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Possible impact of Deficit Rainfall on Water Availability in Sukhna Lake, Chandigarh during summer of 2012

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Abstract : Sukhna Lake located at Chandigarh is a valuable manmade lake. It is very popular destination in the region for tourism and recreation. It also has high ecological value due to its biodiversity. However, in recent years the lake is reported to be engulfed with various problems such as declining water availability, siltation, aquatic weed infestation etc. The condition of the lake is becoming precarious and calls for an urgent remedial action. So, hydrological investigations on the lake have been initiated with the objectives of identifying the causes of various problems of the lake and possible remedial measures for rejuvenation of the lake. This paper presents the results of the preliminary investigations on water availability in the lake carried out so far based on the available data The analysis of the data indicates that about 90% part of the lake is expected to go dry by the end of Summer of 2012.

INTRODUCTION

Lakes are valuable natural and socio-economical resources. They act as catalysts in the development of a region by serving variety of domestic and developmental purposes such as civil water supply, irrigation, fish-culture, recreation, tourism, industrial and other commercial activities etc. They are very significant components of the hydrologic cycle. However, because of the increasing human interference in the catchment, and urbanization etc., many of the lakes are getting affected leading to quantitative and qualitative degradation. Although, lakes being only the transitory features of the landscape, have a definite birth and death, excessive interference with the lakes and their catchments, in many or most cases, actually hastens their death. Hydrologically, because of relative lack of motions of their waters, lake basins act as sediment traps. Sediments bring nutrients with them and this causes growth of the aquatic plants, a process called eutrophication. Human activities significantly increase the natural rate of eutrophication. However, since the demand for fresh water is increasing day by day for variety of uses, due to exponential growth of population, proper conservation and management of all the fresh water resources including lakes, both in terms of quantity and quality, has gained great significance in recent times. Sincere efforts are now being made to conserve the lake water resources for the socio-economic benefit of the society.

For proper conservation of any lake it is essential to have proper understanding of the problems it is facing. Each lake has its own set of problems depending upon its morphology, climate of the region, land use in the catchment, degree of human interference in the catchment and use of the lake water along with other environmental factors. Since the various processes occurring in any lake ecosystem are directly or/and indirectly interrelated with the various hydrological processes, it is essential to understand the various hydrological processes of the lake ecosystem, so that systematic and scientific conservation and management measures can be suggested and taken up for the lake. Integrated hydrological investigations are, therefore, significant and essential for any lake.

Sukhna Lake is a very significant lake of Chandigarh region. However, the lake is in limelight in recent years as it is engulfed with various problems. Its capacity has been reported to have decreased significantly in the past few decades. It has been reported that 51.19 % of the designed storage capacity has been lost by 2010 since its construction in the year 1958 (IPRI, 2011). Moreover, water levels in the lake have been observed to go down considerably in some of the recent years. Also, presence of submerged aquatic weeds is being observed in the lake in recent years which needs to be curbed before becoming a menace. The quantitative and qualitative degradation is reducing the aesthetic value of the lake causing threats to tourism. In general, the condition of the lake is becoming precarious and calls for an urgent remedial action. Although some scattered studies have been reported on the assessment of erosion in the catchment and sedimentation in the lake (Bansal and Mishra, 1982; Shrimali et al., 2001; Singh, 2002; Grewal, 2009) and on its biological characteristics (Sharma et al., 2006), no systematic investigations on the various hydrological processes and hydrological behaviour of the lake have been reported so far. Therefore, detailed hydrological investigation of Lake Sukhna have been initiated by the National Institute of Hydrology, Roorkee to understand the hydrological regime of the lake, to identify the causes of quantitative and qualitative deterioration of the lake and to suggest remedial measures for proper management and conservation of the lake. The present paper presents the analysis of the results obtained so far on possible water availability in the lake during the coming summer of 2012 as deficit rainfall have been received during the monsoon of 2011.

STUDY AREA

Sukhna lake is located in the Union Territory of Chandigarh in the foothills of Siwalik Hills. The lake is kidney shaped. It is a shallow manmade lake constructed as part of the plan prepared by the French architect Le-Corbusier. It was constructed in the year 1958 by constructing a 12.8 m high rockfill earth dam across the Sukhna choe, which is a seasonal stream flowing down from the Shivalik hills. At the time of its construction its storage capacity was 10.74 MCM while its present storage capacity is 5.24 MCM (IPRI, 2011). It is reported that the initially the lake was 1.52 km long and 1.49 km wide (IPRI, 2011). The lake also serves as a sanctuary for a large number of birds. So far, about 150 different species of birds have been reported for the lake (Singh, 2002). Pisciculture is an important economic activity associated with the lake. The annual fish catch from the lake has been reported to be more than 30 tons (Singh, 2002). With a beautiful surrounding and facilities for water sport activities

Table 1. Salient features of Sukhna Lake

Parameter	Value
Longitude	76^0 54' E
Latitude	32^0 42' N
Altitude (m)	350 m
Year of construction	1958
Avg. Annual rainfall (mm)	1121.6
Max. Storage capacity (Mcum)	5.24
Max water spread area (ha)	157.57
Maximum depth (m)	6.7
Mean depth (m)	3.3
Water Use	Tourism, Recreation, Aquaculture

and boating, the lake has become an important source of recreation and tourism. Table 1 shows the salient features of the lake. Fig. 1 presents a view of the lake while Fig. 2 presents the digital elevation map of the lake catchment.

The catchment area of the lake is 42.07 Sq. Km. of which 29.08 Sq. Km. falls in the Union Territory of Chandigarh, 10.22 Sq. Km. in Haryana and 2.77 Sq. Km. in Punjab (Grewal, 2009). It is located in the foothills of the Shivalik hill ranges, which forms part of the fragile Himalayan ecosystem, called Kandi (Bhabhar) region. Geologically the subsurface formation comprises of beds of boulders, pebbles, gravel, sand, silt, clays and some kankar (www.chandigarh.nic.in). The major land uses in the catchment area are forest and agriculture. Out of the 42.07 Sq. Km. catchment area, 33.1 sq. km is forest and 8.97 sq. km is agriculture (Grewal, 2009). The catchment area has rugged terrain with steep slopes. The soils are predominantly alluvial sandy embedded with layers of clay and are highly susceptible to soil erosion (Singh, 2002). As such, the water flowing into the lake is highly turbid. However, a number of soil conservation measures have been taken up in the catchment and a marked decline in the siltation rate has been reported for the lake in recent years (Grewal, 2009).

Fig. 1. A view of Sukhna Lake, Chandigarh

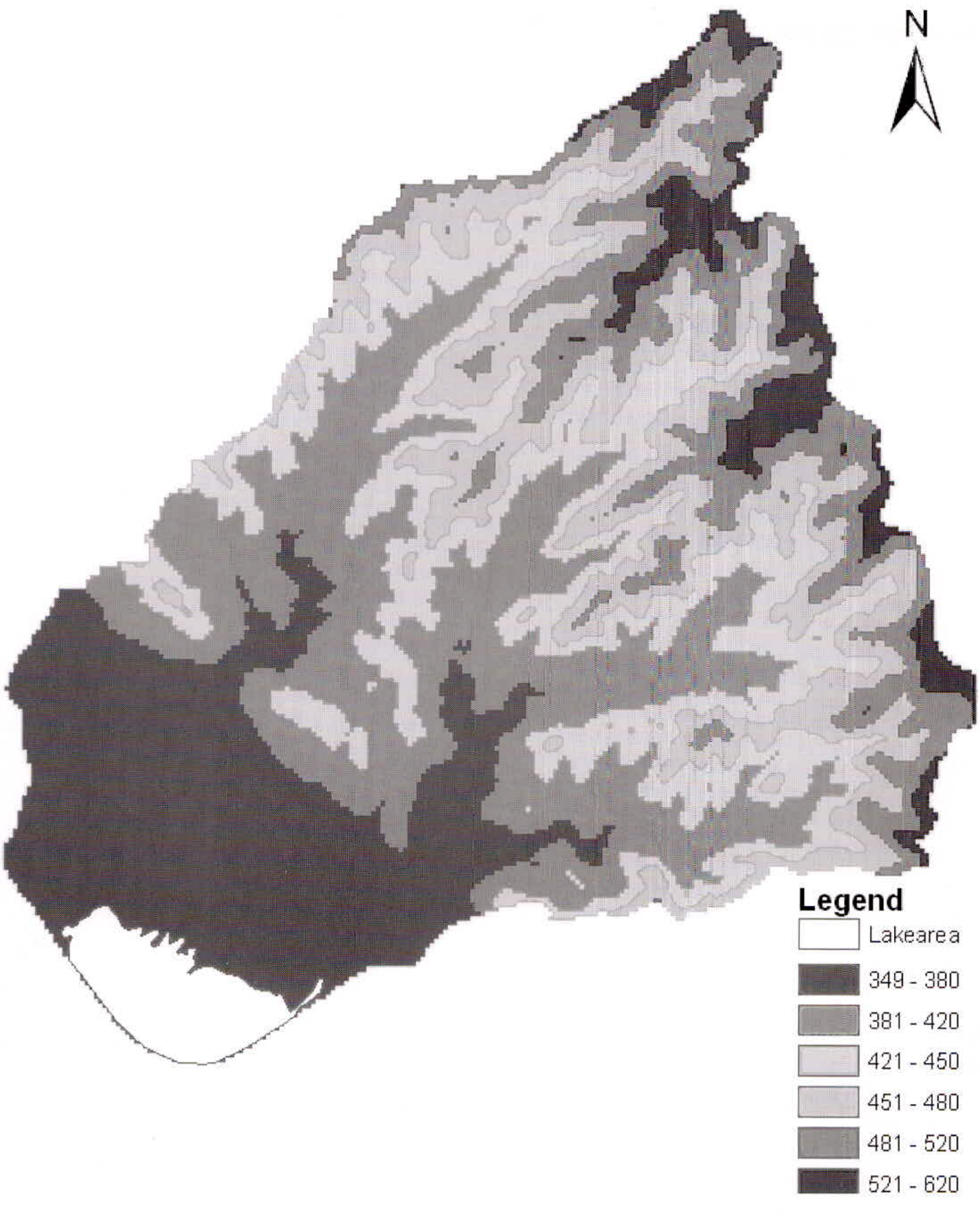

Fig. 2. Lake and its catchment area

CLIMATE OF THE STUDY AREA

The study area has a humid subtropical climate. There are four distinct seasons: (i) Summer or hot season (mid-March to Mid-June) (ii) Rainy season (late-June to mid-September); (iii) Post monsoon autumn/transition season (mid September to mid-November) and (iv) Winter (mid November to mid-March). May and June are the hottest months of the year with the mean daily maximum & minimum temperatures being about 37°C & 25°C, respectively. Maximum temperatures can rise up to 44°C (www.chandigarh.nic.in). The average rainfall of the area is 1120 mm with 80% rainfall occurring in the three monsoon months of July to September (Grewal., 2009). January is the coldest month with mean maximum and minimum temperatures being around 23°C and 3.6°C respectively. Winds are generally light and blow from northwest to southeast direction with exception of easterly to southeasterly winds that blow on some days during the summer season (www.chandigarh.nic.in).

MATERIALS AND METHODS

In the present study, possible impact of the deficit rainfall during 2011 on the water availability in the lake in forthcoming summer season of 2012 has been investigated. In other words, water spread area of the lake has been forecasted. The analysis has been carried out using the data of rainfall, water level of the lake and bathymetry data of the lake. Two Raigauges have been installed, one each at the lake site and in the lake catchment, for collection of rainfall data. Daily data of rainfall have been collected from 1st July, 2011. Rainfall data available at other stations have also been collected. Similarly, lake water levels have been monitored daily for the analysis period of 1st July, 2011 to 31st December, 2011. Bathymetric map prepared by IPRI, Amritsar after the monsoon season of 2010 has been used. Since it is reported that siltation has reduced drastically in recent years and since there has been little inflow to the lake during the year 2011, it is reasonable to assume that not much siltation has taken place during the year and that the bathymetric map of post monsoon period of 2010 holds true for the study period. The map has been digitized and processed using GIS for the purpose of estimating depths of water at different locations in the lake as well as for prediction of water spread area in the lake in different months. Since no data on daily evaporation and daily pumping from the lake are available, total daily loss of water from the lake has been estimated, based on the variation in lake water levels of the non-monsoon period. It is assumed that the pumping of water would be at the same rate and frequency as it has been during the period of 1st October, 2011 to 31st December, 2011, and that there are no significant variation in pumping in the prediction period. Further, it has been assumed that there is no non-monsoon rainfall or negligible non monsoon rainfall during the prediction period.

RESULTS AND DISCUSSION

The average rainfall of Chandigarh for the period 1958-2005 is 1120 mm. 80 % of this rainfall is received during the monsoon months of July to September. The amount of rainfall received during the period of 1st July-30th September, 2011 is 642.6 while and at the lake site it is recorded to be 695.8 mm. Thus, year 2011 has been a year of deficit rainfall. This section discusses the analysis of the impact of this deficit rainfall on the water availability in the lake.

Fig. 3 shows the digital elevation map of the lake prepared from the bathymetric map. The maximum depth of the lake is at the regulator end and in some parts in the north of the lake towards rowing channel end. The average depth of the lake has been calculated to be 3.33 m. However, averaging is affected by few individual values. Barring some parts of the lake towards the regulator end and also toward the end where the boating is carried out, the depths in most parts of the lake in the lake (i.e. middle potion) are in the range of 4.5 to 5.5. m.

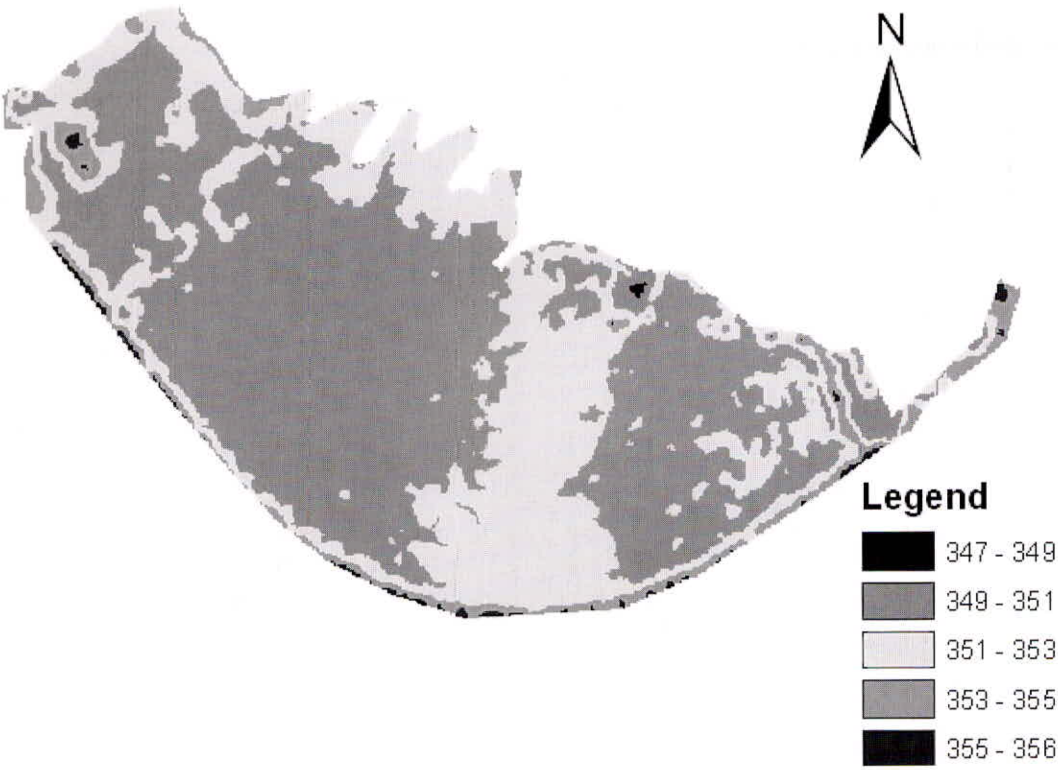

Fig. 3. Digital Elevation model of the Lake

Fig. 4 shows the variation of lake water levels vis-à-vis rainfall during the monsoon period of 1st July to 30th September, 2011. It can be observed that a significant rise of 0.27 m in the lake water is recorded on 27th August, 2011. It is obviously because of the heavy rainfall recorded on 26th August which was 84 mm in the Lake Catchment and 82 mm at the lake site. No such significant rise was recorded prior to that in the season although a number of rainfall events have been recorded during this period, four of them being of more than 30 mm magnitude with one of it being of 72 mm magnitude. The total amount of rainfall received in the catchment during the period of 1st July, 2011 to 25th August, 2011 is 379.2 mm but the net change in the water level of the lake is 0 with water level being recorded to be at 351.75 m amsl on both these days. This implies that the amount of water received during this period through inflow and direct rainfall over the lake equals the net amount of water lost through the processes of evaporation, pumping, and seepage. Field observations made at the gauge located in the inflow channel indicate that there are only a few events of inflow to the lake during this period. This in turn implies that not much significant flow has entered the lake through surface runoff. This brings out that most of the 379.2 mm of rainfall which was received in the lake catchment during 1st July, 2011 to 25th August, 2011 has been absorbed in the catchment

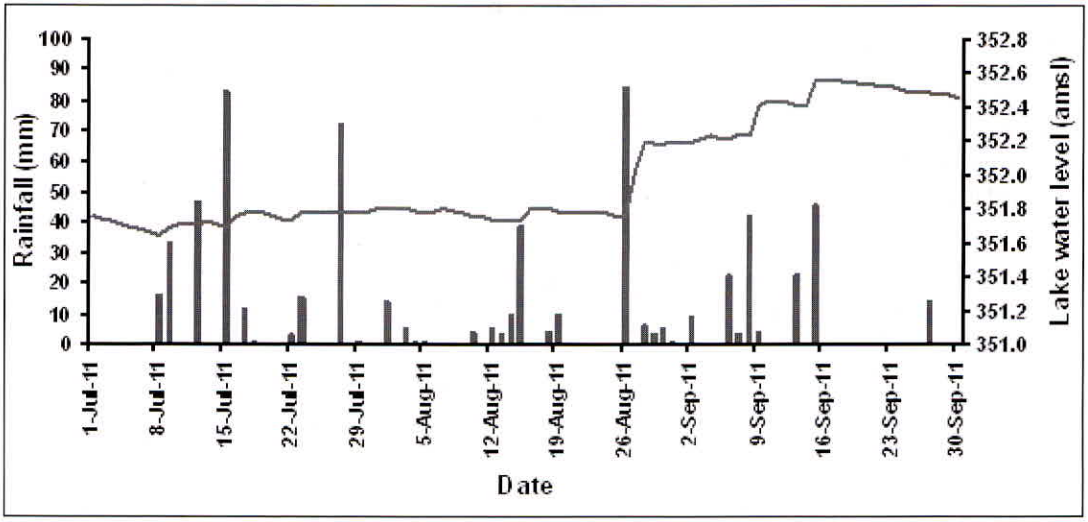

Fig. 4. Variation of lake water level vis-à-vis rainfall during monsoon season of 2011

itself as surface abstraction, evapo-transpiration losses and infiltration and percolation losses to groundwater. One of the major shares of this abstraction goes to the check dams which have been constructed in the catchment as part of the soil conservation measures. About 150 such small storage structures are known to have been constructed in the in the catchment.

The above analysis brings out that if the rainfall of a similar nature (intensity and magnitude) is received by the catchment, an amount of about 380 mm rainfall would not cause any significant increase in the lake levels or any significant runoff from the lake catchment. If we add to it the amount of rainfall received as pre-monsoon showers during May and June, this amount would be more than 400 mm, say 400 mm only. Analysis of the historical data of rainfall and corresponding water levels in the lake for further detailed analysis of this aspect is under progress.

The present capacity of the lake is 5.24 Mcum and the catchment area is 42.07 Sq. km. Assuming 20 % runoff from catchment after the meeting the various surface abstractions (fulfilling capacity of check dams) and losses, an amount of water to be received by the catchment comes out to be 26.2 Mcum. This needs an additional rain of 623 mm (say 600 mm). This has to be in excess of the 400 mm of rainfall required to meet the various initial abstraction to cause significant inflow to the lake. Thus, the lake will be filled or overflow if the rainfall is (400 + 600 mm) = 1000 mm. Since the normal rainfall of Chandigarh is about 1100 mm, the lake will be completely filled or overflow only during the years when the rainfall is about 90% of the normal. Obviously the lake will not fill when there is deficit rainfall, as it happened during 2011.

Fig. 5 shows the water level variation during the post monsoon period (1st October to 31st December, 2011). As can be seen, the lake water has fallen steadily during the period. The average daily fall in the water lake level is 6.22 mm. Since there is no observed inflow to the lake and no direct rainfall over the lake during this period, the water loss is because of the evaporation, pumping from lake and ground water outflow together. With lake becoming shallower and shallower due to water loss, the evaporation rates are also expected to be increasing steadily. Based on this average daily

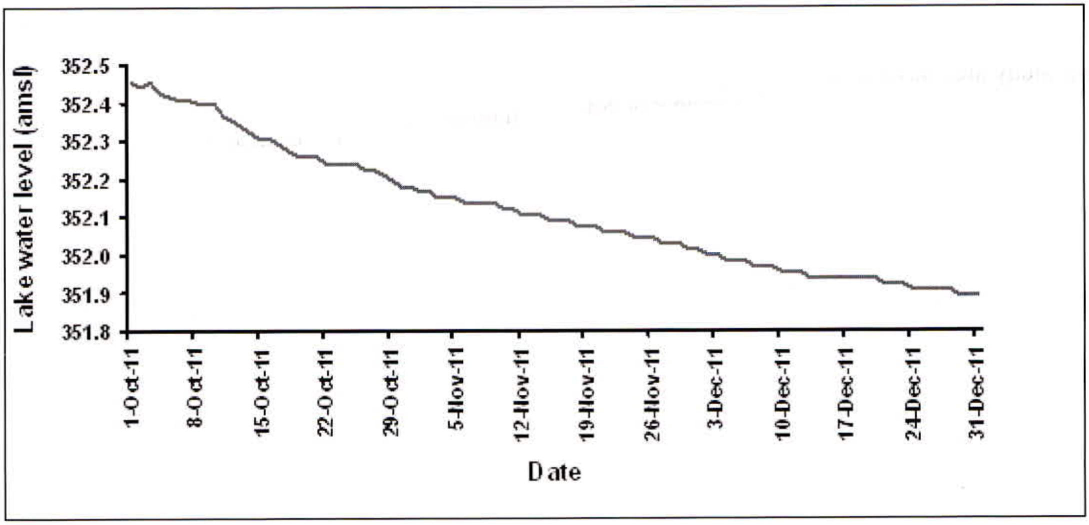

Fig. 5. Variation of lake water level during post monsoon season of 2011

loss, as well as daily loss observed during the first week of July, 2011 average daily loss for the coming months has been interpolated and assumed as follows: 6 mm/day for the months of December and January, 8 mm/day for the months of March, 9 mm/day for the month of April, 10 mm/day for May and 11 mm/day for the month of June.

On the basis of the various assumed rates of daily water loss from the lake, water spread area of the lake for different months has been predicted. Fig. 6, Fig. 7, Fig. 8 and Table 2 present the predicted water spread area of the lake. A significant portion of the lake is expected to go dry as we advance towards the summer, particularly during the months of May and June. Thus, by the end of May, 2012 about 73 % percent area is expected to be dry which is further expected to increase to more than 90 % by the end of June, 2012. Water is expected to be present only in about 6 % of the lake area during July, 2012.

Even if we assume an error of 25% on account of various assumptions including those of the bathymetric survey, it is reasonable to believe that more than 70% percent of the lake area will go dry by June, 2012 end. As such, activities such as boating are expected to be badly affected in the coming summer. As a reminder, the analysis has assumed no significant non-monsoon rains and that pumping is at the same rate as it was during the period of 1st October to 31st December, 2011.

Of the three components which constitute the daily water loss from lake, the most important component which can be controlled, is the daily pumping from the lake. At present the pumping of water is being done to withdraw water for irrigating the gardens along the lake. If the rate of pumping is increased in summer which is very much likely, then the lake can be expected to go dry even earlier. This implies that, if the loss of water availability in the lake has to be checked then pumping of water must be immediately stopped.

CONCLUSIONS

Analysis of the water level data, rainfall data and bathymetric data has been carried out in the present study to predict the impact of deficit rainfall on the water availability in the lake during the forthcoming summer of 2012. The average

Fig. 6. Predicted water spread area of the lake as on 1st April, 2012

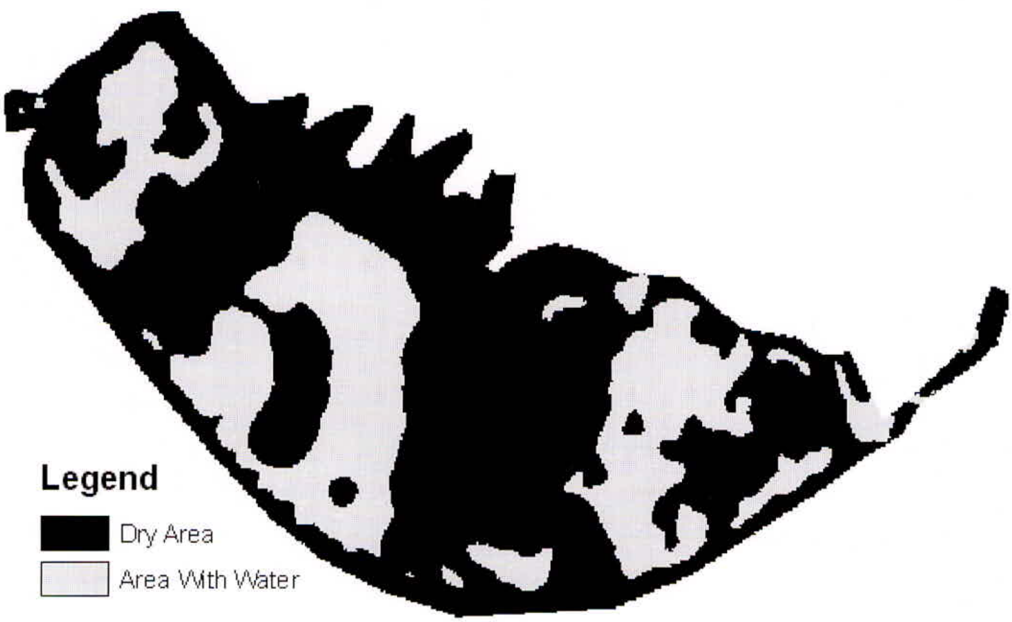

Fig. 7. Predicted water spread area of the lake as on 1st June, 2012.

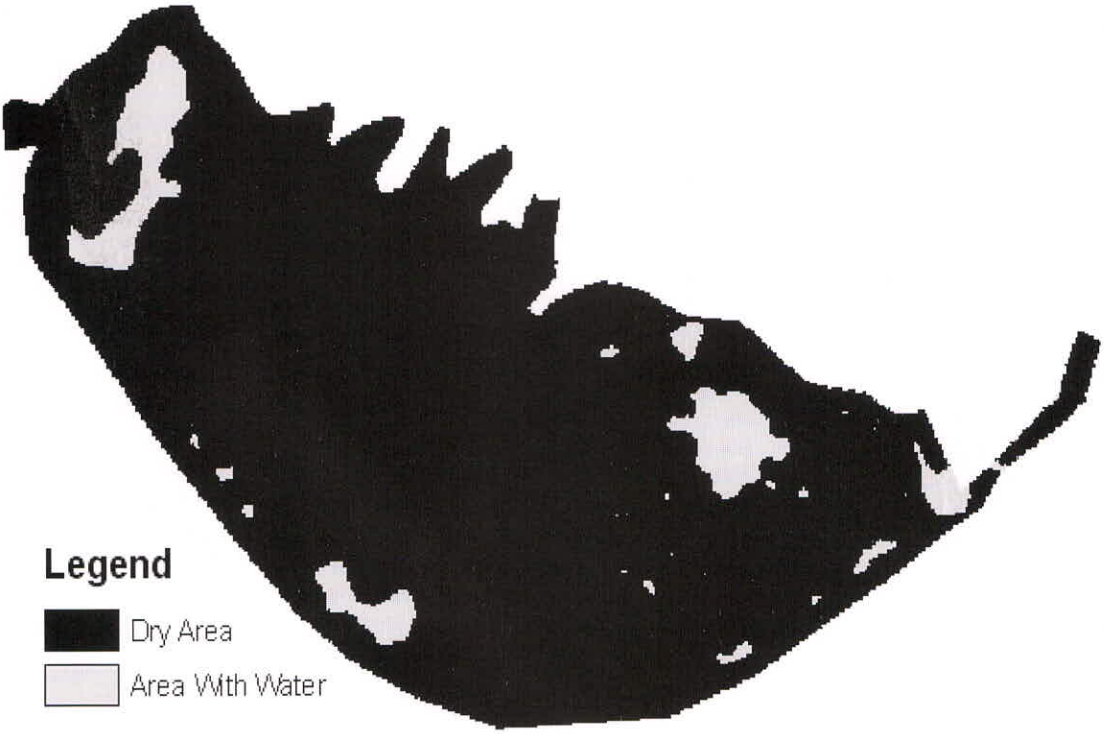

Fig. 8. Predicted water spread area of the lake as on 1st July, 2012

Table 2. Predicted water surface area of lake

Date	Expected Water Spread Area of lake (ha)	Water Spread Area as % of Total Lake Surface Area (%)	Dry Lake bed Area as % of Total Lake Surface Area (%)
1st Jan 2012	136.15	86.41	13.59
1st Mar 2012	132.20	83.90	16.10
1st April 2012	124.73	79.16	20.84
1st May 2012	97.86	62.11	37.89
1st June 2012	42.38	26.90	73.10
1st July 2012	9.55	6.06	93.94

depth of the water at maximum water level is estimated to be 3.33 m, although in most parts of the lake it is in the range of 4.5 to 5.5 m. Analysis of water level data indicates that an amount of about 400 mm rainfall received in the catchment during the monsoon season does not cause any significant increase in the lake levels or any significant runoff from the lake catchment. For the lake to fill up completely, 90% of the normal rainfall should occur in the lake catchment. The observed average daily loss of water from the lake during the post monsoon period of October to December, 2012 is 6.22 mm/day. Based on this, average loss for the subsequent months have been interpolated and water spread area has been predicted. Thus, by the end of May, 2012 about 73 % percent area is expected to be dry which is further expected to increase to more than 90 % by the end of June, 2012.

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