

# GEODESY IN AUSTRALIA, 1956-1972

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## 1. INTRODUCTION

In recent years Australia has become well-known in the surveying world for its modern geodetic surveys.

It is indeed a rare, once in a lifetime, opportunity for surveyors, in a country the size of Australia, to take part in geodetic surveys, concentrated over a period of 15 years, which lead to the determination of a homogeneous horizontal datum, of a nation-wide height datum and of the geoid in that country. This is what happened in Australia between 1956 and 1971.

Geodetic surveys in Australia on a nation-wide scale started relatively late. However, Australian surveyors were able to make use of some important innovations which became available in Australia in 1956, namely the introduction of the Tellurometer, of automatic levelling instruments, of electronic computers as well as the availability of commercial helicopters.

It has been an exciting period guided by the National Mapping Council of Australia, chaired by the Director of National Mapping. Many Survey Authorities in Australia have contributed to the successful completion of these surveys as have a great number of private surveyors, who were engaged in levelling and astronomic surveys financed by the Commonwealth of Australia.

## 2. A DEFINITION OF GEODESY AND GEODETIC SURVEYING

Geodesy and geodetic surveying deal with the art of determining the size and the shape of the earth, and of measuring the earth's surface or large portions of it as distinguished from plane surveying which deals only with limited tracts. Geodetic surveys take into consideration the earth's gravity field.

In a geodetic survey three different reference surfaces are used in order to determine positions on the earth. The first one is the **actual surface of the earth** which is highly irregular, consisting of many topographic landforms such as plains, mountains and valleys. It is the surface on which geodetic measurements are made.

In the first instance these measurements are reduced to the **geoid** which coincides with the smooth but undulated surface to which mean sea level of the earth would adjust if the oceans were free from disturbing forces and would extend through the continents.

The geoid is a surface on which gravity is the same everywhere. This is called an equipotential surface. It is everywhere normal to the gravity vector. Due to the complex distribution of material in the earth's crust and the irregular masses of different densities below the earth's surface, the gravitational force varies from place to place in amount and direction.

The forces that deflect the gravity vector act on sea level as well, causing it to display a warped surface. The slopes of the geoid, though relatively small, are quite troublesome, since the gravity vector is always perpendicular to the geoid and surveying instruments, when properly levelled, will have their vertical axis coinciding with the gravity vector.

Because the geoid is very hard to define mathematically and is an irregularly shaped surface, geodetic measurements are further reduced to a **spheroid** also called ellipsoid which is a geometrical figure which best fits the geoid or portion of it.

A spheroid is a figure obtained by rotating an ellipse around its minor axis. It is defined by two numbers, the length of the semi-major axis also called "a" radius and the flattening  $f = \frac{a - b}{a}$  usually in terms of

its reciprocal  $1/f$ .

Any spheroid which has a regular mathematical surface, does not coincide with the geoid. The separations of the two surfaces are expressed as geoid heights, that means the height of the geoid above the spheroid which is a positive quantity or below it a negative quantity. There is no way of measuring the geoid heights directly but it can be computed from a comparison of

geodetic and astronomic positions as well as from observed gravity.

The selection of a particular spheroid together with the unique placement of it relative to the earth constitutes a Horizontal Geodetic Datum.

## 3. HORIZONTAL CONTROL

Early trigonometrical surveys in Australia started in New South Wales in 1828 and later on in other States extending over the more populated areas only. Most of these surveys were not connected to each other. During the period 1930-1945 the Royal Australian Survey Corps concentrated on the co-ordination of existing triangulation in Victoria and New South Wales and ran a triangulation survey from Port Augusta in South Australia through Victoria and New South Wales into Queensland. Before World War II the Survey Corps, in conjunction with the University of Adelaide, developed a new method involving special electrical resistance measuring equipment to determine temperature correction when standardising baseline tapes in the field (Hurren 1959). By the end of World War II, only a small part of Australia was covered with horizontal control surveys of presently acceptable standard. In 1945 the National Mapping Council of Australia was formed and adopted a basic scheme of a National Geodetic Survey. Traditional methods of triangulation were still used and progress was slow.

The Division of National Mapping acquired a Model 2 Geodimeter in 1954 and subsequently a number of baselines were measured with it in all States, except the Northern Territory, between 1954 and 1957. This constituted the first speed up of geodetic surveys in Australia based on electronic distance measuring equipment. With the introduction of more portable electronic distance measuring equipment, mainly the Tellurometer, in 1956, it took only a further ten years to complete a network of geodetic survey over the whole of the Australian continent and Papua New Guinea (Johnson, 1969). At that time the computation of various parts of this survey, old and new, was based on 20 different geodetic datums using four different figures of the earth. In March 1966, the whole survey of 58 loops containing 2,506 firmly marked geodetic stations including 533 astro geodetic stations and over 50,000 kilometres of Tellurometer traverses, was adjusted by program VARYCORD, using the method of least squares by variation of co-ordinates on the spheroid (Bomford, 1967). The Australian Geodetic Survey is particularly strong in azimuth due to the great number of Laplace stations along the traverse network.

## 4. AUSTRALIAN GEODETIC DATUM

This adjustment resulted in the formation of the Australian Geodetic Datum (AGD) which is a homogeneous system of latitudes and longitudes covering the whole of Australia and Papua New Guinea and which is defined as follows:

The Australian National Spheroid:

Size —  $a = 6\,378\,160$  metres

Shape —  $1/f = 298.25$  exactly.

Orientation: the minor axis was originally defined to be parallel to the mean pole of 1962.0 and subsequently changed to the Conventional International Origin without altering any co-ordinates. The plane of zero longitude was defined to be parallel to the vertical through the Bureau International de l'Heure's mean observatory near Greenwich which is  $149^\circ 00' 18.855''$  west of the vertical through the photo zenith tube at Mount Stromlo in the A.C.T.

The position of the centre of the spheroid can be inferred from the co-ordinates of the ground mark of the Origin, the Johnston Geodetic Station in the centre of Australia:

South Latitude:  $25^\circ 56' 54.5515''$

East Longitude:  $133^\circ 12' 30.0771''$

which defines the direction of the normal to the spheroid

through the mark and from the fact that the spheroid surface is 571.2 metres down the normal from the mark. This height, together with the geographical co-ordinates of the Origin, are those mentioned in Commonwealth Gazette 84 of 6 October 1966. In 1971 the Australian Height Datum (AHD) and the geoid in Australia were determined, resulting in a different spheroidal height for the Origin. However, the spheroidal height of 571.2m as distinct from the sum of the AHD value and the geoid-spheroid separation determined in 1971, must remain unchanged to preserve the definition of the Australian Geodetic Datum.

The latitude and longitude of the Origin of the Australian Geodetic Datum, the Johnston Geodetic Station, were determined from a comparison of astronomic and geodetic co-ordinates at 155 survey stations well distributed over the whole of Australia. This had the desired effect of placing the spheroid very close to the geoid in Australia. The value of the separation of the geoid from the spheroid was everywhere assumed to be zero, and all distances in the adjustment were reduced using trig heights based on mean sea level datums.

The computations and adjustment were carried out by the Division of National Mapping. The methods and instruments used in the field suggest that the standard error between adjacent stations of the originally adjusted net is between 3 to 4 parts per million both linearly and laterally. Errors of 10 parts per million should be rare. Closures of the 58 loops suggest that for distances of about 1500 kilometres, the average misclosure has reduced to about 2 parts per million or 3 metres. New surveys are continually being added by adjusting them to points of the original 1966 adjustment. Over 11,000 geodetic stations are by now computed on the Australian Geodetic Datum. Copies of Computer outputs containing adjusted values of stations on the AGD have been distributed to all members of the National Mapping Council. Figure 1 shows the network of geodetic control on the AGD as at 31.12.71.

The average distance between stations contained in the basic adjustment is 30 kilometres and 3 to 4 parts per million of such distances are equivalent to between 9 and 12 centimetres, about the width of a man's hand.

Geodetic survey stations all over Australia, which are based on the Australian Geodetic Datum, are on a homogeneous system of co-ordinates, free from discontinuities caused by changes of origin. Co-ordinates on the Australian Geodetic Datum provide a firm foundation on which lower order surveys and all mapping can be based. Furthermore they provide a basis for a point reference system, on which any point in Australia — for example an oil well, a mineral deposit, a gravity station, a fire watch tower, a light house or any other station — can be described in precise and unambiguous terms.

## 5. AUSTRALIAN MAP GRID

Geodetic co-ordinates are usually computed in latitude and longitude. For many purposes, including mapping, a system of rectangular grid co-ordinates — eastings and northings — is more convenient. A transverse mercator projection has long been used in Australia for this purpose. The opportunity has been taken to change from the old Australian National Grid in yards, based on different datums all using the Clarke 1858 spheroid, to a Transverse Mercator Grid in metres, which uses the same zone numbers as the Universal Transverse Mercator Grid but is based on the Australian Geodetic Datum. This new grid is called the Australian Map Grid abbreviated AMG. At the same time, all distances and heights, previously quoted in yards or feet, have been converted to metres, in accordance with the policy of a gradual change to the metric system.

The Australian Map Grid corresponds with the Universal Transverse Mercator Grid, as follows:

Co-ordinates are in metres.

Zones are 6° wide with ½° overlap on either side.

Australian Map Grid zones are numbered from zone 47 with central meridian 99° E to zone 58 with central meridian 165° E.

The origin of each zone is the intersection of its central meridian with the equator.

A central scale factor K of .9996 is superimposed on all projected distances.

**The Limits of the Australian Map Grid:** Although the Universal Transverse Mercator reference system is of world-wide application, different countries use different spheroids, and it is therefore necessary to define the limits within which the Australian National Spheroid and the Australian Map Grid are to be used. The Australian Map Grid covers Australia and the Territories administered by Australia within the area as described in the National Mapping Council of Australia Special Publication 7, "The Australian Map Grid". The grid does not cover Heard Island and the McDonald Islands, nor the Australian Antarctic Territory, for which the International Spheroid remains in use. Special Publication 7 can be obtained from the Australian Government Publishing Service book centres in Canberra, Sydney, Melbourne and Perth at a cost of \$4.65.

Before 1966 and up to late 1970, mapping in Australia was based on many heterogeneous datums including astrofixes not related to any datum. An analysis of 1:250,000 sheets has been made recently of sixteen sheets well distributed over Australia in order to find out the difference between the Survey control on which these sheets were based, and control based on the AGD. The differences in latitude ranged from -6" to +6" and the differences in longitude from +9" to -8". The decision to base 1:250,000 maps in areas without geodetic control on astrofixes, before AGD based control became available, was made in the expectation that astro fix control would be nearer to the finally accepted geodetic datum than to a number of datums of isolated geodetic or lower order triangulation networks having large, and at the time unknown, deflections of the vertical at their origins.

Based on the AGD, mapping at any large scale covering the whole of Australia, can be started at widely different locations and should match up perfectly when assembled for the whole of the country.

## 6. VERTICAL CONTROL

Many thousands of kilometres of differential levelling to various standards of accuracy and on at least 15 different datums have been carried out in Australia by survey authorities over the years. However, levelling of geodetic standard with permanent marks placed at adequate intervals had a slow start. Before 1956 about 5000 kilometres of geodetic control levelling had been completed in three of the six States of the Commonwealth of Australia. Between 1956 and 1960, an additional 16,000 kilometres were levelled and at the end of 1970 a total of over 150,000 kilometres had been completed to provide a nation-wide coverage.

The completion of this programme was only possible by adopting third order levelling techniques and the letting of contracts for marking and levelling to private surveyors under the supervision of the States Surveyors-General. The Division of National Mapping arranged a total of 232 such contracts worth about \$2 million during the period 1961 to 1970.

As part of Australia's mapping programme the Division of National Mapping, on behalf of the National Mapping Council and with the help of various State and other Authorities, has been organising a programme of tidal readings at 33 tide gauge stations around the coastline of Australia. The aim of this programme was to obtain simultaneous recordings at all stations on a continuous basis for a common period of one year in order to compute mean sea level at these stations pertaining to the same epoch.

The processing and analysing of the tide record charts has been undertaken by the Horace Lamb Centre for Oceanographic Research of the Flinders University in Adelaide. Hourly values were read from the charts to the nearest 0.1 ft and punched on to cards. All records were digitised in terms of Universal Time. There is a card per day for each station with 24 tide readings on the hour.

During the first twelve months of the programme, which started on 1 January 1966, 24 stations supplied their records for digitising. The programme continued for three years in order to get records from as many stations as possible for the same period of 12 months.

National Mapping sent a survey team to visit each tide gauge. The team's job was to calibrate the tide gauge recorder against a standard instrument, to establish additional permanent marks so that there were at least three permanent marks near every tide gauge and

to determine the difference in height between the gauge zero and the permanent marks as well as to take photographs of all important fixtures of the tide station.

**Adjustment of the National Levelling Survey:** The adjustment of selected loops of the continental net took place in May 1971. Observed orthometric differences based on theoretical gravity were used.

The method of adjustment of this continental net was as follows:

The Australian levelling net was split up into five regional nets. Each net contained up to 140 junction points and was adjusted separately. The five separate adjustments were then combined in a continental least squares adjustment involving 497 junction points, holding mean sea level at 30 tide gauges at zero.

Heights of bench marks on traverses between adjusted junction points were subsequently computed by a linear adjustment, as were heights of marks on traverses not included in the least squares adjustment which are joining points with heights fixed by the continental adjustment or by a subsequent linear adjustment.

## 7. AUSTRALIAN HEIGHT DATUM

The Australian Height Datum (AHD) is a homogeneous set of heights above sea level, i.e. above the geoid, covering the whole of Australia, except Tasmania and other islands, for which:

The basic framework was computed on 5 May 1971. Mean Sea Level at 30 tide gauges pertaining to the same epoch was held at zero.

The height of the mark beneath the cairn at Johnston was computed to be 566.30 metres above the geoid.

Existing heights in the metropolitan areas of Perth and Adelaide were deemed to be on the AHD, and were adjusted to the computed values in "buffer zones".

Details are given in the Division of National Mapping's Technical Report 12 (Roelke et al, 1971) and in Special Publication 8 of the National Mapping Council of Australia, "The Australian Height Datum".

Figure 2 shows the sections contributing to the adjustment in black and other sections tied to adjusted values in red called supplementary sections.

Although classified as third order, because wooden staves were used and sighted distances of up to 90 metres were allowed, the work was performed with modern automatic levels, the main part of it between 1961 and 1970. The standard error in height of a bench mark in the centre of Australia near Alice Springs is only 0.3 metres with respect to mean sea level. This is quite adequate for all users of heights.

Copies of the adjusted values of primary sections and supplementary sections were distributed to all members of the National Mapping Council and to the Bureau of Mineral Resources, before Christmas 1971. A unique retrieval system has been designed which should enable any bench mark contained in an adjusted section to be identified.

The Division of National Mapping will be keeping an up-to-date record of new levelling adjusted to the AHD and any changes in recorded bench marks and will be issuing amended records from time to time to the recipients of the results of the Levelling Adjustment. To date 1420 sections containing 45,500 bench marks have been adjusted.

One phenomenon resulting from the Australian Levelling Network is the rise of mean sea level, along the North-East Coast of Australia between Brisbane and Cape York, of 1.5 metres. A number of theories have been put forward to account for this rise along part of a theoretical equipotential surface. The presence of the Barrier Reef, prevailing ocean currents, the temperature and salinity of the water and the shallowness of the water have been considered. None gives a satisfactory explanation.

## 8. ADJUSTMENT OF TRIGONOMETRIC HEIGHTS

Immediately after the completion of the levelling adjustment, trigonometric heights of horizontal control stations were adjusted to the AHD. To date heights of all the stations included in the 1966 adjustment,

which contributed to the establishment of the Australian Geodetic Datum, have been computed in terms of the AHD, as have heights of stations in many supplementary horizontal control sections. It will take about another year to have heights of all horizontal control stations on the Australian mainland of third order and better, expressed in terms of the AHD.

## 9. AGD CO-ORDINATES AND AHD HEIGHTS

During 1972 the Division of National Mapping has replaced the original 1966 VARYCORD computer outputs with a new set which:

Refer to the National Mapping Council in the heading;

Use the words AHD HEIGHT instead of HEIGHT;  
Show AHD heights in place of the 1966 height values;

In all other respects are identical to the 1966 outputs. No co-ordinates were changed except in the Newcastle to ACT precision network which was adjusted in September 1972 using a combination of observations completed before 1966 and modern Geodimeter measurements and astronomic observation.

Distances were not changed to accord with the new heights except in the Newcastle to ACT network.

These outputs, labelled VARYAHD, giving AGD co-ordinates and AHD heights, are envisaged to be the accepted master documents for a long time.

## 10. THE GEOID IN AUSTRALIA

The separation of the geoid above or below a spheroid is denoted by N, positive or negative, measured in metres. Values of N can be determined by astro-geodetic levelling, by gravity or by observations to artificial satellites.

A preliminary geoid for Australia was determined in 1966 by Madame Irene Fisher of the US Army Topographic Service. About 550 astro-geodetic stations on the AGD were available for this determination.

In 1971 a new geoid in relation to the Australian Geodetic Datum was determined (Fryer, 1971). The first stage of this project was the computation of sections of primary geoidal profiles along traverses where the spacing of astro-geodetic stations was generally less than 35km. These sections formed large loops which were broken up by geoidal profiles along traverses where the spacing of astro-geodetic stations was often in excess of 50km. A weighted least squares adjustment provided values of N for 1133 astro-geodetic stations.

Values of N and the deflections of the vertical were computed from gravity data at 51 geodetic stations and at 1679 points on a half degree grid inside the loops formed by the geoidal profiles. The gravimetrically computed values were adjusted, loop by loop, into the system defined by the adjusted values of N at the astro-geodetic stations on the loop perimeter.

All geodetic values used in the 1971 geoid determination were from the 1966 Geodetic Adjustment and should be free of errors greater than 0.1 seconds of arc. The astronomic observations have been performed in the period 1950 to 1970. Since 1963, 917 stations have been observed with DKM3A theodolites. A single batch of computer programs, combined into one program known as ASTRO in 1967, have been used to reduce all observations. A homogeneity exists throughout the astronomic and geodetic information on the AGD and this has added greatly to the certainty of the results.

The results of the Geoid adjustment were used to plot a geoid contour map of Australia based on the Australian Geodetic Datum, see Figure 3. The range of the geoidal heights is about 18 metres from -6m at the Johnston Geodetic Station to +12 metres at the coast of this continent.

Diagrams showing contours of the components of the deflection of the vertical have also been plotted as well as a diagram showing the deviation of the plumb line. Deviations of up to 20" occur in Australia.

## 11. SATELLITE GEODESY

During the last decade, Commonwealth surveyors from the Division of National Mapping, the Department of the Interior and the Royal Australian Survey Corps have become increasingly involved with satellite geodesy. The field work included the survey of two long baselines in Australia between satellite camera stations for the worldwide Pageos Satellite Triangulation (Leppert, 1972), the geodetic connections to 51 satellite tracking facilities at 24 tracking sites and the assistance given to Pageos, Tranet and Secor Satellite observation teams.

One satellite baseline between Perth and Narrabri in NSW is 3200 kilometres; the other one between Thursday Island and Narrabri is 2300 kilometres. The two baselines follow traverses and triangulation which are part of the 1966 adjustment. The Division of National Mapping re-measured all distances along the two traverses connecting the base terminals mainly with MRA4 Tellurometers and partly with Model 8 Laser Geodimeters. It observed astronomic azimuths simultaneously from both ends of a line on two nights along every line in pure traverse and every second line in triangulation. Almost every station along the two baseline traverses is an astro-geodetic station of which 145 have been observed by private surveyors for the Division of National Mapping which trained them in geodetic astronomy methods employed by the Division and provided them with astro-theodolites, time-recording equipment and star predictions.

Observations along both baselines were reduced to the spheroid using AHD heights and N from the 1971 geoid determination and were then adjusted by program VARYCORD, holding the common terminal at Culgoora near Narrabri fixed. The adjusted co-ordinates of the terminals of the two baselines were then transformed into cartesian X Y Z co-ordinates and the chord distances between the satellite camera stations computed. A comparison of these distances with the values obtained in the 1966 adjustment shows a difference in the east-west baseline of  $-1.2\text{m}$  or  $-0.4\text{ppm}$  and of  $+2.2\text{m}$  or  $+0.9\text{ppm}$  in the north-south baseline.

The two Australian baselines together with bases in America, Europe and Africa provide the scale for the Pageos Satellite Triangulation. Apart from the three satellite triangulation stations at the end of the Australian baselines, there are four more such stations on Australian Territory. They are at Cocos and Heard Islands and at Mawson and Casey in Antarctica.

Geodetic Information Sheets for all satellite tracking stations and radio telescopes in Australia have been prepared by the Division of National Mapping and are available on request.

## 12. HIGH PRECISION TRAVERSING

A network of high precision traverses has been measured by the Division of National Mapping. It links all Australian Capitals except Hobart with the Johnston Origin and contains the two satellite baselines. Except for a section of 500 kilometres in New South Wales the traverses follow existing geodetic work observed during the period 1957-1965 with Tellurometer Models 1 and 2.

On these traverses measurements were made as described in paragraph 11 for satellite baselines. Almost all stations on these traverses are astro-geodetic stations.

After the completion of the two baselines most distances along the traverses started in 1970 have been measured with Model 8 Laser Geodimeters and a few with MRA4 Tellurometers. Lines of up to 70 kilometres in length have been measured with the Model 8 Geodimeter employing up to 42 prisms. Smoke, dust particles in the atmosphere, shimmer and hazy conditions have at times restricted the use of the Laser Geodimeter while high humidity in coastal regions limited the range of MRA4 Tellurometers.

This network of high precision traverses will be included in the formation of the Geodetic Model of Australia described in the next paragraph

## 13. THE GEODETIC MODEL OF AUSTRALIA

At the time of writing this paper, preparations are in hand to readjust all the geodetic surveys in Australia to form the Geodetic Model of Australia (GMA) making use of all modern surveys completed since 1966.

The input data will be adjusted by program VARUDEL which is identical to program VARYCORD, except:

It uses Rudoe's formula instead of Robbin's in the computation of azimuth and distance between co-ordinates of points and vice versa.

It computes the parameters of relative error ellipses of adjusted points.

The maximum number of variable points is 200 instead of 100.

The differences between the parameters of the GMA and the AGD are:

The flattening of the spheroid will be changed to that of the Reference Ellipsoid 1967, i.e. from  $1/f = 298.25$  to  $1/f = 298.247$ .

The minor axis of the spheroid will be rigorously defined to be parallel to the pole of the Conventional International Origin (CIO).

The height above the spheroid at the Johnston Geodetic Station will be 560.3m derived from its AHD height of 566.3m and the spheroid geoid separation  $N = -6\text{m}$ .

The data for the GMA adjustment will have all astronomic latitudes, longitudes and azimuths reduced to the CIO pole and all observed distances reduced to the spheroid using AHD heights and 1971 N values. Laplace azimuths between the three Pageos satellite triangulation stations at the ends of the two Australian satellite baselines, determined from satellite observations, will be included.

The adjustment will result in GMA co-ordinates of the 140 odd junction points of the geodetic network in the first instance. Thereafter only selected survey stations like radio telescopes, satellite tracking stations and other important stations will have their co-ordinates computed in terms of GMA.

Such co-ordinates would be made available on demand in the form of cartesian X, Y, Z values. This is in order to prevent confusion with AGD co-ordinates published in terms of latitude, longitude and height.

Co-ordinates on the Australian Geodetic Datum will remain official for mapping and integrated survey systems.

As time progresses more modern surveys will be made in Australia and further GMA adjustments will be computed. Any GMA adjustment will be transformed to the best available world datum when this becomes available.

## 14. COMPARISON OF EARTH CENTRED GEODETIC DATUMS WITH THE AUSTRALIAN GEODETIC DATUM

A number of such comparisons have been made at single stations and groups of stations for which co-ordinates on the AGD and on earth centred geodetic datums are available. This is a continual process with more comparisons becoming available and more up-to-date earth centred datums being determined.

The co-ordinates based on earth centred datums are usually determined from observations to passive or active satellites. The US Navy Navigational Satellite System, which consists of a number of active satellites transmitting well stabilised radio frequencies, which are received by special ground equipment, has emerged as the leading system for the time being. Table 1 lists transformation parameters between the AGD and two earth centred datums used by the US Navy derived from two groups of eight TRANET stations and from four fixes obtained with commercial satellite receivers in Australia.

Government departments and private companies in Australia using satellite receiving equipment have been encouraged to supply the Division of National Mapping with the results of satellite derived position fixes at known AGD stations so that better transformation parameters can be worked out.

Satellite receivers could very well be used in Australia

and Antarctica in the near future to determine with geodetic accuracy the position of islands and reefs and of marks in parts of this country having sparse or no geodetic control.

## 15. THE POSITIONAL ASTRONOMY SECTION OF THE DIVISION OF NATIONAL MAPPING

The Division of National Mapping took over the Positional Astronomy Section of the Mount Stromlo Observatory in September 1971. This Section, equipped with a Photo Zenith Tube (PZT) and with modern time keeping equipment soon to include three atomic clocks, determines variations in the rotation of the earth and the position of the earth's pole in conjunction with similar observatories in other parts of the world. PZT observations can also be used to determine the movement of the earth's crust between observatories on the same parallel of latitude.

Similar results can be obtained by making laser rangings to reflectors left on the moon and to artificial satellites equipped with reflectors.

At the time of writing this paper there is a good chance that the USA will lend a laser system, capable of ranging to the moon, to the Division of National Mapping for a number of years. It is envisaged that this system would be set up near Canberra.

## 16. CONCLUSION

Australia is fortunate indeed in being one of very few countries having homogeneous geodetic control systems, both horizontal and vertical, surveyed with modern instruments during a short span of time.

These systems form the base for all future mapping in Australia. Looking forward, they provide a firm

base for national reference and retrieval systems without which full efficiency in all future automated thematic, resources, topographic, aeronautical and marine mapping and charting cannot be achieved.

The present reality of these geodetic control systems is mainly due to the foresight, good planning and direction of the Director of National Mapping and the National Mapping Council of Australia, the good co-operation between Australian survey authorities and the perseverance of surveyors and their assistants in all the organisations which have contributed to this great enterprise.

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TABLE 1

TRANSFORMATION PARAMETERS BETWEEN THE AUSTRALIAN GEODETIC DATUM AND TWO  
EARTH CENTRED GEODETIC DATUMS DERIVED FROM A COMPARISON OF AGD CO-ORDINATES  
WITH THOSE OBTAINED FROM SATELLITE OBSERVATIONS

COMPARISON WITH	DIFFERENCES IN X,Y,Z CO-ORDS OTHER DATUM — AGD				DIFFERENCE IN O. ,H+N OTHER DATUM — AGD O POSITIVE N; POSITIVE W				EARTH CENTRED DATUM
	$\Delta X$	$\Delta Y$	$\Delta Z$	VECTOR	$\Delta \phi$	$\Delta \lambda$	$\Delta \lambda \cos \phi$	$\Delta (H+N)$	
	m	m	m	m	"	"	"	m	
Tranet solution NWL8E Mean of 8 stations	-119.2	-29.8	+138.0	184.8	+4.97	-3.85	-3.46	-13.2	MERCURY 1960 a = 6378166 m 1/f 298.3
Tranet Solution NWL8F-9D Mean of 8 stations	-123.6	-28.0	+141.9	190.3	+5.15	-3.93	-3.53	-11.0	MERCURY 1960
Hobart FIX ITT Receiver Pole Corrected	-119.9	-17.2	+139.3	184.6	+5.06	-3.56	-3.20	+ 1.6	APL, a = 6378 144 m 1/f = 298.23
Darwin Fix Magnovox Received, Pole corrected	-107.6	-28.0	+137.4	176.8	+4.77	-3.51	-3.16	-12.2	APL
Mooloolaba FIX, ITT Pole and tropospheric Cn	-117.6	-45.2	+145.4	192.3	+4.92	-4.19	-3.77	-20.9	APL
Canberra FIX, ITT Pole and tropospheric Cn	-122.9	-37.3	+141.4	190.8	+4.93	-4.13	-3.71	-10.5	APL
Mean of APL Comparisons S:E. of Mean	-117.0 3.3	-31.9 6.0	+140.9 1.7	186.1 3.5	+4.92 0.06	-3.85 0.18	-3.46 0.16	10.5 4.6	

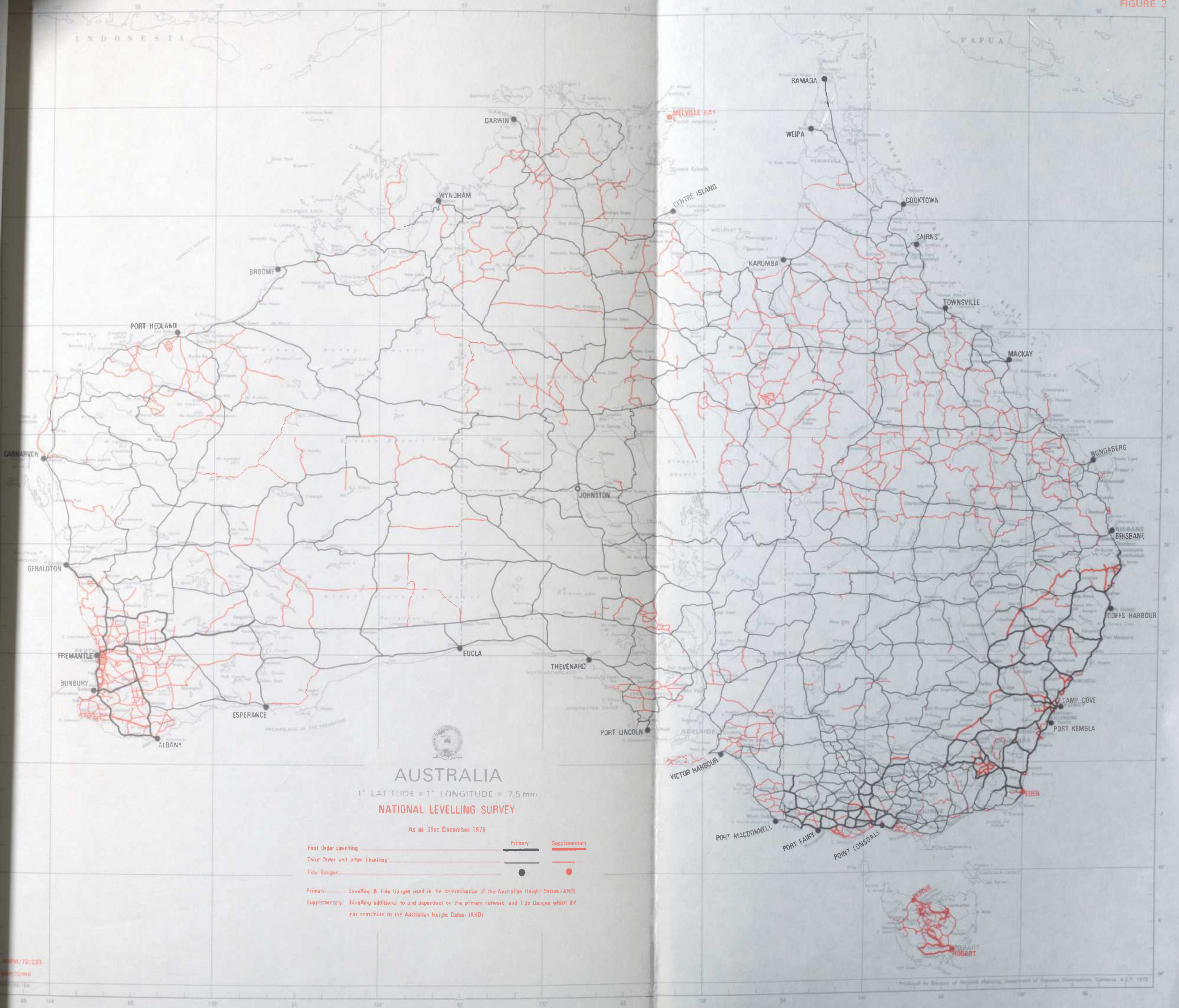


### AUSTRALIA

1" LATITUDE = 1" LONGITUDE = 7.5 mm  
NATIONAL GEODETIC SURVEY

As at 31st DECEMBER 1971

- |                            |  |                         |  |
|----------------------------|--|-------------------------|--|
| First Order Triangulation  |  | Aerodist Station        |  |
| First Order Traverse       |  | Aerodist Trilateration  |  |
| Second Order Triangulation |  | Aerodist Reconnaissance |  |
| Second Order Traverse      |  | Heron Station           |  |
| Laplace Station            |  | Heron Trilateration     |  |
| Astro Geodetic Station     |  |                         |  |
| Satellite Baseline         |  |                         |  |
| Precision Traverse         |  |                         |  |



# AUSTRALIA

1° LATITUDE = 1" LONGITUDE = 7.5 mm

## NATIONAL LEVELLING SURVEY

As at 31st December 1971

- |                                 |                                                                                                                                             |         |  |               |
|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|---------|--|---------------|
| First Order Levelling           |                                                                                                                                             | Primary |  | Supplementary |
| Third Order and other Levelling |                                                                                                                                             |         |  |               |
| Tide Gauges                     |                                                                                                                                             |         |  |               |
| Primary                         | Levelling & Tide Gauges used in the determination of the Australian Height Datum (AHD)                                                      |         |  |               |
| Supplementary                   | Levelling additional to and dependent on the primary network, and Tide Gauges which did not contribute to the Australian Height Datum (AHD) |         |  |               |

NSM/72/233  
NSM/72/058  
NSM/72/154





NMM/72/233  
NMP/71/32

# **REVIEW**

**of :**

Leppert, Klaus (1973), *Geodesy in Australia, 1956-72*, Technical papers presented at 16th Australian Survey Congress, Canberra, 1973, pp.A1-A6.

**from :**

Murphy BT (1973), Reviews, *The Australian Surveyor*, September, 1973, Vol.25, No.3.

"The Geodetic Survey of Australia is one of the outstanding scientific achievements of the post Second World War period. It was made possible by the foresight, technical competence and physical effort of many government and private surveyors and the use of modern precise theodolites, electromagnetic distance measurement equipment, automatic levels, electronic computers and helicopters.

The paper discusses implications of the actual surface of the earth, the geoid, and the spheroid; it describes the Australian Geodetic Datum, the Australian Map Grid and the Australian Height Datum; it outlines contemporary work on the definition of the geoid in Australia and the application of satellite geodesy to the measurement of two long base lines between Perth and Narrabri and between Thursday Island and Narrabri for the worldwide Pageos Satellite Triangulation; it discusses the measurement of high precision traverses with Model 8 Laser Geodimeters and MRA 4 Tellurometers, and it introduces the Geodetic Model of Australia.

This paper is the latest in a series by various officers of the Division of National Mapping. Each has made a valuable contribution by presenting an up to date statement of the remarkable progress of the Australian Geodetic Survey and by detailing the continuing development of methods, instrumentation and results. *Geodesy in Australia, 1956-72* is a valuable reference for all surveyors and survey students".

Brian Thomas Murphy (1927-1983), University of Melbourne, Faculty of Engineering. Department of Surveying.