# Automated Cartography in the Division of National Mapping

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*ABSTRACT: The problems involved in digitising and generalising data before it can be automatically drawn by flat-bed plotters are discussed. A report follows on how National Mapping is acquiring data for future automation, and how they are making orthophotomaps with B8 Stereomats and Zeiss Jena Orthotopocarts.*

Automated cartography means something different to almost every person who uses the term. To some, it means a highly sophisticated, and expensive, method of drawing topograpic maps based on a digitised data bank processed by a very large computer and a battery of automatic plotters. To others, the concept is more limited: it may be a system for drawing atlas maps at various scales and projections; or it may be a system for recording a great variety of information about land-altitude, slope, soil, vegetation, rainfall, etc.—with an ability to compare and contrast these various factors.

### The Cartographic Problem

Modern large flat-bed plotters are technically capable of drawing the most complex of modern topographic maps, even a standard edition 1:100,000 map in seven colours. At the same time, in Australia, there is a chronic shortage of cartographic draftsmen. Why then do we still make so little use of the machines?

The answer is that there is no point in digitising the data and feeding it into a machine, simply to draw it out again. A draftsman can scribe a map as quickly as he can ditigise it. It is only worth using a machine if the data is to be manipulated and published at another scale or on another projection. Simple change of scale is of course more easily achieved by a camera; but as every cartographer knows, change of scale also implies a degree of generalisation.

Few, if any, computer programs have yet been written to cope with the problem of generalisation, because the theory of generalisation is not yet properly understood and codified.

Mr. B. E. Goodrick, Chief Cartographer in the Division of National Mapping, recently presented a paper on this subject[1] to the Automated Cartography Study Group in Canberra. The paper says little that cartographers have not known intuitively for years: but when the details are clearly set out of what actually happens when a cartographer generalises a map from one scale to another, it becomes clear how very difficult many parts of the process will be to automate.

[1] "Problems in Automating Generalisation of map detail."

Generalisation is not the only problem. Digitisation of detail is a new skill, for which efficient drills at the digitising table have to be designed. The first tapes produced by the digitiser will not be satisfactory: the operator's hand will tremble; smooth curves will not be smooth, and rectangular buildings will not be rectangular. Lines must be smoothed, and corners and closures trued up. Before archival storage of the data, for use days, months or even years later, the crude output has to be edited and perhaps compacted so that it can be stored and retrieved efficiently. Then come the well understood problems of change of scale and change of projection, accompanied by the less well understood problem of generalisation. Finally, we have the problems of plotting, which have already largely been solved.

Across the world, many of these problems are being energetically tackled and some are being overcome; but before any automation can take place, a bank of data has to be created on which the machines can operate. It is now opportune to review what data is being obtained in Australia, at what rate, and how it is being stored. We can also look a little way into the future and try to see, in practical realistic terms, what forms of automated mapping are likely to be in production in Australia in three to five years time.

### Air Photography

Many people think of a data bank necessarily being in digitised form, on magnetic tape, drums or discs. A 9" x 9" photograph contains about ten million bits, and if we acquire this information in the first place on magnetic tape—as is the case with some satellite photography—the first thing we do is to rearrange it in the form of a photograph which we can look at. There is no doubt that for many years to come, an air photograph library will form the major part of any topographic data bank.

The last bit of Australia was photographed from the air for the first time in 1965. Many of the original photographs are now very old and they are at a mixture of scales. Since 1960 there has been a programme to rephotograph the whole of Australia with super-wide-angle cameras at a scale of about 1:80,000 on standard flight lines. Expenditure on the air photography of Australia has been running at about $200,000 a year for many years and the systematic rephotography of Australia should be complete in 1974.

In populated areas such as the fringes of the capital cities, man-made detail soon becomes out-of-date. But anyone who has flown over outback Australia will realise how small man's impact on much of Australia is; and the hills and valleys, which are the main basis of the topography, remain unchanged indefinitely. Areas of rapid change will, of course, be re-photographed from time to time.

**Horizontal Control**

Before air photographs can be converted into maps, each photograph ideally needs six points whose coordinates—latitude and longitude on the Australian Geodetic Datum, or easting and northing on the Australian Map Grid—are known without plottable error at the scale of the map which will be produced from them. The height of these points above sea level, i.e., above the Australian Height Datum, needs to be known similarly.

With regard to horizontal control, we in Australia are fortunate: in recent years we have established a fairly dense network of modern Tellurometer traverses and triangulation—see Figure 1—which was adjusted in 1966 into a homogeneous system, free from discontinuities, accurate over long distances to about two parts per million—a foot in every hundred miles, 20 centimetres in every 100 kilometres. The adjustment in 1966, which established the Australian Geodetic Datum (AGD) was computed on a CDC 3600 computer by program VARYCORD. The data for the adjustment is held on punch cards, and the output is held on magnetic tape. An example of a listing is shown in Figure 2.

The gaps within the loops of Tellurometer traverse are rapidly being filled in by airborne surveys, such as Aerodist, or by second-order traverses, so that there will soon be a control point at least at the corner of every one degree square, and in many areas at every half degree square. Nine thousand additional stations have been adjusted on to the AGD since 1966.

Horizontal control can be carried from a surveyed spacing of this density down to the desired six points per photograph by the classical method of slotted templates, or by more expensive but more accurate photographic observation in stereo-plotting machines, followed by mathematical adjustment in an electronic computer. In Australia slotted templates are still being used in the flatter areas, and give satisfactory results for mapping at a scale of 1:100,000.

**Vertical Control**

Lines of levelling now cover the whole of Australia. The network shown in black in Figure 3, 95,000 km of levelling containing 38,000 bench marks, was adjusted by the Division of National Mapping in May 1971. The levelling was adjusted to mean sea level at 33 tide gauges, to form the Australian Height Datum (AHD). The output is held on two magnetic tapes, and an example of a listing is shown in Figure 4.

The National Mapping Council has adopted the AHD for all heights in Australia. The levelling shown in red in Figure 3, and the heights carried by vertical triangulation along the geodetic traverses shown in Figure 1, are now being adjusted to it.

Heights are most neatly carried on to each photograph by an Airborne Profile Recorder (APR). An aircraft flies along the lateral overlap of each strip of photographs and obtains a profile of the ground from a radar or laser altimeter. Private contractors have completed many thousand kilometres of radar profiling, and during the 1971 field season, the Division of National Mapping is measuring profiles with its laser APR at the rate of 2,000 km. per week.

Heights on the photographs can, of course, be supplied by other means—levelling, triangulation, barometric altimetry—followed by observations in a stereo-plotter and electronic computation, as with horizontal control.

**Orthophoto Maps**

Air photographs do not in themselves form an accurate map: they contain distortions due both to the varying height of the terrain, and to slight tilts in the aircraft at the instant of photography. A qualitative impression of relief can be obtained by viewing an overlapping pair of photographs under a stereoscope, but to transform an air photograph into a true-to-scale map, with heights indicated by contour lines, is one of the surveyor's most laborious tasks. Since the Second World War increasingly sophisticated stereo-plotting machines have become available for this job, but they are all expensive, relatively slow, and require skilled operators.

For the last decade automatic stereo-plotters have been under development; they are even more expensive, some extremely expensive, and successful development has not been rapid. However, in 1968 the Division of National Mapping took delivery of its first automatic stereo-plotter, a Wild B8 Stereomat, costing $130,000. A second was delivered in 1969, and a third in 1970.

These machines convert an air photograph, together with horizintoal and vertical control points, into an orthophotograph, which looks similar to the original air photograph, but has all detail transferred into its correct plan position. Orthophotographs can be cut and butt-jointed together on standard sheet lines to form an orthophotomap or OPM, on which the Australian Map Grid can be printed.

OPMs make an acceptable map in some areas at some scales. The scale can seldom be smaller than 1:100,000 for useful readability, and the time is not yet ripe to try and map the whole of Australia at a scale larger than 1:50,000. At these scales, an OPM is often inferior to a line map in populated and developed areas, but in sandridge desert or salt lake country, an OPM even at a scale of 1:100,000 is both superior to a line map and easier to produce.

If made at the same scale as the original photographs, 1:80,000, a three-dimensional stereo image can be obtained by observing the OPM with one eye, and the edge of the photograph with the other. The resolution of the stereo image is better than that of the OPM alone, and AMG coordinates can be read off the OPM for any point visible on the original photo.

OPMs can be screened and printed by lithography, losing a little resolution in the process. Stocks have then to be stored in a map store but copies are cheap and would sell at the same price as any other map, 75c. An example at a scale of 1:100,000 is shown.

Alternatively, for remote areas, the negative only need be stored and bromide positives can be prepared on demand, at a cost of about $3 each. Although response to demand is slower than getting a litho map off the shelf, resolution is better and there is no map storage problem, a particularly desirable benefit since several thousand maps are required to cover Australia.

For use in flatter areas, cheaper instruments than the Stereomat are now available. The Division of National Mapping has bought two Zeiss Jena Orthotopocarts, each costing about $40,000. In contrast to the Stereomat, the Orthotopocart works on optical rather than TV principles, and is thus not only cheaper, but has better resolution and can be used to produce coloured OPMs from coloured air photographs. Although they are only semi-automatic, and require the use of fairly skilled operators, they can scan flat country in fairly wide strips, and are, therefore, capable of a higher output than fully automated stereoplotters.

The Division has also bought a Zeiss SEG V rectifier for use in the photomapping of flat terrain.

Orthophotomaps are easy to revise. A pair of air photographs of any new development can be used to produce a new orthophotograph, which can be cut and inserted into the master copy of the original orthophotomap.

## Automatic Contouring

The Stereomat and the Orthotopocart can both produce contours.

The Stereomat can plot short segments of contours, which are then joined up by hand. This is satisfactory in terrain of average relief, but in complicated terrain it is better to record numerical heights at intervals of 1.5 millimetres in both dimensions. These heights can be recorded automatically on magnetic tape, and are transformable by an electronic computer into a tape which will direct an automatic plotter to plot contours.

The Orthotopocart can produce contours by the "drop-line" system, which depicts areas between contours by lines of different thicknesses. "Drop-lines" are often difficult to interpret, and it is usually better to produce an OPM automatically, but have the contours plotted by an operator, on the same machine, in the traditional manner.

In flat areas it is possible to resort to simple photographic rectification to remove tilt distortion. Heights are best shown by spot heights, between which an occasional contour can be interpolated.

Contour lines can be shown in black or white on bromide OPMs, inevitable losing clarity in dark or light areas, or on a separate overlay. One of the advantages of lithographed OPMs is that they can be printed in colour, with the contours and names superimposed in black—see the example. In hilly country, the countours tend to obliterate the topographic detail, and the problem of how best to show relief on small scale OPMs has not yet been solved.

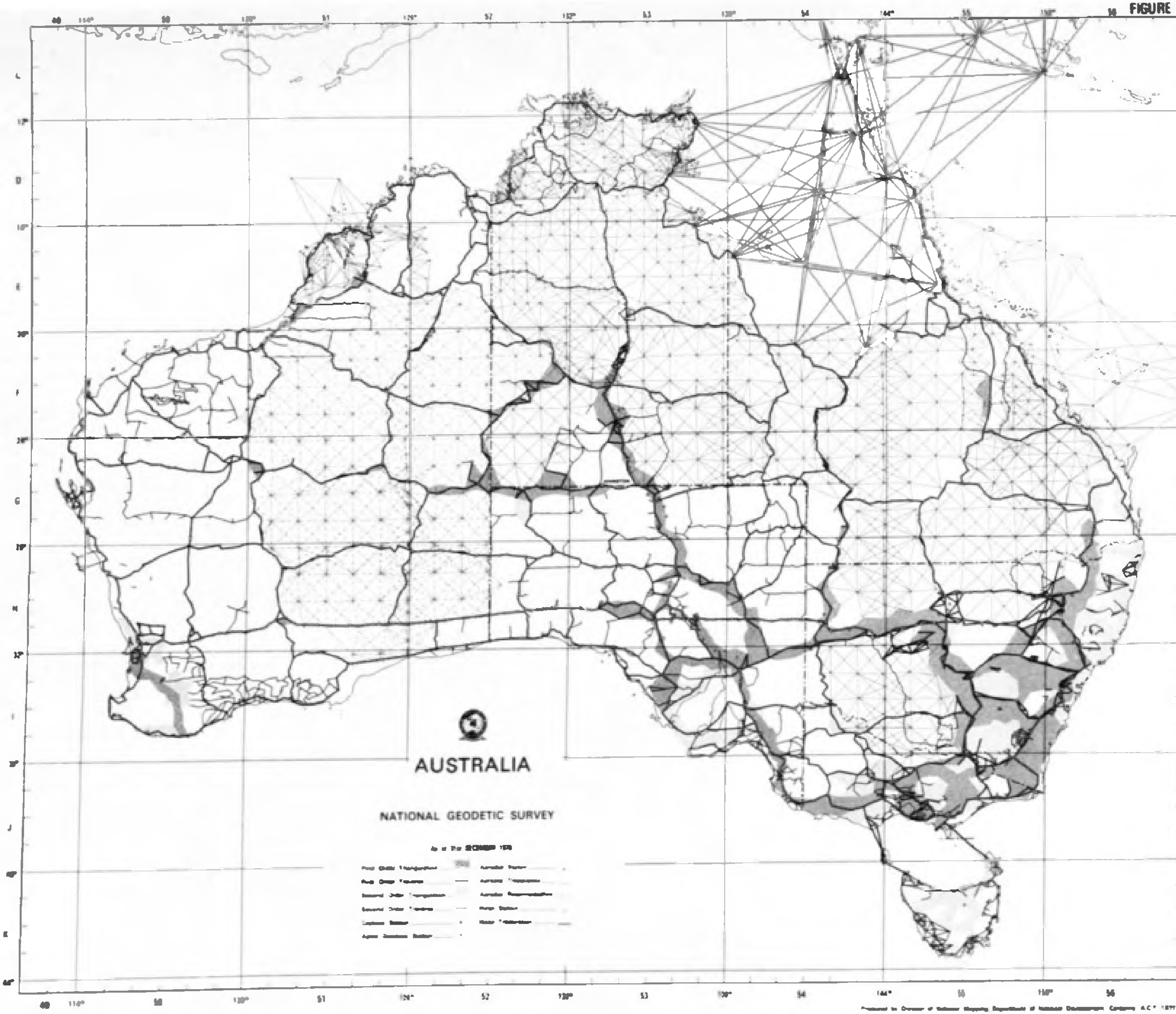
## Digital Heights

The original numerical output of the Stereomat—the 1.5 millimetre mesh of spot heights—can, of course, be retained as part of a digital data bank for other purposes. However, the sheer cost of the tapes would not be negligible, and the usefulness for this digital information needs to be clearly established in advance.

## Instant Mapping

By the mid 1970s, the Division of National Mapping should have a data bank consisting of 1:80,000 air photographs on standard flight lines covering the whole of Australia, with horizontal and vertical control either available for each photograph or capable of being computed in the office without further field survey. Subject to the normal conflict of competing priorities, it should be possible to produce bromide 1:80,000 orthophotomaps, with contours, at short notice, anywhere in Australia. However, high priority mapping of small areas does nothing to increase overall output, and in general complete 1:250,000 areas will be mapped in whatever order circumstances dictate. The production of standard 1:100,000 line maps of the populated and developed areas will of course continue.

FIGURE 1



PROGRAM AMENDED AUG 1971 GEODETIC SURVEY OF AUSTRALIA COMPUTED 26/08/71 FIGURE 2

PREPARED FOR THE NATIONAL MAPPING COUNCIL BY

THE DIVISION OF NATIONAL MAPPING

SURVEY ADJUSTMENT - LEAST SQUARES VARIATION OF COORDINATES ON THE SPHEROID

W.A.- BOBAKINE TO ECLIPSE 1ST ORDER SECTIONBOBECLIP

ANS
A= 6378160.00 MS 1/F= 298.250

| STATION | | SERIAL | SOUTH LATITUDE | EAST LONGITUDE | ZONE | EASTING MS | NORTHING | CONVERGENCE | AHD HEIGHT MS |
|---|---|---|---|---|---|---|---|---|---|
| FIXED POINTS | | | | | | | | | |
| CROWS NEST | | 1 | 31. 34. 13.8060 | 116. 43. 43.9178 | 50. | 474271.152 | 6507125.368 | - 0. 8. 31.03 | 306.9 |
| BOBAKINE | | 2 | 31. 41. 36.4152 | 116. 32. 27.0324 | 50. | 456486.061 | 6493438.630 | - 0. 14. 28.44 | 432.5 |
| SMITHS MILL | | 4 | 31. 40. 41.2692 | 116. 10. 57.4957 | 50. | 422525.809 | 6494937.863 | - 0. 25. 45.32 | 361.2 |
| MUCHEA | | 6 | 31. 35. 45.8900 | 115. 55. 59.2828 | 50. | 398786.527 | 6503828.449 | - 0. 33. 32.43 | 94.5 |
| ECLIPSE | | 7 | 31. 23. 42.4285 | 115. 55. 48.3876 | 50. | 398282.063 | 6526100.803 | - 0. 33. 26.62 | 212.8 |
| ADJUSTED POINTS | | | | | | | | | |
| MORANGUP | | 3 | 31. 39. 33.7459 | 116. 18. 51.1096 | 50. | 434982.980 | 6497102.750 | - 0. 21. 35.89 | 477.8 |
| | NM F 52 | 5 | 31. 40. 29.2169 | 116. 3. 27.3347 | 50. | 410669.712 | 6495213.356 | - 0. 29. 41.60 | 237.9 |

CROWS NEST SECTION BOBECLIP SERIAL 1

| SOUTH LATITUDE | EAST LONGITUDE | ZONE | EASTING | NORTHING | CONVERGENCE | AHD HEIGHT |
|---|---|---|---|---|---|---|
| 31 34 13.8060 | 116 43 43.9178 | 50 | 474271.152 | 6507125.368 | -0 8 31.03 | 306.9 |

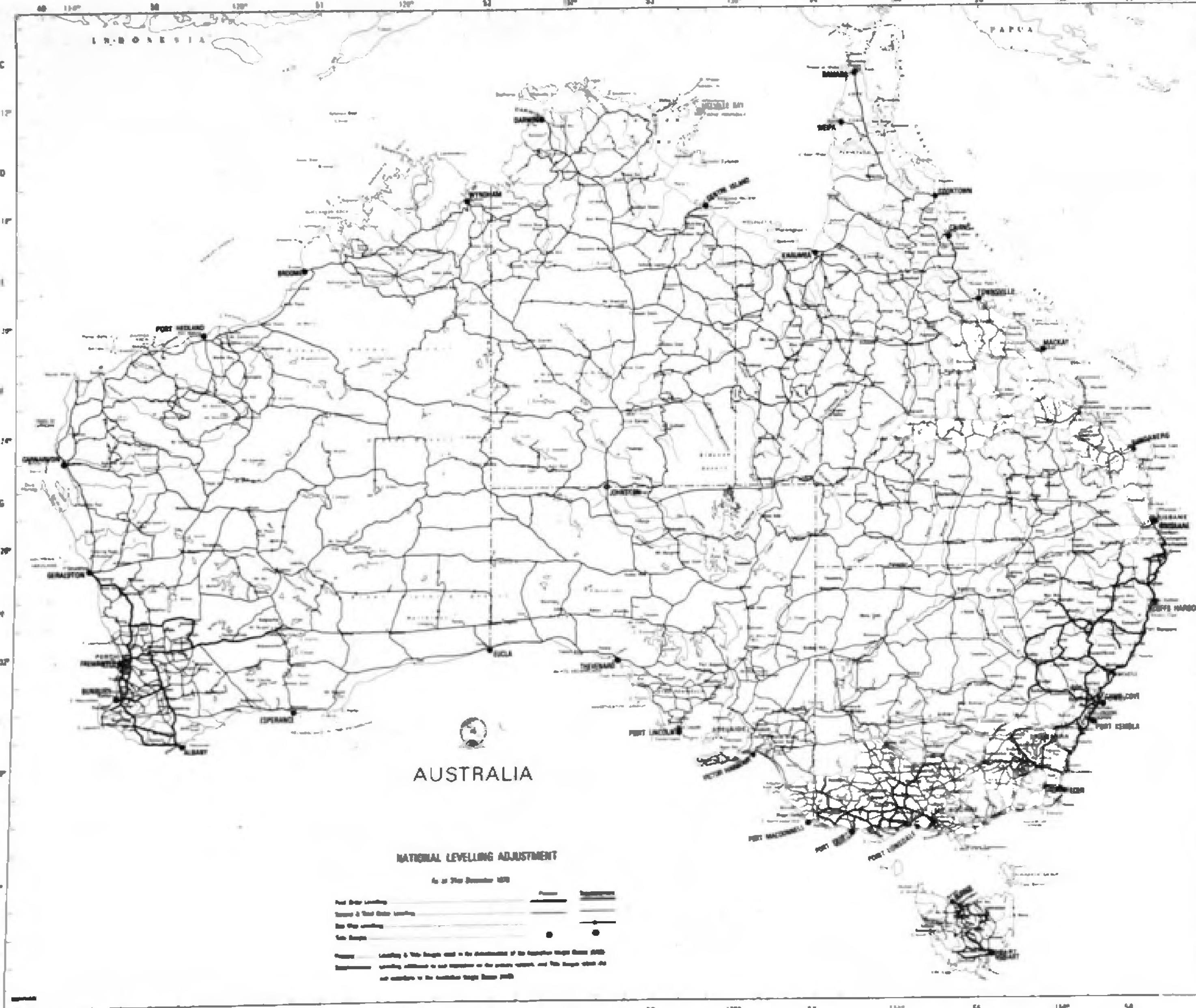
| TO | SERIAL | ADJ AZIMUTH | ADJ LENGTH |
|---|---|---|---|
| BOBAKINE | 2 | 232 33 42.23 | 22450.483 |

BOBAKINE SECTION BOBECLIP SERIAL 2

| SOUTH LATITUDE | EAST LONGITUDE | ZONE | EASTING | NORTHING | CONVERGENCE | AHD HEIGHT |
|---|---|---|---|---|---|---|
| 31 41 36.4152 | 116 32 27.0324 | 50 | 456486.061 | 6493438.630 | -0 14 28.44 | 432.5 |

| TO | SERIAL | ADJ AZIMUTH | ADJ LENGTH |
|---|---|---|---|
| CROWS NEST | 1 | 52 39 37.23 | 22450.483 |
| MORANGUP | 3 | 279 54 41.07 | 21820.955 |

FIGURE 3


AUSTRALIA
NATIONAL LEVELLING ADJUSTMENT
PAPUA
CARNARVON
ESPERANCE
ALBANY
EUCLA
PORT LINCOLN
COFFS HARBOUR
PORT KEMBLA

PROGRAM AMENDED 18/12/70
COMPUTED 05/08/71

NATIONAL LEVELLING ADJUSTMENT OF AUSTRALIA
PREPARED FOR THE NATIONAL MAPPING COUNCIL BY
THE DIVISION OF NATIONAL MAPPING

FIGURE 4

LINEAR ADJUSTMENT BETWEEN PREVIOUSLY ADJUSTED JUNCTION POINTS 108 AND 2

SECTION 2- 108
THIRD ORDER LEVELLING
PRIMARY SECTION

AUSTRALIAN HEIGHT DATUM
SOUTH AUSTRALIA

| BENCHMARKS FROM A | TO B | DISTANCE MILES | KM | HEIGHT DIFFERENCES (INTERNATIONAL FEET) OBSERVED | ORTHOMETRIC | ADJUSTED | CORR | LAT OF B | LONG OF B | LOCATION OF B | ADJUSTED HEIGHT OF B INT FT | METRES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3265 | | | | | | | 32 07 | 133 40 | CEDUNA | 9.63 | 2.935 |
| 3265 | 3264 | 3.0 | 4.8 | 28.984 | 28.984 | 28.981 | -.003 | 32 05 | 133 39 | | 38.61 | 11.769 |
| 3264 | 3263 | 3.1 | 5.0 | -6.980 | -6.980 | -6.984 | -.004 | 32 04 | 133 36 | | 31.63 | 9.640 |
| 3263 | 3262 | 3.1 | 5.0 | 65.078 | 65.078 | 65.074 | -.004 | 32 02 | 133 34 | | 96.70 | 29.475 |
| 3262 | 3261 | 3.0 | 4.8 | 59.838 | 59.838 | 59.835 | -.003 | 32 01 | 133 32 | | 156.54 | 47.712 |
| 3261 | 3260 | 3.1 | 5.0 | 11.565 | 11.565 | 11.561 | -.004 | 31 59 | 133 30 | | 168.10 | 51.236 |
| 3260 | 3259 | 3.0 | 4.8 | 56.116 | 56.117 | 56.114 | -.803 | 31 57 | 133 27 | | 224.21 | 68.340 |
| 3259 | 3258 | 3.1 | 5.0 | 36.604 | 36.604 | 36.600 | -.004 | 31 56 | 133 25 | | 260.81 | 79.495 |
| 3258 | 3257 | 3.1 | 5.0 | 71.586 | 71.586 | 71.582 | -.004 | 31 56 | 133 22 | | 332.39 | 101.314 |
| 3257 | 3256 | 3.0 | 4.8 | -8.960 | -8.960 | -8.963 | -.003 | 31 56 | 133 19 | | 323.43 | 98.582 |
| 3256 | 3255 | 3.1 | 5.0 | -100.587 | -100.587 | -100.591 | -.004 | 31 56 | 133 17 | | 222.84 | 67.922 |
| 3255 | 3254 | 3.1 | 5.0 | -14.985 | -14.985 | -14.989 | -.004 | 31 56 | 133 13 | | 207.85 | 63.353 |
| 3254 | 3253 | 3.0 | 4.8 | -17.378 | -17.378 | -17.381 | -.003 | 31 55 | 133 10 | | 190.47 | 58.055 |
| 3253 | 3252 | 2.9 | 4.7 | -46.264 | -46.264 | -46.267 | -.003 | 31 55 | 133 07 | | 144.20 | 43.953 |
| 3252 | 3251 | 3.0 | 4.8 | -29.084 | -29.084 | -29.087 | -.003 | 31 55 | 133 04 | | 115.12 | 35.087 |
| 3251 | 3250 | 3.1 | 5.0 | -68.748 | -68.748 | -68.752 | -.004 | 31 55 | 133 01 | PENONG | 46.36 | 14.132 |
| 3250 | 3249 | 3.0 | 4.8 | 44.304 | 44.304 | 44.301 | -.003 | 31 54 | 132 59 | | 90.66 | 27.634 |
| 3249 | 3248 | 3.0 | 4.8 | -26.692 | -26.692 | -26.695 | -.003 | 31 53 | 132 57 | | 63.97 | 19.498 |
| 3248 | 3247 | 3.0 | 4.8 | 75.948 | 75.948 | 75.945 | -.003 | 31 52 | 132 54 | | 139.91 | 42.646 |
| 3247 | 3246 | 3.1 | 5.0 | -67.421 | -67.421 | -67.425 | -.004 | 31 51 | 132 51 | | 72.49 | 22.095 |
| 3246 | 3245 | 3.0 | 4.8 | -24.199 | -24.199 | -24.202 | -.003 | 31 49 | 132 47 | | 48.29 | 14.718 |
| 3245 | 3244 | 3.0 | 4.8 | 47.734 | 47.734 | 47.731 | -.003 | 31 49 | 132 44 | | 96.02 | 29.266 |
| 3244 | 3243 | 3.0 | 4.8 | -47.692 | -47.692 | -47.695 | -.003 | 31 50 | 132 41 | | 48.32 | 14.728 |
| 3243 | 3242 | 3.0 | 4.8 | 55.273 | 55.273 | 55.270 | -.003 | 31 50 | 132 38 | | 103.59 | 31.575 |
| 3242 | 3241 | 3.0 | 4.8 | .974 | .974 | .971 | -.003 | 31 50 | 132 35 | | 104.56 | 31.870 |
| 3241 | 3240 | 3.0 | 4.8 | -49.062 | -49.062 | -49.065 | -.003 | 31 50 | 132 32 | | 55.50 | 16.915 |
| 3240 | 3239 | 3.0 | 4.8 | 6.659 | 6.659 | 6.656 | -.003 | 31 50 | 132 29 | | 62.15 | 18.944 |
| 3239 | 3238 | 3.0 | 4.8 | -18.103 | -18.103 | -18.106 | -.003 | 31 50 | 132 26 | | 44.05 | 13.425 |
| 3238 | 3237 | 3.0 | 4.8 | 70.426 | 70.426 | 70.423 | -.003 | 31 50 | 132 23 | | 114.47 | 34.890 |
| 3237 | 3236 | 3.0 | 4.8 | -22.007 | -22.007 | -22.010 | -.003 | 31 50 | 132 20 | | 92.46 | 28.181 |
| 3236 | 3235 | 3.0 | 4.8 | -23.579 | -23.579 | -23.582 | -.003 | 31 50 | 132 18 | | 68.88 | 20.993 |
| 3235 | 3234 | 3.1 | 5.0 | -10.354 | -10.354 | -10.358 | -.004 | 31 49 | 132 15 | | 58.52 | 17.836 |
| 3234 | 3233 | 3.0 | 4.8 | 44.534 | 44.534 | 44.531 | -.003 | 31 46 | 132 13 | | 103.05 | 31.409 |
| 3233 | 3232 | 3.0 | 4.8 | 31.021 | 31.021 | 31.018 | -.003 | 31 44 | 132 11 | | 134.07 | 40.863 |
| 3232 | 3231 | 3.1 | 5.0 | 22.155 | 22.156 | 22.152 | -.004 | 31 41 | 132 08 | | 156.22 | 47.615 |
| 3231 | 3230 | 3.1 | 5.0 | 73.871 | 73.872 | 73.868 | -.004 | 31 39 | 132 06 | | 230.09 | 70.130 |
| 3230 | 3229 | 3.1 | 5.0 | -104.943 | -104.943 | -104.947 | -.004 | 31 38 | 132 05 | COLONA | 125.14 | 38.143 |
| SUMMATION | | 109.2 | 175.7 | 115.632 | 115.635 | 115.510 | -.125 | | | | | |

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20°30'
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Dam
Dam
Creek
Cardigan
Bore
Bendee Dam
Creek
Starlight
MOUNT ALMA
Rollston
Dam
Black
Gin
Creek
Yard
Solitary
Waterhole
Harvest Hom