum number of survey control marks must be increased to account for the size and scope of the survey to ensure that the site validation and transformation parameters are fit-for-purpose.
5. All RTK surveys are required to perform a site validation as an equipment, systems and field check in order to validate the outcome and Class of the survey, see SGD12.
6. Site transformation parameters must be applied so long as they are statistically significant with regards to the uncertainty of Class D and considering the precision of RTK, see SGD12.
7. Rigorous testing has shown that horizontal coordinate differences ($\sqrt{\Delta E^2 + \Delta N^2}$) greater than 0.035 m between two independent occupations, will fail to meet Class D specifications at a station density of 200 m. Observations should be repeated to ensure a minimum of two observations meet this tolerance, otherwise the Class of survey will need to be downgraded. Similar principles apply for the maximum height difference between independent RTK occupations.

6.3. AUSPOS

6.3.1. Equipment Specifications

AUSPOS equipment specifications are listed in **Table 16**.

Table 16: AUSPOS – Equipment specifications.

GNSS Technique	AUSPOS
Verify GNSS equipment annually [1]	Yes
Use Spatial Services GNSS log sheet [2]	Recommended
GNSS antenna support [3]	Stable and good-quality tripod, tribrach and optical / laser plummet.
IGS antenna models applied [4]	Yes
Observation mode	Static
Data format [5]	RINEX
Minimum epoch sampling rate	30 sec
GNSS constellation(s)	GPS only
IGS satellite orbit type ephemerides [6]	Final
Minimum signal tracking capability	Dual-frequency
Minimum elevation mask angle	10°

Notes:

1. All GNSS equipment used for the purpose of a control survey must be verified annually to ensure legal traceability, see *Surveyor-General's Direction No. 9 – GNSS for Cadastral Surveys* (SGD9).
2. It is recommended to use the Spatial Services GNSS log sheet as it indicates the minimum details to be captured as part of a GNSS survey, see SGD12 Resource Pack.
3. Bipods or ranging poles are not permitted. Tribrachs must be used when setting up on trig pillars.
4. International GNSS Service (IGS) antenna models (currently *igs14.atx*) can be accessed at https://files.igs.org/pub/station/general/.
5. All commercial geodetic GNSS software packages are able to convert the observed proprietary data to the international standard Receiver Independent Exchange (RINEX) format (refer to https://www.igs.org/formats-and-standards/ for a full explanation).
6. Final IGS Orbit data must be used to obtain Class D. In regards to latency, it generally takes 2-3 weeks from the day of survey until Final orbits are available for AUSPOS processing.

6.3.2. Observation Procedures

AUSPOS observation procedure specifications are listed in **Table 17**.

Table 17: AUSPOS – Observation procedures.

GNSS Technique	AUSPOS
Maximum achievable Class [1]	D
Minimum independent occupations per station	1
Minimum observation time per occupation [2]	2+ hours
Measure instrument height vertically to the Antenna Reference Point (ARP) to the nearest mm at the start and end of observation [3]	Yes

Notes:

1. Spatial Services allocates a maximum Class D to any survey mark coordinated through the AUSPOS technique as it represents only a single occupation with limited redundancy. Station density should also be considered when attempting to use AUSPOS to achieve Class D, see SGD12.
2. Spatial Services encourages users to observe a minimum of 6+ hours per AUSPOS occupation as these longer datasets can be included in Geoscience Australia's National GNSS Campaign Archive (NGCA). The NGCA propagates datum in the national GDA2020 adjustment.
3. Refer to the instrument manual to determine where the Antenna Reference Point (ARP) is located. A useful independent check is to take a second measurement of the instrument height using imperial units (inches) and to convert to metres. Users must **not** approximate height readings. Instrument heights for re-occupation should change by at least 0.1 m unless set up on a trig pillar.

6.3.3. Processing Specifications

All AUSPOS observations must be processed through Geoscience Australia's free online AUSPOS processing service. Each AUSPOS result will return a processing report that must be submitted to Spatial Services along with the raw GNSS data (RINEX format) and log sheet, see SGD12 for data submission requirements. Users must review the AUSPOS report and ensure the processing specifications listed in **Table 18** are met.

Table 18: AUSPOS – Processing specifications.

GNSS Technique	AUSPOS
Average ambiguity resolution – per baseline indicator	> 50%
Horizontal Positional Uncertainty (GDA2020) achieved	< 0.1 m

7. References and Recommended Reading

Geoscience Australia (2021) *AUSPOS*, https://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/auspos (accessed April 2021).

Intergovernmental Committee on Surveying and Mapping (ICSM) (2007) *Standards and Practices for Control Surveys (SP1)*, Version 1.7, https://www.icsm.gov.au/publications/archived-version-17-september-2007 (accessed April 2021).

Intergovernmental Committee on Surveying and Mapping (ICSM) (2020a) *Standard for the Australian Survey Control Network (SP1),* Version 2.2, https://www.icsm.gov.au/publications/standard-australian-survey-control-network-special-publication-1-sp1 (accessed April 2021).

Intergovernmental Committee on Surveying and Mapping (ICSM) (2020b) *Geocentric Datum of Australia 2020 Technical Manual*, Version 1.5, https://www.icsm.gov.au/gda2020-and-gda94-technical-manuals (accessed April 2021).

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End of Specification