A New Geocentric Datum for Australia

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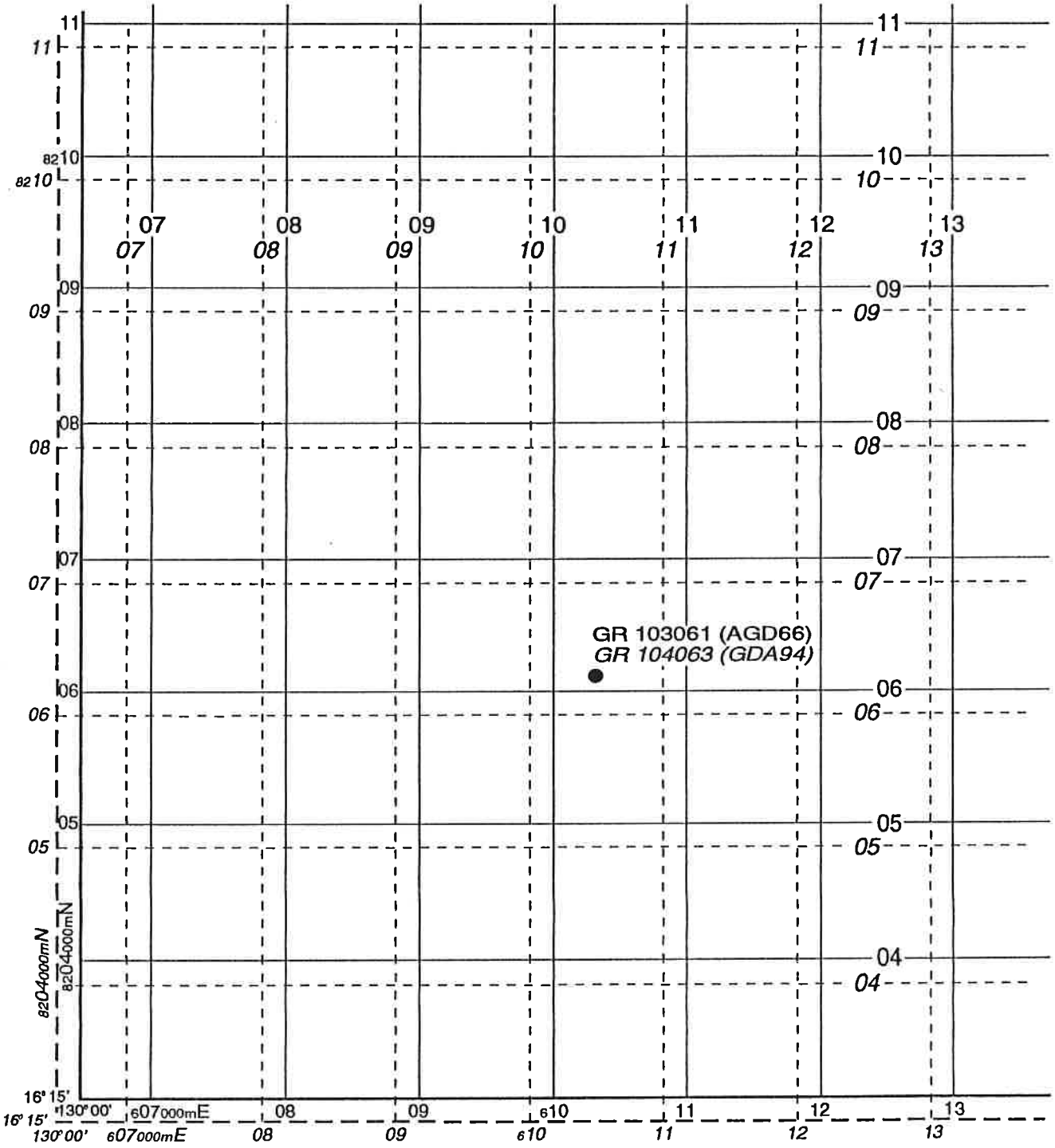
Australian Geodetic Datum (AGD)/Geocentric Datum of Australia (GDA) Comparison

AGD 66 shown in unbroken lines and upright text
GDA 94 shown in broken lines and italic text.

This example has been prepared as a guide to the adoption and implementation of the Geocentric Datum of Australia (GDA) for LIC topographic map products. It is an example only and the conversion values will vary for each map product according to location.



DATUM CONVERSION NOTE

To convert from GDA 94 to this map's co-ordinate system, AGD 66:
DECREASE Eastings by 131 metres
DECREASE Northings by 156 metres
DECREASE Longitudes by 4.4 seconds
INCREASE Absolute value of Latitudes by 5.1 seconds

DATUM CONVERSION NOTE

To convert from AGD 66 to this map's co-ordinate system, GDA 94
INCREASE Eastings by 131 metres
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DECREASE Absolute value of Latitudes by 5.1 seconds

The difference between the Geocentric Datum of Australia 1994 (GDA 94) and the World Geodetic System 1984 (WGS 84) on which the Global Positioning System is based is NEGLIGIBLE AT MAP SCALE.

Abstract

Australia is moving towards the adoption of a New Geocentric Datum - an internationally compatible co-ordinate system for all geographic data.

This paper outlines the reasons behind the change to a new datum, some aspects of the change process and likely impacts for users.

Introduction

A geodetic reference system is a system of widely separated monumented points with known latitude, longitude and height. This system provides the framework for all surveying, mapping, geographic information and navigation applications.

For over a century, a number of different unrelated geodetic datums and co-ordinate systems were used by various surveying and mapping agencies across Australia. It wasn't until 1966 that the first national geodetic datum was adopted, the Australian Geodetic Datum (AGD).

There are still several geodetic co-ordinate sets being used at State, Territory and local levels by surveying and mapping agencies.

The responsibility for managing Australian geodesy, surveying and mapping lies with the Intergovernmental Committee on Surveying and Mapping (ICSM). This Committee comprises Commonwealth, State, Territory and Defence agencies responsible for surveying and mapping in Australia and New Zealand.

With the rapid development of global communication and information technologies and the arrival of satellite based positioning systems, ICSM has recognised the benefits to Australia by adopting a single satellite based reference system compatible with the global geocentric datum developed by the USA Department of Defence.

Current Situation

Nationally, the Australian Map Grid 1966 (AMG66) and 1984 (AMG84), which are projections of geographical co-ordinates from the Australian Geodetic Datum 1966 (AGD66) and 1984 (AGD84), respectively are used for mapping purposes.

New South Wales in the 1970's adopted the Integrated Survey Grid (ISG) for surveying purposes, essentially because the ISG utilises a 2° zone which minimises the difference between ground (or measured) distances and projection distances, simplifying cadastral surveying and, in the absence of cheap computer technology, all survey computations.

Satellite based positioning systems such as the NAVSTAR Global Positioning System GPS uses a geocentric datum known as the World Geodetic System (1984) WGS84.

The advantages of GPS for efficient positioning has prompted many authorities to adopt a geocentric co-ordinate system or to utilise this powerful positioning tool for spatial data capture.

The International Maritime Organisation (IMO), International Civil Aviation Organisation (ICAO), Aviation Australia (formerly CAA) and the Department of Defence have already adopted a geocentric co-ordinate system.

In 1990, the International Federation of Surveyors recommended that its members promote and support the adoption of a global geocentric reference system proposed by the International Association of Geodesy.

Why a Geocentric Datum ?

The adoption of a geocentric datum allows for a single standard for the collection, storage and use of geographic data. This will ensure compatibility across various geographic information systems at the local, regional, national and global level.

A geocentric datum for Australia will facilitate the building of an integrated national geographic data infrastructure and enable the production of an homogeneous series of Australian maps and nautical charts which will meet international navigation requirements.

The number of users of digital geographic data requiring national coverage is increasing. A couple of recent examples include the Australian Bureau of Statistics which will use digital geographic data for socio-economic analysis in the 1996 Census and a major communication carrier which is likely to use digital data for national market research and infrastructure planning.

What System will be adopted ?

A geocentric datum is a reference system that has as its origin the Earth's centre of mass, which is directly related to the orbits of GPS satellites.

New terminology and acronyms have been introduced to accompany the geocentric datum and its associated defining parameters.

The Geocentric Datum of Australia (GDA) will form the new earth-centred Australian co-ordinate datum that will replace the Australian Geodetic Datum (AGD). The GDA will be based upon the GRS80 ellipsoid, determined within the International Earth Rotation Service Terrestrial Reference Frame 1992 (ITRF92) at the epoch of 1994.0, and realised by the co-ordinates of the Australian Fiducial Network (AFN) Geodetic Stations. The spheroid is a mathematical reference surface that best fits the earth's shape, whereas the datum is the adopted co-ordinate set based on the spheroid.

The ITRF is within one metre of WGS84 (GPS reference system) which means that for mapping, navigation or digital database purposes requiring positional accuracies of no greater than 1 metre, GDA will be directly compatible with GPS co-ordinate values.

How will this System be implemented ?

ICSM has recommended that Australia adopt a geocentric datum by the year 2000, however this move will be progressive from 1994. Existing datums and co-ordinate

systems will be supported by ICSM jurisdictions during the transition period until the GDA is fully implemented. Only the horizontal co-ordinates will be geocentric, the Australian Height Datum (AHD) will remain unchanged.

The most noticeable change will be a shift, or displacement of approximately 200 metres across Australia in a north-east direction between co-ordinates of points on the existing Australian Geodetic Datum (AGD) compared with co-ordinates of the same points on the Geocentric Datum of Australia (GDA).

The GDA will be implemented through a "top-down" approach.

The Australian Fiducial Network (AFN), a continent-wide network of eight geologically stable marks (Hobart, Tidbinbilla, Townsville, Ceduna, Alice Springs, Darwin, Karratha and Yarragadee near Perth) was observed with GPS in 1992 as part of the International Geodesy and Geophysics Service (IGS). Global (ITRS) co-ordinates for these stations have been computed, with absolute accuracies in the order of 4-6 centimetres.

Arrangements are underway for Mulley Geodetic Station in Bathurst, which is occupied by a permanent GPS Basestation, to be included in the Australian Fiducial Network to add additional strength to the network.

The Australian National Network (ANN) is a sub-network of the AFN, comprising 70 stations at a nominal 500km spacing over the continent. This network is constrained by the AFN and has an accuracy of 0.1 parts per million. (See Figure 1)

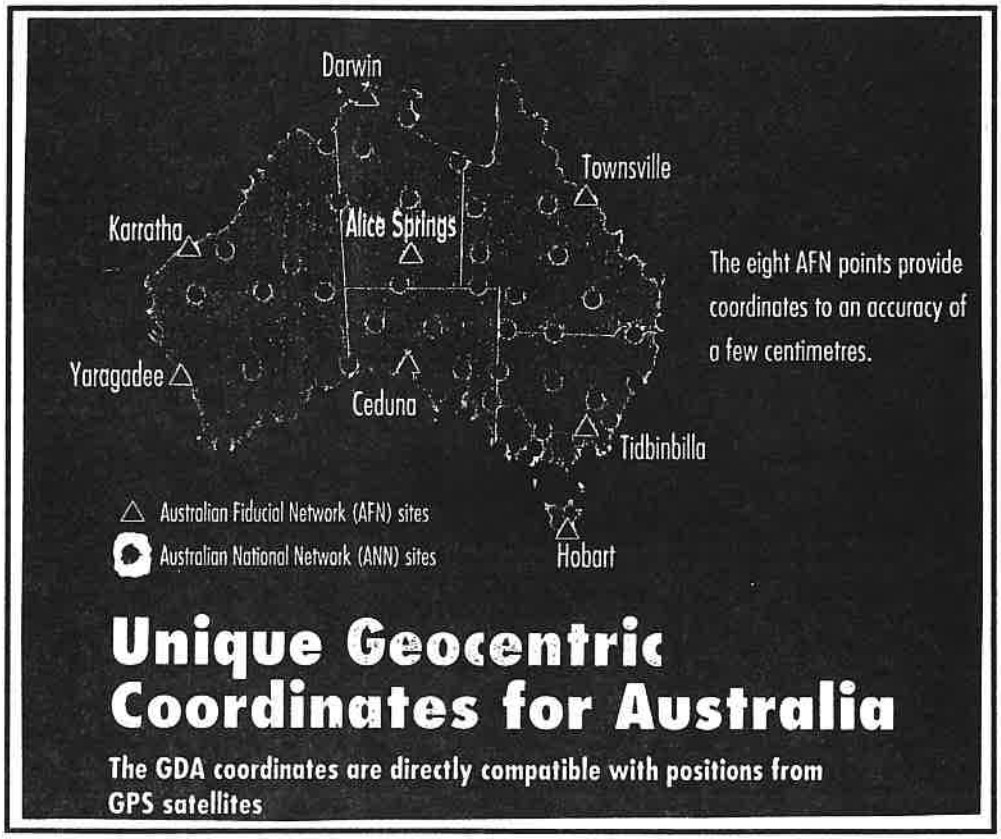

Figure 1

State GPS and conventional networks of geodetic stations will be readjusted using the ANN and AFN stations as constraints to an estimated accuracy of between 1 and 7 parts per million. This readjustment process will remove distortions of up to 1-2 metres, which will dramatically improve the accuracy and confidence in the geodetic network.

The introduction of new co-ordinates will be made progressively over a number of years. There will be a period of overlap with both AGD and geocentric co-ordinates in use. Following the major readjustment mentioned above, transformation parameters will be available to convert between AGD and the new geocentric co-ordinates.

Implications for Users

During the transition to the new datum there may be some confusion about the co-ordinates caused by the datum to which they refer. However a 200 metre co-ordinate change is quite noticeable and should avoid most confusion between co-ordinate sets.

Geographic Information Systems

Geographic Information Systems (GIS) which use co-ordinates for geo-referencing will be affected and will need to take into account.

- The datum used when importing or integrating spatial data during the transition period.
- GIS's generally contain large sets of geo-referenced data which must be transformed so that spatial relationships are preserved.
- Attributes with AGD co-ordinates will need to be transformed to the new geocentric datum. The Land Information Centre will assist with the provision of transformation parameters and advice to assist co-ordinate users during the changeover period.

Cadastre

There are two aspects to the impact of the new datum. Firstly the impact on the Digital Cadastral Data Base (DCDB). This graphical representation of the legal cadastre is currently in digital form and is based on the existing AGD66 datum.

To convert this data set to the new datum requires the availability of transformation parameters and appropriate software which could systematically convert the data set or convert on demand. This is not seen as a significant problem at this stage given the current rate of improvement in spatial data management.

Probably of greater significance is the impact on cadastral surveying. At the moment NSW has adopted a 2° known as the Integrated Survey Grid for all survey purposes. The opportunity exists to move to a new 6° grid to be adopted nationally with the new datum and known as the Map Grid of Australia (MGA).

There are a number of proponents for this change, however there has to be proper debate of the benefits of moving to this approach. One identified benefit is seen as a

significant shift in the numerical values which will clearly label coordinates in the new system. Another identified benefit is the reduction in the number of Zone boundary problems. How often have users become confused about the correct Zone coordinates to use when operating near a Zone boundary e.g. Port Stephens, Rylstone, Forbes.

Mining

The mining industry is a significant user of coordinates for their construction and mining activities. Coal mining is currently required by statute to use the ISG.

This industry will also need to be assisted with the change of a new datum. It is envisaged that an Advisory Council with key stakeholder representatives from mining, surveying, utilities, land titles, education, GIS software/hardware vendors will be established to ensure a smooth changeover.

Utilities

The utility industry is already a significant user of digital spatial data. Their main concern is the maintenance of the integrity of relative spatial relationships, i.e. how far between the pipe and the kerb.

A "block shift" transformation process for their spatial data either systematic or on demand should not be a significant problem, however this needs to be carefully managed, particularly in terms of providing a "change toolkit".

Paper Maps

Another area affected by the shift is mapping. Although the move will allow realisation of an homogeneous map series, its immediate implication is that the GDA map base differs from the current AGD66 or AGD84 map base by 215m (average vector in NSW).

This means that the GDA based map will cover a rectangular ground area which is slightly to the west and to the south of the same sized ground rectangle covered by an AGD based map.

The implications and the proposed approach for various products are as follows:

- **Existing Map Stock**

The only option available is to attach a sticker to the map advising users how to convert co-ordinates and heights scaled from an AGD map to the Geocentric system and vice versa.

- **Reprints of Existing Maps**

For any reprints of existing maps based on either the current AGD or new GDA map sheet border lines the following steps are proposed.

- a full or partial grid of the new or old system, as appropriate, will be added.

- information advising users how to convert co-ordinates and heights from one system to another will be provided.
- overlap information along the edges to cover gaps will be provided subject to technical and financial viability of traditional edge matching techniques.

It is considered that once the appropriate Digital Topographic Data Bases are completed, it will be a simple task to produce both paper as well as digital maps based on a new GDA94 standard, together with the full or partial overlay of the current (AGD) grid, appropriate advice, overlays, geoid information and so on.

Progress to date

On the 20 October 1995, a notice appeared in the NSW Government Gazette proclaiming the introduction of the Geocentric Datum of Australia (GDA) and its progressive implementation Australia wide by 1 January 2000.

The proclamation gives details of the new Reference Ellipsoid and values for the Australian Fiducial Network as well as the co-ordinates of the Australia National Network (ANN) geodetic stations which realise the new datum.

Work is currently underway towards finalizing the supply of observational data (terrestrial and GPS) for the national readjustment of the state's geodetic network comprising about 3500 stations. This National readjustment is being undertaken by Dr John Allman under contract to ICSM.

By the middle of March 1996, terrestrial observations consisting of:

- 27356 directions
- 5667 distances
- 229 azimuths
- 3074 stations

had been validated, integrated with the GMA82 data set (the national data set used for AGD84, but not adopted in NSW, Victoria, or Tasmania) and supplied to AUSLIG.

GPS baselines measured by the Land Information Centre and other public authorities since 1987 have been loaded into a newly developed system known as the Geodetic Observation Management System (GOMS). 2500 baselines have been loaded, validated, and forwarded to AUSLIG for inclusion in the readjustment. This data set includes the GPS High Precision (or AAA Network) which will provide the strength for the readjustment and will complement the terrestrial observations. (See Figure 2)

The total number of geodetic observations in NSW to be included in the National readjustment is most likely equal to all of the other states combined.

Following the completion of the readjustment of the geodetic network, expected in mid-late 1996, Permanent Mark networks will need to be progressively transformed/readjusted onto the new datum prior to 1 January 2000.

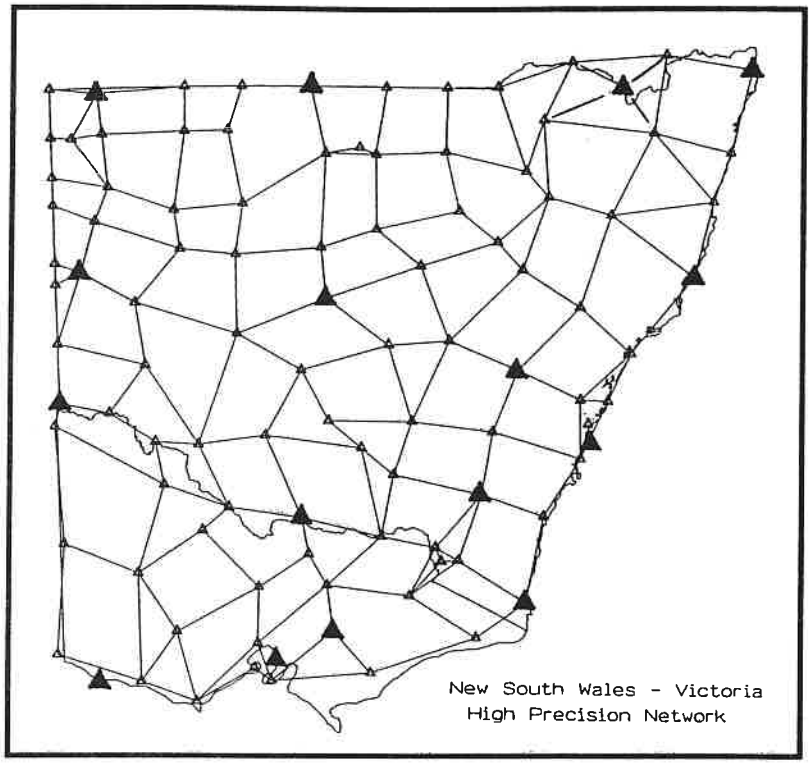

Figure 2

Benefits

Essentially the adoption of a new geocentric datum will simplify all future mapping, surveying and navigation tasks through the following expected benefits.

The new geocentric datum will:

- Ensure an homogeneous, seamless, GPS compatible datum for all users.
- Be compatible with GPS and other similar positioning systems - no transformation will be required.
- Not suffer from boundary - related discontinuities.
- Not contain distortions which exist at the 1m level in parts of the existing AGD66 state geodetic network.

It is anticipated that well before the turn of the century, all Australian geographical co-ordinates will be on a geocentric datum as opposed to the current AGD66 and AGD84 existing datums.

The major issue facing users will be knowing which datum is being used for spatial data capture.

The Land Information Centre will provide support for this change process to ensure users can achieve maximum benefit with minimal problems.

References

Featherstone, W E (1994) "An Explanation of the Geocentric Datum of Australia and its effects upon future mapping", *Cartography,* Volume 23, No. 2, December 1994.

Kinlyside, D A (1994) "The Geocentric Datum of Australia - Transform or Readjust" ?, Proceedings from the 1994 Fig. Congress, Melbourne Australia.

ICSM (1994) "A New Era for Australia" Brochure prepared on the change to a Geocentric Datum.

NSW Department of Lands (1976) "Manual of the New South Wales Integrated Survey Grid".

Attachment A

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NEW GEODETIC DATUM FOR AUSTRALIA

THE meeting of the Inter-Governmental Committee on Surveying and Mapping held in Canberra on 28–29 November 1994, adopted the following new geodetic datum for Australia and recommended its progressive implementation Australia-wide by 1 January 2000.

Designation: The Geocentric Datum of Australia (GDA).

Reference Ellipsoid: Geodetic Reference System 1980 (GRS80) ellipsoid with a semi-major axis (a) of 6 378 137 metres exactly and an inverse flattening (1/f) of 298.257 222 101.

Reference Frame: The GDA is realised by the co-ordinates of the following Australian Fiducial Network (AFN) geodetic stations referred to the GRS80 ellipsoid determined within the International Earth Rotation Service Terrestrial Reference Frame 1992 (ITRF92) at the epoch of 1994.0:

		South Latitude	East Longitude	Ellipsoidal Height
AU 012	Alice Springs	23° 40' 12.44592"	133° 53' 07.84757"	603.358 metres
AU 013	Karratha	20° 58' 53.17004"	117° 05' 49.87255"	109.246 metres
AU 014	Darwin	12° 50' 37.35839"	131° 07' 57.84838"	125.197 metres
AU 015	Townsville	19° 20' 50.42839"	146° 46' 30.79057"	587.077 metres
AU 016	Hobart	42° 48' 16.98506"	147° 26' 19.43548"	41.126 metres
AU 017	Tidbinbilla	35° 23' 57.15627"	148° 58' 47.98425"	665.440 metres
AU 019	Ceduna	31° 52' 00.01664"	133° 48' 35.37527"	144.802 metres
AU 029	Yaragadee	29° 02' 47.61687"	115° 20' 49.10049"	241.291 metres

The new datum was proclaimed in the Commonwealth Gazette No. GN 35 of 6 September 1995.

NEW SOUTH WALES

Within N.S.W., GDA94 is realised by the co-ordinates of the above AFN stations as well as by the co-ordinates of the following Australian National Network (ANN) geodetic stations:

Number	Name	South Latitude	East Longitude	Ellipsoidal Height
7329	Barringun Zero	28° 59' 56.69551"	145° 40' 07.63275"	171.774 metres
5933	Brunswick	28° 31' 29.59007"	153° 32' 17.30597"	135.627 metres
6924	Bullanginya	35° 47' 51.10212"	145° 33' 13.55344"	171.743 metres
5821	Crowdy	31° 50' 36.58469"	152° 45' 12.34357"	84.270 metres
6613	Eden	37° 04' 27.40104"	149° 54' 28.50180"	17.326 metres
7374	Flag	34° 27' 57.57857"	150° 51' 05.54610"	75.172 metres
2191	Gilgunnia	32° 21' 35.60370"	145° 59' 27.58343"	544.369 metres
7235	Lake Littra	33° 55' 45.90840	141° 00' 09.90541"	34.484 metres
5517	Mulley	33° 25' 46.83164"	149° 34' 01.46525"	756.615 metres
3618	Olive	29° 05' 16.66830"	141° 49' 02.71231"	323.838 metres
4224	Sundown	31° 53' 57.29431"	141° 26' 59.62844"	408.792 metres
5196	Texas	28° 51' 19.53613"	151° 12' 38.61303"	537.089 metres

The existing Australian Geodetic Datum 1966 (AGD66), realised by the co-ordinates of the Johnston Geodetic Station and the national geodetic adjustment 1966 (referred to the Australian National Spheroid), will be maintained in parallel with the GDA94 until its full implementation on 1 January 2000.

D. M. GRANT, A.M.
Surveyor General of New South Wales.