

THE LEVELLING SURVEY OF AUSTRALIA

Paper presented by Australia¹

Many thousands of miles of levelling to various standards have been carried out in Australia by survey authorities over the years. However, levelling of first-order to third-order standards (control levelling), with permanent marks placed at adequate intervals, had a slow start. Prior to 1956, about 3,000 miles of control levelling had been completed in three of the six states of the Commonwealth of Australia. Between 1956 and 1960, an additional 10,000 miles were levelled and by the end of 1966 the total amount of control levelling had reached 76,000 miles, covering the whole continent.

The purpose of control levelling is to provide a framework of level traverses along roads, railways and tracks, with permanent bench-marks placed at certain intervals. The heights of these marks are obtained by geometric levelling, with reference to a datum mark which in turn is usually referred to mean sea level of a certain period at the main tidal gauging station of the state.

The control levelling net is designed to form loops of reasonable size. Lower order geometric levelling and other survey methods, including the use of the elevation meter, of which there are two in this country, are then applied to provide heights within loops. These heights may refer to permanent marks, temporary marks or natural and man-made features. The most important ultimate application of such heights is in topographical mapping.

Commonwealth and state mapping authorities are the main customers for levelled heights. Their requirements, however, would be met if the standard error of the height of any mark above the datum mark of the levelling survey did not exceed ± 2 ft.

Faced with a requirement for early levelling data in connexion with gravity and mapping surveys, and the doubtful effects of soil settlement and earth tides, Commonwealth authorities considered that a third-order levelling net, carried out mainly by contract surveyors, would provide the only practical and timely answer.

Commonwealth funds were provided for this purpose and the state surveyors-general have provided supervision at cost to the Commonwealth.

In terms of the National Mapping Council's *Standard Specification and Recommended Practices for Horizontal and Vertical Control Surveys*, the main requirements of the third-order levelling specifications are: the two levellings of each section between permanent bench-marks should not differ by more than $0.05(\sqrt{M})$ ft (M is the distance in miles between bench-marks measured along the levelling route); circuit closures should not exceed the same limit (M is the length of the circuit in miles along the levelling route).

The levelling survey began to take shape on a national basis in 1958. In the first instance, it was to extend vertical control to areas where oil and mineral surveys were in progress. Later on, it was to cover the whole continent with loops. This survey is of primary importance for the topographical mapping of Australia, for geological and geophysical surveys, and will be of enormous value in developing the country's water resources. Its benefit to engineering projects and to road and railway development can only be guessed at.

Some states are observing part of their levelling to second- or first-order standards and paying for this work out of state funds, assisted by a partial Commonwealth subsidy.

A diagram showing the completed and planned level traverses as of December 1966 is attached to this report.*

Since early in 1962, the Commonwealth Government of Australia has made considerable funds available for third-order levelling. The Director of National Mapping, in conjunction with the surveyors-general of the states, selects the routes of levelling. The placing of permanent marks and the actual levelling is carried out by private surveyors under contract and is supervised by the state surveyors-general.

The contract levelling work may be divided into four phases: (a) selection of levelling routes; (b) installation of

¹ The original text of this paper, prepared by K. Leppert, Division of National Mapping, Department of National Development, Canberra, appeared as document E/CONF.52/L.43.

* See pocket at end of volume.

permanent marks along these routes; (c) actual levelling between marks; (d) supervision, checking and recording of the levelling work carried out in phase (c).

This scheme of third-order contract levelling operates in the manner described below.

(a) The surveyors-general of the states recommend their third-order contract levelling programmes to the Director of National Mapping well before the beginning of the next financial year. The programmes are then considered from the point of view of their usefulness to the national scheme and the likely availability of funds. The approved programmes are included in the budget proposals and the surveyors-general are asked to supply detailed proposals for marking and supervisory costs and levelling costs.

(b) When the budget has been approved and after procurement demands have been signed by the Minister of National Development, contracts are let to the surveyors-general by the Contracts Board of the Department of Supply for marking, supervision, checking and recording of levelling work. Placing of permanent marks is then commenced.

(c) In the meantime, the surveyor-general invites private surveyors in his state to take part in the levelling programme. Those who show interest are offered a section of about 100 miles in length of third-order levelling at a price between \$A30 and \$A38 per mile, which includes the successful check-run in the opposite direction. Contracts are then let to these surveyors by the Contracts Board.

(d) All levelling is carried out with modern automatic levels and high quality calibrated wooden levelling staves. The contractor is supplied with a pair of calibrated staves 12 feet long free of charge. He can hire an automatic level for a fee of \$A0.30 per mile from the Division of National Mapping, which also supplies the levelling staves.

(e) The contract surveyor must adhere to a number of specifications which are designed to guarantee that all work is carried out in an expeditious and professional manner to the complete satisfaction of the surveyor-general.

(f) The contract surveyors' levelling is supervised by staff surveyors of the surveyor-general's offices, who also carry out random check levelling. After the completion of the field work, the contract surveyor submits his field notes and other relevant information to the surveyor-general. The notes are checked and if everything appears in order a progress payment of up to 90 per cent of the contract price is made. The final 10 per cent is paid on completion of a thorough check of the work.

In Queensland, where the Survey Branch of the Department of the Interior has levelled many thousands of miles in one direction only, with double-faced staves, selected routes are being levelled in the opposite direction by con-

tract surveyors using foot/metric double-faced staves. These two-way levelled routes form large loops which will be incorporated in the national levelling adjustment. The price for one-way contract levelling varies between \$A16 and \$A20 per mile.

Many contract surveyors operate with one observer, two staffmen and two vehicles, arranging their work in such a way that neither the surveyor nor the staffmen have to walk at all. With a maximum sighting distance of between 200 and 300 ft in flat country, some surveyors have been doing up to 14 miles of single levelling per day. The average per-party day is 7-8 miles.

Permanent marks are placed at intervals of 1 to 4 miles along levelling traverses. There are three types of marks: non-corrodable metal marks in precast concrete set in the ground; non-corrodable metal marks in solid rock or in concrete poured into a roughly cut hole; long galvanized iron or copper pipe marks in black soil or sandy country with a loose concrete collar.

All third-order levelling is being observed with automatic levels. In the early sixties, rather large section misclosures were obtained before the influence of a systematic error in the compensating mechanism of automatic levels was recognized. This error is now being successfully compensated through an appropriate observing technique. Other systematic errors are feared to be the cause of a few misclosures just outside the allowable limit in sections of 50 miles and more in length.

An analysis of the misclosure of 95 loops of between 60 and 930 miles in length, with an average length of 280 miles, results in a standard deviation for 1 mile of levelling of ± 0.036 feet. On this basis, it should be possible to level from the coast to the centre of the continent with a standard error of ± 1.2 feet.

Simultaneous observations at thirty-one tidal gauging stations on a continuous basis for a period of twelve months is being arranged at present by members of the National Mapping Council. The object is to obtain mean sea level at these stations for the same epoch. The digitizing of gauging charts and subsequent computation of mean sea level and tidal constants for each station is being managed by the Horace Lamb Centre for Oceanographic Research of the Flinders University of South Australia.

The adjustment is to take place in 1970, when all the planned level traverses have been completed. Loops to be included in the adjustment will be recommended by the National Mapping Council in the near future. It is almost certain that normal orthometric heights will be adopted.

The adjustment will be the culmination of a concentrated effort to establish a national levelling survey in Australia. It is expected that about 100,000 miles of control levelling will be completed at the time of the adjustment and that the results will be completely satisfactory for mapping and for many other survey purposes.