Proceedings of the

APAS2022 CONFERENCE

FAIRMONT RESORT, LEURA
21-23 MARCH 2022

SURVEYING ON THE EDGE

Edited by Dr Volker Janssen

Presented by the
Association of Public Authority Surveyors
www.apas.org.au

Association of Public Authority Surveyors (NSW) Inc.

These proceedings are proudly sponsored by

Table of Contents

Office Bearers for 2021/2022

Association of Public Authority Surveyors Office Bearers for 2021/2022:

President:	Jarad Cannings (Public Works Advisory)
Vice President:	Nigel Petersen (Nambucca Shire Council)
Secretary:	Michael Armstrong (Transport for NSW)
Treasurer:	Michael Waud (Transport for NSW)
Committee:	Wayne Fenwick (DCS Spatial Services)
	Alecia Goodrich (Transport for NSW)
	Micheal Kocoski (Blue Mountains City Council)
Past President:	Thomas Grinter (DCS Spatial Services)
Publications Officer:	Dr Volker Janssen (DCS Spatial Services)
Conference Manager:	Peter Nilon (Sydney Trains)
ISNSW Representative:	Jarad Cannings (Public Works Advisory)
Public Officer:	Michael Armstrong (Transport for NSW)

Editorial

These proceedings contain the papers presented at the Association of Public Authority Surveyors Conference (APAS2022), held in Leura, NSW, Australia, on 21-23 March 2022. Papers were not peer-reviewed but have been subject to changes made by the Editor. The Editor would like to thank all authors for their contributions covering a wide range of topics relevant to the surveying and spatial information community, thus ensuring an exciting and informative conference.

Authors are welcome to make their paper, as it appears in these conference proceedings, available online on their personal and/or their institution's website, provided it is clearly stated that the paper was originally published in these proceedings. Papers should be referenced according to the following template:

Janssen V. and McElroy S. (2022) A practical guide to AUSPOS, *Proceedings of Association of Public Authority Surveyors Conference (APAS2022)*, Leura, Australia, 21-23 March, 3-28.

APAS is not responsible for any statements made or opinions expressed in the papers included in these proceedings.

DCS Spatial Services, a unit of the NSW Department of Customer Service (DCS), is gratefully acknowledged for providing the front cover artwork and producing these proceedings. The APAS committee is thanked for their hard work in organising this conference.

Dr Volker Janssen
APAS Publications Officer, Program Chair and Editor
DCS Spatial Services
NSW Department of Customer Service
Publications@apas.org.au

A Practical Guide to AUSPOS

Volker Janssen
DCS Spatial Services
NSW Department of Customer Service
Volker.Janssen@customerservice.nsw.gov.au

Simon McElroy
DCS Spatial Services
NSW Department of Customer Service
Simon.McElroy@customerservice.nsw.gov.au

ABSTRACT

AUSPOS is Geoscience Australia's free online Global Positioning System (GPS) processing service and has successfully processed more than 1 million jobs worldwide over the last 10 years or so. It takes advantage of the International GNSS Service (IGS) core network station data and products together with Global Navigation Satellite System (GNSS) Continuously Operating Reference Stations (CORS) in and around Australia to compute precise coordinates and their uncertainties, using static dual-frequency GPS carrier phase and code data of at least 1 hour duration (recommended minimum of 2 hours duration). This paper provides an in-depth practical guide for AUSPOS users, explains how over 12,000 AUSPOS solutions have so far been used to help maintain and improve the NSW survey control network and outlines our desire and the requirements for the inclusion of industry-observed AUSPOS datasets to be submitted to DCS Spatial Services for potential update of the Survey Control Information Management System (SCIMS) and inclusion in the growing GDA2020 state adjustment. It also offers some practical tips and tricks related to measuring the antenna height, observation data recovery and AUSPOS cluster processing.

KEYWORDS: *AUSPOS, GDA2020, datum modernisation, SCIMS, best practice*.

1 INTRODUCTION

Geoscience Australia's free online Global Positioning System (GPS) processing service, AUSPOS, was developed to provide an online positioning service based on Continuously Operating Reference Stations (CORS) primarily for Australian users, although it can process data collected anywhere on Earth (GA, 2022a). Initially released in 2000, it remains GPS-only and has been frequently upgraded to incorporate improvements. For example, in support of national datum modernisation efforts leading to the introduction of the Geocentric Datum of Australia 2020 (GDA2020 – see ICSM, 2022a), AUSPOS started delivering results in both GDA94 and GDA2020, as well as ITRF2014 (Altamimi et al., 2016), with version 2.3 in November 2017. The current version 2.4 was released in August 2020, now running in the Amazon Web Services (AWS) cloud environment with scalability and reliability (rather than on physical servers) to accommodate the increasing use of AUSPOS. Over 10 years from 2011 to 2020, AUSPOS successfully processed more than 1 million jobs worldwide. After AUSPOS was launched in the cloud, more than 200,000 jobs were processed in 15 months, including about 100,000 submissions for the National GNSS Campaign Archive (NGCA).

AUSPOS takes advantage of the International GNSS Service (IGS) core network station data and products (e.g. final, rapid or ultra-rapid orbits depending on availability – see IGS, 2022a) together with CORS in and around Australia to compute precise coordinates, using static dual-frequency GPS carrier phase and code data of at least 1 hour duration (recommended minimum of 2 hours, maximum of 7 consecutive days). When submitting 30-second Receiver Independent Exchange (RINEX – see IGS, 2022b) data (version 2 and 3 are both accepted), users are required to specify the antenna type (using the IGS naming convention) and the vertically measured antenna height from the ground mark to the Antenna Reference Point (ARP). Following processing, an AUSPOS report (pdf) is emailed to the user (generally within a few minutes), which includes the computed coordinates and their uncertainties, ambiguity resolution statistics, and an overview of the GPS processing strategy applied. For advanced users, Solution Independent Exchange (SINEX) files containing more detailed information are also available for download.

In NSW, all 202 CORSnet-NSW sites comprise a fundamental, high-density and long-term component of AUSPOS infrastructure. CORSnet-NSW is Australia's largest state-owned and operated Global Navigation Satellite System (GNSS) CORS network providing fundamental positioning infrastructure for a wide range of applications (e.g. Janssen et al., 2016; DCS Spatial Services, 2022a). It is built, owned and operated by DCS Spatial Services, a business unit of the NSW Department of Customer Service (DCS). All CORSnet-NSW sites are part of the Asia-Pacific Reference Frame (APREF – see GA, 2022b), including 13 concrete-pillared NSW stations incorporated in the IGS network, and subject to the Regulation 13 certification process providing legal traceability with respect to the Recognised-Value Standard (RVS) of measurement of position in Australia (Hu and Dawson, 2020). The Survey Control Information Management System (SCIMS) is the state's database containing more than 250,000 survey marks on public record, including coordinates, heights, accuracy classifications and other metadata, provided in GDA94, GDA2020 and the Australian Height Datum (AHD – see Roelse et al., 1971; Janssen and McElroy, 2021).

This paper provides an in-depth practical guide for AUSPOS users, explains how AUSPOS solutions are used to maintain and improve the NSW survey control network and outlines the requirements for successful industry-observed AUSPOS datasets to be submitted to DCS Spatial Services for potential update of SCIMS and inclusion in the growing GDA2020 state adjustment. It also offers some practical tips and tricks related to measuring the antenna height, observation data recovery and AUSPOS cluster processing.

2 AUSPOS PROCESSING STRATEGY AND PERFORMANCE

2.1 AUSPOS Processing Strategy

AUSPOS uses the Bernese software version 5.2 (Dach et al., 2015) for data processing. As stated in the AUSPOS report, the carrier phase data is cleaned during pre-processing in baseline-by-baseline mode using triple-differencing. In most cases, cycle slips are fixed by the simultaneous analysis of different linear combinations of L1 and L2. If a cycle slip cannot be fixed reliably, bad data points are removed or new ambiguities are set up. While data cleaning is performed at a sampling rate of 30 seconds, the basic observable used is the carrier phase with a sampling rate of 3 minutes and an elevation angle cut-off at 7°. Elevation-dependent weighting is applied according to $1/\sin(e)^2$ where e is the satellite elevation. A-priori coordinates for the user data are obtained via Precise Point Positioning (PPP) using zero-difference carrier phase measurements (between the L1 and L2 frequencies at a single site).

AUSPOS then uses up to 15 surrounding CORS as the reference stations, generally the 7 closest IGS core sites and the 8 closest APREF sites (Jia et al., 2014). This approach provides a relatively dense network for generating a reliable regional ionospheric delay model and tropospheric delay corrections to support ambiguity resolution. Ambiguities are resolved in baseline-by-baseline mode using the following strategies depending on baseline length (stated in order of increasing accuracy):

- Code-based wide-lane/narrow-lane (L5/L3) strategy for 200-6,000 km baselines.
- Phase-based wide-lane/narrow-lane (L5/L3) strategy for 20-200 km baselines.
- Quasi-Ionosphere-Free (QIF) strategy for 20-2,000 km baselines.
- Direct L1/L2 strategy for 0-20 km baselines.

Based on these reference stations, a precise solution for the user data is then computed using double-differencing techniques. The coordinates of the IGS stations (i.e. tier 1 and 2 CORS) are constrained with uncertainties of 1 mm for horizontal position and 2 mm for the vertical component (ellipsoidal height), while lower-tier CORS coordinates are constrained with uncertainties of 3 mm for horizontal position and 6 mm for the vertical (due to the shorter CORS operation time span, lower data quality and/or lower-grade monumentation).

The GPS data is processed in the IGS realisation of the ITRF2014 reference frame and then transformed to GDA2020 via the Australian Plate Motion Model. Derived AHD heights are computed by applying a gravimetric-geometric quasigeoid model (AUSGeoid2020 – see Brown et al., 2018; Janssen and Watson, 2018; Featherstone et al., 2019) to the GDA2020 ellipsoidal heights. It is worth noting that AUSGeoid2020 only extends 33 km offshore. Between 33 km and 50 km offshore, the AUSGeoid2020 N-values are linearly blended with the DTU15 Mean Sea Surface (MSS) model produced by the Technical University of Denmark (DTU) (Andersen et al., 2016), i.e. the weighting of AUSGeoid2020 diminishes to zero at 50 km offshore. Legacy GDA94 coordinates are obtained from GDA2020 by coordinate transformation. More information about GDA94 and GDA2020, along with their technical manuals, can be found on the Intergovernmental Committee on Surveying and Mapping (ICSM) website (ICSM, 2022a).

It is important to note that AUSPOS performs true simultaneous multi-baseline processing, i.e. it combines GPS baseline processing of data collected at several sites in the same time window (which is therefore correlated) with a 3D least squares network adjustment before the results are delivered to the user. Commercial off-the-shelf software packages routinely used by industry and even DCS Spatial Services only mimic this ideal, requiring a 2-step process of single-baseline processing followed by a network adjustment. Simultaneous multi-baseline processing also neatly solves the problem of trivial baselines, which industry tends to struggle with in large networks. Even if the user only submits one RINEX file, AUSPOS still performs simultaneous multi-baseline processing because it uses data from up to 15 CORS. While the traditional 2-step process tends to focus on the delivery of coordinates, simultaneous multi-baseline processing delivers both coordinates and uncertainties, thereby providing better and more realistic uncertainty values. The fact that AUSPOS both processes baselines and adjusts them is often overlooked by novice users who focus on AUSPOS delivering 3D coordinates, which may appear like a ‘fancy’ point position to the uninitiated. However, there is a lot going on under the bonnet.

Positional Uncertainty (PU) is defined as the uncertainty of the horizontal and/or vertical coordinates of a point, at the 95% confidence level, with respect to the defined reference frame (datum). AUSPOS calculates PU based on the East, North and ellipsoidal height coordinate uncertainties according to the Guideline for Adjustment and Evaluation of Survey Control, which is part of ICSM's Standard for the Australian Survey Control Network (SP1), version 2.2 (ICSM, 2020). The coordinate uncertainties of the East, North and ellipsoidal height components are scaled using an empirically derived model, which is a function of duration, data quality and geographical location (latitude and CORS density), and expressed at the 95% confidence level (Jia et al., 2016).

PU can then be stated as Horizontal PU (HPU) for horizontal GDA2020 coordinates, Vertical PU (VPU) for GDA2020 ellipsoidal heights and AHD-PU for derived AHD heights. The PU values for AUSPOS-derived coordinates published in SCIMS are typically larger than those obtained directly by a user because (1) type B uncertainties (those not based on a statistical analysis of data) are applied to CORS (and other survey marks) in the GDA2020 national and state adjustments (see section 4.1), and (2) PU values in SCIMS are rounded up and displayed to the nearest centimetre (causing 0.02 m and 0.03 m to be very common HPU values in SCIMS).

2.2 AUSPOS Performance in NSW

Based on more than 2,400 successful datasets observed by DCS Spatial Services and incorporating observation sessions ranging from 2 hours to 48 hours in length, Janssen and McElroy (2020) showed that AUSPOS routinely delivers PU values at the 0.02-0.03 m level for the horizontal component and about 0.05-0.06 m for the vertical (ellipsoidal) component in NSW. As expected, it was evident that a longer observation span improves PU, particularly in the vertical component. The derived AHD-PU values reported by AUSPOS appeared to be overly conservative for the data investigated, which was attributed to the conservative AUSGeoid2020 uncertainty grid values applied (the best-case official AUSGeoid2020 uncertainty in NSW is about 0.14 m at the 95% confidence level). While AUSPOS uncertainty is known to be affected (scaled) by latitude, it was found that the variation is negligible for user results within the bounds of NSW.

These results illustrated why Geoscience Australia stipulates, and NSW supports, a minimum observation span of 6 hours for direct inclusion into the national GDA2020 adjustment via the National GNSS Campaign Archive (NGCA) to propagate the survey control network. They also showed that shorter observation sessions are of sufficient quality to improve and strengthen state survey infrastructure, provided sky view conditions are reasonable. This justifies the approach taken by DCS Spatial Services to use AUSPOS as one of several suitable methods to maintain and improve the state's survey control network as well as the request for NSW users to submit industry-observed data via the DCS Spatial Services Customer Hub (DCS Spatial Services, 2022b) for the benefit of all (see section 4.2).

3 USING AUSPOS

AUSPOS accepts dual-frequency, geodetic-quality GNSS data in RINEX format that was observed in static mode. While the submitted RINEX file may contain data from multiple GNSS constellations (e.g. GPS, GLONASS, BeiDou and Galileo), only GPS data is used for processing. Similarly, submitted data is resampled (thinned) to a 30-second epoch interval regardless of the initial sampling rate. The AUSPOS website (GA, 2022a) contains background information, a submission checklist, a step-by-step submission guide and frequently asked questions to help users submit data, understand the results and aid trouble shooting. It should be noted that datasets submitted to AUSPOS are neither retained by Geoscience Australia nor passed on to any third party.

3.1 Preparing Data

The thorough preparation of RINEX data files not only facilitates smooth AUSPOS processing but also allows efficient and unambiguous archiving of the data and associated metadata in one place. This paper mainly refers to RINEX version 2.11 because AUSPOS remains GPS-only at present, and this is the format currently used for archiving by DCS Spatial Services. However, it should be noted that the more recent RINEX version 3 format was developed to better support multi-GNSS observations, with version 4 now also available but not yet implemented in most software (IGS, 2022b). The raw observation file in (binary) proprietary format collected by the GNSS receiver needs to be converted to RINEX format and ideally should be decimated to a sampling interval of 30 seconds to decrease the file size.

3.1.1 RINEX File Naming and Editing

The RINEX file name must not contain any spaces, parentheses or symbols. It is beneficial to use the international RINEX v2.11 file naming convention XXXXDDDS.YYO, where XXXX is a 4-character site name, DDD is the day of year (i.e. 001 to 365, or 366 during a leap year), S is the session identifier (i.e. 0 to 9, or A to X indicating the first observation epoch's hour of the day with A = 0 hours and X = 23 hours), YY is the 2-digit year (i.e. 22 for the year 2022) and O indicates that this is an observation file.

It should be noted that the RINEX v3.05 file naming convention stipulates a much longer file name (along with additional header information). For example, the file name BATH00AUS_R_20220501000_03H_30S_MO.rnx would indicate a RINEX observation file for Bathurst CORS (being the first CORS located at this site in Australia), sourced from a receiver, observed in 2022 on day of year 050 and starting at 10:00 UTC, that contains 3 hours of data at a 30-second sampling rate and mixed GNSS observation data (i.e. from more than one satellite constellation) – see IGS (2022b) for details.

For data archival, or more importantly data sharing or submission to third parties (especially where machine-to-machine processes are likely to be employed), the RINEX header should then be checked and edited. Particular attention should be paid to marker name and number, receiver type and serial number, antenna type and serial number, and vertical antenna height to the ARP (Figure 1). Each RINEX file must only include a single occupation on a single mark.

```
1      2.11           OBSERVATION DATA    M (MIXED)           RINEX VERSION / TYPE
2 teqc  2016Nov7                          20210617 05:02:57UTCPGM / RUN BY / DATE
3 Linux2.6.32-279.el6.x86_64|x86_64|gcc|Win64-MinGW64|=       COMMENT
4 BIT 2 OF LLI FLAGS DATA COLLECTED UNDER A/S CONDITION       COMMENT
5 48DE                                                        MARKER NAME
6 PM183662                                                    MARKER NUMBER
7 NSW                 NSW                                     OBSERVER / AGENCY
8 1516405             LEICA GS15          8.00/7.500          REC # / TYPE / VERS
9 1516405             LEIGS15.R2      NONE                    ANT # / TYPE
10  -4585969.9235  2736510.8223 -3477269.8581                  APPROX POSITION XYZ
11        1.5190        0.0000        0.0000                  ANTENNA: DELTA H/E/N
12      1     1                                               WAVELENGTH FACT L1/2
13      6    L1    L2    C1    P2    S1    S2                 # / TYPES OF OBSERV
14     30.0000                                                INTERVAL
15 Source: 6405_0601_103528.m00                               COMMENT
16 Forced Modulo Decimation to 30 seconds                     COMMENT
17 DefaultJobName                                             COMMENT
18 DefaultUserDiscription                                     COMMENT
19 Project creator:                                           COMMENT
20  SNR is mapped to RINEX snr flag value [0-9]               COMMENT
21   L1 & L2: min(max(int(snr_dBHz/6), 0), 9)                 COMMENT
22   2021     6     1     0    37   30.0000000     GPS        TIME OF FIRST OBS
23     18                                                     LEAP SECONDS
24                                                            END OF HEADER
```

Figure 1: Typical RINEX v2.11 header.

3.1.2 Antenna Height

If the antenna height was not measured directly and vertically to the ARP in the field, e.g. when using a vertical height hook measurement or a slant measurement to the bumper or the Slant Height Measurement Mark (SHMM) on the instrument, then it must be converted to the vertical distance between the ground mark and the ARP using the offsets and method (generally applying Pythagoras) specified in the GNSS equipment manual or provided by the manufacturer (see section 5.1 for examples). Third parties, including the authors, often struggle to figure this out when this information is not included. The correctness of antenna height and antenna type is crucial to allow the correct antenna model to be applied correctly. An error in the antenna height will directly translate into an error in the resulting GNSS-derived ellipsoidal height and AHD height. The antenna height should therefore be measured to the millimetre at the start and at the end of the observation session. A useful independent check is to always take a second measurement using imperial units (inches) and convert to metres (multiply by 0.0254).

3.1.3 Antenna Type

Using the incorrect GNSS antenna type for AUSPOS processing can cause the resulting height to be in error by several centimetres and introduce noise into the computed coordinates. Using the default null antenna can easily introduce a 10 cm error in height. The authoritative source for resolving antenna queries are the frequently updated IGS files *rcvr_ant.tab* and *antenna.gra* (IGS, 2022c). The file *rcvr_ant.tab* details the international naming conventions for GNSS receivers, antennas and radomes (antenna covers), which are also used by AUSPOS. Note that the RINEX format stipulates the antenna type as a 20-character name (columns 21-40 of line 9 in Figure 1) including several spaces and ending with a 4-character indication of the radome used (NONE meaning that no radome is present). The file *antenna.gra* provides graphs with physical dimensions of GNSS antennas, including the position of the ARP (generally the bottom of the antenna) and vertical offsets to other features such as the centre of bumper or bottom of choke ring. As an aside, the file *igs14.atx*, containing the IGS antenna models recommended for baseline processing, can be found at the same location (it is frequently updated to include new antennas). If still in doubt, users should contact their equipment provider for the required antenna information.

3.1.4 GNSS Observations

If session length is critical to contractual arrangements and/or data acceptance by a third party (e.g. DCS Spatial Services), always extend session lengths by a few minutes. Also visually inspect the start and end of the GNSS observation section in the RINEX file (the data following the header), particularly to ensure that the first and last few epochs contain reasonably complete data blocks. This may lead to a few epochs at the start or end of the observation window being deleted due to incomplete data or obstructions caused by the observer. Note that AUSPOS may further trim poor data (like missing or incomplete epochs as the receiver struggles to acquire satellites when first turned on under trees) and thin the submitted data to a 30-second sampling rate – this may help explain why a few minutes of data are sometimes mysteriously missing (and can therefore put the acceptance of your data by a third party at risk). If epochs at the start/end of the observation are deleted, the time of the first/last observation in the RINEX header should be modified accordingly. Frequent dropouts of satellite signals in the RINEX file may also indicate poor sky view conditions (e.g. tree cover).

Figure 2 shows a typical RINEX observation data block for the epoch 00:37:30 hours on 1 June 2021. In this epoch, 18 satellites were observed (8 GPS, 6 GLONASS and 4 Galileo) with six types of observations recorded for all but the Galileo satellites (the L2 frequency is not used by Galileo) – see line 13 in Figure 1 for the corresponding observation types in the RINEX header (L1, L2, C1, P2, S1, S2 – i.e. carrier phase measurements, code measurements and signal strengths on the L1 and L2 frequency, respectively).

```
 21  6  1  0 37 30.0000000  0 18G01G03G04G10G21G22G31G32R02R03R04R13
                                R18R19E05E09E11E36
 110137934.272 8  85821775.74248  20958552.220    20958554.400          53.300
        53.550
 119766659.544 7  93324688.12247  22790840.660    22790843.240          45.200
        45.100
 124156873.931 7  96745619.03746  23626267.600    23626269.980          43.200
        40.100
 130281153.04615 101517801.02255  24791680.380    24791685.800          35.450
        34.100
 107660051.087 8  83890939.09847  20487029.500    20487028.240          51.400
        45.600
 109924937.177 8  85655784.12247  20918020.040    20918017.020          52.900
        44.550
 109426889.942 8  85267704.15548  20823245.920    20823244.660          53.300
        53.250
 122182552.628 7  95207188.87447  23250567.920    23250568.700          47.650
        42.200
 122656371.420 6  95399420.181 6  22985753.460    22985758.360          38.500
        39.000
 109283847.384 8  84998559.602 8  20415141.460    20415142.640          52.450
        48.900
 114565531.929 6  89106523.251 5  21394302.360    21394302.020          38.150
        33.950
 110306911.273 6  85794276.777 7  20656940.920    20656944.020          39.850
        42.650
 114943294.330 8  89400354.336 7  21532750.260    21532755.080          50.650
        47.400
 112735465.036 6  87683135.364 6  21074705.120    21074707.020          38.950
        41.550
 129830473.839 8                  24705917.480                          48.750

 117250086.174 9                  22311949.220                          54.400

 133045175.973 7                  25317654.460                          42.450

 128710168.325 8                  24492734.840                          52.900

 21  6  1  0 38  0.0000000  0 20G01G03G04G10G21G22G31G32R02R03R04R12
                                R13R14R18R19E05E09E11E36
```

Figure 2: Typical RINEX v2.11 observation block.

3.2 Submitting Data

Up to 20 RINEX files can be submitted to AUSPOS simultaneously, provided all their observation sessions contain an overlap of at least 1 hour. These are then processed together in a cluster, using an observation window that contains the collected data at all sites (see section 5.3). However, for simplicity, this section assumes submission of a single RINEX file.

3.2.1 When to Submit

When you submit your data will affect your results, in two ways. Firstly, AUSPOS uses the best available IGS orbit product for processing, having a choice of three (final, rapid and ultra-rapid). The final orbit product is available approximately 2-3 weeks after the observation day (with the weekly final orbit product generally being made available to AUSPOS on Monday morning), while the rapid orbit product is available two days after the observation. If both are unavailable, the much less accurate ultra-rapid orbit product is used. Consequently, it is recommended to submit data to AUSPOS at least two days after the observation to get the benefit of the IGS rapid orbits. DCS Spatial Services almost exclusively uses final orbits (i.e. the best available product) for AUSPOS processing. However, AUSPOS solutions using the rapid orbit product are typically very close to final-orbit solution quality and are therefore likely to be more suited to industry due to their much faster availability.

Secondly, the data from local and international CORS needs to be delivered to Geoscience Australia in order to be used by the AUSPOS service. This data can be either streamed (live) or pushed at regular intervals (e.g. hourly). However, on occasion, Information and Communications Technology (ICT) systems may go down, resulting in the missing CORS data being pushed to the AUSPOS service with a delay. This is very rare in NSW because CORSnet-NSW contains a dense network of CORS with reliable primary and backup communications at each site, so local CORS should generally not be affected. Nevertheless, waiting a little longer before submission increases the chance of using the maximum number of 15 CORS in the solution (provided there are no issues with data quality).

3.2.2 Ticking Boxes

After selecting the RINEX file for upload, the user needs to manually input the antenna height (vertically measured between ground mark and ARP) and select the antenna type (IGS naming convention) from the drop-down menu. Alternatively, clicking the ‘scan’ button will scan the RINEX file header for the required information – this option should only be used if it has been confirmed that the RINEX header is correct.

Note that the RINEX header often contains incorrect or incomplete information when initially generated (e.g. the manufacturer’s receiver and antenna names not following the IGS naming convention, a default antenna type or a zero antenna height), so thorough data preparation is very important. Using an incorrect antenna type can introduce significant bias (more than 10 cm in the vertical component) and noise into the computed coordinates.

Finally, the user provides their email address and submits the data. A status message then appears indicating successful submission and stating the job number, e.g. 1627262153022-99999999 in Figure 3.

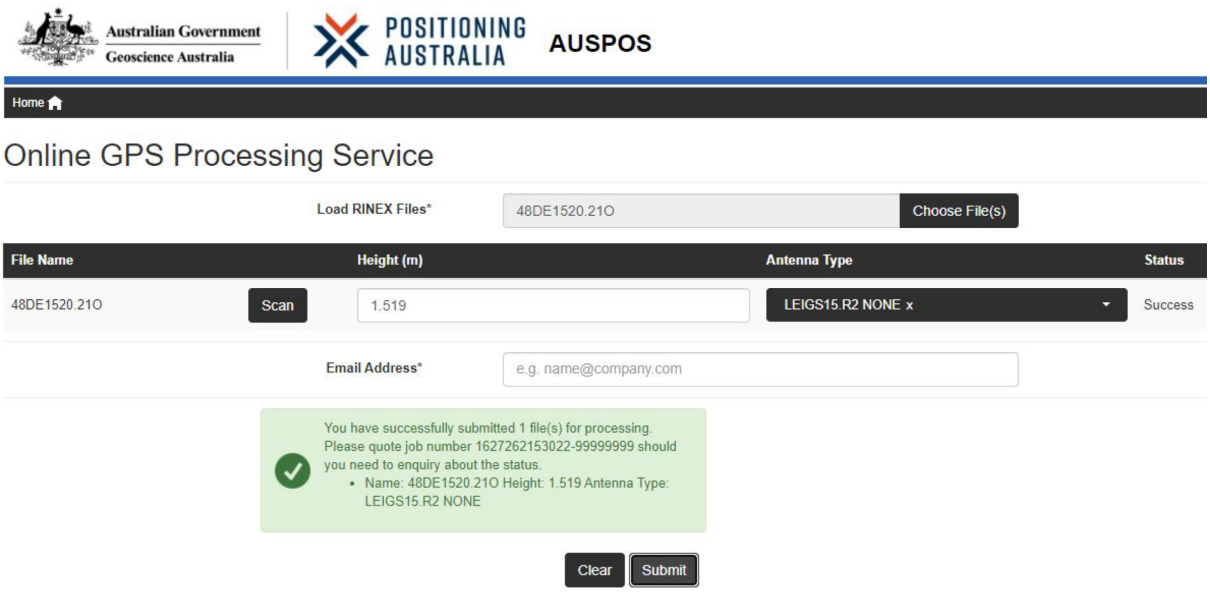


Figure 3: AUSPOS submission page after successful submission of a single RINEX file.

This is followed by an email sent to the user when AUSPOS starts processing the data, generally within a few minutes but depending on current workload, which also includes a list of reminders to ensure successful processing (identical to the submission checklist available on the AUSPOS website):

- AUSPOS only provides a network solution (relative positioning) using a double-difference strategy. Dual-frequency (L1 and L2) measurements are necessary.
- Ensure all RINEX files submitted to the same job contain an overlapping period of more than one hour. Otherwise, submit them individually to different jobs.
- Do not submit measurements for the current UTC day. Please wait until the next UTC day after 03:00 UTC time (i.e. 13:00 AEST or 14:00 AEDT). This allows the RINEX files of reference stations to be downloaded for the current UTC day.
- Do not submit receiver raw binary files (e.g. files with extension M00, T01, T02, DAT, SBF, TPS, etc.).
- Only submit RINEX observation files (e.g. RINEX v2 files with extension O).
- RINEX file names should not contain any special characters, symbols or spaces.
- The station name will be read from the first 4 characters of the MARKER NAME line in the RINEX header.
- Ensure the measurement interval (integer only) is equal to or larger than one second. It is recommended to have the same interval for all RINEX files submitted together.
- Do not use special characters for MARKER NAME and MARKER NUMBER in the RINEX header. Only use numbers and/or letters from the modern English alphabet.
- After the END OF HEADER line in the RINEX header, only observation data should be present (epoch time and measurements).
- If both C1 and P1 (C2 and P2) code measurements exist in a RINEX v2 file, P1 (P2) is given priority to be processed. Ensure that all GPS satellites contain P1 (P2) measurements.
- If only C1 (C2) code measurements exist in a RINEX v2 file, ensure that all GPS satellites contain C1 (C2) measurements.
- For RINEX v3 files, C2S (code measurement) and L2S (phase measurement) from the L2 frequency will not be accepted.
- For RINEX v3 files, the currently accepted L1 frequency measurements are C1P and L1P, C1W and L1W, C1C and L1C, and C1X and L1X.

- For RINEX v3 files, the currently accepted L2 frequency measurements are C2P and L2P, C2W and L2W, C2C and L2C, C2D and L2D, and C2X and L2X.
- If the RINEX files are Hatanaka compressed, use the lower case ‘d’ for the file name extension.

If AUSPOS encounters problems during processing, a further email is sent to the user providing some indication of the issue in the subject, such as:

- ERROR (Please check the format of RINEX file including RINEX header which might be with merging or format errors).
- ERROR (Today’s measurements are not available yet).
- ERROR (Please check whether you submitted different type of RINEX file or not).
- ERROR (Please check whether you submitted receiver raw binary file or not).
- ERROR (PrePPP-Processing).
- ERROR (Final-Processing, RINEX file may be submitted twice or deleted by quality issue).

These errors are generally caused by RINEX format issues (e.g. RINEX header information not in the correct columns or multiple observation sessions present in a single RINEX file) or bad data quality (e.g. short observation session at a site severely affected by tree cover). Furthermore, AUSPOS is limited to accept a maximum total of 130 GNSS satellites in each submitted RINEX file. Geoscience Australia aims to assess the cause of the failure and contact the user if further processing is possible. The AUSPOS website also includes information to aid trouble shooting.

3.3 Interpreting the Results

As mentioned earlier, an AUSPOS report (pdf) is emailed to the user following processing (generally within a few minutes but depending on current workload). This report includes the computed coordinates and their uncertainties, ambiguity resolution statistics, and an overview of the GPS processing strategy applied. For advanced users, or those interested in machine-to-machine applications, SINEX files containing more detailed information about the solution are also available for download.

The reported AUSPOS processing results should be checked to ensure that the solution is reliable:

- Section 1: User Data
    - Is the antenna type correct?
    - Is the antenna height (measured vertically from ground mark to ARP) correct?
- Section 2: Processing Summary
    - Is the number of reference stations used appropriate (i.e. close to 15 CORS)?
    - Is there a good mix of local and distant CORS, i.e. about 8 local CORS and 7 distant CORS (Figure 4)?
    - Are IGS final or rapid orbits used for processing (final orbits are better)?
- Section 3.4: Positional Uncertainty (95% CL) – Geodetic, GDA2020
    - Are the PU values of the GDA2020 coordinates and derived AHD height reasonable, considering observation session length and sky view conditions? (DCS Spatial Services aims for HPU < 0.02 m and ellipsoidal VPU < 0.05 m under good sky view conditions and routinely obtains a reported AHD-PU < 0.19 m.)
    - Is the report void of any warning messages (e.g. large uncertainty)?

- Section 6: Ambiguity Resolution – Per Baseline
  - Are the ambiguity resolution statistics reasonable (i.e. at least 50% of ambiguities resolved per baseline, particularly those to your rover)? (DCS Spatial Services routinely encounters values above 70% in its work.)

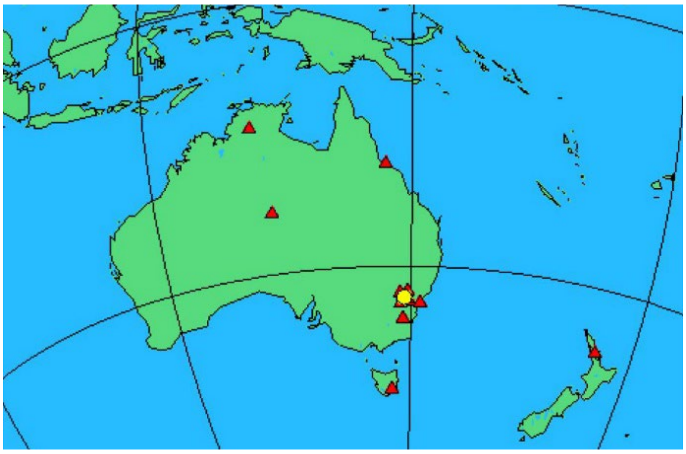


Figure 4: Typical distribution of CORS used as shown in the AUSPOS report (yellow dot indicates user position).

If warning messages occur, the problem needs to be assessed by investigating the magnitude of PU values, session length, sky view conditions and data quality. In most cases, warning messages are due to short or 'dirty' sessions at sites affected by tree cover or other obstructions, resulting in poor sky view conditions and bad data quality (including low or failed ambiguity resolution). Repeating the observation with a longer observation session length will generally result in a better result without any warning messages. Even at heavily treed sites, DCS Spatial Services routinely achieves Class E (sub-metre) results in both the horizontal and vertical component with overnight sessions.

As shown by Janssen and McElroy (2020), most of the improvement in the quality of AUSPOS solutions is gained by increasing the observation length from 2 hours to about 4-5 hours, with minor but not insignificant improvement when the observation span is further increased. Observation sessions exceeding 12 hours provide AUSPOS solutions of substantially higher quality in the vertical component.

Showing the cumulative distribution of PU values to quantify the percentage of AUSPOS solutions meeting a particular PU threshold, Figure 5 can be used as a simple look-up tool to estimate the likelihood of achieving any specified HPU or VPU threshold with 2-6 hour and 6+ hour observation sessions. For example, it shows that about 39% of the 2-6 hour AUSPOS solutions investigated had HPU values of 0.02 m or better, i.e. these survey marks have an absolute horizontal accuracy slightly larger than the size of a 50c piece (radius of 16 mm) with respect to the national datum, while 95% of the 6-24 hour solutions had HPU values at this level. Similarly, about 91% of the 2-6 hour solutions and 99.5% of the 6-24 hour solutions had HPU values of 0.03 m or better.

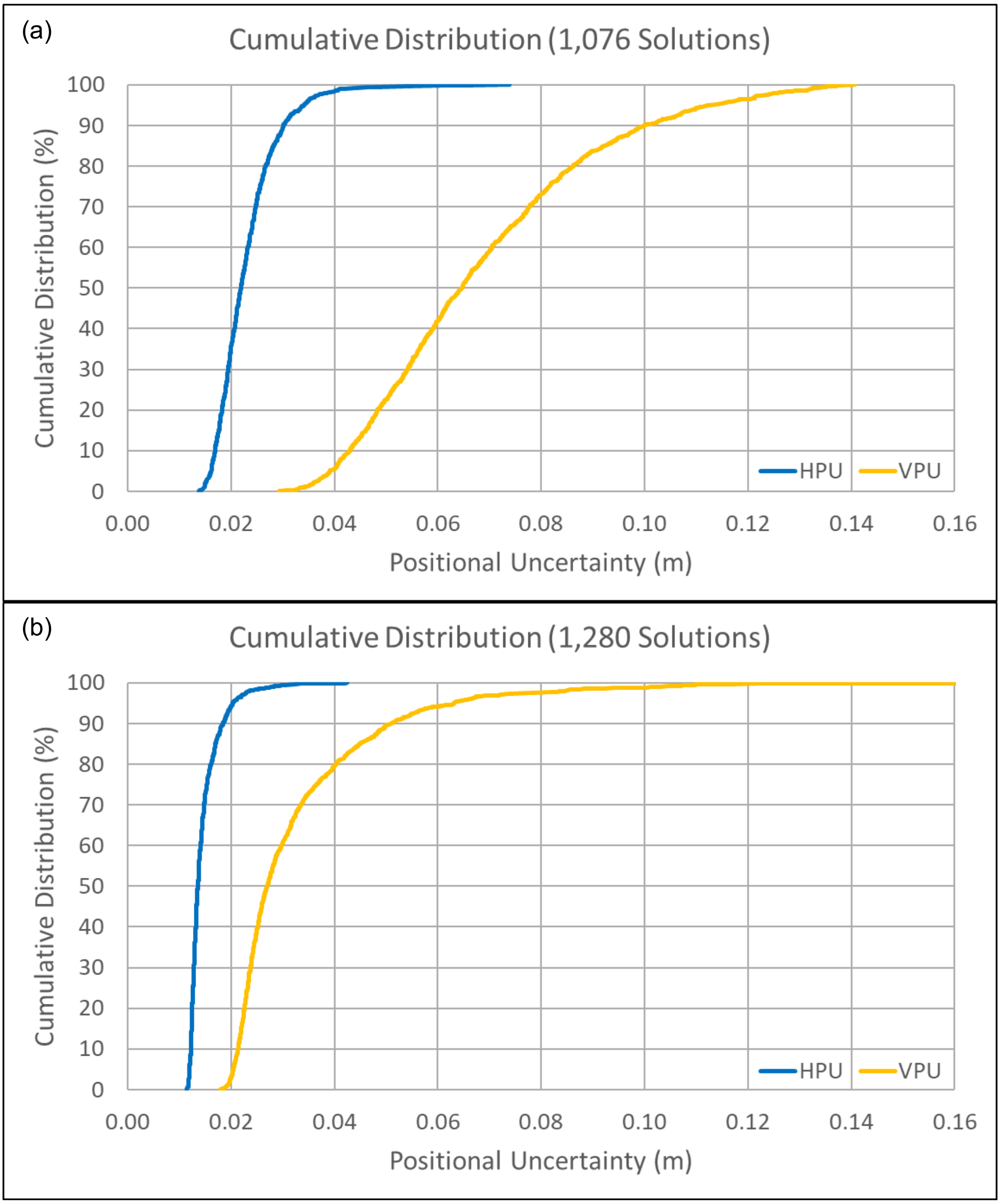


Figure 5: Cumulative distribution of PU reported by AUSPOS in NSW for (a) 2-6 hour datasets, and (b) 6-24 hour datasets (Janssen and McElroy, 2020).

4 MAINTAINING AND IMPROVING THE STATE'S SURVEY CONTROL NETWORK

DCS Spatial Services is responsible for the maintenance of the NSW survey control network. Datum modernisation and further improvement of survey infrastructure is required to accommodate the increasing accuracy and improved spatial and temporal resolution available from modern positioning technologies to an ever-broadening user base. With all CORSnet-NSW stations contributing to the AUSPOS service, it delivers high-quality positioning results even for shorter observation sessions of at least 2 hours across NSW, provided sky view conditions are reasonable (Janssen and McElroy, 2020). Consequently, in some situations, the use of AUSPOS campaigns has developed into a capable and reliable alternative to conducting traditional static GNSS baseline surveys (e.g. Gowans et al., 2015; Janssen and Watson, 2018), simplifying field work logistics and providing significant time savings in regard to processing, adjustment and survey report writing. AUSPOS also forms a new and fundamental component of vertical datum modernisation and the propagation of the Australian Vertical Working Surface (AVWS – see ICSM, 2022b; Janssen and McElroy, 2021) across the state.

4.1 AUSPOS and the NSW Survey Control Network

While traditional GNSS baseline surveys continue to be performed and adjusted by DCS Spatial Services, it also applies, expands and accelerates the use of AUSPOS to improve the state's survey infrastructure. To this end, AUSPOS data of at least 6 hours duration is used to propagate the datum in NSW, while AUSPOS data of less than 6 hours duration strengthens the datum.

Following successful AUSPOS processing of each dataset individually by DCS Spatial Services (GPS-only, using final IGS products), GNSS data of more than 6 hours duration (with a maximum observation length of 48 hours) is submitted to Geoscience Australia toward the National GNSS Campaign Archive (NGCA) of 6+ hour AUSPOS datasets. Currently, this data is then grouped into simultaneously observed sessions and processed by Geoscience Australia using the same online AUSPOS engine in clusters. The results are expressed as baselines to nearby CORS, rather than absolute measurements of position, to avoid introducing additional GDA2020 adjustment constraints outside of APREF.

GNSS data of 2-6 hours duration is handled by DCS Spatial Services according to a similar principle but brought about by slightly different means. Again following successful, individual AUSPOS processing by DCS Spatial Services to verify the required data quality, the AUSPOS results are converted to be expressed as baselines to nearby CORS and then included in the GDA2020 adjustment as part of the state's Jurisdictional Data Archive (JDA). To date, more than 12,000 AUSPOS solutions have been used to help maintain and improve the NSW survey control network.

Currently, DCS Spatial Services allocates a maximum Class D to any survey mark coordinated via AUSPOS as it generally represents only a single occupation with limited redundancy. Marks occupied multiple times, by AUSPOS only, still only receive Class D maximum. The immediate purpose is to upgrade unestablished marks to established marks and make them available to SCIMS users in a timely manner (monthly), until these initial values are updated via the GDA2020 state adjustment (6-monthly). To achieve this, DCS Spatial Services has developed and introduced a monthly workflow to automate as much as possible the update of survey mark coordinates, heights and their uncertainties in SCIMS based on AUSPOS data. Since June 2020, more than 3,200 SCIMS updates for more than 1,600 marks have been undertaken via the new automated workflow, providing a quicker way to deliver more accurate information to our customers as we continue to upgrade the state's survey control network.

The assessment of Class is performed in accordance with ICSM (2007) and Surveyor-General's Direction No. 12 (Control Surveys and SCIMS) (DCS Spatial Services, 2021), and uncertainty as described in Janssen et al. (2019). Table 1 summarises the PU range applicable for the assignment of Class for horizontal coordinates, ellipsoidal height and derived AHD height, based on a single AUSPOS solution.

Table 1: Assigning Class for unestablished survey marks based on the Positional Uncertainty (PU) of a single AUSPOS session.

Class Type	Class	PU Range
Horizontal	D	HPU (95% CL) ≤ 0.1 m
	E	0.1 m < HPU (95% CL) ≤ 1 m
	U	HPU (95% CL) > 1 m
Vertical (ellipsoidal)	D	VPU (95% CL) ≤ 0.1 m
	E	0.1 m < VPU (95% CL) ≤ 1 m
	U	VPU (95% CL) > 1 m
AHD	D	AHD-PU (95% CL) ≤ 0.2 m
	E	0.2 m < AHD-PU (95% CL) ≤ 1 m
	U	AHD-PU (95% CL) > 1 m

Before AUSPOS datasets are processed by DCS Spatial Services, they are subject to a quality assurance process, which ensures a minimum observation session length of 2 hours, certainty about antenna type used and antenna height measured, and involves RINEX file screening and editing to ensure correct header information and sufficient data quality. The AUSPOS results then go through a quality check to ensure that the solution is reliable and suitable for SCIMS update (see section 3.3).

At present, the GDA2020 state adjustment incorporates approximately 96,000 survey control marks across NSW, i.e. 38% of the 250,000 marks on public record in SCIMS. Consequently, 62% of the marks have been transformed from the now superseded GDA94 to GDA2020. Uncertainties of these transformed GDA2020 coordinates cannot be computed until the underlying measurements are sourced and readjusted with a well-defined connection to datum in the GDA2020 state adjustment.

As mentioned in section 2.1, type B uncertainties are applied to CORS (and other survey marks) in the GDA2020 state adjustment. This is to allow for areas of uncertainty which cannot be modelled through least squares (e.g. monument stability). DCS Spatial Services applies two types of type B uncertainty in the state adjustment:

- RVS stations (tier 2 CORS only): 3 mm, 3 mm and 6 mm in East, North and ellipsoidal height respectively.
- Non-RVS stations (everything else): 6 mm, 6 mm and 12 mm in East, North and ellipsoidal height respectively.

These type B uncertainties are added in quadrature to the a-posteriori variance matrix of the adjustment:

$$SD_{final} = \sqrt{SD_{adjusted}{}^{2} + (type\ B\ uncertainty)^{2}} \tag{1}$$

While this is a 'broad-brush' technique, it is suitable in practice and follows the same process as the GDA2020 national adjustment. It is important to emphasise that:

- DCS Spatial Services does not add type B uncertainty to AUSPOS solutions published in SCIMS through the monthly update process.
- Initially, DCS Spatial Services accepts and publishes the AUSPOS-reported uncertainty results without alteration (but rounded up and displayed to the nearest centimetre).
- When the AUSPOS results are converted into correlated baselines and included in the GDA2020 state adjustment, type B uncertainty is applied before the 6-monthly SCIMS update.

In order to support further survey infrastructure improvement, DCS Spatial Services is currently building an updated ‘passive’ survey control network (in the Eastern and Central Divisions) with a minimum of one fundamental survey mark observed by 6+ hour AUSPOS every 10 km. Its vision is to ensure that any future user is no further than 5 km (and often much less) from such a fundamental mark providing direct connection to datum. Similarly, levelled AHD marks are observed by 6+ hour AUSPOS every 10 km, often at a far greater density. This will allow users to achieve DCS Spatial Services’ vision of a PU of 20 mm in the horizontal and 50 mm in the vertical (ellipsoidal height) component anywhere in the state and to easily apply transformation tools to move between current, future and various historical datums and local working surfaces (e.g. railway datum or standard datum).

Using AUSPOS sessions of at least 6 hours duration in this way has several advantages. The field work is quick, logistically simple and very efficient, with multipath effectively being averaged out over the observation session and reliable solutions achieved even under challenging sky view conditions. Data processing via AUSPOS is consistent, of the highest possible standard and very time-efficient, providing a direct connection to the datum via a sophisticated, scientific software package using the best products and models available at the time. The processing results can be ingested by the GDA2020 state adjustment in an automated fashion with minimal effort and without the need for a survey report. Rather than archiving the results, the data is archived and able to be reprocessed at any time to investigate issues or take advantage of improved modelling. While it is recognised that AUSPOS represents an absolute positioning technique because it connects to the surrounding CORS rather than adjacent ground marks, the NSW survey control network is becoming so tight that the authors anticipate there will soon be little difference between relative and absolute positioning.

4.2 Submitting AUSPOS Datasets to DCS Spatial Services

The profession is encouraged to contribute to maintaining, expanding and improving the NSW survey control network by submitting suitable AUSPOS datasets of at least 2 hours duration and related metadata via the DCS Spatial Services Customer Hub on our website (DCS Spatial Services, 2022b). The DCS Spatial Services Customer Hub is a new, user-friendly platform providing a central contact point to interact with DCS Spatial Services staff. It is now the primary way for customers to make an enquiry, submit a data request and provide feedback. Similarly, Survey Operations can (soon) be contacted through the Customer Hub to submit AUSPOS datasets, Locality Sketch Plans (LSPs), Preservation of Survey Infrastructure (POSI) applications, trig station approvals, exemption applications and regulation approvals. Access to the Customer Hub is free and simple, after creating a one-time username and password. Through a ticketed system, users can track the status of their requests at any point in time, which enables DCS Spatial Services to manage these more efficiently and effectively.

AUSPOS data submissions to DCS Spatial Services must include the following:

- RINEX observation file (currently, RINEX v2.11 is preferred) of at least 2 hours duration. Also including the raw binary file in the manufacturer’s native format is optional but strongly recommended.
- Completed log sheet or field notes, clearly indicating observation date/time, mark observed, receiver and antenna type used, and antenna height measured vertically to the ARP.
- AUSPOS processing report.
- Locality Sketch Plan for any new mark placed (submitted separately to the AUSPOS data).
- Photographs of the mark, indicating mark type and sky view conditions (optional but recommended).

For clarity and ease of operation, it is recommended to use the generic DCS Spatial Services GNSS log sheet (Figure 6), available as part of the resource pack for Surveyor-General's Direction No. 12 (DCS Spatial Services, 2021), because it indicates the minimum details to be captured.

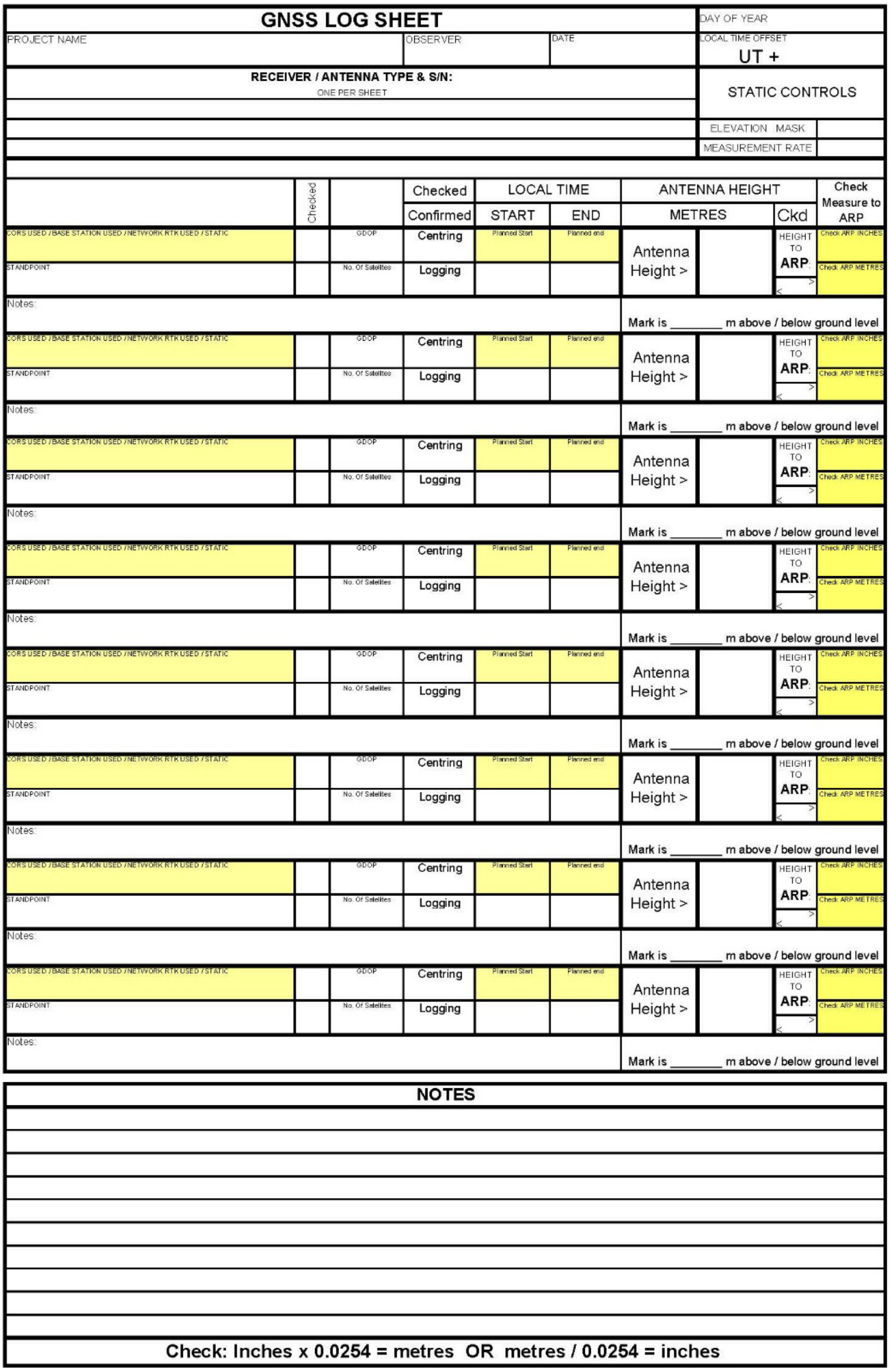


Figure 6: Generic GNSS log sheet (DCS Spatial Services, 2021).

The Excel version of the log sheet can easily be modified to accommodate individual needs (e.g. inserting equipment details), which makes it very efficient when printed for use in the field or converted to pdf format. If the antenna height is routinely measured using a height hook or slant measurement, the relevant antenna diagram and offset calculations to convert this value to the ARP can also be included as an image (generally sourced from the equipment manual), e.g. in the notes/comments section at the bottom of the log sheet or by reducing the number of rows allocated to multiple observation sessions. Surveyors who opt to submit cadastral-type field notes need to ensure that all required information is noted. In this regard, a little preparation provides great benefits in the field and further downstream. We found this very valuable when revisiting log sheets from many years ago to mine data for purposes that were not envisaged when the data was originally collected.

It is worth noting that the local time offset for most of NSW is either +10 hours or +11 hours (if Daylight Saving Time is active). The day of year is simply that, counting from 1 onwards with 1 January being 1 and 31 December being 365 (or 366 in a leap year) – see NGS (2022) for a GPS calendar showing the day of year and GPS week. It is recommended to book start and end times in the 24-hour format, i.e. 16:23 rather than 4.23 pm. The notes section of the log sheet is useful for documenting any antenna height measurement conversions and sky view conditions or unforeseen circumstances that may be relevant.

5 PRACTICAL TIPS AND TRICKS

5.1 Reduction of the Antenna Height to the ARP

One of the two most common reasons for DCS Spatial Services to reject AUSPOS data submissions by third parties is a missing or ambiguous antenna height (the other is an unknown or ambiguous antenna type). Is the provided antenna height the required vertical measurement to the ARP or a slant measurement to some mark on the housing of the antenna? Has it been measured directly or calculated by applying a particular reduction procedure? The ARP is generally the bottom of the antenna, and the antenna height to the ARP should not be confused with a vertical height hook or slant height measurement commonly applied in GNSS baseline processing software.

This section provides selected examples illustrating the offset calculations that need to be applied when the initial antenna height measurement is not a direct, vertical measurement between the ground mark and the ARP. It should be emphasised that the antenna height must be measured with utmost care as any error will directly translate into an error of the resulting GNSS-derived ellipsoidal height (and thus the derived AHD height). If in doubt about the antenna type used and the height reduction required, the equipment manufacturer should be contacted for clarification.

5.1.1 Height Hook Measurement

The height hook allows a vertical measurement from the ground mark to a point below the tripod set up on a mark. A vertical offset is then applied (added) to obtain the height to the ARP (Figure 7). However, this offset depends on the equipment used, i.e. the type of tribrach and antenna carrier (which may include a screw-to-stub adapter). When standard equipment is used, the offset can be obtained from the GNSS equipment manual and the manufacturer. This offset may then be automatically applied in the rover for real-time applications or the GNSS baseline processing software for post-processing applications, provided the software is supplied by the same manufacturer.

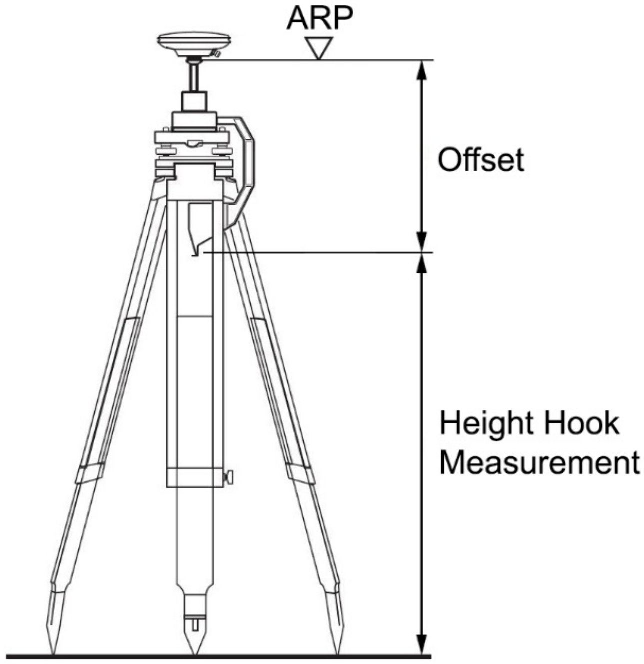


Figure 7: Determining the vertical antenna height to the ARP from a height hook measurement (adapted from Leica Viva Series Technical Reference Manual).

However, AUSPOS does not apply any such offsets because this is simply not workable for the vast number of GNSS antenna makes and models supported. Any comments in the RINEX header pertaining to the antenna height measurement are useful for data archiving but ignored during AUSPOS processing. Following the international standard, AUSPOS expects input of the antenna height vertically measured between the ground mark and the ARP because all antenna phase centre variation models (applied during processing) refer to the ARP.

Consequently, when non-standard equipment is combined, the individual offset for a particular combination needs to be carefully determined and confirmed to avoid antenna height errors. For example, if the Leica Viva GS15 ('LEIGS15.R2 NONE' antenna) is used in conjunction with the standard (small) antenna carrier, the offset to be added to the height hook measurement is 0.254 m. However, if it is combined with the larger antenna carrier, the offset is 0.360 m.

5.1.2 Slant Height to SHMM

Some instruments include a Slant Height Measurement Mark (SHMM), located either on the housing of the antenna or at the tip of a horizontal bar attached to the bottom of the antenna. The GNSS equipment manual should include instructions on the required calculations, including the applicable offsets. For example, Figure 8 illustrates the dimensions and offsets relevant for Topcon's 'TPSHIPER_II NONE' antenna.

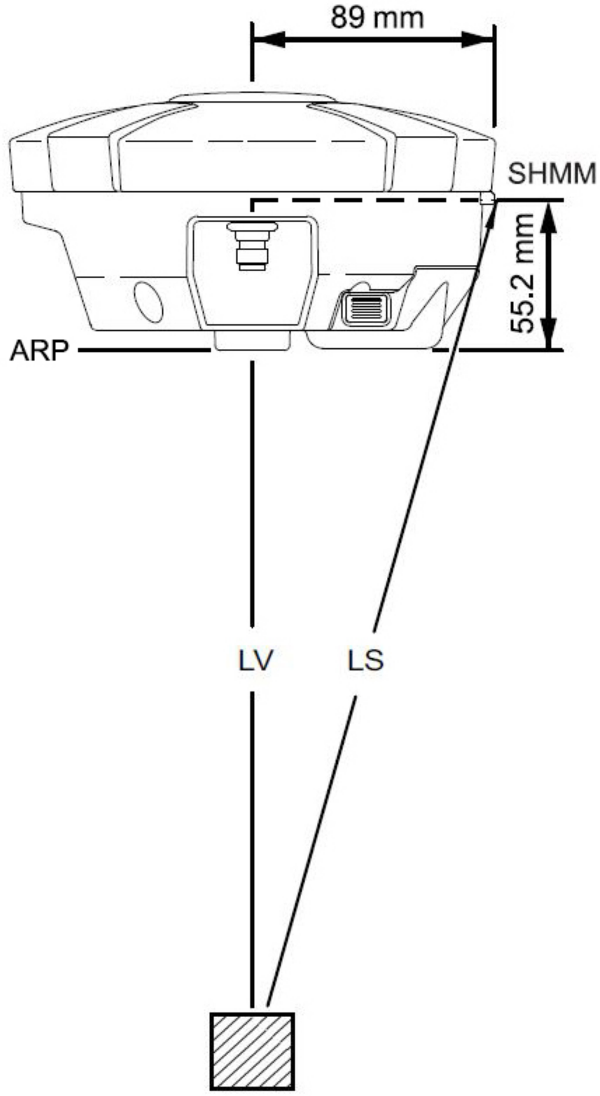


Figure 8: Determining the vertical antenna height to the ARP from a SHMM measurement to the housing of the antenna (adapted from TPS Hiper II Operator's Manual).

Using Pythagoras, the following calculation is required to convert the slant measurement to the SHMM (denoted as LS) to the vertical height from the ground mark to the ARP (LV_{ARP}):

$$LV_{ARP}\ (m) = \sqrt{LS^2 - 0.089^2} - 0.055 \tag{2}$$

In this case, for typical instrument heights ranging from 1.400 m to 2.000 m, ignoring Pythagoras and applying only the vertical offset introduces an error of about 2-3 mm in the antenna height (i.e. the antenna height is too large). While this may be acceptable for cadastral purposes, this approximation should be avoided for control surveys and geodetic purposes because this error will translate directly into the resulting GNSS-derived height.

Similarly, Figure 9 illustrates the offsets relevant for Topcon's 'TPSHIPER_HR NONE' antenna. Since the SHMM and the ARP are on the same horizontal plane, only Pythagoras is required to obtain the vertical height to the ARP from the slant measurement to the SHMM, which is located at the end of a horizontal bar:

$$LV_{ARP}\ (m) = \sqrt{LS^2 - 0.100^2} \tag{3}$$

In this case, for typical instrument heights ranging from 1.400 m to 2.000 m, using the slant height measurement without reduction to the vertical introduces an error of about 3-4 mm in the antenna height (i.e. the antenna height is too large). Again, this should be avoided in practice.

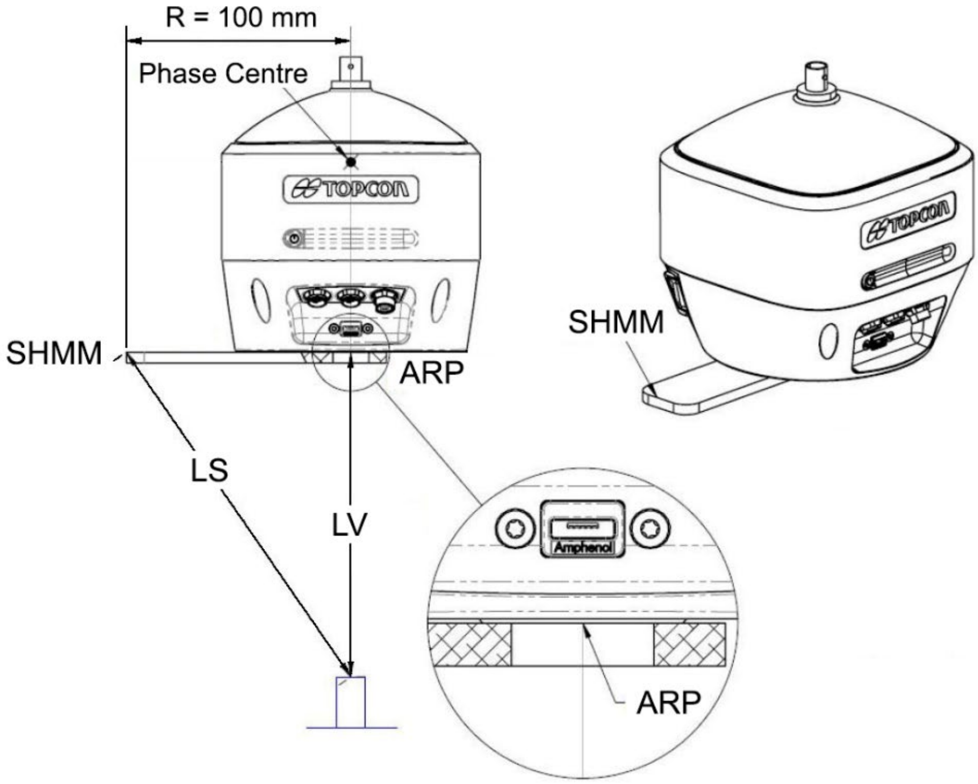


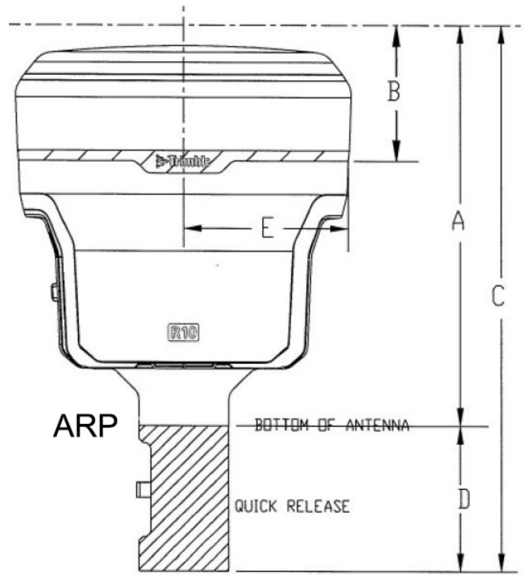
Figure 9: Determining the vertical antenna height to the ARP from a SHMM measurement to a horizontal bar (adapted from TPS Hiper HR Operator's Manual).

5.1.3 Slant Height to Bumper

Other GNSS antennas utilise a distinct marking on the housing of the antenna instead of a specific SHMM as a reference for the slant height measurement. For example, Trimble's 'TRMR10 NONE' antenna features a yellow ring around the housing of the antenna, which is known as the bumper (Figure 10). Using Pythagoras in conjunction with a vertical offset, the measured slant height to the bottom of the bumper is then converted to a vertical antenna height measurement between the ground mark and the ARP:

$$LV_{ARP}\ (m) = \sqrt{LS^2 - 0.058^2} - 0.094 \tag{4}$$

For typical instrument heights ranging from 1.400 m to 2.000 m, ignoring Pythagoras and applying only the vertical offset introduces an error of about 1 mm in the antenna height (i.e. the antenna height is too large). Compared to the previous two cases, the smaller magnitude of the error is due to the smaller radius of the antenna. Consequently, in this particular case, it is acceptable to approximate equation (4) with simply applying a vertical offset of -0.095 m to reduce the measurement from the bottom of the bumper to the ARP. Obviously, the validity of any such approximation needs to be assessed on a case-by-case basis and should be clearly stated on the GNSS log sheet because this approximation may not be suitable when the data is later used for other purposes (e.g. SCIMS update or geodesy).



	DIMENSIONS		DESCRIPTION
A	0.4892 FT	0.1491 M	BOTTOM OF ANTENNA TO NOMINAL PHASE CENTER
B	0.1790 FT	0.0546 M	BOTTOM OF BUMPER TO NOMINAL PHASE CENTER
C	0.6532 FT	0.1991 M	BOTTOM OF QUICK RELEASE TO NOMINAL PHASE CENTER
D	0.1640 FT	0.0500 M	QUICK RELEASE HEIGHT
E	0.1915 FT	0.0584 M	RADIAL: CENTERLINE OF ANTENNA TO OUTER EDGE OF BUMPER BOTTOM

Figure 10: Determining the vertical antenna height to the ARP from a slant measurement to the bumper (adapted from Trimble R10 User Guide).

Furthermore, as indicated in Figure 10, this antenna may also be used in conjunction with a quick release adapter. The antenna height is then sometimes measured vertically from the ground mark to the bottom of the quick release, only necessitating a vertical offset of +0.050 m to be applied for reduction to the ARP. This illustrates the importance of clearly stating what type of measurement was taken (vertical or slant) to where and how this was then reduced to the ARP. The importance of this type of metadata cannot be understated, particularly if multiple survey crews are involved. Thankfully, the required information can easily and effectively be provided by adapting the generic log sheet provided by DCS Spatial Services (see Figure 6) for a specific GNSS receiver-antenna combination with a particular antenna height measuring process.

5.2 Observation Data Recovery

In some cases, the instrument may be disturbed during the observation session, e.g. by failing to tighten the tripod leg screws enough or by people, livestock or storm events bumping the tripod, pushing it over or removing it altogether. For longer observation sessions, useful data may still be salvaged if it can be determined when the unfortunate intervention occurred. Processing the data in kinematic mode (i.e. epoch by epoch) using the PPP technique can be very useful in identifying when the disturbance event occurred.

One option is the CSRS-PPP online positioning service provided by Natural Resources Canada (NRCan), which requires registration but is free (NRCan, 2022). It works similar to AUSPOS but is able to process data in both static and kinematic mode, delivering ITRF2014 positions and graphs that can be used to identify the time of intervention. For example, Figure 11 shows the kinematic (epoch-by-epoch) CSRS-PPP output for a 24-hour observation session where the tripod was intentionally placed on the ground by an unknown person (presumably a good Samaritan) at around 16:15 UTC. Inspecting the observation data blocks of the RINEX file corresponding to this time clearly identified the epoch of intervention through the loss of satellite signals, resulting in almost 19 hours of usable data being retained. Using a variety of software, the offending epochs can then simply be edited out.

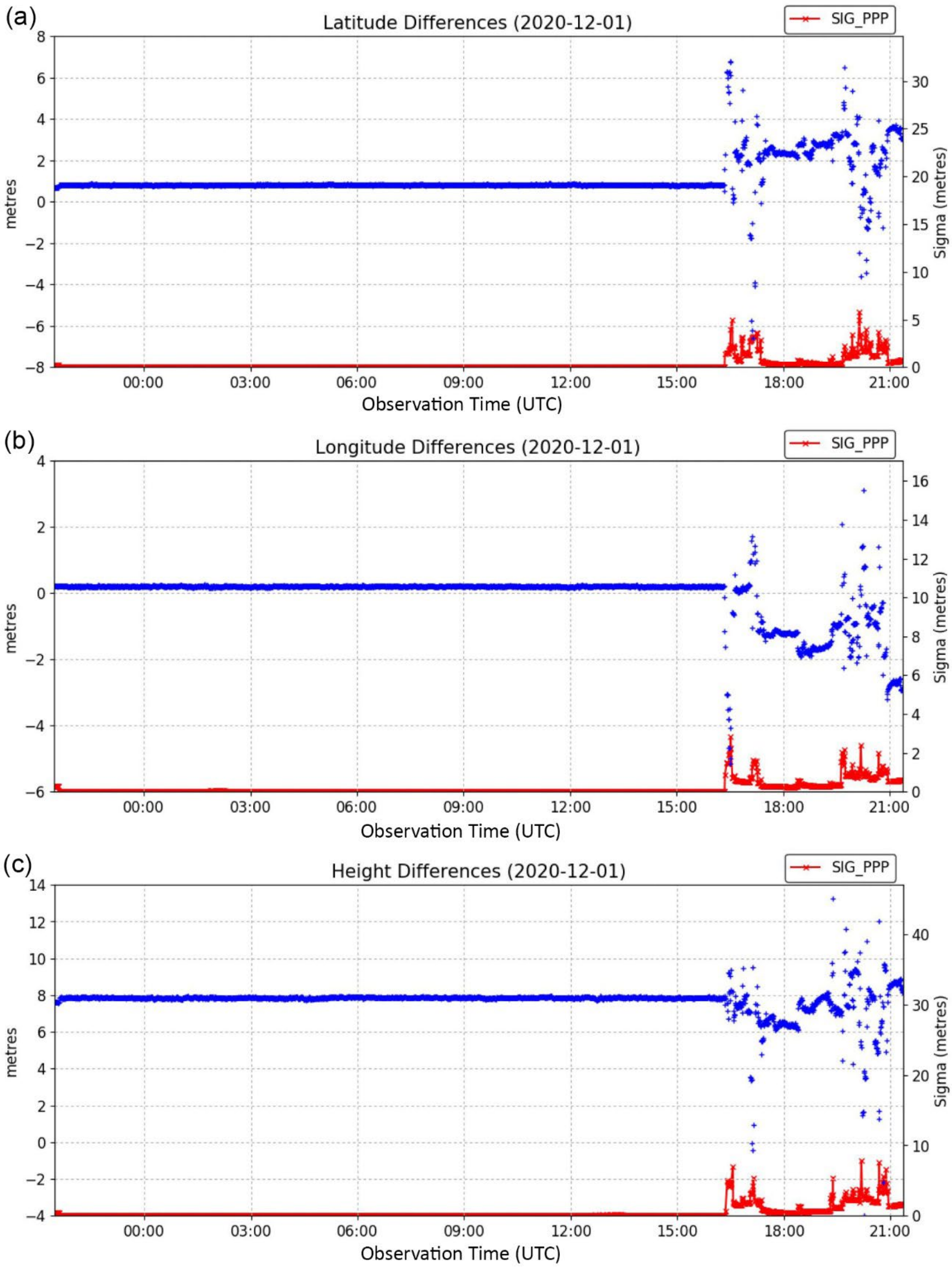


Figure 11: Kinematic CSRS-PPP output for a 24-hour observation session where the tripod was intentionally placed on the ground at around 16:15 UTC, showing (a) latitude, (b) longitude and (c) height differences in blue and their standard deviations in red.

When an accidental disturbance occurs at the end of a survey, e.g. forgetting to correctly turn off the receiver before removing it from the tribach, common sense should be applied. Hopefully, the surveyor will quickly notice the issue as they pack up their equipment, make a note on their log sheet and later delete the last few epochs when the RINEX file is generated. In reality, this issue should not last more than a minute until noticed, so only one or two 30-second epochs may be affected, which should be automatically removed or smoothed out by AUSPOS as noise anyway, considering the hours of good data you have collected. Similarly, a receiver operating in a transport case will not observe any satellites, so the data should not be corrupted, although the end time in the file will be incorrect.

5.3 Cluster Processing

Simply put, AUSPOS data can be submitted and processed either individually (mark by mark) or collectively (in sessions, like it was observed in the field). This paper has so far focused on individual AUSPOS processing, i.e. the data collected at one mark is processed relative to the surrounding CORS with no direct relationship to any other rover that was operating at the same time. Collectively, AUSPOS is a little smarter. It first detects which rover observed the longest, and this becomes the hub for the user data. Basically, the position of the hub is determined relative to the surrounding CORS, and then all other rovers are processed relative to the hub (provided there is sufficient data overlap). Importantly, this places increased emphasis on local relatively between survey marks, which is probably what the surveyor or client generally prefers. Clustered AUSPOS solutions are easily identifiable in the AUSPOS report, as the report is (1) longer, (2) lists multiple stations and files in Section 1: User Data, (3) lists multiple user stations in Section 2: User Stations, and (4) contains results for multiple user stations rather than one.

Digging a little deeper, AUSPOS accepts submissions of up to 20 RINEX files in one job, which are then processed together as a cluster, using an observation window that contains the collected data at all sites (between earliest start time and latest end time). When submitting multiple files, it is important to ensure that the marker name (particularly its first four characters) in the RINEX header is different for each site and does not include special characters. Furthermore, individual observation sessions should overlap by at least 1 hour with respect to the hub, as this overlap is used to compute the baselines between user sites (and the direct L1/L2 ambiguity resolution strategy applied for short baselines is more reliable for data exceeding 1 hour). It should be emphasised that DCS Spatial Services only accepts industry-observed GNSS datasets of more than 2 hours duration, regardless of any overlaps with other user data.

AUSPOS cluster processing considers that the multiple data files were collected during the same time window and are therefore correlated. This means that, rather than individually connecting each user site to the surrounding CORS network, processing includes baselines between the user sites, which provides a stronger local connection. If the survey is planned accordingly, the user site with the longest dataset acts as a hub connecting to all other user sites. However, it should be noted that this can potentially result in baseline lengths that are shorter than the minimum length recommended by legislation (100 m), so sufficient planning prior to observing such a cluster is required. If the data overlap of a particular user site with respect to the hub (or another user site) is too short, AUSPOS attempts to compute a baseline to a CORS instead (a strategy based on the maximum number of single-difference observations is used to form the baselines computed in the cluster), thereby losing the desired local connection. If its data quality is insufficient, the user site may be deleted from the cluster.

In theory, and if the survey is planned appropriately, the AUSPOS cluster should therefore provide a stronger connection between the user sites compared to processing each dataset individually. The savvy reader is encouraged to think about the permutations and combinations of network design and potential advantages of clustering. For instance, if the hub had a good AHD height, could I block-shift all the other rovers' heights and get better AHD for them as well? Or, reversing the scenario, if all the rover sites had good AHD and I made the hub the mark I want to derive good AHD for, can I get a good AHD height via AUSPOS clustering and block shifts? Is this fit-for-purpose for my survey or client? Or what happens if the rover site in the first session becomes the hub for my second session and I start daisy-chaining clusters? Further research is required to investigate the effect cluster processing has on the positioning result in surveying practice and the inclusion of such clusters in the GDA2020 state adjustment via the JDA.

6 CONCLUDING REMARKS

The use of AUSPOS campaigns has developed into a capable and reliable alternative or addition to conducting traditional static GNSS baseline surveys in some situations, particularly in NSW with all CORSnet-NSW stations contributing to the AUSPOS service. AUSPOS has been shown to deliver high-quality positioning results even for shorter observation sessions of at least 2 hours across the state, provided sky view conditions are reasonable (Janssen and McElroy, 2020).

This paper has provided a practical guide for AUSPOS users and explained how AUSPOS solutions are used to help maintain and improve the NSW survey control network. It has outlined the requirements for successful industry-observed AUSPOS datasets to be submitted to DCS Spatial Services via its new Customer Hub for potential update of SCIMS and inclusion in the GDA2020 state adjustment. Finally, we have also offered some practical tips related to the all-important antenna height measurement, observation data recovery and AUSPOS cluster processing. It is hoped that this contribution has shown how easy it is to use AUSPOS and will encourage the profession to contribute to further improve the NSW survey control network for the benefit of all.

REFERENCES

Altamimi Z., Rebischung P., Métivier L. and Collilieux X. (2016) ITRF2014: A new release of the International Terrestrial Reference Frame modelling nonlinear station motions, *Journal of Geophysical Research: Solid Earth*, 121, 6109-6131.

Andersen O.B., Piccioni G., Stenseng L. and Knudsen P. (2016) The DTU15 MSS (Mean Sea Surface) and DTU15LAT (Lowest Astronomical Tide) reference surface, poster presented at ESA Living Planet Symposium 2016 (LPS16), Prague, Czech Republic, 9-13 March, https://ftp.space.dtu.dk/pub/DTU15/DOCUMENTS/MSS/DTU15MSS+LAT.pdf (accessed Mar 2022).

Brown N.J., McCubbine J.C., Featherstone W.E., Gowans N., Woods A. and Baran I. (2018) AUSGeoid2020 combined gravimetric-geometric model: Location-specific uncertainties and baseline-length-dependent error decorrelation, *Journal of Geodesy*, 92(12), 1439-1456 & 1467.

Dach R., Lutz S., Walser P. and Fridez P. (2015) Bernese GNSS software version 5.2, Astronomical Institute, University of Bern, Switzerland, http://www.bernese.unibe.ch/docs/DOCU52.pdf (accessed Mar 2022).

DCS Spatial Services (2021) Surveyor-General's Direction No 12: Control Surveys and SCIMS, https://www.spatial.nsw.gov.au/surveying/surveyor_generals_directions (accessed Mar 2022).

DCS Spatial Services (2022a) CORSnet-NSW, http://www.corsnet.com.au/ (accessed Mar 2022).

DCS Spatial Services (2022b) DCS Spatial Services Customer Hub, https://customerhub.spatial.nsw.gov.au/servicedesk/customer/portals (accessed Mar 2022).

Featherstone W.E., McCubbine J.C., Claessens S.J., Belton D. and Brown N.J. (2019) Using AUSGeoid2020 and its error grids in surveying computations, *Journal of Spatial Science*, 64(3), 363-380.

GA (2022a) AUSPOS – Online GPS processing service, https://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/auspos (accessed Mar 2022).

GA (2022b) Asia-Pacific Reference Frame (APREF), https://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/asia-pacific-reference-frame (accessed Mar 2022).

Gowans N., McElroy S. and Janssen V. (2015) Survey infrastructure preservation and upgrade: Trigonometrical stations in NSW, *Proceedings of Association of Public Authority Surveyors Conference (APAS2015)*, Coffs Harbour, Australia, 16-18 March, 67-84.

Hu G. and Dawson J. (2020) Overview of legal traceability of GPS positioning in Australia, *Satellite Navigation*, 1, 25, https://doi.org/10.1186/s43020-020-00026-8.

ICSM (2007) Standards and practices for control surveys (SP1), version 1.7, http://www.icsm.gov.au/sites/default/files/2017-05/sp1v1-7.pdf (accessed Mar 2022).

ICSM (2020) 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 Mar 2022).

ICSM (2022a) GDA2020 and GDA94 technical manuals, https://icsm.gov.au/gda2020-and-gda94-technical-manuals (accessed Mar 2022).

ICSM (2022b) Australian Vertical Working Surface, https://www.icsm.gov.au/australian-vertical-working-surface (accessed Mar 2022).

IGS (2022a) International GNSS Service products, https://www.igs.org/products (accessed Mar 2022).

IGS (2022b) IGS formats and standards, https://www.igs.org/formats-and-standards/ (accessed Mar 2022).

IGS (2022c) IGS file access for rcvr_ant.tab, antenna.gra and igs14.atx, https://files.igs.org/pub/station/general/ (accessed Mar 2022).

Janssen V., Gowans N., Hine S. and McElroy S. (2019) Removing the uncertainty surrounding Positional Uncertainty and Local Uncertainty in SCIMS, *Azimuth*, 58(8), 28-32.

Janssen V., Haasdyk J. and McElroy S. (2016) CORSnet-NSW: A success story, *Proceedings of Association of Public Authority Surveyors Conference (APAS2016)*, Leura, Australia, 4-6 April, 10-28.

Janssen V. and McElroy S. (2020) Evaluating the performance of AUSPOS solutions in NSW, *Proceedings of APAS Webinar Series 2020 (AWS2020)*, 5 May – 30 June, 3-19.

Janssen V. and McElroy S. (2021) The Australian Height Datum turns 50: Past, present & future, *Proceedings of APAS Webinar Series 2021 (AWS2021)*, 24 March – 30 June, 3-27.

Janssen V. and Watson T. (2018) Evaluating the performance of AUSGeoid2020 in NSW, *Proceedings of Association of Public Authority Surveyors Conference (APAS2018)*, Jindabyne, Australia, 9-11 April, 3-18.

Jia M., Dawson J. and Moore M. (2014) AUSPOS: Geoscience Australia's on-line GPS positioning service, *Proceedings of 27th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS+ 2014)*, Tampa, Florida, 8-12 September, 315-320.

Jia M., Dawson J. and Moore M. (2016) Upgraded AUSPOS and refined solution uncertainty, presented at IGNSS Symposium 2016 (IGNSS2016), Sydney, Australia, 6-8 December.

NGS (2022) GPS calendar, https://www.ngs.noaa.gov/CORS/Gpscal.shtml (accessed Mar 2022).

NRCan (2022) CSRS-PPP, https://webapp.geod.nrcan.gc.ca/geod/tools-outils/ppp.php (accessed Mar 2022).

Roelse A., Granger H.W. and Graham J.W. (1971) The adjustment of the Australian levelling survey 1970-1971, *Technical Report 12*, Division of National Mapping, Canberra, Australia, 81pp.

Determining Positional Uncertainty of NRTK Observations for Inclusion in the GDA2020 State Adjustment

Tom Bernstein
DCS Spatial Services
NSW Department of Customer Service
Tom.Bernstein@customerservice.nsw.gov.au

Volker Janssen
DCS Spatial Services
NSW Department of Customer Service
Volker.Janssen@customerservice.nsw.gov.au

ABSTRACT

The Geocentric Datum of Australia 2020 (GDA2020) is Australia's new national datum and based on a single, nationwide least squares network adjustment that rigorously propagates uncertainty. This paper provides a status update on the growing GDA2020 state adjustment and investigates three options to include Network Real-Time Kinematic (NRTK) observations and their Positional Uncertainty (PU) in the NSW survey control network via the GDA2020 state adjustment. First, PU is empirically estimated based on a dataset of more than 1,500 observations to obtain values that can be uniformly applied to all NRTK observations. Second, PU is calculated for each NRTK observation, based on the coordinate quality indicators provided by the Global Navigation Satellite System (GNSS) equipment. However, both options continue to treat NRTK observations as point-based position solutions, resulting in poor correlation with surrounding survey control marks. The third option overcomes this issue by exploiting the automatically computed GNSS baselines between NRTK observations and their Virtual Reference Station (VRS) to create a connected network that can be adjusted like a static GNSS network. Using a typical urban NRTK survey in Sydney as an example, it is shown that this method offers a rigorous computation of PU, while maintaining the quick and easy nature of NRTK positioning.

KEYWORDS: *GDA2020, least squares network adjustment, NRTK, Positional Uncertainty, Virtual Reference Station.*

1 INTRODUCTION

The Geocentric Datum of Australia 2020 (GDA2020) is Australia's new and much improved national datum, which was adopted in New South Wales (NSW) on 1 January 2020. This modern datum is defined in the International Terrestrial Reference Frame 2014 (ITRF2014 – see Altamimi et al., 2016) at epoch 2020.0 and based on a single, nationwide least squares network adjustment that rigorously propagates uncertainty (ICSM, 2021).

DCS Spatial Services, a business unit of the NSW Department of Customer Service (DCS), is responsible for the establishment, maintenance and improvement of the state's survey control network, which comprises more than 250,000 survey marks on public record made available to users via the Survey Control Information Management System (SCIMS). The backbone of the NSW survey control network is provided by CORSnet-NSW, Australia's largest state-owned and operated Global Navigation Satellite System (GNSS) Continuously Operating Reference Station (CORS) network. CORSnet-NSW currently consists of 202 stations, providing fundamental positioning infrastructure that is authoritative, accurate, reliable and easy-to-use for a wide range of applications (e.g. Janssen et al., 2016; DCS Spatial Services, 2022a).

At present, the GDA2020 state adjustment incorporates approximately 96,000 survey control marks across NSW, i.e. 38% of the 250,000 marks on public record. Consequently, 62% of the marks have been transformed from the now superseded GDA94 to GDA2020. Uncertainties of these transformed GDA2020 coordinates cannot be computed until the underlying measurements are sourced and readjusted with a well-defined connection to datum in the GDA2020 state adjustment. DCS Spatial Services is accelerating the process of including additional survey marks into the state adjustment to improve user access to GDA2020 coordinates and uncertainties, e.g. by using Geoscience Australia's free online Global Positioning System (GPS) processing service, AUSPOS (Janssen and McElroy, 2020, 2022; GA, 2022).

Given that Network Real-Time Kinematic (NRTK) observations are generally treated as point-based position solutions, it is necessary to investigate how to assign realistic uncertainties that can be incorporated into the GDA2020 state adjustment. When using CORSnet-NSW, single-base RTK positioning results can be expressed as a baseline to the CORS used and thus ingested. However, while NRTK has been shown to provide superior positioning quality compared to single-base RTK and is therefore preferable (e.g. Edwards et al., 2010; Wang et al., 2010; Janssen and Haasdyk, 2011), this process is not as straightforward.

Positional Uncertainty (PU) is defined as the uncertainty of the horizontal and/or vertical coordinates of a point, at the 95% confidence level, with respect to the defined datum (ICSM, 2020). It can be separated into Horizontal PU (HPU) for horizontal position and Vertical PU (VPU) for ellipsoidal height. HPU is expressed as the radius of a 95% circle of uncertainty, generally calculated from the standard error ellipse produced by a least squares network adjustment. VPU is a linear quantity and obtained by scaling the standard deviation by 1.96 to convert it to 95% confidence. A description of the practical implementation of PU in SCIMS can be found in Janssen et al. (2019).

This paper provides an update on the growing GDA2020 state adjustment and explores three options to include NRTK observations and their uncertainties in the NSW survey control network. First, the feasibility of empirically estimating the PU of NRTK observations is investigated, although it is acknowledged that it is ultimately desired to compute uncertainties rather than estimate them. Second, the reliability of using coordinate quality indicators provided by the GNSS equipment to calculate PU on an occupation-by-occupation basis is explored to obtain PU values more tailored to each individual occupation. However, these two options continue to treat NRTK observations as point-based position solutions, which results in a lack of correlation with the surrounding network. The third option overcomes this issue by utilising the automatically computed GNSS baselines between NRTK observations and their Virtual Reference Station (VRS – see Landau et al., 2002) to create a connected network, which can be adjusted like a static GNSS network. It is shown that this offers a rigorous computation of PU, while maintaining the quick and easy nature of NRTK positioning.

2 GDA2020 STATE ADJUSTMENT

Currently, the GDA2020 state adjustment consists of approximately 837,000 measurements between 111,000 stations, translating into about 96,000 SCIMS marks and making it the largest Jurisdictional Data Archive (JDA) in Australia. It was computed with DynAdjust (version 1.2.2) using a phased-adjustment least squares methodology that provides rigorous uncertainty across the entire network (Fraser et al., 2021). The GDA2020 state adjustment includes about 111,100 GNSS baselines, 17,800 baselines originating from AUSPOS sessions, and more than 183,000 directions and distances each (Table 1).

Table 1: Most common measurement types and quantities in the GDA2020 state adjustment.

Measurement Type	**Quantity**
GNSS baselines	111,100
AUSPOS baselines	17,800
Directions	183,700
Distances	183,500
Height constraints (for 2D stations)	73,300
Height differences	7,100

In order to achieve this, DCS Spatial Services has developed and implemented several innovative, highly automated tools and workflows to prepare, process and ingest existing and new GNSS baseline data, AUSPOS datasets and street-corner traversing data. Over several years, efforts have been undertaken to source, harvest, clean and utilise legacy geodetic measurements (Haasdyk and Watson, 2013), build state-of-the-art GNSS CORS network infrastructure (Janssen et al., 2016), observe new high-quality GNSS measurements to connect the existing survey network to CORS (Gowans and Grinter, 2013), and systematically rationalise, maintain, upgrade and collect AUSPOS datasets at key sites across the NSW survey control network, including trigonometrical (trig) stations and Australian Height Datum (AHD) spirit-levelled marks (Gowans et al., 2015; Janssen and McElroy, 2021).

Key components of these datum modernisation efforts have been the preservation and upgrade of survey infrastructure, including physical maintenance of permanent survey marks (including TS, PM and SS), and the update of metadata such as survey mark information in SCIMS and survey mark photographs. This will allow future users to achieve DCS Spatial Services' vision of a PU of 20 mm in the horizontal and 50 mm in the vertical (ellipsoidal height) component anywhere in the state and to easily apply transformation tools to move between current, future and various historical datums and local working surfaces.

In this context, it should also be noted that a single, state-wide levelling adjustment for NSW is currently being generated, based on data-mining existing levelling files in the DCS Spatial Services archive and the recently digitised historical levelling data that was used to define the AHD across the state. Currently, the NSW levelling adjustment comprises about 132,000 measurements and 98,000 stations. While still underway, the enormity of this task and its benefits to the profession should not be underestimated. Victoria has already completed a state-wide levelling adjustment, and other jurisdictions are now also starting similar projects.

The profession is encouraged to contribute to the maintenance of the NSW survey control network and the timely update of survey information in SCIMS by submitting suitable AUSPOS datasets of at least 2 hours duration and related metadata via the DCS Spatial Services Customer Hub on our website (DCS Spatial Services, 2022b). The DCS Spatial Services Customer Hub is a new, user-friendly platform providing a central contact point to interact with

DCS Spatial Services and now the primary way for customers to make an enquiry, submit a data request and provide feedback. Similarly, Survey Operations can (soon) be contacted through the Customer Hub to submit AUSPOS datasets, Locality Sketch Plans (LSPs), Preservation of Survey Infrastructure (POSI) applications, trig station approvals, exemption applications and regulation approvals. Access to the Customer Hub is free and simple, after creating a one-time username and password. Through a ticketed system, users can track the status of their requests at any point in time, which enables DCS Spatial Services to manage these more efficiently and effectively. A practical guide to AUSPOS, including the requirements for successful AUSPOS datasets to be submitted to DCS Spatial Services, can be found in Janssen and McElroy (2022).

3 EMPIRICALLY ESTIMATING THE PU OF NRTK OBSERVATIONS

The first option to incorporate NRTK uncertainties into the GDA2020 state adjustment was to determine an empirical estimate of PU that can be applied universally to all NRTK observations. We examined a large and robust historical NRTK dataset collated from several projects conducted by DCS Spatial Services. Data was collected under a range of observing conditions typically encountered in surveying practice (with various NRTK cell sizes, different instruments and including centring errors), providing a suitable indication of real-world NRTK performance. Best practice guidelines were followed, including minimum observation times of 2 minutes (windowing technique) and double (or more) occupations at least 30 minutes apart (ICSM, 2020; DCS Spatial Services, 2021).

In order to obtain a realistic and representative estimate of NRTK PU in practice, the collated data was prepared based on the following criteria to remove large outliers:

- Only marks with two or more occupations were used for comparison.
- Only observations with successful ambiguity resolution were retained, here defined by a coordinate quality (CQ) value of below 0.050 m.
- Marks showing a horizontal coordinate difference larger than 0.060 m between two occupations were removed. This value was chosen based on the standard deviation routinely applied by DCS Spatial Services for horizontal NRTK uncertainty using CORSnet-NSW in practice (0.014 m), by rounding up to 0.015 m and multiplying by 4.
- Marks showing a vertical coordinate difference larger than 0.120 m between two occupations were removed. This value was chosen based on the standard deviation routinely applied by DCS Spatial Services for vertical (ellipsoidal height) NRTK uncertainty using CORSnet-NSW in practice (0.030 m) and multiplying by 4.

After preparation, the dataset consisted of 1,535 observations on 756 marks across eastern NSW (Figure 1). The differences in horizontal coordinates and ellipsoidal height between double (or more) occupations on each mark were determined and analysed. It is recognised that this provides a measure of NRTK precision (repeatability) rather than accuracy with respect to datum. However, the Root Mean Square (RMS), at the 95% confidence level, of these coordinate differences is similar to a measure of PU and deemed a suitable approximation for everyday users.

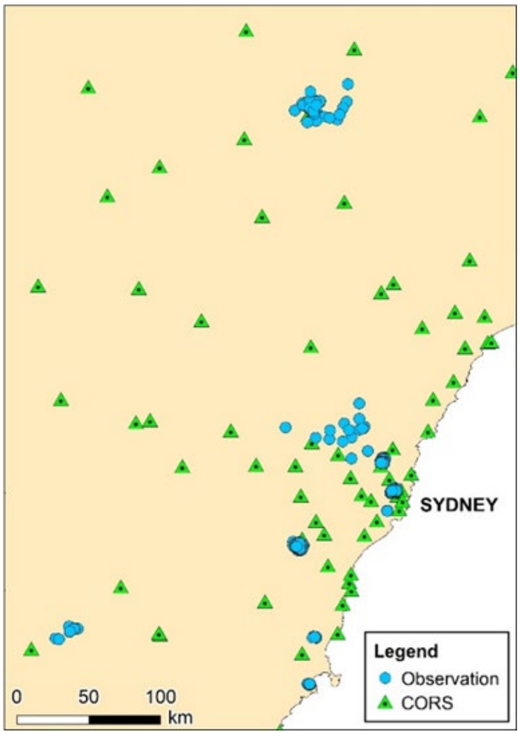


Figure 1: Location of CORSnet-NSW sites and NRTK data collected across eastern NSW.

The differences between multiple NRTK occupations on the same mark in horizontal position and ellipsoidal height were examined to determine an empirical, real-world estimate of PU. Histograms of these differences (799 in total) are shown in Figure 2, while descriptive statistics (minimum, maximum, mean, median, standard deviation and RMS) are summarised in Table 2.

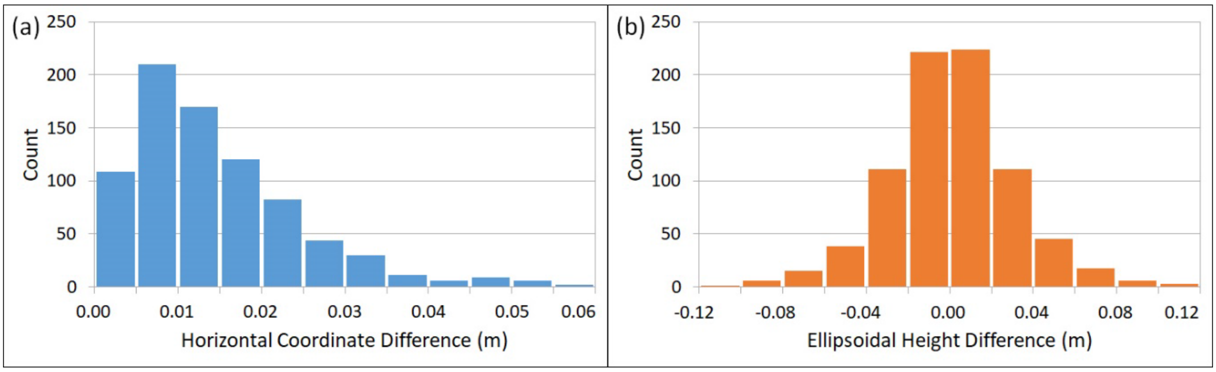


Figure 2: (a) Horizontal coordinate differences and (b) ellipsoidal height differences between multiple NRTK occupations.

Table 2: Descriptive statistics for 799 horizontal distances and ellipsoidal height differences between multiple NRTK occupations (all values in metres).

Descriptive Statistic	Horizontal	Vertical
Minimum	0.000	-0.106
Maximum	0.060	0.108
Mean	0.015	0.001
Median	0.013	0.001
Standard Deviation	0.010	0.030
RMS at 95% CL	0.036	0.059

It is recognised that the PU values in the GDA2020 state adjustment are not normally distributed, but instead present as a skewed, right-tailed distribution (Janssen et al., 2019). For such a skewed distribution, the median provides a more robust measure of central tendency than the mean and is less susceptible to outliers. In this paper, both the mean and median values are shown to illustrate their agreement and that a normal distribution is suitable for the analysis presented here.

The horizontal data shows a normal distribution with a slight positive, right-tailed skew, producing an RMS value of 0.036 m at the 95% confidence level (CL). Using a normal approximation, one can estimate that 95% of NRTK observations have horizontal coordinate differences below two standard deviations from the mean, i.e. below 0.035 m in this case. Given the slight skewness of the distribution, the 95th percentile was also calculated as a method of verification, returning 0.034 m and therefore showing good agreement. The vertical data provides an RMS of 0.059 m (95% CL). Using a normal approximation, it is estimated that 95% of ellipsoidal height differences are within 0.061 m, and the 95th percentile (based on absolute height differences) returns 0.063 m to support this value.

The results of this analysis were verified by comparison to a previous, extensive study quantifying the performance of NRTK across NSW at various distances from the surrounding CORS (Janssen and Haasdyk, 2011). In this previous study, the achievable precision was investigated over three consecutive days using multiple GNSS receivers at four different locations, while the achievable accuracy was determined by comparison to the NSW survey control network in seven test areas exhibiting a range of NRTK scenarios and cell sizes.

Table 3 summarises the precisions achieved for 2-minute NRTK solutions over a range of distances from the surrounding CORS, expressed as RMS and converted to 95% CL to aid comparison. In addition, Janssen and Haasdyk (2011) quantified the achievable NRTK accuracy in GDA94 (based on 1-minute observation windows) as about 0.040 m (or better) in the horizontal and 0.060 m in the vertical component, again expressed as RMS at 95% CL, provided that recommended inter-CORS distances are used.

Table 3: Precisions for NRTK solutions (2-minute observation windows) for a range of NRTK cell sizes (Janssen and Haasdyk, 2011).

Distance to Nearest CORS (km)	**6**	**15**	**50**
Horizontal RMS at 95% CL (m)	0.012	0.024	0.041
Vertical RMS at 95% CL (m)	0.020	0.037	0.110

Considering the densification of CORSnet-NSW since 2011 (Janssen et al., 2016), most of the data in the present study was collected in smaller NRTK cells, with the largest distance to the nearest CORS being 37 km. The empirically estimated values of 0.036 m (HPU) and 0.059 m (VPU) are therefore deemed comparable to the values stated in Janssen and Haasdyk (2011). It should be noted that the previous study was performed under more controlled conditions, so the effects of challenging observing conditions and centring errors had less impact than on the data presented here.

In summary, this approach utilises historical data to assess real-world NRTK performance, providing empirically derived estimates of 0.036 m for HPU and 0.059 m for VPU. This simplistic method can be easily applied to all NRTK observations, including historical NRTK data. However, major limitations are that it provides estimated (rather than rigorously calculated) uncertainties and continues to treat NRTK observations as point-based position solutions, thus exhibiting poor correlation with surrounding marks. It is also acknowledged that these values may not always be realistic, particularly under challenging observing conditions.

4 COMPUTING PU BASED ON NRTK COORDINATE QUALITY OUTPUT

The second option to introduce NRTK uncertainties into the GDA2020 state adjustment attempted to reflect the individual qualities of each NRTK observation in the computation of PU on an occupation-by-occupation basis, thereby introducing more rigor into its determination. We explored the feasibility of using coordinate quality (CQ) indicators provided by the GNSS equipment. CQ is usually calculated at the rover as the RMS of coordinate errors (generally based on ambiguity-fixed, double-differenced observations) and indicates how much the computed position is likely to deviate from the 'true' value. Research has shown that CQ values are prone to be overly optimistic, especially under difficult observing conditions (e.g. Edwards et al., 2010; Wang et al., 2010; Janssen and Haasdyk, 2011), hence this approach needs to be treated with caution. We assessed the reliability of CQ values, along with the possibility of quantifying the disparity between quoted CQ values and the actual quality observed through a scale factor to account for exaggerated CQ reporting.

The method used to compute PU for NRTK observations was adapted from the Queensland Government's cadastral survey requirements (QLD Government, 2021) and is based on the error propagation law. Instead of applying manufacturer specifications to estimate measurement uncertainty, the CQ output (i.e. standard deviation in Easting, Northing and ellipsoidal height) was used – see Bernstein and Janssen (2021) for details. It should be noted that this computation requires input of the PU of the reference station used, which is generally a VRS for NRTK with CORSnet-NSW, with the PU of a VRS not yet suitably quantified. Findings were then compared to the NRTK data presented in section 3 to determine how well the computed values match real-world results.

It was found that all 756 marks investigated had calculated HPU values within the empirical estimate of 0.036 m obtained from the same dataset, with a median HPU of 0.023 m and a 95th percentile of 0.027 m. In the vertical, all values were significantly less than the estimated VPU of 0.059 m, with a median of 0.043 m and a 95th percentile of 0.049 m. In other words, 585 marks (i.e. 77%) had a calculated HPU of 0.024 m or better, while 576 marks (i.e. 76%) had a calculated VPU of 0.045 m or better. The clearly optimistic nature of NRTK PU calculated by this method can be attributed mainly to using unrealistic CQ values. While the need to estimate the PU of the VRS is also acknowledged as a possible cause, the estimates chosen (HPU of 0.020 m and VPU of 0.040 m) are rather conservative based on DCS Spatial Services' experience of using NRTK in practice.

Several studies (e.g. Edwards et al., 2010; Wang et al., 2010; Janssen and Haasdyk, 2011) have shown CQ values to be rather unrealistic in practice, being overly optimistic by a factor of up to 5-7. This is in part due to the CQ calculation not considering external errors such as multipath or centring errors. It would be beneficial for the user to have the option of specifying values for some of these errors in the GNSS rover software, which could result in more realistic CQ values.

We therefore examined the feasibility of modelling the difference between the quoted CQ value and the measured precision. This can potentially provide a scale factor to be applied to the calculation, thereby aligning the computed PU with the observed precision of real-world NRTK observations. To assess the reliability of the reported CQ values, the ratio of the horizontal distance (or the absolute ellipsoidal height difference) between reoccupations on each mark to the horizontal (or vertical) CQ output was computed for each occupation.

As expected, most reported CQ values appeared to be overly optimistic as evident by a coordinate quality ratio larger than 1. In the horizontal component, 84% of the 1,535 occupations delivered overly optimistic CQ values, with a median ratio of about 2.1. In the vertical, 65% of CQ values were overly optimistic, with a median ratio of about 1.6. The mean values were larger than the median, indicating that the dataset is affected by several outliers. A substantial number of observations produced CQ values that were optimistic by more than a factor of 4 (and up to a factor of 9) in both components. This is particularly of concern when attempting to determine a reasonable and reliable scale factor to calculate PU for NRTK observations with a sufficient level of rigor.

Interestingly, and unexpectedly, the vertical CQ values appeared to be more realistic than the horizontal CQ values for the data investigated. Being conservative, a scale factor of 2.1 was applied to both the horizontal and vertical CQ values in the calculations, respectively, to obtain more realistic PU values. This produced the results shown in Figure 3, with descriptive statistics summarised in Table 4.

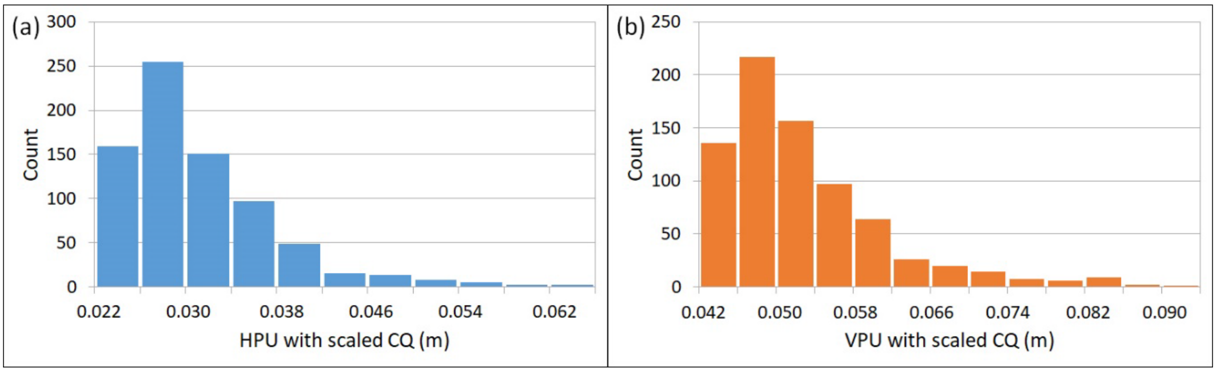


Figure 3: Calculated (a) HPU and (b) VPU for NRTK observations based on CQ output scaled by a factor of 2.1.

Table 4: Descriptive statistics for HPU and VPU, calculated based on CQ output scaled by a factor of 2.1 for 756 marks (all values in metres).

Descriptive Statistic	HPU	VPU
Minimum	0.022	0.042
Maximum	0.066	0.093
Mean	0.032	0.053
Median	0.030	0.051
Standard Deviation	0.006	0.008
RMS	0.032	0.054

The median values of 0.030 m (HPU) and 0.051 m (VPU) are now more closely aligned with the observed quality computed in section 3 (0.036 m and 0.059 m, respectively), indicating that using scaled CQ values in the calculation of PU may be a feasible option for introducing NRTK uncertainties into the GDA2020 state adjustment. However, the scale factor may not be appropriate for all types of GNSS rover equipment due to differences in how CQ is calculated by various equipment manufacturers. Further research would be required to determine appropriate values for different receiver brands and models. Furthermore, the potential need to apply separate scale factors for the horizontal and vertical components should be investigated.

In summary, this approach utilises reported CQ values in the calculation of PU, providing calculated PU values rather than universal estimates. While a scale factor can be applied to account for the overly optimistic CQ output to obtain more realistic PU values, this does add statistical guesswork to a process that was intended to be a more rigorous alternative to the first option considered. The varying proprietary methods of CQ computation between makes and models of GNSS receivers add further complexity to the derivation of a reliable scale factor. This method also continues to treat NRTK observations as point-based solutions with uncertainties, thus exhibiting poor correlation with surrounding marks in the GDA2020 state adjustment, and historical data would have to be reprocessed. Consequently, it does not provide a significant advantage over the use of empirically derived values, while adding a degree of complexity.

5 NETWORK ADJUSTMENT USING AUTOMATIC BASELINES

NRTK observations are generally treated as point-based solutions with VRS data being discarded after computation, which causes issues when attempting to incorporate NRTK observations and uncertainties into a least squares network adjustment. Therefore, the third option investigated a network solution using the automatically computed baselines from the VRS to each observed station. Depending on field work practices, multiple observations share a common VRS and are therefore linked by GNSS baselines. A VRS generally remains active until the GNSS rover is turned off or moves more than 5 km away (Landau et al., 2002), i.e. a typical NRTK survey usually exhibits a high degree of connectivity. These connections potentially allow PU values to be rigorously computed via least squares analysis, facilitating simple integration of NRTK data into the GDA2020 state adjustment.

While the VRS coordinates are computed from surrounding CORS data (with the CORS forming the backbone of the datum), it can be argued that the VRS itself is technically not connected to the datum. However, the VRS can be treated as a pseudo-datum station, with the connection to datum completed by deriving a baseline from each VRS to the nearest (or multiple) CORS. Following the philosophy applied by the Intergovernmental Committee on Surveying and Mapping (ICSM) for including National GNSS Campaign Archive (NGCA) data in the national GDA2020 adjustment, a connection to the two nearest CORS is used here. It is important to note that these derived baselines are not observations, but simply joins used to connect the VRS (and thus the survey) to the datum and to transfer the uncertainty of the datum connection through to the survey network in the adjustment.

As such, this approach employs the automatically computed GNSS baselines between NRTK observations and their VRS together with a derived join between each VRS and the two nearest CORS to create a connected network, which can be adjusted like a traditional, static GNSS network (Figure 4).

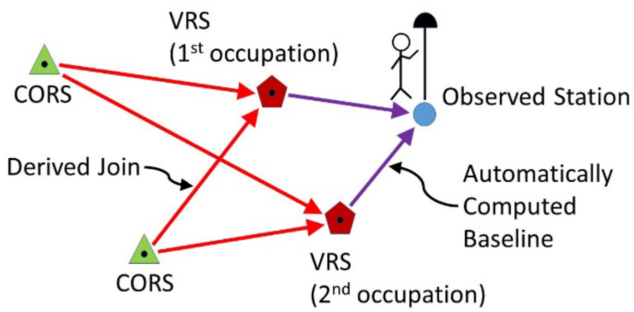


Figure 4: NRTK automatic baseline network being connected to datum via a join between each VRS and the two nearest CORS.

A typical urban NRTK survey incorporating 126 observations on 62 marks in Sydney, conducted by DCS Spatial Services over nine days in 2018, was investigated to illustrate this approach. Best practice guidelines were followed, with each mark occupied at least twice, at least 30 minutes apart, and for a minimum of 2 minutes (ICSM, 2020; DCS Spatial Services, 2021). The use of multiple occupations on each mark adds redundancy, strengthens network geometry and helps minimise outliers. The resulting network exhibited a high degree of connectivity through the baselines automatically generated between VRS and observed mark. While the user has limited control over the network geometry created in this way, the network can be processed akin to a static GNSS survey.

In order to perform a least squares adjustment and allow this survey to influence and be influenced by the datum, it must be connected to it. In this case, six control marks that are part of the GDA2020 state adjustment were observed to provide this datum connection, leaving 56 marks to be adjusted. However, considering that a new VRS is generated when the instrument is turned off or moved more than 5 km from its original VRS location, some marks can potentially become isolated (or disconnected) from the network and datum. To ensure connection of all marks to the network, the VRS were treated as pseudo-datum stations joined to the nearest two CORSnet-NSW sites, which were then also constrained in the adjustment (Figure 5). In order to analyse the statistical results produced by this approach, and to obtain preliminary values of PU, this survey network was adjusted separately to the GDA2020 state adjustment. These PU values will be updated when this network is incorporated into the GDA2020 state adjustment.

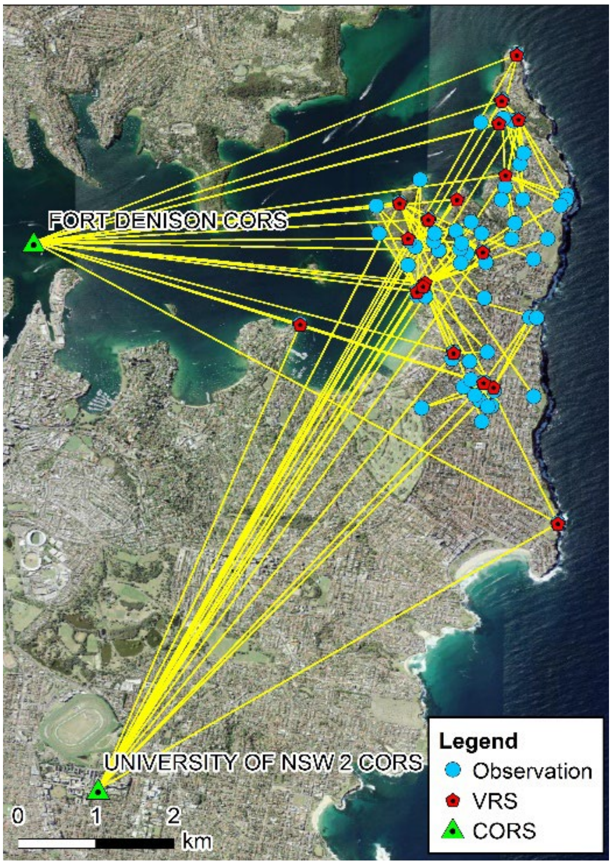


Figure 5: NRTK baseline network including the joins from each VRS to the two nearest CORS.

The determination of NRTK uncertainty based on modelling the contributing errors is an ongoing area of research (e.g. Baybura et al., 2019; Ouassou and Jensen, 2019; Jongrujinan and

Satirapod, 2020). In this case, baseline weightings were chosen to mimic the standard deviation values (1σ) routinely applied by DCS Spatial Services for NRTK uncertainty in practice: 0.014 m (horizontal) and 0.030 m (vertical). These values include allowance for to/from centring errors and have proven realistic in most practical observing conditions using CORSnet-NSW. While it is known that NRTK observations exhibit a small degree of distance dependency, recent studies have found no significant differences in NRTK solutions with baseline lengths of up to 40-50 km to the nearest CORS (Gökdas and Özlüdemir, 2020). Consequently, residual NRTK distance dependency can be ignored in this case.

Since each observation is connected to the datum by two baselines (i.e. CORS to VRS and VRS to occupied mark) and to avoid inflation of the uncertainties through this join in the adjustment, these initial values were divided by √2 according to the error propagation law. This resulted in final weightings of 0.010 m (horizontal) and 0.021 m (vertical) for each baseline, with no distance dependency applied.

As previously mentioned, the two CORS served as constraints in the fully constrained adjustment, along with the six GDA2020 control marks that braced the network. The median HPU of these eight constraints was 0.018 m, and the median VPU was 0.026 m. The adjustment achieved a variance factor of 0.9, which is expected for a network of this nature. In this case, as a business rule, DCS Spatial Services does not tighten the input standard deviations to achieve a variance factor of unity. Histograms of the resulting PU values are shown in Figure 6, while corresponding descriptive statistics are summarised in Table 5.

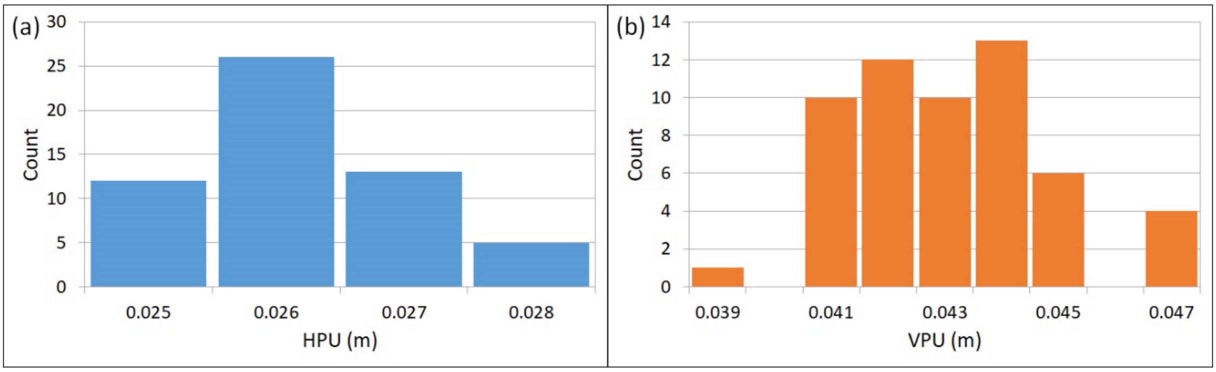


Figure 6: Calculated (a) HPU and (b) VPU for NRTK observations based on the NRTK baseline network.

Table 5: Descriptive statistics for HPU and VPU, calculated based on the NRTK baseline network for 56 adjusted marks (all values in metres).

Descriptive Statistic	HPU	VPU
Minimum	0.025	0.039
Maximum	0.028	0.047
Mean	0.026	0.043
Median	0.026	0.043
Standard Deviation	0.001	0.002

The adjustment provided individual uncertainties for each NRTK observation, with median values of 0.026 m (HPU) and 0.043 m (VPU), i.e. about 0.010 m and 0.015 m better than the empirical estimates obtained in section 3. This can be explained by improved geometry and redundancy due to the network adjustment. These preliminary results demonstrate the appropriateness of the observational weighting strategy used and that this method can provide reliable results.

Of the three options explored to incorporate NRTK observations and their uncertainties into the GDA2020 state adjustment, this provides not only the most rigorous method of computing PU, but the baseline data format also allows easy integration into the least squares network adjustment. Furthermore, these benefits come at no expense to field work time or complexity, and the processing load is only marginally increased compared to the traditional NRTK processing methodology followed by DCS Spatial Services, once CORS-to-VRS baseline derivation is automated. NRTK was intended to be a rapid and precise form of positioning, and this method manages to maintain this spirit whilst providing more in-depth statistical analysis and quality reporting. However, one weakness of this method is the difficulty of applying it to historical data, with each NRTK survey needing to be adjusted individually.

6 CONCLUDING REMARKS

Australia's new national datum, GDA2020, is based on a single, nationwide least squares network adjustment that rigorously propagates uncertainty. On behalf of the Surveyor-General, DCS Spatial Services has a legislative, regulative responsibility to establish, maintain and improve the NSW survey control network. As the GDA2020 state adjustment continues to grow, efforts are underway at DCS Spatial Services to further increase user access to Positional Uncertainty for survey marks on public record via SCIMS. This paper has provided a status update on the GDA2020 state adjustment and investigated three options to include NRTK observations and their PU in the NSW survey control network.

First, the PU of NRTK observations was empirically estimated to be 0.036 m (HPU) and 0.059 m (VPU), based on a robust historical NRTK dataset of 1,535 observations on 756 marks collected under typical conditions encountered in surveying practice. Second, the PU was calculated individually for each NRTK observation, based on the coordinate quality indicators provided by the GNSS rover, resulting in overly optimistic values. A scale factor of 2.1 was applied to obtain more realistic CQ values, delivering uncertainties of 0.030 m (HPU) and 0.051 m (VPU). However, this added complexity and statistical guesswork to a process that was intended to be more rigorous than the empirically derived PU estimate. Both options continue to treat NRTK observations as point-based position solutions, resulting in poor correlation with surrounding survey control marks.

The third option overcomes this issue by handling NRTK data in an entirely different manner. It employs the automatically computed GNSS baselines between NRTK observations and their VRS and derives a join between each VRS and the two nearest CORS to create a connected network, which can be adjusted like a static GNSS network. Using a typical urban NRTK survey incorporating 126 observations on 62 marks in Sydney as an example, PU was calculated to be about 0.026 m (HPU) and 0.043 m (VPU), comparing reasonably well to empirical positioning quality and user experience.

It was demonstrated that this method offers a rigorous computation of PU, while maintaining the quick and easy nature of NRTK positioning. These benefits come at no expense to field work time or complexity, requiring only a slightly more involved processing strategy (network adjustment rather than site transformation) and a tool to generate the derived baselines between CORS and VRS necessary for the join. The need for each historical NRTK survey to be adjusted separately is a reasonable price to pay for this rigorous and comprehensive solution. Current work investigates tweaking the observational weighting strategy to optimise the inclusion of NRTK observations with realistic uncertainties in the GDA2020 state adjustment. Adoption of this methodology will allow NRTK data to be rigorously included in the GDA2020 state adjustment, thus enabling DCS Spatial Services to further maintain and improve the NSW survey control network.

REFERENCES

Altamimi Z., Rebischung P., Métivier L. and Collilieux X. (2016) ITRF2014: A new release of the International Terrestrial Reference Frame modelling nonlinear station motions, *Journal of Geophysical Research: Solid Earth*, 121(8), 6109-6131.

Baybura T., Tiryakioglu I., Ugur M.A., Solak H.I. and Safak S. (2019) Examining the accuracy of Network RTK and long base RTK methods with repetitive measurements, *Journal of Sensors*, 2019, 3572605, https://doi.org/10.1155/2019/3572605.

Bernstein T. and Janssen V. (2021) Positional Uncertainty of Network RTK observations in a modern datum, *Journal of Geodetic Science*, 11(1), 38-47.

DCS Spatial Services (2021) Surveyor-General's Direction No. 12: Control Surveys and SCIMS, https://www.spatial.nsw.gov.au/surveying/surveyor_generals_directions (accessed Mar 2022).

DCS Spatial Services (2022a) CORSnet-NSW, http://www.corsnet.com.au/ (accessed Mar 2022).

DCS Spatial Services (2022b) DCS Spatial Services Customer Hub, https://customerhub.spatial.nsw.gov.au/servicedesk/customer/portals (accessed Mar 2022).

Edwards S.J., Clarke P.J., Penna N.T. and Goebell S. (2010) An examination of Network RTK GPS services in Great Britain, *Survey Review*, 42(316), 107-121.

Fraser R., Leahy F. and Collier P. (2021) DynAdjust user's guide, version 1.1, https://github.com/icsm-au/DynAdjust/tree/master/resources (accessed Mar 2022).

GA (2022) AUSPOS – Online GPS processing service, http://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/auspos (accessed Mar 2022).

Gökdas Ö. and Özlüdemir M.T. (2020) A variance model in NRTK-based geodetic positioning as a function of baseline length, *Geosciences*, 10(7), 262, https://doi.org/10.3390/geosciences10070262.

Gowans N. and Grinter T. (2013) Tying it all together: CORSnet-NSW local tie surveys, *Proceedings of Association of Public Authority Surveyors Conference (APAS2013)*, Canberra, Australia, 12-14 March, 104-119.

Gowans N., McElroy S. and Janssen V. (2015) Survey infrastructure preservation and upgrade: Trigonometrical stations in NSW, *Proceedings of Association of Public Authority Surveyors Conference (APAS2015)*, Coffs Harbour, Australia, 16-18 March, 67-84.

Haasdyk J. and Watson T. (2013) Data-mining in NSW: Towards a new and improved Australian datum, *Proceedings of Association of Public Authority Surveyors Conference (APAS2012)*, Canberra, Australia, 12-14 March, 85-102.

ICSM (2020) 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 Mar 2022).

ICSM (2021) Geocentric Datum of Australia 2020 technical manual, version 1.7, https://www.icsm.gov.au/gda2020-and-gda94-technical-manuals (accessed Mar 2022).

Janssen V., Gowans N., Hine S. and McElroy S. (2019) Removing the uncertainty surrounding Positional Uncertainty and Local Uncertainty in SCIMS, *Azimuth*, 58(8), 28-32.

Janssen V. and Haasdyk J. (2011) Assessment of Network RTK performance using CORSnet-NSW, *Proceedings of IGNSS Symposium 2011 (IGNSS2011)*, Sydney, Australia, 15-17 November, 18pp.

Janssen V., Haasdyk J. and McElroy S. (2016) CORSnet-NSW: A success story, *Proceedings of Association of Public Authority Surveyors Conference (APAS2016)*, Leura, Australia, 4-6 April, 10-28.

Janssen V. and McElroy S. (2020) Assessment of AUSPOS performance in New South Wales, Australia, *Proceedings of IGNSS Symposium 2020 (IGNSS2020)*, Sydney, Australia, 5-7 February, 17pp.

Janssen V. and McElroy S. (2021) The Australian Height Datum turns 50: Past, present & future, *Proceedings of APAS Webinar Series 2021 (AWS2021)*, 24 March – 30 June, 3-27.

Janssen V. and McElroy S. (2022) A practical guide to AUSPOS, *Proceedings of Association of Public Authority Surveyors Conference (APAS2022)*, Leura, Australia, 21-23 March, 3-28.

Jongrujinan T. and Satirapod C. (2020) Stochastic modeling for VRS network-based GNSS RTK with residual interpolation uncertainty, *Journal of Applied Geodesy*, 14(3), 317-325.

Landau H., Vollath U. and Chen X. (2002) Virtual reference station systems, *Journal of Global Positioning Systems*, 1(2), 137-143.

Ouassou M. and Jensen A.B.O. (2019) Network real-time kinematic data screening by means of multivariate statistical analysis, *SN Applied Sciences*, 1(6), 512, https://doi.org/10.1007/s42452-019-0531-3.

QLD Government (2021) Cadastral survey requirements, version 8.0, Queensland Department of Natural Resources, Mines and Energy, Australia, https://www.business.qld.gov.au/industries/building-property-development/titles-property-surveying/surveying/standards-forms (accessed Mar 2022).

Wang C., Feng Y., Higgins M. and Cowie B. (2010) Assessment of commercial Network RTK user positioning performance over long inter-station distances, *Journal of Global Positioning Systems*, 9(2), 78-89.

Updating SCIMS with DEM-Sourced AHD Heights Across NSW

Jonathon Smith
DCS Spatial Services
NSW Department of Customer Service
Jonathon.Smith@customerservice.nsw.gov.au

Volker Janssen
DCS Spatial Services
NSW Department of Customer Service
Volker.Janssen@customerservice.nsw.gov.au

ABSTRACT

The Survey Control Information Management System (SCIMS) is the state's database containing more than 250,000 survey marks on public record across NSW. It was recently updated with Australian Height Datum (AHD) heights (at Class U) sourced from a state-wide Digital Elevation Model (DEM) for 127,154 survey marks with existing Class U or null AHD height values. This allowed 18,854 survey marks to be assigned an AHD height for the first time, while 100 gross AHD height errors in SCIMS were identified and corrected. The updated AHD heights are displayed in SCIMS to the nearest metre and provide important benefits for industry, such as enabling the calculation and reporting through SCIMS of the Combined Scale Factor (CSF), the derivation of GDA2020 ellipsoidal height values at virtually all survey marks in NSW and supporting the readjustment of legacy terrestrial data in the growing GDA2020 state adjustment to further improve user access to survey information. DCS Spatial Services provides a DEM for all of NSW with a vertical uncertainty of ±0.9 m at the 95% confidence level and a horizontal grid density of 5 m. While it has been available through Geoscience Australia's Elevation Information System (ELVIS) as 2 km x 2 km data tiles for some time, the DEM can now be queried directly through a publicly accessible Application Programming Interface (API) to return an AHD height at a specified location. This paper outlines how this new interface has been used to query the coordinates of all marks in SCIMS to retrieve AHD heights from the elevation model, assess the accuracy of these AHD heights by comparison to SCIMS, and update SCIMS with DEM-sourced heights for survey marks with existing Class U or null AHD height values to yield a homogeneous dataset of known provenance and verifiable quality across NSW.

KEYWORDS: *Australian Height Datum (AHD), Digital Elevation Model (DEM), Survey Control Information Management System (SCIMS), datum modernisation.*

1 INTRODUCTION

As surveyors, we know that height and elevation data is crucial for a vast number of applications and that the survey control we provide underpins this data. At a national level, the Elevation and Depth 2030 strategy aims to achieve consistent nationwide digital elevation and depth models that people can interrogate with other information to make informed decisions for the betterment of our community, e.g. to better understand the dynamics of our environment, make sense of uncertainty, and provide a basis for community safety, economic growth and sustainable living (ICSM, 2018).

DCS Spatial Services, a business unit of the NSW Department of Customer Service (DCS), provides various imagery and elevation products as part of its ongoing custodial responsibilities regarding the NSW Foundation Spatial Data Framework (DCS Spatial Services, 2018). Accurate and reliable orthorectified aerial imagery and high-resolution elevation data is critical to effective planning, decision making, change monitoring and risk mitigation across NSW and is utilised by government, industry and the community. Reliable and quality-assured survey control is fundamental to ensuring the integrity of this data, which contributes significantly to economic, social and environmental sustainability in NSW. In this context, it is helpful to clarify the terminology used in this paper: A Digital Elevation Model (DEM) represents the bare-earth surface void of all natural and built features, while a Digital Surface Model (DSM) captures both the natural and built/artificial features of the environment (i.e. including the top of vegetation and buildings).

Survey accurate control and quality assurance underpins each of these imagery and elevation products. As such, the Imagery and Elevation program and project work conducted by the Survey Operations team at DCS Spatial Services supports the following (Powell, 2017):

- Digital Image Acquisition System (DIAS) program, which captures high-resolution 50 cm Ground Sample Distance (GSD) aerial imagery state-wide.
- Digital Town Imagery Capture (DTIC) program, which captures high-resolution 10 cm GSD aerial imagery over cities, towns and villages throughout NSW.
- Light Detection and Ranging (LiDAR) program, which captures highly accurate elevation data in high-risk areas across NSW.
- Surface Model Enhancement (SME) project (2014-19), which utilised a variety of technology including aerial imagery and LiDAR to create a high-resolution, state-wide DSM.

One of the products provided by DCS Spatial Services is a state-wide DEM with a vertical uncertainty of ±0.9 m at the 95% confidence level (CL) and a horizontal grid density of 5 m. It was produced by a combination of category 1 LiDAR, category 3 LiDAR, 10 cm ground resolution imagery and 50 cm ground resolution imagery. While it has been available through Geoscience Australia's Elevation Information System (ELVIS – see GA, 2022a) as 2 km x 2 km data tiles for some time, the DEM can now be queried directly through a new publicly accessible Application Programming Interface (API) to return an Australian Height Datum (AHD – see Roelse et al., 1971; Janssen and McElroy, 2021) height at a specified location (DCS Spatial Services, 2022). An API is essentially a connection between computers or between computer programs, i.e. a software interface offering a service to other pieces of software, which is extremely useful when dealing with large amounts of data and/or machine-to-machine processes.

This paper outlines how this new API has been used to query the coordinates of all marks in the Survey Control Information Management System (SCIMS), the state's database containing more than 250,000 survey marks on public record, to retrieve AHD heights from the elevation model, assess the accuracy of these AHD heights by comparison to SCIMS, and update SCIMS with DEM-sourced heights for survey marks with existing Class U or null AHD height values to yield a homogeneous dataset of known provenance and verifiable quality across NSW.

2 AHD HEIGHT RETRIEVAL FROM THE DEM VIA API

In May 2021, AHD heights from the state-wide DEM were extracted via an in-house developed Python script using a publicly available API called 'public/NSW_5M_Elevation', hosted by DCS Spatial Services on the NSW Spatial Information Exchange (SIX) platform (DCS Spatial Services, 2022). In order to obtain a sufficiently large dataset for evaluation of the accuracy of the returned data, *every* survey mark in SCIMS (including witness marks, destroyed marks and interstate marks along the borders) was submitted to the API for a height retrieval. This included 301,200 survey marks at the time, using the marks' horizontal position in the Geocentric Datum of Australia 2020 (GDA2020 – see ICSM, 2022) for interrogation.

Due to the enormous number of queries required, and to prevent overload of the server, the submission data was separated into sets of 50 marks for asynchronous retrieval, with a wait timer introduced between sets. Retrieval was an iterative process, as failure rates for the server's identify function were as high as 50% of the submitted set at times (likely caused in part by inferior internet connections while working from home during the COVID-19 pandemic). Failed retrievals were re-added to the submission set for the next iteration and automatically resubmitted until completion. This process took approximately 8 days of continuous processor time.

It was found that 872 of the submitted positions returned no data, with 46 of these located on Lord Howe Island (which is not covered by this DEM nor *true* AHD). The remainder (apart from a few anomalies) were located along the Queensland, South Australian and Victorian borders. Closer inspection revealed that all these locations were outside the extent of the DEM (too far into the neighbouring states), noting that SCIMS includes several interstate survey marks close to the NSW border and that the Australian Capital Territory is entirely covered by the DEM.

3 QUALITY ASSESSMENT OF THE DEM ACROSS NSW

3.1 Comparison to SCIMS

For quality assurance, the lower-accuracy AHD heights retrieved from the DEM were compared to existing high-accuracy AHD heights of survey marks on public record in SCIMS that satisfied the following criteria:

- Established (Class D or better) horizontal GDA2020 coordinates.
- Accurate (Class B/LD or better) AHD height.
- Mark at or near ground level (no towers, fence posts, pillars, cairns, reference trees etc.).

The prerequisite for established horizontal coordinates at each survey mark is equally as important as an accurate AHD height, as local terrain undulations can quickly alter the height returned from the DEM. Similarly, selecting marks that are not on the natural surface (above or below ground) renders the comparison invalid. In this instance, 34% of the survey marks in SCIMS (102,437 of 300,328 that returned heights) met the required criteria to be included in the comparison.

Figure 1 illustrates the distribution of these survey marks across the state, while Figure 2 shows those in Greater Sydney. The threshold for a successful comparison was set at ±0.9 m, which is the quoted vertical uncertainty of the DEM (95% CL). It was found that the calculated height differences between the DEM and SCIMS were within this threshold for 95,866 survey marks, i.e. 93.6% of the comparison set (indicated in blue in Figures 1 & 2).

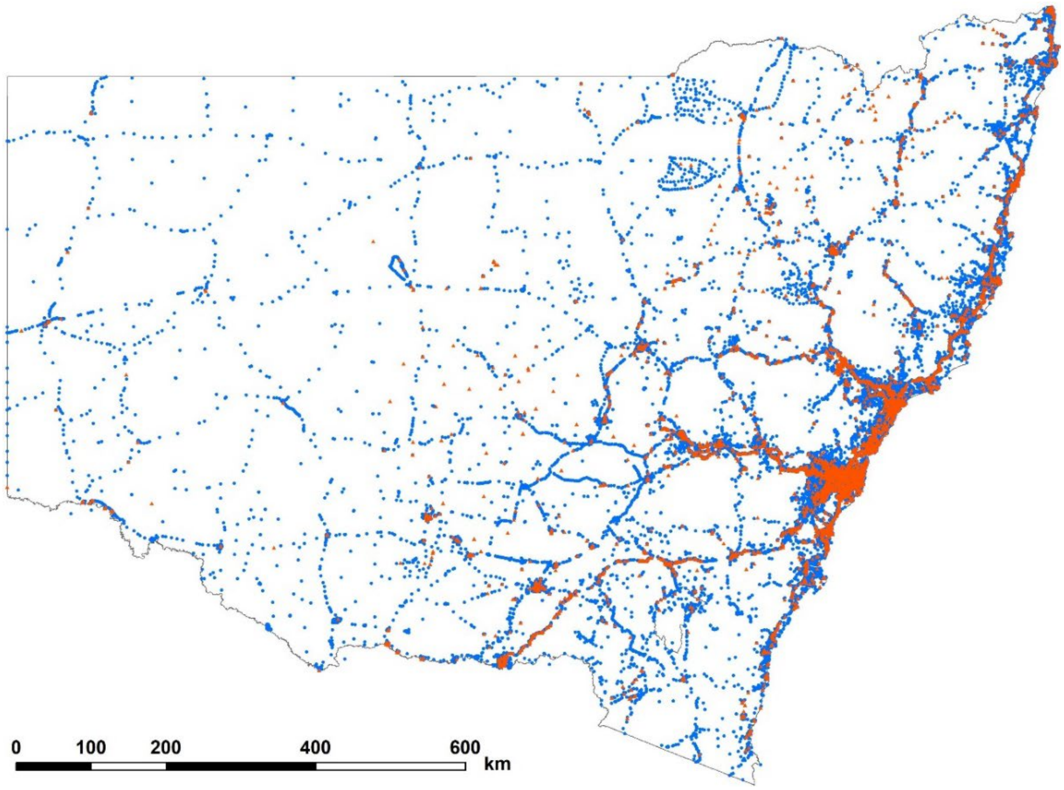


Figure 1: Location of 102,437 SCIMS marks used to assess the quality of the DEM across NSW, with those meeting the ±0.9 m threshold indicated in blue.

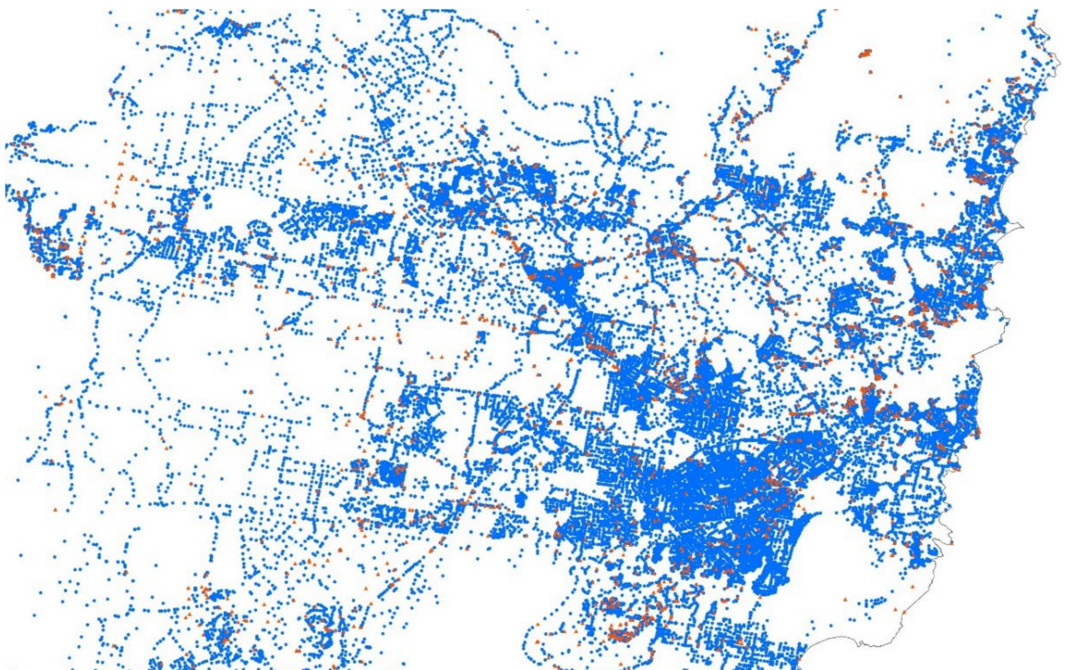


Figure 2: Location of SCIMS marks used to assess the quality of the DEM across Greater Sydney, with those meeting the ±0.9 m threshold indicated in blue.

The obtained pass rate of 93.6% is slightly lower than the quoted vertical uncertainty of the model (95%), which can be attributed to two main reasons:

- The comparison did not consider the vertical position of the survey mark above or below ground level at all survey marks, which typically amounts to up to 0.2 m in either direction for an appropriately placed mark. Accounting for this issue was deemed unnecessary as the result was fit-for-purpose and mark-to-ground-level information was only available for 3.7% of the marks included in the comparison set.
- The horizontal density of the DEM is 5 m, so AHD heights at survey marks located on undulating terrain may show some discrepancy, depending on the position of the mark relative to the sample points of the model (which are used to interpolate the height at the desired position).

For at least the last five years, DCS Spatial Services has recorded the mark-to-ground-level offset at each survey mark occupied or inspected as part of normal field operations. To examine the effect of including such metadata, the analysis was repeated for those 3,849 survey marks in the comparison set with available mark-to-ground-level information. This smaller sample exhibited a pass rate of 97.1% when the mark-to-ground-level correction was applied and a 96.2% pass rate when it was ignored. In combination with the earlier analysis, this result was deemed fit-for-purpose, confirming the stated DEM uncertainty.

It is also worth noting that 960 (14.6%) of the 6,571 marks that failed to meet the ±0.9 m threshold (indicated in orange in Figures 1 & 2) are located within 20 m of the centreline of a major highway or motorway. This can be explained by rapid changes in topography often occurring across the cross-section of the road corridor, including embankments and cuttings. Furthermore, some of these roads are extremely steep, such as the Great Western Highway between Penrith and Glenbrook. Finally, 1,082 (16.5%) of all the marks failing to meet the threshold are specified as ‘destroyed’ in SCIMS, indicating that their AHD height may relate to a time prior to road or other construction earthworks altering the topography.

3.2 Comparison to Independent DEM

Following initial height retrieval, it was noted that the DEM returned an AHD height that was significantly different (> 20 m, e.g. a typical contour) from the value in SCIMS for 787 survey marks with an existing Class U AHD height on public record. This was investigated by querying Geoscience Australia’s 1-second Shuttle Radar Topography Mission (SRTM) DEM for the entire dataset via another API (GA, 2022b). The two DEMs were compared to each other and to SCIMS. Wherever the NSW DEM value differed from SCIMS by more than 10 m (i.e. in 4,690 cases), the 3-way comparison was recorded.

Any AHD height difference exceeding 20 m between the two DEMs was then manually investigated, resulting in 45 of 108 marks (41.7%) to be identified for exclusion from the SCIMS update (see section 4). All these excluded marks were located where an open pit mine had subsequently been created. Any other large differences between the two DEMs were a result of the coarser resolution of the SRTM DEM (1 arcsecond equates to approximately 30 m), e.g. for Trigonometric Station (TS) pillars located on the side of a cliff, the SRTM DEM sometimes returned the height partway down the cliff. Most remaining large differences between the NSW DEM and SCIMS appeared to be the result of transcription errors in the SCIMS height (e.g. 1,000 m instead of 100 m) or rounding to the nearest contour when the heights were initially entered into SCIMS.

4 IMPLEMENTATION OF DEM-SOURCED AHD HEIGHTS IN SCIMS

Reliable and quality-assured survey control is fundamental to ensure the integrity of the imagery and elevation products delivered by DCS Spatial Services (Powell, 2017). However, this connection can work both ways as these products can then be used to improve survey control information on public record in SCIMS. In this case, suitable DEM-sourced AHD heights were used to update SCIMS with these values (at Class U) to yield a homogeneous dataset of known provenance and verifiable quality across NSW. This essentially improved approximate AHD height values in SCIMS that were initially obtained from the nearest contour on 1:25,000, 1:50,000 and 1:100,000 topographic maps to DEM-sourced values with sub-metre uncertainty. Displaying these AHD values to the nearest metre in SCIMS (Class U resolution) fits well with their 0.9 m uncertainty.

4.1 SCIMS Update

Noting the uncertainty of the state-wide DEM product, survey marks were only selected for AHD height update if they met one of the following two criteria:

- The existing AHD height in SCIMS was null.
- The existing AHD height in SCIMS was Class U.

Furthermore, it is important to consider that SCIMS holds records for a wide range of different monument types. A location descriptor also indicates whether the mark was placed in the ground or on a structure. As such, further filtering was applied to limit the height update to only those marks that are likely to be at (or near) ground level. Consequently, several monument types (Table 1) and mark location descriptions (Table 2) were excluded from the update. As an additional precaution, any TS whose name includes the word 'TOWER' was also excluded from the update.

Table 1: Monument types excluded from the SCIMS update.

AERIAL	FIRE TOWER	OBELISK	RESERVOIR
BEACON LIGHT	LIGHTHOUSE	RADAR TOWER	SPIRE
CHIMNEY	LIGHTNING ROD	RADIO MAST	TOWER
FLAGSTAFF	MAST	RADIO TOWER	WIND VANE

Table 2: Mark locations excluded from the SCIMS update.

BUILDING OR STRUCTURE
SILO
OTHER STRUCTURE

It should be noted that RESERVOIR OR TANK should also have been included on the list of mark locations to be excluded in Table 2 but was unfortunately missed. This resulted in 30 trigonometric stations located on reservoirs incorrectly receiving a height at ground level. These will be revisited and corrected during the next 6-monthly GDA2020 SCIMS refresh in June 2022.

Once the update set had been filtered in this way and before the SCIMS update was executed in May 2021, a final test was performed to check for trends. In general, it was found that the data was normally distributed and 99.3% of the AHD heights included in the update were within 20 m of their existing SCIMS values (Figure 3). A 20 m error in height corresponds to approximately a 3 parts per million (ppm) error in the reduction of ground distances to the ellipsoid between two marks, which was deemed acceptable and fit-for-purpose.

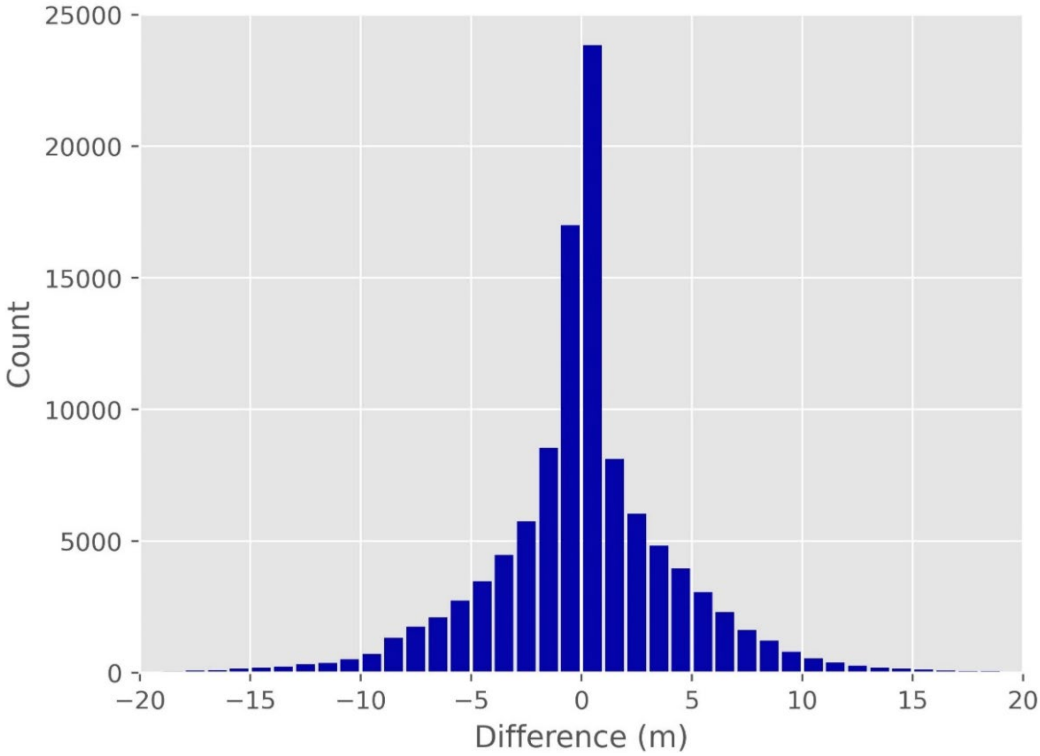


Figure 3: Histogram of the difference between DEM-sourced AHD height and existing AHD height in SCIMS (723 outliers exceeding ±20 m not shown).

Height differences larger than 20 m were generally attributed to either of the following two reasons (see section 3.2):

- Transcription or rounding errors in the existing SCIMS value (corrected by the update).
- Marks located where an open pit mine had subsequently been created (excluded from the update with mark status updated in SCIMS as 'destroyed').

4.2 Results and Benefits

The May 2021 SCIMS update resulted in the provision of DEM-sourced AHD heights at Class U for 127,154 survey marks, of which 18,854 marks (14.8%) were assigned an AHD height for the first time (Figure 4). Putting this large number into perspective, this means that 42.3% of the survey marks that returned a DEM-sourced AHD height during the initial retrieval were updated during this process – a huge improvement in the access to reliable, approximate AHD heights of known quality in SCIMS, ensuring that nearly every survey mark in NSW has an AHD value of 0.9 m uncertainty or better.

When inspecting Figure 4, it is worth noting the near-perfect straight line of AHD height updates to survey marks running from north-west to south-east through the centre of the state. Despite appearing to be an artefact, this is actually a series of marks located along a gas pipeline easement, which connects to the main distribution network on the east coast.

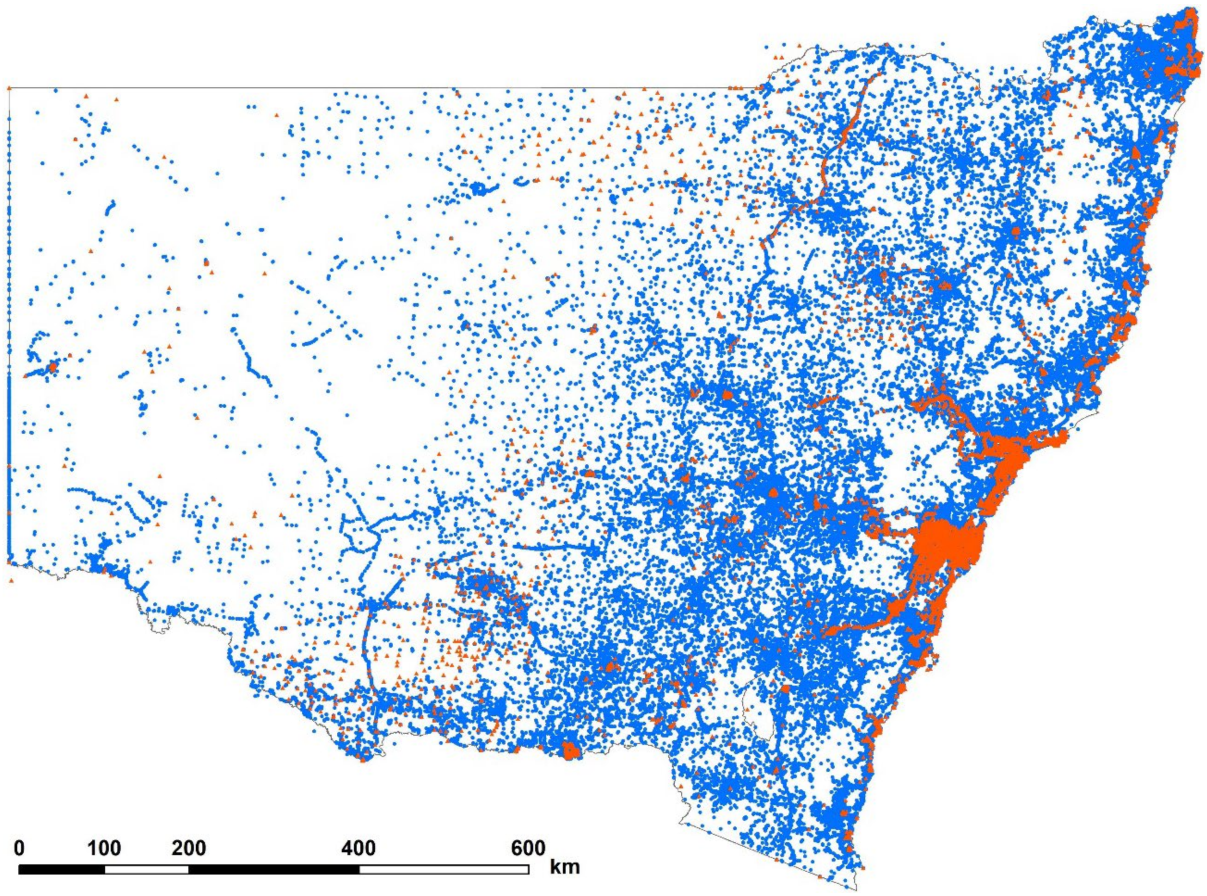


Figure 4: Location of survey marks included in the May 2021 SCIMS update, indicating which marks received an AHD height for the first time in orange.

Table 4 summarises descriptive statistics related to the update dataset, showing the minimum, maximum, mean and median differences between the new and existing AHD height in SCIMS along with the resulting standard deviation. The existence of large outliers, as previously discussed, is confirmed by the difference between the mean and median values.

Table 4: Descriptive statistics of the difference between DEM-sourced and existing AHD height in SCIMS for the update dataset (723 outliers exceeding ±20 m were excluded from the calculation of the standard deviation).

Minimum (m)	-964.725
Maximum (m)	1022.783
Mean (m)	0.185
Median (m)	0.013
Std Dev (m)	4.228

These updated AHD heights provide several important benefits across the state such as enabling the better calculation and reporting of the Combined Scale Factor (CSF) with confidence at virtually all survey marks (99.98%) in NSW through SCIMS. CSFs are now typically up to 1.5 ppm better because heights have been improved from 10-metre to sub-metre accuracy. The DEM-sourced AHD heights also support datum modernisation efforts through the ongoing readjustment of legacy terrestrial data hosted by DCS Spatial Services for inclusion in the growing GDA2020 state adjustment by facilitating the rigorous reduction of terrestrially measured distances to the ellipsoid. This translates into more survey marks in SCIMS being assigned a Positional Uncertainty (PU), directly benefitting our customers.

Furthermore, this process was able to identify and correct 101 extremely large (100-1,000 m) AHD height errors (Class U) in SCIMS. It follows that retrieved DEM-sourced heights can now also be used to identify gross errors on SCIMS marks with existing accurate (Class B/LD or better) AHD heights, further contributing to our 'Saving AHD' efforts, which aim to ensure that users have continued and easy access to reliable physical heights and their uncertainties across NSW (Janssen and McElroy, 2021).

Finally, with SCIMS now holding AHD heights of known quality at virtually all survey marks across the state, ellipsoidal height was derived by applying AUSGeoid2020 (e.g. Brown et al., 2018; Janssen and Watson, 2018; Featherstone et al., 2019) at all applicable survey marks with existing null ellipsoidal height values in SCIMS. During the 6-monthly GDA2020 SCIMS refresh in November 2021, this provided ellipsoidal heights for 267,581 survey marks for the first time, ensuring that virtually all marks in SCIMS now also have an ellipsoidal height. Publishing these values allows surveyors and other users to easily verify that they have set their height datum and/or applied AUSGeoid2020 correctly during both field operations and office processing and reductions.

5 CONCLUDING REMARKS

DCS Spatial Services provides a state-wide DEM to the public with a vertical uncertainty of ±0.9 m (95% CL) and a horizontal grid density of 5 m. This DEM can now be queried directly through a new publicly available API to return an AHD height at a specified location. This paper has described how this new API was used to retrieve AHD heights from the elevation model for about 300,000 survey marks (including witness marks, destroyed marks and interstate marks along the borders) in SCIMS and assess the accuracy of these DEM-sourced AHD heights across NSW by comparison to SCIMS. This revealed that for survey marks at or near ground level, with established GDA2020 coordinates and accurate AHD height, 93.6% of marks showed agreement within ±0.9 m between the DEM and the published SCIMS values (97.1% agreement for a smaller sample considering the mark-to-ground-level correction), thereby confirming the stated DEM uncertainty.

We have then outlined how SCIMS was updated with DEM-sourced heights (at Class U) for 127,154 survey marks with existing Class U or null AHD height values to deliver a homogeneous dataset of known provenance and verifiable quality across NSW. This process allowed 18,854 survey marks to be assigned an AHD height for the first time, ensuring that virtually all survey marks in SCIMS now include an AHD height value, while many gross AHD height errors in SCIMS were identified and corrected. The updated AHD heights provide important benefits for industry such as enabling the calculation and reporting of the combined scale factor with confidence (up to 1.5 ppm better) at practically all survey marks in NSW through SCIMS and supporting the readjustment of legacy terrestrial data in the growing GDA2020 state adjustment to further improve user access to survey information. Lastly, ellipsoidal height values were derived using AUSGeoid2020 and published in SCIMS, allowing 267,581 survey marks to receive an ellipsoidal height for the first time and ensuring that virtually all marks in SCIMS now also have an ellipsoidal height.

REFERENCES

Brown N.J., McCubbine J.C., Featherstone W.E., Gowans N., Woods A. and Baran I. (2018) AUSGeoid2020 combined gravimetric-geometric model: Location-specific uncertainties and baseline-length-dependent error decorrelation, *Journal of Geodesy*, 92(12), 1439-1456 & 1467.

DCS Spatial Services (2018) NSW Foundation Spatial Data Framework, version 3.0, https://data.nsw.gov.au/data/dataset/nsw-foundation-spatial-data-framework (accessed Mar 2022).

DCS Spatial Services (2022) public/NSW_5M_Elevation, API to retrieve NSW 5 m elevation data derived from stereo imagery, https://maps.six.nsw.gov.au/arcgis/rest/services/public/NSW_5M_Elevation/ImageServer/ (accessed Mar 2022).

Featherstone W.E., McCubbine J.C., Claessens S.J., Belton D. and Brown N.J. (2019) Using AUSGeoid2020 and its error grids in surveying computations, *Journal of Spatial Science*, 64(3), 363-380.

GA (2022a) Elvis – Elevation and depth – foundation spatial data, https://elevation.fsdf.org.au/ (accessed Mar 2022).

GA (2022b) DEM_SRTM_1Second, API to retrieve elevation data from the national 1-second Shuttle Radar Topography Mission (SRTM) DEM, https://services.ga.gov.au/site_9/rest/services/DEM_SRTM_1Second/MapServer/ (accessed Mar 2022).

ICSM (2018) Elevation and depth 2030: Powering 3D models of our nation, Elevation and depth information coordination and innovation for Australia – A national strategy, https://www.icsm.gov.au/what-we-do/elevation-and-depth-data (accessed Mar 2022).

ICSM (2022) GDA2020 and GDA94 technical manuals, https://icsm.gov.au/gda2020-and-gda94-technical-manuals (accessed Mar 2022).

Janssen V. and McElroy S. (2021) The Australian Height Datum turns 50: Past, present & future, *Proceedings of APAS Webinar Series 2021 (AWS2021)*, 24 March – 30 June, 3-27.

Janssen V. and Watson T. (2018) Evaluating the performance of AUSGeoid2020 in NSW, *Proceedings of Association of Public Authority Surveyors Conference (APAS2018)*, Jindabyne, Australia, 9-11 April, 3-18.

Powell L. (2017) Survey control and quality assurance for aerial imagery and elevation models across NSW, *Proceedings of Association of Public Authority Surveyors Conference (APAS2017)*, Shoal Bay, Australia, 20-22 March, 32-47.

Roelse A., Granger H.W. and Graham J.W. (1971) The adjustment of the Australian levelling survey 1970-1971, *Technical Report 12*, Division of National Mapping, Canberra, Australia, 81pp.

Standpoint, Cultural Competency and Australian Land

Ruth Ward
Registered Surveyor
ruthwster@gmail.com

ABSTRACT

Indigenous Australians have a very strong connection to land. Native title is the recognition by Australian law that Aboriginal and Torres Strait Islander people have rights and interests to land and waters according to their traditional law and customs. This paper is based on an assignment submitted for the Charles Sturt University (CSU) first-year undergraduate degree subject 'Indigenous Australian Cultures, Histories and Contemporary Realities'. Students were required to reflect on their standpoint with respect to Indigenous Australians and ascertain their degree of cultural competence. The assignment required students to examine Indigenist's perspectives in relation to selected pre and post 1967 referendum events in Australian history. The events were the Wave Hill Walk-Off (1966 to 1975), the Mabo v Queensland No. 2 (1992) case (Mabo case), the Wik Peoples v Queensland (1996) case (Wik case) and the Native Title Amendment Act 1998. These events relate to Indigenous Australians and their connection to their land. This paper outlines the author's learning experience, particularly highlighting how her standpoint limited her understanding of these events and their connection to land. It is hoped that the findings will be of benefit to surveyors when dealing with native title and places of significance to Indigenous Australians.

KEYWORDS: *Cultural competency, land, 1967 referendum, Indigenous Australians, native title.*

1 INTRODUCTION

Standpoints can restrict a person's understanding of events or other cultures. Most of my knowledge of native title and land rights was obtained when studying for a surveying degree at the University of Newcastle in the late 1990s. These topics were presented from a western perspective. Last year, while studying my second degree, I was given the opportunity to study native title and land rights using research material created from an Indigenists' perspective. This allowed me to gain greater understanding of the topics and empathy towards First Peoples.

When working cross-culturally, assessing our standpoint, and widening our worldview by using a cultural competency model as a guide, minimises the risk of harm to the people who are not part of the mainstream culture (Institute for Quantitative Social Science, 2018). This paper outlines my learning experience, particularly highlighting how my standpoint limited my understanding of these events and their connection to land. Hopefully, my example of considering different worldviews in relation to land will encourage other surveyors to examine their standpoint and approach to Indigenous Australians' land matters as well.

2 STANDPOINT

Our standpoints or "how we see the world" are influenced by historical, institutional, social and cultural experiences. Walter (2006, p.11) and Phillips and CSU (2022) state that where we are situated in society "enables and limits our knowledge" and "underpins the questions we see, the answers we seek, the way we go about seeking those answers, and the interpretation we make." For example, my standpoint or worldview, or "who I am", is influenced in part by my family history, schooling, media and conversations with friends and family.

Standpoint or worldview lenses differ between cultures. When working cross-culturally, our different worldview needs to be taken into consideration to ensure a harm-free environment (Taylor and Guerin, 2019). An example of lack of cross-cultural consideration is the displacement of First Peoples from their land by past governments. As Indigenous Australians' connection to land is deeply rooted, some health issues in the Indigenous Australian community are caused by this displacement. Comparing the length of habitation in Australia by non-Indigenous Australians and First Peoples (Figure 1), the long habitation of their land by the First Peoples has resulted in a deep connection with their land (Australian Government, 2013, p.21).

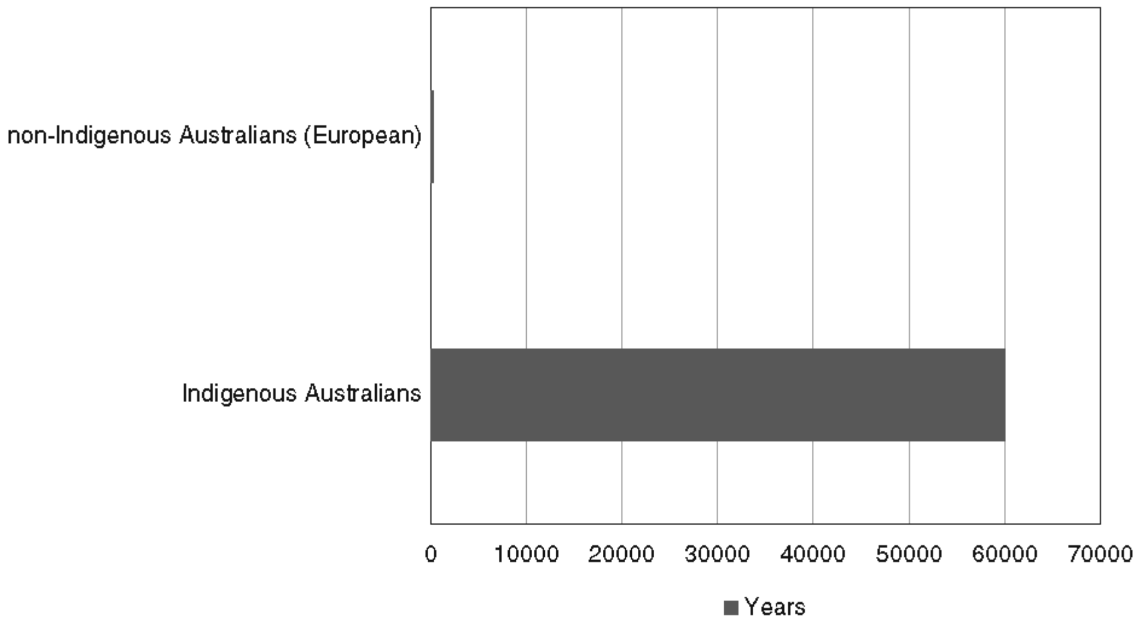


Figure 1: Length of occupation of the land now called Australia by Indigenous Australians and non-Indigenous Australians (Taylor and Guerin, 2019).

3 CULTURAL COMPETENCY AND INDIGENOUS AUSTRALIANS

Being aware of your worldview is a good starting point when adopting a cultural framework to help you work cross-culturally. Health services were one of the first industries to adopt and create cultural frameworks to ensure the best care was delivered to patients from different cultural backgrounds (Taylor and Guerin, 2019, p.12). The cultural competency framework used to assess my ability to work cross-culturally is shown in Figure 2. Descriptions of each of the categories listed in this cultural competence matrix are included in the Appendix.

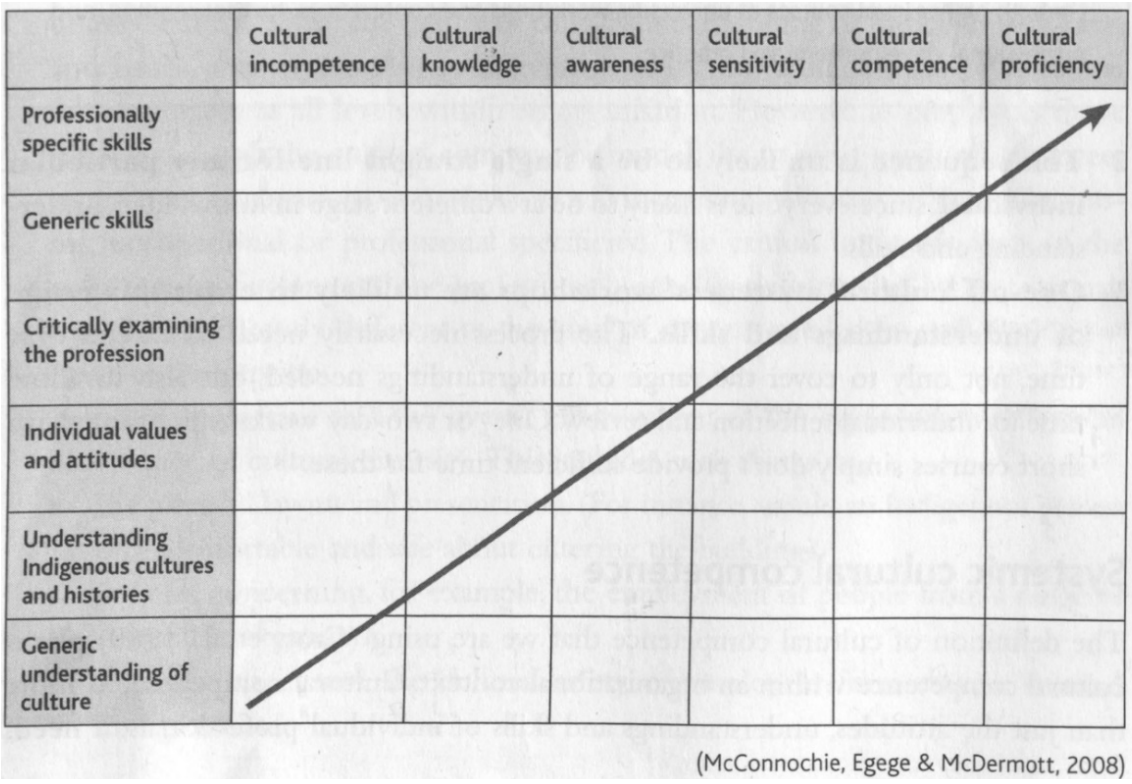


Figure 2: Development of cultural competency (Ranzijn et al., 2009).

When working cross-culturally, cultural competency can be a professional's goal to aim towards to ensure the best workplace outcome is achieved. The Institute for Quantitative Social Science (2018) defines cultural competency as "the need to respect, understand and acknowledge the benefits, values and realities of Indigenous people and communities. This includes being mindful of Indigenous people's right to have different values, norms and aspirations to non-Indigenous people … [and] should recognise that Indigenous communities are diverse, with different languages, cultures, histories and perspectives, and acknowledge the diversity of individuals within these communities." Even if a professional does not meet the cultural competence criteria, knowing where they are placed on the cultural competence matrix will encourage them to seek assistance from others when required.

4 EARLY CROSS-CULTURAL INTERACTION

Early surveyors, explorers, pastoralists, drovers and settlers were fortunate enough to work with and gain knowledge from First Peoples (Figure 3). This assistance helped them to easily travel across different First Nations land and to find water. Even when First Peoples were not included in the field party, Surveyors General John Oxley and Thomas Mitchell identified and followed Indigenous People's traditional pathways during their field trips (Spooner et al., 2010). In the Snowy Mountains, due to the difficulty of the terrain, some of the traditional pathways were adopted as roads by early settlers and now form part of the Omeo Highway and Alpine Way / Snowy Mountains Highway (Spooner et al., 2010).

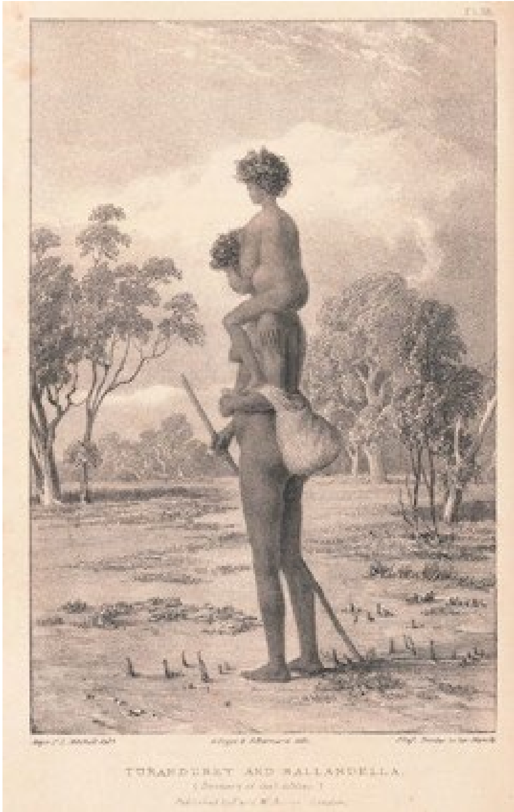


Figure 3: Surveyor General Thomas Mitchell's guide, Wiradjuri woman Turandurey, with daughter Ballendella, drawn by Thomas Mitchell in 1836 (Cadzow, 2022).

5 1967 REFERENDUM

The 1967 referendum was a turning point in Australian history when 90% of Australian voters agreed to the constitution being changed (ANU TV, 2017). Amendments to the constitution removed clauses that discriminated against Indigenous Australians and led to many changes in the future, including the establishment of the land rights legislation. The lead up to and the referendum also shone a light on the unfair treatment of Indigenous Australians (Figure 4).

Figure 4: Faith Bandler and daughter Lilon (right), campaigning for constitutional change (McGregor, 2017).

6 EXAMINING INDIGENOUS PERSPECTIVES THROUGH EVENTS IN AUSTRALIAN HISTORY

The pre and post 1967 referendum events selected were the Wave Hill Walk-Off (1966 to 1975), the Mabo v Queensland No. 2 (1992) case (Mabo case), the Wik Peoples v Queensland (1996) case (Wik case) and the Native Title Amendment Act 1998. These events both relate to Indigenous Australians and their connection to their land (Perera, 2009). They were affected by deficit discourse, especially when politicians chose to not discuss land matters and associated policies and laws with affected Indigenous Australians. Hegemony and institutional racism also occurred predominantly pre-1967, but institutional racism also occurred during the term of the Howard Coalition government when it was implied Indigenous Australians were 'un-Australian'. Post 1967, the Howard Coalition government and industries reinforced cultural norms that made Indigenous Australians feel excluded from mainstream Australian society. As government and industry sentiments were portrayed as Australian cultural norms or values in the media, many non-Indigenous Australians would interpret that the sentiments were the cultural views of the day. With the native title at this time, Indigenous Australians may be portrayed 'un-Australian' by claiming land from mainstream Australians through the Native Title Act. However, the start of the land rights movement and the squashing of Terra Nullius is probably one of the defining moments of decolonisation in Australia.

6.1 Pre 1967 Referendum Events: Wave Hill Walk-Off

The Wave Hill walk-off happened at a very politically charged time with the civil rights movement, apartheid in South Africa and the 1965 Freedom Ride also occurring at the lead up to the referendum. Australians in the mid-1960s also wanted to be in step with the global human rights movement that emerged because of the World War II atrocities.

For example, the 1965 Freedom Ride (Figure 5), which travelled to regional New South Wales (NSW), exposed the treatment and living conditions of Indigenous Australians (AIATSIS, 2022). Media coverage of the 1965 Freedom Ride, changing school and university curriculum, religious views, life experiences and supporting an open mind, allowed the public to see that the race inequality that was being highlighted overseas also existed in Australia. To counteract this behaviour and to portray to the world that Australia is an advanced nation, empathy needed to be shown towards First Nations people by politicians and the general population. From an empathic standpoint, politicians can change legislation and worldviews to ensure Indigenous Australians are treated better.

Figure 5: 'Student Action for Aborigines' 1965 Freedom Bus Ride at Bowraville (Hazzard, 1965).

The original goal of the Wave Hill walk-off was for the Indigenous Peoples to receive better working conditions on the Lord Vestey owned Wave Hill Station (Hokari, 2000). Figures 6 & 7 illustrate the location of the property. Working conditions on many stations were poor with wages for Indigenous Australian stockmen less than their non-Indigenous work colleagues. Also, First Peoples received sub-standard treatment while living on the station. Underlying the request for better work conditions was the want from the Gurindji People for equal rights, better treatment and authority over their land (Hokari, 2000). These rights had been denied due to institutional racism.

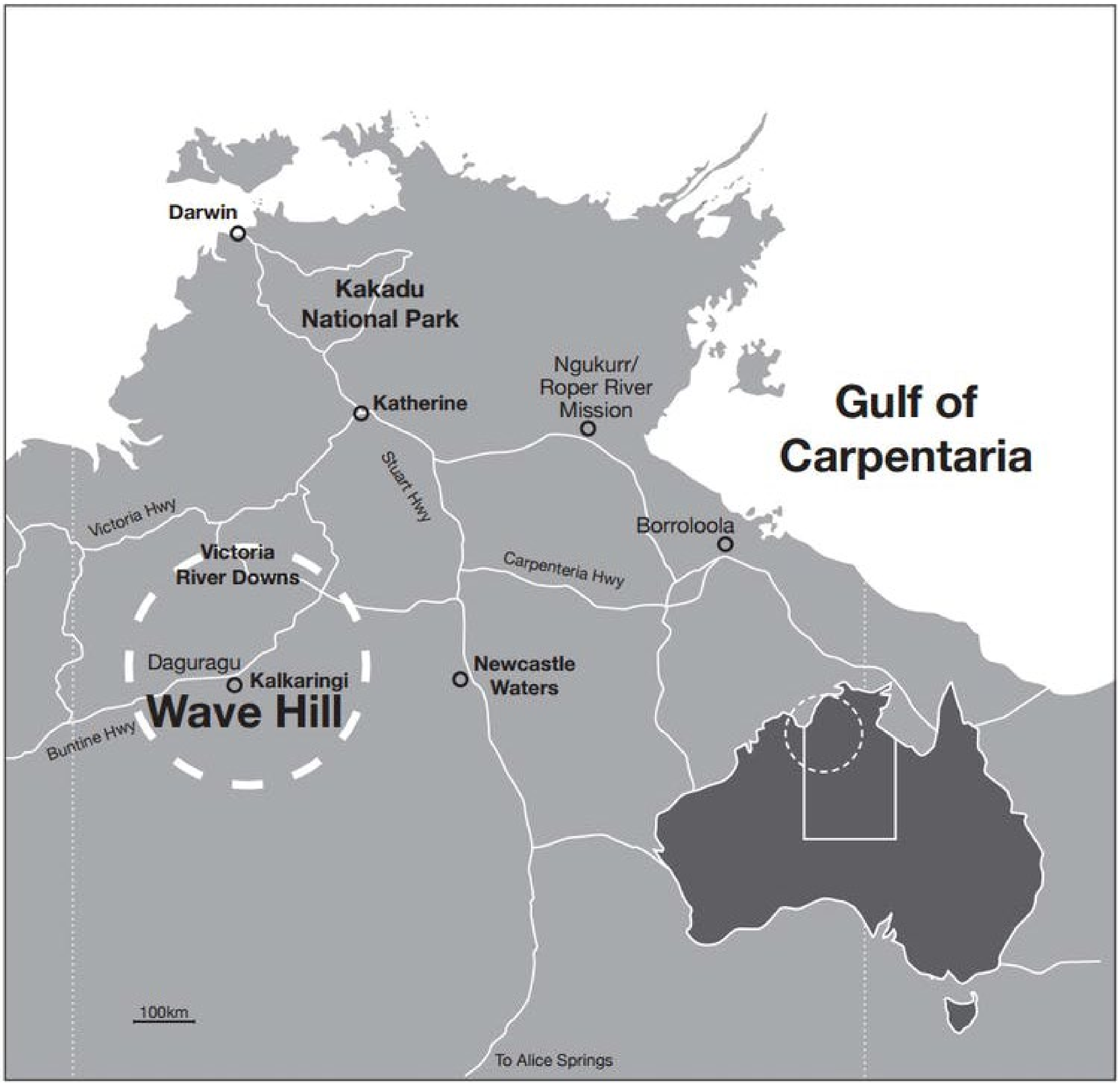


Figure 6: Map showing the location of Wave Hill Station, Northern Territory (Meakins, 2016).

Figure 7: Aerial view of Wave Hill Station in the 1960s (Hayes, 2021).

With respect to power relations, Lord Vestey (and some of his staff) and the Gurindji People did not have a very good or equal relationship. Thea Hayes, a non-Indigenous nurse on Wave Hill Station for many years, stated that the 'two-tiered' system of class, or hegemony, that existed on the station was accepted by the non-Indigenous staff at the time (Hinchliffe, 2020). This was one of the reasons the First Peoples wanted Lord Vestey to leave the property (Hokari, 2000).

Gurindji Elders investigated their people's conditions prior to the Wave Hill walk-off and found that Gurindji and other Territorian stockmen were the lowest paid in the country. In addition, their rights were limited, and treatment of the Gurindji People by the colonists had been substandard for many years (Hokari, 2000). This included massacres, killings, stolen children, brutal treatment and using Aboriginal women for sexual gratification (Meakins, 2016). Figure 8 shows some of the stockmen from Wave Hill Station.

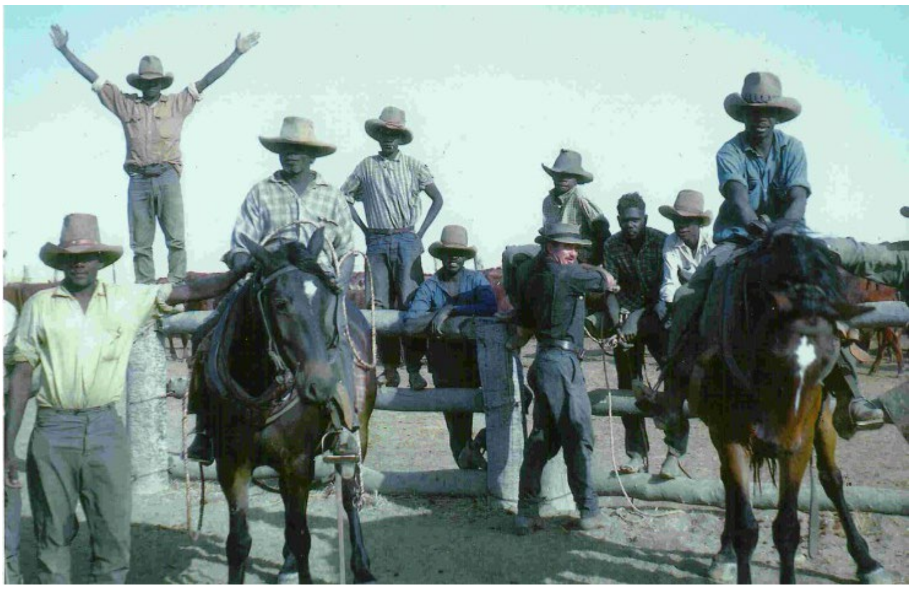


Figure 8: Wave Hill Station stockmen in 1964 (Hayes, 2021).

Prior to and during the walk-off, some non-Indigenous Australians supported the Gurindji People and helped publicise their plight (Hokari, 2000). Also, even though media coverage of the Wave Hill walk-off focused on Vincent Lingiari's efforts leading the Gurindji People, a group of elders would make the final decision in relation to the strike.

The cultural norm accepted by mainstream Australia at the time of the Wave Hill walk-off was that Indigenous Australians' connection to their land was severed at time of colonial settlement and, subsequently, all land then became the property of the Crown (Foley, 2017). However, the Gurindji People did not see that their connection to their land had been broken (ICSM, 2022). Today, similar sentiments exist as a land system based on the British land system is still being used in Australia. Also, due to the assimilation policy of the Northern Territory and protection laws, a deficit discourse existed around black inferiority and white superiority (Dodson, 1996; Wells and Christie, 2000). The Northern Territory Emergency Response introduced in August 2007 by the Coalition government is like previous policies and laws, which controlled Indigenous Peoples behaviours and reinforced existing deficit discourses.

6.2 Post 1967 Referendum Events

After the 1967 referendum, Prime Minister Harold Holt formed an all-white Council of Aboriginal Affairs (CAA) in which he showed great interest. Unfortunately, after Holt's sudden death, when John Gorton took over as Prime Minister, he showed he was not interested in the committee's work or Indigenous Australians (Foley, 2017). The committee members included Dr Herbert Coombes, Barrie Dexter and Bill Stanner (Figure 9), and together they created national policies for First Peoples, consulted with and encouraged leadership from Indigenous Peoples and the protection of First Nations heritage and culture. Also, through their direction, Dr Charles Perkins was appointed to the committee in the late 1960s (National Museum of Australia, 2022). Even though it was the committee's goal to create a just society, this was not created during the time of CAA, with politics or laws enabling the stolen generation, Northern Territory intervention and the destruction of Indigenous heritage during and after the existence of the committee (Dexter et al., 2014).

Figure 9: Council of Aboriginal Affairs in 1968, showing Committee members, left to right, Barrie Dexter, Dr Herbert Coombes and Bill Stanner (Foley, 2017).

Vincent Lingiari, Elder of the Gurindji People, did receive support from non-Indigenous Australians at the Wave Hill walk-off (Hokari, 2000). These talks happened pre and post the 1967 referendum and indicate how the attitudes of members of the community changed to show more empathy towards Indigenous Australians. Hence, by 1975, Prime Minister Gough

Whitlam, as the representative of the government, gave the Gurindji People title to their land (Figure 10). This was the first time the Commonwealth Government of Australia had handed land back to a First Nations community (McKeon, 2016).

Figure 10: Vincent Lingiari, Gurindji Elder, and Gough Whitlam, during the transfer of land from the Commonwealth Government to the Gurindji People at Wave Hill Station, Northern Territory (Bishop, 1975).

In 1975, the federal government gave back 3,000 km^2 of land to the Gurindji People, in a ceremony between Prime Minister Gough Whitlam and Gurindji Elder Tommy Vincent Lingiari (James, 2015). The Wave Hill walk-off was one of the first successful and publicised land rights claims in Australia, which led to the creation of land rights legislation, other successful land rights claims and the education of non-Indigenous Australians about Indigenous Peoples treatment and connection to their land (James, 2015). Since the Wave Hill walk-off, First People's deep connection to the land and the effect of removal from land on Indigenous People's well-being has been highlighted in mainstream society. Segregation of Indigenous Australians, present at the time of the 1965 Freedom Ride, appears to have disappeared from Regional NSW towns.

Therefore, the worldwide civil rights movement, the land rights claim that stemmed from the Wave Hill walk-off, the 1967 referendum and the creation of the Racial Discrimination Act 1975 paved the way for native title and the ending of the doctrine of Terra Nullius (Pascoe, 2012). Despite this, opposition to giving land to the traditional owners has been fierce, with the positioning of Indigenous Australians being changed by different political parties, media outlets, ideology and political donors (Gibson, 2018).

By citing the Racial Discrimination Act, the Mabo case showed the property rights of all Australian people, including the rights belonging to Indigenous Australians prior to the colonisation of Australia by the British, needed to be protected (Hill, 1995). Figure 11 shows the location of the native title claim by Eddie Mabo. This meant that Indigenous People's connection to land was not ended when Australia was colonised and still exists. Further, the Wik case (Figure 12) helped the Mabo decision and native title to be recognised on the mainland and showed native title was not extinguished by leasehold land. The Native Title Act 1993 was created to manage the doctrine created by the Mabo and Wik cases (Gibson, 2018).

Figure 11: Location of the native title claim by Eddie Mabo, Murray Islands, Torres Strait Islands, Queensland.

Figure 12: Gladys Tybingooompa, Wik claimant from Camp York, dancing to celebrate her people's win in the High Court in 1996 (Nicol, 2018).

After the Mabo decision and when the Native Title Act was being formed, Paul Keating (Figure 13) and his government opened a consultation period for Indigenous Australians and other affected parties (Rowse, 1993). This was welcomed by many Indigenous Australians and was the most amount of input given by First Peoples on a piece of Australian legislation to date (Gibson, 2018).

Due to the political climate created by opposition after the Mabo case, Native Title Act and the Wik case, politicians, interest groups and the media portrayed a 'mainstream' Australia or a cultural norm that did not include Indigenous Australians (Gibson, 2018). This is preposterous, as Indigenous Australians are the original occupants or First Peoples of Australia. One of these politicians was John Howard (see Figure 13), who was elected as Prime Minister in 1996. Howard said, he will bring balance back into 'mainstream' Australia by changing the Native

Title Act (McCausland, 2004). Without consulting any Indigenous Australians, his party amended the Native Title Act and created the Wik ten-point plan (Gibson, 2018). This may have been done as the legislation was unworkable or due to immense political pressure. During this time, 'scare tactics' were used in the media to add support to the Howard Coalition government's handling of native title and to show Indigenous Australians' actions as a threat (Hill, 1995; McCausland, 2004). These tactics were used as it was thought native title would impact the property owners, stop or make it difficult to access minerals and lose pastoral leases. By inhibiting native title, mining companies, large landholders, developers, the government, and pastoral lease holders would benefit (Robbins, 2007).

Figure 13: Paul Keating and John Howard in 1996 (The Australian, 2018).

7 SURVEYING AND INDIGENOUS CULTURAL COMPETENCIES

A practical example of Indigenous cultural competency in the field of surveying is the Survey section of Transport NSW creating procedures relating to Aboriginal artefacts and threatened species after artefacts were inadvertently disturbed during two field surveys. One incident occurred when a surveyor placed a drill hole in a rock containing rock carvings, the other occurred during potholing in the vicinity of aboriginal artefacts. After these disconcerting situations, policies and procedures were changed to avoid this happening in the future (Lenton, 2014).

At a larger scale, Universities Australia published guiding principles to develop Indigenous cultural competency at Australian universities. One of the suggested guidelines is that "all graduates of Australian universities should be culturally competent" (Universities Australia, 2011). Charles Sturt University implemented a program that follows these guidelines and made "Indigenous perspectives and knowledge" part of the curriculum for all schools and faculties. The Appendix includes useful information for self-assessing one's level of cultural competence.

8 CONCLUDING REMARKS

Due to the civil rights movement, many non-Indigenous Australians saw the inequality in Australian society and wanted First Peoples to be treated better. The Wave Hill walk-off and the Mabo case, the Wik case and the Native Title Act show that conditions and rights of Indigenous Australians have evolved since the 1967 referendum. This has not been without opposition, especially when First Peoples rights and ownership of land is debated.

This paper has shown that by looking at material created from an Indigenist perspective, a different understanding of a topic can be gained, which may help change one's standpoint and start an associated cultural competency journey. Also, understanding that an Indigenous Australian worldview in respect to land can differ from a surveyor's view of land will help if working cross-culturally in the future.

As a non-Indigenous Australian, I cannot fully understand an Indigenous Australian's connection to their land. Nevertheless, it was enjoyable and eye-opening to learn about these events in Australian history from an Indigenous Australians perspective. It is hoped that these findings will be of benefit to surveyors when dealing with native title and places of significance to Indigenous Australians.

REFERENCES

AIATSIS (2022) 1965 freedom ride, Australian Institute of Aboriginal and Torres Strait Islander Studies, https://aiatsis.gov.au/explore/1965-freedom-ride (accessed Mar 2022).

ANU TV (2017) Does the '67 referendum still matter? YouTube, https://www.youtube.com/watch?v=iW7ZZC9aRDw&t=804s (accessed Mar 2022).

Australian Government (2013) National Aboriginal and Torres Strait Islander health plan 2013-2023, https://www.health.gov.au/resources/publications/national-aboriginal-and-torres-strait-islander-health-plan-2013-2023 (accessed Mar 2022).

Bishop M. (1975) Prime minister Gough Whitlam pours soil into the hands of traditional land owner Vincent Lingiari, Northern Territory, 1975, photograph, Art Gallery of NSW, https://www.artgallery.nsw.gov.au/collection/works/58.2000/#bibliography (accessed Mar 2022).

Cadzow A. (2022) Turandurey (c. 1806-?), Australian Dictionary of Biography, National Centre of Biography, Australian National University, https://ia.anu.edu.au/biography/turandurey-29903 (accessed Mar 2022).

Dexter B., Foley G. and Howell E. (2014) *Pandora's box: The Council for Aboriginal Affairs 1967-1976*, Australian Scholarly Publishing, Melbourne, 527pp.

Dodson M. (1996) Assimilation versus self-determination: No contest, Australian Human Rights Commission, https://humanrights.gov.au/about/news/speeches/assimilation-versus-self-determination-no-contest-dodson-1996 (accessed Mar 2022).

Foley G. (2017) Harold Holt's death and why the 1967 referendum failed Indigenous people, The Guardian, https://www.theguardian.com/australia-news/2017/may/27/harold-holts-death-and-why-the-1967-referendum-failed-indigenous-people (accessed Mar 2022).

Gibson D. (Director) (2018) Wik v Queensland, TV broadcast, 8 July, NITV.

Hayes T. (2021). Australian author Thea Hayes outback nurse, https://www.theahayes.com.au/ (accessed Mar 2022).

Hazzard N. (1965) Freedom riders at Bowraville, photograph, State Library of New South Wales, https://timeline.com/student-aboriginal-rights-activists-australia-bf12e115a370 (accessed Mar 2022).

Hill R.P. (1995) Blackfellas and whitefellas: Aboriginal land rights, the Mabo decision, and the meaning of land, *Human Rights Quarterly*, 17(2), 303-322.

Hinchliffe J. (2020) Thea Hayes the walkabout nurse, Conversations [audio recording], https://www.abc.net.au/radio/programs/conversations/thea-hayes/11964300 (accessed Mar 2022).

Hokari M. (2000) From Wattie Creek to Wattie Creek: An oral historical approach to the Gurindji walk-off, *Aboriginal History*, 24, 98-116.

ICSM (2022) Systems of ownership and registration, https://www.icsm.gov.au/education/fundamentals-land-ownership-land-boundaries-and-surveying/land-and-land-ownership/systems (accessed Mar 2022).

Institute for Quantitative Social Science (2018) What is meant by cultural competency and cultural standpoint? Australian Data Archive, https://ada.edu.au/wp-content/uploads/2018/11/What_is_meant_by_cultural_competency_and_cultural_standpoint.pdf (accessed Mar 2022).

James F. (2015) Gough Whitlam's Wave Hill hand back celebrated by Indigenous elders 40 years on, https://www.abc.net.au/news/2015-08-16/gough-whitlams-wave-hill-hand-back-celebrated-after-40-years/6700704 (accessed Mar 2022).

Lenton G. (2014) When is a rock not a rock? *Proceedings of Association of Public Authority Surveyors Conference (APAS2014)*, Pokolbin, Australia, 31 March – 2 April, 228.

McCausland R. (2004) Special treatment – The representation of Aboriginal and Torres Strait Islander People in the media, *Journal of Indigenous Policy*, 4, 84-98.

McGregor R. (2017) 'Right wrongs, write yes': What was the 1967 referendum all about? *The Conversation*, https://theconversation.com/right-wrongs-write-yes-what-was-the-1967-referendum-all-about-76512 (accessed Mar 2022).

McKeon N. (2016) Vincent Lingiari & Gough Whitlam: The story behind the image, NITV, https://www.sbs.com.au/nitv/article/2016/03/02/vincent-lingiari-gough-whitlam-story-behind-image (accessed Mar 2022).

Meakins F. (2016) Friday essay: The untold story behind the 1966 Wave Hill walk-off, *The Conversation*, https://theconversation.com/friday-essay-the-untold-story-behind-the-1966-wave-hill-walk-off-62890 (accessed Mar 2022).

National Museum of Australia (2022) Charles Perkins, https://www.nma.gov.au/explore/features/indigenous-rights/people/charles-perkins (accessed Mar 2022).

Nicol E. (2018) Warrior spirits: The Wik women who stood up for their land and communities, NITV, https://www.sbs.com.au/nitv/article/2018/06/12/warrior-spirits-wik-women-who-stood-their-land-and-communities (accessed Mar 2022).

Pascoe B. (2012) Andrew Bolt's disappointment: Why didn't you ring their mums? *Griffith Review*, 36, 226-233.

Perera S. (2009) Girt by sea, in *Australia and the insular imagination: Beaches, borders, boats, and bodies*, Palgrave Macmillan, New York, 15-32.

Phillips J. and CSU (2022) Mini-lecture – Framing your learning – Indigenist and standpoint, https://csu.ap.panopto.com/Panopto/Pages/Viewer.aspx?id=29b8dda4-46a7-4030-bc02-adda01821c81 [requires CSU login] (accessed Mar 2022).

Ranzijn R., McConnochie K. and Nolan W. (2009) Introduction to cultural competence, in *Psychology and Indigenous Australians: Foundations of cultural competence*, Palgrave Macmillan, Melbourne, 3-12.

Robbins J. (2007) The Howard government and Indigenous rights: An imposed national unity? *Australian Journal of Political Science*, 42(2), 315-328.

Rowse T. (1993) How we got a Native Title Act, *The Australian Quarterly*, 65(4), 110-132.

Spooner P.G., Firman M. and Yalmambirra (2010) Origins of travelling stock routes: 1. Connections to Indigenous traditional pathways, *The Rangeland Journal*, 32(3), 329-339.

Taylor K. and Guerin P.T. (2019) *Health care and Indigenous Australians: Cultural safety in practice* (3rd edition), Bloomsbury Publishing, London, 274pp.

The Australian (2018) Cabinet paper 1996-1997: Keating invited Howard to the Lodge after election defeat, https://www.theaustralian.com.au/subscribe/news/1/?sourceCode=TAWEB_WRE170_a_GGL&dest=https%3A%2F%2Fwww.theaustralian.com.au%2Fnation%2Fpolitics%2Fkeating-invited-howard-to-the-lodge-after-election-defeat%2Fnews-story%2F7e3753db893ddc10b46da09da1aa49f0&memtype=anonymous&mode=premium (accessed Mar 2022).

Universities Australia (2011) Guiding principles for developing Indigenous cultural competency in Australian universities, https://www.universitiesaustralia.edu.au/wp-content/uploads/2019/06/Guiding-Principles-for-Developing-Indigenous-Cultural-Competency-in-Australian-Universities.pdf (accessed Mar 2022).

Walter M. (Ed.) (2006) *Social research methods: An Australian perspective*, Oxford University Press, Melbourne, 390pp.

Wells J.T. and Christie M.F. (2000) Namatjira and the burden of citizenship, *Australian Historical Studies*, 31(114), 110-130.

APPENDIX

Extracts from Ranzijn et al. (2009), describing each of the categories of the cultural competence matrix shown in Figure 2.

INTRODUCTION TO CULTURAL COMPETENCE 7

with the following sequence of stages along a continuum from cultural incompetence to cultural proficiency:

- **Cultural incompetence**: lack of knowledge of the cultural implications of health behaviour
- **Cultural knowledge**: learning the elements of culture and their role in shaping and defining health behaviour
- **Cultural awareness**: recognising and understanding the cultural implications of behaviour
- **Cultural sensitivity**: the integration of cultural knowledge and awareness into individual and institutional behaviour
- **Cultural competence**: the routine application of culturally appropriate health care interventions and practices
- **Cultural proficiency**: the integration of cultural competence into one's repertoire for scholarship (e.g. practice, teaching and research).

Exercise 1.2	Cultural competence continuum

Where do you think you sit on the cultural competence continuum?
What are some of the reasons why you placed yourself there?
What do you think you need to learn or do to move further along the continuum?

Content of cultural competence training

What should be included in cultural competence training? A focus group convened to identify the skills and attributes that Indigenous Australians think practising psychologists should possess provided detailed suggestions for the content of training. The main issues arising from the focus group were:

- the lack of awareness amongst professionals about Indigenous clients, cultures and contexts
- the absence of specific skills and strategies for working in Indigenous contexts
- the culturally specific nature of the assumptions and practices of professions and agencies
- the failure of the professions to engage in broader issues of justice and human rights—including an advocacy role and a role for the professions in developing understanding of, and strategies for challenging, prejudice, ethnocentrism and racism
- the need for individuals to be aware of their own values, assumptions and expectancies, and how these impact on their interaction with Indigenous clients and communities.

(Ranzijn et al., 2007, p. 25)

In the area of understanding Indigenous cultures, histories and communities, the group thought that the content should include:

- the basis of Indigenous spirituality and belief systems
- the sources and contemporary characteristics of families and family structures
- relationships with land and the interconnectedness of land, family and spirituality
- the diversity of concepts of identity—different concepts of identity across cultures
- the importance of understanding the impact of historical processes
- the impact of historical processes on identity (colonialism, institutionalisation, discrimination, stolen generations, etc.)
- community and individual responses to colonialism
- the broad characteristics of contemporary Indigenous communities
- an awareness of relevant social indicators
- relevant national and international legislation and obligations.

(Ranzijn et al., 2008, p. 133)

Finally, the group felt that exploring the nature of the profession should include:

- critically exploring the major paradigms of professions and the impact of these paradigms on how the profession impacts on clients from diverse backgrounds
- analysing the extent to which professional activities are structured around unrecognised assumptions which are culture specific and recognise the need for the profession to identify and question these assumptions
- exploring issues of power relations within a range of contexts, including researcher–researched contexts, client–practitioner contexts and more general issues about cultural dominance
- examining the extent (or lack) of engagement of their professions in broader social–political issues as a significant issue
- examining personal values and belief systems within a context which is both supportive and challenging.

(Ranzijn et al., 2008, p. 133)

These points can be grouped into six categories, two for each of the three main attributes of cultural competence, namely, knowledge (steps 1 and 2 below), values (steps 3 and 4), and skills (steps 5 and 6). Developing cultural competence in relation to Indigenous Australians in a thorough and comprehensive manner involves progressing more or less in the following sequence from basic knowledge through to professionally specific skills:

1. obtaining a generic understanding of the nature and significance of culture
2. obtaining a general understanding of Indigenous cultures, histories, contemporary societies and issues
3. exploring individual and societal values and attitudes (individual, institutional and cultural racism)
4. critically examining the nature of one's profession or occupation

5 developing generic skills for working in Indigenous contexts
6 developing professionally specific skills for working in Indigenous contexts.

Mapping the development of cultural competence

Combining the previous six steps with the six stages of Wells's (2000) cultural competence continuum produces a matrix (figure 1.1) which can be used to guide the development of cultural competence. The matrix encompasses many levels of experience, from those beginning higher education studies through to practitioners who may have been working in the field for many years. The model outlines a process or journey which commonly (but not necessarily, depending on experience) begins at the bottom left hand corner (in the case of people who are culturally incompetent), and progresses towards the upper right hand corner. (However, note the earlier comments about the need to revisit the basics.)

Any particular person could be located at any point in the matrix, or indeed at a number of points simultaneously, not necessarily on the arrow. In fact, it is unlikely that someone would be located right on the arrow, since people are likely to be at different levels of cultural competence depending on which content area they are proficient in. For instance, someone may be high on cultural proficiency in their generic understanding of culture while at the same time being culturally incompetent in the area of critically examining their profession.

Figure 1.1 Development of cultural competence

	Cultural incompetence	Cultural knowledge	Cultural awareness	Cultural sensitivity	Cultural competence	Cultural proficiency
Professionally specific skills						
Generic skills						
Critically examining the profession						
Individual values and attitudes						
Understanding Indigenous cultures and histories						
Generic understanding of culture						

(McConnochie, Egege & McDermott, 2008)

The Cadastre of Little Cattai Creek (Re-Defining Original Crown Grants)

Fred de Belin
City of Ryde
fdebelin@ryde.nsw.gov.au

ABSTRACT

Little Cattai Creek flows into the Hawkesbury River at South Maroota. In 1880, as part of Crown land release, surveys were carried out by Mr George Matcham Pitt Jr., which created portion boundaries along Little Cattai Creek. The area of investigation includes Portions 50-65 which were all the subject of Torrens Title Crown grants in 1880. This paper delves into some of the interesting and fascinating questions raised when trying to re-establish the original Crown grants using plans of survey, which were not survey accurate, and from pawing through the scant chain of subsequent subdivision plans and re-definition plans. This paper describes in detail some of the anomalies and strange happenings uncovered during the research and tries to answer such poignant questions as: How is the original intention of the Crown grant survey determined? Does the original intention of the plan of survey for the Crown grant override all else? How does one uncover remnant slivers of land? How does one manage remnant slivers of land? How does one account for differences in definitions by different surveyors?

KEYWORDS: *Intention, Crown grants, grant boundary, rock face reference marks, sliver.*

1 INTRODUCTION

Investigating cadastral issues along urban watercourses can involve a journey back in time to the first Crown land grants and uncover interesting anomalies and strange occurrences in the name of the cadastre (e.g. de Belin, 2019, 2020a, 2020b). One such example is Little Cattai Creek, which flows into the Hawkesbury River at South Maroota. As part of Crown land release, surveys were carried out in 1880 that created portion boundaries along Little Cattai Creek. The area of this investigation includes Portions 50-65, delving into some of the interesting and fascinating questions raised when trying to re-establish the original Crown grants using plans of survey, which were not survey accurate, and from pawing through the scant chain of subsequent subdivision plans and re-definition plans.

This paper describes some of the anomalies and strange happenings uncovered during the research and tries to answer such poignant questions as: How is the original intention of the Crown grant survey determined? Does the original intention of the plan of survey for the Crown grant override all else? How does one uncover remnant slivers of land? How does one manage remnant slivers of land? How does one account for differences in definitions by different surveyors?

2 FIRST GRANTS IN THE DISTRICT

In April 1832, a Crown grant survey, Crown Plan 33.690 (Figure 1), comprising 60 acres and situated on Little Cattai Creek, was carried out by Felton Matthew (Assistant Surveyor), and much later, in 1885, was adopted as Crown Portion numbered 14.

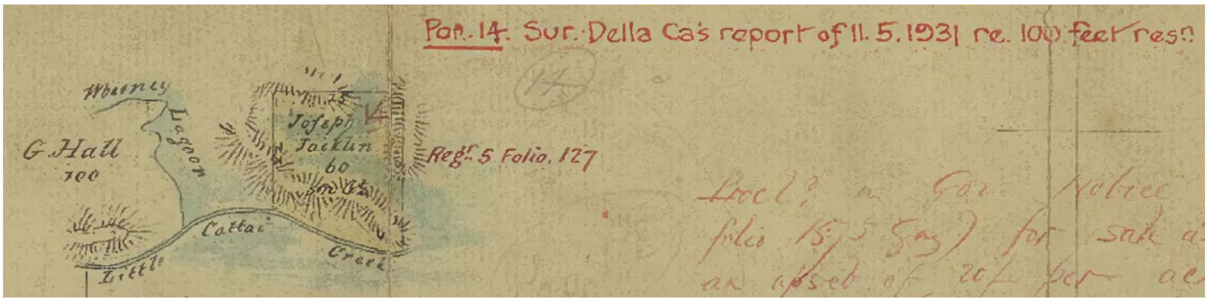


Figure 1: Crown Plan 33.690 of Portion 14 – 1832.

In November 1833, a Crown grant survey, Crown Plan 139.690 (Figure 2), comprising 50 acres, was also carried out by Felton Matthew, and later adopted as Crown Portion 18 in 1885.

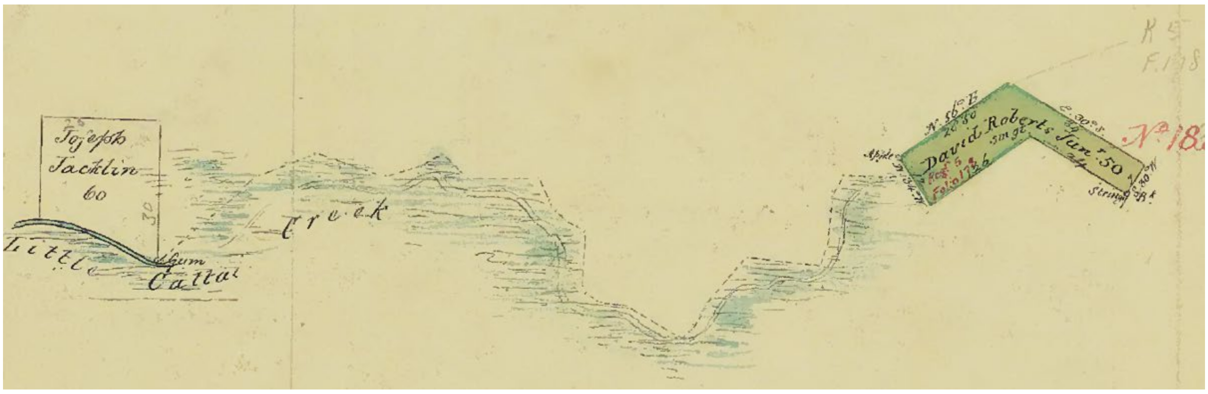


Figure 2: Crown Plan 139.690 of Portion 18 – 1833.

These Crown Plans make no mention of the survey instruments that were used at the time, but it was most probably a compass and linked chain. The wife of Felton Matthew wrote in her journal of 1833, describing the district: “The road is of course very bad, nothing but rock and sand. In some few spots the scenery is mild and rather pleasing but generally of the usual monotonous description.” This sounds like a typical comment from any land surveyor’s wife.

Country Lot A, now known as Portion 2 (Figure 3), was surveyed in 1867 with circumferentor and chain by Licensed Surveyor George Matcham Pitt Jr. (who was licensed in 1859). Unfortunately, the Crown Plan (M2.636) of the adjoining 160-acre parcel is unobtainable.

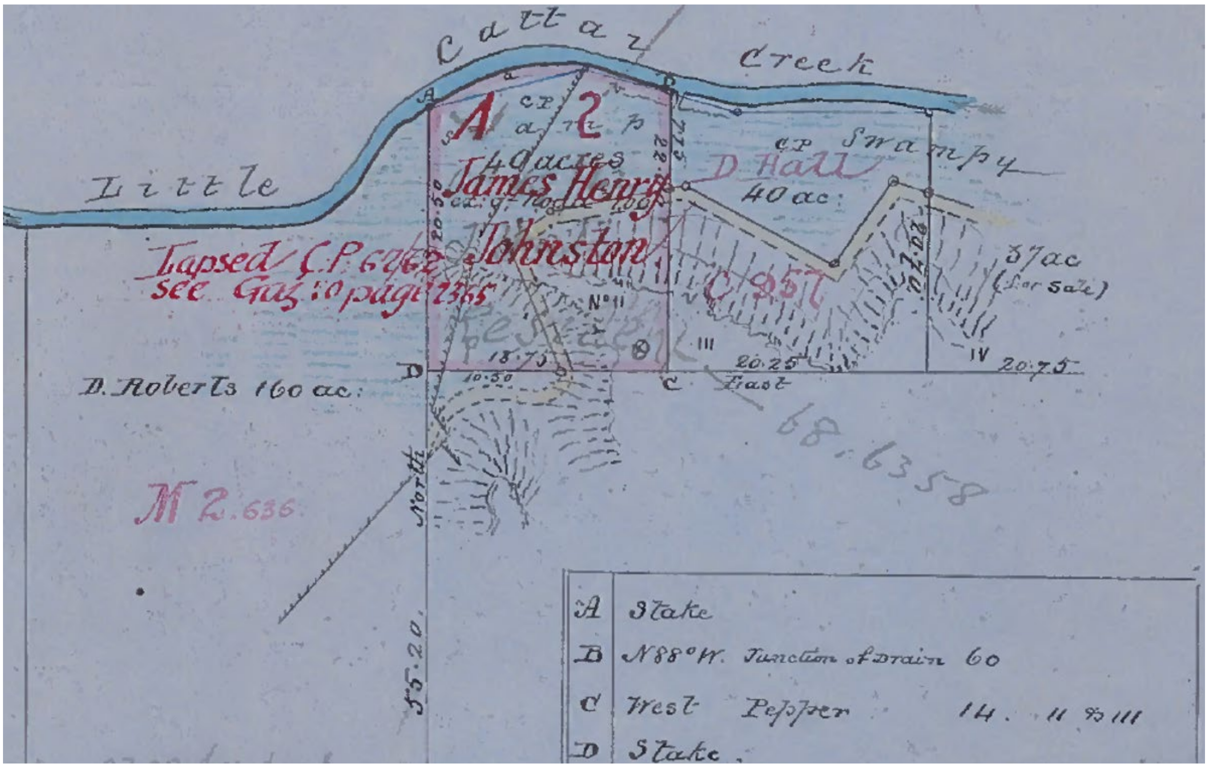


Figure 3: Detail from Crown Plan 956.690 – 1867.

Note that corner ‘B’ is referenced from the junction of a drain 60 links distant. It is unknown at this stage if there is existing evidence of this drain on site. A drain cut through rock (constructed in 1820) was adopted as a corner on Portion 10 in the Parish of Maroota in 1871 (Figure 4). Portion 10 was situated on the banks of the Hawkesbury River, and even though the survey for the grant did not occur until 1871 (surveyed by George Matcham Pitt Jr.), the land had been occupied and farmed since 1809.

Figure 4: Drain cut through rock c. 1820 as shown by George Matcham Pitt Jr. in 1871 and photo in 2018.

Alongside Country Lot A, Country Lots B, C and D, now known as Portions 3, 4 and 5 (Figures 5 & 6), were also surveyed in 1867 by Licensed Surveyor George Matcham Pitt Jr. with circumferentor and linked chain. The intention of the surveys was to create land parcels of 40 acres in area, with the side boundaries parallel and the rear boundaries being on one straight line. This meant that the width of the parcel varied because of the irregularity of Little Cattai Creek being a natural boundary. In fact, the variability of the creek was so influential that Portion 4 could only achieve an area of 37 acres and yet maintain the straight-line rear boundary. It appears that Portion 5, which comprised only 27 acres, was governed more by the surrounding terrain. The view upstream of the swamplands of Portions 2, 3 and 4 in flood is shown in Figure 7.

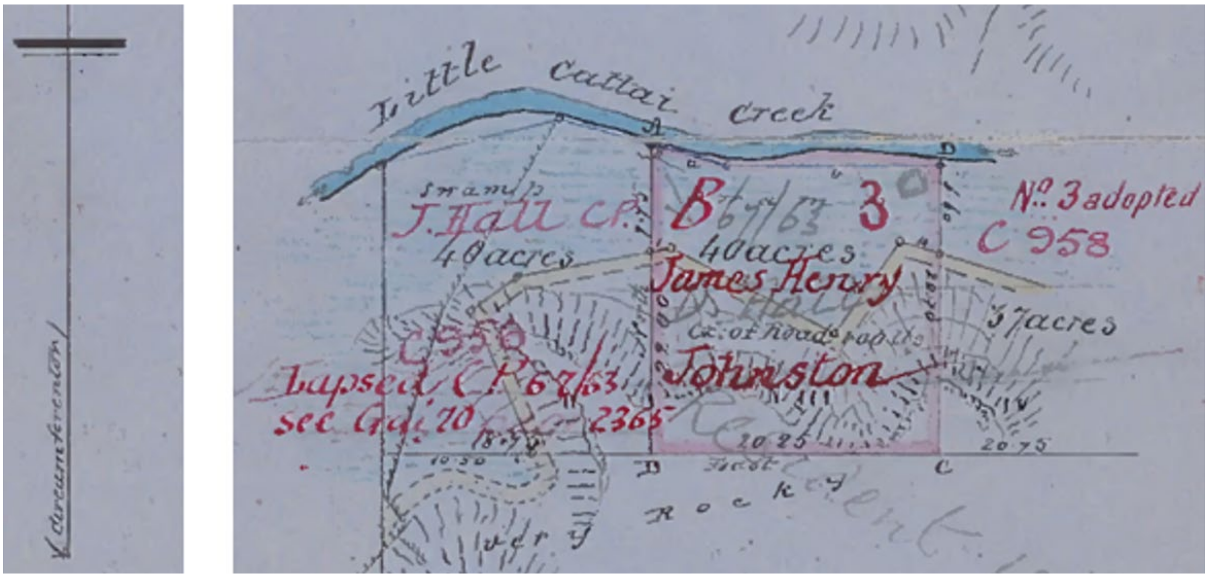


Figure 5: Detail from Crown Plan 957.690 showing circumferentor reference – 1867.

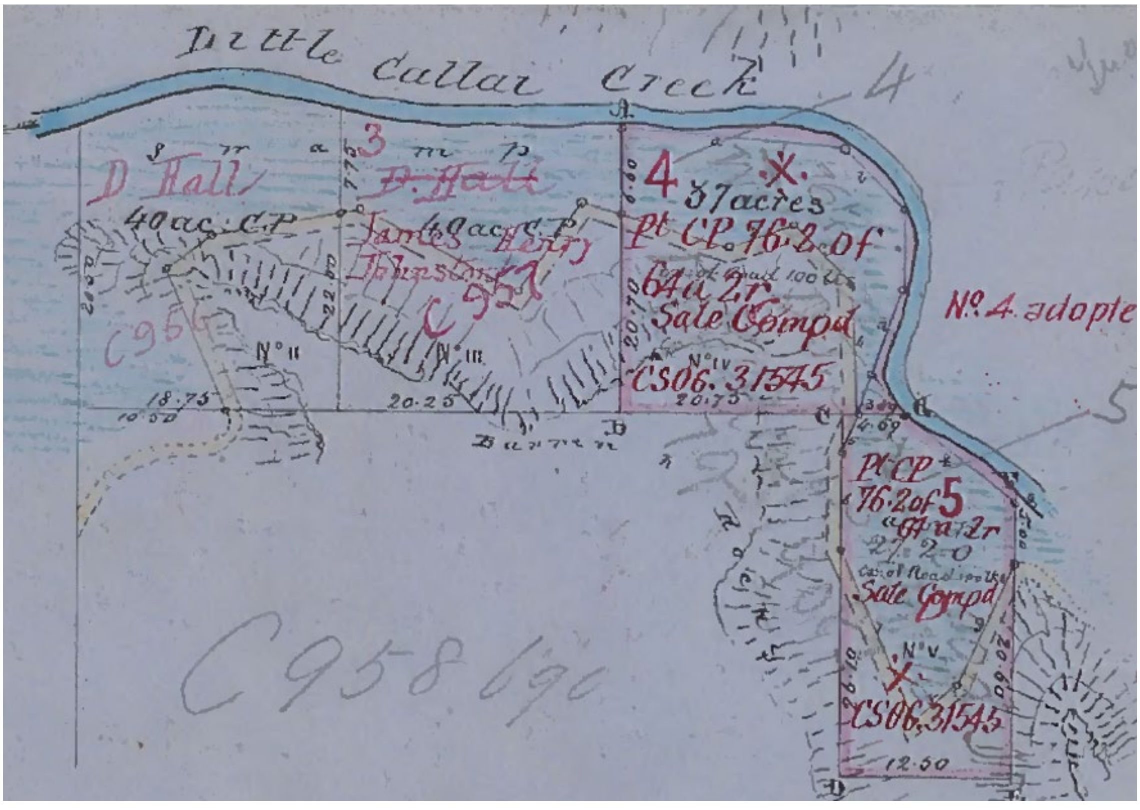


Figure 6: Detail from Crown Plan 958.690 – 1867.

Figure 7: The view upstream, with the swamplands of Portions 2, 3 and 4 under flood – 2020.

The grant for Portion 2 was created in 1871 as Certificate of Title Volume CXLVII Folio 37. Certificates of Title commenced in 1863, with Roman numerals being used to denote the volumes in the register. This practice continued from Volume I Folio 1 up until 1875 with Volume CCXXIX Folio 250 (which is Volume 229 Folio 250). Then Volume 230 Folio 1 became the first Certificate of Title not using the Roman numerals.

3 FURTHER FIRST GRANTS ALONG LITTLE CATTAI CREEK

Upstream along the creek, between Portion 14 and Portion 18, Portions 50 to 60 (applied for under the Crown Lands Alienation Act 1861) were surveyed in 1880. Each of these portions was 40 acres in area. The original intention was for each portion to comprise 40 acres and that the side boundaries of each portion would be parallel and on the cardinal (i.e. running north-south), with the rear boundary being a line square. The first three portions (numbered 50, 51 and 52) were surveyed 20 chains wide (Figure 8), with the land area of 40 acres being governed and determined by the shape of Little Cattai Creek (a natural boundary) and the length of the side boundary. Note that the watercourse was notated as 'Little Cattai Creek' in the plans of 1833 but called 'Little Caddai Creek' in the survey of 1880, which was later amended back to the original 'Cattai'.

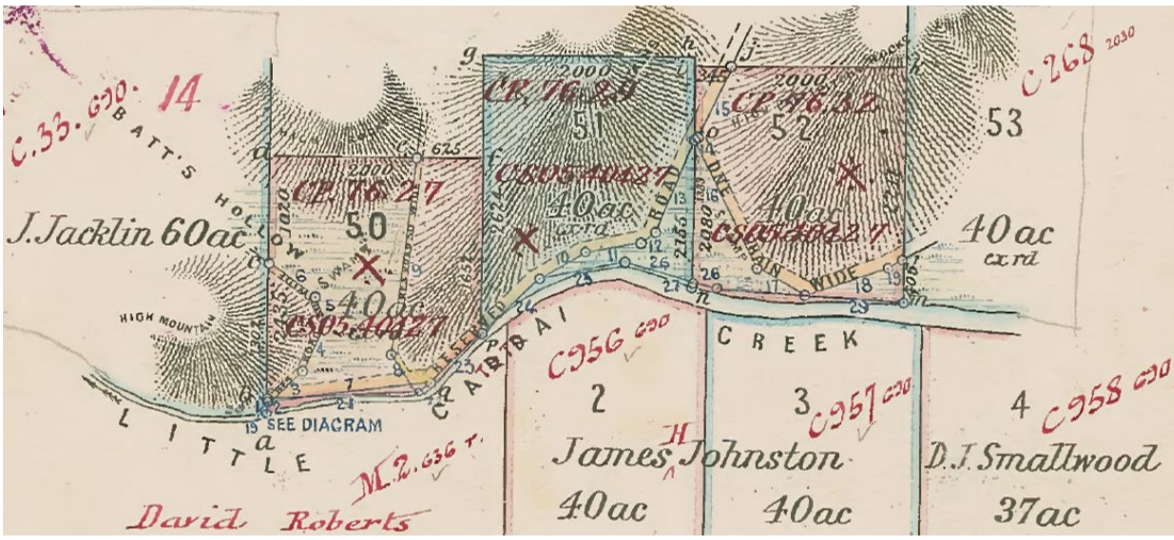


Figure 8: Detail from Crown Plan 267.2030 showing Portions 50 to 52 – 1880.

These surveys in 1880 were conducted using a theodolite (Figure 9) and chain. From 1872, the use of a theodolite in land surveys was mandatory. Accurate distance measurements were not attainable in all Crown land areas until the mid-1880s with the introduction of the steel riband, so we know that at Little Cattai Creek in 1880 the angles were survey accurate and the distances not quite so.

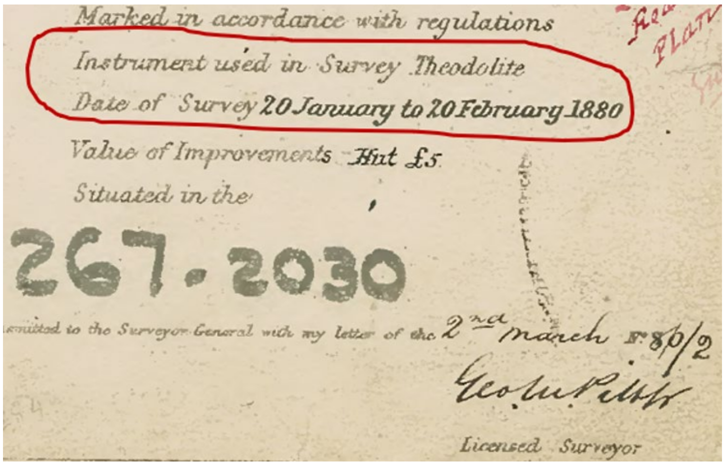


Figure 9: Detail from Crown Plan 267.2030 showing instrument used is theodolite – 1880.

Corner 'a' of Portion 50 (Figure 10) is a large stake placed 'near corner of fence'. There appears to be no other reference to the eastern side boundary of Portion 14, which is the intended kick-off point for the land grants in 1880. These latest land grants were also surveyed by Licensed Surveyor George Matcham Pitt Jr. Remembering that the boundary of Portion 14 was first surveyed by Felton Matthew in 1832, there is a good chance that the fence at corner 'a' was *adopted* by Pitt Jr. as defining the south-eastern corner of Portion 14 and therefore common to both surveys.

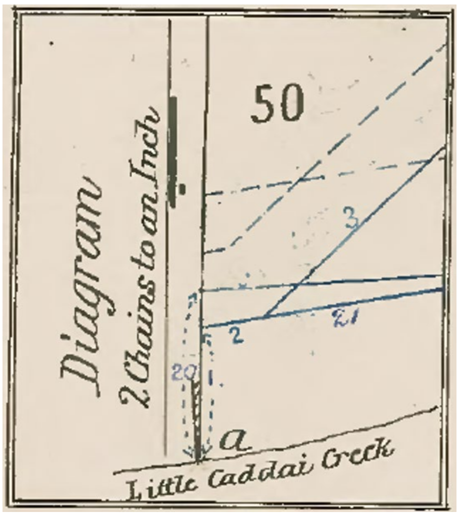


Figure 10: Diagram from Crown Plan 267.2030 showing corner 'a' – 1880.

Portion 53 is only 14.6 chains wide (Figures 11 & 12) and adjoins Portion 52. The common side boundary extends further inland in order to maintain the acreage of 40.

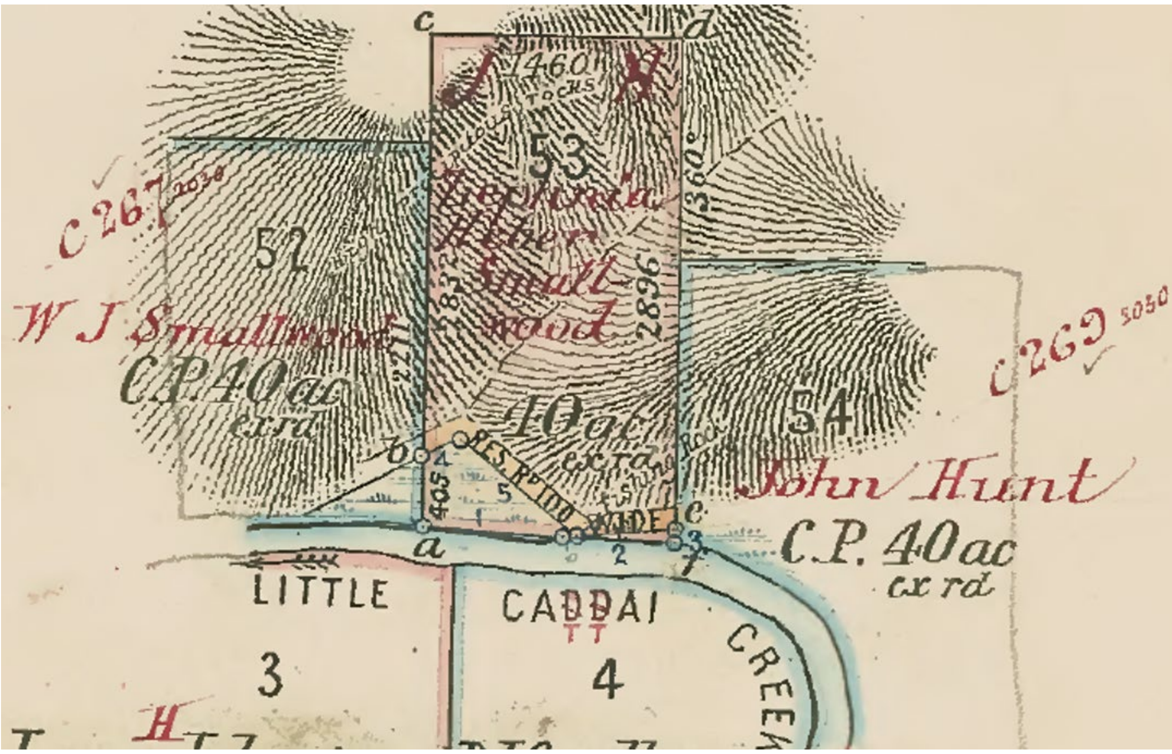


Figure 11: Detail from Crown Plan 268.2030 showing Portion 53 – 1880.

Figure 12: View downstream from high on Portion 53 – 2020.

Detail from Portion 53 (Figure 13) shows a feature called 'Fishing Rock'. The obvious first question is: Was this a recognised Aboriginal heritage site? Various landowners, over the decades, have scoured the Fishing Rock in the hope of finding evidence of Aboriginal carvings or artefacts but have remained unfulfilled. Perhaps the Fishing Rock (Figure 14) was simply a natural waterside feature used by the early survey teams to indulge in a little food gathering and recreation.

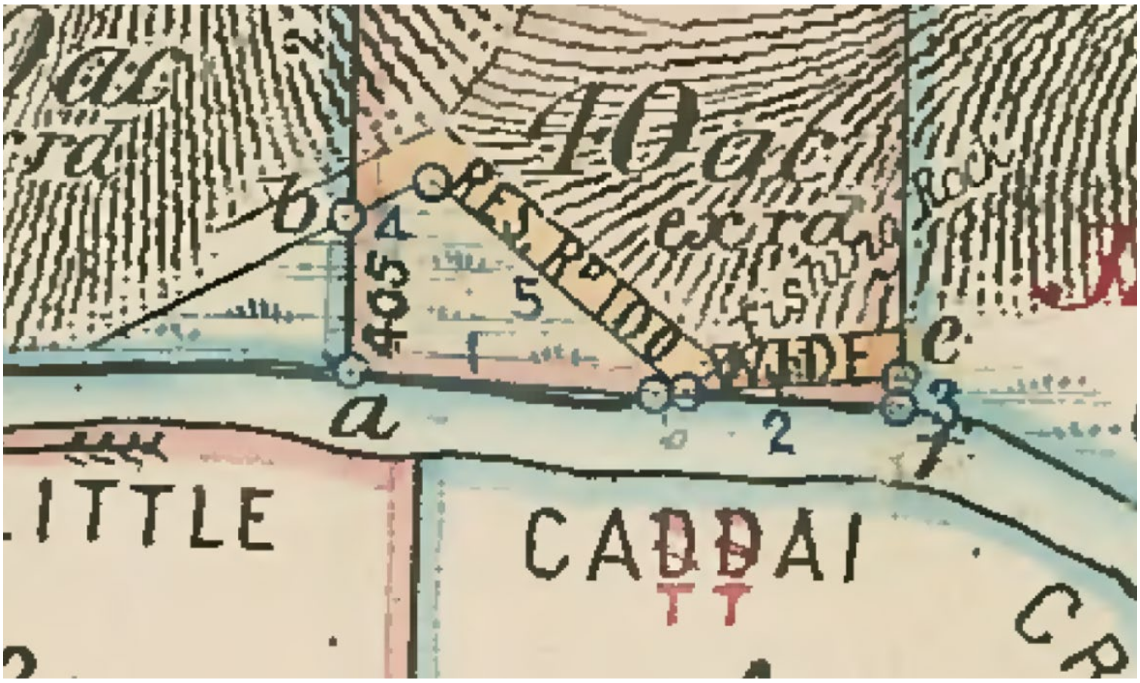


Figure 13: Detail from Crown Plan 268.2030 showing 'Fishing Rock' – 1880.

Figure 14: The 'Fishing Rock' feature – 2020.

Portion 54 is 15.81 chains wide (Figure 15) and adjoins Portion 53. Once again, the side dimensions are set to achieve the desired area of 40 acres.

Figure 15: Detail from Crown Plan 269.2030 showing Portion 54 – 1880.

Portion 55 is 15 chains wide, Portion 56 is 14.88 chains wide, Portion 57 is 15.26 chains wide and Portion 58 is 13.11 chains wide and all adjoin, with sides on the cardinal (Figure 16).

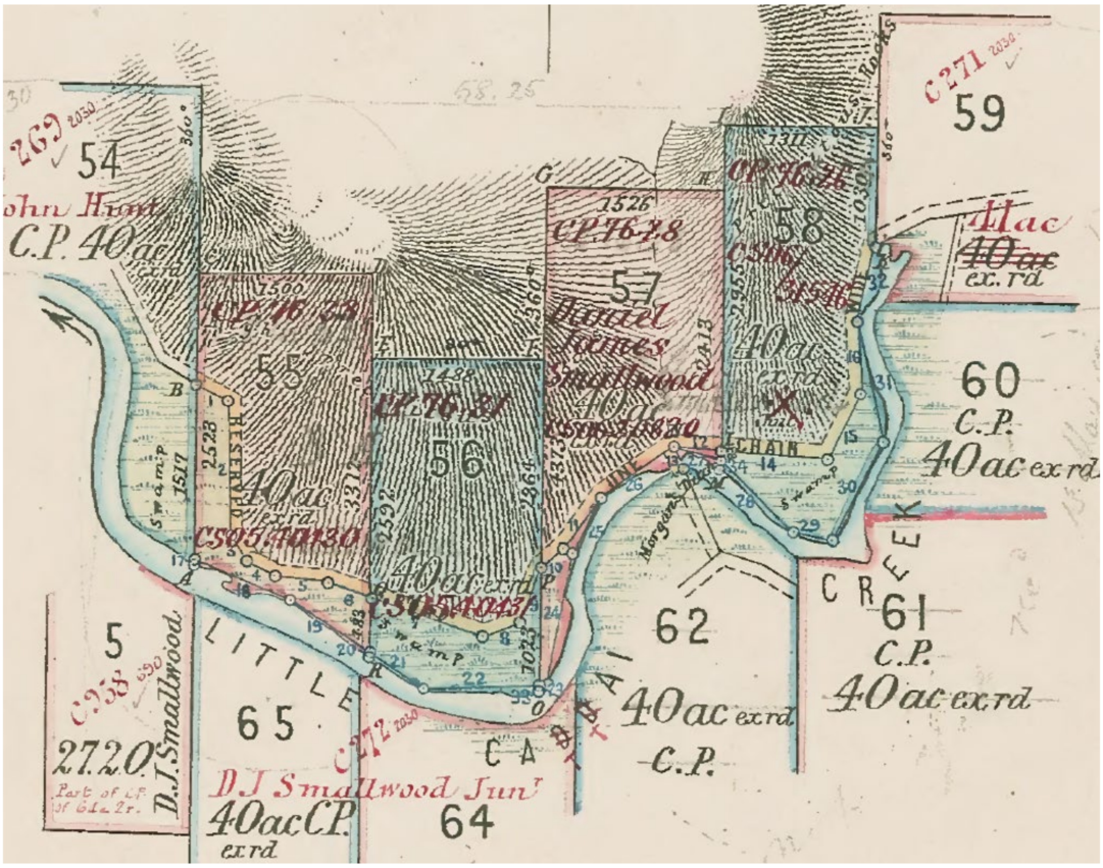


Figure 16: Detail from Crown Plan 270.2030 showing Portions 55 to 58 – 1880.

There is a notation of another drain, ‘Morgan’s Ditch’, between Portions 57 and 58 (Figure 17).

Figure 17: Detail from Crown Plan 270.2030 showing ‘Morgan’s Ditch’ – 1880.

Portion 59 returns to 20 chains wide but is 41 acres in area because common corners have been formed with the south western boundary line of original Portion 18 (Figure 18). A tree was found and adopted for the westernmost corner of Portion 18: ‘Apple (old corner)’. A rock reference mark was cut at Corner ‘g’, after maintaining the original dimensions for Portion 18. Note that Portion 59 is situated at the very head of Little Cattai Creek. The grant description for Portion 58 cites the *right bank* of the creek being the boundary, while the description for Portion 59 cites the *left bank* of the creek being the boundary!

Figure 18: Detail from early Parish Map 271.2030 showing original marks as found – 1880.

Portions 60 to 65 are each of varying widths in order to achieve a consistent area of 40 acres. The original intent was for all side boundaries to be parallel and on cardinal with the rear boundary being a right-angled line (Figures 19 & 20).

Figure 19: Detail from Crown Plan 291.2030 showing Portions 60, 61 and 63 – 1880.

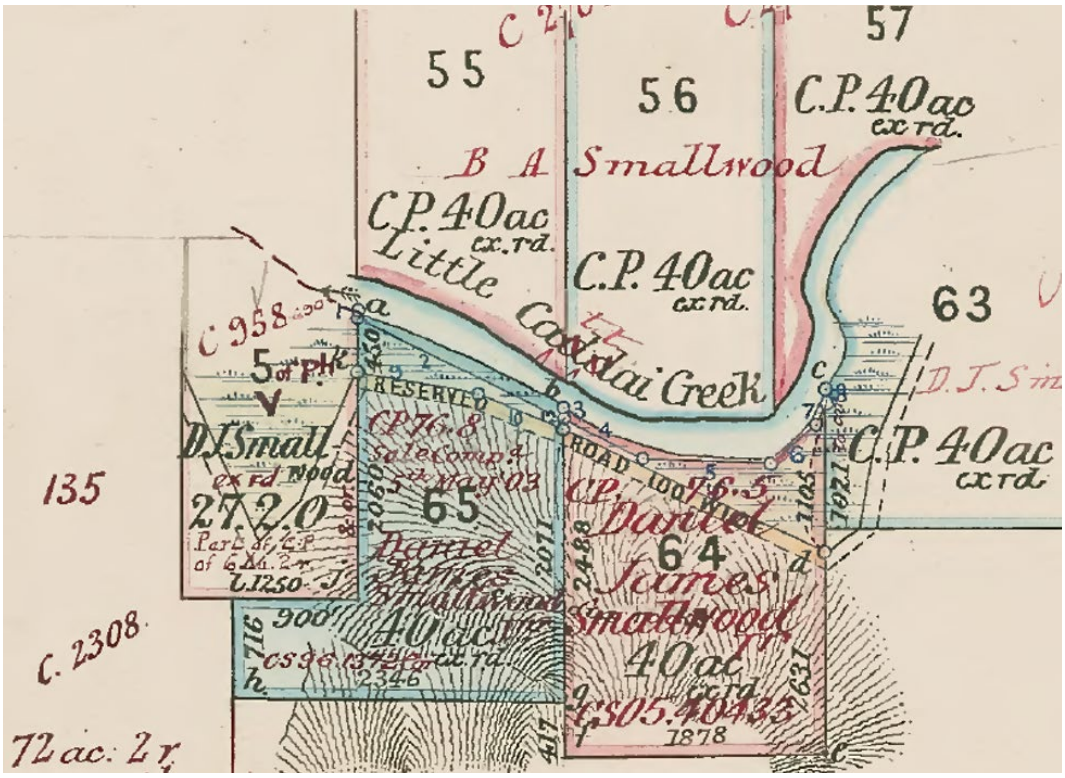
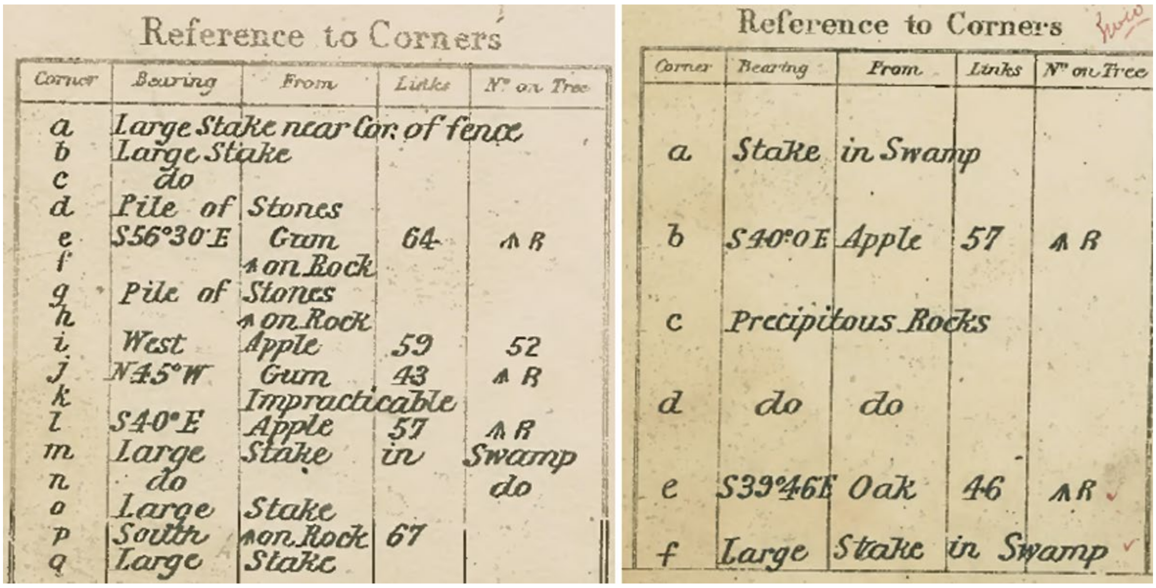


Figure 20: Detail from Crown Plan 272.2030 showing Portions 64 and 65 – 1880.

However, not every corner was marked. It appears that a cliff or tall rock ledge was sufficient to deter our intrepid survey team from occupying and marking some of the more difficult corners. ‘High rock impracticable’, ‘impracticable’ and ‘precipitous rocks’ are common notations to be found on the Crown plans (Figure 21).



Reference to Corners

Corner	Bearing	From	Links	No. on Tree
a	Large Stake near Cor. of fence			
b	Large Stake			
c	do			
d	Pile of	Stones		
e	S56°30'E	Gum	64	∧ R
f		∧ on Rock		
g	Pile of	Stones		
h		∧ on Rock		
i	West	Apple	59	52
j	N45°W	Gum	43	∧ R
k		Impracticable		
l	S40°E	Apple	57	∧ R
m	Large	Stake	in	Swamp
n	do			do
o	Large	Stake		
p	South	∧ on Rock	67	
q	Large	Stake		

Reference to Corners

Corner	Bearing	From	Links	No. on Tree
a	Stake	in Swamp		
b	S40°0E	Apple	57	∧ R
c	Precipitous Rocks			
d	do	do		
e	S39°46E	Oak	46	∧ R
f	Large	Stake	in Swamp	

Figure 21: Detail from Crown plans showing corners not marked – 1880.

Detail from an early Parish map shows all the grants along the upper reaches of Little Cattai Creek (Figure 22). To this map has been added a coloured symbol at portion corners to indicate the nature of the corner marking, i.e. rock marks or rock reference marks (blue), tree reference marks (green), piles of stone (light blue) or no mark placed at all (red).

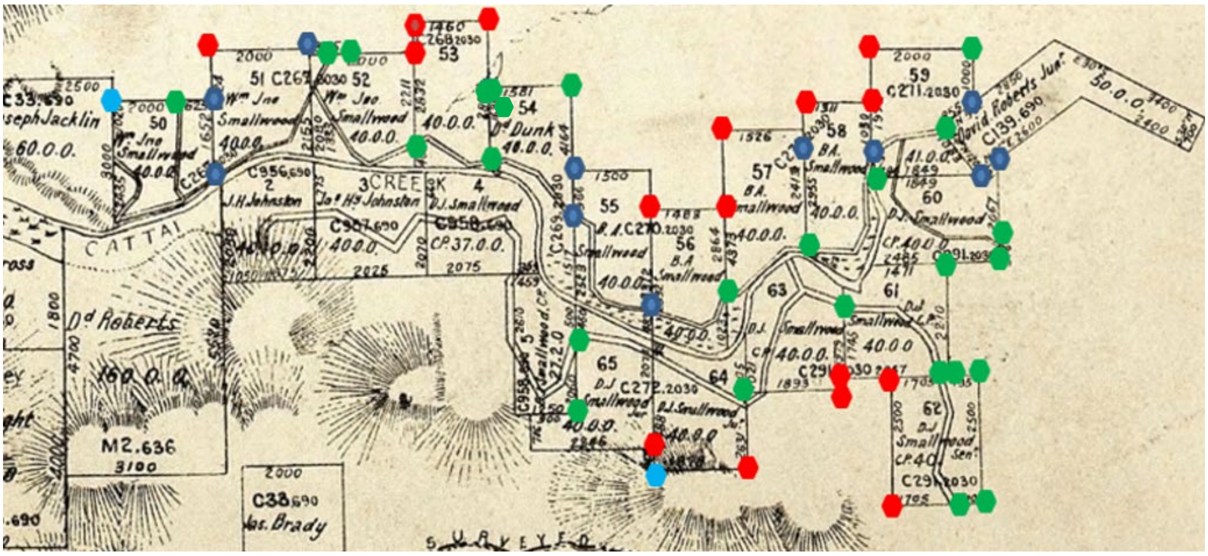


Figure 22: Grants along the upper reaches of Little Cattai Creek showing corner marking – 1880. Red = corners where marks were not placed, green = corners where reference trees were placed, blue = corners where rock marks or reference rock marks were placed, light blue = corners where piles of stones were placed, all other corners were marked by stakes.

4 LATER SURROUNDING CROWN GRANTS

The survey of Portions 133, 134 and 135 was the first of the later surrounding Crown grants and occurred in 1902 (Figure 23), 35 years after the survey of Portions 2 to 5 and forming a common boundary with these portions.

Figure 23: Later grants by Crown Plan 2308.2030 showing the abuttal with Portions 2 to 5 – 1902.

'Old marks found' on the western boundary of Portion 5 and 'corner found' (Figure 24) determine a bearing of 179° 49'. Along the southern boundary of Portions 3 and 4 a 'corner found' at the south-west of Portion 3 and the 'corner found' at the north-west of Portion 5 determine a bearing of 89° 50', almost at a right angle. This is interesting in that the earlier angle work was by circumferentor.

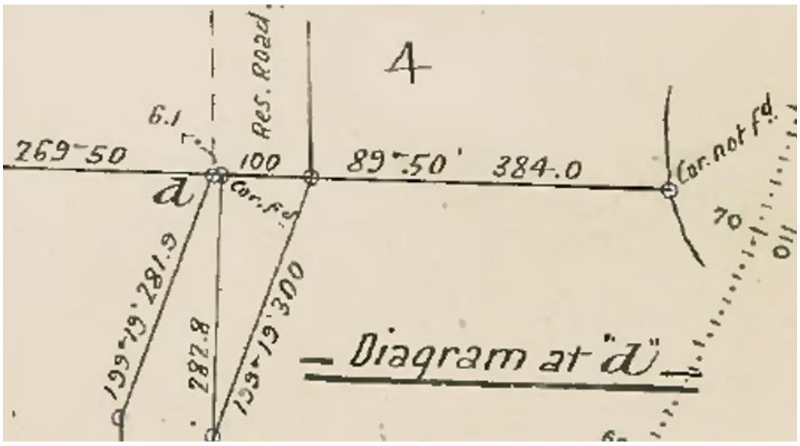


Figure 24: Detail from diagram on Crown Plan 2308.2030 – 1902.

The first of the surveys north of Little Cattai Creek for later surrounding Crown grants came with Portion 141 in 1911, 30 years after the original survey for Portions 51 and 52 (Figure 25). A peg, a broad arrow rock mark and a 'marked line' were found at the north-east and north on Portion 51. Short lines 1, 2, 3 and 5 are all parallel or at right angle, indicating a bearing of 89° 37'. It is interesting that the side boundaries of Portion 141 were then created on cardinal.

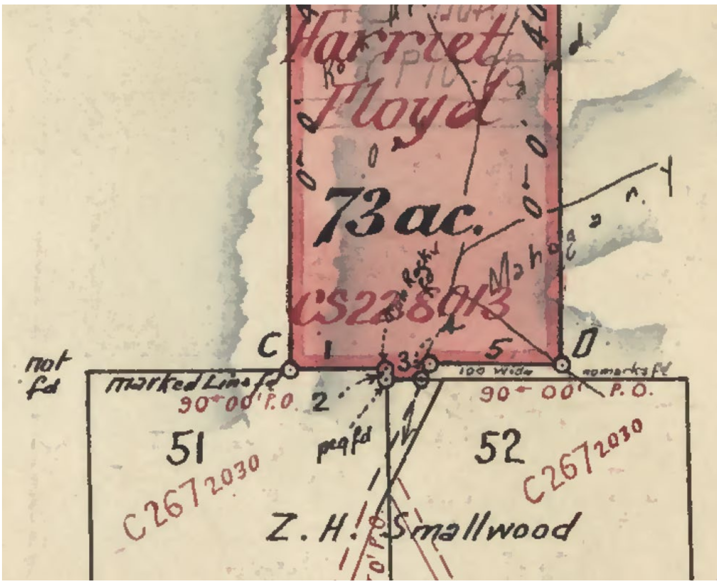


Figure 25: Later grant by Crown Plan 2826.2030 showing the abuttal with Portions 51 and 52 – 1911.

No further Crown grant activity occurred north of Little Cattai Creek until 1952, another 40 years later, when Crown land surrounding the first grants was once again released. Portion 219 was created, with the intention of forming a common boundary with original Portions 52, 53, 54 and 55 and the more recent Portion 141 (Figure 26).

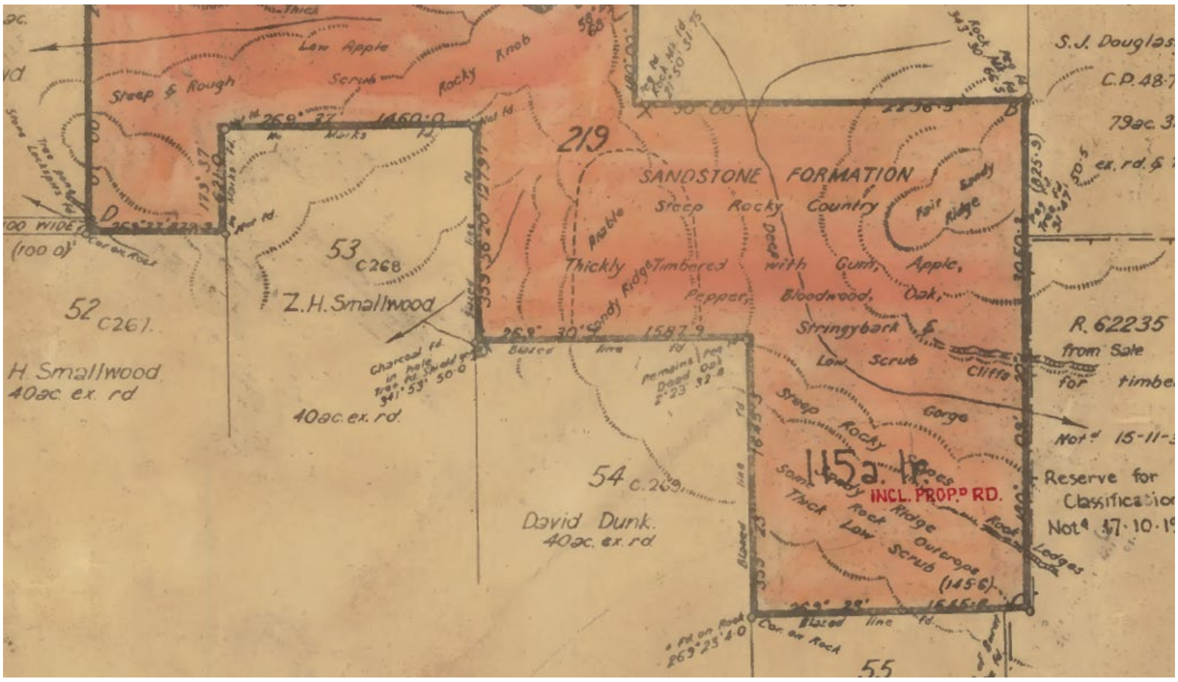


Figure 26: Detail from Crown Plan 7371.2030 showing Portion 219 adjoining the original portions – 1952.

The survey for Portion 219 formed a common boundary with Portion 141, on cardinal, then continued at 89° 37', laying 'per original' angle and distance all the way to the north-west corner of Portion 54, where an original reference tree was found. It is interesting that the survey of Portion 219 shows corner marks for Portion 53 (Figure 27) as 'not found'. Not surprisingly, as we know that the survey for Portion 53 placed no marks at those corners. Marks *were* found along the rear of Portion 54, which indicates a clear excess of 6.9 links (1.4 m). Does this suggest that laying 'per original' across the rear of Portion 53 is erroneous?

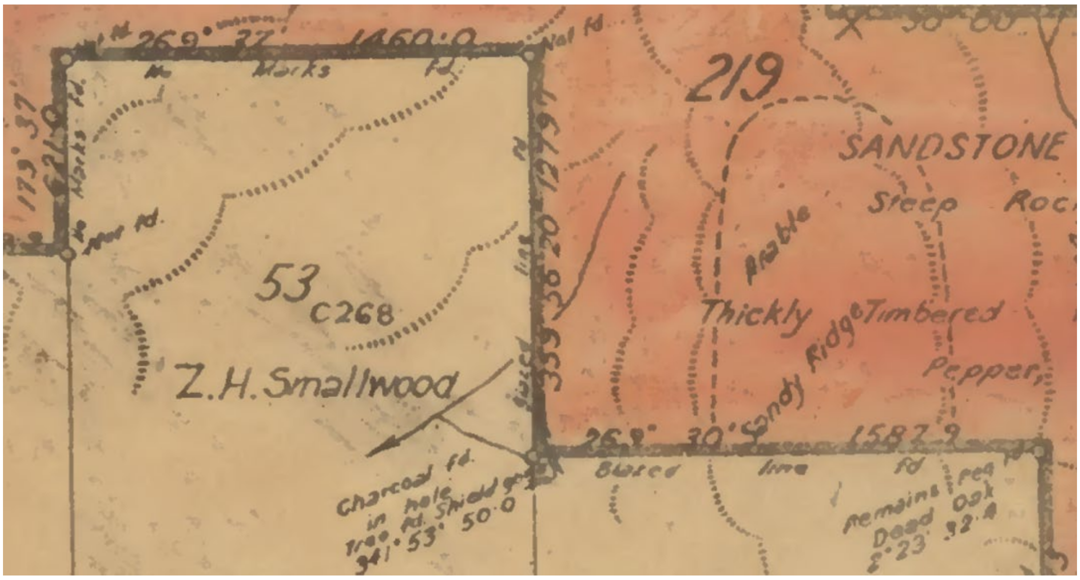


Figure 27: Detail from Crown Plan 7371.2030 showing no marks found on original Portion 53 and marks found on original Portion 54 – 1952.

Crown Plan 7371.2030 also found a broad arrow in rock reference mark at the north-west corner of Portion 55 (Figure 28) and a purported burnt-out stake at the north-east corner of Portion 55.

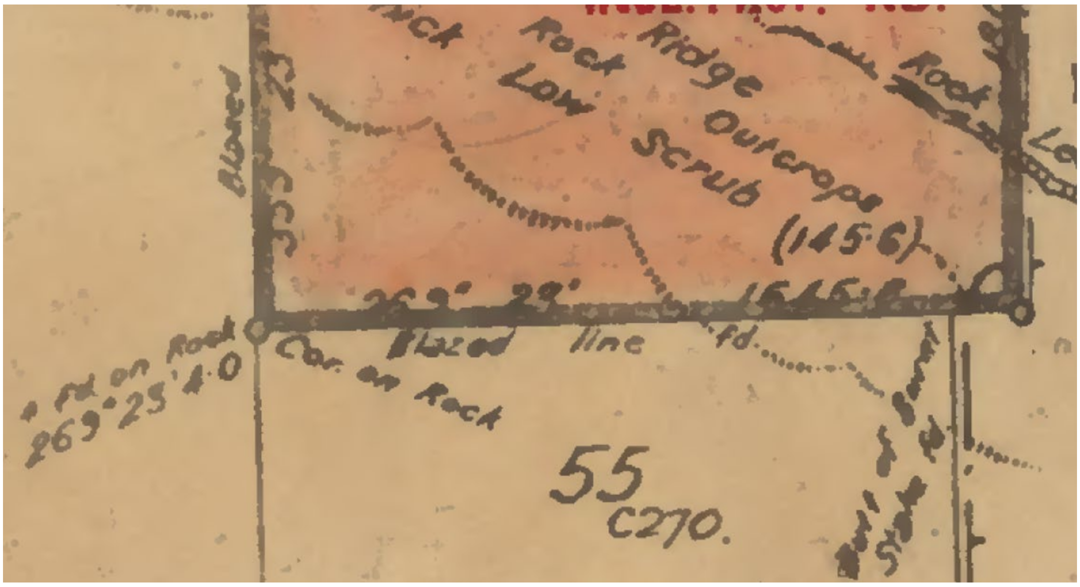


Figure 28: Detail from Crown Plan 7371.2030 showing original marks found on Portion 55 – 1952.

Crown Plan 7930.2030*,* in 1958, connected to the western boundary of Portion 141 but also found three original rock marks from the survey of Portion 51 in 1880 (Figure 29). This was the only surrounding survey that connected back down to marks at Little Cattai Creek and displays an excess of 5 links. This is supported by mark evidence and a post and rail fence occupation along the northern boundary of Portion 51, which now displays a bearing that is 11’ off being square. The north-west corner of Portion 51 was not marked in the original survey and neither corner was occupied by the original surveyor to read or set the angle from one corner to the other.

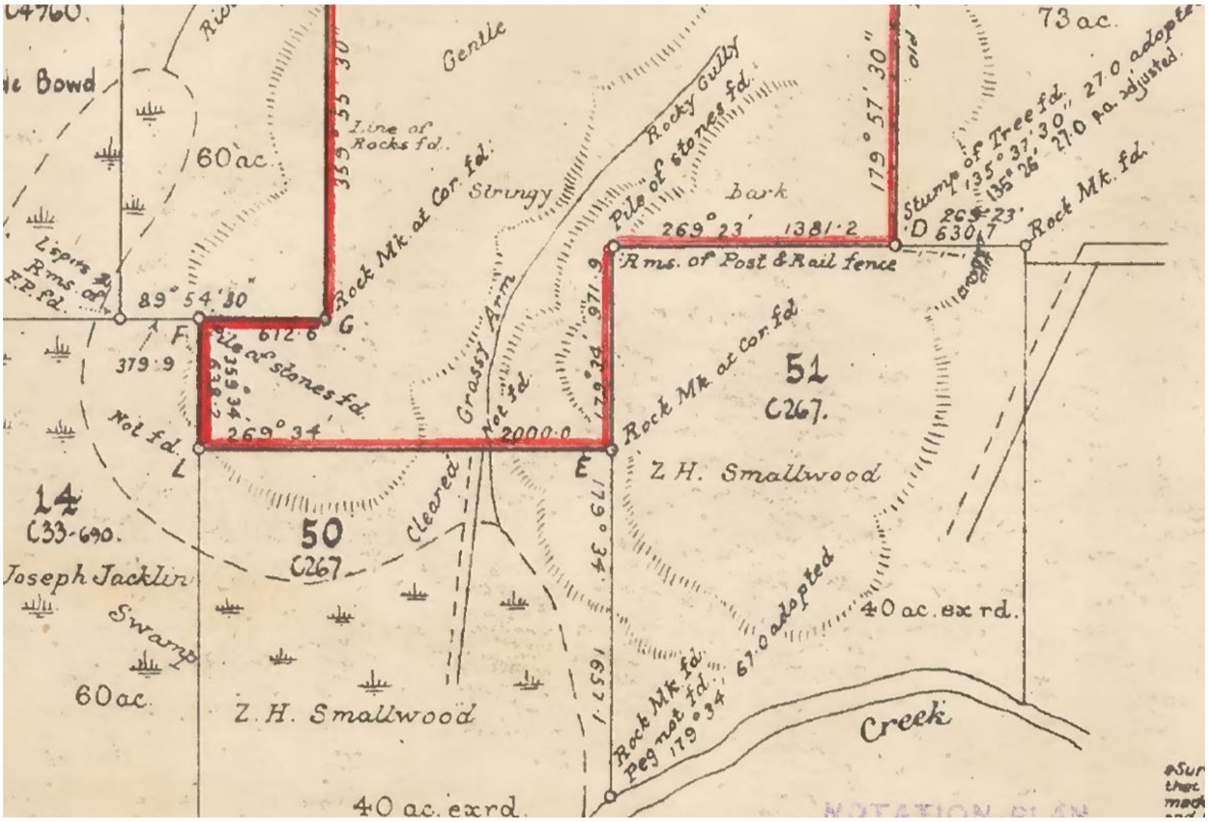


Figure 29: Detail from Crown Plan 7930.2030 showing three original rock marks found on Portion 51 – 1958.

The remainder of the surveys for the surrounding Crown grants were all compiled Departmental Plans in 2009 (DP 1139713, DP 1142075 and DP 1152513), which meant that the titles created from them carried a limitation as to survey accuracy and veracity. DP 1152513 did, however, include a short survey along the boundary of Portion 219 where it was common with original Portions 54 and 55. All the marked corners from the 1952 survey were found.

5 DO ANY ORIGINAL MARKS REMAIN?

In 1985, DP 730390 subdivided Portions 58 and 61 but in so doing also surveyed across Portions 56, 57, 60 and 62 (Figure 30). Five original broad arrow rock marks were found, together with one original reference tree and one original stake in swamp. Additionally, over the last two years, several of the early Crown grant portions have been used to prepare re-definition surveys as rural projects for candidates of the Board of Surveying and Spatial Information (BOSSI) assessments. Portions 52 through to 56 were surveyed completely (Figure 31). Reference rock marks cut into the face of the cliff are examples of some of the original marks that were found (Figure 32).

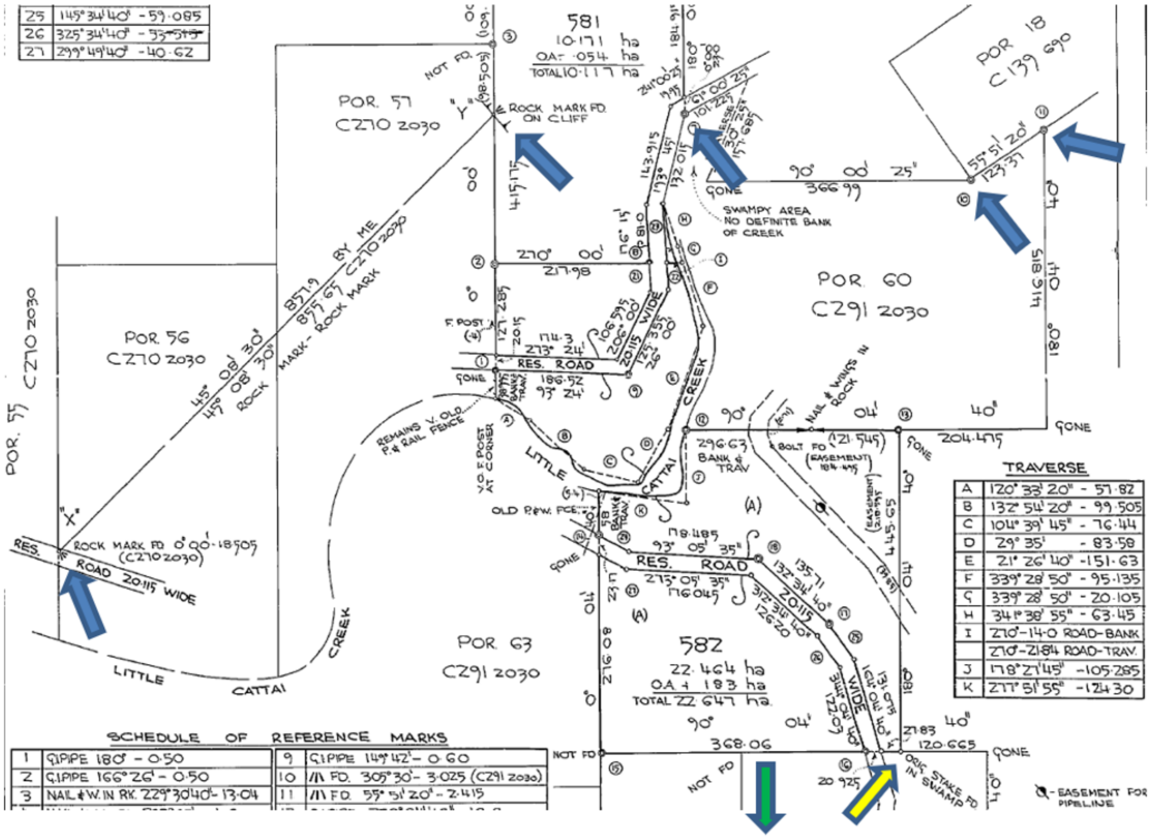


Figure 30: Detail from DP 730390 showing original marks found – 1985.

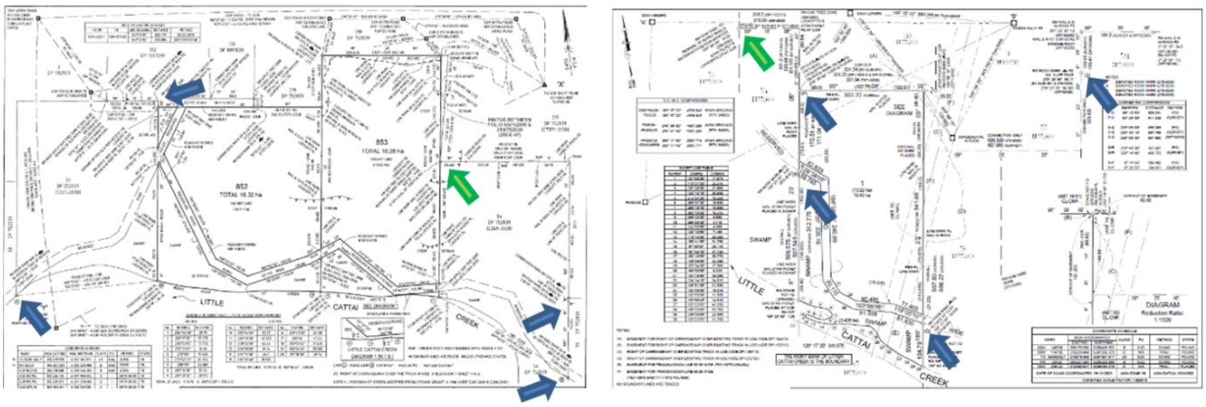


Figure 31: Detail from two BOSSI rural projects showing original marks found – 2021.

Figure 32: Original broad arrow in rock reference marks cut into vertical cliff face – 2021.

In comparison to the situation in 1880 (see Figure 22), the original marks remaining after 140 years consist of 10 rock marks and one reference tree (Figure 33). Two side boundaries (one on Portion 51 and one on Portion 55) both retain *pairs* of original rock marks, which the modern surveys find to be parallel.

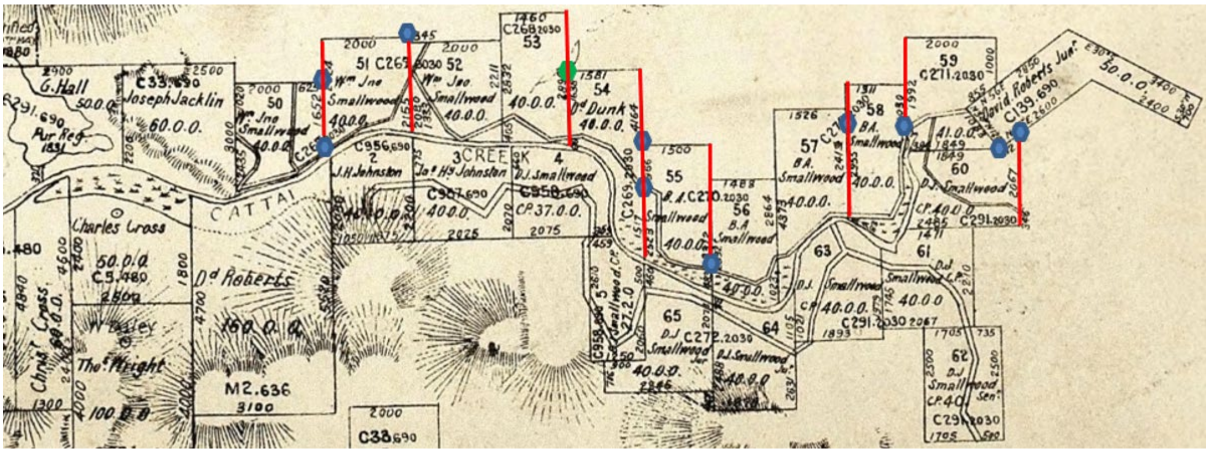


Figure 33: Original rock marks (blue) and reference tree (green) still existing – 2021.

6 SLIVERS OF LAND: OVERLAP, HIATUS AND ORIGINAL INTENT

Even without the direct evidence from field books (this evidence should be revealed soon by a research visit to State Archives), it can be surmised how the 1880 field work was undertaken: a traverse along the flat land of Little Cattai Creek and the turning of parallel side boundary lines. Portion width and offset area to the creek bank were calculated along with the required depth of each portion in order to achieve a total area of 40 acres, which in most cases was then laid in, away and up from the creek. Terrain restraints meant that some rear corners were neither occupied nor marked.

So, what do we do in a survey for re-definition purposes? The side boundaries are definitely parallel, the width of the portion is not 'per original' and the lengths of the side boundaries are also not 'per original' because of the uncertainty in the measuring of the original distances. A common boundary can be formed with the later Crown grants (which were survey accurate when it came to measured distances) across the rear of the original portions, but the side boundaries are kept parallel and straight. In some cases, this will leave a hiatus between the original and later grants, in other cases it will create an overlap of title where a part of Crown land has been granted twice.

Portion 219 in 1952 laid 'per original' distances across the rear of Portion 53, which introduced a significant bend in the eastern side boundary of Portion 53 that created the hiatus to the original straight-line boundary (Figure 34). The sliver of land forming the hiatus is now fully defined by survey and can be dealt with. The question is whether Portion 53 (new Lot 853) is entitled to claim this additional sliver and area. Lot 853 is vacant and unoccupied, and the boundary is not fenced, so there would appear to be little evidence of claiming rights. A re-definition survey of Portion 219 would result in the same scenario except that the original intention of Crown Plan 7371.2030 in 1952 was to form a common boundary with original Portion 53!

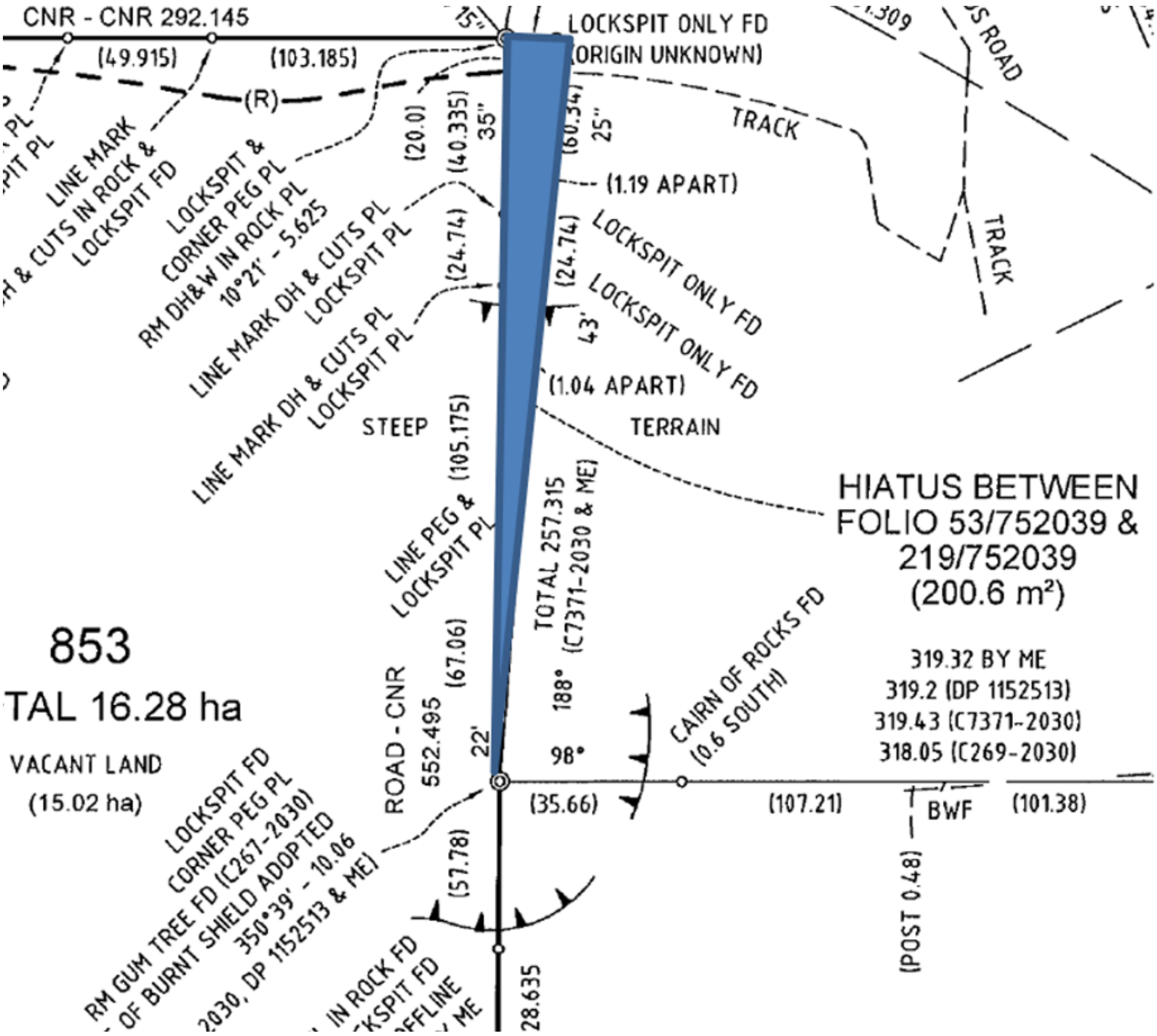


Figure 34: Detail from re-definition survey showing hiatus with Portion 219 – 2020.

The eastern boundary of Portion 54 was overlapped by the survey of Portion 219 in 1952. The intended straight-line side boundary of Portion 54 was compromised by a swing of 13' being introduced as a result of laying in 'per original' distances (Figure 35).

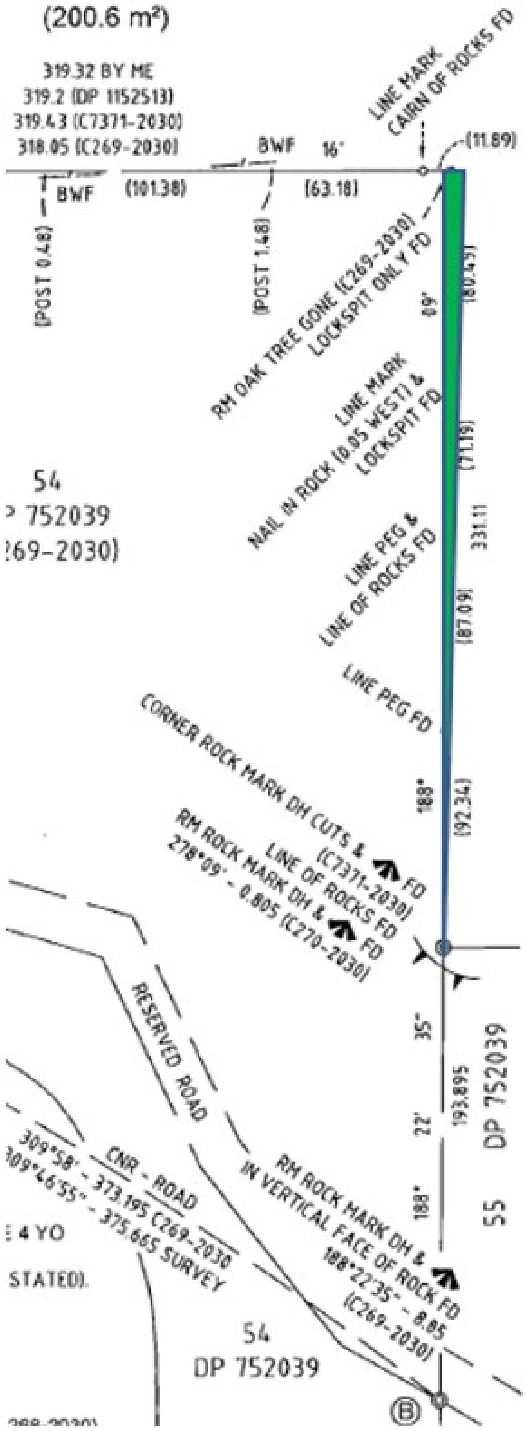


Figure 35: Detail from re-definition survey showing overlap of Portion 54 – 2020.

7 CONCLUDING REMARKS

This paper has outlined some of the interesting and fascinating questions raised when trying to re-establish the boundaries of original Crown grants. So, how do the original grants along Little Cattai Creek stand up? Too many of the surveyors involved in following and re-defining the original surveys have, in the absence of finding original marks, decided to lay 'per original' distances, without regard to the original intention of the first Crown grants.

These later surveys have created bends in the side boundaries, left slivers of land unalienated and in some cases defined a fresh grant over a sliver of land which had already been granted. There was no reliable distance measuring tool available at the time of first grant surveys, so reliance must be placed on the angular relationships between boundaries. The lengths of the side boundaries can only be determined from any original marks that are found. With the knowledge of such uncertainty, it is acceptable to re-define the original portions as having a rear boundary common with that of the surrounding later Crown grants. The finding of rock marks from the original surveys has enabled side boundaries to be placed in the same relationship to each other as in the original surveys of 1880.

A plan of re-definition of any original portion should examine the intent of the original survey, indicate and define any remnant slivers of land between parcels and then decide if such a sliver can or should be included within the re-defined parcel. Noting that 40 acres are equivalent to 16.19 ha, the parcel areas after re-definition by surveys discussed in this paper are:

- Portion 52: 16.32 ha.
- Portion 53: 16.28 ha.
- Portion 56: 16.45 ha.
- Portions 58 and 61: 32.76 ha total combined (average 16.38 ha).

REFERENCES

de Belin F. (2019) Status of a stream: Who owns the creek? *Proceedings of Association of Public Authority Surveyors Conference (APAS2019)*, Pokolbin, Australia, 1-3 April, 231-250.

de Belin F. (2020a) The skeletons in Shrimpton's Creek, *Proceedings of APAS Webinar Series 2020 (AWS2020)*, 5 May – 30 June, 39-58.

de Belin F. (2020b) Martin's Creek: Small flow, big issue, *Proceedings of APAS Webinar Series 2020 (AWS2020)*, 5 May – 30 June, 71-90.

Upgrades to the Australian Geospatial Reference System

Anna Riddell
Geoscience Australia
Anna.Riddell@ga.gov.au

Craig Harrison
Geoscience Australia
Craig.Harrison@ga.gov.au

Jack McCubbine
Geoscience Australia
Jack.McCubbine@ga.gov.au

Nicholas Brown
Geoscience Australia
Nicholas.Brown@ga.gov.au

ABSTRACT

The Australian Government has committed $225 million to provide 5-10 cm accurate positioning to anyone, anytime, anywhere in Australia. This is a significant improvement from the 5-10 m accuracy you can currently achieve using Global Navigation Satellite System (GNSS) enabled devices. In anticipation for the growing use and reliance on positioning technology, the Intergovernmental Committee on Surveying and Mapping's Permanent Committee on Geodesy (ICSM PCG) is working to ensure we have the datums (GDA2020), reference frames (Australian Terrestrial Reference Frame, ATRF), working surfaces (Australian Vertical Working Surface, AVWS), models (e.g. AUSGeoid) and standards (e.g. GeodesyML) implemented as part of the Australian Geospatial Reference System (AGRS) to make best use of precise positioning. This includes delivering on the commitments of the Positioning theme of the Foundation Spatial Data Framework (FSDF) and the Geoscience Australia Positioning Program. Furthermore, these upgrades will underpin key strategic priorities of Digital Earth Australia, Cadastre 2034, Building Information Modelling (BIM) and the Spatial 2026 Agenda including the creation of a 4D cadastre underpinned by a coordinate system with a time-dependent reference frame and improved spatial accuracy (particularly in height). With a focus on improving the AVWS, airborne gravity surveys are proposed for areas in Eastern Victoria and state-wide coverage of NSW during 2022. The objective of these surveys is the collection of consistent and evenly distributed airborne gravity data over regions of interest. This data is required to significantly improve the gravity data over these priority regions to enhance the gravity model (known as the gravimetric quasigeoid model) and improve height determination from GNSS positioning. It will also assist geoscience researchers to further develop their understanding of the geological 'architecture' and how it has evolved over time. The current version of the gravity model has an uncertainty of 5-8 cm, and the airborne gravity data will reduce this uncertainty to 1-3 cm. Enhancing the gravity model will also significantly improve height determination from GNSS positioning. This presentation outlines these developments and provides an overview over current activities to further improve the AGRS.

KEYWORDS: *Datum, reference system, GDA2020, ATRF, AVWS.*

GNSS Analysis at Geoscience Australia

Vincent Rooke
Geoscience Australia
Vincent.Rooke@ga.gov.au

Simon McClusky
Geoscience Australia
Simon.McClusky@ga.gov.au

Carl Wang
Geoscience Australia
Carl.Wang@ga.gov.au

Guorong Hu
Geoscience Australia
Guorong.Hu@ga.gov.au

Salim Masoumi
Geoscience Australia
Salim.Masoumi@ga.gov.au

Minghai Jia
Geoscience Australia
Minghai.Jia@ga.gov.au

Umma Zannat
Geoscience Australia
Umma.Zannat@ga.gov.au

ABSTRACT

Geoscience Australia (GA) is responsible for the operation, improvement and development of Global Navigation Satellite System (GNSS) positioning for Australia, including geospatial reference systems in the Australian region, Continuously Operating Reference Stations (CORS) and the GNSS data archive. The GNSS Analysis section is responsible for high-quality GNSS data processing and analysis. Currently, this includes the provision of Regulation 13 (Reg 13) certificates, GNSS antenna calibrations and the AUSPOS online service. Through Positioning Australia, the team is also delivering Ginan, a multi-GNSS analysis centre software that GA is developing as an open-source software to operate a real-time positioning correction service enabling Precise Point Positioning (PPP) for the surveying industry and other users. Ginan version 1.0 alpha is currently available, with a planned beta release in early 2022 and the highly anticipated operational release of Ginan version 1.0 planned for June 2022. Moreover, the GNSS Analysis team is the International GNSS Service (IGS) Analysis Center Coordinator (ACC) for the delivery of combined IGS products including three different accuracy levels of GNSS satellite orbits and clocks (ultra-rapid, rapid, final). These delivered IGS products are used worldwide for comprehensive purposes of research and applications. The near-real-time (NRT) hourly Zenith Total Delay (ZTD) retrieved from GNSS signals is also provided by the GNSS Analysis team to the Bureau of Meteorology in Australia and the Met Office in the UK for the weather forecasting, now being part of operational weather forecasting. This presentation outlines how the GNSS Analysis team continues to enhance the accuracy and reliability of positioning through innovative technology and services.

KEYWORDS: *GNSS, Reg 13, Ginan, AUSPOS, IGSACC.*

Digital Survey Plans in Practice

Adrian White
DCS Spatial Services
NSW Department of Customer Service
Adrian.White@customerservice.nsw.gov.au

Daniel Griffin
NSW Land Registry Services
Daniel.Griffin@nswlrs.com.au

ABSTRACT

NSW is currently transitioning from paper to digital survey plans. In August 2020, a discussion paper was released seeking industry feedback on the transition and a potential future state scenario for digital survey plans. The future state included moving to an online plan creation to registration process, requiring surveyors to lodge digital data with their plans and the circumstances by which data could in the future be considered the legal point of truth. That feedback has subsequently been reviewed and incorporated into the implementation of new digital survey plan services, which are being released through NSW LRS Connect (https://connect.nswlrs.com.au), the new online portal of NSW Land Registry Services (LRS). This presentation provides an overview of stakeholder views and how concerns raised by stakeholders are being addressed in the transition from paper to digital survey plans. It also demonstrates how surveyors can more easily generate digital survey plans using the new services and the benefits that will be available to industry as a result.

KEYWORDS: *Digital survey plans, cadastre, land titles.*

Evolution of Surveying at TAFE NSW to Meet the Needs of Industry During the COVID-19 Pandemic and Beyond

Sam Ebert
TAFE NSW, South Region
samuel.ebert@tafensw.edu.au

ABSTRACT

Most surveying organisations or individuals have a connection to TAFE NSW. Whether as a former or existing student themselves or working with someone who completed a vocational qualification. Surveying delivery has been occurring for over 50 years, with TAFE NSW delivering Certificate III, Certificate IV and Diploma qualifications to hundreds of surveyors throughout NSW and interstate. It is pivotal that TAFE NSW engages with industry to ensure we are meeting their demands and keeping abreast of the technological changes. There is complexity associated with training students who already work in the industry, students who have not yet found work in the industry, working with a declining number of teachers, and trying to remain effective amidst a global pandemic. In recent years, TAFE NSW has undergone structural changes, which has now resulted in a collaborative approach to delivery across the campuses of Ultimo, Wollongong, National Environment Centre (Albury) and Newcastle. Born out of this collaboration is a model of delivery incorporating face-to-face, online and connected (MS Teams) sessions. This model is scalable, allowing it to accommodate growing enrolment numbers, student location and available teachers. This paper demonstrates that TAFE NSW is able to meet the demands of industry, while working with and better utilising that industry.

KEYWORDS: *Training, TAFE NSW, qualifications, teachers, surveying.*

1 INTRODUCTION

TAFE NSW has existed for over 130 years and is the leading provider of vocational education and training in Australia, with more than 470,000 students enrolling in our courses and training each year (TAFE NSW, 2022a). Surveying delivery has occurred for over 50 years, with TAFE NSW delivering Certificate III, Certificate IV and Diploma qualifications to hundreds of surveyors throughout NSW and interstate. TAFE NSW has a great reputation for industry and business partnerships, which are crucial to providing a high-quality, job-ready workforce. The same emphasis on industry engagement applies to the industries of surveying and spatial information services. TAFE NSW maintains relationships with various industry bodies to ensure we are meeting their needs, keeping up with technological changes and learners are graduating job ready. TAFE NSW is going through structural changes, while the ongoing COVID-19 pandemic has also forced the organisation to modify the way it delivers its training and how learners interact with their teachers. This paper outlines these changes and demonstrates that TAFE NSW remains adaptive to meet the training demands from this key industry sector.

2 HOW TAFE NSW IS CHANGING

2.1 One TAFE Restructure

Until January 2017, TAFE NSW comprised 130 campuses across 10 institutes. Each institute had its own main campus and operated quite independently from each other. From 2017, TAFE NSW returned to a centralised model which abolished the 10 institutes and instead created five regions covering the state: South, North, West, Sydney and South-West Sydney. The 100% online part of TAFE NSW is called TAFE Digital and is the largest online education provider in Australia (TAFE NSW, 2022b). From 1 January 2019, the organisation started operating as one Registered Training Organisation (RTO) called TAFE NSW or One TAFE NSW. The impetus for this reform was a growth in competition from other smaller, more agile providers, as well as the advent of the NSW Smart and Skilled entitlement funding model. Among other things, TAFE NSW has a vision of increased capacity to support more students in those qualifications that lead to jobs, as well as being a significant provider in regional NSW and to people facing disadvantage.

2.2 Australian Skills Quality Authority (ASQA) Governance

TAFE NSW is regulated by the Australian Skills Quality Authority (ASQA). The role of ASQA is to protect the quality and reputation of the Vocational Education and Training (VET) sector. It utilises a risk-based approach, acknowledging that no RTO can be perfect (ASQA, 2022a). Its approach of proportionate compliance and enforcement supports quality through engagement and support. To ensure there is confidence in the outcomes delivered by RTOs, ASQA regularly engages with:
- Industry regulators and licencing bodies.
- Peak industry and employer groups.
- Other government agencies.
- Industry associations.

The Standards for RTOs 2015 (ASQA, 2022b) have been developed by ASQA to guide all RTOs, including TAFE NSW, to understand their obligations. These include:
- Trainers and assessors must hold a Diploma or higher-level qualification in adult education, or the latest Certificate IV TAE40116 (or equivalent).
- Providing national consistency in regulation of the VET sector.
- Providing clear and accurate information about the training an RTO offers, including duration, cost and RTO expectations of students.
- Protecting students from pre-enrolment through to course completion or withdrawal.
- Ensuring students are protected through their educational journey through adequate support and access to a complaints and appeals process.
- Ensuring teachers and assessors are both vocationally and educationally current.
- Ensuring RTOs adequately engage with industry.
- Ensuring training and assessment strategies are relevant, current and meeting the intent of the training package.

2.3 Australian Qualifications Framework (AQF)

The Australian Qualifications Framework (AQF) was introduced in 1995 to structure a national system of qualifications in Australia (AQF, 2022). This encompasses schools, higher education and VET. One of the key objectives of the AQF is to facilitate an effective pathway through formal qualifications. In the case of TAFE NSW, teachers and training and assessment resource developers will use the detail in the AQF to prepare educational material that meet the qualification level. For example:

- Level 1 – Certificate I: Graduates at this level will have knowledge and skills for initial work, community involvement and/or further learning.
- Level 3 – Certificate III: Graduates at this level will have theoretical and practical knowledge and skills for work and/or further education.
- Level 5 – Diploma: Graduates at this level will have specialised knowledge and skills for skilled/paraprofessional work and/or further specialised learning or training.

2.4 Training Packages and the Transition to Industry Clusters

A training package is a bundle of units of competency that combine to form a qualification that complies with the AQF. For example, the 'CPP – Property Services Training Package (Release 15)' includes:

- CPP20121 Certificate II in Surveying and Spatial Information Services.
- CPP30221 Certificate III in Surveying and Spatial Information Services.
- CPP41721 Certificate IV in Surveying and Spatial Information Services.
- CPP50121 Diploma in Surveying.
- CPP50221 Diploma in Spatial Information Services.
- CPP60121 Advanced Diploma in Surveying.

A Training package is important to an RTO because it provides a structure to develop training curriculum. Similarly, it is important to employers as it assists with workforce design and structure (ASQA, 2022c). Training packages are developed by industry and then endorsed by the Australian Industry and Skills Committee (AISC). Industry Reference Committees (IRCs) are the key industry advisory bodies to the AISC. For example, two members of the Property Services IRC are Consulting Surveyors National and the Surveying and Spatial Sciences Institute (SSSI). The IRC is supported by Skills Service Organisations (SSOs) whose role is to engage with industry to drive development and review of the training package. There are 6 SSOs covering all training packages. For the Property Services training package, the SSO is Artibus Innovation.

From 1 January 2023, the SSOs and IRCs will be replaced by industry clusters to better engage with industry as well as strengthen outcomes for both learners and employers. One chief result from this change will be a better alignment of training product development with industry skills requirements. This should lead to increased workforce productivity. Industry clusters will work with RTOs to develop improved resources for teachers, assessors and employers. The process to establish the new industry clusters is now underway and will be built around a recommended operational structure (Australian Skills Reform, 2022).

2.5 Smart and Skilled and Training Services NSW

The NSW VET system introduced 'Smart and Skilled' as a reform to offer people in NSW the opportunity to get the skills they need to advance their career. Funding is available to applicants aged 15 years or older, who are no longer at school, live or work in NSW and are an Australian citizen. There are two options to the funding (Smart and Skilled, 2022):

- Entitlement: Government-subsidised training up to and including Certificate III.
- Targeted priority: Government funding for Certificate IV and above.

Training Services NSW is a division of the NSW Department of Education and is responsible for government-funded VET in NSW. It controls the implementation and compliance of funded programs including ‘Smart and Skilled’, apprenticeships and traineeships. Central to its operation is offering students the best outcome for their VET studies (Training Services NSW, 2022).

3 SURVEYING AND SPATIAL INFORMATION DELIVERY AT TAFE NSW

3.1 Overview

TAFE NSW has been delivering surveying qualifications for over 50 years. In the early days, at the Ultimo campus in Sydney, there were two sections: Surveying and Drafting. Enrolments from both the public and private sector were always high, and this was demonstrated by a staff of 15 full-time teachers. In time, Cartography evolved as a third section. Many TAFE graduates transitioned to university. These learners were always readily accepted as universities knew that these students had sound practical skills (I. Pozzato, pers. comm.). Roberts and Harvey (2019) stressed the importance of all surveying graduates from university having the practical skills necessary to contribute to the industry and society, i.e. being job-ready.

In 2022, TAFE NSW offers the following surveying and spatial information qualifications:

- CPP30221 Certificate III in Surveying and Spatial Information Services: To fulfil the role of a surveying or spatial information services assistant who works under supervision.
- CPP41721 Certificate IV in Surveying and Spatial Information Services: To fulfil the role of an entry-level technician who works under supervision to assist a surveying or spatial information services team.
- CPP50121 Diploma in Surveying: To fulfil the role of a skilled survey technician.
- CPP50221 Diploma in Spatial Information Services: To fulfil the role of a skilled spatial information system technician.

These are delivered from the campuses of Ultimo (Sydney), Newcastle, Wollongong and Thurgoona (Albury). Across these campuses, there are over 30 full-time and part-time teachers and additional support staff. Industry demand for surveyors is high with a 5-year projected growth of 13.8% and currently around 600-900 job opportunities nationally. The average age of surveyors is in the mid-50s, so opportunities will continue to rise (Seek, 2022).

3.2 Importance of Assessing a Student Before Enrolment

TAFE NSW students can be broadly classified into two groups: those working in industry and those not yet working in industry. For this reason, it is mandatory for prospective students to be assessed prior to enrolment to ensure they are given the best educational journey. Students who have enjoyed many years in industry are not expected to commence at Certificate III level. Similarly, we cannot expect a school leaver to start at the Diploma level. It is a balancing act of ascertaining a student for:

- Industry experience, currency and knowledge.
- Foundation skills, especially English and numeracy.
- Digital literacy.
- Access to the latest equipment to hone practical skills.

It is important to offer these students a pathway through TAFE NSW, and then onto university for those who aspire to become registered land surveyors. In most cases, at university, credit will be given to students with a Diploma in Surveying qualification. The pathway is not always a one-way street though. Some students who commenced at university have withdrawn and come to TAFE to develop their practical skills and underpinning knowledge first. In many cases, a VET qualification is enough to gain them a rewarding and well-paid job in industry. As mentioned, those graduates who aspire to become registered must complete a recognised qualification from university, undertake prescribed training and work experience under the supervision of a registered surveyor, and undertake prescribed examinations by state boards such as the Board of Surveying and Spatial Information (BOSSI) in NSW.

According to the Organisation for Economic Co-operation and Development (OECD), an estimated 3 million Australians have low basic skills. Although our literacy levels are above other OECD countries, our numeracy levels are average (OECD, 2022). Similarly, the National Foundation Skills Strategy for Adults (Australian Government, 2012) suggests that Australians will need to strengthen their foundation skills to function in an increasingly complex workplace and contemporary life. This is reflected by what TAFE NSW surveying and spatial information teachers note in the classroom. Not all students are equipped for the computations and digital literacy required by industry. One of the key attractions of completing the Certificate III – Certificate IV and Diploma pathway is that students can build upon the foundation skills at each AQF level, equipping them to be functional workers upon course completion. Following enrolment with TAFE NSW, all students undertake a Language Literacy Numeracy (LLN) assessment to ascertain course suitability and possible needs. Given LLN forms part of the ‘Certificate IV Training and Assessment’ teaching qualification, every TAFE NSW teacher has LLN skills. In addition, several support services are available to students, e.g. Aboriginal student support, learning support, multicultural support, and accessibility and disability services.

3.3 Models of Delivery

As previously mentioned, there are two broad categories of TAFE NSW learners: those in industry and those that are not. Students are scattered across NSW and beyond, and everyone has different learning styles. This all means that delivery to students must be flexible, adaptable and contemporary. Each of the four campuses delivering surveying and spatial information qualifications uses a mix of face-to-face, online (called Moodle) and connected (generally Microsoft Teams). The relative mix of each of these components depends on:

- Industry experience and exposure to using surveying equipment.
- LLN levels and whether additional support is required.
- Qualification level – generally, the higher the qualification the more self-directed a student is.
- Whether the training is theoretical or practical.
- Where the student is located – generally, students within the catchment of the four campuses are more able to attend campus than those that are not.
- The willingness of employers to allow staff to attend campus or have designated study days at work.

Wollongong, Newcastle and Ultimo have traditionally provided a predominantly face-to-face delivery. This enables learners who are not yet in industry to attend classes during the day sessions. For those students who are working in industry, night sessions are offered. Given the relative lack of available teachers at these campuses, it is anticipated that a blended delivery model will be offered in the future. This means that students do not have to travel to campus – for theory sessions they can participate via connected technology at home or remotely work on their computer, tablet or phone.

The Thurgoona campus caters to those learners who are working in industry across the state and interstate. The majority of delivery is online or connected with a small number of week-long practical block-release camps on campus. This enables students to continue working with the occasional release to attend camp. Even though there are students with many years industry experience, TAFE NSW requires mandatory attendance for these face-to-face sessions. This provides teachers the opportunity to ascertain practical competence via observation. It is also acknowledged that some surveyors can have narrow areas of expertise. Attending camp broadens that experience, creates networking with other students and exposes them to equipment they may not be familiar with.

One of the most important factors contributing to effective training is access to and use of current industry equipment. This can be difficult for an RTO when the discipline you manage undergoes continual technological change and the equipment used is expensive. Thankfully, TAFE NSW understands the importance of ensuring students use the latest equipment to make them industry ready. Each of the four campuses uses equipment that is stipulated in the training package. TAFE NSW has also made a conscious effort to vary the manufacturers of equipment so that students either experience what is available in industry or use equipment they are familiar with in their workplace. In the latest training package update in 2021, the unit 'CPPSSI5061 Survey Subsurface Utility Information' was added to the Diploma in Surveying qualification. This was the result of industry (Transport for NSW) approaching TAFE NSW and discussing the need of including this capability in the skillset of surveyors. From there, this organisation participated in the training package process managed by Artibus Innovation. Inherent in this unit is the need to use electromagnetic locating equipment, ground penetrating radar, Global Navigation Satellite System (GNSS) technology and total stations. Some of this equipment was donated by industry, further exemplifying the important relationship between industry and RTOs.

4 OUR TEACHERS

4.1 Experience

Currently, TAFE NSW employs over 30 full-time and part-time surveying and spatial information services teachers across the four campuses, including several registered surveyors. Given that delivery includes online and connected components, some of our teachers are located interstate. The breadth of experience includes:
- Cadastral surveying.
- Mining surveying.
- Engineering.
- Monitoring.
- Subdivision.
- Construction.
- Drafting.
- Spatial analysis.
- Spatial data capture.
- Remotely Piloted Aircraft Systems (RPAS) or drones.

- Subsurface utility mapping.
- Project management.
- Hydrographic surveying.
- GNSS.

In conjunction with the support staff within the campuses, TAFE NSW ensures that students have an enriching educational journey, catering to all elements of the industry.

4.2 Individual Delivery Profile (IDP)

As part of ASQA obligations (ASQA, 2022d), TAFE NSW has instigated the Individual Delivery Profile (IDP) for each teacher. Before a teacher starts delivering any training, they must demonstrate:

- Vocational competency at least to the standard being delivered and assessed: This could mean holding the unit of competence that is being delivered or demonstrating through other relevant qualifications and industry experience or currency that a teacher is compliant and competent to deliver the unit.
- Current industry skills relevant to the training and assessment: Currency activities need to be collected every year, e.g. via returning to industry, engaging with industry meaningfully or self-directed learning.
- Current knowledge and skills in vocational training and learning: This means holding the latest 'Certificate IV Training and Assessment' qualification.

Each semester, teachers must update their IDP to ensure compliance. In addition, when there is a training package update, teachers must ensure they are mapped against the latest units of competency.

5 THE IMPACT OF COVID-19 ON TRAINING SURVEYING STUDENTS

5.1 TAFE NSW During the COVID-19 Pandemic

In January 2020, Australia became aware of the COVID-19 pandemic. It quickly became apparent that this would disrupt every Australian, whether directly or indirectly. TAFE NSW halted most programs from 30 March until 27 April 2020, although nursing and aged care continued. Given TAFE NSW is an essential service, the priority in that short period of shutdown was to be innovative in developing online or connected delivery to ensure our students' educational journey could continue. In some cases, such as surveying and spatial information qualifications, this was straight-forward as these modes of delivery were already being utilised. In other cases, including most trades areas, this was a significant shift from traditional face-to-face delivery. Teachers needed to be taught how to use the various technologies, and similarly resources needed to be transferred across for remote delivery. In most cases, TAFE NSW was able to continue the theory component of delivery without too much disruption. Not surprisingly, it was the practical side that became problematic. Throughout the pandemic, the organisation followed the public health orders, trying to maintain delivery where it could. TAFE NSW understood the importance of trying to keep a semblance of normality to students who could continue learning even though their social and working lives were severely impacted.

5.2 Virtual Classroom Experience

Although there were obvious downsides to the COVID-19 pandemic, one positive for TAFE NSW was the development and utilisation of virtual classrooms. Primarily, this was enabled through Microsoft Teams and/or Moodle. Teachers and support staff quickly realised the advantages and efficiencies that connected delivery offered. As flagged already, not all qualifications were suitable as the lower AQF levels that were practically focussed found it difficult to keep students engaged. Similarly, some employers did not embrace the technology as they believed TAFE should maintain face-to-face delivery. Everything was a balancing act.

Teachers found that completing a ‘Certificate IV Training and Assessment’ qualification did not prepare them for connected delivery to large numbers of learners connected via a computer, laptop or tablet. Face-to-face cues from students were missing, understanding the etiquette of a virtual classroom was unknown, and promoting collaboration and engagement amongst teachers and students became difficult. TAFE NSW, through its ICT and digital capability support unit, was able to develop a suite of resources for both teachers and students. Given an element of connected delivery is now part of nearly every TAFE qualification, virtual classrooms are becoming the norm.

Over the past 5 years, TAFE NSW has developed a network of Connected Learning Centres (CLCs) across the state. These state-of-the-art facilities have been custom-designed and built in some of our more remote campuses (TAFE NSW, 2022c). They enable learners from across the state to attend a digitally enabled facility and participate in a connected session where the teacher is invariably located elsewhere. Practical training is also possible through the advanced technologies available (simulations and virtual reality). In 2021, as a direct result of the success of virtual classrooms, TAFE NSW has now established 200 Connected Learning Points (CLPs) at campuses across the state. These are set up to enable teachers to deliver training via advanced hardware and software technologies, and for students to attend a smaller room where they can participate in the class remotely from the teacher. These CLPs are basically a cut-down version of a CLC.

6 THE FUTURE

6.1 Industry Engagement is Key

The future success of TAFE NSW hinges on its relationship with industry. This paper highlights how effective industry engagement leads to effective training that will meet the needs of a rapidly advancing world. As already mentioned, industry clusters will replace IRCs and SSOs in 2023. This is a response to the fact that industry needs to work together with all RTOs to create responsive and relevant training meeting the demands of today and tomorrow. A small example of this was the inclusion of the unit ‘CPPSSI5061 Survey Subsurface Utility Information’ into the latest Diploma in Surveying qualification.

Currently, TAFE NSW interacts with industry across multiple fronts:

- At individual teacher level through annual currency activities captured through the IDP process.
- TAFE NSW and the Surveying and Mapping Industry Council (SMIC) meet regularly through general meetings and the annual Training and Assessment (TAE) scholarship recruitment.

- TAFE NSW must seek industry verification as part of ongoing training and assessment validation.
- TAFE NSW has industry leads who are staff designated to liaise with the industry sectors in their portfolio.
- Some TAFE NSW teaching staff belong to industry body committees, such as the Surveying and Spatial Sciences Institute (SSSI).

6.2 Attracting the Best New Teachers from Industry

One of the key limiting factors in growing TAFE NSW surveying and spatial information services enrolments is a lack of teachers across the four campuses. Even though a total of 30 teaching staff may seem high, the reality is that most of these are part-time teachers and therefore restricted with their time. The upside to this is that these same teachers are continuously working in industry and are therefore providing our students the very best of contemporary training.

There are a few incentives available to attract the next surveying teacher at TAFE NSW:
- SMIC TAE scholarship: SMIC will pay the student fee for a successful candidate. Study can be undertaken through any relevant RTO.
- TAFE NSW TAE scholarships: TAFE NSW will pay the student fee for a successful candidate. Study must be undertaken through TAFE NSW.
- Remote working (can be located anywhere): With the online and connected components of delivery, in theory teachers can be based anywhere. There is no need to travel to one of the four main campuses.

6.3 Full Qualifications or Skill Sets / Micro Credentials

A future direction of training are micro credentials. These are smaller industry-recognised, skill-specific certifications that suit a student with a busy lifestyle (TAFE NSW, 2022d), with the option of having these nationally accredited. Rather than studying a full qualification, students can pick and choose the skills they require. TAFE NSW has experienced success with these in the past with a drone-related skillset targeted at surveyors. Similarly, a spatial information skillset utilising the three main Geographic Information System (GIS) software packages on the market was popular. It is envisaged that the surveying of subsurface utilities will be in similar demand in the future.

6.4 Working with our Competitors to Support Industry

Even though TAFE NSW is the biggest provider of VET training in Australia, the market must support other RTOs. In the case of surveying and spatial information training, there are not many providers across Australia. During the 2021 CPP training package update, these providers all worked together to ensure the new qualifications were meeting the needs of industry as well as the RTOs. As a result of resource development requirements with the new training package, some of these RTOs are working together or sharing their learning and assessment resources. It is envisaged that some RTOs may specialise in micro credentials only.

6.5 Taking the Training to the Students: Mobile Training Units (MTUs)

A final option is to take the training to the students. Mobile Training Units (MTUs) have been created since 2018 to enable training to be undertaken anywhere around the state. The MTU can range from being a truck with full classroom on the back, through to a small trailer that contains relevant tools and accessories to run practical training where the students are located (Figure 1). The original concept was that MTUs would travel to CLCs to deliver the practical training that augments the theory component of what students have been studying. This quickly morphed into the realisation that properly constructed MTUs can travel anywhere and be totally self-sustaining. If the cohort of students exists, then the MTU can travel. As discussed earlier, having a network of remote teachers across the state enables the MTU to travel to them also. This mode of delivery would have been ideal to offer on-site to surveyors associated with the Pacific Highway upgrade.

Figure 1: Remotely Piloted Aircraft System (RPAS) Mobile Training Unit (MTU) set-up in Western NSW.

7 CONCLUDING REMARKS

This paper has outlined the structural changes TAFE NSW is going through and demonstrated that TAFE NSW has remained adaptive during the COVID-19 pandemic to meet the training demands from industry. A Registered Training Organisation (RTO) cannot survive without effective industry engagement. The very nature of VET is intrinsically tied to its industry. This ensures that training is relevant and current to meet the workforce demands of today and the future.

TAFE NSW also demonstrates that an RTO needs to be adaptive to changes that may be encountered. The COVID-19 pandemic created worldwide disruption, but TAFE NSW was able to quickly upskill its teachers and assessors to utilise connected delivery to keep training going. When a student's social and sporting life was thrown into turmoil during the pandemic, it was sometimes their studies that allowed their life to retain some structure and have a positive impact on their mental health. The demand for surveyors continues to grow, and TAFE NSW is confident to meet that demand by using a blended approach to its delivery, a better utilisation of its existing staff, and a reputation to entice new teachers who are keen to give back to the profession they love.

REFERENCES

AQF (2022) What is the AQF, https://www.aqf.edu.au/about/what-aqf (accessed Mar 2022).

ASQA (2022a) How we regulate, https://www.asqa.gov.au/about/how-we-regulate (accessed Mar 2022).

ASQA (2022b) Standards for RTOs 2015, https://www.asqa.gov.au/about/asqa/key-legislation/standards-rtos (accessed Mar 2022).

ASQA (2022c) Training packages, https://www.asqa.gov.au/about/vet-sector/training-packages (accessed Mar 2022).

ASQA (2022d) Clauses 1.13 to 1.16 – Employ skilled trainers and assessors, https://www.asqa.gov.au/standards/training-assessment/clauses-1.13-to-1.16 (accessed Mar 2022).

Australian Government (2012) National foundation skills strategy for adults, https://www.readingwritinghotline.edu.au/wp-content/uploads/2019/09/National-Foundation-Skills-Strategy-for-Adults-LR.pdf (accessed Mar 2022).

Australian Skills Reform (2022) New industry engagement arrangements – industry clusters, https://www.skillsreform.gov.au/faqs/industry-engagement-faq/ (accessed Mar 2022).

OECD (2022) Basic skills in Australia, https://www.oecd-ilibrary.org/sites/9789264281110-4-en/index.html?itemId=/content/component/9789264281110-4-en (accessed Mar 2022).

Roberts C. and Harvey B. (2019) The critical importance of practical exercises in a modern surveying curriculum, *Proceedings of Association of Public Authority Surveyors Conference (APAS2019)*, Pokolbin, Australia, 1-3 April, 139-151.

Seek (2022) Surveyor, https://www.seek.com.au/career-advice/role/surveyor (accessed Mar 2022).

Smart and Skilled (2022) About Smart and Skilled, https://smartandskilled.nsw.gov.au/about (accessed Mar 2022).

TAFE NSW (2022a) Our history, https://www.tafensw.edu.au/about/history (accessed Mar 2022).

TAFE NSW (2022b) Why TAFE Digital? https://www.tafensw.edu.au/digital/why-tafe-digital/about-us (accessed Mar 2022).

TAFE NSW (2022c) Your new world-class digitally-enabled campus, https://www.tafensw.edu.au/clc (accessed Mar 2022).

TAFE NSW (2022d) Microcredentials, https://www.tafensw.edu.au/study/types-courses/microcredentials (accessed Mar 2022).

Training Services NSW (2022) About Training Services NSW, https://www.training.nsw.gov.au/about_us/ (accessed Mar 2022).

Proceedings of the 25th Association of Public Authority Surveyors Conference (APAS2022)
Leura, New South Wales, Australia, 21-23 March 2022

Surveyors on Banknotes, Coins and Stamps

John F. Brock
Brock Surveys
brocksurveys@bigpond.com

ABSTRACT

How many banknotes, coins, medallions and stamp issues do you know of that feature surveyors and surveying? After starting off on a quest to track down these elusive objects, I was quite thrilled and amazed to find many different numismatic and philatelic tributes to the surveying profession and a selection of its legendary characters. Even significant historical icons like George Washington, Abraham Lincoln, James Cook, Thomas Mitchell, William Light and a cast of many made the cut to be immortalised on these collector special editions as highlighted in this paper. Surprisingly, there are nearly 100 countries and territories that have chosen our profession to adorn their monetary and stamp products for many assorted reasons and to honour some of the world's greatest individuals who just happened to be surveyors. A lot of these colourful surveyor-centric objets d'art, which have been issued by an incredible number of world nations and territories, are shown in the paper's appendix. We can be proud to be surveyors.

KEYWORDS: *Surveyors, instruments, banknotes, coins, stamps.*

1 INTRODUCTION

Around 540 AD, Cassiodorus said "…the land surveyor is like a judge: the deserted fields become his forum, crowded with eager spectators. You would fancy him a madman when you see him walking along the most devious paths. But in truth he is seeking for the traces of lost facts in rough woods and thickets. *He walks not as other men walk*. His path is the book from which he reads; he shows what he is saying; he proves what he hath learned; by his steps he divides the rights of hostile claimants; and like a mighty river he takes away the field of one side to deposit them on the other."

Now, if this powerful quote from the ancient Greek philosopher is not enough to demonstrate that surveyors are a special group, then the following collection of banknotes, coins and stamps minted to honour surveyors and their work should certainly reinforce the high regard held for surveyors and their work by the entire world. It is not just the notion of someone standing behind a tripod which is emphasised. Great projects and some of the concepts we all take for granted in our everyday life have been created by surveyors. Standard world time, Celsius temperature scale, Sistine Chapel masterpieces and construction of the Sydney Harbour Bridge and Sydney Opera House are just a handful of wonders that could not have been possible without the input of surveyors. In honour of his work leading the monumental Survey of India, even the world's highest mountain, Mt Everest, was named after Surveyor-General George Everest. This paper showcases how many tributes have been afforded to surveyors.

2 SUBJECT CATEGORISATION OF ISSUES

There are several websites which contain a remarkable number of coins and stamps associated with surveying, mapping and the individuals who carried out the work to create them (e.g. Mazzucato, 2020; ThemePhil, 2022; Uenishi, 2022; US Surveyors Historical Society, 2022a, 2022b; Wydera, 2022). Many stamps have been issued bearing maps of various periods, but I only include 'map' stamps if the surveyor is also shown or a cadastral map is depicted. Stamps and coins commemorating geodetic surveys are part of this analysis, with many adding a surveying instrument, control network or portrait of the principal geodetic surveyor in the artwork. Some famous surveyors are often more renowned for other major contributions made by them, but they may still be shown in a commemoration doing surveying, so these I consider to be my most treasured items. Upon some of the envelopes which are First Day Covers (FDCs), the stamp may not always bear a portrait of the surveyor or the surveying event memorialised, but the artwork does feature some excellent images of great surveyors or surveying scenes, while occasionally there will be a specially created postmark for the cancellation of the stamp on its day of issue as well.

For any item contained within my personal collection, a number is allocated as follows:

- JBCB#1 – John Brock Collection Banknote number 1
- JBCC#10 – John Brock Collection Coin number 10
- JBCM#6 – John Brock Collection Medallion or Token number 6
- JBCS#20 – John Brock Collection Stamp or FDC number 20

For other surveyor banknotes, coins and stamps, a corresponding reference identifies the source (INTB, C, M or S#1 – Internet Search number 1) from which I have obtained the images.

3 SIGNIFICANT COUNTRY COMMEMORATION

3.1 Australia

For surveyors shown on banknotes, some websites portray a famous surveyor or individual plus a surveying instrument, such as the Croatian note issue set with hero surveyor-inventor Ruder Boskovic or a Portuguese note with a portrait on the front and a theodolite on the other, as well as a German 10 Mark note with geodetic surveyor Carl Gauss on one side and a sextant on the reverse. However, I became very excited when, in the last few years, the Royal Mint of Australia issued a new $100 note which has an image of World War I hero Sir John Monash carrying out a survey in Victoria (Figure 1). There are a notable number of stamps, coins and medals struck in his honour, but without reference to his surveying achievements. Trawling deeper into the unfriendly internet, I found a brilliant $50 note issued by the Antarctica Overseas Exchange Office Ltd. with one side having Sir Wally Herbert doing a survey in the polar region (Figure 2). I am unsure from where this organisation comes, so I have placed it in a section for the Antarctic continent until I find out.

Figure 1: (Top) Enlarged part of new Australian $100 note showing Sir John Monash surveying, and (bottom) new Australian $100 note with Monash surveying – JBCB#1.

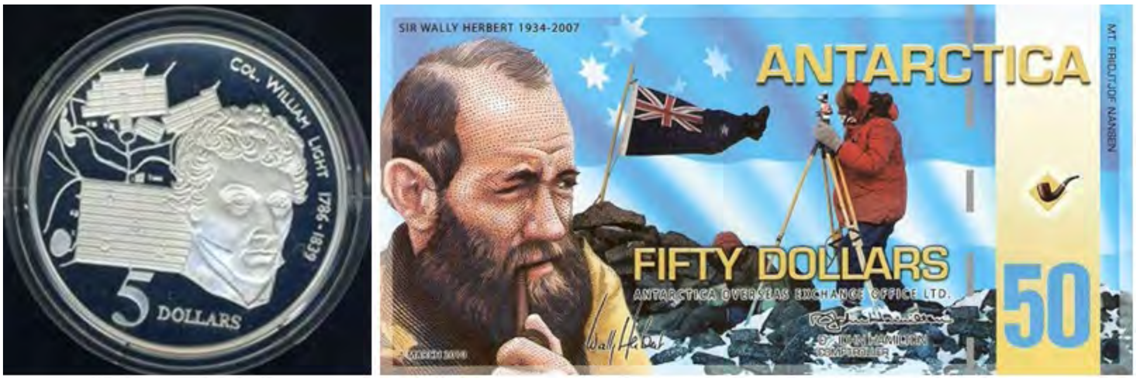


Figure 2: (Left) 1995 Australian $5 coin with Col. William Light and his Plan of Adelaide – JBCC#1, and (right) Antarctica Overseas Exchange Office Ltd. $50 note with Sir Wally Herbert surveying – JBCB#2.

There are many notable surveyors and explorers for whom Australia has issued banknotes, coins and stamps. To name but a few, we have James Cook, Matthew Flinders, NSW Surveyor-General Sir Thomas Mitchell, South Australian 1st Surveyor-General Colonel William Light (Figure 2), William John Wills (of Burke and Wills), William Lawson (of Blaxland, Lawson and Wentworth), Hamilton Hume (of Hume and Hovell), Western Australian 1st Premier Lord John Forrest, South Australian Surveyor-General Charles Sturt, wheat pioneer and NSW Lands Department surveyor William Farrer and so on. A selection of these is shown in Appendices A-C, especially if a surveying instrument or map accompanies the image of the individual. In the mintage of coins and medals Australia has struck, many issues bear images of the aforementioned characters in various scenes of their exploits, but two such mementoes are of notable mention. An Australian 5 cent stamp issued to commemorate the centenary of settlement in Northern Australia from 5 February 1969 features a photo of Surveyor George Woodryffe Goyder and his survey party around 1869 with one FDC showing his vessel, the 'Moonta', also appearing on the postmark (Figure 3).

Figure 3: (Left) 1969 Australian 5c stamp with 1869 photo of George Goyder & survey party – JBCS#5, and (right) FDC of Centenary of Settlement of Northern Australia with Goyder vessel 'Moonta' – JBCS#6.

To commemorate the Australian Surveyors Congress held in Sydney in 1988, I arranged for a medal to be minted for this event in gilt-bronze and silver with the Institution of Surveyors Australia (ISA) crest on one side and a satellite sending beams to the Sydney Opera House on the other with the wording 'Two Hundred Years of Surveying Australia – 1988 Sydney' (Figure 4). A great medal was struck for the 1932 Sydney Harbour Bridge opening. Another Australian FDC came in 1990 for the 75th anniversary of the creation of the Royal Australian Survey Corps in 1915 during World War I. This issue has a Parramatta postmark '29 June 1990' (where I live), showing an Army surveyor on a field survey with a pre-stamped envelope bearing a map on the stamp, while the background also displays a military map (Figure 5).

Figure 4: (Left & centre) 1988 medal for the ISA Congress in Sydney facilitated by the author – JBCM#6, and (right) 1932 medal struck for the opening of the Sydney Harbour Bridge – INTC#3.

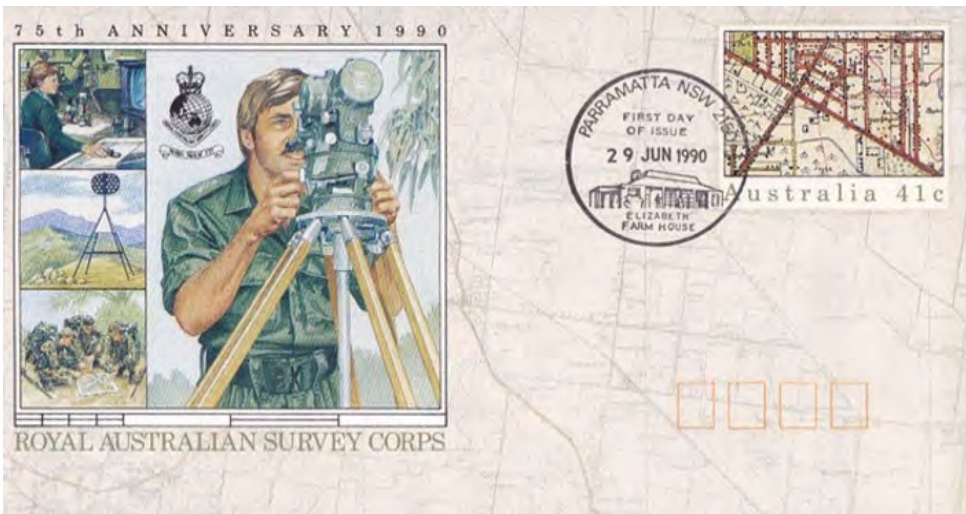


Figure 5: 1990 FDC to commemorate the 75th anniversary of the Royal Australian Survey Corps – JBCS#7.

3.2 United States of America

With only two candidates for surveyors on banknotes, I was delighted to find a rather unusual and old $20 banknote issued in 1860 by the Miners and Planters Bank (USA) with a vignette of a survey party at work alongside a portrait of George Washington (Figure 6).

Figure 6: 1860 $20 banknote minted by The Miners & Planters Bank (USA) with a vignette of surveyors at work in the field alongside a portrait of US President George Washington – INTB#1.

A special type of coin issued in the US is the geocoin, and there is one depicting a Bilby Tower on one side. These survey-purpose portable sighting towers were designed by US Surveyor Jasper Bilby (Figure 7).

Figure 7: (Left) US gilt-bronze Geocoin depicting a Bilby Tower for survey control – INTM#1, and (right) US pewter Geocoin depicting a Bilby Tower for survey control – INTM#2.

By far, the US has been a veritable Fort Knox of coins minted depicting surveyors standing behind their compass or transit, even choosing to show some of their greatest characters at work in this area. The Franklin Mint has been a gold mine in my quest for such items. In the first collection, named ‘Great Moments in the Life of George Washington’ there is a collector silver coin (1970s) described as ‘First Surveying Expedition’, where George Washington is seen with his surveyor’s compass, then another coin titled ‘Vintage Postmaster & Surveyor’ (‘The Life and Times of Abraham Lincoln’ collection, Lincoln Mint, Chicago, Illinois) has Abraham Lincoln working in the field with his survey instrument (Figure 8). In 2020, I found two more great US Franklin Mint coin issues within a collection titled ‘The Official History of Colonial America’ (1976-80), one showing the surveyor in the background (‘New Orleans founded 1718’), the other bearing two of my special men of survey history, Charles Mason and Jeremiah Dixon, shown surveying a newly placed boundary stone along their Mason-Dixon line, the survey of which was completed in 1767 (Figure 9). The inscriptions on the reverse side of these four collector coins can be found in Appendix B.

Figure 8: (Left) George Washington silver medal 'First Surveying Expedition' at age 17 with survey instrument – JBCM#1, and (right) Abraham Lincoln in the field on silver medal with surveyor's compass – JBCM#2.

Figure 9: (Left) Pewter medal with surveyor in background while carrying out the survey to found New Orleans in 1718, (centre) Mason & Dixon with surveying instrument alongside newly placed boundary stone on the famous line which still bears their names, and (right) obverse of medal to mark the bicentenary of Hagerstown 1776-1976 with Surveyor Jonathan Hager behind his instrument – JBCM#5.

For the survey to establish the true boundary line between Pennsylvania (owned by William Penn) and Maryland (under the custodianship of William Calvert), Lord Baltimore had been conscripted by these two wealthy colonialists to resolve a dispute which had been violently contested and boiling over for many years. While searching for these coins I came across a medal struck in 1976 for Hagerstown, Maryland, (about 45 km north of Harpers Ferry, West Virginia) to mark 200 years since its foundation in 1776 by Jonathan Hager calling the Town Surveyor 'The Architect of Hagerstown, MD' (see Figure 9). Two such medals were struck, one in silver and one in bronze, both of which I have been able to obtain.

The first known stamp bearing an image of a surveyor was a 5 cent US issue from 1898 (Figure 10) upon which renowned explorer/surveyor John Charles Fremont is depicted with a flag in hand atop one of the hills to which he had traversed. There are also other stamps printed in his honour along with an assortment of FDCs from various years. As previously mentioned, George Washington was shown on a collector coin surveying, and, although there are thousands of world stamps minted to honour this statesman of world renown, there are less stamps and FDCs made which refer to him as a surveyor or that depict him in action in the field. However, I have been able to obtain a few fine examples of US FDCs which feature images of him surveying. My favourite is a 1939 US FDC titled 'The Young Surveyor Washington…' with an etching of him standing behind his surveyor's compass. There are other FDCs referring to George Washington as a surveyor in addition to a few more which have images of the great US President carrying out his field measurements (see Appendix C).

Figure 10: (Left) First known 'surveyor' stamp in 1898 with John Charles Fremont atop a hill with flag – JBCS#2, and (right) 1939 US FDC of 'Young Surveyor Washington' – JBCS#1.

One brilliant FDC issued in 1934 for the tercentenary (300 years) of the US state of Maryland has a sketch titled 'Surveyors Laying Out Baltimore Town August 8, 1729' (Figure 11). Another stamp from 1934 shows the painting known as Whistler's Mother – artist James Abbott McNeill Whistler worked in the Surveyors Department and father, George Washington Whistler, was a railway surveyor.

Figure 11: (Left) FDC of 'Surveyors Laying Out Baltimore Town August 8, 1729' issued in 1934 – INTS#1, and (right) Bangladesh 1976 stamp of Mt Rushmore – JBCS#84.

It should be quite well known that the monolithic sculpture atop Mt Rushmore in the US state of South Dakota displays the busts of three US Presidents who were surveyors: George Washington – District Surveyor of Culpepper County, Thomas Jefferson – District Surveyor of Albermarle County, and Abraham Lincoln – Deputy District Surveyor of Sangemon County in Illinois (see Figure 11). Not unexpectedly, there are many coins, medals, stamps and FDCs with this magnificent monument on them along with some unofficial collector banknotes emblazoned with this sky-high sculpture (see Appendices A-C).

There was a stamp issued to commemorate the 150th anniversary of the US Coast and Geodetic Survey (USCGS) in 1957 which was accompanied by a good number of FDCs showing various scenes of surveyors in action or transits featuring as illustrations on the FDC envelope. One example of these USCGS FDCs is shown in Figure 14, while many more can be viewed in my extended electronic storage file upon request.

Most surprisingly, I could find only two US stamps which depict a surveyor *plus* his survey instrument. The first US 'surveyor' stamp was issued in 1944 to celebrate the 75th anniversary of the first Transcontinental Railroad with a number of FDCs to mark the occasion (Figure 12).

Figure 12: First US stamp showing a surveyor at work (1944) at right of the locomotive with his rodman to the left of the train – JBCS#3.

Then in 1980, as part of the Black Heritage Stamp series, we have the first African-American Man of Science, Benjamin Banneker, on one of the issues with his transit. Many FDCs accompanied this stamp issue, one of which is illustrated on the envelope with Benjamin Banneker standing alongside Andrew Ellicott, the other surveyor engaged by George Washington to survey the site of the nation's capital, Washington DC, with its surrounding territory, placing prominent boundary stones along the way. A competition was held to choose a design for a District of Columbia quarter featuring a noted African-American. One entry had Benjamin Banneker surveying on it (Figure 13), but the final winner was the design which showed famous musician 'Duke' Ellington on its reverse. The Benjamin Banneker design received 34% of the vote… maybe next time he will get the nod.

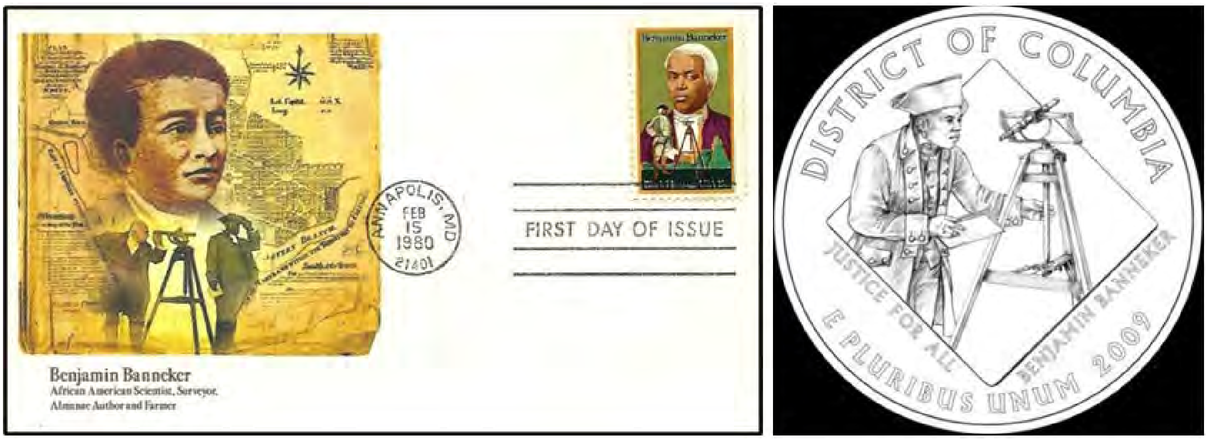


Figure 13: (Left) 1980 US FDC with Benjamin Banneker standing next to Andrew Ellicott surveying Washington DC – JBCS#4, and (right) unsuccessful coin design for District of Columbia competition to select a new commemorative quarter showing Benjamin Banneker surveying.

In 2011, the US Mint struck a half-dollar coin titled 'U.S. Army – Service in Peace', which included a military surveyor behind his total station (Figure 14), being the first legal tender coin minted with such an image.

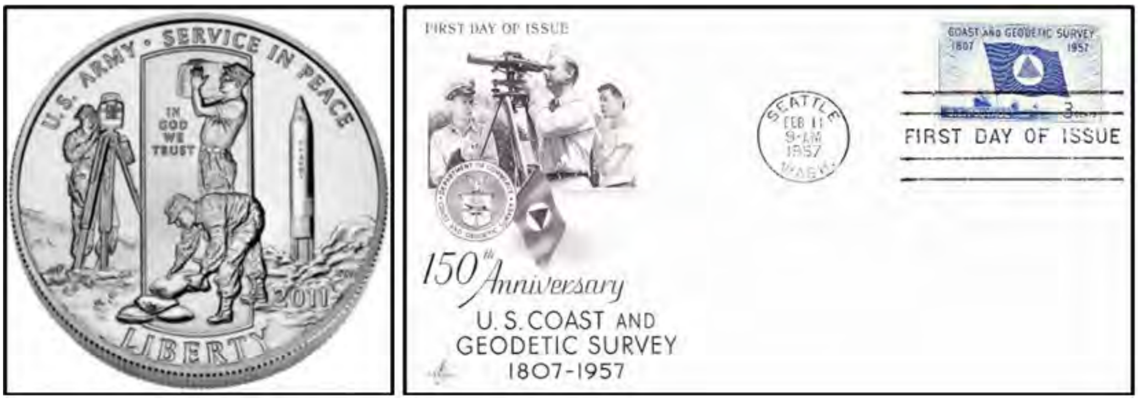


Figure 14: (Left) 2011 US Army surveyor coin – JBCC#2, and (right) USCGS 1957 FDC with surveyor – JBCS#7.

3.3 Egypt

Egypt is a land revered for its extravagant culture and figures of renown, but more importantly it is also remembered for its scribes/surveyors responsible for the many surveys to mark out large capital works, such as the pyramids and temples, as well as remarking boundary corners after Nile inundations. It is quite fitting that the Egyptian Survey Authority was commemorated in its 100th year through the issuance of both a stamp with FDC and two coins depicting the most famous scene of a survey party from the tomb art of Scribe Menna from around 1400 BC, which is the only attestation of the rod of chord (sacred surveyor's rope) being pulled tightly revealing the knots which graduate the measuring medium into 100 cubits (about 52.5 metres or 172 feet) (Figure 15).

Figure 15: (Top left) 1998 Egyptian stamp with scene from the Tomb of Menna depicting surveyors with the sacred rope (rod of chord) pulled tight to show knots at each 5 cubits up to 100 cubits – JBCS#9, (right) FDC with above stamp on it and '1898 Egyptian Survey Authority' – JBCS10, and (lower left) 1998 Egyptian 5 pound coin for the 100th anniversary with a Menna surveying scene – JBCC#3.

3.4 United Kingdom

The Ordnance Survey in the United Kingdom turned 200 in 1991, so a release of four stamps featuring maps of that distinguished organisation hit the market along with a host of FDCs with many images. The best one and hardest to get features two surveyors (Figure 16), but others with triangulation networks, maps and instrument manufacturer Jesse Ramsden with his Great Theodolite along with other scenes are obtainable (see Appendix C). There is also a souvenir pamphlet with a first day postmark cancellation on the four stamps accompanying the booklet which includes a brief history of the Ordnance Survey.

Figure 16: (Left) set of four UK stamps from 1991, and (right) FDC for 200 years of the Ordnance Survey with surveyors of yore and current – JBCS#8.

3.5 Canada

The Canadian pieces in my collection are significant with trade tokens (i.e. a 'coin' with a monetary value not being legal tender) struck for two most notable icons of their history, Samuel Holland, first Surveyor-General of Canada and mentor of James Cook during his time surveying in North America, as well as Sir Sandford Fleming, the Scottish-born land surveyor who created world standard time in addition to surveying and overseeing construction of the Transcolonial Railway from Ottawa to the Pacific Ocean and the 13,000 km long undersea communication cable from western Canada to Australia via Fiji and Norfolk Island (Figure 17). A double Canadian commemorative stamp issue with Sir Sandford Fleming and Joseph Bernier, an explorer, was printed in 1977 with numerous FDCs as part of the edition, some of which featured illustrations of a theodolite and sextant on the envelope. Pacific island nation Tonga produced a stamp depicting Fleming to mark the centenary of world standard time in 1884, also including the introduction of the international date line, which passes by in close proximity, and the 24-hour day (Figure 18).

Figure 17: (Left) Canadian Charlottetown $1 trade token with 1st S-G Samuel Holland (expiry 1980) – JBCM#7, and (right) Canadian $1 trade token from Peterborough with Sir Sandford Fleming (expiry 1984) – JBCM#8.

Figure 18: (Left) Canadian 1977 FDC with Sir Sandford Fleming stamp with theodolite & sextant – JBCS#12, and (right) 1984 Tonga FDC showing a diagram & postmark of the international date line and two stamps with Sir Sandford Fleming and Sir George Airy of Greenwich Observatory – JBCS#13.

3.6 Malaysia

In 2010, Malaysia minted a set of three legal tender coins of 1, 10 and 100 ringgit, each with a surveyor, to honour the 125th anniversary of Jabatan Ukur dan Pemetaan Malaysia (JUPEM, the Surveyor's Department) (Figure 19). While a very limited number of the 3-coin sets were minted, and they are now expensive to buy, the silver 10 ringgit coin is part of my collection.

Figure 19: Three legal tender Malaysian coins set including a gold 100 ringgit, silver 10 ringgit and Nordic bronze 1 ringgit to honour the 125th anniversary of JUPEM (Surveyor's Department) – JBCC#5.

3.7 Finland

Finland struck a 10 Euro coin in 2011, showing geologist Pehr Kalm surveying, while there were FDCs and a 1962 stamp issued to celebrate 150 years of the Lantmateriet (Surveyor's Board) of Finland (Figure 20).

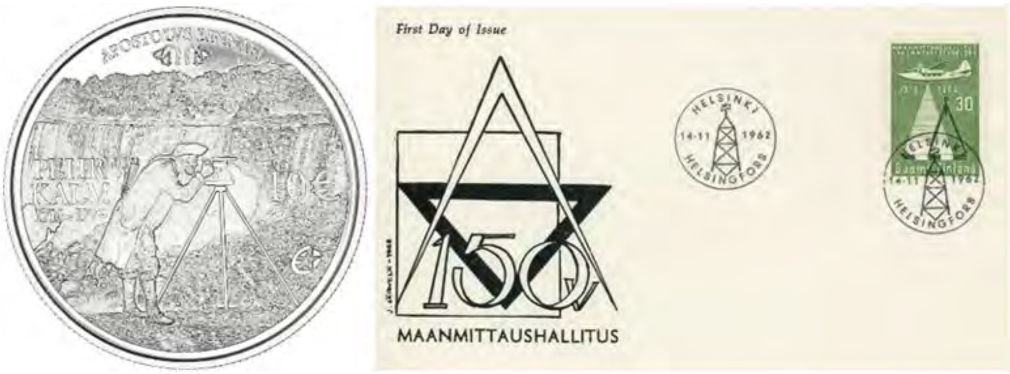


Figure 20: (Left) 2011 Finland 10 Euro coin with geologist Pehr Kalm surveying – JBCC#6, and (right) 1962 FDC with stamp to mark the 150th anniversary of the Surveyor's Board of Finland.

3.8 Latvia

Latvia issued a 1 Lats coin in 2009 and a 40 Santimi stamp for ‘Mernieku Laiki’, which is Latvian for ‘The Times of the Land Surveyors’ (Figure 21). An FDC was also produced (see Appendix C).

Figure 21: (Left) 2009 Latvia 1 Lats coin – JBCC#7, and (right) 40 Santimi stamp featuring “The Times of the Land Surveyors” (Mernieku Laiki) – JBCS#11.

3.9 Czech Republic and Ireland

Figure 22 shows issues from the Czech Republic and the Republic of Ireland, the latter being the first (and only?) stamp depicting a female surveyor.

Figure 22: (Left) 2000 Czech Republic 500 Sk coin with Surveyor Samuel Mikovini & instruments – JBCC#8, and (right) 1986 Republic of Ireland stamp being the first (and only?) to show a female surveyor – JBCS#14.

3.10 Israel

My good friend Haim Srebro**,** Director of the Survey of Israel, gave me information about two Israeli stamps featuring surveyors behind their instruments (Figure 23). The blue stamp pictures the Negev (southern Israel) where a pipeline project had been surveyed and it mentions ‘Minhelet HaAm’ (Directorate of the People) which only lasted one month from 12 April to 14 May 1948 to prepare the government of the Jewish State before the British mandate ended. The 1955 brown stamp marks 20 years of ‘The Immigration of the Youth’ organisation.

Figure 23: (Left & centre) Two very rare examples of an Israeli stamp from the interim period of early settlement of their nation, one with a 14 May 1948 postmark – INTS#2 & 3, and (right) 1955 stamp for the 20th anniversary of a youth group with a young person surveying – JBCS15.

3.11 Bhutan

Although there are hundreds of coins, banknotes and stamps featuring George Washington, there are still some examples of George Washington doing surveying on a coin and illustrations on FDC envelopes. However, there is only one stamp of which I am aware which depicts George Washington at work in the field, and surprisingly it was issued in 1982 to commemorate the 250th year since his birth by the secluded Himalayan nation of Bhutan (Figure 24).

Figure 24: (Left) 1982 Bhutan stamp with George Washington surveying – JBCS#16, and (right) the FDC – JBCS#17.

3.12 Turks and Caicos Islands

Benjamin Banneker was engaged by George Washington to carry out the Survey of Washington DC along with its surrounding territory, in cooperation with Andrew Ellicott. Nevertheless, there is only one country which has minted a stamp to honour both men on the same stamp – Turks and Caicos Islands – again on the year of George Washington's 250th birthday in 1982 (Figure 25).

Figure 25: (Left) 1982 stamp – JBCS#18, and (right) FDC from Turks & Caicos Islands with Benjamin Banneker & George Washington on it along with three other stamps to honour the occasion – JBCS#19.

3.13 Australian and British Antarctic Territories

The Australian Antarctic Territory (AAT) and the British Antarctic Territory (BAT) have issued many excellent surveyor stamps along with a collection of FDCs with scenes of field work taking place (Figures 26 & 27).

Figure 26: (Left) 2014 AAT FDC with explorer/surveyor Douglas Mawson & a field surveyor on 2 of the 5 stamps plus an image of a surveyor on the envelope – JBCS#20, and (right) 1997 AAT FDC with a surveyor illustration – JBCS#21.

Figure 27: (Top) 1998 BAT set of 5 stamps titled 'The History of Mapping' series depicting 5 aspects of survey work utilised to acquire data to create maps of Antarctica – JBCS#25, (bottom left) 1969 BAT stamp with a survey party – JBCS#22, (bottom centre) 1998 BAT stamp for clothes worn while surveying with instrument – JBCS#23, and (bottom right) 1994 BAT stamp with a survey party – JBCS#24.

3.14 Pitcairn Islands

The Pitcairn Islands, officially the Pitcairn, Henderson, Ducie and Oeno Islands, which are a group of four volcanic islands in the southern Pacific Ocean forming the sole British overseas territory in the Pacific, issued a stamp to commemorate a top-secret joint venture between the British and US governments for satellite recovery (Figure 28).


Pitcairn Islands Space Issue

This stamp issue commemorates the joint venture between the Governments of Great Britain and the United States of America in the mid 1960's. This top secret mission was to investigate the feasibility of building an airstrip on Henderson Island, part of the Pitcairn group in the South East Pacific.

Henderson was identified as a potential base to facilitate 'Polar Orbit' satellite recovery from the California launch site of Vandenberg Air Force Base.

This mission was conducted in 1966, and consisted of the uninhabited Henderson Island being surveyed by personnel of the United States Air Force with assistance from the satellite recovery vessel USNS Sunnyvale. The plan was submitted recommending the airstrip proceed but failed to gain support at higher levels and the project was abandoned.

In 1988 Henderson Island was declared a World Heritage Site. Today it is visited by just a few small cruise vessels and yachts and the Pitcairners still visit occasionally to collect Miro wood to carve as souvenirs for tourists.

Figure 28: 2000 Pitcairn Islands stamp showing a satellite recovery surveyor measuring for an airstrip – JBCS#26.

3.15 Sri Lanka

Sri Lanka has the honour of being the only nation to my knowledge that has produced a stamp issue in honour of 'Surveyors' Day', which features some ancient maps of their island nation and a map of the triangulation control network of their land on the FDC envelope (Figure 29).

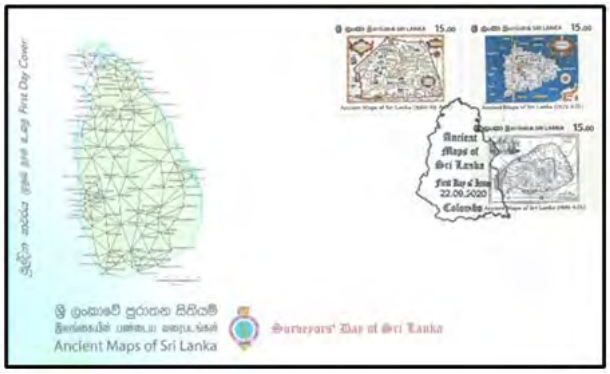


Figure 29: (Left) 2020 Sri Lanka stamp mini-sheet – JBCS#27, and (right) FDC with ancient maps and plan of survey network illustrated on the envelope – JBCS#28.

3.16 Thailand

Figure 30 shows examples from Thailand, including a stamp to commemorate the Joint Land Titling Project with Australia and a FDC to celebrate the centenary of the Royal Thai Survey Department.

Figure 30: (Left) 1991 Thailand stamp for the Joint Land Titling Project with Australia showing a surveyor – JBCS#29, and (right) 1976 FDC to celebrate the centenary of the Royal Thai Survey Department with images of theodolites on the envelope and the postmark – JBCS#30.

3.17 Norfolk Island

After the arrival of the Pitcairn Islanders on Norfolk Island in 1856, a party of two land surveyors being George Jamieson and Thomas Kennedy were sent by Governor Gipps to make the cadastral survey to create the Crown allotments for distribution among the newcomers. The top part of the 1860 plan is the wallpaper of a stamp mini-sheet with images of Rev. George Hunn Nobbs and Queen Victoria (Figure 31). The plan was drawn in Parramatta.

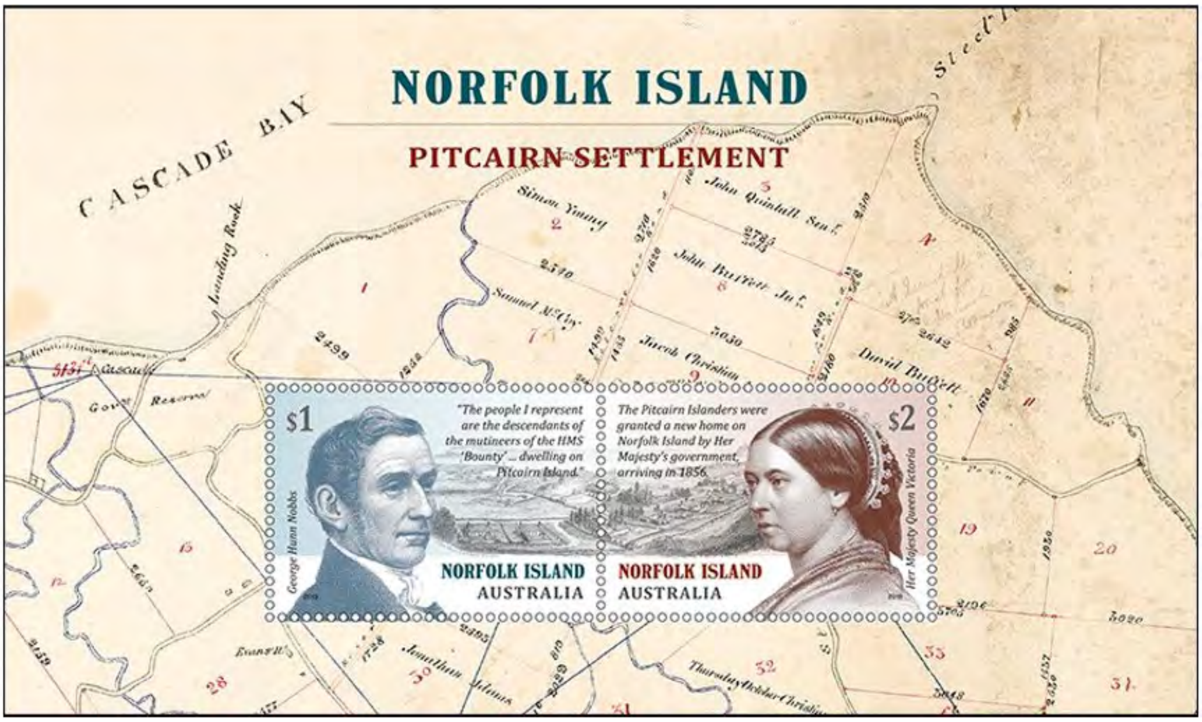


Figure 31: 2019 Norfolk Island stamp mini-sheet with portraits of Rev. George Hunn Nobbs and Queen Victoria with the 1860 Cadastral Plan of Allotments as a background – JBCS#31.

3.18 China

In 2001, China issued a stamp with FDCs to signify the completion of the China-Tibet Railway, constructed through areas of most precipitous country troubled with icy/glacial terrain. The stamp shows a survey party with one member pointing to the distant hills while another stands behind the survey instrument (Figure 32).

Figure 32: (Top left) China 2001 stamp – JBCS#32, (right) mini-sheet on FDC showing the train and rugged terrain – JBCS#33, and (bottom left) recently issued 2021 China 5 yuan coin with theodolite to mark another railway line project constructed through the mountains of highland China – JBCC#9.

3.19 Japan

Figure 33 shows a 10-stamp mini-sheet issued in 2019 and depicting many aspects of modern surveying, including Very Long Baseline Interferometry (VLBI) and air-based surveying along with historical instruments.

Figure 33: 2019 Japan 10-stamp mini-sheet showing many aspects of modern surveying (150 years) – JBCS#34.

3.20 Other Countries

There are many more examples from a notable number of other countries featuring surveying scenes on stamps. Some of these are shown in Figures 34-57.

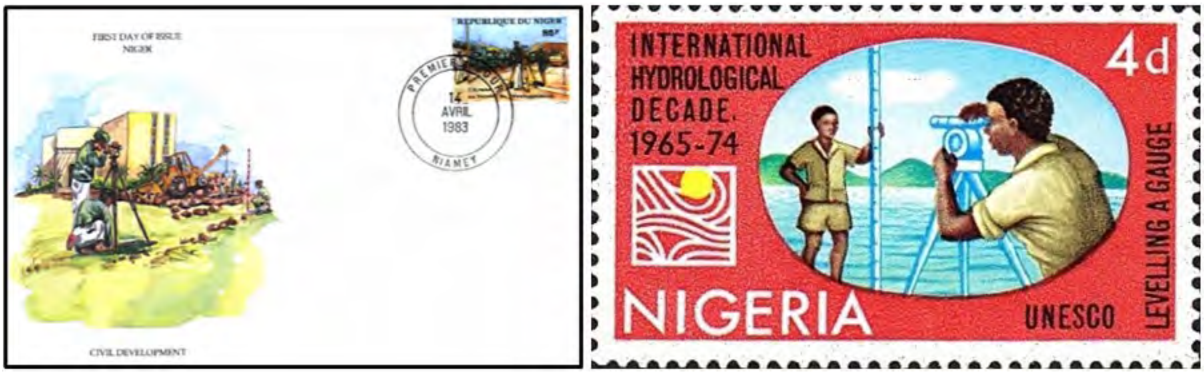


Figure 34: (Left) 1983 Niger FDC – JBCS#35, and (right) 1974 Nigeria stamp UNESCO – JBCS#36.

Figure 35: (Left) 1980 Algerian stamp – JBCS#37, (centre) 1989 Algerian stamp – JBCS#38, and (right) 2011 Argentina stamp mini-sheet with a surveyor on a triangular issue in the polar regions plus a sketch of a surveyor underneath to the lower right – JBCS#39.

Figure 36: (Left) 1971 Belgium stamp with surveyor & tellurometer and penguin escort – JBCS#40, and (right) 1966 Belgium stamp with polar surveyor and dog team in the background – JBCS#41.

Figure 37: (Left) 1962 construction surveyor stamp from Bolivia – JBCS#42, and (right) 2015 Brazilian stamp with a surveyor representative of the Porte Carta Comercial (Commercial Mapping Industry) – JBCS#43.

In Brunei, three stamps were issued in 2002 to mark the Golden Jubilee (50th anniversary) of the Brunei Survey Department with one image being a silhouette of a surveyor at work (Figure 38).

Figure 38: 2002 Brunei 3-stamp set to mark the Golden Jubilee of the Brunei Survey Department – JBCS#44.

Figure 39: (Left) 1983 Bulgaria stamp for the FIG Working Week held there – JBCS#45, (centre) 1989 Chile issue with polar surveyor and penguin parade – JBCS#46, and (right) 2009 Costa Rica stamp with a tunnel surveyor – JBCS#47.

Figure 40: (Left) 1980 Christmas Island stamp for the phosphate industry with surveyor – JBCS#48, and (right) 2016 Cuba stamp with an image of a survey party at work with plans & total station – JBCS#49.

Figure 41: (Left) 1983 Czechoslovakia stamp with construction surveyor at work – JBCS#50, and (right) 1987 Falkland Islands issue of military surveyors from the Corps of Royal Engineers – JBCS#51.

Figure 42: (Left) 1984 German Democratic Republic (DDR) surveyor stamp – JBCS#52, and (right) 1976 Guatemala issue with surveyor – JBCS#53.

Figure 43: (Left) 1972 Hungary stamp showing ancient surveyors setting out a town in 972 – JBCS#54, and (right) 2004 India FDC with portraits of two surveyors of the Great Survey of India – JBCS#55.

Figure 44: (Left) Indonesian stamp from 1974 with construction survey work – JBCS#56, and (centre & right) two 1971 Iraq stamps with a surveyor & theodolite – JBCS#57.

Figure 45: (Left) 2006 Kazakhstan stamp with survey instrument and man – JBCS#58, and (right) 1971 stamp from Tanzania/Kenya/Uganda with survey party & map – JBCS#59.

Figure 46: (Left) 1982 North Korea stamp – JBCS#60, and (right) 1984 Laos stamp – JBCS#61, each with different scenes of surveyors with their assistants.

Figure 47: 2009 Lithuania combination stamp issue with geodesist Wilhelm Struve, two of his astronomical surveying instruments and a boundary stone marker alongside the triangulation network – JBCS#62.

Figure 48: (Left) 1935 Luxembourg stamp with survey party at work – JBCS#63, (centre) 1994 Madagascar stamp showing a statue of a Roman surveyor with a groma – JBCS#64, and (right) 1962 Mexico issue with the survey party at work observing and recording data – JBCS#65.

Figure 49: (Left) 1984 Nauru stamp – JBCS#66, (centre) 2003 Peru stamp – JBCS#67, and (right) 1972 Qatar stamp – JBCS#68, all with surveyors looking through their theodolites in various scenes of field work.

Figure 50: (Left) 1976 Philippines stamp celebrating the 75th year of the Bureau of Lands – JBCS#69, and (right) 2006 Norway stamp with surveyor, theodolite and stone cairn – JBCS#70.

Figure 51: (Left) 1967 Papua New Guinea stamp with illustration of instrument – JBCS#71, and (right) 2019 Poland stamp with a surveyor and theodolite under an umbrella – JBCS#72.

Figure 52: (Left) 2018 Sierra Leone stamp with Percy Fawcett surveying – JBCS#73, and (right) 1979 South Africa stamp with Dr Wadley and his tellurometer – JBCS#74.

Figure 53: (Left) 1989 South Georgia & South Sandwich Islands stamp – JBCS#75, and (right) 2005 stamp from same territory – JBCS#76.

Figure 54: (Left) 1962 Russia stamp with surveyor – JBCS#77, (centre) 1975 Switzerland stamp – JBCS#78, and (right) 1981 Switzerland stamp for the FIG Working Week held in Montreux that year – JBCS#79.

Figure 55: (Left) 1989 Sweden stamp with surveyor and bird – JBCS#80, and (right) 1971 Suriname stamp with illustration of instrument and a map stamp & postmark– JBCS#81.

Figure 56: (Left) 1987 Tristan Da Cunha (a very remote island south-west of Africa) stamp with illustration of survey party – JBCS#82, and (right) 2017 Tristan Da Cunha issue with surveyor Allan Crawford at work – JBCS#83.

Figure 57: (Left) 1990 Tuvalu stamp with survey party – JBCS#84, and (right) 1986 Niuafo'ou (Tonga) stamp with road construction surveyors – JBCS#85.

4 CONCLUDING REMARKS

As can be seen from the impressive number of illustrations with surveyors shown upon the sample of the productions within this paper, it has been a most exhaustive search for the many banknotes, coins and stamps featuring our profession in their philatelic themes. The incredible number was extremely surprising and most rewarding, just another example of how greatly appreciated surveyors are in the community. But not only that, many famous world figures were regarded so highly in their professional work as surveyors, there is also an eminent representation of these notable characters turning up on commemorative issues of this media of paying tribute. When it comes to tracking down surveyors on banknotes, coins and stamps, the internet appeared next to useless, even if you enter the exact words and description of an object you already know about. Entering in a general request for these items will not take you far, but if you drill down into websites, it is possible to discover an Aladdin's cave full of surveying treasures for your viewing pleasure.

Anyone interested in viewing my entire collection of these brilliant specimens of banknotes, coins, medals and stamps is welcome to contact me to arrange delivery of a USB or electronic file transfer, so that you can appreciate that there are indeed many countries who really do know and appreciate just what we surveyors are capable of and the many aspects of human life which are impacted through our work. We can be proud to be surveyors.

ACKNOWLEDGEMENTS

Sincere thanks are extended to the trail blazers who went before me in finding and cataloguing many of the very difficult to find productions of surveyors on coins and stamps (see References). It was actually Mary Root's fantastic folders of surveyors on US and international postage on the US Surveyors Historical Society website that sparked me into action to carry out this research and collect these objets d'art which now form my treasured collection.

REFERENCES

Mazzucato M.T. (2020) MykeLand's Collection – Geodesy stamps et alia, http://web.tiscali.it/nilium/Nilium%20Site/MykeLand's%20Collection%20-%20Geodesy%20Stamps%20et%20alia.pdf (accessed Mar 2022).

ThemePhil (2022) Geodesy stamps / sheets / booklets 1964-1989, https://www.themephil.com/themes/geodesy-1864-1989 (accessed Mar 2022).

Uenishi K. (2022) Stamps and coins on the subject of surveying and geodesy [Japanese], http://uenishi.on.coocan.jp/50lib-stamp/805stamp.html (accessed Mar 2022).

US Surveyors Historical Society (2022a) Surveyor's in postage, http://www.surveyhistory.org/surveyor's_in_postage.htm (accessed Mar 2022).

US Surveyors Historical Society (2022b) Surveyors in international postage, http://www.surveyhistory.org/surveyors_in_international_postage1.htm (accessed Mar 2022).

Wydera M. (2022) Geodäsie in der Philatelie [German], http://www.wydera.de/vermessung/ (accessed Mar 2022).

APPENDIX A: SURVEYORS ON BANKNOTES

Figure A1: Australia – $100.

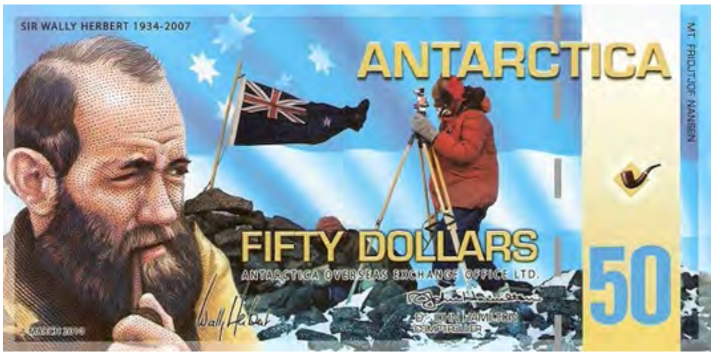


Figure A2: Antarctica – $50 Antarctic Exchange Office.

Figure A3: USA – $20 The Miners & Planters Bank (1860).

Figure A4: Portugal – 1,000 Escudos.

Figure A5: Germany – 10 Marks with Geodetic Surveyor Carl Gauss and sextant.

Figure A6: Croatia – Surveyor and inventor Ruder Boskovic on note series (4 of 10).

Figure A7: USA – $1 million Mt Rushmore souvenir banknote with 1941 Mt Rushmore stamp on it.

APPENDIX B: SURVEYORS ON COINS AND MEDALLIONS

Australia

Figure A8: 1932 silver medal for the opening of the Sydney Harbour Bridge with theodolite (63 mm diameter) – INT#4.

Figure A9: 1932 bronze medal for the opening of the Sydney Harbour Bridge with theodolite (63 mm diameter) – INT#3.

Figure A10: 1995 Australian proof silver coin of Col. William Light & his Plan of Adelaide – JBCC#1.

United States of America

Figure A11: Coins and medals shown are listed from top left, then across left to right. Coins in this figure consist of both sides of each minting for the US Army 2011 half-dollar, Franklin Mint 1970 Abraham Lincoln/Petersburg Point of Beginning 1836, William Clark coin with transit on reverse and Meriwether Lewis coin with surveyor's compass on reverse each from the Rugged American series of medals, 1976 Founding of Hagerstown medal 200th anniversary with surveyor Jonathan Hager on the obverse and the town symbol of 'Little Heiskell' on the reverse, Franklin Mint History of America bronze medal collection with surveyor measuring for the 1785 Land Law Ordinance, George Washington coin for 'First Surveying Expedition' silver medals for the 'Life and Times of George Washington' set (1970s), and the Lincoln Mint series of 'The Life of Abraham Lincoln' with Abraham Lincoln surveying titled 'Postmaster & Surveyor' – JBCC#2, JBCM#7, JBCM#8, JBCM#9, JBCM#5, JBCM#6, JBCM#1 and JBCM#2.

Figure A12: (Left) Prospector/surveyor medal with survey instruments on reverse – JBCM#10, and (right) bronze ingot 'Surveyor' with surveyor on front and job bio on rear – JBCM#11.

Figure A13: (Top left) Surveyors founding New Orleans in 1718, (top right) image details – JBCM#3, (bottom left) surveyors Mason & Dixon survey one of the recently installed boundary stones, many of which can still be found today along the line which still bears their names, and (bottom right) details of year of completion of the Mason/Dixon line 1767 – JBCM#4.

Figure A14: 1991 Mt Rushmore coins for the 50th anniversary, (left) $1 and (right) half dollar – JBCC#10 & 11.

APPENDIX C: SURVEYORS ON STAMPS

United States of America

Figure A15 shows two more examples of the vast collection of FDCs issued by the US Postal Service on 15 February 1980 for the Benjamin Banneker stamp, which was part of the Black Heritage Series. The FDC on the left is number 10 of a hand-painted rare group of only 100 such works by artist Thelma Mayer and her husband, and it is signed by Thelma.

The second FDC is the only one which has postmarks from three cities in which Benjamin Banneker surveyed (Annapolis, Washington DC and Ellicott City), and it is the example used by Mary Root in her 'Surveyor's in Postage' selection on the US Surveyors Historical Society website. I am the only International Life Member of this society, Member No. 499. There are many other brilliant FDCs honouring Benjamin Banneker, which can be found in my electronic storehouse of more surveyor stamps, available upon request.

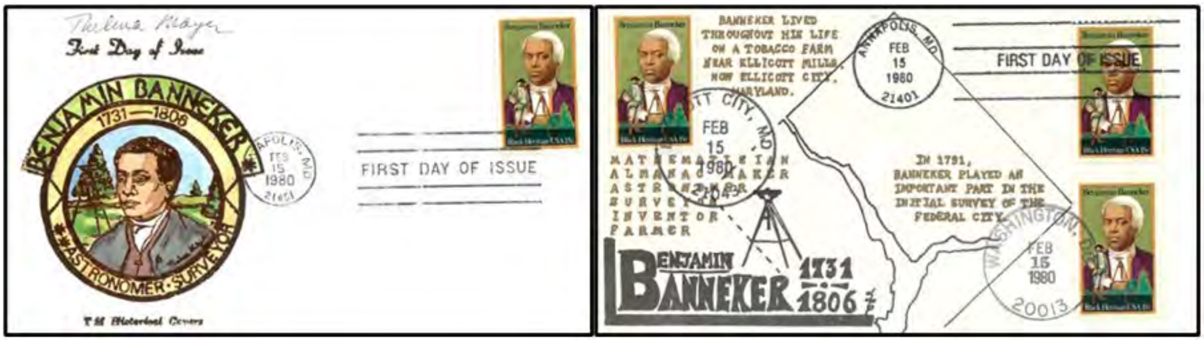


Figure A15: Two fine examples of Benjamin Banneker 1980 FDC issues – JBCS#86 & 87.

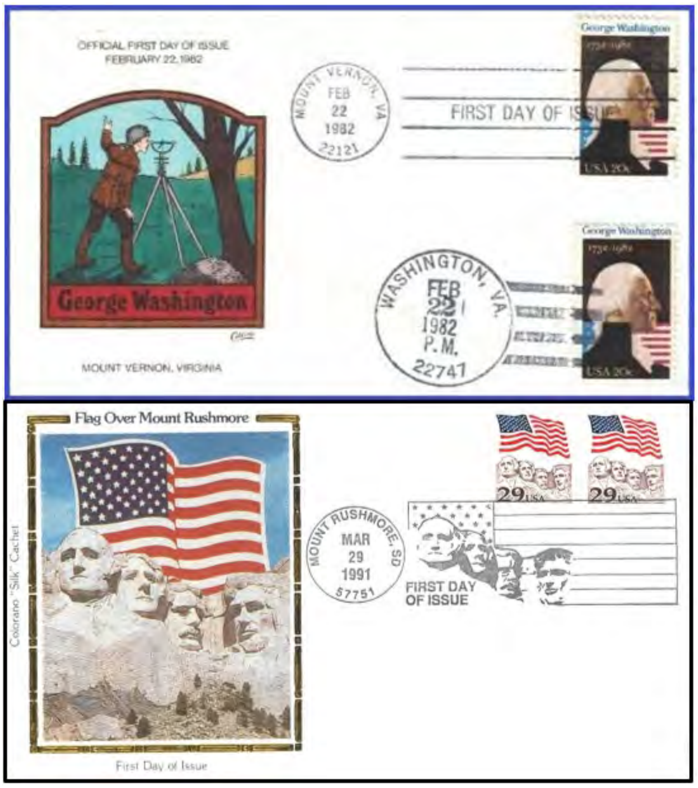


Figure A16: (Top) 1982 FDC of George Washington surveying – JBCS#108, and (bottom) 1991 Mt Rushmore FDC – JBCS#109.

Egypt

Figure A17 shows a 1995 FDC from Egypt celebrating the 75th anniversary of the Egyptian Society of Engineers founded in 1920 and the stamp, each having illustrations of a statue of a seated scribe/surveyor and an ancient Egyptian surveying device, called a sbz, with a right-angled frame holding a plumb bob hanging vertically.

Figure A17: 1995 FDC and stamp for the Egyptian Society of Engineers with an ancient Egyptian surveying instrument (sbz) and a scribe/surveyor statue – JBCS#88 & 89.

Latvia

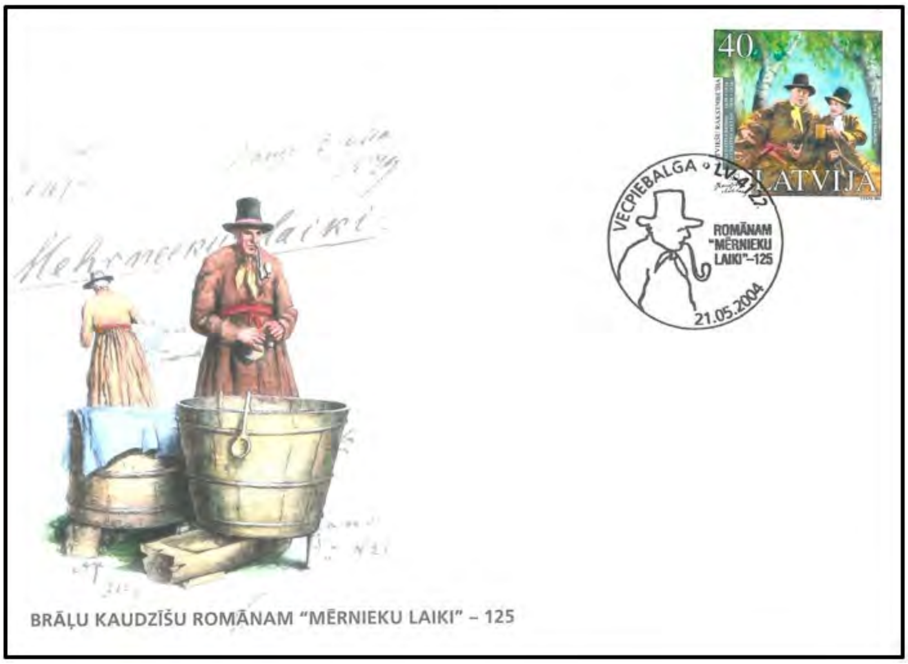


Figure A18: 2004 FDC from Latvia with stamp, postmark and illustration commemorating ‘Mernieku Laiki’ which translates as ‘The Times of the Land Surveyors’ – JBCS#110.

Japan

Figure A19: (Left) 1991 FDC of stamps and illustration with surveyor's level for the centenary of the levelling network in Japan – JBCS#111, and (right) 1995 FDC and postmark from Japan to honour their greatest surveyor, Ino Tadataka, with the stamp featuring part of his iconic 1821 Map of Japan – JBCS#112.

Australia

Figure A20: (Left) 1955 postcard from Australia with Surveyor-General Sir Thomas Mitchell on three stamps with a map of Queensland as background – JBCS#113, and (right) 1980 Australia Day stamp with Matthew Flinders in front of a map of Australia – JBCS#114.

Figure A21: (Left) 1976 Australia stamps featuring NSW Surveyor-General John Oxley – JBCS#115, and (right) first WA Premier, Surveyor John Forrest – JBCS#116.

Samples of Various Other Countries

Figure A22: (Left) 1974 Albania stamp – JBCS#90, (centre) 1987 Ascension stamp – JBCS#91, and (right) 2014 Bahamas stamp – JBCS#92.

Figure A23: (Left) 1954 China stamp – JBCS#93, (centre) 1955 China stamp – JBCS#94, and (right) 1999 Montserrat stamp with a globe & theodolite – JBCS#95.

Figure A24: (Top left) 1986 stamp from the Netherlands with staff man and part of staff – JBCS#96, (top right) 1981 Nicaragua issue with surveyor on site of road construction – JBCS#97, (bottom left) 1979 Cyprus stamp for the Centenary of the Lord Kitchener survey of Northern Cyprus – JBCS#98, and (bottom right) 1994 Denmark stamp for the 1906-08 expedition – JBCS#99.

Figure A25: (Left) 1959 Soviet Union stamp with a surveyor & tellurometer – JBCS#100, (centre) 1961 Soviet Union stamp with a surveyor – JBCS#101, and (right) 1962 Soviet Union stamp with a surveyor – JBCS#102.

Figure A26: Twin surveyor 1951 stamp issue by Spanish Guinea (now Equatorial Guinea) – JBCS#103.

Figure A27: (Left) 2000 Sri Lanka stamp – JBCS#104, and (right) FDC to mark the 200th anniversary of the Sri Lanka Survey Department – JBCS#105.

Figure A28: (Left) 1972 Turkey stamp – JBCS#106, and (right) 1987 UN 'Shelter for the Homeless' stamp – JBCS#107.

High-Productivity, High-Efficiency, Wide-Area Ground Subsidence Monitoring: A Blended Technique

Brady Rengger
Geodata KODA Australia
Brady.Rengger@geodatakoda.com

Steven Garlinge
Geodata KODA Australia
Steven.Garlinge@geodatakoda.com

Craig Roberts
School of Civil and Environmental Engineering
University of New South Wales
c.roberts@unsw.edu.au

ABSTRACT

With tunnelling forming a crucial backbone to Sydney's transport future, unique and challenging demands are imposed on surveyors to accurately measure and detect ground settlement from tunnelling activities. In one section of a recent mega-project, a wide zone-of-influence caused by groundwater drawdown required daily measurements from a distant, stable reference. Existing levelling methods were questioned, and alternatives were sought. To adapt to these requirements, a unique One Person Levelling method was created to fulfill client requirements and satisfy resource constraints. One Person Levelling is a high-productivity, high-efficiency total station levelling technique designed primarily for ground settlement monitoring. Monitoring performance of the method is to a high standard of accuracy and a high level of reliability. Originally written as an undergraduate thesis for a Bachelor of Surveying / Civil Engineering at the University of New South Wales (UNSW) with support from Geodata KODA, which received the Excellence in Surveying and Spatial Information (EISSI) University Student Project Award 2021, this paper is a condensed outline of the One Person Levelling method, containing more recent results since the original submission. Details on further testing and improvements to the technique are also discussed.

KEYWORDS: *Ground subsidence monitoring, groundwater drawdown settlement, One Person Levelling, precision levelling.*

1 INTRODUCTION

Tunnelling is an important augmentation in shaping infrastructure in large cities. It forms a crucial alternative path for traffic flow around cities. Sydney is one example of a city that is transforming its infrastructure utilising motorway and metro tunnels. A key concern by both community stakeholders and contractors during tunnel excavation is the issue of ground settlement. As specialists in measurement, surveyors play an important role in measuring and reporting on such ground movement. Numerous examples of current tunnelling projects in Sydney are presenting challenges for monitoring engineers. The ability to accurately detect and report on significant ground settlement was tested, leading to a realisation that innovation was necessary to transform existing methods into something more suitable for the task at hand.

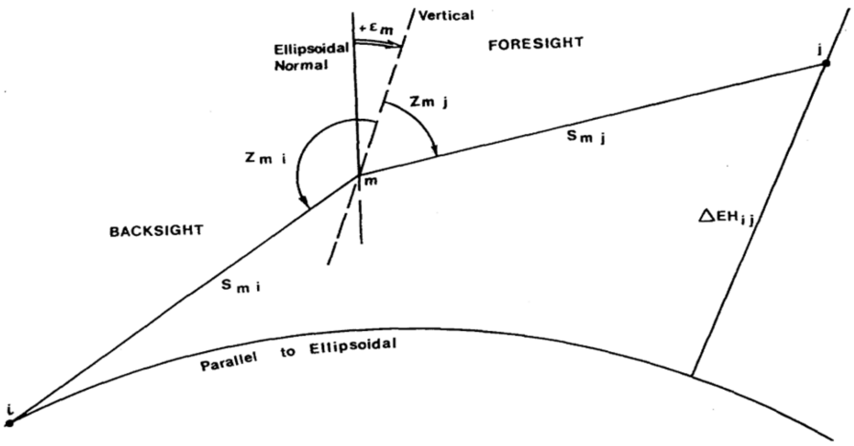
To address this issue, a unique One Person Levelling method was created to provide a high-productivity, high-efficiency total station levelling technique designed primarily for ground settlement monitoring. Originally undertaken as an undergraduate thesis for a Bachelor of Surveying / Civil Engineering at the University of New South Wales (UNSW) with support from Geodata KODA, which received the Excellence in Surveying and Spatial Information (EISSI) University Student Project Award 2021, this paper outlines this new approach, shows that monitoring performance is to a high standard of accuracy and reliability, incorporates more recent results and discusses details on further testing and improvements to the technique.

2 BACKGROUND

The unique monitoring requirements prompted the deployment of uncommon levelling techniques such as Total Station Differential Levelling (ICSM, 2020). A combination of wide-area ground subsidence from groundwater drawdown and levelling sections consisting of very steep topography necessitated the use of these techniques. Monitoring of building movement using purpose-built reflectors was an additional requirement of the project, which is well suited to this method.

2.1 Total Station Differential Levelling (TSDL)

Total Station Differential Levelling (TSDL) is one of the methods of precise Electronic Distance Measuring (EDM) height traversing outlined by Rüeger and Brunner (1981, 1982), which combines measured zenith angles with slope distances to a fixed height pole. Using these measurements, the height difference between two points can be calculated. Backsight and foresight differences are minimised as per traditional levelling. An instrument operator aims the total station at an assistant who holds the reflector pole plumb on top of a survey point (often a nail or change plate, bipod recommended). Measurement sequences and workflows follow conventional precision levelling. The principle is illustrated in Figure 1, with the corrections for the deviation from the vertical (*DE*), earth curvature (*CU*) and refraction (*RE*) shown. *R* is the radius of ellipsoid, *k* is the coefficient of refraction, and ε is the deviation from the vertical.



$$\Delta EH_{ij} = S_{mj} \cos Z_{mj} - S_{mi} \cos Z_{mi} - DE + CU - RE$$

$$DE = \epsilon_m \left(S_{mj} \sin Z_{mj} + S_{mi} \sin Z_{mi}\right)$$

$$CU = \frac{1}{2R}\{(S_{mj} \sin Z_{mj})^2 - (S_{mi} \sin Z_{mi})^2\}$$

$$RE = \frac{1}{2R}\{(S_{mj} \sin Z_{mj})^2 \, k_{mj} - (S_{mi} \sin Z_{mi})^2 \, k_{mi}\}$$

Figure 1: Principle for measuring a height difference using TSDL (Rüeger and Brunner, 1982).

2.2 Wide-Area Subsidence from Groundwater Drawdown

Both due to human-induced and natural causes, the theory of effective stress in soils states that as the water level changes in the soil, so does the effective stress from the change in pore water pressure, therefore resulting in the heave or subsidence of the soil (Terzaghi et al., 1996). In certain geotechnical environments, a drop in the water table (from tunnelling or other external causes) can lead to widespread ground settlement. When water retreats from a soil medium, known as 'pore water loss', soil particles consolidate (squeeze closer together). Since there is no water between particles, the soil medium shrinks in size, leading to settlement. This is known as the process of soil consolidation.

Groundwater drawdown is expected by geotechnical engineers during tunnelling because excavation exposes saturated rock, which leads to water seeping into the freshly cut tunnel. Most of the time, seepage derives from rock layers that do not cause settlement, therefore 'volume loss' settlement may be the only concern.

2.3 The Need for an Alternative

Tunnel construction progress and design require many points over a large area to be measured daily (Monday to Sunday). With existing methods, the time taken for measuring points was lengthy and caused capacity constraints for monitoring deliverables. This created a need for a high-productivity, high-efficiency levelling method that could still deliver on client requests, but also alleviate resource constraints.

The need for an alternative was recognised and supported by the project. The existing, robust levelling network allowed for innovation to be explored with a fallback should any complications with the alternative arise. This alternative formed a 6-month research and experimentation opportunity for an Honours research thesis at UNSW and a path for Geodata KODA to advance a technique suitable for unique monitoring circumstances. The solution was a levelling technique, which blends existing total station differential levelling with purpose-built processes requiring only one surveyor.

3 THE ONE PERSON LEVELLING (OPL) TECHNIQUE

The One Person Levelling (OPL) method takes inspiration from the TSDL principles and augments this with permanent reflectors mounted to structures (telegraph poles in most cases) to mimic an assistant holding a reflector pole over a nail to act as a change point. Any monitoring points (often cats-eye reflectors glued to ground and building structures) were then delegated as intermediate sights.

During this project, OPL networks for monitoring were kept simple, holding all measurements fixed against their respective starting points. These starting heights were applied to specifically chosen stable benchmarks, well outside the zone of settlement influence. These starting benchmarks were in turn connected to far-field established survey marks external to the zone of influence, enabling far field check surveys to be undertaken with conventional TSDL. A closing benchmark at the end of an OPL line allowed for a misclose check to be recorded for all rounds of measurements. On occasion, when these points were also affected by far-reaching settlement, check surveys were required to calculate corrections for closing benchmark points.

3.1 Loseby Park Test – A Preliminary Investigation

Prior to applying the method in a monitoring scenario, a test site was set up to examine the quality of the method as a simple height transfer technique. The site chosen at the time was Loseby Park. It was a long, open, straight stretch of road with similar, urban conditions to the future area of application. Each levelling bay was defined by power poles along the eastern side of the road. These would serve as objects to mount spigot prisms for the experiment. As shown in Figures 2 & 3, different bay lengths were measured so that their overall misclose quality can form a basis behind the design of a monitoring OPL network. The different colours indicate the unique bays.

Figure 2: Plan view of the Loseby Park / Bowral Hospital site, with each of the bays represented by a different colour and an approximate distance shown (imagery obtained from Nearmap).

	Start	Bay Lengths (m)						End
	Orange	Yellow	Green	Aqua	Blue	Violet	Pink	Red
Short	55	57	58	54	48	62	53	37
Medium	112		112		110		90	
Long	224				200			
No Change Points	424							

Figure 3: Different bay lengths for the four separate experiments (colour coding indicates the different bays).

On each power pole, two 11R2-40W wall bolts were drilled into them so that the prisms could be attached. One was placed at eye height (approximately 1.7 m from ground level) and the other was placed at about ground height to highlight any ground proximity effects (about 200 mm above the ground surface, i.e. high enough not be obstructed by grass). L-bar mini prism reflectors were chosen as the four permanent start and end benchmarks. Examples of the reflectors used are shown in Figures 4 & 5.

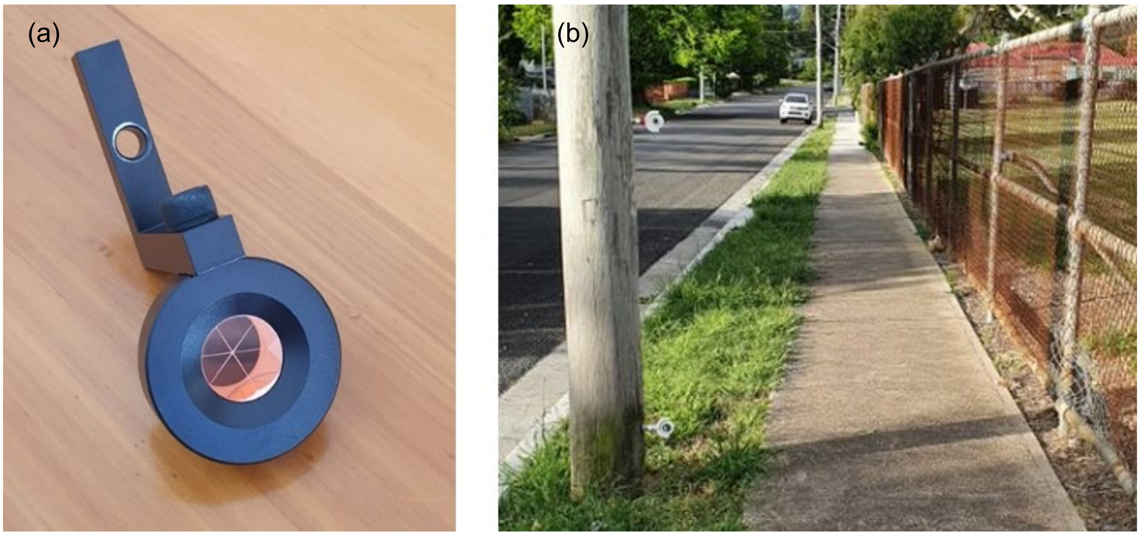


Figure 4: (a) L-bar mini prism (the reflector chosen for the start and end benchmarks), and (b) example of two spigot prisms attached to a pole at both eye and ground height.

Figure 5: Spigot reflectors mounted to a power pole. The spigot screws into a 'wall plug' that rests firmly inside a hold drilled into the pole. The reflector can turn freely on two axes in any direction, allowing measurements of the same point to be taken from both sides.

The instrument used was a Leica Nova TS60 0.5" total station, chosen for its precise angular measurements and rapid telescope transitioning with its piezoelectric motors. The A'B'B"A" measurement sequence in the 'measure sets' application was used at each setup to measure the four points, i.e. the eye-height backsight, the ground-height backsight, the ground-height foresight and the eye-height foresight, respectively. It should be noted that eye-height measurements and ground-height measurements were taken on two separate sets of measurements, with the instrument being relevelled between taking eye-height measurements and ground-height measurements. Each new day of taking measurements consisted of carrying out a check and adjustment (if required) of the instrument.

Before any OPL measurements were taken, a controlled levelling run using TSDL was carried out to measure absolute height differences between benchmarks. This formed the control height differences between benchmarks to be compared with any height differences between the OPL experiments.

3.2 Preliminary Test Results

Overall testing at Loseby Park took approximately 50 hours to carry out reconnaissance, install the points and observe. This was spread out over 7 weeks on 9 individual days. For a total length of 850 m (forward and backwards), the allowable misclose was 1.8 mm based on the 1st order levelling misclose of $2\sqrt{k}$ tolerance with k being the distance in km (ICSM, 2020).

Across all 40 sets of results, two had to be repeated due to two accounts of misdirected pointing of Automatic Target Recognition (ATR) during one of the sets of measurements. The affected surveys were a short bay-length run for eye-level prisms on 10 October 2020 and a medium bay-length run at eye-level on 23 September 2020. Both were re-taken on the last day of experiments (20 October 2020) to ensure a full set of results were achieved. The results for all measurements are summarised in Tables 1-4.

Table 1: Misclose summary for multiple arcs.

Misclosure - Short (mm)			Misclosure - Medium (mm)			Misclosure - Long (mm)			Misclosure - No Change Point (mm)		
Date	Eye	Ground	Date	Eye	Ground	Date	Eye	Ground	Date	Eye	Ground
23-Sep	-0.2	-0.9	17-Oct	0.4	-1.0	17-Oct	0.8	-2.3	17-Oct	-0.4	0.8
30-Sep	0.1	0.7	14-Oct	-0.3	-0.8	14-Oct	-0.4	-1.5	14-Oct	-0.3	1.1
10-Oct	0.1	-0.9	13-Oct	0.1	-0.1	13-Oct	-0.3	1.3	13-Oct	1.3	0.1
14-Oct	-0.3	-0.4	10-Oct	0.1	-0.1	10-Oct	0.1	-1.8	10-Oct	0.3	-0.1
20-Oct	0.4	-1.2	20-Oct	0.6	0.5	23-Sep	0.2	-0.3	23-Sep	0.0	0.3
std	0.2	0.7	*std*	0.3	0.5	*std*	0.4	1.3	*std*	0.6	0.4
average	0.2	0.8	*average*	0.3	0.5	*average*	0.3	1.4	*average*	0.5	0.5
max	0.4	1.2	*max*	0.6	1.0	*max*	0.8	2.3	*max*	1.3	1.1
min	0.1	0.4	*min*	0.1	0.1	*min*	0.1	0.3	*min*	0.0	0.1

Table 2: Summary of all measurements taken (eye- and ground-level measurements separated, including overall results).

	Eye (mm)	Ground (mm)	Overall (mm)
std	0.4	0.9	0.8
average	0.3	0.8	0.6
max	1.3	2.3	2.3
min	0.0	0.1	0.0

Table 3: Misclose summary for single arcs.

Misclose - Short			Misclose - Medium			Misclose - Long			Misclose - No Change Point		
Short	Eye	Ground	Short	Eye	Ground	Short	Eye	Ground	Short	Eye	Ground
23-Sep	0.0	-1.1	23-Sep	-0.2	0.5	23-Sep	-0.7	-1.4	23-Sep	0.4	0.2
30-Sep	-0.1	1.0	30-Sep	0.9	0.6	30-Sep	0.0	-1.0	30-Sep	1.9	0.3
10-Oct	0.5	-0.7	10-Oct	0.3	0.5	10-Oct	0.6	0.4	10-Oct	-8.4	3.2
14-Oct	-0.2	-1.1	14-Oct	-0.3	-1.6	14-Oct	0.7	-1.3	14-Oct	-0.9	3.3
20-Oct	-0.2	-1.2	20-Oct	-1.0	-1.4	20-Oct	-0.7	-6.7	20-Oct	-0.2	2.3
std	0.3	0.8	*std*	0.6	1.0	*std*	0.6	2.4	*std*	3.6	1.3
average	0.2	1.0	*average*	0.5	0.9	*average*	0.5	2.2	*average*	2.4	1.9
max	0.5	1.2	*max*	1.0	1.6	*max*	0.7	6.7	*max*	8.4	3.3
min	0.0	0.7	*min*	0.2	0.5	*min*	0.0	0.4	*min*	0.2	0.2

Table 4: Summary of all measurements taken, single two-face measurements only (eye- and ground-level measurements separated, including overall results).

	Eye (mm)	Ground (mm)	Overall (mm)
std	2.0	2.1	2.0
average	0.9	1.5	1.2
max	8.4	6.7	8.4
min	0.0	0.2	0.0

While a lot can be extrapolated from these results across all four tables, the key highlights are:

- Miscloses were tighter in eye-height prisms than in ground-level prisms, which can be explained by well documented ground proximity refraction.
- A notable decline in misclose quality can be seen in results for measurements not using any change points (longer distance, benchmark-to-benchmark height differences).
- When analysing results for single sets of two-face measurements (as opposed to averaging three in total), there is only a miniscule difference to the overall misclose quality. Having tested different bay lengths in the preliminary investigation and should the need arise, long sighting distances between backsights and foresights could therefore be integrated with an OPL monitoring network without considerable impact to result quality. Balancing foresight and backsight distances remains paramount.

4 APPLICATIONS TO SETTLEMENT MONITORING

Recall that the motivation for developing this method was to use it as a reliable way to measure ground subsidence in unique circumstances with large zones of influence and with fewer resource constraints. The Loseby Park data shows OPL to be a reliable method to transfer height accurately and precisely. This section outlines how the method was used in a monitoring scenario over a period exceeding 12 months and its success as a monitoring technique. Custom-built reflectors (Figure 6) were used as network change points. These reflectors have only 0.3 mm of separation between them but are uncalibrated. Since these prisms are used repeatedly in successive surveys, any absolute error is cancelled out in monitoring results. Once established, the system is monitoring for ‘change’ relative to a known reference state.

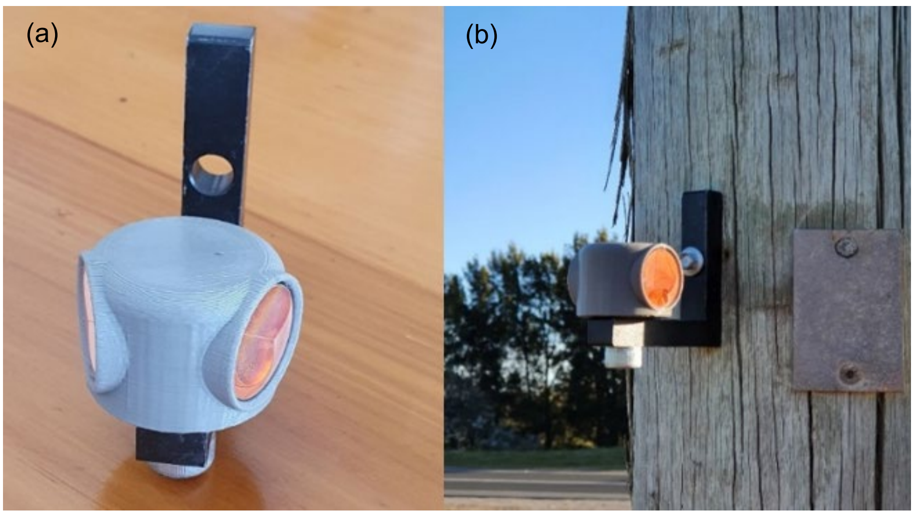


Figure 6: (a) Custom-made 3D printed housings with mini prisms glued into them for a ‘back-to-back’ fit, and (b) example of an L-bar prism mounted onsite.

Unfortunately, this does leave an OPL network vulnerable to these reflectors being vandalised or stolen, therefore requiring replacement. However, it is assumed that the error differences between each of these reflectors is marginal and hence has negligible impacts on monitoring quality. Figure 7 shows the reflectors used as intermediate sights for monitoring the ground surface.

Figure 7: (a) Cats-eye prism ground target glued to a footpath, (b) underside of a ground target, and (c) megapoxy glue used for installation of ground targets.

4.1 Benchmark-to-Benchmark Height Differences

Initially, an OPL line was designed to close on a ‘stable’ benchmark, which was assumed to be unaffected by the groundwater drawdown. Based on early measurements, this would act as a floating benchmark that would provide a quality check on the overall run based on a daily misclose onto this point. These miscloses were calculated based on the first ‘baseline’ survey of the line, setting the control survey tolerance of $2\sqrt{k}$ as a guideline for overall quality.

This benchmark misclose check later became redundant since the subsidence effect was wider than expected, therefore compromising this point as a stable check. Results were still useful, as it eventually stopped moving and could still be used for examining the overall change in height differences between the benchmarks. This could be further verified through its ties to the existing TSDL network via check surveys. As can be seen from Figure 8, the TSDL measurements followed the same trajectory as the OPL change in height differences. It is important to note that while the two methods agree, TSDL and OPL cannot be perfectly compared based on absolute height differences. This is due to the un-quantified errors from the minor prism separation in the purpose-built OPL reflectors. Therefore, comparing the two methods based on the change in height differences cancels out these errors.

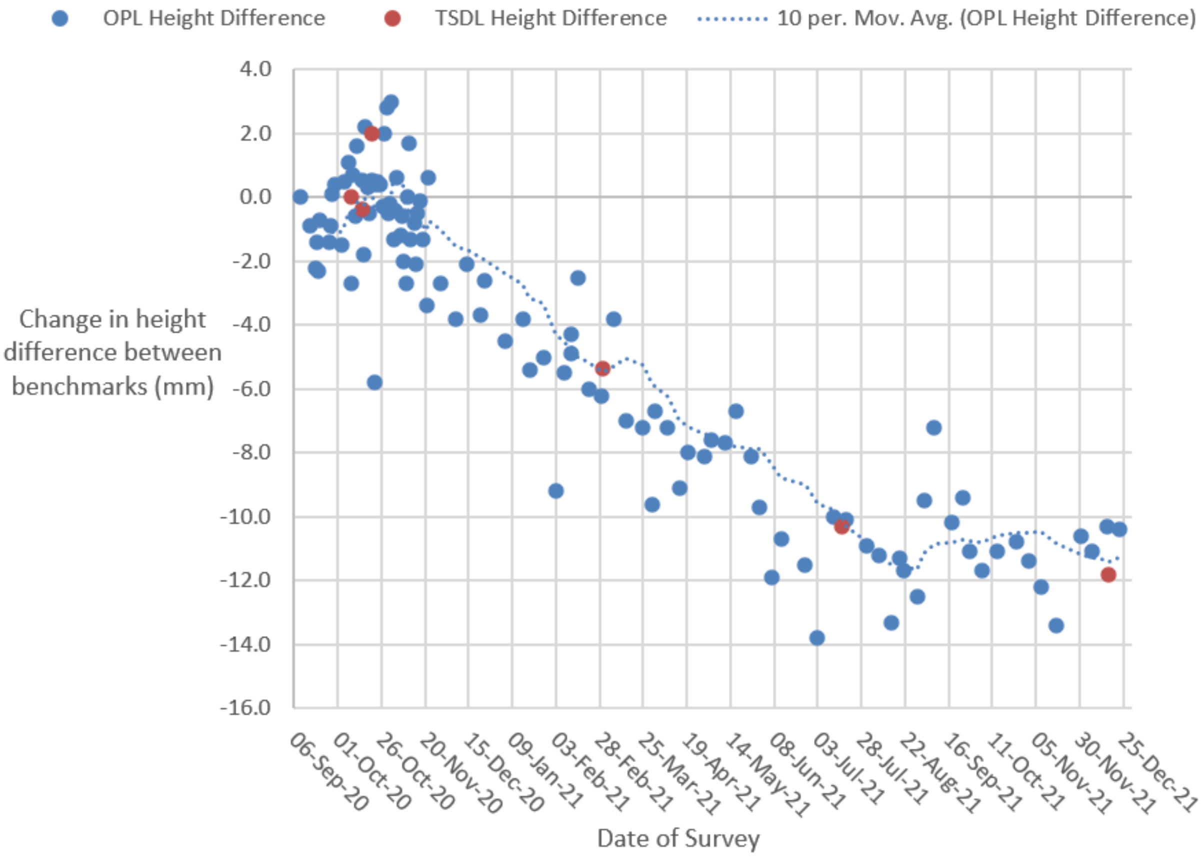


Figure 8: Overall spread of benchmark-to-benchmark height differences for all surveys at the monitoring site.

4.2 OPL vs. TSDL

A total of 14 check points were measured that could be referenced directly against TSDL. The point exhibiting the most movement has been chosen to demonstrate results. Figure 9 shows an example of how close the levelling nails were in relation to the cats-eye monitoring prism. For the most part, OPL monitoring was conducted daily, and then tapered off to a weekly schedule thereafter. TSDL check surveys were initially carried out weekly but were then reduced to a monthly schedule as per client requests.

Figure 9: Levelling nail (left) adjacent to a ground target (right) on the kerb, in close enough proximity to check if movements between the marks are consistent.

Figure 10 clearly shows that the monitoring results of the OPL technique were very accurate. The few check surveys conducted (in orange) closely follow the movement trajectory of OPL. It is quite clear that the TSDL measurements provided 'smoother' results, with OPL being fairly 'spikey' between successive surveys, with measurements jumping up and down by 2-3 mm in some places. Across the sample period, the same Leica Nova TS60 total station was used every day, including the TSDL check surveys. While the operator of the instrument varied depending on the day, this did not appear to have significant effects on the results. Both TSDL and OPL results were in strong agreement.

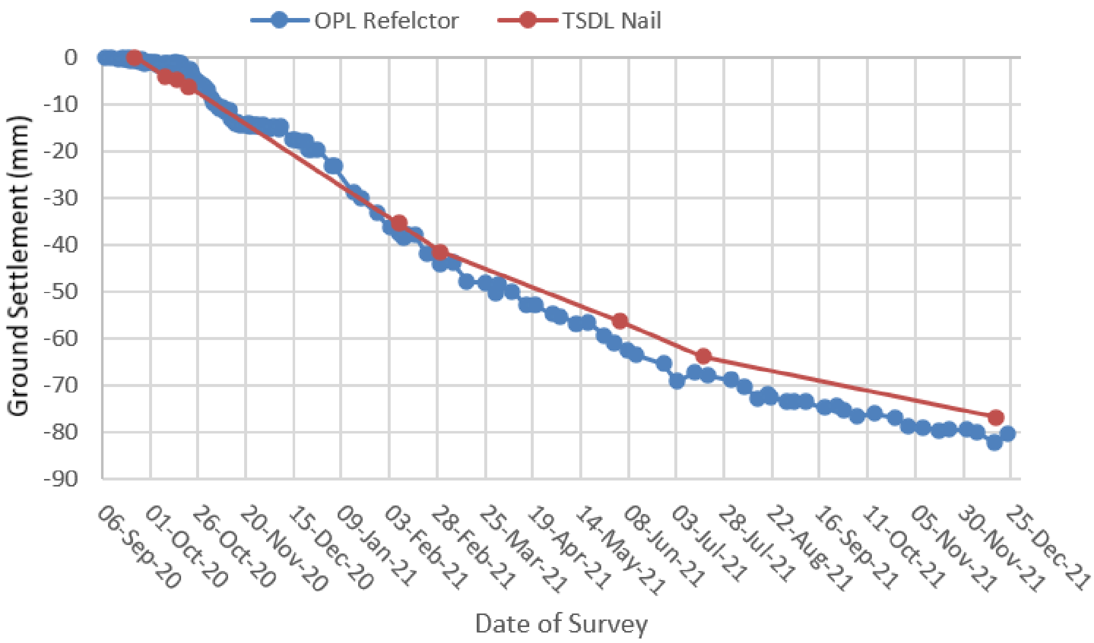


Figure 10: Movement of a specific point demonstrated by measuring with both OPL and TSDL.

It should also be noted that the 'spikiness' of movement vectors indicates the high susceptibility to errors. One characteristic of the simple network design is that if at any point a certain bay has low quality measurements, this gets propagated through to all measurements. As mentioned above, since measurements are from the same operator and instrument serial number, time of day and weather could be the main cause of inconsistency in measurements. Most measurements therefore would have been taken in the afternoon where temperature gradients are larger, hence leading to effects of refraction causing dips and spikes.

4.3 OPL vs. Digital Levelling

Often overlooked (or unspecified at the start of monitoring) is the criteria for 'closing out the monitoring campaign'. In this instance, a value of less than 1 mm/week of subsidence was designated as the basis for consideration of cessation of monitoring. Since OPL's repeatability is of that magnitude, digital levelling was incorporated into the measurement regime. It is worth acknowledging that OPL was proven to be successful using TSDL, not digital levelling. The growing engineering interest in the site's data and the monitoring team's interest in a comparison with the higher-precision digital levelling method led to these investigations. Therefore, to track slower rates of movement and an eventual zero movement, levelling points were installed adjacent to historical OPL points (Figure 11). These were then incorporated into the existing TSDL check network and measured with a digital level.

Initial measurements taken with a Leica LS15 0.3 mm accurate digital level showed that movements observed by the LS15 match the underlying movement measured by OPL. Figure 12 shows how closely aligned the two datasets are. Furthermore, the starting benchmarks for both OPL and digital levelling were maintained in close proximity (Figure 13), so that in the event of any change, the error will be present in both sets of results. Ideally, all measurements were to be observed on the same day for trueness, but this was not always possible. For digital levelling, a 2 m invar staff was used for all points, with the LS15 being calibrated by a two-peg test each day.

Figure 11: Levelling point glued just below the building mark reflector for OPL (including invar staff on right).

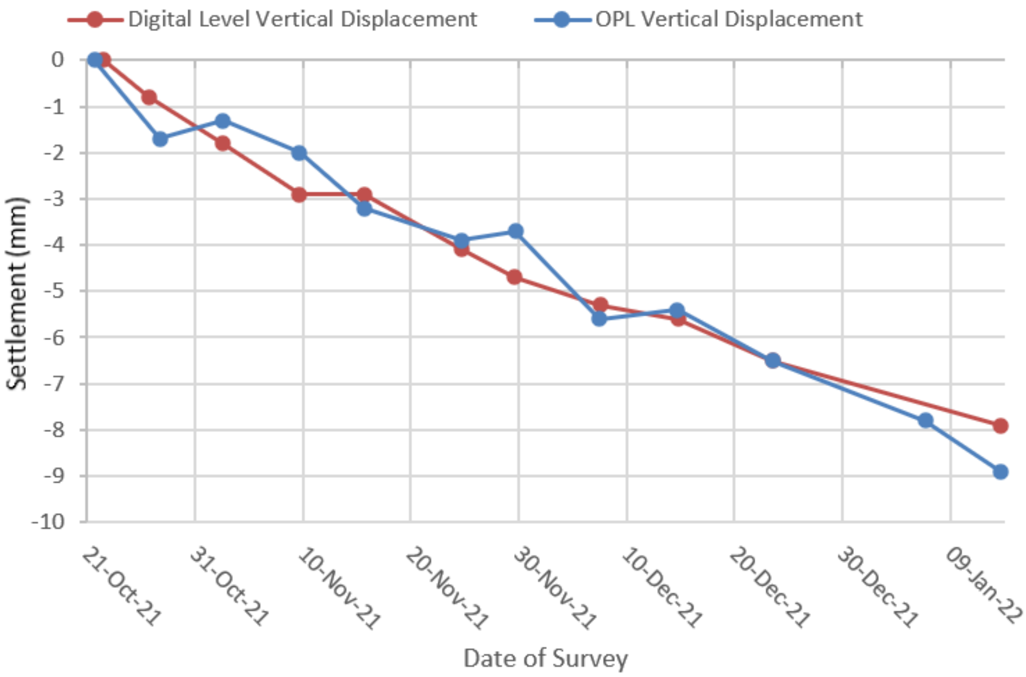


Figure 12: Movement chart comparison between OPL (blue) and digital level (red).

Figure 13: Close proximity of the starting benchmark reflector for OPL (left) and the starting nail for digital levelling below the 2 m invar staff (right).

5 DISCUSSION OF PERFORMANCE

The OPL method has provided impressive monitoring quality and has since been adopted along different areas of the project. While it is most suited for the unique conditions described earlier, more traditional methods of monitoring ground movement should always be used to check the quality of any OPL results. It is important to always incorporate a reliable control check for an OPL line. Having all measurements tied to one fixed benchmark makes data more vulnerable to compromised results, hence trusting a single starting benchmark is not sufficient to achieve high-quality OPL results.

5.1 Comparison between Levelling Techniques

Along a suitably flat and straight test line (approximately 400 m in length one-way), all three levelling methods were tested to analyse the time required to complete the measurement. Table 5 summarises the time taken to complete a double run with each of the three methods, and the respective number of setups. Times were from the first measurement to the last, where TSDL and digital levelling occupied exactly the same setups and where no intermediate sights were taken for either method. The digital level was taking an average of six measurements, and the TS60 was measuring three sets of two-face shots to each backsight and foresight. OPL is unique in this case due to the nature of having to place the special reflectors on power poles, and design setups around them. OPL only took one set of two-face measurements to each backsight and foresight for a double-run survey.

Table 5: Time and number of setups comparison between the three methods (measurements carried out along the same distance).

Method	Time (min)	Setups
TSDL	75	14
Digital Levelling	46	14
OPL	34	12

Based on Table 5, TSDL has an average setup time of 5.3 minutes, digital levelling is 3.3 minutes, and OPL is 2.8 minutes. With half a minute difference between OPL and digital levelling, this makes for a negligible time comparison. However, it is important to note that for both TSDL and digital levelling, two team members were required as opposed to only one for OPL. Therefore, OPL is reliable and efficient as a one-person operation. Data processing for measurements using the digital level is not needed because all heights are adjusted with the onboard firmware. Both OPL and TSDL require post-processing adjustments and calculations to determine results before they can be of any use.

5.2 Lessons Learnt for Future Use

When setting out future monitoring arrays where OPL is deployed, a few key take-aways have been identified. The first is to have a rigorous and robust far-field connection to stable height control. While a starting benchmark is intended to be outside the zone of influence of settlement, connecting this point to control further away is always suggested as it can verify any suspicious movement that may have occurred at this point. Furthermore, these check surveys should be neatly documented for traceability and record any adjustments that may need to be made to starting heights.

Secondly, having an efficient and reliable system for processing OPL results is necessary for good performance of the method. Initially, raw slope distances and zenith angles were exported in addition to measured 3D monitoring results. These raw measurements were used to calculate movement against the starting benchmark and to then adjust monitoring points and control heights for each setup manually. Since then, processing has improved, no longer requiring raw slope distances and zenith angles for post-processing adjustments. Results are now adjusted based on calculated height differences from the 3D exported measurement, where an efficient least squares processing spreadsheet uses these height differences to calculate their adjusted heights based on the starting benchmark. While processing has improved, an enhancement would be firmware that can execute all levelling calculations onboard the instrument, so that unadjusted point movement can be detected in real-time in the field.

6 CONCLUDING REMARKS

Tunnelling in urban areas is showing no signs of slowing. If anything, it is set to increase. With these projections, greater importance will be shouldered by surveyors to measure and report on accurate and consistent ground settlement as a result of tunnelling. The onus is then on surveyors to provide reliable deliverables to construction and design engineers. Anything less cultivates a distrust in the profession and hence the ability to innovate further. It is crucial for a monitoring engineer to have deliverables and workflows to assess monitoring data reliably and regularly against the project limits.

This paper has outlined OPL as a new approach, showing that monitoring performance is to a high standard of accuracy and reliability. OPL is one solution to a unique problem, with the potential to be progressed for other uses that are not yet realised. The method is used as part of a tailored monitoring campaign that skilfully balances resources against precision requirements during the different construction phases. Different rates of movement and overall magnitude will dictate the most appropriate method.

REFERENCES

ICSM (2020) SP1 Guideline for control surveys by differential levelling, version 2.2, https://www.icsm.gov.au/standard-australian-survey-control-network-special-publication-1-sp1 (accessed Mar 2022).

Rüeger J.M. and Brunner F.K. (1981) Practical results of EDM-height traversing, *Australian Surveyor*, 30(6), 363-373.

Rüeger J.M. and Brunner F.K. (1982) EDM-height traversing versus geodetic levelling, *The Canadian Surveyor*, 36(1), 69-88.

Terzaghi K., Peck R.B. and Mesri G. (1996) *Soil mechanics in engineering practice* (3rd edition), John Wiley & Sons, New York, 534pp.

Proceedings of the 25th Association of Public Authority Surveyors Conference (APAS2022)
Leura, New South Wales, Australia, 21-23 March 2022

Cadastral Surveys, Ground Distance and the Australian 6° UTM Survey and Mapping Coordination System: The 1970s Ground Distance vs. Grid Distance Dimension Dispute

John Read
FIS NSW, Emeritus Surveyor (Retired)
jrread@bigpond.net.au

ABSTRACT

This paper refers back 50 years ago to the NSW survey integration proposal to show grid distance dimensions on plans and introduce 2° 'narrow zone' survey coordination so that the stated grid distance dimension was "substantially equal" or "near enough" to ground distance dimensions. Grid distance dimensions were (and are) the only exception to dimensions in linear standard units where measured and used. Being a distance at sea level (and not where measured) it also varied from height to height so that the combined difference was often much greater than that claimed with the 2°-zone projection. So, this (or any) difference, with ground distance dimensions, was opposed for what (to me) were sound precision, surveying, cadastral and title dimension reasons. The NSW survey integration proposal was convened by the Surveyor General with the backing of University of New South Wales (UNSW) academics, the Institution of Surveyors NSW (ISNSW), and "peers of the profession" – so it had to be right! It seemed to have just been adopted from USA and overseas practice without any apparent regard to its underlying rationale. The proposal's duplexity of grid as well as ground distance dimensions, and survey as well as mapping coordination, was imbedded in survey practice overseas, and it still remains unquestioned today. This paper relates to circumstances existing at the time and contains the rationale found so lacking in the NSW survey integration proposal. The adoption of this underlying rationale resulted in the Australian practice of only ground distance dimensions and only the 6° Universal Transverse Mercator (UTM) survey and mapping coordination. Comparatively simple and unconfused, it is probably the best surveying, cadastral and coordination system in the world. Yet, it so nearly did not happen, and that is why this paper has been written.

KEYWORDS: *Ground distance, grid distance, cadastre, UTM projection, 2° ISG zones, 6° MGA zones.*

1 INTRODUCTION

In July 1969, the Integrated Survey Grid (ISG) was proposed in New South Wales (NSW) to replace the Australian Map Grid (AMG), requiring all land, survey and title dimensions to be projection (grid) distance. This plane coordinate system, based on the narrower 2° zone width, ensured that all dimensions were mathematically consistent with the to-be-introduced survey coordination on the projection plane at sea level. However, grid distance dimensions were opposed and then rejected, so that all dimensions in surveys and land titles remained and continued as ground distances in Australia. Nevertheless, the ISG (Lands, 1976) was introduced and practised in NSW for 20 years, until it was discontinued to be replaced by the 6°-zone Universal Transverse Mercator (UTM) Map Grid of Australia (then MGA94, now

MGA2020 – see ICSM, 2022). Subsequently, over the last 25 years, the MGA system has worked extremely well, with all land, survey and title dimensions being ground distances while all survey, spatial data and mapping coordinates are referred to MGA.

In contrast, many other countries have plane coordinate systems with grid distance land dimensions. This paper argues against the statement of grid distances as dimensions in survey and land titles as they often differ with ground distance and other dimensions where measured and used. It also asserts that it is advantageous to state ground distance dimensions with an orientation to grid north and the already existing 6°-zone UTM mapping coordinate system, particularly in relation to modern surveying equipment producing more precise measurements and modern computer software simplifying and speeding up the calculation of coordinates. As ground distances and 6°-zone UTM maps already exist globally, this Australian system could be established worldwide, simply by doing away with the duplexity of grid distance dimensions and their plane or 'narrow zone' coordination. From a cadastral perspective, this paper explains and promotes the use of precise ground distance dimensions and the Australian 6° UTM survey and mapping coordination system (known in Australia as MGA) throughout the world.

1.1 The Surveying of Land in NSW

In 18th century Britain, boundaries were usually visible fences, walls, ditches, hedges, rivers and the like, defined and acknowledged in increasing precision by maps, surveys and written description. This metes-and-bounds marking and description was adopted following the colonisation of NSW in 1788, where surveying vacant Crown land (public domain) made the visible marking of property boundaries essential, and where the precision of their metes (measurement) also improved as surveying equipment became more precise.

The early surveying of land in NSW was for the expediency of the granting of title for the colony's ever-expanding farming, grazing and settlement needs. Consequently, there were never enough surveyors to keep up with the demand following the first land grant in 1791, the first sale of Crown land in 1825, and the 'Selection before Survey' Act in 1861. At the same time, the Ordnance Survey of Great Britain (1791-1821) and the Great Trigonometrical Survey of India (1802-1852) took place, which prompted the Colonial Office to instruct the Surveyor General to undertake the trigonometrical survey and mapping of NSW. This resulted in Sir Thomas Mitchell's Map of the Nineteen Counties (1827-1834). The major difference between the Ordnance Survey's and Mitchell's map was that the former was over (mainly) settled land and for cadastral purposes, whereas Mitchell's map was a reconnaissance trigonometrical, military-style map of (mainly) undeveloped lands. The NSW Trigonometrical Survey commenced in 1865, then 1873 to 1916, when it was abandoned as a World War I economy measure. While the Royal Australian Survey Corps did some coastal mapping from 1907 to 1945, the NSW Trigonometrical Survey did not recommence until 1946. This on-off government support for trigonometrical surveys raised some doubts about the future of the NSW survey integration proposal, especially if its control surveys and coordination relied predominately on government support, staffing and funding. (This, and other public cost concerns, resulted in the 1974 Overall Inquiry, which found that the future savings of survey integration more than offset the basic survey costs involved.)

Initially, surveyors marked property boundaries, corners and monuments using a circumferentor, compass, magnetic north and a Gunter's chain. From 1853, blazed lines, lock spits and numbered reference trees became mandatory. As corner marking was removed by land improvements and fencing, Reference Marks (RMs) and Permanent Marks (PMs) became necessary. The first theodolite in the colony was Mitchell's theodolite in 1827 used for his Map of the Nineteen Counties. Use of the circumferentor was prohibited in 1872, to be superseded by the more precise theodolite and, coincidently, Surveyor Woolrych introduced the steel riband or wire to replace the Gunter's chain. Both resulted in a significant improvement in the precision of surveys.

The NSW colonial cadastre was a patchwork of parcels where new parcels generally abutted existing parcels, using their abuttals for boundary origin and azimuth. Crown land portions were plotted on county, parish and town maps and, after 1863, on Registrar General charting maps, to make up a mosaic of parcels for cadastral maps. Watercourses often joined the early portions together, and then roads and the survey of public roads. When fencing replaced corner marking, public road surveys, road alignment surveys and Ordinance 32 permanent marking (1920, 3'6" offset) of subdivision roads were often relied upon in retracement surveys. However, contrary to footpath space allocations, underground telephone cabling destroyed much of the post 1933 (1'6" offset) PMs. Subsequently, the Survey Practice Regulations were amended in 1964 to make permanency of the location of PMs a prime requirement, and to regulate pairs of Drill Hole & Wings (DH&Ws) on kerbs as permanent marks.

The NSW Survey Co-ordination Act 1949 was introduced to provide state-wide survey control and coordination of effort by public authorities. However, progress was slow, and, in proclaimed survey areas, PMs were seldom connected to the cadastre. In 1970, approval was gained to use brass State Survey Marks (SSMs) set in concrete as permanent marks in a subdivision. By placing and connecting them to the title survey, the integrated survey was partly implemented at a reduced public cost.

1.2 The Public Land Survey System in the USA

In 1785 (three years before the colonisation of Australia), the US Congress introduced a rectangular system of dividing up the public domain (similar to Crown land) for agriculture, settlement and as a source of public revenue. The US Public Land Survey System (PLSS) was very innovative at a time when the US population was about 4 million and when it was about to expand westwards from its founding 13 colonies. It covers about 72% of the area of the US and continues today. For survey purposes, the public domain was divided into a cadastral checkerboard of 35 *regions*. Each region had an *initial point* from which the *principal meridian* of longitude and a *base line* of latitude were laid out. Marks were placed at 24-mile intervals, north-south and east-west, and then the region was divided into rectangular tracts of land approximately 24 miles square. This was further subdivided into 6-square-mile *townships* and then into *sections*, etc.

In 1822, Governor Brisbane directed that the PLSS be used for rural surveys in NSW, and it was introduced in parts of the Hunter, Bathurst, Goulburn and Illawarra regions. However, it was a costly use of scarce resources and Surveyor General Thomas Mitchell thought that the PLSS was wasteful of the scarce stream frontages. He believed that a more equitable share of water would be provided to the land holders when boundaries were orientated at, or near to, right angles to the stream. Circumstances differed with Australia being far more dry and arid than the US, so that emphasis was given to water access and agricultural viability, rather than copying the PLSS grid pattern in the subdivision of NSW Crown lands.

2 THE COORDINATE SYSTEM

Coordination provides a position reference for features on the surface of the Earth and for the location and analysis of land data. The geographical location of position is usually depicted by the degrees, minutes and seconds of its latitude and longitude. This can be complex and was simplified by using a plane or projection coordinate system where position is linear distance stated in Easting and Northing ordinates. The use of a projection converts the coordinates of large, curved surfaces of the Earth to a flat plane but with some distortion. Some preserve shape, some area, and others distance and direction.

2.1 State Plane Coordinate Systems

In 1933, the US Coast and Geodetic Survey created State Plane Coordinate Systems that replaced comparatively complex geographic coordination (latitude and longitude) with more user-friendly rectilinear coordination (Easting and Northing). Revolutionary at the time, this comparatively easy two-dimensional plane rectangular coordinate system became the most widely used expression of coordinate information in local and regional surveying and mapping in the United States. It is embedded in US surveying practice and is still being used today. Apparently, similar plane coordinate systems operated elsewhere (in Canada, Malaysia, South Africa and New Zealand), and they were used as models for the ISG proposal in NSW. Grid distance dimensions were and are still used.

2.2 The 6° UTM Projection Coordinate System

The Universal Transverse Mercator (UTM) system originated in 1936 and was developed for military mapping during World War II. Like the 1933 State Plane Coordinate System, it replaced geographical coordination with rectilinear coordination and was adopted worldwide for small scale military mapping. The UTM coordinate system is conformal (preserving true angles and shapes) but it distorts distance and area over larger areas. In surveying, the distance and direction between two points can be calculated easily using the Pythagorean theorem and plane trigonometry. Its adoption provides consistency in the analysis and editing of data.

The UTM system is the most commonly used projection. Noting that surveying data is brought together through the mapping and digital representation of the cadastre combining both position and property information, the UTM system is also Geographic Information System (GIS) and MGA compatible. However, with its wider width of 6° longitude zones, it presents greater 'grid-to-ground' differences for grid distances to pass off as 'near enough' or 'pseudo' dimensions. Consequently, State Plane Coordinate Systems and grid distance continued to be used for survey coordination purposes.

3 THE 1970s DISCERNABLE NEED FOR A COORDINATED CADASTRE

In considering the discernible need for a coordinated cadastre, it is important to distinguish between:

1. The Digital Cadastral Database (DCDB) where data coordinates often relate to the centroid of the parcel, which can be simply, quickly and adequately digitised from existing 6° AMG/MGA maps and calculated from surveys. Commenced in the early-to-mid 1980s, this met most community needs for coordinates without a survey-precision cadastre. It

should be noted that the DCDB is graphical in nature, used for administrative purposes and has no legal weight in land boundary definition.

2. The Integrated Survey Grid (ISG), which requires boundaries and corners coordinated with surveying precision. This needs the extra work and cost of control surveys to connect property surveys to the coordinated cadastre.

In determining surveying-precise coordinated corners, it should be appreciated that:

1. The NSW survey and (Torrens) title system was relatively simple and easy to understand. It was based on boundaries being physically identified on the ground and described in simple, easily understood, usable terms. Other than the unfortunate destruction of permanent marks, it was working satisfactorily and was generally trusted. However, there was a need for better permanent marking to improve boundary relocation.
2. A coordinated cadastre does not remove the obligation on the part of the surveyor to accurately mark boundaries on the ground as permanently and visibly as possible and to state the details and parcel dimensions on the title plan that is clear and easily understood. Coordinates (and their datum) must be stated on the relevant survey or title plans to have any legal credence in boundary definition.
3. In a coordinated cadastre, all other evidence of boundaries precedes that of coordinates. Boundary location is a matter of law whereby precedence is given to where boundaries are identified or marked on the ground. The plan of survey, deed, drawing or document purports to record, in a convenient form, particulars of the survey of the boundary marked and/or visible on the ground. In the metes-and-bounds boundary definition, the surveyed lengths and bearings (the metes) prescribe the mathematical framework, or surrounds, of the property, while the bounds relate and anchor the framework to abuttals, being adjoining legal property features identifiable on the ground. Well-regarded NSW land title Barrister, Frank Hallmann, wrote in 1973: "*It is the visible objects and marks that … determines the extremities of the property lines that the engineer, the builder, the fencer and the retracement surveyor will follow on the ground (not the recorded coordinates of the extremities from a distant origin). Moreover, it is these objects and marks, or the occupations erected in reliance upon them, that the courts will consider more favourable in settling boundary disputes*" (Hallmann, 1973). So, in redefining boundaries, emphasis is given to the priority of evidence according to the law where it is only in the absence of other evidence that measurement, then direction, and lastly calculation from a 'distant origin' coordinated cadastre, 'invisible' coordinates, would then apply. This priority of boundary evidence is what the public wants and what the law relies upon.
4. The legal aspects of boundary definition reinforce the importance of surveys underpinning the state-guaranteed Torrens title system. Consequently, the legal acceptance of grid distance dimensions and coordinated corners would ultimately require the legal approval of the Registrar General.

Having regard to the foregoing, the NSW survey integration proposal:

- Sought a coordinated cadastre that defined boundaries and corners with survey-precise coordinates when, legally, other boundary definition criteria had higher credibility than the coordinates.
- Proposed an additional 2° 'narrow zone' plane coordination system for the coordinated cadastre, assuming the use of grid distance dimensions. The survey integration proponents did not show why the existing 6° Australian Map Grid (AMG) coordination used for mapping and (later) for the DCDB could not alternatively be used for survey-precision coordination.

- Proposed grid distances for property dimensions. These differ with the linear standard units (of the already accepted ground distance dimension) where measured and used. In effect, grid distance dimensions are a *variable linear standard unit* varying from place to place and height to height. The survey integration proponents did not show why the alternative ground distance dimensions could not continue to be stated on plans, measured and used.

The survey integration proposal was timely. It was claimed to be "the first comprehensive system of surveys in the state" and sought to integrate ad-hoc surveys with control surveys and a coordinated cadastre. Also, magnetic north, true north and azimuth from abuttals would be replaced with grid north. However, by ignoring that these benefits equally applied to the alternative 6°-zone proposal, any opposition to any part or detail was viewed as opposition to the proposal as a whole, and disregarded. (The alternative proposal was presented to the NSW Integration Committee without receiving a response.) Consequently, by excluding the matters held in common, this paper specifically examines those matters that differ and the underlying rationale for both the NSW proposal and the alternative Australian ground distance on 6° AMG proposal (e.g. Read, 1975, 1981; Nation and Read, 1985).

4 AN INITIAL EXPLANATION

In mapping, all distances on the projection plane are grid (or projection) distances, being in linear standard units on that plane. Distance on the ground, where measured and used, is in linear standard units at ground level. Consequently, grid distance dimensions (in plane, or 'narrow zone' coordination) vary from place to place and height to height with the distance measured at ground level by (1) a scale (projection) factor and (2) a height (above sea level) factor. These are combined as the 'grid-to-ground' conversion factor between grid and ground distances. As mathematical consistency of data is required in calculation, this must be in linear standard units, either on the projection plane or at ground level, with the 'grid-to-ground' conversion between them. (Mathematical consistency is when data or units of calculation are of the same uniform standard measure.) This conversion is ignored in many 'narrow zone' or plane coordinate systems and grid distances are stated as 'substantially equal', 'near enough', 'quasi-' and/or 'pseudo-' (ground distance) dimensions.

The matter of dispute between the NSW survey integration proposal and the submitted alternative was mathematical consistency and what to show on plans. Copied from overseas practice, the NSW 2° 'narrow zone' coordination proposal required the mathematical consistency of calculating coordinate data, and showing both projection dimensions and coordinates, on plans. This required a 'narrow zone' projection to minimise the size of the 'grid-to-ground' conversion factor so that grid distance, when stated as a dimension on plans, approximated ground distance and measurement.

By contrast, considering the available measuring equipment at the time, the alternative proposal preserved the fundamental mathematical consistency between dimension and measurement. This meant that ground distance dimensions and projection coordinates were to be shown on plans but required that the 'ground-to-grid' difference had to be calculated between them for coordinate calculation. Unlike the NSW proposal with (often) approximate dimensions, the alternative proposal ensured the exactness of dimensions with measurement where measured and used. So, the essential issues of the 1970s NSW survey integration debate were mathematical consistency and what to show on plans, either (1) introduce the overseas practice of mathematical consistency of the coordinate calculations derived from measurement, but show grid dimensions on plans that are approximate of those measurements, or (2) maintain the long accepted mathematical consistency of dimensions with measurement by calculating the projection coordinates from measurement and then, stating on plans, dimensions that are mathematically consistent (and agree) with those measurements.

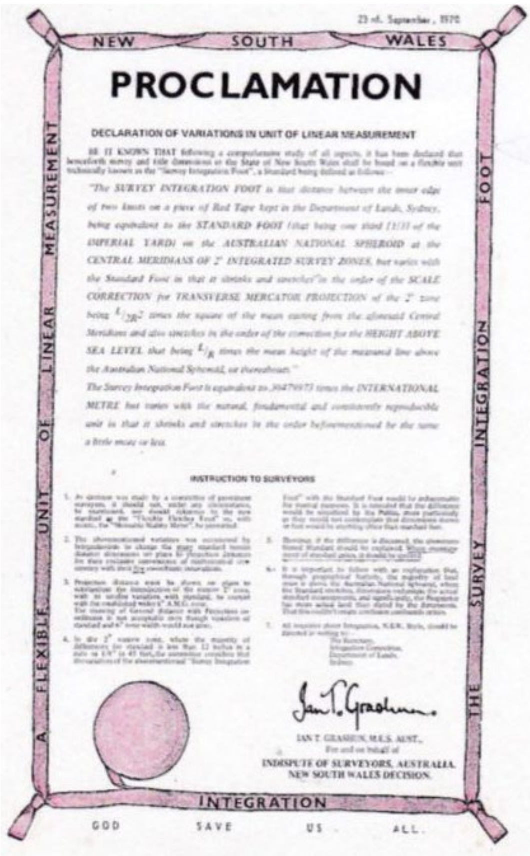
5 THE 1970s NSW INTEGRATION OF SURVEYS PROPOSAL

The "Integrated Surveys" report by an investigating committee convened by the NSW Surveyor General, Noel Fletcher, was published in July 1969 (Lands, 1969). It adopted the 2°-zone coordination ideology copied from similar 'narrow zone' plane coordinate systems overseas. This proposal was prepared and promoted by the Survey Integration Committee chaired by the Surveyor General and with membership and support from University of New South Wales (UNSW) 'academic' surveyors, the Institution of Surveyors NSW (ISNSW) and the heads of most government departments. In its 85-page "comprehensive study of all aspects", it once mentioned the statement of projection (grid) distance dimensions and once the alternative system which could be based on already existing ground distance dimensions and the 6°-zone UTM mapping projection system used for AMG (and later MGA).

The initial dispute concerning the NSW proposal was about whether 2° or 6° zone widths should be used. However, following the Hobart 'proclamation' (Figure 1), the NSW proposal for grid distance dimensions, and its variation with ground distance in linear standard units from place to place and height to height, became apparent. Together with the knowledge that survey integration could be alternatively based on a ground distance dimension with 6°-zone AMG coordination, the NSW grid distance 2°-zone proposal was opposed by the Institution of Surveyors Australia (ISA) and, except for NSW, the rest of Australia. The alternative ground distance 6° AMG proposal was submitted to the Survey Integration Committee for consideration. However, the Committee (7 votes to 6) refused to hear the case for the 6°-zone system or discuss written submissions for the continued statement of ground distance dimensions. Condescendingly, they were prepared to amend the Act (which was never presented to Parliament) should their decision be wrong. Subsequently, the Surveyor General prepared and published the Manual of the New South Wales Integrated Survey Grid (Lands, 1976) and implemented the 2°-zone ISG proposal for survey control and large-scale mapping.

After considering the arguments for and (notably) against the proposed statement of grid distance dimensions, the proposal was rejected by Jack Watson, Registrar General of NSW, who required that all title dimensions in NSW continue to be "horizontal ground distances". Consequently, all land, survey, title and Deposited Plan dimensions remained, and have continued, as ground distances in Australia. Once this decision was made (and the need for grid distance dimensions on plans and their closeness to ground distances was no longer an issue), the existing 6° UTM (AMG) map projection could have also been used for survey coordination. Irrespective of this, the Surveyor General introduced the 2°-zone ISG for survey coordination in NSW, but with ground (and not grid) distance dimensions. This practice continued for about 20 years (until 1995) when the *geodetic* 6°-zone AMG was replaced by the *geocentric* 6°-zone MGA (see ICSM, 2022). From then, and for the last 25 years, all survey and mapping coordinates, the DCDB and all maps have been based on the 6°-zone MGA (first MGA94 and now MGA2020).

This background information is included with the hope that the reader will forego the presupposition, generally accepted with the NSW proposal, that the grid distance dimension and 'narrow zone' coordination practised elsewhere around the world was the only means of survey-precision position reference. Its general acceptance overseas, and by the NSW professional elite, in effect discouraged the consideration of any credible alternative. However, by examining its underlying rationale, this paper deduces that it was fundamentally flawed and that a much better alternative was to have *only* ground distance dimensions and *only* 6°-zone UTM coordinates, used Australia-wide, for *all* surveys, spatial data and mapping.



[X 315 % for actual size]

DECLARATION OF VARIATIONS IN UNIT OF LINEAR MEASUREMENT"

BE IT KNOWN THAT following a comprehensive study of all aspects, it has been declared that henceforth survey and title dimensions in the State of New South Wales shall be based on a flexible unit technically known as the "Survey Integration Foot", a Standard being defined as follows:

"The SURVEY INTEGRATION FOOT is that distance between the inner edge of two knots on a piece of Red Tape kept in the Department of Lands, Sydney, being equivalent to the STANDARD FOOT [that being one third [1/3] of the IMPERIAL YARD on the AUSTRALIAN NATIONAL SPHEROID at the CENTRAL MERIDIANS OF 2⁰ INTEGRATED SURVEY ZONES, but varies with the Standard Foot in that it shrinks and stretches in the order of the SCALE CORRECTION for TRANSVERSE MERCATOR PROJECTION of the 2⁰ zone being L/2R² times the square of the mean easting from the aforesaid Central Meridians and also stretches in the order of the correction for the HEIGHT ABOVE SEA LEVEL that being L/R times the mean height of the measured line above the Australian National Spheroid, or thereabouts..

[Presented at the 14th Australian Survey Congress in Hobart on 12 February 1971]

Figure 1: Proclamation of a variable standard of length.

6 GROUND DISTANCE LAND DIMENSIONS, ONLY AND ALWAYS

According to the Oxford Dictionary, a dimension is a measurable extent of any particular kind, such as length, breadth, depth or height. The word comes from the Latin *dimensis* meaning "a measuring" and the old French word *dimetiri* meaning to "measure out" and, hence, has a direct nexus with measurement. It is the written statement of a measurement.

Over many years, the standardisation of units of measurement has been refined to the extent that linear standard units can be reproduced with exactitude. The dimension should replicate that exactitude as measured in standard units. Every country maintains national linear standards (in Australia, by the National Measurement Institute) and every surveyor must verify their measuring equipment with baselines certified from these standards. Consequently, every measurement (and dimensions derived from these measurements) should replicate the "most scrupulous exactness" of the linear standard unit.

Precision and accuracy of measurement is important to, and expected of, a surveyor. The surveyor makes adjustments (not corrections, unless there is an error) to replicate the exactness of the linear standard units in their measurement. All measurements resulting in dimensions shown on a cadastral survey plan are adjusted to the horizontal or level at its mean height and stated as a dimension. This is known as ground distance, the survey and land dimension that a surveyor determines and what the public understands and expects. In this context, the deliberate departure by grid distance dimensions from ground distance measurements and dimensions, in linear standard units at its location, no matter how small, would seem to be a specious practice by surveyors. Being 'near enough' is contrary to the professionalism expected of surveyors and the competence, precision and exactitude of the measurements surveyors make, and the dimensions that they then state.

6.1 Advantages of Using the Ground Distance

Ground distance (also called site or terrain distance) is defined as "the distance on the horizontal plane at the mean elevation of its measurement". It is stated in linear standard units, i.e. metres in Australia. Its use (instead of grid distance) is supported by the following five reasons outlined in the following subsections.

6.1.1 Measurement and Usage Support Ground Distance Dimensions

Usage (practically all development is built on the horizontal plane where their measurement is made), calculation, and convenience of record commonly support ground distance as the dimension in land measurement, surveys, property plans and titles.

6.1.2 Ground Distance Dimensions are Mathematically Consistent with all other Dimensions in Linear Standard Units

Ground distance, when measured and stated in linear standard units, also maintains mathematical consistency with existing and other dimensions and their inter-related systems of area, volume, etc. In this context, this mathematical consistency is particularly important in design when construction materials and products are manufactured or prefabricated off-site. Incidentally, grid distance dimensions are the *only exception* to this mathematical consistency and statement of dimensions in linear standard units where measured and used.

6.1.3 Ground Distance Dimensions are Mathematically Consistent with Measurement at Specific Locations, Heights and Surfaces

It would be illogical for metes and distance relative to bounds, distances to and from monuments, strata and strata titles, and titles restricted to often 50' (15.24 m) from the surface, to be shown by linear standard unit dimensions at any other place (i.e. the projection plane or at sea level) than the location, height and surface to which such distances and areas are referred to, measured and used.

6.1.4 Ground Distance Dimensions do not Change with Coordinate Systems

Unlike grid distance, ground distance does not change, irrespective of the zone width and coordinate system used. (Grid distance dimensions can vary, and be an issue, when more than one zone width or coordinate system is used, as in the 2°-versus-6° zone debate regarding the NSW proposal.)

6.1.5 'Narrow Zone' Projection Coordinate Systems, State Plane Coordinate Systems and Low Distortion Projection Coordination Acknowledge the Significance of Ground Distance

Specifically, the important function of ground distance is acknowledged by these systems to limit the difference between their grid (or projection) distances and the ground distance. However, the fundamental consideration is not an 'acceptable' amount of difference, but the need to have a difference, *any difference*, between the dimension shown and the ground distance measurement of what exists.

7 GRID DISTANCE LAND DIMENSIONS, NOT NOW AND NOT EVER

7.1 Use and Statement of Grid Distance Dimensions on 'Narrow Zone' Projection Planes

Initially, in plane coordination, dimension and measurement were the same, and there was mathematical consistency with plane coordinates. Naturally, this mathematically consistent relationship could not be maintained over larger land areas and greater height differences, so measured (ground distance) data had to be multiplied by a 'ground-to-grid' conversion factor for coordinate calculation on the projection plane (Figure 2).

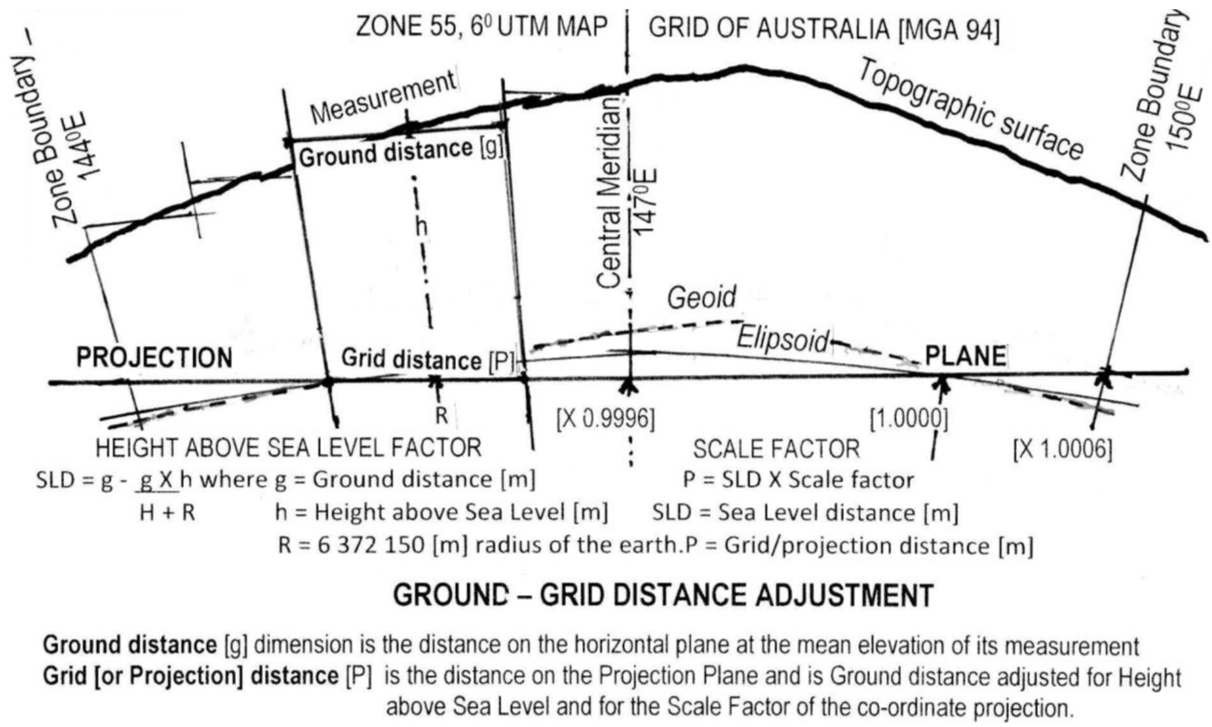


Figure 2: Ground distance to grid distance adjustment.

The validity of calculation requires mathematical consistency of all data used in the calculation. This is irrefutable and forms the basis of support for the nexus of grid distance dimensions with grid distance coordinates. However, *the real issue was whether, or not, grid distance should be shown as dimensions on plans*. The NSW 'narrow zone' coordinate supporters argued that they should, otherwise the mathematically inconsistent data would invalidate coordinate calculations. So, instead of mathematical consistency of stated dimensions with ground distance, they proposed a 2° 'narrow zone' projection to reduce the scale (projection) factor of the 'grid-to-ground' difference to an 'acceptable' limit for mathematical consistency of the grid distance dimensions stated on plans with grid distance projection coordinates.

The NSW survey integration proposal claimed that, with a 2°-zone projection plane, grid distance dimensions would "significantly equal" ground distance in the "vast majority of cases" and that the scale (projection) factor was within an "acceptable" limit, being the maximum allowable survey closure error ratio of 1:8,000 in the (then) Survey Practice Regulations. Yet, in this:

- Allowance was not made for the often-greater height (above sea level) factor, so that the 'grid-to-ground' conversion factor often exceeded this claimed "acceptable" limit (about 15% of the area of NSW exceeded the 1:8,000 limit and 70% exceeded 1:20,000, noting that Australia is an old, comparatively flat continent).
- Often overlooked was that grid distance dimensions can overstate ground distance and measurement at sea level near the edge (and overlap) of the proposed 2°-zone. Overstated dimensions and quantities are not legally acceptable.
- Tolerance was still needed for the maximum error in measurement to not exceed 1:12,000 (see the Survey Practice Regulations 1968).

However, this action to narrow the zone width to ensure that the grid distance was 'near enough' to the ground distance detracts from the essential issue of why grid distances need to be stated as dimensions in the first place.

7.2 Statement of Mathematically Inconsistent Data on Plans

The 'narrow zone' coordination practice of mathematical consistency of calculation data is used to justify the statement of grid distance dimensions on plans. This was to prevent any calculation error due to different and inconsistently stated data. Yet, unless clearly declared otherwise, confusion and error can occur when grid distance dimensions replace the more-expected ground distance dimension, especially as their similar size and same mode of statement tends to hide the difference. However, *dimensions and coordinates are stated differently, in different modes*. In this way, both ground distance dimensions and grid distance coordinates can be shown on the same plan (with a calculable difference) and (although mathematically inconsistent) without confusion, simply by stating ground distance in dimension form and grid distance as coordinates and in coordinate form.

Coordinates can be stated either as or in:

1. Coordinate mode at the relevant point on the plan (and potentially in *italics*), or
2. An (accompanied?) schedule of coordinates referenced to relevant points, and/or
3. To dispel any confusion, a ground distance conversion statement with
   (a) the multiplication factor for conversion from ground to grid, and
   (b) the applicable static coordinate datum (e.g. MGA94), acknowledging that, for title clarity, data and statements on title plans must be kept to a minimum.

Adoption of a particular mode and means of statement allows both ground (dimension) and projection (coordinate) data to be shown on the same plan without confusion, without 'near enough' approximate grid dimensions, without the need for 'grid-to-ground' conversion for measurement and without an additional 'narrow zone' coordination system (Figure 3).

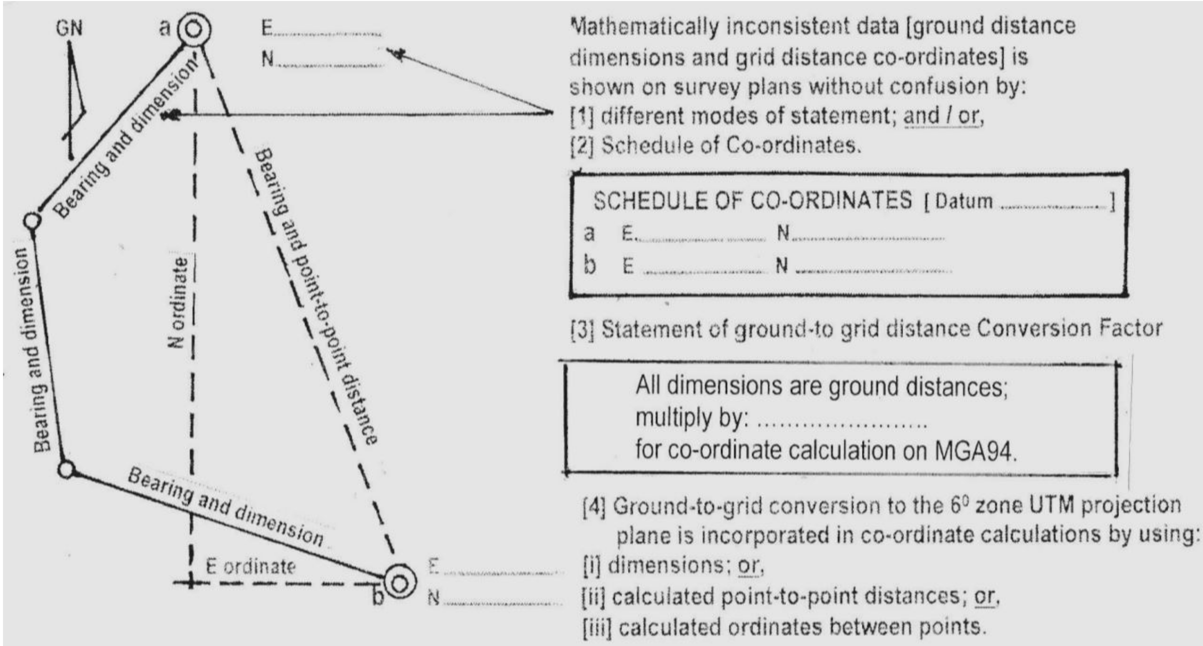


Figure 3: Statement of mathematically inconsistent data on plans without confusion.

7.3 Calculation of Mathematically Inconsistent Data in Coordination

In 'narrow zone' or State Plane Coordinate Systems, either (1) grid distance is deemed 'near enough' for use as a dimension or (2) a 'grid-to-ground' conversion is applied to the grid distance when the more-precise ground distance dimension is to be determined, measured and used. However, there is another option: (3) The 'grid-to-ground' conversion can be made with the coordinate calculation. This is supported by the six reasons outlined in the following subsections.

7.3.1 Conversion Only when Required, with Coordinate Calculations

The conversion should be carried out only when it is required, with coordinate calculations. The introduction of mapping coordinates using UTM maps and survey coordinates using State Plane Coordinate Systems in the 1930s was revolutionary at the time and continued to underpin the 'narrow zone' NSW survey integration proposal of the 1970s. However, the NSW proposal created a paradox whereby the precision of the 'ground-to-grid' conversion applied when initially establishing coordinates from measurement did not apply in reverse, when the comparatively imprecise 'near enough' grid distance dimensions used in 'narrow zone' coordination was stated on plans. That is, unless the 'grid-to ground' conversion was applied, the stated grid dimension was imprecise and mathematically inconsistent with the measurement from which it was derived. A further reason is that (unlike ground distances at the topographic surface) coordinates on the projection plane cannot be measured and must be calculated. Therefore, it makes sense that the 'grid-to-ground' conversion should be calculated with the coordinate calculation, and then only when it is required. Conversely, with 'narrow zone' coordination (as in the NSW survey integration proposal), the stated grid distance dimension required the 'grid-to-ground' calculation for precision, and this was required every time a dimension was used, even if coordination was not. The statement of ground distance allows dimensions to be readily measured and used without any need for 'grid-to-ground' calculation, without the imprecision of (often) approximate grid distance dimensions, without coordination, and without a 'narrow zone' projection. This is what most users want.

It seemed odd at the time that surveyors, known for precise measurement, advocated imprecise 'near enough' dimensions in the 1970s NSW survey integration proposal. This practice still continues in the United States and overseas today, even when computers and software has made the conversions easier and calculations almost automatic. At the same time, the use of Electronic Distance Measurement (EDM) along with more precise measuring equipment and techniques have improved the precision of dimensions. So, today, the easier calculation and more precise measurement supports ground distance dimensions and makes the use of the 'near enough' grid distance dimension practice outdated, unprofessional and unsustainable.

7.3.2 Choice for 'Grid-to-Ground' Conversion with the Coordinate Calculation

'Grid-to-ground' conversion with the coordinate calculation offers a choice in calculation method, acknowledging that these methods may vary in accuracy. The 'grid-to-ground' conversion can be carried out without involving dimensions, by also using 'point-to-point' working or by adjusting the East and North ordinates between points. This is especially relevant when comparatively few coordinates are stated or used.

7.3.3 Less Risk of Mistake and Error

There is less confusion and less risk of mistake and error when only ground distance dimensions are stated on plans, as opposed to grid distance dimensions being stated. Apparently, there have been incidents where off-site materials, prefabricated structures and other items made in linear standard units did not fit on-site when grid distance dimensions were stated on plans and were mistaken for the usually expected ground distance. There is no likelihood of this confusion and error happening in Australia where all land dimensions have always been, and always will be, ground distance. Similarly, with ground distance dimensions, there is not the need for 'grid-to-ground' conversion of grid distance when dimensions are measured and used. Furthermore, there is advantage and convenience in calculation by having both grid (coordinates) and ground (dimension) data on plans with a common grid north orientation. Consequently, there is a less likely overall risk of mistake and error. This is evidenced in the Australian ground distance dimension-only practice.

7.3.4 Functional Uselessness of Grid Distance Dimensions

The projection plane is assumed for the special purpose of coordinate position referencing in surveying and mapping. For convenience of calculation and mathematical consistency of stated data, grid distance dimensions and projection coordinates are shown on 'narrow zone' coordination projection planes. However, because stated grid distance (dimensions) vary from place to place and height to height in its conversion to ground distance (and because it cannot be actually measured at sea level), it does not perform the function of a dimension in land measurement. Also, as it is not stated in coordinate form, it does not perform the function of position reference. Thus, unlike ground distance dimensions and projection coordinates, which (as separate entities) function in their own right, grid distance dimensions are functionally useless by themselves. To be of any use in reality, grid distance dimensions must be multiplied by trigonometrical functions for coordination or by 'grid-to-ground' conversion for ground distance land dimensions. Also, as part of the coordinate calculation with 'point-to-point' or ordinate calculation, grid distance (as a dimension) is not required at all.

Grid distance (in dimension form) is a transitory, non-essential component in coordinate calculation. Being the only exception to dimensions in linear standard units where measured and used, its similar 'near enough' size makes it not only deceptive as a dimension, but it also requires its own superfluous 'narrow zone' coordination system. There is no justification for the ambiguity, and (often) the approximation, of grid distance dimension compared to ground distance dimension. Grid distance should not be used as a dimension in land, property and title measurement and, as such, should be deprecated from surveying practice.

7.3.5 Difference between Grid and Ground Distance as a Calculating Quantity Only

By stating ground distance (instead of grid distance) dimensions on plans, the matter of the magnitude of the difference between them, and the need for 'near enough' grid distances and 'narrow zone' widths, is no longer an issue. Without the need for grid distance dimensions, the 'ground-to-grid' difference becomes a calculating quantity *only*, as part of the coordinate calculations, and can be larger than the 'near enough' magnitude needed in State Plane Coordinate Systems, Low Distortion Projection coordination and other 'narrow zone' coordination.

7.3.6 Using Any Projection Zone Width

When ground distance is stated as the land dimension, any (or just one) zone width can be used. Stated conversely, ground distance dimensions maintain their direct nexus with measurement *without* the need for 'grid-to-ground' conversion and *without* it placing limits on the choice of zone widths and coordinate systems.

8 THE USE OF THE 6° UTM COORDINATE SYSTEM

As previously mentioned in section 2.2, the 6° UTM projection coordinate system was introduced for mapping in the 1930s and during World War II. It is now universally used for worldwide mapping. Consequently, as any zone width can be used with ground distance dimensions, it is hard to argue against using the existing and established 6° UTM mapping system for survey coordination as well. This is supported by the four reasons outlined in the following subsections.

8.1 One Coordinate System for all Land Spatial Position Reference Purposes

Ideally, there should be *one* coordinate system for *all* uses. Surveying is only part of a wider application in areas such as cadastres, information systems, databases, mapping, and military and emergency location services. Although positions for these other uses may not be required to the precision of surveys, they must be underpinned by precise survey control. On the other hand, coordinate cadastre reference is only part of surveying practice. It is used for the determination and reference of unique absolute position as part of control, cadastral and boundary re-establishment surveys. In the coordinated cadastre, property surveys, boundary marks, monuments, relative position and dimensions have greater legal status, significance and substance to the surveyor (and user) than absolute coordinate values, especially as the coordinates cannot be seen. However, (GNSS-derived and MGA) coordinates can supplement this other evidence for the location, determination and marking of property boundaries.

8.2 Avoiding Coordinate Confusion

Using only the 6° UTM coordinate system (MGA) for all coordinate and mapping purposes overcomes the need and confusion of calculating, and showing on plans and maps, State Plane

Coordinate Systems, Low Distortion Projection systems and other ‘narrow zone’ coordinate systems. Apparently, such confusion occurred during the 25 years when the 2°-zone ISG was used in NSW.

8.3 Overcoming the Discontinuity of Smaller Systems

The much larger 6° (by 4°) UTM zone size (or 600 km by 450 km) overcomes the overlaps, discontinuity and confusion of many smaller and/or ‘narrow zone’ coordinate systems. For instance, NSW is covered by three 6° MGA zones compared to its seven 2° ISG zones.

8.4 Allowing for Project-Specific Coordination

The use of the 6° UTM system for survey coordination does not preclude use of project-specific coordination at the mean ground distance plane (i.e. Low Distortion Projection coordination, centreline and cross sections, datum lines and other forms of coordination at a height and/or orientation convenient for the project), provided that (1) there is evident advantage in doing so, (2) survey precision is mandatory, (3) only ground distance dimensions and coordinates are stated and (4) there is survey control and, where appropriate, coordinate connection to (or tied to) the cadastre and mapping of the 6° UTM survey and mapping coordinate system.

9 THE IDEAL DIMENSION AND COORDINATE SYSTEM

9.1 Ground Distance Dimension – 6° UTM Survey and Mapping Coordination System

One underlying and easily overlooked reason for the adoption of the ground distance dimension – 6° UTM coordinate system in Australia was that both already existed. They just needed to be used in survey integration. This also applies worldwide. By outlawing grid distance dimensions (and phasing out its ‘narrow zone’ coordination), the 6°-zone UTM coordinate system used worldwide for mapping can also be used for survey coordination and survey integration. In Australia, the ground distance dimension – 6° UTM (MGA) system provides:

- One homogenous national datum and one common spatial data system.
- A complete and unambiguous dimension and coordination system for all uses.
- Direct compatibility with Global Navigation Satellite System (GNSS) observations.
- Less confusion by not having two different dimensions and two different coordinate systems.
- Reduction in conversions required between different dimensions and coordinate systems.
- Reduction in the number of zone borders and their associated overlap issues due to the wider 6° UTM zone width.

The foregoing is made more realistic with the advances in surveying and measuring equipment, GNSS technology, computers and software since the 1970s (when the NSW integrated survey dispute occurred) and from many years before when State Plane Coordinate Systems were implemented elsewhere.

9.2 Benefits of the Australian 6° UTM Survey and Mapping Coordination System

The benefits of the Australian 6° UTM survey and mapping coordination system far outweigh its cost in comparison with having also the duplicate NSW survey integration proposal. The 1970s decision to continue with ground distance dimensions was incisive by avoiding the confusion and calculation with the NSW proposal's statement of grid distance dimensions. Also, with resulting benefits, Australia converted from imperial to metric units on 1 July 1972. Yet, especially with satellite-based positioning and computer software, the major benefit was having all mapping, databases and all survey coordination on the one, existing 6° UTM projection coordination system. This finally occurred in 1995 when NSW adopted the Australia-wide 6°-zone MGA system. This avoided the confusion, calculation and cost of duplicate survey dimension and mapping coordinate systems. In doing so, the Australian experience shows that it is never too wise, and never too late, to benefit from the change. So, considering the reasoning in this paper, and the improvements in technology since the 1930s, it would be beneficial to make the change by banning grid distance dimensions and instead state ground distance dimensions, and by doing so also benefit by having a coordinated cadastre and mapping system based only on the existing 6° UTM mapping projection.

10 CONCLUDING REMARKS

From a cadastral perspective, this paper has explained and promoted the use of ground distance dimensions and the Australian 6° UTM survey and mapping coordination system throughout the world. In summary, it has outlined the following:

- From 1788 (and the initial settlement of NSW) the primary function of the cadastral surveyor was to physically locate and mark deed boundaries on the ground. Further, it is the visible evidence of the property boundary in the field (and not invisible coordinates) that the public wants and the law relies upon in settling boundary disputes.
- Copied from overseas, the 1970s NSW survey integration proposal introduced survey control, the coordinated cadastre, and grid north into survey practice. However, its proposal for grid distance and 2° zone plane coordination was disputed, and then dismissed.
- Instead, emphasis was given to the importance of land, survey and title dimensions (ground distance) being stated in linear standard units where they are measured and used. This (and not distance down on a projection plane at sea level) is what the public wants. The US (and overseas) surveyors' grid distance dimension is the *only exception* to this precept.
- It was explained that grid distance dimensions are functionally useless in themselves, and that their statement as an (often) deceptively approximate dimension is an anomaly, unnecessary and should be deprecated. For cadastral surveys, grid distance dimensions should not be used, ever.
- It followed that plane (or 'narrow zone') coordinate systems elsewhere that are based on and use grid distance dimensions should also be phased out and replaced.
- Instead, it was recommended to use the successful Australian practice (the Australian 6° UTM survey and mapping coordination system), which applies *only* ground distance dimensions and *only* 6° UTM coordination (initially MGA94 and now MGA2020).
- As its basis (i.e. ground distance dimensions and 6° UTM coordination) already exists and is used throughout the world, this Australian best-practice could easily replace the confusion and duplication (i.e. grid and ground dimensions, plane and 6° UTM coordination) that applies where plane (or 'narrow zone') coordinate systems and 6° UTM mapping are both used.
- By combining ground distance dimensions and 6° UTM coordination, *one* unified worldwide system of survey dimensions, coordination and mapping could be established.
- Less confusion, less calculation and considerable cost savings and benefits would result from using *only* ground distance dimensions and *only* 6° UTM coordination.

- The recent datum modernisation efforts conducted in Australia (resulting in the introduction of GDA2020 and MGA2020) and associated software should provide an ideal opportunity for this change to occur elsewhere.

It is interesting to note that currently the US National Geodetic Survey (NGS) is building the State Plane Coordinate System 2022 (SPCS2022) for the future by shifting the projection plane in various states to reduce 'grid-to-ground' differences. This (reduction) actually acknowledges the importance of ground distance dimensions. However, the SPCS is so embedded in US survey practice that it seems that those designing SPCS2022 did not consider the underlying rationale that shows logical advantage in the (Australian) practice of stating ground distance (rather than grid distance) dimensions on all survey and title plans.

All the foregoing just goes to show that you cannot take anything for granted, even with the most credible of sources and supporters. By 'thinking outside the box' in the 1970s NSW survey integration dispute (and with the decision of the Registrar General), Australia can claim to have the best survey coordination and mapping system in the world.

REFERENCES

Dennis M.L. (2018) Building a State Plane Coordinate System for the future, US National Geodetic Survey (NGS) webinar series on State Plane Coordinate System of 2022 (SPCS2022), 12 April, https://geodesy.noaa.gov/web/science_edu/webinar_series/state-plane-coordinates-2.shtml (accessed Mar 2022).

Hallmann F.M. (1973) *Legal aspects of boundary surveying as apply in New South Wales*, The Institution of Surveyors NSW, Australia.

ICSM (2022) GDA2020 and GDA94 technical manuals, https://www.icsm.gov.au/gda2020-and-gda94-technical-manuals (accessed Mar 2022).

Lands (1969) Integrated surveys, Report of investigating committee convened by the Surveyor General, New South Wales, Survey Integration Investigation Committee, NSW Department of Lands, Sydney, 85pp.

Lands (1976) *Manual of the New South Wales Integrated Survey Grid*, Department of Lands, Sydney, 166pp.

Nation J. and Read J. (1985) Legal implications of changes to the current survey systems in conveyancing, presented at the Overview Seminar for the Review of the State Survey System, Sydney, Australia, 29 August 1985.

Read J.R. (1975) The advantages of 6° wide zone integration over 2° narrow zone integration in Australia, *Australian Surveyor*, 27(1), 29-40 & Erratum in 27(4), 232, due to misplaced text by the Editor.

Read J.R. (1981) A coordinate system for North America based upon the 6° U.T.M. zone, *Surveying and Mapping*, 41(1), 83-87.

Proceedings of the 25th Association of Public Authority Surveyors Conference (APAS2022)
Leura, New South Wales, Australia, 21-23 March 2022

Recent Updates to Surveyor-General's Direction No. 12 Control Surveys and SCIMS

Jerom Vanderstappen
DCS Spatial Services
NSW Department of Customer Service
Jerom.Vanderstappen@customerservice.nsw.gov.au

Vittorio Sussanna
DCS Spatial Services
NSW Department of Customer Service
Vittorio.Sussanna@customerservice.nsw.gov.au

ABSTRACT

Surveyor-General's Direction No. 12 Control Surveys and SCIMS (SGD12) aims to standardise the undertaking of control surveys that contribute towards the ongoing extension, maintenance and preservation of the NSW State Control Survey Network, and to outline the requirements for survey results and information to be placed on public record in the Survey Control Information Management System (SCIMS). This includes aspects of best survey practice, appropriate survey equipment, network design, reduction techniques and adjustment strategies needed to achieve a required standard for update of coordinates, heights and statements of accuracy for survey marks. In April 2021, DCS Spatial Services released a new version of SGD12 after extensive internal and external review, which also introduces the 'Technical Specifications for NSW Secondary Control Surveys'. Both are available on the DCS Spatial Services website at https://www.spatial.nsw.gov.au/surveying/surveyor_generals_directions. This is the most major update to the document since 2012 and is in response to several changes in the surveying industry, including the introduction of the Geocentric Datum of Australia 2020 (GDA2020), the adoption of rigorous uncertainty in SCIMS and the technological advances in surveying equipment. Similarly, the recent update and enforcement of Surveyor-General's Direction No. 11 Preservation of Survey Infrastructure (SGD11) has resulted in surveyors increasingly undertaking their own control surveys in an effort to preserve the integrity of the State Control Survey Network and the state's cadastre. This presentation provides an overview of some of the fundamental changes in SGD12 and how these affect control surveys intending to update SCIMS. It also provides a big-picture overview of the State Control Survey Network with a discussion on some of the changes that have occurred since the adoption of GDA2020.

KEYWORDS: *Surveyor-General Direction No. 12, control survey, SCIMS, geodesy, standards.*

Preservation of Survey Infrastructure (POSI): Practical Tips for New Players

Alecia Goodrich
Transport for NSW
alecia.goodrich@transport.nsw.gov.au

Michael Dunn
Transport for NSW
Michael.Dunn@transport.nsw.gov.au

ABSTRACT

Transport for NSW (TfNSW) is currently undertaking the largest infrastructure program in the history of NSW with over $70b being invested in major road, rail, light rail, bus, ferry and transport access programs. With these construction projects comes elevated potential for widespread destruction of permanent survey and cadastral reference marks, putting at risk both cadastral and survey control integrity. Together with DCS Spatial Services, a business unit of the Department of Customer Service (DCS), TfNSW surveyors have an important role to play in protecting survey infrastructure along transport corridors. As such, we have a dedicated team raising awareness and providing practical advice, supervision and guidance to project managers, local government and external consultants to help stakeholders through the Preservation of Survey Infrastructure (POSI) process. With several small and large surveying consultancies being engaged to undertake POSI projects on TfNSW infrastructure projects, many challenges exist in achieving consistency and delivery in a meaningful timeframe. The result currently is a 'mixed bag' of POSI outcomes. This presentation showcases some examples of the challenges that we deal with daily and highlights examples of good practice with the aim of assisting consultants in achieving successful POSI outcomes that benefit us all in the long run. The DCS Spatial Services POSI Resource Pack and other resources available to guide surveying consultants are outlined, and we reinforce and emphasise the critical aspects of the process, including the POSI strategy, the timing and extent of POSI site activities, and the importance of early consultation and involvement of TfNSW surveyors on transport infrastructure projects.

KEYWORDS: *Survey infrastructure, transport, POSI, cadastral integrity, strategy.*

POSI – TfNSW practical tips for new players

Overview

- TfNSW POSI team
- TfNSW DTM, design and pre- construction
- Consider the placement of survey marks
- Tips when preparing Strategy
- Tips during construction and deliverables
- Projects not funded by TfNSW but on State Roads
- Roadwork impact
- POSI control survey

2

OFFICIAL

POSI – TfNSW practical tips for new players

TfNSW projects

Government funded projects in NSW, POSI comes through TfNSW Survey Services.

Specialised team -

Geoff Lenton – Senior Surveyor Survey Infrastructure – Sydney focus

Alecia Goodrich – Senior Surveyor Survey Infrastructure – Regional focus

Technical support -

Michael Dunn – Senior Surveyor Control Surveys

3

OFFICIAL

POSI – TfNSW practical tips for new players

TfNSW projects pre-construction

- TfNSW provide a cadastral overlay and SMAS at digital terrain model stage
- Project impact is assessed at design stage
- All information provided by TfNSW, <u>must</u> be verified and updated
- Start up meeting with TfNSW Survey Services. <u>THE EARLIER THE BETTER</u>.
- Provide understanding of individual roles, access to data from TfNSW and early advice on the process

4

OFFICIAL

POSI – TfNSW practical tips for new players

SGD11 Preservation of Survey Infrastructure

- Recommend downloading the latest Resource Pack for each project
- Strategy Report – SMAS
  - – Survey Project Plan
  - – Control Network diagrams
- End of project compliance statement and DPoSIO checklist
- DPoSIO examples and how to use in future plans
- Bulk survey mark status update


NSW

Preservation of Survey Infrastructure Strategy Report

Contents

5

OFFICIAL

POSI – TfNSW practical tips for new players

Placement of survey marks

For consideration

- Future construction
- Safe to occupy post construction, i.e. traffic
- Lines of sight
- Potential movement of marks

6

OFFICIAL

POSI – TfNSW practical tips for new players

Placement of survey marks

For consideration

- Future construction
- Safe to occupy post construction, i.e. traffic
- Lines of sight
- Potential movement

7

OFFICIAL

POSI – TfNSW practical tips for new players

Placement of survey marks

For consideration

- Future construction
- Safe to occupy post construction, i.e. traffic
- Lines of sight
- Potential movement

8

OFFICIAL

POSI – TfNSW practical tips for new players

Placement of survey marks

If it is important to be saved, place it in a ‘safe’ place where possible.

For TfNSW projects:

•Avoid, where possible, placement of any mark in the kerb of a trafficable lane

•Type 15 SSM’s are not to be used

PM can have a better longevity than an SSM.

Give consideration to GI Pipes, monuments (cor bldg etc).

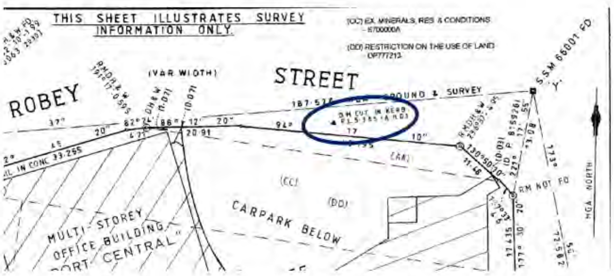
9

OFFICIAL

POSI – TfNSW practical tips for new players

TfNSW tips when preparing strategy

- Acquisition plans registered but land not yet acquired
- Bench mark on a stratum plans are cadastral marks
- Follow Spatial Services <u>latest</u> SGD11 Resource Pack
- Permanent survey marks shown on a DP – as a reference mark or for azimuth
- Preferred symbols are square for PSMs and circle for cadastral reference marks



10

OFFICIAL

POSI – TfNSW practical tips for new players

TfNSW tips during construction and deliverables

- **<u>All</u>** marks to be surveyed prior to construction
- Inductions to raise awareness to the construction crews
- Importance of maintaining datum and cadastral integrity, over the physical mark itself
- Should this mark be preserved?
- Be aware of new marks placed during the life of project.

11

OFFICIAL

POSI – TfNSW practical tips for new players

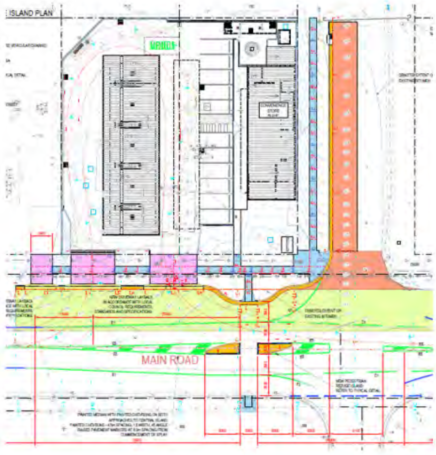
TfNSW work authorisation deed (WAD)

A deed entered between the Developer and TfNSW

- Upgrade intersection or turning lane
- Access to private/commercial land

TfNSW Developer Works team collects internal comments and provides feedback.

TfNSW initiative - Survey Services are now able to review Survey Infrastructure and comment.



12

OFFICIAL

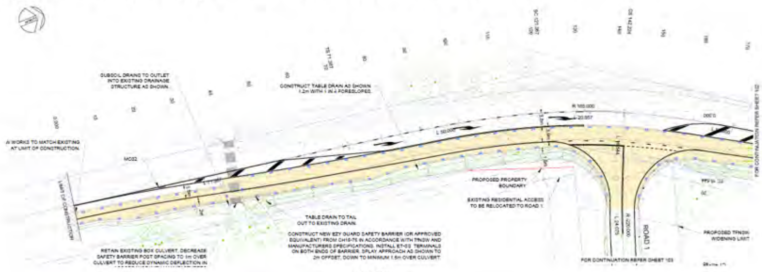
POSI – TfNSW practical tips for new players

TfNSW WAD - Survey process

TfNSW Survey Services will conduct a quick desktop review - Developer aware

Developer Works team requests the Spatial Services approval letter and an acknowledgement letter

WAD – funded by private Developer > TfNSW does not review

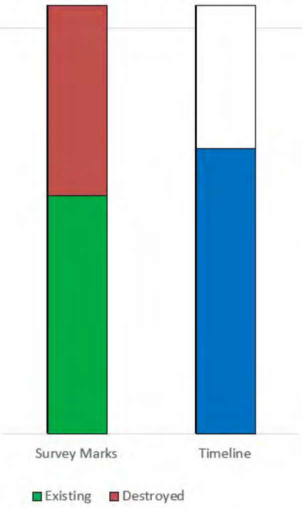


13

OFFICIAL

POSI – TfNSW practical tips for new players

Impact – roadwork on survey marks

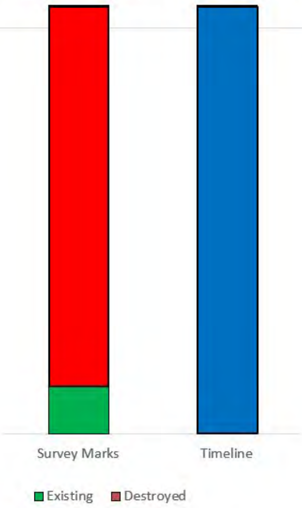


14

OFFICIAL

POSI – TfNSW practical tips for new players

Impact – roadwork on survey marks



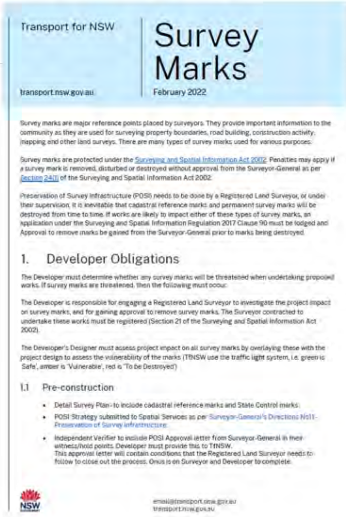
15

OFFICIAL

POSI – TfNSW practical tips for new players

Improvements and Summary

- Council - place a general statement regarding survey infrastructure within their condition of the DA consent. Surveyors to educate colleagues - footpath kerb and gutter upgrades, utilities.
- WAD projects, increased education to wider audience.
- If a mark is important to place and be protected, it is important for it to remain safe.
- TfNSW projects – early communication with Survey Services is the key.



Transport for NSW

transport.nsw.gov.au

Survey Marks

February 2022

Survey marks are major reference points placed by surveyors. They provide important information to the community as they are used for surveying property boundaries, road building, construction activity, mapping and other land surveys. There are many types of survey marks used for various purposes.

Survey marks are protected under the Surveying and Spatial Information Act 2002. Penalties may apply if a survey mark is removed, disturbed or destroyed without approval from the Surveyor-General as per Section 24(1) of the Surveying and Spatial Information Act 2002.

Preservation of Survey Infrastructure (POSI) needs to be done by a Registered Land Surveyor, or under their supervision. It is inevitable that cadastral reference marks and permanent survey marks will be destroyed from time to time. If works are likely to impact either of these types of survey marks, an application under the Surveying and Spatial Information Regulation 2017 Clause 90 must be lodged and Approval to remove marks be gained from the Surveyor-General prior to marks being destroyed.

1. Developer Obligations

The Developer must determine whether any survey marks will be threatened when undertaking proposed works. If survey marks are threatened, then the following must occur:

The Developer is responsible for engaging a Registered Land Surveyor to investigate the project impact on survey marks, and for gaining approval to remove survey marks. The Surveyor contracted to undertake these works must be registered (Section 21 of the Surveying and Spatial Information Act 2002).

The Developer's Designer must assess project impact on all survey marks by overlaying these with the project design to assess the vulnerability of the marks (TfNSW use the traffic light system, i.e. green is 'Safe', amber is 'Vulnerable', red is 'To be Destroyed')

1.1 Pre-construction

- Detail Survey Plan - to include cadastral reference marks and State Control marks.
- POSI Strategy submitted to Spatial Services as per Surveyor-General's Directions No11 - Preservation of Survey Infrastructure.
- Independent Verifier to include POSI Approval letter from Surveyor-General in their witness/hold points. Developer must provide this to TfNSW.
  This approval letter will contain conditions that the Registered Land Surveyor needs to follow to close out the process. Onus is on Surveyor and Developer to complete.

NSW

email@transport.nsw.gov.au
transport.nsw.gov.au

16

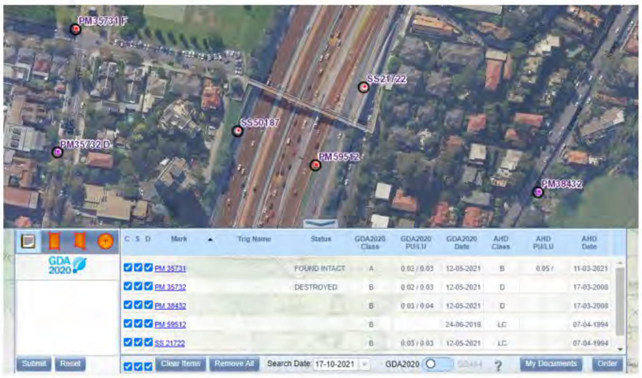
OFFICIAL

POSI – TfNSW practical tips for new players

POSI control surveys

Overview

- GDA2020, Positional Uncertainty (PU) and Local Uncertainty (LU)
- Compliance with SGD12 and SP1 ver 1.7
- Control survey strategy for large scale projects
- Construction control surveys versus POSI control surveys



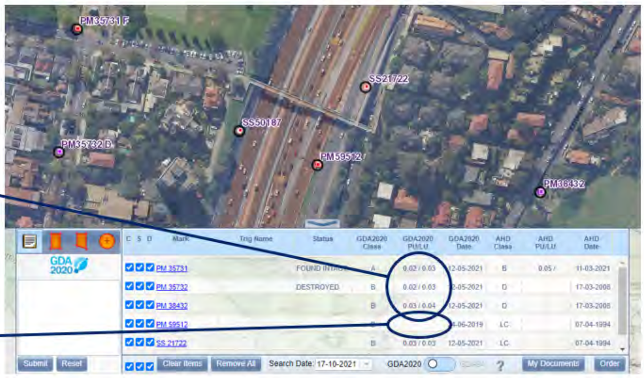
OFFICIAL

POSI – TfNSW practical tips for new players

GDA2020, Positional Uncertainty (PU) and Local Uncertainty (LU)

- GDA2020 attributes include PU and LU
- **Positional Uncertainty (PU):**
  - *Level of uncertainty of a survey mark with respect to datum*
  - *Only published where it has been rigorously computed with a well-defined connection to datum (e.g. least squares adjustment)*
- Survey marks without a GDA2020 PU value have been transformed from GDA94 to GDA2020 using a "conformal plus distortion" NTv2 transformation grid, or determined via a non-rigorous approach

GDA2020



OFFICIAL

POSI – TfNSW practical tips for new players

Requirements for POSI control surveys

- Infrastructure construction projects often lead to destruction of permanent survey marks defining the horizontal and vertical datum
- Each project requires a strategy to maintain datum. Strategy requirements vary depending on the size of the project – large scale versus small scale
- POSI management requires a strategy to ensure the post-construction environment contains a sufficient density of permanent survey marks to define GDA2020 and AHD
- Regardless of their pre-construction status, all post-construction permanent survey marks must have GDA2020 PU (and eventually LU) attributes

4

OFFICIAL

POSI – TfNSW practical tips for new players

Spatial Services' requirements

- All POSI control surveys submitted to Spatial Surveys must:
  - Connect the network into a sufficient number of local survey control marks containing the equivalent or better Class;
  - Propagate PU through the network via connection to marks with PU attributes. Static GNSS may be required for connection to CORS or AUSPOS; and
  - Adopt any additional best practice specifications as per *Technical Specifications for Secondary Control Surveys* and SP1

Surveyor-General's Direction

No. 12

Control Surveys and SCIMS

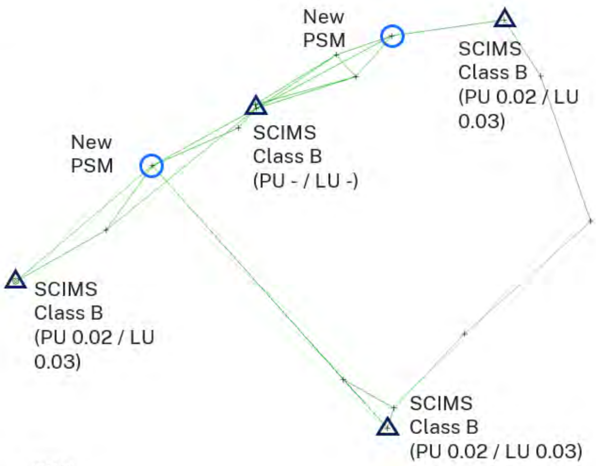
OFFICIAL

5

POSI – TfNSW practical tips for new players

POSI control survey – sample traverse

- Traverse:
  - Must connect to appropriate SCIMS marks to coordinate new marks to the required Class
  - Connection to at least two established SCIMS marks with PU values



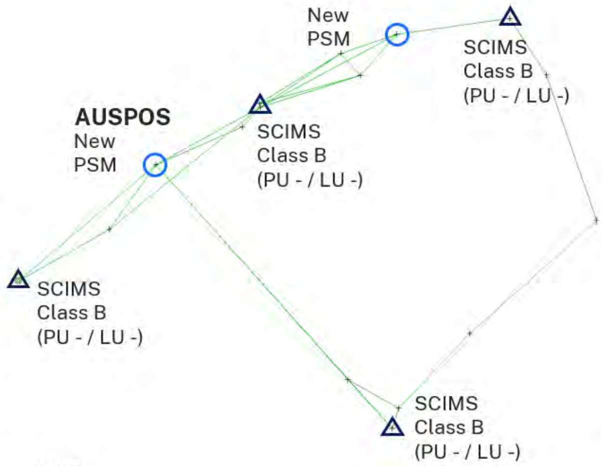
OFFICIAL

21

POSI – TfNSW practical tips for new players

POSI control survey – sample AUSPOS

- AUSPOS connections:
  - Purpose is to propagate PU into a network of terrestrial observations
  - Results in a Class D assignment to the survey mark only.
    For higher Class survey requirements connection to appropriate SCIMS marks is required and survey to Class standard described in SP1 version 1.7



22

OFFICIAL

POSI – TfNSW practical tips for new players

Survey-General's Directions No. 11, No. 12 and SP1 version 1.7

Surveyor-General's Direction
No. 11
Preservation of Survey Infrastructure

Surveyor-General's Direction
No. 12
Control Surveys and SCIMS

Technical Specifications for NSW Secondary Control Surveys

SGD 11 →
- Application
- Strategy
- High level procedures
- Deliverables

Control surveys

SGD 12 →
Technical aspects of control surveys
SP1 version 1.7
Technical Specs

Based on ICSM's SP1 ver 1.7 and has been updated to ensure best practice surveying techniques are adopted

8

OFFICIAL

POSI – TfNSW practical tips for new players

SGD12 supporting documentation

- Technical Specification for NSW Secondary Control Surveys

Spatial Services

WHAT WE DO | SURVEYING | PRODUCTS AND SERVICES | PUBLICATIONS | CONTACT US | NEWS

Home » Surveying » Surveyor-General's Directions

SCIMS online
Surveying services
Surveyor-General's Directions
Surveyor-General's Directions - mining
Surveying publications
Geodesy and GDA
CORSnet-NSW
Online forms

Surveyor-General's Directions

Current Surveyor-General's Directions. The Surveyor-General's Directions provide information about survey practice in New South Wales.

Direction No. 12
(PDF 530.4 KB)

Control Surveys and SCIMS

Technical Specifications for NSW Secondary Control Surveys (PDF 562.1 KB)

Download the Resource Pack (ZIP 2.1 MB)

Technical Specifications for NSW Secondary Control Surveys

NSW GOVERNMENT

Spatial Services

9

OFFICIAL

POSI – TfNSW practical tips for new players

SGD12 supporting documentation

- Technical Specification for NSW Secondary Control Surveys
- “Modernises” SP1 version 1.7 for modern instrumentation, observation and processing techniques

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**

OFFICIAL

POSI – TfNSW practical tips for new players

Control survey strategy for large projects

7. Procedure for Large-Scale infrastructure or development projects

Large-Scale projects are anything other than Small-Scale projects that extend over a significant area, e.g. infrastructure upgrade to road, rail or ports, greenfield development or urban renewal projects. These projects may result in the damage or removal of a significant number of Permanent Survey Marks or Cadastral Reference Marks.

7.1 Aim

In Large Scale projects the applicant must submit a well-documented strategy to maintain the integrity of the State Control Network and State Cadastre. The application will be evaluated for approval by the Surveyor-General.

The public authority or organisation responsible for the project shall ensure that all survey marks affected by the works are protected or that on completion of the works:

- The control survey must be of sufficient horizontal and vertical class to allow existing and/ or replacement mark(s) to be coordinated to a similar standard as the mark(s) affected by the works.
- Sufficient cadastral infrastructure is preserved or additional marks are placed with appropriate measurements to re-establish the cadastre at the accuracies specified in the SSI Reg.

To facilitate this process the Surveyor-General has established formal lines of communication and liaison with various public authorities responsible for the maintenance and construction of Large-Scale infrastructure in NSW.

In addition to the general aims and procedures detailed in section 5, the following procedure must be followed for Large-Scale infrastructure or development projects.

7.2 Application

The application must include the following:

- Where possible, provide at least 30 business days notification before the proposed removal or replacement of survey marks (Permanent Survey Marks or Cadastral Reference Marks), thereby extending the timeframe of 14 days minimum notice under clause 90, SSI Reg.

Surveyor-General's Direction

No. 11

Preservation of Survey Infrastructure

"...the applicant must submit a well-documented strategy to maintain the integrity of the State Control Network and the State Cadastre"

NSW GOVERNMENT

26

OFFICIAL

POSI – TfNSW practical tips for new players

Control survey strategy for large projects - template

- Strategy report addresses:
  - Impact of project
  - Protection strategy
  - Replacement strategy, including location and type of mark to be placed
  - Network design
  - Least squares adjustment strategy
  - Deliverables

NSW GOVERNMENT

Spatial Services

Preservation of Survey Infrastructure Strategy Report

Project Name:			
Project Location:			
Prepared By:			
Surveyors Reference:		POSI Reference:	
Date:		Document Version:	

12

OFFICIAL

POSI – TfNSW practical tips for new players

Control survey strategy for large projects - Considerations

- Replacement strategy based on holistic view, not a one-for-one replacement
- Lots of variables!

How many marks affected?

Distribution of affected marks

Density and class of surrounding SCIMS marks

Class of survey required

Number of new marks are required

Type of mark(s) to be placed

How to propagate PU?

Timing / staging of construction

GNSS?

... all of which needs to be documented in the strategy.

Also consider:
Project datum versus GDA2020

13

OFFICIAL

POSI – TfNSW practical tips for new players

Construction control versus POSI control – POSI control

- POSI control:
  - TfNSW QA Specification G71 *Construction Surveys* applies
  - Clause 3.1.2 applies

HOLD POINT

Process Held:	Commencement of construction activities near Survey Infrastructure.
Submission Details:	Application for authorisation to remove Permanent Survey Marks, Cadastral Reference Marks and Bench Marks, together with Items (a) to (b) in Clause 3.1.2, at least 30 working days prior to commencement of construction activities near Survey Infrastructure.
Release of Hold Point:	The Principal and TfNSW Director Surveying or delegate will consider the submitted documents and may request further work, carry out their own site inspection and survey field measurement, prior to authorising the release of the Hold Point.

14

OFFICIAL

POSI – TfNSW practical tips for new players

Construction control versus POSI control – Construction control

- Construction control:
  - TfNSW QA Specification G71 *Construction Surveys* applies
  - Clause 3.2.1 applies

HOLD POINT

Process Held:	Use of survey control marks forming part of the Survey Control Network.
Submission Details:	Survey Report verifying coordinates and level values of the survey control marks, at least 10 working days before use of the marks. Where requested, submit the procedure for replacing the affected Primary Survey Control Marks.
Release of Hold Point:	The Principal will consider the submitted documents and may inspect the marks prior to authorising the release of the Hold Point.

15

OFFICIAL

POSI – TfNSW practical tips for new players

Construction control versus POSI control

- Construction control:
  - **Construction control survey data *may* be used for the POSI control survey**
  - Need to consider:
    - Datum (construction control may be GDA94, POSI is ALWAYS GDA2020)
    - Method to constrain network
    - Class of survey required
    - Extent of control network for each activity
    - Deliverables

30

OFFICIAL

POSI – TfNSW practical tips for new players

Construction control versus POSI control – Summary

Consideration	Construction control	POSI control
Datum	GDA94 (legacy projects) **OR** GDA2020	GDA2020
Network constraints	Original network supplied by TfNSW	SCIMS
Class	Refer to G71/Clause 3.5 (Varies for each type of construction activity)	Determined by Class of SCIMS marks affected by construction
Network extent	Within network supplied by TfNSW	Dependent on distribution of SCIMS marks and survey methodology
Deliverables	Survey Report, network adjustments, raw data to TfNSW Senior Surveyor via Project Manager	As per SGD12

31

OFFICIAL

POSI – TfNSW practical tips for new players

Control survey summary

- All POSI control surveys submitted to Spatial Services must:
  - Connect to local SCIMS marks consistent with the Class of survey required; and
  - Be undertaken to the appropriate Class, and
  - Propagate GDA2020 PU values through the network
- Control survey strategies for large scale projects require a holistic view
- SGD12 applies to the control survey component of POSI
- Construction control and POSI control surveys overlap yet have different requirements in terms of network constraints, network extents, standard of survey, deliverables and datum
- For TfNSW projects, consultation with TfNSW Senior Surveyors at all stages of the POSI process is critical to a successful outcome

18

OFFICIAL

Proceedings of the 25th Association of Public Authority Surveyors Conference (APAS2022)
Leura, New South Wales, Australia, 21-23 March 2022

Discussion Forum:
Digital Survey Plans

Adrian White
DCS Spatial Services
NSW Department of Customer Service
Adrian.White@customerservice.nsw.gov.au

Daniel Griffin
NSW Land Registry Services
Daniel.Griffin@nswlrs.com.au

ABSTRACT

This discussion forum provides a step-by-step demonstration of how surveyors can prepare and lodge digital survey plans using new NSW Land Registry Services (LRS) Connect services. Following the demonstration, an open discussion is facilitated to address industry concerns and questions from the audience. The demonstration session will cover the creation of a plan workspace and administration sheet via NSW LRS Connect, the preparation of data layers in accordance with the NSW Deposited Plan CAD Layering Standard, using the CAD to LandXML translator, validation of the data and interpretation of the summary report, and the export of 'part-rendered' data ready for drafting. The open discussion forum covers topics such as 'data before drafting', industry benefits and the appropriate use of digital data.

KEYWORDS: *Digital survey plans, cadastre, land titles*.

Surveying in the Desert: Sealing the Silver City and Cobb Highways in Far Western NSW

Thomas Casey
Casey Surveying and Design
Thomas@csad.com.au

ABSTRACT

The Cobb and Silver City highways provide a north-south connection between north-western Victoria and north-western NSW. They are the only roads in the NSW state highway network that are not entirely sealed and can easily flood and remain closed for weeks after periods of rain. Highway closures regularly impact the roads, directly affecting local residents and businesses, essential services and interstate road users. Both highways had been progressively sealed as funding became available, although this was sporadic to say the least. In 2018, the NSW Government announced increased and accelerated funding to upgrade their alignment, pavement and drainage and to place an initial seal on the 209 km remaining unsealed on these outback state highways. Since January 2018, Casey Surveying and Design has been engaged by Transport for NSW (TfNSW) on multiple occasions to provide both surveying and design services. We have provided equipment, human resources and experience over that time to deliver TfNSW over 150 km of detail and control surveys, 30 km of road design, road acquisition surveys, a 55 km identification survey, multiple Protection of Survey Infrastructure (POSI) investigations and a dozen machine control installations to keep the initial sealing project on track to achieve the targeted completion of mid-2022. This presentation outlines this unique project, which recently received the 2021 EISSI Award for Infrastructure & Construction. The sheer remoteness of the project sites was a major challenge in every instance, particularly the travel times involved, and Casey Surveying worked collaboratively with TfNSW to remain in touch with Broken Hill and Parkes based survey, design and engineering project teams, and with the multiple TfNSW and council road construction crews to complete works on multiple sites on most occasions when a visit to the area was conducted. The desert threw everything from drought, 51°C heat, rain storms (which saw the crew becalmed for days) and dust storms to snakes, hordes of emus and even wild camels at the field crews. An enormous amount of boot leather was used, with blood, sweat and (yes, at times) tears shed, and our approach might not be considered the most high-tech in the current era of data collection, but it was appropriate, timely and accurate. The consistent provision of surveying and spatial information to the project teams in multiple offices and multiple crews on-site has been central to the success and smooth running of the entire initial sealing project, leading to a greatly increased local awareness and appreciation of the specialised services and input the surveying profession provides in the project development and implementation of road infrastructure projects. The author has been working on the Silver City Highway his entire 27-year career and says that "finally sealing the highway to Tibooburra, providing an all-weather road to the local families and businesses, is quite simply the project with the greatest community benefit I will ever be involved in". Today, less than 60 km of highway remain to be sealed.

KEYWORDS: *Silver City Highway, Cobb Highway, Tibooburra, Wilcannia, Ivanhoe.*

RPA LiDAR Surveys for TfNSW Specification G73

Michael Dunn
Transport for NSW
Michael.Dunn@transport.nsw.gov.au
Shaune Coates
Linke & Linke Surveys
S.Coates@llsurveys.com.au

ABSTRACT

Remotely Piloted Aircraft (RPA), or drones as they are commonly known, have been used for several years within Transport for NSW (TfNSW). RPAs have traditionally used a high-definition digital camera and photogrammetric techniques to model ground surfaces. However, advances in technology (i.e. the increased payload of RPAs and the miniaturisation of high-end measuring devices) allow highly specified Light Detection and Ranging (LiDAR) and inertial navigation units to be mounted on drones to survey ground features. High-spec LiDAR systems, measuring many hundreds of thousands of points per second, enable a selection of points to reflect from the true ground surface in heavily vegetated environments. This offers significant advantages over image-only systems which rely on an unobstructed view of the ground surface. TfNSW has recently partnered with Linke & Linke Surveys, a national surveying company with in-house aeronautical expertise, to undertake multiple RPA LiDAR surveys throughout NSW. The first of these surveys was in south-western Sydney. Initially commencing as a trial on a small, previously surveyed area, the aim was to determine whether a mature RPA LiDAR system could meet the ground survey tolerances provided in TfNSW Specification G73 Detail Surveys across various surface types. The results demonstrated that it is possible to achieve Specification G73 tolerances for natural surface, batters, trees, overhead non-utility cables and natural surface drainage in a heavily vegetated environment. Accordingly, the project was extended to include survey of all such features over the 4.5 km length of the project. However, the project highlighted the surveying expertise necessary to obtain accurate ground models in vegetated areas. This includes, but is not limited to, a thorough and comprehensive processing regime, a rigorous checking process and additional ground survey by traditional means in areas of uncertainty. This project led to several similar surveys for TfNSW with each project refining the processes to achieve an optimal solution. This presentation highlights these processes and discusses the advantages in time, cost, safety and environmental impacts experienced on RPA LiDAR surveys.

KEYWORDS: *RPA, LiDAR, drone, survey, G73 specification.*

George Hedgeland: A Colossus of Roads

Angela Pippen
Local Studies Librarian, City of Ryde
angelap@ryde.nsw.gov.au

Fred de Belin
City of Ryde
fdebelin@ryde.nsw.gov.au

ABSTRACT

The first author has been researching the life story of one George Caleb Hedgeland. He was an Alignment Surveyor with the Lands Department from 1874, with a direct link to Ryde, but he was much more before. Here we present the more survey-centric edited and abridged highlights from her research on George Hedgeland. He was a well-to-do Englishman who sailed to Australia in 1859 at the age of 33. Eventually, he trained as a surveyor, becoming licensed in New South Wales in 1871 and working for the Lands Department over the following 18 years. We are told that anyone born today will have four or five changes of profession during their working lifetime. George Caleb Hedgeland was such a 21st century man, even though he lived entirely in the 19th century. This paper follows his early career in England, his migration to New South Wales and his path to becoming a major figure in surveying. A recently created street in Ryde is named 'Hedgeland Close', and he remains close as his bones are interred in Ryde's Field of Mars Cemetery.

KEYWORDS: *Cadastral surveying history, stained glass, early Queensland, alignment, City of Ryde.*

1 INTRODUCTION

Being the Local Studies Librarian at City of Ryde, the first author has been researching the life story of one George Caleb Hedgeland who was a Lands Department Alignment Surveyor from 1874 (Figure 1). This paper is a re-presentation of edited highlights from her presentation on George Caleb Hedgeland. He was a well-to-do Englishman, who sailed to Australia in 1859 at the age of 33 years and stayed. Eventually, he trained to be a surveyor, becoming licensed in 1871, and working for the Lands Department over the next 18 years.

In 1833, legislation was introduced requiring the Surveyor General "to set out the breadth of the carriageways and footways in the town and cause the footways to be marked by posts at the corners and intersections" (Marshall, 2006). Consequently, alignment posts are survey marks (monuments) placed at intersections and bends in the roadways to indicate the kerb lines. The first alignment posts were 6 inch (150 mm) square, dressed hardwood timber posts and appeared in Sydney City from 1836.

Mr Surveyor George Hedgeland undertook street alignment surveys in newly created Municipalities such as Ryde, Ashfield, Prospect, Waverley, Marrickville and anywhere in between (Figure 2). His advice was also sought as to whether roads should even be formed when the street alignment was requested by the local Councils.

Figure 1: George Caleb Hedgeland (1825-1898).

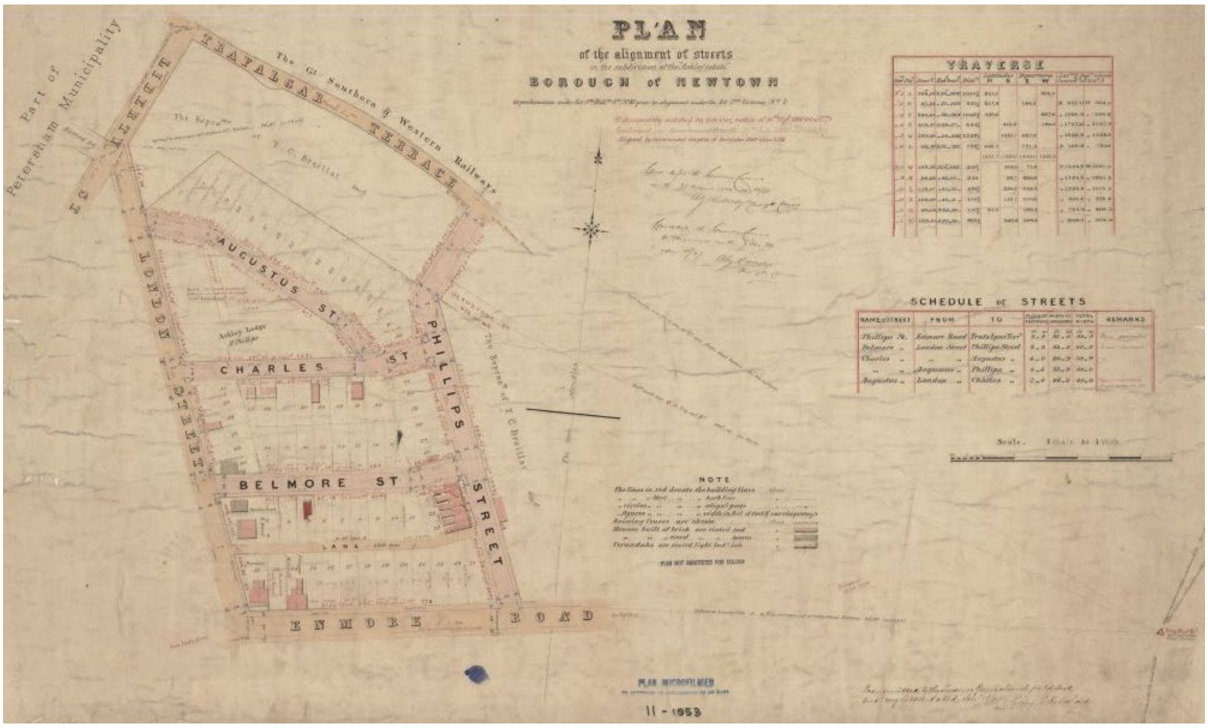


Figure 2: Crown Plan 11.1953, showing alignment survey in the Borough of Newtown – 1879.

The first alignment posts were made of hardwood timber and it was such timber posts that Hedgeland was using to mark his kerb lines (Figures 3 & 4). Stone alignment posts were first used in Parramatta, by surveyor Charles Ebbsworth in 1882, followed in Ryde by surveyor Charles Scrivener in 1885 (de Belin, 2014).

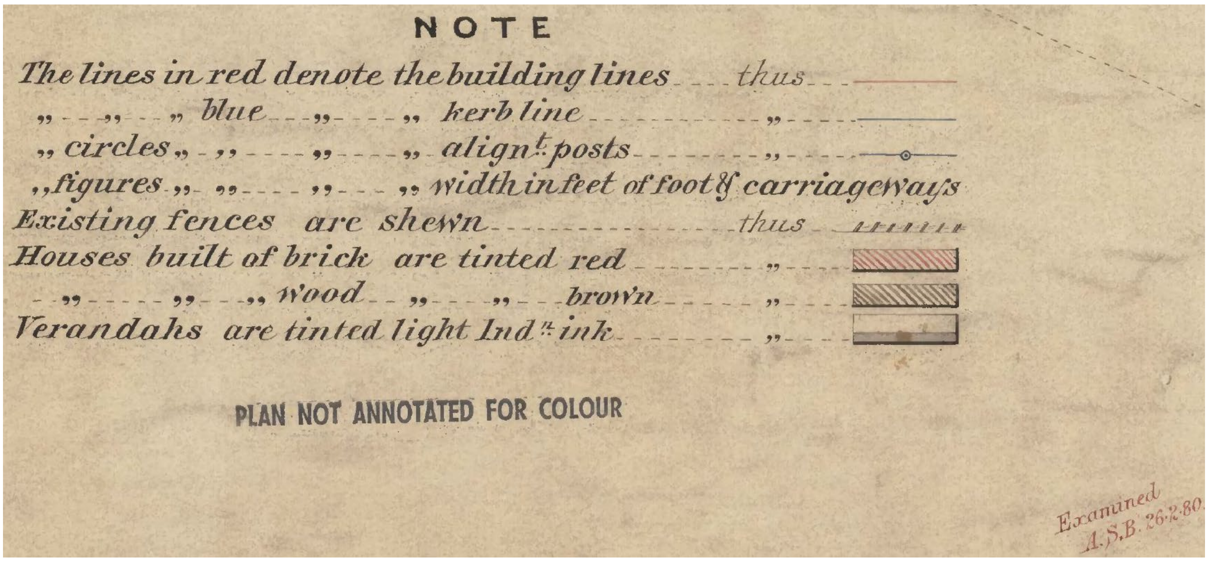


Figure 3: Detail from Crown Plan 11.1953, showing timber alignment posts were placed – 1879.

Figure 4: Examples of timber alignment posts that have survived to this day – 2014.

Images of two of George Hedgeland's Ryde alignment field books are shown in Figure 5, with the interesting side note that one is titled Field Book 10½ (indicating shades of Harry Potter). Both have been signed G. Hedgeland LS Parramatta 1874, which begs the intriguing question: Did the Department of Lands have an office in Parramatta in 1874?

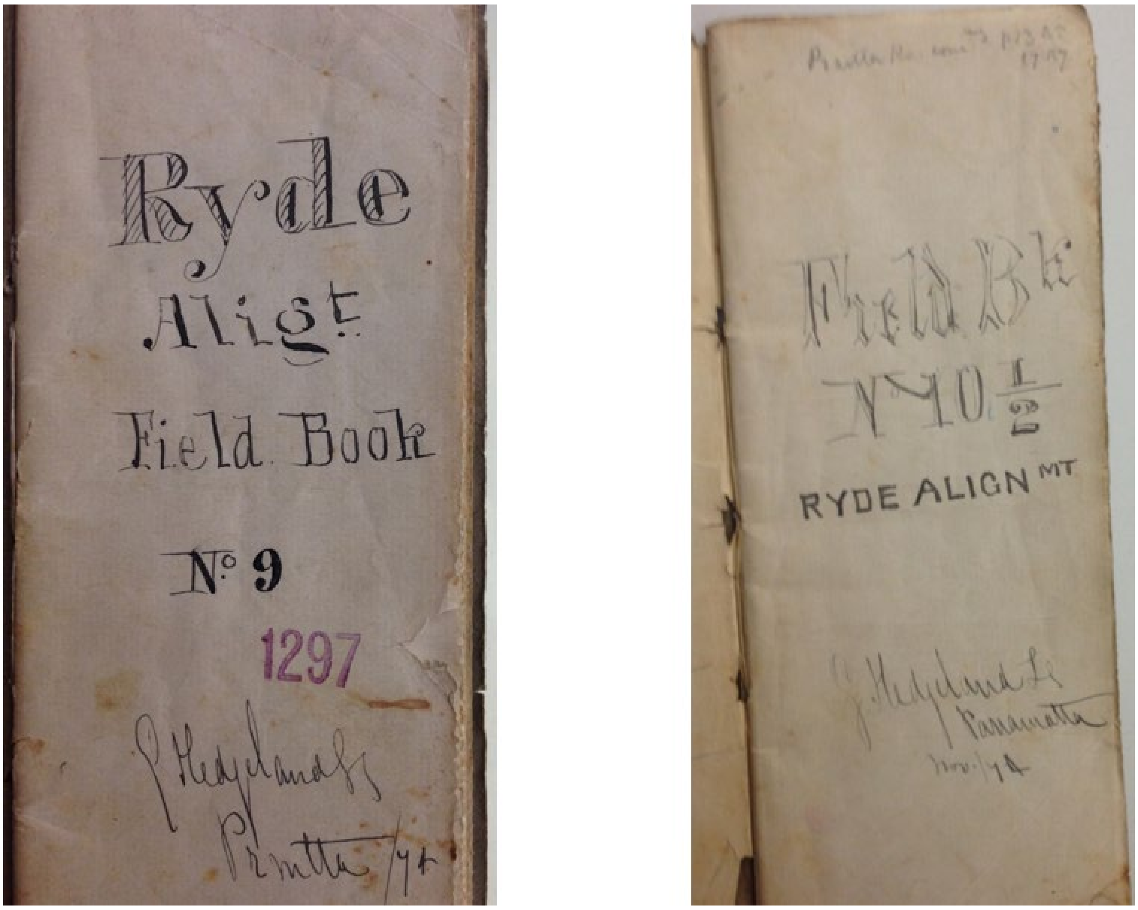


Figure 5: Two of George Hedgeland's Ryde alignment field books, including one titled Field Book 10½ – 1874.

Theodolites (Figure 6) were being used to read angles, with chains and short tapes being used to measure distances (Figures 7 & 8).

Figure 6: An early theodolite.

Figure 7: Feet and link short measuring tapes – c. 1879.

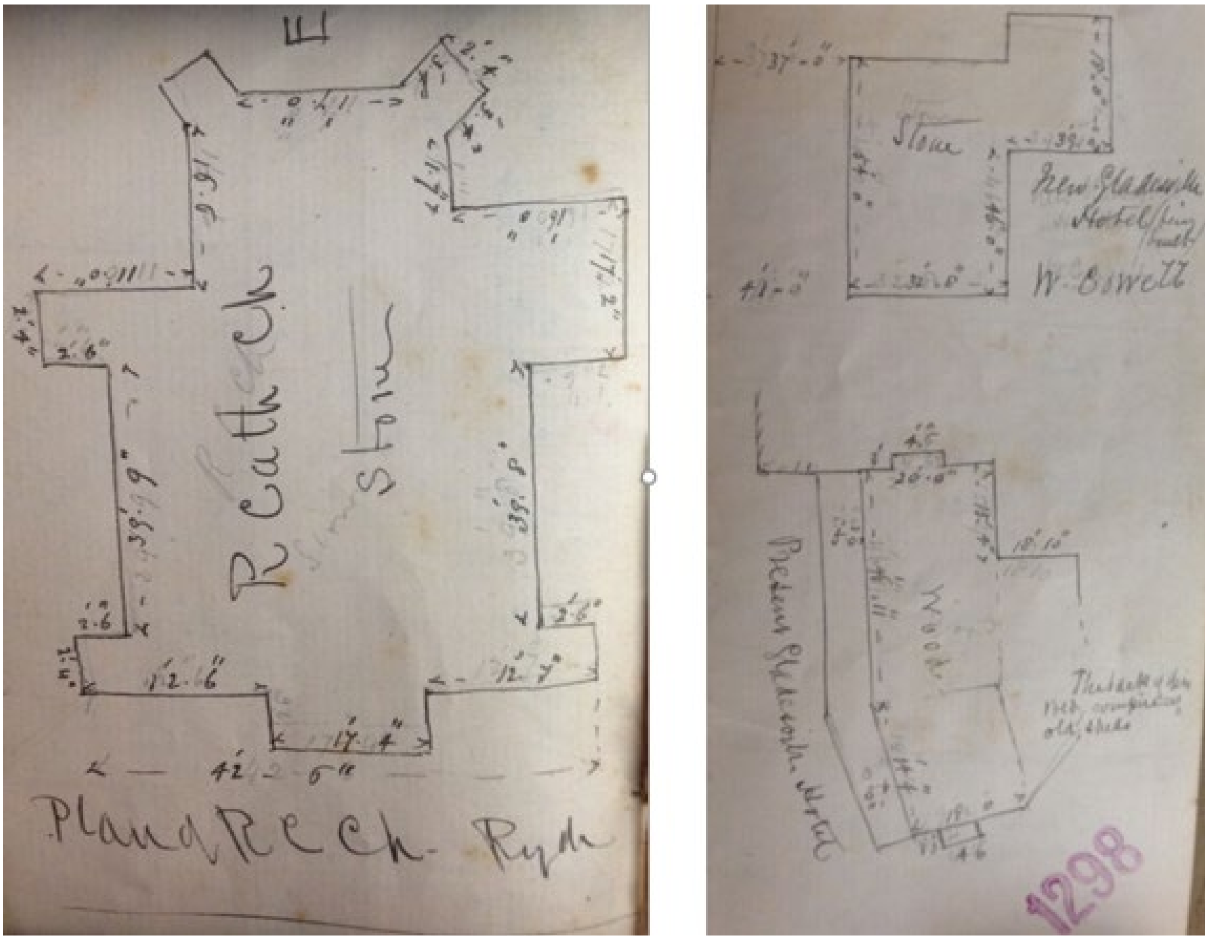


Figure 8: Field notes showing plan view of church in Ryde and hotel in Gladesville – 1874.

2 A 21st CENTURY MAN

We are told that anyone born today will have four or five changes of profession during their lifetime. George Hedgeland was such a 21st century man, even though he lived entirely in the 19th century. George had five distinct occupations: Artist, stained-glass artist, pastoralist, land surveyor and fruit grower. George Hedgeland was born in 1825 and was baptised in Guildford, Surrey, in 1826. His father, John, was an architect and later a stained-glass artist. George did not immediately follow into his father's profession. In 1845, aged 19, he was admitted into the Royal Academy of Arts in London (Figure 9) to become a painter.

Figure 9: Royal Academy of Arts in London, which is now the National Portrait Gallery.

The qualification for admission was a "proficiency in drawing in chalk from an undraped antique", i.e. classical statue. The candidate needed to be "recommended by any person of known respectability". In George's case he was recommended by Sir John Prescott who was himself from the Royal Academy and Professor of Perspective. The full tuition would be three 'schools' over a 10-year period. First was Antique School, next was Life School (drawing from live subjects) and the third was the School of Painting.

Few students completed the full 10 years, and it is not known exactly when George left. In 1851 he entered a sample piece of stained glass into the Great Exhibition of London. It was described as the best piece of coloured English glass there. During the 1850s George designed more than 26 windows in 23 locations throughout England. These works included cathedrals, parish churches, school chapels and university chapels. His first major window was completed in 1854, which was the great west window of Norwich Cathedral (Figure 10).

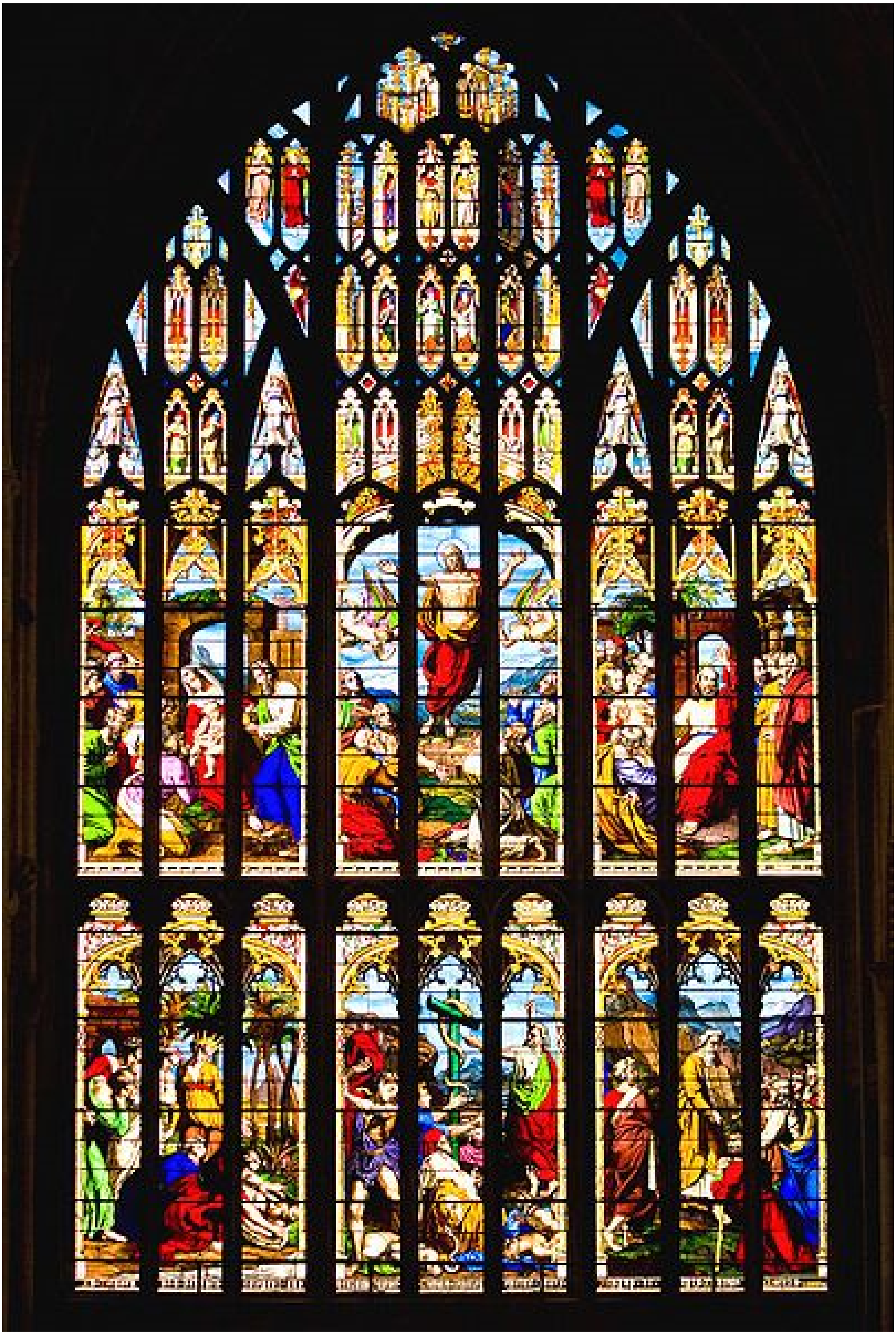


Figure 10: The great west window of Norwich Cathedral.

This window, an exceptional explosion of colour and artistry, created much controversy because of its vibrant colours, its naturalistic approach to the human figure and because the Christ figure was being intersected by the window mullions (Figure 11).

Figure 11: Detail from the great west window at Norwich Cathedral.

In December 2018, George Hedgeland's great-grandson who lives in Perth, Western Australia, revealed that he had, in his possession, a trunk which contained many of George's artworks, including his design sketch for the top of the west window at Norwich Cathedral (Figures 12 & 13).

Figure 12: Recently uncovered design sketch of the top section of the west window – 2019.

Figure 13: Comparison of sketch and as built.

This is a fine example of offering the client what they want but giving them instead what they really need (another surveying maxim). His window for the Ely Cathedral depicts Jonah and the Ninevites (Figure 14). George has included in this window the winged bull statue, which had recently been discovered by Austen Layard during archaeological excavations at Nineveh in the early1850s (Layard, 1854). Notice that the winged bull has five legs, so that it displays two legs when viewed from the front and four legs when viewed from the side.

Figure 14: Window at Eli Cathedral, including the winged bull statue.

George Hedgeland received only minor recognition in England for his work, and in one writing he is simply described as a person “who went to Australia and died”. It has been stated that George emigrated to Australia “because of his health”, but he had a brother and close family friends, the Hennings (Edmund Biddulph Henning, Annie, Rachel and Amelia Henning), who had already emigrated in 1852 and 1853. George left England in 1859, aged 33, and sailed to Melbourne.

3 A LIFE IN THE NEW COLONY

In 1859, Queensland had separated from New South Wales and the new state government was offering leases of frontier land to those people who would stock and manage the land. Edmund Biddulph Henning took up several of these north Queensland leases. A lease comprised a parcel of 40 miles square. George Hedgeland lived and worked on Biddulph’s Queensland property, Exmoor (Figure 15). Details of his life in Queensland are known from his work and living with Edmund Biddulph Henning and two of Biddulph’s sisters, Annie and Rachel Henning, who also lived at the Exmoor homestead. Another sister Amelia was married and lived in the New South Wales town of Bathurst.

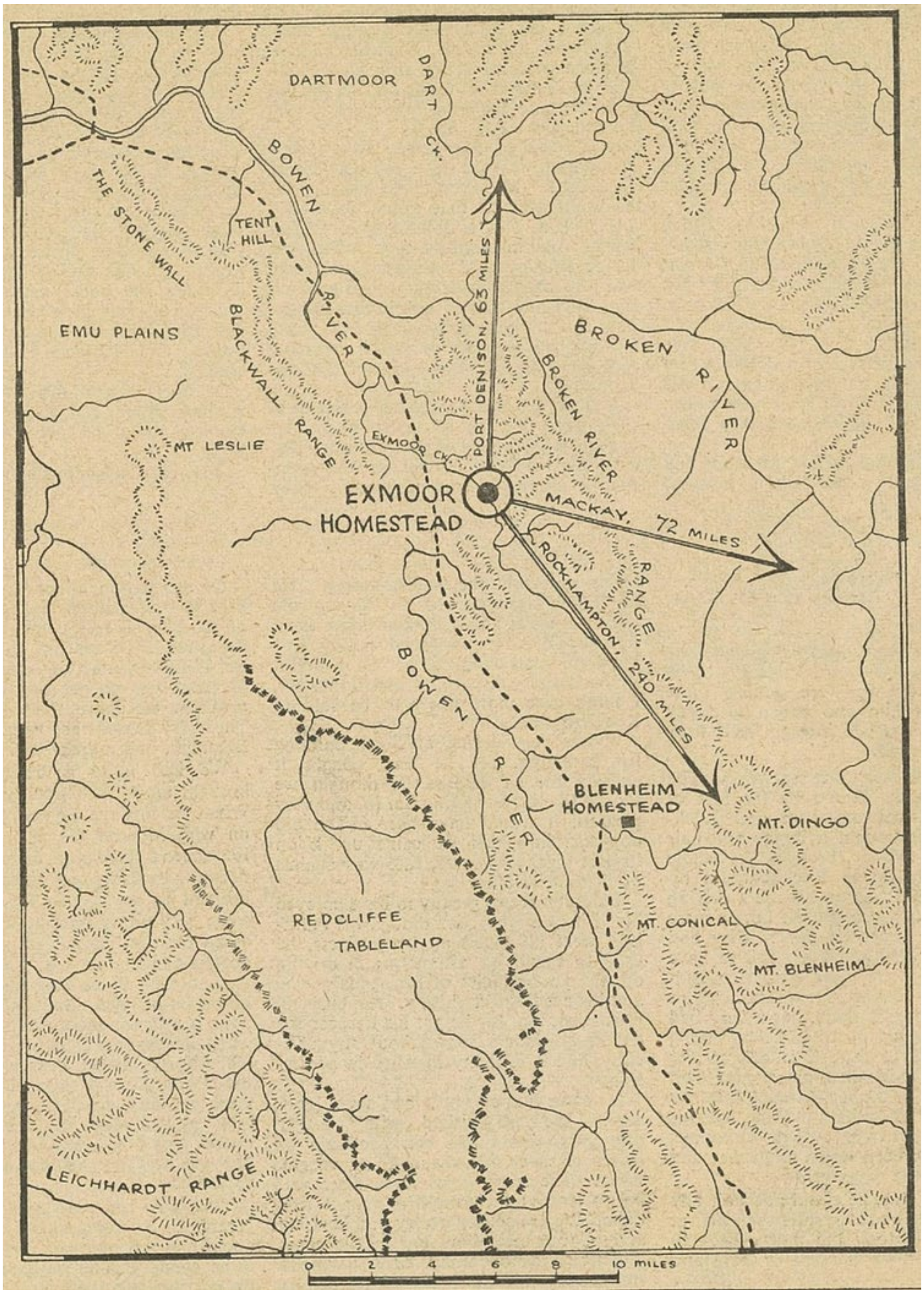


Figure 15: Exmoor Homestead, 72 miles inland from Mackay, Queensland.

So, what did George do on the Queensland lease? There is no evidence of any of his writings, so it is entirely dependent upon references made by Rachel Henning in letters which she sent back to her sister, Henrietta, who had remained in England. Rachel always referred to George as “Mr. Hedgeland” and described him as “hardworking and methodical”. George maintained the station’s store (Figure 16), and once a week would ride out to supply the widespread shepherds with rations. George was a good horseman and loved horses, and he was adept at droving sheep, as evidenced in 1865 when he helped move thousands of sheep hundreds of miles inland to central Queensland.

Figure 16: Sketch of Exmoor Station by Rachel Henning – c. 1860.

George helped wallpaper the rooms of the homestead and made furniture for the house (Figure 17). This sketch by Rachel Henning shows a slung canvas verandah chair, as designed and built by George. Rachel commented: "It was a very comfortable chair." George also appears to have been a dab hand in the kitchen, although there may have been an ulterior motive, because there was a romance blossoming between himself and Annie Henning (Figure 18).

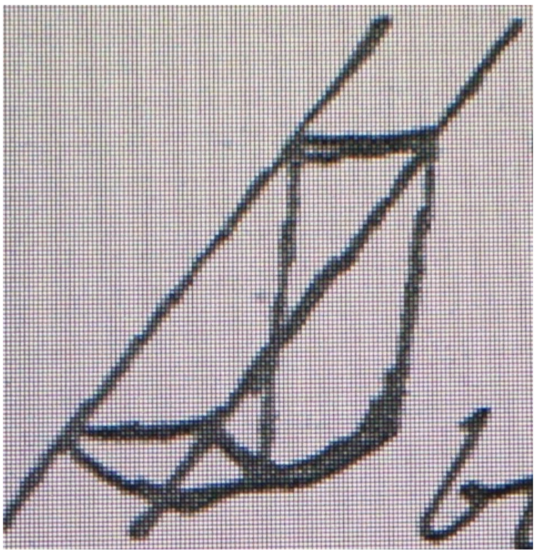


Figure 17: Design of slung canvas verandah chair.

Figure 18: Annie Henning and George Hedgeland.

Rachel Henning's letters from the 1860s were discovered in England in 1950 and published in Australia by the 'Bulletin' (Henning, 1951-52), with illustrations by famous artist Norman Lindsay (Figure 19). George and Annie were married at St Marks church at Darling Point in Sydney in January 1866 and afterwards returned to Queensland. The birth of George and Annie's only child, Edmund Woodhouse Hedgeland, in 1867 brought them once again back to Sydney, where they remained. The name Woodhouse does not appear to be of any family significance. However, the last stained-glass window that George created was at Woodhouse in Leistershire. All up, George spent eight years in the Queensland bush.

Figure 19: Pen-drawing of Annie and George by Norman Lindsay.

4 A NEW LIFE IN SYDNEY

Why did George then choose the surveying profession? Annie's cousin Lindon Biddulph was a surveyor in the Wollongong/Shoalhaven area, and close family friend George Armitage was a clerk in the Surveyor General's Department. So, George began a new career as a Lands Department surveyor and became a colossus of roads (see section 1). There may appear to be no similarity between stained-glass window making and surveying, although of course "One is beautiful and sublime, while the other deals with coloured glass." George Hedgeland's final survey was an alignment of streets at Marrickville. He retired in 1887, aged 62. He then moved to Canley Vale where directories describe him as a fruit grower, with further information about his final profession being very hard to come by (Figure 20).

Figure 20: George Hedgeland in his later years.

Finally, in 1896, George and Annie moved to Denistone, in the Ryde Local Government Area, where they shared a house with Annie's sister Rachel and her husband, Deighton Taylor. It was here, in Ryde, where George died of cardiac failure in 1898. His obituary, as published in *The Surveyor* in November 1898, states in part: "Those who came in contact with Mr. Hedgeland during his career as a surveyor, held his professional qualifications in the highest estimation, and his alignment surveys of many of the more populous and wealthy suburbs, such as Waverley and Bondi, were made mainly by his skill, … and provided a means of supplementing the lamentably deficient records of the offices of the Registrar General." A recently created street in Ryde is named 'Hedgeland Close', and he remains close as his bones are interred in Ryde's Field of Mars Cemetery (Figure 21).

Figure 21: George's gravesite in a family plot at Field of Mars Cemetery in Ryde.

5 CONCLUDING REMARKS

The letters of Rachel Henning (Henning, 1951-52) are highly recommended reading for anyone who wants to vividly experience the historical times of the early settlement of New South Wales and Queensland. George Hedgeland's son, Edmund Woodhouse Hedgeland, passed his surveying exams in 1895 and eventually worked in Thailand. By 1907, he was in Malaya, working in the Trigonometric Survey Branch and was appointed Assistant Surveyor General to the Federated States of Malaya in 1920. After the eventual deaths of their respective spouses, the three Henning siblings, Annie, Rachel and Edmund, ended up living together again, as when they first came to Australia in 1853 and 1854. Their final Sydney residence was in Hunters Hill (Figure 22). The house still exists to this day, and now its claim to fame is that it is the home of Eddie Obeid!

This paper has followed George Hedgeland's early career in England, his migration to New South Wales and his path to becoming a major figure in surveying. Being a 21st century man living in the 19th century, he had five distinct occupations: Artist, stained-glass artist, pastoralist, land surveyor and fruit grower – quite a remarkable man indeed.

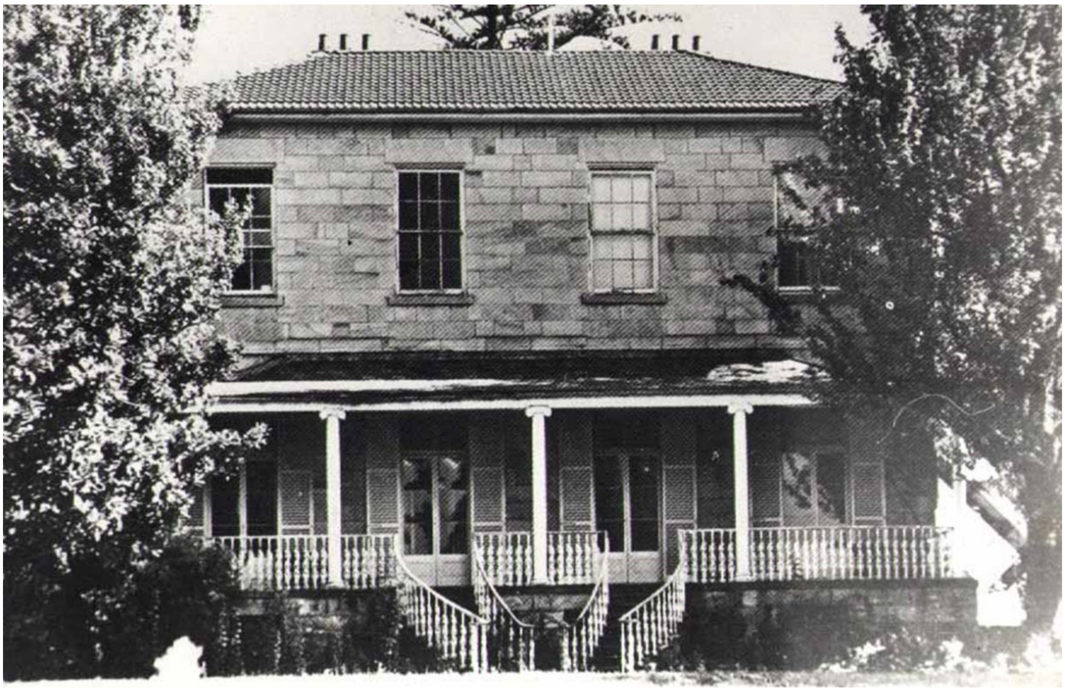


Figure 22: "Passy", the house in Hunters Hill where the Henning siblings resided.

REFERENCES

de Belin F. (2014) Game of stones… The big stone alignment posts of Ryde, *Proceedings of Association of Public Authority Surveyors Conference (APAS2014)*, Pokolbin, Australia, 31 March – 2 April, 115-128.

Henning R. (1951-52) *The letters of Rachel Henning*, Project Gutenberg Australia eBook, https://gutenberg.net.au/ebooks06/0607821.txt (accessed Mar 2022).

Layard A.H. (1854) *Discoveries at Nineveh: A popular account of discoveries at Nineveh*, J.C. Derby, New York, 402pp.

Marshall I.H. (2006) The history of alignment surveys in New South Wales: A retrospective, http://www.bossi.nsw.gov.au/__data/assets/pdf_file/0020/54632/BOSSI_History_of_Alignment_Surveys.pdf (accessed Mar 2022).

Remake of the Surveying and Spatial Information Regulation: Proposed Changes

Les Gardner
Office of the Surveyor-General, DCS Spatial Services
NSW Department of Customer Service
Les.Gardner@customerservice.nsw.gov.au

ABSTRACT

In New South Wales (NSW), practising surveyors are subject to the Surveying and Spatial Information Act 2002 and the Surveying and Spatial Information Regulation 2017. Every five years, each regulation is remade to ensure that the requirements of the regulation remain current and up to date with technology, community, industry and government needs. Pursuant to section 10 of the Subordinate Legislation Act 1989, the Surveying and Spatial Information Regulation 2017 is scheduled to be replaced on 1 September 2022. The objectives of the Surveying and Spatial Information Regulation are to ensure the competency of surveyors, maintain the integrity of the NSW cadastre and the NSW State Control Survey, and ensure measurement and marking standards are delivered from modern surveying and communication technologies. This paper outlines the key changes proposed in the new Surveying and Spatial Information Regulation. These changes include that all surveys adopt an accurate Map Grid of Australia (MGA) orientation, that surveyors connect to established survey marks or BYO accurate MGA coordinates using an approved Global Navigation Satellite System (GNSS) method, place less permanent survey marks, preserve survey infrastructure, provide a survey report for all water boundaries, and the review of survey certificates.

KEYWORDS: *Regulation, legislation, surveying, standards.*

1 INTRODUCTION

In New South Wales (NSW), practising surveyors are subject to the Surveying and Spatial Information Act 2002 (NSW Legislation, 2022a) and the Surveying and Spatial Information Regulation 2017 (NSW Legislation, 2022b). The objectives of the Surveying and Spatial Information Regulation are to ensure the competency of surveyors, maintain the integrity of the NSW cadastre and the NSW State Control Survey, and ensure measurement and marking standards are delivered from modern surveying and communication technologies.

Under the Subordinate Legislation Act 1989 (NSW Legislation, 2022c), all statutory rules, i.e. regulations, must be remade every 5 years to ensure they remain relevant to government, community and industry needs. The Surveying and Spatial Information Regulation 2017 is due for repeal on 1 September 2022. An online questionnaire was distributed to the industry in early 2021 for comment, and a workshop with industry associations and industry leaders to obtain additional feedback and comment was conducted in September 2021.

This paper provides an update of the issues, amendments and reforms that are proposed to ensure the surveying industry is enabled and capable to provide modern surveying services.

The reforms and amendments outlined in this document are generally minor in nature and do not make significant changes to survey practice in NSW.

2 PROCESS

The review process began in March 2021 by outlining possible and probable changes to the regulation (Gardner, 2021), followed by a corresponding series of presentations to the surveying industry. An online questionnaire was conducted from March to May 2021 to obtain views, comments and suggestions for improvement from the surveying industry. The results were used to refine the final submission to the Parliamentary Counsel's Office to prepare the new draft regulation that will be circulated to all surveyors, users of surveying services, government agencies and relevant industry associations in a final draft exposure regulation.

A Regulatory Impact Statement will accompany a draft exposure version of the proposed regulation this year to gain final industry, government and community comments in order to ensure that all alternatives, options, cost and benefits have been considered and determined for the final regulation.

3 SUMMARY OF PROPOSED CHANGES TO DATE

A summary of the proposed changes from the Surveying and Spatial Information Regulation 2017 to the proposed Surveying and Spatial Information Regulation 2022 is outlined in Table 1. The sequence of numbers in the table is based upon the clause numbers in the current Regulation. These may change in the final version.

Table 1: Summary of proposed changes to the Surveying and Spatial Information Regulation 2017 for implementation in 2022.

Current Regulation	Proposed Regulation	Reason for Change
4 Mining surveys	Update reference to the current "Survey & Drafting Directions for Mine Surveyors 2020 (NSW-Mines)".	Updated references.
5 Definitions		
Accurate MGA orientation	Add "positional uncertainty of 0.1m or less" to the existing survey Class of "D" or better.	Enable more flexibility and correct definition when determining accurate MGA orientation.
Established survey mark	Means a survey mark as approved. (By Surveyor-General, in SGD.)	Enable more flexibility.
Recognised Professional Training Agreement	Remove definition.	Recognised Professional Training Agreement is not used by the industry.
Validation	Means an approved rigorous method that assesses an instrument or method of measurement against a verified instrument or approved network.	A holistic scientific rigorous test performed once a year. For instruments or methods that do not carry their certification.
Verification	Means an approved rigorous method that assesses an instrument against the National Measurement Standard or the State Primary Standard.	In terms of instrument testing, a scientific rigorous test against a reference standard for instruments that can carry their certification.

Current Regulation	Proposed Regulation	Reason for Change
9 Surveys not requiring strict accuracy	The "agreement" between the client & surveyor for the survey not requiring strict accuracy is to be in writing. Review & update the clauses that apply. Refer to "Classifications" of survey rather than "Class" of survey. Plan to report the "agreed" accuracy. Update the survey certificate.	When a Clause 9 survey is undertaken, there is no documented agreement of what was to occur or to what accuracy. Class has a specific meaning in surveying. The survey plan must convey the accuracy agreed.
10 Re-marking surveys	New clause. Separate identification surveys from re-marking surveys. Title and/or report to indicate intent of survey. Update clauses that apply. New survey certificate.	Better understanding of requirements.
11 Identification surveys	New clause. Separate identification surveys from re-marking surveys. Title and/or report to indicate intent of survey. Update clauses that apply. New survey certificate.	Better understanding of requirements.
12 Datum line	MGA for <u>all</u> surveys. No magnetic meridian as datum (unless compiled plan). 3 survey marks for <u>all</u> surveys. Use established SCIMS coordinates for all 3 marks <u>or</u> use an approved GNSS method for all 3 marks. All marks must be within 1500m of the site. Approved GNSS coordinates must have a PU of 0.1m or less.	Simplifies the datum requirements and makes all plans have the same requirements. 80% of surveyors (from Survey Monkey results) agree that all plans should be on MGA. 2.5% of plans of survey currently use a magnetic meridian (MM) orientation.
13 Bench marks	At least one bench mark within 30m must have accurate AHD. "Confirm", not "verify", the results. Add to the requirement from Clause 70 that requires all PSMs to be shown to the nearest 3m, that all bench marks need to be shown on the plan to at least 3m. Add that only good SCIMS marks can be used, the same as Clause 12.	Height is becoming more important. The majority of surveyors place a local bench mark at the job site, however.
14 Equipment for measurement of surveys	Standardise the use of the term "verification" and "verified". Verification is a rigorous annual assessment of the capabilities of the EDM. Steel bands have been replaced with an option to verify a metal tape every 2 years. Verification to be stored by the surveyor. Verification to be supplied for an audit or investigation.	Clearer breakdown of process required to ensure accuracy of equipment.
15 Validation of measurement methods	GNSS & remote measuring equipment to be validated every year, after services or repair. Validate using an approved method. Must use "verified" equipment in test method. Results stored by the surveyor.	Clearer breakdown of process required to ensure accuracy of equipment.

Current Regulation	Proposed Regulation	Reason for Change
	All measurement methods listed on survey plan.	
16 Confirmation of measurement methods	Clarifies that boundary, dimensions & connections are to be made by the most direct method practicable. Sufficient redundancy of measurements to ensure that the boundary, dimensions & connections determined are correct.	Due to changes in technology, indirect methods of obtaining measurements are possible. Sufficient redundancy of measurements is required to ensure that the correct value is quoted.
18 Surveys for affecting interests	Clarifies that this clause applies to surveys for affecting interests that extend beyond the main surveyed or subdivided area.	Clarifies the application of the clause.
19 Re-survey of property boundaries	Ensure that the surveyor either forms a common boundary with the adjoining parcel or provides a report to justify the discrepancy between the location of the boundary. Surveyor needs to ensure that there is appropriate land available for the surrounding titles & roads and any excess or shortage is dealt with appropriately.	A re-survey is to place the boundary in the same position as it was located prior. Thus, forming a common boundary if all the plans are in agreement or justifying the location of the boundary with extra survey if there is a discrepancy in the plans. The surveyor needs to survey enough land to justify that the proposed survey does not cause any issues or problems with the adjoining parcels and roads.
21 Calculation of area	Areas of land to be calculated using commercial software. Approved method – Surveyor-General's Directions.	Refer to the Surveyor-General's Directions & commercial software as suitable methods of determining area of land.
22 Surveys using GNSS equipment	Old GNSS clause proposed to be deleted.	Surveyor-General's Directions to include outcomes from approved GNSS methods.
24 Accuracy of length measurement	Surveyor to 'check' measurements. Independent checks. Use independent method to check. GNSS not to check GNSS.	Clarify the requirement & be more rigorous.
26 Confirmation accuracy of measurement & calculations	Use the word "check". Combine the outcome for age of partial survey and terrain details of lot into single mm+ppm for each lot. Add mm+ppm to survey certificate.	Simplify the outcome and enable E-plan digital compliance.
28 Boundary marks	Use "●" obstructed boundary symbol at corners that cannot be marked and no need for exemption. Remove requirement for clearing and blazing of rural un-fenced boundaries. Use 3" x 2" pegs as line marks (rural).	Where it is physically impossible to place a survey mark (when the boundary corner lies within the material of a structure that does not have an accessible surface), use ●. Avoid conflict with environmental legislation to prevent or limit clearing. Enable appropriate marking.
29 Marking of urban surveys	For urban survey that creates or redefines a boundary that intersects with a water boundary, place a reference mark for that intersection.	Intersections with roads and rivers are treated the same.
30 Marking of rural surveys	For rural survey that creates or redefines a boundary that intersects with a water boundary, place a reference mark for that intersection. No 500m limit. Allow double referencing if existing RM is within 30m.	Intersections with roads and rivers are treated the same. Allow efficient use of survey marks.

Current Regulation	Proposed Regulation	Reason for Change
31 Roads to be marked with reference marks	Delete Clause 31(3)(d), this will be dealt with in the amended Clause 63. If Reference Mark Tokens are used, then 2 must be placed (same as Drill Holes & Wings). Show connections across road intersections and where width varies.	Improve understanding of Regulation. A Reference Mark Token is no more stable or durable than a DH&W and therefore a second mark is required to provide adequate redundancy of marks and the ability to determine if one token moves. Connections across intersections & where variable enables the road to be crossed mathematically without assumptions.
35 Surveyor to note nature and position of survey marks etc.	If RM found deeper then 300mm, note on plan. List the state of all survey marks.	All surveyors will dig 150mm without special instructions.
36 Placement of reference marks	A second reference mark (RM) must be placed at any corner referenced by a 'reference tree' (as described in Schedule 3) that is found, that does not already have a second reference mark for that corner. If a specific point is used as RM, then additional RM must be placed in road.	Enable the preservation of basic cadastral infrastructure. Enable preservation of survey marks to ensure the integrity of the cadastre.
38 Deferment of placement of survey marks	Delete Clause 38.	This clause is rarely used by industry and same result can be achieved by using the exemption process currently in place.
41 Surveys redefining or creating multiple parcels, roads or affecting interests	Simplify the requirements for placing PSMs. Reduce to number of PSMs placed. Use 250m of road frontage as the basis for network propagation.	The current formula is based on the number of parcels and the lot size is reducing, hence there is oversupply of PSMs in some areas. The new methodology is based on the distance of road frontage.
42 Connection to permanent survey marks	Amend subclause 42(2) to be consistent with subclause 41(1). Connections are limited to 250m (urban) and 1000m (rural). All PSMs must be shown in a closed loop.	This ensures that only close PSMs are used and direct connections between PSMs are shown. PSMs are not more than 250m apart along the length of any road.
43 New permanent survey marks	Remove reference to GNSS techniques in subclause 43(1). Locality Sketch Plans must be lodged before the plan is lodged or within 2 months. New requirement to ensure there is a diversity of PSM types placed.	The lodgement of a sketch plan is the trigger that creates a PSM in SCIMS. The plan once lodged is assessed against the SCIMS database. Missing sketch plans cause delays in mark creation in SCIMS and significant cost in following up un-lodged sketch plans. Improve survey mark preservation and survey integrity by placing a variety of survey marks.
44 Definitions Water boundary definitions	Amend Clause 44 to be consistent with the Crown Lands Management Act 2016: bank, bed, lake and river. Remove the definition of stream. Use the term non-tidal instead of the description of "lake and stream" to define a non-tidal water boundary.	To enable greater consistency of specific terms, use the Crown Lands Management Act 2016 as the source of all definition. The use of the term 'non-tidal' to describe a water feature that does not have tidal influence is explicitly clear as to what is the defining factor that separates tidal and non-tidal water boundaries.

Current Regulation	Proposed Regulation	Reason for Change
45 First surveyor of landward boundary	Update reference to Crown Lands Management Act 2016.	Be consistent with other legislation.
46 First survey of a Mean High Water Mark or bank	All water boundaries require comprehensive report. First definition will require consent of adjoining owner.	Enable efficient approvals process. Ensure correct boundary is defined.
47 Surveys where the boundary includes tidal or non-tidal waters or other natural feature	Surveyor to use approved methods to determine tidal and non-tidal boundaries. Move 47(2) to Clause 64.	Surveyor-General's Direction No. 6 to be expanded and provide list of methods & better guidance.
48 Changes in boundaries formed by tidal waters	MHWM boundary consent will be required after 20 years, or if no approval or erroneous plan is basis of the current title.	The clause is clarified so that the surveyor is required to refer to a survey plan on public record prepared prior to the change in position of MHWM.
50 Surveyor to report of certain determinations	Survey report will be required for all water and natural feature boundary surveys.	Ensure smoother and correct approvals process.
52 Surveyor to make field notes	Field notes must include all measurement methods used. All dates in field notes must be correct. Include requirements of former Clause 53 for electronic field notes and data.	Simplify the requirement of the Regulation.
57 Method of recording observations	Change title of clause to "Method of recording angles & bearing". All distances, coordinates and heights must be recorded in metres.	Simplify the requirement of the Regulation.
60 Survey plan to indicate name of locality, street address and type of survey	Use the correct name (if any) assigned by the Geographical Names Board for any water feature shown on the plan. For partial surveys, the misclose vector tolerance for each parcel in accordance with Clause 26(3) to be shown. A complete description of all land affected on the first sheet for any acquisition or road plan.	The correct names must be used on survey plans. This is particularly important for survey plans as they are often the point where change is proposed. The misclose vector tolerance for each lot of a partial survey (mm+ppm). To ensure correct indexing and searching is applied, the current Lot/DP reference must be shown.
61 Method of recording datum line	The datum line statement must be shown as approved. The datum must be shown adjacent to the North Point. The orientation must be confirmed to a 3rd mark and shown on the plan. Orientation and datum marks to be shown in a single loop with sequential lines.	Datum line must be shown as approved to assist understanding of the survey. It is important to maintain consistent language; the confirmation line is confirming the orientation. The orientation marks must be shown in a closed loop with direct connections.
63 Method of showing boundaries generally	Complete dimensions to include bearings, distances & area. Every road created must be a complete parcel. Connections across intersections, terminals and at variable width.	Better compression of the plan and ensure complete and accurate lot/road dimensions.
64 Method of showing water boundaries and other natural feature boundaries	Amend title of clause. If present waterline is different to adopted MHWM or bank, then both are shown. Was in Clause 47.	Increases the integrity of cadastral plans.

Current Regulation	Proposed Regulation	Reason for Change
65 Method of showing natural feature boundaries	Renumbered as Clause 64.	
65 Surveys adjoining MHWM, bank & natural feature boundaries	Include details of any improvements, retaining walls, slip rails, jetties, etc. near water boundary.	Ensure all interests are recorded on the survey plan.
66 Surveys of land adjoining tidal waters	Renumbered as Clause 65. Minor alteration to require the descriptions and relationship to be shown on “the survey plan” instead of “a survey plan”.	The requirement is for the descriptions and relationship to be shown on the survey plan that is the subject of the clause, not on a separate survey plan.
67 GNSS-derived lines to be indicated	Amend title of clause. Delete reference to GNSS surveys. Show confirmations of datum line and confirmation line on plan.	Simplify the Regulation. Show greater rigour and integrity of datum of survey while enabling greater flexibility for the surveyor.
68 Surveyor to report doubts, discrepancies & difficulties	Amend the difference tolerance to: 40mm + 175ppm	Minor change to be in accordance with datum line tolerance.
70 Survey plan to show coordinate schedule	Due to changes in Clause 12, surveyor can adopt MGA orientation from established survey marks or approved GNSS. If approved GNSS method, hz Positional Uncertainty (PU) must be $\leq$ 0.1m. If stratum survey only (limited in height and/or depth), hz PU $\leq$ 3m.	All survey plans adopt MGA and the surveyor has more flexibility as to what survey method is adopted. New PU requirement of marks surveyed accurately. New PU requirement for stratum survey.
72 Surveyor to furnish survey certificate	Expand when a survey certificate is required. New certificate for Clause 9 (not strict accuracy), 10 (remark) & 11 (identification). Delete reference to Deferred Survey Marks.	Ensure reports and survey plans carry an appropriate survey certificate. New survey certificates.
73 New consent certificate	New clause to enable new digital plans to obtain approvals prior to final completion of the survey. Consent certificate may be used prior to all marks being placed. All boundaries must be defined, parcel design layout, easements, etc. must be final. Only minor amendments allowed. All survey marks must be placed before final survey certificate.	Enable more efficient workflow and shorten times for approvals in the development process.
74 Standards for public surveys under section 4 or 5 of the Act	Clarify outcomes of the Act are also provided by surveys for public authorities. Verified measuring equipment to be used. GNSS & remote surveying methods for public authorities are also validated.	Ensure traceability of measurements and all surveys are using the same datum.
75 Constitution of Board	Update the name “Institution of Surveyors NSW Ltd”, not incorporated. Add the “Association of Consulting Surveyors NSW (ACS NSW)” as one of the professional associations under section 27(2)(c) of the Act.	Allow greater input to the Board from more industry groups.
77 Formal Board determination	Delete reference to “recognised professional training agreement”.	No candidates are using this pathway to become registered.

Current Regulation	Proposed Regulation	Reason for Change
Schedule 1 Bench marks	Re-order into preference of use. Bench mark token has full description. All bolts, nails or spikes combined.	Minor reforms.
Schedule 2 Boundary marks	Line pegs 3' x 3'. All bolts, nails or spikes combined. Boundary mark token has full description.	Minor reforms.
Schedule 3 Reference marks	Reference mark token has full description. Nail & wing added.	Minor reforms.
Schedule 4 Permanent survey marks	Small enhancements for most diagrams. Recess SSM to stop "topping". Ensure gap between cover box & pin/picket to stop "topping".	Minor reforms.
Schedule 6 Form 1: Survey certificate	Amendment to survey certificate. Only one date of completion.	Minor reforms.
Schedule 6 Form 2: Survey certificate not requiring strict accuracy	Amendment to survey certificate. Only one date of completion.	Minor reforms.
Schedule 6 Form 5: Land survey & ident certificate	Amendment to survey certificate. Only one date of completion.	Minor reforms.
Schedule 6 Form 6: Consent certificate	New form. Enable approvals and consents to be obtained simultaneously before final plan of survey in finalised.	Enable approvals and consents to be obtained simultaneously in a new digital lodgement/workflow before the final plan of survey in finalised.

4 CONCLUDING REMARKS

The current Surveying and Spatial Information 2017 is due to cease operation on 31 August 2022 and a new Regulation is proposed to commence on 1 September 2022. This paper has outlined some of the changes that are being considered at this time. Considerable liaison, presentations and communication with industry groups, associations, government agencies and utilities will continue to obtain comments and ideas for the new Regulation. In addition, it is planned to ensure that new documentation, e.g. updated Surveyor-General's Directions and updated Registrar General's Guidelines, new plan forms and certificates, along with updated communication and education programs are provided to inform surveyors of the proposed changes before and after the new Regulation commences.

REFERENCES

Gardner L. (2021) Remake of the Surveying and Spatial Information Regulation: Possible and probable changes, *Proceedings of APAS Webinar Series 2021 (AWS2021)*, 24 March – 30 June, 184-187.

NSW Legislation (2022a) Surveying and Spatial Information Act 2002, https://legislation.nsw.gov.au/view/whole/html/inforce/current/act-2002-083 (accessed Mar 2022).

NSW Legislation (2022b) Surveying and Spatial Information Regulation 2017, https://www.legislation.nsw.gov.au/view/html/inforce/current/sl-2017-0486 (accessed Mar 2022).

NSW Legislation (2022c) Subordinate Legislation Act 1989, https://www.legislation.nsw.gov.au/view/html/inforce/current/act-1989-146 (accessed Mar 2022).