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Ministry of Water Resources

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Central Ground Water Board

GROUND WATER BROCHURE,
DISTRICT TEHRI GARHWAL, UTTARAKHAND

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Uttaranchal Region

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June 2011

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Dehradun

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DISTRICT GROUND WATER BROCHURE OF TEHRI GARHWAL DISTRICT, UTTARAKHAND

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DISTRICT TEHRI GARHWAL AT A GLANCE

1. GENERAL INFORMATION	
1.1 Geographical area	3796 km^2
1.2 Administrative Divisions	
District Headquarter	New Tehri
Number of Tehsil	5
Number of Blocks	9
Number of Villages	1836
Number of Villages (Inhabited)	1768
Number of Nyay Panchayats	76
Number of Gram Panchayats	928
Number of Nagar Panchayats	4
Number of Municipalities	2
1.3 Population (Census, 2001)	
Total population	604750
Male population	295170
Female population	309580
Population density	159 per km^2
Population of Scheduled Caste	87320
Population of Scheduled Tribe	690
1.4 Climate	
Normal Rainfall	1706.8 mm
Average Annual Rainfall	1395 mm
Average number of Rainy Days (Daily Rainfall $\geq$ 2.5 mm)	61.5
Mean Minimum Temperature	14.8°C
Mean Maximum Temperature	29.3°C
Average Relative Humidity	60.5%
Average Wind Speed	2.3 km/hr
2. GEOMORPHOLOGY	

Major physiographic units	Lesser Himalayan Zone and Central Himalayan Zone
Major Drainage	Bhagirathi, Bhilangana and Alaknanda Rivers

3. LAND USE

(a) Forest area	3220.51 km^2
(b) Net Sown area	562.06 km^2
(c) Gross Sown area	884.61 km^2
(d) Area sown more than once	322.55 km^2

4. MAJOR SOIL TYPES:

1. Soils of Lesser Himalaya: (a) Dystric Eutrudepts, (b) Lithic Udorthents and (c) Typic Udorthents.
2. Soils of Central or Higher Himalaya.

5. AREA UNDER PRINCIPAL CROPS

5.1 Rabi	32258 ha
5.2 Kharif	56203 ha
5.3 Total	88461 ha

6. IRRIGATION BY DIFFERENT SOURCES

6.1 Net Irrigated Area	7913 ha
6.2 Gross Irrigated Area	15058 ha
6.3 No. of Dug Wells	Nil
6.4 No. of Government Tube Wells	Nil
6.5 No. of Hauj	3119
6.6 No. of Hydrums	153
6.8 No. of Private Tube Wells and Pump Sets	19
6.9 Total length of Canals	675 km
6.10 Area under Canal Irrigation	4182 ha
6.11 Total length of Guls	4087.591 km
6.12 Area under Surface Water Irrigation	29741.95 ha
6.13 Area under Ground Water Irrigation	Nil

7. NUMBER OF GROUND WATER MONITORING WELLS OF CGWB

7.1 Number of Dug Wells	Nil
7.2 Number of Piezometers	Nil

8. PREDOMINANT GEOLOGICAL FORMATIONS: Central Crystallines, Bhilangana Formation, Rautgarha Formation, Bijni Formation, Jaunsar Group, Blaini-Krol Group, Tal Group, Granitoids of Kedarnath and Basic volcanic of Garhwal Group (after Geological Survey of India)

9. HYDROGEOLOGY

9.1 Fissured Formation of Lesser Himalaya (comprising shale, quartzite, slate, phyllite, sandstone, limestone, dolomite) – 1. Local or Discontinuous Aquifers: Transmissivity – Not Available, Yield – Low (1 to 5 LPS) and 2. Localised Aquifers: Transmissivity – Not Available, Yield – Very Low (<1LPS)

9.2 Fissured Formation of Central or Higher Himalaya (Central Crystallines comprising gneiss, schist, migmatite, amphibolite, quartzite and granites of various ages) – Localised Aquifers: Transmissivity – Not Available, Yield – Very Low (<1 LPS)

10. GROUND WATER QUALITY

10.1 Presence of Chemical Constituents more than the Maximum Permissible Limits of BIS: EC – 2720 µS/cm at 25°C from Kaddukhal Gadhera, Fluoride – not reported, Arsenic – not reported, Iron – not analysed.
10.2 Type of ground water: Suitable for drinking and domestic use, no contamination in ground water samples from hand pumps, springs and gadheras reported.

11. WATER AVAILABILITY AND GROUND WATER POTENTIAL

11.1 Number of Villages Fully Covered for Drinking Water Supply by India Mark-II Hand Pumps	1766
11.2 Total Population benefited by Water Supply through India Mark-II Hand Pumps	543843
11.3 Annual Ground water Resource by RIF Method	NA

12. MASS AWARENESS AND TRAINING ACTIVITY

12.1 Number of Mass Awareness Programmes organized	Nil
12.1 Number of Water Management Training Programmes organized	Nil

13. EFFORTS OF ARTIFICIAL RECHARGE AND RAINWATER HARVESTING

13.1 Projects completed by CGWB	Nil
13.2 Projects under technical guidance of CGWB	Nil

14. GROUND WATER CONTROL AND REGULATION

14.1 Number of Over Exploited Blocks	Nil
14.2 Number of Critical Blocks	Nil
14.3 Number of Blocks Notified	Nil

1. INTRODUCTION

Tehri Garhwal is one of the mountainous districts of Uttarakhand State. The district was included in Uttarakhand after the state was carved out of Uttar Pradesh on 9th November 2000. Re-organisation of the district took place subsequently when Jakholi block of the district was included in the neighbouring Rudraprayag district. The district lies between latitudes 30º03' and 30º53' N and longitudes 77º56' and 79º04' E. The district falls in Survey of India toposheet nos. 53J and 53N. The district is bounded by Uttarkashi district in the north, Rudraprayag district in the east, Pauri Garhwal district in the south and Dehradun district in the west. The geographical area of the district is 3796 km^2.

1.1 Accessibility The district is well connected with Dehradun, the capital of Uttarakhand, by a network of metalled roads namely Rishikesh-Devprayag road (NH-58) and also Narendranagar-Chamba-Tehri-Ghanshali road. New Tehri Town, the present district headquarter, has been shifted from the erstwhile district headquarter, Old Tehri, after the construction of Tehri Dam (sprawling over an area of 45 km^2), the tallest dam of Asia and the fourth tallest earth and rock fill dam in the world. New Tehri is well connected with Dehradun (139 km), Old Tehri (16 km) and Rishikesh (84 km). The total length of motorable roads in the district is 1824 km. Uttarakhand Transport Corporation Limited provides bus service to important places in the district. The nearest airport for New Tehri is Jolly Grant (93 km) whereas the nearest railway station is Rishikesh (76 km).

1.2 Administrative Details For the administrative convenience Tehri Garhwal district, a part of Garhwal Division, has been divided into five tehsils viz. Pratapnagar, Tehri, Narendranagar, Ghanshali and Devprayag and nine Developmental Blocks viz. Pratapnagar, Bhilangana, Jakhnidhar, Jaunpur, Thouldhar, Chamba, Narendranagar, Devprayag and Kirtinagar. There are 1836 villages, out of which 1768 villages are inhabited, 42 villages are uninhabited and the rest 26 are categorised as forest villages. According to Census, 2001 there is one Census Town (New Tehri). There are 928 Gram Panchayats, 76 Nyay Panchayats, 4 Nagar Panchayats, 2 Municipal Boards and 6 Police Stations in the district. The Base Map of Tehri Garhwal district is shown in ***Fig. 1.***

1.3 Land Use The salient land use features of Tehri Garhwal district are given below:

Forest Area	322051 ha
Land under Cultivation	88461 ha
Cultivable Barren Land	5681 ha
Total Fallow Land	15707 ha
Barren and Non-cultivable Land	5844 ha
Land under Non-agricultural Use	78366 ha
Pasture and Other Grazing Land	539 ha

Land under Gardens, Bushes, Groves etc.	1372 ha

The area wise break up of land use pattern is represented as a pie chart ***(Fig. 2)***. A study of the figure reveals that majority of the district (62%) is under forest cover followed by land under cultivation (17%) and land under non-agricultural use (15%). Together these three land use categories account for 94% of the total area. The cultivable barren land, total fallow land (current fallow and other fallow), pasture and other grazing land and land under gardens, bushes, groves etc. account for only 5%, which indicate that apart from the forest cover, remaining areas are primarily utilised for agricultural use.

1.4 Agriculture Agriculture is the main occupation of the people. However, intensive cultivation is not possible as major part of the district is mountainous. Agricultural activities are common on gentle hill slopes and in relatively plain, broad river valleys of Bhagirathi, Bhilangana and Alaknanda basins. Rice, wheat, mandua, barley, maize and sawan are the principal crops grown in the district. The salient features of agricultural statistics in the district are given below:

Gross sown area	88461 ha
Area sown under Rabi Crops	32258 ha
Area sown under Kharif Crops	56203 ha
Net sown area	56206 ha
Percentage of gross sown area against net sown area (Cropping Intensity)	157.39%
Area sown more than once	32255 ha
Production of food grains	117970 Mt

Wheat is the major crop grown in 26962 ha (47.97% of the net sown area) followed by sawan (17488 ha), mandua (14630 ha) and rice (12642 ha). Apart from this, other important crops sown in the district are barley (2620 ha), maize (1641 ha) and urad dal (1524 ha).

1.5 Irrigation Major sources to develop irrigation potential are the perennial rivers flowing in the district like Bhagirathi, Bhilangana and Alaknanda. However, main means of irrigation in the district is the irrigational canals through which 4182 ha is irrigated. The salient features of irrigational statistics in the district are as given under:

Gross Irrigated Area	15058 ha
Net Irrigated Area	7913 ha
Percentage of Gross Irrigated Area to Net Irrigated Area (Irrigation Intensity)	190.29%
Length of Canals	675 km
Actual Irrigated Area through Canals	4182 ha
Length of Guls	4087.591 km
Irrigation potential created through Gul Irrigation	24525.55 ha

Number of Hydrums	153
Irrigation potential created through Hydrum Irrigation	918 ha
Number of Tanks (Hauj)	3119
Irrigation potential created through Tank (Hauj) Irrigation	3119 ha
Number of Boring Pump Sets	15
Irrigation potential created through Boring Pump Sets	75 ha
Number of Private Tubewells	4
Irrigation potential created through Private Tubewells	48 ha
Total area irrigated under surface water irrigation	29741.95 ha
Total area irrigated under ground water irrigation	Nil

Irrigation through canals, guls, hydrums, tanks (hauj) etc. is practised widely for growing both Rabi and Kharif crops. The relevant data obtained from the Minor Irrigation Department and District Statistical Diary on Tehri Garhwal district is summarized above. The high irrigation intensity is a result of surface water irrigation (surface flow schemes like guls and surface lift schemes like hydrums) in some parts of the district. However, there are many areas where irrigation potential of surface water is very low or virtually absent. In such areas ground water irrigation potential needs to be created after conducting feasibility studies. The conjunctive use of surface and ground water will greatly enhance the irrigation potential existing presently in the district.

1.6 Drainage Drainage of the area is mainly controlled by the major perennial rivers like Bhagirathi, Bhilangana, Alaknanda and their tributaries like Bal Ganga and Dharma Ganga. Bhagirathi River flows from north to south and meets Alaknanda River at Devprayag. Bhilangana River flows from north east to south west and meets Bhagirathi River near Old Tehri. Bhagirathi and Bhilangana Rivers drain the central part of the district while Alaknanda River flows in the southernmost part close to the district boundary. Apart from the major rivers, many seasonal streams and rivulets (locally called gad and gadhera) drain the area. Important among them are Nailchami Gad, Lastar Gad, Nagun Gad, Bhadri Gad, Chandrabhaga Gad, Bandal Nadi etc. Sub-trellis and sub-dendritic are the most common drainage patterns in the area. The perennial rivers are primarily fed by snowmelt with relatively smaller contribution from ground water. However, during the lean period, the rivers are fed by ground water occurring as base flow. The drainage map of the district is given as ***Fig. 3***.

1.7 Previous Work Systematic hydrogeological investigations were carried out by the officers of Central Ground Water Board from time to time. Sh. S. A. H. Jaffery and Sh. P. N. Singh carried out hydrogeological surveys during the AAP 1983-84. The studies were continued during the AAP 1984-85 by Dr. A. N. Lal. Later, an area of 4421 km^2 was covered by Sh. G. D. Barthwal during the AAP 2002-2003 when thirty eight cold water springs and group of springs (gadheras), two surface streams and 14 India Mark-II hand pumps were inventoried.

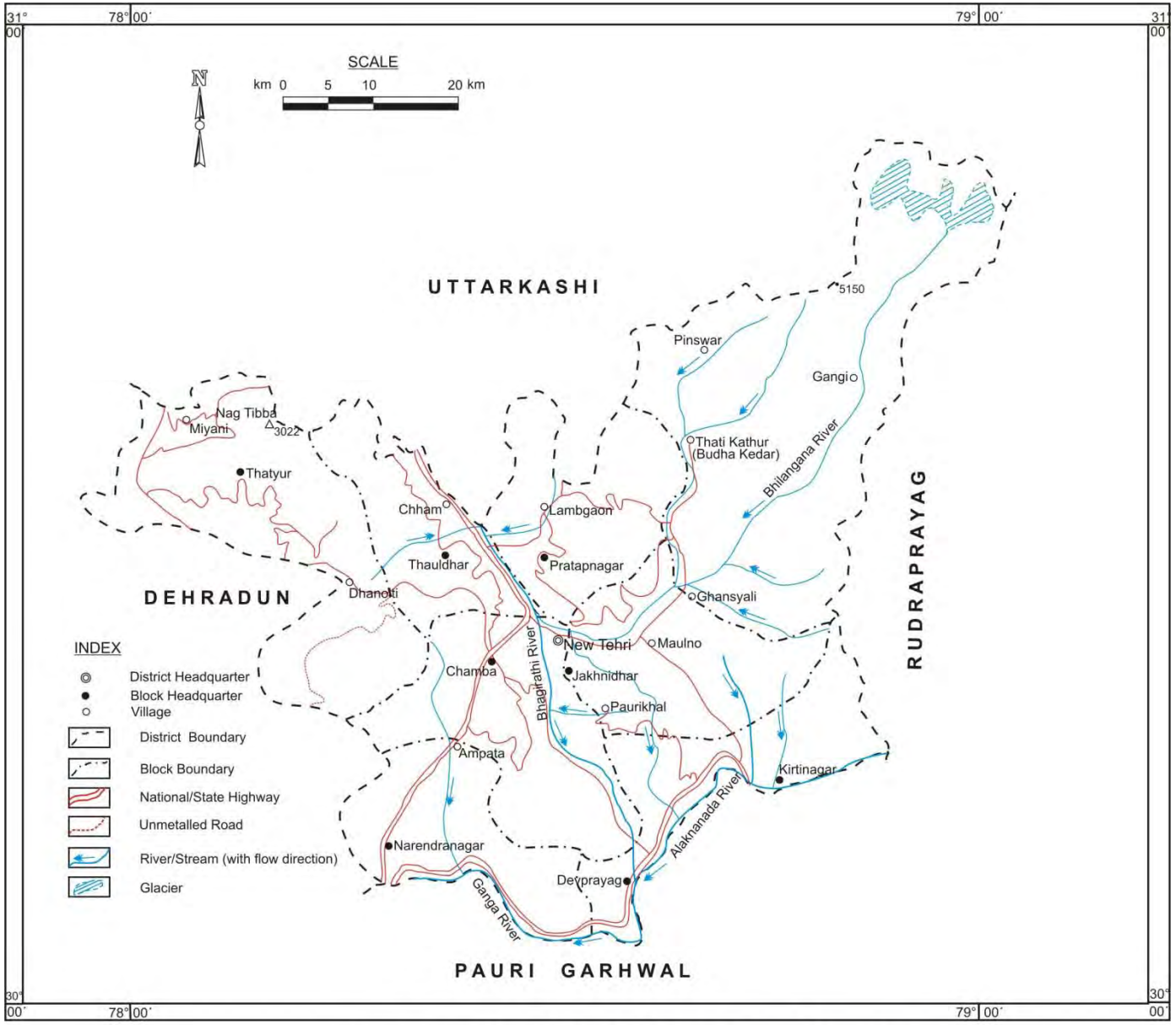

Fig. 1. Base Map of District Tehri Garhwal, Uttarakhand

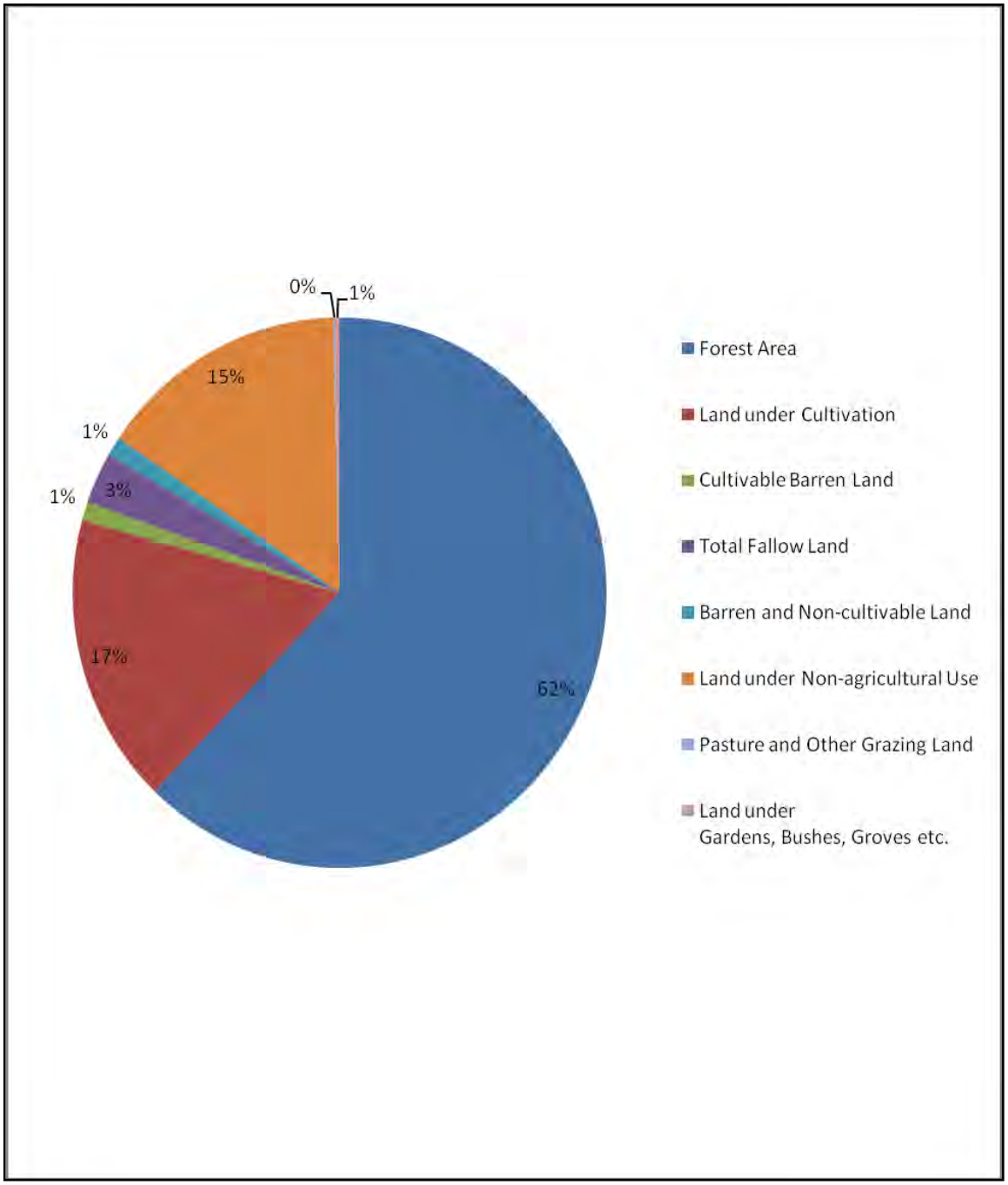

Fig. 2. Land use map, District Tehri Garhwal, Uttarakhand

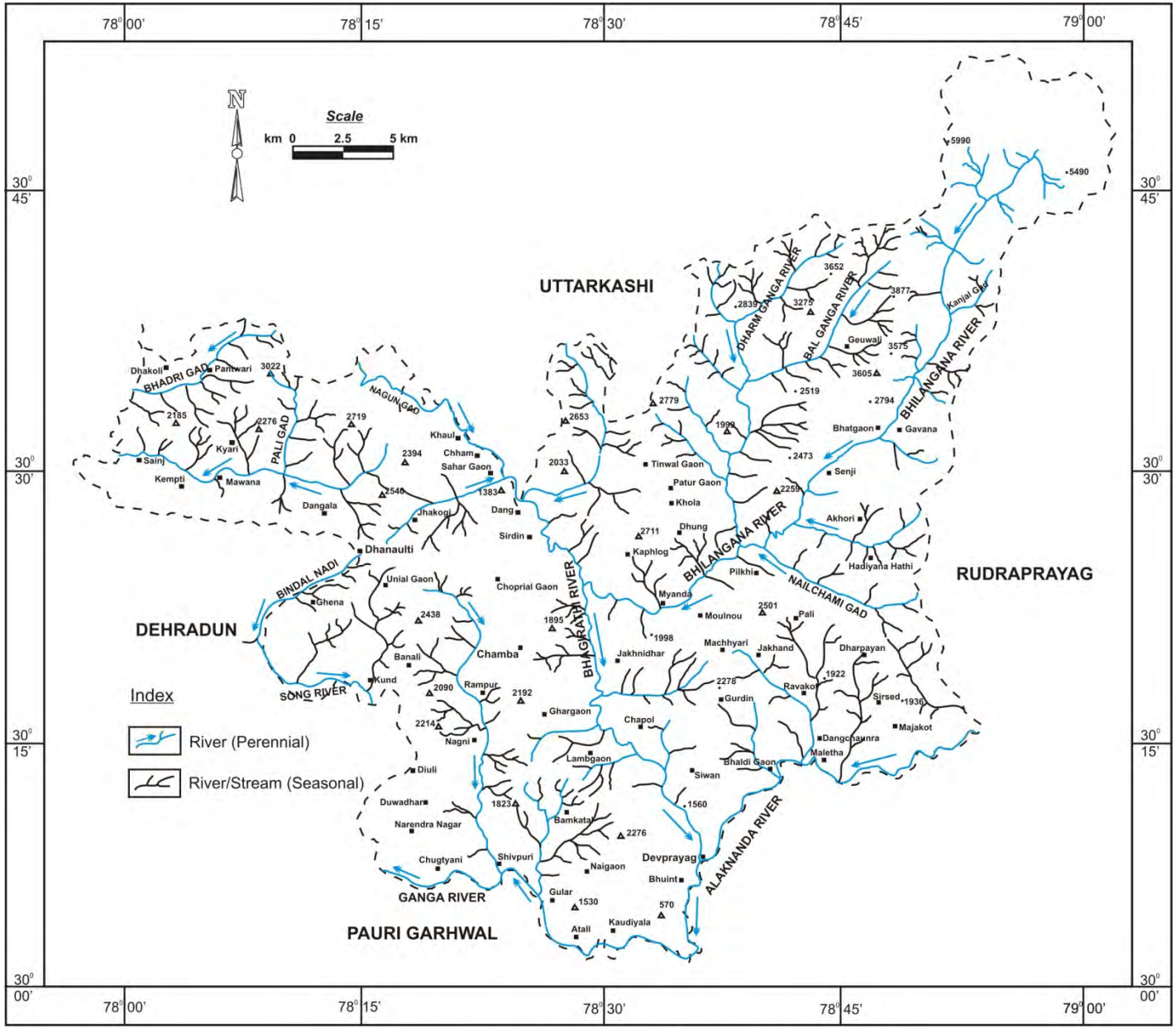

Fig. 3. Drainage Map of District Tehri Garhwal, Uttarakhand

2. RAINFALL AND CLIMATE

The climate in Tehri Garhwal district varies from cold temperate, tropical to sub-tropical. The northern and north western parts of the district experiences sub-zero temperature during the winter whereas the central and southern parts are comparatively warm and humid. In the southern part, at Narendranagar and west of New Tehri (e.g. Chamba, Dhanolti and Surkanda Devi), the weather is very cold in winter and pleasant in summer. Snowfall is quite common during the winter in these areas. Other parts of the district experience dry, hot summer and cold winter.

2.1 Temperature, Relative Humidity and Wind Based on long-term climatological data of the district, it is surmised that January is the coldest month with mean maximum temperature of 19.6°C and the mean minimum temperature of 4.6°C. Temperature becomes highest usually during June, having mean minimum and mean maximum temperatures of 32.6°C and 36.5°C respectively. Relative Humidity in the area increases rapidly with the onset of monsoon and reaches maximum (85% in the morning and 84% in the evening) during August, when peak monsoon period sets in. Relative Humidity is minimum during the summer months (from April to June) with May being the driest month (47% in morning and 25% in evening). Skies are heavily clouded during the monsoon months and for short spells when the district is affected by Western Disturbances. Two broad wind patterns are observed in the district viz. north easterly to easterly (May to September) and south easterly to westerly (October to March). The average wind speed is minimum (0.8 km/hr) in December and maximum in July (4.1 km/hr) whereas the average annual wind speed is 2.3 km/hr.

2.2 Rainfall Rainfall, in the district, occurs almost throughout the year. Maximum rainfall is recorded during the monsoon period i.e. from July to September. During the non-monsoon season, rainfall is quite low in November and increases from December onward till March. Winter precipitation is associated with the passage of the Western Disturbances and is in the form of snowfall on higher elevations. The monthly and annual rainfall in Tehri Garhwal district is quite variable and ranges between 956 mm and 2449 mm at Narendranagar. The annual rainfall at Tehri Observatory is 1028.6 mm whereas the average number of rainy days (having daily rainfall ≥2.5 mm) is 61.5 days. The annual rainfall at Mukhim Observatory is 1708.8 mm and the average number of rainy days is 87.4 days. The average annual rainfall (AAR) of the district is 1395 mm.

3. GEOMORPHOLOGY AND SOIL TYPES

Tehri Garhwal district comprises two broad physiographic divisions viz. Central Himalayan Zone (north of the Main Central Thrust) exposed in the north eastern part and Lesser Himalayan Zone (south of the Main Central Thrust) in rest of the area. The physiography of the district is characterised by high mountain peaks, deep gorges and valleys. Major part of the area is inaccessible due to extremely rugged topography and dense forest cover.

The altitude varies from 369 to 6672 m. The regional trend of major ridges is NNW-SSE, which is usually parallel to the strike of the country rocks. However, E-W, NW-SE and N-S trending ridges are also observed which are mainly structurally controlled.

The soils of Tehri Garhwal district can be broadly classified into two types, viz. soils of Central/Higher Himalaya and soils of Lesser Himalaya. The soils of Central Himalaya have been broadly classified under a) Soils of Summits, Ridge Tops and Mountain Glaciers, b) Soils of Side Slopes, c) Soils of Upper Glacio-Fluvial Valleys and d) Soils of Cliffs. Major part of the district is covered by soils of Lesser Himalaya, which may be broadly subdivided into three soil types. Soils of the first type are moderately shallow, excessively drained, thermic, fine loamy, moderately eroded and slightly stony and are known as Dystric Eutrudepts. The second type, Lithic Udorthents, is characterised by very shallow, excessively drained, severely eroded and strongly stony, thermic loamy soils exposed on steep slopes with loamy and sandy surface. Typic Udorthents, the third major soil type, is moderately shallow, excessively drained, moderately eroded and slightly stony, loamy soils on moderate slopes with loamy surface.

4. GEOLOGY

District Tehri Garhwal is represented by the rocks of Lesser Himalaya and Central Himalaya. The geological set up is very complex due to the repeated tectonic disturbances caused by different orogenic cycles. Valdiya (1980) carried out extensive geological and structural mapping in the area. The salient features of geology are depicted in the geological map of Tehri Garhwal district ***(Fig. 4).*** The map is based on Geological Survey of India, 2002.

The rock units exposed in various parts of Tehri Garhwal district are exposed in two broad geotectonic zones viz. Central or Higher Himalaya and Lesser Himalaya. The Central Himalaya lies to the north of Main Central Thrust (MCT) whereas the Lesser Himalaya occurs to the south of it. A group of regionally metamorphosed rocks known as Central Crystallines are exposed in the Central Himalaya. The Central Crystallines occur as thrust sheets over the metasedimentary and sedimentary rocks of Lesser Himalaya in varied tectonic settings. Major rock types of Central Crystallines are migmatites, psammitic and mica gneiss, calc gneiss, quartzite, marble, mica schist and amphibolite. Granites of different ages ranging from Paleoproterozoic to Mesozoic-Tertiary intrude the Central Crystallines. The Lesser Himalaya occupies major part of the district and comprises of different groups like Jaunsar Group, Blaini-Krol Group and Tal Group. The groups are subdivided into various formations like Bhilangana Formation, Rautgara Formation, Bijni Formation. A suite of granitic intrusives known as Granitoids of Kedarnath and basic volcanics of Garhwal Group are also exposed in parts of the district. Generally, the rocks of the Lesser Himalayan Zone show signs of multiple phases of deformation and metamorphism.

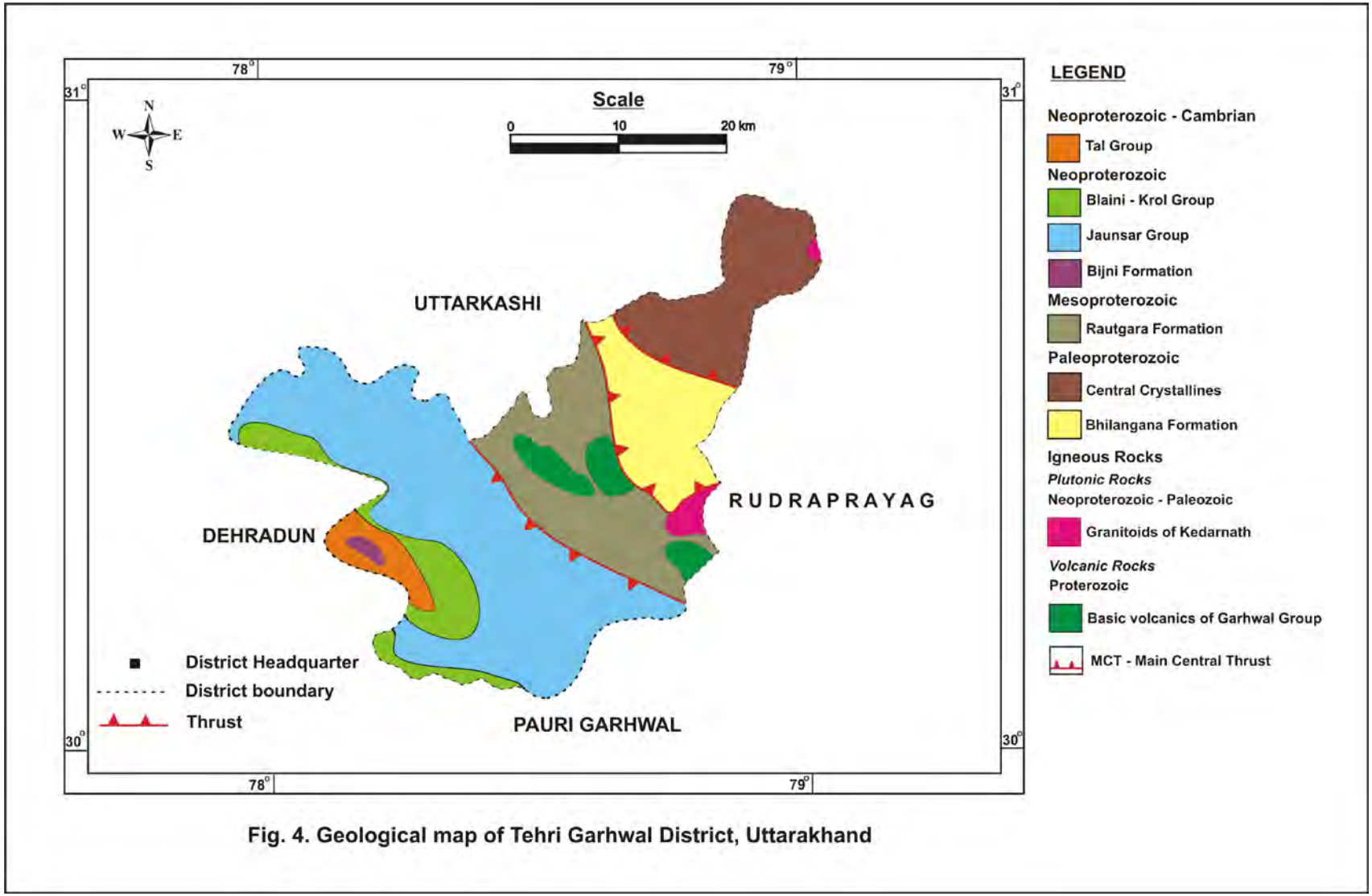

Fig. 4. Geological map of Tehri Garhwal District, Uttarakhand

GROUND WATER SCENARIO

5.1 HYDROGEOLOGY

Ground water, in Tehri Garhwal district, generally occurs locally within disconnected bodies under favourable geohydrological conditions such as in channel and alluvial terraces of river valleys, joints, fractures and fissures of crystalline and metasedimentary rocks, well vegetated and relatively plain areas of valley portions and in subterranean caverns of limestone and dolomitic limestone country rocks. The occurrence and movement of ground water depend not only on the nature of the litho units and the nature of the interspaces/ interstices, but also on the degree of interconnection between them, the vertical and aerial extension of joints, faults and/or shear zones and the local and regional geomorphology. Ground water emerges as springs and seepage (locally called Srots and Naolas) under favourable physiographic conditions such as in gently sloping areas, broad valleys of rivers and along the lithological contacts. Gadheras are the group of springs coming from higher reaches of the mountainous tracts.

Rainfall is the principal source of ground water replenishment. A part of the precipitation received (either as rainfall or snowfall) is lost into the atmosphere as evaporation and evapotranspiration from soils and plants, another considerable part flows as surface run off due to extremely rugged and undulating topography with steep slope and the remaining part directly infiltrates through the soil profile to form the ground water storage in joints, fractures, fissures etc. In Tehri Garhwal district, ground water flows out as springs and seepages where the water table intersects the ground surface. Based on the observations of various workers of Central Ground Water Board over the last couple of decades, a hydrogeological map of Tehri Garhwal district is prepared ***(Fig. 5).*** A study of this map indicates the general hydrogeological scenario of the district and reveals the presence of two main types of aquifers viz. a) Local or Discontinuous Aquifers and b) Localised Aquifers. Ground water in the district occurs in fissured formations characterised by secondary porosity. A brief description of the main types of aquifers is given below:

5.1.1 Local or Discontinuous Aquifers: These aquifers occur within the Lesser Himalayan Zone and are seen as two patches exposed in the south western/southern and east central/central parts of the district. Ground water in these areas occurs generally under unconfined to semi-confined conditions in the sedimentary rocks (sandstone, shale and limestone), metasedimentary and low-grade metamorphic rocks like dolomite, slate, phyllite, quartzite etc. Calcareous rocks like limestone and dolomite host ground water in solution cavities and subsurface channels of limited areal extent. Aquifer characteristics are not available in this area, as no pumping test has been carried out so far. However, a study of the springs and naolas indicates that in general, the yield is low and varies from 1 to 5 litre per second (LPS).

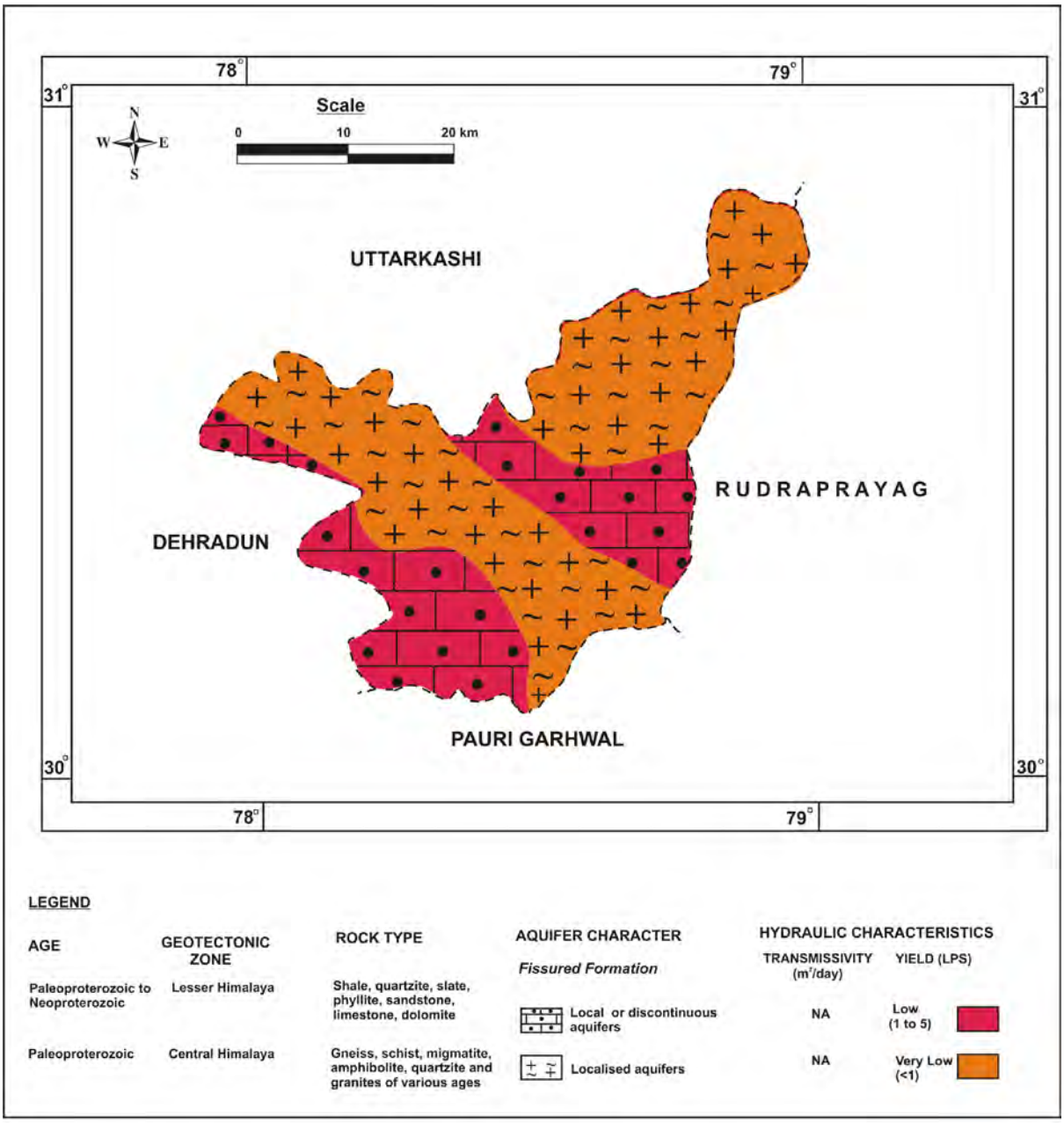

Fig. 5. Hydrogeological map of District Tehri Garhwal, Uttarakhand

5.1.2 Localised Aquifers: Localised aquifers occur in both the Lesser Himalayan and the Central Himalayan Zones. In the Lesser Himalayan Zone, these aquifers are exposed as a NW-SE trending patch occupying the western, central and south eastern parts of the district. In the Central Himalayan Zone north of the Main Central Thrust, these aquifers constitute the only source of potable water. Occurrence of ground water in localised aquifers is very restricted because of the nature of hard, crystalline rocks. Compact and massive crystalline igneous rocks (granite, granodiorite etc.) and medium to high-grade metamorphic rocks (gneiss, amphibolite, quartzite etc.) contain very little ground water in the secondary porosity of fractures, joints and fissures of limited vertical and areal extent. Study of a few spring

shows that, as expected, yield of localised aquifers is very low, i.e. even less than 1 LPS.

5.1.3 Study on Springs: A total of 48 cold water springs and 6 group of springs (gadheras) were inventoried in Tehri Garhwal district by Central Ground Water Board. Besides these, measurement of discharge and water temperature of two streams was also carried out during the systematic studies. A brief description of the springs and gadheras occurring in different rock types is given below:

(a) Phyllite: A total of 22 springs and gadheras were inventoried. The discharge data available shows that the maximum pre-monsoon discharge was 56 litre per minute (LPM) at Badkot (pre-monsoon, 2002) whereas the minimum discharge of 0.71 LPM was recorded at Malupani (pre-monsoon, 2010). During the post-monsoon the maximum discharge of 57.36 LPM was observed at Malupani while the minimum discharge of 1.32 LPM was observed at Nand Gaon (post-monsoon, 2010). The discharge of gadheras was considerably higher than individual springs. The maximum discharge in gadheras was ~700 LPM at Syansu followed by ~150 LPM at Budgi Khala (pre-monsoon, 2002). The pre-monsoon water temperature ranges between 21°C and 24°C while during the post-monsoon period, water temperature ranges from 7.0°C to 27.0°C.

(b) Limestone and Dolomite: 9 cold water springs and gadheras were inventoried by CGWB in this rock type. The minimum discharge during pre-monsoon is as low as negligible (<0.001 LPS) at Nagni followed by 1.39 LPM near Yamuna Bridge (pre-monsoon, 2010). During the post-monsoon, spring discharge varies from 4.92 LPM at Kauriyala to a maximum of 60 LPM near Chaudana (period: 2010). Very high discharge (both during pre-monsoon and post-monsoon) is recorded in the gadheras. The pre-monsoon discharge in gadheras is 800 LPM at Neergarh and 600 LPM near Dhaulagiri. Free flow (Artesian) conditions are also observed at Dhaudapani, where a discharge of 140 LPM has been recorded. Similar condition has been also observed around Nagni. The pre-monsoon water temperature of springs/gadheras varies from 19.0°C to 29.5°C while the post-monsoon water temperature varies from 7.5°C to 30.0°C at Neergarh.

(c) Quartzite: A total of 29 springs/gadheras were inventoried. The discharge of springs/gadheras in quartzite, which is a metamorphic rock of medium to high grade, is comparatively lower than the discharge in other rock types. The minimum pre-monsoon discharge of 0.19 LPM is seen at Muneth while the maximum discharge is 54.5 LPM at Silasu Bridge (period: 2010). During post-monsoon the discharge varies from 0.41 LPM near Aindi to a maximum of 100 LPM near Phakot (period: 2010). The water temperature during pre-monsoon period varies from 13.0°C to 35.5°C while during the post-monsoon, water temperature ranges from 2.5°C to 27.0°C.

5.1.4 Study on Hand Pumps: Apart from the springs and gadheras, 71 India Mark-II hand pumps, installed by Uttarakhand Jal Sansthan, Garhwal Division were also inventoried during Ground Water Management Studies in the AAP: 2010-2011. The depth to water level, both during pre-monsoon and post-

monsoon, was also recorded during the Ground Water Management Studies in District Tehri Garhwal.

The depth to water level data has indicated that water level ranges from 0.62 m bgl at Dhaudapani to a maximum of 70.07 m bgl at Arakot (period: pre-monsoon, 2010). During the post-monsoon monitoring, the minimum depth to water level is 0.90 m bgl at Dhaudapani while the deepest water level is 63.38 m bgl, again found at Arakot. Water level fluctuation (rise or fall) has been calculated from the pre-monsoon and post-monsoon depth to water level data of the hand pumps. Analysis of water level fluctuation indicates that minimum rise of 0.47 m is found at Chaudana whereas maximum rise of 38.75 m is observed near Motna, close to Tehri Reservoir. Decline in water level in hand pumps ranges from a minimum of 0.01 m at Durgapur to a maximum of 26.42 m near Jakhnidhar (period: 2010-11).

Discharge in the hand pumps varies from a minimum of 14 LPM at Saurjaripan and Kunjapuri to a maximum of 24 LPM at New Tehri, the district headquarter (Source: Uttarakhand Jal Sansthan, New Tehri). During the drilling of a hand pump at Dhaudapani, about 3.5 km from Narendra Nagar, artesian flow was encountered in the bore well at a depth of 90.0 m bgl with a discharge of 140 LPM (period: pre-monsoon, 2002). Water temperature in hand pumps during pre-monsoon survey varies from 8.0°C to 37.0°C while during post-monsoon, water temperature ranges from 4.5°C to 32.0°C (period: 2010-2011).

Hand pumps are extensively used by the local people for drinking and domestic works and are rapidly replacing traditional sources of water supply like springs and gadheras in the district. Almost all of them are installed along the motorable roads, thereby making them easily accessible. A total of 1766 villages were fully covered through water supply from all the India Mark-II hand pumps, thereby benefiting a total population of 543843 (Source: District Statistical Diary, 2007).

5.2 GROUND WATER RESOURCES

Ground water is an important source of water supply in an area. However, due to hilly tracts, its utilisation in a major part of Tehri Garhwal district is much less than the desired level. Besides, the complex hydrogeological set-up coupled with lack of hydrogeological database hampers precise estimation of ground water resource potential and its development in the district. Hence, no figure on estimation of annual ground water recharge as per the standard norms of Ground water Estimation Committee (GEC, 1997) is available for Tehri Garhwal district.

5.3 GROUND WATER QUALITY

To assess the chemical quality of ground water in Tehri Garhwal district, 37 water samples were collected from springs, gadheras and India Mark-II hand pumps. A perusal of hydrochemical data shows that ground water in Tehri Garhwal district is mildly alkaline having pH varying from 8.0 to

8.2. The pH values are within permissible limit as per the guidelines of the Bureau of Indian Standards (BIS, 1991).

The electrical conductivity varies generally between 91 µS/cm (at 25ºC) and <800 µS/cm except at Neergad (1150 µS/cm) and Kaddukhal Gadhera (2720 µS/cm), which is possibly due to higher degree of mineralisation imparted by the rocks of Krol Formation. Concentration of bicarbonate varies from 85 to 409 mg/L. Concentration of chloride varies between 7.1 and 21 mg/L. Nitrate concentration in ground water of the district varies from 0.14 to 22 mg/L, which indicates that ground water is free from anthropogenic sources of pollution. Concentration of sulphate varies from 4.8 to 557 mg/L, except at Kaddukhal Gadhera where a very high concentration of 1465 mg/L is observed. This is possibly due to higher mineralisation of ground water in the area. Concentration of calcium in Tehri Garhwal district varies between 8 and 325 mg/L while concentration of magnesium varies from 4.9 to 212 mg/L. Sodium concentration in ground water varies from 1.6 to 44 mg/L whereas potassium concentration varies between 0.3 and 3.7 mg/L. The Total Hardness as $CaCO_3$ varies from 50 to 1681 mg/L. In general, the values of Total Hardness are low to moderately high thereby indicating that ground water is suitable for drinking and domestic uses. Concentration of fluoride in ground water of Tehri Garhwal district is generally well below the acceptable limit of 1.0 mg/L (BIS, IS: 10500, Second Revision, 2003). It varies from 0.02 mg/L in a spring at Kemri Khala to a maximum of 0.75 mg/L in a spring at Narendra Nagar. Hence, ground water is safe as far as fluoride concentration is concerned. Concentration of silica in ground water varies between 11 and 25 mg/L indicating the absence of highly acidic source rocks (aquifer material) in the area.

From the concentrations of different inorganic constituents in ground water in Tehri Garhwal district, it is concluded that the quality of ground water is excellent and it is suitable for drinking, domestic and irrigational purposes.

6. GROUND WATER MANAGEMENT STRATEGY

6.1 GROUND WATER DEVELOPMENT

Taking into consideration the extremely rugged topography in major parts of the district, it is not feasible to go for a large-scale ground water development. However, small to medium scale development may be planned and materialised in a systematic manner.

In the northern part of the district, which is covered with snow almost throughout the year, the possibility of ground water development is nil. However, remaining areas of the district show moderate to good scope for ground water development. As most of the springs in the area are of gravitational type, they should be tapped at the higher reaches of mountains and subsequently collected in multi-stage hauzes (surface tanks) and bund systems. The water thus tapped should be supplied by gravity flow through parallel pipe lines to different villages depending on the discharge.

Ground water development for irrigational use is almost nil in the district. However, surface lift schemes like Hydrums systems may become successful for irrigational purpose, especially in the lower reaches of mountains, near *Nal*as and small rivers/streams. Group of springs (Gadheras) having high discharge may be tapped at higher elevations of the hills by making Guls (surface flow schemes) and small canals for supply of water round the year. Hand pumps may be installed along roads by locating sites on prominent lineaments and structurally weak zones as ground water in such terrain occurs in joints and fractures.

Hydrogeological investigations regarding feasibility for constructing tube wells in the district were carried out in Chauras area (for Uttarakhand Jal Sansthan) and at Kaudiyala (for Kotlibhel Hydroelectric Project of NHPC Limited). The studies revealed that drilling in these areas can be carried out by deploying a DTH rig (preferably with ODEX attachment) down to a depth range of 50-70 m and 203 mm (8 inch) diameter pipe assembly may be lowered for construction of tube wells. The depth to water levels is usually between 5 to 6 m bgl. Expected discharge of tube well in Chauras is around 800 to 1000 LPM whereas in Kaudiyala, tube wells having drilled depth of 40 to 50 m would yield around 250 to 300 LPM. Thickness of unconsolidated sediments, deposited by Alaknanda River in Chauras varies from 15-20 m. These sediments show good porosity and permeability and form potential aquifers. The contact between the unconsolidated sediments and the underlying rocks of Jaunsar Group (Chandpur phyllites) also has good ground water potential.

Apart from this, limestone and dolomite of Mussoorie Group may also become promising for construction of tube wells after proper hydrogeological surveys and ground water exploration in selected areas.

6.2 WATER CONSERVATION AND ARTIFICIAL RECHARGE

Due to the high Average Annual Rainfall in Tehri Garhwal district, there is good scope of water conservation through Roof Top Rainwater Harvesting. Due to high land slope in major part of the district, a significant amount of rainfall goes waste as immediate surface run off or overland flow, resulting in very less percolation to shallow aquifers. In such areas construction of suitable water conservation structures is required. Gully plugs and contour bunds are quite suitable for this purpose as they arrest surface run off, increase soil moisture, recharge the shallow aquifers, help in preventing soil erosion and increase the discharge of nearby springs and naolas. Construction of small check dams, nala bunds and continuous contour trenches depending on the local topographic and hydrologic conditions can be taken up in project mode. Continuous contour trenches would cover the entire slopes uniformly whereas nala bunds constructed in a series would cover the entire stretch of drainage in the hilly tracts. The local populace should be adequately trained through training and mass awareness programmes on artificial recharge and roof top rain water harvesting at feasible areas.

7. GROUND WATER RELATED ISSUES AND PROBLEMS

As far as the overall hydrogeological scenario of Tehri Garhwal district is concerned, there are no significant problems. However, some local problems encountered in the district and their possible remedies are listed below:

1. Poor quality of ground water in some naolas. This may be due to misuse and/or disuse of the structures. This problem may be tackled by development and renovation of the structures, cleaning of dirt and other garbage (frequently dumped in and around naolas) and periodic maintenance, either by the gram panchayat or by the state agencies and non-government organizations under self help programmes. Local people need to be trained by the district authorities and state/central government departments so that they can understand the importance of naola-based drinking water supply.

2. Higher concentration of some inorganic constituents like calcium, magnesium, sulphate and the total hardness (as $CaCO_3$) are observed, particularly in gadheras. However, this is attributed to high degree of mineralisation of Krol Formation and is therefore, geogenic.

3. There is scarcity of safe drinking water in some villages in the district. This is mainly due to unavailability of hand pumps and naolas/springs nearby. The problem can be mitigated either by installing hand pumps in the areas where accessibility is not a problem or by storing rainwater in storage tanks (surface or underground) and harnessing surplus monsoon runoff through small check dams and/or gully plugs in suitable areas. The latter solution is more attractive as the system of rainwater harvesting in hilly areas has proved cost-effective and sustainable.

8. AWARENESS AND TRAINING ACTIVITY

8.1 Mass Awareness Programme (MAP) and Water Management Training Programme (WMTP) by CGWB: Nil.

8.2 Participation in Exhibition, Mela, Fair etc. Nil.

8.3 Presentation and Lectures Delivered in Public Forum/Radio/T.V./Institution of Repute/ Grassroots Association/ NGO/Academic Institutions etc. Nil.

9. AREAS NOTIFIED BY CGWA/SGWA

No area in Tehri Garhwal district has been notified by Central Ground Water Authority (CGWA). There is no State Ground Water Authority (SGWA) in Uttarakhand State.

10. RECOMMENDATIONS

The following recommendations are made for sustainable ground water development and management in Tehri Garhwal district:

- Springs and gadheras should be tapped at higher elevations and water supply should be done by gravity flow through parallel pipe lines so as to reach multiple villages down slope. Consideration of spring discharge is essential to arrive at the optimum number of water supply schemes for this purpose.
- Hydrums can be quite successful for catering to irrigational needs of the local populace in the hilly tracts of the district.
- Guls, whose primary source of supply is ground water, need to be constructed in series for irrigational use.
- Springs and naolas should be properly renovated and maintained by the local people and/or gram panchayat in active collaboration with Non Government and Voluntary Organisations and state government departments.
- Hand Pumps should be constructed scientifically avoiding landslide prone areas. They should be properly maintained by the villagers to avoid any possible source of anthropogenic contamination like incidence of high nitrate.
- Proper hydrogeological surveys and feasibility studies should be conducted before constructing any tube well in the district. Drilling of tube wells may be carried out with DTH rig (preferably having an ODEX attachment) and any fractured or granular zones should be tapped through ISI Mark slotted pipes.
- In areas having water scarcity, large diameter infiltration wells may be constructed after proper site selection studies, depending upon the local topographic and geotectonic/ hydrogeological conditions of the area.
- Villagers should be properly educated through mass awareness and water management training programmes for an effective water conservation practice.
- Villagers should be encouraged to tap roof top rain water as the system of roof top rain water harvesting in hilly areas with high amount of monsoon rainfall has been found useful and cost-effective.
- Unnecessary wastage of water should be stopped by putting valves or taps in the storage tanks (Hauj) and by periodic checking and repairing of pipe lines used for drinking water supply.

For any Technical Guidance, please contact

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