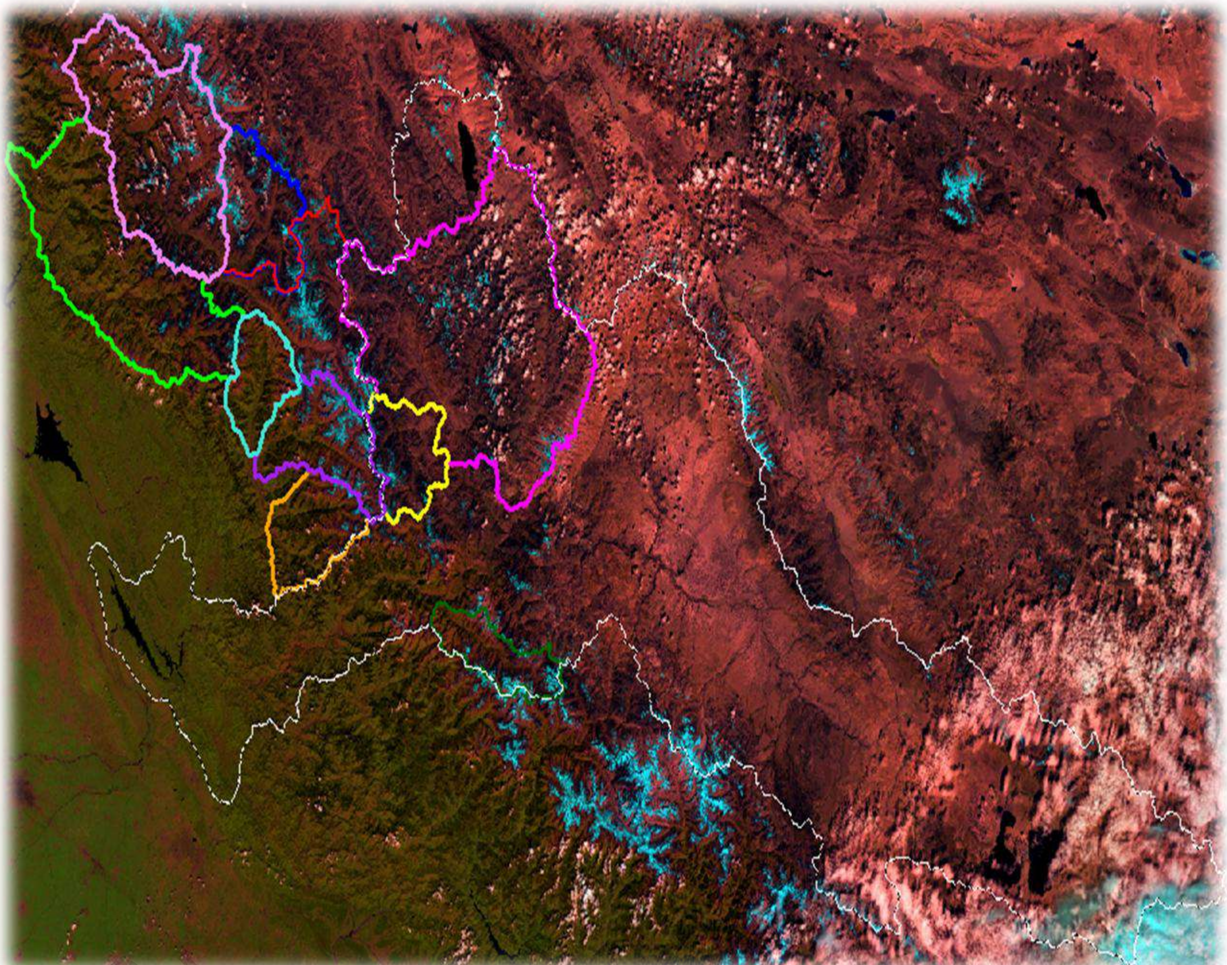
A technical report on the inventory of moraine dammed glacial lakes (GLOFs) in Satluj, Beas, Chenab and Ravi Basins in Himachal Pradesh using IRS LISS III satellite data (2013)



Spatial extent of different basins in Himachal Pradesh

Prepared by

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(State Council for Science Technology & Environment)

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Abstract	**With the projected increase in the frequency and intensity of extreme events including floods, droughts, landslides etc which are attributable to climate change, disaster management need greater attention. Susceptibility of the State of Himachal Pradesh to the vagaries of climate change has now been well documented. Scientific insight gained from the analysis of multi spectral Satellite images carried out by the authors suggests that spatial extent of majority of glaciers is changing very fast leading to the formation of moraine dammed lakes. Formation of such lakes is posing potential threat to the infrastructure and human life thriving in the downstream areas of many drainage systems originating from the snow clad mountains ranges of the State. Various studies have been carried out on this vital issue of climate change and reveals that there is an alarming increase in such potential lakes which can be disastrous in the event of any break due to one or the other reasons. The present study has been carried out using LISS III satellite data for the year 2013. The mapping has been carried out in Chenab, Beas, Ravi and Satluj basins for the delineation of all such lakes in the higher regions. The area mostly being inaccessible where about 70% catchment as in case of the Satluj basin is on the international territory, so the investigation is inaccessible as in the present case where the mapping by any other conventional method is just not possible because of rugged topography of the area besides the area under International boundary, so the remote sensing technology has been found to be very useful in acquiring the information. The interpretation has been carried out using ERDAS Imagine 9.0 software. Based on this, a complete inventory of moraine dammed glacial lakes (GLOFs) basin wise has been generated which forms the base line data for future monitoring as far as disaster preparedness in the state is concerned. Besides this, the monitoring of Parechhu lake has also been carried out separately using LISS IV data during the year 2013 from April to September and the up to date status was conveyed to the Govt.of Himachal Pradesh and other stakeholders in the State. The regular monitoring of all such moraine dammed lakes is thus important and needs regular monitoring in order to meet out any eventuality at the pre disaster level.**
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ACKNOWLEDGEMENT

The State Centre on Climate Change of the State Council for Science Technology & Environment took up the initiative to prepare an inventory of the moraine dammed lakes in all the four basins viz. Chenab, Beas, Ravi and Satluj basins using high resolution satellite data. The author is thankful to the Principal Secretary (Env,S&T) Govt. of H.P. and the Member Secretary (EC) State Council for Technology & Environment and the Joint Member Secretary for constant support and guidance and allowing us to undertake the investigation as part of the disaster management activities in the State Center on Climate Change of the State Council using space technology.

A technical report on the inventory of moraine dammed glacial lakes (GLOFs) in Satluj, Beas, Chenab and Ravi Basins in Himachal Pradesh using IRS LISS III satellite data.

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A technical report on the inventory of moraine dammed glacial lakes (GLOFs) in Satluj, Beas, Chenab and Ravi Basins in Himachal Pradesh using IRS LISS III satellite data.

1. Background:

During its geological history, the earth has experienced alternate cycles of warm and cold climates. During cold climate, glaciers and ice sheets have formed on the surface of the earth. Geological evidence suggests that the earth has experienced glaciations during Permo-Carboniferous and in the Pleistocene period (Embleton and King, 1975). Precambrian tillites and boulder-beds are reported from many parts of the world, such as Scotland, U.S.A. Clear evidence of Carboniferous-Carboniferous ice age is also established in India and South Africa. The Carboniferous-Carboniferous glaciation was followed by Mesozoic era, during which the world temperature was higher than that of today and no evidence of glaciation was observed in the geological formations of that period. In Cenozoic era, large-scale glaciation was experienced, which includes glaciation during Pleistocene and Quaternary periods (Smith *et al.,* 2005). It has also influenced the present distribution of glaciers on the earth's surface. During Pleistocene the earth's surface had experienced repeated glaciation over a large land mass. During the peak of glaciation, the area covered by the glaciers was 46 Million sq. km. (Embleton and King, 1975). This was more than three times the present ice cover of the earth. Available data indicates that during the Pleistocene, the earth has experienced four or five glaciation periods separated by an interglacial periods. During an interglacial period, climate was warmer and deglaciation occurred on a large scale. The most recent glaciation reached its maximum advance about 20,000 years ago when the Himalayan snow line was depressed from 600 to 1000 meters lower then the present elevation due to fall of temperatures by 5 to 8ºC. At present total glaciated area on the earth is about 14.9 million sq. km. Out of this 2.5 million sq km is located in Arctic and 1.7 million sq km in the Greenland ice sheet (Flint, 1971). The remaining 0.7 million sq km area is distributed in the other parts of the World. Himalaya has one of the largest concentrations of glaciers outside the Polar Regions and some estimates suggest that the number could be as high as five thousand (Kulkarni and Bahuguna, 2001).

In the Himalaya, glaciers cover approximately 33000 sq km area, and this is one of the largest concentrations of glacier-stored water outside the Polar Regions. Melt water from these glaciers forms an important source into run-off of North Indian rivers during critical summer months. This makes these rivers perennial and has helped to sustain and flourish the Indian civilization along the banks of Ganga and Indus. This supply is available during dry periods and naturally regulates the flow of large rivers thus compensating extremes of precipitation. Glacial activity also generates sediments. However there have been several evidences in recent geological history about the glacier mass fluctuations resulting in the stream runoff originating from them. Stream runoff is an important component in planning of water resources and micro and mini hydroelectric projects. Glacier mass fluctuations are also indicators of global climatic changes. In the context of the Himalayan glaciers, which are source of many giant north Indian rivers, systematic monitoring of Himalayan glaciers is of paramount importance in view of their large number and area covered.

Global warming has already caused a significant glacier ice loss since the Little Ice Age (AD 1550-1850) (Denton and Hughes, 1981) resulting in both glacier retreat and thinning (loss of ice volume). Many glaciers in the Himalayan mountain chain are reported to be gradually retreating (Mayeswki and Jeschke, 1979; Li *et al.,* 1998; Kulkarni and Bahuguna, 2002; Raina, 2004; Kulkarni and Alex, 2003; Kulkarni *et al.,* 2005; Kulkarni *et al.,* 2006). Catastrophic natural processes triggered by these glacier changes were responsible for considerable death and destruction throughout the mountains. These processes included ice avalanches, landslides and debris flows, outbursts from moraine-dammed lakes and also outbursts from glacier dammed lakes. Glacier avalanches have occurred where glaciers have retreated up steep rock slopes. Sources of debris flows are frequently moraine complexes exposed during glacier retreat, which may be ice-cored. Outbursts from moraine dammed lakes result from the catastrophic breaching of the moraine dam - a process that is commonly initiated by glacier avalanches - generated waves that overtop the moraine. Himalayan and Trans-Himalayan glaciers are in general state of retreat since 1850 AD. Most of the Himalayan glaciers are covered by debris, which slows down their melting.

Glaciers in the Himalayas are fast retreating like other ice mountains the world over. A recent study showed that the last three decades of the 20th century have been the hottest period in 1,000 years. The melting of the Gangotri glacier is accelerating at an average retreat rate of 30 meters annually. The rate between 1935 and 1990 was 18 meters per year and 7 meters annually between 1842 and 1935. The overall deglaciation from 1962 to 2001 in the Baspa basin of Himachal Pradesh has been estimated as 19%. Chhota Shigri glacier of Chandra valley also retreated by about 12% in the last one and half decade. The deglaciation processes are also noticeable for large glaciers in Ganga headwater like Gangotri which shows about 10% decrease during the last 18 years. The maximum retreat of 34.5 metres per year has been observed at Meola glacier in Dhauliganga river basin. The retreat of the Parbati glacier is reported to be unusual and more alarming.

2. An overview of Snow and Glaciers in Himachal Himalaya

Himachal Pradesh is a small hilly state that forms a part of the Western Himalayan region. The five major rivers of the Northern India viz. Beas, Chenab, Ravi, Satluj and Yamuna of the Indus and the Ganges River System either originates or passes through this Himalayan State forming the life line of the people of the Himalayan region and that of the Punjab Plains. The discharge dependability of these rivers mainly depends upon the solid precipitation available in the form of snow and glaciers in the higher reaches of the Himalayan region and the also to some extent on the liquid precipitation available in the form of monsoonal rains and the winter rains in the upper catchments. Based on the earlier studies carried out using LISS I and LISS II satellite data in Satluj basin suggests the presence of 334 glaciers in the Satluj basin. The aerial extent of the glaciers in the basin has been calculated as 1515 sq.km.. The study also shows the presence of 1987 permanent snow fields having a total area of 1182 sq.km. Thus the total area under glaciers and permanent snow fields in the Satluj basin has been calculated as 2607 sq.km. Similarly the interpretation in Chenab basin were carried out using IRS LISS III satellite data for the year 2000-01 and the results obtained from the investigation suggest the presence of 457 glaciers in the Chenab basin having total aerial extent as 1055.27 Sq.Km. The total number of permanent snow fields in this basin is 732 having total area as 245.0 Sq.Km. This makes total number of glaciers and snowfields in Chenab basin as 1189 having an aerial extent of 1300.27 Sq.Km.

The distribution of glaciers and permanent snow fields in Beas and Satluj & Chenab Basins in Himachal Himalayas :

Basin Name	No. of Glaciers	Aerial Extent (Sq.Km.)	No.of snow fields	Aerial Extent (Sq.Km.)
Beas Basin	**51**	**503.725**	**237**	**312.564**
{Parvati Sub Basin	36	450.627	131	188.188
{ Sainj Sub Basin	09	37.255	59	51.934
Satluj Basin	**151**	**616.299**	**857**	**544.173**
{ Spiti Sub Basin	71	258.237	597	368.366
Baspa Sub Basin	25	203.300	66	64.964
Chenab Basin	**457**	**1055.27**	**732**	**245.000**

3. Hazard vulnerability of the State

Mountain areas are especially vulnerable to natural disasters where development over the years has further accentuated the problem by upsetting the natural balance of various physical processes operating in the mountain eco-system. The increased pressure on the mountain environment has contributed in some measure to environmental problems such as landslides, land subsidence, removal of vegetation and soil erosion. According to one estimate, about 58.36% of the land is subjected to intense soil erosion, majority of which is located in the Himalaya. The State of Himachal Pradesh, which forms part of the Northwestern Himalaya, is environmentally fragile and ecologically vulnerable. Geologically the Himalaya is considered to be the youngest mountain chains in the world and is still in the building phase. Natural hazards are matter of immediate concern to the State of Himachal Pradesh, as every year the State experiences the fury of nature in various forms like earthquakes, landslides, cloud bursts, flash floods, snow avalanches and droughts etc. The fragile ecology of the mountain state coupled with large variations in physio-climatic conditions has rendered it vulnerable to the vagaries of nature. The incidence of cloudbursts in the last few years has baffled both the meteorologist and the common man equally. Notwithstanding, the continuous efforts made by the Government to cope with natural hazards through relief and rehabilitation measures, landslides and snow avalanches continue to inflict widespread harm and damage to human life as well as property. The roads that are the State's lifeline are repeatedly damaged, blocked or washed away by one or other acts of nature. In the circumstances, the Government has to divert the already scarce resources of the state for relief and rehabilitation measures as opposed to long term development.

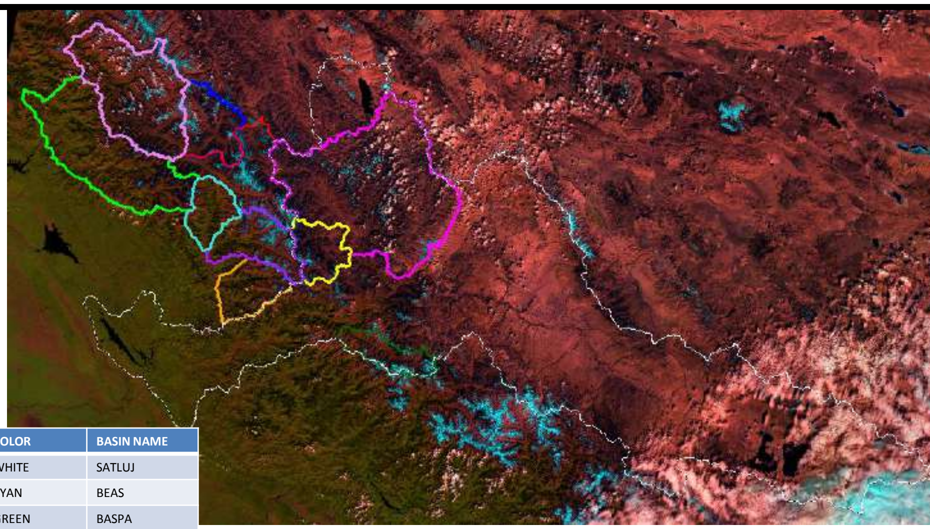
In the Himalayas, during the retreating phase a large number of lakes are being formed either at the snout of the glacier as a result of damming of the morainic material known as moraine dammed lakes or supra glacial lakes formed in the glacier surface area. A glacial lake is defined as a water mass existing in a sufficient amount and extending with a free surface in, under, beside and/or in front of a glacier and originated by glacier activities and/or retreating processes of a glacier. Most of these lakes are formed by the accumulation of vast amounts of water from the melting of snow and by blockade of end moraines located in the down valleys close to the glaciers. In addition, the lakes can also be formed due to landslides causing artificial blocks in the waterways. The sudden break of a moraine/block may generate the discharge of large volumes of water and debris from these glacial lakes and water bodies causing flash floods namely GLOF. A Glacial Lake Outburst Flood (GLOF), also known as a jökulhlaup in Icelandic (A jökulhlaup is technically a sudden and often catastrophic flood that occurs during a volcanic eruption, but is also used to describe other sorts of glacial flooding), can occur when a lake contained by a glacier or a terminal moraine dam fails. This can happen due to erosion, a buildup of water pressure, an avalanche of rock or heavy snow, an earthquake, or if a large enough portion of a glacier breaks off and massively displaces the waters in a glacial lake at its base. Many countries has a series of monitoring efforts to help prevent death and destruction that are likely to experience due to these events. The importance of this situation has magnified over the past century due to increased population, and the increasing number of glacial lakes that have developed due to glacier retreat. There are a number of GLOF events that have been reported worldwide. There are number of such events that have happened in Nepal Himalayas but no such event has been reported so far from Indian Himalayas. On the basis of earlier studies carried out in Himachal Himalayas in Satluj basin, there are about 38 such lakes in entire Satluj basin out of which 14 falls in Himachal part. Similarly 50 moraine dammed lakes in Chenab basin and 5 supra glacial lakes have been mapped using remote sensing. The state of Himachal Pradesh invariably experience flash floods, the cause of which is unknown. In the year 2000, the Satluj valley experiences the heaviest floods causing loss of more than 800 crores. It is still a matter of investigation weather the floods were caused by cloud bursting or due to Glacier Lake Outburst Floods (GLOF) phenomena. The formation of landslide dammed lakes in high altitude zones such as Parachoo in the upper catchment of Spiti basin in Tibet caused tremendous threat to the life and property located in the downstream areas. It is therefore necessary that a constant and repeated monitoring of the upper catchment areas having international dimensions required to be carried out on a regular basis.

4. Objectives of the Study

The main objectives of the study is to have an updated inventory of all the moraine dammed glacier lakes/ water bodies in the upper catchments of the Satluj , Beas, Ravi & Chenab basins in Himachal Pradesh using high resolution satellite data of LISS III.

5. Study area and data used

Satluj basin has been studied in detail right from its origin Mansarovar Lake in Tibetan Region using AWIFS and LISS III satellite for monthly temporal variation, where as the other basins viz. Chenab, Ravi, Beas have been studied for their area of interest in Himachal Himalaya only. The river Sutlej is one of the main tributaries of Indus and has its origin near Manasarowar and Rakas lakes in Tibetan plateau at an elevation of about 4,500 m (approx.). The entire Satluj basin has been divided in three sub basins viz. Spiti as sub basin number 1, Upper Tibet as 3 and Lower Satluj as sub basin number 2.Likewise the other sub basins viz. Ravi, Beas, Jiwa, parbati, Chandra, bhaga, Miyar which have been studied in detail for mapping of the moraine dammed lakes (GLOFs) are as per Fig.5.1



COLOR	BASIN NAME
WHITE	SATLUJ
CYAN	BEAS
GREEN	BASPA
YELLOW	PIN
MAZENTA	SPITI
ORANGE	JIWA
PURPLE	MIYAR
MAUVE	PARBATI
RED	CHANDRA
BLUE	BHAGA
LIGHT GREEN	RAVI

Fig. 4.1 : Different sub basins in Himachal Pradesh

6. Methodology

The LISS III satellite data having spatial resolution of 23.5mts have been used for the delineation of all the moraine dammed glacial lakes (GLOFs) in different basins viz. Chenab, Beas, Ravi and Sutlej basins. Satluj basin has been studied in detail right from its origin from Mansarovar lake in the Tibetan Himalayas. The cloud free data during the months of August-September 2013 has been used for the mapping purpose. The geometric rectification was done using polynomial transformation of third order with resulting Root Mean Square (RMS) error less than one pixel. The basin boundaries were superimposed on the satellite image and the lakes which are visible and clearly demarkable were delineated using ERDAS software. The lake boundaries were digitized using Erdas/Imagine vector module tools. The digitized polygons have been cleaned for open ends and built into a polygon layer. All the polygons have been assigned polygon ID's. Water spread area is considered to represent the boundary of lake. The flowchart explaining the methodology is given in Fig. 6.1.

Sr.No.	**Date of Pass**	**Path –Row**	**Satellite Sensor**
1	03 Sept.2013	96-48	Resourcesat2/LISS 3
2	29 July 2013	96-49	Resourcesat2/LISS 3
3	20 Sept.2013	97-48	Resourcesat2/LISS 3
4	20 Sept.2013	97-49	Resourcesat2/LISS 3
5	20 July 2012	98-48	Resourcesat2/LISS 3
6	20 July 2012	98-49	Resourcesat2/LISS 3
7	01 July 2012	99-49	Resourcesat2/LISS 3
8	09 Oct.2013	96-48	Resourcesat2/LISS 3
9	12 July2013	94-47	Resourcesat2/LISS 3
10	12 July 2013	96-48	Resourcesat2/LISS 3
11	31 July 2013	94-47	Resourcesat2/LISS 3

12	29 July2013	96-48	Resourcesat2/LISS 3
13	12 July 2013	95-48	Resourcesat2/LISS 3
14	04 Oct.2013	94-48	Resourcesat2/LISS 3

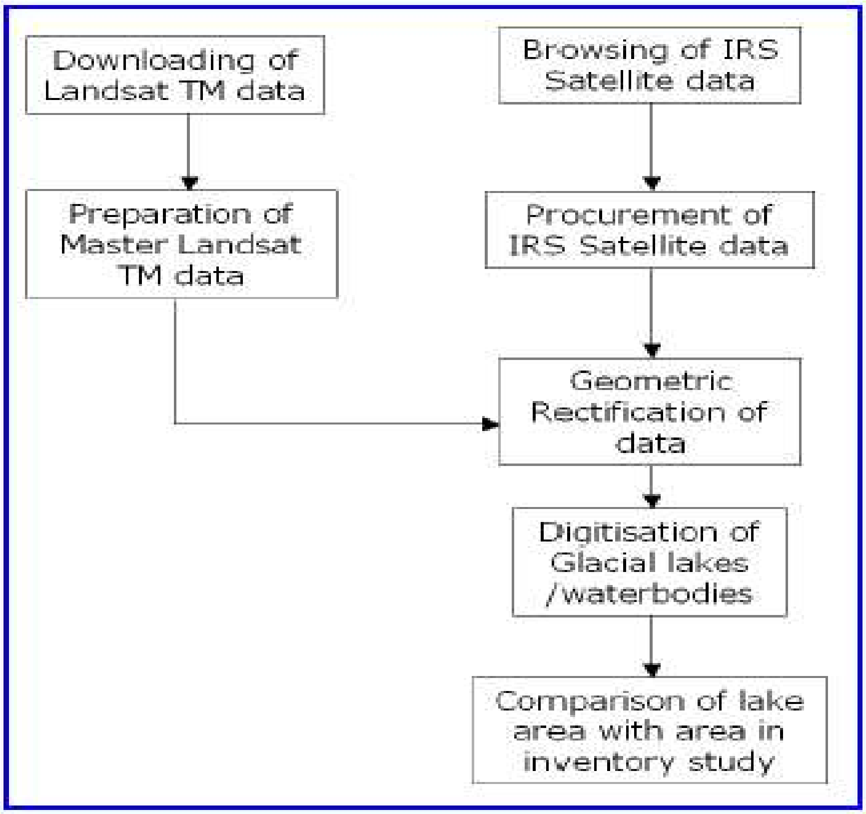


Fig 6.1: Flow Chart Methodology

7. Monitoring of Parechhu Lake during 2013

Parechhu lake which has been known for its damage and since 2001 is being monitored every year during the ablation season from April to September. This year also the lake was monitored and its status was conveyed to all the stakeholders including SJVNL

Shimla as well as the Government of Himachal Pradesh, Deputy Commissioner Kinnaur and Shimla.

7.1 Observations derived from the satellite data Analysis:

Parechhu Lake is a small geomorphic depression along the Parechhu River which joins the Spiti River on its left bank near Sumdo in Spiti Sub Division of District Lahaul & Spiti. The fragile geology of the area and the Sumdo Kurik fault passing nearby causes activation of the landslides which results in chocking of the river course in the downstream, this causes accumulation of the water in the depression. During the year 2013, the lake was regularly monitored and some of its findings along with observations are as per Fig 7.1 to Fig 7.5

Accumulated water in the depression could be seen mainly on the frontal and left side of the lake.

Inflow is quite normal in nature where as the outflow on the downstream side seems to be accumulating as some debris could be seen on the forntal side along the main stream channel.

As on day, there does not seem any perceptible threat from the Parechhu Lake, but needs proper monitoring from the accumulated water on the downstream side as the snow line is quite low and still melting will take place in the time to come.

Cartosat 1-Satellite View of Parehhu Lake as on 22 June 2013

IRS LISS III Image 05 July 2013

Observations:

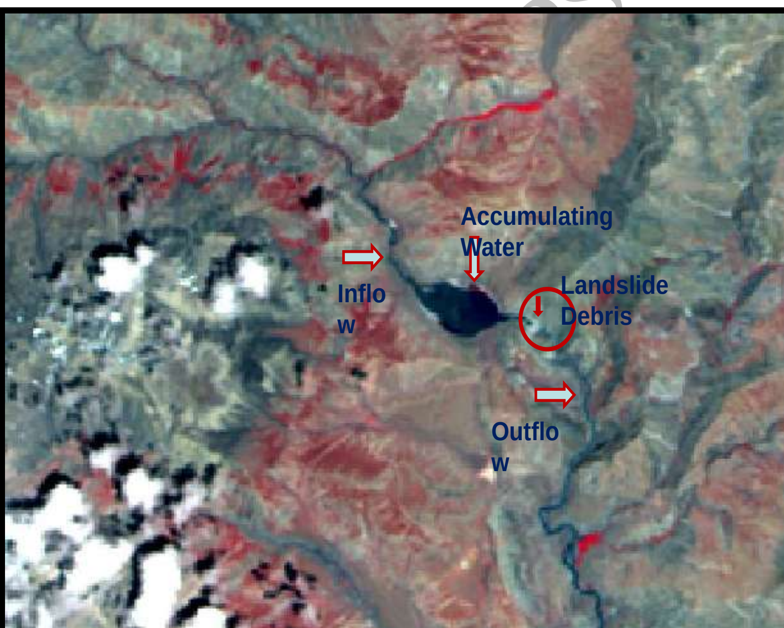
On analyzing the satellite data for 05 July 2013, it is found that the accumulated water as on 22 June 2013 has been released as a result the inflow and outflow seems normal. However, it is seen that outflow is overtopping the debris cover as encircled and would be monitored in the next image.

Satellite View of Parechhu Lake as on 5 July 2013

Parechhu lake was verified using LISS 4 data of 29 July 2013 which has spatial resolution of 5.8 mts, indicates that the water spread is mainly on the downstream side of the lake and accumulated water could be clearly seen in the image. The tonal difference between two in encircled portions indicates the extent of accumulated water along the river course. Water on the top seems to be quite shallow in nature, where as in the middle portion isolated patches could be seen. As a whole the lake seems to be stable and thus seems no threat as on day.

Observations: Based on the analysis of the Parechhu lake on satellite data for IRS –RS2-LISS 3-96-48-03 September 2013, the following observations were made:

1. Most of the lake depression as on 3rd September 2013, remains free from accumulated water.
2. The accumulated water is mostly on the frontal side of the lake and on the extreme right corner on the top. The central part seems to be free from the accumulated water.
3. The input and output seems to normal.
4. No fresh debris could be seen on the river course on the downstream side.
5. As on day, there does not seem to be any threat from the accumulated water in the lake.



Satellite view of Parechhu Lake as on 15 July 2013 through IRS AWIFS

On analyzing the AWIFS satellite data for 15 July 2013, it is found that there is a slight increase in the accumulated water in the Parechhu depression i.e lake area in comparison to 5 July 2013. In flow seems to be normal, but the outflow seems to be obstructed due to landslide debris. Slight back water in inflow side could also be seen , but needs further monitoring using high resolution data product.

Fig 7.1-7.5

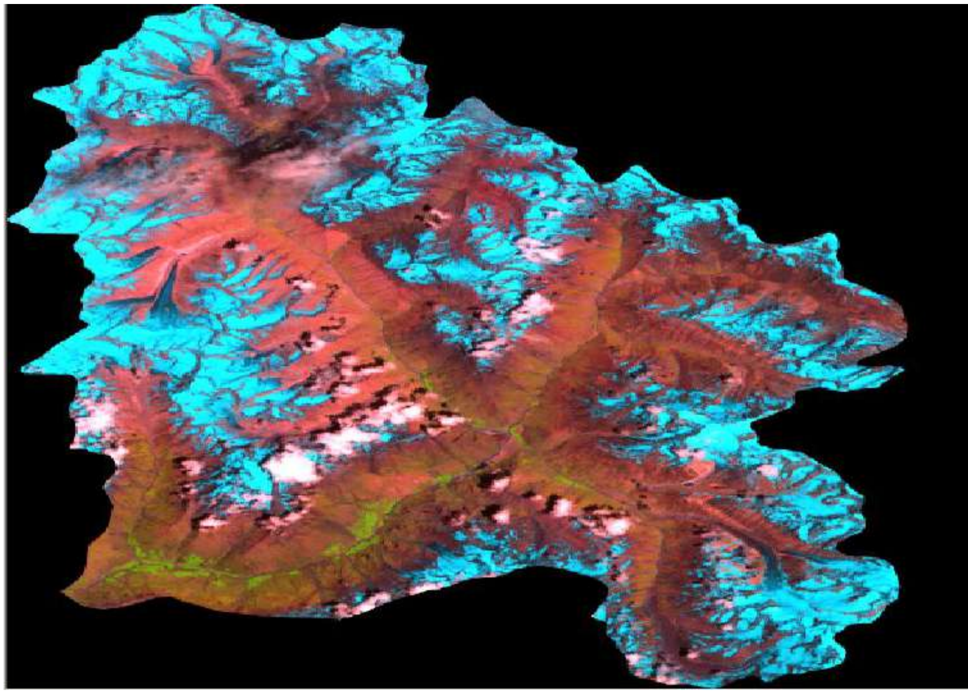
8. LISS III Based inventory of moraine dammed lakes in Chenab (Chandra, Bhaga & Miyar Sub basins) Beas, Ravi & Satluj Basins in Himachal Pradesh.

8.1 Inventory of lakes in Chenab Basin

Chenab basin is one of the major river basin which originates from Himachal Himalaya near Baralacha Pass. Two river viz. Chandra and Bhaga originates from this place and flows in opposite direction before they confluence each other at a place known as Tandi near Keylang. Besides this, another major subbasin i.e. Miyar Sub basin has been studied in detail for having an updated inventory of moraine dammed lakes in the catchment.

8.1.1 Inventory of lakes in Bhaga Sub Basin

In Bhaga sub basin a total of 14 lakes on 12 July 2013 could be delineated from the LISS III satellite image which has the spatial resolution of 24mts. Out of these 14 lakes, 01 lake is such which have the area more than 10 hectares, 03 lakes with area between 5-10 hectare and 10 lakes are such have the aerial range less than 5 hectare. In other words we can say that the lakes with area more than 5 hectare needs proper monitoring in order to avoid any eventuality in the time to come (Fig 8.1.1 & Table 8.1.1).



IRS- RS2 –LISS III- 94-47-12 July2013 Satellite Image of Bhaga Sub Basin, District Lahaul & Spiti

Lake Inventory in Bhaga Basin based on IRS- RS2 –LISS III- 94-47-12 July2013 satellite data

Fig.8.1.1

Table 8.1.1 : Aerial extent of lakes in Bhaga Sub Basin

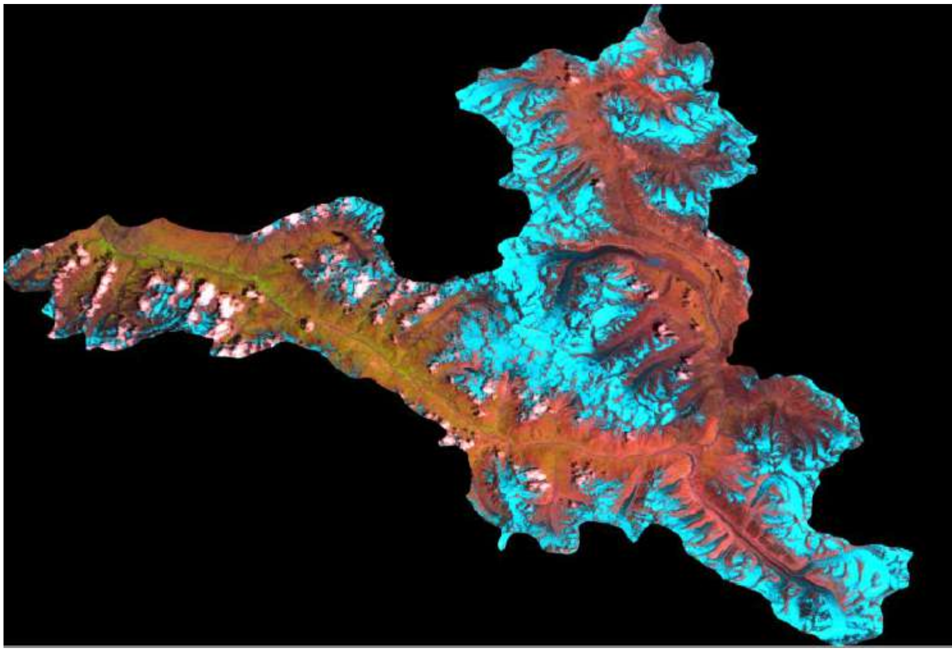
Sr.No.	Name of the Basin	Lake id Number	Longitude	Latitude	Area(hectare)
1	Chenab	1	77.1745593	32.87162664	3.86
2	Chenab	2	77.2807145	32.84446095	4.87
3	Chenab	3	77.3984325	32.76198871	6.71
4	Chenab	4	77.3941138	32.75613763	0.06
5	Chenab	5	77.3274864	32.76424885	0.084
6	Chenab	6	77.3293854	32.72257279	7.73
7	Chenab	7	77.3427941	32.70723298	2.49
8	Chenab	8	77.3474776	32.70524413	5.13
9	Chenab	9	77.2698482	32.67824708	2.23
10	Chenab	10	77.3190177	32.63585247	0.081
11	Chenab	11	77.3062891	32.6302067	10.2
12	Chenab	12	77.2749456	32.58656408	1.38
13	Chenab	13	77.0162965	32.71299986	1.51
14	Chenab	14	77.3043393	32.49360735	0.059

8.1.2 Inventory of lakes in Chandra Sub Basin

In Chandra sub basin a total of 19 lakes were mapped from the satellite image of 12 July 2013 with spatial resolution of 24mts. The aerial distribution of these 19 lakes indicates that the lake with id number 1 and 3 are such which have the area of 80.12 hectare and 146.31 hectare respectively (Fig 8.1.2.1 a & b). These two lakes appears to be highly vulnerable especially the lake with id number 1 which seems to be quite deep in nature and have been studied by Geological Survey of India in detail. The other lake with id number 3 although appears to have larger aerial extent but seems to be shallow in nature. Thus as a whole there are 02 lakes which have the area more than 10 hectares , 02 lakes with aerial range between 5-10 hectares and 15 lakes are such which have the area less than 5 hectare (Fig 8.1.2.2 & Table 8.1.2).

Fig.8.1.2a

Fig.8.1.2b



IRS- RS2 –LISS III- 96-46- 12 July2013 Satellite Image of Chandra Sub Basin, District Lahaul & Spiti

Lake Inventory in Chandra Sub Basin based on IRS- RS2 – LISS III- 96-48-12 July2013 satellite data

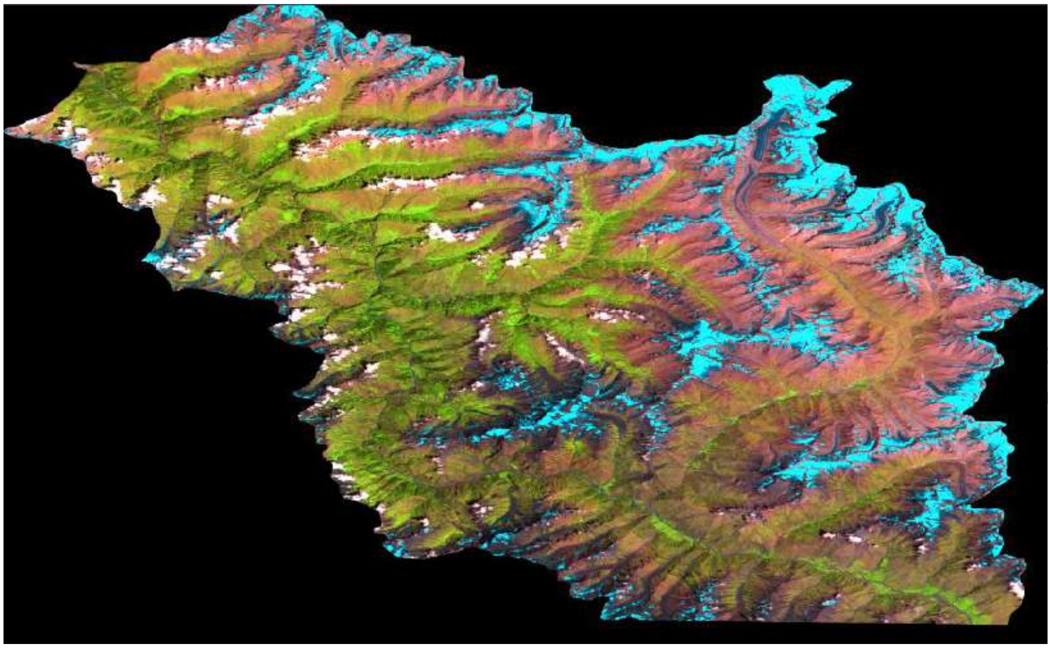
Fig. 8.1.2.2

Table 8.1.2 : Aerial extent of lakes in Chandra Sub Basin

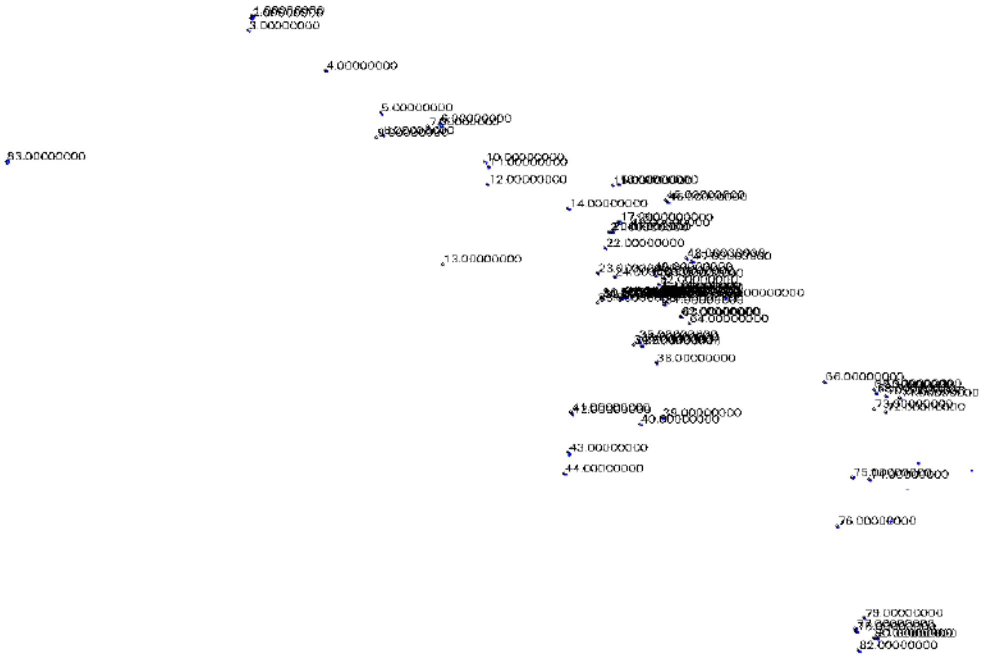
Sr.No.	Name of the Basin	Lake id Number	Longitude	Latitude	Area(hectare)
1	Chenab	1	77.22262	32.524214	80.12
2	Chenab	2	77.565094	32.394302	1.72
3	Chenab	3	77.546984	32.499906	146.31
4	Chenab	4	77.363287	32.692432	0.091
5	Chenab	5	77.366673	32.692794	1.71
6	Chenab	6	77.617488	32.60403	5
7	Chenab	7	77.546233	32.582586	0.08
8	Chenab	8	77.714457	32.343178	1.61
9	Chenab	9	77.724844	32.325992	0.043
10	Chenab	10	77.646349	32.196528	0.91
11	Chenab	11	77.646723	32.199249	0.032
12	Chenab	12	77.64305	32.201527	0.038
13	Chenab	13	77.636043	32.207242	0.063
14	Chenab	14	77.627676	32.21486	1.53
15	Chenab	13	77.625432	32.216085	0.032
16	Chenab	14	77.642234	32.204248	0.043
17	Chenab	13	77.594763	32.24741	1.3
18	Chenab	14	77.449309	32.24037	3.24
19	Chenab	13	77.447949	32.245131	7.44

8.1.3 Inventory of lakes in Miyar Sub Basin:

In Miyar sub basin a total of 83 were mapped from the satellite image of 12 July 2013 with spatial resolution of 24mts. Out of these 83 lakes, 03 lakes with aerial range between 5-10 hectares, and 80 lakes with area less than 5 hectares. The higher frequency of smaller lakes indicates that in this basin the impact of climatic variations is more pronounced in the formation of moraine dammed lakes (GLOFs) in the region (Fig 8.1.3 & Table 8.1.3).



IRS- RS2 –LISS III- 94-47- 31 July2013 Satellite Image of Miyar Sub Basin, District Lahaul & Spiti



Lake Inventory in Miyar Sub Basin based on IRS- RS2 –LISS III- 94-47-12 July2013 satellite data

Fig 8.1.3

Table 8.1.3 : Aerial extent of lakes in Miyar Sub Basin

Sr.No.	Name of the Basin	Lake id Number	Longitude	Latitude	Area(hectare)
1	Chenab	1	76.36302955	33.3112585	2.9
2	Chenab	2	76.36224956	33.3088071	2.88
3	Chenab	3	76.3590276	33.2976071	0.089
4	Chenab	4	76.43487373	33.2629667	2.08
5	Chenab	5	76.48869165	33.2261666	1.82
6	Chenab	6	76.54622414	33.216837	8.33
7	Chenab	7	76.53461292	33.2140651	0.073
8	Chenab	8	76.49061865	33.2066595	0.049
9	Chenab	9	76.48450955	33.2043741	0.042
10	Chenab	10	76.5903798	33.1831634	0.066
11	Chenab	11	76.59331138	33.1791124	1.92
12	Chenab	12	76.59304487	33.1639215	0.061
13	Chenab	13	76.54896457	33.0942032	0.049
14	Chenab	14	76.67161121	33.1427076	1.76
15	Chenab	13	76.71467878	33.1629621	0.076
16	Chenab	14	76.72064854	33.163655	0.053
17	Chenab	13	76.72086175	33.1311944	4.52
18	Chenab	14	76.73557295	33.1305548	0.084
19	Chenab	13	76.73226826	33.1261841	0.047
20	Chenab	20	76.71393256	33.1227728	2.57
21	Chenab	21	76.71116089	33.1223464	1.81
22	Chenab	22	76.70740383	33.1082552	0.03
23	Chenab	23	76.69997506	33.0862604	2.31
24	Chenab	24	76.71638069	33.0833653	0.097
25	Chenab	25	76.72860449	33.0656729	1.55
26	Chenab	26	76.72699609	33.066638	0.053
27	Chenab	27	76.72442266	33.0651904	1.03
28	Chenab	28	76.72297511	33.063582	0.082
29	Chenab	29	76.72152755	33.0655121	1.7
30	Chenab	30	76.70411668	33.0651904	0.048
31	Chenab	31	76.70387542	33.0642656	0.054
32	Chenab	32	76.70576528	33.0637429	0.098
33	Chenab	33	76.69985443	33.0606869	0.085
34	Chenab	34	76.73471639	33.0238547	0.054
35	Chenab	35	76.73986325	33.0283582	2.66
36	Chenab	36	76.74106955	33.0262673	2.32
37	Chenab	37	76.74308004	33.0232113	3.03
38	Chenab	38	76.75699265	33.008012	2.16
39	Chenab	39	76.76270245	32.9602427	1.16

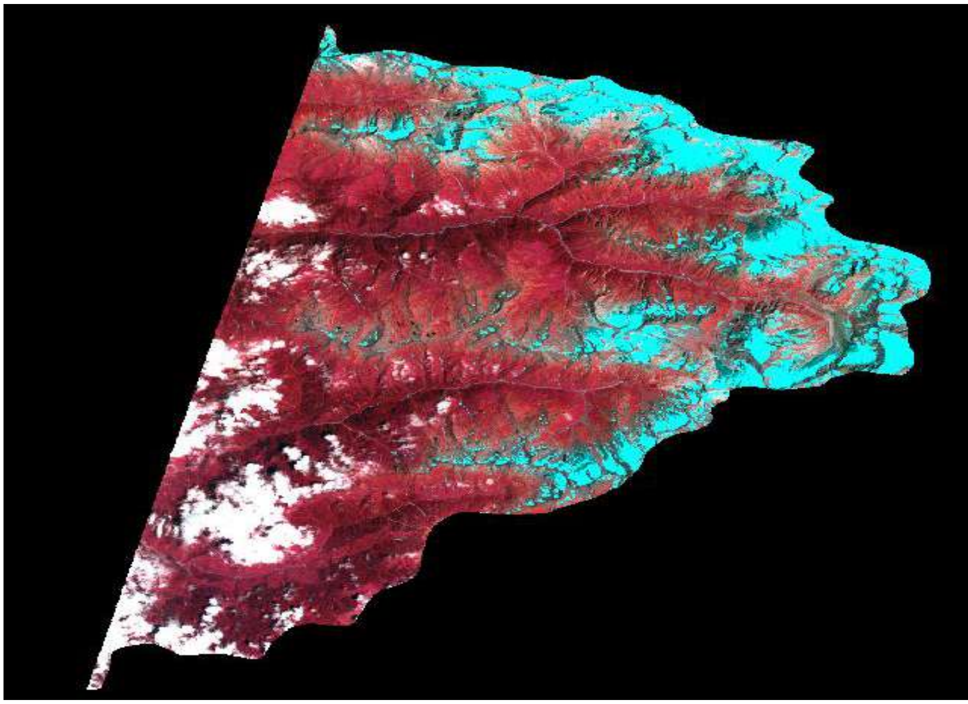
40	Chenab	40	76.74131081	32.9546133	0.073
41	Chenab	41	76.67432117	32.9649874	0.054
42	Chenab	42	76.6748841	32.9632182	1.92
43	Chenab	43	76.67174774	32.9297636	5.91
44	Chenab	44	76.66748549	32.911649	1
45	Chenab	45	76.76640176	33.1503549	2.82
46	Chenab	46	76.76841226	33.1486661	1.7
47	Chenab	47	76.79245776	33.0968758	1.94
48	Chenab	48	76.78618502	33.0994492	1.57
49	Chenab	49	76.75441922	33.0873863	0.042
50	Chenab	50	76.75610804	33.0840891	0.054
51	Chenab	51	76.76519547	33.0817569	0.048
52	Chenab	52	76.75924441	33.0767709	1.62
53	Chenab	53	76.76238078	33.070659	0.057
54	Chenab	54	76.76390875	33.0704177	0.067
55	Chenab	55	76.76181784	33.0680855	0.061
56	Chenab	56	76.75956609	33.0668792	0.048
57	Chenab	57	76.76181784	33.0662359	0.061
58	Chenab	58	76.76467274	33.0670401	1.45
59	Chenab	59	76.76346644	33.0639037	0.079
60	Chenab	60	76.76515526	33.0614107	0.042
61	Chenab	61	76.76535631	33.0589981	0.053
62	Chenab	62	76.78056833	33.0485679	0.051
63	Chenab	63	76.78188045	33.0480758	0.046
64	Chenab	64	76.78899865	33.0423025	0.077
65	Chenab	65	76.82399922	33.0649365	1.87
66	Chenab	66	76.92109547	32.991327	1.08
67	Chenab	67	76.96859391	32.9847664	1.81
68	Chenab	68	76.97108692	32.9812237	0.073
69	Chenab	69	76.97725384	32.9852257	0.055
70	Chenab	70	76.98073094	32.9789276	0.03
71	Chenab	71	76.99418008	32.977353	0.042
72	Chenab	72	76.98014049	32.9650848	0.03
73	Chenab	73	76.96885633	32.967381	0.042
74	Chenab	74	76.96439515	32.9060398	2.07
75	Chenab	75	76.94786254	32.9078767	1.94
76	Chenab	76	76.93264205	32.8654955	2.96
77	Chenab	77	76.95035556	32.7756979	3.99
78	Chenab	78	76.95140524	32.7736641	2.42
79	Chenab	79	76.9583813	32.7852162	1.84
80	Chenab	80	76.9678757	32.7678307	0.084
81	Chenab	81	76.97127568	32.7674117	2.28
82	Chenab	82	76.9530599	32.7569164	2.88
83	Chenab	83	76.12366773	33.1826199	8.56

8.2 Inventory of lakes in Beas Basin:

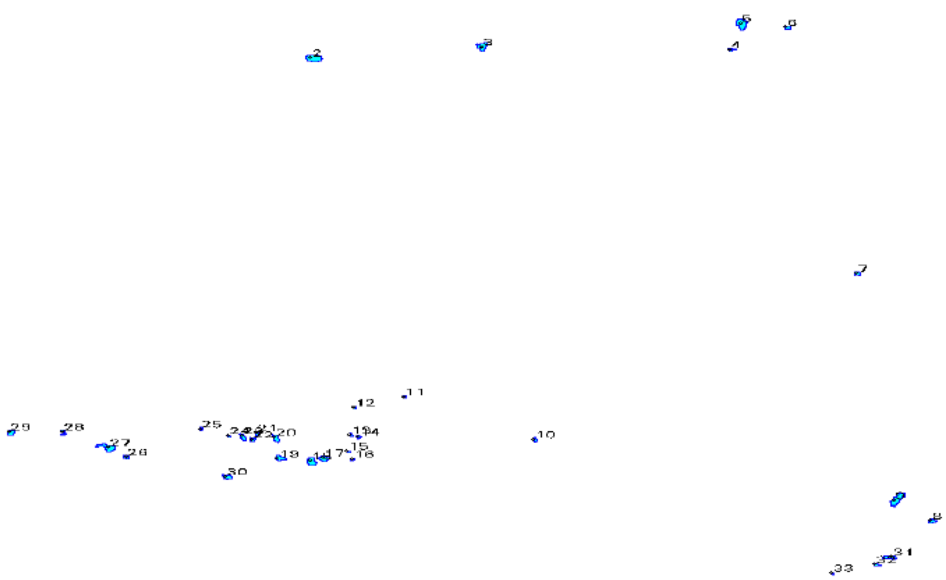
Beas is another major river in Himachal Pradesh which originates from Rohtang area in Kullu district. Beas Basin has been divided into three sub basins i.e. Jiwa, Parbati and the Beas its own basin in Himachal Pradesh. Since the Beas basin falls in the transition zone, so the effect due to the climatic variations seems to be more pronounced which could be seen in the snow and glaciated regions of the state.

8.2.1 Inventory of lakes in Jiwa sub basin:

Jiwa sub basin which falls on the southeastern part of the Beas River and comprises of the Jiwa and Sainj as two major tributaries of the Beas basin. On analyzing the satellite data of 29 July 2013 having spatial resolution of 24 meters, a total of 39 lakes could be mapped in the basin. Out of these 39 lakes, 2 lakes are such which have the area between 5-10 hectares and 37 lakes are having are less than 5 hectares (Fig 8.2.1 &Table 8.2.1).



IRS- RS2 –LISS III- 96-48- 29 July2013 Satellite Image of Jiwa Sub Basin, District Kullu



Lake Inventory in Jiwa Sub Basin based on IRS- RS2 –LISS III- 96-48-29 July2013 satellite data

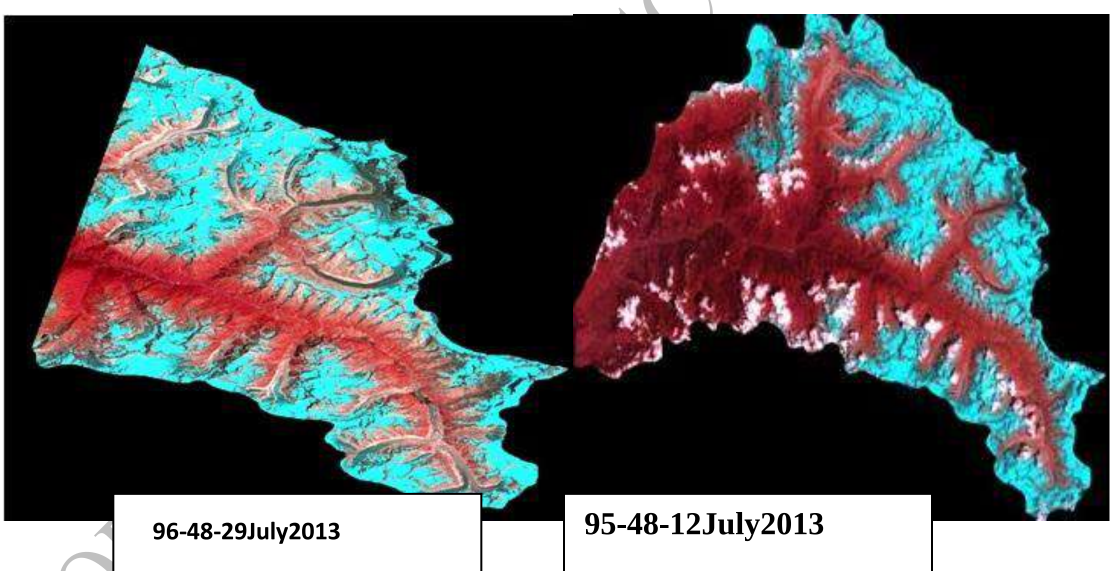
Fig 8.2.1

Table 8.2.1 : Aerial extent of lakes in Jiwa Sub Basin

Sr.No.	Name of the Basin	Lake id Number	Longitude	Latitude	Area(hectare)
1	Beas	1	77.54003192	31.879863	1
2	Beas	2	77.5612502	31.84167	4.05
3	Beas	3	77.59271178	31.844597	2.9
4	Beas	4	77.63829448	31.843865	0.067
5	Beas	5	77.64034314	31.850889	4.58
6	Beas	6	77.64875728	31.849865	0.085
7	Beas	7	77.66163458	31.783283	1.07
8	Beas	8	77.67531671	31.716263	1.24
9	Beas	9	77.66851223	31.721823	5.07
10	Beas	10	77.60229658	31.738286	0.05
11	Beas	11	77.57837115	31.749919	0.033
12	Beas	12	77.56915218	31.746919	0.028
13	Beas	13	77.56842051	31.73953	0.034
14	Beas	14	77.56995701	31.739091	0.049
15	Beas	13	77.56790835	31.73514	0.028
16	Beas	14	77.56893268	31.733018	0.038
17	Beas	13	77.56344519	31.733384	2.06
18	Beas	14	77.56117703	31.732506	2.62
19	Beas	13	77.55517738	31.733164	2.3
20	Beas	20	77.55459205	31.738944	1.92
21	Beas	21	77.55115323	31.740115	0.04
22	Beas	22	77.55042156	31.738286	0.095
23	Beas	23	77.5485924	31.739383	1.38
24	Beas	24	77.54610474	31.739383	0.039
25	Beas	25	77.54090992	31.741139	0.05
26	Beas	26	77.52730096	31.73353	1.23
27	Beas	27	77.52408164	31.736164	3.34
28	Beas	28	77.51559433	31.740408	0.089
29	Beas	29	77.50579002	31.740408	1.17
30	Beas	30	77.54559258	31.728262	1.35
31	Beas	31	77.6681464	31.706458	1.3
32	Beas	32	77.66492707	31.704483	0.059
33	Beas	33	77.65709826	31.702142	0.021
34	Beas	34	77.61802737	31.665046	6.07
35	Beas	35	77.59856509	31.668704	0.094
36	Beas	36	77.59710176	31.668119	1.02
37	Beas	37	77.58993145	31.667973	4.32
38	Beas	38	77.56417686	31.675582	3.13
39	Beas	39	77.60983273	31.65612	1.22

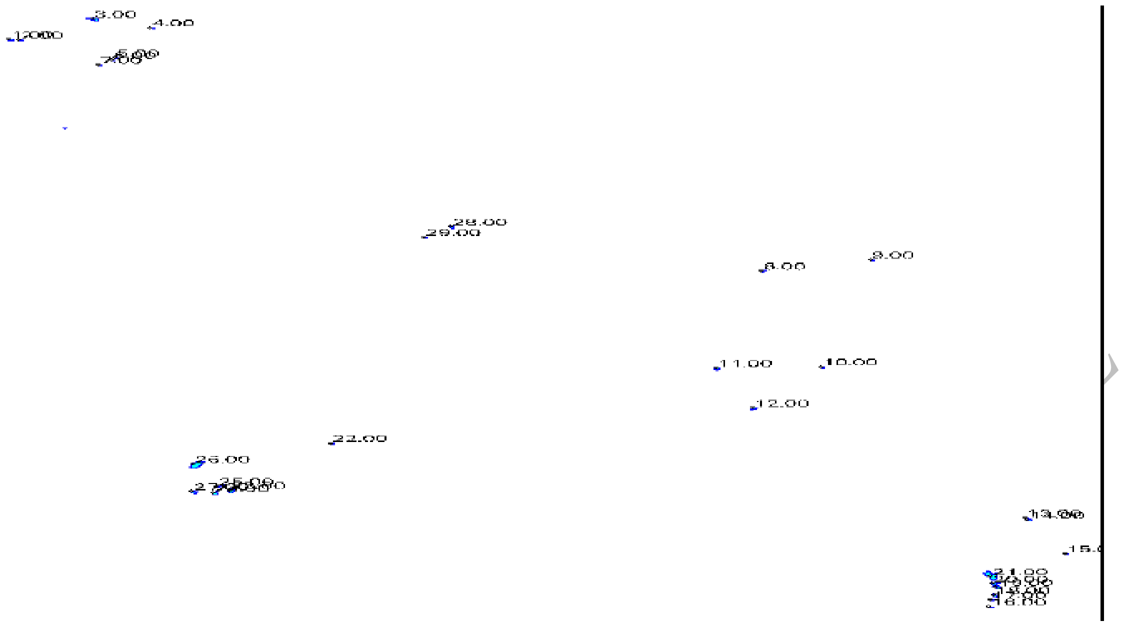
8.2.2 Inventory of lakes in Parbati sub basin:

Parbati is another major tributary of Beas Basin that joins the Beas River on its left bank near Bhuntar in Kullu district. On analyzing the LISS III image of 29 July 2013, a total of 28 lakes were mapped. Out of these 28 lakes, 2 lakes with id No. 21 and 26 are larger lakes i.e. with are more than 10 hectares. Besides this 26 lakes are having area less than 5 hectare respectively (Fig 8.2.2 & Table 8.2.2).



IRS- RS2 –LISS III- 96-48- 29 July2013 Satellite Image of Parbati Sub Basin, District Kullu

Fig 8.2.2.



Lake Inventory in Parbati Sub Basin based on IRS- RS2 – LISS III- 96-48-29 July2013 satellite data

Fig. 8.2.2

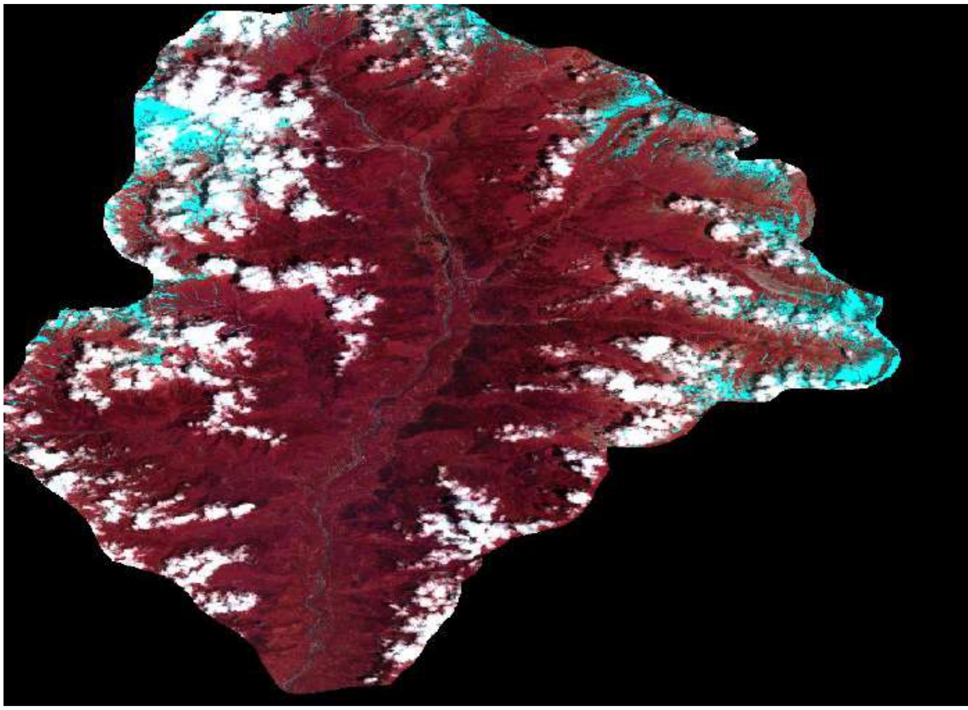
Table 8.2.2 : Aerial extent of lakes in Parbati Sub Basin

Sr.No.	Name of the Basin	Lake id Number	Longitude	Latitude	Area(hectare)
1	Beas	1	77.46929	32.167795	0.083
2	Beas	2	77.49367	32.180207	0.09
3	Beas	3	77.51293	32.174958	4.35
4	Beas	4	77.50125	32.157064	0.078
5	Beas	5	77.50003	32.155655	0.054
6	Beas	6	77.49555	32.152897	0.035
7	Beas	7	77.71525	32.029475	0.03
8	Beas	8	77.7511	32.035971	0.078
9	Beas	9	77.73474	31.971993	0.051
10	Beas	10	77.69993	31.971258	0.094
11	Beas	11	77.71214	31.947384	1.71
12	Beas	12	77.80202	31.881459	1.29
13	Beas	13	77.80296	31.88026	0.055
14	Beas	14	77.81516	31.860151	0.082
15	Beas	13	77.79017	31.828308	0.046

16	Beas	14	77.79037	31.832565	0.038
17	Beas	13	77.79148	31.83525	0.038
18	Beas	14	77.7924	31.839834	1.94
19	Beas	13	77.79083	31.841995	1.74
20	Beas	20	77.7907	31.846317	4.72
21	Beas	21	77.57269	31.926278	13.58
22	Beas	22	77.53903	31.898118	0.089
23	Beas	23	77.53366	31.896677	3.42
24	Beas	24	77.5351	31.900476	2.18
25	Beas	25	77.52724	31.913835	1.25
26	Beas	26	77.52689	31.897405	13.08
27	Beas	27	77.6123	32.055845	2.59
28	Beas	28	77.60353	32.049678	2.12

8.2.3 Inventory of lakes in Beas Basin:

On analyzing the LISS III image of 12 July 2013 for the area falling in the Beas river basin, it has been found that most of the catchment on the higher reaches is under the impact of the cloud cover as a result of which delineation was not possible (Fig 8.2.3).

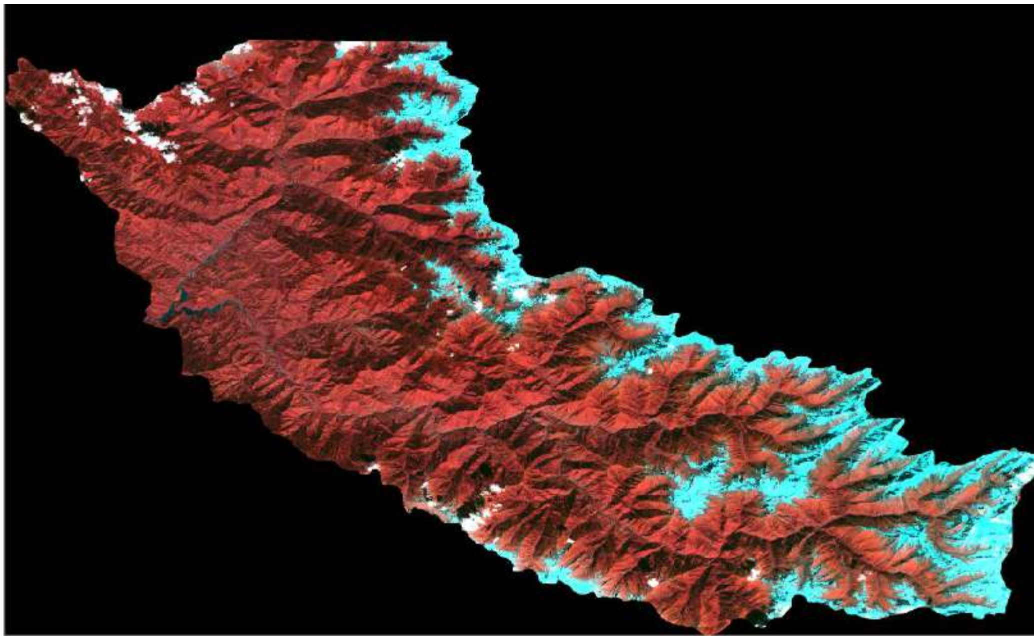


IRS- RS2 –LISS III- 95-48- 12 July 2013 Satellite Image of Beas Sub Basin, District Kullu

Fig 8.2.3

8.3 Inventory of lakes in Ravi Basin:

Ravi is another major river that originates from Himachal Himalaya in Bara Bhangal area of Kangra district beyond which it enters the Chamba district. On analyzing the LISS III satellite image of 04 October 2013, a total of 22 lakes have been delineated in the entire basin. Since the analysis has been carried out with the image acquired in the month of October, so the impact of fresh snow fall could be clearly seen in the image as a result of which total glaciated area is not fully exposed and thus the complete picture for the delineation of lakes could not be achieved. Besides this, out of these 22 lakes, few lakes that have been mapped along the Dhauldhar range are not formed because of the damming of the moronic material but these exists along the depressions on the higher reaches and are naturally formed one. The 22 lakes thus mapped include 2 lakes with area more than 10 hectare, 01 falling within the aerial range of 5-10 hectares and 19 lakes are such which have the area less than 5 hectare (Fig 8.3. Table 8.3.)



IRS- RS2 –LISS III- 94-48- 04 October 2013 Satellite Image of Ravi Sub Basin, District Chamba

Lake Inventory in Ravi Sub Basin based on IRS- RS2 –LISS III- 94-48-04 October 2013 satellite data

Fig.8.3

Table 8.3 : Aerial extent of lakes in Ravi Basin

Sr.No.	Name of the Basin	Lake id Number	Longitude	Latitude	Area(hectare)
1	Ravi	1	76.59598488	32.397168	2.52
2	Ravi	2	76.63724418	32.3951	0.082
3	Ravi	3	77.01332294	32.335901	0.092
4	Ravi	4	76.96729216	32.263072	1.17
5	Ravi	5	77.01377882	32.231897	0.063
6	Ravi	6	77.02435473	32.227161	1.17
7	Ravi	7	77.03058978	32.216822	1.69
8	Ravi	8	76.89985583	32.213134	1.29
9	Ravi	9	76.82014172	32.223458	0.088
10	Ravi	10	76.78714141	32.24453	14.87
11	Ravi	11	76.5360866	32.234172	4.3
12	Ravi	12	76.500869	32.237279	7.09
13	Ravi	13	76.48856874	32.269001	2.79
14	Ravi	14	76.3557259	32.335681	2.52
15	Ravi	13	76.34497936	32.331797	3.57
16	Ravi	14	76.33073695	32.337624	33.51
17	Ravi	13	76.3260758	32.342673	2.69
18	Ravi	14	76.31597663	32.342544	4.57
19	Ravi	13	76.31170391	32.344227	1.62
20	Ravi	20	76.30497114	32.345263	3.34
21	Ravi	21	76.30173422	32.346557	0.096
22	Ravi	22	76.9219806	32.296364	1.04

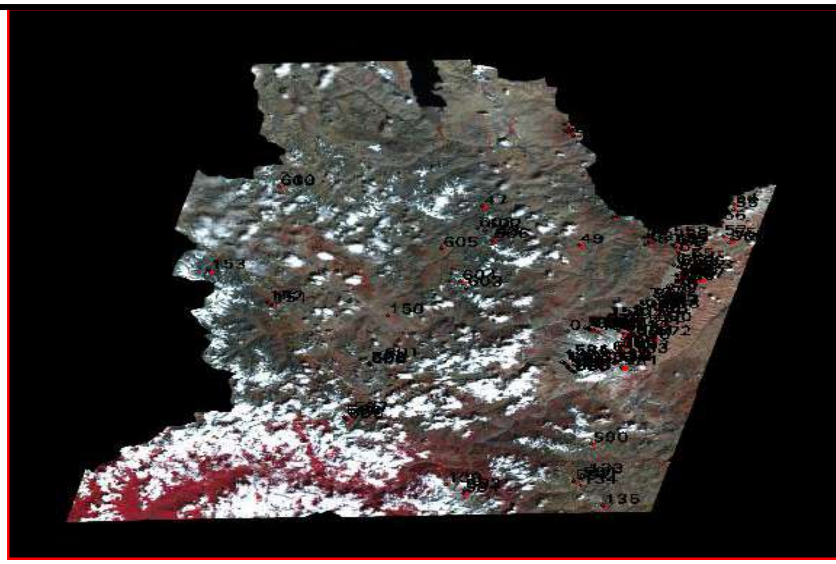
8.4 Inventory of lakes in Satluj basin:

Using IRS LISS III Resourcesat 2 satellite data for the period September & October 2013 & 2012, the inventory of all the moraine dammed lakes and the water bodies was prepared to have an updated inventory in the Satluj River Basin as this sensor has the spatial resolution of 23,5mt which will give more information about the terrain (Fig.9.1-9.8). Using visual interpretation techniques and the same methodology adopted for the AWIFS satellite data, a total of 391 moraine dammed lakes /water bodies have been delineated from the satellite data (Fig 8.4.1a,b to 8.4.6 ab & Table 8.4). Further analysis reveals that out of these 391 lakes delineated, 150 lakes forms a part of the 96-48 path row of the satellite image of 03 September 2013 which includes 76 lakes in sub basin 1 i.e. Spiti Sub Basin, 10 lakes in the Lowe Satluj Basin and 64 lakes in the Upper Satluj Basin respectively. Likewise a total of 43 lakes were delineated in 96-49 path row of 29 July 2013 which includes 41 lakes in Lower Satluj Basin and 1 lake in the Upper Satluj Basin. 97-48 path row of 20 September 2013 includes total 45 lakes which comprises of 5 lakes in Lower Satluj Basin and 40 lakes in Upper Satluj basin. 98-48 path row of 20 July 2012 and 99-49 of 01 July 2012 comprises of total 12 and 118 lakes respectively which all forms a part of the Upper Satluj Basin. As far as the lakes with area more than 10 ha are concerned, it includes a total 9 lakes in 96-48, 4 lakes in 96-49, 5 lakes in 97-48, 2 lakes in 97-49, 4 lakes in 98-48 and 16 lakes in 99-49 path row respectively in the entire Satluj basin which are clearly visible as per the satellite image.

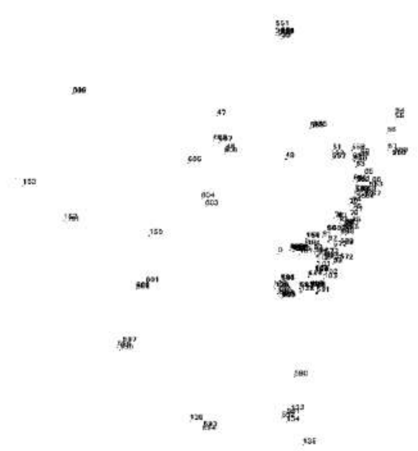
On further analyzing the 391 lakes mapped in the entire Satluj basin using LISS 3 satellite data, although most of these lakes are of small dimensions i.e having area less than 5ha (276), which may be due to the fact the LISS III sensor has the better resolution (23.5mts) than the AWIFS (56mts) which enables to more features coverage in a unit pixel. Besides this there are 75 lakes are such which have their area between 5-10ha based on the LISS III mapping. Hence these small dimensional lakes/water bodies can be future vulnerable sites and thus needs proper monitoring after regular intervals in order to avoid any eventuality in future.

It is further analyzed that while analyzing the LISS III images, it was observed that at 30.63 to 30.90 North Latitude and 81.09 to 81.18 East Longitude along the Satluj River on the downstream of the Rakas Tal and the Mansarovar lake, accumulated water could also be seen on the main river course, the approximate length of which is 3295mts and 2649.83mts respectively during

2013 . This accumulated water has also been mapped during the year 2013 also in the AWIFS as well as in LISS 3 images and thus seems to be regular phenomena along the Satluj River.

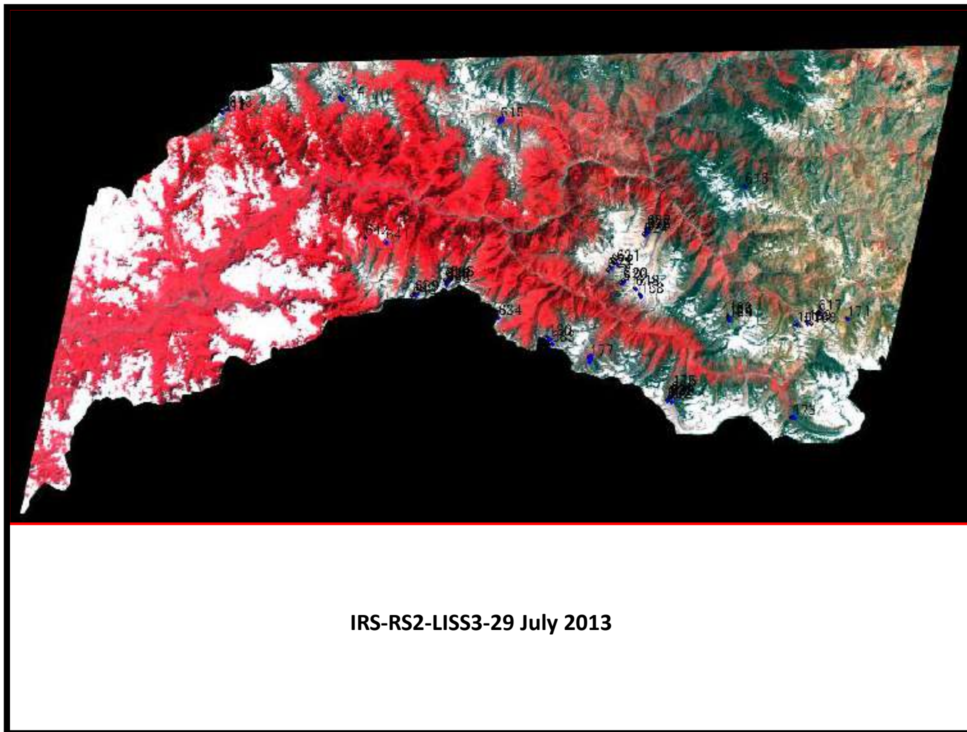


IRS-RS2-LISS3-03 Sept 2013



96-48-03 Sept 2013

Fig.8.4.1 a&b: Resourcesat-2 LISS III image 96-48 , 03 Sept.2013 & the Interpreted layer



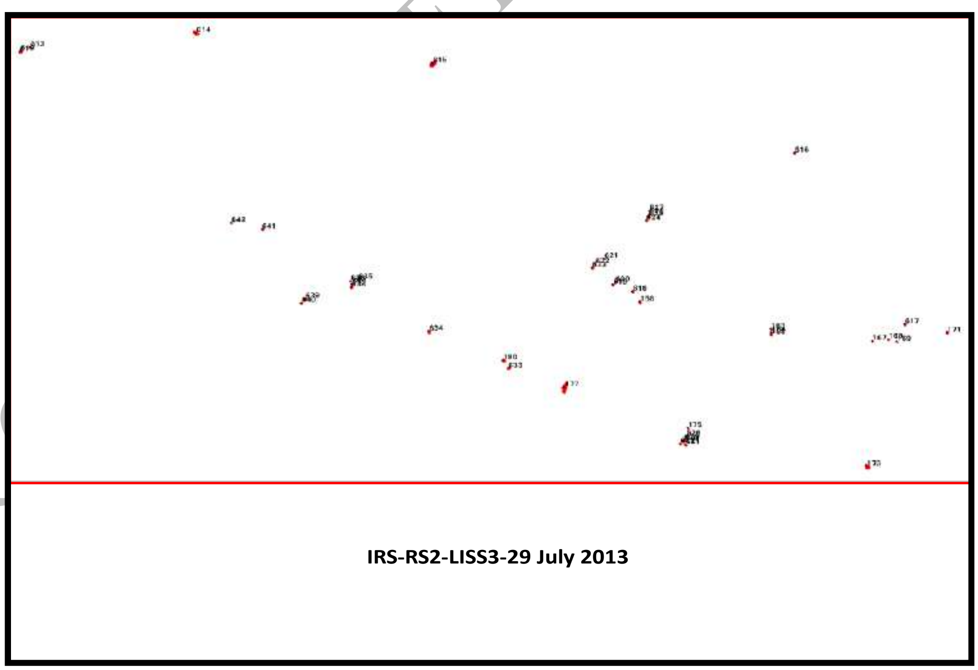
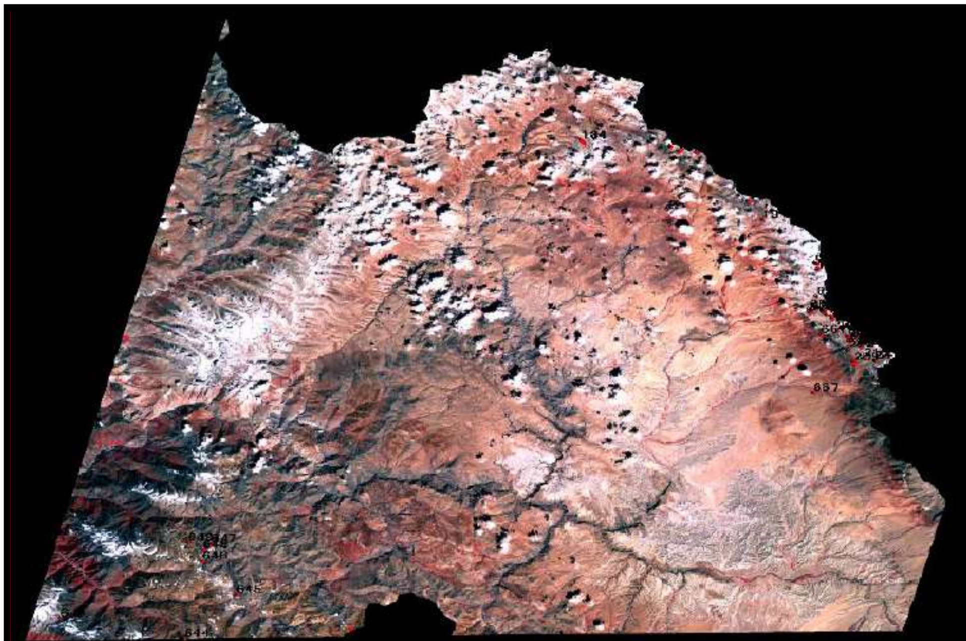
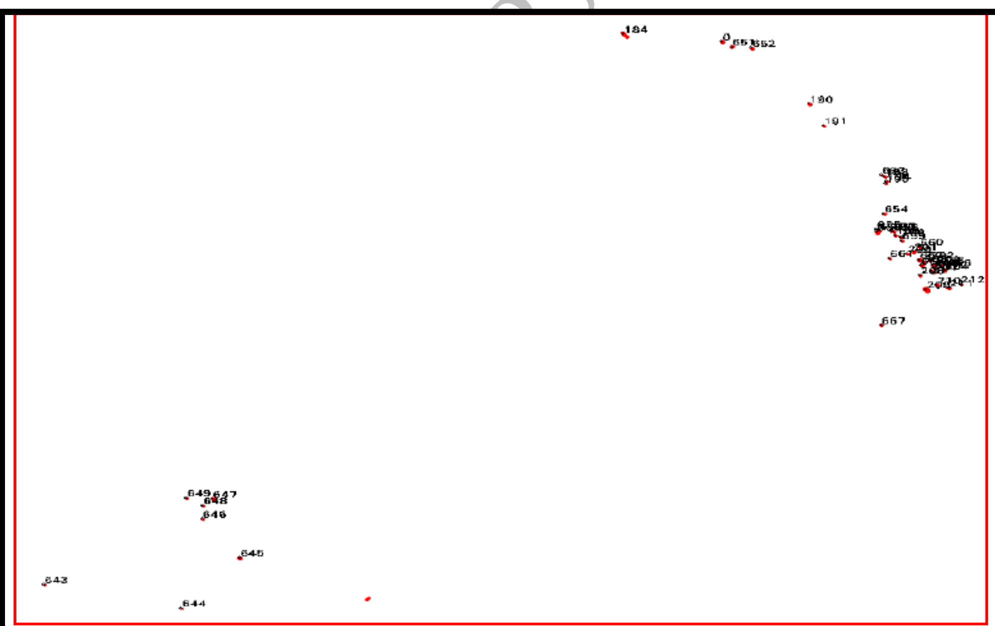


Fig.8.4.2 a&b: Resourcesat-2 LISS III image 96-49 , 29 July 2013 & the Interpreted layer



IRS-RS2-LISS3-20 Sept 2013



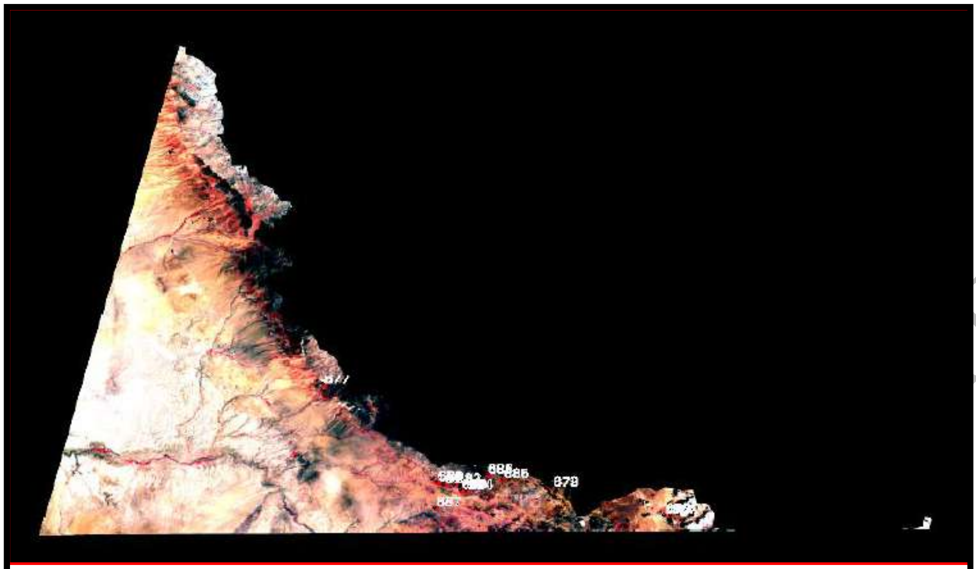
IRS-RS2-LISS3 97 48-20 Sept 2013

Fig.8.4.3 a&b: Resourcesat-2 LISS III image 97-48 , 20 Sept.2013 & the Interpreted layer

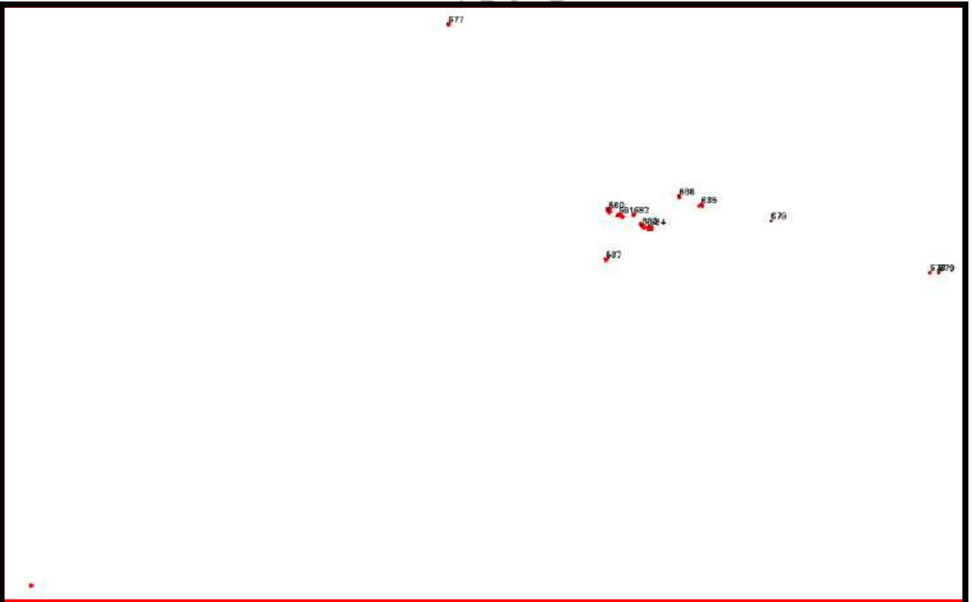
IRS-RS2-LISS3 97 49-20 Sept 2013

IRS-RS2-LISS3 97 49-20 Sept 2013

Fig.8.4.4 a&b: Resourcesat-2 LISS III image 97-49 , 20 Sept.2013 & the Interpreted layer

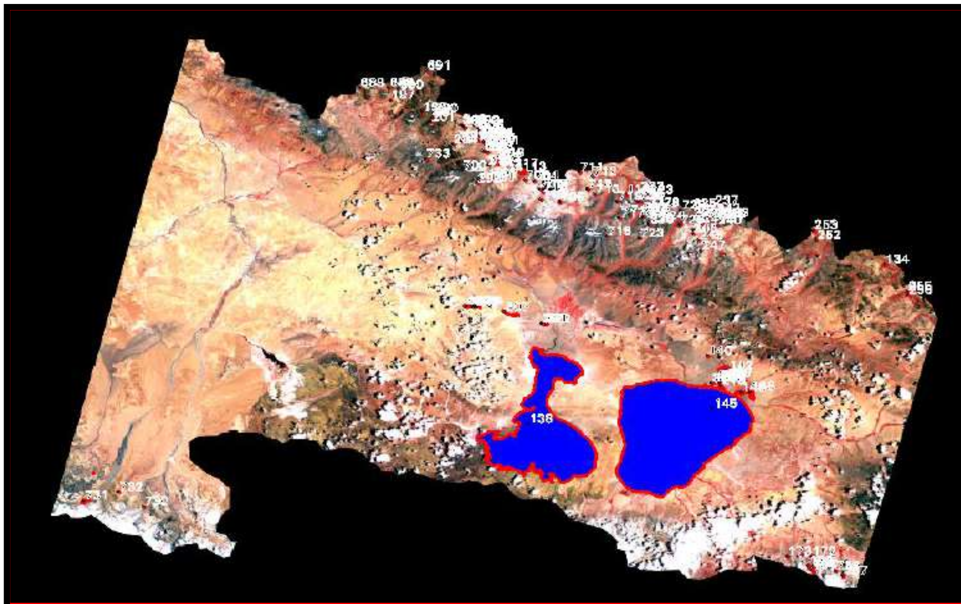


IRS-RS-LISS3 98 48-20 July 2013

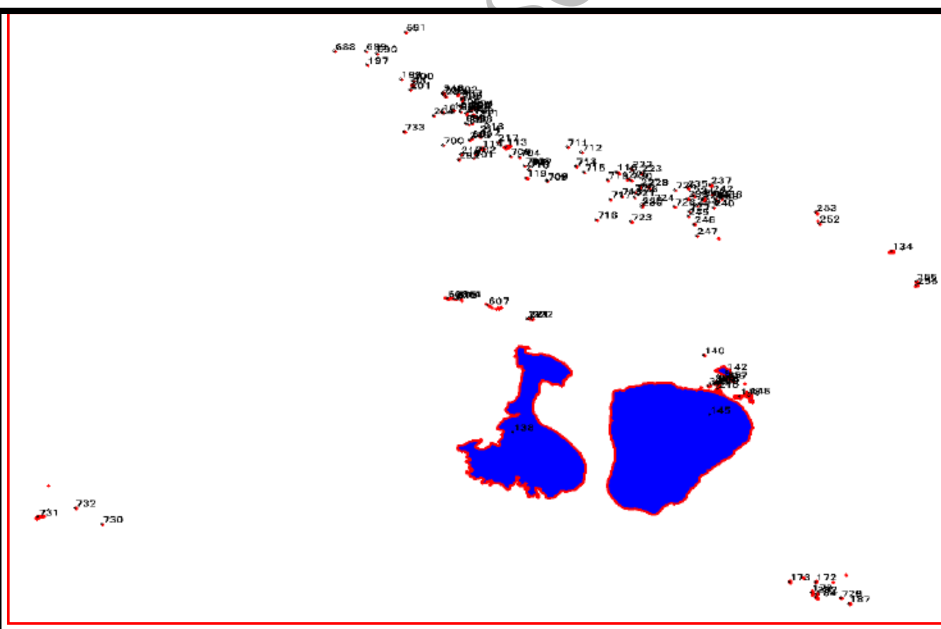


IRS-RS2-LISS3 98 48-20 July 2013

Fig.8.4.5 a&b: Resourcesat-2 LISS III image 98-48 , 20 July 2013 & the Interpreted layer



IRS-RS2-LISS3-01 July 2012



IRS-RS2-LISS3-01 July 2012

Fig 8.4.6 a&b: Resourcesat-2 LISS III image 99-49 , 01 July 2012 & the Interpreted layer

Table 8.4:Distribution of Lakes as per satellite data interpretation for the year 2012 & 2013 using LISS 3 sensor

Sr.No.	Lake id	Basin No.	Longitude	Latitude	Area extent (in hect)
		96-48-03September 2013			
1	37	1	78.70461	32.69416	5.40
2	38	1	78.72437	32.69708	2.02
3	39	1	78.72717	32.68133	2.28
4	47	1	78.49398	32.44269	6.61
5	48	1	78.52712	32.34028	1.50
6	49	1	78.74175	32.31269	**20.30**
7	51	1	78.90976	32.33798	2.50
8	52	1	78.92005	32.32065	2.22
9	54	3	79.13733	32.44976	2.88
10	55	3	79.13755	32.43334	4.45
11	56	3	79.10626	32.39096	1.24
12	57	3	79.10937	32.34093	3.28
13	58	3	79.01097	32.32503	9.93
14	59	3	79.01026	32.31555	2.60
15	60	3	79.00213	32.3029	1.37
16	62	3	78.98791	32.30671	8.8
17	63	3	78.99401	32.28709	9.57
18	64	1	78.98539	32.24512	2.92
19	65	3	79.0242	32.26352	3.05
20	66	3	79.05237	32.23851	1.52
21	67	3	79.05035	32.19611	**23.74**
22	68	3	79.03454	32.21077	8.53
23	69	3	79.02765	32.19511	2.82
24	70	3	79.01758	32.20157	2.16
25	71	3	79.01313	32.21171	2.40
26	72	3	79.00551	32.21142	2.59
27	73	1	78.99114	32.21278	2.22
28	74	1	78.98079	32.17743	5.31
29	75	1	78.96872	32.17182	3.22
30	76	3	78.98079	32.15716	1.78
31	77	3	78.9864	32.14782	9.17
32	78	3	78.97116	32.13589	1.61
33	79	1	78.91612	32.13072	1.14

34	80	**1**	78.9274	32.12792	3.01
35	81	**1**	78.93545	32.11591	1.13
36	82	**3**	78.95104	32.10916	5.26
37	83	**3**	78.9565	32.10887	1.40
38	84	**3**	78.95966	32.106	1.77
39	85	**3**	78.97921	32.11548	2.94
40	86	**3**	78.94946	32.09378	**10.12**
41	87	**3**	78.9417	32.09407	**11.46**
42	88	**3**	78.95636	32.07898	5.02
43	89	**3**	78.93825	32.07883	8.14
44	90	**1**	78.89039	32.08976	1.07
45	91	**1**	78.87372	32.07222	1.92
46	92	**1**	78.89427	32.05857	2.44
47	93	**3**	78.95291	32.04592	7.59
48	94	**3**	78.92	32.00424	5.67
49	95	**3**	78.9118	31.99044	1.68
50	96	1	78.88522	32.00697	2.28
51	97	1	78.88407	32.00381	8.33
52	98	1	78.84167	32.0304	2.05
53	99	1	78.85532	32.01603	**17.36**
54	100	3	78.85475	31.998	2.26
55	101	1	78.85464	31.97947	**22.81**
56	102	3	78.87972	31.95617	7.00
	103	3	78.87728	31.94341	3.90
57	104	3	78.84815	31.96377	1.85
58	105	3	78.84688	31.96505	1.37
59	106	3	78.8476	31.96766	6.59
60	107	1	78.7903	32.01952	1.04
61	109	1	78.77321	32.02695	8.6
62	110	1	78.76977	32.02795	1.77
63	111	1	78.76805	32.03095	6.54
64	112	1	78.75685	32.03345	1.02
65	113	1	78.76372	32.02884	6.63
66	114	3	78.82333	31.95185	2.33
67	116	3	78.82657	31.91962	2.18
68	117	3	78.83234	31.91934	5.53
69	118	3	78.8365	31.91645	5.28
70	119	3	78.83168	31.91673	9.61
71	120	3	78.8299	31.91695	4.37
72	121	3	78.82885	31.91557	8.04

73	122	3	78.79484	31.90425	**11.65**
74	128	1	78.69821	31.91989	3.48
75	129	1	78.70398	31.91535	4.28
76	130	1	78.70614	31.91385	3.77
77	131	1	78.71485	31.90381	5.20
78	133	2	78.76188	31.5392	7.32
79	134	3	78.74591	31.50427	4.02
80	135	3	78.8036	31.4354	7.48
81	139	2	78.40046	31.50776	4.13
82	150	1	78.25105	32.07578	2.52
83	151	1	77.95521	32.11361	1.82
84	152	1	77.94473	32.1211	1.84
85	153	1	77.79591	32.2265	3.15
86	154	1	78.81737	32.04471	**10.50**
87	155	1	78.81706	32.06681	8.21
88	156	1	78.81601	32.06745	3.15
89	157	1	78.81376	32.06762	1.00
90	551	1	78.70612	32.71675	8.00
91	552	1	78.71477	32.69042	3.86
92	553	1	78.72321	32.69407	7.00
93	554	1	78.72233	32.69336	7.53
94	555	1	78.82855	32.40566	4.76
95	556	1	78.84073	32.40785	7.9
96	557	1	78.90868	32.31144	8.02
97	558	3	78.97861	32.33855	4.97
98	559	3	79.13269	32.33004	3.13
99	560	3	79.12591	32.321	5.95
100	561	1	78.99955	32.24172	1.31
101	562	1	78.9954	32.23965	8.77
102	563	3	79.0425	32.22487	1.44
103	564	1	78.99342	32.20859	4.25
104	565	1	78.99138	32.20799	1.19
105	566	3	78.99553	32.18799	1.18
106	567	3	78.95518	32.10657	5.23
107	568	3	78.95625	32.09329	6.44
108	569	1	78.93655	32.04971	1.51
109	570	3	78.9132	32.0406	1.13
110	571	3	78.93541	32.001	9.59
111	572	3	78.88207	32.01855	4.11
112	573	1	78.84455	32.02254	7.67

113	574	1	78.80882	32.04242	1.55
114	575	1	78.78078	32.02669	4.30
115	576	1	78.76645	32.03093	7.85
116	577	1	78.76407	32.03102	3.88
117	578	1	78.75727	32.03224	3.73
118	579	1	78.84686	31.96188	3.37
119	580	3	78.85223	31.90085	**22.32**
120	581	3	78.79443	31.91341	6.59
121	582	3	78.79151	31.91524	1.02
122	583	3	78.7251	31.93855	3.02
123	584	1	78.72653	31.93632	4.78
124	585	1	78.71304	31.89844	7.92
125	586	1	78.72099	31.89248	1.55
126	587	1	78.73075	31.88669	5.84
127	588	3	78.72678	31.88437	1.06
128	589	1	78.77362	31.64421	1.30
129	590	2	78.74747	31.52819	6.03
130	591	2	78.7281	31.5171	1.68
131	592	2	78.44954	31.48747	1.45
132	593	2	78.44557	31.47671	4.93
133	594	2	78.14824	31.72493	3.03
135	595	2	78.14109	31.73377	6.97
136	596	2	78.15884	31.74647	4.40
137	597	2	78.20633	31.90931	6.49
138	598	1	78.20617	31.91251	3.19
139	599	1	78.20578	31.91366	2.18
140	600	1	78.2402	31.92987	1.24
141	601	1	78.45281	32.16677	5.64
142	602	1	78.43818	32.18993	3.23
143	603	3	78.38981	32.30022	1.86
144	604	3	78.52043	32.32927	1.18
145	605	1	78.50053	32.362	7.0
146	606	1	78.48171	32.36703	4.3
147	607	1	78.93655	32.04971	1.51
148	608	1	78.43818	32.18993	3.23
149	609	1			1.12
150	610	1			2.85
		96-49-29July2013			

1	158	2	78.42086	31.4039	3.17
2	163	2	78.58055	31.37428	0.64
3	164	2	78.5811	31.37065	0.33
4	165	2	78.58094	31.36814	1.07
5	167	2	78.70402	31.36088	1.07
6	168	2	78.72376	31.36295	1.25
7	169	2	78.73391	31.35989	0.39
8	171	3	78.79541	31.3696	2.99
9	173	2	78.69657	31.22521	**11.86**
10	175	2	78.47893	31.26734	1.63
11	177	2	78.3288	31.31149	**24.84**
12	180	2	78.25397	31.34068	5.94
13	611	2	77.66227	31.67207	1.26
14	612	2	77.66341	31.6735	2.84
15	613	2	77.67543	31.67754	2.27
16	614	2	77.87832	31.69373	**10.84**
17	615	2	78.16767	31.66174	**27.70**
18	616	2	78.61013	31.56429	3.61
19	617	2	78.74379	31.37895	1.50
20	618	2	78.41221	31.41476	1.89
21	619	2	78.38809	31.42232	1.50
22	620	2	78.39097	31.42538	0.64
23	621	2	78.37747	31.45067	0.62
24	622	2	78.36649	31.44482	0.56
25	623	2	78.36253	31.44059	2.06
26	624	2	78.42863	31.49127	0.92
27	625	2	78.4323	31.49585	0.86
28	626	2	78.43253	31.49832	0.87
29	627	2	78.43283	31.502	2.04
30	628	2	78.47708	31.25851	0.95
31	629	2	78.47566	31.25461	0.90
32	630	2	78.47393	31.25303	1.14
33	631	2	78.47626	31.24883	0.44
34	632	2	78.46996	31.25026	1.49
35	634	2	78.16349	31.37198	3.38
36	635	2	78.07724	31.42779	1.20
37	636	2	78.06786	31.42603	0.82
38	637	2	78.06951	31.42305	1.53
39	638	2	78.06885	31.41963	1.91

40	639	2	78.01247	31.40694	7.87
41	640	2	78.00784	31.4022	0.82
42	641	2	77.95952	31.48152	1.83
43	642		77.92211	31.48847	0.82
			97-48-20September 2013		
1	184	3	79.39264	32.37784	**27.63**
2	190	3	79.68327	32.25382	6.96
3	191	3	79.70597	32.215	2.30
4	193	3	79.80132	32.12502	2.46
5	194	3	79.80419	32.11659	2.96
6	195	3	79.80224	32.11261	1.1
7	196	3	79.81068	32.0281	0.56
8	197	3	79.81244	32.02903	3.64
9	198	3	79.81781	32.02069	3.30
10	199	3	79.82633	32.01754	4.54
11	200	3	79.83634	31.98789	2.81
12	201	3	79.84579	31.99178	5.43
13	202	3	79.87211	31.97695	**10.78**
14	203	3	79.87563	31.96732	8.50
15	204	3	79.89453	31.95787	4.55
16	205	3	79.87896	31.96306	3.67
17	206	3	79.87433	31.95824	1.99
18	207	3	79.87748	31.95564	5.17
19	208	3	79.85636	31.9499	1.90
20	209	3	79.86544	31.92432	**34.57**
21	210	3	79.88193	31.93229	3.16
22	211	3	79.90176	31.92738	2.56
23	212	3	79.91918	31.93368	1.85
24	643	2	78.48992	31.40099	2.24
25	644	2	78.70406	31.36069	1.27
26	645	3	78.79411	31.44988	**10.61**
27	646	3	78.73496	31.51858	3.49
28	647	2	78.75113	31.55366	8.66
29	648	2	78.73632	31.54236	1.22
30	649	2	78.71079	31.556	0.64
31	651	3	79.5623	32.35528	4.82
32	652	3	79.59381	32.35287	6.20
33	653	3	79.797	32.12758	3.32

34	654	3	79.80017	32.05887	1.27
35	655	3	79.78814	32.03206	1.98
36	656	3	79.78836	32.02724	**10.35**
37	657	3	79.79186	32.02834	1.79
38	658	3	79.81527	32.02746	0.90
39	659	3	79.82753	32.0116	0.69
40	660	3	79.8551	32.00055	1.51
41	661	3	79.80849	31.9803	3.34
42	662	3	79.85466	31.97757	7.21
43	663	3	79.86101	31.971	4.09
44	664	3	79.85751	31.96684	5.37
45	665	3	79.88837	31.96706	3.06
46	666	3	79.89865	31.96378	4.99
			97-49-20September 2013		
1	96	3	79.60051	31.30347	**24.34**
2	161	3	78.76209	31.65851	1.64
3	166	3	79.31896	31.15439	0.78
4	167	3	79.34165	31.1531	4.36
5	168	3	79.35747	31.15033	1.09
6	169	3	79.36559	31.1436	4.55
7	170	3	79.41055	31.06053	4.31
8	171	3	79.514	31.13195	6.70
9	174	3	79.64938	31.07708	1.93
10	175	3	79.65186	31.07185	1.60
11	177	3	79.77805	31.00284	0.76
12	178	3	79.41423	31.05959	6.22
13	398	3	79.75362	31.04013	4.86
14	399	3	79.72944	31.02881	6.04
15	668	3	78.75073	31.66163	0.88
16	669	3	79.4774	31.3577	**11.92**
17	670	3	79.36223	31.1496	0.66
18	672	3	79.56742	31.08924	0.38
19	673	3	79.56964	31.09213	1.01
20	674	3	78.87788	31.30588	2.02
21	675	3	78.90081	31.32144	0.76
22	676	3	78.95637	31.37586	0.51
			98-48-20 July 2012		
1	677	3	79.99036	31.6194	4.12

2	678	3	80.5713	31.38873	1.65
3	679	3	80.58189	31.38846	1.17
4	679	3	80.38	31.43698	1.25
5	680	3	80.18395	31.44718	**19.79**
6	681	3	80.19622	31.44245	**17.71**
7	682	3	80.21426	31.44279	4.907
8	683	3	80.22435	31.43245	**17.20**
9	684	3	80.23391	31.43146	**18.24**
10	685	3	80.29606	31.45177	8.56
11	686	3	80.26917	31.45958	6.28
12	687	3	80.18071	31.40144	7.49
			99-49-01 July 2012		
1	98	3	81.0332	31.28473	**14.95**
2	106	3	81.10346	31.24271	4.63
3	107	3	81.0845	31.23876	5.85
4	109	3	81.13771	31.23316	**11.01**
5	112	3	81.14911	31.1978	**12.15**
6	113	3	81.19457	31.18094	**52.00**
7	114	3	81.15269	31.17821	**23.25**
8	116	3	81.38243	31.1381	9.21
9	119	3	81.2284	31.12841	4.78
10	134	3	81.85202	31.00371	**24.36**
11	138	3	81.20662	30.69885	2.58
12	140	3	81.531	30.82868	6.57
13	142	3	81.56941	30.80125	**364.14**
14	145	3	81.54085	30.7279	**41066.37**
15	148	3	81.59198	30.7591	**194.77**
16	172	3	81.71995	30.44545	7.12
17	173	3	81.67561	30.44572	9.89
18	179	3	81.71341	30.42744	**25.09**
19	184	3	81.71968	30.41953	**16.95**
20	187	3	81.77671	30.40834	7.28
21	197	3	80.95639	31.31829	2.21
22	199	3	81.01383	31.29469	3.50
23	200	3	81.03429	31.2921	3.17
24	201	3	81.02965	31.27627	2.39
25	202	3	81.08668	31.26904	1.15
26	203	3	81.09009	31.26536	5.06
27	205	3	81.11424	31.24947	1.33

28	206	3	81.11772	31.25942	4.30
29	207	3	81.11704	31.26304	1.99
30	210	3	81.13389	31.24449	4.74
31	210	3	81.55487	30.77131	**53.00**
32	211	3	81.14616	31.22989	1.94
33	213	3	81.15494	31.20768	1.44
34	214	3	81.14859	31.20317	1.19
35	215	3	81.13127	31.1924	0.94
36	216	3	81.11626	31.16716	2.56
37	217	3	81.17929	31.18803	1.83
38	221	3	81.23291	30.89016	3.13
39	222	3	81.23864	30.89023	2.55
40	223	3	81.42486	31.1366	5.46
41	226	3	81.4175	31.1014	2.99
42	227	3	81.42309	31.1134	2.00
43	228	3	81.43578	31.11286	7.25
44	229	3	81.42582	31.08271	3.82
45	230	3	81.42554	31.07916	1.86
46	233	3	81.50399	31.09335	5.50
47	234	3	81.5134	31.0984	4.83
48	235	3	81.50304	31.11081	7.50
49	237	3	81.54287	31.116	**11.88**
50	238	3	81.56156	31.09267	2.20
51	239	3	81.55522	31.08946	1.97
52	240	3	81.54826	31.07773	2.34
53	241	3	81.55126	31.0928	1.14
54	242	3	81.54608	31.10174	6.81
55	243	3	81.53182	31.0943	3.50
56	244	3	81.51968	31.08134	2.31
57	245	3	81.50447	31.06286	1.20
	246	3	81.51518	31.04983	1.62
58	247	3	81.51948	31.03032	1.73
59	252	3	81.72842	31.0501	1.33
60	253	3	81.72296	31.06934	8.60
61	255	3	81.89363	30.95214	3.18
62	256	3	81.89418	30.94532	3,64
63	257	3	81.56989	30.78747	1.76
64	258	3	81.55399	30.78261	0.93
65	259	3	81.54962	30.77999	1.06

66	260	3	81.5543	30.77731	0.84
67	282	3	81.72186	30.42526	4.15
68	292	3	81.11285	31.15897	2.29
69	607	3	81.16383	30.91277	**14.70**
70	608	3	81.09476	30.92422	**15.97**
71	614	3	81.11585	30.92353	1.14
72	615	3	81.11034	30.92311	1.11
73	616	3	81.1062	30.92342	2.05
74	688	3	80.90089	31.34124	1.49
75	689	3	80.95398	31.34166	0.69
76	690	3	80.9719	31.33731	0.44
77	691	3	81.02154	31.37433	1.96
78	692	3	81.1102	31.26913	5.24
79	693	3	81.11544	31.23976	1.00
80	694	3	81.13653	31.24624	0.76
81	696	3	81.12461	31.22046	1.33
82	697	3	81.12998	31.21825	0.95
83	698	3	81.13536	31.22011	1.01
84	699	3	81.13529	31.19453	0.70
85	700	3	81.08634	31.18309	0.65
86	701	3	81.13812	31.16075	0.96
87	702	3	81.14143	31.1682	1.13
88	703	3	81.22588	31.14848	1.85
89	704	3	81.21678	31.1631	1.72
90	705	3	81.20093	31.16489	1.20
91	706	3	81.23367	31.1481	0.57
92	707	3	81.23619	31.14762	0.25
93	708	3	81.26428	31.12349	0.24
94	709	3	81.26364	31.12239	0.69
95	710	3	81.23236	31.14216	0.63
96	711	3	81.29819	31.18	0.89
97	712	3	81.32253	31.17187	1.00
98	713	3	81.31358	31.14872	0.97
99	714	3	81.31334	31.14644	1.59
100	715	3	81.32749	31.13765	1.54
101	716	3	81.34858	31.05774	0.46
102	717	3	81.37222	31.09191	1.64
103	718	3	81.39059	31.09732	0.83
104	719	3	81.36734	31.12483	1.15
105	720	3	81.40747	31.1243	1.28

106	721	3	81.41326	31.09506	0.82
107	722	3	81.41335	31.10323	1.86
108	723	3	81.40785	31.05396	2.86
109	724	3	81.44535	31.08714	0.58
110	725	3	81.48299	31.10764	1.27
111	726	3	81.4814	31.07957	3.07
112	727	3	81.50568	31.07091	0.90
113	728	3	81.53009	31.09129	3.76
114	729	3	81.76314	30.41817	3.64
115	730	3	80.50932	30.54147	0.94
116	731	3	80.40077	30.55246	**37.88**
117	732	3	80.4638	30.56814	1.76
118	733	3	81.02002	31.20613	3.64

Based on the analysis carried out in Satluj basin using AWIFS satellite data for the year 2013 to assess the temporal variation in the spatial extent of the lakes on monthly basis, the data generated is as per Table 8.4.1

Table 8.4.1: Temporal variation in lakes with area >10ha as mapped on 2007, 2009, 2011 & 2012 & 2013

Lake Sr. Number	Aerial Extent on 18 August 2007 (hect.)	Aerial Extent on 29 Sept. 2009 (hect.)	Aerial Extent on 29 Sept. 2011 hect.)	Aerial Extent on 25 September 2012 (hect)	Aerial Extent on 09 October 2013 (hect)	Overall trend w.r.t. 2007 onwards in case of the lakes with area more than 10ha.
23	8.00	4.00	------	12.58	11.76	Increasing
25	20.00	21.00	24.06	31.07	31.90	Increasing
31	3.00	9.00	24.06	15.98	12.87	Decreasing
32	70.00	51.46	46.40	30.26	21.52	Decreasing
41	20.00	21.23	------	------	23.59	Increasing
55	8.00	13.90	10.96	11,19	13.11	Increasing
54	7.00	8.00	10.58	15.30	13.12	Increasing

61	10.00	23.11	28.38	23.86	21.21	Decreasing
65	10.00	31.27	33.51	32.46	25.22	Decreasing
71	8.00	------	------	------	10.74	Increasing
85	10.00	21.72	31.38	35.32	27.81	Increasing
96	30.00	34.67	23.12	36.91	24.20	Decreasing
98	10.00	14.31	23.64	17.18	14.32	Decreasing
109	7.00	12.09	11.20	12.25	11.34	Decreasing
112	6.00	11.61	15.87	19.69	16.96	Increasing
113	40.00	59.96	45.18	56.47	53.78	Increasing
114	10.00	28.23	25.19	30.75	29.43	Increasing
118	7.00	12.79	12.71	12.67	14.38	Increasing
122	3.00	----	------	------	11.57	Increasing
134	20.00	25.87	21.51	28.15	24.69	Increasing
138	26268.07	26825.71	------	------	26428.93	Decreasing
138A1	------	------	53.86	45.34	39.18	Decreasing
141	2.00	------	------	4.63	10.63	Increasing
142	340.00	340.53	322.54	320.80	326.66	Decreasing
145	41225.33	42111.76	------	------	41673.91	Increasing
147	------	------	14.42	15.20	10.42	Decreasing
148	------	------	------	187.54	228.93	Increasing
159	10.00	15.38	17.37	11.79	15.97	Increasing
173	6.00	----	7.30	7.05	10.85	Increasing
174	7.00	4.00	12.25	13.28	11.47	Increasing
178	190.00	212.93	173.35	237.77	201.42	Decreasing
179	20.00	26.38	31.11	17.30	19.11	Decreasing
181	9.00	15.42	22.66	26.08	21.82	Increasing
184	10.00	13.75	26.75	20.40	22.74	Increasing
187A3	------	------	7.57	8.02	10.02	Increasing
202	------	------	63.17	44.20	69.93	Increasing
210	------	------	63.79	85.67	84.49	Increasing
211	------	------	13.98	8.81	15.36	Increasing
228	------	------	8.22	11.93	12.70	increasing
312	------	------	11.62	10.88	10.70	Decreasing
313	------	------	8.83	11.00	17.20	Increasing
343	------	------	------	------	35.38	------

399	------	------	11.72	9.36	11.93	Increasing
556	------	------	------	------	10.50	------
558	------	------	------	------	60.35	------
606	------	------	------	54.32	57.02	Increasing
607	------	------	------	121.29	116.17	Increasing
619	-----	-----	-----	19.64	13.78	Decreasing
642	-----	-----	-----	18.53	18.14	Decreasing
643				-----	19.36	------
644	------	------	------	----	20.08	------
651	------	------	------	----	11.30	------
659	-----	-----	-----	-----	17.23	------
660				-----	12.35	------
662	------	------	------	------	10.93	------

Distribution of the lakes in different sub basins in Satluj basin carried out using AWIFS & LISS III satellite for 2013 is as per the Table 8.4.2

Table 8.4.2: Basin wise distribution of total number of lakes in Satluj Catchment during the year 2013 based on AWIFS and LISS III satellite data interpretation.

Date of Pass	No.of lakes in Basin 1	No.of lakes in Basin 2	No.of lakes in Basin 3	Total No. of lakes (2013)	No.of Lakes with area more than 10Ha(2013)	No.of Lakes with area more than 10Ha(2012)
17 March 2013	----	----	2	02	2	----
24 April 2013	----	----	14	14	8	05 (5 April 2012)
28 May 2013	1	----	27	28	20	05 (28 may 2012)
21 June 2013	----	----	20	20	14	29 (21 June2012)
15 July 2013	10	----	37	47	16	56 (01 July 2012)
29 July 2013	13	1	47	61	33	----
03 August 2013	11	1	60	72	38	----
20	19	3	58	80	29	39

September 2013						(20 Sept.2012) 66 (25 Sept.2012)
09 October 2013	6	2	116	124	56	52 (05 Oct.2012)
14 October 2013	2	3	125	130	58	35 (14 Oct2012)
24 October 2013	2	2	94	98	57	46 (19 Oct. 2012
						04 (02 Nov 2012)
						13 (17 Nov 2012)
96-48	76	10	64	150	09	
96-49	41	----	1	42	04	
97-48	----	5	40	45	05	
97-49	----	----	22	22	02	
98-48	----	----	12	12	04	
99-49	----	----	118		16	
					>10 ha ---40 5-10ha----75 <5ha ---276	>10ha---59(2011) 5-10ha----106 <5ha----293

9.0 Basin wise distribution of lakes:

Based on the analysis carried out for the year 2013 in all the basins in Himachal Pradesh using LISS III satellite data, the distribution of total number of lakes is as per Table 9.0. The inventory thus generated is further divided into the number of lakes based on their aerial range with area more than 10 hectare, between 5-10 hectare and the lakes with area less than 5 hectare. Thus the Satluj basin as a whole includes a total of 391 lakes out of which 275 are of smaller dimensions i.e with area less than 5 hectare, 75 lakes with aerial range between 5-10 hectare and 40 lakes with area more than 10hecatre. Likewise in Chenab basin (Chandra, Bhaga, Miyar) a total of 116 lakes have been identified which is almost double than the lakes which were identified earlier using 2001 (55) satellite data (Randhawa et.al. 2005). When these 116 lakes seen based on their aerial range, it has been found that maximum lakes (105) falls in the category where the area is less than 5 hectare, 08 lakes where area is between 5-10 hectare and only 03 lakes where area is more than 10 hectare. In Beas basin(Jiwa, Parbati), total number of lakes (67) has been further divided into 63 lakes which are having less than 5 hectare, 02 lakes with aerial range between 5-10 hectare and 02 lakes which are having area more than 10 hectare. In the upper part of the Beas basin, information could not be retrieved due to cloudy data. Likewise in Ravi basin, 22 lakes when seen based on aerial distribution found that 02 lakes are having area more than 10 hectare, only 01 lake is having area between 5-10 hectare and 19 lakes are such which have area less than 5 hectare.

Table 9.0: Distribution of lakes in different sub basins in Himachal Pradesh based on LISS III satellite data analysis for 2013.

Sr.No.	**Name of the basin**	**No.of lakes with area >10ha**	**No.of lakes with area between 5-10 ha**	**No.of lakes with area <5ha**	**Total No.of lakes**
1	**Chenab**	**03**	**08**	**105**	**116**
	Bhaga	01	03	10	14
	Chandra	02	02	15	19
	Miyar	----	03	80	83
2	**Beas**	**02**	**02**	**63**	**67**
	Jiwa	----	02	37	39
	Parbati	02	-----	26	28
	Beas	----	-----	----	Cloud free Data not available
3	**Ravi**	**02**	**01**	**19**	**22**
4	**Satluj**	**40**	**75**	**275**	**391**

10.0 Concluding remarks

The analysis carried out using LISS III for 2013 reveals that there has been a considerable increase in the number of moraine dammed lakes (GLOFs) in each basins which is evidenced by the fact that as per the earlier studies carried out using IRS IA & IB satellite data for 1993, a total of 38 moraine dammed lakes were identified in the Satluj basin(Kulkarni et.al.1999), out of which 14 lakes were in the Himachal part and the remaining 24 lakes were in the Tibetan part which has been increased to 391 which includes the Spiti and the Baspa basins as well. Likewise in Chenab basin, a total of 55 lakes were identified using IRS IC/ID satellite data for 2003, which has now increased to 116 in 2013. Thus from the above observations, it is inferred that formation of such lakes in the Higher Himalayan region is on the increasing side. The analysis further reveals that the higher number of smaller lakes i.e. the lakes with area less than 5 hectare indicates that the effect of the climatic variations is more pronounced on the glaciers of the Himalayan region resulting in the formation of small lakes in front of the glacier snouts due to the damming of the morainic material. The recent tragedy of 2013 in the Uttrakhand Himalaya has also been correlated with the bursting of a lake having a total area of about 08 hectare in front of the snout of the Chorabari glaciers that caused widespread damage in the downstream areas besides the heavy rainfall (Dobhal et.al.2013). Thus the magnitude of such lakes as far as the destruction is concerned cannot be overruled. Besides this, the lakes with area >10 hectare and the area between 5-10 hectare can be seen as the potential vulnerable sites for causing damage in case of bursting of any one of them. Thus a proper monitoring of all such lakes is very much essential in the Himalayan region in order to any eventuality like in Uttrakhand in future, which will not only save the precious human lives but also the public and the Govt. property.

11.0 References

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