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BATHYMETRIC STUDY OF MANSAR LAKE DISTRICT UDHAMPUR (J&K)

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PREFACE

Lakes are natural resources available to mankind. Lakes situated in the mountainous area are a source of water for a variety of purposes such as irrigation, drinking, hydropower generation, pisciculture and recreation. Any change within the catchment area of the lake affects the complex physical, chemical and biological processes in the lake. In recent years the impact of human activities on lakes have been acutely felt throughout the entire Himalaya. The major problems being noticed in the Himalayan lakes are deterioration in water quality, increasing sedimentation rate, reduction in lake water capacity and water input.

A large number of natural fresh water lakes exist in Jammu and Kashmir State and these are of great socio-economic importance. Mansar lake has been developed asa tourist spot in the Jammu region. This lake is also being used for drinkingwater supply and irrigation purposes. It is also famous for its religious importance.

In order to develop tourism, many construction activities have taken place in the lake catchment. Increasing impact of local residents and tourists are causing ecological imbalance. Deforestation in the lake basin and inflow of domestic wastes, detergents etc. into the lake are main factor responsible for change in trophic stage of lake. For the proper management of the lake water body it is essential to study the complex hydrological behavior of the lake. In this connection, it is obvious to know the detail morphometric features of the lake.

Keeping in view the above concern, Regional Coordination Committee of the Western Himalayan Regional Centre of the Institute recommended to carry out the bathymetric study of Mansar lake. In a first systematic study, a detailed survey has been carried out to prepare a bathymetric map of Mansar lake. This map will be highly useful in any study of the lake and to compute of lake volume, determinate of sedimentation rate and also to identify high siltation zone in the lake.

The report has been prepared by Dr. S.P. Rai Sc. 'B', Shri Omkar Sc. 'C' and Dr. Vijay Kumar Sc. 'C'. Shri V.K. Agrawal, RA, and Shri C.S. Chawhan Tech. II assisted at various stage in the report and Shri Suraj Prakash Kotwal, attendant, has assisted during the field work.

(S.M. Seth)
Director

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ABSTRACT

Mansar lake is situated about 55 km East of Jammu City, between longitude 75^0 5' 11.5" to 75^0 5' 12.5" E and latitude 32^0 40' 58.25" to 32^0 40' 59.25" N and at an elevation of 666 metres above mean sea level in the Siwalik Himalaya. An attempt has been made to study the morphometric features of the Mansar lake.

The area adjoining the lake was surveyed (scale, 1:2000) using the plane table and measured by a digital planimeter. The lake surface comes to be 0.59 km^2. As measured from Survey of India toposheet No. 43 P/2 (surveyed in 1961, Scale 1:50,000), the lake surface area is 0.58 km^2 and lake basin area is 1.67 km^2.This shows that surface area of the lake has not reduced during the last 40 years. The maximum water depth in the lake is 38.25 meter. The maximum length and width of the lake is 1204 metres and 645 metres, respectively. The lake mean width is 490 metres and mean depth is 20.23 m. Circumference of the lake is 3.4 km. The mean slope of the lake floor is 0.14 m/m. Slope of the lake between 0.0 - 5.75 m depth is 0.21 m/m, 5.75 - 10.75 m depth 0.30 m/m (maximum) and 35.75 -38.25 m depth 0.04 m/m (minimum).

Volume of the lake has been determined using a contour map prepared on the basis of bathymetric survey. Total capacity of the lake is 12.37 Mm^3. Out of the total lake volume, 63 % is up to 15.75 m depth and remaining 37% water between the 15 m to 38.25 m. Lake water can be managed for drinking and irrigation purposes for the area suffering from the water scarcity such as Kandi belt in the Jammu region.

1.0 INTRODUCTION

Fastly deteriorating conditions of the fragile Himalaya have posed a serious threat to existence of lakes situated within the Himalayan region. In recent years, the impact of human activities on lakes have been acutely felt throughout the entire Himalaya. Deforestation and accelerated erosion rate in the Lesser Himalaya at the rate of 170.3 cm/yr have greatly affected the hydrological regime in the past 50 years (Valdiya and Bartarya, 1989). It has been felt that the lakes volume are reducing fastly due to high siltation rate. In addition indiscriminate construction activities in the lake catchment and untreated disposal of wastes and pollutant have aggravated the eutrophication process of the lakes, which is resulting into deterioration of water quality.

A large number of natural fresh water lakes, such as Dal, Wular, Manasbal, Nagin, Mansar, Surinsar and Sanasar lake, etc exist in Jammu and Kashmir State, and these are of great socio-economic importance. These lakes are famous for their picturesque view and most of them are being used for drinking and irrigation purposes. Further, these lakes play significant role in maintaining the hydrological, ecological and environmental balance in the region.

In Jammu region, there are two prominent lakes, namely Mansar and Surinsar, located in the east of the Jammu city. These lakes are 16 km apart in Siwalik Himalaya. Mansar lake is comparatively larger than the Surinsar lake. It has been developed as tourist spot in the Jammu region due to its natural beauty. This lake is also being used for drinking and irrigation purposes. It is famous also for its religious importance. In order to develop tourism, large number of construction activities have taken place in the lake catchment. However, increasing impact of local residents and tourists are causing ecological imbalance due to deforestation in the lake basin and inflow of domestic wastes, detergents etc. into the lake. One of the major causes of change in trophic stage of lake is inflow of sediments at higher rate from agricultural land area and hill slopes. For proper management of the lake water body it is essential to study the complex hydrological behavior of the lake. In this connection, it is desirable to know the detail morphometric features of the lake.

1.1 Objectives and Scope of Study

An attempt has been made to study the morphometric features of the Mansar lake. The bathymetric map will be useful in other studies, such as computation of lake volume, determination of sedimentation rate and also identification of zones of high siltation in the lake. It is also helpful in studying the lake morphometric parameters and to identify the process of lake origin. To the best of our knowledge, it is first systematic study to conduct the detail bathymetric survey of Mansar lake.

2.0 THE STUDY AREA

Mansar lake is situated about 55 km East of Jammu City, between longitude 75^0 5' 11.5" to 75^0 5' 12.5" E and latitude 32^0 40' 58.25" to 32^0 40' 59.25" N and at the elevation of 666 metres above mean sea level in the Siwalik Himalaya. There is no surface channel flowing into the lake (Fig. 1). The lake receives the fresh water from the precipitation over the lake basin area which enters in the lake through overland flow. During the rainy season, when the water level rises in the lake, overflow from the lake takes place through outlets (in the form of pipes) which drains into the Khad which joins Gamhir Khad. Lake water level varies between 1.5 to 2 m in a year, it reaches maximum in September/October and minimum in May/June. It is famous due to its picturesque view and religious importance (Fig. 2a). Lake basin area is covered by varios type of human activities. Western flank of the lake basin is covered by the agricultural fields, school and Sesnag temple, Northern flank by Mansar Bazaar, Block Offices and forest rest house etc (Fig. 2b), Eastern flank by Sesnag Temple, tourism guest house etc, and Southern flank by wild life sanctuary, Samshan Ghat, and the hill slope is covered by forest.

Climatically, area falls under the subtropical region. Monsoon rains are received from July to September and winter rains during January to March. The average rainfall is 150 cm. Air temperature varies between 3^0 C in winter to 43^0 C during peak summer. Lake water temperature at surface varies between 14^0 C (minimum) in January to 31^0 C (maximum) in July.

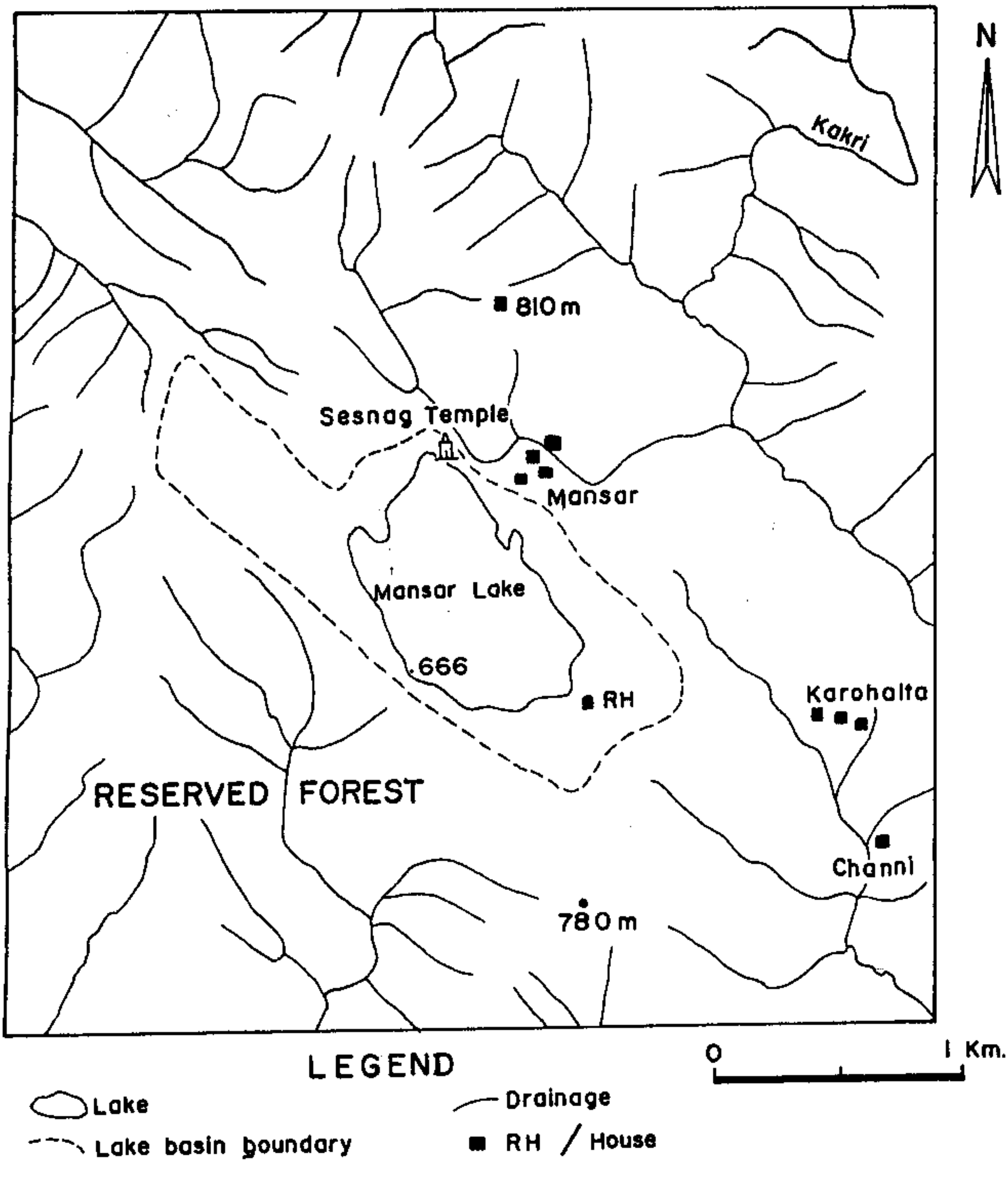


Figure 1: Location map of the Mansar lake with drainage.

Figure 2 a: A view of Mansar lake

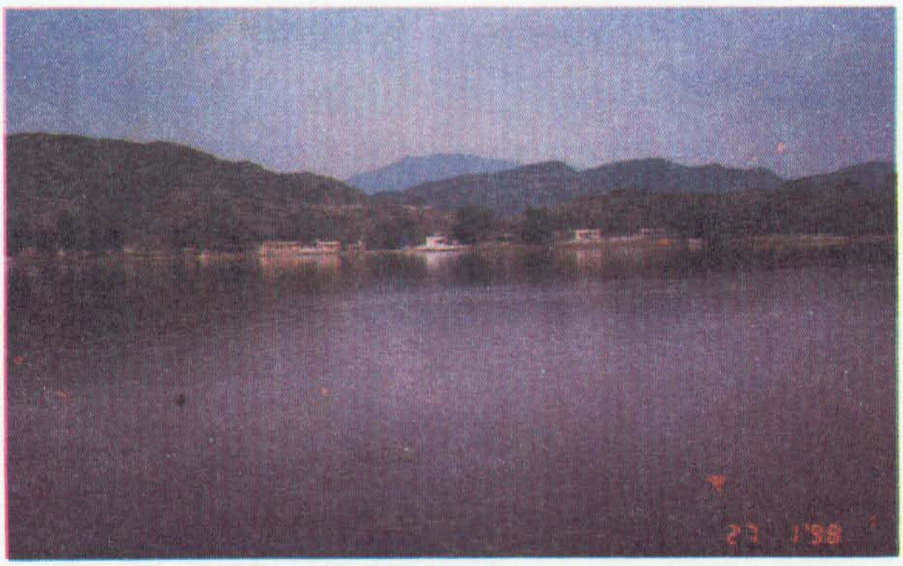


Figure 2b: Recent construction activities on the periphery

The reserve forest on the western bank of the catchment covers 0.11 km^2 and is mainly represented by *Mangifera indica, Ficus religiosa, Pinus roxburghii* and other subtropical type plants. The lake is heavily infested with macrophytes, weeds, submerged and floating plants in addition to ichthyofauna, amphibia and reptiles. Chlorophyceae, Bacillariphyceae and Cynaophycean are dominated species of phytoplankton. Besides, there is abundance of nectons and plankton invertebrates, diatoms, algae which form ecological link in the food chain of both invertebrate and vertebrate. Besides aquatic fauna, the lake has very intimate association with the wild life of the area. Fishes in the lake belong to three families and five genera. These are *C. gachua* (family-Ophiocephalidae), *Puntius conchonius, Rasbora, Danio rerio* (all cyprinids) and *Trichogaster fastiatus* (Anabantidae) (Gupta, 1992).

2.1 Geology of the Area

Medlicott (1876) first studied the geology of the Siwalik belt in Jammu Region. Among various workers, Wadia (1928), Hazra (1938), Bhatt (1963) and Karuna Karan and Ranga Rao (1976) have studied in detail the stratigraphy and depositional environment of Siwalik belt of Jammu.

Gupta and Verma (1988) have studied the geology of the area and classified the Siwalik Group rocks. The oldest litho-unit of the Siwalik Group, the Mansar Formation, is exposed in Suruin - Mastgarh Anticline in Mansar (Lake Basin) area. It consists of alternating layers of fine grained, hard and compact sandstone, silt stone, mudstone and clay. The sandstone are buff, grey and light greenish grey in colour. The clays are purple, brown, red and yellowish red. The massive sandstone bands stand out as prominent small mounds and ridges, while clay and siltstone generally form depressions. At places, the sandstone bands contain lenticles of pseudo conglomerate consisting of pellets and fragments of mudstone, claystone and shale which is bounded with arenaceous matrix. The clay invariably contain interbedded siltstone which at places has been lithified into hard mudstone. The sandstone is frequently transversed by thin calcite veins along the joint planes. Geomorphologically, the area is young and neotectonically active. Although the Mansar formation lies in a different tectonic unit, it appears homotaxial to the lower Siwalik of Ramnagar, Vashishat et al. (1978).

2.2 Origin of the Lake

There are several myths about its origin, but a common geological belief is that the lake owes its origin due to the damming of the river which was flowing along the strike of the Lower Siwalik range (Zutshi, 1985). The peaty and sticky soil surrounding almost the entire area of the lake which might had been of greater dimensions in the past support to these observations. Krishnan and Prasad (1970) have reported that the Mansar and Surinsar lakes are ten to fifteen thousand years old.

Trellis and parallel type drainage pattern (Fig. around the lake basin are evidence of the structural control on the drainage pattern. NW and SE trend of strems reveals that these are flowing along the Surin Mastgarh anticline. There is more possibility that origin of Mansar and Surinsar lakes are due to the neotectonic movements along Surin Mastgarh anticline in the Siwalik Himalaya.

3.0 BRIEF SUMMARY OF PREVIOUS WORK

In the last two decades, Himalayan lakes have drawn attention of many ecologists. Several studies have been carried by various investigators on the morphological and ecological aspects of the Himalayan region lakes. Bathymetric survey of natural lakes in the Himalayan region has been attempted by various workers. Holland (1895) has carried out the bathymetric survey of the Naini lake. Public Works Department, Nainital is taking the depth measurement of Naini lake every year since 1947. Rawat (1987) has compared the volume of the Naini lake with the 1895 and 1979 results and concluded that the lake volume has been decreased by 31,699 m^3 in 84 years. Bathymetric survey of the Kumaun lakes of U.P. Himalaya has been carried out by Khanka (1991). Hashimi et al. (1993) have prepared the bathymetric map of Naini lake with one meter contour interval under the collaborative study of Geology Department, Kumaun University, Nainital and National Institute of Oceanography, Goa using the high frequency ecosounder.

In J&K State, Various workers have made attempt to understand the ecological aspects of Dal, Wular, Nagin lakes, etc., but no attention has been paid to the hydrological aspects of the lakes. There was dispute among the workers regarding the maximum depth of the Mansar lake because no detailed bathymetric survey was carried out.

Attempt has been made by the workers to the study the biological and ecological aspects of the J&K lakes. Among the various workers, Zutshi et al., 1972, 1980; Zutshi and Khan 1978, Zutshi and Vass, 1971, 1977, 1978; Kant and Kachroo, 1974, 1977; and Kaul et al., 1980 have studied in detailed the limnological and biological aspects. Zutshi et al. (1980) have reported that lakes of Jammu and Kashmir are different in their morphology and thermal behavior and vary from sub-tropical monomictic to dimictic type. Zutshi and Khan (1977) have carried out comparative study of the morphometric, physico-chemical and biological parameters of the Mansar and Surinsar lake. Using radioactive Carbon Isotope (^{14}C), production rates of Surinsar lake is much higher than that of the Mansar lake. On the basis of production rates, Surinsar lake has been categorised as Eutrophic and Mansar as Mesotrophic (Khan and Zutshi, 1979). Omkar and Sharma (1994-1995) has carried out the water quality study of the Surinsar lake. This study suggested that water of the lake is suitable for drinking and irrigation purposes. Recent studies reveal that the trophic level in the Mansar lake is rapidly advancing during last few years (Zutshi, 1985, 1989; Chandra Mohan, 1992; Gupta, 1992). The trace elements study of the Mansar lake water has been carried out by Durani (1993) and Phytoplankton study by Kant and Anand (1976, 1978).

4.0 METHODOLOGY

Basically, there are two methods to carry out bathymetric survey of lakes/reservoirs. These are the range-line survey and the contour survey. The range-line method is most widely used for medium to large lakes/reservoirs. The range-line method usually requires less field work and is less expensive than the contour method. In this method, number of cross sections are selected to survey the lake. These cross sections are called the ranges. The most important is measurement of bed elevation at many known locations in the lake. These measurements are almost always made by measuring the water depth beneath a boat and the exact location of the boat on the lake's surface. So, two basic types of measurements are required, (i) location measurements (ii) depth measurements.

4.1 Location Measurements

The basic measurement required for a lake/reservoir survey is the location of the cross sections (range line) and points of depth measurement. It requires a base map of the lake with locations of cross section points around the lake. The location points around the lake are helpful in positioning the cross sections on the map for bathymetric survey. Mapping of the lake surface area has been carried out on the scale of 1:2000 using the plane table method. The methodology used for plane table survey has been described briefly in the following paragraphs.

<u>4.1.1 Plane Table Method</u>

Plane Table Surveying, also called plane tabling, is a method of surveying in which field work and office work are done simultaneously on a plane table. The field observations are taken and recorded side by side on the sheet fixed upon the plane table and a map of the area is obtained. It is commonly employed for small and medium scale mapping.

The equipment essentially needed for plane tabling is a plane table or drawing board which carries a drawing sheet and is mounted on a tripod stand and an alidade which provides line of sight and a straight graduated edge. The accessories to the plane table are a trough compass, which is used for marking the direction of the magnetic meridian on the sheet of the plane table, and a plumbing fork or U-frame with a plumb bob, used for centering the table. Besides these, the other accessories are drawing sheet, a water proof cover to protect the drawing sheet and drawing instruments like pencils, eraser and scale etc.

Surveying with the plane table may be classified under four distinct heads viz. (i) radiation, (ii) intersection (iii) traversing and (iv) resection. Traversing method has been used in this survey, and is explained below in brief.

Traversing is the main method of plane tabling and is similar to that of compass or theodolite traversing. It is used for running survey lines of a closed or open traverse. The detail may be located by offsets taken in the usual manner or by the radiation or by intersection method of plane tabling. The procedure of plane table survey is explained below:

(1) Select the traverse stations A, B, C (Fig 3).

(2) Set up the table over one of them, say A. Select the point a suitably on the sheet. Level and centre the table over A. The setting up of the plane table includes three operation viz. Levelling, Orientation, and Centering.

For levelling place the table over the station point and spread out legs to make it level and at a convenient height, preferably not below the elbow. Then orient and centre the table approximately as explained in the following two operations and complete the final levelling with reference to a circular level or a level tube placed in two positions at right angles to each other.

Orientation is placing of table such that all lines on the paper are parallel to the corresponding lines on the ground. This is necessary when more than one stations have to be occupied by the table as otherwise the board would not be kept parallel to itself at the various stations. Orientation can be done by the using of a magnetic needle and/ by back sighting. Orientation by the Magnetic Needle can be done by placing the trough compass along the line representing the meridian drawn already on the paper at the first station and then turn the table until the ends of the needle are opposite the zeros of the scale or points towards north south direction. Orientation by back sighting consists in bringing a line *ba* on the paper over a line BA on the ground. This is accurate of the two methods and should be preferred.

Centering of the table is the process of placing the point on the paper, representing the station being occupied, vertically over the point on the ground. This may be done by means of a plumbing fork or U frame by placing the pointed end of the fork touching with the point on the paper and shifting the table bodily until the plumb bob hangs vertically over the centre of the station. Orientation and centering are

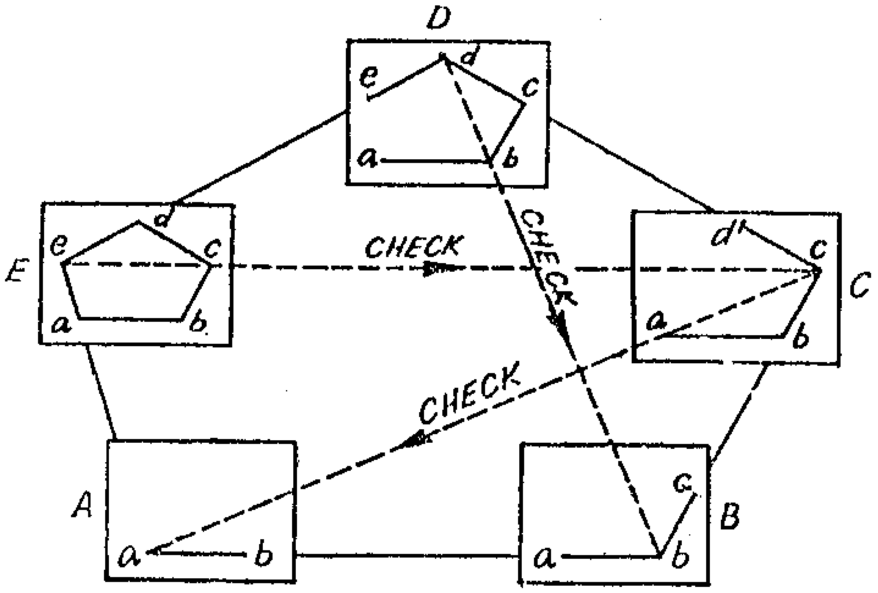


Figure 3: Procedures followed during plane table survey method.

interrelated because when one is done, the other gets disturbed, therefore, both of them have to be done simultaneously.

(3) Mark the direction of the magnetic meridian on the top corner of sheet by means of trough compass.

(4) With the alidade touching a sight B and draw the ray.

(5) Measure the distance AB and scale off *ab*, thus fixing the position of *b* on the sheet, which represents the station *b* on the ground.

(6) Locate the nearby details by offsets taken in the usual manner or by radiation and the distant objects by intersection.

(7) Shift the table and set it up at *b*, with *b* over B and orient it.

(8) With the alidade touching *b* sight C and draw a ray.

(9) Measure the line BC and cut off *bc* to scale.

(10) Locate the surrounding detail as before.

(11) Proceed similarly at other stations, in each case orienting by a back sight before taking the forward sight until and the remaining stations are plotted.

Thus, after the completion of the plane table survey, surface area of the lake is determined using digital planimeter and graphic method.

There are several techniques to locate the position of the survey points. Many manual techniques have been used in the past to determine the boat position. The simple technique which is useful on small reservoirs is the tag line method. For larger reservoirs, the boat is often located by triangulation methods using transits on shore.

In the present study, range-line method has been used to conduct the bathymetric survey of the Mansar lake. This study was conducted during the months of November and December 1998. During the present survey, thirty points were identified on the map along the lake boundary. These locations were used to position the 15 cross sections along which survey has been carried out (Fig. 4). These 15 cross sections were selected such that they cover the entire lake for bathymetric survey. Cross section interval is approximately 50 m to 100 m. Near the banks, the cross sections are at about 50 m apart and in the middle part

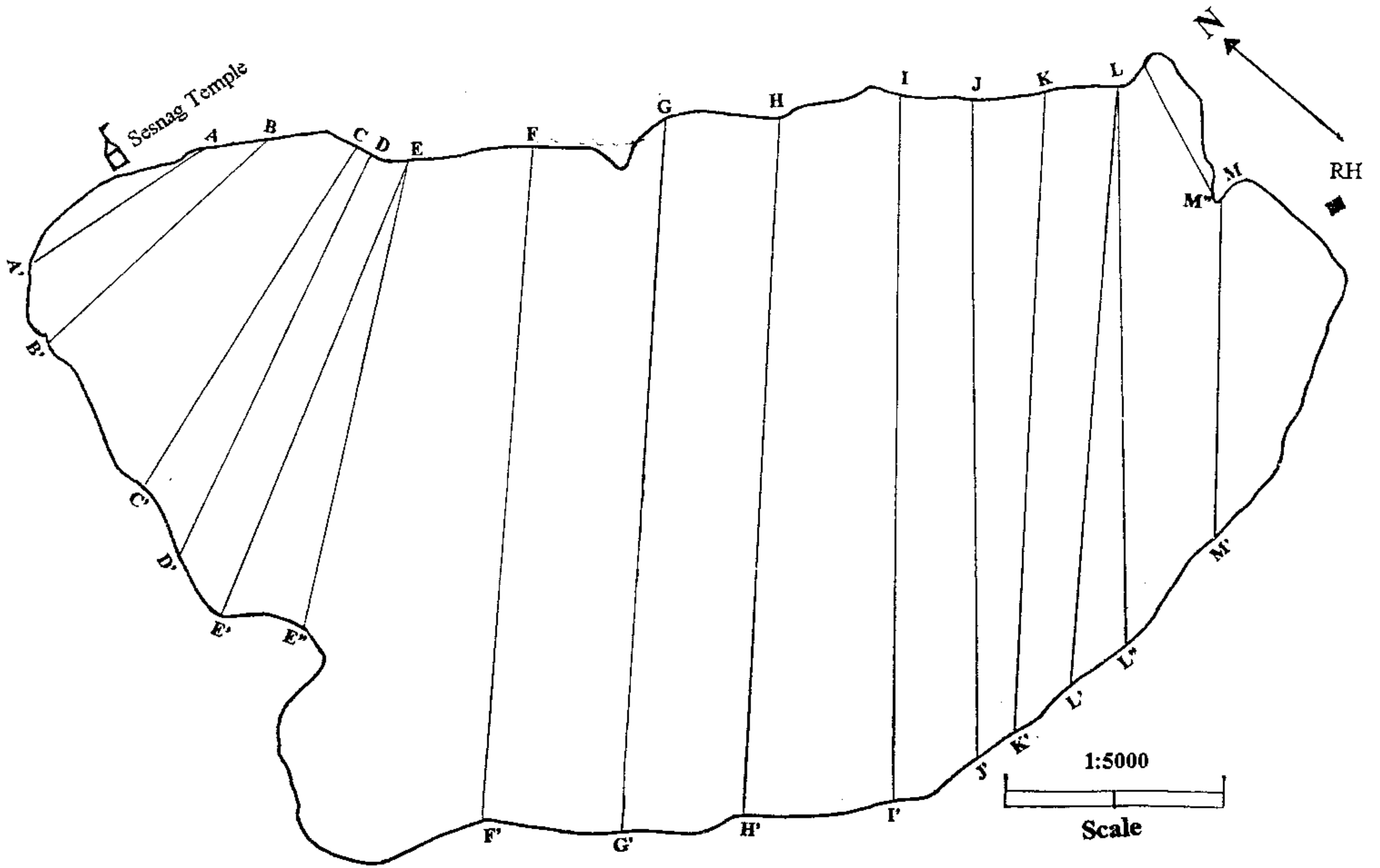


Figure 4: Lake surface area map with the cross sections along which bathymetric survey has been conducted

of the lake, spacing is approximately 100 m. Survey has been conducted along thefifteen cross sections at 620 points. For positioning the range-line and boat, a nylon rope of ISI mark was used to define the cross section lines (Fig. 5). Empty sealed drums/containers were tied to the rope at every 100 m interval to keep the rope above the water level. Marking on the rope at every 12.5 m interval was made using different colour ribbons.

4.2 Depth Measurement

The simplest way of measuring the water depth is to use a sounding weight or a pole to obtain it directly. The other method is use of sonic sounding equipments. Sounding weight can be fabricated of iron plate or angles. To determine the sedimentation rate on the basis of bathymetric survey, the shape and weight of sounding weight should be in record for future survey. Sonic sounding equipment for measurement of depth is preferred on most reservoir and lakes. The scientific depth sounding equipment currently available can be used to provide a continuous record or chart of the bottom profile. The basic components are a recorder, a transmitting and receiving transducer and a power supply. By careful calibration, a high degree of bottom profile accuracy can be maintained. Sonic sounding equipment can be relatively inaccurate in situations where the bottom slope is extremely large (Vanoni, 1977). An ordinary sonic sounder operates with a signal frequency of 60 Khz which is quite acceptable for the detection of the water bottom interface, when the bottom is composed of sand or gravel. For a very soft muddy bottom however, it might indicate the interface is 10-15 cm deeper than the true value (Jobson and Payne, 1985). Sonic devices with about 120 KHz frequency can solve this problem and give some information about the underlying strata, however the interpretation of the results is often difficult due to the poor degree of resolution. Through skilled interpretation, these records may provide useful information related to particle size, degree of compaction, rate of deposition and other desirable characteristics of the bed.

To measure the depth of Mansar lake, a sounding weight of mild steel angles, approximately of 10 kg weight, was fabricated (Fig. 6a). The sounding weight was tied with a rope on which a measuring tape of 60 m length was pasted with the help of adhesive tape. An ultrasonic ecosounder (Silva 30, measuring range 0.6-150 m, accuracy +/- 0.1 m upto

Figure 5 a: Aview of bathymetric survey of Mansar lake

Figure 5 b: A view of rope tightening for bathymetric survey

Figure 6 a: A view of manual sounder

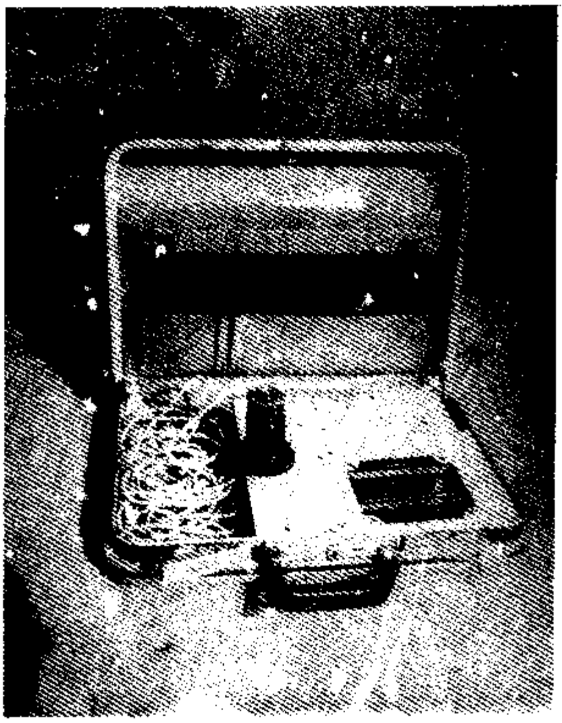


Figure 6b: A ultrasonic depth ecosounder used for bathymetric survey

20 m & +/- 1.0 m upto 150 m) was also used for the depth measurement (Fig. 6b). The principle of echo sounder is simple. An acoustic signal is sent from the transducer and is received back as an echo from the bottom. The time is measured and depth is calculated. Using the data of different cross sections a contour map of 5 m interval for the Mansar lake has been prepared (Fig. 7).

Sounding weight and ultra sonic depth ecosounder were used simultaneously to measure the depth of the lake. The datum base level of soundings is the present overflow outlet costructed near Sesnag temple. The results of ultrasonic depth ecosounder and sounding weight are more close in the zones lake having more than 5 m depth. Above 5 m depth, ultrasonic depth ecosounder showing 0.5 to 1.0 m less depth than that of sounding weight while in the area of shallow zones where depth is less than 5 m, ecosounder results are 0.5 to 1.5 m higher than that of sounding weight. Both the techniques are suitable for measurement of lake depth. For morphometric analysis of lake, depth measurements as measured by manual sounder are used.

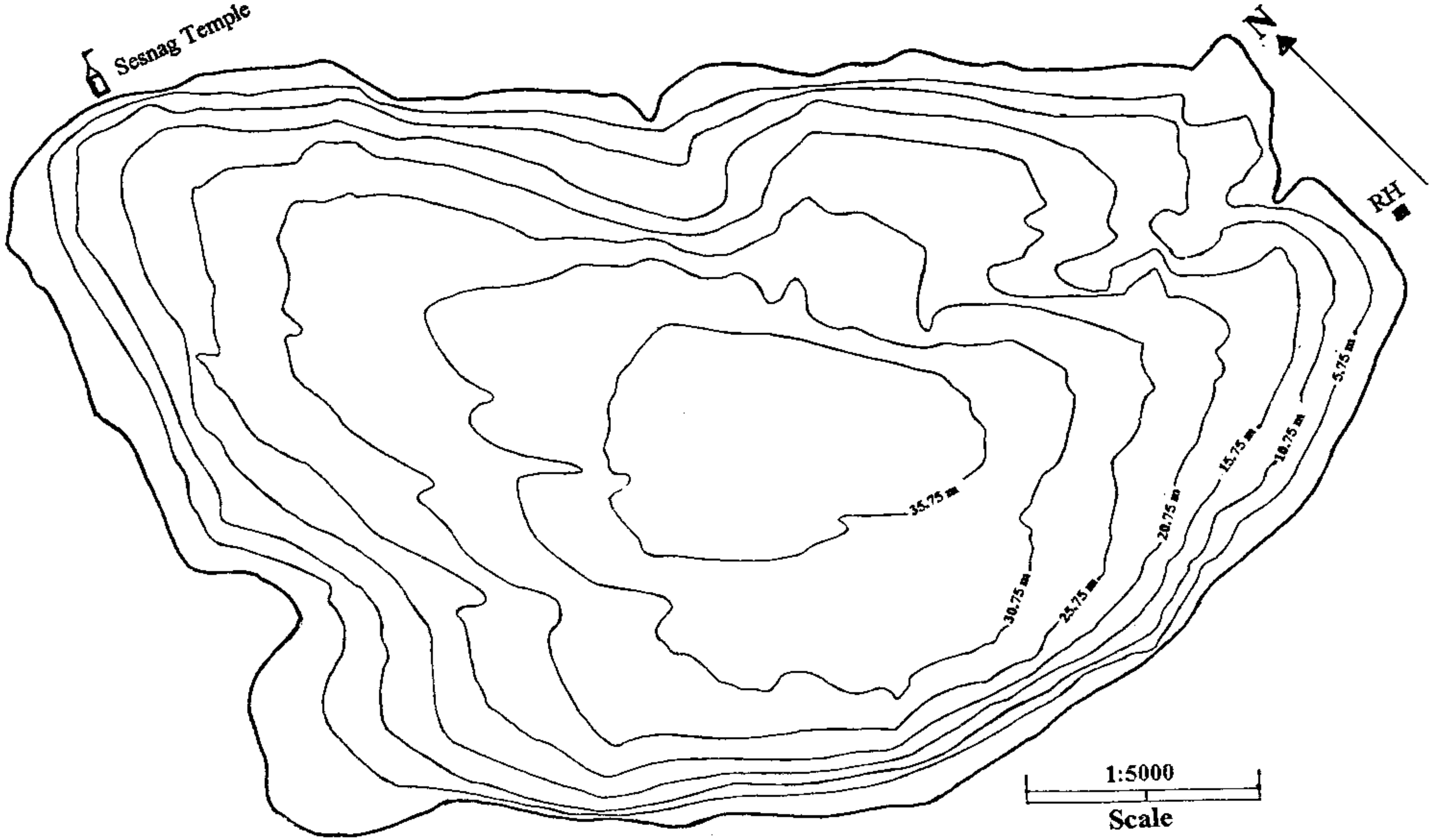


Figure 7: Bathymetric map of Mansar lake as on Nov/Dec 1998.

5.0 RESULTS AND DISCUSSION

The detailed results obtained by bathymetric survey of the Mansar lake are discussed below.

5.1 Bathymetry and Topography

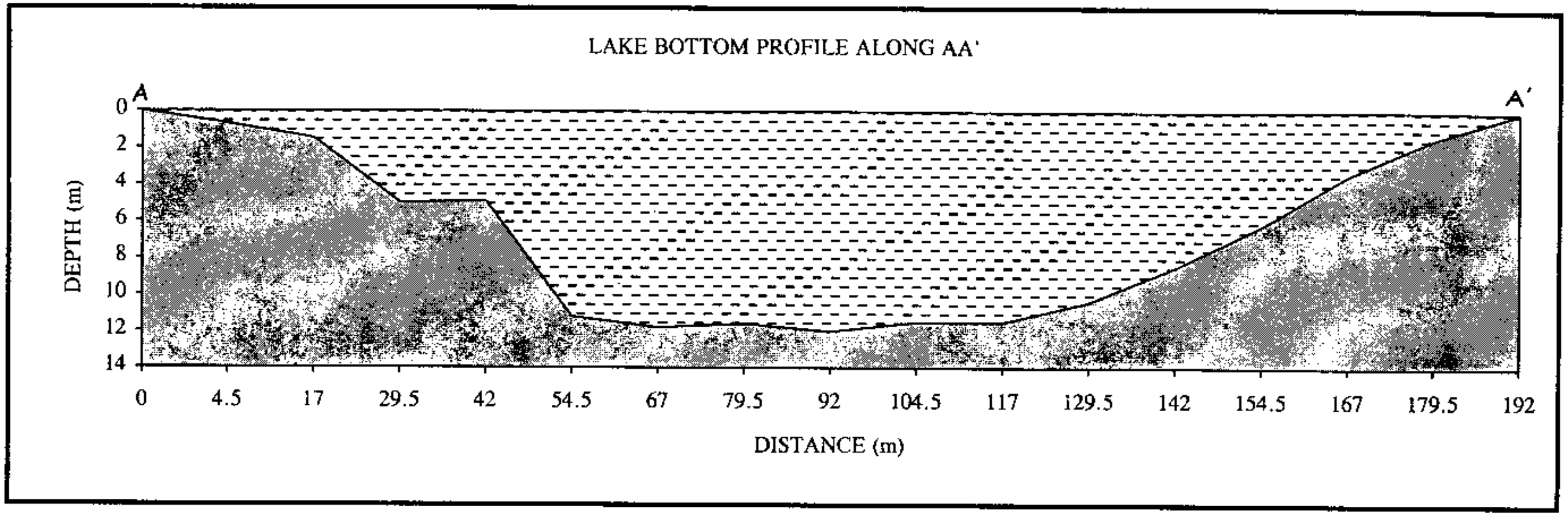
Bathymetric mapping of the lake floor has resulted in gaining a detailed topographic data-base of crucial importance, both for future comparison and computation of lake volume. Since sounding data are very closely spaced, a bathymetric map of 5 m interval has been prepared (Fig. 7). The survey shows that E-W oriented suboval- shaped lake is steeper on the bank and flatter in the middle zone. Keeping in view the topography, the lake floor may be described under three parts or segments i.e., (i) North Western or Sesnag Temple Zone, (ii) Central Zone (iii) Eastern or Tourism Guest House Zone

5.1.1 North Western or Sesnag Temple Zone

The lake floor is characterised by steep slopes in northern - zone (Fig. 8, 9 and 10) and gentle slope on the southern part. The isobaths run parallel to the shore and trend commonly north-south in right of temple and east-west in the front of the temple. The convergence of bathymetric contours towards the northern bank in front of BDO office establishes the steepness of the slopes near bank upto 20 m depth. Cross sectional profiles show the presence of U shaped valley with steep slopes in northern part and gentle slopes in southern part (Fig. 8,9 and 10). Gentle slopes in southern part reveal that the lake is receiving sediments at higher rate in this part. The presence of dense floating plants are also supporting evidence.

5.1.2 Central Zone

It is the widest zone (638 m) of the lake with the maximum depth of 38.25 m. The convergence of bathymetric contours causes steep slope in the southern bank between wildlife guest house and bathing ghat in the southern part of the lake. It is 514 m long and extends



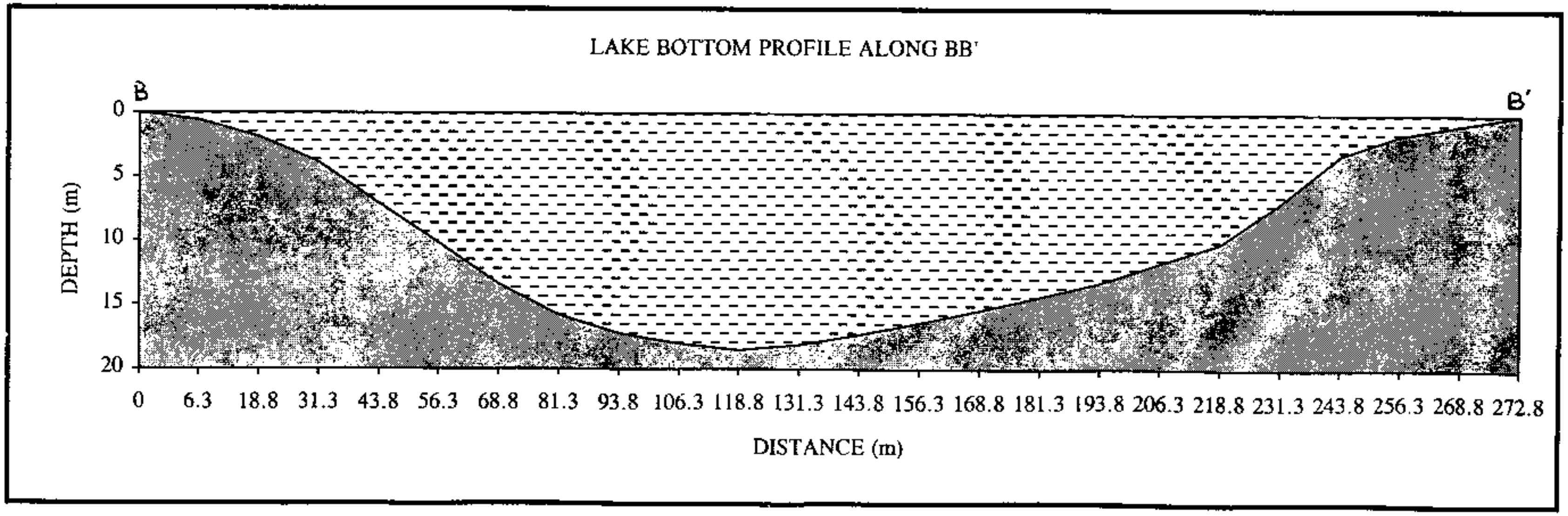


Figure 8: Cross section profile along AA' and BB'.

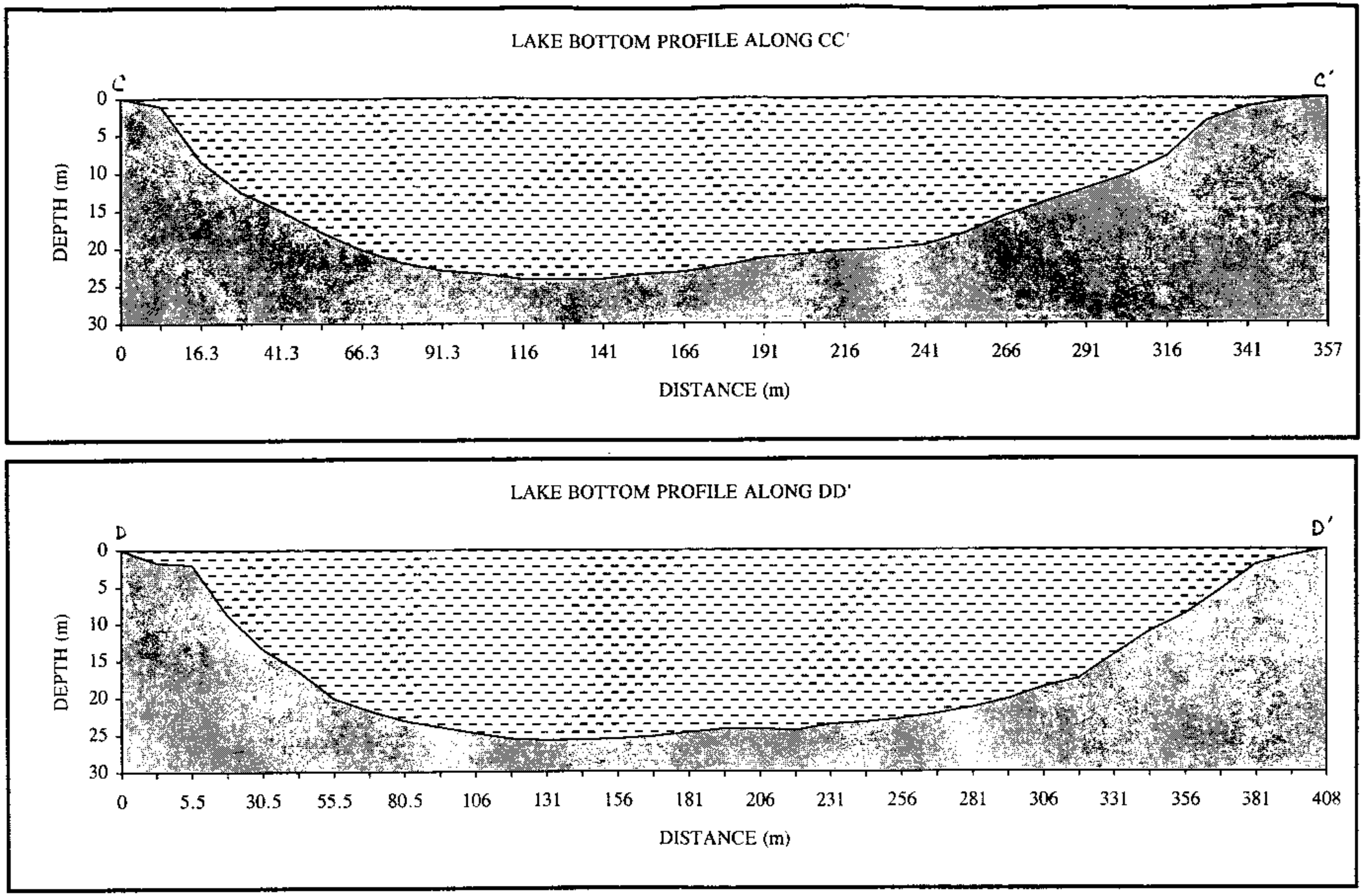
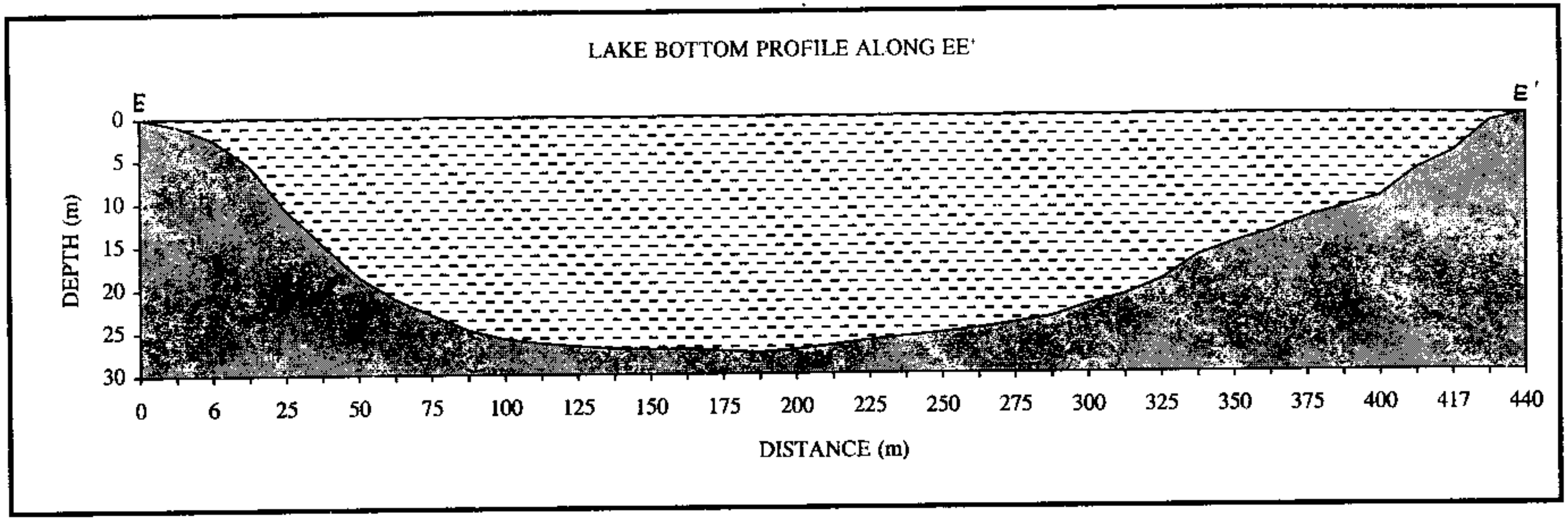


Figure 9: Cross section profile along CC' and DD'.



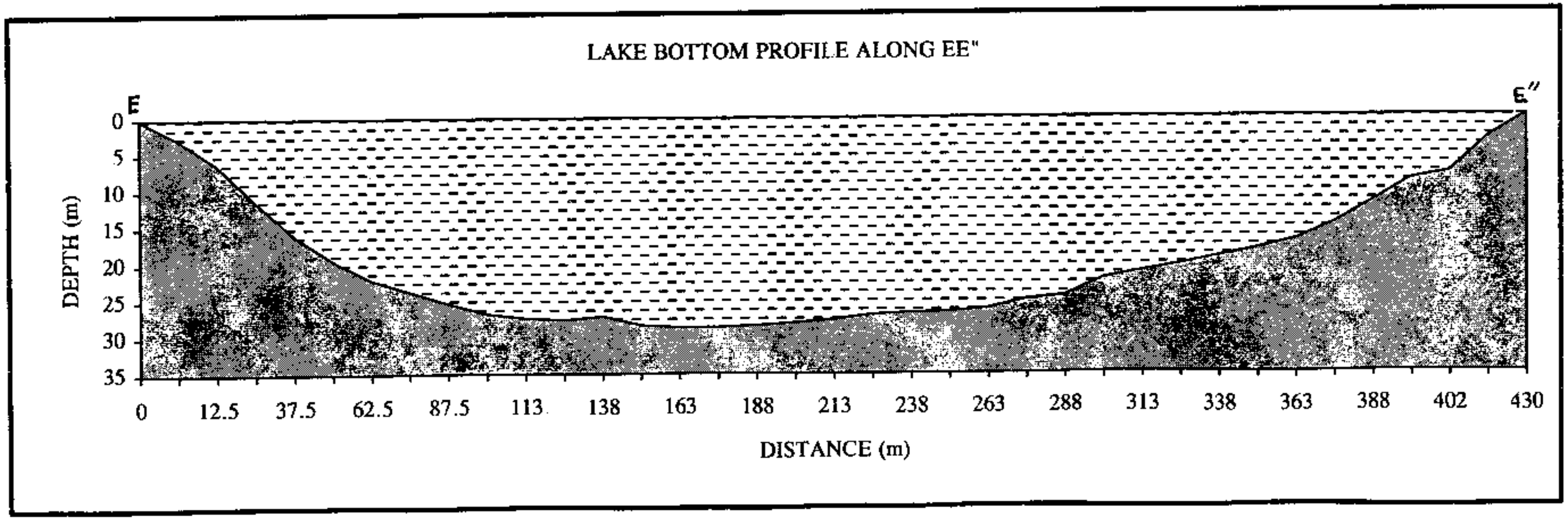


Figure 10: Cross section profile along EE' and EE".

upto 20 m depth. Ridge extends up to the central zone of the lake. Another ridge is identified in the front of the boat house. FF' cross section reveals that northern bank of lake is steeper than that of the southern part (Fig. 11) while GG', HH', II', JJ' section show U shape structure with steep southern side and flat bottom (Fig. 11, 12 and 13).

5.1.3 Eastern or Tourism Guest House Zone

This segment of lake floor is wider than that in the Sesnag Temple side. The contour run parallel to the shore line trending in ENE to WSW direction (Fig 7). There is underwater ridge measuring about 326 m in length and, on an average 35 m wide and rising from depth of 25 m to 5 m (Fig. 7). The ESE-WNW oriented ridge gradually merge with the adjoining lake floor. The southern flank of the ridge is a steeply sloping terrace while the northern flank is gently sloping. Cross sectional profiles are showing that the lake is divided in two sub-basin (Fig.13 and 14). The southern bank' slopes are steeper than that of the northern side. Figure 15 reveals that slope is less on the bank.

5.2 Morphometric Characteristics

Lake surface area surveyed (scale, 1:2000) using the plane table, measured by a digital planimeter, comes out to be 0.59 km^2. As measured from survey of India toposheet No. 43 P/2, (surveyed in 1961, Scale 1:50,000), it is 0.58 km^2 and the lake basin area is 1.67 km^2. In the present survey, lake surface area is slightly higher than that of the Survey of India Toposheet. The reason behind it is that tourism development authority has build up the retaining wall at the outlet of the lake so the lake surface has been slightly increased. The maximum depth is 38.25 meter. The maximum length and width of the lake is 1204 metres and 645 metres, respectively. The lake mean width is 490 metres and mean depth is 20.97 m. Circumference of the lake is 3.4 km. The ratio of mean depth and maximum depth is 0.55. This higher ratio reveals that the lake basin is U shaped with steep sided and flat bottom.

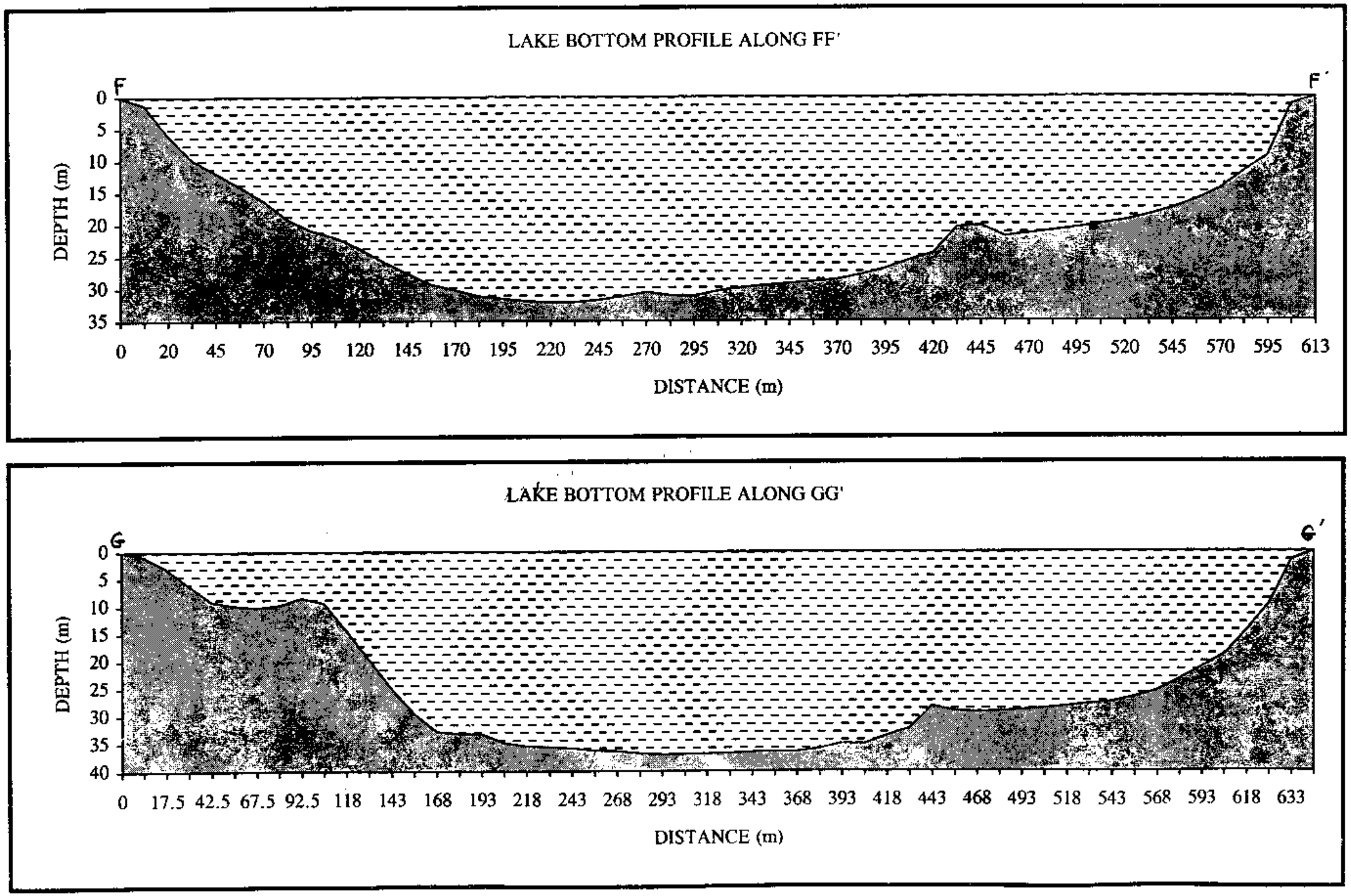


Figure 11: Cross section profile along FF' and GG'.

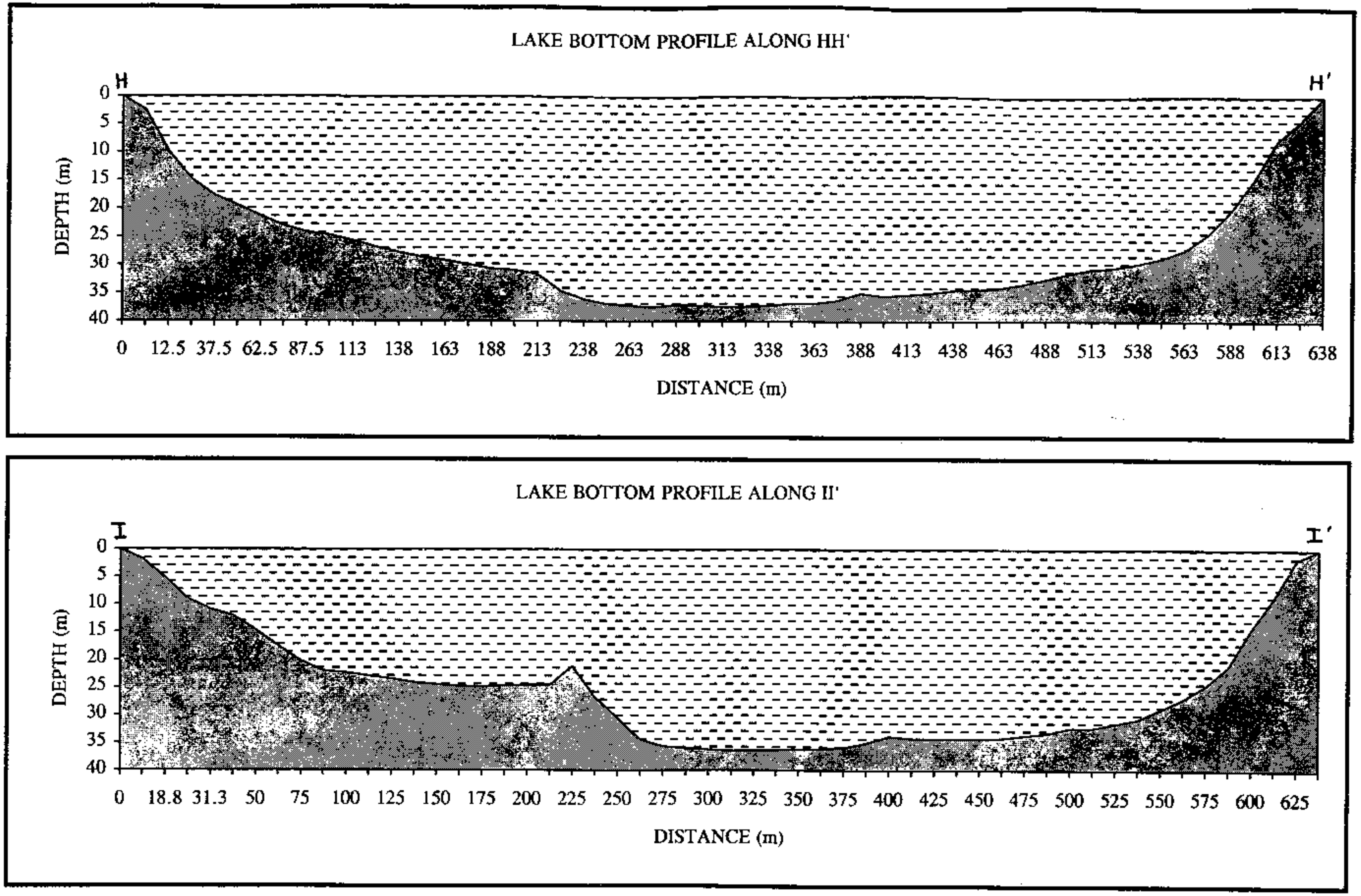
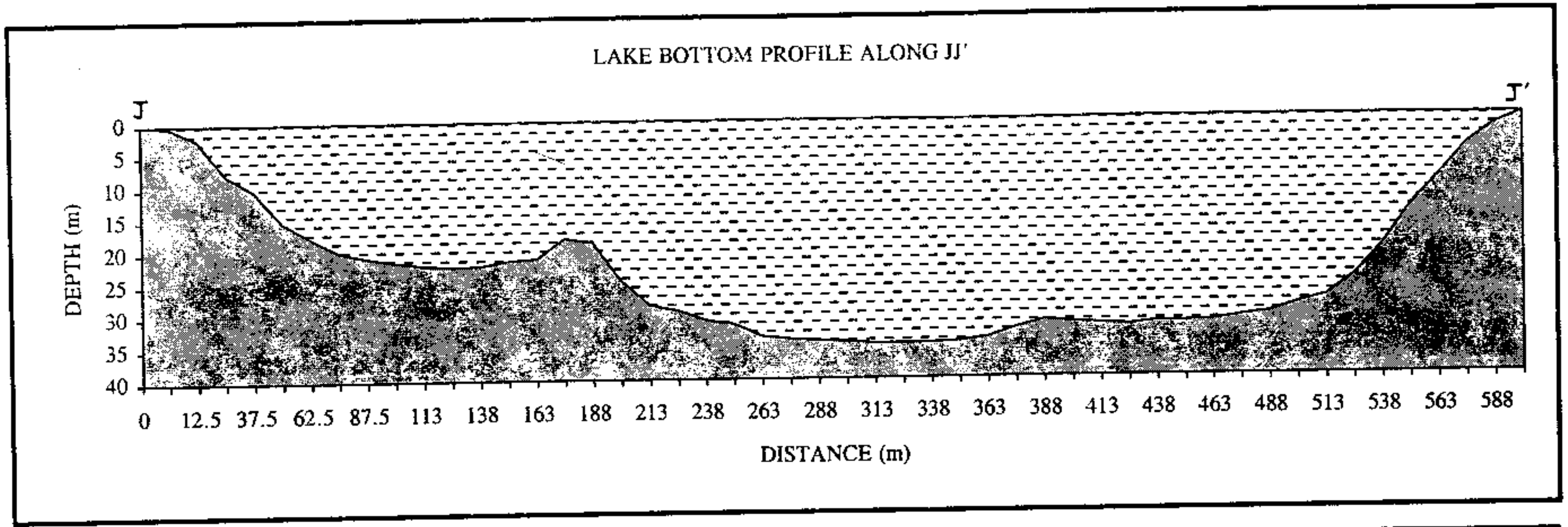


Figure 12: Cross section profile along HH' and II'.



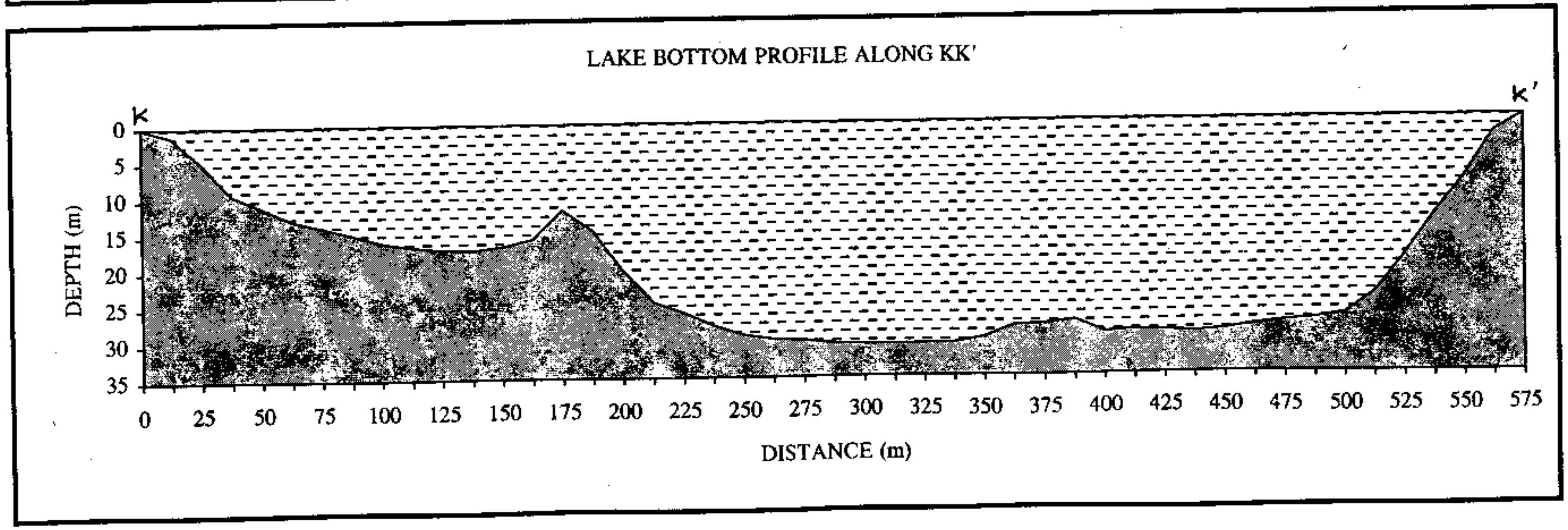


Figure 13: Cross section profile along JJ' and KK'.

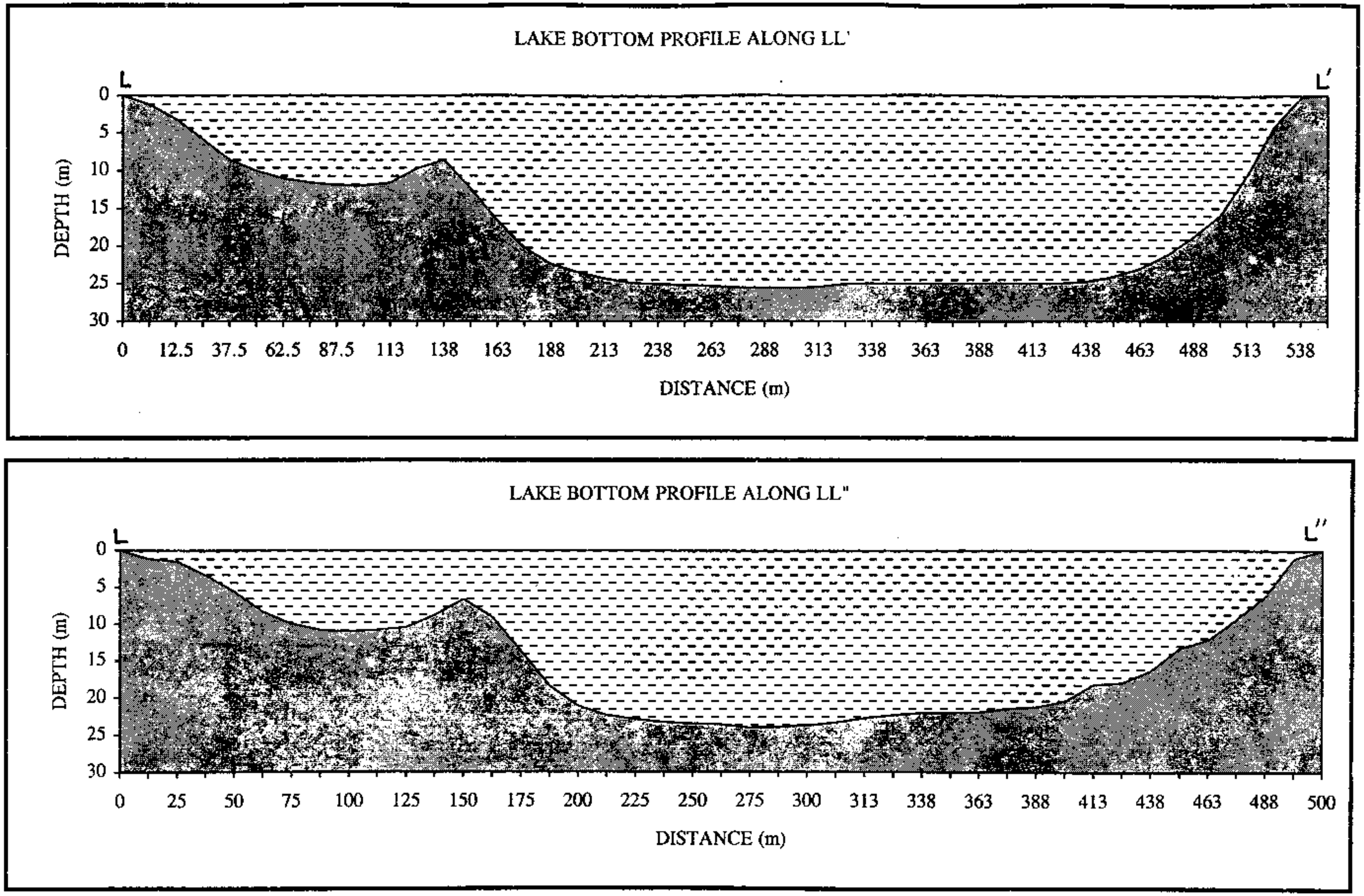


Figure 14: Cross section profile along LL' and LL".

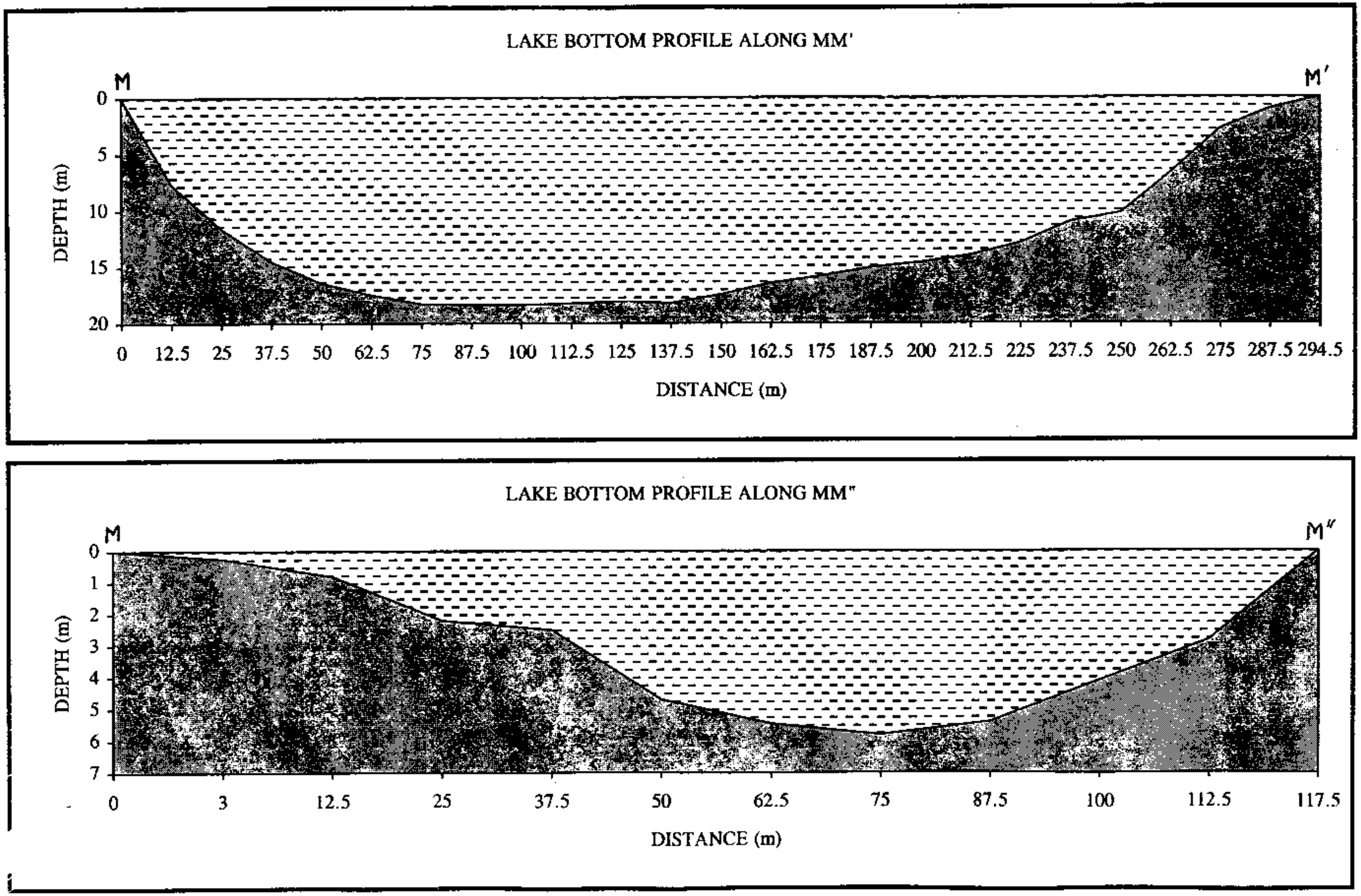


Figure 15: Cross section profile along MM' and MM".

Development of the volume is also calculated. It is a comparison of the volume of the lake to that of a cone, with a basal area equal to the lake's surface area and a height equal to the lake's maximum depth (Zumberge and Ayers, 1964). The ratio approaches unity when the lake basin approaches conicity. It is less than unity when the basin's sides are essentially convex towards the water and more than unity in lakes whose basin walls are essentially concave towards water. In the case of Mansar lake, Development of the volume is 1.64, indicating that basin walls are essentially concave towards the water.

5.3 Lake Slope

Slope of the lake basin shows pattern of lake sharpness in the bank and flatness of the lake bottom. It also reveals the pattern of sediment accumulation in different zone. Another important aspect of the study is the identification of origin of the lake. Slope of the lake basin between the adjacent depth contours and mean slope of the entire lake can be computed by using the following formula (Zumberge and Ayers, 1964)

$$S = \frac{1}{2}(C_1 + C_2)\frac{I}{A_B}$$

Where C_1 and C_2 are the lengths of the contours, I is contour interval, and A_B is area of the bottom included between the two contours. The mean slope of the basin can be defined by

$$S = \frac{(\frac{1}{2}C_0 + C_1 + C_2 + \ldots + C_n - 1 + 1/2Cn)\, d_m}{nA_o}$$

Where C_0, C_1 etc., are lengths of the contours, n is the number of contours, d_m is the maximum depth, and A_o is the surface area of the lake.

Slope of the lake between 0.0 - 5.75 m depth is 0.21 m/m, covers 12.7% area of the total lake. It is maximum (0.30 m/m) between 5.75 - 10.75 m depth contour interval and minimum (0.04 m/m) between 35.75 to 38.25 m depth. The mean slope of the lake basin is

0.14 m/m. About 17% of the area of the total lake is with 0.08 m/m slope between 25.75 - 30.75 m depth interval.

5.4 Lake Volume

Volume of the lake may be determined by plotting the depth area map and the area under the curve obtained may be planimetered or otherwise measured. In another method, the area enclosed by successive pairs of depth contours are averaged and multiplied by the contour interval to yield a series of volume elements which are summed (Zumberge and Ayers, 1964).

$$V_{A1A2} \quad \frac{h}{3}(A_1 + A_2 + \sqrt{A_1 A_2})$$

V_{A1A2} is volume between two adjacent depth contours, h distance apart, A_1 is the area enclosed by the upper and A_2 is area enclosed by the lower. Summation of the results of repeated successive use of the above equation will yield lake volume.

The area enclosed by the successive isobaths has been determined using the digital planimeter (Fig 16a). The maximum area of the 0 depth contour is 59409 m^2 and the minimum area of the 38.25 m depth contour is 47939 m^2 (Fig. 16 a and b). Maximum capacity of lake is 12.37 Mm^3 of which maximum 25.85% is between 0-5.75 m depth, 19.76% lying between 5.75-10.75 m and 17.41% between 10.75-15.75 m depth. Thus, 63 % of the total lake volume is up to 15.75 m depth and remaining 37% below the 15 m (Fig. 17 a and b).

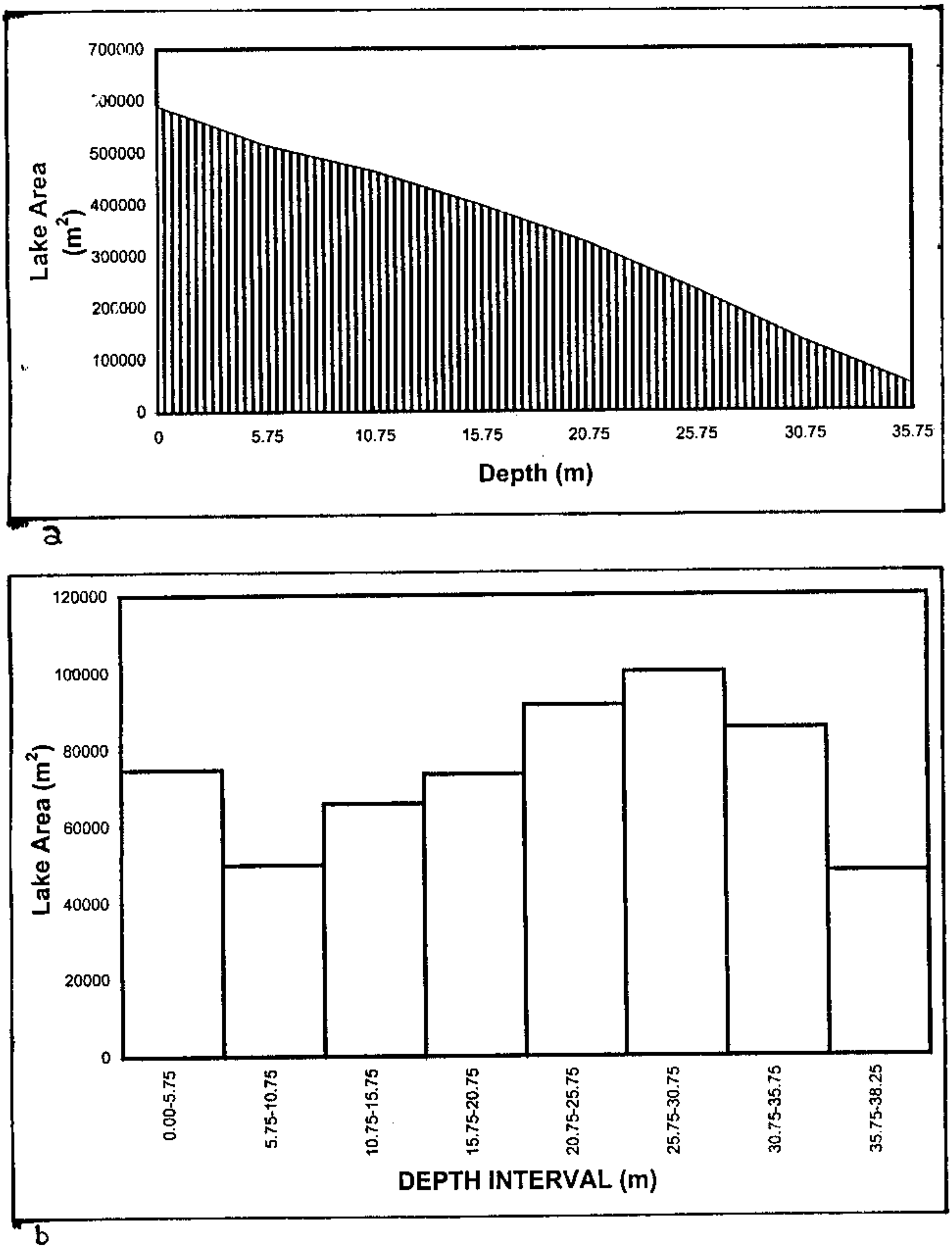
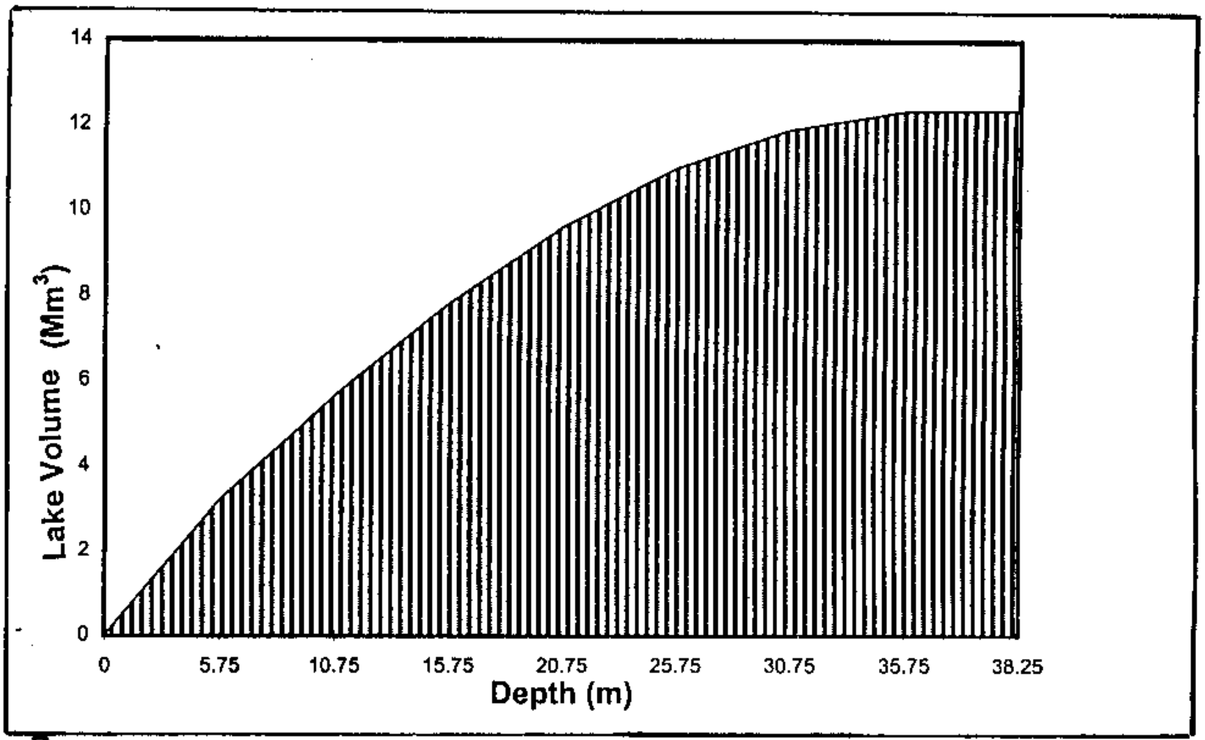
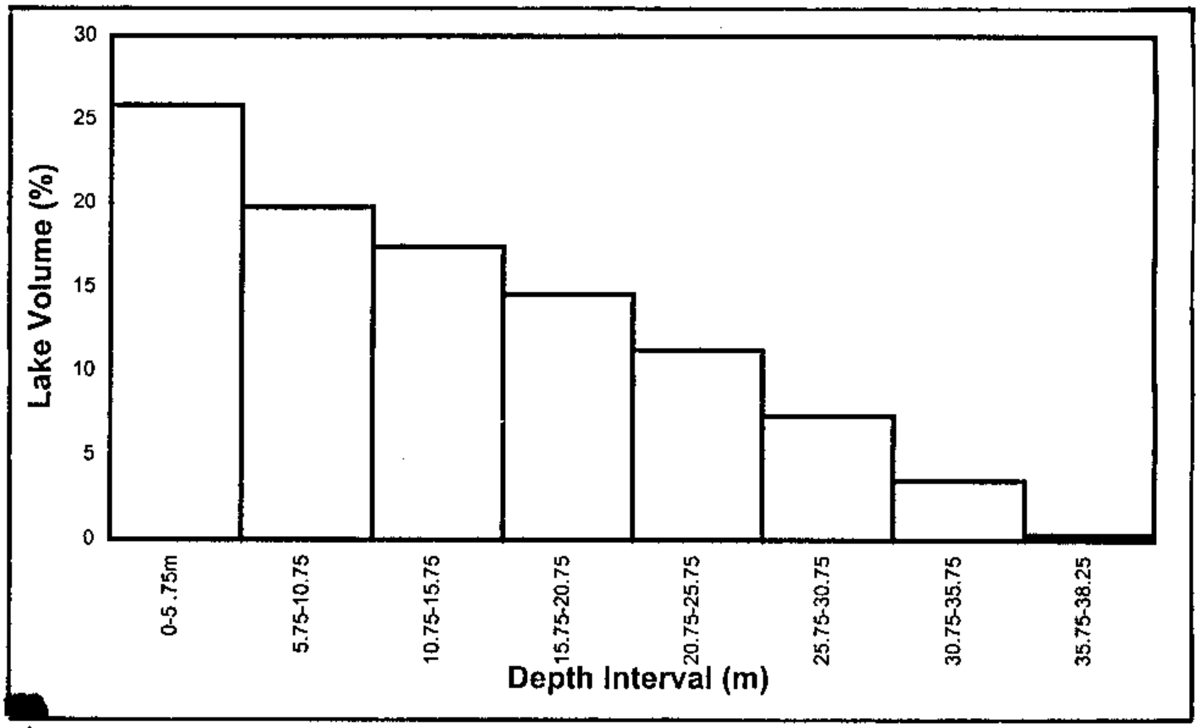


Figure 16 a: Variation of lake area with depth
b: Area of lake between different depth interval.



a



b

Figure 17 a: Variation of lake volume with depth
b: Lake volume under different depth interval.

6.0 CONCLUSIONS

The bathymetric survey of the Mansar lake has been carried out along the 15 cross sections. Lake surface area of the Mansar lake is 0.59 km^2 measured using plane table method. Maximum length and width of lake are 1205 m and 645 m, respectively. Maximum depth and mean depth of the lake are 38.25 m and 20.97 m, respectively. The mean slope of the lake floor is 0.14 m/m with the maximum 0.30 m/m and minimum 0.04 m/m.

Total volume of the lake water is 12.37 Mm^3. It was found that the lake is having large amount of fresh water which is mainly fed by ground water because there is no major surface channel flowing into the lake. Contour map shows that lake receives comparatively higher rate of sediment at some locations (e.g.,near boat stand, rest house).

On the basis of the present study, it is recommended that a detailed hydrological study should be carried out to study the water balance, identification of recharge zone, leakage zone, and sedimentation rate of the lake. Hydrodynamics and water quality study are also essential to understand the movement of pollutants into the lake. On the basis of these studies, a strategy may be developed for the environmental management and development of the lake.

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