PROVISIONAL

STANDARDS AND GUIDELINES
FOR THE USE OF GNSS ON CONTROL SURVEYS
WITHIN THE NORTHERN TERRITORY

Version 3.5 – 13 March 2017

Document History

Endorsement

Version	Date	Author	Reason	Sections
3.4	23 February 2017	Rob Sarib	Provisional adoption	
3.5	13 March 2017	Rob Sarib	Minor Amendments - grammatical	Various

Amendments:

Section Title	Section Number	Amendment Summary
Various	Various	Grammatical changes

Note - As GNSS technology in measurement and applications are constantly changing, this document will need to be reviewed regularly. As such, proposed modifications should be communicated to either the Surveyor-General or Secretariat of the Surveyors Board of the NT.

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TERMS AND DEFINITIONS

AHD - Australian Height Datum. Commonly used in reference to Australian Height Datum 1971 (AHD71).

AHD71 - The Australian Height Datum 1971 is the NGRS normal–orthometric height datum for mainland Australia.

AusGeoid - The national quasi–geoid model for converting between GDA94 ellipsoidal heights and AHD heights. The current version of AUSGeoid is AUSGeoid09.

Circular confidence region - A circular measure of uncertainty in the horizontal plane calculated from the standard error ellipse.

Constrained adjustment, fully - An adjustment which has a sufficient number of constrained coordinates to optimally propagate datum and uncertainty throughout the survey control mark network.

Constrained adjustment, minimally - An adjustment which has the minimum number of constrained coordinates required to calculate all dimensions of the network datum (one, two or three dimensions).

CRM – means co-ordinated reference mark, being a tertiary level survey control mark or geodetic mark, approved and registered by the Surveyor-General, with geographical co-ordinate values in the approved geodetic datum – GDA94.

Elevation mask - A GNSS receiver setting that determines whether GNSS signals are recorded below a certain angle above the horizon.

EDM - Electronic Distance Measurement instrument that uses light or sound waves to measure distance.

GDA94 - Geocentric Datum of Australia 1994. Realised by the derived coordinates of the Australian Fiducial Network (AFN) geodetic stations, referenced to the GRS80 ellipsoid and determined with respect to ITRF92 at epoch 1994.0.

Geoid - The equipotential surface of the Earth's gravity field which best fits global mean sea level.

GNSS - A Global Navigation Satellite System(s) – a generic term for satellite based positioning systems.

GRS80 - Geodetic Reference System 1980 reference ellipsoid, where a = 6378137 m, f = 1 / 298.257222101

ITRF - International Terrestrial Reference Frame - a realisation of the International Terrestrial Reference System (ITRS) produced by the International Earth Rotation and Reference Systems Service (IERS).

Measurement - A measurement is an observed value, the outcome of a repeated set of observations, or the result of processing such observations.

Multipath - Errors in GNSS observations caused by reflected GNSS signals interfering with the direct GNSS signal due to their common time origin but different path lengths.

NGRS - National Geospatial Reference System – is Australia's authoritative, reliable, high accuracy spatial referencing system for Australia. It includes the GDA94, and AHD71 datums.

Redundancy - A least squares solution is said to contain redundancy if the total number of measurements exceeds the minimum number required to compute the unknown parameters.

RINEX - Receiver INdependent EXchange – An internationally accepted format for the exchange of GNSS data between software applications and for GNSS data archiving.

SPDs - Survey Practice Directions 2014 Surveys Outside or Within Coordinated Survey Areas

Survey control mark - A monument that provides a physical realisation of one or more datums.

Uncertainty - Means the doubt about the validity of a measurement or result of a measurement (e.g. a coordinate). It is an indication of how wrong a value may be and is used to quantify the level of survey quality. Uncertainty is expressed as a standard deviation in the International System of Units (SI) expanded to the 95% confidence level.

Uncertainty, Positional (PU) - The uncertainty of the horizontal and/or vertical coordinates of a survey control mark with respect to datum.

Uncertainty, Survey (SU) - The uncertainty of the horizontal and/or vertical coordinates of a survey control mark independent of datum. That is, the uncertainty of a coordinate relative to the survey in which it was observed, without the contribution of the uncertainty in the underlying datum realisation.

STANDARDS AND GUIDELINES FOR THE USE OF GNSS ON CONTROL SURVEYS WITHIN THE NORTHERN TERRITORY

INTRODUCTION

The following Standards and Guidelines for the use of Global Navigation Satellite Systems (GNSS) measurements for control surveys has been developed at the request of the Surveyors Board of the Northern Territory (NT), who have responded to a need identified by the survey community.

For this document "control surveys" refers to co-ordinated reference mark (CRM) surveys, and surveys which connect to CRMs or survey control (i.e. geodetic) marks. As a consequence such surveys will also assist the Department to maintain the NT geodetic datum and the Geospatial Reference System.

Surveyors who use this document shall also comply with the Survey Practice Directions issued by the Surveyors Board and other requirements as issued by the Surveyor-General from time to time.

STANDARDS and GUIDELINES

Geodetic Datum

The official horizontal geodetic datum for cadastral and geodetic control surveys in the NT is the Geocentric Datum of Australia 1994 (GDA94). GDA94 is a static coordinate datum based on ITRF 1992, held fixed at the reference epoch of 1 January 1994.

For terrestrial or GNSS based control surveys or co-ordinated reference mark (CRM) surveys, connection to the Geodetic Datum will generally consist of independent and direct measurement to at least 3 survey control points that have known GDA94 coordinates OR using a technique as specified or approved by the Surveyor-General and consistent with the Intergovernmental Committee on Surveying and Mapping (ICSM) SP1, Standard and Guidelines for Australian Survey Control networks (Version 2.1) available at http://www.icsm.gov.au/geodesy/sp1.html.

Note - the official vertical geodetic datum for cadastral survey control or CRM survey in the NT is the Australian Height Datum (AHD) and to compute derived AHD heights from GDA94 ellipsoidal heights, the latest AusGeoid model shall be used. The current model is AusGeoid09.

Quantifying and Expressing GNSS Control Survey Quality

In the future the quality for a control or CRM survey will be quantified in terms of 'positional uncertainty' (PU), however presently the Surveyor is ***not*** required to propagate PU as this will be determined by the Department based on the survey data lodged by the Surveyor and validated geodetic information in NTGESS (NT Geodetic Survey System). Consequently the Surveyor will only be required to propagate ‘survey uncertainty’ (SU).

This means the Surveyor will be required to prove the position of the new control survey relative to existing survey control or surrounding survey marks is within the specified tolerances or allowable limits. Accordingly, the Surveyor who performs a GNSS control survey must ensure their survey complies with relevant clauses pertaining to CRM conditions as stated in the SPDs, in particular the specified marking, survey accuracy and lodgement requirements.

To quantify the quality of SU for cadastral survey control or CRM surveys, SU shall be expressed in terms of a circular confidence region or more specifically an error circle radius, at the 95% confidence region for horizontal co-ordinates only. Please note, this standard enables the quality of survey control to be expressed in a way that is compatible with other geospatial datasets. Refer to Annexure 1, “Reference Formula for expressing ‘Survey Uncertainty’ ” for technical information regarding the formulae.

Planning a GNSS Survey

When planning a GNSS survey the Surveyor should consider the following –

- The selection of equipment, field technique and reduction method will be assessed and selected by the Surveyor so as to comply with the accuracy requirements for the survey.
- The layout or location and distribution of points to be surveyed by GNSS should ensure sufficient redundancy for carrying out the intent of the survey.
- The GNSS technique and / or observation method chosen should be selected and planned so as to minimise associated errors. For example GNSS survey control points should be placed at locations that have a “clear sky view” and minimal obstructions to avoid interference and multi-path; avoid periods of high solar activity; longer observation times should reduce atmospheric effects due to the ionosphere and troposphere.
- Ensure the GNSS survey forms a closed figure or closes onto known points that facilitate a comparison with previously surveyed information.
- The Surveyor-General’s office is available to assist with planning a GNSS control survey.

GNSS Control Survey and Measurement Accuracy

For a control survey, in either urban or rural areas, the Surveyor will need to ensure (as a minimum requirement) that the derived SU for the co-ordinates of each new survey control mark or CRM satisfy the accuracy clauses in the SPDs. This clause states “… that all CRMs placed relative to both the nearest datum mark and to adjoining CRMS are positioned within an error circle whose radius is determined by the following formula:

$$r = 2.45 \times 15 (d + 0.2)$$

where “r” = length of *maximum* allowable radius in mm;
and “d” = distance in ‘km’ to either the nearest datum mark or adjoining CRMs.”

Please note, “r” is determined for the 95% confidence limit for 2 dimensions (horizontal only); and for this standard a control survey is categorised as densification survey of the NT geodetic network. Also, it is recognised that the underlying formula used to specify survey accuracy is from the Class / Order era. This accuracy specification was adapted to:

- accommodate our existing survey control network which comprises terrestrial and GNSS measurements;
- facilitate non-GNSS measurements (such as terrestrial survey observations) for the estimation of survey control mark coordinates;
- account for survey control marks (CRMs) at variable spacing; and to
- cater for the immaturity of the NT’s geodetic network with respect to the derivation and propagation of PU.

Marking

Marking standards, which include the placement of recovery marks and finders, for control surveys in urban and rural areas must comply with the SPDs. Any relaxation of marking standards may be considered by the Surveyor-General prior to survey commencement or lodgement of survey.

Unique Numbering of Survey Control Marks

Typically, unique numbering of survey control marks or points is provided by the Department in accordance with the SPDs. Point identifiers (ID) are to be unique, **capitalised** alpha/numeric identifiers, to a maximum of ten characters, prefixed by the Plan number and followed by the point number. Note – non alphanumeric symbols such as forward slash, decimals, colons, hyphens etc. should not be used. If a plan shows, for example, several marks tagged as No.1 and there is likely to be confusion, then the point can be renumbered as say 501 to identify this point as mark No.1 on the 5th traverse leg. Table 1 provides some examples.

Table 1: Point Identifiers

SURVEY No.	POINT	CONTROL ID	COMMENTS
LTO 93/246A	1	L93246001	
S 96/48B	1	S96048001	
S 97/177	1	S97177001	
A 1050	1	A1050001	
B 800	1	B800001	
C 2	1	C002001	
OP 1620	1	OP1620501	if plan shows several marks “1's” then show 501 as point 1 on 5th trav. leg
RP 506	1	RP506001	
DIA 512	1	DIA512001	

GNSS Equipment, Measurements and Observations

It is expected Surveyors will follow the ICSM publication “Guideline for Control Surveys by GNSS Special Publication 1 Version 2.1” for the use of GNSS for control surveys.

It is recommended Surveyors adhere to fundamental GNSS surveying principles such as working from the whole to the part, observe sufficient redundancy, survey closed figures, avoid radiations, and minimise GNSS site measurement related errors, such as multi-path, electrical interference, and obstructions (clear view to the sky). Surveyors also need to be familiar and generally abide with the procedures, guidelines, and recommendations contained in the GNSS equipment manuals, and also other reputable survey best practice or guideline documents pertaining to techniques.

Generally, it is suggested that the following points also be considered -

- All ancillary equipment must be in good adjustment and repair and operated by trained and competent personnel.
- Satellite geometry during the field observation of any GNSS survey must be sufficient to ensure results that meet the required SU. The maximum geometric dilution of precision (GDOP) should be no greater than 8.
- The minimum number of common healthy satellites simultaneously observed by all receivers required to determine 3 dimensional positioning is four, however 5 is the preferred minimum.
- The elevation mask should generally be not less than 15^{O}, except for specialised applications where a lower elevation mask is allowable.
- Where orthometric heights are to be calculated from the GNSS observations, the selected vertical control stations should have known AHD values. Also, antenna heights should be confirmed by independent measurements.
- Predominantly, GNSS receivers capable of making carrier phase observations are preferred.
- Metrological observations are not necessary as these earth surface observations are not representative of the air mass and result in inferior modelling of tropospheric delay when processing GNSS observations. Consequently it is recommended to use the GNSS reduction software defaults for tropospheric modelling.
- Most errors associated with GNSS measurement can be overcome with redundancies in observations and / or independent observations.
- The Surveyor-General will not accept multiple consecutive observations to the same GNSS set up over a mark. Redundancy is only achieved by independent occupations OR preferably observations from a different mark.

For control surveys the following field techniques and observations are permitted –

- Static or rapid static – that is GNSS raw data is collected in the field and post-processed to compute baselines between stations.

  Static Observations

  - Dual frequency receivers should be used for baselines greater than 15km; single frequency survey quality receivers may be used for shorter lines.

- Are used primarily for control surveys and therefore high quality tripods and tribrachs with optical plummets must be used.
- The observation period and collection of GNSS data should be sufficient to resolve ambiguities (fix solution) and fulfil accuracy requirements or project specifications
- For some situations, ambiguity “float” solutions (that is unresolved ambiguity) will be accepted on baselines greater than 80km.
- A 15 second epoch recording rate is recommended.
- The satellite geometry should change significantly during the observation period.

Rapid Static Observations

- Dual frequency receivers are preferred, as they allow various data combinations in estimating the solution.
- Baseline lengths should be limited to a maximum of 10km.
- Operators should refer to the manufacturer's specifications concerning the length of observation. Ideally enough data must be collected to resolve ambiguities with at least 5 minutes of "clean" data, and more as determined by the baseline length and number of satellites available.
- Preferably 5 or more satellites should be common to all survey sites simultaneously occupied.
- The epoch recording rate normally may vary between 5 and 10 seconds, but can be up to 15 seconds.

- Absolute positioning or similar – static observations from a single geodetic receiver that are processed by a web based on-line service that computes a position from several permanent GNSS reference stations. An example of such positioning service is AusPos by Geoscience Australia. Refer to web site – http://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/auspos

  The accuracy of this technique is dependent on observation length, number and distribution of GNSS reference stations used in the solution, the antenna model, the satellite orbit data adopted for processing, and the transformation parameters used. Consequently the following is recommended for ‘survey’ accurate positioning –
  - The use of geodetic, dual frequency, carrier phase and code receivers and antennae in static mode;
  - the duration of the static observations to consist of multiple 6 to 12 hour sessions at a GNSS collection rate of 30 seconds;
  - Positioning solutions based on the IGS final orbit products;
  - At least 3 GNSS reference stations are used in the positioning solution.
  - The positioning solution should be repeatable, with results and / or derived coordinates between 0.025 m and 0.05 m
  - The GDA94 coordinates derived from the positioning service have been transformed from the current ITRF using the ITRF to GDA94 Transformation Parameters.

Processing, Adjustment and Evaluation of a GNSS Control Survey

For guidelines with respect to GNSS survey processing, adjustments and evaluation, please refer to the ICSM publication “Guideline for the Adjustment and Evaluation of Survey Control: Special Publication 1 Version 2.1”. This document details recommended procedures, and provides information on testing and evaluating survey uncertainty.

Please note, it is recommended that Surveyors use recognised GNSS software in order to achieve the required SU. In most circumstances this will be the proprietary software provided by the manufacture of the GNSS equipment to facilitate the reduction or processing of GNSS data or observations, least squares adjustment and derivation of survey accuracy and uncertainty (error circle) of the GNSS survey measurements.

Legal Traceability and Equipment Validation

Presently the legal traceability of GNSS measurements cannot be readily achieved in the NT as there are insufficient survey control marks that are *recognised value standards for position.* The Surveyor-General will however allow the use of GNSS measurements and “quasi” traceability to a reference standard if the Surveyor -

- adheres to industry best practice guidelines on the use of GNSS measuring equipment
- validates the GNSS measuring device by a method as prescribed by the Surveyor-General (see below), and
- ensures that an appropriate number of lines in the GNSS survey are measured by or compared with a legally traceable instrument or measurement technique? such as a calibrated EDM. Note the common lines should be selected to provide a long enough distance to identify any possible errors, and should be located at appropriate geometry through the survey. Alternatively, the subject survey should have a ***direct*** connection to at least 2 survey control points that have known GDA94 coordinates, the subsequent least squares adjustment of the survey is constrained to the known GDA94 points, and the length and orientation between the 2 known points satisfy accuracy standards specified for the survey.

To validate and check the GNSS measuring device as per the SPDs, Surveyors are required to undertake GNSS observations at the EDM baseline arrays at either Howard Springs or Morrie Hocking.

For Howard Springs, the Surveyor is required to observe between stations - NTS 903, NTS 675, Pillar 2 and 6; process the baselines, adjust (using NTS 675 as the constraining station) and provide the Surveyor-General with GDA94 coordinates and survey uncertainties of occupied points. In addition, the Surveyor must supply spheroidal distances, and true mid bearings from NTS 675 to the other stations.

At Alice Springs, the Surveyor is required to observe between pillars at the Morrie Hocking Baseline – Pillars 6, 4, 1 and 0; process the baselines, adjust (using Pillar 6 as the constraining station) and provide the Surveyor-General with GDA94 coordinates and survey uncertainties of occupied points. In addition, supply spheroidal distances, and true mid bearings from Pillar 6 to the other stations.

For further information, field and reduction instructions, please contact the Surveyor-General's office.

Data Lodgement and Field Information

For control surveys, the Surveyor shall lodge the required survey data or information in accordance with the relevant clauses of the SPDs or survey requirements as specified by the Surveyor-General. The requirements include -

- A GNSS Report that addresses - observation technique, adjustment methodology, ambiguity resolution, connection to datum, network diagram, final geographic and grid coordinates and Survey Uncertainty / Accuracy (tabulated), least squares adjustment, evidence of meeting the survey accuracy requirements as specified in this document and / or the Survey Practice Directions 2014 Surveys Outside & Within Coordinated Survey Areas, and certification / proof of instrument standardisation.
- GNSS Log field sheets and notes of the field recorded GNSS data and equipment used (including allocated or official mark name, file name (if different from mark name), instrument type / model and serial numbers, antenna details, antenna height measurement and its derivation relative to the antenna reference plane, receiver firmware); refer to attached example – Annexure 2 ;
- Observational data - raw GNSS data of all static observations in RINEX, including the navigational file along with the observation file; OR in a format approved by the Surveyor-General.
- AusPOS Report where applicable (released with final ephemeris data "final orbits")
- Co-ordinate listing of the CRMs surveyed - a schedule of the adjusted GDA 94 co-ordinates, both geographic and grid, ellipsoidal height and either observed or derived AHD height;
- CRM diagrams/locality sketches; and
- NTGESS spreadsheet detailing metadata for all newly established and occupied control marks.

ANNEXURE 1

Reference Formula for expressing 'Survey Uncertainty'

The following will be the 'reference' formula to determine the survey uncertainty (horizontal component) or the error circle radius, at the 95% confidence region –

$$r = a \times K$$

where:

a	=	the semi-major axis of the standard (1 sigma) error ellipse (m)
K	=	$q_0 + q_1H + q_2 H^2 + q_3H^3$
H	=	b/a
b	=	the semi-minor axis of the standard (1 sigma) error ellipse (m)
q_0	=	1.9608
q_1	=	0.0041
q_2	=	0.1143
q_3	=	0.3716

Note "a" and "b" are derived from the least squares adjustment.

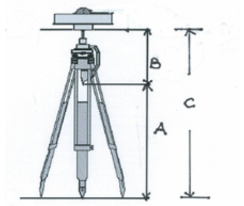
If required, the survey uncertainty for the vertical component, also at the 95% confidence region, can be obtained by:

Vertical uncertainty = sd x 1.96

where sd = standard deviation of the adjusted height (m).

Example GNSS log field sheets and notes

GNSS LOGSHEET												
PROJECT				JOB NAME				LOCATION				
MASK		COLLECTION RATE			DATE			GPS DOY		OPERATOR		
POINT Name	Receiver PT ID	Receiver / Antenna model	Receiver Serial No.	START TIME	END TIME	DURATION	HEIGHT A	OFFSET B	HEIGHT C	Check HT	CHECK HT - End of session	COMMENTS



NOTES:-
A = Height Hook if used
B = Vertical offset
C = Antenna Height ground mark to Antenna Reference Point (ARP) or Phase Centre (PC) depending on the make of GNSS measuring device
Check Height is independent measurement ground mark to ARP/PC.
Please check instrument manual for measuring points and any applicable offsets.
Start/finish time should be CST
This log sheet is for CLASSIC STATIC survey control and the use of geodetic grade (phase measurement) survey receiver and antenna, with high quality tripod, tribrach and optical plummet ancillary equipment.