NSW GDA2020 and AGRS Implementation policy

November 2021

NSW GOVERNMENT

1. Document control

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Enquiries on products and services affected by this policy are welcomed at via the Spatial Services Customer Hub: https://customerhub.spatial.nsw.gov.au/servicedesk/customer/portals

Contents

1.1 Document history

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16/09/2020	3.0	Joel Haasdyk	GDA2020 and WGS 84 update
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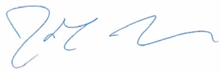
1.2 Document approval

Name	Position	Role	Date	Signature
Joel Haasdyk	GDA2020 Program Manager	Approver	29/10/2021	
Thomas Grinter	A/ Surveyor-General of NSW	Approver	29/10/2021	
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2. Policy summary

For data and services provided by / to Department of Customer Services, Spatial Services.

GDA2020 and GDA94 are the Geocentric Datum of Australia 2020 and Geocentric Datum of Australia 1994 respectively which, for the purpose of this policy, include data expressed in the Map Grid of Australia (MGA) projections, MGA2020 or MGA94.

1. **From 1 January 2020** the *Surveying and Spatial Information Act 2002* (NSW) and *Regulation 2017* (NSW) prescribe GDA2020 for surveys under their authority and advise GDA2020 adoption for all other spatial information in NSW.

2. **From 1 July 2020** Foundation Spatial Data is provided in GDA2020 via select delivery channels. Additional delivery channels will be made available at the earliest opportunity. Refer to the Spatial Data webpage for an up-to-date and comprehensive list of GDA2020 services offered or under development.

3. **From 1 July 2021** any new service deployed will support GDA2020. Where possible, new services will also support requests in GDA94, and WGS 84-aligned-to-GDA2020.

4. **From 1 July 2021** any new WGS 84 service deployed will be aligned to GDA2020.[1]

   i. Existing WGS 84-aligned-to-GDA94 services will be deprecated over time, with advanced notice provided to assist with transition to replacement services.

   ii. WGS 84 dataset metadata shall indicate alignment with GDA2020, GDA94, another CRS, or 'unknown'. All data custodians are encouraged to record similar metadata.

5. **Until 1 July 2023** DCS Spatial Services will also support services in GDA94.

6. The 'conformal and distortion' NTv2-CPD grid is the preferred method for transformation of spatial data in NSW between GDA94 and GDA2020, and shall be employed unless otherwise indicated. Where data is outside the extents of the NTv2-grid, the transformation method shall default to the 7-parameter conformal transformation.[2]
   The same transformation preference applies to WGS 84 aligned to GDA94/GDA2020.

7. Special care must be taken when transforming 3D data. Refer to Section 5.3 and contact Spatial Services for more information on the appropriate transformation methods for:

   i. 3D datasets (e.g. GDAxx horizontal component and GDAxx Ellipsoidal height)

   ii. 2D+1D datasets (e.g. GDAxx horizontal component with AHD height)

   iii. other height systems (e.g. ATRF, AVWS, Hydrographic)

(continued next page)

1 In January 2021, the EPSG registry updated GDAxx <> WGS 84 transformations to include both NULL and non-NULL options. This allows users greater flexibility to 're-align' WGS 84 data as required. WGS 84, and its Web Mercator projection, are defined as low-accuracy and remain best suited to visualisation and applications at small scale / zoom level. Users may expect metre-level misalignments if mixing WGS 84 data from different sources or providers. Refer to WGS 84 Information Sheet.

Note: Consuming GDA2020-aligned services into GDA94-aligned applications can generally (but not always) be supported via client-defined or custom transformations. This provides users with an alternative to the current WGS 84-aligned-to-GDA94 services.

2 GDA94 <> GDA2020 NTv2_CPD 'conformal and distortion' transformation (EPSG:8447, accuracy 0.05 metres).
GSB files are available from http://www.icsm.gov.au/datum/gda-transformation-products-and-tools/transformation-grids

For data outside the NTv2 grid extents as it applies in NSW (effectively Long: 140.9^{0} E to 154.1^{0} E, Lat: 27^{0} S to 9^{0} S) the transformation should default to the 7 parameter conformal-only transformation (EPSG:8048, accuracy 0.01 metres). Refer to Section 3.7 and Figure 3.3. in GDA2020 Technical Manual v1.7.pdf

8. Any spatial dataset provided to Spatial Services shall have associated metadata detailing Coordinate Reference System (CRS), epoch (where appropriate) and data lineage including transformation method(s). Refer to ANZLIC metadata advisory. Data provided as 'WGS 84' shall also indicate whether the data is aligned to (i.e. equivalent to) GDA94, GDA2020, another CRS, or 'unknown'.

9. The Australian Height Datum (AHD71) will continue as the legislated height datum in NSW for the foreseeable future. This is consistent with reported intentions across Australia.

10. Spatial Services will not expressly advocate or legislate adoption of ATRF and AVWS until relevant standards and software provide wide-spread support. However, where significant benefits can be realised, ad hoc support will be considered.

3. Policy context

The purpose of this document is to describe how the Department of Customer Service, Spatial Services (hereafter referred to as Spatial Services) will address the management of GDA2020, GDA94 and WGS 84 in NSW, as it implements Australia's datum modernisation program.

The objective is to facilitate the adoption of GDA2020 by current and future NSW geospatial consumers and to ensure that timelines for introduction and support of the above datums are clear to all users.

This policy also describes an agreed approach to modernise WGS 84 and its Web Mercator projection by re-alignment to GDA2020, acknowledging the potential for misalignment resulting from the low-accuracy (2m) nature of WGS 84 and existing WGS 84-aligned-to-GDA94 data. (Refer to Section 5.6 for more information.)

3.1 Authority

This policy draws its authority from the Australia and New Zealand Spatial Information Council (ANZLIC) and the NSW Standard for Spatially Enabling Information (SSEI)[3]. The SSEI is released by the NSW ICT and Digital Leadership Group (IDLG) in accordance with NSW Government ICT strategies.

The SSEI forms a part of the NSW Government Information Management Framework. It also supports several key initiatives at the national, state and agency levels of government. Aligned initiatives and priorities are detailed in the following:

- The Australian and New Zealand Foundation Spatial Data Framework[4]
- NSW Foundation Spatial Data Framework[5]
- NSW Beyond Digital Strategy[6]

The SSEI Standard defines coordinates as one of the four core spatial indexes. It identifies the Geocentric Datum of Australia (GDA) as the reference datum for consistent and common referencing of spatial data across NSW. While the SSEI (2018) currently refers to GDA94 the next revision will adopt GDA2020, and reflect changes in the *Surveying and Spatial Information (S&SI) Act 2002 (NSW) and Regulation 2017 (NSW) which now:*

- **prescribes** the use of GDA2020 in NSW for the State Control Survey, state cadastre and surveys carried out for or on behalf of the Surveyor-General or a public authority; and
- **advises** the use GDA2020 for all other spatial information.

3 available from https://www.spatial.nsw.gov.au/publications/policies_and_guidelines
4 https://www.anzlic.gov.au/resources/foundation-spatial-data-framework
5 https://data.nsw.gov.au/data/dataset/nsw-foundation-spatial-data-framework
6 https://www.digital.nsw.gov.au/strategy

3.2 Scope

This policy supports the adoption of the Geocentric Datum of Australia (GDA2020) across NSW, in a manner consistent with the longer-term application of the Australian Geospatial Reference System (AGRS) across Australian jurisdictions.

Specifically, this policy applies to the management and provision of all Spatial Services datasets and services to NSW stakeholders. External agencies, such as other NSW government departments or private stakeholders, are encouraged to adopt a policy for GDA2020 implementation which is informed by and consistent with this policy

The Intergovernmental Committee on Surveying and Mapping (ICSM) will continue to expand the definition and capabilities of the AGRS. The new time-dependent Australian Terrestrial Reference Frame (ATRF) and the Australian Vertical Working Surface (AVWS) have also been introduced by ICSM and are available via ICSM from 01 January 2020. ATRF and AVWS are anticipated to experience significant adoption through the implementation of the Australian Civil Space Strategy 2019-2028 and the introduction of improved positioning capabilities for the mass market.

In general, GDA2020 and AHD71 remain fit for purpose for most users. Spatial Services will not expressly advocate or legislate adoption of ATRF and AVWS until relevant standards and software provide wide-spread support. However, where significant benefits can be realised, ad hoc support for all AGRS capabilities will be considered.

This policy also aims to support the adoption of WGS 84-aligned-with-GDA2020 data and services. WGS 84 and Web Mercator have long been a low-accuracy defacto standard aligned with GDA94, best suited for web mapping and field data collection. After significant debate, the majority (but not unanimous) conclusion of the national GDA Modernisation Implementation Working Group (GMIWG), is that the best long-term approach is to realign WGS 84 / Web Mercator with modern positioning technologies and GDA2020. Spatial Service agrees with this majority decision. During this transition period it is recognised that users may experience metre-level misalignments if mixing WGS 84 data from different sources and that special care must be taken with WGS 84 metadata. Refer to the Section 5.6 and the WGS 84 Information Sheet for more information.

4. Policy components

4.1 Key accountabilities and responsibilities

Each of the following parties has specific assigned responsibilities under this policy.

4.1.1 Spatial Services Project Management Office (PMO) & Program Control Board (PCB)

- Ensure that all new and inflight projects that deliver or maintain spatial datasets beyond January 2020 comply with the GDA2020 implementation policies.

4.1.2 Spatial Services Information Services (ICT)

- Ensure data delivery channels are upgraded to support implementation of this Policy.

4.1.3 Office of the Surveyor-General

- Manage the update of legislation and standards to support GDA2020.
- Promote multi-datum support for fundamental positioning infrastructure and Foundation Spatial Data.
- Provide internal and external advisory services relating to best practice for GDA2020 implementation and issues regarding the use of WGS 84.

4.2 Communication and consultation

This policy has been developed in collaboration with stakeholders in NSW and other Australian jurisdictions to ensure that a consistent and/or compatible national approach is adopted, where possible, to support the management of GDA94, GDA2020 and WGS 84.

Communication of this policy and related contents will occur through the ‘NSW Datum Modernisation Working Group’ to other government, industry and education representatives, and through the Spatial Services web site.

4.3 Monitoring and review

This policy will be reviewed after July 2022, in the context of any updated national policy or advisory on GDA94, GDA2020, and/or WGS 84.

5. Background

5.1 Datum modernisation: GDA2020 and the AGRS

The Geocentric Datum of Australia 2020 (GDA2020) is Australia's new National Datum, defined via a National Measurement Determination in October 2017 to replace GDA94. GDA2020 is of higher accuracy than GDA94, aligns more closely with GPS and GNSS positioning services and supports nationally consistent datasets, free of the known distortions of GDA94. In NSW, GDA2020 coordinates are approximately 1.5 metres to the north-east of GDA94 coordinates, a change which represents the tectonic motion of the Australian tectonic plate between 1994 and 2020.

GDA2020 is the first product of the modernised Australian Geospatial Reference System (AGRS) which provides the framework for coordinating all spatial information in Australia. Modernising the datum ensures that users have access to accurate and nationally consistent spatial data and services, and the associated economic benefits. (CRSCI, 2008; CRCSI, 2017; FrontierSI, 2019; Australian Civil Space Strategy 2019-2028).

ANZLIC nominated 30 June 2020 as the date to nationally coordinate GDA2020 support across ANZLIC member agencies. In preparation, Spatial Services updated fundamental positioning infrastructure including CORSnet-NSW and SCIMS, as well as NSW legislation, to support GDA2020. Spatial Services now also provides multi-datum support for datasets of the NSW Foundation Spatial Data Framework (FSDF) via the Spatial Collaboration Portal and continues to expand this support across all delivery channels. (Refer to the Spatial Services Spatial Data webpage for a comprehensive list of supported products).

5.2 GDA94 – GDA2020 transformation methods

In NSW, the 'Conformal and Distortion NTv2-CPD' grid transformation is the preferred transformation method between GDA94 and GDA2020 for all spatial data (2 dimensional). The 'NTv2-CPD' transformation is one of 3 transformations defined by ICSM:

- **3D conformal 7-parameter** similarity transformation (EPSG:8048):
  A 'similarly' transformation which defines only 'translation, rotation and scale' between GDA94 and GDA2020, and describes only simple linear tectonic motion. The conformation transformation preserves the shape of spatial data.

- **2D 'NTv2-CON' conformal-only grid transformation** (EPSG:8446):
  The conformal transformation described as a grid of latitude and longitude shift vectors (~1.5 km spacing).

- **2D 'NTv2-CPD' conformal and distortion grid transformation** (EPSG:8447):
  The conformal transformation grid combined with additional modelling to account for known distortions which are present in GDA94, but removed in GDA2020 (~1.5 km spacing).

Within NSW, the known distortions in GDA94 modelled within the NTv2-CPD grid can be as large as +/-300 mm, and are irregular in distribution.

Where data has a spatial accuracy of metre-level (or worse), the conformal methods are sufficient in theory. However, even low-accuracy datasets may be expected to be topologically aligned. In order to maintain consistency with other fundamental positioning infrastructure (i.e. CORSnet-NSW, SCIMS), Spatial Services advises the use of the NTv2-CPD transformation for all spatial data, except where explicitly noted.

> **Note:** The only exception currently identified within Spatial Services is for existing 'Elevation' products. Digital Elevation Models (DEM) are spatially defined by top-left corner coordinates

only, but determined in part from underlying dense LiDAR (LAS: x,y,AHD) datasets. In order to keep LAS and DEM products aligned, the NTv2-CON transformation is employed. These Elevation products have a horizontal accuracy requirement of 0.8m, and are therefore not degraded by ignoring GDA94 distortions.

Where spatial data falls outside the NTv2 grid extents (for NSW, grid extents are effectively 140.9^{0} E to 154.1^{0} E longitude, 27^{0} S to 9^{0} S latitude) the transformation should default to the 7-parameter conformal-only transformation (EPSG:8048).

Further information on transformations methods and tools can be found at:

- www.spatial.nsw.gov.au/surveying/geodesy/transformation_methods
- www.icsm.gov.au/datum/gda-transformation-products-and-tools
- www.icsm.gov.au/sites/default/files/DatumMattersFactSheet4.pdf

It is important that the transformation method is stored within 'lineage' metadata for any transformed dataset. Refer to the ANZLIC advisory Preparing metadata for GDA2020 and the AGRS for more information.

5.3 3D data and vertical transformation methods

Special care must be taken when transforming data which is 3 dimensional. Contact Spatial Services to confirm the appropriate 3D transformation methods for particular datasets, especially considering the different requirements for:

- 3D datasets (e.g. GDAxx horizontal component with GDAxx ellipsoidal height).
  - Use the 2D NTv2-CPD grid for the horizonal component
  - Use the 3D 7P conformal transformation, applied to height component only.
  - Note, this compound approach may not yet be supported in all software
- 2D+1D datasets (e.g. GDAxx horizontal component with AHD height)
  - Use the 2D NTv2-CPD for the horizonal component
  - AHD requires no transformation.
- transformations between the above 3D and [2D + 1D] systems
  - e,g, use appropriate AUSGeoid models for AHD <> ellipsoidal heights.
- other height systems (e.g. ATRF, AVWS, Hydrographic).

GDA94 and GDA2020 are both fully 3-dimensional datums, and both define an 'ellipsoidal height' (h) which provide height above an artificial / mathematical surface known as the ellipsoid. GNSS positioning yields ellipsoidal heights, unless expressly modified by an appropriate geoid-model (Refer to AUSGeoid models, and AVWS section, below).

In contrast, most historical (and contemporary) datasets supported by Spatial Services define height in terms of the Australian Height Datum. AHD describes 'orthometric heights' (H), which are best suited to describe how fluid flows under the influence of (local) gravity, e.g. how water flows 'downhill'. However, AHD is known to have biases and errors which limit its accuracy over larger distances compared to GNSS based methods.

Orthometric and ellipsoidal heights can be interconverted with the help of various 'AUSGeoid' models. More information on this topic is available from:

- https://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/ahdgm
- https://icsm.gov.au/australian-vertical-working-surface
- https://www.spatial.nsw.gov.au/surveying/geodesy

Demand and support for high accuracy height and 3D data is growing quickly. Three emerging areas of interest are the Spatial Digital Twin (to coordinate and visualise 3D and 4D data) the development of a state-wide gravity model (to support sub-decimetre-accurate vertical positioning derived from GNSS positioning, among other applications), and the associated development of the new Australian Vertical Working Surface (AVWS). Future updates of this policy are expected to address these issues in more detail.

5.4 Time dependence: ATRF

While GDA2020 is a static datum which behaves just like GDA94 (albeit positioned ~1.5 m to the NE in NSW), updates to the AGRS also include the dynamic (or "time-dependent") Australian Terrestrial Reference Frame (ATRF). ATRF includes the ~7 cm / year Australian Plate Motion Model needed to properly combine centimetre-level data observed at different epochs, in the light of metre-level movements of the Australian plate.

Most users will be shielded from the complexity of these dynamics. 'Under the bonnet', ATRF is expected to play a significant role in mass-market decimetre-level positioning applications supported by the new Australian Satellite Based Augmentation System (SBAS), expected to be operational by 2023 (and fully operational by 2025). ATRF will allow present-day satellite-derived positions to be merged across time with existing datasets with minimal user-intervention.

GDA2020 meanwhile, will remain fit for purpose as a conventional reference for long-term storage, analysis, manual interrogation, and presentation of spatial data.

Standards and software are currently under development to support ATRF.

The ATRF technical implementation plan can be downloaded from the 'ATRF' hyperlink above.

See also Section 5.7 addressing metadata for 4D data.

5.5 Australian Vertical Working Surface

Also available from ICSM is the new Australian Vertical Working Surface (AVWS), which aims to provide easy access to decimetre-level heights across Australia, based on existing ellipsoidal height data, or via the same SBAS system that will support ATRF.

AVWS provides access to high accuracy (nominally 4-8cm) orthometric heights (i.e. describing the direction of water flow), without the need to connect directly to local survey infrastructure. A high-density model of the Australian gravity field allows users to compute AVWS heights directly from GNSS ellipsoidal heights, in the same way that the AUSGeoid model(s) currently support calculation of AHD heights from GNSS observations.

AVWS is especially suited to larger-scale applications (e.g. greater than 10km). At this large scale, spirit-levelling techniques are less accurate than GNSS, and known biases and distortions in AHD may be encountered. Relevant applications for AVWS include environmental studies (e.g. flood and storm modelling), LiDAR surveys, geodesy, and hydrography.

While Spatial Services is not expressly advocating or legislating adoption of AVWS at this time, we are collecting and maintaining new ellipsoidal height datasets with an aim to support future applications of AVWS. A current proposal to develop a NSW state-wide gravity model may further improve the accuracies and applications supported by AVWS.

Meanwhile, AHD remains the only prescribed height datum for Australia, and is still fit for purpose for cadastral, civil engineering, construction, mining and other applications.

The AVWS technical implementation plan can be downloaded from the 'AVWS' hyperlink above.

5.6 WGS 84 / Web Mercator misalignments

WGS 84, when used to describe the datum of the Global Positioning System (GPS) is time-dependent and is updated on a regular basis to account for the earth's tectonic motion. However, this only applies to specific 'realisations' of WGS 84, for example, 'WGS 84 (G1762)' which is operational since GPS week 1762 (October 2013) and uniquely defined in the EPSG registry as EPSG:1156). WGS 84 spatial data is RARELY defined in terms of these specific WGS 84 realisations.

In stark contrast, WGS 84 (EPSG:6326, EPSG:4326) and the 'WGS 84 / Web Mercator' projection (EPSG:3857) which are commonly used for web mapping represent a low accuracy 'ensemble' or collection of all WGS 84 realisations. This ensemble is expressly 'static' in definition, ignores tectonic motion and is considered suitable only for low-accuracy (several-metre-level) applications.

This issue and associated solutions are described in the WGS 84 Information Sheet and the GMIWG Advisory on WGS 84 and web mapping.To date, low-accuracy WGS 84 used in web mapping has not presented a problem due to:

(1) GPS / GNSS positioning historically providing metre-level (or worse) spatial accuracy for civilian users.

(2) the historic application of web mapping, generally restricted to low-accuracy (i.e. metre-level or worse) field positioning or small-scale (low zoom) display of spatial data, where high accuracy – and tectonic motion – is unimportant.

(3) the practice of equating WGS 84 with a single national datum, resulting in an implicit timestamp being adopted. Historically in Australia, WGS 84 has been assumed to be aligned to GDA94, at epoch 1994.0. Note that this implicit epoch is regionally specific, and differs between Australia, Europe, North America, etc.

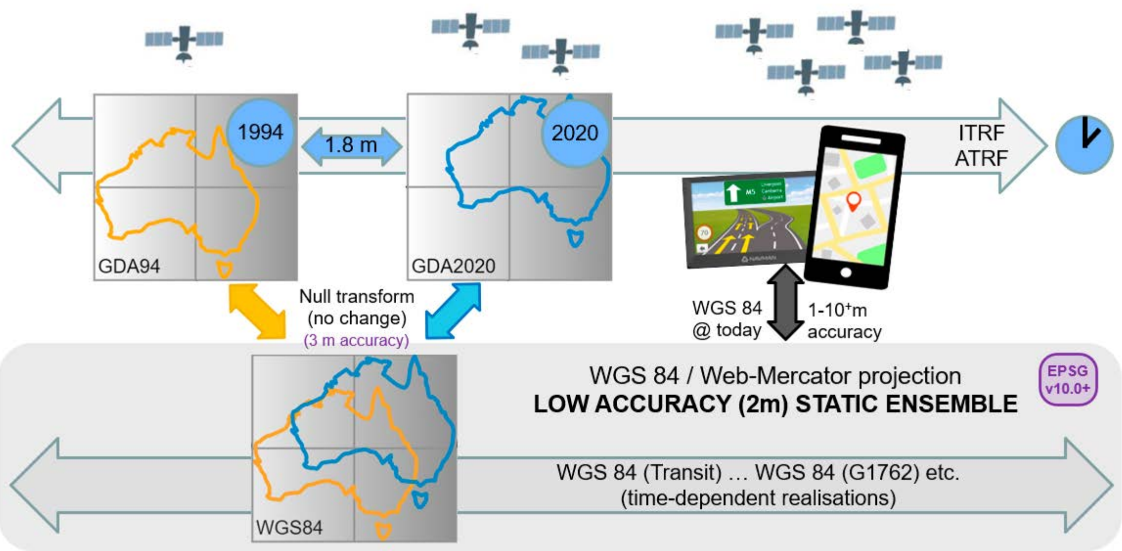

Figure 1 WSG 84 misalignments resulting from ignoring tectonic motion.

When GDA94 was created, the WGS 84 (ensemble) was described as 'equivalent to GDA94 for all intents and purposes', i.e. GDA94 ≈ WGS 84 (EPSG:1150). Unfortunately, GDA2020 was later also defined as 'equivalent to WGS 84 (ensemble) at low accuracy' (EPSG:8450). While technically true, this suggested a false equality where GDA94 ≈ WGS 84 ≈ GDA2020 (albeit at a nominal accuracy of 3 metre).

This has resulted in potential misalignments in data when attempting to combine GDA94 and GDA2020 data in WGS 84 web-mapping applications, or when combining WGS 84 data from different sources.

In practice, avoiding misalignments between all WGS 84 datasets is impossible: If authoritative datasets are re-aligned to adopt WGS 84-aligned-to-GDA2020, then existing WGS 84-aligned-to-GDA94 datasets are at risk of misaligning. If instead, 'authoritative' WGS 84 data were to remain aligned to GDA94, then modern GNSS positioning, despite its ever-increasing accuracy, will be permanently misaligned against WGS 84-aligned-to-GDA94 authoritative maps – by 2 metres and growing. For many users, the low accuracy of existing WGS 84 datasets should mean that any misalignment is inconvenient rather than consequential. Modern positioning of higher accuracy is expected to drive WGS 84 applications towards a modern alignment with GDA2020. Where the greatest accuracy is required, applications should adopt a high accuracy datum such as ITRF or ATRF.

There has been much discussion to determine a nationally consistent approach to cater for WGS 84 and avoid misalignments. Unfortunately, at the time of publication, no national consensus has yet been reached, highlighting the difficult nature of the issue. However, the majority conclusion of the national GDA Modernisation Implementation Working Group (GMIWG), is that the best long-term approach is to realign WGS 84 / Web Mercator with modern positioning technologies and GDA2020.

Modernising WGS 84 to align with GDA2020 brings web mapping in line with modern GNSS positioning and places the onus of modernisation of WGS 84 datasets onto data custodians and service providers, who are anticipated to be more sophisticated than the average mass-market user of GNSS hardware and software.

5.6.1 Spatial Services policy on WGS 84 alignment to GDA94/2020

Ultimately in line with national advice, and in agreement with the majority of Australian jurisdictions, Spatial Services has adopted WGS 84-aligned-to-GDA2020 for all new data and services published after 01 July 2021. Existing WGS 84-aligned-to-GDA94 services will be deprecated over time, to be re-aligned with GDA2020. Advanced notice will be provided prior to deprecating services to assist with transition to replacement services.

It is recognised and acknowledged that this transition to WGS 84-aligned-to-GDA2020 may result in metre-level visual misalignments for some users when mixing WGS 84 data from different sources or services. It is also noted that the new GDA2020-aligned services provided by Spatial Services can generally be re-aligned locally by client-defined transformations, which provides an alternative to WGS 84-aligned-to-GDA94 services.

As noted above, the consequences of WGS 84 data misalignment are expected to be a source of confusion, but to have low severity. Feedback on this issue is welcomed via the Customer Hub https://customerhub.spatial.nsw.gov.au/servicedesk/customer/portals

It is further recommended that:

- users exercise caution when combining WGS 84 datasets
- NSW agencies and data custodians adopt a metadata and labelling policy that clearly communicates whether WGS 84 or Web Mercator data is equivalent to GDA94, GDA2020, another source / epoch, or if that alignment is unknown.

- NSW agencies and data custodians adopt WGS 84-aligned-to-GDA2020 for all new data and applications at the earliest convenience, and prior to the July 2023 conclusion of general support for GDA94.

5.7 National advisory on metadata for 3D and 4D data

3D and 4D data require unambiguous definitions to facilitate integration with other data.

True 3D spatial data, as noted in Section 5.3, must clearly identify not only a 2D horizontal CRS, but also an unambiguous vertical height system as a 1D vertical CRS or as part of a true 3D or compound [2D+1D] CRS.

To date 4D data is most commonly created from 3D spatial data with time-stamped observations at defined location(s). Two simple examples are a bus leaving 'breadcrumbs' along its route, or a water-level gauge recording river height over time, both at GDA2020 location(s) with time-stamped observation(s) of additional spatial or non-spatial quantities.

In the near future however 4D data may, in some circumstances, also employ true time-dependent coordinate reference frames (e.g. ATRF) in which x,y,z and time are required to unambiguously define a '4D location'. This would apply for datasets where local land deformation and tectonic motion must be accounted for, and the coordinate reference system itself changes over time.

The international community is aware of the importance of recording, applying and communicating the time stamp or 'epoch' associated with data. Standards and software are currently under development to support this requirement, with updates to ISO19115 and ISO19111 published in early 2021 now supporting mandatory epoch metadata for time-dependent or 'dynamic' datums. Additional work is underway to develop the models and standards required to communicate and apply complex deformation models.

Best practice for 4D data requires that spatial metadata carefully distinguish between a 'Temporal Extent' (i.e. the time(s) at which the data was observed or measured), versus an 'Coordinate Epoch' (the point in time at which coordinates in a dynamic coordinate reference system are referenced).

Refer to the ANZLIC Advisory: Preparing metadata for GDA2020 and the AGRS.

Despite the WGS 84 ensemble not being defined as a time-dependent datum, the above advisory still offers a practical 'interim' method; the implicit epoch of a WGS 84 dataset can be recorded where this offers a useful shorthand to describe WGS 84 alignment to GDA94, GDA2020 or ATRF@epoch.

It is worth nothing that in most circumstances, future applications and advanced software employing time-dependent coordinates and deformation models are expected to hide the complexity of these processes from the major of users. Most spatial data users will not need to consider time-dependency in coordinates, (or perhaps coordinates at all). The long-term aim is that spatial data is seamlessly integrated as needed for viewing and analysis. However, this will require accurate metadata maintenance processes.

In practice, most users in Australia will adopt and employ the static GDA2020 for everyday applications of spatial data in 2D, 3D, and even 4D applications. ATRF and time-dependent CRS should remain the concern of geodesists and software developers.

6. Glossary of terms

Term	Acronym	Definition
Australian Height Datum	AHD	The Australian Height Datum (AHD) is used to refer collectively to AHD71 defined for use on the Australian mainland, and AHD-TAS83 defined for use on Tasmania. Since 2017, the EPSG:5111 definition of AHD also includes the Christmas Island Height Datum (CIHD) and Cocos (Keeling) Island Height datum (CKIHD).
Australian Height Datum 1971	AHD71	Australian Height Datum 1971 establishes the height reference in Australia (mainland), nominally representing height above mean sea level.
The [Australia and New Zealand] Spatial Information Council	ANZLIC	The Spatial Information Council (ANZLIC) is a joint initiative of the Australian and New Zealand Governments, and the State and Territory Governments of Australia. ANZLIC is the peak Government body in Australia and New Zealand with the core responsibility for the stewardship of spatial information.
Australian Geospatial Reference System	AGRS	The collection of Australian horizontal and vertical reference frames and the model(s) required to transform between them.
Australian Terrestrial Reference Frame	ATRF	A regional densification of the International Terrestrial Reference Frame. ATRF is a time-dependent reference frame, defined from several hundred permanent CORS on the Australian mainland and external territories. ATRF is equivalent to GDA2020 at 01/01/2020 and changes over time according to the Australian Plate Motion Model. The extent of ATRF is the same as GDA2020.
Australian Vertical Working Surface	AVWS	A new reference surface for height in Australia, free of the bias and distortion known in AHD; A nationally consistent model to transform heights from GNSS ellipsoidal heights to physical heights (i.e. indicating water flow) with sub-decimetre accuracy over large regions.
Coordinate epoch		The date/time at which coordinates in a dynamic coordinate reference system are referenced (ISO19111) This is usually provided as a decimal year (YYYY.yy).
CORSnet_NSW	CORS	CORSnet-NSW is a network of Global Navigation Satellite System (GNSS) Continuously Operating Reference Stations (CORS) covering the state of NSW and providing centimetre-level real-time positioning.
Coordinate Reference System	CRS	A coordinate system with a defined origin which allows unambiguous description of location. CRS can define either geographic datums (e.g. GDA2020) and their projections (e.g. MGA2020). A CRS is typically identified by a unique EPSG code.
Department of Customer Service (NSW)	DCS	NSW Government agency responsible for the maintenance and distribution of Foundation Spatial Data Framework data in NSW.

Term	Acronym	Definition
Datum		Datum (more recently called a Reference Frame) is a mathematical model of the earth that defines the origin, scale and orientation of a coordinate system against which features can be represented as coordinates.
Dynamic datum or more appropriately: “Time-dependent Datum”		A reference frame in which the defining parameters include time evolution. With a dynamic datum, the reference frame is fixed to the earth as a whole. As the earth’s tectonic plates move (by a few centimetres a year), a feature’s coordinates also change to reflect that movement. Examples include the WGS 84 datum used by Global Positioning Systems (GPS), and the International Terrestrial Reference Frame (ITRF).
Datum ensemble		A group of multiple realizations of the same terrestrial or vertical reference system that, for approximate spatial referencing purposes, are not significantly different
Epoch		A point in time, as applied to time dependent datums, expressed in decimal years. Example 2017-03-25 in the Gregorian calendar is epoch 2017.23. See also Coordinate Epoch and Observation Epoch.
European Petroleum Survey Group geodetic parameter dataset	EPSG / EPSG code	Online database that contains definitions of numerous datums and map projections, along with formulas to translate between them. Each is uniquely identified via an EPSG code. See https://epsg.org/ Note also ISO 19127:2019 which may in future replace or complement the EPSG registry.
Global Positioning System / Global Navigation Satellite Systems	GPS / GNSS	Satellite delivered navigation systems which provide geo-spatial positioning with global coverage, allowing small autonomous receivers to determine position, altitude and time.
NSW Foundation Spatial Data/ Foundation Spatial Data Framework	FSD FDSF	The NSW Foundation Spatial Data Framework (FSDF) provides a common point of reference for the assembly and maintenance of foundation level spatial data held by NSW Government agencies. It contains the best available, most current, authoritative source of foundation spatial data under ten foundation themes.
Geocentric Datum of Australia 1994	GDA94	The national Australian mapping datum in force from 1994 to 2017, superseded by GDA2020.
Geocentric Datum of Australia 2020	GDA2020	The current Australian mapping datum. *Gazetted by the Commonwealth according to the National Measurement (Recognized-Value Standard of Measurement of Position) Determination 2017* (https://www.legislation.gov.au/Details/F2017L01352)

Term	Acronym	Definition
GDA Modernisation Implementation Working Group	GMIWG	A dedicated working group within ICSM, established to oversee the implementation of the Geocentric Datum of Australia 2020. Members include government representatives from the Commonwealth, states and territories.
Intergovernmental Committee on Surveying and Mapping	ICSM	ICSM is a join initiative representing surveying and mapping agencies across Australian and New Zealand Governments, and the State and Territory Governments of Australia. ICSM working groups address specific spatial data issues, with specialist membership from key government, academic, and private organisations. ICSM initiatives aim to provide a consistent and modern approach to surveying, mapping and charting for national development and defence.
Map projection		Coordinate conversion from the earth's ellipsoidal coordinate system to a plane.
Observation epoch		The date/time at which the data was observed or measured; the date/time of data acquisition.
Reference frame		See – Datum
Survey Control Information Management System	SCIMS	SCIMS is a database that contains the coordinates, heights and related attributes for Permanent Survey Marks constituting the State Control Survey established under the direction of the Surveyor-General of NSW.
Spatial data		Data that identifies a geographic location, usually stored as coordinates and can be mapped.
Static datum		A reference frame in which the defining parameters exclude time evolution. With a static datum, the reference frame is locked to the regional tectonic plate; features on a static datum have coordinates which remain the same over time. For example, both GDA94 and GDA2020 are static datums for Australia.
Web Mercator		WGS 84 Web Mercator (EPSG:3857) is the defacto standard projection used in web-mapping. (Its official name is "Pseudo Mercator"). WGS 84 Web Mercator is projected from the WG84 datum ensemble (EPSG:6326).
World Geodetic System	WGS 84	WGS 84 is a geocentric mapping datum first developed by the United States Department of Defense [sic] in 1960 (as WGS60). WGS has since evolved with continued improvements to the measurement and modelling of the global system and is currently referred to as WGS 84 (EPSG:1156) In contrast the 'WGS 84 / Web Mercator' used in web mapping (EPSG:6326, 3857) is not a single unique reference frame, but an 'ensemble' of WGS 84 realisations which have been updated six times to date, with significant changes (up to 0.7m) especially between older realisations. The WGS 84 ensemble should be taken to have an accuracy of several metres, and to be appropriate for approximate spatial referencing purposes only.

7. Related policies and documents

Issuer	Reference	Document Name
DFSI	Version 2.0 May 2018	NSW Standard for Spatially Enabling Information