GOVERNMENT OF WESTERN AUSTRALIA

Landgate

Landgate Requirements for Geodetic Surveys by GNSS

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Document control

Landgate Requirements for Geodetic Surveys by GNSS

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Document version history

Date	Author	Version	Revision Notes
Sept 2025	Khandu	6.0	Title change from “Landgate Requirements for GNSS Geodetic Surveys” to “Landgate Requirements for Geodetic Surveys by GNSS” and minor revisions
Sept 2023	Survey	5.0	Update to new style and refresh hyperlinks
	Survey	1.0	Initial

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1. Purpose

GNSS surveys for the establishment of Geodetic Standard Survey Marks (SSMs) are to be conducted in accordance with the Special Publication No 1 (SP1 v2.2). Minimum acceptable practice for surveying and data processing should conform to SP1 v2.2 Guideline for Control Surveys by GNSS to achieve positional uncertainty of 30 mm or less.

This document outlines the requirements and procedures for static GNSS surveys, processing, and documentation in Western Australia. If there is inconsistency between this document and SP1 v2.2, the requirements in this document shall prevail.

2. Definitions and abbreviations

Abbreviation	Definition
ARGS	Australian Geospatial Reference System
ARP	Antenna Reference Point
BM	Bench Mark
GDA2020	Geocentric Datum of Australia 2020
Geodetic Survey Mark	SSM or BM or RM
GNSS	Global Navigation Satellite Systems
IGS	International GNSS Service
NADJ	National geodetic ADJustment
NGCA	National GNSS Campaign Archive
NGS	National Geodetic Survey (USA)
PDOP	Positional Dilution of Precision
RINEX	Receiver Independent Exchange Format
RM	Reference Mark
RMS	Root Mean Square
RTK	Real Time Kinematic
SSM	Standard Survey Mark
TCM	Temporary Control Mark
VRS	Virtual Reference Station

3. Mark verification

3.1.1 An existing SSM occupied for GNSS surveys must be checked for horizontal and vertical stability in the field using a minimum of two Reference Marks (RMs). Reference Marks chosen for horizontal validation should be of good geometry to ensure validation without ambiguity. See ***GSU-04 – Landgate Requirements for Inspection, Validation & Maintenance of Geodetic Survey Marks*** for more information on validation.

3.1.2 A sample annotated Station Summary or Redline Markup is given in Appendix A to demonstrate mark validation carried out by Landgate.

3.1.3 If the SSM is suspected of physical movement, refer to ***GSU-06 – Landgate Guidelines for Dealing with Disturbed Geodetic Survey Marks*** to determine any further action required.

3.1.4 If the SSM is covered by a cairn or is not suitable for GNSS surveys, occupy any one of the existing RMs or install a new RM to occupy. The new RM must be connected to the SSM and existing RMs by observing all distances, angles and height differences. Also observe an azimuth and distance to the centre of the cairn or to the SSM. **Do not remove the cairn**.

3.1.5 If the SSM is found damaged or destroyed, notify Landgate as soon as practicable. Landgate may issue instructions for its replacement and re-survey or suggest an alternative SSM or abandon the part of the survey relating to the destroyed/damaged SSM.

3.1.6 Connect to another SSM, if minimum number of RMs is not located to validate the SSM. Replace any damaged or destroyed RMs. Where only one RM is in good condition, a geodetic azimuth must be observed from the SSM to the RM. See ***GSU-04 – Landgate Requirements for Inspection, Validation & Maintenance of Geodetic Survey Marks*** for more information.

3.1.7 Update access sketch and location details, where necessary.

3.1.8 Levelling can be reduced on the Landgate excel spreadsheet ***GSU-03A – Abstract for Class C Levelling*** (Levelling abstractv3.xlsm).

4. Instrument and observation guidelines

4.1.1 Installation of new Geodetic Survey Marks shall conform to the requirements outlined in ***GSU-01 – Landgate Requirements for Placement of Geodetic Survey Marks***.

4.1.2 Survey equipment used to establish the horizontal and vertical position of Geodetic Survey Marks shall have current calibration certificates, which must be supplied to Landgate on request.

4.1.3 GNSS receivers used shall be high precision, capable of dual frequency code and carrier phase tracking, and must be equipped with antennas certified by the International GNSS Service (IGS) or National Geodetic Survey (NGS, USA). GNSS antennas can be identified from the Antenna Calibrations (noaa.gov). Details of the receiver and antenna type, model and serial number and the processing software used must be provided.

4.1.4 GNSS observations or data shall be logged at intervals of 15 or 30 seconds. It is also recommended to log data from all available GNSS constellations, including GPS, GLONASS, GALILEO, and others, if available.

4.1.5 Static observations require longer observation time to enhance measurement accuracy, improve satellite geometry and help resolve carrier phase integer ambiguity problem. For a typical GNSS baseline, the minimum observation time must be at least **1 hour plus 2 minutes per kilometre of baseline length**. Rapid or quick static surveys of less than 1 hour per baseline will not be accepted. Also, longer observation times are recommended for sites with limited sky visibility. For SSMs not suitable for GNSS surveys due to potential safety issues and very limited sky visibility, an eccentric mark shall be installed or an existing RM shall be used for observation (see **Clause 3.1.4**).

4.1.6 Set the satellite elevation mask angle to 0 degrees.

4.1.7 Antennas shall be aligned within +/- 5 degrees of true north. Where the antenna does not have a designated north point and the manufacturer documentation does not designate a north point, align the cable connector to north. This will ensure that antennas of same make and model are oriented in the same direction. If in doubt, contact Landgate for advice. Where improvised north point is used, record details on log sheets and take images to document the orientation of the antenna.

4.1.8 GNSS observation details are to be recorded on a log sheet for all occupied marks. For muti-baseline observations or survey networks, session numbers and times should be recorded clearly on a daily basis (preferably in UT or Local time). If possible, record the raw data filename on the receiver in the log sheet (***GSU-02A – GNSS Log Sheet***). See Appendix B for a sample log sheet.

4.1.9 Incorrectly recorded/entered or incorrectly derived antenna heights constitute the largest common source of error in deriving the GNSS position and/or calculating GNSS baselines. In order to avoid this:

- All antenna heights are to be carefully measured and recorded on the log sheet along with **four images** taken of the following (see also Appendix D):
  - Image of the Station summary of the SSM being occupied
  - Image of mark occupied
  - Image of the antenna height measurement. The measured value must be readable for confirmation of the antenna height
  - Image of the instrument setup, showing the location and configuration of the setup
- Record the exact location on the antenna, where the height is measured to
- Draw a sketch showing the relationship between the Antenna Reference Point (ARP) and the measurement point on the antenna.
- Record details of the antenna type, model and serial number on the log sheet.
- The RINEX file supplied must have the following information in the header:

  i) Name of the Mark occupied

ii) Antenna model and serial number

iii) Antenna height (reduced to ARP)

5. Independent baselines

5.1.1 For a given session with n receivers used, there are $n-1$ independent baselines. Therefore, in a survey network observed with three receivers logging signals simultaneously, there are two independent baselines and one trivial or dependent baseline.

5.1.2 Trivial baselines should be ideally removed or deleted at the time of baseline processing or when the software file is required to be supplied to Landgate.

6. National GNSS Campaign Archive (NGCA)

6.1.1 The National GNSS Campaign Archive (NGCA) is a crucial component of the Australian Geospatial Reference System (ARGS). It is an archive of high-quality, national-scale GNSS data set or observations of six hours or more on any single Geodetic Survey Mark to enable accurate positioning. The NGCA archive facilitates the ongoing maintenance and refinement of the national geodetic adjustment (NADJ), ensuring that it remains state-of-the-art.

6.1.2 Landgate may request for at least six hours of GNSS observation on any single mark in a survey network or when a SSM included in a NGCA is notified to be destroyed. Landgate also regularly process GNSS dataset of high quality to NGCA, if it is more than six hours and the mark has been validated horizontally and vertically.

7. Baseline processing

7.1.1 GNSS observations should be processed using a sufficiently comprehensive processing software in order to achieve reliable estimates of baselines and baseline uncertainties.

7.1.2 Each baseline session should be checked to ensure that mark names are correct, antenna types, method, and heights are correctly selected, session durations are in line with **Clause 4.1.5** and start and finish times are correctly displayed.

7.1.3 Use absolute antenna models from IGS, where possible. If IGS absolute antenna models are not available, use the NGS absolute models.

7.1.4 Disable or remove all trivial or dependent baselines as well as the baselines with durations shorter than those provided in **Clause 4.1.5**.

7.1.5 When processing baselines, use the known or published Geocentric Datum of Australia 2020 (GDA2020) co-ordinates for all the existing SSMs occupied.

7.1.6 Best practice requires that baselines are processed with the IGS Final, Rapid or Ultra Rapid ephemerides. However, if this is not practical, baselines less than 30 km may be processed with broadcast ephemeris.

7.1.7 The software default atmospheric models can be used for processing the baselines.

7.1.8 All baseline solutions should be (ambiguity) fixed, irrespective of length of baseline. The processing software should be able to produce errors/warnings and reports to assist with finding and fixing processing issues, including but not limited to:

- Solution Type - Fixed or Float
- Positional Dilution of Precision (PDOP) – a number indicating how satellite geometry affects the positional accuracy. A lower PDOP value shows better satellite geometry and better positional accuracy
- Root Mean Square (RMS) – a number indicating the quality of the solution. A lower RMS value (typically less than 15 mm) indicates observed values are consistent and precise.
- Horizontal and vertical precision – a number indicating the estimated accuracy of the baseline.

7.1.9 Processed baseline(s) of poor quality based on **Clause 7.1.8** must be either excluded from the GNSS network or re-observed.

7.1.10 If the survey network is observed over multiple days, Landgate recommends processing them based on daily observation sessions.

7.1.11 Document the name of baseline processing software, its version number, and baseline processing options or settings used.

8. Adjustment

8.1.1 Perform a minimally constrained 3-dimensional (3D) least squares adjustment of the survey network observed to prove that the quality of the measured GNSS baselines meets the required standard.

8.1.2 Refer to the SP1 v2.2 Guideline for Adjustment and Evaluation of Survey Control for the recommended procedure for evaluating the quality of the GNSS survey.

9. Data submission and reporting

A digital data submission of a geodetic survey or a GNSS survey to Landgate usually includes the following and is mandatory for all surveys conducted for or on behalf of Landgate:

a) **A survey report** outlining the purpose of survey, methods used, and the results obtained from the data processing. A checklist is provided in Appendix C.

b) **Sketch or diagram of the survey network** and a list of baselines observed in the order of date.

c) **Baseline processing report** and network adjustment report.

d) **Fieldnotes** - scanned copies of any handwritten notes, digital files and files downloaded from the instruments.

e) **GNSS data**– both raw (processing software file) and RINEX (preferably in version 3.xx) files, log sheets, and required photographs or images stipulated in **Clause 4.1.9**.

f) **Terrestrial observations and calculations** – scanned copies and digital files.

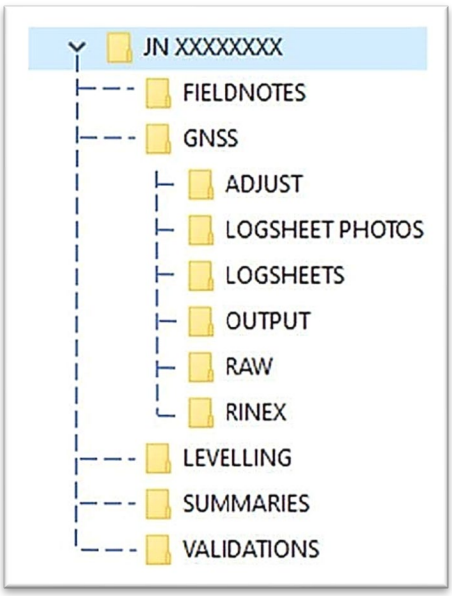
g) **Mark validation** – a redline markup or the observed values marked against the original values on a station summary.

h) **Abstract of level reductions** for any levelling conducted in the survey, including spirit levelling or vertical reductions from total station used for measuring RMs. See ***GSU-03 – Landgate Requirements for Geodetic Surveys by Differential Levelling***.

i) ***Station summary –*** Drawing files (.dwg) of new or redrafted station summaries that have the required amendments. In amending station summaries of marks found to have disturbed or moved, refer to ***GSU-06 – Landgate Guidelines for Dealing with Disturbed Geodetic Survey Marks.***

9.1. Folder structure

The digital data submission of the geodetic survey must be organized into a single folder (e.g. JN XXXXXXXX) containing several subfolders, structured as outlined below. The survey report (preferably in pdf format) can be placed in the main folder and data involving GNSS instruments shall be put in the **GNSS** folder.



9.2. Folder contents

9.2.1 Adjust

Includes the input and output files of the least square adjustments performed. Software file(s) of GNSS baseline processing and network adjustments should be included as well for surveys conducted for Landgate.

9.2.2 Logsheet photos

Digital photos or images of the logsheet includes (see example in Appendix D):

- Image of the Station Summary for identification.
- Image of mark occupied
- Image of the antenna height measurement. The measured value must be readable for confirmation of the antenna height
- Image of the instrument setup, showing the location and configuration of the setup

There is no need to rename the images. The ‘date taken’ property of the image files metadata should be preserved so that they are in a logical order and correspond to the start of each RINEX file. If this date and time is not preserved, the photos must be renamed appropriately.

9.2.3 GNSS / Logsheet

Includes scanned copies of log sheets and each log sheet should correspond to a RINEX file, so that it can be easily matched. Log sheets should contain as a minimum, the following information:

- Full station or mark name
- Station name as entered into the receiver
- Mark description
- Project name or number, if applicable
- Antenna height as measured and reduced to ARP
- Images taken
- Date of observation and UT day of year
- Start and finish times in Local Time or UT
- Epoch or sampling interval
- Session number, if applicable
- Antenna make, model, serial number and IGS or NGS antenna model code
- Receiver make, model and serial number, if applicable
- Name of operator
- RINEX File name

Additional information on log sheet could include sketches of the antenna height measurements and reductions and a site map showing nearby obstructions (e.g., tree covers, powerlines or nearby buildings).

9.2.4 Output

Includes the baseline processing and/or adjustment reports as well as the baseline processing software file(s). Depending on the processing software, the baseline report may contain the following details:

- Processing parameters
- Start and finish times (UT)
- Epoch interval
- Initial coordinates
- Antenna height (including where on the antenna height is observed to)
- Satellite information (which satellites used in solution?)
- Ambiguity resolution
- Final coordinates
- Delta X, Y, Z baseline
- Standard deviations of Delta X, Y, Z and Correlation or Covariance Matrix of same

Landgate uses the latest version of Trimble Business Center (TBC) for processing GNSS data. Thus, the output contains a TBC archived (zip) or the file consisting of the vce file(s) in. vce and the corresponding folder containing the input files (e.g., RINEX). Other processing softwares may have a different format.

9.2.5 Raw

Includes all raw data files as downloaded from the instrument or GNSS receivers.

9.2.6 Rinex

All observed GNSS data shall be converted in a RINEX format. Most GNSS receivers automatically store data in RINEX format and/or processing softwares can convert raw files into RINEX format. The RINEX files supplied to Landgate must have the following information in the header of the observation file (.yyo):

- Name of the SSM or mark occupied – **MARKER NAME** line in the RINEX file.
- The antenna model code on **ANT # / TYPE** line.
- The antenna height (i.e., vertical offset of the Antenna Reference Point (ARP) above the ground mark) on **ANTENNA: DELTA H**/E/N line.

Other information such as MARKER NUMBER and OBSERVER|AGENCY can be provided as well as shown in the diagram below.

```
     3.04           OBSERVATION DATA    M: MIXED            RINEX VERSION / TYPE
GS15 V12.00         LAND SURVEYS        20240520 004457 UTC PGM / RUN BY / DATE
SNR is mapped to RINEX snr flag value [1-9]                 COMMENT
LX:      < 12dBHz -> 1; 12-17dBHz -> 2; 18-23dBHz -> 3      COMMENT
       24-29dBHz -> 4; 30-35dBHz -> 5; 36-41dBHz -> 6       COMMENT
       42-47dBHz -> 7; 48-53dBHz -> 8; >= 54dBHz -> 9       COMMENT
BLV42                                                       MARKER NAME
107460                                                      MARKER NUMBER
KW                  LANDGATE                                OBSERVER / AGENCY
1508362             LEICA GS15          12.00.065/6.524     REC # / TYPE / VERS
                    LEIGS15         NONE                    ANT # / TYPE
 -3305641.5316  4632839.4648 -2870504.5878                  APPROX POSITION XYZ
       1.5250        0.0000        0.0000                   ANTENNA: DELTA H/E/N
G   12 C1C L1C D1C S1C C2W L2W D2W S2W C5Q L5Q D5Q S5Q      SYS / # / OBS TYPES
```

10. GNSS system testing

Landgate provides a GNSS system testing facility at Curtin University to support the GNSS users in Western Australia. This facility enables users to verify the performance of their GNSS equipment under semi-controlled conditions, helping to identify potential issues with hardware, firmware, or software configurations. The testing procedure is given in ***GSU-08 Guidelines for testing survey grade GNSS equipment on the Curtin Test Network.***

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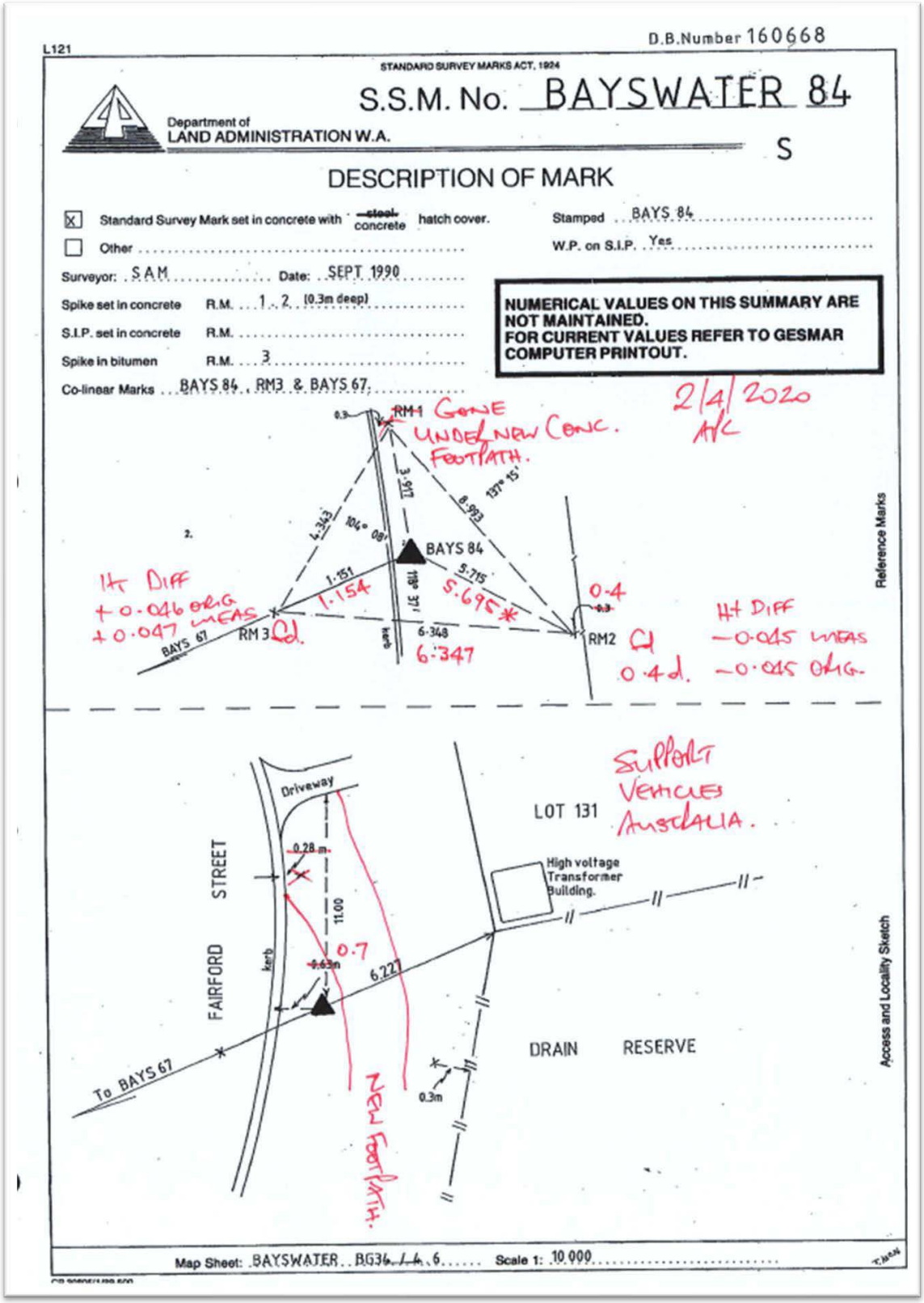
11. Public relations

Maintaining good public relations is vital and essential to Landgate. Where entry onto private or leasehold land or vested reserves is required to access Geodetic Survey Marks (SSMs or BMs), the relevant owner(s), occupier(s), or authority(s) must be contacted prior to entry.

Entry onto land is governed by the *Standard Survey Marks Act 1924*.

Geodetic Survey Marks located in restricted areas such as Rail Reserves, Airport Airside, Port restricted and Military installations will require access permission from the relevant authority before entry. These areas may be controlled by statutory legislation and the process of obtaining entry can make visiting a mark impractical or impossible.

12. Appendix A – Example of annotated Station summary (or Redline Markup)


L121

D.B.Number 160668

STANDARD SURVEY MARKS ACT, 1924

S.S.M. No. BAYSWATER 84

Department of LAND ADMINISTRATION W.A.

S

DESCRIPTION OF MARK

☒ Standard Survey Mark set in concrete with ~~steel~~ concrete hatch cover. Stamped BAYS 84

☐ Other W.P. on S.I.P. Yes

Surveyor: S.A.M. Date: SEPT 1990

Spike set in concrete R.M. 1, 2 (0.3m deep)

S.I.P. set in concrete R.M.

Spike in bitumen R.M. 3

Co-linear Marks BAYS 84, RM3 & BAYS 67

NUMERICAL VALUES ON THIS SUMMARY ARE NOT MAINTAINED. FOR CURRENT VALUES REFER TO GESMAR COMPUTER PRINTOUT.

RM1 GONE UNDER NEW CONC. FOOTPATH. 2/4/2020 A/C

BAYS 84

RM2

RM3

BAYS 67

Ht DIFF +0.046 ORIG +0.047 MEAS

1.154 1.151 5.695* 5.715 6.347 6.348

0.4 0.4d.

Ht DIFF −0.045 MEAS −0.045 ORIG

Reference Marks

Driveway

FAIRFORD STREET

kerb

0.28 m

11.00

0.7

6.227

LOT 131

SUPPORT VEHICLES AUSTRALIA.

High voltage Transformer Building.

DRAIN RESERVE

To BAYS 67

NEW FOOTPATH.

0.3m

Access and Locality Sketch

Map Sheet: BAYSWATER BG36 1-4, 6 Scale 1: 10 000

13. Appendix B – GNSS Log sheet

Job Details			
Station Name:		RINEX File Name:	
Entered in receiver as (As Above ☐) or:			
Mark Description (SSM ☐) or:		Survey Project:	

Measuring rods/offset tape					
Measurements (Slant)	(1)	m (2)		m (3)	m
Radius:		m	Calced vertical ht =		m
Meas check height =		m	(Or) SKYHOOK ht =		m
Offset check ht to ARP =		m	Offset to A.R.P =		m
Check ARP ht =		m	ARP ht above Mark =		m
ARP ht - check ARP ht =		m	ARP ht entered in receiver:		Y / N
Images Taken: Summary (☐) Mark (☐) Setup (☐) Antenna Height Measurement (☐)					

Observation Time and Validations			
Date:	UT Day:	Session/s:	
Start time: (UT/Local)	Finish time:	Length:	Mins
Epochs set to (e.g. 15): sec	Antenna orientated to North: Y / N		
Mark Validated:	Horizontal (☐) Vertical (☐)	Operator Name:	

Equipment details				
	Make	Model	Serial #	IGS/NGS Antenna code
Receiver				
Antenna				

(Tick If) Antenna occupied main mark and site clear above 15 Deg. Show ray diagram with observing schedule and/ or site obstructions below or over page.	☐

14. Appendix C – Geodetic survey checklist

Enter Y (Yes), N (No) or N/A (Not Applicable) plus the number of items if relevant in the appropriate boxes.

Geodetic Survey Job No:			
Digital Data Supplied			
GNSS Observed Data in RAW Format	[ ]		
GNSS Observed Data in RINEX Format	[ ]	Required File Name Convention	[ ]
GNSS Processed Baseline Report	[ ]		
GNSS Scanned Logsheets and Images	[ ]		
GNSS Adjustment Reports	[ ]		
GNSS Network Plan	[ ]		
GNSS Baseline Observation Schedule	[ ]		
Terrestrial Observation File	[ ]		
Levelling Files	[ ]		
Evidence Of Existing Mark Stability			
Horizontal Stability Provided	[ ]		
Vertical Stability Provided	[ ]		
Eccentric Observing Points			
Horizontal Connection to Main Mark Supplied	[ ]		
Vertical Connection to Mark Supplied	[ ]		
Other Data Supplies			
EDM Calibration Certificate	[ ]		
Staff Calibration Certificate	[ ]		
Scanned Field Books (Levelling/Others)	[ ]		
Levelling Abstract	[ ]		
Survey and Data Processing Report	[ ]		
Station Summaries Drafted/Amended	[ ]		
I …… have carried out the surveys according to the technical specifications and provided details in accordance with the requirements.			
Signed: ……	Date: ……		

15. Appendix D – Example of Photos | Images

Mark Photo

Antena Height

Instrument set up