Hydraulics Research
Wallingford

SEDIMENTATION IN RESERVOIRS
TANA RIVER BASIN, KENYA

III - Analysis of hydrographic surveys of three reservoirs in June/July 1983

Part B - Computer graph plots of cross-section data

by

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In collaboration with :

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1 INTRODUCTION

1.1 The Tana River is the largest river in Kenya and the country's major surface water resource (Figure 1). The catchment area is 94 700km ^{2} - representing about 16% of the land area of Kenya and containing some 20% of the national population. Including the headwaters of the Sagana, the river is 1012 km long and flows from Mount Kenya and the Aberdare Range to the Indian Ocean. The potential for development of the river for hydropower and irrigation is high and several reservoir schemes are in existence (Figure 2) or planned for the near future. Since the first reservoir was impounded in 1974 (Kamburu), the problems of erosion from the catchments and the subsequent deposition of sediment in successive reservoirs have been noted by the relevant Kenyan authorities. The magnitude of the problem in Kenya and the need for the Overseas Development Unit (ODU) of Hydraulics Research Limited to collect reliable field data over a number of years led to an investigation being undertaken by ODU in collaboration with the Tana and Athi Rivers Development Authority (TARDA), the Ministry of Water Development (MOWD) and the Kenya Power and Lighting Company Limited (KP & L). Proposals for an investigation based on the upper Tana River were submitted following a visit to Kenya by a member of the ODU staff in December 1979(1); a revised summary of these proposals was agreed after a series of meetings on site during July 1980(2).

1.2 The proposals included a requirement to collect cross-section data for the three reservoirs, Kindaruma, Kamburu and Masinga. The tabulated data is given in Part A of this report and Part B contains computer-plotted cross-sections.

2 SITE DETAILS

Location of range lines

2.1 The position and number of range lines for any given reservoir needs to be chosen with considerable care to ensure that subsequent soundings along the lines will give all the data necessary for an accurate assessment of the sediment volume. It is fairly easy to list the points which should be considered when selecting range line locations under ideal conditions. However, it is possible that many items included in the list may have to be modified to suit the particular site, so it is difficult to set down hard-and-fast rules.

2.2 In selecting the range lines for this investigation, the following recommendations were complied with whenever possible:

(a) the range lines were not more than 1 km apart and preferably about ½ km.

(b) the range lines were approximately normal (ie. at right angles) to the old river channel.

(c) the divergence between adjacent range lines was not more than about 30° except where major bends in the channel made it impracticable; in this case the divergence went up to 60° and, in exceptional conditions, 90°.

(d) range lines were drawn directly across the mouth of any tributaries joining the main river channel.

(e) the end-of-line markers were sited above the maximum high water level. Where there was an island on the line, care was taken to ensure that it did not obscure either of the markers. If there was any doubt, additional markers were sited on each side of the island.

(f) the positions of the end-of-line markers were chosen to give the maximum inter-visibility.

2.3 With the above points as a guide, maps of the three reservoirs were drawn to show 10 range lines on Kindaruma, 29 on Kamburu and 71 on Masinga reservoirs (Figures 3, 4 and 5). Each section was given a unique code by which it was identified on the ground, in field books and throughout the analysis. Care was taken to ensure that the names would still be recognisable even when written hurriedly in a field book on board a moving survey boat. The standard convention was used whereby the ends of the lines were labelled "left" and "right" when looking downstream.

2.4 During the period 1975 - 1978, Consultants to the Kenya Power and Lighting Company Limited (KP & L), for the first four reservoirs - Engineering and Power Development Consultants (EPDC) - ran a series of annual hydrographic surveys of Kamburu reservoir using a total of eight range lines. This was repeated in 1980 with three additional range lines and these eleven lines were included as a part of the 1982 ODU survey. Ten of the eleven range lines are identified on Figure 4 - the remaining line (TN1) is not shown because co-ordinate data for the end-of-section markers are not available, as is also the case for TN2.

Reservoir beacons

2.5 The positions of the range lines were chosen after a careful study of a series of contour maps produced from an aerial survey flow in February 1965 by Hunting Surveys Limited. On site, the precise locations of the end-of-section markers were selected to be in front of any major obstructions (such as rocks or large trees) and, where possible, to be away from areas frequently visited by people and animals.

2.6 Each marker had to be a permanent structure which would be relatively easy to locate after two or three years. The design and construction of the markers on Kindaruma and Kamburu reservoirs were carried out by EPDC staff with finance made available by KP & L. They were made from in-situ mass concrete and designed to stand about 4.5ft (1.4m) above ground level and were about 1.5ft (0.5m) square in section. The design and installation of markers on Masinga reservoir was under the control of TARDA; they were concrete posts 1.4m high and 0.4m square. The locations and levels of these beacons were surveyed by Geosurvey International Limited.

2.7 The human eye can resolve a minimum of one second of arc (1/3600 degree) if the target is set against a plain, contrasting background. On Kamburu reservoir, the longest range line was approximately 1700m, which required a minimum target size of 0.49m. In practice, this was doubled to 1m to reduce the risk of losing sight of the beacon when viewing it from a moving boat. The face of the target was also covered with flourescent pink sheeting to increase the contrast when seen against a background which varied from bright, clear sky to dark, variegated foliage.

2.8 After construction, the precise locations of the markers round Kindaruma and Kamburu reservoirs were surveyed for KP & L by Griffiths Engineering and Hydrographic Surveys of Nairobi, and the co-ordinates and levels were sent to ODU in November 1981. The co-ordinates were related to the Plane Local Engineering (PLE) grids which were used during the periods of dam construction and were specific to each project site (ie. the PLE grid at Kindaruma is not directly related to the PLE grid at Kamburu) and EPDC found that it was not possible to tie the PLE grids into the Kenya Survey grid. In order to locate the range lines, each marker position was plotted relative to the PLE grid, and to the same scale as the reservoir drawings. This plot was then superimposed on the reservoir drawings and the position adjusted until all the markers were above the maximum reservoir water level. The Kenya survey grid and the assumed PLE grid are shown on Figures 3 and 4 for Kindaruma and Kamburu reservoirs respectively.

2.9 This method of locating the markers, by plotting their relative positions and then adjusting the whole pattern, has been vindicated by comparing the surveyed ground levels with those taken from the contour maps. In most cases, the levels agreed to within accuracy with which the contours were drawn, that is $\pm\frac{1}{2}$ contour interval $\pm$(5ft).

3 HYDROGRAPHIC SURVEY

3.1 The basic technique which was followed throughout the surveys required a minimum team of four people - 3 men in the boat and one onshore.

3.2 The shore man was equipped with a VHF radio and a theodolite which he set up either over or behind a range line marker. The theodolite was aligned to sight the corresponding beacon on the opposite bank - the man was therefore looking along the range line. A small boat fitted with an echo sounder and radio was talked along the line following instructions from the theodolite observer. Initially, the position of the boat was fixed as often as possible by observing single, horizontal sextant angles from the boat between the range line and any suitable visible beacon; this method was later superseded by the use of a direct reading laser range finder. At the same instant that the position fix was taken, a "fix mark" was made on the echo-sounder trace.

3.3 A topographic survey was made at each end of the range line from the top of the end-of-range marker to the water's edge, so that the marker top became the elevation reference datum for the soundings.

3.4 The echo-sounder was calibrated on several occasions during the course of the survey using the conventional bar-check technique. This involved lowering a metal target to known depths below the water surface. The "speed of sound" control was adjusted until the recorded depths corresponded to the actual depths of the target. It was found that very little, if any, adjustment was necessary from one calibration to the next.

3.5 Details of the computer programs used in the plotting and analysis of these data are given in Part A of this report.

Figures

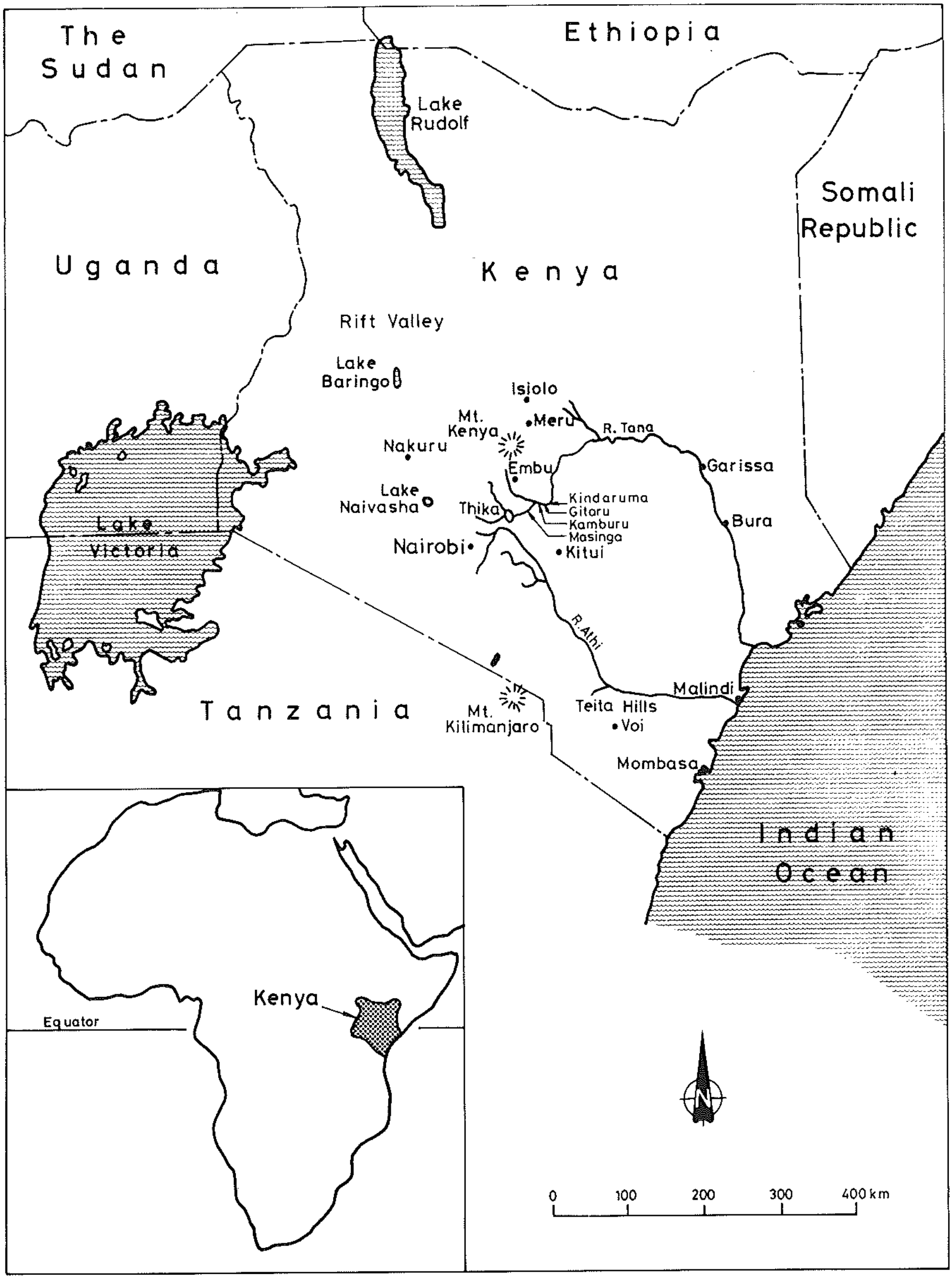


Fig 1 Location map

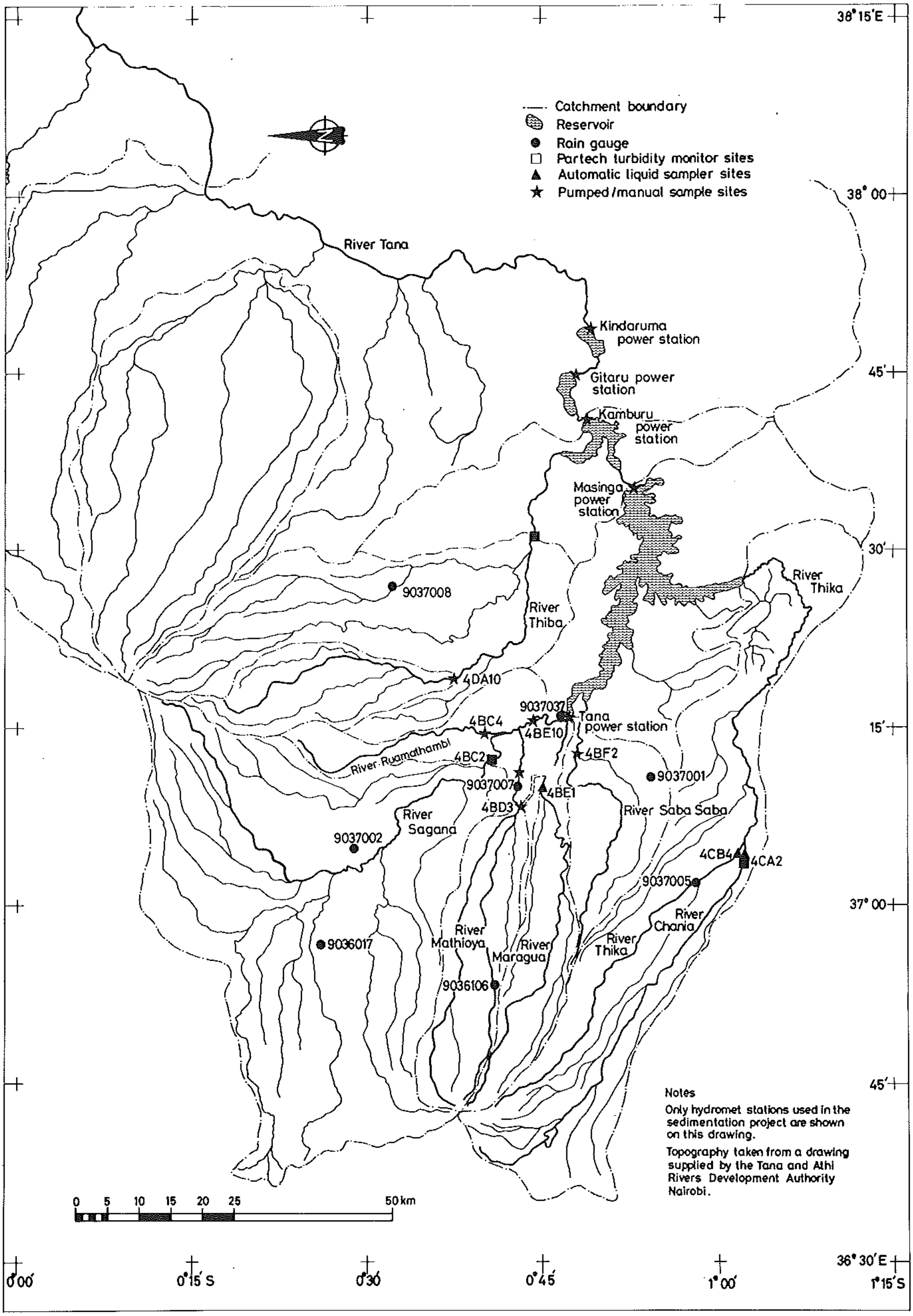


Fig 2 Tana River basin

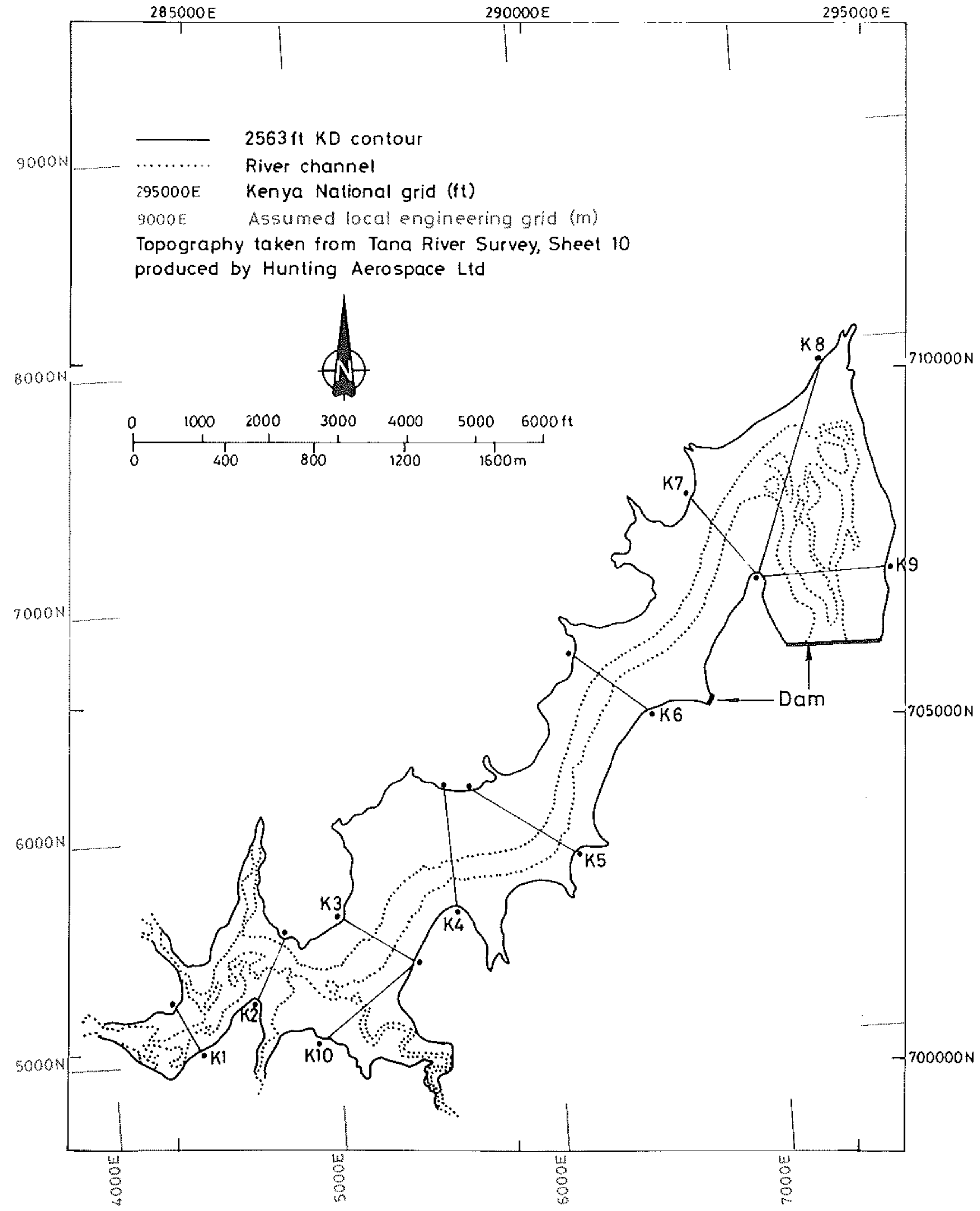


Fig 3 Kindaruma Reservoir

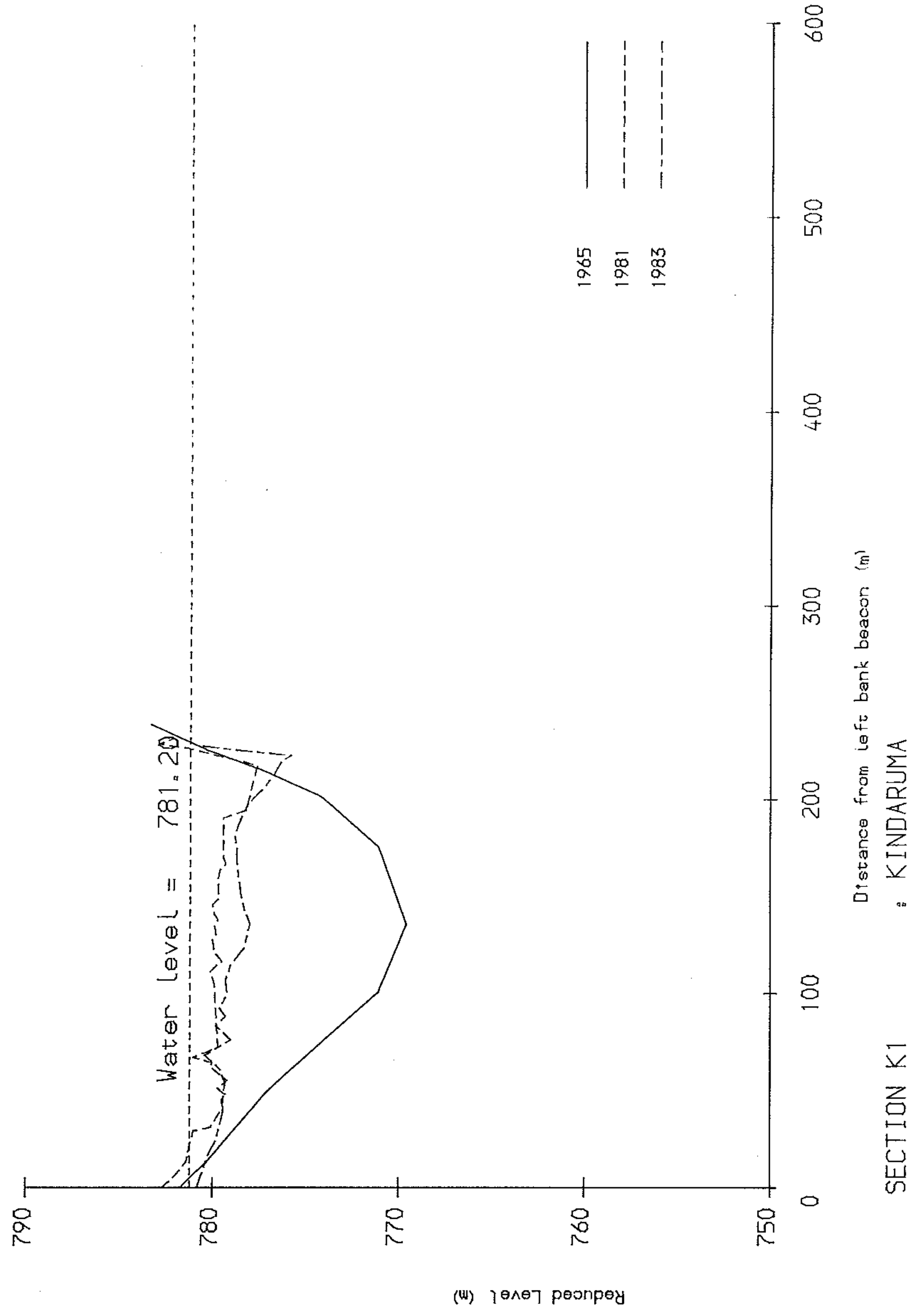


Fig 3·1 Kindaruma Reservoir - section K1

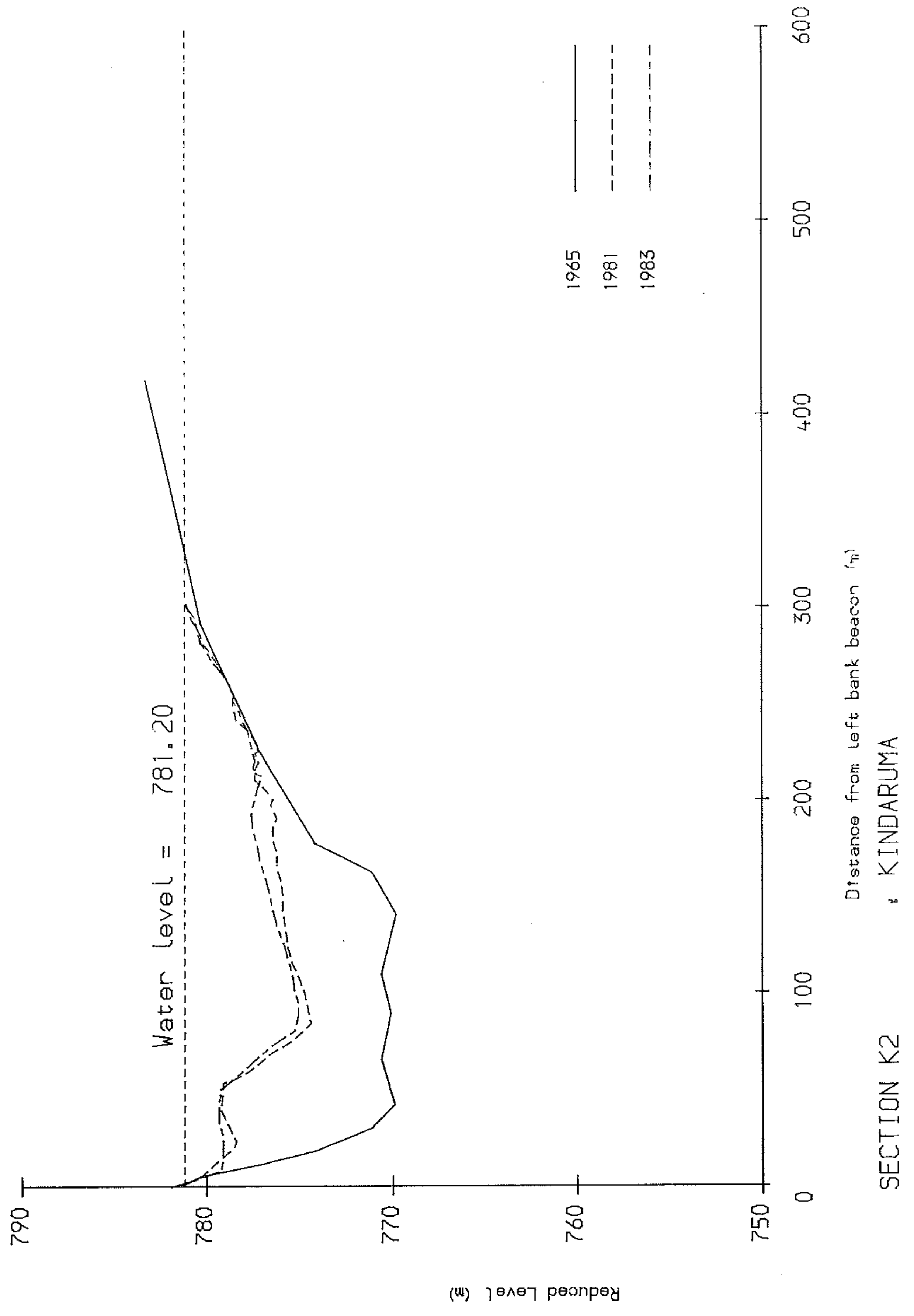


Fig 3·2 Kindaruma Reservoir - section K2

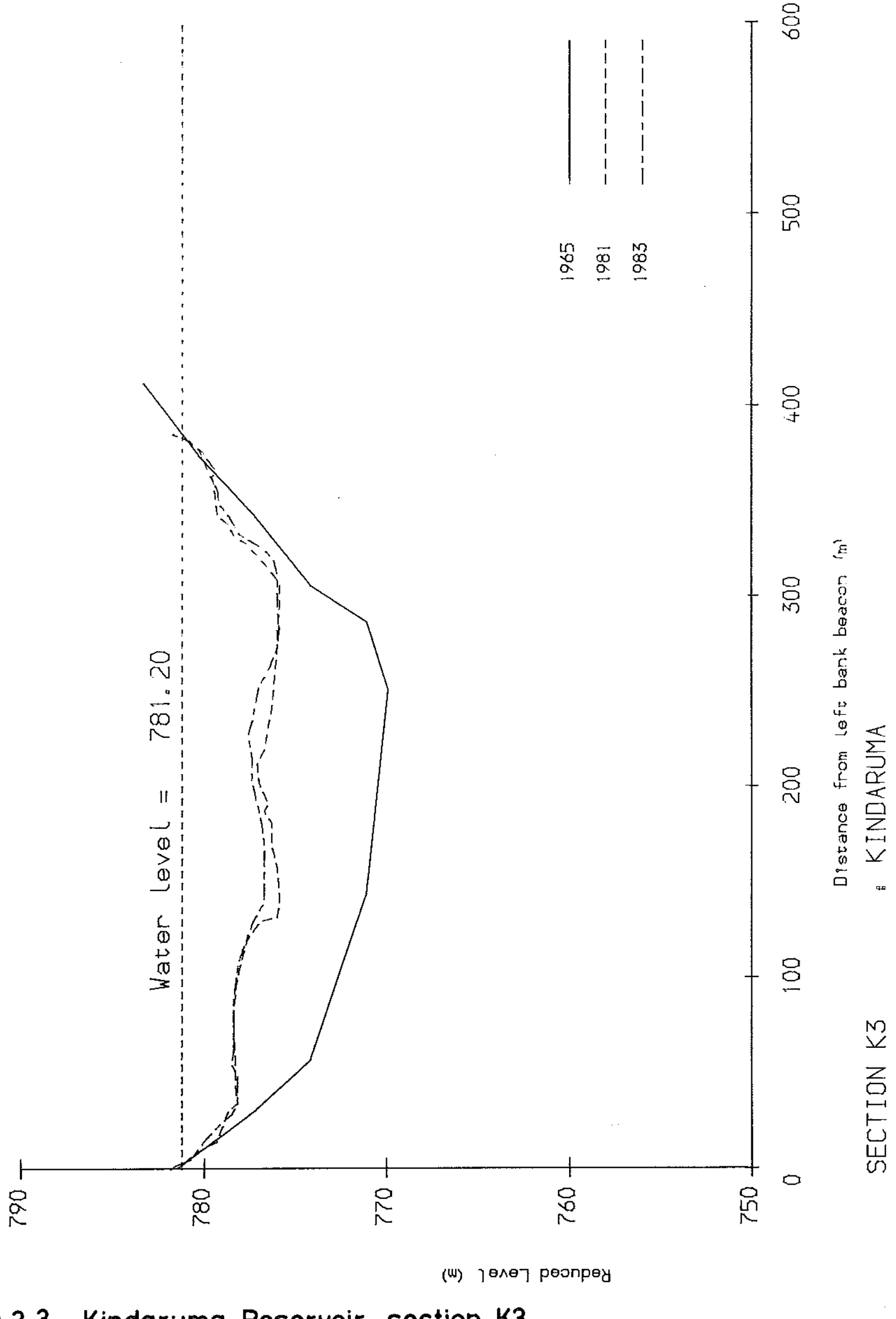


Fig 3·3 Kindaruma Reservoir-section K3

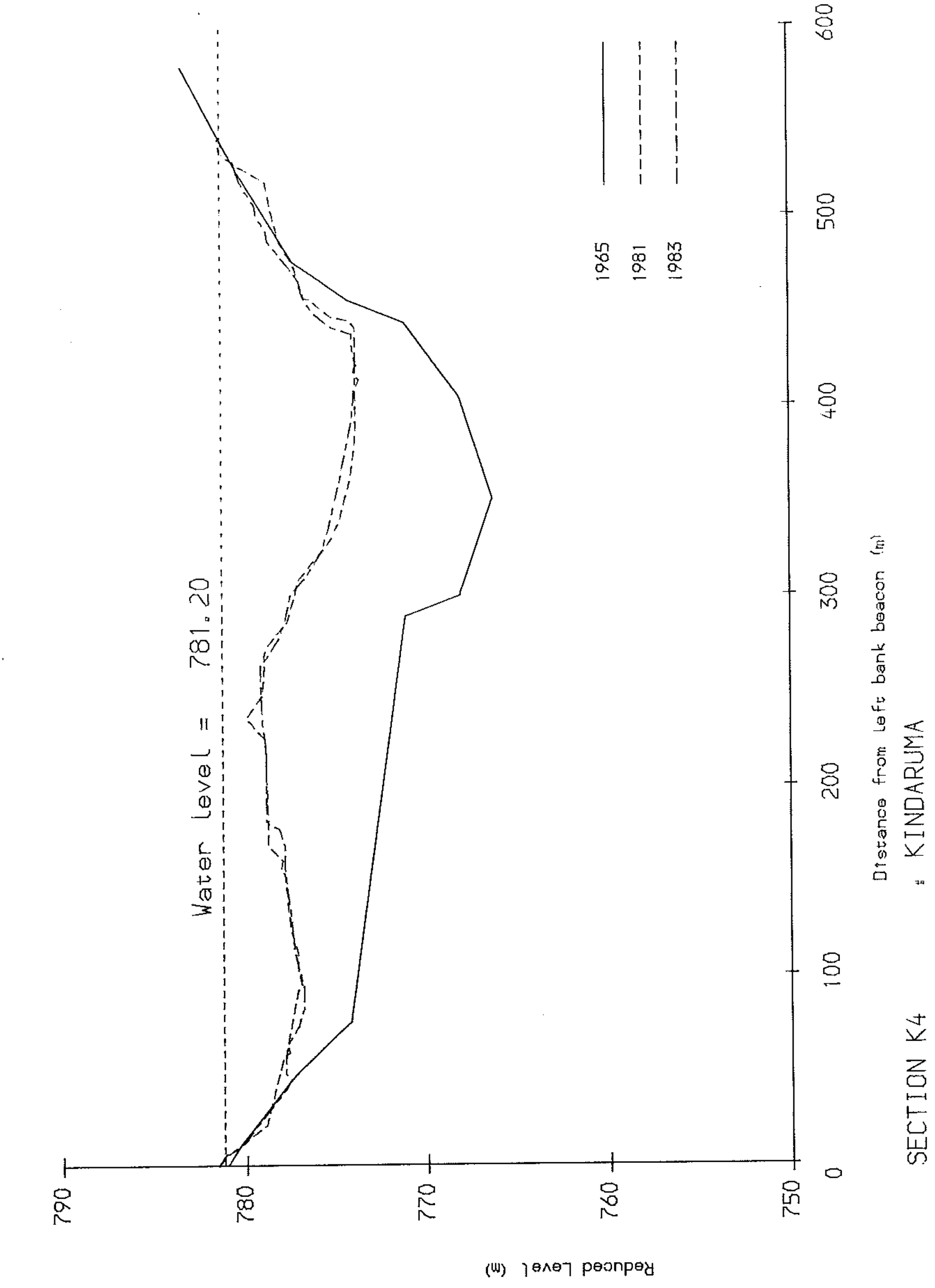


Fig 3·4 Kindaruma Reservoir – section K4

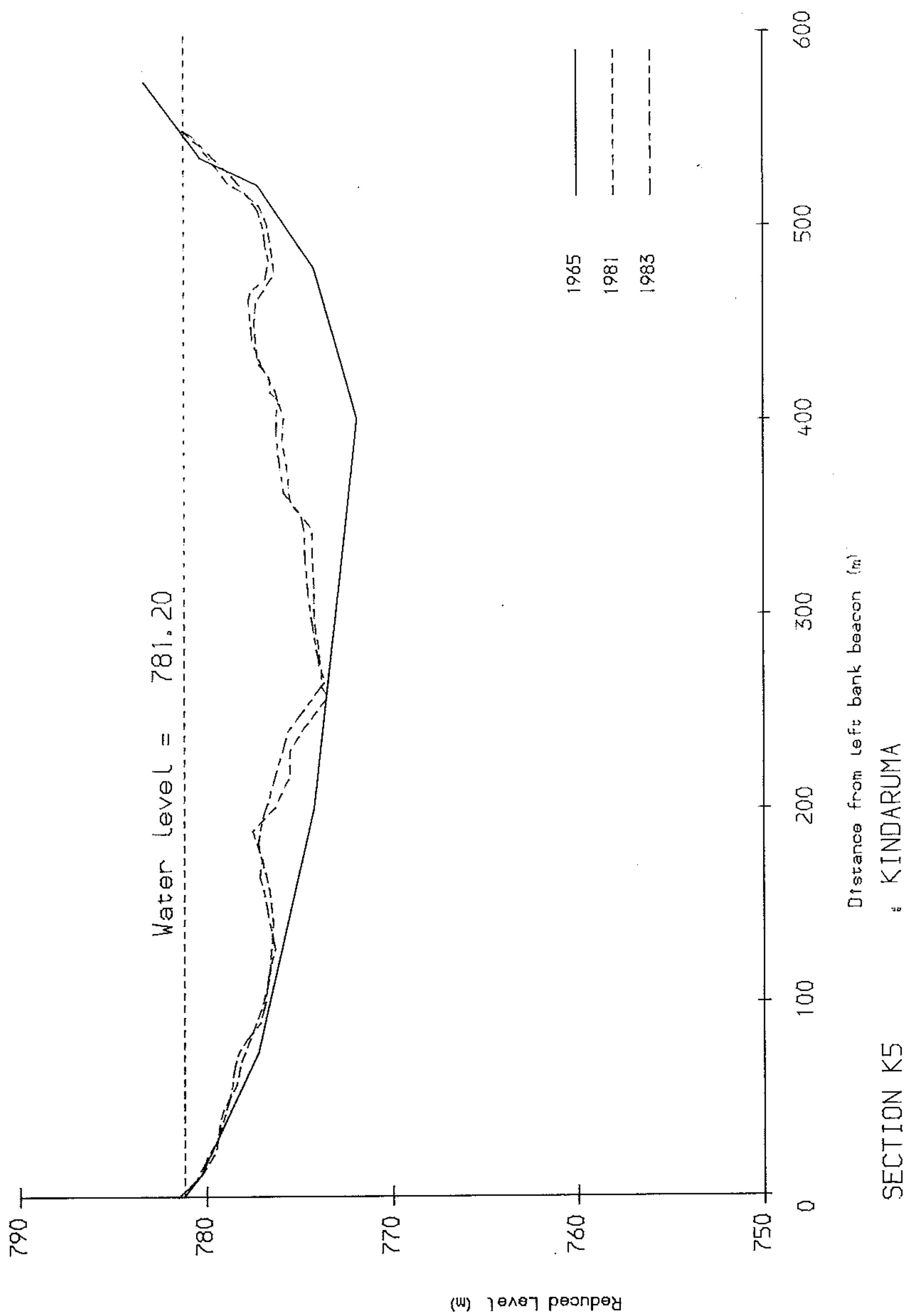


Fig 3·5 Kindaruma Reservoir - section K5

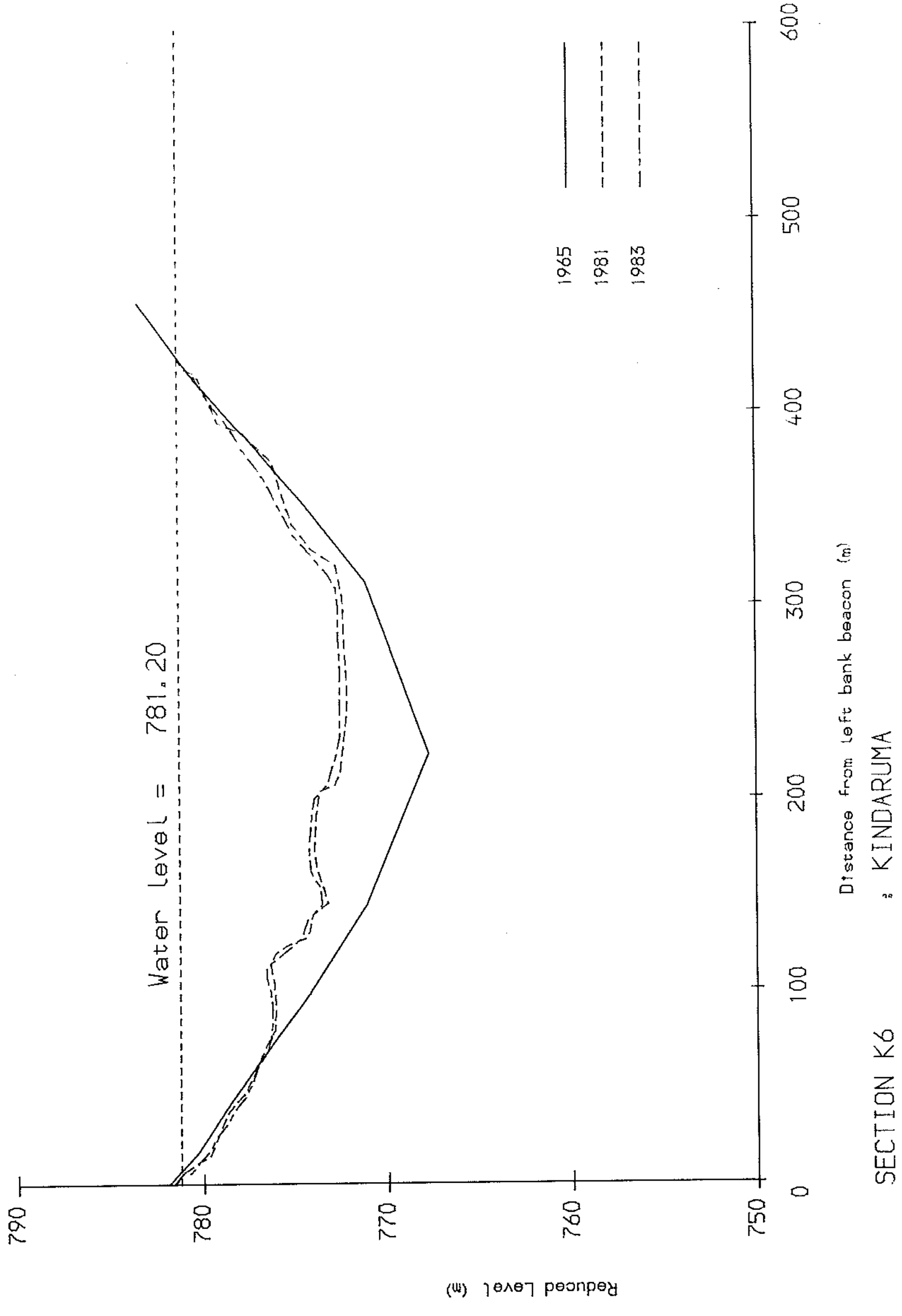


Fig 3·6 Kindaruma Reservoir - section K6

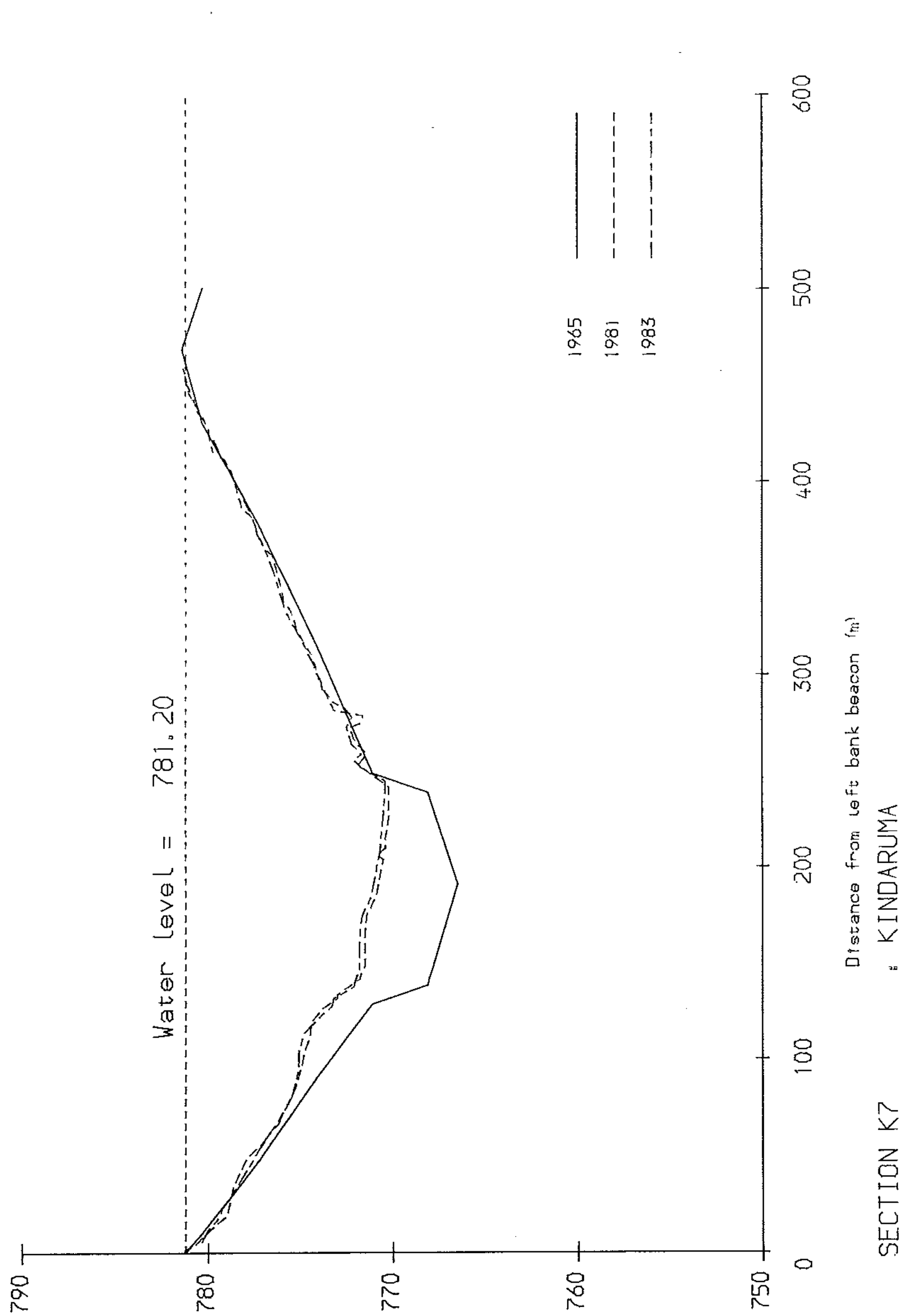


Fig 3·7 Kindaruma Reservoir - section K7

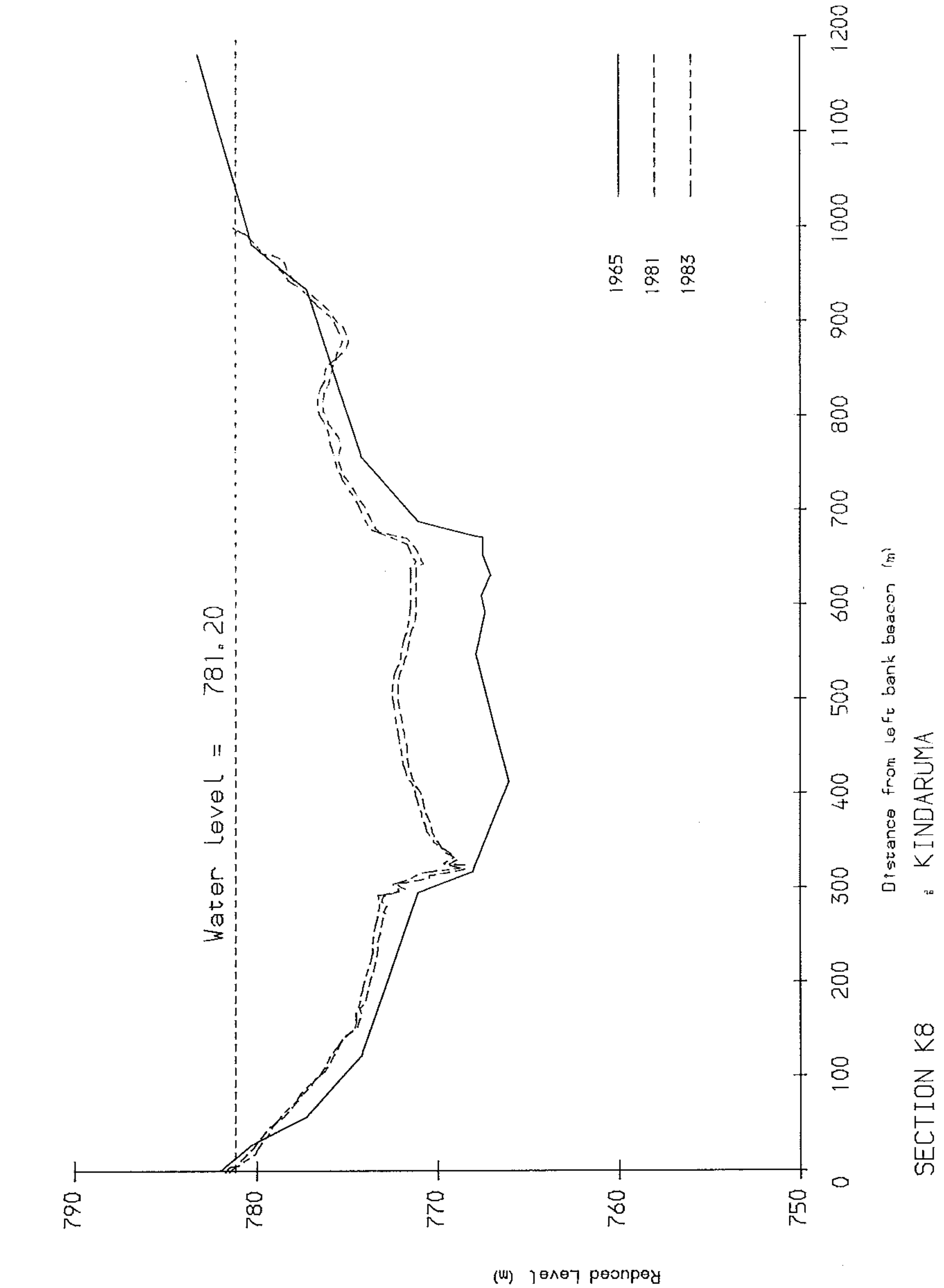


Fig 3·8 Kindaruma Reservoir – section K8

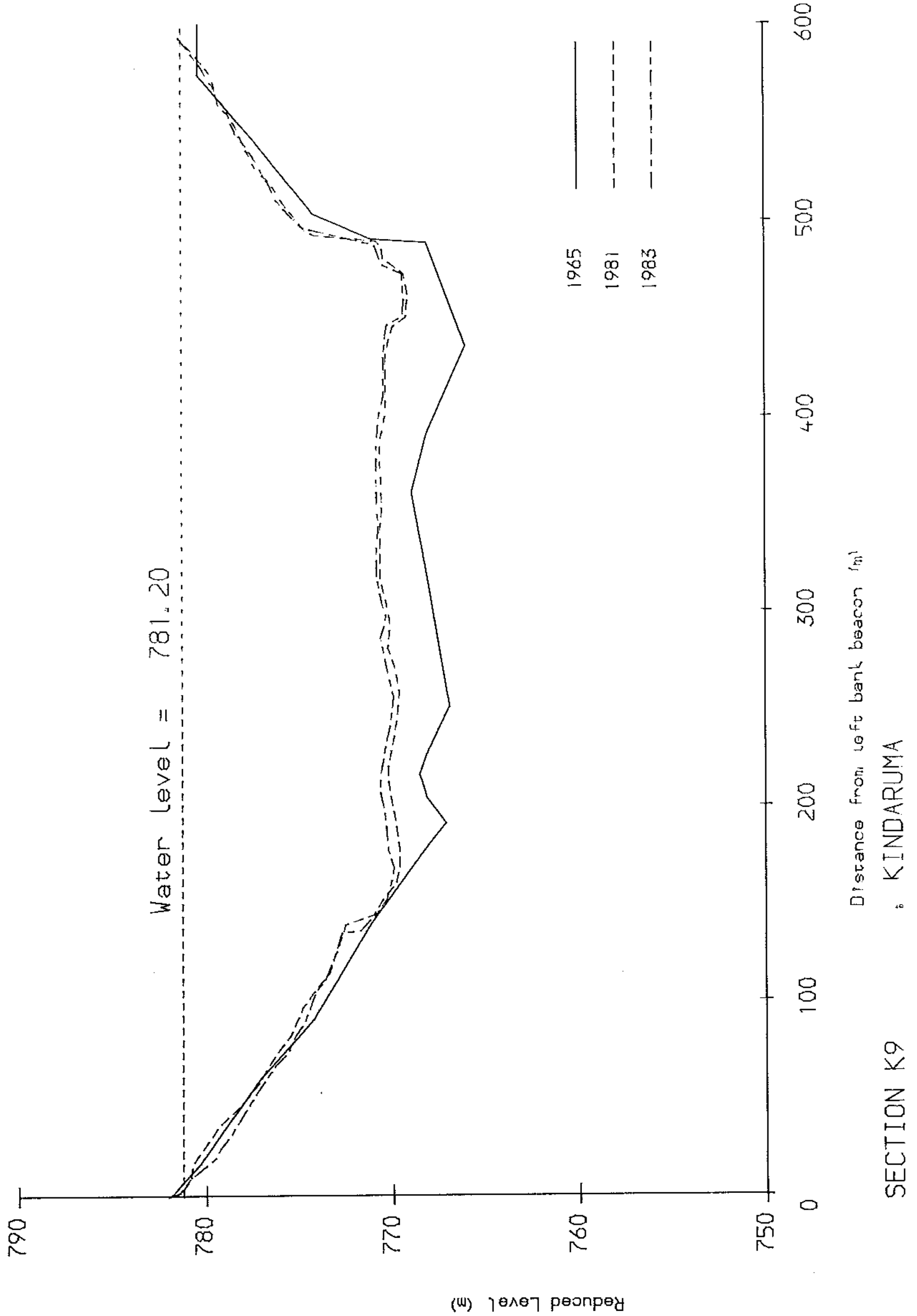


Fig 3·9 Kindaruma Reservoir – section K9

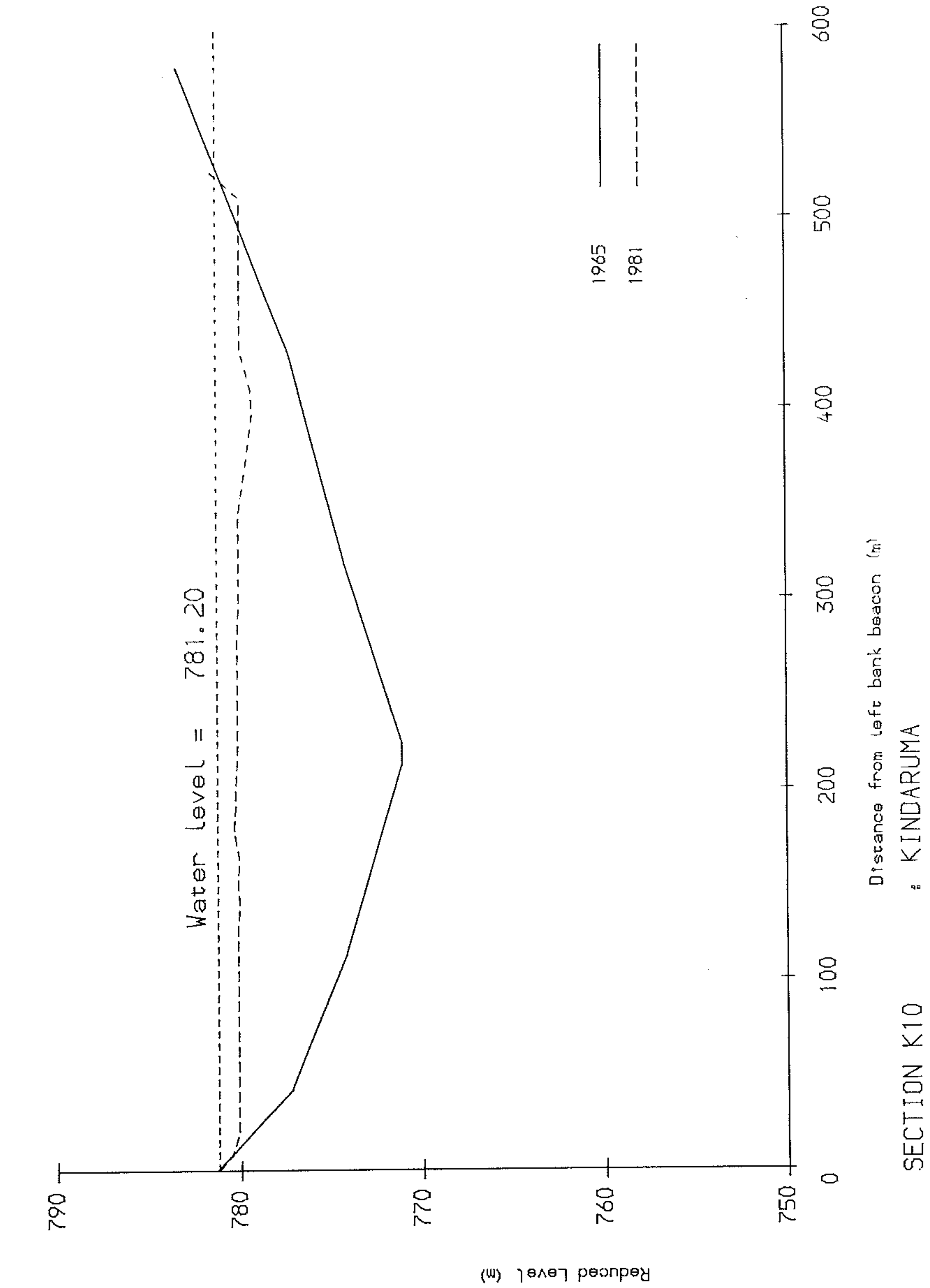


Fig 3·10 Kindaruma Reservoir - section K10

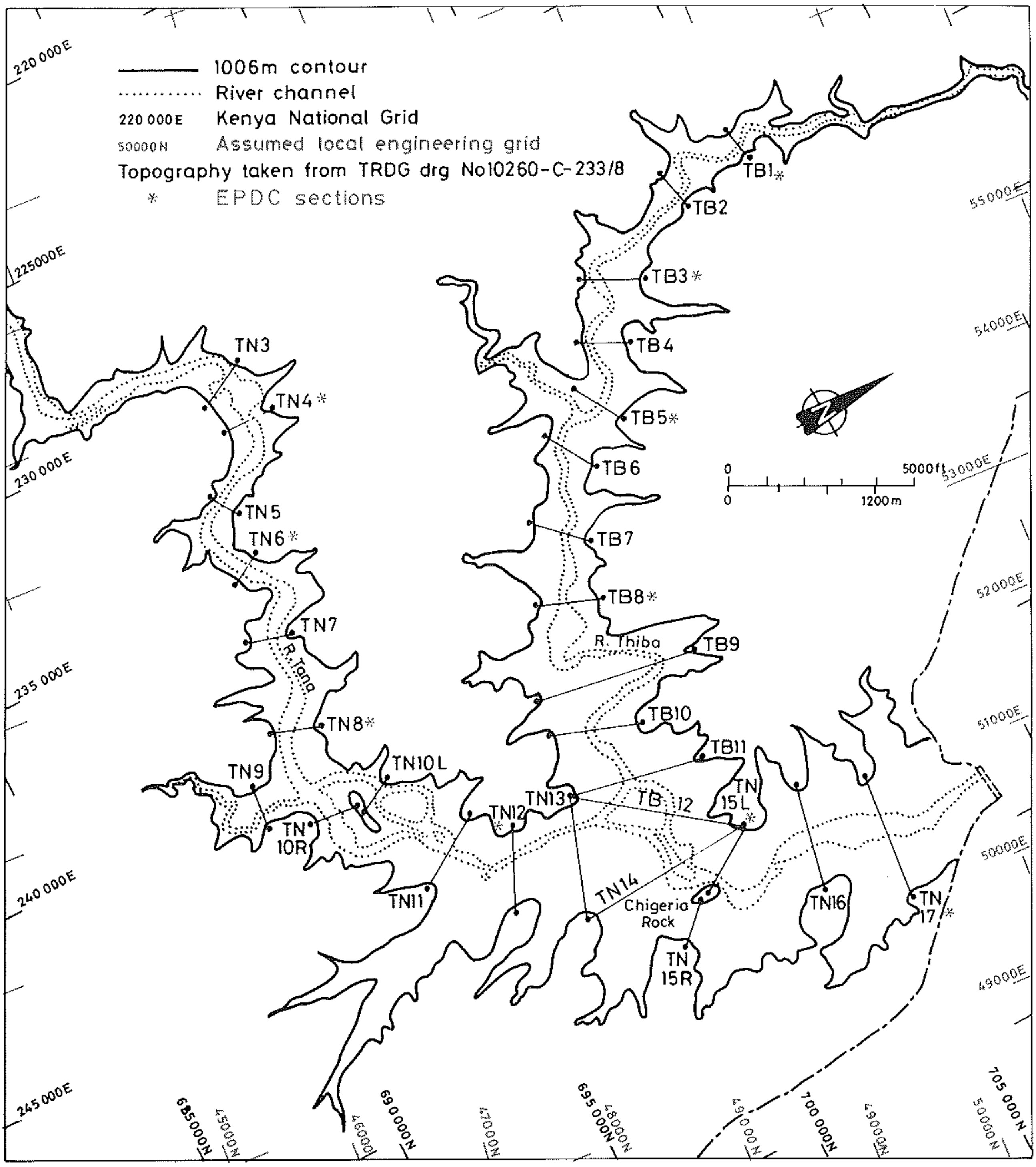


Fig 4 Kamburu Reservoir

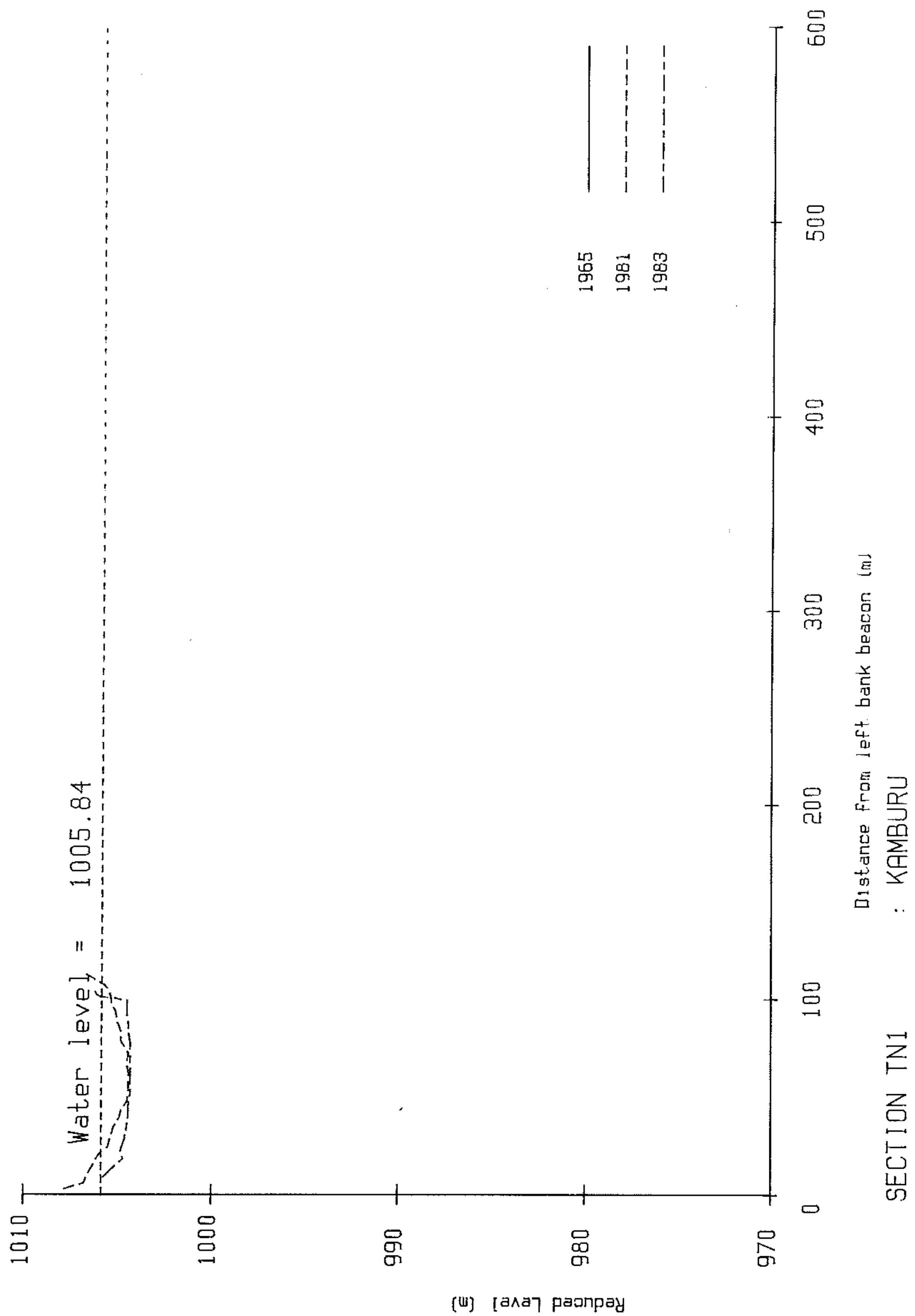


Fig 4·1 Kamburu Reservoir – section TN1

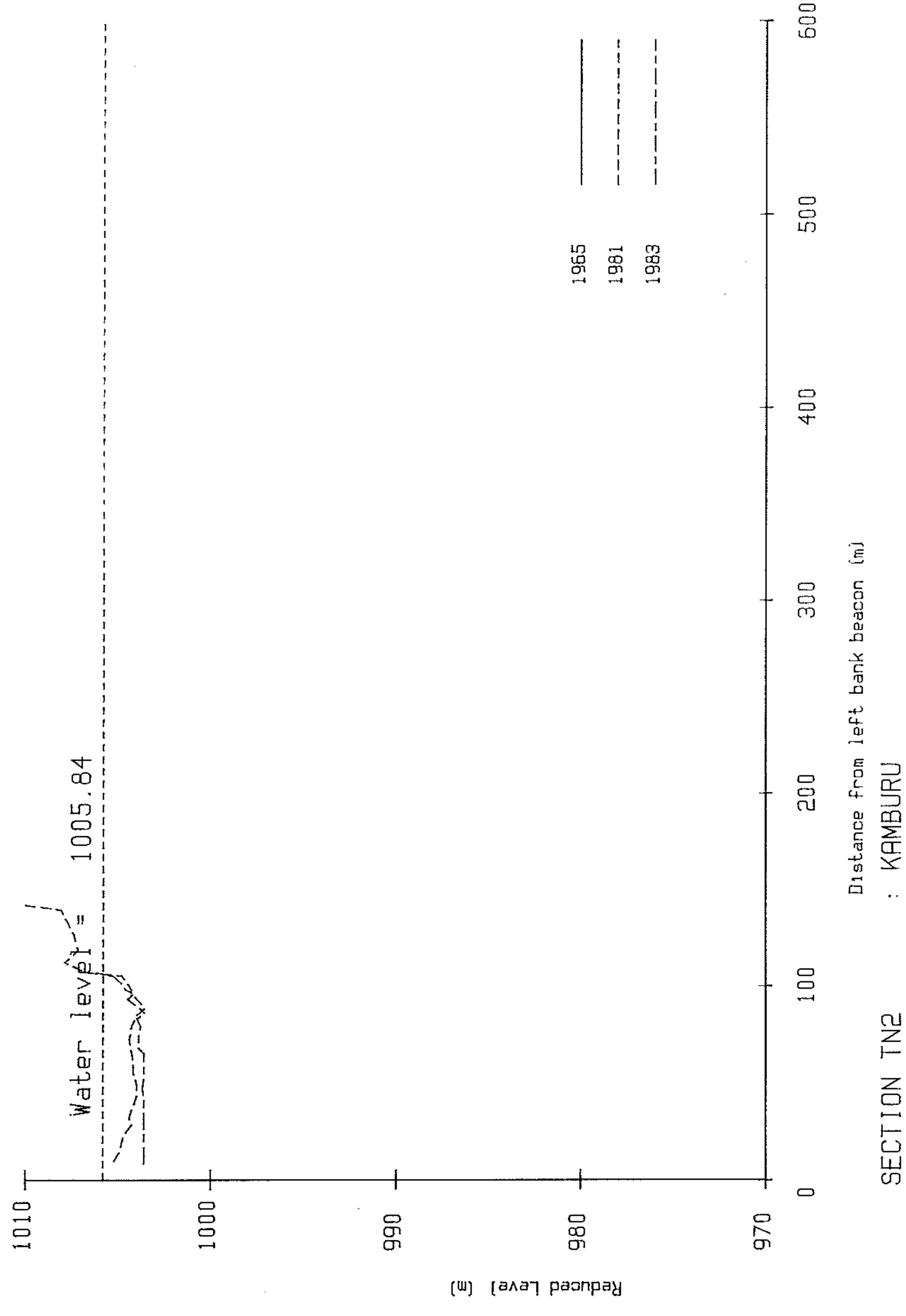


Fig 4·2 Kamburu Reservoir- section TN2

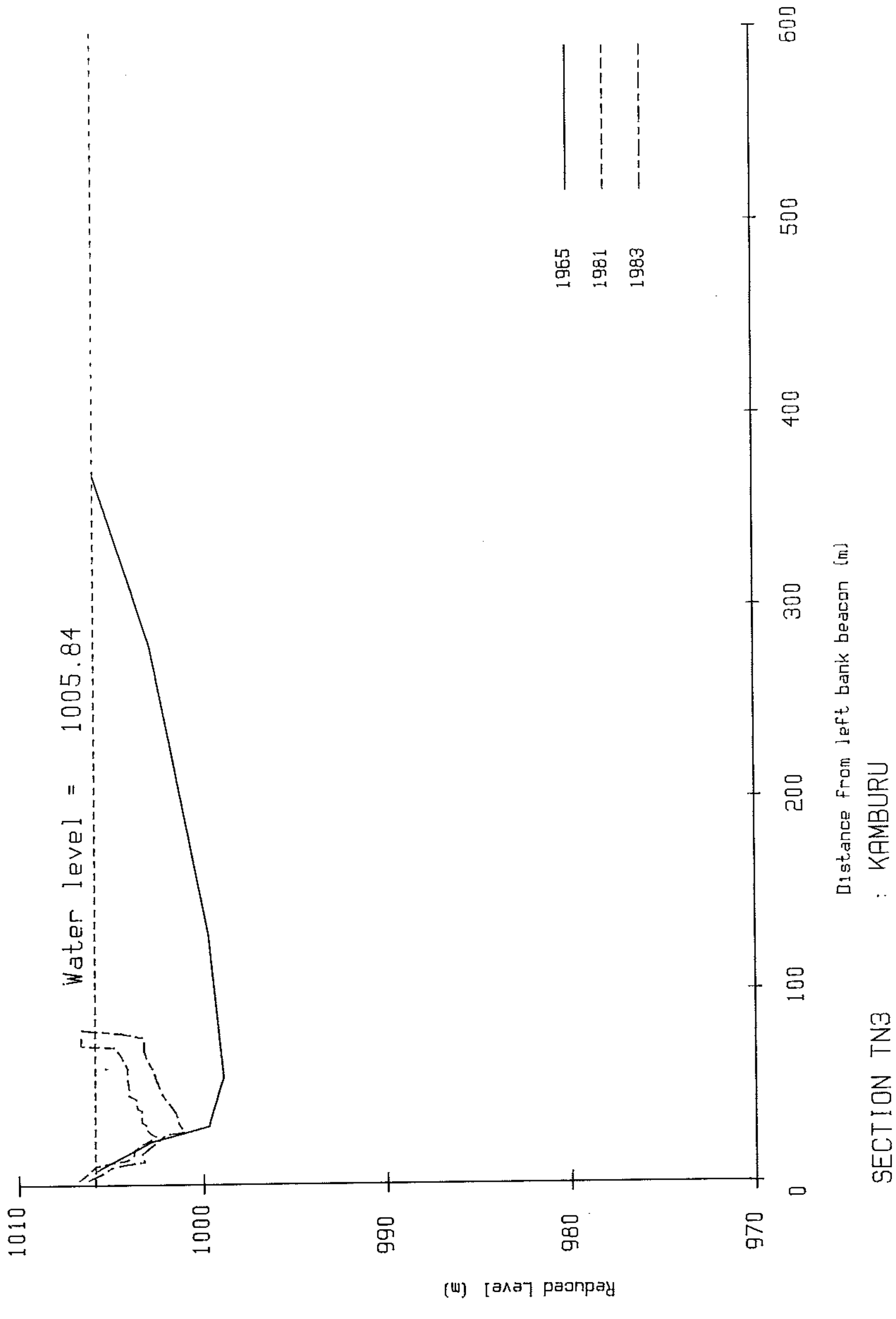


Fig 4.3 Kamburu Reservoir - section TN3

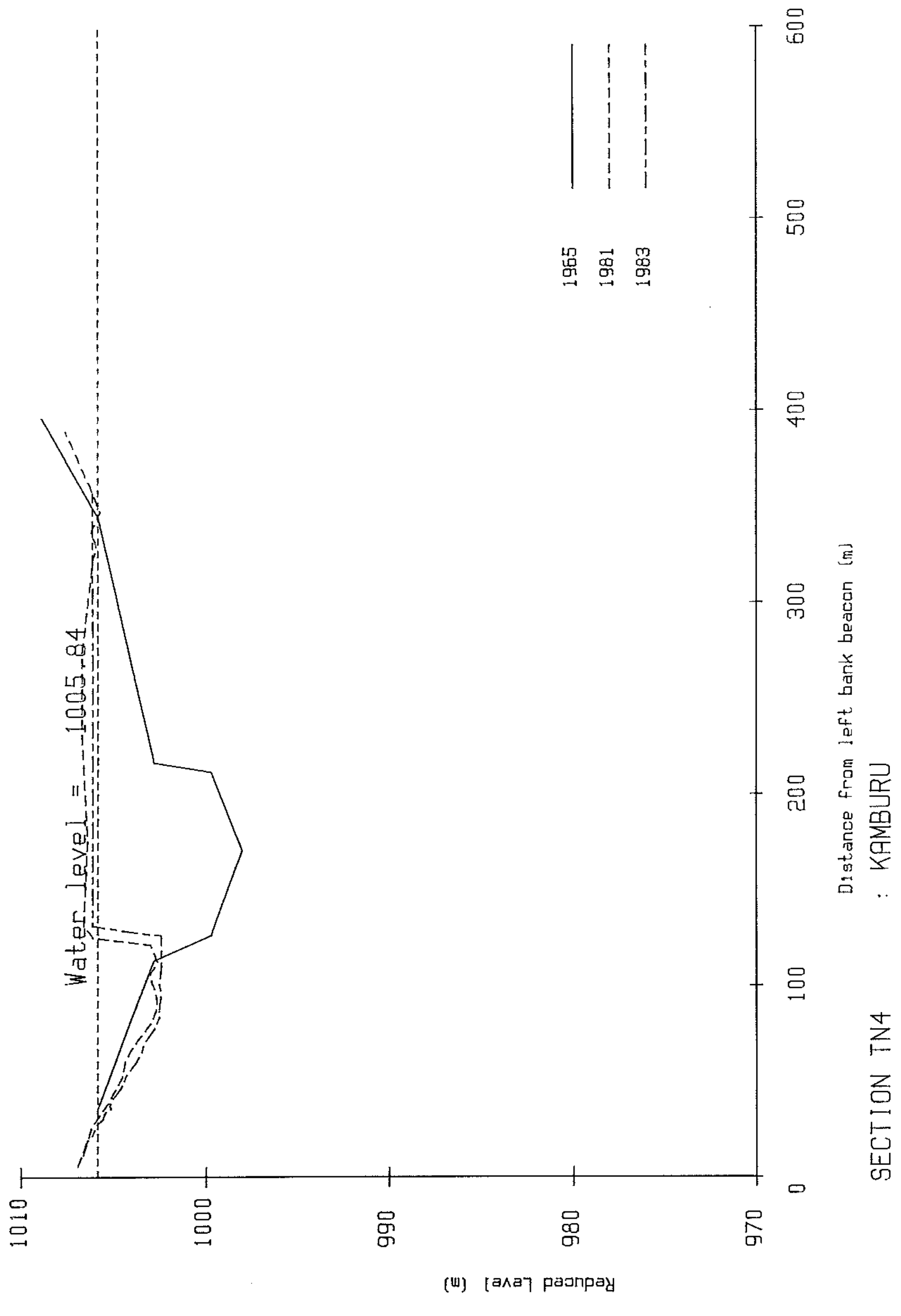


Fig 4·4 Kamburu Reservoir – section TN4

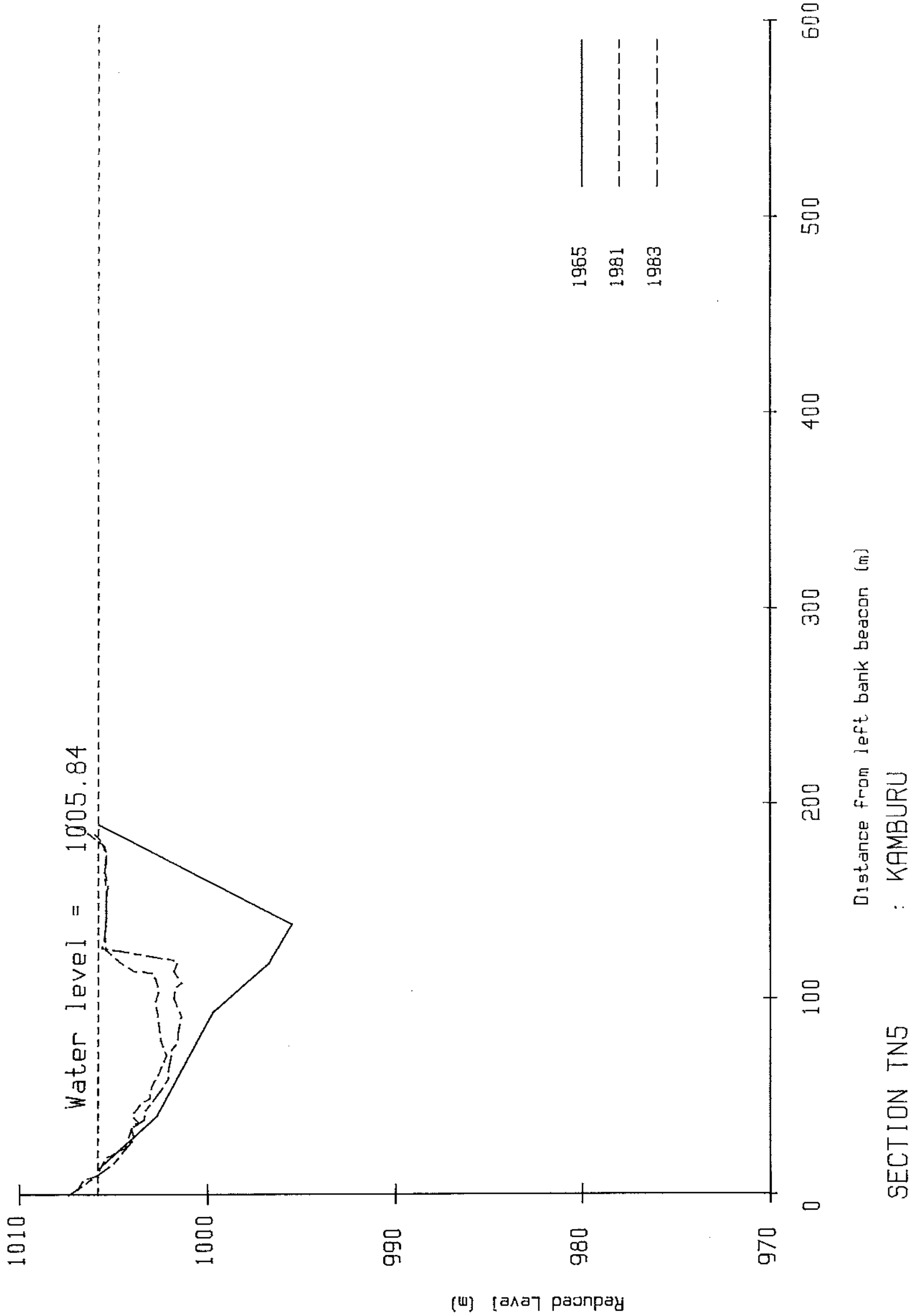


Fig 4·5 Kamburu Reservoir – section TN5

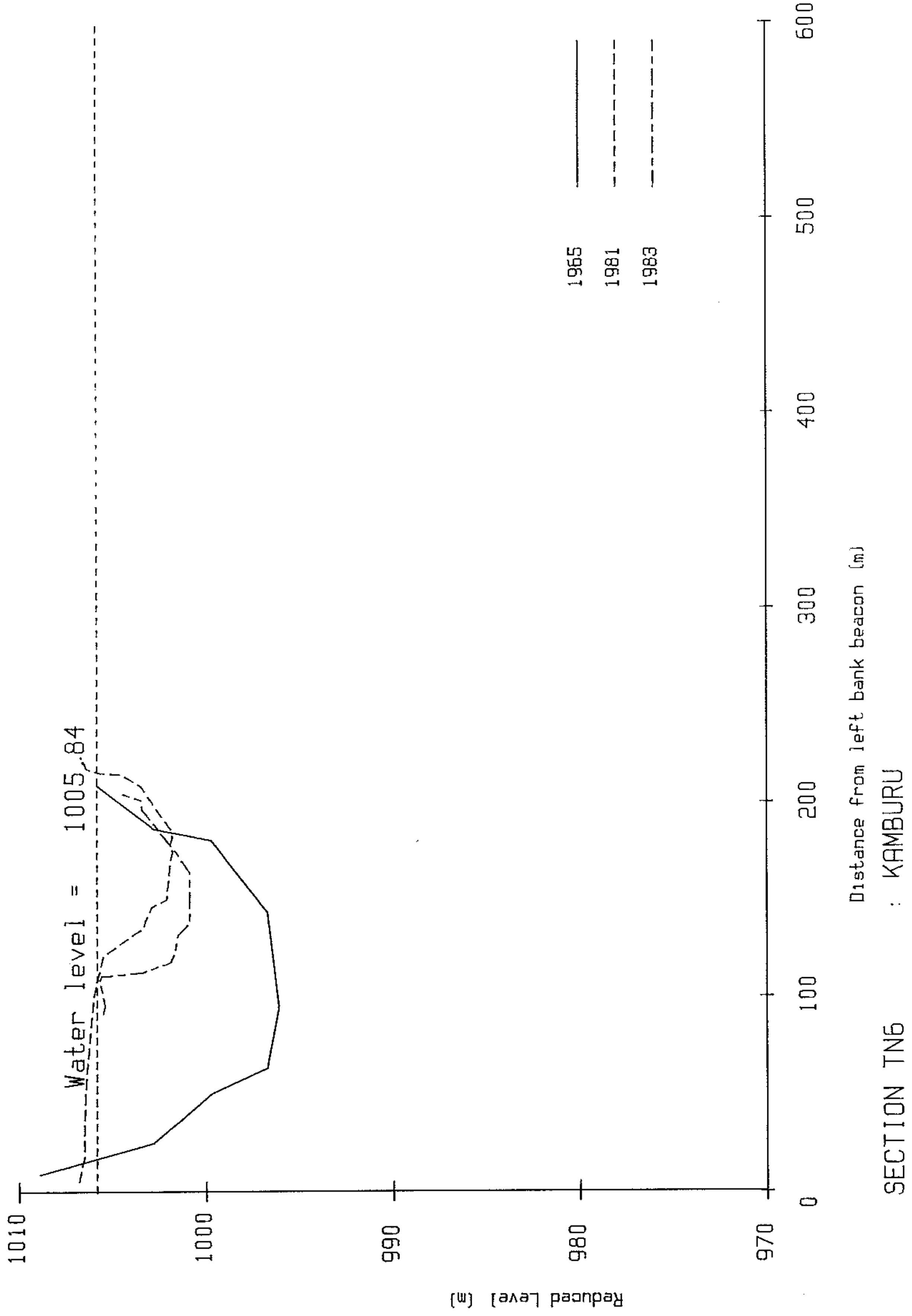


Fig 4·6 Kamburu Reservoir - section TN6

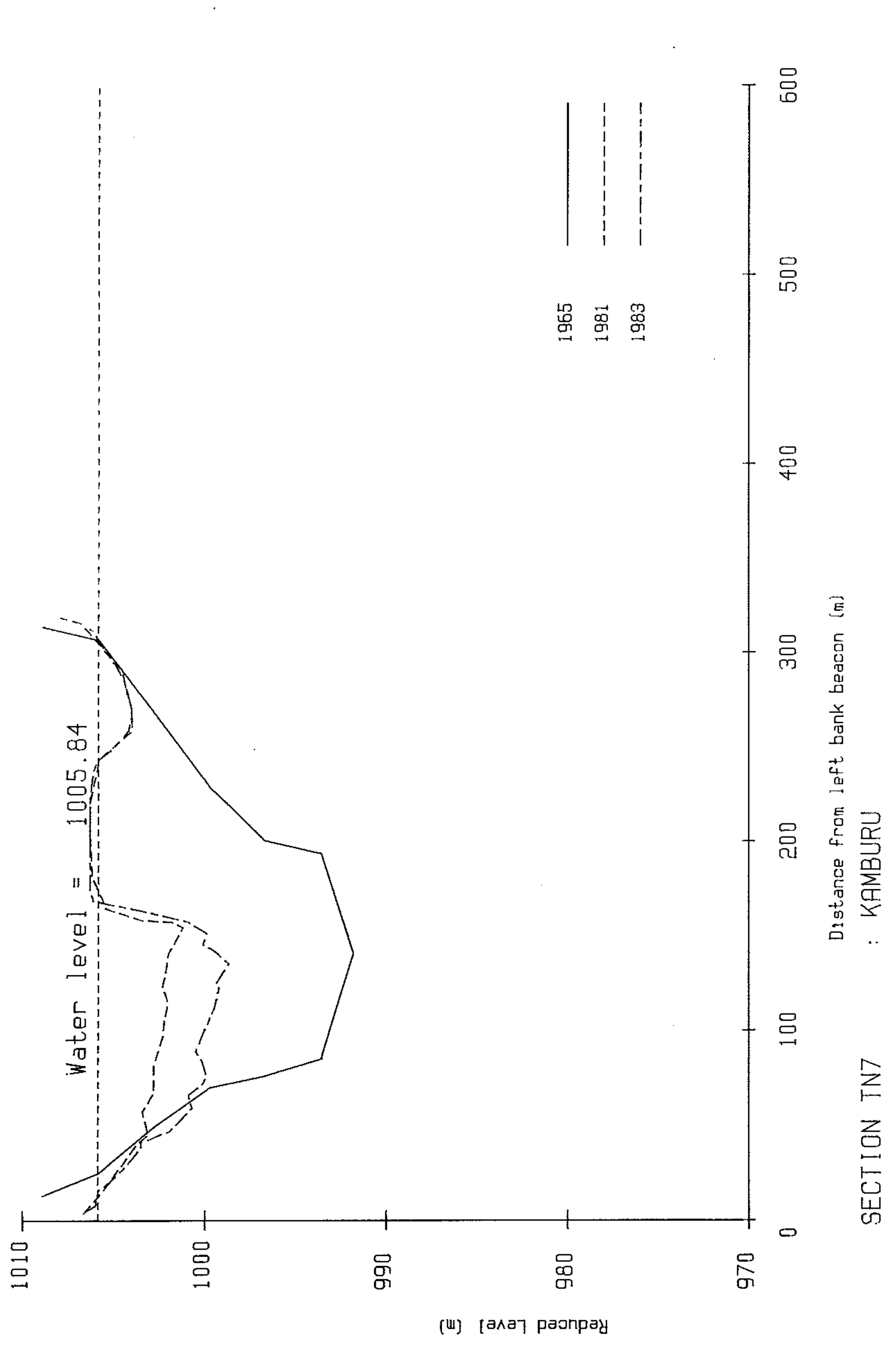


Fig 4·7 Kamburu Reservoir–section TN7

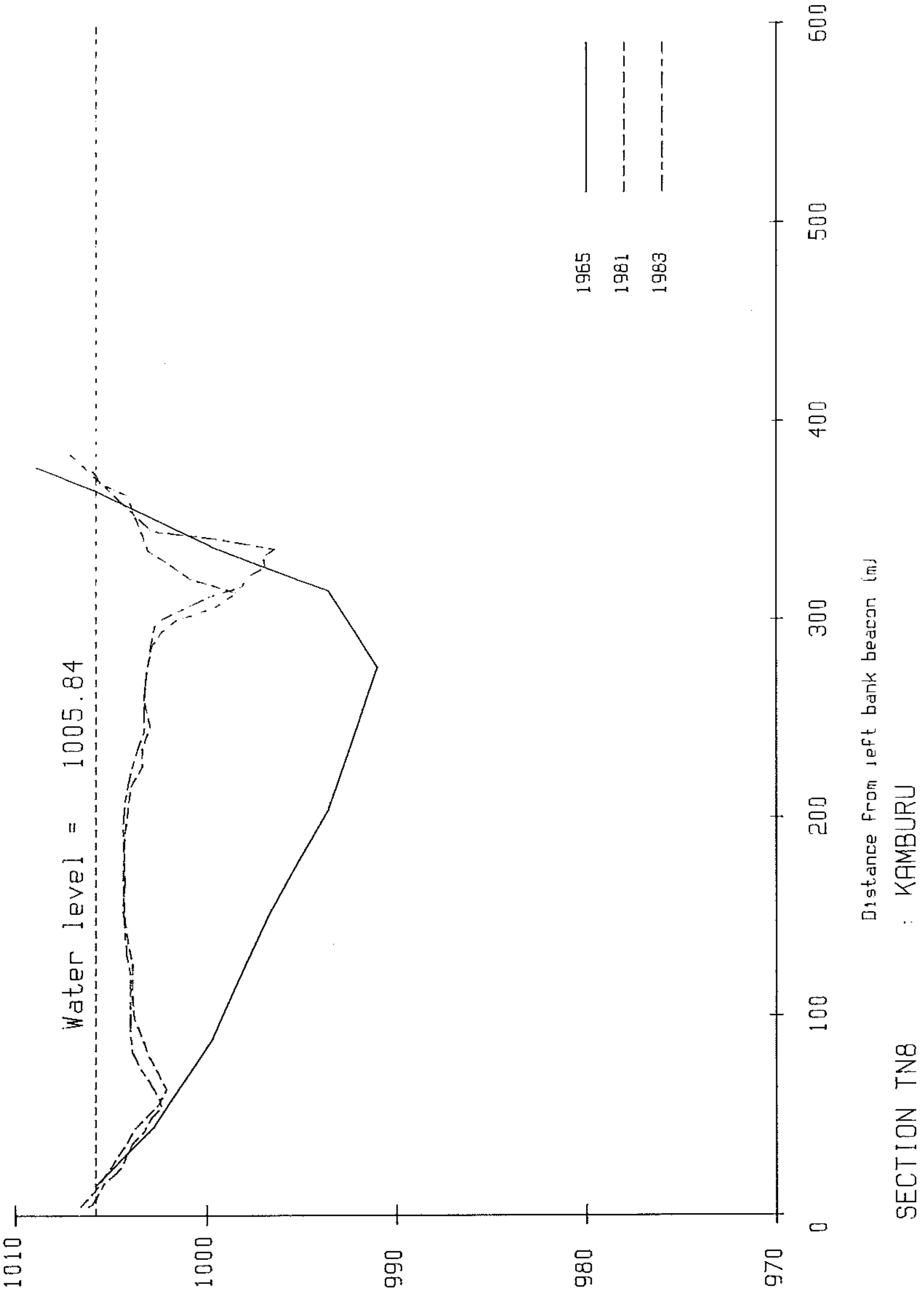


Fig 4·8 Kamburu Reservoir - section TN8

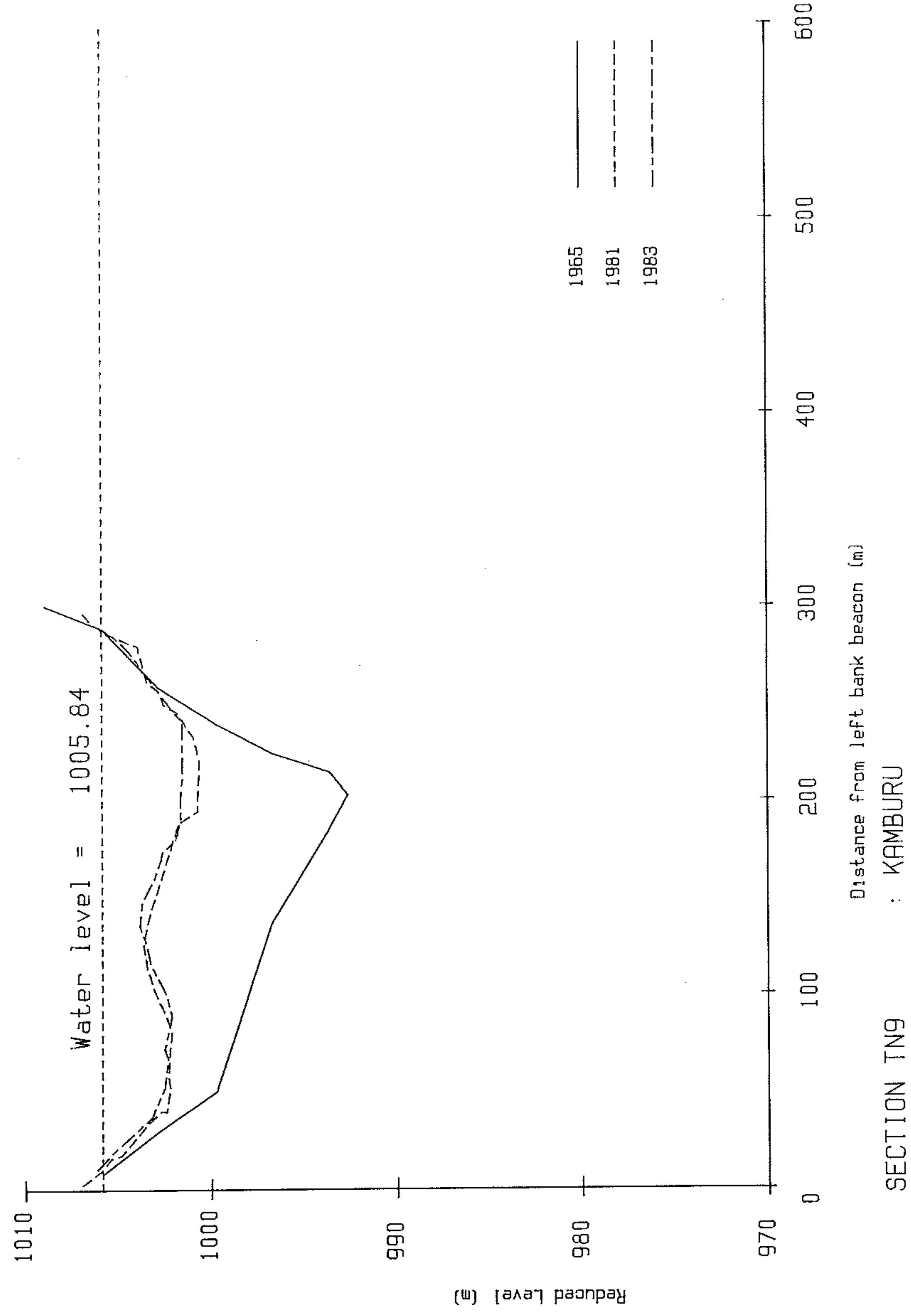


Fig 4·9 Kamburu Reservoir-section TN9

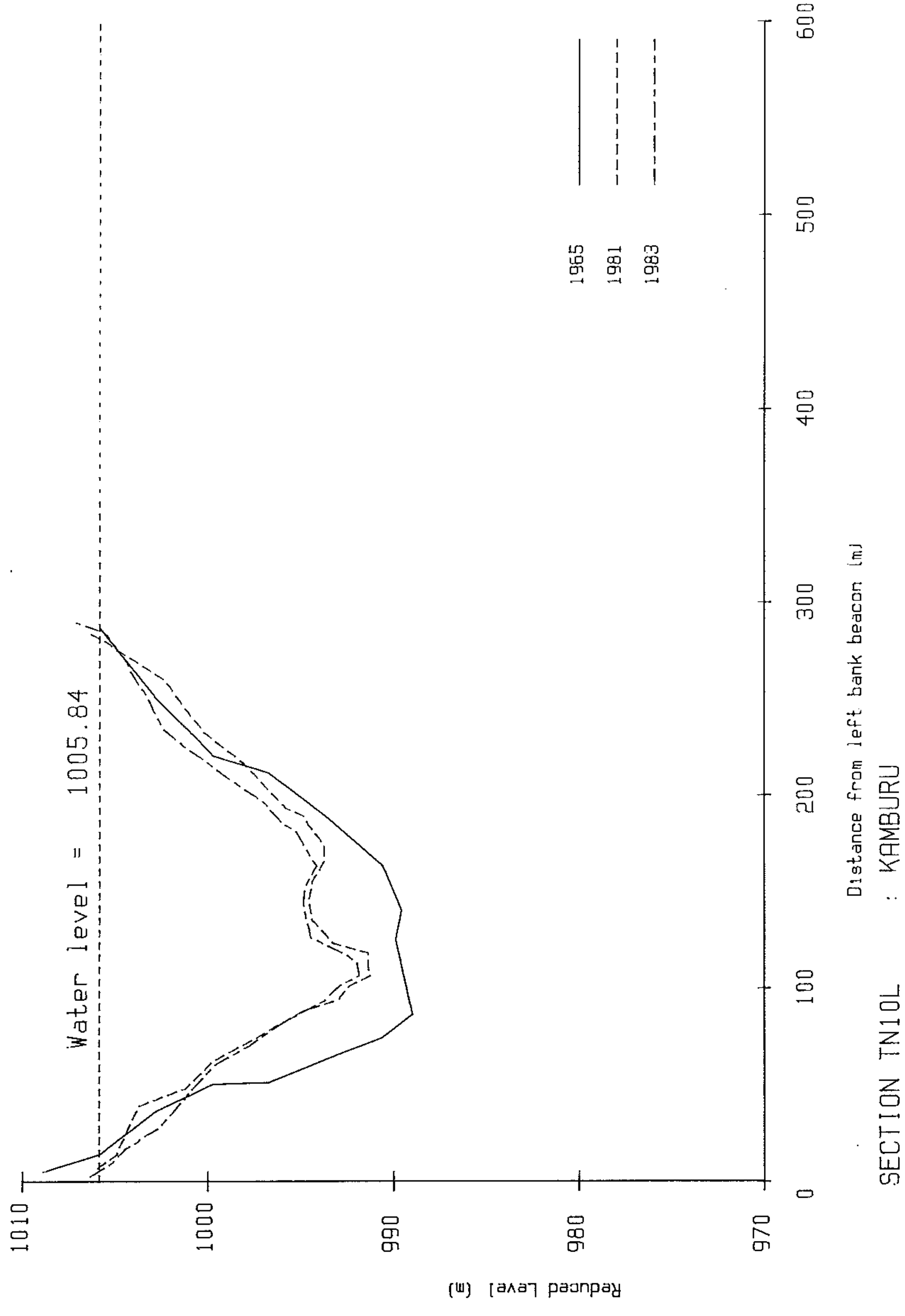


Fig 4·10 Kamburu Reservoir - section TN10L

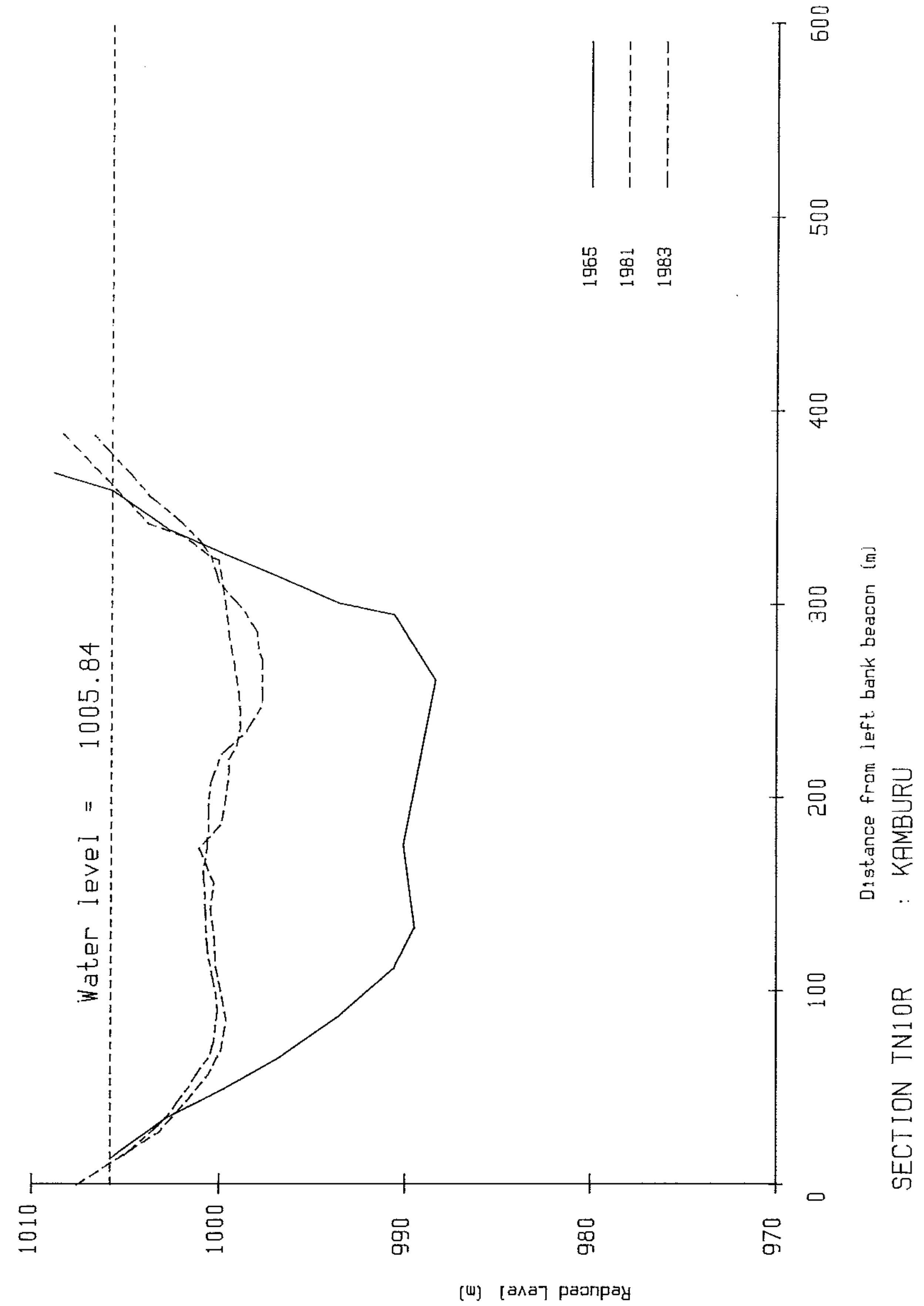


Fig 4·11 Kamburu Reservoir - section TN10R

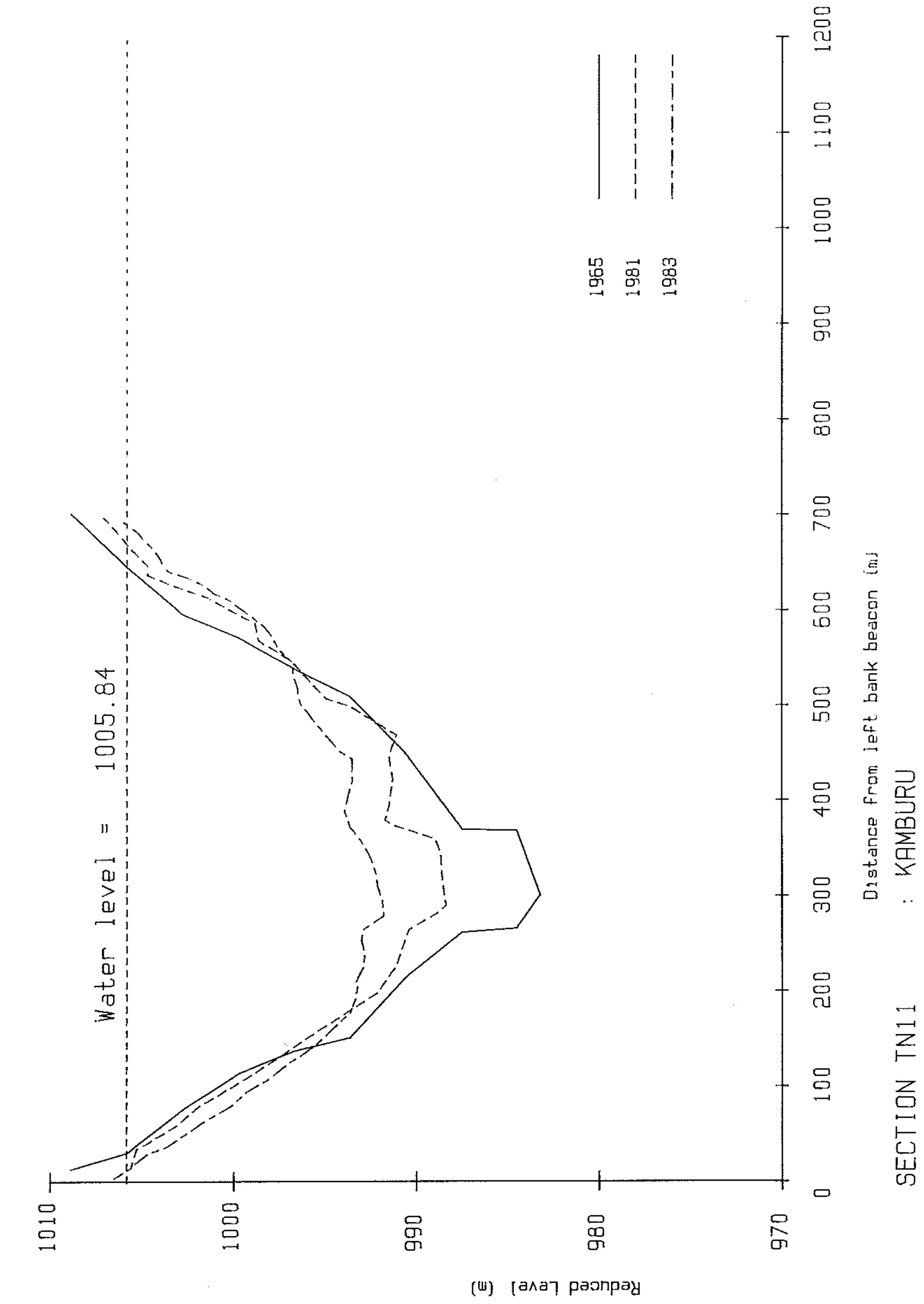
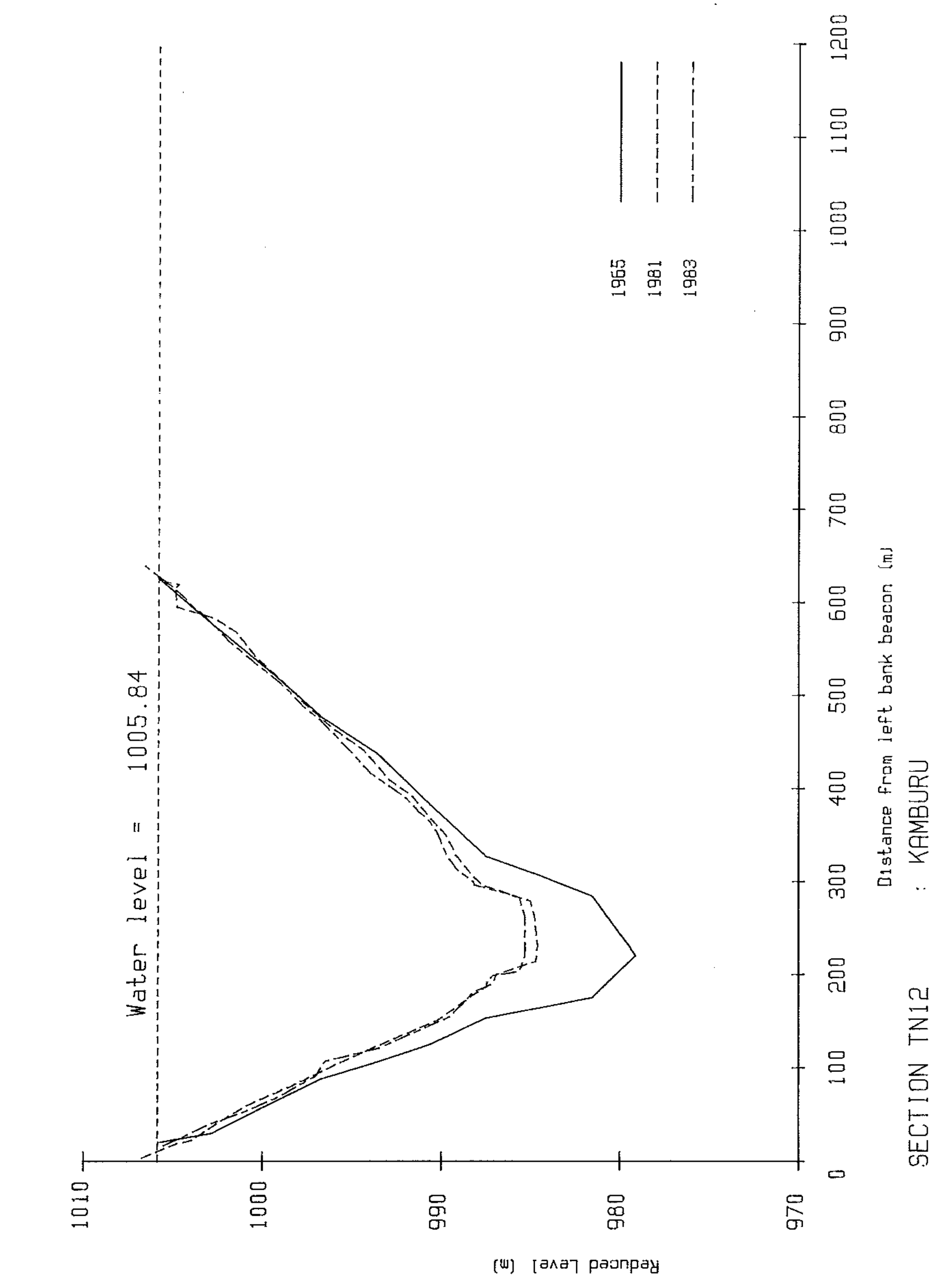


Fig 4·12 Kamburu Reservoir – section TN11



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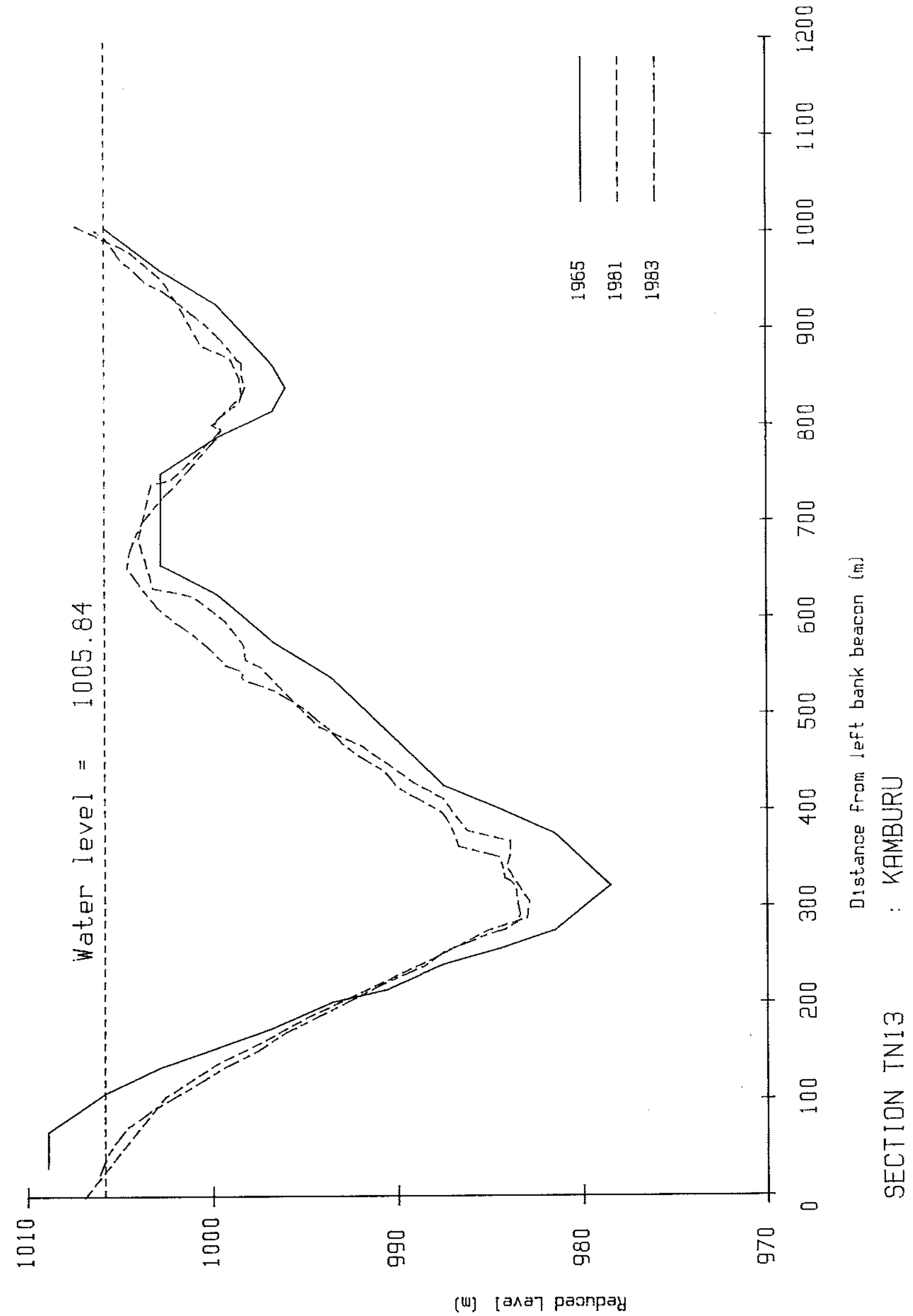


Fig 4·14 Kamburu Reservoir- section TN13

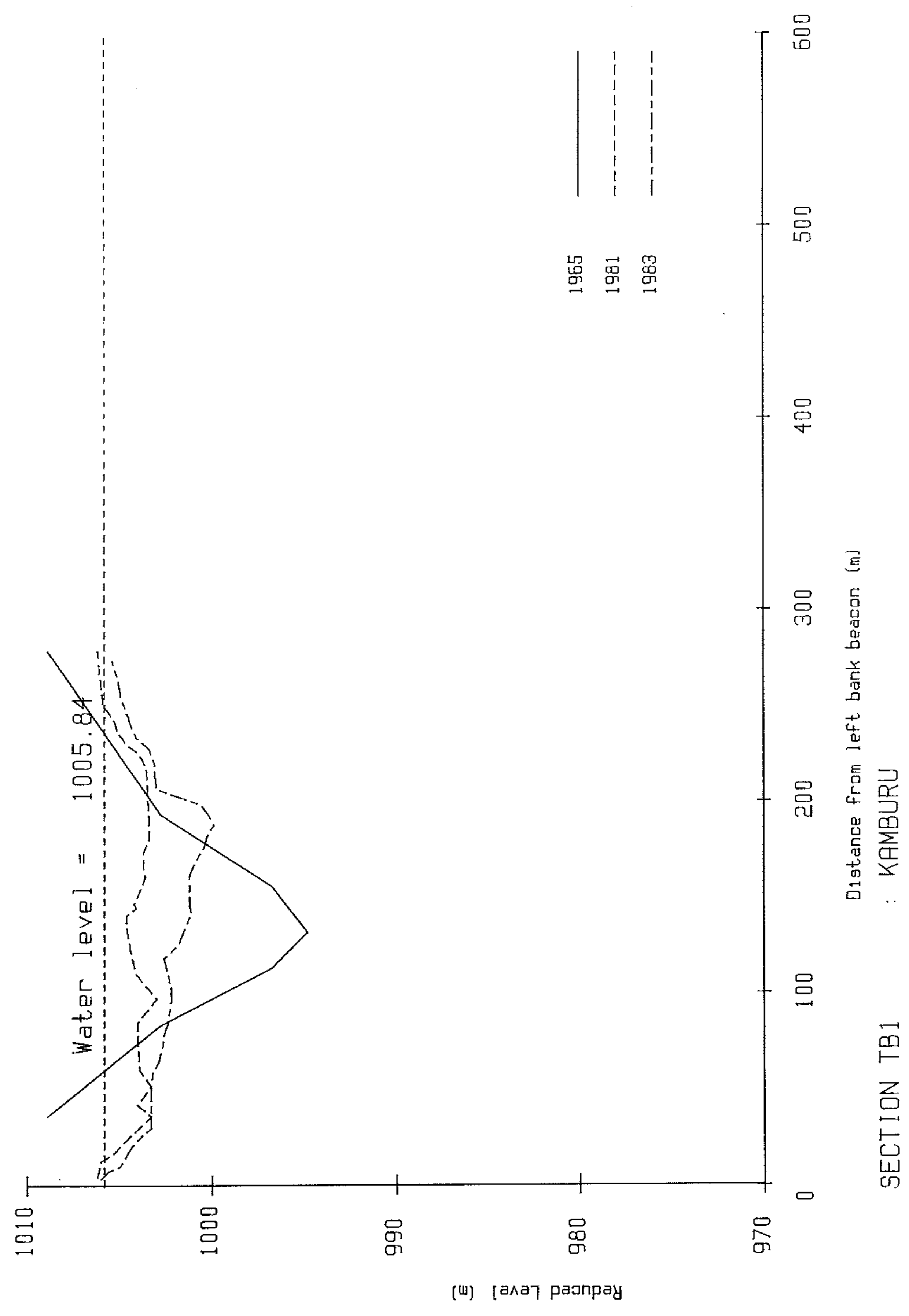
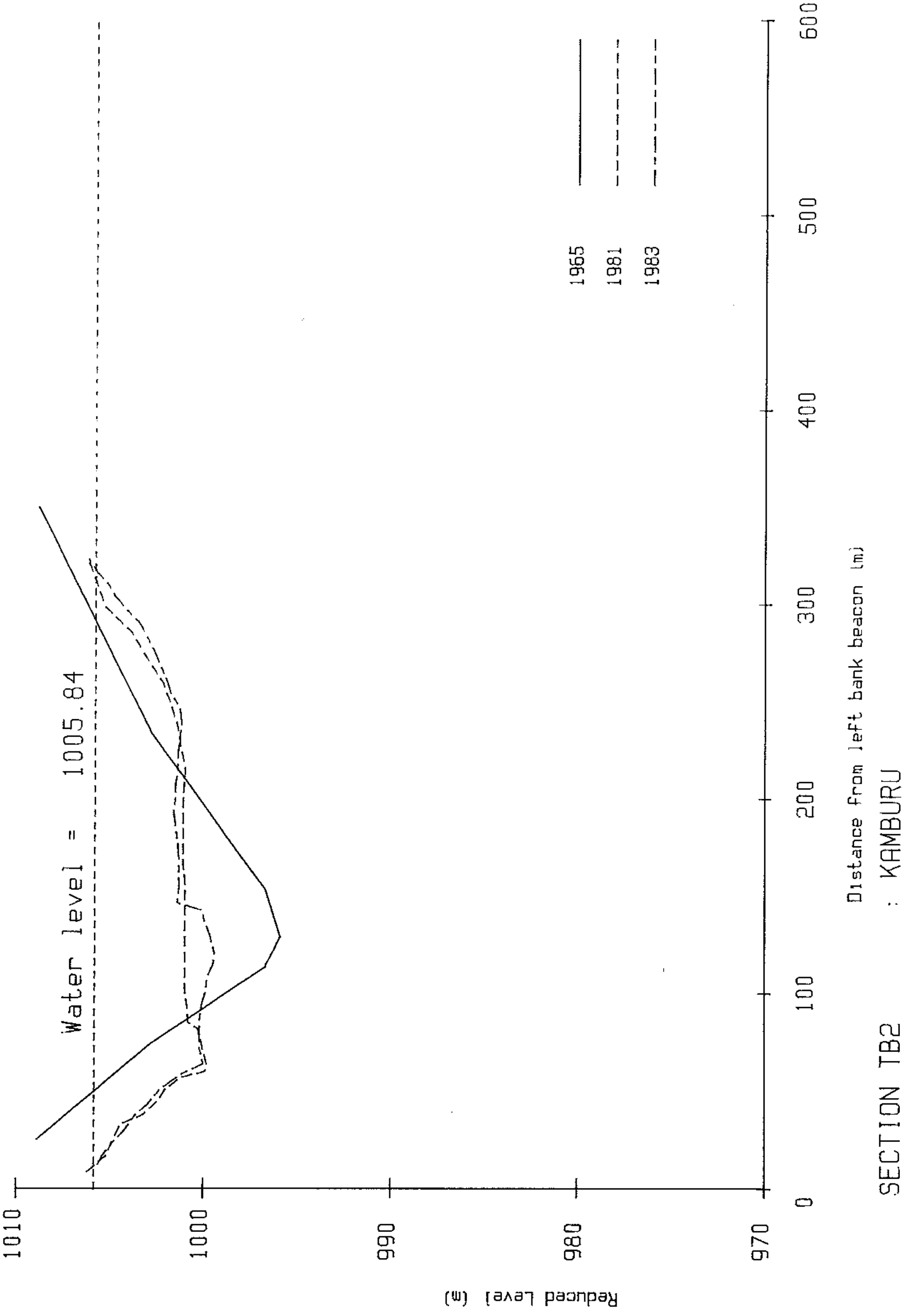


Fig 4·15 Kamburu Reservoir-section TB1



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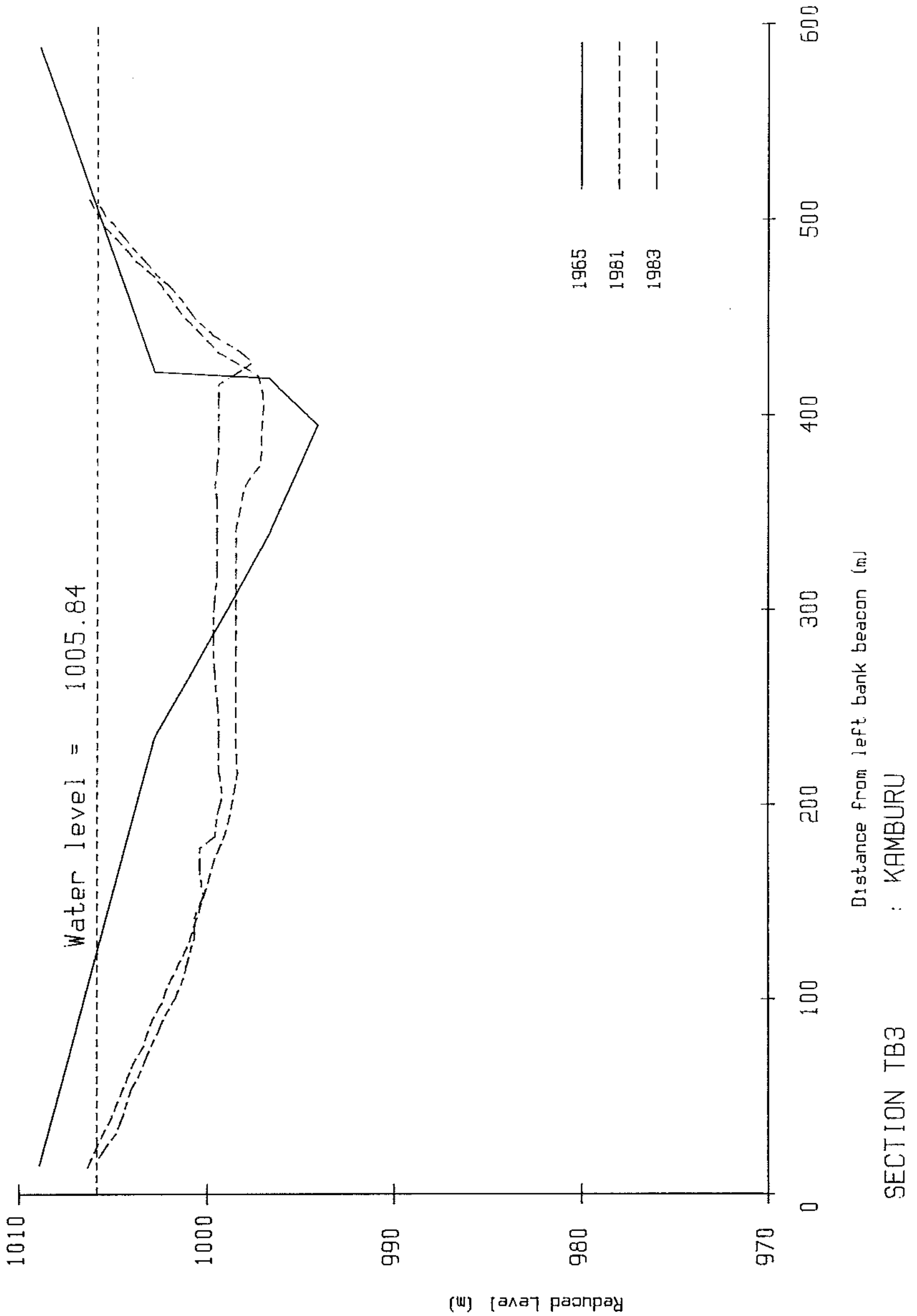


Fig 4·17 Kamburu Reservoir - section TB3

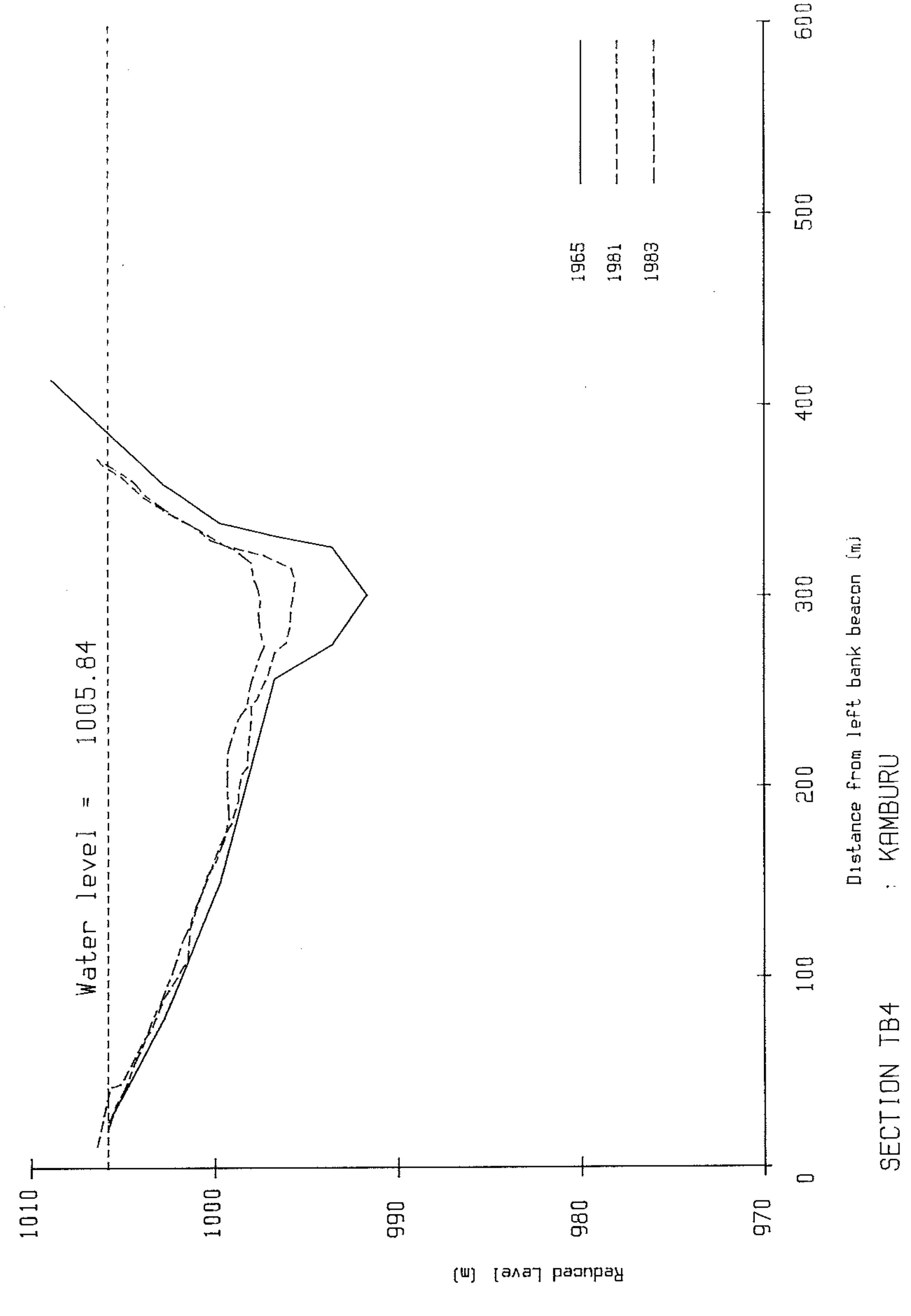
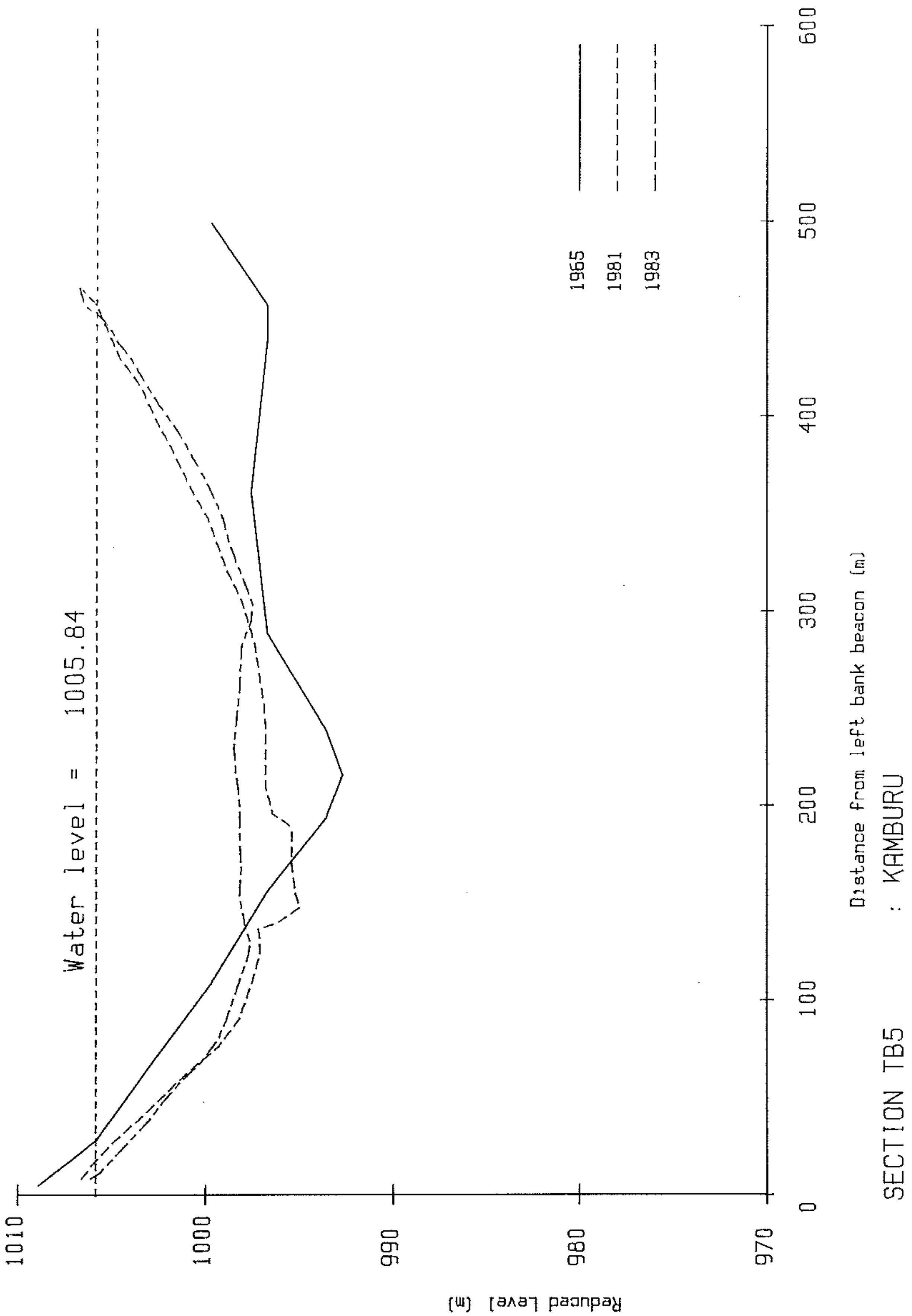


Fig 4·18 Kamburu Reservoir - section TB4



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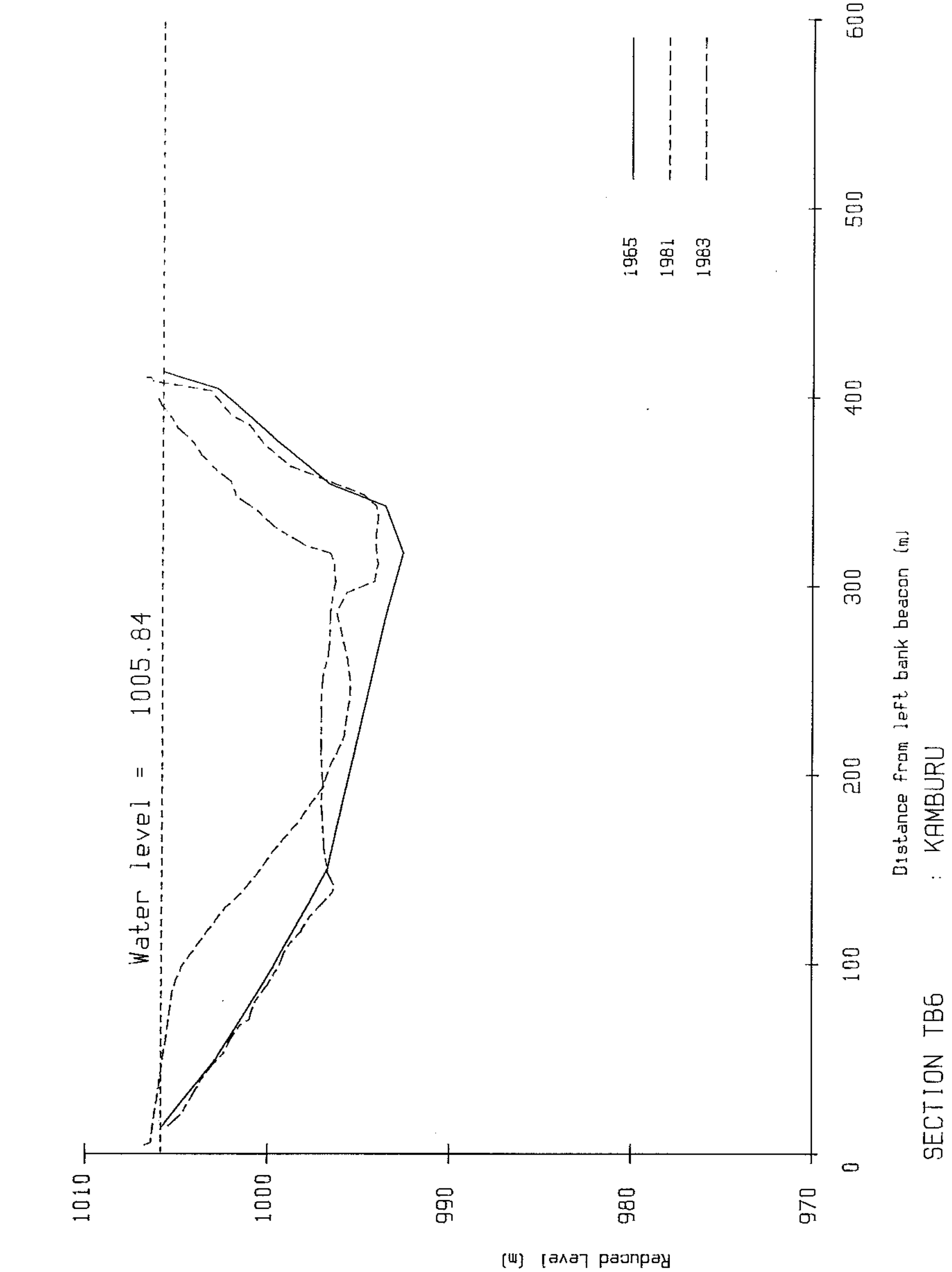


Fig 4·20 Kamburu Reservoir – section TB6

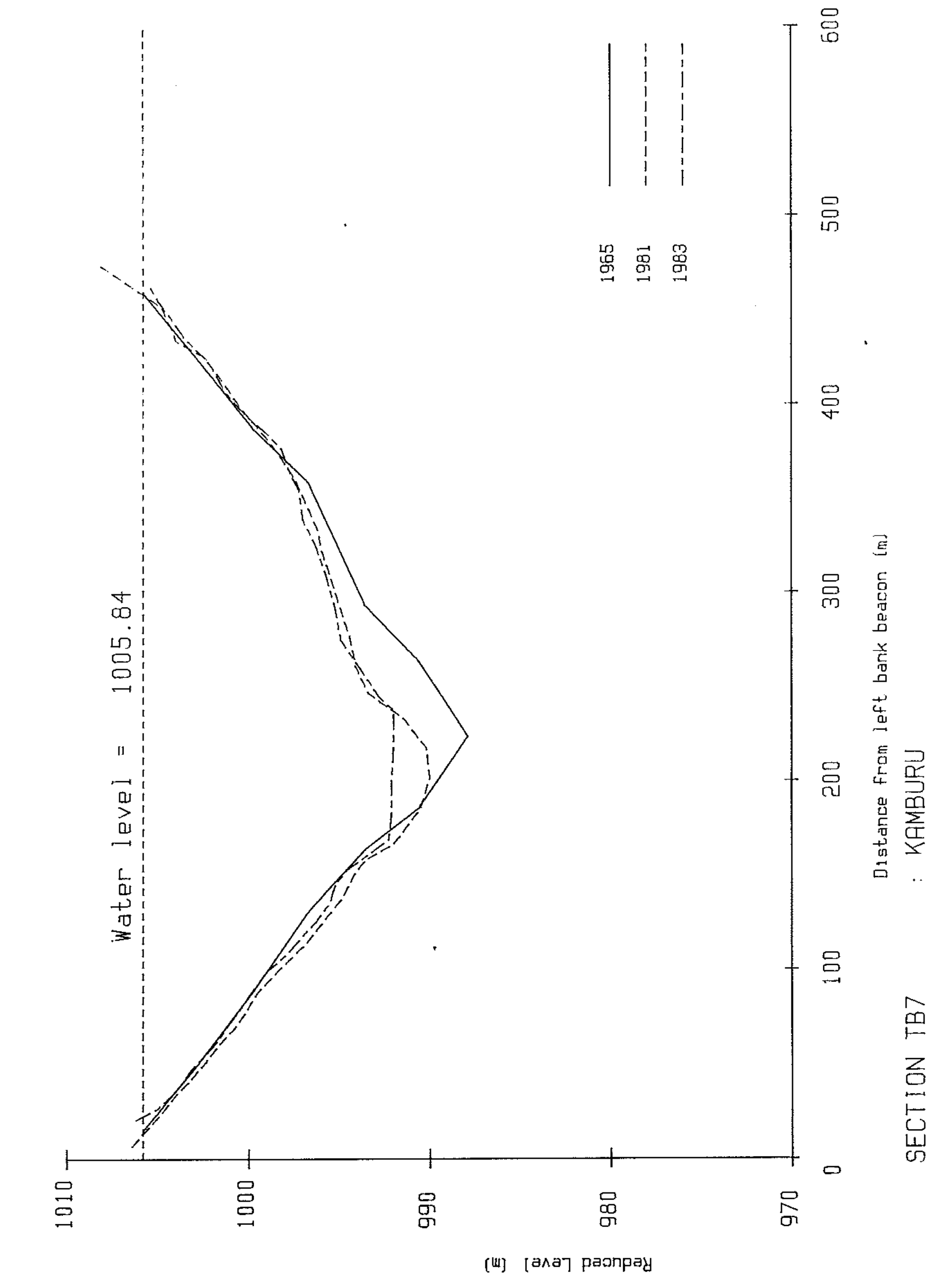


Fig 4·21 Kamburu Reservoir-section TB7

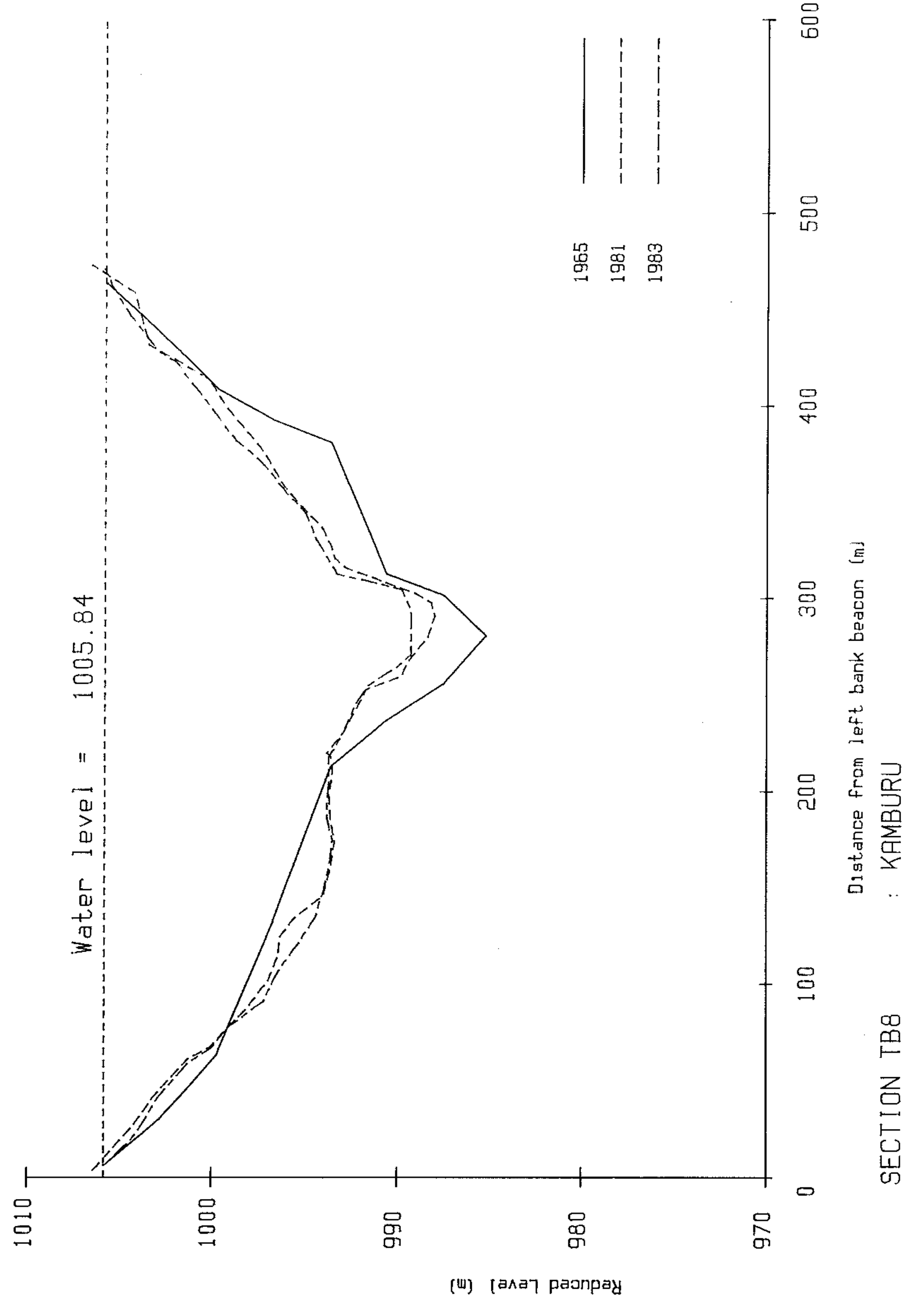
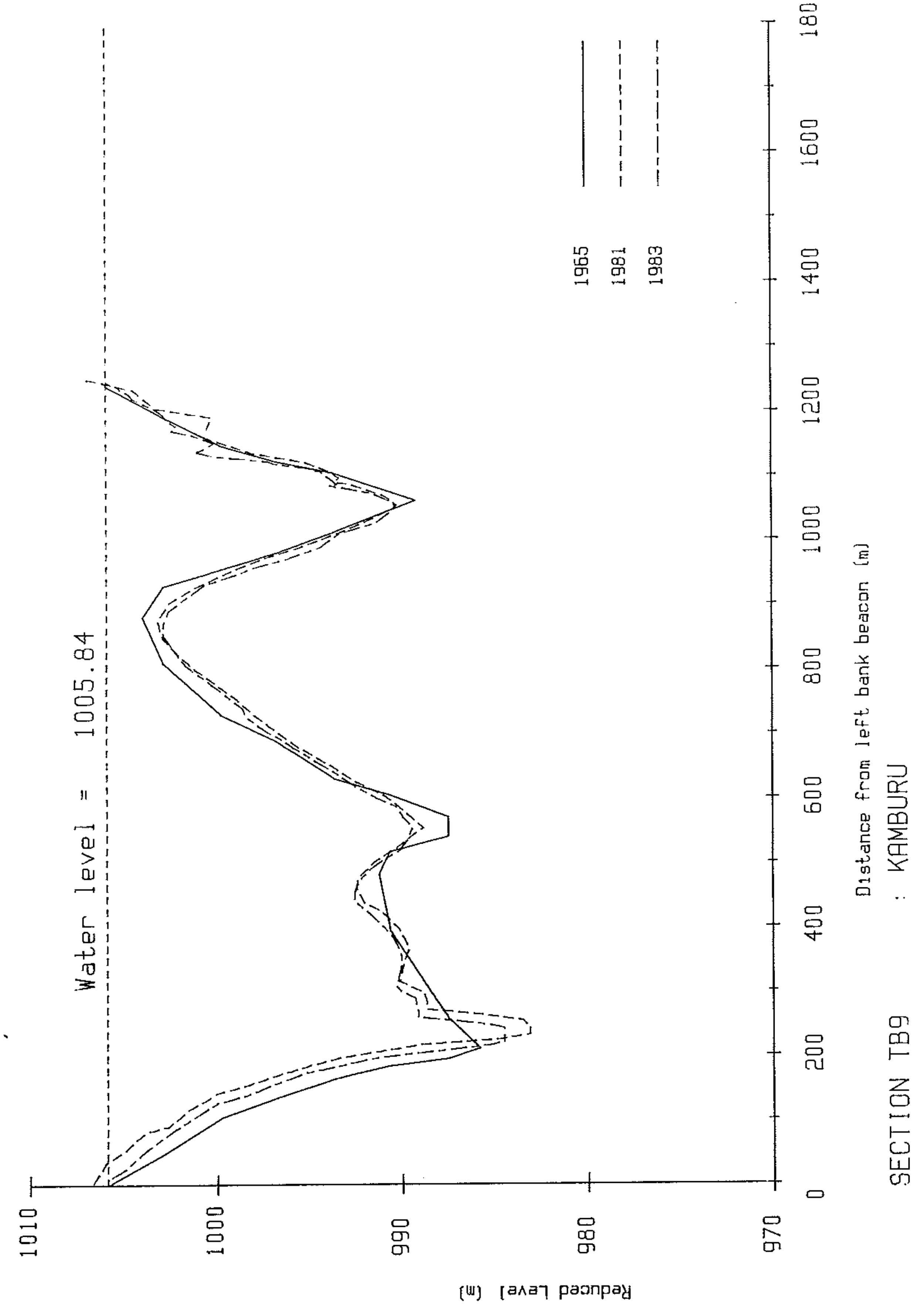


Fig 4·22 Kamburu Reservoir - section TB8



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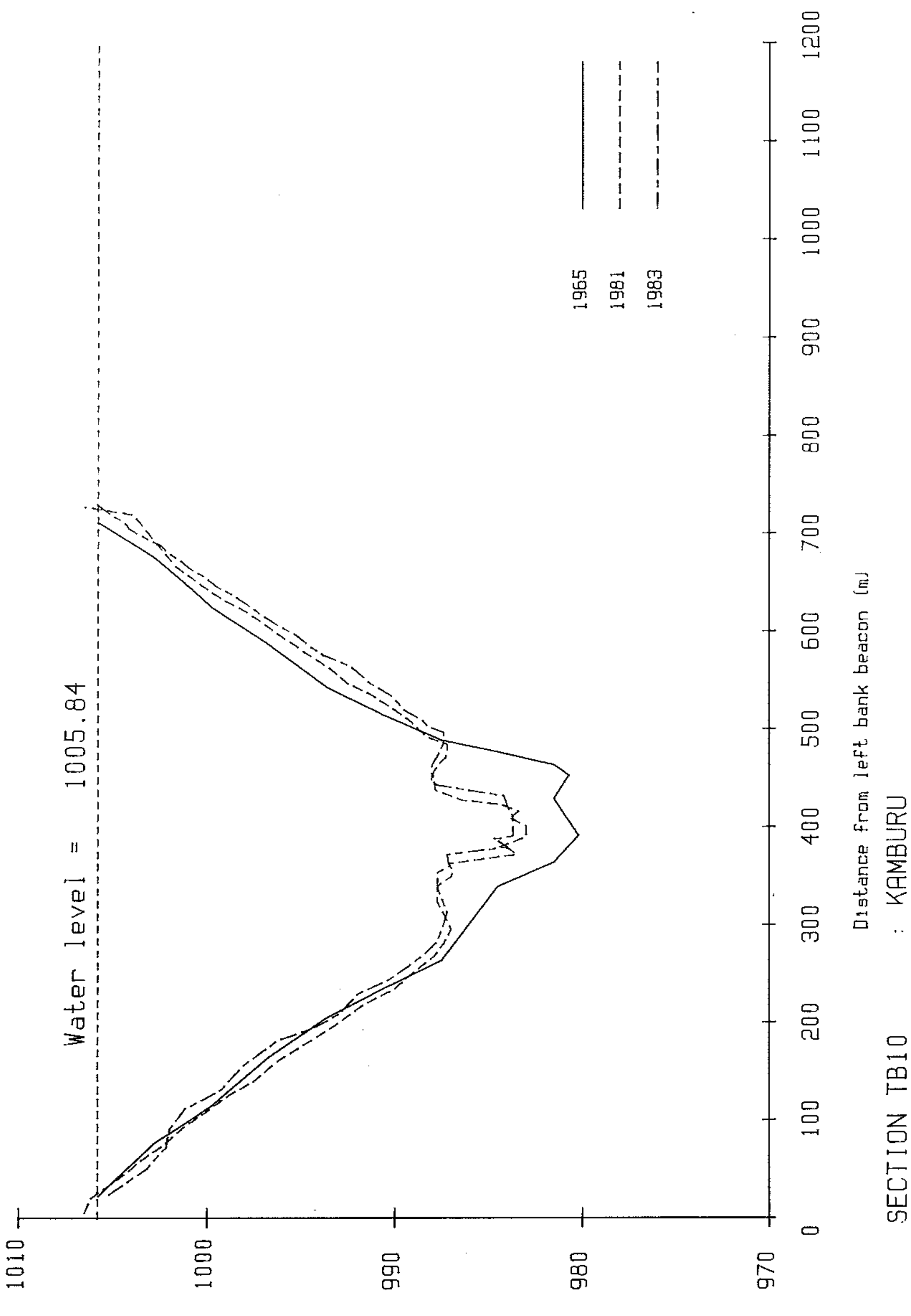


Fig 4·24 Kamburu Reservoir – section TB10

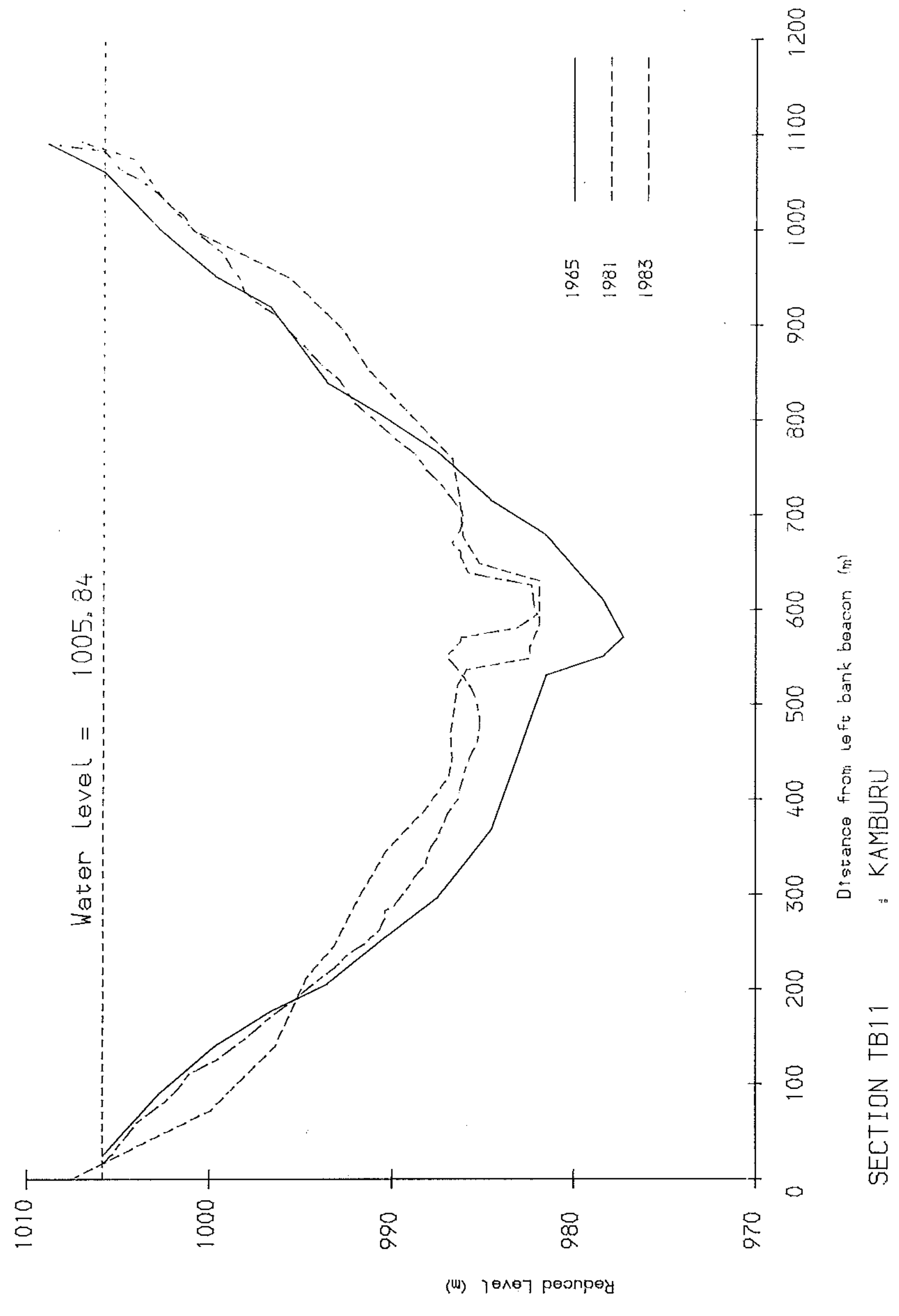


Fig 4·25 Kamburu Reservoir - section TB11

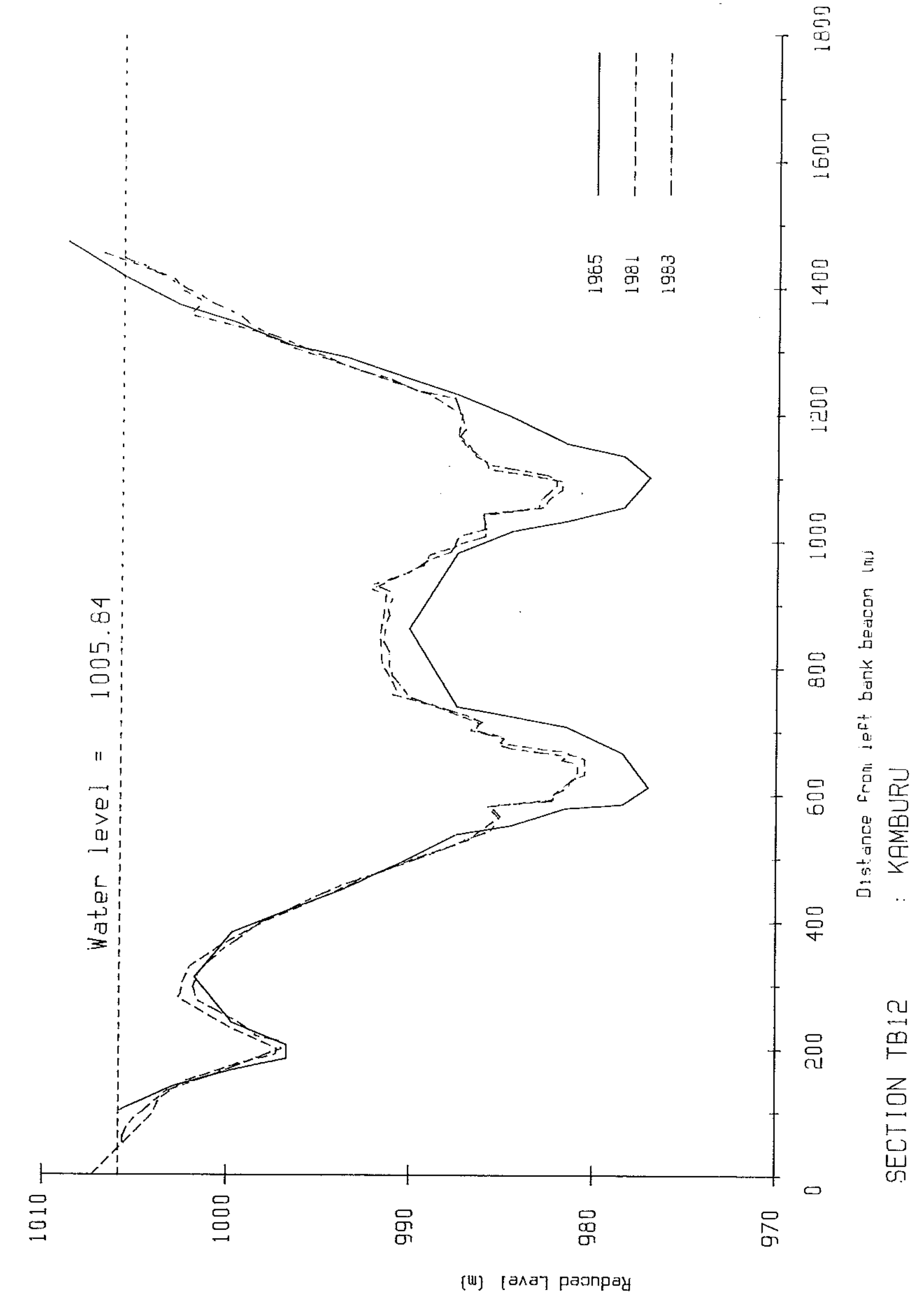


Fig 4·26 Kamburu Reservoir – section TB12

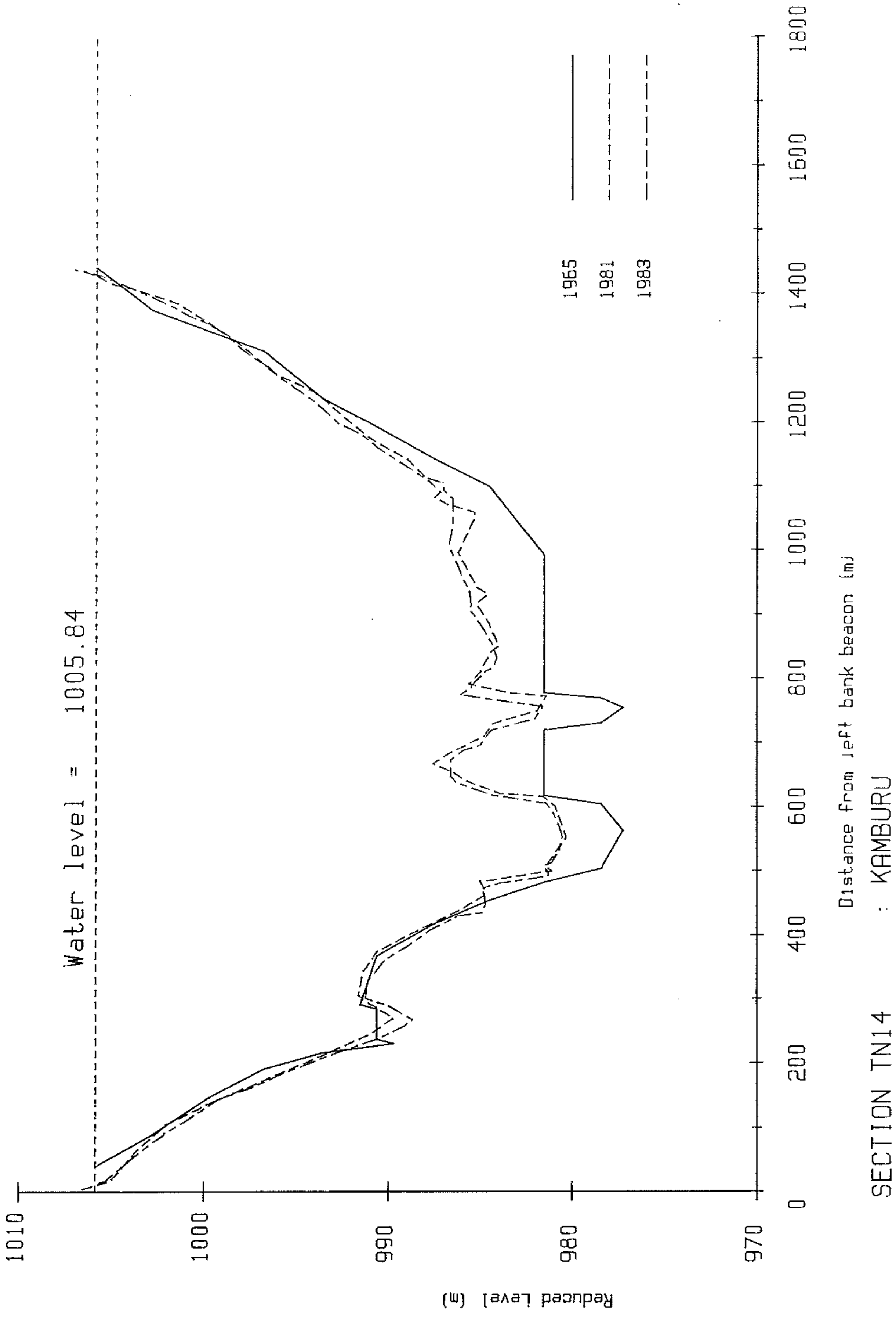
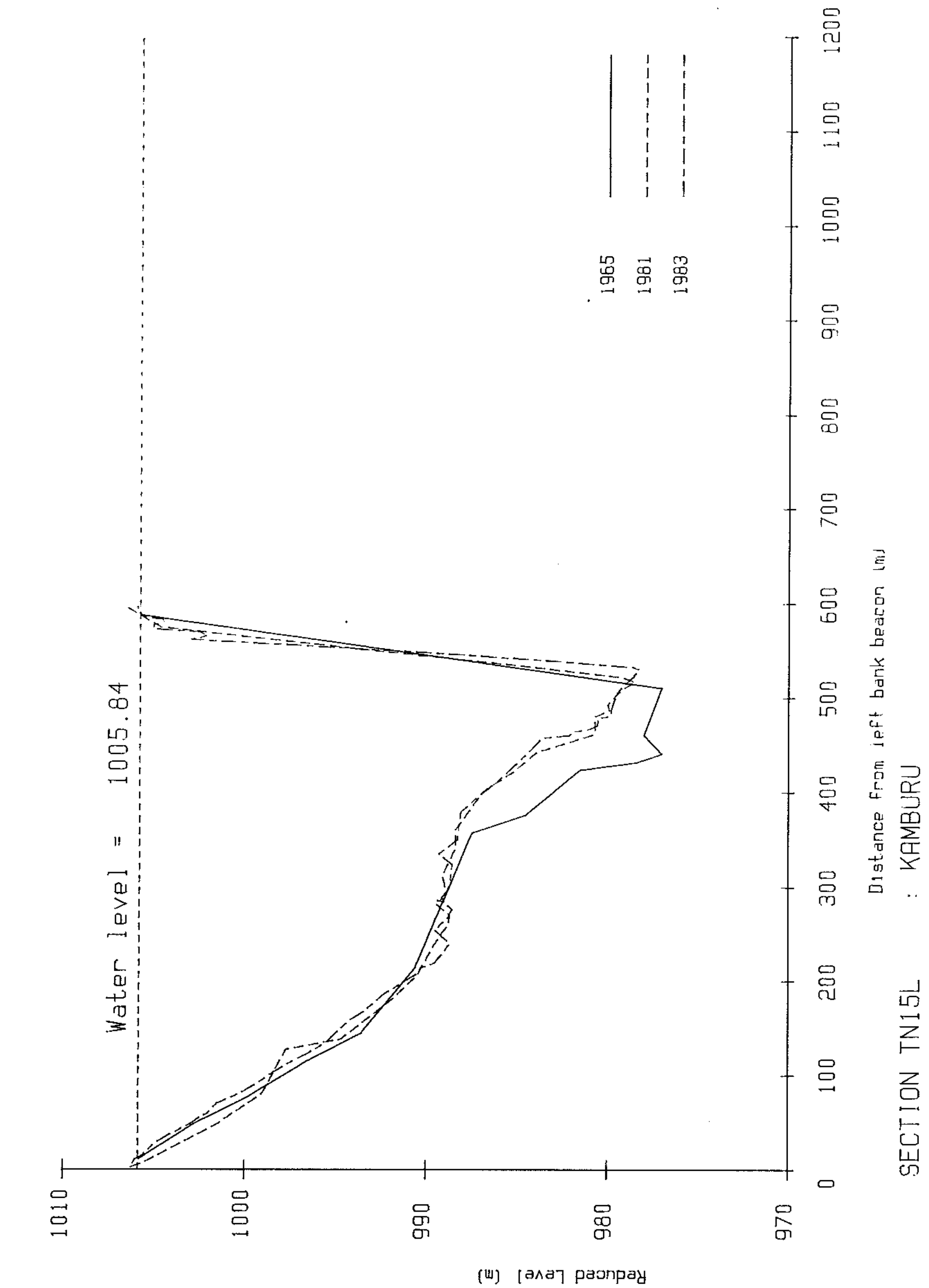


Fig 4·27 Kamburu Reservoir - section TN14



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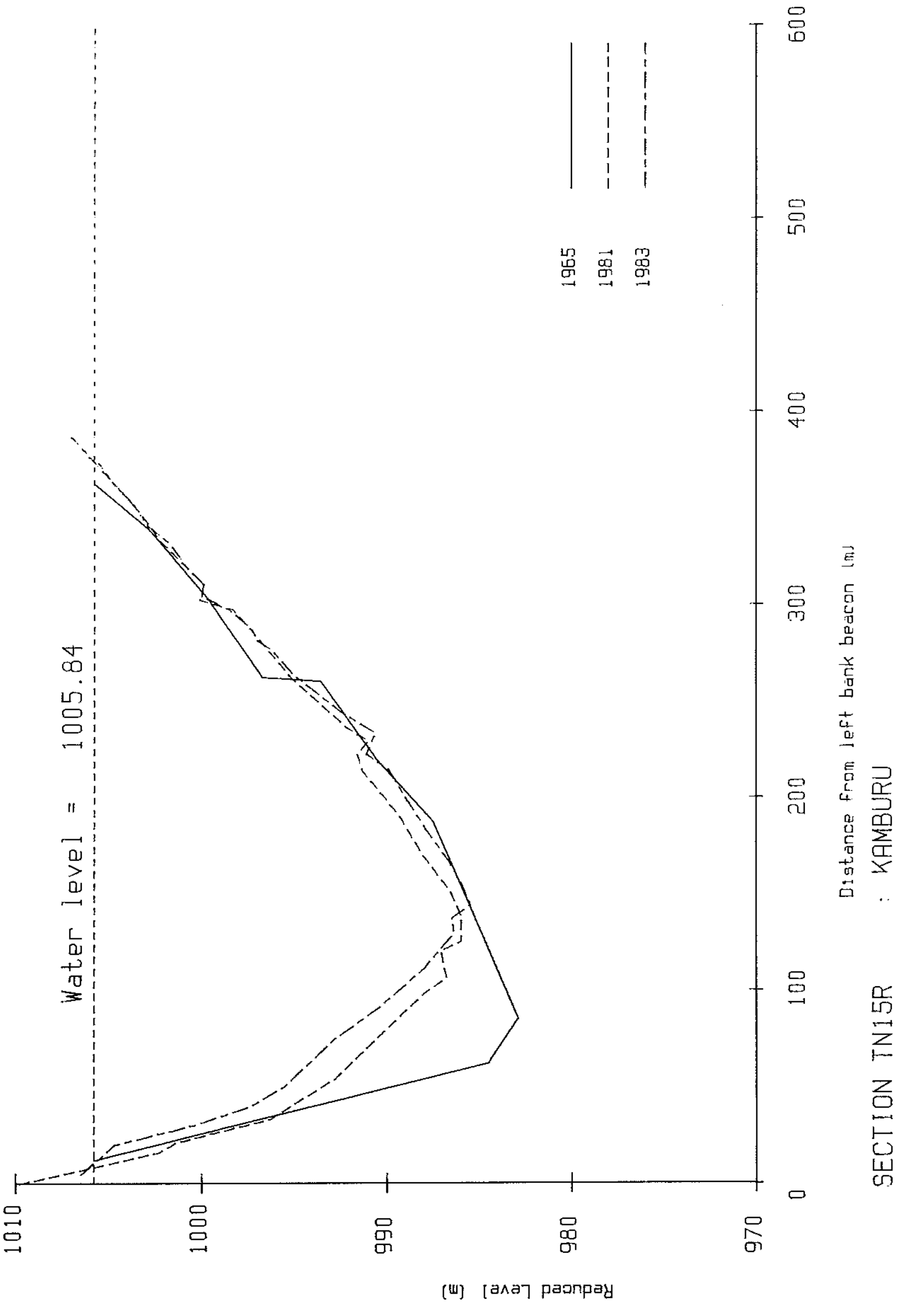

Fig 4·29 Kamburu Reservoir-section TN15R

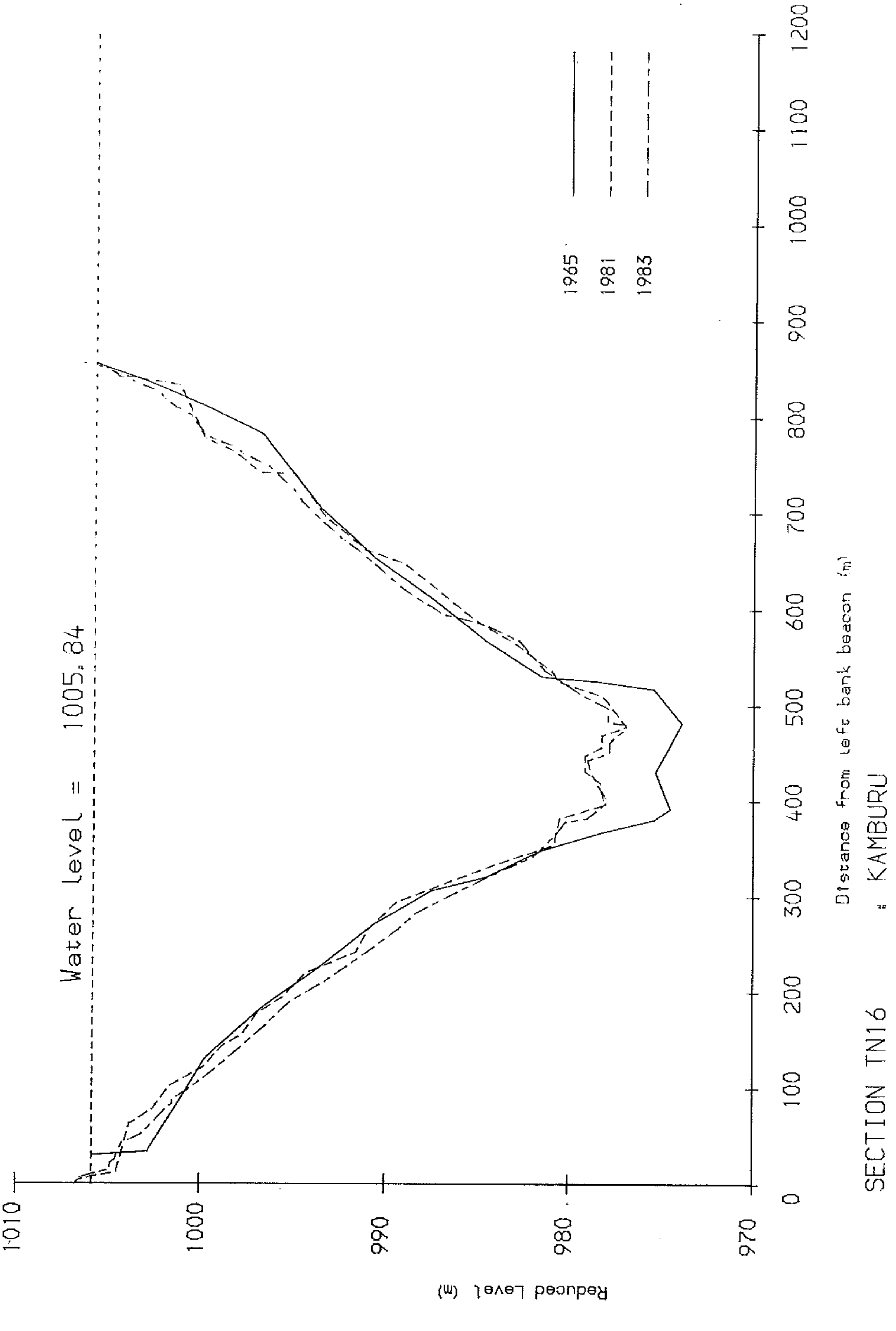

Fig 4·30 Kamburu Reservoir - section TN16

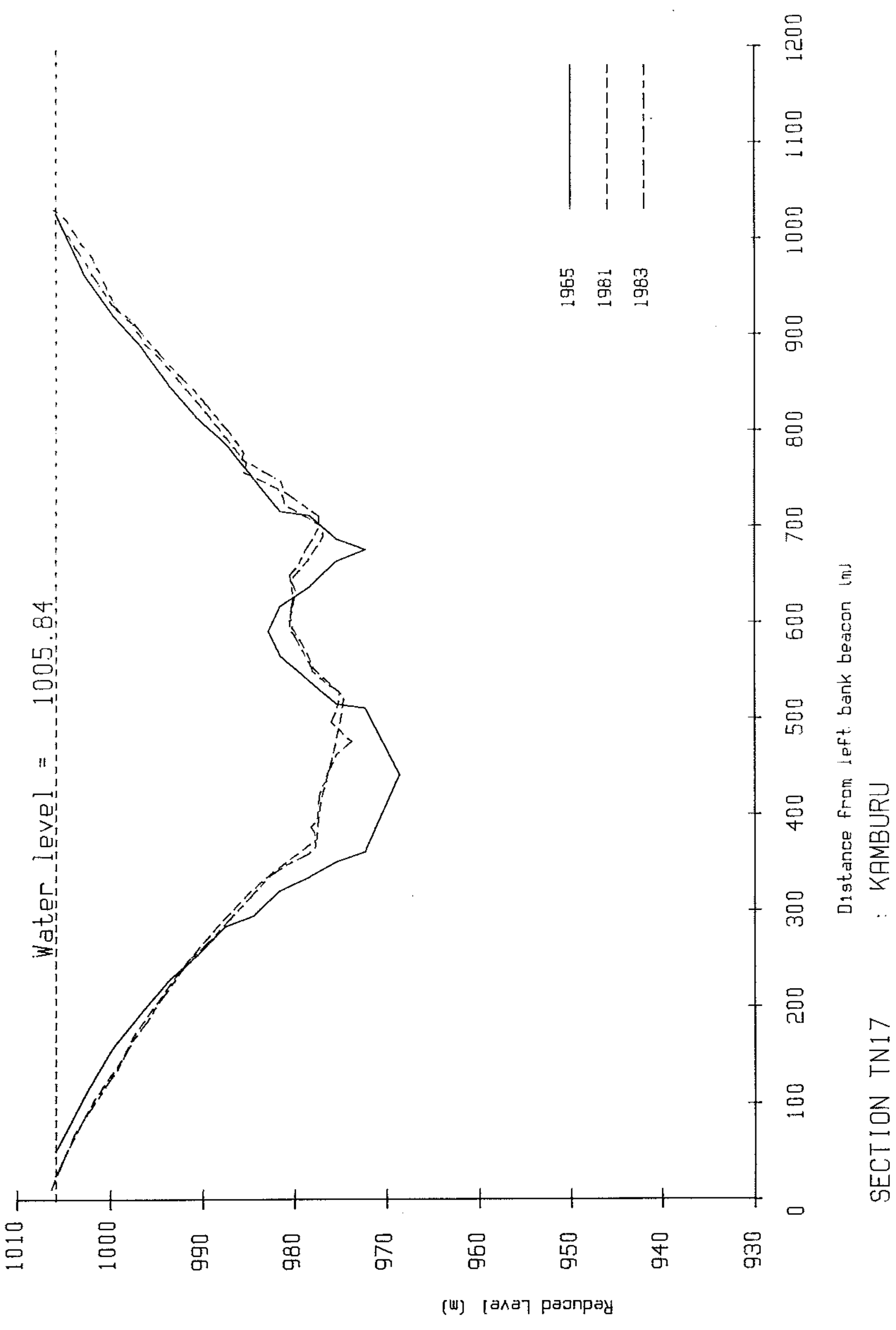

Fig 4·31 Kamburu Reservoir - section TN17

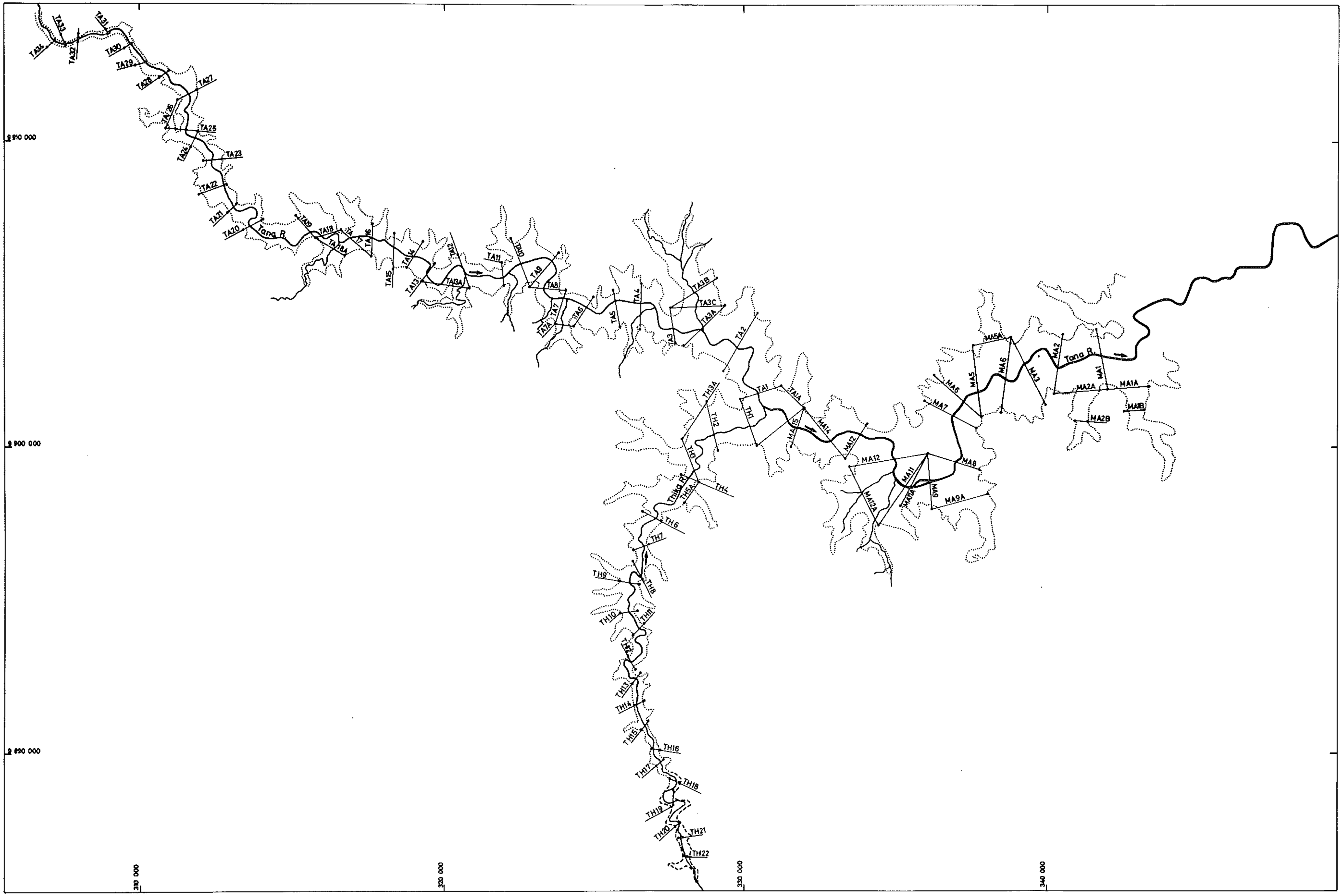

Fig 5 Masinga Reservoir

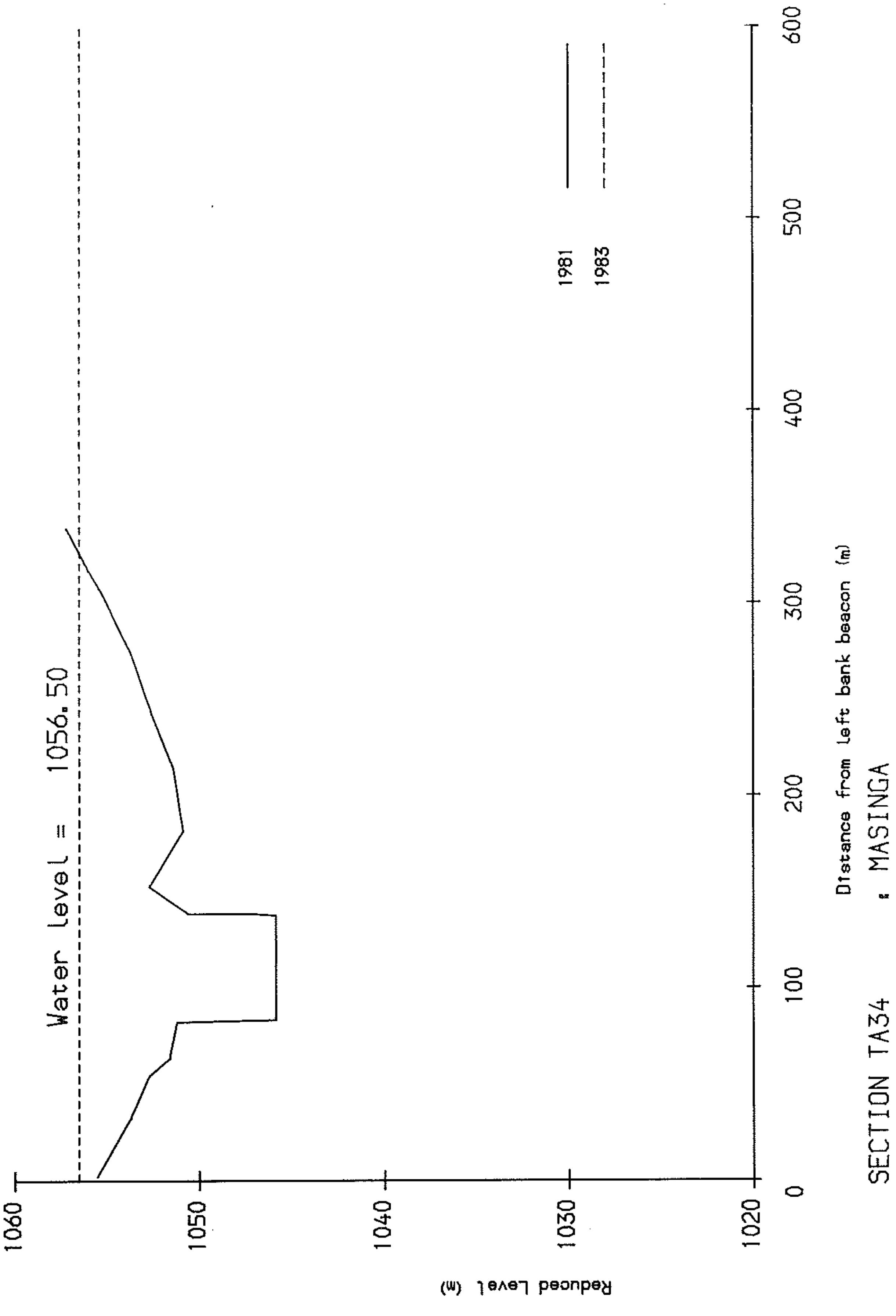

Fig 5.1 Masinga Reservoir - section TA34

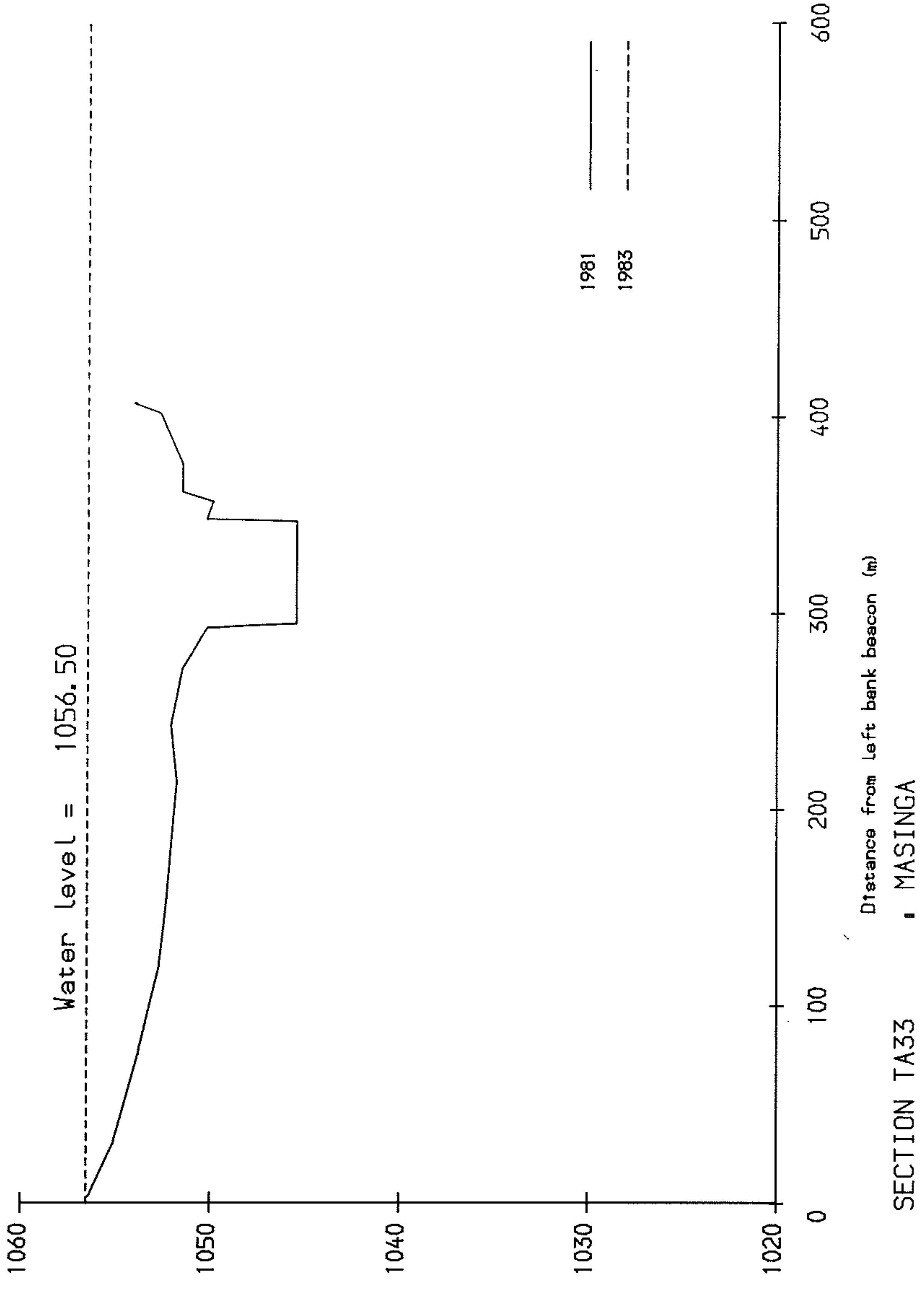

Fig 5·2 Masinga Reservoir - section TA33

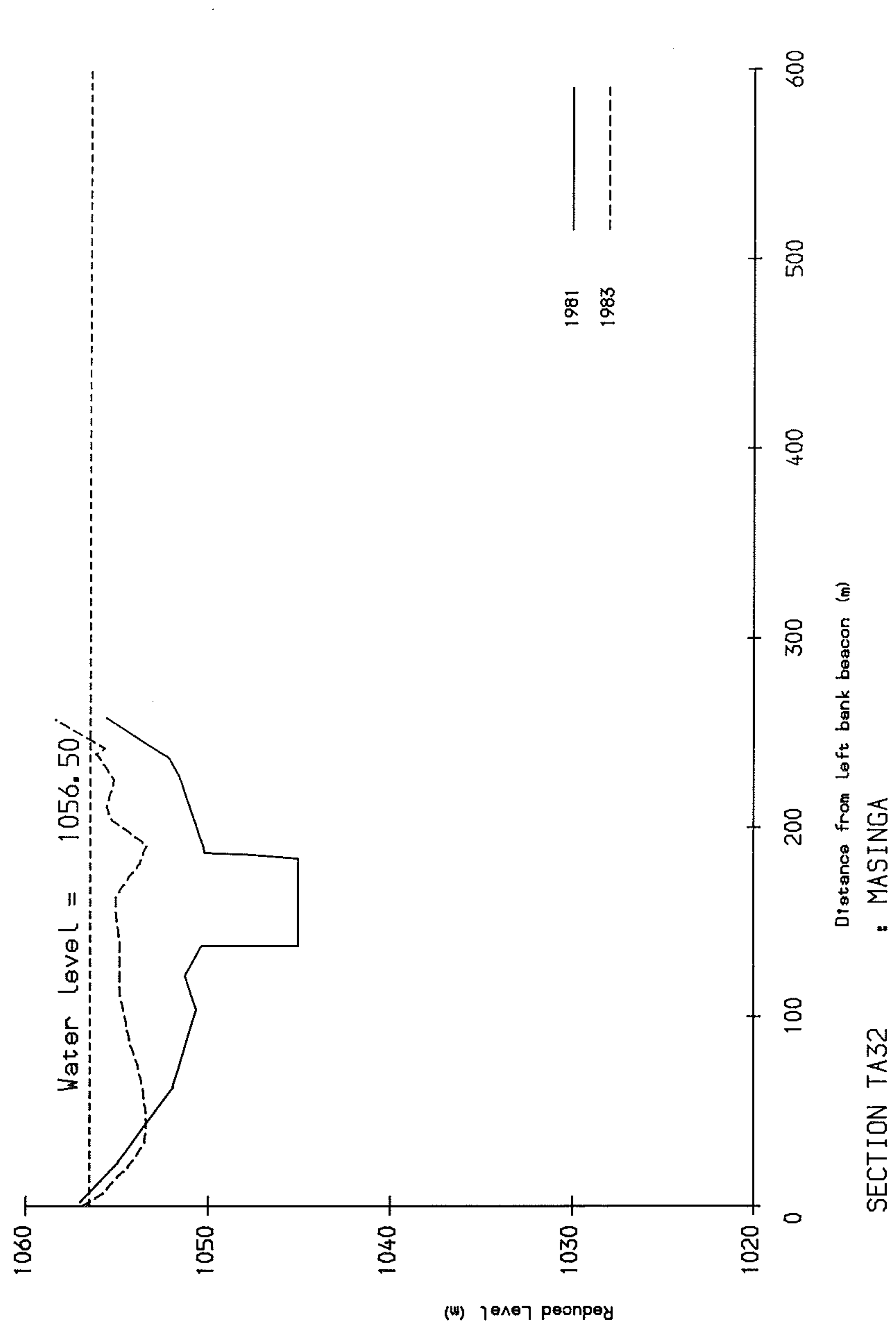

Fig 5·3 Masinga Reservoir - TA32

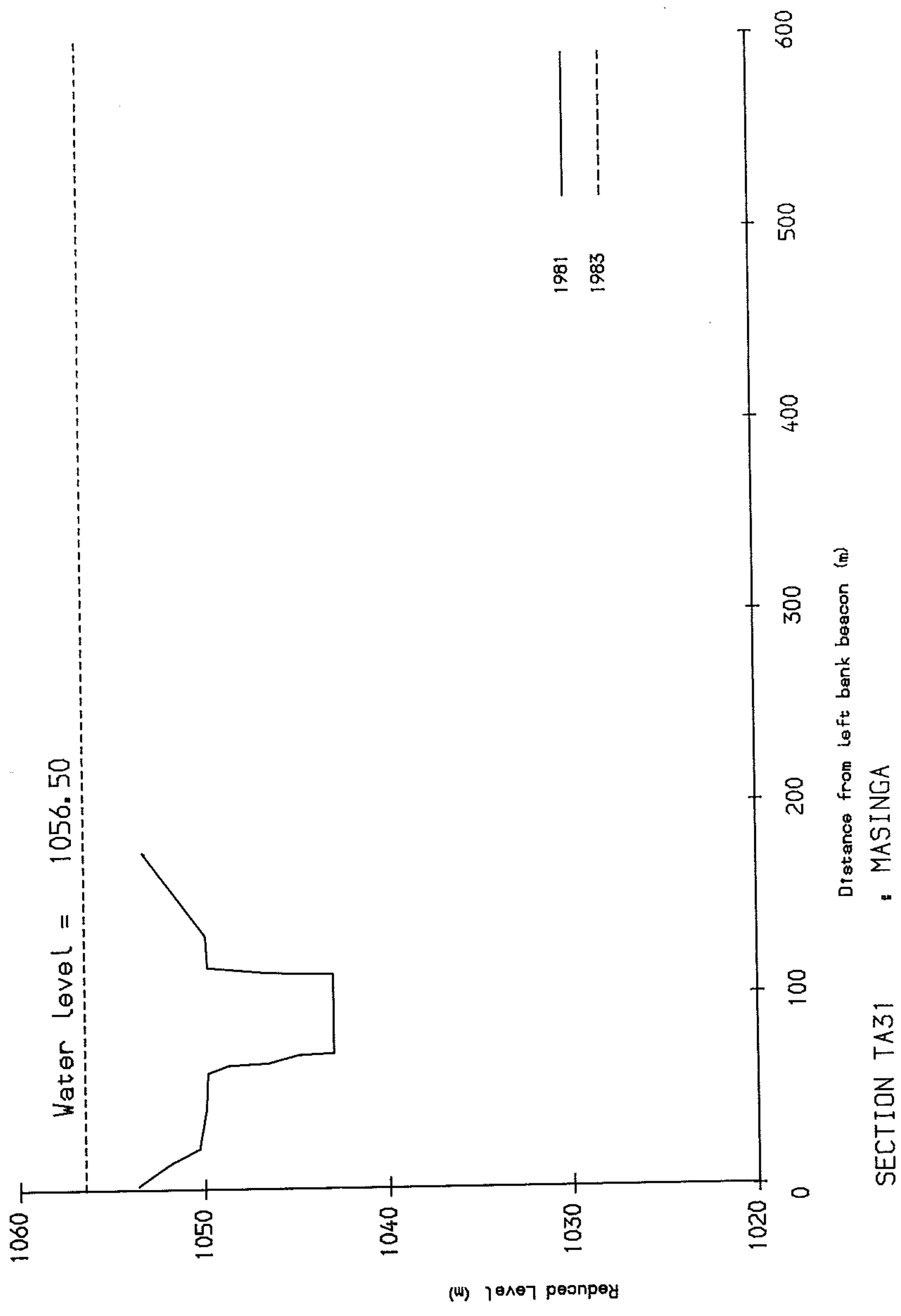

Fig 5·4 Masinga Reservoir - section TA31

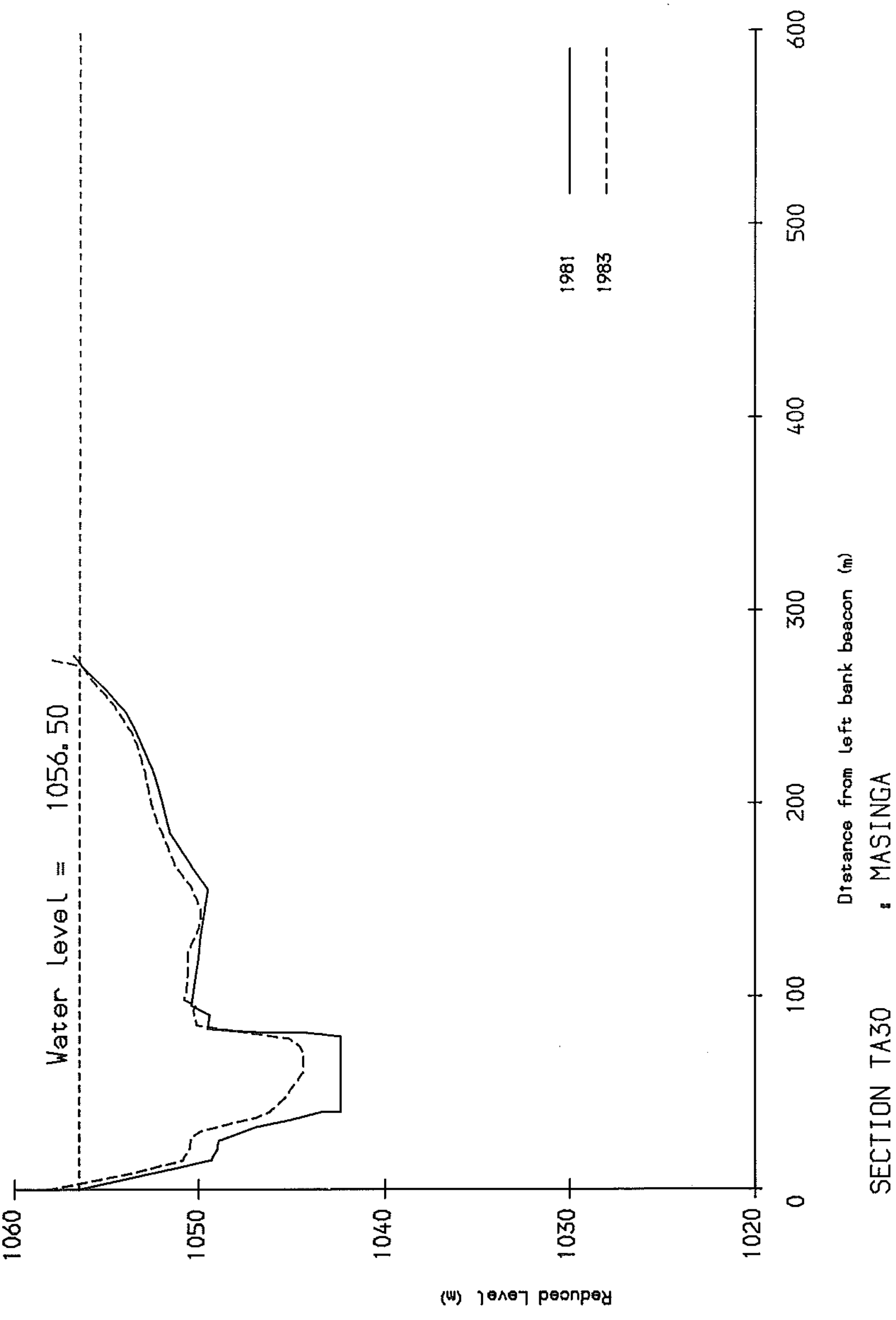

Fig 5·5 Masinga Reservoir - section TA30

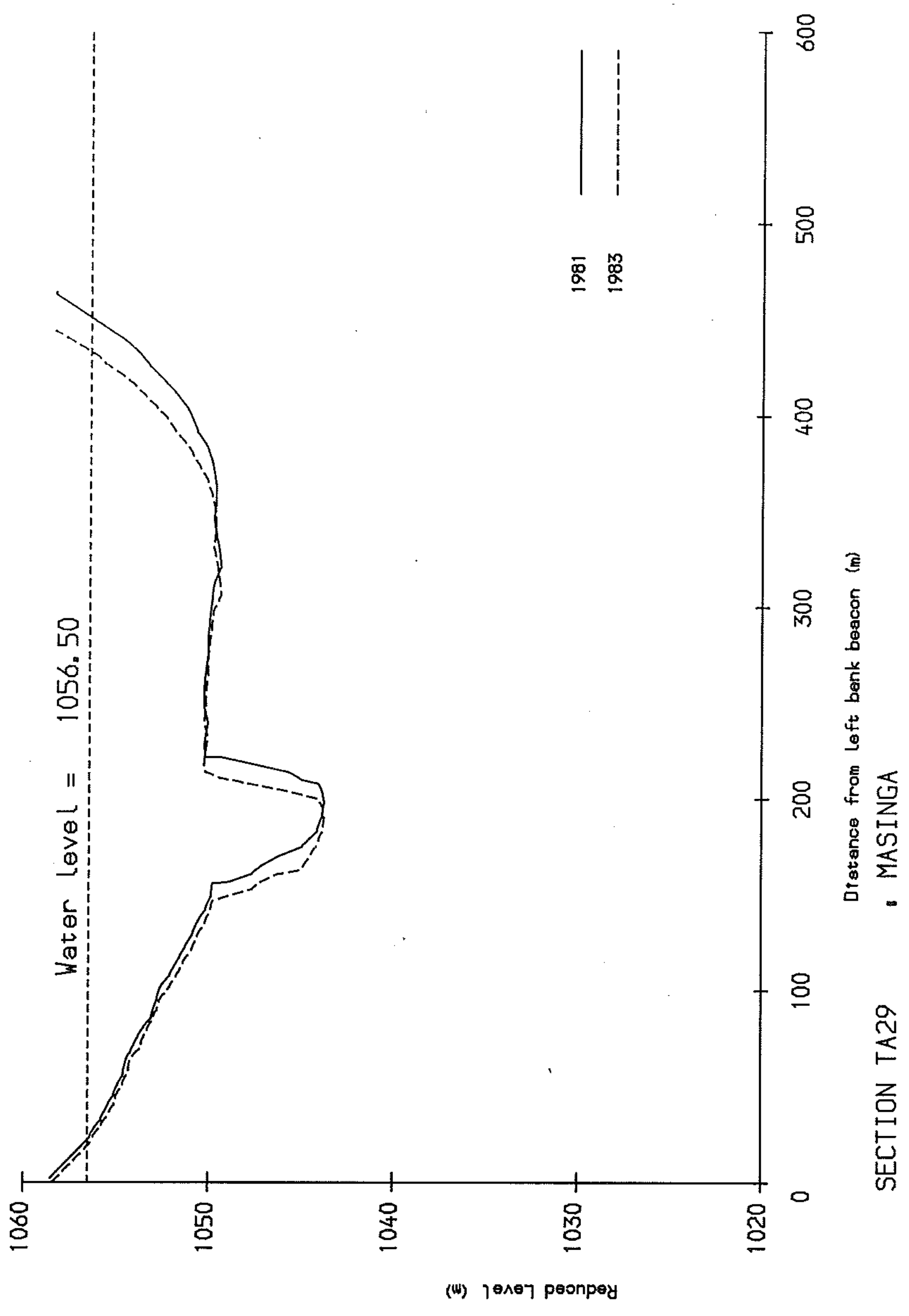

Fig 5·6 Masinga Reservoir-section TA29

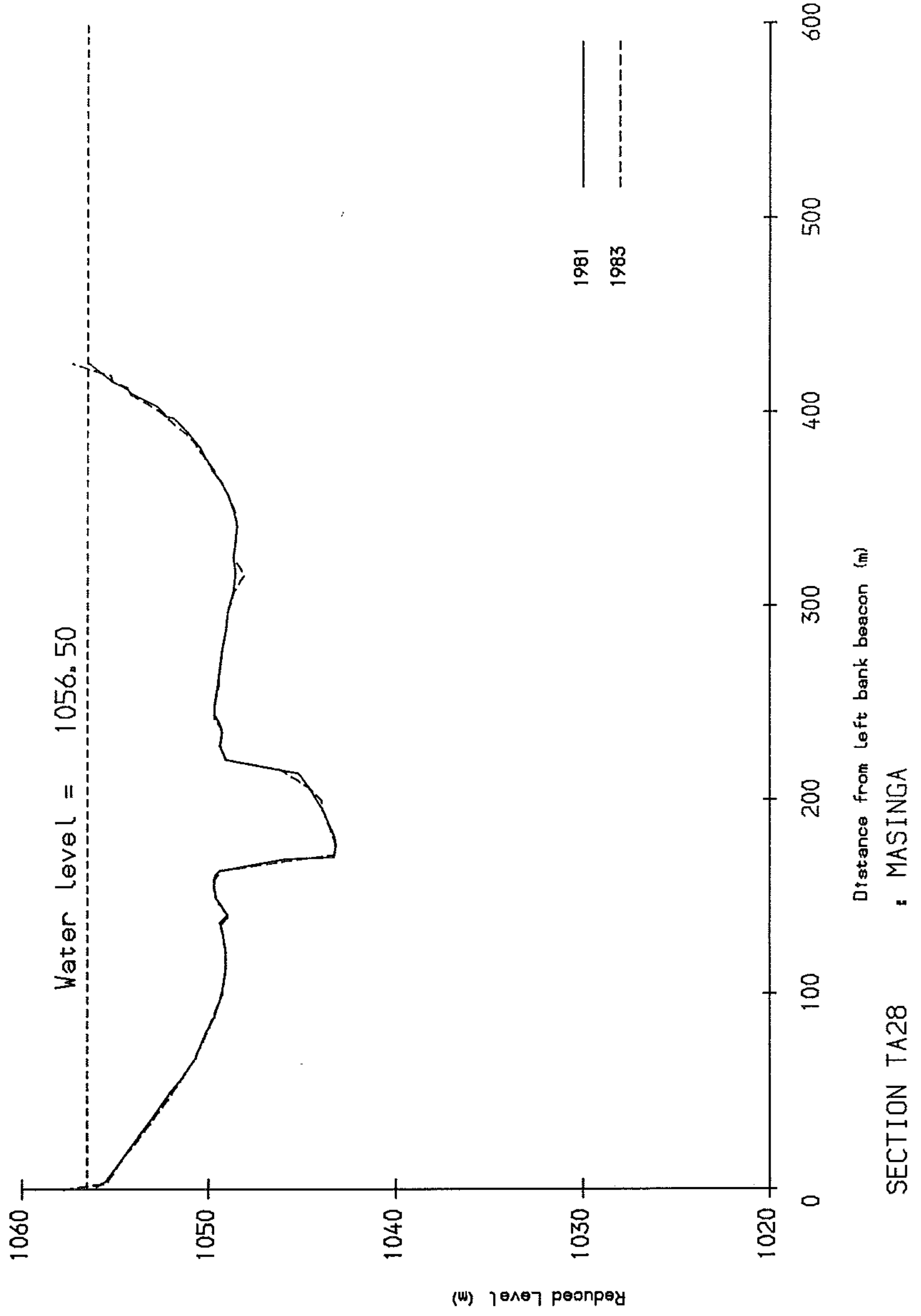

Fig 5·7 Masinga Reservoir - section TA28

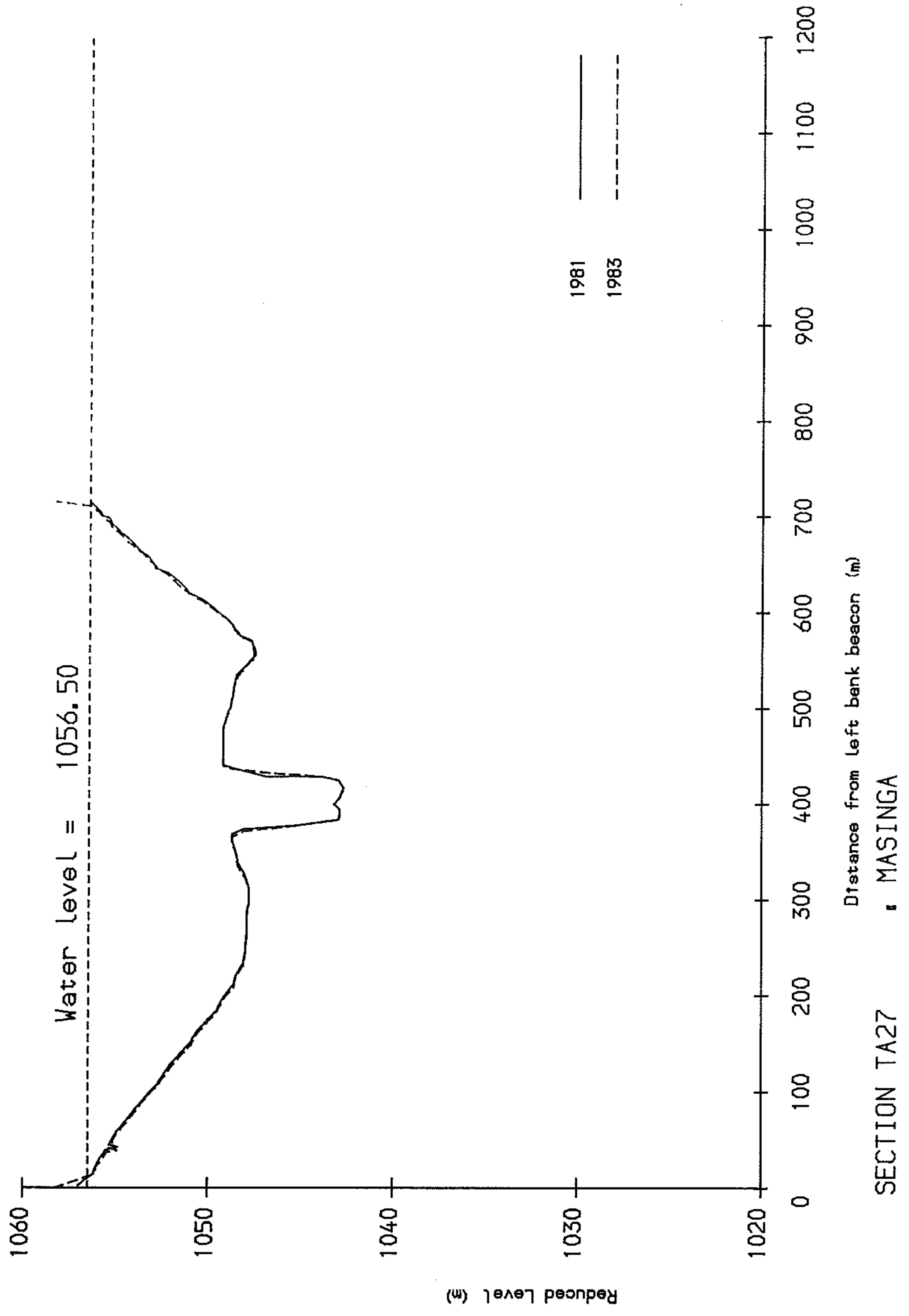

Fig 5·8 Masinga Reservoir - section TA27

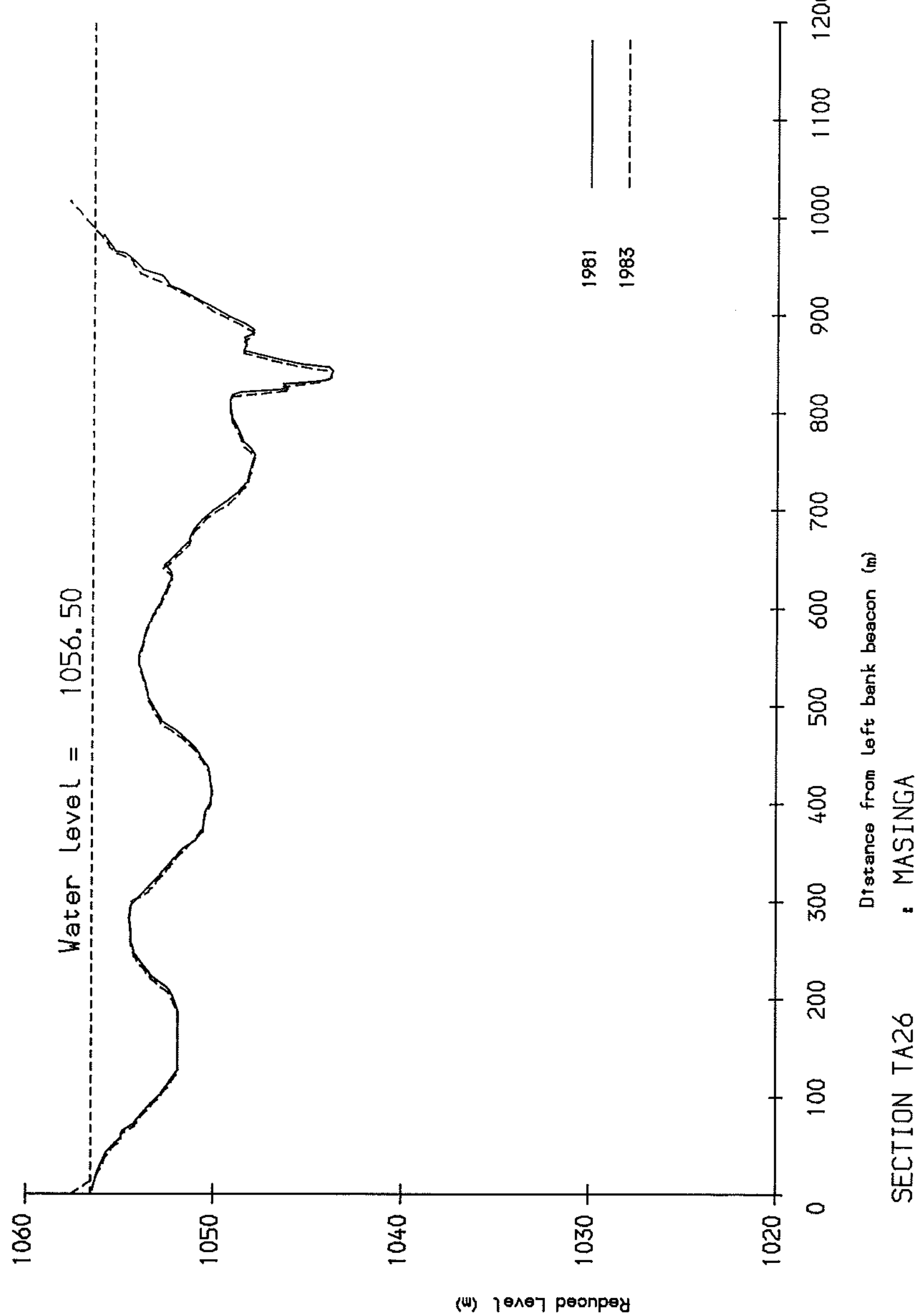

Fig 5.9 Masinga Reservoir – section TA26

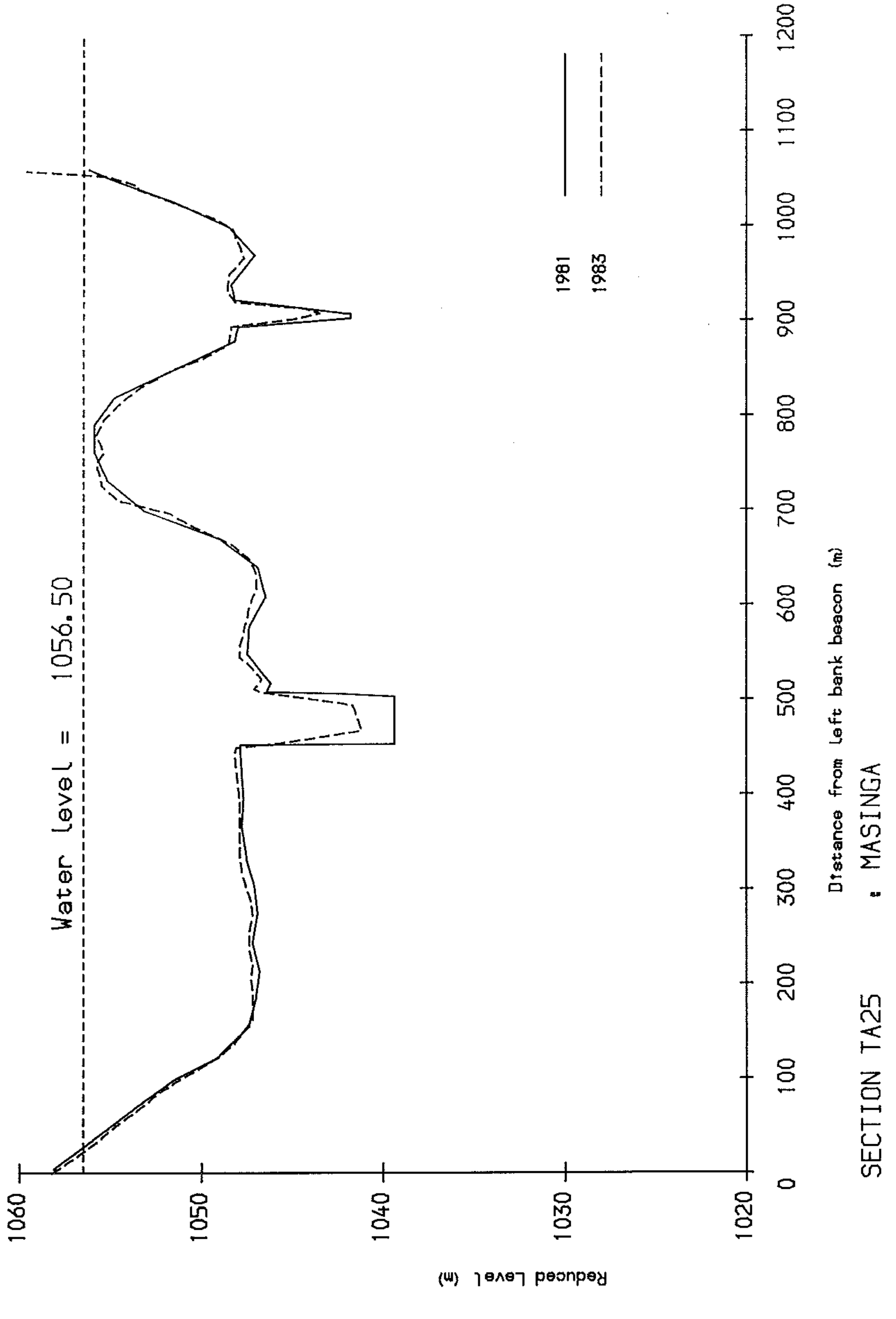

Fig 5·10 Masinga Reservoir – section TA25

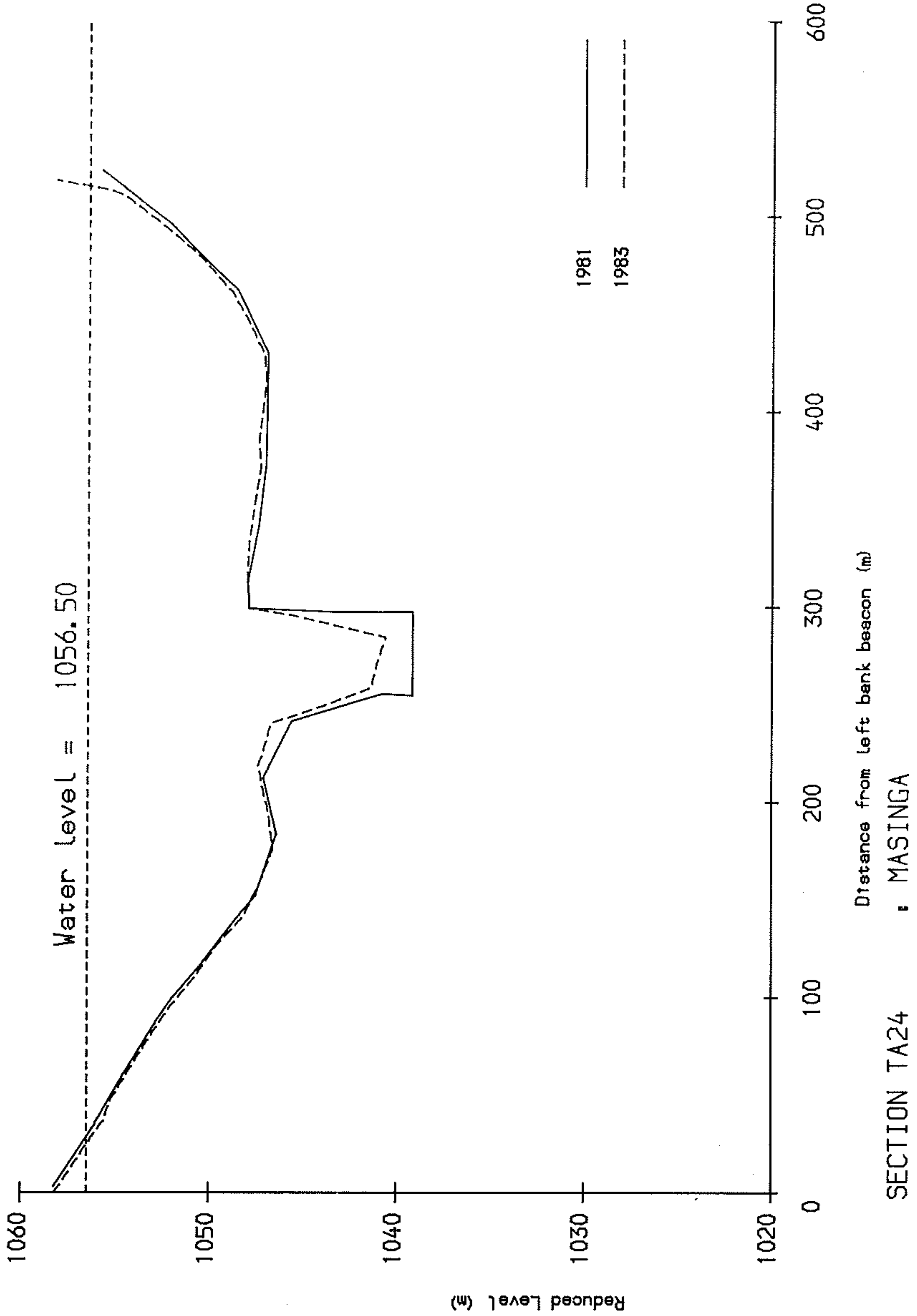

Fig 5.11 Masinga Reservoir-section TA24

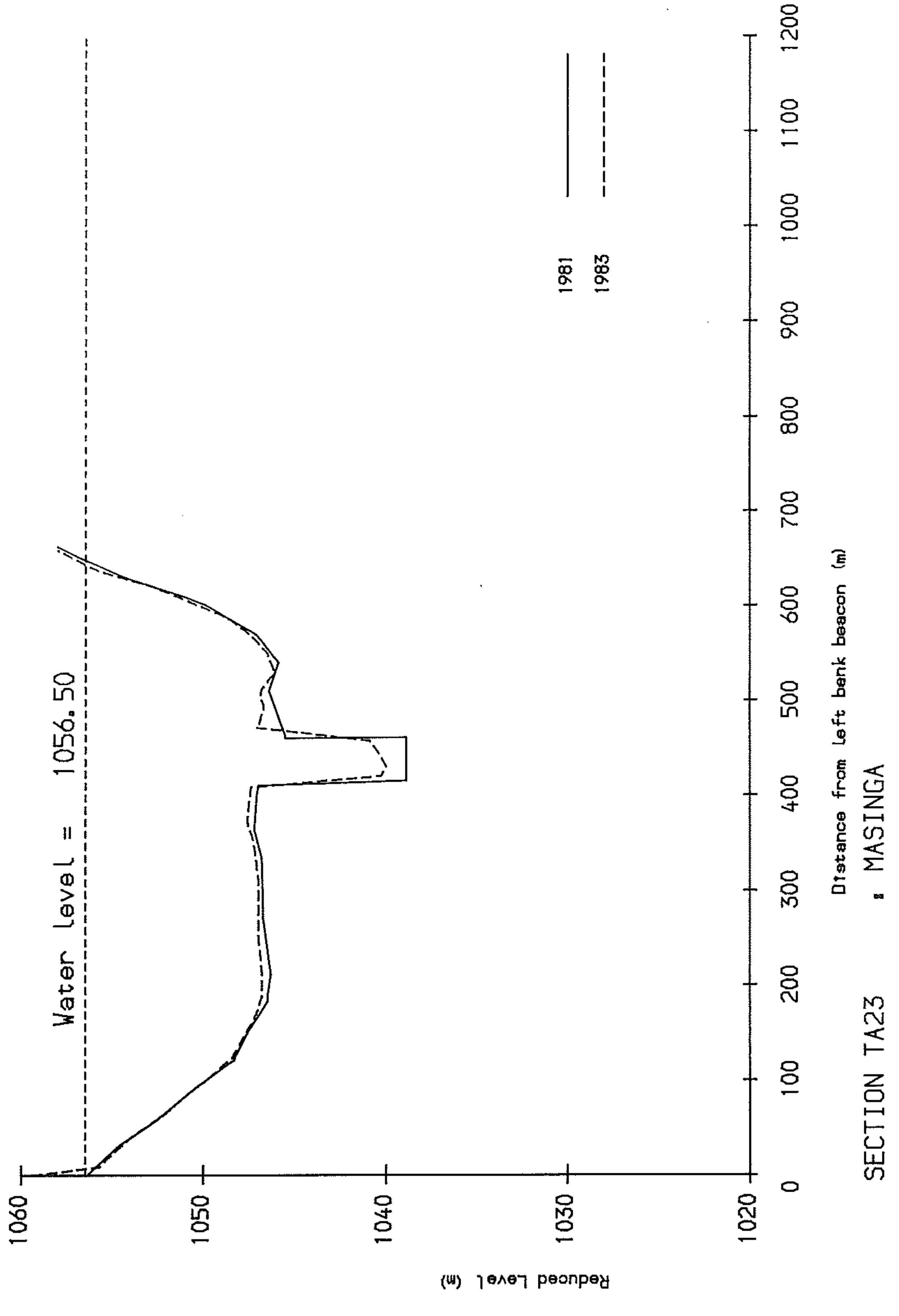

Fig 5·12 Masinga Reservoir - section TA23

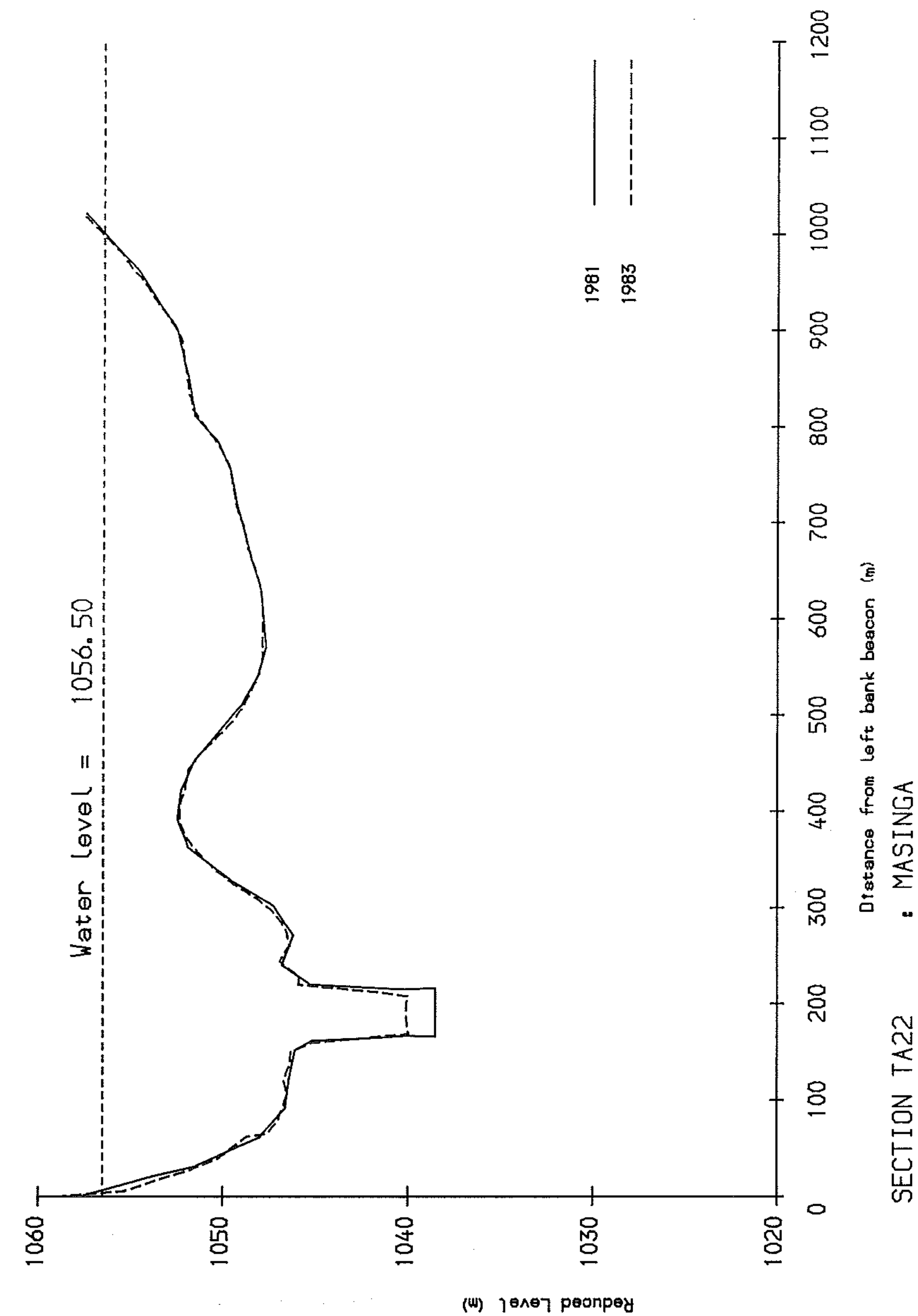

Fig 5.13 Masinga Reservoir- section TA22

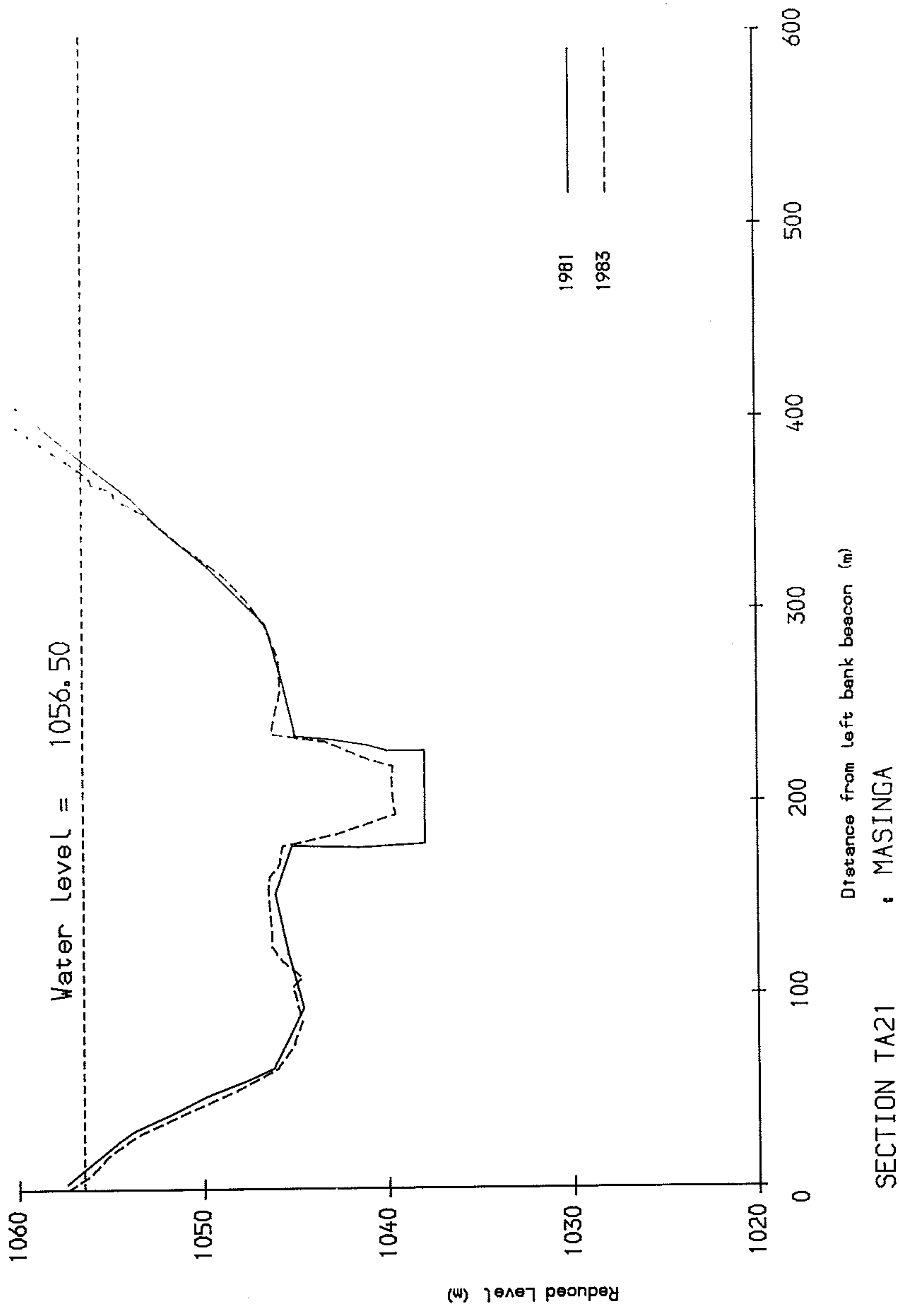

Fig 5·14 Masinga Reservoir - section TA 21

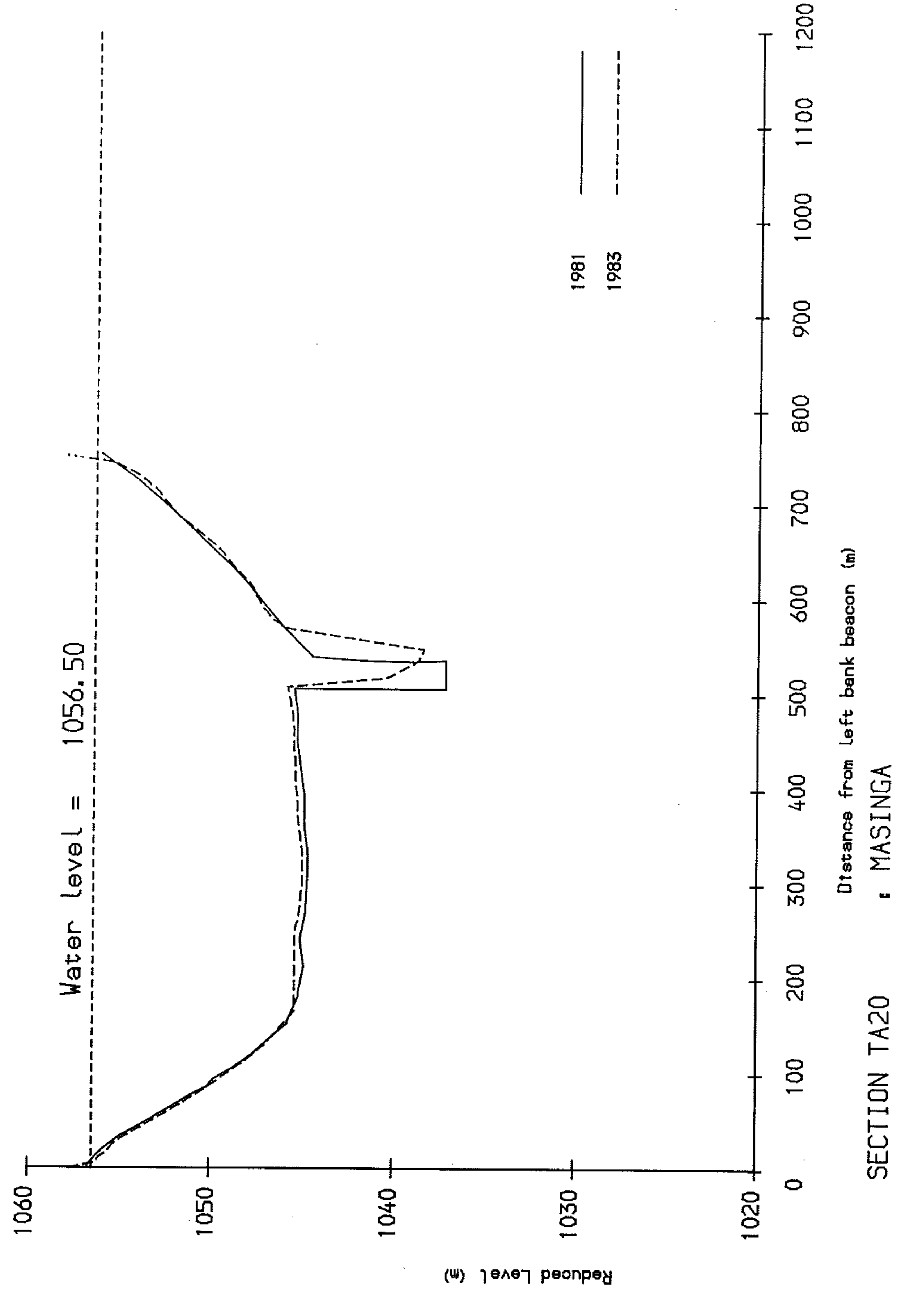

Fig 5·15 Masinga Reservoir - section TA20

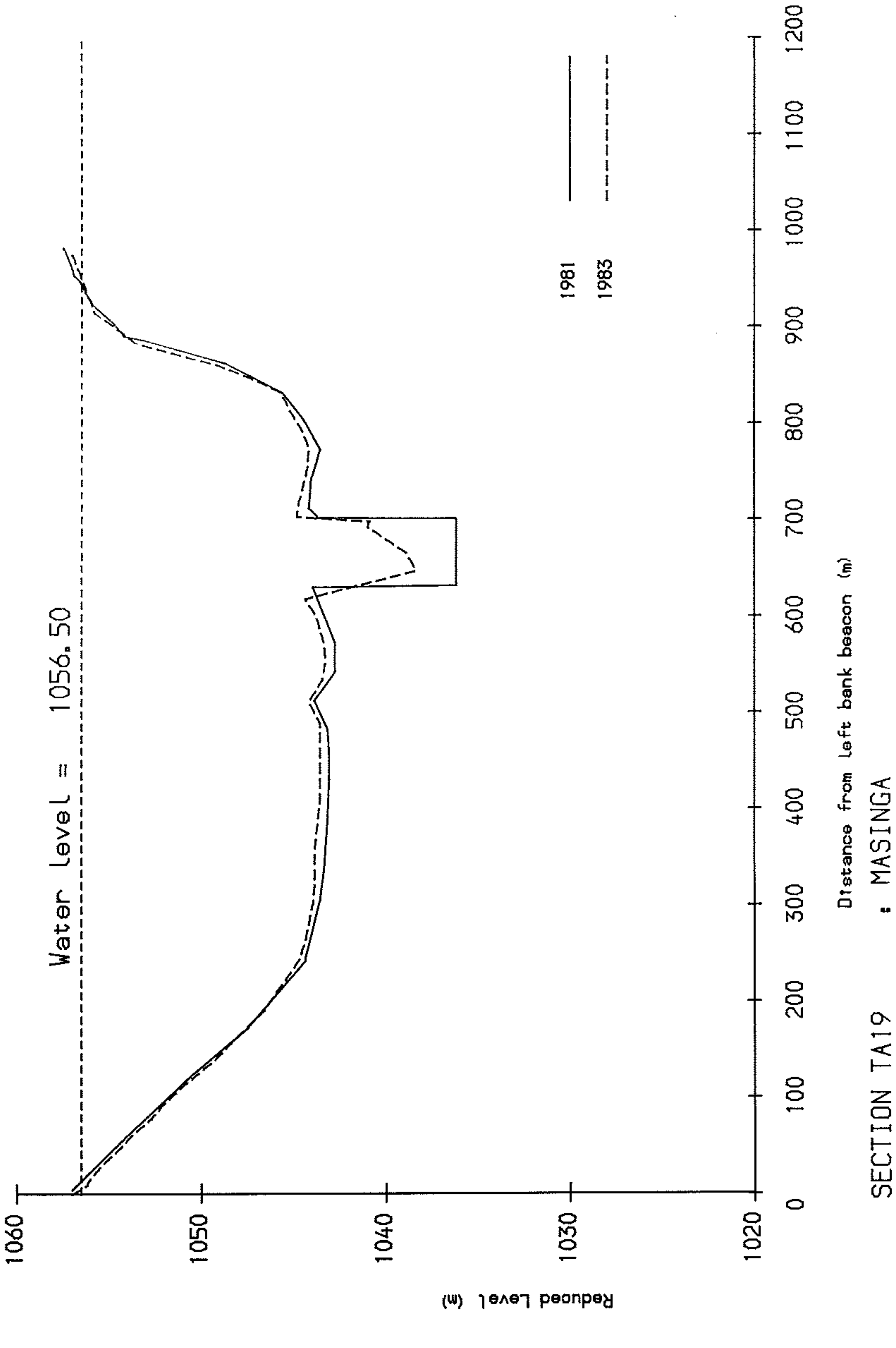

Fig 5·16 Masinga Reservoir-section TA19

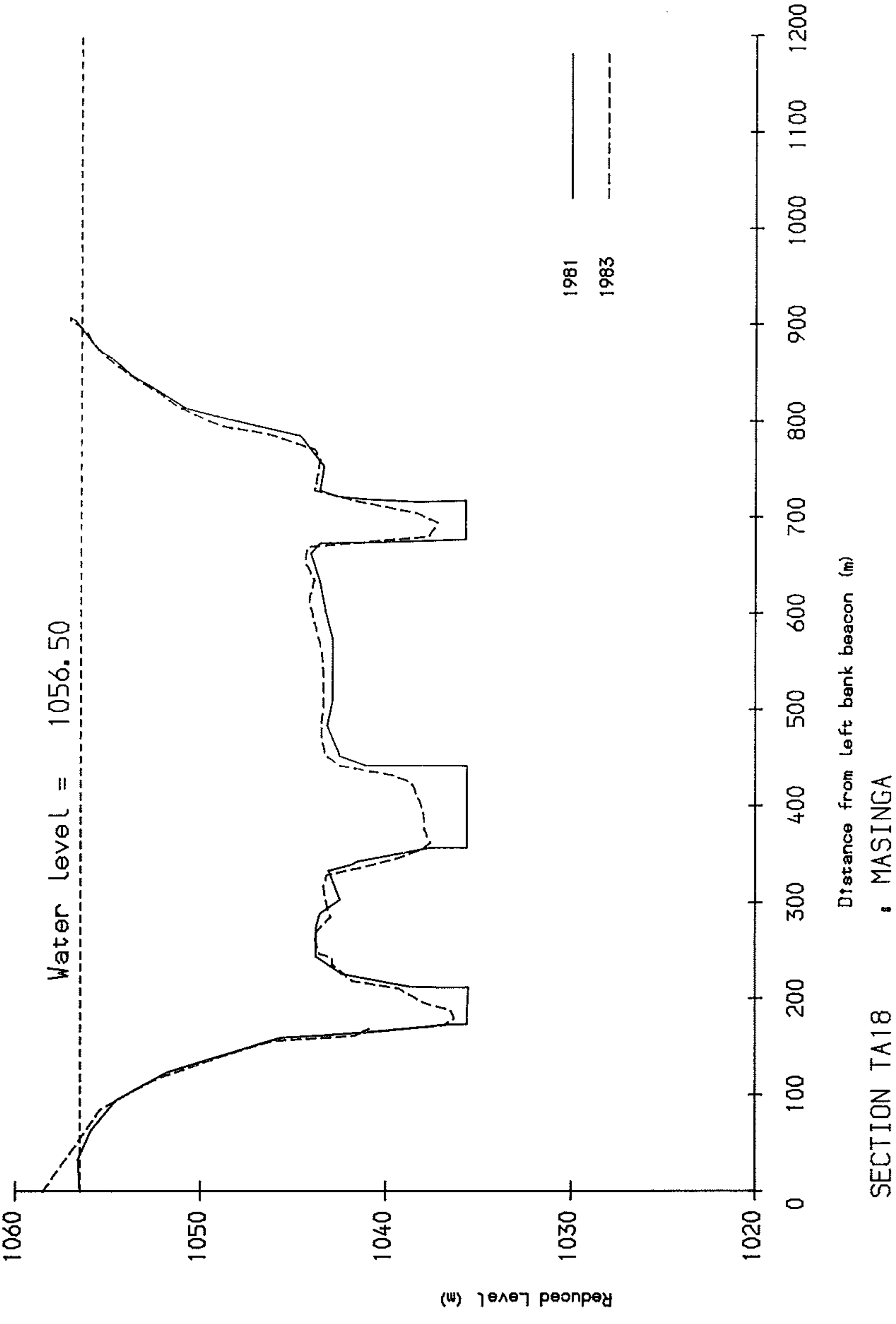

Fig 5·17 Masinga Reservoir - section TA18

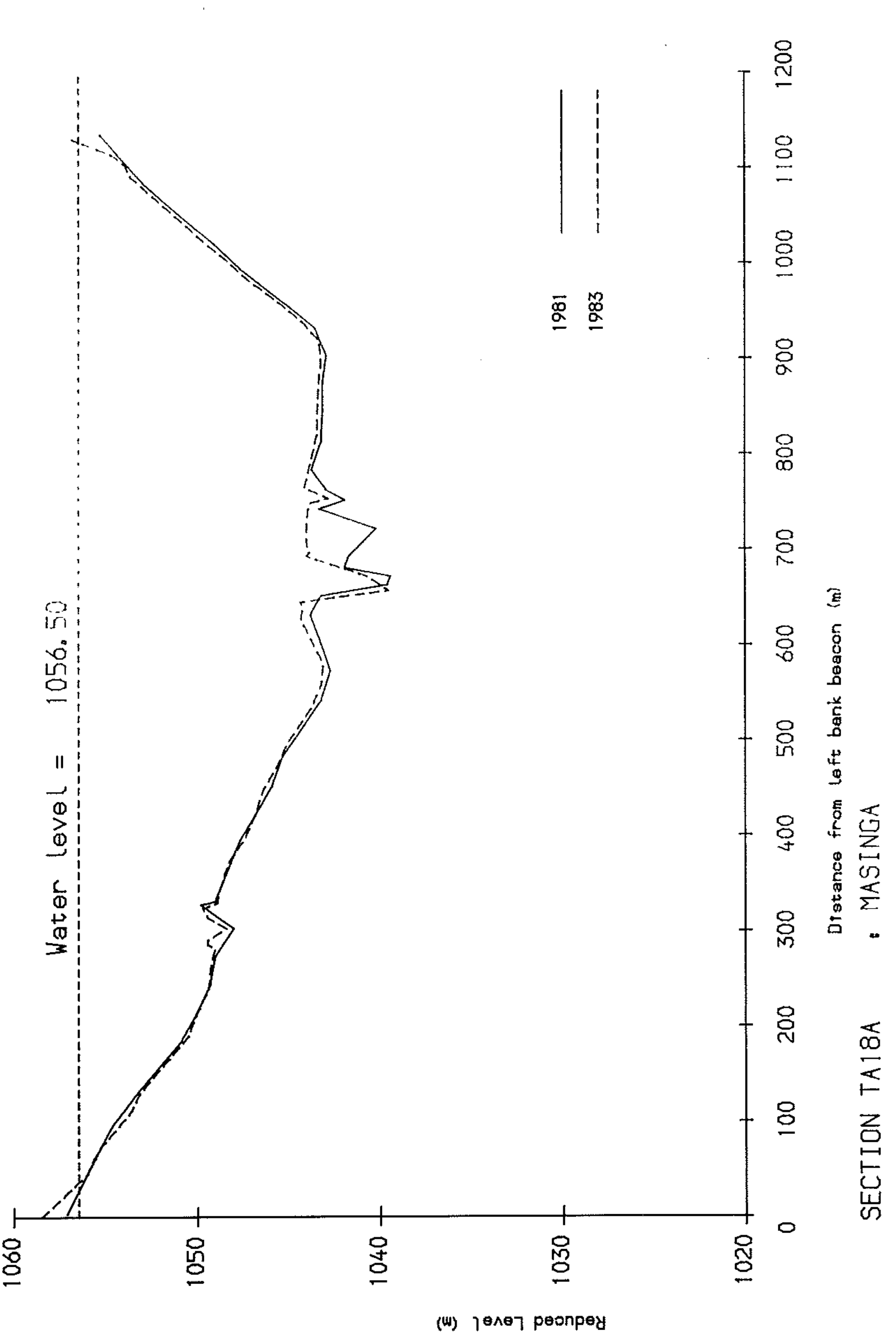

Fig 5.18 Masinga Reservoir-section TA18A

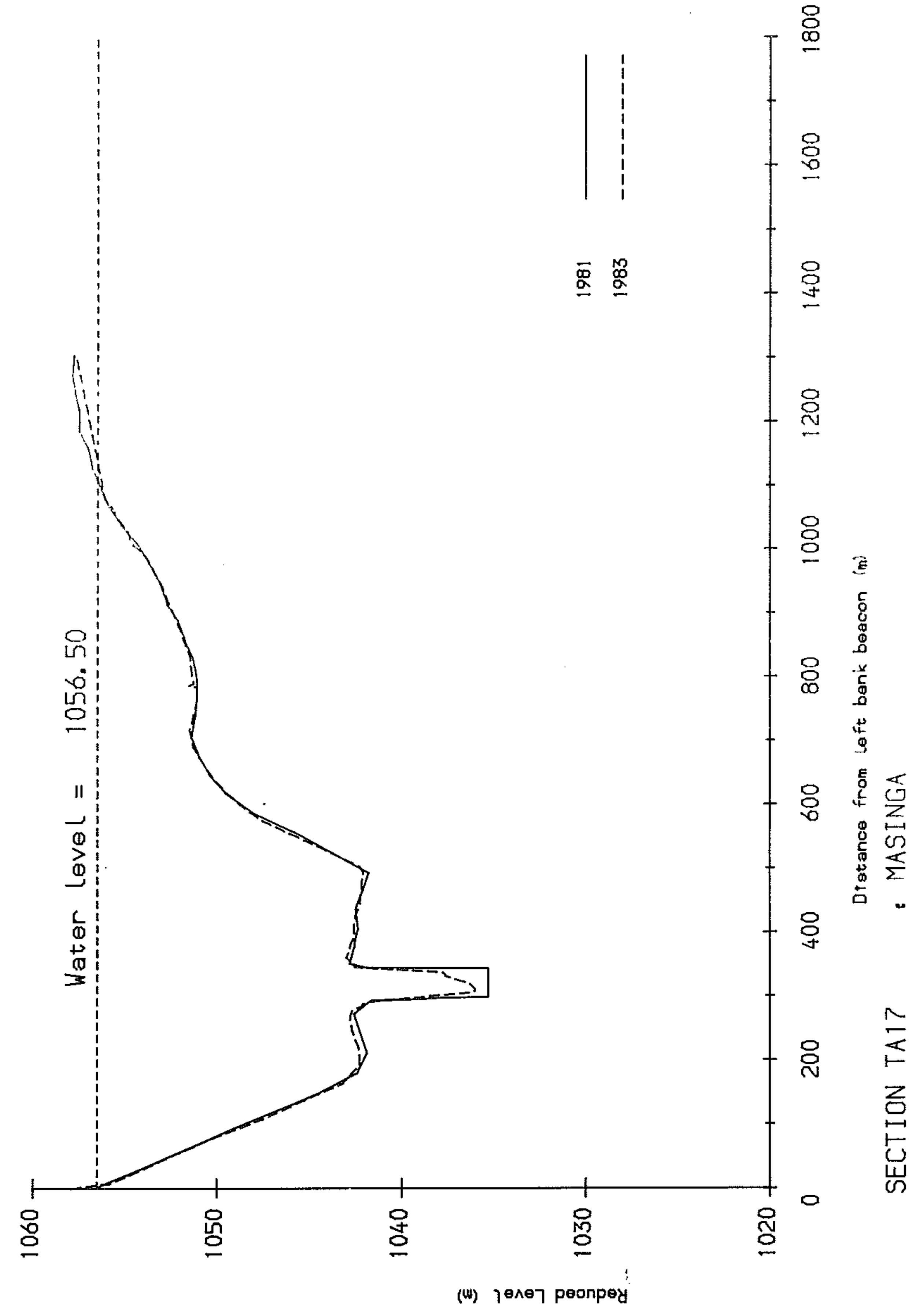

Fig 5·19 Masinga Reservoir - section TA17

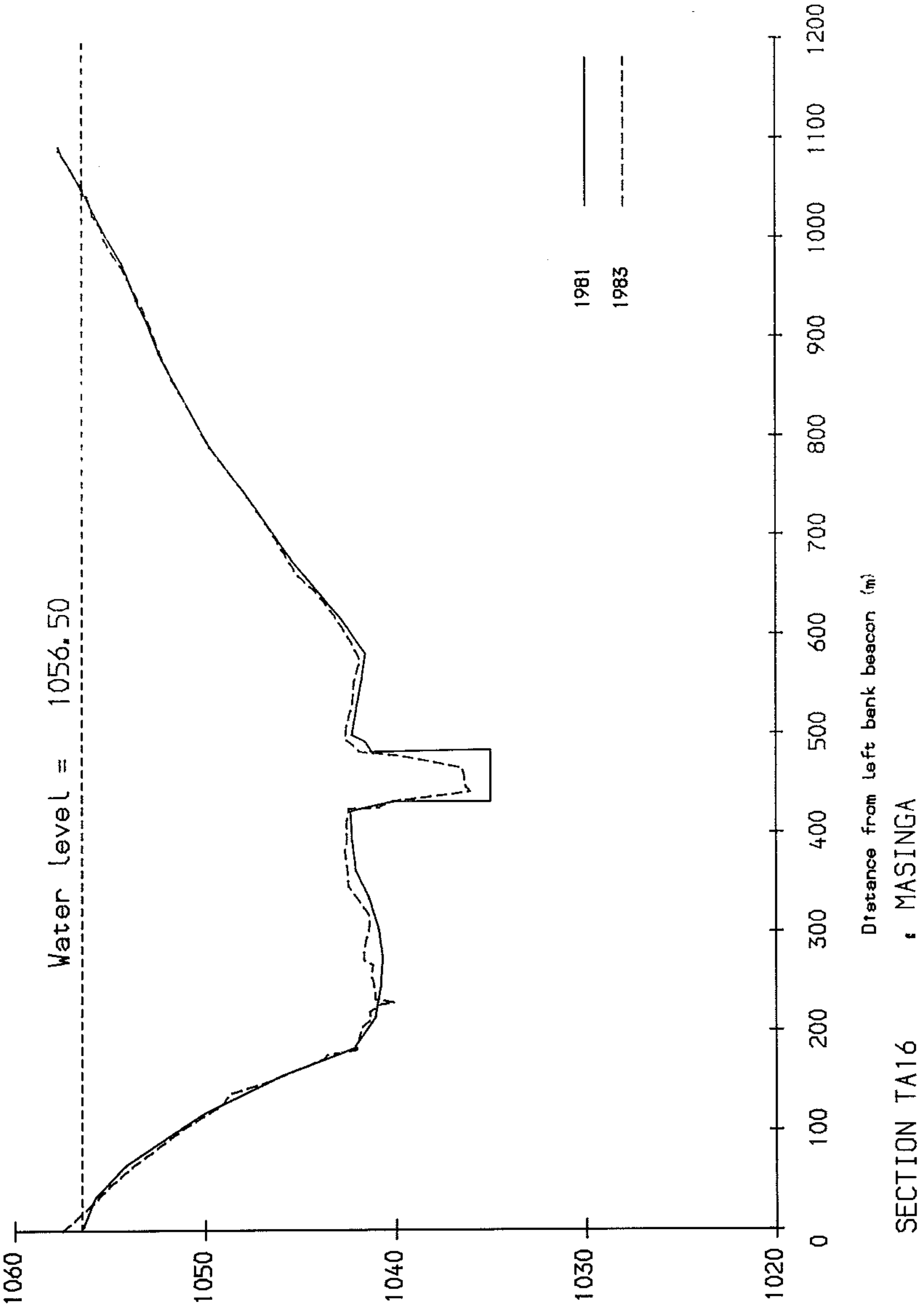

Fig 5·20 Masinga Reservoir – section TA16

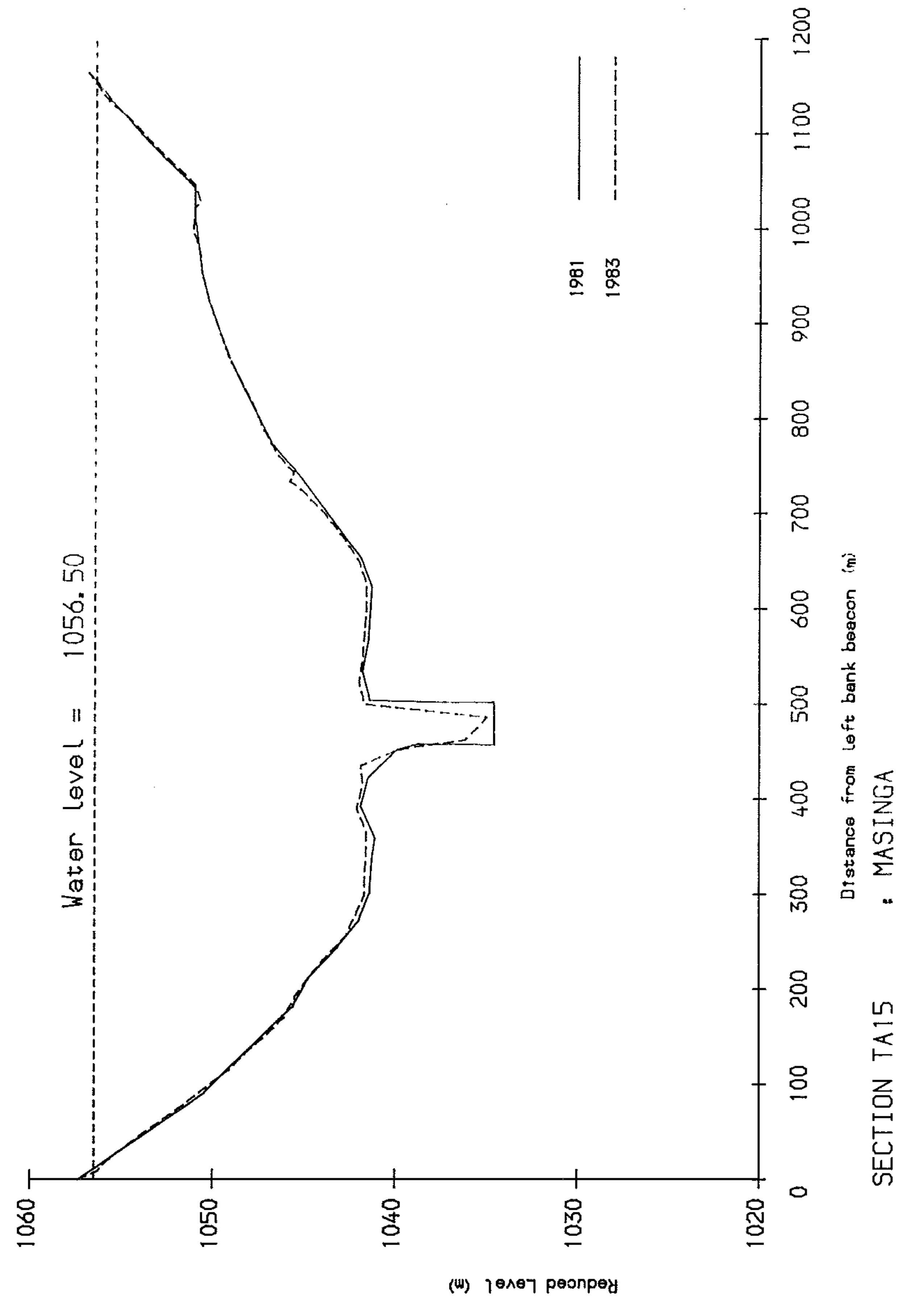

Fig 5·21 Masinga Reservoir-section TA15

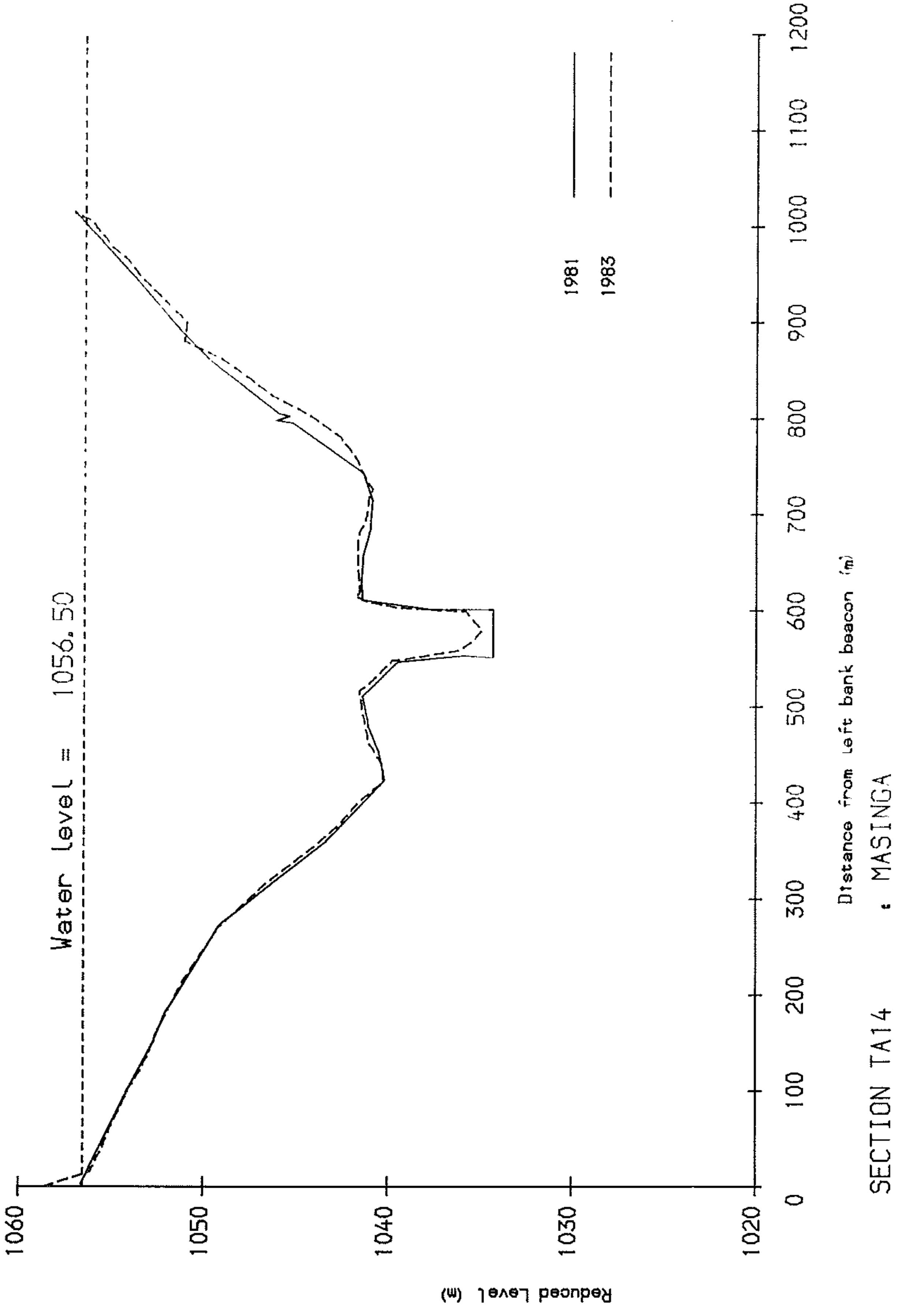

Fig 5·22 Masinga Reservoir – section TA14

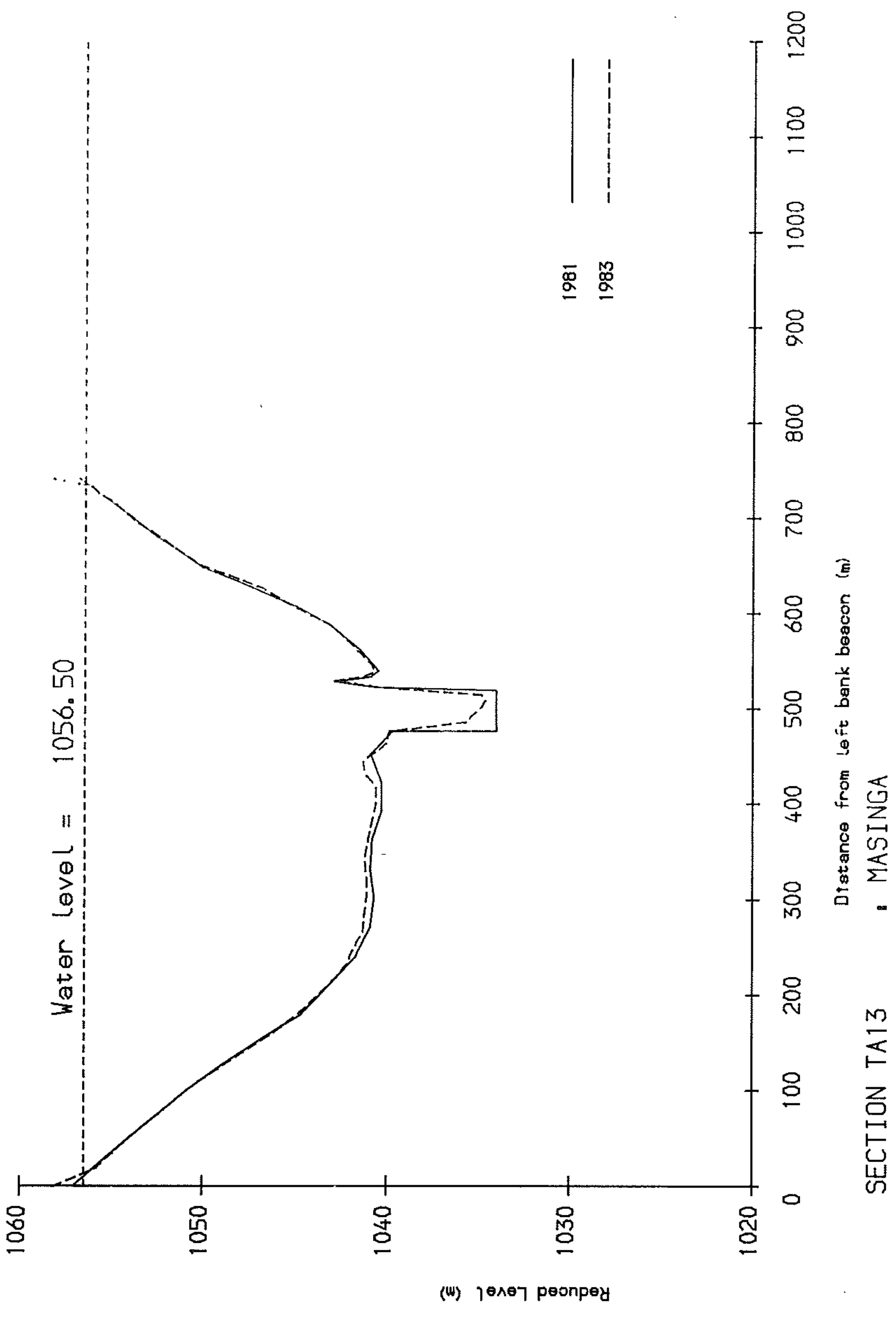

Fig 5·23 Masinga Reservoir – section TA13

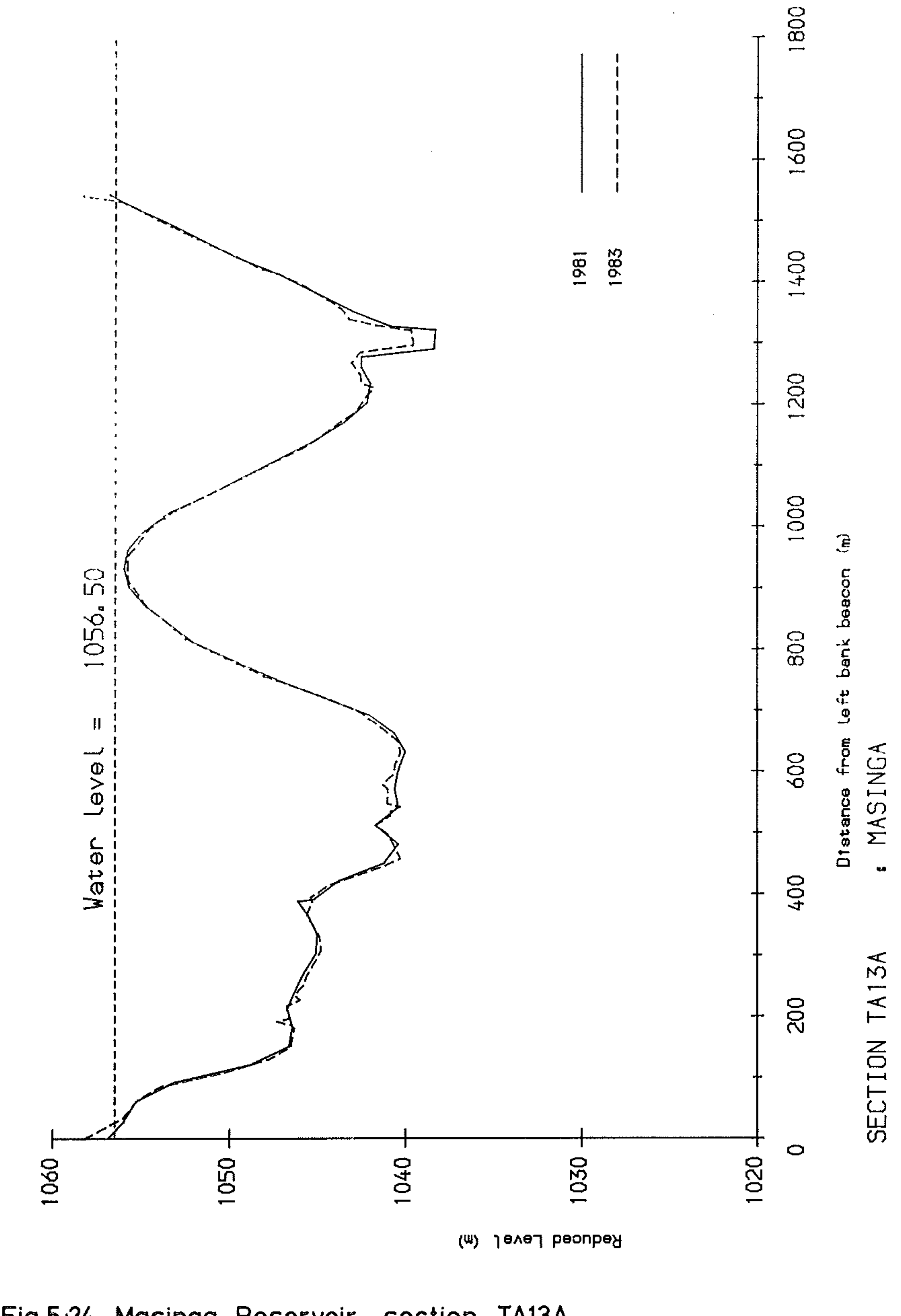

Fig 5·24 Masinga Reservoir – section TA13A

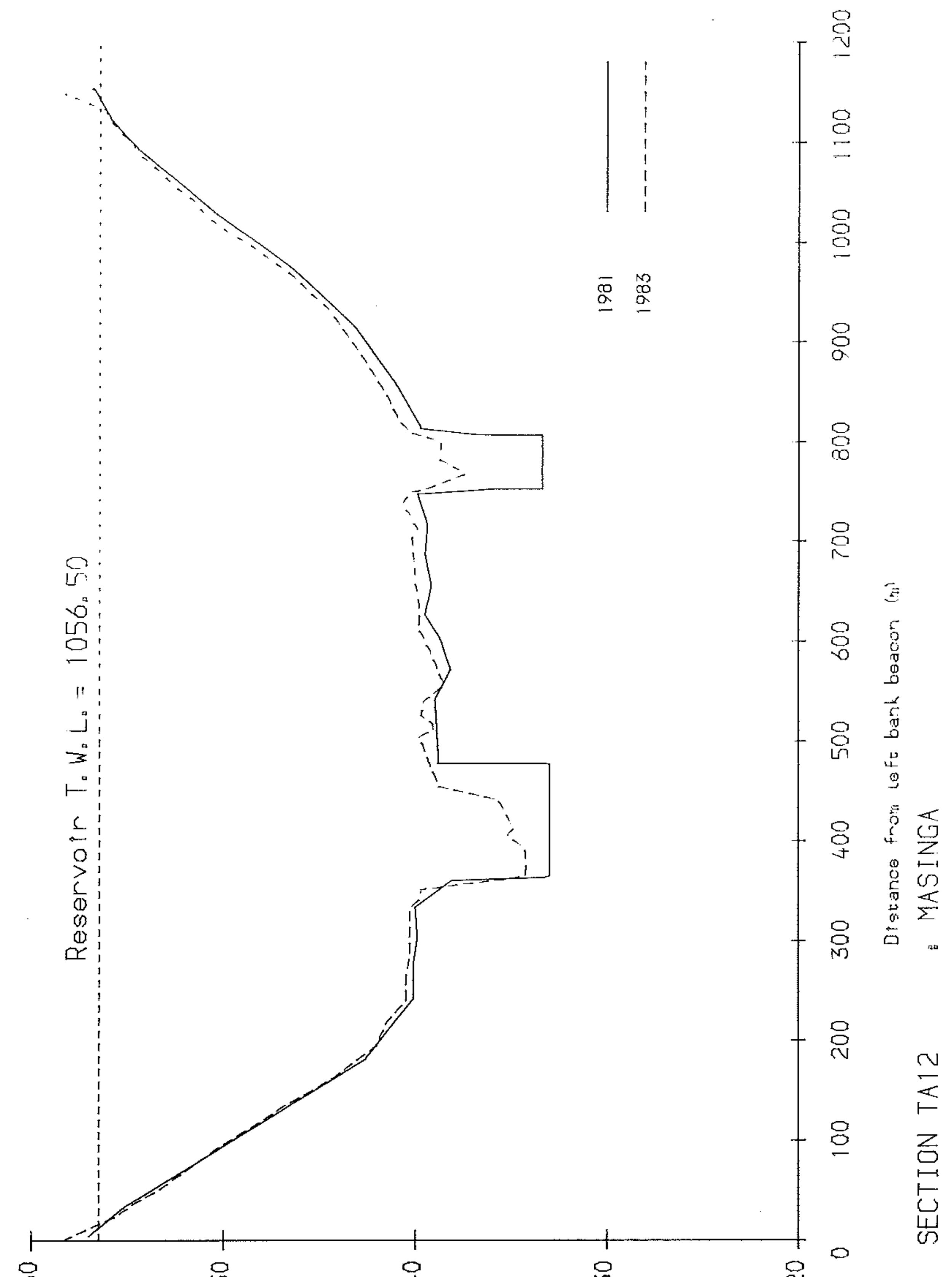

Fig 5·25 Masinga Reservoir - section TA12

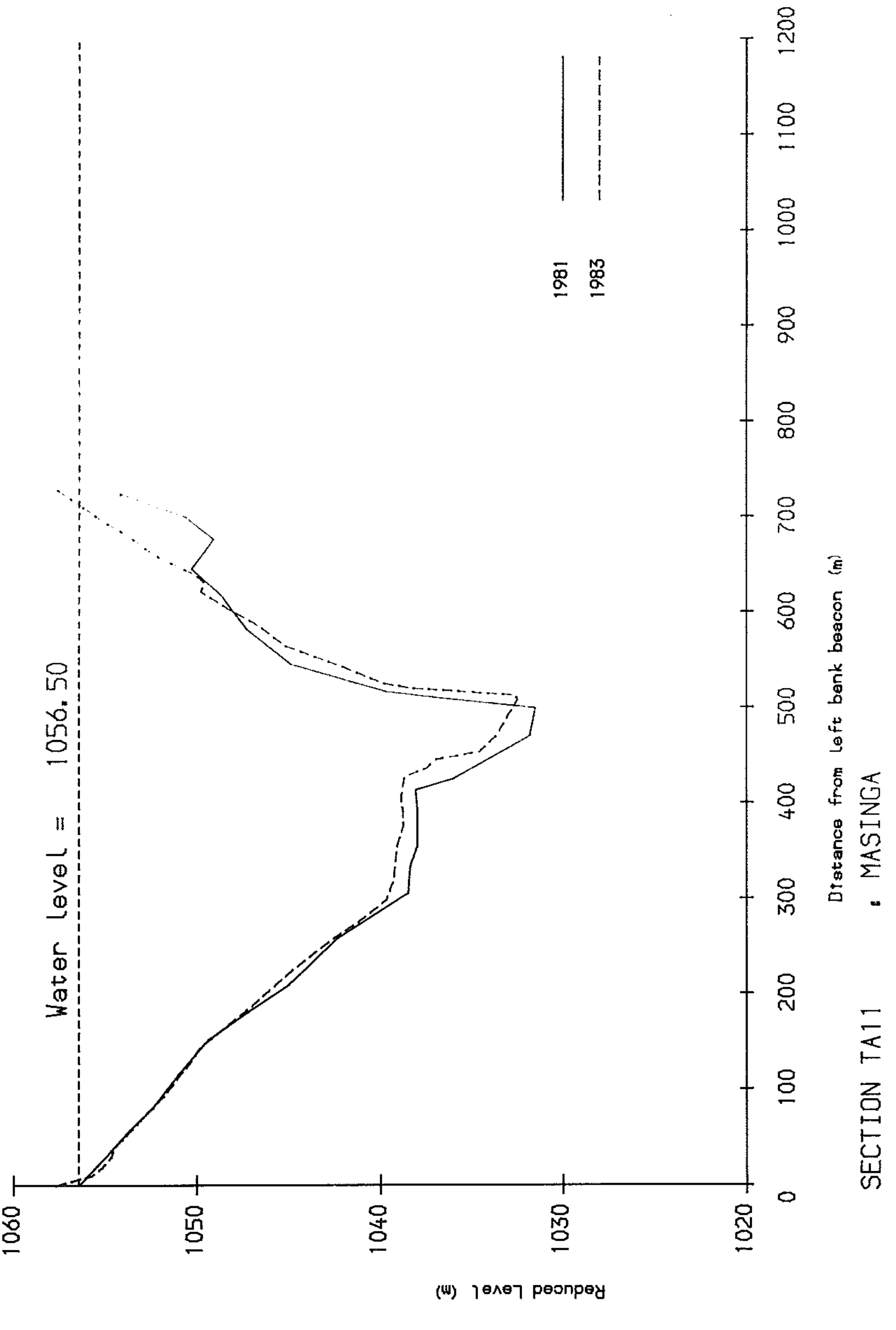

Fig 5·26 Masinga Reservoir – section TA11

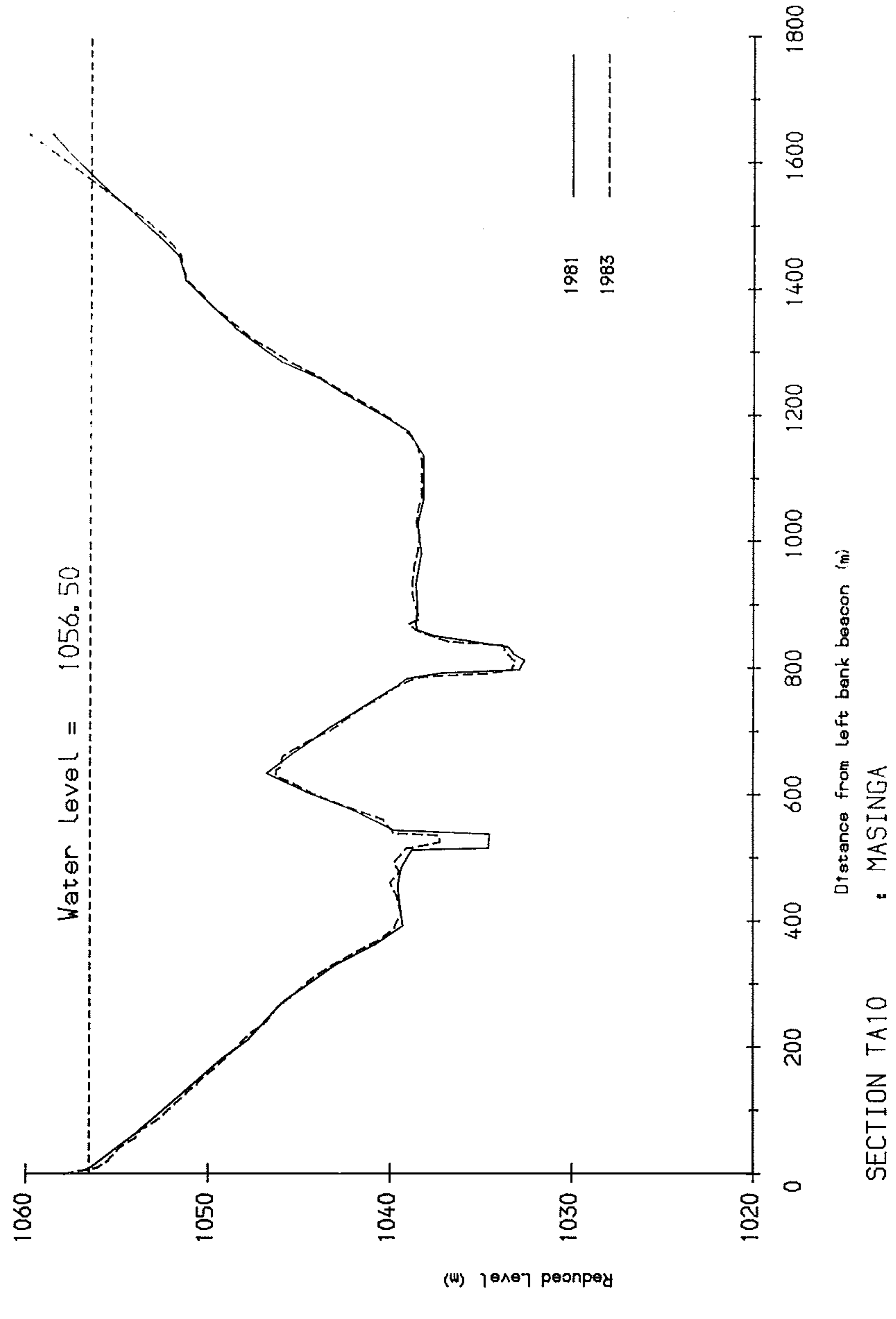

Fig 5·27 Masinga Reservoir - section TA10

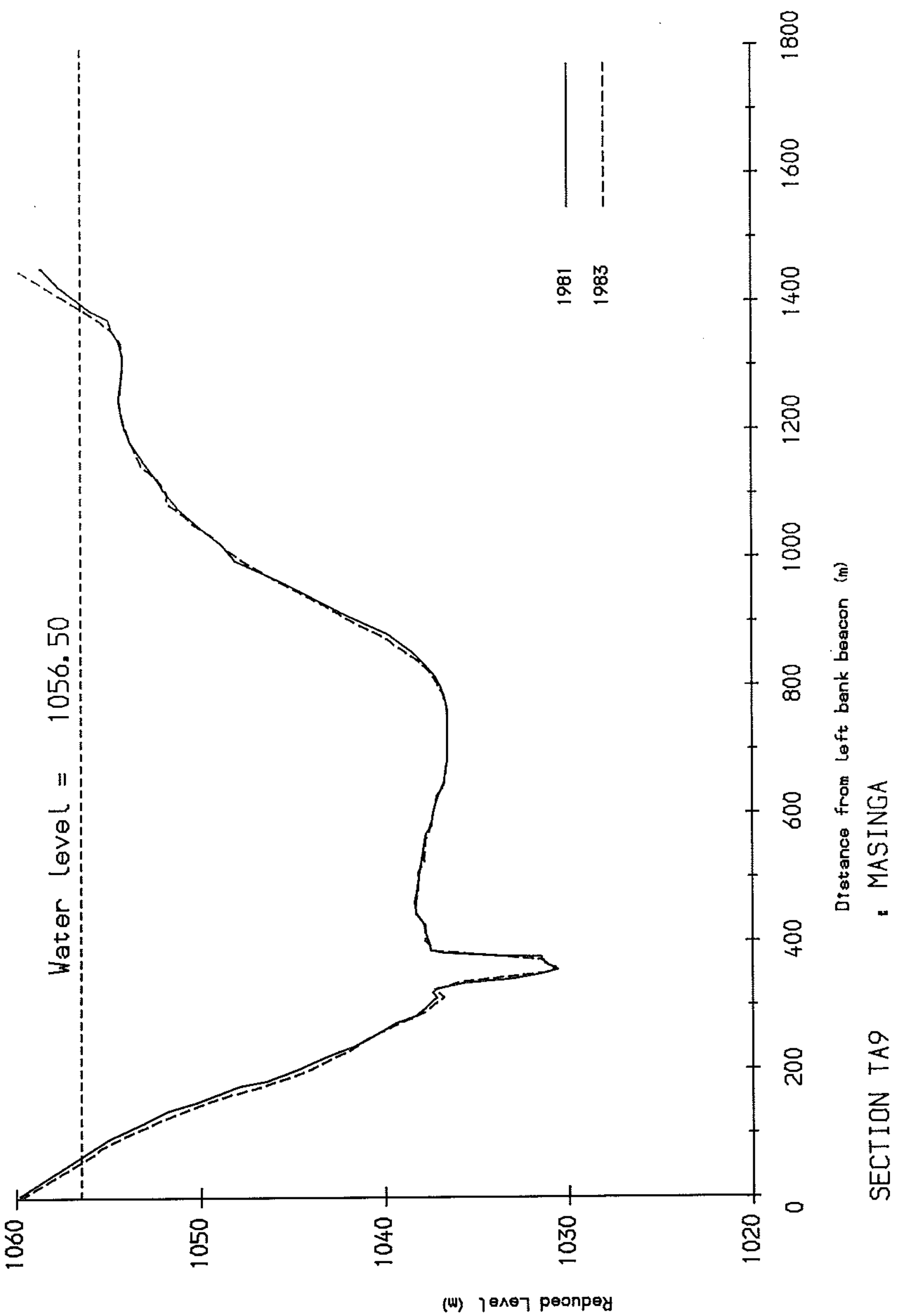

Fig 5.28 Masinga Reservoir - section TA9

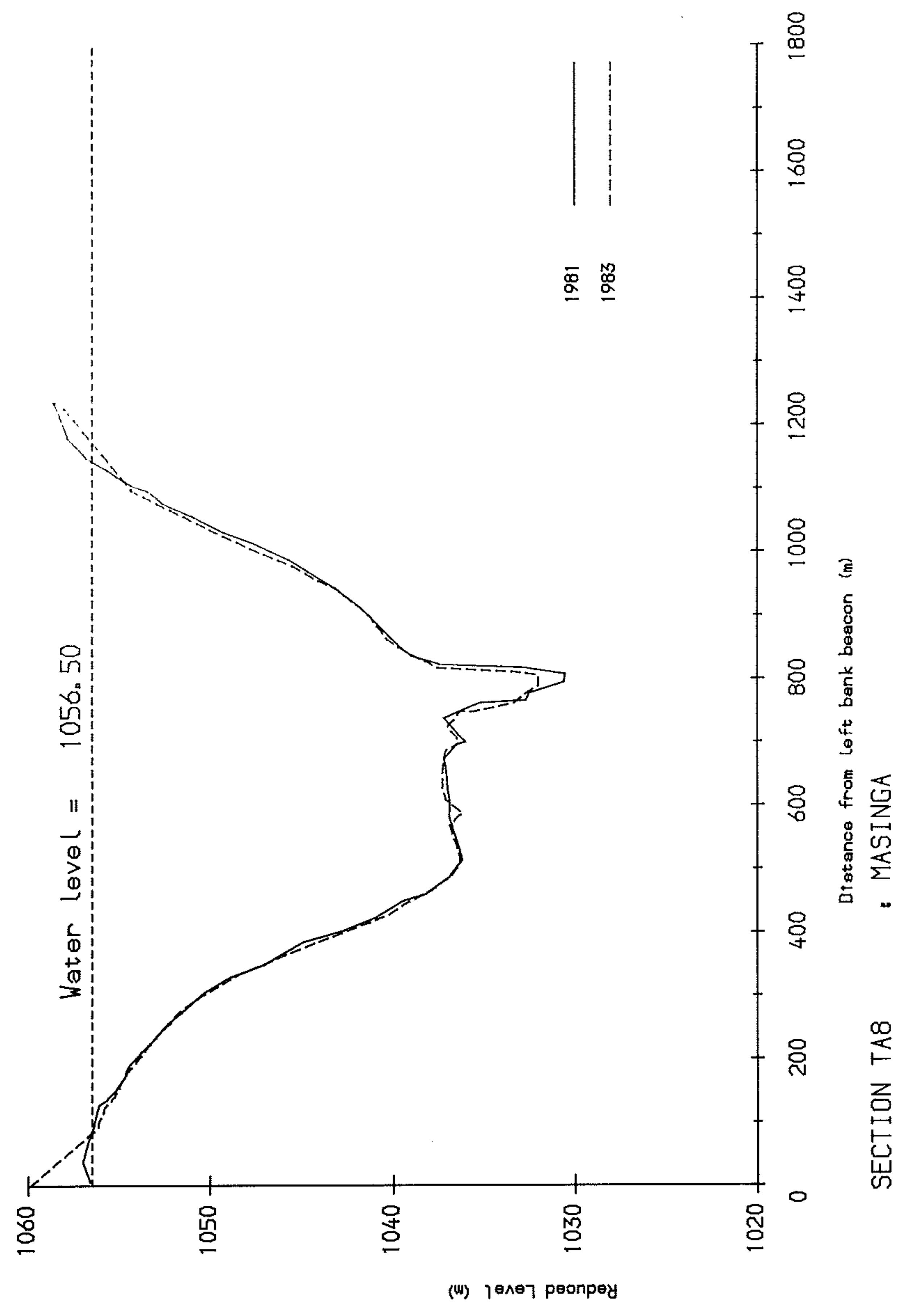

Fig 5·29 Masinga Reservoir - section TA8

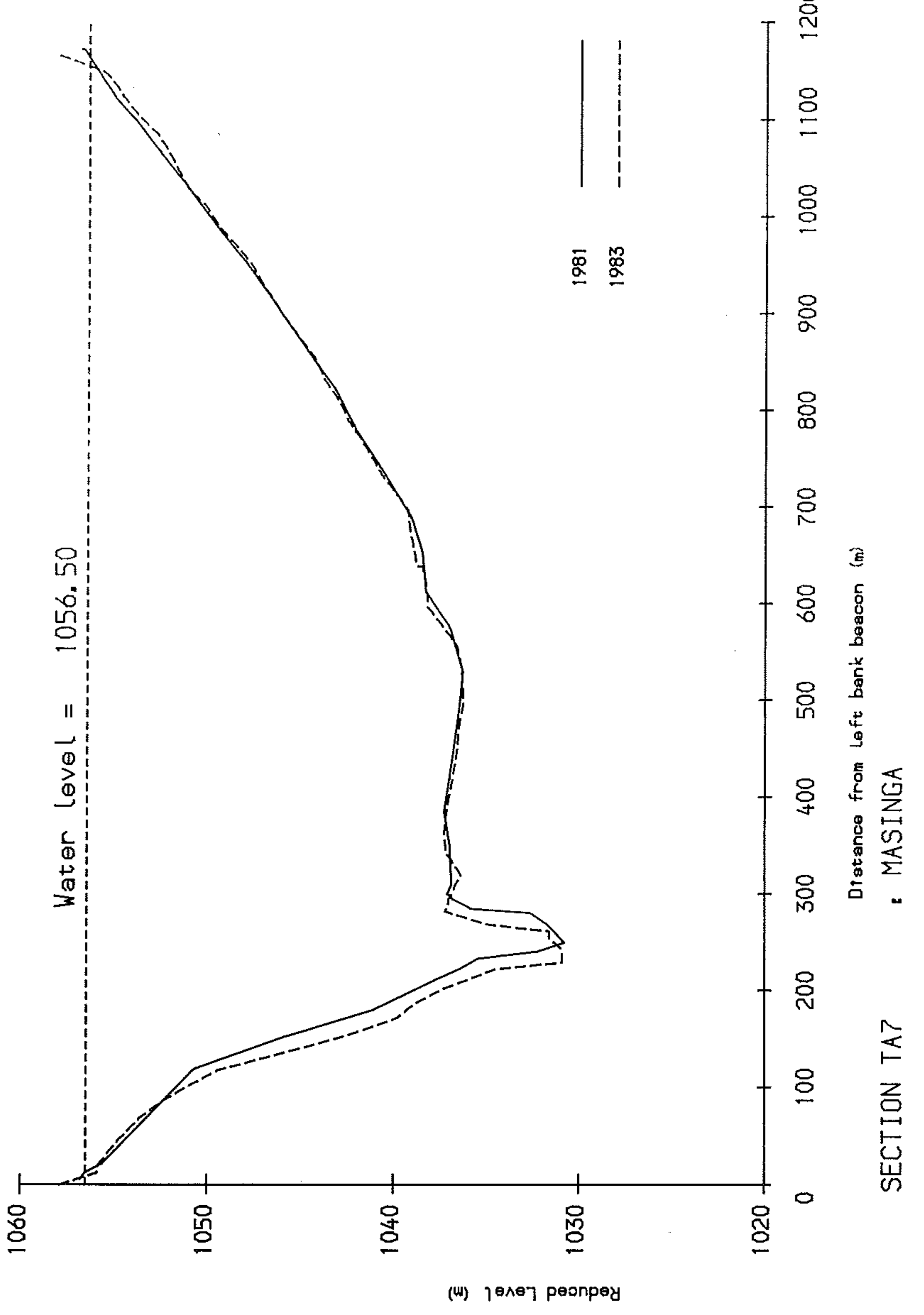

Fig 5·30 Masinga Reservoir – section TA7

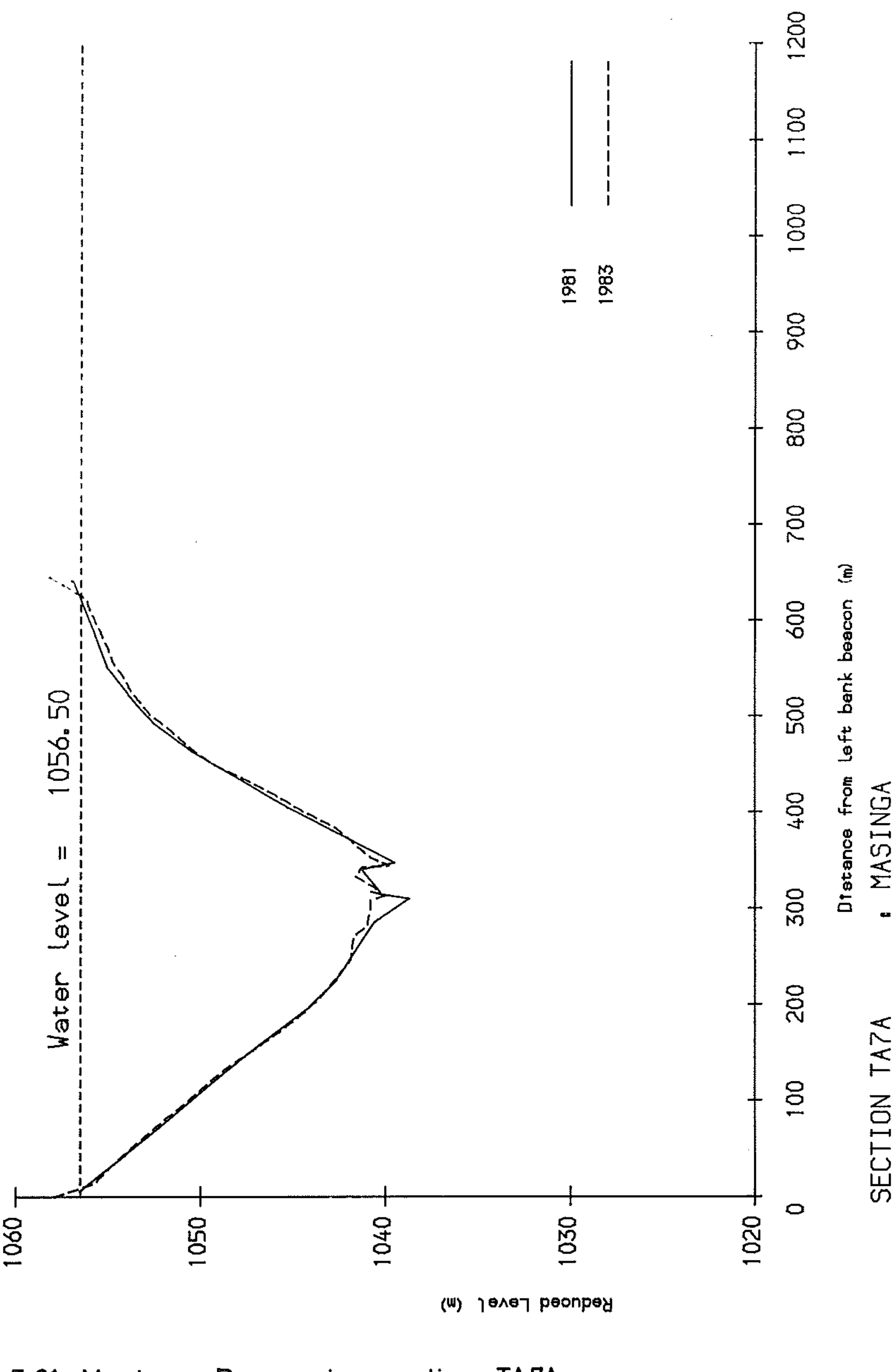

Fig 5·31 Masinga Reservoir – section TA7A

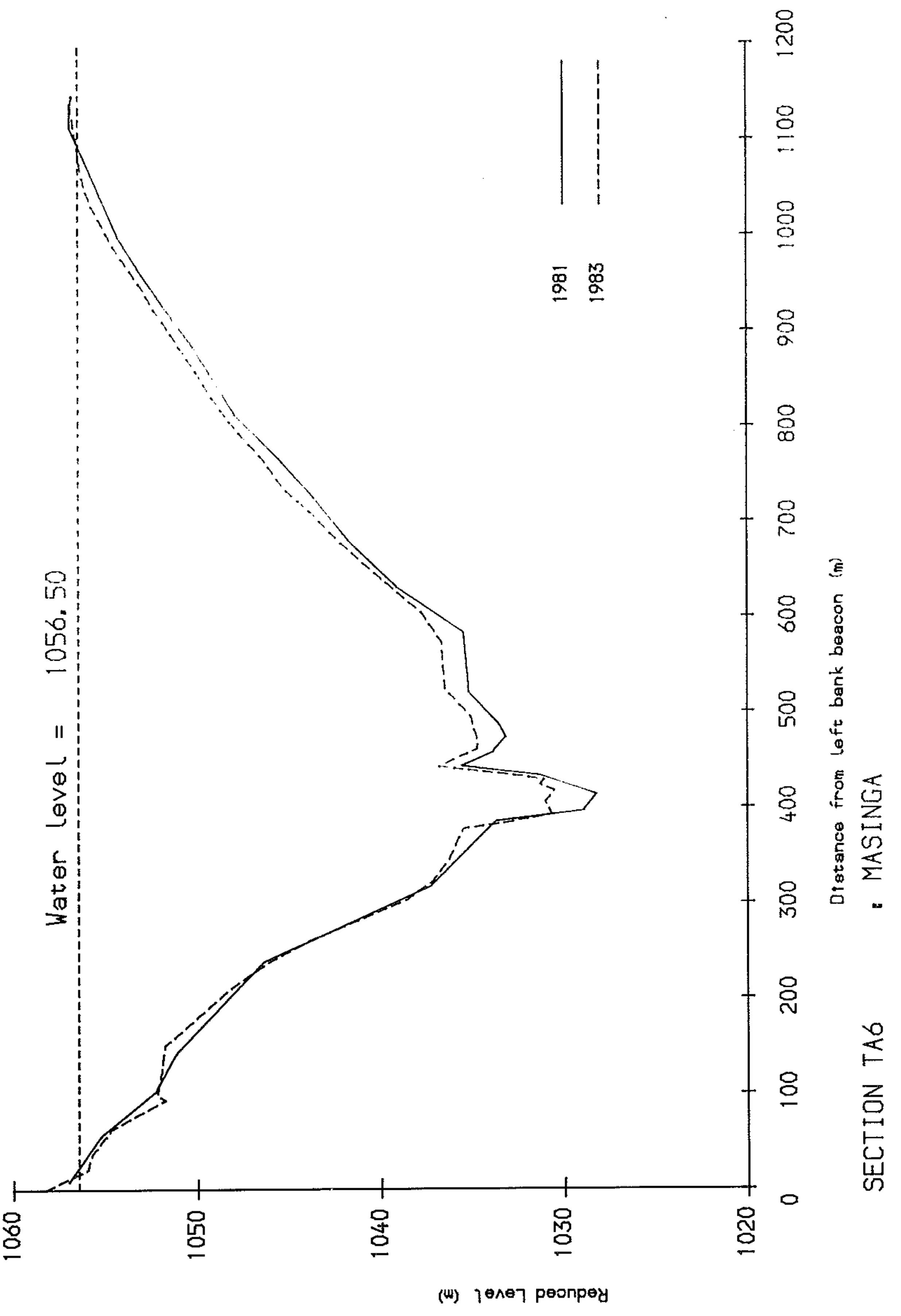

Fig 5·32 Masinga Reservoir - section TA6

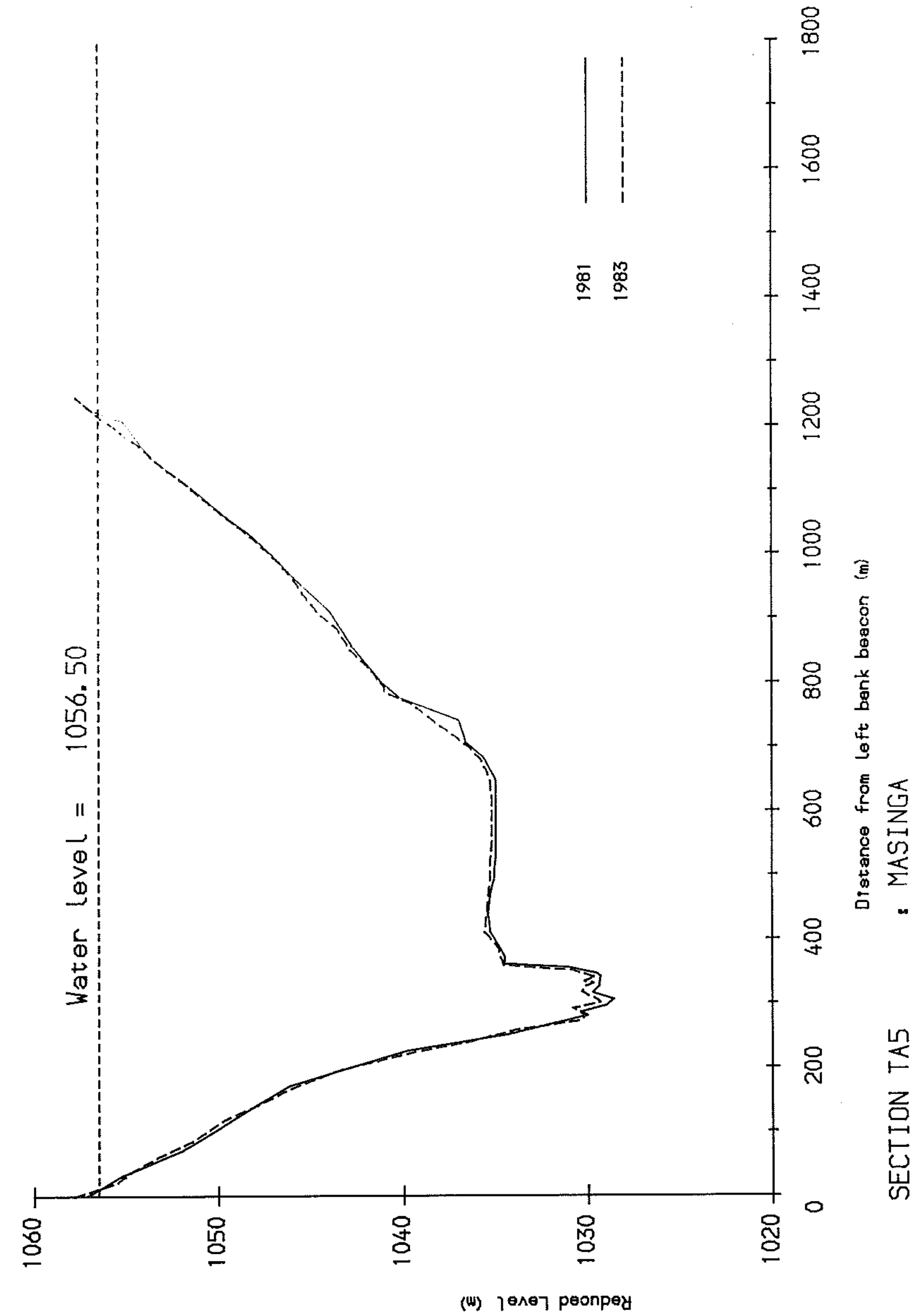

Fig 5·33 Masinga Reservoir – section TA5

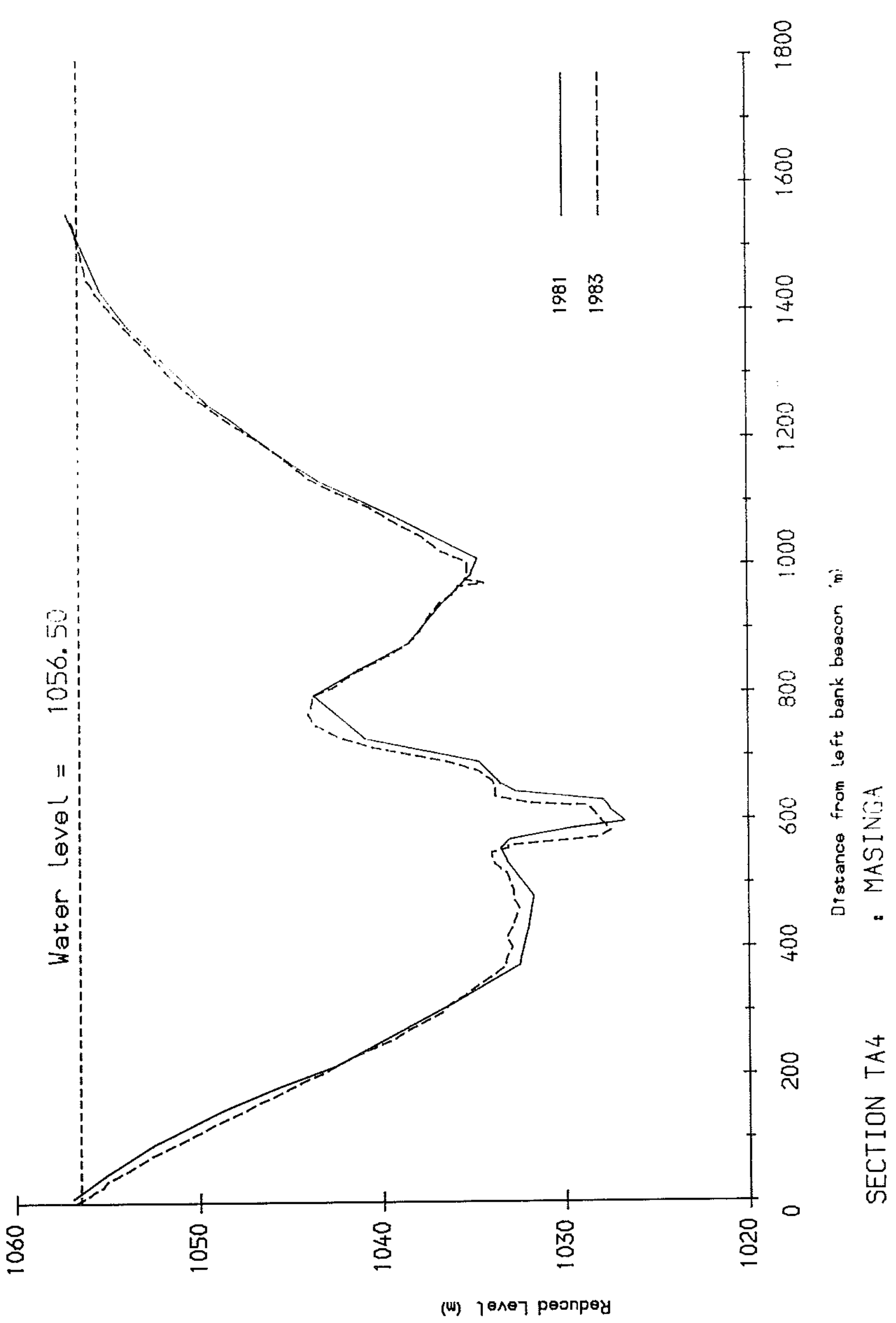

Fig 5·34 Masinga Reservoir - section TA4

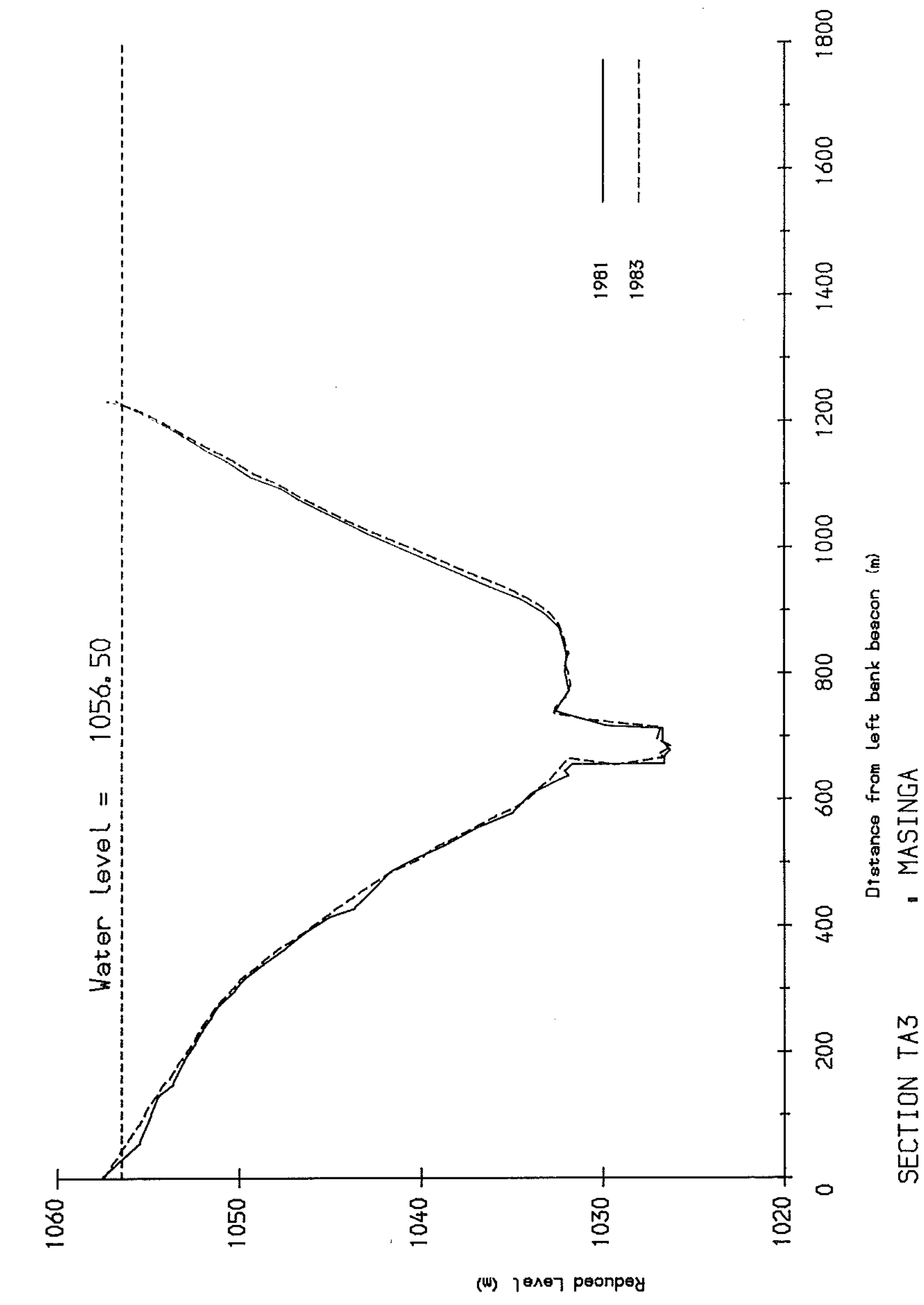

Fig 5.35 Masinga Reservoir - section TA3

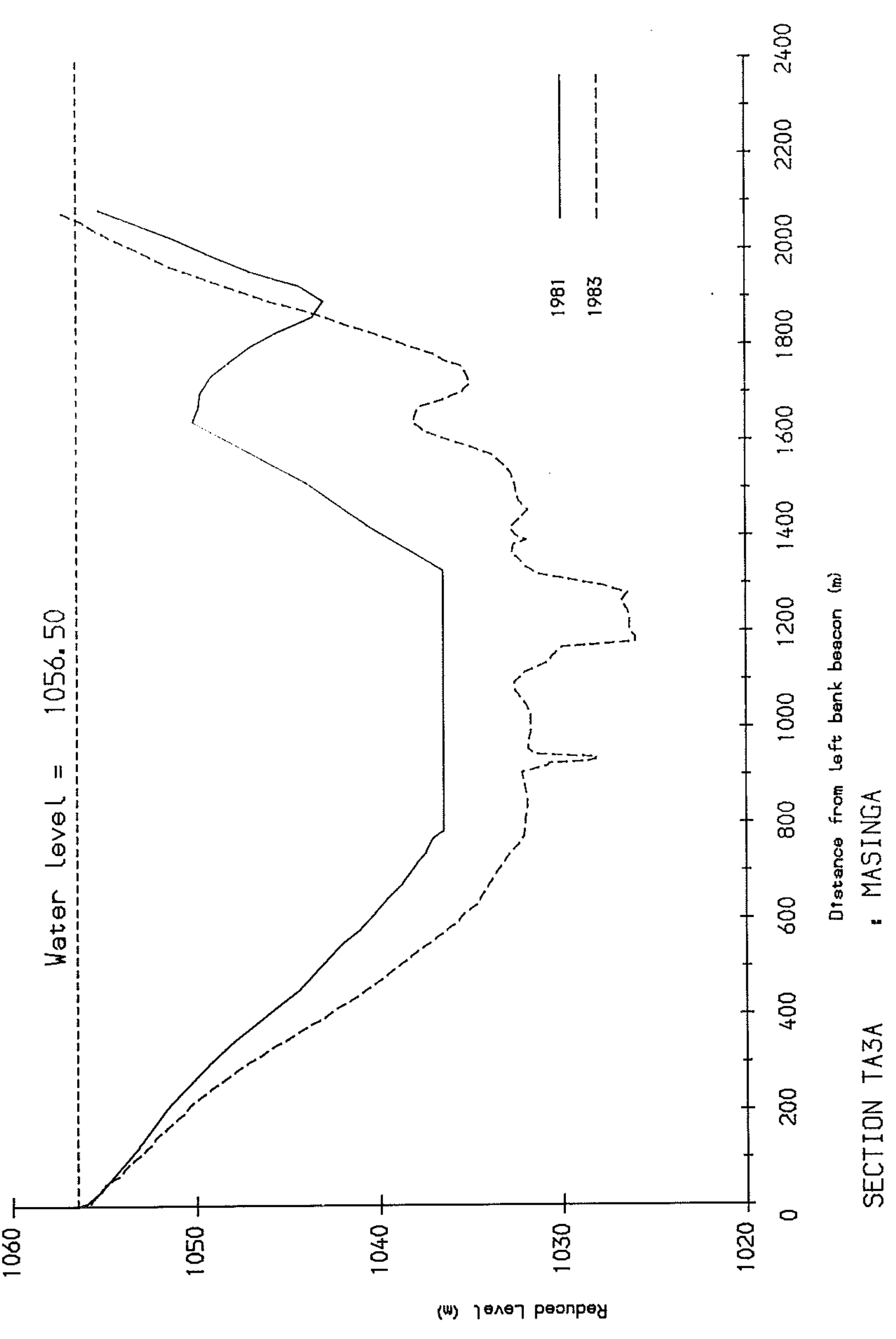

Fig 5·36 Masinga Reservoir – section TA3A

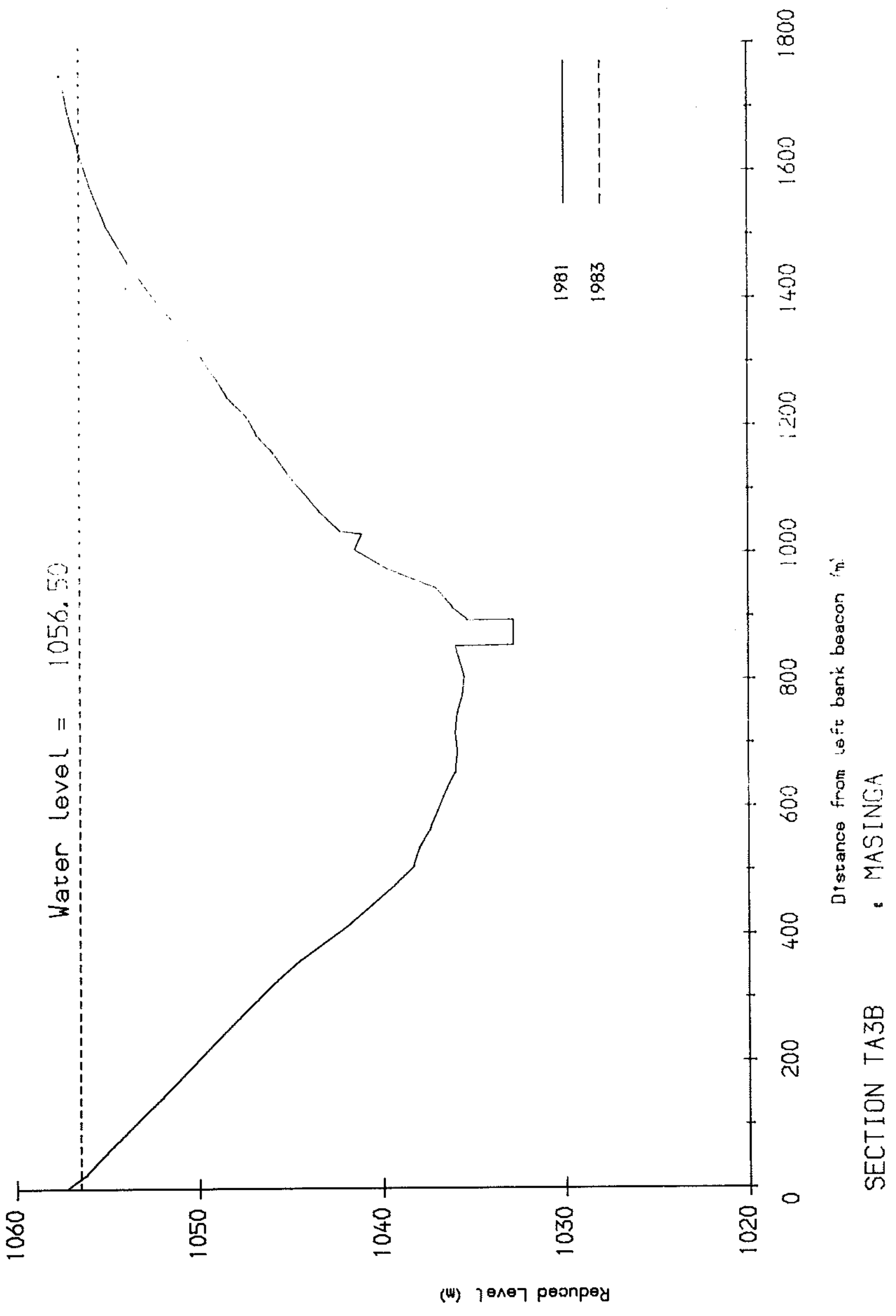

Fig 5·37 Masinga Reservoir – section TA3B

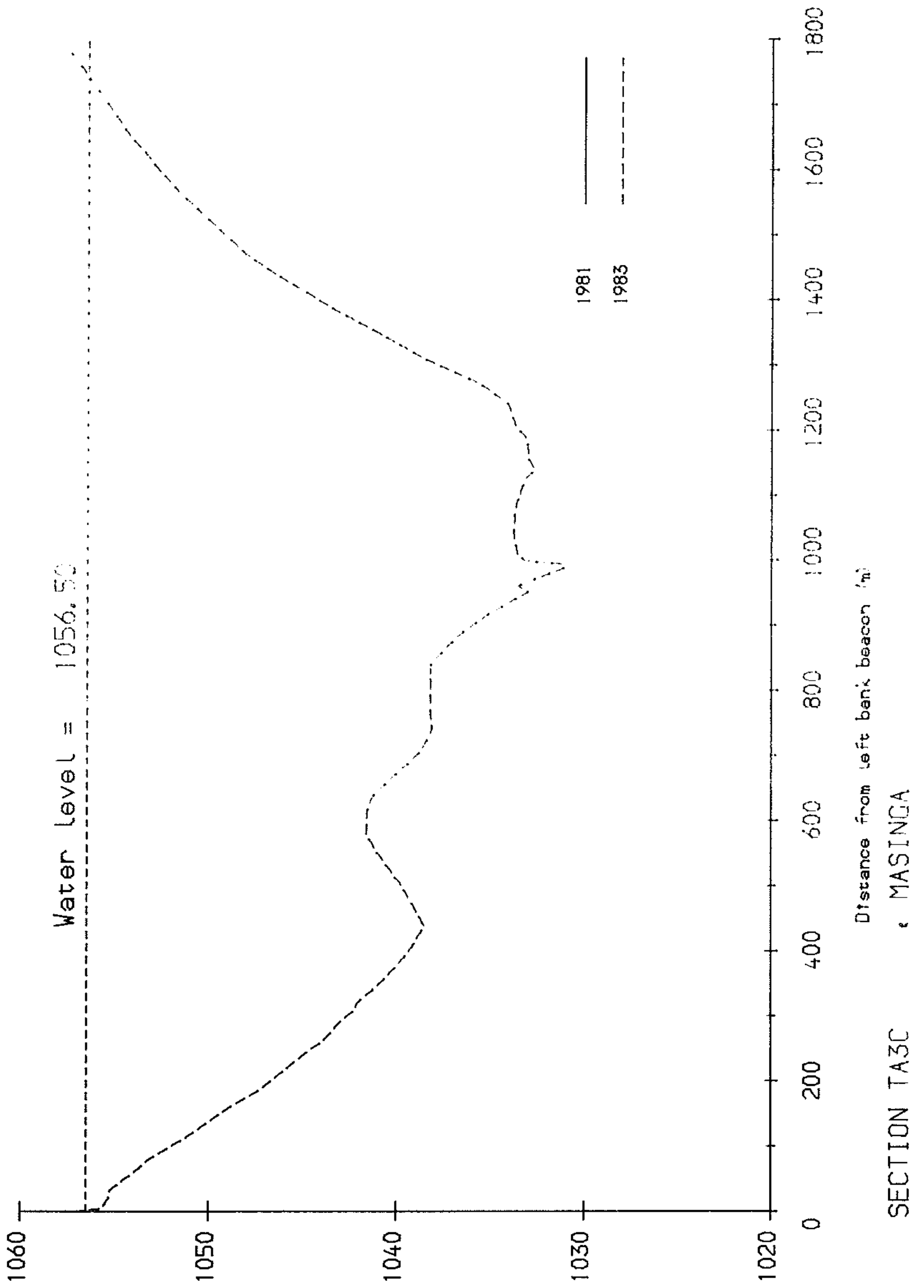

Fig 5·38 Masinga Reservoir – section TA3C

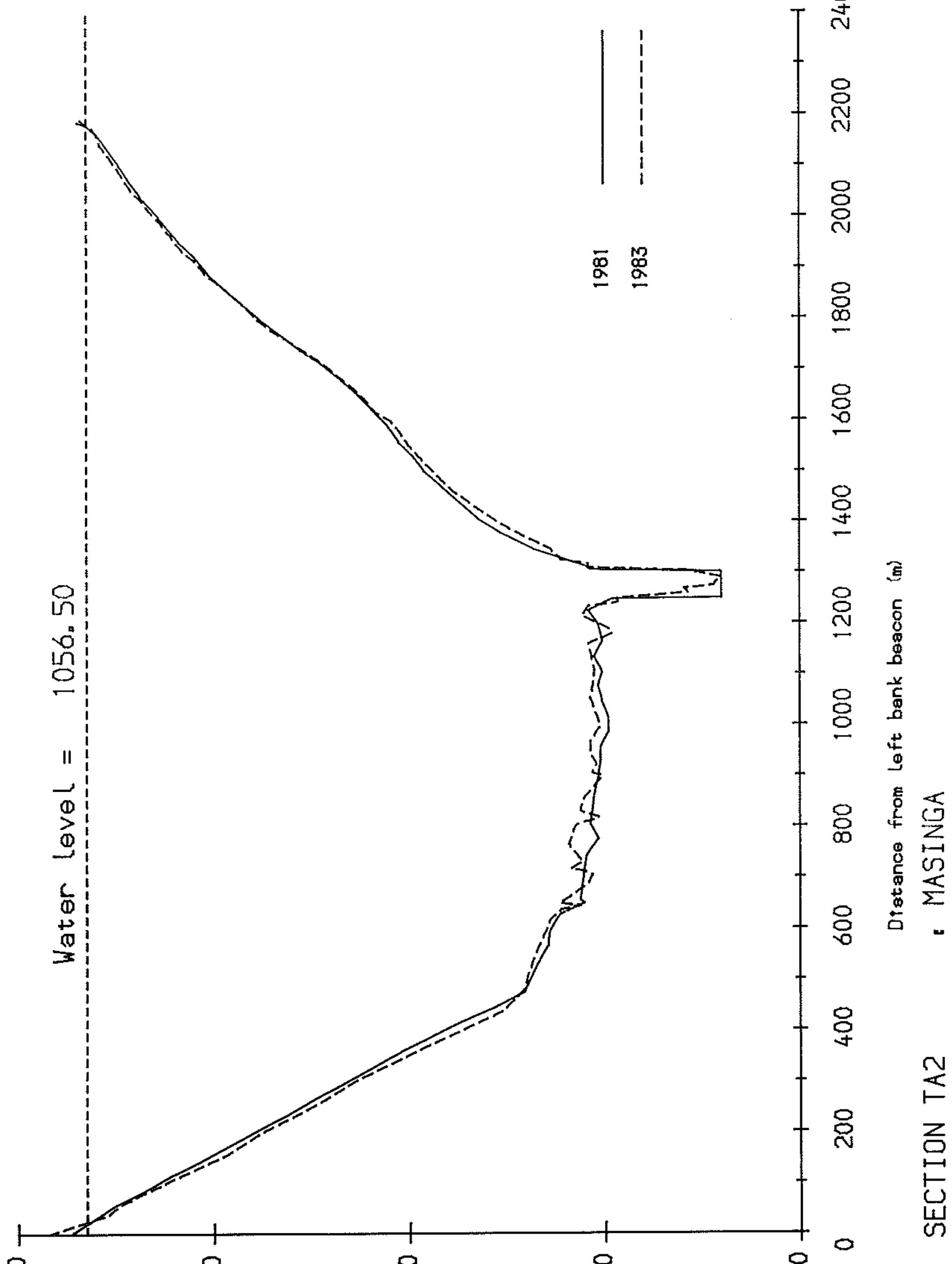

Fig 5·39 Masinga Reservoir- section TA2

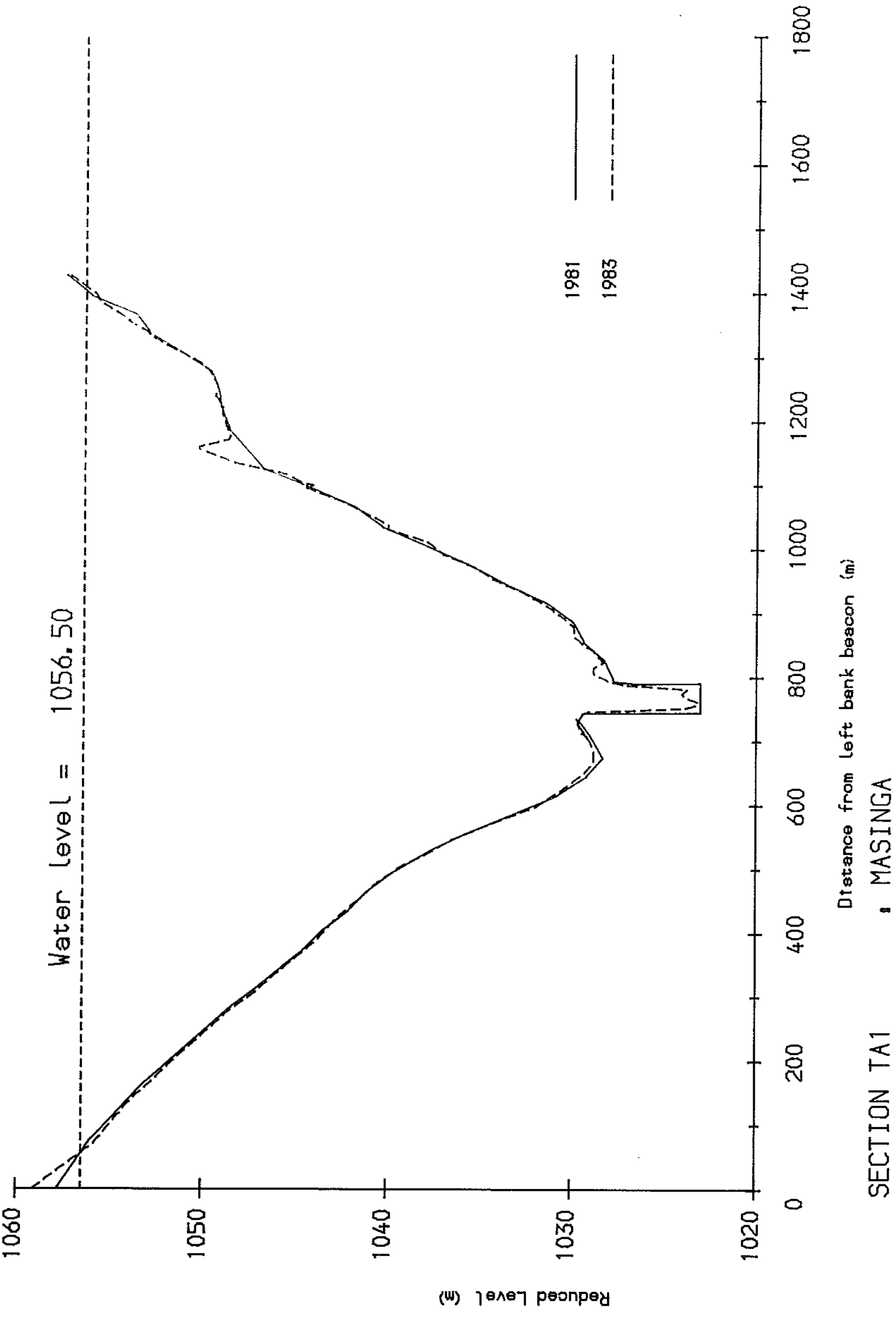

Fig 5·40 Masinga Reservoir - section TA1

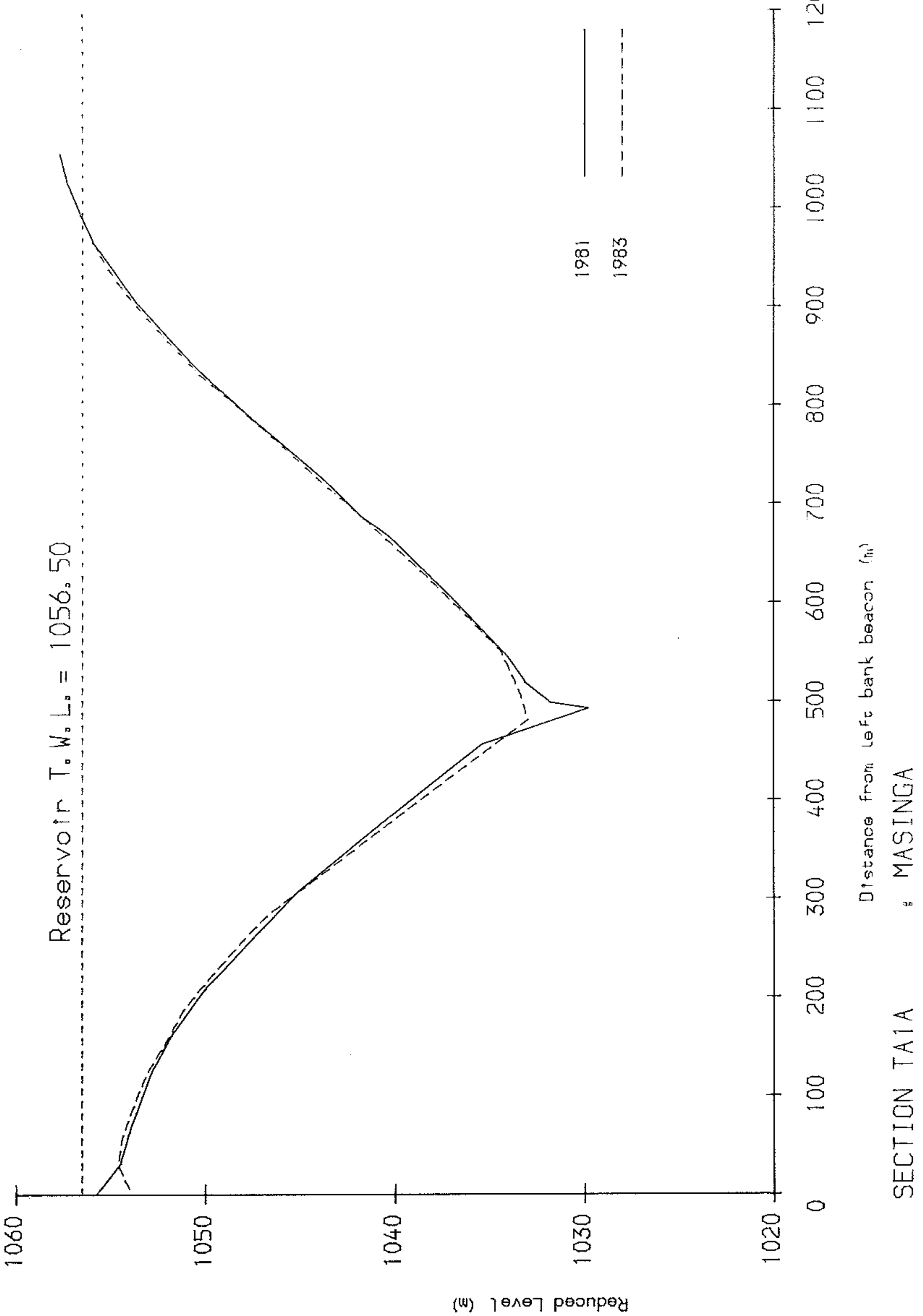

Fig 5·41 Masinga Reservoir - section TA1A

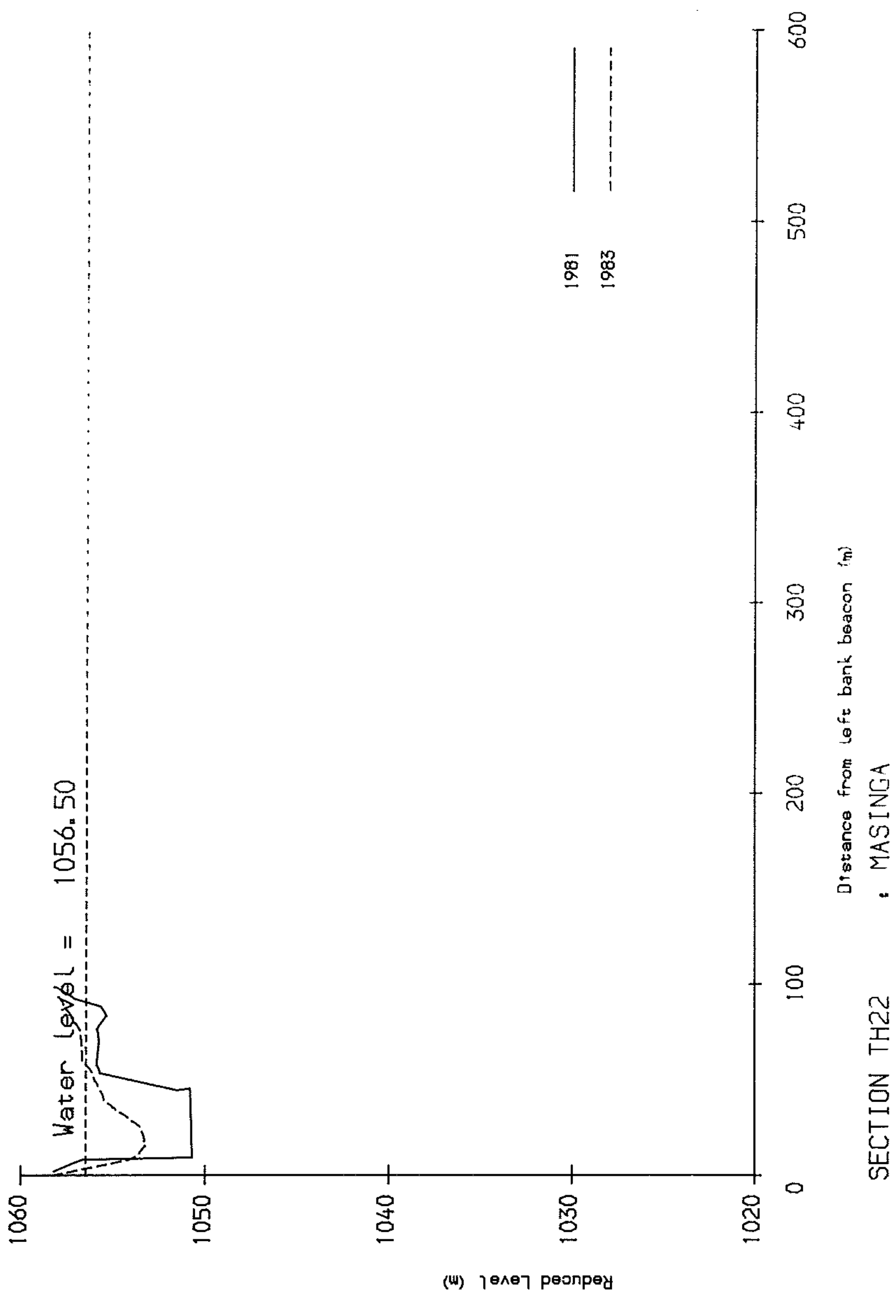

Fig 5·42 Masinga Reservoir – section TH22

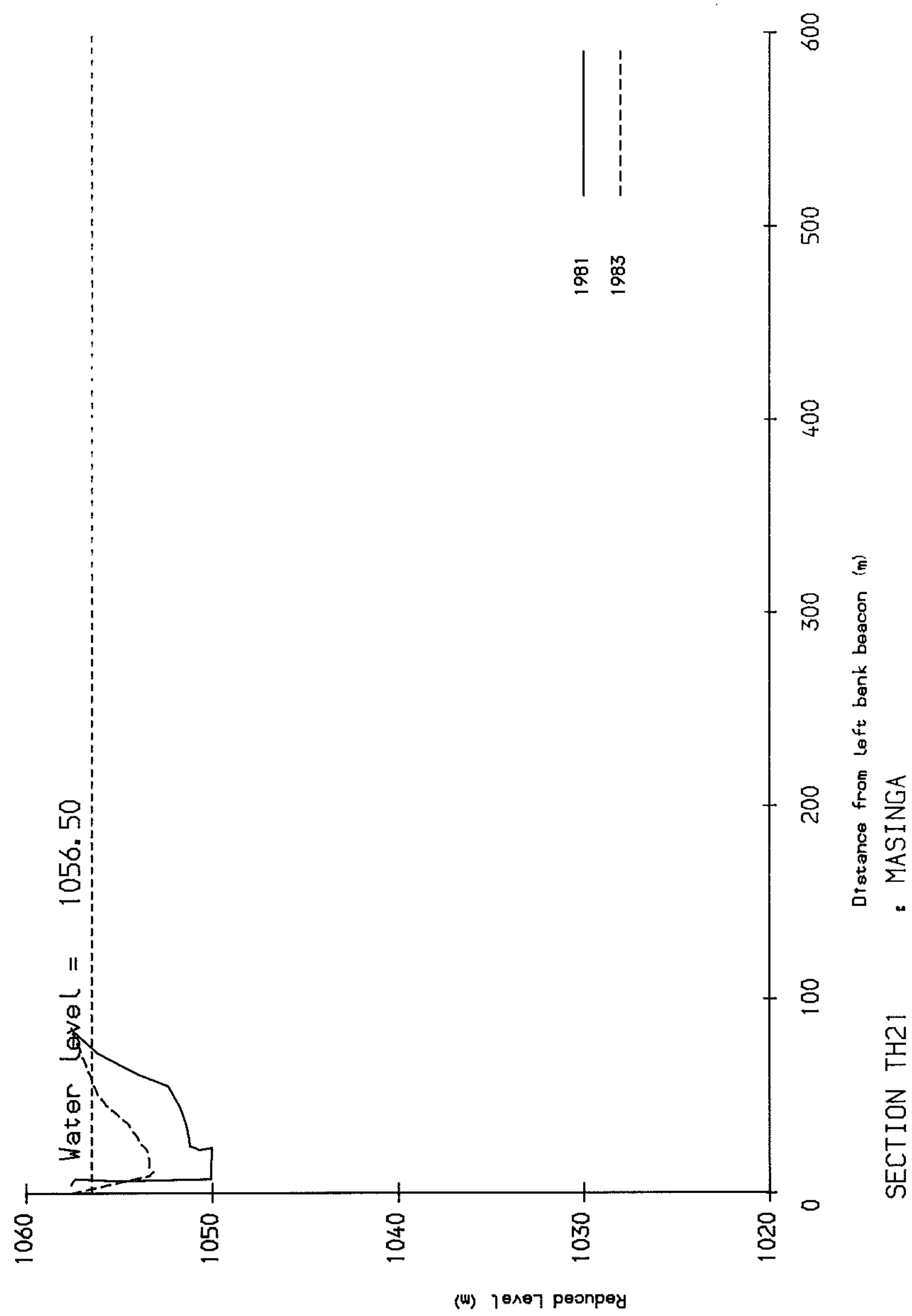

Fig 5·43 Masinga Reservoir - section TH21

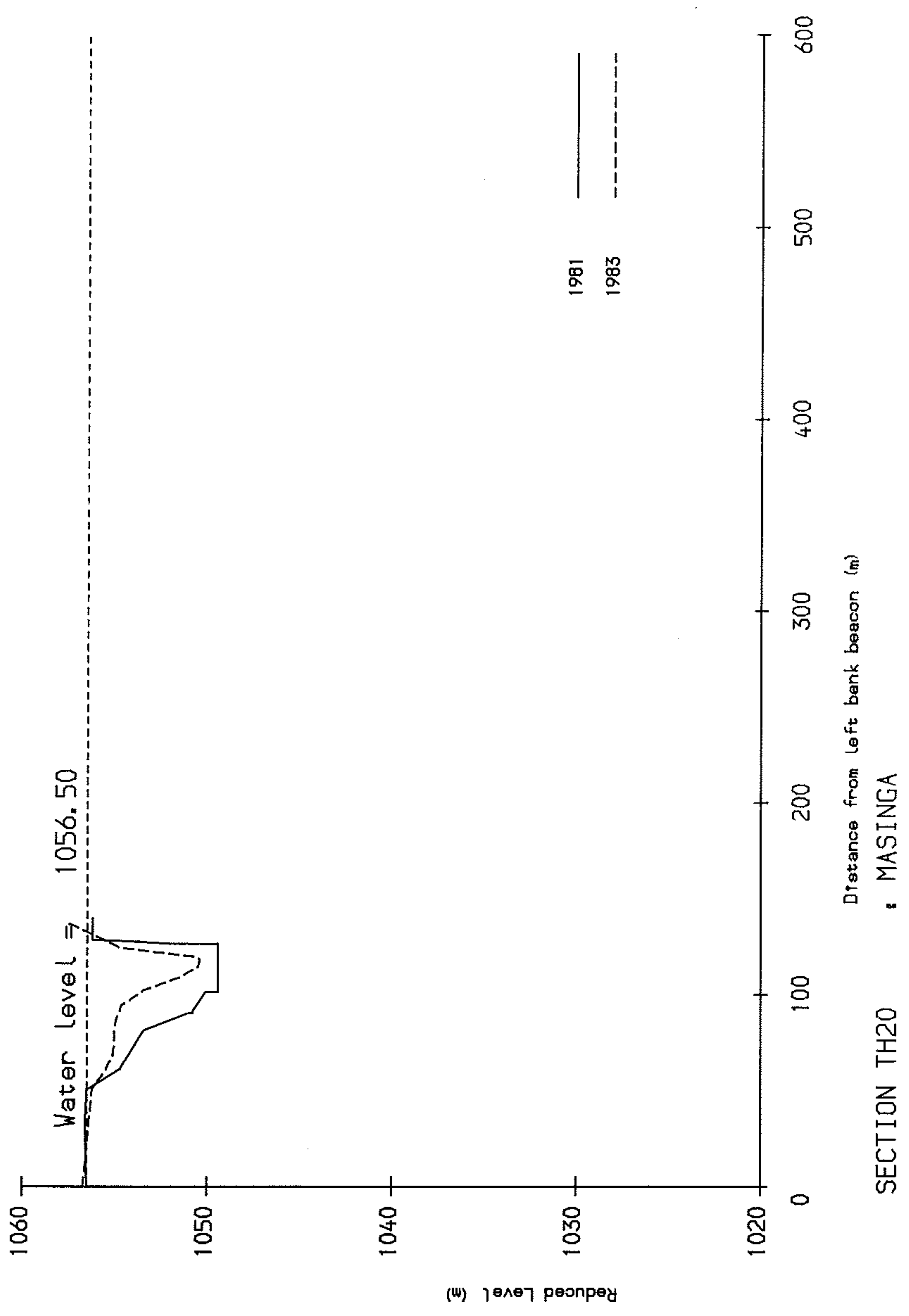

Fig 5·44 Masinga Reservoir - section TH20

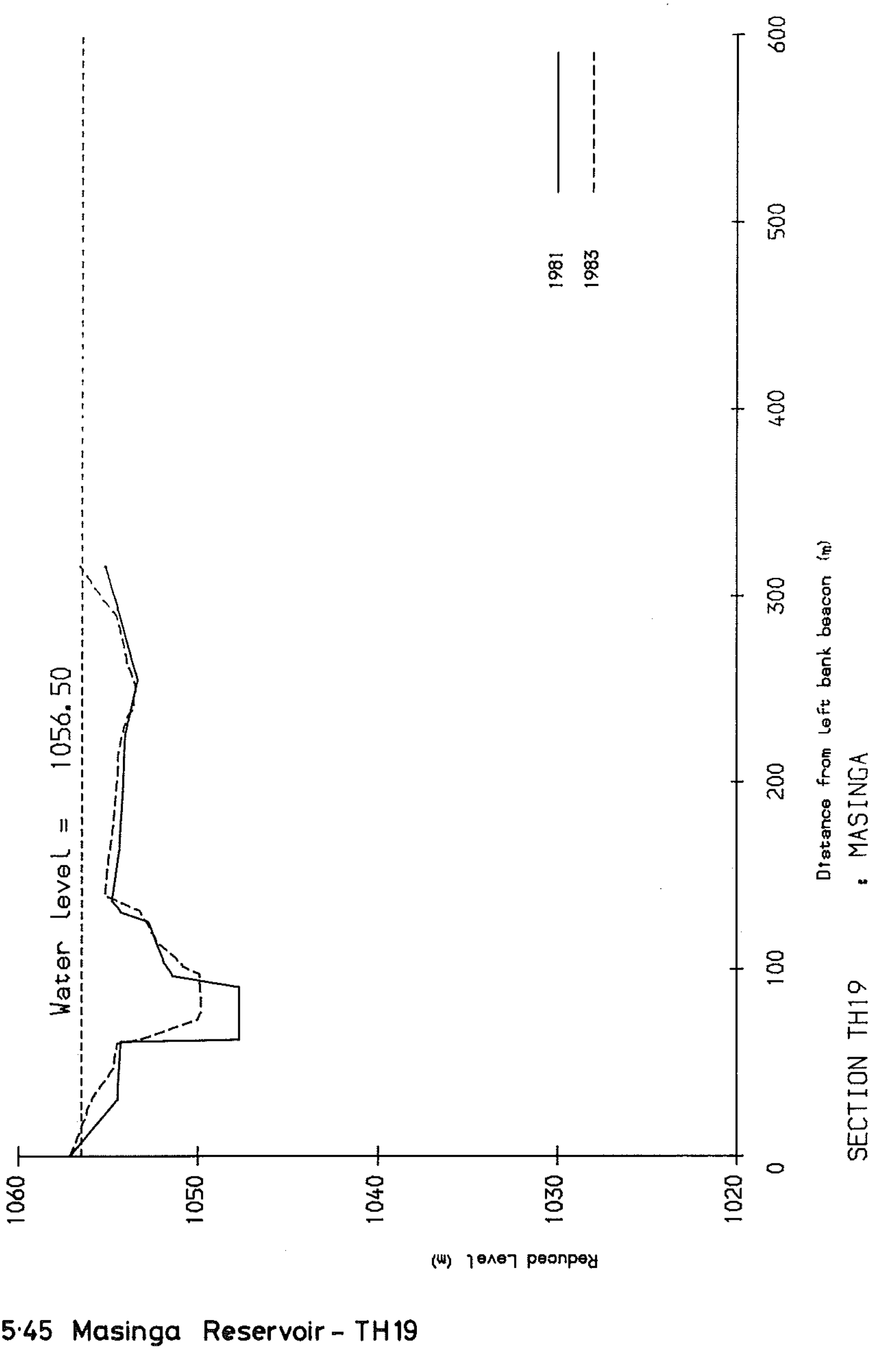

Fig 5·45 Masinga Reservoir - TH19

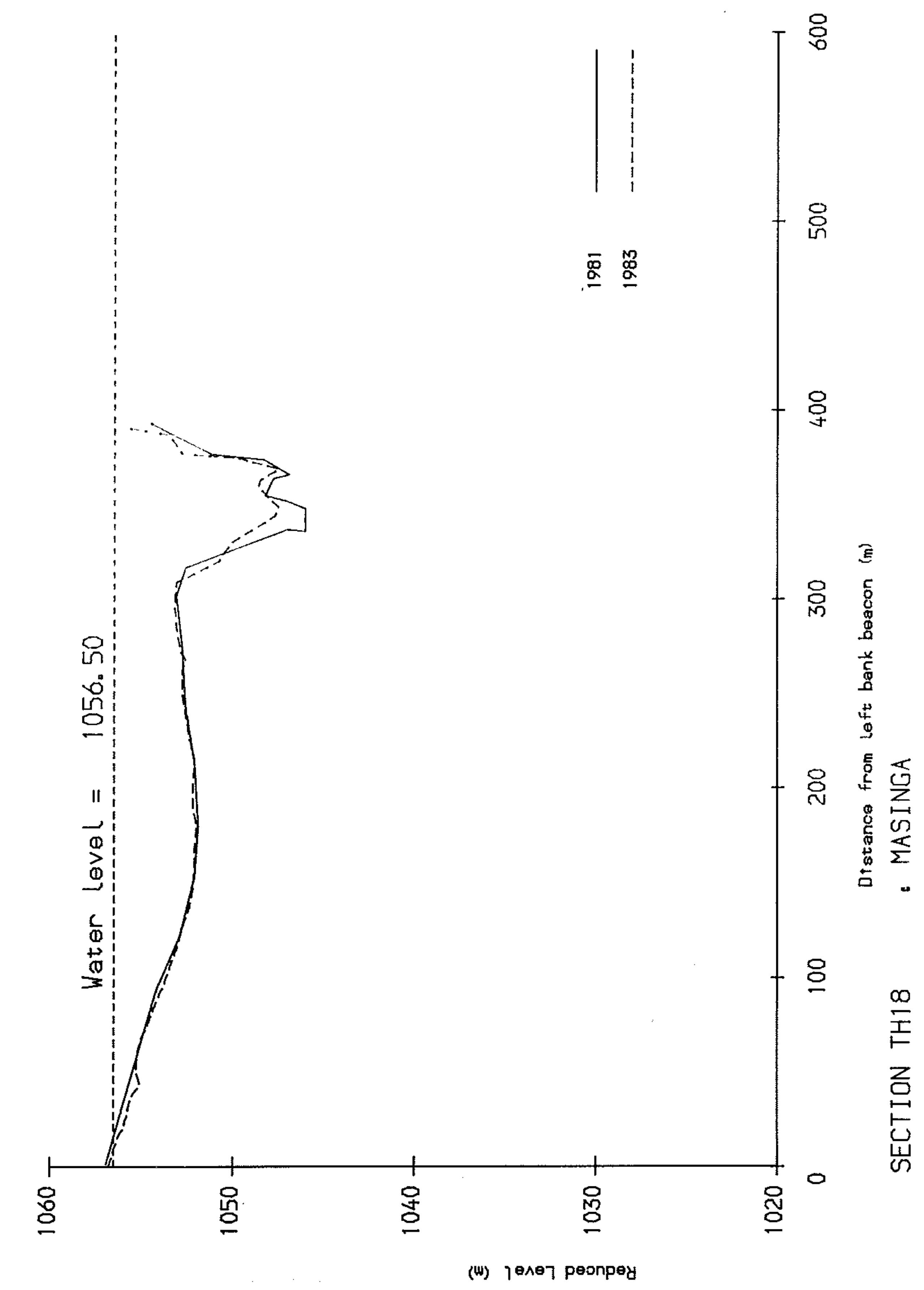

Fig 5·46 Masinga Reservoir - section TH18

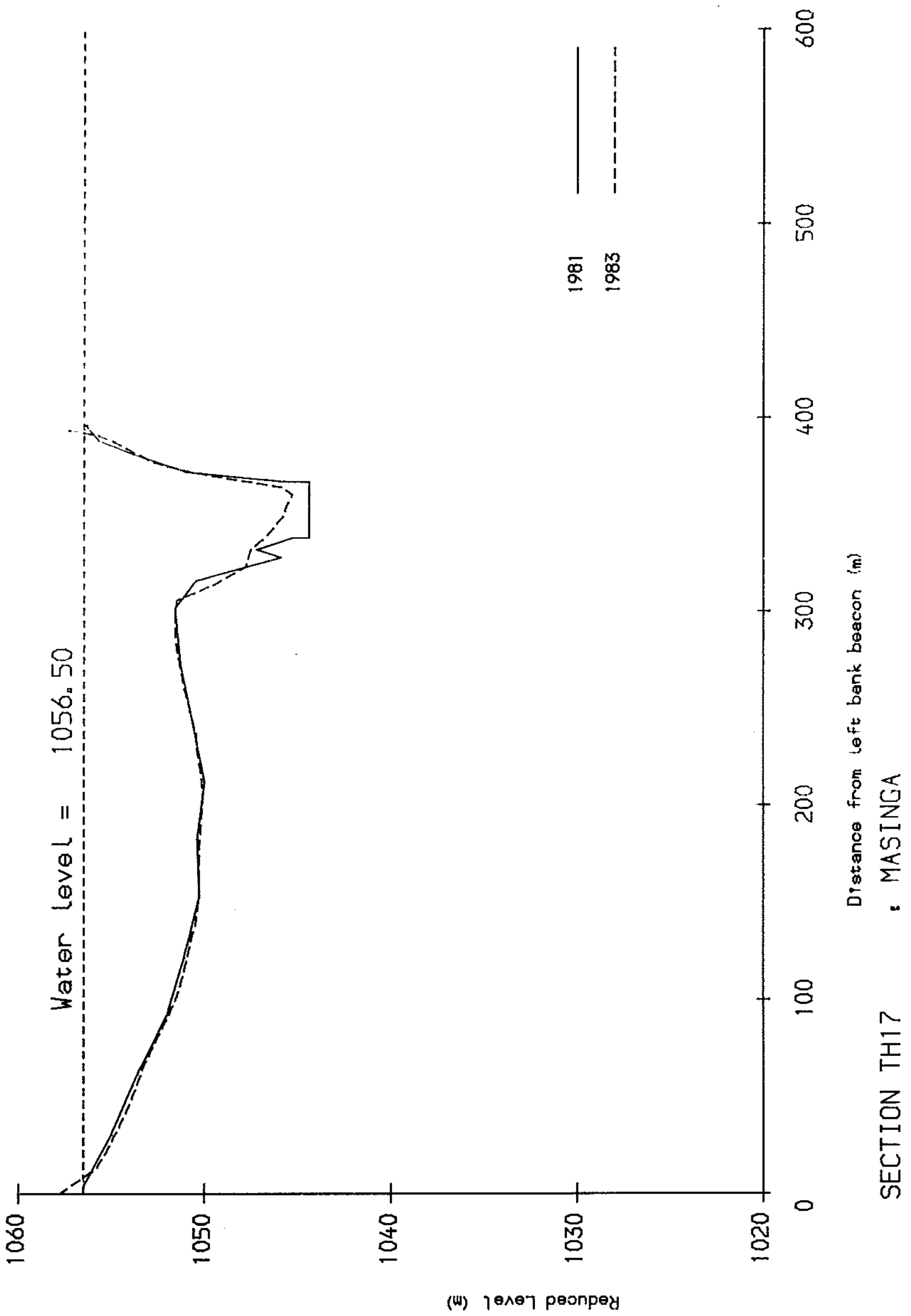

Fig 5·47 Masinga Reservoir - section TH17

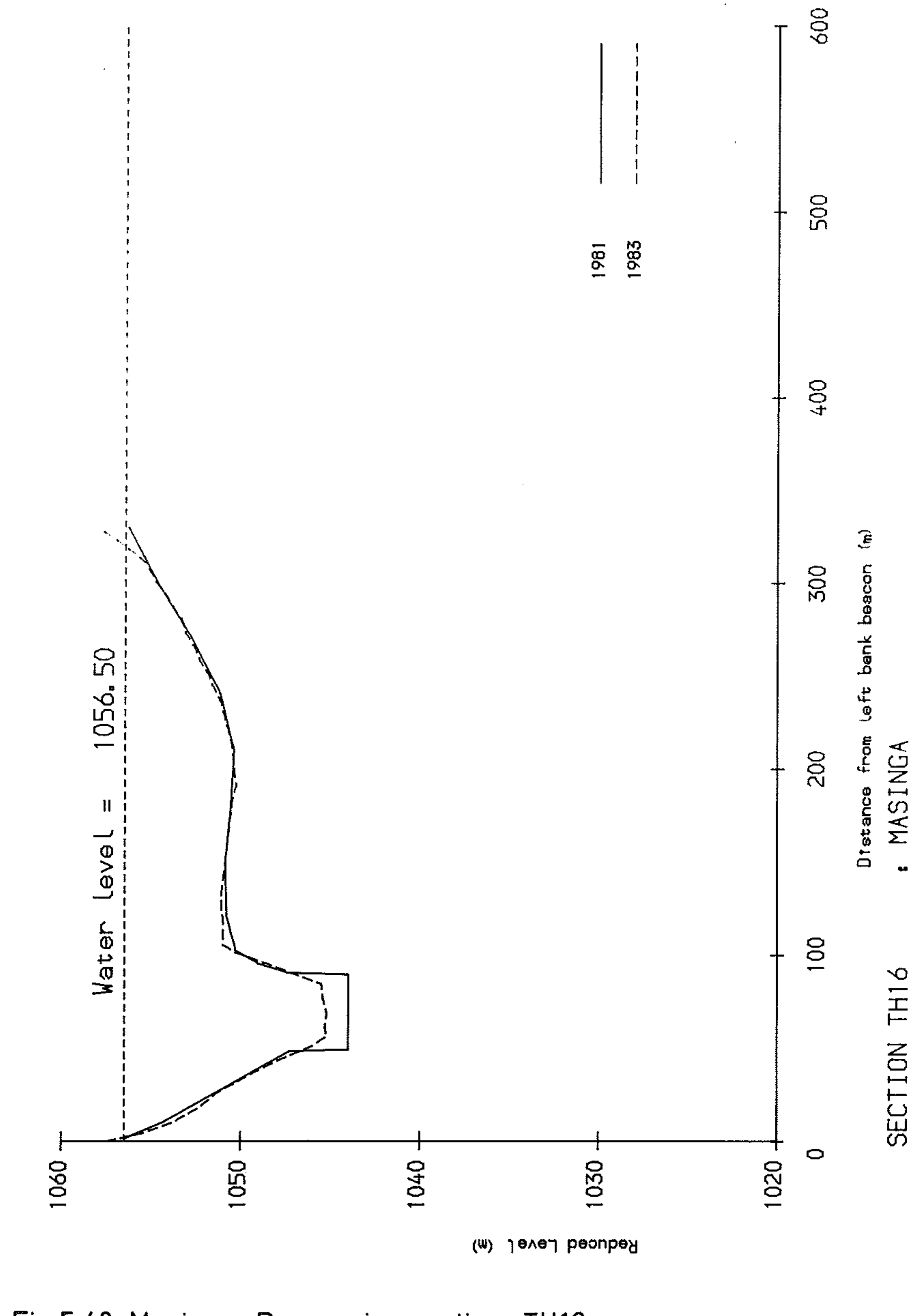

Fig 5·48 Masinga Reservoir - section TH16

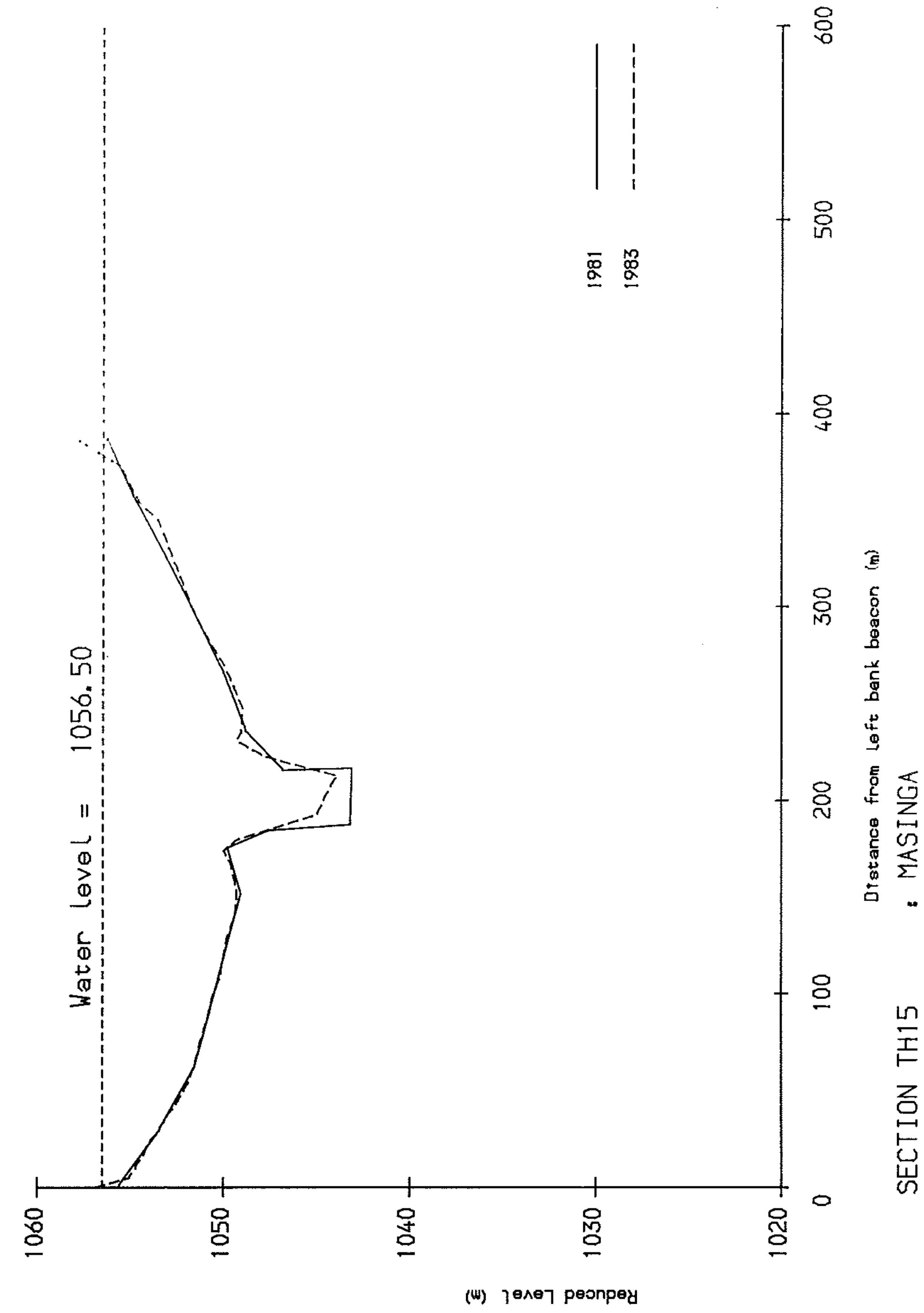

Fig 5·49 Masinga Reservoir – section TH15

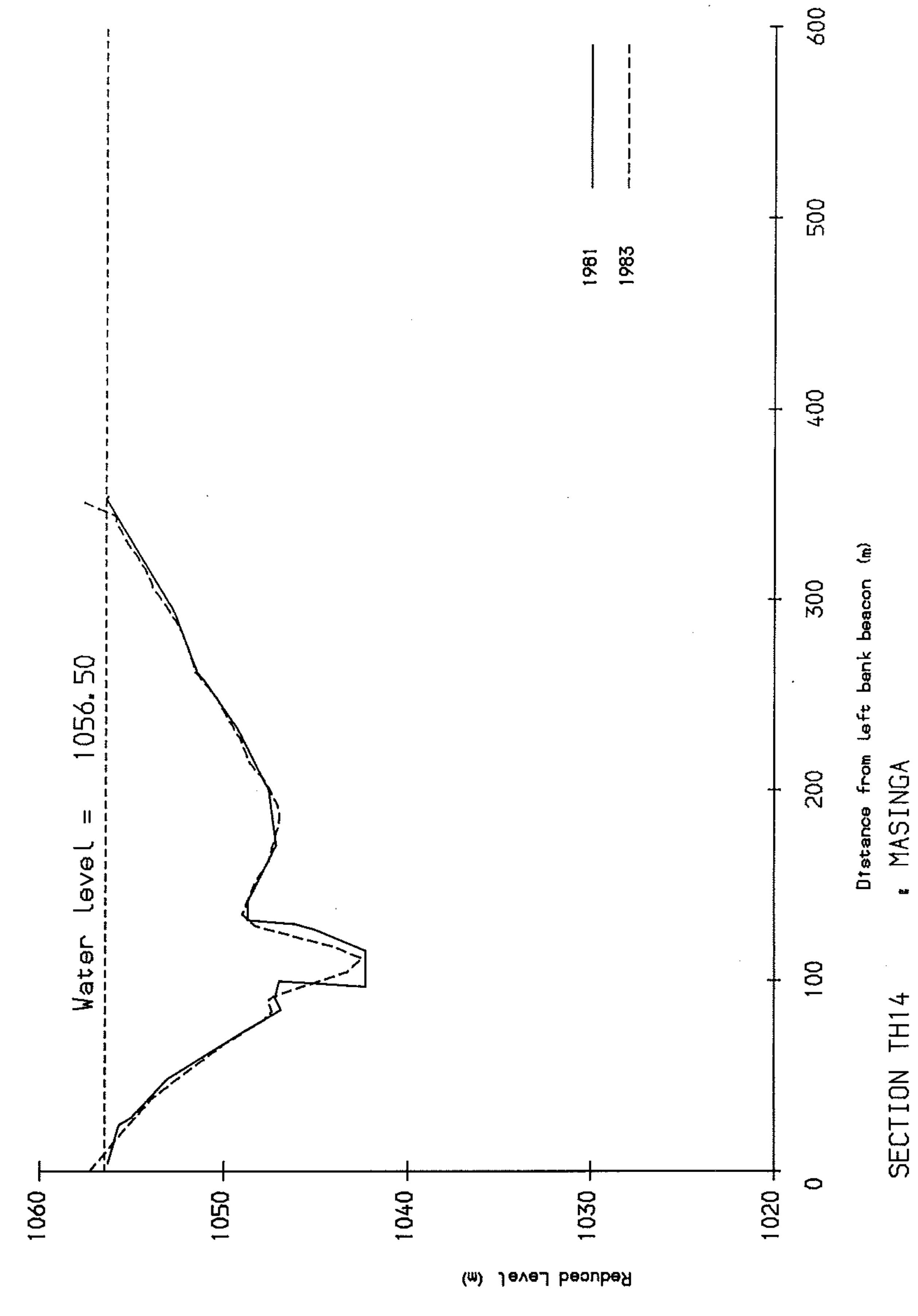

Fig 5·50 Masinga Reservior - section TH14

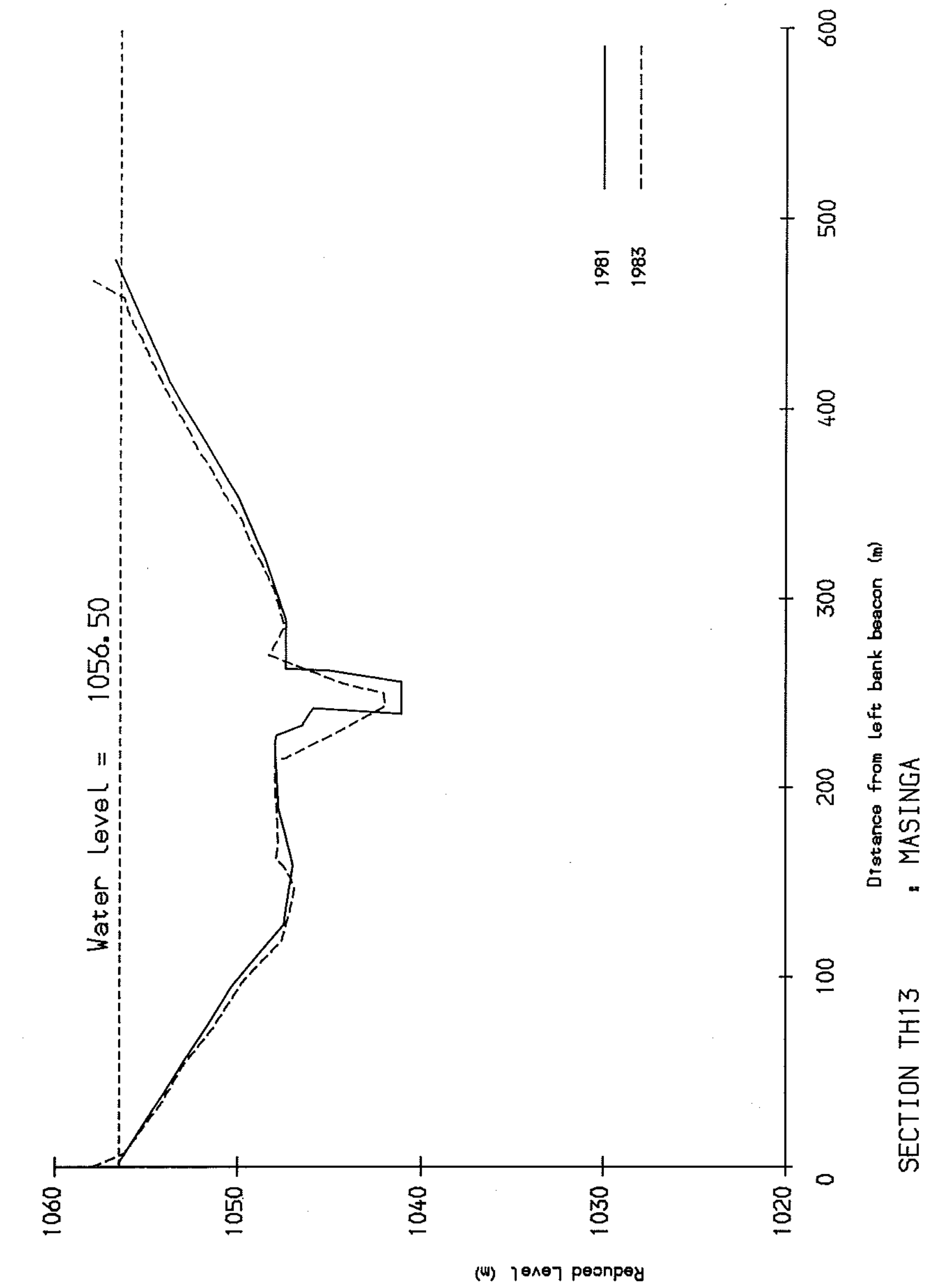

Fig 5.51 Masinga Reservoir-section TH13

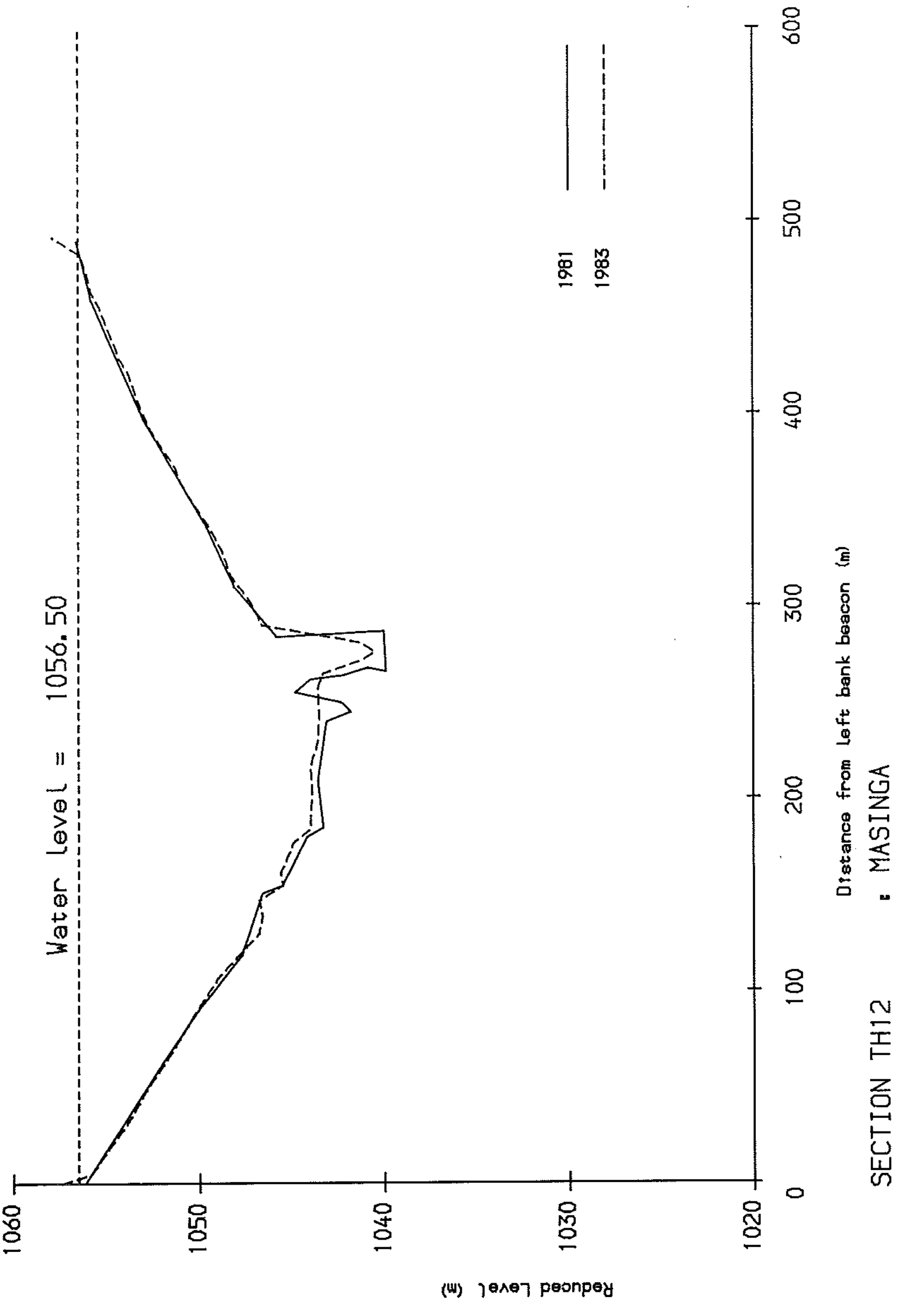

Fig 5·52 Masinga Reservoir- section TH12

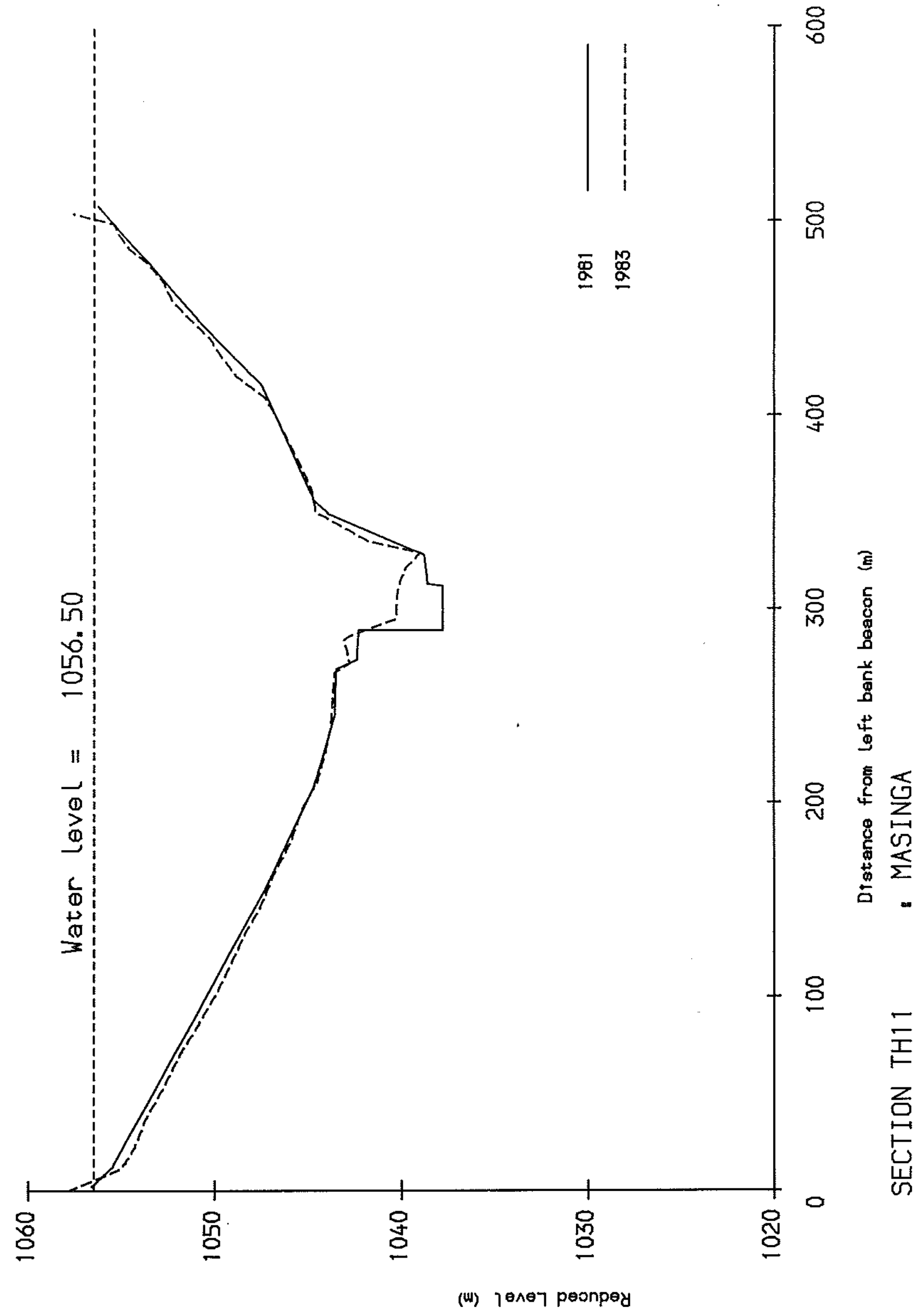

Fig 5·53 Masinga Reservoir-section TH11

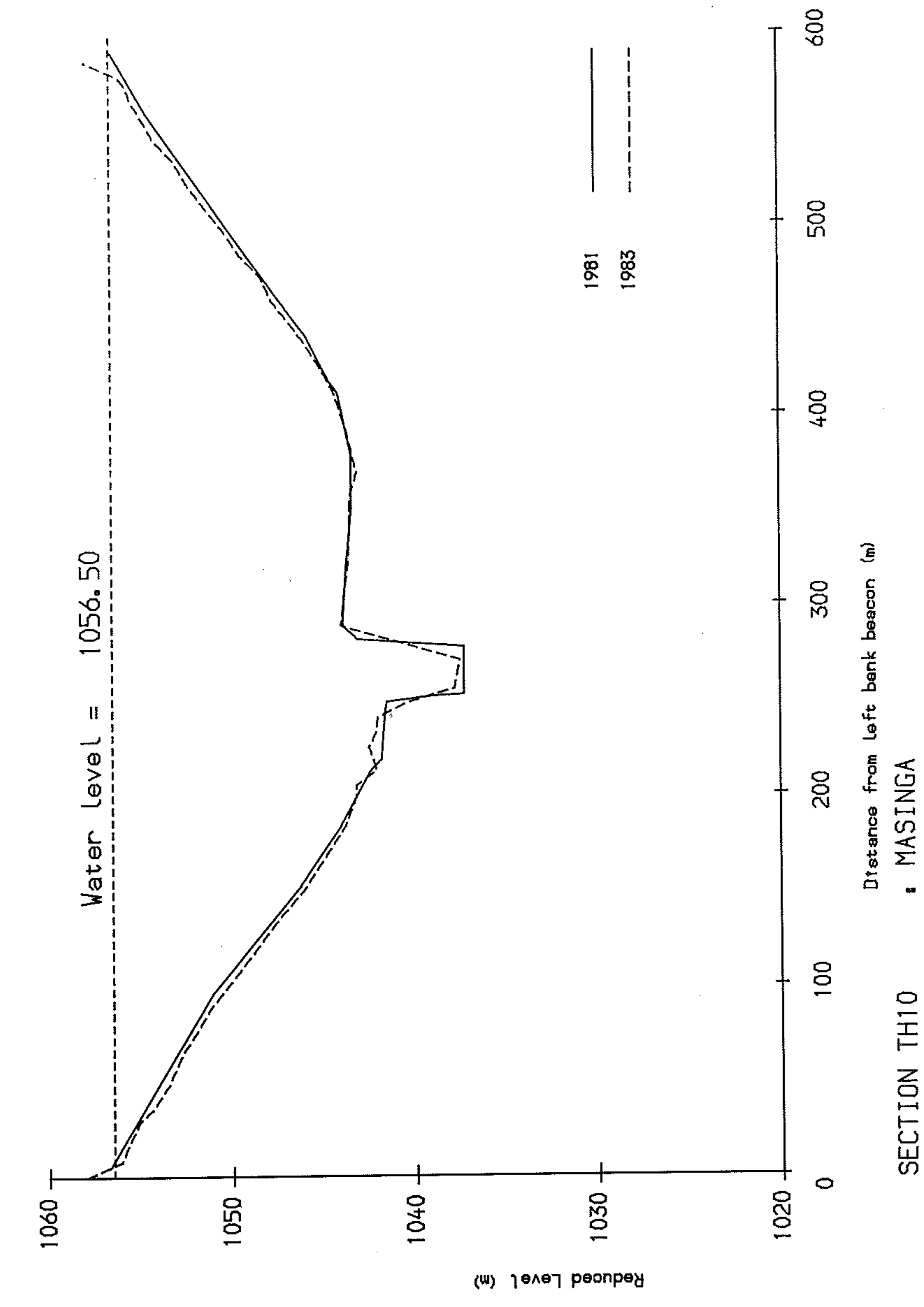

Fig 5·54 Masinga Reservoir – section TH10

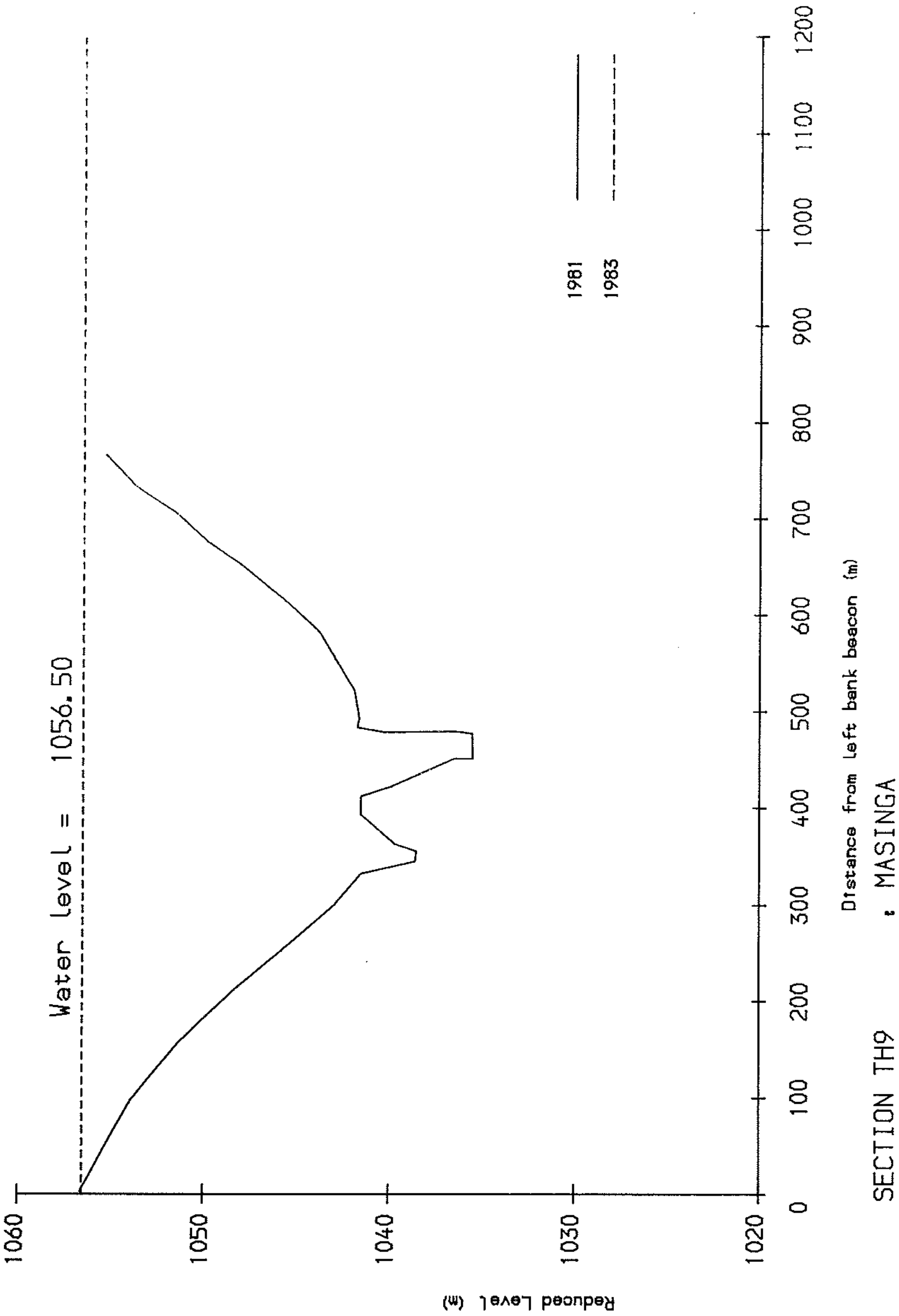

Fig 5·55 Masinga Reservoir - section TH9

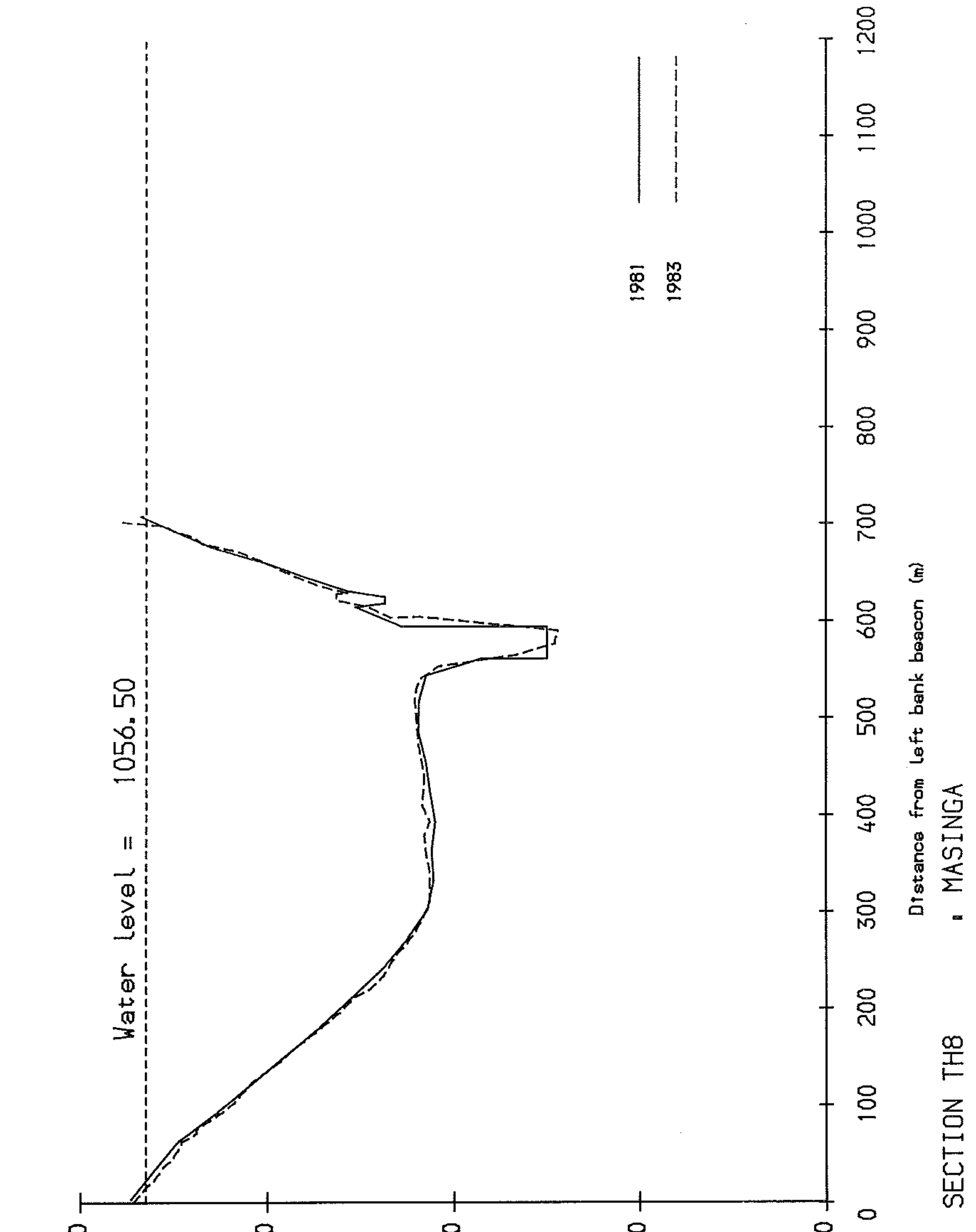

Fig 5.56 Masinga Reservoir - section TH8

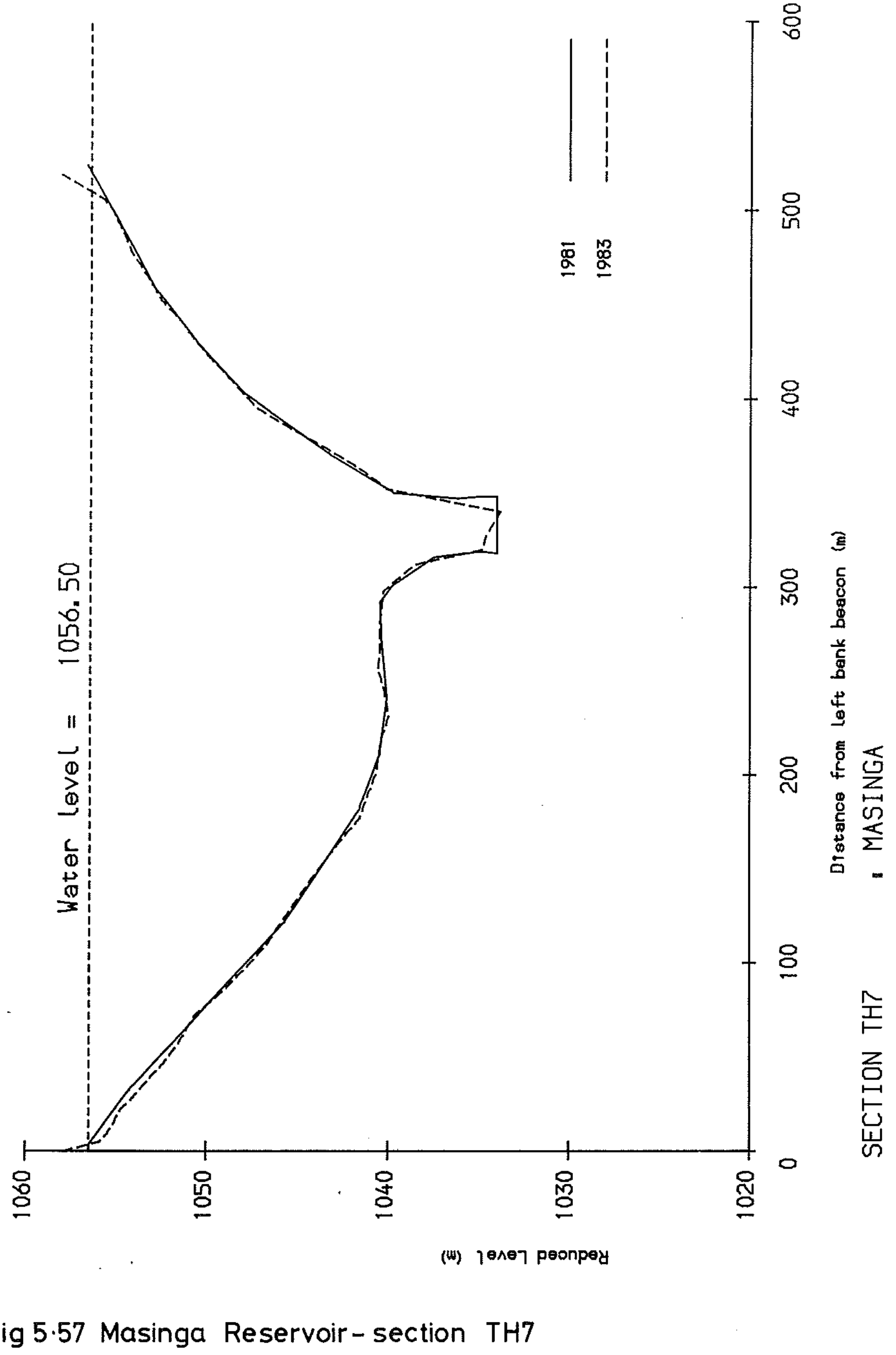

Fig 5·57 Masinga Reservoir - section TH7

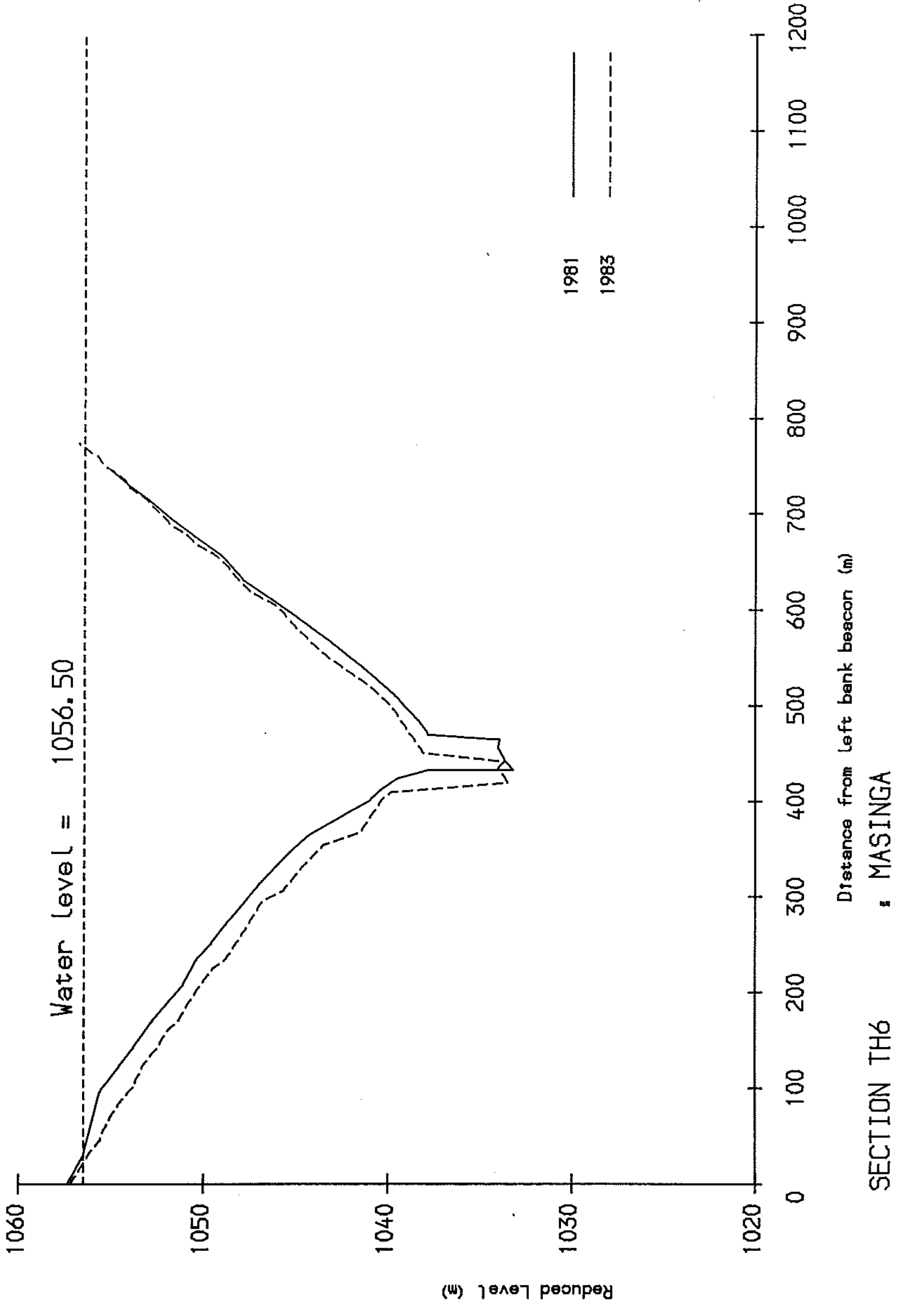

Fig 5·58 Masinga Reservoir - section TH6

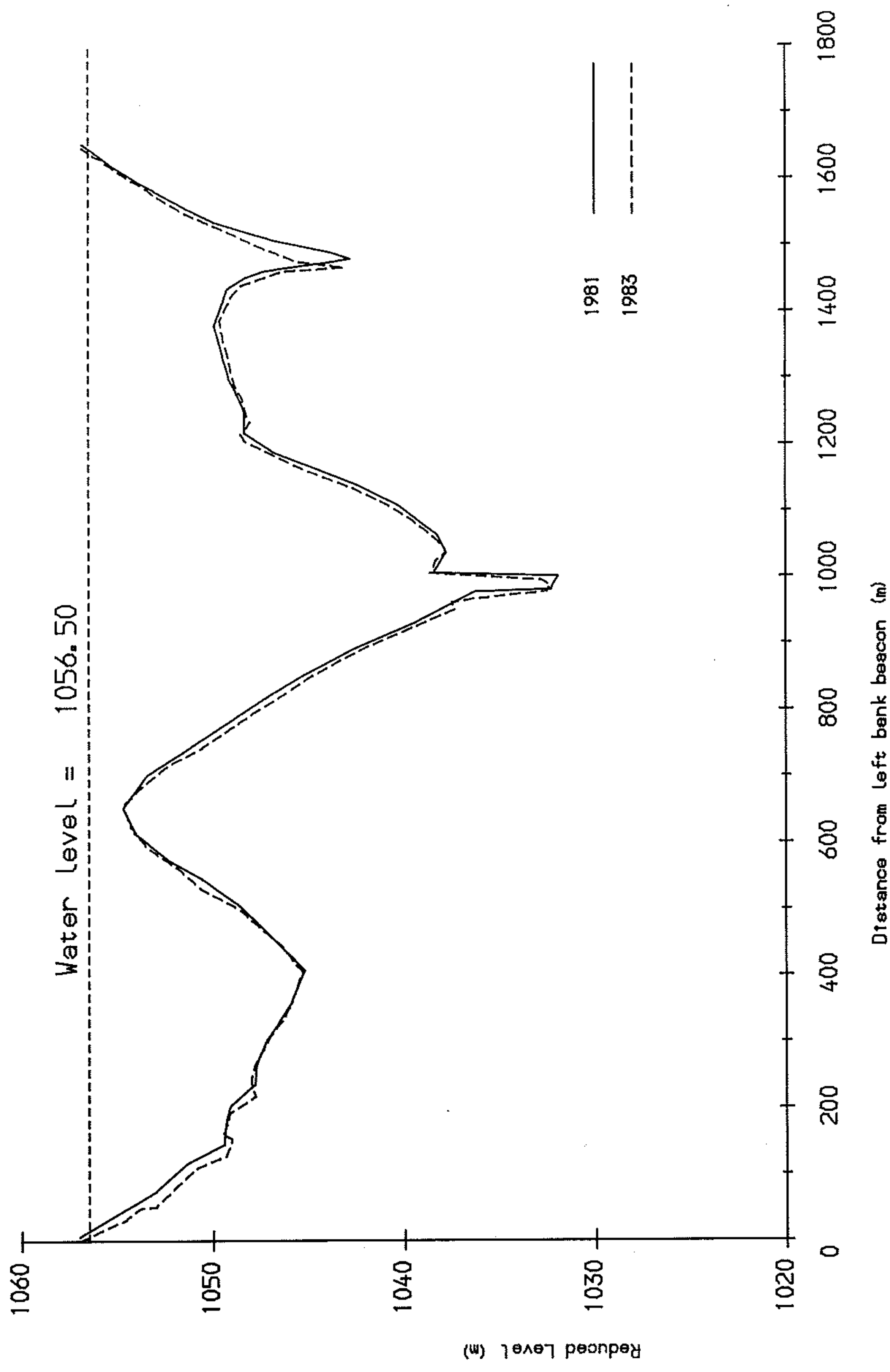

Fig 5·59 Masinga Reservoir – section TH5

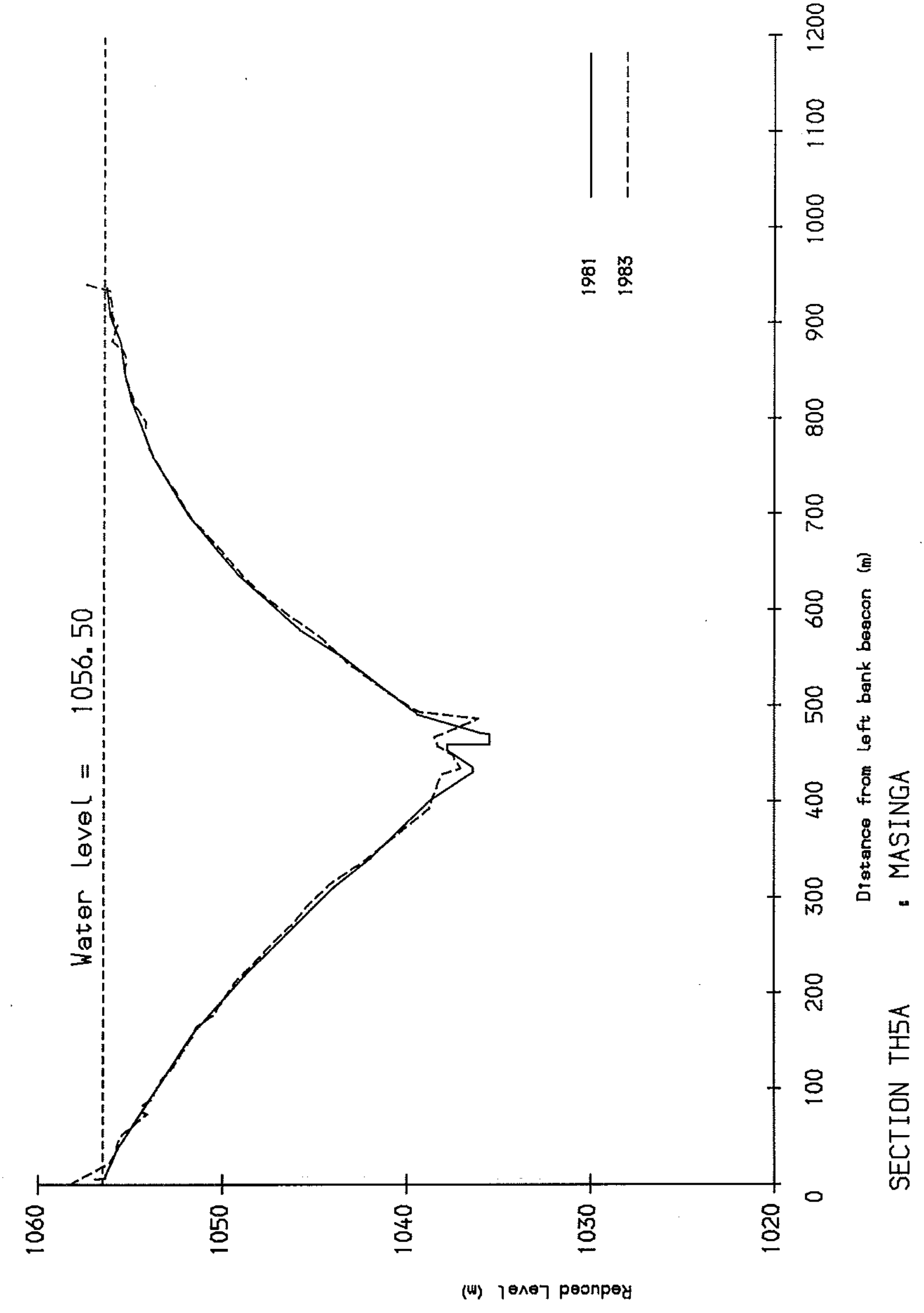

Fig 5·60 Masinga Reservoir- section TH5A

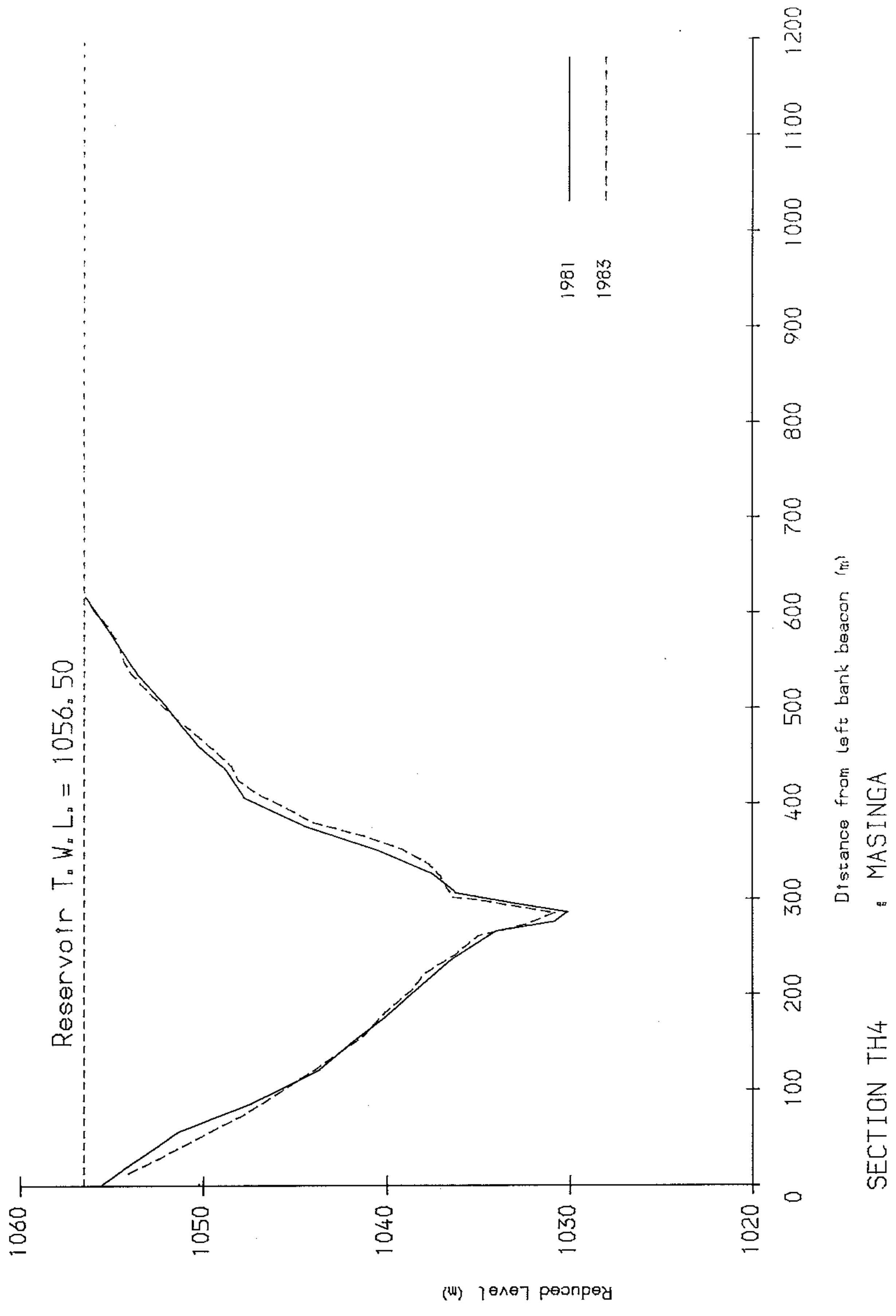

Fig 5·61 Masinga Reservoir - section TH4

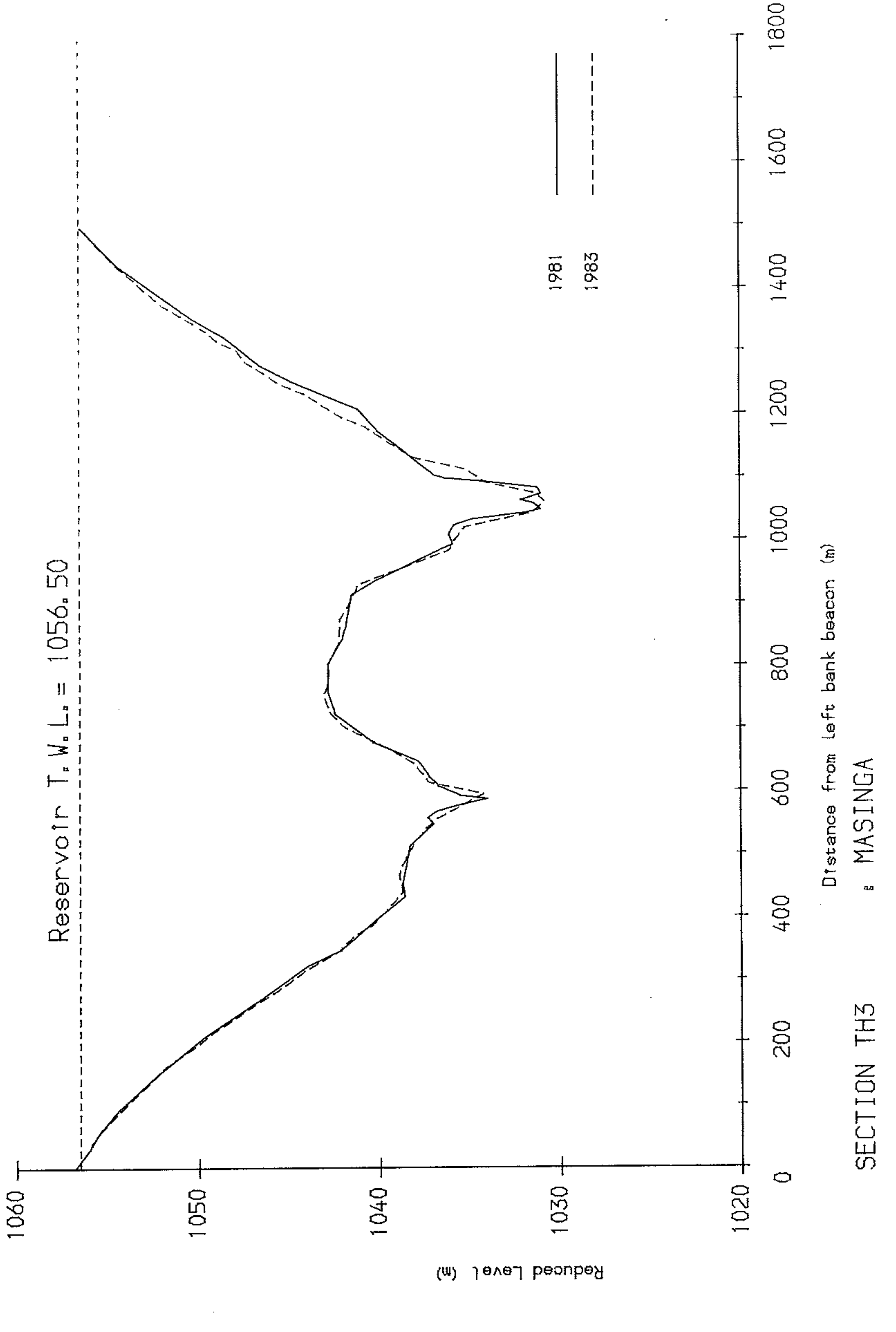

Fig 5·62 Masinga Reservoir – section TH3

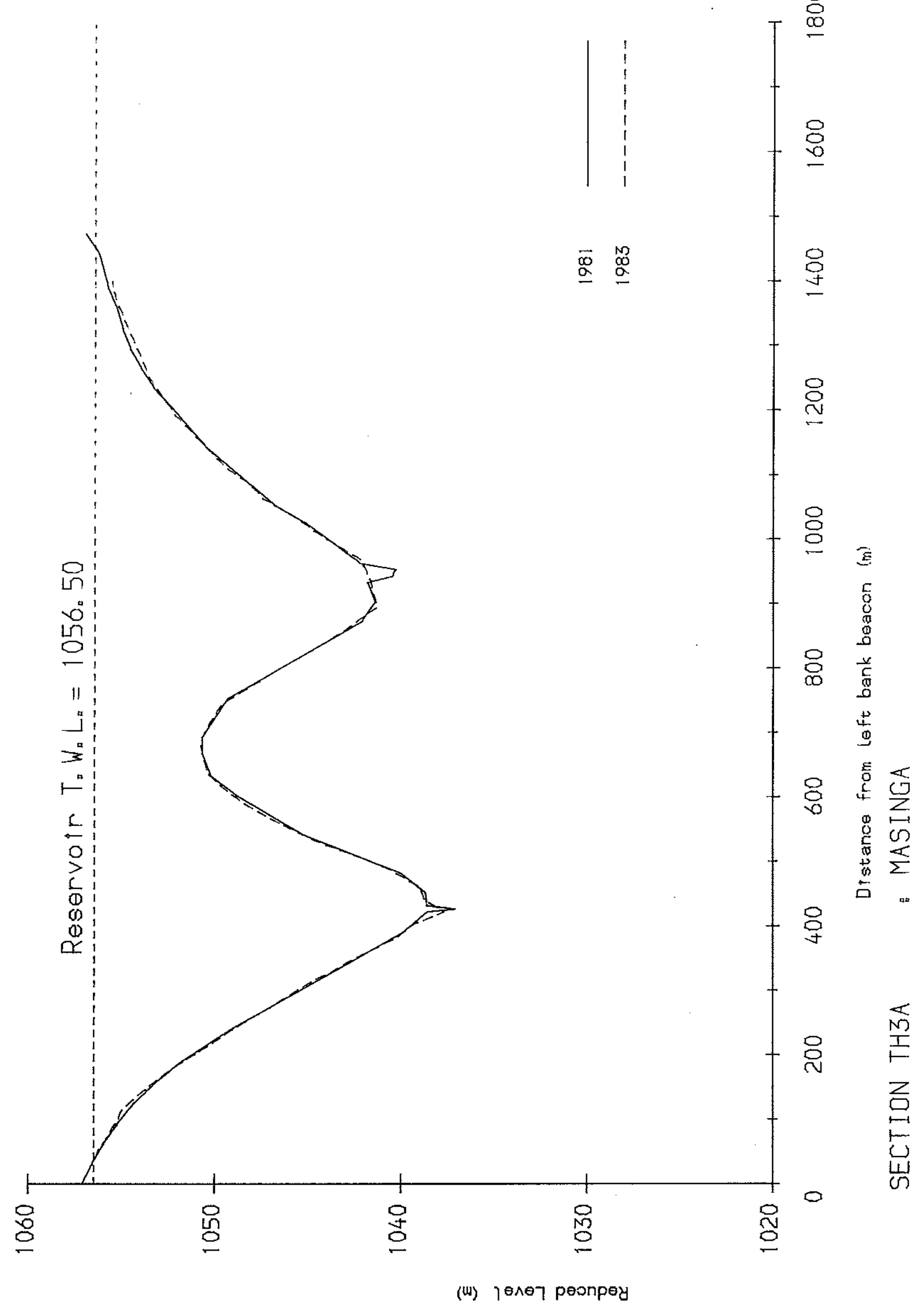

Fig 5·63 Masinga Reservoir - section TH3A

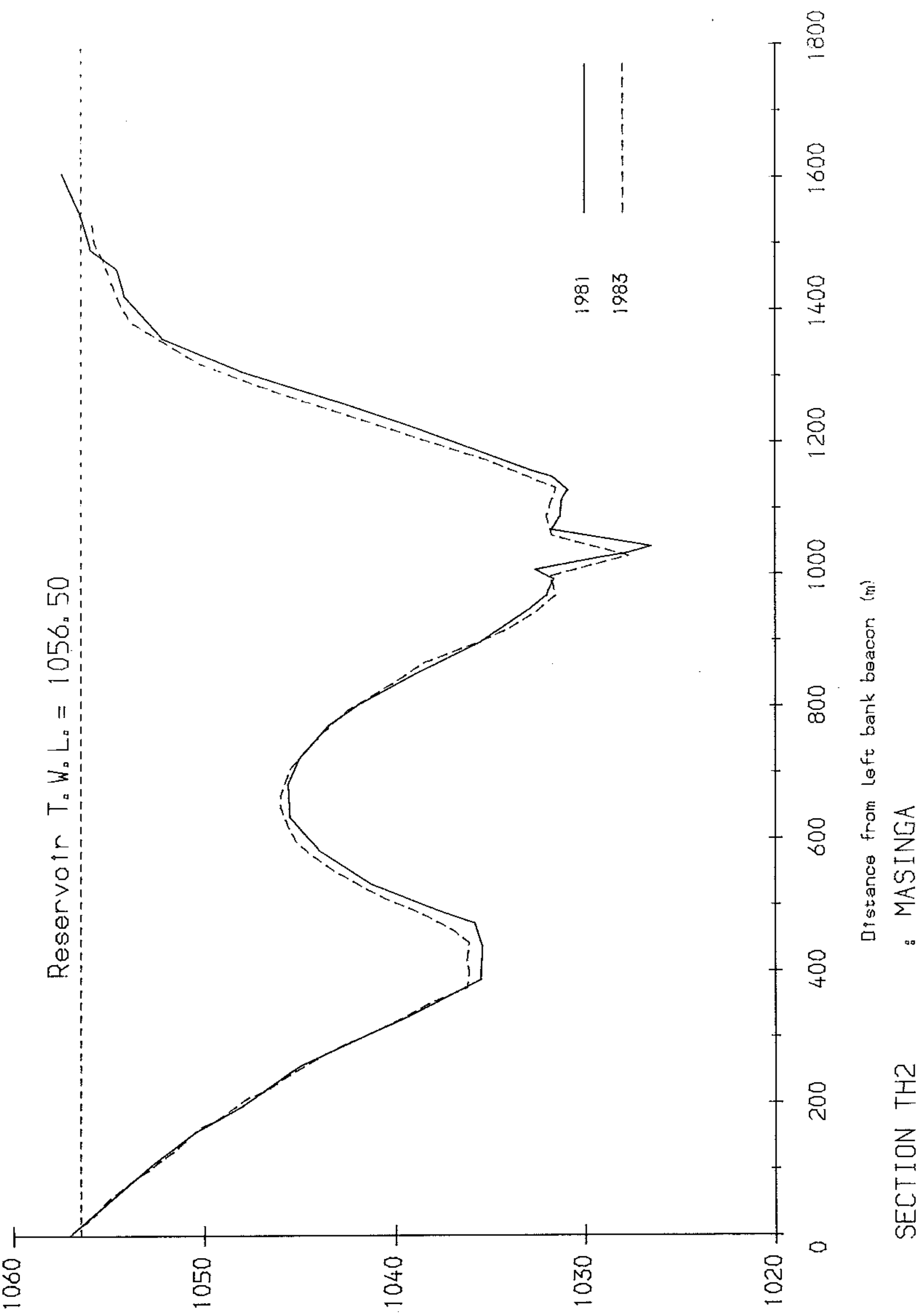

Fig 5·64 Masinga Reservoir - section TH2

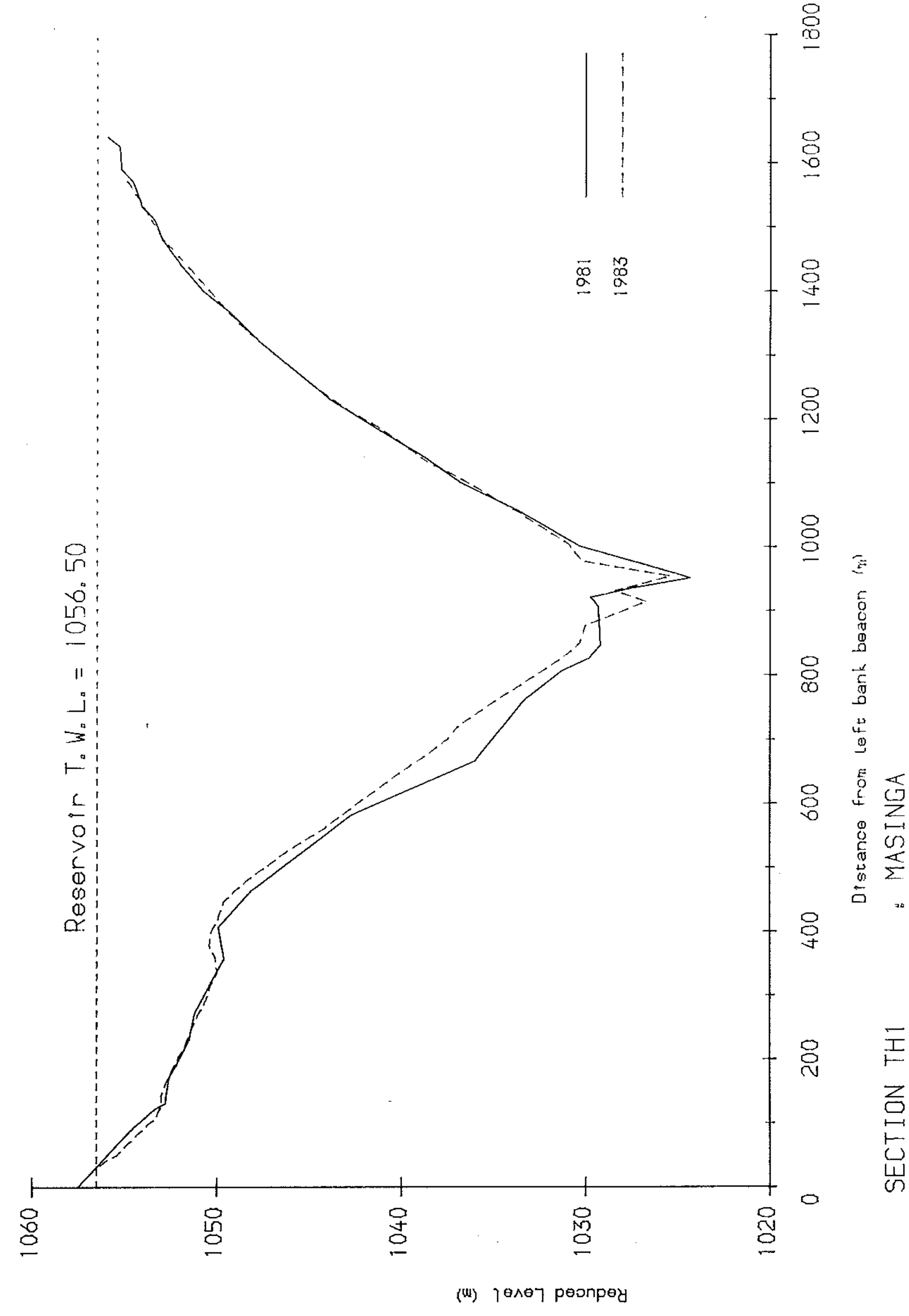

Fig 5·65 Masinga Reservoir- section TH1

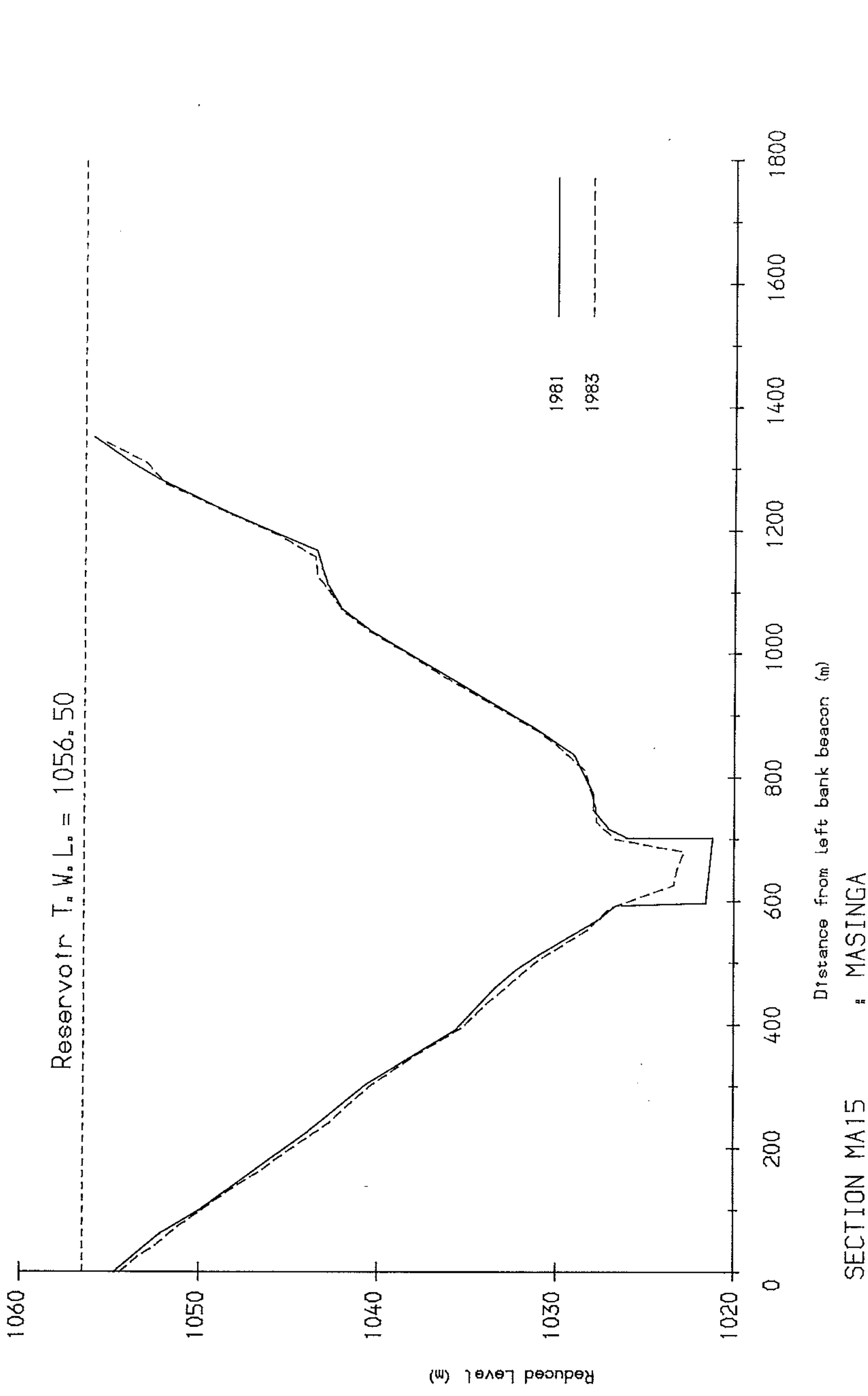

Fig 5·66 Masinga Reservoir - section MA15

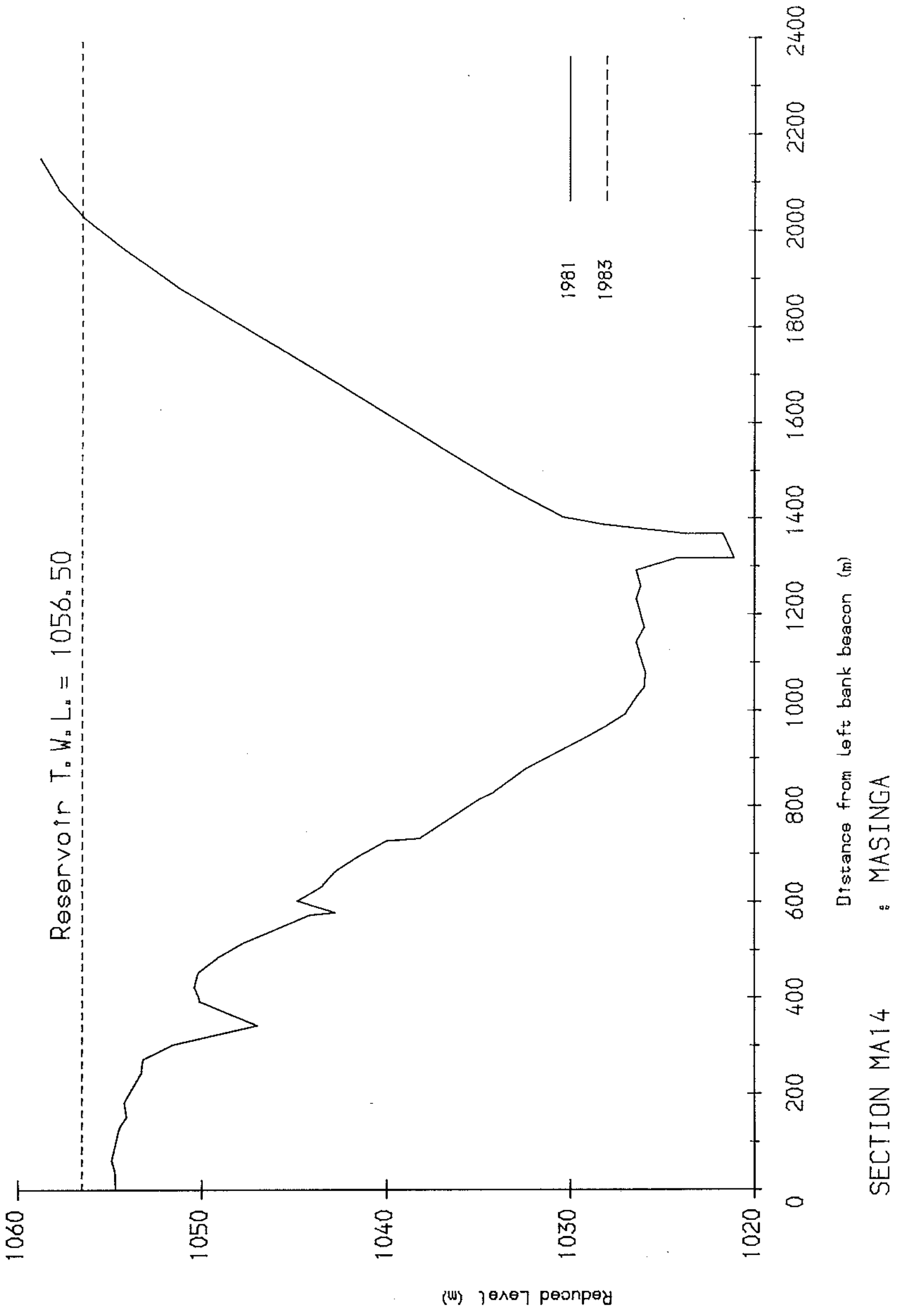

Fig 5·67 Masinga Reservoir – section MA14

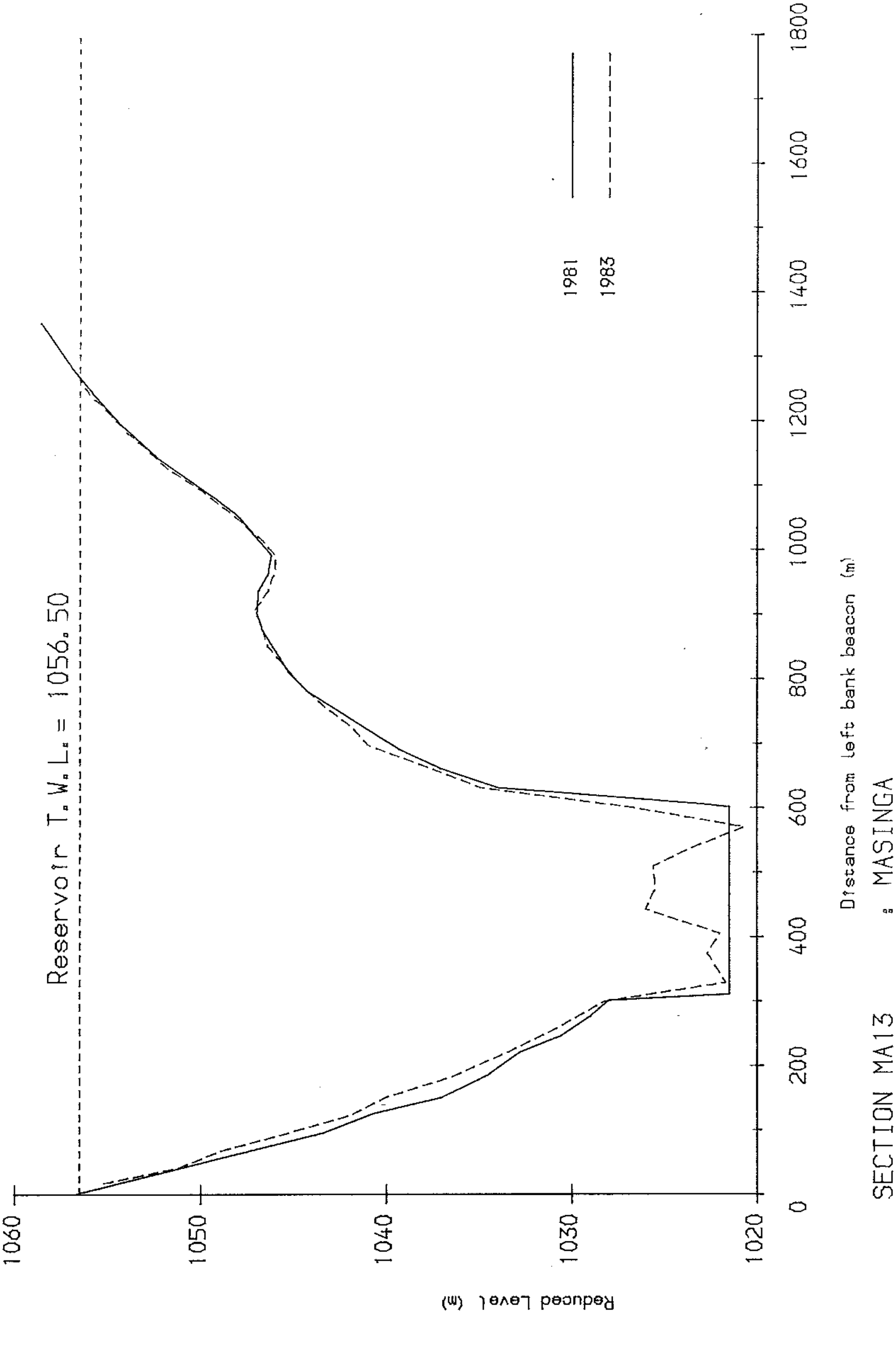

Fig 5·68 Masinga Reservoir – section MA13

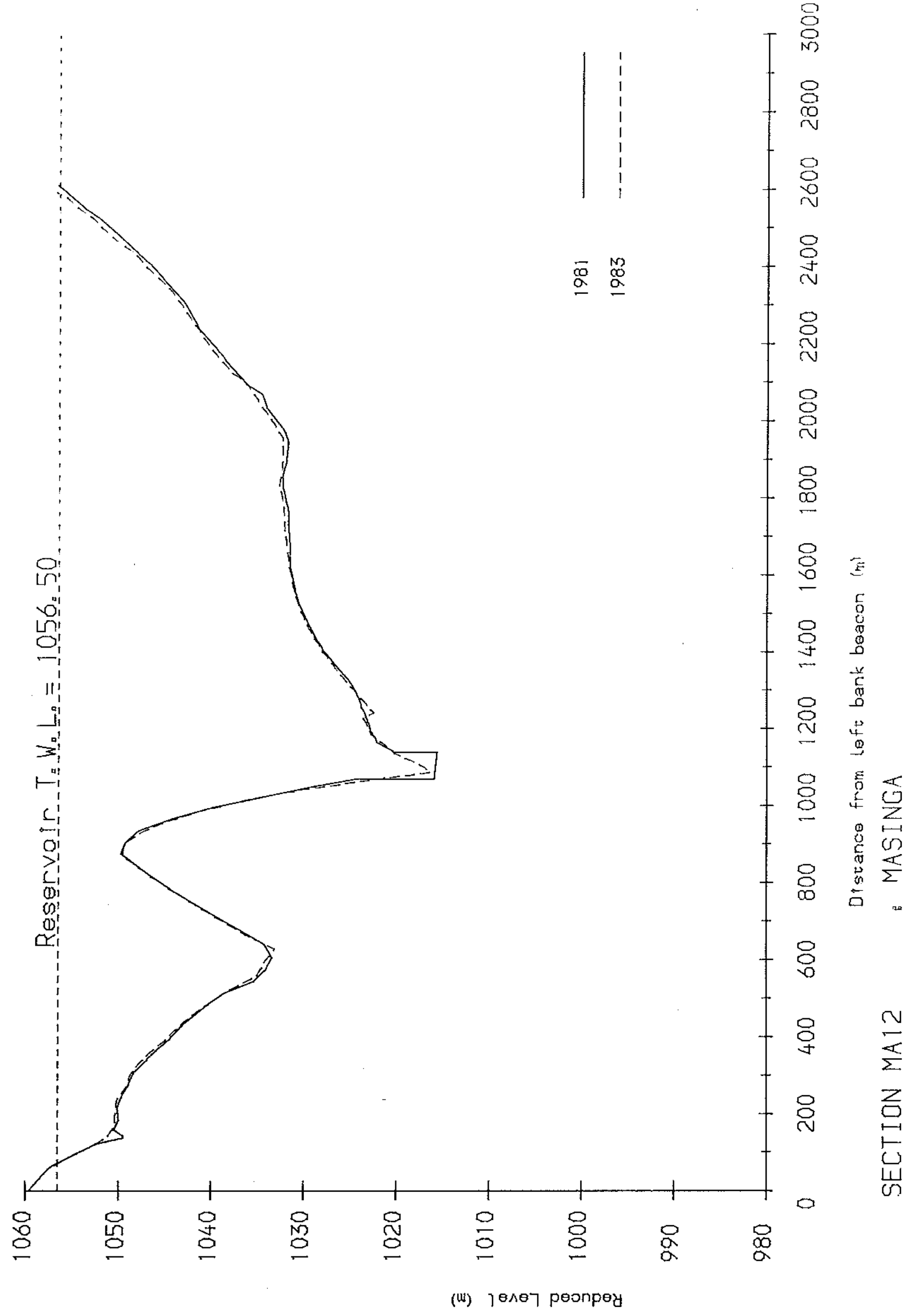

Fig 5.69 Masinga Reservoir - section MA12

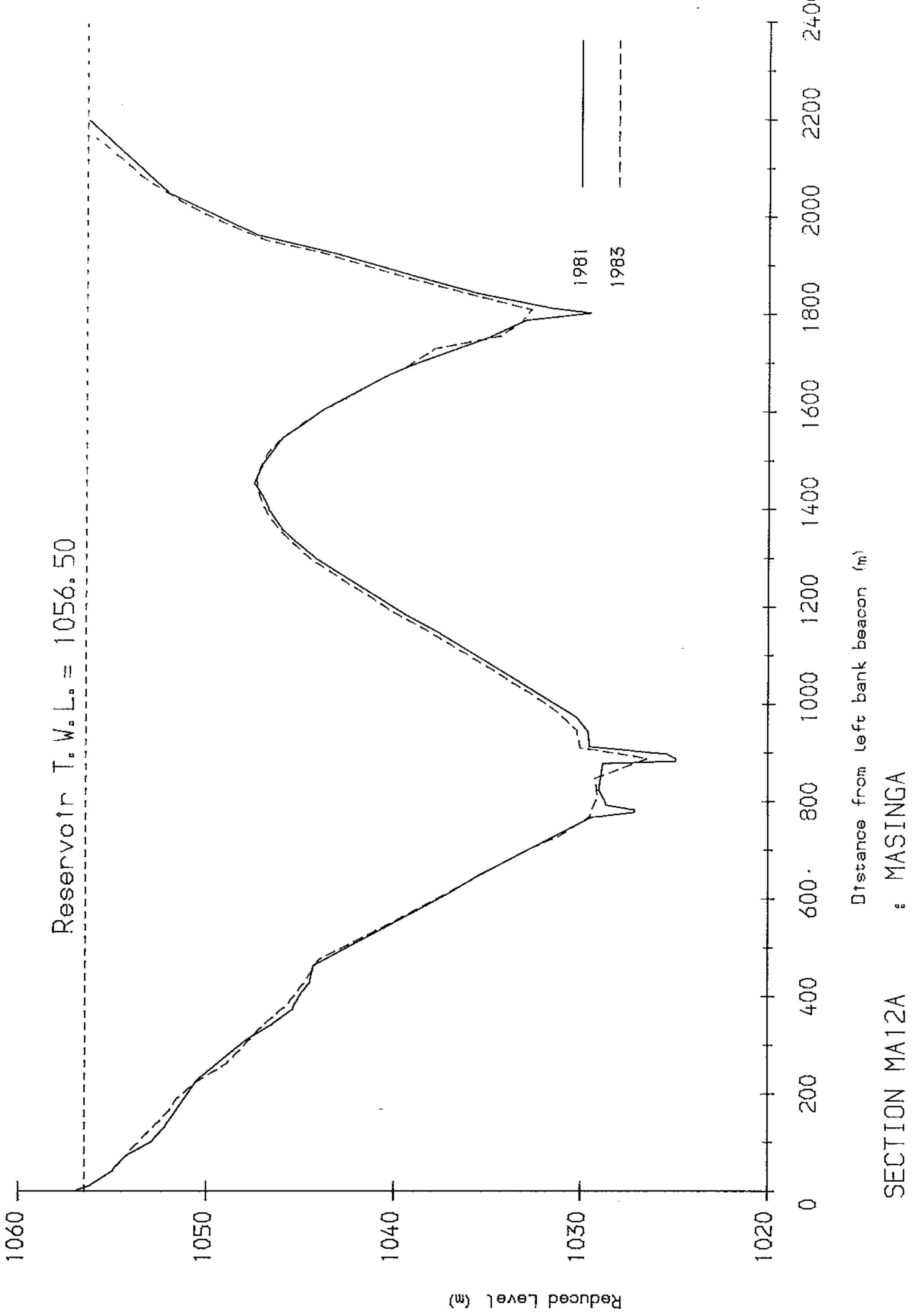

Fig 5·70 Masinga Reservoir – section MA12A

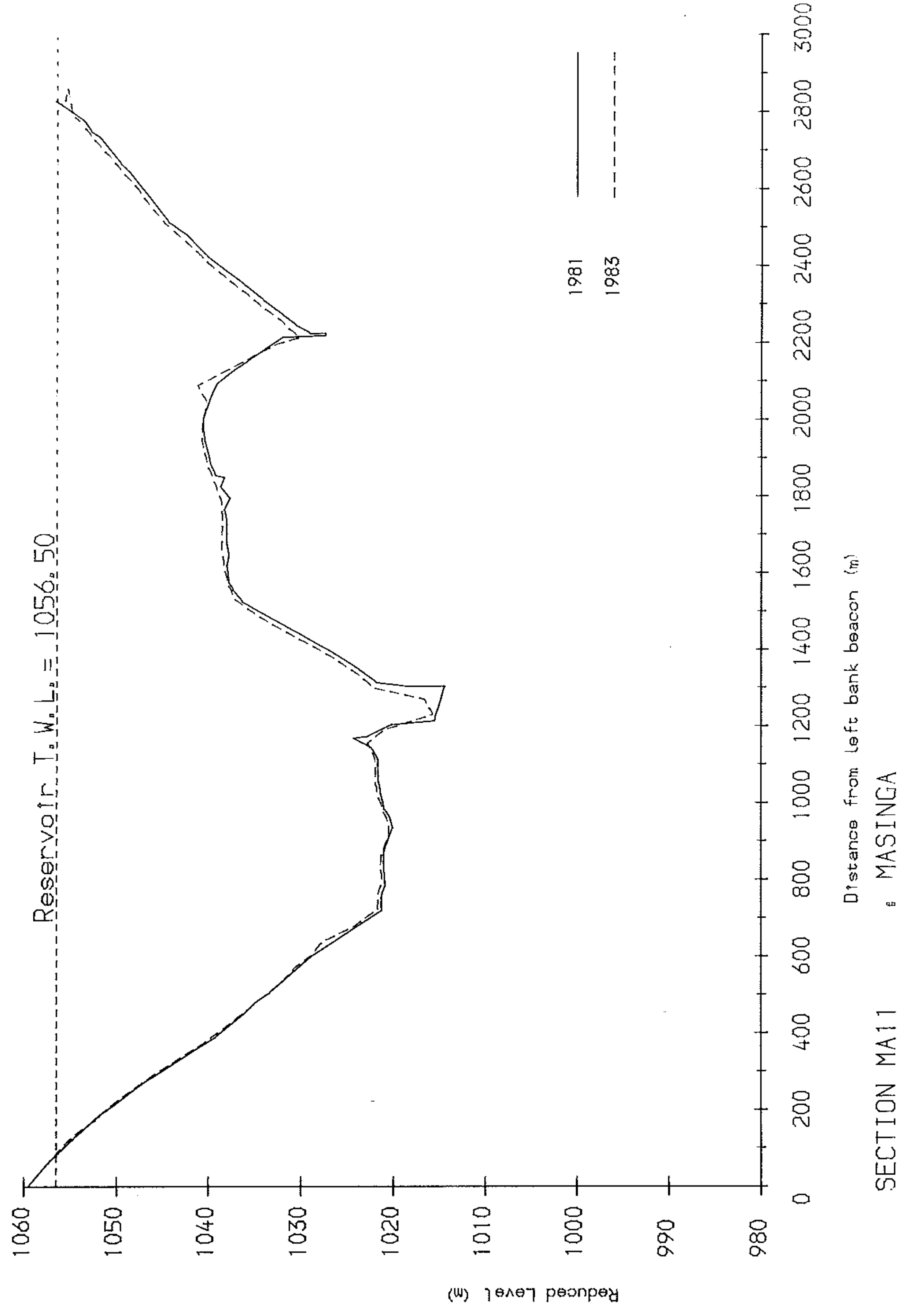

Fig 5·71 Masinga Reservoir - section MA11

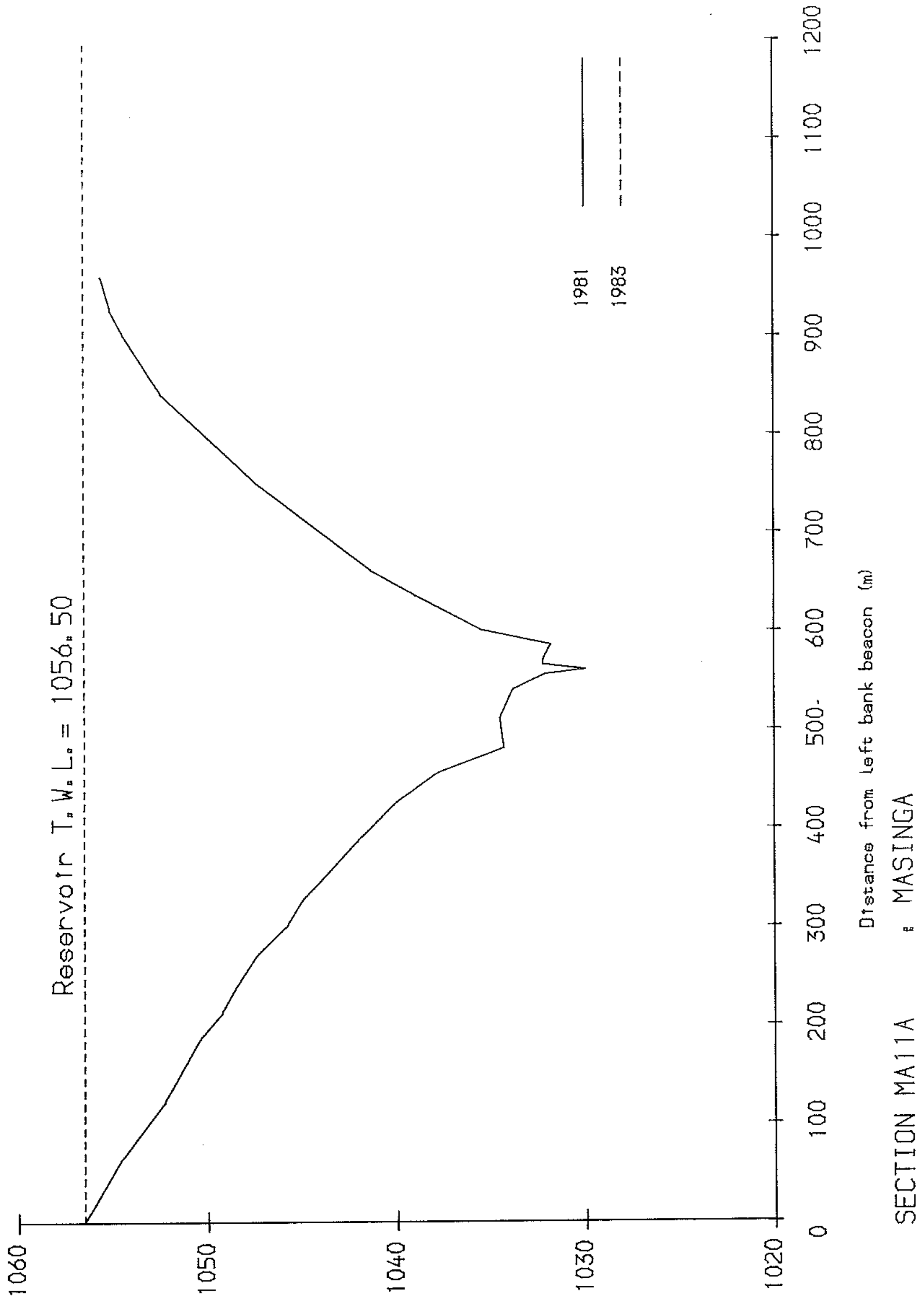

Fig 5·72 Masinga Reservoir-section MA11A

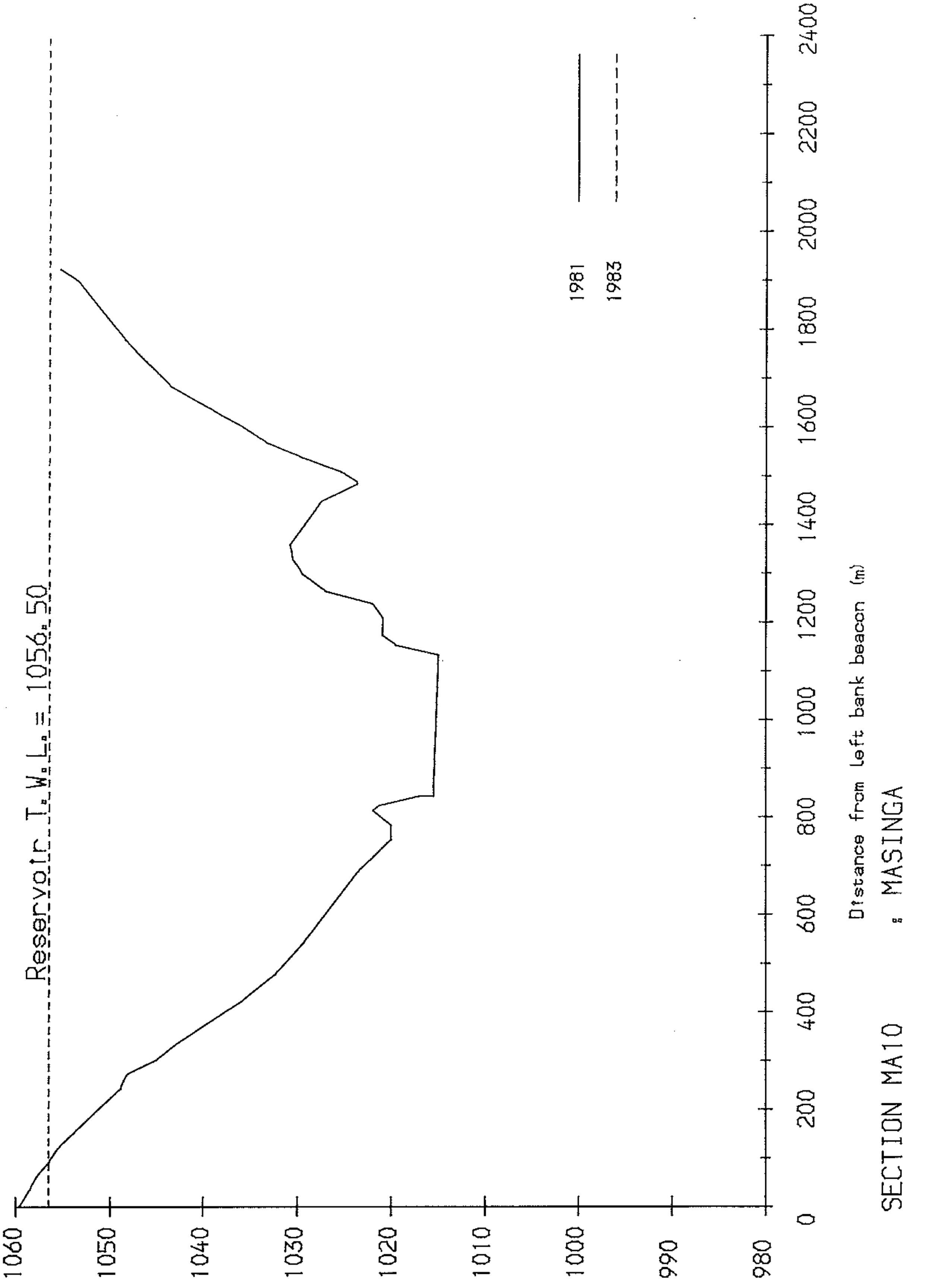

Fig 5·73 Masinga Reservoir – section MA10

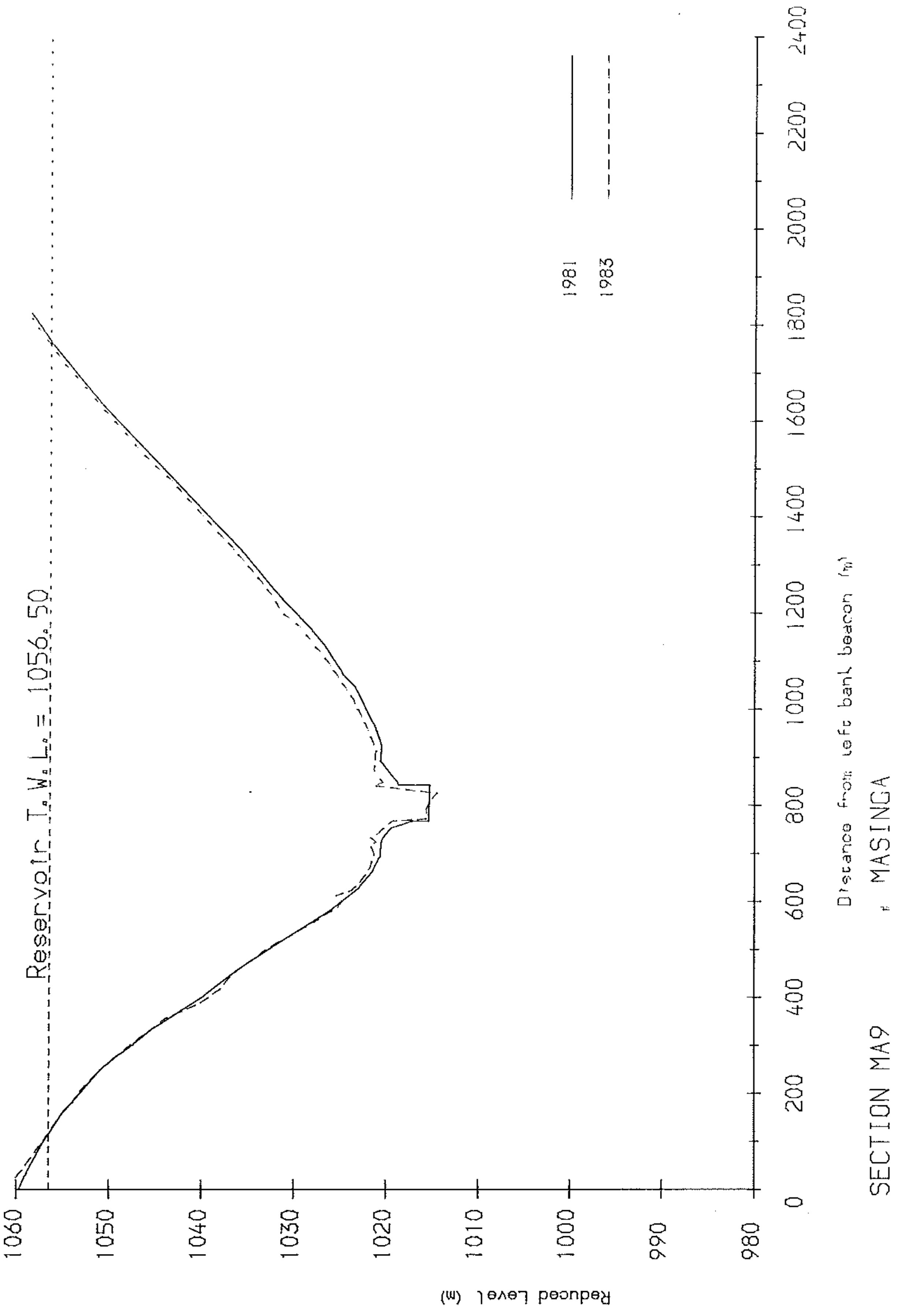

Fig 5·74 Masinga Reservoir - section MA9

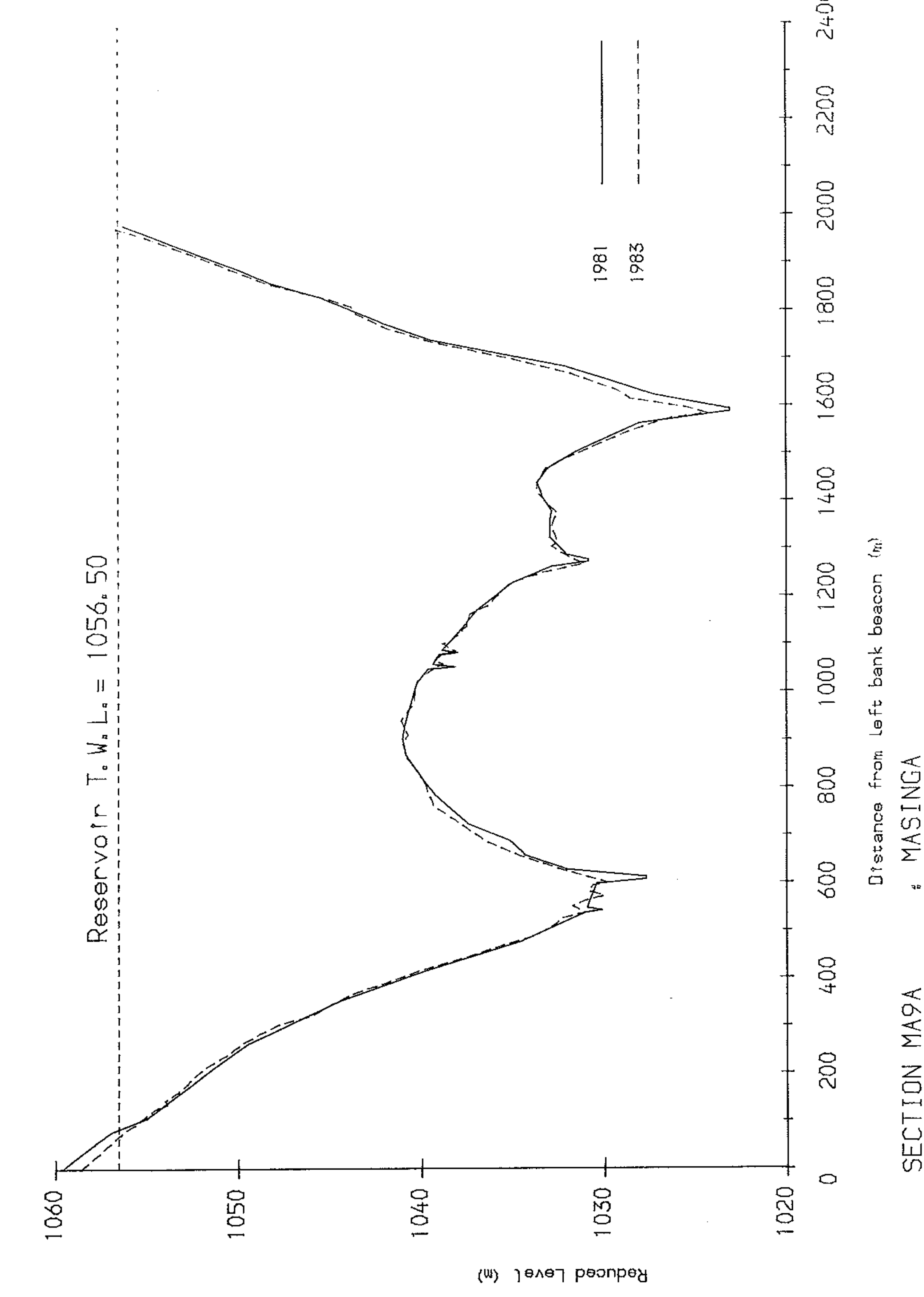

Fig 5·75 Masinga Reservoir- section MA9A

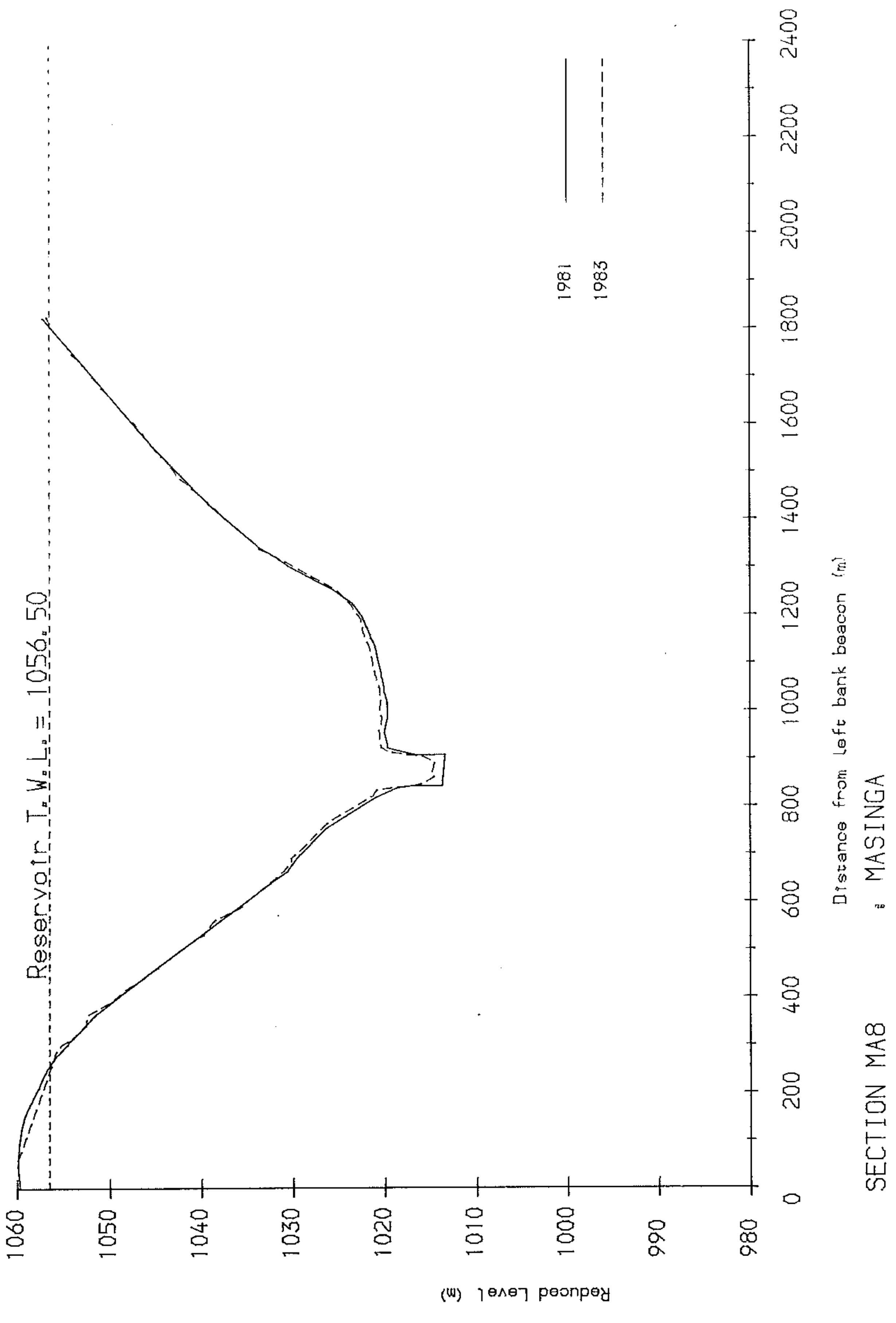

Fig 5·76 Masinga Reservoir- section MA8

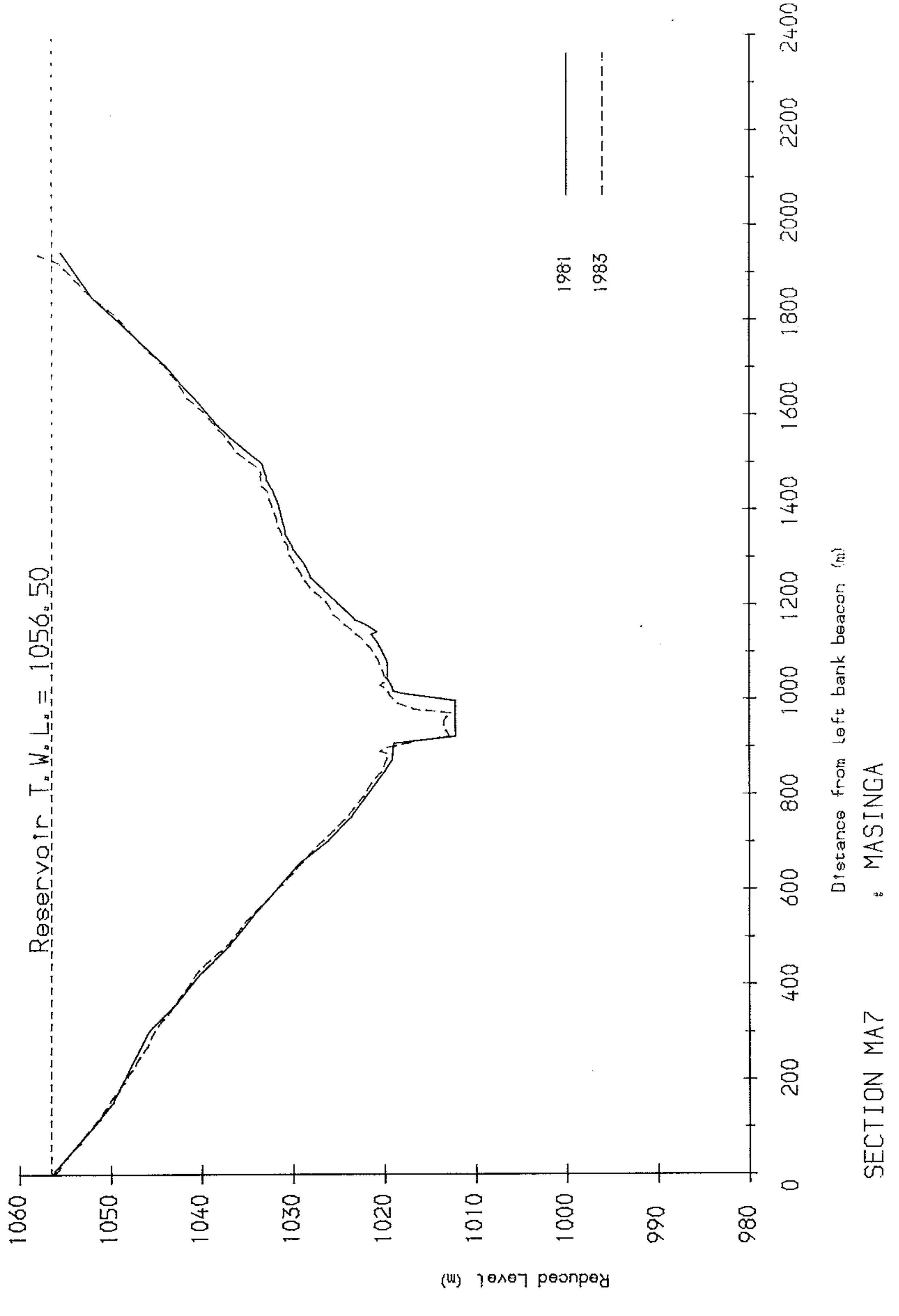

Fig 5·77 Masinga Reservoir – section MA7

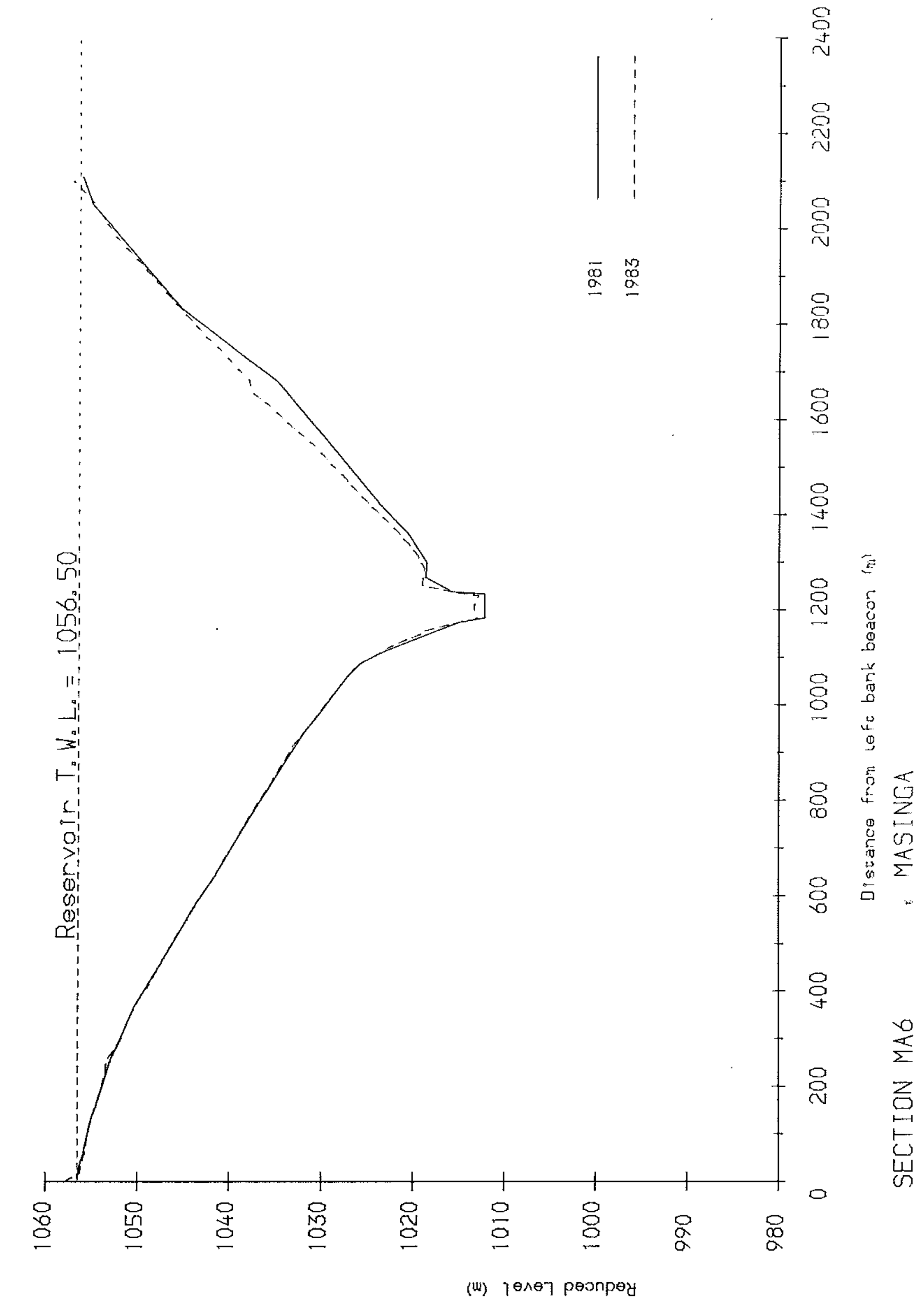

Fig 5·78 Masinga Reservoir - section MA6

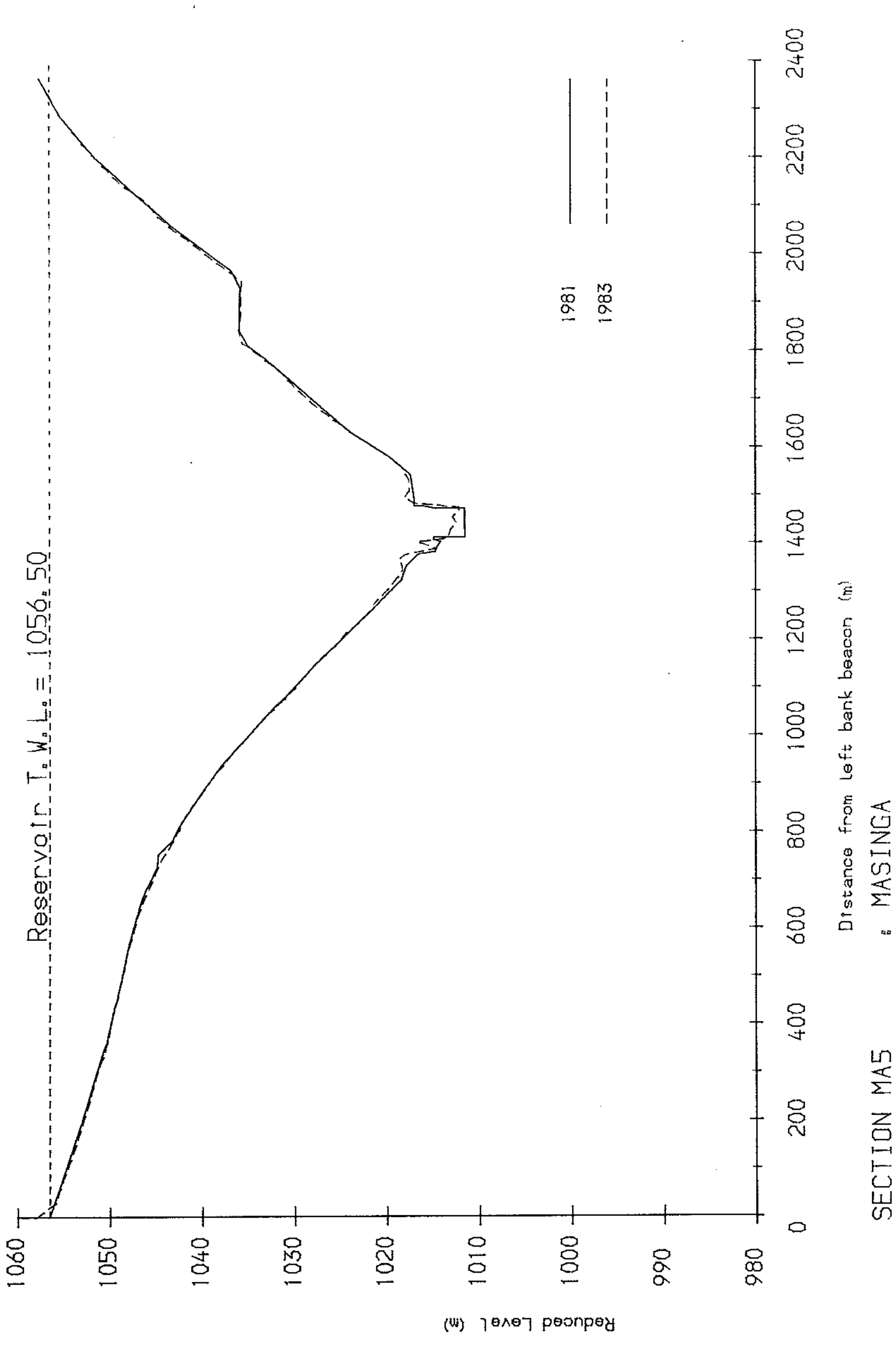

Fig 5·79 Masinga Reservoir – section MA5

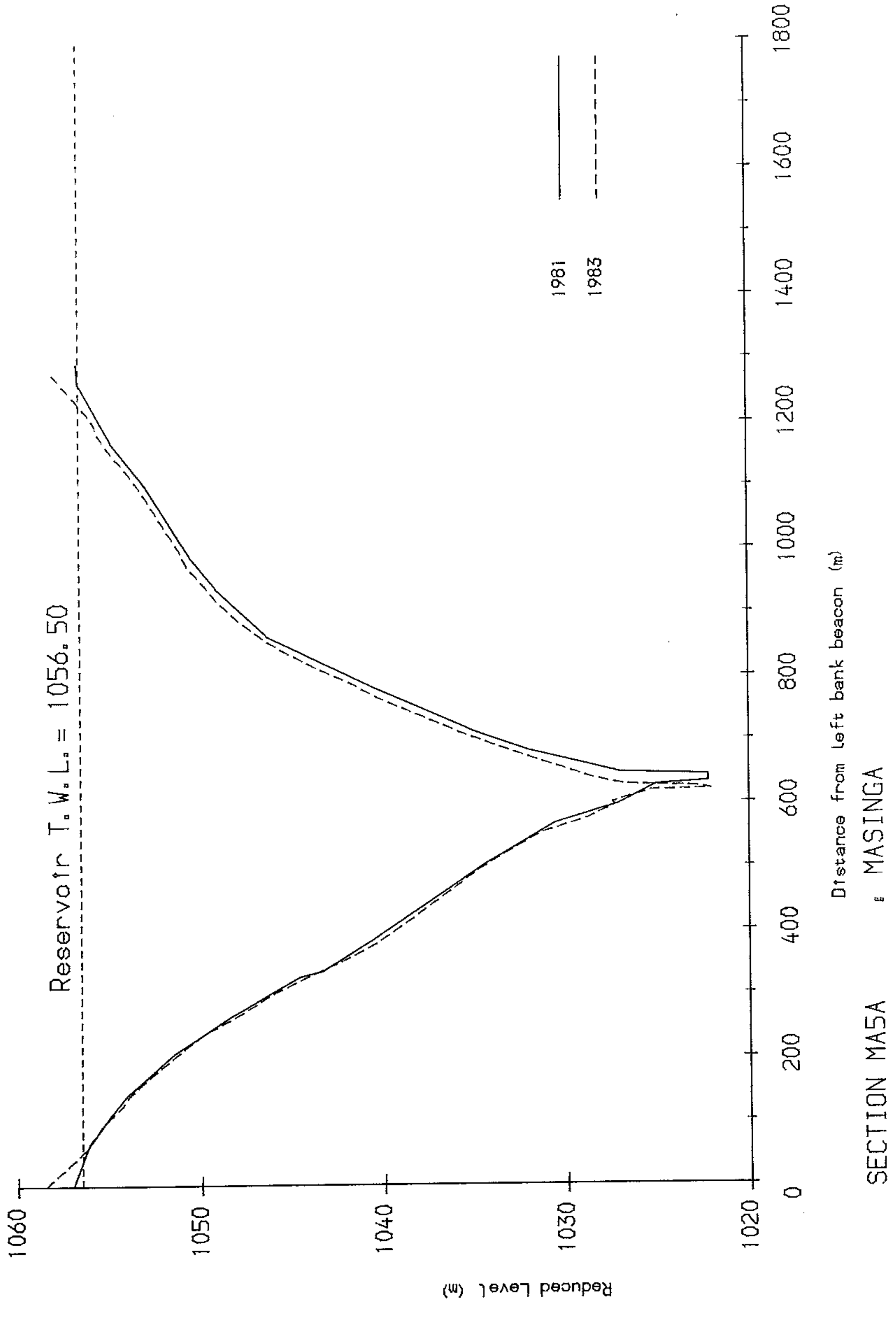

Fig 5·80 Masinga Reservoir - section MA5A

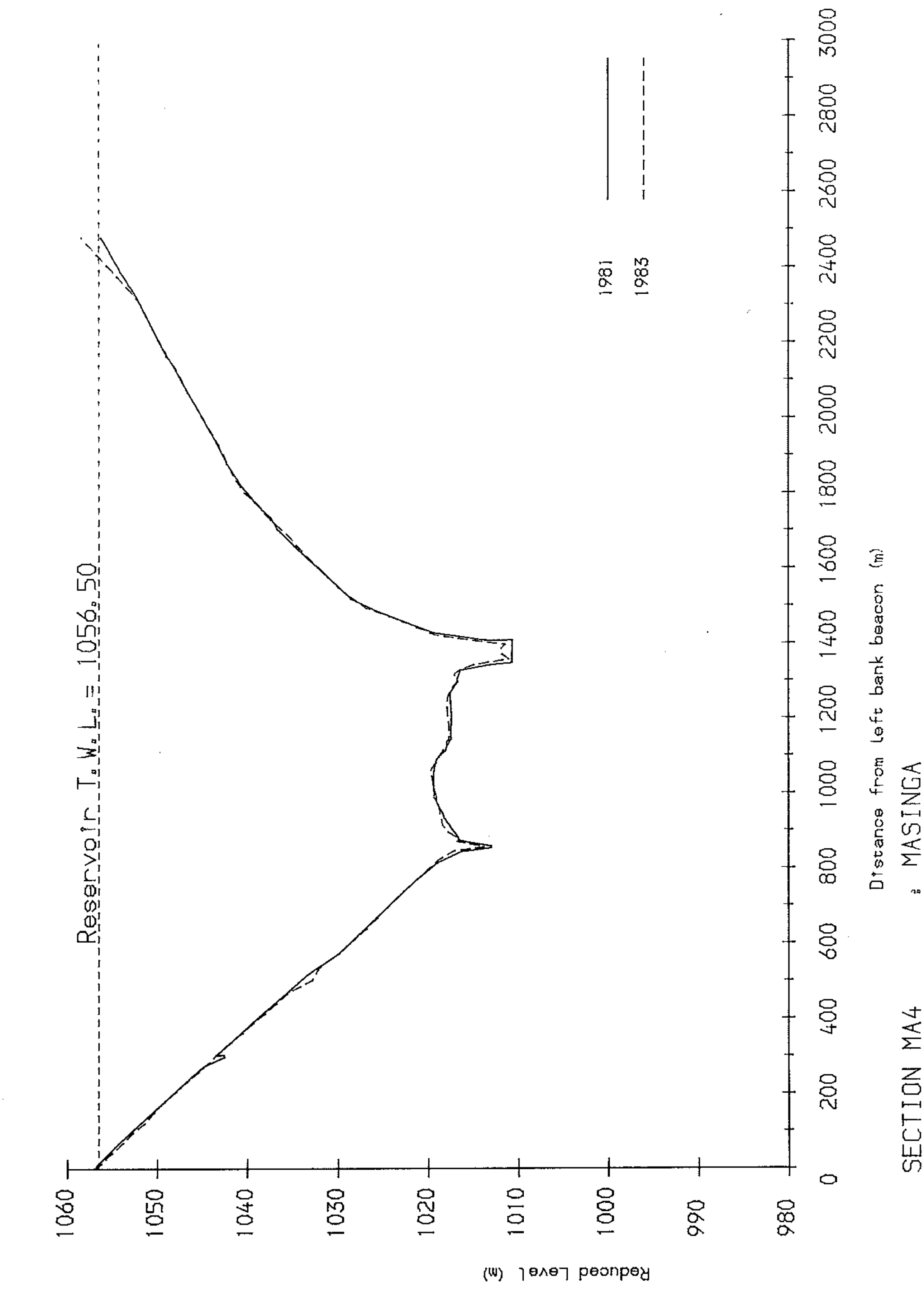

Fig 5·81 Masinga Reservoir - section MA4

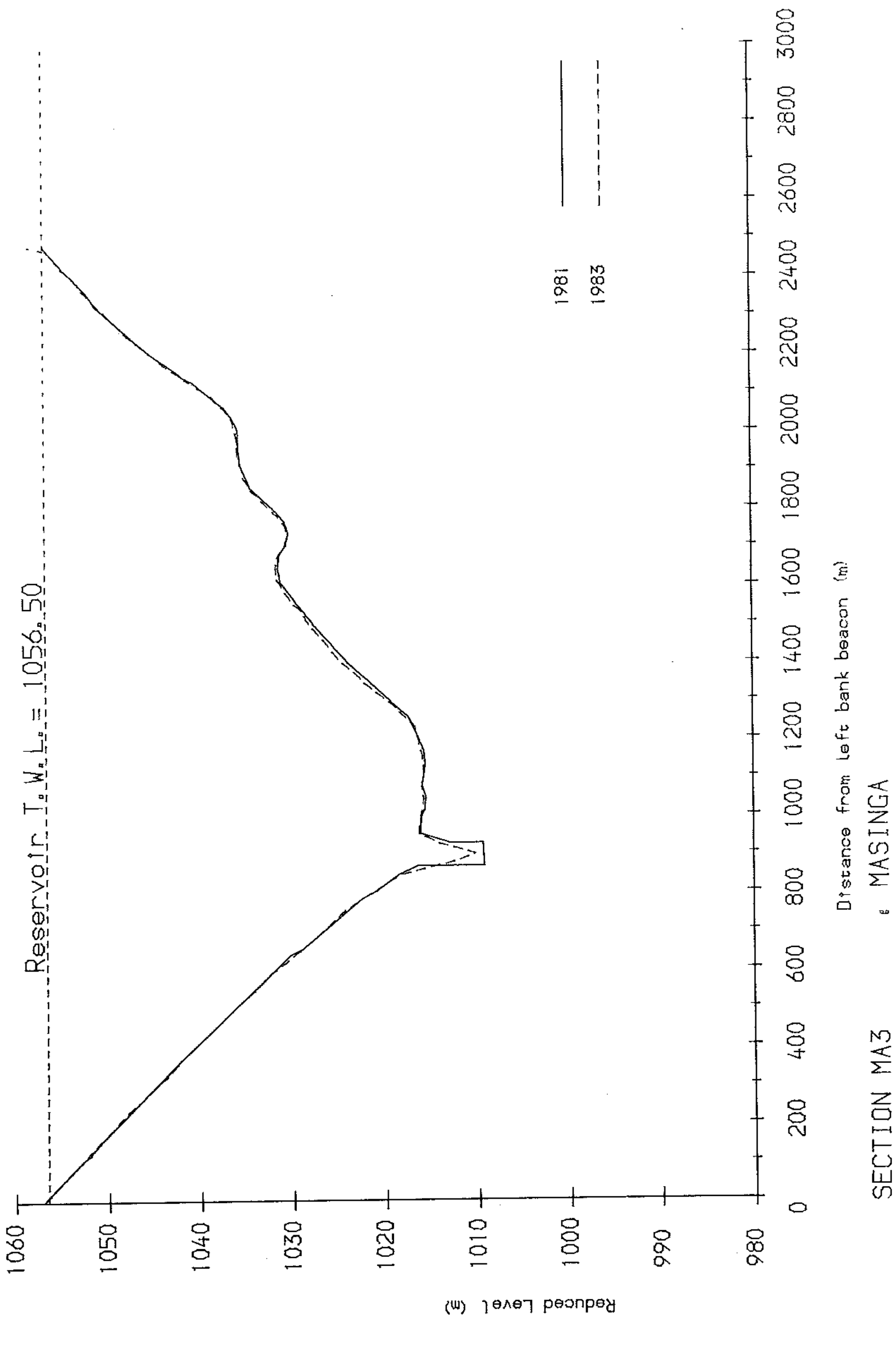

Fig 5·82 Masinga Reservoir - section MA3

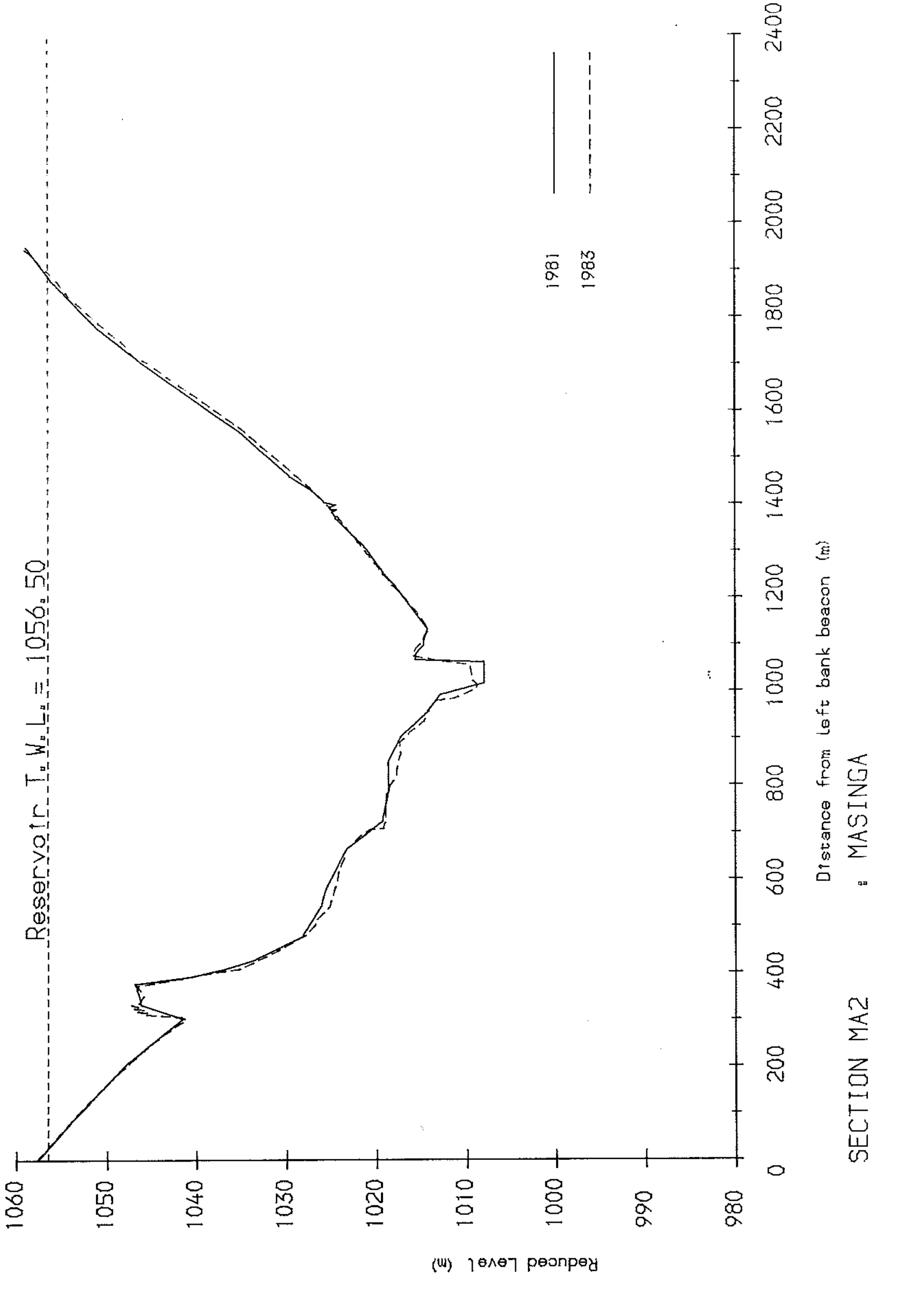

Fig 5·83 Masinga Reservoir - section MA2

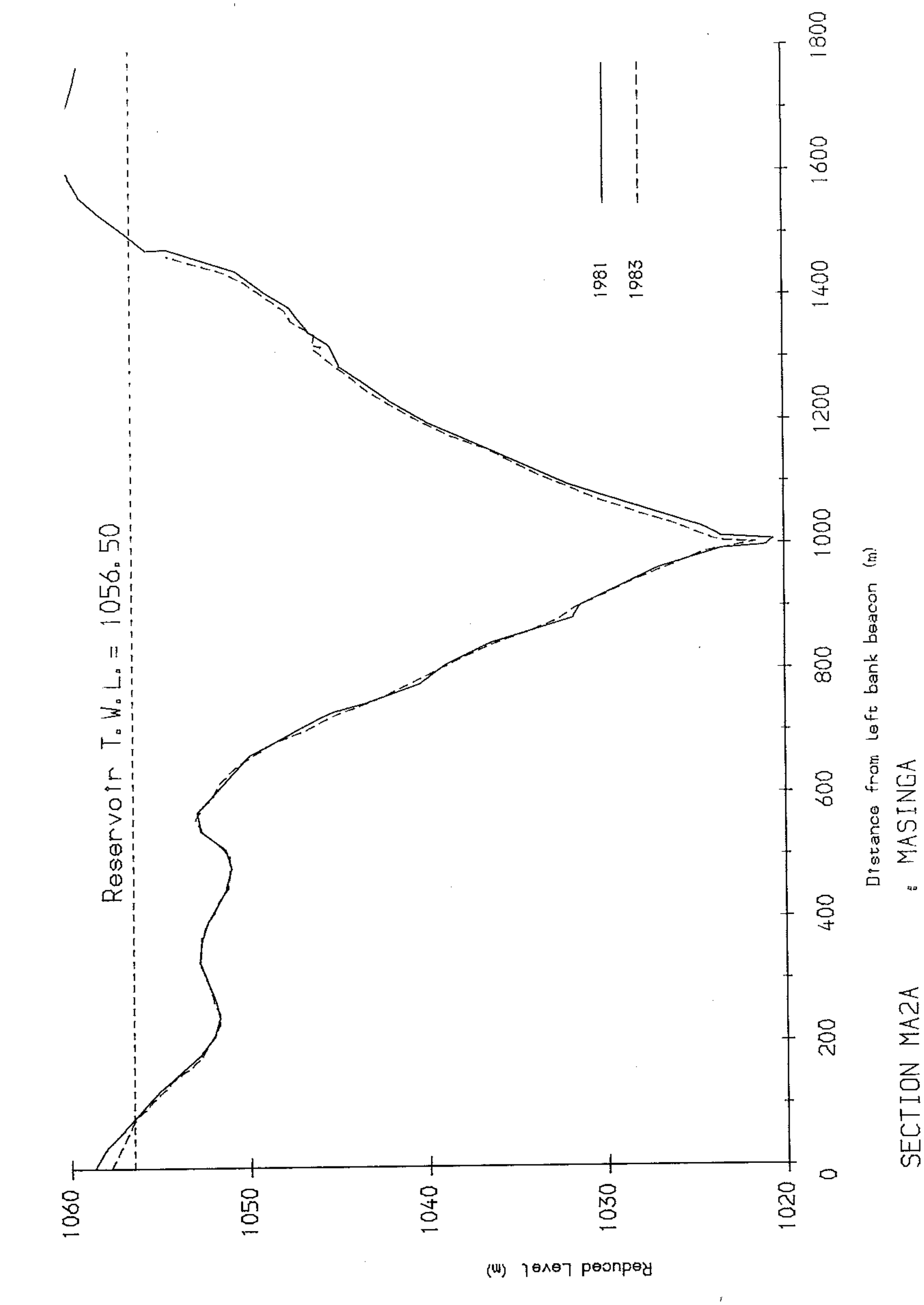

Fig 5·84 Masinga Reservoir - section MA2A

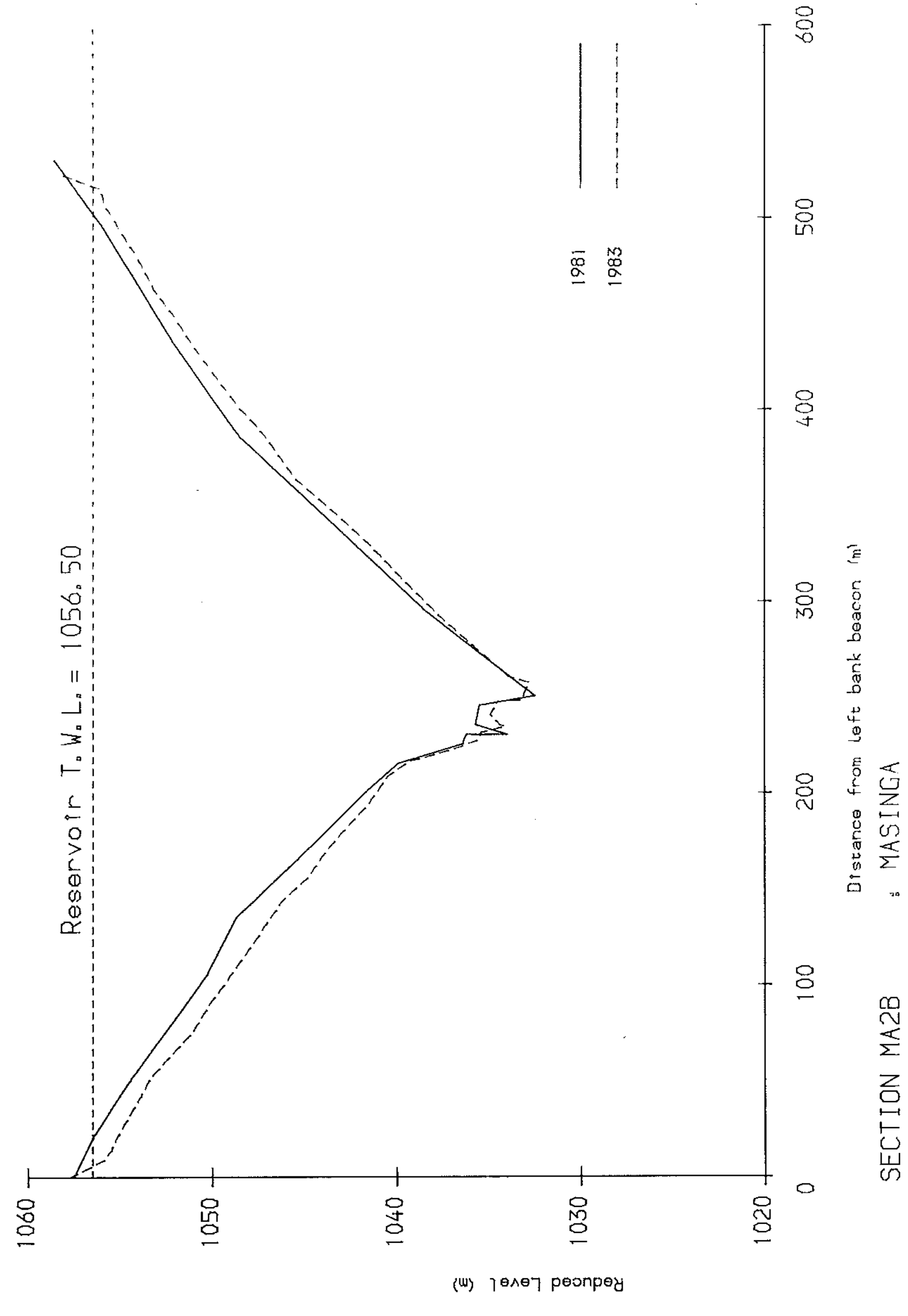

Fig 5·85 Masinga Reservoir - section MA2B

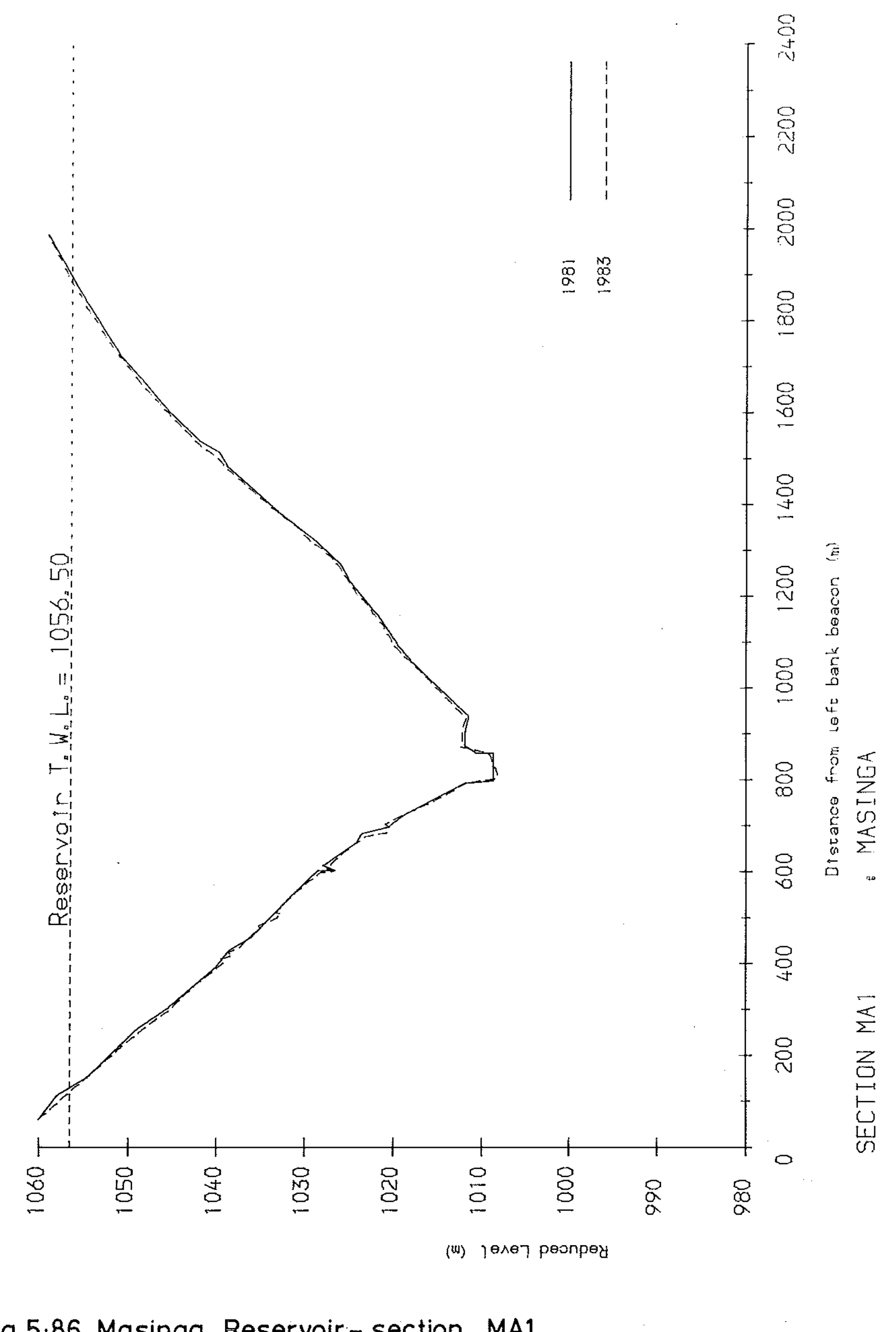

Fig 5·86 Masinga Reservoir – section MA1

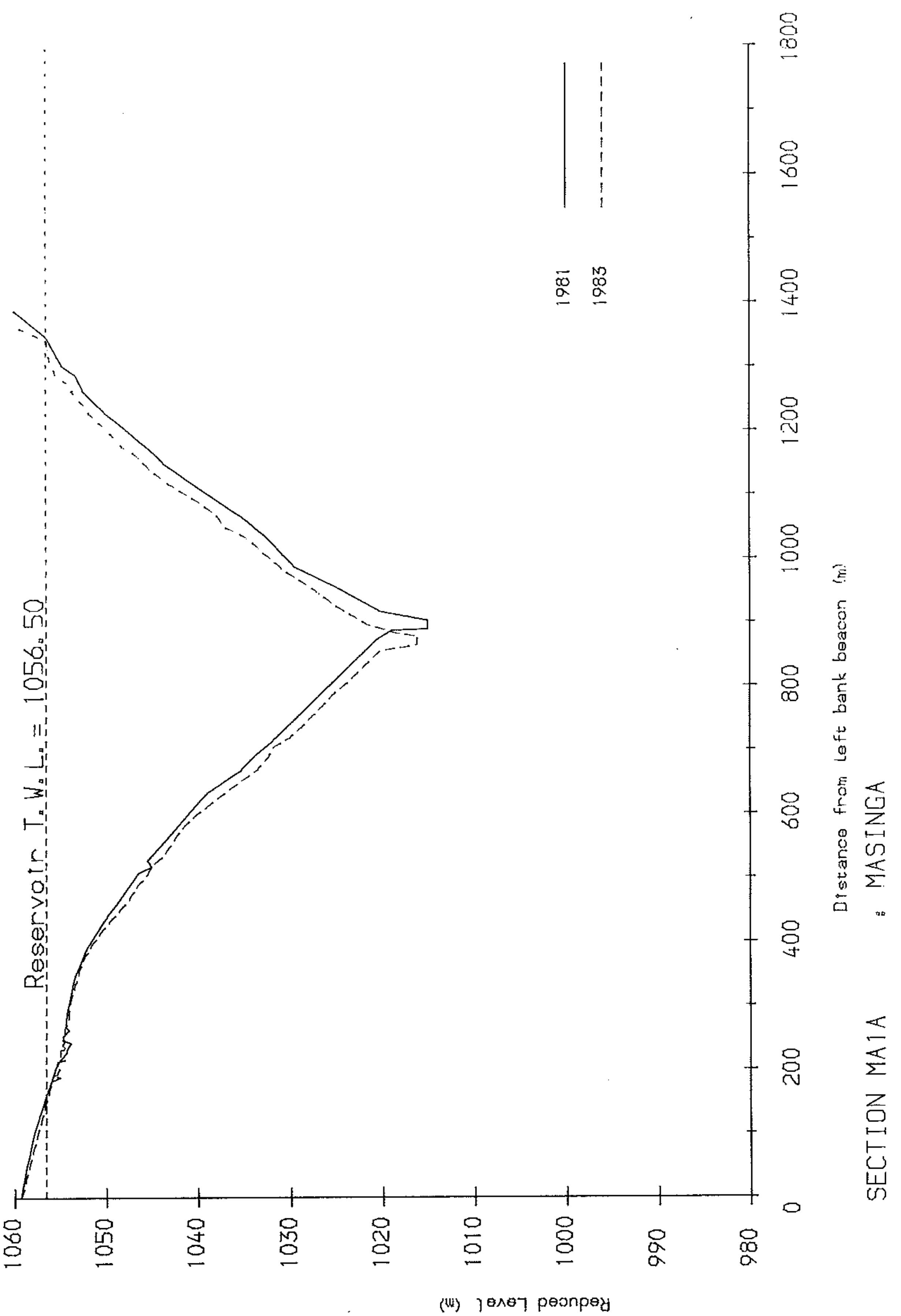

Fig 5·87 Masinga Reservoir– section MA1A

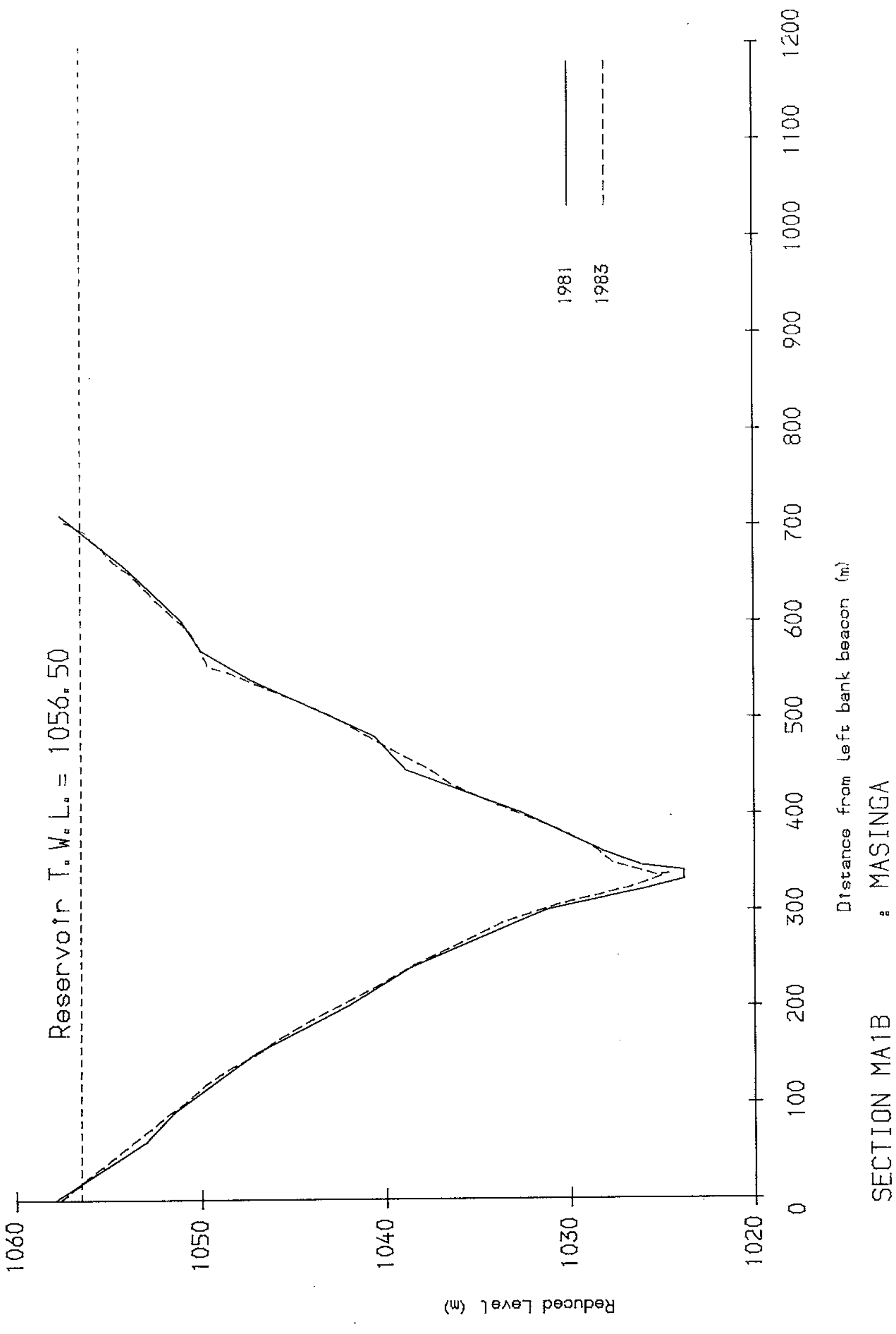

Fig 5·88 Masinga Reservoir - section MA1B

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