Government of Jammu and Kashmir (UT)
Geology and Mining Department,

The Hon'ble Chairman,
National Green Tribunal,
New Delhi

No:-1171/MCC/DGM/2021/ 4563 Dated:- 06.09.2022

Subject:- Raja Muzaffar Bhat V/s State Environment Impact Assessment Authority, J&K and Ors.

Sir,

Most respectfully, it is to submit that Hon'ble National Green Tribunal has passed an interim order dated 12/08/2022 in Appeal No. 24/2022 titled **Raja Muzaffar Bhat V/s State Environment Impact Assessment Authority, J&K and Ors** wherein the Hon'ble Bench, after observing that as per the records no replenishment study was conducted for the Minor Mineral Blocks (Reserved and allotted for mining of RBM to the respondent 04) in Shalliganga nalla of District Budgam have restrained the mining activity from the said Minor Mineral Blocks. The final order in this regard has been reserved.

The fact of the matter is that before passing the Interim Order response of this department could not be brought before the Hon'ble Bench which in the form of factual note is given as under:

A. Reservation/Allotment of Minor Mineral Blocks/Quarries in favour of NKC Project Pvt. Limited.

- National Highway Authority of India awarded contract to the M/S NKC Projects Pvt. Ltd. on 30-03-2021 for construction of four Lane Ring Road/ bypass around Srinagar City from Km 0.000 to Km 42.100 (Phase -I) under NHDP Phase-VII in the Union Territory of Jammu and Kashmir under Bharat Mala Pariyojana.
- Project Director PIU- Srinagar, National Highway Authority of India vide letter No. PD/SGR/14054/01/2021/NKC/01 dated; 07/05/2021, requested this Directorate for grant of permission for mining at the identified sites in favour of the Principal Executing Agency i.e., M/S NKC Projects Pvt. Ltd. for construction of the aforementioned project.
- This office vide letter no. MSK/JDK/DGM/Sgr/F-STP-Bud-01/3369-72 dated; 20/05/2021 intimated the executing agency to apply for the

proper permission under the relevant provisions of SRO-105 Dated 31st March 2016" i.e., "The Jammu and Kashmir Minor Mineral Concession Storage, Transportation of Minerals and Prevention of illegal Mining Rules, 2016 read with Director, Geology and Mining J&K Circular No. 469/MCC/DGM/STP/20/1305-1309, dated: 17.01.2021.

- Subsequently M/S NKC Projects Pvt. Ltd. Vide no. NKCPPL/HO/Srinagar/2021-22/010 dated; 21/06/2021 informed that they have identified four minor mineral blocks in Shaliganga nalla, District Budgam and requested Project Director, NHAI PIU Srinagar to take up the matter with Director, Geology & Mining so that the identified blocks can be reserved for the project under Rule 91 of J&K "The Jammu and Kashmir Minor Mineral Concession Storage, Transportation of Minerals and Prevention of Illegal Mining Rules 2016.
- Project Director PIU- Srinagar, National Highway Authority of India vide no. PD/SGR/14054/01/2021/NKC/13 dated; 22/06/2021, requested Divisional Commissioner, Kashmir to direct the concerned authorities/administration for early allotment of quarries for mining at identified locations so that project related activities do not get hampered.
- Divisional Commissioner, Kashmir vide his office communication no. DivCom/RA/2021/Misc/145 dated; 29/06/2021, referred the communication of National Highway Authority of India vide letter No.PD/SGR/14054/01/2021/NKC/13 dated; 22/06/2021, to Deputy Commissioner, Budgam for examination and appropriate necessary action in the matter.
- Dy. Commissioner, Budgam vide no. DDCB/Permission/3285-86 dated; 03/07/2021 to DMO Budgam endorsed the instant case to District Mineral Officer, Budgam who vide his letter no.DMO/Bud/DGM/F-87/714-15, dated: 08.07.2021 forwarded the said case to this office along with four site plans of Minor Mineral Blocks identified by the M/S NKC Projects Pvt. Ltd.
- DMO Budgam vide No. DMO/BUD/DGM/819 dated; 09/08/2021, forwarded the case along with letter of Deputy Commissioner Budgam vide No. 4932-39, dated: 09.08.2021 enclosing four site plans of Minor Mineral Blocks identified by the M/S NKC Projects Pvt. Ltd, and the NOC/Clearances/Title verification from the stake holding Departments issued through District Level Single Window committee headed by Deputy Commissioner, Budgam.

- The Rule 91 of The Jammu and Kashmir Minor Mineral Concession, Storage, Transportation of Minerals and Prevention of Illegal Mining Rules 2016 provides that the Minor Mineral Blocks can be reserved for exploitation of Minor Minerals by the Centre or State Govt., agencies for developmental projects of National importance.
- Keeping in view the importance of this time bound National Level infrastructural development project wherein huge quantity of construction material (RBM) is required, the Geology and Mining Department in pursuance to aforementioned quoted Rule 91 reserved four Minor Mineral Blocks with the description as: Bunderpoa upstream Shaliganga Nallah over an area of 1.29 ha (Block No 2); Hushroo downstream Shaliganga nallah over an area 2.68 ha (Block No 3); Driegam Bridge downstream Shaliganga nalla over an area of 3.17 ha (Block No 1), and Panzan Bridge to Tumbibagh (Lalgam) downstream Shaliganga Nalla, over an area of 3.92 ha(Block No 4) respectively vide Order Nos. 1171/MCC/DGM/NKC/21/3516-22, and even nos. 3523-29, 3530-36 and 3537-43 all dated 14-08-2021 for the allotment of quarry licenses in favour of National Highways Authority of India for exploitation of minor minerals such as Boulders, RBM, Sand and Nalla Bajri to be used in construction of standalone Ring Road/Bypass around Srinagar city Phase-I in the Jammu and Kashmir UT by M/S NKC Project Private Limited being Principal Executive Agency of NHAI subject to the condition that M/S NKC Projects Pvt. Ltd. shall obtain all the statutory clearances viz; approved Mining Plan, Environmental Clearance & Consent to Operate from Competent Authority etc. for formal grant of Mineral Concession i.e Quarry license in their favour.
- The Party submitted the statutory clearances viz, Environmental Clearances for Blocks no 1, 2 & 4 issued by JKEIAA vide No. JKEIAA/ 2021/609/699-32 dated 11-04-2022, 608/6905-18 dated 11-04-2022 and 610/6933-46 dated 11-04-2022, Approved Mining Plans and Consent to Operate besides NOCs of the stake holding Departments.
- Accordingly, in pursuance of Rule 48 of Chapter-V of J&K Minor Mineral Concession, Storage, Transportation of Minerals and Prevention of Illegal Mining Rules 2016, the Director, Geology and Mining granted Quarry Licenses for the Minor Mineral Blocks under reference i.e., Blocks no 1, 2 & 4 falling in Shaliganga Nalla, District Budgam (reserved under Rule 91 of the said rules) in favour of the party vide order nos. 1250/MCC/DGM/NKC/ Projects/22/ 1295-1304,

1305-14,1285-94 all dated 13-05-2022. The said minor mineral blocks were made operational for extraction of RBM by the M/S NKC Project Pvt. Ltd w.e.f. 01.06.2022.

B. District Survey reports with Replenishment Study.

- The Ministry of Environment, Forest & Climate Change vide S.O. No. 141 dated 15th January 2016 enjoined all State/UT Governments to prepare District Survey Reports which is a vital document for overview of mining activity at District level and serves as a model and guiding reference for processing/consideration of the applications for Environmental Clearance of mining projects by the Environmental Impact Assessment Authorities.
- As per the said notification of MoEF&CC, the District Survey Reports are to be prepared by District Environment Impact Assessment Authority (DEIAA) with the assistance of Geology & Mining Department or Irrigation Department or Forest Department or Public Works Department or Ground Water Boards or Remote Sensing Department or Mining Department etc. in the District. The District Level Environment Impact Assessment Authorities (DEIAA) was disbanded vide National Green Tribunal Order dated: 11.12.2018 in OA 520/2016 and its powers were entrusted to State Environment Impact Assessment Authority (SEIAA).
- In the UT of Jammu and Kashmir, the Department of Geology & Mining, prepared the District Survey Reports of all the Districts during the year 2017-18 as per the Notification of Ministry of Environment, Forest & Climate Change under reference for the then District Level Environment Impact Assessment Authorities (DEIAA) headed by District Magistrates.
- The District Survey Reports thus prepared were put in the public domain for 15 days by the respective Chairman of the District Level Environment Impact Assessment Authorities as per the guidelines. After the dissolve of The District Level Environment Impact Assessment Authorities (DEIAA), the District Survey Reports were forwarded/submitted to Jammu and Kashmir UT Environment Impact Assessment Authority (JKEIAA) who are currently processing the applications of Environment Clearances of all the mining projects based on these District Survey Reports.

- As per the MoEF&CC Notification issued Vide S.O. No. 141 dated 15th January 2016, the District Survey Reports shall be updated once every five years. As such the validity of the District Survey Reports (DSR) is upto March 2023 and as such the revision of entire District Survey Reports shall be taken up during the field season 2023-24.
- However, the updation of the District Survey Reports by incorporating the detailed sediment/replenishment studies of various rivers/nallas to prescribe the limits for river bed mining was taken up during the field season 2018-19 and 2021-22. **The sediment replenishment study for Shaliganga nalla, District Budgam was carried out by Geology and Mining Department using the Erosion Model of Garde and Kothyari which is a widely used empirical method to quantify the annual rate of sediment yield in a particular river system using GIS platform and spatial data of the watershed i.e., land use land cover, morphometry, discharge and precipitation data.** The rate of sediment replenishment of Shaliganga nalla as per the current study comes out to be 0.343 meters per annum.
- The Replenishment Study of Shaliganga Nalla, District Budgam was submitted to Director, Geology and Mining vide No. JDK/DGM/AFP/2021/F-93-III/901-02 dated: 09.06.2022 which was forwarded to J&K Environment Impact Assessment Authority (JKEIAA) vide letter No. 1038/MCC/DGM/DMO/Budgam/2121 dated: 17.06.2022. Subsequently JKEIAA vide their letter No. JKEIAA/2021/584/7707-09 dated; 08.08.2022 informed the Director, Geology and Mining Department to update the said report as per the Enforcement and Monitoring Guidelines on Sand Mining 2020 which provide inclusion of the physical measurements of river bed material to be taken on four points of time in a year as detailed below:

1. ***The first survey needs to be carried out in the month of April for recording the level of mining lease before the monsoon.***
2. ***The second survey is at the time of closing of mines for monsoon season. This survey will provide the quantity of the material excavated before the offset of monsoon.***
3. ***The third survey needs to be carried out after the monsoon to know the quantum of material deposited/replenished in the mining lease.***

4. ***The fourth survey at the end of March to know the quantity of material excavated during the financial year.***

- The sediment replenishment is a dynamic process highly dependent on geology, geomorphology and hydrometeorological characteristics of the river/nalla which may vary with respect to time and as such its monitoring is a continuous process.
- As the extraction from the Minor Mineral blocks under reference has commenced w.e.f. 01.06.2022, the Department has taken up the above referred stage wise ground survey which shall be completed within a period of one year.

In light of the above, it is most humbly and respectively prayed that the Hon'ble Tribunal may be pleased to consider the facts stated above before passing the final order

Yours faithfully,

Encl: A/A

06.09.2022

Director,
Geology and Mining Deptt.,
J&K Govt. Jammu

Government of Jammu & Kashmir (UT)
DIRECTORATE OF GEOLOGY & MINING, JAMMU

The Director,
Department of Ecology, Environment & Remote Sensing,
Member-Secretary,JKEIAA,J&K, Jammu.

No: -1038/MCC/DGM/DMO/Budgam/2121 Dated: - 17 .06.2022

Subject: - Geological Report on "Minor Mineral Resource Estimation, Hydrology,Hydrogeology and Replenishment Studies of NallaDoodhganga and NallaShaliganga, District Budgam.

Sir,

Kindly find enclosed herewith the "**Geological Report on "Minor Mineral Resource Estimation, Hydrology, Hydrogeology and Replenishment Studies of Nalla Doodhganga and Nalla Shaliganga, District Budgam, J&K UT"** as received from the Joint Director (K), Geology & Mining Department, Srinagar vide letter No. JDK/DGM/AFP/2021-22/F-93-III/901-02 dated 09.06.2022 for favour of kind information and further necessary action.

Encl:- __Lvs.

Yours faithfully

Director
Geology & Mining Deptt;
J&K(UT) Govt;Jammu.
17/6/22

0191-2474553/0194-2490602
Government of India
Ministry of Environment, Forest & Climate Change
J&K ENVIRONMENT IMPACT ASSESSMENT AUTHORITY
(at) DEPARTMENT OF ECOLOGY, ENVIRONMENT AND REMOTE SENSING
S.D.A Colony, Bemina, Srinagar-190018 (May-Oct)/ Parivaran Bhawan, Transport Nagar, Gladni, Jammu-181206 (Nov-Apr)
Email: jkeiaa@gmail.com, website:www.parivesh.nic.in

The Director,
Geology & Mining Department.
Jammu.

No.JKEIAA/2021/584/7707-09 ated 08.08 - 2022

Subject:- Report titled, 'Minor Mineral Resource Estimation, Hydrology, Hydrogeology and replenishment Studies of Nallah Doodganga and Nallah Shaliganga, District Badgam, JK UT formulated by Geology &Mining Department

Reference:-i) Minutes of 98th Meeting of JKEAC held on 04th July, 2022
ii) Minutes of 85th Meeting of JKEIAA held on 1st August, 2022

Sir,

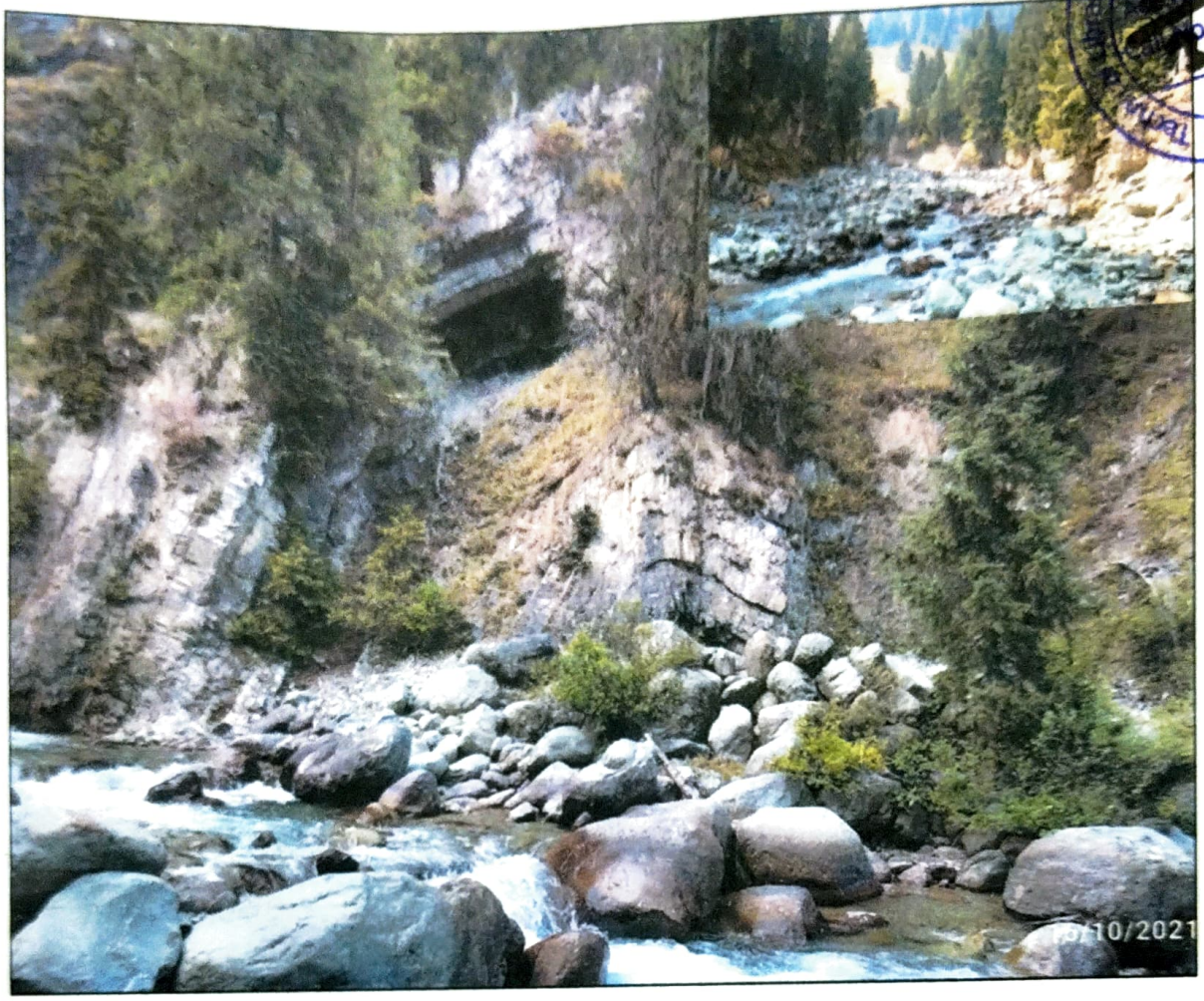
In pursuance to the recommendations/decisions of JKEAC/JKEIAA, you are advised to update the report titled, 'Minor Mineral Resource Estimation, Hydrology, Hydrogeology and Replenishment Studies of Nallah Doodganga and Nallah Shaliganga, District Badgam, UT of J&K' with details on sites of aggradations/deposition, measurement of aggradations/deposition of mineral annually replenished (supported with field photographs) as per the "Enforcement and Monitoring Guidelines for Sand Mining 2020".The report should be technically vetted by senior officers of the G&M Dept. before forwarding to JKEIAA.

Yours faithfully,

(S. Rakesh Kumar) IFS
Member-Secretary, JKEIAA
J&K U.T.

Copy for favour of kind information to:-

1.The Hon'ble Chairman, JKEIAA.
2.The Secretary, JKEAC



REPORT ON

MINOR MINERAL RESOURCE ESTIMATION, HYDROLOGY, HYDROGEOLOGY AND REPLENISHMENT STUDIES OF NALLA DOODHGANGA AND NALLA SHALIGANGA, DISTRICT BUDGAM J&K UT

Field Season, 2021-22

By

SARAFRAZ SHABAN
Geological Assistant

Sarafraz Shaban
(GA)
O/C Investigation

Coordinator Geology (K)

Joint Director Geology Srinagar

Department of Geology & Mining, J&K (UT)
4th FLOOR, SANAT GHAR BEMINA, SRINAGAR

Technical Library J&K Govt. Geology & Mineral Deptt. Srinagar
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REPORT ON

MINOR MINERAL RESOURCE ESTIMATION, HYDROLOGY, HYDROGEOLOGY AND REPLENISHMENT STUDIES OF NALLA DOODHGANGA AND NALLA SHALIGANGA, DISTRICT BUDGAM J&K UT

(Field Season 2021-22)

By

SARAFRAZ SHABAN
(Geological Assistant)

lam

LIST OF PLATES

TITLE:

MINOR MINERAL RESOURCE ESTIMATION, HYDROLOGY, HYDROGEOLOGY AND REPLENISHMENT STUDIES OF NALLA DOODHGANGA AND NALLA SHALIGANGA, DISTRICT BUDGAM J&K UT

Abstract:

The present study has been conducted to determine the annual sediment replenishment of Doodhganga watershed and Shaliganga watershed in District Budgam for assessment of permitted mineral extraction in optimal quantities. Geological and hydrogeological data was collected during the course of the field work. The monthly precipitation data for last ten years as recorded at Srinagar observatory and monthly discharge data of Doodhganga nalla and Shaliganga nalla for last 06 years were collected for calculation of catchment yield. Geographical Information System (GIS) and Remote sensing techniques were used for land use land cover classification and for calculation of morphometric parameters and hydrological features of the drainage basins. The collected data and calculated parameters were then used to estimate annual mean sediment yield of Doodhganga and Shalinganga drainage basins. The calculated annual mean sediment yield of Doodhganga basin is about 4.3 lac tonnes and that of Shaliganga basin is about 3.1 lac tonnes.

CHAPTER-1

INTRODUCTION

Ministry of Environment, Forest & Climate Change vide notification no. S.O.141 (E) dated 15.01.2016 amended erstwhile Environmental Impact Assessment (EIA) Notification No. S.O.1533 (E) dated 14.09.2006 which led to the constitution of the District Level Environment Impact Assessment Authority (DEIAA) and District Level Expert Appraisal Committee (DEAC) at district level for grant of environmental clearances for category B2 projects for mining of minor minerals for all the districts in the country. District Level Expert Appraisal Committee (DEAC) will scrutinize and recommend the prior environmental clearance of mining of minor minerals to District Level Environment Impact Assessment Authority (DEIAA) on the basis of District Survey Report (DSR).

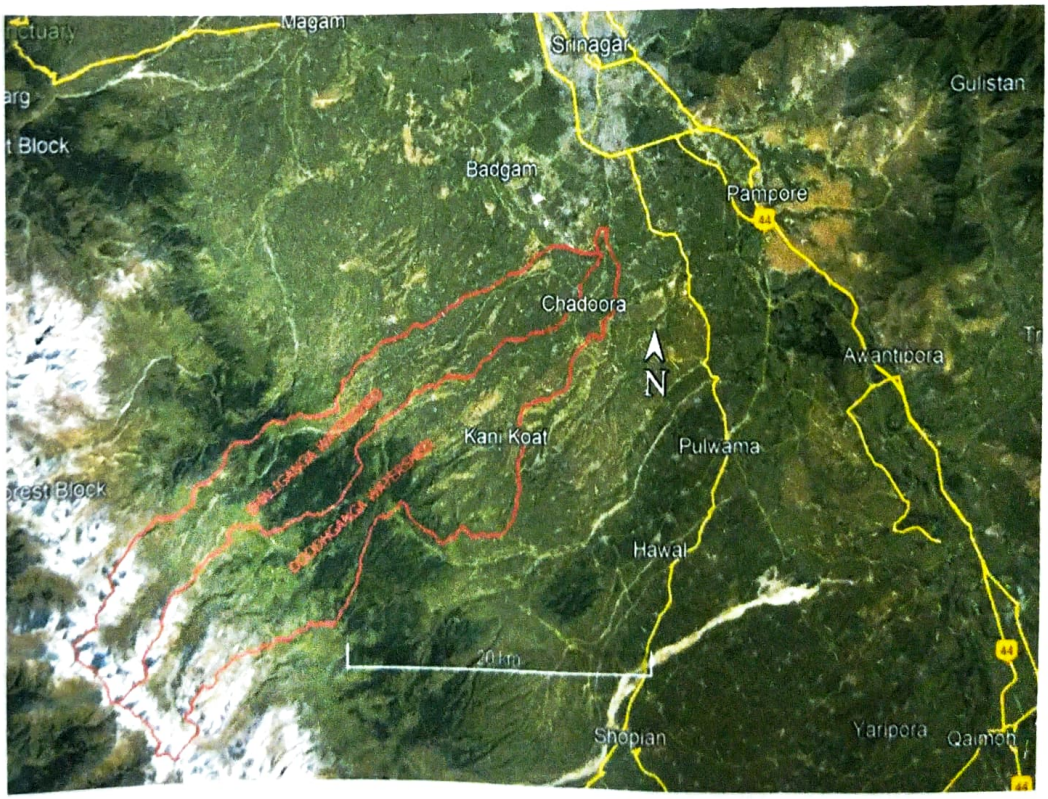
In accordance with guidelines laid down in above referred notification, District Survey Report (DSR) of Budgam District for Sand Mining/River Bed Mining and other Minor Minerals was prepared in year 2017 and environmentally viable and feasible sites were identified for mining purposes. However, annual rate of sediment replenishment was not calculated at that time. Thus, the rate of annual replenishment being part of District Survey Report has been calculated in the current study for the updation of District Survey Report (DSR).

The present investigation forms the part of Annual Geological Field Programme (AFP) 2021-22 of Kashmir Province, included as Field Item No. 03 titled "Minor Mineral Resource Estimation, hydrology, hydrogeology and replenishment studies of nalla Shaliganga and nalla Doodhganga, District Budgam Jammu & Kashmir Union Territory" dully approved by the Director Geology and Mining Department, Jammu vide Order No. 986/TG/DGM/FP/2020-21/4037-44 dated:-31.07.2021. The estimated targets of the field programme are given in the table below:

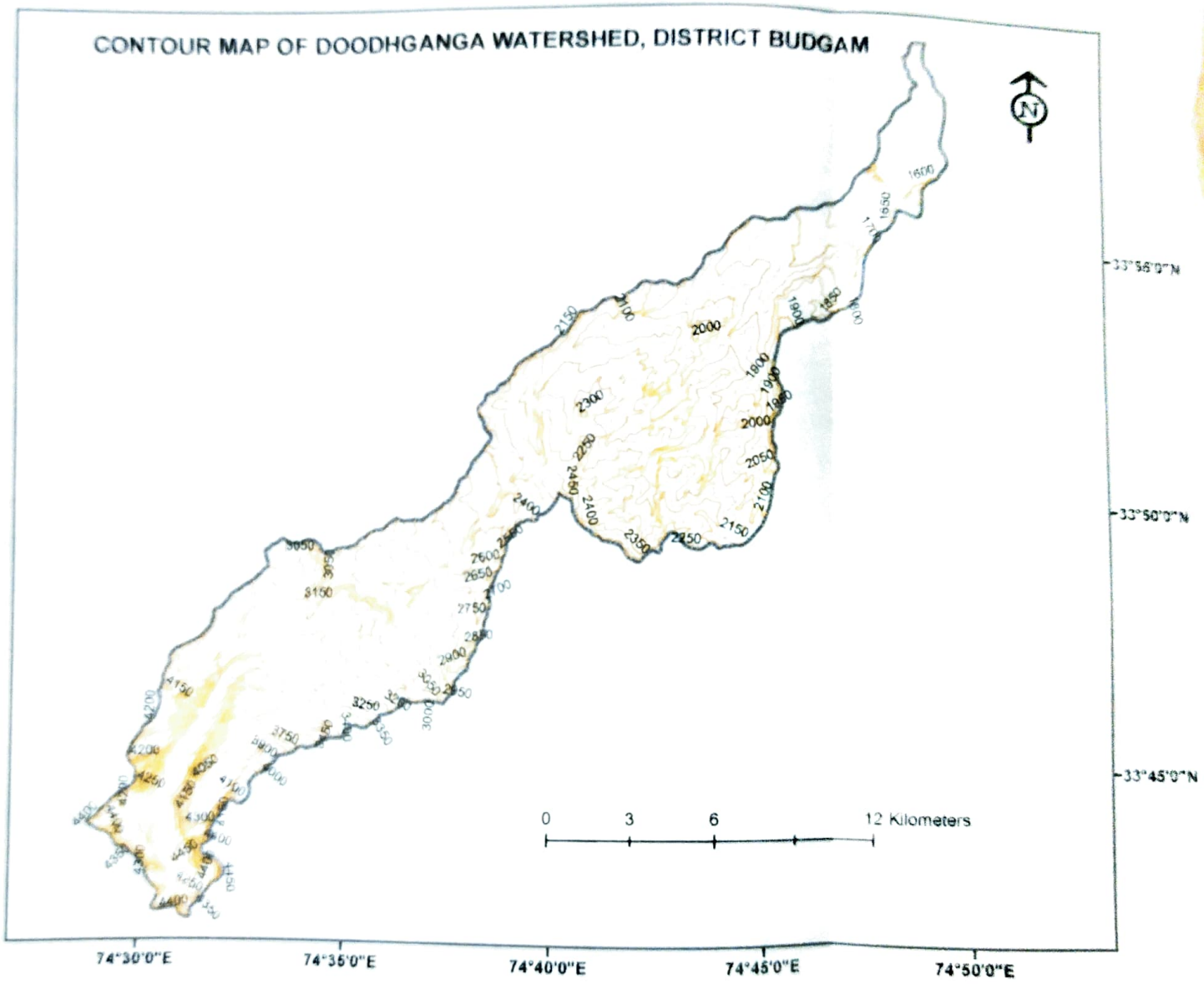
S. No.	Nature of work	Targets
01	Reconnaissance Geological Mapping (Scale 1:50,000)	100 Sq.Kms
02	Pitting and Trenching	30 m^3
03	Time schedule	04 months

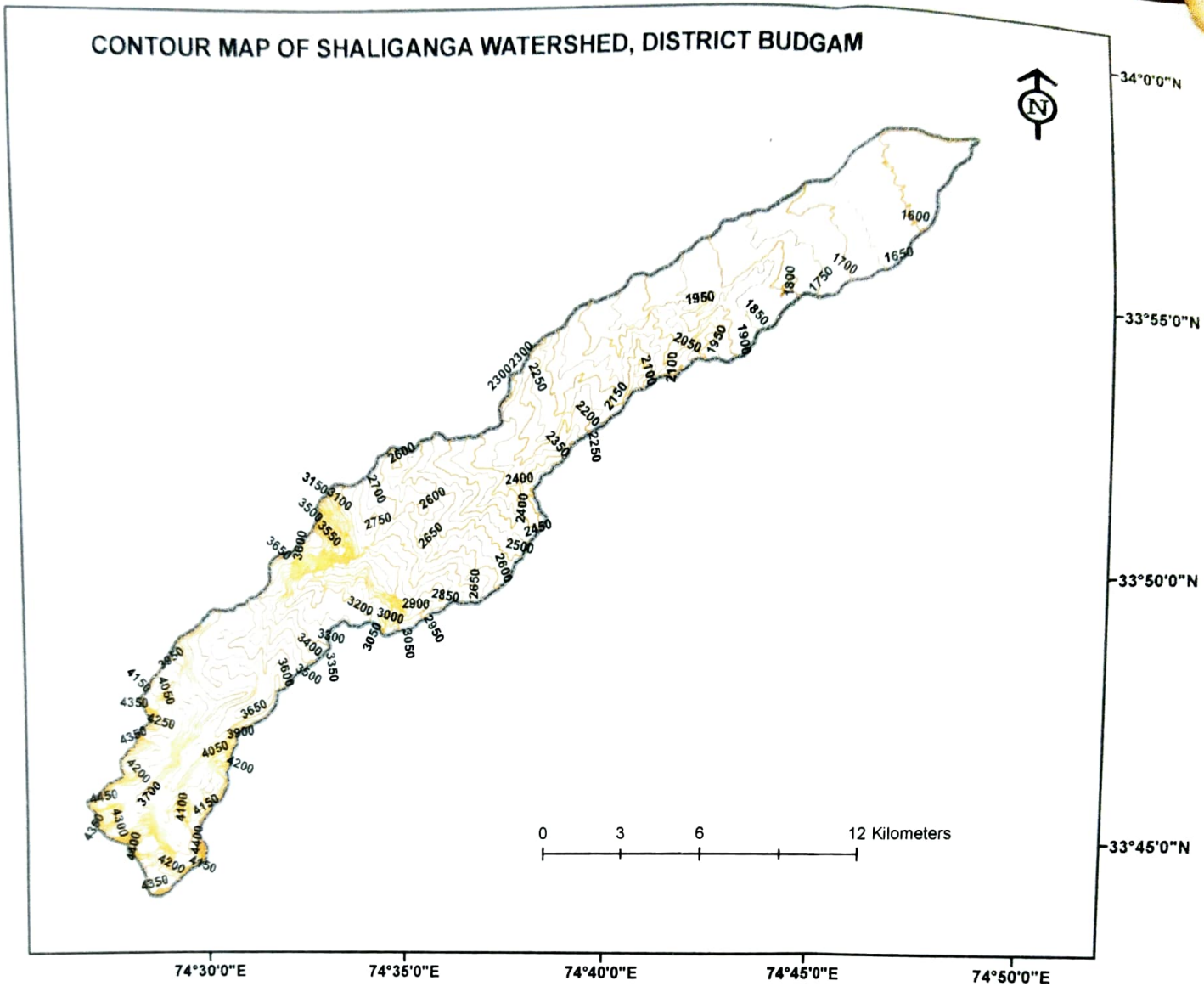
In order to achieve the targets fixed in the annual field programme, part of Doodhganga watershed that lies in District Budgam and its sub-watershed Shalinganga were taken for carrying out the present study. During the course of the fieldwork of four months, the relevant data of both the watersheds pertaining to the present studies was collected for further analysis.

1.1 Location & Accessibility: The study area lies in south-western part of Budgam District. It falls between 33°42'07" - 33°59'08" North latitude and 74°26'58" - 74°49'18" East longitude, forming the parts of Survey of India Toposheet Nos. 43 K/5, K/6, K/9, K/10 and K/13 with average altitude of 3106 m amsl. The area is well connected with the summer capital Srinagar. The Doodhganga watershed is accessible via all-weather road upto Yusmarg tourist resort. Likewise, Shaliganga watershed is accessible upto Doodhpathri health resort. Moreover, upper reaches of both watersheds are accessible only from April to Mid-November via foot-tracks and ponies.



Location map of Doodhganga watershed and Shaliganga watershed, District Budgam.


CONTOUR MAP OF DOODHGANGA WATERSHED, DISTRICT BUDGAM
N
0 3 6 12 Kilometers
33°55'0"N
33°50'0"N
33°45'0"N
74°30'0"E
74°35'0"E
74°40'0"E
74°45'0"E
74°50'0"E


CONTOUR MAP OF SHALIGANGA WATERSHED, DISTRICT BUDGAM
N
34°0'0"N
33°55'0"N
33°50'0"N
33°45'0"N
74°30'0"E
74°35'0"E
74°40'0"E
74°45'0"E
74°50'0"E
0
3
6
12 Kilometers

1.2 Topography and drainage: The topography of the study area is varied and exhibits altitudinal extremes of 1556-4661 m amsl. It is bounded by lofty Pir Panjal mountain range on southwest. Its relief is diverse, comprising of escarpments, steep slopes, plateaus, plains, hanging valleys, U-shaped valleys, moraines and alluvial fans. The upper reaches of the catchment area is usually snow covered and has extremely steep slopes, followed by comparatively lesser steep slopes. Plateaus traversed by deep gullies occur in the middle part of the area. Moreover, the northeastern downstream part has very gentle slope.

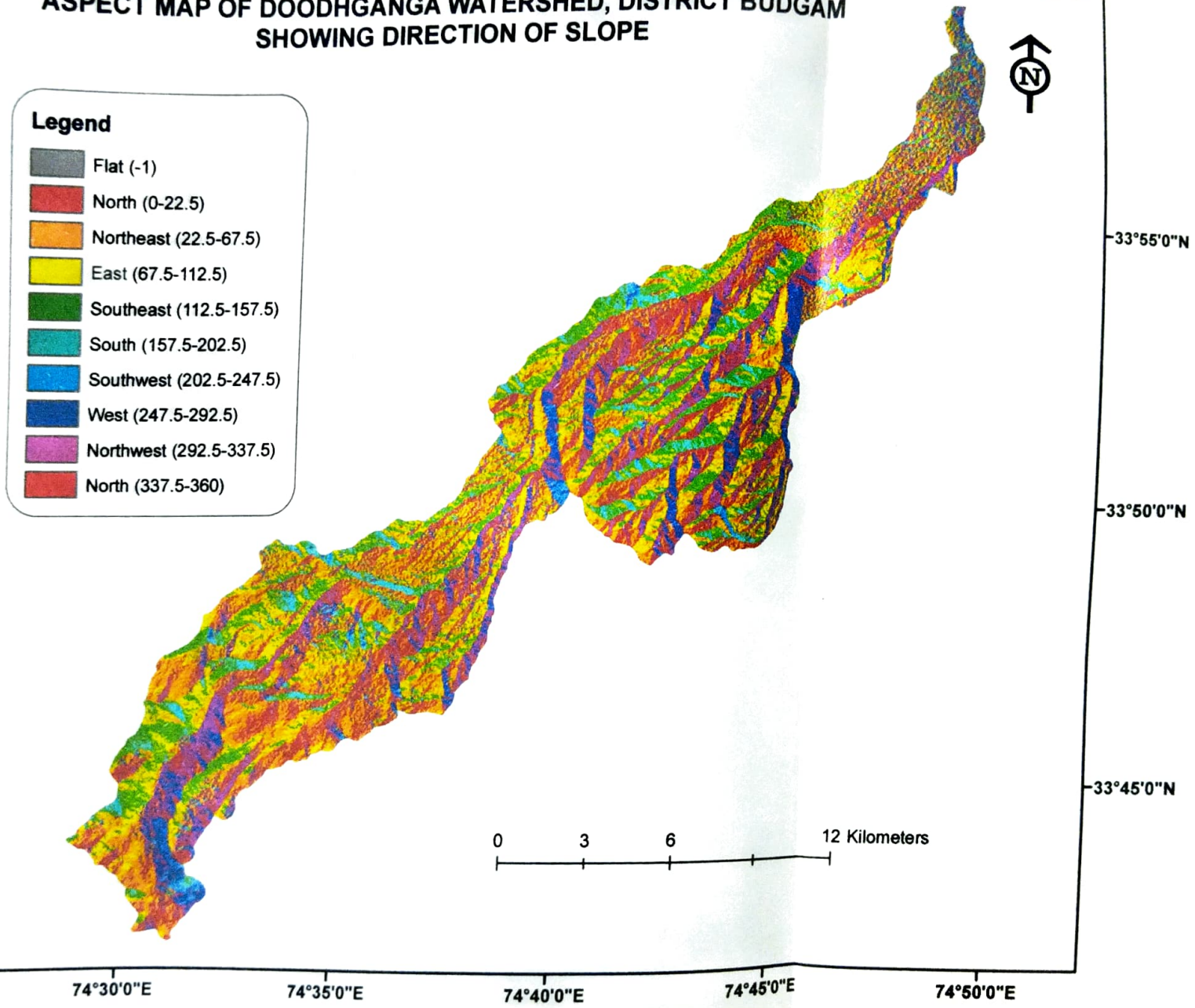
The most commonly encountered drainage pattern in the area is dendritic. It is by far the most common drainage type, characterized by irregular branching of stream tributaries in many directions. The general direction of flow of the drainage in the study area is towards north-west. Doodhganga and Shaliganga are the main streams of this area that drains it along with its tributaries. Besides, there are many small lakes in the area. Among them, *Nilnag* Lake is noteworthy to mention.

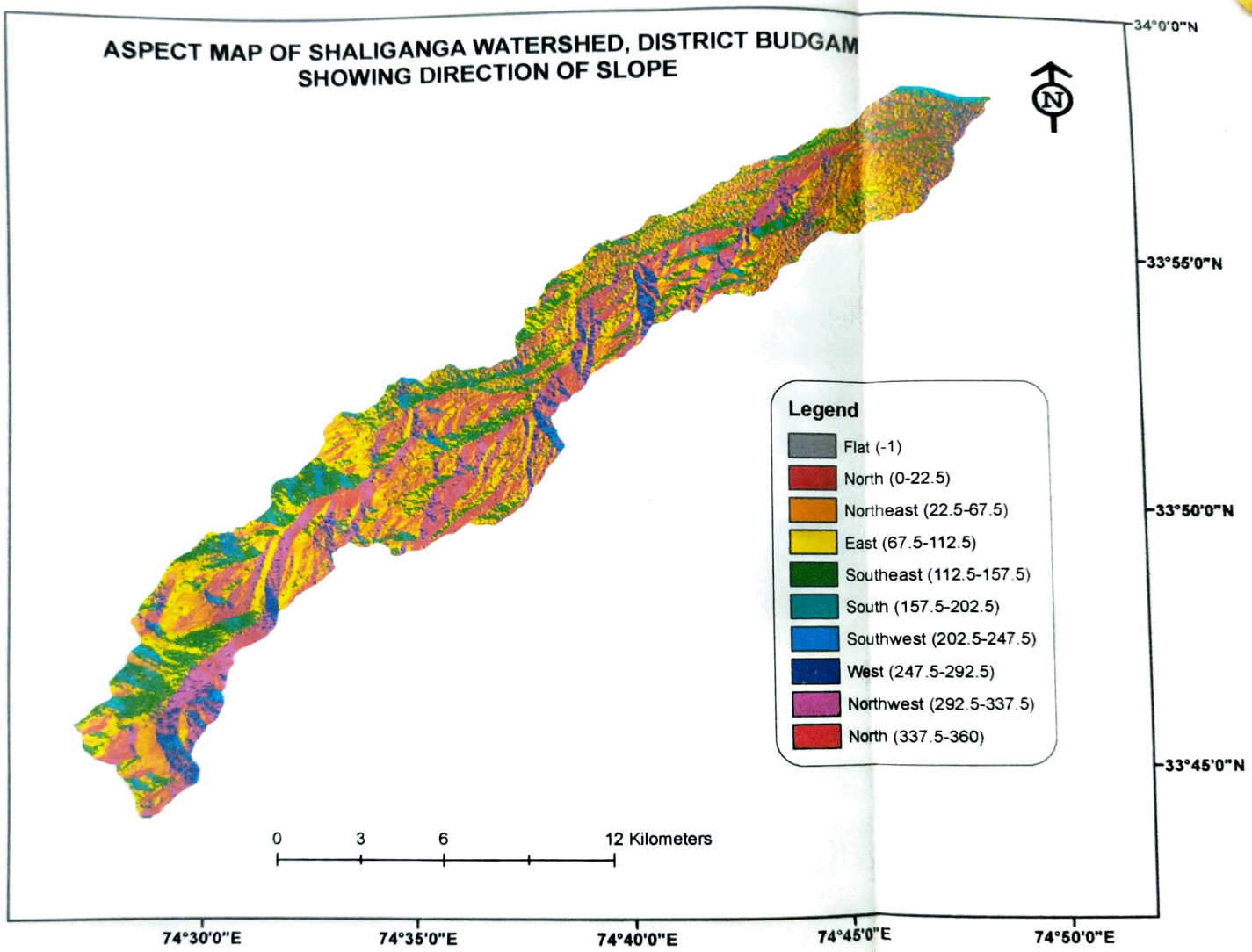
1.3 Flora and Fauna: Thick vegetation of *Gmelina arborea* (teak), *Cedrus deodara* (Deodar) and *Betula utilis* (Birch) is found upto elevation of 3100 m. Thorny bushes, open scrubs along with grass is common vegetation in higher areas upto an elevation of above 3500 m. Besides, *Juglans regia* (Walnut), willow and poplar trees are also common in the area.

Brown bears, black bears and monkey are common, particularly in forest areas. Besides, wild bulls, musk deer and markhors are also found in these forests.

1.4 Climate: The study area is characterized with moderate type of climate, largely defined by its geographic location and is generally described as cool in the spring and autumn, mild in the summer and cold in the winter. Due to varied altitudinal extents, there is a wide variation in climatic conditions in different parts of the area. The western and south western parts of the area being mostly hilly, experience heavy snowfall from mid-November to mid-May. As a result, the winters are severe and intolerable. The unfavourable climatic conditions

ASPECT MAP OF DOODHGANGA WATERSHED, DISTRICT BUDGAM SHOWING DIRECTION OF SLOPE




ASPECT MAP OF SHALIGANGA WATERSHED, DISTRICT BUDGAM
SHOWING DIRECTION OF SLOPE
N
Legend
Flat (-1)
North (0-22.5)
Northeast (22.5-67.5)
East (67.5-112.5)
Southeast (112.5-157.5)
South (157.5-202.5)
Southwest (202.5-247.5)
West (247.5-292.5)
Northwest (292.5-337.5)
North (337.5-360)
0 3 6 12 Kilometers
34°0'0"N
33°55'0"N
33°50'0"N
33°45'0"N
74°30'0"E
74°35'0"E
74°40'0"E
74°45'0"E
74°50'0"E

restrict permanent habitation in this part of the area. May to October months are pleasant but the precipitation is not uncommon.

The middle and downstream parts of the watershed experiences moderate snowfall and pleasant weather from April to October with scanty rainfall.

1.5 Acknowledgement

The author is highly thankful to senior geologists and colleagues of the Department of Geology and Mining, Srinagar for their guidance throughout the field session and their support during the completion of this report.

CHAPTER-2
GEOLOGICAL SETTING OF THE STUDY AREA

Introduction

Kashmir Valley comprises a very important place in the geotectonics of the Kashmir Himalayas. The intermontane Kashmir basin constituting the Nappe Zone is bounded by two linear mountain ranges - the Pir Panjal in the Southwest and the Zanaskar in the northeast. It contains one of the finest developments of the stratigraphic succession right from Proterozoic to Recent, witnessing a complete stratigraphic sequence of marine Paleozoics, Mesozoics and Cenozoics.

District Budgam forms the western part of Kashmir Basin wherein Palaeozoic to Quaternary rocks of diverse origin are exposed. The regional Stratigraphic sequence of geological Formations with lithology in the study area is given below.

	Age	Group/Formation		Lithology
CENOZOIC	Holocene	Alluvium/moraine		Clay, sand, loam, gravel and boulders
	Plio-Pleistocene	Karewa Formation	Dilpur Formation	Loess with interbedded paleosols
			Nagum Formation	yellow silt, grey clay, calcareous layers and sand with conglomerate
			Hirpur Formation	grey clay, silt, lignitic marl, lignite and green sand and conglomerate
MESOZOIC	Upper Triassic	Dudpathri Group		Bluish grey massive, bedded and siliceous limestone
PALEOZOIC	Early Permian	Panjal Volcanics		Andesitic and basaltic lava flows
		Agglomeratic Slates		Sandstone, siltstone, diamictite and tuff

Table_1: Geological succession of Doodhganga watershed and Shaliganga watershed, District Budgam.

Lithological Description

2.1 Agglomeratic Slates: The agglomeratic slates constitutes a conspicuous and an interesting group of rocks exposed in various parts of Kashmir. In the study area, some good exposures occur from Tattakuti peak in the north to *Katsgalu* pass in the south. The Agglomeratic Slate consists of pyroclastic slates, conglomerates and Agglomeratic/pyroclastic products. These are heterogeneous in composition and consist essentially of a mixture of crystals, vitrified glass and rock fragments. In view of the fact that the debris constituting the slates is of rhyolitic composition and that the tuffs were welded, it is very likely that these rocks were originally of the nature of rhyolitic crystals vitric welded tuffs which have subsequently been altered and devitrified.

2.2 Panjal Volcanics: Panjal volcanic rocks, a thick series of bedded and massive andesitic and basaltic flows are well exposed from *Ashtar Gali,* through *Bod Angan* to *Dain Zab* ridges trending NW and dipping westerly. The primary constituents are plagioclase and augite in a fine-grained semi crystalline ground mass. The ferromagnesian minerals have been chloritized and/or epidotized to give the traps a green colour. These lava flows are amygdaloidal or porphyritic in texture, although compact fine-grained varieties are most common and show a glomero-porphyritic texture. These rocks are light to dark green in colour, containing vesicles, partly filled by secondary materials.

2.3 Dudpathri Group (Triassic Limestone): The Formation is a thick succession of limestone and shale of Triassic Age. The limestone is dark grey in colour,

siliceous and unfossiliferous with a general trend N45°W – S45°E with a dip amount of 50°-60° Easterly. The rocks of this Formation are well exposed all along the hills and ridges from *Parihas Maidan*, through Doodhpathri to *Fresnag.* This formation is mostly covered under thick forest cover. Besides, the Formation is extensively folded, jointed and cavernous in nature.

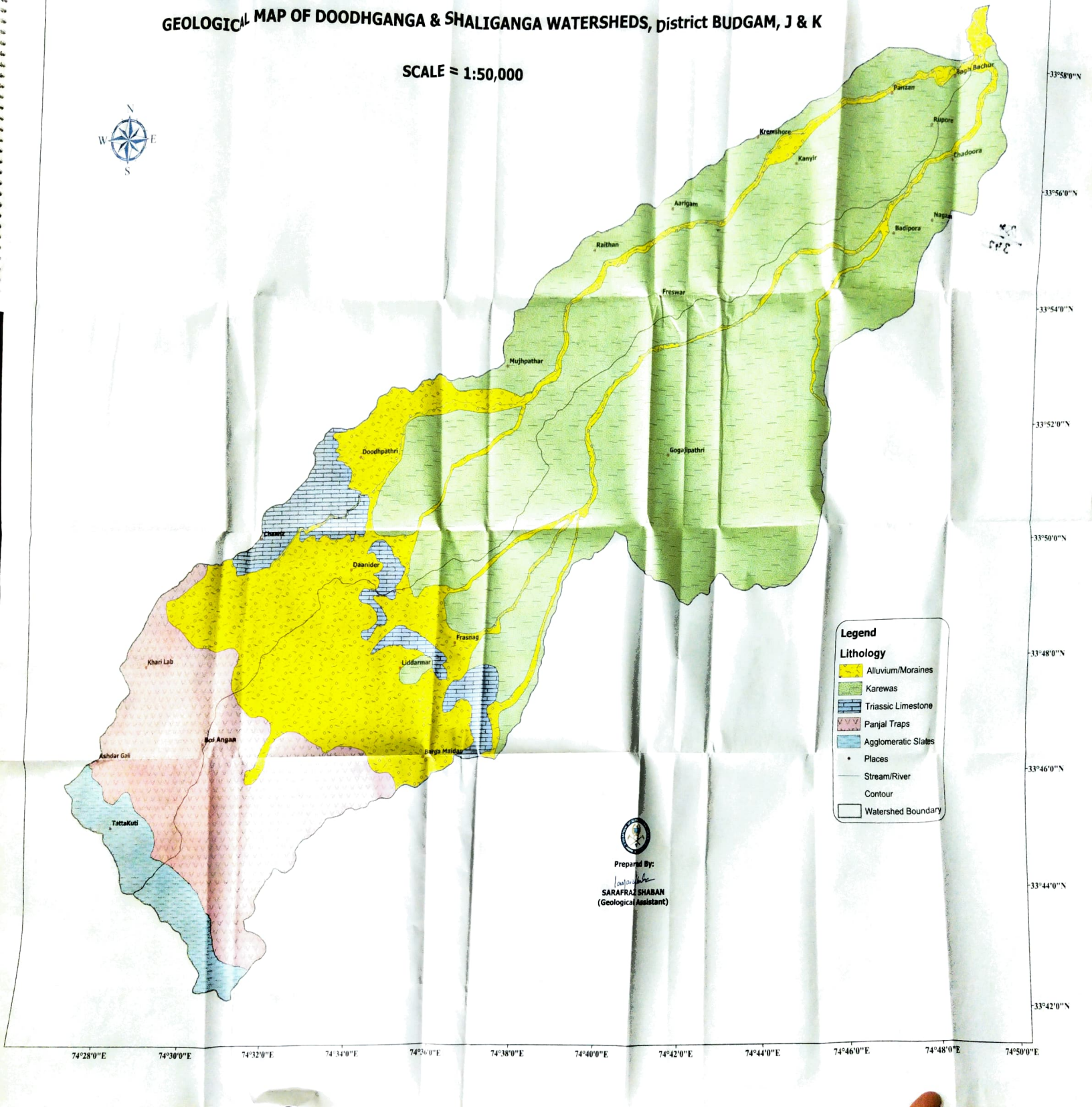
2.4 Karewa Formation: The Late Neogene to Quaternary Karewa sediments comprising mainly of clays, loam, silt and gravels occupy a large part of the study area. The sediments of Karewa Formation are well exposed in the foothill areas and the plateau landforms (*Wudars).*

The sediments of **Hirpur Formation** containing many lignitic seams (1-3 m thick) are well exposed along the course of Shaliganga stream form Mujpathri to Arigam. The sediments of **Nagum Formation** are exposed from Nilnag hamlet to *Qasba* Nagum. The sediments of the Dilpur Formation occur as cap sediments over Nagum formation and constitute a major portion of the study area.

2.5 Alluvium/Moraines: The moraine material covers a sizeable part of the study area. The moraines and glacial drifts overlies the basement rocks in the upper reaches of the study area along the meadows and stream tracks. These loose deposits comprises mostly of rounded to sub-rounded boulders derived from Panjal Volcanics with occasional clasts of Agglomeratic Slates. Besides, the loose and heterogeneous alluvial sediments occurs along the stream channels, courses and low-lying flood plains.

GEOLOGICAL MAP OF DOODHGANGA & SHALIGANGA WATERSHEDS, district BUDGAM, J & K

SCALE = 1:50,000



CHAPTER-3

HYDROLOGY, HYDROGEOLOGY AND MORPHOMETRY

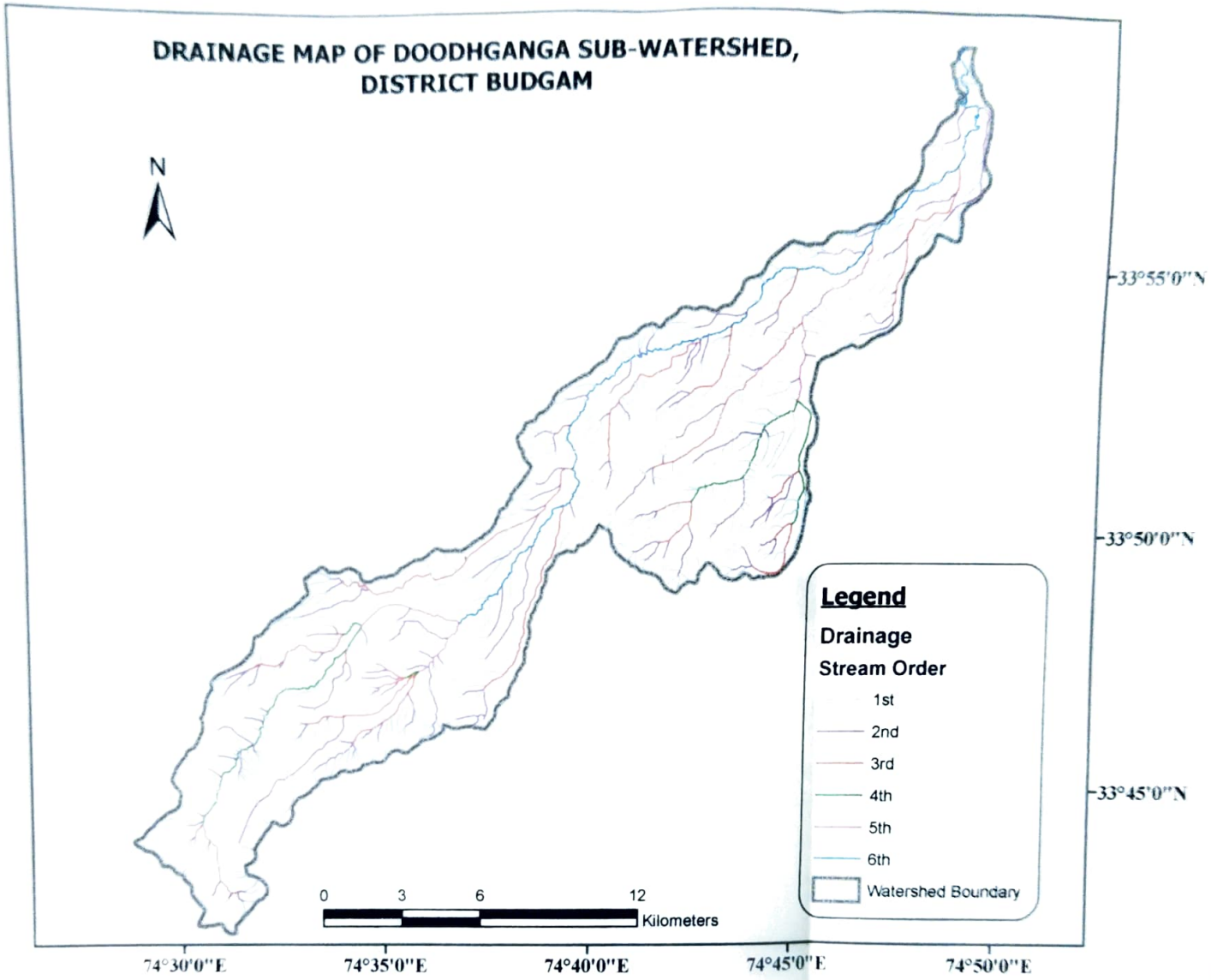
3.1 HYDROLOGY

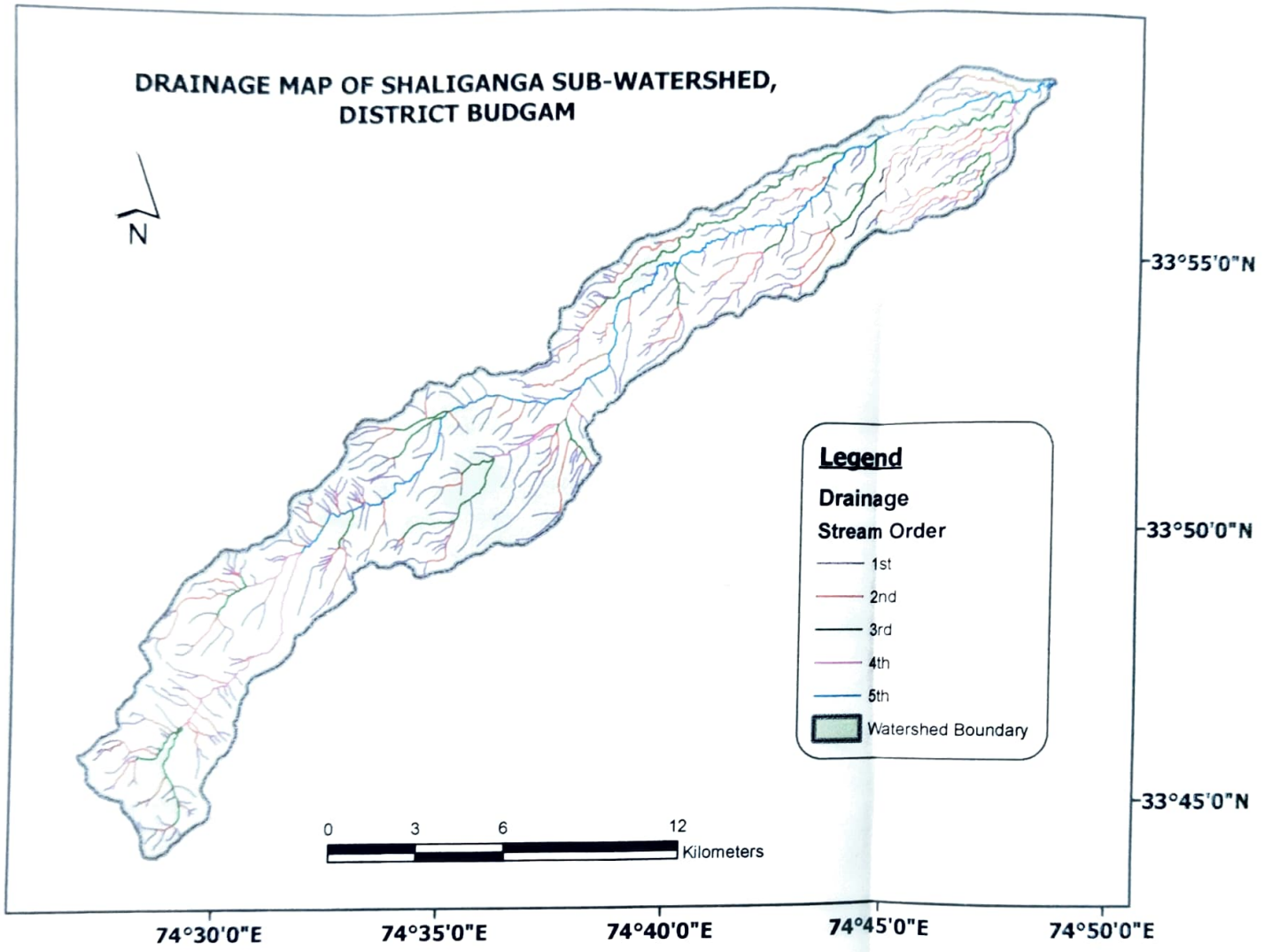
Hydrology is the scientific that encompasses the occurrence, distribution, movement and properties of waters of the Earth and their relationship with the environment within each phase of the hydrological cycle. It is a very significant study and facilitates the learning and to understand the vast and highly complex network of water systems on the surface of the Earth and also to help to resolve water related problems being faced by all living beings be it plants, animals or humans. The hydrographic basin can be considered, in general terms, as a physical system where the input of water is the volume precipitated and the output is the volume of water drained by the river mouth and the amount infiltrated.

a) **Drainage System:** It refers to the pattern formed by streams, rivers and lakes in a drainage basin. In a drainage system, streams or rivers always connect together to form networks. Many factors such as topography, soil type, bedrock type, climate and vegetation cover influence input, output and transport of sediment and water in a drainage basin.

Doodhganga nalla, a left bank tributary of river Jhelum, rises in the central Pir Panjal mountain range near Tattakutti peak in District Budgam. Two mountain streamlets, the Sangesafed and the Yachera, join near Fresnag to form this stream. The stream flows adjacent to the famous tourist resort Yusmarg. The length of this stream is about 35 Kms from *Fresnag* to Wathoora with a basin area of about 213 Sq.Kms.

Shaliganga stream is a left bank tributary of Doodhganga stream. It also originates near Tattakutti peak in the Pir Panjal mountain range. It is formed by the union of two streamlets viz. *Ashdar nallah* and *Razdain nalla.* The stream flows through the Doodhpathri meadows and the total length of this stream is about 37 kms with a basin area of about 162 Sq.kms. This stream flows almost parallel to Doodhganga nalla in northeast direction before joining it at Bagh-i-Bachur village near Wathoora.


DRAINAGE MAP OF DOODHGANGA SUB-WATERSHED,
DISTRICT BUDGAM
N
33°55'0"N
33°50'0"N
33°45'0"N
74°30'0"E
74°35'0"E
74°40'0"E
74°45'0"E
74°50'0"E
0 3 6 12
Kilometers
Legend
Drainage
Stream Order
1st
2nd
3rd
4th
5th
6th
Watershed Boundary



down a stream or river per unit of time, commonly expressed in cubic feet per

b) Precipitation: There is no meteorological observatory located in the in the Budgam District. Hence the meteorological parameters recorded at the nearest observatory i.e. Srinagar has been taken as representative for the study area. The monthly rainfall details of last ten years was acquired from Indian Metrological Department (IMD), Metrological Centre Srinagar. The monthly details of rainfall for last years are given in Tables_2 below:

Year-wise months total rainfall (in mms)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
JAN	54.2	60.2	58.7	86.9	5.6	21.4	162.2	1.2	83.8	136.4
FEB	100.9	78.7	111.9	39.1	164.9	47.8	97.2	44.7	122.2	7.3
MAR	100.8	58.0	69.4	220.1	294.6	170.1	67.2	36.7	75.4	93.9
APR	105.8	82.7	102.0	113.7	164.1	90.8	193.7	109.2	45.3	63.6
MAY	20.1	39.8	51.8	50.9	63.4	45.9	30.2	31.5	75.7	38.7
JUN	27.0	24.3	54.1	18.6	87.5	17.9	73.9	60.9	97.3	47.0
JUL	37.1	12.1	79.8	55.8	139.3	60.9	34.4	85.1	63.2	9.7
AUG	68.4	26.6	88.8	72.2	53.4	54.5	24.0	50.9	87.6	123.9
SEP	46.5	111.5	34.2	184.8	56.4	2.0	16.3	23.7	0.6	22.7
OCT	29.1	10.8	18.5	35.7	65.9	1.2	0.0	7.4	36.4	0.0
NOV	24.1	11.7	4.1	15.1	36.6	0.0	11.1	118.1	225.8	20.5
DEC	33.1	27.1	16.6	0.0	23.0	2.4	37.2	2.4	36.0	49.0
Annual	**647.1**	**543.5**	**689.9**	**892.9**	**1154.7**	**514.9**	**747.4**	**571.8**	**949.3**	**612.7**

The annual mean precipitation is **732.42** mm (73.242 cm).

c) Stream Discharge: Discharge or streamflow is the volume of water moving down a stream or river per unit of time, commonly expressed in cubic feet per second or gallons per day. A commonly applied methodology for measuring and estimating the discharge of a river is based on a simplified form of the continuity equation. The equation implies that the discharge (Q) is equal to the product of the stream's cross-sectional area (A) and its mean velocity (V).

Discharge is a function of meteorological runoff and drainage basin area. It is an integrated result of hydrological processes in a river system in transporting runoff from rainfall. The monthly discharge data of nalla

Doodhganga as recorded at Gauge station Brenwar (T-22a) and nalla Shaliganga as recorded at Gauge station Raithan (T-21) from January, 2016 to December, 2021 was acquired form Irrigation & Flood Control Department. The monthly discharge details are given in the table_3a & 3b below:

TABLE _3a

Average monthly discharge (in Cusecs) of nalla DOODHGANGA						
	2016	**2017**	**2018**	**2019**	**2020**	**2021**
January	24.67	39.0	8.33	21.0	30.67	15.15
February	27.67	94.0	12.33	34.67	41.33	34.67
March	56.67	51.0	44.67	60.67	117.50	167.33
April	79.0	266.75	107.0	169.33	178.67	274.67
May	102.67	128.67	147.0	154.0	147.0	318.67
June	117.0	160.67	283.25	172.33	126.0	362.33
July	120.33	121.0	88.67	178.0	109.67	448.67
August	102.0	91.33	77.0	134.0	802.0	335.33
September	79.33	54.0	30.67	88.33	92.33	262.0
October	40.33	20.67	21.0	66.67	35.0	74.67
November	8.67	15.67	44.67	95.67	22.0	30.33
December	6.67	4.12	28.33	43.32	18.29	11.33
MEAN	**63.75**	**92.09**	**80.05**	**100.57**	**162.39**	**189.75**
Average discharge (in ft^3/Sec)						**114.76**

Average monthly discharge (in Cusecs) of nalla DOODHGANGA

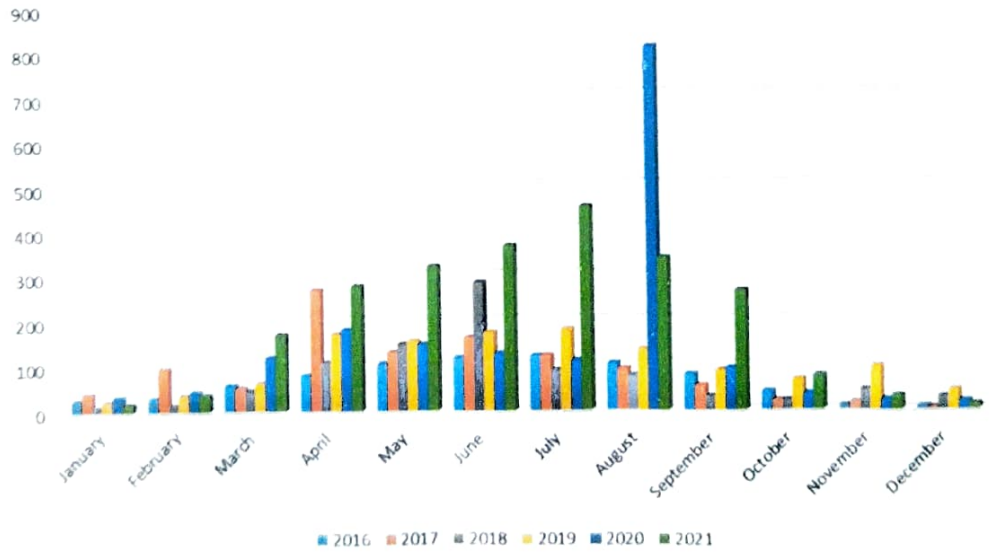
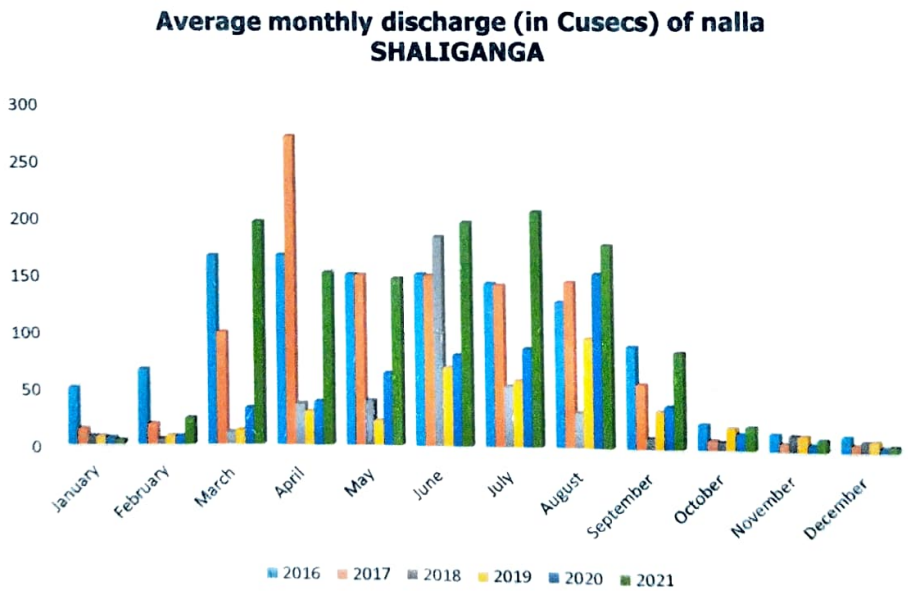


TABLE _3b

Average monthly discharge (in Cusecs) of nalla SHALIGANGA						
	2016	**2017**	**2018**	**2019**	**2020**	**2021**
January	50.0	13.67	7.33	7.0	6.0	3.63
February	66.0	18.0	5.0	7.67	7.17	23.0
March	165.33	98.67	11.0	12.67	32.0	195.0
April	166.0	270.50	36.33	29.33	38.0	150.67
May	149.33	149.0	39.33	22.0	63.33	146.33
June	150.0	149.0	182.50	69.0	79.67	195.0
July	142.33	141.0	53.33	58.0	86.0	205.0
August	127.0	144.33	31.0	95.67	151.50	176.67
September	89.0	56.33	9.67	33.0	37.33	84.0
October	22.33	8.33	7.0	19.33	14.0	20.33
November	15.0	6.67	14.0	13.67	6.11	10.67
December	13.50	6.33	9.0	9.33	4.07	5.0
MEAN	**96.32**	**93.41**	**37.81**	**31.39**	**50.82**	**101.28**
Average discharge (in ft^3/Sec)						**68.50**

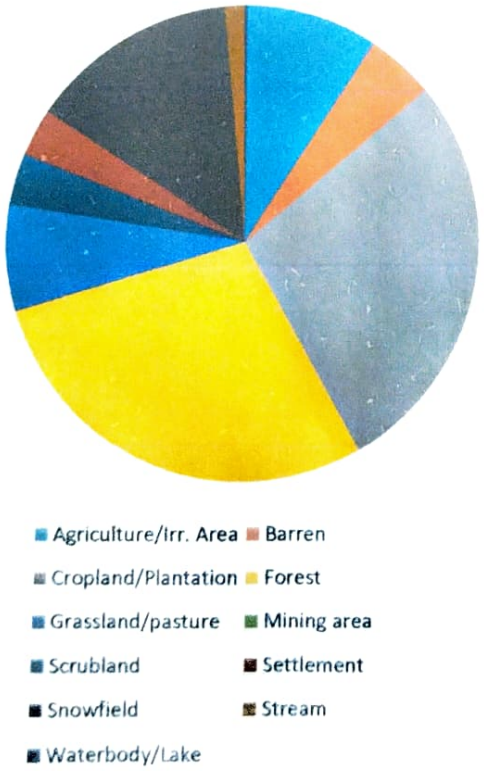


3.2 Land Use (LU)/Land Cover (LC) Pattern

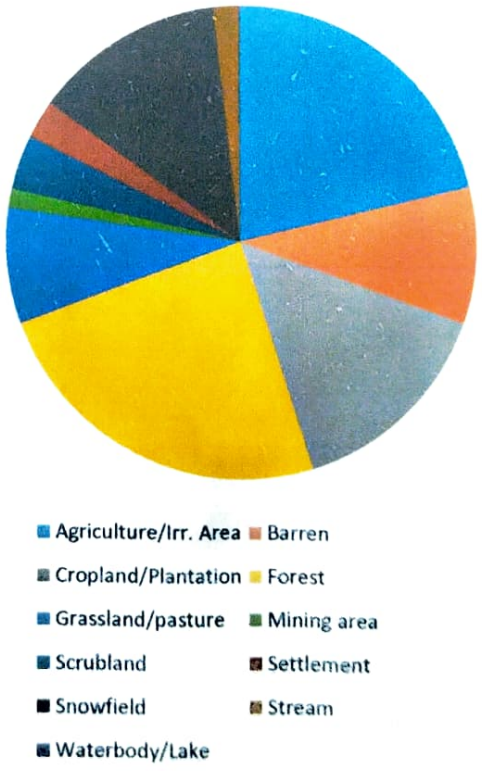
The land use / land cover pattern of a region is determined by the natural and socioeconomic factors and their utilization by humans in space and time. For the proper management of natural resources and for monitoring environmental changes, the information on the rate of change of land resources is utilized. Moreover, land utilization pattern plays an important role in the annual sediment yield of a region

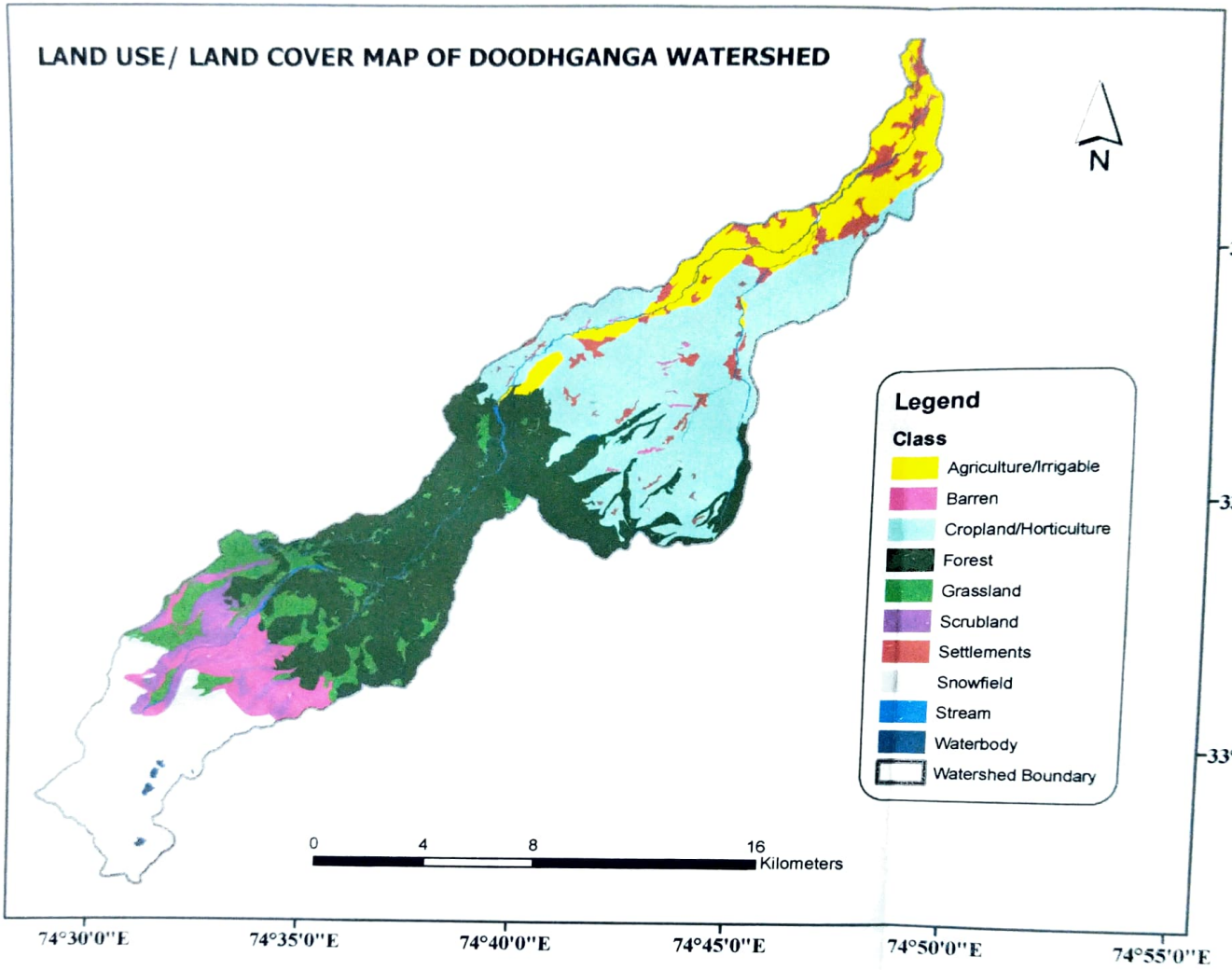
For the present study, land use / land cover classification of Doodhganga and Shaliganga watersheds was done by analysis and interpretation of multi-spectral satellite imageries of various datasets in GIS and RS platform. Satellite Imageries of Landsat-8 (Oct-2020, Oct-2017) with a spatial resolution of 30 m; Sentinel-2 (Oct-2021, Oct-2020) with a spatial resolution of 10 m were used. The land use land cover classes were delineated as per the requirement of current study. The existing land use pattern of Doodhganga watershed and Shaliganga watershed is given in the table_4 below:

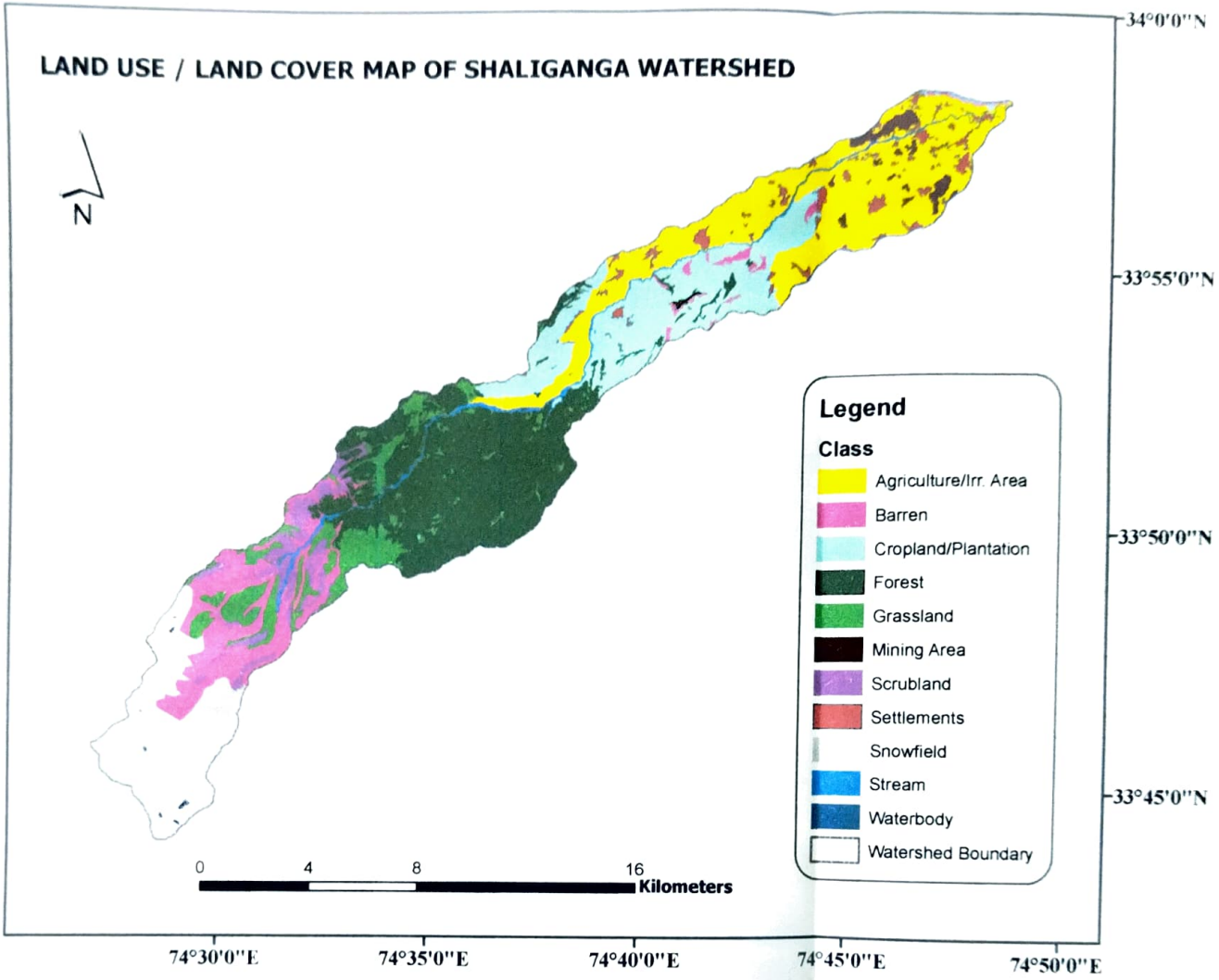
DOODHGANGA WATERSHED



SHALIGANGA WATERSHED




LAND USE/ LAND COVER MAP OF DOODHGANGA WATERSHED
N
Legend
Class
Agriculture/Irrigable
Barren
Cropland/Horticulture
Forest
Grassland
Scrubland
Settlements
Snowfield
Stream
Waterbody
Watershed Boundary
0
4
8
16
Kilometers
33°55'0"N
33°50'0"N
33°45'0"N
74°30'0"E
74°35'0"E
74°40'0"E
74°45'0"E
74°50'0"E
74°55'0"E


LAND USE / LAND COVER MAP OF SHALIGANGA WATERSHED
N
Legend
Class
Agriculture/Irr. Area
Barren
Cropland/Plantation
Forest
Grassland
Mining Area
Scrubland
Settlements
Snowfield
Stream
Waterbody
Watershed Boundary
0
4
8
16
Kilometers
34°0'0"N
33°55'0"N
33°50'0"N
33°45'0"N
74°30'0"E
74°35'0"E
74°40'0"E
74°45'0"E
74°50'0"E

LU/LC Class	Doodhganga watershed	Shaliganga watershed
	Area (in Km^2)	Area (in Km^2)
Agriculture/Irr. Area	19.55	34.447
Barren	10.15	15.08
Cropland/Plantation	59.44	23.525
Forest	61.04	39.18
Grassland/pasture	15.40	12.922
Mining area	00	2.127
Scrubland	7.43	6.083
Settlement	6.84	4.344
Snowfield	30.45	21.36
Stream	2.90	2.841
Waterbody/Lake	0.45	0.131
Total	**213.65**	**162.04**

3.3 HYDROGEOLOGY

It is the study of the laws governing the movement of subterranean water, the mechanical, chemical, and thermal interaction of this water with the porous solid, and the transport of energy, chemical constituents, and particulate matter by flow. It deals with the distribution and movement of groundwater in the soil and different rocks types of the Earth's crust.

Hydro-geologically, the area has both hard-rock as well as soft-rock aquifer systems. The consolidated formations which occur in the western and south-western parts of the watersheds form the hard-rock aquifer system. Occurrence and movement of the ground water in this system is mainly controlled by secondary porosity. This type of aquifer system in the area has fair to moderate yield. Groundwater oozes in the form of springs, seepages in the hilly areas and is either utilizing for domestic purposes or drains into the nearby streams.

Unconsolidated sediments comprising of fluvio-glacial and lacustrine deposits of Karewa Formation and Recent alluvium constitutes the porous/soft aquifer system of the area. Occurrence and movement of ground water is mainly controlled by the primary intergranular porosity. The groundwater occurs in confined, leaky and

lay

unconfined conditions. Many tube-well drilled 50 m to 150 m deep occur in the catchment area of the streams. The depth to water-table ranges from 10 m to 60 m BGL and the discharge varies from 500 gph to 5,000 gph.

3.3 MORPHOMETRY

Morphometry refers to the measurement and mathematical analysis of the Earth's surface and of the shape and dimensions of its landforms. This analysis can be achieved through measurement of linear, aerial and relief aspects of basin and slope contributions. The development of a drainage system over space and time is influenced by several variables such as geology, structural components, geomorphology, soil and vegetation of an area through which it flows.

Morphometric analysis of a river/ stream basin provides a quantitative description and characteristics of the drainage system, based on evaluation of different parameters. Morphometric parameters such as relief, shape and length influence basin discharge patterns strongly through their varying effects on lag time. The methods of Horton, Strahler, Miller, Schumm are generally used for calculation and evaluation of different parameters of a drainage basin. The morphometric parameters used for the current sediment replenishment studies are given as under:

a) **Stream Order (U):** It is defined as a measure of the position of a stream in the hierarchy of tributaries within the drainage basin. For the analysis, Strahler's scheme of ordering, popularly known as 'stream segment method' has been followed because of its simplicity.

   The observations show that Doodhganga stream has upto 6^{th} order tributaries where 1^{st}, 2^{nd}, 3^{rd}, 4^{th}, 5^{th} and 6^{th} stream are 432, 114, 22, 7, 3 and 1 respectively in numbers.

   Similarly, the observations show that Shaliganga stream has upto 5^{th} order tributaries where 1^{st}, 2^{nd}, 3^{rd}, 4^{th} and 5^{th} stream are 332, 105, 30, 5 and 1 respectively in numbers.

b) **Stream Length (Lu):** It indicates the behaviour of surface runoff on the basin. The stream with longer lengths is normally indicative of flatter gradient whereas

the smaller length is characteristics of areas with larger slopes and finer textures. The total length of stream segments is maximum in first-order stream and decreases as stream order increases. The order-wise stream lengths of Doodhganga and Shaliganga streams in given in table_1 below:

Table _5: Stream length measurements

DOODHGANGA STREAM			
Stream Order	**Stream Number**	**Total length (Km)**	**Mean stream length (Km)**
1st	432	286.805	0.663
2nd	114	120.122	1.053
3rd	22	72.955	3.316
4th	7	22.933	3.276
5th	3	13.945	4.648
6th	1	35.318	35.318
SHALIGANGA STREAM			
1st	332	228.332	0.687
2nd	105	87.738	0.835
3rd	30	49.164	1.638
4th	5	17.088	3.417
5th	1	36.576	36.576

c) **Bifurcation ratio (R_b)**: It is related to the branching pattern of a drainage network. It is defined as the ratio between the total numbers of stream segments of one order to that of the next higher order in a drainage basin. The lower value of bifurcation ratio are characteristics of the watershed which have flat or rolling watersheds while the higher values of bifurcation ratio indicate strong structural control on the drainage pattern. The higher bifurcation ratio leads to less chances of flooding.

- **The calculations for Doodhganga is given below:**

Rb 12 = 432/114 = 3.789

Rb 23 = 114/22 = 5.181

Rb 34 = 22/7 = 3.142

Rb 45 = 7/3 = 2.333

Rb 56 = 3/1 = 3

Mean bifurcation ratio = (3.789+5.181+3.142+2.333+3)/5 = **3.489**

- **The calculations for Shaliganga is given below:**

Rb 12 = 332/105 = 3.161

Rb 23 = 105/30= 3.5

Rb 34 = 30/5 = 6.0

Rb 45 = 5/1 = 5

Mean bifurcation ratio = (3.161+3.5+6+5)/4 = **4.410**

d) Drainage density (Dd): It is defined as a ratio of total length of all stream segments cumulated for all orders in a given drainage basin to the total area of that basin. The drainage density is an expression of closeness of spacing of channels. The low value of drainage density indicates high permeability and thick vegetation cover in the basin. High value of drainage density is the result of weak or impermeable subsurface material, sparse vegetation and mountainous relief. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture.

Dd of Doodhganga stream = 552 km/213 km^2 = **2.59 km/km^2**

Dd of Shaliganga stream = 419 km/162 km^2 **= 2.58 km/km^2**

The value of drainage density of both the streams is moderate which indicates semi permeable basin and overall mountainous terrain with thick vegetation cover.

e) Stream Frequency (Fs): It is the measure of number of streams per unit area (Sq.Km). It exhibits positive correlation with drainage density in the watershed indicating an increase in stream population with respect to increase in drainage density. Climatic character, vegetation coverage, rock and soil types, rainfall intensity, infiltration capacity, relief, run-off intensity, permeability terrain, slope has played vital role in controlling the drainage frequency and density. Greater the drainage density and stream frequency in a basin, the runoff is faster, and therefore, flooding is more likely in basins with a high drainage and stream frequency. The stream frequency (Fs) for the Doodhganga basin is **2.718** and for the Shaliganga basin is **2.919**.

lang

f) Texture ratio (T): Texture ratio is an important factor in the drainage morphometric analysis and is expressed as the ratio between the number of first-order streams and the perimeter of the basin. It is depending on the underlying lithology, infiltration capacity, and relief aspect of the terrain of the basin. The texture ratio of Doodhganga watershed is 3.84 km^{-1} while that of Shaliganga is 3.36 km^{-1}.

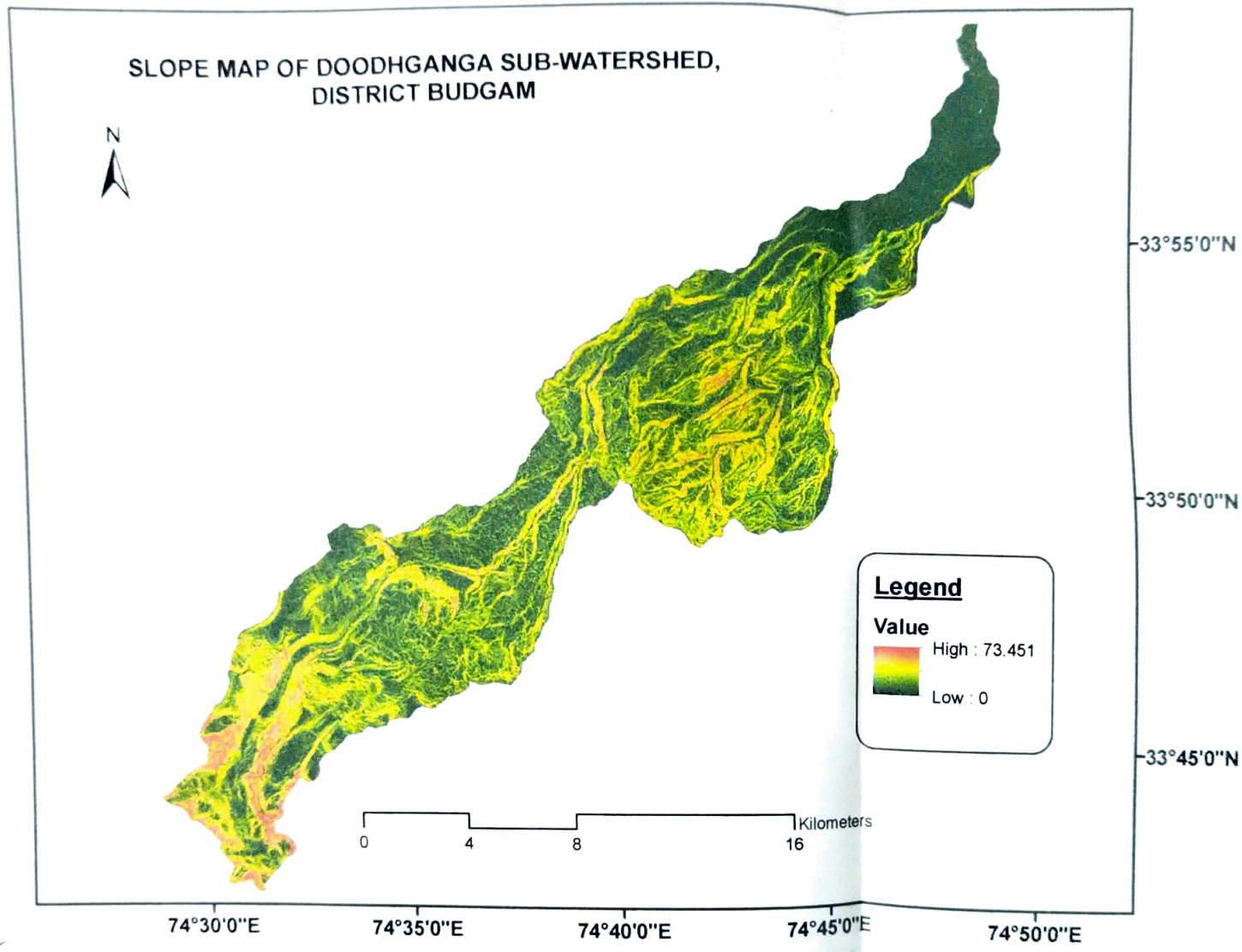
g) Circulatory ratio (Rc):

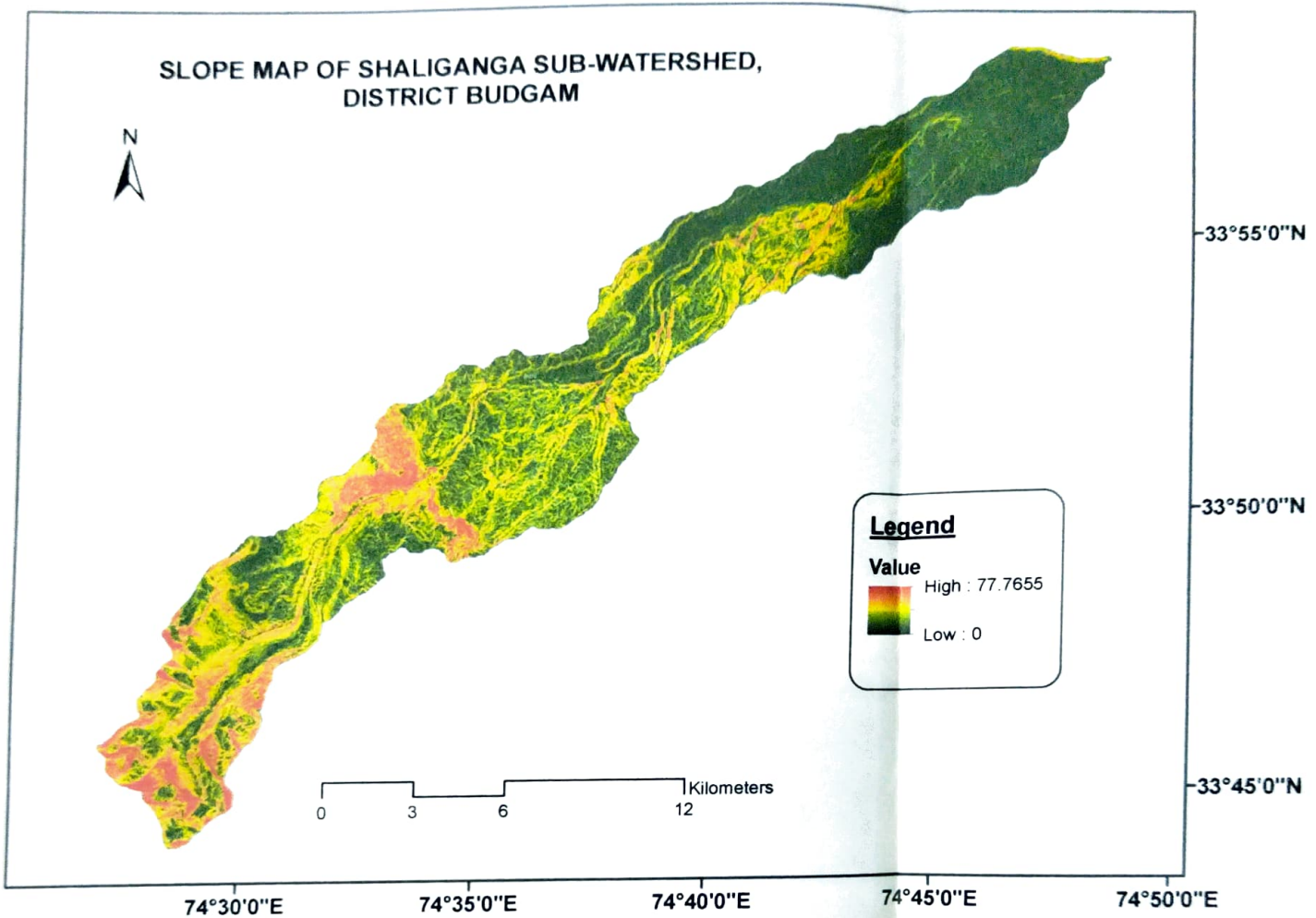
Circulatory Ratio is defined as the ratio of the area of a basin to the area of the circle having the same circumference as the perimeter of the basin. Rc is influenced by the frequency of stream, slope, relief, geologic structure, climate and land use/land cover of the basin.

The value of circulatory ratio (Rc) of the Doodhganga basin is 0.211 while that of Shaliganga basin is 0.209. The values of Rc for both watersheds indicates elongated shape, low discharge of runoff, and high permeability of the subsoil conditions. The low values of both is indicative of the youth stages of the life cycle of the tributary basins.

h) Average/mean Slope (H): Slope is defined as angular inclinations of terrain between hill-tops and valley bottoms, resulting from the combination of many causative factors like geological structure, absolute and relative reliefs, climate, vegetation cover, drainage texture and frequency, dissection index etc. are significant morphometric attributes in the study of landforms of a drainage basin. Slope analysis is an important parameter in morphometric studies. The slope elements, in turn are controlled by climate-morphogenic processes in areas having rock of varying resistance.

The average slope values of Doodhganga watershed and Shaliganga watershed were calculated from their respective slope maps. These maps were generated in ArcGIS 10.8 software from ALOS PALSAR DEM with a spatial resolution of 12.5 m. The value of Average/mean slope (H) for Doodhganga watershed is **13.85** and for Shaliganga watershed is **12.86**.


SLOPE MAP OF DOODHGANGA SUB-WATERSHED,
DISTRICT BUDGAM
N
33°55'0"N
33°50'0"N
33°45'0"N
Legend
Value
High : 73.451
Low : 0
0
4
8
16
Kilometers
74°30'0"E
74°35'0"E
74°40'0"E
74°45'0"E
74°50'0"E


SLOPE MAP OF SHALIGANGA SUB-WATERSHED,
DISTRICT BUDGAM
N
Legend
Value
High : 77.7655
Low : 0
0
3
6
12
Kilometers
33°55'0"N
33°50'0"N
33°45'0"N
74°30'0"E
74°35'0"E
74°40'0"E
74°45'0"E
74°50'0"E

i) **Ruggedness Number (R_n):** It is the product of maximum basin relief (H) and drainage density (Dd), where both parameters are in the same unit. An extreme high value of ruggedness number occurs when both variables are large and slope is steep. The value of ruggedness number of Doodhganga basin is 7.97 and that of Shaliganga basin is 7.99.

Table_6: Morphometric results of Doodhganga and Shaliganga Basin.

Morphometric Parameter	Doodhganga	Shaliganga
Basin Area	213 Sq.Kms	162 Sq.Kms
Perimeter	112.50 Kms	98.58 Kms
Basin Order (U)	6^{th}	5^{th}
Basin Length (Lu)	552.05 Kms	419 Kms
Mean Bifurcation ratio (Rb)	3.489	4.410
Drainage density (Dd)	2.59	2.58
Stream frequency (Fs)	2.718	2.919
Texture ratio (T)	3.84	3.36
Circulatory ratio (Rc)	0.211	0.209
Mean Slope (H)	13.85°	12.86°
Ruggedness number (R_n)	7.97	7.99

CHAPTER-4
MINOR MINERAL RESOURCE ESTIMATION

Introduction

Sediment yield refers to the amount of sediments exported by an area/ basin over a period of time. Estimates of sediment yield are needed for studies of sedimentation, river morphology, soil and water conservation planning, water quality modelling and design of efficient erosion control structures. Sediment yield estimation of a river or stream is highly dependent on its geomorphological characteristics.

Running water is the most widespread exogenetic process on this planet earth. The geological works of fluvial processes comprises of erosion, transportation and deposition. Rivers obtain the eroded materials and transport them from one place to another place. Rivers have their limits to transport materials, they cannot transport loads if they exceed the transporting power of the streams. The size and amount of load and the velocity of streams determine their transporting power. The velocity of streams depends on channel gradient, form and nature of valley floors and valley walls, sinuosity of river course and volume and discharge of water. Steep channel gradient, less sinuous course, smooth valley floor and required amount of volume of water increase the velocity of streams which in turn increases the transporting power of the streams.

Rivers transport their load in different ways: by traction, by saltation, by suspension and by solution. The deposition of load carried by the streams is effected by a variety of factors e.g. (1) decrease in channel gradient, (2) spreading of stream water over larger area, (3) obstructions in channel flow, (4) decrease in the volume and discharge of water, (5) decrease in the velocity of streams, (6) increase in the load etc.

The amount of sediments carried by the streams/rivers varies significantly among drainage basins and rivers. During high flow period, it can be assumed that the coarser sediments in suspension would be deposited mainly in the river segment. The replenishment rate approach has the virtue of scaling extraction to the river load in a general way, but bed load transport can be notoriously variable from year to year.

Sediment yield estimation:

The process of sediment yield / replenishment highly depends on geological and topographical characters of the catchment area, climatic conditions, vegetation cover, and land-use characteristics of a particular drainage basin, as well as changes in these factors over time. The sediment discharge regimes of a river/ stream are directly dependent on its longitudinal profile. Sediment yield estimation is an important parameter in the evaluation of the sediment effects on the projects and activities occurring due to land use. Models available for sediment yield estimation can be grouped into two categories: (i) physically-based models; and (ii) lumped models.

In the physically-based models the ground surface is generally separated into inter-rill and rill areas. Physically-based models are expected to provide reliable estimates for the sediment yield. However, these models require the coordinated use of various sub-models related to meteorology, hydrology, hydraulics and soil. The physically-based models used for sediment yield estimation include AGNPS, ANSWERS, WEPP and SHE methods.

The lumped methods of sediment yield estimation are in frequent use in many parts of the world. Some of the famous sediment transport methods which are suitable for use in the prediction of the replenishment rate of rivers/ watershed are Garde & Kothyari method; Dandy – Bolton Equation; Yang Equations; Engelund-Hansen Equation and Modified Universal Soil Loss Equation (MUSLE) developed by Williams and Berndt (1977).

Of the above mentioned methods, the most detailed study for estimation of sediment yield of drainage basins is the work of Garde & Kothyari (1987). Their study analysed the data from 50 catchments in Indian subcontinent with areas ranging from 43 km^2 to 83, 880 km^2 and incorporated information about rainfall, landuse and drainage density. They arrived at the following relationship for calculation of annual mean sediment yield

$$S_{am}=C\,P^{0.6}\,F_e^{1.7}\,H^{0.25}\,D_d^{0.10}\,(P_{max}/P)^{0.19} \quad (1)$$

with

$$F_e = (0.8F_A + 0.6F_G + 0.3F_F + 0.1F_W) / A \quad (2)$$

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Here S_{am} is the mean annual sediment yield in cm/km^2/year, **C** is a coefficient, **P** is the average annual rainfall in cm, **A** is the catchment area in km^2, **H** is the land slope, D_d is the drainage density in km/km^2 and P_{max} is the average maximum monthly rainfall in cm. F_e is defined as the erosion factor, F_A is the arable land area, F_G is the area under grass and scrub while F_W is the area of barren land and F_F is the forest area.

In the current sediment estimation studies of Doodhganga watershed and Shaliganga watershed, the method proposed by Gardy & Kothyari in 1987 was employed. After calculations, the sediment yield of Doodhganga watershed is found to be about **4.3 lac** tonnes per annum while that of Shaliganga watershed is about **3.1 lac** tonnes per annum.

The annual rate of sediment replenishment is a dynamic process and its estimation through stream bed and residence period is one of the most hard task in sediment budgeting as it requires sophisticated instruments and establishment of many gauging stations. Moreover, it is evident from the precipitation data of last 10 years that there is a high degree of variation in intensity as well as amount of precipitation received. Likewise, the monthly discharge of both streams show quantitative variations over the period of time. Hence, the estimation of actual rate of sediment replenishment is difficult to calculate accurately. However, the accuracy of the method used in the current study is considerably satisfactory.

On the basis of the mean annual sediment yield and morphometric studies of both watersheds, it is inferred that the mean rate of sediment replenishment for Doodhganga stream is about **0.402 m/year** and for Shaliganga stream is about **0.343 m/ year**. The basic need for replenishment study for river bed material is required in order to nullify the adverse impacts arising due to excessive extraction. Therefore, it is imperative that the extraction of material from a given stream should be either less or equal to the rate of replenishment of sediments.

CHAPTER-5

CONCLUSION

Rivers /streams plays an important role in shaping the Earth's surface. Rivers/streams obtain the eroded materials from their catchments and transport them at favourable places. The sediment load of a stream/river represent a natural resource for use by society. The alluvial deposits form the main source of minor mineral such as boulder, bajari and sand which form essential raw material in construction industry and for infrastructural development works. The river deposits being replenished periodically become renewable resources. However, it is necessary to maintain a balance between annual sediment replenishment rates and extraction of sediments to minimize the impacts of over exploitation. Sediment yield estimation is an important parameter in the evaluation of permitted mineral extraction in optimal quantities.

Annual sediment replenishment studies of Doodhganga and Shaliganga watersheds were carried out for the updation of District Survey Report. The data collected in the field was analysed in Geographical Information System software (ArcGIS 10.8) for generation of different maps. The monthly precipitation data of last ten years and monthly discharge data from Jan-2016 to Dec-2021 of both the streams was collected for this study. Geoprocessing techniques in GIS were used for morphometric analysis of Shalinganga watershed and Doodhganga watershed to evaluate the value of different morphometric parameters and hydrological features. Similarly, land use land cover classification maps of both watersheds were generated from multi-spectral satellite imageries of various datasets.

The quantified parameters were utilised for estimation of annual mean sediment yield by using Garde & Kothyari method. The mean annual sediment yield of Doodhganga watershed stands to the tune of about 4.3 lac tonnes while that of Shaliganga watershed stands to the tune of about 3.1 lac tonnes.

O/C Investigation

Sarfraz Shaban
(G/A)

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