COMMONWEALTH OF AUSTRALIA

By Clifford J. Mugnier, C.P., C.M.S.

Originally populated by aborigines who probably came from Asia about 40,000 years ago, Australia was first sighted by the Spanish in the early 17th century. In 1606, the Dutch landed on the eastern coast of the Bay of Carpentaria and named it New Holland. The eastern part was claimed by Capt. James Cook in 1770, and named New South Wales. The first English settlement at Port Jackson was mainly populated by convicts and seamen in 1788.

Capt. Matthew Flinders circumnavigated Australia from 1801-1803 and exhibited a level of professionalism not previously seen in the hydrographic charting expeditions of others in the British Admiralty, such as Vancouver. Capt. Flinders received his initial instruction in navigation and chart making as well as tongue-lashings by Capt. William Bligh of the Bounty during the successful breadfruit voyage from Tahiti to the Caribbean. It was on that early voyage that Capt. Flinders was in charge of the navigation chronometers. (*The Admiralty Chart* by RADM G. S. Ritchie, 1995.)

Capt. Flinders proved the continental unity of New Holland and New South Wales. Named Australia in the 19th century, the entire continent was claimed by the United Kingdom (*PE&RS*, October 2003) in 1829. The continent of Australia is slightly smaller than the United States; the lowest point is Lake Eyre (–15 m), and the highest point is Mount Kosciusko (2,229 m). The *CIA Factbook* describes the country as mostly low plateau with deserts; fertile plain in southeast and having a generally arid to semiarid climate that is temperate in the south and east; tropical in the north. A further note points out that Australia is the "world's smallest continent but sixth-largest country; population concentrated along the eastern and southeastern coasts; regular, tropical, invigorating, sea breeze known as 'the Doctor' occurs along the west coast in the summer."

The first astronomical "fix" or precise position determination along the coast of southern Australia was by Capt. Flinders in 1801 when he wrote: "The latitude of our tents at the head of Port Lincoln, from the mean of four meridian observations of the Sun taken from an artificial horizon was 34° 48' 25" S. The longitude from thirty sets of distances of the sun *(sic)* and stars from the moon was 135° 44' 51" E. – (Ritchie, 1995). The enormous size of the country and the fact that this continent is surrounded by water has resulted in many local datums being established in coastal areas and little early geodetic work in the vast interior. Among those lesser datums known to exist on the Clarke 1858 ellipsoid are: Adelaide Observatory, Astro Fixation Western Australia 21, Army OP LA22 Lacrosse Island, Valentine, Australian Pillar, Central Origin 1963, Cookes Pillar Broome, Townsville, Emery Point Lighthouse, Final Sidney 1941, Gladstone Observatory Spot, Old Sidney, Maurice 1962, Melbourne Observatory, Weipa Mission Astro, Mildura Aerodrome, Mt. Rapid Fleurien Peninsula, Plantation Point Jervis Bay, Point Langdon South Base, Groote Eylandt, Port Huon Hospital Bay Observation Spot, New South Wales, New Sidney, and Mount Campbell.

Prior to the Australian Geodetic Datum of 1966, the Clarke 1858 ellipsoid as used in Tasmania was a = 6,378,293.645 meters and $1/f$ = 294.26 and in Australia proper was a = 6,378,339.78 meters and $1/f$ = 294.26. The difference between the two was the Clarke foot = 0.3047972654 meters *versus* the British foot of 1926 = 0.30479947 meters. Of the earlier more important datum origins, there were: Sydney Observatory where: Φ_o = 33° 51' 41.10" S and Λ_o = 151° 12' 17.85" E, Perth Observatory 1899 where: Φ_o = 31° 57' 09.63" S and Λ_o = 115° 50' 26.10" E, Darwin Origin Pillar where: Φ_o = 12° 28' 08.452" S and Λ_o = 130° 50' 19.802" E, and Lochmaben Astro Station in Tasmania where: Φ_o = 41° 38' 23.389" S and Λ_o = 147° 17' 49.725" E. The astronomic longitudes differed from geodetic longitudes on either the Sidney or Perth origins on an average of 10", which indicated the magnitude of the deflections of the vertical.

During the 1930s, the Australia Belts were devised on the Transverse Mercator projection. Referenced to the Clarke 1858 ellipsoid, and an ersatz military datum, the scale factor was equal to unity; the belts were numbered from 1 to 8 and were 5° wide, starting with a central meridian at 116° and continuing east. Each belt had a false Easting at the central meridian of 400,000 yards, and the False Northing origin was 800,000 yards at 34° S. A caveat published by the U.S. Lake Survey, New York Office in 1944 cautioned: "If these false coordinates are used, negative values will result in Tasmania." The Clarke foot was implemented for this grid. A test point was published where: φ = 39° 31' 12.767" S, λ = 143° 27' 46.321" E, X = 631,629.24 yds, Y = 126,892.94 yds.

The least squares adjustment of the Australian geodetic network performed in March 1966 used the Australian Geodetic Datum. This adjustment produced a set of coordinates which, in the form of latitudes and longitudes, was known as the Australian Geodetic Datum 1966 coordinate set (AGD66). The grid coordinates derived from a Universal Transverse Mercator projection of the AGD66 coordinates, used the Australian National Spheroid, and was known as the Australian Map Grid 1966 coordinate set (AMG66). New South Wales instituted the Integrated Survey Grid (ISG) where the projection was the Transverse Mercator truncated to the cubic terms since the belts were only 2° wide with a ¼ ° overlap. The scale factor at origin, m_o = 0.99994, the False Easting (FE) = 300 km and the False Northing (FN) = 5,000 km at the equator. The central meridians λ_o = 141°, 141°, etc. to 153° E.

Thanks to Geomatics Australia, "While much early mapping was based on these origins, some 1:250,000 maps were based only on astronomical observations with an accuracy of the order of 100 metres or more, or by a mixture of astro and conventional surveying. A comparison of coordinates based on different origins of this kind will include differences due to the uncertainty of the astronomical observation as well as the deflections of the vertical and could show differences of several hundreds of metres.

For a short period in 1962, geodetic computations were performed on the so-called 'NASA' spheroid with an origin at Maurice as below; but these computations were completely superseded." a = 6,378,148 m, $1/f$ = 298.3. "From the end of 1962 until April 1965, the computation and adjustment of the Australian Geodetic Survey was done on the '165' spheroid: a = 6,378,165 m, $1/f$ = 298.3. Prior to April 1963, the 'Maurice' origin used with the NASA spheroid was retained. As

a result of these computations, new origin values were determined and from April 1963 to April 1965, computations were made on the 165 spheroid and this new 'Central' origin. Computations still emanated from Maurice whose various coordinates were: 165 Central: S 32° 51' 13.979", E 138° 30' 34.062", 165 Maurice: S 32° 51' 13.000", E 138° 30' 34.000", Clarke 1858, Sydney: S 32° 51' 11.482", E 138° 30' 42.29", and Astronomic: S 32° 51' 11.341", E 138° 30' 25.110". The Central origin was based on the best mean fit to 155 Laplace stations spread over the whole of Australia with the exception of Cape York and Tasmania. The residual mean deflection was less than 0.1" in both latitude and longitude whether isostatic topographic corrections were applied to the astronomic values or not. It was therefore considered unlikely that there was a significant artificial component in N with the Central origin. As no observed values of N from geoid surveys existed, it was assumed that N is everywhere zero. *("N" here refers to the separation between the geoid and the ellipsoid – Ed.)*

"In April 1965, it was changed to the spheroid adopted by the International Astronomical Union and this spheroid was called the Australian National Spheroid: a = 6,378,160 m, and $1/f$ = 298.25. In May 1965 a complete recomputation of the geodetic surveys of Australia was begun, emanating from the trigonometrical station Grundy, whose coordinates on both the 165, Central datum and the Australian National Spheroid, Central origin were: S 25° 54' 11.078", E 134° 32' 46.457. By December 1965, the total number of Laplace stations in Australia was 533. From these, 275 stations were selected ... no corrections for the topography were applied ... and it was found that random undulations in the geoid make it impossible to locate a centre for the spheroid with a standard error of less than 0.5 seconds, about 15 metres, even with a very large number of stations.

"The Central origin was therefore retained, but is now defined in terms of the Johnston memorial cairn. The Central origin was originally defined in terms of the trigonometrical station Grundy. The spheroid is oriented by defining the minor axis to be parallel to the earth's mean axis of rotation at the start of 1962 and defining the origin of geodetic longitude to be 149 00'18.855" west of the vertical through the photographic zenith tube at Mt. Stromlo. The size, shape, position and orientation of the spheroid are thus completely defined, and together define the Australian Geodetic Datum: Johnston S 25° 56' 54.5515", E 133° 12' 30.0771", h = 571.2 metres ellipsoid height."

"The Geocentric Datum of Australia 1994 (GDA94) is the new Australian coordinate system, replacing the Australian Geodetic Datum (AGD). GDA is part of a global coordinate reference frame and is directly compatible with the Global Positioning System (GPS). It is the culmination of more than a decade of anticipation and work by the Intergovernmental Committee on Surveying and Mapping (ICSM) and its predecessor, the National Mapping Council (NMC). When the NMC adopted the AGD84 coordinate set in 1984, it '*recognised the need for Australia to eventually adopt a geocentric datum.*' This was further recognised in 1988 when ICSM '*recommended the adoption of an appropriate geocentric datum by 1 January 2000.*'

The state of Western Australia has the "Project Grids" that closely correspond to what we use in the United States as State Plane Coordinates. The new Project Grids for the GDA94 Datum as well as for the previous datum for each are used for the following regional areas: Albany GDA94 – λ_o = 117° 53' 00", m_o = 1.00000440, FE = 50 km, FN = 4,000 km, and for Albany AGD84 – λ_o = 117° 55' 00", m_o = 1.000012, FE = 50 km, FN = 4,000 km; for Broome GDA94 – λ_o = 122° 20' 00", m_o = 1.00000298, FE = 50 km, FN = 2,200 km, and for Broome AGD84 – λ_o = 122° 20' 00", m_o = 1.000003, FE = 50 km, FN = 2,200 km; Busselton GDA94 – λ_o = 115° 26' 00", m_o = 0.99999592, FE = 50 km, FN = 3,900 km, and for Busselton AGD84 – λ_o = 115° 26' 00", m_o = 1.000007, FE = 50 km, FN = 3,900 km; for Carnarvon GDA94 – λ_o = 113° 40' 00", m_o = 0.99999796, FE = 50 km, FN = 2,950 km, and for Carnarvon AGD84 – λ_o = 113° 40' 00", m_o = 1.000005, FE = 50 km, FN = 3,050 km; for Christmas Island GDA94 – λ_o = 105° 37' 30", m_o = 1.00002514, FE = 50 km, FN = 1,300 km, and for Christmas Island WGS84 – λ_o = 105° 37' 30", m_o = 1.000024, FE = 50 km, FN = 1,300; for the Cocos (Keeling) Islands AGD94 – λ_o = 96° 52' 30", m_o = 0.99999387, FE = 50 km, FN = 1,500 km, and for the Cocos (Keeling) Islands WGS84 – λ_o = 96° 52' 30", m_o = 1.0, FE = 50 km, FN = 1,400 km; for Collie GDA94 – λ_o = 115° 56' 00", m_o = 1.0000190, FE = 40 km, FN = 4,000 km; for Esperance GDA94 – λ_o = 121° 53' 00", m_o = 1.00000550, FE = 50 km, FN = 3,950 km, and for Esperance AGD84 – λ_o = 121° 53' 00", m_o = 1.000012, FE = 50 km, FN = 3,950 km; for Exmouth GDA94 – λ_o = 114° 04' 00", m_o = 1.00000236, FE = 50 km, FN = 2,650 km, and for Exmouth AGD84 – λ_o = 114° 04' 00", m_o = 1.000009, FE = 50 km, FN = 2,750 km; for Geraldton GDA94 – λ_o = 114° 35' 00", m_o = 1.00000628, FE = 50 km, FN = 3,350 km, and for Geraldton AGD84 – λ_o = 114° 40' 00, m_o = 1.000016, FE = 50 km, FN = 3,350 km; for Goldfields GDA94 – λ_o = 121° 30' 00", m_o = 1.00004949, FE = 60 km, FN = 3,700 km, and for Goldfields AGD84 – λ_o = 121° 27' 00", m_o = 1.000057, FE = 60 km, FN = 4,000 km; for Jurien GDA94 – λ_o = 114° 59' 00", m_o = 1.00000314, FE = 50 km, FN = 3,550 km, and for Jurien AGD84 – λ_o = 114° 59' 00", m_o = 1.000010, FE = 50 km, FN = 3,550 km; for Karratha GDA94 – λ_o = 116° 56' 00", m_o = 0.99999890, FE = 50 km, FN = 2,450 km, and for Karratha AGD84 – λ_o = 116° 56' 00", m_o = 1.000004, FE = 50 km, FN = 2,450 km; for Kununurra GDA94 – λ_o = 128° 45' 00, m_o = 1.00001650, FE = 50 km, FN = 2,000 km, and for Kununurra AGD84 – λ_o = 128° 45' 00", m_o = 1.000014, FE = 50 km, FN = 2,000 km; for Lancelin GDA94 – λ_o = 115° 22' 00", m_o = 1.00000157, FE = 50 km, FN = 3,650 km, and for Lancelin AGD84 – λ_o = 115° 22' 00", m_o = 1.00000157, FE = 50 km, FN = 3,650 km; for Margaret River GDA94 – λ_o = 115° 10' 00", m_o = 1.00000550, FE = 50 km, FN = 3,950, and for Margaret River AGD84 – λ_o = 115° 06' 00", m_o = 1.000014, FE = 50 km, FN = 4,050 km; for Perth GDA94 – λ_o = 115° 49' 00", m_o = 0.99999906, FE = 50 km, FN = 3,800 km, and for Perth AGD84 – λ_o = 115° 50' 00", m_o = 1.000006, FE = 40 km, FN = 3,800 km; for Port Hedland GDA94 – λ_o = 118° 36' 00", m_o = 1.00000135, FE = 50 km, FN = 2,400 km, and for Port Hedland AGD84 – λ_o = 118° 35' 00", m_o = 1.000004, FE = 50 km, FN = 2,400 km.

Datum shifts between the various classical datums and the various scientific reference frames of the GPS satellites are available for cartographic-accuracy transformations. However, for precise geo-

continued on page 1319

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continued from page 1317

detic applications, the parameters change monthly because the entire continent is moving to the Northeast at about 3 centimeters per year! For instance, a couple of cartographic transform accuracy parameter sets are given as follows: From Australian Geodetic Datum 1966 (Victoria/New South Wales) to WGS84: $\Delta X = -119.353$ m, $\Delta Y = -48.301$ m, $\Delta Z = +139.484$ m, $R_x = -7.243 \times 10^{-3}$ radians, $R_y = -4.538 \times 10^{-3}$ radians, $R_z = -7.627 \times 10^{-3}$ radians, and $\Delta s = -6.13 \times 10^{-1}$. From Australian Geodetic Datum 1984 to WGS84: $\Delta X = -117.763$ m, $\Delta Y = -51.51$ m, $\Delta Z = +139.061$ m, $R_x = -5.096 \times 10^{-3}$ radians, $R_y = -7.732 \times 10^{-3}$ radians, $R_z = -4.835 \times 10^{-3}$ radians, and $\Delta s = -1.91 \times 10^{-1}$. Australia is a free and open society. Their geodesy is not a secret and their history, their coordinates, and their datum transformations are an open book – a very large open book, but definitely open. Thanks go to Malcolm A. B. Jones, "Geodesy Jones," of Perth for the enormous accumulation of Australian historical geodetic documents he has sent to me over the years.

Cliff Mugnier teaches Surveying, Geodesy, and Photogrammetry at Louisiana State University. He is the Chief of Geodesy at LSU's Center for GeoInformatics (Dept. of Civil and Environmental Engineering), and his geodetic research is mainly in the subsidence of Louisiana and in Grids and Datums of the world. He is a Board-certified Photogrammetrist and Mapping Scientist (GIS/LIS), and he has extensive experience in the practice of Forensic Photogrammetry.