HYDROLOGICAL INVESTIGATIONS FOR CONSERVATION OF LAKES: A CASE STUDY OF LAKE MANSAR, J & K

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HYDROLOGICAL INVESTIGATIONS FOR CONSERVATION OF LAKES: A CASE STUDY OF LAKE MANSAR, JAMMU AND KASHMIR

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INTRODUCTION

A case study of Mansar lake was carried out during the year the 1998-2000. The Mansar lake (longitude 75° 5' 11.5" to 75° 5' 12.5" E and latitude 32° 40' 58.25" to 32° 40' 59.25" N) is located 60 km east of Jammu at an elevation of 666 m a.m.s.l. in the Siwalik terrain (Fig. 1). It attracts religious pilgrim and tourists and is being used as a source of water for drinking and irrigation by the people living in the Mansar and surrounding villages.

The increasing anthropogenic activities in recent years have greatly affected the hydrological regime of the lakes in the Lesser Himalayan. For example, the inflow of eroded material and other contaminant from the lake catchment have accelerated eutrophication process in the Dal and Wular lakes in Kashmir (Ishaq & Kaul, 1988) and the higher rate of sedimentation has diminished the useful life of the Khajjiar lake in Himachal Pradesh and Sanasar lake in Jammu. The Dal lake is reduced to 20×10^6 m^2 from the beginning of nineteenth century (Handa et al., 1991). While, physico-chemical and biological characteristics of lakes in Western and Central Himalayan regions (Zutshi et al., 1972; Zutshi and Khan. 1977; Kaul, 1977; Zutshi, 1985; Pant et al., 1985, Trisal, 1987; Rai et al., 1998; Gopal and Zutshi, 1998; Kumar et al., 1999) have been studied in detail, little is known of the bathymetry, sedimentary and physico-chemical characteristics of the Mansar lake in Jammu region. In this case study the bathymetry, determine sedimentation rate and physcio-chemical characteristics of the Mansar lake have been presented.

The average annual rainfall is 1500 mm, the air temperature varies between 3 °C (minimum) in winter to 43 °C (maximum) during peak summer while lake water temperature at surface varies between 14 °C (minimum) in January to 31 °C (maximum) in July. Lake water level varies between 1 m to 1.5 m in a year. There is no perennial stream flowing into the lake from the 1.67×10^6 m^2 lake catchment (Fig. 2). The lake is thus fed by rainwater entering as overland flow and through two ephemeral streams. The Mansar Wali Khad, a tributary of the Tawi River drains out this lake.
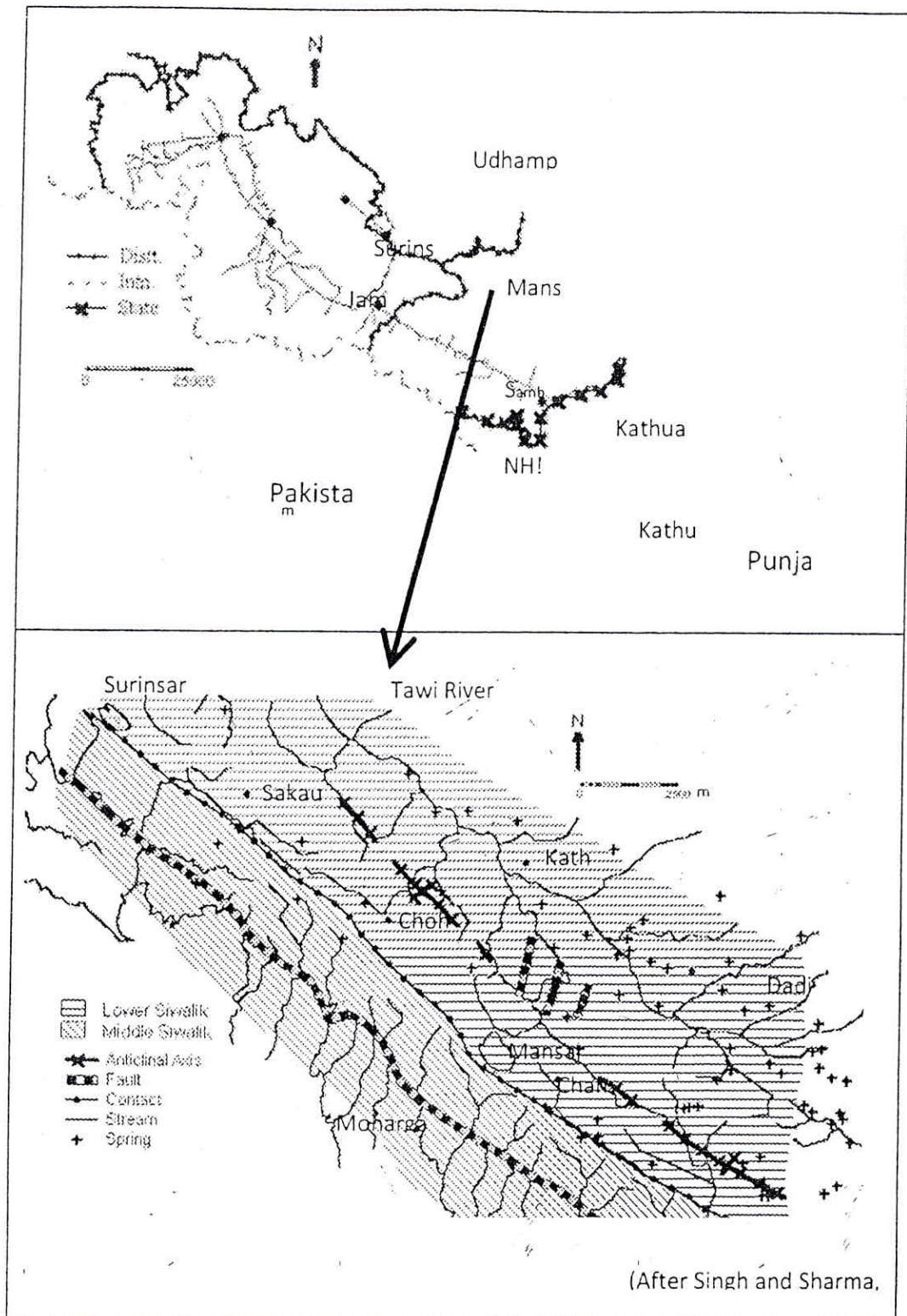
Fig. 1. Location of Mansar Lake in the Jammu and Kashmir,
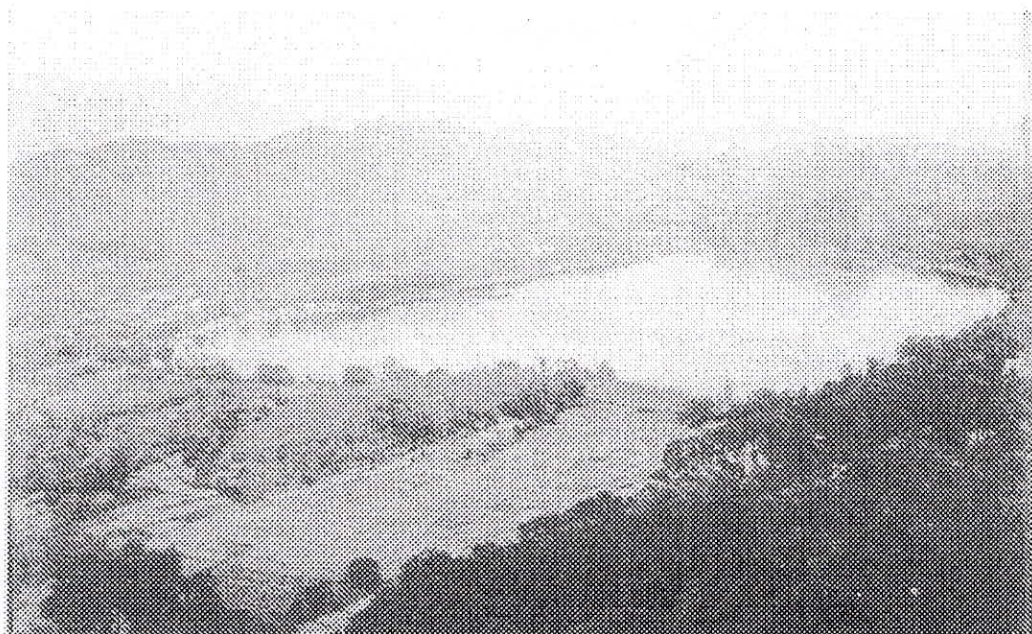showing hydrogeological set up of the area

Fig. 2. View of Mansar lake and its catchment area

The Mansar lake catchment is composed of fine-grained sandstone alternating with silt stone, mudstone and clay of the Lower Siwalik (Fig 1). Both the Mansar and Surinsar (a near by lake) lakes are located at the crestal part of the WNW-NW to ESE to SE trending sub-horizontal anticlinorium. Associated with upright fold plunging 5° towards S52°E, the NNE-SSW trending faults have displaced the anticlinorial axes at several places (Singh & Sharma, 1999) and are responsible for the crushed nature of the Lower Siwalik. These crushed rocks form the porous and permeable zone for recharge of the lakes.

METHODOLOGY

Bathymetric Survey

Range-line method survey was conducted along 15 cross section at 620 points using a sounding weight of mild steel. For positioning the range-line and boat, a scaled nylon rope was used to define the cross sections and depth points. Lake surface area and locations of 15 cross sections were mapped (scale 1:2000) using plane table survey. For the bathymetric survey, top of present outlet constructed near Sesnag temple is the datum base level of soundings. Bathymetric map was prepared using GIS-ILWIS software (ITC, 1997) and formulae of Zumberge & Ayers (1964) are applied to compute lake volume and slope.

Dating Techniques

Sedimentation rate of the Mansar Lake was estimated in Nuclear Hydrology Laboratory of the Institute using ^{137}Cs and ^{210}Pb dating techniques. For this purpose sediment cores 18 to 60 cm in length were collected from different parts of the lake with a gravity corer. Five cores, viz. A, B, C, D and E (Fig 3) were considered to be representative of lake's sedimentary

environment. The cores were sliced into 2cm sections and analysed for ^{210}Pb and ^{137}Cs activities.

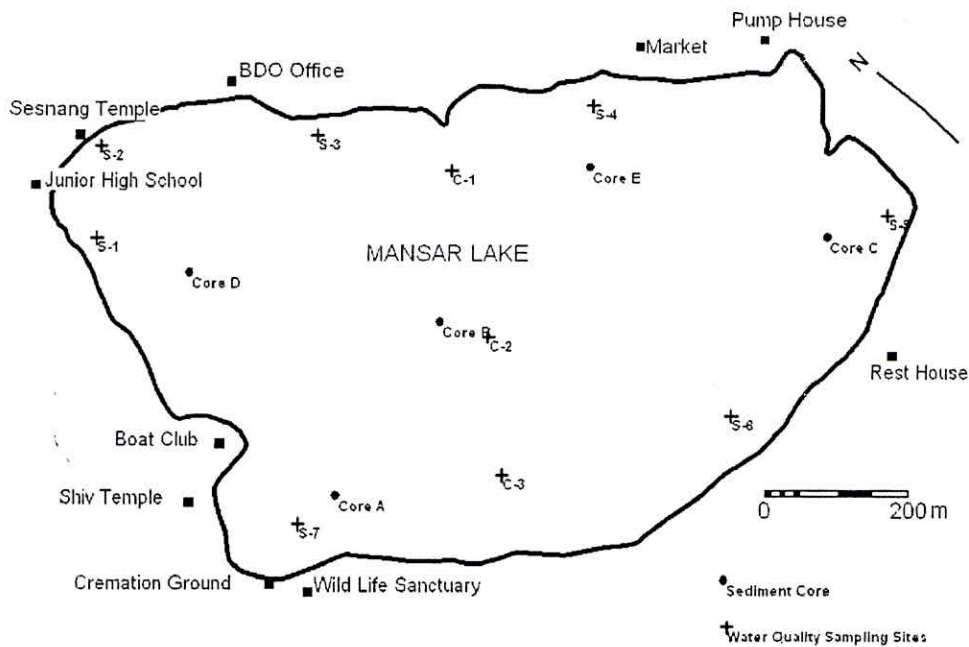Fig. 3: Sites of water samples and sediment cores collected from the lake

The ^{137}Cs activity in each section was determined by gamma counting of the oven-dried samples using HyperPure Germanium detector coupled with a 4096 channel multi-channel analyser system. A ^{137}Cs standard (IAEA-300), having essentially the same geometry and density was used. About 10 g or less (if the weight of sediment core was less than 10 g) weight of the sliced cores were counted for about 7200 to 28800 sec to obtain good statistical accuracy. The detection limit for ^{137}Cs by this method is 0.25 mBq/g and the standard counting error was less than 10% in the core sections.

The basic radiochemical procedure involves adding of ^{209}Po as a yield tracer, leaching the sediment samples with aqua regia, the residual solids were filtered off and the solution was dried and converted to chloride with concentrated HCl. The final solution was taken in 0.5 N HCl. Polonium (Po-210) nuclides were then spontaneously deposited on silver planchettes by adding ascorbic acid in the HCl solution prior to alpha counting using Si surface barrier detectors connected to a multi-channel analyser. However, due care was given to get ^{210}Po in secular equilibrium with ^{210}Pb. The standard counting error was generally less than 10% in the upper sections of the cores and slightly higher values at the deeper sections since the counting time was kept constant for the entire core sections. As the supported ^{210}Pb results from the decay of ^{226}Ra present in the sediment core with which it is in equilibrium, ^{226}Ra activity was determined directly by gamma counting. The ^{210}Pb activity was also measured in terms of beta radiation using ^{210}Bi which is its daughter product and has half life of ~5 days. The extracted solution containing ^{210}Pb was allowed to stay for a period of one month (4-5 half lives are sufficient) for getting ^{210}Bi in secular equilibrium with ^{210}Pb activity. The activity of ^{210}Bi was measured using an Ultra Low level Liquid Scintillation spectrometer.   In the present

study, constant rate of supply (CRS) model has been used for estimating rates of sedimentation.

Sampling and Water Quality Analysis

Monthly water samples from the lake were collected from the periphery (S1 to S7) and depth-wise from three locations (C1, C2, and C3) at 3m depth interval (surface to bottom) during August 1998 to July 1999 using Standard Water Sampler (Fig. 3). Temperature was measured using in-built thermometer of sampler while pH and electrical conductance was measured using the portable pH and conductivity meter at the sampling sites. The physico-chemical analysis of water samples was performed following standard methods (Eaton et al., 1995). The total hardness and calcium hardness was determined by EDTA titrimetric method. Sodium and potassium were determined by flame emission method using Flame Photometer. Chloride concentration was determined by argentometric method in the form of silver chloride. Acidity/alkalinity was determined by titrimetric method using phenolphthalein and methyl orange indicators. Phosphate, sulphate, nitrate concentrations were determined using UV-VIS Spectrometer. The charge balance (calculated by the formula: TZ^+-TZ^-/ TZ^++TZ^- *100) between cations and anions <10% confirms the reliability of analytical results.

RESULTS AND DISCUSSION

Bathymetry

The bathymetric map of 5m interval (Fig. 4a) shows that NW-SE oriented sub-oval shaped lake, is steeper on the bank and flatter in the middle zone. The gentle slopes between boat club and Samshan ghat ia attributed sediments accumulate rapidly. There is underwater ridge in eastern part of the lake, measuring about 326 m in length and, on an average 35 m wide and rising 25 m to 5 m from depth.

The lake surface area with the circumference of 3400 m at present outflow level is 0.59×10^6 m^2, the maximum depth 38.25 m, the maximum length 1204 m and maximum width 645 m. The mean width is 490 m and mean depth is 20.97 m. The mean slope of the lake basin is 0.14 m/m with maximum (0.29 m/m) between 10 to 15 m depth contour interval and minimum (0.04 m/m) between 35 to 38.25 m depth. Slope of the lake basin reveal steep banks and flat lake bottom.

The storage capacity of lake up to outlet is 11.57×10^6 m^3 of which maximum 23% is between 0 to 5 m depth, 20% lying between 5 to10 m and 17% between 10 to 15 m depth. Thus, 60% of the total lake volume is up to 15 m depth and remaining 40% lying below 15 m depth (Fig. 4b & 4c).
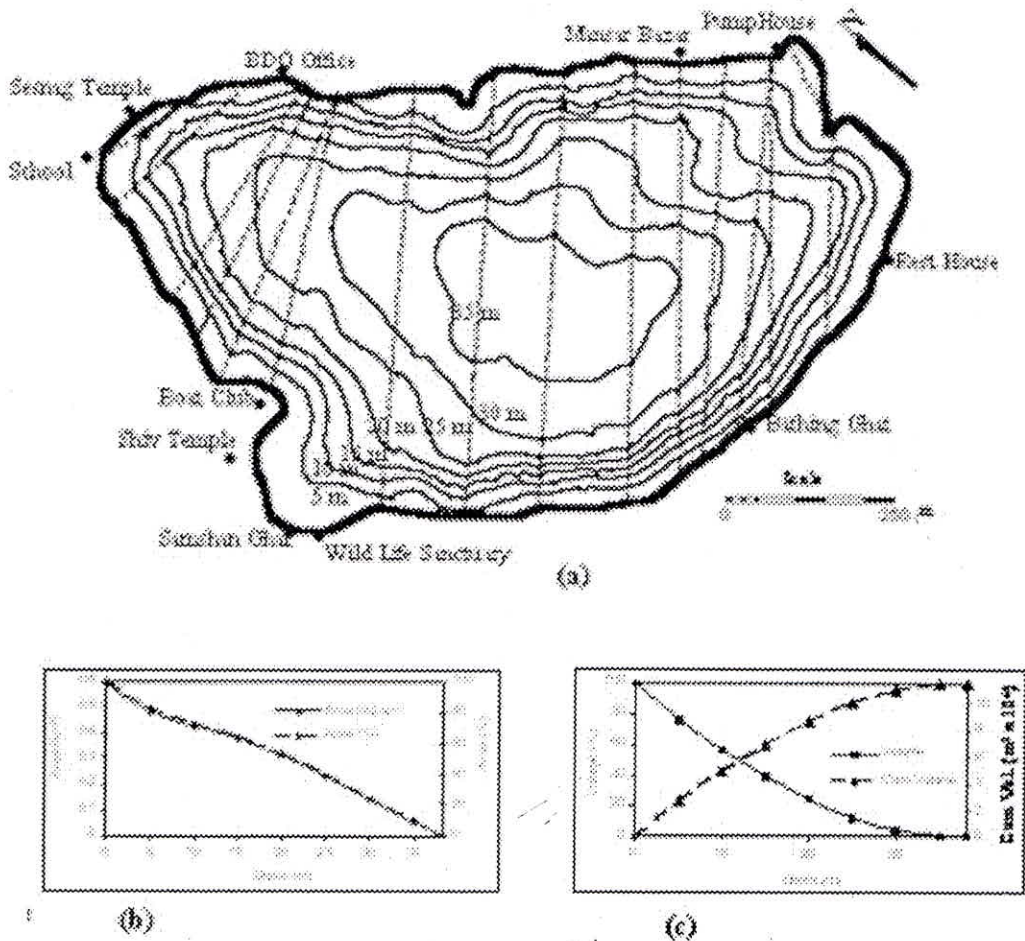
Fig. 4: (a) Bathymetric map of Mansar lake prepared from the present survey;
(b and c) hypsographs showing variation of lake area and volume with depth.

Sedimentation Rate

The profiles of ^{137}Cs activities in different sediment cores with respect to depth are shown in Fig. 5. At the sampling locations D and E, ^{137}Cs profile closely paralleled its weapon fallout record pattern reported by earlier investigators (McHenry et al., 1973; Livingston & Cambray, 1978) i.e., an initial appearance in 1952-53; a subsidiary peak in 1957-58 and a major peak in 1963-64. With the depth corresponding to 1963-64 as a time marker, the average sedimentation rates of Mansar lake has been computed. The close similarity in the deposition and fall-out pattern of ^{137}Cs probably indicates that the residence time of ^{137}Cs in the lake water is small and post-depositional mobility of the radionuclide in the sediment core, if any, is insignificant (Kumar et al., 1999). Due to short length of the core obtained, the initiation and subsidiary peaks of 1952-53 and 1957-58 are not clearly seen in core samples 'A' and 'B' respectively (Fig. 5).

[210]Pb dating technique was also used to determine sedimentation rate in order to cross-check of the results obtained using ^{137}Cs dating techniques at sites A, D and E. The results show that

sedimentation rate varies from 0.24 cm/y to 0.34 cm/y that are comparable with the rates estimated using ^{137}Cs dating technique (Table 1). The higher rate of sedimentation at site 'A' and 'E' is due to sediment load entering in this part of the lake directly from agriculture land.

Table 1. Sedimentation rate in Mansar lake

Sediment Core	Sedimentation Rate (cm/y)	
	^{137}Cs	^{210}Pb (using CRS model)
Core A	0.37 ± 0.029	0.34±0.033
Core E	0.37 ± 0.029	0.31±0.027
Core D	0.20 ± 0.029	0.24±0.015
Core C	0.20 ± 0.029	ND*
Core B	0.14 ± 0.029	ND*

ND*: not determined

Physico-chemical Characteristics

The depth versus temperature plots (Fig. 6a) of the Mansar lake depict that temperature decreases with depth from April to November. In these months the upper, relatively warm and wind mixed layer called epilimnion range upto 6 m depth and below epilimnion, temperature decreases rapidly between 6 to 10 m depth and this plane of maximum temperature change is called thermocline. The zone lying below 10m depth, relatively cold layer that is not mixed by wind comes under the hypolimnion. The stable stratification that persists from April to November tends to become unstable during early winter (i.e., December), because of falling air temperature resulting in decrease of water temperature of epilimnion and thermocline zone due to net heat loss from the lake. The development of uniform temperature conditions in January-February starts the process of convection, which coupled with the increased action of wind, results in the deepening of surface layer (sinking of thermocline) and complete mixing of lake takes place. This period of vertical mixing of mansar lake is "winter overturn" when lake may be considered well mixed. As consequence of rise in air temperature in March, thermal stratification starts and establishes in April and lake remains stratified till November. Therefore, Mansar Lake undergoes two distinct stages namely complete mixed stage and a stratified stage of minimal vertical mixing.
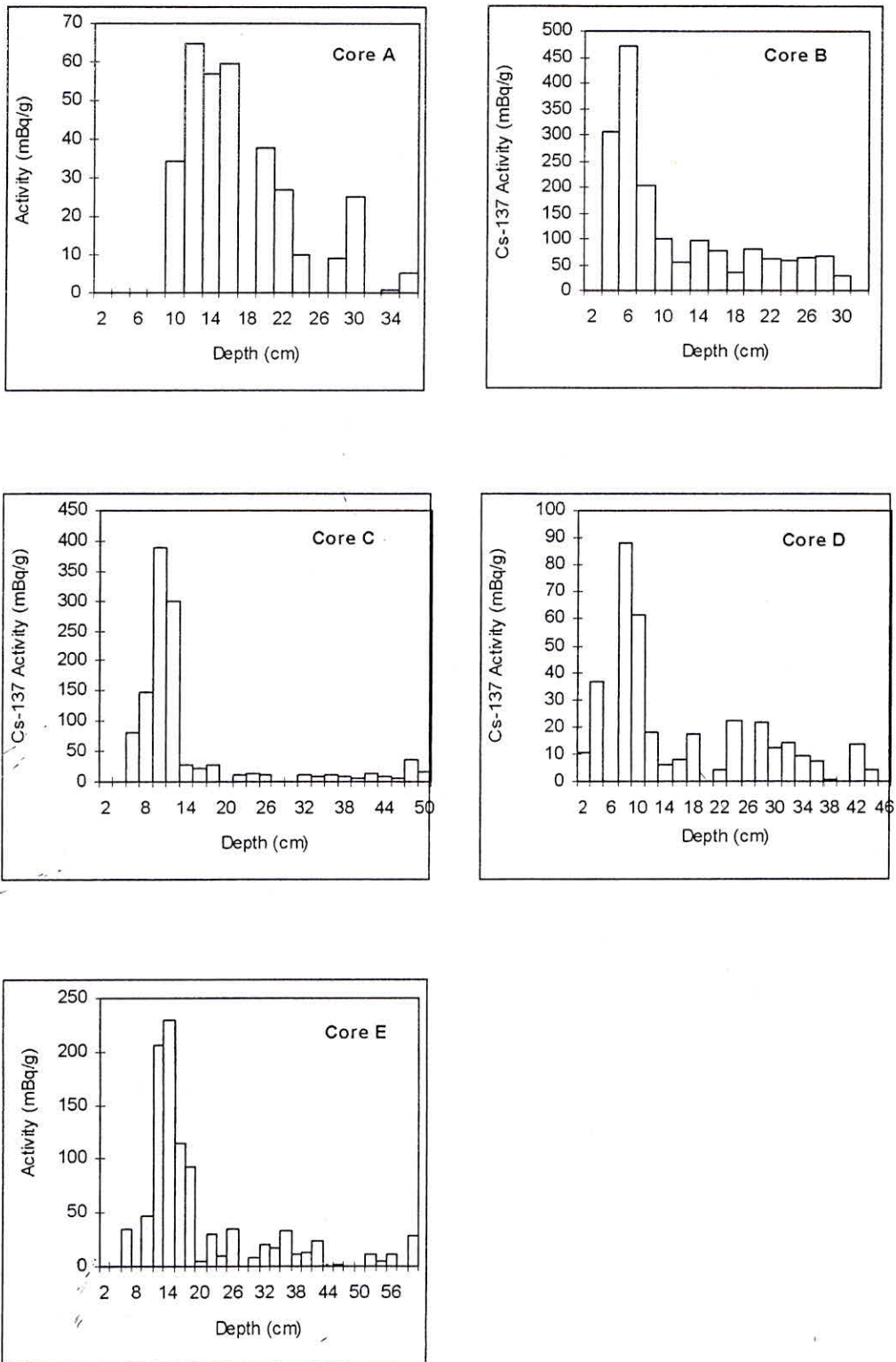
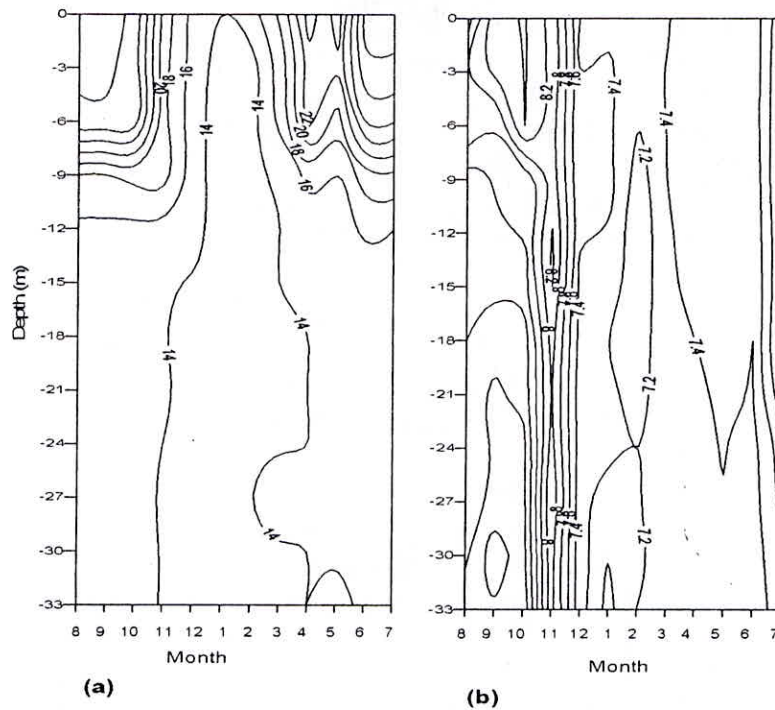Fig. 5: ^{137}Cs activities of the analysed sediment cores

Fig. 6 a, b: Depth-time isopleths of temperature (a) (°C), pH (b), of Mansar lake during August 98 to July 99.
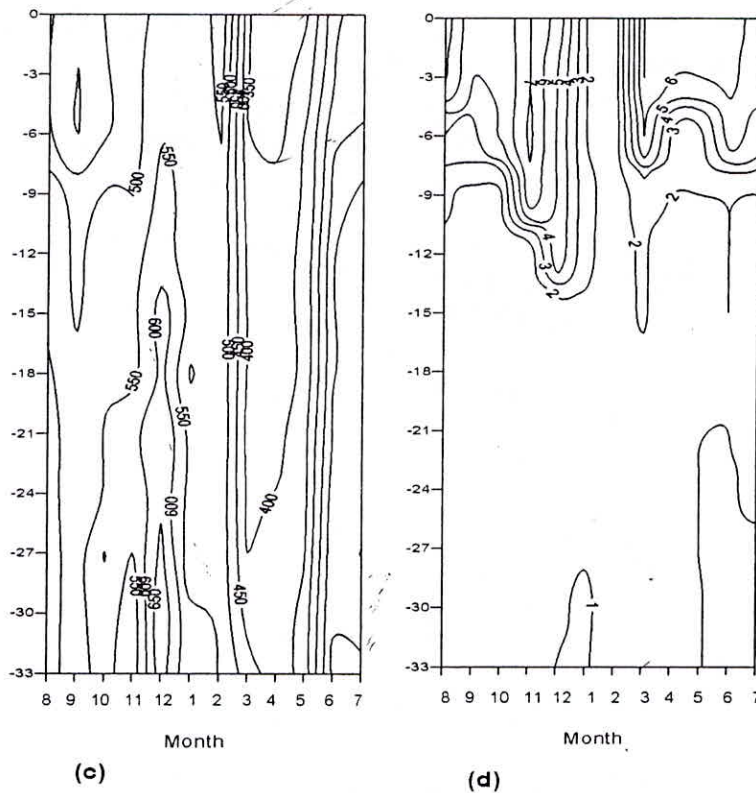

Fig. 6 c, d: Depth-time isopleths of Electrical Conductivity (c) (μmho/cm) and Dissolved Oxygen (mg/l) (d)

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The pH in surface water varies from minimum 7.4 (January) to maximum 8.7 (August and September). The higher pH value during monsoon and post monsoon months is obviously related to the metabolic activities of the autotroph. The pH decreases with depth (epilimnion to hypolimnion) during months of lake stratification and it is uniform from surface to bottom during winter overturn (Fig. 6b). The low pH value occurred in hypolimnion due to the liberation of acids from the decomposing organic matter under low oxygen conditions and uniform pH value in January and February may be correlated with homogeneous mixing of lake. Increasing trend of conductivity with depth (Fig. 6c) is due to mineralization of organic matter under reducing condition prevailing in the hypolimnion zone and as a result bottom lake water shows maximum conductance in comparison to surface.

The dissolved oxygen (DO) is an important indicator of water pollution, it is varying between minimum 1.6 mg/l (17% saturation) in January and February to maximum 7.5 mg/l (109% saturation) in August at surface. Maximum DO during monsoon and post monsoon months is correlated with the photosynthesis of flourishes biota. The lower value of DO in January and February in the epilimnion zone is due to mixing of lake water. The depth-wise analysis of the DO show decreasing trend from epilimnion to hypolimnion (Fig. 6d) during lake stratification period and prevailing anoxic conditions in the hypolimnion zone. The main reason for anoxic conditions in the hypolimnion region are (1) dissolved oxygen is not produced due to the photosynthesis and (2) bottom water not exchanges with atmosphere at the surface due to stratification. However, available oxygen is consumed in respiration and decomposition process in this zone. The clinograde curve formed during stratified month of Mansar lake water is characteristics of stratified eutrophic lake.

Hardness in lake water is due to calcium and magnesium and alkalinity is mainly due to bicarbonate ions. Both the hardness and the alkalinity show increasing trend with depth in lake during stratification while uniform distribution in winter overturn. Alkalinity varies from minimum 70 mg/l (in August) to maximum 123 mg/l (January and February) in the surface water.

Piper's diagram (Fig. 7) reveals that lake water belongs to the $Ca-Mg-HCO_3-CO_3$ facies. Calcium and magnesium are major cations in the Mansar lake, together accounting for about 70 to 85% of the cations. The Ca:Mg equivalent ratio varies from 0.45 to 6.40 in the present study. Bicarbonate is major anion accounting for about 77 to 91% of the total anions. The plot of Ca+Mg Vs total cations, show that most of the points approach equiline i.e., 1:1 (Fig 8a). The higher concentration of HCO_3 in lake water and its positive correlation with Ca and Mg indicates their common source, from dissolution of carbonates. The stoichiometry of carbonate weathering reaction demands that carbonate derived Ca and Mg should be equal to the carbonate derived bicarbonate (Singh and Hasnain, 1998). A plot of (Ca+Mg) Vs HCO_3 (Fig. 8b) shows that most of the samples fall on the 1:1 trend line and in few (Ca+Mg) content is slightly in excess of HCO_3 suggesting that excess of (Ca+Mg) in these waters should be balanced by SO_4 and Cl. The major contribution of (Ca+Mg) to total cations (TZ^+), the relatively high (Ca+Mg)/(Na+K) ratio (4.0) and low (Na+K)/TZ^+ ratio (0.20) indicate that calcareous sandstone and mudstone of the Siwalik Group are the major source of lake water.

The Trophic status of the Mansar lake has been determined based on the boundary values of total phosphorus given by Wetzel (2001). The orthophosphate phosphorous in the epilimnion

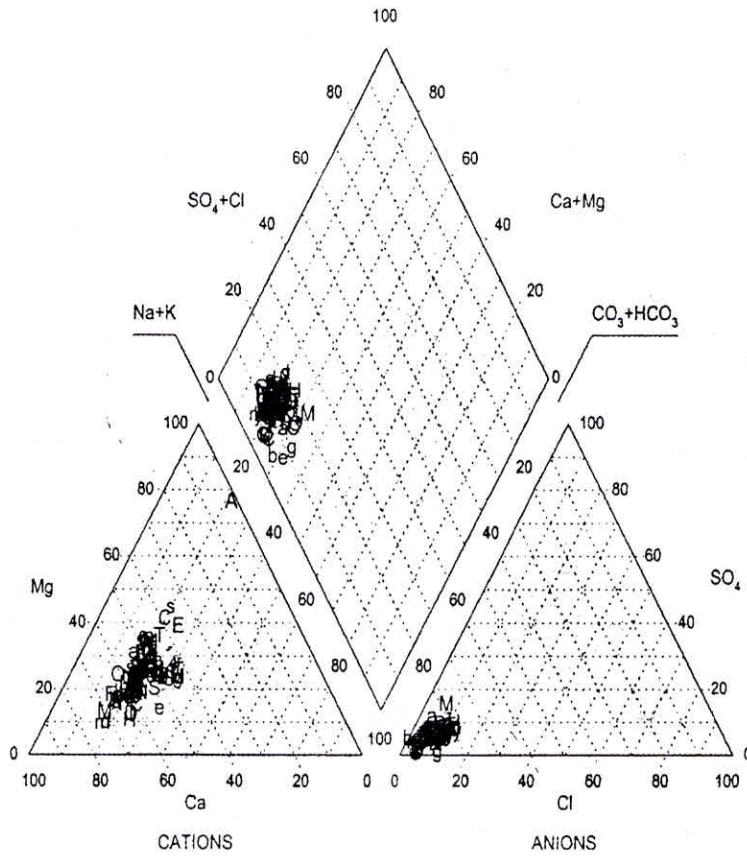zone varies between 30 µg/l to 160 µg/l indicate lake has been entered in the eutrophic condition.

Fig. 7: Water Chemistry diagram, showing hydrochemical facies
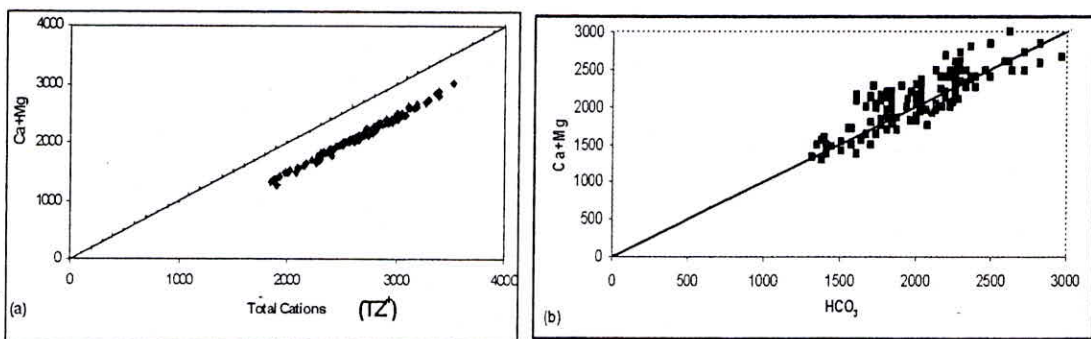

Fig. 8: Scatter diagram between (a) (Ca+Mg) Vs Total cations (TZ$^+$); (b) (Ca+Mg) Vs bicarbonate

SUMMARY AND CONCLUSIONS

An attempt has been made to workout the bathymetry, determine rate of sedimentation and physico-chemical characteristics of the Mansar lake of Jammu region. The bathymetric survey conducted using Range-line method shows present lake surface area is 0.59×10^6 m^2 and volume to be 11.57×10^6 m^3. The bathymetric map prepared in the present study will be useful to compare changes in lake surface area and storage capacity in future. The variation in sedimentation rate and pattern exhibits influence of human activity on lake. The rate of sedimentation determined using ^{137}Cs and ^{210}Pb radiometric dating technique in the lake varies between 0.14 cm/y to 0.37 cm/y with a mean rate of 0.23 cm/y $\pm$ 0.002 cm/y. The higher rate of sedimentation (0.37cm/y) is observed in the zone where sediments directly enter from the agricultural land. The variation of temperature, pH, electrical conductivity, dissolved oxygen, hardness and alkalinity suggest that Mansar lake undergoes two distinct stages, viz., complete mixing stage in the months of January and February and stratified stage in other months. Physico-chemical characteristics of lake change with depth and seasons. Depthwise variation of physico-chemical parameters are thought to be controlled by mixing and stratification processes of lake. The seasonal changes in pH, DO, hardness and alkalinity in epilimnion zone are mainly due to biological activities. The catchment lithology contributes a large part of the major constituents in lake water; Ca and Mg account 70 to 85% of the cations and HCO$_3$ accounts for 77 to 91% of the total anion, and equivalent ratio of Ca:Mg varies from 0.45 to 6.40. The average (Ca+Mg)/HCO$_3$ equivalent ratio of 1.04, major contribution of (Ca+Mg) to total cations and high (Ca+Mg)/(Na+K) ratio indicate that weathering of calcareous sandstone and mudstone Siwalik Group could be the primary source of major ions in the lake water. Analytical results of total phosphate show that Mansar lake has entered in the eutrophic stage. A well developed clinograde curve of DO, accumulation of bicarbonate at the bottom, marked stratification in pH, low chloride content, high total potential content of nutrients like soluble phosphate and nitrate-nitrogen clearly indicate eutrophic nature of lake. Occurance of fish mortality during winter (January/February) seems related to low DO (1.6 mg/l) during mixing of the lake water.

ACKNOWLEDGEMENT

RECOMMENDATIONS FOR MANAGEMENT OF MANSAR LAKE

i)   The public awareness programme for the people living in surrounding area of Mansar lake including tourists should be organised at different levels in order to avoid the pollution problem.

ii)   Inflow of domestic waste should be checked immediately.

iii) Afforestation drive in the lake catchment area in order to reduce the erosion.

iv) Construction of suitable engineering/biological structure in the lake catchment to reduce the eroded material being fed into lake.

v) Removal of deltas and aquatic plants every year from the area near the entry points of the sediments especially near boat club and mandir.

vi) Construction of sluice gate at the outlet of the lake to maintain desired water level in the lake.

vii) Installation of suitable water circulation devices to increase the D.O. level in the deep portion of the lake.

viii) Use of Copper sulphate to control algal biomass in the lake.

ix) Phosphorous inactivation by using aluminium salt

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