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INVENTORY OF WATER BODIES IN THE WESTERN HIMALAYAN REGION : PART-I (JAMMU & KASHMIR)

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PREFACE

The importance of wetlands has increased considerably in recent years with the growing interest in them not only as life supporting ecosystems but also as supporting mechanisms for flood control, water purification, micro-climatic regulation, etc. A wide variety of wetlands exist in India owing to the extensive geographical coverage, and varied terrain and climatic conditions.

A holistic and sustainable use of wetlands requires the availability of a comprehensive and reliable information on wetlands. This necessitates creation of an information database covering details of the hydrologic behaviour of wetlands in terms of their physical and chemical parameters as well as catchment characteristics. With the availability of high-resolution satellite imageries, remote sensing and GIS techniques play an important role in compiling the information on natural resources, including the water bodies, facilitating the conservation and management of such water bodies.

The present report is an attempt in compilation of useful information on the water bodies in the Western Himalayan region. The study generated information on type of water bodies including location, elevation, and seasonal variation in water spread as manifested on pre- and post-monsoon season imageries. I hope classification of the water bodies according to altitude, river basin and districts will enhance the utility of the document.

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ABSTRACT

Wetlands in India have assumed a considerable significance in recent years because of their ecological significance in terms of flood control, water purification, aquatic productivity and microclimatic regulation, and as habitats of fish, birds and wild life. A wide variety of wetlands, if managed properly, can be used profitably for meeting some of the human requirements and for environmental amelioration. A complete understanding of the structure and functions of wetland ecosystem requires a multidisciplinary, multiyear study, including quantitative analysis of the hydrologic regime of the wetlands. Inventory of water bodies through a combination of satellite data and Survey of India toposheets is the first step in carrying out further analysis.

An inventory of water bodies in the Jammu & Kashmir State of Western Himalayan region was prepared using available satellite data of IRS-1A (standard FCC, Scale 1:250000) for 1988/89 and digital data of IRS -1C for 1998. Also, a database was prepared with the help of Survey of India (SOI) topographic maps, which includes name and type of the water body, nearest place, district, river basin, geographical coordinates and elevation. The water spread area and perimeter of the water body, both in pre-monsoon (March/April/June) and post-monsoon (October/November/December) periods, were calculated using a GIS package. Tables presenting classification of the water bodies according to altitude, river basin and districts are included.

1.0 INTRODUCTION

Wetlands in India exist in various ecological regions ranging from the cold-arid zone of Ladakh through the wet Manipur, warm and arid zone of Rajasthan and Gujarat, to the tropical monsoonic central India, and the wet humid zone of the southern peninsular region. Wetlands have assumed a considerable significance in recent years because of their ecological significance in terms of flood control, water purification, aquatic productivity and microclimatic regulation, and as habitats of fish, birds and wild life. A wide variety of wetlands, if managed properly, can be used profitably for meeting some of the human requirements and for environmental amelioration.

The wetlands have been facing a variety of threats, both human and natural, and there is a need for making scientific assessment of the problems and for mitigation of the hazards causing threats to the wetlands. Publication of a Directory of Wetlands in India (Anonymous, 1992) by the Ministry of Environment & Forests, Govt. of India, and inventory of Wetlands of India (Anonymous, 1998a) by the Space Applications Centre, Department of Space, Govt. of India, provide the necessary base for taking up further investigations in tackling the problem.

A complete understanding of the structure and functions of wetland ecosystem requires a multidisciplinary, multiyear study, including quantitative analysis of the hydrologic regime of the wetlands. Inventory of water bodies through a combination of satellite data and Survey of India toposheets is the first step in carrying out further analysis.

2.0 OBJECTIVES

A detailed inventory of water bodies in the Western Himalayan region has not been prepared so far. This inventory is intended to provide an overall view of the surface water bodies and will be useful in planning and development of water resources in the region. Preparation of inventory of surface water bodies, mainly lakes and reservoirs, is to be carried out using remote sensing data. This study will cover one of the three states i.e Jammu and Kashmir, covered under the Western Himalayan Region. During

subsequent years the other two states i.e. Himachal Pradesh and Uttar Pradesh Hills will be considered.

The main objectives of this study are: (1) To identify and delineate various surface water bodies and their water spread through visual and digital analysis during pre- and post-monsoon seasons using standard FCC of IRS-1A, LISS II satellite data on 1:250,000 scale and digital satellite data of IRS-1C respectively. (2) To build an information base on the water bodies for further investigation and research by interested users.

3.0 REVIEW

The earth land is dotted with hundreds of thousands of lakes. Lakes contain over 95% of the Earth's fresh liquid water (Scott, 1989). It has been estimated that there are about three million lakes on earth. They have total area of about 2.7 X 10^6 Sq. Km and volume of water equaling 165.8 X 10^3 Cu. Km. and it is not an easy task to evaluate the lake water resources (Bowen, 1982). Most of the world's fresh water lakes occur on three continents North America, Africa and Asia and account for 25%, 30% and 20% i.e more than 70% of the world's fresh surface water. Large lakes in other continents, e.g. Europe, South America and Australia, contain a comparatively small amount, about 20%. The large lakes of North America contain approximately 32,000 Cu. Km of water, of which over three fourth is in the five Great Lakes. Large lakes in East Africa contain some 36,000 Cu. Km of fresh water. Lake Baikal in the South Eastern Soviet Union in Central Asia is the World's deepest and most voluminous body of fresh water and contains nearly as much water as the five Great Lakes of North America (Bowen, 1982).

Thousand of lakes occur in the North Central U.S.A. The state of Minnesota alone has more than 15,000 lakes greater than 0.04 Sq. km in area (Winter, 1977). The number of lakes in some countries, like Sweden and Finland is very large. Although fresh water lakes are much more numerous and important, some of the world's largest lakes are saline. Saline lakes cover an estimated total area of 700,000 Sq. km and contain 105,000 Cu. Km of water. Both the combined areal extent and volume of saline lakes are therefore

about 85% of the respective totals for fresh water lakes. Saline lakes are located mostly in Asia and are dominated by the Caspian Sea, which, despite its name, is considered the world's largest lake. By itself, the Caspian Sea contains about 80,000 Cu. km or about 76% of the total volume of all the world's saline lakes (Nace, 1978).

Most of the lakes are minor in size and shape and very few are large. The lakes with areas more than 900 Sq. km or even 90 Sq. km are exceptional. Lakes Baikal and the lake Tanganyika in Africa are known to have maximum depth over 1000 m and mean depth over 500 m (Walton, 1970). The large lake i.e lakes with more than 500 Sq. km surface area, account for 93% of the total surface area of the fresh water in the world and 88% of the total fresh water volume of the world (Munawar, 1987). 87% of these lakes are found in the northern hemisphere (Asia, Europe and North America), while large lakes of the southern hemisphere are located mostly in the African Rift Valleys (Munawar, 1987). The nineteen major lakes of the earth account for 38% of the total area of the lakes. (Bowen, 1982). The total volume of lake water and river water with respect to total fresh water of the earth are about 0.3% and 0.003%, respectively (Black, 1991). In other words, in terms of the earth's total fresh water, lake water is 10 times more than the river water.

Unfortunately not enough studies were carried out in India. Negi (1991) compiled a brief description of the rivers, lakes and glaciers of the Himalayas. Kawosa (1988) was among the first workers to use the Remote Sensing technique in the estimation of natural resources of the Himalayas. National Institute of Hydrology initiated the study of the hydrological aspects of lakes, and brought out a good compilation of natural lakes in India (Khobragade and Bhar, 1992-93).

Realising the importance of wetlands in India, Ministry of Environment and Forest (MOEF), Govt. of India, has published a Directory of Wetlands (Anonymous, 1992) based on the survey carried out during 1972. However, the survey is not comprehensive and many inland wetlands and most of the coastal wetlands have not been included in the compilation. In order to fill this void, Space Application Center (ISRO)

carried out a Wetland inventory in the country using remote sensing data. Mapping has been carried out on 1: 250,000 for most of the states except for all NE states. According to the results of wetland inventory there are 27403 wetland units in the country occupying 7581871 ha area. Coastal wetlands are 3959 (4022956 ha.) while inland wetlands are 23444 (3558915 ha). Directorate of Remote Sensing and Environment, Govt. of Jammu and Kashmir, have prepared a Classified Directory of Lakes and Water Bodies of J&K using Survey of India toposheets maps (Anonymous, 1998b).

4.0 REMOTE SENSING IN WETLAND MANAGEMENT

Wetlands are the potential resources for a variety of human uses. In this fast growing era of industrialization and urbanization, total water requirement is increasing at a very high rate. To take any decision regarding water management or in deriving any policies to conserve this scarce resource, the first and foremost task is to make an inventory of its availability. The extent of surface water bodies is dependent on many parameters, e.g. topography, soil, climate, rainfall. In different seasons the extent of each water body changes. During and after monsoon, spread area of most of the water bodies increases. However, during the pre-monsoon season, the extent of many water bodies shrink and even smaller bodies disappear due to snow cover. To gather this information, we need to know about existing wetlands/water bodies over a time period. For this purpose, remote sensing is most useful. Spatial, spectral and temporal attributes of remote sensing provide invaluable synoptic and timely information regarding the water spread and temporal changes in a water body. GIS techniques facilitate integrated and conjunctive analysis of large volumes of multi-disciplinary data, both spatial and non-spatial, within the same georeference scheme. The concept of integrating remote sensing and GIS comparatively new. Probably, the fullest utilisation of the potential of the two technologies can be realised only when an integrated approach is adopted. The spectral characteristics and other properties of the LISS-II & LISS-III (Indian Remote Sensing) sensors are summarised in Table 1.

Water quality studies have conventionally being carried out using in-situ measurement of various parameters. However, it has not been possible to carry out these

analyses using satellites due to non-availability of specific sensors onboard the presently available satellites. Broadly, satellite remote sensing allows detection and mapping of sediments, changes in colour and temperature variations in aquatic ecosystems. Table 2 gives information for management of aquatic ecosystems.

Table 1. Details of the IRS-1A &1C Sensors (LISS-II &LISS-III)

Sensor	Spectral Band	Spectral Range (μm)	Spatial Resolution (m)	Application	Swath (Km)	Orbital Altitude (Km)	Repetitive Coverage (days)	Quantisation (bits)
LISS -II	B1	0.45-0.52	36.25	a. Coastal environmental studies b. Soil/Vegetation differentiation c. Coniferous/deciduous vegetation differentiation	141	904	22	7
	B2	0.52-0.56	36.25	a. Vegetation vigor b. Rock/soil discrimination c. Turbidity and bathometry in shallow water				
	B3	0.62-0.68	36.25	A strong chlorophyll absorption leading to discrimination of plant species				
	B4	0.77-0.86	36.25	a. Delineation of water features b. Landform/geomorphic studies				
LISS-III	B1	0.52-0.59	23.5	Same as B2 of LISS-II	141	817	24	7
	B2	0.62-0.68	23.5	Same as B3 of LISS-II				
	B3	0.77-0.86	23.5	Same as B4 of LISS-II				
	B4	1.55-1.70	70.5	a. Leaf water content b. Canopy water status c. Forest and crop type mapping d. Lithological studies	148			

(Source: IRS-data User Handbook, 1989 & 1995)

Table 2. Details of the Monitoring Needs for Aquatic Ecosystems

Parameter	Spatial Resolution (m)	Radiometric Resolution (bits)	Spectral Region/Band (μm)
Areal extent, Type, dynamics	10-20	8	0.42-0.52 0.53-0.59
Hydrophytic vegetation/weed infestation, type, trophic status, eutrophication	5-20	8	0.53-0.59 0.63-0.69 0.77-0.86 1.55-1.75 2.08-2.35
Pollution sources/ waste outfall	1-5	8	0.53-0.59 0.63-0.69 0.76-0.86 3.66-3.84 3.93-3.98 10.78-11.28 11.77-12.27
Turbidity, sediments, suspended solids	30	8	0.56-0.58 0.64-0.66 0.74-0.78
Phytoplankton/ algal blooms	30-50	8-10	0.51-0.53 0.555-0.575 0.62-0.64 0.66-0.67
Thermal pollution	5-10 0.5°C	8-10	3.66-3.84 3.93-3.98 10.78-11.28 11.77-12.27
Oil pollution	50-100	10	SAR X (9.6 GHz) Lidar (0.35-0.75 μm)
Water pollutants and bio-physical parameters			Sensors yet to be developed

(Source: Anonymous, 1998a)

5.0 WETLAND CLASSIFICATION SYSTEM

Wetlands are historically defined by scientists working in specialized fields such as botany, hydrology, etc. Various definitions used officially by different government departments and institutions are listed in Anonymous (1998a). The definition adopted by the Department of Space, Govt. of India, which is amenable for use with remote sensing data reads as "all submerged or water-saturated lands, natural or man-made, inland or coastal, permanent or temporary, static or dynamic, vegetated or non-vegetated, which necessarily have a land-water interface are defined as wetlands".

The classification derived by the Dept. of Space after a comprehensive discussion by experts in the country is given in Table 3. The main criteria followed in this system are:

a) Wetland hydrology, i.e. manifestation of water on the satellite imagery,

b) Wetland vegetation- mainly hydrophytes and other aquatic vegetation in a part or whole of the water body as seen through the satellite data,

c) It provides qualitative information on the turbidity status of the water bodies,

d) It provides information on the extent of vegetation present in the wetlands, both in pre- and post-monsoon seasons, wherever discernible on satellite imagery.

Table 3. Water bodies classification system

1. Natural	1.1 Lakes/ponds
	1.2 Ox-bow lakes/cut-off meanders
	1.3 Waterlogged (seasonal)
	1.4 Playas
	1.5 Swamp/marsh
2. Man-made	2.1 Reservoirs
	2.2 Tanks
	2.3 Waterlogged
	2.4 Abandoned quarries
	2.5 Ash pond/cooling pond

Standard definitions of wetland categories used in the study are given below:

A. Natural

a) **Lakes:** Larger bodies of standing water occupying distinct basins.

b) **Pond:** Generally, suggests a small, quiet body of standing water, usually shallow enough to permit the growth of rooted plants from one shore to another.

c) **Ox-bow lakes:** A meandering stream may erode the outside shores of its broad bends, and in time the loops may become cut off, leaving basins. The resulting shallow crescent-shaped lakes are called ox-bow lakes.

d) **Waterlogged (seasonal):** Said of an area in which water stands near, at, or above the land surface, so that the roots of all plants except hydrophytes are drowned and the plants die. Such types of waterlogging occurs due to floods during monsoon and can be delineated using post-monsoon satellite data.

e) **Playas:** Term used in south-west United States for marsh-like ponds similar to potholes but with different geologic origin. These are normally found in arid regions in the undrained areas. Due to heavy rains the playa may be covered with a shallow sheet of water. In India, these are found in the desertic region of Rajasthan and Gujarat.

f) **Swamp:** Wetland dominated by trees or shrubs (U.S. definition). In some areas reed grass dominated wetlands are also called swamps.

g) **Marsh:** A frequently or continually inundated wetland characterised by emergent herbaceous vegetation adapted to saturated soil conditions. Using satellite data it is not possible to differentiate between swamp and marsh; hence clubbed together.

B. Man-made

a) **Reservoir:** A pond or lake built for the storage of water, usually by the construction of a dam across a river.

b) **Tanks:** A term used for an artificial pond, pool or lake formed by building a mud wall across the valley of a small stream to retain the monsoon.

c) **Waterlogged:** Man-made activities like canals induce waterlogging in adjacent areas due to seepage.

d) **Abandoned quarries:** Quarry is defined as "an open or surface working or excavation of stone, ore, coal, gravel or minerals". In such pits, water accumulates after being abandoned.

e) **Ash pond/cooling pond:** The water body created for discharging effluents in industry, especially in thermal power plants. **Cooling pond:** an artificial lake used for the natural cooling of condenser-cooling water serving a conventional power station.

5.1 Notified Wetlands

The Ministry of Environment and Forests has notified 21 wetlands in the country of paramount importance needing special conservation measures. The notified category implies that detailed studies are needed to be carried out on larger scale in terms of water spread, invasion of aquatic weeds, turbidity levels (qualitative) and the possible impact of land use in their catchments on the wetland ecosystem. In the Western Himalayan region, the following wetlands are notified (Table 4).

Table 4. Notified Wetlands in Western Himalayan Region

S No.	Wetland	State
1.	Wular	Jammu & Kashmir
2.	Tso Morari	Jammu & Kashmir
3.	Renuka	Himachal Pradesh
4.	Chandratal	Himachal Pradesh
5.	Pong Dam lake	Himachal Pradesh

(Source: Anonymous, 1998a)

6.0 STUDY AREA

The Western Himalayan Region (WHR) is located between Longitudes 72^0 49′ and 81^0 35′ E and Latitudes 29^0 and 37^0 03′, and consists of 3 sub-zones of Jammu and Kashmir, Himachal Pradesh, and Uttar Pradesh hills (Figure 1). The geographical area of the zone is 328484 km^2 and perimeter is 3599 km. The zone is mostly bounded by international boundaries; Indo-China border in the north and north-east, Indo-Pakistan border in the west, and Indo-Nepal border in the east. The major rivers that flow through the zone are:

1) The Indus river along with its tributaries are Jhelum, Chenab, Ravi, Beas and Sutlej,
2) The Ganga river along with its tributaries are Yamuna, Ramganga and Sharda.

The catchment area of the various rivers/tributaries within the Western Himalayan region is given in Table 5.

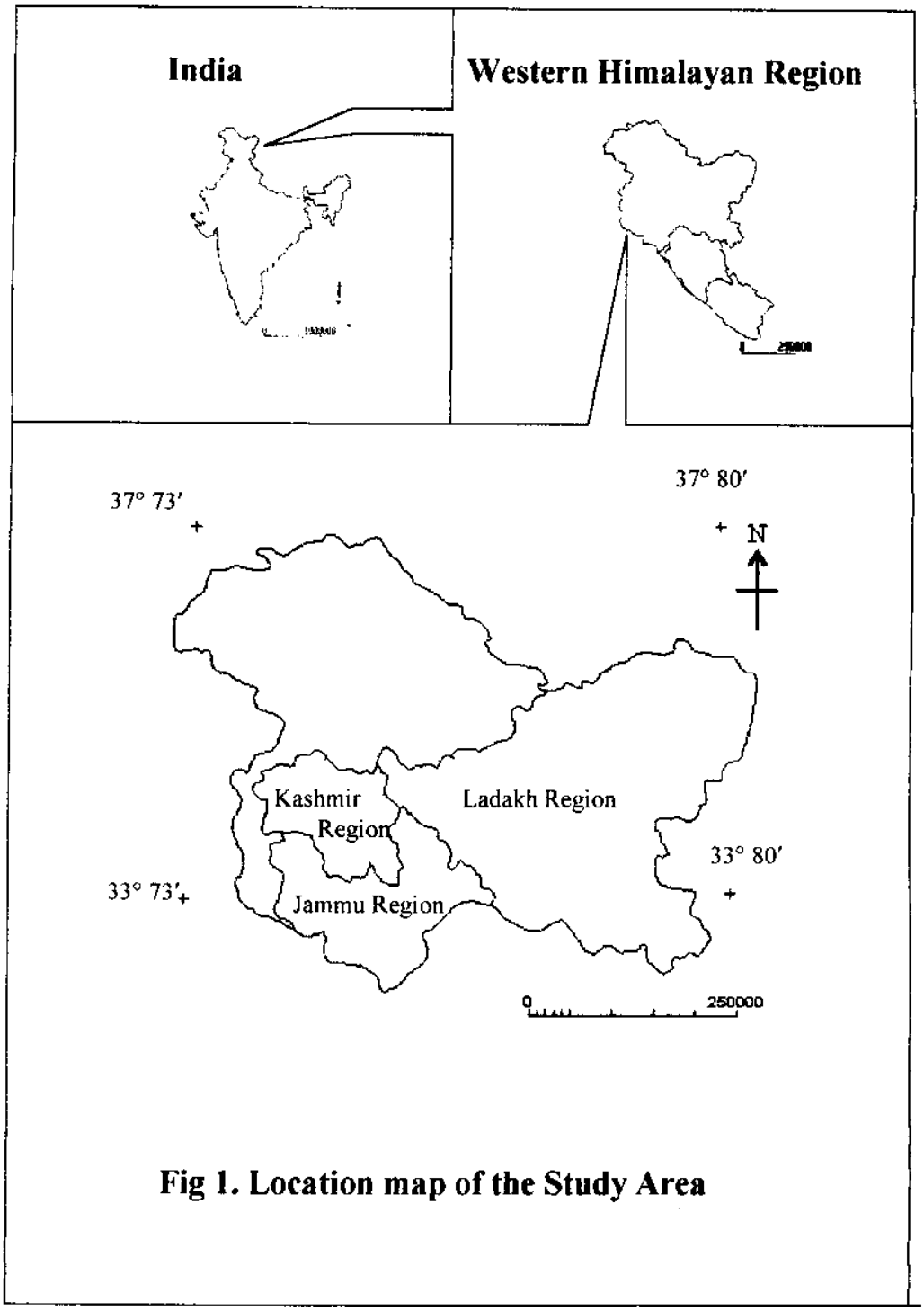


Fig 1. Location map of the Study Area

Table 5. Catchment Area of River Basins in Western Himalayan Region

S No.	River	Catchment Area (km^2)
1.	**Indus River System**	
1.1	Indus	171102
1.2	Jhelum	30749
1.3	Chenab	31047
1.4	Ravi	8034
1.5	Beas	15773
1.6	Sutlej	15870
	Sub Total	**272575**
2.	**Ganga River System**	
2.1	Ganga	24004
2.2	Yamuna	12498
2.3	Ramganga	3174
2.4	Sharda	9919
	Sub Total	**49595**
	Total	**322170**

(Source: Anonymous, 1994)

6.1 General Setup

In this report, the area falling under Jammu & Kashmir is considered and the remaining Himachal Pradesh and the hills of Uttar Pradesh will be considered subsequently. The state of Jammu and Kashmir lies between latitude 32^0 07′ to 37^0 06′ N and longitude 72^0 44′ to 80^0 34′ E (Figure 1). The State has 10 districts according to SOI maps. However, districts have been reorganised and now the State comprises 14 districts, falling under three divisions, i.e. Jammu, Kashmir, and Ladakh. The total reported area of the J&K State is 222236 Sq.Km, which includes the area under illegal occupation of Pakistan and China (Anonymous, 1999).

According to the estimates by the Ministry of Environment & Forests, the state of Jammu and Kashmir has 29107 Ha area under the wetlands out of which 7227 Ha area is under natural and 21880 Ha under man-made wetlands (Anonymous, 1998a).

6.2 Physiography

Topographically J&K state is divisible into three district regions: (i) outer Himalayas, also known as Siwalik; (ii) lesser Himalayas, north of Siwalik, also known as Pir Panjal range. Kashmir Valley is like a bowl formed north of Pir Panjal range and south of Zanaskar range; and (iii) North of valley and Zanaskar range is Greater Himalayas. The valley between Zanaskar range in south and Karokaram in north is called the Ladakh valley.

6.3 River Systems

The three river systems of J&K State drain the three regions of Jammu, Kashmir and Ladakh. Chenab drains most of the Jammu division, Jhelum drains the Kashmir Valley and Poonch district. Both rivers meet the river Indus in Pakistan. The Indus itself rises in the Tibet and drains Ladakh north of Zanaskar and South of Karokaram. The drainage and river basins in the study area are shown in Figures 2 and 3, respectively.

The river Indus rises from near the lake Mansarovar on the Tibetan plateau and enters the Himalayas in Ladakh. Thereafter it flows through the Ladakh region of Jammu and Kashmir before entering the plains of Pakistan. The main tributaries of the river Indus in Ladakh are Shyok, Shigar, Gilgit, Astor, Shigar (south), Zaskar, and Hanle.

Besides the above tributaries, other important tributaries of the Indus system drain the western Himalayas. These are:

(a) **Jhelum:** The Jhelum river rises from the northern slopes of the Pir Panjal range. It drains the Kashmir valley before cutting a deep gorge through Pir Panjal range near Baramulla. Its major tributaries are Liddar, Sind, and Kishenganga,

(b) **Chenab:** The river Chenab is another major tributary of the river Indus. It rises from the Lahul valley of Himachal Pradesh and enters Kishtwar after flowing through the

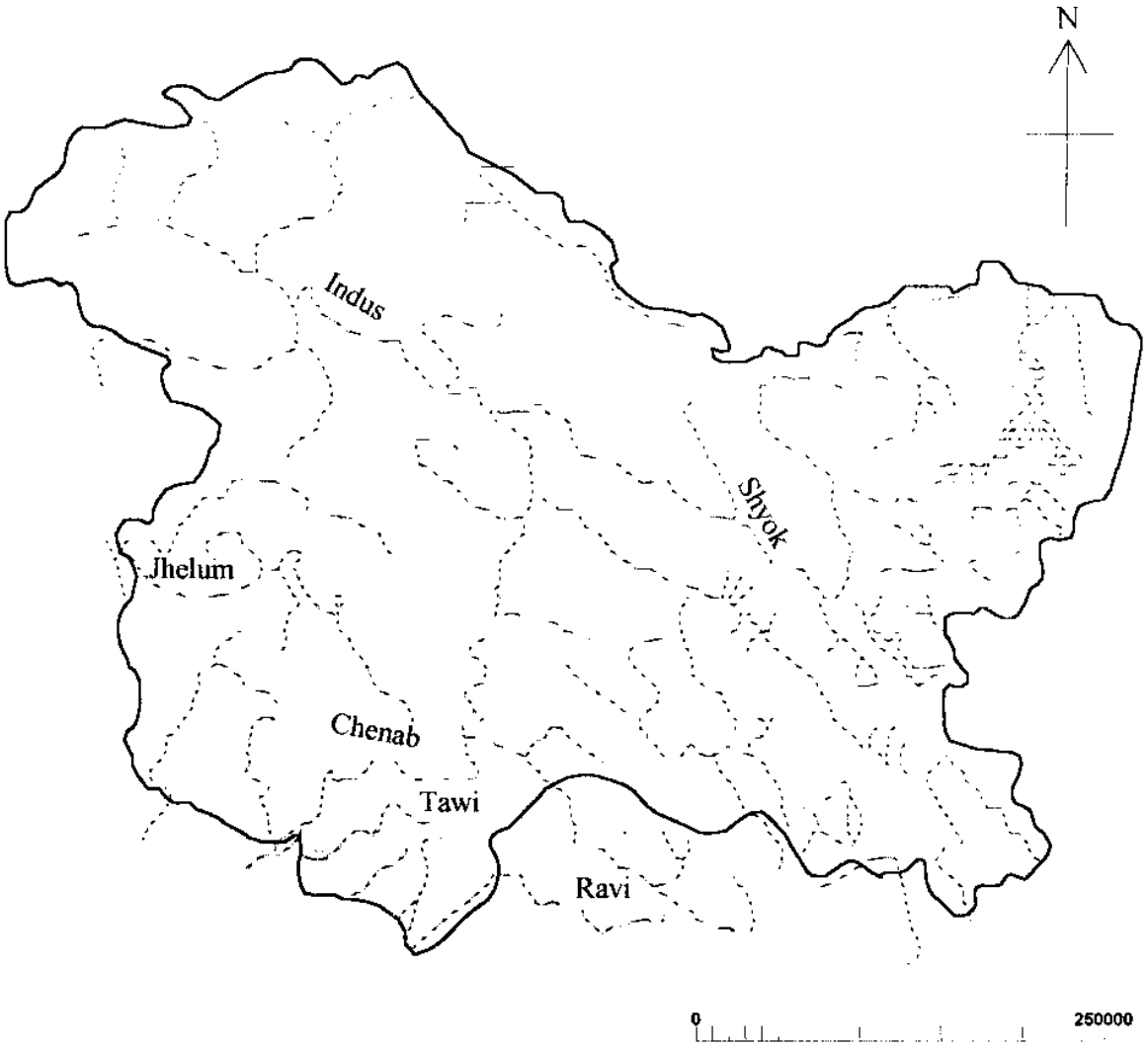


Fig 2. Drainage in the Study Area
(Source: Irrigation Atlas of India,1989)

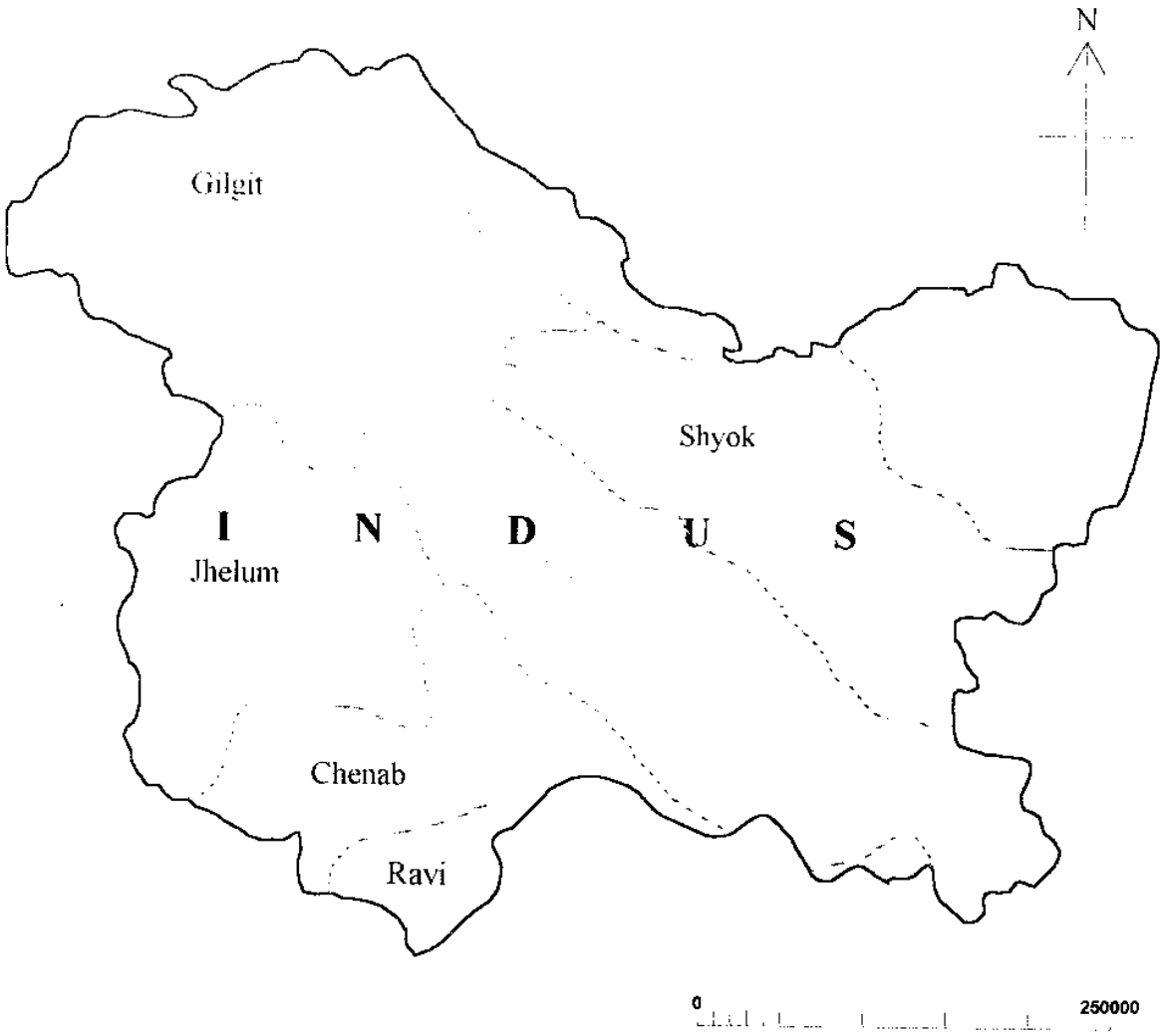


Fig 3. River Basins in Jammu & Kashmir
(Source: Irrigation Atlas of India,1989)

Pangi valley of Himachal Pradesh. Thereafter it flows along the base of the Pir Panjal range and enters the plains, and

(c) **Ravi:** The river Ravi is the third of the five major tributaries of the river Indus. It originates in the Bara Banghal tract between the Dhauladhar range in the south and the Pir Panjal in the north. This river flows in a more or less westerly direction before it cuts across the Dhauladhar range downstream of which it flows towards southeast to enter the plains of Punjab.

6.4 Climatology

The effect of south-west monsoon is felt in J&K state inspite of the fact that it lies in tropics. However, the climate of the three distinct divisions is also determined by orography. In Jammu division (mostly south of Pir Panjal ranges) in Siwalik the general climate is similar to plains. Kashmir valley has temperate climate i.e. mild summer and snowfall in winter. Leh and Kargil districts, north of Zanaskar, receive scanty rainfall and prolonged sub-zero temperatures in winter.

Normal mean daily temperature at Leh remains sub-freezing during the months of November to March. Srinagar is relatively warmer with mean daily temperature varying between 1 to about 8^0C during these months. During April to October, the temperature at Srinagar varies between 13 to 25^0C. The normal mean daily temperature at Jammu and nearby areas remains high, varying between 13^0C in January to 34^0C in June.

6.5 Rainfall Pattern

The average annual rainfall in the State varies considerably from about 200 cm in south-western Greater Himalayas (e.g. Udhampur district) to about 10 cm in Ladakh region. The district annual average rainfall excepting Srinagar and Ladakh exceeds 100 cm. In southern areas the month of maximum rainfall is August, while in the north and Ladakh maximum rainfall occurs in March. Western disturbances have a dominating influence in determining the extent of rainfall in winter and spring in J&K state. In Jammu division monsoon rainfall ranges about 68% of the annual rainfall. Dominance of the rainfall is observed in Kashmir Valley due to western disturbances. Monsoon rainfall

is just about 20 to 22%. Most of the spring / winter precipitation in Kashmir and Ladakh regions falls in the form of snow and this forms the biggest reservoir sources of perennial water in river systems in J&K State. Districtwise seasonal rainfall for selected districts where most of the water bodies in the State occur is shown below.

District	Average Rainfall (mm)	
	Nov-Apr	May-Oct
Udhampur	496	1192
Anantnag	660	385
Baramulla	652	369
Srinagar	342	287
Leh	220	78

6.6 Soils

Soils of Jammu & Kashmir have been classified into 8 major groups (Gupta et. al, 1985). Brown earth or brown forest soils occur in parts of Kathua, Udhampur, Doda, Poonch, Rajouri, Anantnag and Baramulla districts. Red and yellow soils cover the southern half of Kathua, northern half of Jammu, southern half of Reasi (Udhampur), and parts of Rajouri and Poonch districts. The southern half of Jammu and plain areas of Kathua, Rajouri, Poonch, Udhampur, and valleys in Kashmir and Ladakh regions has alluvial soils. Saline and alkali soils are found in the alluvial belts of Jammu (R S Pura and Bishnah tehsils), Kathua (Ramkot and Challain) and Chanthang area of Ladakh. Mostly sub-montane soils prevail in the rest of the State, except in Ladakh and pasture areas of Gulmarg, Pahalgam, Lolab, Gurez, Baramulla, Sonamarg, which have mountain and meadow soils (Anonymous, 1976; Gupta et. al, 1985).

6.7 Land Use

Forests occupy nearly 27% of the total reported area (according to village papers) in the State. The total area occupied under forests and non-agricultural uses, barren and un-cultivated land is reported as 6580 Km^2 and 5820 Km^2, respectively. Other uncultivated land (excluding fallows) is reported as 3380 Km^2, while 1050 Km^2 is

reported under fallow land, and net sown area in the State is 7330 Km^2 (Anonymous, 1999).

Doda district has the largest forest cover (2190 Km^2), followed by Udhampur (1920 Km^2), Rajouri (940 Km^2), Kathua (730 Km^2), Jammu (400 Km^2), Poonchh (340 Km^2); Anantnag, Pulwama, Baramulla and Srinagar districts have only 10-20 Km^2 area under forest cover. More than 55% of land in Leh district falls under barren and un-cultivable category. The districts with large areas under permanent grazing land are Rajouri, Poonchh, Baramulla, Jammu, Kathua, and Jammu.

7.0 METHODOLOGY

Pre-monsoon and post-monsoon seasons, IRS-1A LISS-II data pertaining to 1988/89 in the form of False Colour Composites (FCC) and digital data of IRS-1C of Path 93 and Row 47, acquired on 13 October, 1998, were used for the delineation of water bodies. Besides the satellite data, SOI toposheets alongwith collateral data were made use of in the study.

7.1 Identification of Water Bodies

Mapping of water bodies in the Western Himalayan Region was carried out using the available FCCs on 1:250,000 scale. First, the water bodies on a FCC were visually interpreted along with the details of latitude, longitude and the date of pass. The interpretation is based on shape, size, tone/colour, texture, pattern, and location of the water body feature on the satellite imagery. **A water body comprises areas of surface water, impounded in the form of pond, lake or reservoir**. These are clearly seen on satellite false colour imagery in blue colour. The geometric resolution of IRS-1A, LISS-II camera is 36.25 m.

After visual interpretation of water bodies for pre-monsoon (March/April/June) and post-monsoon (October/November/December) on each imagery, these were traced on the Garware polyester film, then digitized using ILWIS GIS and stored in different segment files. Using Vector operations module, all such segment files were then

combined to get a single final segment map for pre- and post-monsoon of the entire study area. These final segment maps of pre- and post-monsoon were polygonized to get the water spread area and perimeter of the water body. Digital analysis was also carried out on multispectral digital data of IRS-1C, LISS-III of Path 93 and Row 47, for delineation of the water bodies. The Contrast and Spatial enhancement techniques were applied on raw data in order to make the raw image more interpretable. A standard FCC (RGB: 432 band combination) was prepared and this image was registered with the help of SOI toposheet No.43O. The registered image was resampled at a pixel size of 20 m. The whole image was classified into two category, i.e. water and non-water. Using the corresponding Survey of India toposheets and other available literature, name, type, nearest place, district, river basin and elevation of the water body has been identified and arranged with the delineated water bodies.

The minimum size of the water body mapped in the present study is 2mm x 2mm, which corresponds to 0.25 Sq.Km on 1:250,000 scale. Thus water bodies smaller than 0.25 Sq.Km (at least in one season) are not discernible at 1:250,000 scale.

7.2 Classification of Parameters

The database created for this study includes the information on the following:

- Name and type of the water body
- Name of the nearest place, and district
- Name of the river basin
- Geographical location (latitude, longitude, elevation)
- Extent (spread area) of water body in both pre and post-monsoon seasons
- Perimeter of water body in both pre and post-monsoon seasons
- Satellite, sensor, path/row, date of pass

8.0 RESULTS AND DISCUSSION

An inventory of water bodies in the Jammu & Kashmir State of Western Himalayan region was prepared using available satellite data of IRS-1A (standard FCC, Scale 1:250,000) and digital data of IRS -1C. A total of 38 major water bodies, with

water spread area greater than 0.25 Sq Km, were delineated in the study area (Figures 4 & 5). Majority of the water bodies belong to natural category, except Salal which is a reservoir. Only seven water bodies were identified as marshy or swamps; all others were lakes.

Also, a database was prepared with the help of Survey of India (SOI) topographic maps, which includes name and type of the water body, nearest place, district, river basin, geographical coordinates and elevation. The water spread area and perimeter of the water body, both in pre- and post-monsoon periods, were calculated using a GIS package. Some of the prominent water bodies in Jammu and Kashmir are shown in Plates 1 to 8. The details of the delineated water bodies, arranged alphabetically, are given in Table 6.

Majority of the water bodies exhibits little seasonal changes. During pre-monsoon, some of the water bodies at high altitudes were either completely or partially covered with snow. As a result, the shape of the water body changed in such a way that the perimeter decreased while the water spread area increased on the post-monsoon imageries, e.g. Pangong Tso lake. In the case of Pangong Tso lake, there was a decrease in the perimeter of about 0.7 km on the post-monsoon scene. Also, the water spread area for this lake was considered only upto the boundary of India.

As seen in Table 6, the spread area for the Pangong and Tso Morari lakes during pre-monsoon period was computed less than actual as the lakes were shown partially covered with snow on the satellite imageries. Out of 38 water bodies, the spread area for 15 could not be computed from the pre-monsoon imageries as the water bodies were not at all visible due to snow cover. Also, in 4 cases, pre-monsoon imageries were not available and the analysis was restricted to only post-monsoon data.

Among the larger lakes (with spread area more than 10 km^2), Amto Gor and Dal showed only less than 5% increase in the post-monsoon period, while Wular (10.6%) and Hygam Jhil (23.9%) showed higher increases. Salal reservoir showed only a marginal increase of 1.9%. The other water bodies with high increases in the post-monsoon period

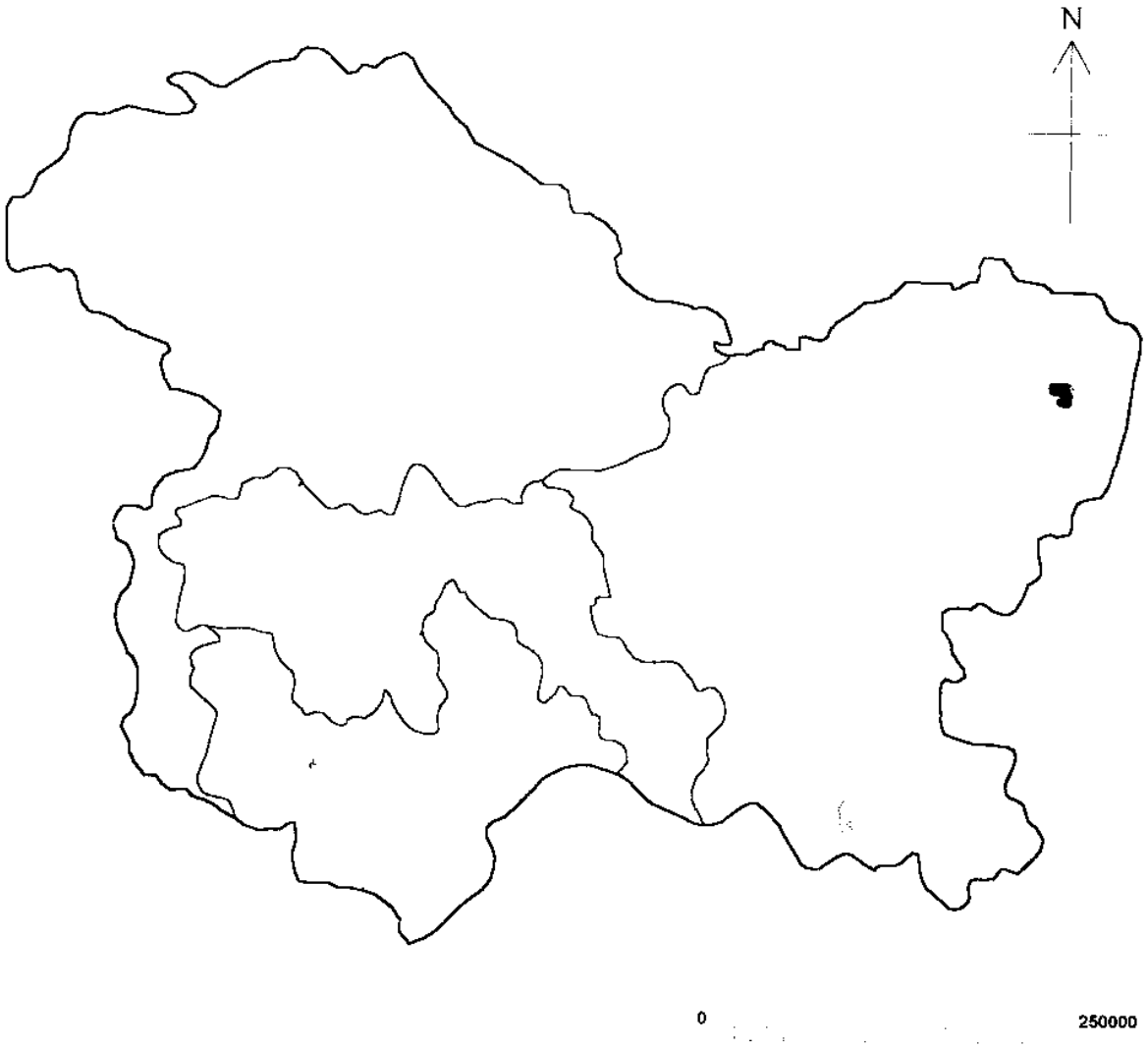


Fig 4. Location map of the Waterbodies (Pre-monsoon)

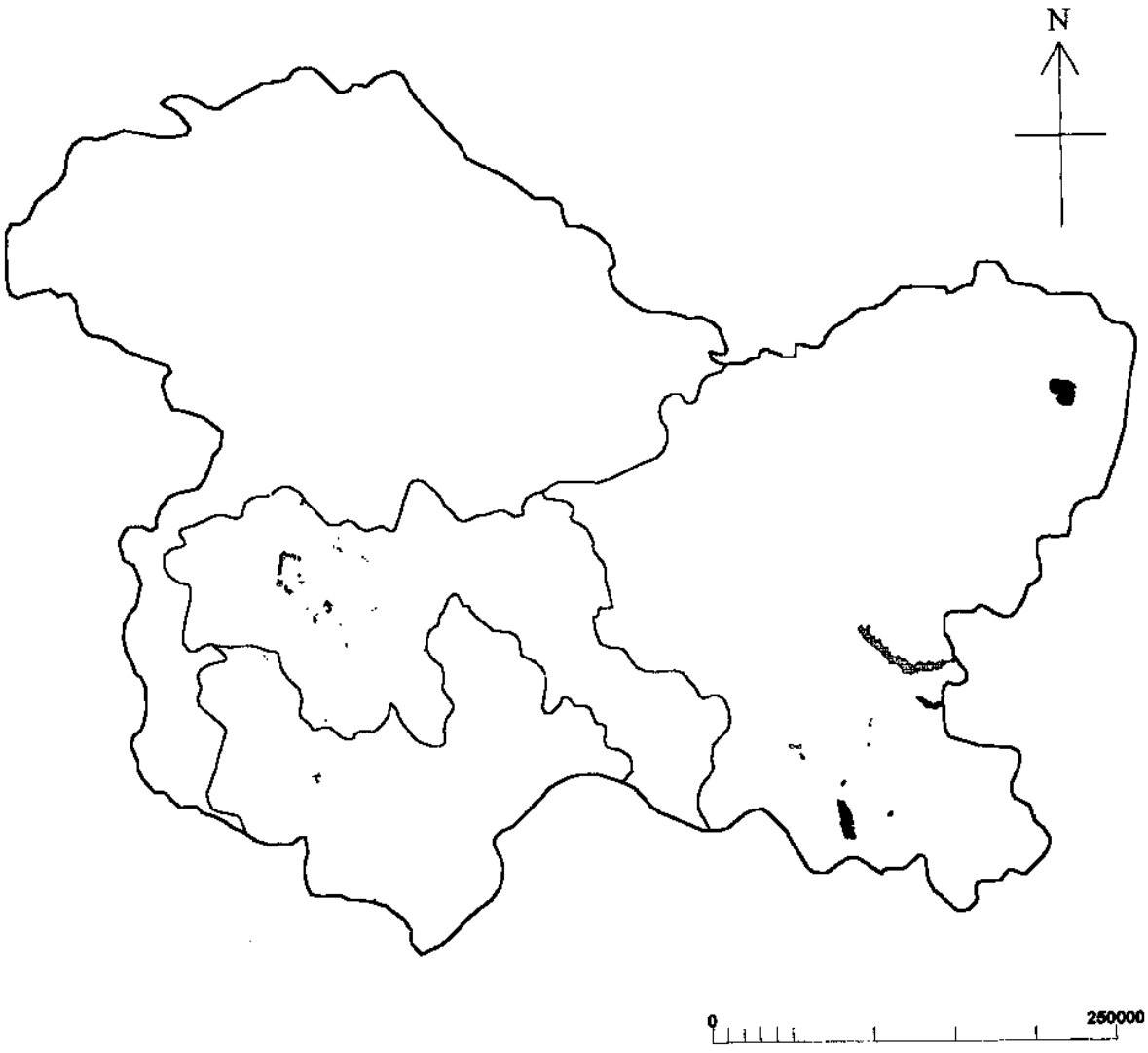
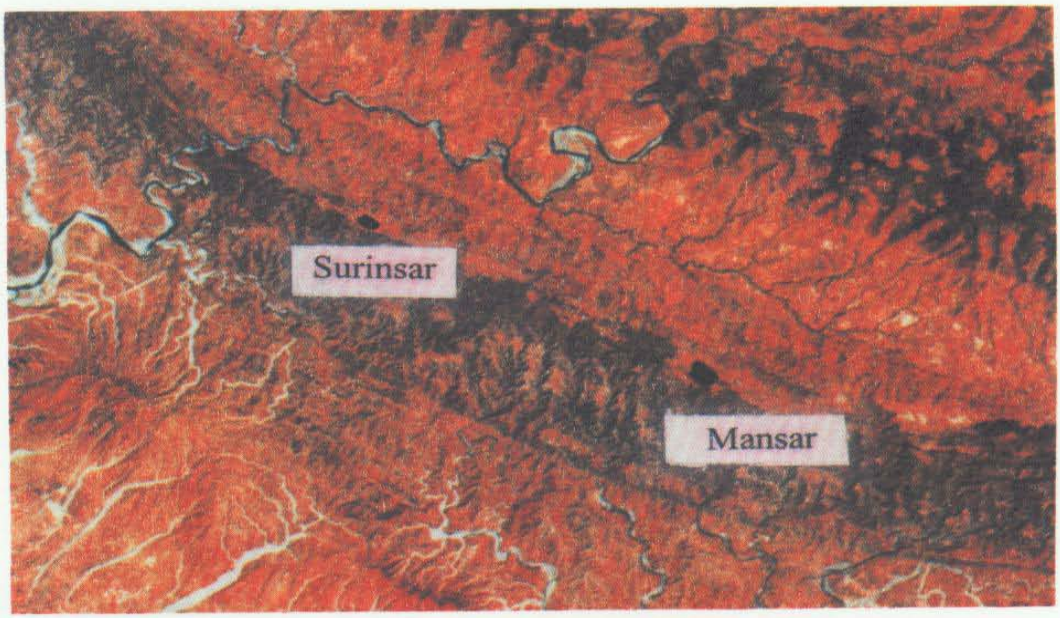
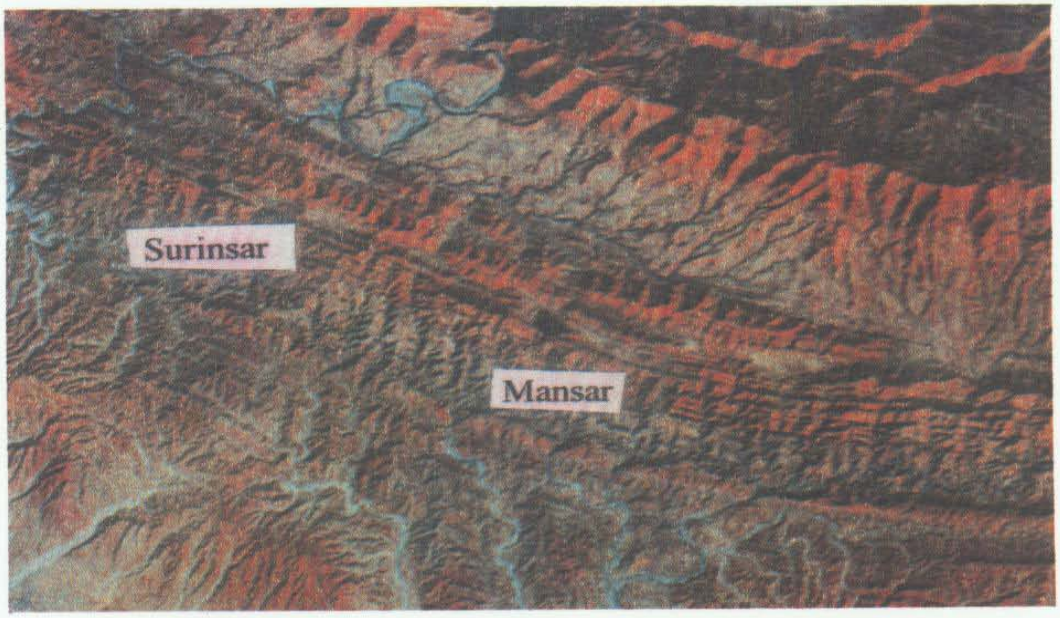


Fig 5. Location map of the Waterbodies (Post-monsoon)

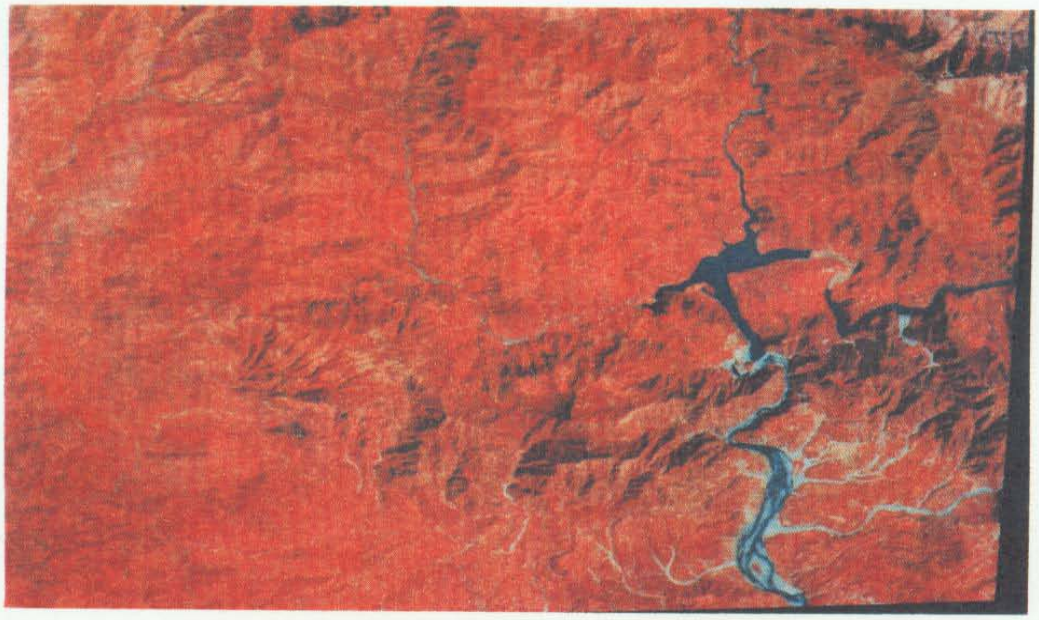


Pre-monsoon



Post-monsoon

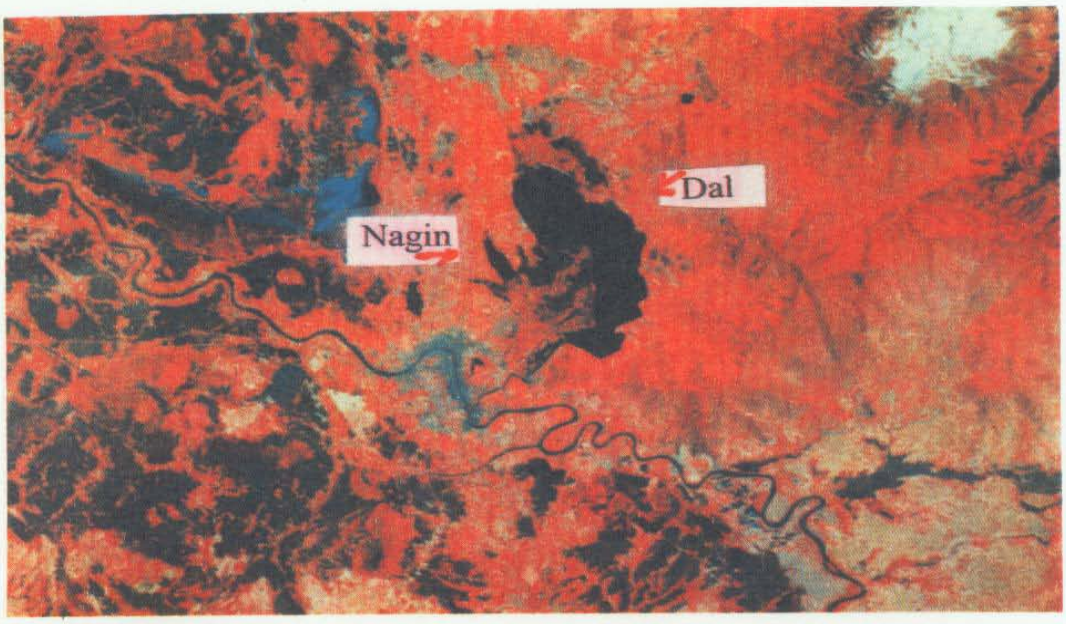
PLATE 1. Satellite view of Mansar & Surinsar lakes



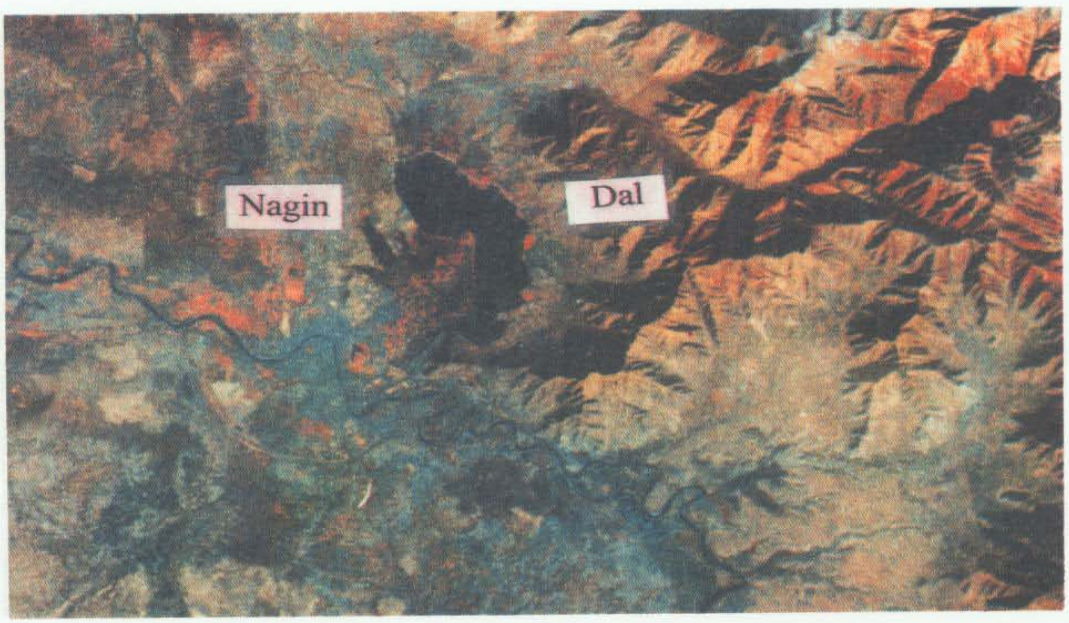
Pre-monsoon

Post-monsoon

PLATE 2. Satellite view of Salal reservoir

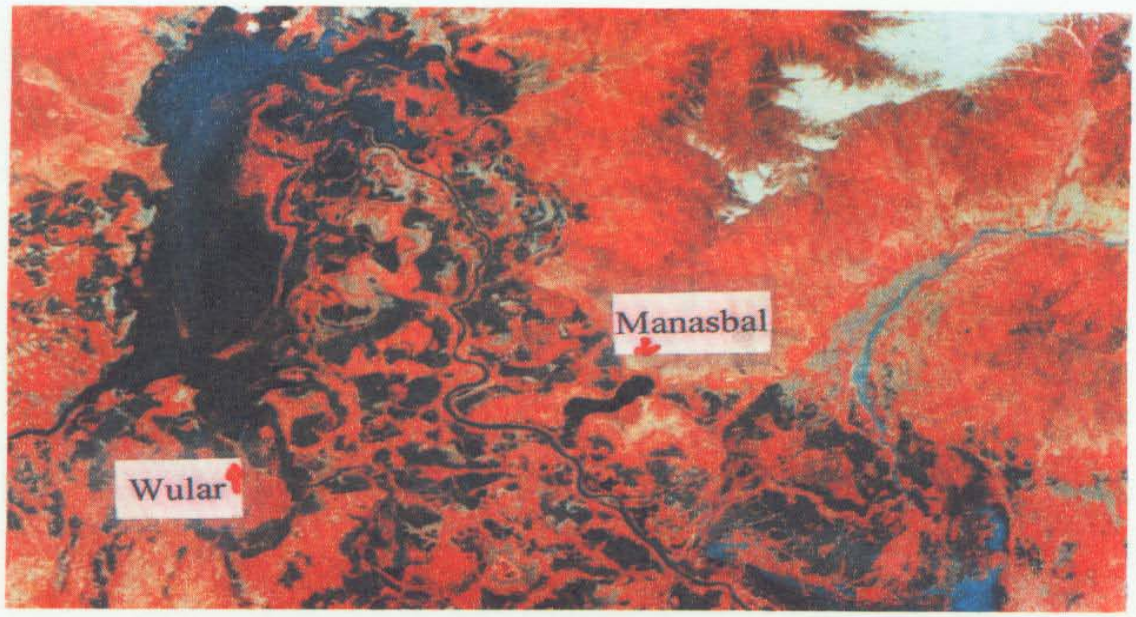


Pre-monsoon

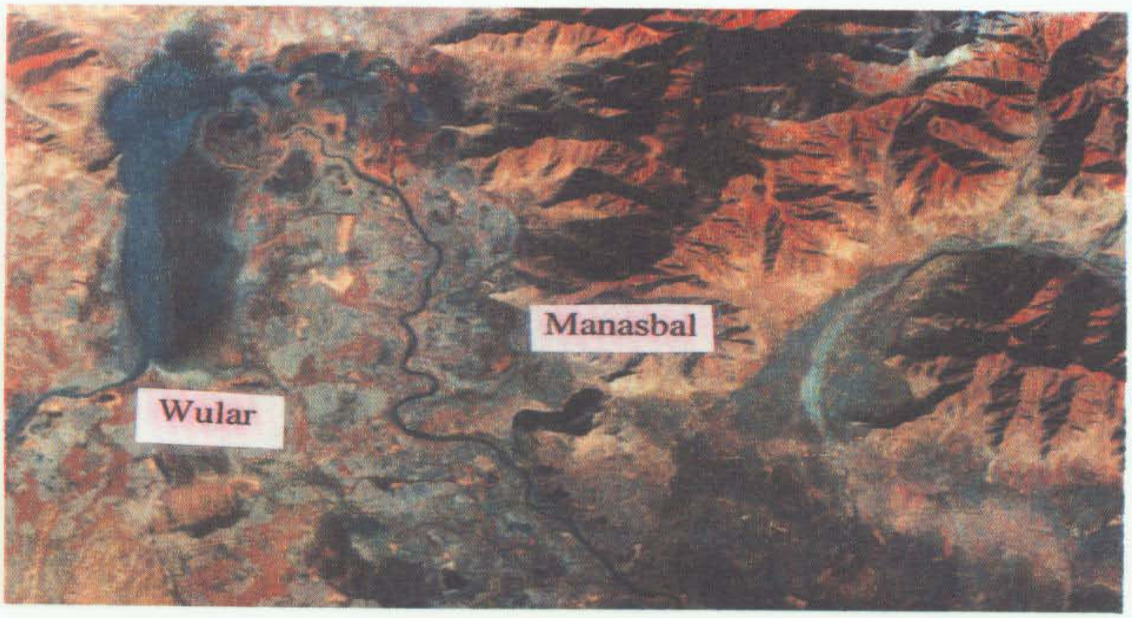


Post-monsoon

PLATE 3. Satellite view of Dal & Nagin lake

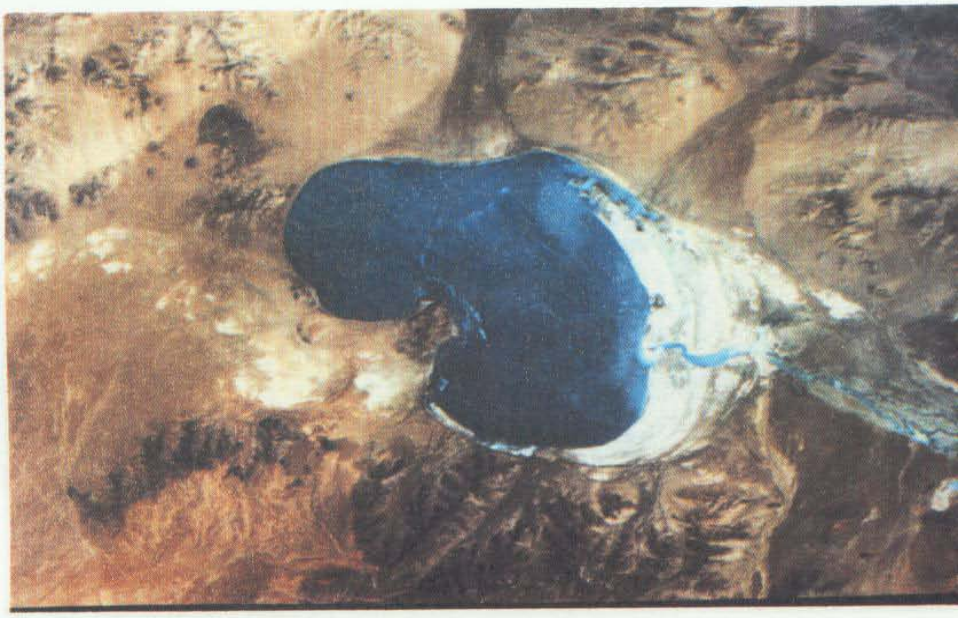


Pre-monsoon

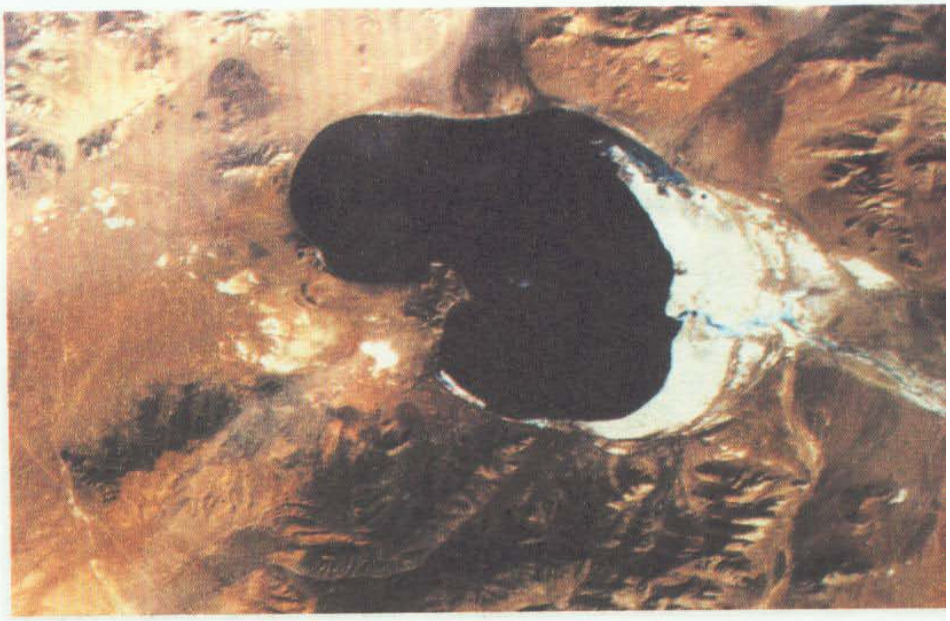


Post-monsoon

PLATE 4. Satellite view of Wular & Manasbal lakes

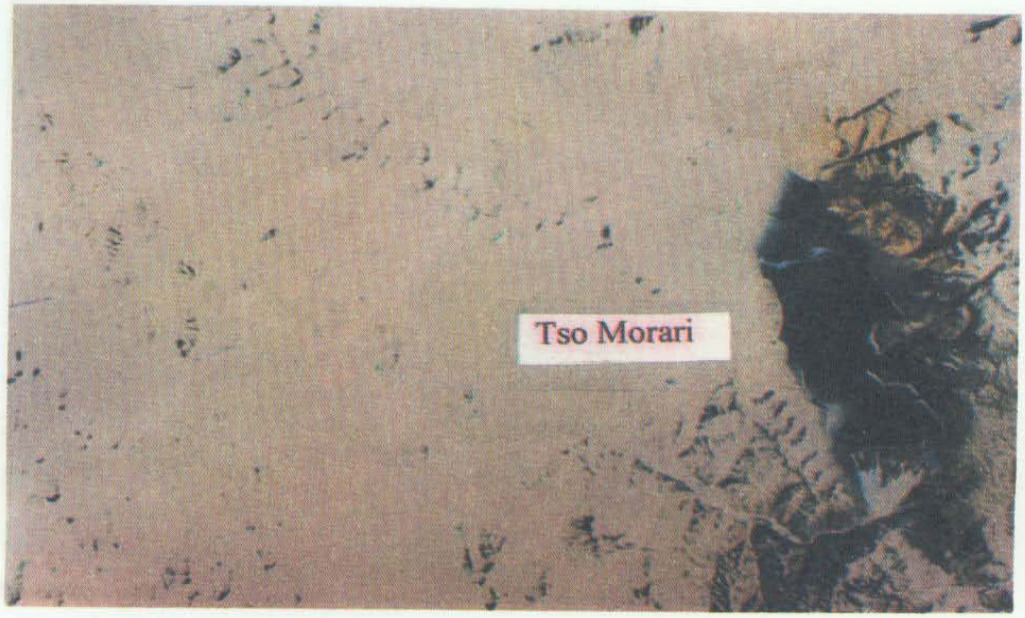


Pre-monsoon

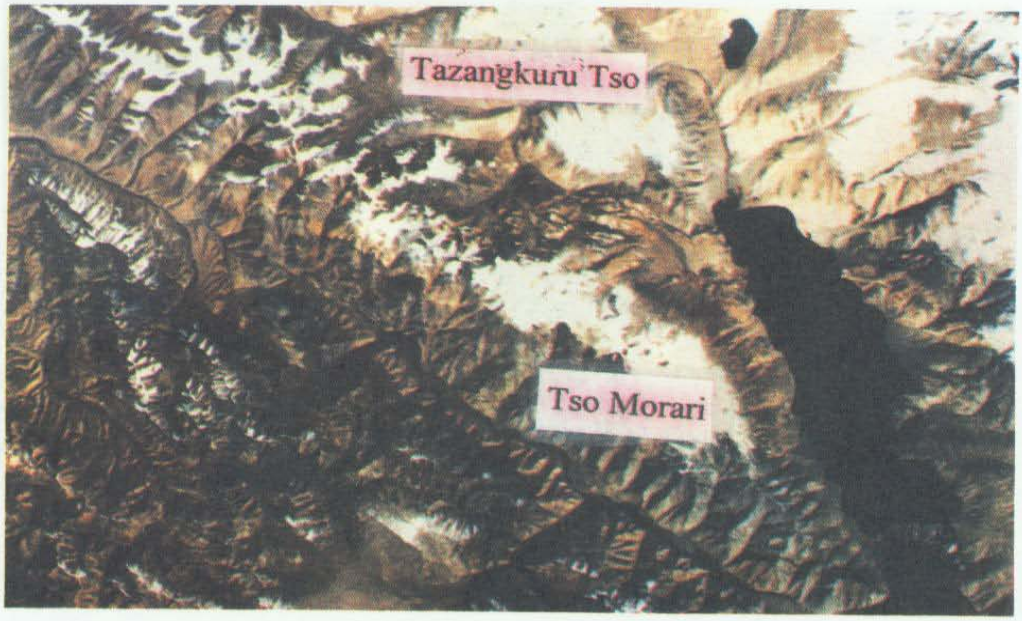


Post-monsoon

PLATE 5. Satellite view of Amto Gor la



Pre-monsoon



Post-monsoon

PLATE 6. Satellite view of Tso Morari & Tazangkuru Tso

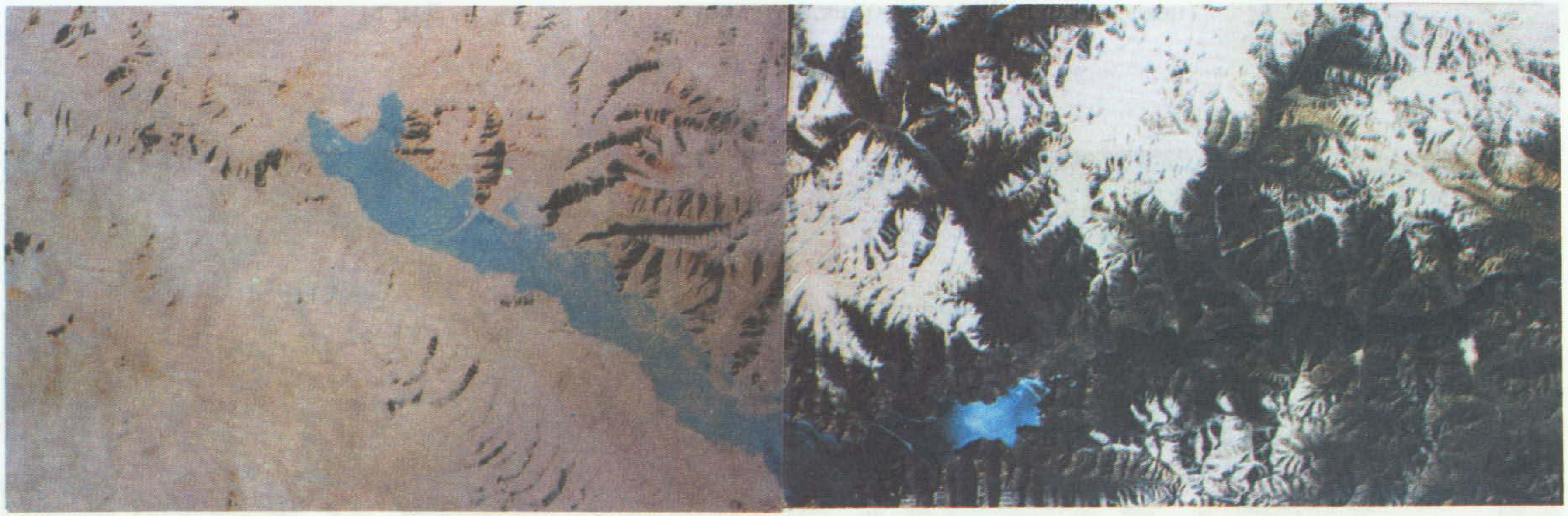


PLATE 7. Satellite view of Pangong Tso (Pre-monsoon)

PLATE 8. Satellite view of Pangong Tso (Post-monsoon)

Table 6. Details of Water bodies in Jammu & Kashmir (Alphabetical)

Name of Water Body	Type	Nearest Place	District	River Basin	Latitude	Longitude	Elevation (m)	Water Spread Area (Sq.Km)		Perimeter (Km)		Sensor/scene, Path / Row, Date of Pass	
								Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Amto Gor	Lake	-na-	Leh	Shyok	35° 08′ 28″ to 35° 17′ 22″	79° 43′ 18″ to 79° 53′ 11″	-na-	174.080	174.385	65.032	65.846	L2B2,29/42, 03 MAR 89	L2B2,29/42, 22 NOV 89
Bodhsar	Lake	Bodhsar	Budgam	Jhelum	33° 50′ 47″	74° 26′ 18″	3956	snow	0.262	snow	2.201	-do-	-do-
Bod Sar	Marshy	Nambalbal	Srinagar	Jhelum	34° 02′ 18″	74° 55′ 43″	1593	0.228	0.318	2.024	2.342	-do-	-do-
Dal	Lake	Dalgate	Srinagar	Jhelum	34° 06′ 25″ to 34° 10′ 18″	74° 50′ 10″ to 74° 52′ 26″	1586	13.186	13.629	21.978	21.047	-do-	-do-
Gangabal Lake	Lake	Naranag	Srinagar	Jhelum	34° 27′ 33″	74° 54′ 56″	3569	snow	1.634	snow	6.420	-do-	-do-
Godsar	Lake	Godsar Nala	Baramulla	Jhelum	34° 24′ 51″	75° 04′ 38″	3810	snow	0.607	snow	3.755	-do-	-do-
Gundi-i-Khalil	Lake	TaraZu	Baramulla	Jhelum	34° 13′ 18″	74° 36′ 23″	1569	0.388	0.535	2.442	2.840	-do-	-do-
Hokar sar	Lake	Zainakot	Baramulla	Jhelum	34° 07′ 49″	74° 42′ 23″	1584	0.475	0.732	3.095	3.414	-do-	-do-
Hygam jhil	Swamp	Tarazu	Baramulla	Jhelum	34° 15′ 06″	74° 32′ 28″	1569	15.127	18.745	27.517	30.303	-do-	-do-
Kar Tso	Lake	-na-	Leh	Indus	33° 19′ 35″	77° 56′ 45″	4537	snow	10.536	snow	20.018	L2A1,29/44, 03 MAR 89	L2A1,29/44, 09 OCT 89
Konsar Nag	Lake	Phutin Pansaisali	Pulwama	Jhelum	33° 30′ 21″	74° 50′ 00″	3585	-na-	0.329	-na-	2.565	-na-	Do
Krishan Sar	Lake	Vishansar	Baramulla	Jhelum	34° 24′ 12″	75° 05′ 35″	3819	snow	0.448	snow	2.900	-do-	-do-
Kyule Tso	Lake	Kyule	Leh	Indus	33° 26′ 00″	78° 26′ 57″	5400	snow	1.864	snow	5.605	-do-	-do-
Kyun Tso	Lake	Chila	Leh	Indus	32° 55′ 46″	78° 34′ 00″	5000	Snow	5.420	Snow	10.823	L2B2,29/44, 03 MAR 89	L2B2,29/44, 09 OCT 89
Madmatti sar	Lake	Waril Gali	Baramulla	Jhelum	34° 31′ 17″	74° 54′ 50″	4449	Snow	0.348	Snow	2.316	-do-	-do-
Manasbal	Lake	Gratabal	Baramulla	Jhelum	34° 16′ 05″ to 34° 17′ 01″	74° 38′ 38″ to 74° 40′ 51″	1600	2.591	3.486	9.346	8.981	-do-	-do-
Mansar	Lake	Mansar	Udhampur	Chenab	32° 41′ 30″	75° 07′ 30″	700	0.629	0.747	3.198	3.413	L2B2,32/44, 19 APR 89	L2B2,32/44, 17 DEC 89
Marsar	Lake	Nagabcran	Srinagar	Jhelum	34° 07′ 18″	75° 08′ 30″	3849	-na-	0.271	-na-	2.926	-na-	Do

Nagin lake	Lake	Sadrabal	Srinagar	Jhelum	34° 08' 45"	74° 49' 23"	1604	0.776	0.907	4.385	4.815	-do-	-do-
Nambi Narku	Marshy	Narkur	Srinagar	Jhelum	34° 03' 37"	74° 45' 34"	1583	4.570	5.951	9.459	10.300	-do-	-do-
Nund kol	Lake	Dandlod	Srinagar	Jhelum	34° 26' 45"	74° 55' 45"	3607	Snow	0.351	snow	2.854	-do-	-do-
Pangong Tso	Lake	-na-	Leh	Shyok	33° 40' 58" to 33° 45' 46"	78° 40' 39" to 79° 03' 00"	4250	273.454*	296.564	185.251	184.554	L2A2 & L2B2,29/43, 03 MAR 89	L2A2 & L2B2.29/43, 22 NOV 89
Rakh Malang	Marshy	Safapora	Baramulla	Jhelum	34° 18' 59"	74 38' 56"	1538	1.845	2.035	5.332	5.441	-do-	-do-
Rakhi Gandka Shah	Marshy	Barthana	Srinagar	Jhelum	34° 05 53"	74° 46 23"	1583	0.701	0.820	3.853	4.119	-do-	-do-
Salal	Reservoir	Riasi	Udhampur	Chenab	33° 10' 59"	74° 46' 01"	1038	7.169	7.305	29.372	26.483	L2A1,32/44 19 APR 89	L2A1. 32/44 17 DEC 89
Salnai sar	Lake	Lolgul Gali	Baramulla	Jhelum	34° 28' 14"	74° 53' 00"	4055	Snow	0.425	snow	2.892	-do-	-do-
Startsapu Tso	Lake	Kurjok	Leh	Indus	33° 15' 48"	78° 00' 00"	4337	Snow	4.866	snow	11.753	-do-	-do-
Surinsar	Lake	Surinsar	Udhampur	Chenab	32° 47' 21"	75° 00' 48"	736	0.302	0.324	2.283	2.123	-do-	-do-
Tar sar	Lake	Pahilmazar	Anantnag	Jhelum	34° 08' 00"	75° 10' 08"	3785	-na-	0.430	-na-	3.398	-na-	Digital data
Tazangkuru Tso	Lake	Tsakshang	Leh	Indus	33° 06' 23"	78° 15' 53"	4800	Snow	5.063	snow	9.449	L2A2,29/44 03 MAR 89	L2A2,29/44, 09 OCT 89
Tso Kur	Lake	-	Leh	Indus	33° 04' 14"	79° 05' 32"	4225	0.357	0.549	2.431	3.156	L2B1,29/44, 03 MAR 89	L2B1,29/44, 09 OCT 89
Tso Morari	Lake	Karzok	Leh	Indus	32° 48' 16" to 33° 00' 01"	78° 12' 51" to 78° 19' 56"	4527	115.845*	141.054	61.823	74.705	-do-	-do-
Un-named	Marshy	Nusu Ghat Kalhum	Baramulla	Jhelum	34° 24' 10"	74 39' 01"	1581	2.138	2.390	5.644	6.024	-do-	-do-
Un-named	Marshy	Kulul	Pulwama	Jhelum	33° 55' 48"	74° 55' 08"	1591	-na-	1.639	-na-	6.075	-na-	Do
Vishan Sar	Lake	Vishansar	Baramulla	Jhelum	34° 23' 27"	75° 06' 48"	3677	Snow	0.635	snow	4.077	-do-	-do-
Wular	Lake	Bandipur	Baramulla	Jhelum	34° 19' 15" to 34° 26' 19"	74° 30' 42" to 74° 35' 45"	1580	50.15	55.05	66.07	49.06	L2A2,32/43, 02 JUN 89	L2A2,32/43, 16 NOV 88
Yaye Tso	Lake	Yayala	Leh	Indus	33° 19' 05"	78° 26' 14"	4800	Snow	1.637	snow	4.869	-do-	-do-
Yusup Tso	Lake	Zulungpha	Leh	Indus	33° 27' 41"	78° 27' 30"	5400	Snow	1.542	snow	6.205	-do-	-do-

included Nambi Narku (30.2%), Gundi-I-Khalil (37.9%), Bod Sar (39.5%), Tso Kur (53.8%), and Hokar Sar (54.1%).

Maximum increase in the perimeter was observed for Tso Kur (29.8%), followed by Gundi-I-Khalil (16.3%), Bod Sar (15.7%), Hokar Sar (10.3%), and Hygam Jhil (10.1%). However, in four cases, the perimeter was found to decrease in the post-monsoon period: Wular (-25.8%), Salal (-9.8%), Surinsar (-7%), Dal (-4.2%), and Manasbal (-3.9%).

From the above analysis based on the available data, it is inferred that Amto Gor lake is among the stable water bodies, i.e. with very minor changes in the pre- and post-monsoon periods.

For convenience of the users, the water bodies have been classified according to the following criteria:

(i) According to the altitude,

(ii) According to the river basin,

(iii) According to the district, and

(iv) According to the size (water spread area).

8.1 Classification According to Altitude

The delineated water bodies have been classified into following three categories (Zutshi, 1989):

(a) Water bodies at low altitudes (elevation < 1000m AMSL)

(b) Water bodies at moderate altitudes (1000m< elevation < 3000m AMSL)

(c) Water bodies at high altitudes (elevation > 3000m AMSL)

8.1.1 Water Bodies at Low altitudes

Two natural freshwater lakes, Surinsar and Mansar situated to the south of Udhampur. The lakes are found in the strike valley of lower Sivaliks of the main Sivaliks belt in between the longitudinal ridges in the central range. They are 12 Km. apart and are believed to have originated by the damming of a river, which was flowing along the strike. The lakes are oval to sub-oval in shape and are classified as fault basin non-

drainage types having no regular inflow and out flow channels. The Salal reservoir is situated west of Udhampur in Udhampur district. The details of these three water bodies are given in Table 7.

8.1.2 Water Bodies at Moderate altitudes

The valley of Kashmir abounds in natural fresh water lakes, which have supported tourism and fishery for many centuries. The lakes are found at an average altitude of 1580 m and are either ox-bow or flood plain types. Both the urban and the rural society are heavily dependent on the waters of these lakes. During the pre-monsoon most of the lakes at high altitude in these region are either partly are fully covered with the snow. The details of these water bodies are given in Table 8.

8.1.3 Water Bodies at High altitudes

The high altitude water bodies are located above 3000 m altitude in the south of Srinagar within the Pir Panjal Himalayas and Leh & Ladakh region. Most of these water bodies have glacier origin with little seasonal fluctuation in terms of water spread and are situated in Baramulla and Leh districts of J&K. The details of these water bodies are given in Table 9.

8.2 Classification According to River Basin

The delineated water bodies are found to be falling under three river basins, namely Chenab, Indus, Jhelum and Shyok. Maximum water bodies were found in the Jhelum basin, followed by the Indus basin. The Chenab basin contains only two lakes: Mansar and Surinsar, and one major reservoir, i.e. Salal. Only two lakes are covered under Shyok basin. The details are provided in Table 10.

8.3 Classification According to District

The State of Jammu & Kashmir has 10 districts according to SOI maps. However, districts have been reorganised and now the State comprises 14 districts. Seven of these districts have water bodies grater than 0.25 Sq Km. The delineated water bodies are found to be falling under seven districts, namely Udhampur in Jammu region; Anantnag, Baramulla, Budgam, Pulwama, and Srinagar in Kashmir region; and Leh in Ladakh

Table 7. Water bodies in Jammu & Kashmir at Low Altitudes

S No	Name of Water Body	Type	Nearest Place	District	River Basin	Elevation (m)	Water Spread Area (Sq.Km)		Perimeter (Km)	
							Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
1	Mansar	Lake	Mansar	Udhampur	Chenab	700	0.629	0.747	3.198	3.413
2	Surinsar	Lake	Surinsar	Udhampur	Chenab	736	0.302	0.324	2.283	2.123
3	Salal	Reservoir	Riasi	Udhampur	Chenab	1038	7.169	7.305	29.372	26.483

Table 8. Water bodies in Jammu & Kashmir at Moderate Altitudes

S No	Name of Water Body	Type	Nearest Place	District	River Basin	Elevation (m)	Water Spread Area (Sq.Km)		Perimeter (Km)	
							Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
1	Dal	Lake	Dalgate	Srinagar	Jhelum	1586	13.186	13.629	21.978	21.047
2	Rakh Malang	Marshy	Safapora	Baramulla	Jhelum	1538	1.845	2.035	5.332	5.441
3	Gundi-I-Khalil	Lake	TaraZu	Baramulla	Jhelum	1569	0.388	0.535	2.442	2.840
4	Hygam jhil	Swamp	Tarazu	Baramulla	Jhelum	1569	15.127	18.745	27.517	30.303
5	Wular	Lake	Bandipur	Baramulla	Jhelum	1580	50.15	55.05	66.07	49.06
6	Un-named	Marshy	Nusu Ghat Kalhum	Baramulla	Jhelum	1581	2.138	2.390	5.644	6.024
7	Nambi Narku	Marshy	Narkur	Srinagar	Jhelum	1583	4.570	5.951	9.459	10.300
8	Rakhi Gandka Shah	Marshy	Barthana	Srinagar	Jhelum	1583	0.701	0.820	3.853	4.119
9	Hokar sar	Lake	Zainakot	Baramulla	Jhelum	1584	0.475	0.732	3.095	3.414
10	Un-named	Marshy	Kulul	Pulwama	Jhelum	1591	-na-	1.639	-na-	6.075
11	Bod Sar	Marshy	Nambalbal	Srinagar	Jhelum	1593	0.228	0.318	2.024	2.342
12	Manasbal	Lake	Gratabal	Baramulla	Jhelum	1600	2.591	3.486	9.346	8.981
13	Nagin lake	Lake	Sadrabal	Srinagar	Jhelum	1604	0.776	0.907	4.385	4.815

-na- data not available

Table 9. Water bodies in Jammu & Kashmir at High Altitudes

S No	Name of Water Body	Type	Nearest Place	District	River Basin	Elevation (m)	Water Spread Area (Sq.Km)		Perimeter (Km)	
							Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
1	Gangabal Lake	Lake	Naranag	Srinagar	Jhelum	3569	snow	1.634	snow	6.420
2	Vishan Sar	Lake	Vishansar	Baramulla	Jhelum	3677	snow	0.635	snow	4.077
3	Konsar Nag	Lake	Phutin Pansaisali	Pulwama	Jhelum	3585	-na-	0.329	-na-	2.565
4	Nund kol	Lake	Dandlod	Srinagar	Jhelum	3607	snow	0.351	snow	2.854
5	Tar sar	Lake	Pahilmazar	Anantnag	Jhelum	3785	-na-	0.430	-na-	3.398
6	Godsar	Lake	Godsar Nala	Baramulla	Jhelum	3810	snow	0.607	snow	3.755
7	Krishan Sar	Lake	Vishansar	Baramulla	Jhelum	3819	snow	0.448	snow	2.900
8	Marsar	Lake	Nagaberan	Srinagar	Jhelum	3849	-na-	0.271	-na-	2.926
9	Bodhsar	Lake	Bodhsar	Budgam	Jhelum	3956	snow	0.262	snow	2.201
10	Salnai sar	Lake	Lolgul Gali	Baramulla	Jhelum	4055	snow	0.425	snow	2.892
11	Pangong Tso	Lake	-na-	Leh	Shyok	4250	273.454*	296.564	185.251	184.554
12	Tso Kur	Lake	-	Leh	Indus	4225	0.357	0.549	2.431	3.156
13	Startsapu Tso	Lake	Kurjok	Leh	Indus	4337	Snow	4.866	snow	11.753
14	Madmatti sar	Lake	Waril Gali	Baramulla	Jhelum	4449	Snow	0.348	snow	2.316
15	Tso Morari	Lake	Karzok	Leh	Indus	4527	115.845*	141.054	61.823	74.705
16	Kar Tso	Lake	-na-	Leh	Indus	4537	Snow	10.536	snow	20.018
17	Yaye Tso	Lake	Yayala	Leh	Indus	4800	Snow	1.637	snow	4.869
18	Tazangkuru Tso	Lake	Tsakshang	Leh	Indus	4800	Snow	5.063	snow	9.449
19	Kyun Tso	Lake	Chila	Leh	Indus	5000	Snow	5.420	snow	10.823
20	Kyule Tso	Lake	Kyule	Leh	Indus	5400	Snow	1.864	snow	5.605
21	Yusup Tso	Lake	Zulungpha	Leh	Indus	5400	Snow	1.542	snow	6.205
22	Amto Gor	Lake	-na-	Leh	Shyok	-na-	174.080	174.385	65.032	65.846

* partly covered with snow

snow fully covered with snow

-na- data not available

Table 10. Details of Water bodies in Jammu & Kashmir (River basin wise)

Name of Water Body	Type	Nearest Place	District	Elevation (m)	Water Spread Area (Sq.Km)		Perimeter (Km)	
					Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Chenab								
Mansar	Lake	Mansar	Udhampur	700	0.629	0.747	3.198	3.413
Salal	Reservoir	Riasi	Udhampur	1038	7.169	7.305	29.372	26.483
Surinsar	Lake	Surinsar	Udhampur	736	0.302	0.324	2.283	2.123
Indus								
Kar Tso	Lake	-na-	Leh	4537	Snow	10.536	Snow	20.018
Kyule Tso	Lake	Kyule	Leh	5400	Snow	1.864	Snow	5.605
Kyun Tso	Lake	Chila	Leh	5000	Snow	5.420	Snow	10.823
Startsapu Tso	Lake	Kurjok	Leh	4337	Snow	4.866	Snow	11.753
Tazangkuru Tso	Lake	Tsakshang	Leh	4800	Snow	5.063	Snow	9.449
Tso Kur	Lake	-	Leh	4225	0.357	0.549	2.431	3.156
Tso Morari	Lake	Karzok	Leh	4527	115.845*	141.054	61.823	74.705
Yaye Tso	Lake	Yayala	Leh	4800	Snow	1.637	Snow	4.869
Yusup Tso	Lake	Zulungpha	Leh	5400	Snow	1.542	Snow	6.205
Jhelum								
Bodhsar	Lake	Bodhsar	Budgam	3956	Snow	0.262	Snow	2.201
Bod Sar	Marshy	Nambalbal	Srinagar	1593	0.228	0.318	2.024	2.342
Dal	Lake	Dalgate	Srinagar	1586	13.186	13.629	21.978	21.047
Gangabal Lake	Lake	Naranag	Srinagar	3569	Snow	1.634	Snow	6.420
Godsar	Lake	Godsar Nala	Baramulla	3810	Snow	0.607	Snow	3.755
Gundi-I-Khalil	Lake	TaraZu	Baramulla	1569	0.388	0.535	2.442	2.840
Hokar sar	Lake	Zainakot	Baramulla	1584	0.475	0.732	3.095	3.414
Hygam jhil	Swamp	Tarazu	Baramulla	1569	15.127	18.745	27.517	30.303
Konsar Nag	Lake	Phutin Pansaisali	Pulwama	3585	-na-	0.329	-na-	2.565
Krishan Sar	Lake	Vishansar	Baramulla	3819	Snow	0.448	Snow	2.900
Madmatti sar	Lake	Waril Gali	Baramulla	4449	Snow	0.348	Snow	2.316
Manasbal	Lake	Gratabal	Baramulla	1600	2.591	3.486	9.346	8.981
Marsar	Lake	Nagaberan	Srinagar	3849	-na-	0.271	-na-	2.926
Nagin lake	Lake	Sadrabal	Srinagar	1604	0.776	0.907	4.385	4.815
Nambi Narku	Marshy	Narkur	Srinagar	1583	4.570	5.951	9.459	10.300
Nund kol	Lake	Dandlod	Srinagar	3607	Snow	0.351	Snow	2.854
Rakh Malang	Marshy	Safapora	Baramulla	1538	1.845	2.035	5.332	5.441
Rakhi Gandka Shah	Marshy	Barthana	Srinagar	1583	0.701	0.820	3.853	4.119
Salnai sar	Lake	Lolgul Gali	Baramulla	4055	Snow	0.425	Snow	2.892
Tar sar	Lake	Pahilmazar	Anantnag	3785	-na-	0.430	-na-	3.398
Un-named	Marshy	Nusu Ghat Kalhum	Baramulla	1581	2.138	2.390	5.644	6.024
Un-named	Marshy	Kulul	Pulwama	1591	-na-	1.639	-na-	6.075
Vishan Sar	Lake	Vishansar	Baramulla	3677	Snow	0.635	Snow	4.077
Wular	Lake	Bandipur	Baramulla	1580	50.15	55.05	66.07	49.06
Shyok								
Amto Gor	Lake	-na-	Leh	-na-	174.080	174.385	65.032	65.846
Pangong Tso	Lake	-na-	Leh	4250	273.454*	296.564	185.251	184.554

* partly covered with snow
Snow fully covered with snow
-na- data not available

region. The two districts of Baramulla (12) and Leh (11) comprise the majority of water bodies in the state. Most of the lakes located in the temperate regions of Ladakh and Baramulla districts have low turbidity and are devoid of aquatic vegetation. The district-wise distribution of water bodies of the area is given in Table 11.

8.4 Classification According to Size (Water Spread Area)

38 major water bodies, with water spread area greater than 0.25 Sq Km, occupying a water spread area of 743 Sq Km were mapped in the study area (Table 12). The three largest lakes are located in the Leh district; Pangong Tso (296 km^2) being the largest, followed by Amto Gor (174 km^2) and Tso Morari (141 km^2). Seven water bodies have area larger than 10 Sq Km, thirteen have area between 1 and 10 Sq Km, and eighteen have area less than 1 Sq Km.

Wular and Dal lakes are the other important water bodies of the State. Salal, the only reservoir mapped in the present study, is a major man-made reservoir (7 km^2) on the river Chenab in district Udhampur. The two low-altitude natural lakes, i.e. Mansar and Surinsar, are small lakes with area 0.75 km^2 and 0.32 km^2, respectively.

A special mention is made here of the Wular lake, whose spread area is reported to be varying considerably. The Directorate of Environment & Remote Sensing, J&K, reported the spread area of the lake as 65 Km^2, based on the Survey of India toposheet (43J/11, scale 1:50,000, surveyed in 1965). The same document also reported the figures of 132.5 Km^2, 124.5 Km^2, and 56.5 Km^2, based on the satellite imagery of April 27, 1988, June 1, 1989, October 31, 1992, respectively (Anonymous, 1998b). The reasons for such variation could be an irregular shape as well as formation of many islands at the confluence of the river Jhelum. In the present study, the spread area on the satellite imageries (IRS-1A, LISS-II) for pre-monsoon (June 2, 1989) and post-monsoon (November 16, 1988) periods are found to be 50.15 and 55.05 Km^2, respectively.

Table 11. Details of Water bodies in Jammu & Kashmir (District wise)

Name of Water Body	Type	Nearest Place	River Basin	Elevation (m)	Water Spread Area (Sq.Km)		Perimeter (Km)	
					Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
JAMMU REGION								
Udhampur								
Mansar	Lake	Mansar	Chenab	700	0.629	0.747	3.198	3.413
Salal	Reservoir	Riasi	Chenab	1038	7.169	7.305	29.372	26.483
Surinsar	Lake	Surinsar	Chenab	736	0.302	0.324	2.283	2.123
KASHMIR REGION								
Anantnag								
Tar sar	Lake	Pahilmazar	Jhelum	3785	-na-	0.430	-na-	3.398
Baramulla								
Godsar	Lake	Godsar Nala	Jhelum	3810	Snow	0.607	Snow	3.755
Gundi-i-Khalil	Lake	TaraZu	Jhelum	1569	0.388	0.535	2.442	2.840
Hokar sar	Lake	Zainakot	Jhelum	1584	0.475	0.732	3.095	3.414
Hygam jhil	Swamp	Tarazu	Jhelum	1569	15.127	18.745	27.517	30.303
Krishan Sar	Lake	Vishansar	Jhelum	3819	Snow	0.448	Snow	2.900
Madmatti sar	Lake	Waril Gali	Jhelum	4449	Snow	0.348	Snow	2.316
Manasbal	Lake	Gratabal	Jhelum	1600	2.591	3.486	9.346	8.981
Rakh Malang	Marshy	Safapora	Jhelum	1538	1.845	2.035	5.332	5.441
Salnai sar	Lake	Lolgul Gali	Jhelum	4055	Snow	0.425	Snow	2.892
Un-named	Marshy	Nusu Ghat Kalhum	Jhelum	1581	2.138	2.390	5.644	6.024
Vishan Sar	Lake	Vishansar	Jhelum	3677	Snow	0.635	Snow	4.077
Wular	Lake	Bandipur	Jhelum	1580	50.15	55.05	66.07	49.06
Budgam								
Bodhsar	Lake	Bodhsar	Jhelum	3956	Snow	0.262	Snow	2.201
Pulwama								
Konsar Nag	Lake	Phutin Pansaisali	Jhelum	3585	-na-	0.329	-na-	2.565
Un-named	Marshy	Kulul	Jhelum	1591	-na-	1.639	-na-	6.075
Srinagar								
Bod Sar	Marshy	Nambalbal	Jhelum	1593	0.228	0.318	2.024	2.342
Dal	Lake	Dalgate	Jhelum	1586	13.186	13.629	21.978	21.047
Gangabal Lake	Lake	Naranag	Jhelum	3569	Snow	1.634	Snow	6.420
Marsar	Lake	Nagaberan	Jhelum	3849	-na-	0.271	-na-	2.926
Nagin lake	Lake	Sadrabal	Jhelum	1604	0.776	0.907	4.385	4.815
Nambi Narku	Marshy	Narkur	Jhelum	1583	4.570	5.951	9.459	10.300
Nund kol	Lake	Dandlod	Jhelum	3607	Snow	0.351	Snow	2.854
Rakhi Gandka Shah	Marshy	Barthana	Jhelum	1583	0.701	0.820	3.853	4.119
LADAKH REGION								
Leh								
Amto Gor	Lake	-na-	Shyok	-na-	174.080	174.385	65.032	65.846
Kar Tso	Lake	-na-	Indus	4537	Snow	10.536	Snow	20.018
Kyule Tso	Lake	Kyule	Indus	5400	Snow	1.864	Snow	5.605
Kyun Tso	Lake	Chila	Indus	5000	Snow	5.420	Snow	10.823
Pangong Tso	Lake	-na-	Shyok	4250	273.454*	296.564	185.251	184.554
Startsapu Tso	Lake	Kurjok	Indus	4337	Snow	4.866	Snow	11.753
Tazangkuru Tso	Lake	Tsakshang	Indus	4800	Snow	5.063	Snow	9.449
Tso Kur	Lake	-	Indus	4225	0.357	0.549	2.431	3.156
Tso Morari	Lake	Karzok	Indus	4527	115.845*	141.054	61.823	74.705
Yaye Tso	Lake	Yayala	Indus	4800	Snow	1.637	Snow	4.869
Yusup Tso	Lake	Zulungpha	Indus	5400	Snow	1.542	Snow	6.205

* partly covered with snow
Snow fully covered with snow
-na- data not available

Table 12. Details of Water bodies in Jammu & Kashmir (Area wise)

S No	Name of Water Body	Type	Nearest Place	District	Elevation (m)	Water Spread Area (Sq.Km)		Perimeter (Km)	
						Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
1.	Pangong Tso	Lake	-na-	Leh	4250	273.454*	296.564	185.251	184.554
2.	Amto Gor	Lake	-na-	Leh	-na-	174.080	174.385	65.032	65.846
3.	Tso Morari	Lake	Karzok	Leh	4527	115.845*	141.054	61.823	74.705
4.	Wular	Lake	Bandipur	Baramulla	1580	50.15	55.05	66.07	49.06
5.	Hygam jhil	Swamp	Tarazu	Baramulla	1569	15.127	18.745	27.517	30.303
6.	Dal	Lake	Dalgate	Srinagar	1586	13.186	13.629	21.978	21.047
7.	Kar Tso	Lake	-na-	Leh	4537	Snow	10.536	Snow	20.018
8.	Salal	Reservoir	Riasi	Udhampur	1038	7.169	7.305	29.372	26.483
9.	Nambi Narku	Marshy	Narkur	Srinagar	1583	4.570	5.951	9.459	10.300
10.	Kyun Tso	Lake	Chila	Leh	5000	Snow	5.420	Snow	10.823
11.	Tazangkuru Tso	Lake	Tsakshang	Leh	4800	Snow	5.063	Snow	9.449
12.	Startsapu Tso	Lake	Kurjok	Leh	4337	Snow	4.866	Snow	11.753
13.	Manasbal	Lake	Gratabal	Baramulla	1600	2.591	3.486	9.346	8.981
14.	Un-named	Marshy	Nusu Ghat Kalhum	Baramulla	1581	2.138	2.390	5.644	6.024
15.	Rakh Malang	Marshy	Safapora	Baramulla	1538	1.845	2.035	5.332	5.441
16.	Kyule Tso	Lake	Kyule	Leh	5400	Snow	1.864	Snow	5.605
17.	Un-named	Marshy	Kulul	Pulwama	1591	-na-	1.639	-na-	6.075
18.	Yaye Tso	Lake	Yayala	Leh	4800	Snow	1.637	Snow	4.869
19.	Gangabal Lake	Lake	Naranag	Srinagar	3569	Snow	1.634	Snow	6.420
20.	Yusup Tso	Lake	Zulungpha	Leh	5400	Snow	1.542	Snow	6.205
21.	Nagin lake	Lake	Sadrabal	Srinagar	1604	0.776	0.907	4.385	4.815
22.	Rakhi Gandka Shah	Marshy	Barthana	Srinagar	1583	0.701	0.820	3.853	4.119
23.	Mansar	Lake	Mansar	Udhampur	700	0.629	0.747	3.198	3.413
24.	Hokar sar	Lake	Zainakot	Baramulla	1584	0.475	0.732	3.095	3.414
25.	Vishan Sar	Lake	Vishansar	Baramulla	3677	Snow	0.635	Snow	4.077
26.	Godsar	Lake	Godsar Nala	Baramulla	3810	Snow	0.607	Snow	3.755
27.	Tso Kur	Lake	-	Leh	4225	0.357	0.549	2.431	3.156
28.	Gundi-I-Khalil	Lake	TaraZu	Baramulla	1569	0.388	0.535	2.442	2.840
29.	Krishan Sar	Lake	Vishansar	Baramulla	3819	Snow	0.448	Snow	2.900
30.	Tar sar	Lake	Pahilmazar	Anantnag	3785	-na-	0.430	-na-	3.398
31.	Salnai sar	Lake	Lolgul Gali	Baramulla	4055	Snow	0.425	Snow	2.892
32.	Nund kol	Lake	Dandlod	Srinagar	3607	Snow	0.351	Snow	2.854
33.	Madmatti sar	Lake	Waril Gali	Baramulla	4449	Snow	0.348	Snow	2.316
34.	Konsar Nag	Lake	Phutin Pansaisali	Pulwama	3585	-na-	0.329	-na-	2.565
35.	Surinsar	Lake	Surinsar	Udhampur	736	0.302	0.324	2.283	2.123
36.	Bod Sar	Marshy	Nambalbal	Srinagar	1593	0.228	0.318	2.024	2.342
37.	Marsar	Lake	Nagaberan	Srinagar	3849	-na-	0.271	-na-	2.926
38.	Bodhsar	Lake	Bodhsar	Budgam	3956	Snow	0.262	Snow	2.201

* partly covered with snow
Snow fully covered with snow
-na- data not available

9.0 LIMITATIONS OF THE STUDY

The satellite data used for this study was of IRS-1A/B LISS-I/II, except for a single digital scene, and the minimum mapping unit was 2mm x 2mm, which corresponds to 0.25 Sq.Km on 1:250,000 scale. Therefore, water bodies smaller than 0.25 Sq.Km (at least in one season) were not discernible at 1:250,000 scale. **A clear dark tone of water was considered while delineating the spread of a water body, in a particular season. The digitized boundary of a water body was then used for calculation of the spread area and the perimeter, using a GIS package**. The water bodies were directly mapped from the 1:250,000 scale FCCs, and no optical enlargement was attempted. Due to non-availability of data, some water bodies could not be mapped.

The water spread area reported in this document may, therefore, differ from the area reported in other documents where wetlands are considered as "all submerged or water-saturated lands, natural or man-made, inland or coastal, permanent or temporary, static or dynamic, vegetated or non-vegetated, which necessarily have a land-water interface", as reported in Anonymous (1998a).

This inventory has been created with utmost care so that the information generated should be accurate. The IRS satellite imageries of 1988/89, and a single scene of digital data of 1998, have been used as the basic source. With the passage of time, the ground situation might have undergone some change during the intervening period. The Institute, however, does not take any responsibility on account of any consequences due to some error, which might have remained in this inventory even after the best efforts of the authors.

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